Experimental Challenges for the HL-LHC

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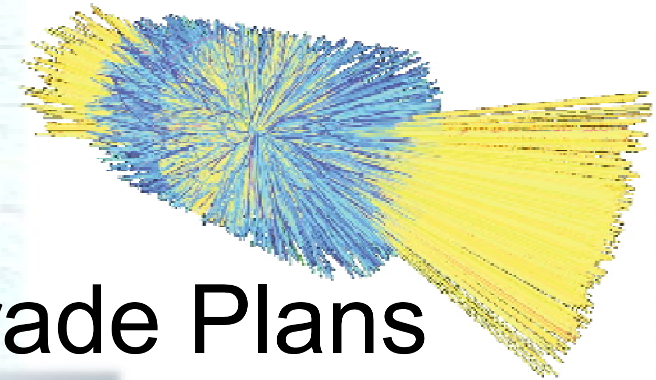
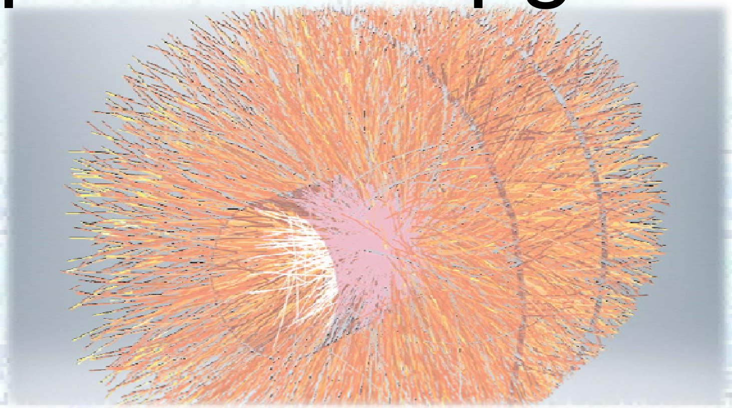
- Introduction
- Present LHC Planning
- General Purpose Detector Upgrade Plans
  - ATLAS
  - CMS



- Specialist Experiment Upgrade Plans
  - LHCb
  - ALICE
  - TOTEM



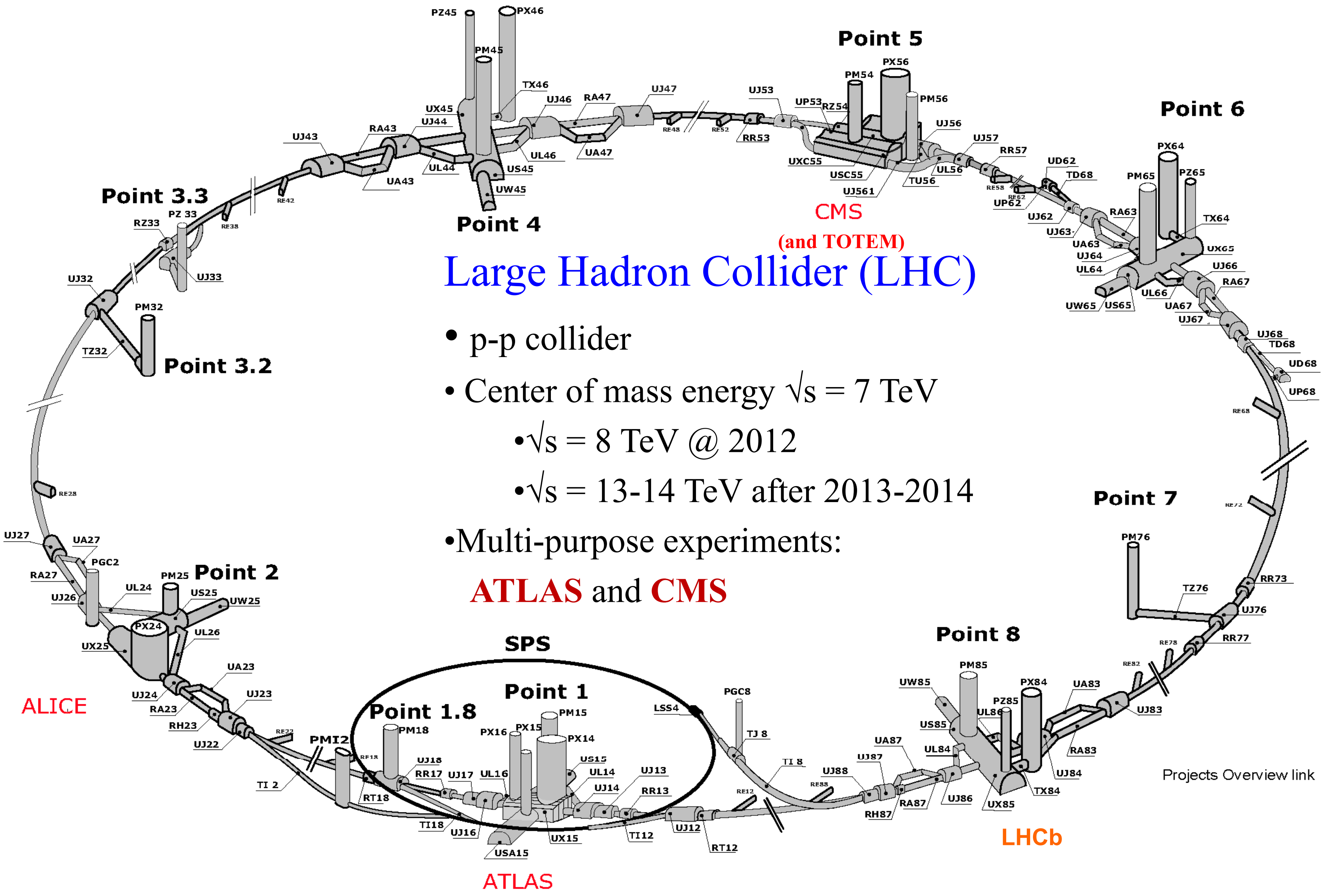
- Conclusions

LHC

Large Hadron Collider (LHC)

- p-p collider
- Center of mass energy $\sqrt{s}$ = 7 TeV
    - $\sqrt{s}$ = 8 TeV @ 2012
    - $\sqrt{s}$ = 13-14 TeV after 2013-2014
- Multi-purpose experiments:

  ATLAS and **CMS**



LHC Schedule Assumptions

(As of Chamonix, February 8th, 2012)

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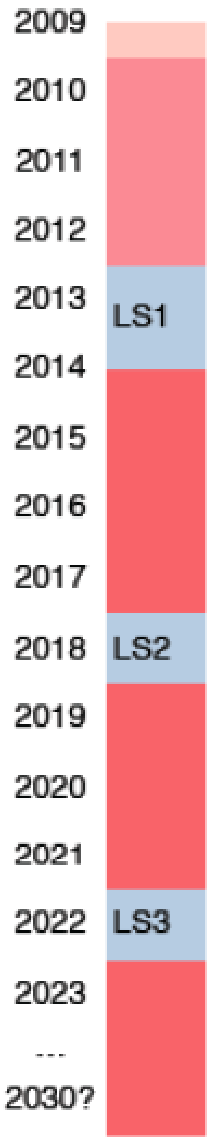


✧ LHC startup, $\sqrt{s}$ = 900 GeV

$\sqrt{s}$=7~8 TeV, L=6x10^{33} cm^{-2} s^{-1}, bunch spacing 50 ns

Go to design energy, nominal luminosity (Phase-0)

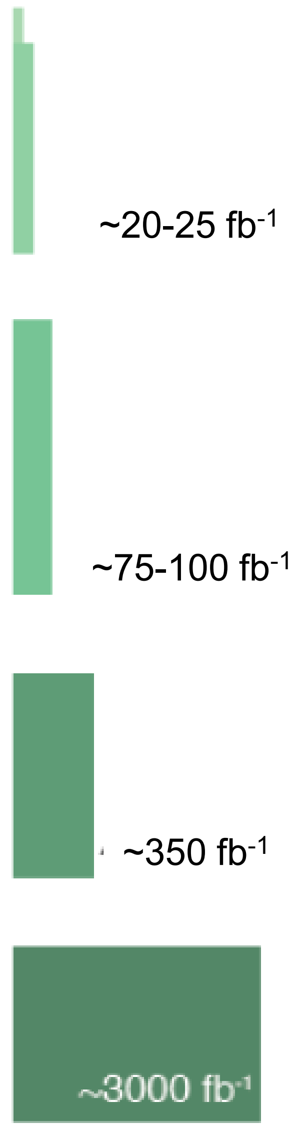
$\sqrt{s}$=13~14 TeV, L~1x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

Injector and LHC Phase-1 upgrade to full design luminosity

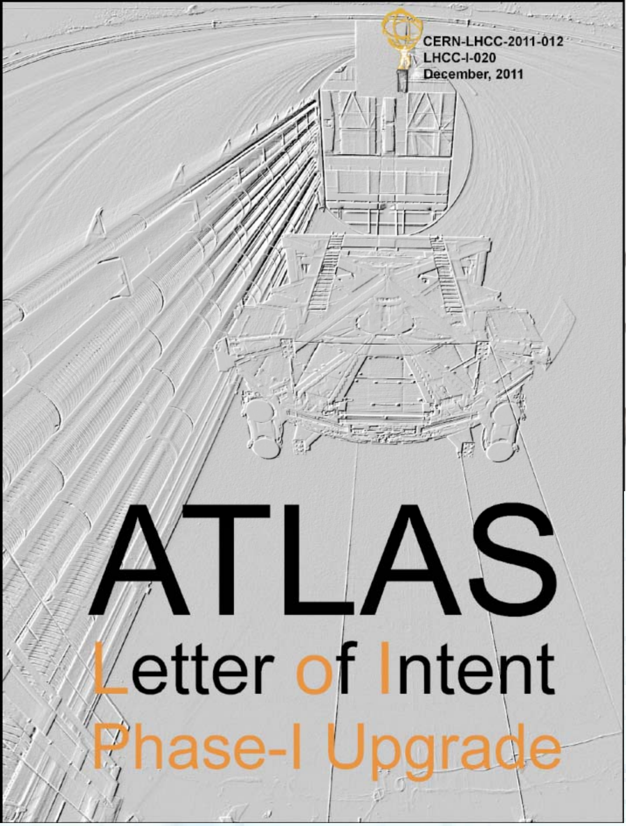
$\sqrt{s}$=14 TeV, L~2x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

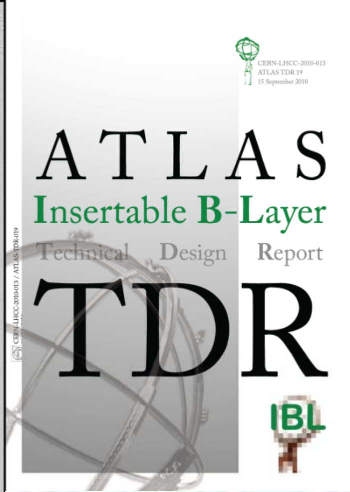
HL-LHC Phase-2 upgrade, IR, crab cavities?

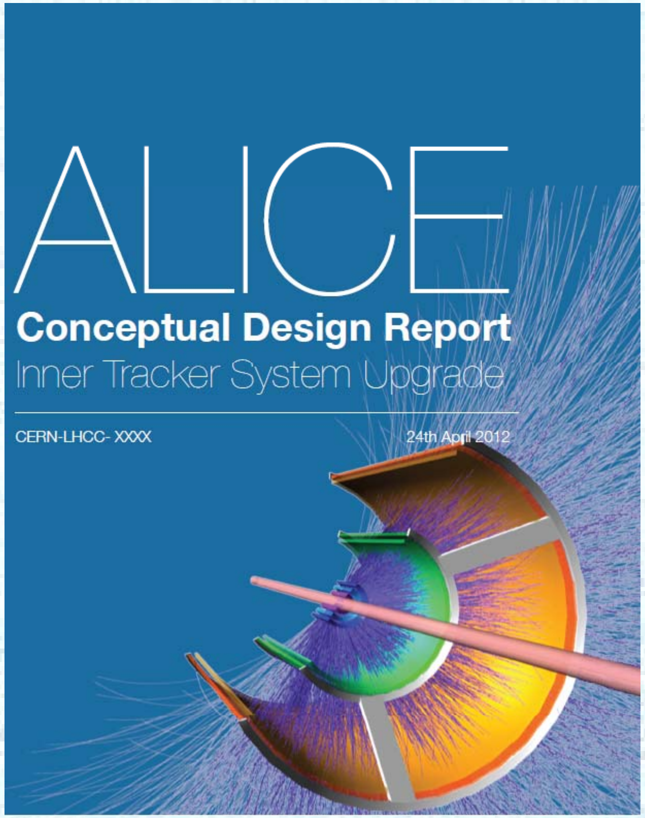
$\sqrt{s}$=14 TeV, L=5x10^{34} cm^{-2} s^{-1}, luminosity levelling

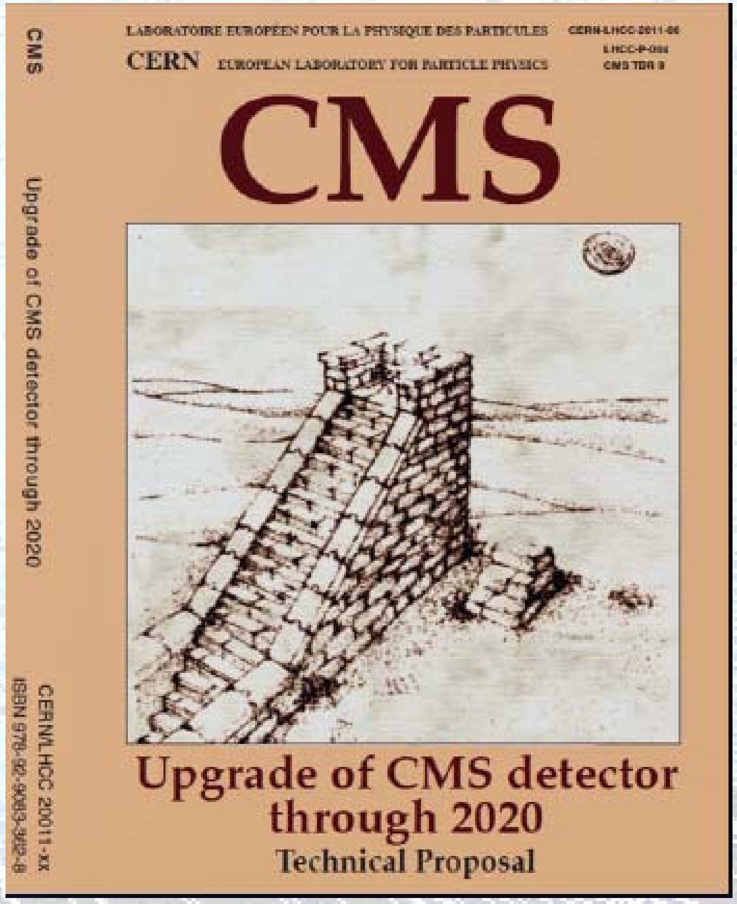


Many Detailed Plans Already Presented to CERN's LHCC

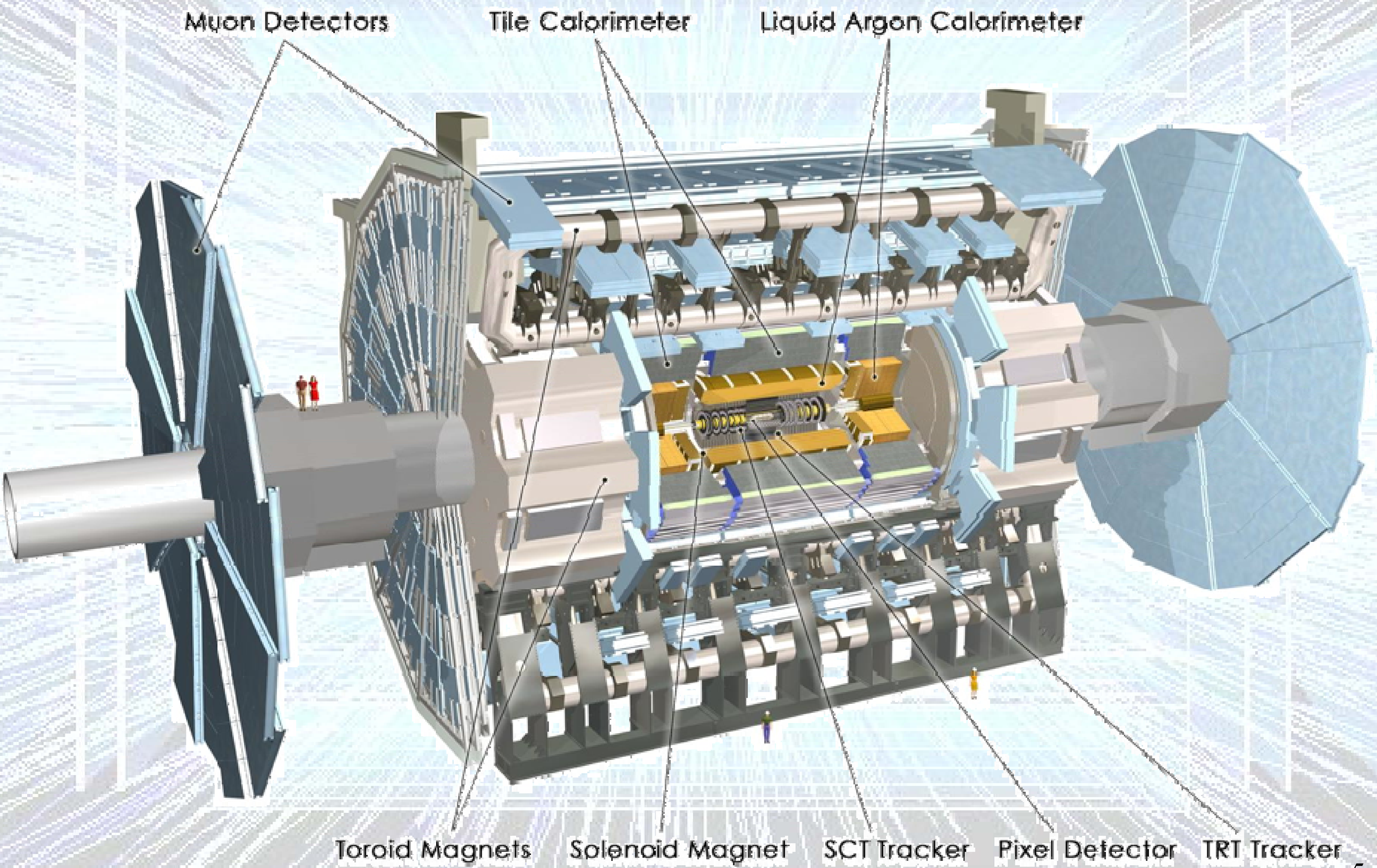








ATLAS



Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

Phase-0: During the 2013/2014 Shutdown (LS1)

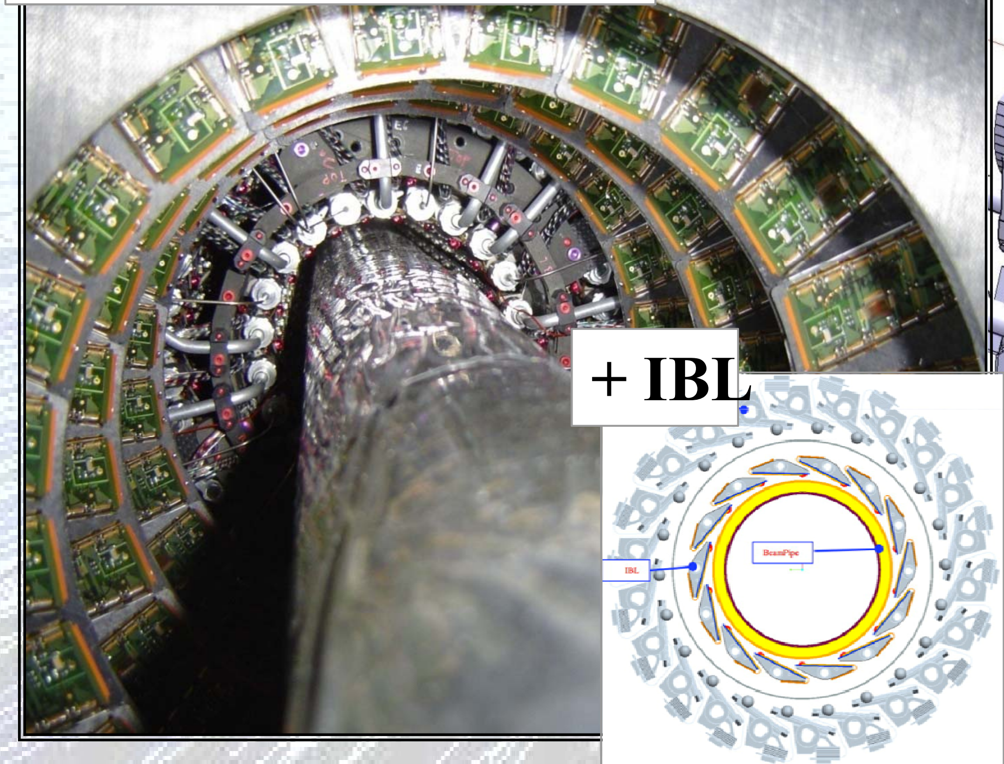
Detector consolidation:

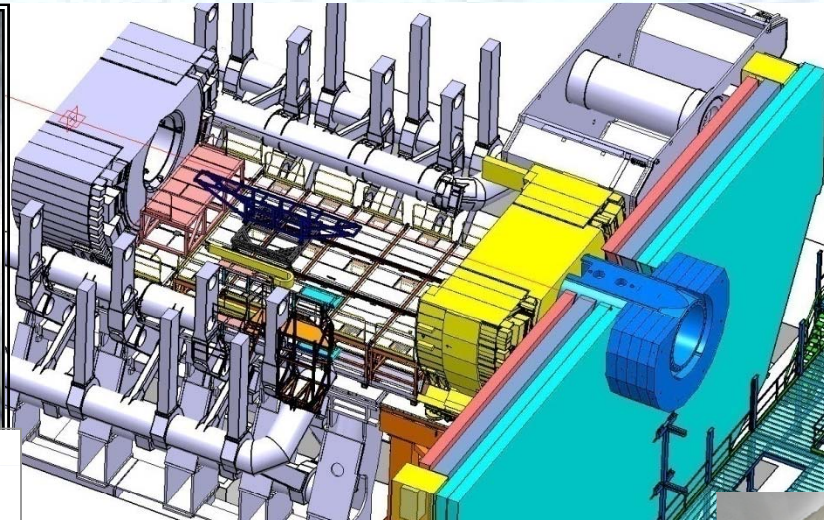
- New tracker evaporative cooling plant
- New Calorimeters LV power
- Magnets cryogenics consolidation
- Muon spectrometer consolidation
- Infrastructure consolidation (electronics, ventilation, radiation protection,…)
- Maintenance and repairs everywhere

Detector upgrade:

- New Aluminum beam pipes
- New small radius central Be pipe
- Insertable B Layer (**IBL**): pixel 4^{th} layer
- New pixel services (nSQP)? - decision during 2012
- New chambers in the muon spectrometer to improve geometrical coverage

ATLAS Pixel detector

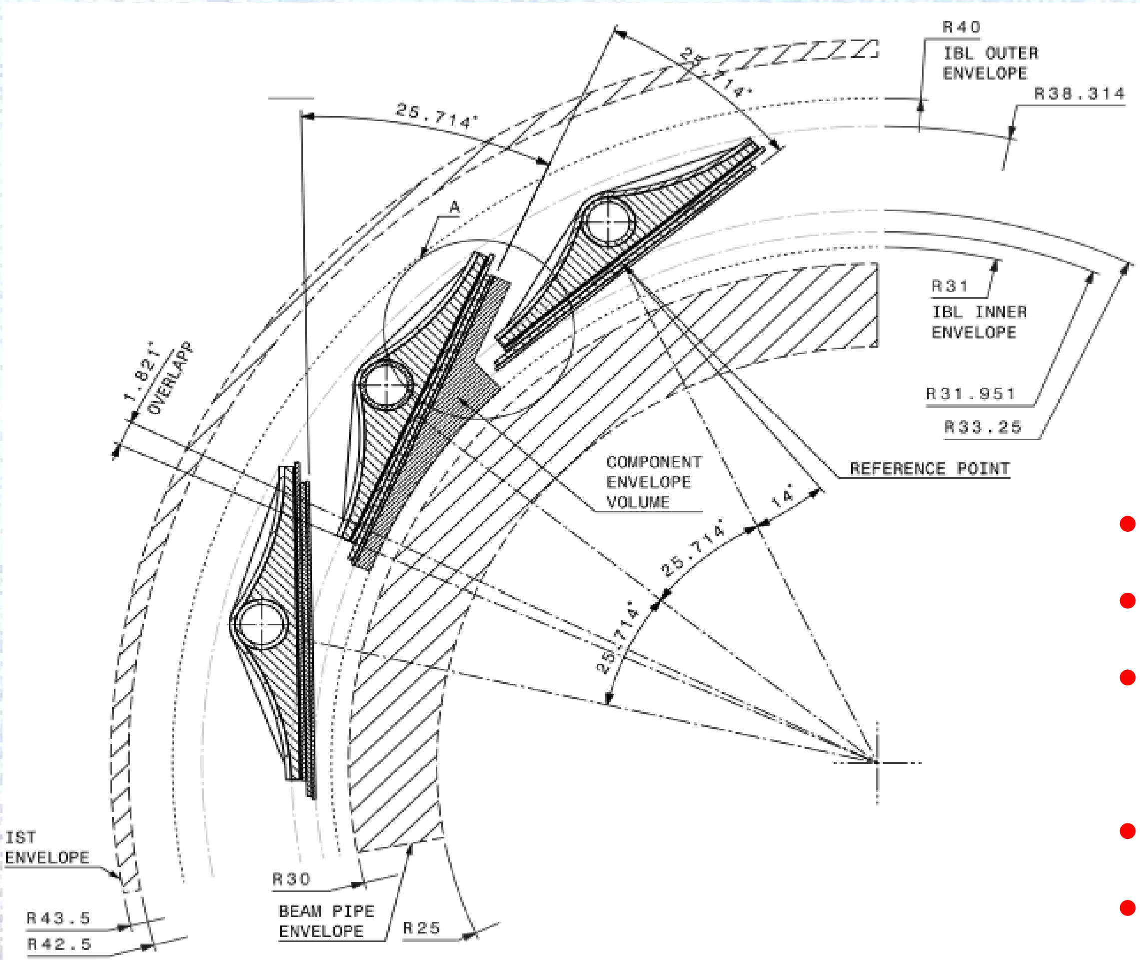


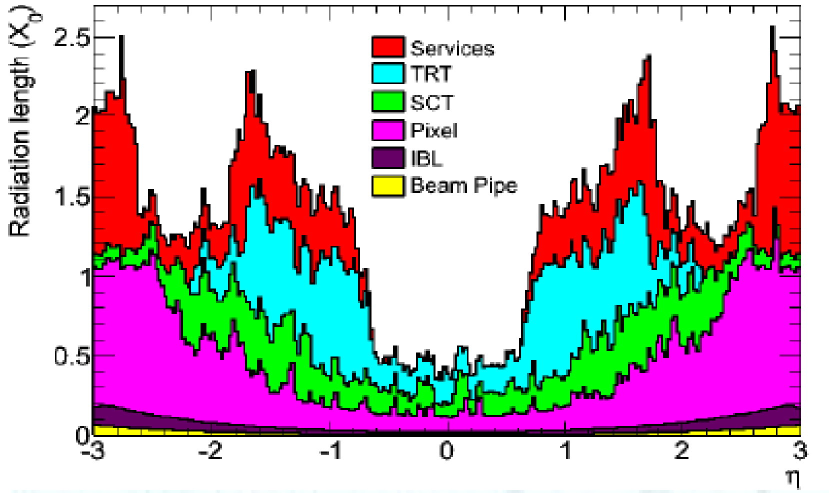


Complex access with only ~20 months available

Insertable B-Layer

- Improve performance of current ATLAS pixel detector
  - tracking, vertexing, b-tagging for high pile-up
- Technology step towards HL-LHC





- Very low material budget: **0.015 X_0**
- Coverage: z = 60cm, **|η| < 2.5**
- Sensors **@33mm** (now @50.5mm)
  => smaller beam pipe (29 -> **25mm**)
- **14 staves** with phi overlap
- No z overlap due to clearance
  => minimize sensor insensitive edge

Technology Proposal:
75 % planar sensors at low η and 25 % 3D sensors at large η along same stave

ATLAS Phase-I: The Challenge

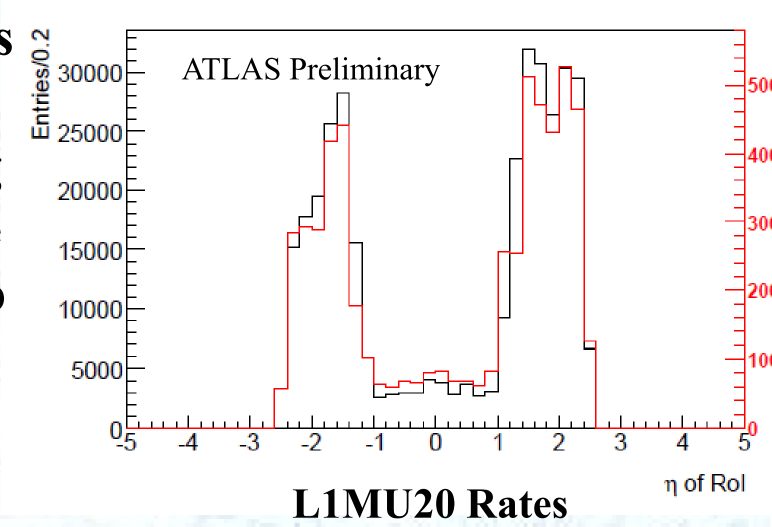
The physics of Phase-I will continue to require a Level-1 trigger on single leptons with p_T thresholds of order 20-25GeV even with pile-up as high as 55 ($\mathcal{L}$ =2×10^{34}cm^{-2}s^{-1}, 25ns) or even 80 ($\mathcal{L}$ =3×10^{34}cm^{-2}s^{-1}, 25ns).

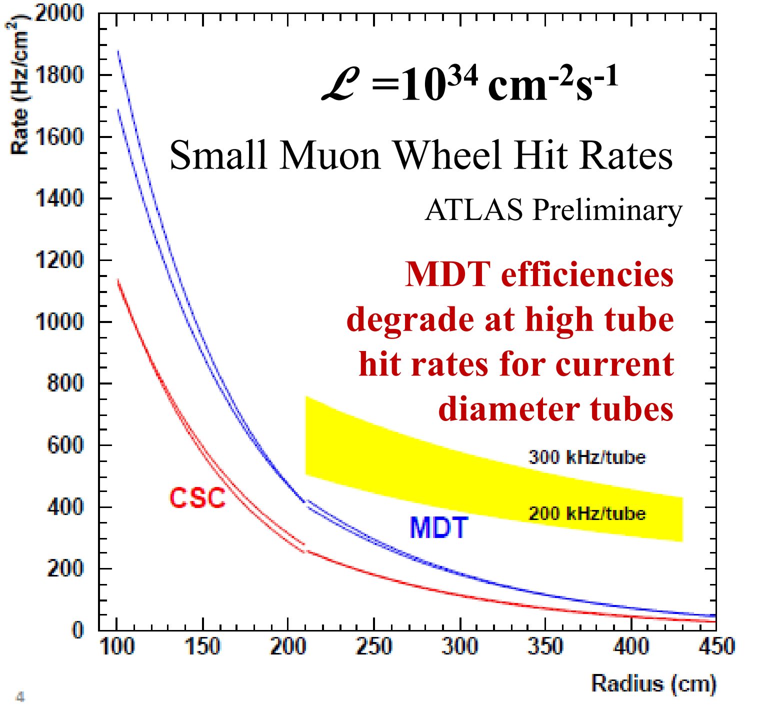
- **Preserve nominal luminosity trigger acceptance even for $\mathcal{L}$ >10^{34}cm^{-2}s^{-1} (and take account that offline cuts will be above where the threshold curve plateaus to avoid complicated corrections)**
- **Retain some "simple" triggers in the menu to avoid and/or understand physics biases**
- **Keep acceptances high and similar between barrel and forward**
- **In addition, aim to use secondary vertexing and track information to retain high purity, good efficiency samples of interesting channels at HLT**

We should aim, wherever possible, to retain sensitivity to beyond the SM physics with as little model dependence as possible

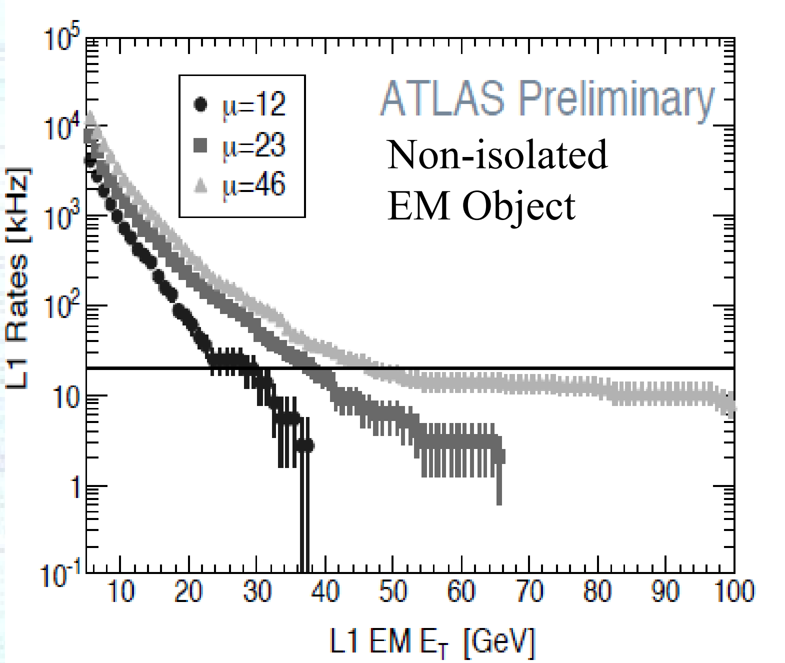
ATLAS Phase-I: The Challenge

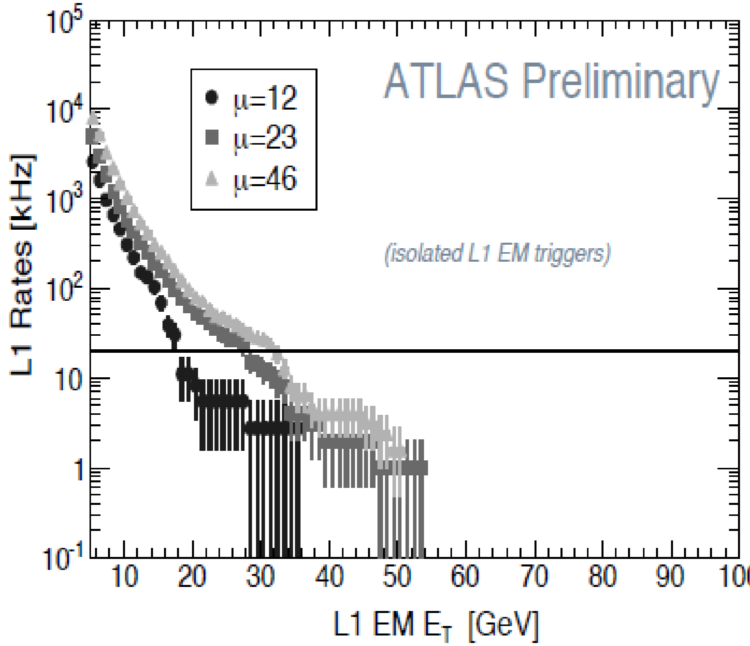
Raising muon thresholds becomes progressively less effective in reducing rates, particularly in the forward direction due to trigger chamber resolution limitations





Raising EM threshold reduces rates but thresholds needed at high μ start to eat into physics acceptance





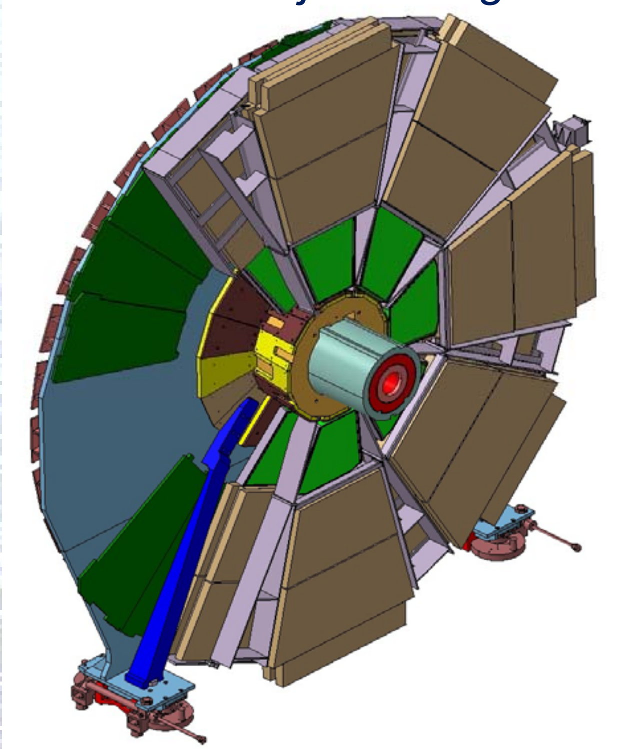
Solution: Replace Small Muon Wheels and upgrade LAr R/O granularity at L1 to improve L1 threshold turn-on

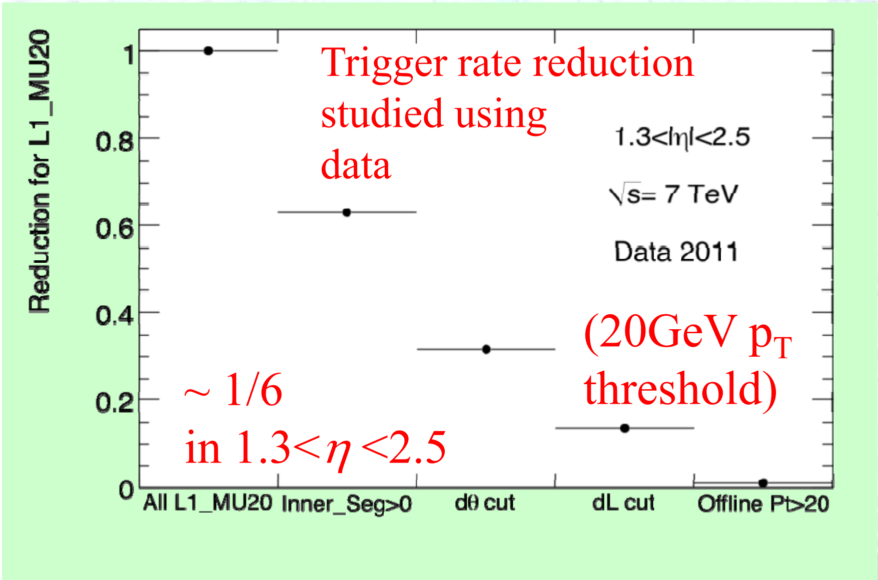
ATLAS Phase-I (installation in or Before LS2)

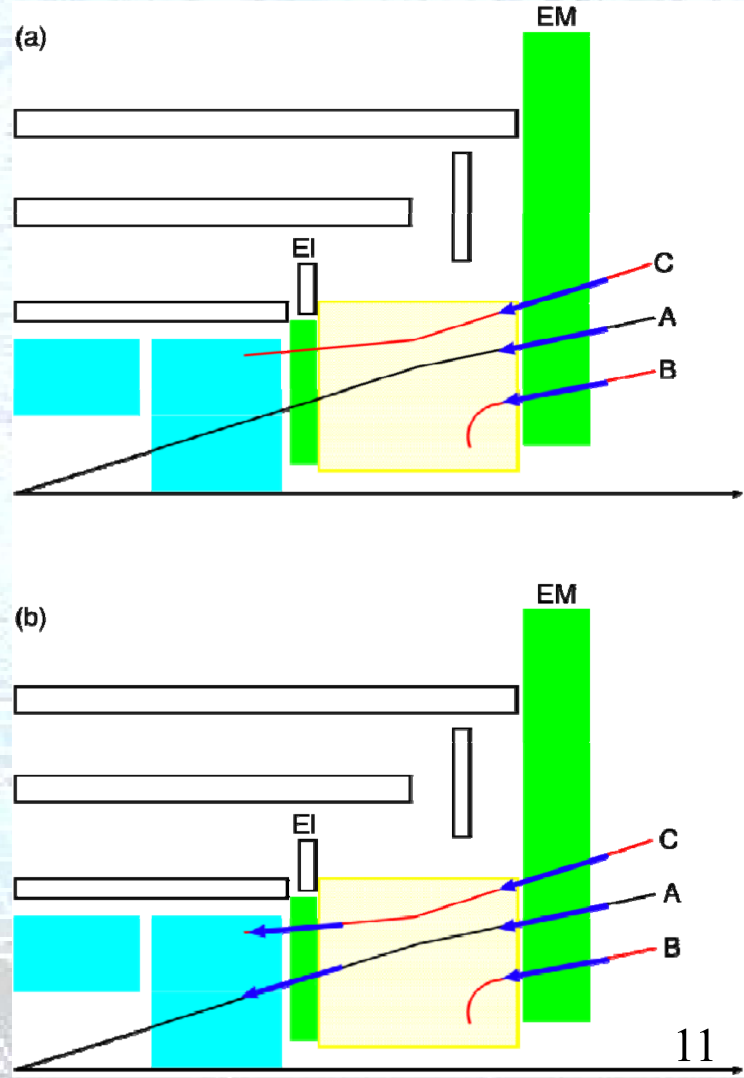
- **New muon small wheels with more trigger granularity and trigger track vector information**
- ***Higher-granularity calorimeter LVL1 trigger and associated front-end electronics***
- **Fast track trigger (FTK) using silicon strip tracker and pixel hits (input to LVL2) expected installation before LS2**
- ***Topological trigger processors combining LVL1 information from different regions of interest (improvements starting well before LS2)***
- **Adapt central LVL1 trigger electronics to new requirements**
- ***New diffractive physics programme detector stations planned at ~210 m (full 3D edgeless and timing detectors, to start taking data before LS2)***
- **New Tiles crack-gap scintillators and some new trigger electronics**
- ***Adaptations to the High Level Trigger hardware (in particular network)***

New Muon Small Wheels (More Granularity)

- Plan to replace muon small wheels with improved trigger capability: need <1mrad angular resolution and associated trigger vector capability
- Status:
  - *Converging on the choice of the technology for precision tracking and trigger*
  - *MicroMegas for precision coordinates and TGC for trigger are the main candidates*
  - *Vigorous milestone plan for 2012 to demonstrate feasibility*
  - *TDR to be ready for early 2013*
  - *Project being set up for ATLAS internal approval in 2012*



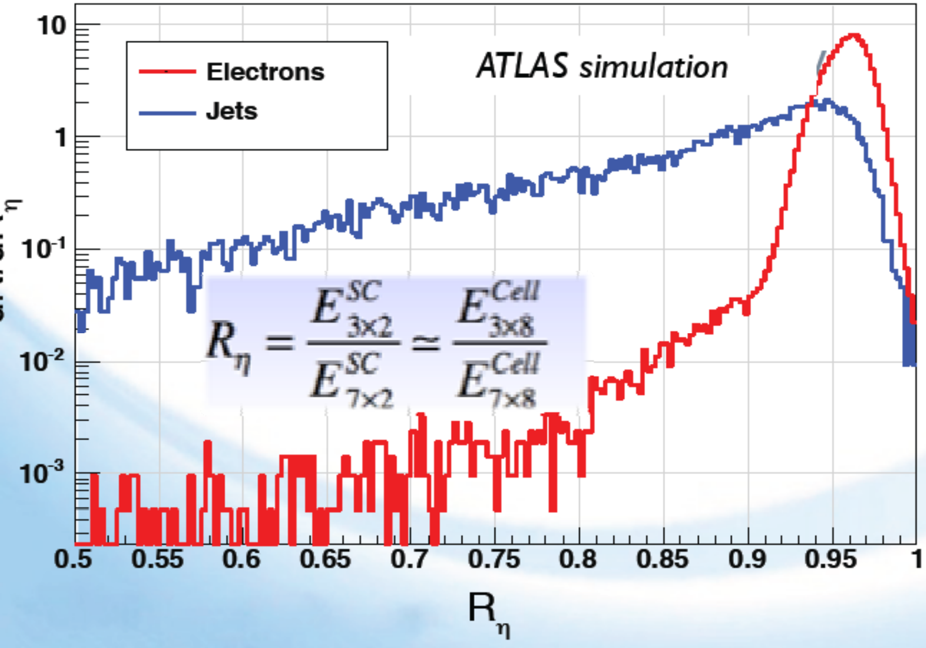


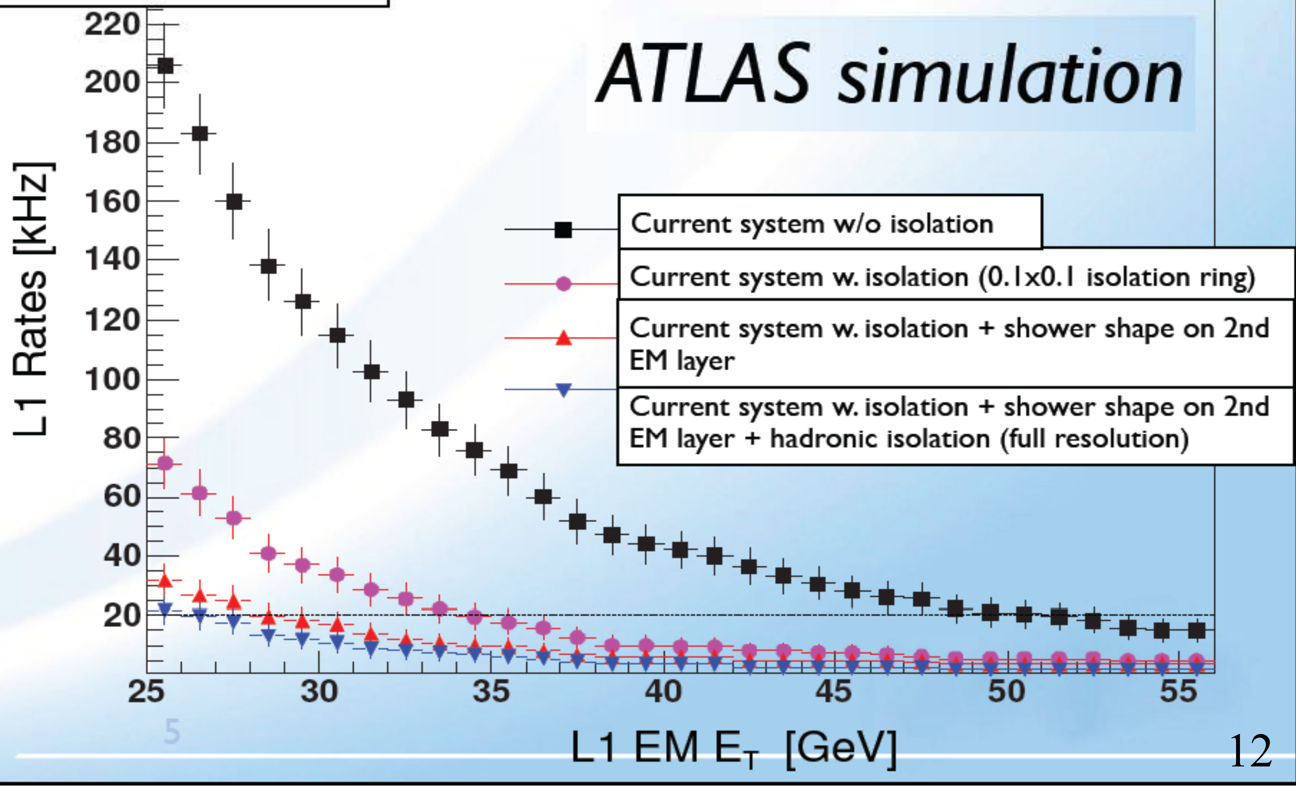


New LVL1 Calorimeter Trigger (More Granularity)

- Plan to use in the LVL1 trigger much more of detector granularity present in the LAr Calorimeter. Develop a new front-end digital chain (trigger leg for phase I)
- GOAL: *Preserve un-prescaled LVL1 thresholds for single electron trigger at P_T ~ 25 GeV for LHC operation beyond the nominal design (Phase-I LHC)*
  At the LVL1 trigger level, use new shower shape variable based on ratio of energies (2nd layer of the EM calorimeter) in clusters of different sizes

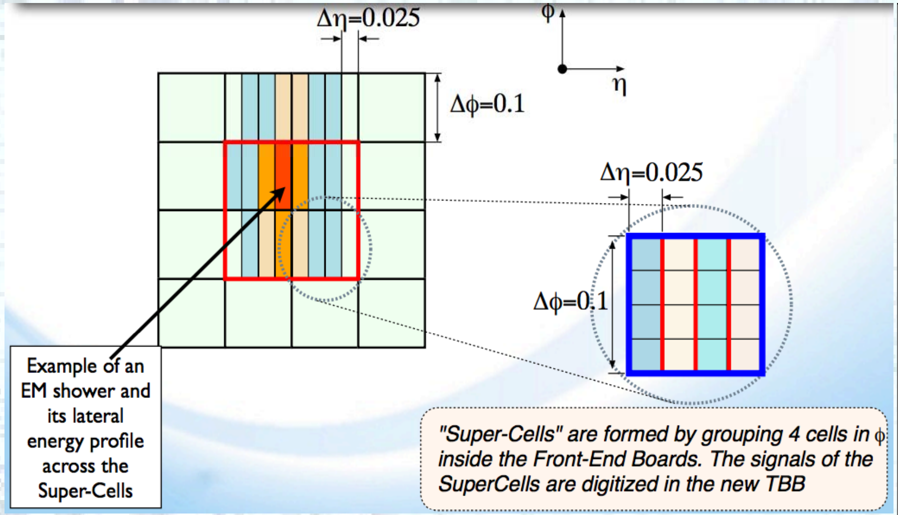
Simulations for $\mathscr{L}$ = 1.7×10^{34} cm^{-2}s^{-1} @25ns

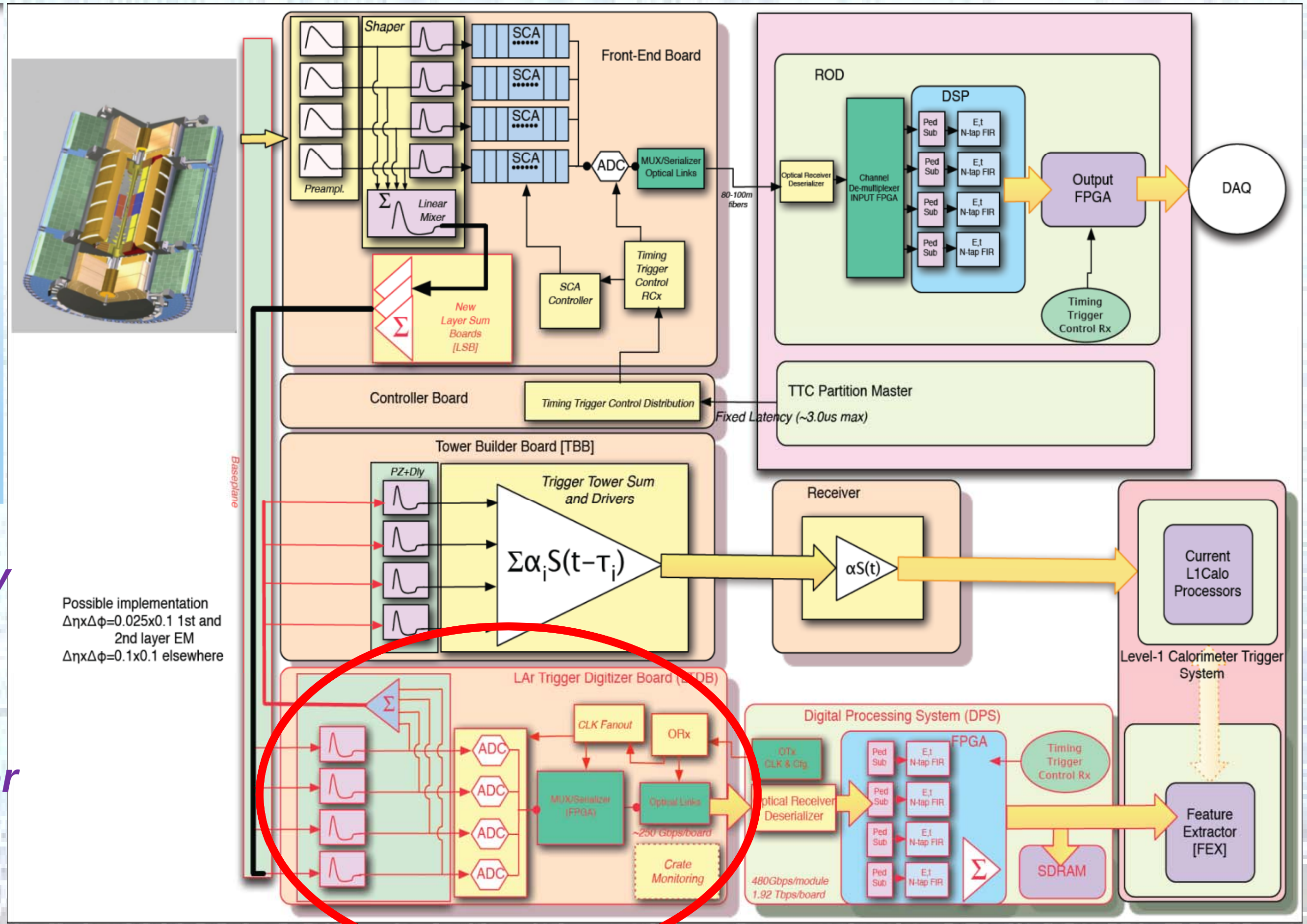




New LVL1 Calorimeter Trigger (More Granularity)

- Plan to use in the LVL1 trigger much more of detector granularity present in the LAr Calorimeter. Develop a new front-end digital chain (trigger leg for phase I)
- In practice: Super-Cells with higher granularity are formed in the Front-End shaper sum ASIC and individually digitized:

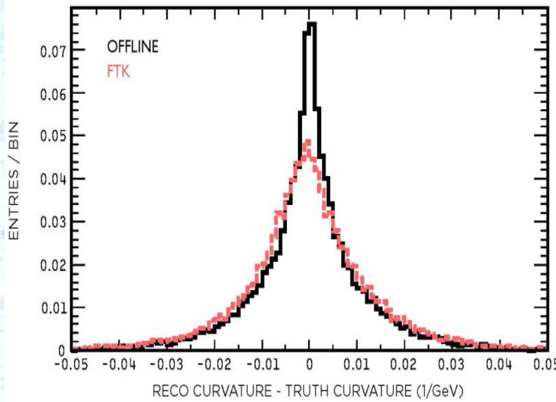




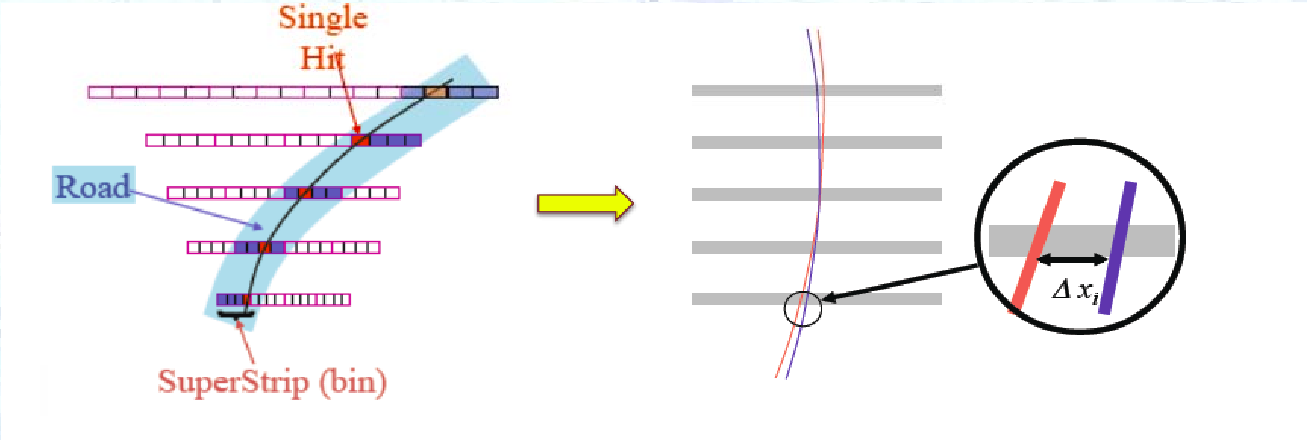
- *Converging on the choice of technology necessary in the next 6 months*
- *Converging toward a mixed option with analog and digital information*
- *Prove feasibility through a demonstrator in the next 2-3 years*
- *Project being set up for ATLAS internal approval in 2013/14*

Phase-I: FastTracKer

- ATLAS trigger system based on:
  - Level-1 (L1): hardware based (~50 kHz)
  - Level-2 (L2): software based with access to full granularity data (~5 kHz)
  - Event Filter: software trigger (~500 Hz)



- FTK: Global hardware based tracking by start of L2
  - Descendent of the CDF Silicon Vertex Trigger (SVT)
  - Inputs from Pixel and SCT.
  - Data in parallel to normal read-out.
  - Provides inputs to L2 in ~ 25 μs. Track parameters at ~offline precision
  - Two phases:
    - Pattern recognition (10^9)
    - Track fitting
  - Major L2 improvement for
    - b-tagging
    - tau ID
    - lepton isolation

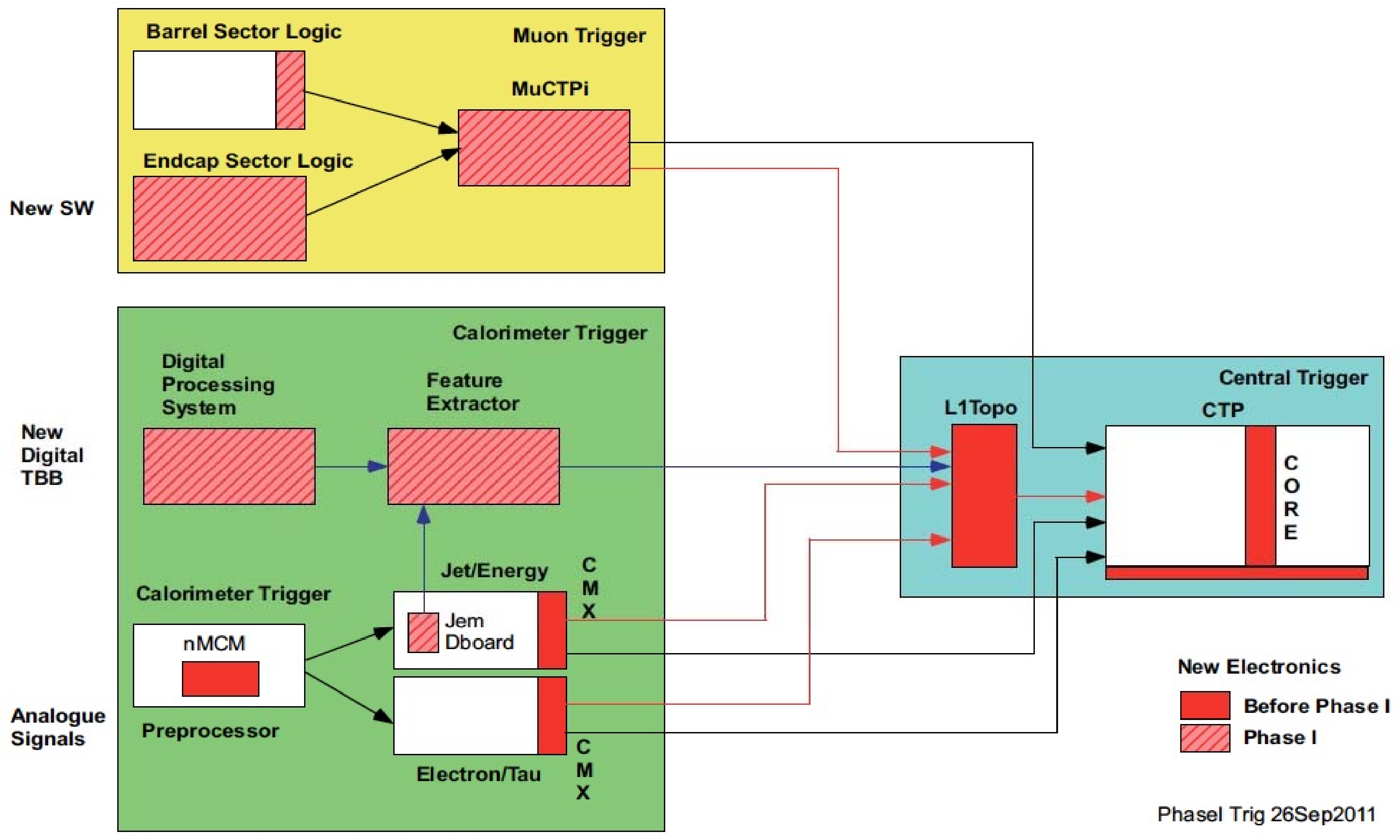


Pattern recognition in coarse resolution (superstrip→road)

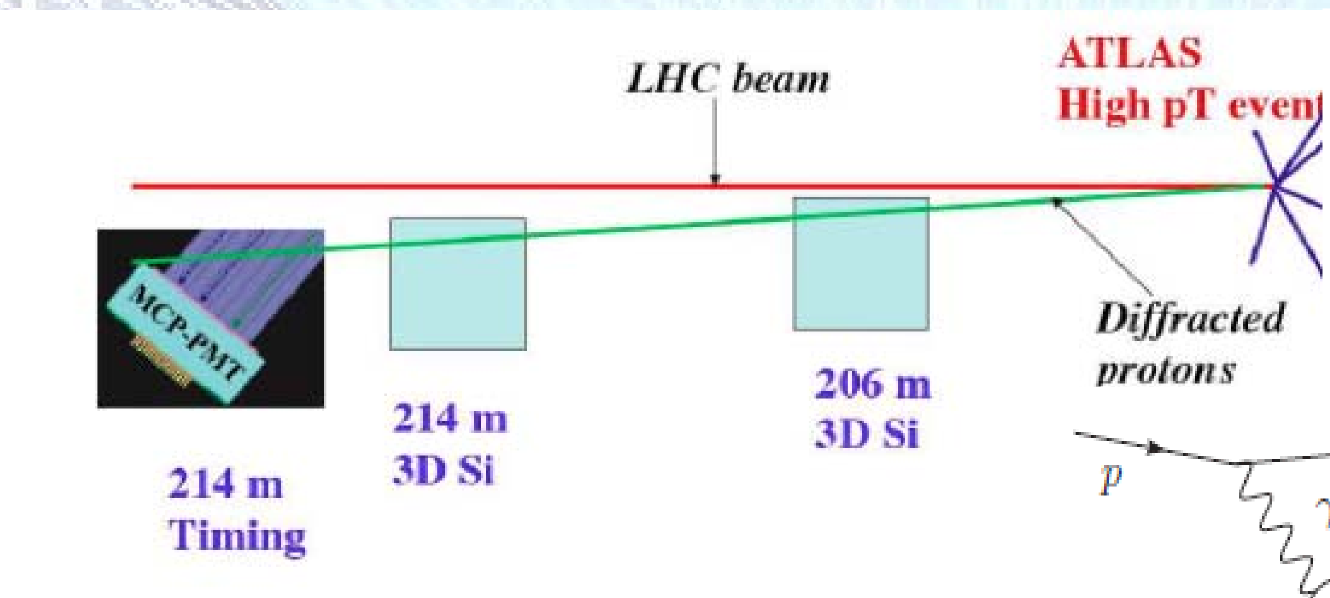
Track fit in full resolution (hits in a road)
$F(x_1, x_2, x_3, \ldots) \sim a_0 + a_1\Delta x_1 + a_2\Delta x_2 + a_3\Delta x_3 + \ldots = 0$

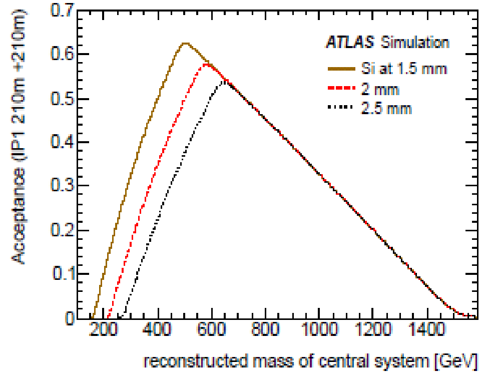
Phase 1: Trigger & DAQ Upgrades

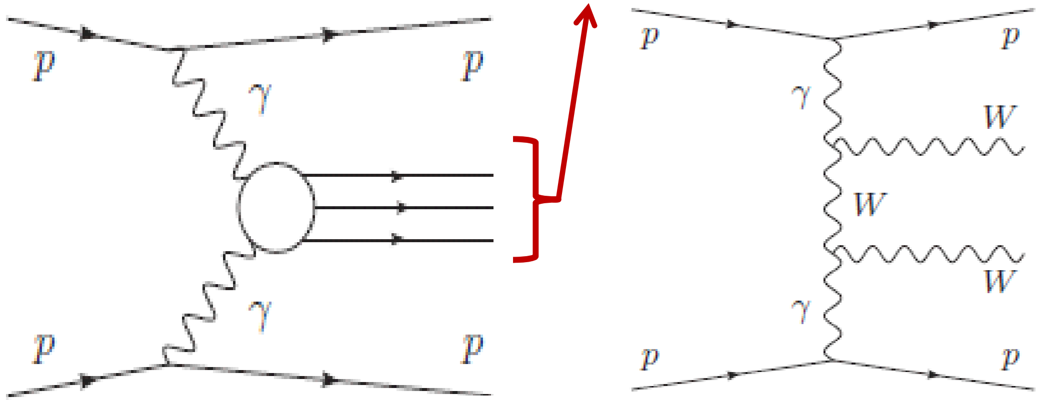
- Incorporate Muon Small Wheels, L1Calo higher granularity, FTK
- L1 (including topological trigger) -> FTK -> L2 & EF
  - Greater integration of Level-2 and Event Filter selections + Event Builder



AFP : ATLAS Forward Physics

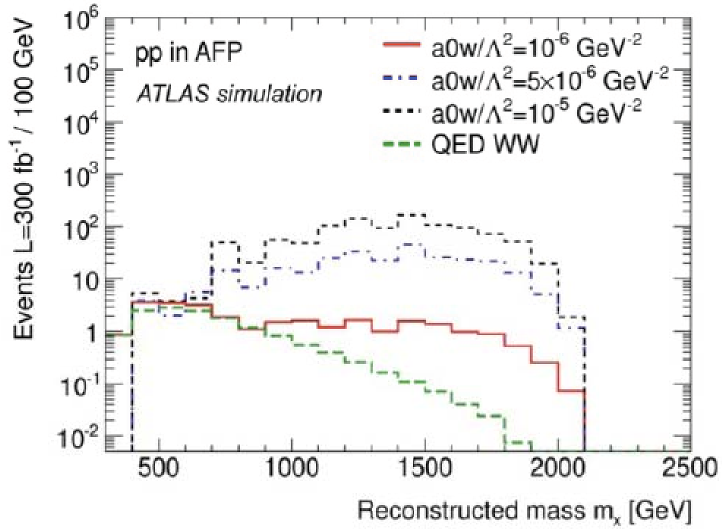


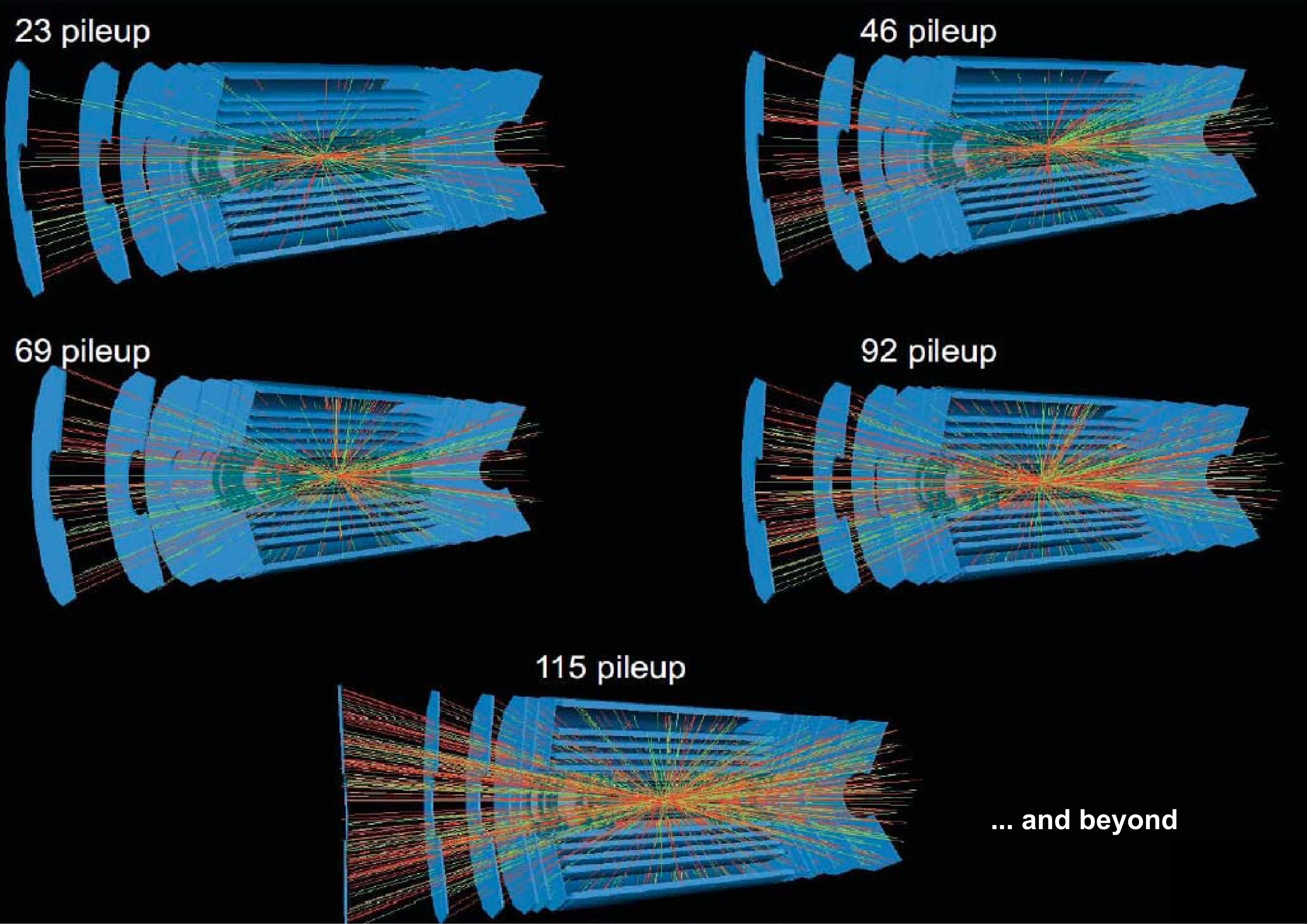




- ✓ Tag and measure protons at ± 210 m
- ✓ Trigger: rely on ATLAS high-P_T LVL1 trigger
- ✓ Detectors: radiation hard "edgeless" 3D Silicon as tracker and also 10 ps timing detectors

Allows running in high pileup conditions with association with the primary vertex → **giving extension of ATLAS sensitivity for rare processes with exchange of colour-singlet objects (e.g.: anomalous quartic-gauge couplings, hard diffractive processes, monopoles, ...)**




23 pileup
46 pileup
69 pileup
92 pileup
115 pileup
... and beyond

Phase-II (installation 2022-23)

Integrated radiation levels and particle densities per beam crossing well beyond the design specifications of the experiment.

Requirements include:

- **New Inner Detector (strips and pixels)**
  – very substantial progress in many R&D areas
- **New LAr front-end and back-end electronics**
- **New Tiles front-end and back-end electronics**
- **TDAQ upgrade**
- **TAS and shielding upgrade**
- **Various infrastructure upgrades**
- **Common activities (installation, safety, …)**
- **New FCAL (if conditions require it)?**
- **LAr HEC cold electronics consolidation (radiation hardness)?**
- **L1 track trigger (latency budget and physics case)?**
- **Muon Barrel and Large Wheel system electronics upgrade?**
- **Forward detectors upgrade?**

ATLAS: Draft Target Specifications

LHC up to 2021		
		safer value
Peak Luminosity expected	$2 * 10^{34}$	$3 * 10^{34}$
Integrated Luminosity expected	300 fb^{-1}	400 fb^{-1}
μ = mean number of interactions per crossing (25nsec)	55	80
Safety factor to be used in the dose rate and integrated dose calculations	2?	2?

HL-LHC after 2022		
		safer value
Peak Luminosity expected	$5 * 10^{34}$	$7 * 10^{34}$
Integrated Luminosity expected	2500 fb^{-1}	3000 fb^{-1}
Int. Luminosity per year expected	250 fb^{-1}	300 fb^{-1}
μ = mean number of interactions per crossing (25 nsec)	140	200
Safety factor to be used in the dose rate and integrated dose calculations	2?	2?

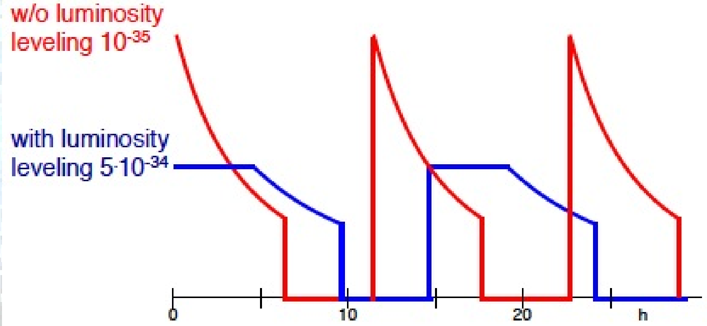
Plan for occupancy numbers based on this (see μ values below)

Plan integrated dose figures based on this

μ values going with the peak luminosity figure if achieved with 25ns beam crossing

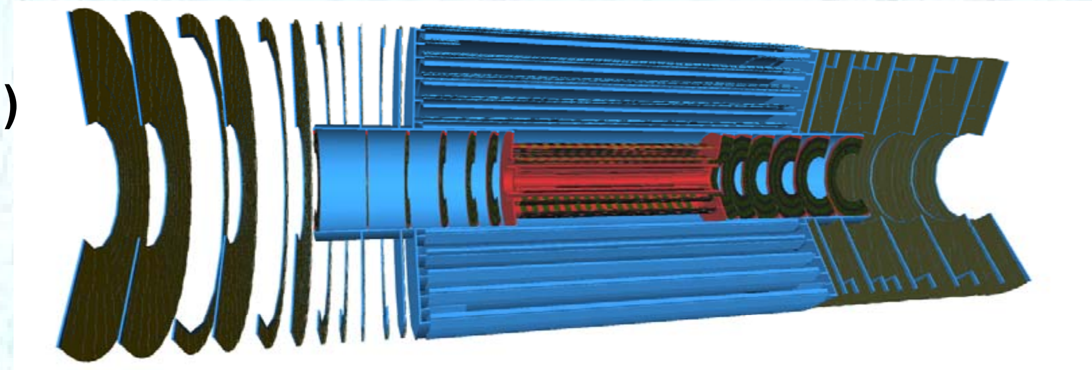
Apply this safety factor to the dose calculations in setting the radiation survival specification

Levelling from effective luminosity of $\sim 10^{35} cm^{-2}s^{-1}$ to give equivalent integrated luminosity



Phase-II Tracker Upgrade Requirements

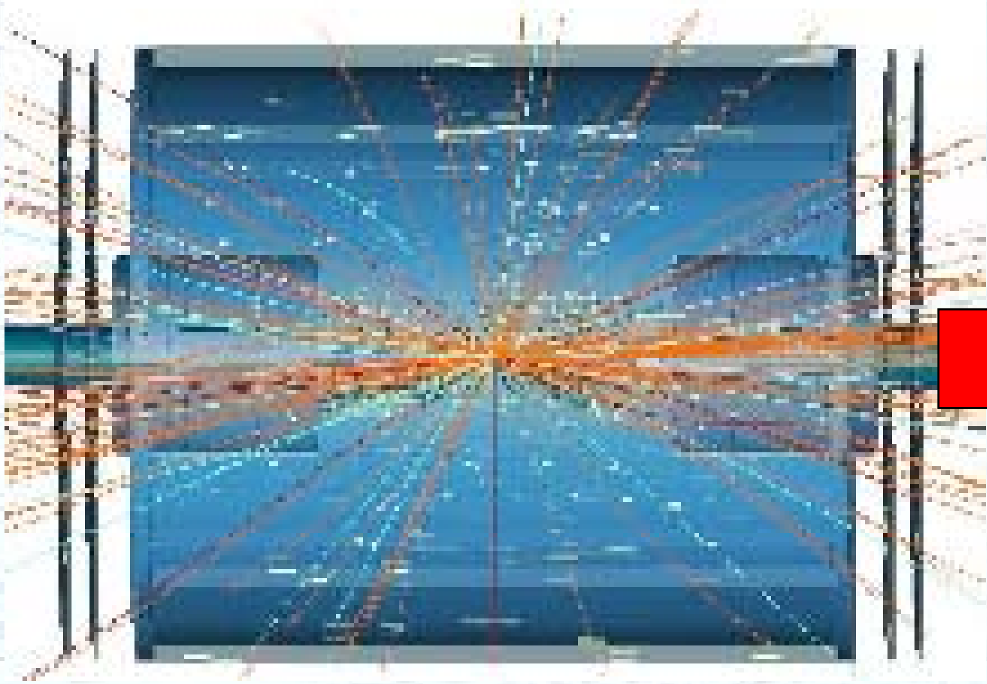
- To keep ATLAS (and CMS) running beyond ~10 years requires tracker replacement
- Current trackers designed to survive up to 10MRad in strip detectors (≤ 700 fb^{-1})
- For the luminosity-upgrade, the new trackers will have to cope with:
  - much higher integrated doses (a factor of 10 more)
  - much higher occupancy levels (up to 200 collisions per beam crossing)
  - Up to 10m^2 of pixels, »100m^2 of strips with some layers possibly having dedicated (level-1) trigger capability
  - Installation inside an existing 4π coverage experiment



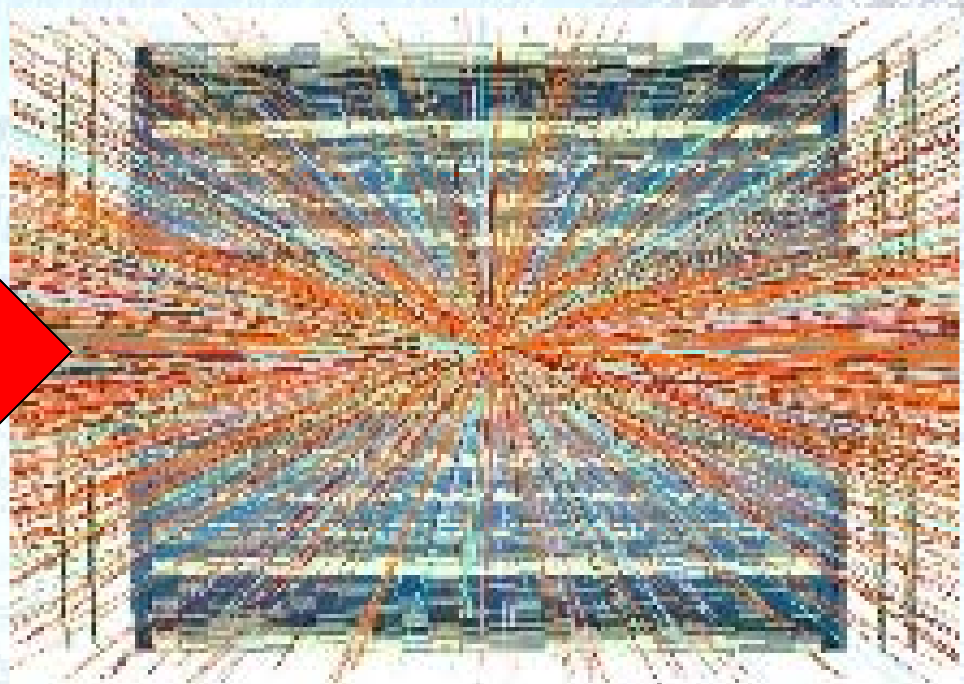
- Budgets are likely to be such that replacement trackers cannot cost more than the ones they replace - while needing higher performance to cope with the extreme environment

To complete a new tracker by ~2020/21, require Technical Design Report 2014/15
(Note the ATLAS Tracker TDR: April 1997; CMS Tracker TDR: April 1998)

Radiation Background Simulation



LHC in 2011: $1x10^{33}cm^{-2}s^{-1}$



HL-LHC: $5x10^{34}cm^{-2}s^{-1}$

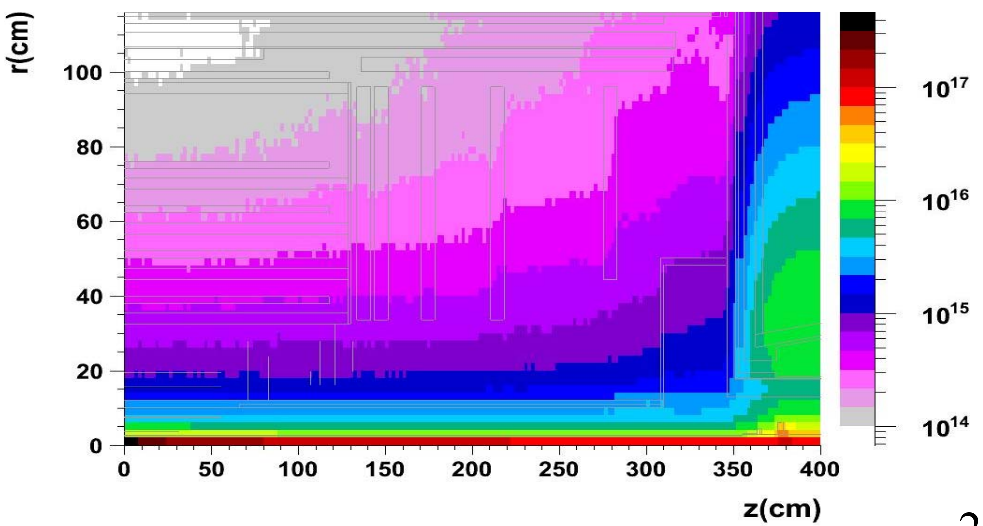
At inner pixel radii - target survival to 2-3×10^{16} n_{eq}/cm^2

Numbers obtained 9/10/09 (corresponding to new layout) assuming 3000fb-1 and 84.5mb

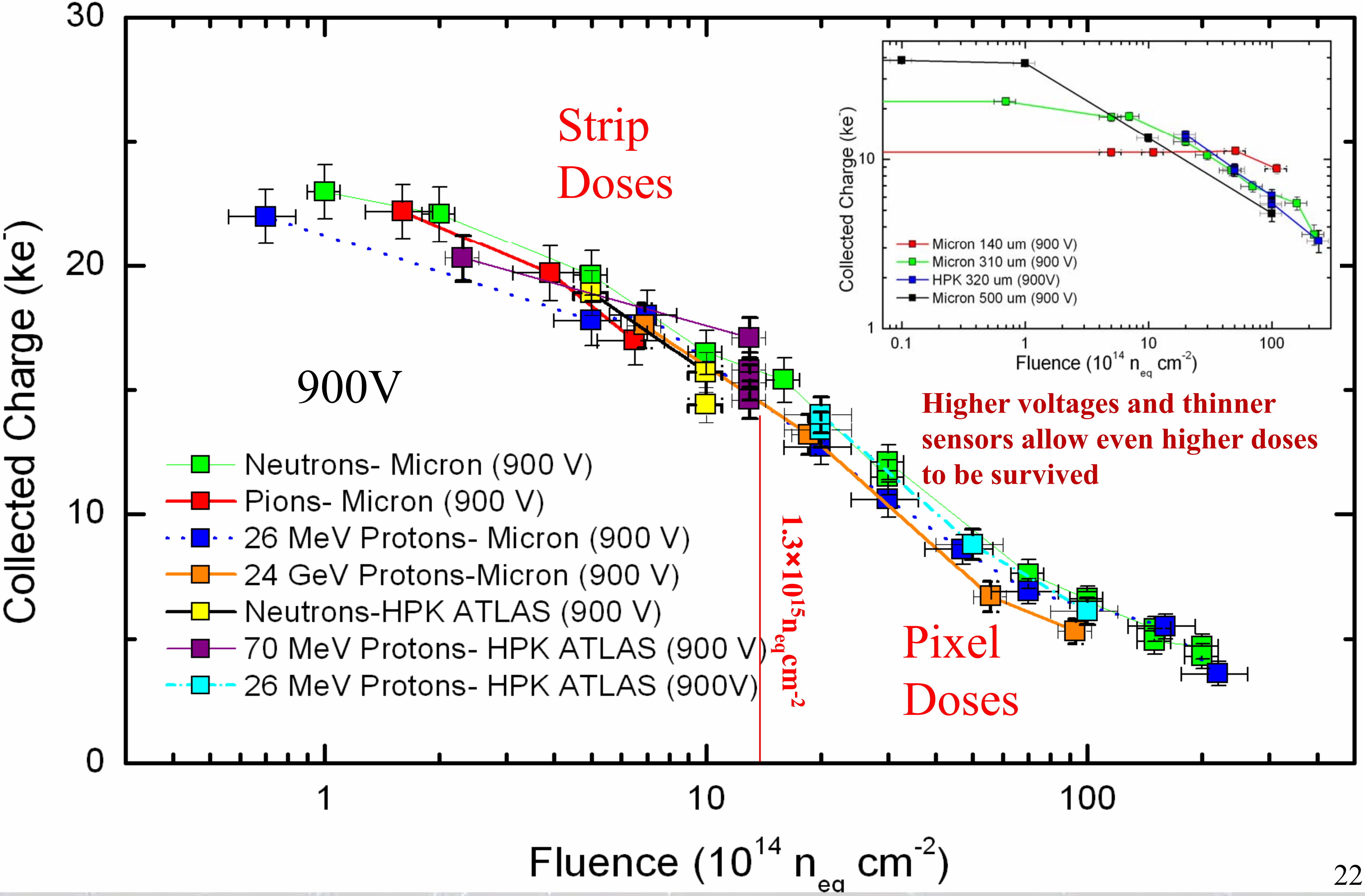
Strip barrel 1 (SS)	(r=38cm; z=0cm)	4.4x10^14
	(r=38cm; z=117cm)	4.9x10^14
Strip barrel 4 (LS)	(r=74.3cm; z=0.0cm)	1.6x10^14
	(r=74.3cm; z=117cm)	1.8x10^14
Strip Disc 1 (z=137.1, Rinner=33.6)		6.0x10^14
Strip Disc 2 (z=147.6, Rinner=33.6)		6.2x10^14
Strip Disc 3 (z=174.4, Rinner=33.6)		5.8x10^14
Strip Disc 4 (z=214.1, Rinner=33.6)		6.1x10^14
Strip Disc 5 (z=279.1, Rinner=44.4)		5.8x10^14
Strip Disc 5 (z=279.1, Rinner=54.1)		4.4x10^14
Strip Disc 5 (z=279.1, Rinner=61.7)		3.9x10^14
new		
Strip Disc 5 (z=279.1, Rinner=73.6)		3.0x10^14
Strip Disc 5 (z=279.1, Rinner=84.9)		2.7x10^14

For strips $3000fb^{-1}$ ×2 implies survival required up to ~1.3×10^{15} n_{eq}/cm^2

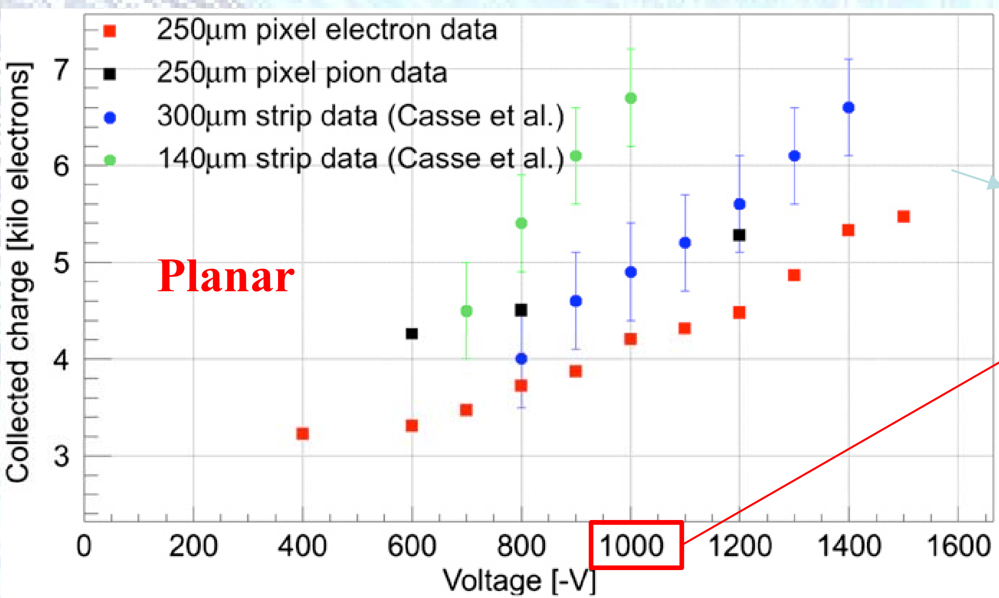
1 MeV neutron eq fluence



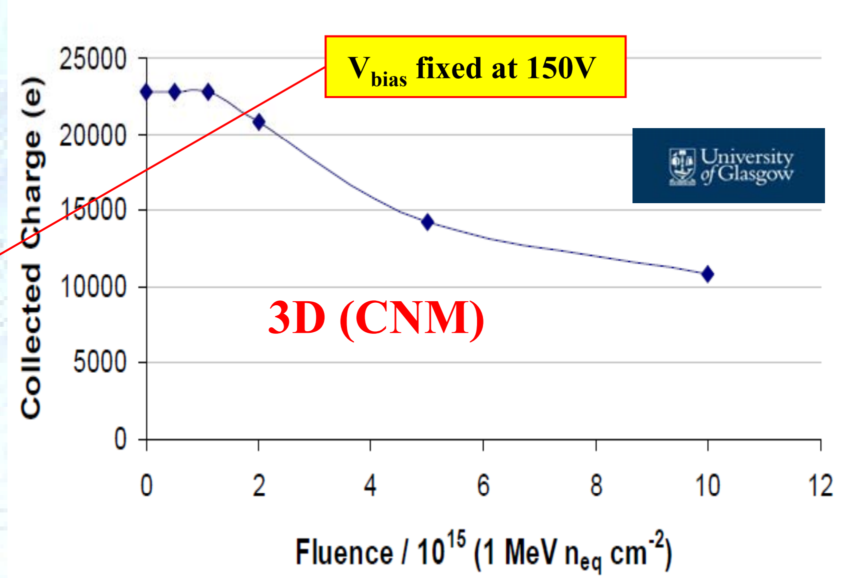
n-in-p Planar FZ Sensor Irradiations



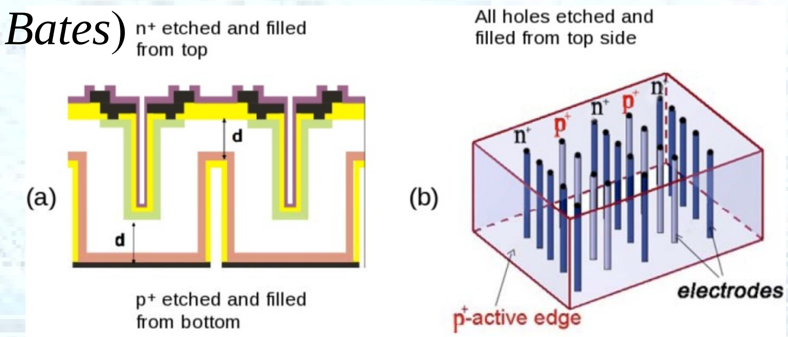
3000fb^{-1}: Inner Pixel Charge Collection



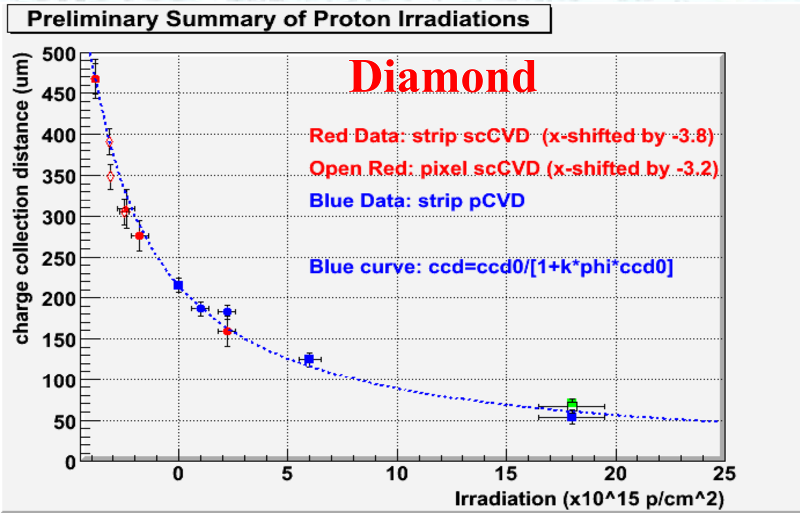
p-type (n-in-p) and n-in-n pixel and miniature strip planar silicon detectors irradiated to HL-LHC inner layer doses of **$2\times10^{16} n_{eq} cm^{-2}$** (*D. Muenstermann*)



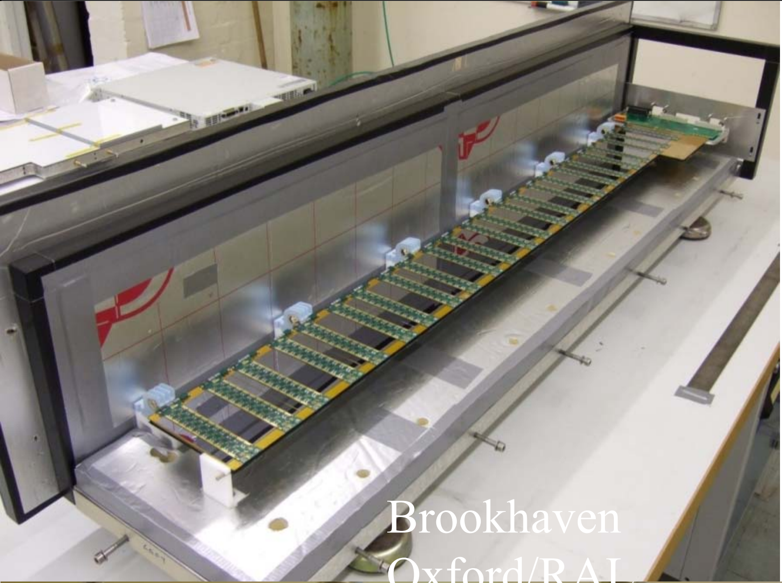
3D strip read-out detector signal vs dose (*R. Bates*)

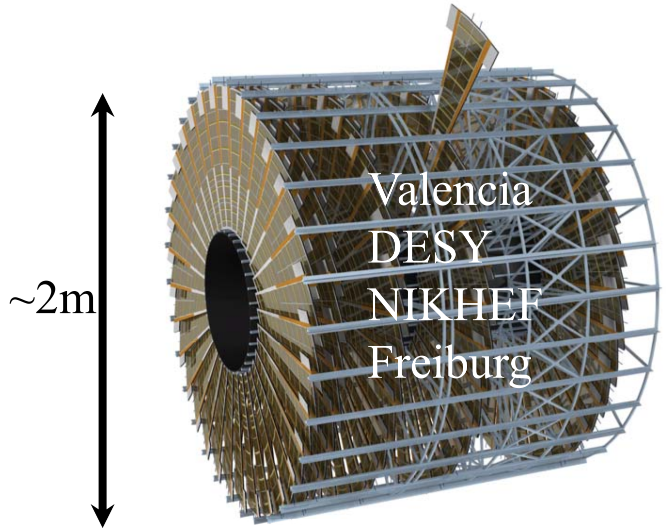


FE-I4 thresholds down to 1600*e* (even lower for diamond)

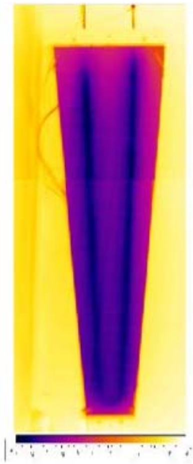


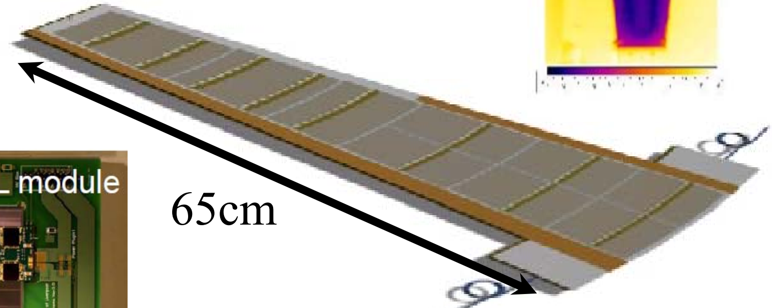
Diamond detector charge collection distance vs dose (*H. Kagan*)

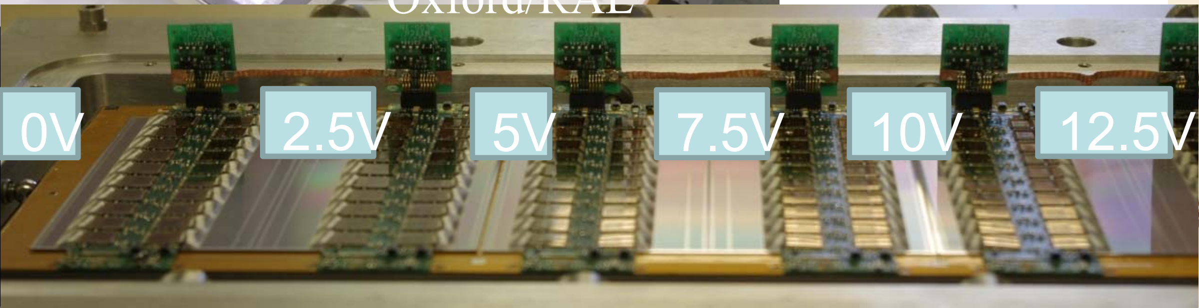


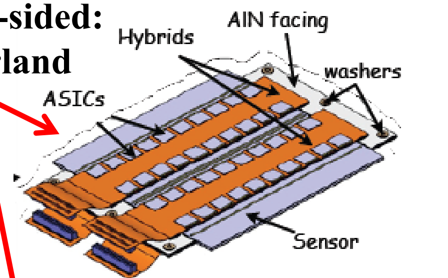


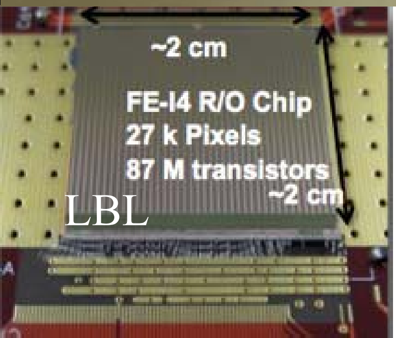
IR Image of Core Prototype for EndCap Petal

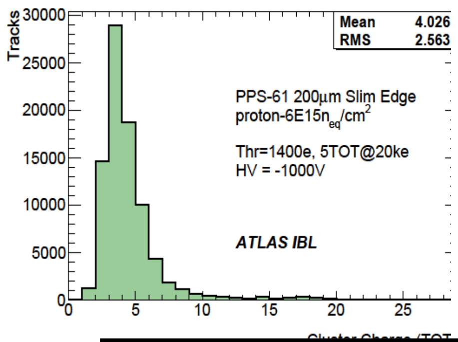


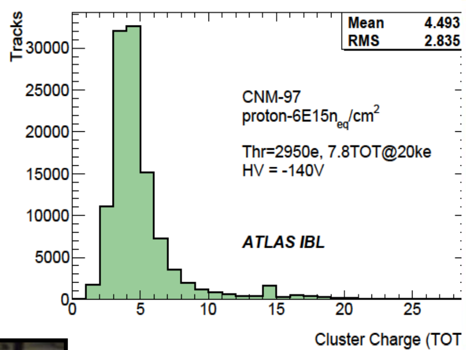


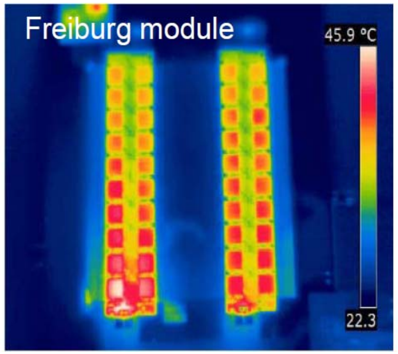


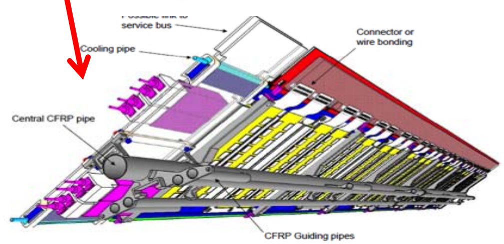


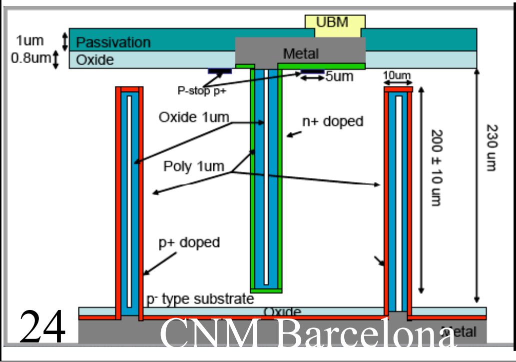


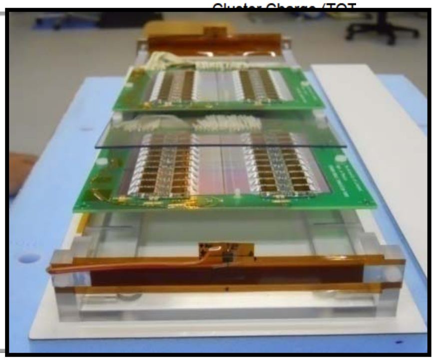


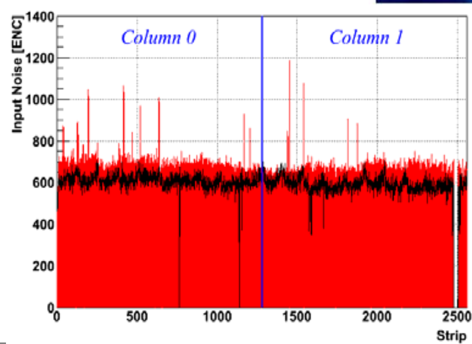


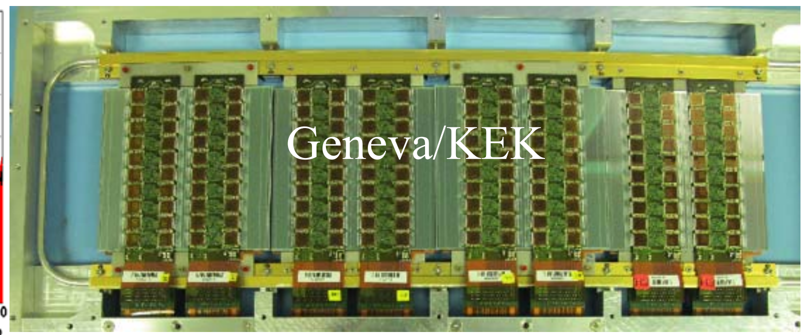


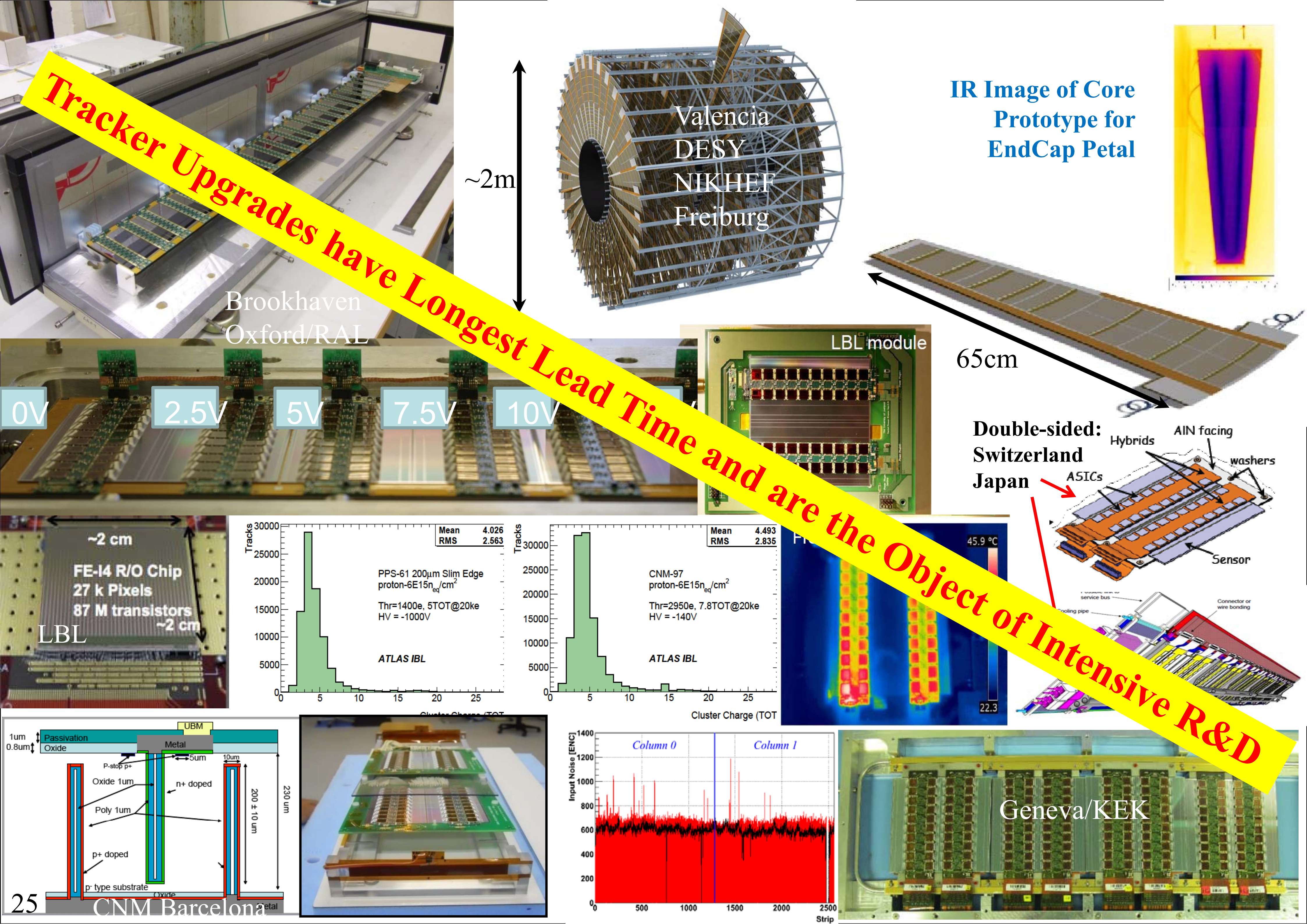




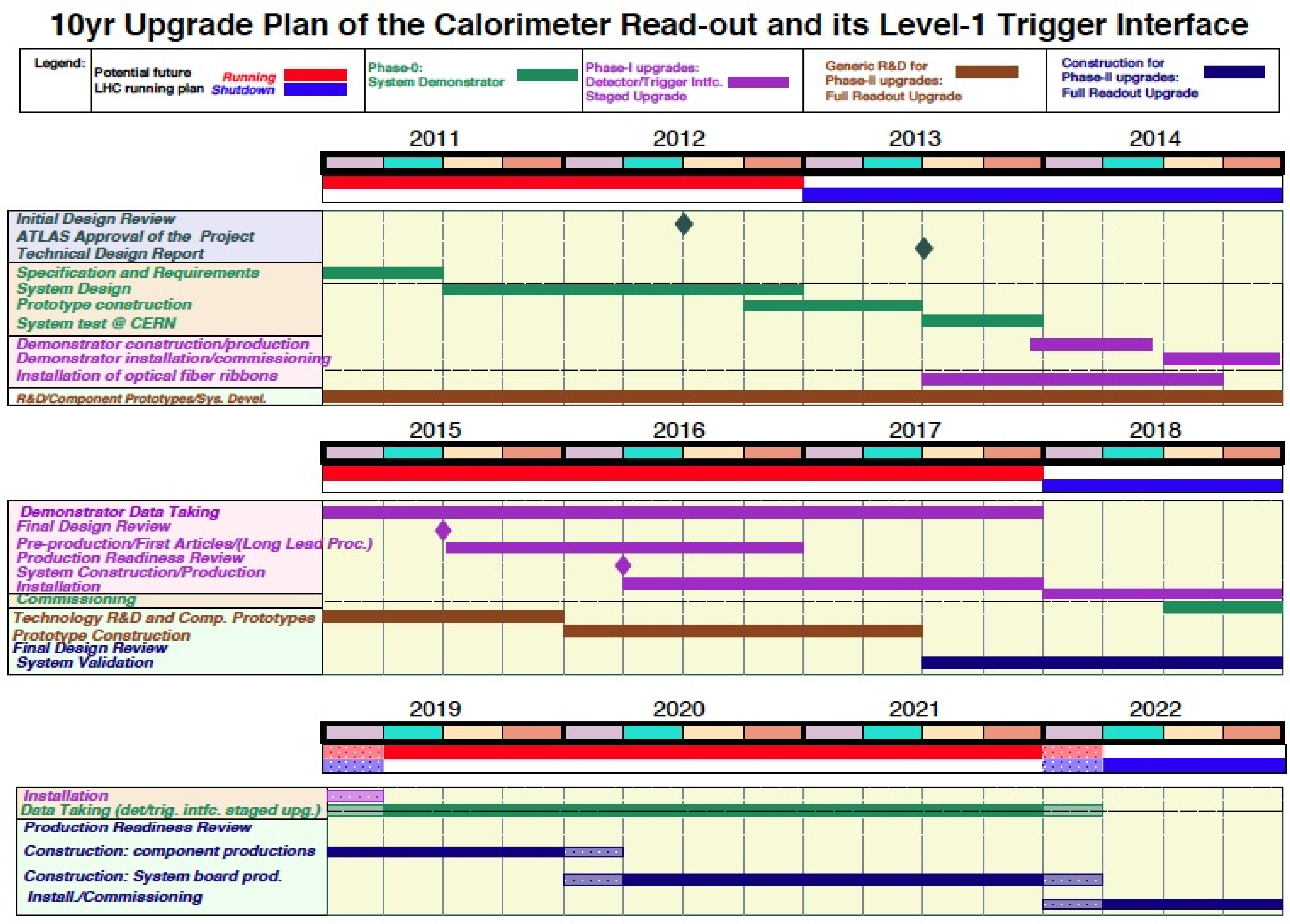




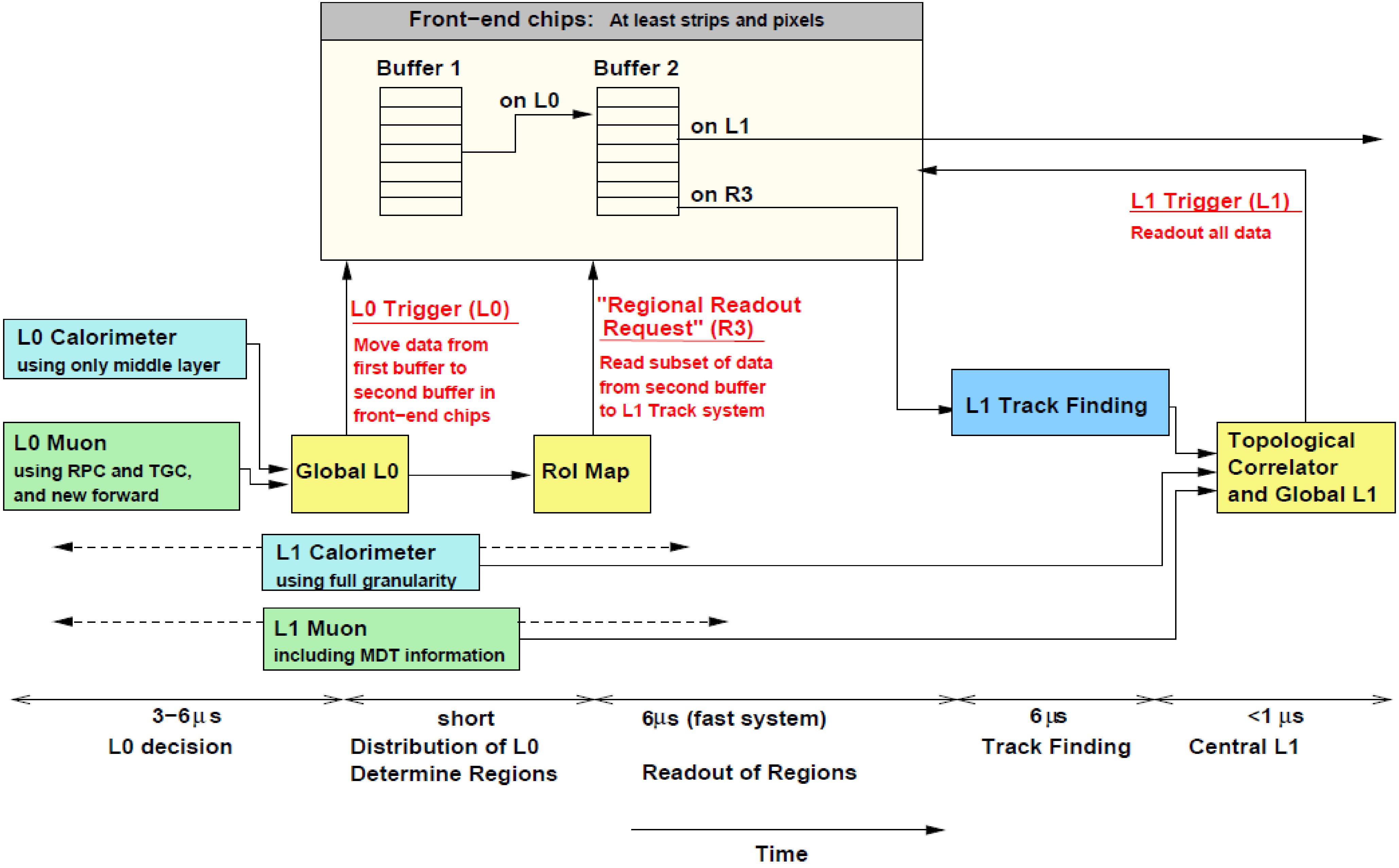



Tracker Upgrades have Longest Lead Time and are the Object of Intensive R&D
~2m
Valencia
DESY
NIKHEF
Freiburg
IR Image of Core
Prototype for
EndCap Petal
Brookhaven
Oxford/RAL
65cm
LBL module
0V
2.5V
5V
7.5V
10V
Double-sided:
Switzerland
Japan
Hybrids
AlN facing
washers
ASICs
Sensor
~2 cm
FE-I4 R/O Chip
27 k Pixels
87 M transistors
~2 cm
LBL
Mean 4.026
RMS 2.563
PPS-61 200µm Slim Edge
proton-6E15n$_{eq}$/cm^2
Thr=1400e, 5TOT@20ke
HV = -1000V
ATLAS IBL
Tracks
Mean 4.493
RMS 2.835
CNM-97
proton-6E15n$_{eq}$/cm^2
Thr=2950e, 7.8TOT@20ke
HV = -140V
ATLAS IBL
Cluster Charge (TOT
45.9 °C
22.3
Passivation
Oxide
UBM
Metal
P-stop p+
5um
10um
Oxide 1um
n+ doped
Poly 1um
p+ doped
p- type substrate
200 ± 10 um
230 um
CNM Barcelona
Column 0
Column 1
Input Noise [ENC]
Strip
Geneva/KEK

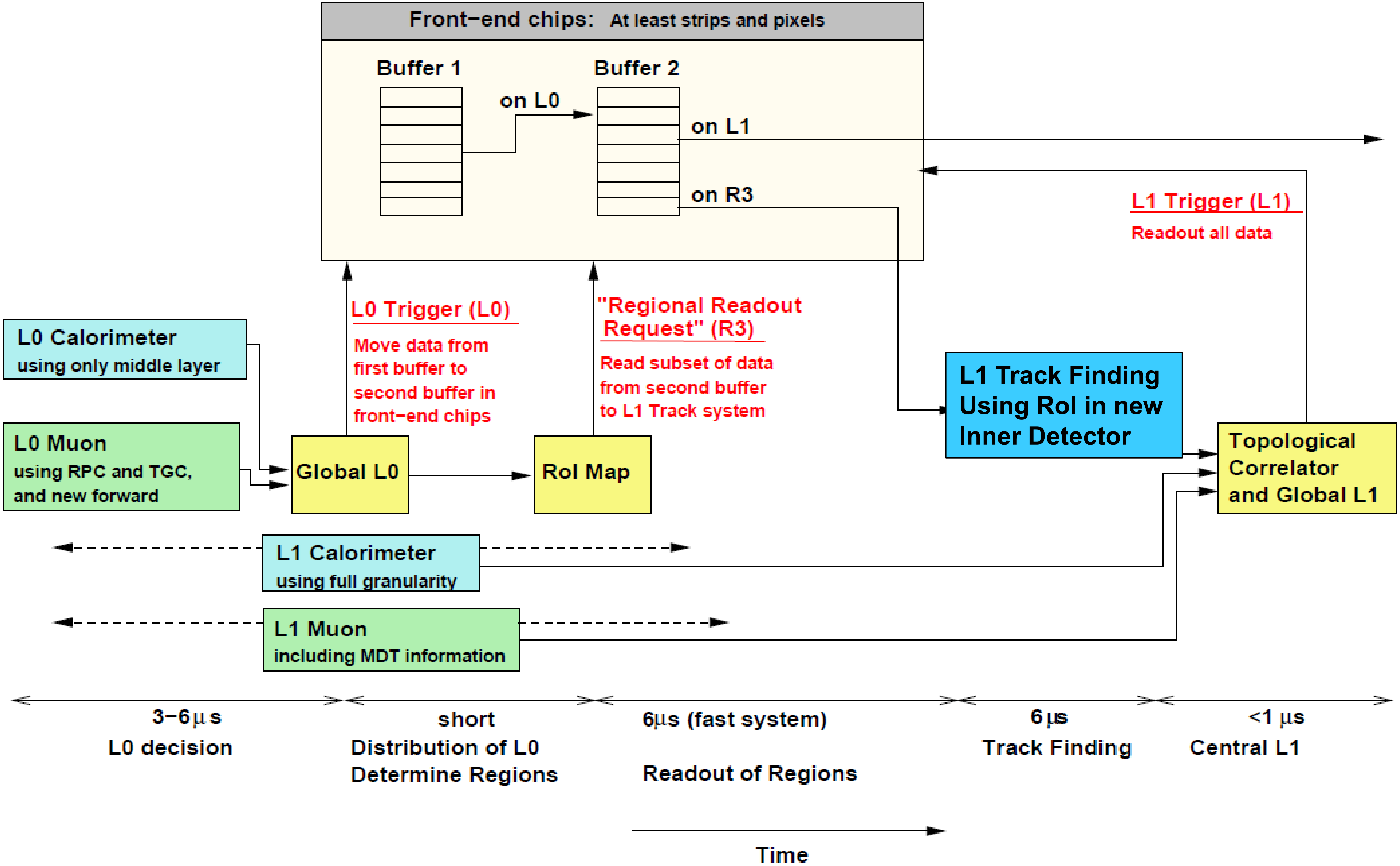
New LVL1 Calorimeter Trigger (Full Granularity)

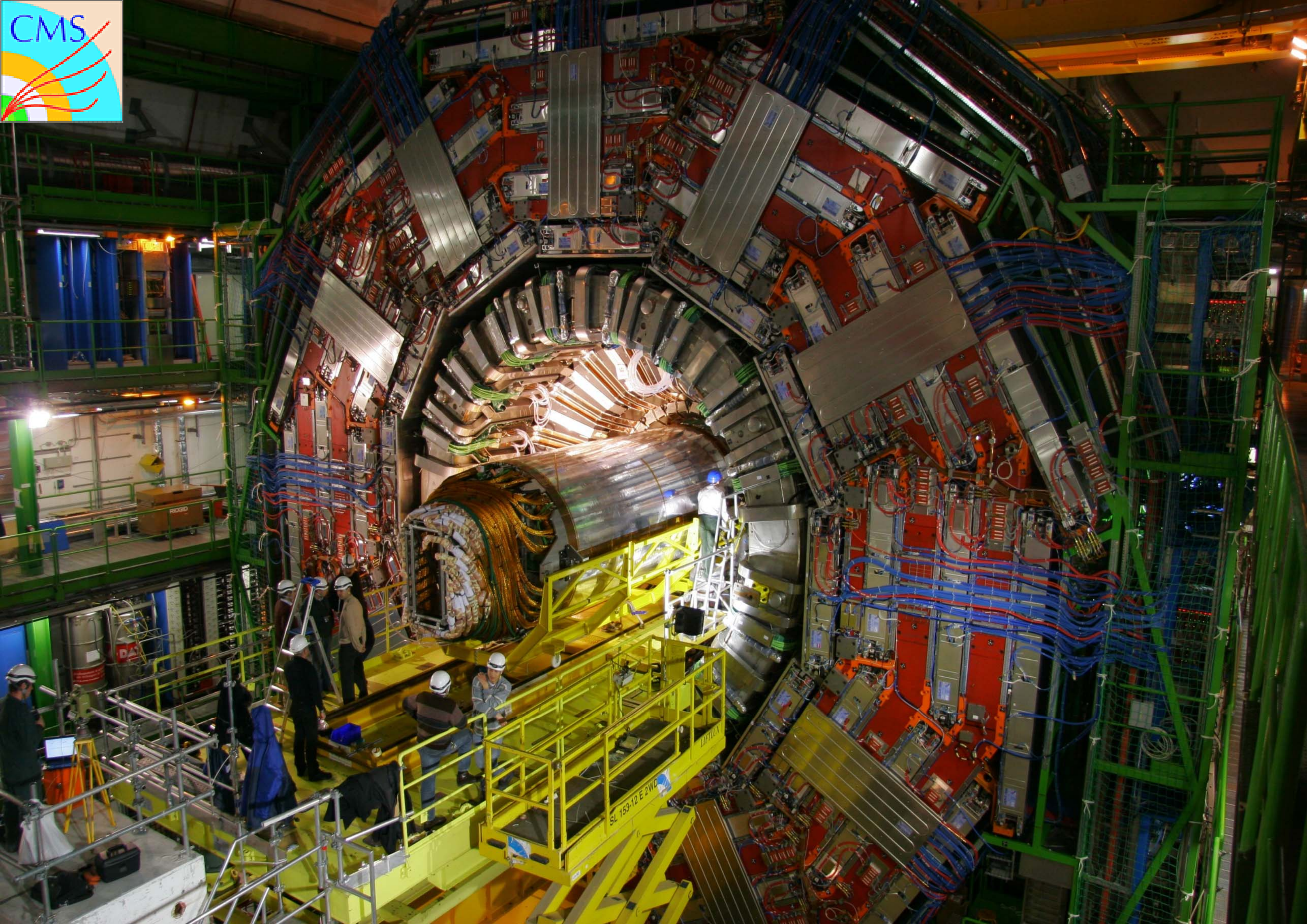


Phase-II: Possible TDAQ Scheme



Phase-II: Possible TDAQ Scheme





Upgrade Program for CMS

- LS1 Projects
  - Complete muon systems (the outer endcap layer) during LS1
  - Replace Hadron Outer calorimeter photo-transducers
  - Replace Hadron Forward calorimeter PMTs

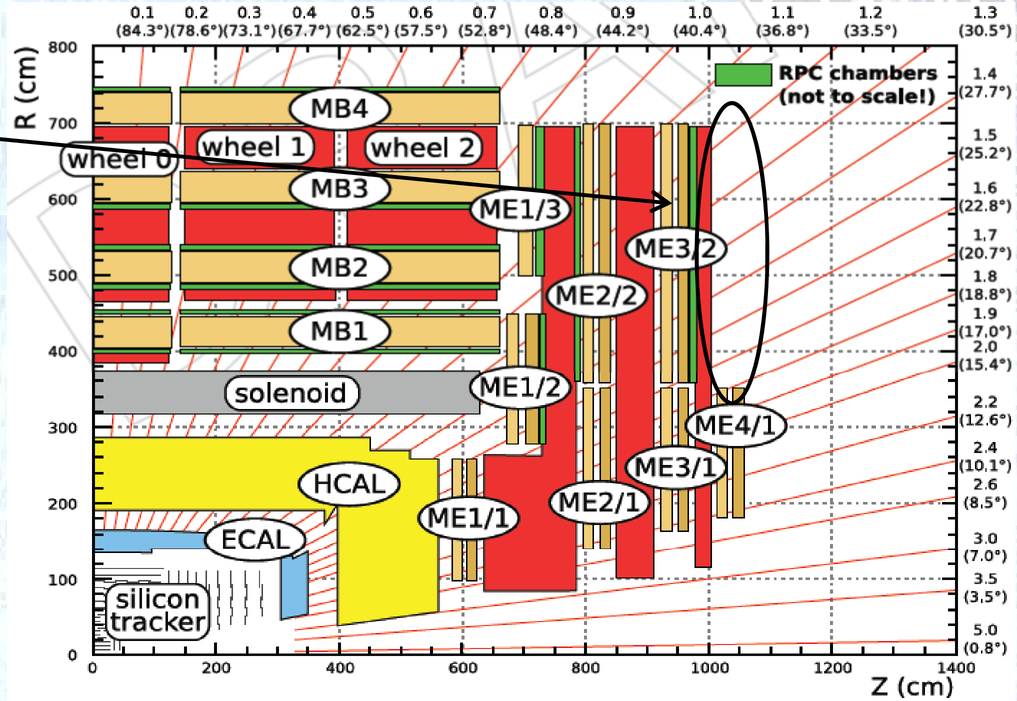
- Phase 1 Projects (by LS2)
  - Replace Pixel detector
    - Ready to install Pixel end 2016 in extended YETS of 5 month (install new beam pipe in LS1)
  - Replace HCAL Photo-transducers in HE/HB and electronics
    - Back-end in YETS (prior to FE for commissioning)
    - Photo-transducers and Front-end in extended YETS HF and in LS2 HE/HB
  - New L1-Trigger
    - Prepare to grow new L1- Trigger in parallel, de-coupled from LS2

- Phase 2 Projects (LS3)
  - Replace Tracker – implement track L1-triggering
  - Upgrade Trigger
  - Upgrade Forward Detector region

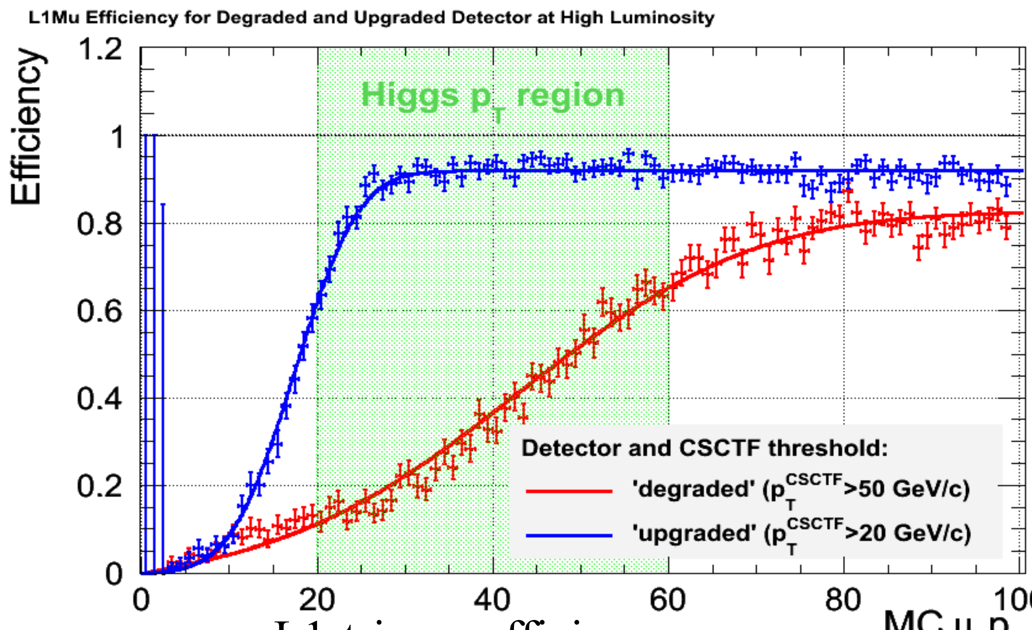
Muon Upgrade Phase 1

Complete the system in the region $1.25<|\eta|<1.8$ and install more robust electronics

- Endcap4 ring 2 muons (ME4/2)
  - Cathode Strip Chamber (CSC)
  - Resistive Plate Chambers (RPC)



CSC chamber production at CERN



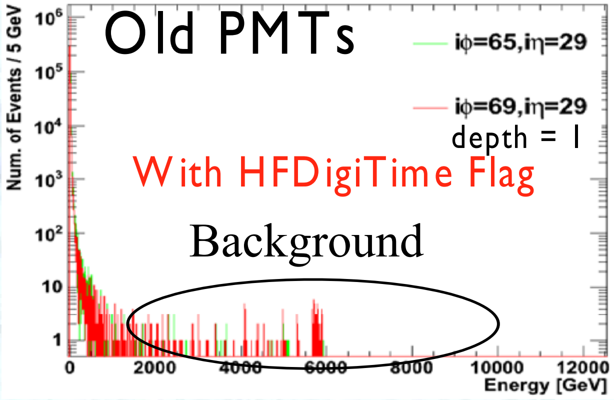
L1-trigger efficiency

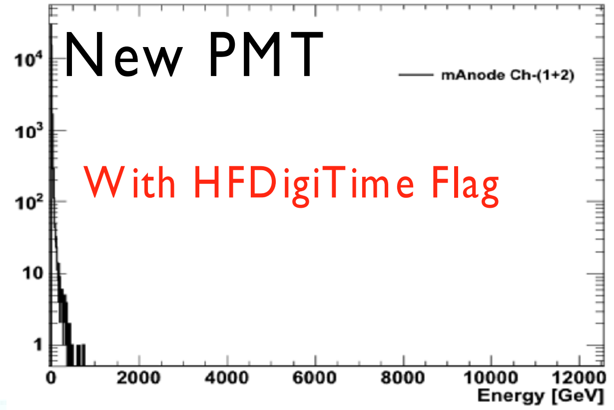
HCAL Upgrade

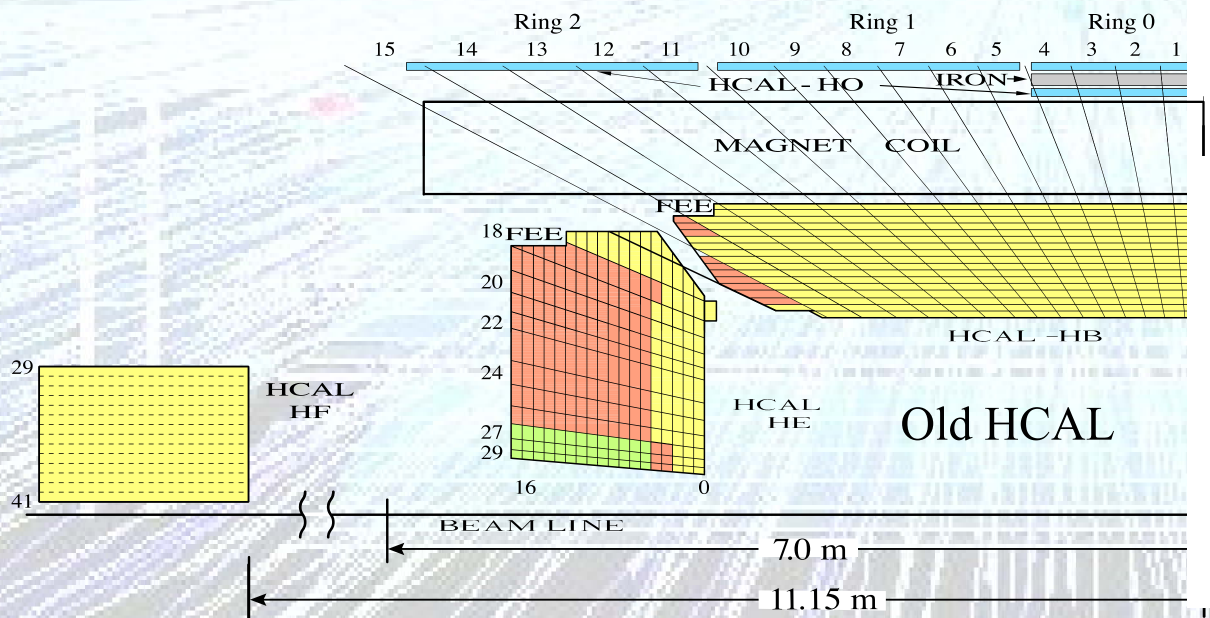
HCAL Photodetector replacements:

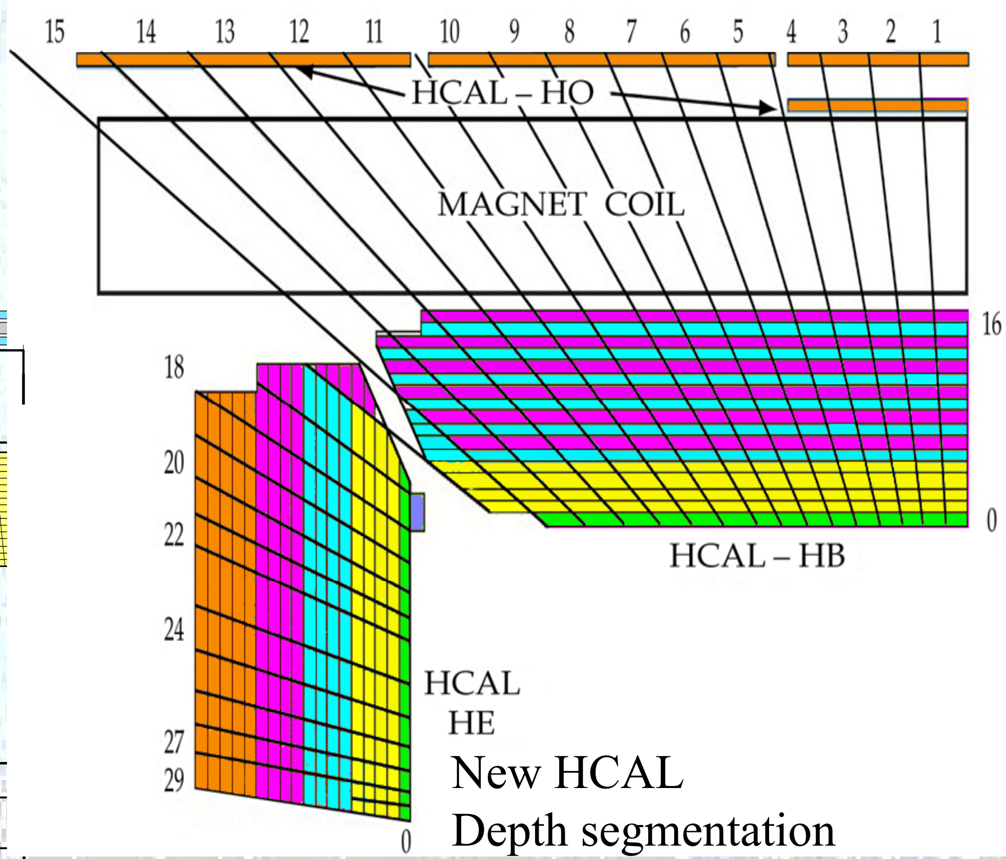
- Photo-multiplier tubes (PMT) in HF
- SiPMs in HB/HE/HO
  - Improve Signal/Noise (S/N)
  - Magnetic-field immune
- Electronics:
  - Front-End with new ADC and TDC
  - Backend in μTCA
- Depth segmentation

→ Background rejection, improved ID and isolation, radiation damage compensation







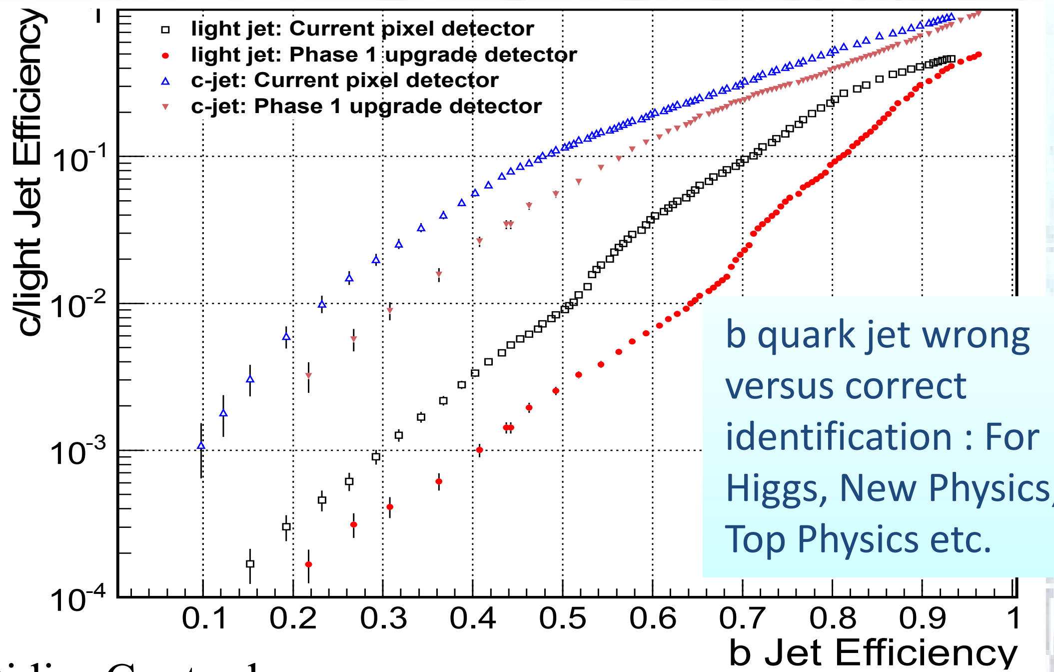


Pixel Upgrade

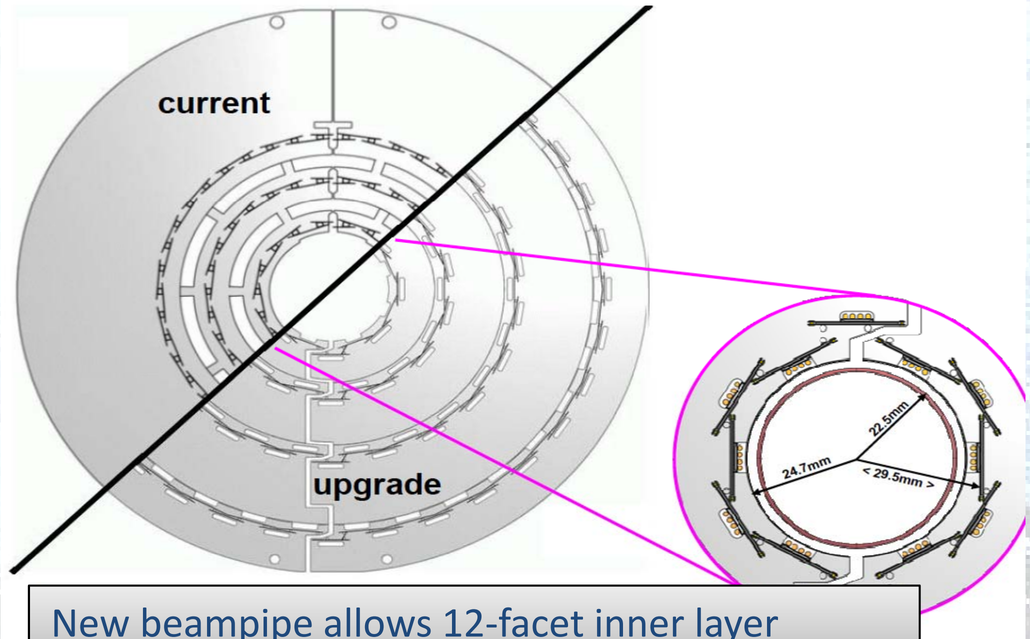
- New features:
  - New readout chip
    - Addresses data-loss at high rates
  - One more layer in all directions
    - 4 barrel layers and 3 endcap disks at each end
  - Reduced inner radius (new beampipe)
  - Reduced mass
    - CO_2 cooling
    - Powering using DC-DC converters
    - New cabling

FPIX Disk

BPIX Layout



b quark jet wrong versus correct identification : For Higgs, New Physics, Top Physics etc.



New beampipe allows 12-facet inner layer

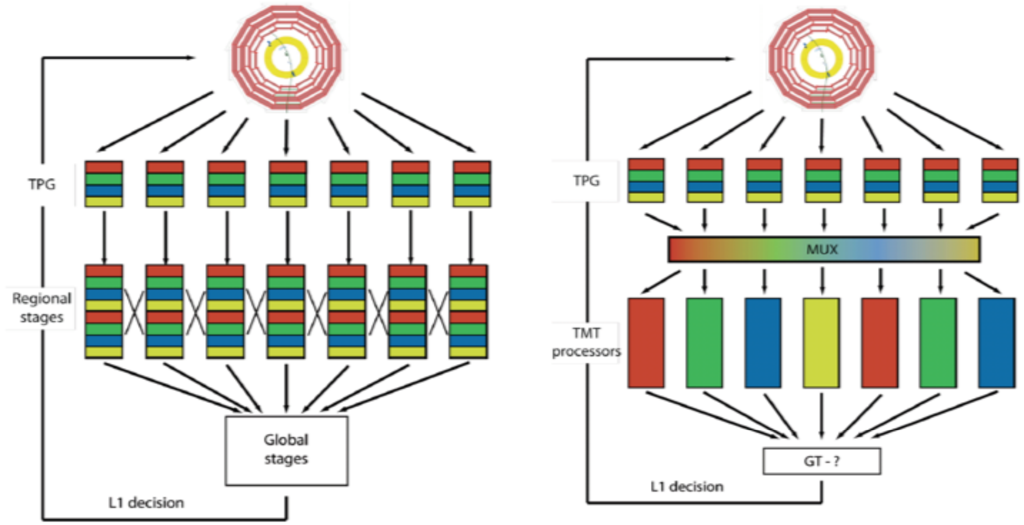
L1-Trigger Upgrade Phase 1

Improved bandwidth, granularity and capability with μTCa BE and new FPGA generation

- New Regional Calorimeter Trigger to use full tower granularity of ECAL and HCAL
  - → Better precision in η, ϕ and ET
  - → Flexibility to implement more sophisticated trigger algorithms
- Muon trigger, new CSC/RPC chambers, new electronics
  - → Increased granularity, higher precision in η, ϕ and pT, improved algorithms
- Global trigger
  - → More algorithms: better corrections, pile-up and background handling
    more correlations: invariant masses
    - ΔR – Ptrel

- Studying alternative architectures
  - Regional parallel trigger
  - Time multiplexed trigger
- Looking at common hardware solutions (standard FPGA boards for several functions)

Calorimeter Trigger System



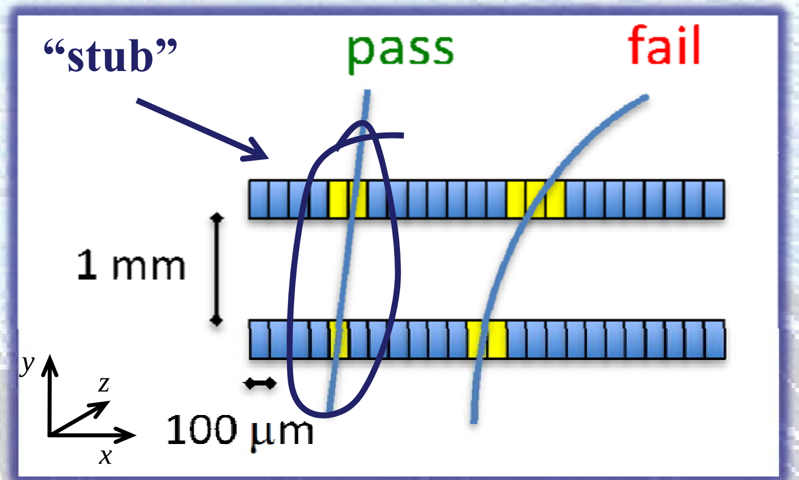
conventional regional approach and time multiplexed

Phase-II Basic Requirements and Guidelines

- Radiation hardness
  - Ultimate integrated luminosity considered ~ 3000 fb^{-1}
    - To be compared with original ~ 500 fb^{-1}
- Resolve up to ~200 collisions per bunch crossing, with few % occupancy
  - Higher granularity
- Improve tracking performance
  - Improve performance @ low $p_{T,,}$ reduce rates of particle interactions
    - Reduce material in the tracking volume
  - Improve performance @ high p_T
    - Reduce average pitch
- Tracker input to Level-1 trigger
  - μ, e and jet rates would exceed 100 kHz at high luminosity
    - Even considering “phase-1” trigger upgrades
  - Add tracking information at Level-1
    - Move part of HLT reconstruction into Level-1!
  - Objective:
    - Reconstruct “all” tracks above 2 ÷ 2.5 GeV
    - Identify the origin along the beam axis with ~ 1 mm precision

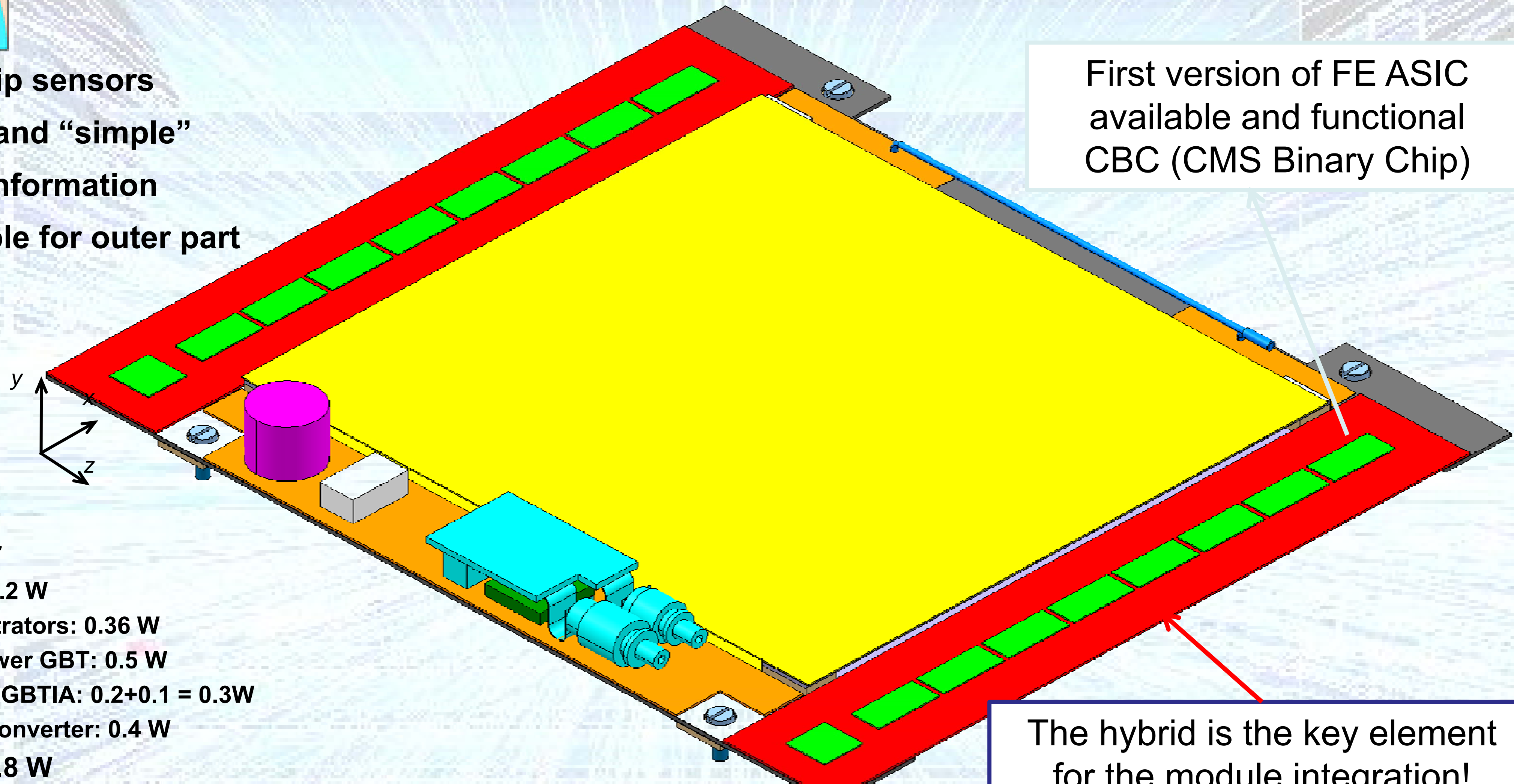
General Tracker Upgrade Concept

- Silicon modules provide at the same time “Level-1 data” (@ 40 MHZ), and “readout data” (@ 100 kHz, upon Level-1 trigger)
  - The whole tracker sends out data at each BX: “push path”
- Level-1 data require local rejection of low-p_T tracks
  - To reduce the data volume, and simplify track finding @ Level-1
    - Threshold of ~ 1÷2 GeV ® data reduction of one order of magnitude or more
- Design modules with p_T discrimination (“p_T modules”)
  - Correlate signals in two closely-spaced sensors
    - Exploit the strong magnetic field of CMS
- Level-1 “stubs” are processed in the back-end
  - Form Level-1 tracks, p_T above 2÷2.5 GeV
    - To be used to improve different trigger channels
- Different module types under development



Module with 2 Strip Sensors: “2S” Module

- **2x Strip sensors**
- **Light and “simple”**
- **No z information**
- **Suitable for outer part**

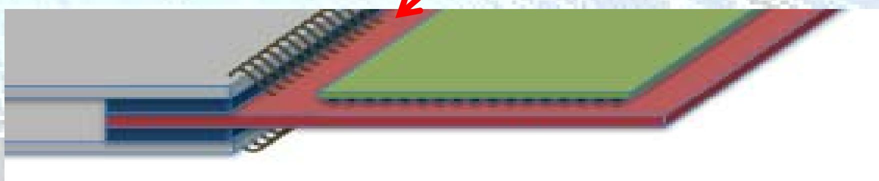


First version of FE ASIC available and functional CBC (CMS Binary Chip)

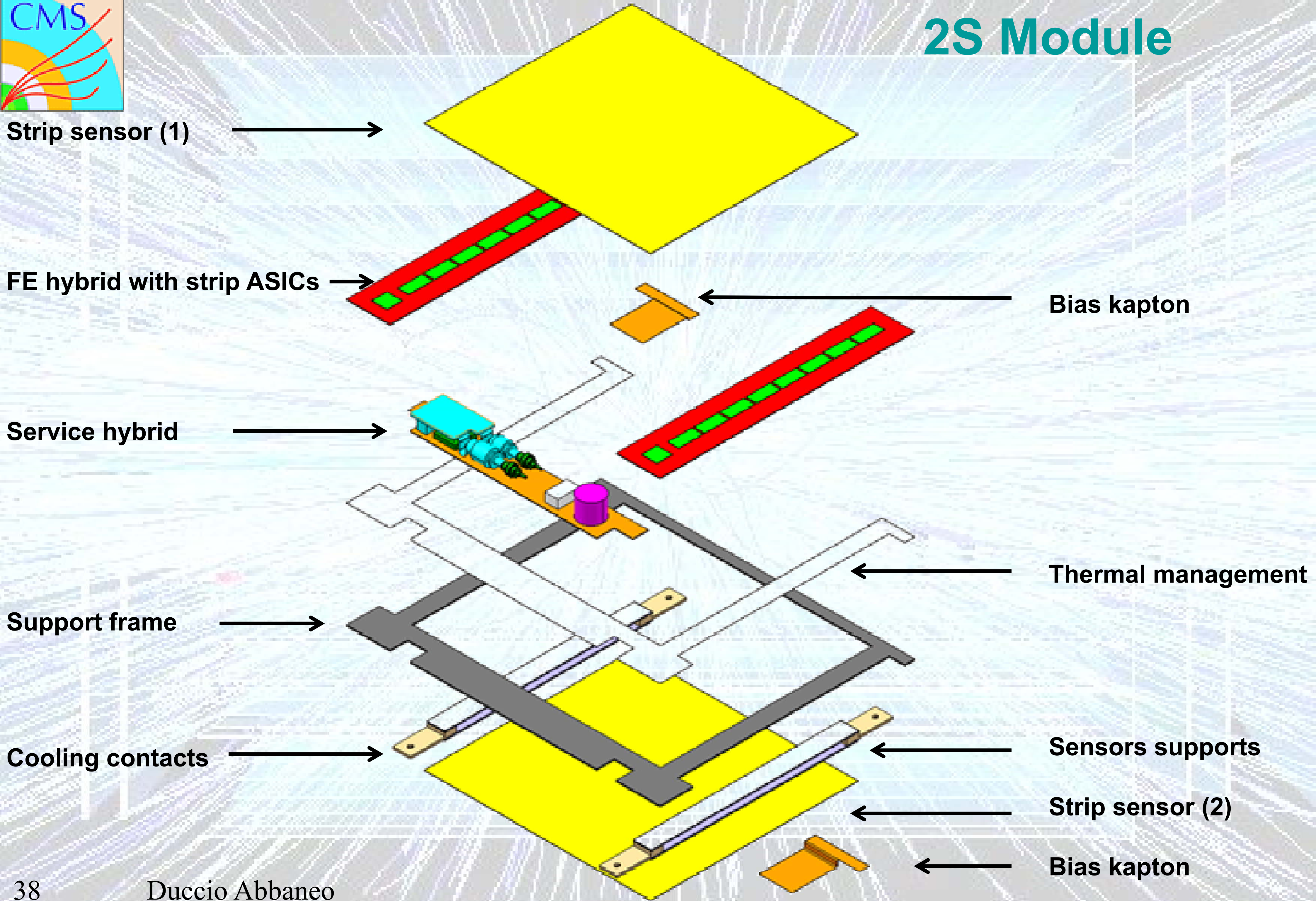
- **Power**
- **CBCs: 1.2 W**
- **Concentrators: 0.36 W**
- **Low-power GBT: 0.5 W**
- **GBLD + GBTIA: 0.2+0.1 = 0.3W**
- **Power converter: 0.4 W**
- **Total 2.8 W**

The hybrid is the key element for the module integration!

- **≈ 5 cm long strips, ≈ 90 μm pitch, ≈ 10x10 cm^2 overall sensor size**
- **Wirebonds from the sensors to the hybrid <u>on the two sides</u>**
- **2048 channels on each hybrid**
- **Chips bump-bonded onto the hybrid**
- **Prototyping to start during 2012!**

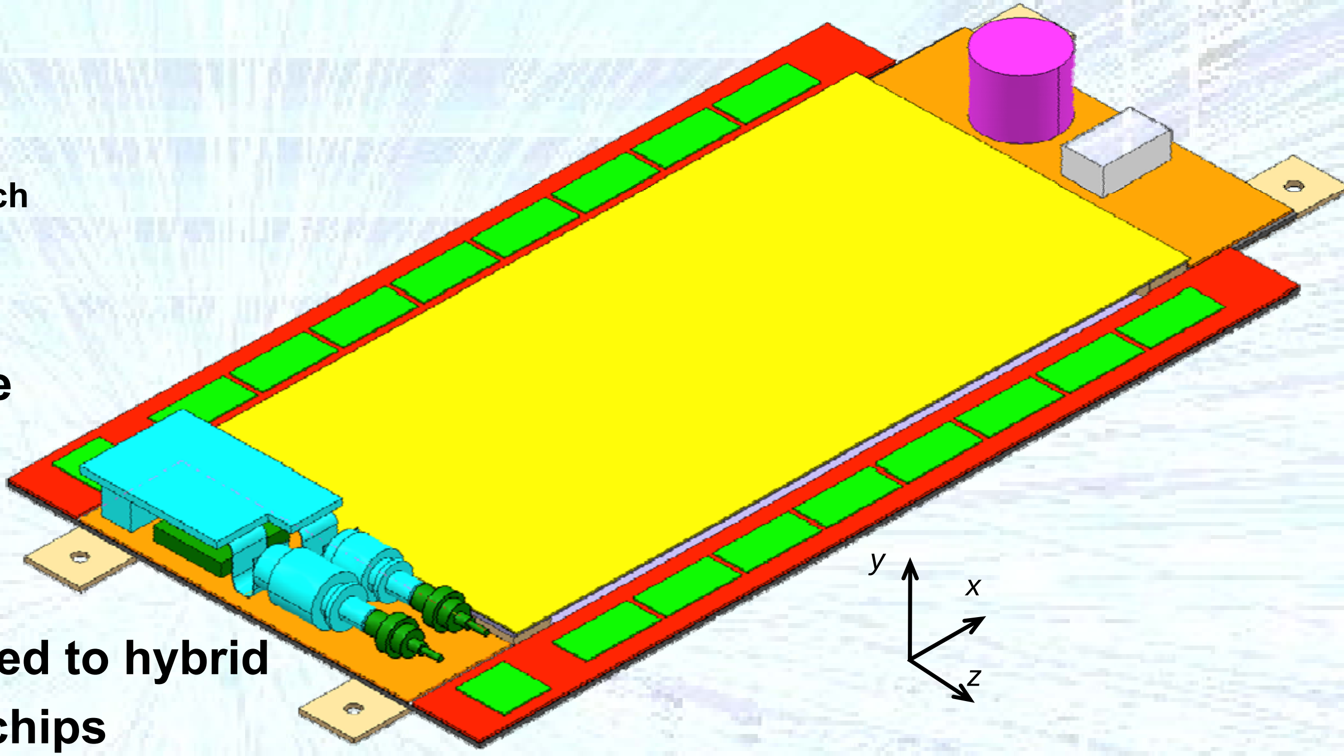


2S Module

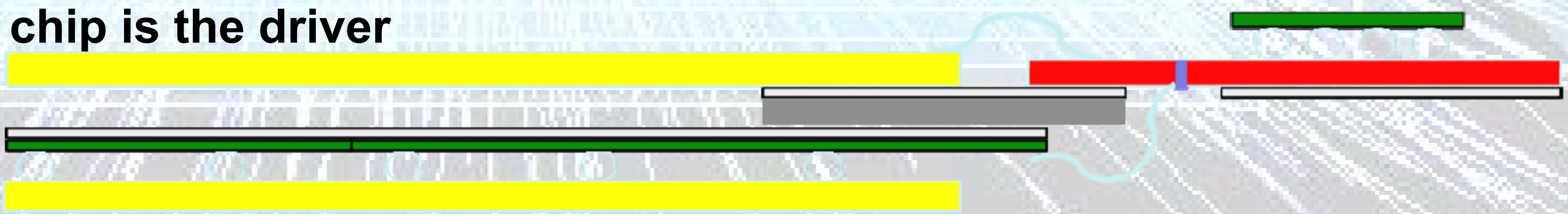

Strip sensor (1)
FE hybrid with strip ASICs
Bias kapton
Service hybrid
Thermal management
Support frame
Cooling contacts
Sensors supports
Strip sensor (2)
Bias kapton

Pixel-Strip module with Horizontal Connections: "PS" Module

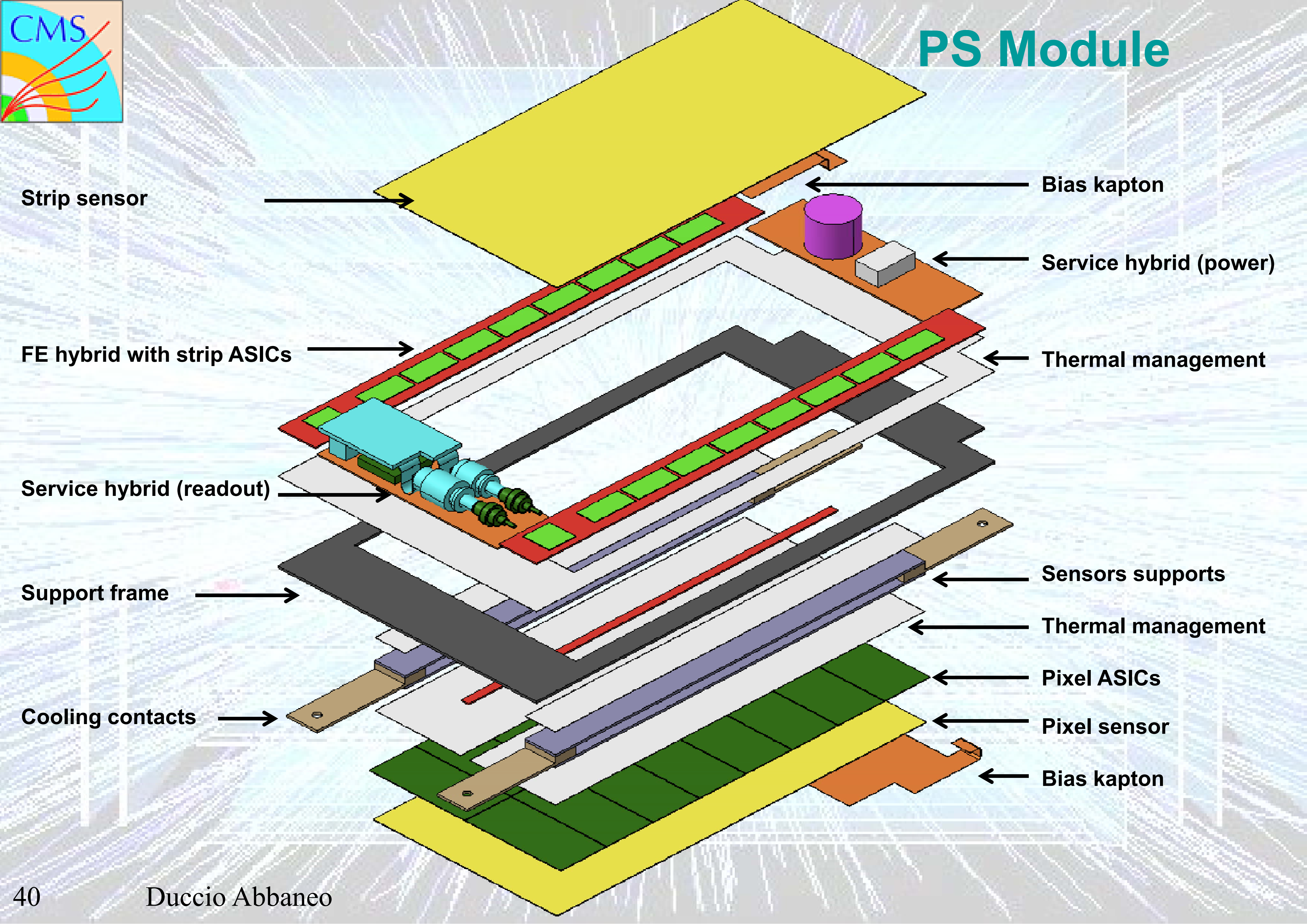
- **Sensors:**
  - Top sensor: strips
    - 2×25 mm, 100 μm pitch
      - Option to move to 50 μm pitch
  - Bottom sensor: long pixels
    - 100 μm × 1500 μm
  - ≈ 5x10 cm^2 overall sensor size



- **Readout:**
  - Top: wirebonds to "hybrid"
  - Bottom: pixel chips wirebonded to hybrid
  - Correlation logic in the pixel chips
- **No interposer, sensors spacing tunable**
- **Power estimates**
    - Pixels + Strips + Logic ~ 2.62 + 0.51 + 0.38 W = 3.51 W
    - Low-power GBT + GBLD + GBTIA ~ 0.5 + 0.2 + 0.1 = 0.8 W
    - Power converter ~0.75 W
  - Total ~ 5.1 W, pixel chip is the driver

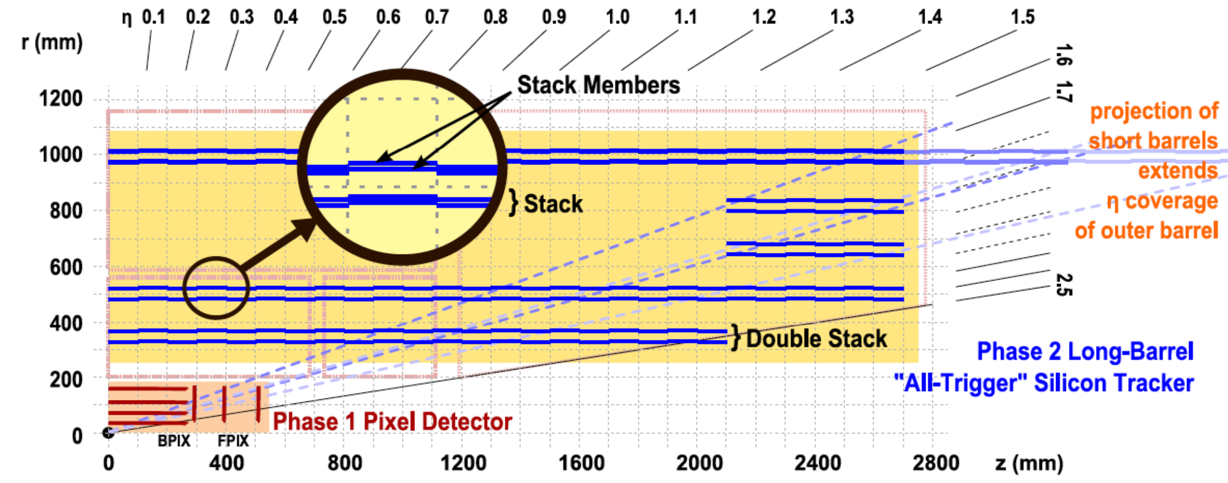


PS Module

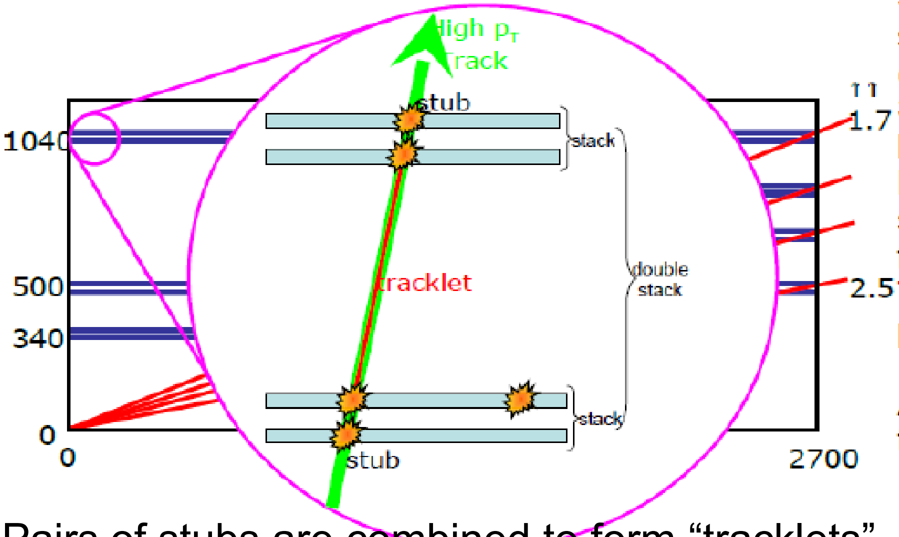

Strip sensor
Bias kapton
Service hybrid (power)
FE hybrid with strip ASICs
Thermal management
Service hybrid (readout)
Sensors supports
Support frame
Thermal management
Pixel ASICs
Cooling contacts
Pixel sensor
Bias kapton

Optimized Layout of L1 Track Finding

- The "long-barrel" double-stack layout

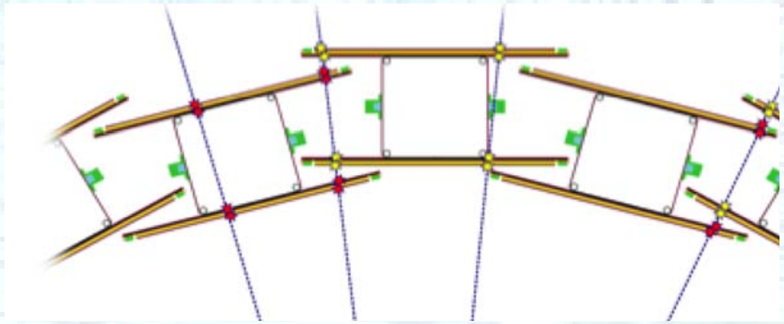


6 long layers = 3 Super layers



Pairs of stubs are combined to form "tracklets"

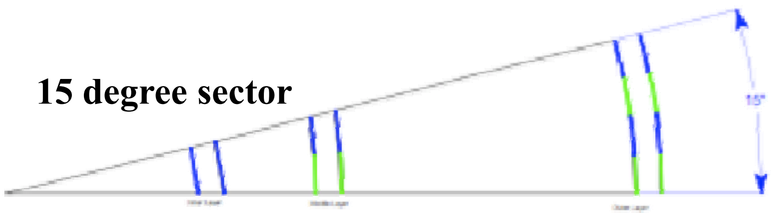
ϕ arrangement within double-stack layer



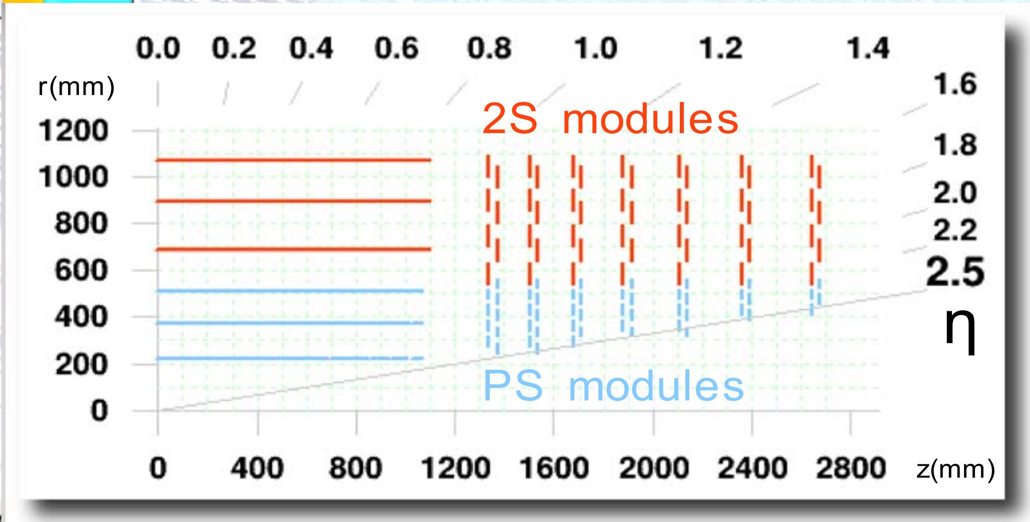
Common supporting mechanics

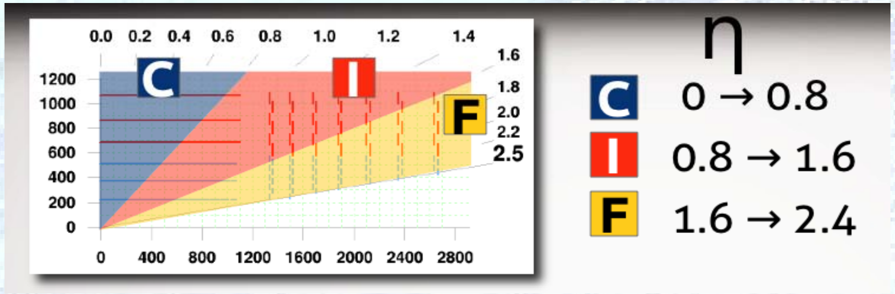
(See back-up slide 80 on vertical integration with interposer version of PS module)

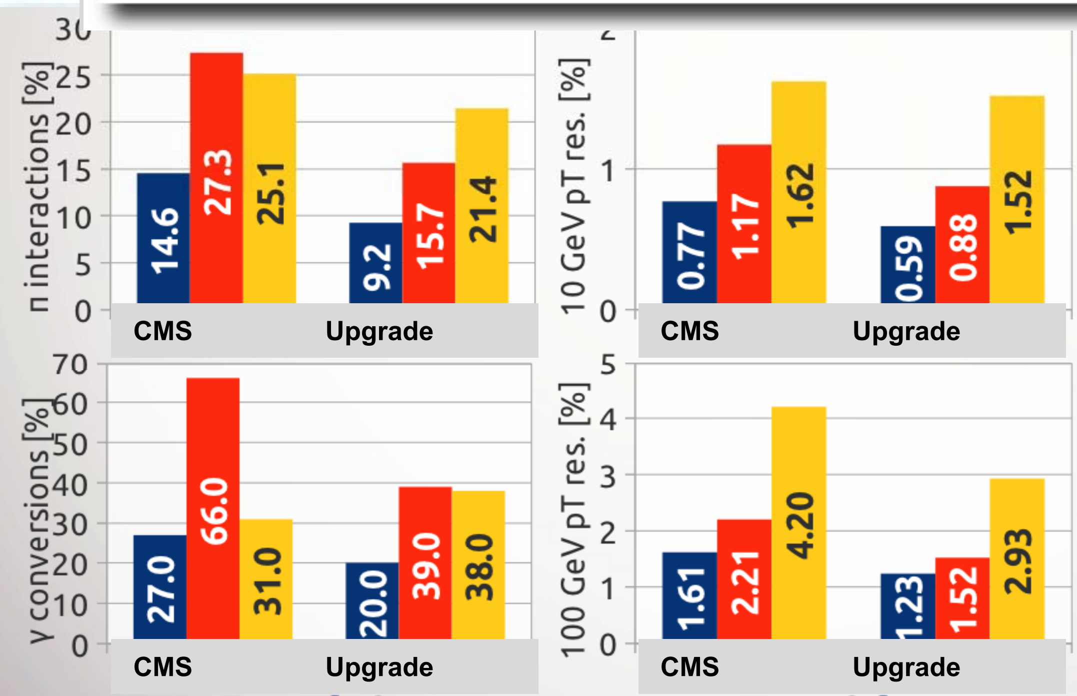
Self-contained ϕ sectors.
Each sector needs to be combined with the two neighbouring sectors (left and right) to "contain" ~2.5 GeV tracks.



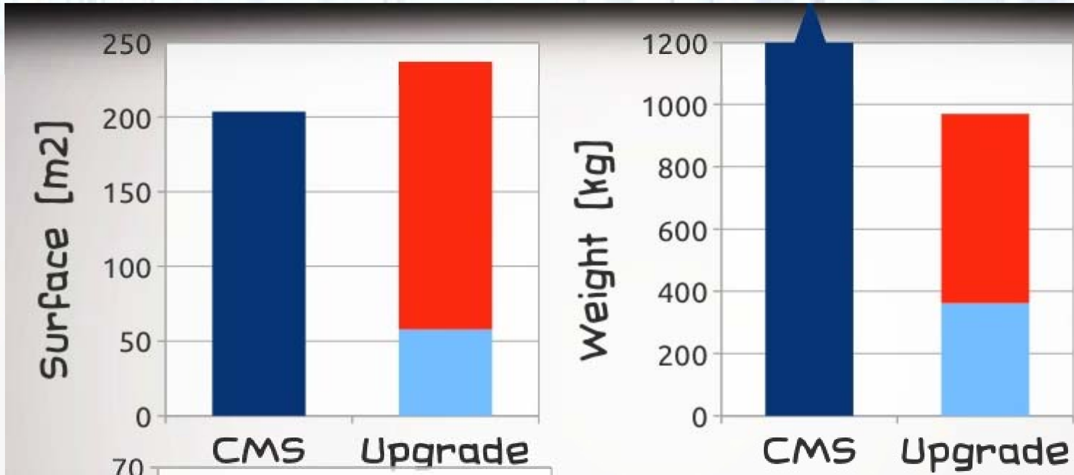
Alternative Tracker Layout

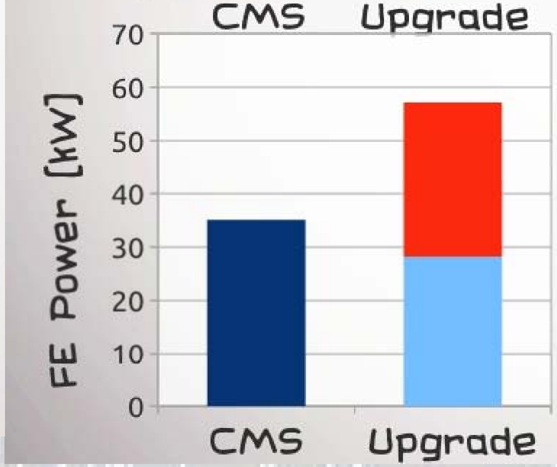






Particle interactions **Tracking resolution**





This model implements a "phase-1" pixel detector

Assumptions on material are rather conservative!

Phase 2 Pixels

- The phase-1 pixel detector is not the CMS ultimate pixel
- Construction time is shorter, ~ 2 more years to converge on a design compared to the outer tracker
- Discussions started; convergence on some basic concepts
  - Aiming at a significantly smaller pixel size. Possibly as small as 30×100 μm^2?
  - 65 nm seems to be a good technology choice for the ASIC
    - Strong technology node, likely to be available for very long
    - Can squeeze 4× digital logic in same area wrt 130 nm
  - Thin planar sensors with small pixels could be a robust baseline
  - 3D silicon very appealing option with potentially excellent performance
  - Diamonds the ultimate radiation hardness? Production and cost still an issue
- Sketch of a 5-year development plan defined

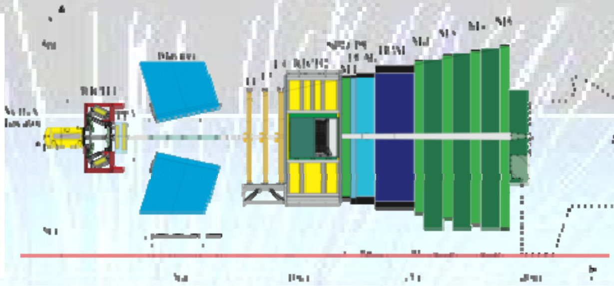
CMS Outlook

– LS1 Projects
  - Muons: construction in progress
  - HCAL: Photo-transducers delivered and qualified

– Phase 1 Projects (by LS2) Pixel – HCAL – L1-Trigger
  - Good technical progress
  - Physics Performance studies ongoing
  - TDR in preparation

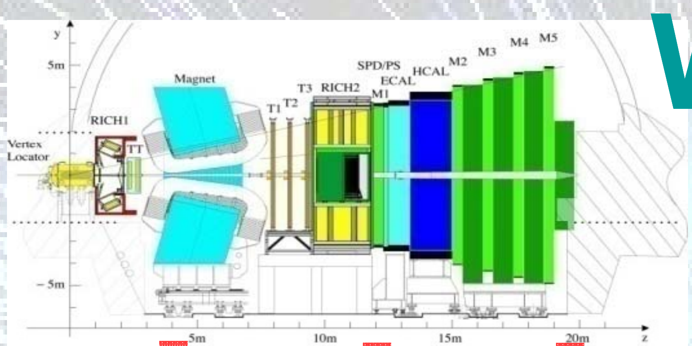
– Phase 2 Tracker design and R&D (LS3)
  - All the necessary R&D activities are ongoing
  - Encouraging indications that the goals could be met
  - Need to converge on an optimal design in the next ~ 2 years

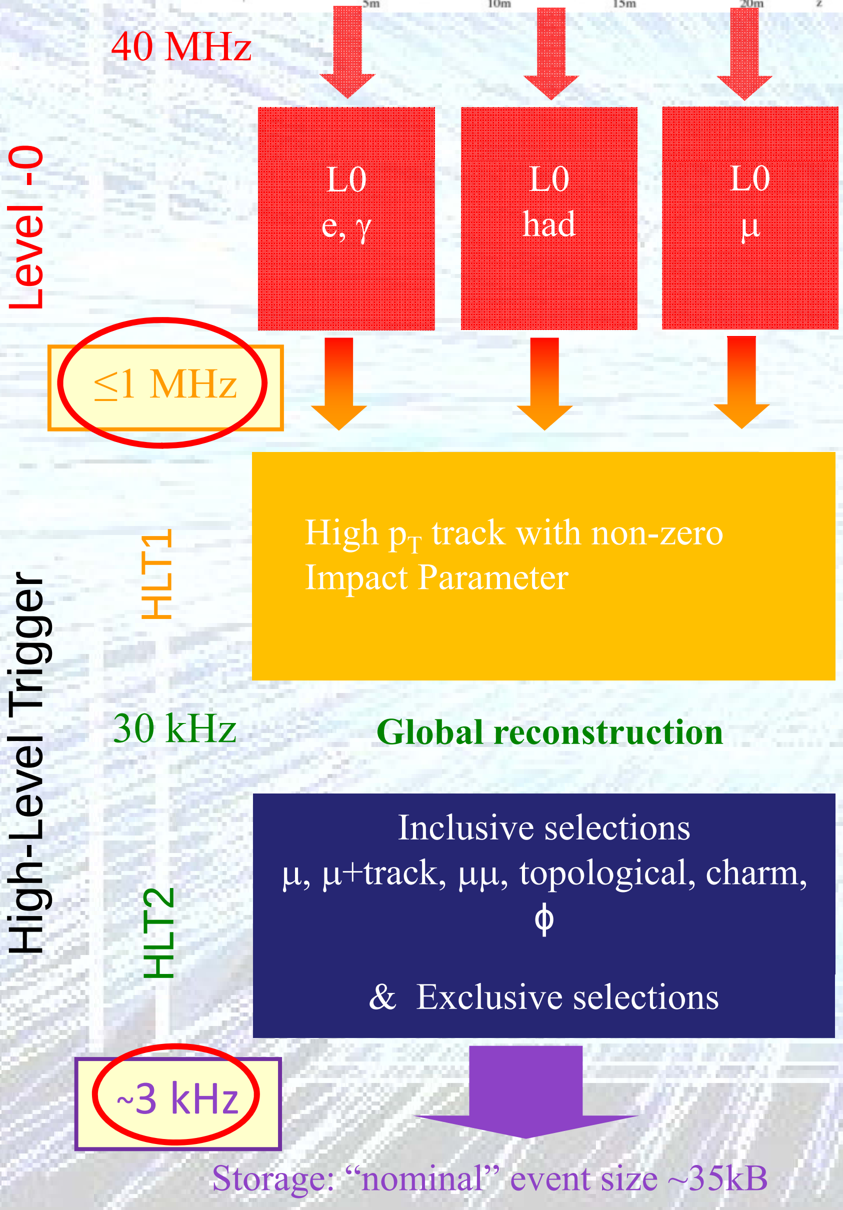
LHCb



Why Upgrade LHCb?

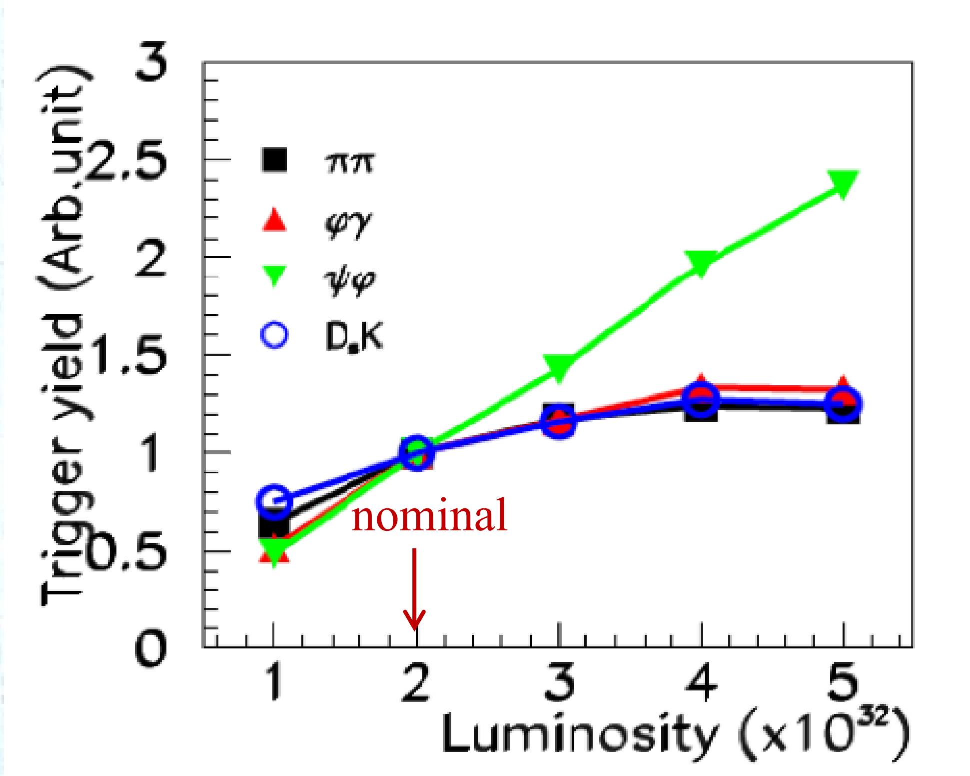
CERN, LHCC Upgrade Session, 6th December 2012
A. Schopper for the LHCb Collaboration





main limitation of current detector:

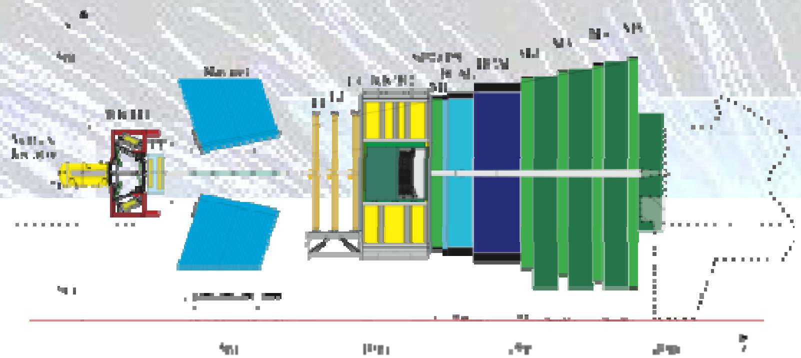
- **bandwidth & rate limitation of L0 trigger**
- **trigger yield for hadronic channels flattens out at $\mathcal{L} \sim 2\text{-}3{\cdot}10^{32}\ \mathrm{cm^{-2}\,s^{-1}}$ (E_T - cut!)**



→ **allows to accumulate ~1-1.5/fb per year**

→ **~5-7/fb in 5 years up to LS2**

Upgrade of LHCb



- ✓ flexible software trigger with up to 40 MHz input rate and 20 kHz output rate
- ✓ run at ~ 5-10 times nominal LHCb luminosity → $\mathcal{L}$ ~ 1-2 · 10^{33} cm^{-2} s^{-1}
- ➢ big gain in signal efficiency (up to x7 for hadron modes)
- ➢ upgrade electronics & DAQ architecture
- ➢ collect ≥ 5/fb per year and ~ 50/fb in 10 years

40 MHz

Calorimeters
Muon

LLT

p_T of h, μ, e/γ

LLT custom electronics

1 – 40 MHz

All detectors information

HLT

tracking and vertexing
p_T and impact parameter cuts
inclusive/exclusive selections

CPU Event Filter Farm

20 kHz

LLT-rate (MHz)	1	5	10
$B_s \to \phi\phi$	0.12	0.51	0.82
$B^0 \to K^*\mu\mu$	0.36	0.89	0.97
$B_s \to \phi\gamma$	0.39	0.92	1.00

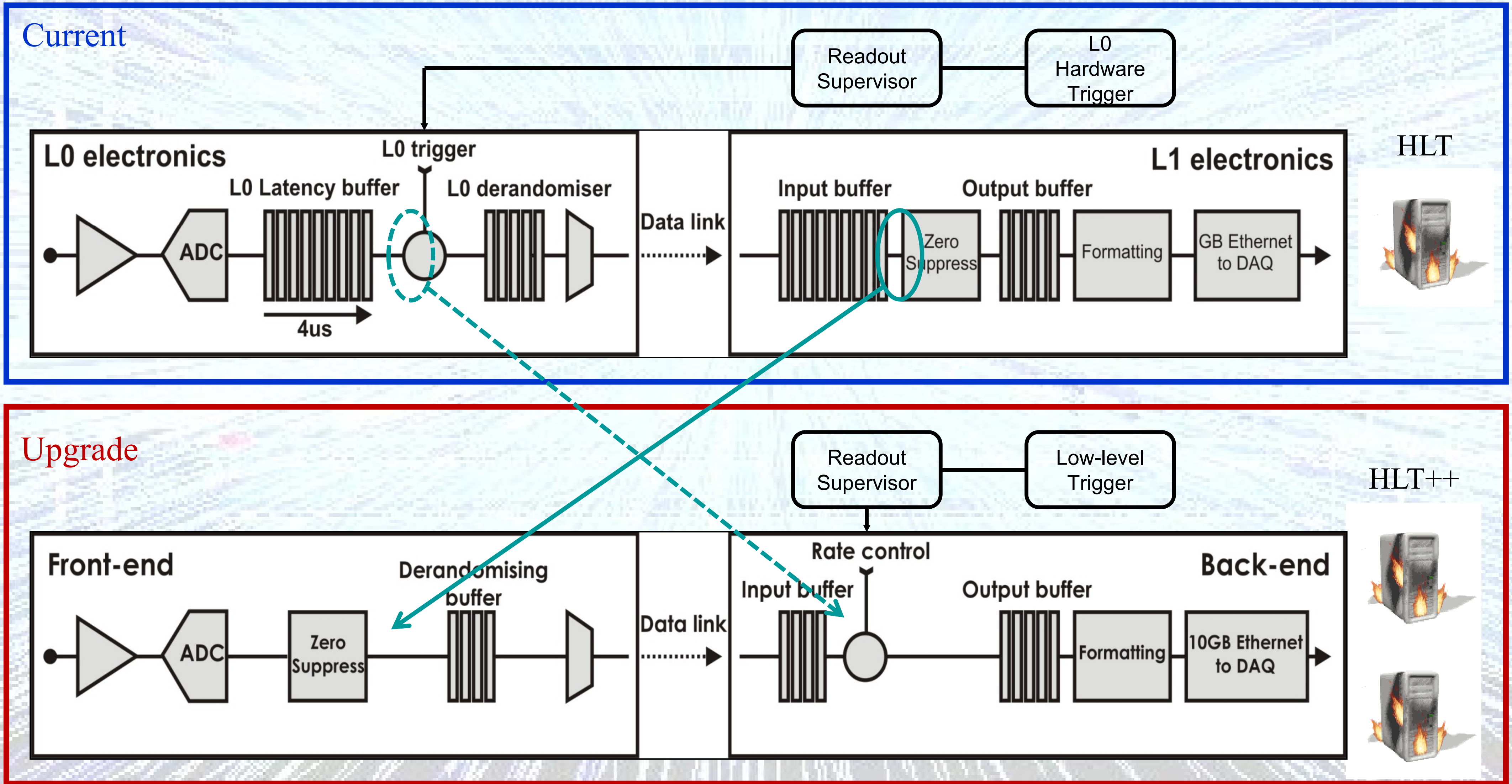
EFF size	5×2011	10×2011
LLT-rate (MHz)	5.1	10.5
HLT1-rate (kHz)	270	570
HLT2-rate (kHz)	16	26
Total signal efficiency		
$B_s \to \phi\phi$	0.29	0.50
$B^0 \to K^*\mu\mu$	0.75	0.85
$B_s \to \phi\gamma$	0.43	0.53

Sensitivities to Key Quark Flavour Channels

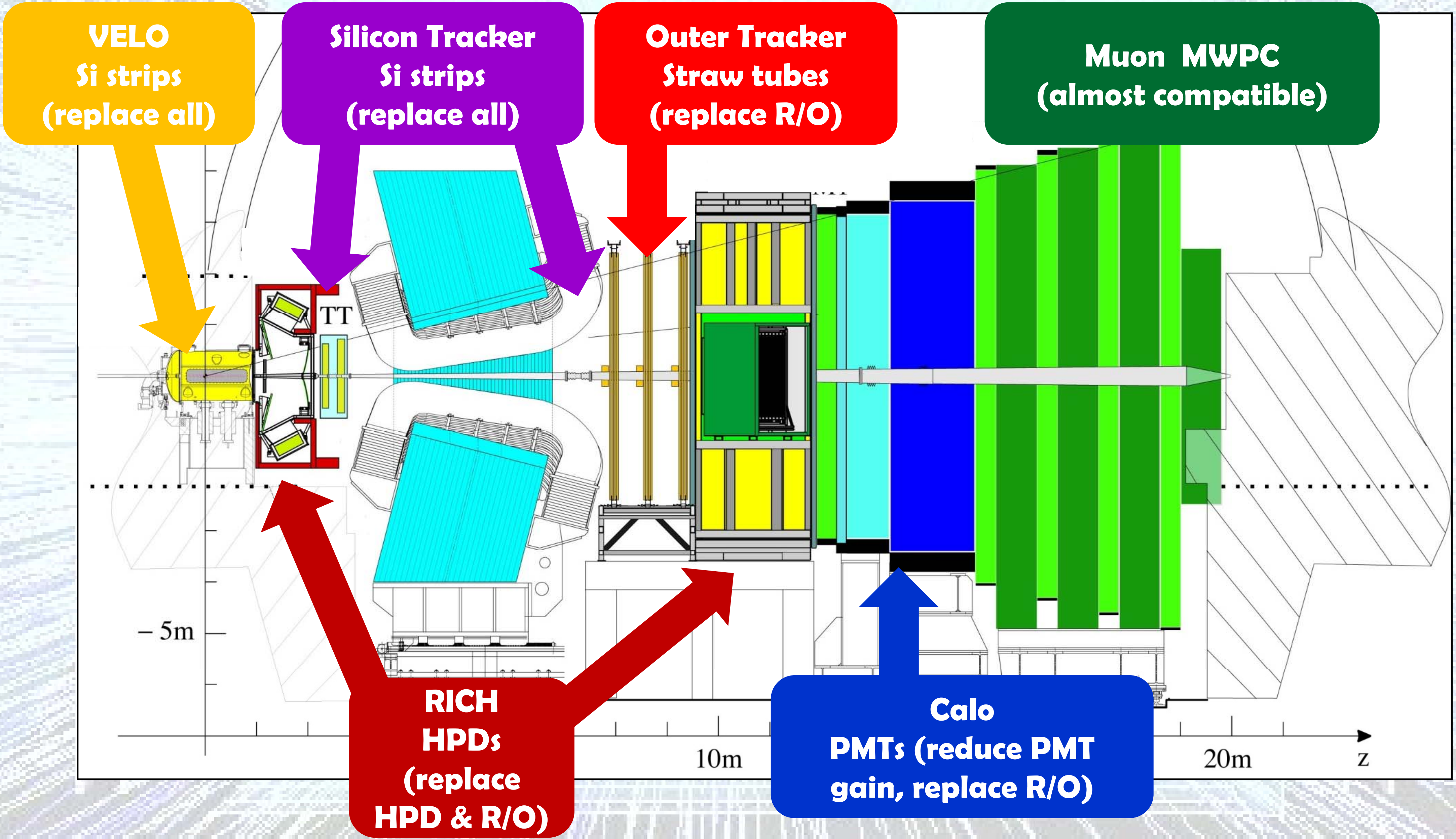
Type	Observable	Current precision	LHCb (5 fb^{-1})	Upgrade (50 fb^{-1})	Theory uncertainty
Gluonic penguin	$S(B_s \to \phi\phi)$	-	0.08	0.02	0.02
	$S(B_s \to K^{*0}\bar{K}^{*0})$	-	0.07	0.02	< 0.02
	$S(B^0 \to \phi K^0_S)$	0.17	0.15	0.03	0.02
B_s mixing	$2\beta_s\ (B_s \to J/\psi\phi)$	0.35	0.019	0.006	~ 0.003
Right-handed currents	$S(B_s \to \phi\gamma)$	-	0.07	0.02	< 0.01
	$\mathcal{A}^{\Delta\Gamma_s}(B_s \to \phi\gamma)$	-	0.14	0.03	0.02
E/W penguin	$A_T^{(2)}(B^0 \to K^{*0}\mu^+\mu^-)$	-	0.14	0.04	0.05
	$s_0\ A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	-	4%	1%	7%
Higgs penguin	$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	30%	8%	$< 10\%$
	$\frac{\mathcal{B}(B^0 \to \mu^+\mu^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)}$	-	-	$\sim 35\%$	$\sim 5\%$
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	$\sim 20°$	$\sim 4°$	0.9°	negligible
	$\gamma\ (B_s \to D_s K)$	-	$\sim 7°$	1.5°	negligible
	$\beta\ (B^0 \to J/\psi\ K^0)$	1°	0.5°	0.2°	negligible
Charm CPV	A_Γ	2.5×10^{-3}	2×10^{-4}	4×10^{-5}	-
	$A^{dir}_{CP}(KK) - A^{dir}_{CP}(\pi\pi)$	4.3×10^{-3}	4×10^{-4}	8×10^{-5}	-

Common 40 MHz Electronics Architecture

Front-end electronics: transmit data from every 25ns BX



Detector Upgrade to 40 MHz R/O



VELO Upgrade Options

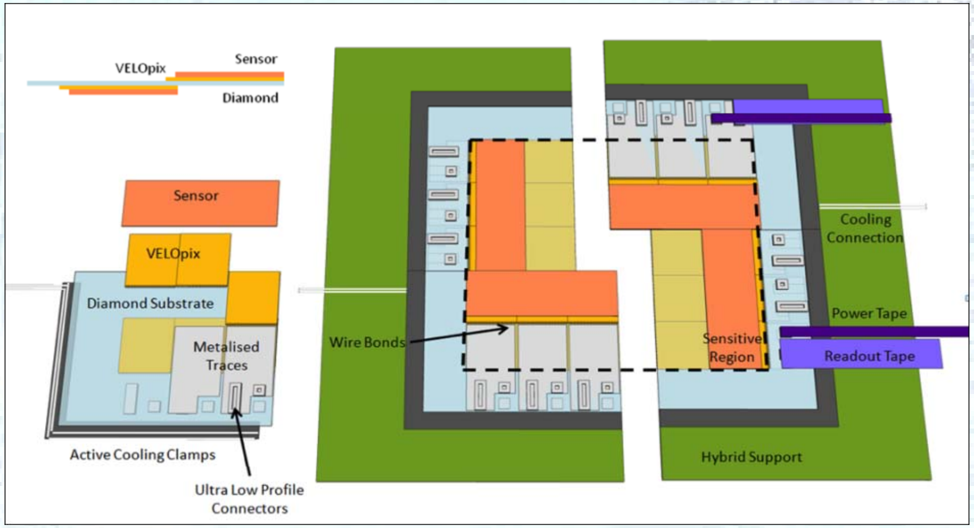
Pixel detector:

- VELOPIX based on Timepix chip with 55 µm x 55 µm pixel size, advantageous for pattern recognition
- L-shaped half modules with two blocks of 6 chips
- several sensor options being investigated

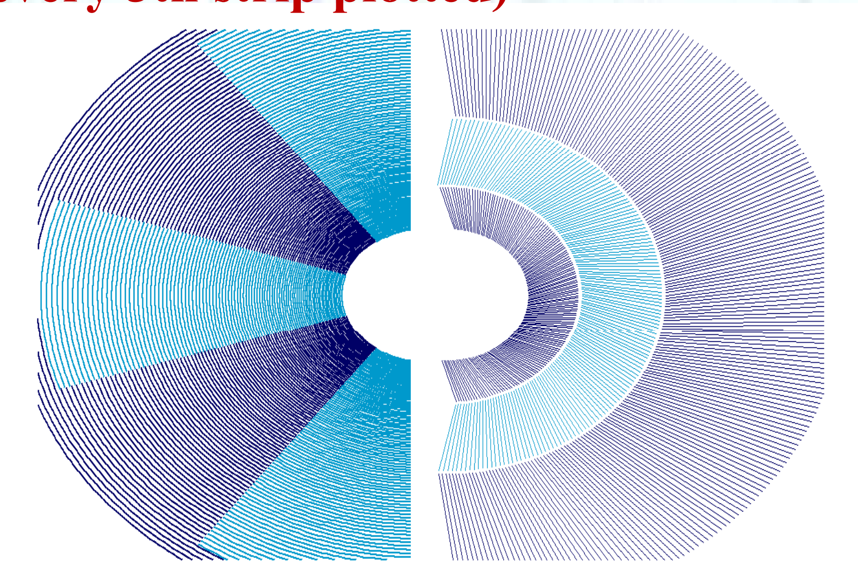
Strip detector:

- based on proven design, but with reduced strip pitch and increased number of strip
- prototypes in production (Hamamatsu & Micron)
- same chip as other silicon strip detectors

LOI pixel layout

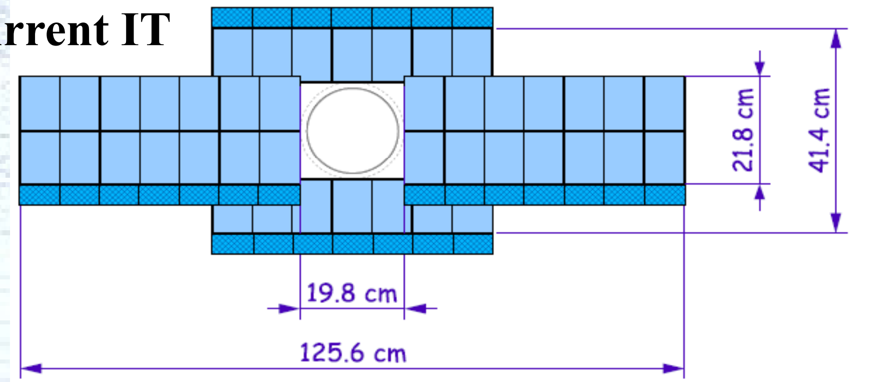


Layout of R and Φ strip sensor prototypes (every 5th strip plotted)

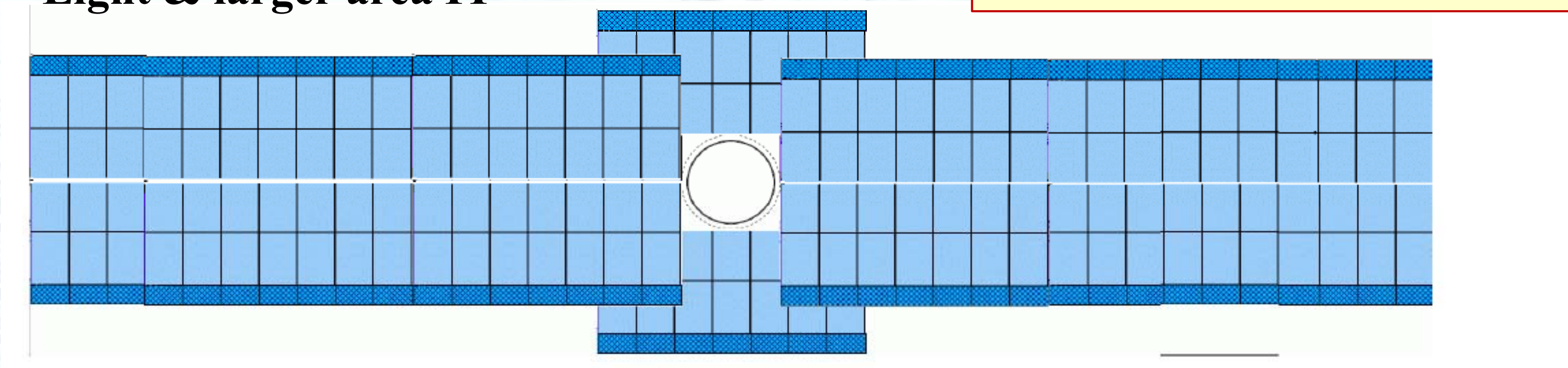


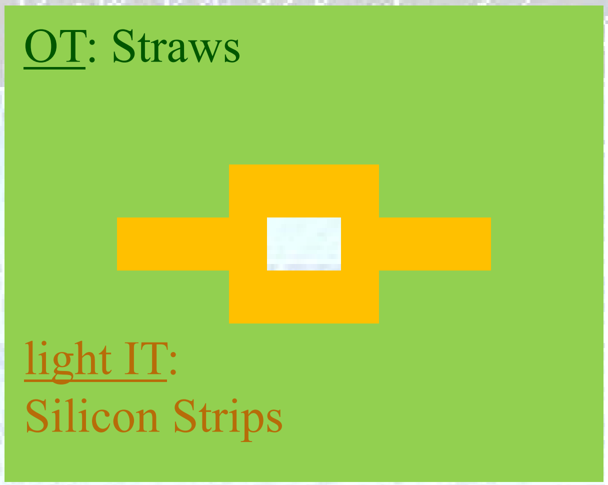
Upgraded Silicon Strip Inner Tracker

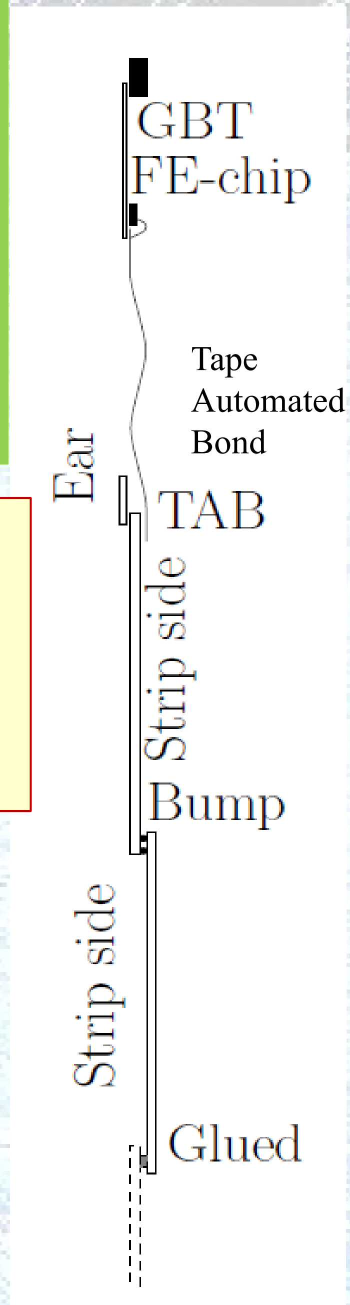
Current IT



Light & larger area IT







Effort started
- strip chip design
- cooling proof of concept (air flow)
- received 10 sensors for testing TAB, module assembly, HV, etc.

- **light: reduce X/X0 ~ 2**
- **large: increase area by ~ 3.3-4 : from 126x22(42)cm to 255x42(63)cm**
- **optimise station layout: now 3x(xuvx)=12 layers in-front of T3 to 2x(xuxvx)=10 layers behind T1 & T3**

ALICE Upgrade Plans

CERN, LHCC Upgrade Session, 20th March 2012
L. Musa for the ALICE Collaboration

- **Progress on the characterization of QGP properties is made by studying multi-differential observables:**
  - **Flavour, Centrality, Transverse momentum, Reaction plane, …**

➡ **This requires high statistics (high luminosity)**

- **Physics plans focused on physics observables where ALICE is unique at (PID, low material thickness, precise vertexing down to low p_t, …), such as**

- precision measurements of spectra, correlations and flow of heavy flavour hadrons and quarkonia at low transverse momenta
- precision measurements of low-mass lepton pairs emitted from the QGP
- energy loss and flavour tagging of partons in the QGP via γ-jet and jet-jet with hadron PID
- search for the existence of exotic objects such as the H dibaryon or Λ-neutron bound states and systematic study of production of anti-matter

➡ **This requires high statistics and precision measurements**
Standard trigger strategy not applicable in most cases

ALICE Upgrade Plans

- Physics goals and experimental approach outlined **for a run of at least 10 nb^{-1} with PbPb**
  - run ALICE at high rates, 50kHz Pb-Pb (i.e. $L = 6x10^{27}\ cm^{-1}s^{-1}$), with minimum bias (pipeline) readout (☹ max readout with present ALICE set-up ~500Hz)
  - Improve vertexing and tracking at low p_t

  The Pb-Pb run would be complemented by p-Pb and pp running

- It entails building
  - New beam pipe
  - New silicon tracker (scope and rate upgrade)
  - High-rate upgrade for the readout of TPC, TRD, TOF, CALs, Muons, DAQ/HLT
- This will allow a data driven readout architecture with continuous readout and event selection done by software algorithms in the online systems (DAQ/HLT)
- Upgrade targets LS2

Heavy Flavour Challenges

Current detectors:

- ALICE uniqueness: PID (→ charm); low p_t (low material budget);
- Present limits:
  - charm difficult for $p_t \rightarrow 0$ (background is too large);
  - resolution not sufficient for charmed baryons (Λ_c $c\tau$=1/2 D^0=1/5 D^+);
  - Λ_c impossible in Pb-Pb collisions , at the limit in pp (only high p_t);
  - Λ_b impossible in Pb-Pb collisions (insufficient statistics and resolution)
  - B/D separation difficult, especially at low p_t (e PID + vertexing);
  - indirect B measurement via electrons;
- General purpose detector limits:
  - much larger material thickness (even after upgrade)
  - minimum p_t at about 5-6 GeV/c?
  - no PID
  - ➡ low p_t charm and Λ_c very difficult.

ALICE Inner Tracker System Upgrade Requirements

1. Improve impact parameter resolution by a factor of ~3

- Get closer to IP
- Reduce material budget
- Reduce pixel size

2. High standalone tracking efficiency and p_t resolution

- Increase granularity
- Increase radial extension

3. Fast readout

- readout of Pb-Pb interactions at > 50 kHz and pp interactions at > 2MHz

4. Fast insertion/removal for yearly maintenance

- possibility to replace non functioning detector modules during yearly winter shutdown

ALICE ITS Upgrade

I) Get closer to the IP

- radius of innermost pixel layer is constrained by central beam pipe

Present beam pipe: R_{OUT} = 29.8 mm, ΔR = 0.8 mm

⇩

New reduced beam pipe: R_{OUT} = 19.8 mm, ΔR = 0.8 mm

II) Reduce material budget (especially inner layers)

- present ITS: X/X_0 ~1.14% per layer

⇩

- target value for new ITS: X/X_0 ~0.3 – 0.5% per layer (STAR HFT 0.37% per layer)

➡ reduce mass of silicon, electrical bus (power and signals), cooling, mechanics

III) Reduce pixel size

- currently 50μm x 425μm

monolithic pixels ➡ O(20μm x 20μm),

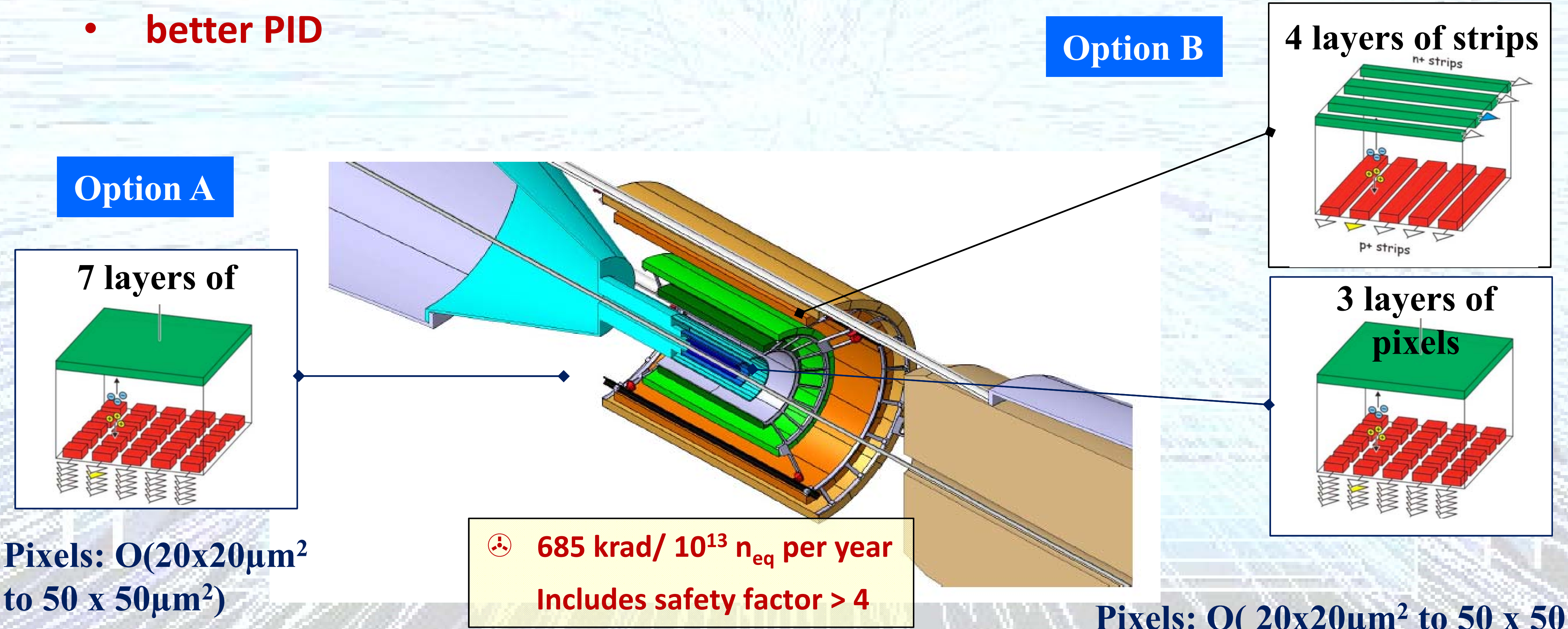
hybrid pixels ➡ O(30μm x 30μm), state-of-the-art O(50μm x 50μm)

ITS Upgrade Options

Two design options are being studied

A. 7 layers of pixel detectors
   - better standalone tracking efficiency and p_t resolution
   - worse PID

B. 3 inner layers of pixel detectors and 4 outer layers of strip detectors
   - worse standalone tracking efficiency and momentum resolution
   - better PID



Pixels: O(20x20µm² to 50 x 50µm²)

Pixels: O(20x20µm² to 50 x 50µm²)
Strips: 95 µm x 2 cm, double sided

ITS Detector Technologies

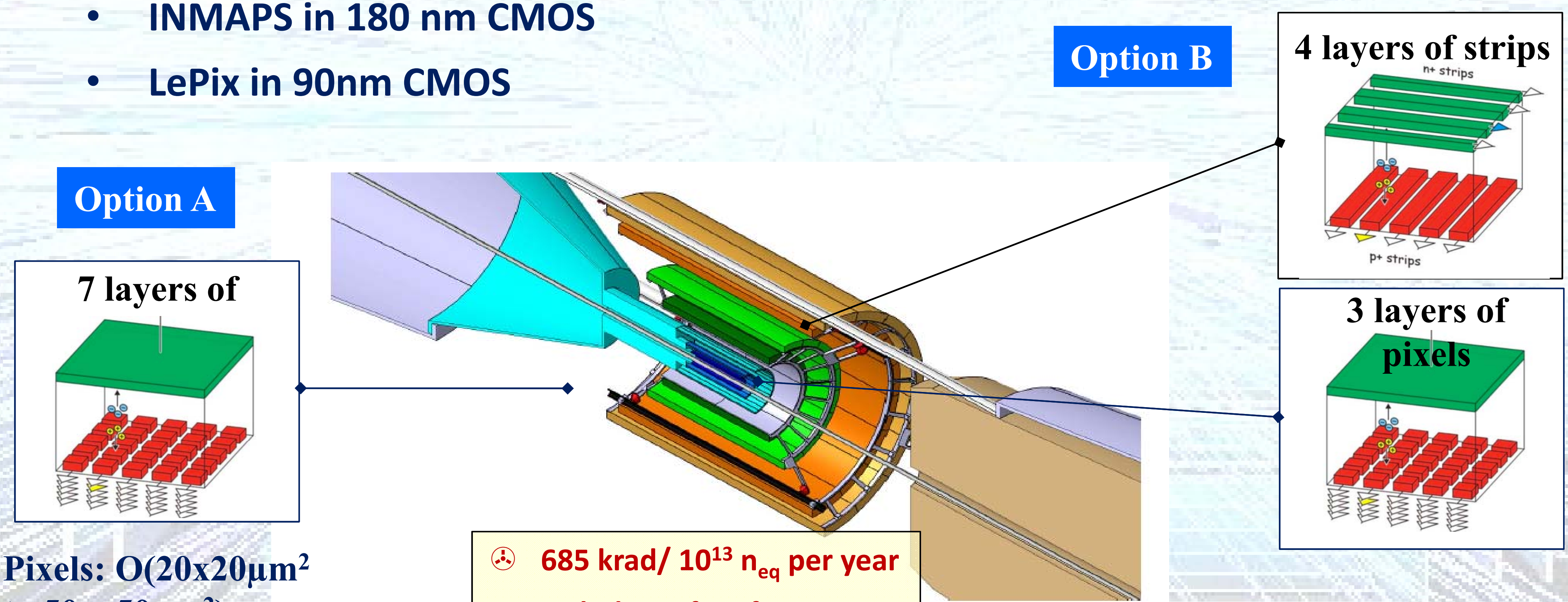
Several technologies are being considered for pixel detectors

Hybrid pixel detectors

- Edgeless sensors (100μm) + front-end chip (50μm) in 130 nm CMOS

Monolithic active pixel sensors

- MIMOSA like in 180 nm CMOS
- INMAPS in 180 nm CMOS
- LePix in 90nm CMOS

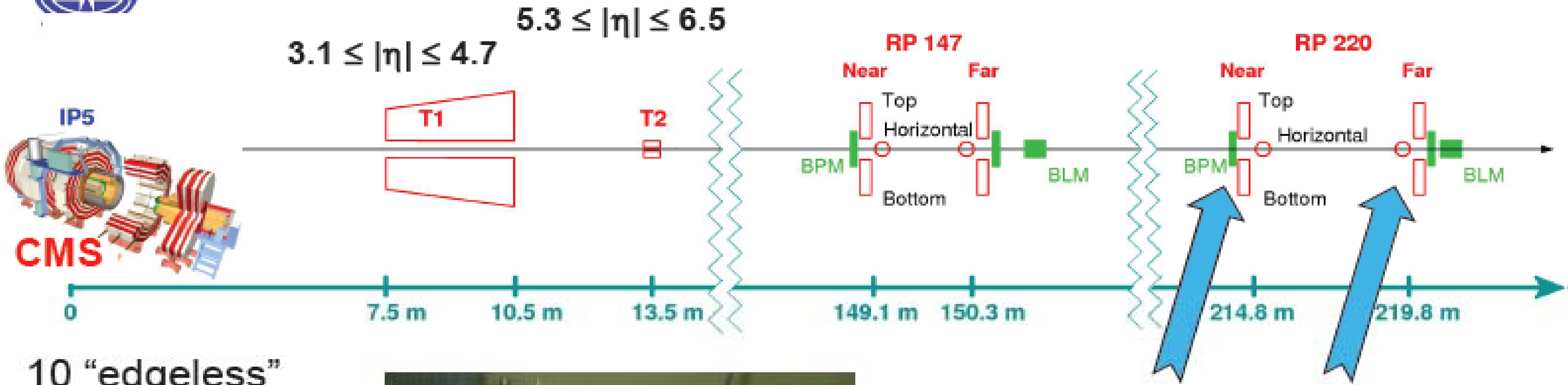


Pixels: O(20x20μm² to 50 x 50μm²)

685 krad/ 10^{13} n_{eq} per year
Includes safety factor > 4

Pixels: O(20x20μm² to 50 x 50μm²)
Strips: 95 μm x 2 cm, double sided

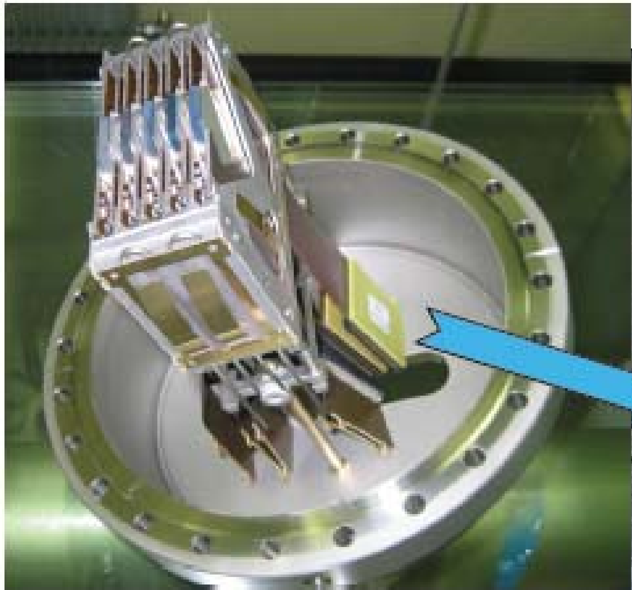
TOTEM Current Roman Pot Detectors

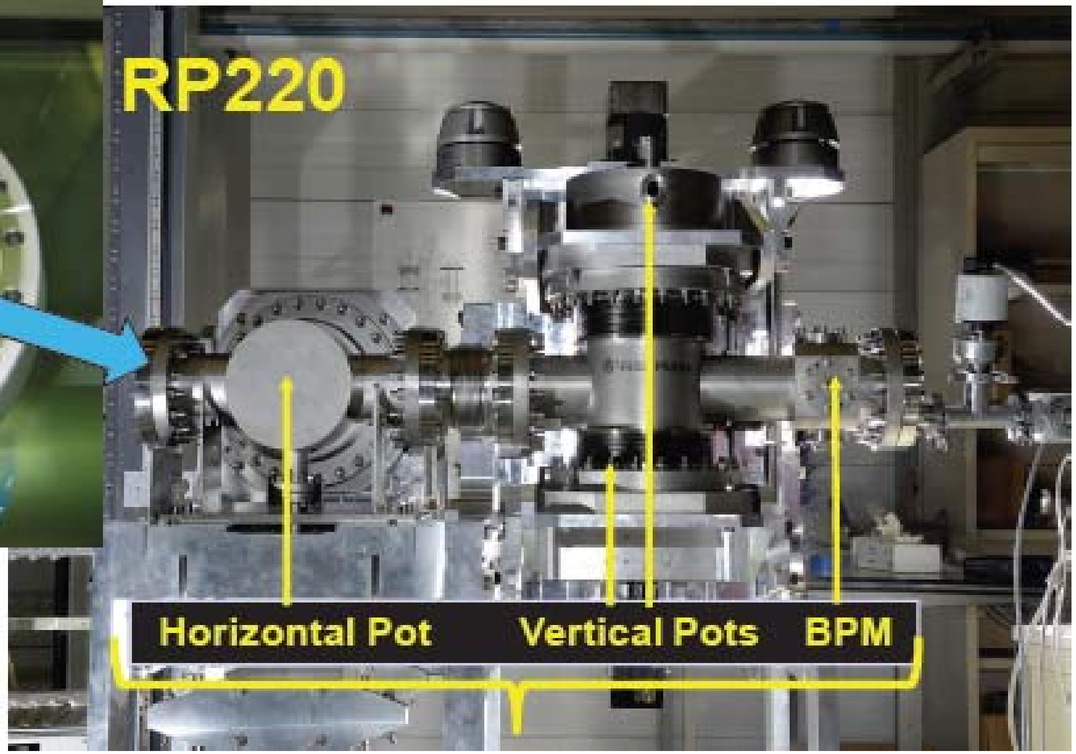


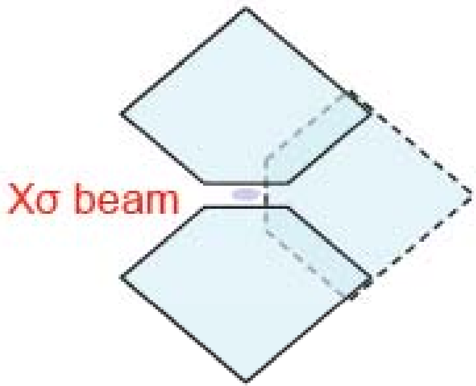
10 “edgeless” (< 50 μm) Si micro strip detectors measuring u or v projection / RP

leading p detection

resolution: ~15 μm







horizontal RPs:
- alignment
- diffraction

RP unit

https://indico.cern.ch/getFile.py/access?contribId=24&sessionId=6&resId=0&materialId=slides&confId=162948

Conclusions

- All LHC experiments have plans in hand to fully exploit the unique physics offered by the LHC operating at the energy frontier
- Given the length of operation of the Tevatron and the history of upgrades during its two and a half decades at the energy frontier, the plans at the LHC look reasonable and well justified
- Alongside HL-LHC, an ep/eA collider (LHeC) with a new dedicated experiment could be considered (http://www.ep.ph.bham.ac.uk/exp/LHeC/)
- Beyond the HL-LHC, CERN's infrastructure could support a possible high-energy upgrade, HE-LHC

BACK-UP

Timeline (presented by the DG to CERN Council)

2009 — Start of LHC

Run 1: 7 TeV centre of mass energy, luminosity ramping up to few 10^{33} cm^{-2} s^{-1}, few fb^{-1} delivered

2013/14 — LHC shut-down to prepare machine for design energy and nominal luminosity, phase 0, consolidate

Run 2: Ramp up luminosity to nominal (10^{34} cm^{-2} s^{-1}), ~50 to 100 fb^{-1}

2017 or 18 — Injector and LHC Phase-I upgrades to go to ultimate luminosity

Run 3: Ramp up luminosity to 2.2 x nominal, reaching ~100 fb^{-1} / year accumulate few hundred fb^{-1}

~2021/22 — Phase-II: High-luminosity LHC. New focussing magnets and CRAB cavities for very high luminosity with levelling

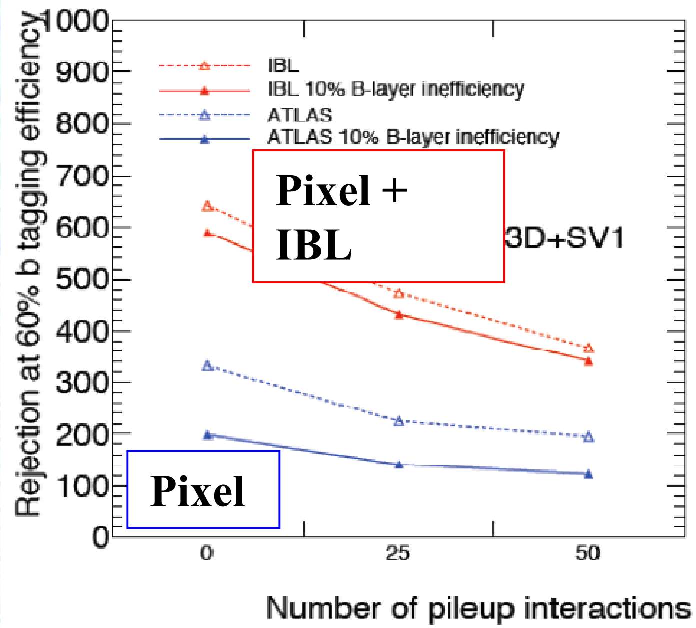
Run 4: Collect data until > 3000 fb^{-1}

2030

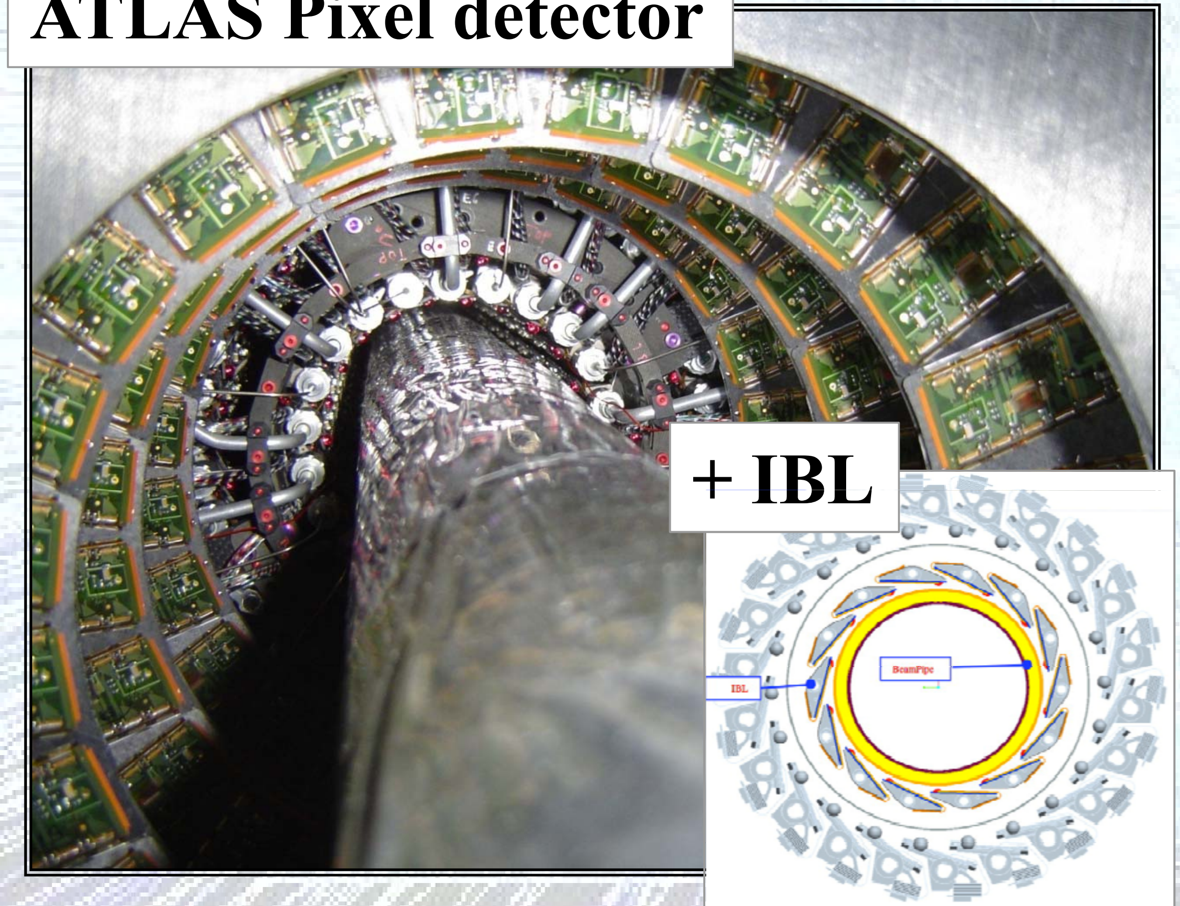
Insertable B-Layer

Phase 0 Upgrade 2012-14 Run 2014-18 => 50fb^{-1} @ 13 TeV

- Improve performance of the pixel detector
  - tracking, vertexing, b-tagging for high pile-up
- Technology step towards HL-LHC



ATLAS Pixel detector

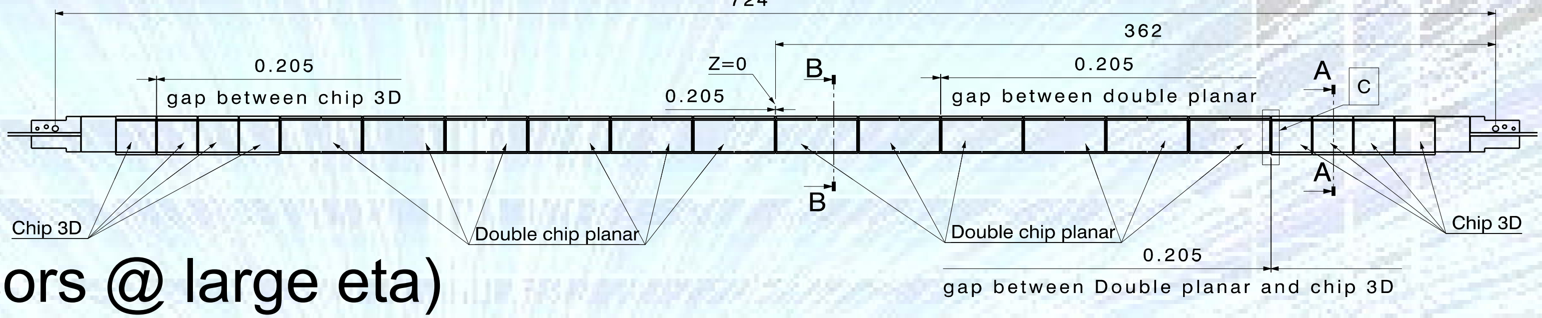


- **Option A**: build around a new Be beam pipe and slip inside the present detector in situ
- **Option B**: if the pixel package is removed to replace the services, this operation can be carried out on the surface

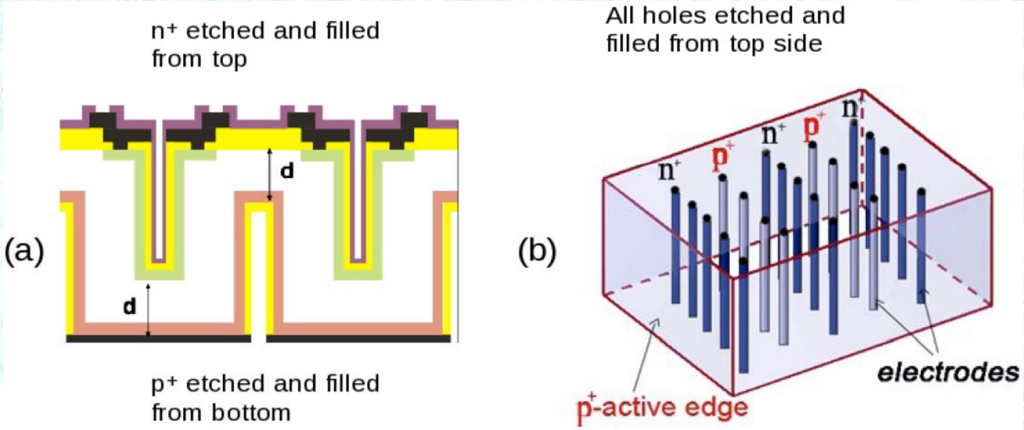
Phase 0 Upgrade 2012-14 Run 2014-18 => 50fb^{-1} @ 13 TeV

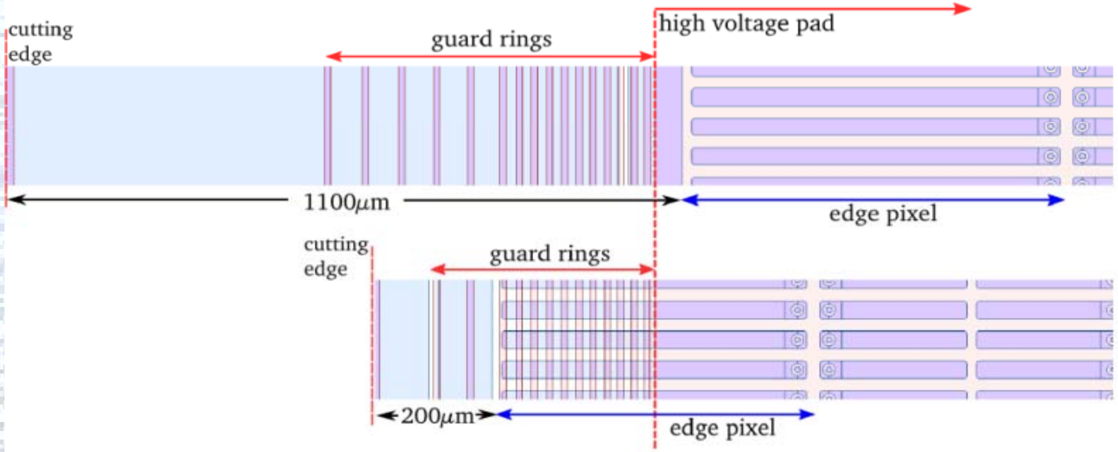
Insertable B-Layer

- IBL baseline
  - 75 % planar
  - 25 % (3D sensors @ large eta)



Planar (slim edge):
- 200 mm thickness
- Inactive edge <250 mm, was 1100 mm
- Low Q generated after irradiation -> low threshold operation and high HV

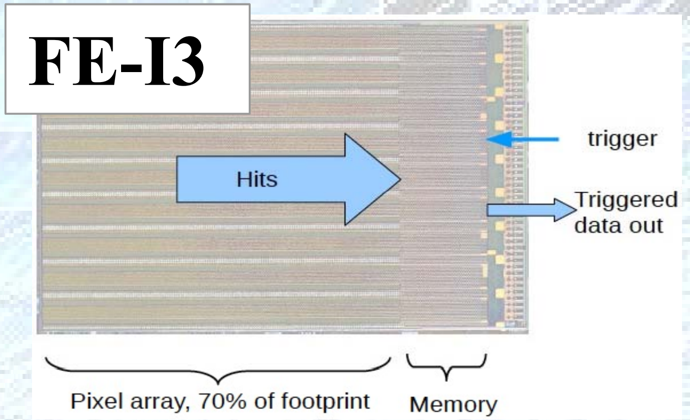


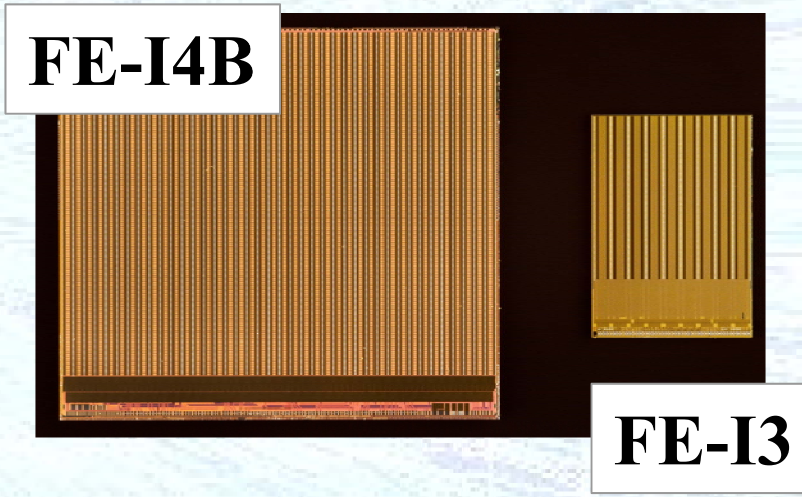


Double-sided 3D (forward region):
- 230 mm thickness
- Inactive edge 200 mm
- Low depletion voltage (<180V)
- Medium operating T
- Complex Process => Low yield/ High cost

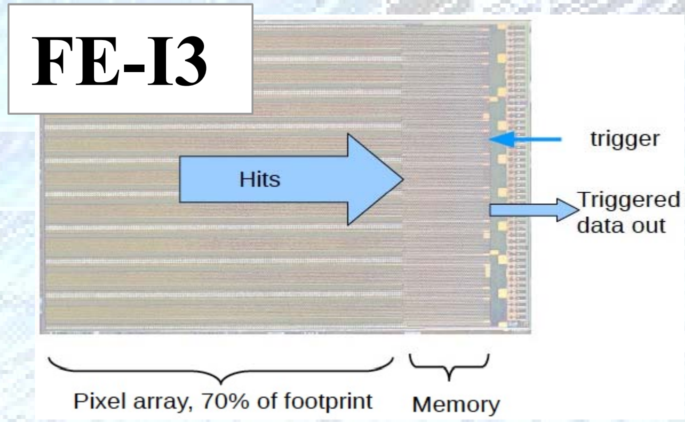
Insertable B-Layer: Front-End

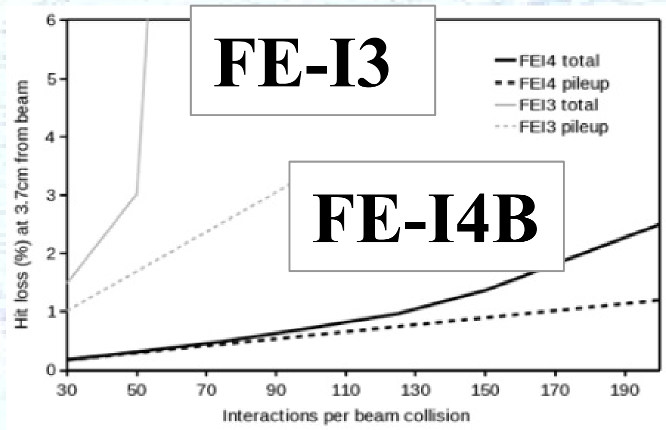
- Front-end chip FE-I4B: upgrade of FE-I3
- Much cheaper module manufacture
  - **Chip size as big as possible**
- Greater fraction of the footprint devoted to pixel array
  - **Move the memory inside the array**
- Lower power
  - **Don't move the hits around unless triggered**
- Able to take higher hit rate
  - **Store the hits locally and distribute the trigger**
- Still able to resolve the hits at higher rate
  - **Smaller pixels and faster recovery time**
- No need for extra control chip
  - **Significant digital logic blocks on array periphery**
- => 19 x 20 mm^2 130 nm CMOS process, based on an array of 80 by 336 pixels (each 50 x 250 μm^2)





Insertable B-Layer: Front-End





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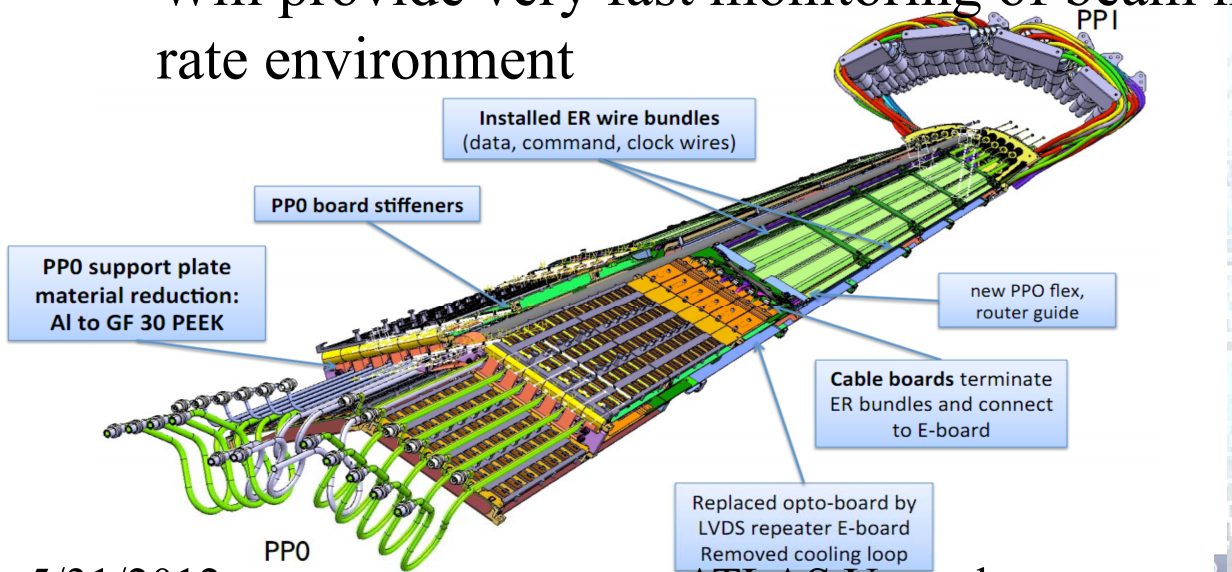
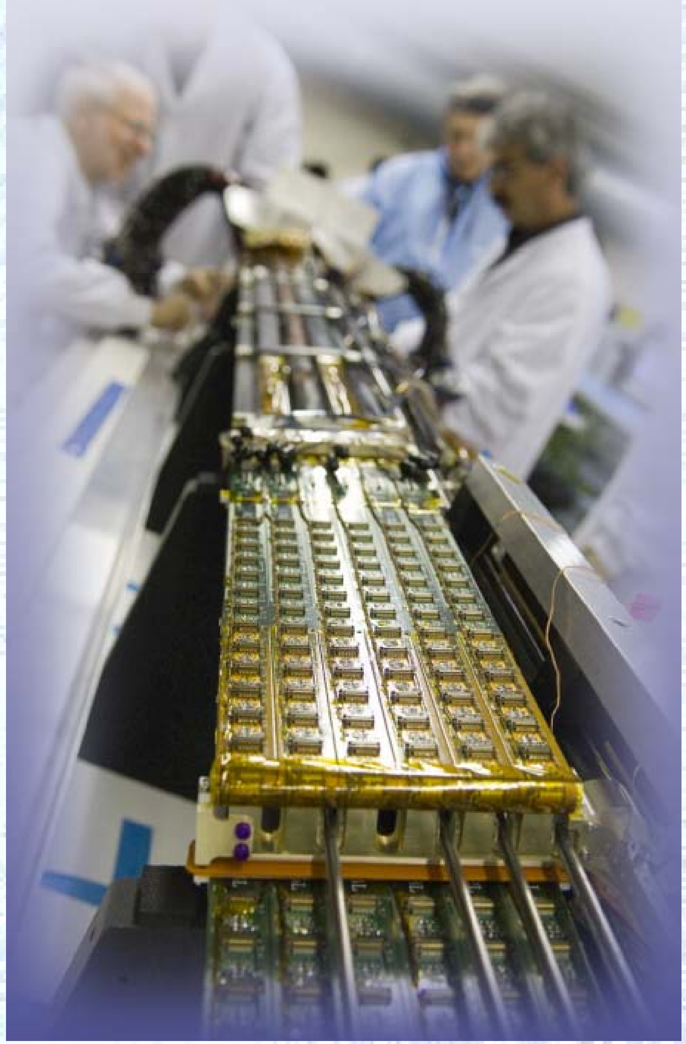
New Service Quarter Panels / Diamond Beam Monitor

Phase 0 Upgrade 2012-14 Run 2014-18 => 50fb^{-1} @ 13 TeV

- New service layout for all pixel service (**nSQP**)
- Redundant and safer location for fibers transmitters
- Doubling of the readout bandwidth in view of Phase 1 upgrade
- **Diamond Beam Monitor** attached to nSQP
  - Uses Diamond Si detectors produced for IBL trials
  - Will provide very fast monitoring of beam in high rate environment

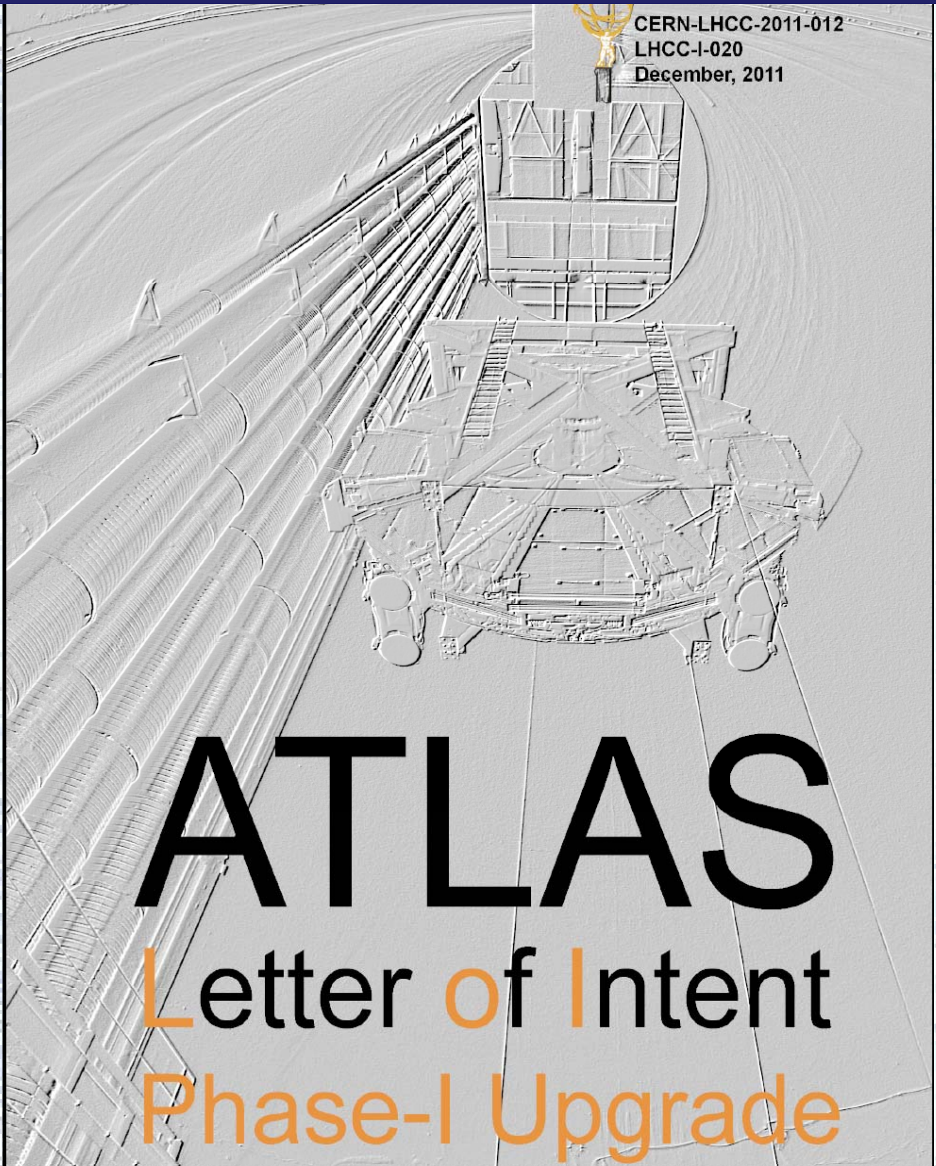




PHASE 1 : up to the 2018 shutdown (LS2):

LHC RRB Meeting April 2012: M. Nessi on behalf of the ATLAS Collaboration

https://indico.cern.ch/materialDisplay.py?contribId=21&sessionId=3&materialId=slides&confId=174803



https://cdsweb.cern.ch/record/1402470/

(CERN-LHCC-2011-012)

- *Presented in December 2011*
- *Approved by the ATLAS CB in January 2012*
- *March 2012 positive LHCC outcome*

Four upgrade projects:

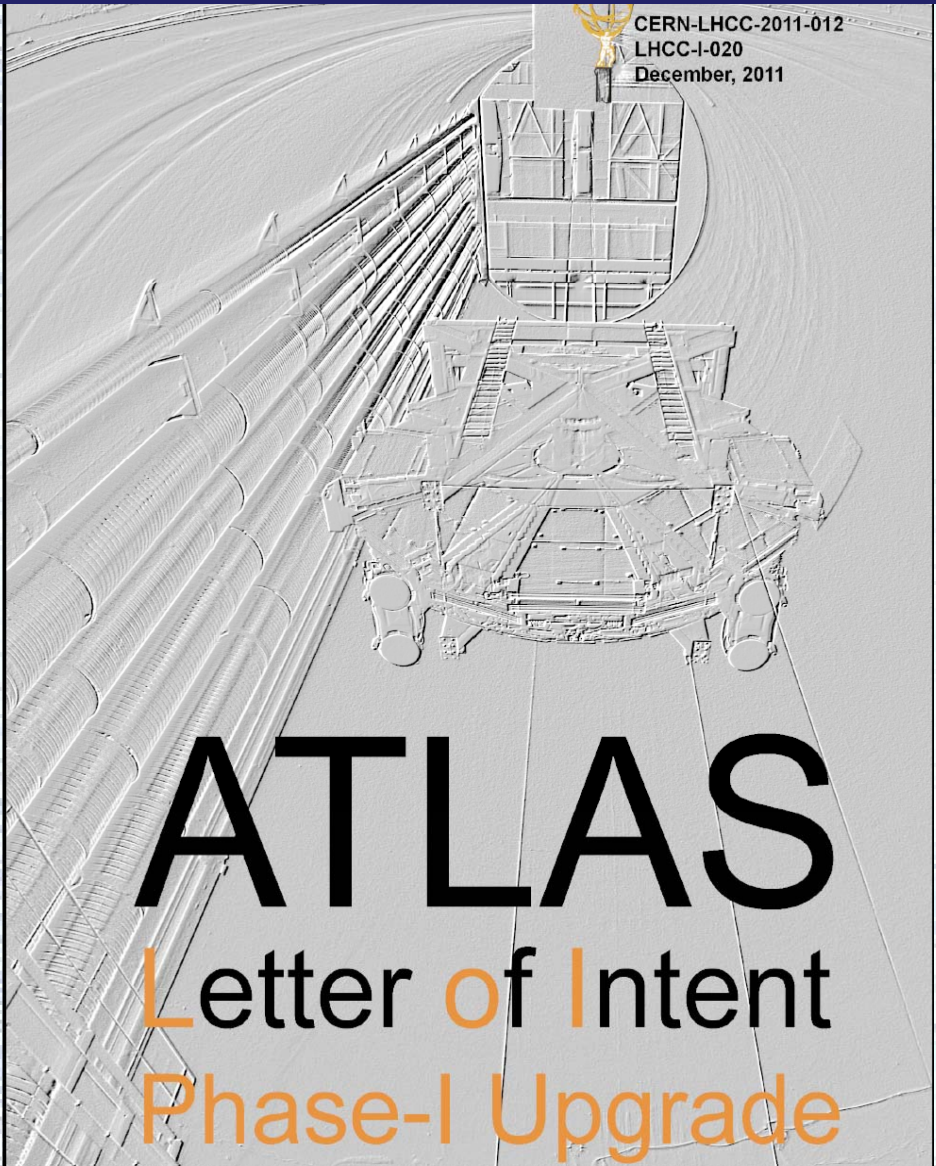
- New muon small wheels
- Fast tracking trigger (input to LVL2 trig)
- New Calorimeter Trigger tower builders (LVL1 calo trigger)
- Various trigger/DAQ upgrades

One new project:

- AFP : New forward detectors at +- 210 m

Positive LHCC referees report:

LHC RRB Meeting April 2012: M. Nessi on behalf of the ATLAS Collaboration
https://indico.cern.ch/materialDisplay.py?contribId=21&sessionId=3&materialId=slides&confId=174803



https://cdsweb.cern.ch/record/1402470/
(CERN-LHCC-2011-012)

- The committee felt that the LOI presented to us was excellent. It was very well written and the thought process behind was already quite mature. The LHCC committee felt that the physics justification was very well made for all of the upgrades that were designed to maintain capability.
- The committee also felt that the technology options or choices were sound and sensible and felt that this program could be executed and with it, the collaboration would be able to accomplish its physics goals.
- The physics case for the AFP detector rests on the capability of using a proton double tag to constrain the centrally produced system and includes Higgs production and WW final states in a high-luminosity environment. Superb timing, at the 10 ps-level, will be required to associate the proper primary vertex and remove accidentals. Whereas the technical viability of the approach will have to be demonstrated this detector extends the physics capabilities without interfering with the upgrade work on the detector proper.
- The LHCC endorses the LOI and encourages the collaboration to present its plans to the RRB and FAs and to proceed to the next step of detailed TDR's for each upgrade.

PHASE 1 : cost estimations and next step

LHC RRB Meeting April 2012: M. Nessi on behalf of the ATLAS Collaboration

https://indico.cern.ch/materialDisplay.py?contribId=21&sessionId=3&materialId=slides&confId=174803

Item	CORE COST(MCHF)	Possible Additions	2012	2013	2014	2015	2016	2017	2018
New muon Small Wheels (SW)	**9.20**	0.14	0.00	0.63	1.75	2.54	2.95	1.28	0.04
New LAr Calorimeter Electronics(LAr)	**7.98**	0.00	0.19	0.78	0.13	0.94	4.06	1.88	0.00
New Tile Calorimeter upgrade (Tiles)	**0.38**	0.00	0.00	0.03	0.03	0.14	0.14	0.03	0.00
Fast TracKer (FTK)	**3.59**	0.00	0.51	0.96	0.63	0.89	0.34	0.26	0.00
Trigger and DAQ Upgrade	**8.78**	3.21	0.33	1.41	0.67	0.54	1.14	1.46	3.75
Forward Physics (AFP)	**2.70**	0.00	0.33	1.04	0.88	0.10	0.35	0.00	0.00
	= 36 MCHF								
Total [MCHF]	***32.62***	***3.35***	***1.37***	***4.85***	***4.08***	***5.15***	***8.98***	***4.91***	***3.78***

NEXT STEPS:

Def. 5 projects → Internal review process → EB, CB approval → TDR + MOUs

(2012/2013)

(2013/2014)

(Next cost estimation revision with TDRs)

PHASE 1 : LOI in preparation

LHC RRB Meeting April 2012: M. Nessi on behalf of the ATLAS Collaboration

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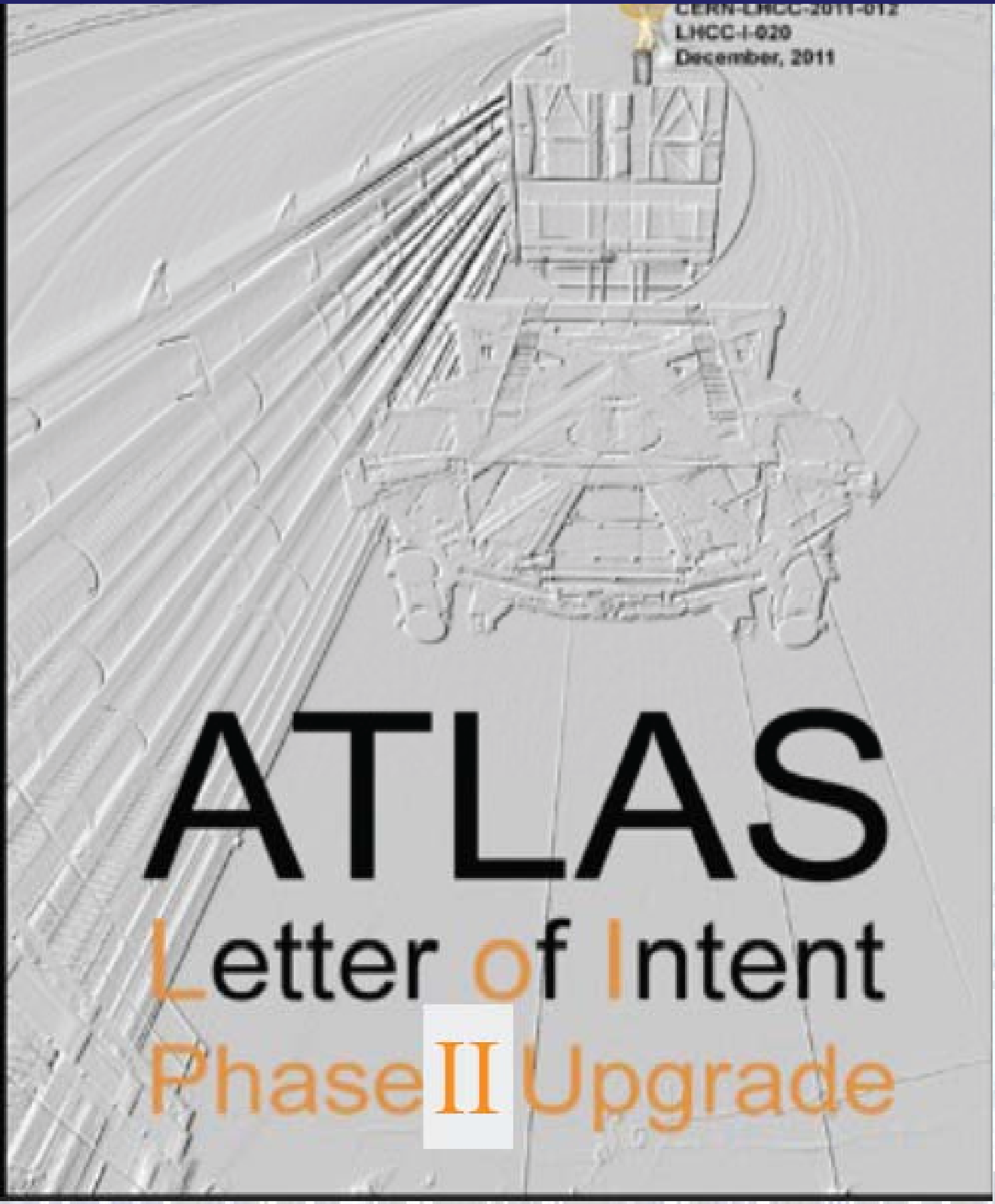


Today's plans :

- *Editorial board active*
- *LOI will be presented in December 2012*
- *Approved by the ATLAS CB in January 2013*
- *March 2013 looking for positive LHCC outcome*

Today's cost estimations (to be revised for the LOI) :

ATLAS PHASE II upgrade (LS3)

	it will happen [MCHF]	it might happen [MCHF]
1. New ID (strips and pixels)	*111.4*	*43.0*
2. New LAr front end and back end electronics	*32.0*	
3. New Tiles front end and back end electronics	*6.3*	
4. LAr new FCAL ?		*13.9*
5. LAr HEC cold electronics consolidation ?		*6.4*
6. Muon Barrel and Large Wheel system upgrade ?	*5.6*	*6.2*
7. TDAQ upgrade	*22.1*	*8.3*
8. L1 Track Trigger ?		*3.7*
9. TAS and shielding upgrade	*8.7*	
10. LUCID upgrade ?		*1.2*
11. Various infrastructures upgrade	*13.5*	
12. Common activities (installation, cabling, safety, …)	*8.4*	
= 291 MCHF TOTAL	***208.0***	***82.7***

Pile-up (μ) Estimation

- μ(luminosity) needed for Phase-I and Phase-II studies
- Assume $\sigma_{inelastic}$=73mb (8TeV) and using the most recent running 1380 bunches not 1404 (*n.b.* #slots/2=3564/2= 1782)
  - assuming that 25ns running might be with 2760 (1380×2) bunches
  - assuming $\sigma_{inelastic}$=85mb (14TeV extrapolation from above)
  - Using that this includes double and single diffractive events which are also included in ATLAS MC (30% of $\sigma_{inelastic}$) so ~self-consistent assumptions

► Predict μ=27.5 per 10^{34}cm^{-2}s^{-1} at 14 TeV (77% available slots filled)

This is the number assumed in the ATLAS Phase-I LoI, extrapolating from current Peak<Events>/BX and start-of-fill luminosities

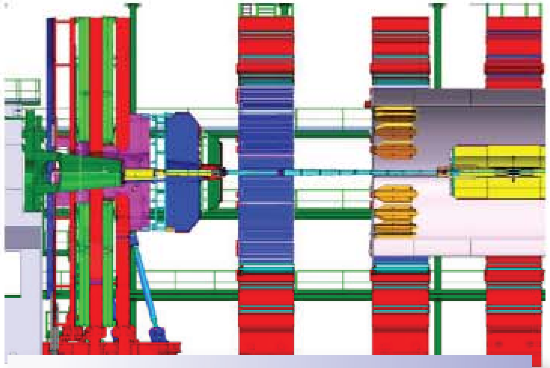
Preparing for LS1: Nov 2012-Sept 2014

- **Main CMS objectives**
  - Achieve operation with **Tracker & ES cooling** fluid at –25°C
  - Complete **Muon upgrade** tasks
  - 1st stage of **HCAL photo-transducers** consolidation
  - Install 45mm o.d. **Beampipe**
  - Correct **detector faults** affecting physics performance
  - Eliminate major **CMS-specific risks** to data quality & acquisition efficiency

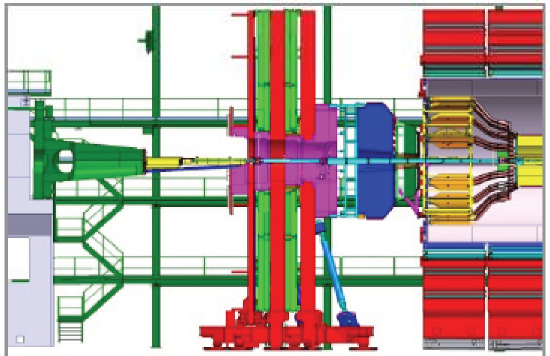
- Chamonix 2012: CMS committed to “ready for beam” 1 Sept 2014
  - Intention is still to complete the whole program if time permits.
    - But we incorporated an escape point:
      - Some endcap 4 muon installation can be postponed to Year-End Technical Stops
  - Working groups studying task sequence, resources in each logistic scenario
    - Draft detailed plan to be reviewed at TC workshop planned for early May.

Consolidation Work During LS1

Prepare for 13-14 TeV, 100-200fb^{-1} and 1 x 10^{34}cm^{-2}s^{-1}, 25ns



Principal configurations

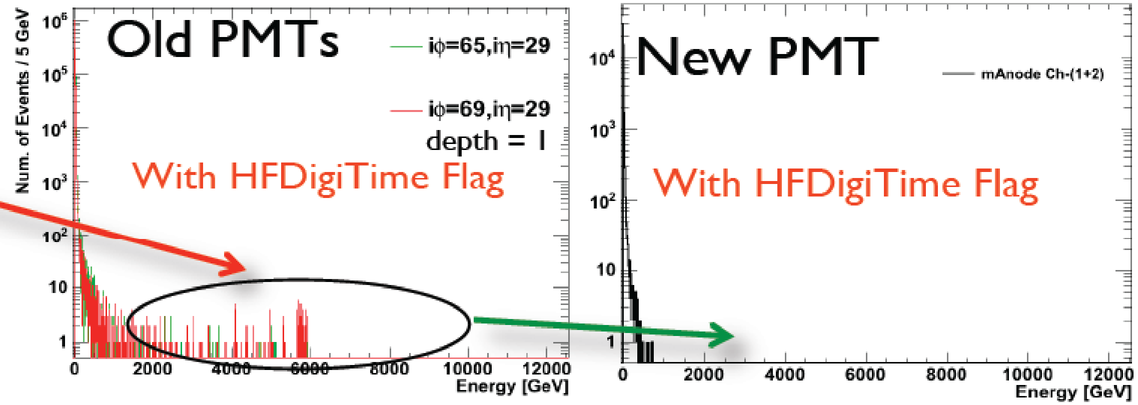


Maintenance of existing systems (> 50% tasks) is not listed here

- Mu barrel electronics: move some to USC, replace some
- **Pixel concentric adjustment system**
- **Barrel-endcap seal revision for colder Tracker operation**
- **PLT installation, BRM improvements**
- **N_2/dry-air system upgrade for colder Tracker operation**
- Radioactivity shield tests around beampipe and Tracker
- Magnet Cryogenics: redundancy, power cut tolerance, He purity
- UPS extension in service caverns for glitch tolerance
- Guiding system improvement to lower risk: YE disks + HF
- Cooling consolidation of busbars, racks, YE3

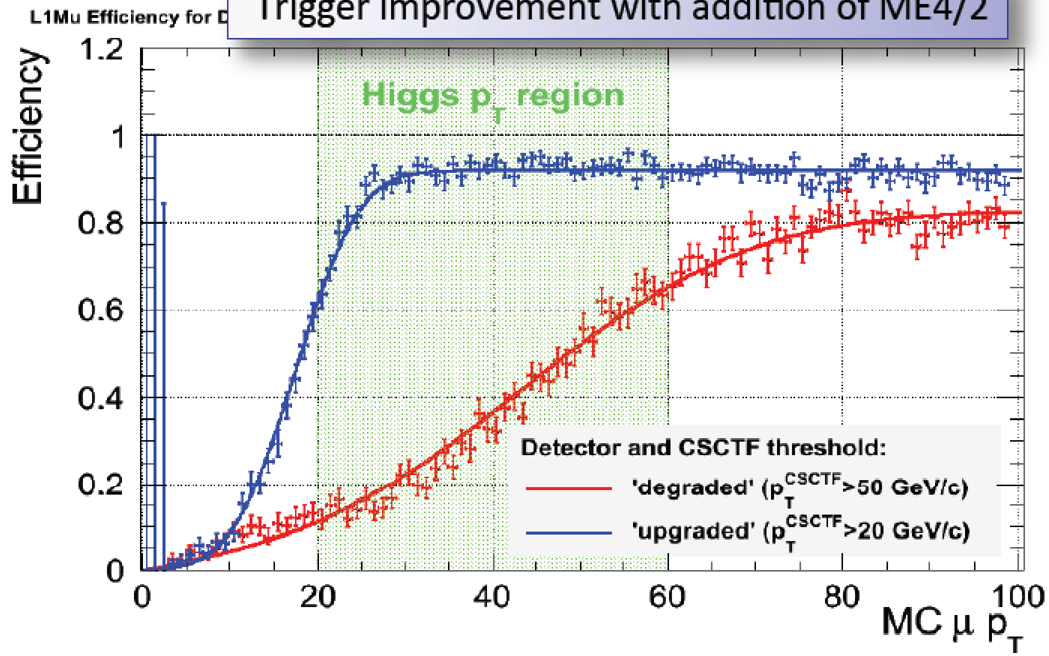
Projects for Long Shutdown 1 (LS1) 2013-14: Hadron Calorimeter (HCAL), Endcap Muons

- HCAL Photodetector replacements:
  - Photo multiplier tubes(PMT)
    - Hadron Forward (HF)
      - >50% of 1800 received and tested.
      - 8 PMTs (2011) 24 (2012) inside CMS
  - Hybrid Photo Diodes (HPD) and Silicon Photo Multipliers (SiPM)
    - Hadron Outer (HO)
      - All SiPMs delivered
      - System tests of Front End (FE) electronics and full board production are underway
- Muons :
  - Complete the system in the region 1.25<|η|<1.8 and install more robust electronics
    - Endcap4 ring 2 muons (ME4/2)
      - Cathode Strip Chamber (CSC) pre-production of new chambers has been qualified
    - Resistive Plate Chambers (RPC)
      - First chambers scheduled to arrive in August
  - Electronics
    - CSC Endcap1 ring1 (ME1/1)
      - New read-out electronics
    - Drift Tubes (DT)
      - New read-out board and relocation of track selector electronics away from radiation



In-situ data 2011. Benefit from thinner window and metal sides in new PMT.

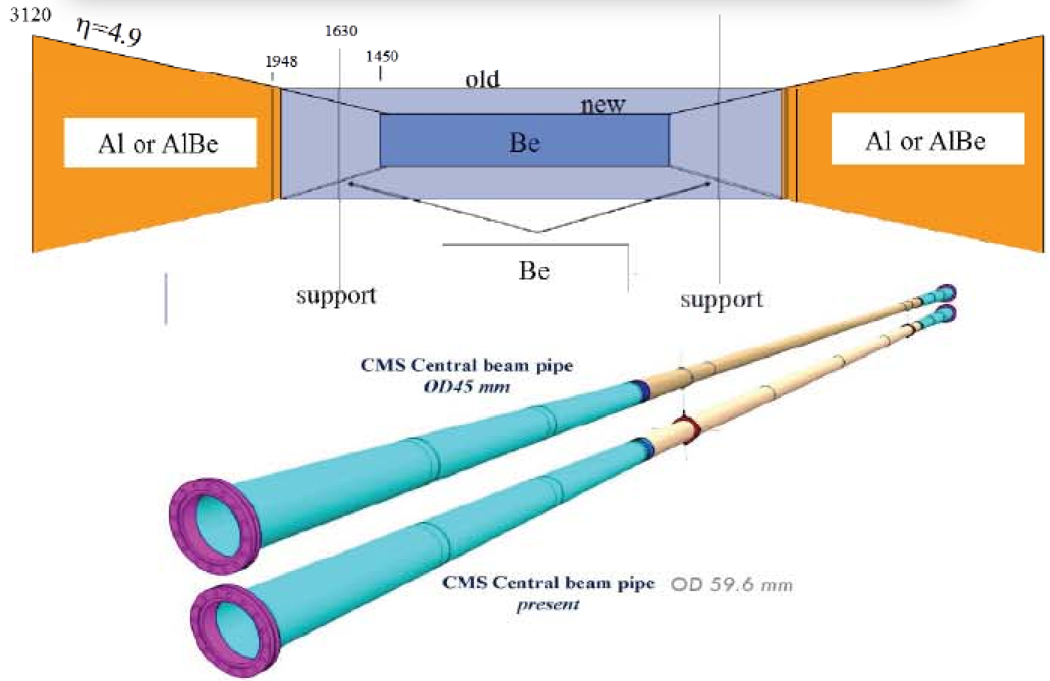
Trigger improvement with addition of ME4/2



LS1 Common Projects Are Underway!

1st YE4 disk:
- Key for endcap muon upgrade
- Passed its load test at HMC-3 Pakistan
- En route to CERN now

Reduced, 45mm diameter beam-pipe:
- Key for pixel upgrade. Order placed.
- Berylium central section
- Aluminium-alloy end cones
  - Replace stainless steel
  - Cuts backgrounds, radioactivity
  - Very cost effective

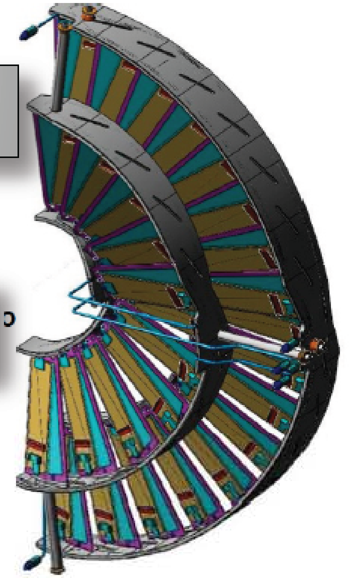


Projects beyond LS1 : Pixels - HCAL - Trigger

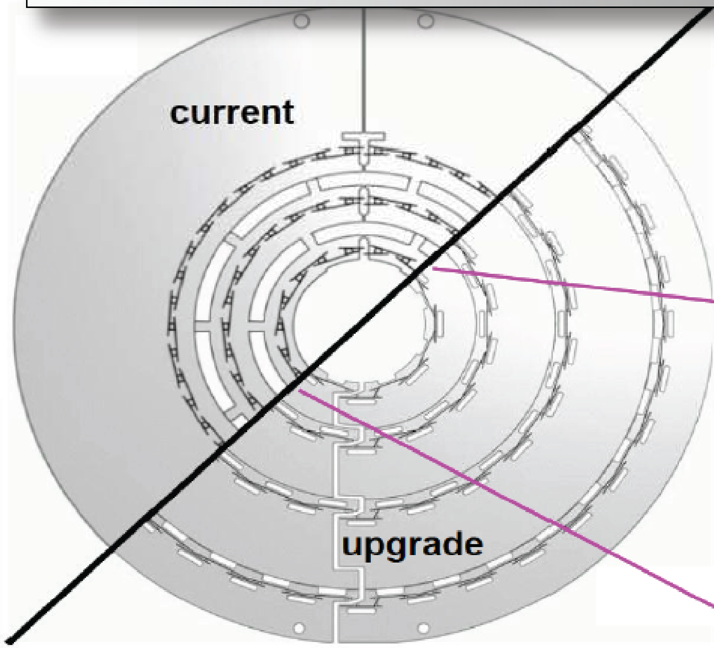
- Technical Design Reports in preparation:
  - Pixels and HCAL TDRs by September, Level 1-Trigger TDR in early 2013
    - To cope with step-wise increases in luminosity via improvements in injector chain
  - We're designing for 50 overlapping interactions per event also known as Pile-Up(<PU>=50) as our "baseline" and will study degradation for <PU>=100

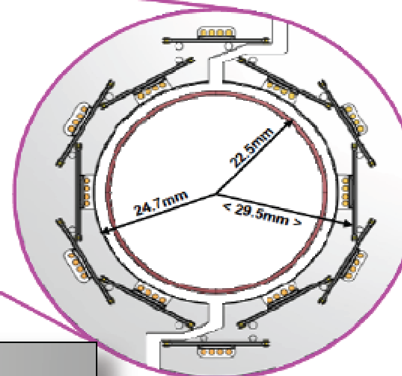
- Pixels new features:
  - New readout chip
    - Addresses data-loss at high rates
  - One more layer in all directions
    - 4 barrel layers and 3 endcap disks at each end
  - Reduced inner radius (new beampipe)
  - Reduced mass
    - CO_2 cooling
    - Powering using DC-DC converters

FPIX Disk

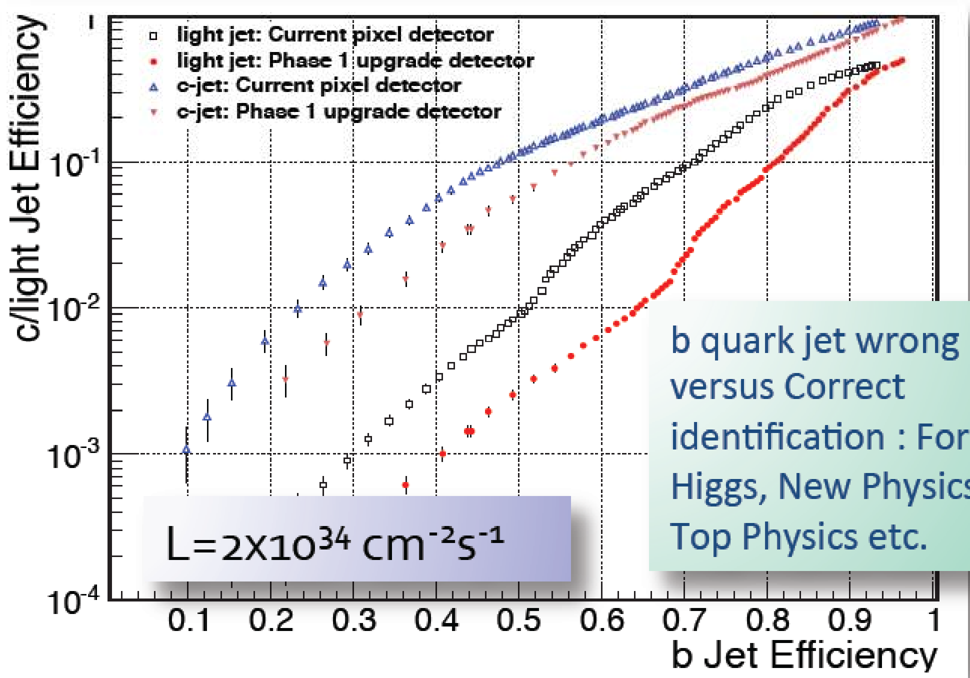


BPIX Layout





New beampipe allows 12-facet inner layer

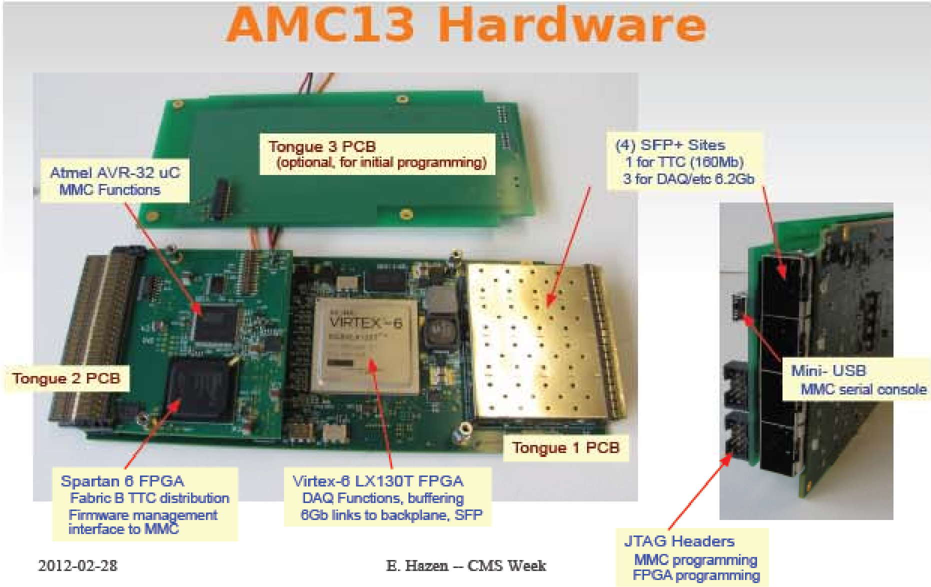


$L=2x10^{34}\ cm^{-2}s^{-1}$

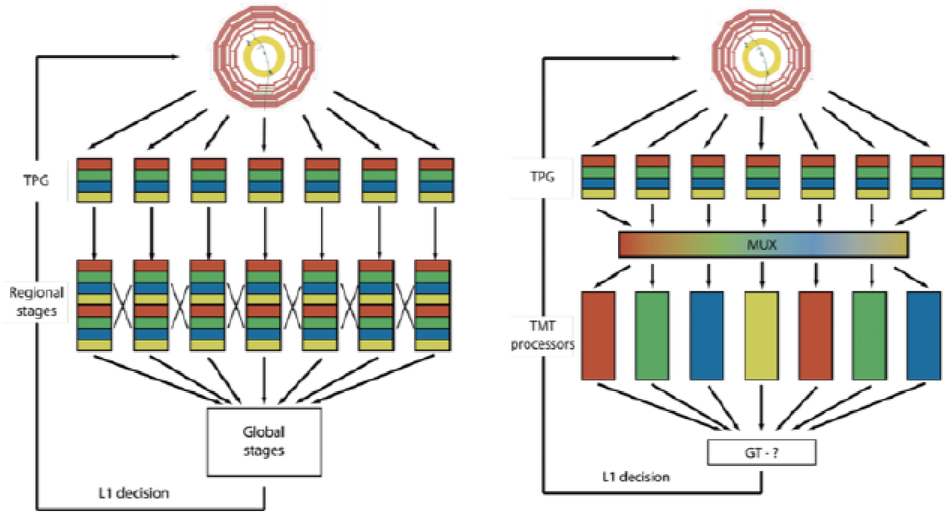
b quark jet wrong versus Correct identification : For Higgs, New Physics, Top Physics etc.

Projects beyond LS1 : Pixels - HCAL - Trigger

- HCAL new features
  - SiPMs:
    - Improve Signal/Noise (S/N)
    - Magnetic-field immune
    - Test beam program converging to final design.
  - Depth segmentation and improved timing:
    - Background rejection, improved isolation, radiation damage compensation
  - *Electronics: Proto QIE10 under test, μTCA system prototype slice tests at P5 in 2012*
  - *Develop common μTCA for CMS eg. AMC13: clock and control, and data-transmission*
- L1-Trigger new features
  - Improve bandwidth, granularity and capability w/new electronics and FPGAs
  - Studying new algorithms with higher precision (invariant mass, $\Delta R, P_t^{rel}$)
  - *Studying alternative architectures for optimal flexibility*



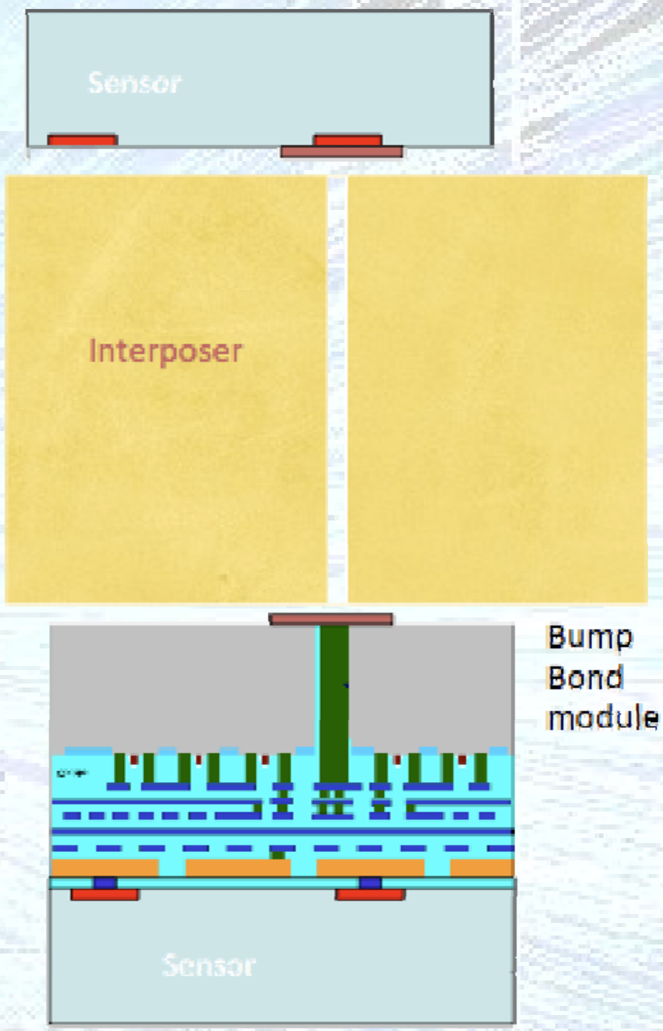
Calorimeter Trigger System

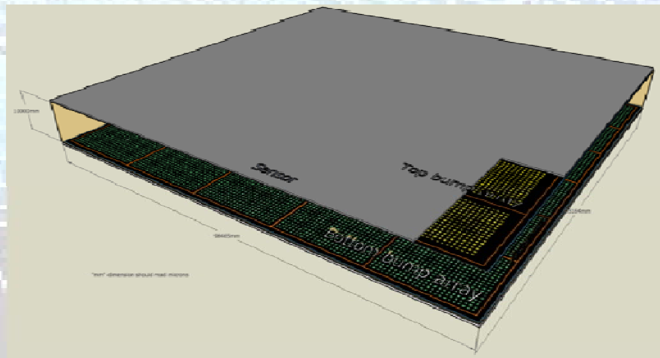


conventional regional approach and time multiplexed

Vertically integrated Pixel-Strip Module

- Strip / Pixel module with vertical interconnections
- Single chip connected to top and bottom sensors
- Analogue paths through interposer from top sensor, segmented in ~ cm long strips
- Bottom sensor gives z info (~ mm long pixels)
- Electronics and connectivity (interposer) are technological challenges (yield, robustness, mass, large–size module)
- Several developments ongoing in parallel
  - 2D demonstrator chip functional
  - TSVs functional, 3D assembly difficult
  - Technology for interposer still an open problem
  - Data processing simulation started
  - Option to use active edge sensors





CMS Phase I Upgrade Project Costs

- Financial plan
  - Table presented previously
- Technical Design Reports
  - Refine and firm up all costs
- Early commitments are vital to pave the way
  - For stable, robust future running
  - To capitalize on Long shutdown One to prepare for upgrades

Subsystem/Common Item	Budget
	k CHF
HF - Phototubes	1,990
Muon CSC	5,570
Muon DT	2,200
Muon RPC	4,220
DAQ	6,700
Pixel Tracker	17,350
HCAL	5,817
Trigger	4,600
Common Items	
Magnet power and cryo	1,330
Beam Instrumentation	1,540
Infrastructure	6,315
Test Beam Facilities Upgrade	610
Safety systems upgrade	964
Electronics Integration	1,575
Engineering Integration	3,666
Grand Total	**64,447**
10% of which, Common Fund	6,445

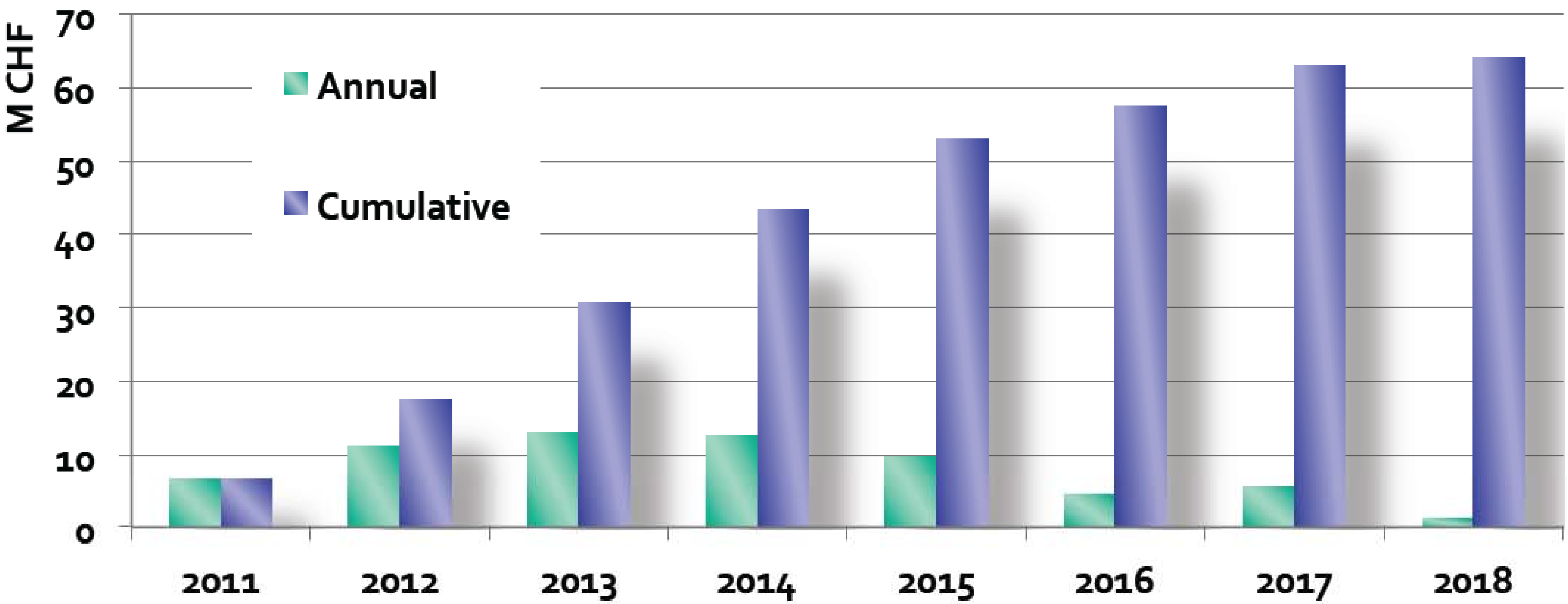
Upgrade Cost Profile

Subsystem/Upgrade Item	2011	2012	2013	2014	2015	2016	2017	2018	Total
HF - Phototubes	1.80	0.19							1.99
Muon CSC	2.33	1.78	1.22	0.22					5.55
Muon DT		1.04	0.55	0.19	0.41	0.15			2.34
Muon RPC	1.09	1.78	0.75	0.52					4.14
DAQ				0.30	0.30	1.60	4.50		6.70
Pixel Tracker	0.08	1.51	3.62	5.60	5.14	0.89	0.63		17.47
HCAL		0.05	0.92	2.16	2.07	0.60	0.00		5.80
Trigger		0.20	1.10	1.30	1.10	0.90	0.00		4.60
Magnet power and cryo	0.27	1.01	0.03	0.03	0.00	0.00	0.00	0.00	1.34
Beam Instrumentation	0.04	0.43	0.31	0.22	0.15	0.05	0.05	0.30	1.55
Infrastructure	0.39	2.23	2.31	0.65	0.24	0.10	0.10	0.30	6.32
Test Beam Facilities Upgrade	0.14	0.09	0.22	0.13	0.03				0.61
Safety systems upgrade	0.12	0.25	0.34	0.13	0.05	0.01	0.01	0.06	0.97
Electronics Integration	0.00	0.18	0.53	0.53	0.18	0.04	0.04	0.10	1.60
Engineering Integration	0.15	0.37	1.19	1.15	0.15	0.07	0.23	0.36	3.67
Subtotal Common Items	1.10	4.55	4.91	2.83	0.79	0.27	0.43	1.12	16.00
Total	6.40	11.10	13.07	13.12	9.81	4.41	5.56	1.12	64.59

M CHF

Technical Design Reports are in preparation for the projects in green

Cost estimates for 2013 and beyond will be updated



CMS Summary and Outlook

- Designing an Outer Tracker with:
  - Higher granularity
  - Enhanced radiation hardness
  - Improved Tracking performance (i.e. lighter!)
  - L1 Track finding capability
    - Reconstruct tracks above ~ 2.5 GeV
    - With ~ 1mm z_0 resolution
- All the necessary R&D activities are ongoing
- Encouraging indications that the goals could be met
- Need to converge on an optimal design in the next ~ 2 years
- Draft schedule developed for delivery in LS3
- Phase 2 pixel project starting
  - Development plan for the next 5 years defined

VELO module building activities

R&D phase

Pixels:
Finalise ASIC
Chip attachments
to diamond heat spreader

Strips:
Large, thin sensors:
Handling, irradiation
ASIC design

Items in common:
R/O development for testing
CVD diamond as support
Hybridisation options
Cooling within module
Cooling integration
Fast flex development
Connectors
Irradiation tests
Sensor choice

Conservative design:
55 um pixel pitch bump bonding is well established technology
sensor and wafer thinning accomplished routinely for 10M ALICE pixel system

Construction phase

Pixels:
Chip Production
Wafer Testing
Metal deposition
Wafer thinning and dicing
Flip Chip assembly
and probing

Strips:
Sensor QA
ASIC production
High density sensor
wire bonding

Items in common:
Bonding and assembly jigs
Common DAQ systems
Cooling plane attachment
Flex attachment
Module wire bonding
Quality Control
Burn-in

→ a lot of items in common

Tentative VELO Milestones

2018:	Installation
2017:	Production, integration
2016:	Production readiness reviews, module production launch
2015:	readout chain prototype, module prototype, final FE chip
early 2014:	TDR
end 2013:	12-chip demonstrator module
2013:	decision on thermal management of module
2013:	FE chip prototype
	➢ pixel Chip => 2012: Timepix3, 2013: VELOpix
	➢ strip Chip => 2012: ADC submission, 2013: 1^{st} multichannel
2012:	demonstrator module 0

Tentative Milestones Central Tracker (CT)

- Timeline:

2012	•R&D towards full SciFi Tracker design •test beam with first 1.5m-long module
2013	•TDR •build and install prototype in LHCb cavern for in situ testing
2014-2018	•final design + production + installation

Declaration of Interests, Common Projects and Cost

Interests for participation to sub-systems, as declared at the upgrade workshops:

(still evolving!)

Subsystem	BRASIL	CHINA	FRANCE IN2P3	GERMANY BMBF	GERMANY MPG	ITALY INFN	NETHERLANDS	POLAND	ROMANIA	RUSSIA	SPAIN	SWITZERLAND	UK	UKRAINE	CERN	IRELAND	USA
VELO	x	x					x	x		x	x		x		x		x
SiStrip-TT								x									x
SiFi-CT		x	x	x						x	x	x	x		x		
large SiStrip-IT	?							x		x					x		
short OT modules				x			x										
OT electronics				x			x	?									
RICH						x							x		x		
Calo electronics			x								x						
Muon system						x				x					x		
Tell40 & LLT	x	x	x			x									x		
DAQ & CPU 10MHz	Common Projects																
ECS & TFC																	
GBT																	
Infrastructure																	
Computing																	

Baseline upgrade:
- detector R/O at 40 MHz
- $\mathcal{L} \sim 2\cdot10^{33}$ cm^{-2} s^{-1} ; 25ns
- HLT at $\geq$ 10 MHz rate

Total re-estimated investment cost
→ ~ 52 MCHF
(does not include R&D and MP)

Common Fund part → ~ 30%
(= investment to Common Projects)

- First "LHCb Upgrade Resources Board" took place to discuss manpower and funding situation
- For the R&D phase manpower is an issue in particular for simulation and Common Projects
- New Collaborators welcome to join LHCb upgrade effort!

LHCb Conclusions

- LHCb is planning to upgrade to 40 MHz R/O and for a luminosity of up to $\mathcal{L} \sim 2{\cdot}10^{33}\ \mathrm{cm^{-2}\ s^{-1}}$ for installation in LS2 (2018)
- LoI endorsed → aiming at
  - ✓ addendum to LoI in 2012
  - ✓ detector TDRs in ~2013
  - reviewing and monitoring progress in the various R&D activities, simulation efforts, planning and cost
  - clarifying interests by collaborating institutes and funding
- Requirements to the LHC
  - ✓ IP8 to be compatible with HL-LHC after LS3 (shielding!?)
  - ✓ 25 ns bunch spacing essential (pile-up!)
  - ✓ keep possibility of swapping B-field (systematic errors!)

ALICE Upgrade Studies - Organization

Four working groups to study the upgrade and coordinate R&D activties

I) Physics Motivations and Detector Functional requirements

(convenors: A. Dainese, G. Usai)

II) Detector Specifications and Performance Simulations

(convenors: G. Bruno, M. Sitta)

III) Detector design and implementation

(convenors: P. Riedler, A. Rivetti, G. Contin)

IV) Cooling, Cabling, Services, mechanics and integration

(convenors: A. Tauro, R. Santoro)

CDR preparation

editorial board: L. Musa, V. Manzari, G. Usai, A. Dainese, G. Bruno, P. Riedler, G. Contin, A. Rivetti, R. Santoro, A. Tauro, R. Lemmon, S. Rossegger

contributing authors: C. Di Giglio, M. Kweon, M. Mager, A. Mastroserio, S. Moretto, A. Rossi, C. Terrevoli, S. Bufalino, S. Piano, F. Prino, S. Senyukov, R. Shahoyan, L. Bosisio, M. Campbell, C. Cavicchioli, T. Kugatashan, W. Snoeys, M. Winter, G. Aglieri Rinella, R. Turchetta, C. Pastore, I. Sgura, E. Da Riva, C. Bortolin, A. Mapelli, S. Coli

Institutes that Participate in the Upgrade Studies

Participating Institutes		
Short	**Full**	**Representative**
Bari ★	Sezione INFN and Dipartimento di Fisica dell'Università e del Politecnico di Bari, Italy	V. Manzari
Birmingham	University of Birmingham, United Kingdom	D. Evans
Cagliari	Sezione INFN and Dipartimento di Fisica dell'Università di Cagliari, Italy	G. Usai
Catania ★	Sezione INFN and Dipartimento di Fisica dell'Università di Catania, Italy	F. Riggi
CERN ★	European Organization for Nuclear Research, Geneva, Switzerland	L. Musa
COMSATS	Faculty of Sciences , CIIT (COMSATS Institute of Information Technology), Pakistan	A. Bhatti
Daresbury	STFC Daresbury Laboratory, United Kingdom	R. Lemmon
Frankfurt	Institut für Kernphysik, Johann-Wolfgang-Goethe Universität, Germany	H. Appelshaeuser
Frankfurt	Frankfurt Institute for Computer Science, Germany	V. Lindenstruth
Heidelberg	Physikalisches Institut, Ruprecht-Karls-Universität, Germany	K. Schweda
Darmstadt	GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany	S. Masciocchi
Kharkov ★	Ukrainian Academy of Sciences, KIPT-KFTI, Kharkov, Ukraine	M. Maslow
Kharkov ★	Scientific Research Technological Institute of Instrument Engineering, Kharkov, Ukraine	V. Borshchov
Kiev ★	Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine	G. Zinovjev
Kosice ★	Slovak Academy of Sciences, IEP, Slovakia	L. Sandor
LNF	Laboratori Nazionali INFN di Frascati, Frascati, Italy	N. Bianchi
LNL ★	Laboratori Nazionali INFN di Legnaro, Legnaro, Italy	L. Vannucci
Padova ★	Sezione INFN and Dipartimento di Fisica dell'Università di Padova, Italy	M. Lunardon
RAL	Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, United Kingdom	R. Turchetta
Rez y Praha ★	Nuclear Physics Institute of the ASCR, Czech Republic	M. Sumbera
Roma ★	Sezione INFN and Dipartimento di Fisica dell'Università "La Sapienza" di Roma, Italy	F. Meddi
St. Petersburg ★	Institute for Physics of St. Petersburg State University, St. Petersburg, Russia	G. Feofilov
Strasburg ★	IPHC, Université de Strasbourg, CNRS-IN2P3, Strasbourg, France	C. Kuhn
Turin ★	Sezione INFN and Dipartimento di Fisica dell'Università di Torino, Italy	F. Prino
Trieste ★	Sezione INFN and Dipartimento di Fisica dell'Università di Trieste, Italy	G. Margagliotti
Wuhan	Hua-Zhong Normal University Institute of Particle Physics, China	D. Zhou

★ Institutes in the present ITS Project

- About 10 new Institutes joined the ITS project to participate in the upgrade studies and the preparation of the CDR

CERN, INFN, St-Petersburg, Kharkow - long standing expertise in

- ASIC design
- construction of detector ladder and support mechanics
- manufacturing of composite materials
- integration and characterization of hybrid pixel and microstrip

IPHC, RAL - among world leaders

- Monolithic pixels detectors

Project Timeline

Project timeline (to be adapted according to LHC schedule)

2012 – 2014 R&D

- 2012 finalization of detector specifications
  evaluation of detector technologies (radiation and beam tests)
  ➡ first prototypes of sensors, ASICS, and ladders (demonstrators)

- 2013 selection of technologies and full validation
  engineered prototypes (sensors, ASICs, ladders, data links)
  engineered design for support mechanics and services
  ➡ Technical Design Report

- 2014 final design and validation
  start procurement of components

2015-16 production, construction and test of detector modules

2017 ➡ assembly and pre-commissioning in clean room

2018 ➡ installation in ALICE

ALICE Conclusions

In line with the ALICE general upgrade strategy, the collaboration proposes to build a new ITS based on 7 silicon layers characterized by

- Continuous readout
- Factor ~3 improvement in impact parameter resolution
- Very high standalone tracking efficiency down to low p_t
  (> 95% for p_t > 200MeV/c)
- Fast access (winter shutdown) for maintenance interventions

After a couple of years of studies, ALICE are confident that this ambitious proposal can be turned into a real detector to be ready for physics in 2019

Strong support from Funding Agencies for R&D phase

Aim for review and approval by the LHCC to secure necessary resources