CMS Status Report
and
Early Physics Plans

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on behalf of the CMS Collaboration

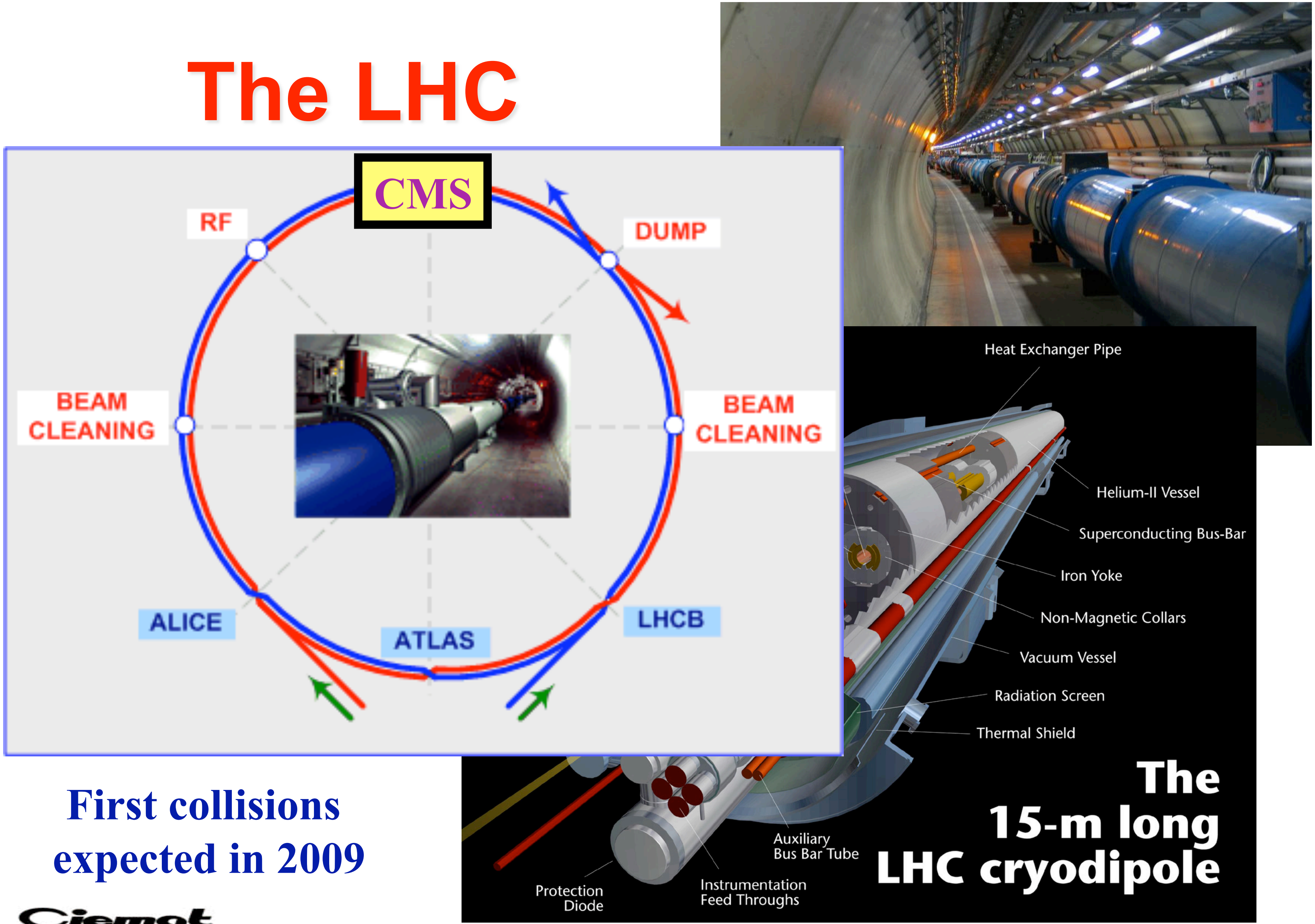
XXXVII International Meeting on Fundamental Physics, Benasque (Spain)

9 February 2009

Outline

- The CMS experiment.
- CMS commissioning, performance with cosmics and first LHC beams
- Early physics: first analyses, EWK and top physics, early discoveries
- Conclusions.

The LHC



The 15-m long LHC cryodipole

First collisions expected in 2009

The CMS design: goals

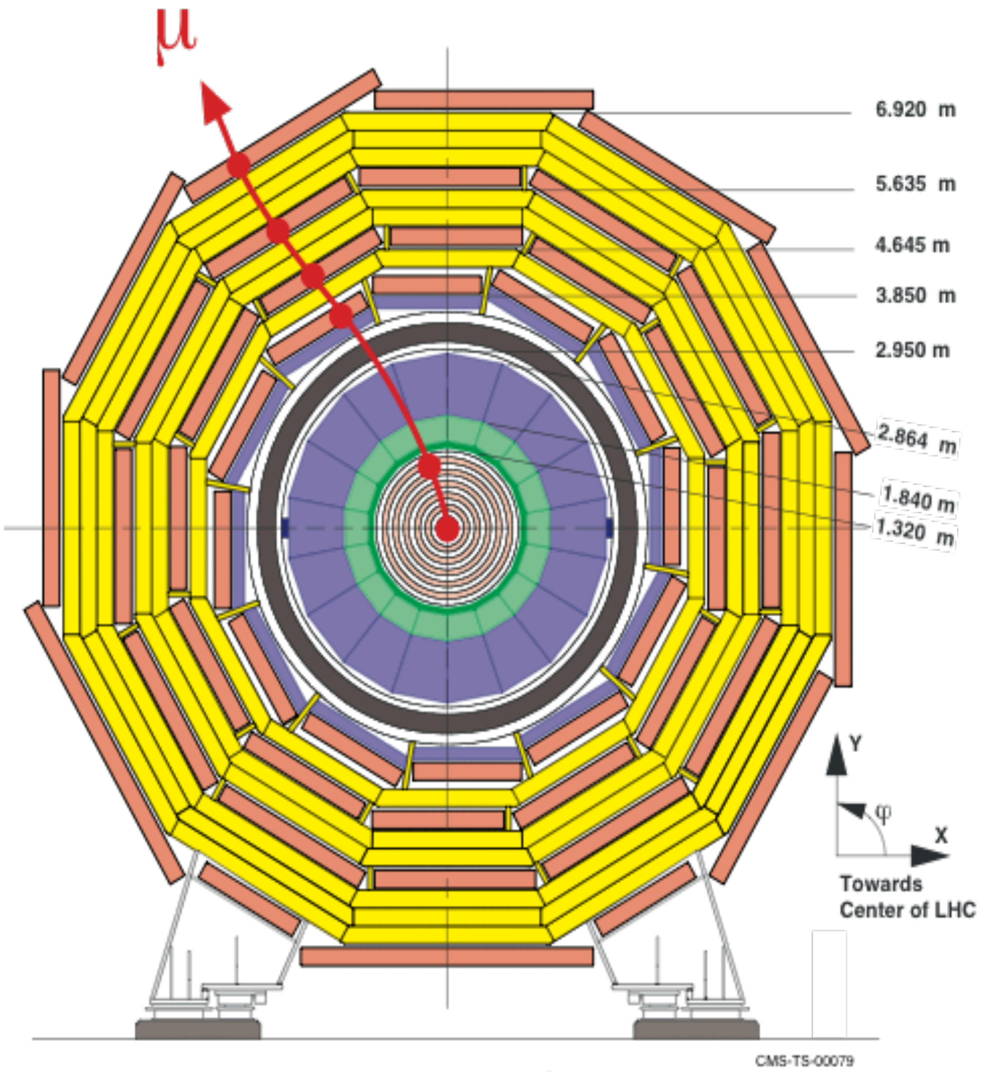
- Good muon identification and momentum resolution:
  - Redundant measurements and redundant trigger systems
  - $\Delta M_{\mu\mu} / M_{\mu\mu} \approx 1\%$ at 100 GeV
  - Unambiguous determination of the charge for $p_\mu < 1$ TeV

- Good electromagnetic identification and photon/electron energy resolution:
  - $\Delta M_{ee} / M_{ee}$, $\Delta M_{\gamma\gamma} / M_{\gamma\gamma} \approx 1\%$ at 100 GeV
  - Large coverage and goof granularity, π^0 rejection

- Precise and efficient inner tracking, including vertex capabilities:
  - Efficient triggering and offline tagging of taus and b-jets
  - Pixel detectors close to the interaction region

- Good jet and missing transverse energy resolution:
  - Hermetic coverage, fine lateral segmentation

Compact… Muon… Solenoid



Transverse View

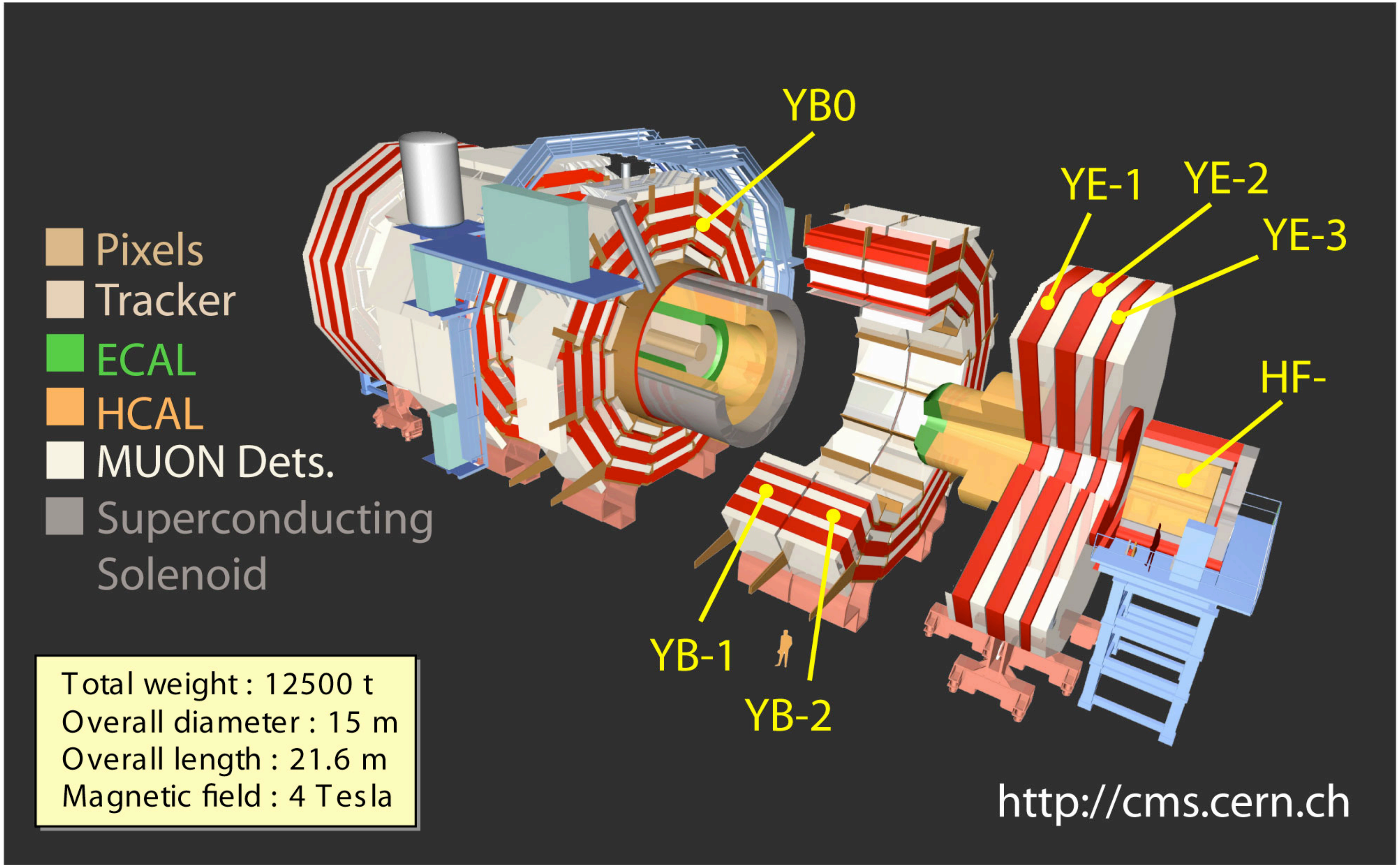
- **All central tracking and calorimetry contained inside a superconducting solenoid (L = 13 m, r = 3m)**

- **Strong field (3.8 T) => very large BL^2**

- **Iron yoke instrumented to host the muon spectrometer => Measurement of muon momentum thanks to the saturation of the iron**

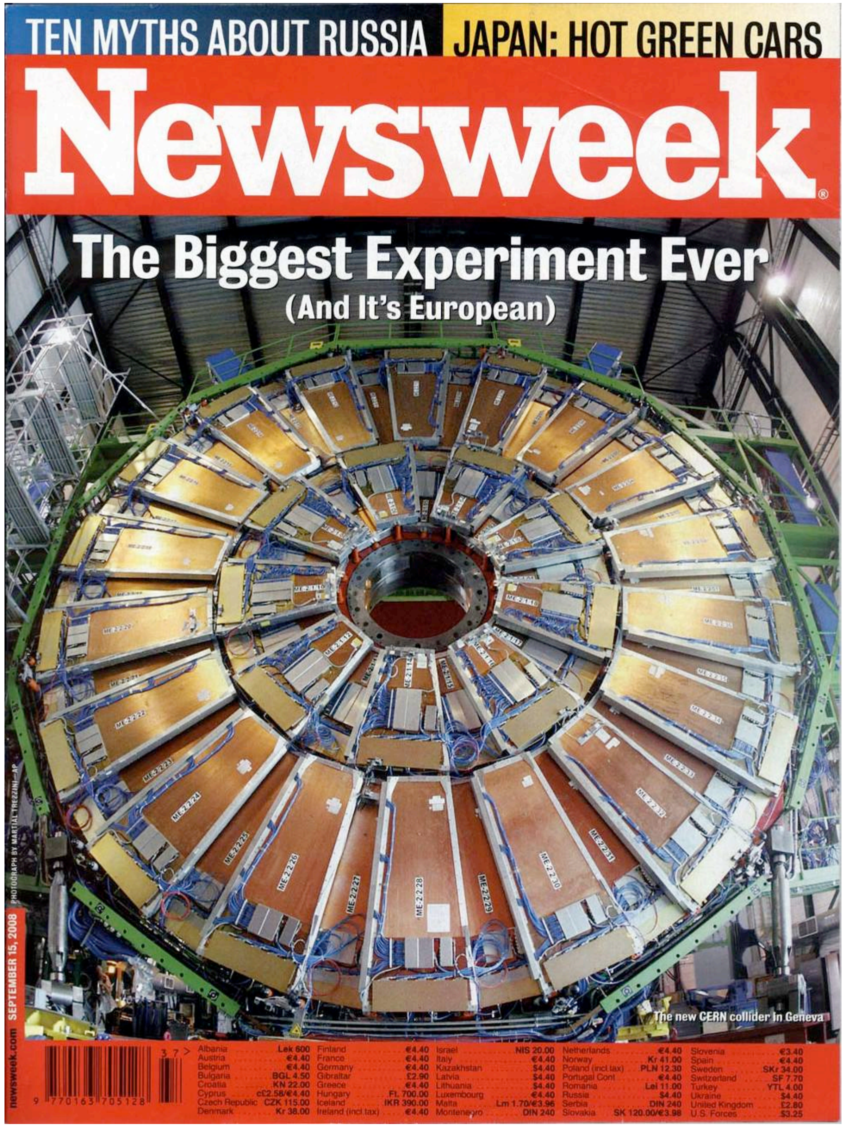
Simple, compact, but heavy and still enormous !

The CMS detector at the LHC



Total weight : 12500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

Another way of presenting it…



TEN MYTHS ABOUT RUSSIA JAPAN: HOT GREEN CARS

Newsweek

The Biggest Experiment Ever
(And It's European)

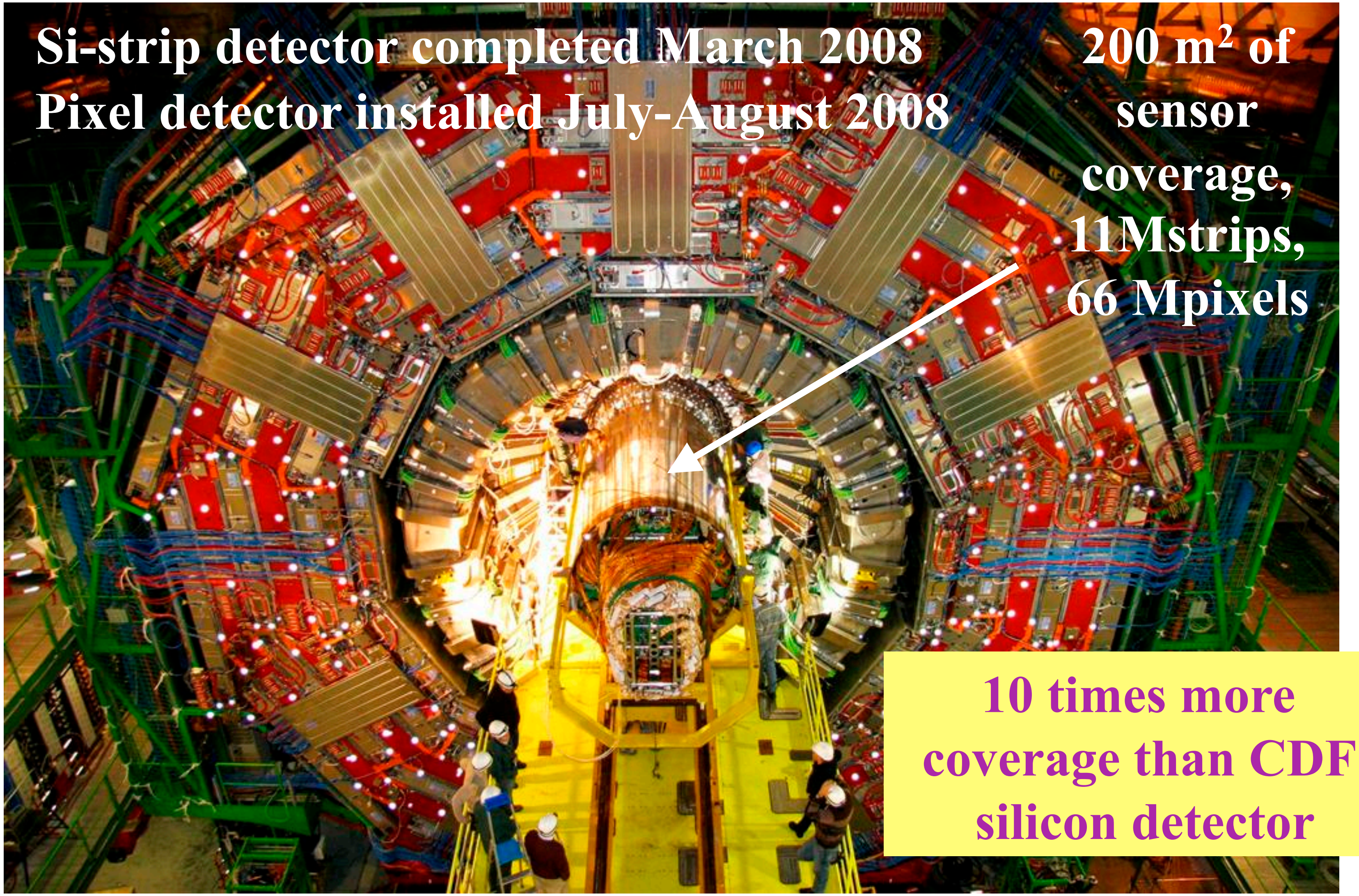
The new CERN collider in Geneva

newsweek.com SEPTEMBER 15, 2008

PHOTOGRAPH BY MARTIAL TREZZINI—AP

Albania	Lek 600	Finland	€4.40	Israel	NIS 20.00	Netherlands	€4.40	Slovenia	€3.40
Austria	€4.40	France	€4.40	Italy	€4.40	Norway	Kr 41.00	Spain	€4.40
Belgium	€4.40	Germany	€4.40	Kazakhstan	$4.40	Poland (incl tax)	PLN 12.30	Sweden	SKr 34.00
Bulgaria	BGL 4.50	Gibraltar	£2.90	Latvia	$4.40	Portugal Cont	€4.40	Switzerland	SF 7.70
Croatia	KN 22.00	Greece	€4.40	Lithuania	$4.40	Romania	Lei 11.00	Turkey	YTL 4.00
Cyprus	c£2.58/€4.40	Hungary	Ft. 700.00	Luxembourg	€4.40	Russia	$4.40	Ukraine	$4.40
Czech Republic	CZK 115.00	Iceland	IKR 390.00	Malta	Lm 1.70/€3.96	Serbia	DIN 240	United Kingdom	£2.80
Denmark	Kr 38.00	Ireland (incl tax)	€4.40	Montenegro	DIN 240	Slovakia	SK 120.00/€3.98	U.S. Forces	$3.25

CMS inner tracking system



Si-strip detector completed March 2008

Pixel detector installed July-August 2008

200 m^2 of sensor coverage, 11Mstrips, 66 Mpixels

10 times more coverage than CDF silicon detector

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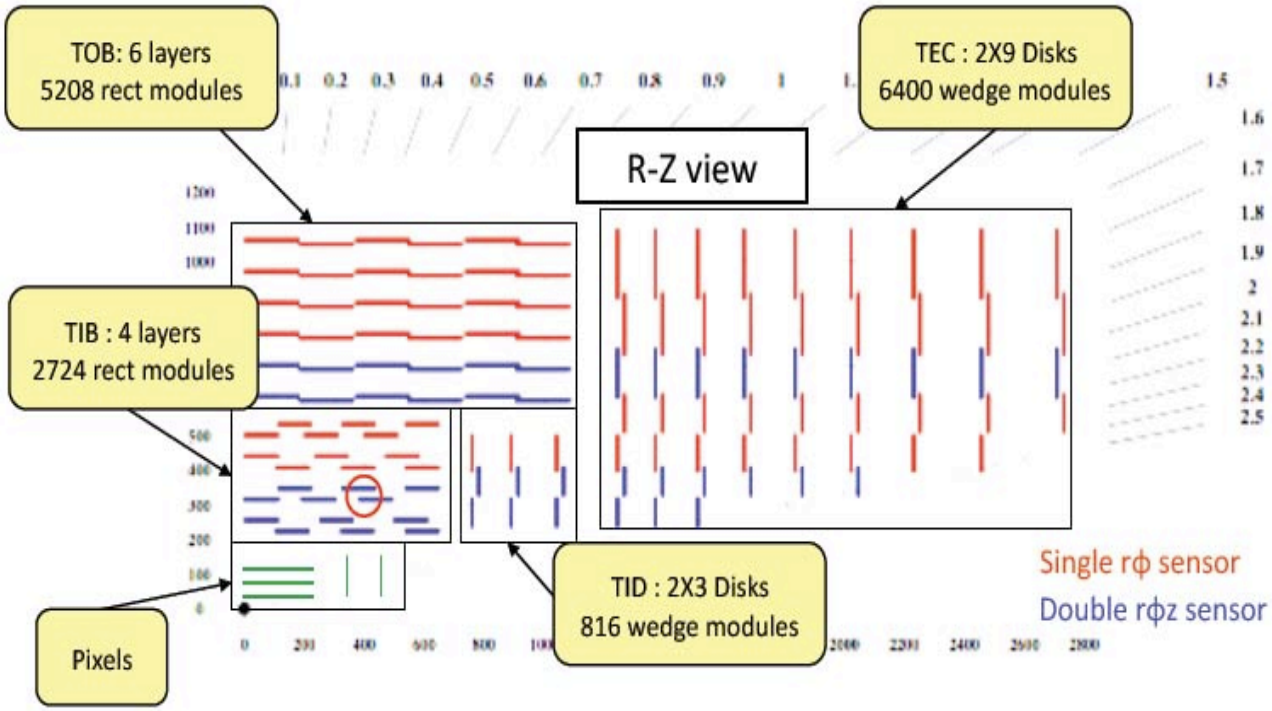
CMS inner tracking system



TOB: 6 layers
5208 rect modules

TEC : 2X9 Disks
6400 wedge modules

R-Z view

TIB : 4 layers
2724 rect modules

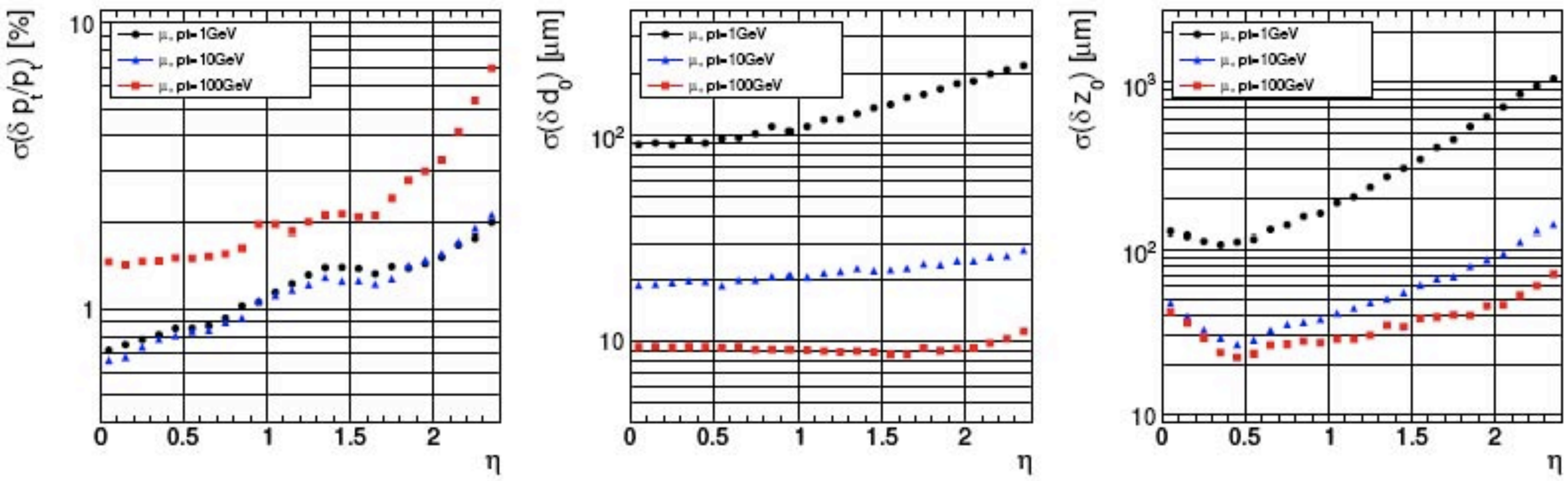
Pixels

TID : 2X3 Disks
816 wedge modules

Single rϕ sensor
Double rϕz sensor

- 3 layers of silicon pixel detectors: 66M pixels (sixe 100 x 150 μm^2)
- 10 layers of silicon micro-strip detectors: 10M strips (80-180 μm variable strip pitch, ≈10 measurements, ≈4 of them two-dimensional in $|\eta|<2.4$

CMS inner tracking system

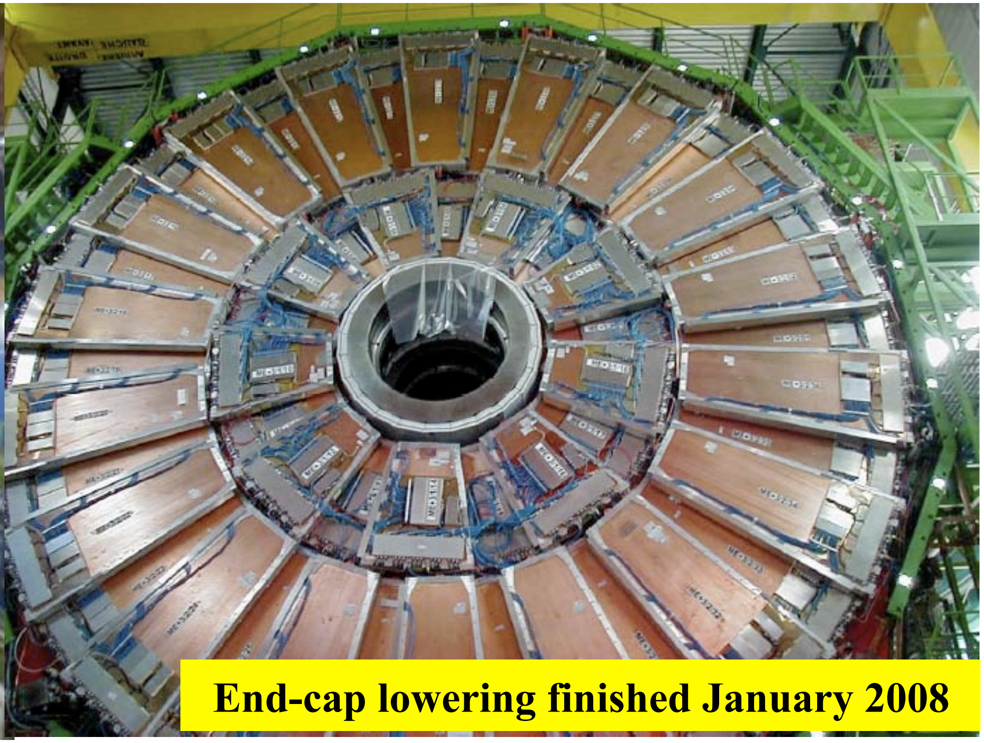


AN IMPRESSIVE TRACKER SYSTEM

- $\Delta p_T / p_T \approx$ 1-2% ($|\eta|<1.6$) at $p_T \approx 100$ GeV
  - Muon resolution dominated by inner tracking resolution for $p_T < \approx 100$ GeV
- $\Delta d_{xy} \approx 10$ μm resolution at 100 GeV
- $\Delta z \approx$ 20-40 μm ($|\eta|<2$) resolution at 100 GeV

CMS Muon Chambers

Barrel installation finished August 2007



End-cap lowering finished January 2008

Drift Tubes (DT) used in the barrel

Cathode Strip Chambers (CSC) used in the end-caps

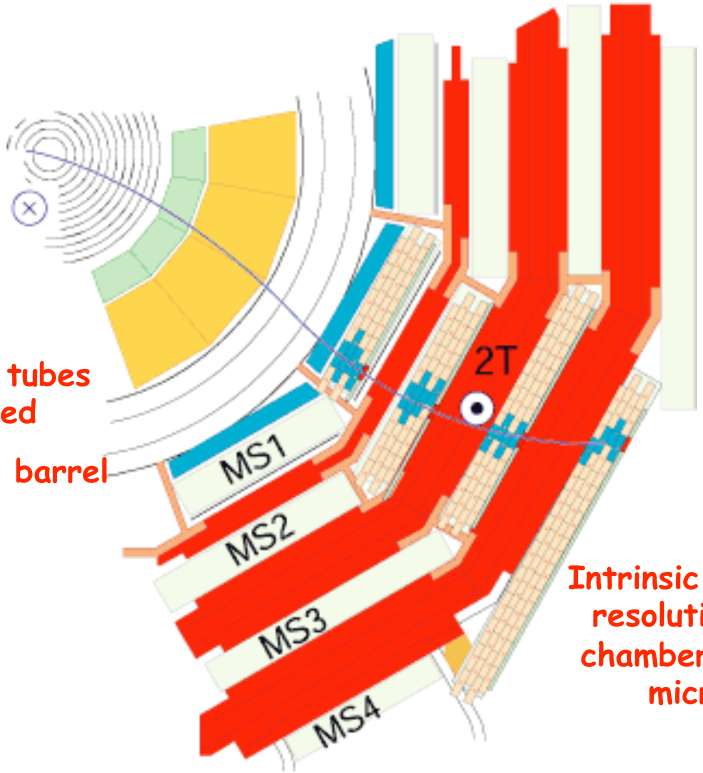
RPCs for fast trigger response

CMS Muon Chambers

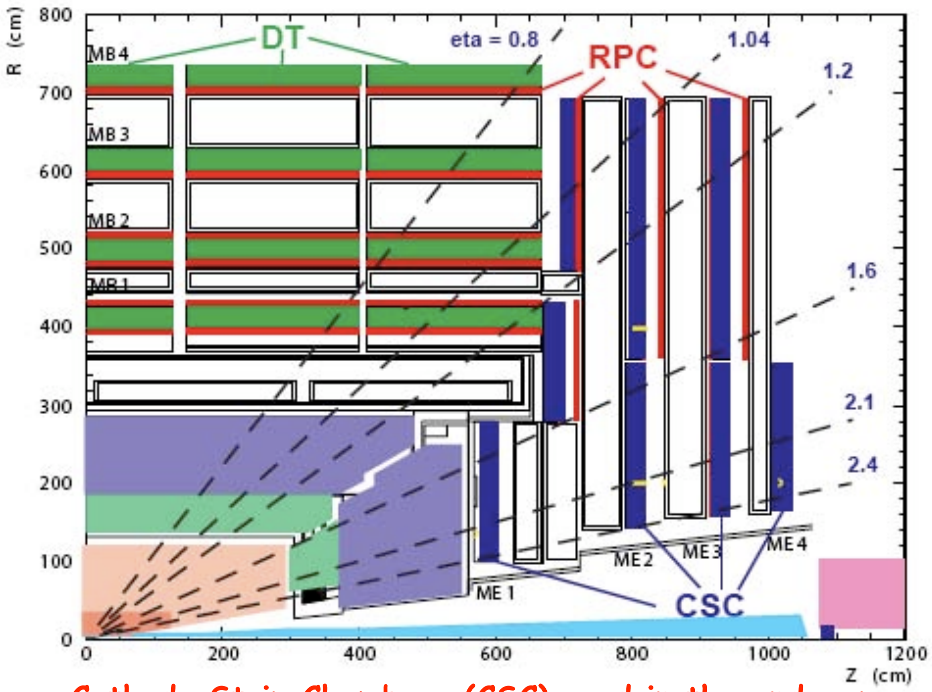
- ❑ The CMS muon system (barrel and also endcap) is optimized for:
  - ➢ Robust, efficient and redundant muon triggering system (chambers+RPCs)
  - ➢ Efficient muon identification and reconstruction (|η|<2.4, redundant coverage)
  - ➢ Precise measurement (< 10%) for TeV momenta (good alignment + level arm)

Drift tubes used

in the barrel



Intrinsic position resolution per chamber ~ 100 microns



Cathode Strip Chambers (CSC) used in the end-caps

RPCs for fast timing and trigger response

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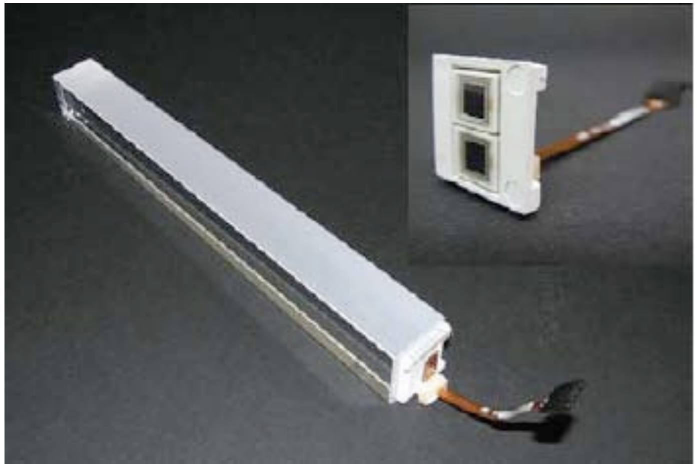
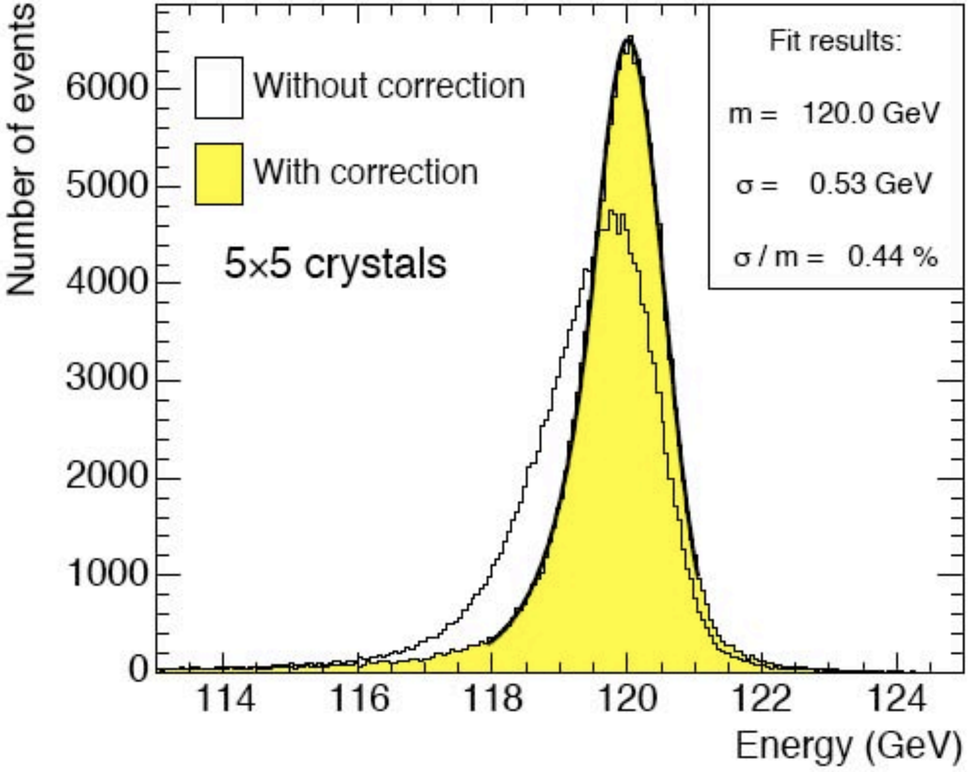
CMS Electromagnetic Calorimeter

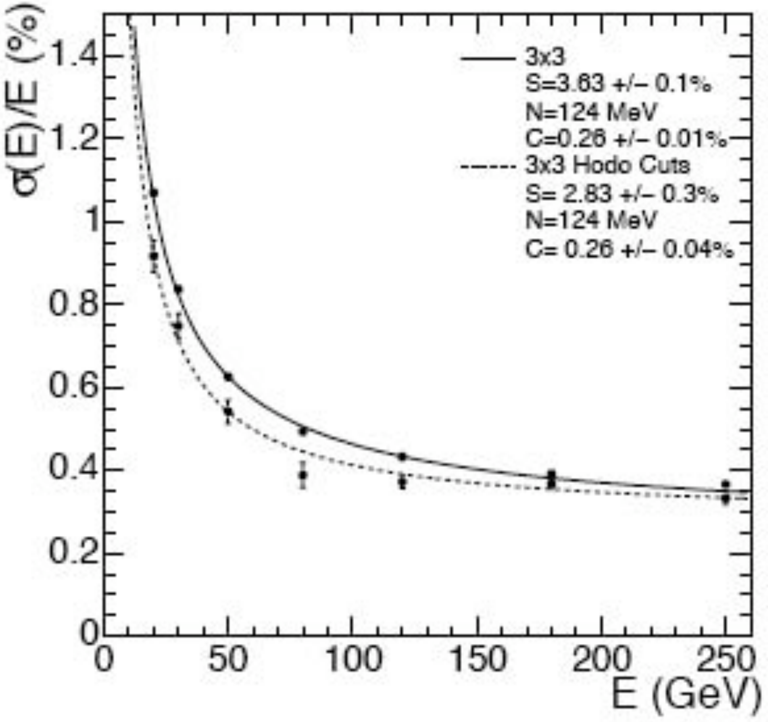


More crystals (in volume or number) than in all previous HEP experiments combined

- 76K $PbWO_4$ crystals (≈ [Molière radius]^2 × 25 X_0) for precise electron/photon angular/energy measurements
  - Very high density, small radiation length (X_0=8.9 mm). small Molière radius (2.2 cm) radiation hard, fast response (80% of light output collected in 25 ns) ➔ compactness, high granularity and precision
- System to be completed in February 2009 with lead+silicon pre-shower detector (≈ 3 X_0 depth, ≈ 2 mm pitch in X,Y) to increase granularity in front of end-caps

CMS Electromagnetic Calorimeter



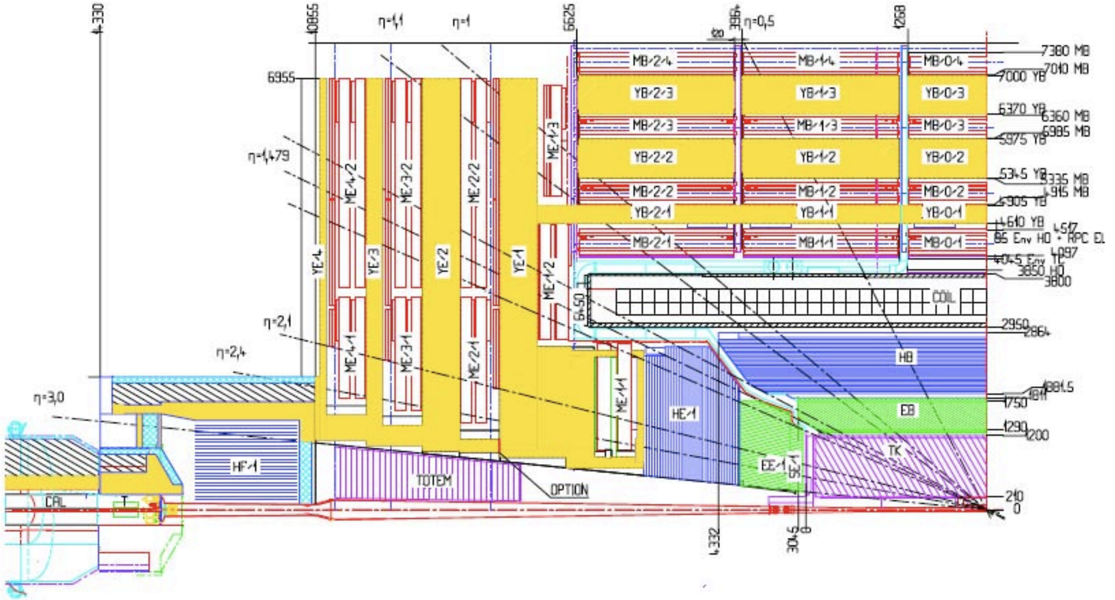


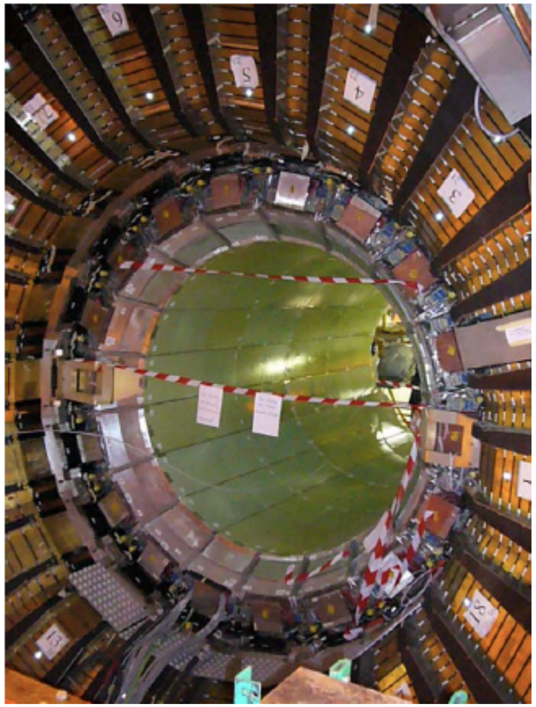
- Extremely good resolution (stochastic term ≈ 2.8% at 1 GeV), low noise (noise term ≈ 120 MeV), and good uniformity/intercalibration (uniformity ≈ 0.3% from test-beam studies):

$$\left(\frac{\sigma}{E}\right)^2 = \left(\frac{2.8\%}{\sqrt{E}}\right)^2 + \left(\frac{0.12}{E}\right)^2 + (0.3\%)^2$$

CMS Hadronic Calorimetry

HCAL installed July 2007

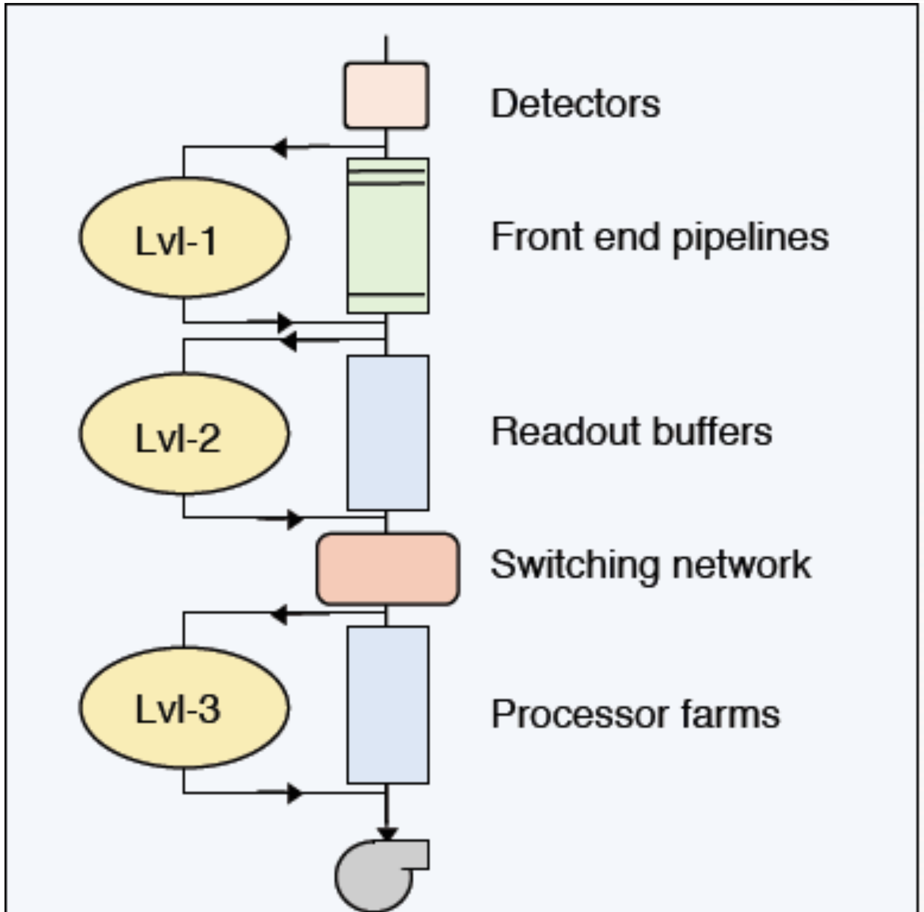




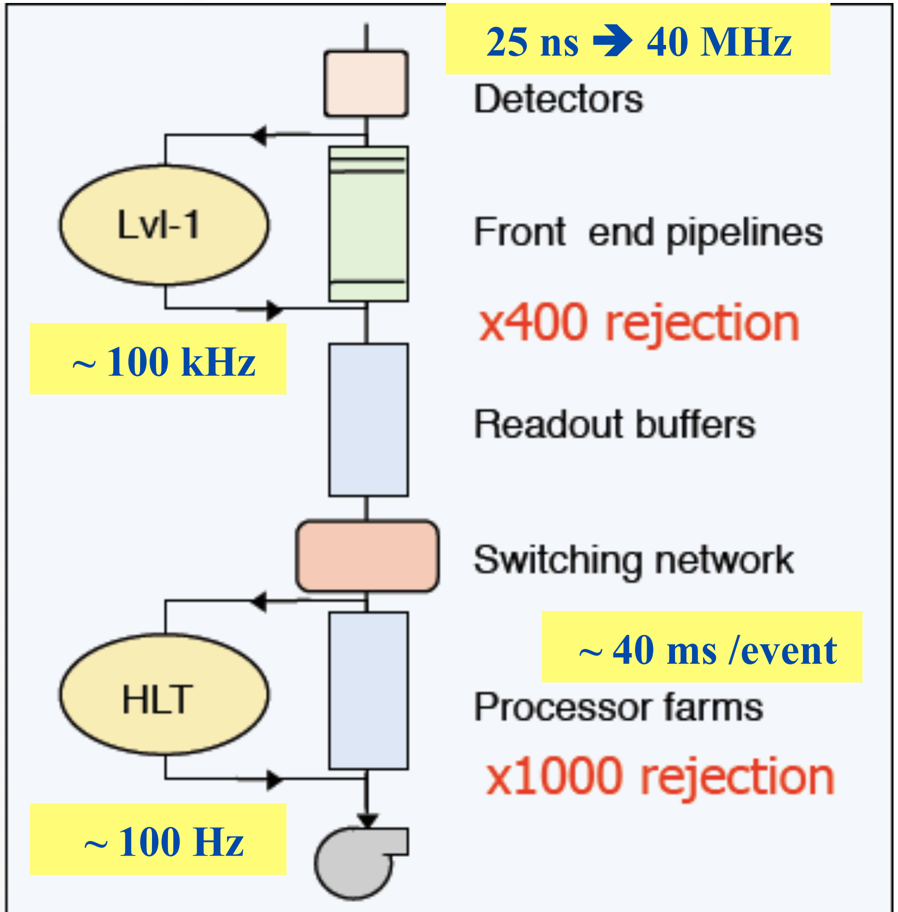
- Scintillator-brass/steel tile calorimeter: compact, hermetic, good segmentation and coverage ($|\eta|<5.2$)
- Jet angular resolution ~ 20 (30) mrad in φ (θ) at $E_T \geq 100$ GeV
- Jet transverse energy resolution (using ECAL+HCAL only, barrel):

$$\left(\frac{\sigma}{E_T}\right)^2 = \left(\frac{1.25}{\sqrt{E_T}}\right)^2 + \left(\frac{5.6}{E_T}\right)^2 + (3.3\%)^2$$

CMS Trigger system



“Traditional”: 3 physical levels, ATLAS



CMS: 2 physical levels

- Challenging, but allows to be dependent on ``software’’ and use fully (more precise) reconstructed information at earlier stages..

CMS Completed and closed, September 2008


Ready for the LHC

CMS Commissioning

Summer 06 ………………………………………… Fall 08

MTCC ….. CRUZET … BEAM … CRAFT

- MTCC: Magnet Test and Cosmic Challenge (summer 2006)
- CRUZET: Cosmic RUn at ZEro Tesla (Spring-Summer 2008)
- BEAM (September 2008)
- CRAFT: Cosmic Run At Four Teslas (Fall 2008)

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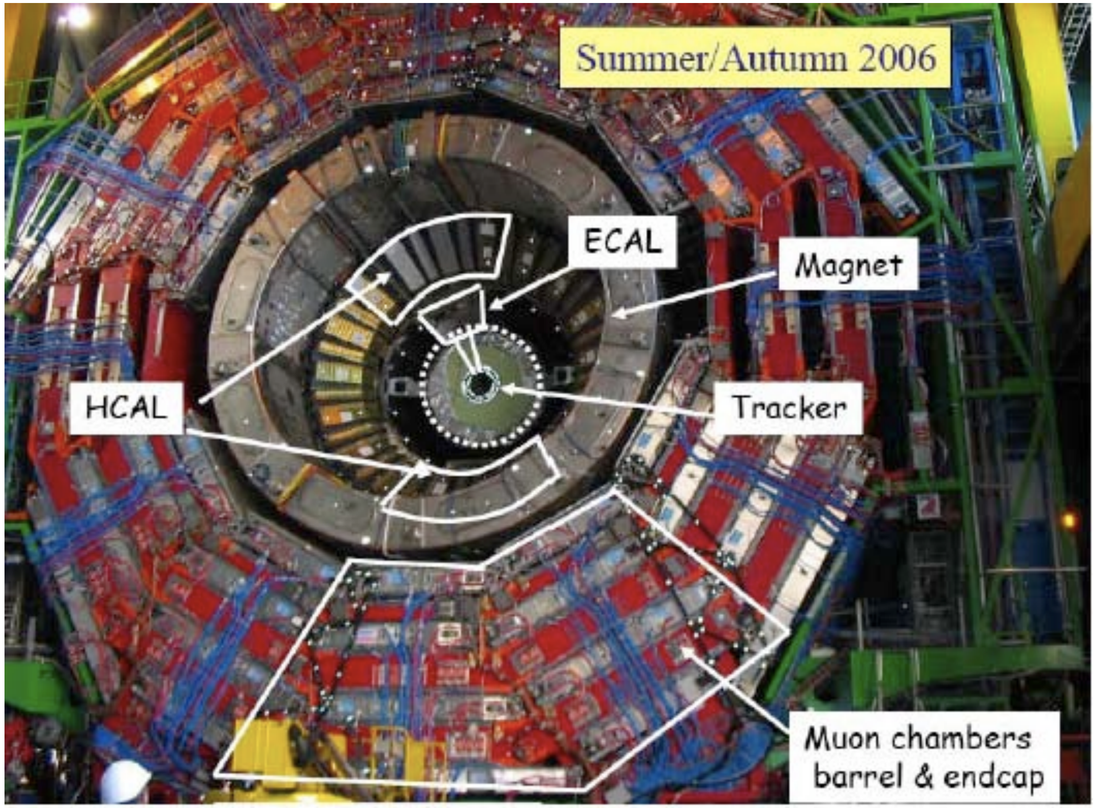
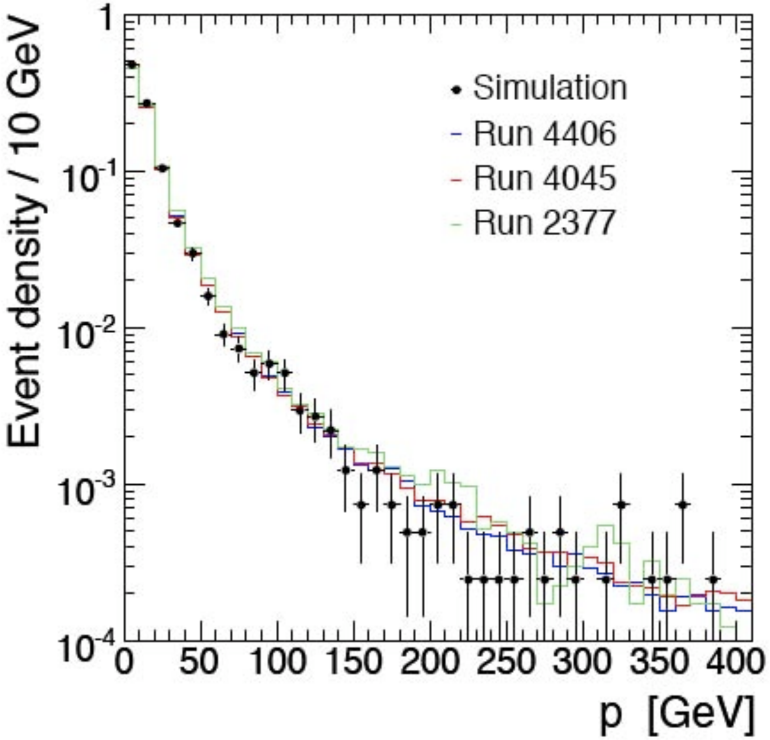
Magnet Test and Cosmic Challenge (MTCC, Summer 2006)



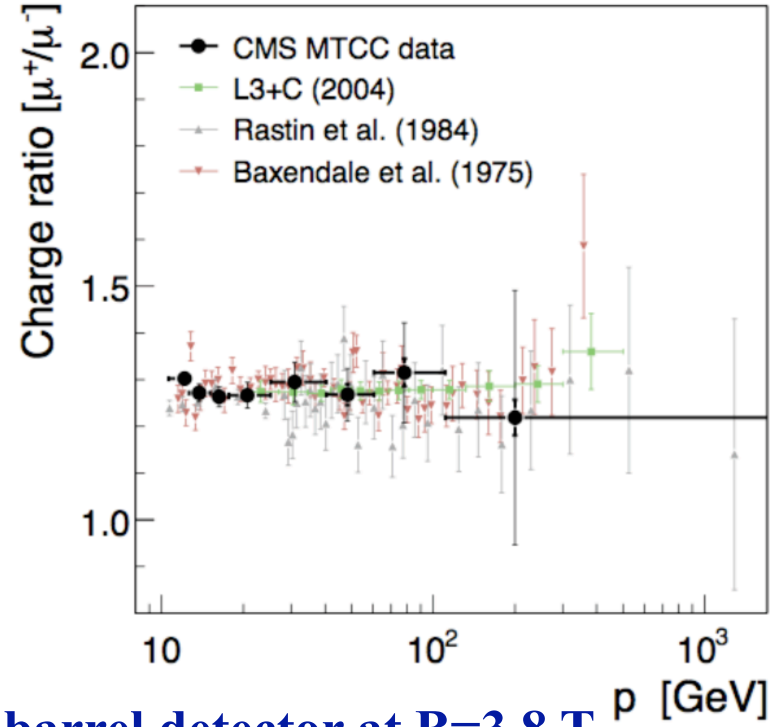
- a) Tests of CMS on surface with cosmic rays
- b) Detailed measurements of the magnetic field maps at different field strengths

Portions of the five sub-detectors taking simultaneously data for the first time

First physics results from CMS



CMS Note 2008/016
M. Aldaya, P.Garcia-Abia (CIEMAT)



- **15 M cosmics through 5% of the muon barrel detector at B=3.8 T**
- **Stringent test of the alignment parameters in the muon detector**
- **Interesting measurement of the cosmic charge ratio!**

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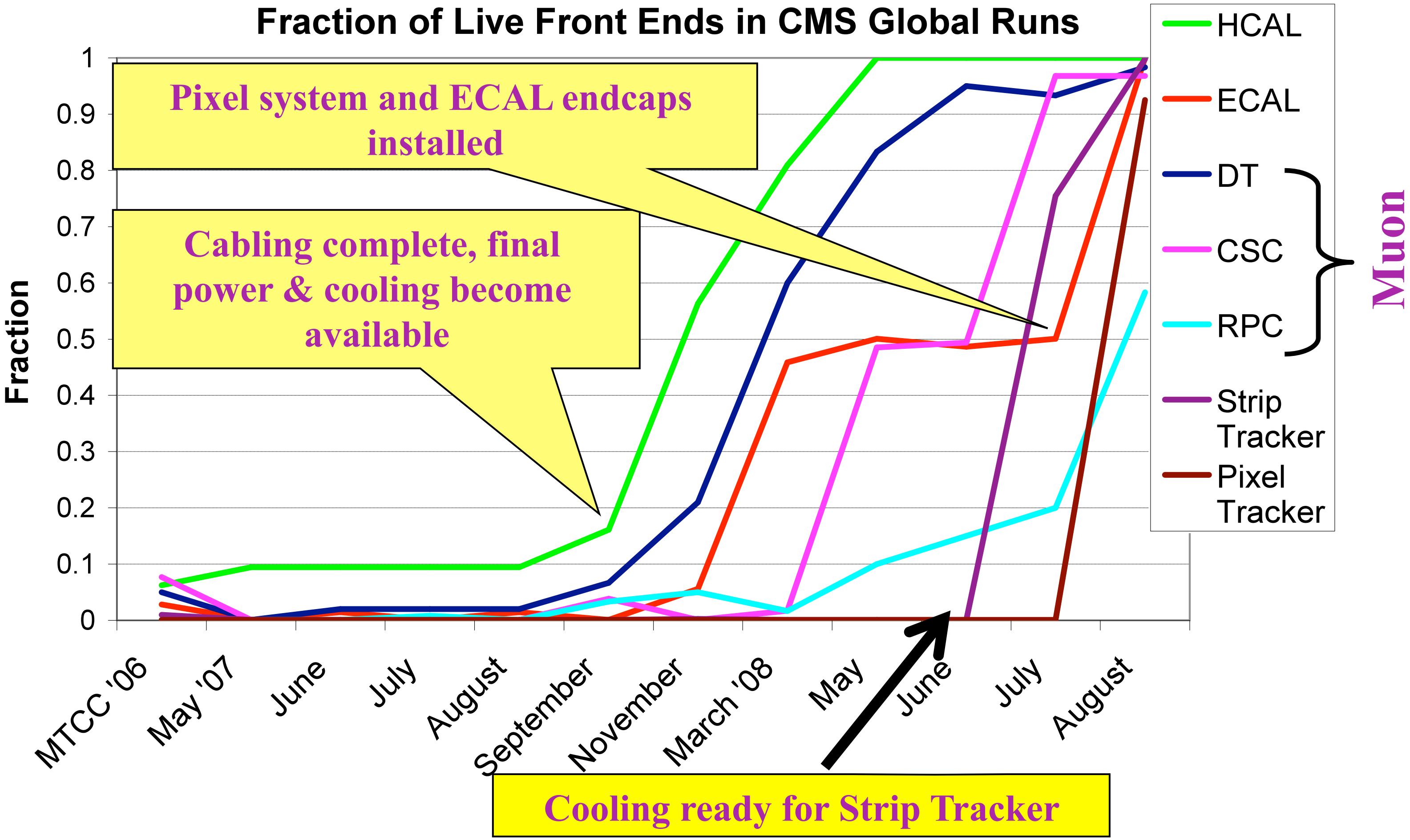
J. Alcaraz, CMS Status Report and Early Physics Plans, 9 February 2009

Fraction of CMS Systems in Global Runs



Pixel system and ECAL endcaps installed

Cabling complete, final power & cooling become available

Cooling ready for Strip Tracker

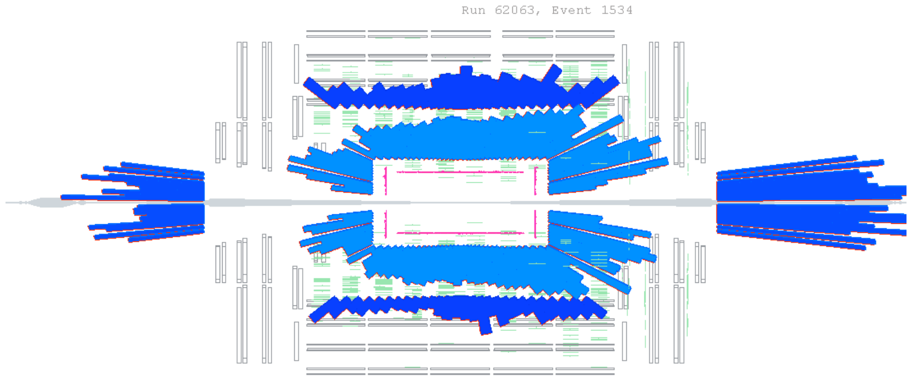
August 2008: all subsystems operational and ready for beam

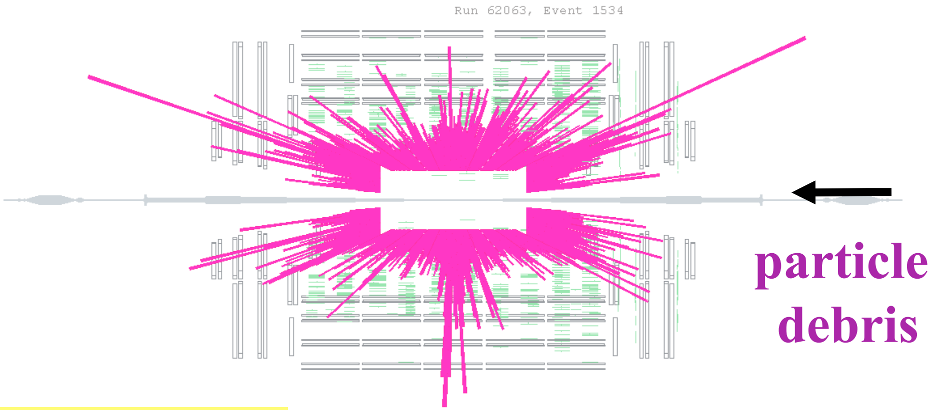
First LHC beams seen in CMS

HCAL energy

Longitudinal views

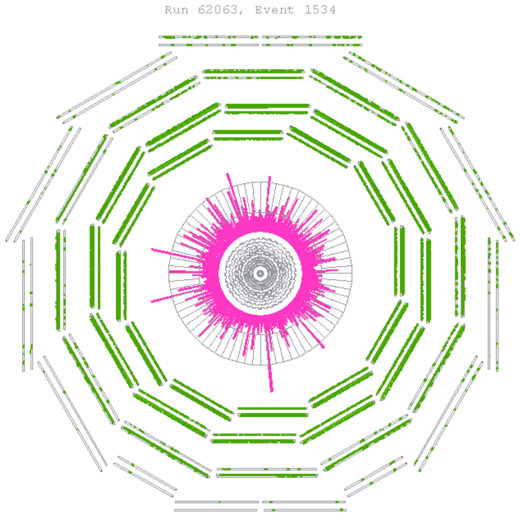
ECAL energy





particle debris

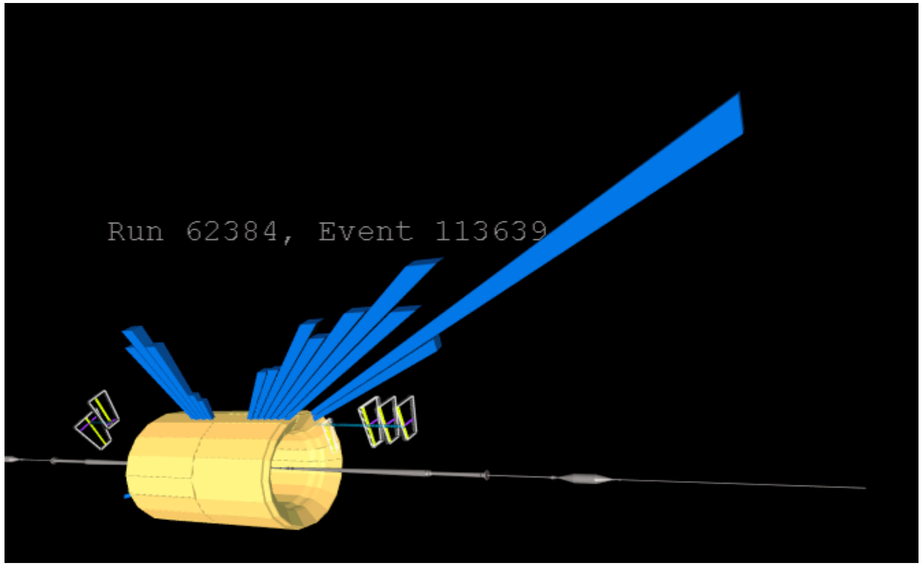
Inner silicon tracking systems kept OFF

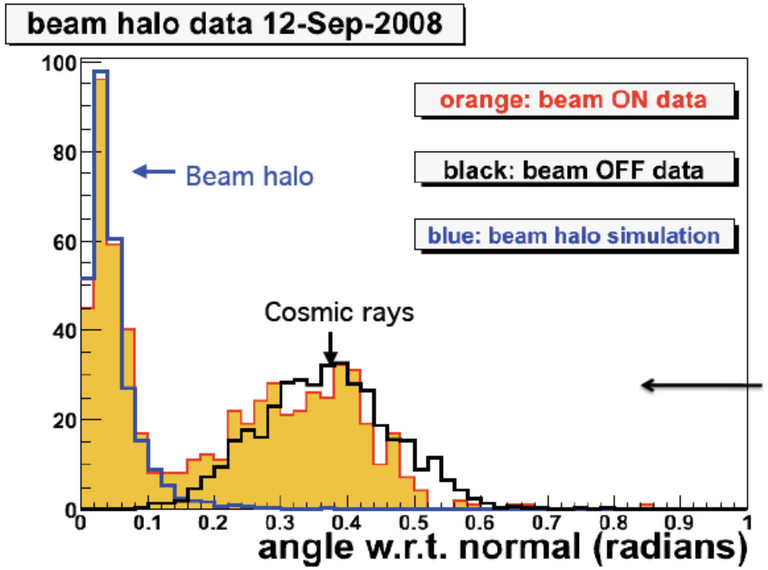


Muon hits

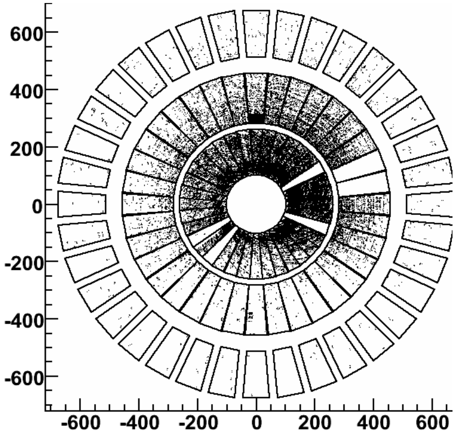
1. **10^9 protons incident on (closed) collimators at 150 m upstream CMS (September 10th 2008):**
   a) **Dedicated triggering system was used**
   b) **Time synchronization and energy correlation studies were performed**

First LHC beams seen in CMS

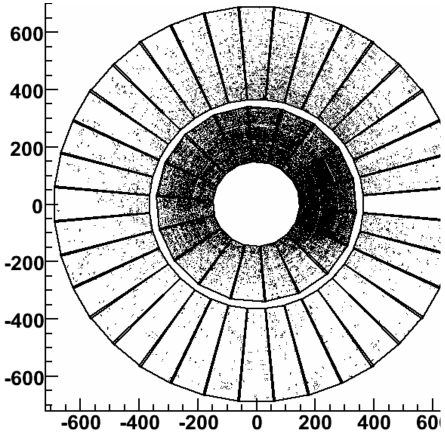




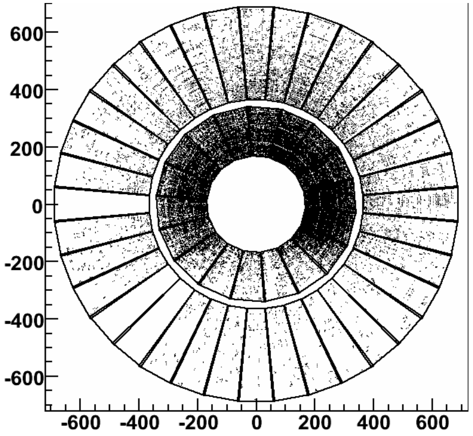
ME-1



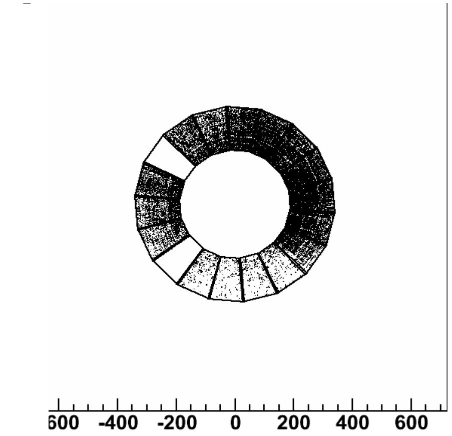
ME-2



ME-3

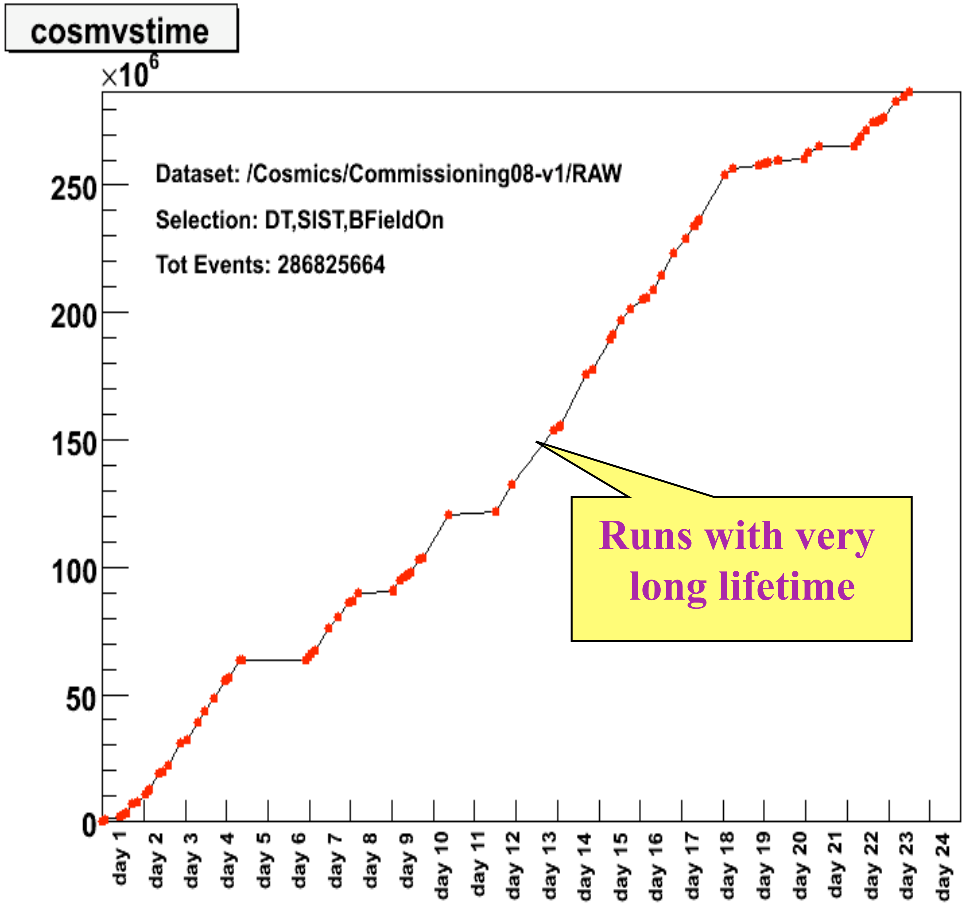


ME-4



2. Circulating beams -> halo muons (important for alignment)

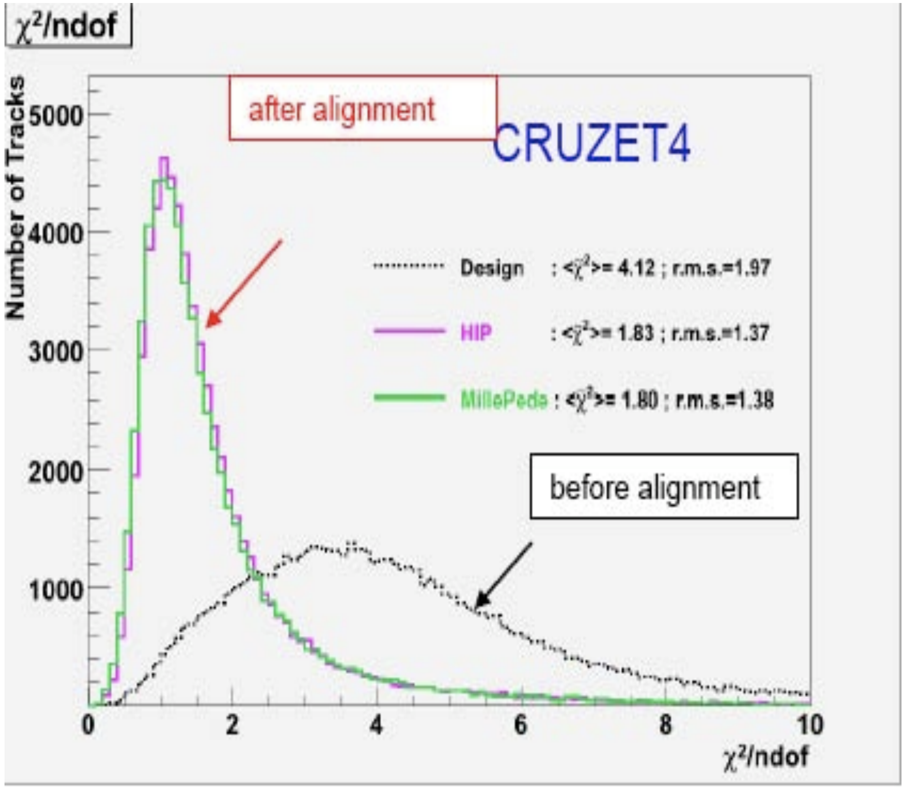
Cosmic Runs At Four Teslas (CRAFT, Fall08, after LHC incident)

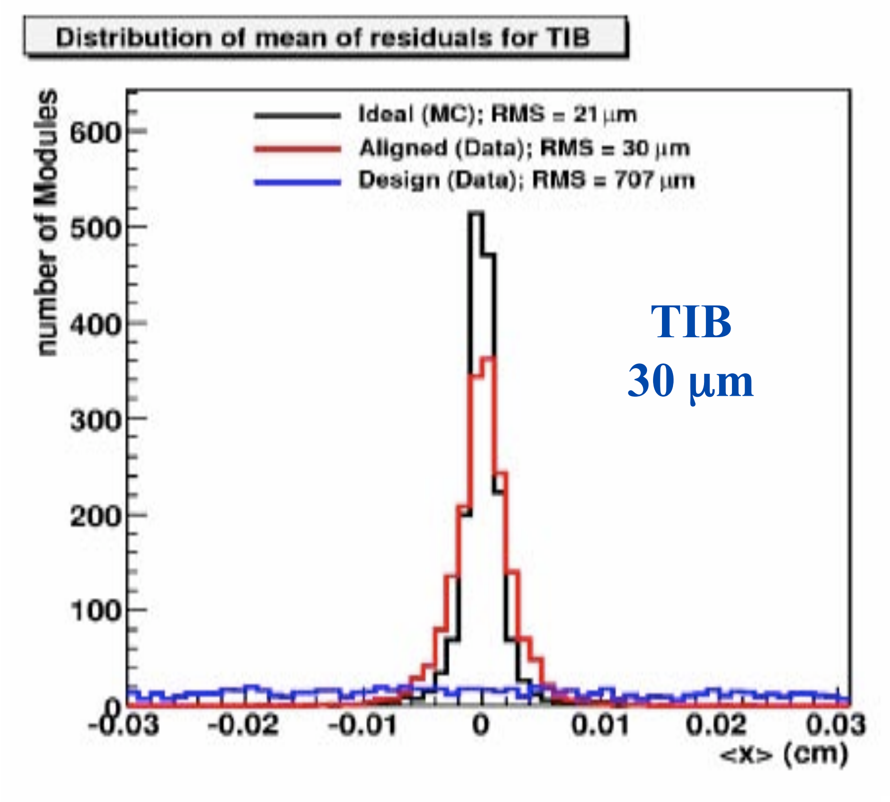


Runs with very long lifetime

- ~ 1 month (Oct-Nov 2008) of continuous/smooth running, mostly at 3.8 T, with the whole CMS detector:
  - 370M cosmics collected (~ 200M with all relevant components in)
  - ~ 60-70% operational efficiency
  - Some runs with > 15 horus lifetime, 2 Tbytes/hour
  - ~ 400 Tbytes of raw and processed data
  - Whole reconstruction/analysis chain in place (Tier0+Tier1+Tier2)

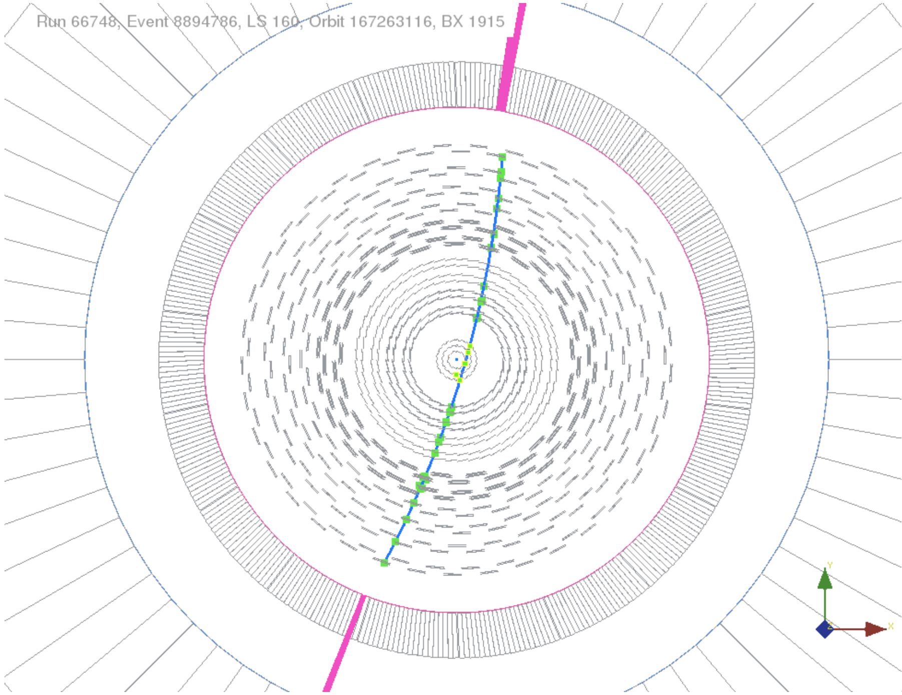
Some highlights of CRUZET/CRAFT

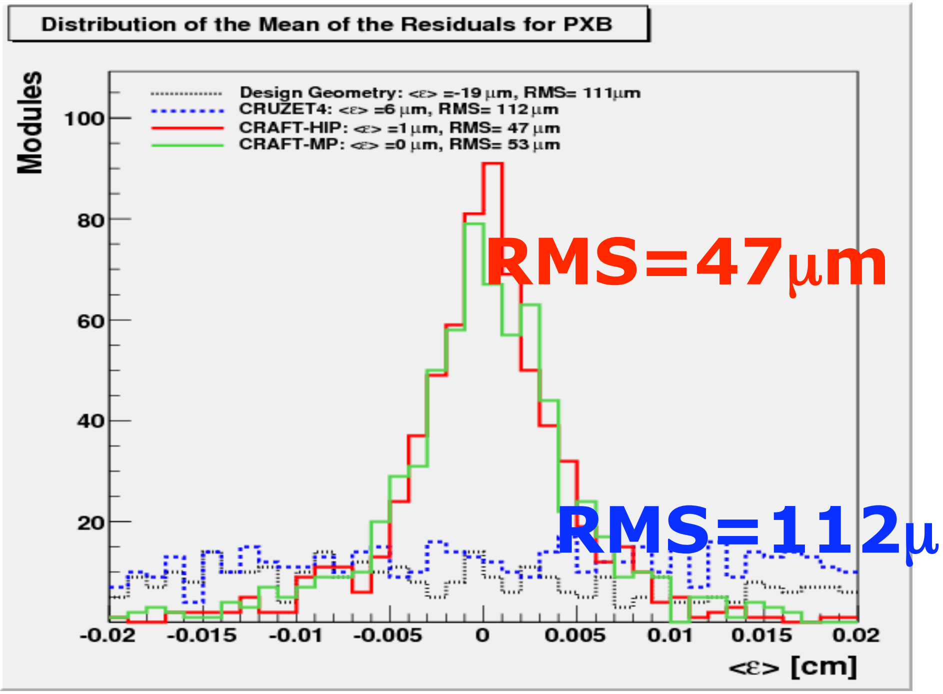




- **Impressive evolution of the Si-tracker internal alignment with time (and using only cosmic muons):**
  - **We already have a reasonably well aligned tracker detector NOW!**

Some highlights of CRUZET/CRAFT



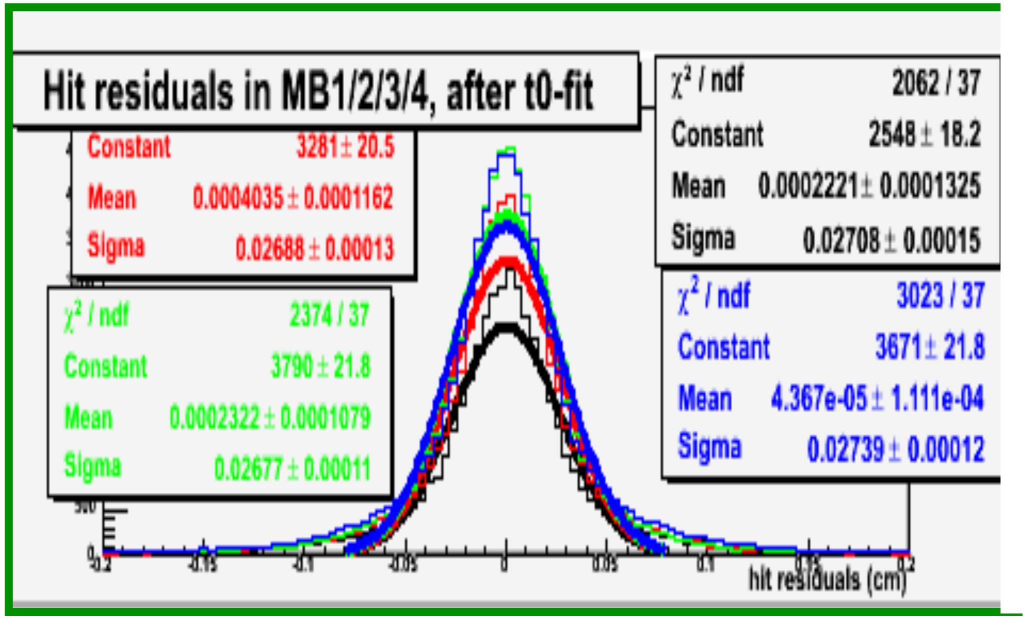


RMS=47μm

RMS=112μm

- **Pixel-detector operational (99% barrel, 94% end-cap) and reasonably aligned:**
  - **55k tracks, ~ 300 hits/module collected**

Some highlights of CRUZET/CRAFT

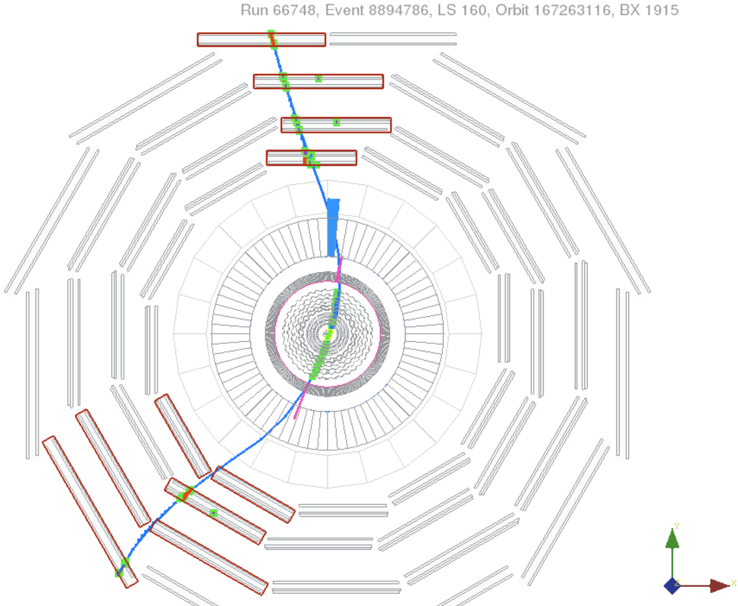


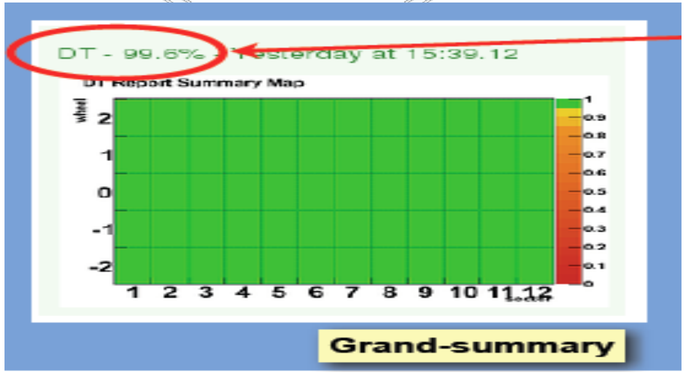
MB1 res.: 271 μm

MB2 res.: 269 μm

MB3 res.: 268 μm

MB4 res.: 274 μm





DT - 99.6% - Yesterday at 15:39.12

Barrel muon chambers almost 100% efficient and providing the expected resolution/wire

Early physics with CMS

- NOT discussed: initial LHC “engineering” runs at √s = 900 GeV (injection energy), very low luminosities (< 10^{30} cm^{-2} s^{-1}).

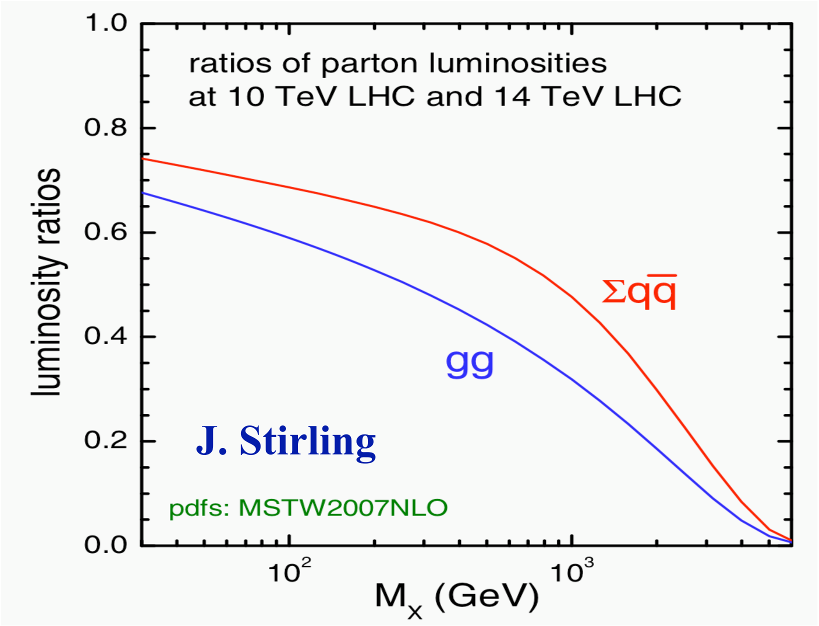
- We mostly discuss physics studies at √s = 14 TeV, for instantaneous luminosities in the range10^{30}-10^{32} cm^{-2} s^{-1} . The very first data (2009) will be collected at an energy near √s = 10 TeV (see next slide).

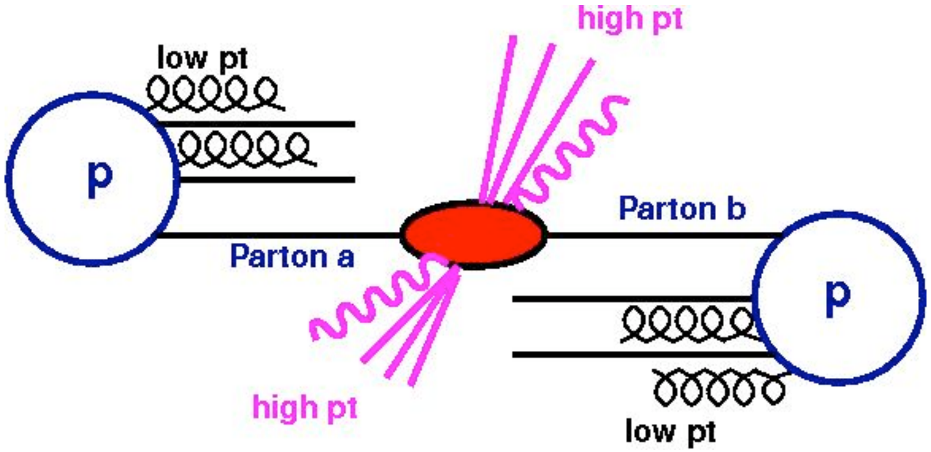
- We discuss physics for integrated luminosities << 1 fb^{-1} in the CMS detector.

- In summary: the focus will be on:

EARLY PYHSICS MEASURENTS WITH THE CMS DETECTOR

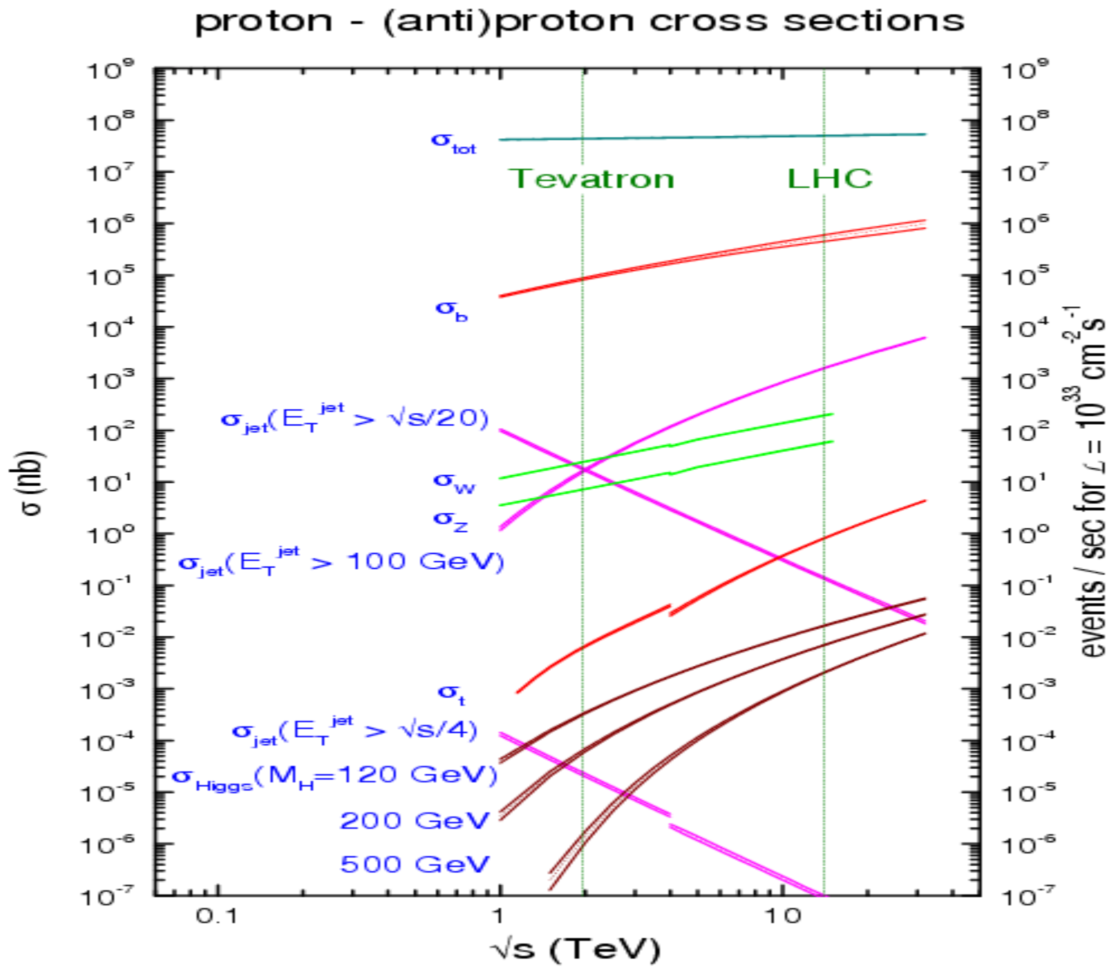
The LHC at √s = 10 TeV





- ✓ Major changes with respect to √s = 14 TeV:
  - ✓ Cross sections reduced by a factor of two:
    - ✓ W/Z cross sections ~ 70% (slightly compensated by larger acceptance at lower rapidities)
    - ✓ Ttbar cross section ~ 50%
    - ✓ Higgs (m=200 GeV) ~ 50%
- ✓ Strong reduction of the energy reach for high masses and energy scales
  - ✓ Z' resonance (m=2 TeV) ~ 30%
  - ✓ One order of magnitude less reach for new physics effects at scales of ≥ 4 TeV
- ✓ Subtle effects:
  - ✓ Less gluon-gluon relative to qqbar hard interactions (PDF effect)

How does it compared with previous hadron colliders?



(Campbell, Huston, Stirling, hep-ph/0611148)

(Inelastic) cross sections at the LHC are essentially one order of magnitude larger than at the Tevatron

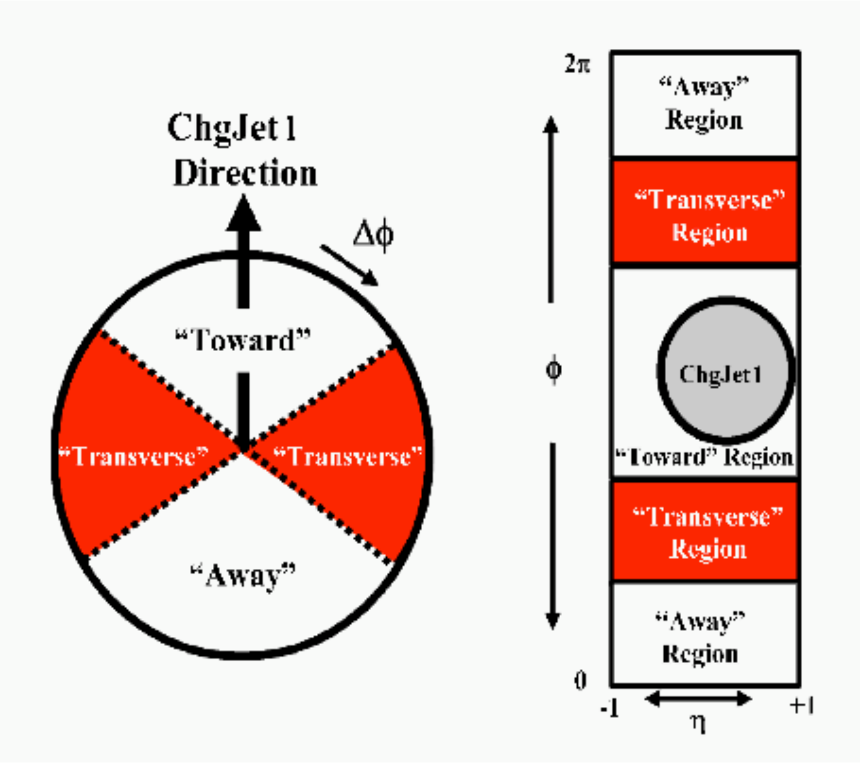
This increase is even larger for some relevant cross sections, like pp→Higgs, top-antitop, …

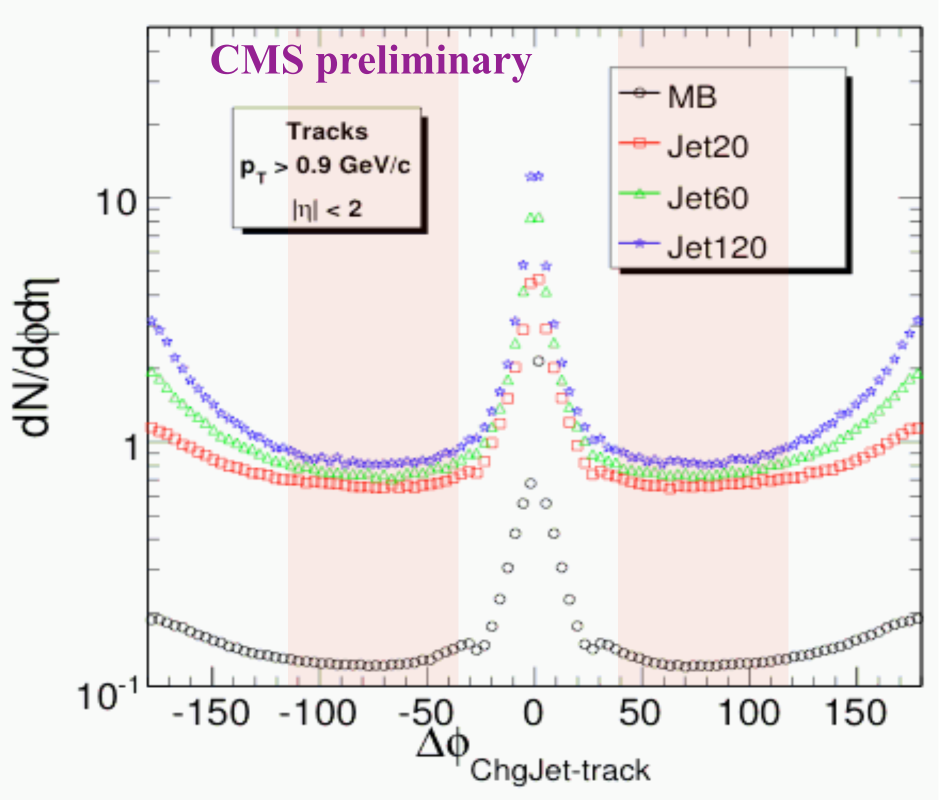
Typical amount of events in 1 pb^{-1}

Process	**# events in 1 pb^{-1}**
QCD jets with $p_T > 150$ GeV	1000 (10% trigger bandwidth)
$J/\Psi \rightarrow \mu^+\mu^-$	15000
$Y \rightarrow \mu^+\mu^-$	3000
$W \rightarrow \mu\nu$	6000
$Z \rightarrow \mu^+\mu^-$	600
Top-antitop $\rightarrow \mu\nu$ + jets	20, but distinguishable from background?
Jets with $p_T > 1$ TeV	10

At $\sqrt{s} = 14$ TeV, per experiment, in the acceptance

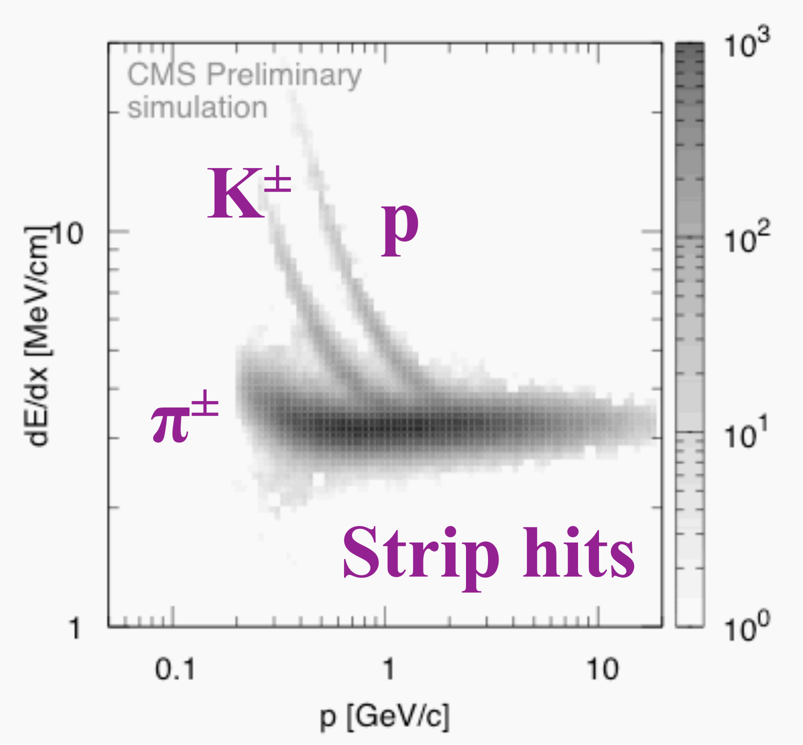
What should we do first?

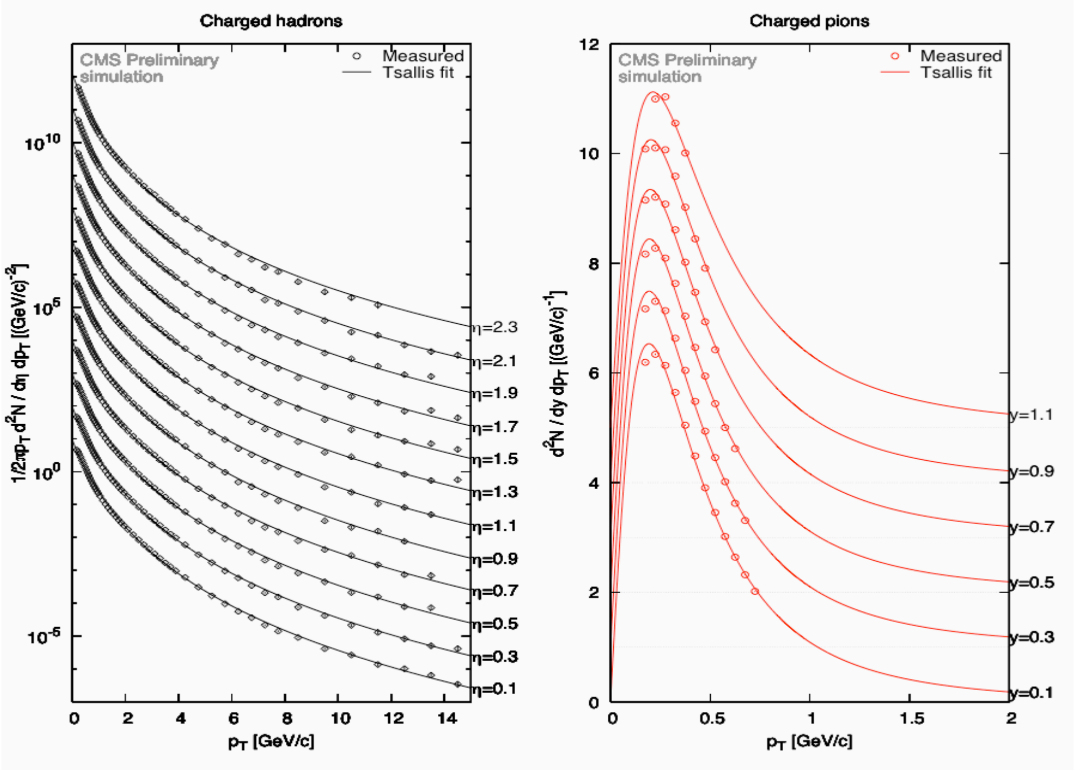




- Understanding the LHC underlying event environment:
  - The underlying activity mainly affects the "transverse" region (in red)
  - This is a necessary step to tune our Monte Carlos (multiple interactions, …)

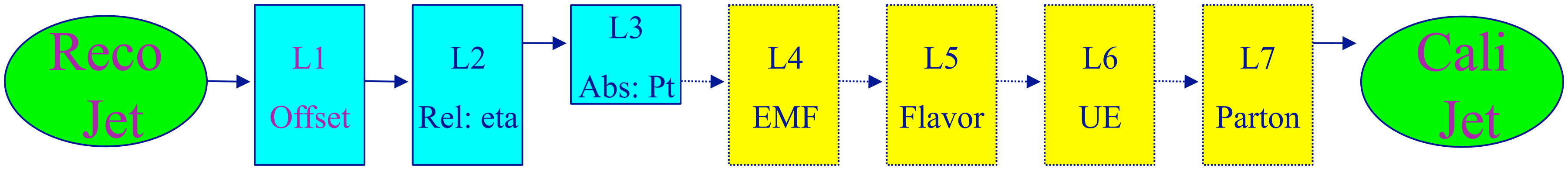
What should we do first?



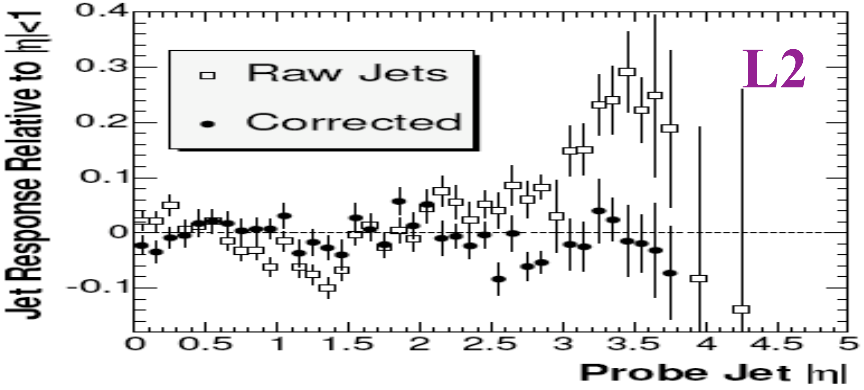


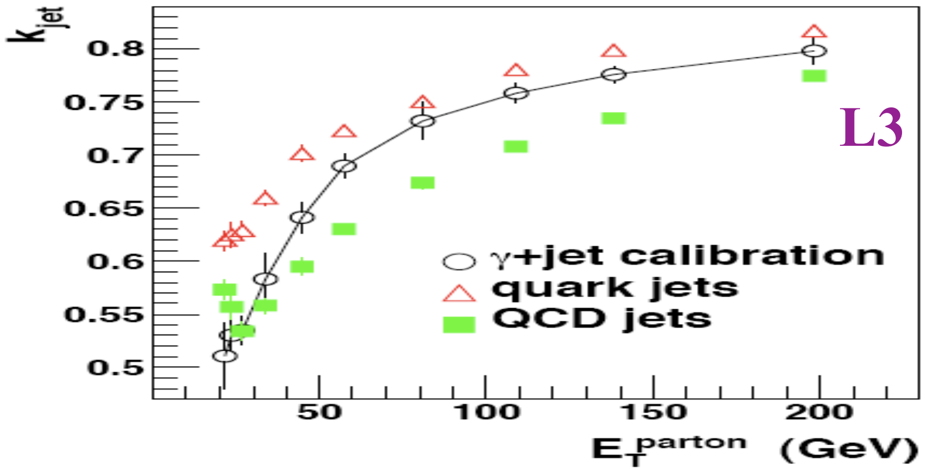
- **Understanding the charged hadron spectrum:**
  - **LHC is a new energy domain, track multiplicities are huge.**
  - **Studying the tracker performance: low pT, tracking, pattern recognition, dE/dX particle identification, ..**

What should we do first?

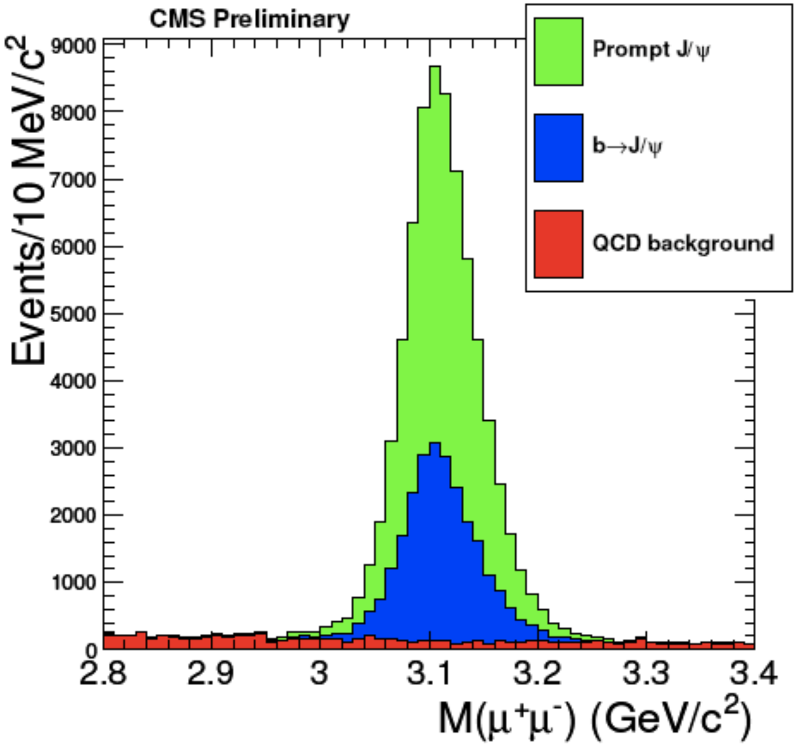


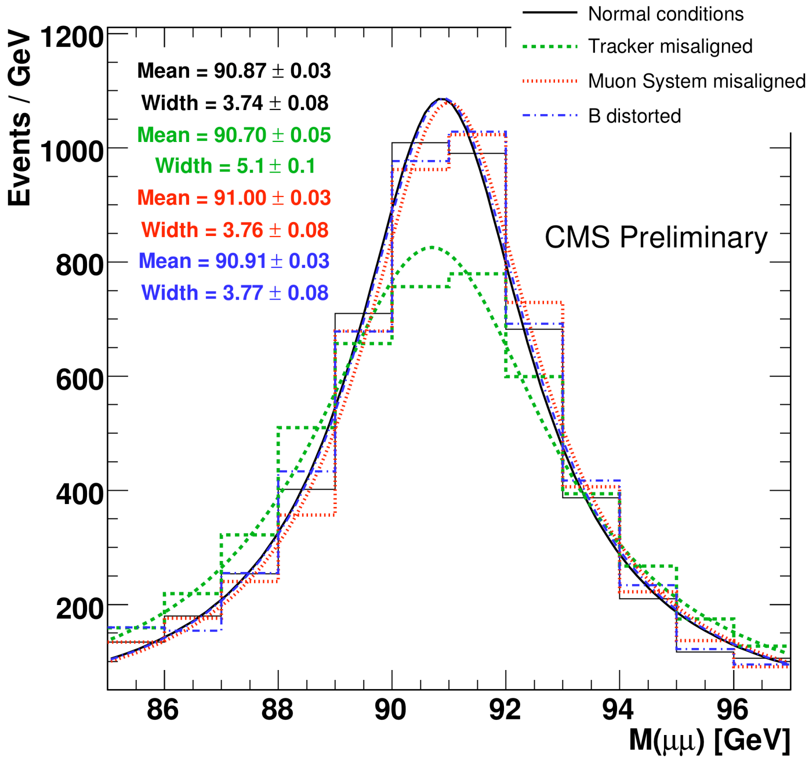
- **Understanding jets. First steps (CMS):**
  - **L1: offsets. Basic calibrations, pedestals, noise treatment, …**
  - **L2: equalize response as a function of pseudo-rapidity**
  - **L3: Absolute scale corrections.**





What should we do first?





- **Understanding the lepton resolutions using mass constraints:**
  - **Thousands of di-muons from J/Psi and Upsilon for 1 pb^{-1}, hundreds from Z.**
  - **Opportunity to measure very precisely tracking and muon resolutions as a function of p_T (multiple scattering, alignment, magnetic field map, …)**

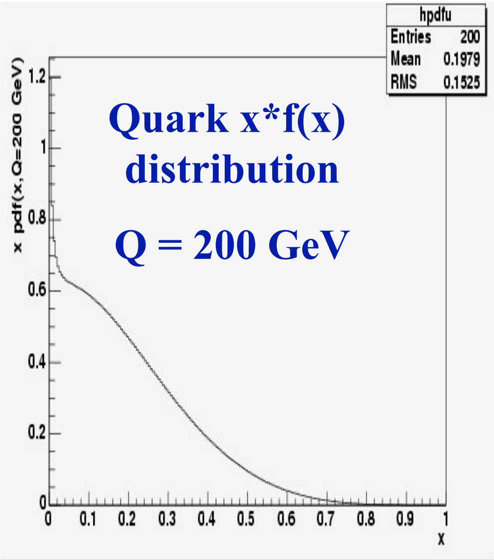
Why are early EW measurements interesting?

- 1) Because they are related with ‘known’ physics...
  - EW properties precisely ‘measured’ in previous colliders like LEP, HERA, Tevatron.
  - W/Z/γ*/top production already ‘studied’ in previous hadronic colliders (Tevatron)

- ... they become a unique tool to
  - Calibrate our detectors and their response (muons, electrons/photons, jets)
  - Understand detector details and develop sophisticated tools (b-tagging, b-jets, measurement of missing transverse energy)
  - Study the detector response in difficult kinematic regions (for new physics searches)

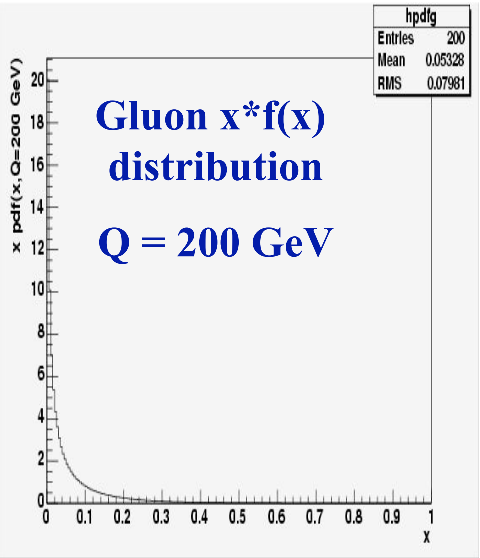
Why are early EW measurements interesting?

- 2) Because they are NOT so well 'known' processes at the LHC:
  - This is a new (x, Q^2) regime... Are parton density functions (PDF) as 'predicted'?
  - Gluons play a more dominant role at higher energies.
  - Top precision physics is in a starting phase.



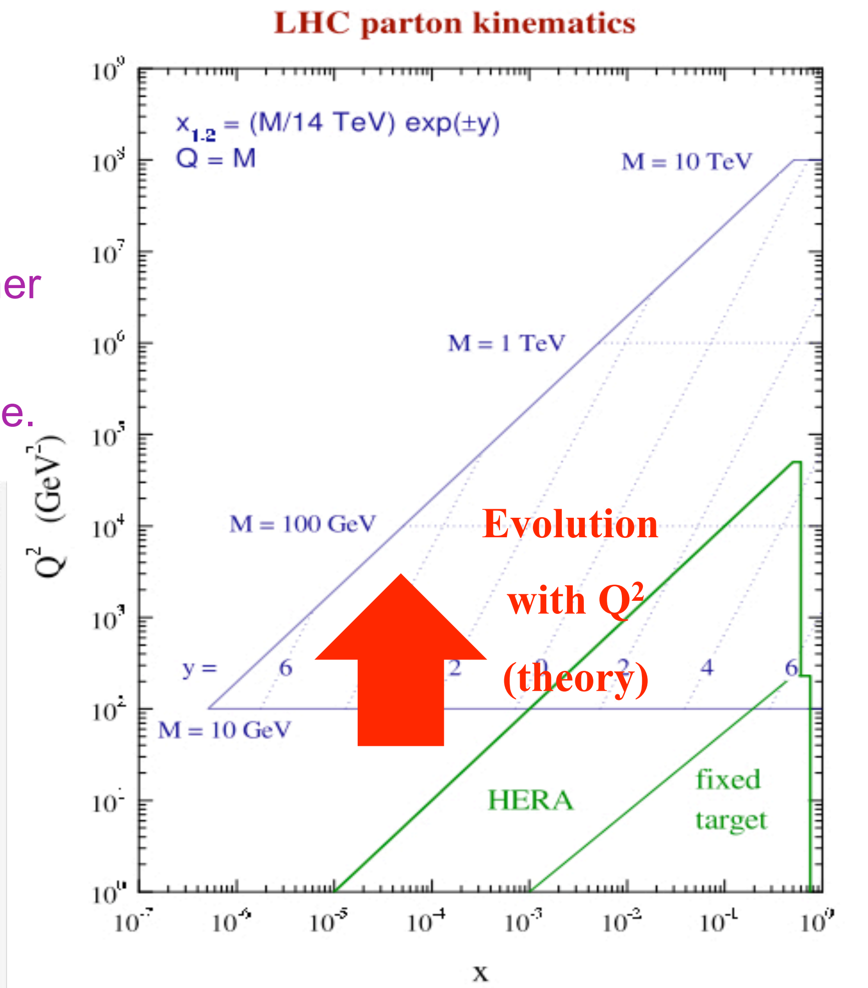
Quark x*f(x) distribution

Q = 200 GeV



Gluon x*f(x) distribution

Q = 200 GeV



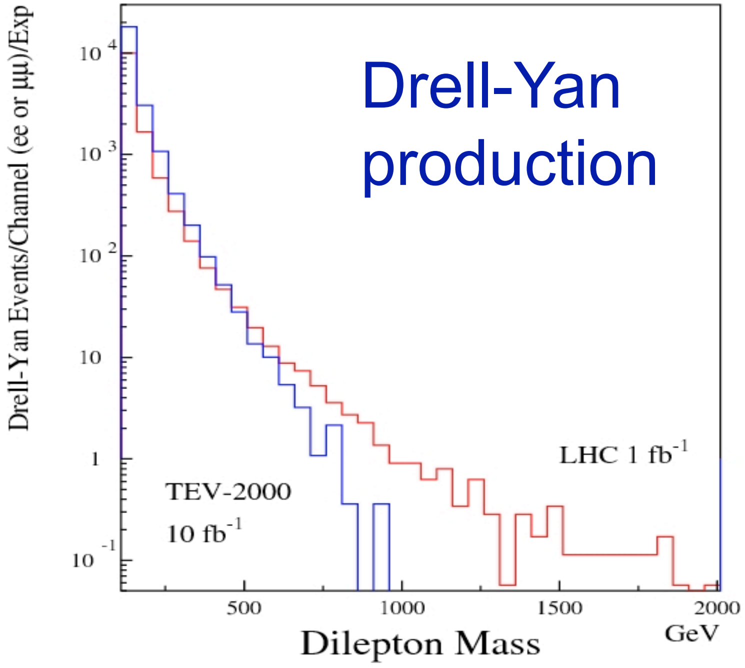
Evolution with Q^2 (theory)

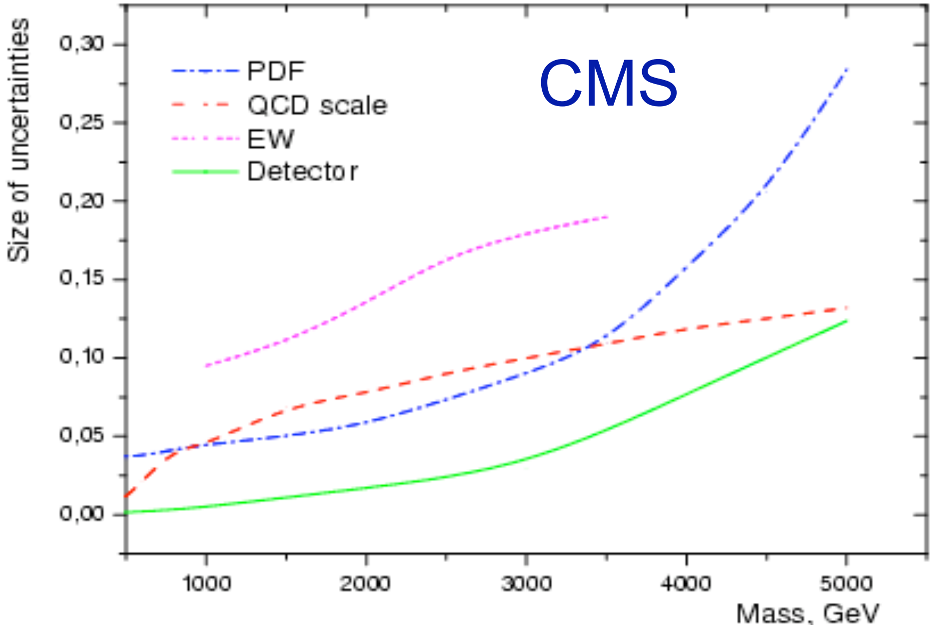
(Campbell, Huston, Stirling, hep-ph/0611148)

Why are early EW measurements interesting?

- 3) Because physics channels involving Z,W,γ^*,top production are easily distorted by almost any new physics sources at the new energy scales opened up by the LHC, even with low luminosity:

√s (LHC) ~ 7-10 √s (Tevatron, LEP) !!





Systematic error ~ 10% ?

Inclusive W/Z production

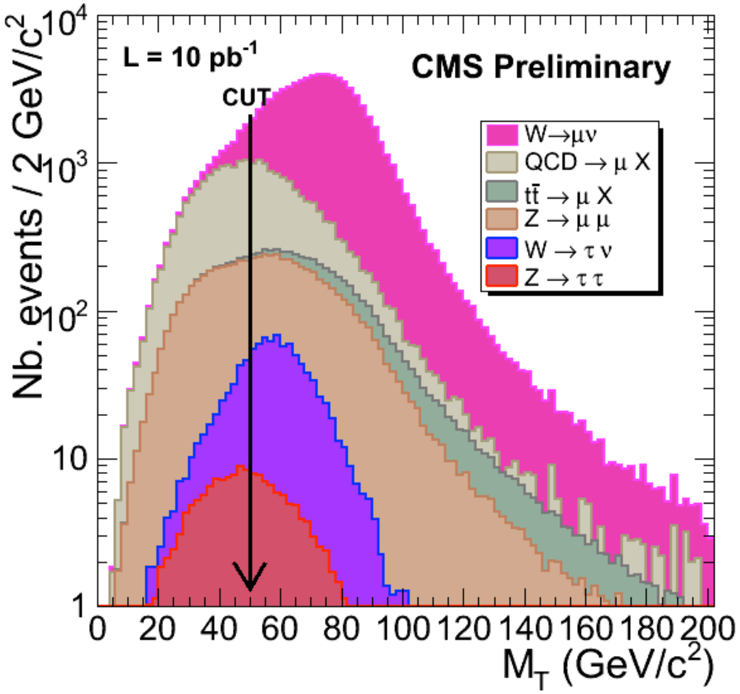
- ✔ **First 'electroweak' signals to be observed. Already at a luminosity of 1 pb^{-1}, thousands of W/Z leptonic decays will be at our disposal: σ(LHC) ~ several nb ~ 10 σ(Tevatron).**

- ✔ **Main guidelines:**
  - ✔ Selection W and Z samples with decays into leptons of high purity
  - ✔ Simple criteria
  - ✔ Minimally dependent on calibration uncertainties and limited knowledge of the detector response (i.e. start-up oriented).

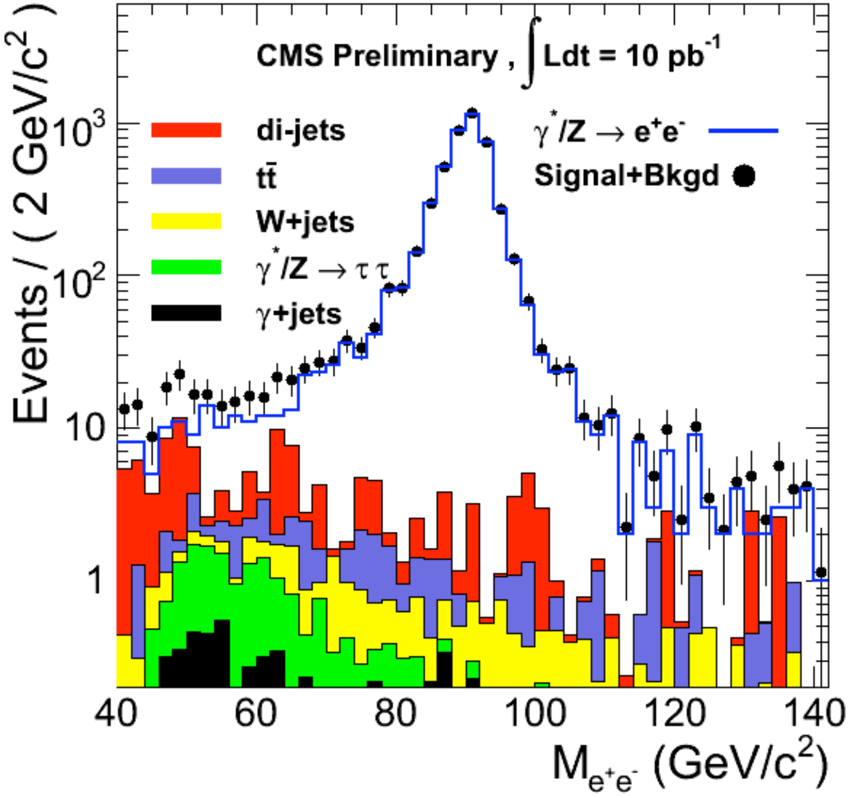
Example: Z/W->leptons

- Safe definitions of ‘hard’ leptons ($L=10^{32}$ $cm^{-2}s^{-1}$):
  - P_t > 20-25 GeV (well above trigger thresholds)
  - Well inside the detector acceptance (good control of trigger and detector efficiencies).
  - Loose isolation criteria.
- Efficiencies and backgrounds determined from data as much as possible.

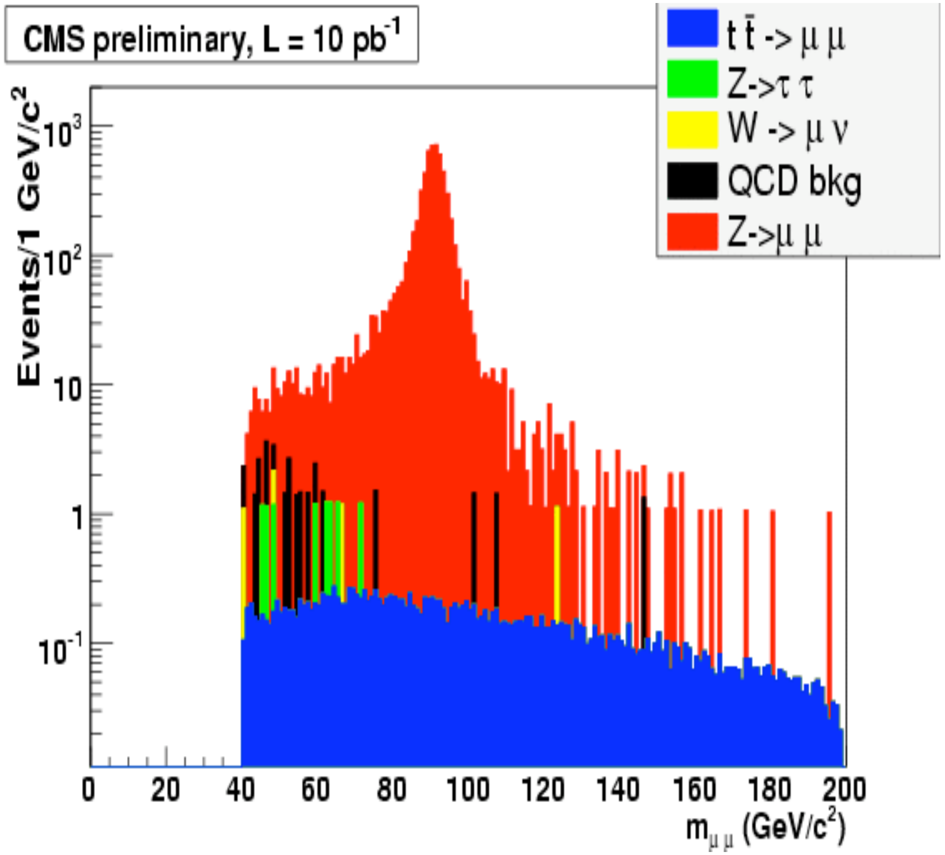
- Relaxed cuts in general on reconstructed masses for Z, on missing transverse energy/mass for W



$Z\rightarrow\mu\mu$: invariant mass criteria

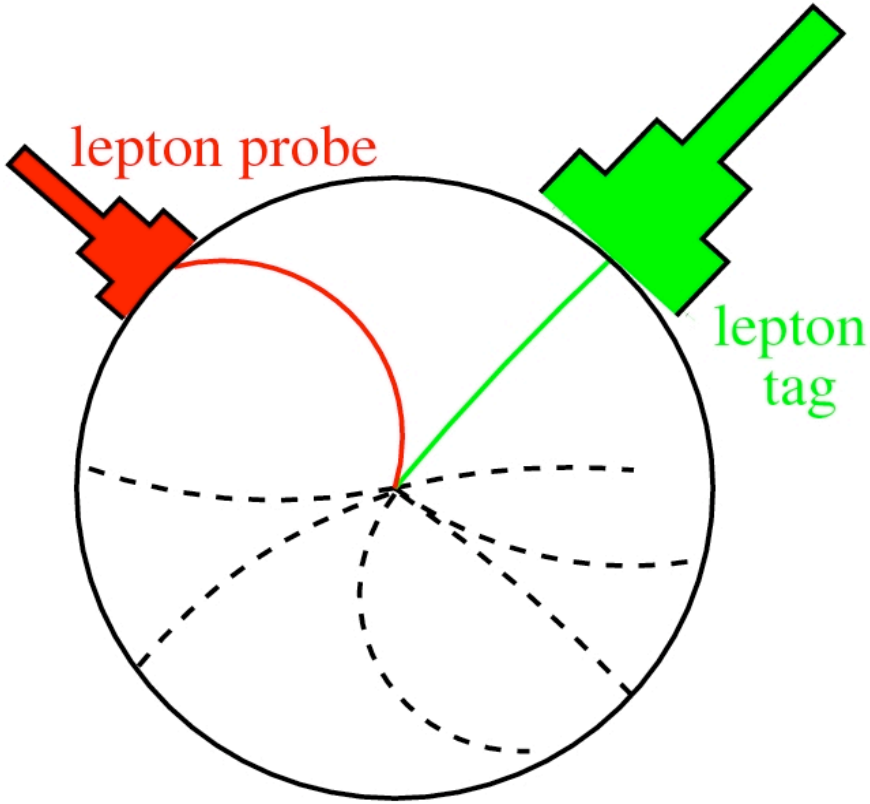


No stringent cuts on the invariant mass are required



Initial tracker misalignment does not distort the shape dramatically =>
selection criteria OK to get initial samples for alignment and energy scale calibration

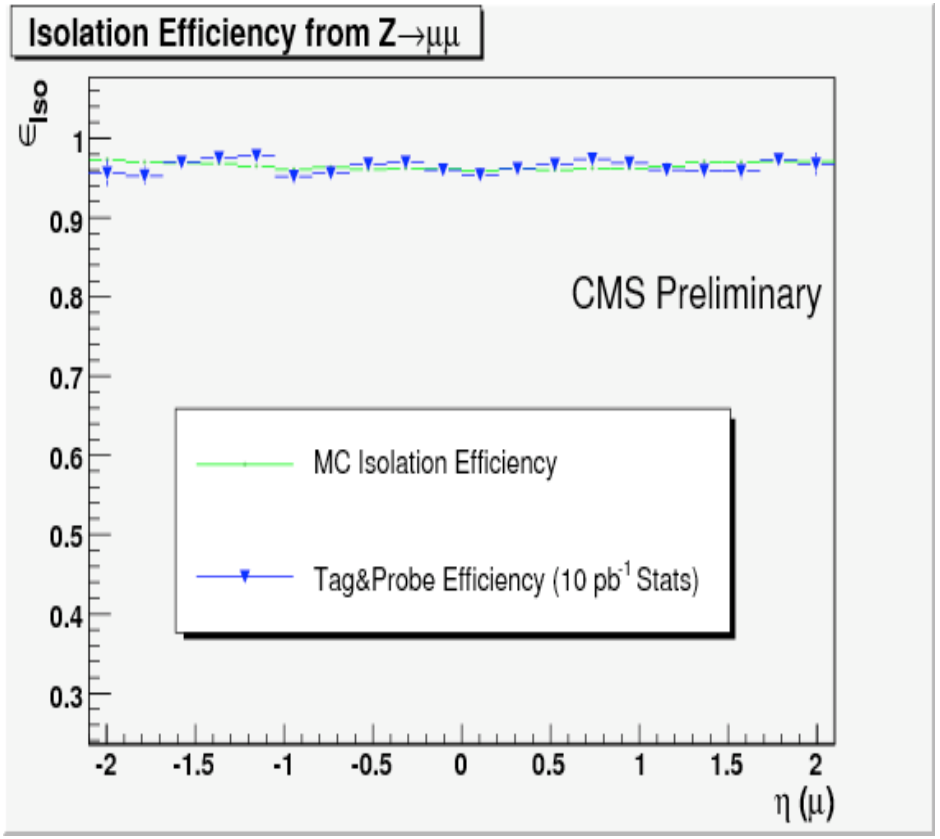
Extracting efficiencies from data



- Extensive use of tag-and-probe methods with L ≥ 10 pb^{-1}:
  - Select pure Z samples by tightening criteria on the ‘tag’ lepton
  - Measure directly the efficiency on the unbiased ‘probe’

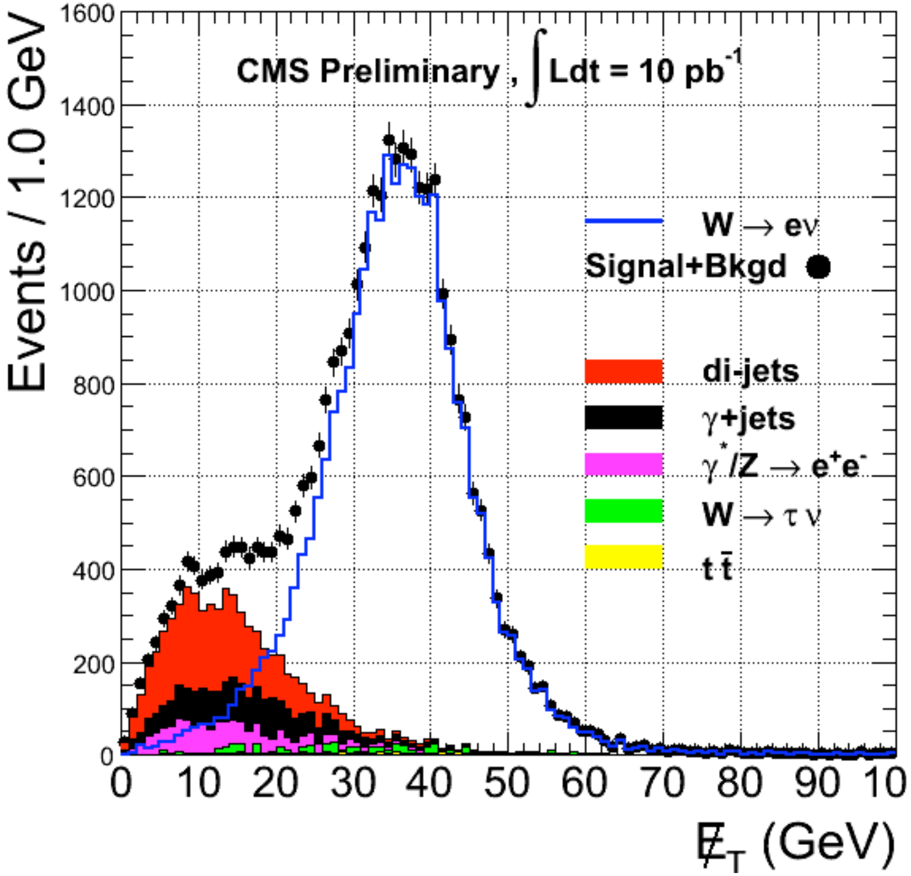
Tag-and-probe method: simple example

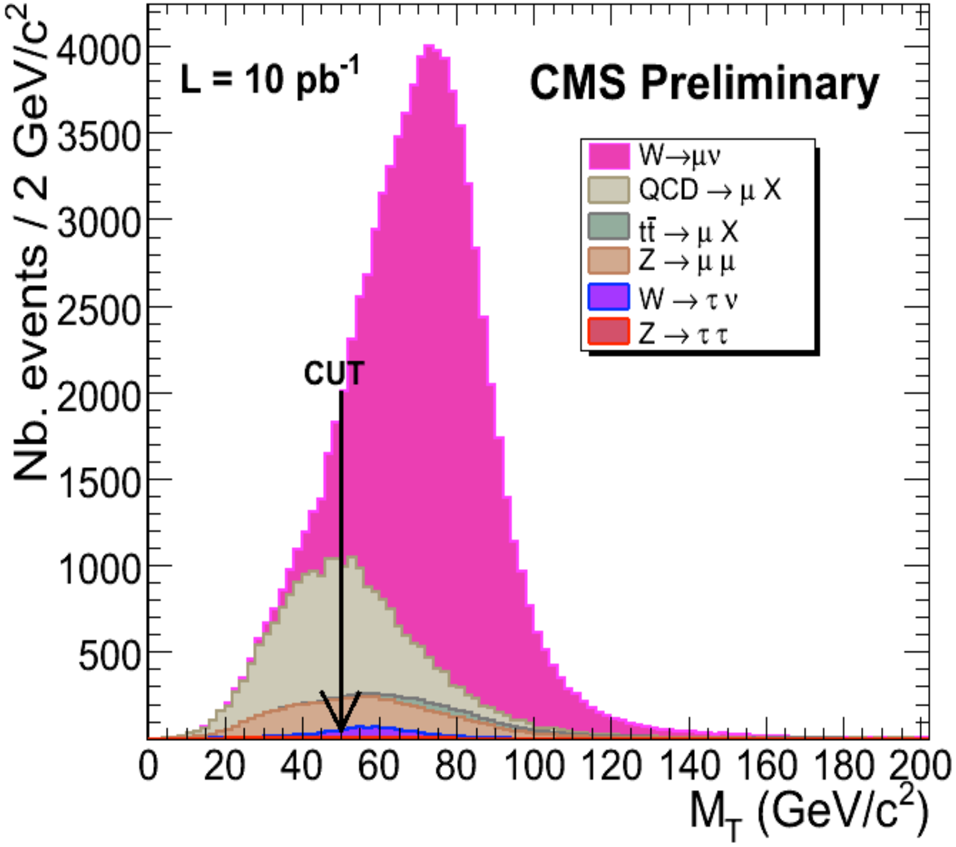
Side	Definition
Tag	Isolated global muon with pt>20 GeV
Probe	Global muon with pt>20 GeV
Probe Type	**Description**
Isolated	Probe side is isolated
Non isolated	Probe side is not isolated



- Important comments:
  - The method must be validated on Monte Carlo simulations
  - Some biases may arise due to intrinsic correlations between sides

Determining backgrounds from data

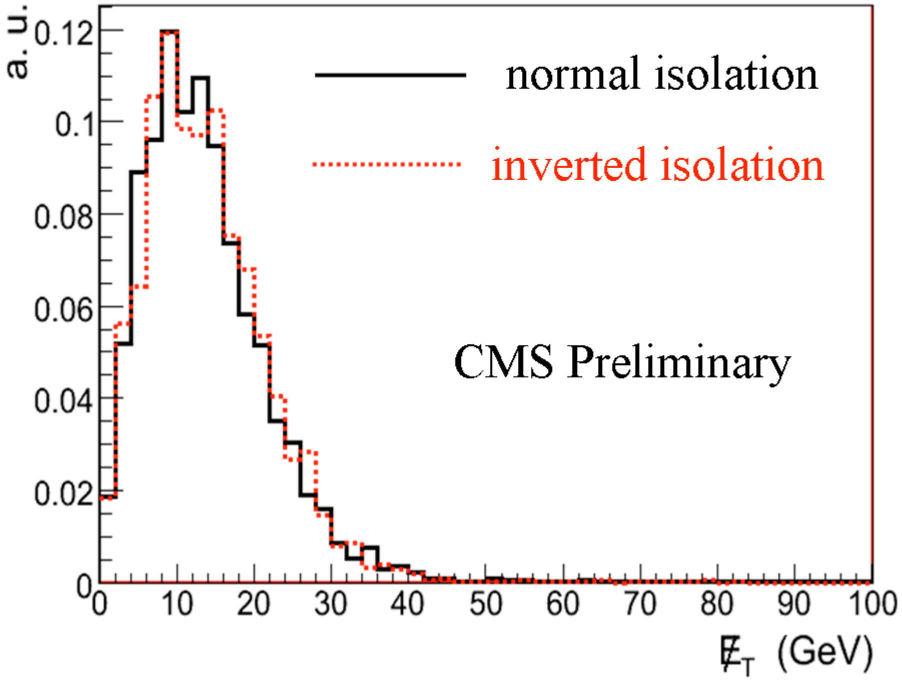




Backgrounds are relatively small after cuts, but there can be disagreements with simulations: estimate them from data too

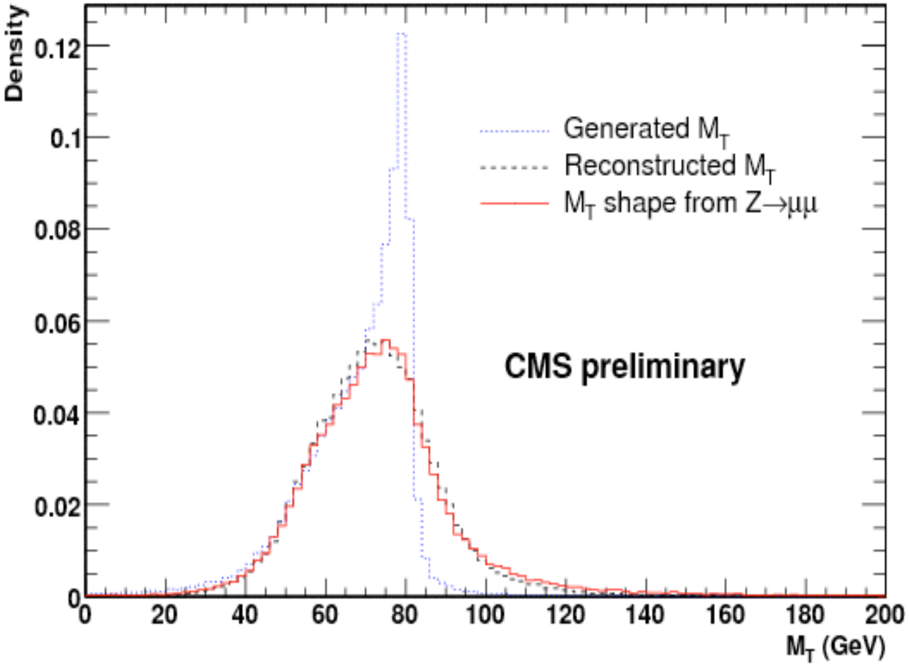
Determining backgrounds from data

Methods to determine QCD backgrounds in W->lν



Missing transverse energy for 'selected' electrons in QCD background for W->eν

Inverting the isolation cut



Missing transverse mass in W->μν signal events

Use Z->μμ in data to study/describe the calorimetric response

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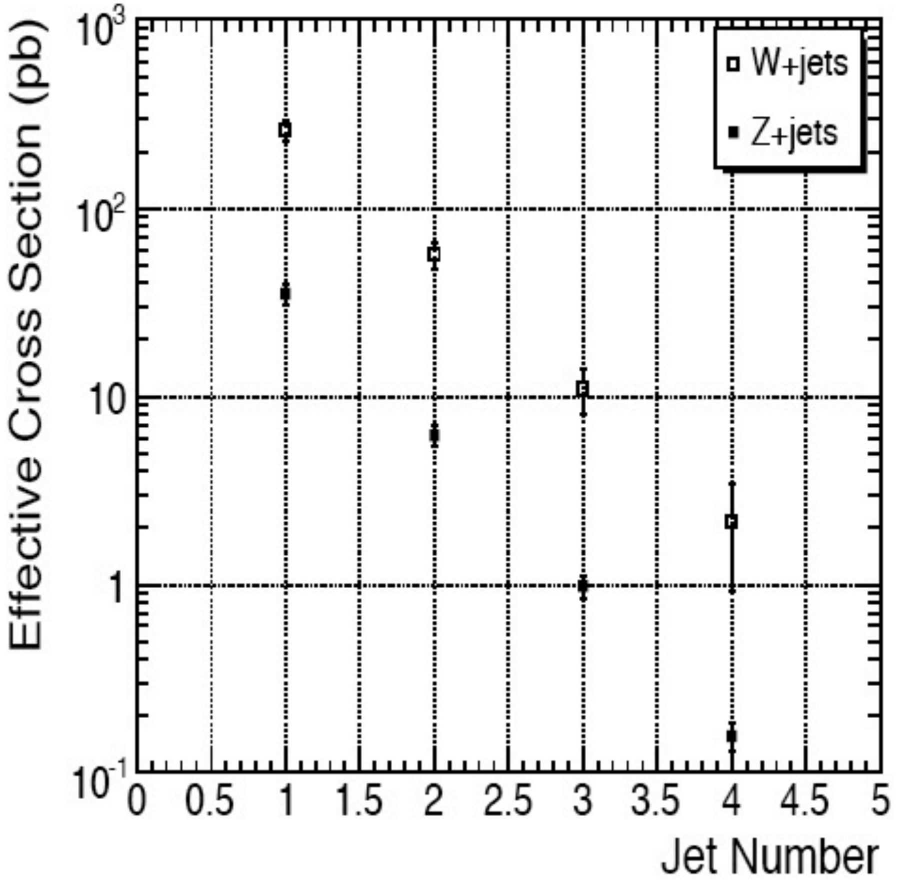
pp->W/Z + jets

CMS: visible cross sections [pb]



This channel is relevant for:

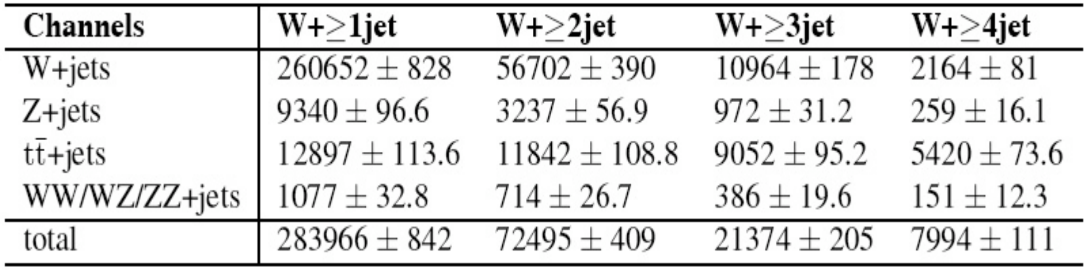
- Physics: QCD studies, understanding of QCD jet production in initial state
- Reduce jet energy scale uncertainties (via Z + jet)
- It is an important background for many new particle searches (when looking for leptons and jets)

pp->W/Z + jets

- Not so different from inclusive W/Z production. Jet must be identified and the QCD background must eliminated via very stringent lepton isolation cuts

Analysis from CMS (E_T(jet) > 50 GeV)

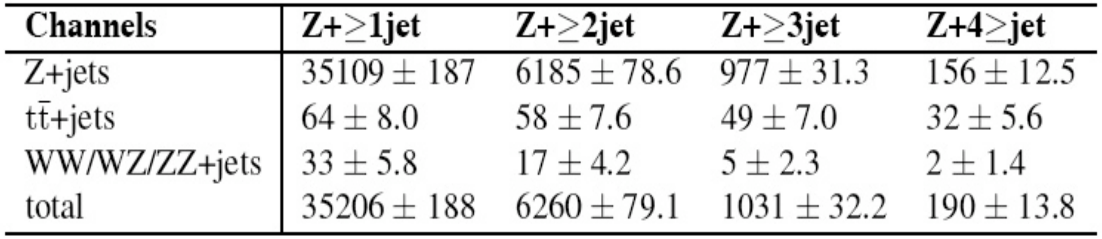
Number of W+jets events for L = 1 fb^{-1}



Channels	W+≥1jet	W+≥2jet	W+≥3jet	W+≥4jet
W+jets	260652 ± 828	56702 ± 390	10964 ± 178	2164 ± 81
Z+jets	9340 ± 96.6	3237 ± 56.9	972 ± 31.2	259 ± 16.1
$t\bar{t}$+jets	12897 ± 113.6	11842 ± 108.8	9052 ± 95.2	5420 ± 73.6
WW/WZ/ZZ+jets	1077 ± 32.8	714 ± 26.7	386 ± 19.6	151 ± 12.3
total	283966 ± 842	72495 ± 409	21374 ± 205	7994 ± 111

sizeable top background in W+jet channels

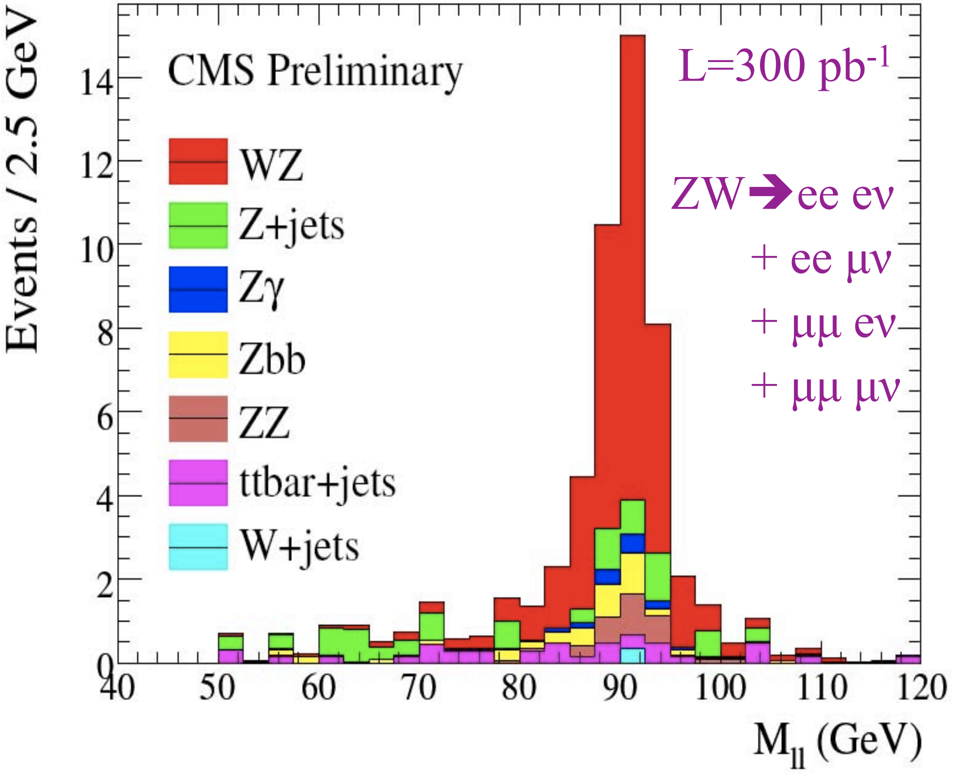
Number of Z+jets events for L = 1 fb^{-1}

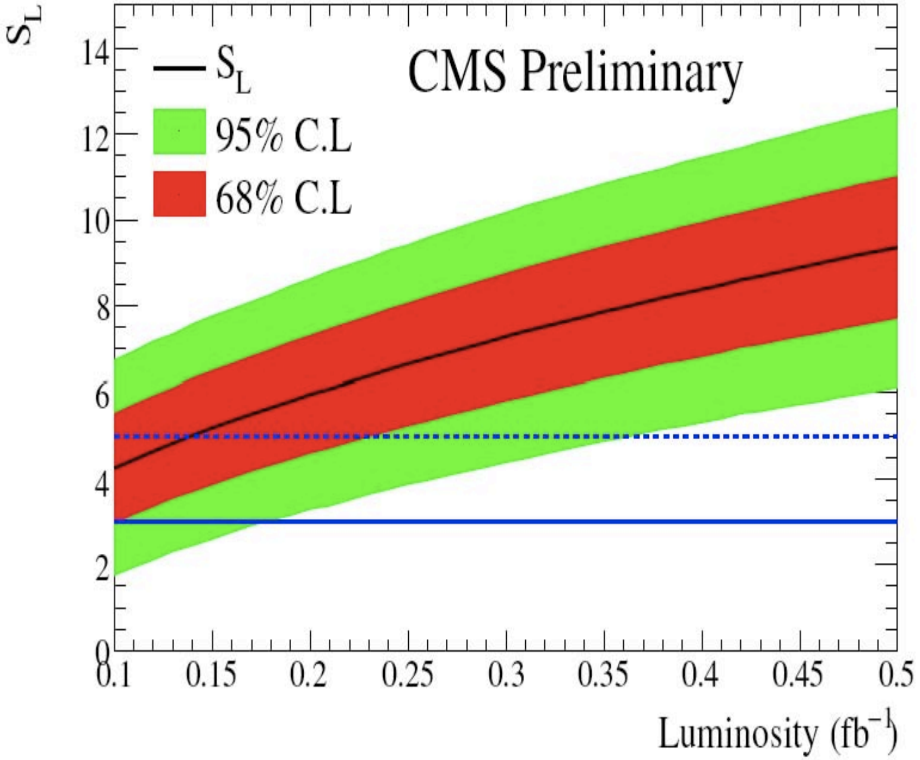


Channels	Z+≥1jet	Z+≥2jet	Z+≥3jet	Z+4≥jet
Z+jets	35109 ± 187	6185 ± 78.6	977 ± 31.3	156 ± 12.5
$t\bar{t}$+jets	64 ± 8.0	58 ± 7.6	49 ± 7.0	32 ± 5.6
WW/WZ/ZZ+jets	33 ± 5.8	17 ± 4.2	5 ± 2.3	2 ± 1.4
total	35206 ± 188	6260 ± 79.1	1031 ± 32.2	190 ± 13.8

Z + 2 jets ‘easily observable’ with L ~ 10 pb^{-1}

Diboson production





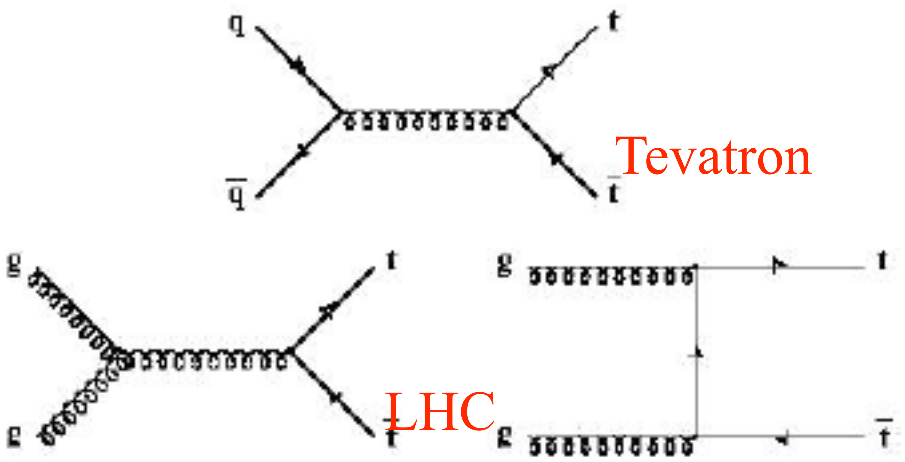
Di-boson production is important for:

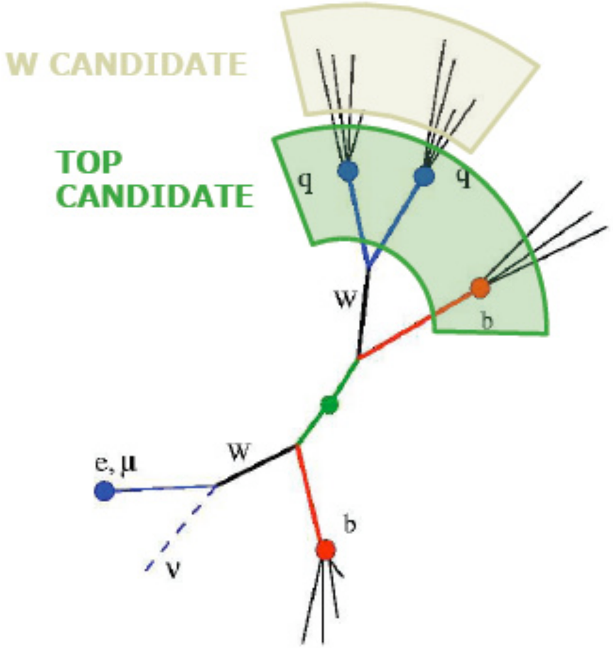
- TGC measurements (but not early)
- Understand backgrounds for new physics (H->WW, for instance)

WZ production already observable in CMS with L = 150 pb^{-1} !!

Top production

- ✓ Top production is huge at the LHC: σ ~ 800 pb, dominant process is gg->ttbar , rate ~ 100 times Tevatron for the same luminosity.



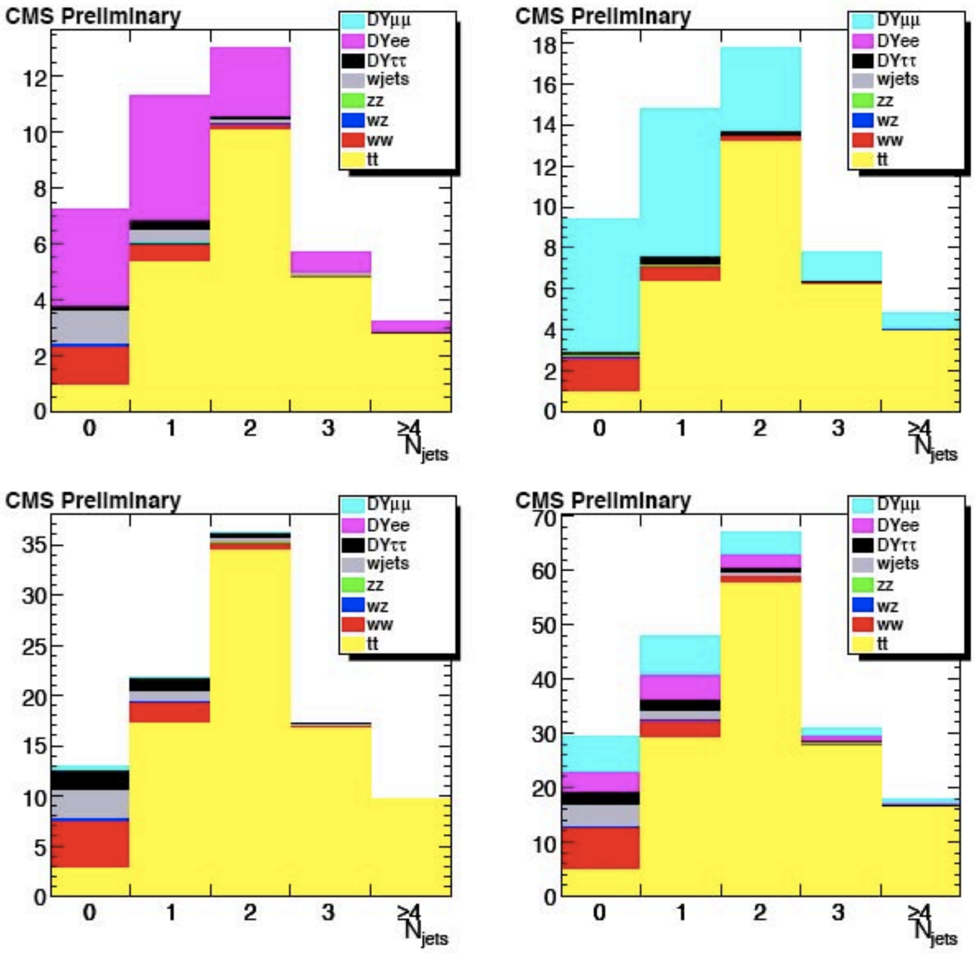


- ✓ Understanding top production => understanding the whole detector: lepton identification, resolutions, isolation, jets, missing energy, b-tagging, ... => spin-offs: jet scale calibration, b-tagging efficiencies,...

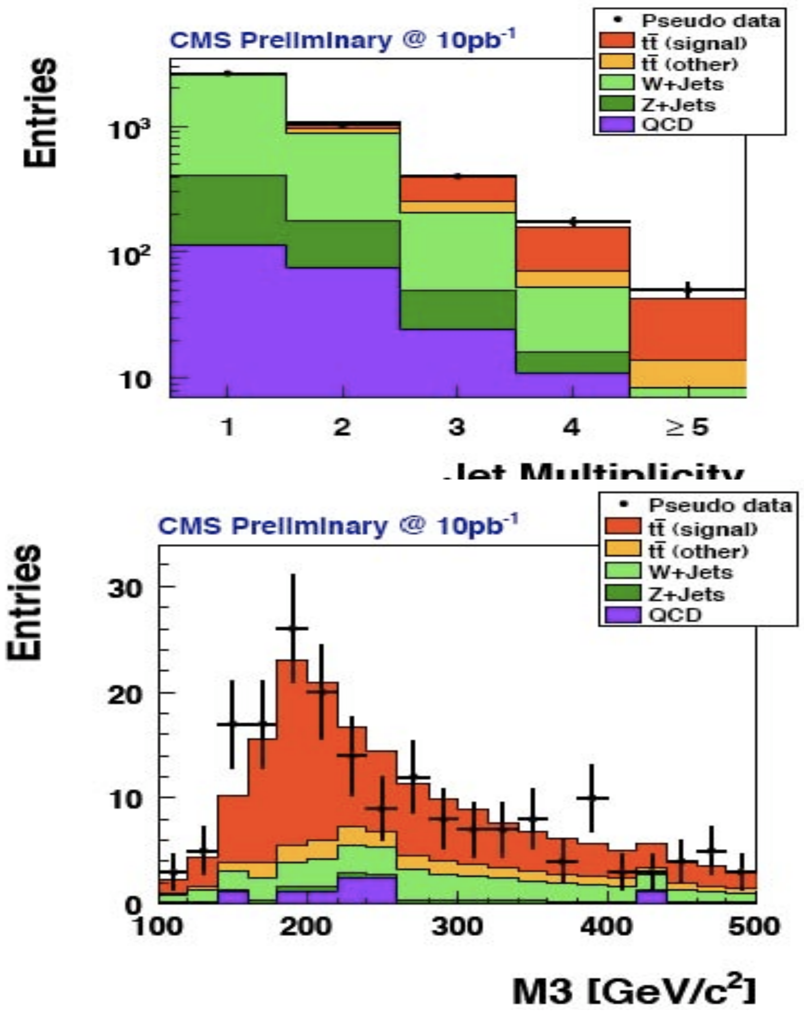
Top production

- ✓ Progressive scenarios considered by CMS:
  - ✓ L ~ 10 pb^{-1}: rediscover the top (leptonic W decays, semi-leptonic channels, measure cross sections for the first time)
  - ✓ L ~ 100 pb^{-1}: establish methods, precise measurement of cross sections, first measurements of the top mass, start to understand detector effects in more detail.
  - ✓ L ~ 1 fb^{-1}: detector ‘almost’ understood, exploit full physics potential.

Top studies at 10 pb^{-1} (no b-tag)

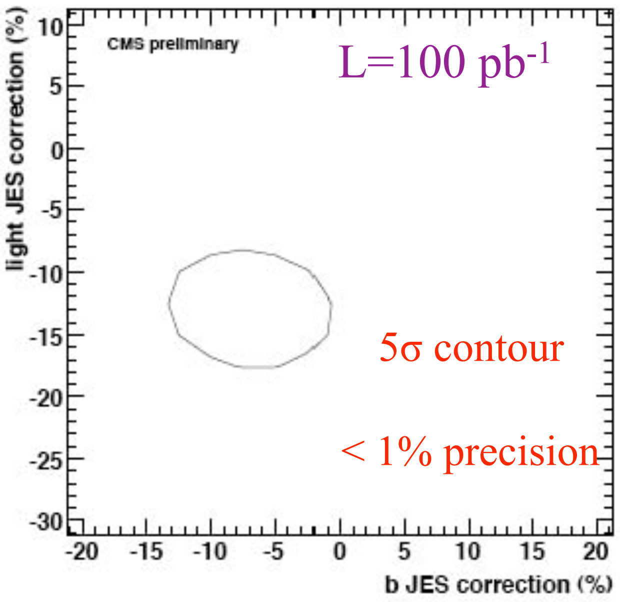


Final states ~ 2 jets + ll + MET



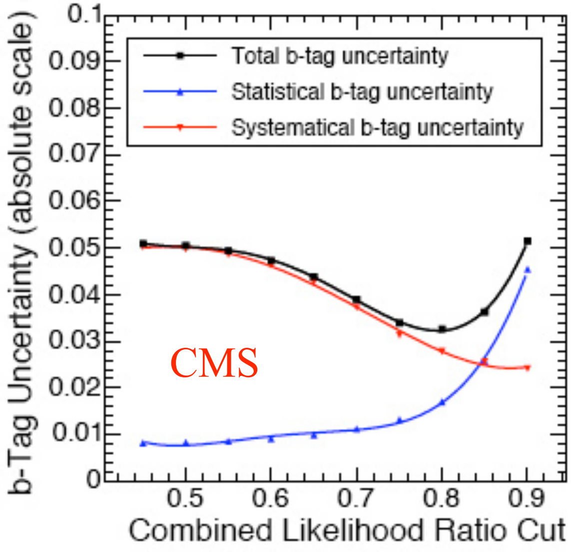
Final state ~ 4 jets + μ + MET

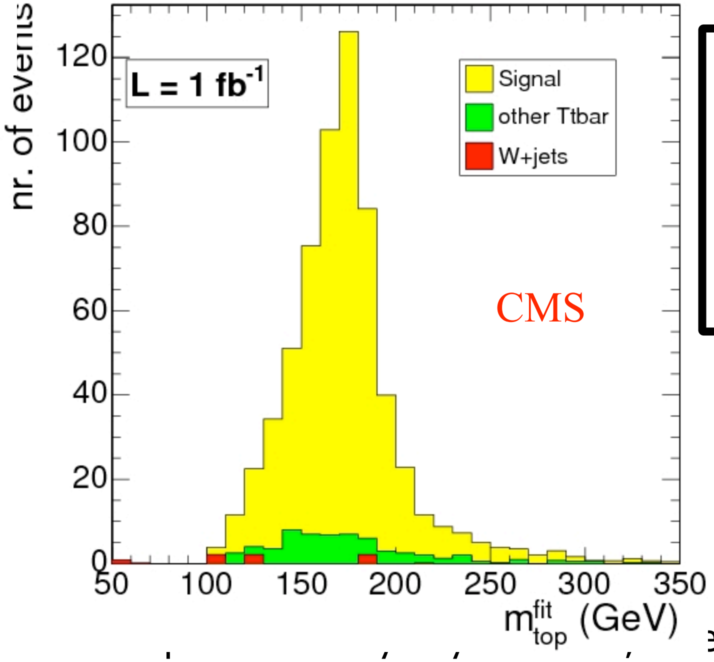
Top studies at L > 10 pb^{-1}



Energy scale calibration (with W bosons and b-jets in ttbar events)

b-tagging efficiency determination (in ttbar events)





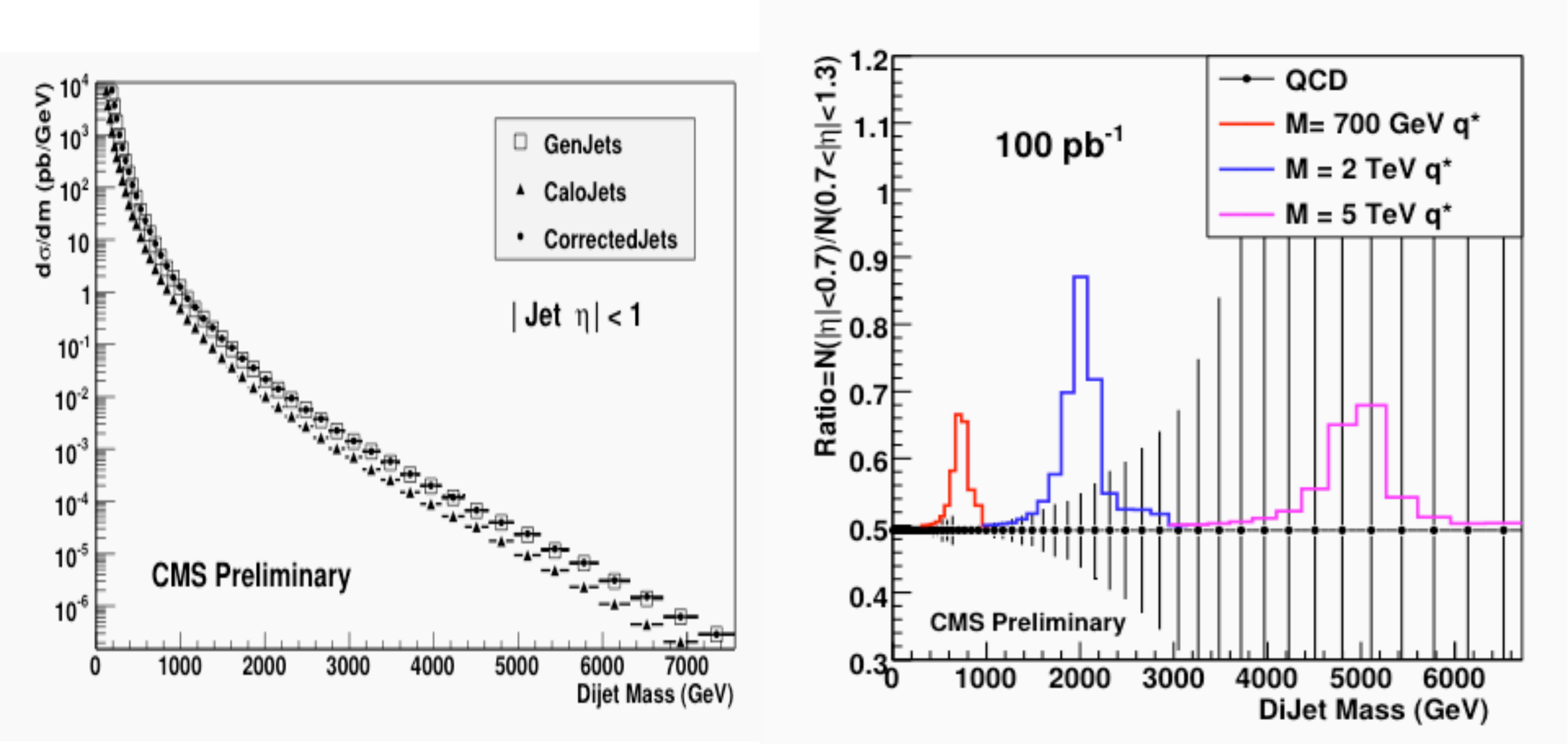
+ many other inputs (alignment, calibrations, missing E_T,...)

Final mass plot

General misconception?

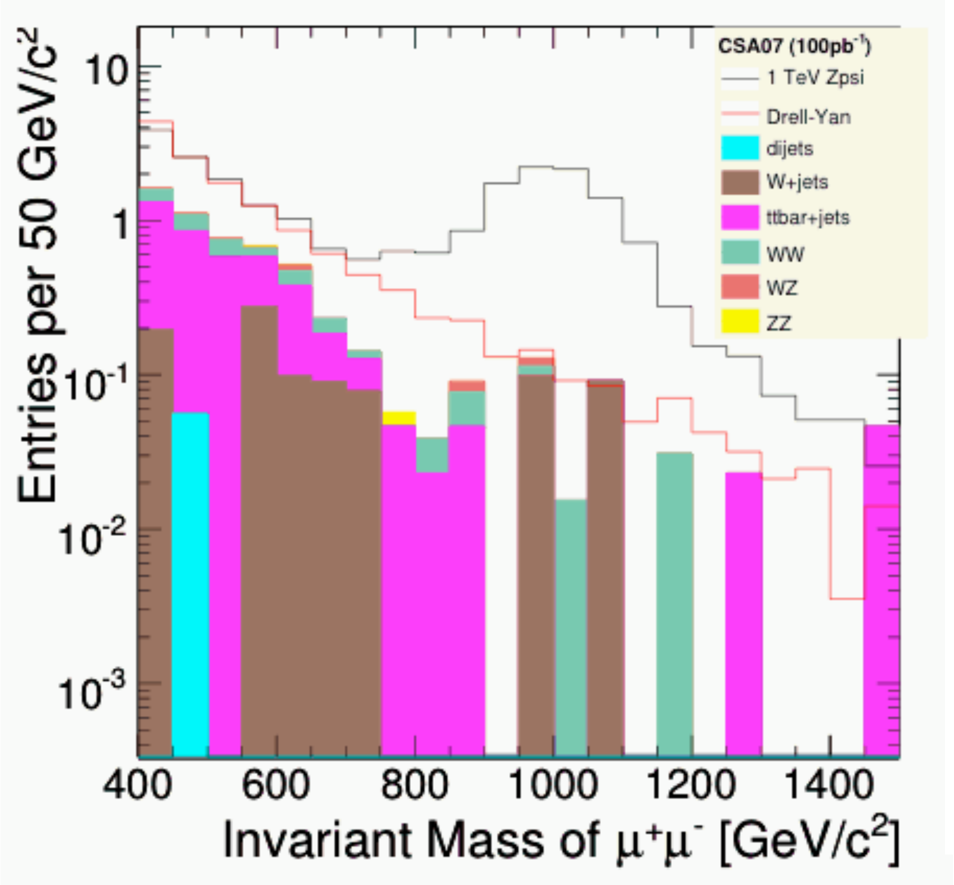
- ✓ There is the general assumption that detectors in hadronic colliders take too much time to calibrate and understand. This might not be the case at the LHC.
  - ✓ Note that at Tevatron top cross sections are small and collecting large EW samples for calibration took some time.
  - ✓ LHC detectors with an integrated luminosity of L ~ 100 pb^{-1} will have an enormous amount of dilepton events at resonances (J/Psi. Y, Z) and ttbar events to understand jet resolutions and b-tagging.
  - ✓ The challenge is rather on the organizational side: we need to process and analyze all these useful data as soon as possible.

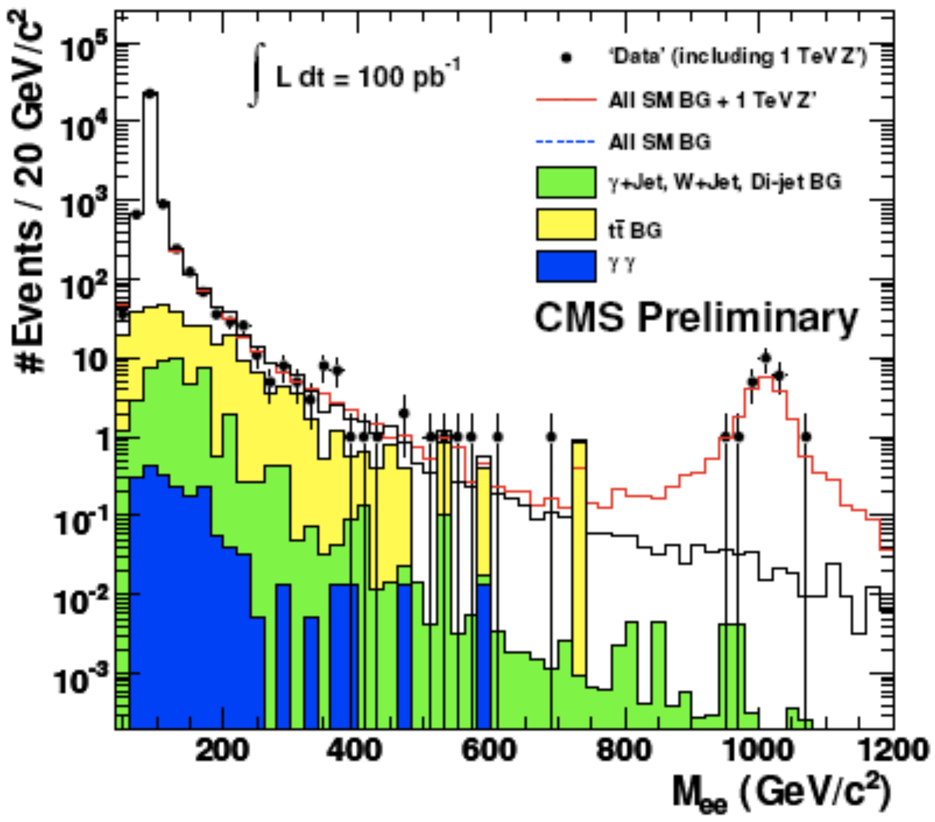
What about early discoveries?



- **Using di-jet invariant mass spectrum. CMS: use ratios in different angular regions (new physics manifests at low eta).**

What about early discoveries?

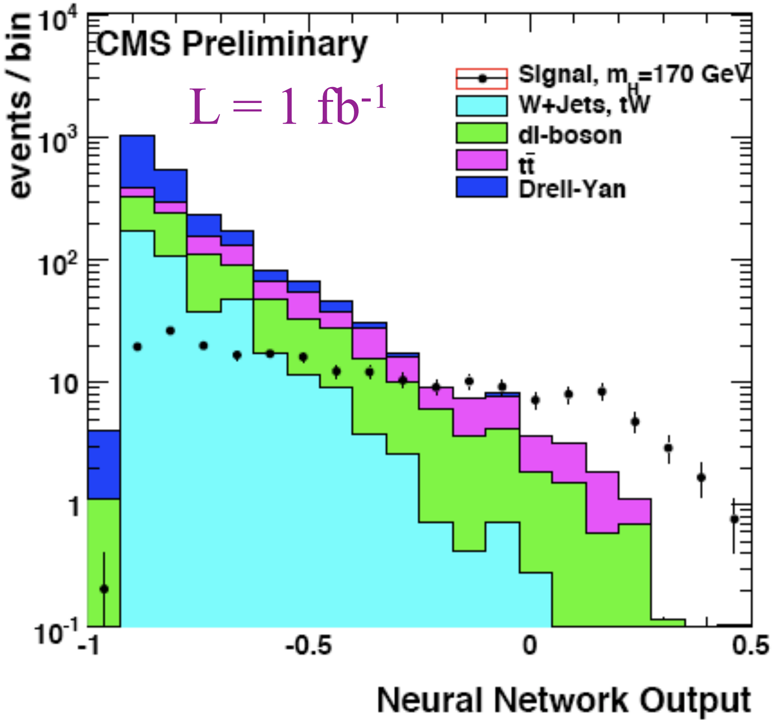




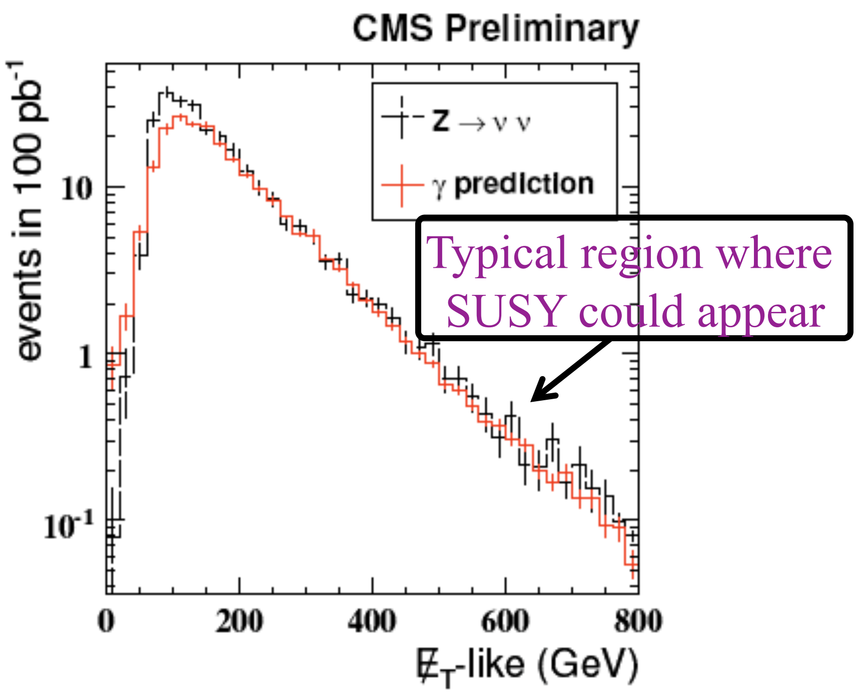
- **100 pb^{-1} are enough to discover di-lepton resonances in the TeV range, as predicted in some extensions of the Standard Model.**

What about early discoveries?

H→WW analysis


L = 1 fb^{-1}

Data-driven estimates of MET+jets bacgrounds (Z+jets, …) from γ+jets


Typical region where SUSY could appear

- **Higgs and SUSY discoveries are not simple for L ~ 100 pb^{-1}**
  - **One needs to understand backgrounds and tails in detail first…**
  - **Many data-driven methods being developed (trying not to depend on Monte Carlo assumptions)**

Conclusions

- The CMS detector is essentially ready to analyze collisions at the LHC:
  - Our sub-detectors seem to work according to expectations
  - This has been extensively shown in several commissioning and test phases (MTCC, CRUZET, LHC beams, CRAFT).
  - The degree of understanding of our detector performance is already impressive (and we are still improving it). Probably we have never seen in the past such a degree of detector understanding previous to a running phase !

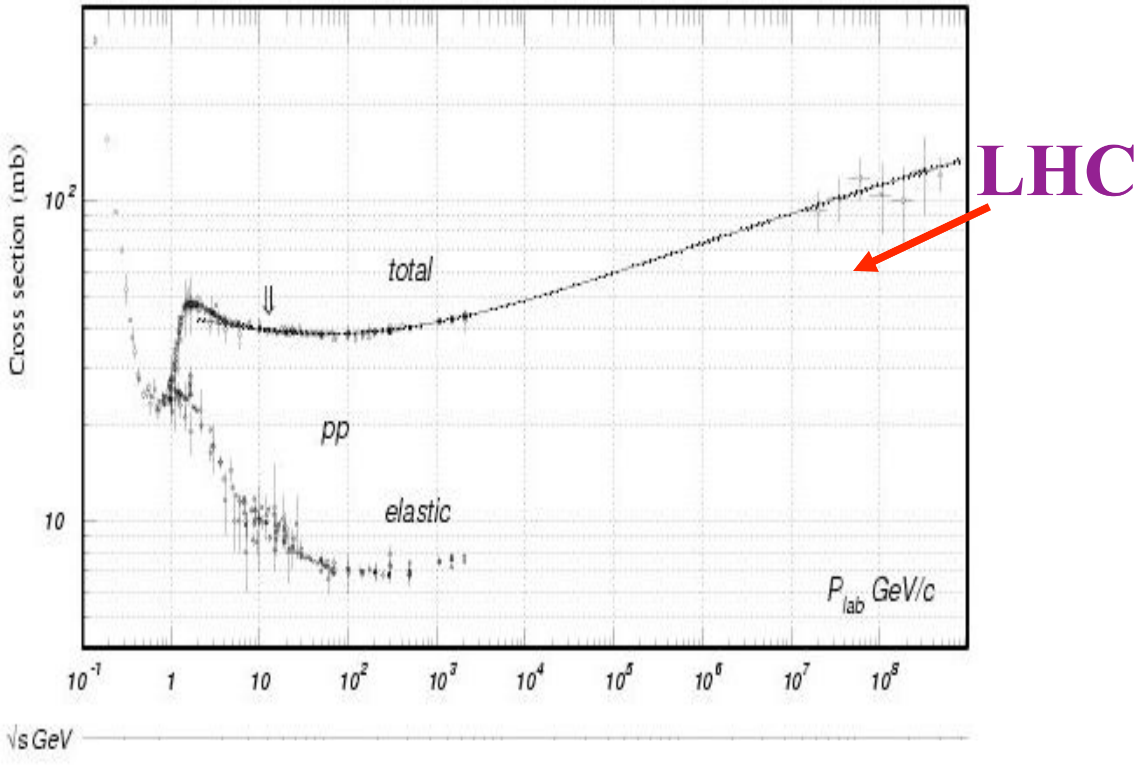
- LHC will provide sizeable EWK samples already at luminosities as low as 1 pb^{-1} (jets, W/Z). Many processes will become observable before reaching 1 fb^{-1}: top (~ 10 pb^{-1}), W/Z + 4 jets (~100 pb^{-1}) ,dibosons (WZ, ~150 pb^{-1}). They will allow us to understand the CMS detector response in detail.

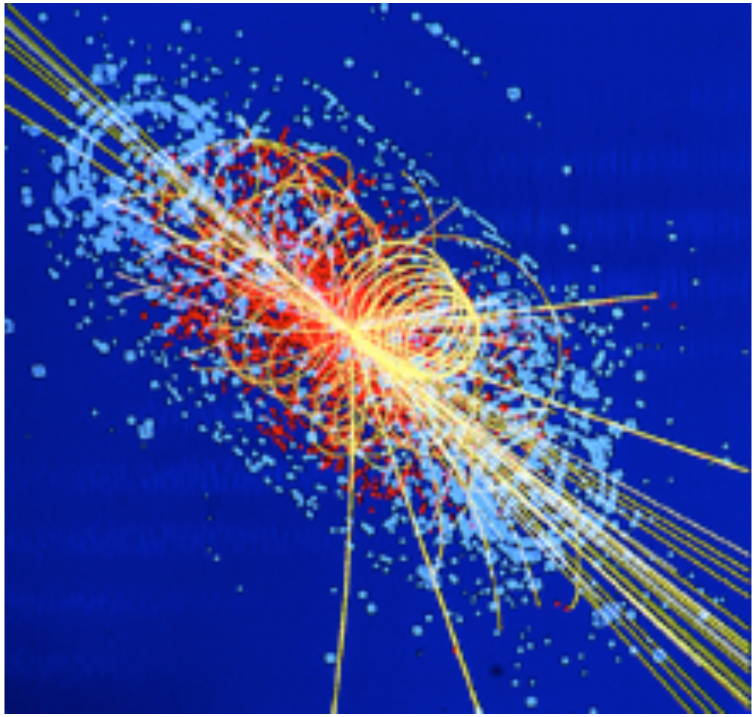
- Many new physics searches will be carried out in detail in CMS with $L \leq 100\ pb^{-1}$

- CMS is now developing strategies and organizing efforts to understand as soon as possible our detectors and the basic QCD/EWK processes. This is very important for the success of the LHC physics programme.

Backup

The LHC environment





Inelastic cross section ~ 100 mb

10^3-10^6 events/s already at startup (L ~ 10^{28}-10^{31} $cm^{-2}s^{-1}$)

Very 'busy' events: mostly hadronic activity

Huge radiation levels !!

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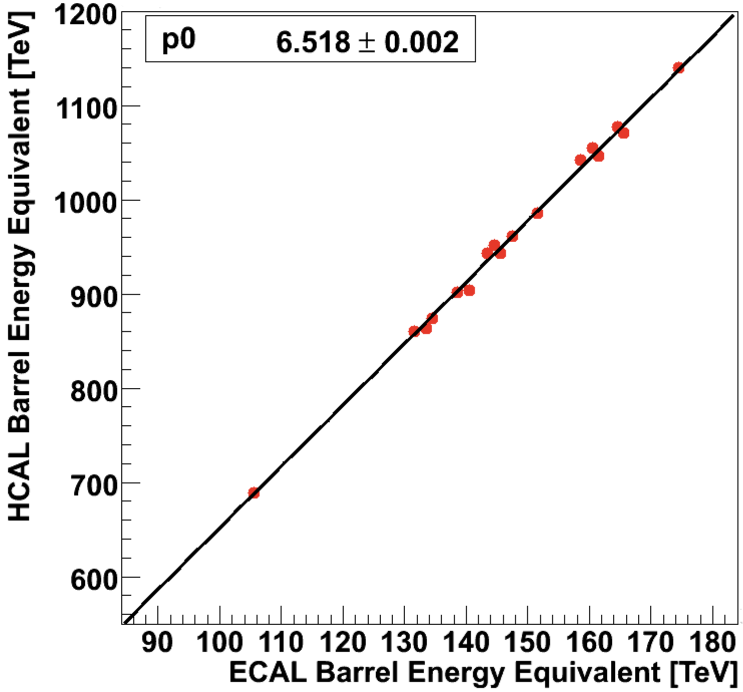
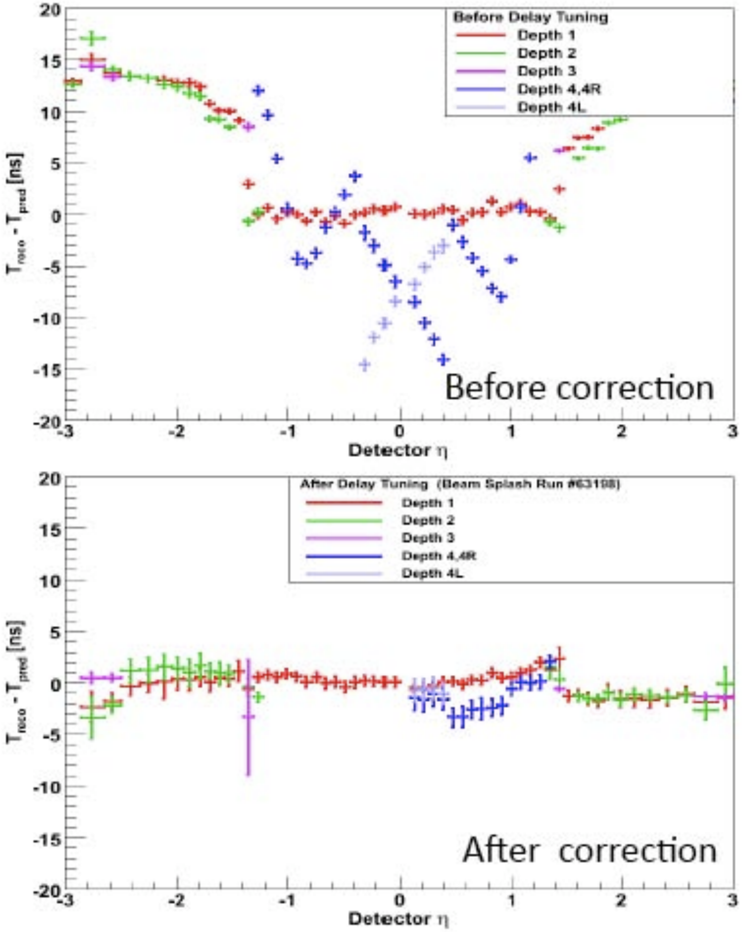
Beam dumped in collimators

ECAL-HCAL energy correlation



Internal HCAL synchronization



Time synchronization: time at a given detector position approximately known (protons spend ~ 15 ns travelling from one side to the other of the detector)

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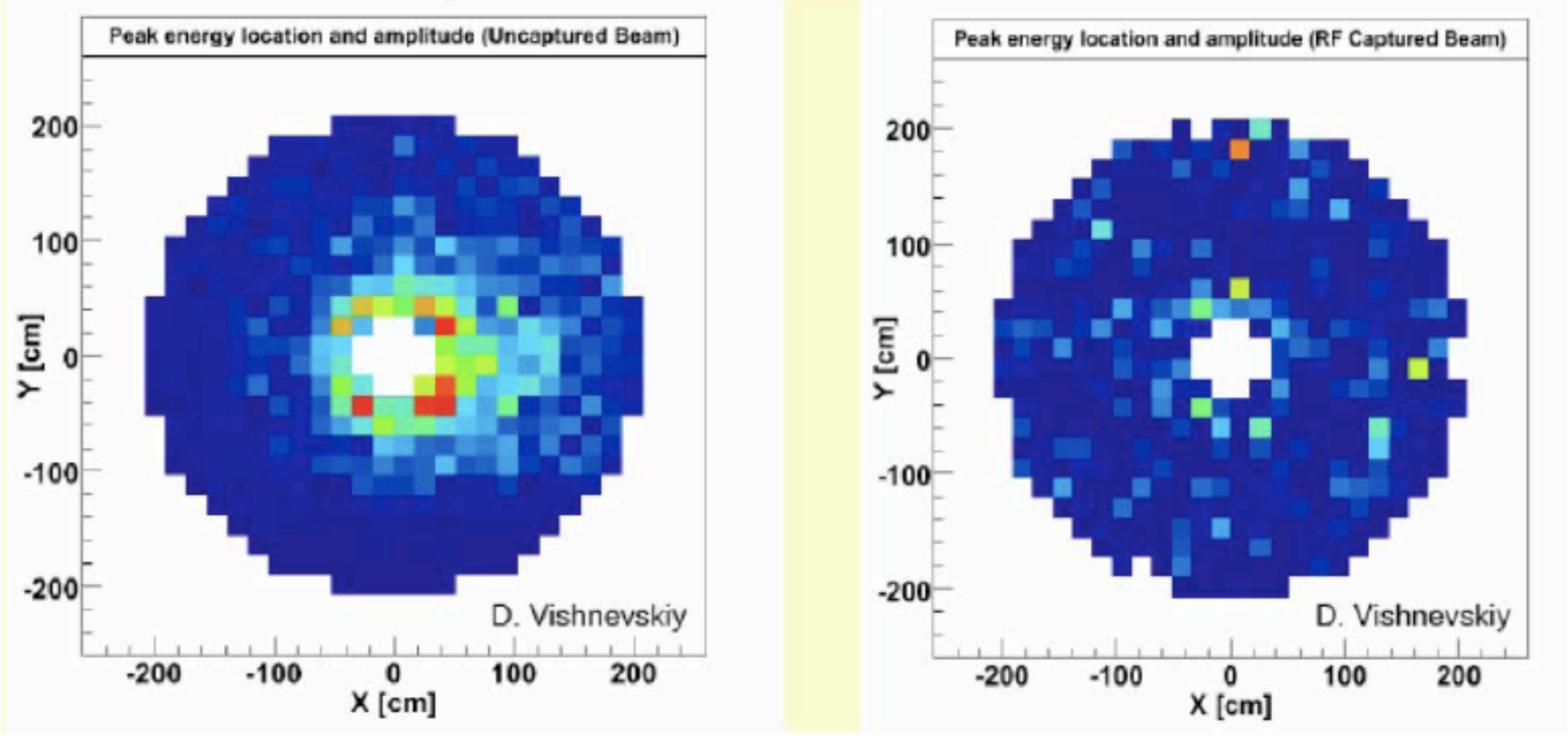
First LHC beams seen in CMS

Before capture

After capture



3. Circulating beams -> captured beams in RF cavities