IFAE:
WHO ARE WE, WHAT WE DO

- The Institute
- The research:
  - With Earth-based accelerators
  - With cosmic accelerators
  - With applications (Medical Physics)

THE INSTITUTE: BASICS

- A Consortium of (UAB) and the Generalitat de Catalunya (GenCat), operating through the Department of Innovation, Universities and Enterprise (DIUE).
  - Since 1991.
- With "juridical personality".
  - It can autonomously apply and manage funds, manage projects, hire personnel.
- IFAE is managed by a Board (Consell de Govern, CdG), with 3 UAB and 3 GenCat representatives, which meets twice per year.
- The director is appointed by the CdG and must execute the CdG's decisions.
- IFAE has 2 divisions (TH, EXP) and provides administrative support to Port d'Informació Científica (PIC), the Spanish Tier-1 LHC data center.
  - PIC is managed and funded by CIEMAT and GenCat, and has its own director.

IFAE PERSONNEL

The scientific personnel of IFAE is composed by:

- IFAE's own research faculty (9, all in EXP, currently).
- UAB faculty (7 in TH, 3 in EXP).
- 8 ICREA (a GenCat Institute "without buildings": 3 TH, 3 +2 junior in EXP)
- Ramon y Cajal contracts (4 EXP, 1 TH)
- Postdocs, paid by research projects or State or Catalan fellowships
- PhD students, paid as above

- The support personnel of IFAE consists of about 9 engineers (ME, EE, SW), 3 technicians, and 4 administrative persons.
  - Paid by a combination of IFAE, project and UAB funds
- Altogether, 105 persons

IFAE FUNDING/OPERATION

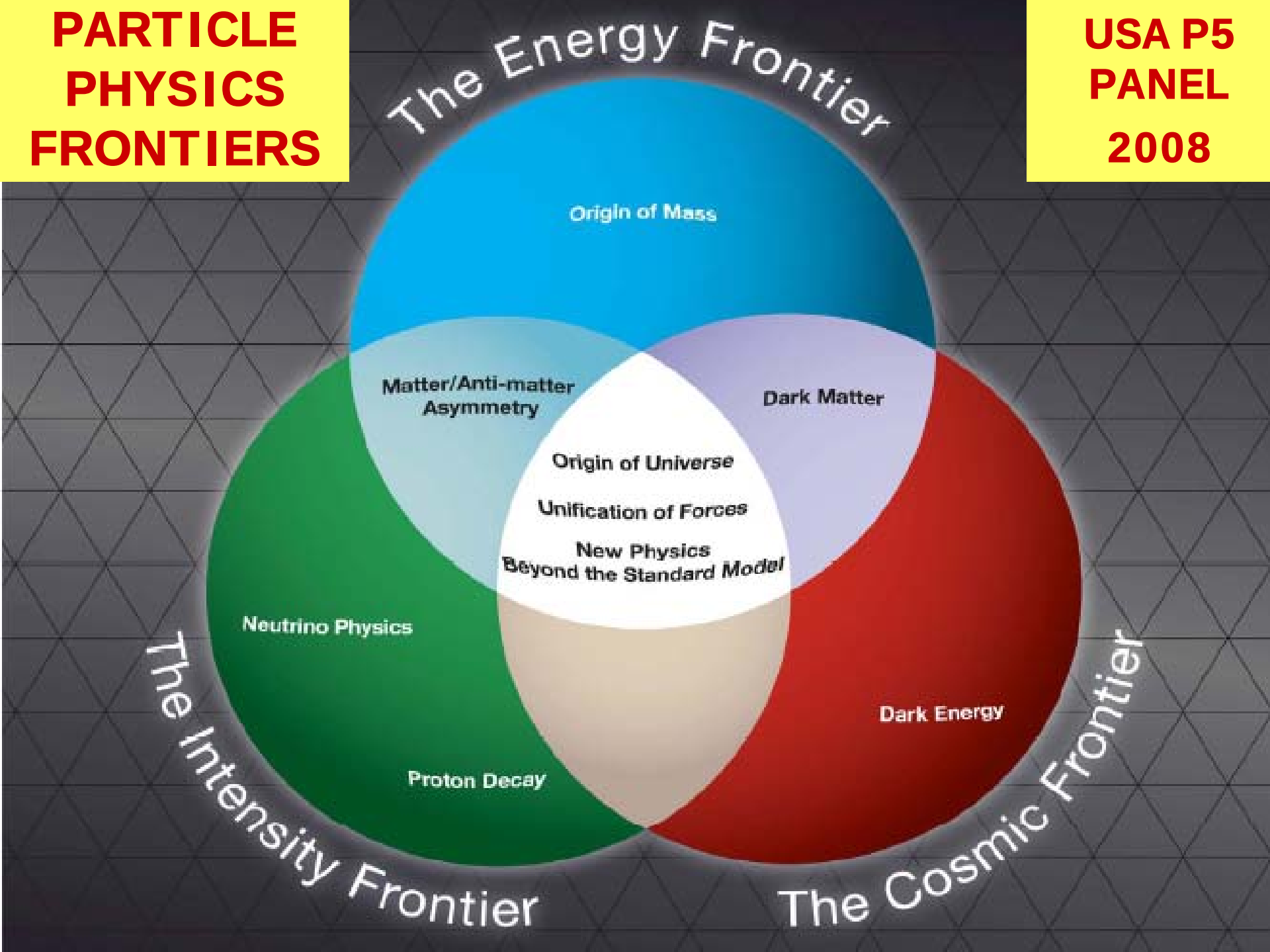
- Institutional funding from GenCat via DIUE, under 6-year "Contract-Program".
  - Almost entirely devoted to salaries.
  - Provides stability.
- Research almost entirely funded by National, European, Catalan competitively awarded projects.
  - Most projects funded from National Research Plan, Particle (FPA) and Astro. (AYA) Programs (1-3 yr projects).
  - Principal Investigators autonomously dispose of project funds.
- In 2010, ~20% of funding from GenCat, remainder from research projects.

RESEARCH LINES
THEORY DIVISION

- Three lines:
  - Standard Model: QCD and Flavor Physics
  - Beyond the Standard Model
  - Astroparticles and Cosmology
- Personnel:
  - 7 U.A.Barcelona faculty
  - 3 ICREA
  - 10 postdocs
  - 6 PhD students

PARTICLE PHYSICS FRONTIERS

USA P5 PANEL 2008

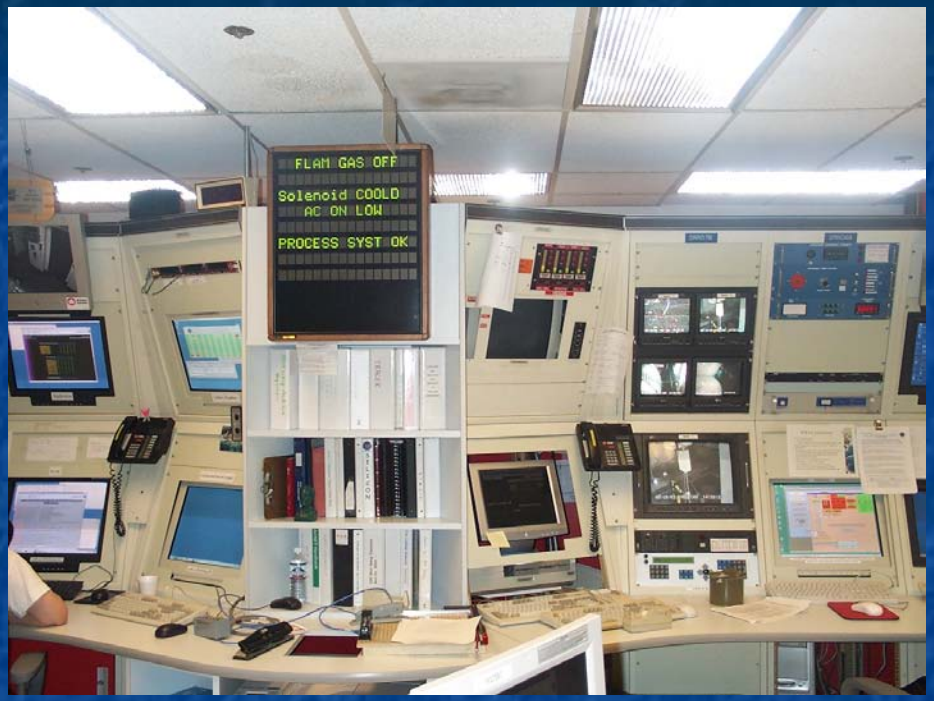


1: HADRON-HADRON COLLISIONS AT THE ENERGY FRONTIER: CDF AND ATLAS

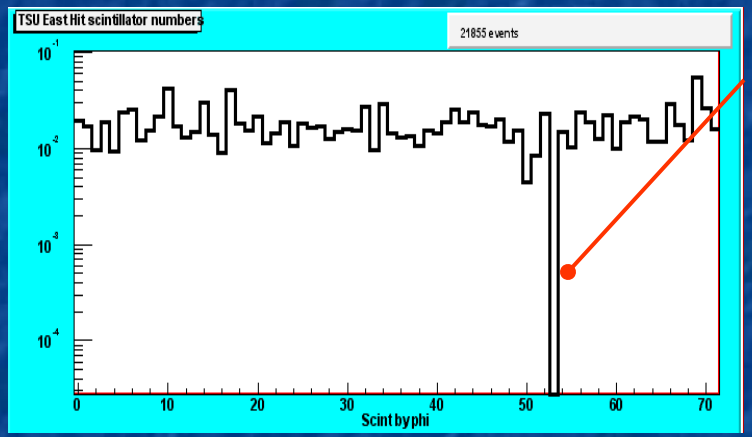
A. CDF AT THE TEVATRON

- Since 2003
- Initial goals Prepare for LHC physics by pursuing appropriate analyses:
  - SM processes, relevant for early LHC analyses
  - SUSY searches
  - Train students (from ATLAS, towards ATLAS postdoctoral jobs)
- Small group (6) partially overlaps with ATLAS group
- Current goal: Higgs search

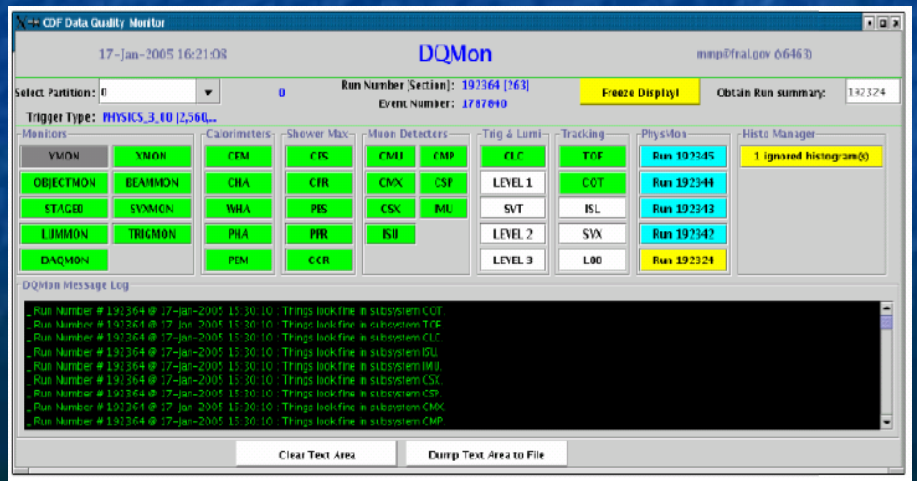
IFAE Commitments: DQ Monitoring



Online Monitors (C++ based) produce online histograms to monitor the basic performance of the different sub-systems (occupancy levels, HVs)



dead channel

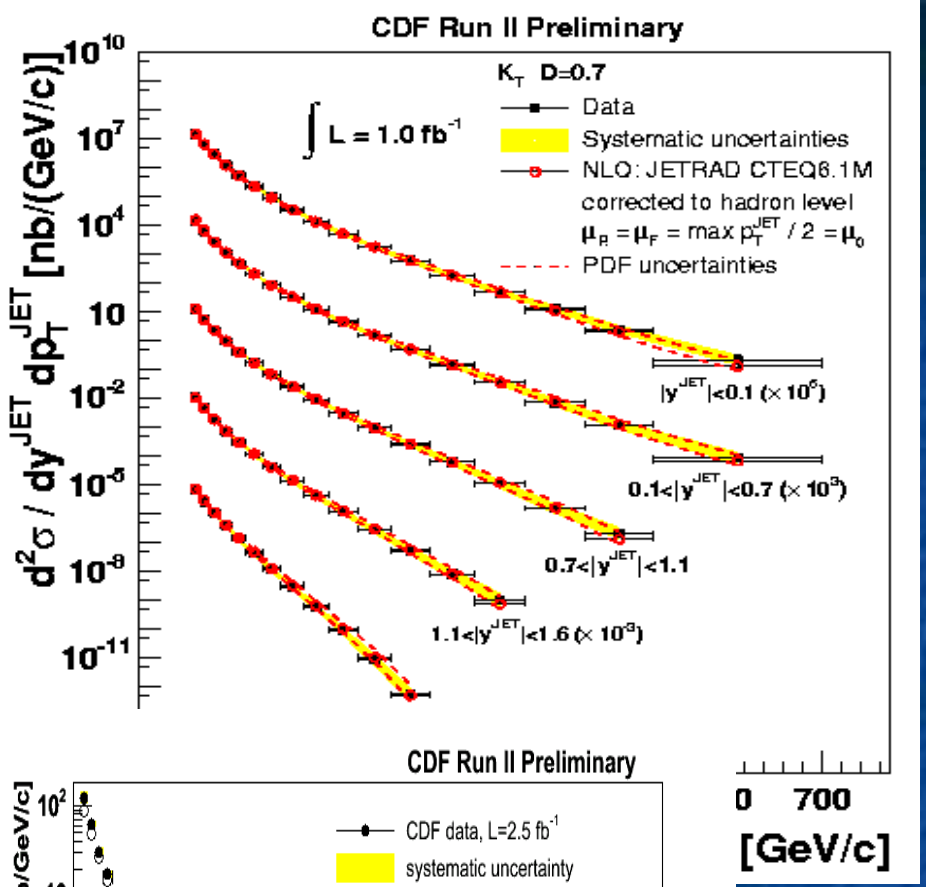


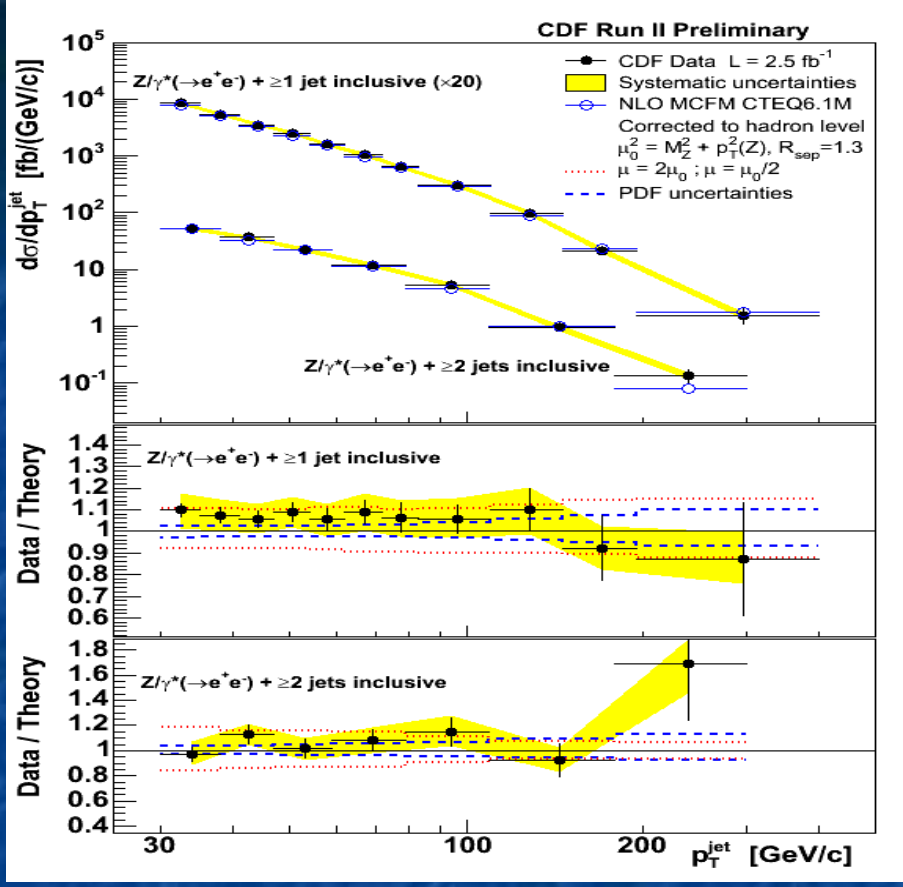
Expert System runs @ CDF control room

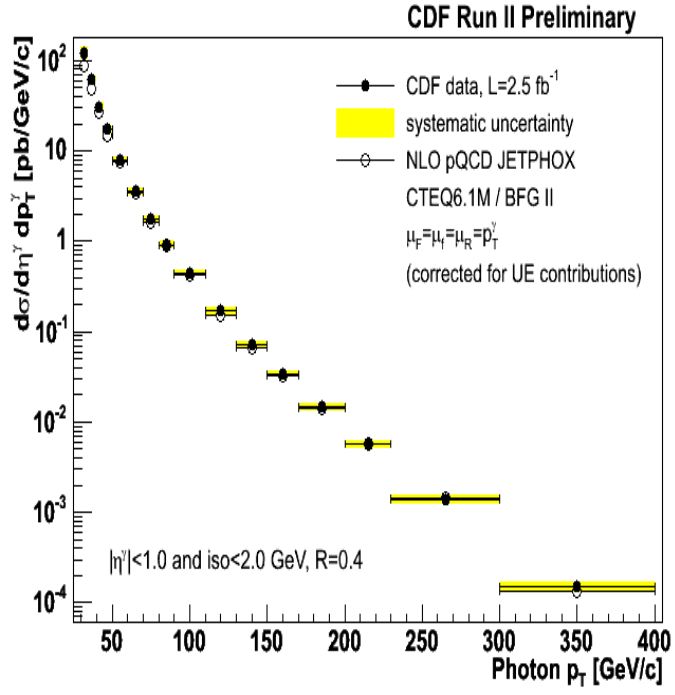
Monitors online histograms & status of Consumers, HVs and Tevatron Beams

Alerts shift-crew in case of problems

-> Determines Online Good Run Status



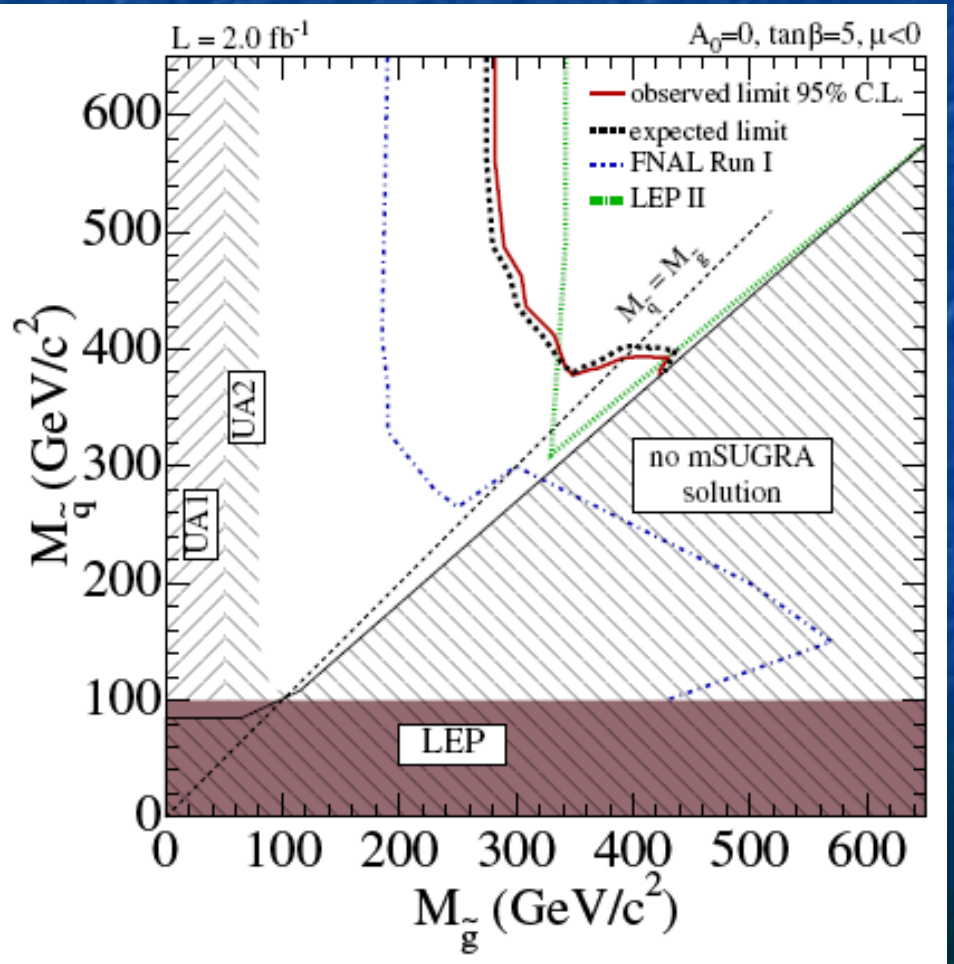




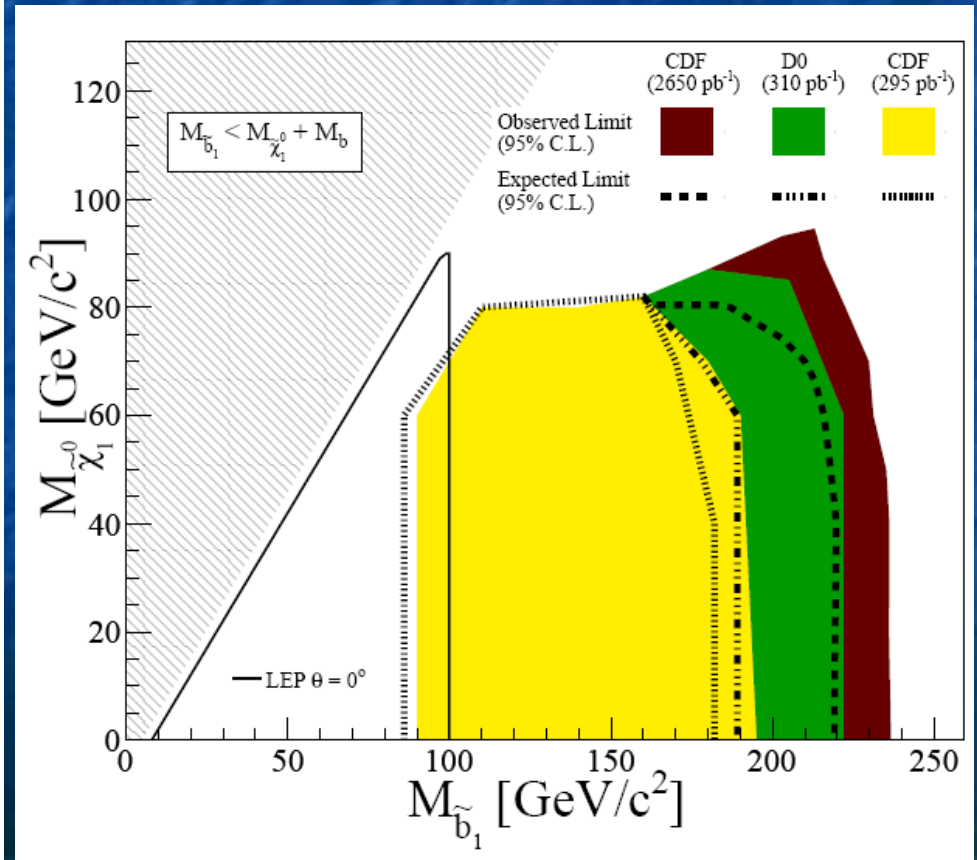
- SM processes:
  - Jet inclusive x-section to highest E_T, differential in η
    - Springer-Verlag monograph
  - γ + jet x-section
    - Springer-Verlag monograph
  - Z + jets x-section

(Our) SUSY searches at CDF

Squark – gluino mass limits in jets + missing ET, in MSUGRA

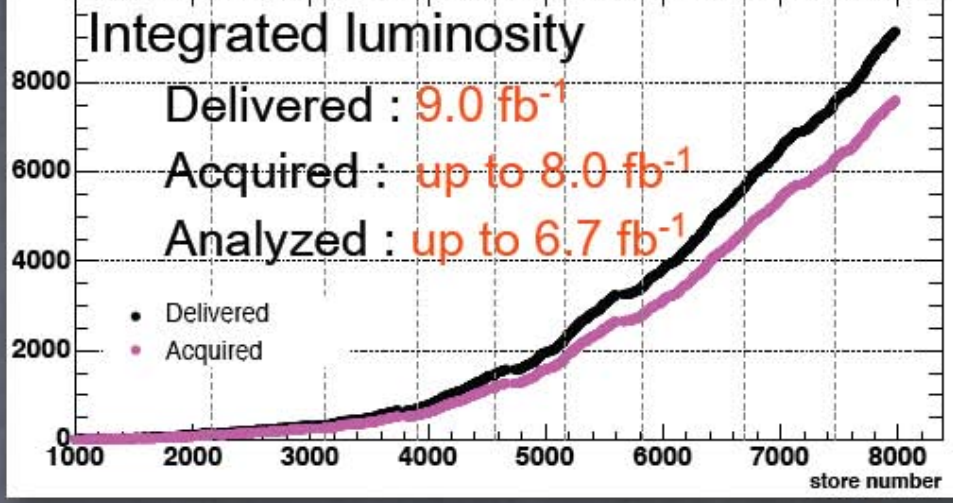


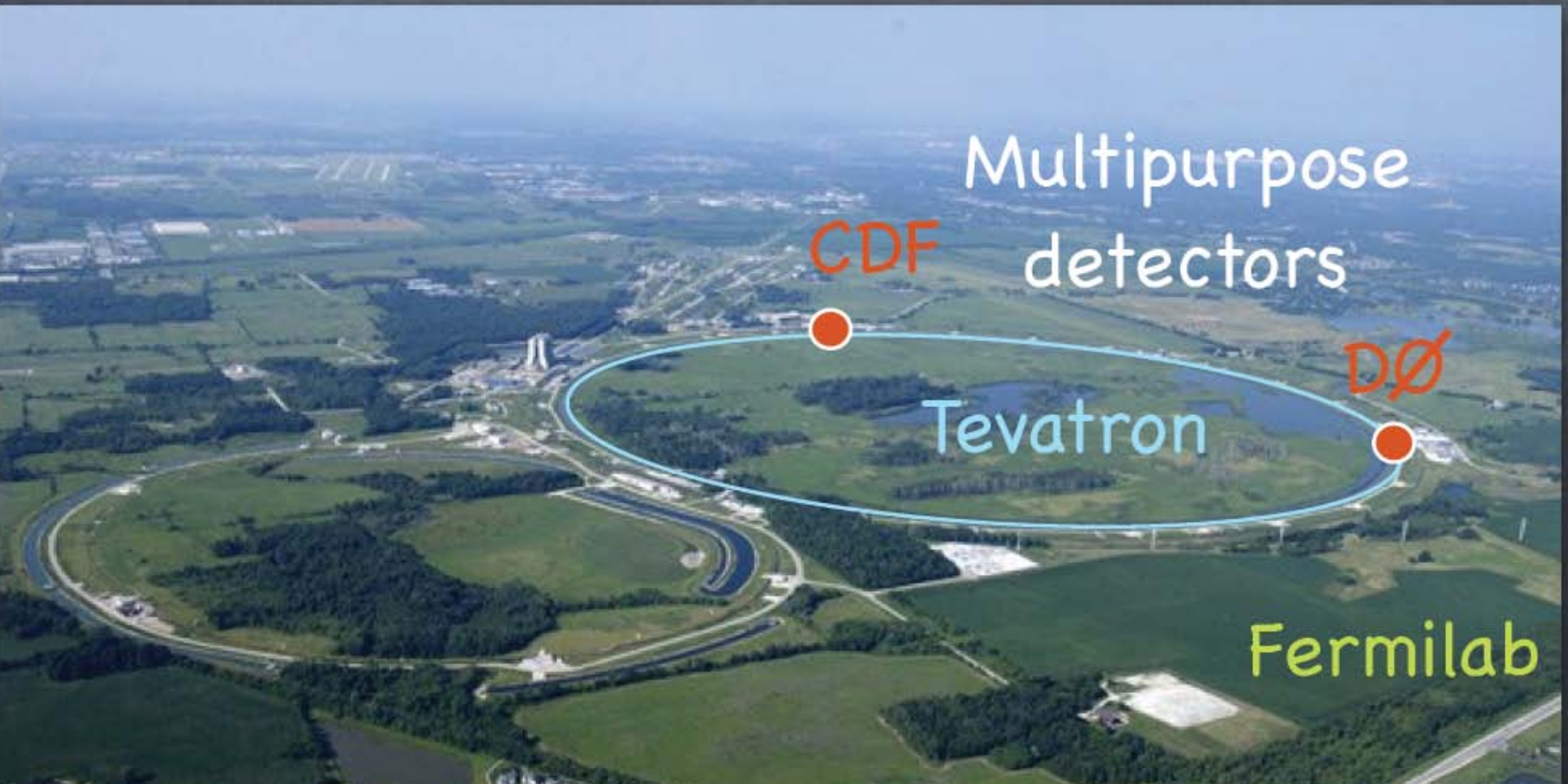
Sbottom quark vs. neutralino mass limits



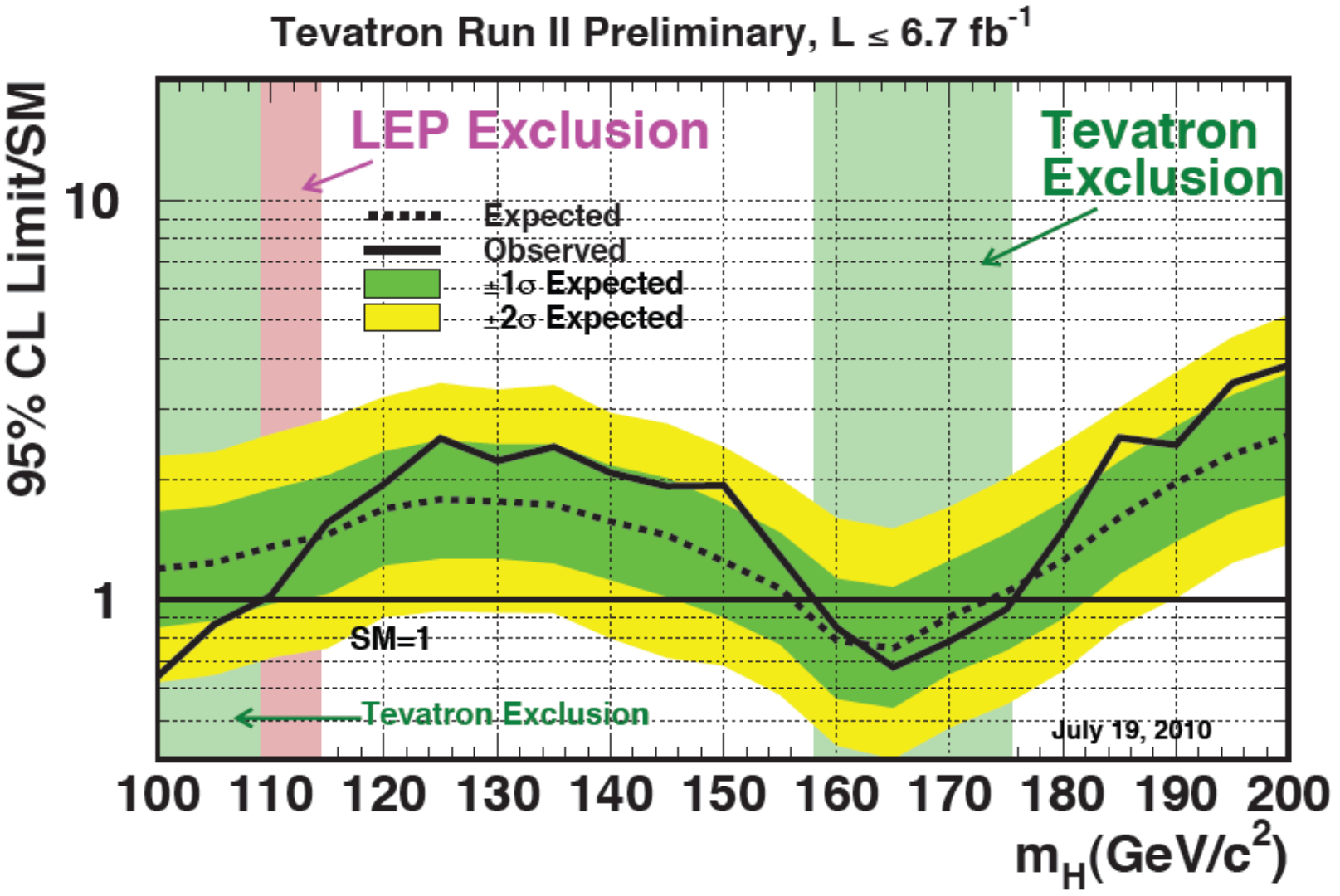
Tevatron

- $p\bar{p}$ collisions with $\sqrt{s}$ = 1.96 TeV
- Two collider experiments, CDF & DO





Tevatron combination



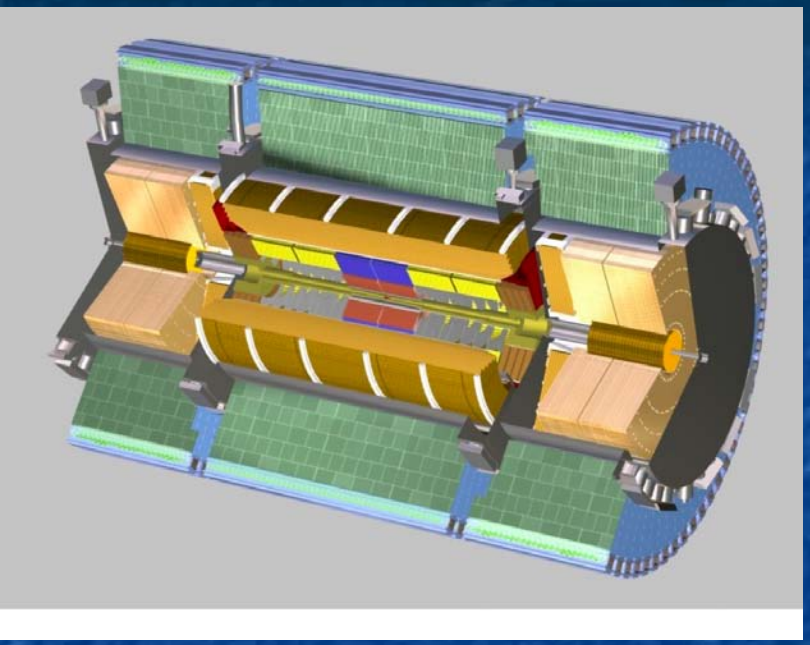
- High mass 95% CL exclusion :
  - $158 < m_H < 175$ GeV

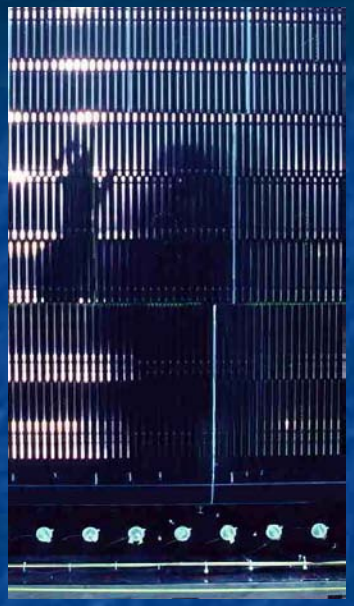
1: HADRON-HADRON COLLISIONS AT THE ENERGY FRONTIER: CDF AND ATLAS

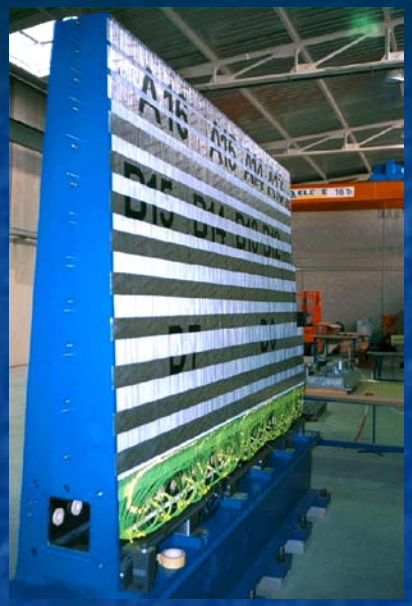
B. LHC: ATLAS

- Since 1992. Now about 24 persons.
- Substantial contributions to calorimetry, trigger
- Very visible in physics preparations, governance
- Starting up in sLHC upgrade activities.

The Hadronic Tile Calorimeter





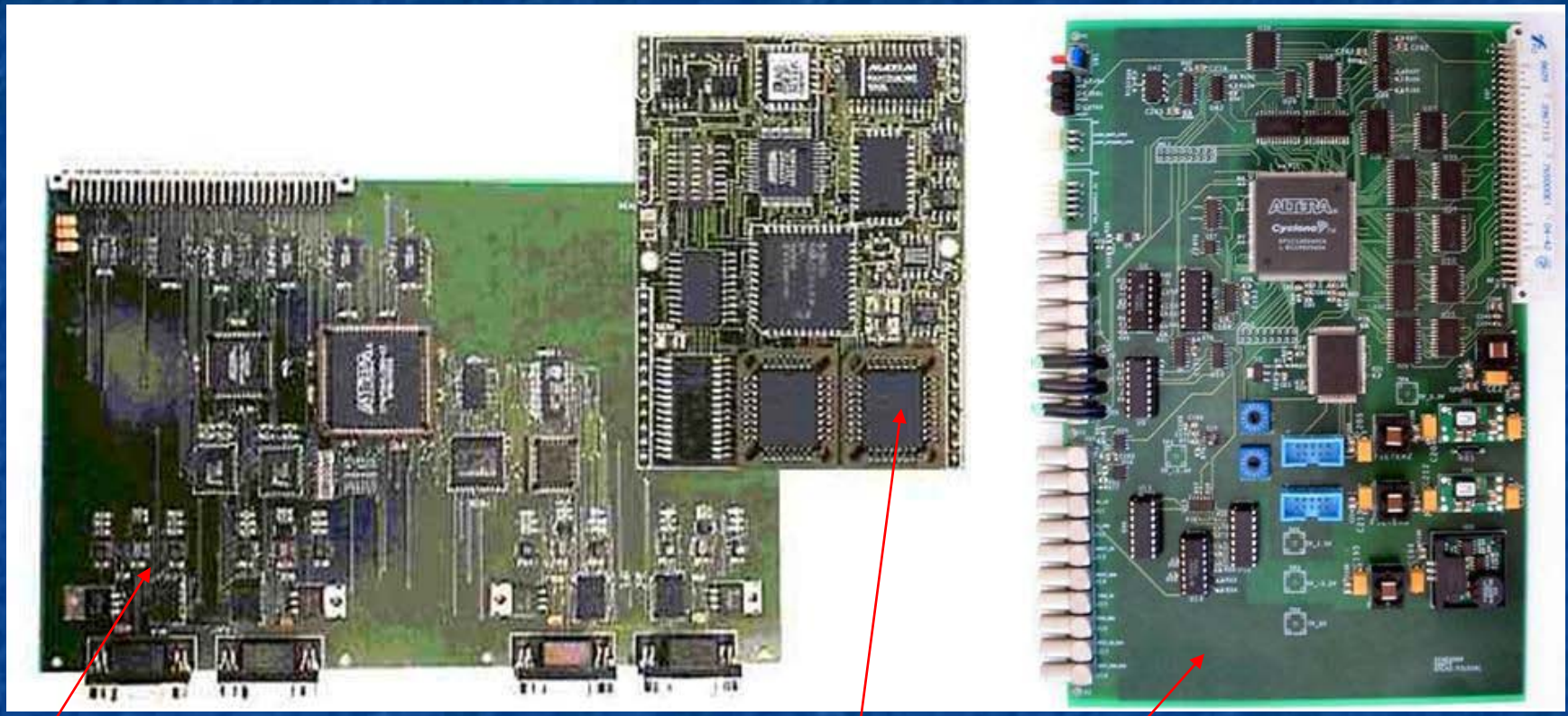


Iron-Scintillator read by fibers & PMTs

- early R&D (since 1993)
  many prototypes - test beams
- construction of an Extended Barrel
  64 modules (1997-2002)
- Installationa at CERN(2002-06)
- Commission/operations(2006-10)

Tile Calorimeter – Calibration Electronics

read PMT currents produced by Cs137 sources, or "Minimum Bias" collisions



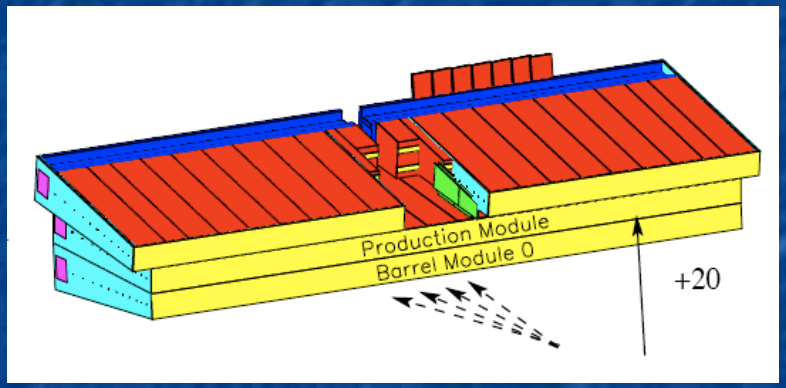
Design of integrating amplifiers (10,000)

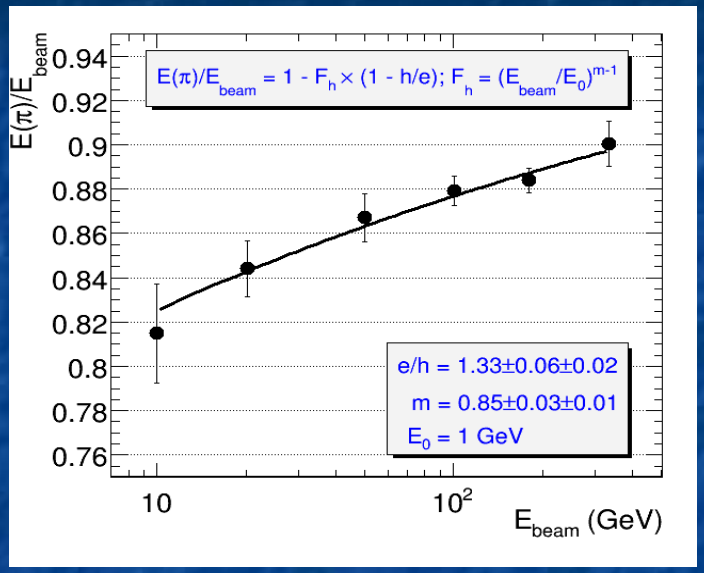
300 analog-to-digital conversion (ADC) circuits

interface to Detector Control System (DCS) VME/Canbus: 20 Read Out Buffer (RB)

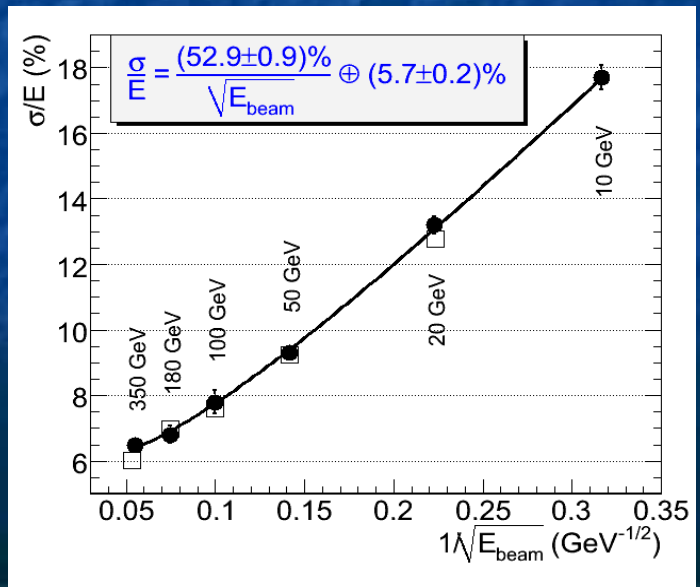
6 calibration & monitoring control boards SHAFTS

Understanding of Test Beam Data





- During 2007 and 2008 members of IFAE actively participated in an effort to re-analyze *ab initio* the TileCal test-beam data
- Important input to an in situ calibration of the detector using isolated tracks in MB events in ATLAS
- NIM publication, 2009



ATLAS Overview Week 2009

5th-9th October, Barcelona, Spain

Organized by IFAE

Organizing Committee:

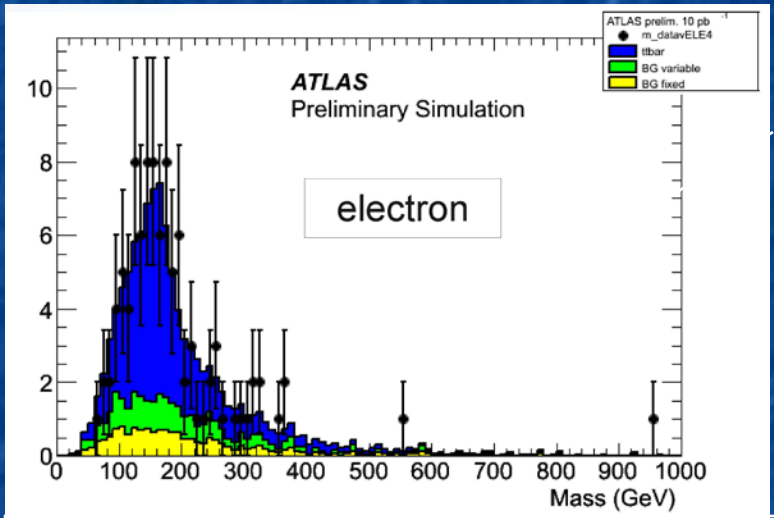
M.Bosman, M.P.Casado, M.Cavalli-Sforza, M.D'Onofrio, L.Fiorini, S.Grinstein, I.Korolkov, M.Martínez, Ll-M.Mir, J.Nadal, A.Pacheco, C.Padilla(chair), E.Pérez, I.Riu, F.Vives, V.Vorwerk

Information and Registration:
http://atlasweek09.ifae.es

Top Physics @ IFAE

Now: “top rediscovery” cross-section measurement in semileptonic channel decay mode: ttbar→bW(ℓ,nu)bW(qqbar) (ℓ=electron or muon)

Future: search for new physics in same final state

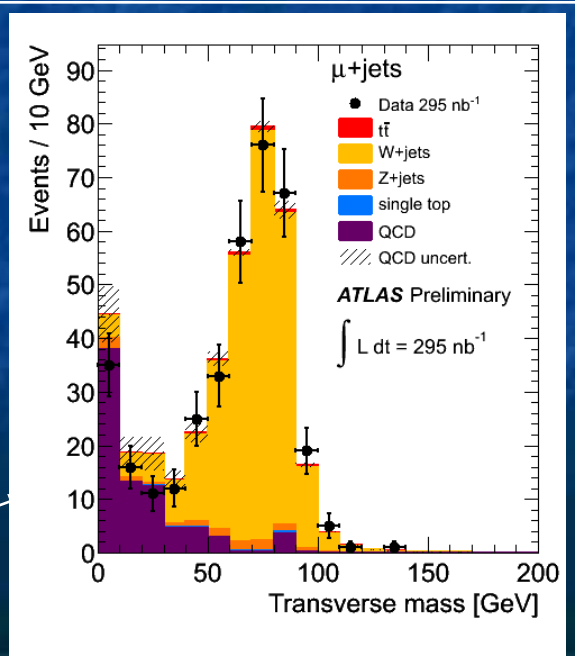


analysis strategy: template fit of invariant mass of candidate hadronic top decay

combines electron and muon channel for maximum sensitivity for early cross-section measurement

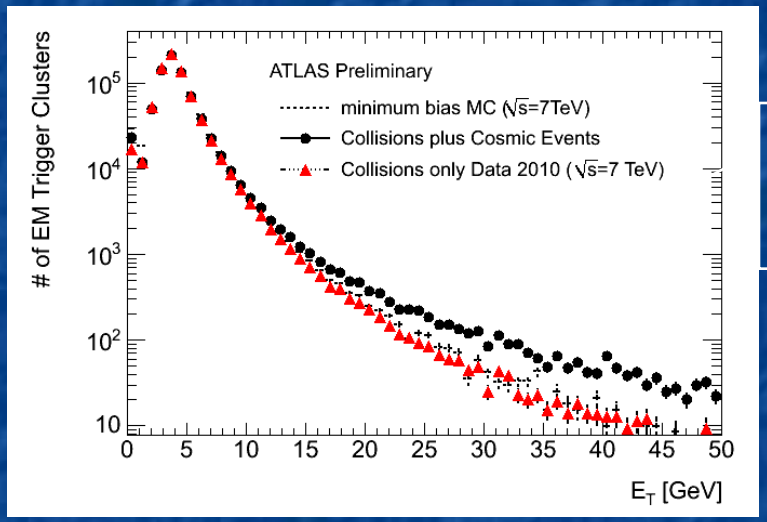
data-driven background estimation techniques have been developed for the releant background W+jets and QCD

Transverse mass of lepton and PTmiss in events with 1 muon and 1 jet with IFAE data-driven QCD contribution - presented at HCP conference ATLAS-CONF-2010-087



Tau Physics @ IFAE

Now: Z→ττ withe one tau decaying to electron or muon and one tau decaying hadronically (commissioning of "tau identification" and tau trigger efficiency measurement)



IFAE responsible of Level Tau calorimeter trigger

Example of public performance study with data

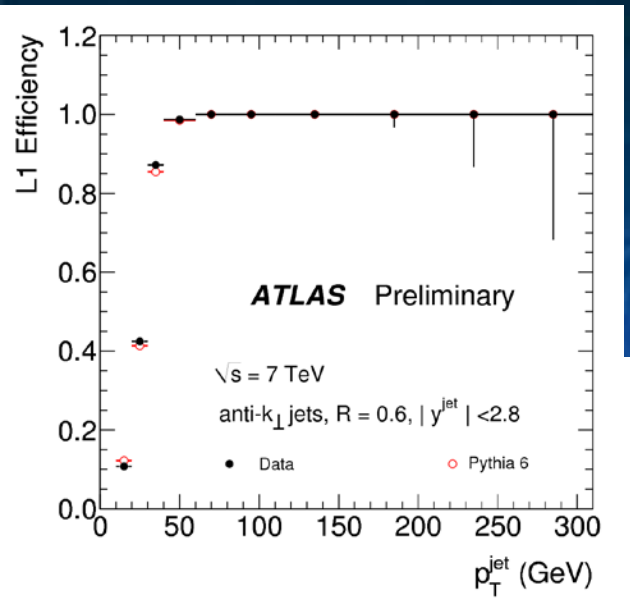
ATL-COM-DAQ-2010-085 Performance of the ATLAS tau trigger in p-p collisions at $\sqrt{s}$=7 TeV, in preparation

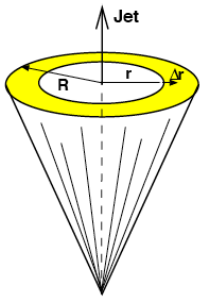
Future: search for new physics in tau in final state like Charged Higgs in ttbar→bW/H⁺(tau,nu)bW(qqbar)

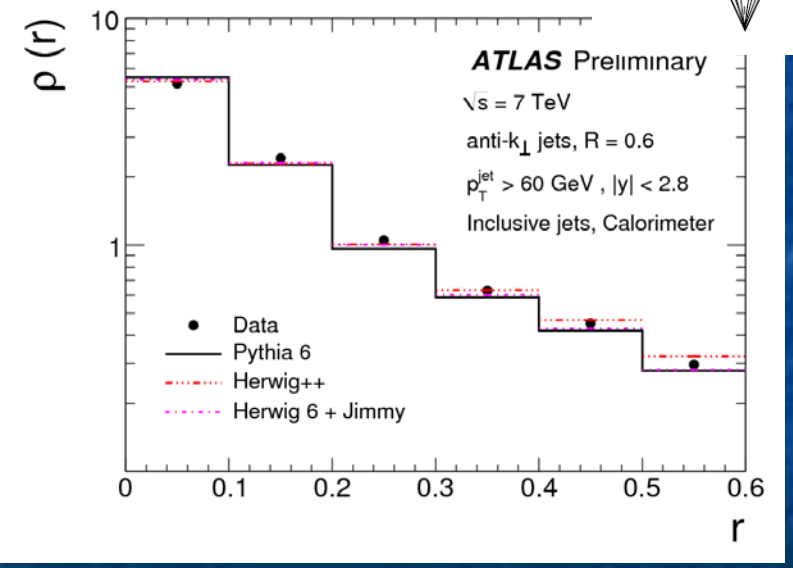
Jet Physics @ IFAE

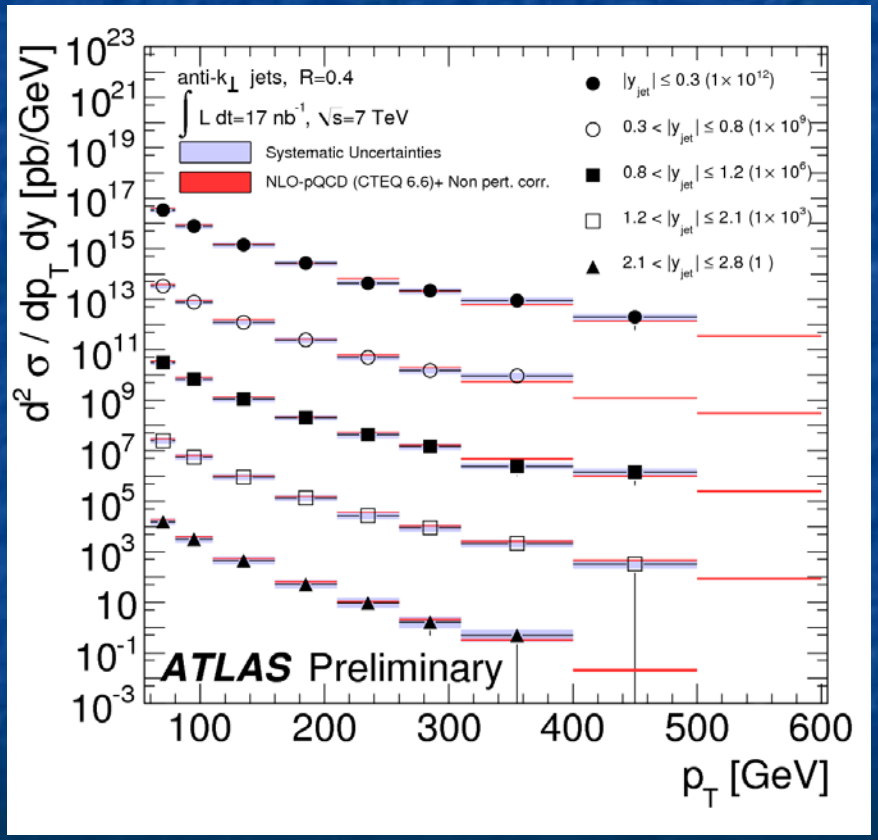
Strong involvement in inclusive jet analyses

- Editor of first Jet Observation conf paper by ATLAS
- Responsible evaluation of jet trigger performance
- Measurement of Jet shapes



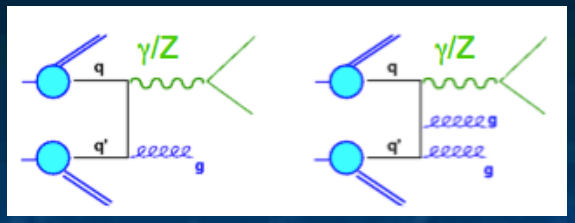




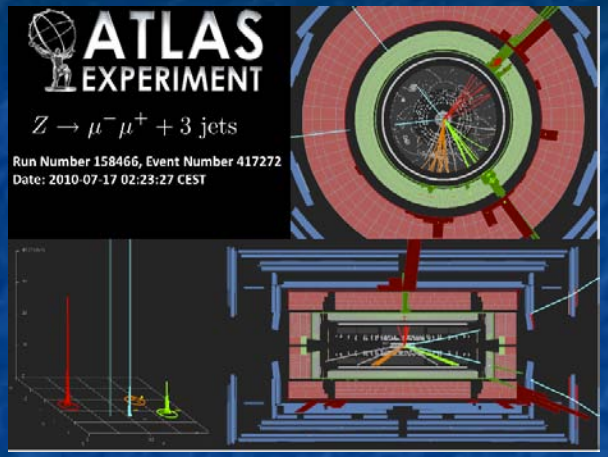


Measured Inclusive Jet Production well described by NLO pQCD predictions

Presented in ICHEP, HCP, PIC … final ATLAS internal review process for publication



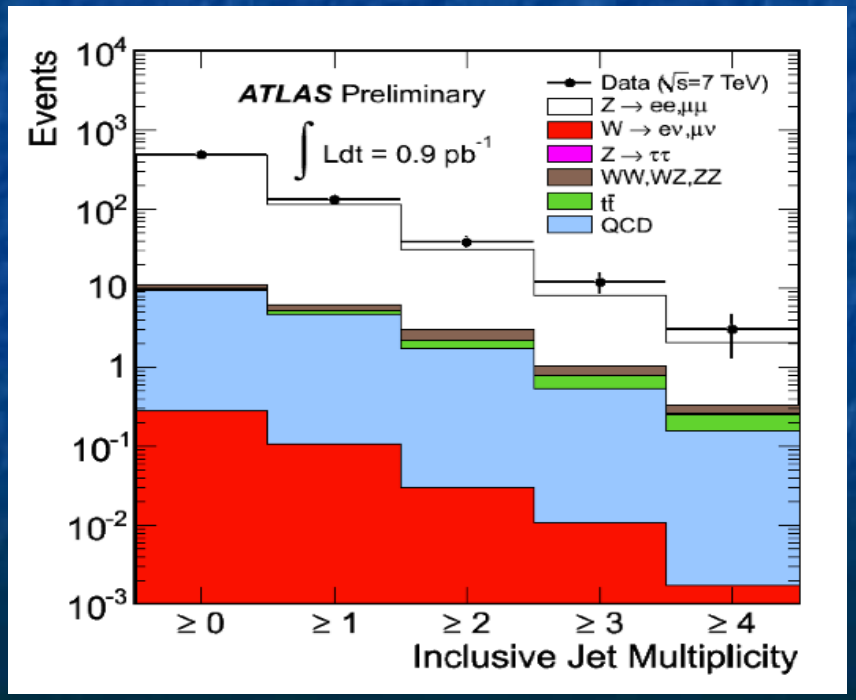
Z/γ*+Jet Physics @ IFAE

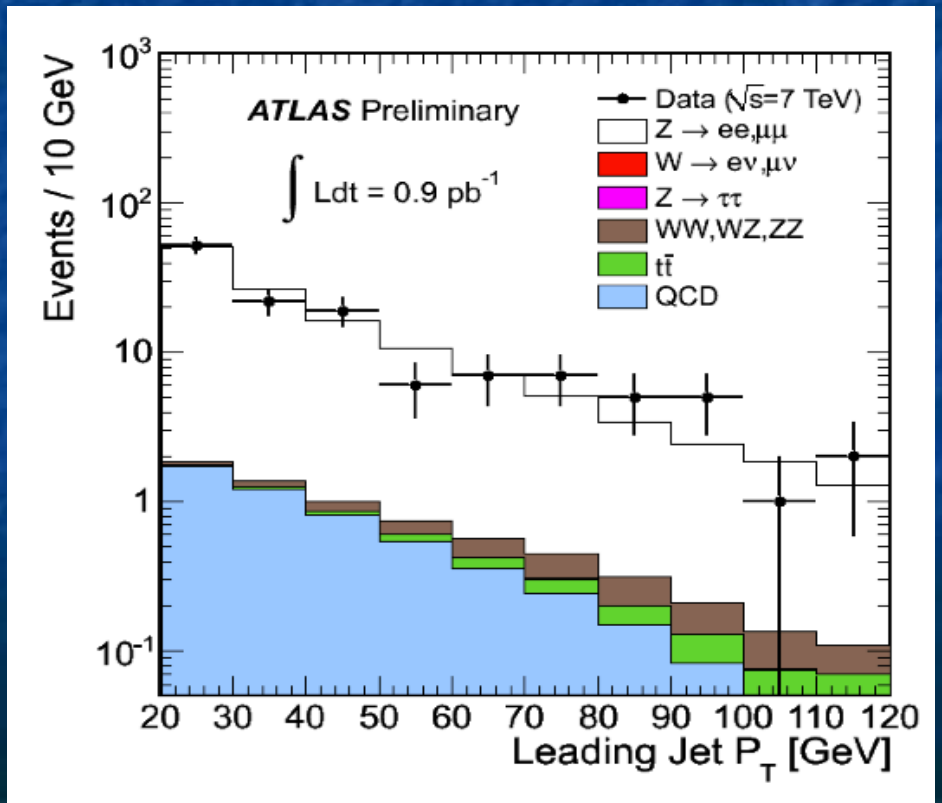


Understanding of Boson+jets SM processes fundamental for (our) future SUSY, ED and Beyond SM searches in ATLAS

Strong involvement in Z+Jet(s) analyses (e,μ channels)

- **First PR plots presented in HCP 2010**
- Editor of first Z+Jet(s) cross section conference paper by ATLAS (coming soon)





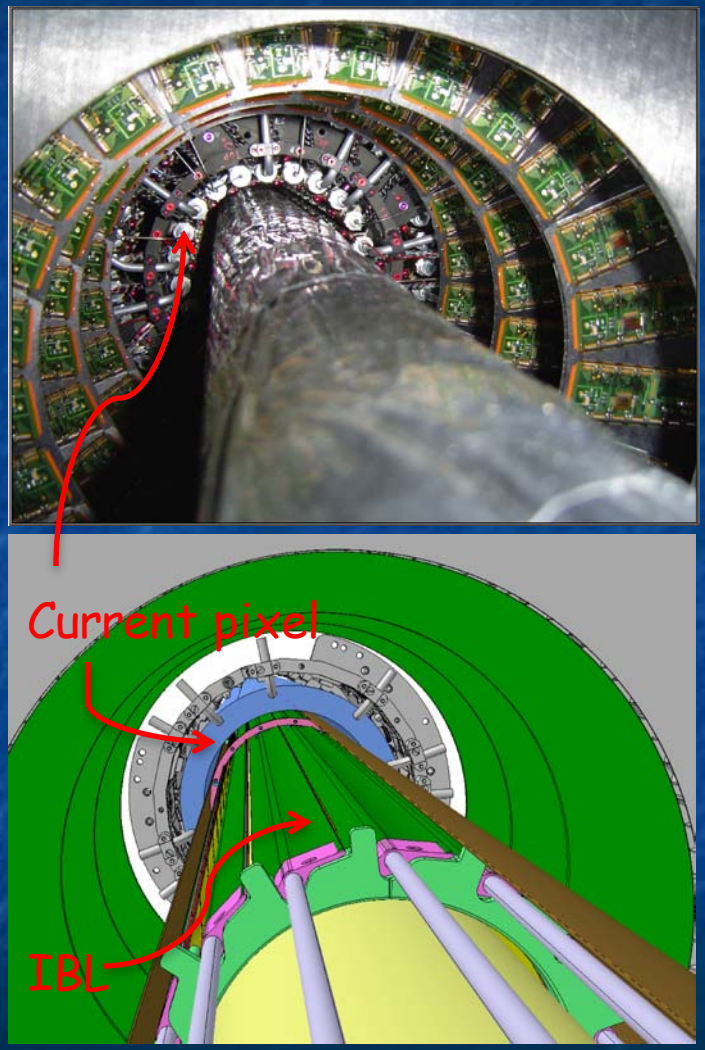
ATLAS Pixels at IFAE

- Long-term goal:
  - Development and contruction of pixel sensors for sLHC ATLAS upgrade (by 2020)
  - by combining IFAE and CNM expertise to position Barcelona (UAB campus) as a pixel production and testing site.

- Short term goal:
  - develop and construct pixel deectors for Intermediate B-Layer (IBL) for ATLAS tracker.
  - by 2015

Insertable B-Layer (IBL)

- New pixel layer mounted directly on new beampipe
  - radius=33mm, same η coverage, 0.2m²
  - requires smaller beampipe
- Reasons for IBL:
  - Back-up existing B-Layer (hard failures)
  - Improve physics performance
    (Based on smaller radius and low mass)



Stringent requirements on sensor and front-end electronics

(Need of larger and faster font-end chip)

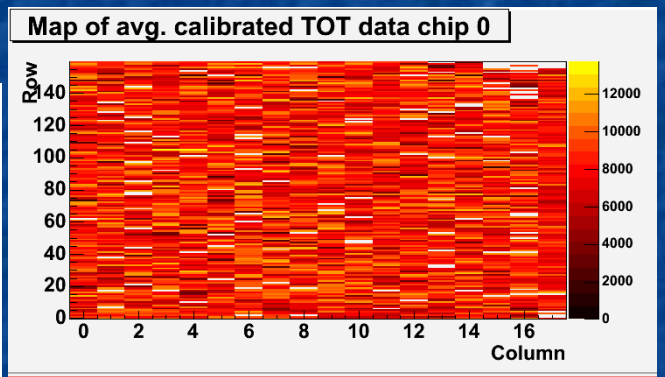
- ➢ Project officially approved
- ➢ TDR and iMoU drafts circulating

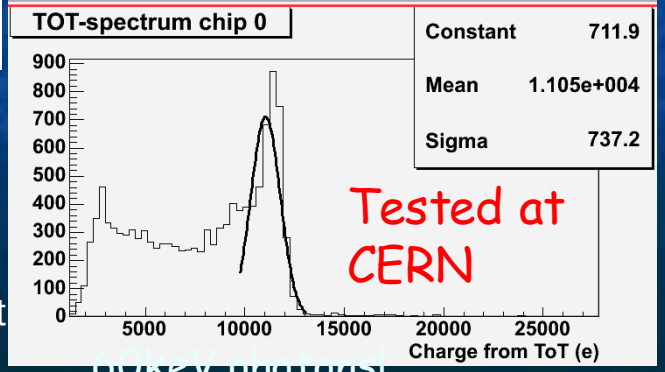
Recent IFAE Pixel Activities

- Participation in pixel activities at CERN
  - Working with Planar Pixel Sensor and 3D Sensors ATLAS groups
  - Commissioning shifts, pixel teststand at CERN, testbeams

  ↳ Collaboration with other groups, publications, expertise...
- Designed single chip card for FE-I3 readout (with Genova)
  - Produced in Spain (Lab Circuits) for the collaboration

Front End Chip





Tested at CERN

- Sensor/Chip integration
  - Bump-bonding devices since May 09
  - Using current ATLAS sensor

  (n-on-n, 50x400um pixels)

60keV photons!

2. AT THE INTENSITY FRONTIER: NEUTRINO OSCILLATIONS, NATURE OF NEUTRINOS

- Started out on K2K near detector and analysis:
  - 3 PhD theses, 1 Master thesis
- Now on T2K (first events, end of 2009)
  - Work on near detector TPC, magnet
  - Physics emphasis: electron appearance
- NEXT:
  - sensitive $2\beta0\nu$ search, in Xe pressurized TPC
  - In Canfranc underground lab
- Group: 1 senior, 3 postdocs, 3 students.

Oscillations with 3 ν's

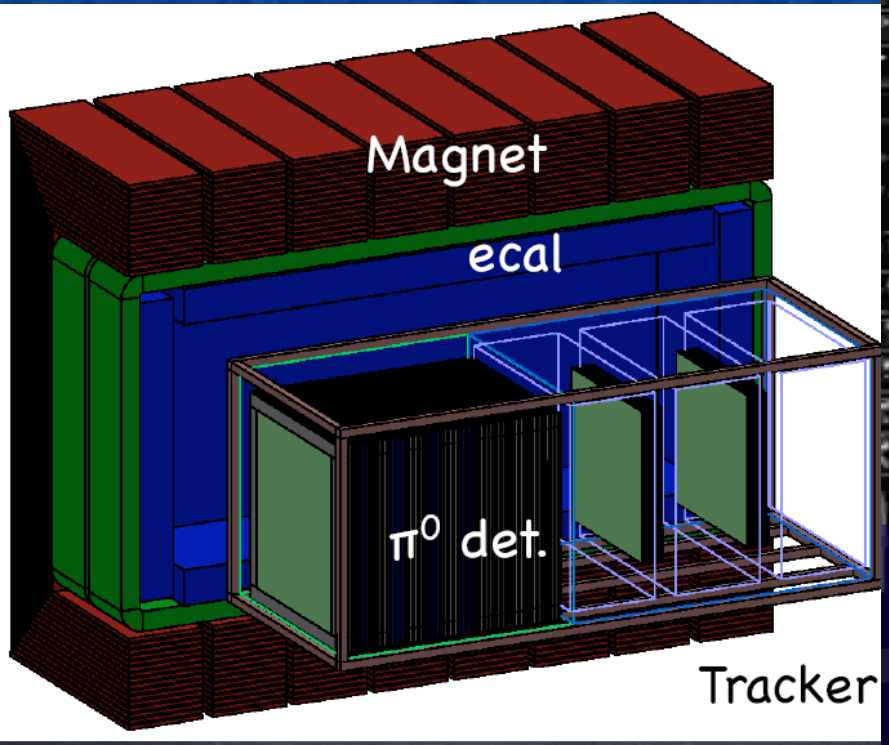
$$U_{PNMS} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta_{CP}} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{i\delta_{CP}} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{21} & \sin\theta_{21} & -\sin\theta_{21} \\ 0 & \cos\theta_{21} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} \nu_e & \nu_\mu & \nu_\tau \end{pmatrix} = U_{PNMS} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

- With 3ν, there are 3 angles and 1 imaginary phase:
- The phase allows for CP violation similar to the quark sector.
- There are also 2 values of Δm^2, traditionally Δm^2_{12} & Δm^2_{31}.

- Angles θ_{23} and θ_{21} well-measured by atmospheric and solar neutrino disappearance experiments
- Angle θ_{13} small, only U.L. If large enough, observation of CP violation in lepton sector possible. (Great cosmological implications)
- To measure θ_{13} need
  - Precise reactor ν_e disappearance experiments, or
  - Sensitive ν_e appearance experiment
- Latter possible with long-baseline ν_μ oscillation experiment
- Sharp energy, low backgrounds for appearance experiment possible with “off-axis” ν_μ beams
- This is realized with new beam at new Japanese J-PARC facility, at Tokai, shooting neutrinos to SuperKamiokande detector

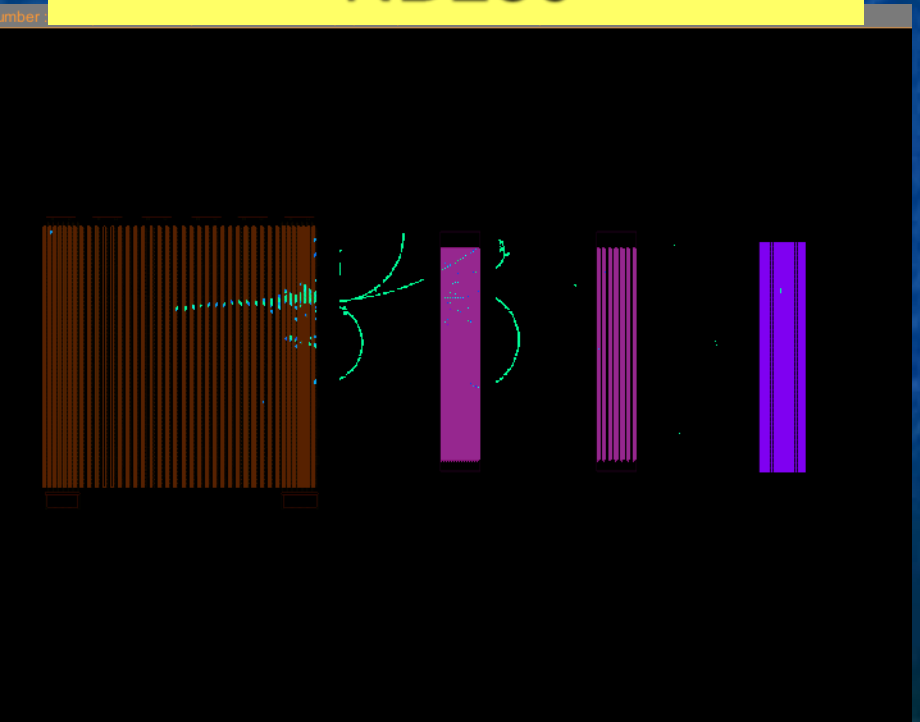
T2K (Tokai – to – Kamiokande) experiment



FAR DETECTOR

FIRST EVENTS FROM T2K:(end 2009- early 2010)

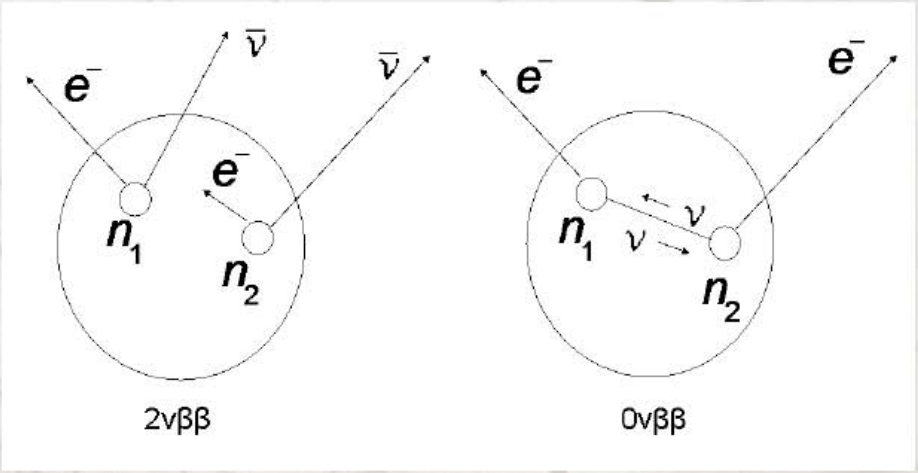
NEAR DETECTOR ND280

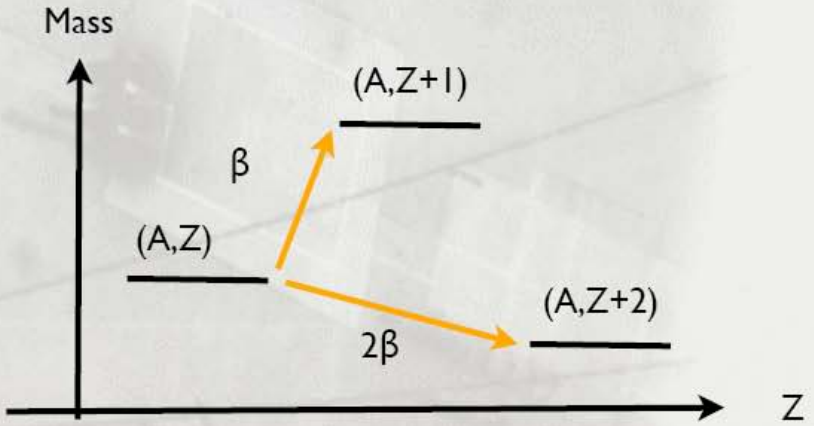


FAR DETECTOR

ARE NEUTRINOS THEIR OWN ANTI-PARTICLES?

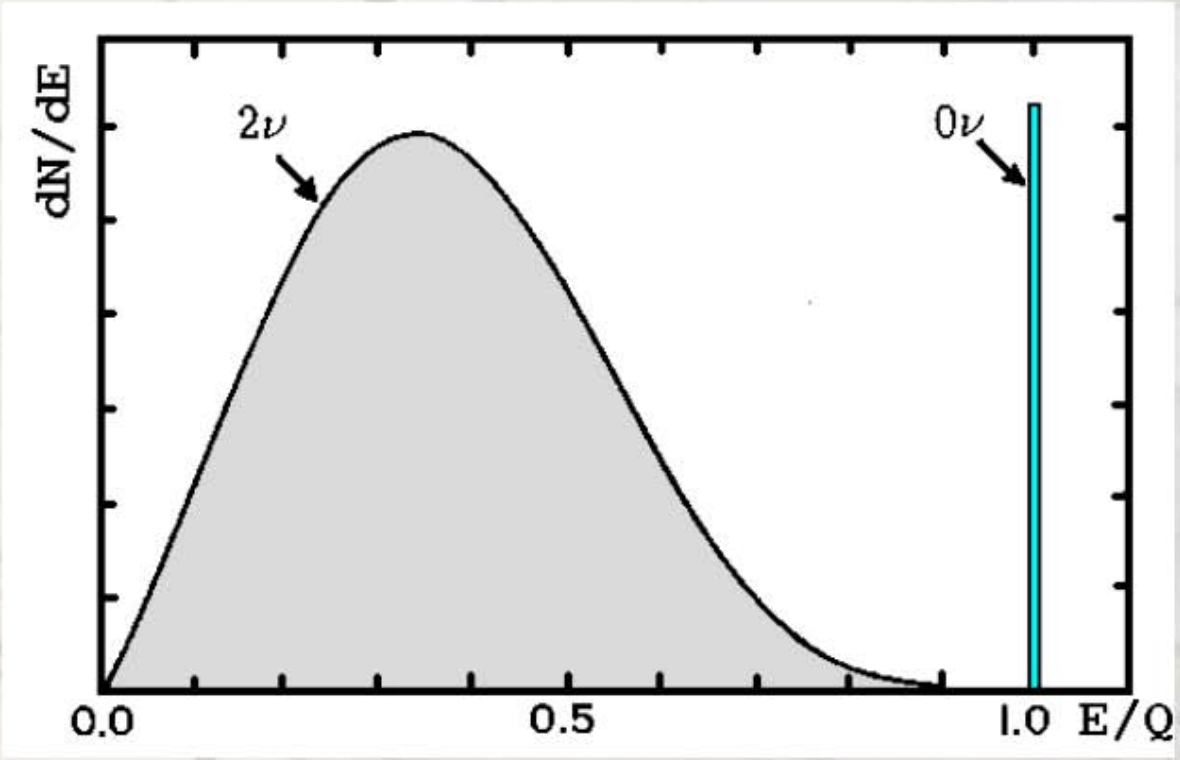
$0\nu\,2\beta$ process





- The $2\nu\,2\beta$ has been measured for several isotopes.
- The $0\nu\,2\beta$ has been search in many of them ("almost") without success.
- Experimentally is complex, both processes are rare: $T_{\frac{1}{2}} >> 10^{20}$ s

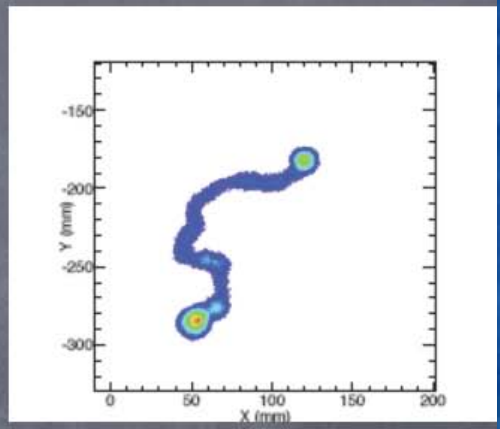
$0\nu\,2\beta$ process

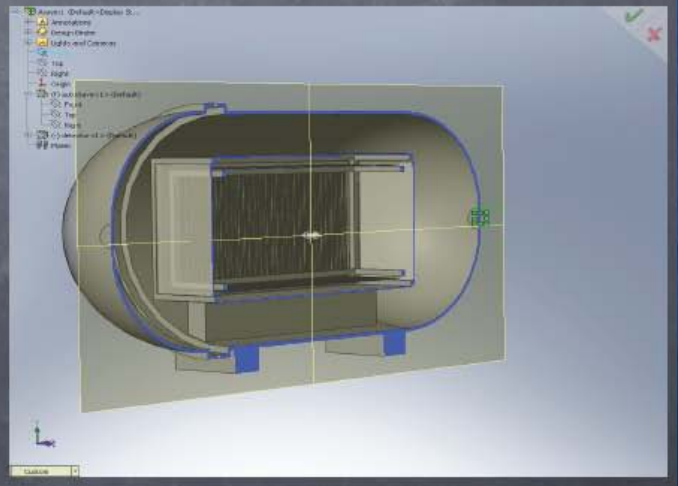


- The $0\nu\,2\beta$ is characterized by a monochromatic 2e emission.
- The experiments are mainly low background underground high resolution calorimeters ($\Delta E/E \sim 0.2\ \%$)

NEXT

- Neutrino Xenon TPC (NEXT) is a new enriched Xenon gas TPC proposal for $2\beta0\nu$ searches.
- High pressure for compactness and containment.
- Gas for extended topologies & background rejection.
- Measurement of prompt light for T_0.
- Energy resolution at $^{Xe}Q_{\beta\beta}$ < 1% FWHM.
- Electron readout via electroluminescence.
- ~100 kg in a first phase.

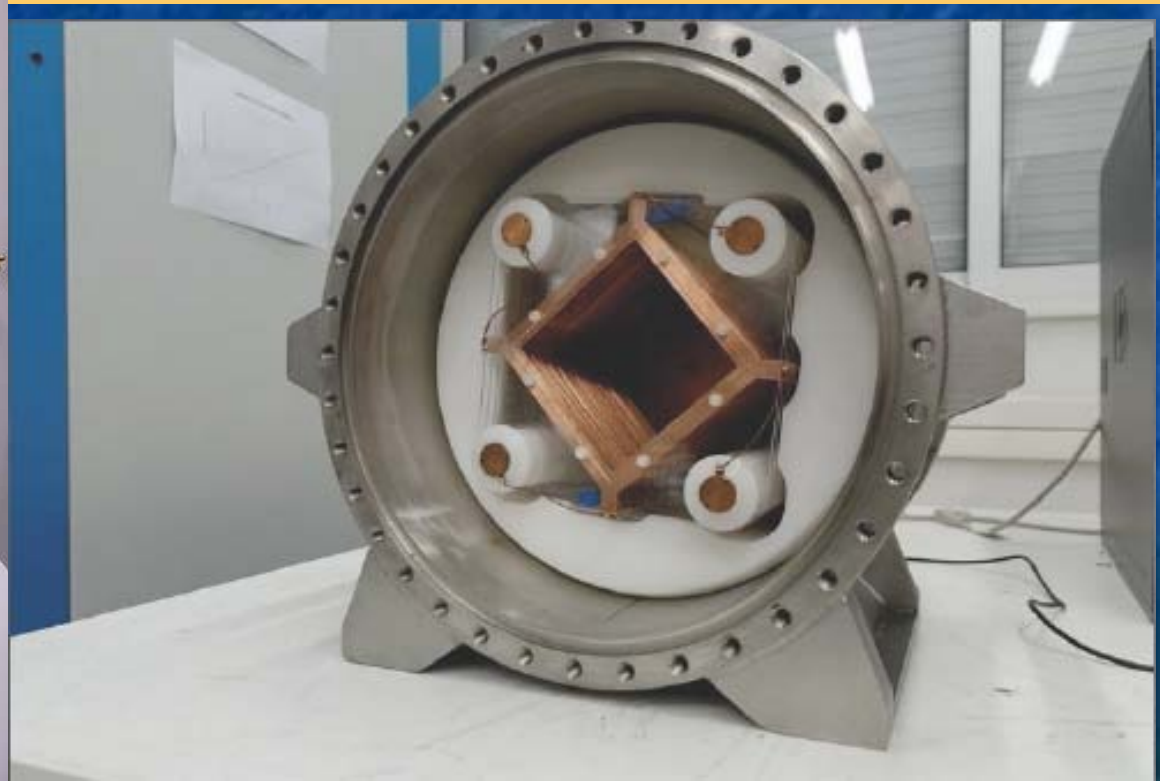




INSTRUMENTATION R&D FOR NEXT AT IFAE

STUDYING XENON SCINTILLATION LIGHT DETECTION WITH AVALANCHE PHOTODIODES

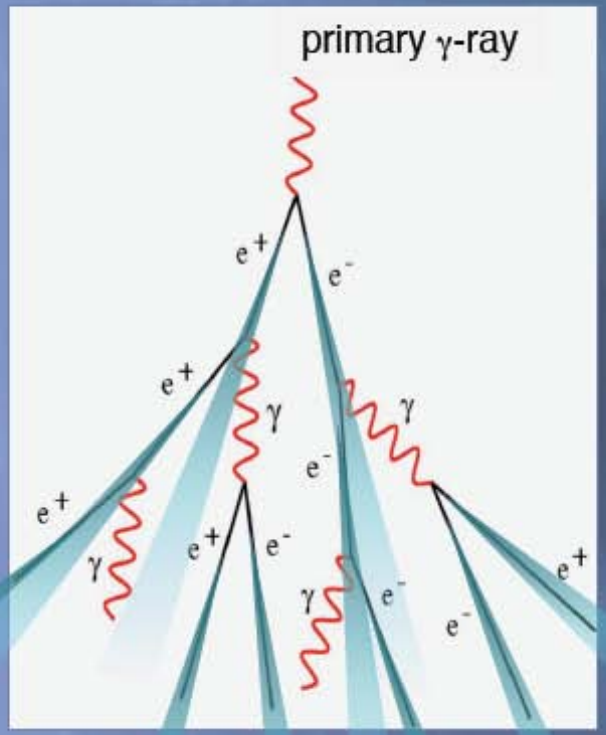
TIME PROJECTION CHAMBER SMALL-SCALE PROTOTYPE



3. APPROACHING THE COSMIC FRONTIER : GAMMA-RAY ASTROPHYSICS

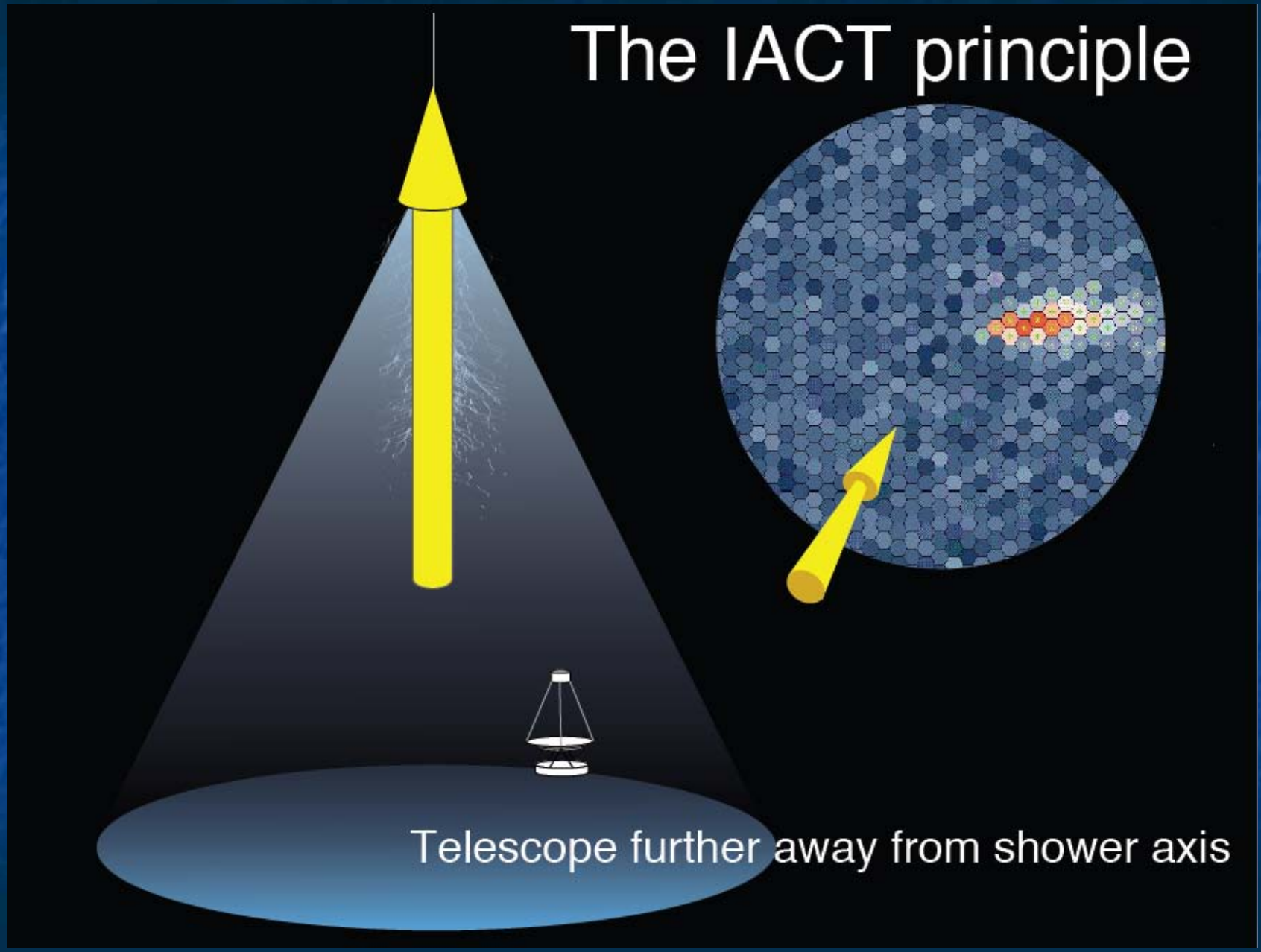
Ground-based γ-ray astronomy

- Observe particle showers induced in the atmosphere (28 X_0 at s.l.) by γ-rays
- Most successful technique:
  - Imaging
  - Atmospheric
  - Cherenkov
  - Telescopes



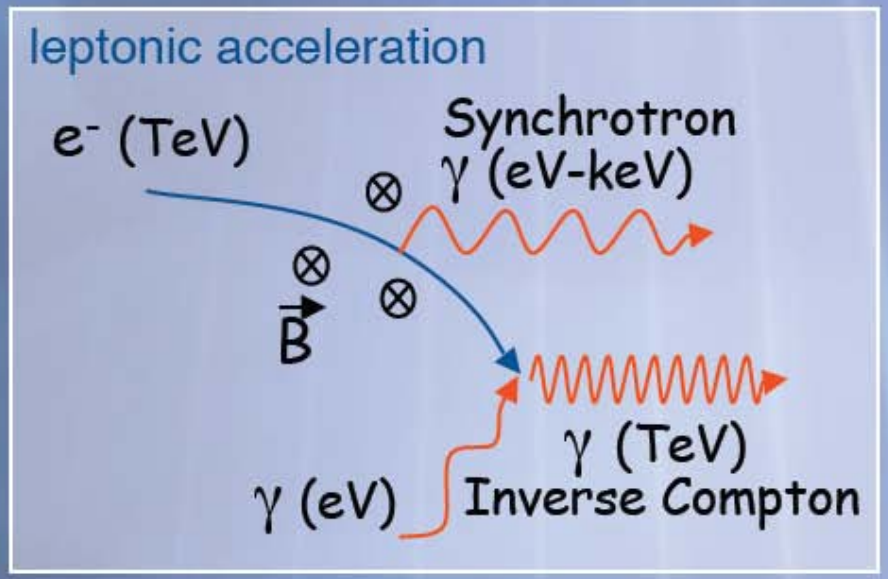
Very High Energy = $E_\gamma > 30$ GeV

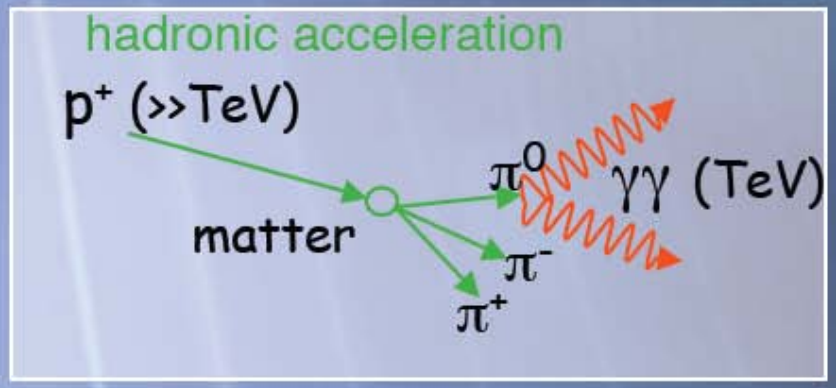
The IACT principle



VHE γ-rays

- Originate in the most energetic and violent phenomena in the universe
  - Cosmic particle accelerators (hadronic, leptonic)
  - Heavy particle annihilation or decay ?

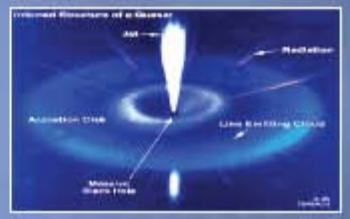




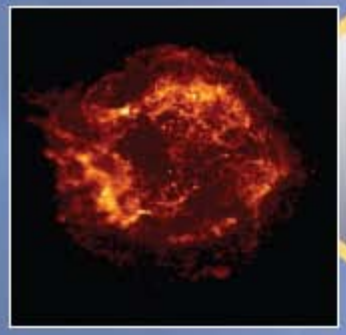
Physics goals of ground-based γ-ray astronomy

Binaries
μQSRs

Pulsars, PWN



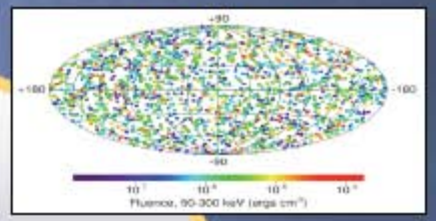
AGNs



SNRs
Origin of
Cosmic
Rays

Astrophysics

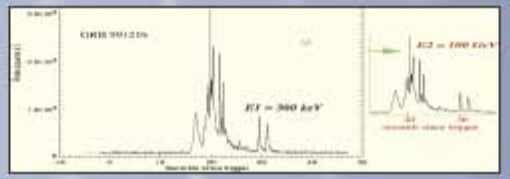
Fundamental Physics



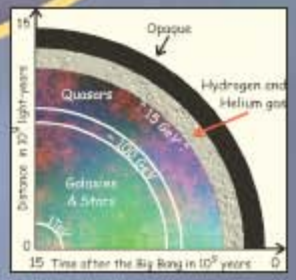
GRBs

Propagation effects

Cold Dark
Matter

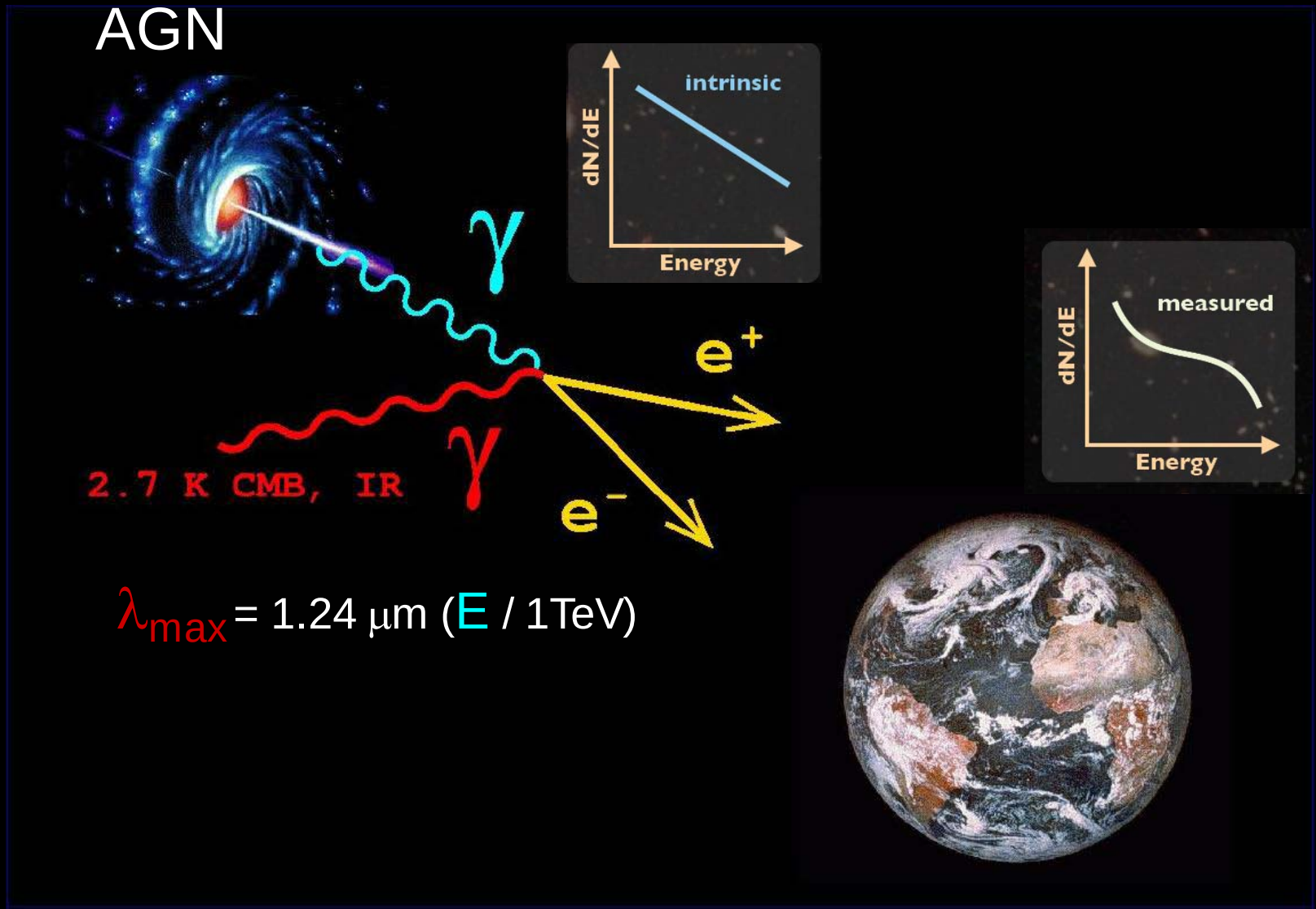


Quantum Gravity

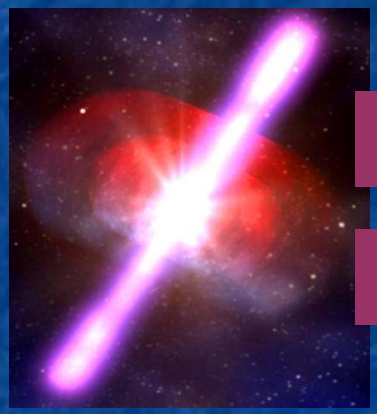


EBL and
γ-Ray Horizon

Attenuation of γ-rays in the Extragalactic Background Light



Tests of speed of light invariance



source

L

observer

E_0

E

Δt

Some QG models predict

$$c' = c\left(1 - \frac{E}{M_{QG1}}\right)$$

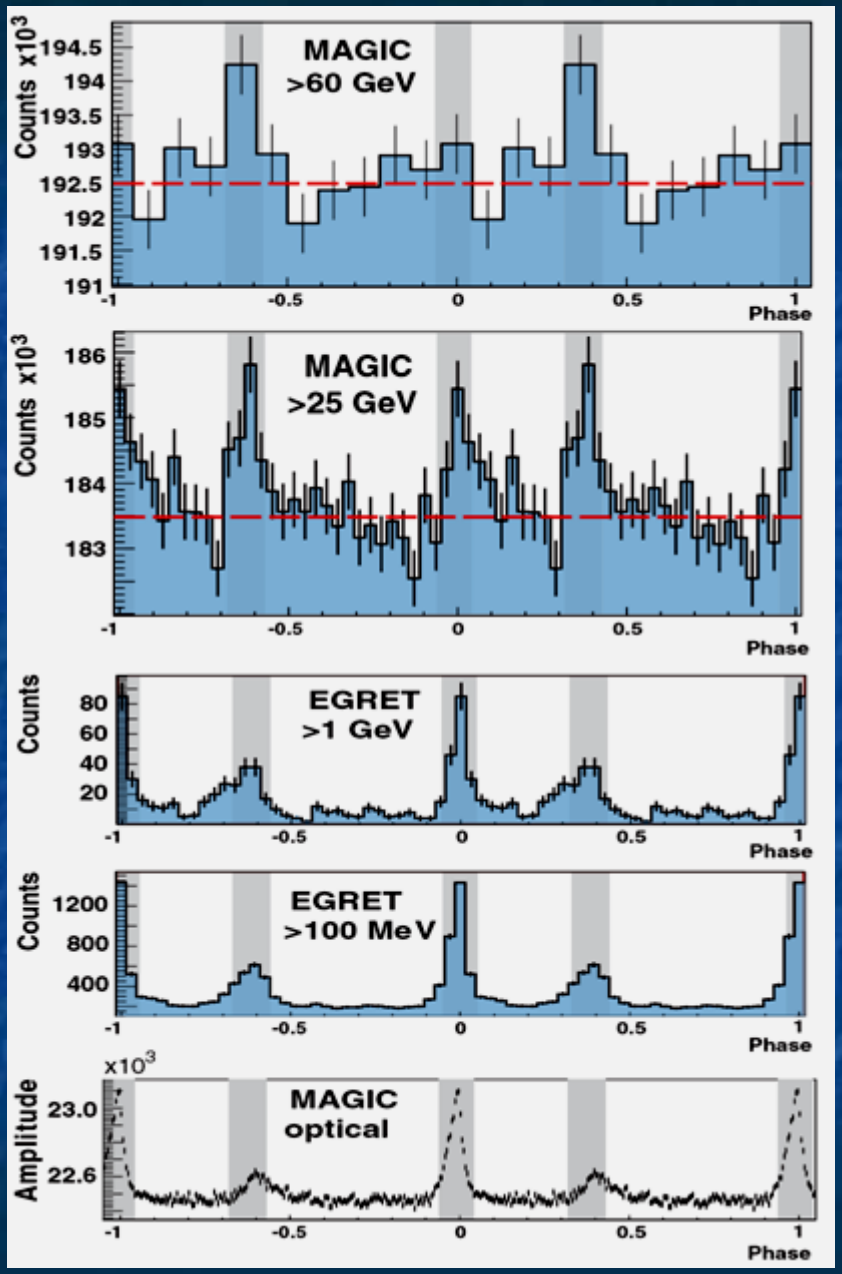
or

$$c' = c\left(1 - \frac{E^2}{M_{QG2}^2}\right)$$

$$\Delta t \approx \frac{E^n - E_0^n}{M_{QG}^n} \frac{L}{c}$$

n = 1 or 2

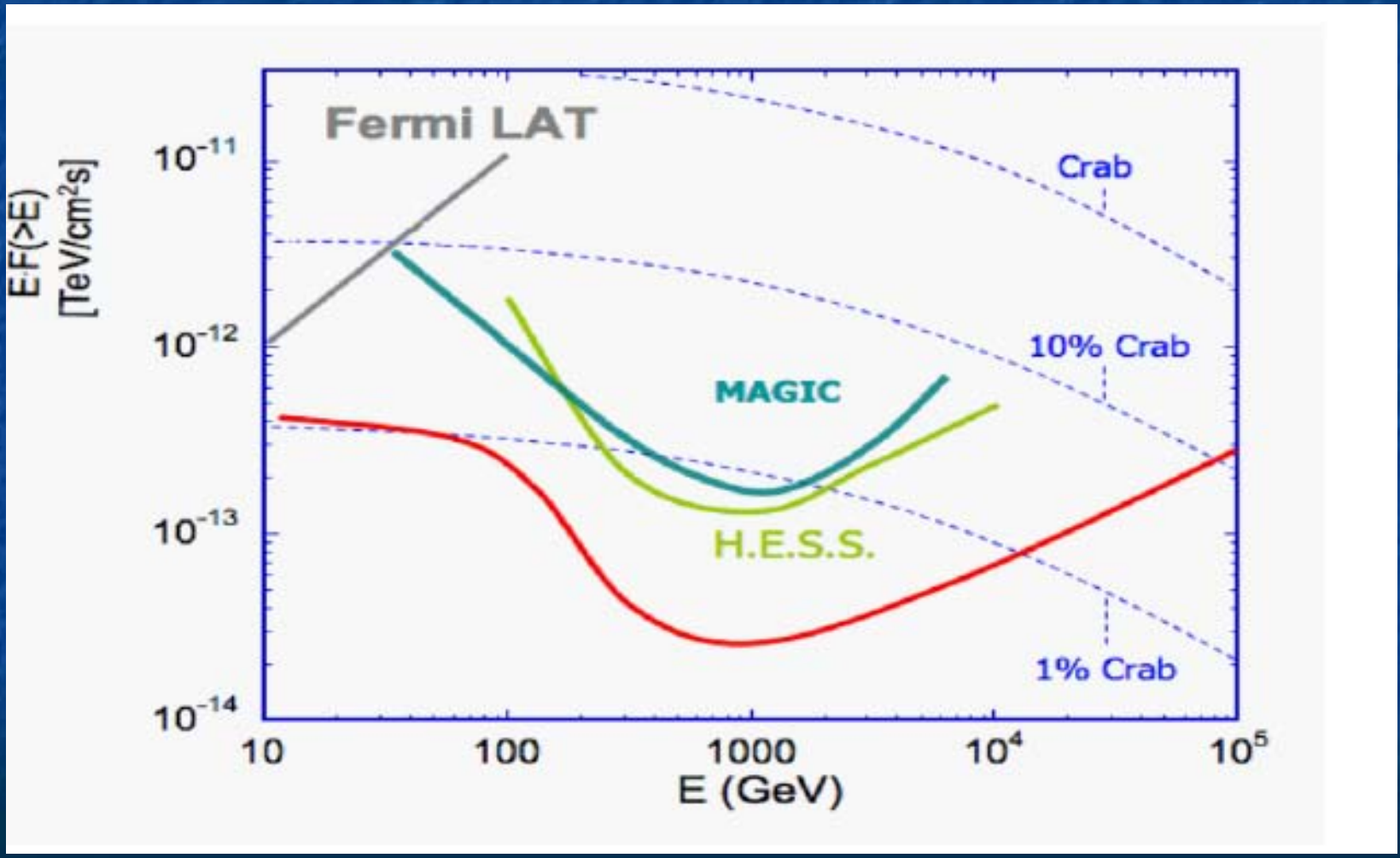
- Need fast-varying source (AGN flares...)



Science 322 (2008)

γ-rays above 25 GeV from the Crab pulsar

- Clear detection of two pulses, in phase with other E's
- Highest energy radiation ever measured from a pulsar
- Lowest energy γ-rays ever detected by an IACT


Fermi LAT
MAGIC
H.E.S.S.
Crab
10% Crab
1% Crab
E·F(>E)
[TeV/cm²s]
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10
100
1000
10⁴
10⁵
E (GeV)

Low-energy section:
few O(24) m tel. (LST)
=> push low threshold
- Parabolic reflector
- FOV: O(5) degrees
- O(0.09 deg/pix)
- f/d: O(1.2)

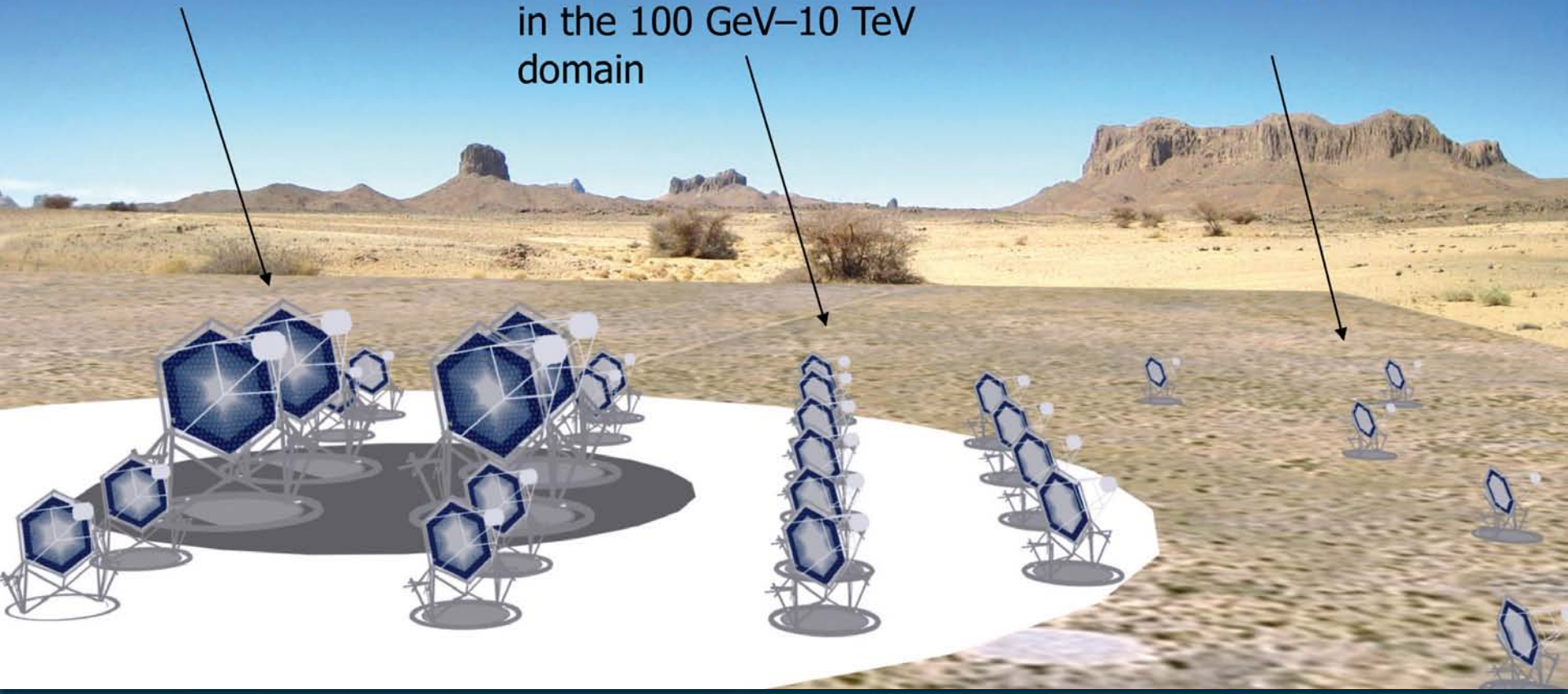
energy threshold
of some 10 GeV

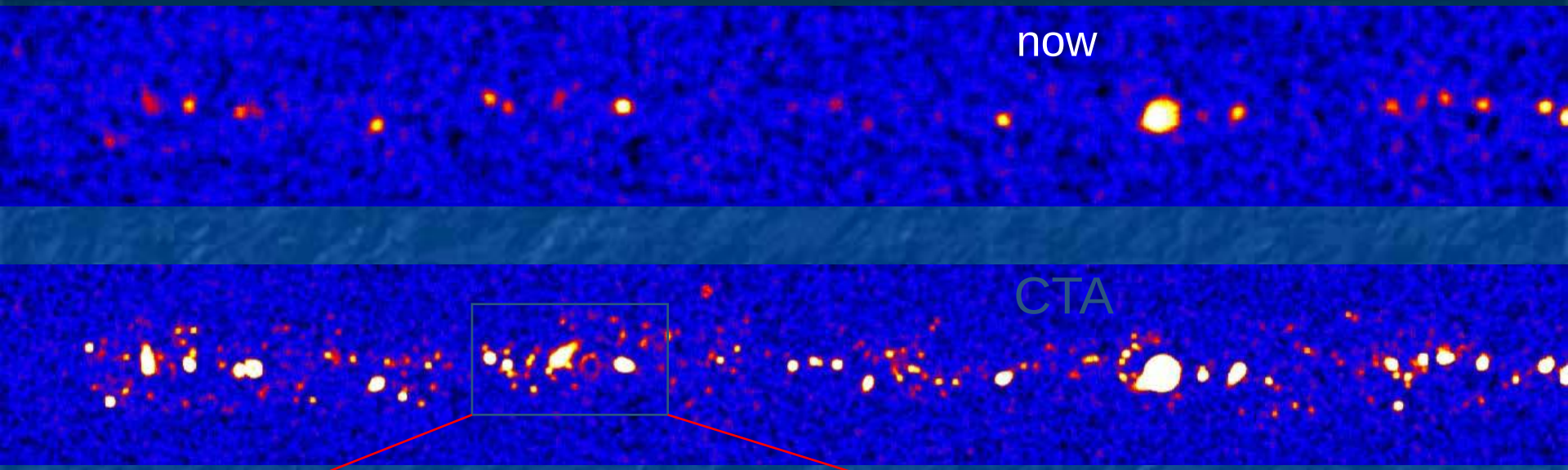
Core-energy array:
many O(12) m tel. (MST)
=> workhorse of CTA
-> push cost & reliability
- Davies-Cotton reflector
- FOV: O(8) degrees
- O(0.18 deg/pix)
- f/d: O(1.4)

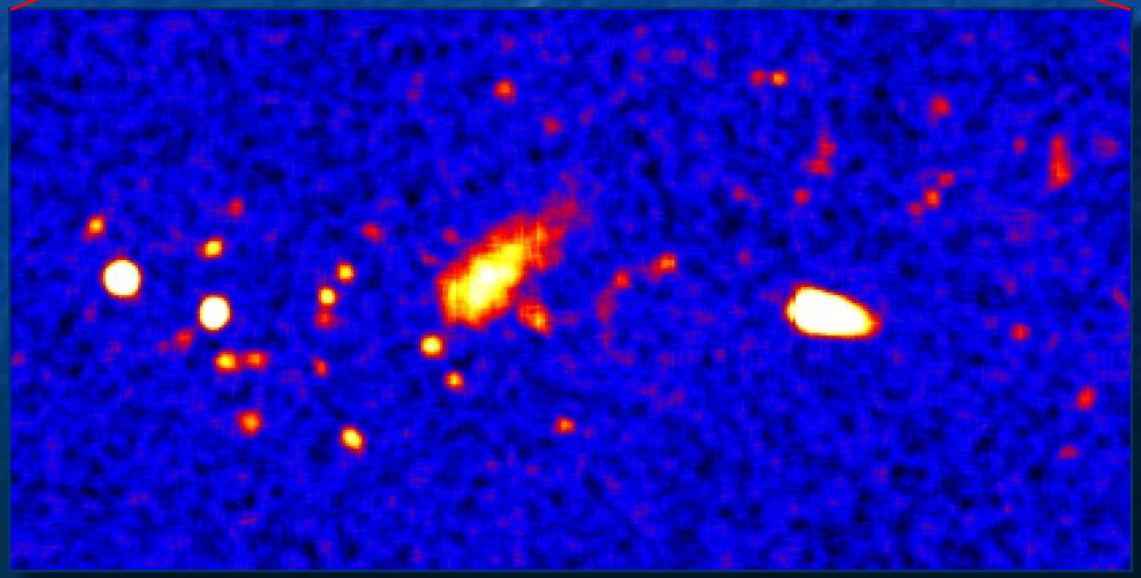
O(1 km^2) area
mCrab sensitivity
in the 100 GeV–10 TeV
domain

High-energy section:
many O(6) m tel. (SST)
=> push low-cost
- Davies-Cotton reflector
(or Schwarzschild-Couder)
- FOV: O(10) degrees
- O(0.25 deg/pix)
- f/d: O(1.2-1.5)

O(10 km^2) area at
multi-TeV energies





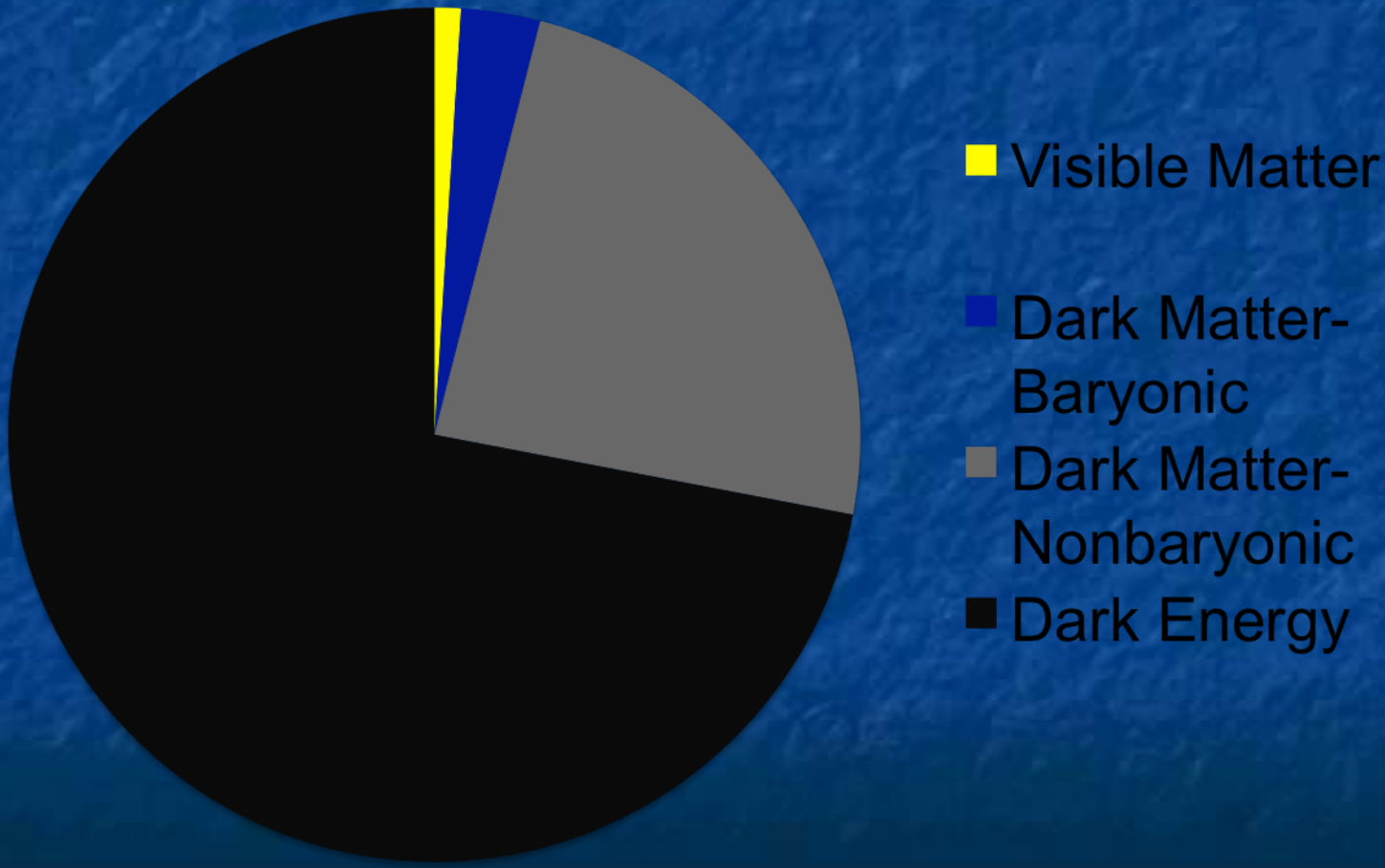


~1000
sources
expected

GAMMA-RAY ASTROPHYSICS AT IFAE: PRESENT AND FUTURE

- Now: MAGIC: 2 x 17 m telescopes
  - IFAE among founding groups (1996)
  - Substantial contributions to MAGIC-I telescope:
    - Camera, control building...
  - ... And to MAGIC-II
  - Very visible in performing analyses and operations
  - 10 PhD theses completed
- Next, CTA : 80-100 telescope array(s), $\rightarrow$ 2015
  - M. Martínez co-spokesperson
  - EU ($\rightarrow$ world-wide) collaboration
  - Leading Spanish 8-group design initiative
  - Seeking substantial Spanish funding
- Group: 5 senior, 3 postdocs, 6 PhD students

4. ON THE COSMIC FRONTIER: OBSERVATIONAL COSMOLOGY



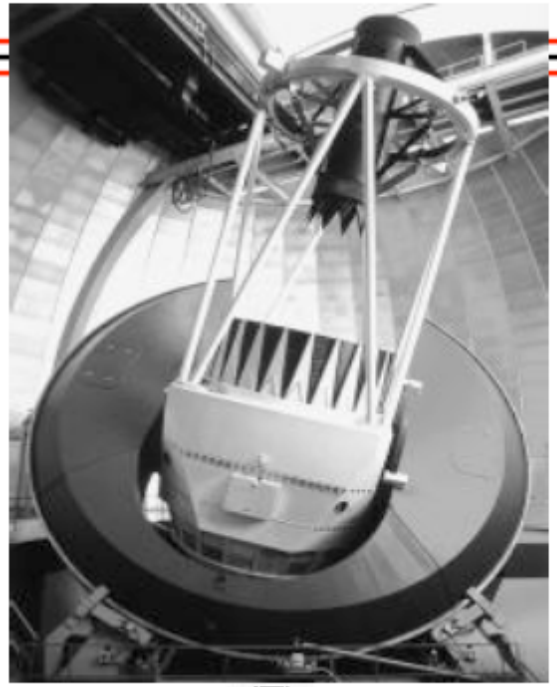
OBSERVATIONAL COSMOLOGY AT IFAE

- 2 surveys (North, South hemispheres) focused on Dark Energy measurements.
- DES (Dark Energy Survey)
  - In collaboration with UK, USA, Spanish (ICE, CIEMAT) groups
  - Building camera for telescope at Cerro Tololo, Chile
  - Will survey 300 M galaxies
- PAU (Physics of the Accelerating Universe)
  - Spanish Consolider project, w/ ICE, CIEMAT, PIC, UAM.
  - 10 M galaxy survey w/ novel observation technique
  - Designing camera for W.Herschel telescope at La Palma
- Small involvement in SDDS-II/SNe
- Group: 2 senior, 2 postdoc, 2 students
- funding from Astronomy and Astrophysics program

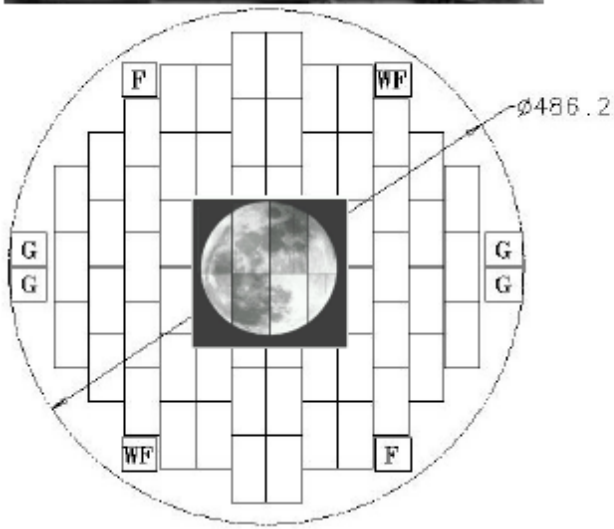
Dark Energy Survey (DES)

DARK ENERGY SURVEY

- Proposal to refurbish the 4-meter Blanco (USA) telescope in Chile.
  - New wide-field optics (3 deg^2)
  - New 500 Mpixels camera, more sensitive in the red
  - New data pipeline software
  - Got DOE CD-3b approval in Oct. '08, UK's STFC funding in Apr. '08.



- Will be operating in fall 2011
  - Two multiband surveys:
    - 5000 deg^2 *g, r, i, Z, Y* to *i~24*
    - 9 deg^2 repeat (SNe)
  - Survey gets 30% (in fall-winter) of 5 years



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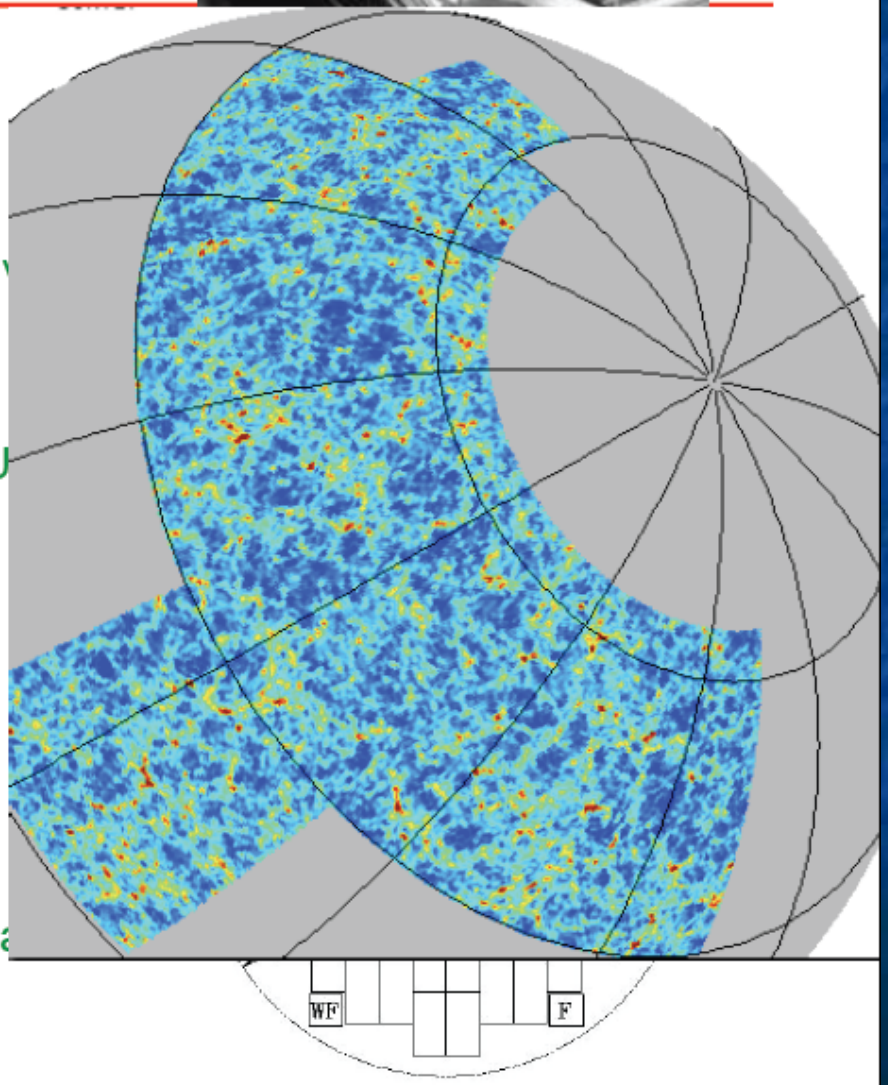


Dark Energy Survey Science Program

DARK ENERGY SURVEY

Four Probes of Dark Energy

- Galaxy Cluster Counting: N(M,z)
  - Measure redshifts and masses
  - ~15,000 clusters to z=1 with M > $2 \times 10^{14}\ M_{\odot}$
- Weak lensing
  - ~300 million galaxies with shape measurements
- Baryon Acoustic Oscillations (BAO)
  - ~300 million galaxies to z = 1
- Standard Candles
  - >1000 type-Ia SNe to z ~ 1

Probes are complementary in systematics and cosmological parameter degeneracy

DES Key Features

- Survey area: overlap with the South Pole Telescope (SPT) SZ survey to measure cluster masses
- Deep, multi-band survey: g,r,i,Z,Y filters to measure photometric redshifts, red sensitive CCDs
- Use 525 nights on the Blanco telecope: 3 sq. deg camera to cover survey area in 5 years

DES Forecasts

DARK ENERGY SURVEY

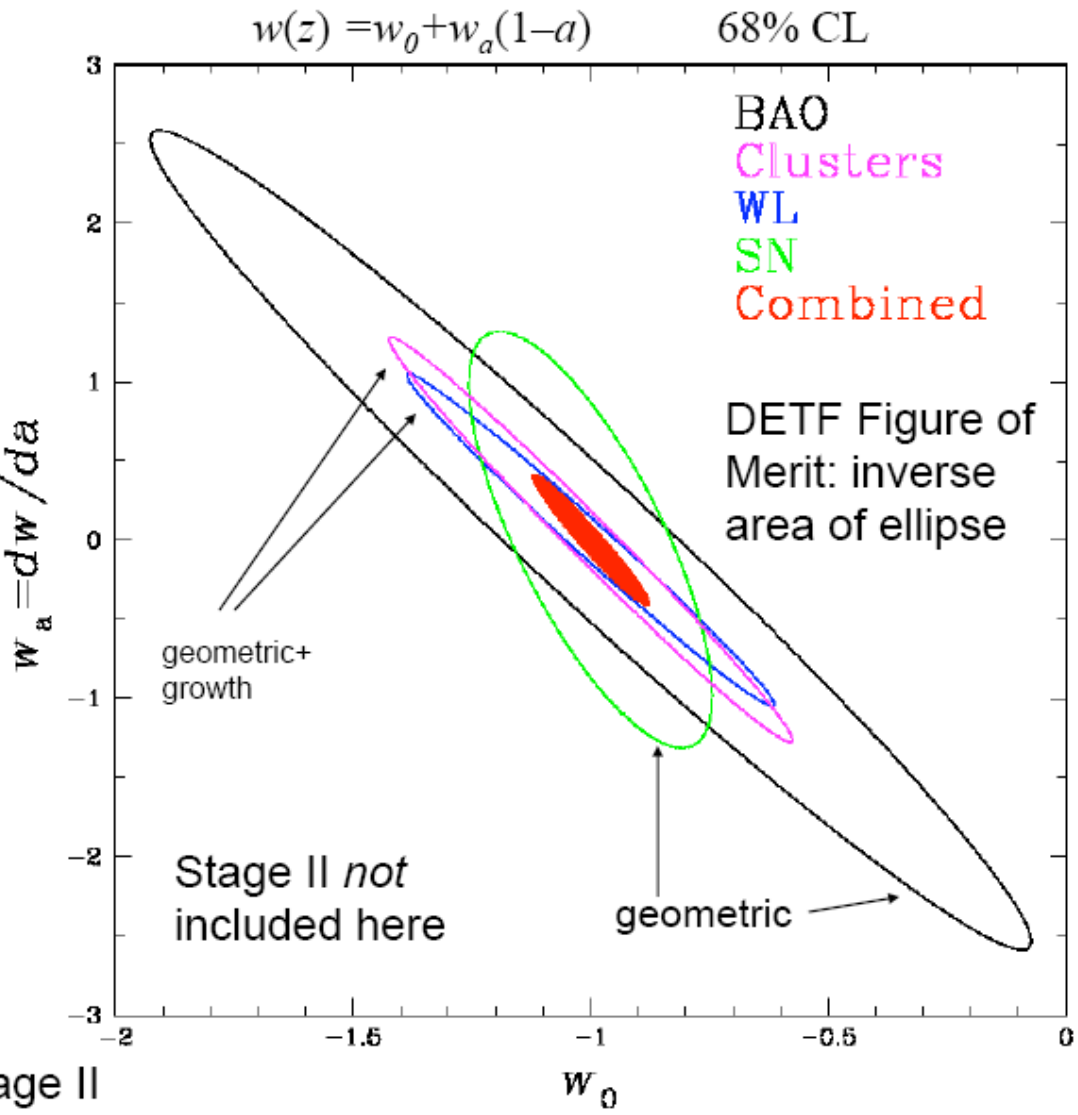
Assumptions:
Clusters:
σ_8=0.75, z_{max}=1.5,
WL mass calibration

BAO: ℓ_{max}=300
WL: ℓ_{max}=1000
(no bispectrum)

Statistical+photo-z
systematic errors only

Spatial curvature, galaxy bias marginalized,
Planck CMB prior

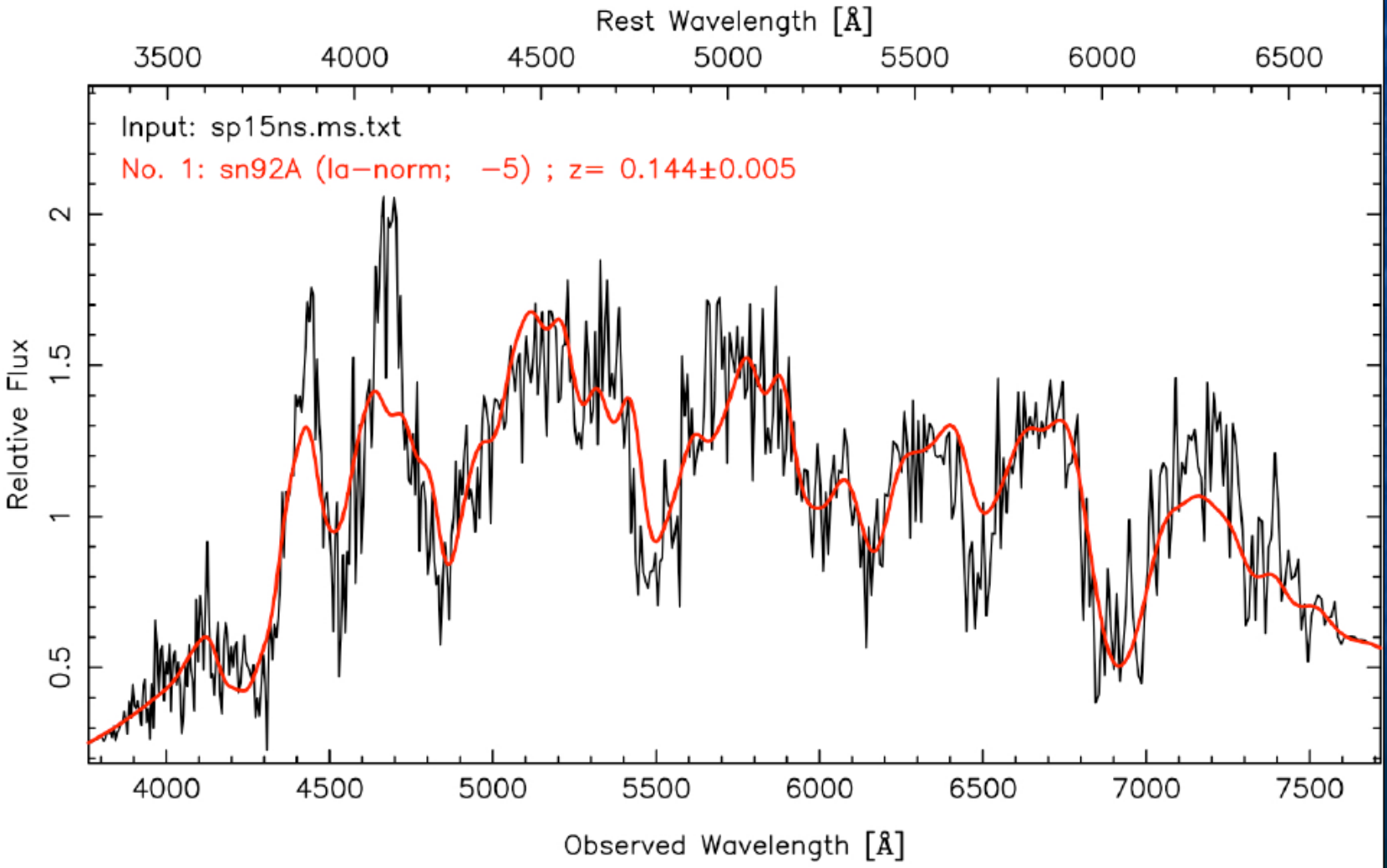
Factor 4.6 improvement over Stage II



Huterer, Ma, Miquel, Weller, et al, 2007

Follow up on SNe discovered by SDSS-II

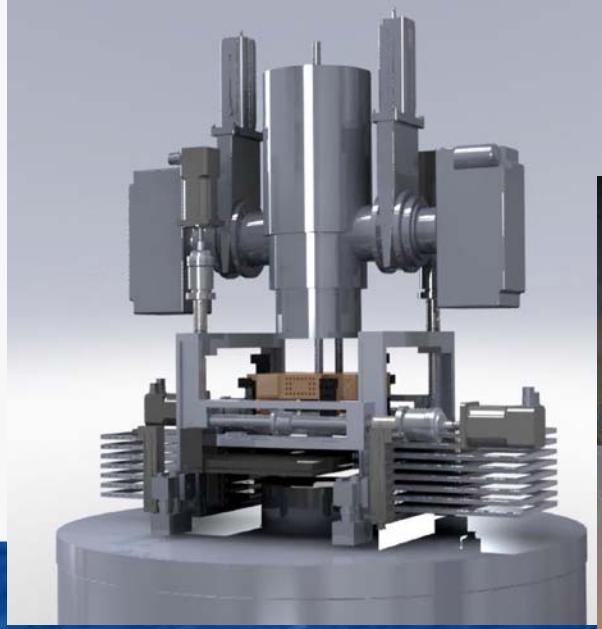
SN 2007ph @TNG (La Palma) 2007-11-04



PAU: Physics of the Accelerating Universe

- At the W. Herschel Telescope (4m), part of the Isaac Newton group (UK – H – E) at Roque de los Muchachos
- Camera focal plane will cover (now) almost 1º
  - With 18 x 8M pixels
  - and 40 narrow-band (100 Ang.) filters
  - Allowing precise measurement of SNe redshift
  - Possible upgrade with corrector optics, for full focal plane coverage
- Approved by WHT Board as Visiting Instrument
- Program: measure *red-shift space distortions* and *magnification bias* as DE probes
  - Observables sensitive to matter distributions along line-of-sight
  - And carrying information on DE via structure formation in time

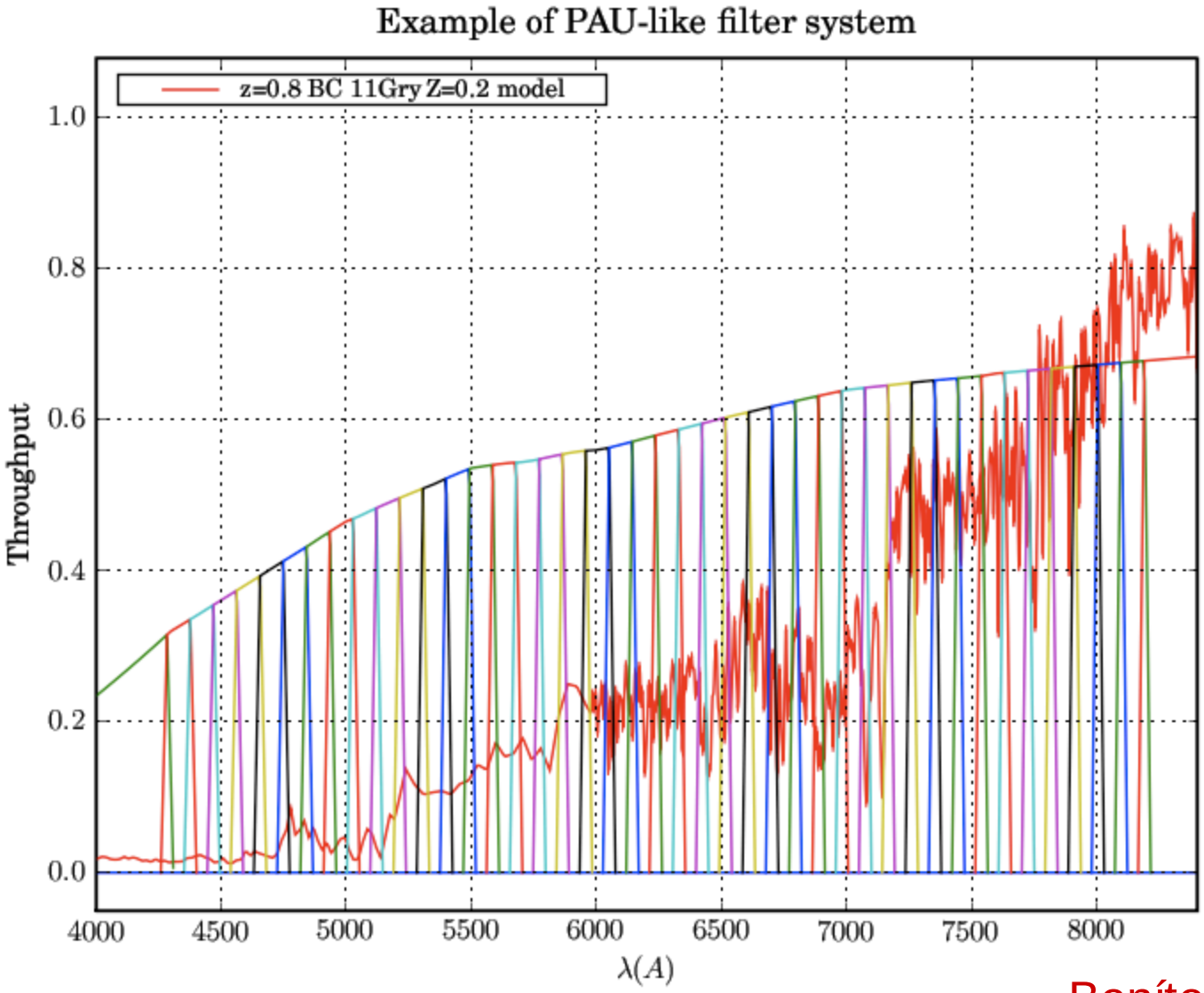
PAU WHT



PAUCam

PAU will focus on magnification and redshift space distortions:

The PAU Survey: use a filter system consisting of ~40 filters (100Å wide), plus two wide filters (similar to S



Benítez

5. APPLIED PHYSICS: PARTICLE DETECTORS FOR MEDICAL IMAGING APPLICATIONS

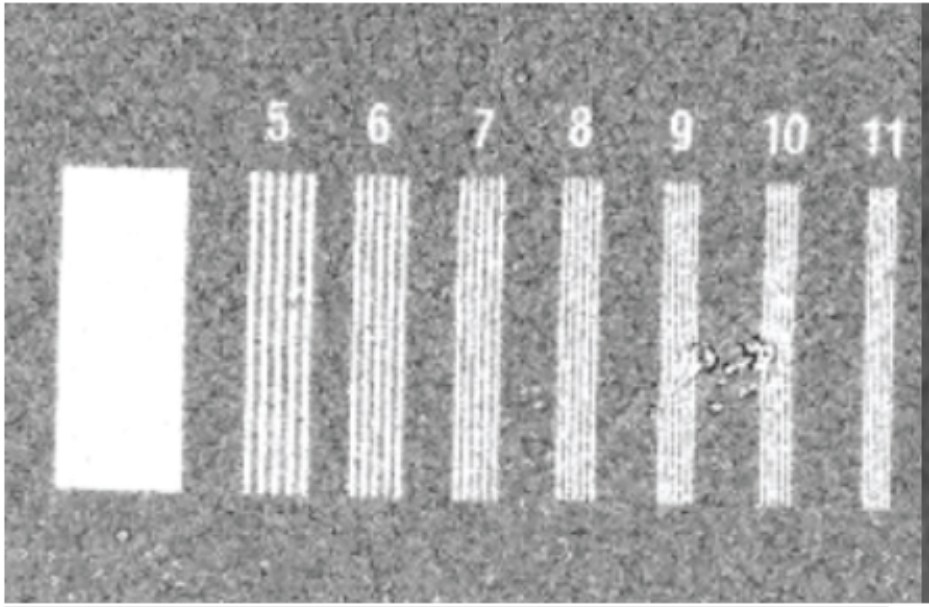
- Use of pixelized semiconductors for digital radiography
  - Based on CERN Medipix 2 chip
  - Offering higher contrast, resolution with lower dose to patient
  - First machine built (2002) with EU project (patent)
  - 2nd machine, with 3D breast biopsy device·(patent)
- All by one person (M.Chmeissani) + engineers.
- Spinoff company created: X-RAY IMATEK
- NEW: a concept for higher-resolution PET scans was awarded an advanced ERC grant.

PAST X-RAY IMAGING ACTIVITIES

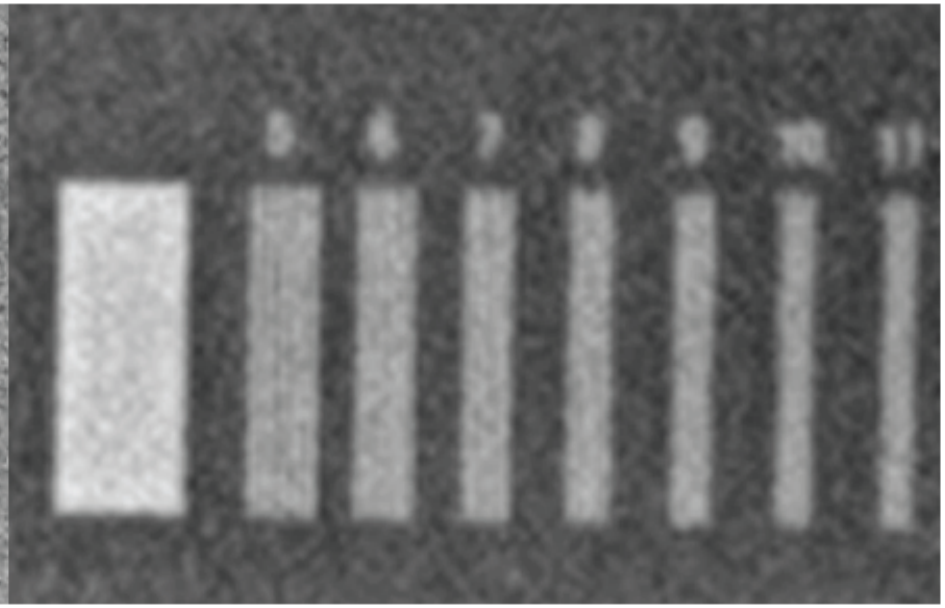
- In 1999, joined Medipix-2 collaboration that developed a pixel ASIC for medical and other applications.
- In 2000, proposed the Dear-Mama project (Detectionof Early Markers in Mammography), with 6 partners, coordinated by IFAE and funded (2001-2006) by EU FP5 program with 2.3 M€.
- Dear-Mama built and tested 2 machines, for mammography and biopsy imaging

Mammography machine using
700um Si pixel detector (22-39kV)

General Radiology using 800um
CdTe pixel detector (40-120kV)



phantom with Dear-Mama-II machine using 40kV and 2mAs dose which corresponds to **5.7µGy**. One can see easily the separation of 8 lines per mm.



Same phantom with AGFA CR 75.0 system using 40kV and 5mAs dose which corresponds to **35.7µGy.**

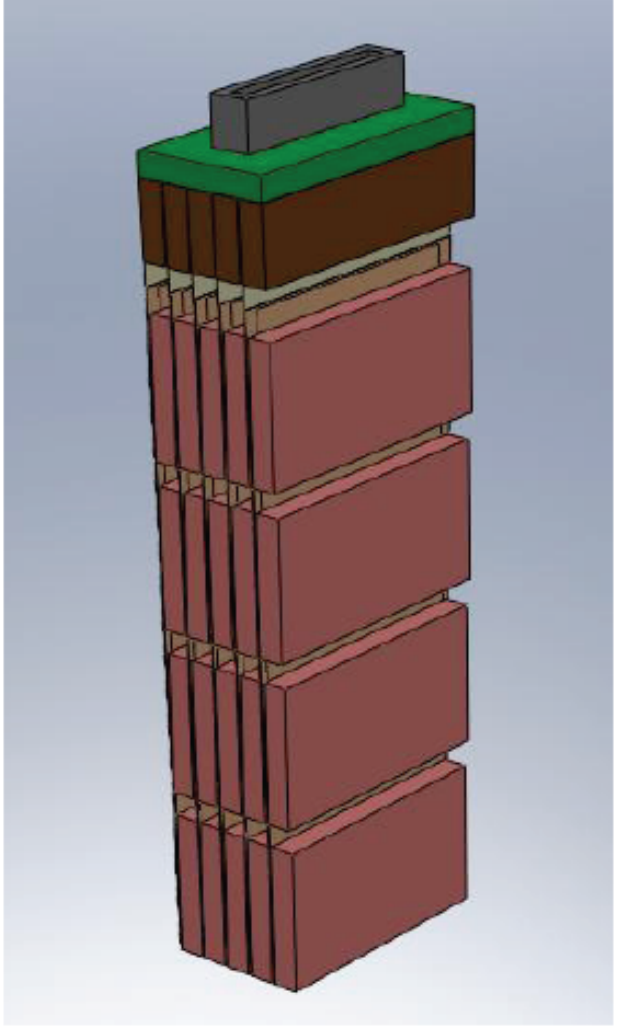
- Images obtained with Dear-Mama X-ray machine favorably compare with those from commercial devices, while using much smaller dose.
- Results led to founding of a spinoff, X-Ray Imatek S.L., supported by Dear-Mama partners and private investors.
- XRI (www.Xray-imatek.com) in 2007 patented a 3D imaging system, for efficient biopsy taking.

3D biopsy machine

Silver medal at “Salon international de l’invention”, Geneva, 2008

New project on PET using pixel CdTe detector has been initiated in collaboration with CNM and Ciemat.

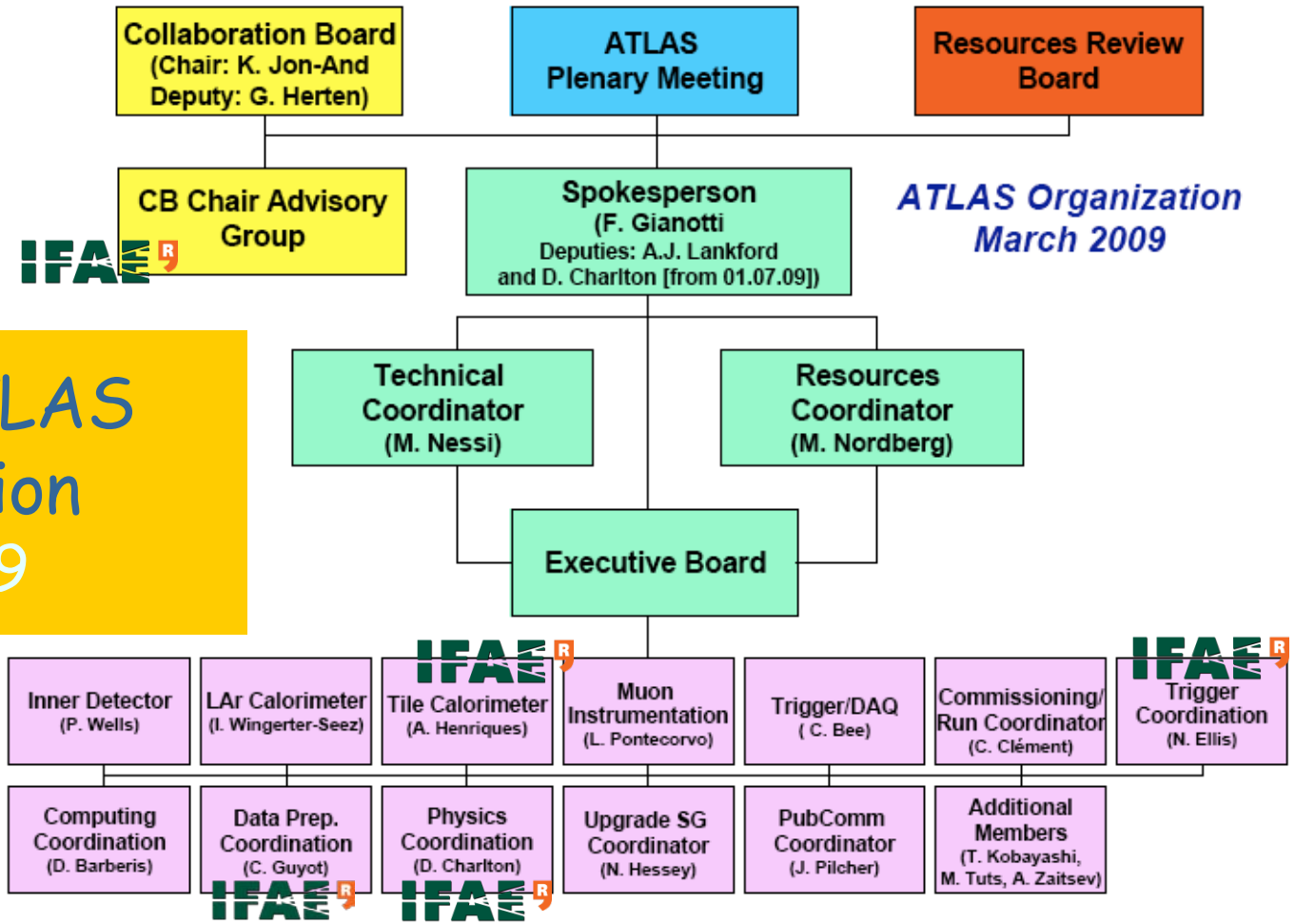
It is based on module detector made of the stack of 5 layers detectors. Such design will provide sufficient depth of CdTe to capture the 511keV photons with high efficiency (around 85%)



- Pixel-PET concept should allow higher space resolution, much higher efficiency in PET scans.
  - Based on efficient detection of 511 keV photons
  - With excellent energy, angular resolution.

SPARES

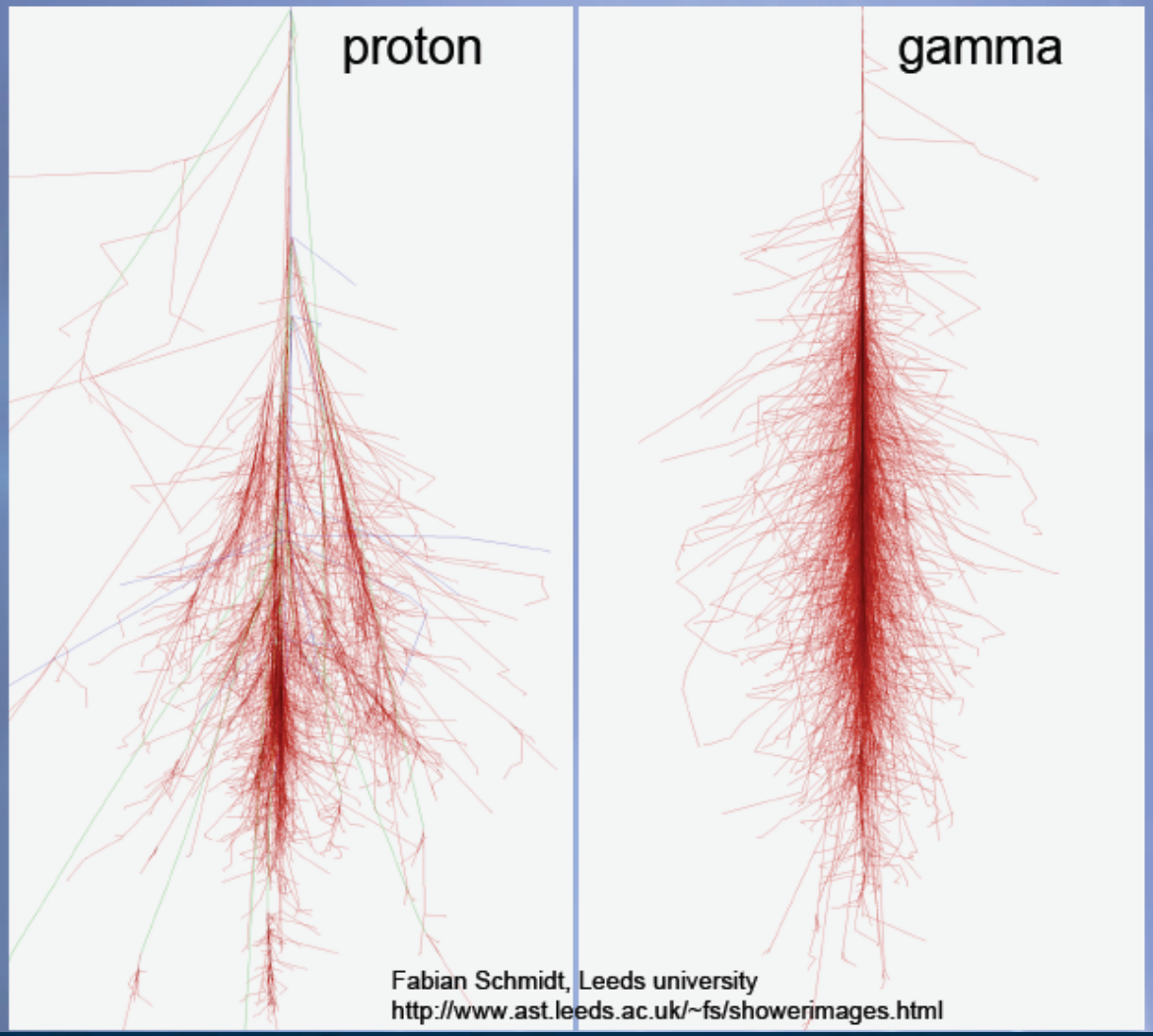
IFAE @ ATLAS Organization as of 2009



Co-convener Top Physics
Coordinator TileCal Calibration
Coordinator Trigger Operations
Co-convener TDAQ Online Integration
Co-coordinator DQ Group

In the past:
Speakers Committee Chair
Collaboration Board Chair
Tilecal IB chair
Jet/ETmiss convener

Suppression of showers initiated by charged cosmic rays



Based on the different lateral and longitudinal development of gamma- and hadron - initiated showers

Signal / Background
~ 10^{-3} -10^{-4}

at trigger level

DES Collaboration

DARK ENERGY

- **Fermilab:** J. Annis, E. Buckley-Geer, H. T. Diehl, S. Dodelson, J. Estrada, B. Flaugher, J. Frieman, S. Kent, H. Lin, P. Limon, K. W. Merritt, J. Peoples, V. Scarpine, A. Stebbins, C. Stoughton, D. Tucker, W. Wester
- **University of Illinois at Urbana-Champaign** W. Barkhouse, C. Beldica, R. Brunner, I. Karliner, J. Mohr, C Ngeow, R. Plante, T. Qian, P. Ricker, M. Selen, J. Thaler
- **University of Chicago:** J. Carlstrom, S. Dodelson, J. Frieman, M. Gladders, W. Hu, E. Sheldon, R. Wechsler Graduate students: C. Cunha, M. Lima, H. Oyaizu
- **Lawrence Berkeley National Laboratory:** N. Roe, C. Bebek, M. Levi, S. Perlmutter
- **University of Michigan:** R. Bernstein, B. Bigelow, M. Campbell, D. Gerdes, A. Evrard, W. Lorenzon, T. McKay, M. Schubnell, G. Tarle, M. Tecchio
- **NOAO/CTIO:** Tim Abbott, Chris Miller, Chris Smith, Nick Suntzeff, Alistair Walker
- **Spanish Consortium:** Institut de Ciències de l'Espai (ICE/IEEC-CSIC): Francisco Castander, Pablo Fosalba, Enrique Gaztañaga; Institut de Física d'Altes Energies (IFAE): Enrique Fernández, Ramon Miquel; CIEMAT, Madrid: Eusebio Sánchez, Juan García-Bellido (UAM)
- **United Kingdom Consortium:** University College London: O. Lahav, D. Brooks, P. Doel, M. Barlow, S. Bridle, S. Viti, J. Weller: University of Cambridge: G. Efstathiou, R. McMahon, W. Sutherland; University of Edinburgh: J. Peacock; University of Portsmouth Institute of Cosmology and Gravitation: R. Crittenden, R. Nichol, W. Percival; University of Sussex: A. Liddle, K. Romer
- **University of Pennsylvania:** M, Bernardi, G. Bernstein, M. Devlin, B. Jain, M. Jarvis, L. Gladney, M. Sako, R. Seth
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