Physics Program

of the experiments at

Large Hadron Collider

Prof. dr hab. Elżbieta Richter-Wąs

Outline of this course

- 10.10 - Introduction: accelerator, detectors, basic info
- 17.10 – soft QCD
- 24.10 – hard QCD
- 7.11 - W, Z bosons: inclus. cross-sections, W/Z+jets
- 14.11 – W, Z bosons:precise measurements
- 21.11 – Top: xsection, mass
- 28.11 – Dibosons and anomalous couplings
- 5.12, 12.12 **- Higgs**
- 19.12 – **SUSY**
- 9.1 – other searches for New Physics
- 16.1 - B-physics programme
- 23.1 – heavy ion programme

LHC at CERN laboratory

CERN: the world's largest particle physics laboratory

- international organisation created in 1953/1954, initial membership: 12 countries
- Poland is a member starting from year 1991
- About 10 000 active physicists, computing scientists, engineers

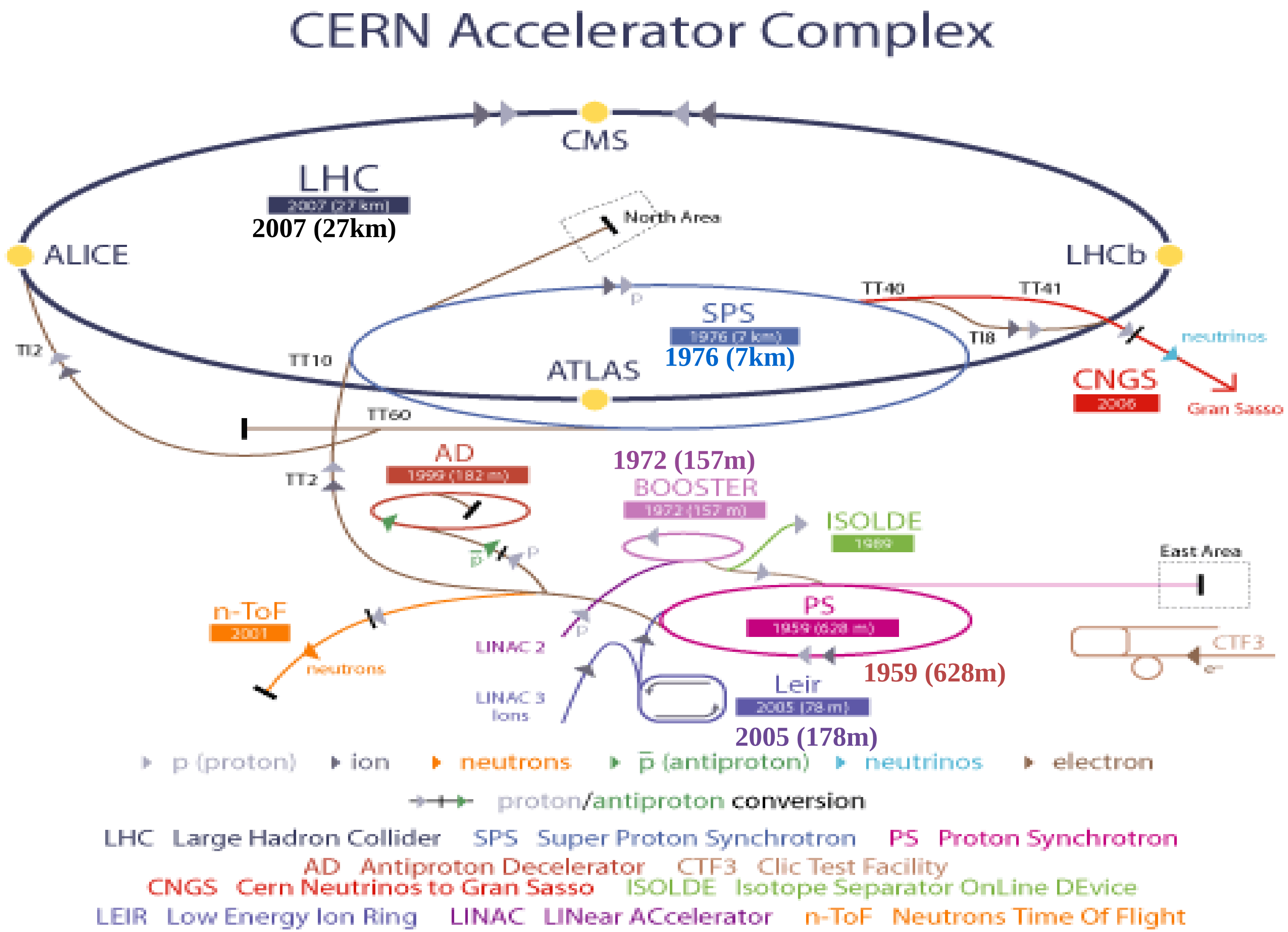
situated between
Jura mountains and Geneva
(France/Swiss)

http://public.web.cern.ch

Accelerator complex

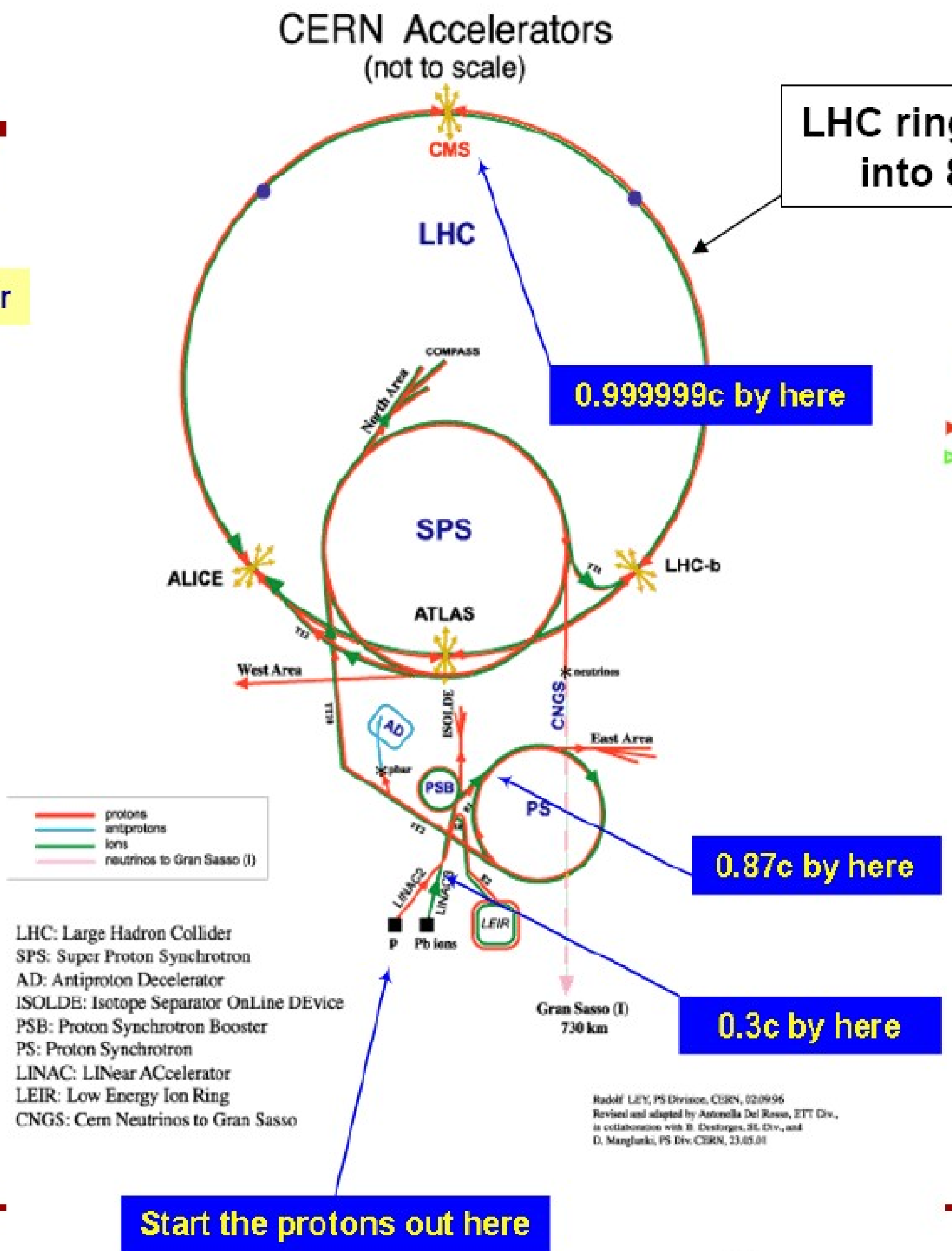
- Accelerator complex is a **succession of particle accelerators** that can reach increasingly higher energies. Each boosts the speed of beam of particles before injecting it into the next one in the sequence
- **Protons** are obtained by removing electrons from hydrogen atoms. They are injected from the linear accelerator **(LINAC2)** into the **PS Booster**, then the **Proton Synchrotron (PS)**, followed by the **Super Proton Synchrotron (SPS)**, before finally reaching the Large **Hadron Collider (LHC)**. Protons will circulate in the LHC for 20 minutes before reaching the maximum speed and energy.
- **Lead ions** for the LHC start from a source of vaporised lead and enter **LINAC3** before being collected and accelerated in the **Low Energy Ion Ring (LEIR)**. Then they follow the same route to maximum acceleration as the protons.

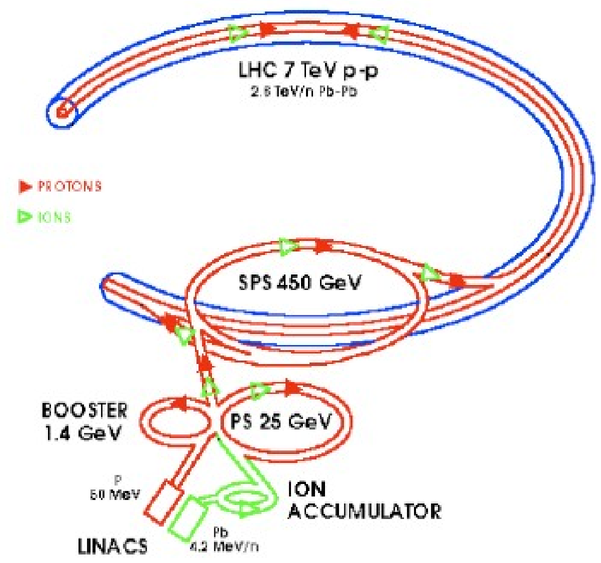
Accelerator complex



The full LHC accelerator complex

Linac → Booster → PS → SPS → LHC





> 50 years of CERN history still alive and operational

Experiments

- At the lowest energies, the Proton-Synchrotron Booster supplies beam to **ISOLDE**, a unique source of **radioactive isotopes** for experiments with applications that range from astrophysics to industry and medicine.
- The **Proton Synchrotron (PS)** delivers higher energy protons to two contrasting experiments. **DIRAC** is testing ideas about the strong fundamental force, while **CLOUD** is finding out how natural high-energy particles might influence the formation of clouds. The PS also provides the protons that create the antiprotons for the **Antiproton Decelerator** (AD), where physicists are learning more about antimatter in the **ALPHA, ASACUSA** and **ATRAP** experiments. The **ACE** experiment also uses antiprotons, in this case to assess their suitability for cancer therapy.

Experiments

- The next largest accelerator is the **Super Proton Synchrotron (SPS)**, where **COMPASS** focuses on investigating hadrons - particles made of quarks, including the nucleons (protons and neutrons) of ordinary matter. **NA61/SHINE** is studying properties of the production of hadrons. **NA62** uses protons from the SPS to study rare kaon decays.
- The **Large Hadron Collider (LHC)**, CERN's most powerful accelerator, hosts **six experiments** designed to find out how the particles of matter behave at a new high energy frontier.
- There is also one experiment that uses none of the beams from CERN. **CAST** looks at the Sun for hypothesised particles called 'axions'.

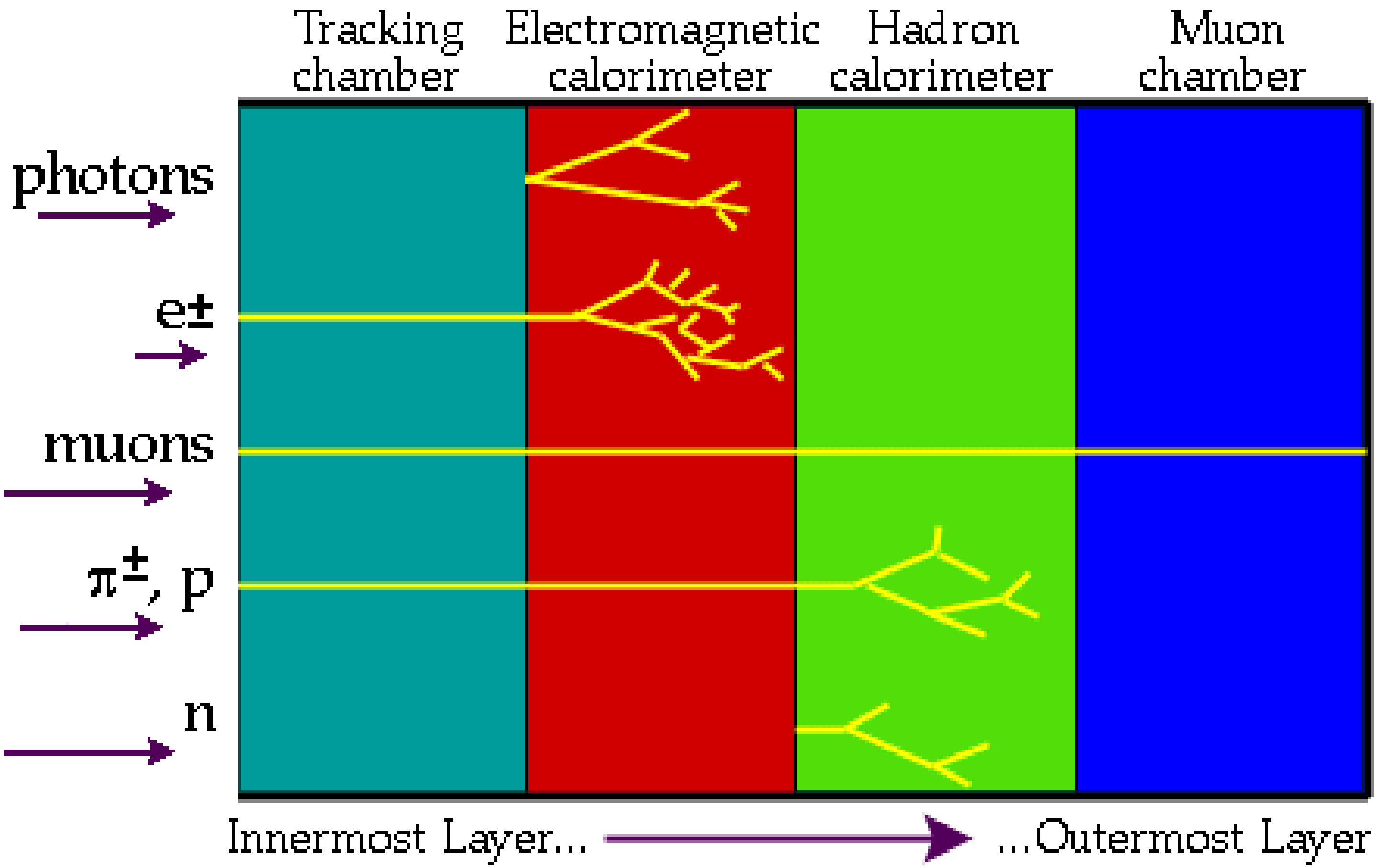
LHC experiments

- **Six experiments** at the LHC, all run by international collaborations.
  - The two large experiments, **ATLAS** and **CMS**, are based on general-purpose detectors, designed to investigate the largest range of physics possible. Having two independently designed detectors is vital for cross-confirmation of any new discoveries made.
  - Two medium-size experiments, **ALICE** and **LHCb**, have specialised detectors for analysing the LHC collisions in relation to specific phenomena.
  - Two further experiments, **TOTEM** and **LHCf**, are much smaller in size. They are designed to focus on "forward particles" (protons or heavy ions). The detectors used by the **TOTEM** experiment are positioned near the **CMS** detector, whereas those used by **LHCf** are near the **ATLAS** detector.

ATLAS Collaboration

- Over 3000 collaborators from 174 Institutes and 38 countries.

General purpose detectors



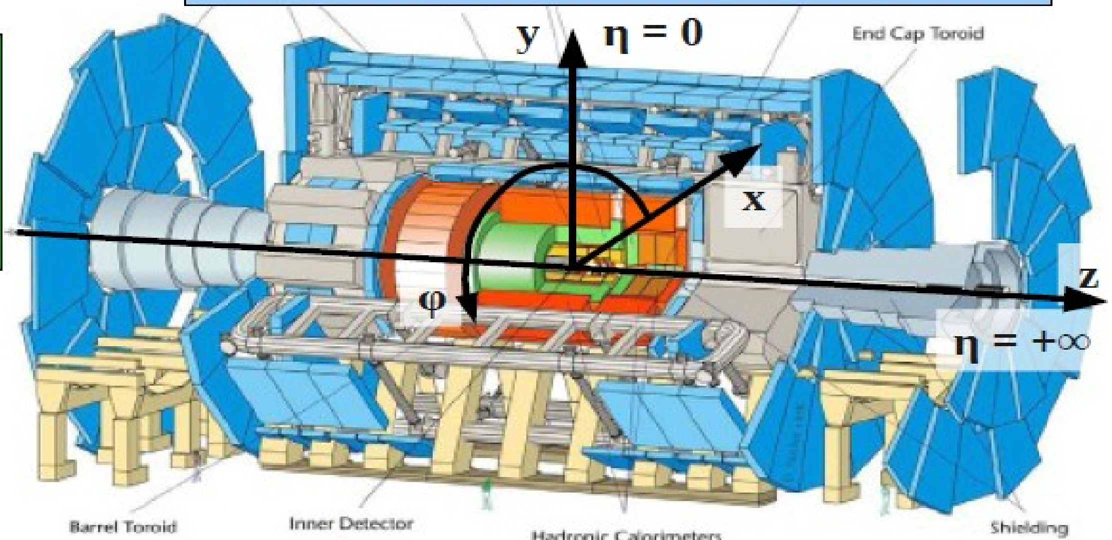
ATLAS Detector

Inner detector (2 T)
$|\eta| < 2.5$
Si Pixel et SCT, TRT
tracks, vertex
$\sigma/p_T \sim 0.05\%\ p_T\ (\text{GeV}) \oplus 1\%$

Electromagnetic calorimeter
$|\eta| < 3.2$
Pb + LAr
electrons, photons, trigger
$\sigma/E \sim 10\%/\sqrt{E}\ (\text{GeV}) \oplus 0.7\%$

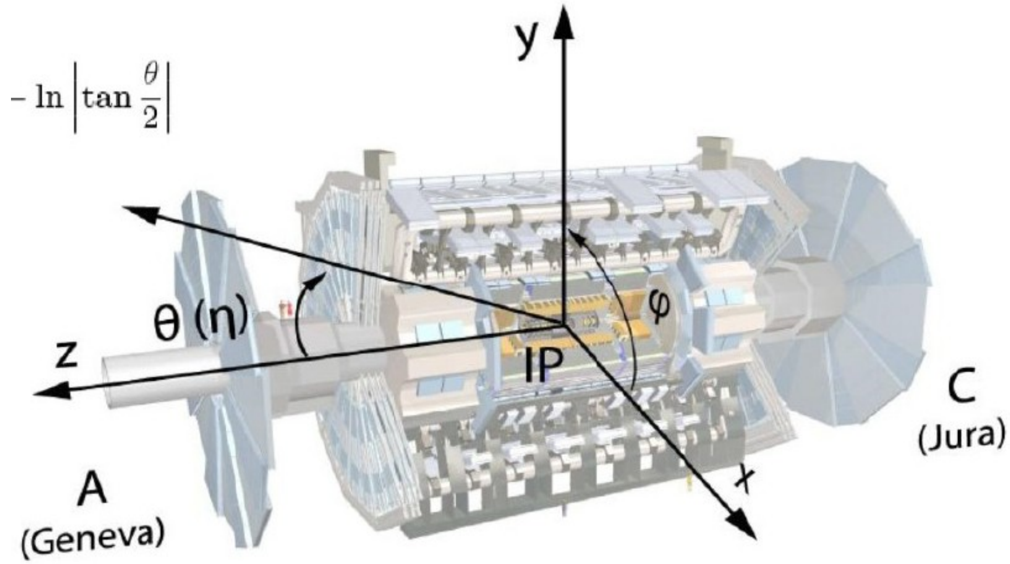
Hadronic calorimeter
$|\eta| < 4.9$
Fe/Tile (central)
Cu/W + LAr (forward)
jets, E_T^{miss}, trigger
$\sigma/E \sim 50\%/\sqrt{E}\ (\text{GeV}) \oplus 3\%$

Muon spectrometer (0.5 T)
$|\eta| < 2.7$
gas chamber in toroidal magnetic field
tracks, trigger
$\sigma/p_T < 10\%$ up to 1 TeV



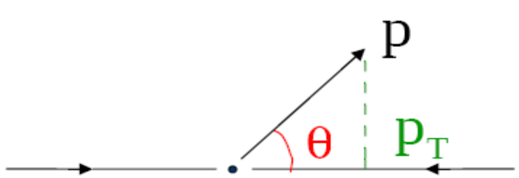
$$\eta = -\ln(\tan(\frac{\theta}{2}))$$

ATLAS Detector



THE ATLAS DETECTOR IS REALLY BIG!

- Length : ∼ 46 m
- Radius : ∼ 12 m
- Weight : ∼ 7000 tons
- ∼ 10^8 electronic channels
- 3000 km of cables



Transverse momentum

(in the plane perpendicular to the beam)

$$p_T = p \sin\theta$$

Rapidity: $\eta = -\log\left(\mathrm{tg}\,\frac{\theta}{2}\right)$

$\theta = 90^\circ \rightarrow \eta = 0$

$\theta = 10^\circ \rightarrow \eta \cong 2.4$

$\theta = 170^\circ \rightarrow \eta \cong -2.4$

Energy and momentum resolution

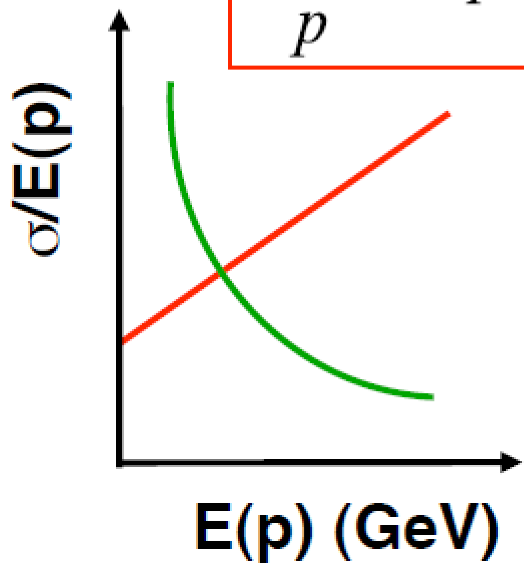
Calorimetry:

$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

- a the stochastic term accounts for Poisson-like fluctuations
  - naturally small for homogeneous calorimeters
  - takes into account sampling fluctuations for sampling calorimeters
- b the noise term (hits at low energy)
  - mainly the energy equivalent of the electronics noise
  - at LHC in particular: includes fluctuation from non primary interaction (pile-up noise)
- c the constant term (hits at high energy)
  - Essentially detector non homogeneities like intrinsic geometry, calibration but also energy leakage

Tracking

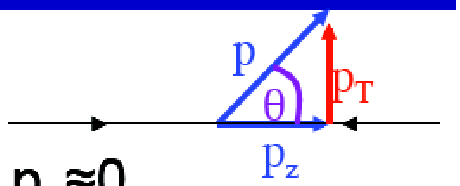
$$\frac{\sigma(p)}{p} = ap \oplus b$$



$$\frac{\sigma(E)}{E} \approx \frac{a}{\sqrt{E}}$$

Calorimetry

Kinematical constraints



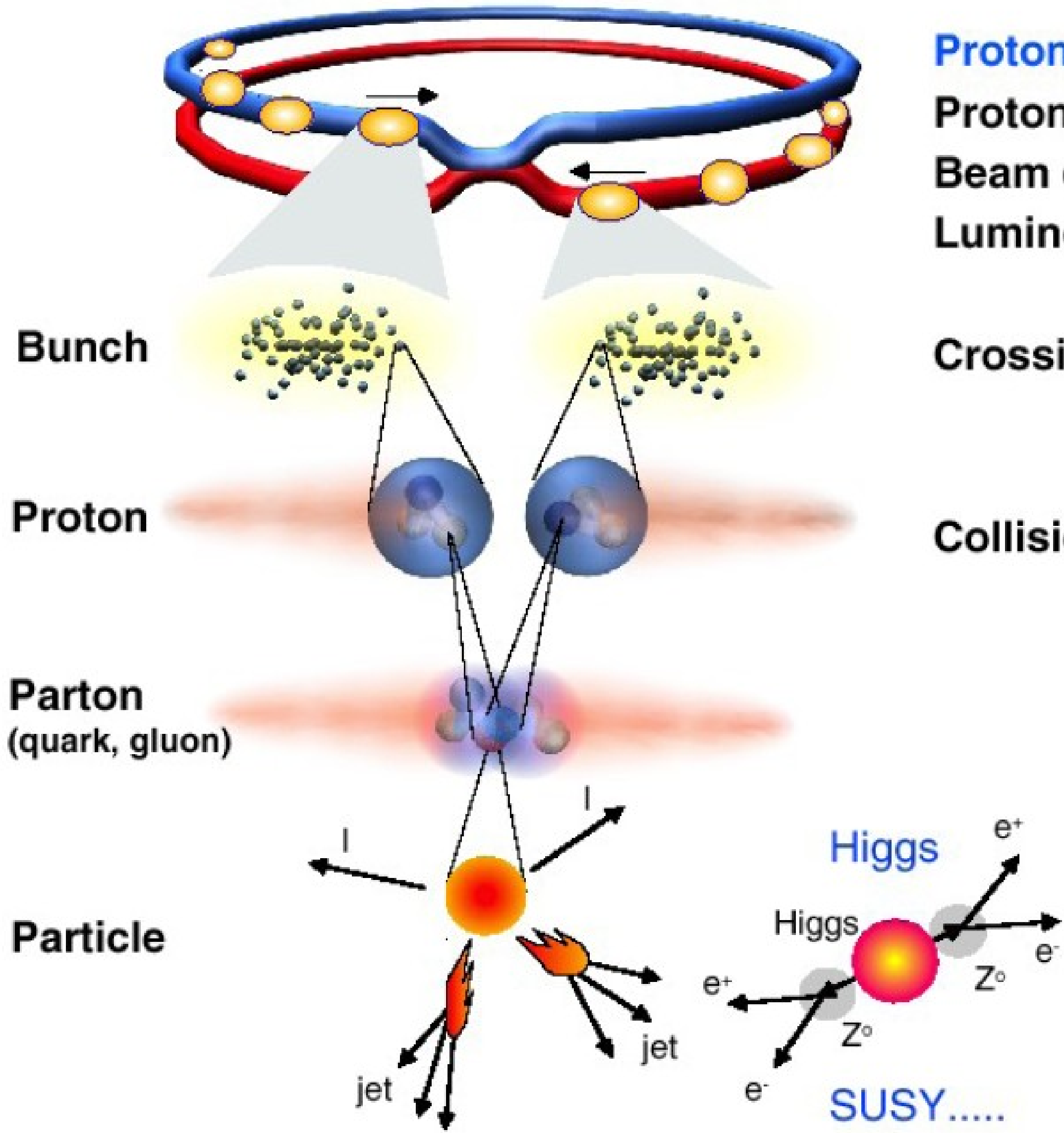
- **Transverse momentum, p_T**
  - Particles that escape detection ($\theta<3^o$) have $p_T \approx 0$
  - Visible transverse momentum conserved $\sum_i p_T^i \approx 0$
    - **Very useful variable!**
- **Longitudinal momentum and energy, p_z and E**
  - Particles that escape detection have large p_z
  - Visible p_z is not conserved
    - **Not a useful variable**
- **Polar angle θ**
  - Polar angle θ is not Lorentz invariant
  - Rapidity: y
  - Pseudorapidity: η

$$y = \frac{1}{2} \ln \frac{E + p_z}{E - p_z}$$

For M=0

$$y = \eta = -\ln(\tan \frac{\theta}{2})$$

Collisions at LHC



Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV ($7x10^{12}$ eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz
Collisions ≈	10^{7} - 10^{9} Hz

Selection of 1 in 10,000,000,000,000

Luminosity

- Single most important quantity
  - Drives our ability to detect new processes

LHC: f=c/26.7 km

$$L = \frac{f_{rev}\, n_{bunch}\, N_p^2}{4\pi\sigma_x\sigma_y}$$

revolving frequency: f_{rev}=11245.5/s
#bunches: n_{bunch}=2808
#protons / bunch: N_p= 1.15 x 10^{11}
Area of beams: $4\pi\sigma_x\sigma_y$~40 μm

  - Rate of physics processes per unit time directly related:

$$N_{obs} = \int L dt \cdot \varepsilon \cdot \sigma$$

Efficiency: optimized by experimentalist

Cross section σ: Given by Nature (calc. by theorists)

17

Ability to observe something depends on N_{obs}

Units of cross-section

- Originally introduced to express areas of nuclei and nuclear reactions.

Conversion to SI units

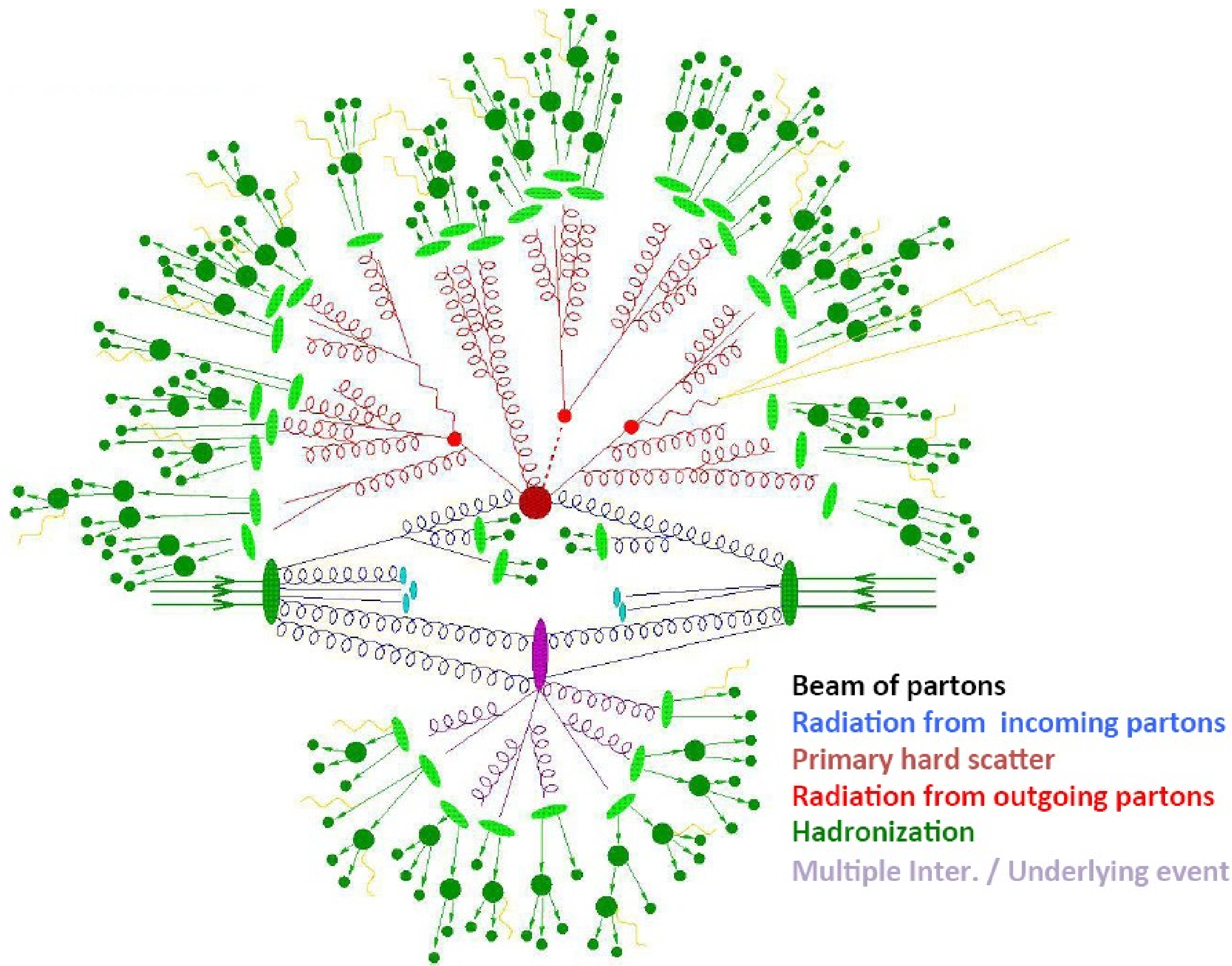
Unit	Symbol	m^2	cm^2
megabarn	Mb	10^{-22}	10^{-18}
kilobarn	kb	10^{-25}	10^{-21}
barn	b	10^{-28}	10^{-24}
millibarn	mb	10^{-31}	10^{-27}
microbarn	µb	10^{-34}	10^{-30}
nanobarn	nb	10^{-37}	10^{-33}
picobarn	pb	10^{-40}	10^{-36}
femtobarn	fb	10^{-43}	10^{-39}
attobarn	ab	10^{-46}	10^{-42}
zeptobarn	zb	10^{-49}	10^{-45}
yoctobarn	yb [6][7]	10^{-52}	10^{-48}

- → "inverse femtobarn (fb^{-1})": is a measurement of particle collision events per femtobarn of target cross-section (area) and is conventional unit for integrated luminosity
- → "integrated luminosity: an indication of particle collider productivity

eg. Tevatron: 1fb^{-1} in 4 years

ATLAS: 5 fb^{-1} in 2011

Typical pp collision



Calculating a cross-section

- Cross-section is convolution of pdf's and matrix element

Physical cross section

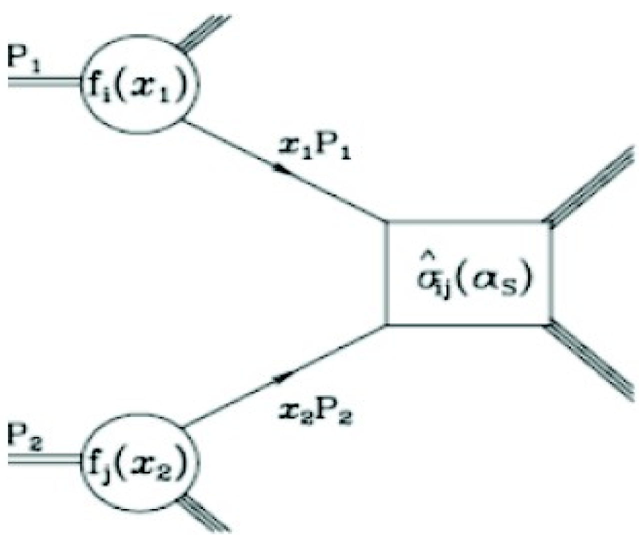
Parton distribution function

Renormalization scale μ_R

$$\sigma(P_1, P_2) = \sum_{i,j} \int dx_1 dx_2 \; f_i(x_1, \mu_F) f_j(x_2, \mu_F) \; \hat{\sigma}_{ij}(p_1, p_2, \alpha_S(\mu_R), Q^2, \mu_R, \mu_F).$$

Factorization scale μ_F

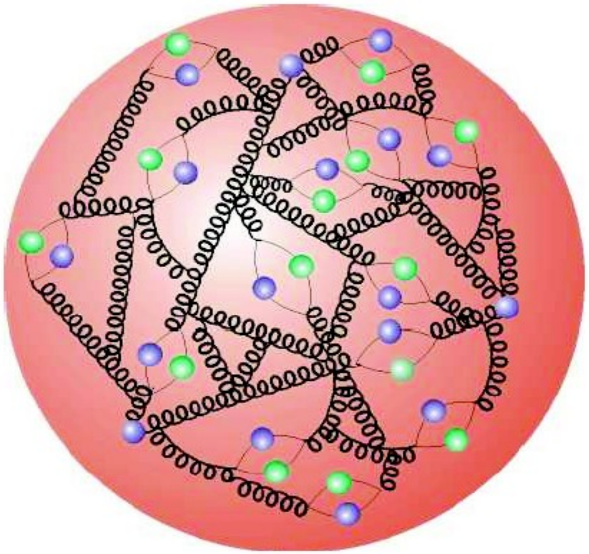
Short distance cross section, calculated as a perturbation series in α_S



- Calculations are done in perturbative QCD
  - Possible thanks to factorisation of hard ME and pdf's
    - Can be treated independently
  - Strong couplings **(α_s)** is large
    - Higher orders needed
    - Calculations complicated

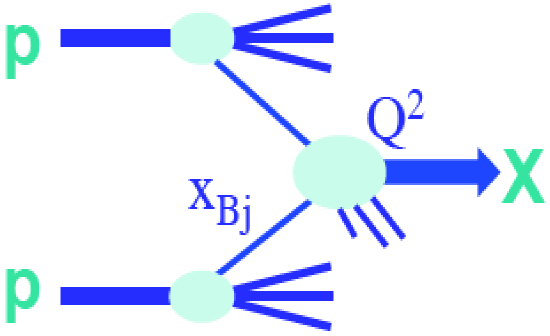
The proton composition

- It's complicated:
  - Valence quarks, gluons, sea quarks
- Exact mixture depends on:
  - Q^2: ~ $(M^2+p_T^2)$
  - Bjorked-x: fraction of momentum caried by a parton



$$\hat{s} = x_p \cdot x_{\bar{p}} \cdot s$$

$$M_X = \sqrt{\hat{s}}$$



Parton kinematics

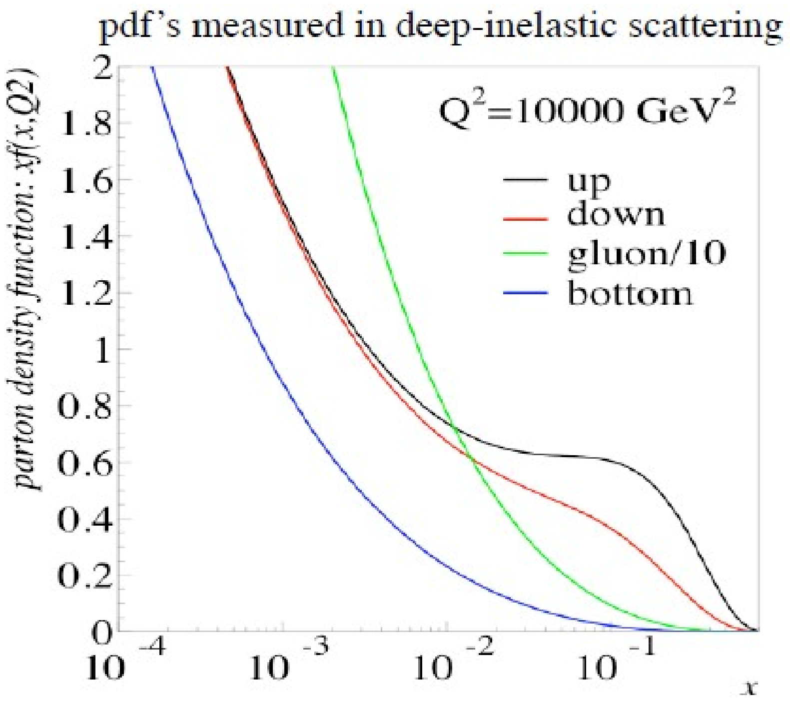
- Examples:

Higgs: M~100 GeV

- LHC: <xp> = 100/7000 ~ 0.014

Gluino: M ~ 1TeV

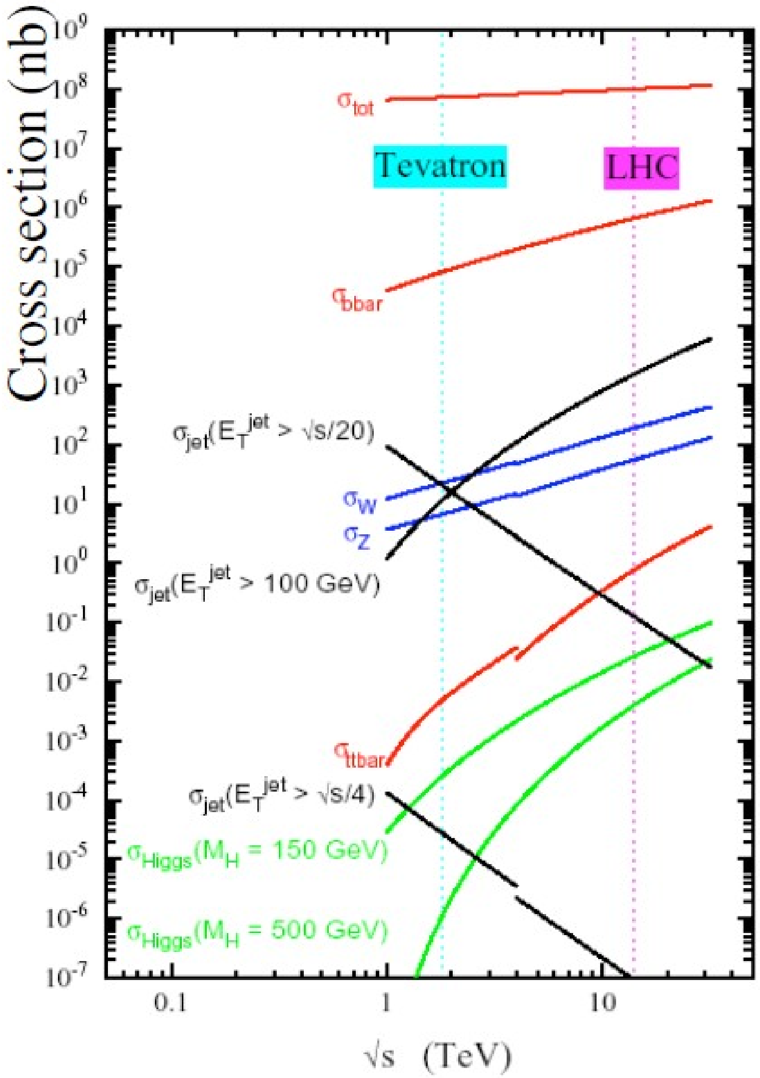
- LHC: <xp> = 1000/7000 ~ 0.14



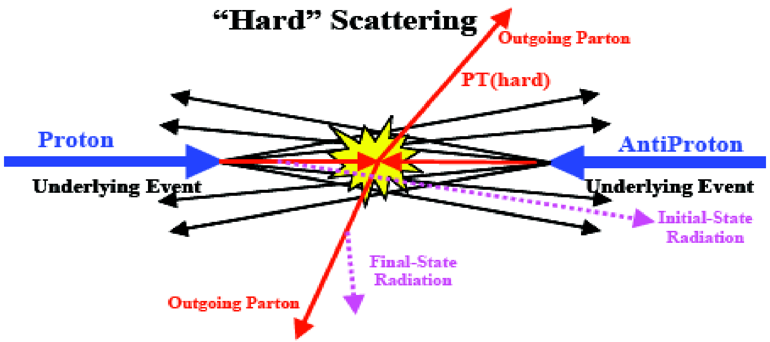
- Partons densities rise dramatically towards low x
  - Larger cross-sections at LHC than in previous experiments (Tevatron).

Cross-sections at LHC

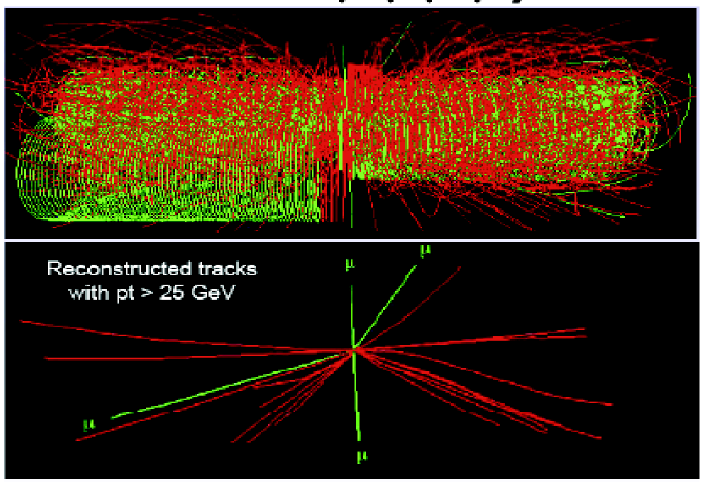
- A lot more "uninteresting" than "interesting" processes at design luminosity ($L = 10^{34} cm^{-2} s^{-1}$)
  - Any event: 10^9/sec
  - W boson: 150/sec
  - Top quark: 8/sec
  - Higgs (125GeV): 0.2/sec
- Interesting events gets selected:
  I. trigger (decision!)
  II. physics analysis (selection)



Every event is complicated

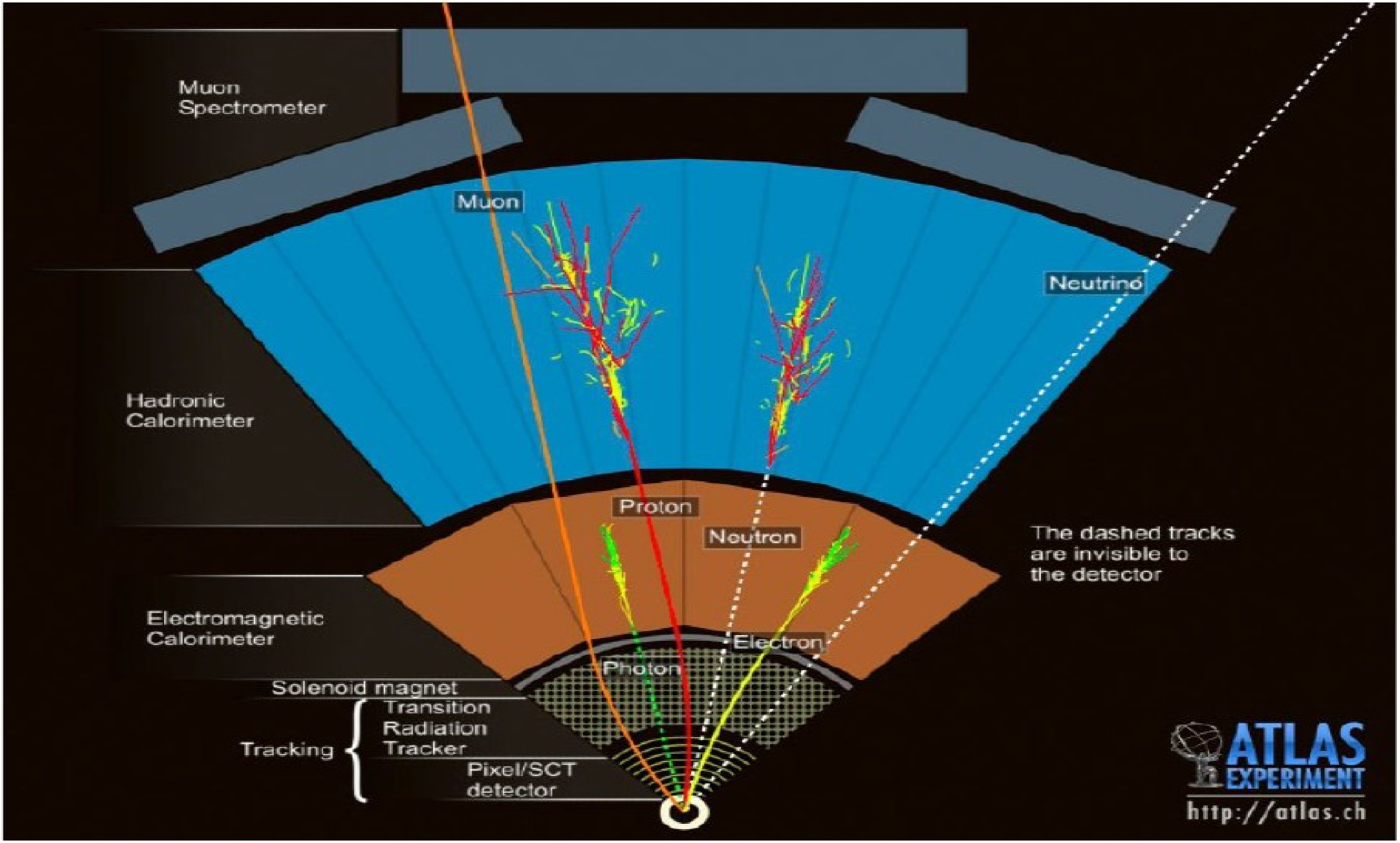


$H \rightarrow ZZ \rightarrow \mu^+\mu^-\mu^+\mu^-)$

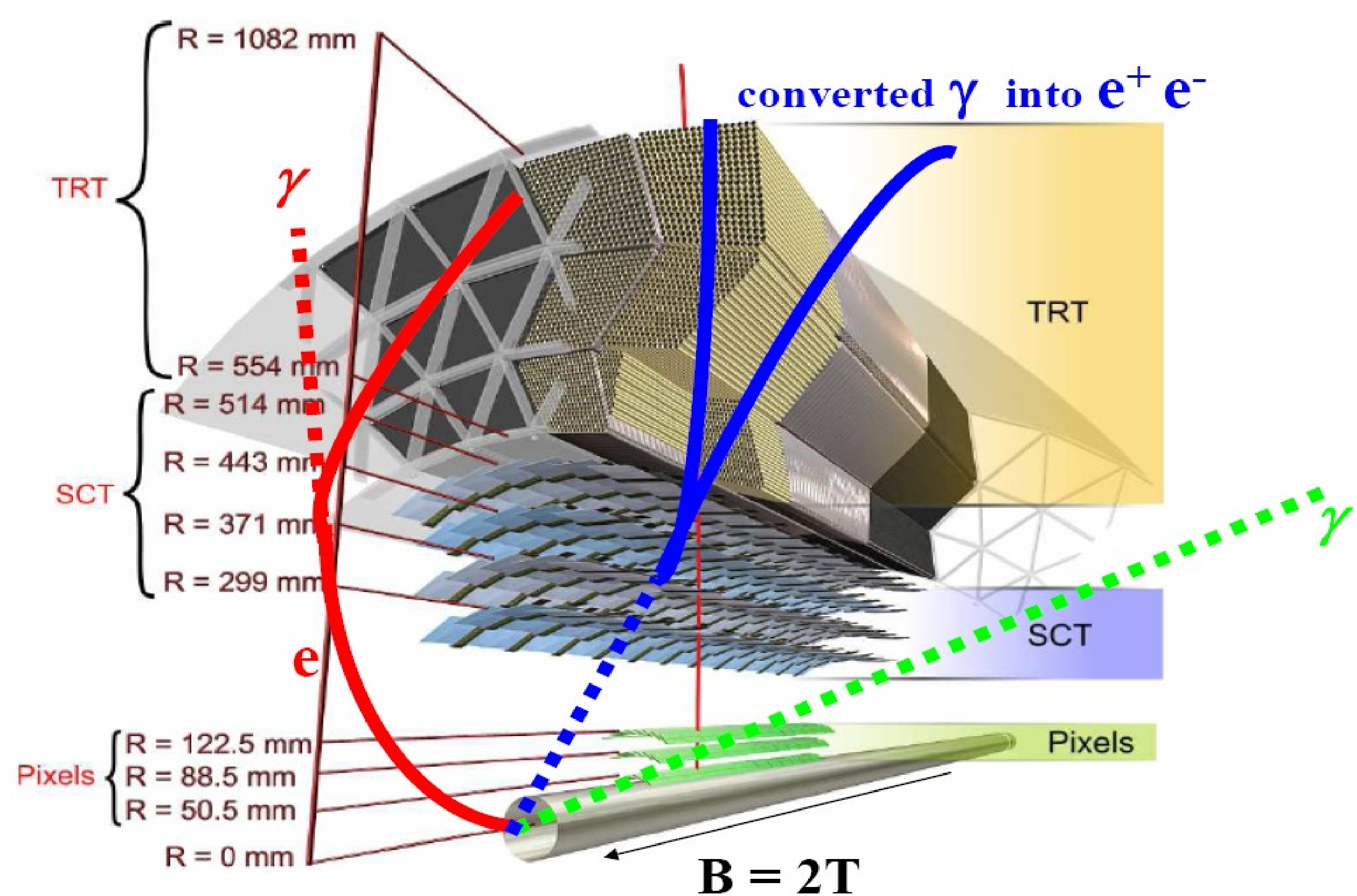


- "Underlying event":
  - Initial state radiation
  - Interactions of other partons in proton
- Additional pp interactions
  - LHC: ~1.5 (~23 at design values) → **Even >30 with present operation conditions**
  - Tevatron: ~10
- Many forward particles escape detection
  - Transverse momentum ~0
  - Longitudinal momentum >>0

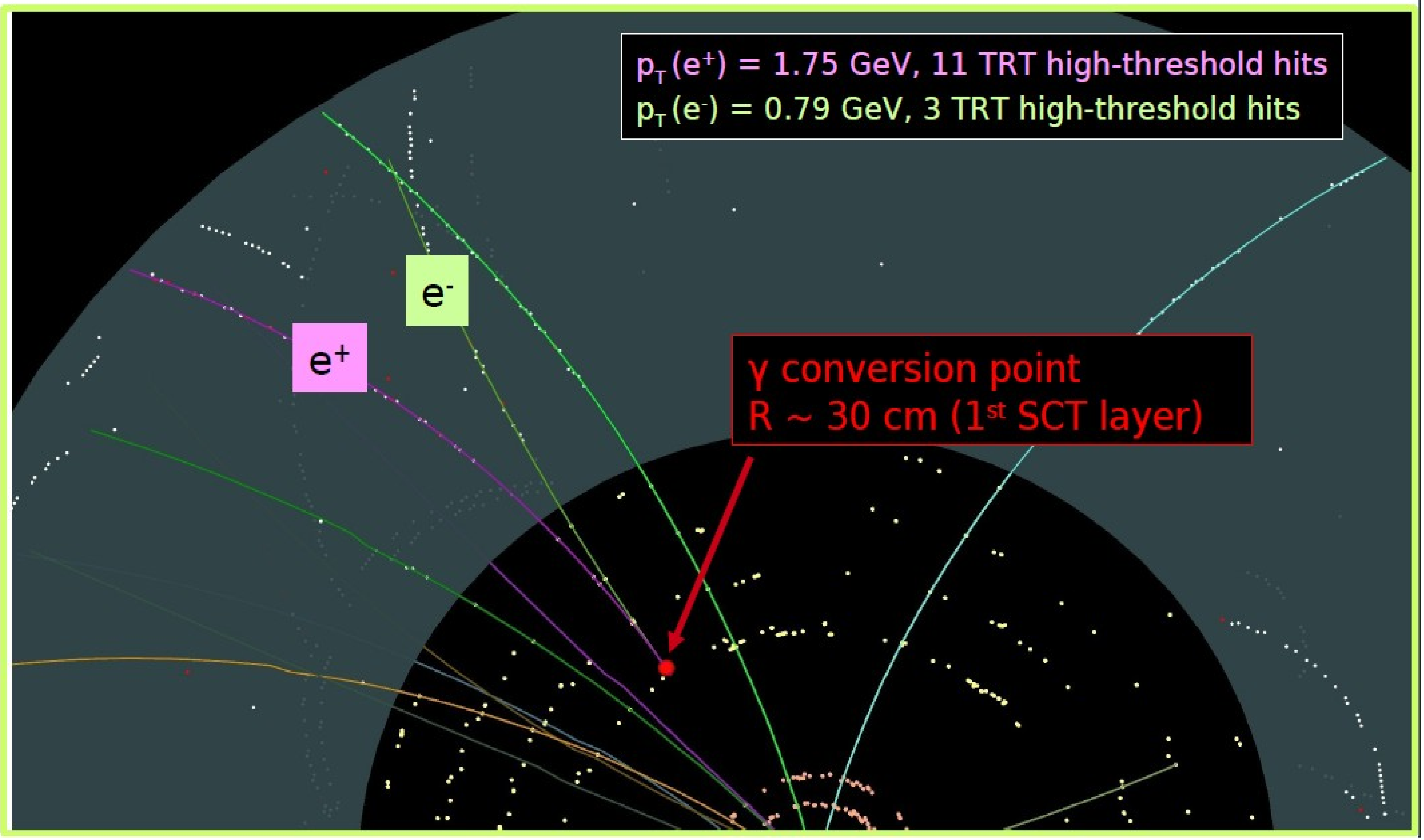
Particle identication



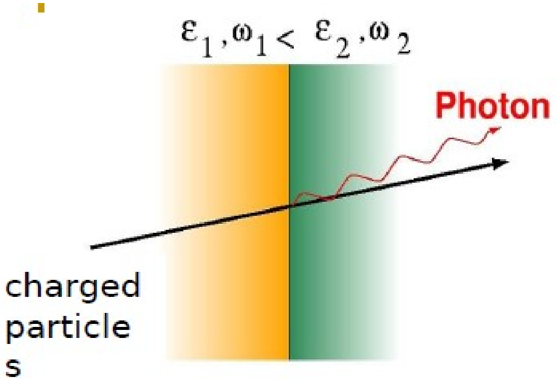
Inner Detector



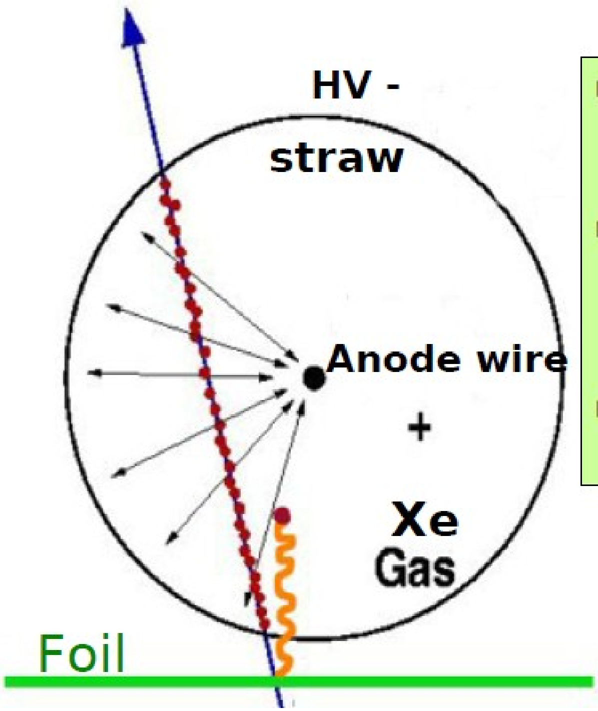
Inner Detector



Transition Radiation Tracker



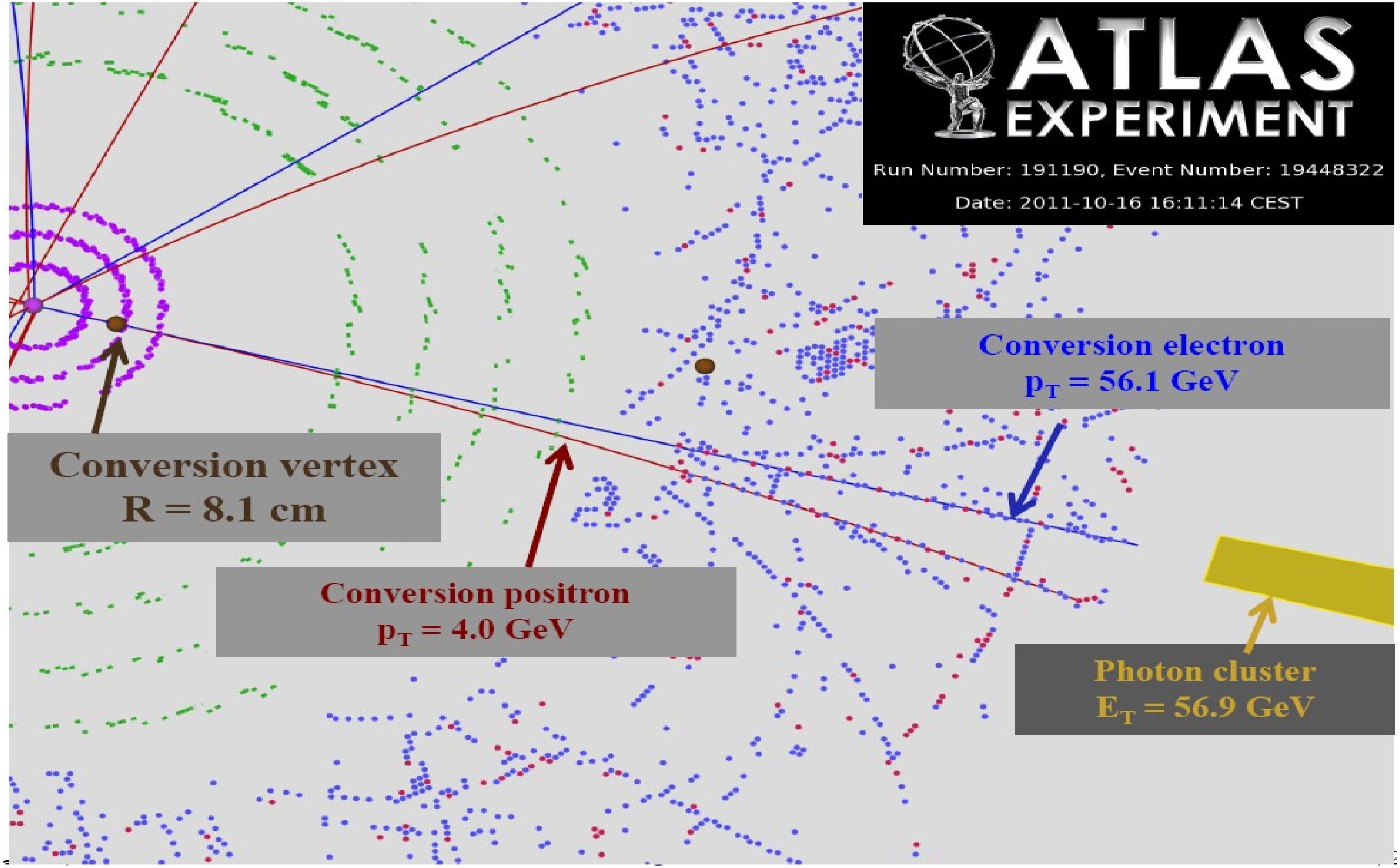
Transition radiation is emitted whenever a relativistic charged particle traverses the border between two media with different dielectric constants.
TR intensity is proportional to the particle γ -factor
$\rightarrow$ for a given particle momentum p, electrons emit more TR than pions $\rightarrow$ TR detectors used for particle identification



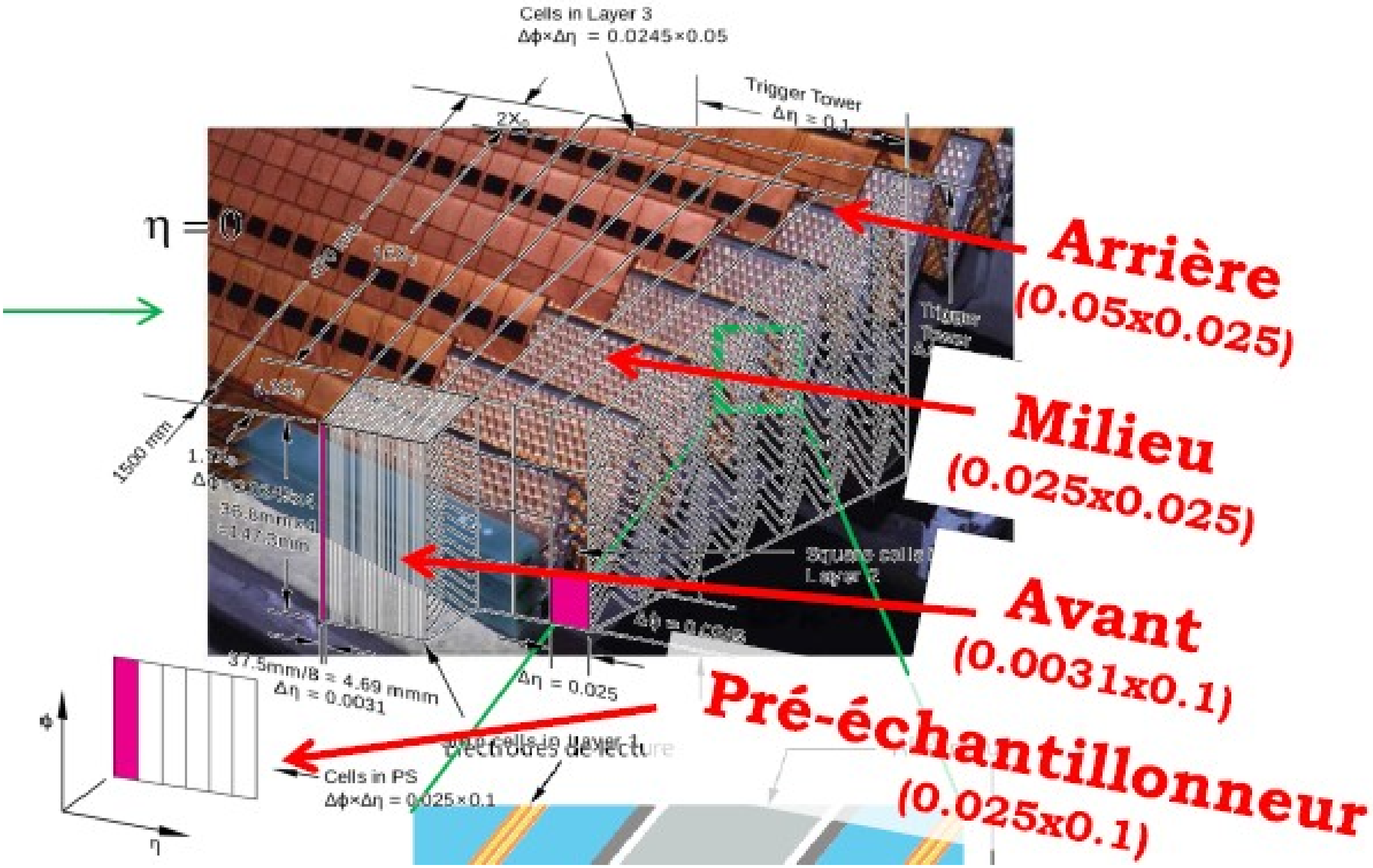
- Energy of TR photons (proportional to ε_1-ε_2): ~ 10-30 keV (X-rays)
- Many crossings of polypropylene foils (radiator) to increase TR photons
- Xenon as active gas for high X-ray absorption

Radiator: Polypropylen foils (15 μ) interleaved with straws

Inner Detector



Barrel Electromagnetic Calorimeter

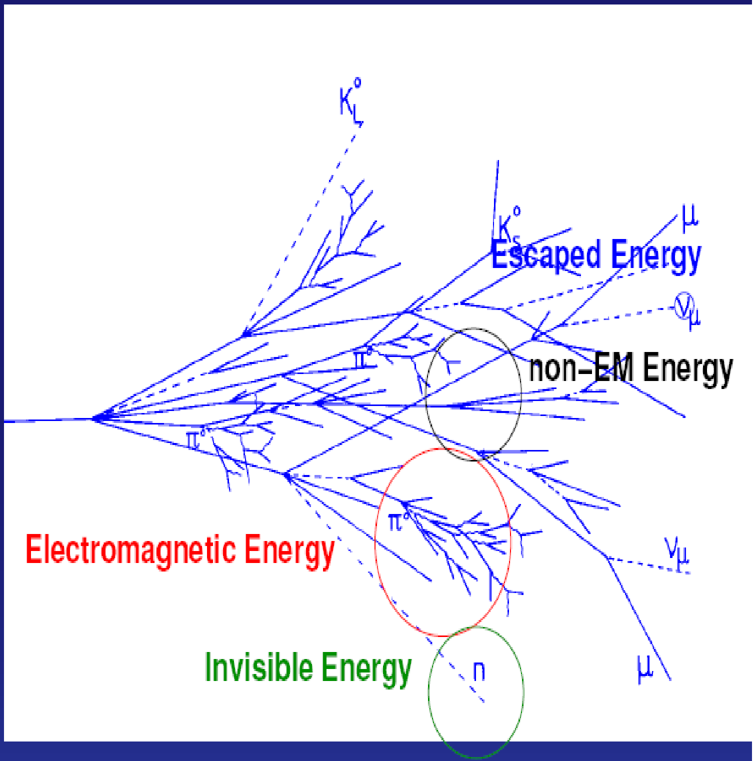


Hadronic and EM calorimeters

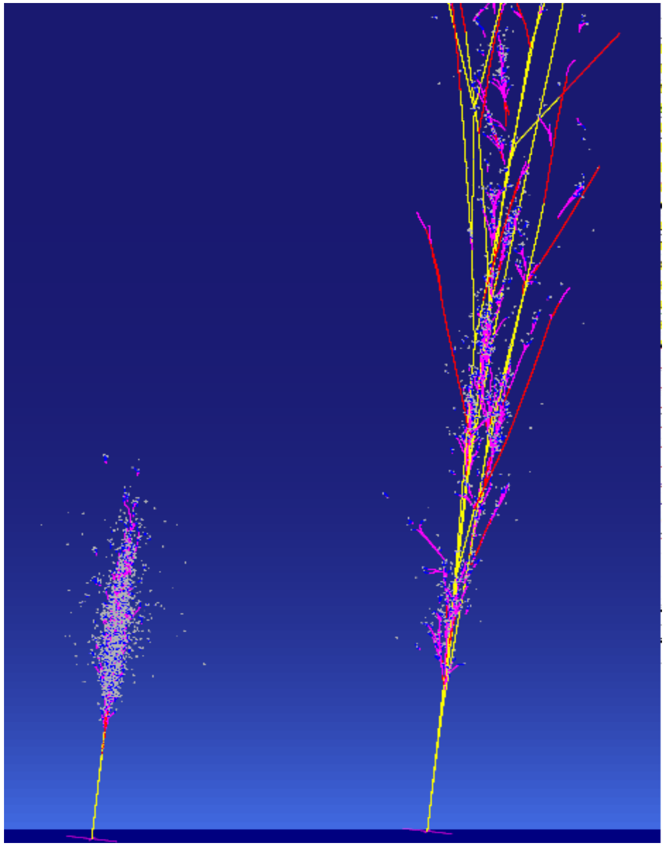
A hadronic shower consists of

- EM energy (e.g. $\pi^0 \to \gamma\gamma$) $O(50\,\%)$
- visible non-EM energy (e.g. dE/dx from $\pi^\pm, \mu^\pm$, etc.) $O(25\,\%)$
- invisible energy (e.g. breakup of nuclei and nuclear excitation) $O(25\,\%)$
- escaped energy (e.g. ν) $O(2\,\%)$

each fraction is energy dependent and subject to large fluctuations



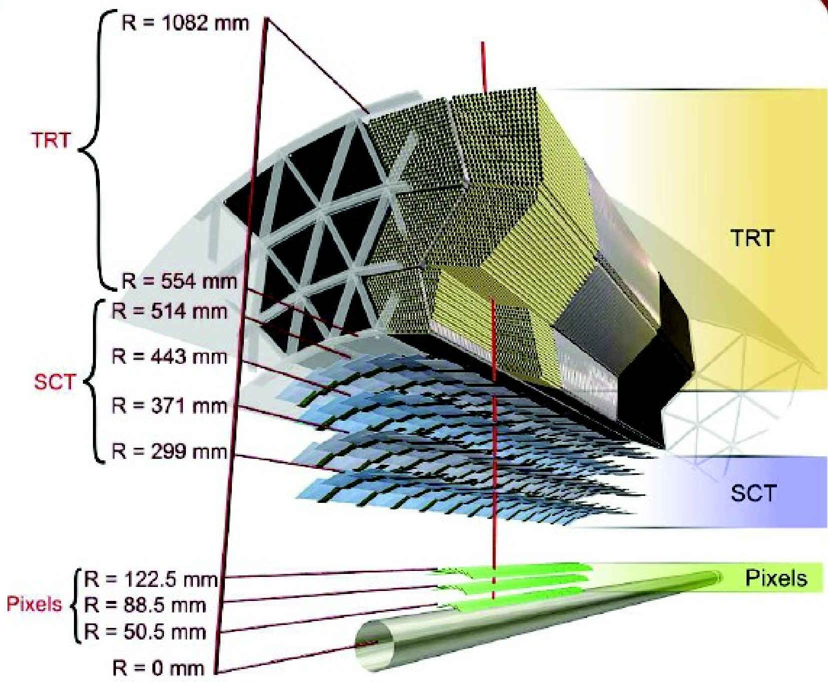
50 GeV showers of electron (left) and pion (right) in iron



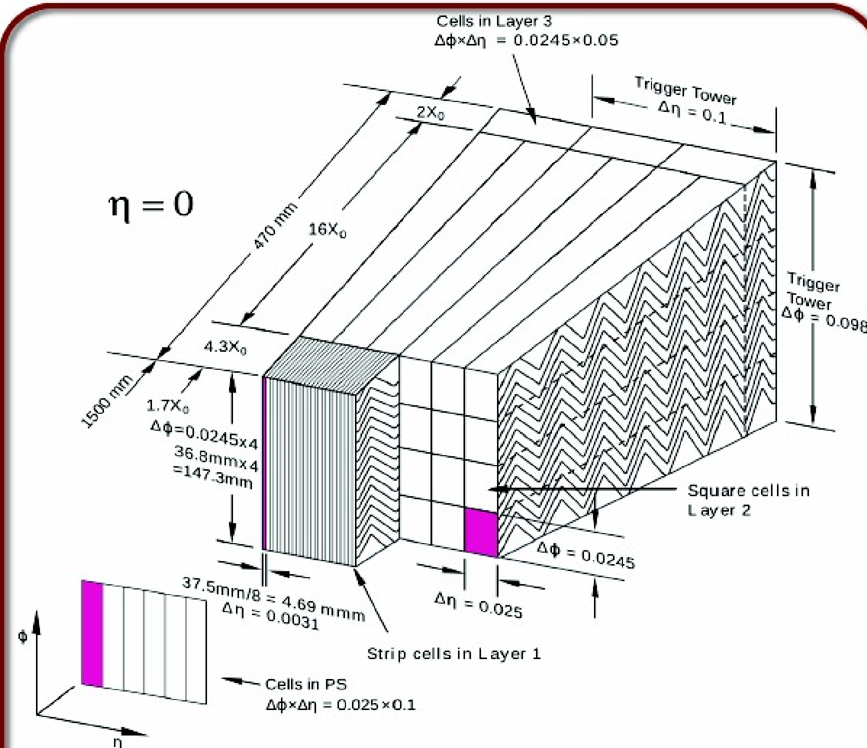
invisible energy is the main source of the non-compensating nature of hadron calorimeters

hadronic calibration has to account for the invisible and escaped energy and deposits in dead material and ignored calorimeter parts

Measuring electrons and photons



- Inner detector
  - ✓ track charged particles
  - ✓ measure transition radiation
  - ✓ e/γ discrimination
  - ✓ γ conversion reconstruction



- Pb-LAr EM calorimeter
  - ✓ η/φ/longitudinal segmentation
  - ✓ fine granularity in 1st layer up to η<2.37
  - ✓ γ energy and direction
  - ✓ γ/π0 separation (EM shower moments)

Last three years ……………

- Years of constructions and test beams: prototypes or parts of detectors tested at SPS beamline
- **September 2008** – first beam, first collisions, few first days of collecting data
- After few days accident with accelerator …. long months of repair
- Restarting fall in **2009:** first collisions with sqrt(s) = 900 GeV
- Long run in **2010**: 36pb^{-1} / experiment, sqrt(s) = 7 TeV
- Long run in **2011**: 5fb^{-1}/experiment, sqrt(s) = 7 TeV
- Ongoing run in **2012**: 13fb^{-1} /experiment so far
  - Ongoing run till Xmass, sqrt(s) = 8 TeV

September 2008

First beams – September 10, 2008

After Sept 10

Successful continuation of commissioning with beam

(low intensity, 10^9 protons)

Sept 11:

Switched on RF for beam 2 circulating beam for 10 min

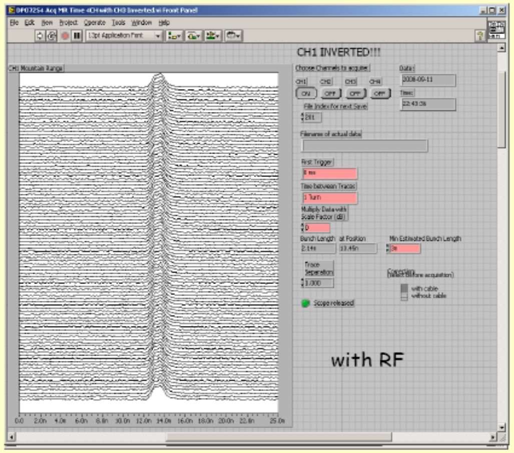
Many tests (orbit, dump,...)

Sept 12:

Measure horizontal beam profile with wire scanner

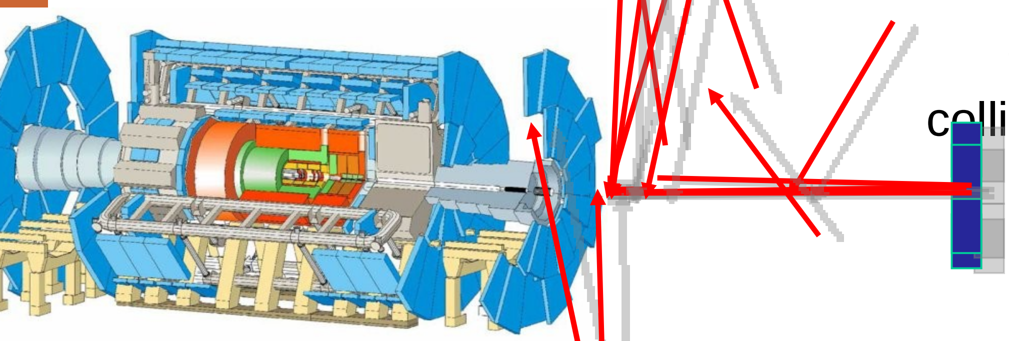
Evening: transformer failure pt8 replacement + recovery

Continue with machine checkout (without beam)

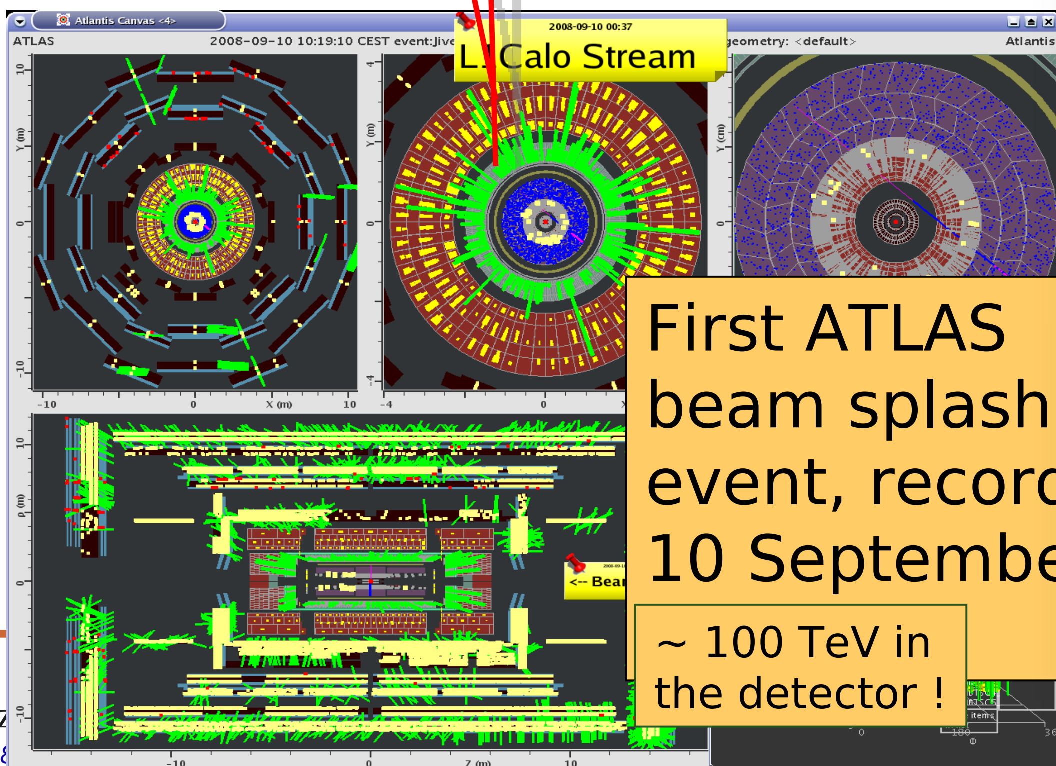


First beams – in ATLAS...

Beam bunches (2x10⁹ protons at 450 GeV) stopped by (closed) collimators upstream of experiments → "splash" events in the detectors (debris are mainly muons)

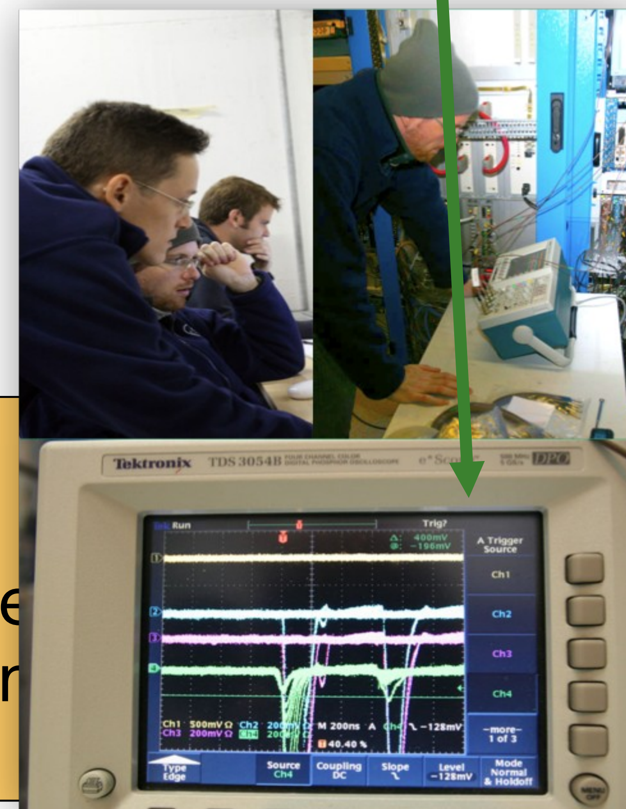


Beam pick-ups (BPTX)
(175 m)



First ATLAS
beam splash
event, recorde
10 September

~ 100 TeV in
the detector !

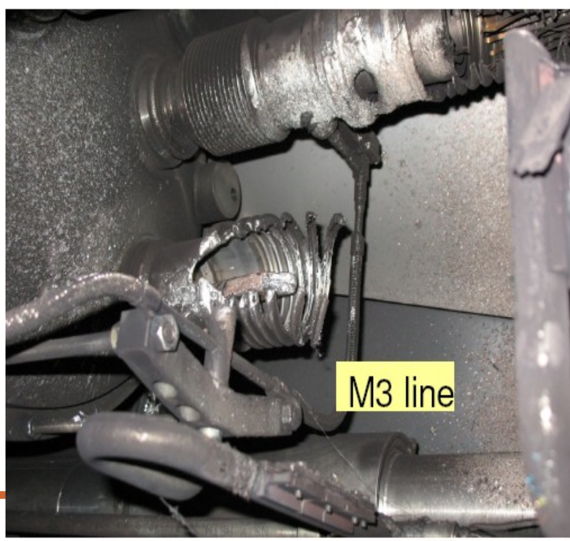


LHC damages

Problem in Sector 34

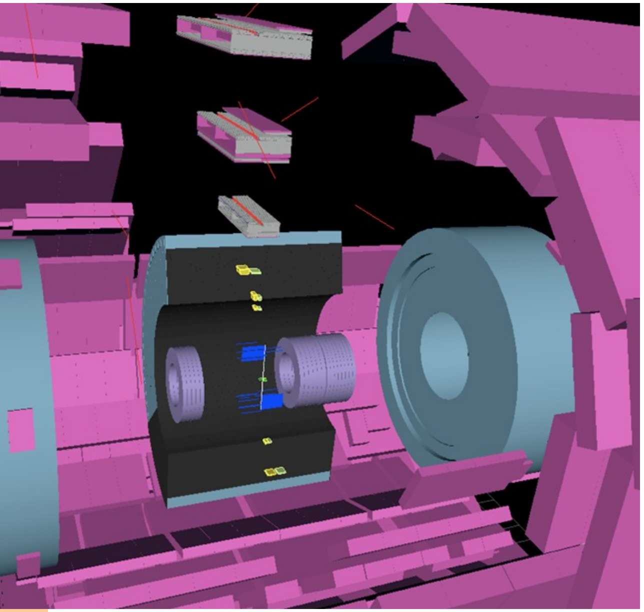
Friday, Sept 19

- Commissioning without beam of final sector for 5 TeV operation
- Faulty electrical connection between two magnets
- Leading to large helium leak into the tunnel
- Sector has to be warmed up (started, takes several weeks) before diagnosis and repair can start, then cool down again (several weeks)
  → runs into winter shutdown
- Restart of accelerators spring 2009 – LHC beams to follow

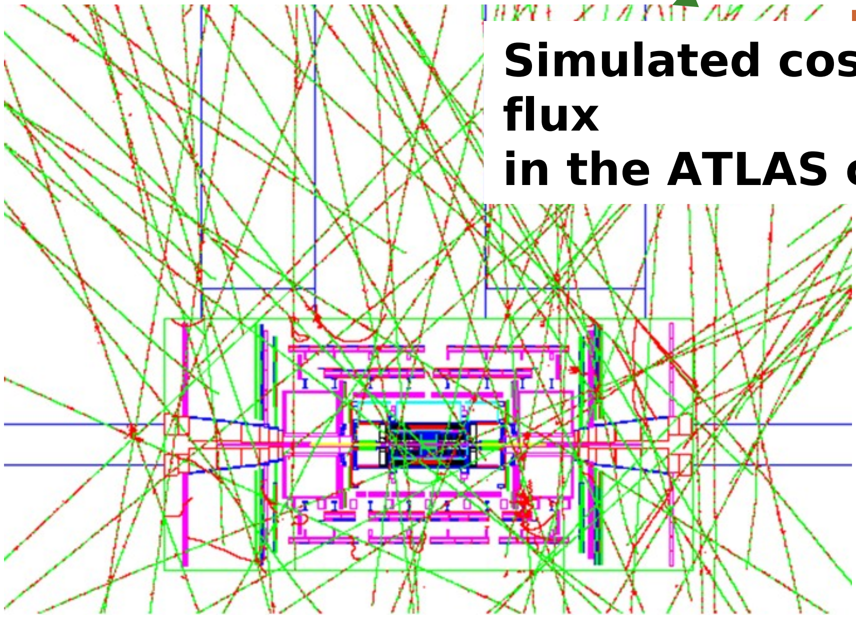


QQBI.27R3 M3 line

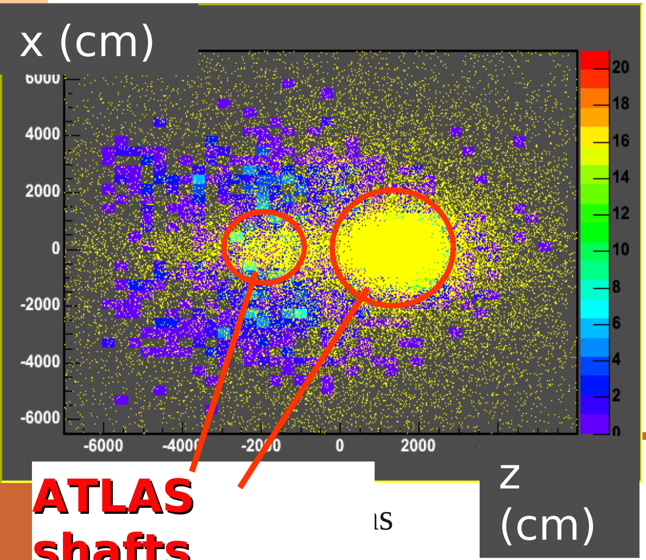
Cosmic Muons in ATLAS (2009)



Real Cosmic Event

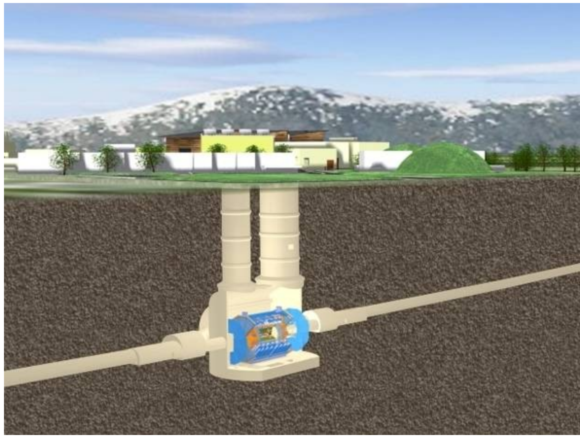


Simulated cosmics flux in the ATLAS cavern

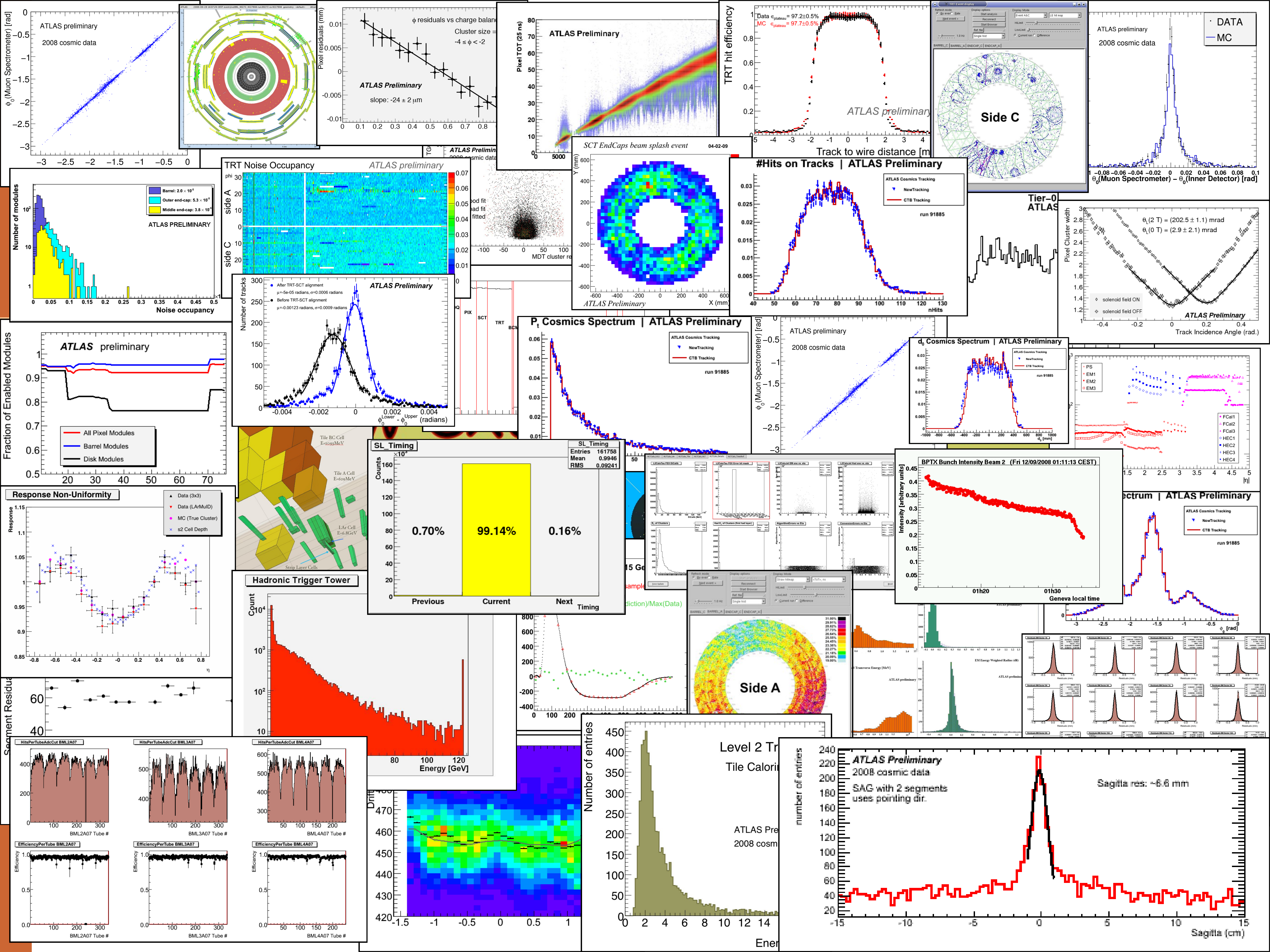


Muon impact points extrapolated to surface as measured by Muon Trigger chambers (RPC)

(Calorimeter trigger also



Rate ~100 m below ground: ~ O(15 Hz) crossing Inner Detector

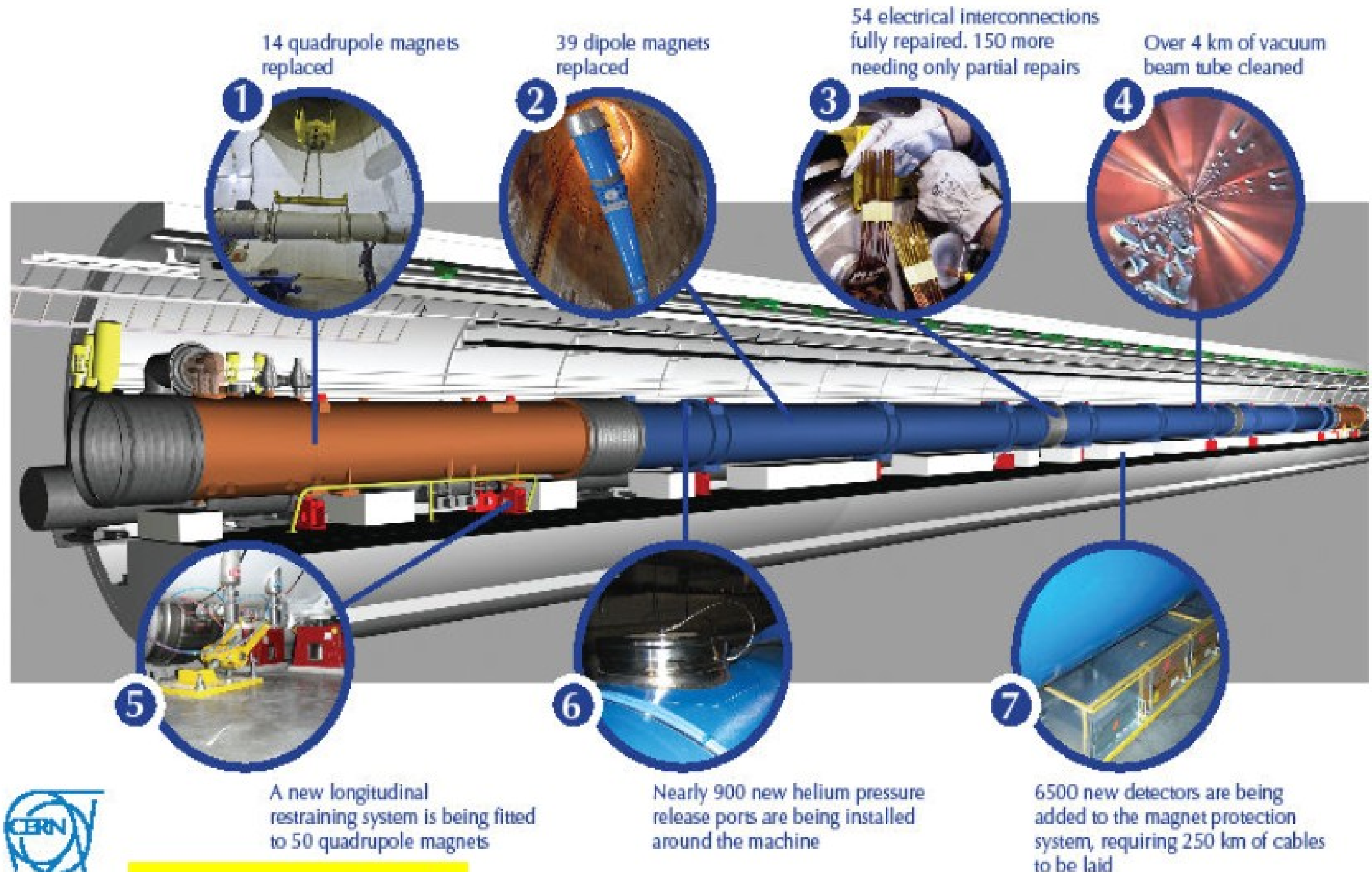


ATLAS preliminary
2008 cosmic data
φ residuals vs charge balance
ATLAS Preliminary
slope: -24 ± 2 μm
Pixel TOT (25 ns)
TRT hit efficiency
ATLAS preliminary
Track to wire distance
Side C
DATA
MC
Number of modules
ATLAS PRELIMINARY
Noise occupancy
TRT Noise Occupancy
ATLAS preliminary
SCT EndCaps beam splash event
ATLAS Preliminary
#Hits on Tracks | ATLAS Preliminary
run 91885
nHits
Pixel Cluster width
ATLAS Preliminary
Track Incidence Angle (rad.)
Fraction of Enabled Modules
ATLAS preliminary
All Pixel Modules
Barrel Modules
Disk Modules
Number of tracks
ATLAS Preliminary
Pt Cosmics Spectrum | ATLAS Preliminary
d0 Cosmics Spectrum | ATLAS Preliminary
Response Non-Uniformity
SL_Timing
Counts
0.70%
99.14%
0.16%
Previous
Current
Next
Timing
BPTX Bunch Intensity Beam 2 (Fri 12/09/2008 01:11:13 CEST)
Intensity [arbitrary units]
Geneva local time
Hadronic Trigger Tower
Count
Energy [GeV]
Side A
Number of entries
Level 2 Tr
Tile Calori
ATLAS Pre
2008 cosm
ATLAS Preliminary
2008 cosmic data
SAG with 2 segments
uses pointing dir.
Sagitta res: ~6.6 mm
number of entries
Sagitta (cm)

Phase 1 +2

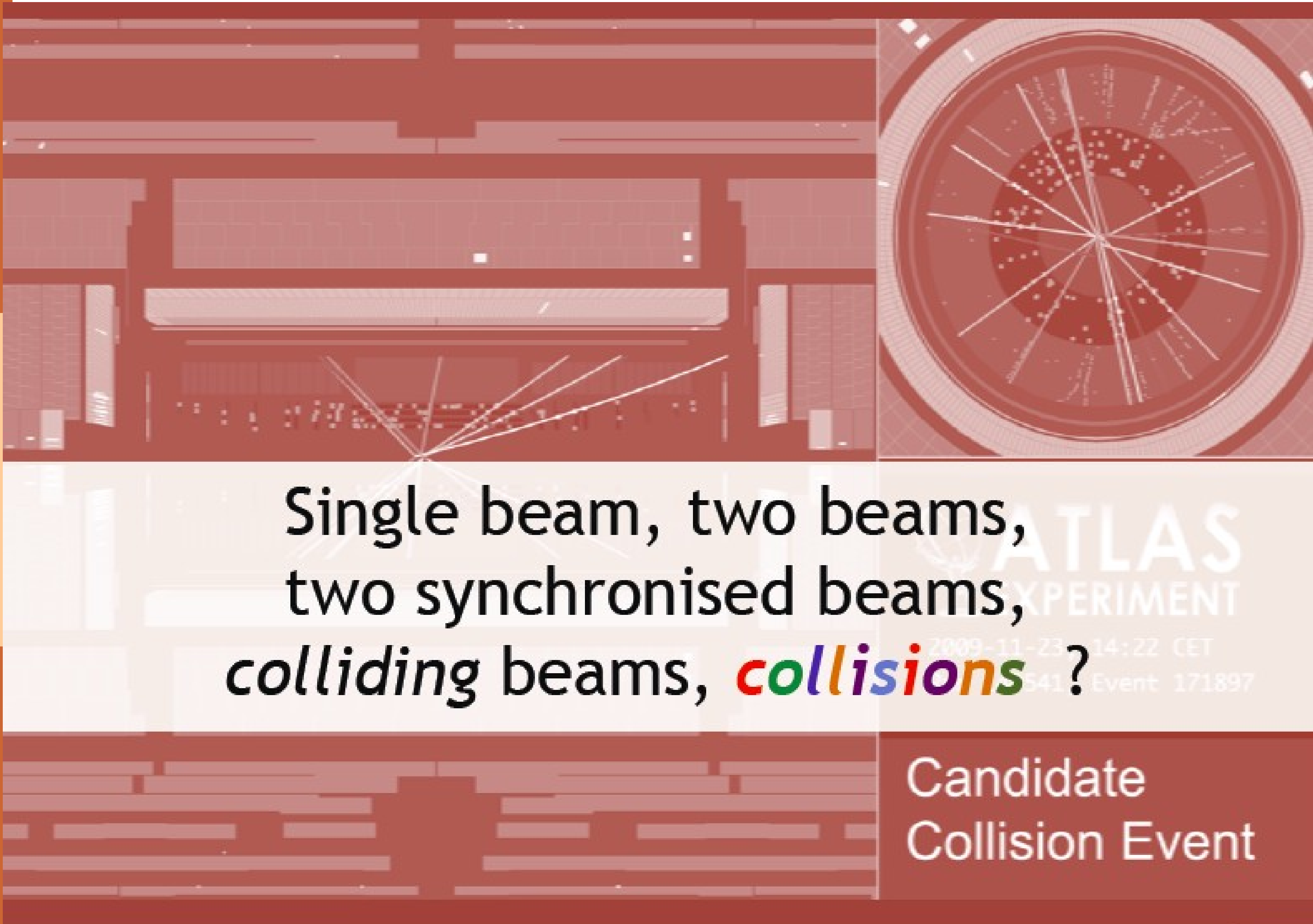
S.Myers
CERN November 2009

The LHC repairs in deta...



+ cryogenics!

Single beam, two beams,
two synchronised beams,
colliding beams, **collisions** ?



ATLAS

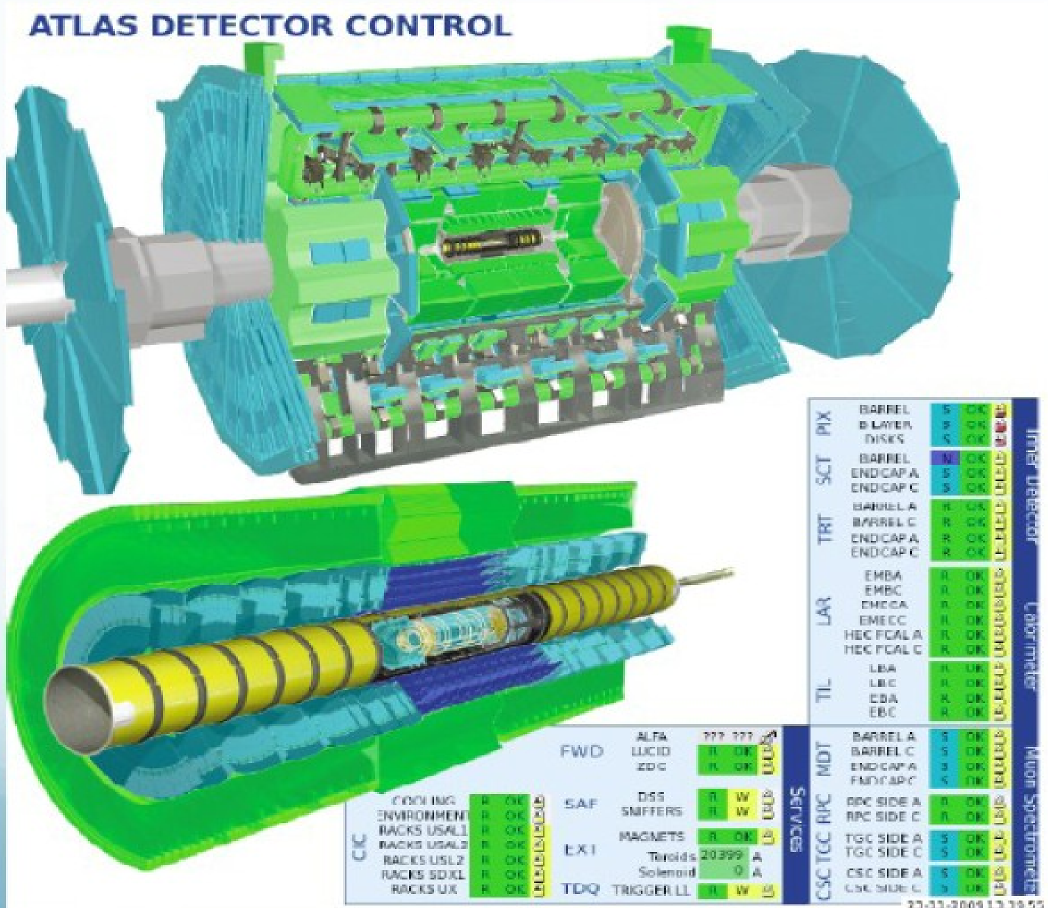
Beams and first collisions

Andreas Hoecker (CERN) **on behalf of the ATLAS Collaboration**

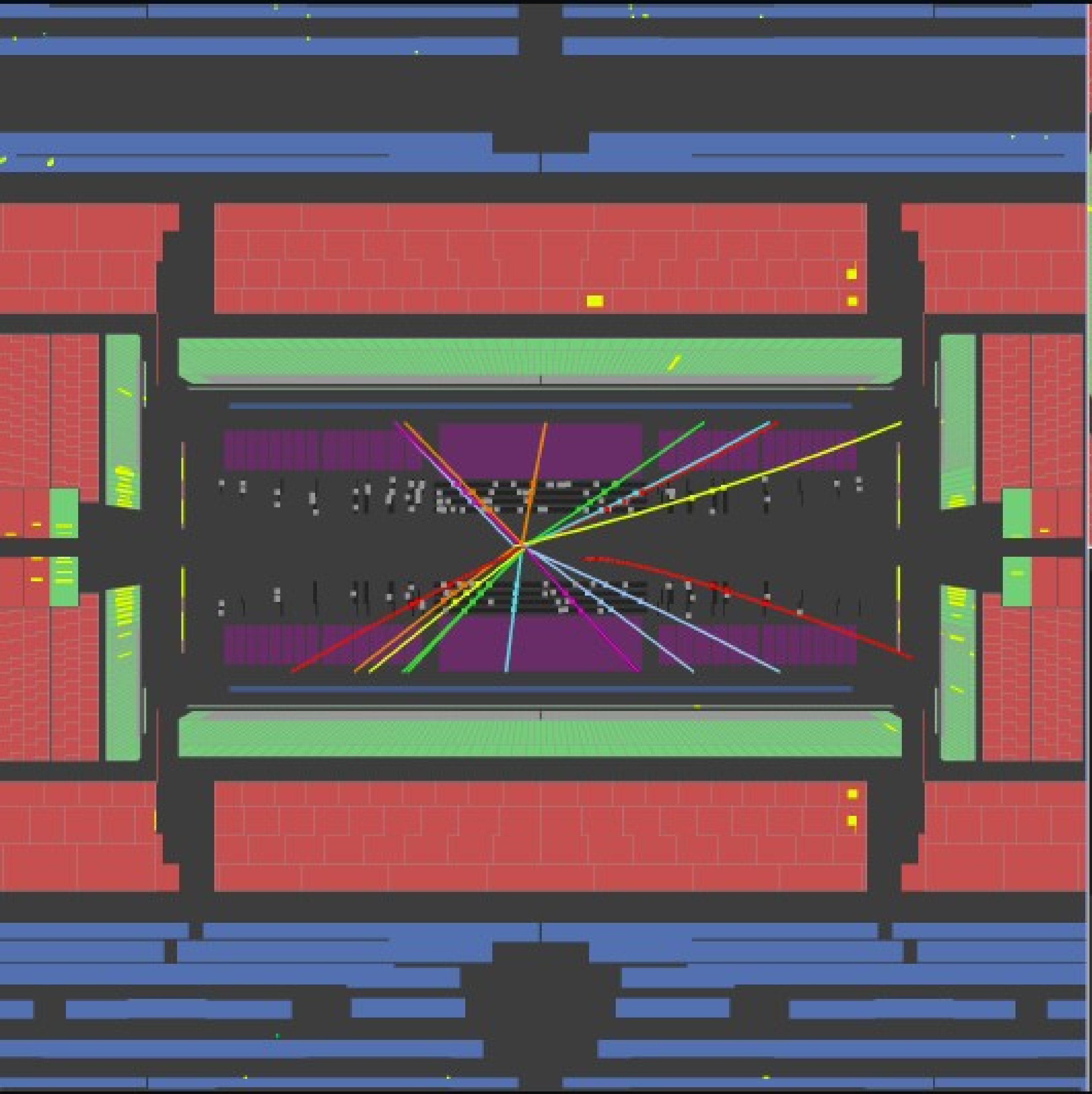
CERN seminar “LHC, week 1”, Nov 26, 2009

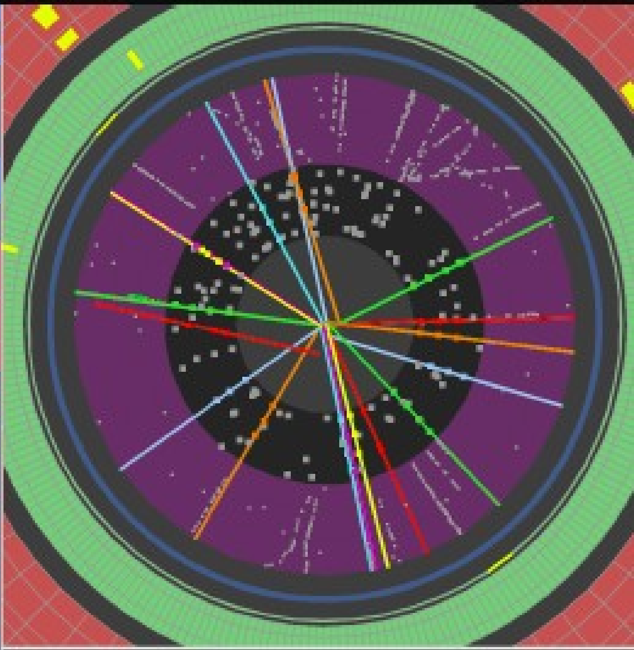
Status for first collision

After a vast multi-year programme of cosmic ray data taking and system commissioning …



- Pixel - off (no stable beam)
- SCT - standby
  - Standby V is 20 V → ~50% hit efficiency (increases with incidence angle)
  - Barrel and endcap increased to 50V for short stable beam periods during collisions
  - Barrel voltage sometimes lower than 20V for beam set up (eg. splash events)
- All other systems (Muon system, Calorimeters, TRT, Forward detectors) on
- Trigger and DAQ ready
- Solenoid off, toroids on
- Waiting for beam …



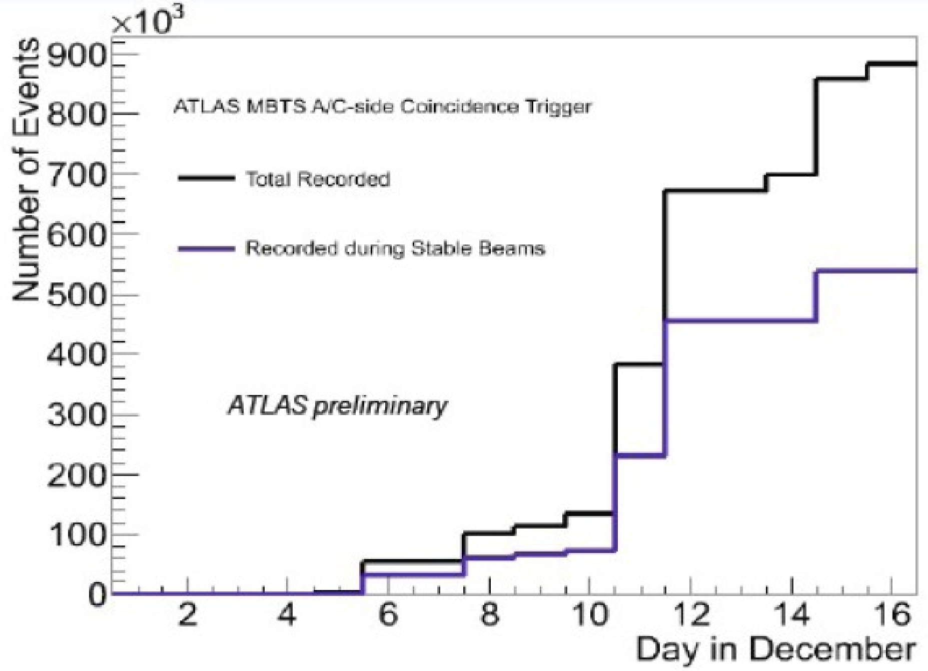


ATLAS EXPERIMENT

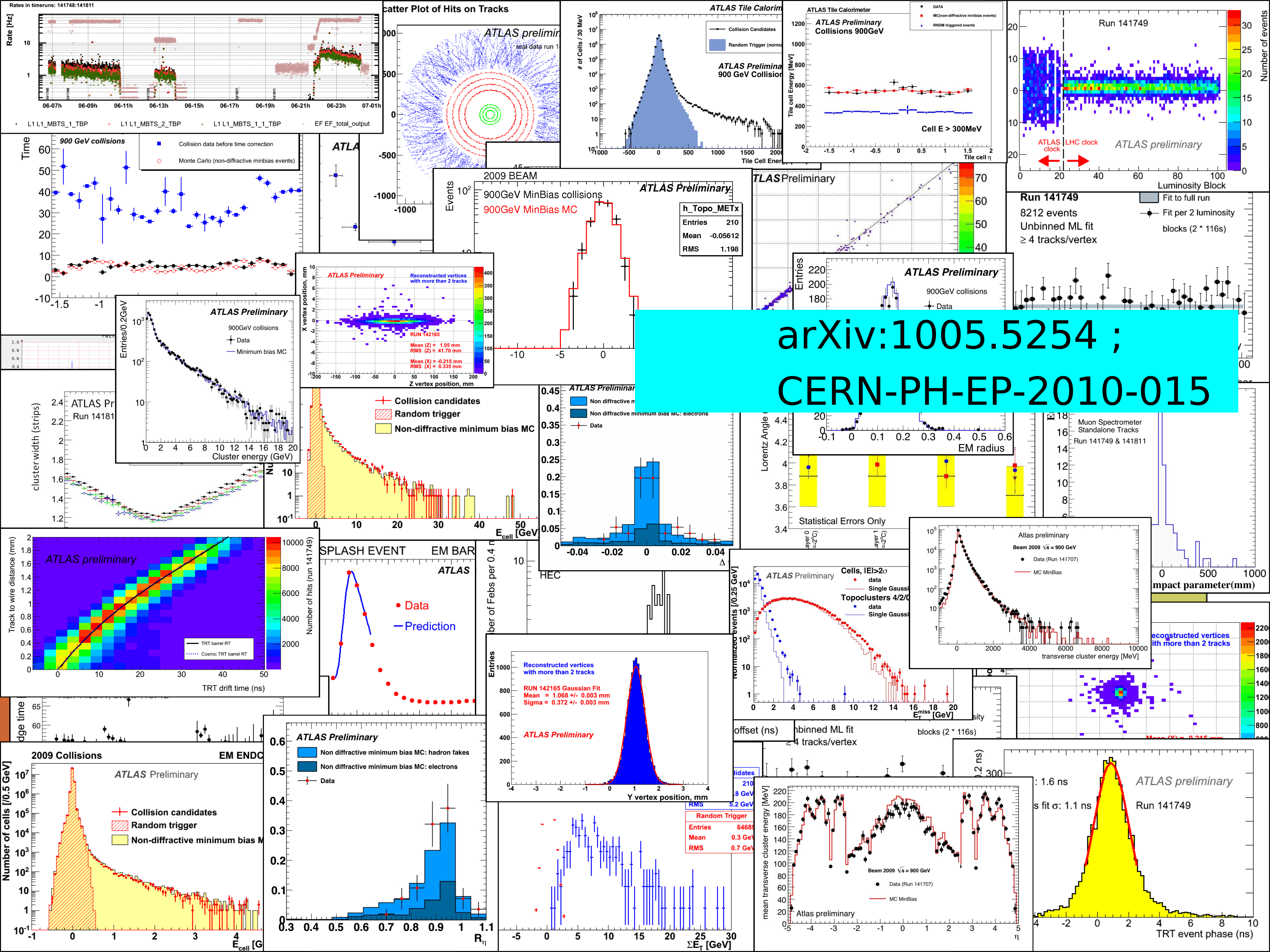
2009-11-23, 14:22 CET
Run 140541, Event 171897

Candidate Collision Event

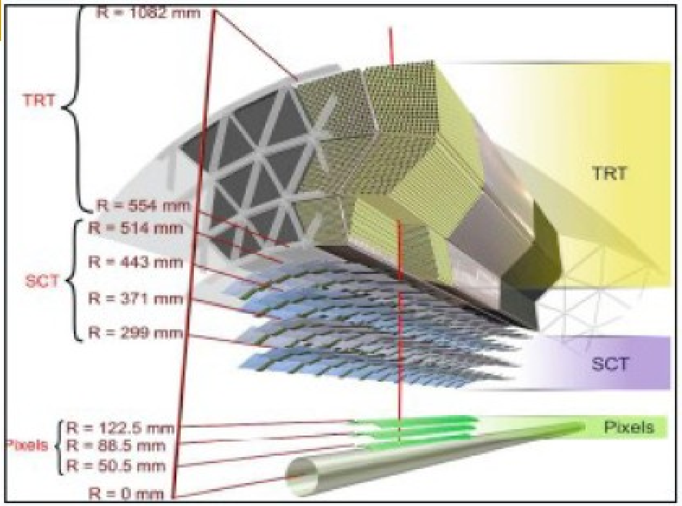
Lumi recorded with 900 GeV and 2.36 TeV

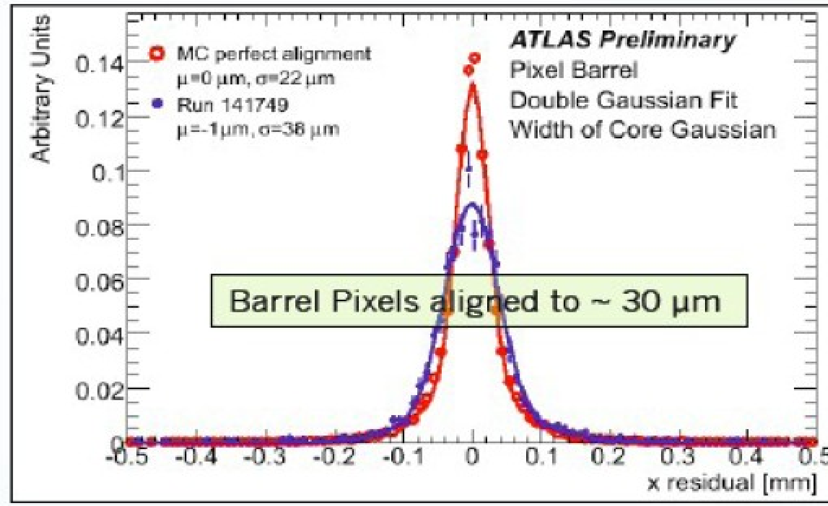


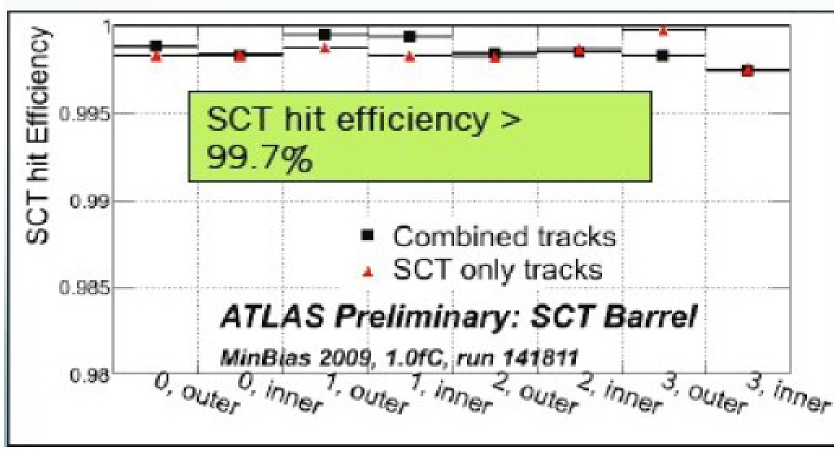
- Total number of collisions recorded: ~880k
  - ~540k with stable beams → Tracker fully on
  - ~34k at $\sqrt{s}$=2.36 TeV
- Recorded integrated luminosity with stable beams: ~ 11 μb^{-1}
- Max peak luminosity seen by ATLAS : ~ 7 x 10^{26} cm^{-2} s^{-1}

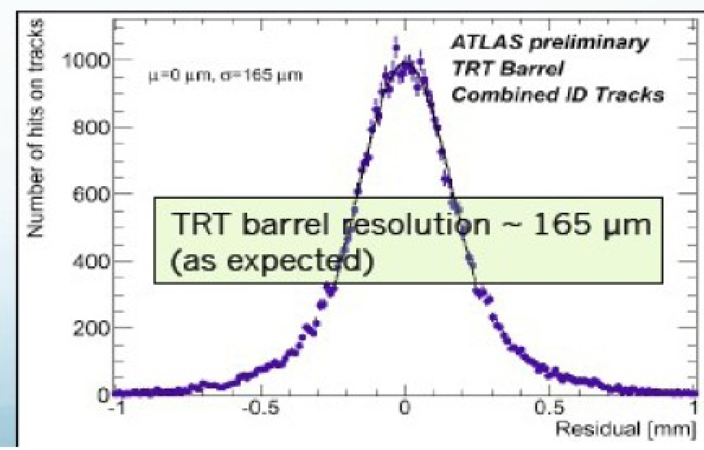

arXiv:1005.5254 ;
CERN-PH-EP-2010-015
ATLAS Preliminary
900 GeV Collisions
Run 141749
2009 Collisions
SPLASH EVENT

Tracking

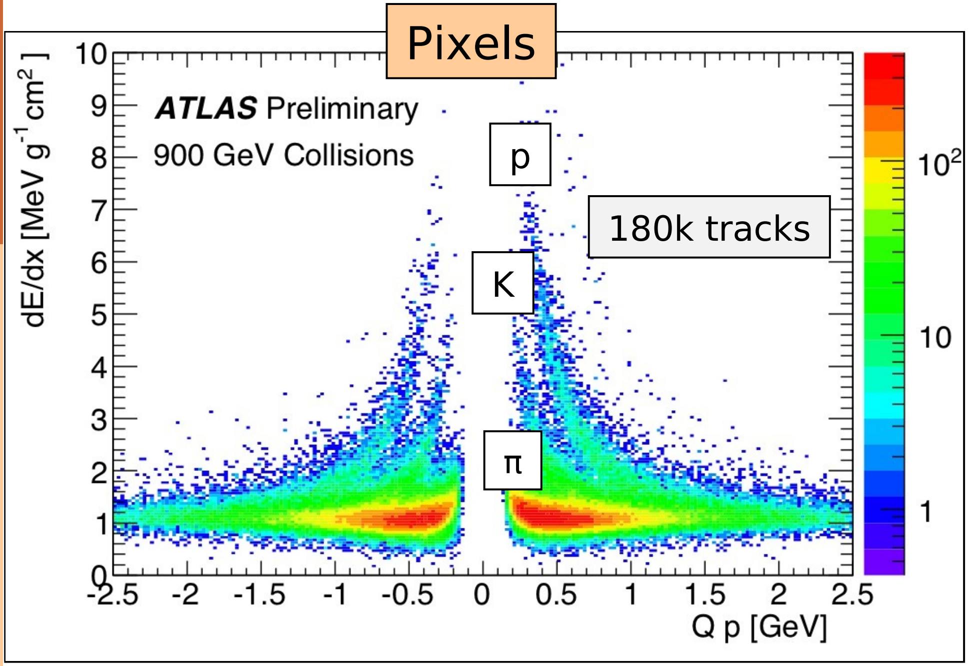

R = 1082 mm
TRT
R = 554 mm
R = 514 mm
R = 443 mm
SCT
R = 371 mm
R = 299 mm
TRT
SCT
Pixels
R = 122.5 mm
R = 88.5 mm
R = 50.5 mm
R = 0 mm
Pixels

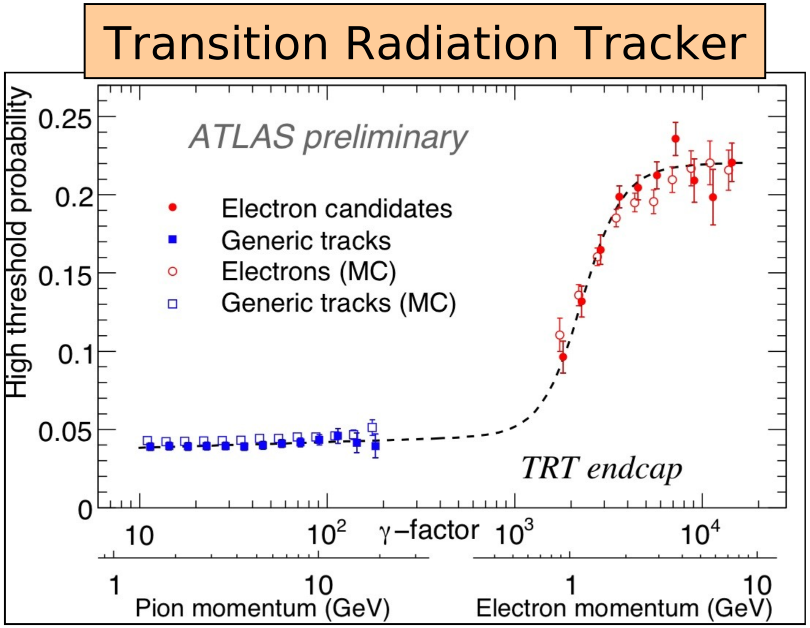

Arbitrary Units
MC perfect alignment
μ=0 μm, σ=22 μm
Run 141749
μ=-1μm, σ=38 μm
ATLAS Preliminary
Pixel Barrel
Double Gaussian Fit
Width of Core Gaussian
Barrel Pixels aligned to ~ 30 μm
x residual [mm]


SCT hit Efficiency
SCT hit efficiency > 99.7%
Combined tracks
SCT only tracks
ATLAS Preliminary: SCT Barrel
MinBias 2009, 1.0fC, run 141811
0, outer
0, inner
1, outer
1, inner
2, outer
2, inner
3, outer
3, inner


Number of hits on tracks
μ=0 μm, σ=165 μm
ATLAS preliminary
TRT Barrel
Combined ID Tracks
TRT barrel resolution ~ 165 μm
(as expected)
Residual [mm]

Particle identification in Inner Detector

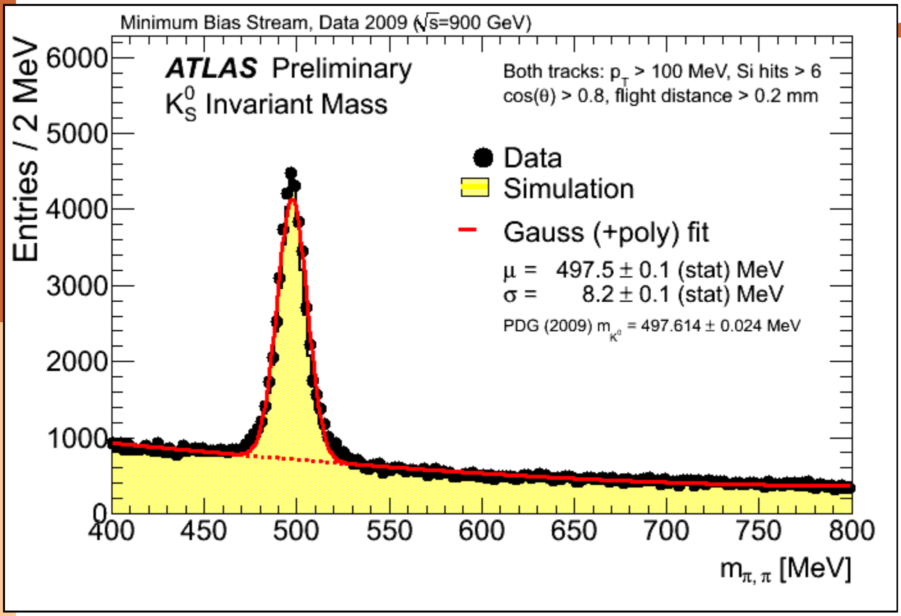


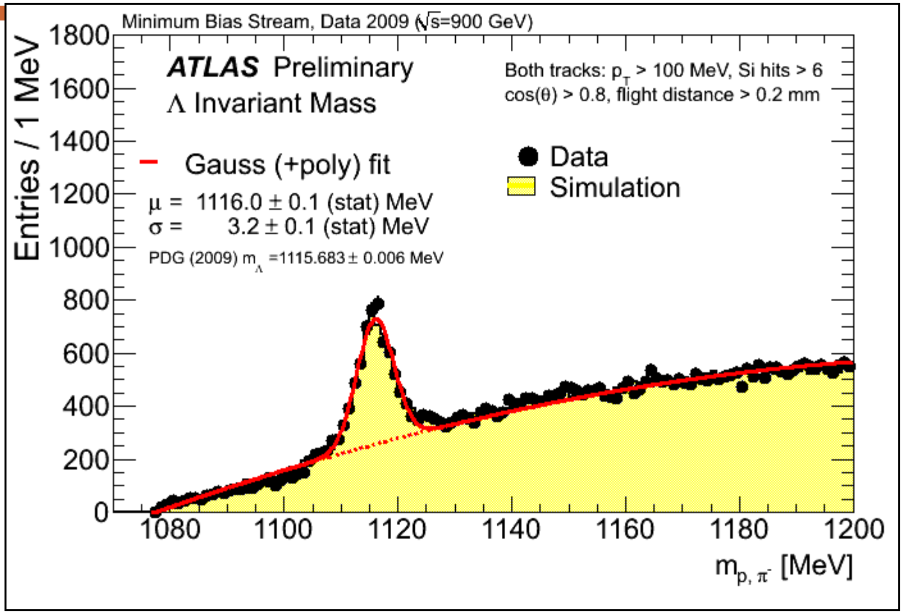


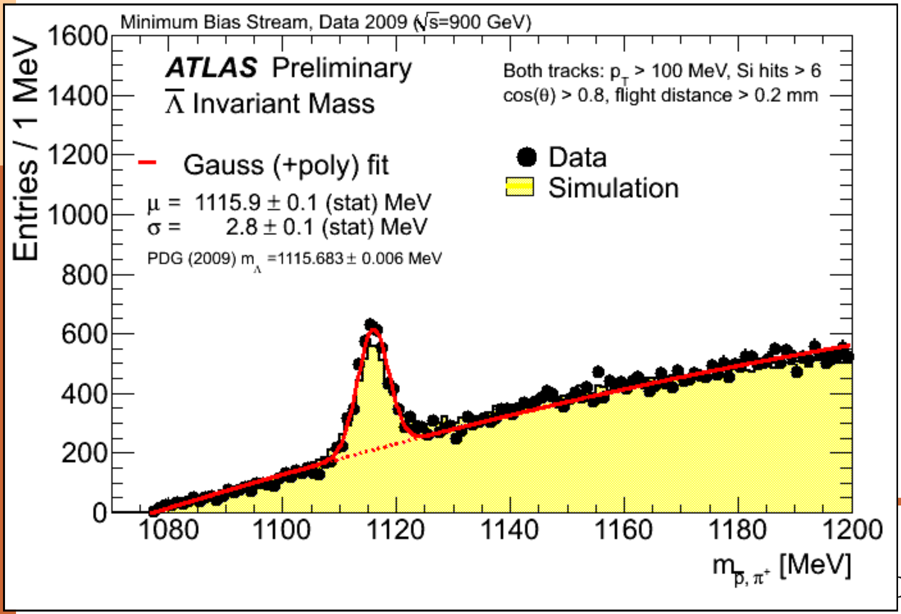
Transition radiation intensity is proportional to particle relativistic factor $\gamma=E/mc^2$.

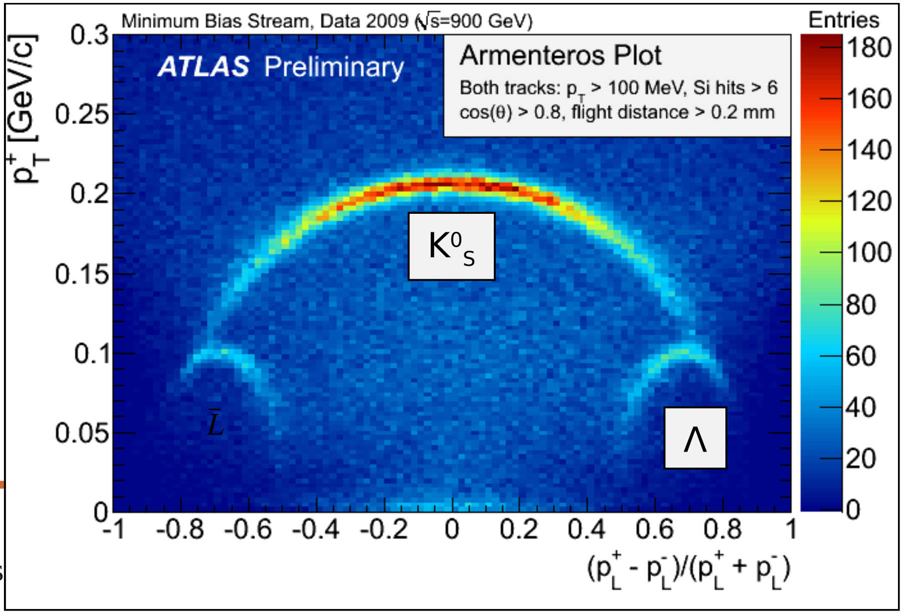
Onset for $\gamma \sim 10$

p_T (track) > 100 MeV
MC signal and background normalized independently









Identifying Kaons

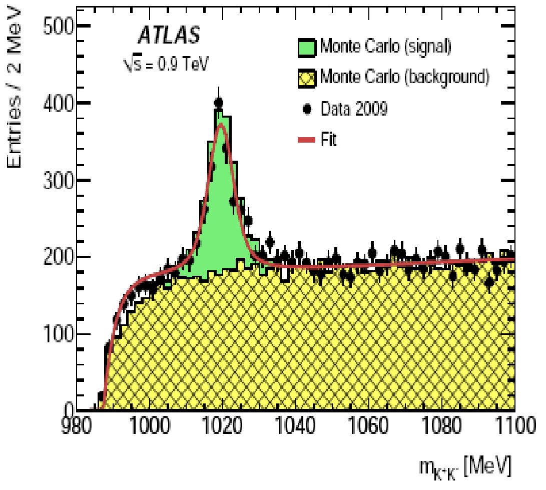


Figure 11: The measured and simulated mass spectra of K^+K^- pairs. The ϕ peak is fitted with a Breit-Wigner with a fixed width convoluted with a Gaussian. Both kaons must be identified through the dE/dx measurement.

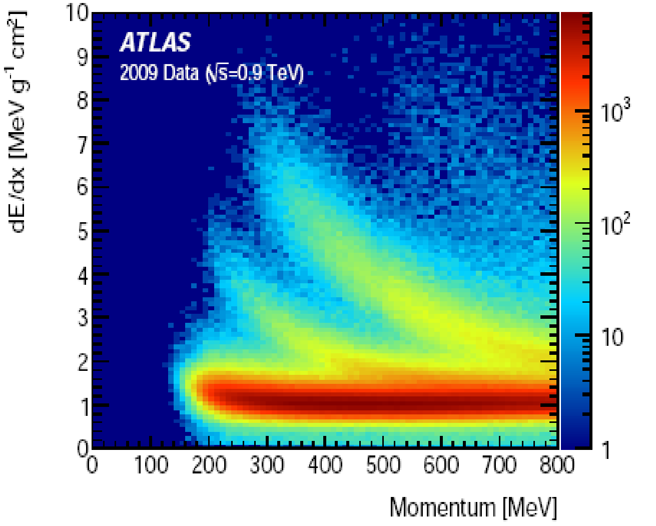
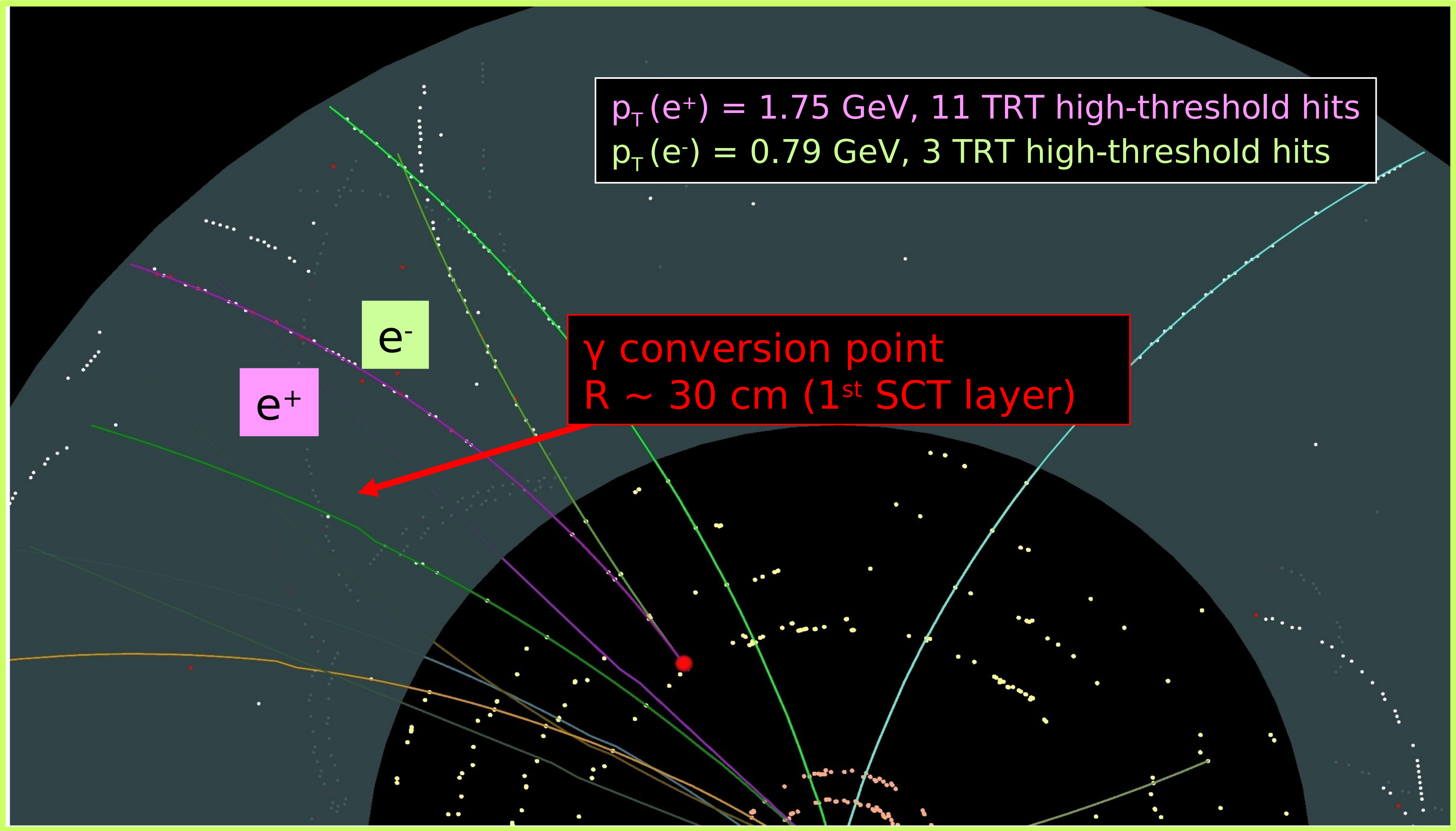


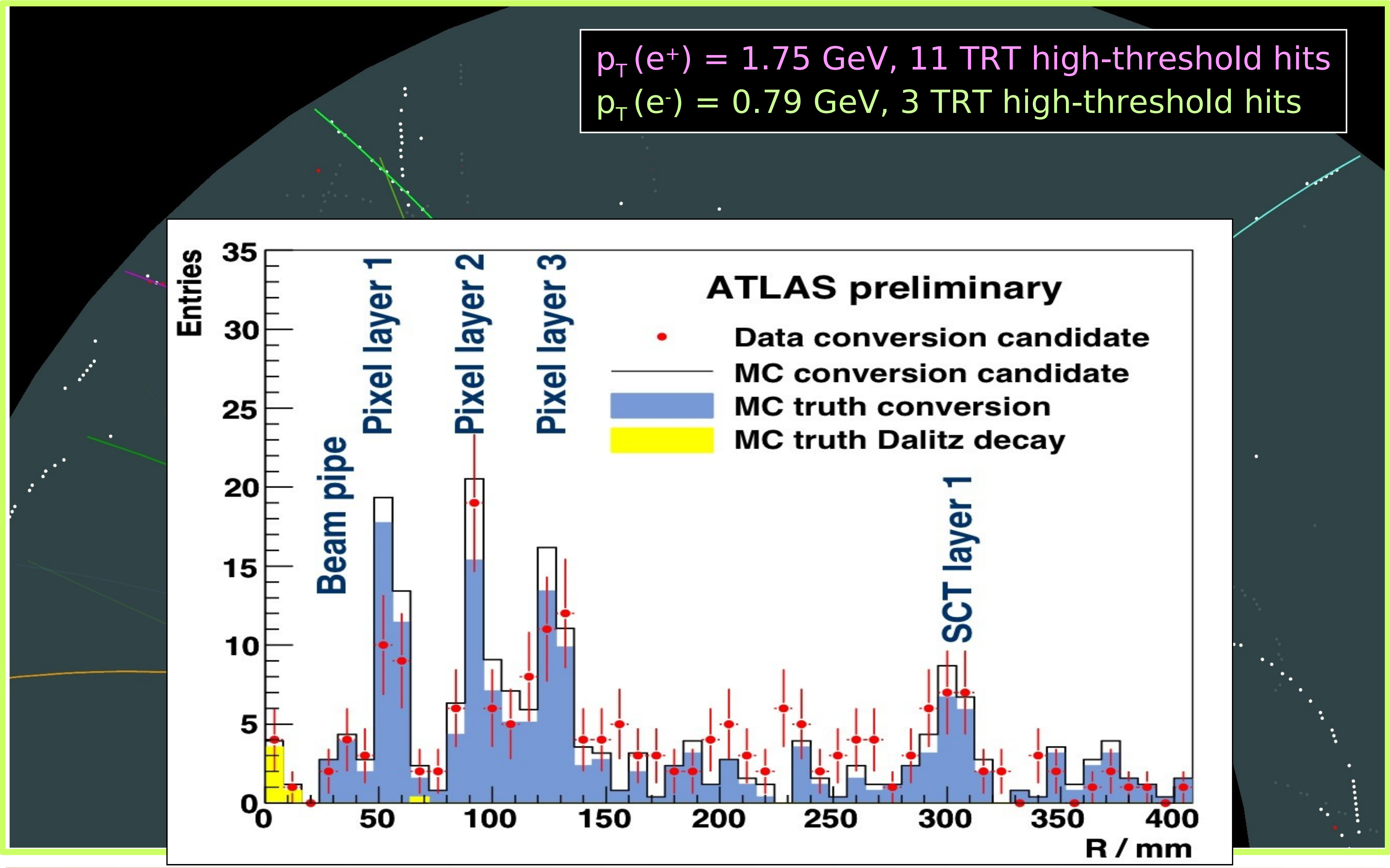
Figure 10: The dE/dx measured in data as a function of momentum.

- Charge particles with $200 < p_T < 800$ MeV with dE/dx tag.
- Mass in agreement with PDG value.

γ→ e⁺e⁻ conversions

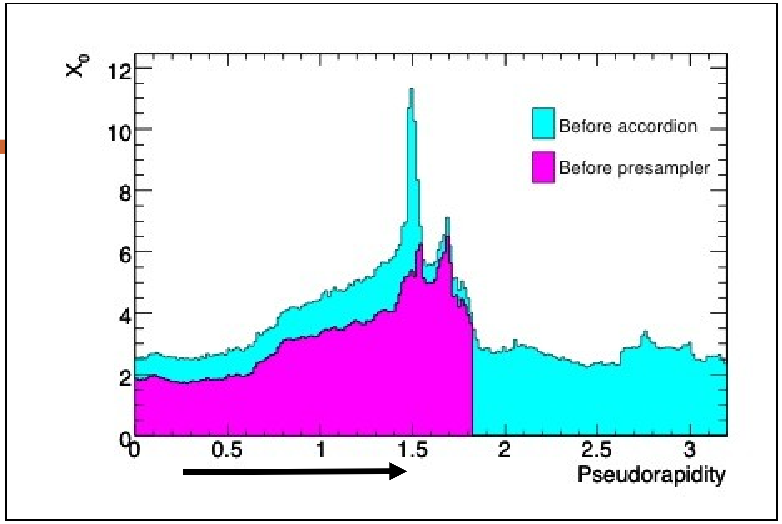


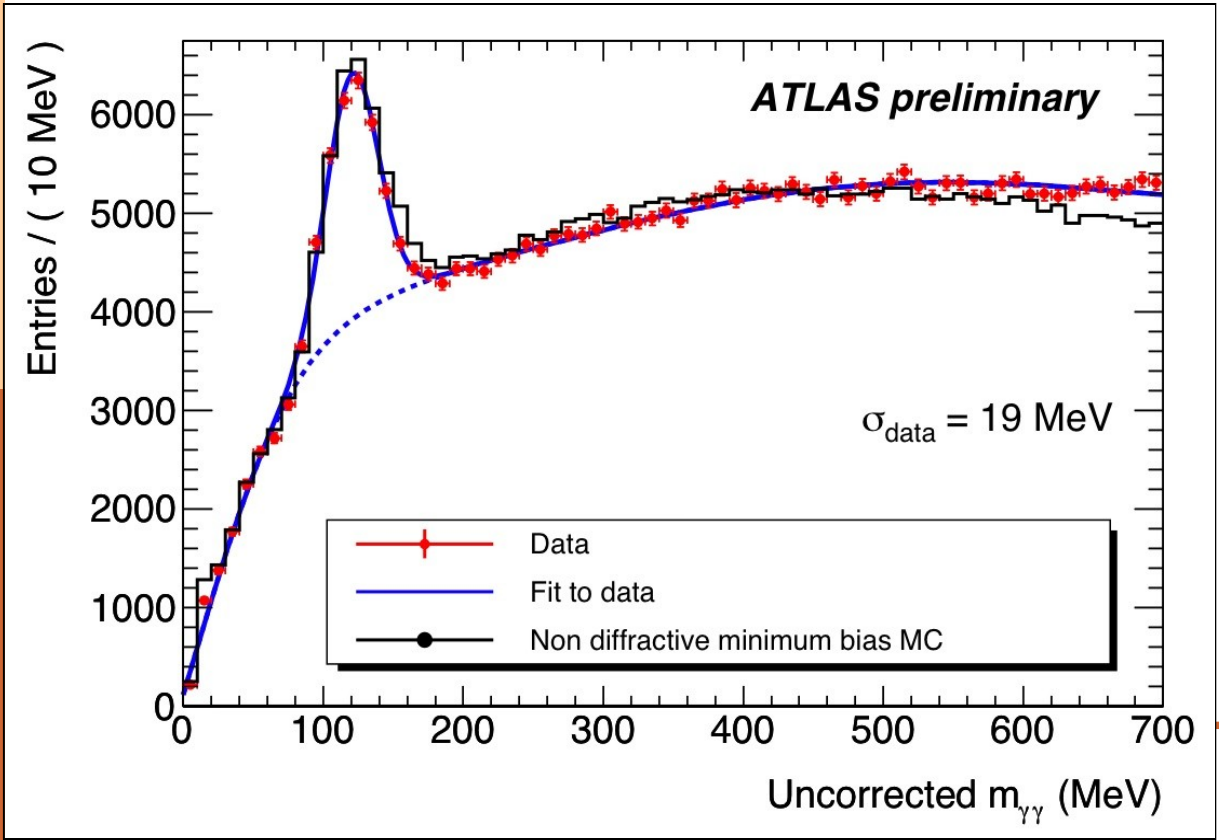
γ→ e+e- conversions



$\pi^0 \to \gamma\gamma$

- 2 photon candidates with $E_T(\gamma) > 300$ MeV
- $E_T(\gamma\gamma) > 900$ MeV
- Shower shapes compatible with photons
- No corrections for upstream material

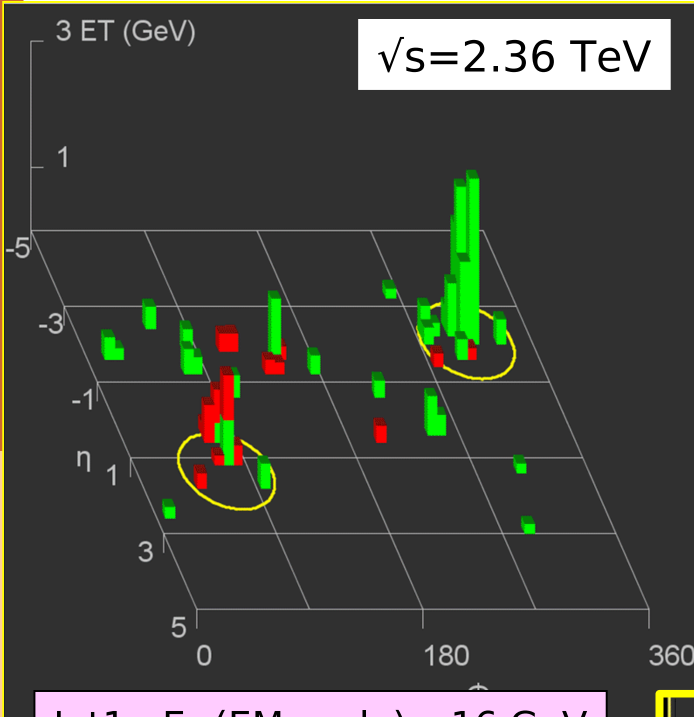




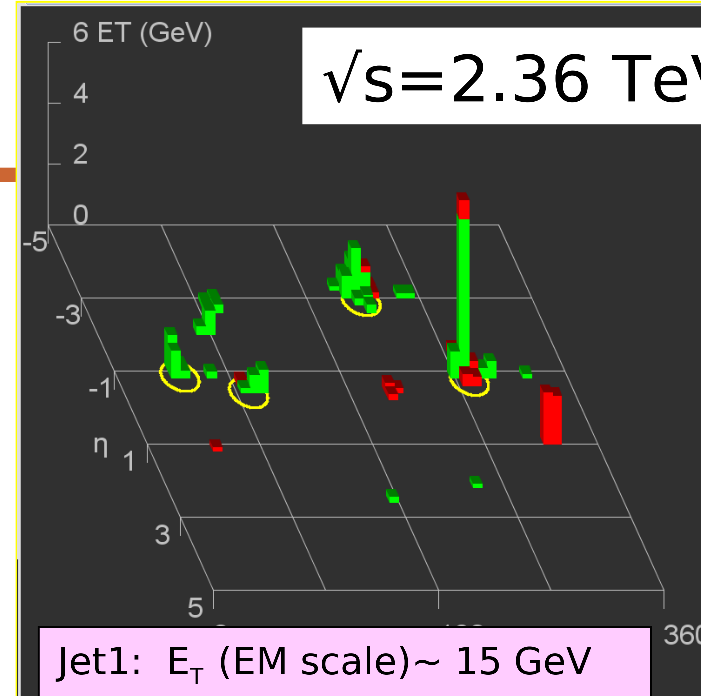
Note: soft photons are challenging because of material in front of EM calorimeter (cryostat, coil): ~ 2.5 X_0 at η=0

Data and MC normalised to the same area

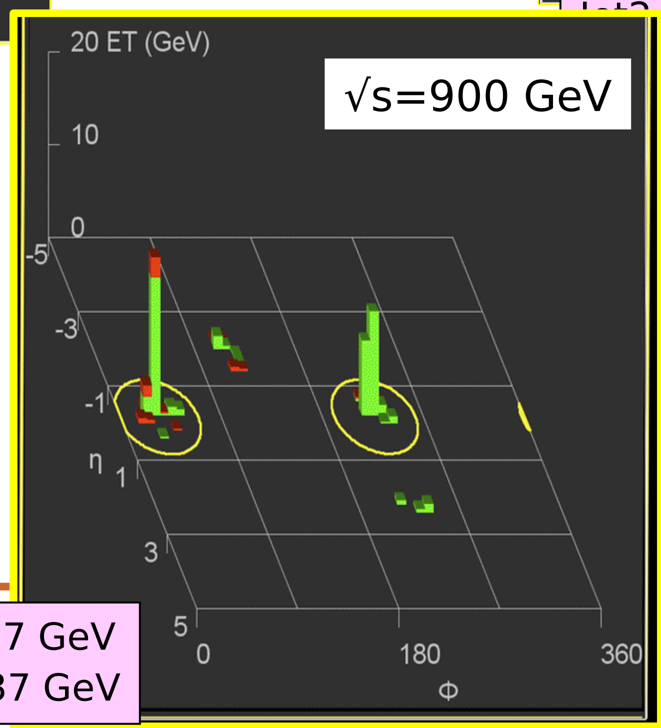
Jets



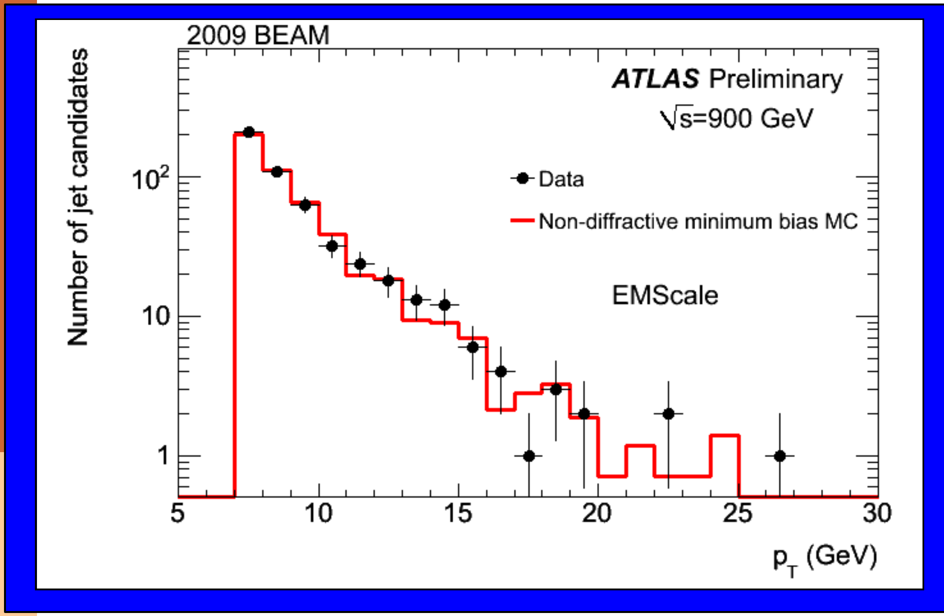
Jet1: E_T (EM scale)~ 16 GeV
Jet2: E_T (EM scale) ~ 6 GeV

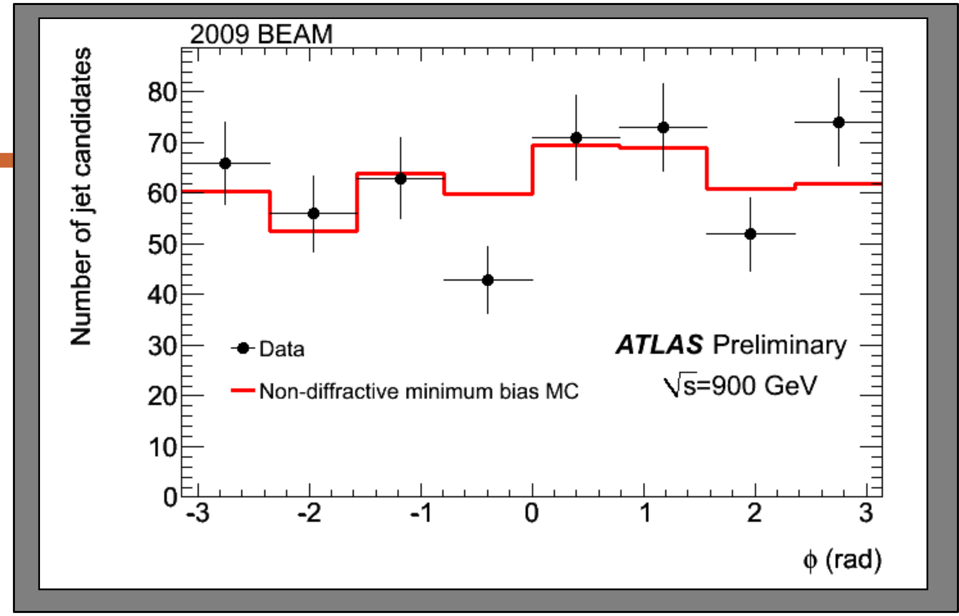


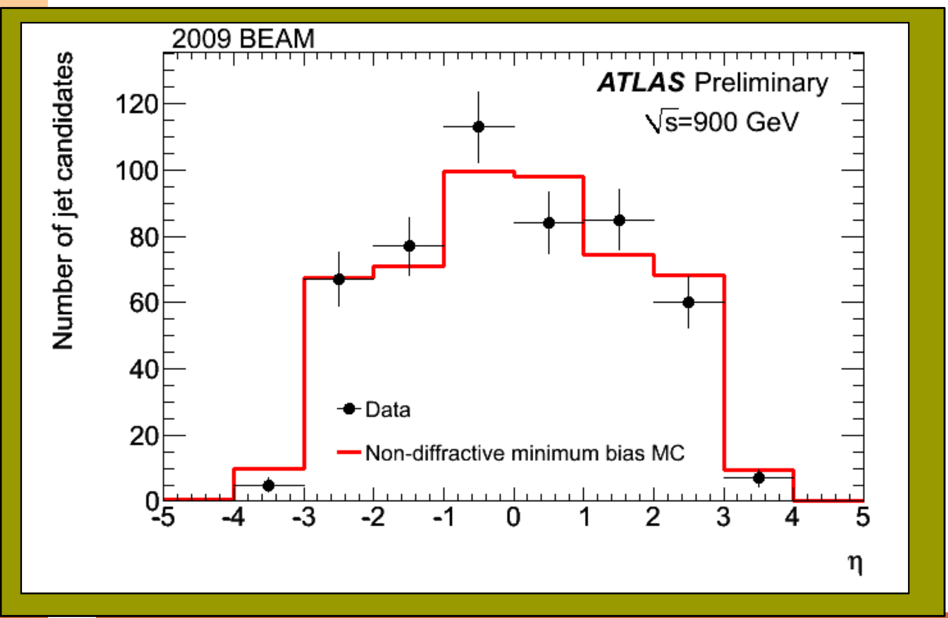
Jet1: E_T (EM scale)~ 15 GeV
Jet2: E_T (EM scale) ~ 12.5 GeV

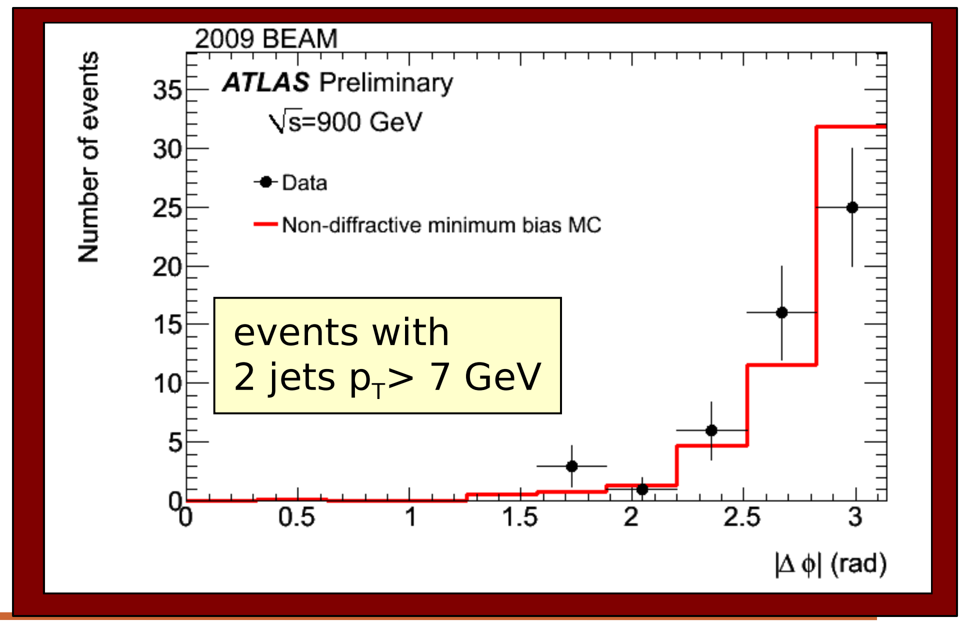


Jet1: E_T (EM scale)~ 37 GeV
Jet2: E_T (EM scale) ~ 37 GeV







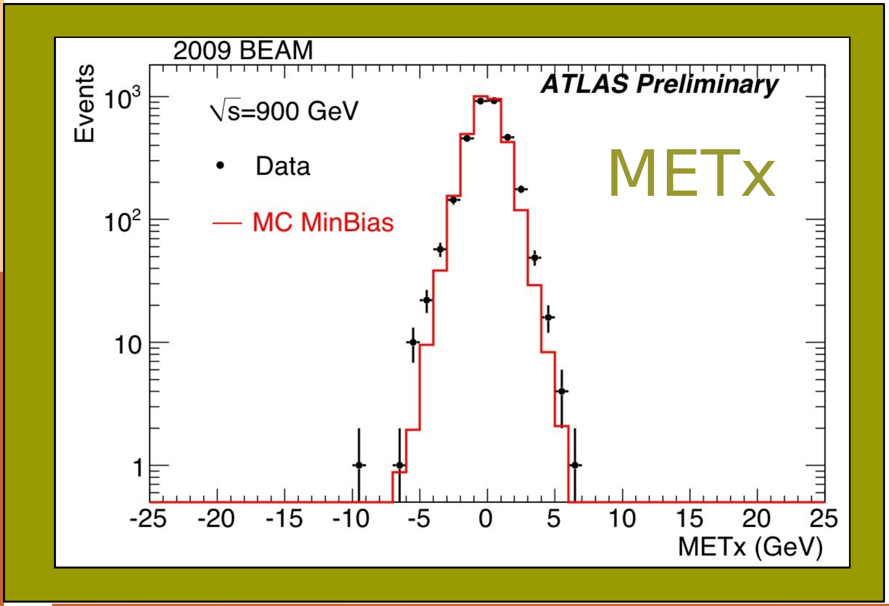


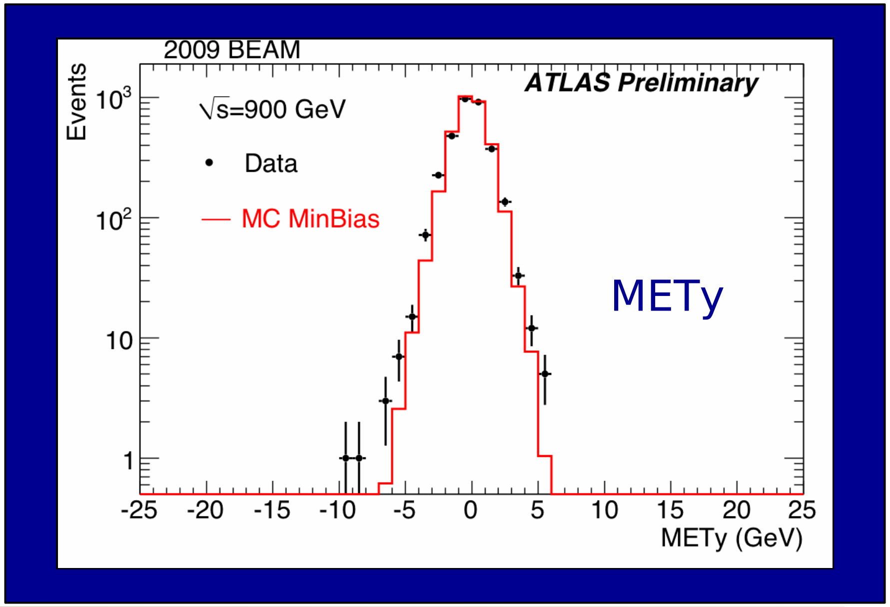
Uncalibrated EM scale
Monte Carlo normalized to number of jets or events in data

Missing transverse energy

- Sensitive to calorimeter performance (noise, coherent noise,
- dead cells, mis-calibrations,
  cracks, etc.) and backgrounds from cosmics, beams, ...
- Measurement over full calorimeter coverage (360^0 in φ, |η| < 5, ~ 200000 cells)

METx / METy indicate x/y components of missing E_T vector

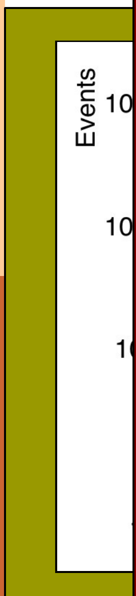


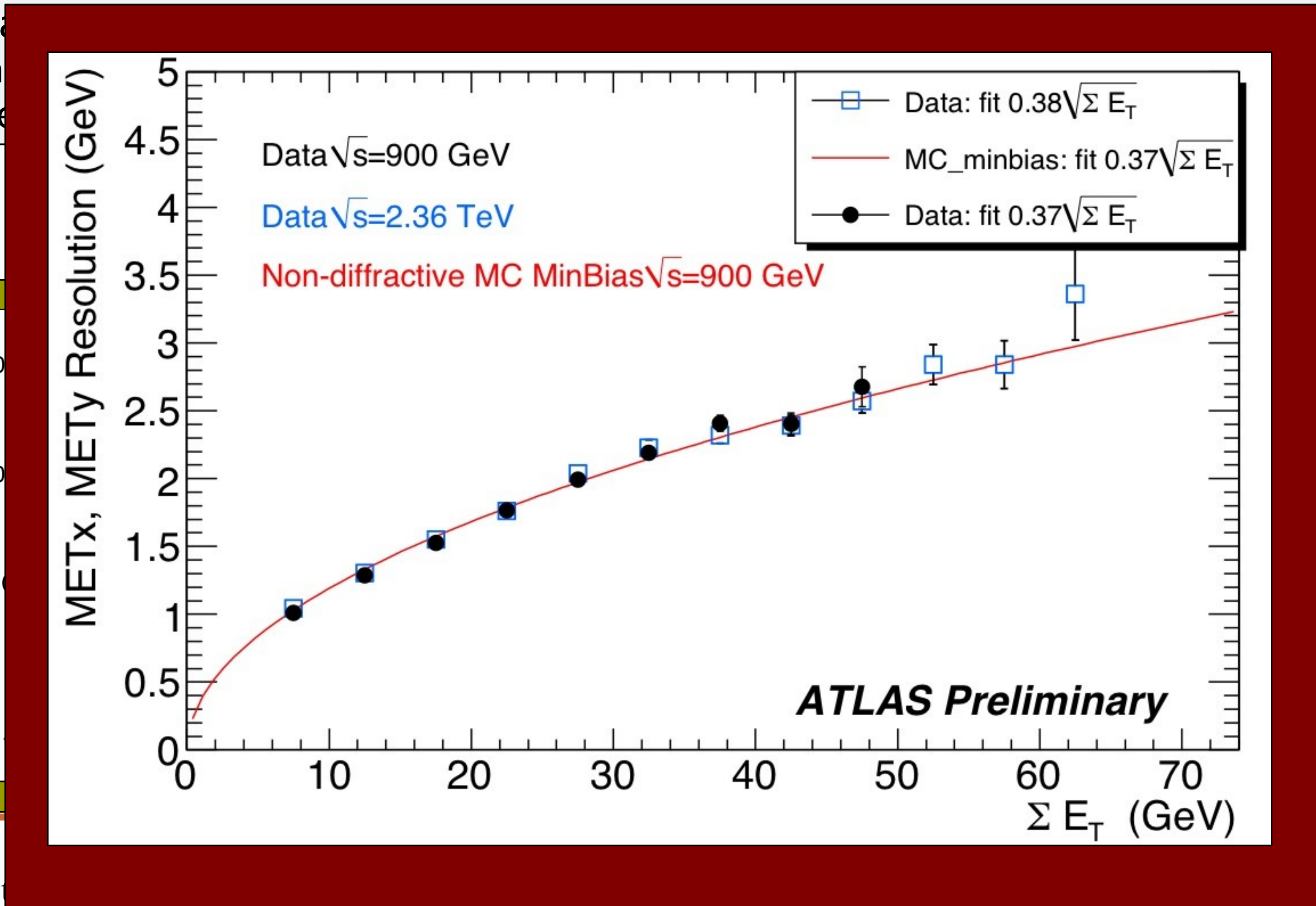


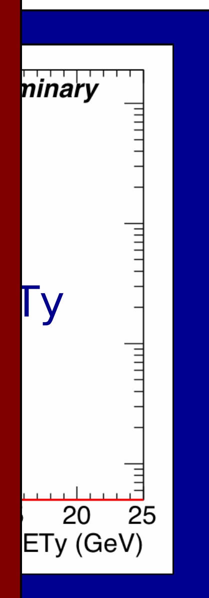
Missing transverse energy

- Sensitive to calorimeter performance (noise, coherent noise,
- dea
  cra
- Me ... 00 cells)

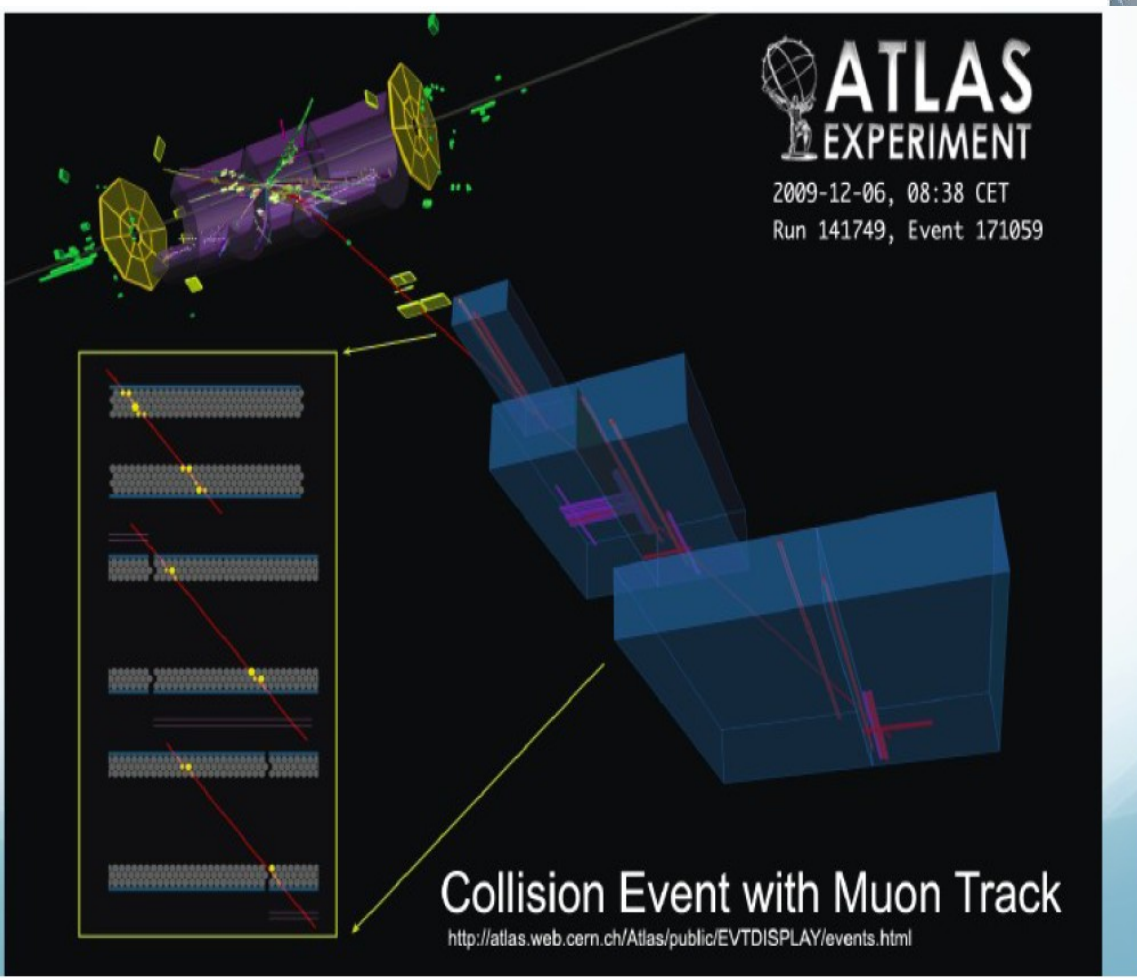
... vector

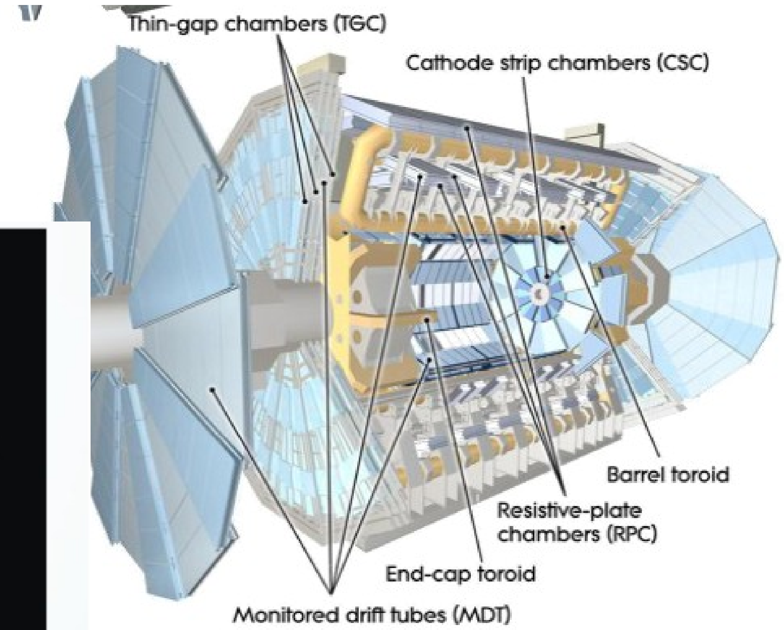






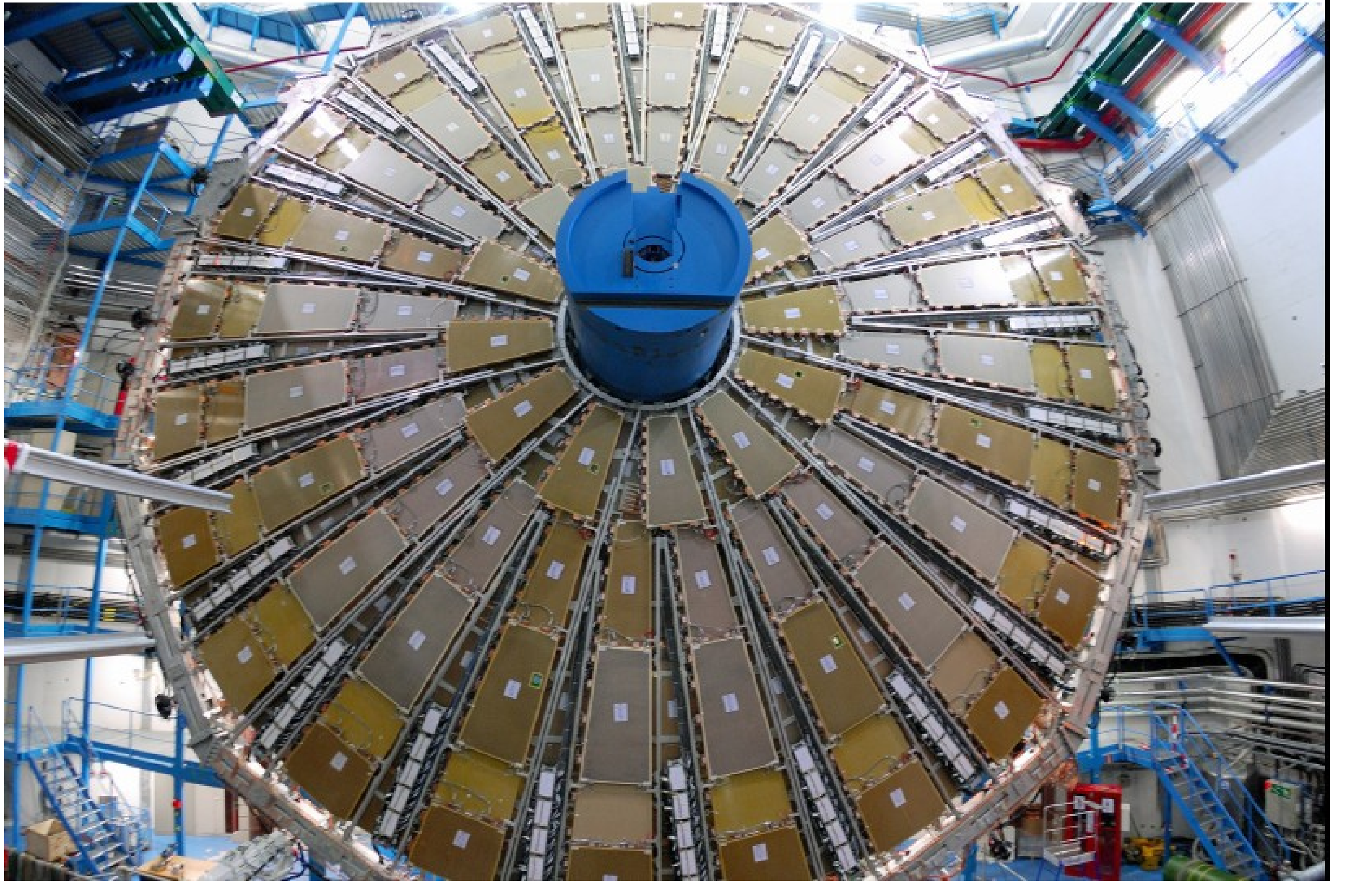
Muons


ATLAS
EXPERIMENT
2009-12-06, 08:38 CET
Run 141749, Event 171059
Collision Event with Muon Track
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html


Thin-gap chambers (TGC)
Cathode strip chambers (CSC)
Barrel toroid
Resistive-plate chambers (RPC)
End-cap toroid
Monitored drift tubes (MDT)

Muon detector

One more view of the first installed TGC Big Wheel



Summary

- Based on the 2009 datasets ATLAS has published
  - XX conference notes (winter conferences)
  - Performance paper:
    - arXiv:1005.5254 ; CERN-PH-EP-2010-015
  - Physics paper: “Charged-particle multiplicities in pp interactions at $\sqrt{s}$ = 900 GeV measured with the ATLAS detector at the LHC”
    - arXiv:1003.3124; CERN-PH-EP-2010-004

      Phys. Lett. B 688 (2010) 21-42

Then…more data and publications came very quickly…

Next topics

- 17.10 – soft QCD
- 24.10 – hard QCD
- 7.11 - W, Z bosons: inclus. cross-sections, W/Z+jets
- 14.11 – W, Z bosons:precise measurements
- 21.11 – Top: xsection, mass
- 28.11 – Dibosons and anomalous couplings
- 5.12, 12.12 - **Higgs**
- 19.12 – **SUSY**
- 9.1 – other searches for New Physics
- 16.1 - B-physics programme
- 23.1 – heavy ion programme