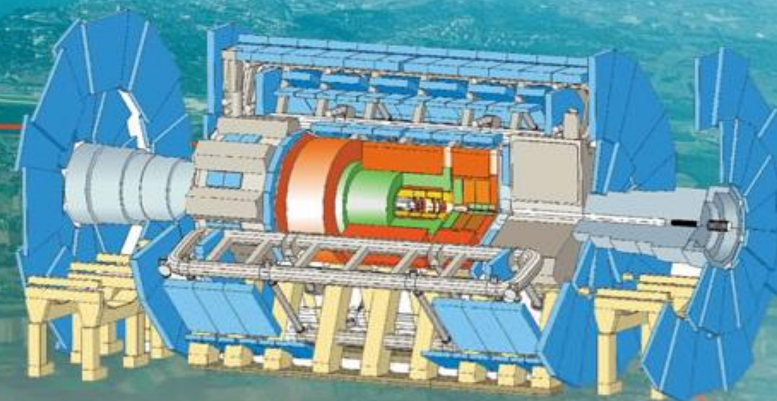
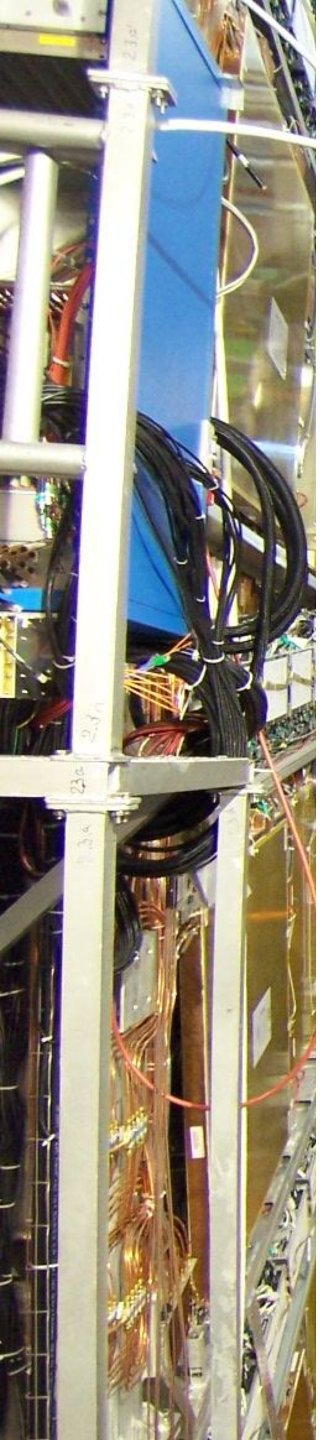
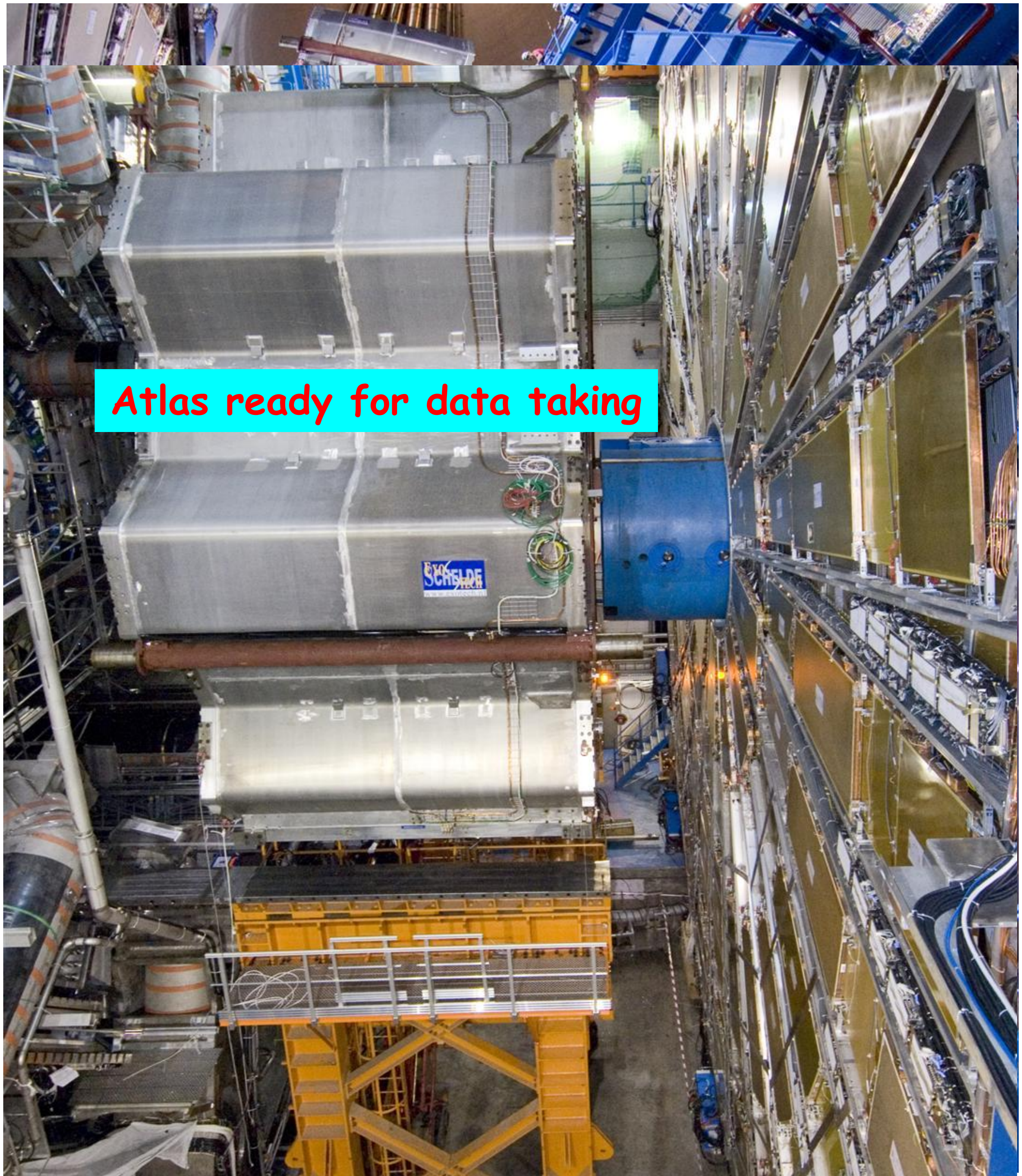
Status of the LHC program

Emmanuel MONNIER
CPPM/CERN

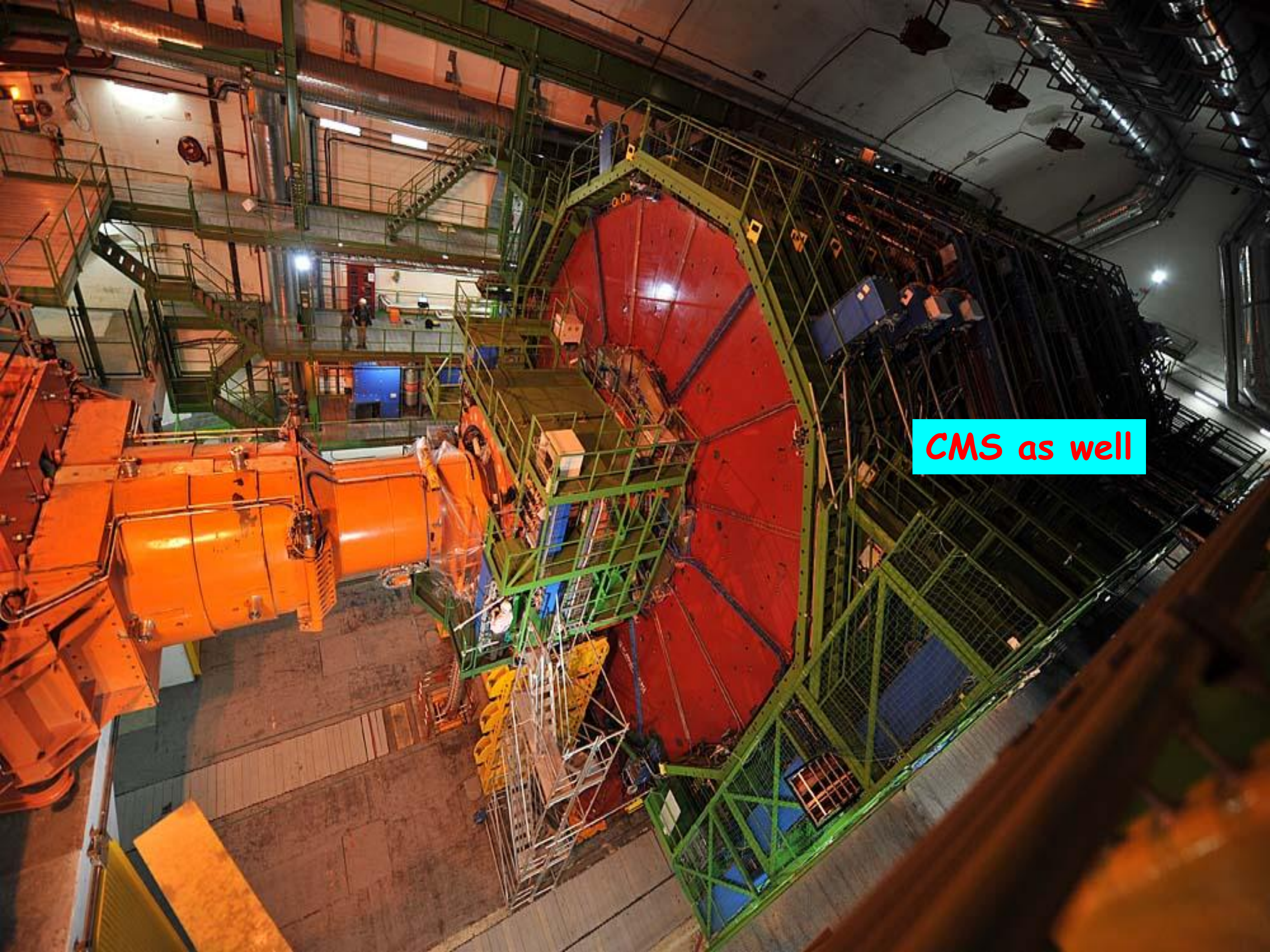


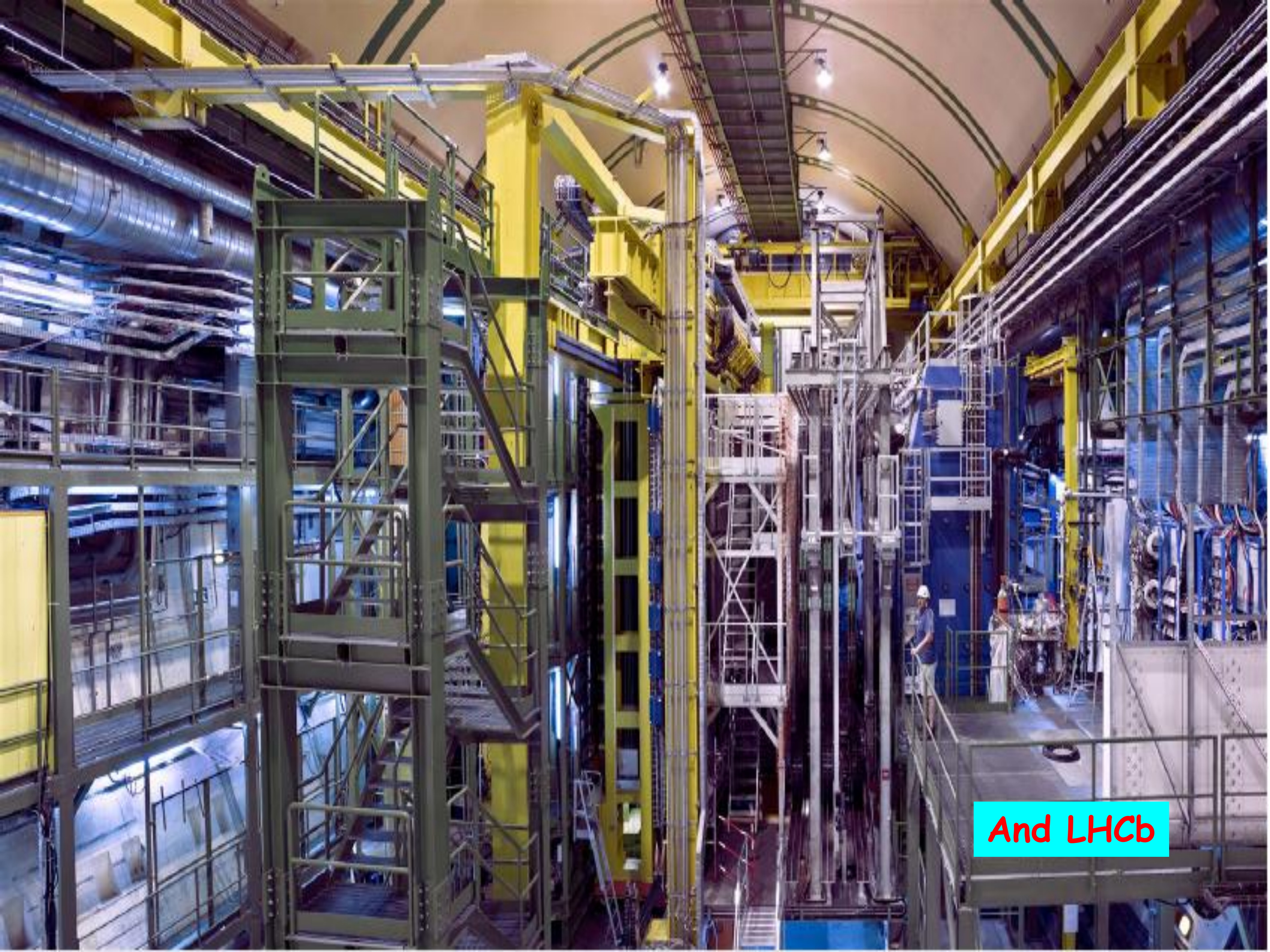
Wuhan 17 March 2009





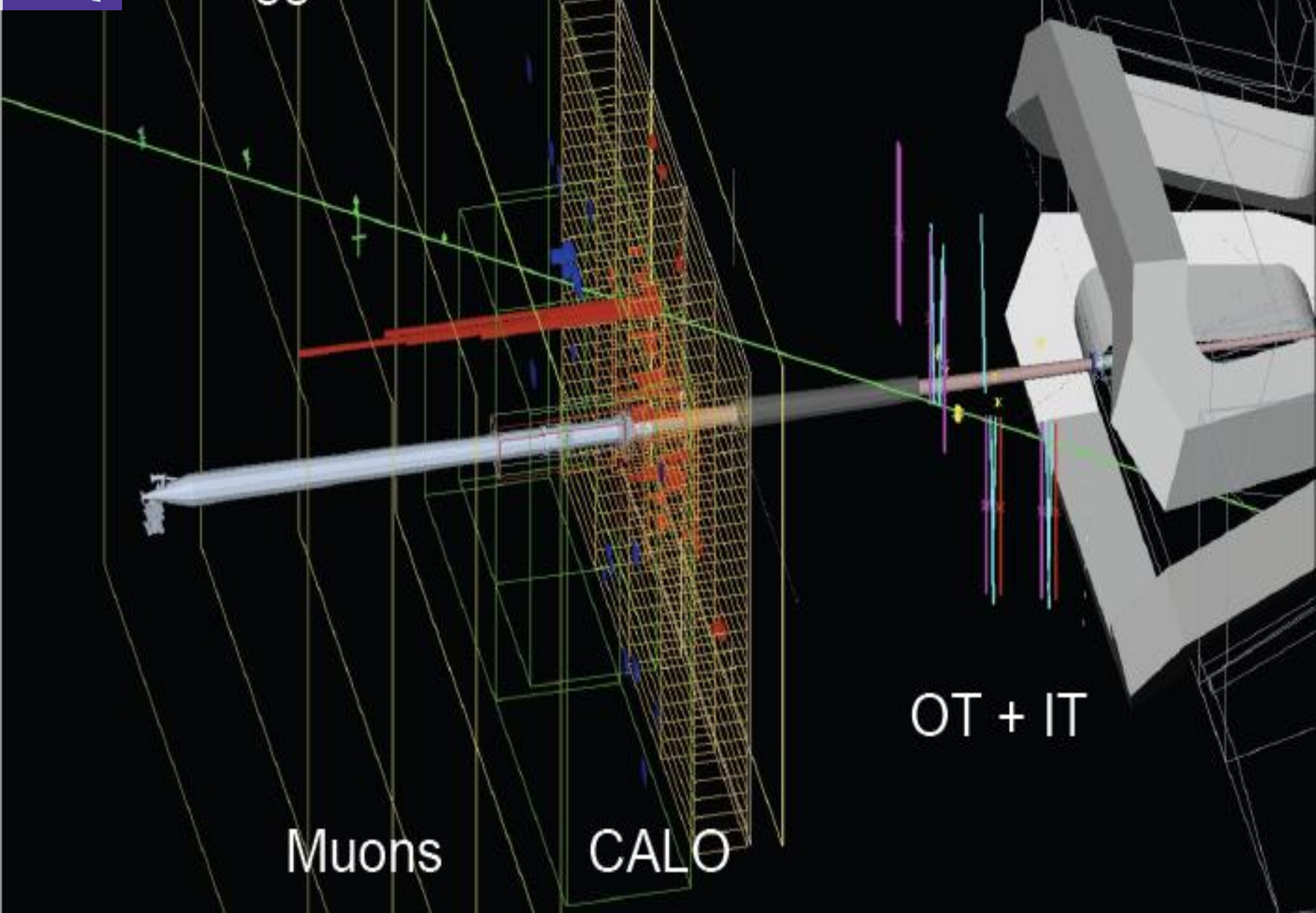
Atlas ready for data taking

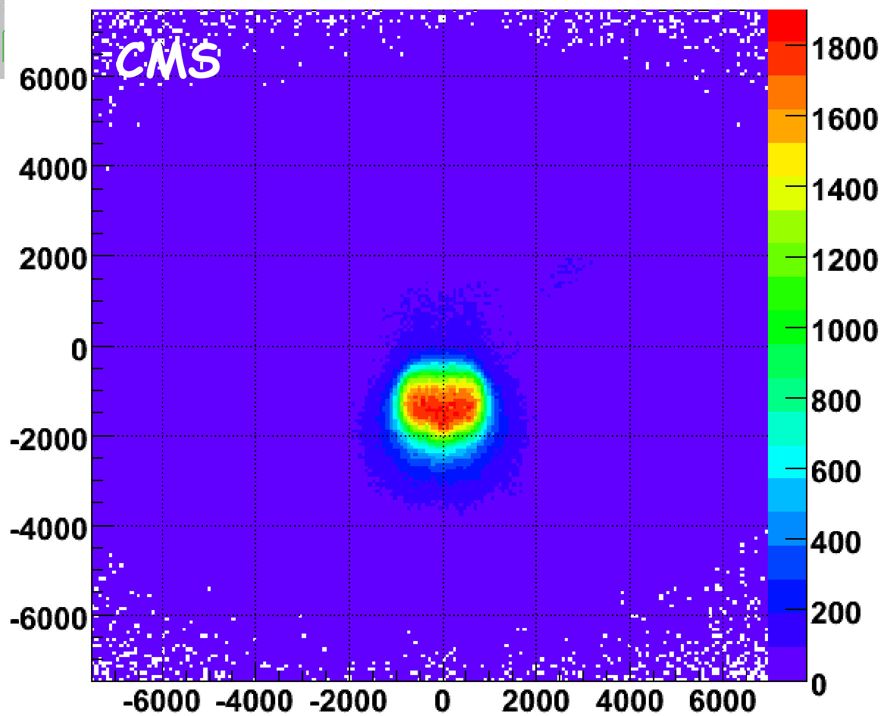

CMS as well

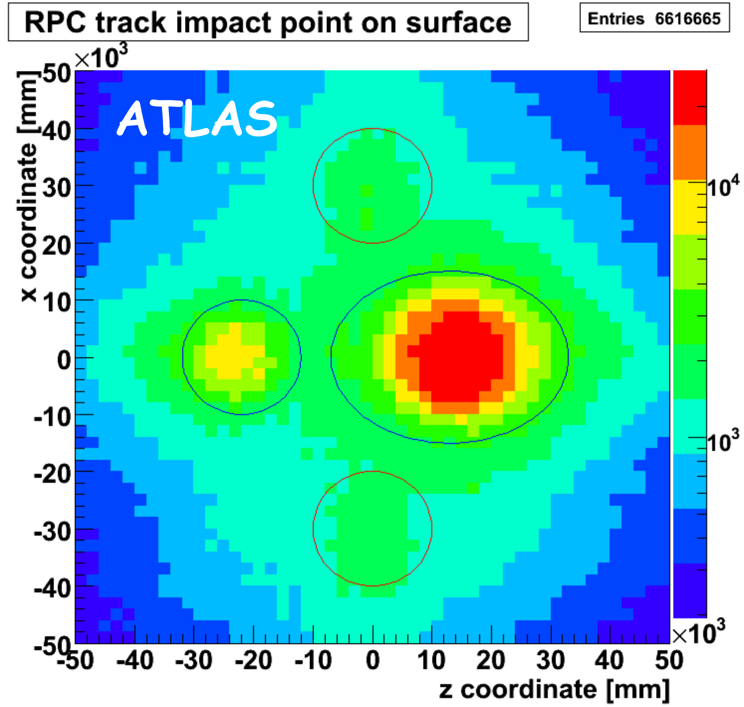

And LHCb

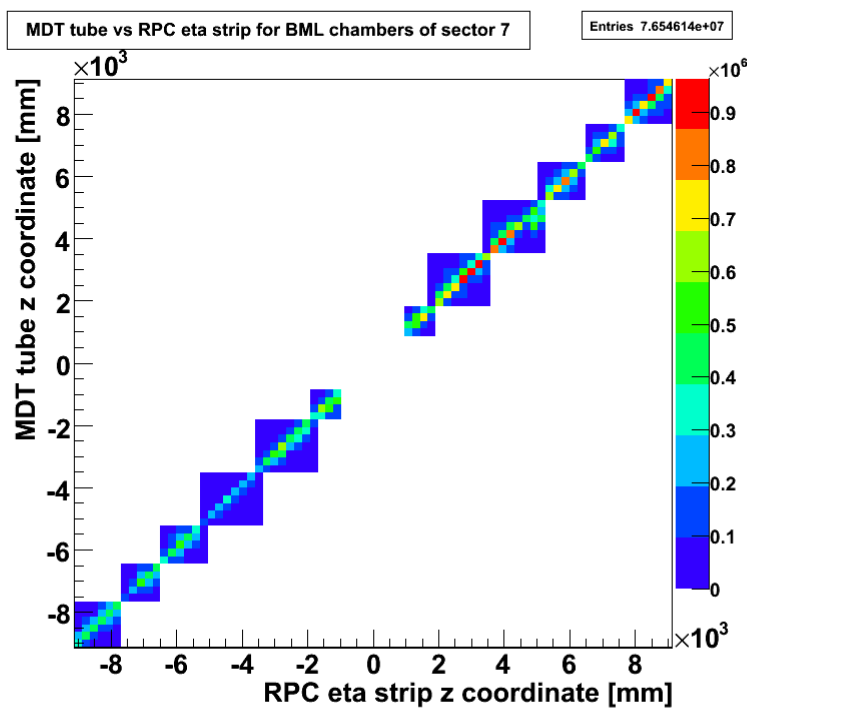
And Alice

Trigger: ECAL and HCAL coincidence.

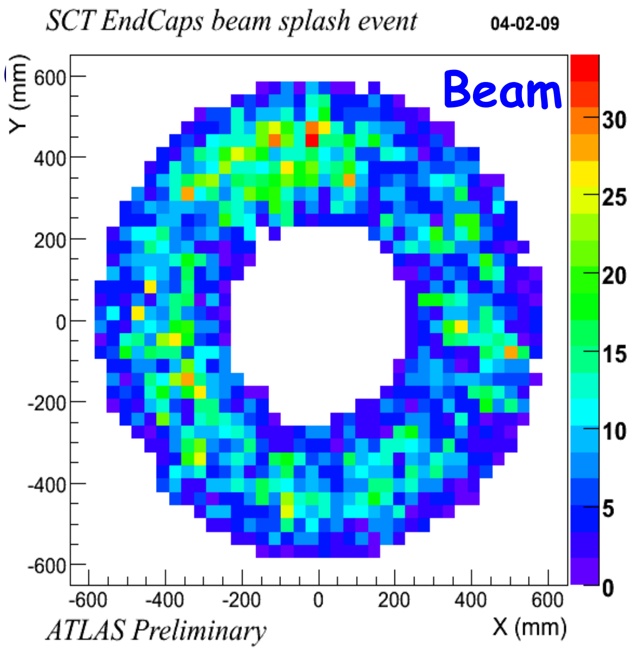


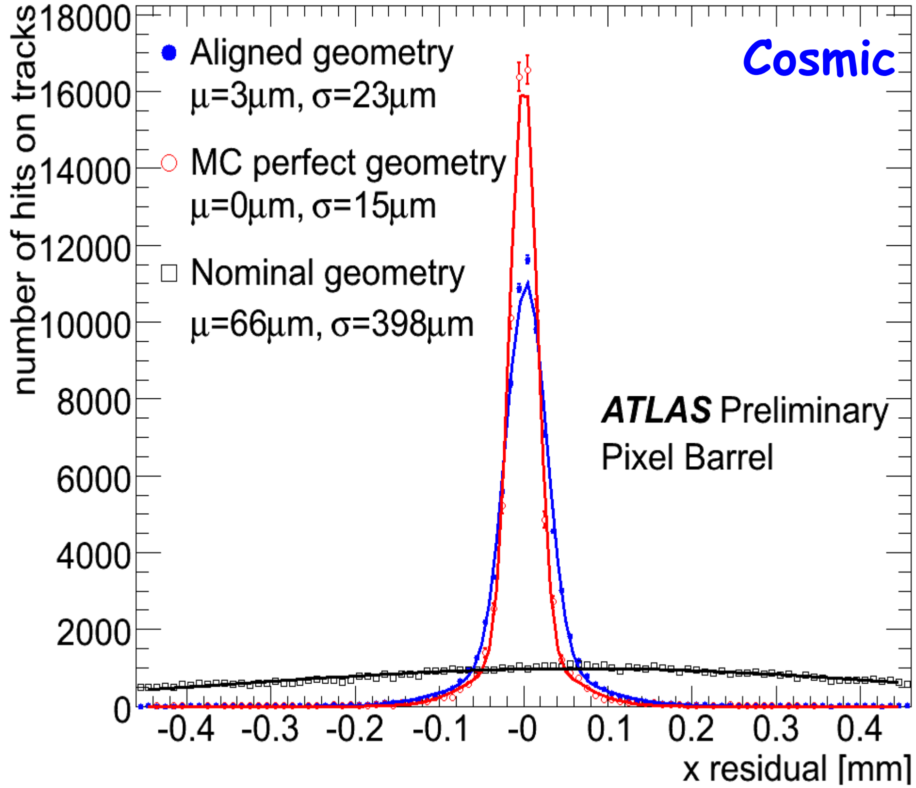


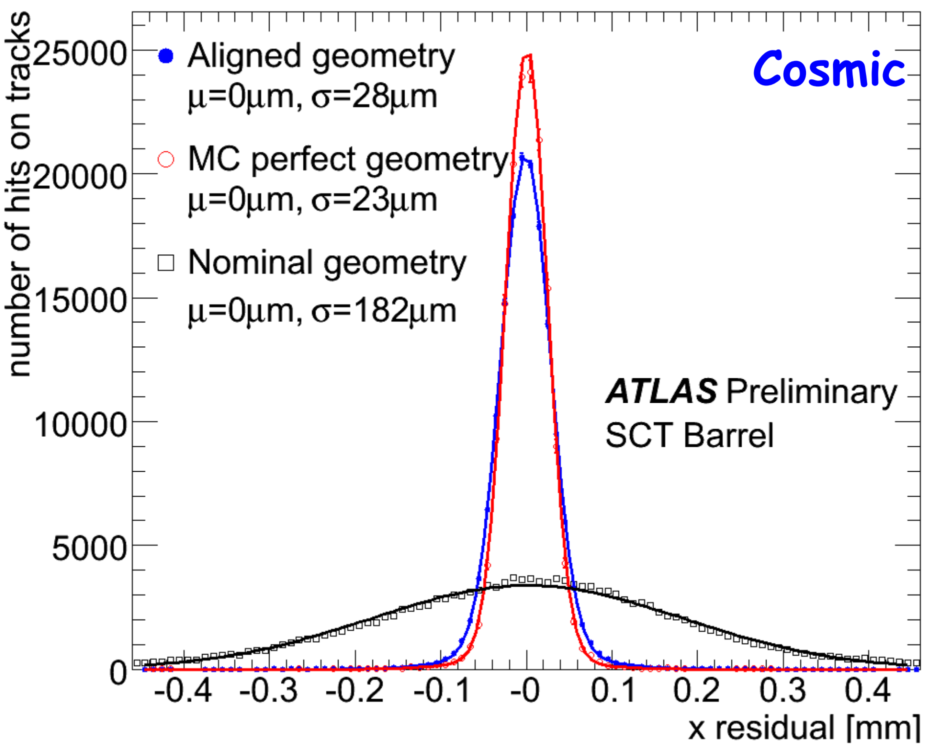


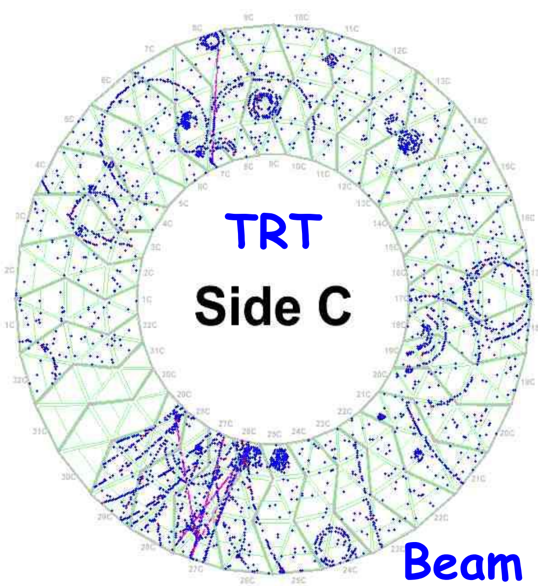


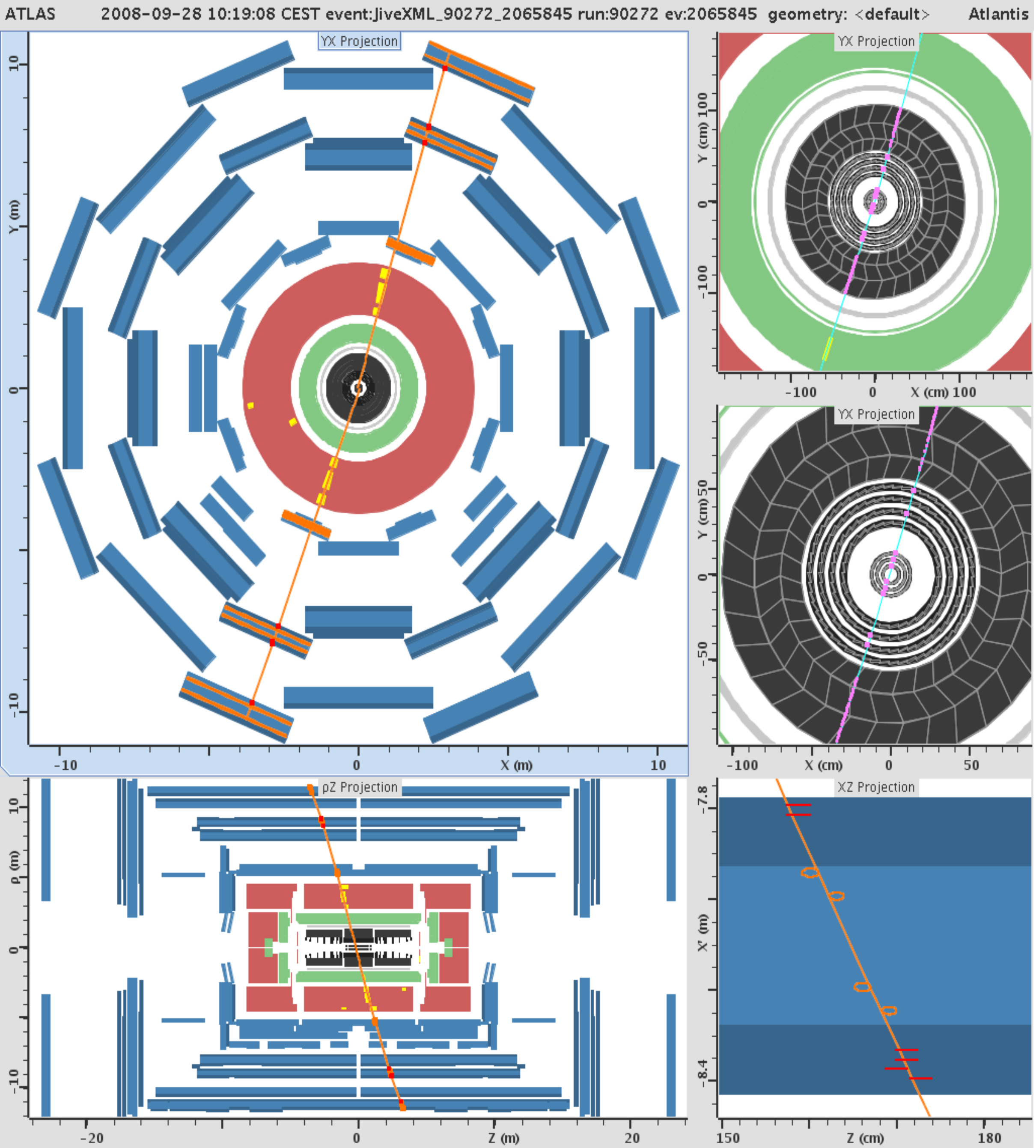
Cosmic tracks extrapolated to the surface

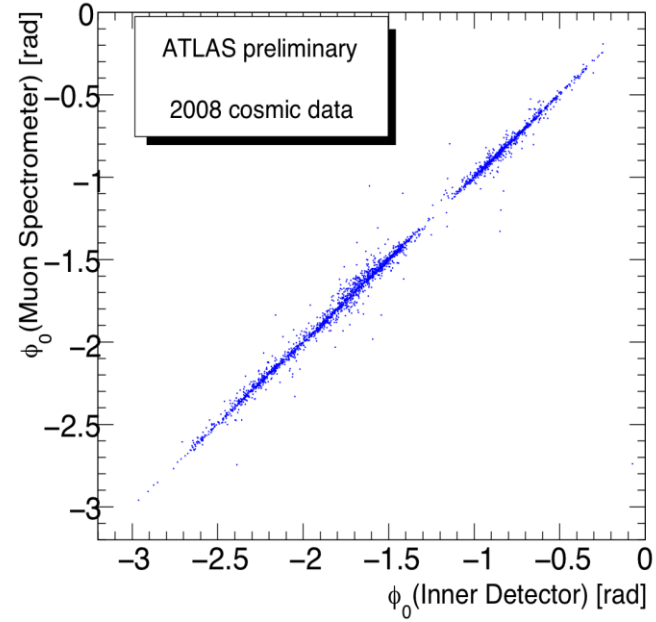

SCT EndCaps beam splash event
04-02-09
Beam
Y (mm)
X (mm)
ATLAS Preliminary

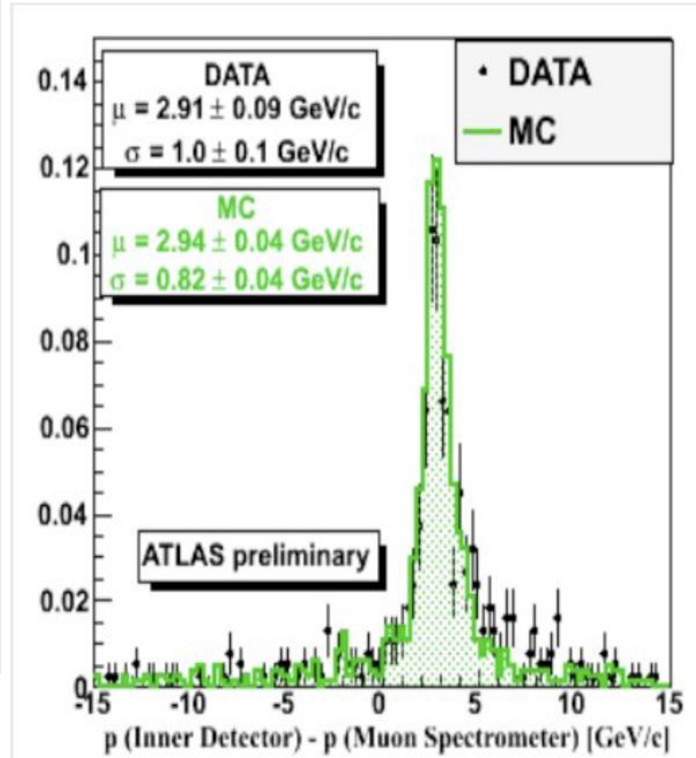

Cosmic
Aligned geometry
μ=3μm, σ=23μm
MC perfect geometry
μ=0μm, σ=15μm
Nominal geometry
μ=66μm, σ=398μm
ATLAS Preliminary
Pixel Barrel
number of hits on tracks
x residual [mm]


Cosmic
Aligned geometry
μ=0μm, σ=28μm
MC perfect geometry
μ=0μm, σ=23μm
Nominal geometry
μ=0μm, σ=182μm
ATLAS Preliminary
SCT Barrel
number of hits on tracks
x residual [mm]


TRT
Side C
Beam


ATLAS 2008-09-28 10:19:08 CEST event:JiveXML_90272_2065845 run:90272 ev:2065845 geometry: <default> Atlantis
YX Projection
Y (m)
X (m)
YX Projection
Y (cm)
X (cm)
YX Projection
Y (cm)
X (cm)
ρZ Projection
ρ (m)
Z (m)
XZ Projection
X' (m)
Z (cm)


ATLAS preliminary
2008 cosmic data
ϕ_0(Muon Spectrometer) [rad]
ϕ_0(Inner Detector) [rad]

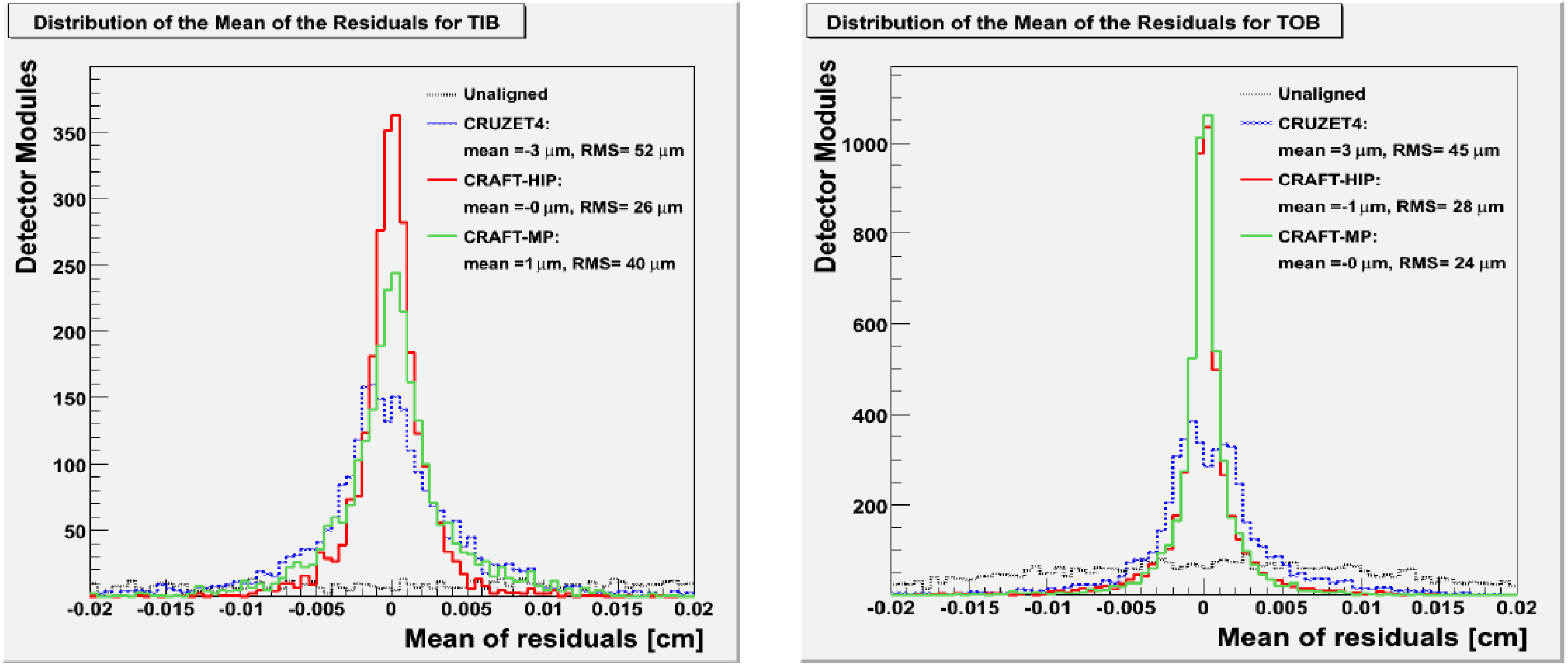

DATA
μ = 2.91 ± 0.09 GeV/c
σ = 1.0 ± 0.1 GeV/c
MC
μ = 2.94 ± 0.04 GeV/c
σ = 0.82 ± 0.04 GeV/c
DATA
MC
ATLAS preliminary
p (Inner Detector) - p (Muon Spectrometer) [GeV/c]

Tracker Barrel Alignment

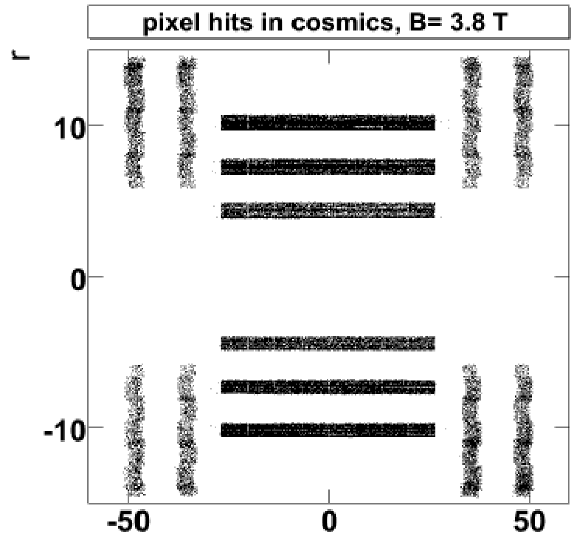
- Use 4M tracks for alignment and 1M for validation
- The second update on alignment constants delivered 1 day after CRAFT ended

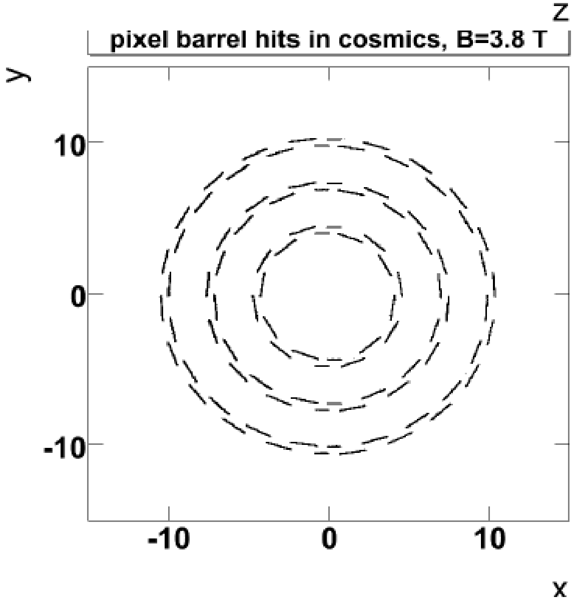
Mean of residual distributions (cm), sensitive to module displacements

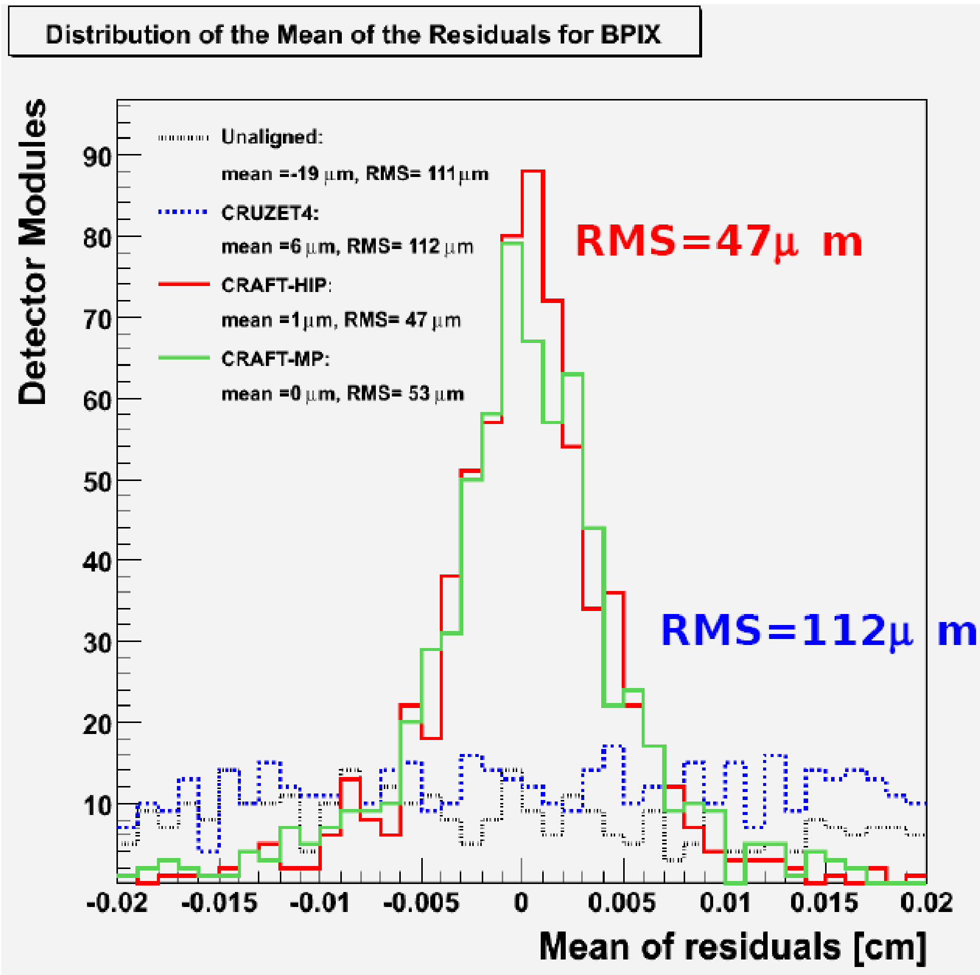
- Only modules with >30 hits considered
- Tracker Inner Barrel RMS = 26µm Tracker Outer Barrel RMS = 28µm



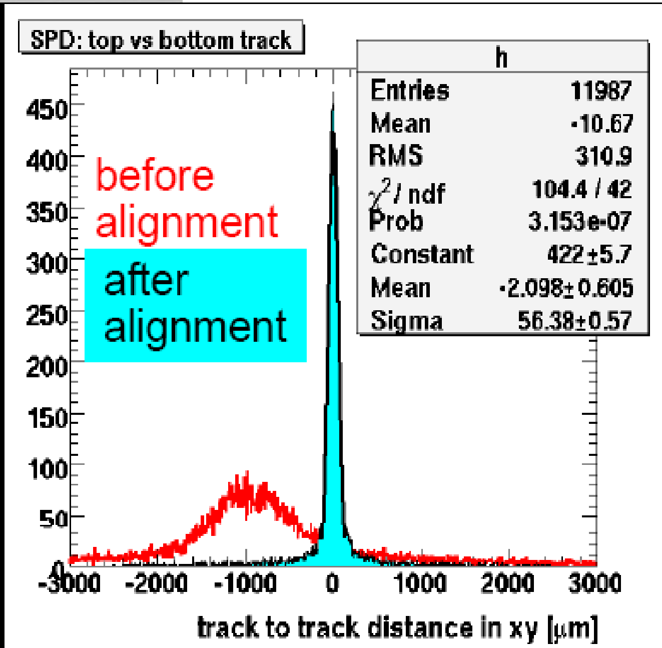
Pixel Occupancy and Alignment

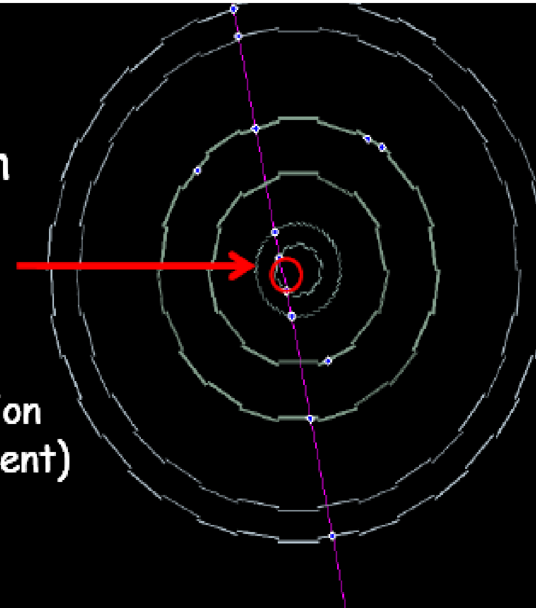




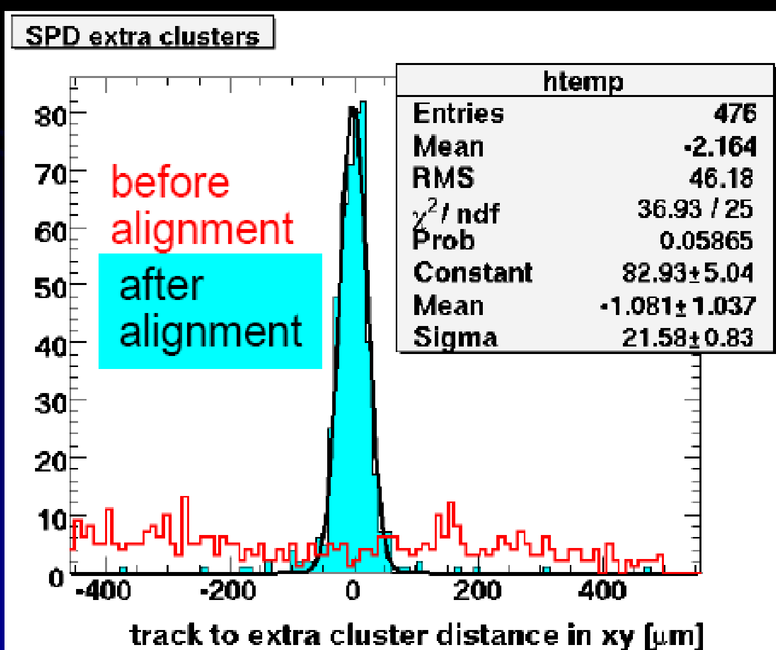


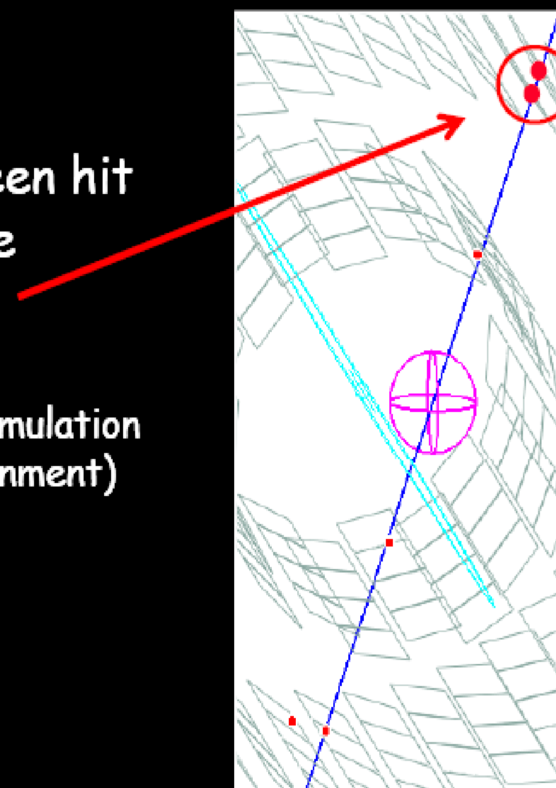
- ~75K tracks yielding 200-300 hits per module in Barrel
- Barrel aligned at module level and endcap at disk level





- Distance between upper and lower track segments
  - σ = 56 μm
  - (40 μm in simulation with no misalignment)





- Distance between hit and track in the overlap region
  - σ = 22μm
  - (15 μm μm in simulation with no misalignment)

ALICE: TPC Performance

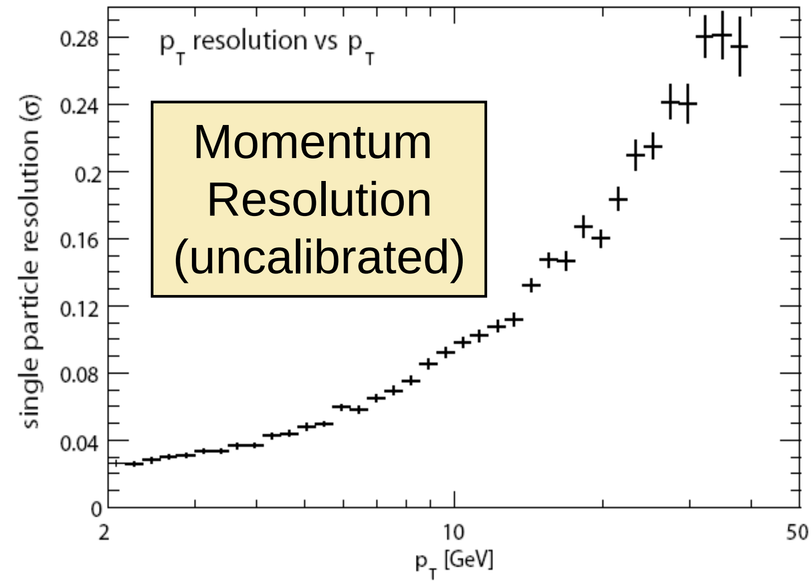
First preliminary results from cosmics

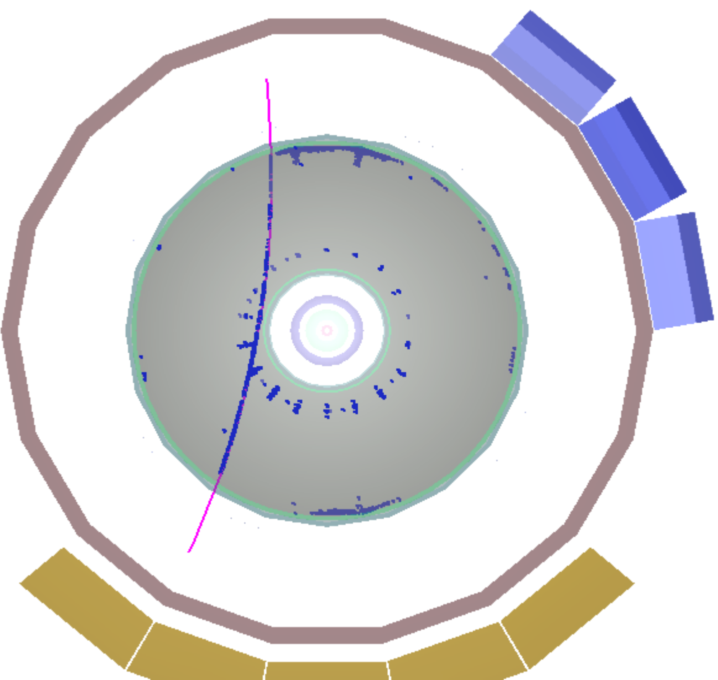
dE/dx resolution < 6% (goal: ~ 5.5%)

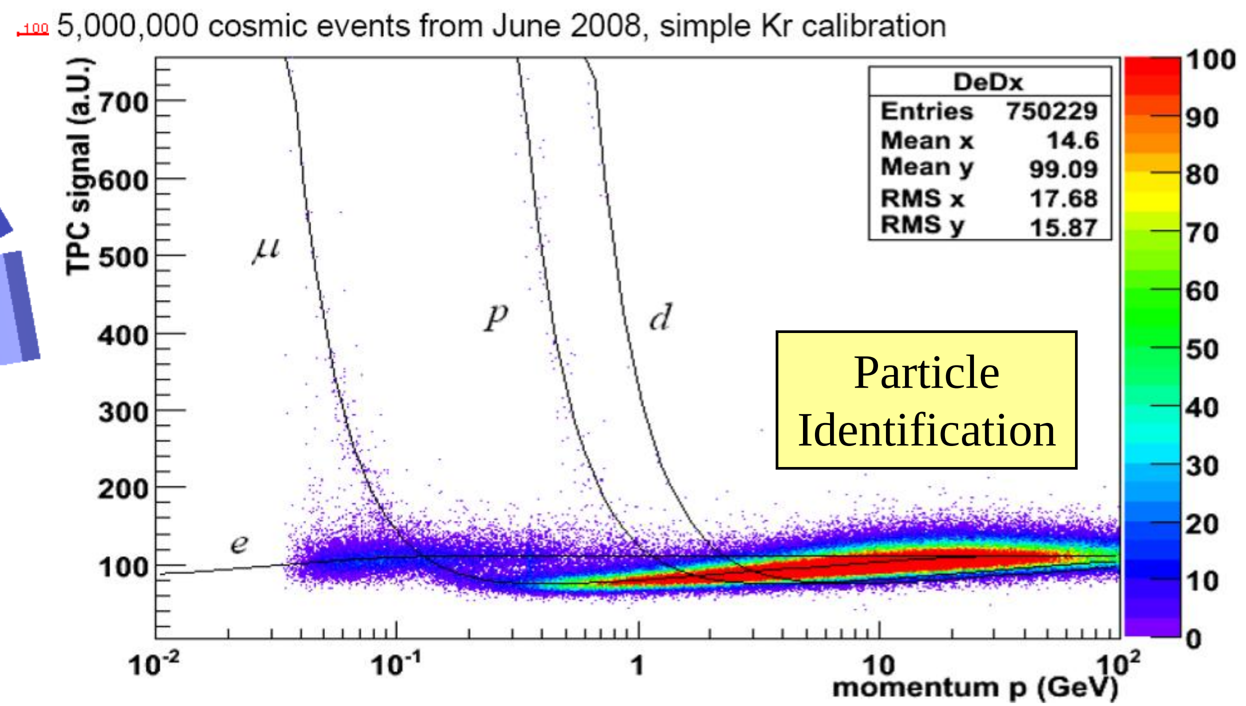
p_t resolution

~ 10% @ 10 GeV w/o calibration

(goal: ~ 5% @ 10 GeV)



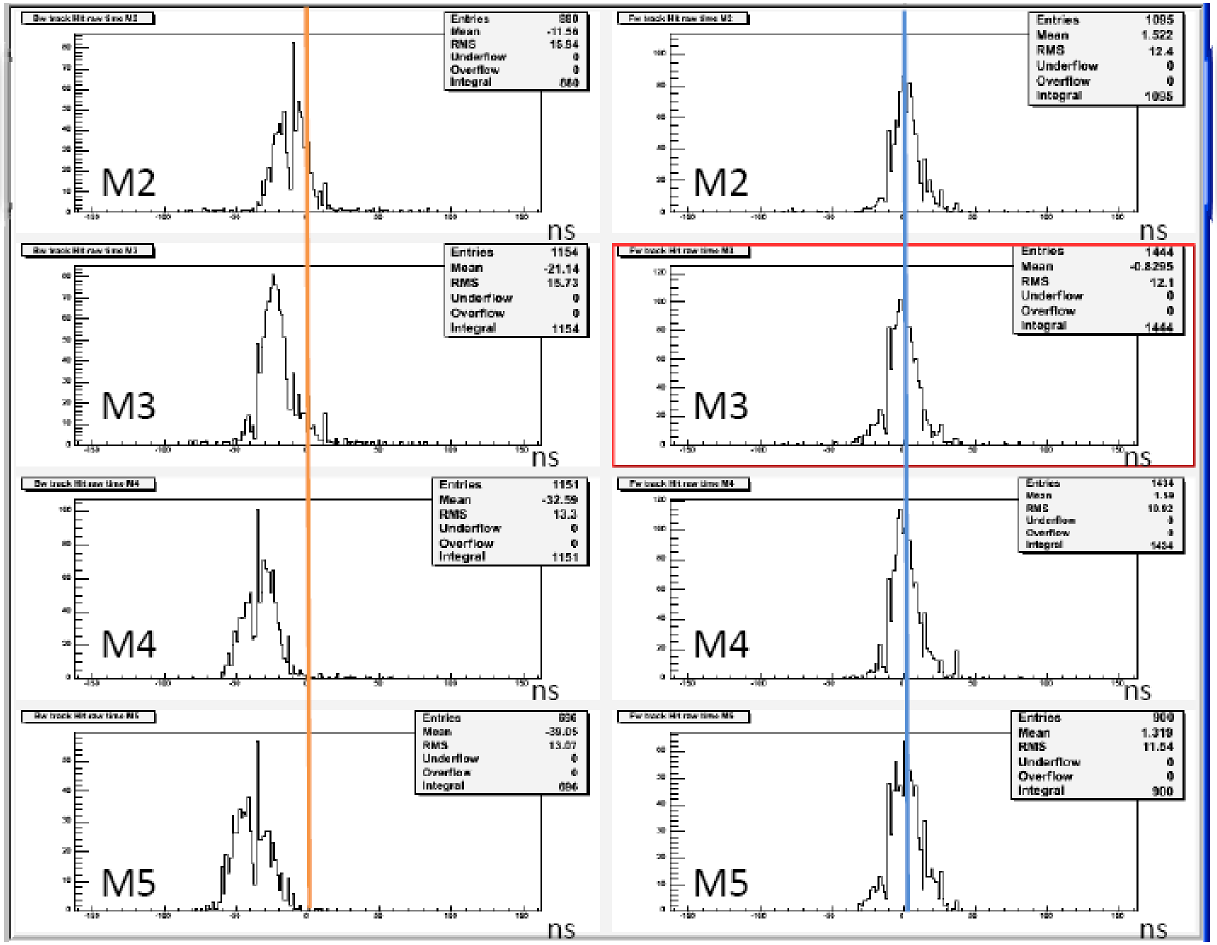


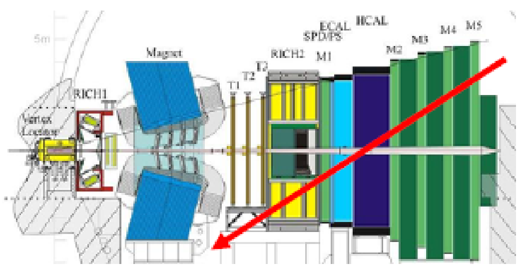


Commissioning with Cosmics (II)

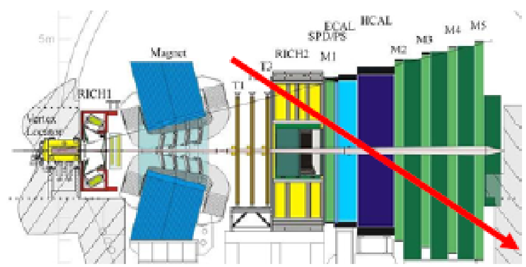
MUON Chambers

Time alignment

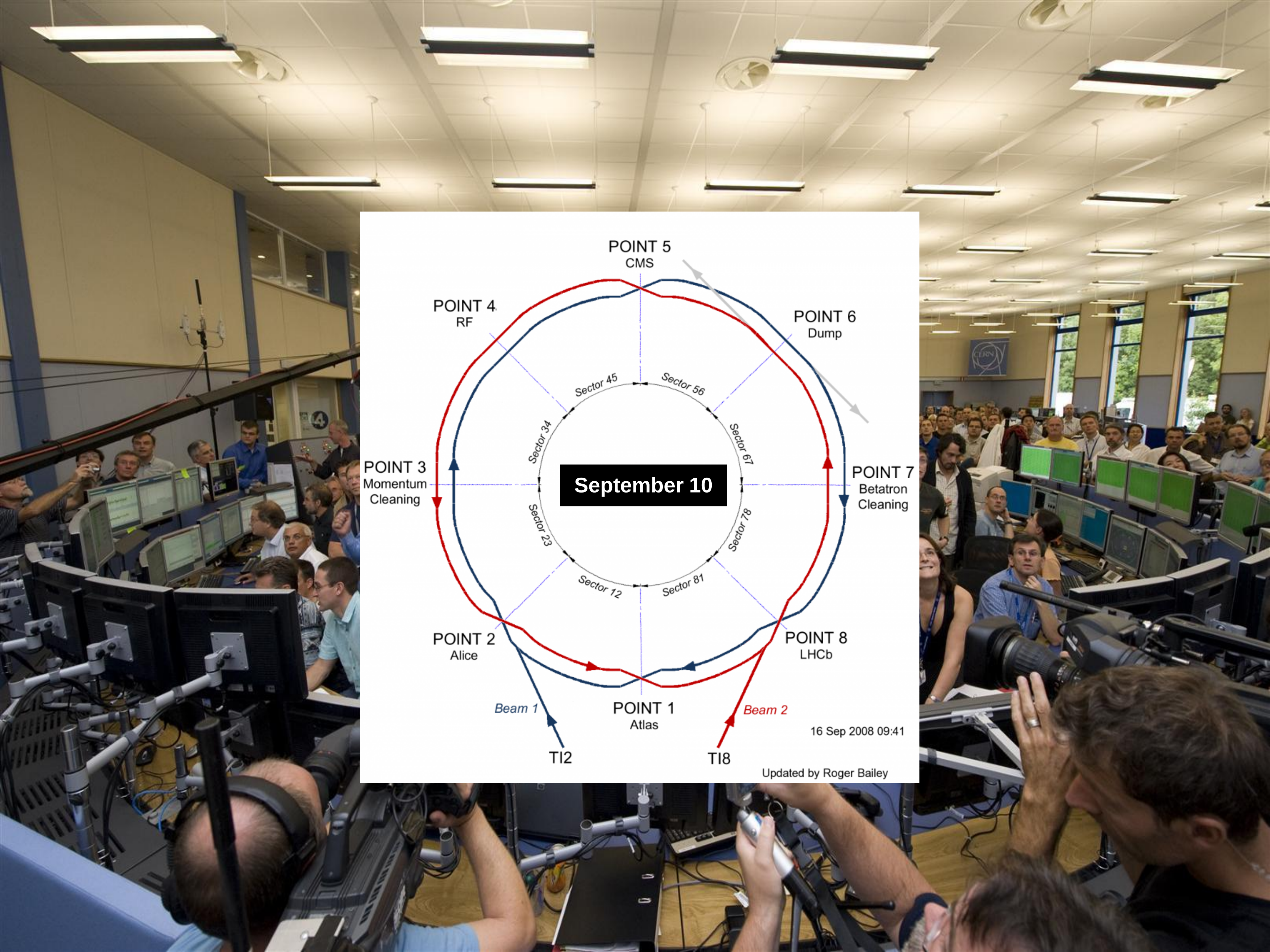




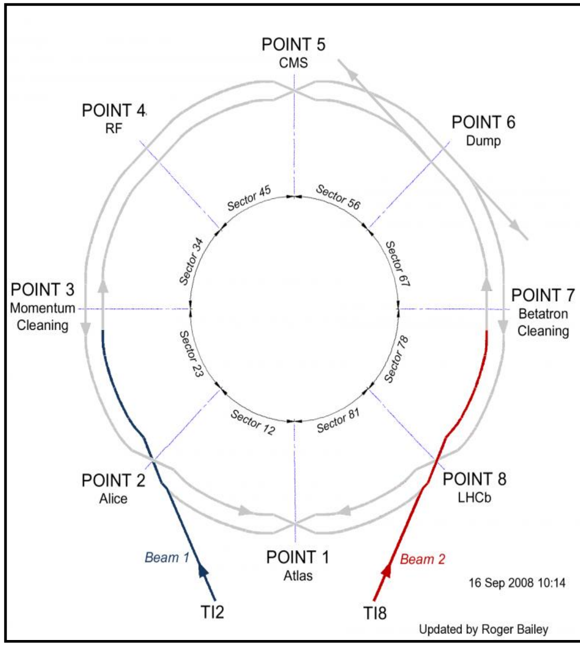
Backward tracks are skewed



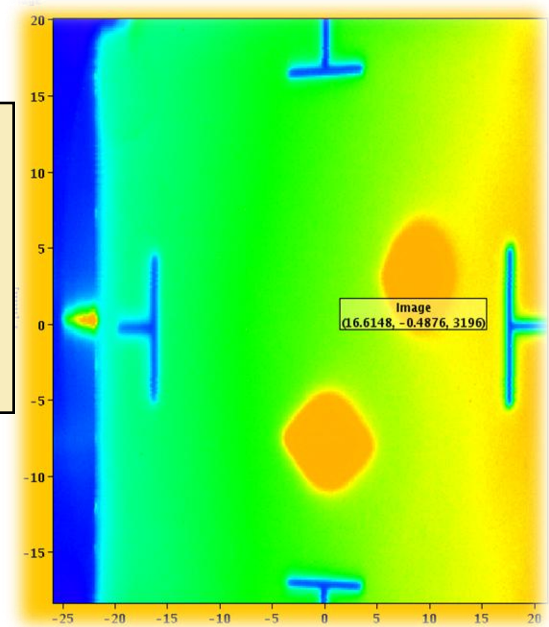
Forward tracks are aligned


POINT 5
CMS
POINT 4
RF
POINT 6
Dump
POINT 3
Momentum
Cleaning
POINT 7
Betatron
Cleaning
POINT 2
Alice
POINT 8
LHCb
POINT 1
Atlas
Sector 45
Sector 56
Sector 34
Sector 67
Sector 23
Sector 78
Sector 12
Sector 81
September 10
Beam 1
Beam 2
TI2
TI8
16 Sep 2008 09:41
Updated by Roger Bailey

First Turn! 10 Sept 2008



10:30 am
Two beam spots on a screen near ALICE indicate that Beam 1 has made 1 turn

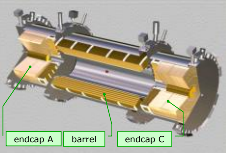


10:30 : Beam 1 (clockwise) around the ring (in ~ 1 hour), makes ~ 3 turns, then dumped

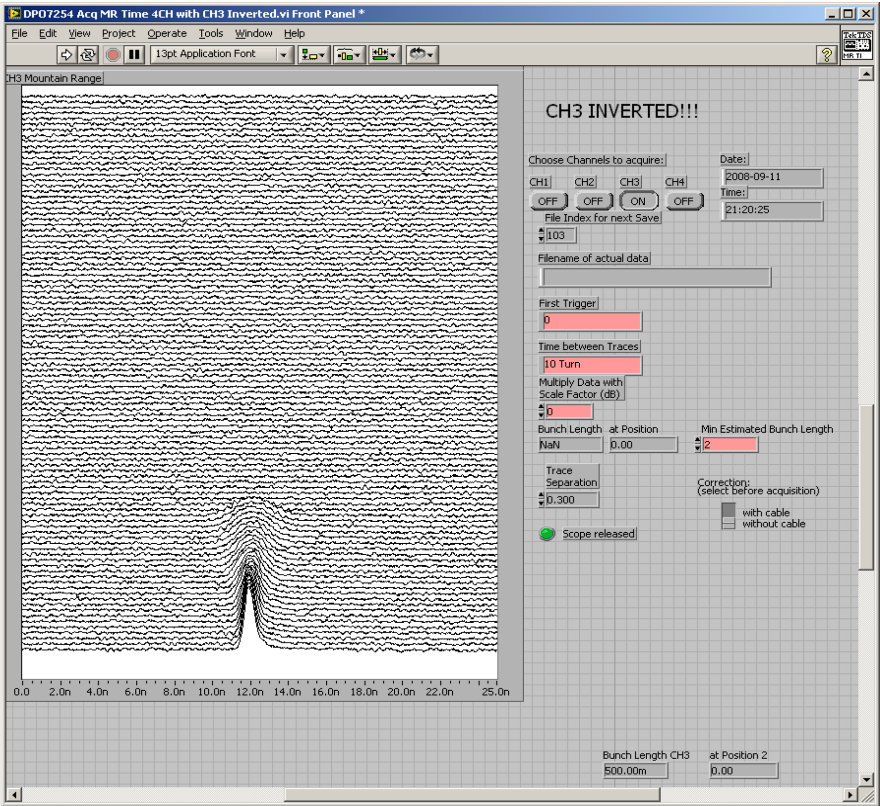
15:00 : Beam 2 (counter-clockwise) around the ring, makes 3-4 turns, then dumped

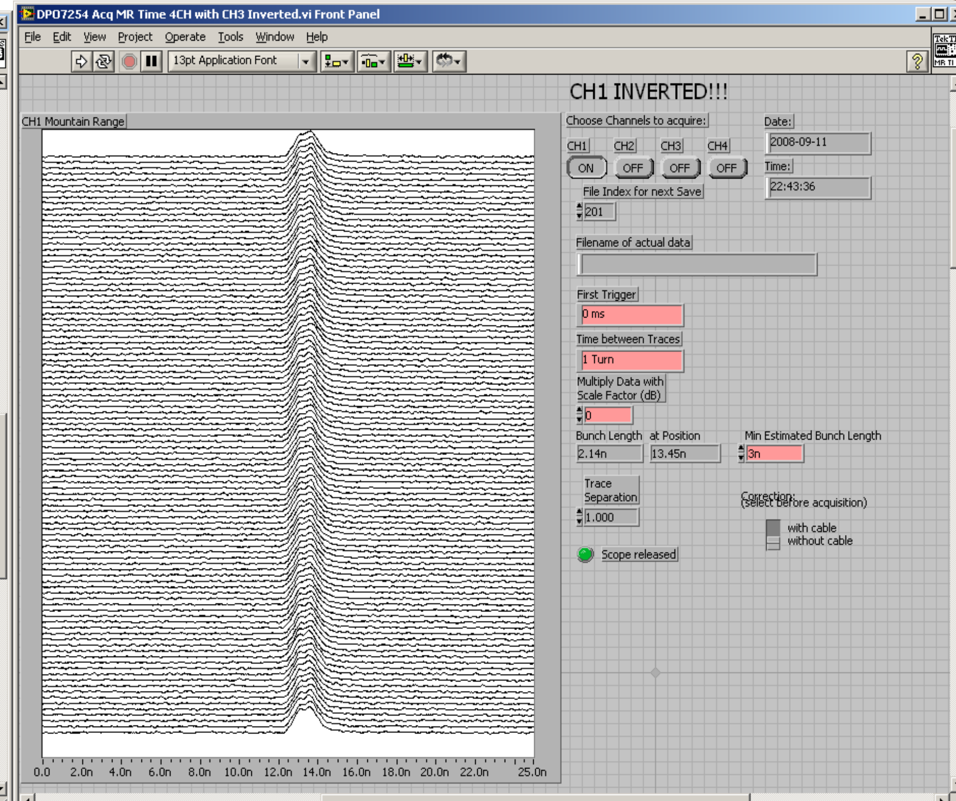
22:00 : Beam 2 circulates for hundreds of turns …

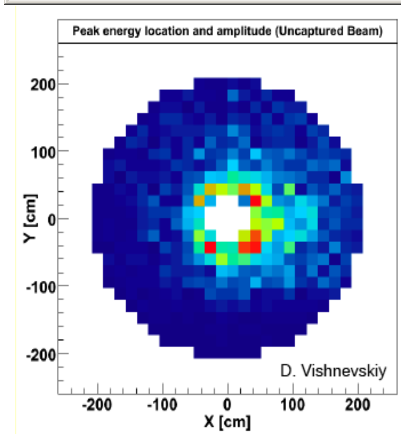
Beam Energy: 450 GeV, Beam Intensity: 2 x 10^9 protons per bunch



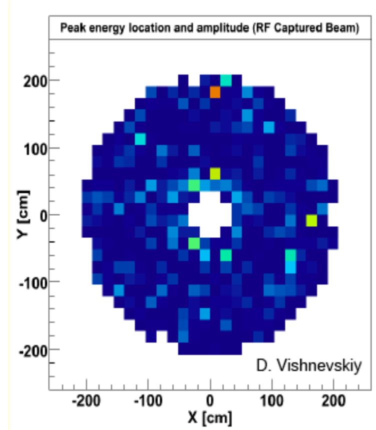
Beam RF Capture

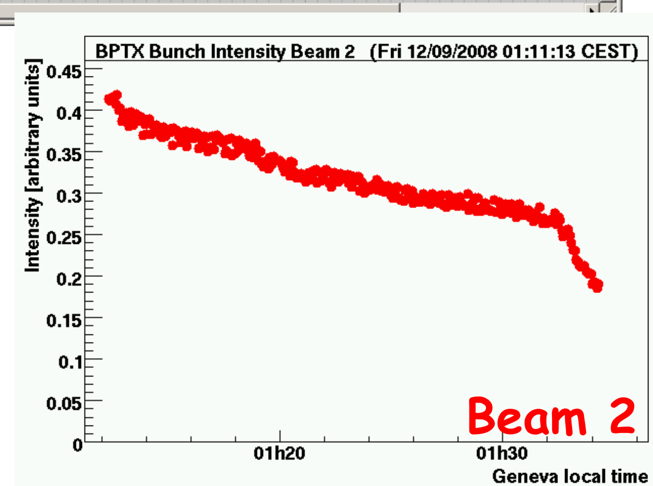






CMS HCAL Endcap





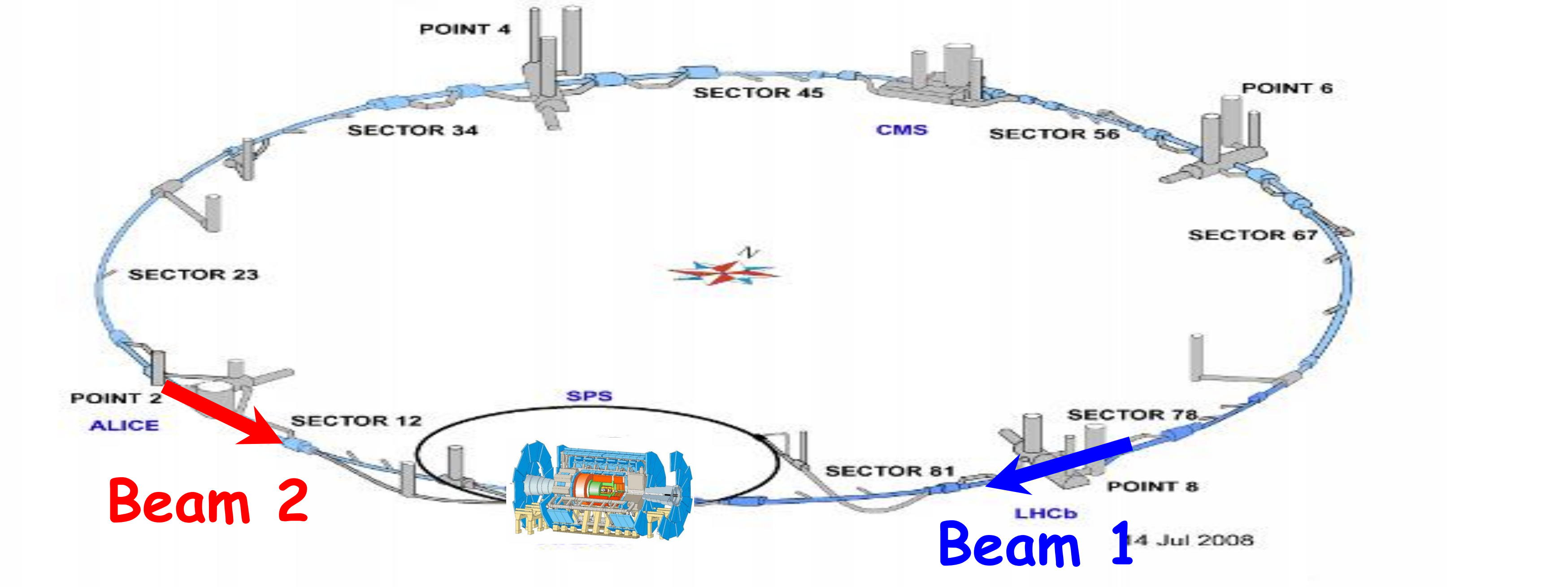
10 September: first beam

No beam in advance to test synchronization, all was extrapolated from cosmics runs.

Active detectors near to the beam pipe (inner tracker, forward calorimeters,….) were set at reduced HV or off (Pixel det.)

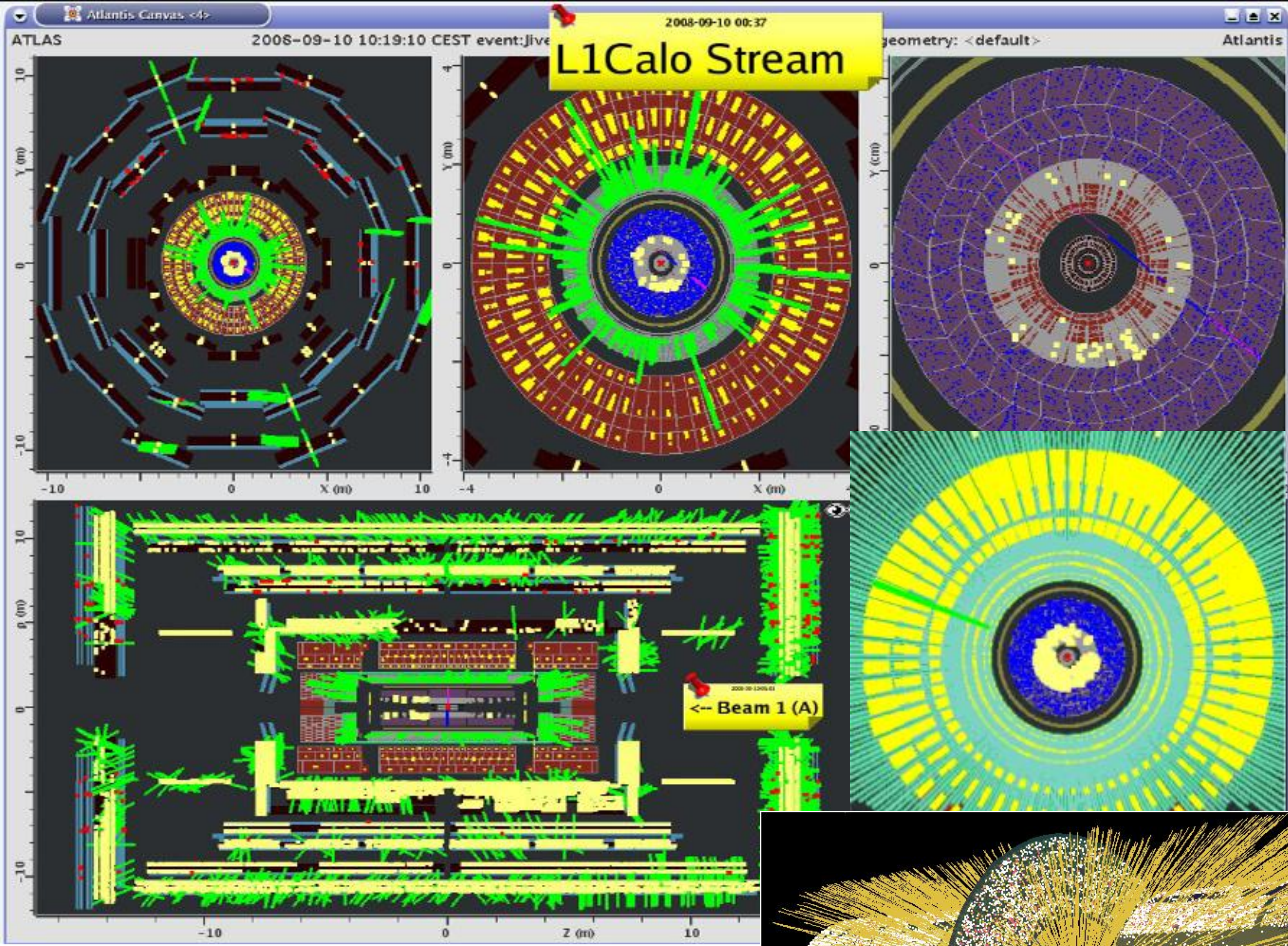
….. and it worked … first shots, first detector pictures … a lot of energy released in the detector

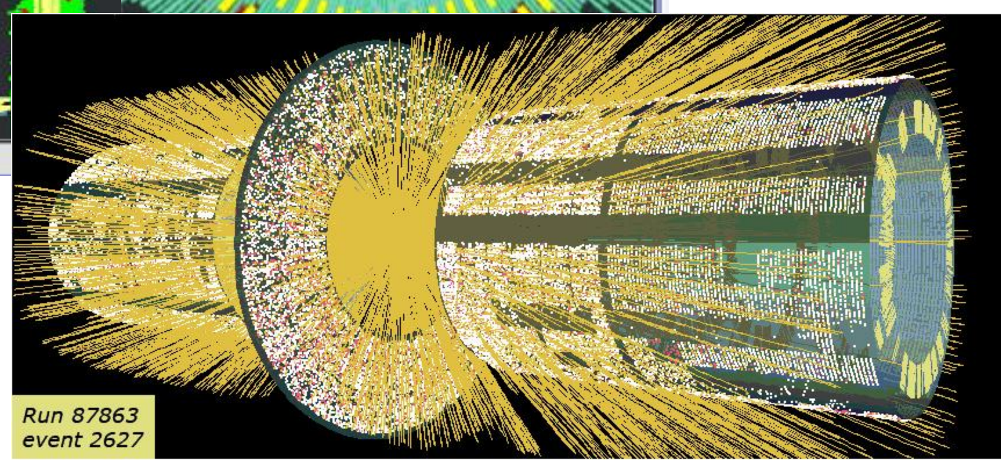
….. once beam RF captured, started looking for beam halo



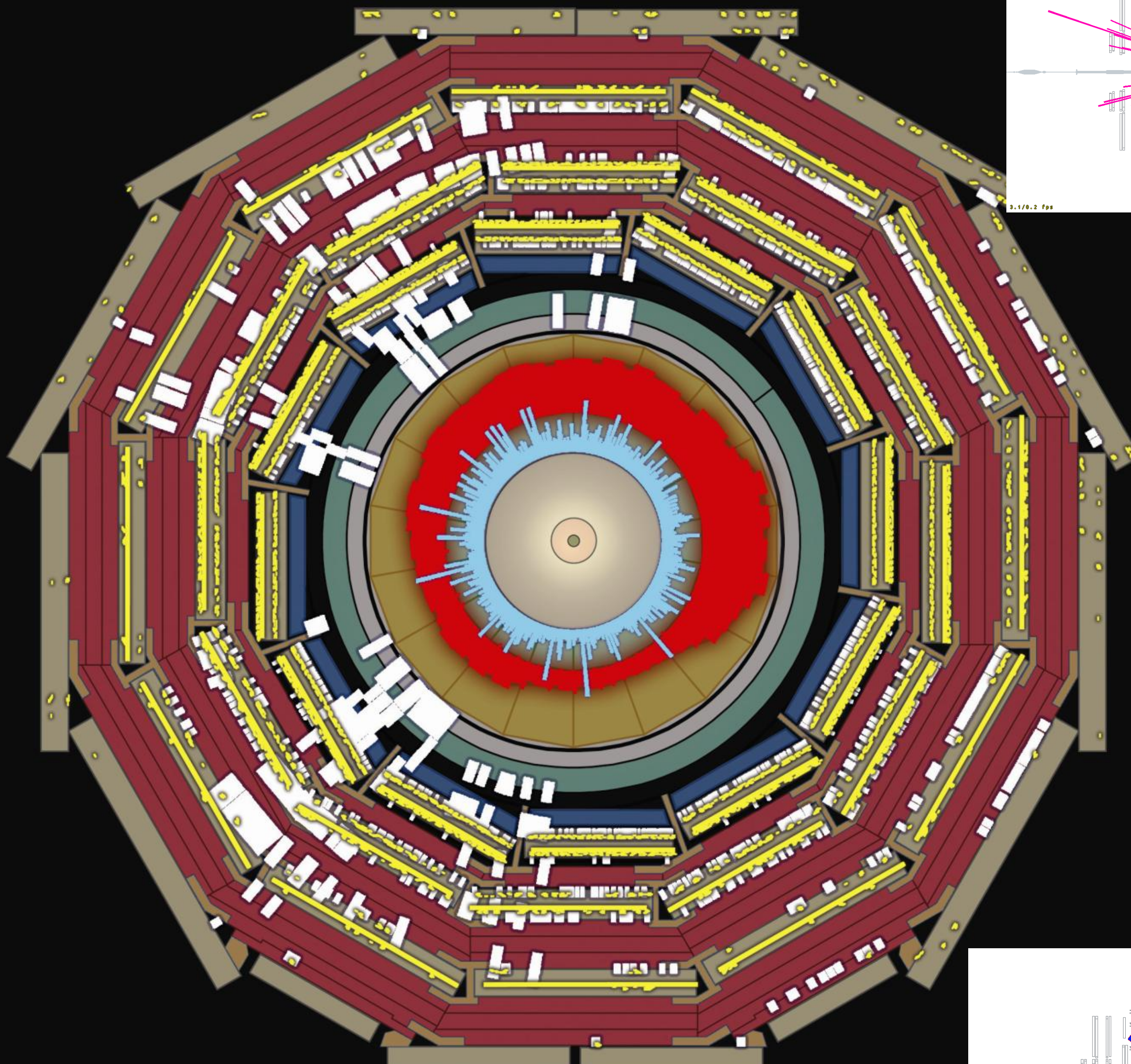


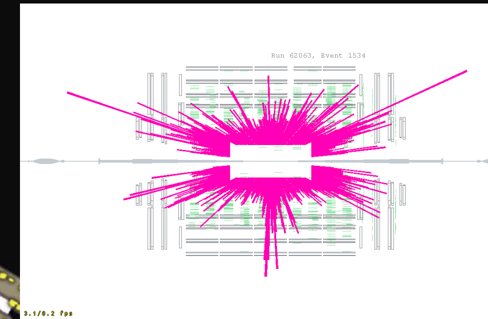

First Beam Day

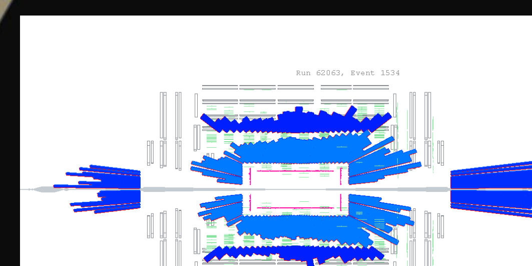


Atlantis Canvas <4>
ATLAS
2008-09-10 10:19:10 CEST event:Jive
geometry: <default>
Atlantis
2008-09-10 00:37
L1Calo Stream
Y (m)
X (m)
Y (cm)
ρ (m)
Z (m)
<-- Beam 1 (A)


Run 87863
event 2627

Run No. 62063, Evt# 1534, Sep. 10, 2008 09:38:21

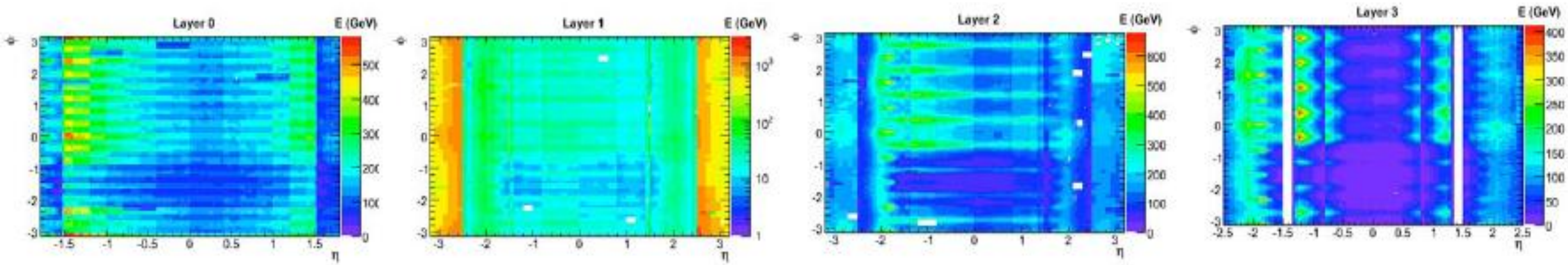


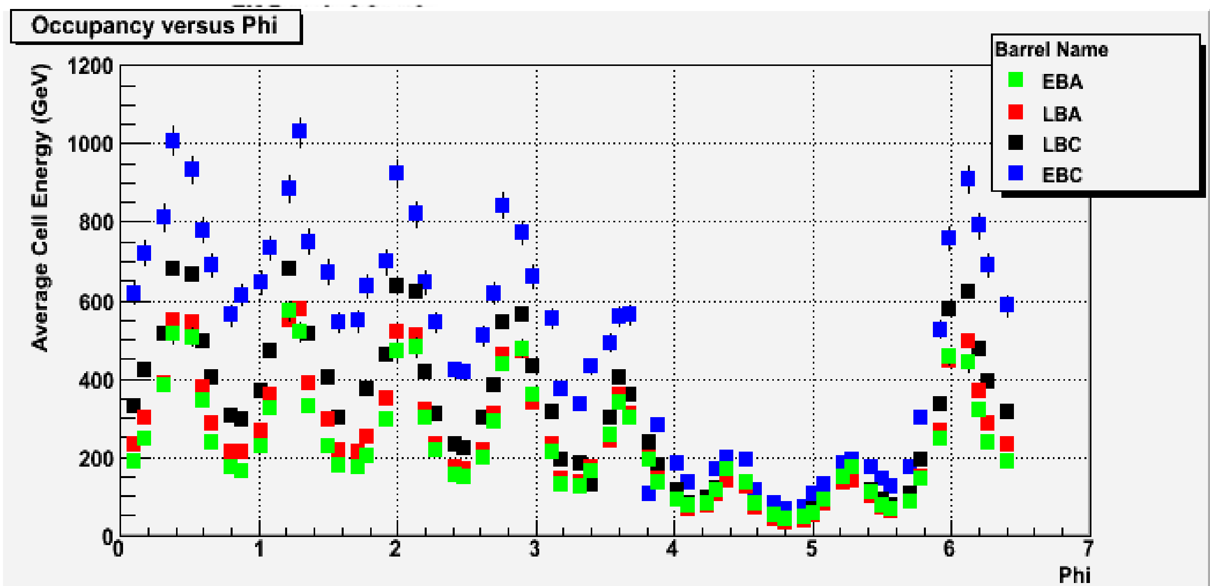


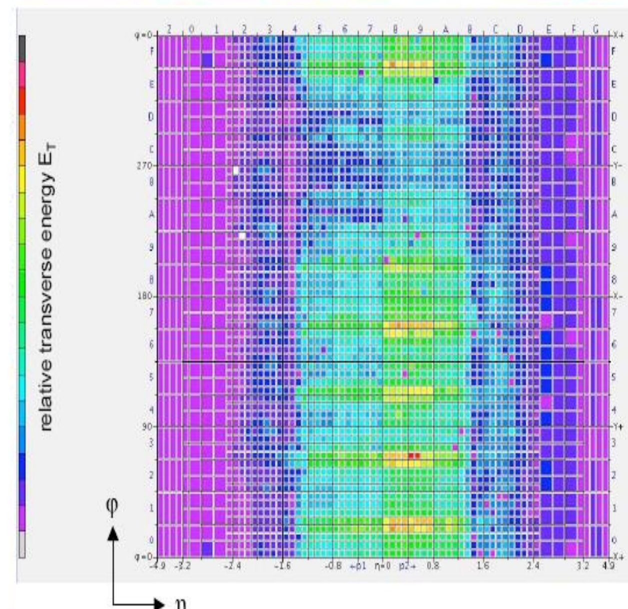


Energy Deposits in the LAr EM Calorimeter

Layer η-ϕ plots show EM Calorimeter coverage and exhibit the 8-fold structure also seen in Tile Calorimeter.







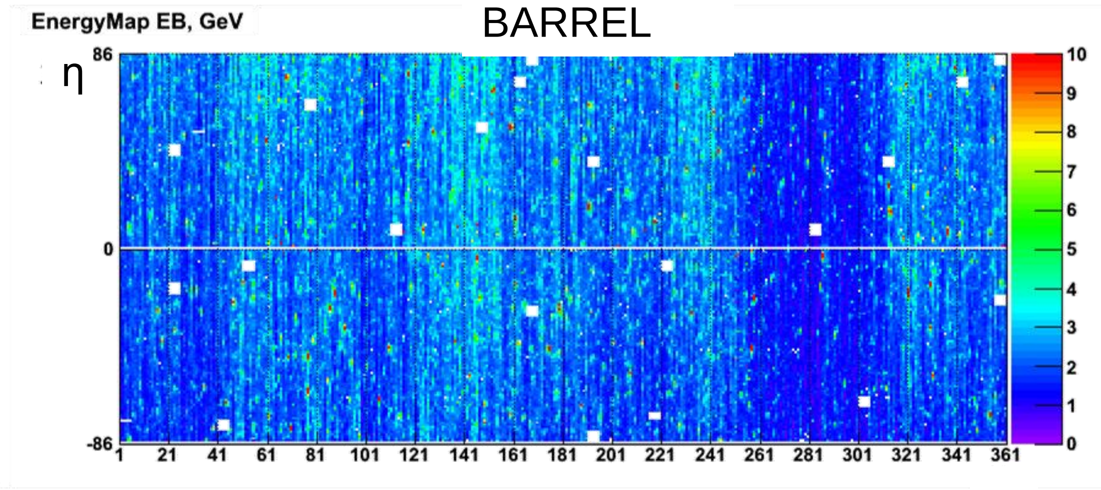
Tile hadronic calorimeter phi coverage

response
onal material
(mainly detector support structure)

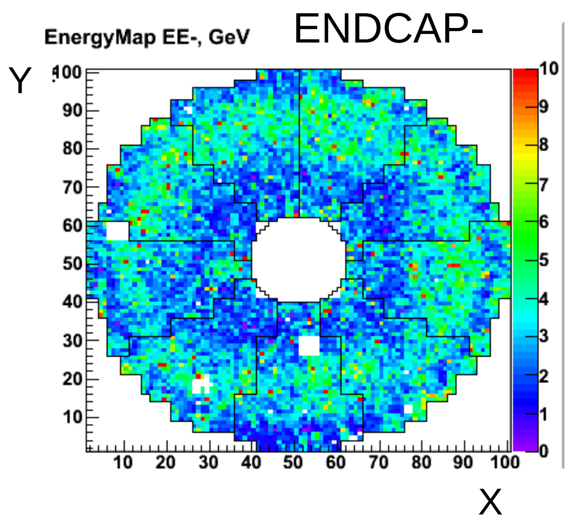
L1calo trigger coverage

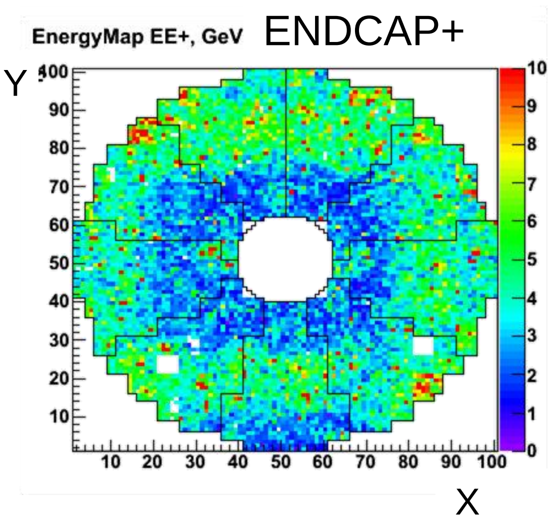
ECAL energy from collimator shots

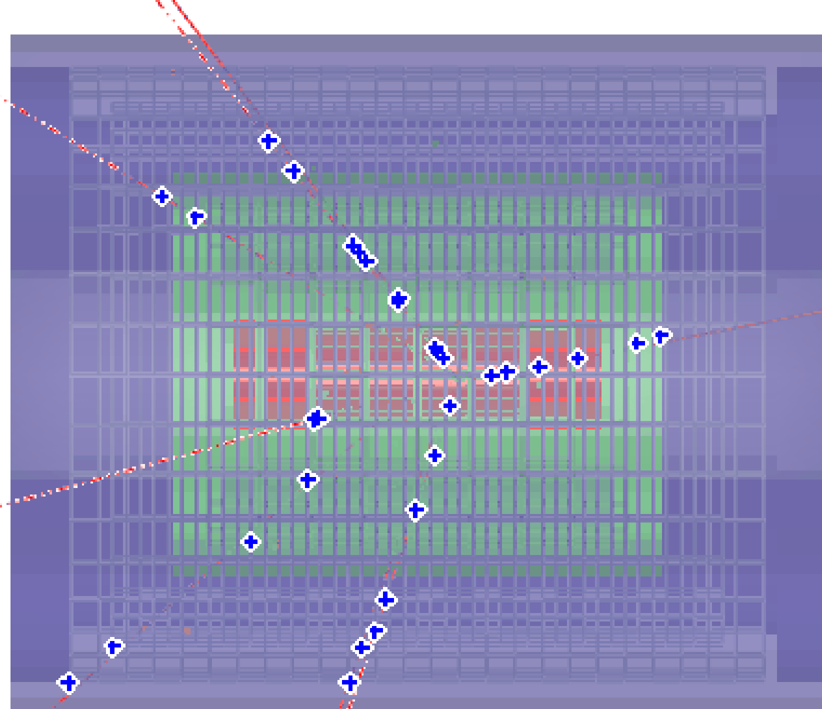
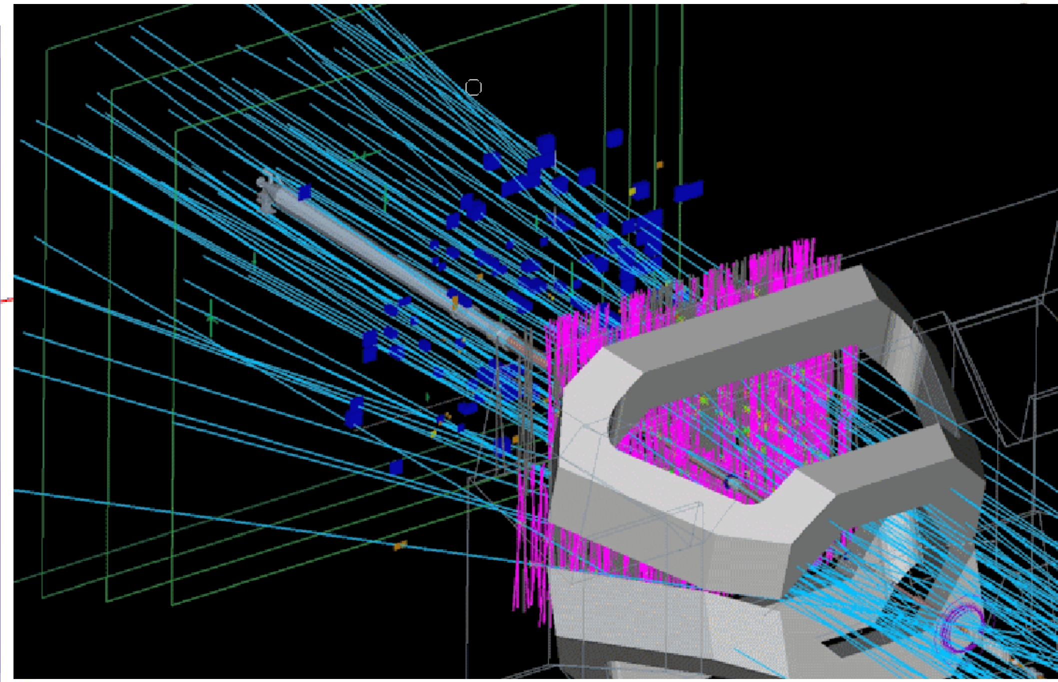
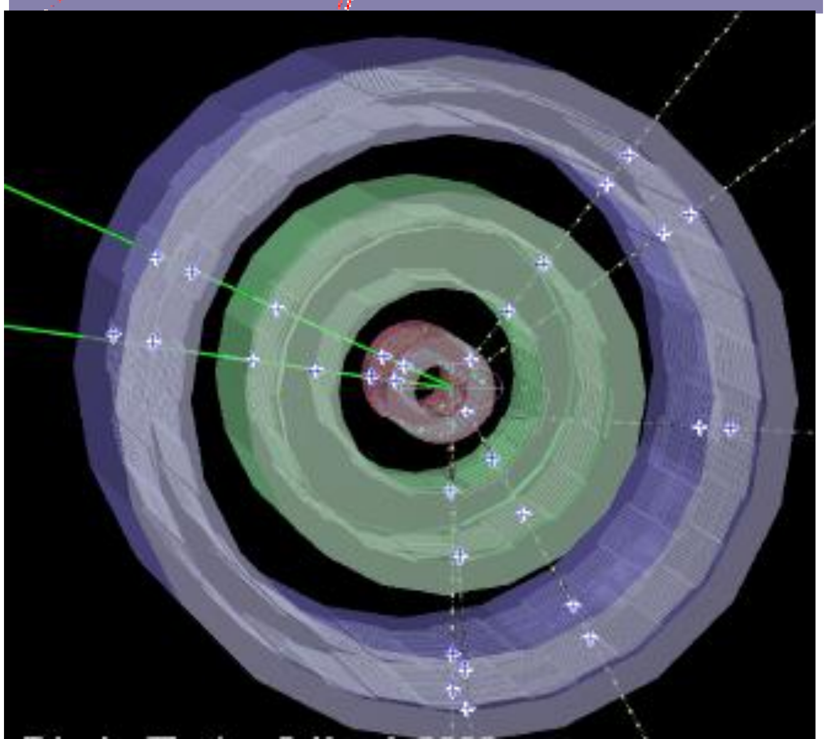
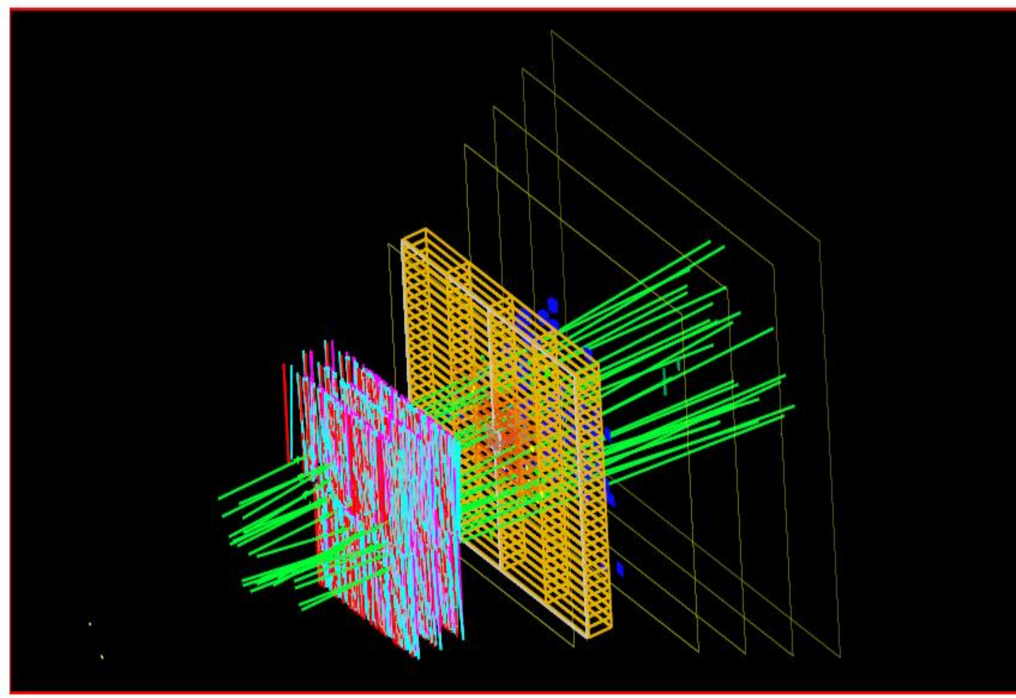
- 17 events where all active channels had >5 GeV
- Used for internal synchronization



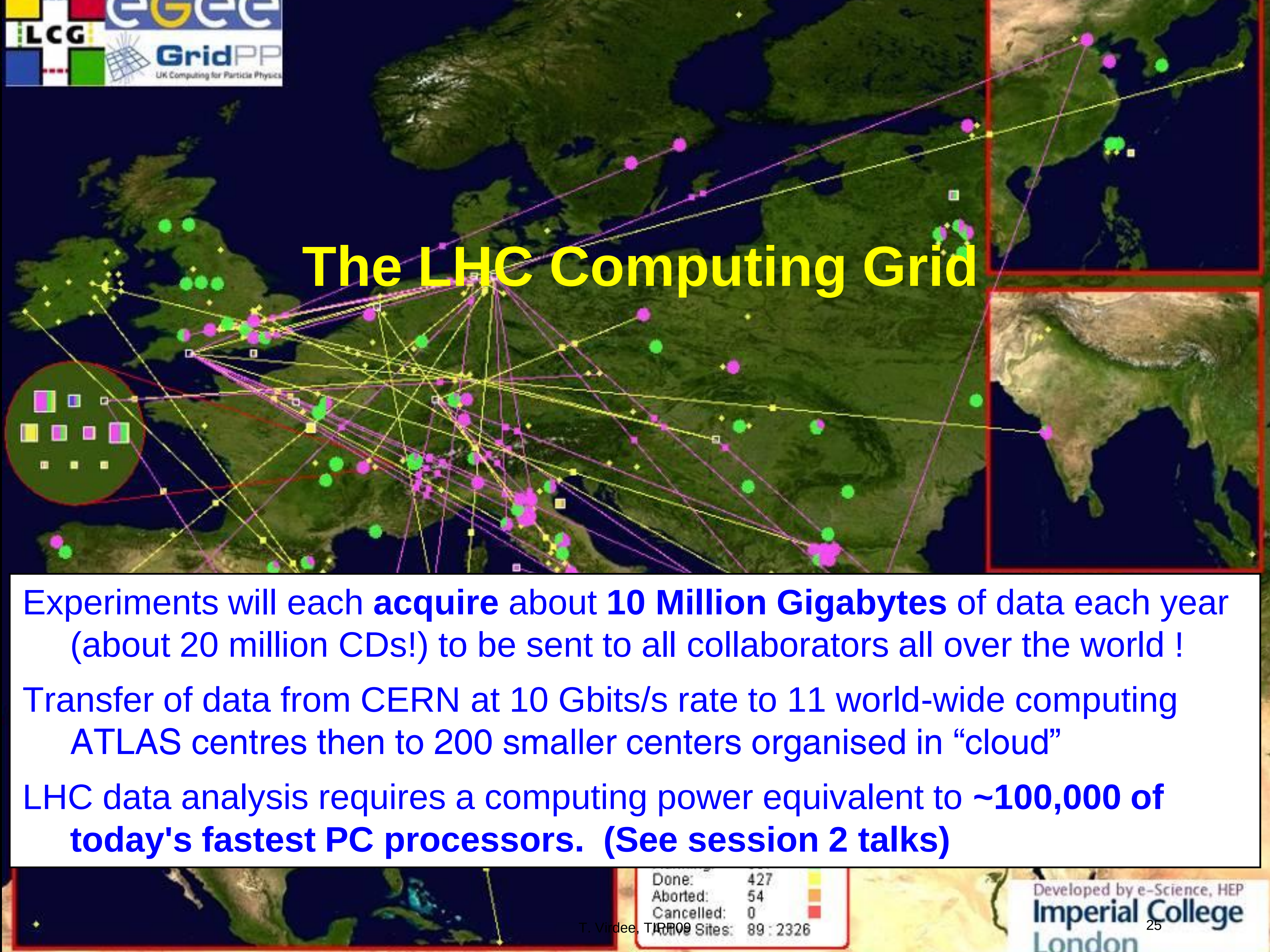
End caps are not calibrated →lower gain photodetectors nearest the beam pipe





The LHC Computing Grid

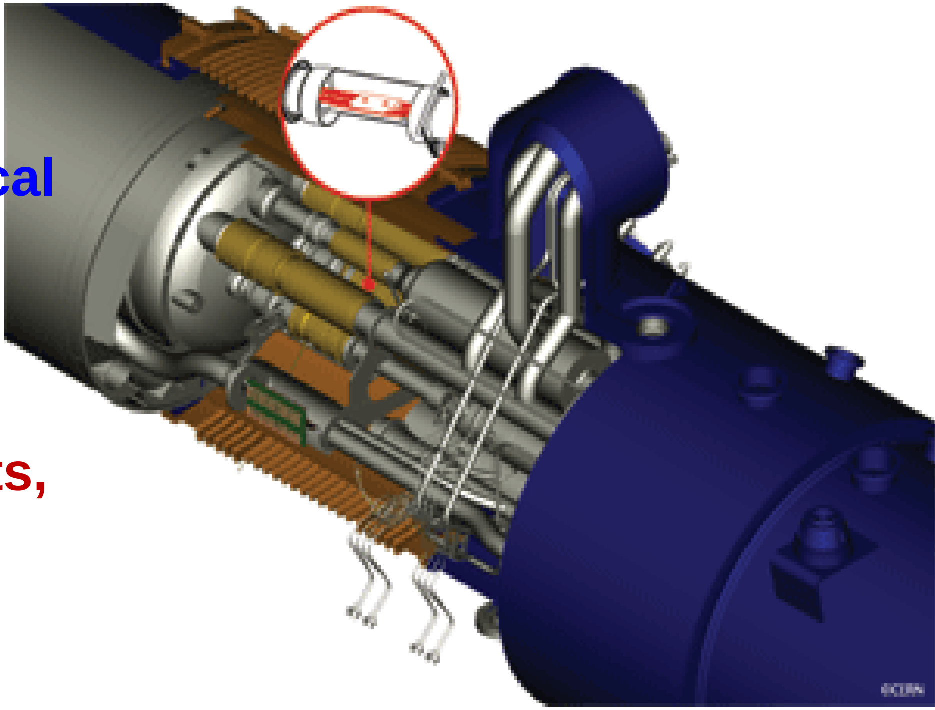


- Experiments will each **acquire** about **10 Million Gigabytes** of data each year (about 20 million CDs!) to be sent to all collaborators all over the world !
- Transfer of data from CERN at 10 Gbits/s rate to 11 world-wide computing ATLAS centres then to 200 smaller centers organised in “cloud”
- LHC data analysis requires a computing power equivalent to **~100,000 of today's fastest PC processors. (See session 2 talks)**

LHC Incident on 19 Sept. 2008

A few days of downtime to replace a failed power converter were being used to complete the final powering tests in sector 3-4

During powering test of the last main-bend circuit to just above 5 TeV an incident occurred resulting in the triggering of quench heaters of about 100 magnets and a large He discharge into the tunnel, provoking a shock-wave within 2 cells (about 300 m)



This resulted in collateral mechanical damage in a part of this sector

The cause was a faulty electrical connection between two magnets, and the repairs are ongoing, 53 magnets have been removed to be repaired and reinstalled

2 other magnets will be replaced

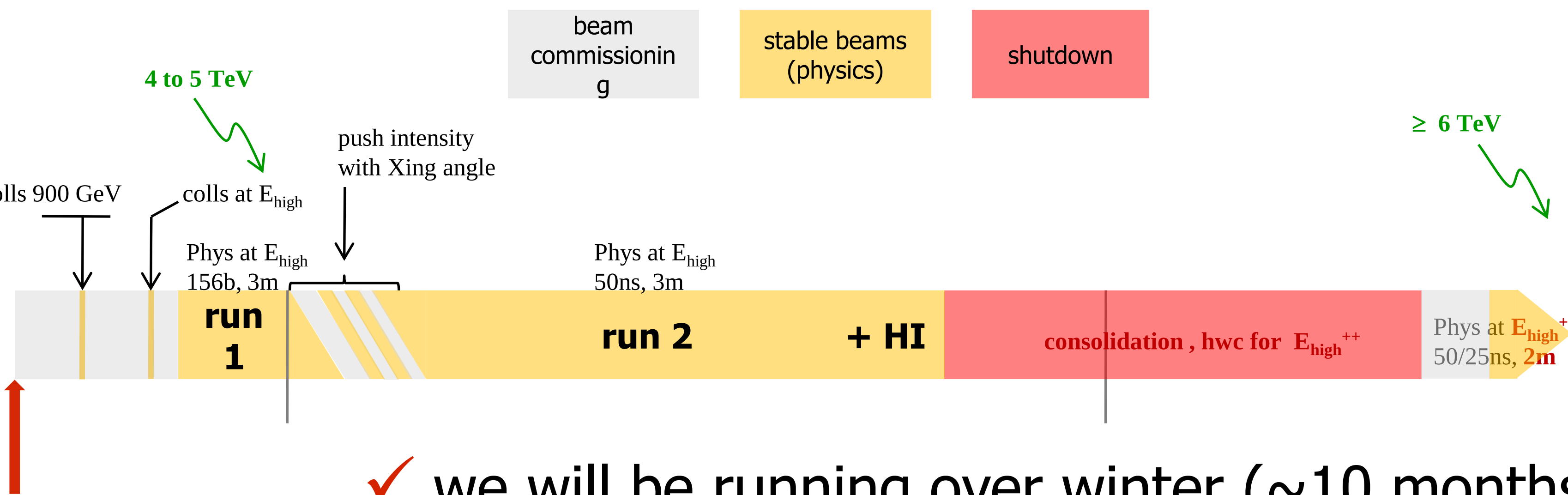
Collateral Damage

1. High pressure build up damaged the magnet interconnects and the super-insulation
2. Perforation of the beam tubes resulted in pollution of the vacuum system with soot from the vaporization and with debris from the super insulation.

Lots of work ongoing to repair and add many protection to reduce the potential risk and collateral damage effect

What is next (experiments desiderata) ?

Year	2009										2010															
Month	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Base '	SH	SH	SH	SH	SH	SH	SH	SH	SU	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	PH	SH	SH	SH	SH	SH	SH
	44 weeks physics possible																									



Beginning October 2009

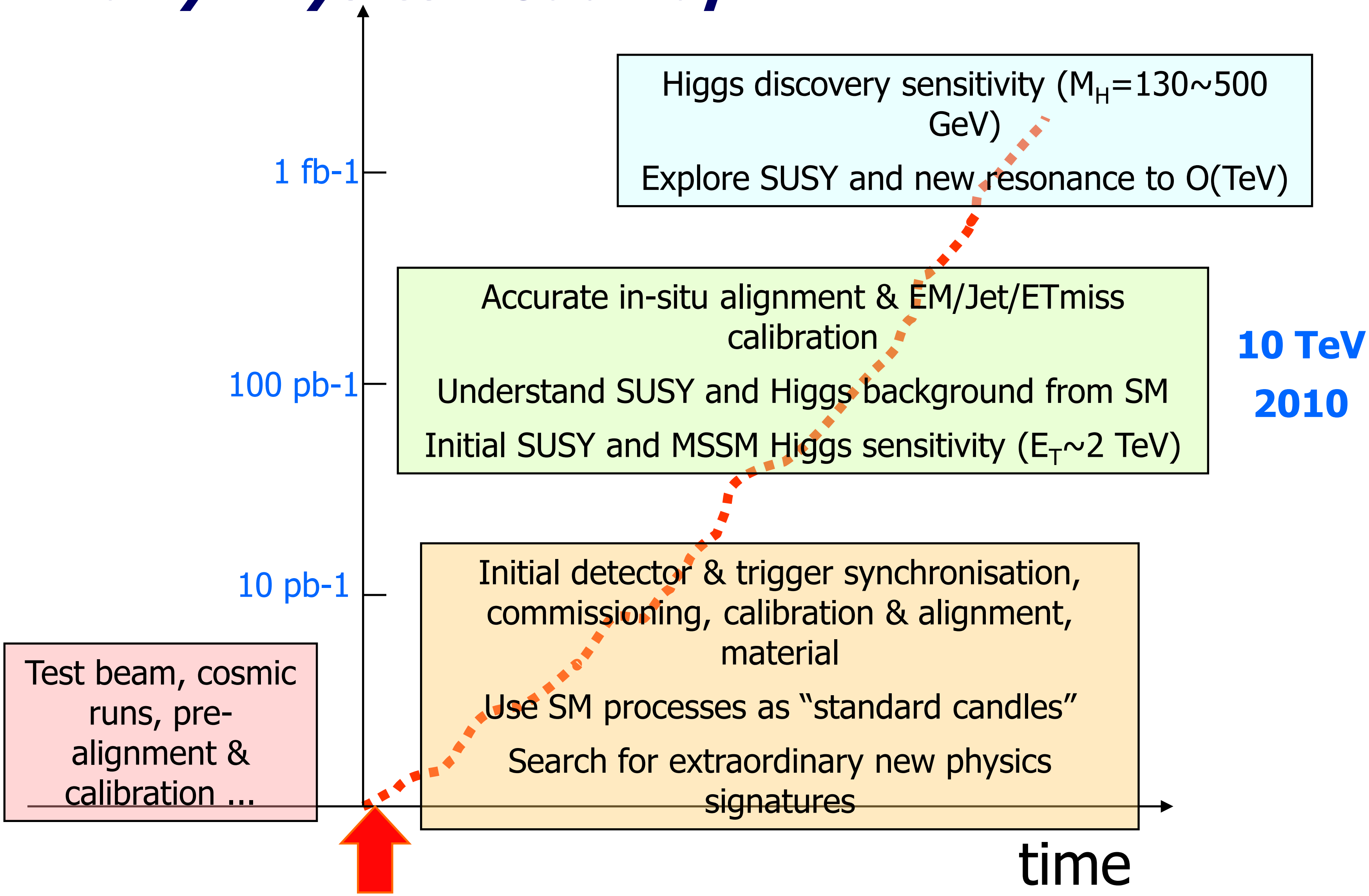
- ✓ we will be running over winter (~10 months)
- ✓ 4+4 going to 5+5 TeV in 2010
- ✓ ~100 pb^{-1} to match today's Tevatron statistics
- ✓ ~200 pb^{-1} to open discovery windows

Data Sample in 2009/2010

- **Energy:**
  - 10 TeV centre-of-mass energy for physics
  - 8 TeV "on the way" to 10 TeV
  - Small data samples at 0.9 TeV (injection energy) and perhaps 2 TeV
  - (mainly for earlier timing-in/commissioning of detectors)

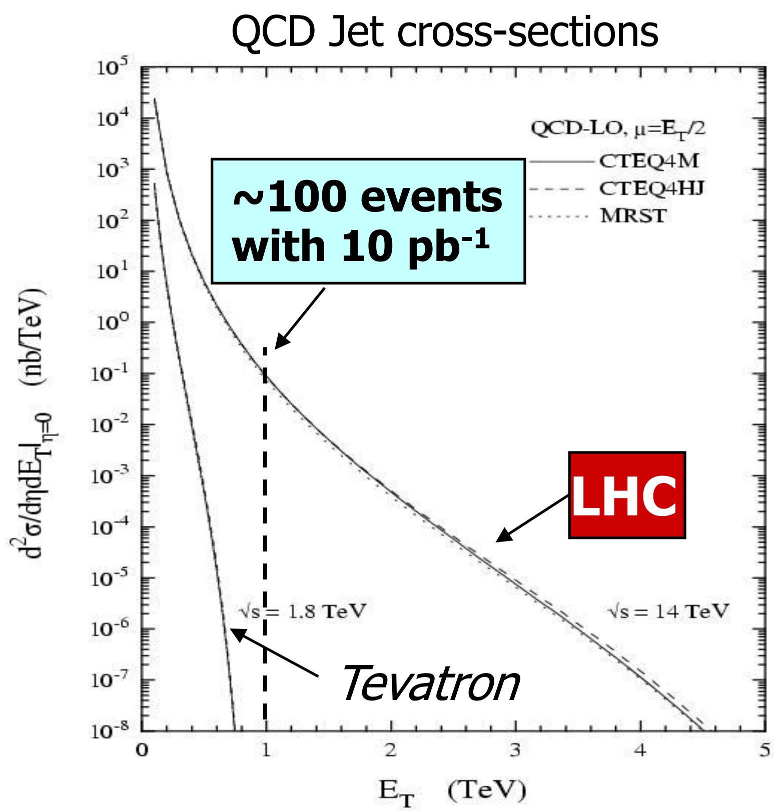
- **Luminosity:**
  - 5 x 10^{31} $cm^{-2}s^{-1}$ to 2×10^{32} $cm^{-2}s^{-1}$ peak
  - With 200 days and 10% efficiency ~200-300 pb^{-1}
  - Quite a large uncertainty…

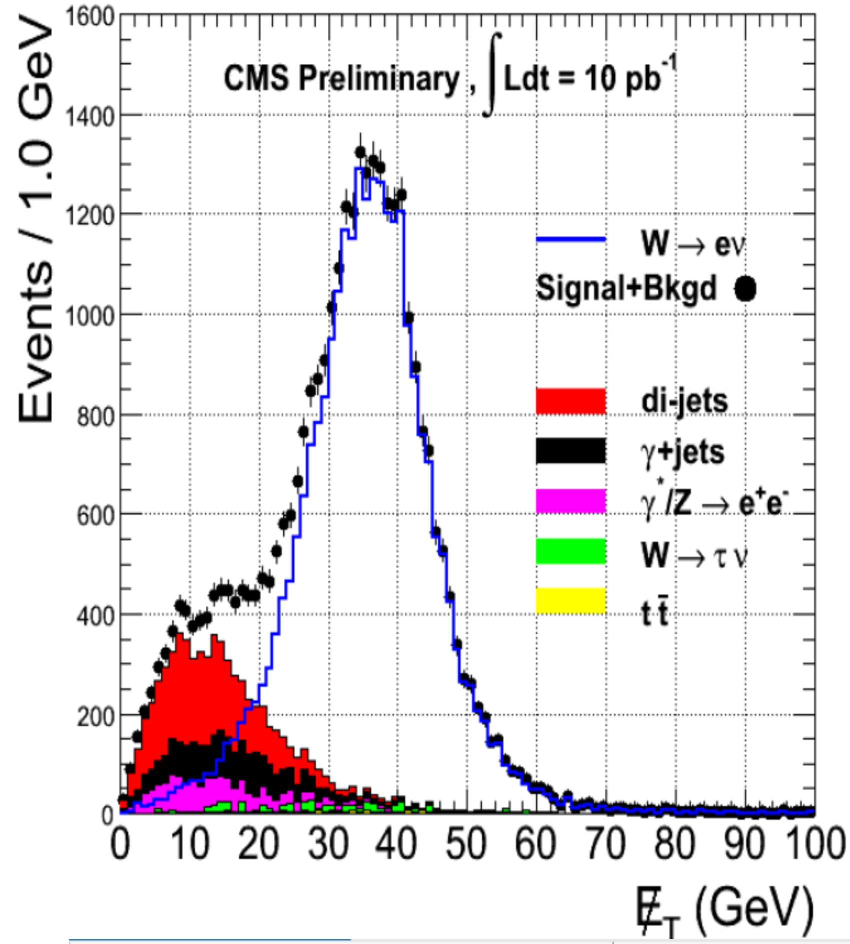
Early Physics Roadmap



Recall: $1\ pb^{-1} = 10^{36}\ cm^{-2}$
1 second at $L = 10^{31}\ cm^{-2}s^{-1} \rightarrow \int L dt = 10^{-5}\ pb^{-1}$
10h running day at $L = 10^{31}\ cm^{-2}s^{-1} \rightarrow \int L dt = 0.36\ pb^{-}$

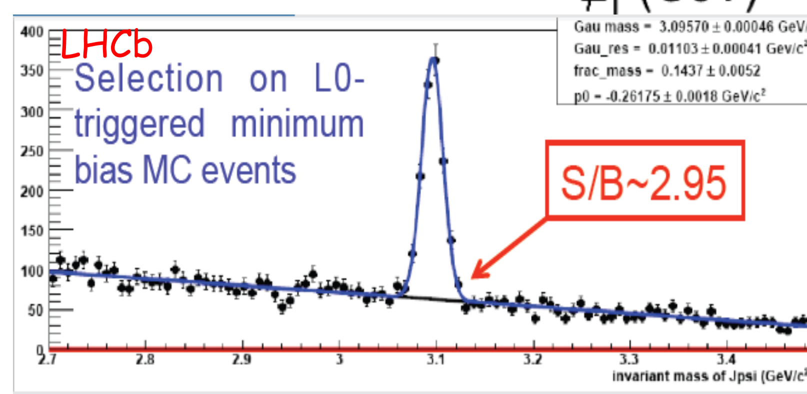
… then look for the first physics





Early data analysis mostly focus on SM:

1. understand performance of complex detector
2. measure basic SM processes and compare to theory and simulation



Early top physics

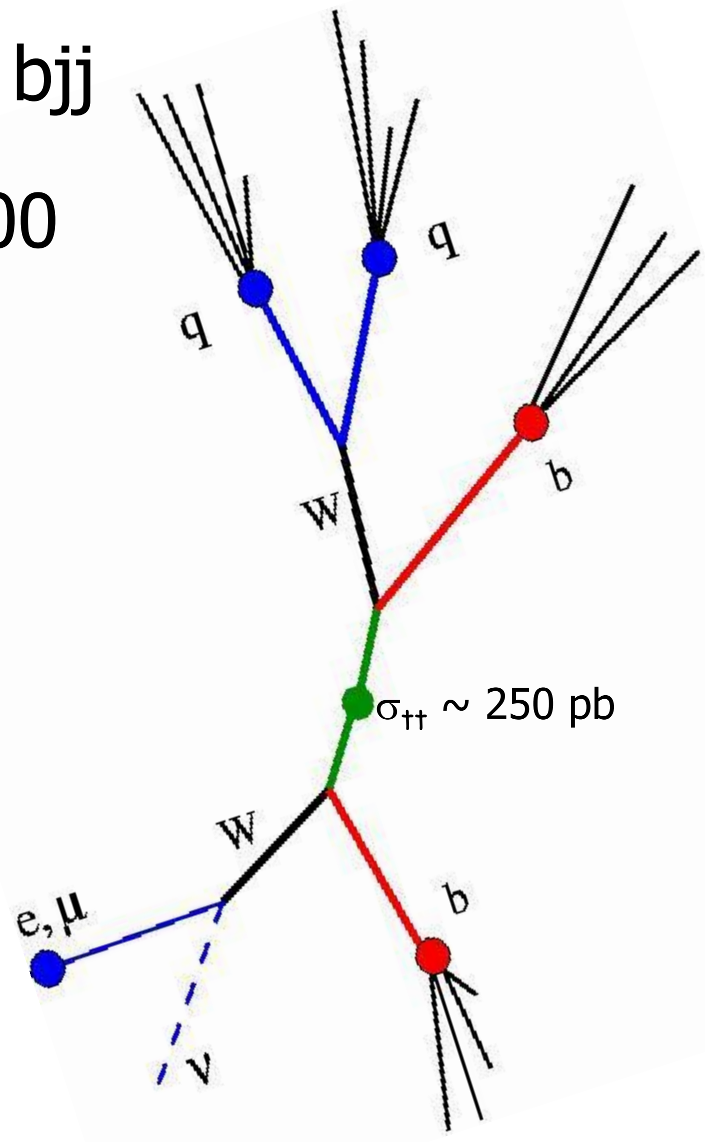
$\sigma_{tt} \approx 250$ pb for tt → bW bW → blν bjj

Note: σ_{tt}(LHC)/σ_{tt}(Tevatron)~100

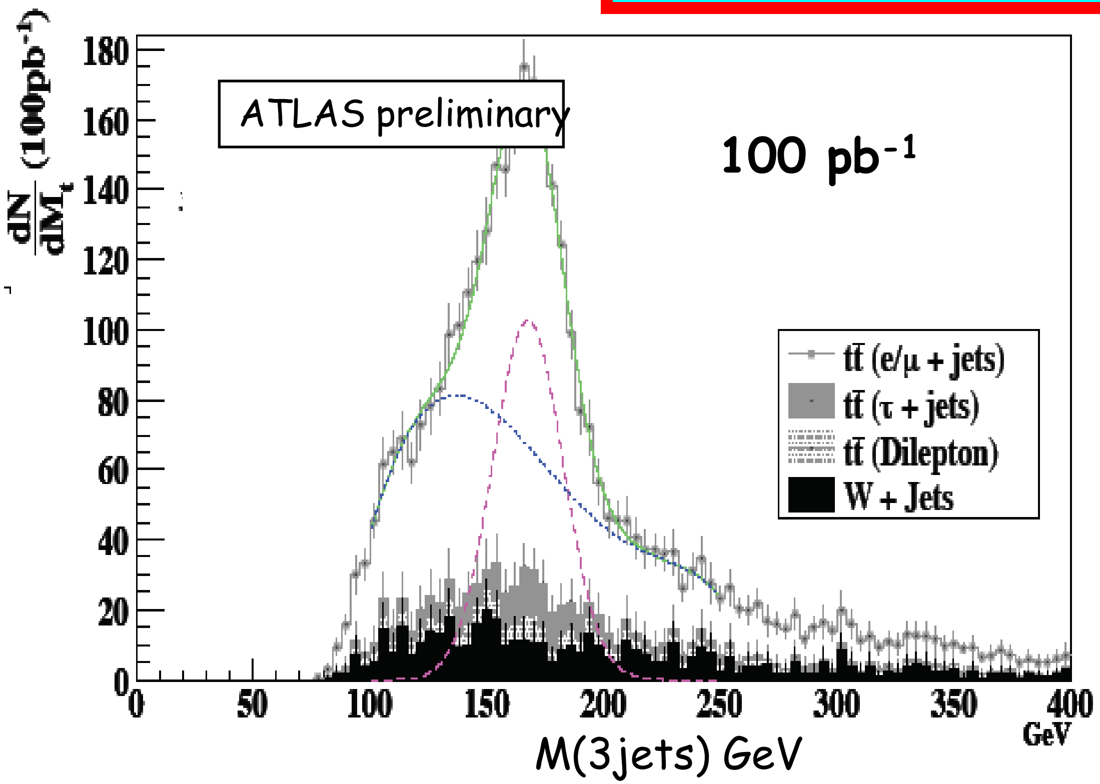
✓ *use simple and robust selection cuts:*

p_T (l) > 20 GeV
E_T^{miss} > 20 GeV
only 3 jets with p_T > 40 GeV
1 jet with p_T > 20 GeV

✓ *no b-tagging required (too early to begin with …)*



Early top physics



Invariant mass of the 3 jets with largest $\sum p_T$

(~3000 evts for 100 pb^{-1})

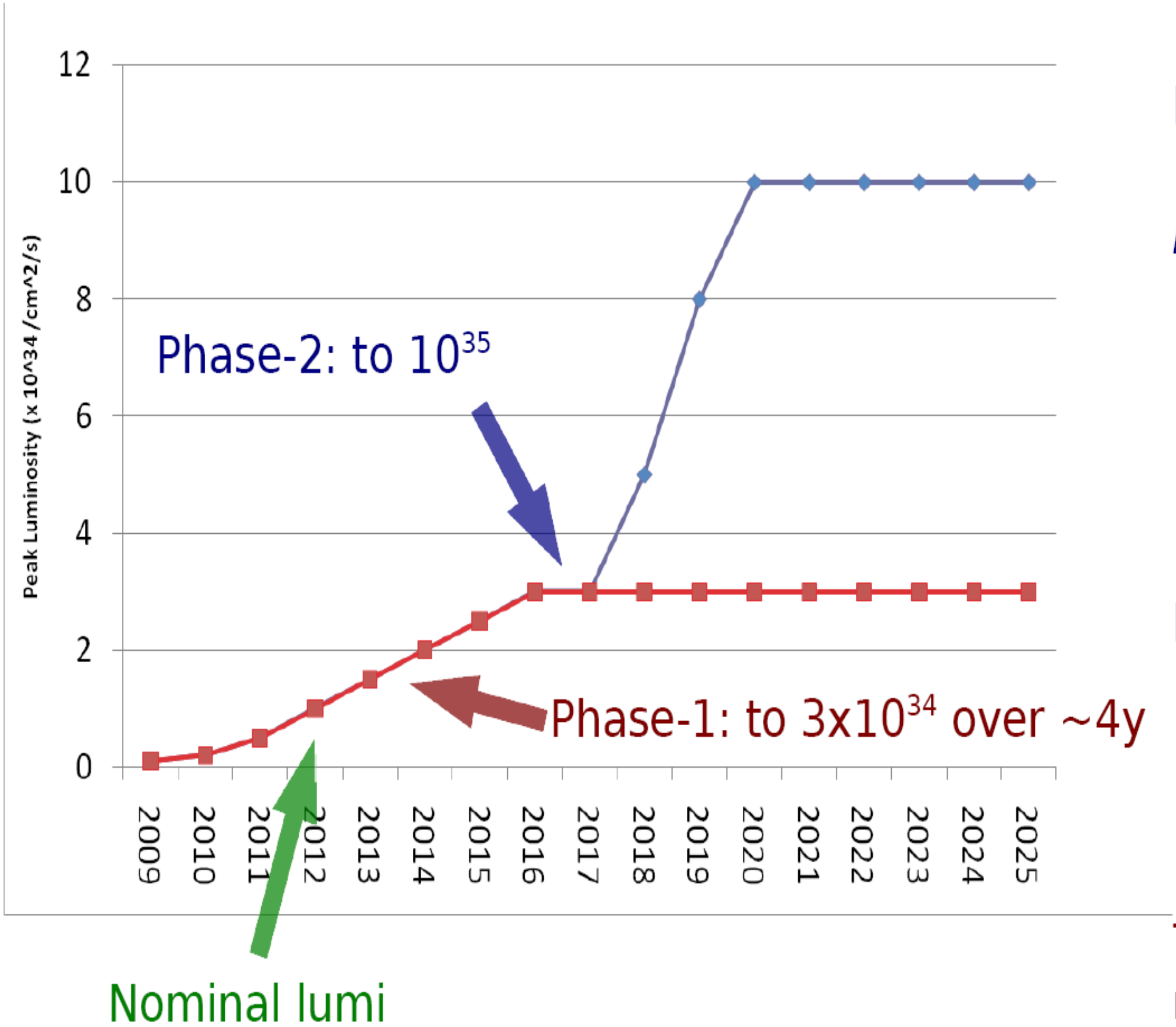
→ measure σ_{tt} to ~20%

- *commission b tagging*
- *calibrate the jet energy scale using $W \rightarrow jj$ peak*
- *tune various MC generators (e.g. using P_T spectra)*

Then, SUSY, Higgs,….

LHC Upgrades (sLHC)

- See A. Rozanov talk



Phase-1:

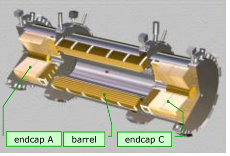
Machine:

- Injector upgrades
- New inner triplets (focussing magnets at experiments)

Experiments:

- Pixel det. upgrades
- Modest trigger & readout upgrades

Timescale is optimistic - not adjusted for LHC



Conclusion

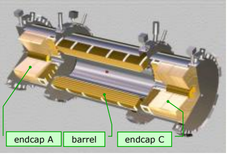
- LHC is on its way to start its physics program fall 2009
- After a few improvement performed during the shutdown, all 4 experiments have never been so ready to go !

- After 15 years of intense work, at the edge of an exciting new era for particle physics
- Program will continue for at least the next 10 years
- R&D program for sLHC ongoing
- Our future looks bright for new discoveries

- Need lots of good physicist to look at those data
- Room for excited students to participate to a new adventure

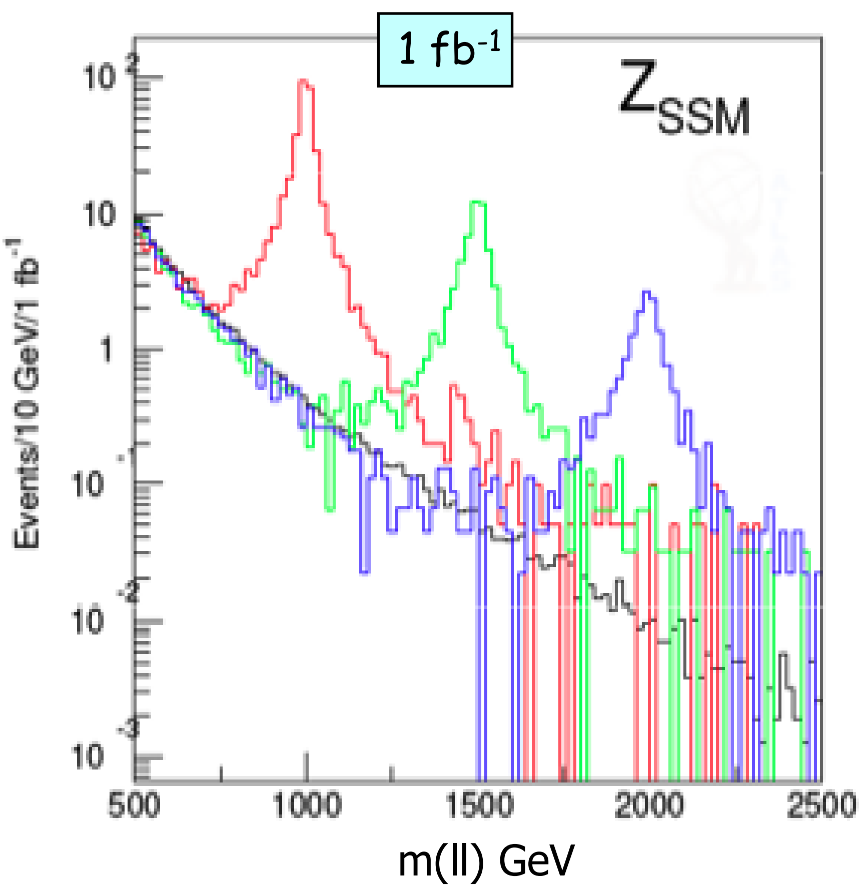
- Strong cooperation program between France and China very fruitful for getting the best physics out of those data


谢谢



Back up

Easiest …. Heavy di-Lepton Resonances

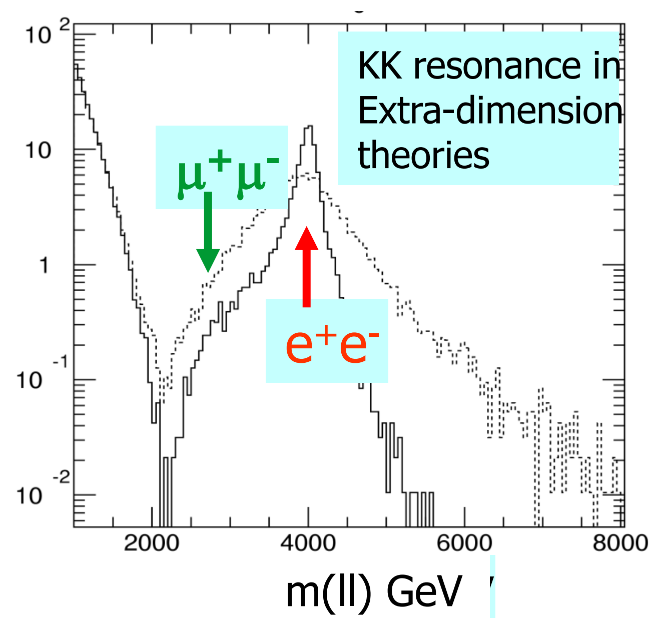


$Z' \to e^+e^-$ with SM-like couplings (Z_{SSM})

Mass	#events for 1 fb^{-1} (after all cuts)	discovery Lum. (10 observed evt
1 TeV	~ 160	~ 70 pb^{-1}
1.5 TeV	~ 30	~ 300 pb^{-1}
2 TeV	~ 7	~ 1.5 fb^{-1}

Discovery (10 events $\mu^+\mu^-$, 1TeV, >5σ) with 100 pb^{-1}, possible at E_{cm}=10 TeV

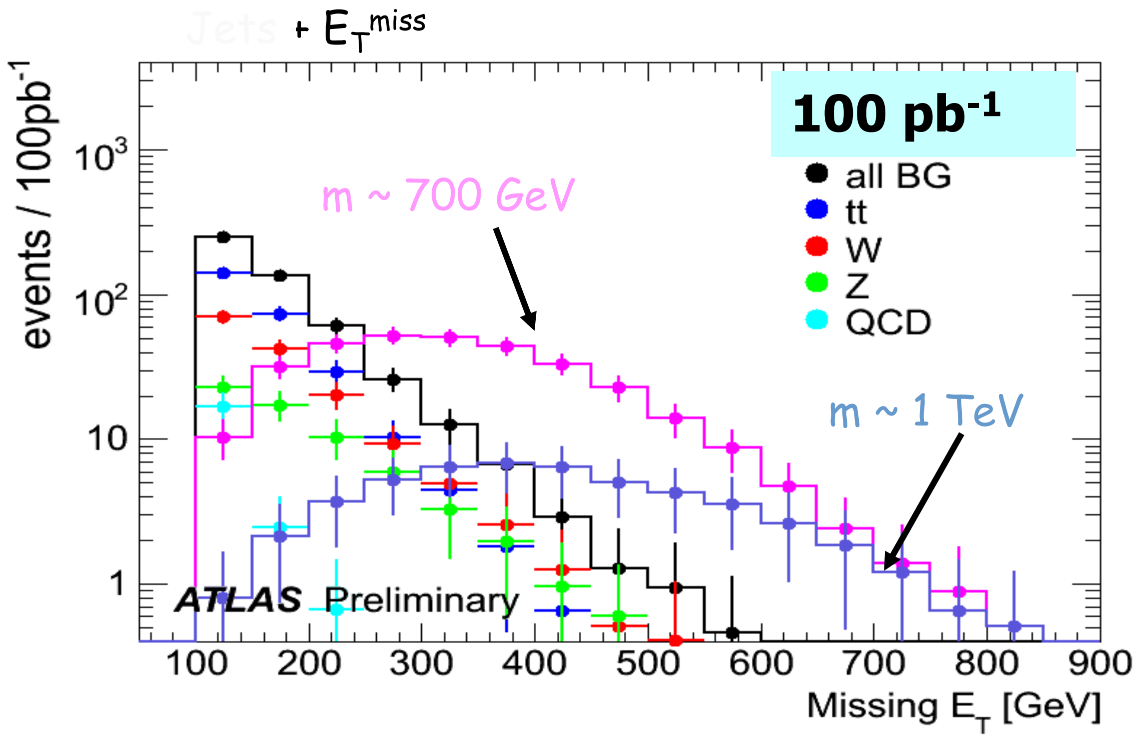
Ultimate ATLAS reach (300 fb^{-1}): ~ 5 TeV

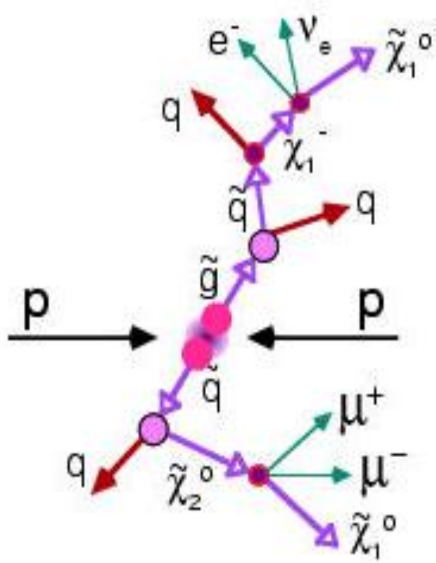


What about SUSY discovery in 2010 ?

Finding the signal already at 100-200 pb^{-1} should not be a problem

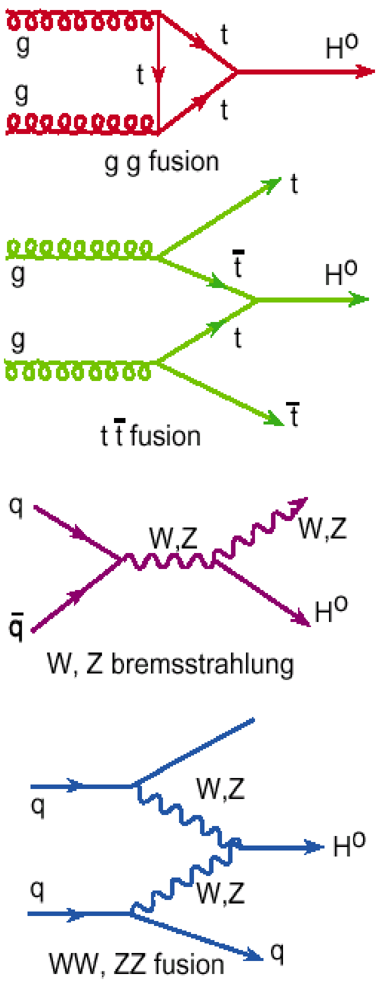
→ **the problem is to be sure it is real**



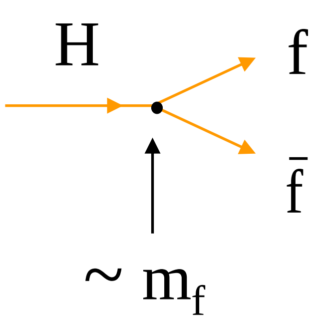


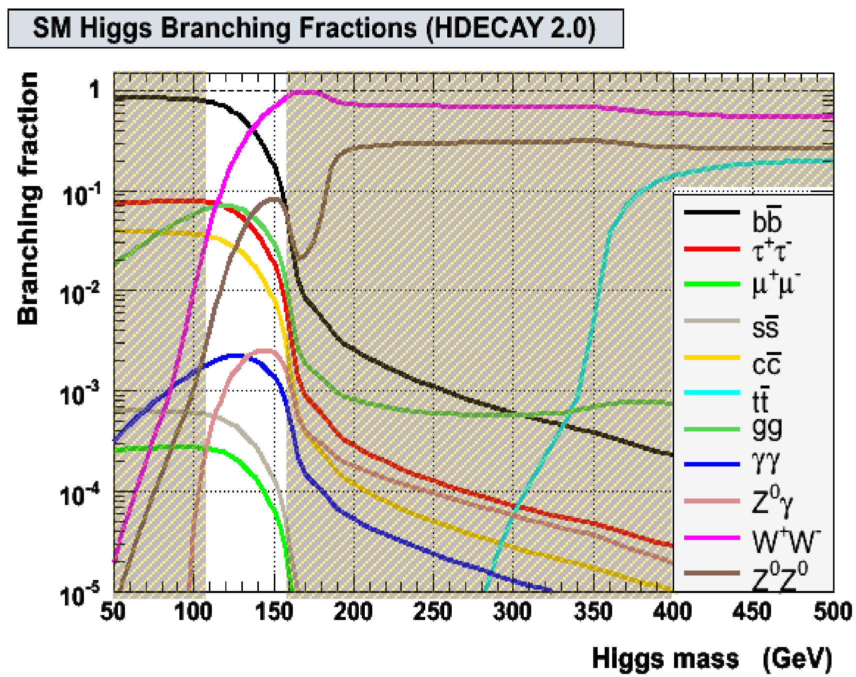
5σ discovery beyond current limits possible with ~20 pb^{-1} at 10 TeV

… and finally the Higgs



- $m_H < 120$ GeV: $H \to bb$ dominates
- 130 GeV $< m_H < 2\, m_Z$: $H \to WW^{(*)}, ZZ^{(*)}$
- $m_H > 2\, m_Z$: 1/3 $H \to ZZ$, 2/3 $H \to WW$
- important rare decays : $H \to \gamma\gamma$

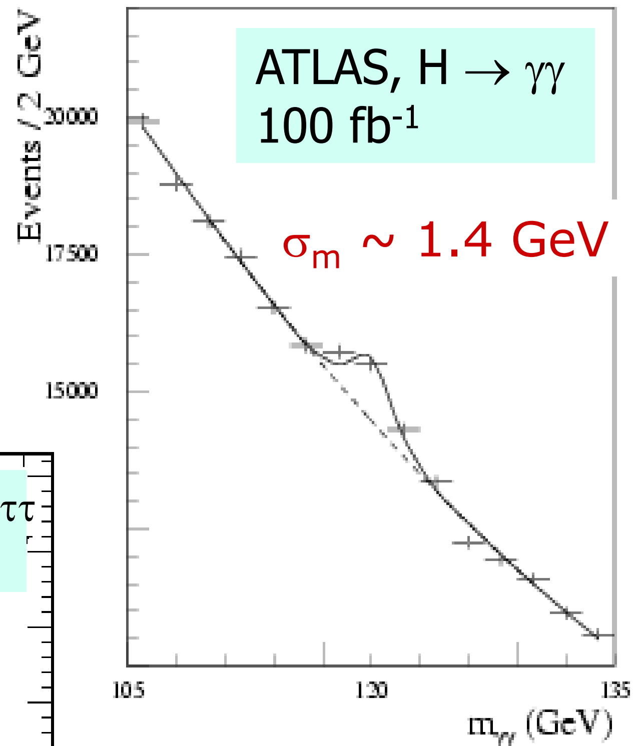




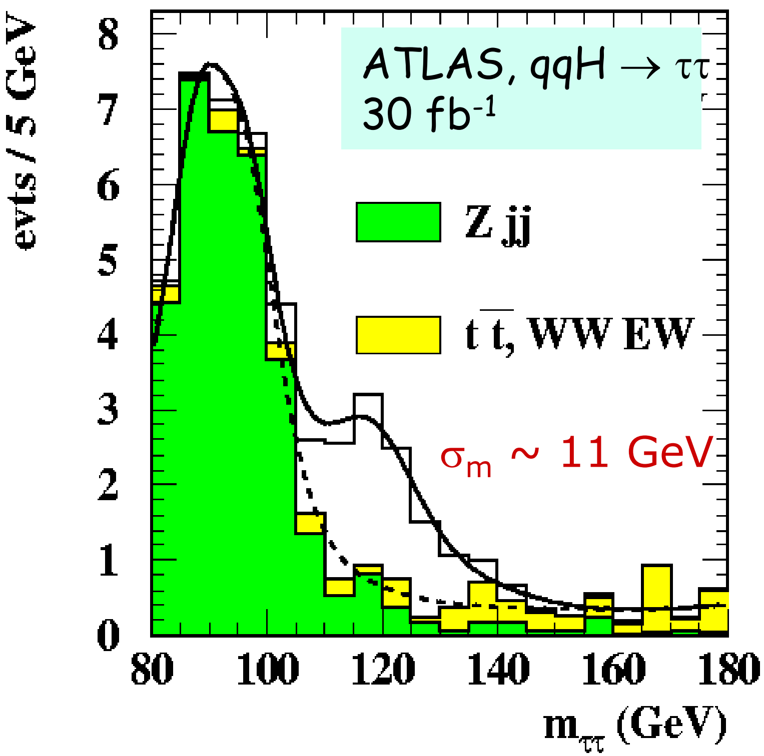
N. B.: $\Gamma_H \sim m_H^3$

A light Higgs will not be easy at the beginning

$m_H \sim 120$ GeV



It will need a perfectly understood detector in terms of photon identification, calorimetry, tracking, ….



BG dominated by irreducible

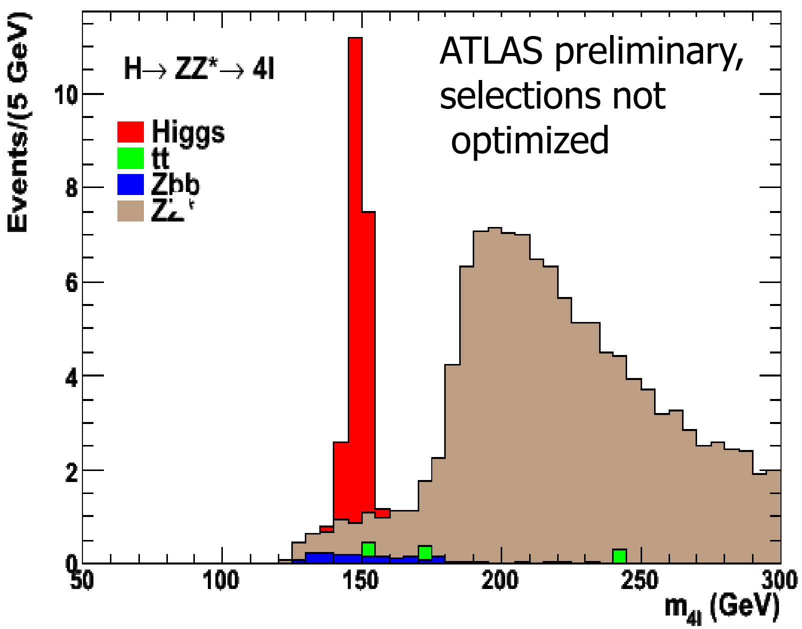
components

2011 ?

$M_H > 130$ … is easier

$m_H > 130$ GeV : $H \to ZZ^{(*)} \to 4l$ (gold-plated), $H \to WW^{(*)} \to l\nu\, l\nu$

$H \to ZZ^* \to 4l$, 10 fb^{-1}



May be observed with 3-4 fb^{-1}

2011-2012 ?

$H \to 4l$: low-rate but very clean : narrow mass peak, small background

- requires:
  - ~ 90% e, μ efficiency at low p_T
  - $\sigma/m \sim 1\%$, tails < 10% → good quality of E, p measurements in ECAL and tracker
- background dominated by irreducible ZZ production (tt and Zbb rejected by Z-mass constraint, and lepton isolation and impact parameter)

$H \to WW \to l\nu l\nu$: high rate (~ 100 evts/expt) but no mass peak

→ not ideal for early discovery …