Commissioning of the ATLAS Detector with cosmic rays / single beam data

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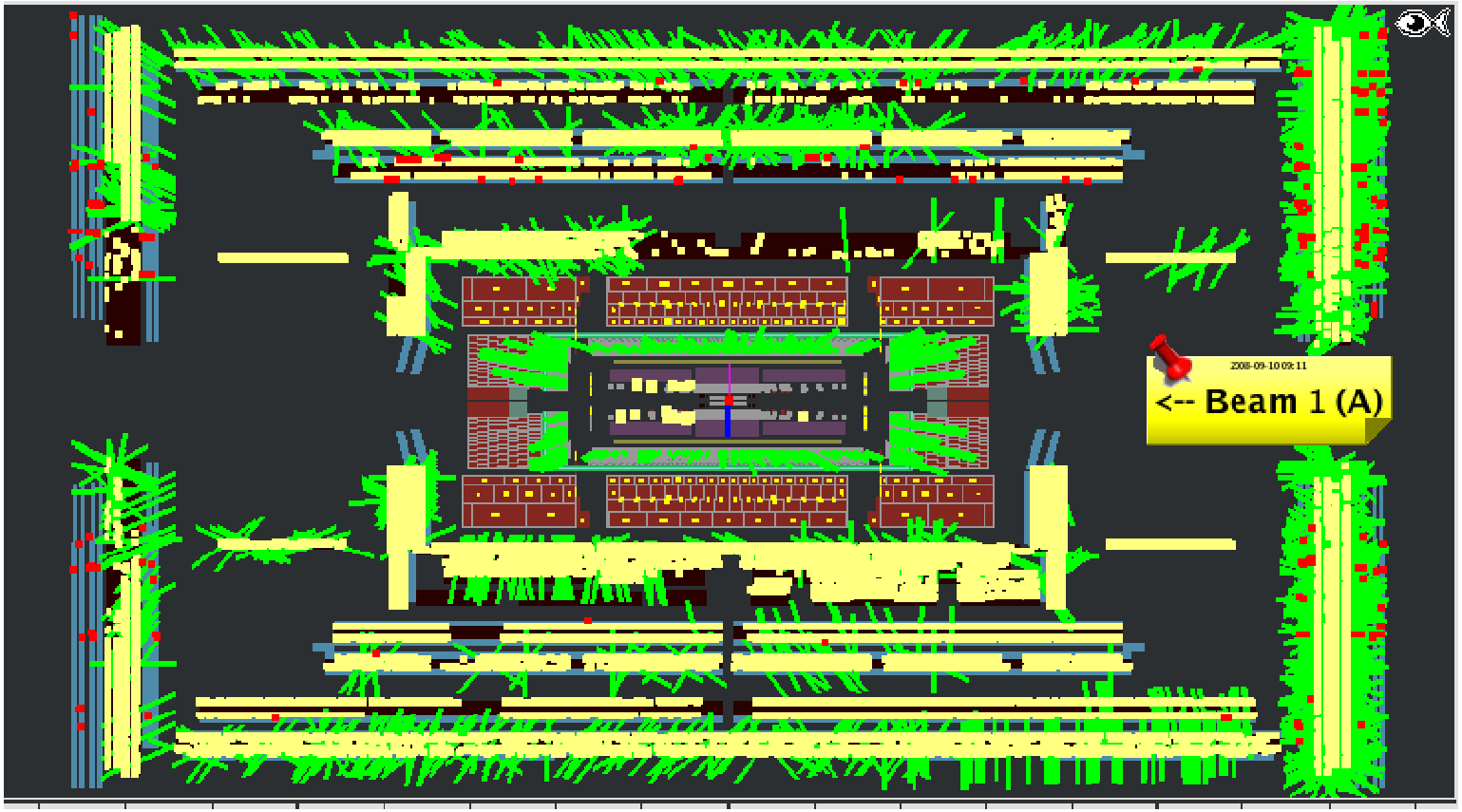
for ATLAS-Italia

- Fall 2008 data taking
- (sub)Systems review:
  - status
  - characterization/calibration with cosmics ray
- Putting all together
- Experience with calibration and data flow
- Thanks for help in selecting material:

  Michele Bianco, Gianpaolo Carlino, Fabio Cerutti, Claudia Ciocca, Claudio Costa, Andrea Dotti, Domizia Orestano, Silvia Resconi...

Single beam data

- Few days starting on September 10th.
- Limited statistics but complementary information to cosmic rays:
  - mainly relevant for calorimetry
  - verification of timing and response uniformity



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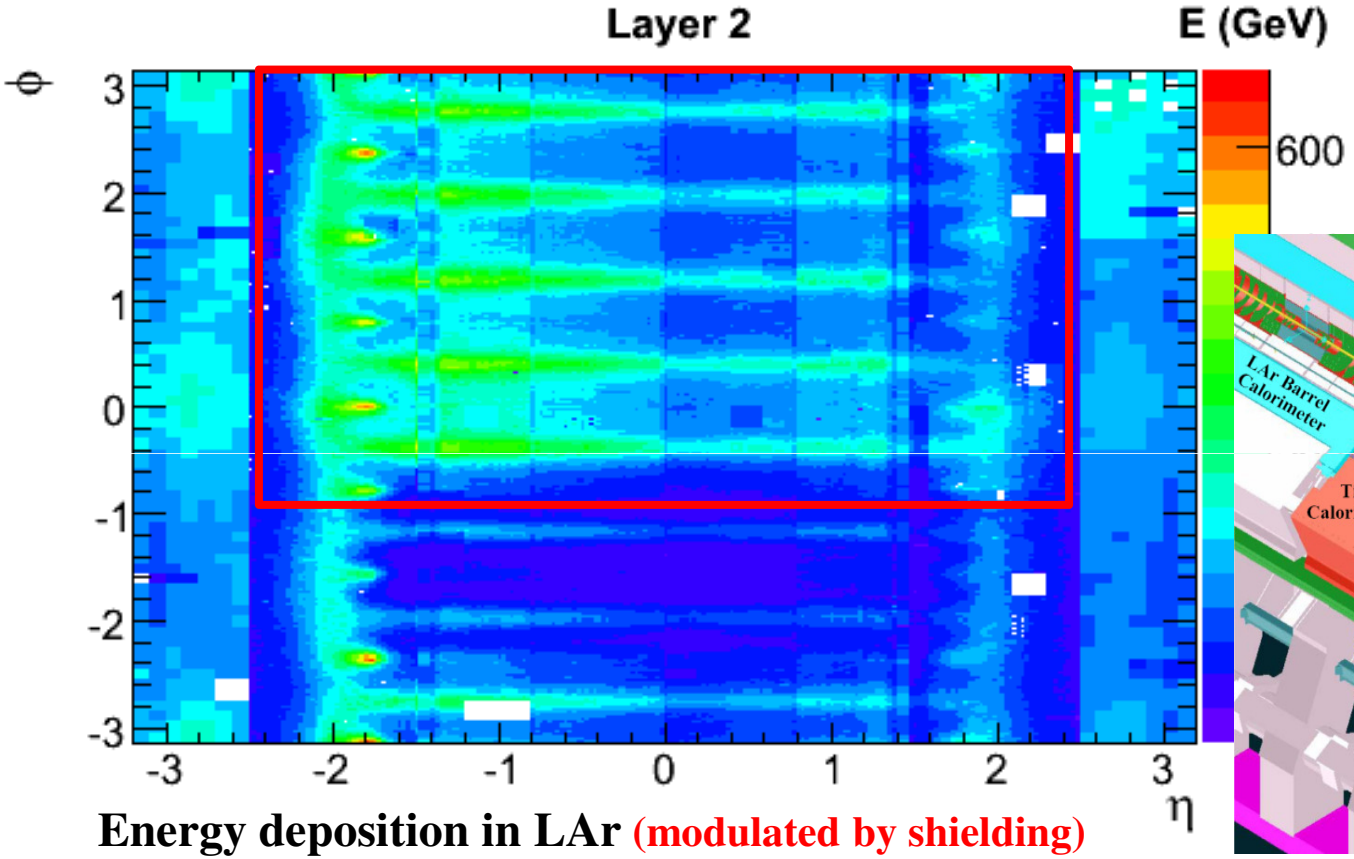
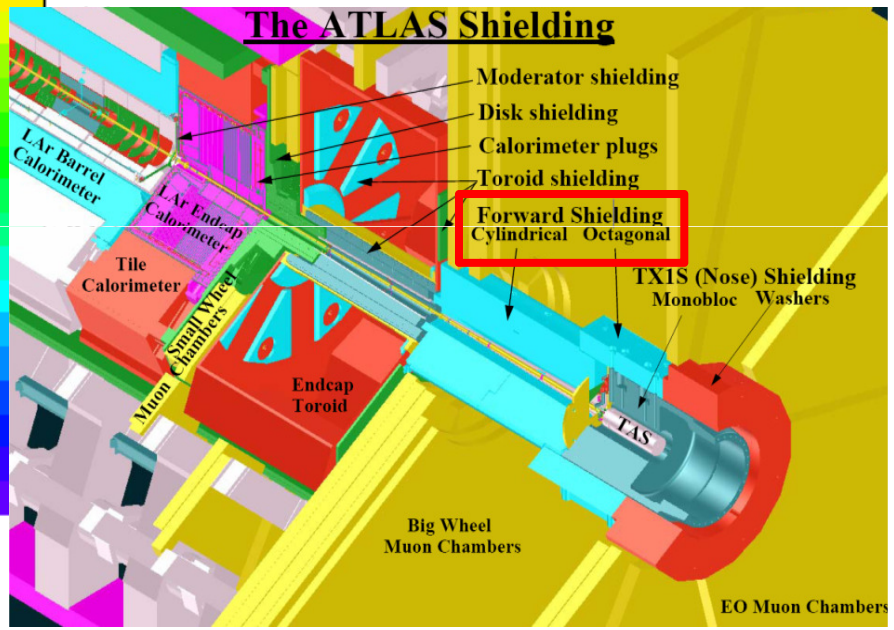
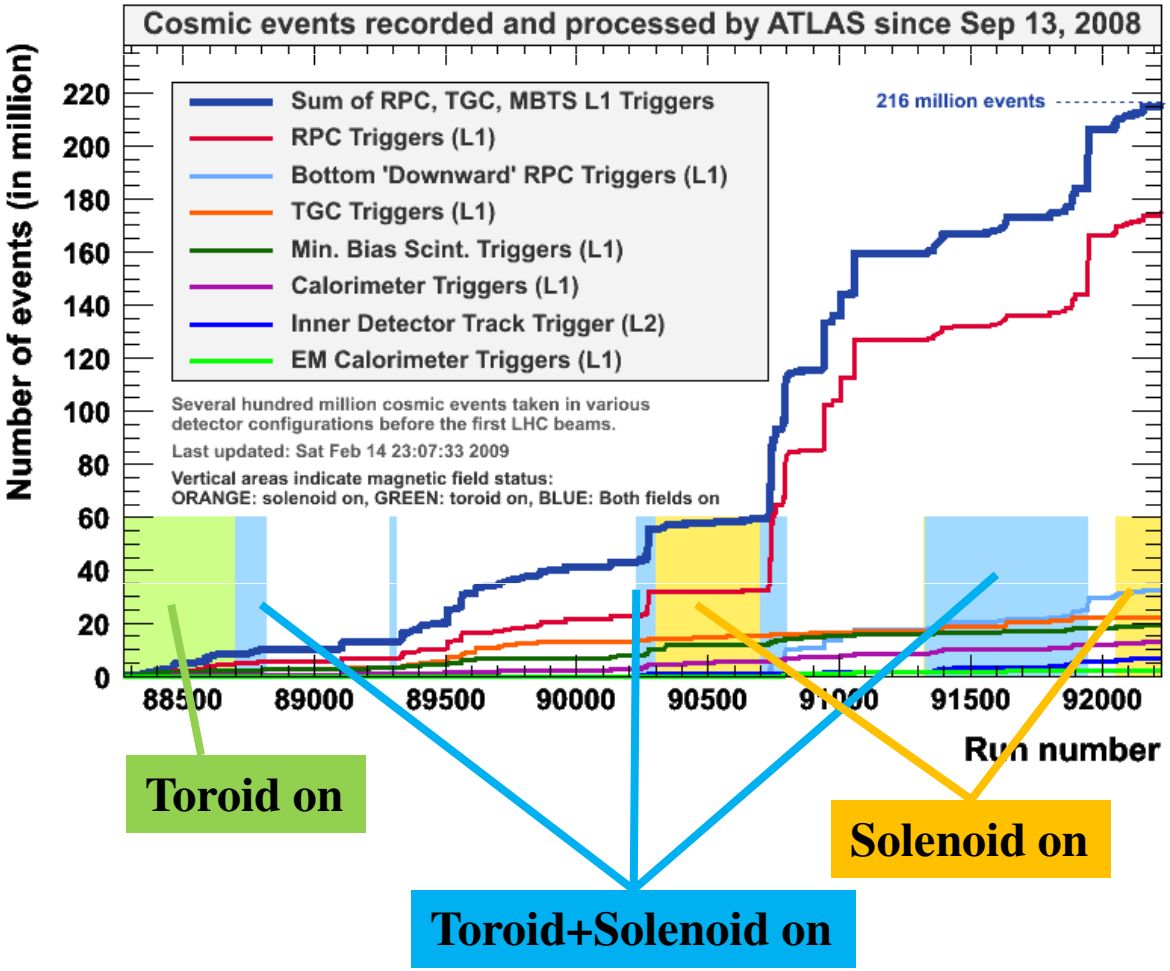


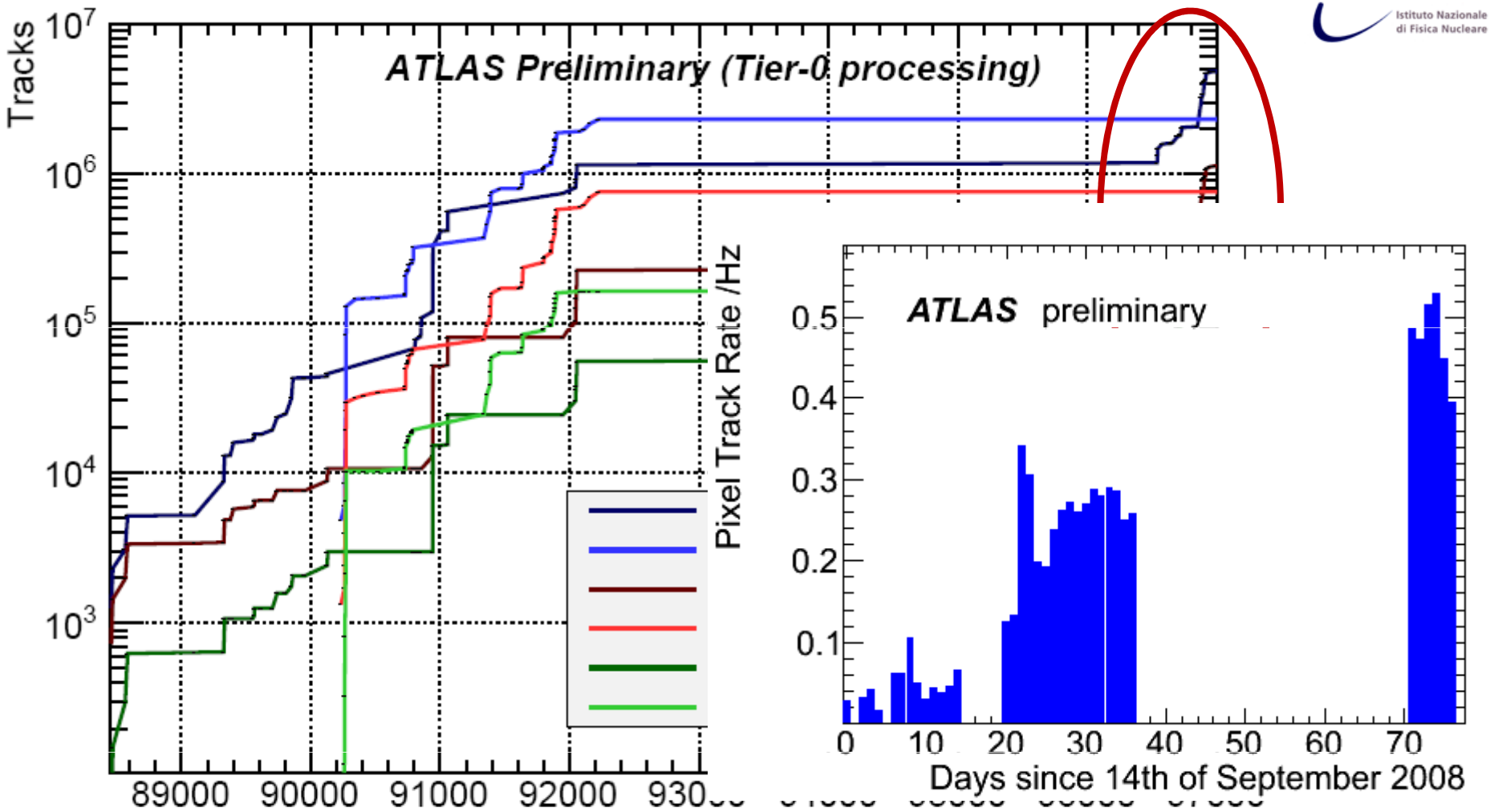
Energy deposition in LAr (modulated by shielding)



Fall-2008 cosmic rays data

- Most significant cosmic rays run period
  September 13th- October 26th.
  - detector was ready for LHC startup in September 10th
  - including the whole ID:
    - Si stopped by cooling accident on May 1st
    - repaired in July
    - tuning and calibration runs in August.
- 216 million events on tape:
  - Different magnetic field configurations
  - Alignment
  - ID performance
  - Combined reconstruction

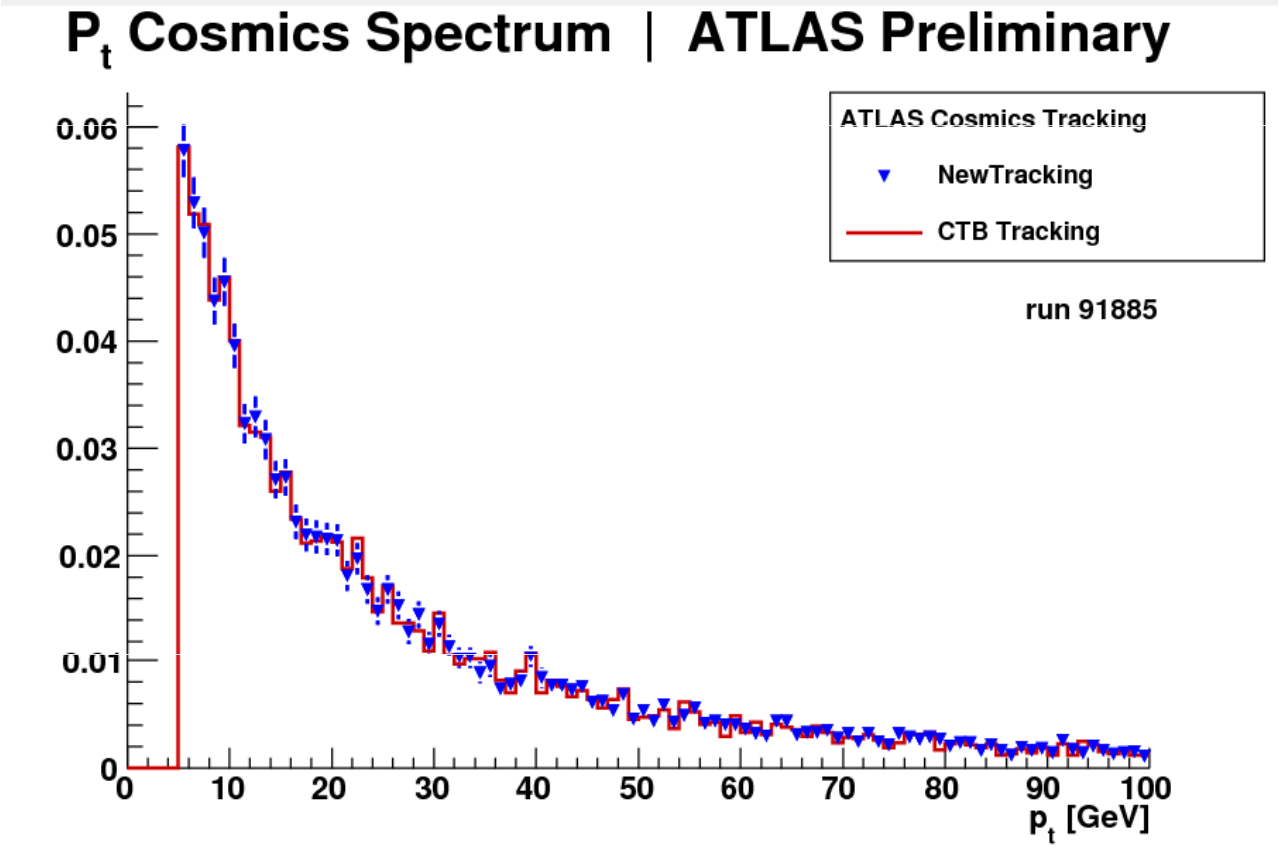


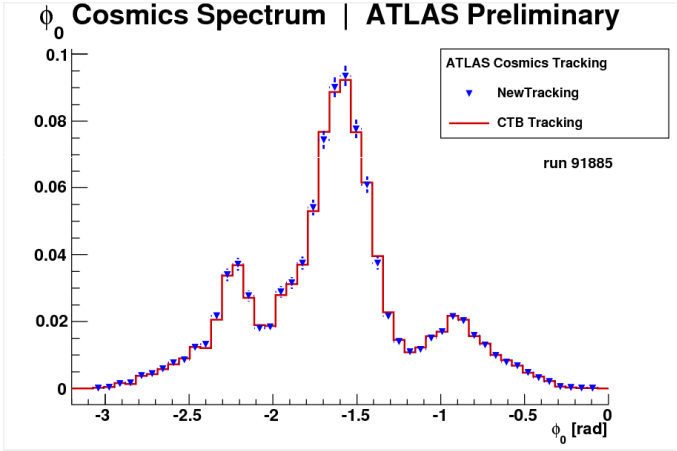


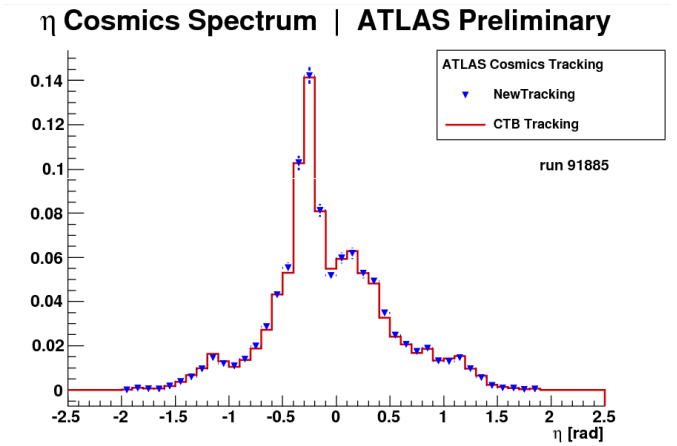
- **Additional ID Combined run**
  - November 26th-December 1st
  - no magnetic field (4× statistics)
  - Track trigger at L2

	Solenoid off	Solenoid on
TRT tracks	4940k	2670k
SCT tracks	1150k	880k
Pixel tracks	230k	190k

Cosmics ray properties

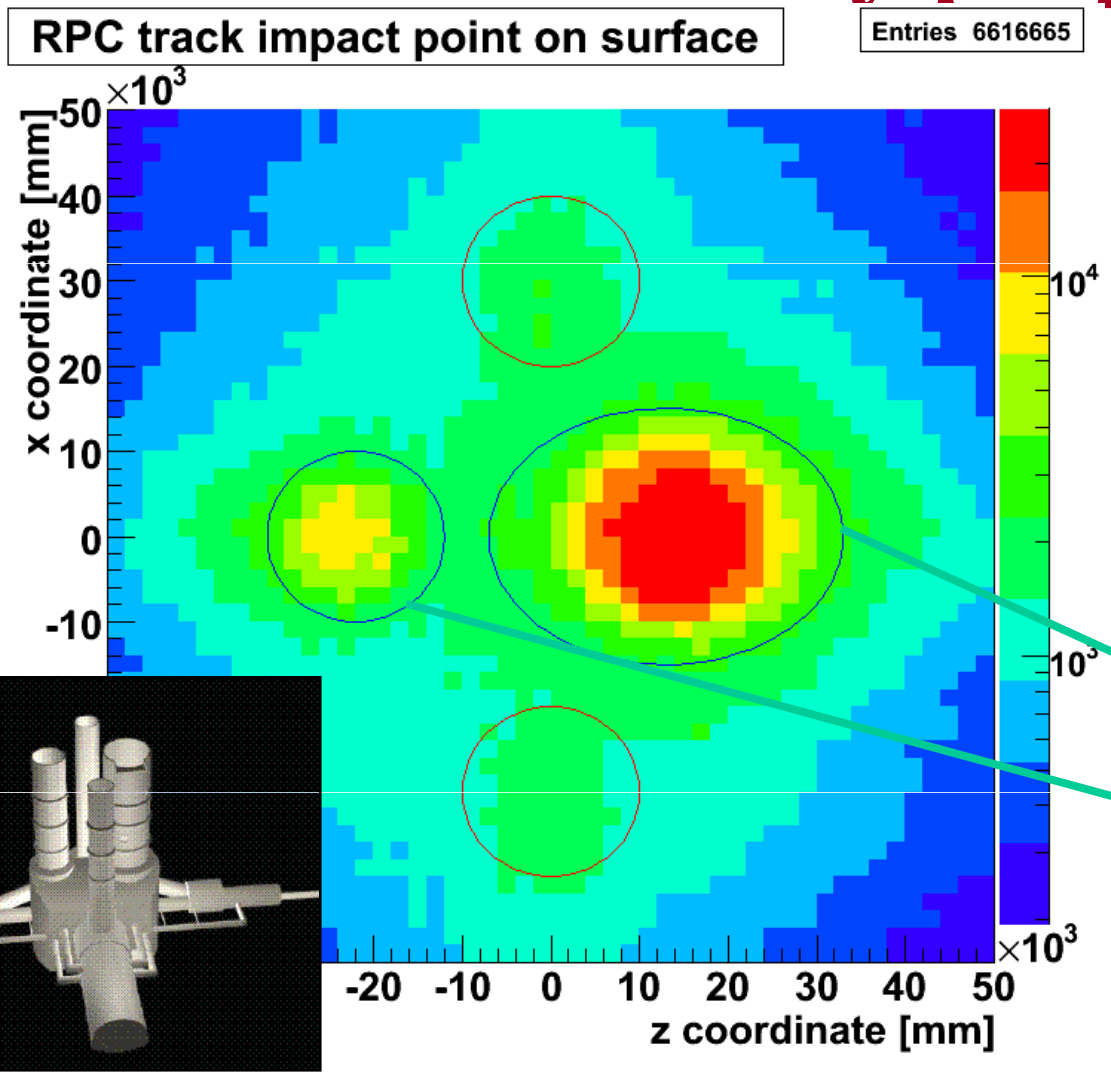


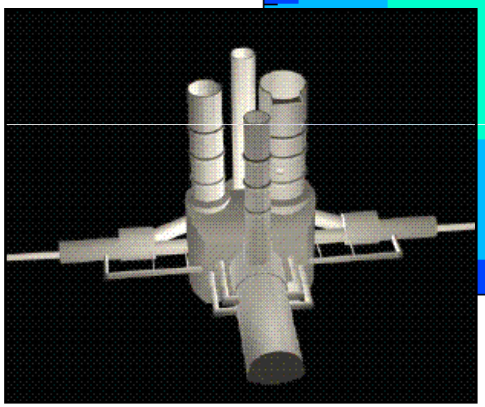


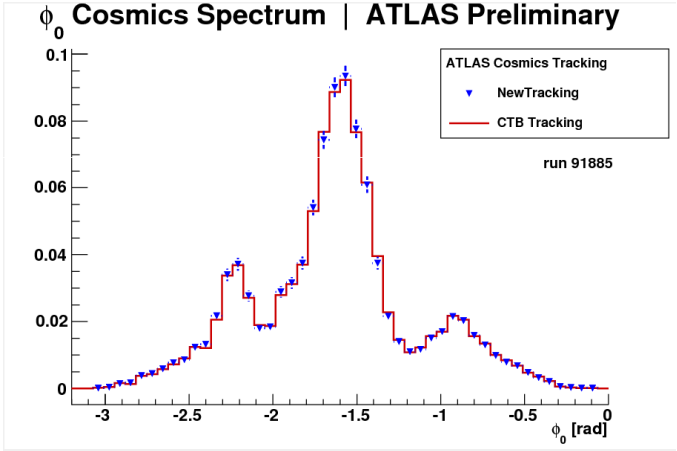


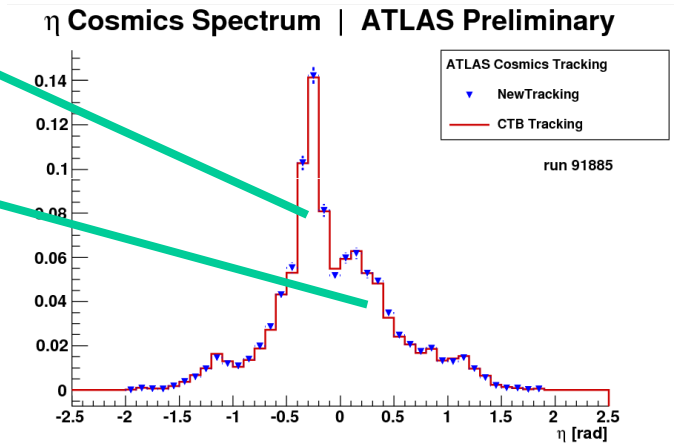
N.B.: **blue** and **red** are two different tracking algorithms

Cosmics ray properties









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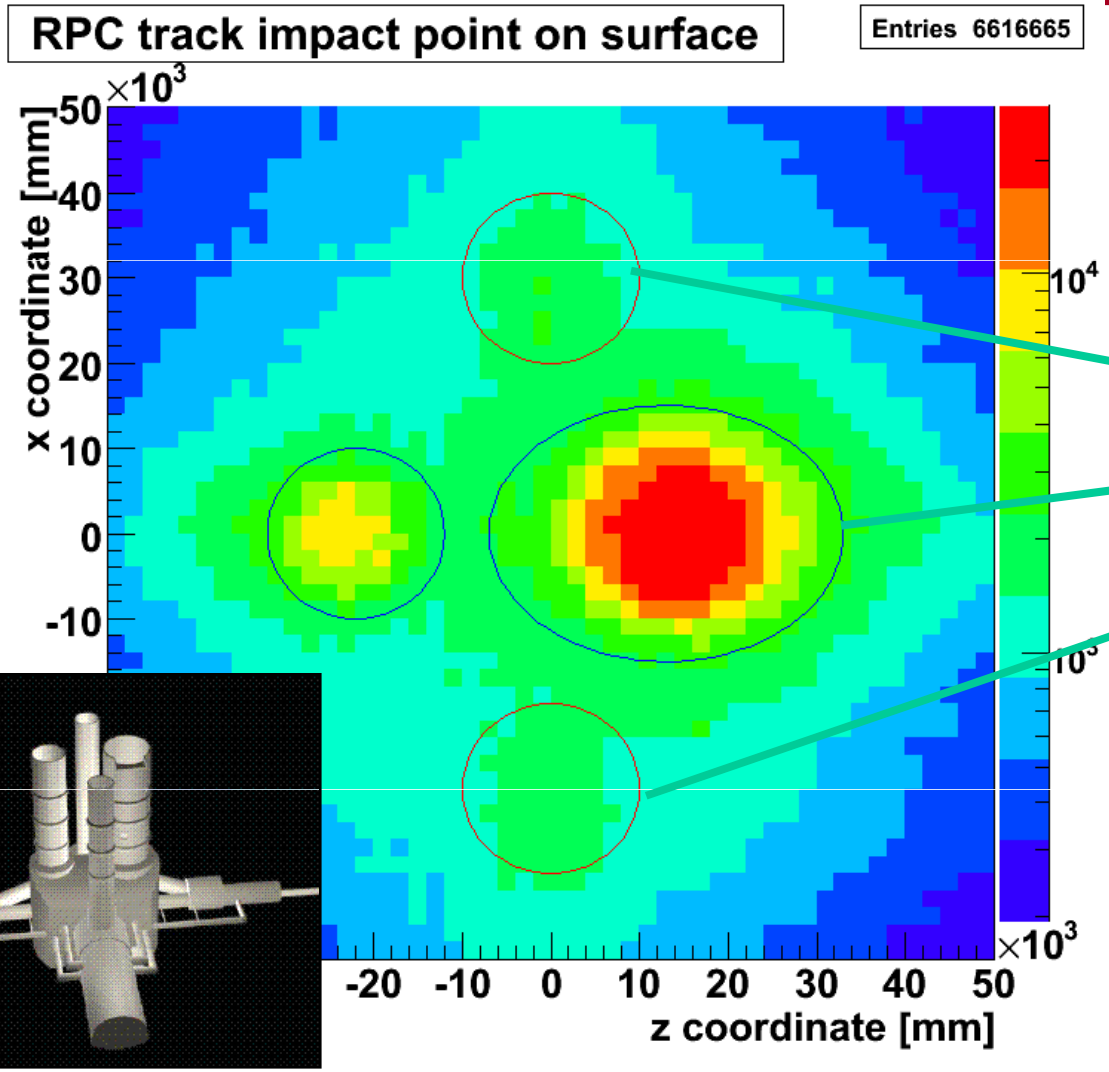

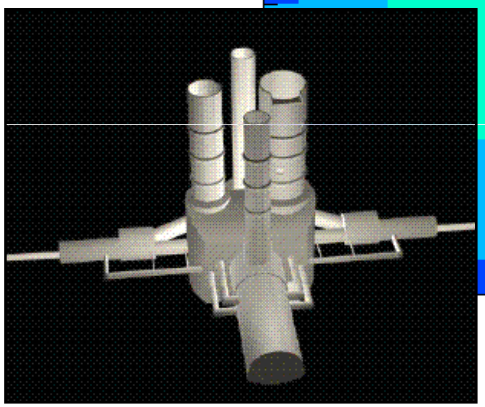

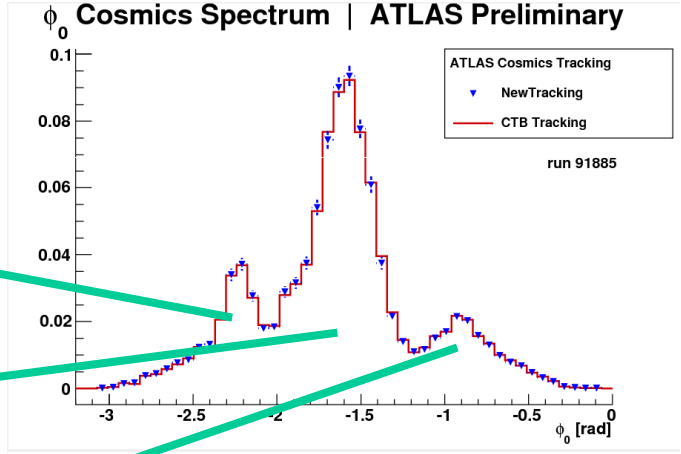

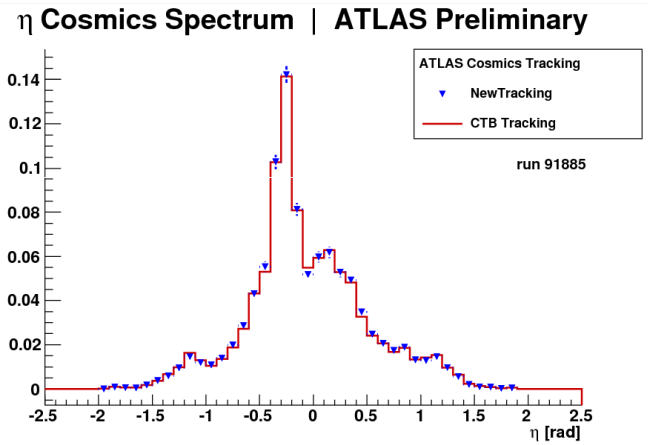

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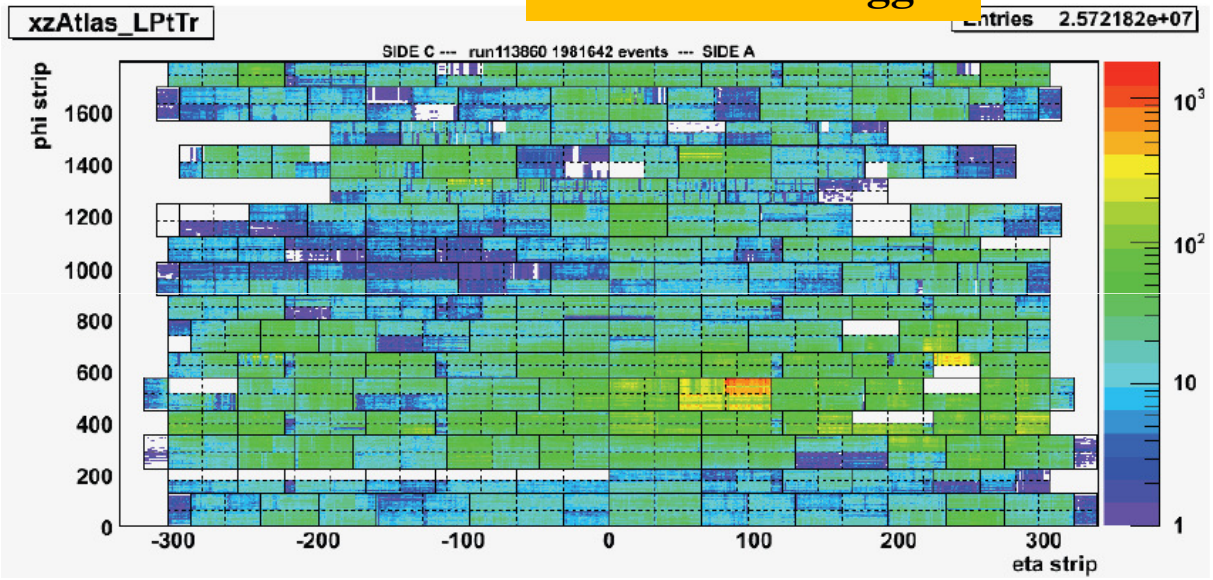
DETECTOR STATUS AND STANDALONE CALIBRATIONS

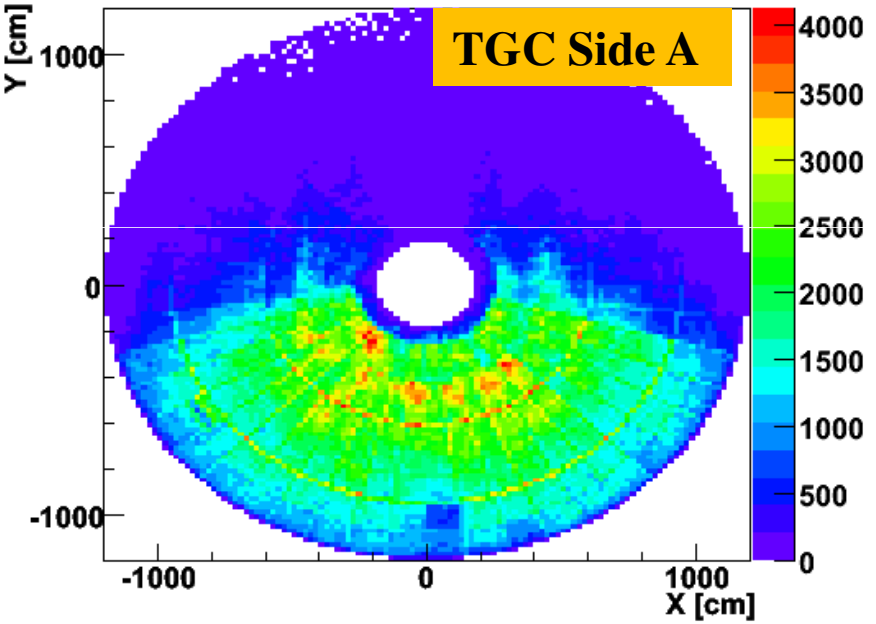
Muon System

- **MDT**
  - **99.8% operational**
- **RPC**
  - **95.5% operational**
  - 70% of trigger coverage for 2008 run
  - commissioning completed for 2009 run
- **TGC**
  - **99.8% operational**
- **CSC**
  - **100% operational**
  - but only in calibration mode
  - problem in ROD firmware fixed in 2009 (under test at CERN).

RPC Low Pt trigger

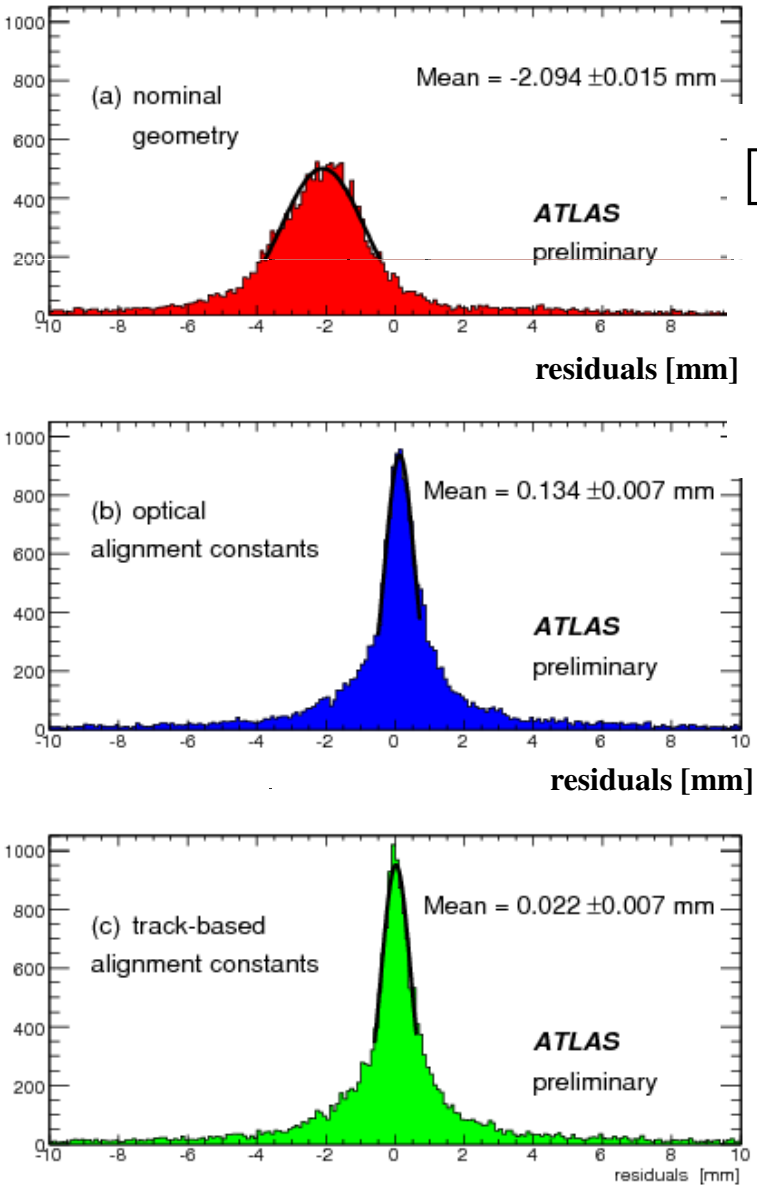


TGC Side A



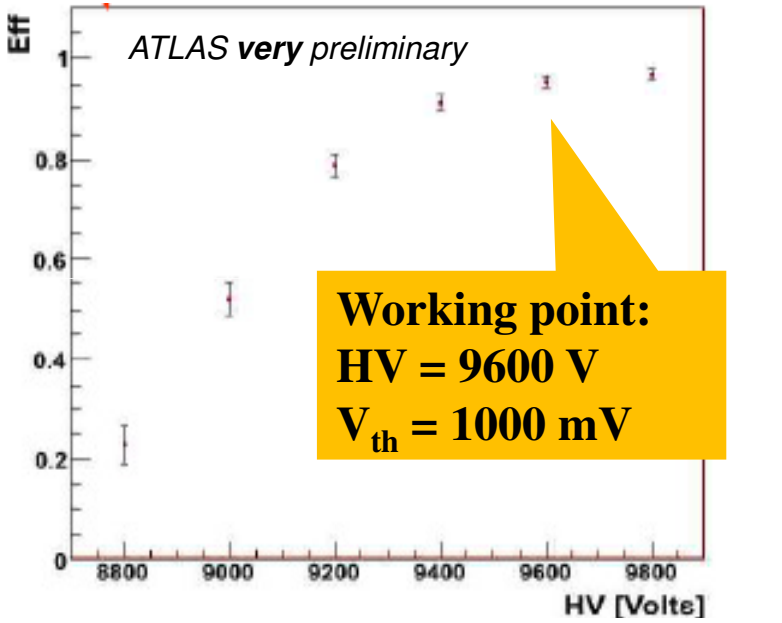
MDT Performance

- MDT efficiency study
  - 683/1110 chambers analyzed:
    - missing statistics on EO and EM chambers due to limited acceptance for cosmics
- Faulty channels <1%
  - most of them involve clusters of tubes sharing HV or FE boards
  - are being repaired for 2009 running
  - expected final dead channels 0.11%
- Chamber resolution
  - single hit resolution <100 μm (comparable with test beam data)
  - **for curvature measurement:**
    - **optical alignment recovers most of distortions**
    - **residual systematics fixed with tracks**



RPC performance

- Efficiency
  - cross checked with several methods
  - most inefficiencies are related to HV
  - typical strip efficiency is 98% at the nominal working point
  - 90% on average due to bad channels in 2008 run.
  - **Similar values (92% average) have been measured on TGC.**
- Point resolution
  - Computed with respect to MDT tracks
  - Value comparable to expectation from digital readout.



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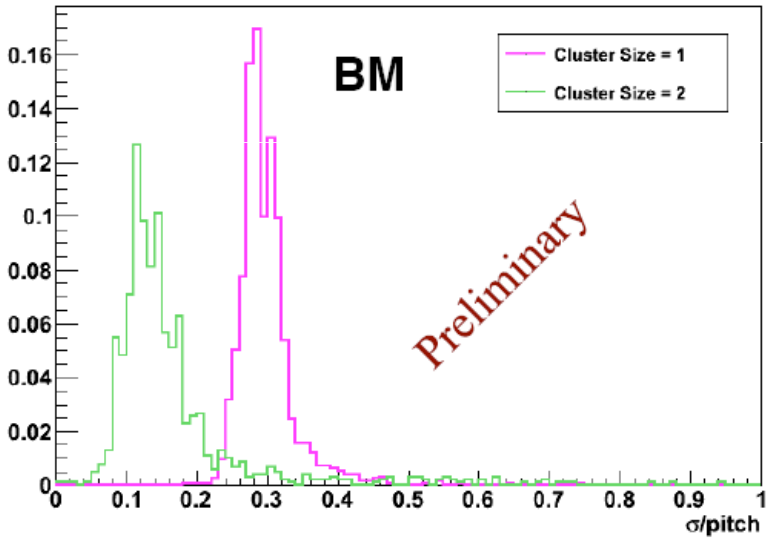
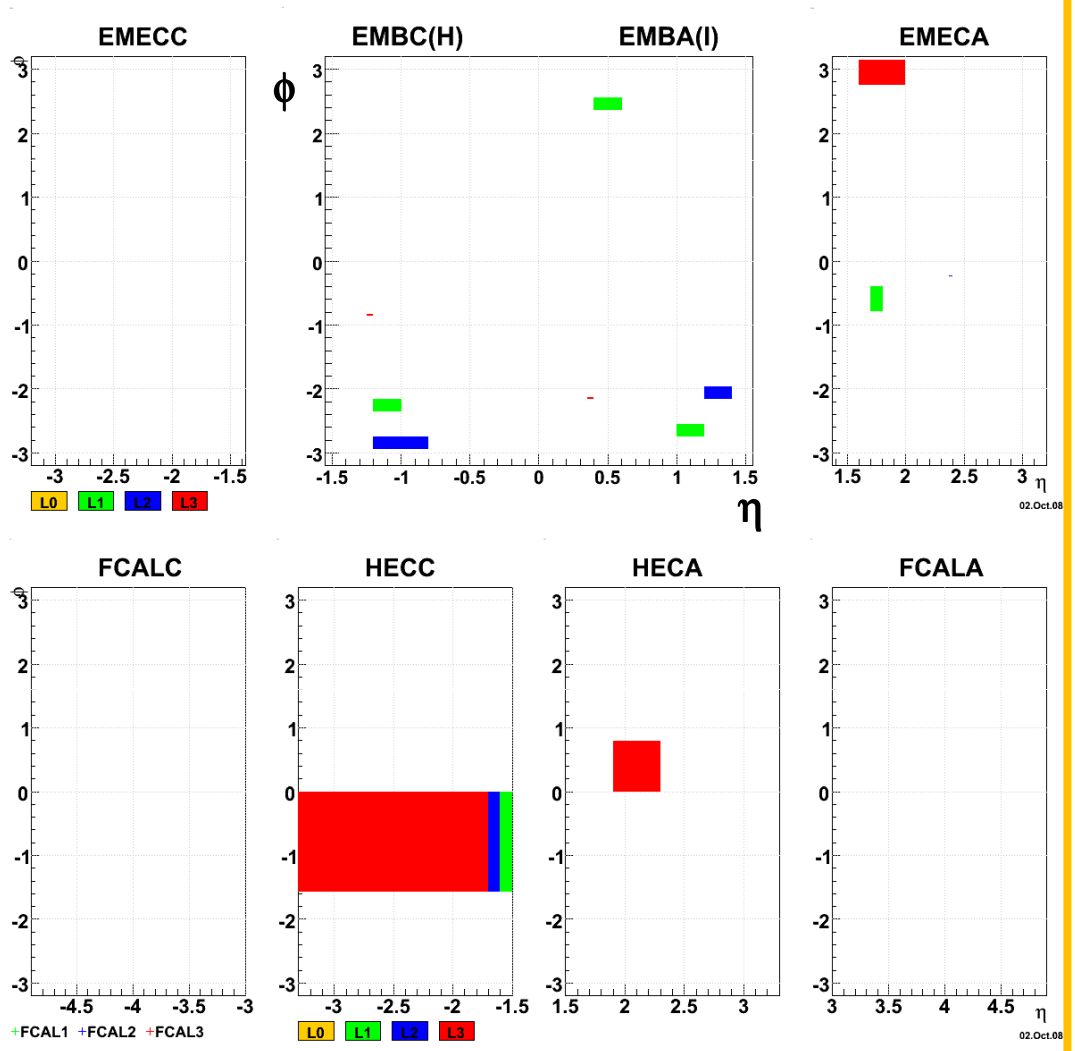


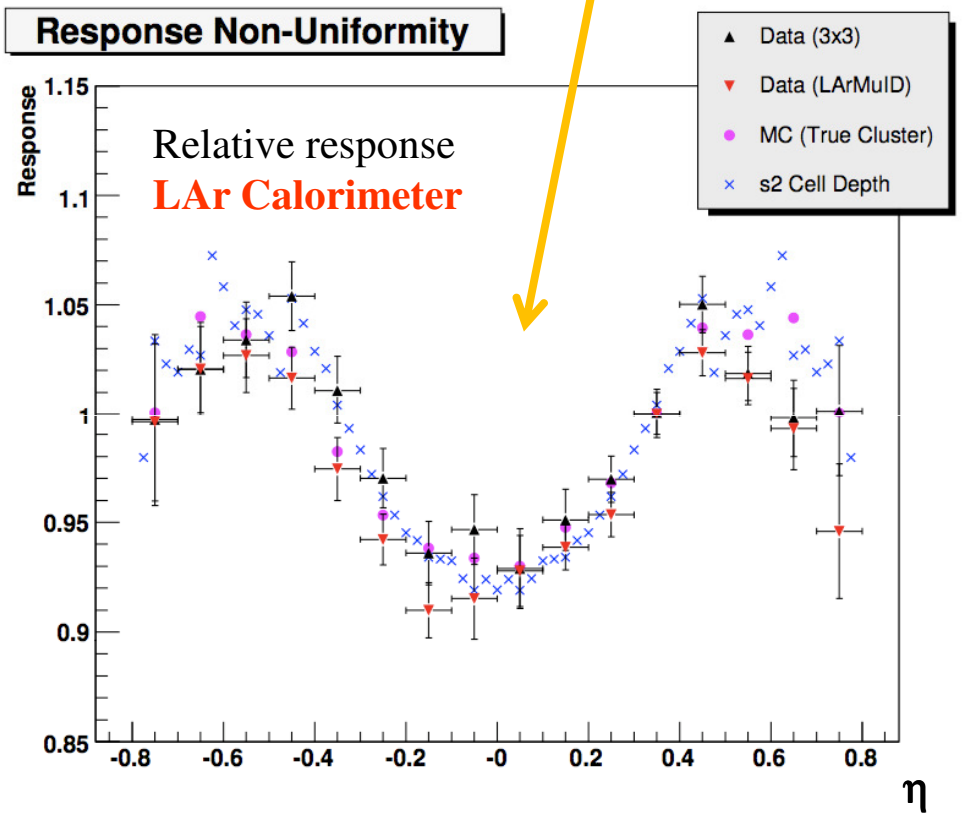
Calorimetry status

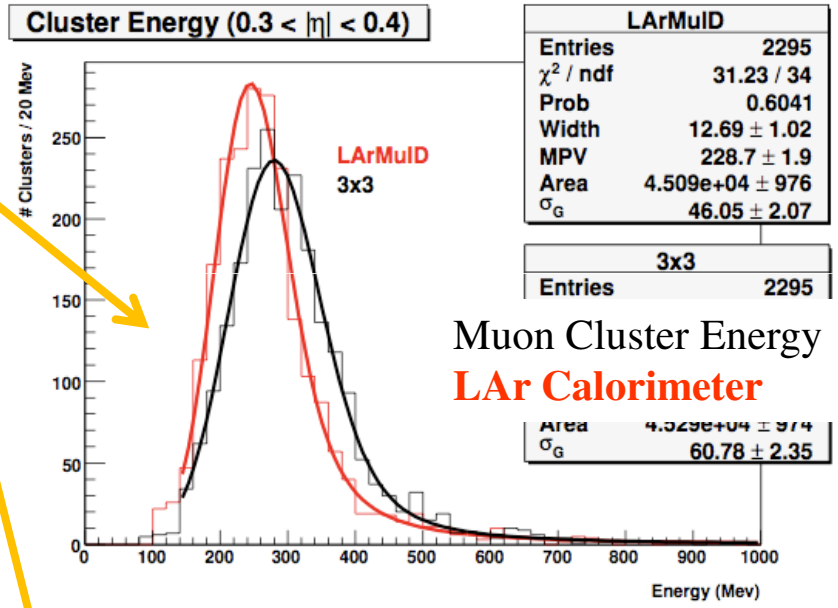
- **LAr**
  - Dead readout regions <0.95%
  - Under repair during shutdown
  - individual dead channels 0.02%
  - Not to be repaired
- **Tile**
  - 0.8% defective LVPS
  - 1.4% FE inefficiencies
  - Under repair for 2009 run: side A finished 100% efficient

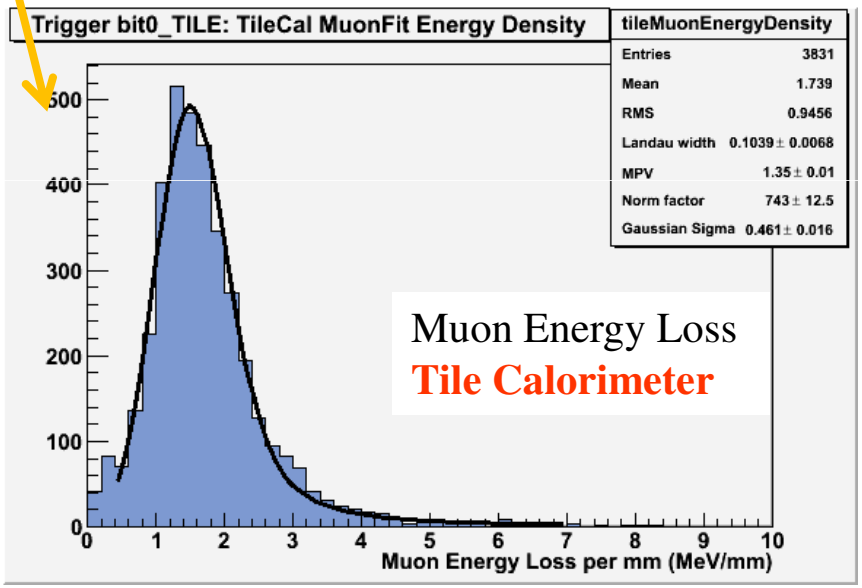


Pre-september cosmics data

- Sensitivity to minimum ionizing particles already tested before the September run.
- Response uniformity <2% (LAr)

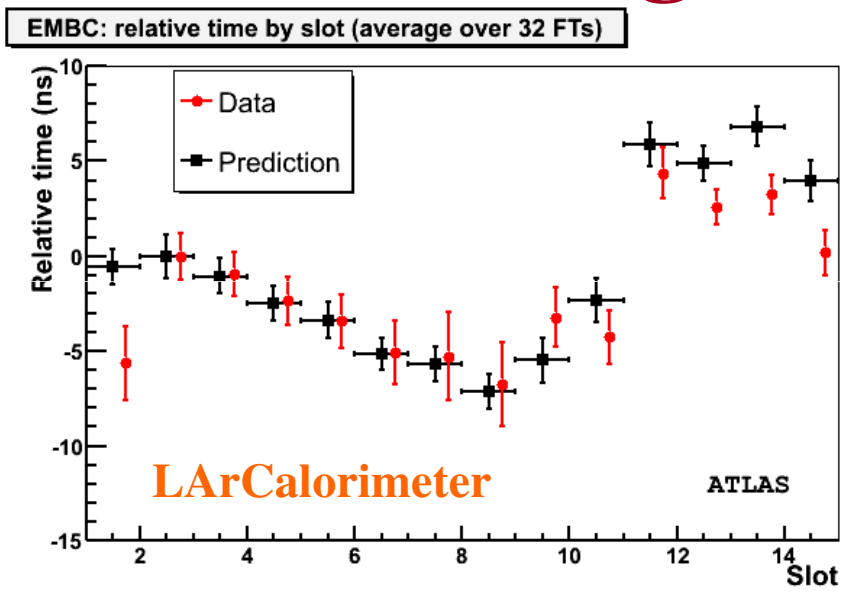


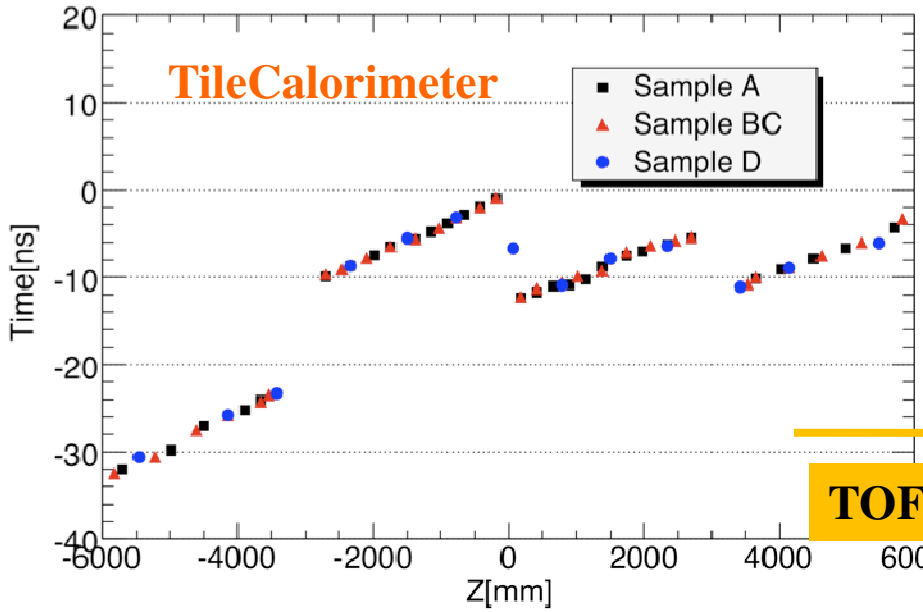




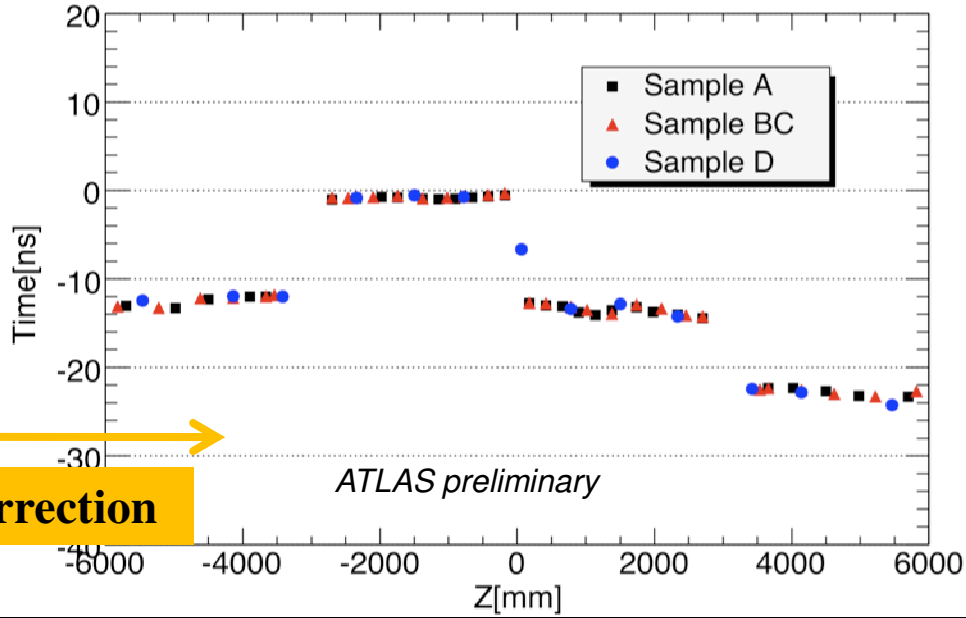
Single beam calibrations: timing

- Beam halo particles cross different detector elements.
- Correction for
  - Time Of Flight,
  - Electronic response
- Offset between different partitions can be measured and corrected.
- Synchronization <2 ns



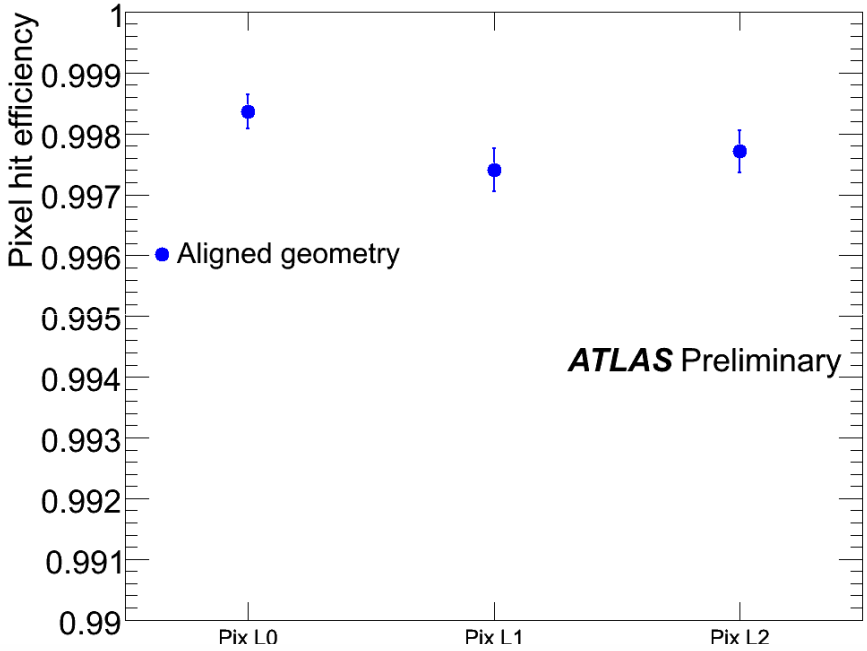


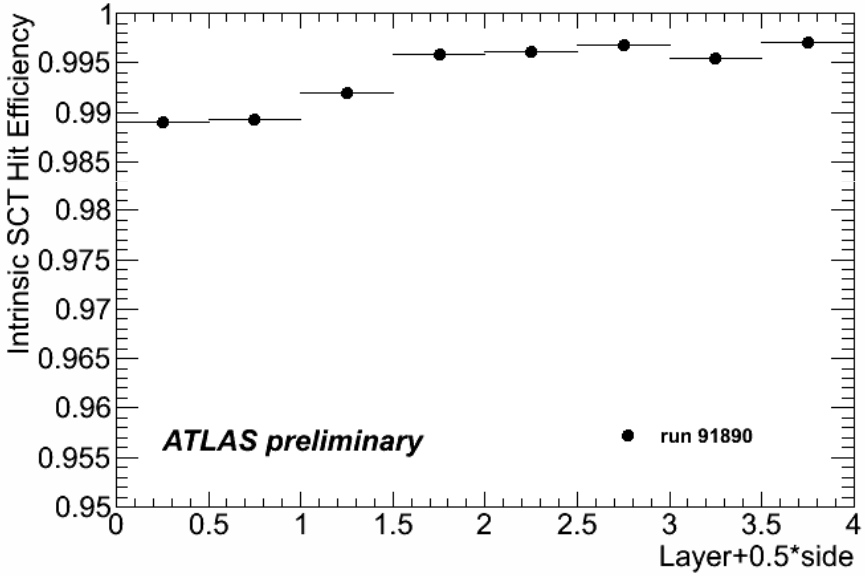
TOF correction



Inner detector status

- **Pixel detector**
  - 98.5% of detector operational
  - during cosmics run:
    - 98% of barrel
    - 85% of disks
- **SCT**
  - 99% of barrel operational
  - 97% of endcap operational
- Difference between Si barrel and Si endcaps maily due to leaky cooling loops
  - cooling system operated continuously from August till end of December run
- Measured intrinsic detector efficiency >99.5%
- **TRT**
  - 98% of channels operational
  - 2% dead from assembly and installation

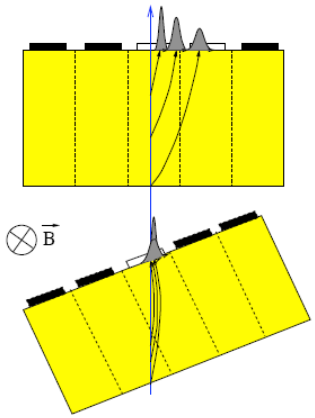




Lorentz angle determination

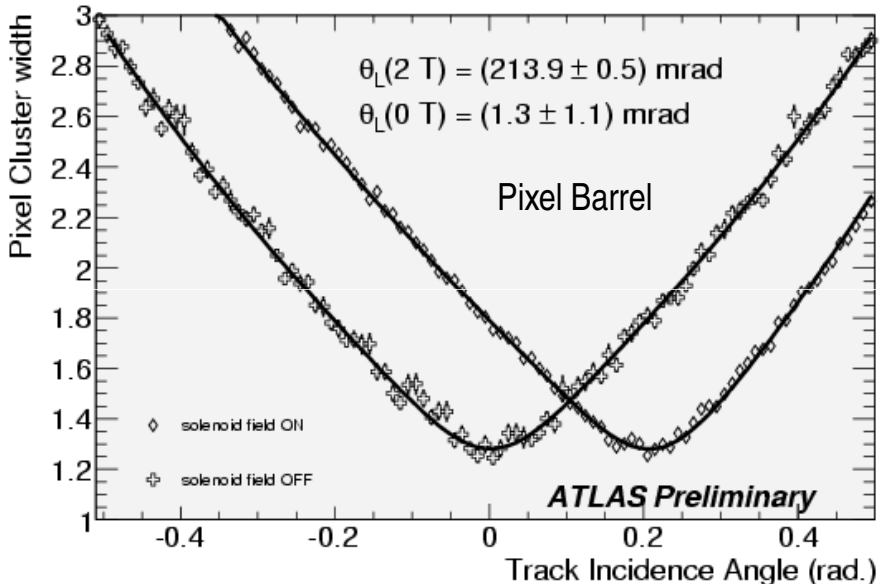
- Drift in silicon is affected by E×B effect
- Charge is (de)focused along the Lorentz angle direction:

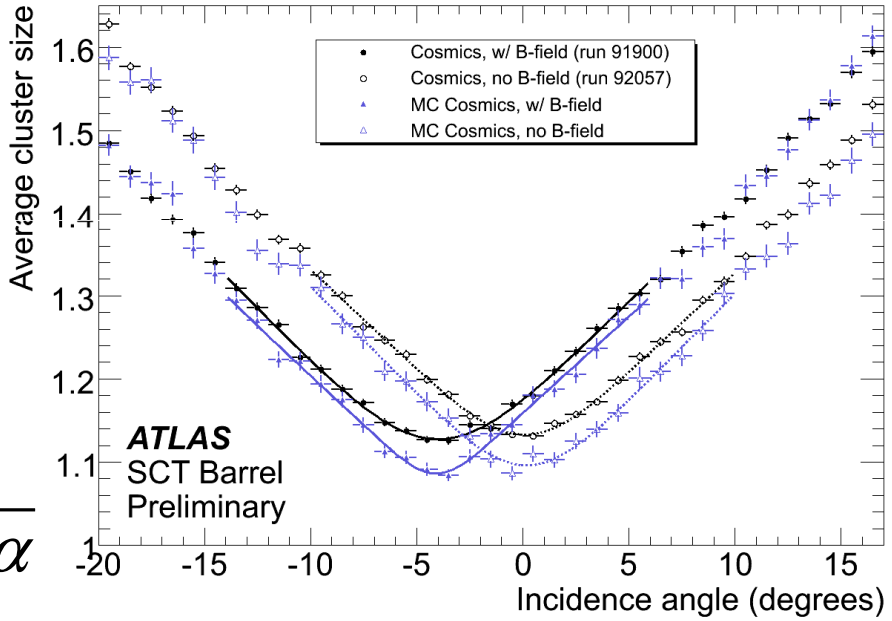
$$\tan\alpha_L = \mu_H B$$



- Point displacement: thickness×tan(α_L)/2
  - ≈ 30 μm for pixels
  - ≈ 10 μm for SCT
- measurement using cluster size vs. incidence angle α:

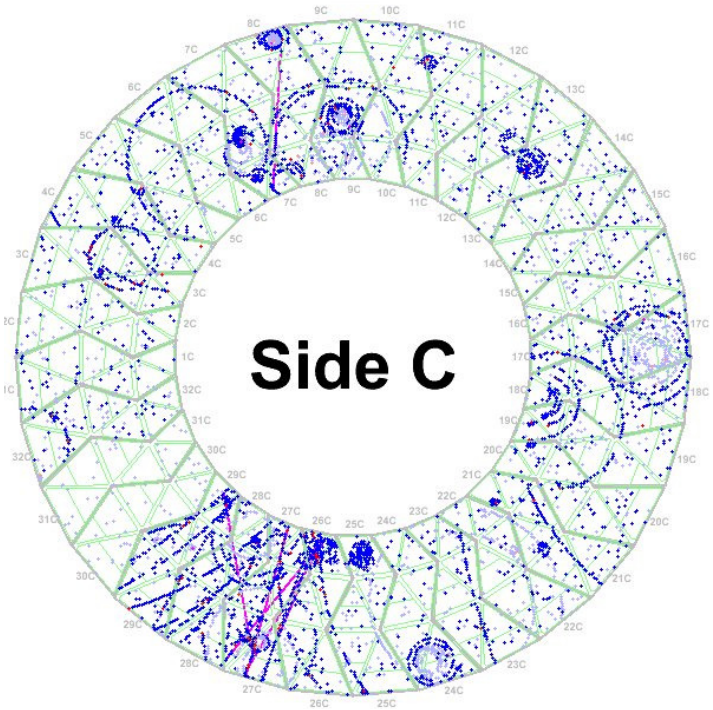
$$\text{cluster size} = a\left(\tan\alpha - \tan\alpha_L\right) + b/\sqrt{\cos\alpha}$$

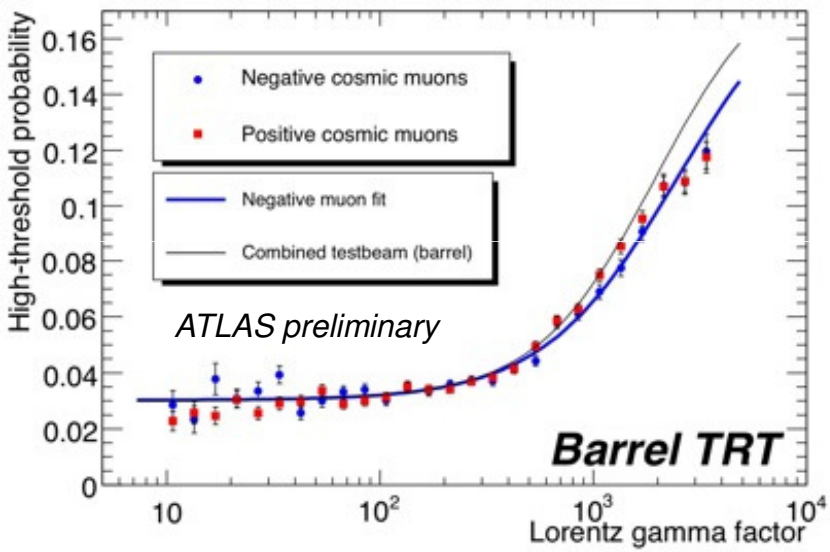


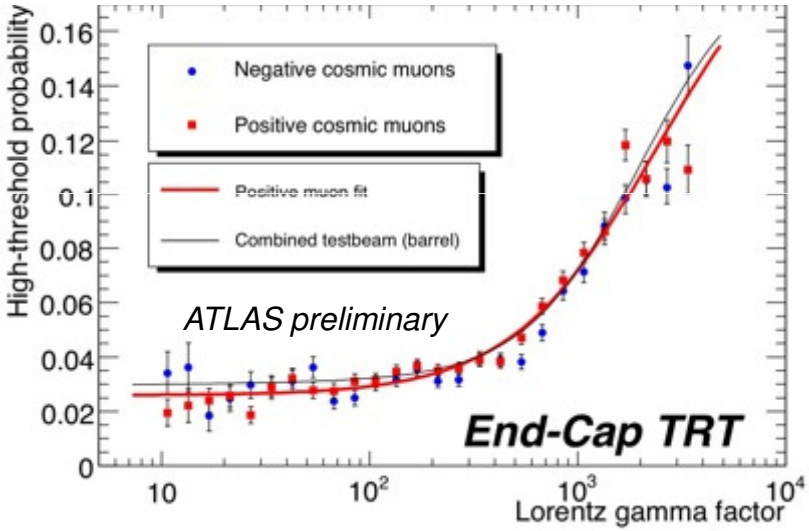


TRT threshold behavior

- TRT provides "bubble chamber" quality tracking...
- ...and transition radiation for high momentum particles.
- **Observed the on-set of transition radiation for high p muons!**



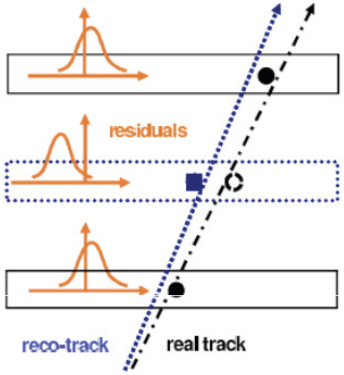




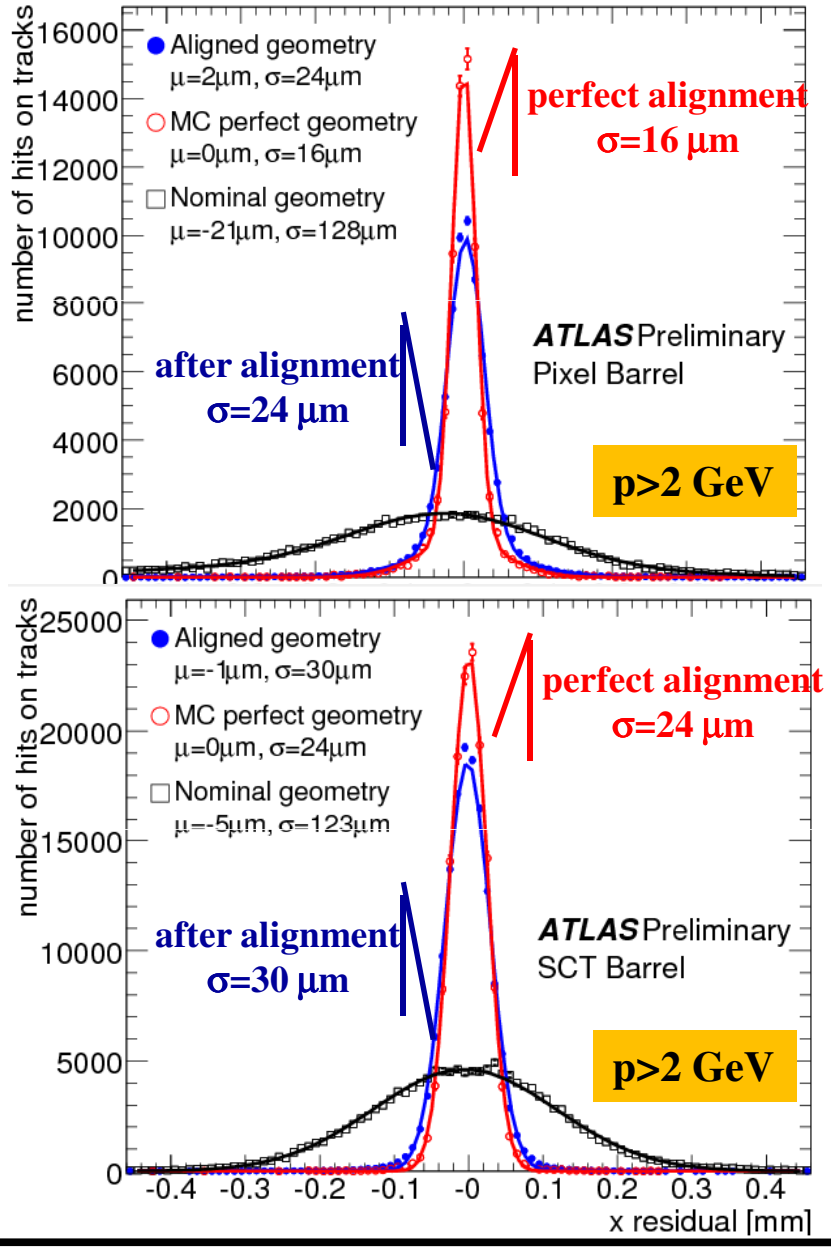
PUTTING ALL TOGETHER

Inner detector alignment

- Put together all ID subsystems by minimizing residuals

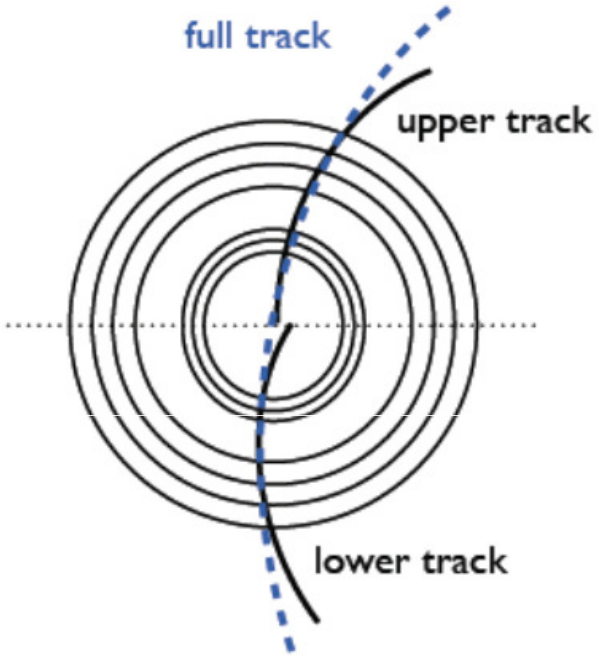


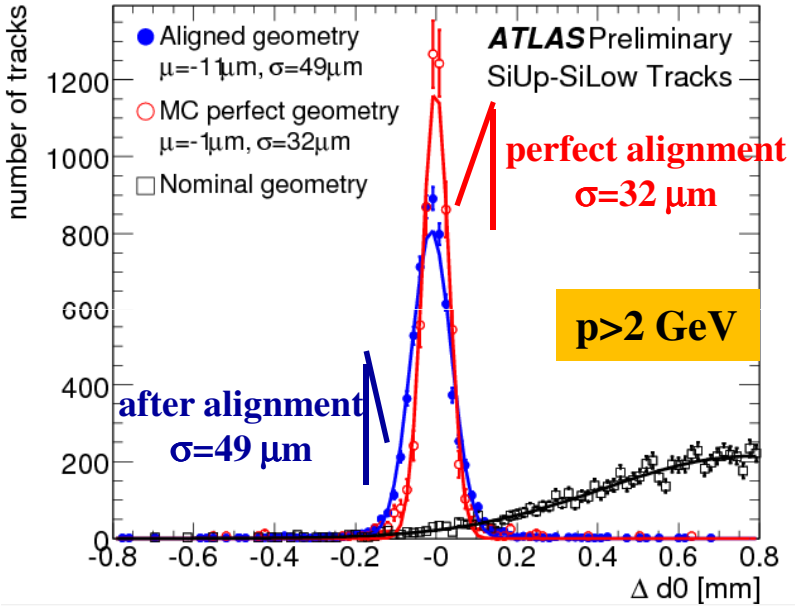
- Different strategies tested:
  - **global χ^2** ($6N \times 6N$ matrix)
  - local χ^2 (N 6×6 matrices)
  - robust (specific residuals distribution)
- Limited statistic/not uniform coverage:
  - N cannot be all Si objects
  - limit to macro structures layers, half shells, staves...

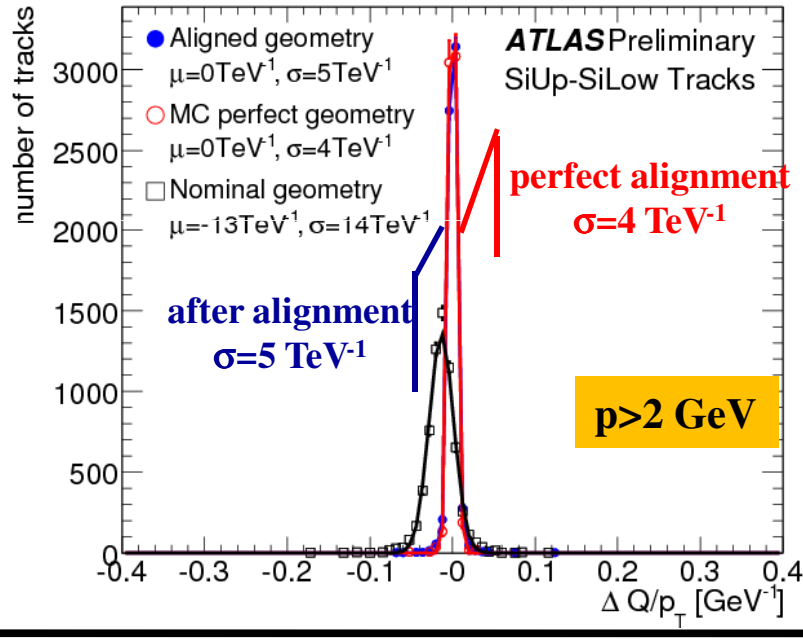


Track parameter resolution

- Precision on determination of track parameters can be obtained:
  - splitting the track in two segments
  - compare extrapolation at the interaction point of the segments.







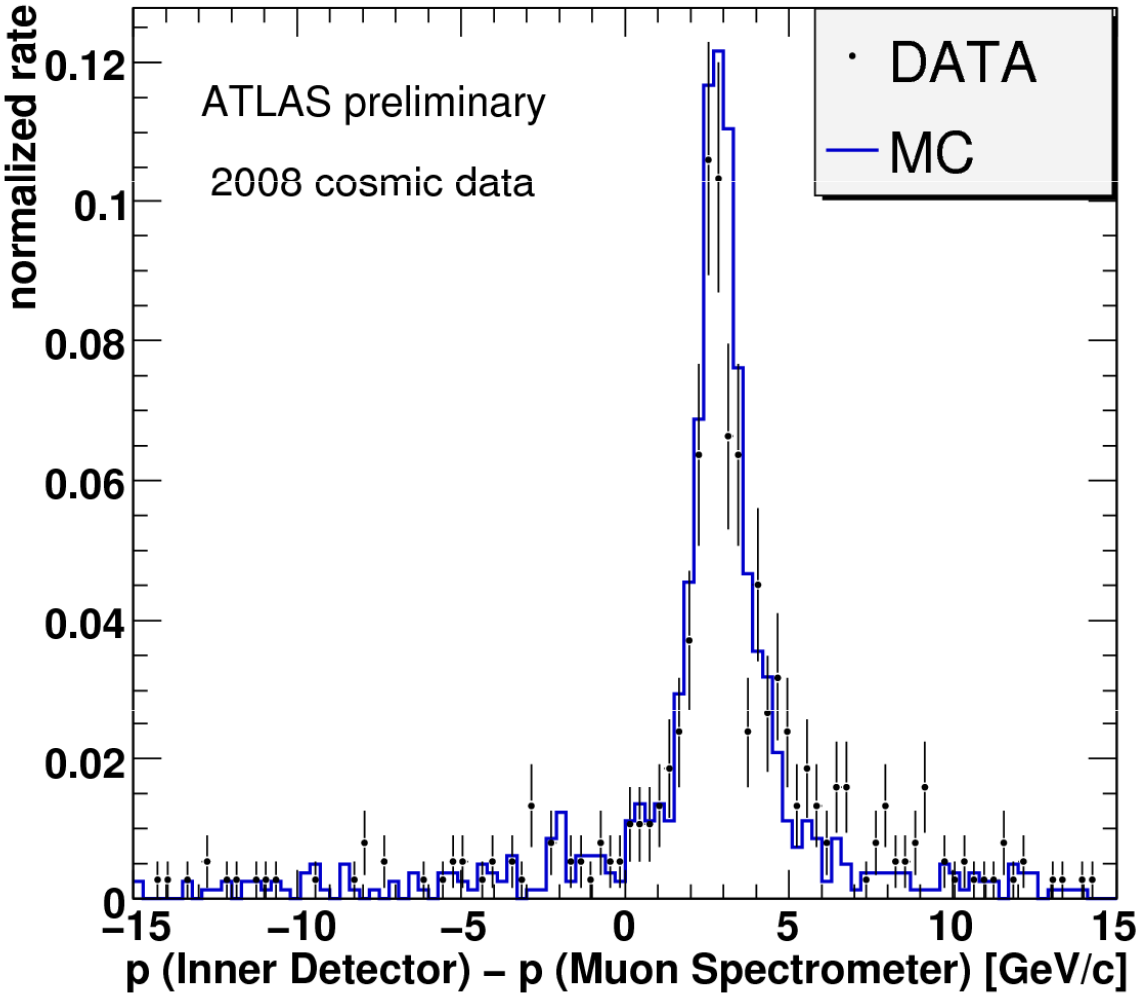
- Resolution already acceptable for LHC startup!

Muon energy loss in calorimeters

- Comparing standalone muon and ID tracks, it is possible to measure energy loss in the calorimeter:

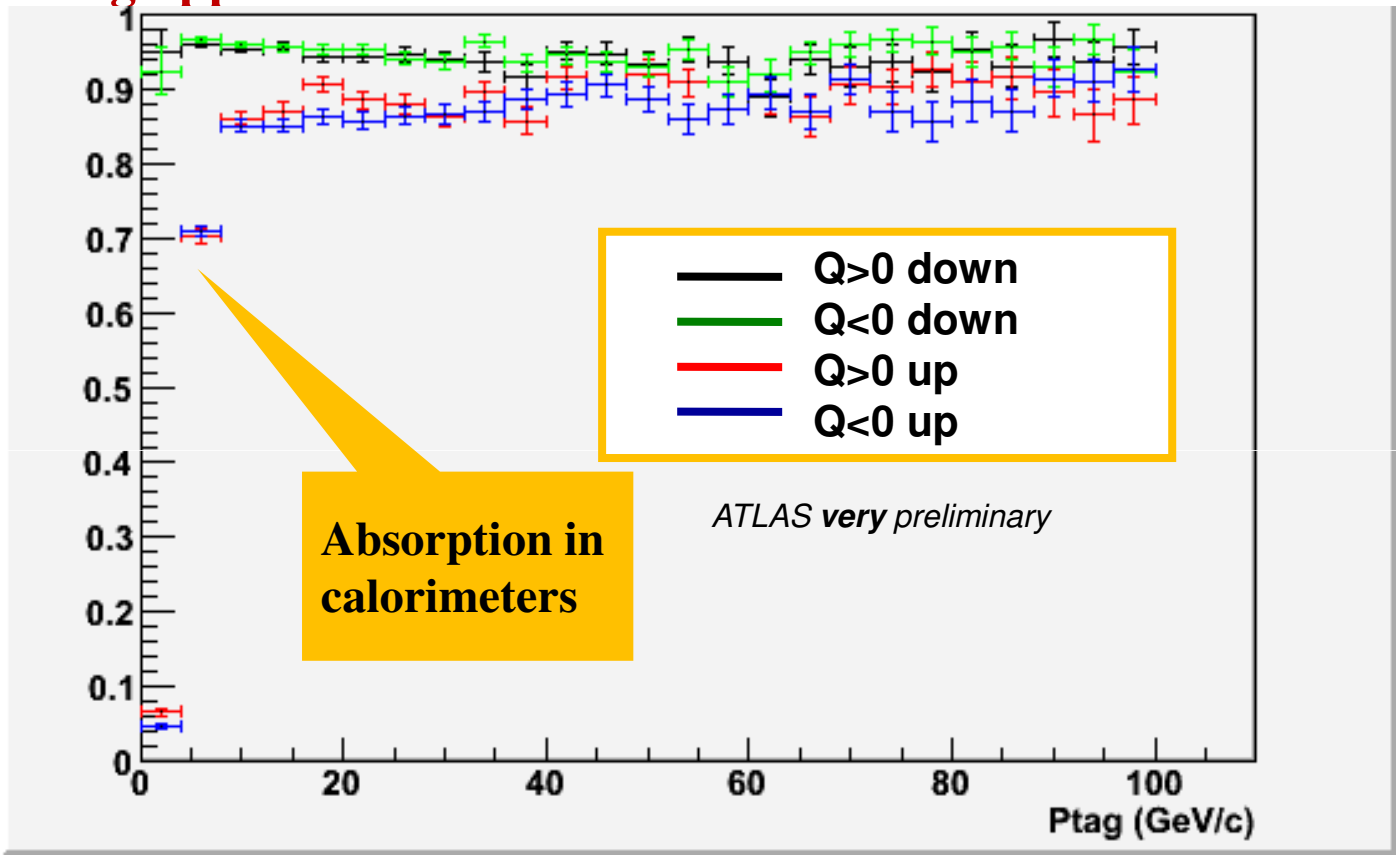
- Measurement consistent with expectations:

$$\Delta P_{\text{ID-Muon}} \approx 3 \text{ GeV/c}$$



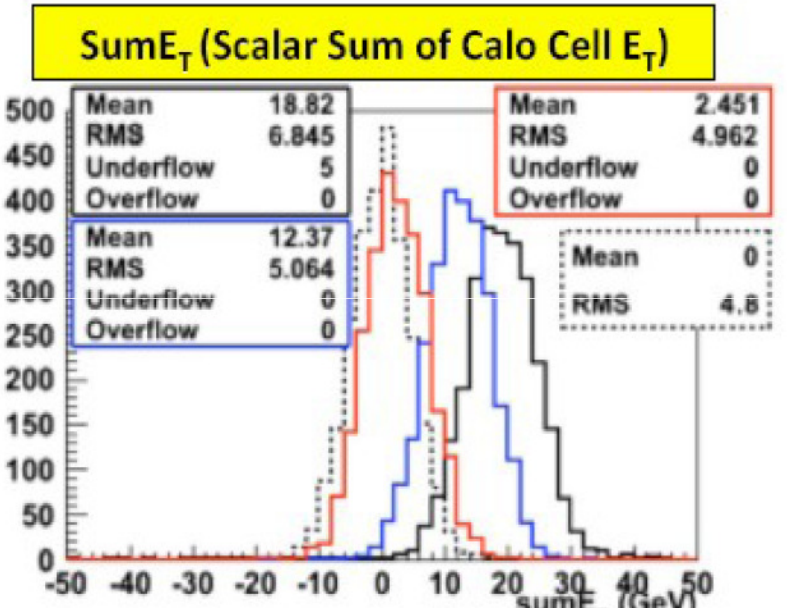
Tag and probe efficiency

- Tag and probe will be the basic tool for efficiency measurement
- First test of this approach on real data:
  - **existing lower track → look for upper track**
  - **existing upper track → look for lower track**



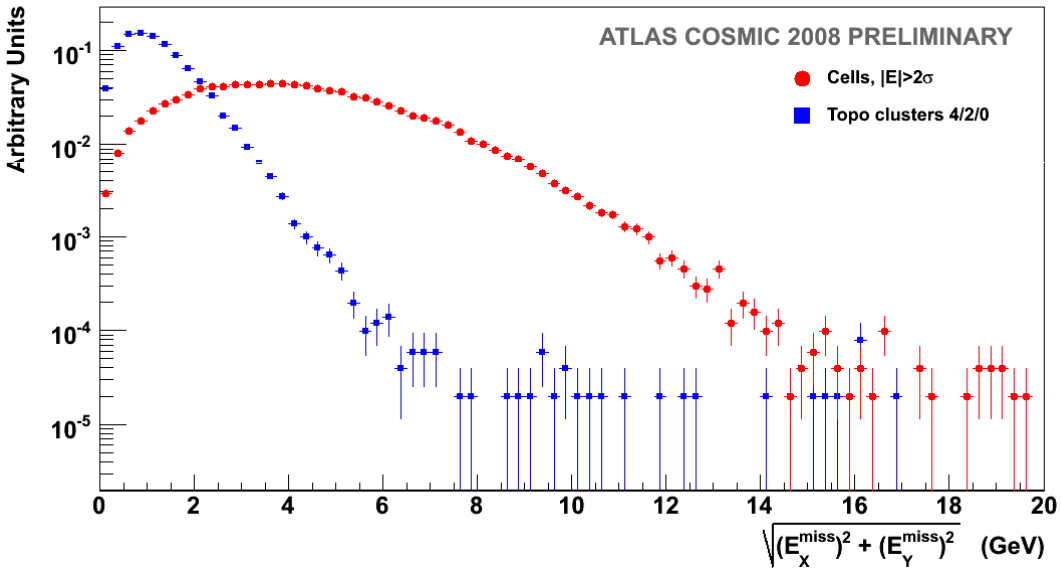
(Missing)E_T measurement

- Significant improvements in the measurement of transverse energy in events with **random triggers**:
  - energy calibration
  - correction for running conditions (HV, hardware problems...)
  - bad-channels masking
  - noise description



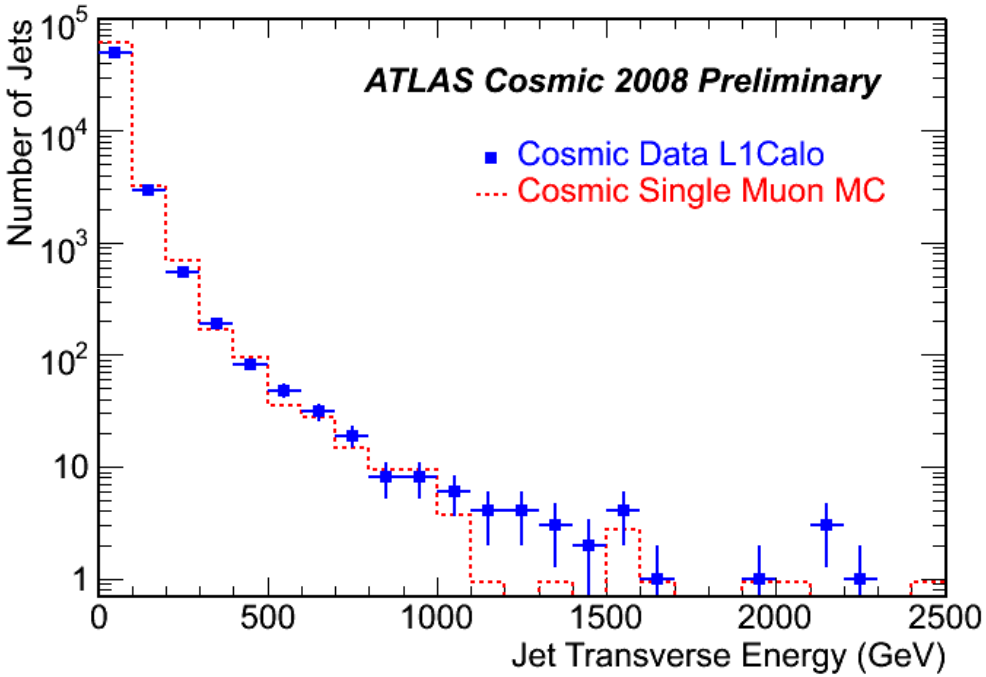
1st processing — offline correction
2nd processing — Monte Carlo

- Still maintaining two algorithms:
  - **base** (cells with E>2σ)
  - **topo**logical clustering



Fake jets from cosmics

- Cosmics muon can provide fake high energy jets:
  - physical (showering)
  - instrumental
    (not pointing geometry)
  - well reproduced by Monte Carlo
- Identify cosmics fakes offline!



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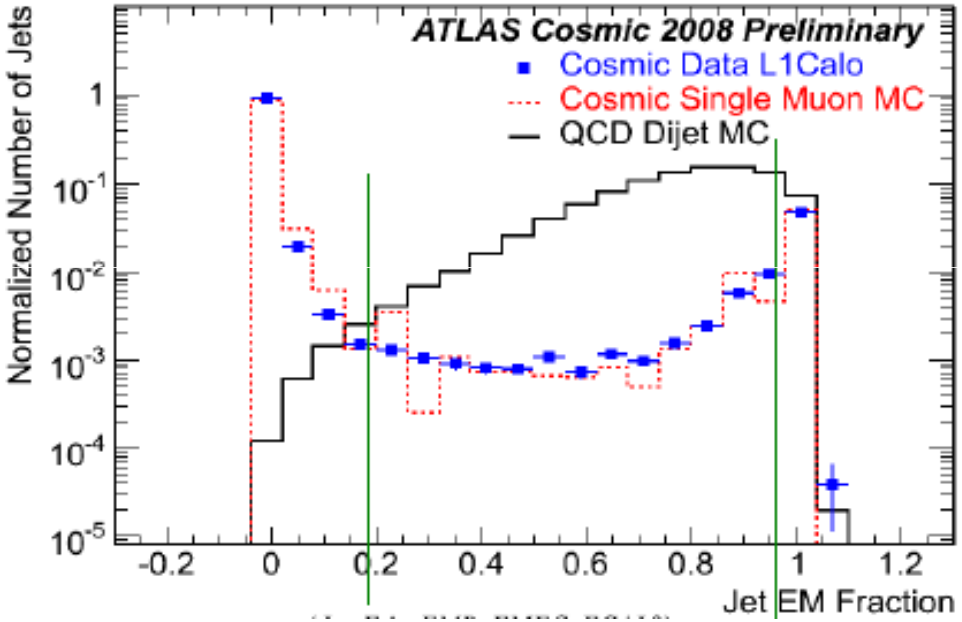
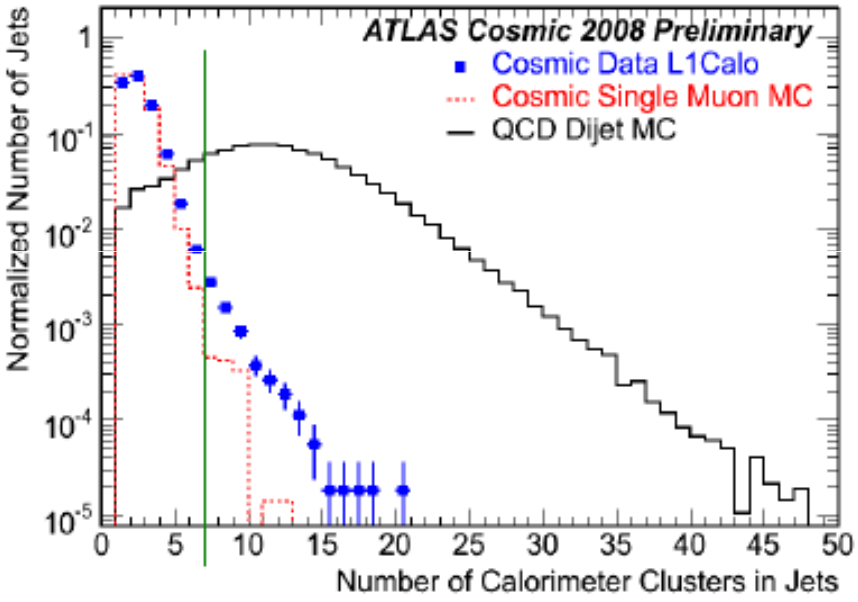
  - charge deposition only in EM or HAC calorimetry
  - localized charge deposition





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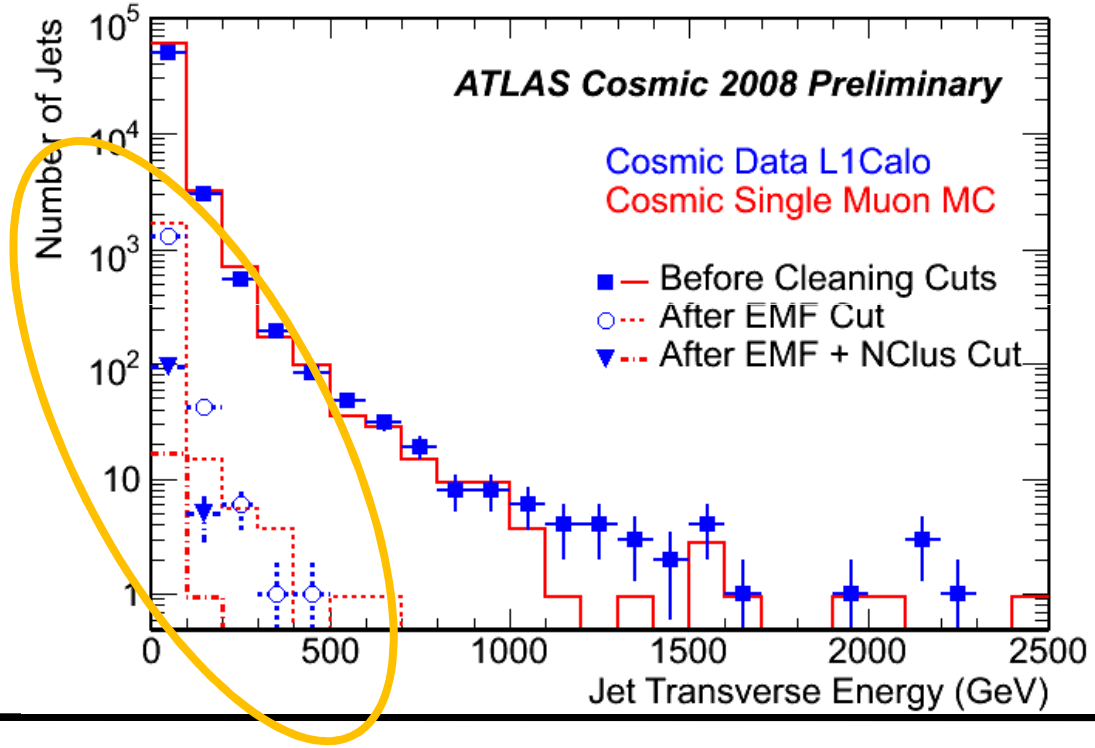
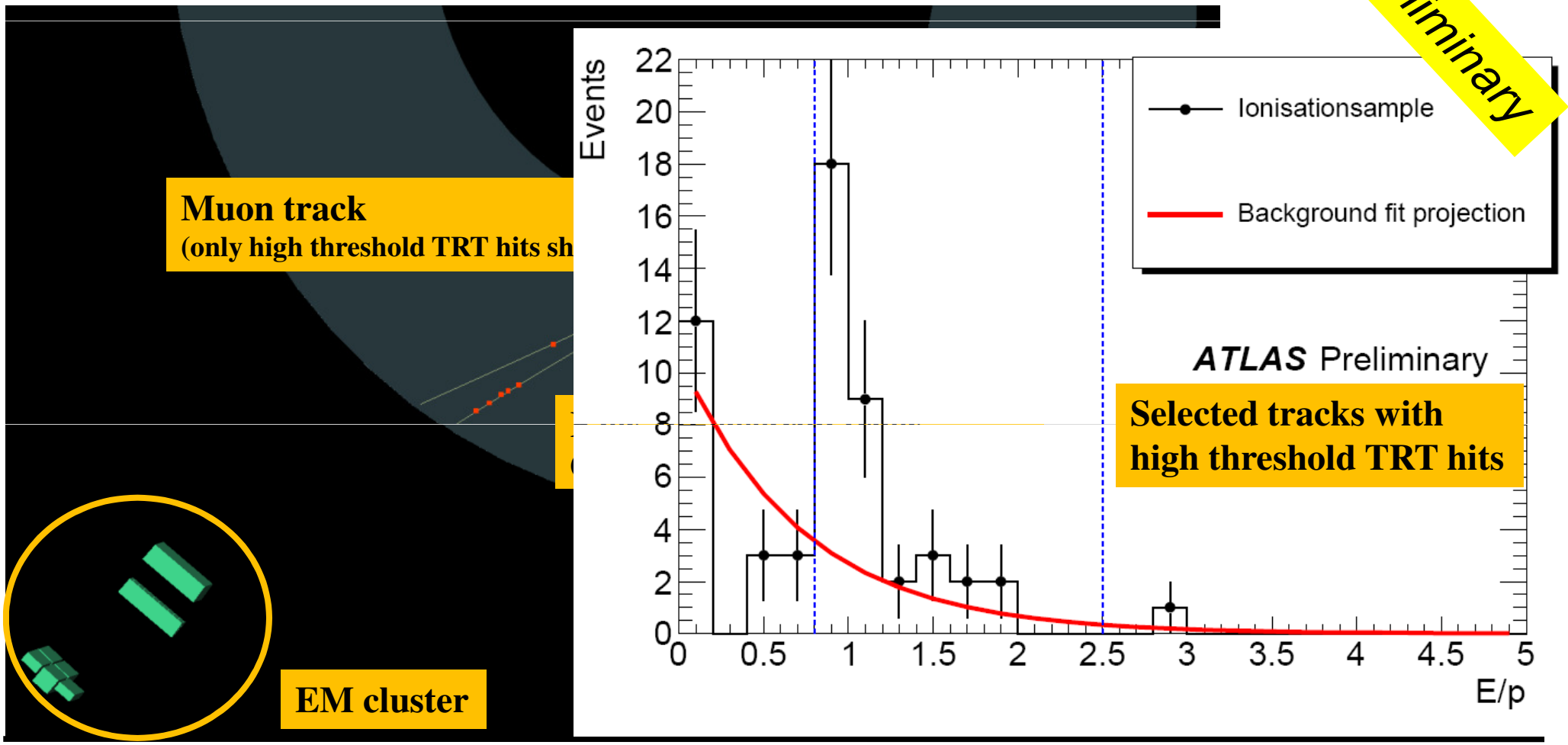
  - instrumental (not pointing geometry)
  - well reproduced by Monte Carlo
- Identify cosmics fakes offline!
  - charge deposition only in EM or HAC calorimetry
  - localized charge deposition
  - **almost no fakes after cleaning**



Electron Identification

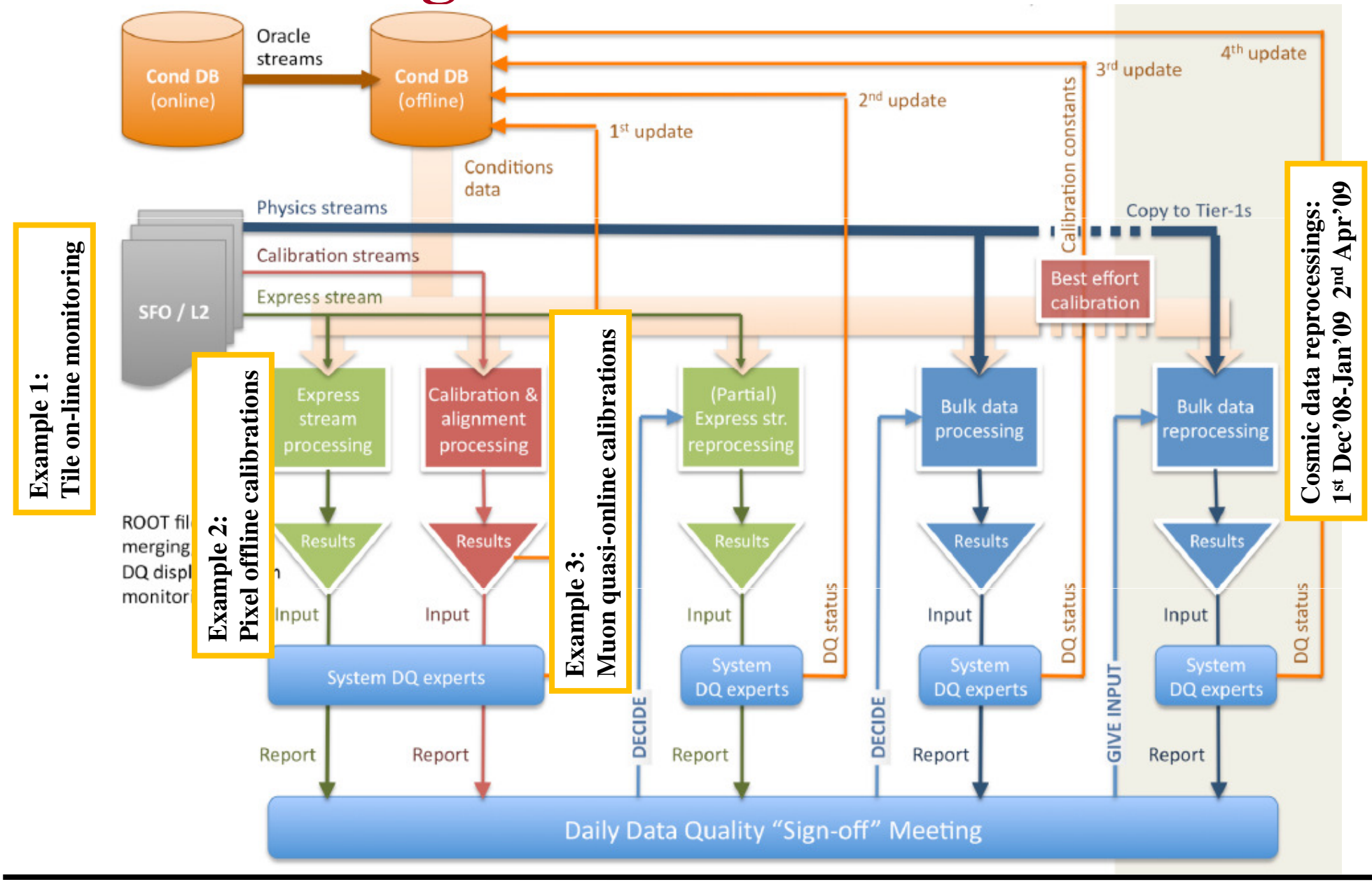
ATLAS very very preliminary

- First attempt to check electron identification capability:
  - energetic delta rays from cosmics
  - TRT high threshold hits+ E/p



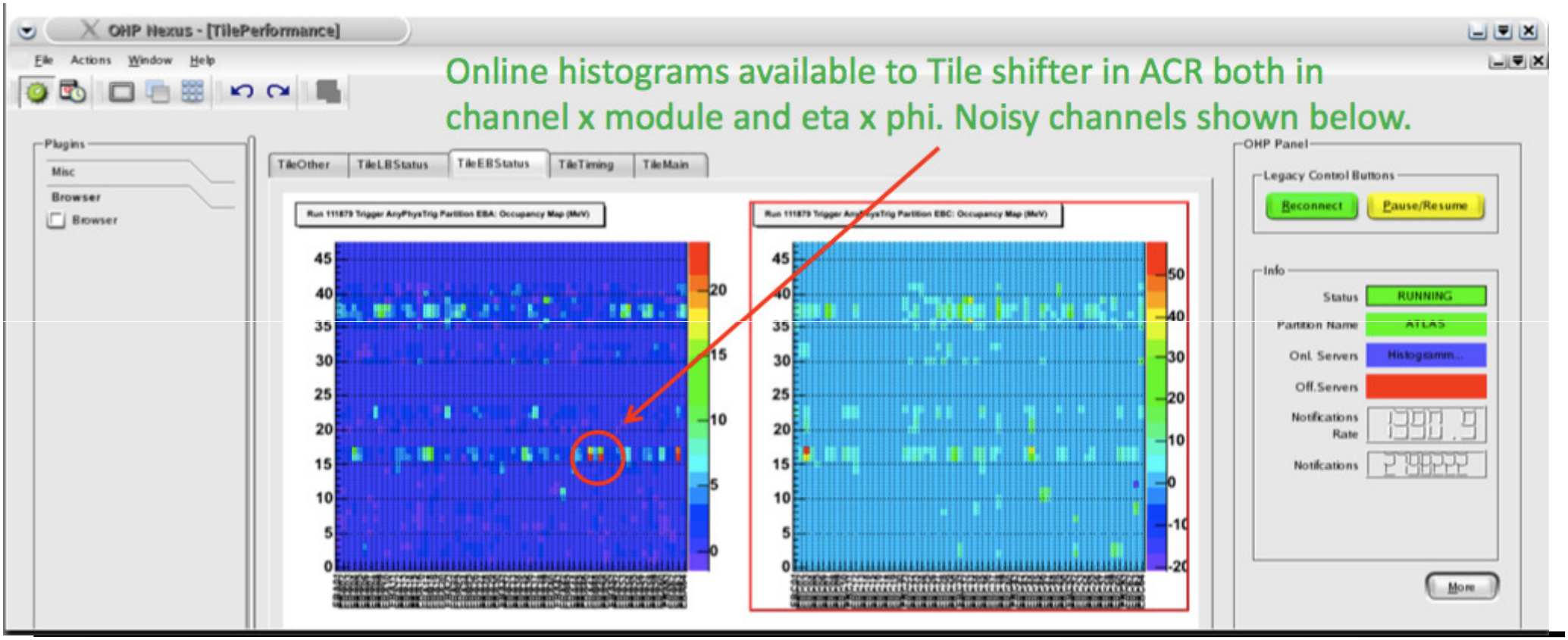
EXPERIENCE WITH CALIBRATIONS AND DATA FLOW

Processing and calibration data flow



On-line monitoring

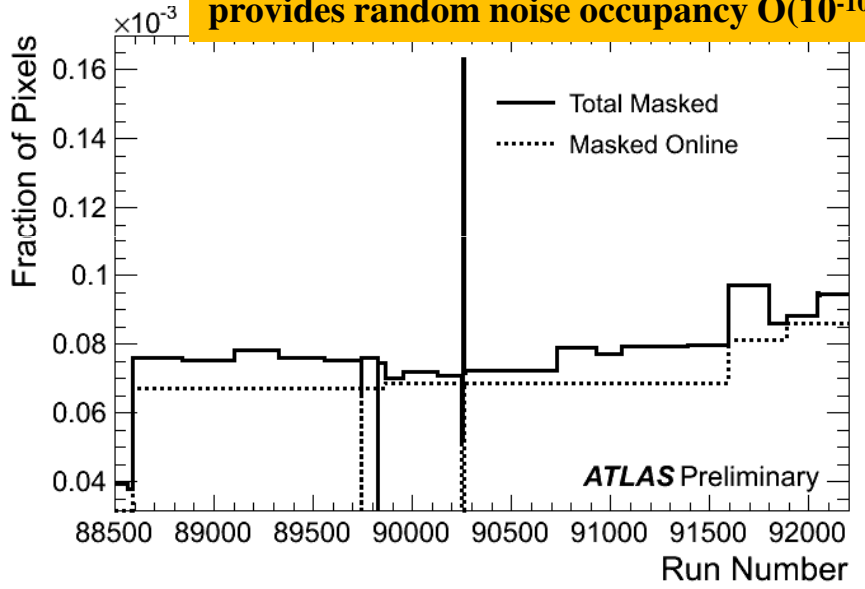
- Data taking activity requires immediate feedback
  - unacceptably high trigger rate
  - take proper action in case of inefficiencies
- All detector use on-line monitoring system as fast reaction tool.

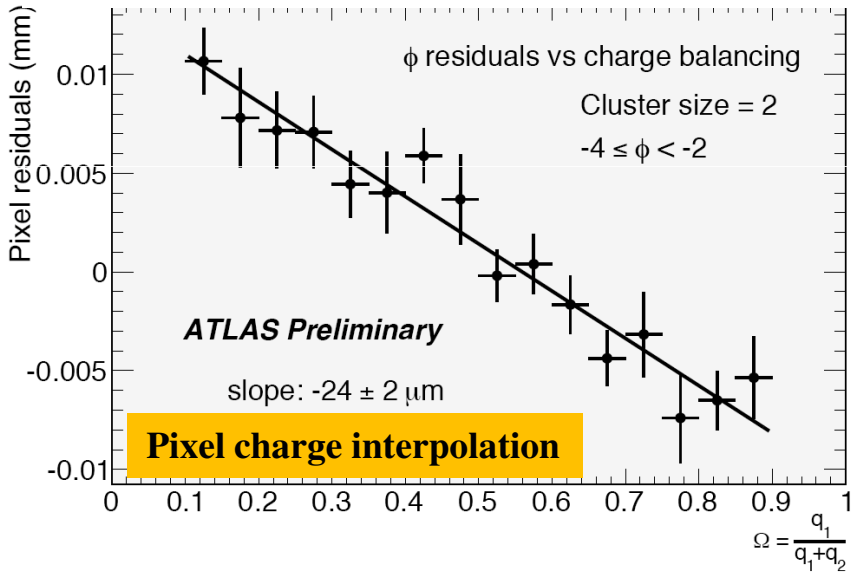


24h calibration loop

- After data taking some devoted stream are user for calibrations:
  - general purpose express stream
    - in cosmics replaced by "extended" ESDs
  - specialized streams (alignment, **muons**...)
- During data taking, expected to provide calibrations within 24 h
  - in some cases mainly *monitoring*
- Not fully in place for 2008 running:
  - in many cases single run statistics not enough
- but most algorithms exercised

Pixel noise mask determination provides random noise occupancy O(10^{-10})

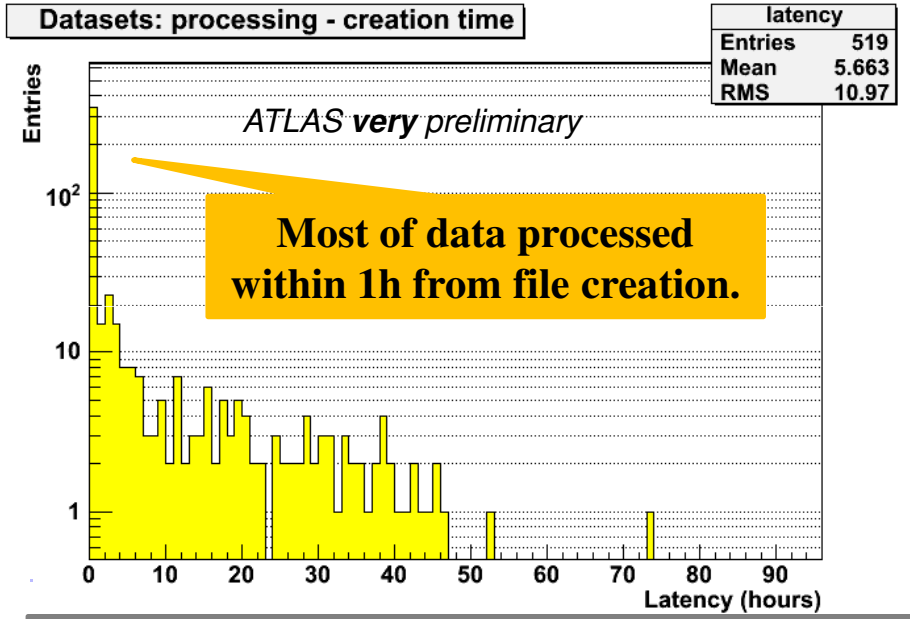


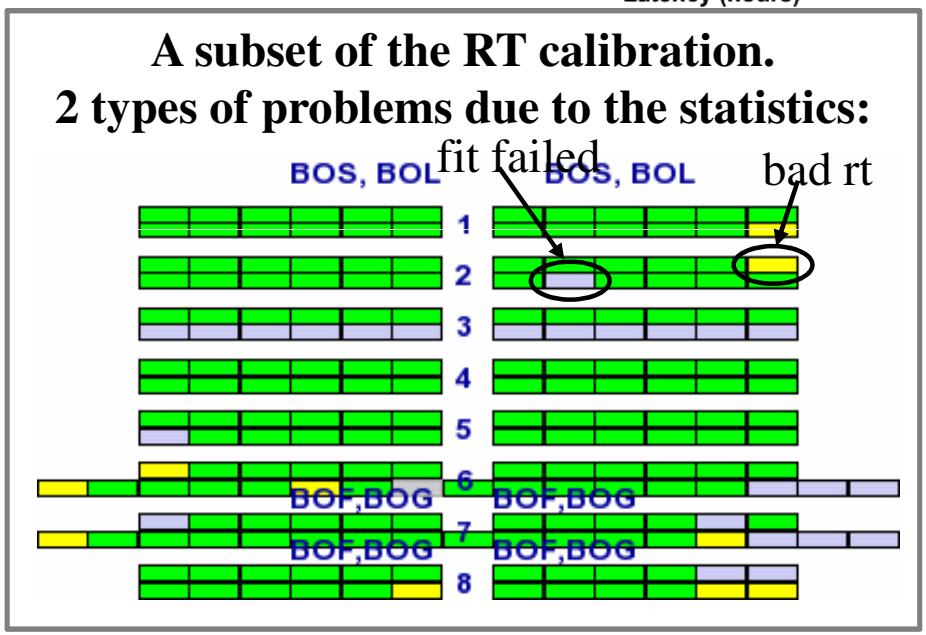


Pixel charge interpolation

Muon system calibration

- Specialized stream based on LVL2 muon trigger:
  - 60M events in 2008 run
  - 25M in current data taking (since 30/04)
- Data stream distributed to Tier2 for processing:
  - MDT: Rome, LMU, Ann Harbor, MPI
  - RPC: Naples
- **Data distribution and processing are in place**
- Calibrations for reprocessing from offline analysis:
  - LVL2 pointing geometry biases the acceptance
  - limited coverage of endcap chambers





Reprocessing

- Reprocessing task are shared by all ATLAS Tier1s
- Key feature of the ATLAS computing model
- Significant computing challenge:
  - massive retrieve of raw data from tape
  - multiple access to the conditions and calibration data
- Two reprocessings of single beam and cosmics data:
  - Dec '08 – Jan '09
  - Apr '09
    (very smooth: **most T1s completed in 1 week**)

- **CNAF performance:**
  - **in line with other Tier1's in both processings**
  - **significant improvements between the two runs**
- job efficiency:
  - 95.6% (1st reprocessing)
  - 99.5% (2nd reprocessing)
- attempts before job success:
  - 1.83 (1st reprocessing)
  - 1.43 (2nd reprocessing)
- job retries:
  - 10% due to ATLAS software: excessive memory usage or crashes in specific events
  - 30% due to temporary site issues

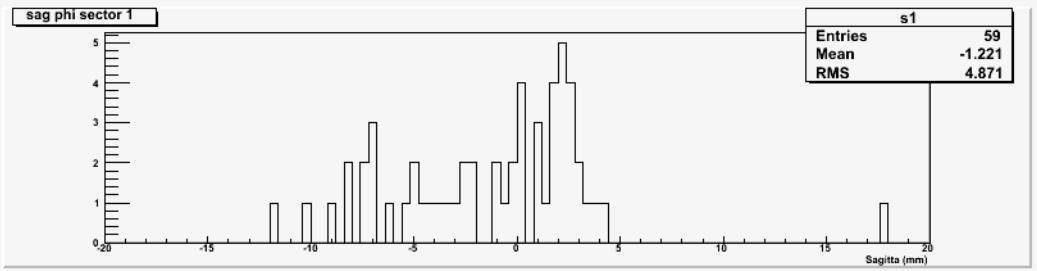
Summary and outlook

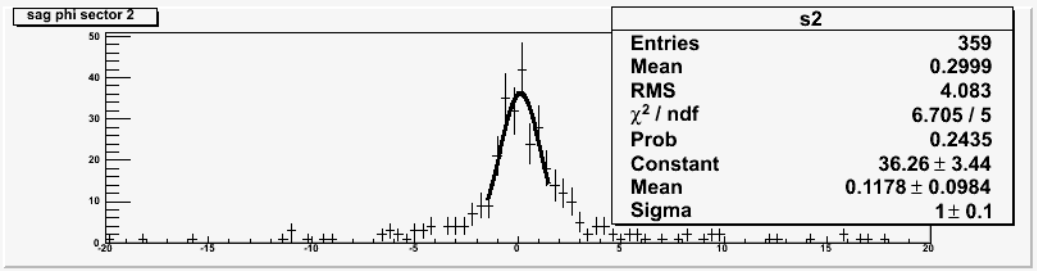
- Most of the ATLAS detector took cosmics and single beam data in 2008:
  - main combined run with full ID in September;
  - for 2009 data taking expected full detector coverage.
- Since than made extensive use of available cosmics data:
  - sub-detector characterization
  - calibrations
  - **combined performance**
  - practice of monitoring and computing infrastructures
- Many interesting results!
  - ...but remember they are not collision data
    - limited coverage by cosmics / not pointing kinematics
  - further progress in detector understanding needs beams

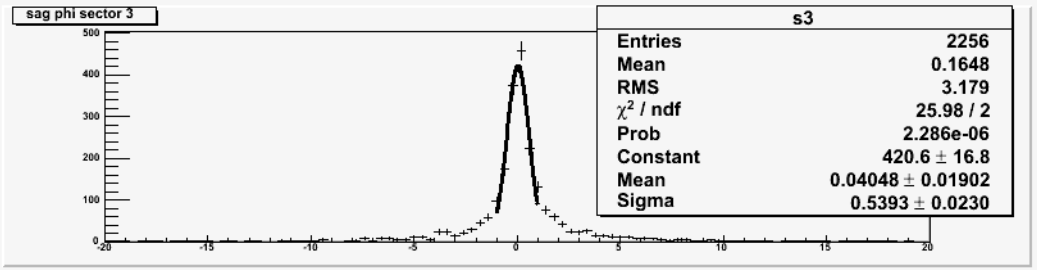
ATLAS is ready for 2009 data taking!

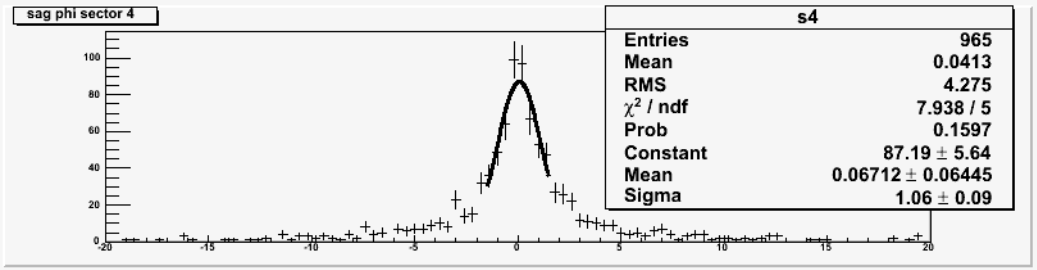
BACKUP

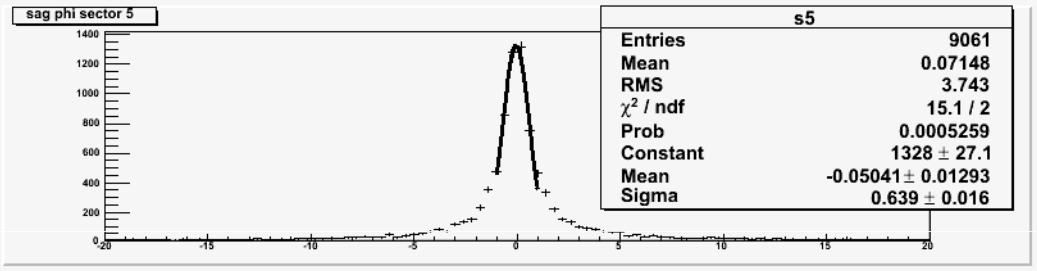
Track based align. sectors 1 to 8

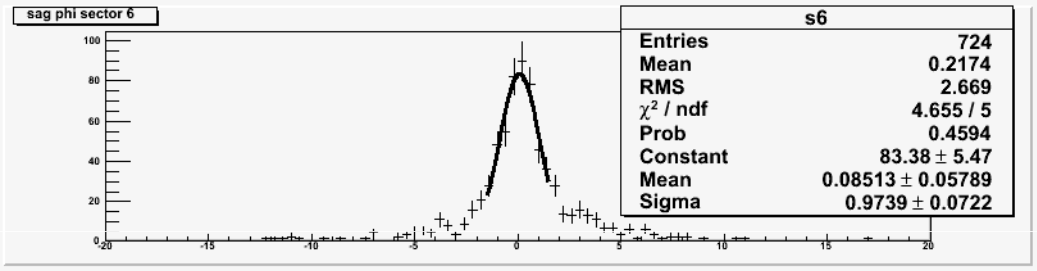


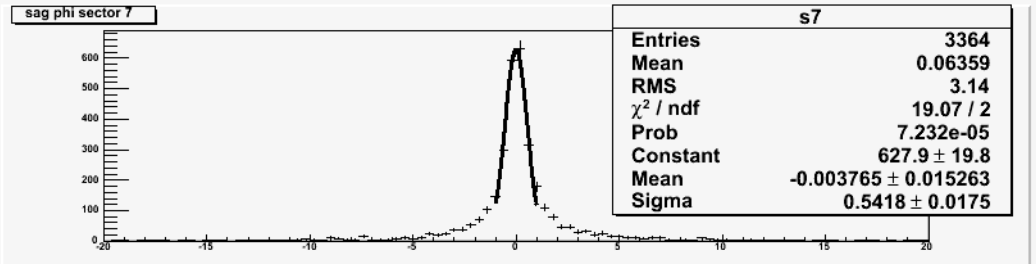


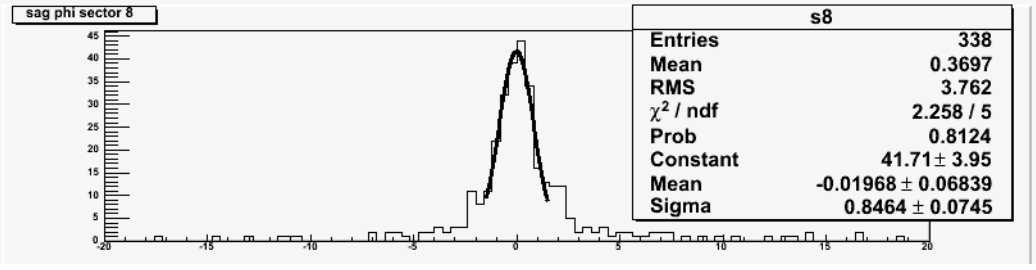




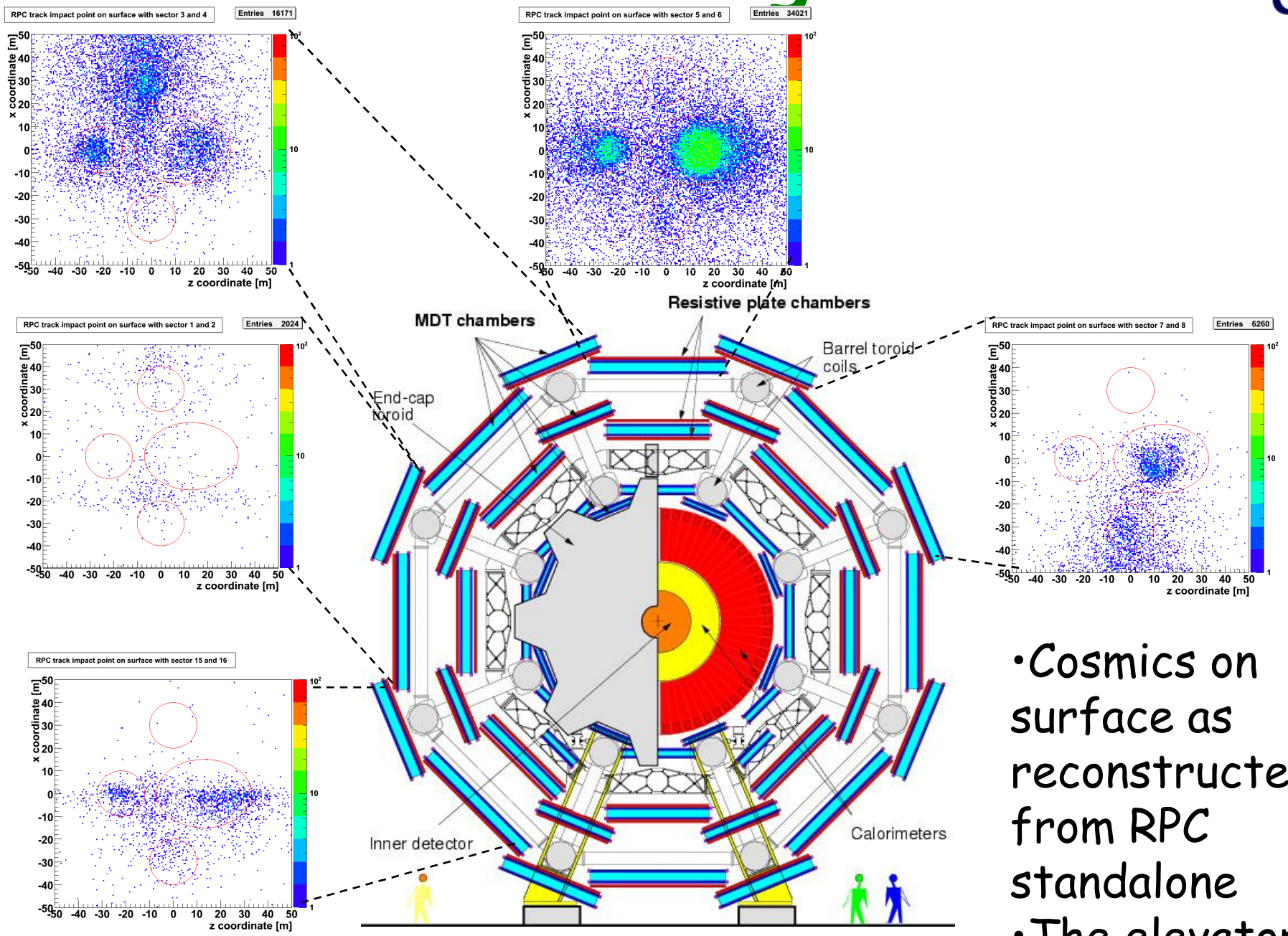








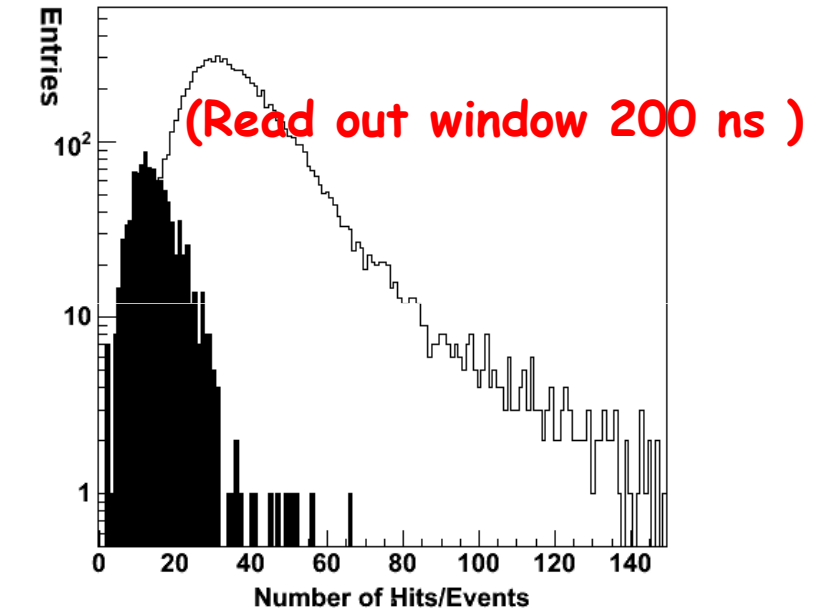
Cosmics along sector

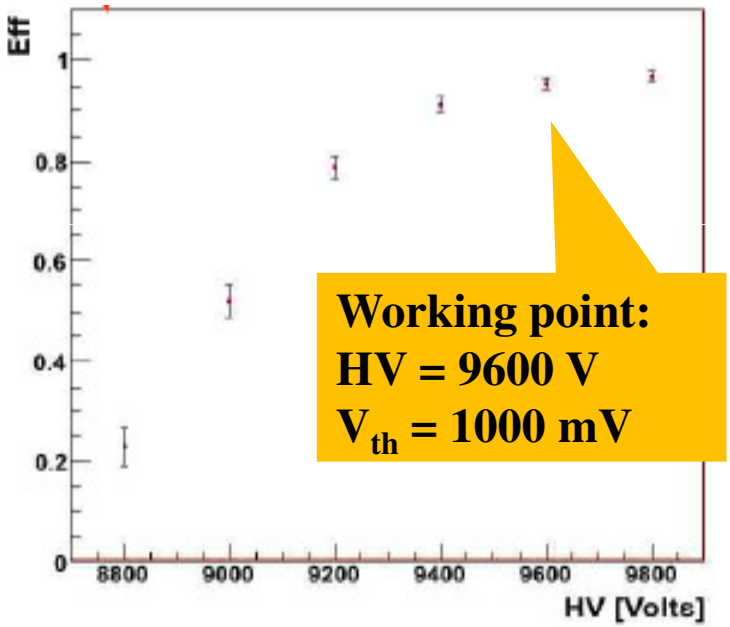


- Cosmics on surface as reconstructed from RPC standalone
- The elevators are important for a lot

RPC performance

- Noise rate
  - measurement using random trigger (black histogram)
  - goo separation from real muon triggers (open histogram)
  - average rate <0.02 Hz/cm^2
  - <0.1% noisy channels
- Efficiency
  - cross checked with several methods
  - most inefficiencies are related to HV
  - typical strip efficiency is 98% at the nominal working point
  - 90% on average due to bad channels in 2008 run.
- Similar values (92% average) have been measured on TGC.

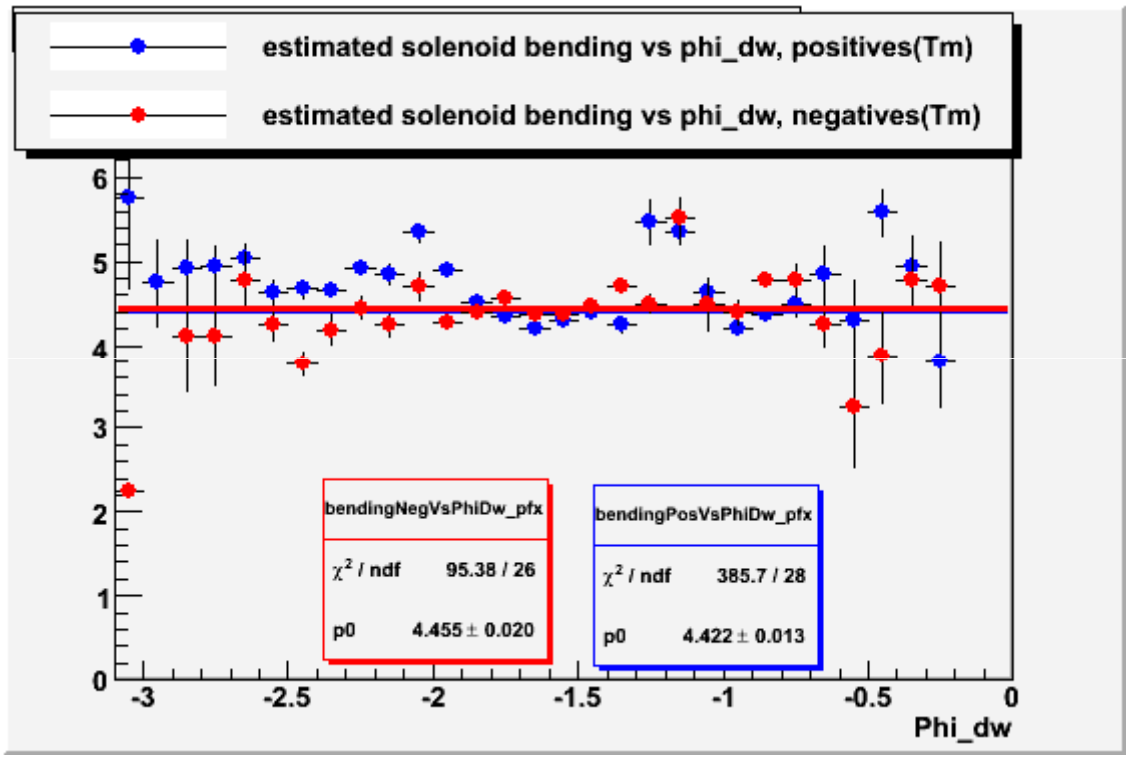




Solenoid bending power

- Change in direction between upper and lower track segments in the muon chambers, allow determination of bending power in the solenoid:

$$0.3\int Bd\ell \text{ [Tm]} = p\text{[GeV/c]}\left(\phi_{\text{up}} - \phi_{\text{down}}\right)$$



- Measured value:
  4.4 Tm
- Expectation:
  4.6 Tm
  - contribution from return yoke

ADC Review March 11-12 2009, CERN

Reprocessing. Dec08-Jan09

96.5% of 1beam and cosmics data were reprocessed in Dec08-Jan09 Ultimate goal to reprocess 100% of events. No events losses in reconstruction. Necessary changes in Production system is ready for March08 reprocessing

Reprocessing Jobs Statistics (1 job : 1 RAW data file)

T1	CA	CERN	ES	FR	IT	NG	NL	UK	US	sum
Total Jobs	20707	26348	364	48288	13619	12561	23472	54360	128764	329609
Done Jobs	20150	26015	364	46937	13018	12281	23167	51344	124667	317943
%%	97.3	94.7	100.	97.2	95.6	97.8	98.7	94.5	96.8	**96.5**
Aborted jobs	557	1459	0	1351	601	280	305	3016	4097	11666
%%	2.7	5.3	0	2.8	4.4	2.2	1.3	5.5	3.2	3.5

Number of attempts per successful job

T1	CA	CERN	ES	FR	IT	NL	UK	US	<av>
##	1.02	1.16	1.18	1.11	1.83	2.86	2.31	1.39	1.8

Alexei Klimentov : ATLAS Computing

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Spring 08 reprocessing

date-tier	CA	CERN	DE	ES	FR	IT	ND	NL	UK	US	sum
09-04-01	0	4240	0	0	0	0	16	0	1492	0	5748
09-04-02	1806	2054	1510	1059	2166	0	513	1711	6530	3411	20760
09-04-03	4369	227	2565	2602	1572	0	1795	4732	8407	4192	30461
09-04-04	3303	3	2775	6013	10003	0	4322	2271	12621	5710	55901
09-04-05	4327	418	5856	19	15819	0	4449	5634	13373	4166	54061
09-04-06	3559	0	3298	2	249	0	1633	1573	3518	8782	22614
09-04-07	442	0	817	0	2543	0	481	3544	6208	6417	20452
09-04-08	2	0	1605	22	5669	0	726	1335	1602	6495	17456
09-04-09	0	0	1440	0	886	253	65	817	62	6017	9540
09-04-10	0	0	1027	1	11	2586	1	650	3	8426	12705
09-04-11	0	0	0	0	6	2052	0	2192	0	2912	7162
09-04-12	0	0	0	0	0	3002	0	1925	0	5087	10014
09-04-13	0	0	0	0	0	4226	0	5040	0	5807	15073
09-04-14	0	0	0	0	179	1423	0	660	0	5536	7798
09-04-15	8	0	20	0	0	399	1	2	0	1436	1866
09-04-16	0	0	0	0	0	7	0	2	1	1079	1089
09-04-17	0	0	0	0	0	4	0	0	0	151	155
09-04-18	0	0	0	0	0	0	0	0	0	2699	2699
09-04-19	0	0	0	0	0	0	0	0	0	8040	8040
09-04-20	0	0	0	0	0	0	0	0	0	5940	5940
09-04-21	0	0	0	0	0	0	0	0	0	5116	5116
09-04-22	0	0	0	0	0	0	0	0	0	2442	2442
09-04-23	0	0	0	0	0	0	0	0	0	1839	1839
09-04-24	0	0	0	0	0	0	0	0	0	626	626
09-04-25	0	0	0	0	0	0	0	0	0	2368	2368
09-04-26	0	0	0	0	0	0	0	0	0	5220	5220
09-04-27	0	0	0	0	0	0	0	0	0	3862	3862
09-04-28	0	0	0	0	0	0	0	0	0	1915	1915
09-04-29	0	0	0	0	0	0	0	0	0	250	250
09-04-30	0	0	0	0	0	0	0	0	0	1	1