The ATLAS Experiment: Status and Performance

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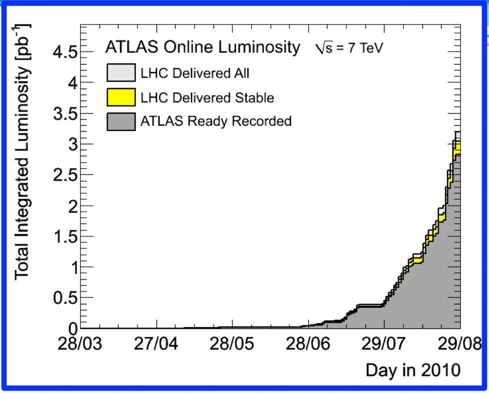
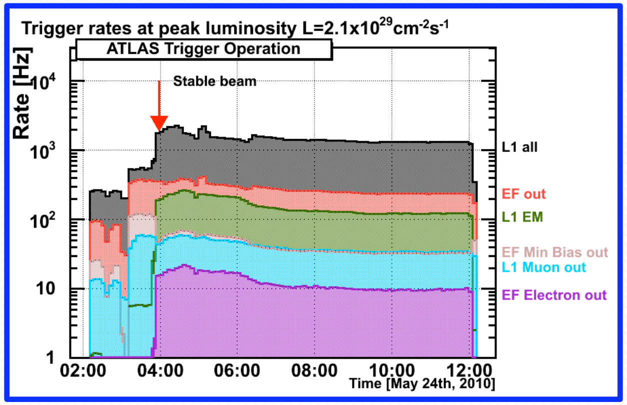
Outline

- *Status of the ATLAS detector*



- *ATLAS trigger: operation and performance*



- *Detector performance on physics objects: few selected results*

- for first physics results: *see talk by G. Pasztor*
- for physics prospective (2011): *see talk by C. Topfel*
- for upgrade activities: *see talk by S. Gonzales Sevilla*

The ATLAS detector

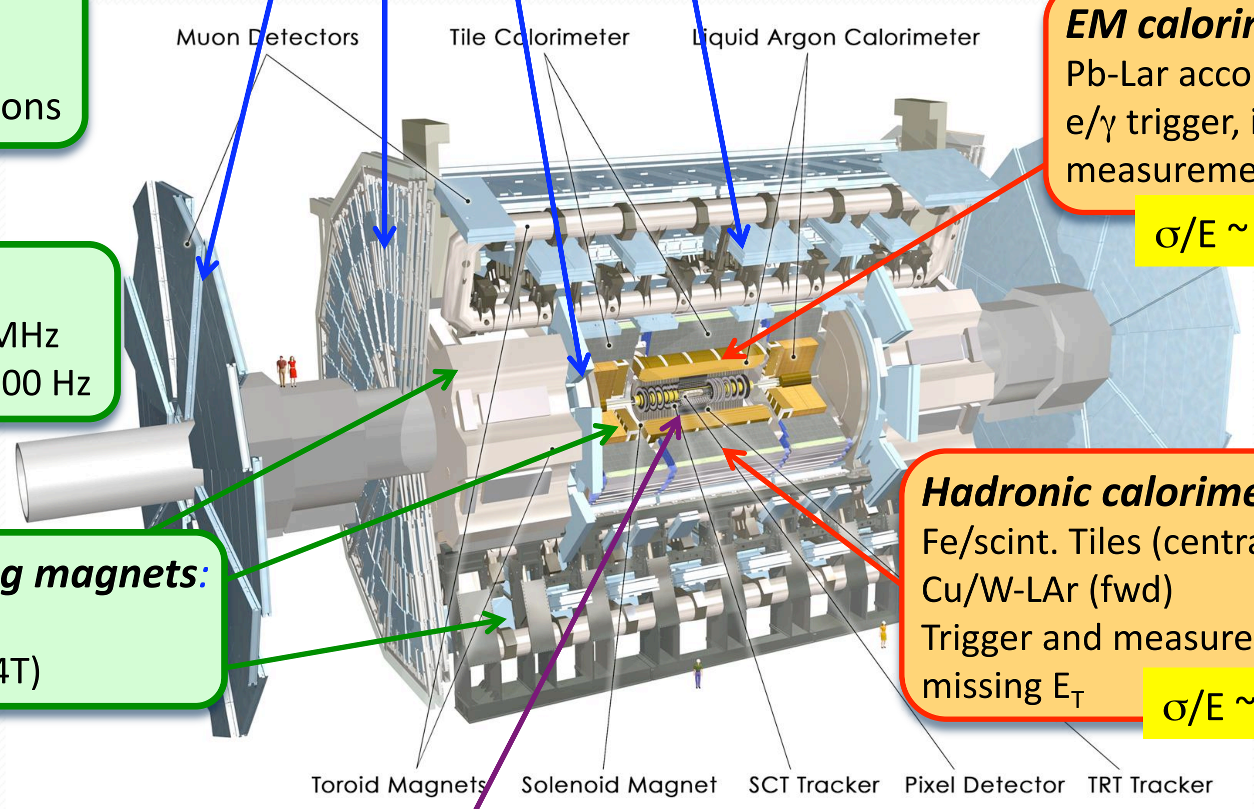
Muon Spectrometer ($|\eta|<2.7$) : 3 layers gas based muon chambers
Standalone muon triggering and reconstruction

$\Delta p/p < 10\%$ up to 1 TeV

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons

3 level trigger
Collision Rate 40 MHz
Recording rate ~ 300 Hz

Superconducting magnets:
- 2 T solenoid
- 3 toroids (up to 4T)



EM calorimeter ($|\eta|<2.5$):
Pb-Lar accordion structure
e/γ trigger, identification and measurement

$\sigma/E \sim 10\%/\sqrt{E} \oplus 0.7\%$

Hadronic calorimeter: ($|\eta|<5$)
Fe/scint. Tiles (central),
Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T

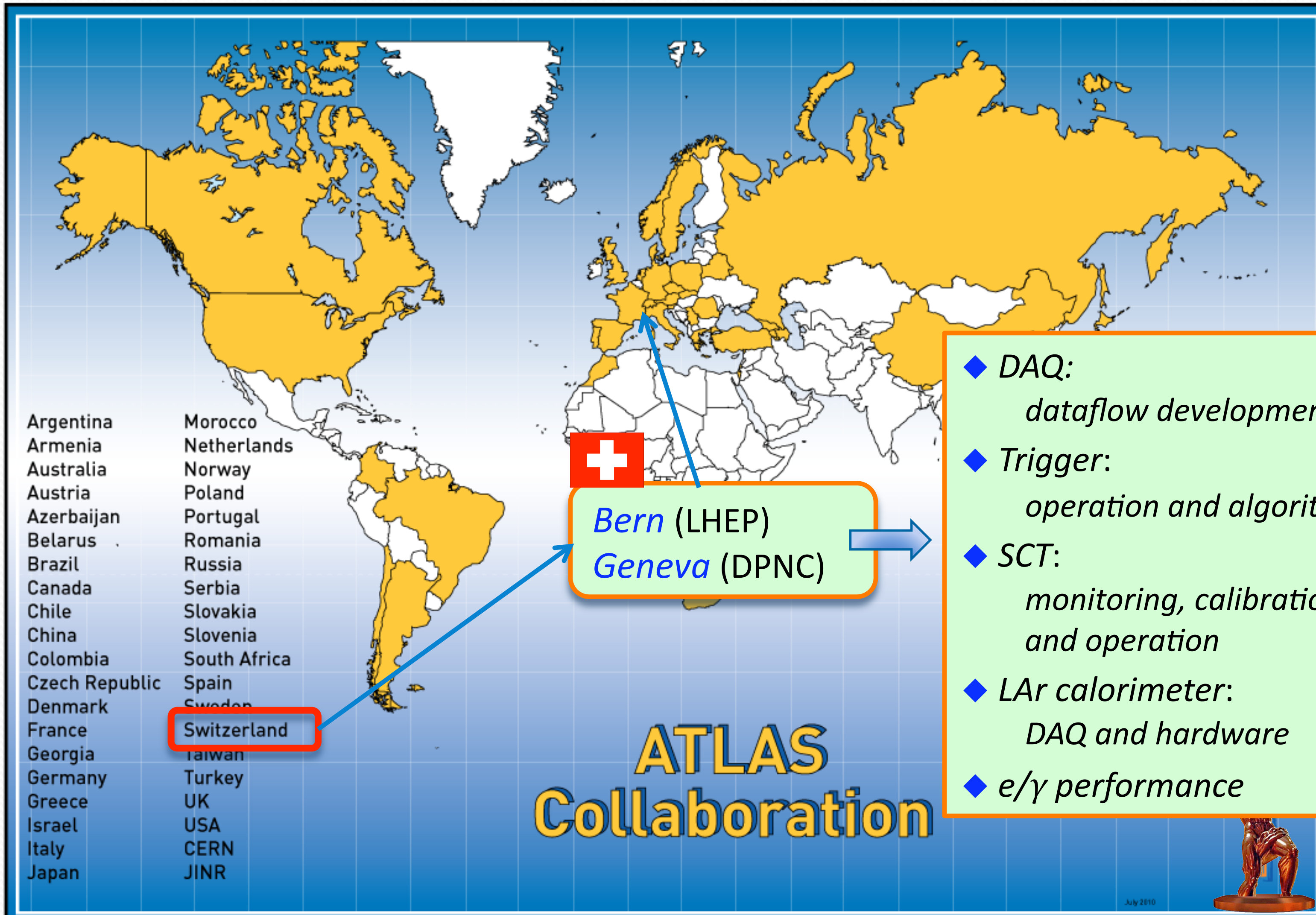
$\sigma/E \sim 50\%/\sqrt{E} \oplus 3\%$

Inner Detector ($|\eta|<2.5$): 3 Si pixel layers, 4 Si strips (SCT), straw tube tracker (TRT) with transition radiation medium. Precise vertexing, tracking, e/π separation

$\sigma/p_T \sim 0.04\% p_T \oplus 1.5\%$

The ATLAS collaboration

- combining the effort of thousands of physicists in the past 20 years ….

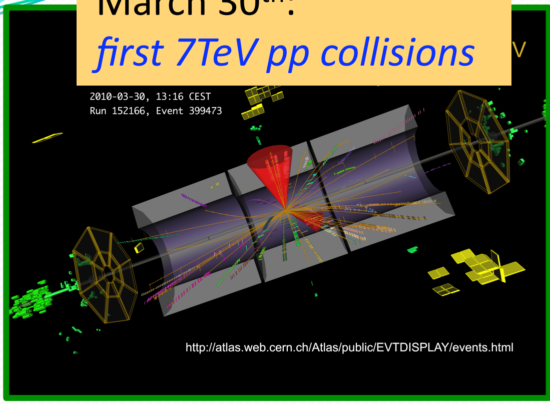


- *DAQ:*
  - *dataflow development*
- *Trigger*:
  - *operation and algorithms*
- *SCT*:
  - *monitoring, calibration and operation*
- *LAr calorimeter*:
  - *DAQ and hardware*
- *e/γ performance*

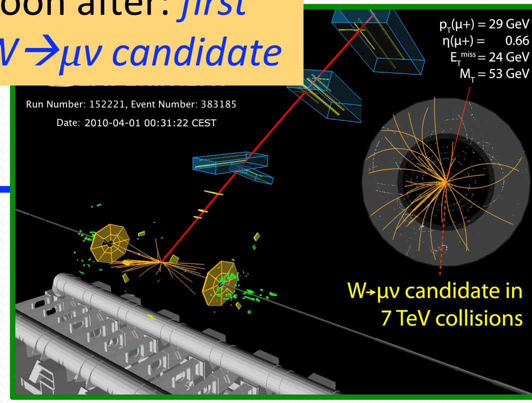
will indicate parts where Swiss groups made a significant contribution to the work

A very exciting 2010 ...

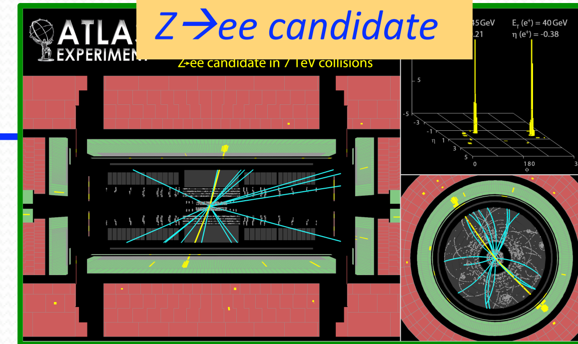
March 30th: *first 7TeV pp collisions*



Soon after: *first W→μν candidate*

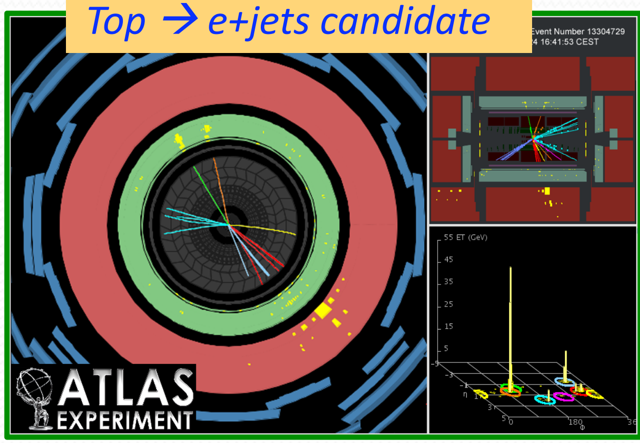


End of May: *first Z→ee candidate*

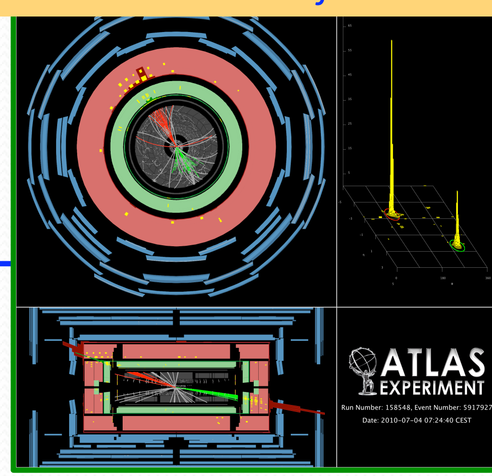


.... with increasing LHC luminosity ....

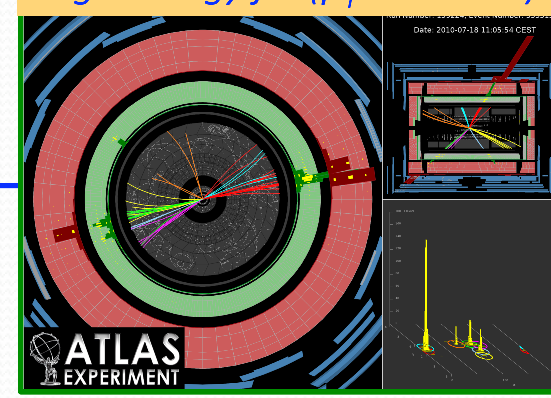
Top → e+jets candidate



2.55 TeV mass di-jet event



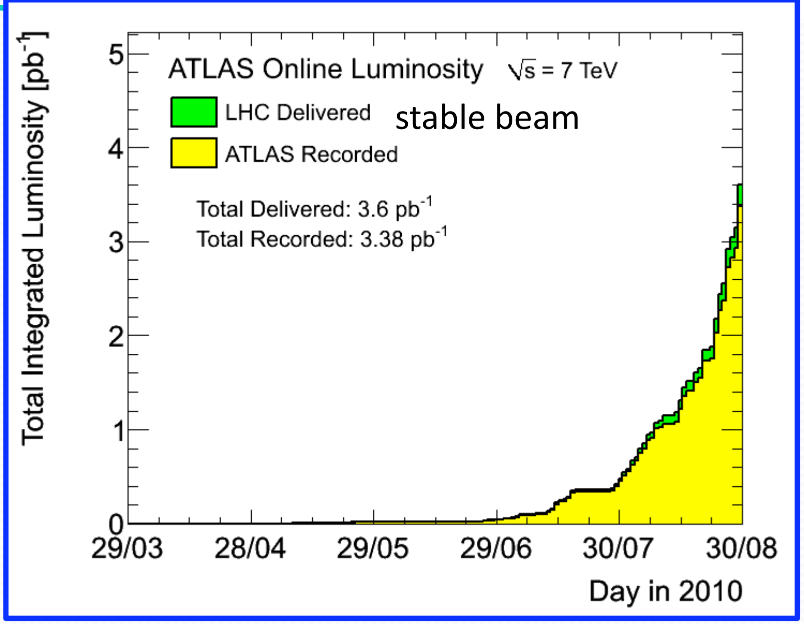
High energy jet (p_T=1.12 TeV)



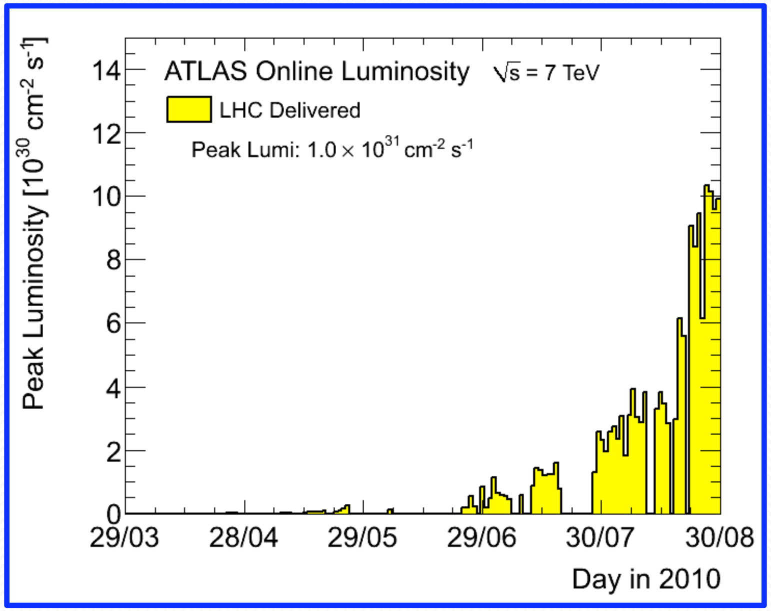
...... and many other interesting events

Luminosity

- **Collected up to last weekend:** ***3.38 pb^{-1}***
- Up to *70 pb^{-1}* expected by the end of October



- Luminosity measured from counting rates of luminosity detectors + crosscheck with ID and EM calorimeters
- Absolute calibration from Van-der-Meer scans: *11% systematic uncertainty* dominated by the accuracy on beam current value



- **Max peak luminosity:** ***1·10^{31} cm^{-2}s^{-1}***
- Rapid increase of LHC delivered peak instantaneous luminosity with time (~3 orders of magnitude since first collisions)
- Need a very flexible trigger to rapidly adapt to such big variation

Detector Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	97.4%
SCT Silicon Strips	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	98.0%
LAr EM Calorimeter	170 k	98.5%
Tile calorimeter	9800	97.3%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trigger	370 k	99.5%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	98.6%

More than 97 % of each subdetector fully operational

90 M channels

Total fraction of good quality data: ~ 95 %

Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	TGC	CSC
97.7	96.4	100	94.4	98.7	99.3	99.2	98.5	98.3	98.6	98.3

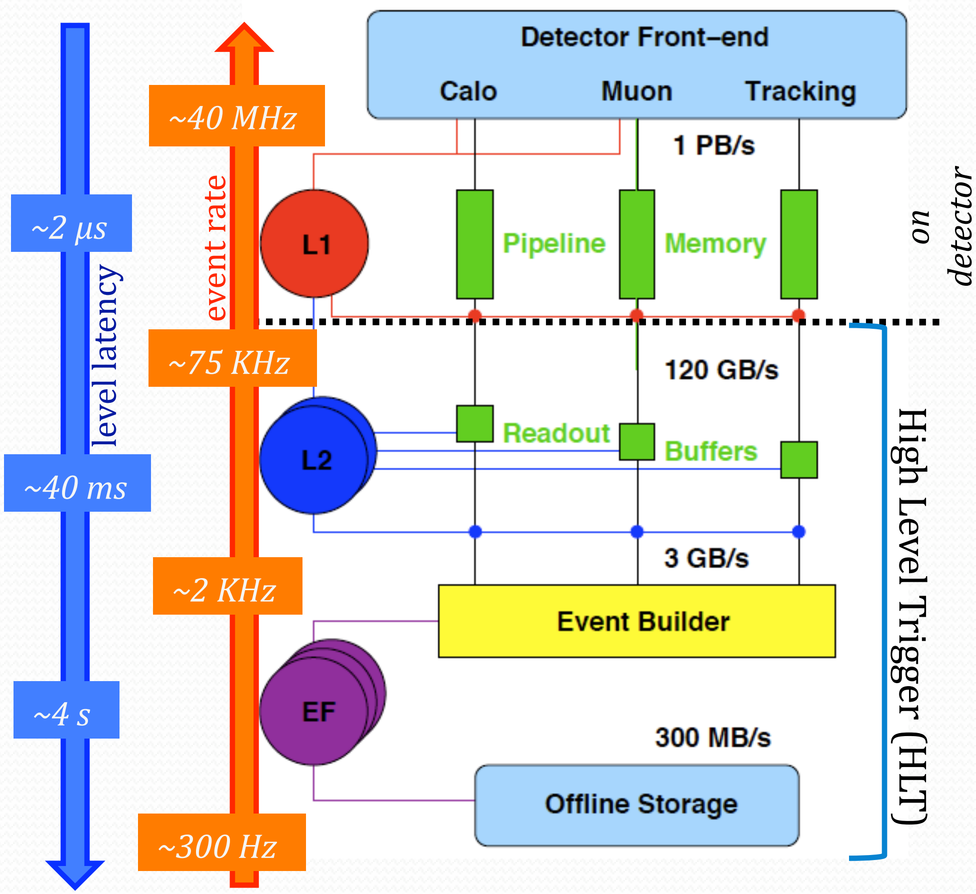
Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams at √s=7 TeV between March 30th and August 14th (in %)

Very high data taking efficiency of DAQ system

Few percent losses in Silicon and Muon detectors due to time to ramp up HV after stable beams are declared

ATLAS Trigger (and DAQ) system

trigger and dataflow architecture:



- Recording rate limited to *300 Hz* by storage and offline data analysis capabilities *(hardware limit ~ 450 Hz)*

A 3 level trigger system:

- *Level 1* (L1):
  - hardware based
  - only muon and calo information
  - reduced granularity
  - Define Region of Interest (RoIs)
- *Level 2* (L2):
  - software based
  - full granularity available
  - running only on L1 RoIs
  - dedicated algorithms and calibration
- *Event Filter* (EF):
  - software based
  - full event reconstruction available
  - offline-like algorithms

Trigger operation

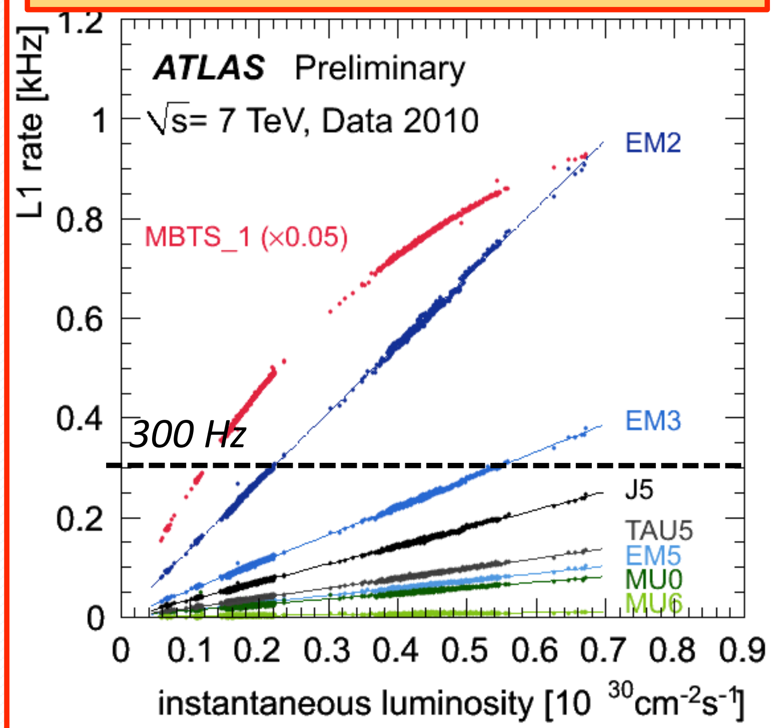
- *commissioning of chains to be used at higher luminosity*
- *respect the allocated bandwidth*
- *provide good data for performance and physics measurements*

A lot of work 'behind the scenes' from Swiss institutes in order to fulfil these tasks

2010 trigger road map

- *L<few 10^{27} $cm^{-2}s^{-1}$:*
  - ***minimum-bias L1 trigger***: scintillator counters (MBTS)
  - HLT running in transparent mode for commissioning
- *L> 5 10^{27} $cm^{-2}s^{-1}$: mid April*
  - MBTS prescaled (record only fraction of the events)
  - relying on other **L1 triggers** (EM, jets, taus, muons)
- *L> 10^{29} $cm^{-2}s^{-1}$: May 24^{th}*
  - ***activation of HLT chains in rejection mode***
  - starting from low threshold EM triggers, followed by tau and muon signatures
  - low p_T jet triggers prescaled since HLT rejection is small
- *L> 10^{30} $cm^{-2}s^{-1}$: July 12^{th}*
  - ***new physics menu deployed*** *(with triggers up to 10^{32} $cm^{-2}s^{-1}$)*
  - almost all the HLT chains have being activated
  - tightening the selection or prescaling (according to physics needs) low p_T triggers

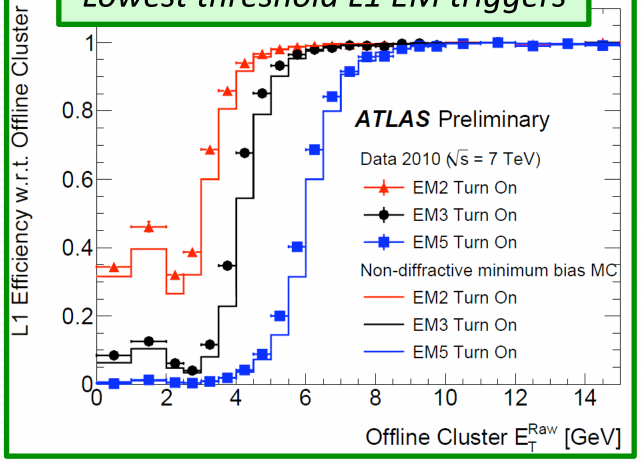
L1 rates VS inst. luminosity (up to 7 10^{29} $cm^{-2}s^{-1}$)



Trigger Performance

Electron/photon triggers : inclusive electrons, W, Z, top, prompt photons

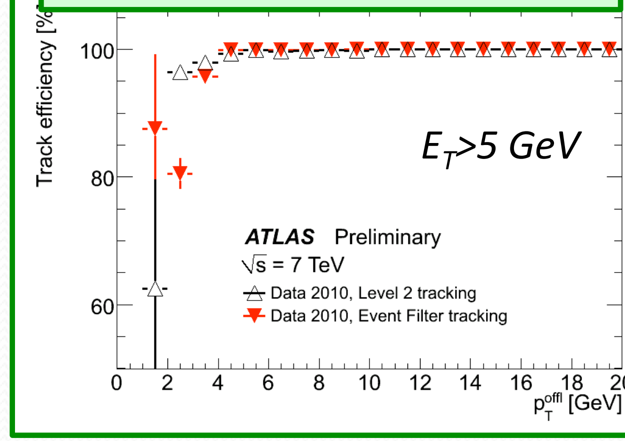
Lowest threshold L1 EM triggers



Good performance from both L1 and HLT (agreement with MC on selection variables)

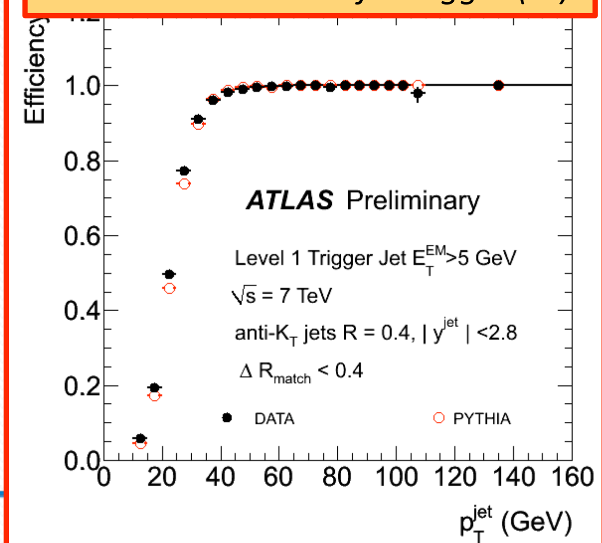
Moving towards data driven technique to get efficiency for signal

HLT tracking efficiency for electron



Jet triggers: jet cross section, di-jet resonances, SUSY (high jet multiplicity events)

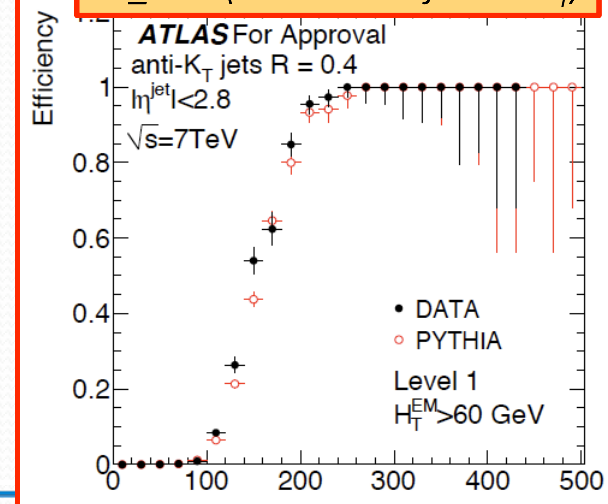
Lowest threshold L1 jet trigger (J5)



good data/MC agreement

trigger efficiency in the plateau ~ 100 %

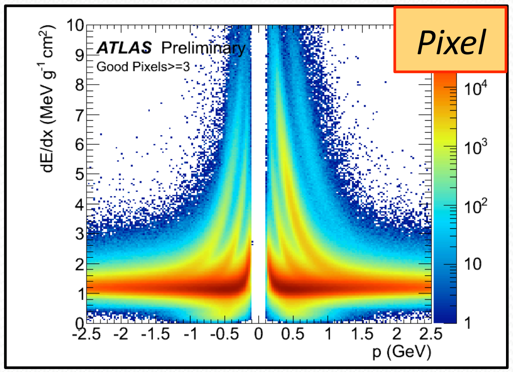
L1_JE60 (scalar sum of L1 Jet E_T)

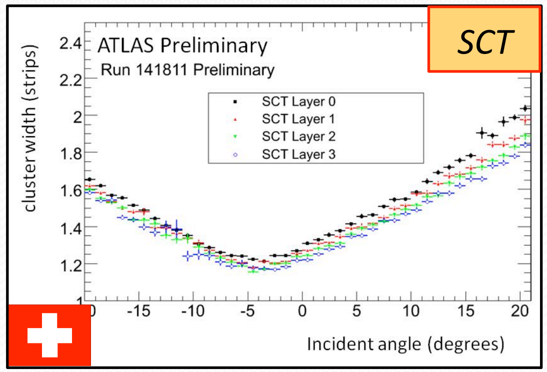


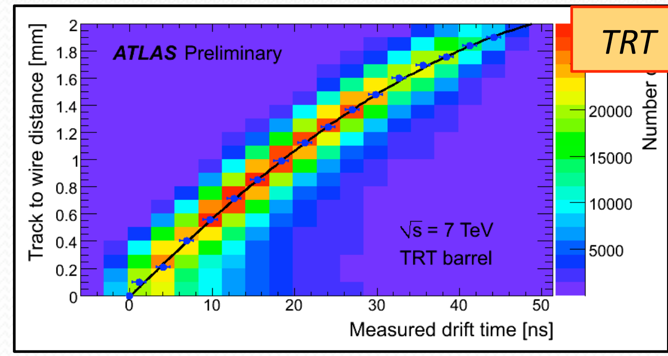
Under development ...

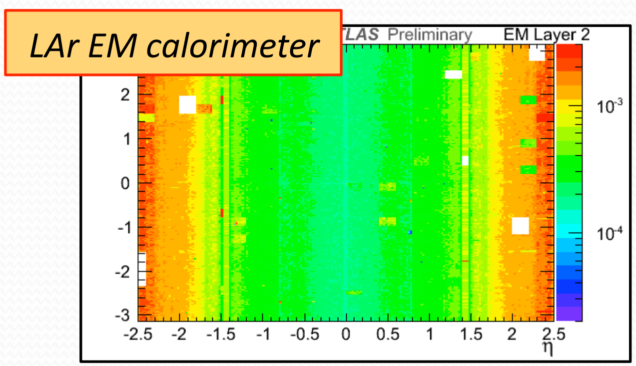
Detector Performance

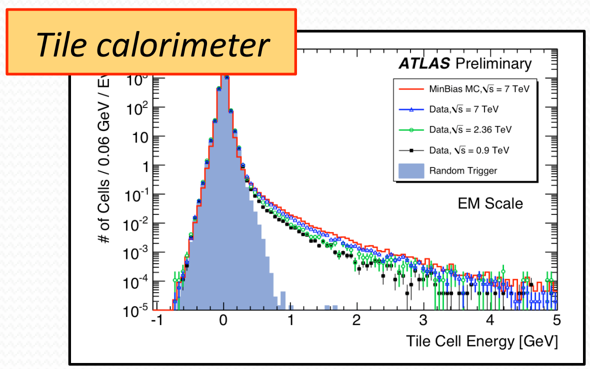
- with current LHC road map we could ‘soon’ (within less than one year) reach the same statistics as Tevatron in some analyses
- **a good understanding of the detector is essential for reducing systematics**
- Many interesting results have been produced from data collected at 7 TeV …..

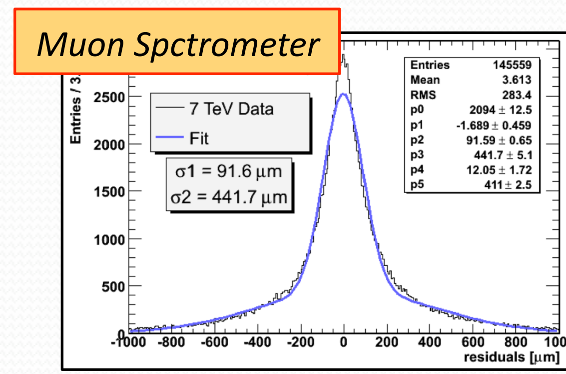








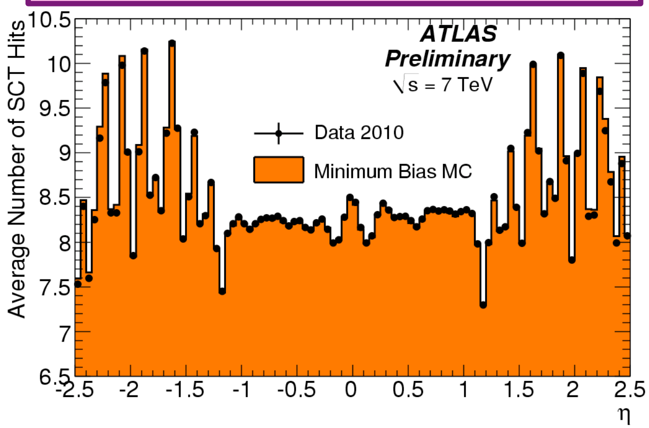




- *……. only a relatively small subsample will be shown in next slide concentrating on physics objects and 7 TeV collisions based results.*

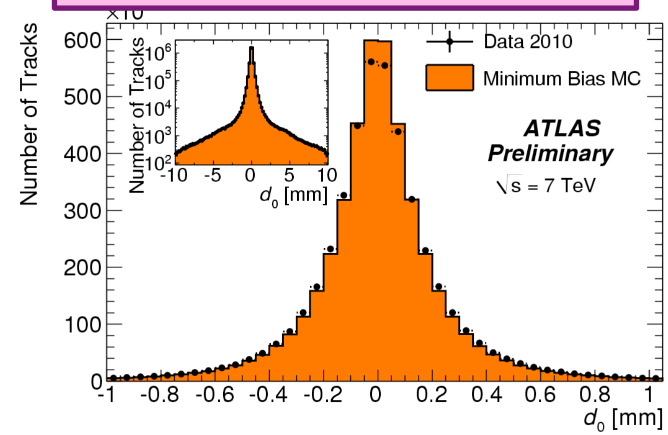
Tracking (for MinBias)

Average number of SCT hits per track



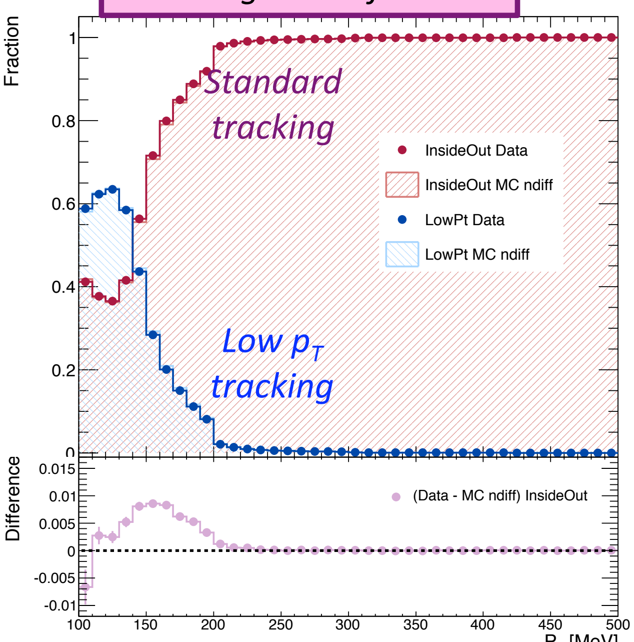
Tracks with:
- p_T> 500 MeV
- ≥ 1 pix hits
- ≥ 6 SCT hits
- d_0< 1.5 mm

Track transverse impact parameter



Track Parameters and detector conditions (dead module, holes, etc) well described in MC

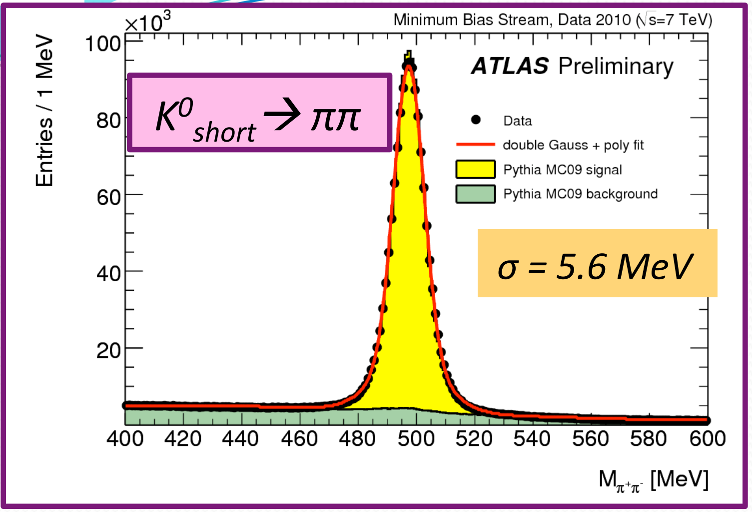
Track algorithm fraction

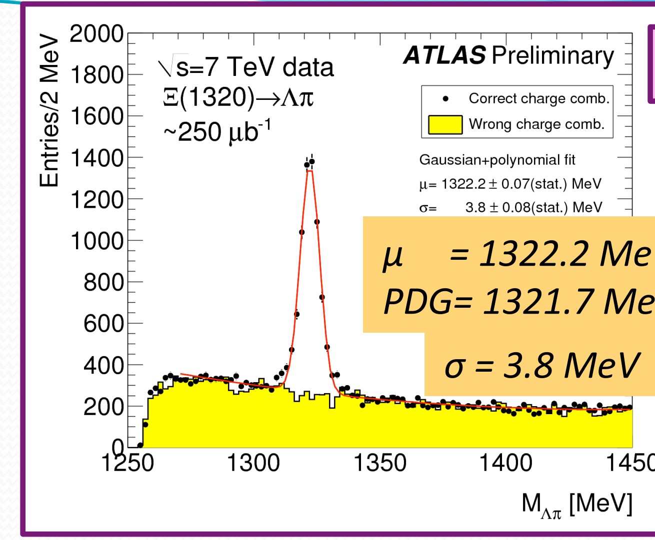


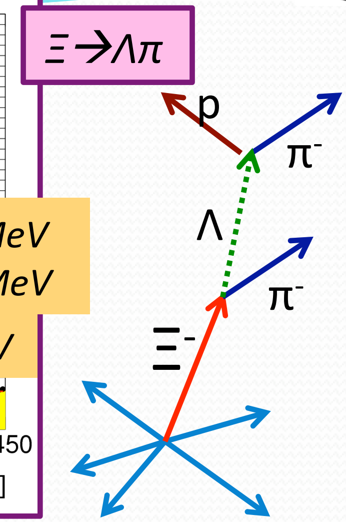
In Minimum Bias analysis needs to measure track down to 100 MeV:

- standards inside-out tracking algorithm quite inefficient at very low p_T
- new 'tuning' of tracking algorithm (*low p_T tracking*) developed to recover such inefficiency
- algorithm are run sequentially and they do not share any track spacepoint
- data/MC agreement within 1%

Tracking (resonances)

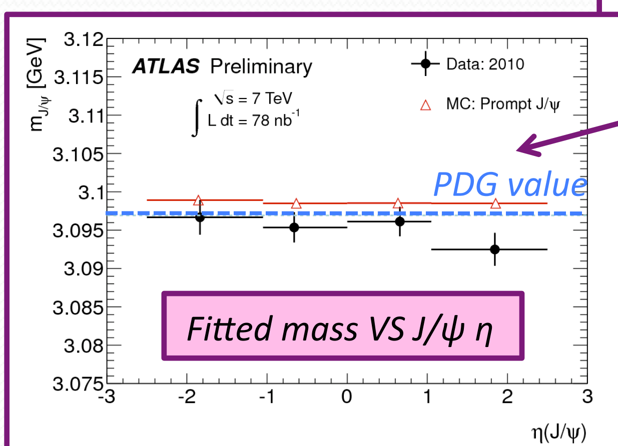


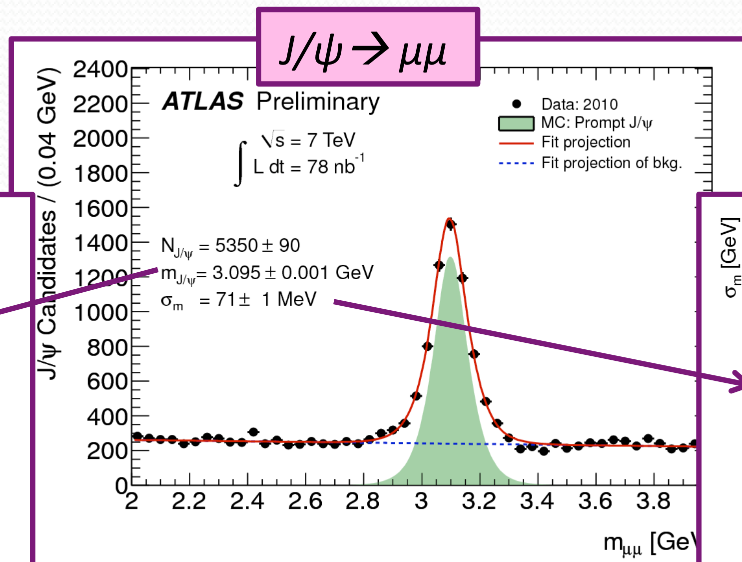




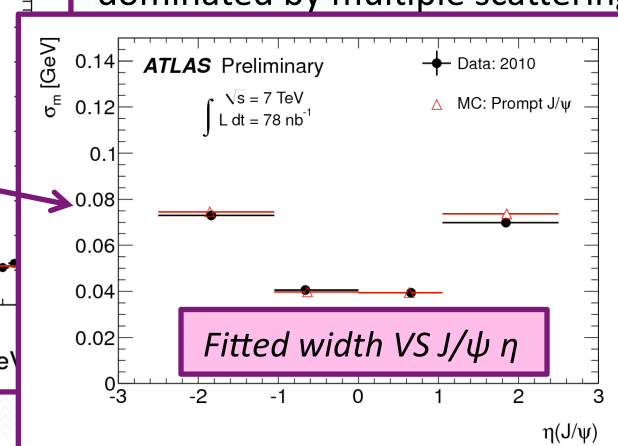
Fitted invariant masses are in agreement with PDG values, widths well reproduced by MC

- Probing an higher p_T range …



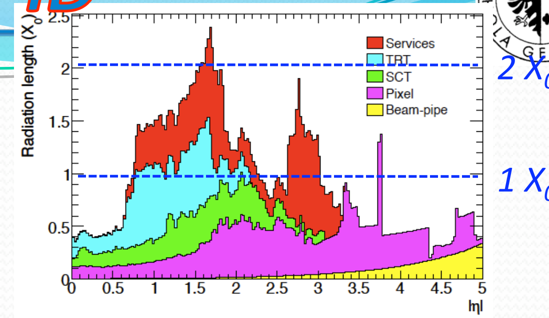


resolution as expected,
dominated by multiple scattering



Material mapping in the ID

Unprecedented amount of material in the tracker volume.



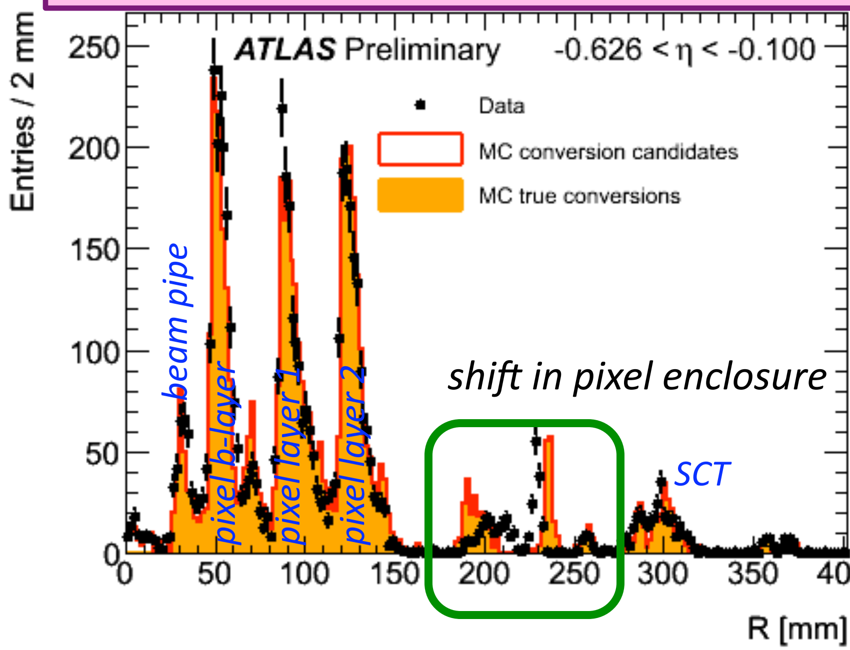
3 complementary 'tools' available to inspect material effects:

- *photon conversion*
- *hadronic interaction (vetoing decays)*
- *energy flow in the calorimeter*

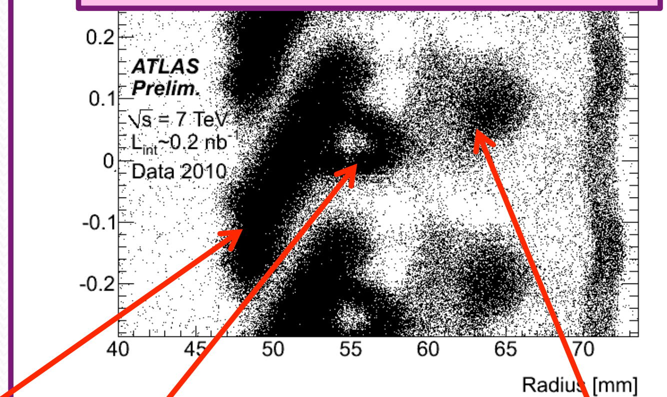
Results from 3 methods are compatible

- Present understanding: ~ 10 %
- Goal: < 1 %

Radial position of reconstructed photon conversions

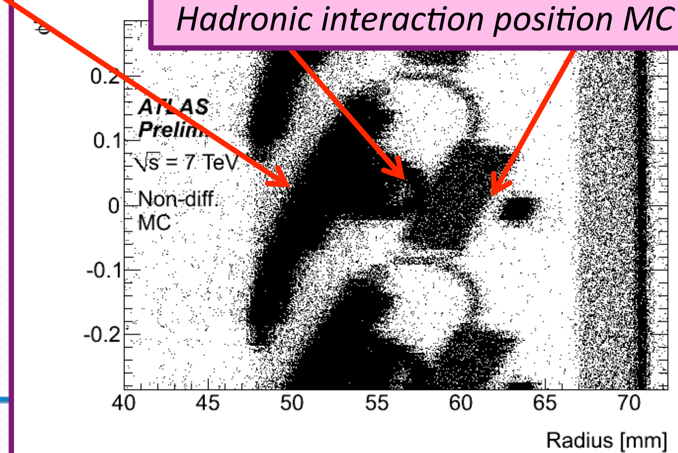


Hadronic interaction position Data



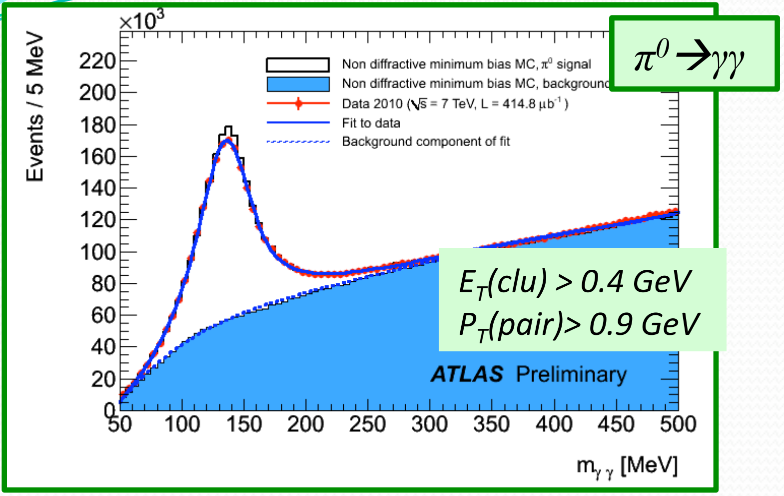
pixel module *cooling pipe* *services*

Hadronic interaction position MC

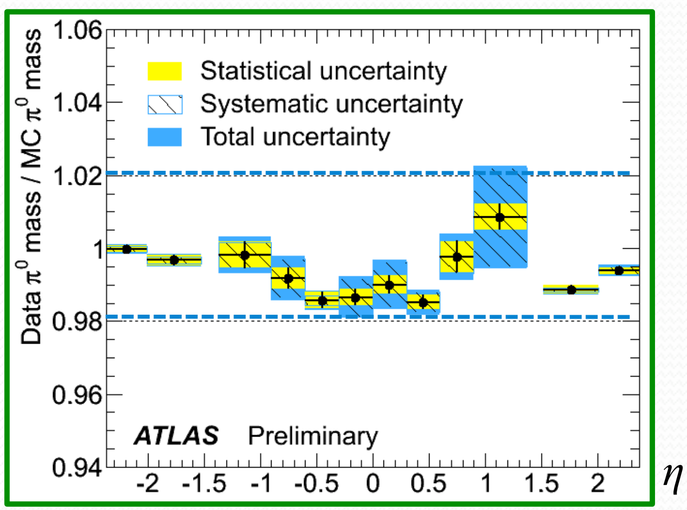


Photons

From ***low E_T photons from mesons*** *.....*



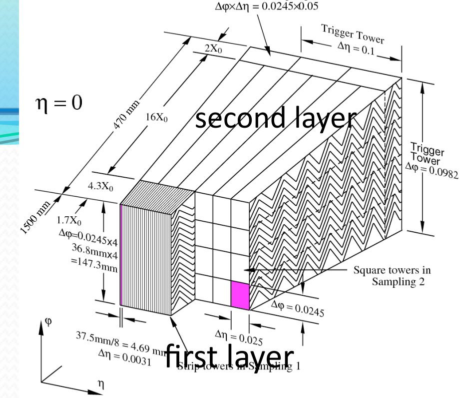
Data-MC : <1% for m_{π}, 5% for σ

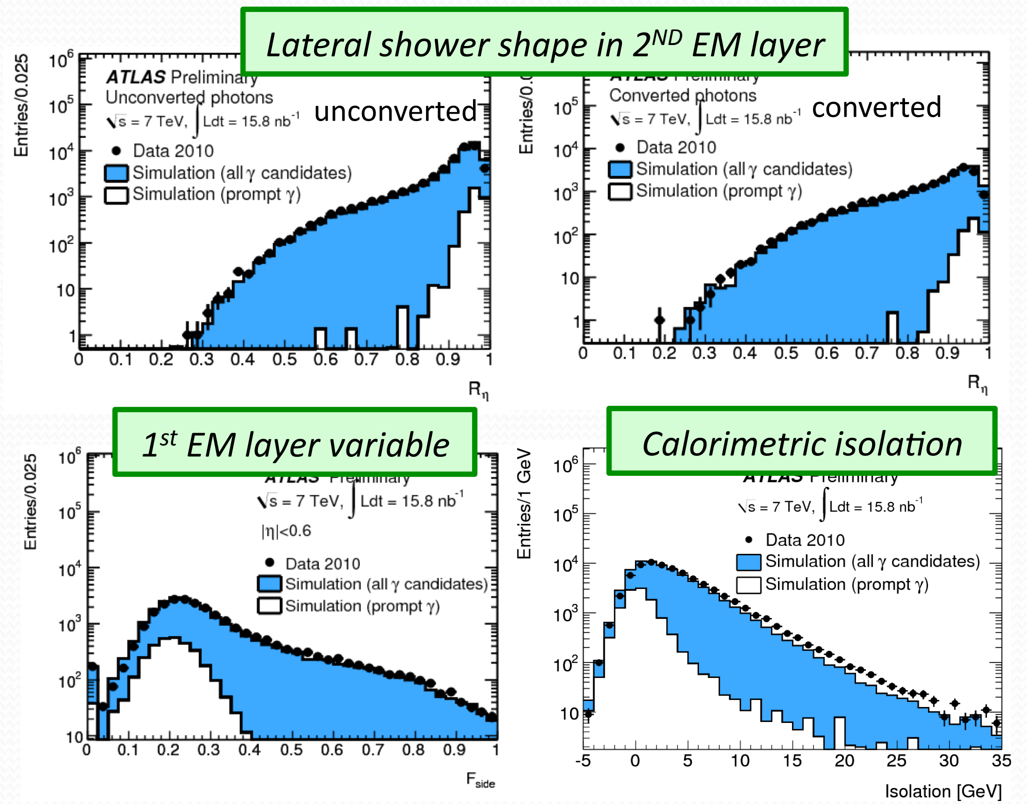


Uniformity of calorimeter response vs. η < 2%

...... *to* ***prompt photons***

- photon identification uses calorimetric shower shapes
- exploit the *good segmentation* of the EM calorimeter

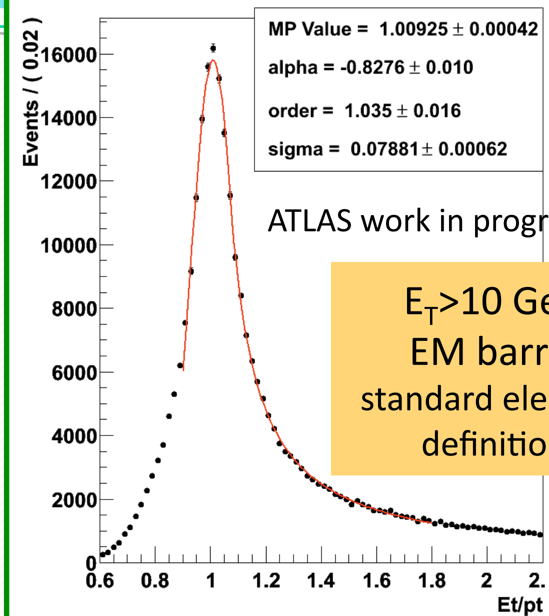




good data/MC agreement: distributions still dominated by background

Electrons

- Combining tracking and calorimetry …
  - ***in-situ calibration of the EM calorimeter with electrons using E/p***
  - take the scale from the ID (p) to get the scale factor for the EM calorimeter (E)
  - aiming at a precision less the 1% for several EM calorimeter regions → many electrons are needed
  - ….. work in progress (*plot for 1.2 nb^{-1}*)



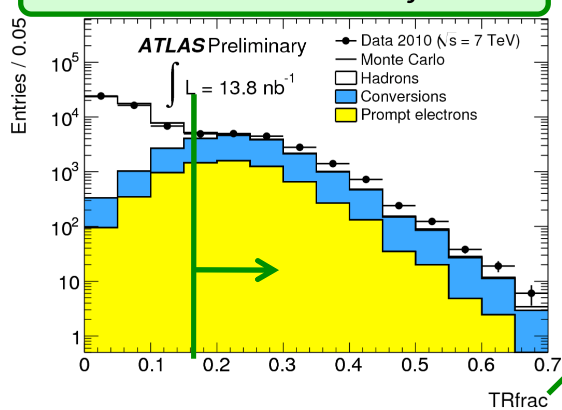
E_T>10 GeV
EM barrel
standard electron definition

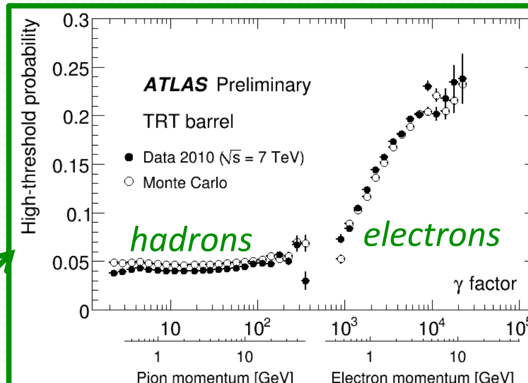
- Electron identification *uses same calorimetric variables* as photons + tracking related variables

Validation of tracking identification variables

High threshold hits: signal from charged particle is enhanced by photons from TR thus overcoming a second threshold

Transition Radiation hits fraction

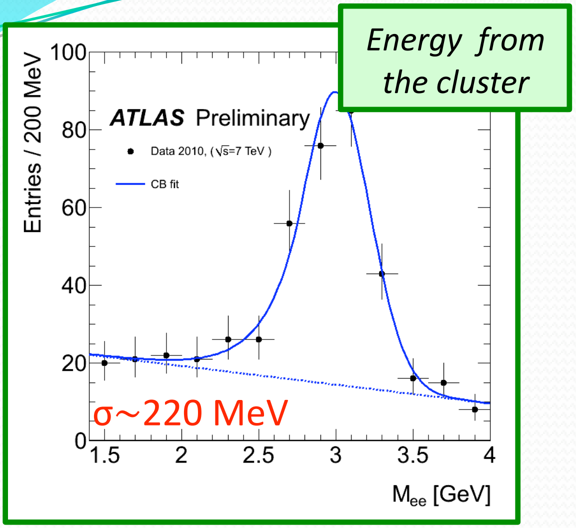


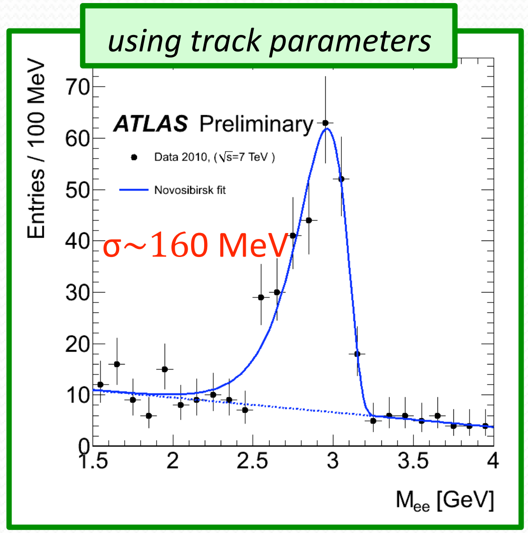


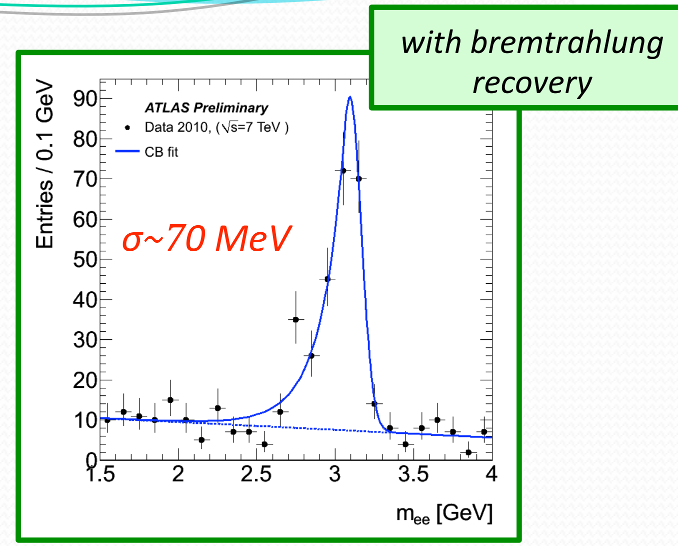
Very efficiency variable for removing hadrons background

Electrons from J/ψ

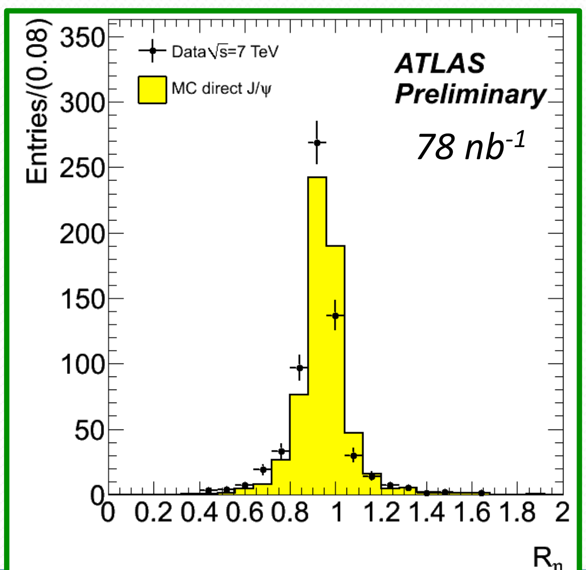
- Improving mass resolution







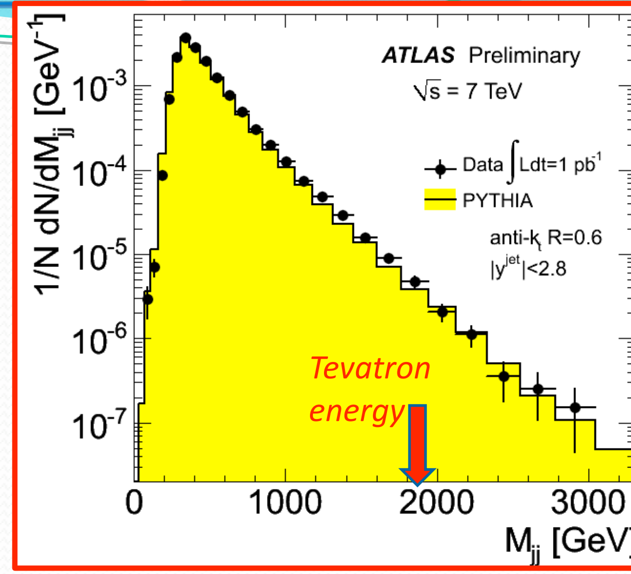
Tracker resolution is better than calorimeter in this energy range



- Shower shape extraction from Tag and Probe:
  - possible to obtain a very pure electron sample to ***crosscheck both tracking and electromagnetic variables***
  - accessing electron identification efficiency systematics
  - ***starting point to improve calorimeter simulation***
  - work in progress, need more statistics for detailed η mapping
  - *… also waiting for enough Zs …*

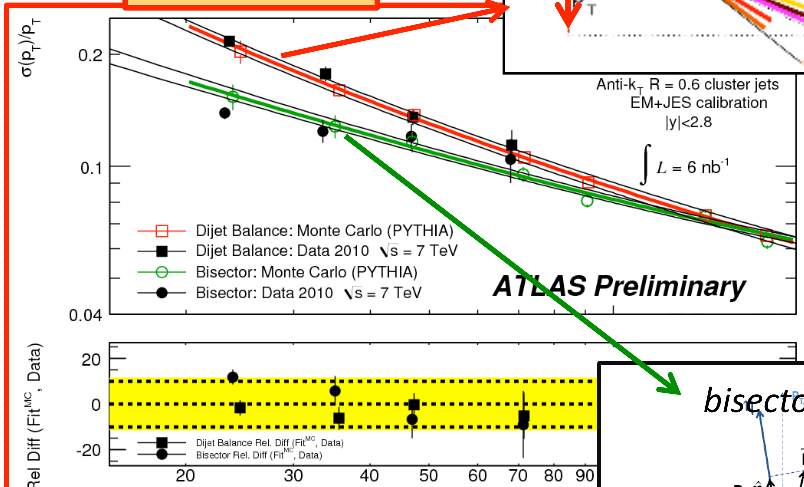
Jets

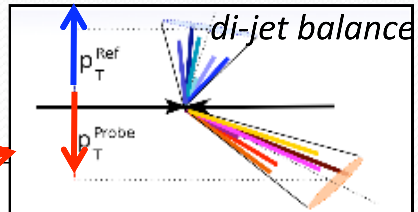
- Jet physics is the field where LHC experiment can be competitive with TEVATRON already with the first pb^{-1}

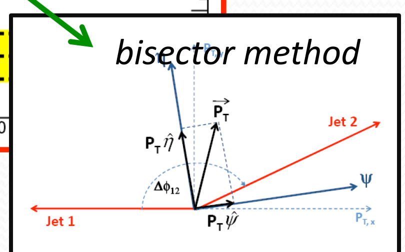


- EM scale jet momentum corrected with p_T/η calibration factor from MC
- JES uncertainty from accurate MC studies
- First Jet resolution from in-situ techniques

Jet resolution

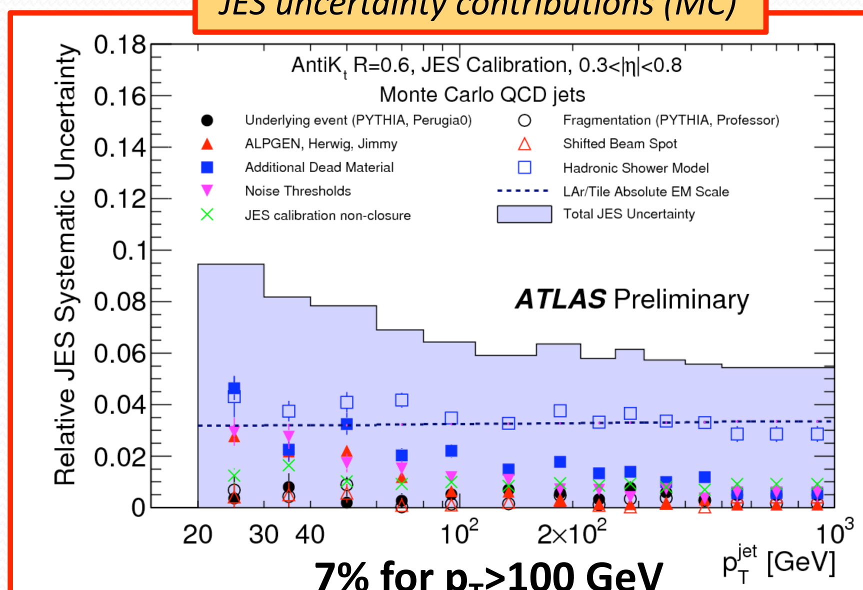






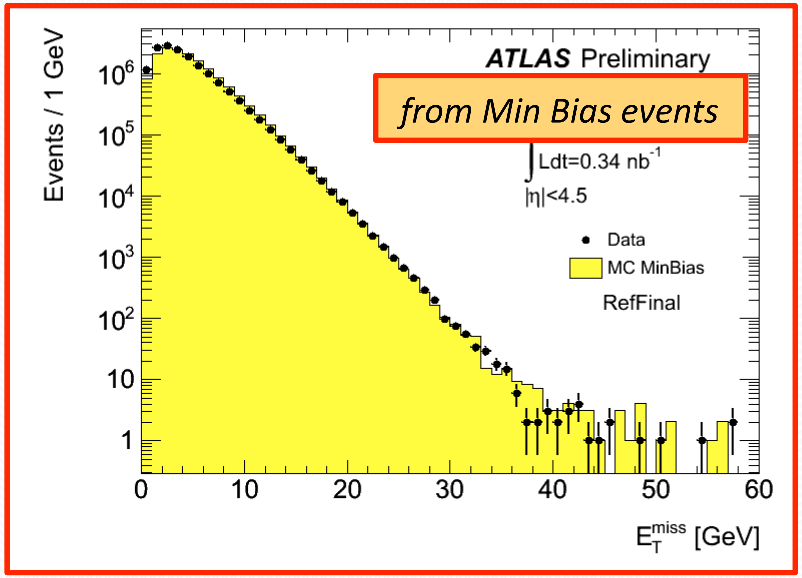
Data-MC agreement within 15%

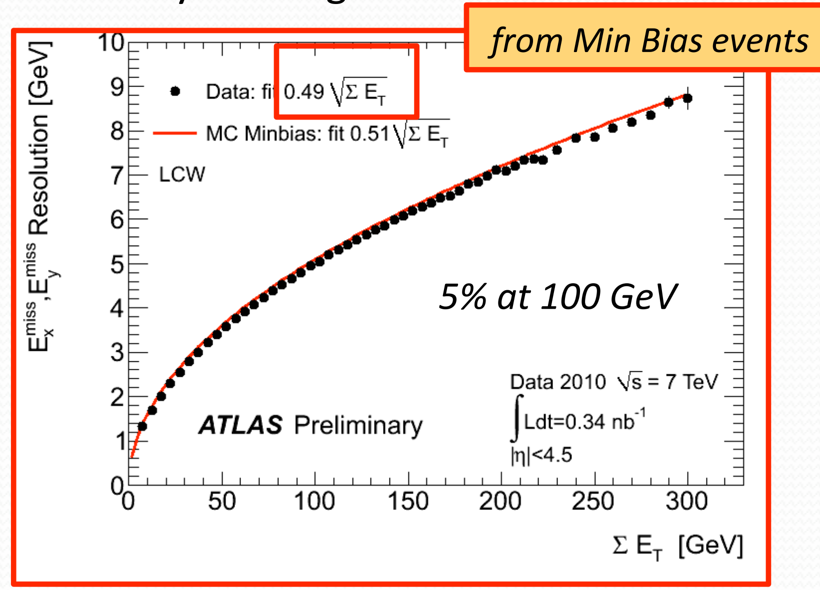
JES uncertainty contributions (MC)



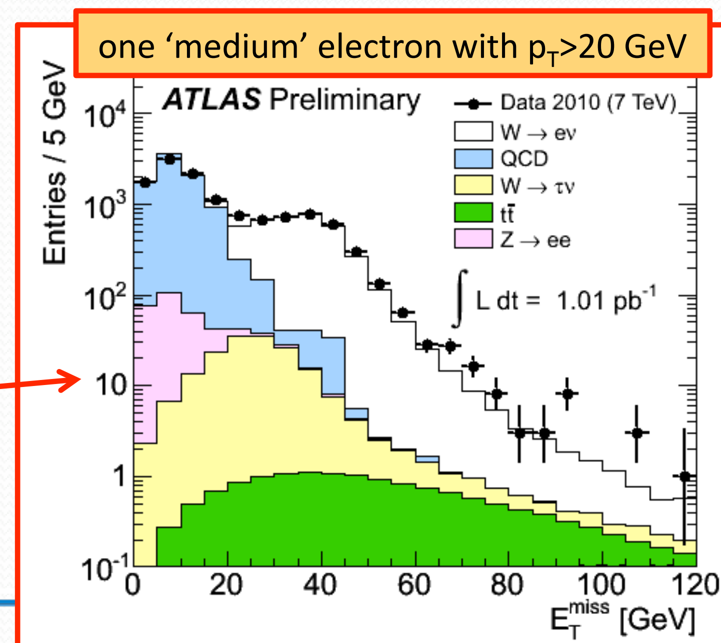
Missing E_T

- Computed from ***calibrated physics objects***, using full calorimetry coverage





- No tails after cleaning cuts (removing fake jets from noisy cells)
- No tails introduced by calibration
- Resolution well described by MC
- Distribution in agreement with MC for QCD events as well as standard for model processes (W)



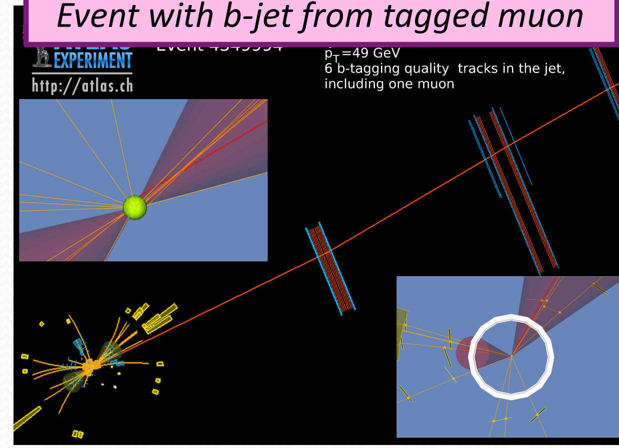
Very important for BSM searches

(see talk by C. Topfel)

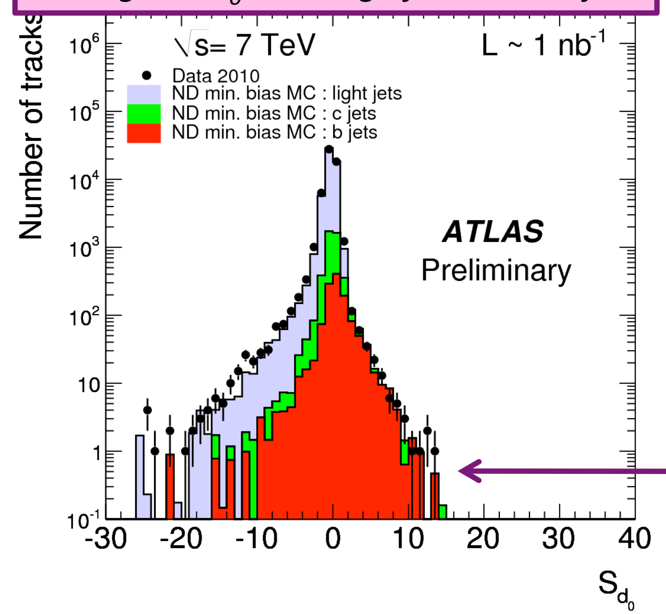
b-tagging

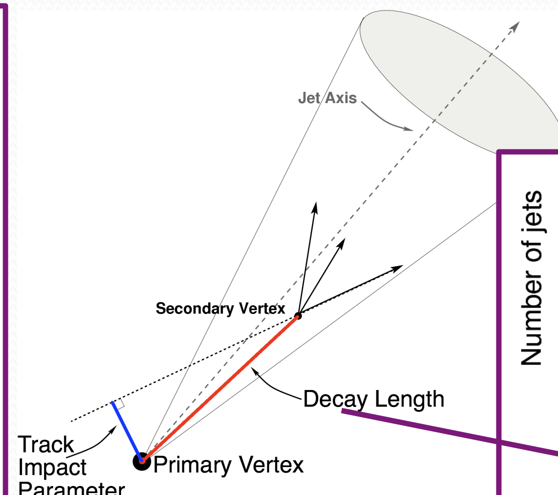
- Powerful tool to reduce background in many physics analyses *(top, SUSY)*
- Different taggers available:
  - *soft lepton tagging (looking for lepton in the jet)*
  - *secondary vertex*
  - *impact parameter track counting*

Event with b-jet from tagged muon

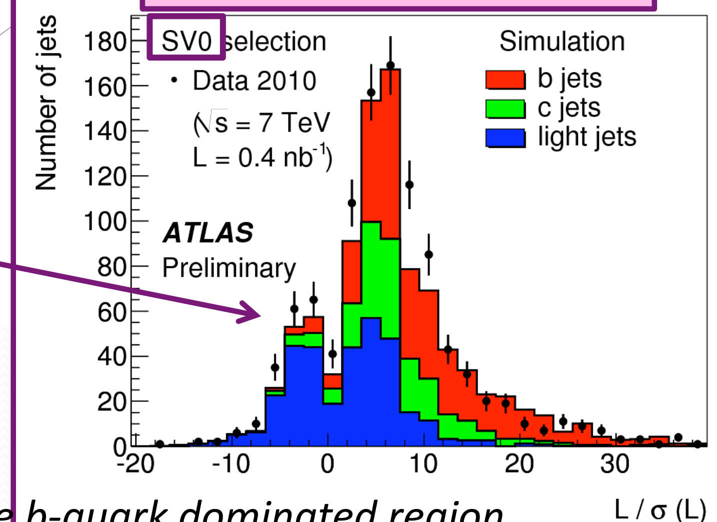


3rd highest d_0 track significance in a jet





Decay length significance for secondary vertex in a jet



Fair agreement between data and MC especially in the b-quark dominated region

Conclusions

- Since 30th March the ATLAS detector has been successfully collecting collision data at 7 TeV
- *Significant contributions from Swiss groups in detector operation and performance measurements*

- **More than 3 pb^{-1} collected so far**:
  - ✓ all ATLAS sub-detectors are working as expected
  - ✓ very high data taking efficiency with good data quality
  - ✓ High level trigger activated in many chains to cope with high LHC luminosity

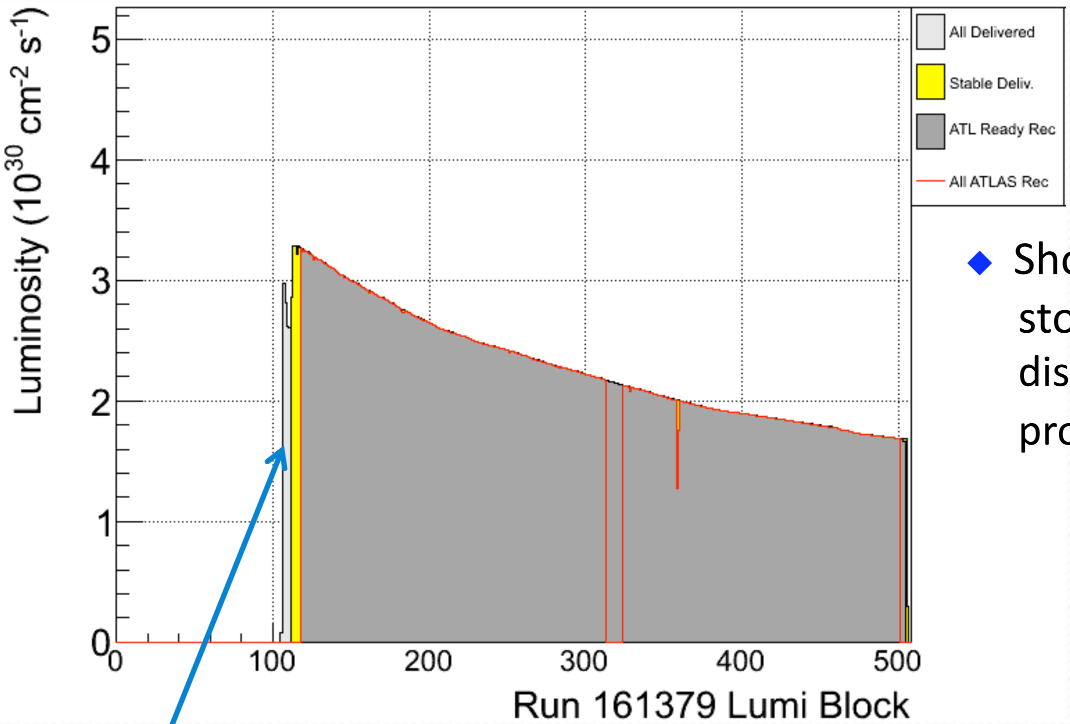
- **Good detector performance for all physics objects**:
  - ✓ excellent agreement between data and simulation given the (initial) stage of the experiment
  - ✓ few source of discrepancies (material description) are being addressed
  - ✓ *progressively moving to data driven technique to estimate performance*
  - ✓ already allow to produce many physics results

- The detector understanding will further improve as more data is collected:
  - ✓ it will allow to increase the ATLAS physics potential already with the first 100 pb^{-1}

backup

Data Quality

- Example from one fill (13th august):



- Short 'dips' in recorded rate due to stopless recovery (automatic disabling and reenabling of noisy or problematic channels)

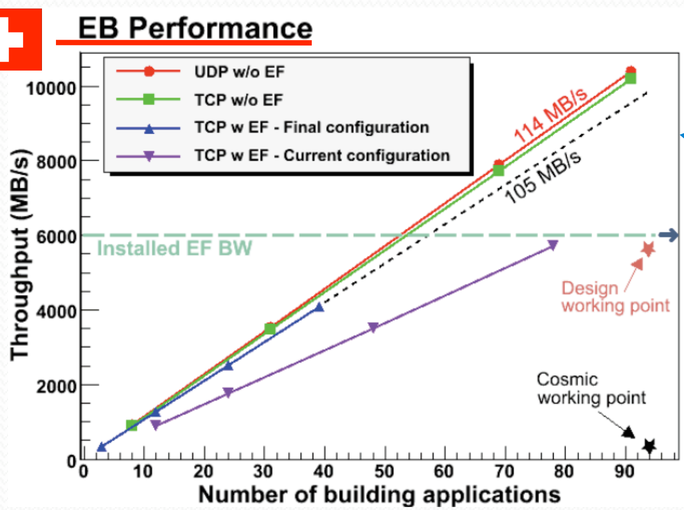
- Silicon detectors have HV off during non stable beam for system safety
- Only few minutes needed for tracking detectors to rump up HV once stable beam flag has been raised

DAQ status/operation

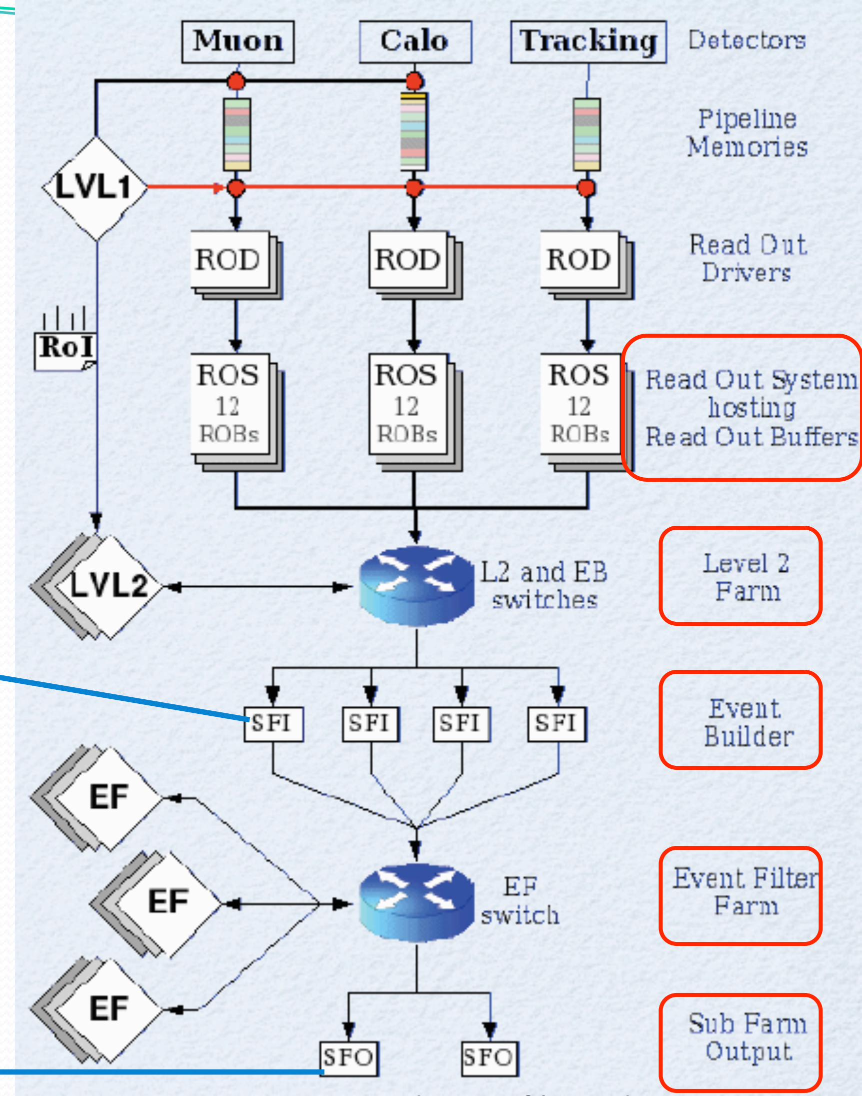
◆ ***Hardware status*** *(number of nodes)*

	now	designed
ROS	150	150
LVL2	150	500
EB	63	63
EF	600	1800
SFO	6	6

L2/EF core assignement can be configured



max installed EF bandwidth



writing data to file and transfert to tape

◆ *Writing to tape as many events as possible:* ***550 MB/s*** *(SFO limit)*

◆ *Stable designed working point:* ***300 MB/s***

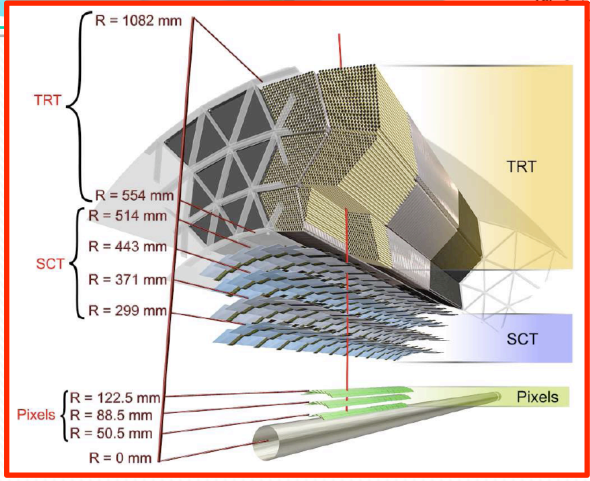
SCT status and operation

ATLAS SCT Configuration May 2010

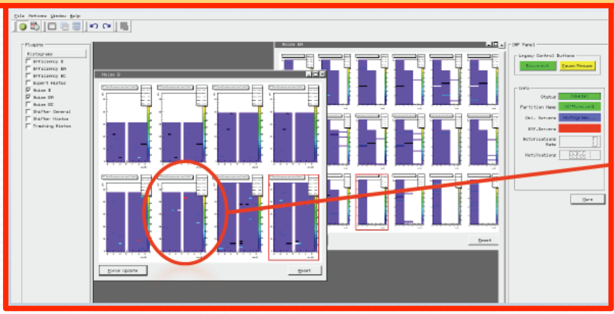
Disabled Readout Components	Endcap A	Barrel	Endcap C	SCT	Fraction (%)
Disabled Modules	5	10	15	30	0.73
Disabled Chips	5	24	4	33	0.07
Masked Strips	3,364	3,681	3,628	10,673	0.17
Total Disabled Detector Region					*0.97*

4 barrel layers

9 disks on each side

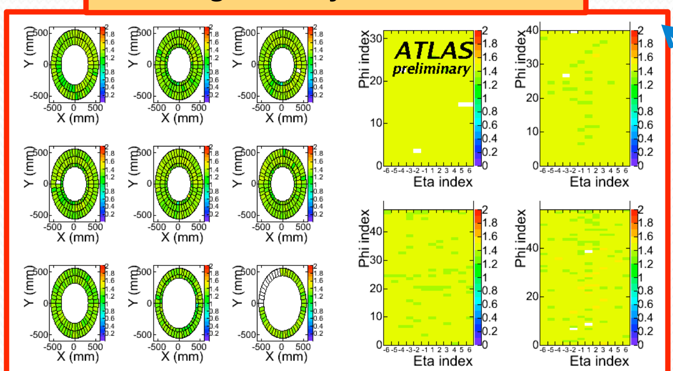


Occupancy histograms from online monitoring framework



Timing scan of each module

disks C side



barrel

Geneva group heavily involved in SCT operation:

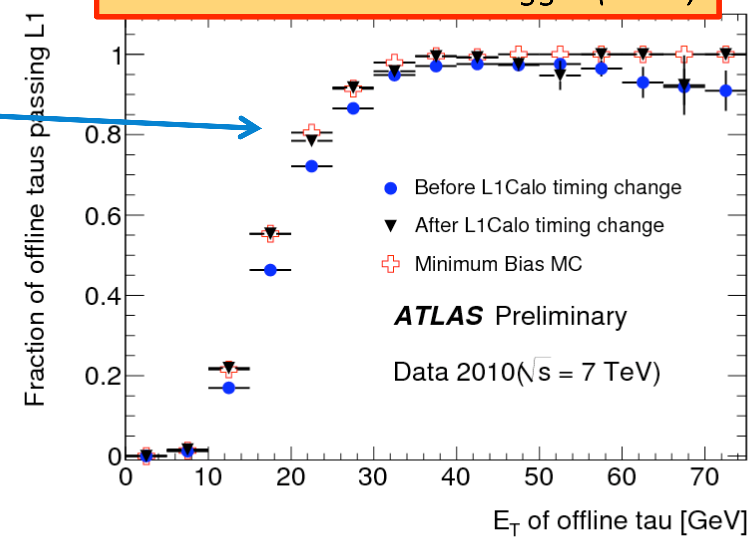
- technical coordination
- online monitoring
- calibration *(detector stability measurements)*

Trigger Performance: taus and muons

Current analyses aiming at:

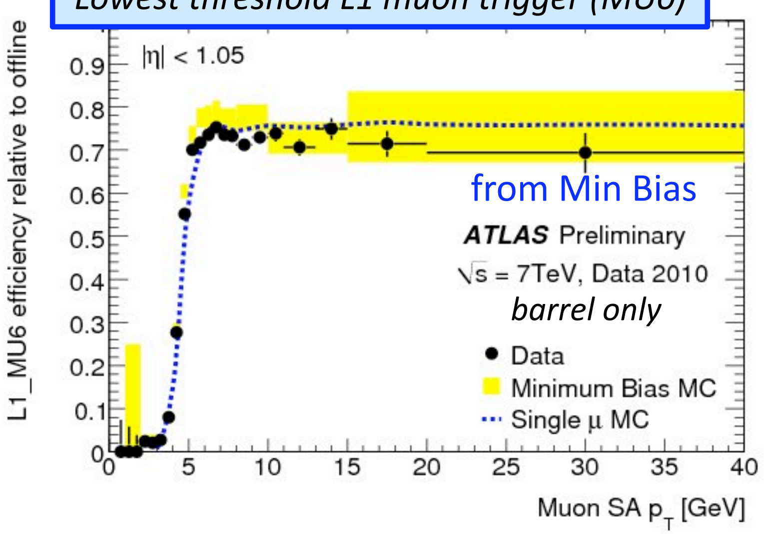
- finalizing timing of L1 system
- complete the commissioning/validation of all the HLT chains
- checking the data/MC agreement
- ***measuring signal trigger efficiency with data driven methods as input to physics analysis***

Lowest threshold L1 tau trigger (TAU5)

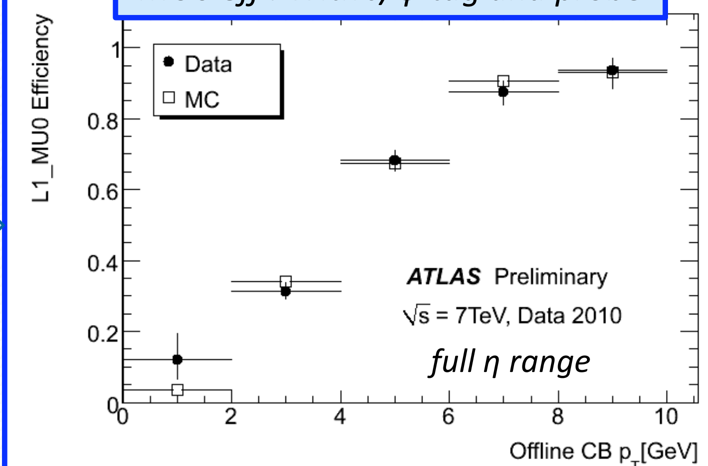


Muon triggers: J/ψ, inclusive muons, W, Z, top, BSM

Lowest threshold L1 muon trigger (MU0)



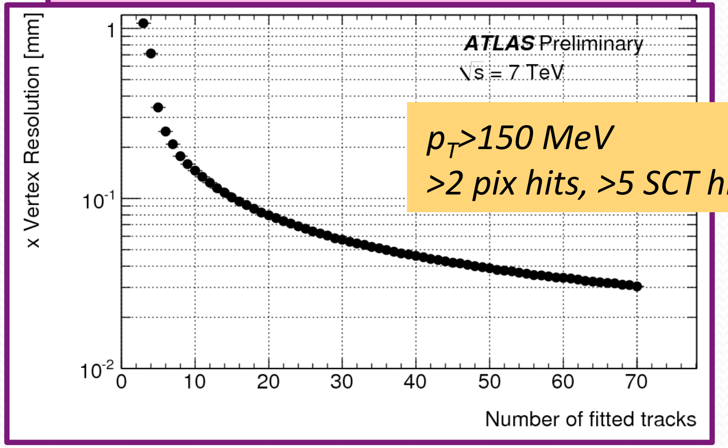
MU0 eff . With J/ψ tag and probe



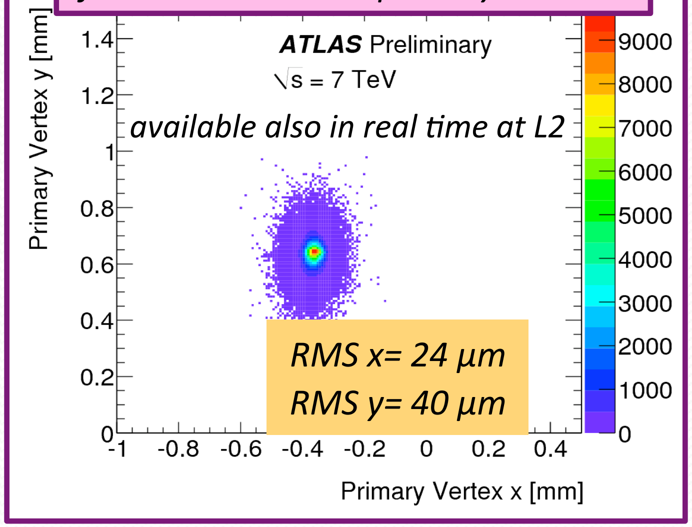
Primary vertex

Precise knowledge of ***beam spot*** and ***primary vertex*** position crucial for tracking application.

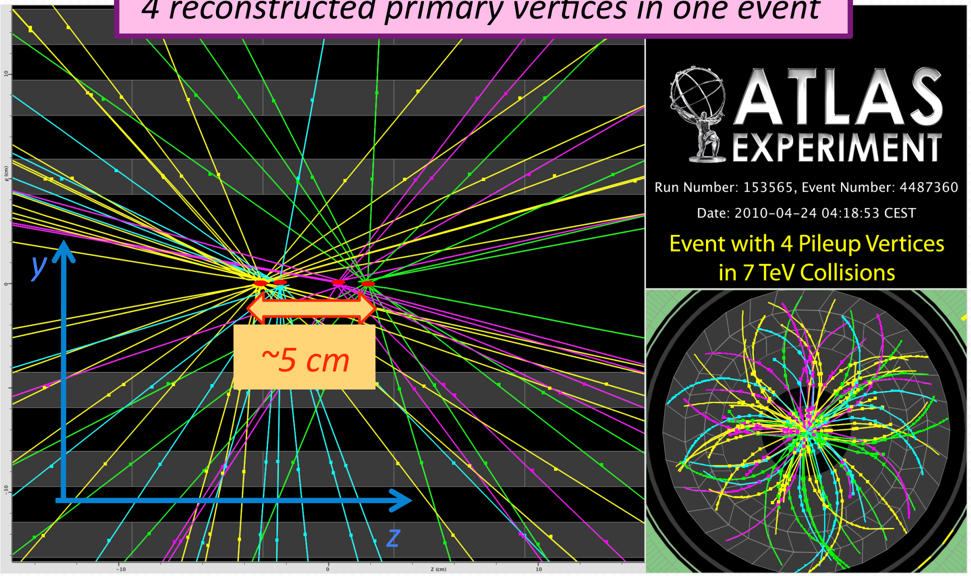
primary vertex resolution VS # of tracks



beam spot x,y position from reconstructed primary vertices



4 reconstructed primary vertices in one event



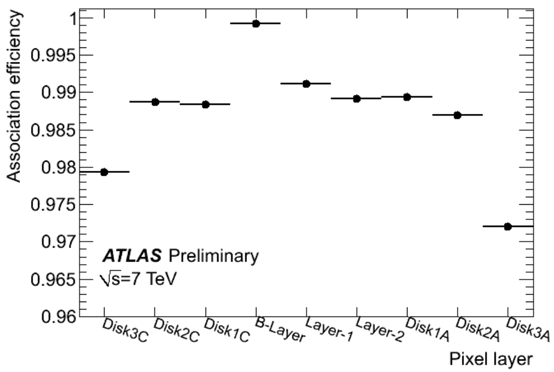
Pile-up:

- with present LHC bunch intensity ~ 50% of events with >1 primary verteces
- need to study and correct the effect on MET and lepton/photon isolation (jet areas correction)
- for jets the use of Jet Vertex Fraction (tracks in jets coming from each PV) under investigation

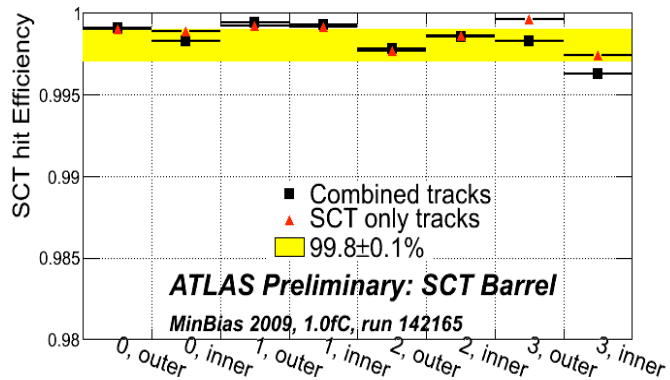
Inner detector

- Very high hit efficiency

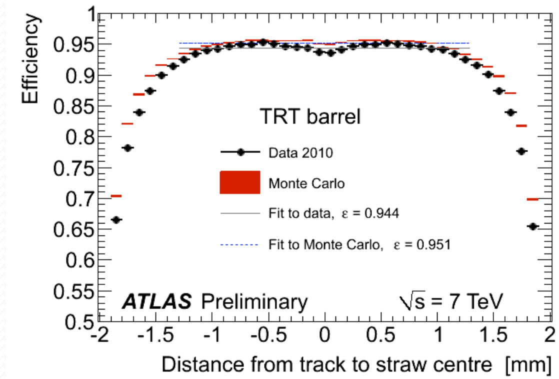
Pixel



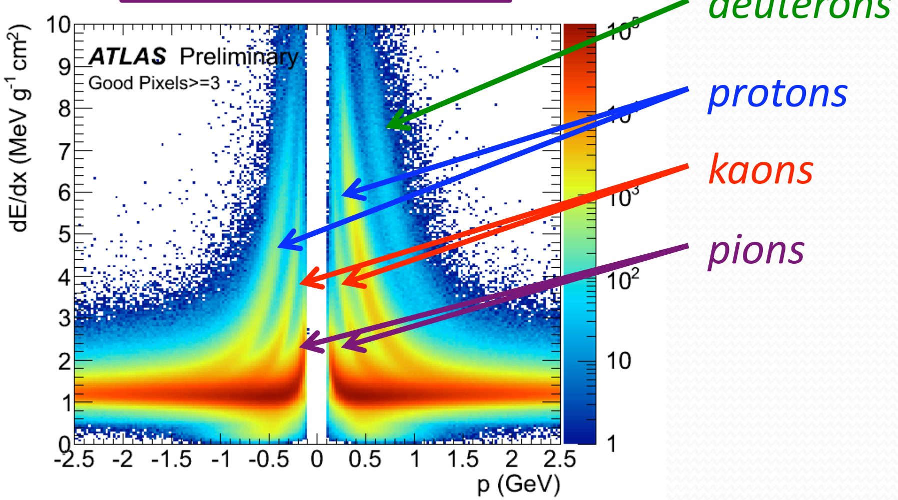
SCT



TRT

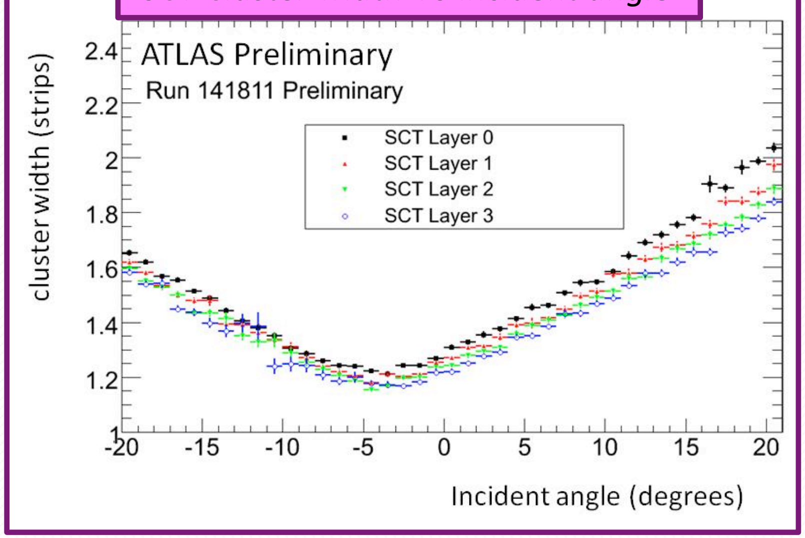


dE/dx in pixel detector



Could be used for particle id at low Pt

SCT Cluster width VS incident angle

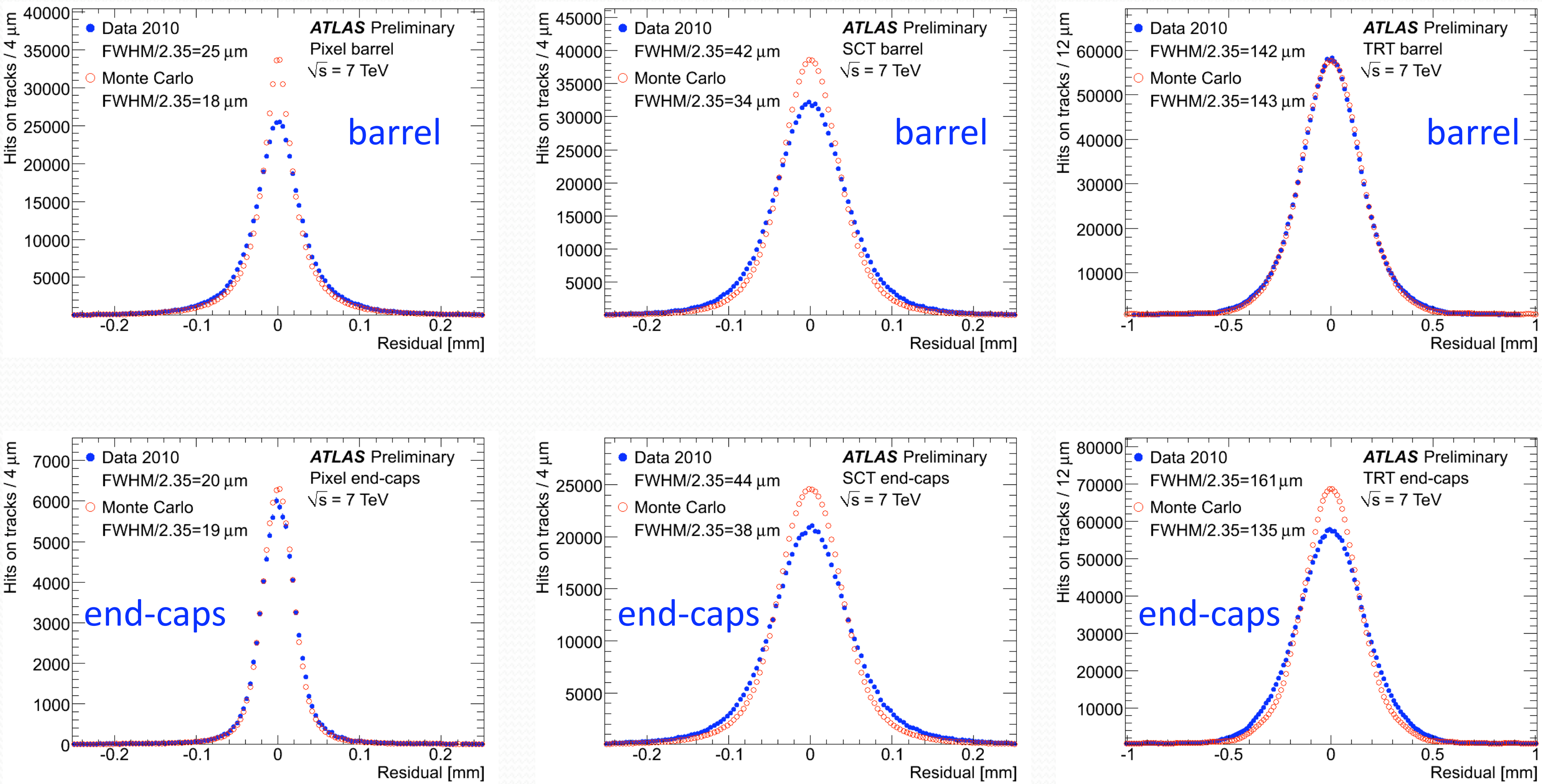


Measured Lorentz angle agrees with MC

ID alignment

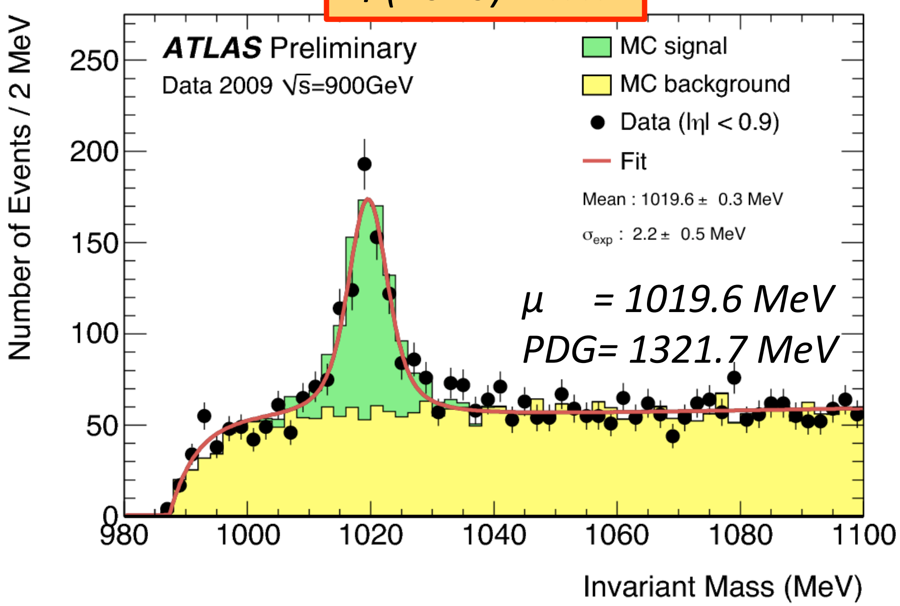
- Further refinement in alignment with 2010 collision data

Pixel *SCT* *TRT*

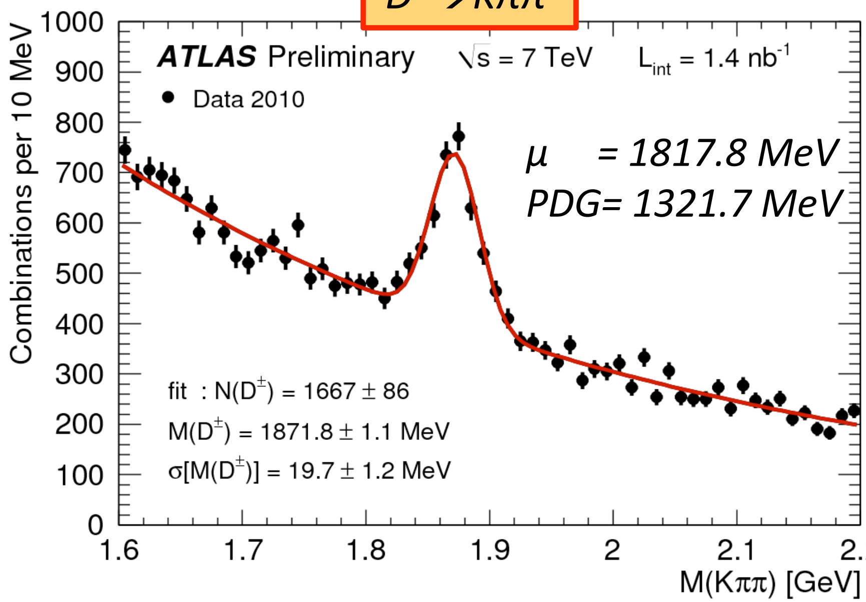


Tracking (2)

$\Phi(1020) \rightarrow K^- K^+$



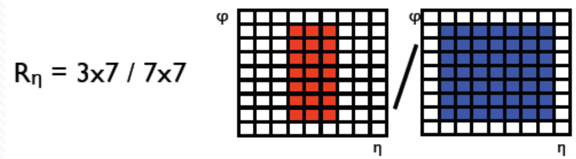
$D^+ \rightarrow K\pi\pi$

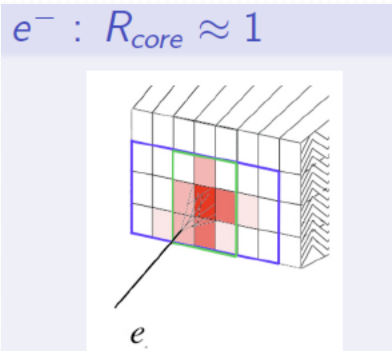


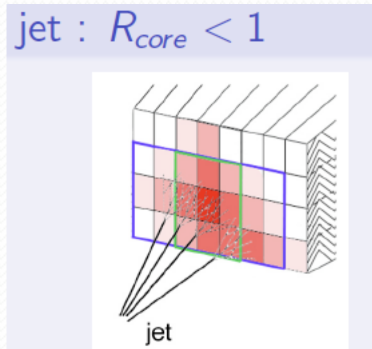
Particle dE/dX in pixel detector required to be compatible with kaon hypothesis

Electrons and Photons identification

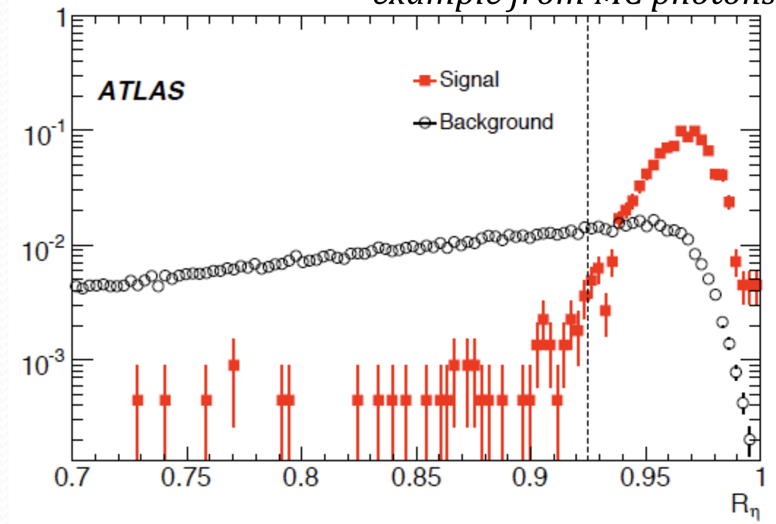
- Example of identification variable from second EM layer:







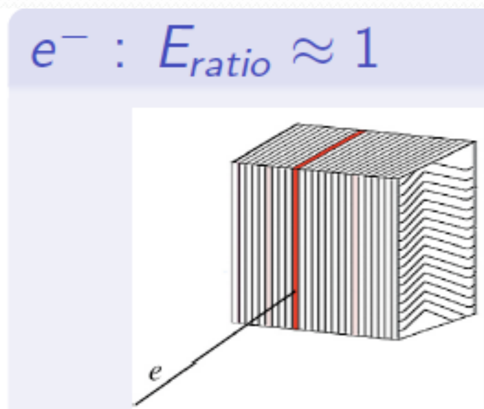
example from MC photons

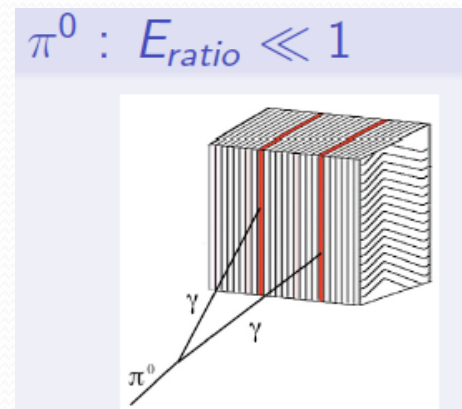


- Example of identification variable from first EM layer:

$$E_{ratio} = \frac{E_{1st} - E_{2nd}}{E_{1st} + E_{2nd}}$$

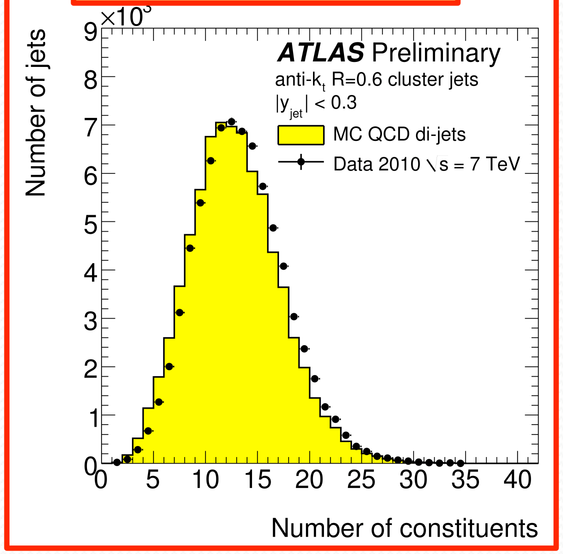
E_{1st}: highest energy deposition in the strips
E_{2nd}: second highest energy deposition in the strips



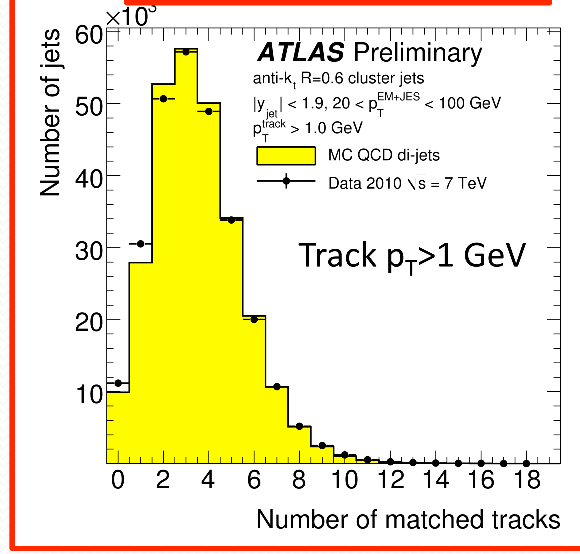


Jets substructure

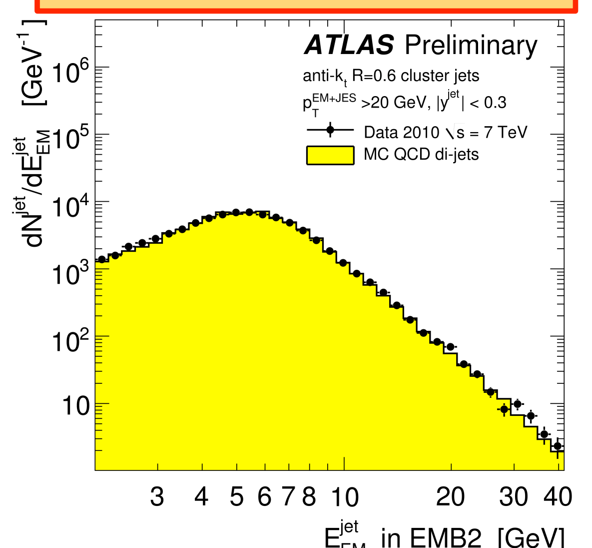
Topoclusters per jet



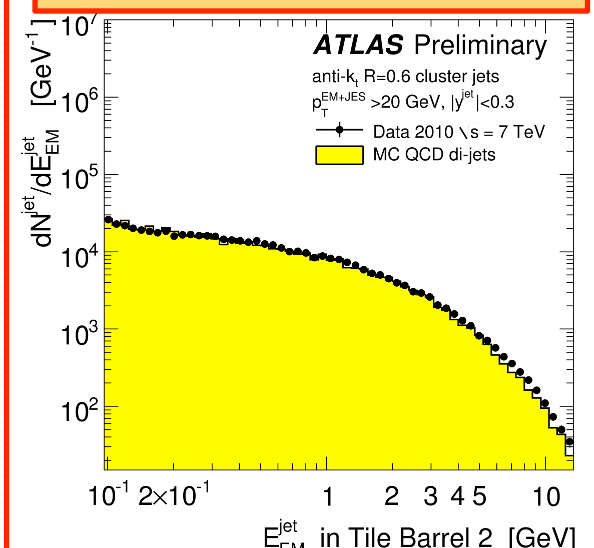
Matched track per jet



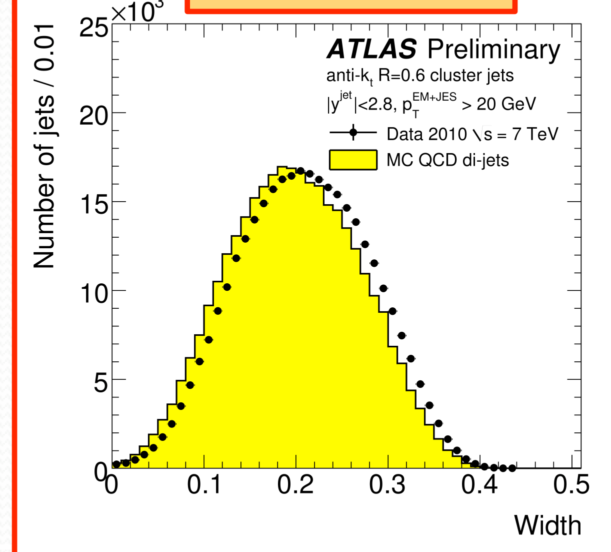
Longitudinal profile (EM cal)



Longitudinal profile (Had cal)



Jet lateral width



Missing E_T reconstruction

Refined Calibration (RefFinal)

- Associates calorimeter cells to reconstructed high-p_T physics objects

Electrons | Photons | Taus | Jets | Muons | Unused TopoClusters

↓

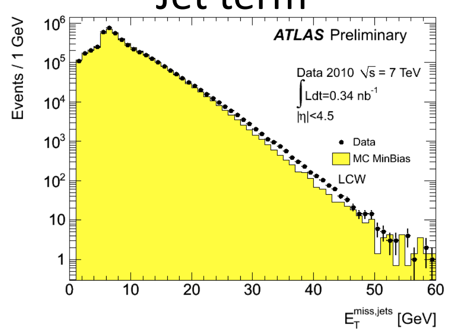
Go back to constituent Calorimeter Cells → apply overlap removal at Cell level → Cell calibration weights dependent on the object → add them to calculate partial terms

↓

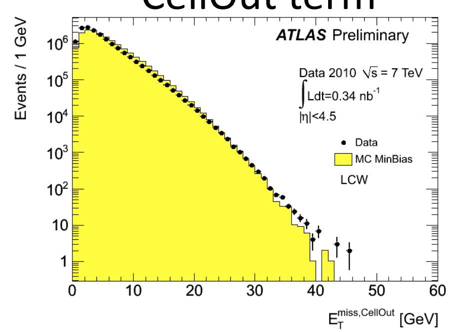
MET_RefEle + MET_Refγ + MET_RefTau + MET_RefJet + MET_RefMuo + MET_CellOut + MET_Cryo + MET_Muon = MET_RefFinal

- Distribution from Min Bias event (MC normalized to data)

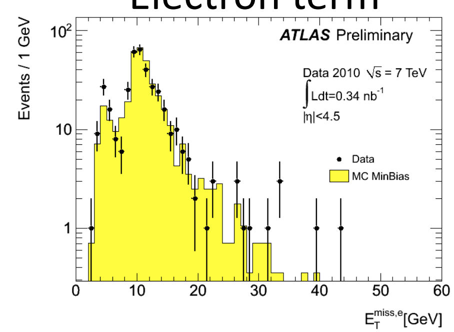
Jet term



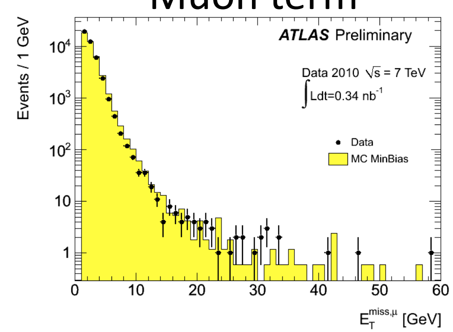
CellOut term



Electron term



Muon term

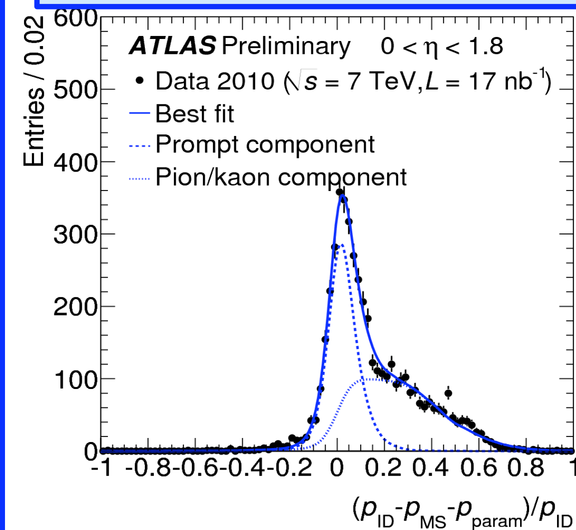


- Gamma and taus term negligible in Min Bias events

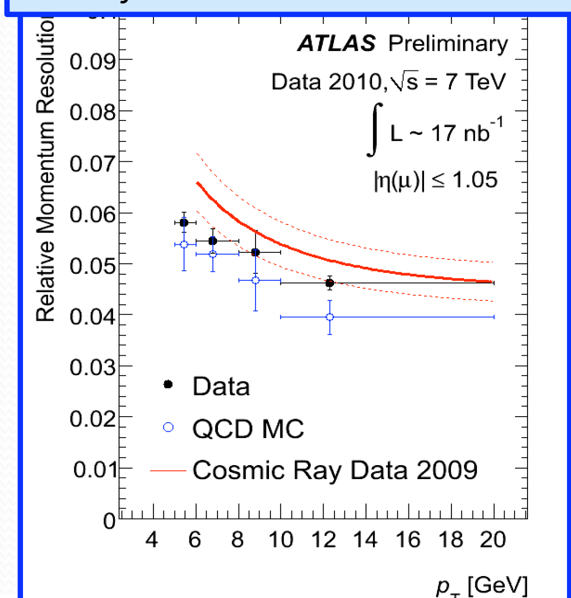
Muons

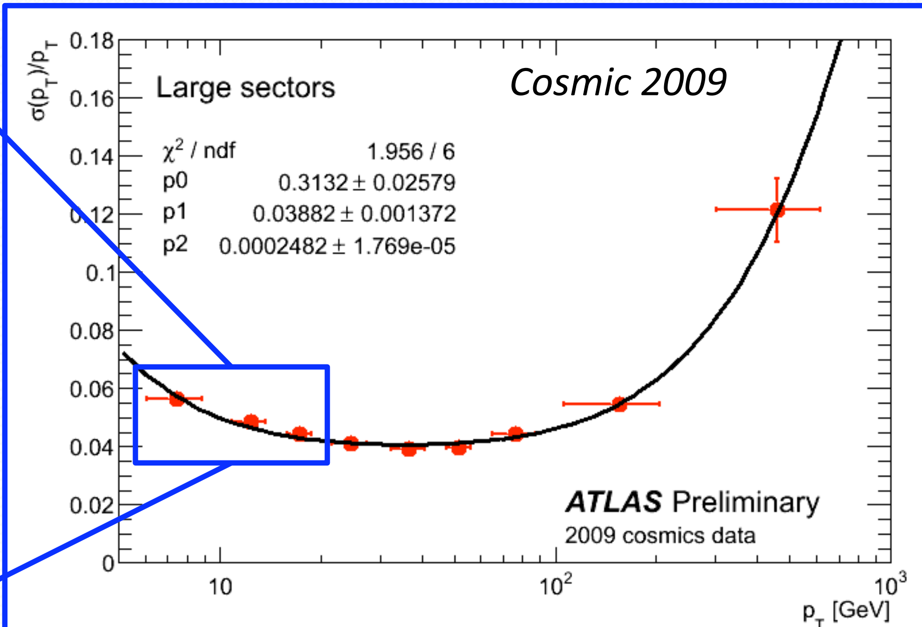
- A muon can be separately reconstructed in the Inner Detector (ID) and in the Muon Spectrometer (MS)
- MS resolution is different for *prompt muon* (from heavy quark, J/ψ, W,Z) and for muon from *decay in flight* (background from pion and kaon)
- Use a ML fit to extract signal component
- ***Measuring MS resolution w.r.t. ID tracking***

P_T resolution between ID and MS

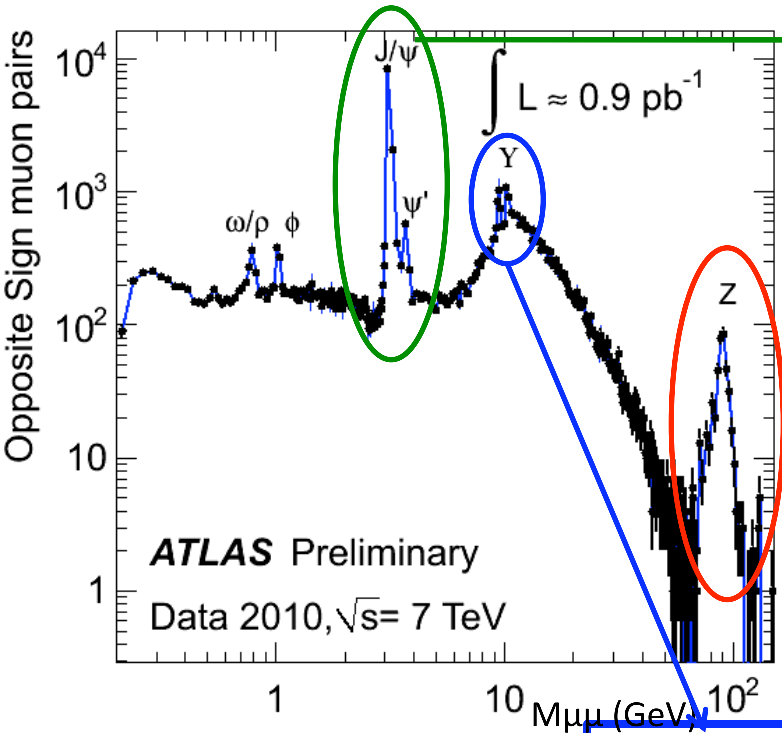


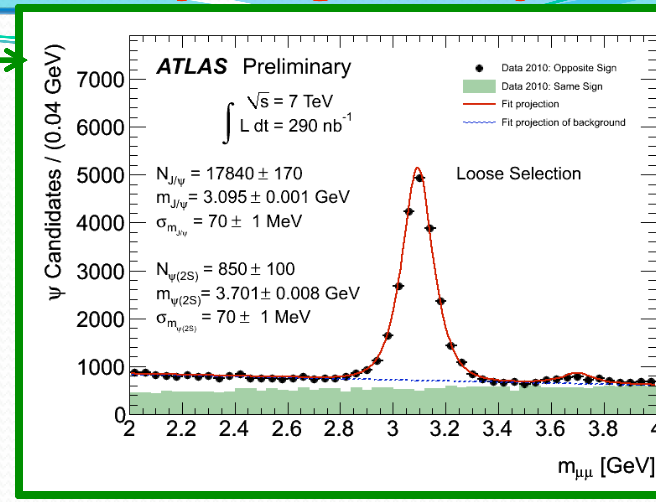
BARREL: resolution dominated by losses fluctuation in the calorimeter

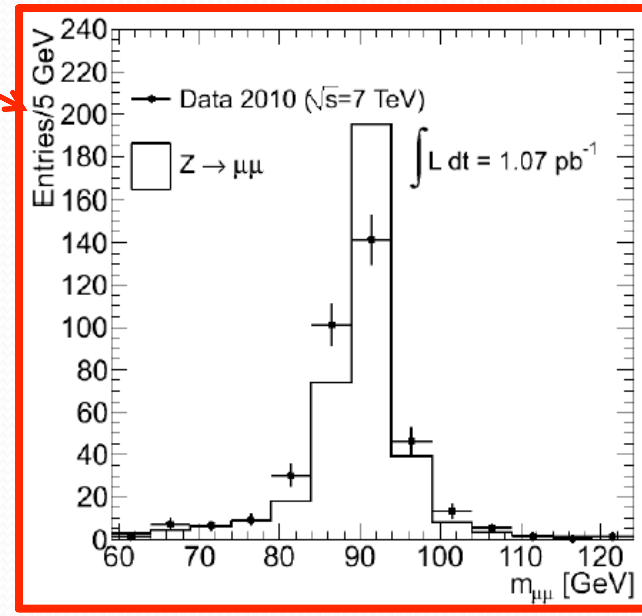




Di-Muon spectrum (2 orders of magnitude)







- single muon trigger
- p_T> 6 GeV
- 2 opposite sign combined muons (ID+MS)
- primary vertex constraint