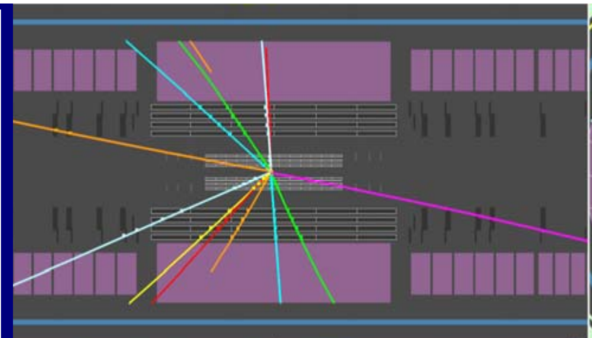
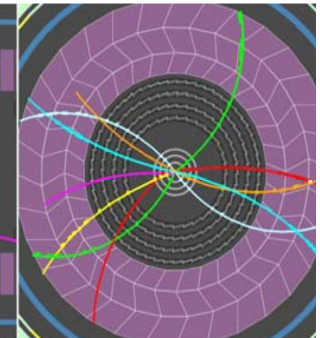
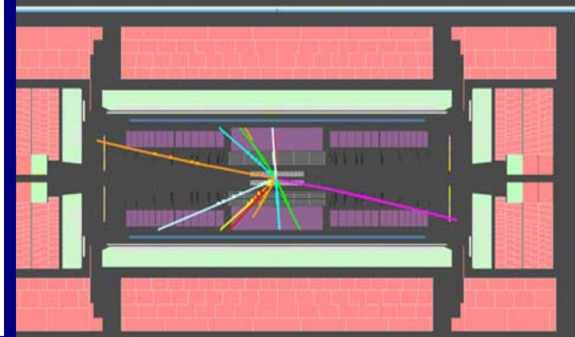
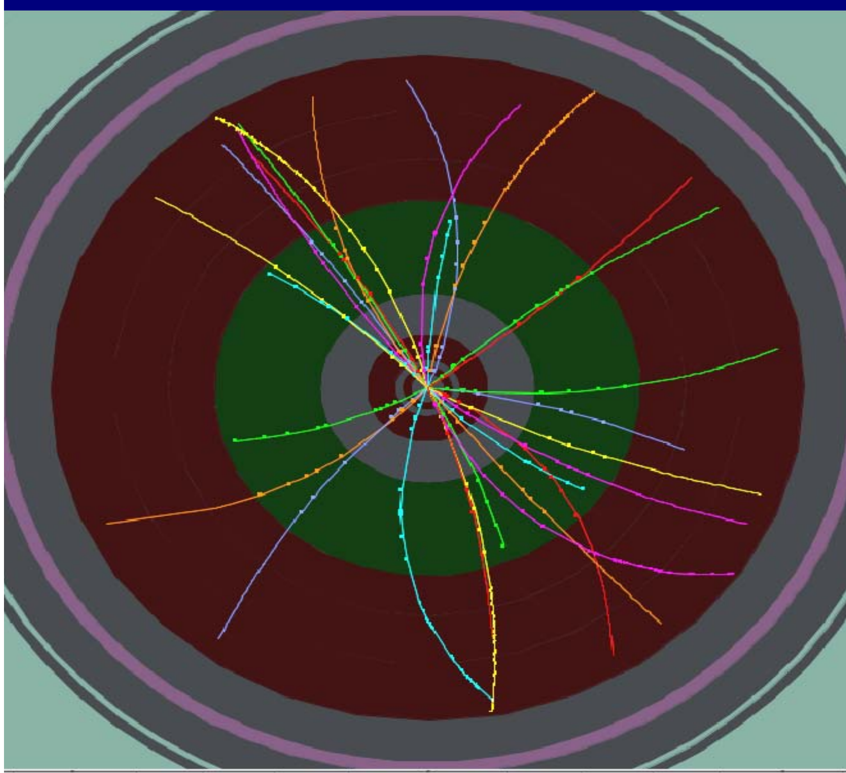
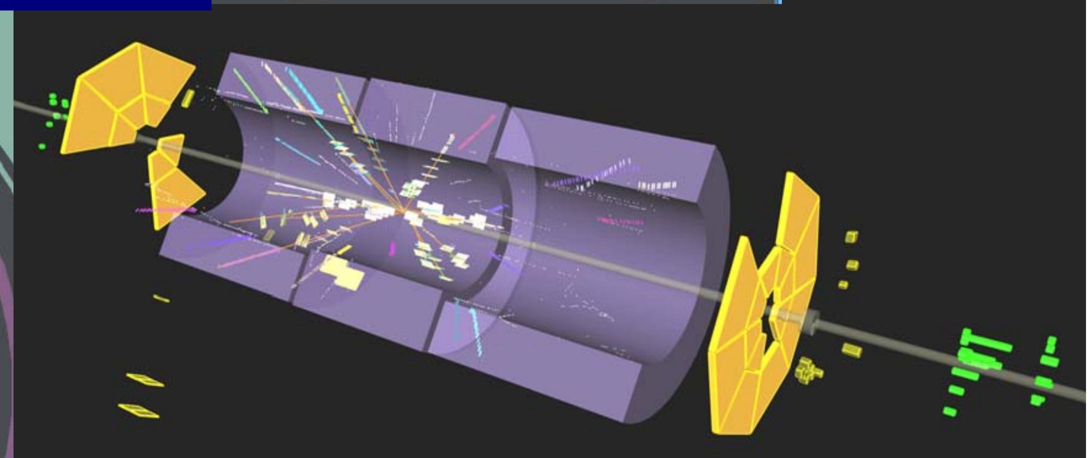
ATLAS Experiment: Status and First Results

Rencontres de Moriond 2010

"Electroweak Interactions and Unified Theories"

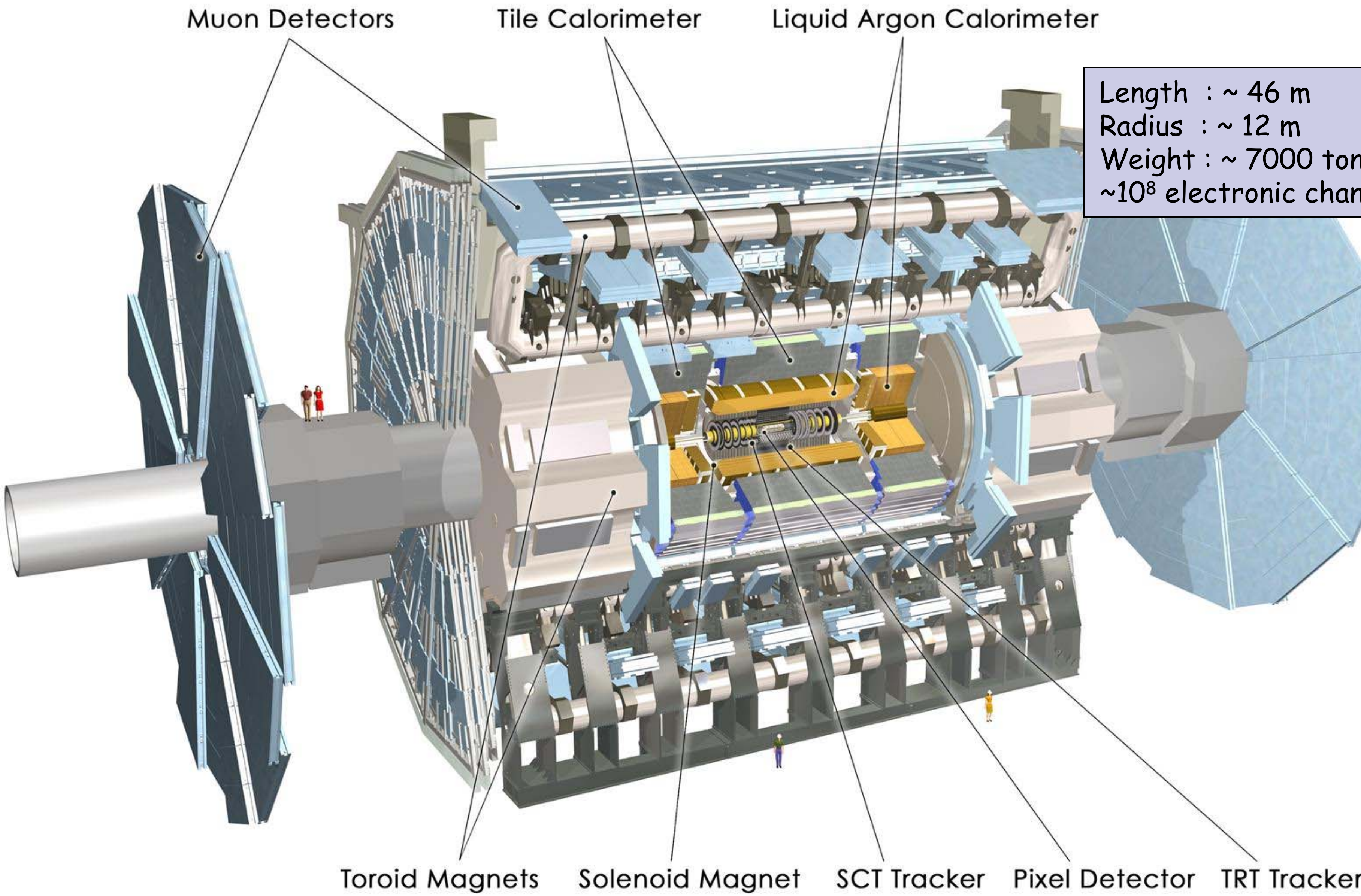
Jean-Francois Arguin (LBL) on Behalf of the **ATLAS Collaboration**

March 6-13, 2010

Outline

- Introduction
- Detector Performance Results During 2009 Run
  - Trigger
  - Muon Spectrometer
    - Muon reconstruction
  - Calorimeters
    - Electrons and photons
    - Jets and missing E_T
  - Inner Detector
    - Tracking Performance
    - B-tagging
- First ATLAS Physics Result:
  - "Charged-particle multiplicities in pp interactions at $\sqrt{s}$=900 GeV measured with the ATLAS detector at the LHC"

ATLAS Detector



Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels

> 20 years of efforts of the worldwide ATLAS scientific community

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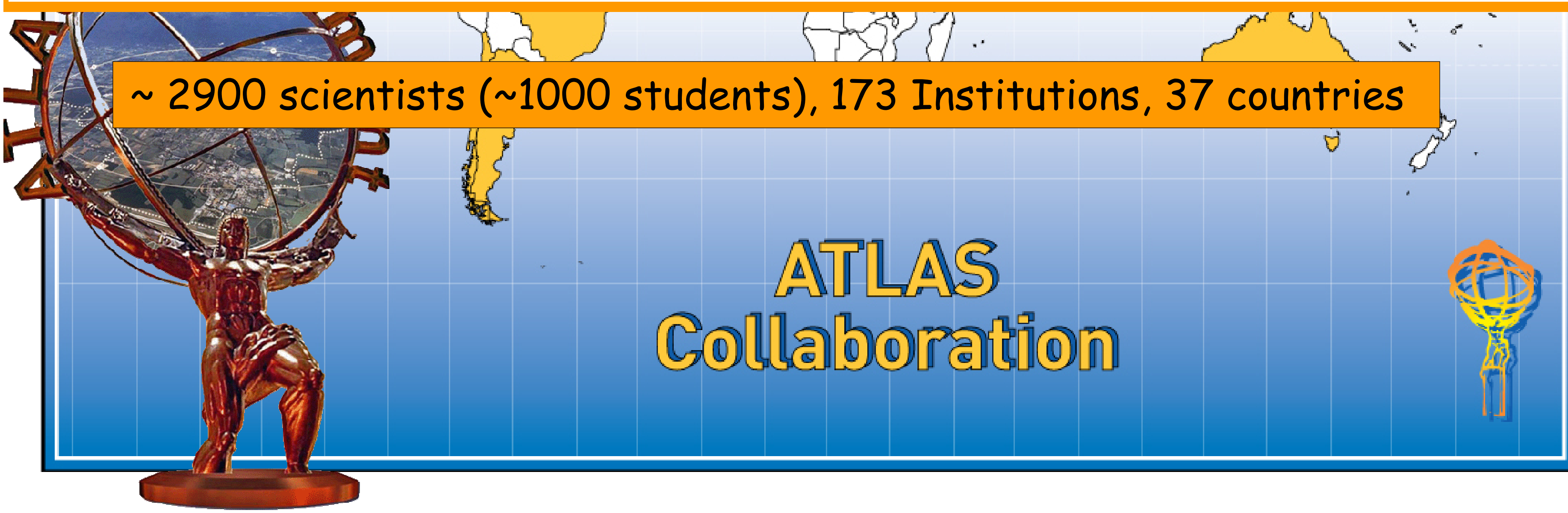
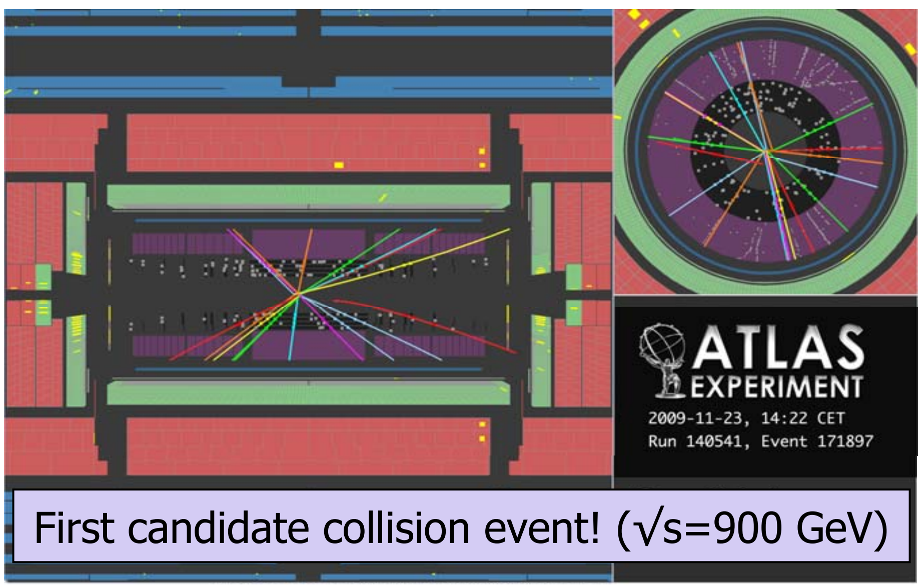
Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Brasil Cluster, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, SMU Dallas, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Edinburgh, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Iowa, UC Irvine, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, NIU, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, Sussex, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Tokyo Tech, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, UI Urbana, Valencia, UBC Vancouver, Victoria, Waseda, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

~ 2900 scientists (~1000 students), 173 Institutions, 37 countries

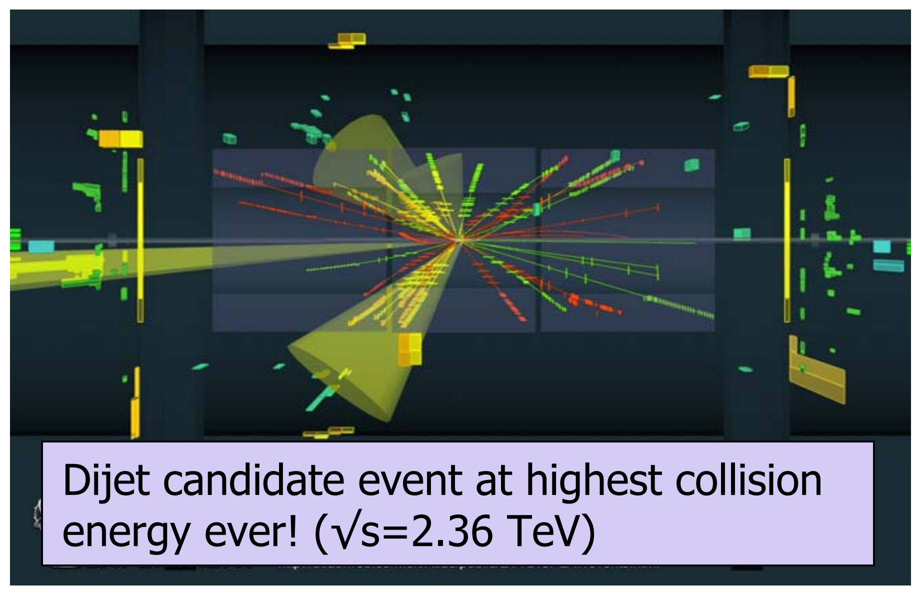


First Collision Run! (Nov.-Dec. 2009)

ATLAS Control Room (Nov. 20)



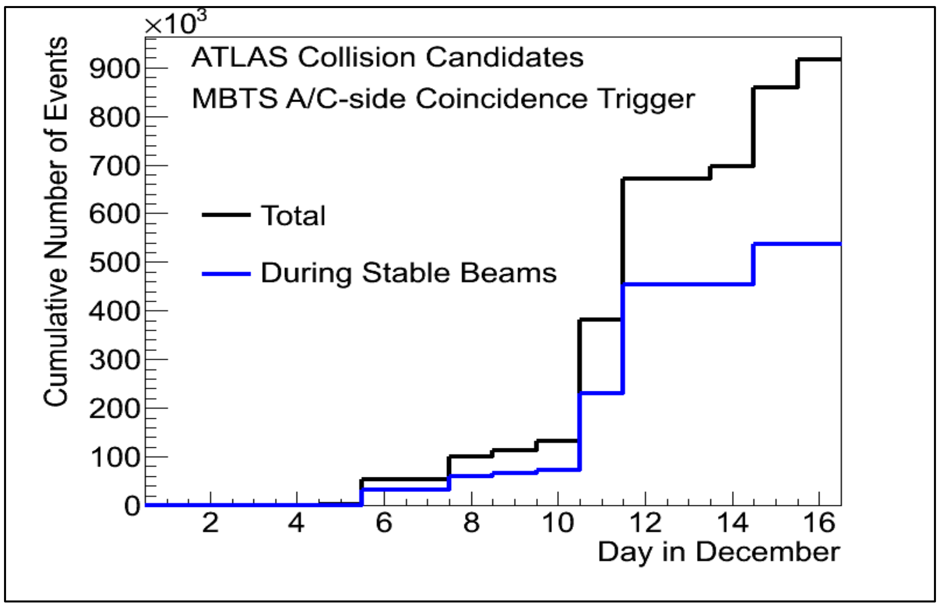
First candidate collision event! ($\sqrt{s}$=900 GeV)



Dijet candidate event at highest collision energy ever! ($\sqrt{s}$=2.36 TeV)

2009 Run Summary

Recorded data samples	Number of events	Integrated luminosity (< 30% uncertainty)
Total	9.2×10^5	~ 20 μb^{-1}
Stable beam (Full ID on), good quality	3.8×10^5	~ 9 μb^{-1}
At $\sqrt{s}$=2.36 TeV (ID not fully on)	3.4×10^4	~ 1 μb^{-1}

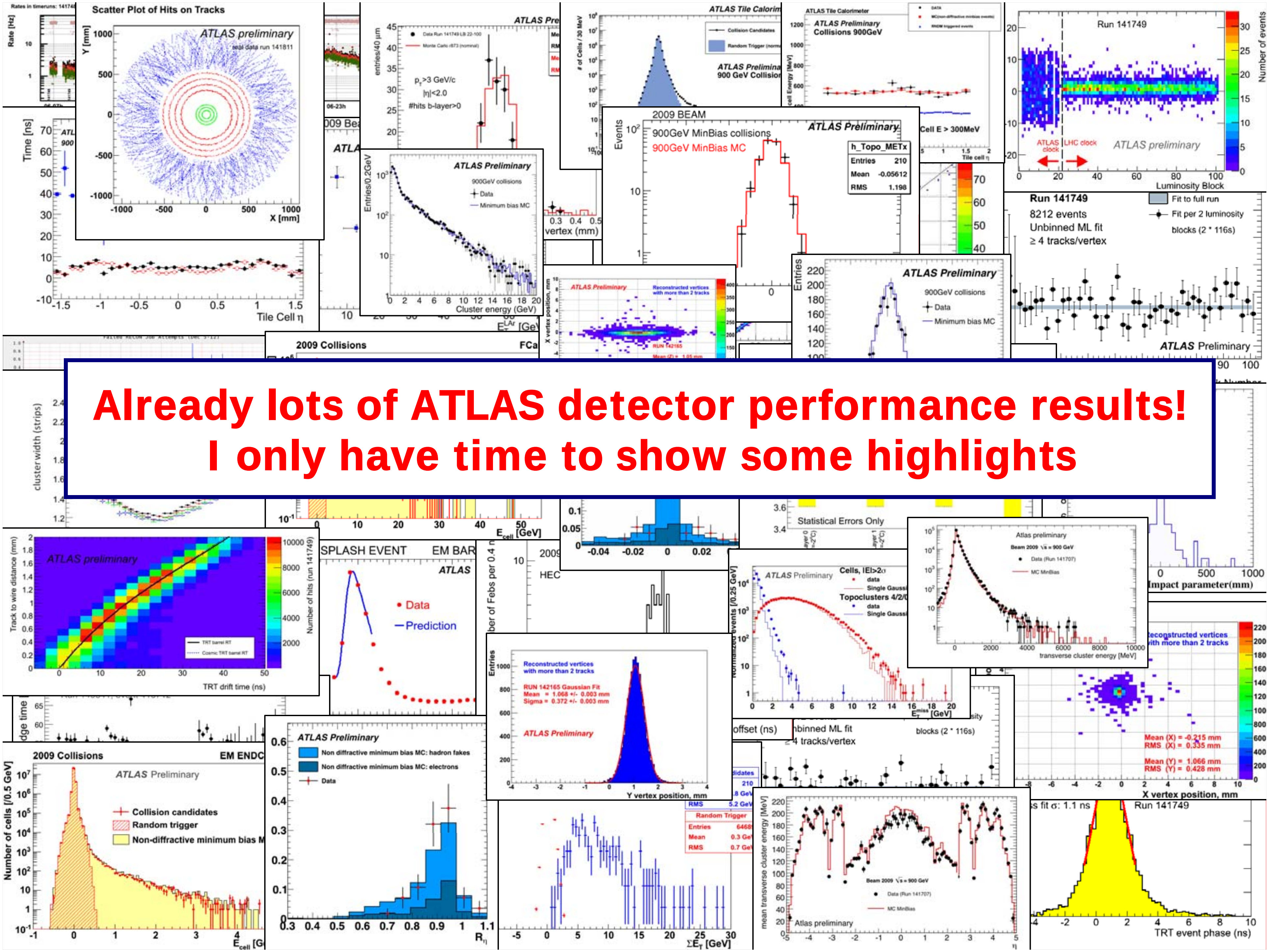


- Max peak luminosity seen by ATLAS: ~7 x $10^{26} cm^{-2} s^{-1}$
- Average ATLAS data-taking efficiency: ~90%
- Efficient offline computing
  - 99.98% prompt reconstruction efficiency
  - Data at analysis farm (Tier-2) ~4 hours after collection

ATLAS was fully operational

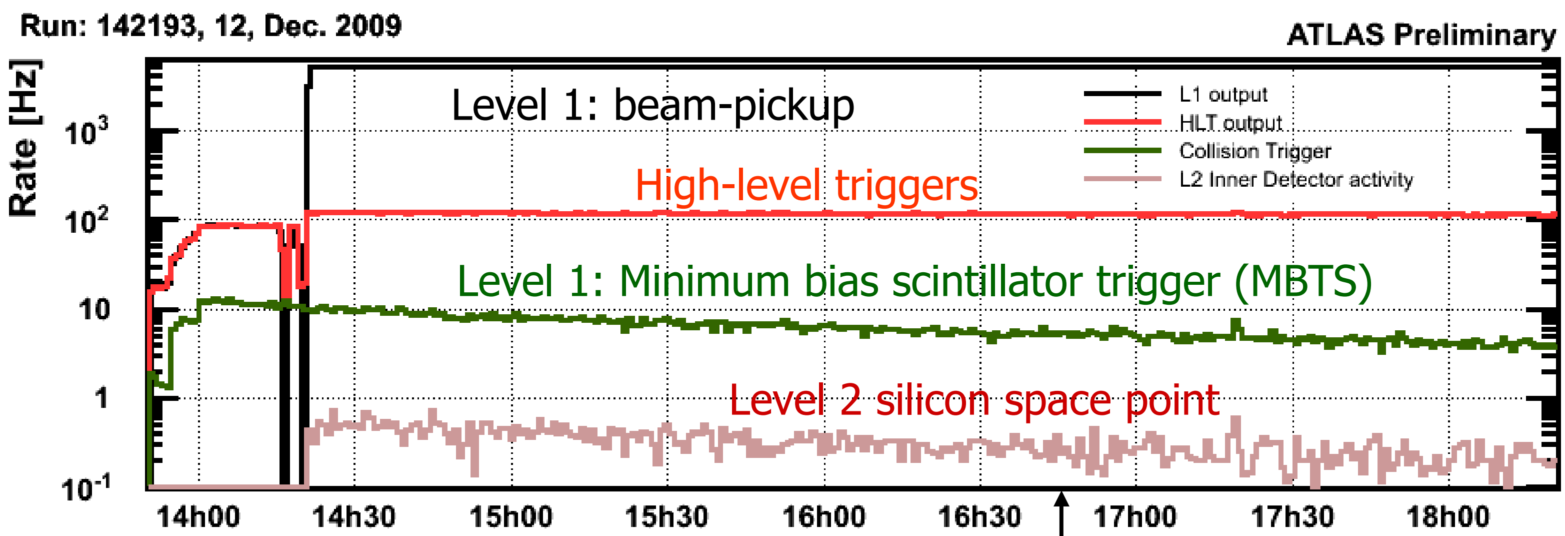
Status of December 2009

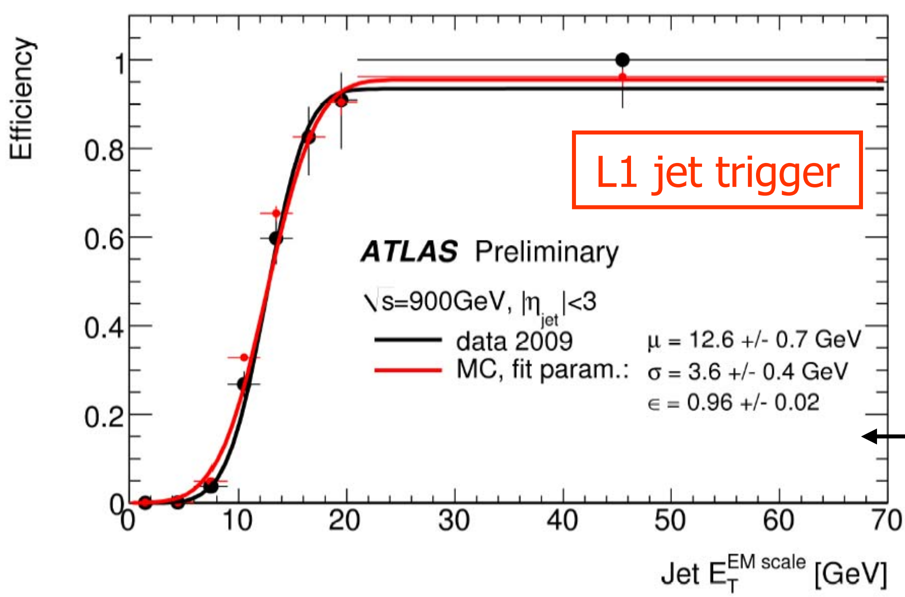
Subdetector	Number of Channels	Operational Fraction
Pixels	80 M	97.9%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.2%
LAr EM Calorimeter	170 k	98.8%
Tile calorimeter	9800	99.2%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.4%
RPC Barrel Muon Trigger	370 k	98.5%
TGC Endcap Muon Trigger	320 k	99.4%
LVL1 Calo trigger	7160	99.8%



Already lots of ATLAS detector performance results!
I only have time to show some highlights

Trigger Performance





2009 Run Trigger Configuration

Level 1: MBTS (scintillators) + beam pickup (Sampling=5%)

Level 2, selection mode: silicon space points to check MBTS

+ >200 high-level triggers in "pass-thru" mode

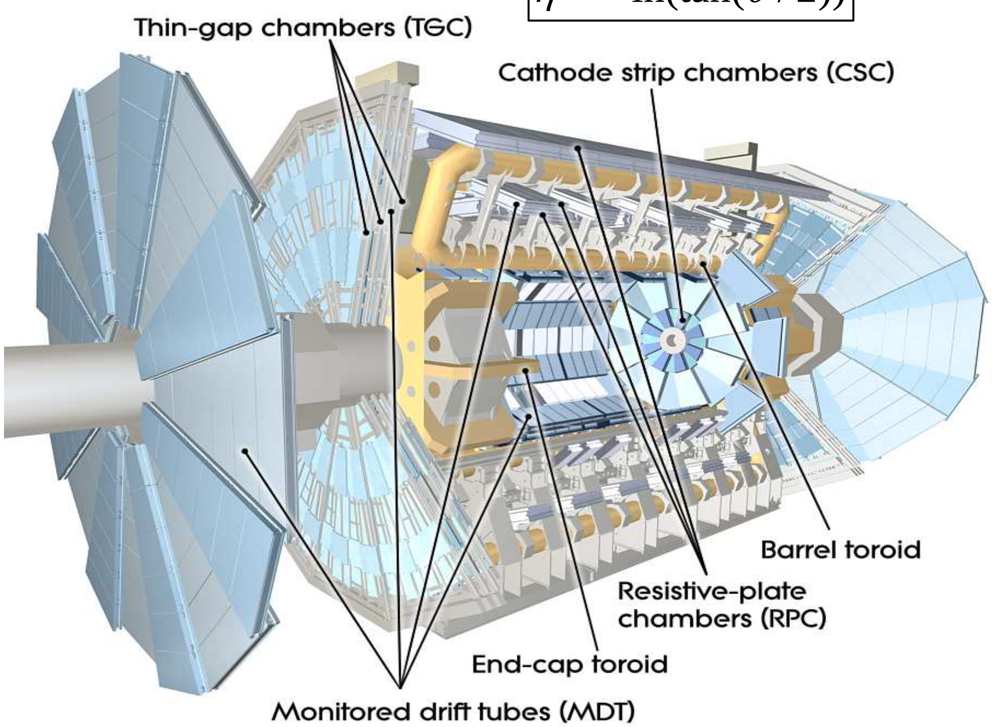
Measurement of trigger turn-on curves

Example: L1 jet trigger

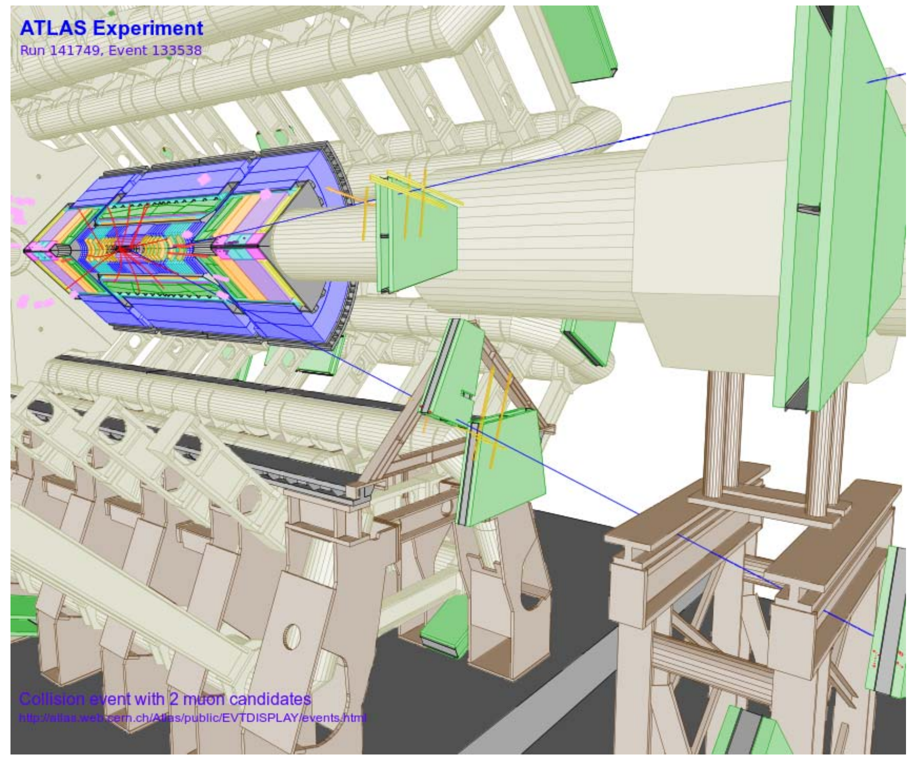
Muon Spectrometer

Muon trigger and momentum resolution < 10% up-to E_{μ}~TeV
Coverage: |η|<2.7

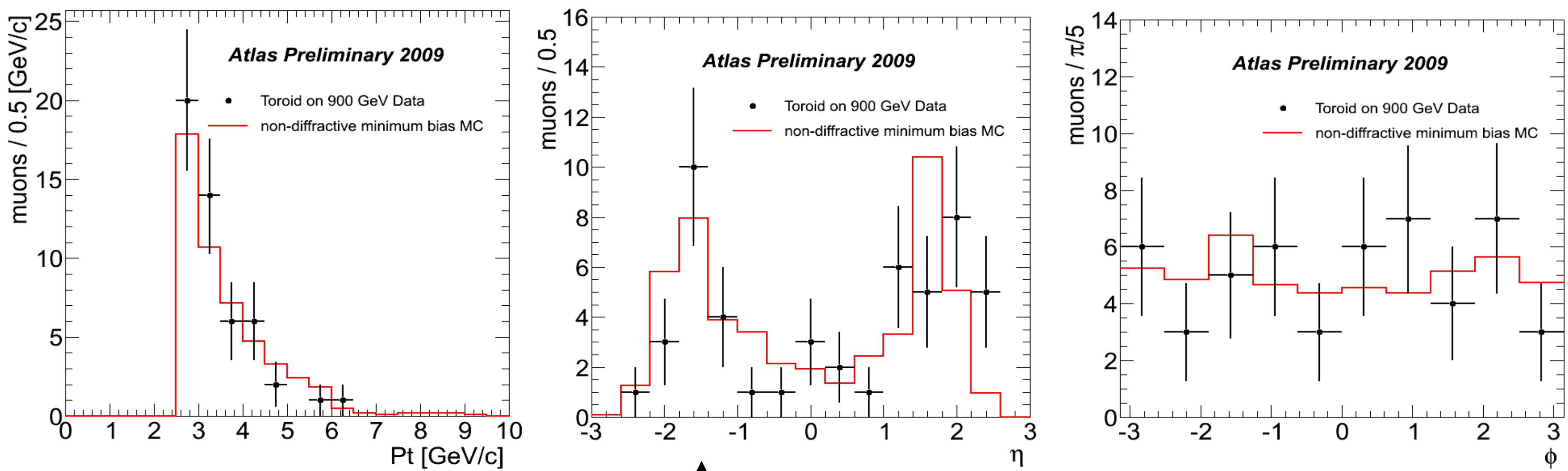
$$\eta = -\ln(\tan(\theta/2))$$



Collision di-muon candidate event



Muon Spectrometer Performance



<u>Collision muon candidates distributions:</u>

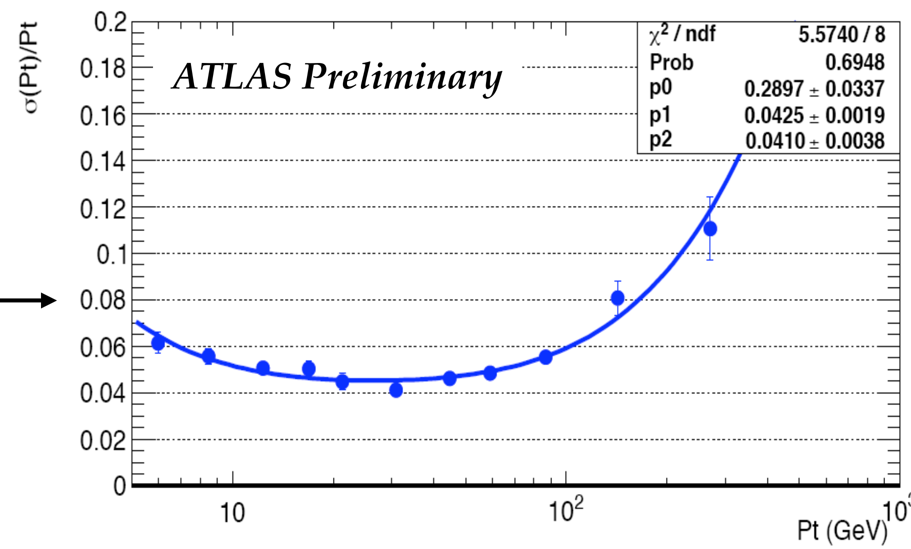
Good agreement within limited statistics (50 candidates)

<u>2008-09 Cosmic Ray Commissioning:</u>

~half-billion muon-triggered events!

<u>Example</u>: resolution better than 10% up-to a few hundred GeV

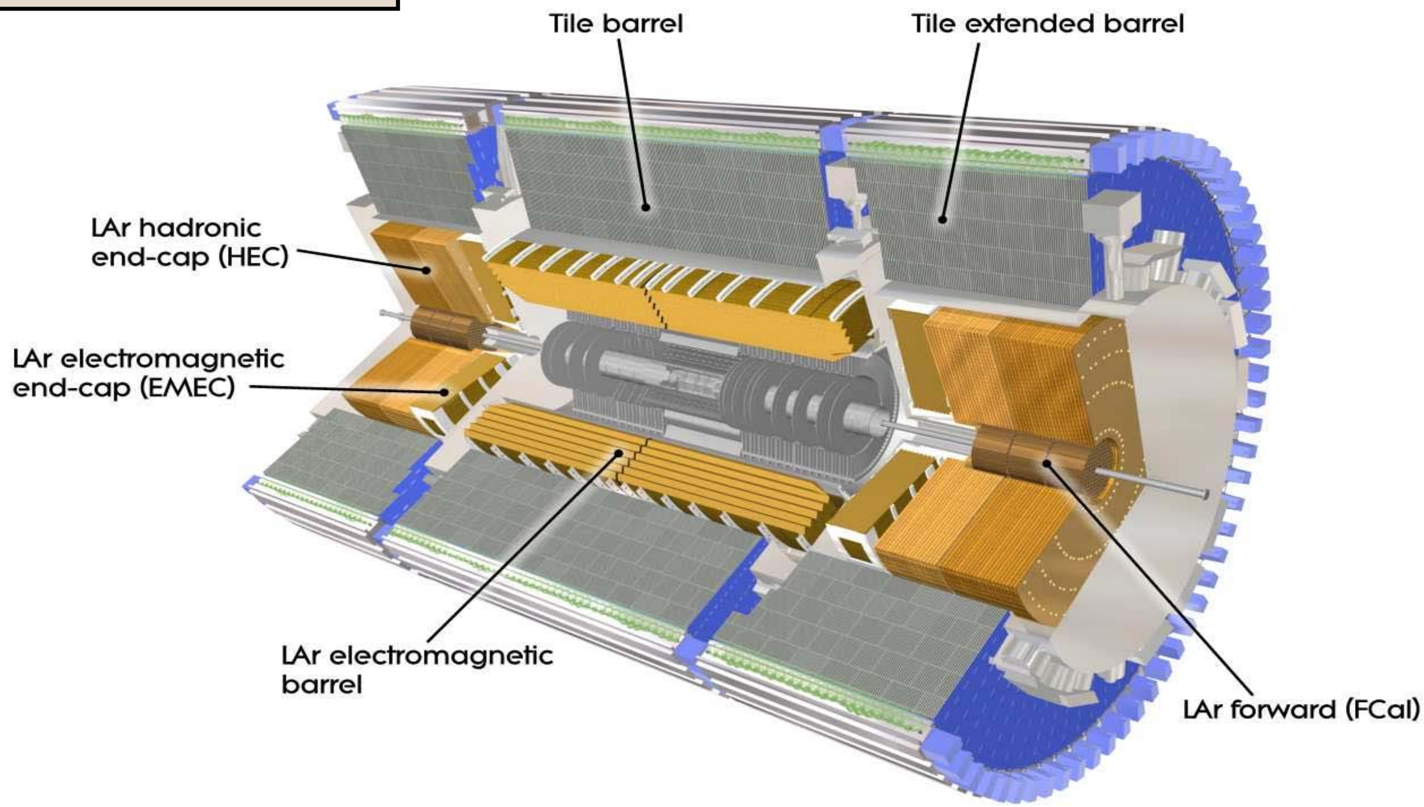
(Above that: resolution limited by asynchronous cosmic ray arrival time and mis-alignment)



Calorimeters

EM Calo: LAr/Pb
|η|<3.2
σ(E)/E (e/γ)~10%/√E⊕0.7%

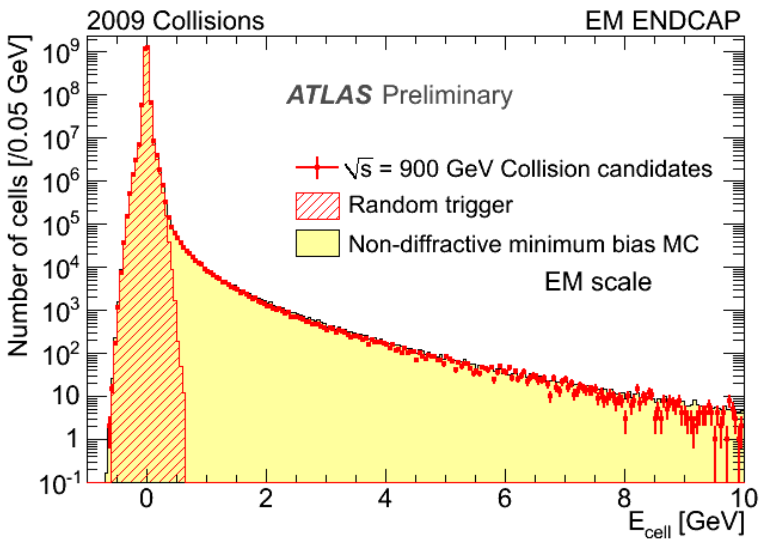
Hadronic barrel: Scin/Fe
|η|<1.7
σ(E)/E (jet)~50%/√E⊕3%

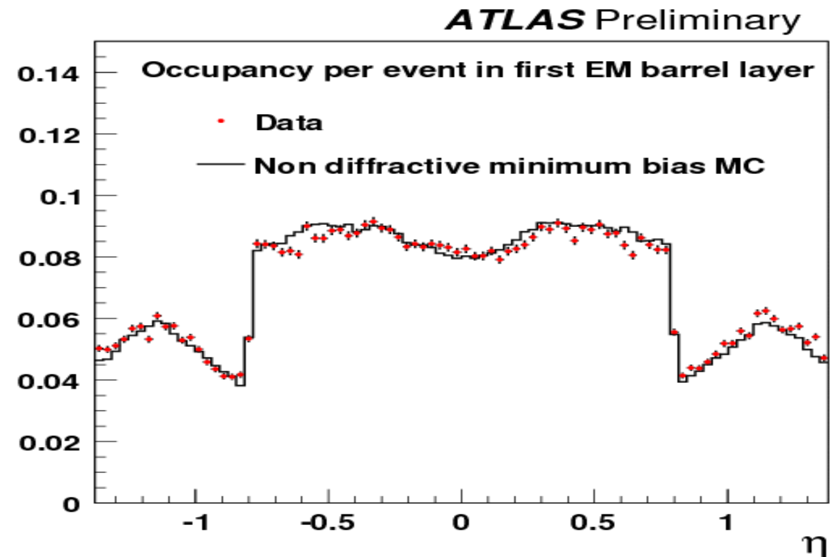


Hadronic endcap: LAr/Cu
1.5<|η|<3.2
σ(E)/E (jet)~50%/√E⊕3%

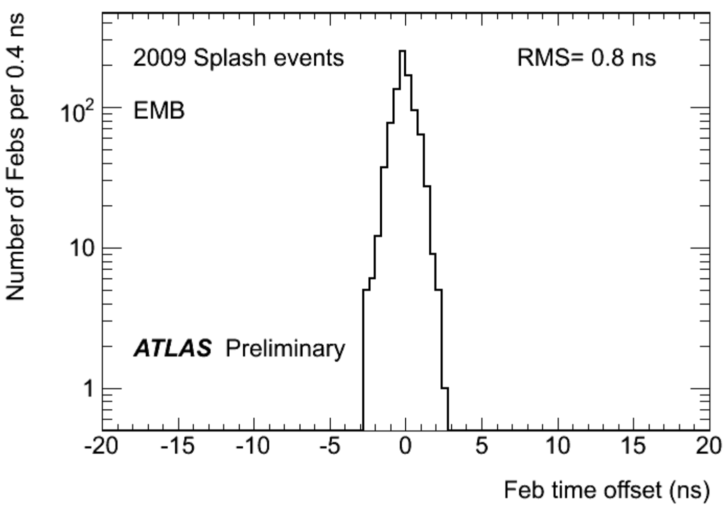
Hadronic Forward: LAr/Cu,W
3.1<|η|<4.9
σ(E)/E (jet)~100%/√E⊕10%

Calorimeter Performance





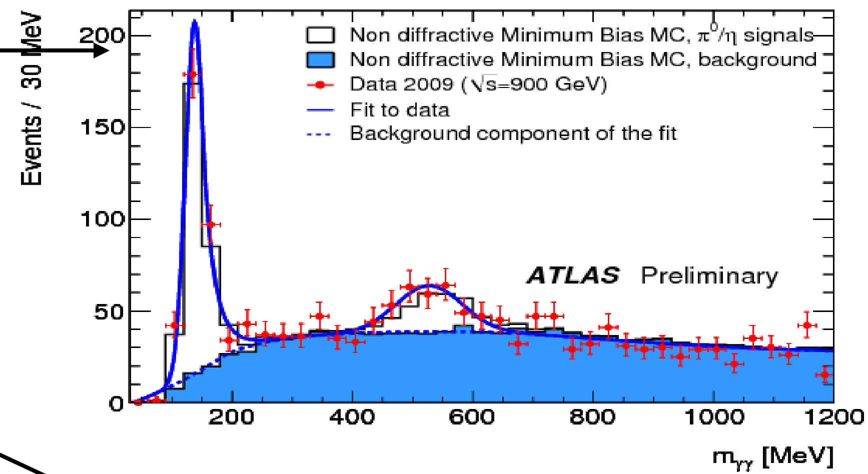
Good agreement data/MC of raw cell energy and detector occupancy



Relative timing adjusted to < 1ns
(important for E resolution)

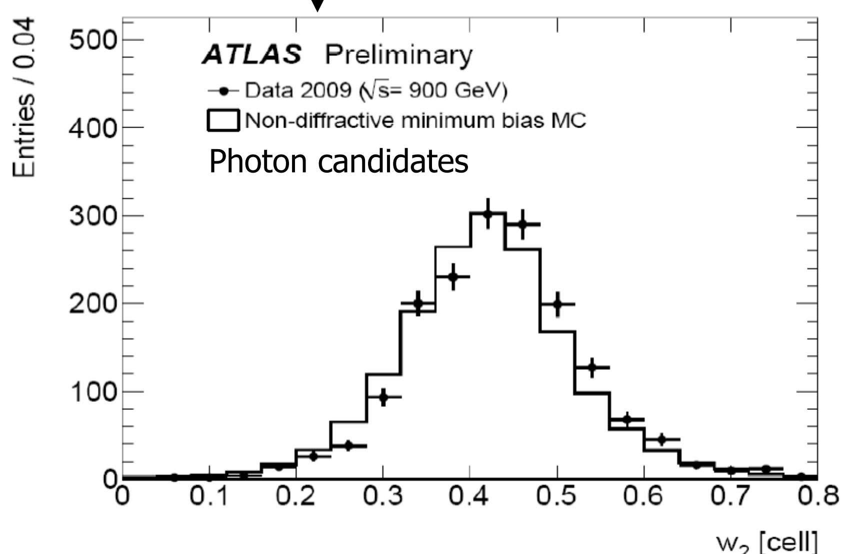
Electron/Photon Reconstruction

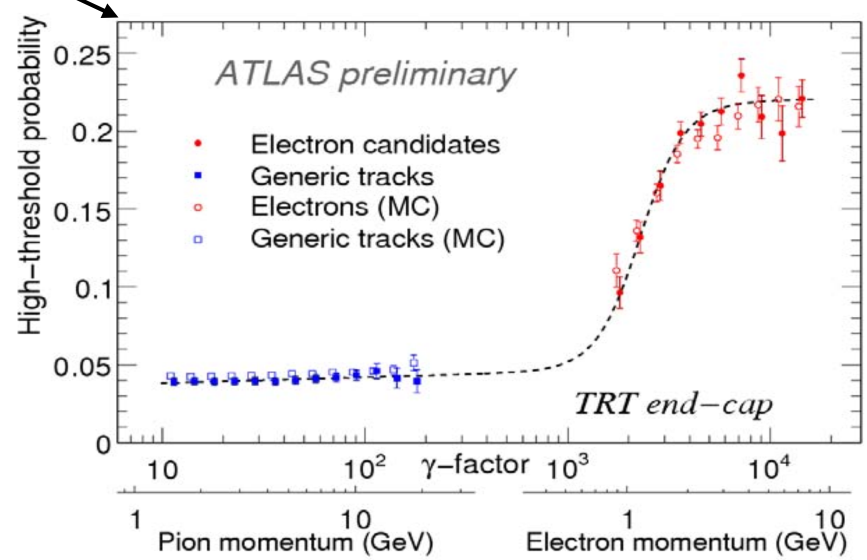
Diphoton mass distribution (π^0 and η)
Widths and positions well described by MC



Validation of e/γ ID variables:

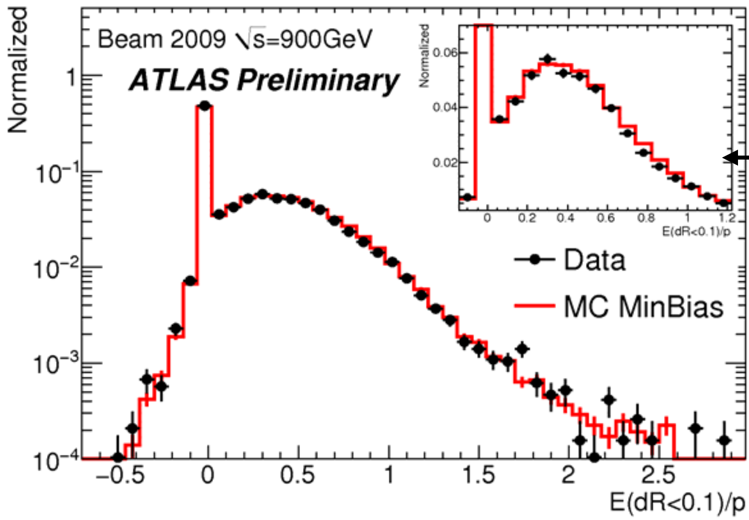
- Ex.: 1: cluster width at shower max
- Ex.: 2: Transition Radiation Tracker





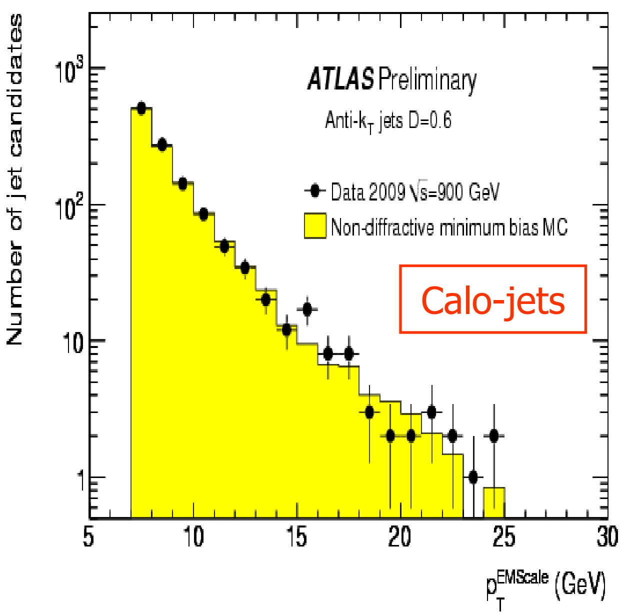
→ More on this topic in talks of H. Abreu (Tue PM) and F. Dudziak (Wed PM)

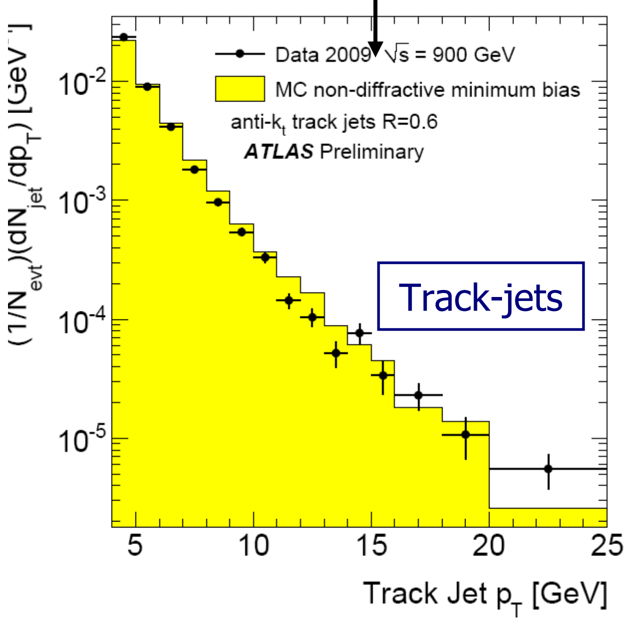
Jet Reconstruction

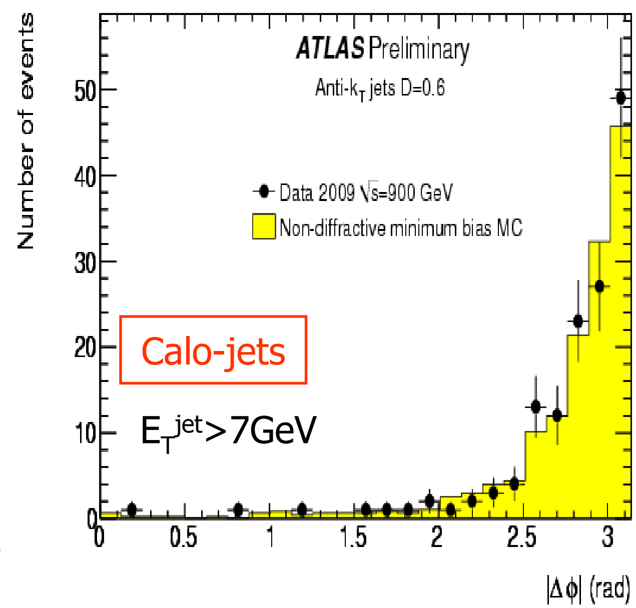


E/p(pions): excellent simulation of calo response
- Promising for jet energy calibration
- Years of test beams and tuning of simulation

Hadronic jet reconstruction: Good agreement
- p_T spectrum of calo- and track-jets (different syst.)
- $\Delta\phi$ distribution (sensitive to soft QCD radiation)

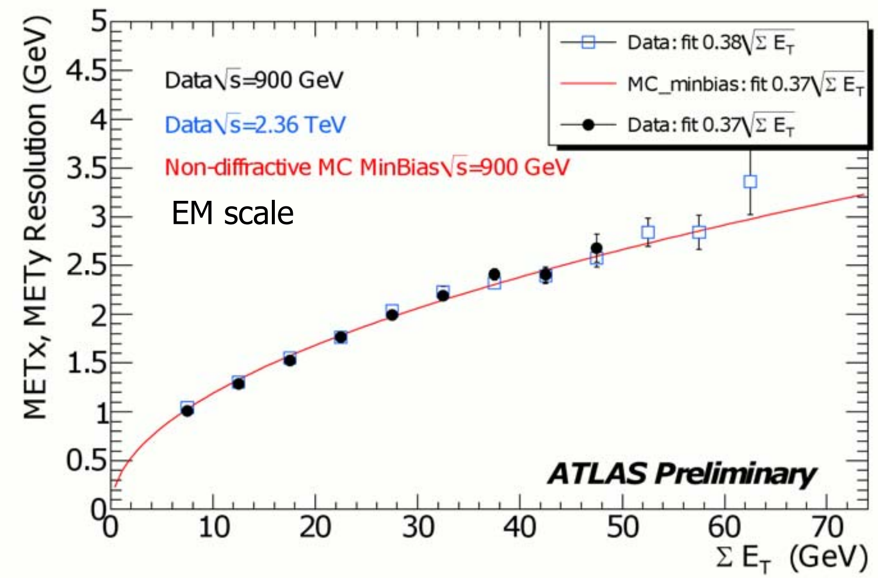


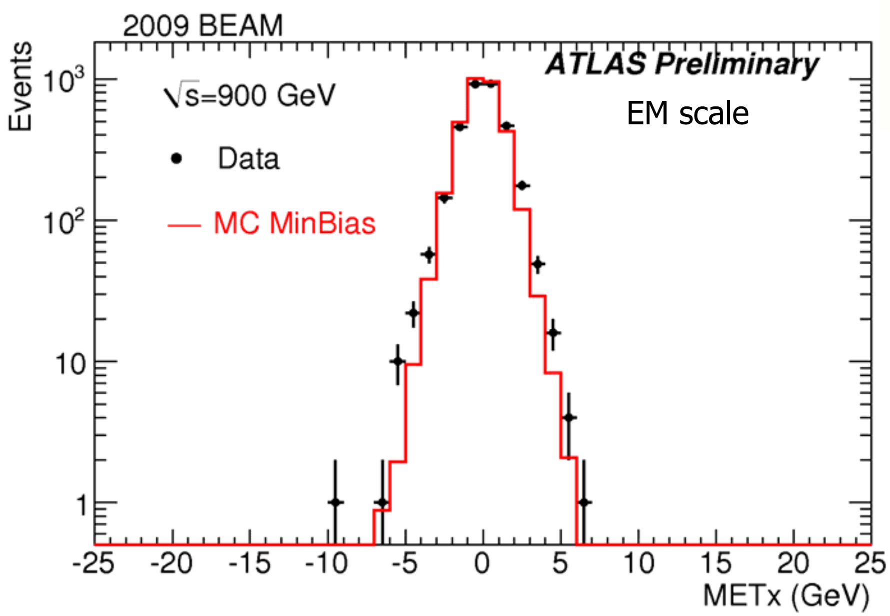




Missing E_T Performance

Missing E_T gaussian resolution:
Excellent agreement up-to available total deposited E_T~60 GeV

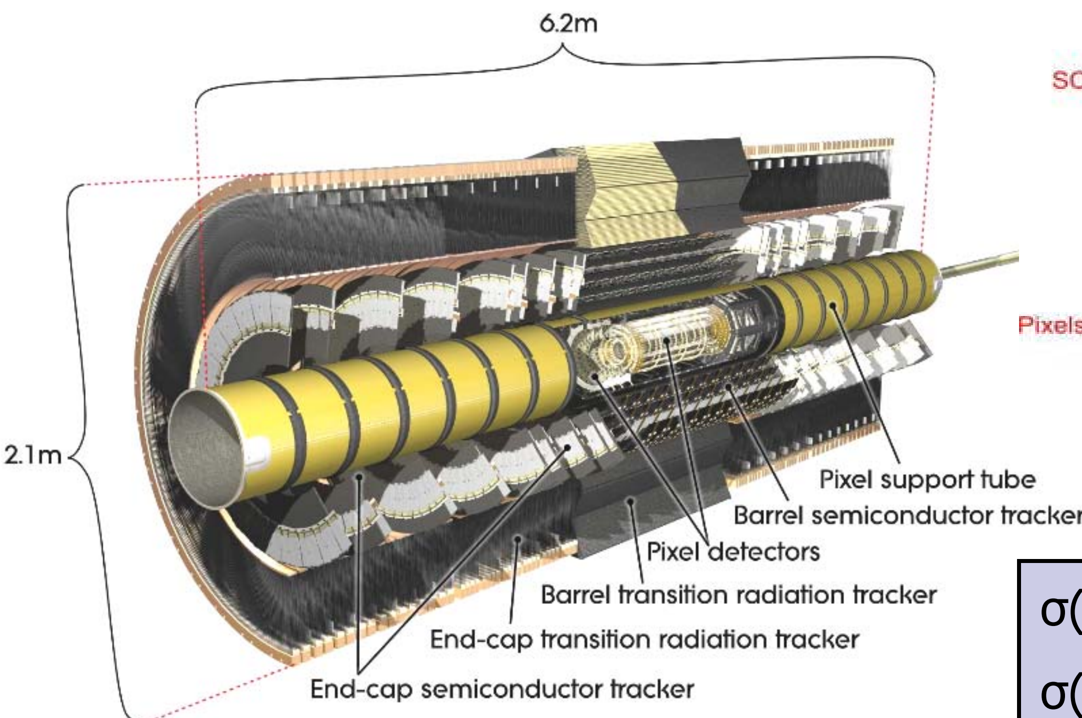


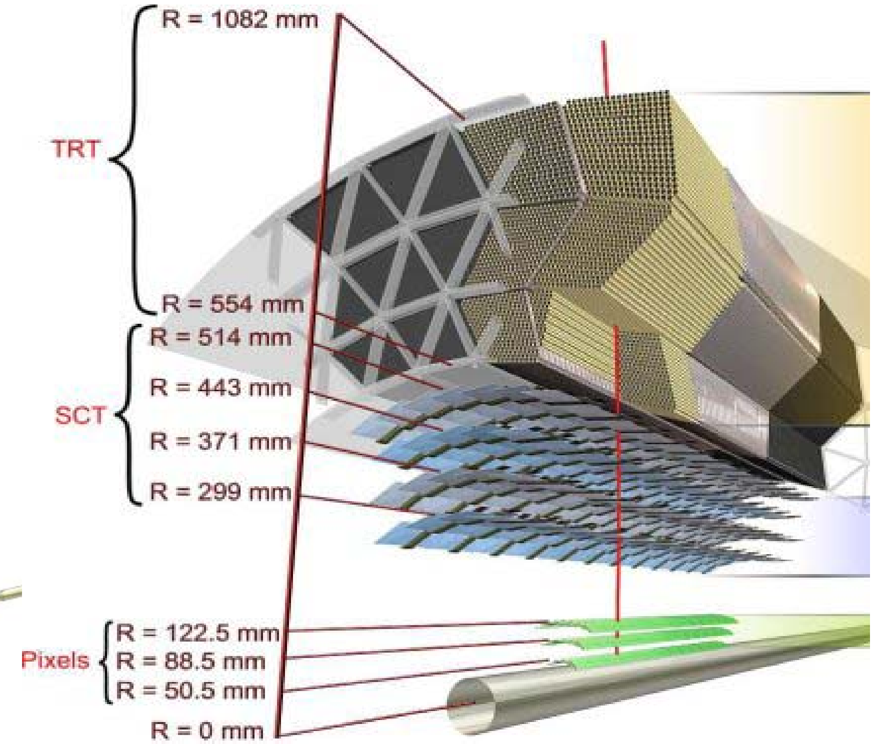


Missing E_T component:
Good description, no large tails

Inner Detector

Purpose: charged-particle tracking, particle ID
Coverage: $|\eta|<2.5$
Embedded in 2T solenoidal field

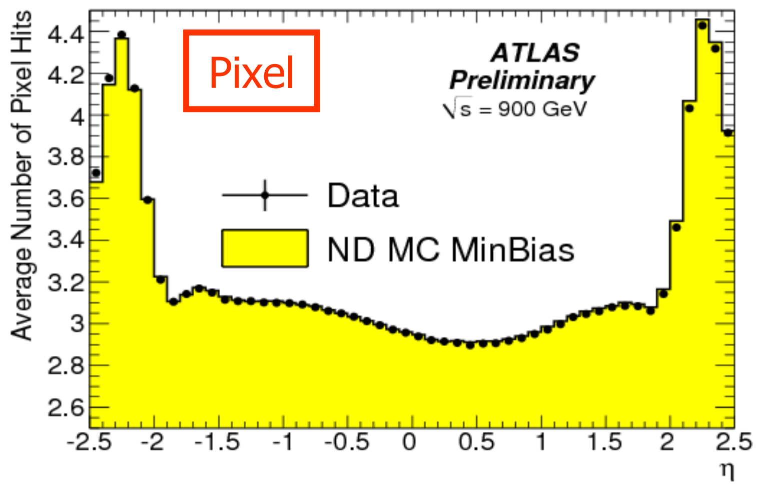


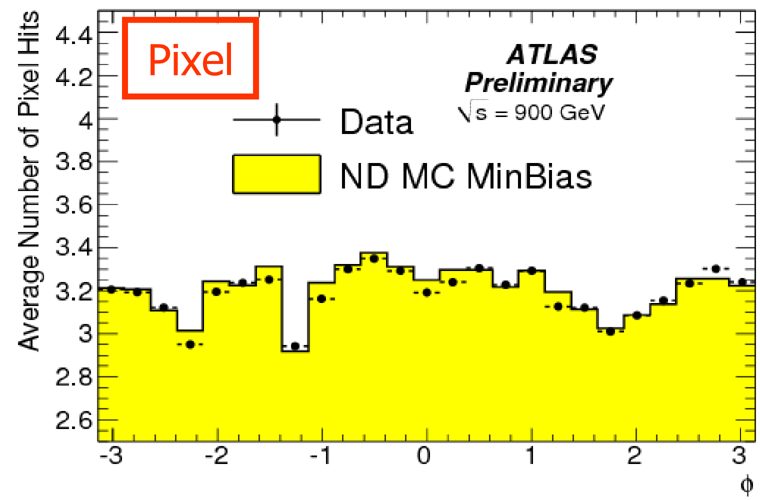


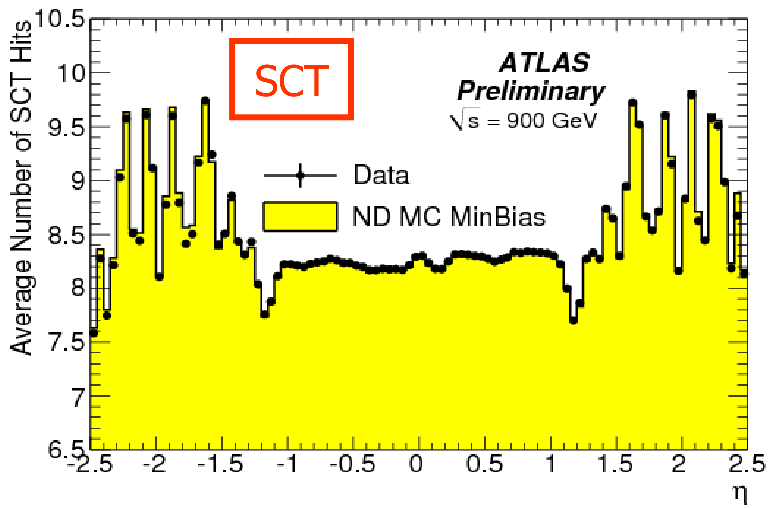
$\sigma(p_T)/p_T \sim 3.4\times10^{-4}\times(p_T/\mathrm{GeV}) \oplus 0.015$

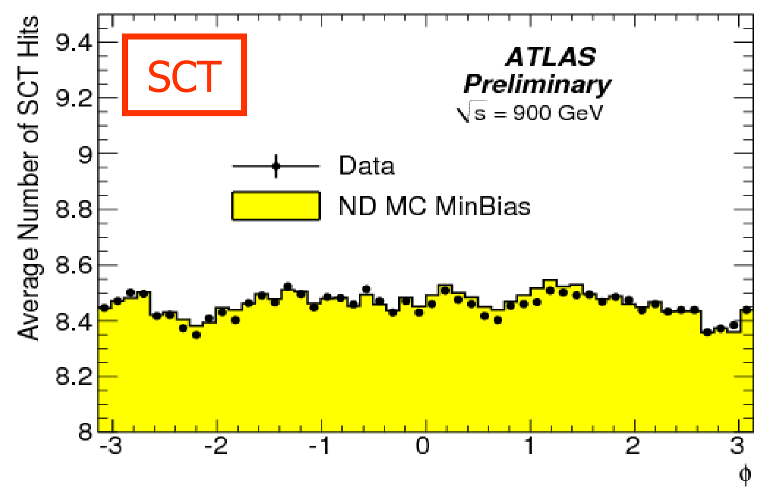
$\sigma(d_0) \sim 10 \oplus 140/(p_T/\mathrm{GeV})\ \mu\mathrm{m}$

Number of Hits on Tracks



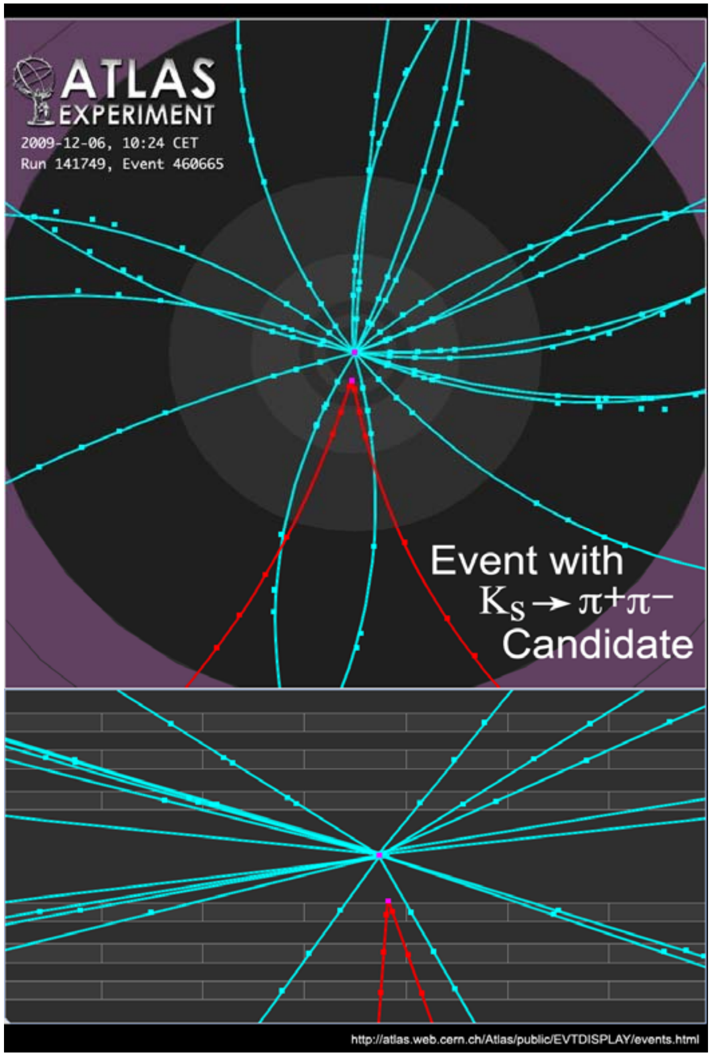


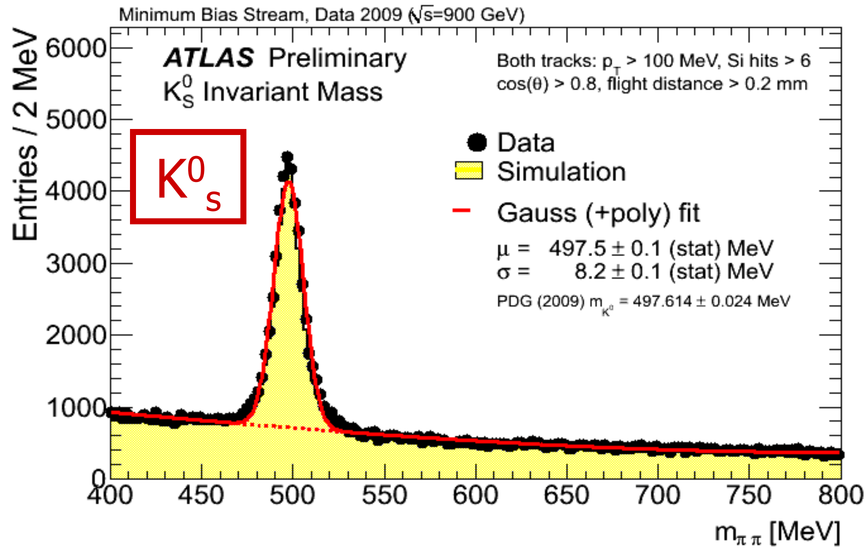


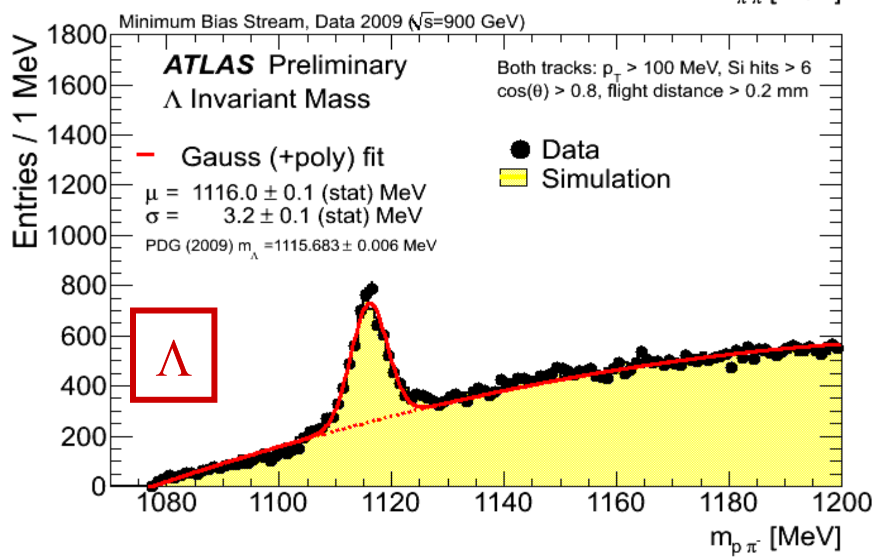


Sensitive to MC description of geometry, material, beamspot, dead modules → **excellent agreement**

Inner Detector Performance: K_S^0 and Λ

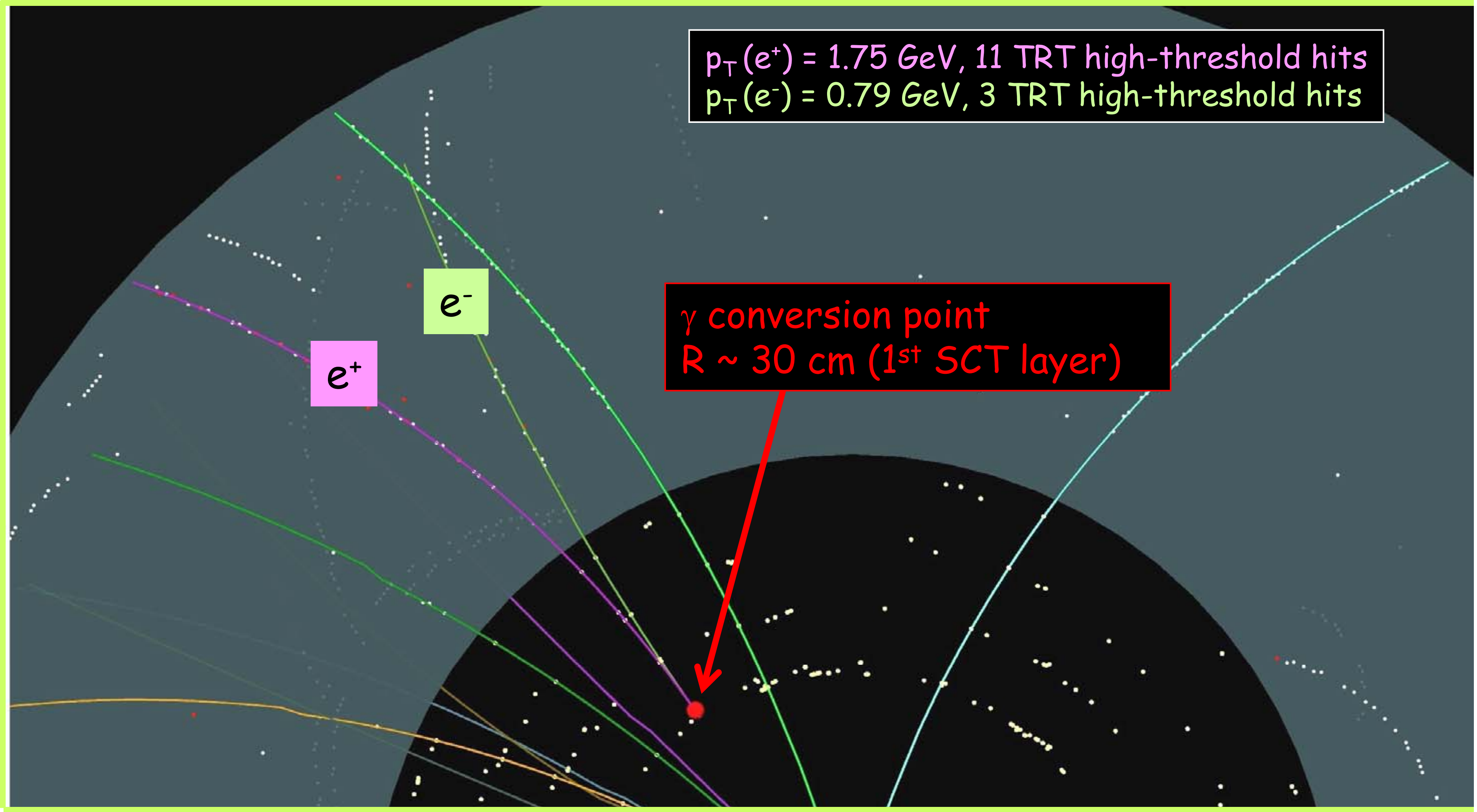




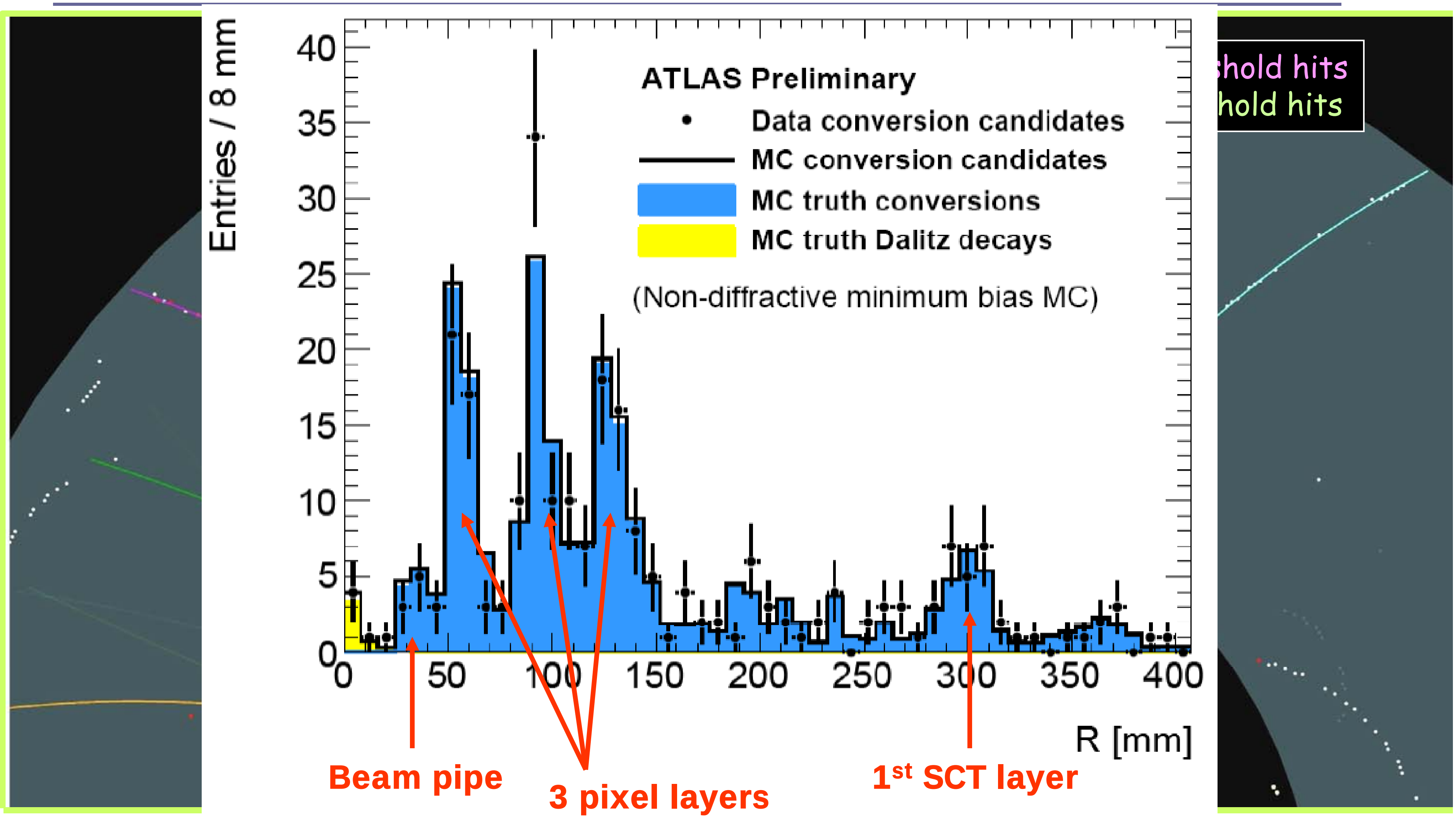


Test of vertexing, momentum scale and resolution → excellent agreement

Conversion Reconstruction

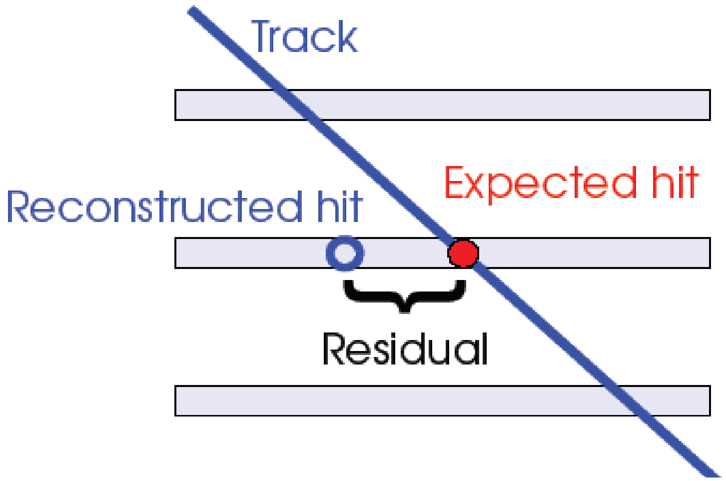


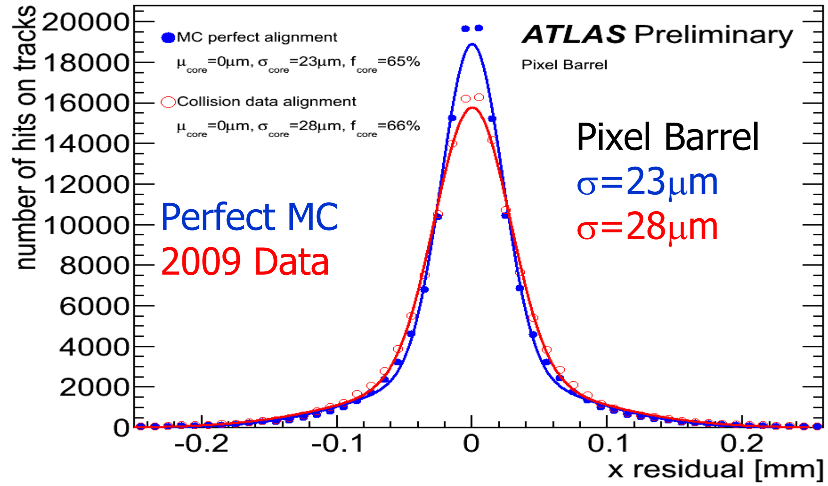
Conversion Reconstruction

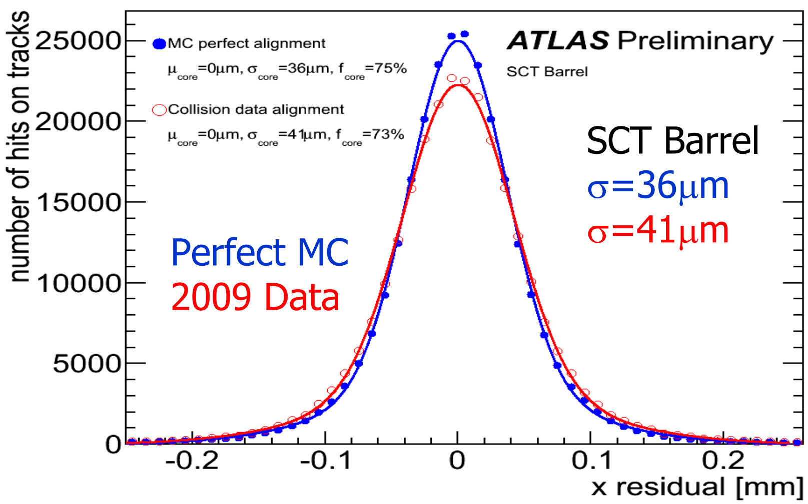


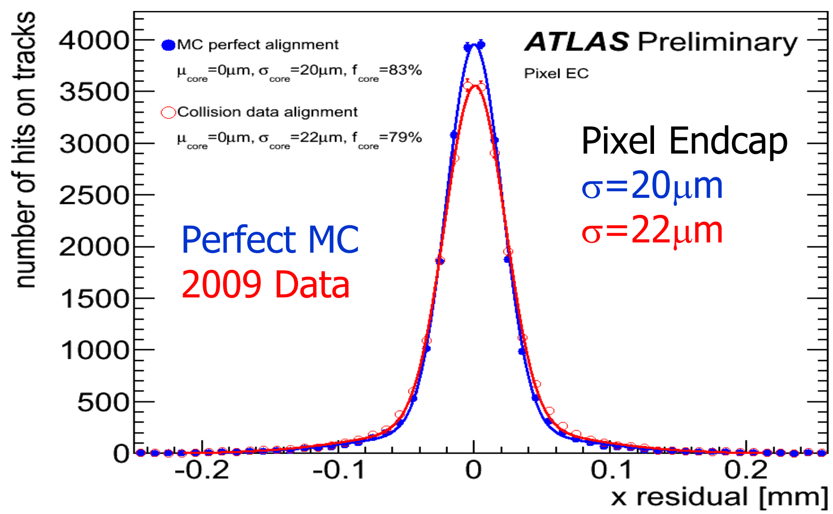
Validation of MC material description → crucial for tracking efficiency

Inner Detector Alignment: Track Residual



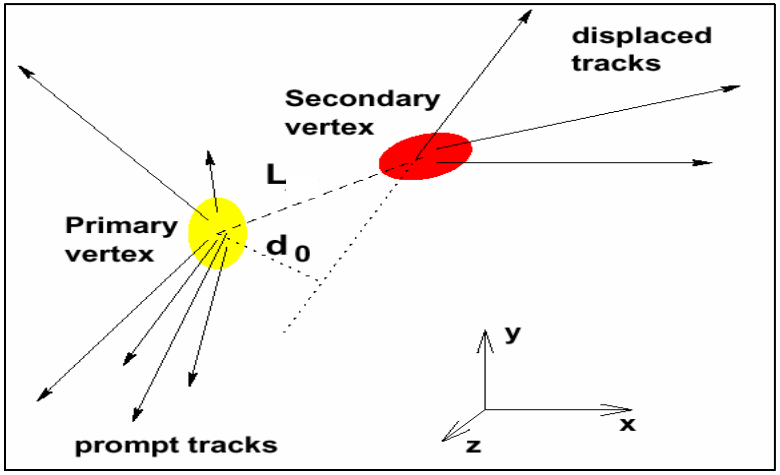






Detector resolutions already close to ideal simulation

Secondary Vertex: Toward B-Jets Tagging



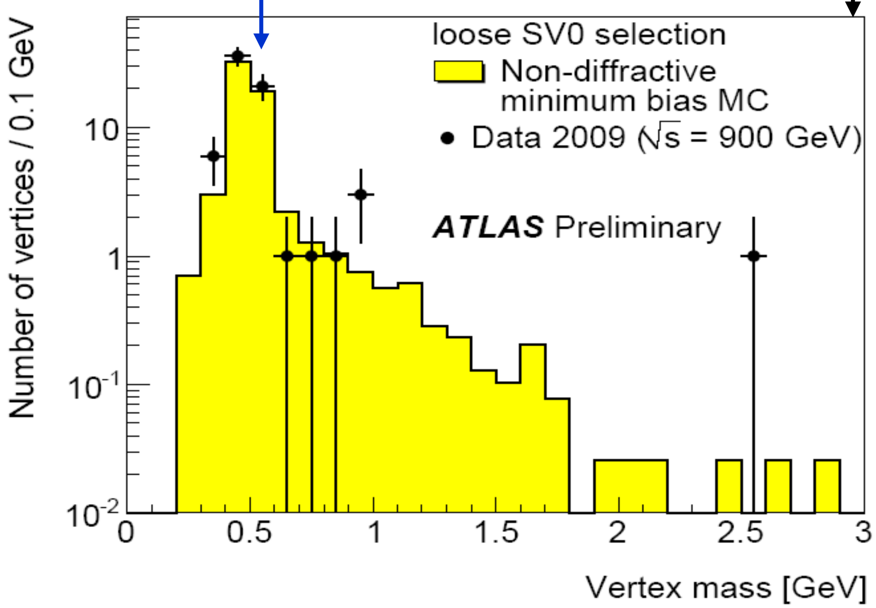
Secondary vertex tagger performance

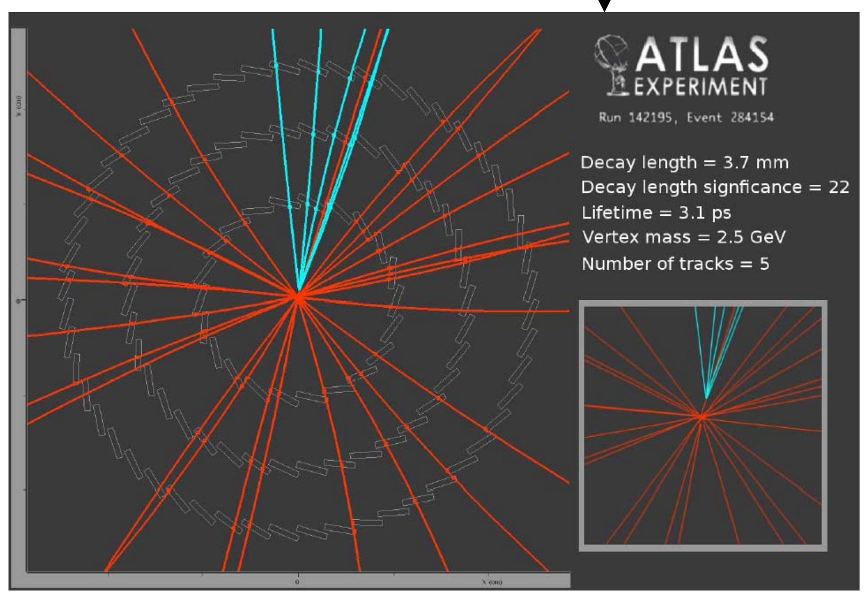
Few heavy-flavor jets expected in 2009 dataset →Relax cuts to exercise algo. (no veto on K_s^0, Λ^0, material interactions) **Excellent agreement of e.g. tagging efficiency and vertex mass**

High-mass candidate!

5 tracks vertex, mass=2.5 GeV, Lifetime=3.1 ps

Note: MC normalized to number of untagged jets!



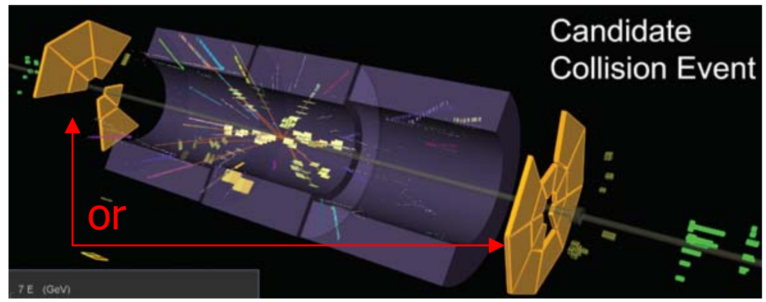


First Physics Result: Charged-Particle Multiplicity

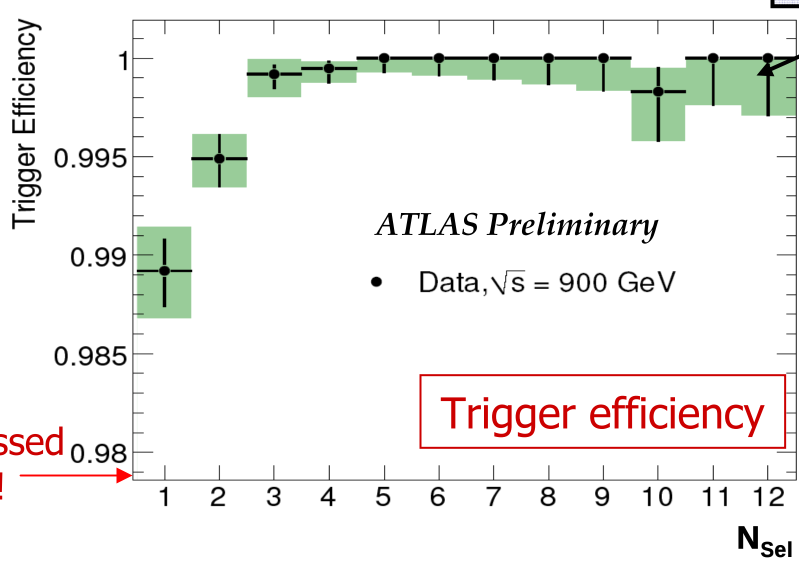
Motivation: constrains soft QCD models (underlying event "tunes")
→ **important for high-p_T physics measurements!**
What we measure: inclusive inelastic distributions of charged-particles with p_T>0.5 GeV, $|\eta|$<2.5
Note: we do not attempt to extrapolate outside our phase space (avoid model dependence)

Event selection:
- One-arm MBTS trigger
- Reconstructed primary vertex
- ≥ 1 track with p_T>0.5 GeV, $|\eta|$<2.5
  - $|d_0|$<1.5mm, $|z_0|\sin\theta$<1.5mm

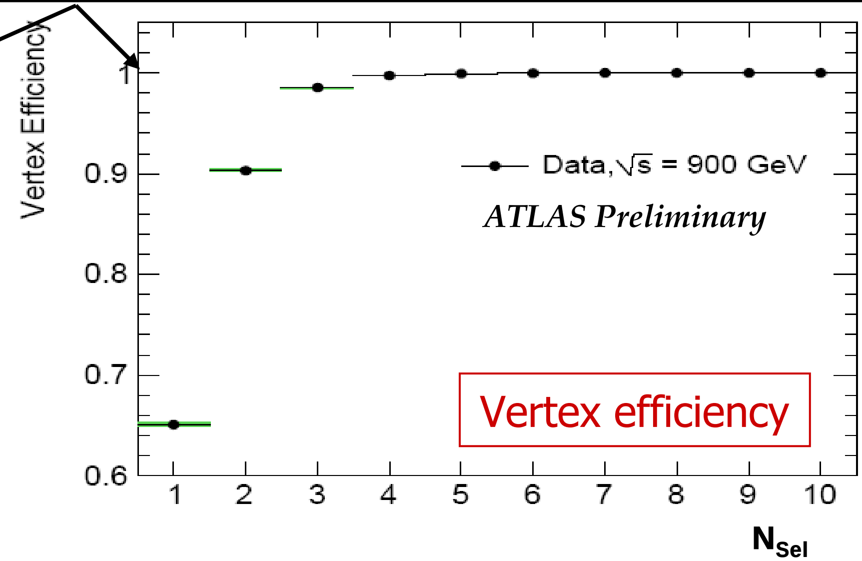
→ Sample of ≈326k events



Extract **corrections** for detector inefficiencies

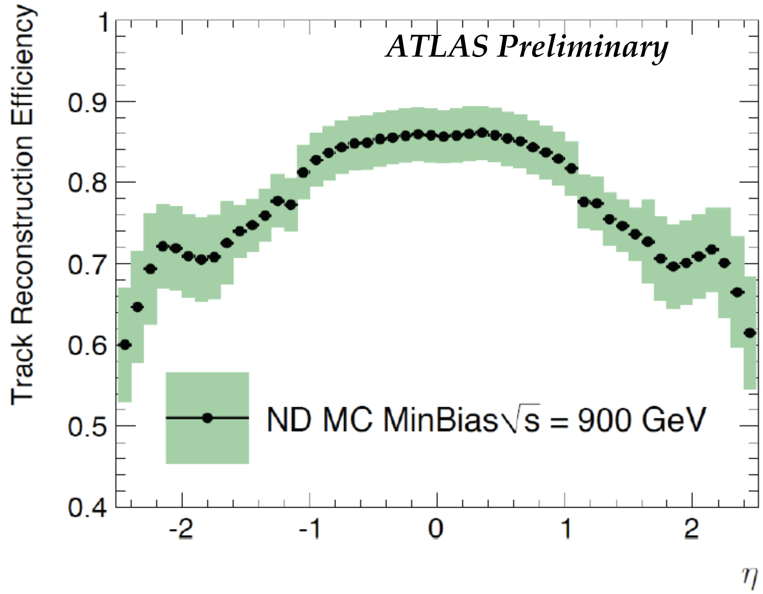


Note: suppressed y-scale!

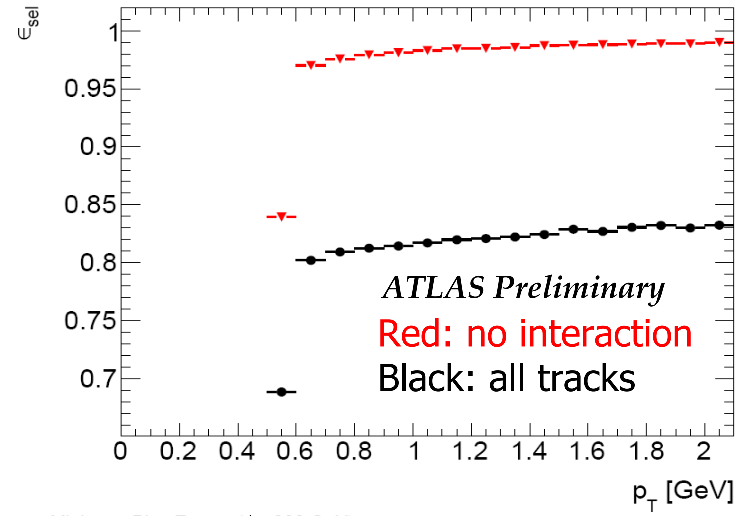


From Track to Particles: Tracking Efficiency

Efficiency taken from MC → **need validation**

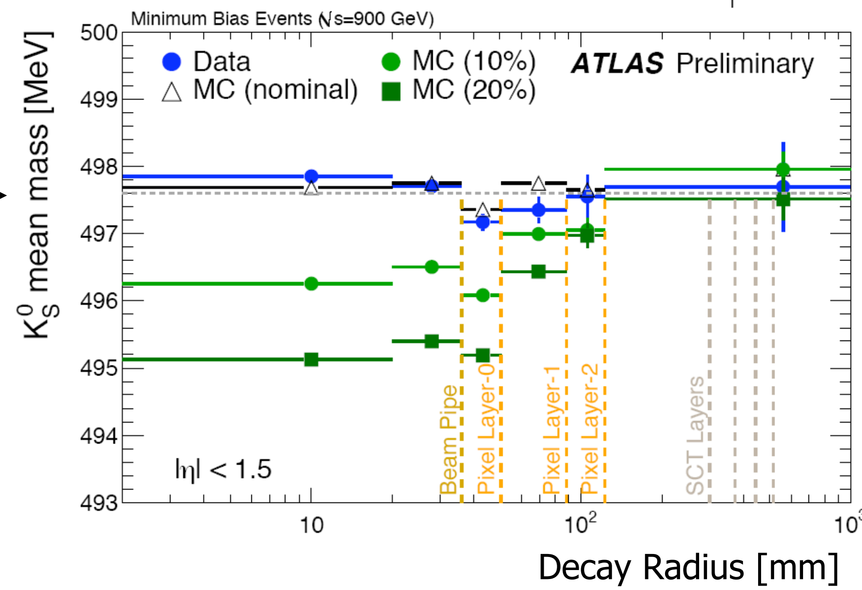


Dominant effect: **material interactions**



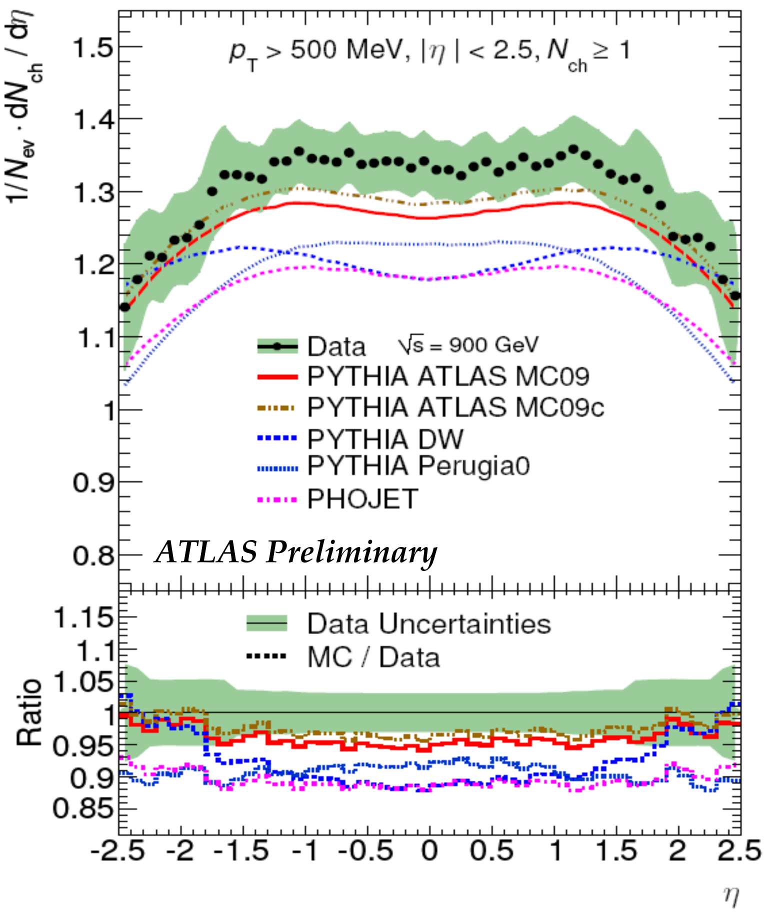
Many studies to validate material in MC:
- Example: K^0_S mass vs radius →
- Conclusion: Data inconsistent with extra-material MC

→ 4.0% uncertainty on tracking efficiency

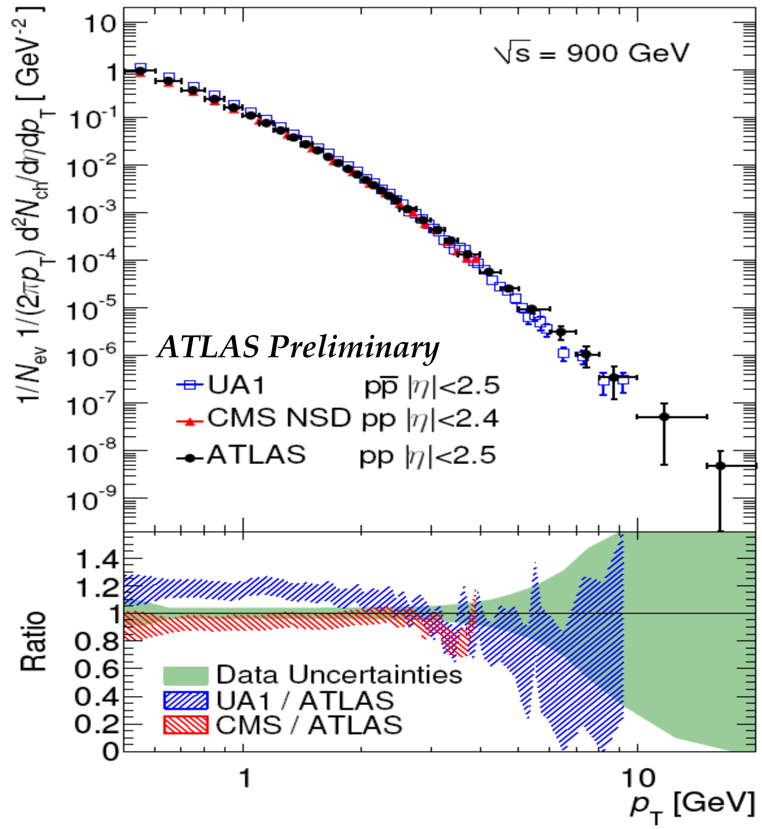


Charged-Particle Multiplicity: Results

dN/dη for various MC models:
Good shape agreement, ATLAS data tend to be higher (*Note: models tuned in different region of phase space)*



dN/dp$_T$ experiment comparison:



ATLAS preliminary <Nch> (p_T>0.5 GeV) :

|η|<2.5:	1.333 ± 0.040
|η|<2.4, NSD:	1.241 ± 0.040

CMS (NSD, |η|<2.4, p_T>0.5 GeV): 1.202 ± 0.043

Prospects for Physics at $\sqrt{s}=7$ TeV (1 fb^{-1})

Expected Number of Standard Model Events (After Selections)

Process	Number Events
$W^{\pm} \rightarrow l^{\pm}\nu$	4M
$Z^0 \rightarrow l^+l^-$	400k
ttbar l+jets	6000
ttbar dilepton	2500

Samples comparable or larger than Tevatron!

- Commissioning of the detector
- Tests of the Standard Model

Significant discovery potential

- Ex. 1: Supersymmetry → 5σ discovery above current Tevatron limit with a few hundred of pb^{-1}
- Ex. 2: Can discover up-to ~1.5 TeV $Z' \rightarrow \mu\mu$
- Ex. 3: 3σ evidence for SM Higgs in mass range ~145-180 GeV

YSF

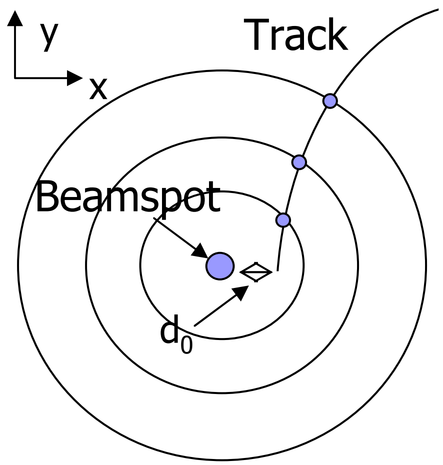
→ More on SUSY potential in early data in talks of J. Dietrich (Wed PM)

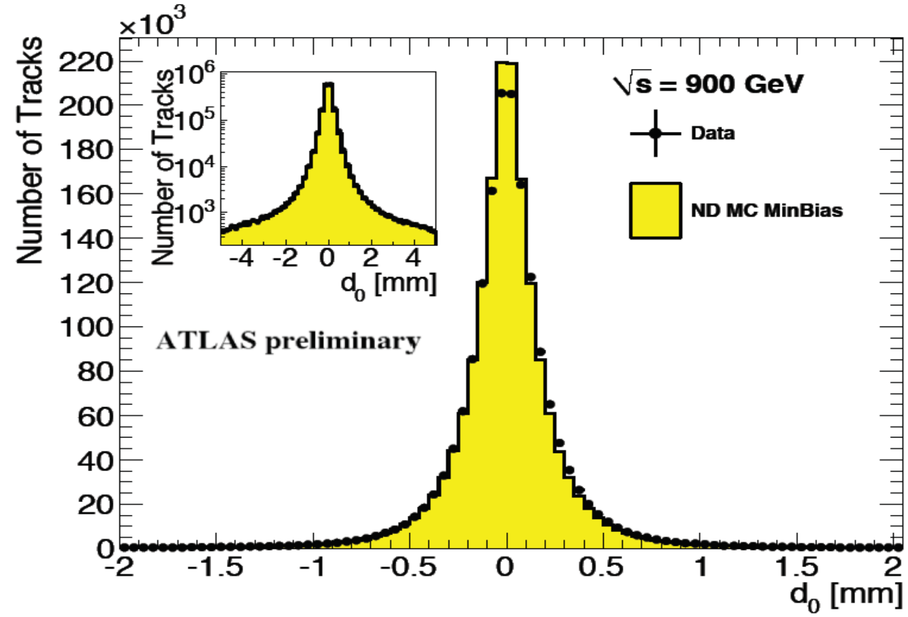
Summary

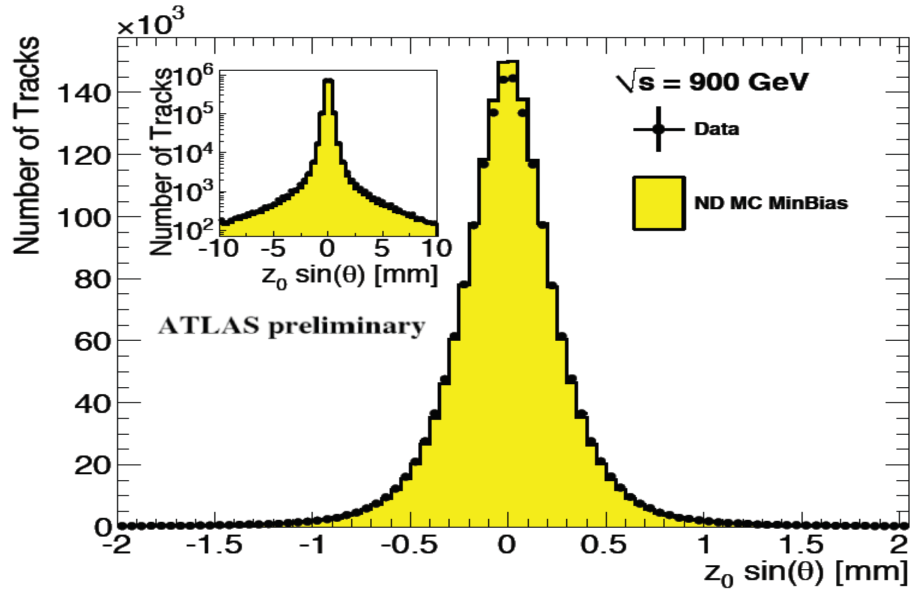
- After 20 years of preparation, **ATLAS collected successfully the first LHC data**
  - ~1 million collected events
- **Remarkable detector and simulation performance** at this early stage
- **First ATLAS Physics results:** charged-particle multiplicity at √s=900 GeV
- **Extensive Physics program** for first extended LHC run at √s=7 TeV

Additional Material

Impact Parameter Distributions



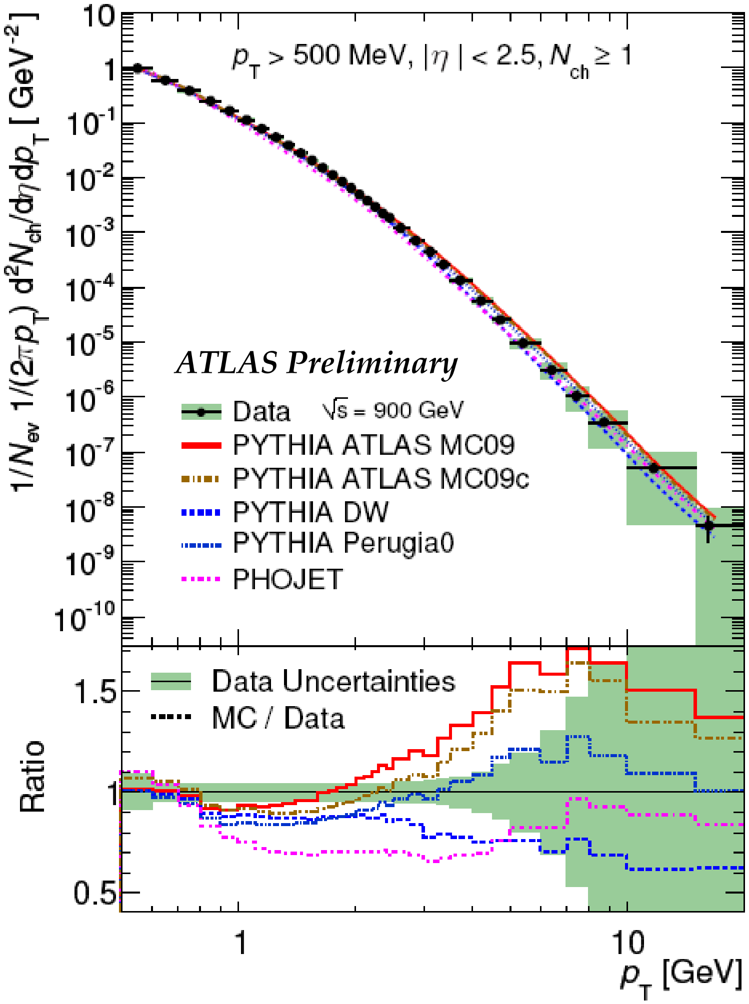




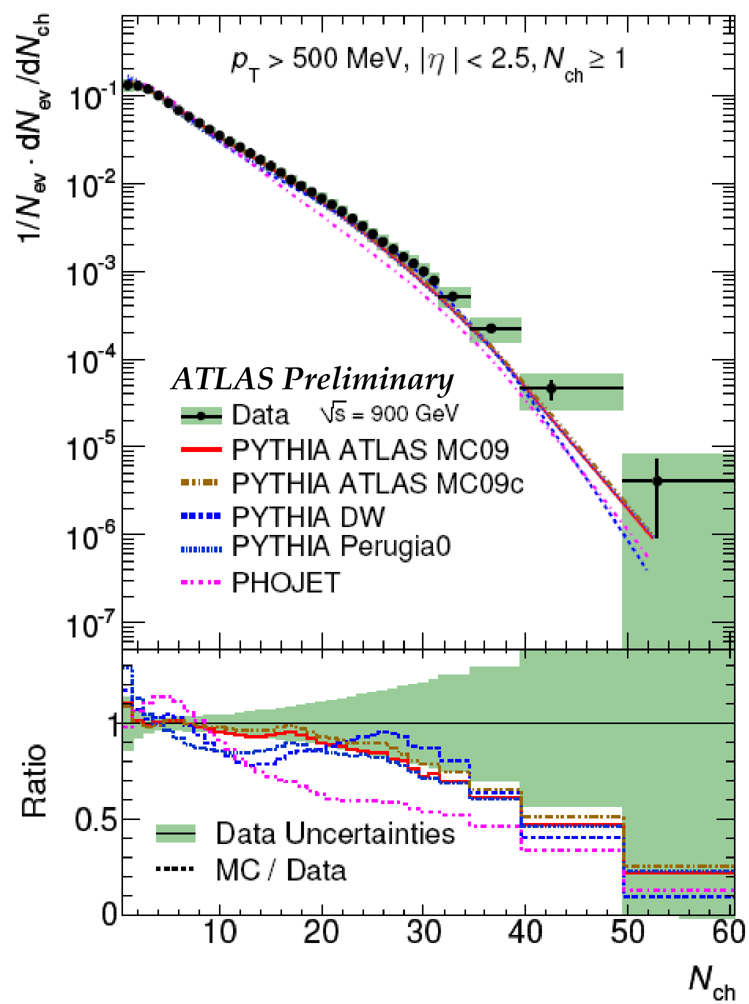
Impact parameter distributions:
Good description of the data by the simulation

More Charged-Particle Mult. Results

dN/dp_T

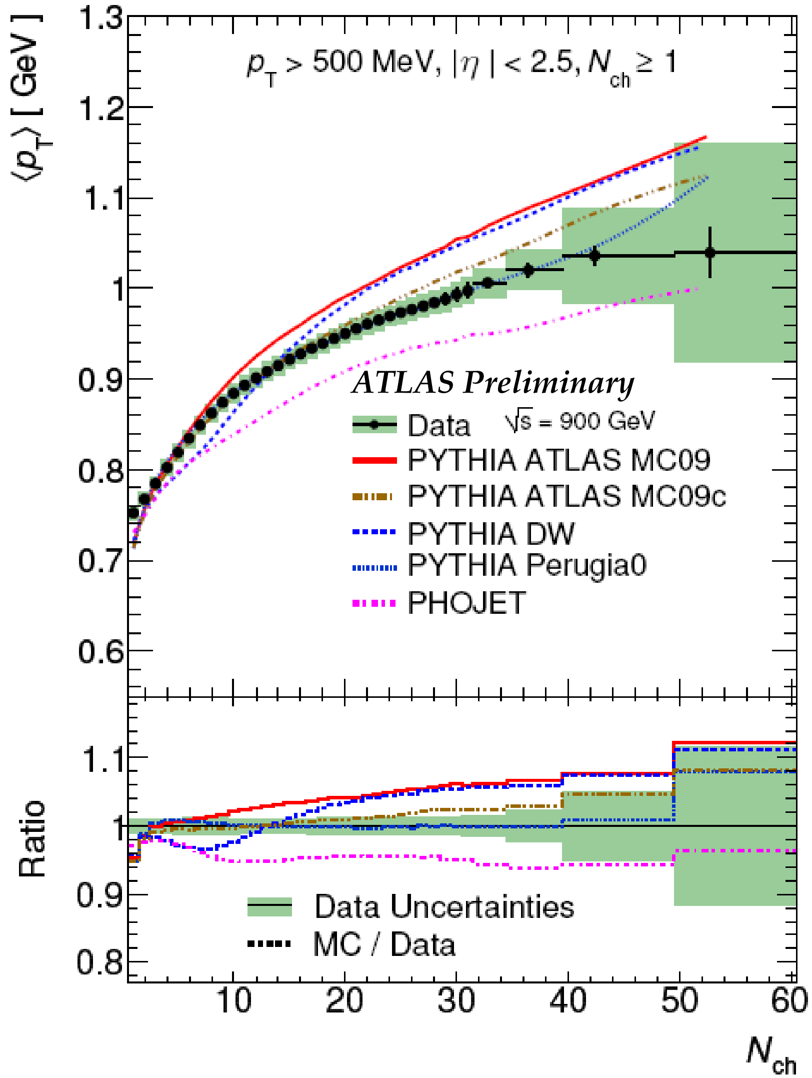


dN/dN_{ch}



More Charged-Particle Mult. Results

$\langle p_T \rangle$ vs N_{ch}



Charged-Multiplicity: Systematics

ATLAS Preliminary

Systematic uncertainty on the number of events, N_{ev}	
Trigger efficiency	$< 0.1\%$
Vertex-reconstruction efficiency	$< 0.1\%$
Track-reconstruction efficiency	1.1%
Different MC tunes	0.4%
Total uncertainty on N_{ev}	1.2%

Systematic uncertainty on $(1/N_{ev})\cdot(dN_{ch}/d\eta)$ at $\eta = 0$	
Track-reconstruction efficiency	4.0%
Trigger and vertex efficiency	$< 0.1\%$
Secondary fraction	0.1%
Total uncertainty on N_{ev}	-1.2%
Total uncertainty on $(1/N_{ev})\cdot(dN_{ch}/d\eta)$ at $\eta = 0$	2.8%

Charged-Multiplicity: Soft QCD Models

Name	Generator	Shower	Input Data	Note
ATLAS MC09	Pythia 6.4	p_T-ordered	CDF √s=0.63, 1.8 TeV	PDF: MRST LO*
ATLAS MC09c	Pythia 6.4	p_T-ordered	Same as above + CDF $<p_T>$ vs N_{ch}	PDF: MRST LO*
DW	Pythia 6.2	Virtuality-ordered	CDF √s= 1.96 TeV	
Perugia0	Pythia 6.4	p_T-ordered	CDF √s=0.63, 1.8, 1.96 TeV SppS 200, 630, 900 GeV	PDF: CTEQ5L
PHOJET	Phojet	Dual-Parton Model	Hadro-production and photo-production measurements	Pythia for particle spectra