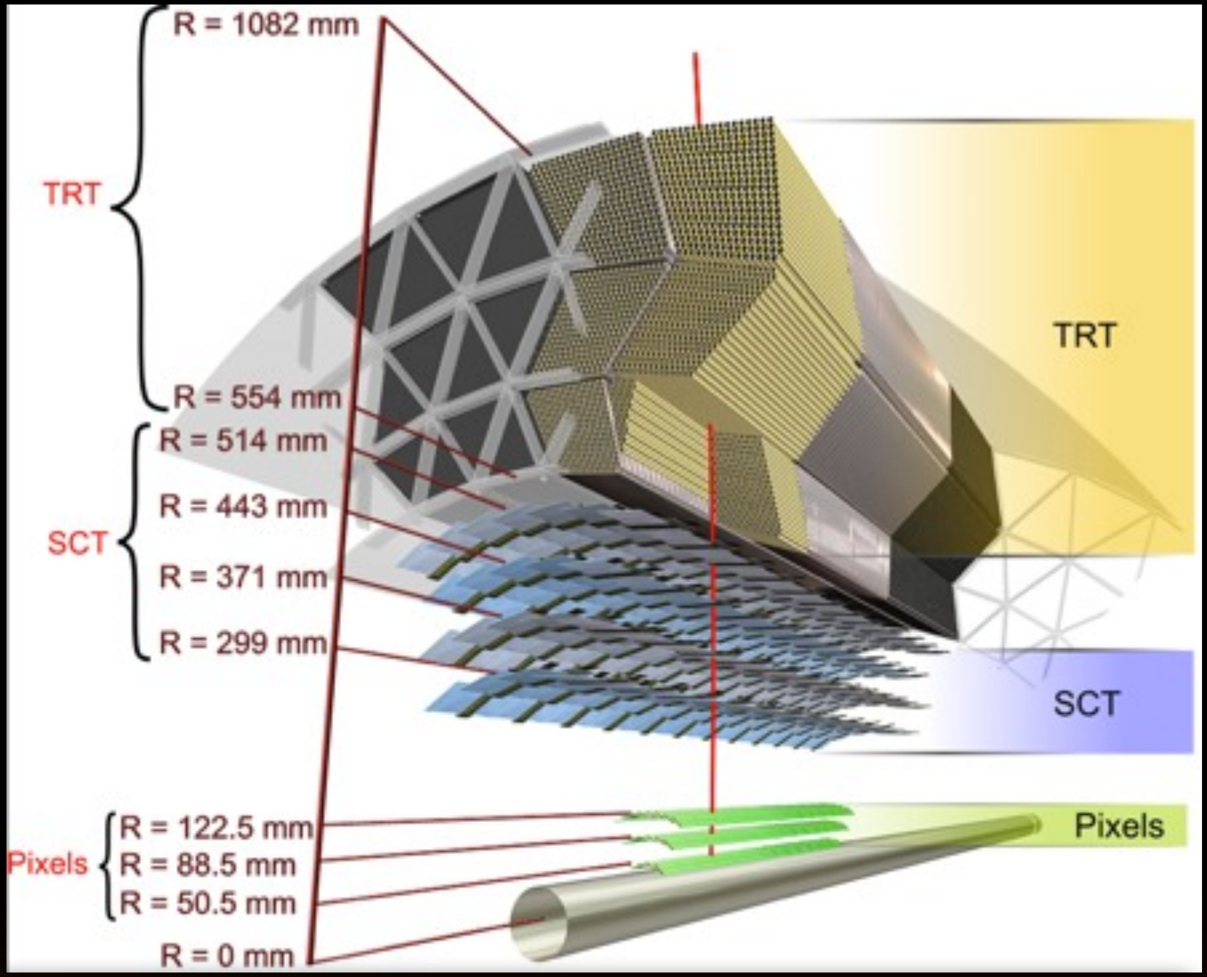
Markus Elsing

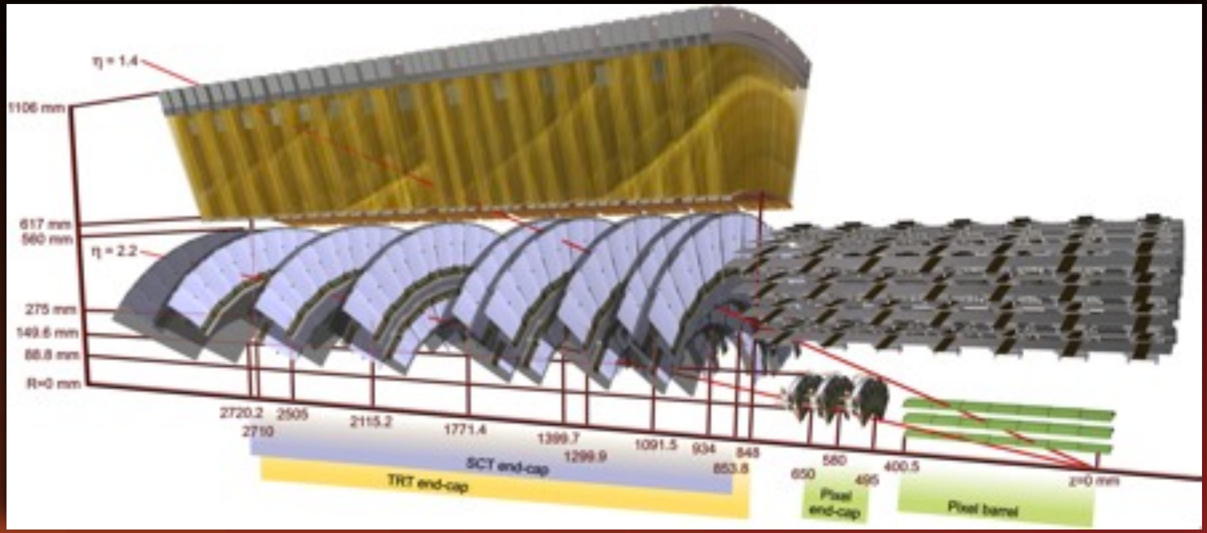
Performance of the ATLAS (Silicon) Tracking Detectors

- on behalf of the ATLAS Collaboration

ATLAS Inner Detector

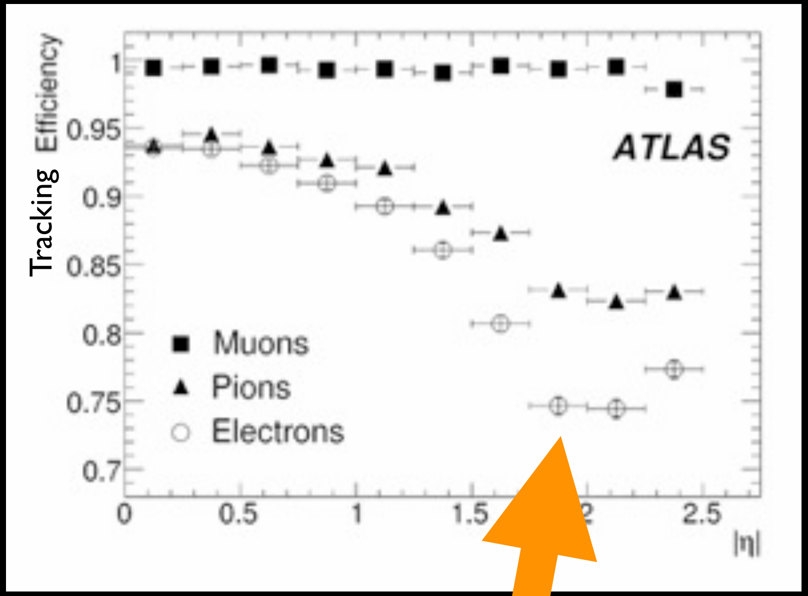
- requirements to cover ATLAS physics program
  - ➡ precision tracking at LHC luminosities with a hermitic silicon tracker covering over 5 units in eta
  - ➡ Pixel Detector for precise primary vertex reconstruction and to provide excellent b-tagging
  - ➡ reconstruct electrons and converted photons, including transition radiation in TRT for electron identification
  - ➡ tracking of muons combined with toroid Muon Spectrometer
  - ➡ enable tau reconstruction
  - ➡ V0, b- and c-hadron reconstruction, ...
  - ➡ dE/dx from T.o.T. in Pixels and TRT
  - ➡ **and:** fast tracking for high level trigger

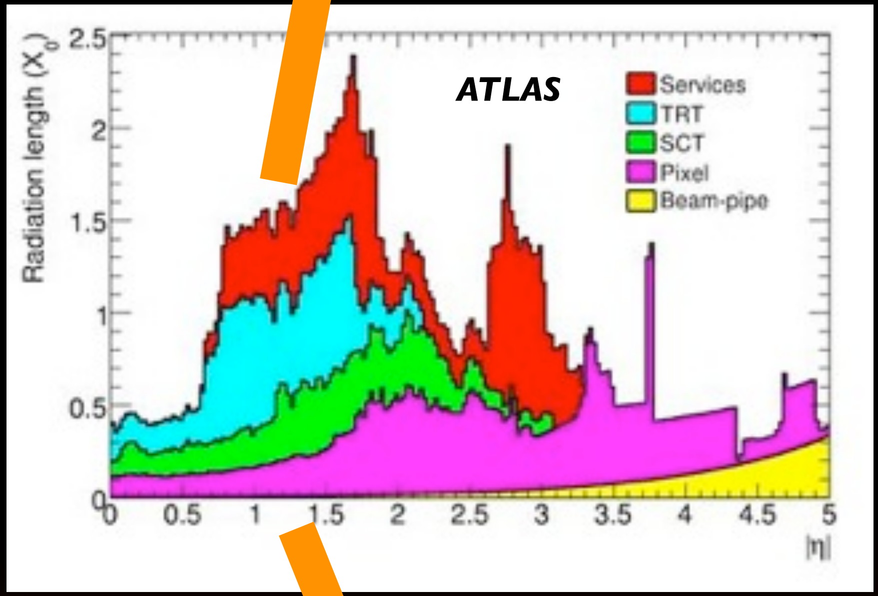


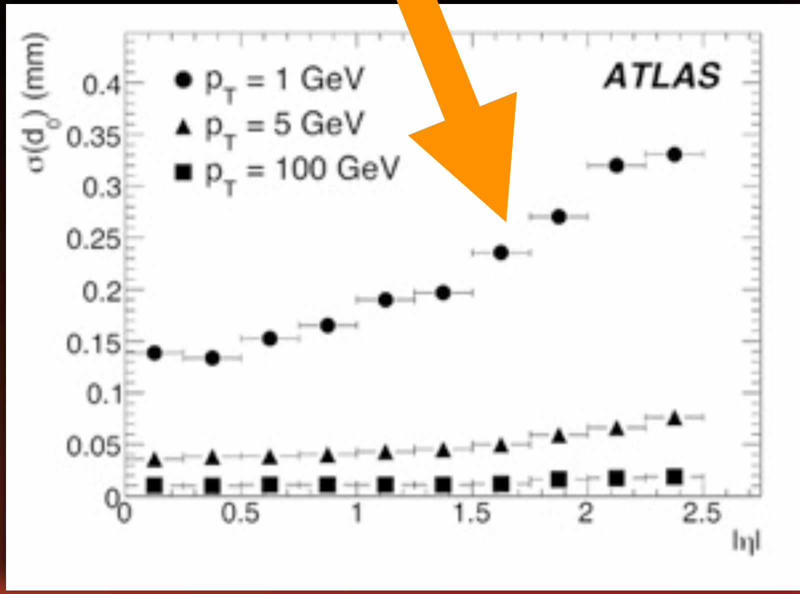


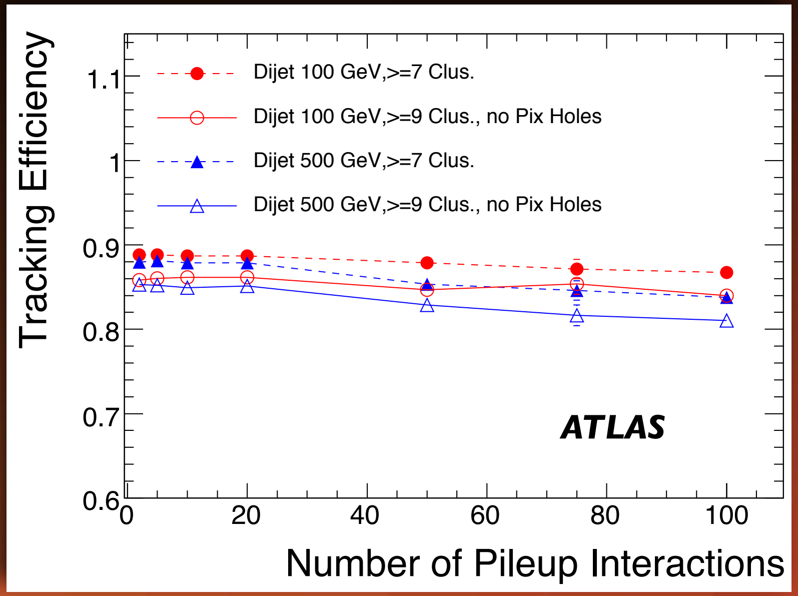
Expected Performance

- excellent preparation before startup
  - ➡ more than 10 years of simulation and test beam
  - ➡ cosmics data taking in 2008 and 2009
  - ➡ payed off last year !
- detailed simulation studies
  - ➡ document expected performance
  - ➡ few of the known critical items:
    - – material effects limit efficiency and resolution at low p_t
    - – good (local) alignment for b-tagging
    - – momentum scale and alignment "weak modes"
  - ➡ focus for commissioning of tracking and vertexing

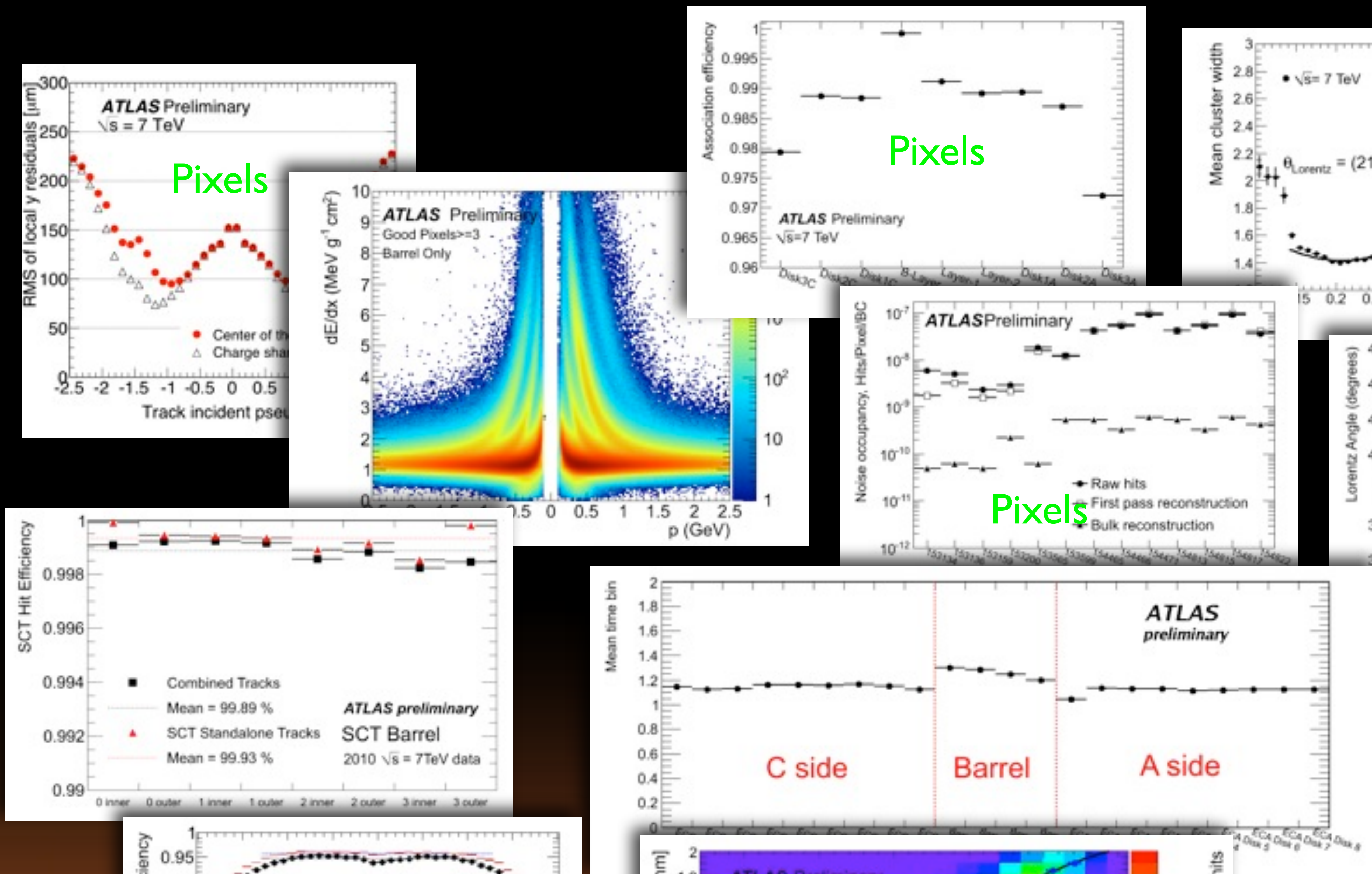


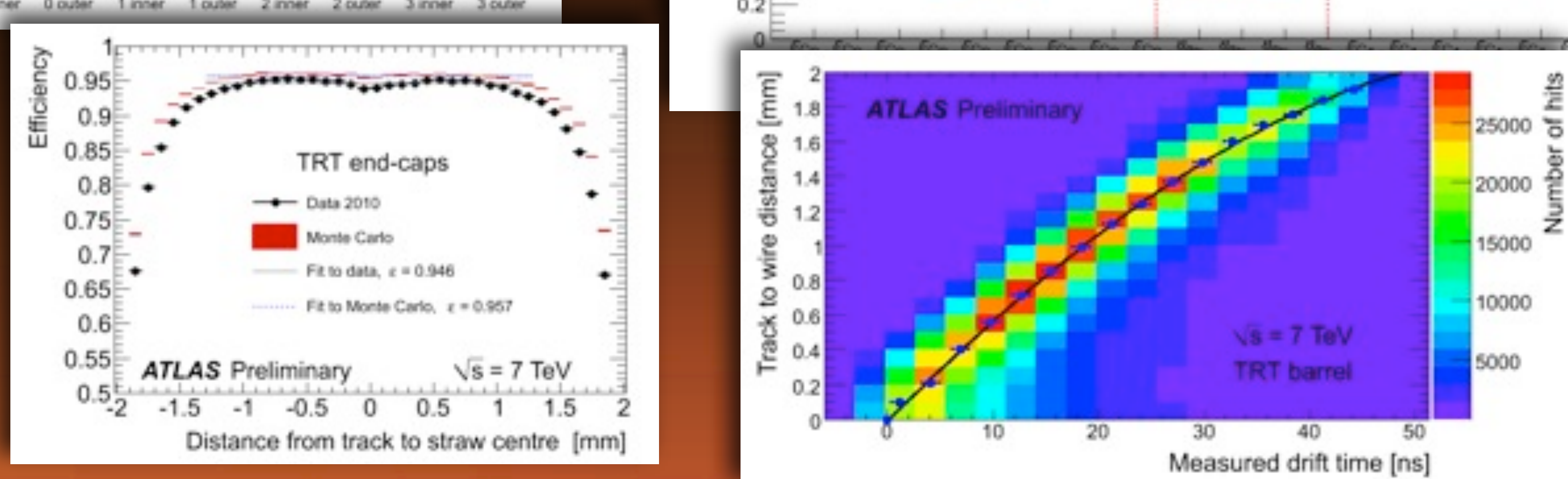


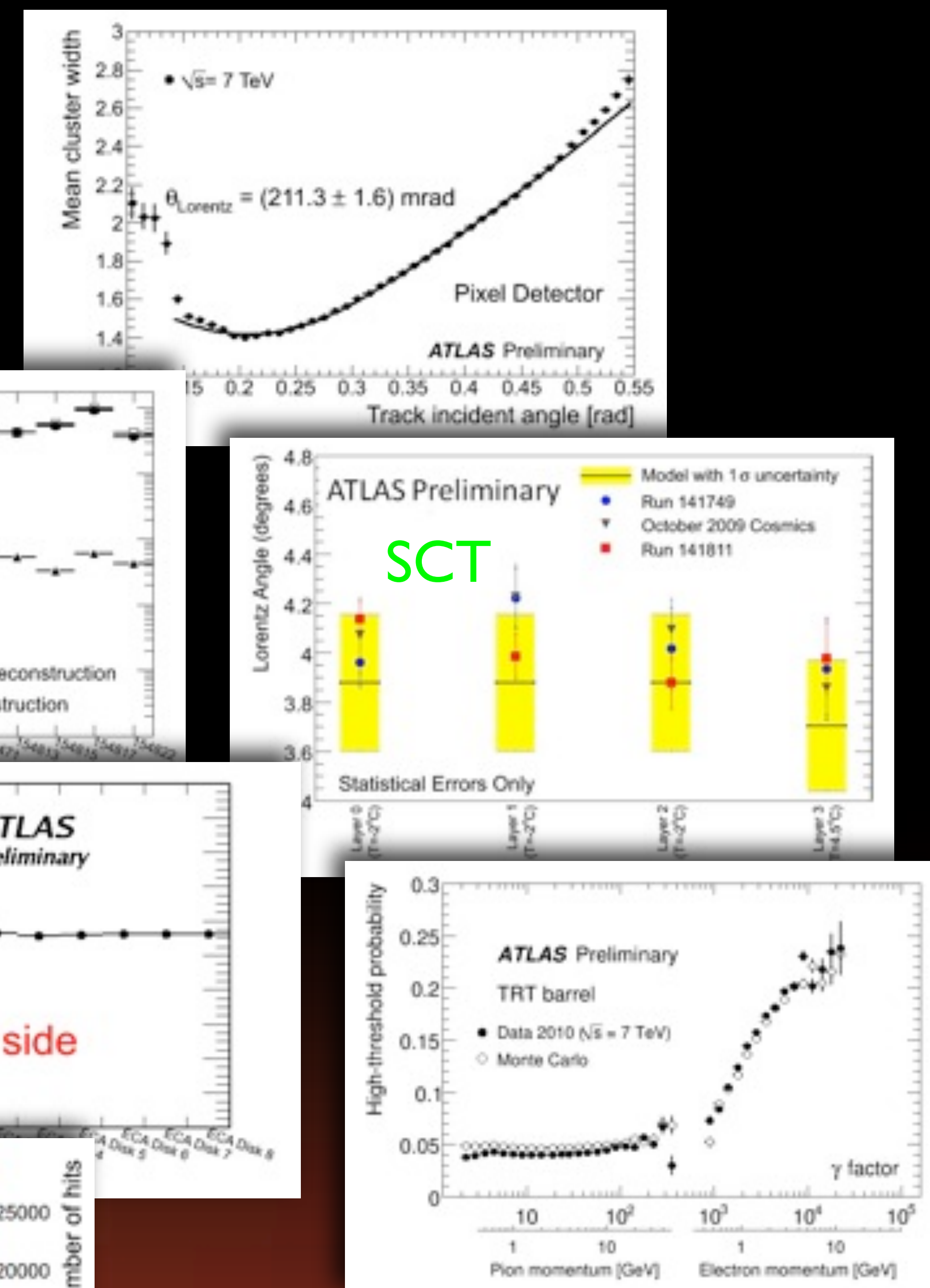




Basis is excellent Work on Detectors !



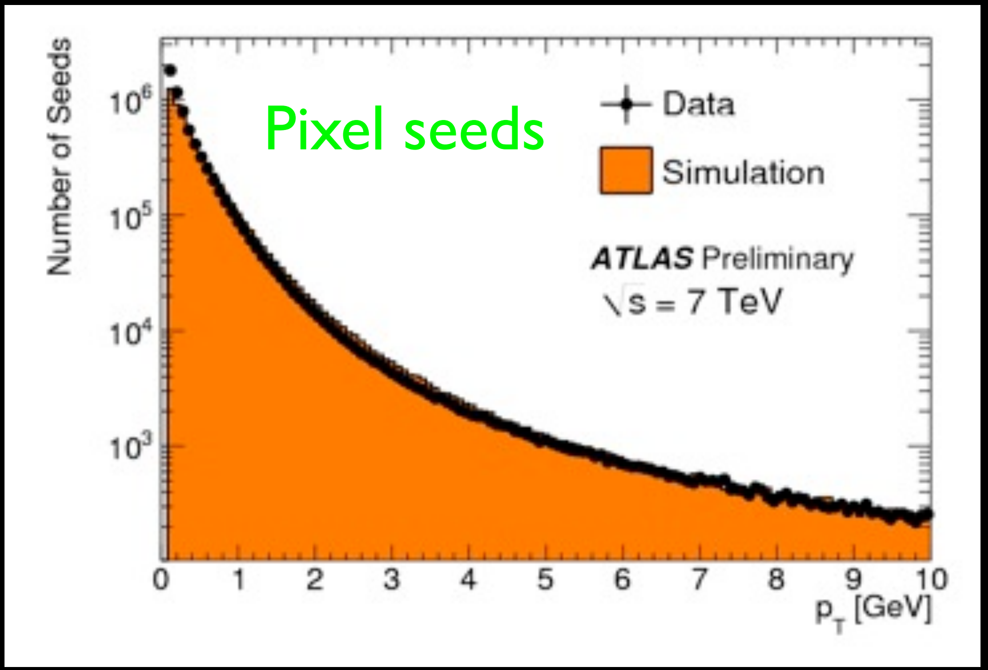


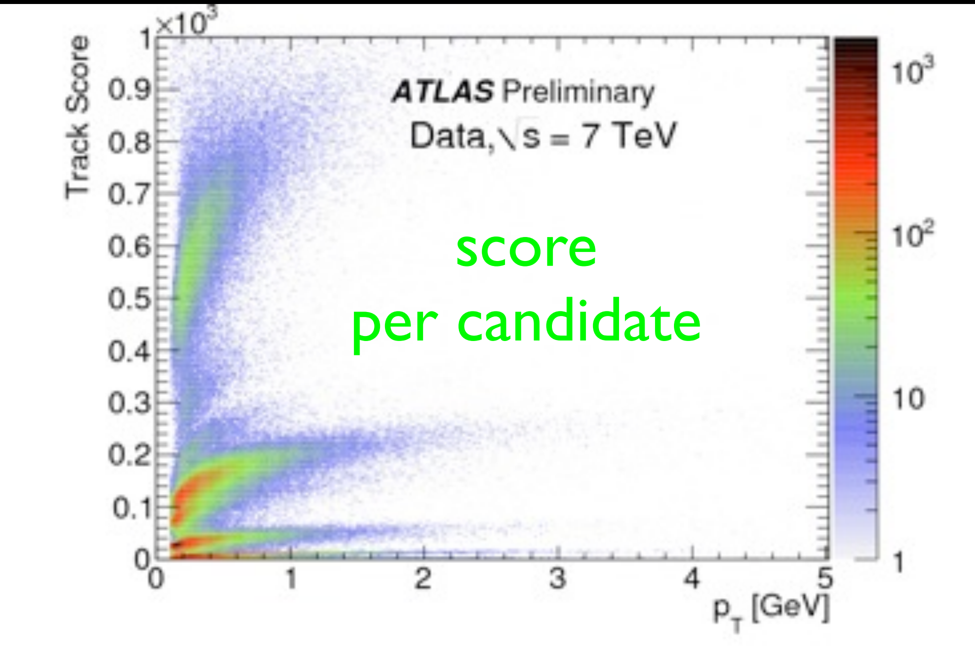


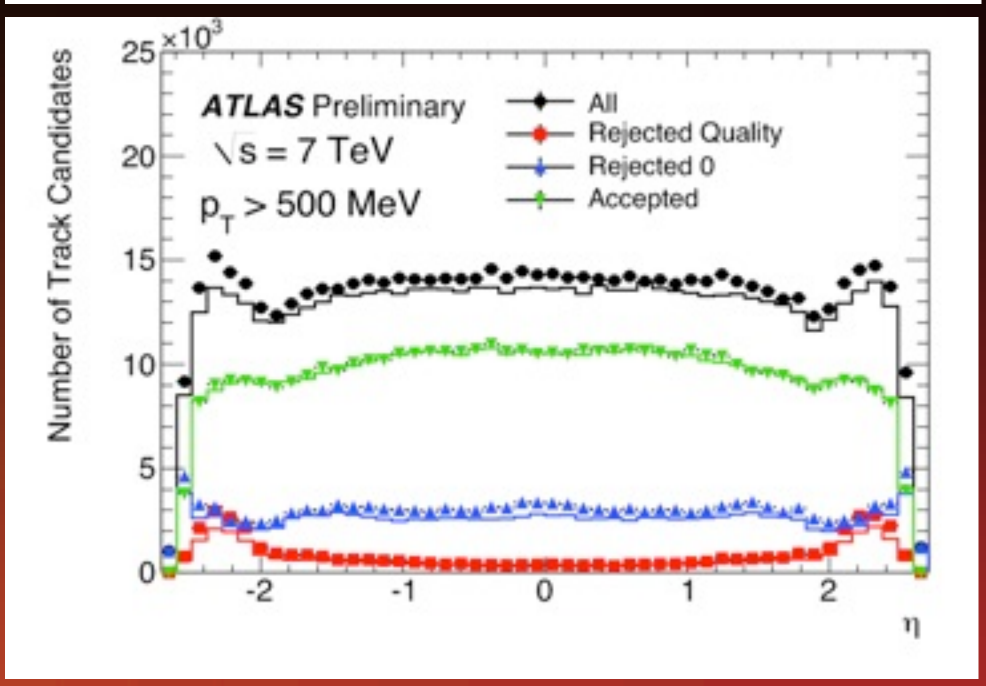
➡ see talks by Beniamino and Petra for details ...

Pattern Recognition

- staged track reconstruction
  - ➡ inside-out: Pixel seeded + extending outwards
  - ➡ outside-in: seeded on TRT segments
- study performance at different levels in reconstruction process
  - ➡ seeding / candidate fitting / ambiguity
- ensure "robustness"
  - ➡ allow for dead/noise modules
  - ➡ error scaling to reflect calibration + alignment
- very good performance even with early data
  - ➡ example: results from summer 2010...





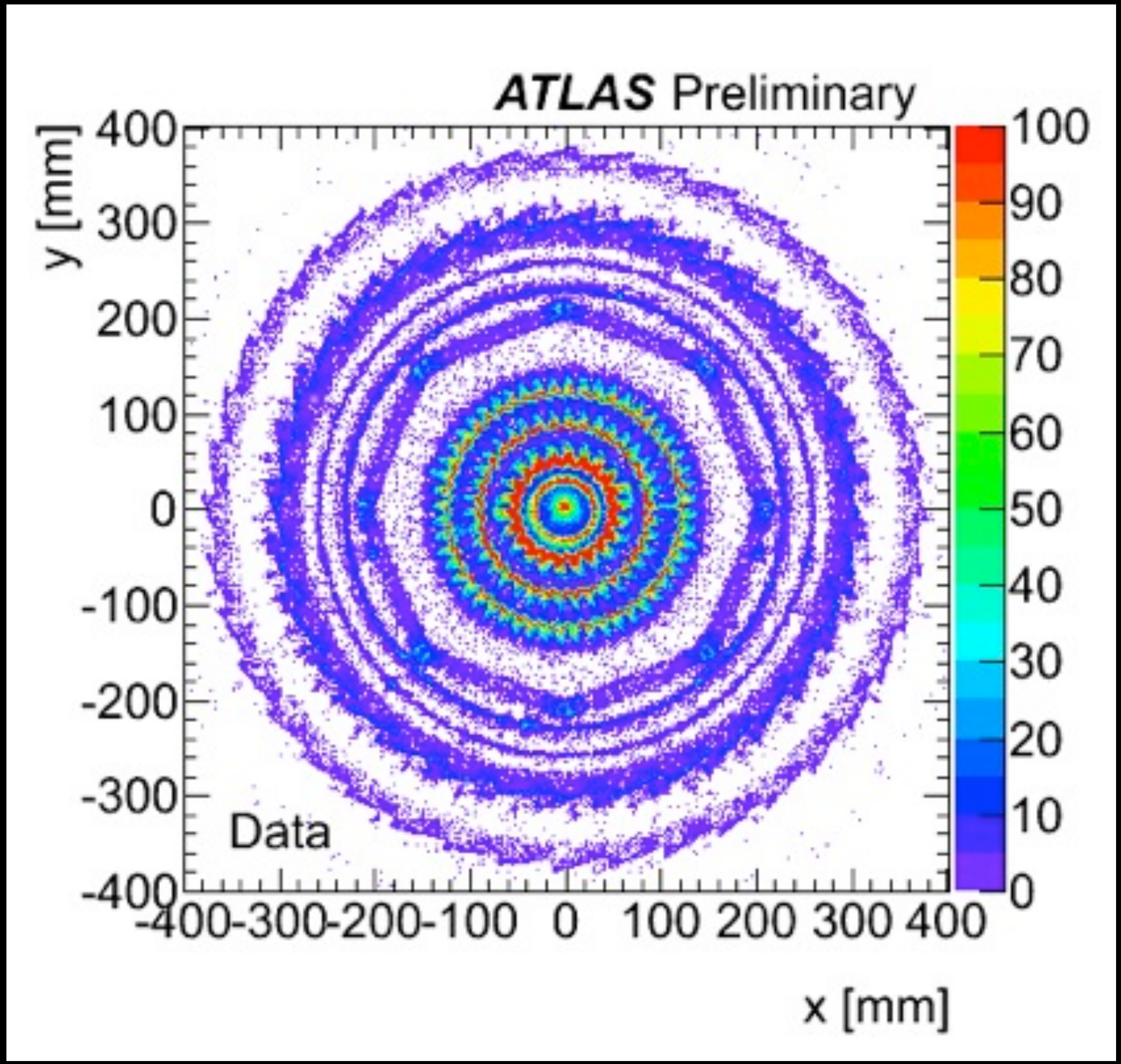


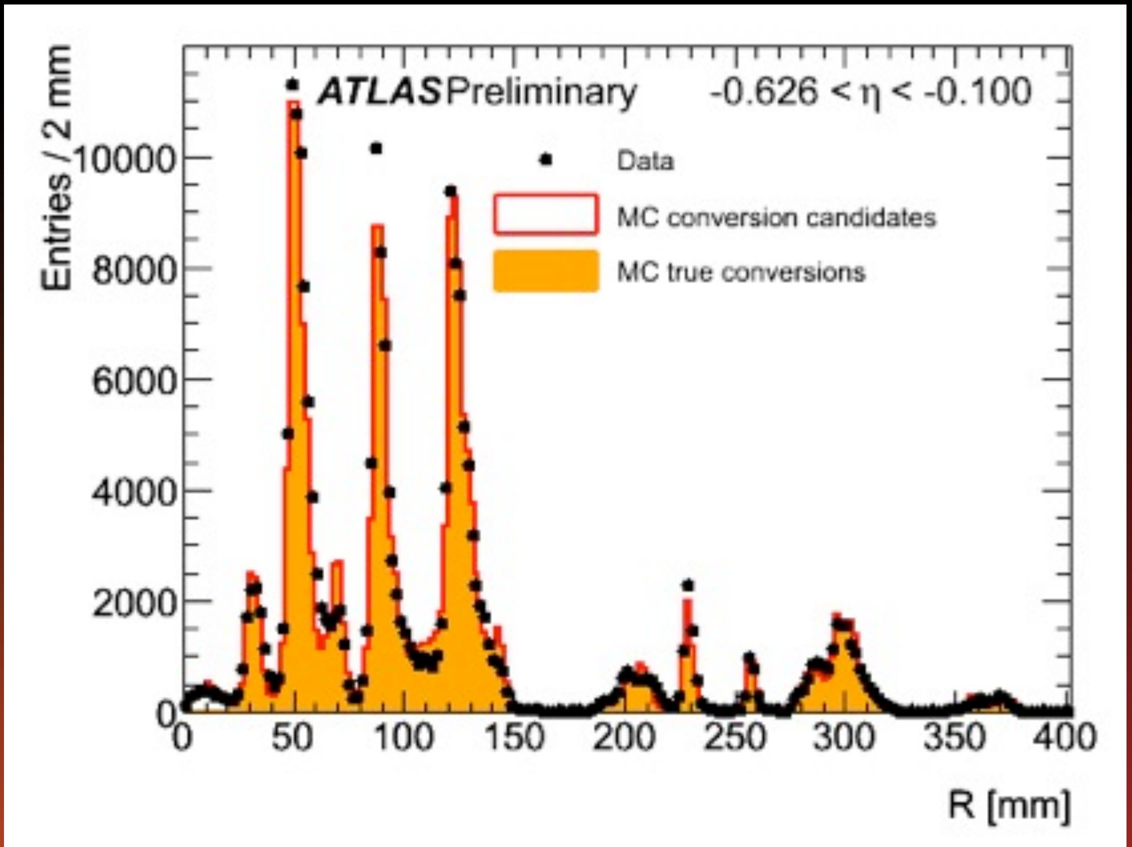
Material Studies

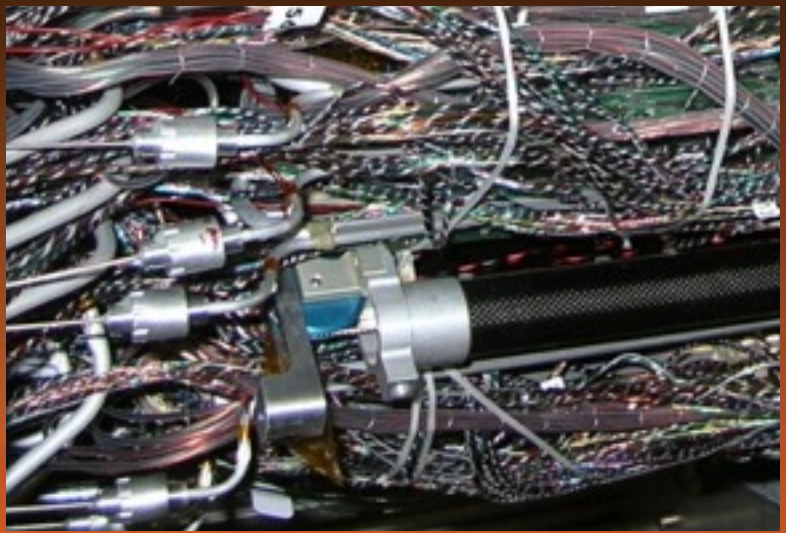
- crucial input to understand tracking performance

- early studies
  - ➡ K^0_s / J/ψ mass signals
  - ➡ efficiency to extend Pixel seeds into SCT
  - ➡ impact parameter resolution vs p_t

- tomography with γ conversions
  - ➡ allows very precise estimate of material
  - ➡ calibrate e.g. on “known” beam pipe
  - ➡ measure difference in data/MC, e.g. PP0

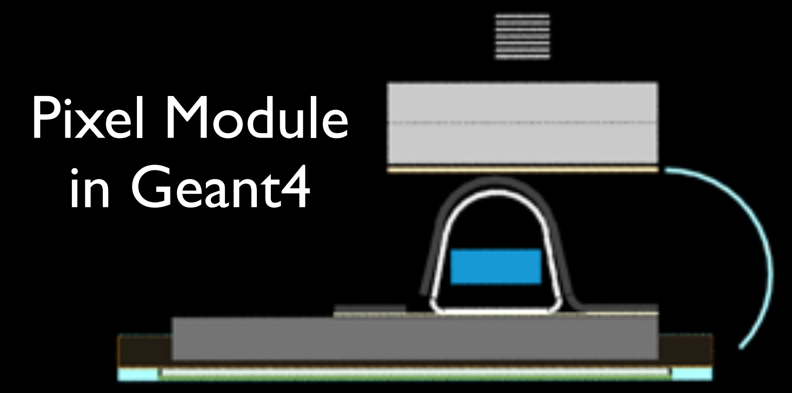




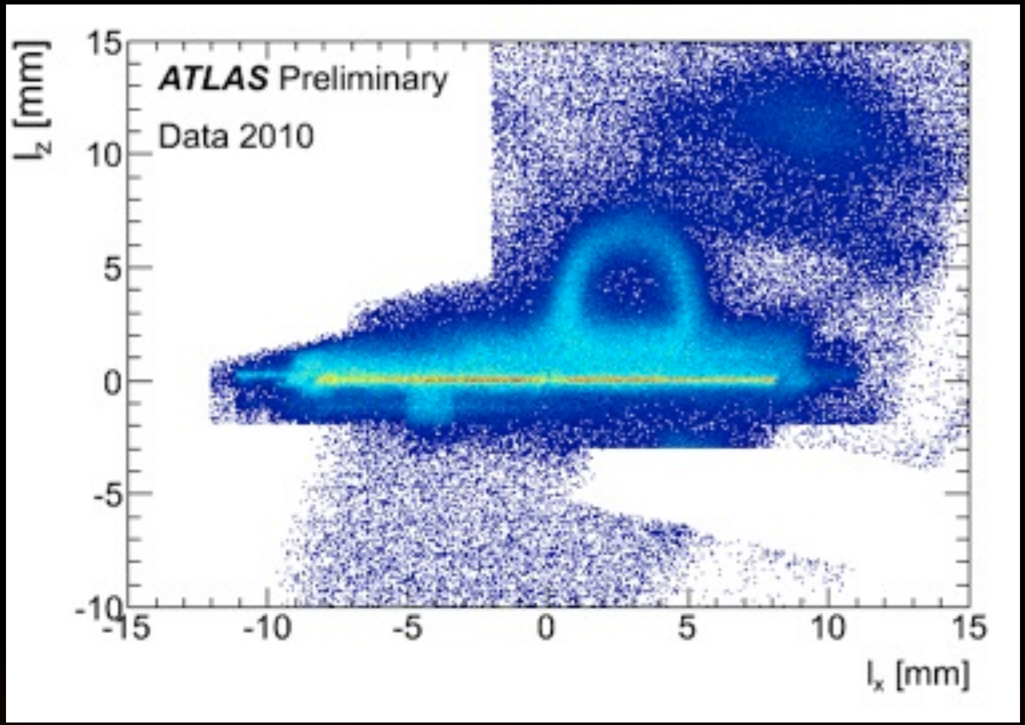


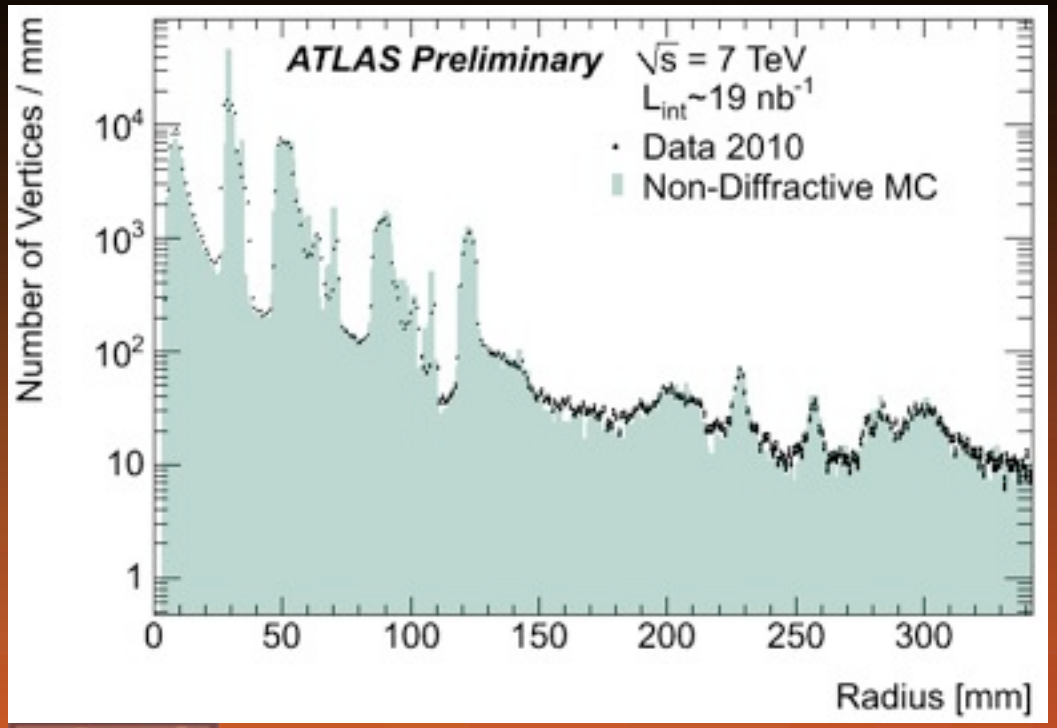
Pixel PP0 region

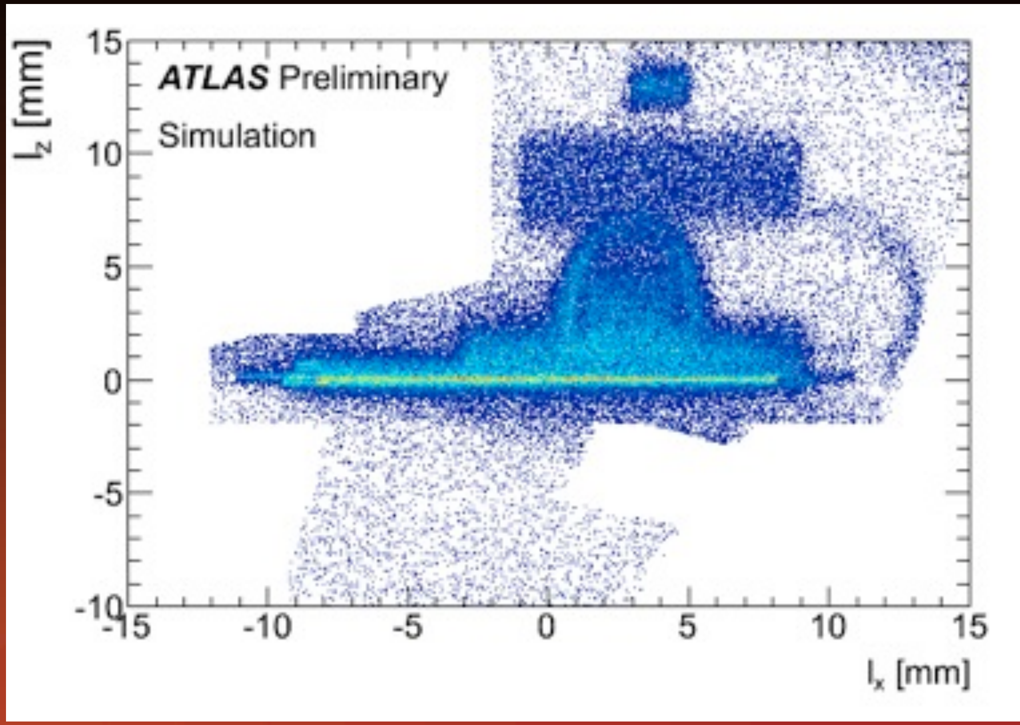
Hadronic Interactions



- 2nd method for a precise tomography of detector material
  - ➡ good vtx resolution allows to study fine details
- material uncertainty in simulation
  - ➡ better than ~5% in central region
  - ➡ at the level of ~10% in most of the endcaps
  - ➡ study of systematics ongoing

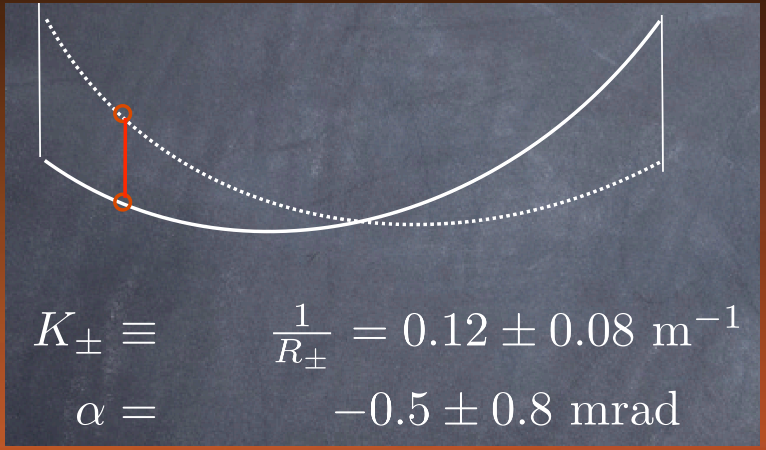




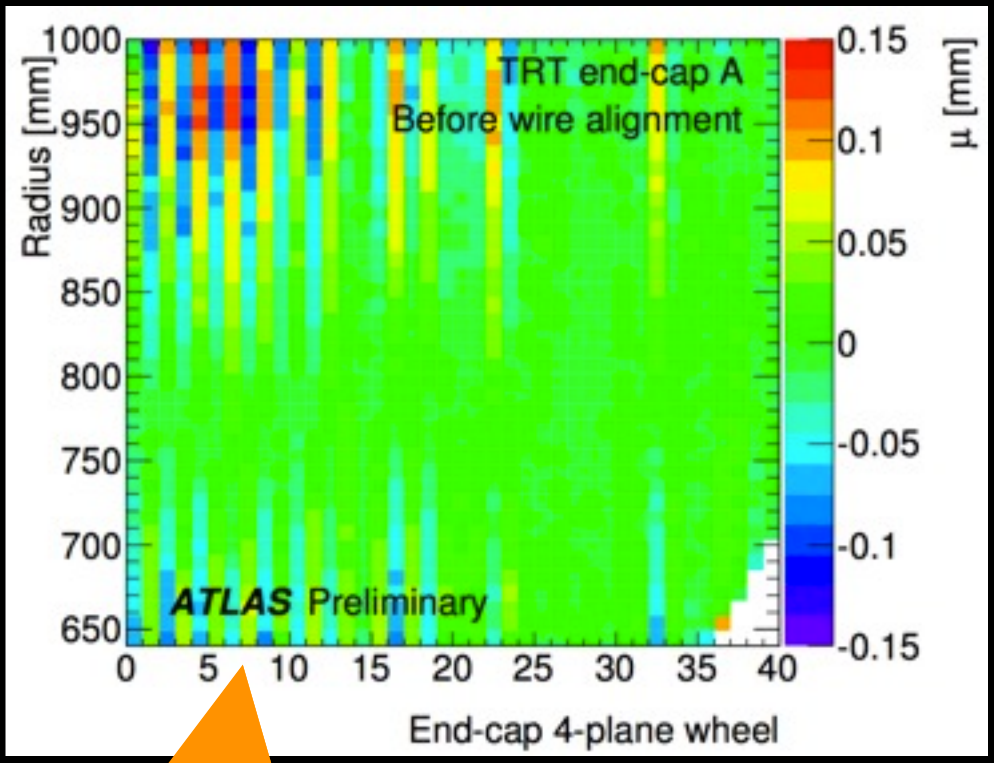


Detector Alignment

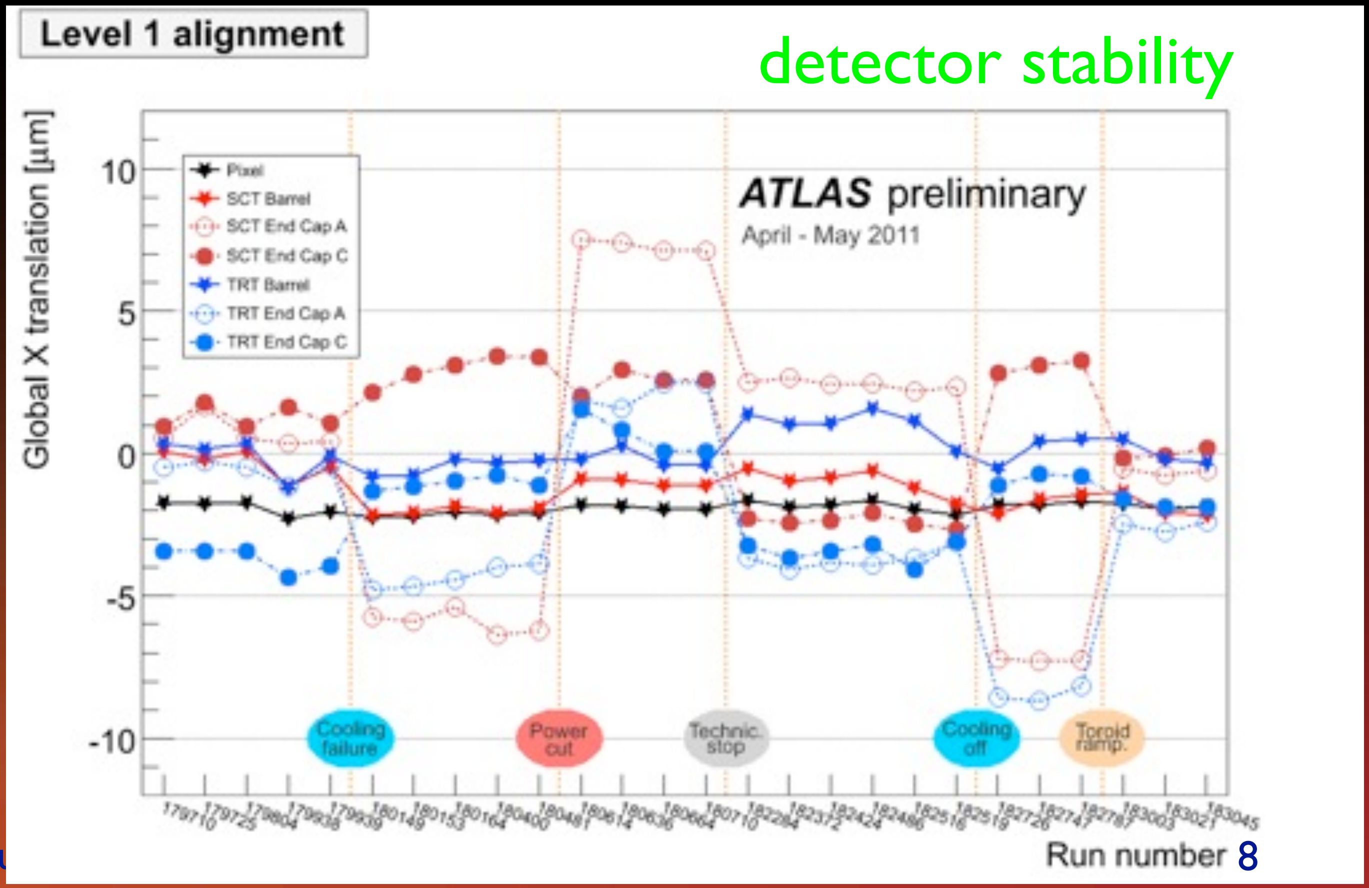
- alignment strategy
  - ➡ starting point is detailed survey
  - ➡ alignment stream with high-p_t tracks
  - ➡ define different levels of granularity
    level 1 (e.g.SCT barrel) to level 3 (module)
  - ➡ global-χ^2 and local alignment
- also allow for
  - ➡ Pixel model deformations (survey)
  - ➡ Pixel stave bowing
  - ➡ TRT wire alignment
  - ➡ movements of the detector
  - ➡ ...



schematics of module bow

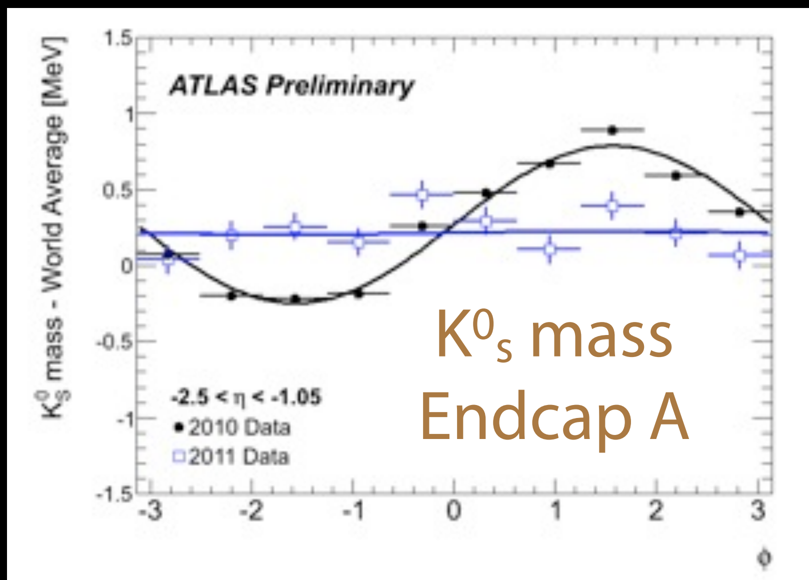


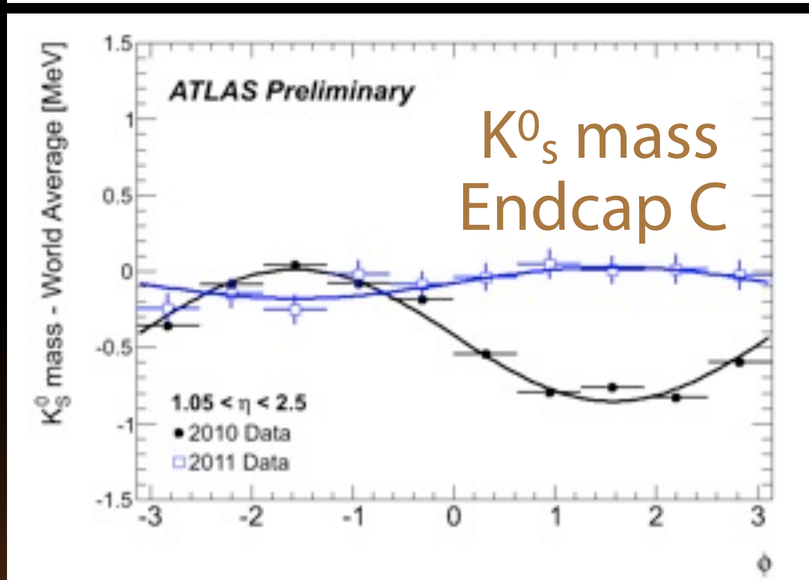
apparent twist between TRT 4-plane wheels



detector stability

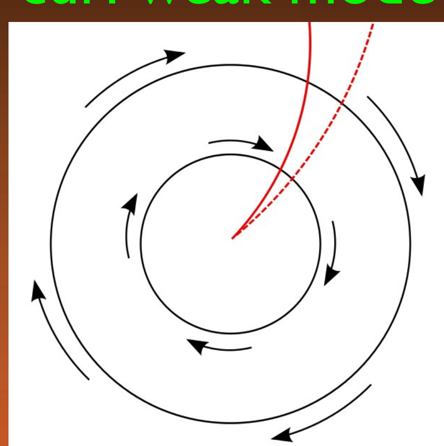
Field Tilt ? Weak Modes ?

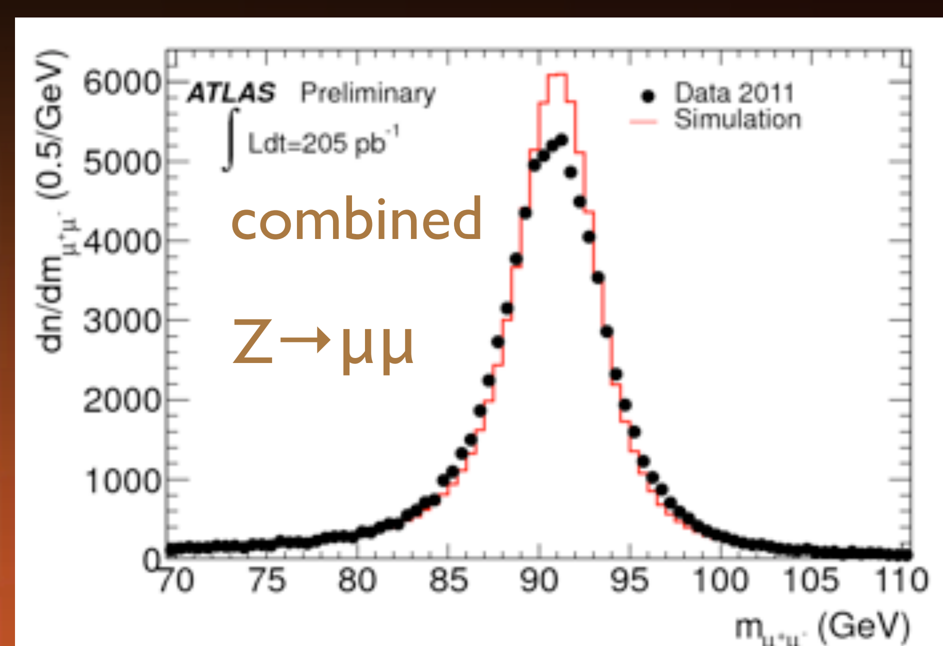


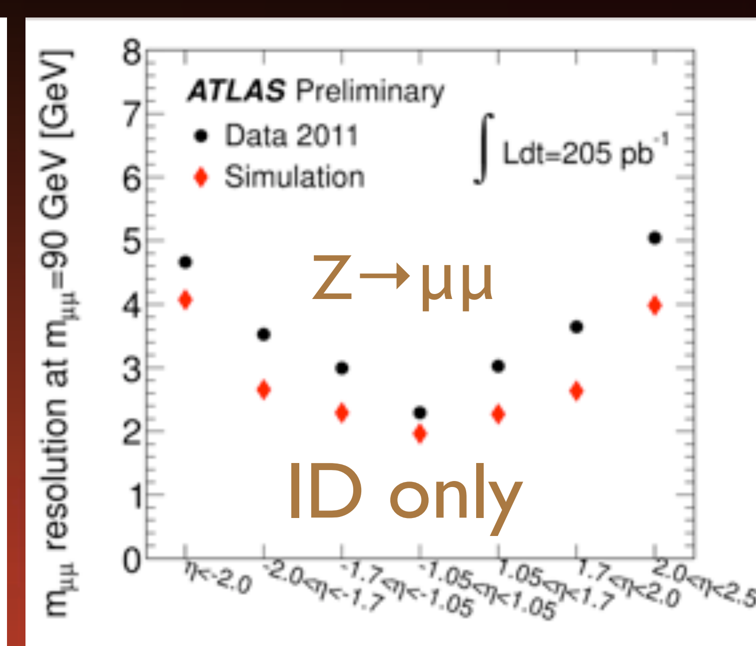


- field tilt visible in K^0_s mass bias vs ϕ
  - ➡ shifts mass in opposite directions in both endcaps
  - ➡ corrected by 0.55 *mrad* field rotation around y axis
- “weak modes” are global deformations
  - ➡ leave fit-χ^2 nearly unchanged
  - ➡ affect momentum scale, e.g. Z-mass resolution
  - ➡ several techniques to control weak modes
    - TRT to constrain Silicon alignment
    - electron E/p using calorimeter
    - muon momentum in Inner Detector vs Muon Spectrometer

curl weak mode

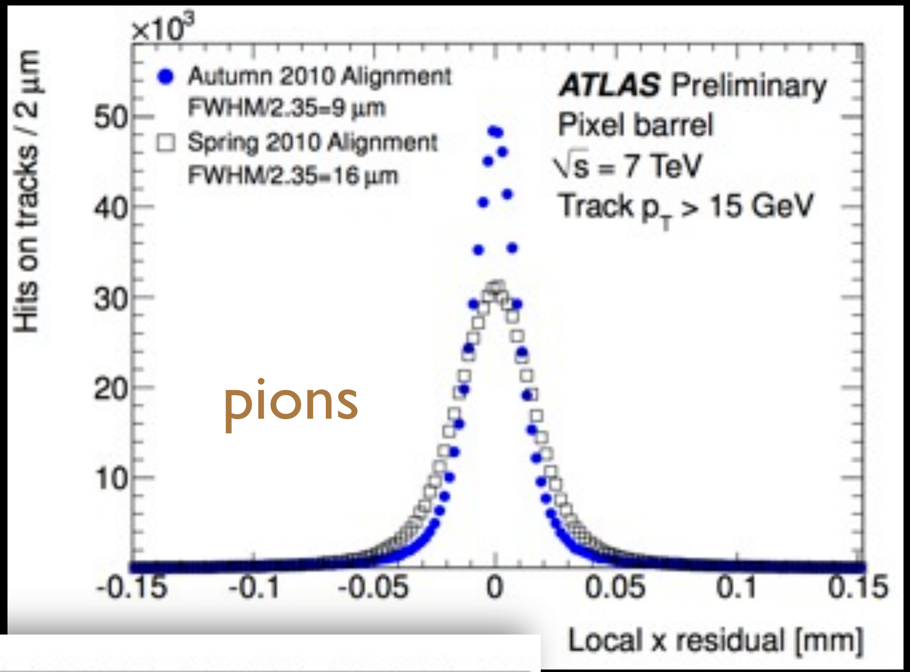


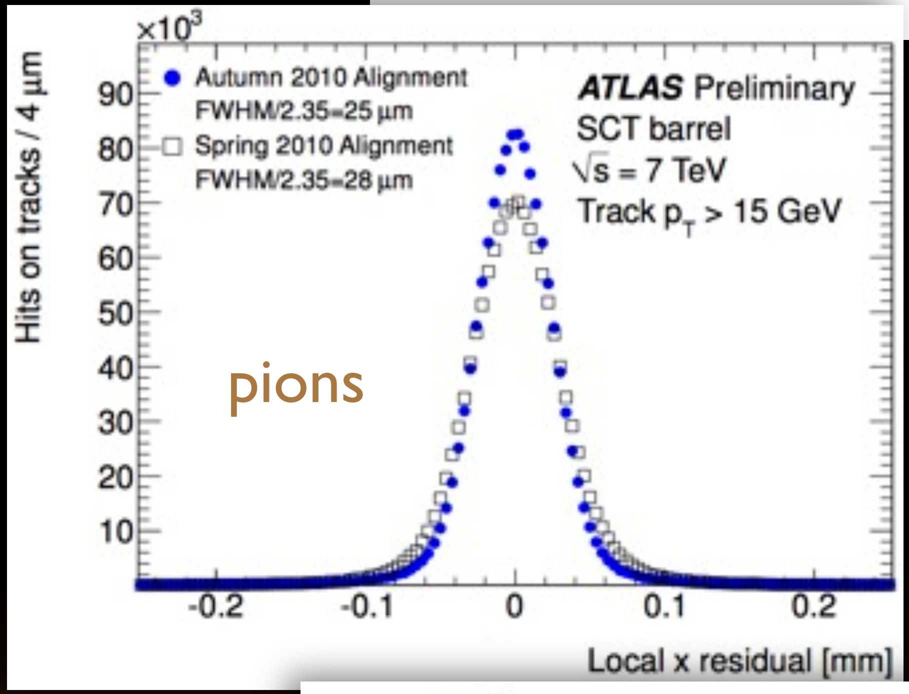


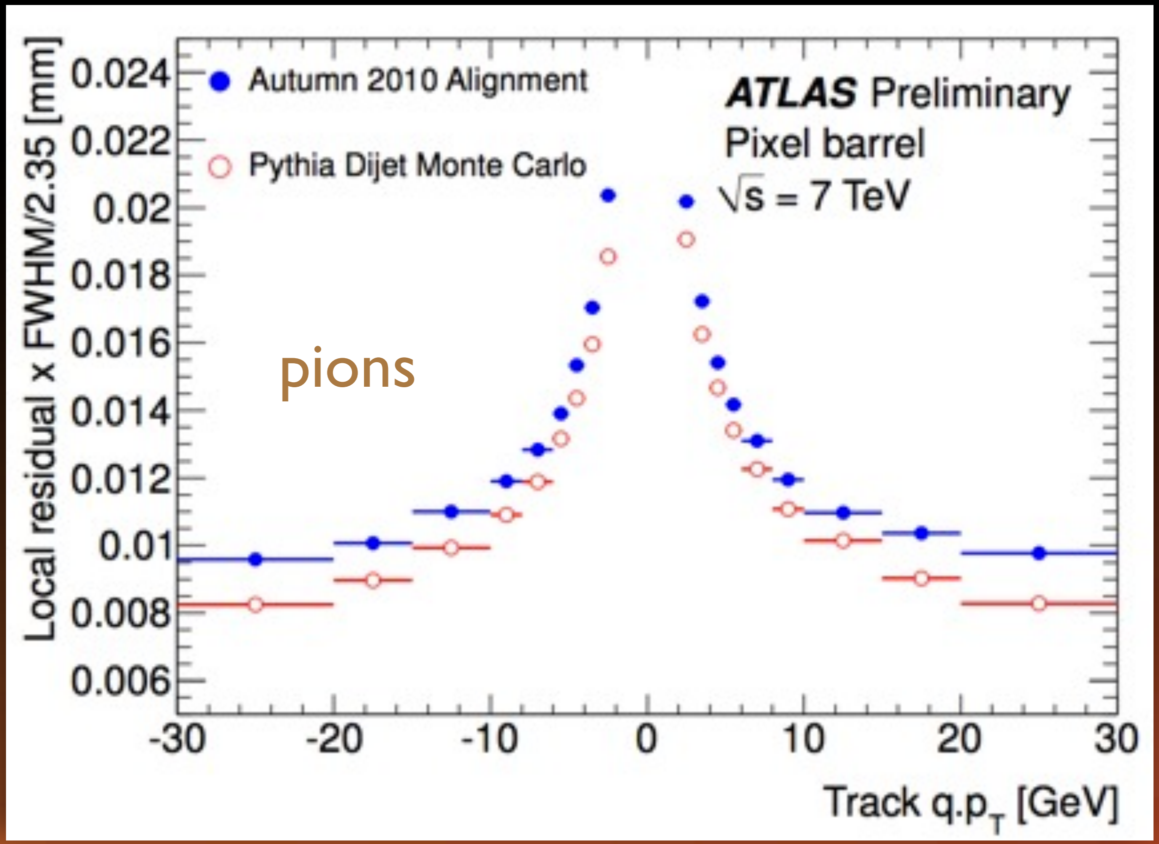


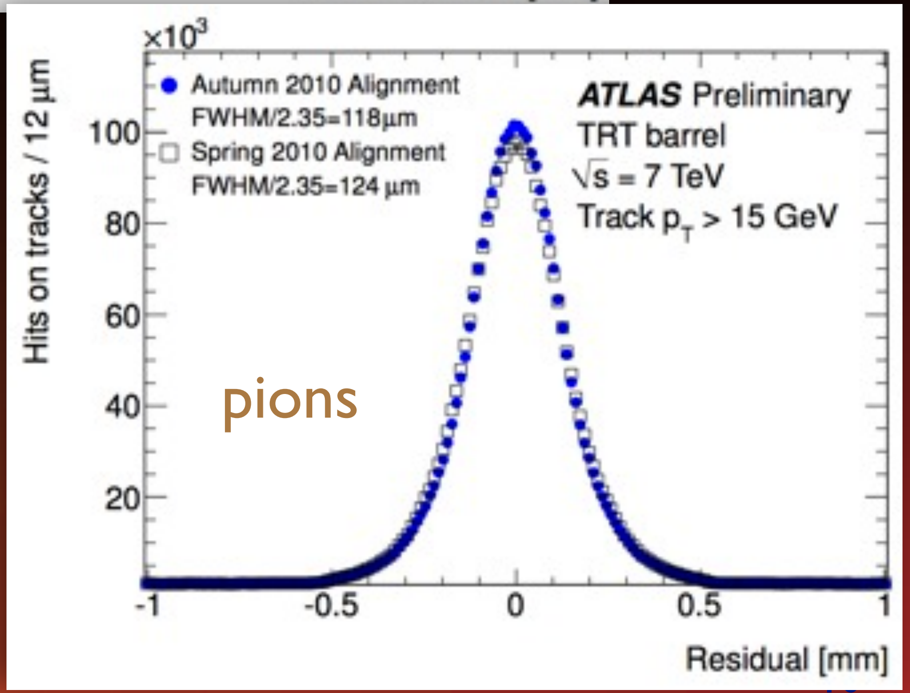
Alignment Performance

- approaching design resolutions
  - ➡ error scaling to allow for residual misalignments in fit



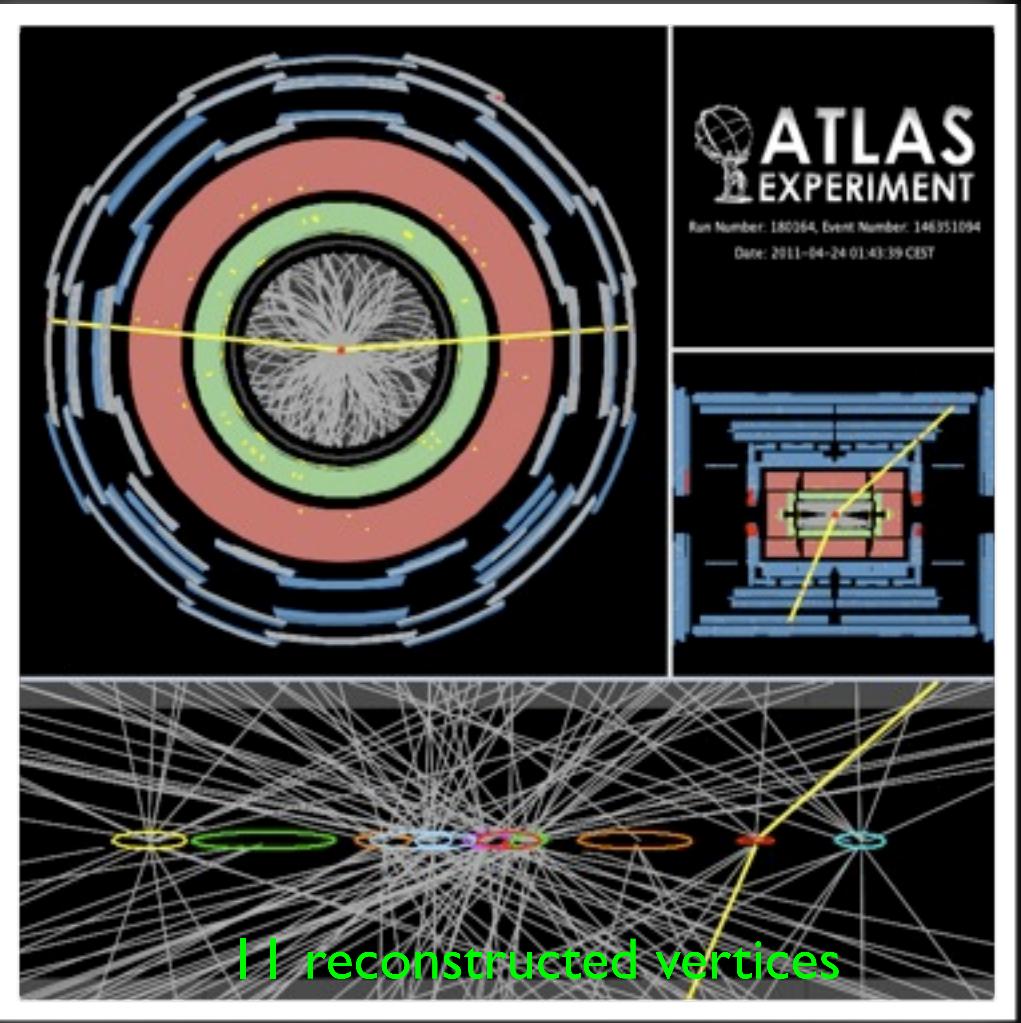


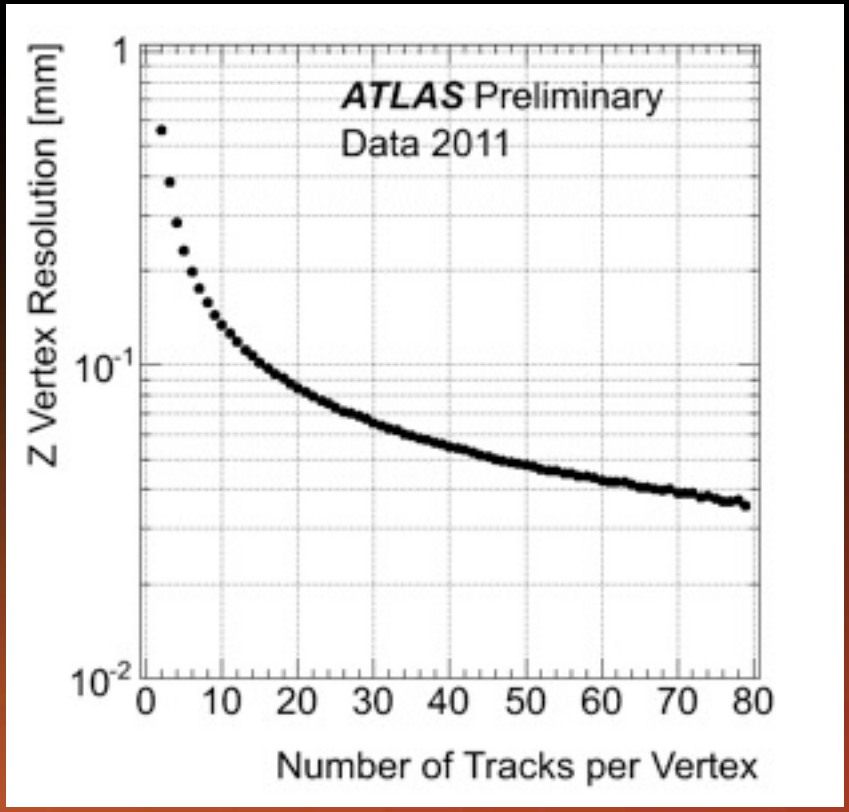


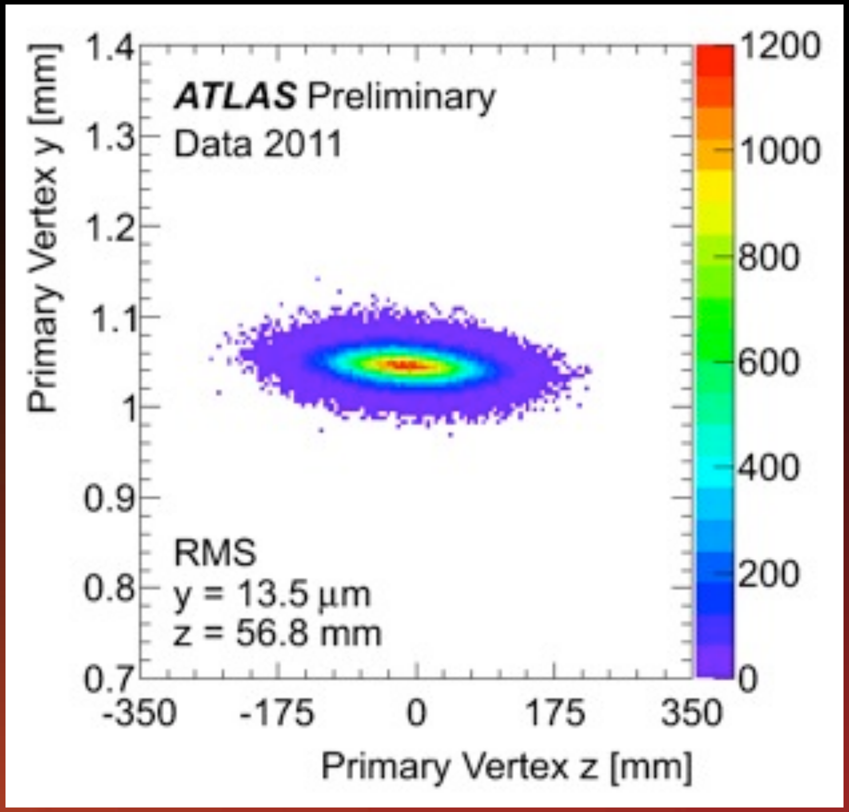


Primary Vertexing

- iterative vertex finder, adaptive fitter
  - ➡ reconstruct primary and pileup vertices
- beam spot routinely determined
  - ➡ input to vertexing
- measure primary vertex resolution
  - ➡ split vertex technique on data
- many applications
  - ➡ primary vertex counting (luminosity)
  - ➡ Jet-Vertex-Fraction to reject pileup jets
  - ➡ jet energy scale correction
  - ➡ ...

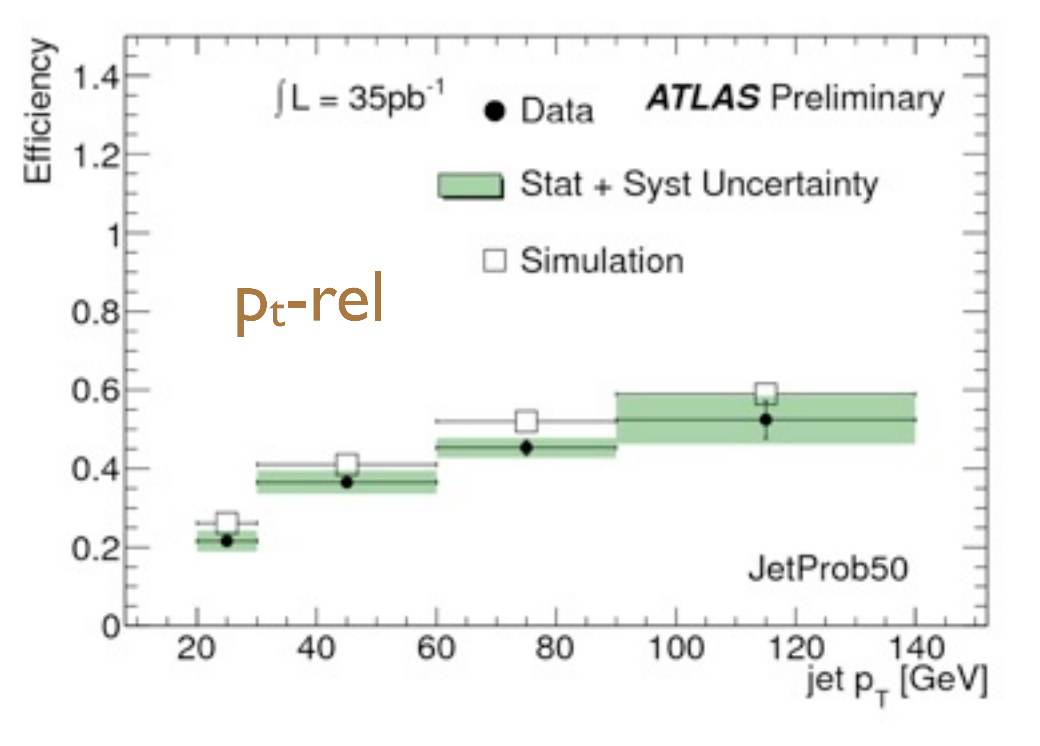


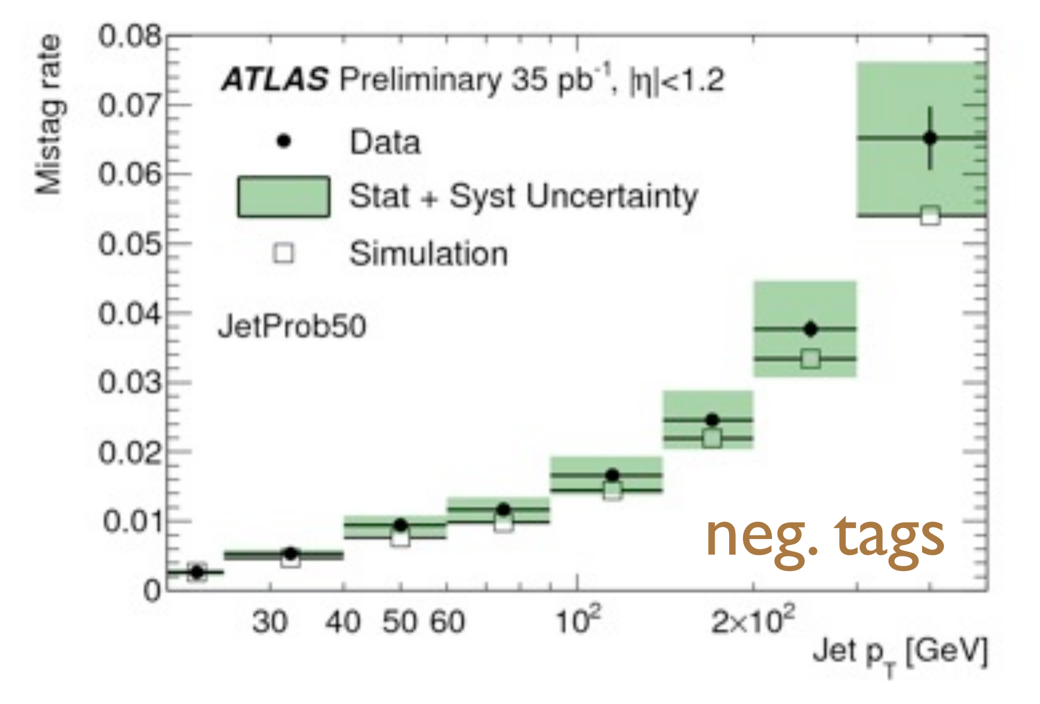


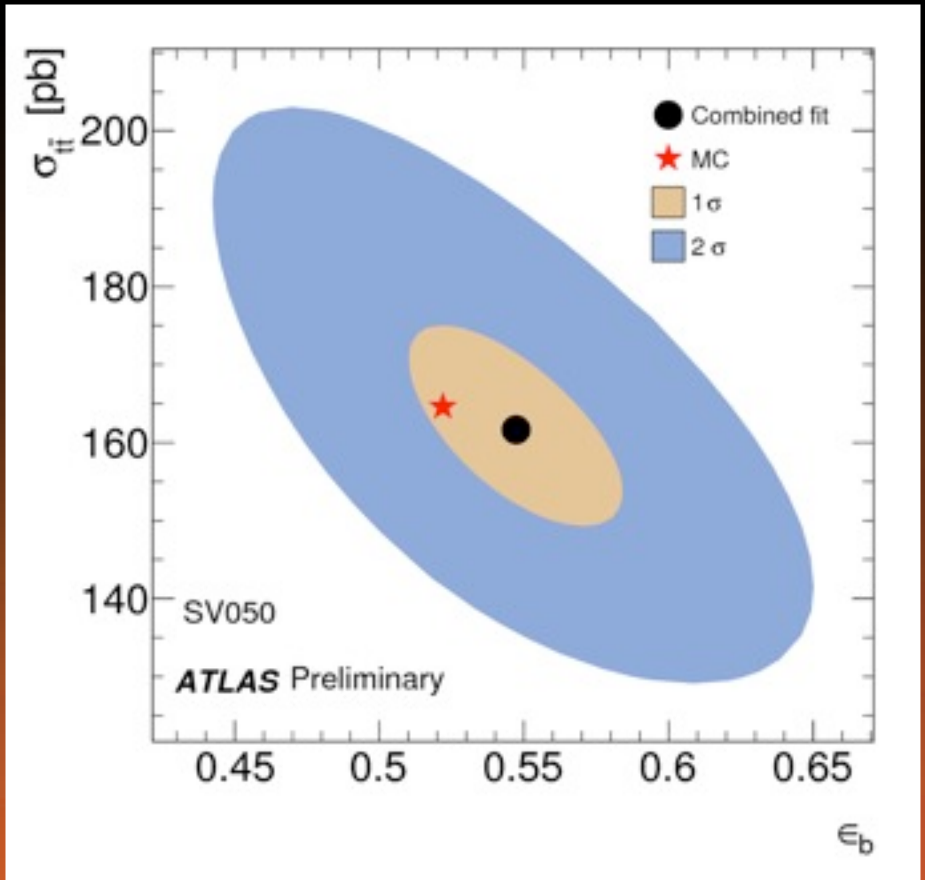


b-Tagging

- robust taggers
  - ➡ inclusive secondary vertex tagger (SV0)
  - ➡ impact parameter significance (JetProb)
- performance well studied
  - ➡ efficiency e.g using "muon p_t-rel", "D*μ", "tt" ...
  - ➡ mistags e.g. using "vtx mass", "neg. tags" ...



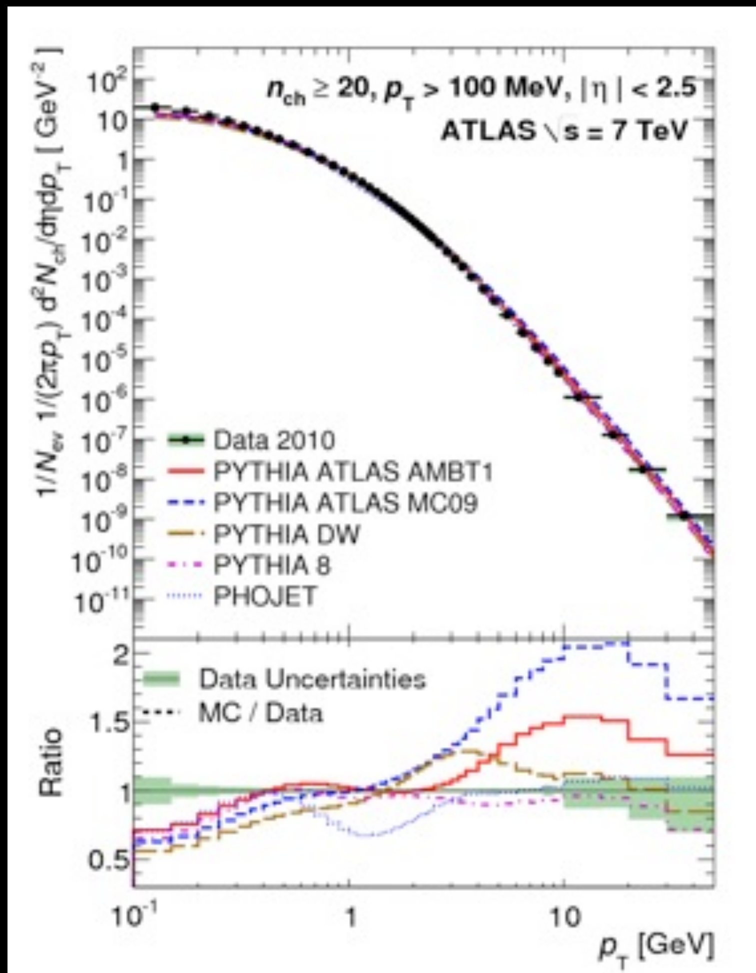




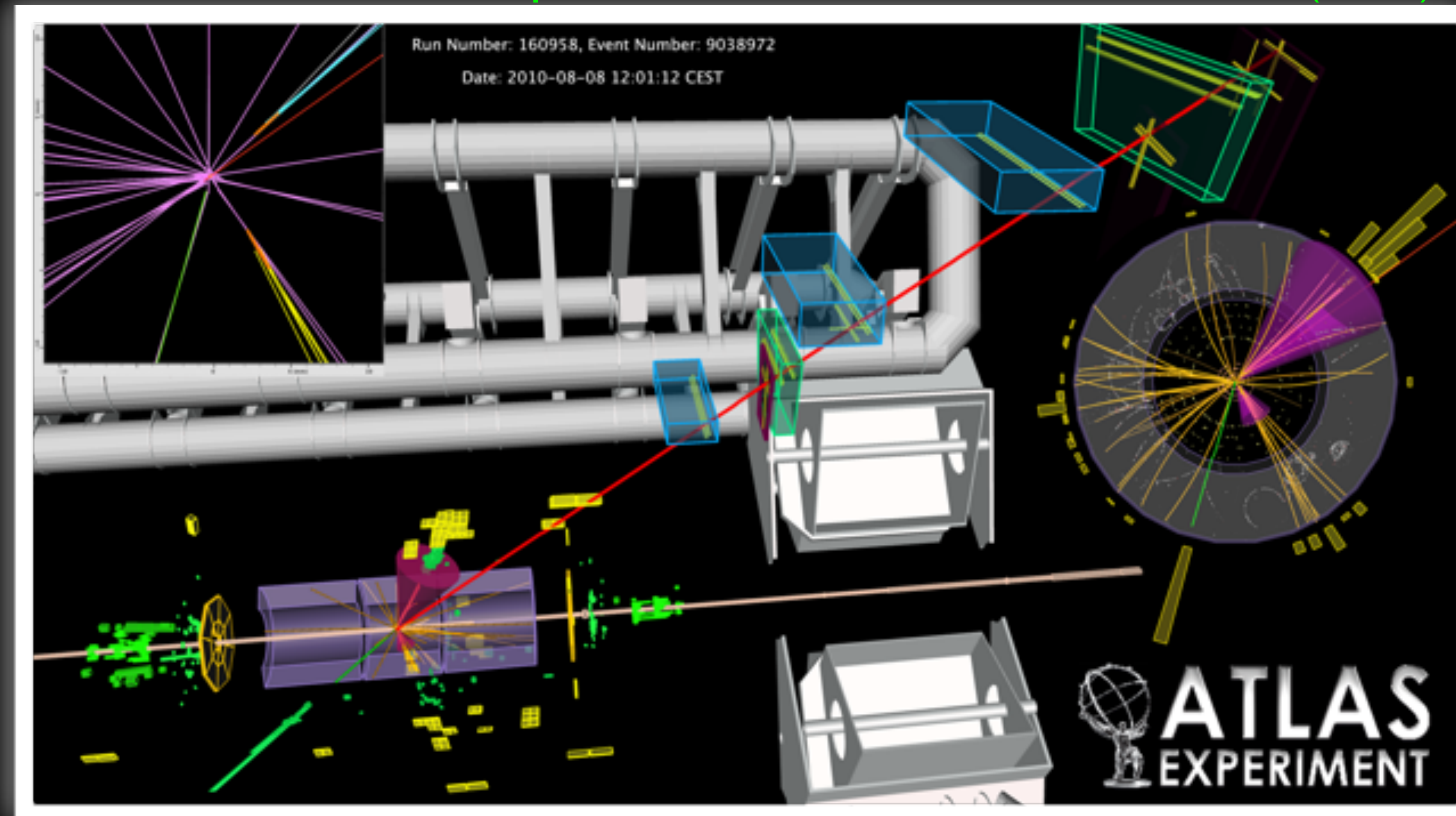
- used in analysis up to now
- towards using likelihood based taggers
  - ➡ optimal combination of IP and vertex information
  - ➡ interplay between tracking performance, properties of jets and fragmentation in different event topologies

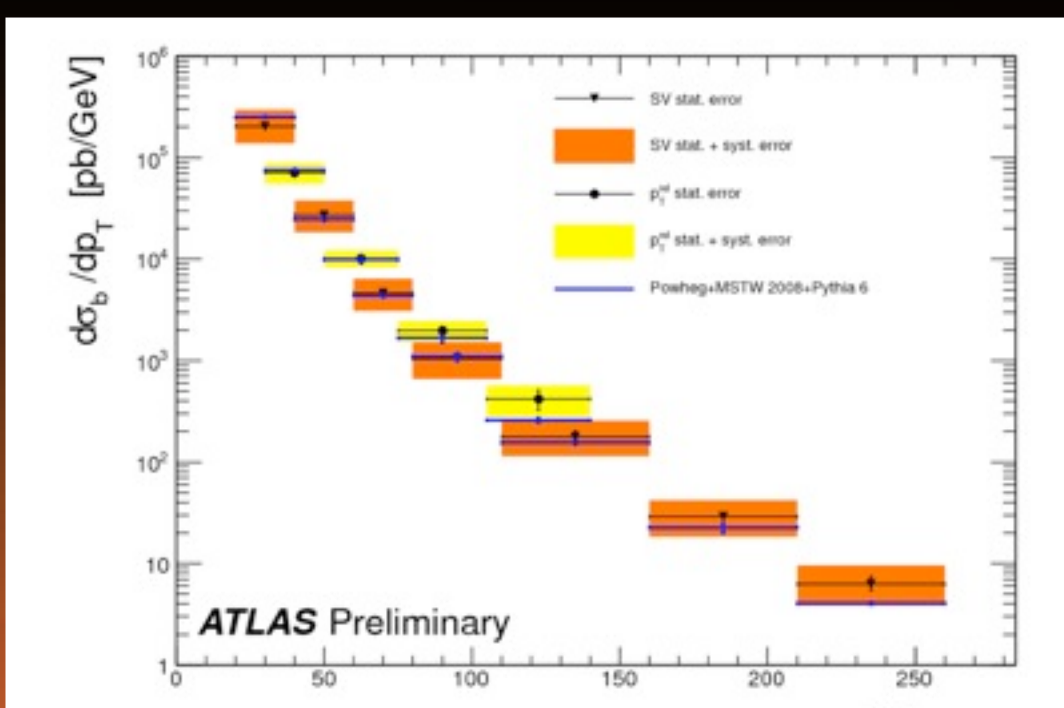
... Physics ...

min.bias charged particle spectra

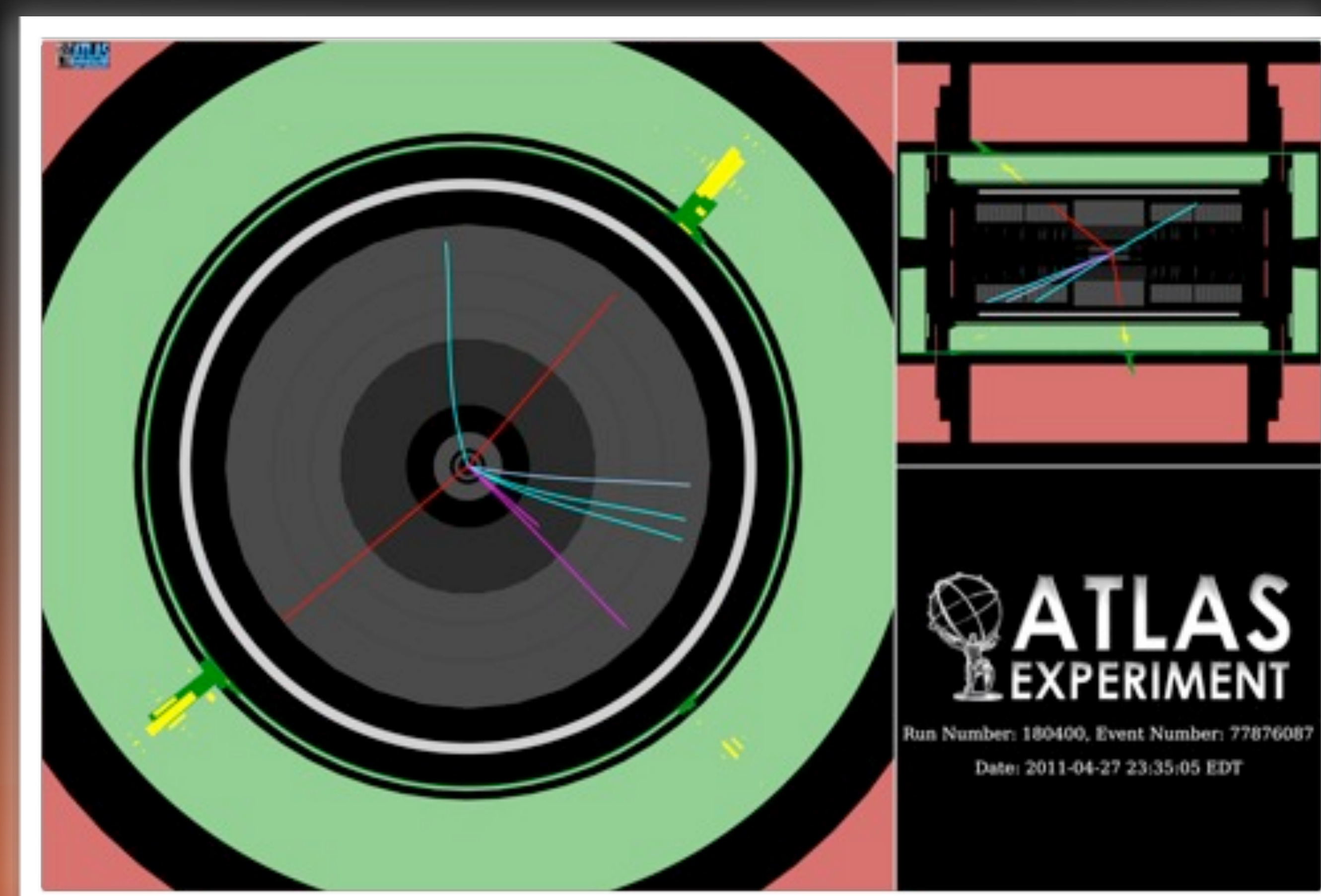


first top event in ATLAS with nice b vertices (2010)





inclusive b-jet cross-section

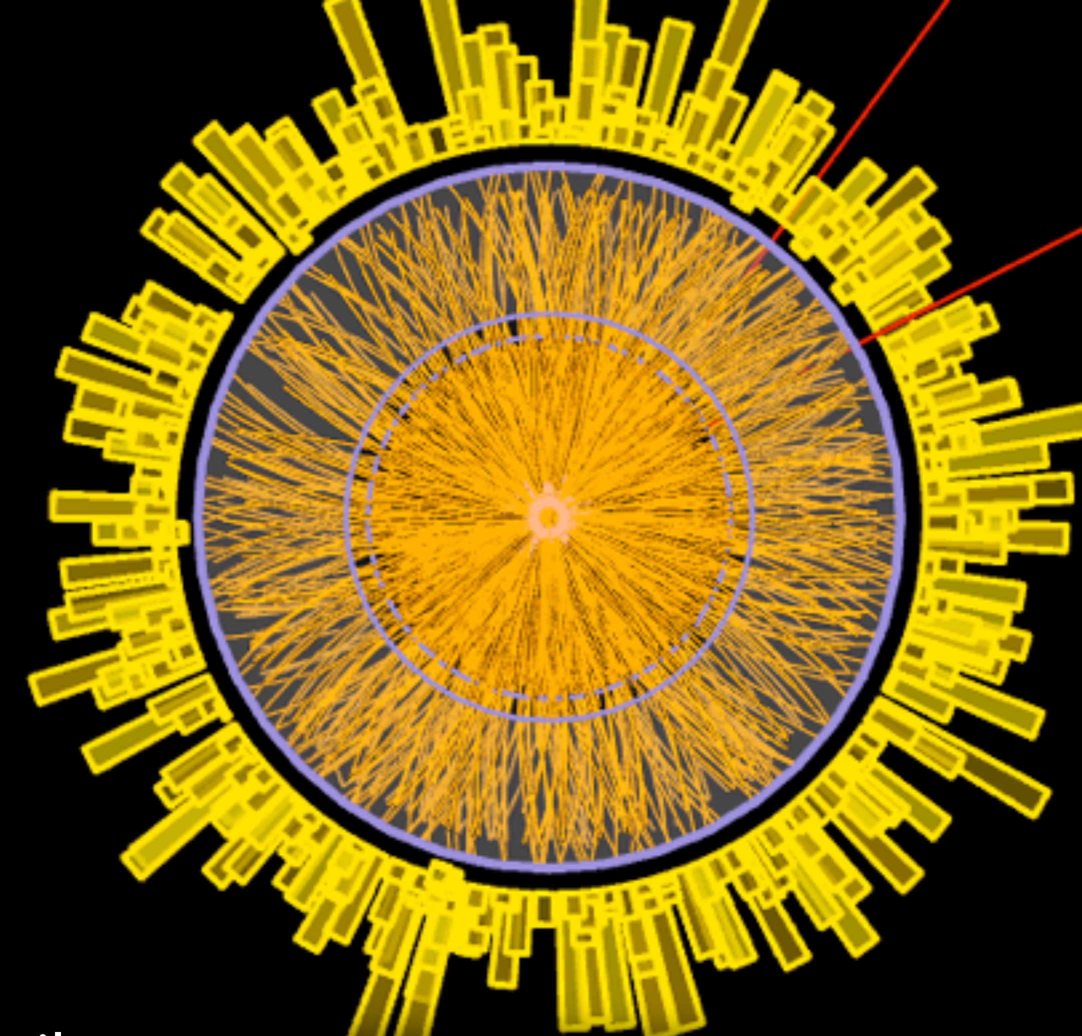


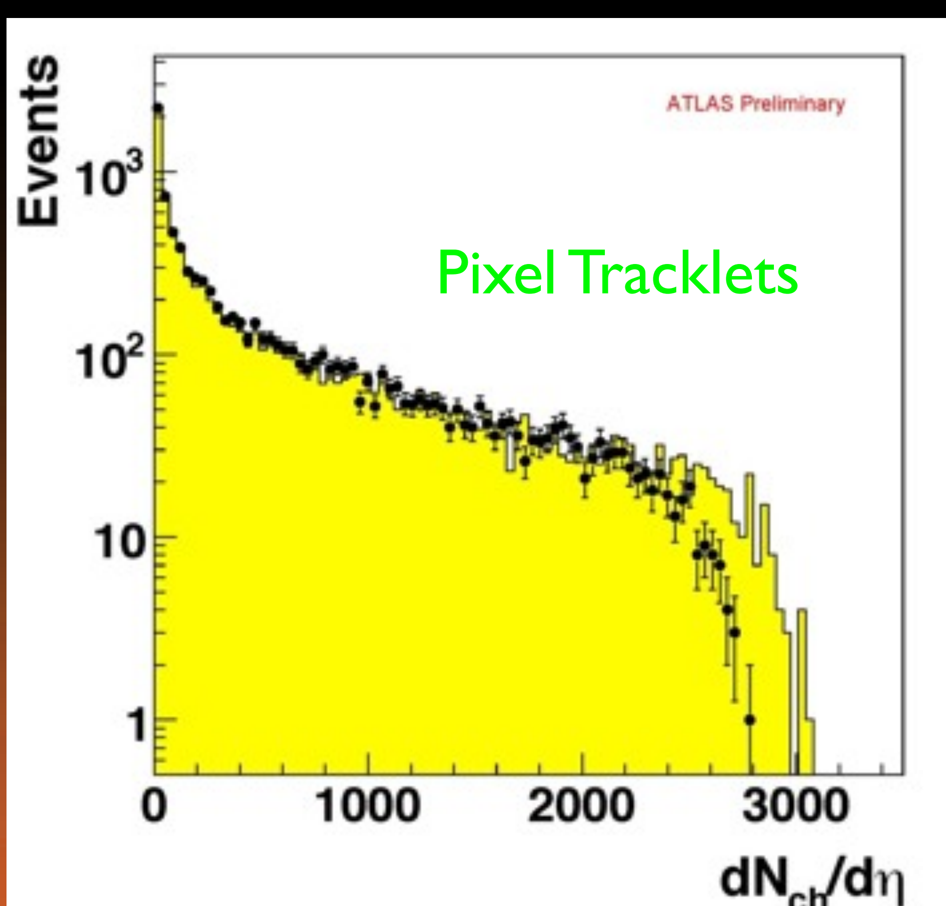
920 GeV ee invariant mass candidate (2011)

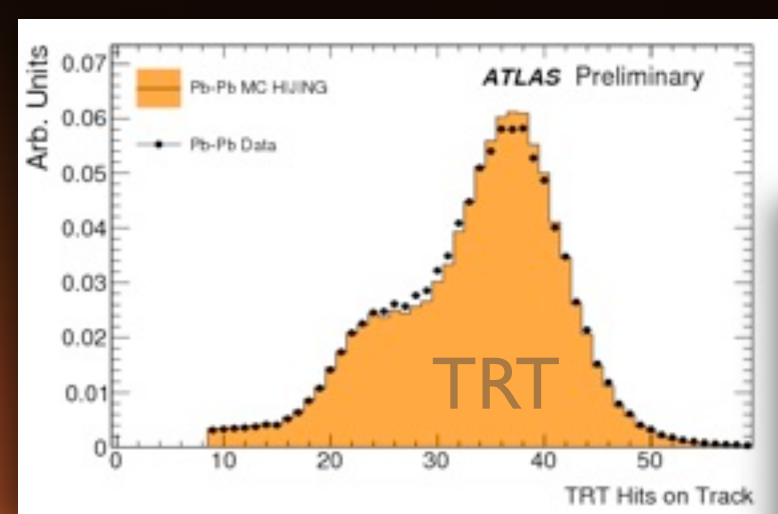
Heavy Ion Tracking

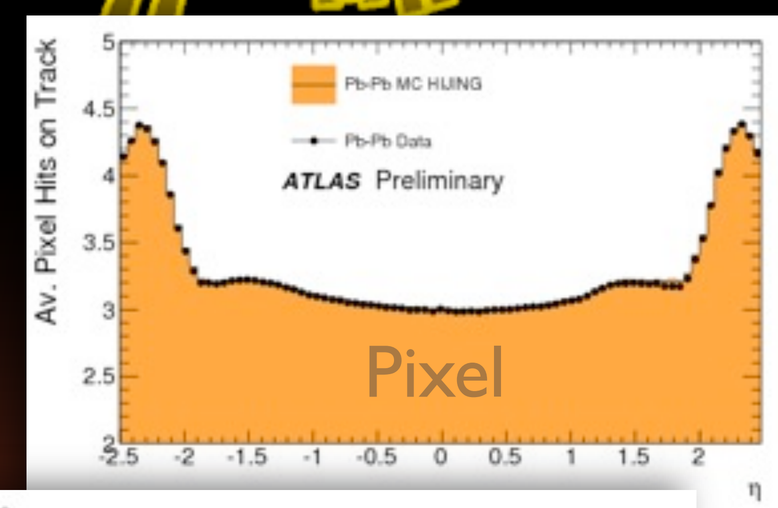
- high multiplicity tracking
  - ➡ adapt seed finding
    (z vertex constraint to save CPU)
  - ➡ tighten hit requirement to control fakes in central events (similar to sLHC setup)

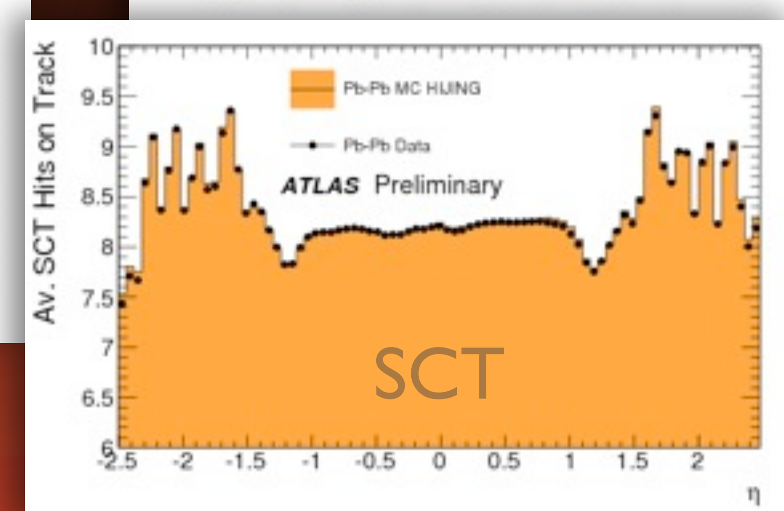
- excellent tracking performance
  - ➡ as well good testing ground for high in-time pileup





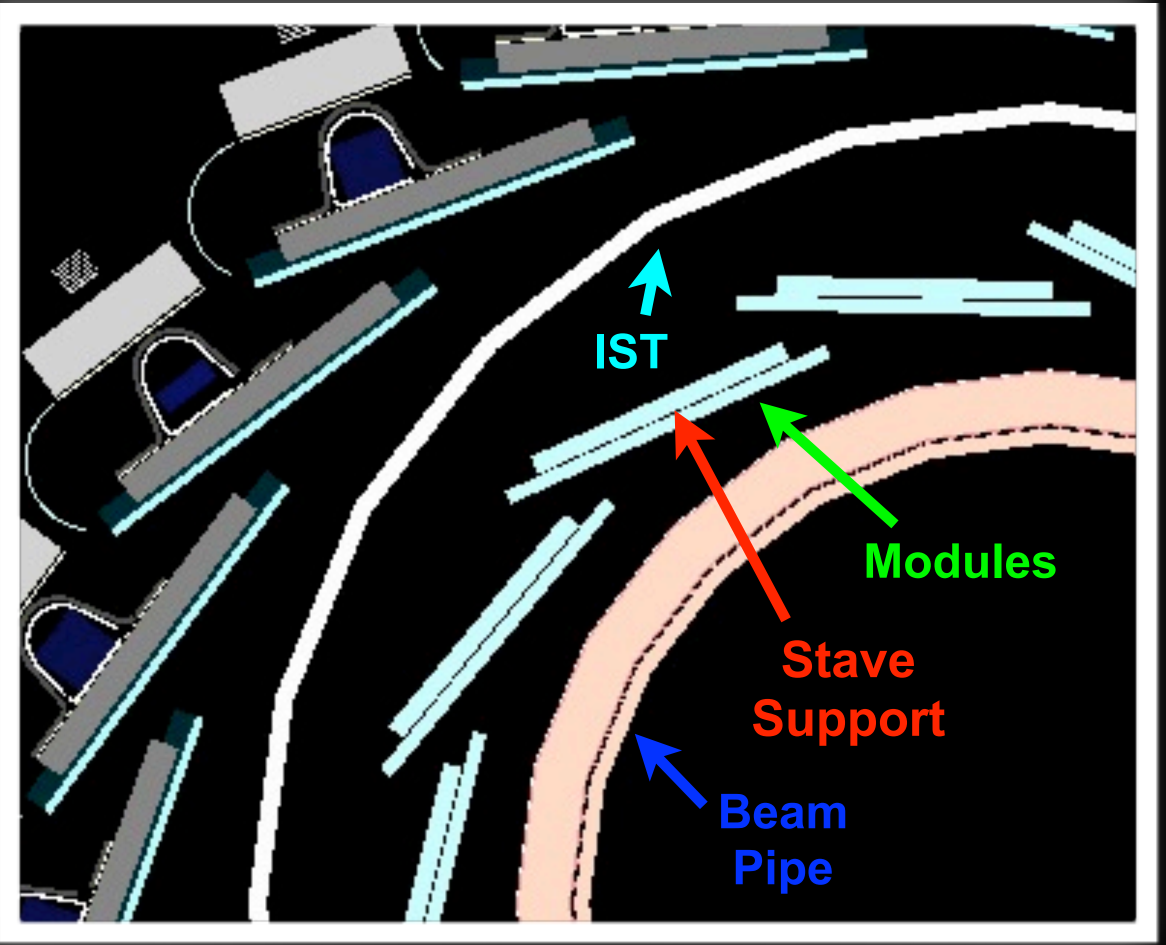


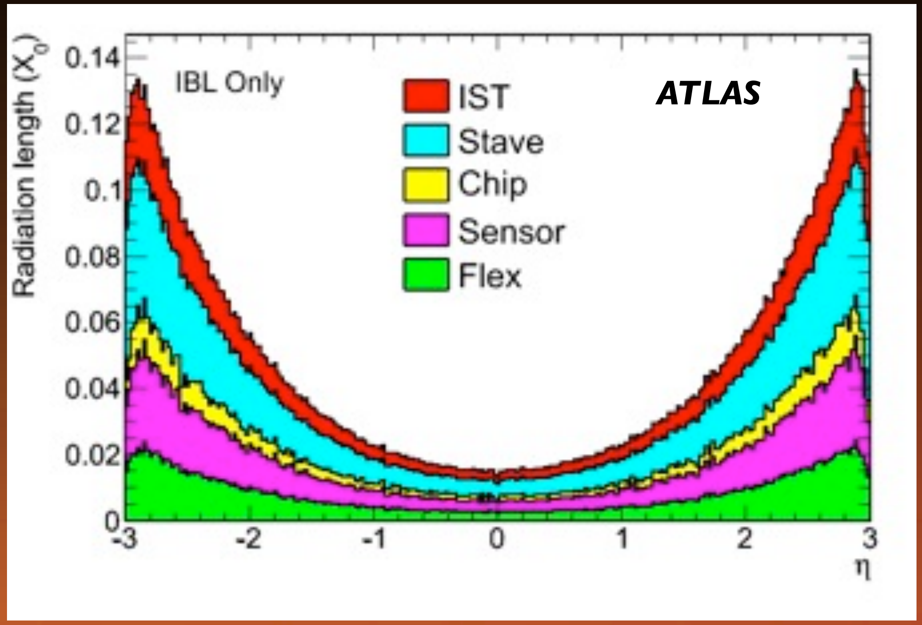


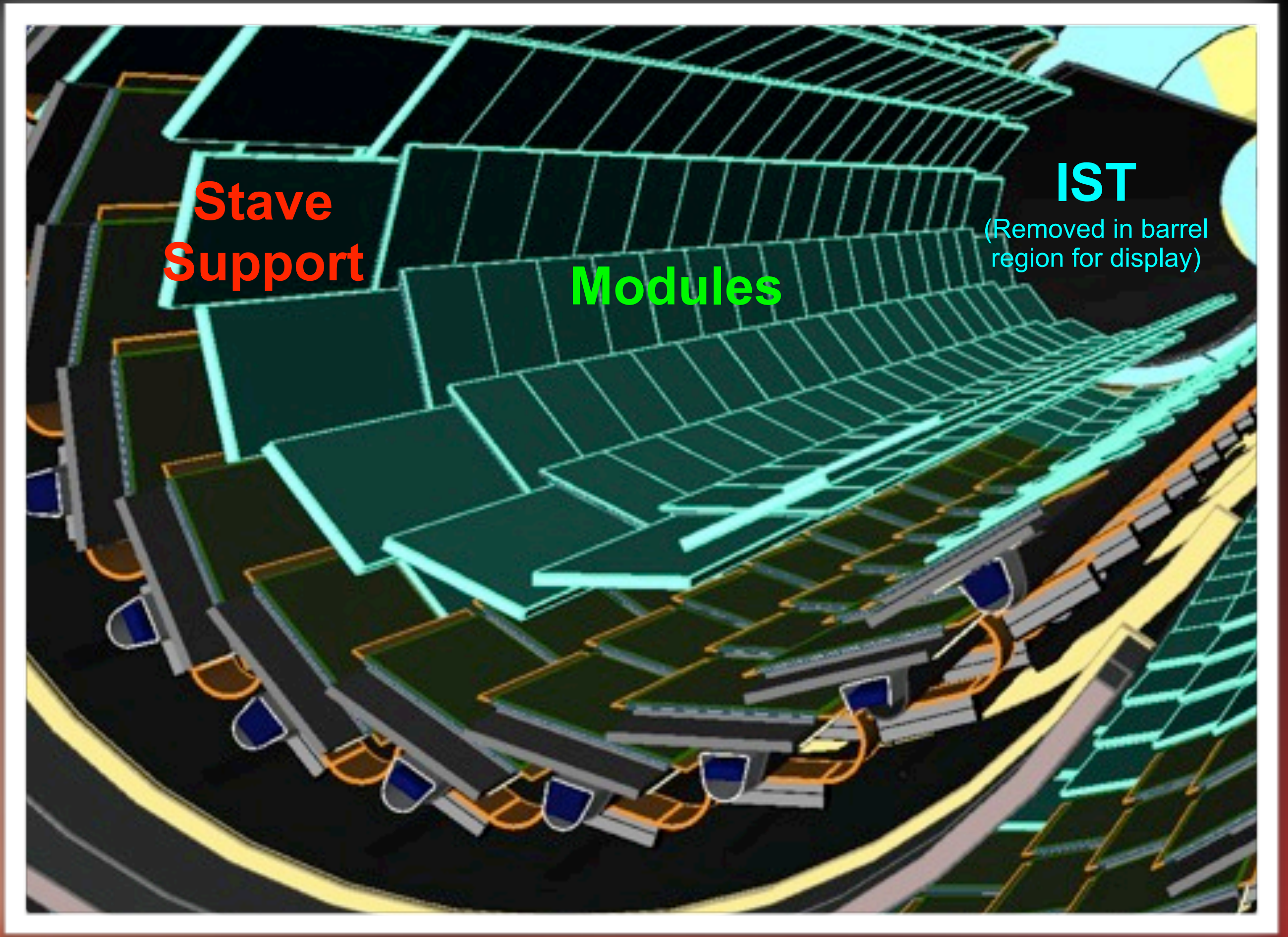


Outlook: IBL Tracking

- performance studies in G4
  - ➡ smaller beam pipe (R_{min} = 25 mm)
  - ➡ reconstruction: 4th Pixel layer
  - ➡ IBL material adjusted to 1.5% X0
  - ➡ smaller z pitch (250 um)
- installation next shutdown
  - ➡ ready for 14 TeV running
  - ➡ peak luminosities of $2{*}10^{34}$ $cm^{-2}s^{-1}$
  - ➡ 25-50 pileup events

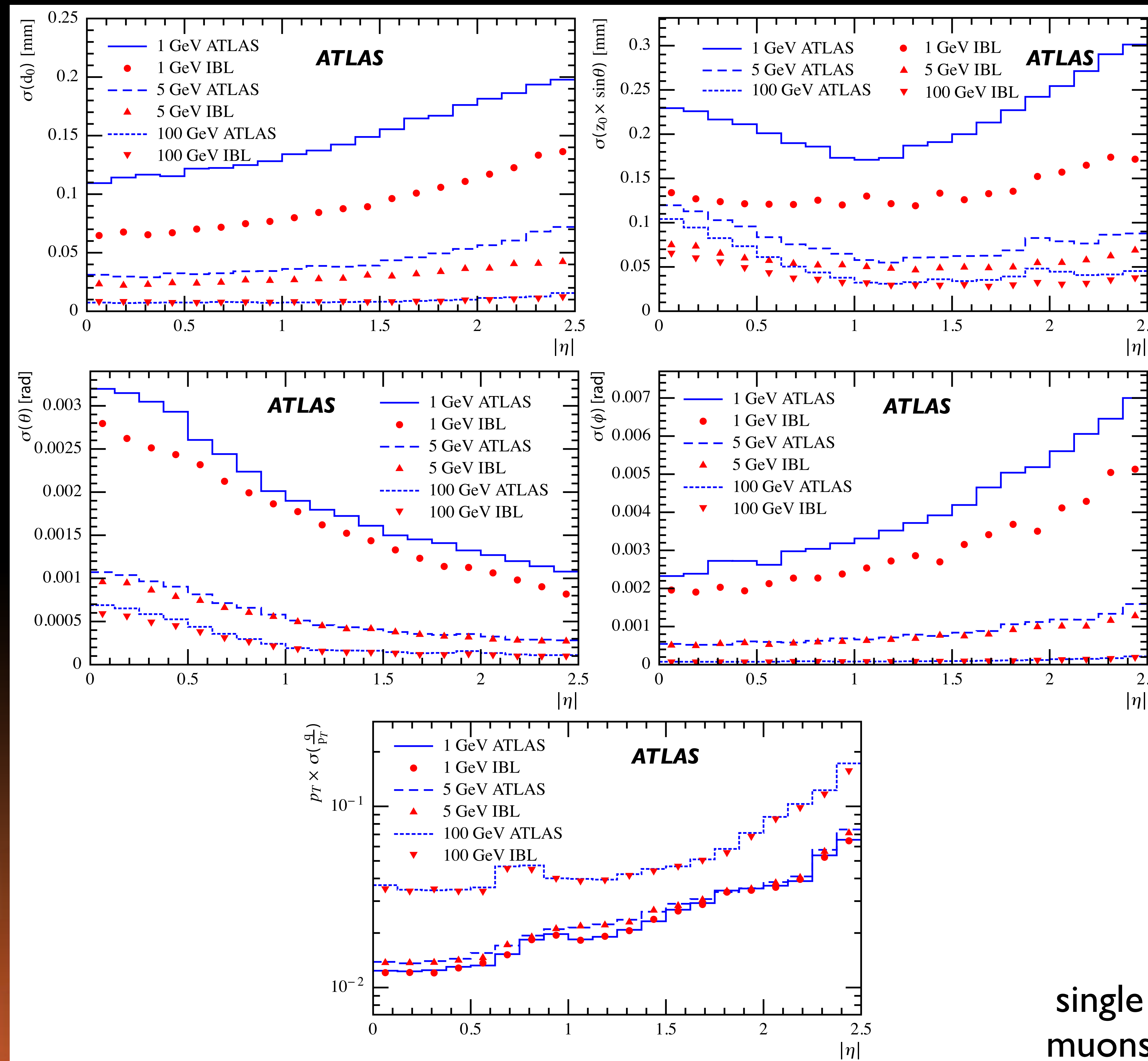






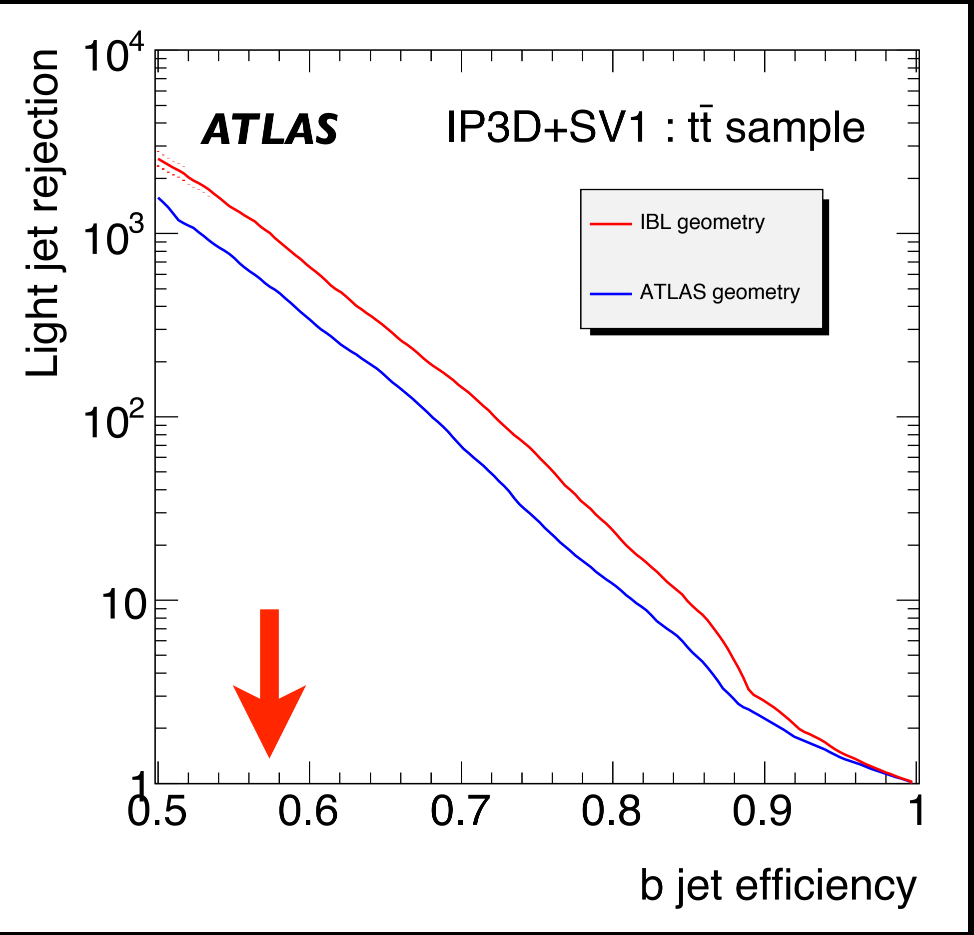
Tracking Performance with no Pileup

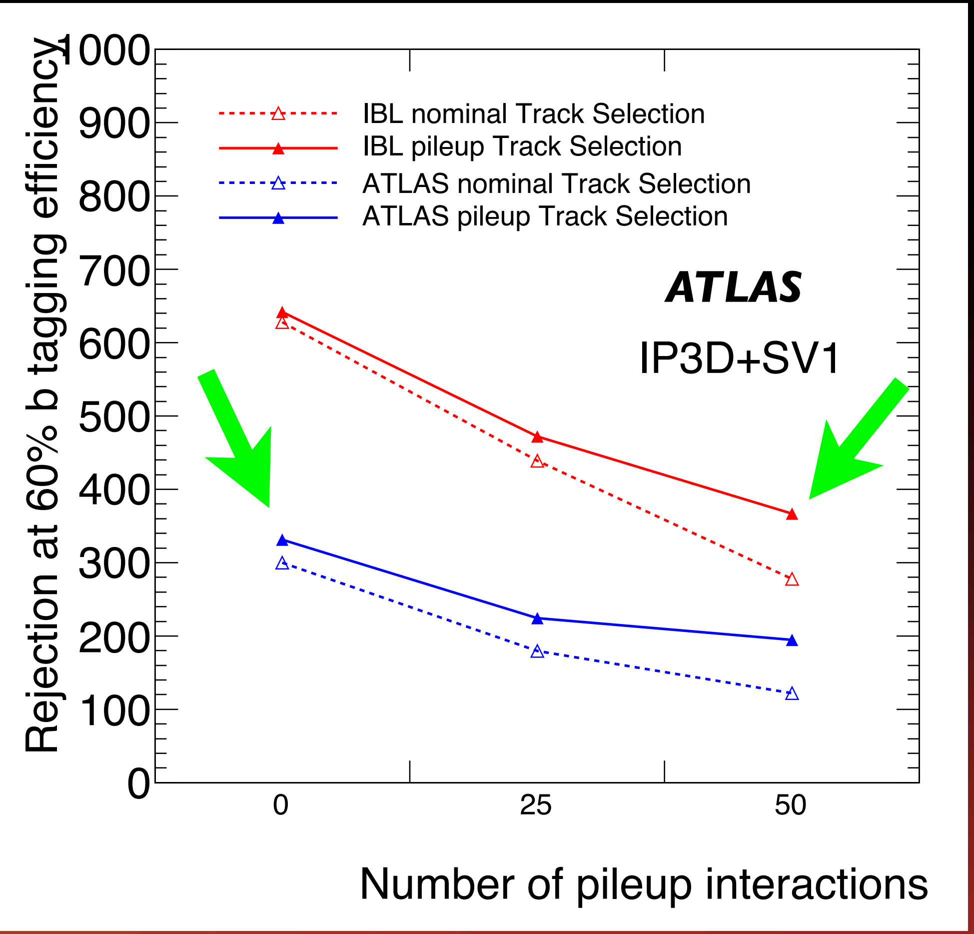
- expected results
  - ➡ smaller radius
  - ➡ small z pitch
  - ➡ less material between first and 2nd layer
  - ➡ track length ~ same
- improvements
  - ➡ better d_0 resolution
  - ➡ better z_0 resolution
  - ➡ θ and ϕ improved at low-pT
  - ➡ momentum resolution ~ unchanged
- as expected !



b-Tagging with IBL

- pileup selection with IBL
  - ➡ ≥10 IBL+Pixel+SCT hits, ≤1 pixel hole
  - ➡ benefit from additional layer
  - ➡ leaves room for eventual inefficiencies in b-layer (tracking robustness)
- state of the art b-tagging
  - ➡ "IP3D" ~ $d_0 \oplus z_0$ impact significance likelihood
  - ➡ "IP3D+SV1" ~ adding secondary vertex information
- good performance with IBL and pileup
  - ➡ as good or better as for current ATLAS without pileup
- more on IBL in Heinz's talk...





Summary

- stringent requirements on Inner Detector track reconstruction to cover ATLAS physics program
- excellent performance reached !
  - ➡ years of preparation based on simulation and test beam
  - ➡ commissioning with cosmics and early beam
  - ➡ detailed studies of detector, tracking, material, alignment, ...
- Heavy Ion running as well gave good insightes into tracking at high occupancy
- tracking studies with IBL demonstrate performance of the detector with a 4 layer Pixel system at Phase 1 luminosities