Vertex and track reconstruction in ATLAS and CMS

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Outline

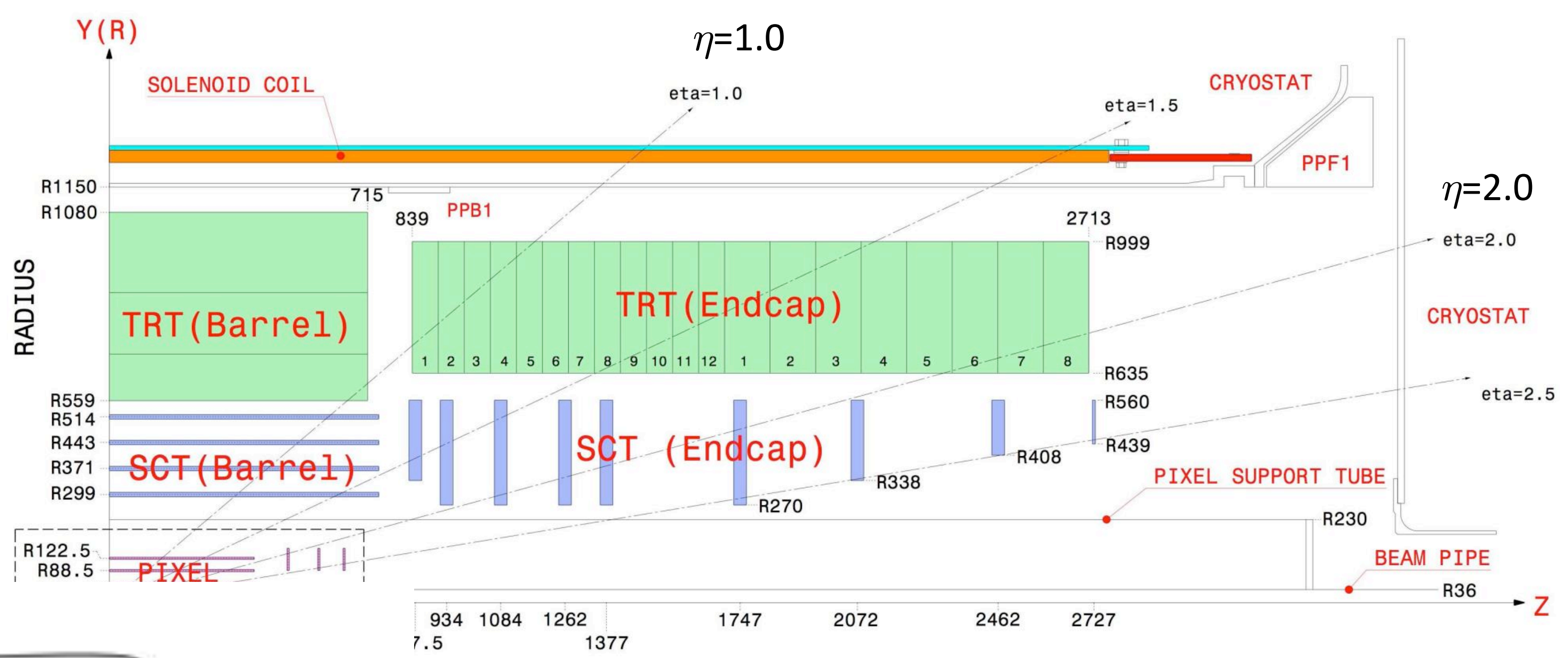
- ATLAS and CMS
  - tracking detectors
  - track and vertex reconstruction
- Performance of vertexing
- The pile-up related effects
- Outlook to Run 2
- Summary

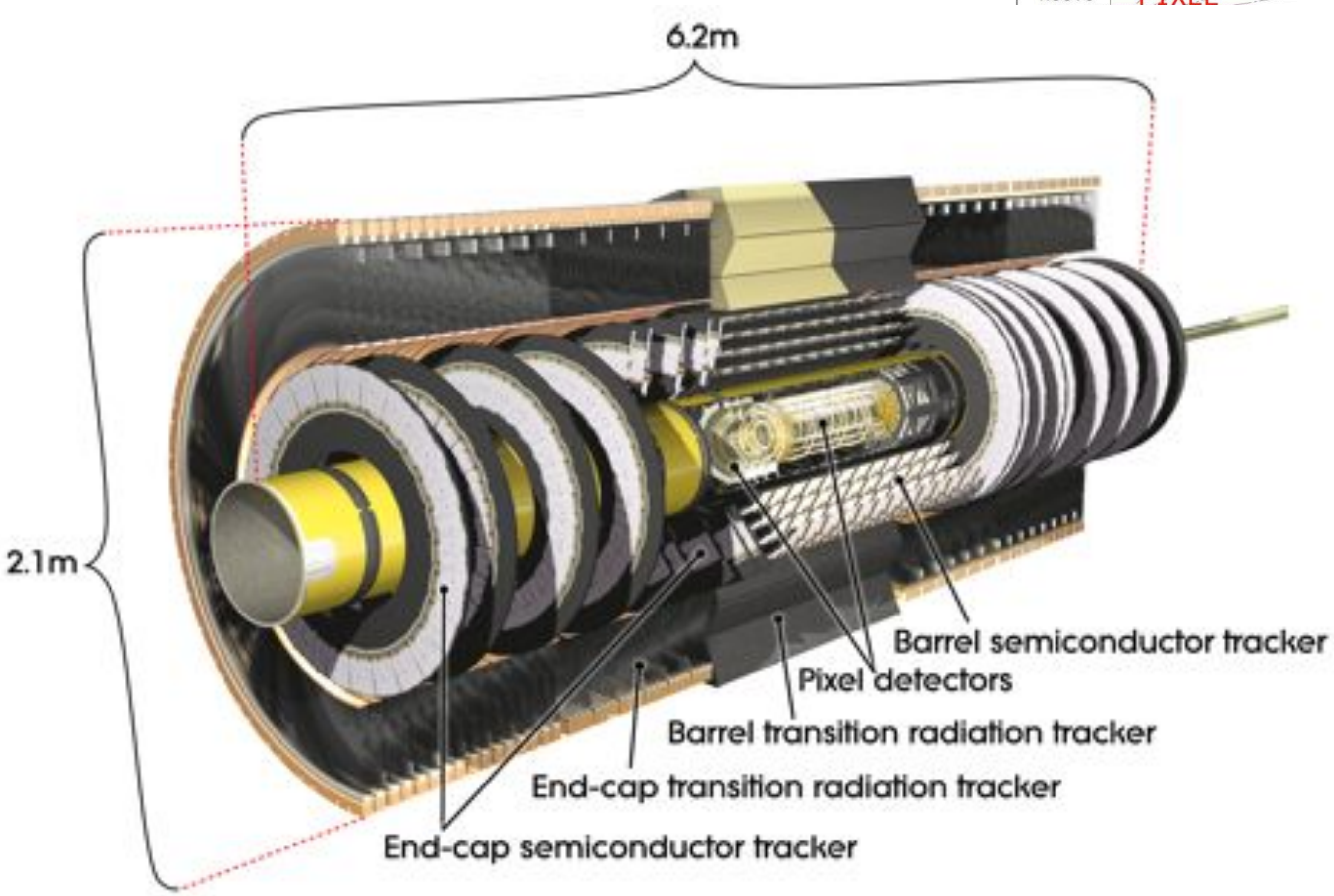
Track and Vertex reconstruction

- tracking and vertexing performance crucial for B-physics
  - identification of the primary interaction
  - reconstruction of the decay
  - precise measurements of decay lengths/time
  - fundamental for separation of signal and background
- high efficiency and high precision essential
  - vertex resolutions and resolutions of track parameters (impact parameters in particular)
- ATLAS and CMS have excellent tracker systems to explore heavy flavour physics

ATLAS Inner Detector

- pixel+ double sided silicon strip+ transition radiation tracker technologies
- in 2T solenoidal field
- |η|<2.5

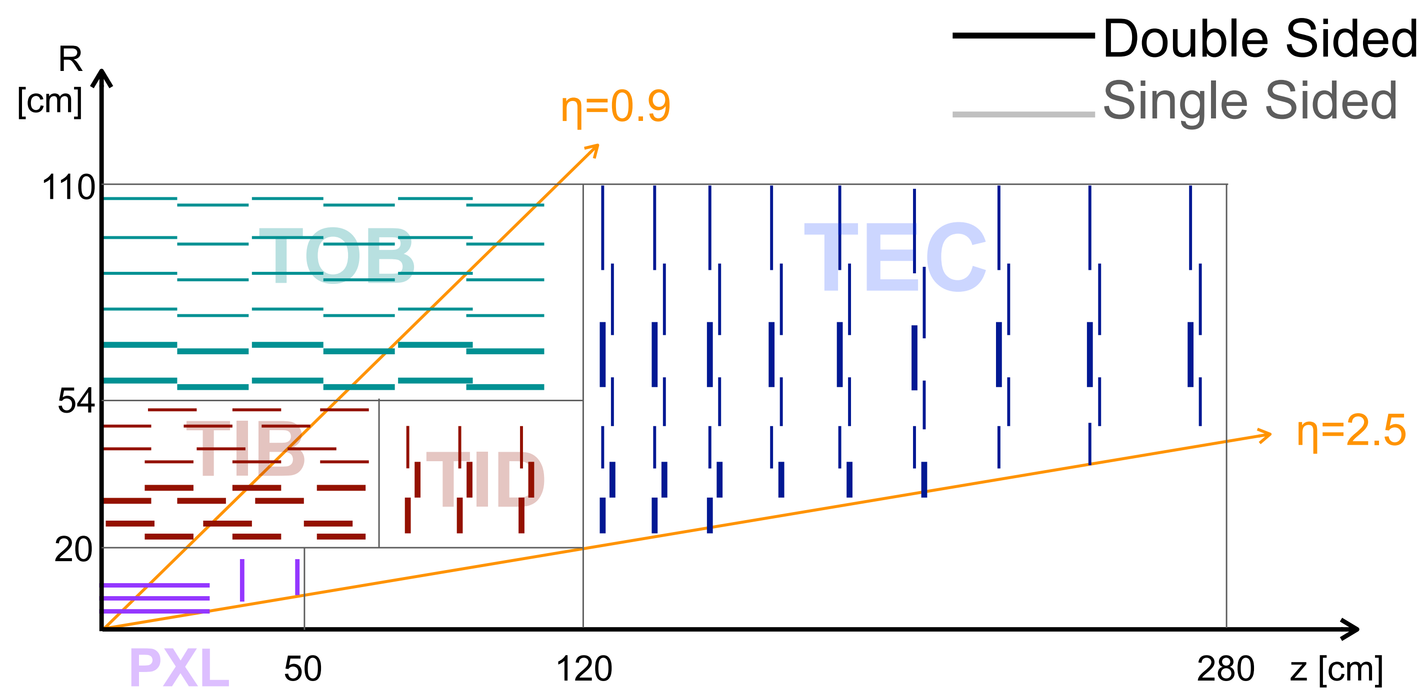


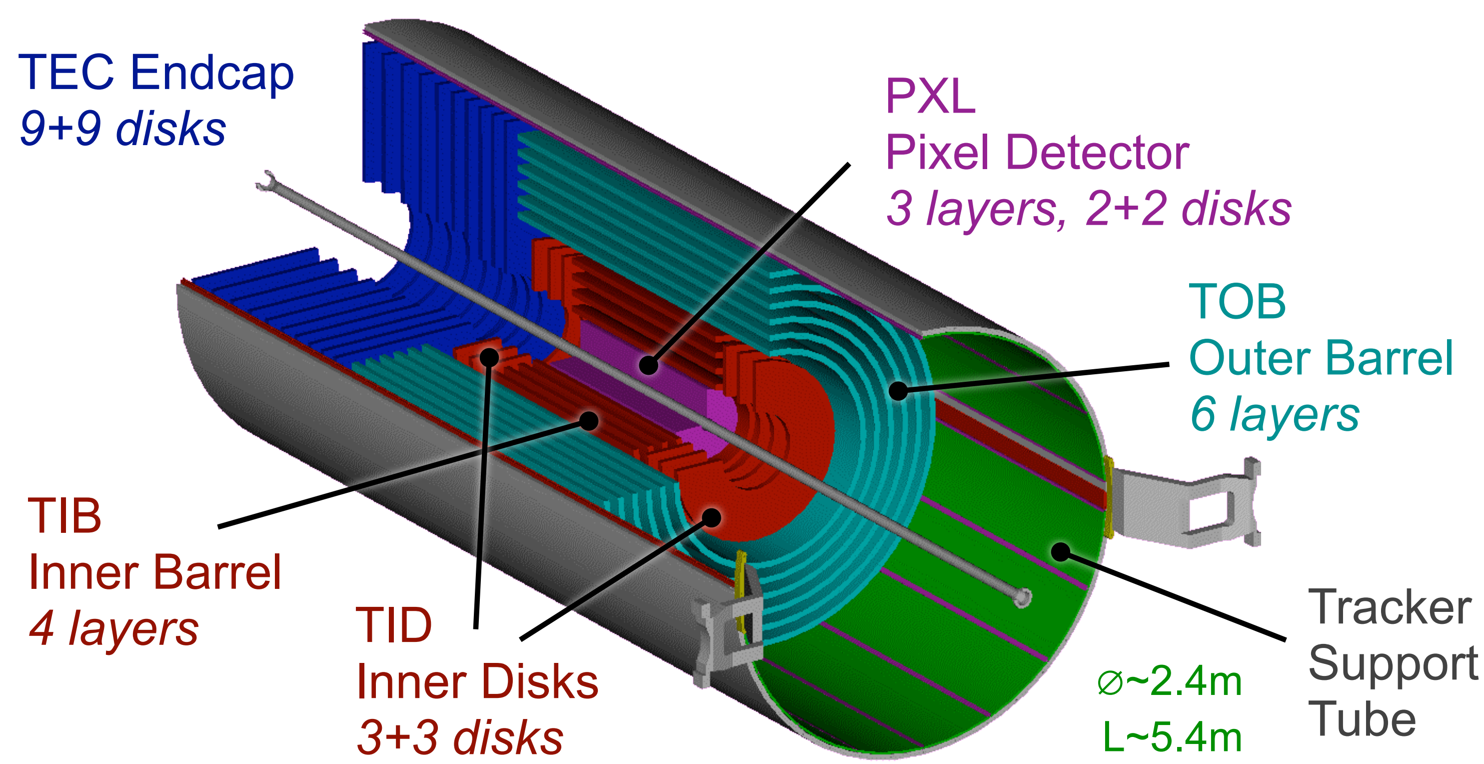


	channels	dimensions	<hits on track>
Pixel	80M	50μmx400μm	3
SCT	6.3M	~80μm	8
TRT	350k	straws R=2mm	~30

CMS tracker

- Pixel (100μm x 150μm) in
  - 3 barrel layers (R =4.4cm - 10.2cm)
  - 2 endcap disks
  - 66M channels
- Strip tracker (~100μm strip pitch)
  - 10 barrel layers (R=25.5cm-110cm)
  - 12 endcap disks, single sided and double sided layers
  - 10M channels
- |η|<2.5
- typically ~16 hits on track
- 3.8T solenoidal field
- with 200m^2 of sensitive area the largest silicon tracker





Track and Vertex Reconstruction

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- ATLAS tracking
  - 3 space point seeds
  - combinatorial Kalman filter adding hits
  - resolution of ambiguities between track candidates
  - track extension to TRT
  - track fit
  - pT>400MeV in the baseline inside-out reco
    - lower pT tracks can be reconstructed in second stage by repeating the seeding on unused hits
  - also outside in with seeds from TRT and extending to silicon
- iterative vertex finding
  - vertex seeds from z-distributions of tracks along beamline
  - χ^2 weight for each track @vtx
    - if weight >7σ->a new vtx seed
    - iterate until no new seeds

CMS

Tracking

•similar principles as in ATLAS, the reconstruction makes use of the iterative track finding

•7 passes of seeding+kalman filter

- •removal of used seeds/hits
- •loosening the pT, d0 compatibility with beam line

•the seeds triplets or doublets with beam constraint

•Tracks from secondary vertices special seeding after first pass

•Vertexing

- clustering tracks with required criteria (impact param significance wrt beam line, number of hits, X^2) along z
- adaptive vertex fit

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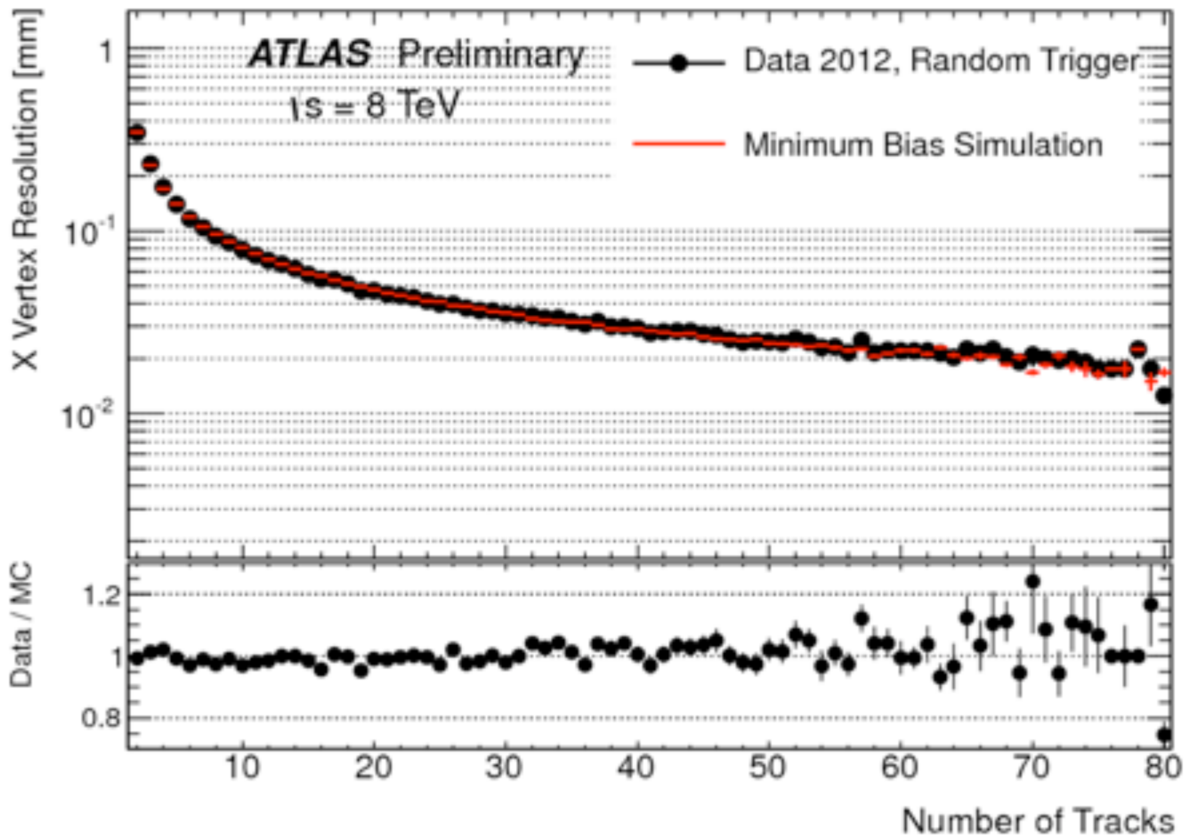
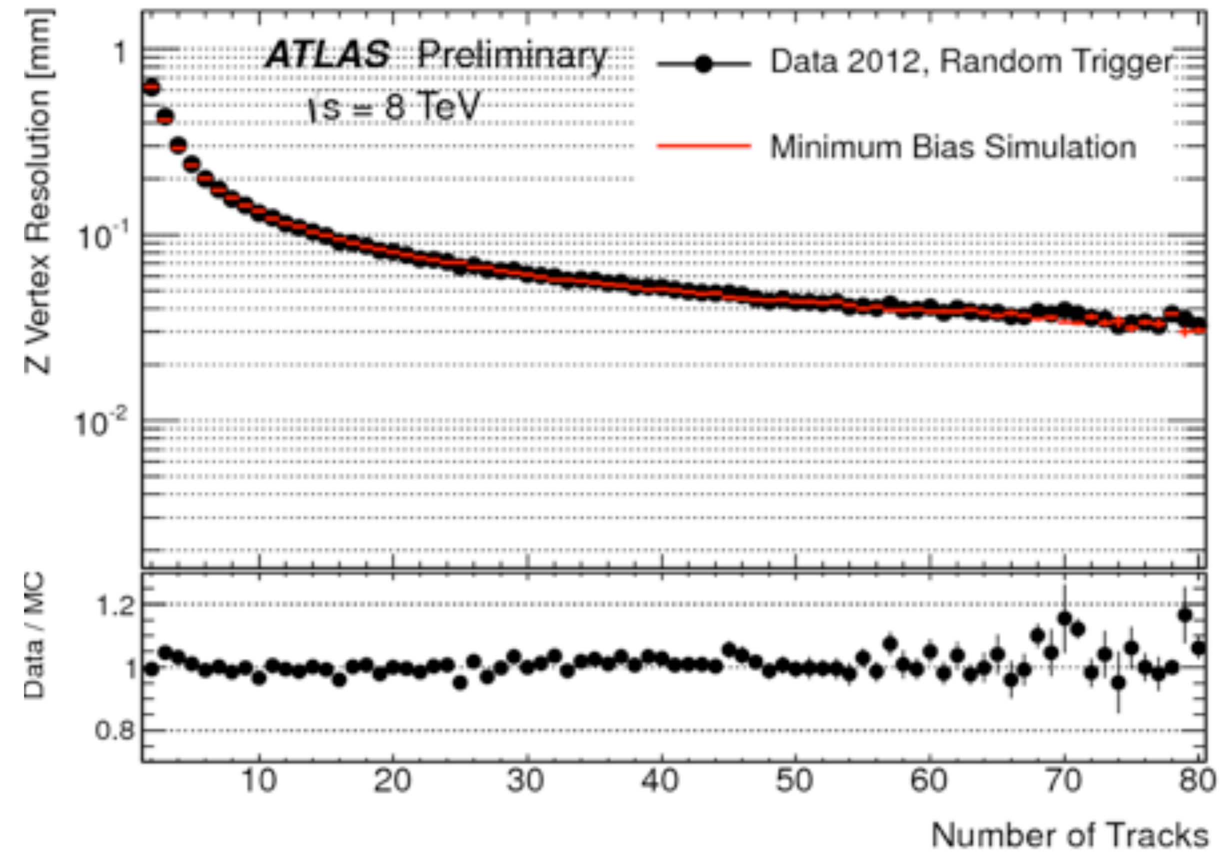
Performance of the vertexing and of the tracking

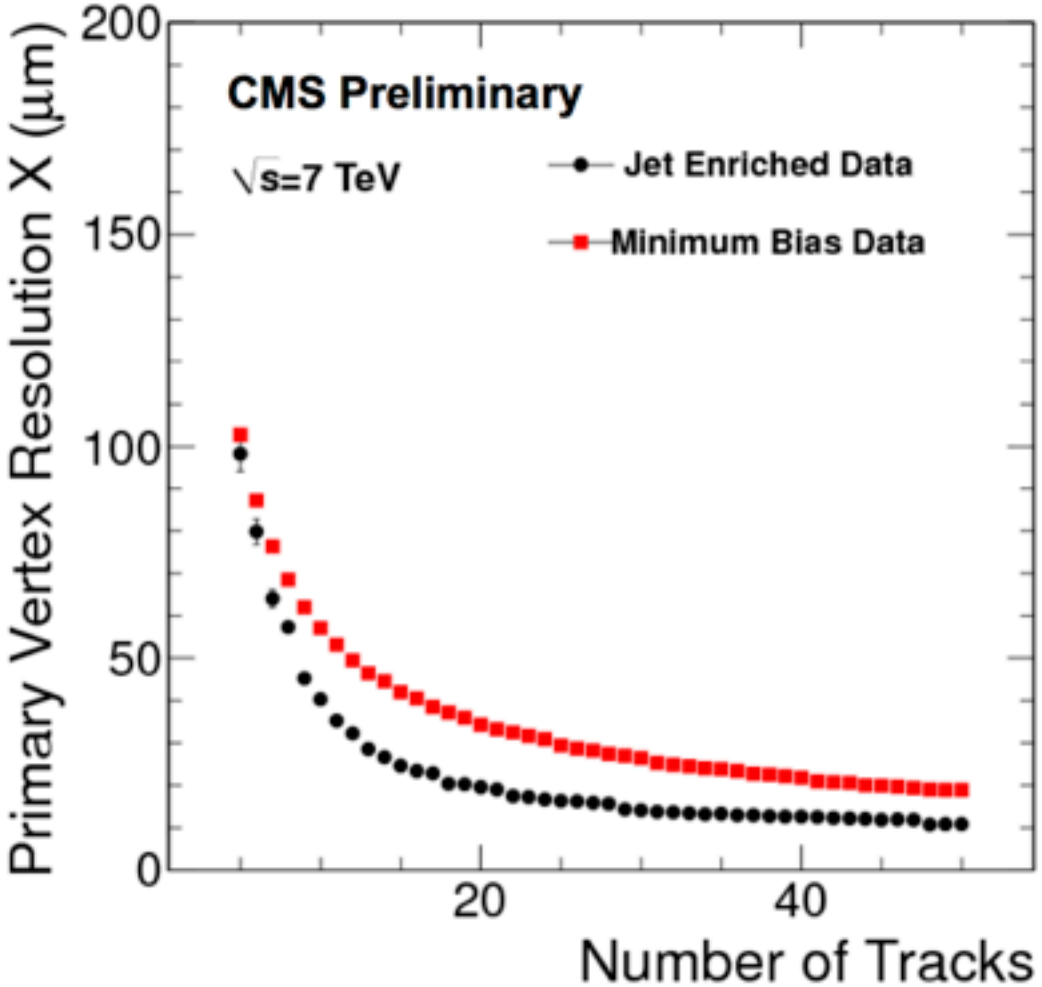
Vertexing resolution/ATLAS

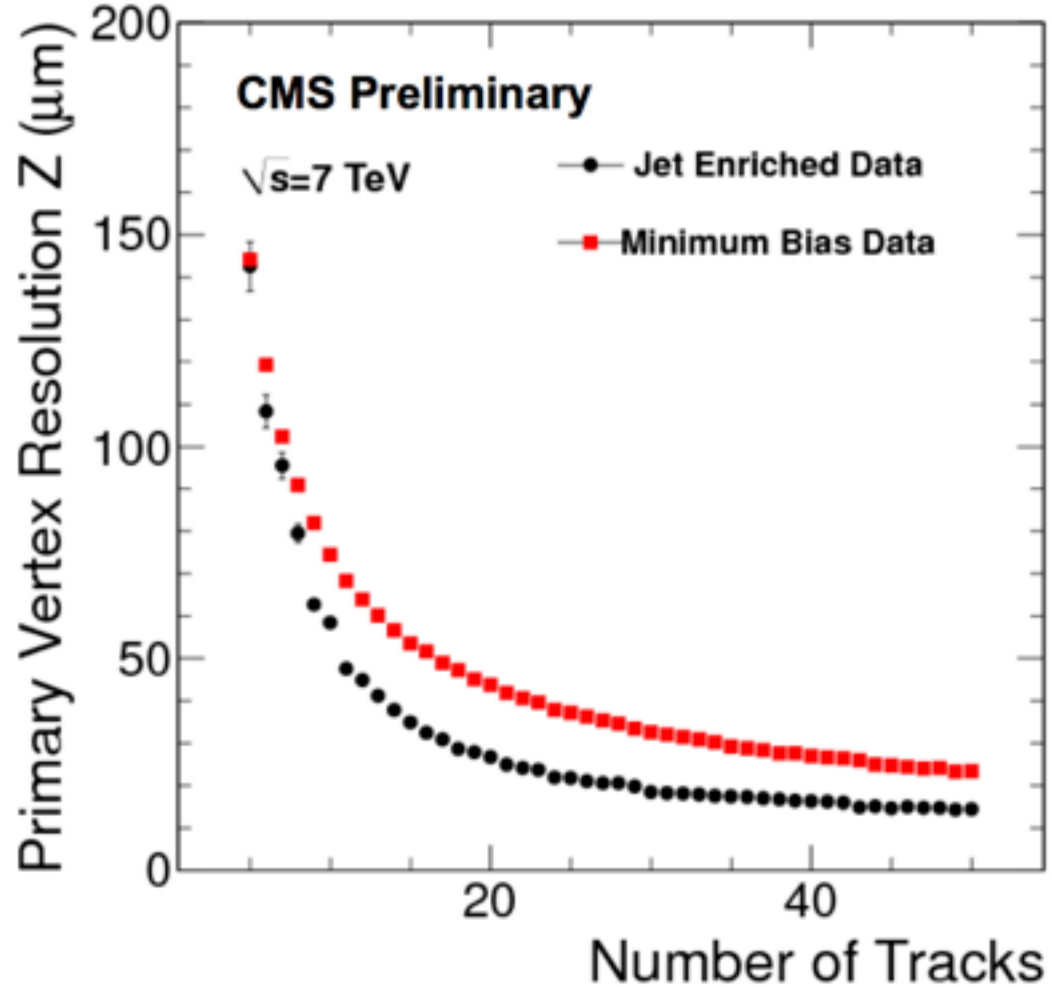




- Resolutions obtained from comparison of split vertices
  - tracks from a single vertex split into 2 sets and new vertices formed
  - resolutions derived from the difference of their position
- The resolutions are improving with the number of tracks at vertex
  - smallest resolutions ~20μm and 30μm for X and Z positions respectively
  - agreement between data and MC behaviour

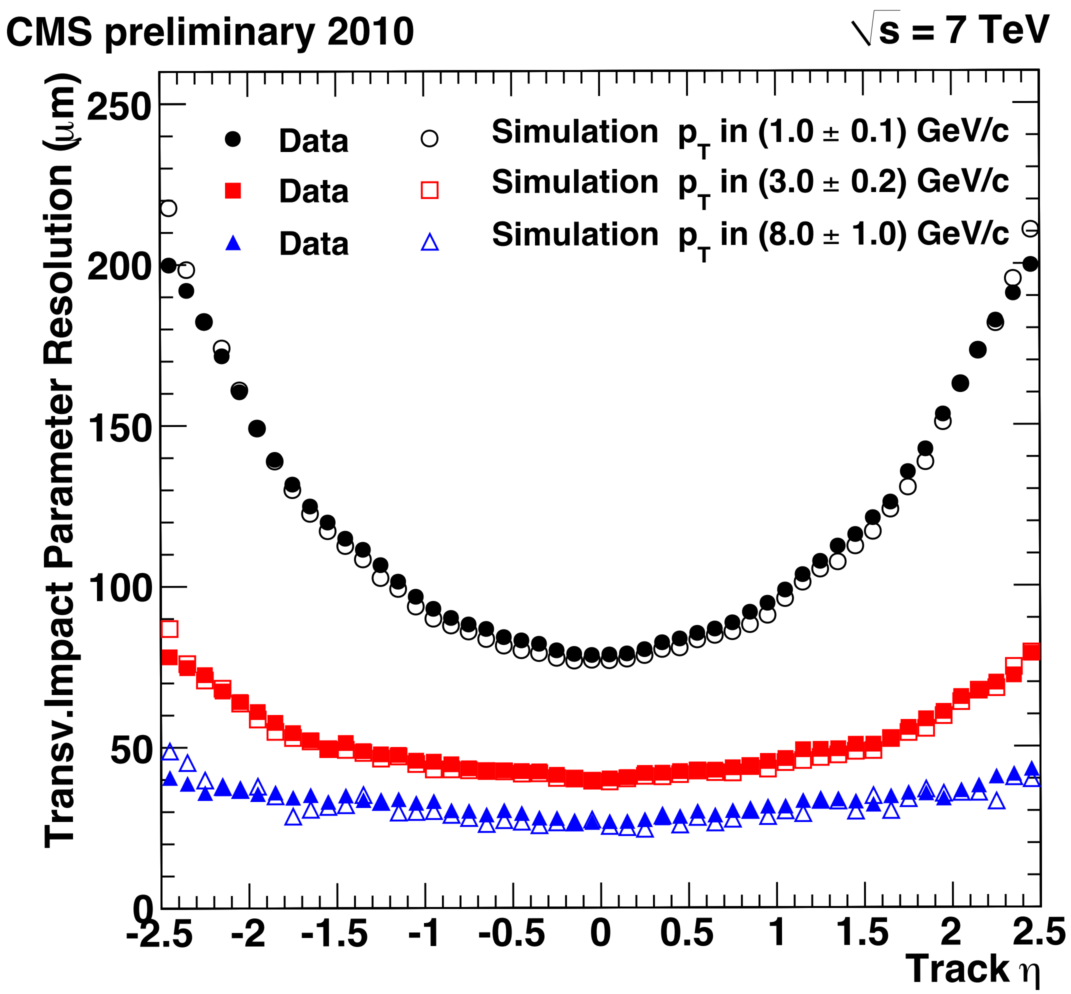
Vertexing resolution/CMS

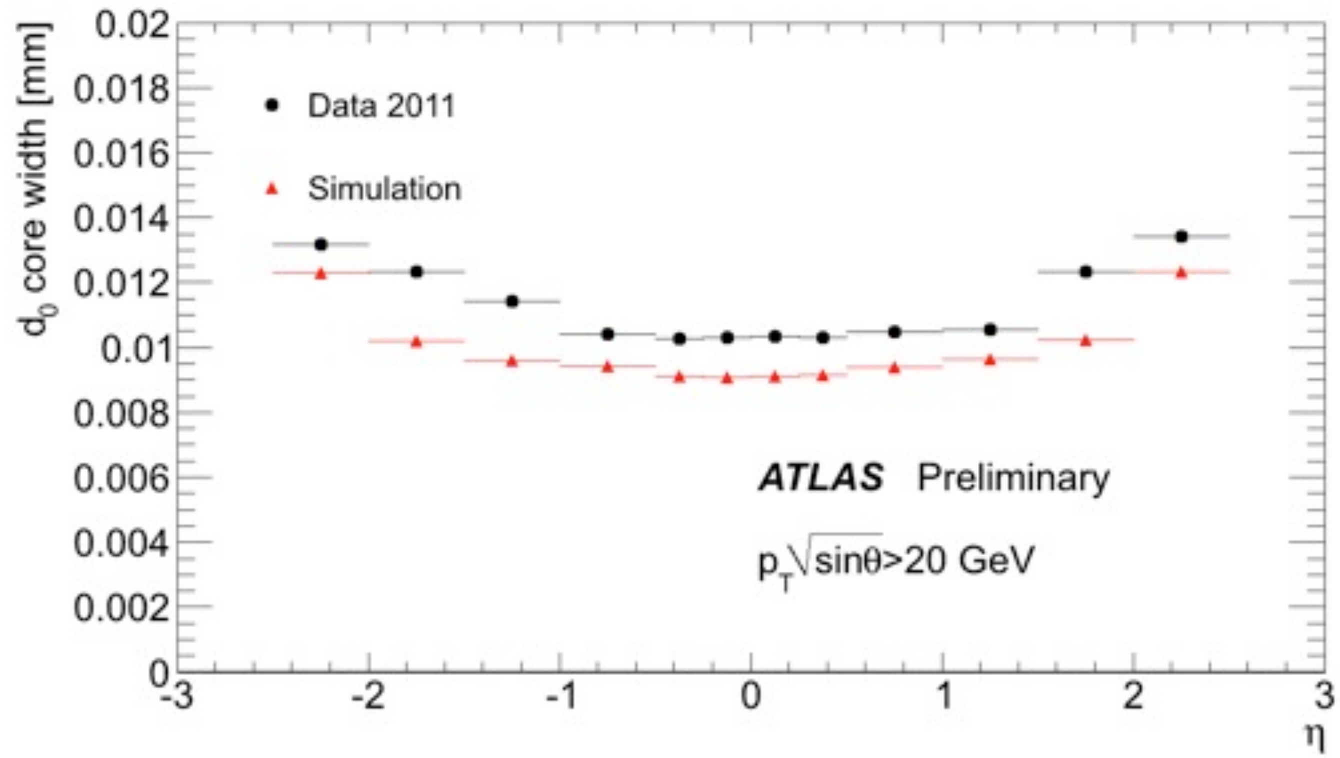


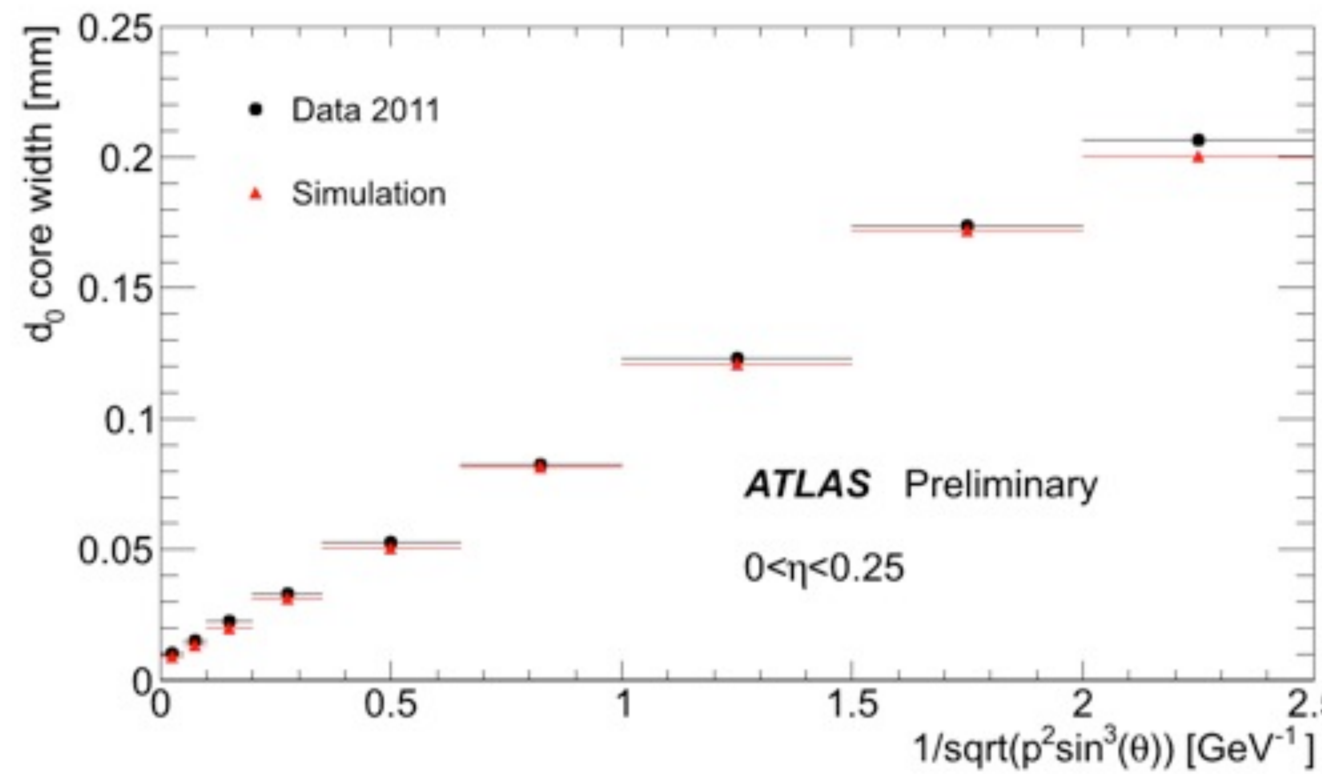


- Jet enriched and Minimum bias selections of events
- split vertex method for data-driven estimation of the resolution
- Minimum bias comparable with ATLAS plots
- equivalent values obtained with less populous vertices than in ATLAS, reached ~20µm in Z resolution

Track parameter resolutions

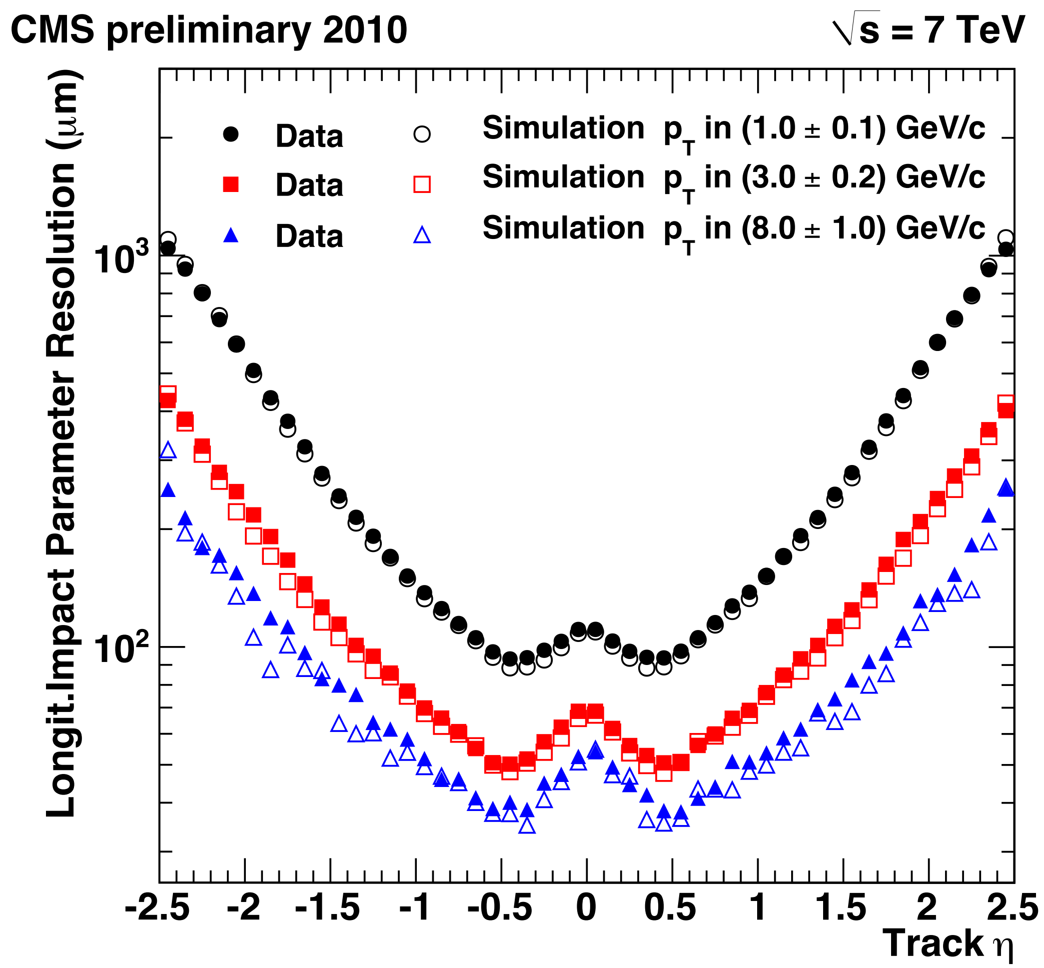


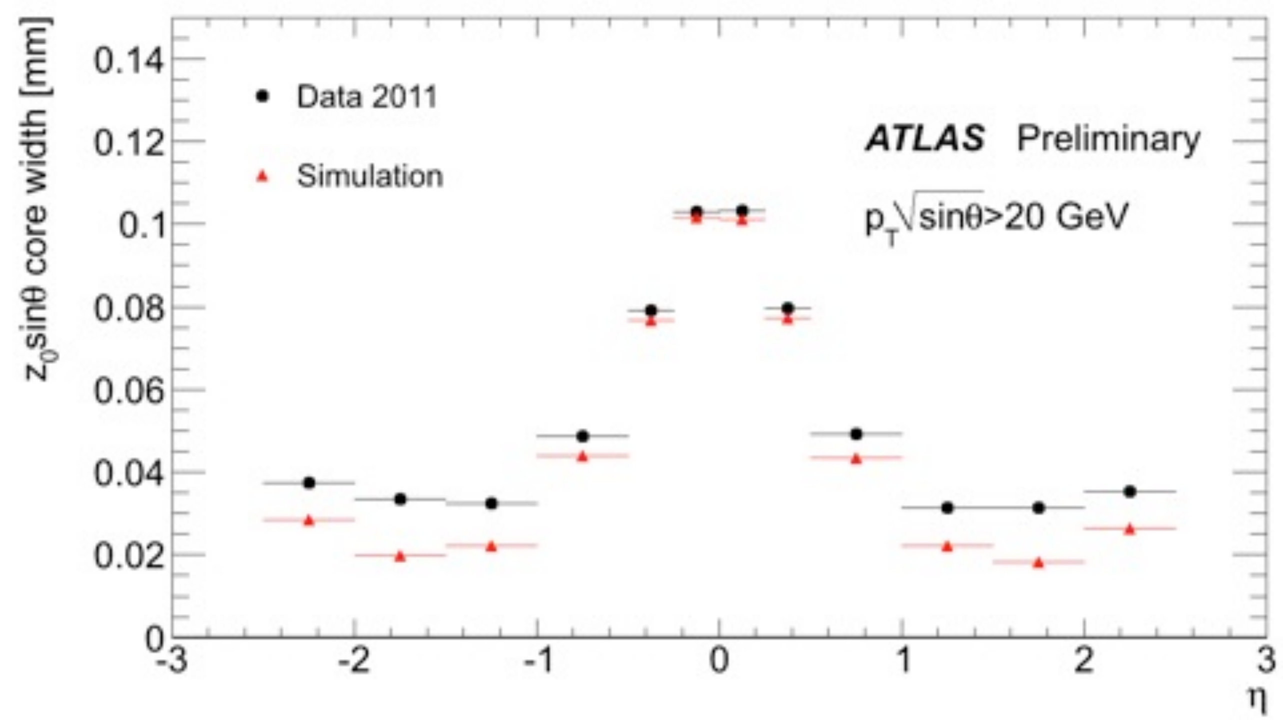




- transverse impact parameter d_0
  - resolution function of η (and increasing amount of traversed material), of pT
  - $p_T\sqrt{\sin\theta}$ from multiple scattering

Track parameter resolutions/II

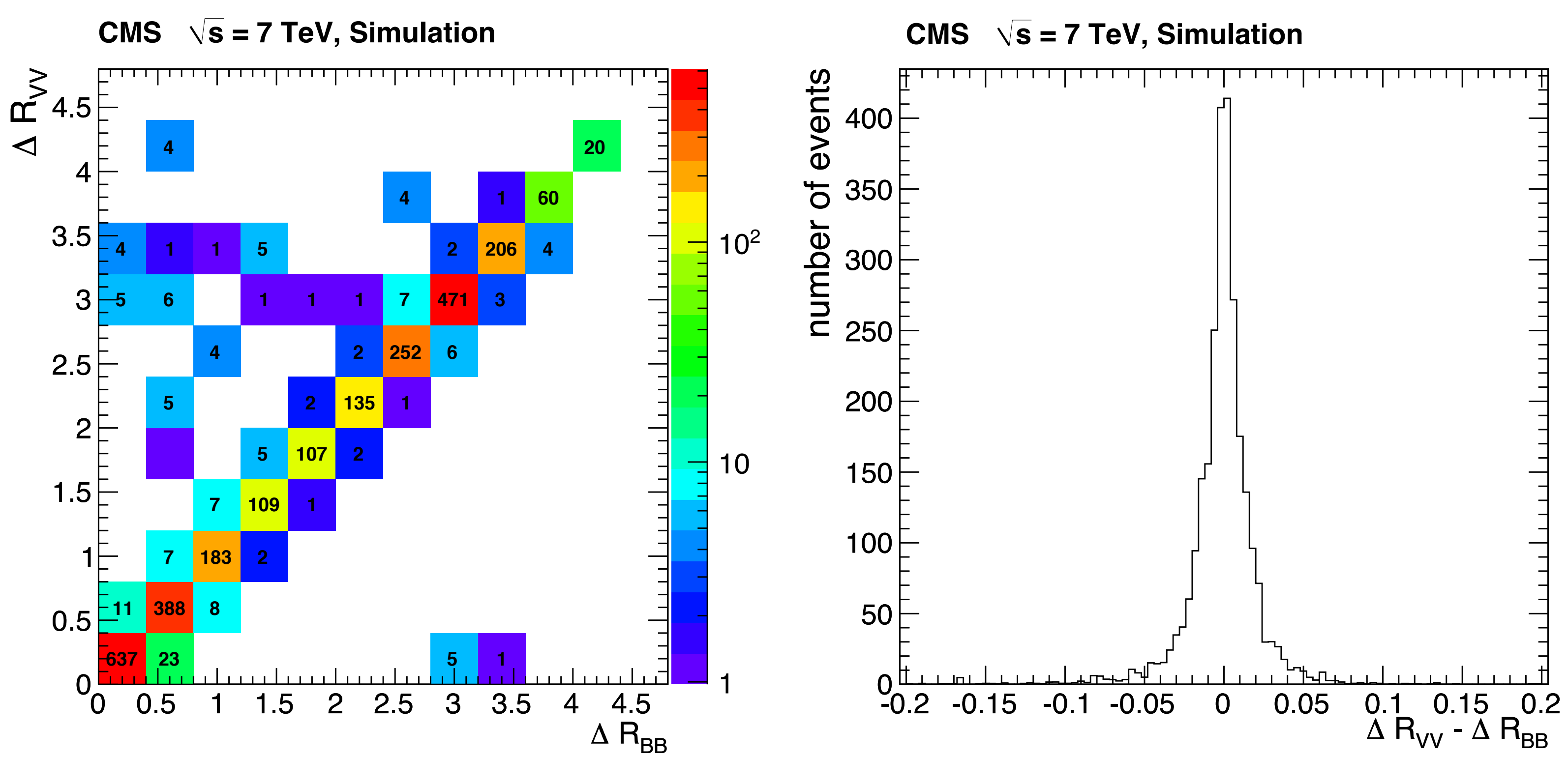




- similar effects as on d_0
- depends on momenta and multiple scattering
- resolution at η=0 worse due to minimal charge sharing
- smaller dimension of CMS pixels along z profitable

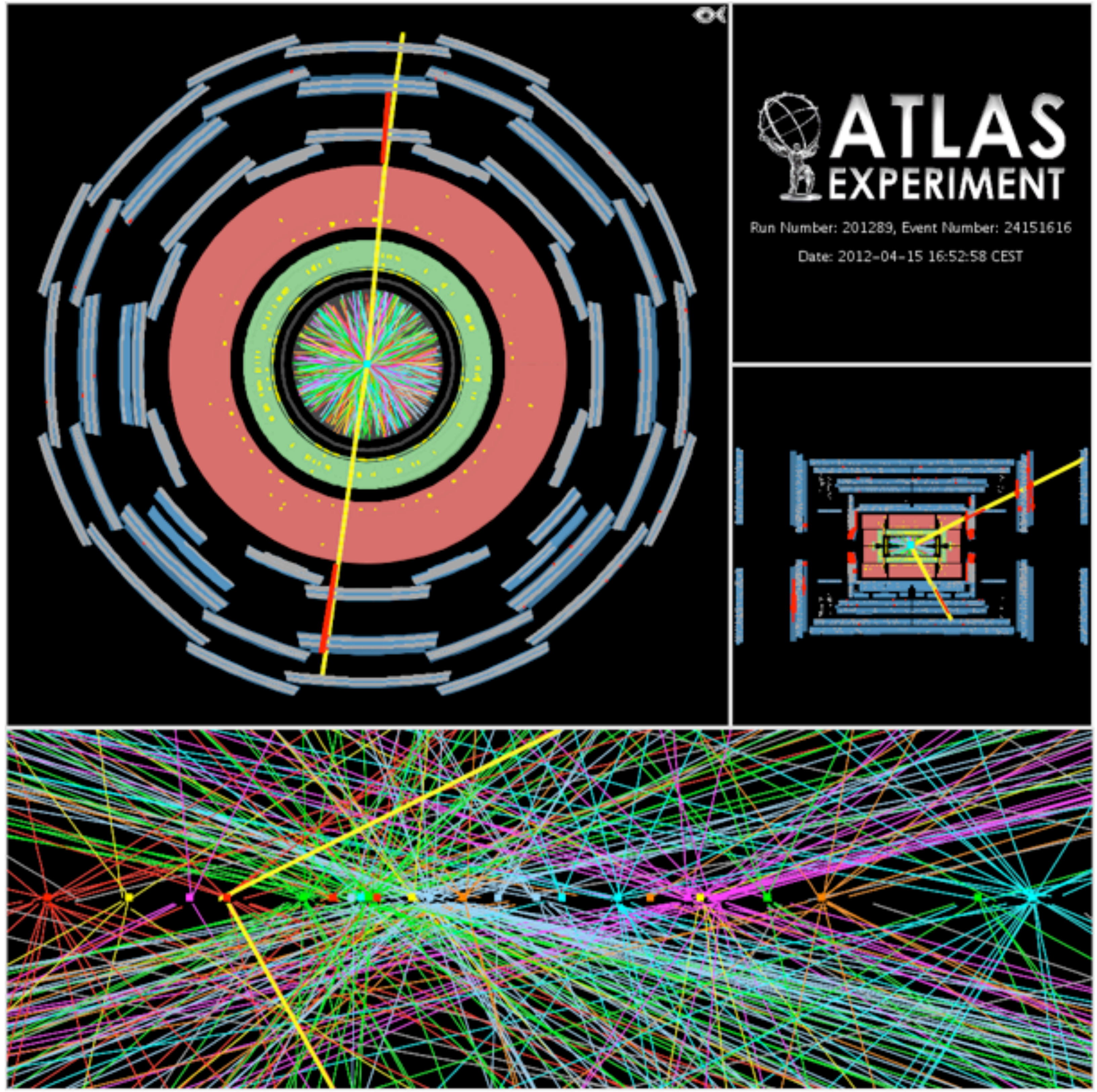
Secondary vertex reconstruction

- iterative inclusive secondary vertex finder technique developed by CMS
  - enhances the capability to detect nearby B hadrons otherwise unresolvable by standard b-tagging method
  - Measurement of BBbar angular correlations based on secondary vertex reconstruction JHEP 03 (2011) 136
- method
  - primary vertex reconstructed from tracks compatible with beamline, sorted by Σp_T^2
  - secondary vertices seeded from tracks with high impact param significance, clustering tracks by separation in distance in 3d, separation significance and angular separation
  - vertex fit and subsequent merging of vertices if more than 70% shared tracks
  - tracks reassigned to primary & secondary vertices based on significance of track to vertex distance



Pile-up

- LHC excellent operation in Run1
  - 50ns bunch spacing-> the level of pileup exceeds design values for the run 1
  - further increase of luminosity after LS1
    - start up again in 50ns
- Challenging reconstruction in the presence of multiple interactions and higher detector occupancy



Z->μμ decay with pileup interactions (25 reconstructed vertices)

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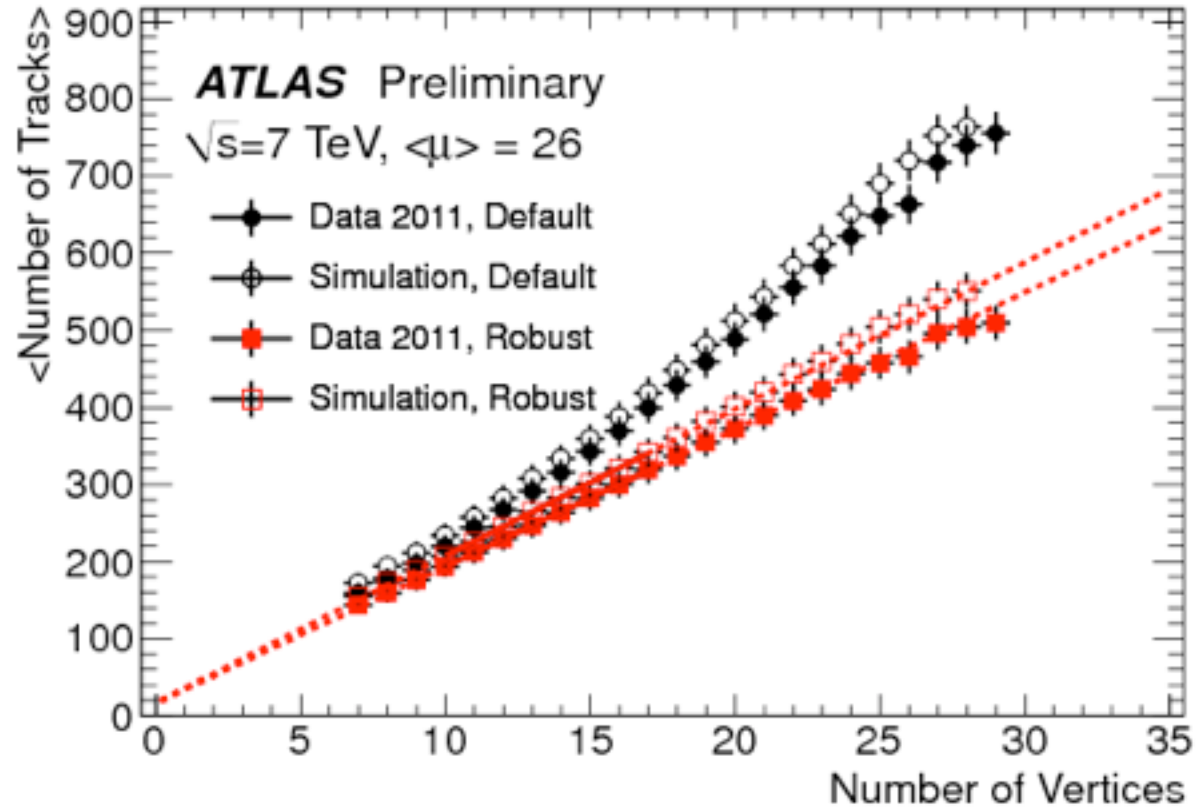
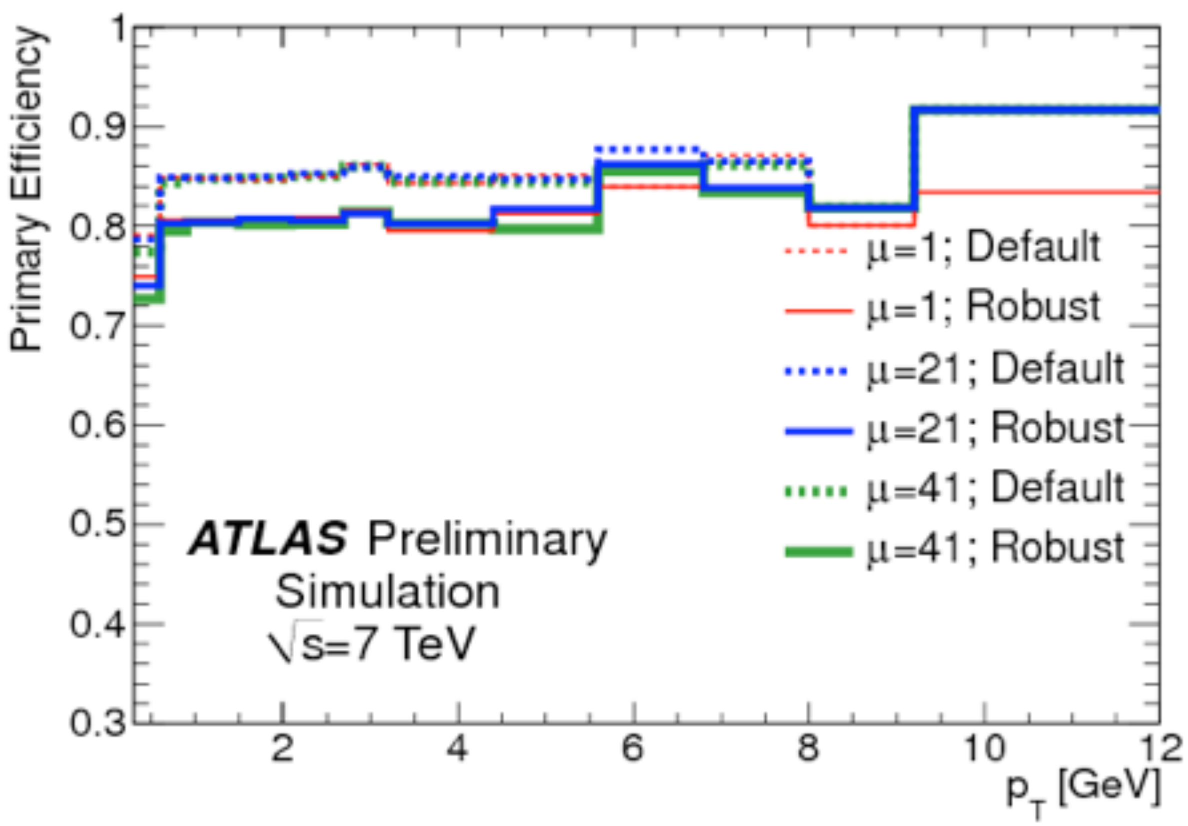
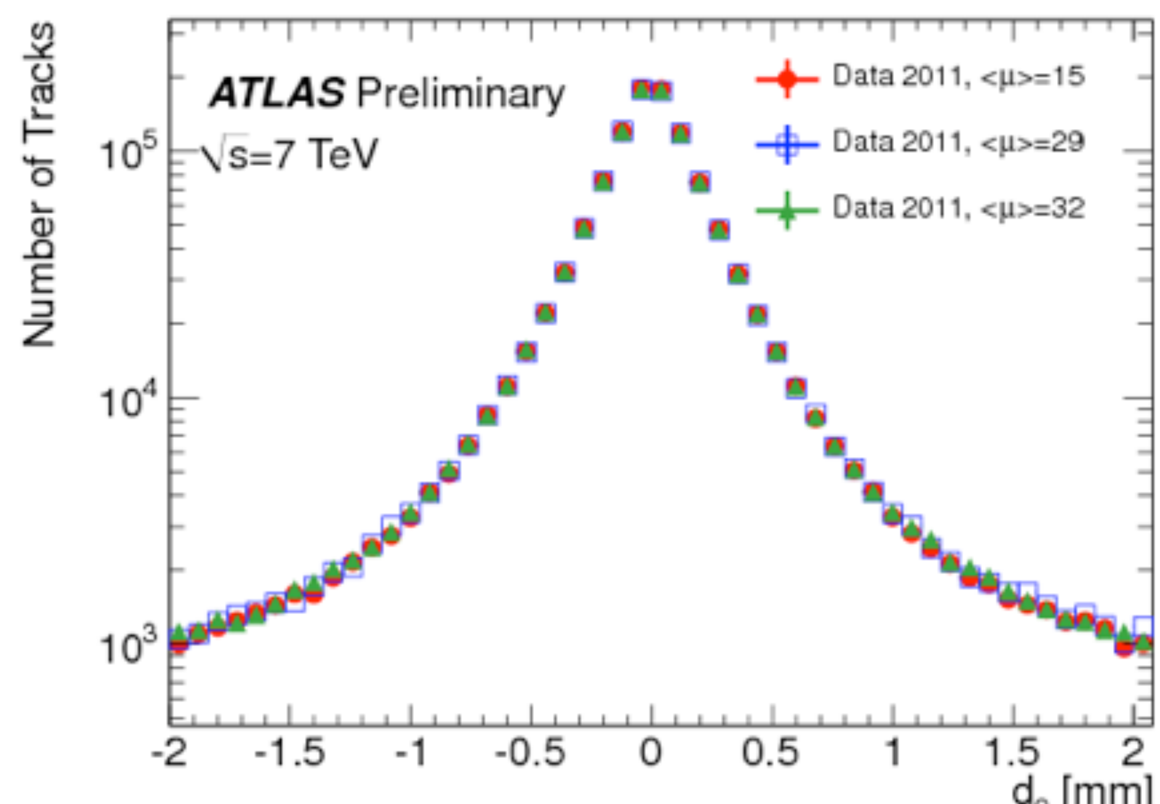
The effects of pile-up

- extensive studies of pile up effect on the reconstruction
- an increase of track fake rate
  - combinatorial background from the pileup
  - esp tracks with increased d_0
- track reconstruction cuts
  - Robust set developed for high pileup (7 vs 9 measurements on track, 0 missing in pixel)
  - decreases the rate of fake tracks wrt Default cuts
  - small effect on track efficiency
  - less redundancy wrt detector operation



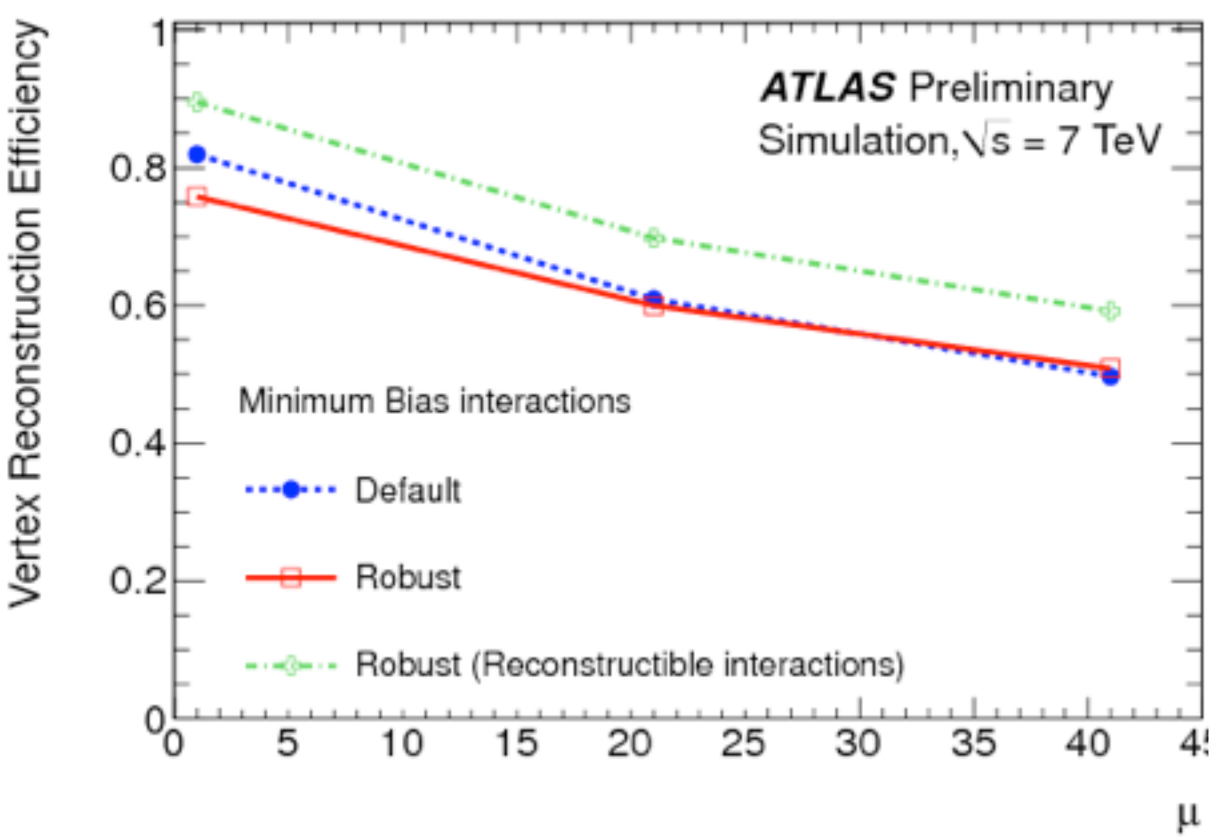


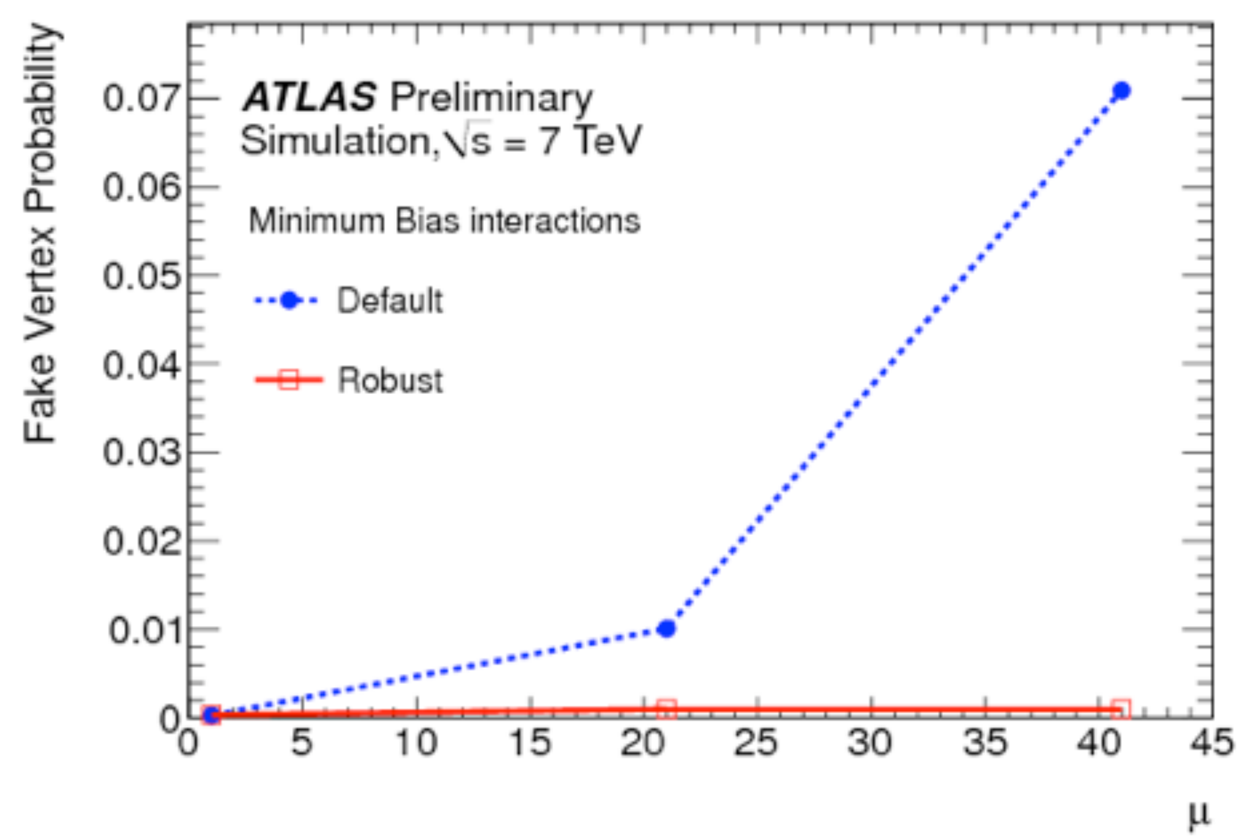


Robust settings

The effects of pile-up/II

- Vertexing efficiency and fake rate also studied as a function of pile up
- fake tracks increase the chance to reconstruct a fake vertex (7% @ μ=40)
- Robust reconstruction effective also against fake vertices
- The decrease of vertex reconstruction efficiency with μ
  - vertex shadowing when a nearby interaction too close to be resolved and only one vertex gets reconstructed

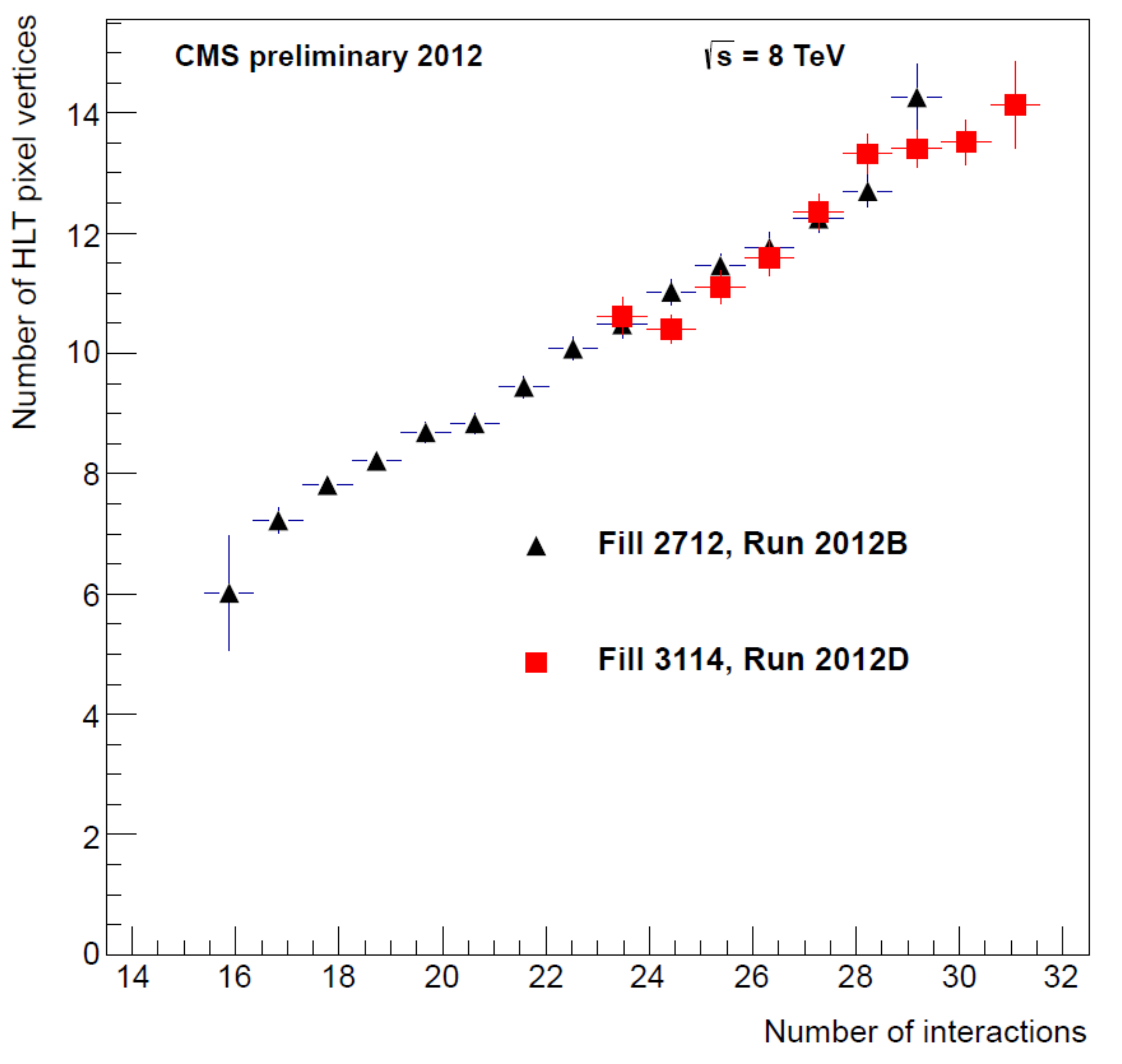




More Pile-up Studies

- performance of the reconstruction algorithms wrt pile-up studied also in the trigger of CMS
- number of reconstructed pixel vertices in HLT as a function of number of interactions in an event
  - Comparison of data from early 2012 and later runs with an increased pile-up
  - linearity preserved during 2012 data taking
- confirmed a robust performance of the reconstruction/trigger

Number of Pixel Vertices in High Level Trigger of CMS



Outlook to Run 2

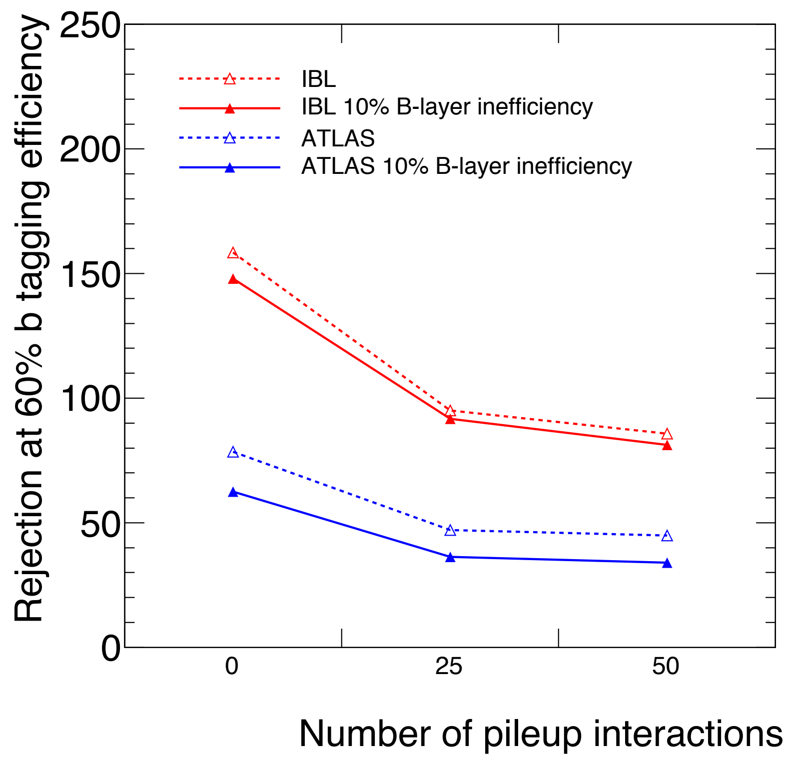
N.B. More complete presentation of the detectors upgrade beyond the current long shutdown in

Ulrich Parzefall/ATLAS and CMS Upgrade Plans /on Friday

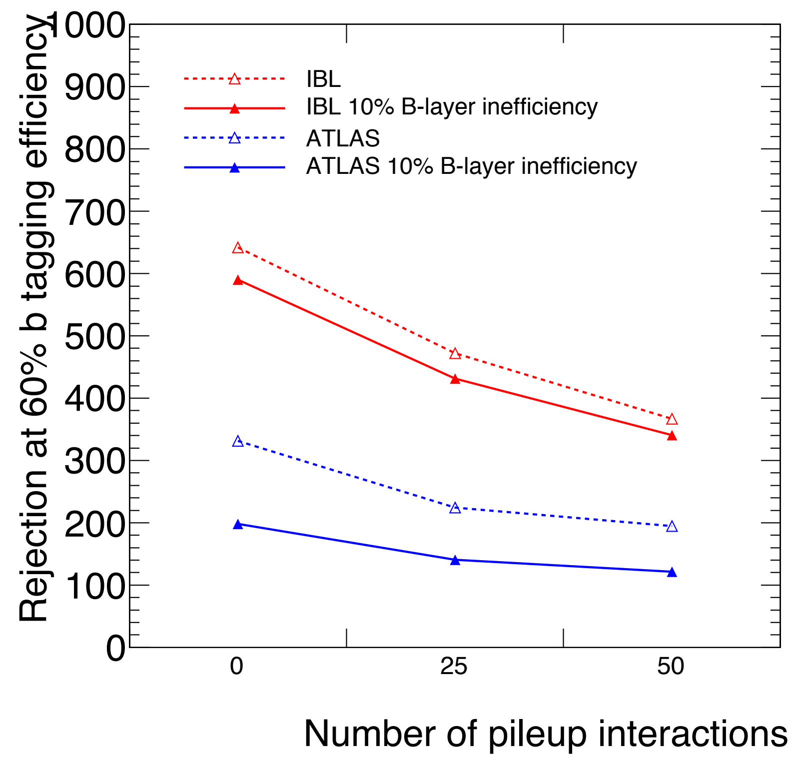
IBL in ATLAS

- Insertable B-Layer
  - will be installed during the current long shutdown
- addition of the 4th Pixel layer @3.3cm between the current Pixel detector and a smaller beam-pipe
- improvement for tracking and vertexing
  - a smaller radius
  - a smaller z granularity to help against pile-up (50x250µm)
  - redundancy (detector problems, aging of the current innermost layer)

b tagging rejection factors as a function of pileup. Comparison of ATLAS and ATLAS +IBL and aging of the current innermost layer



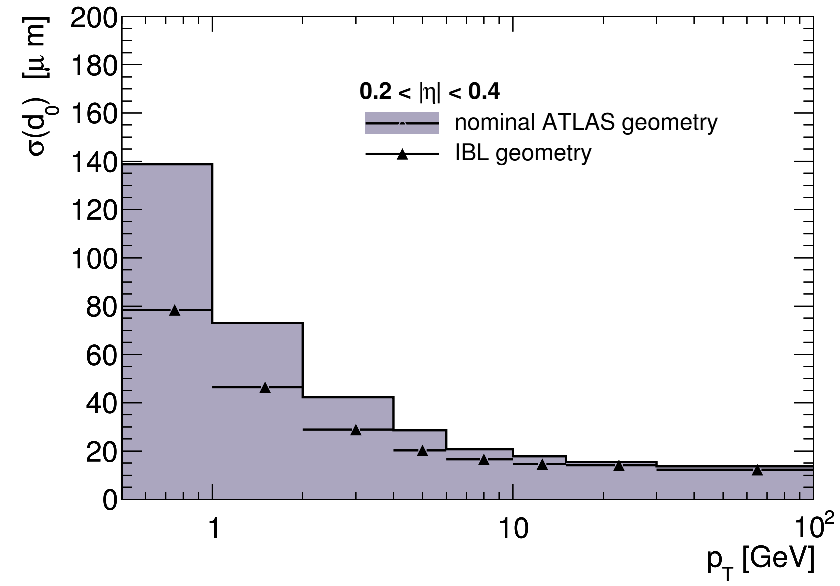
b tagging based on Impact parameter

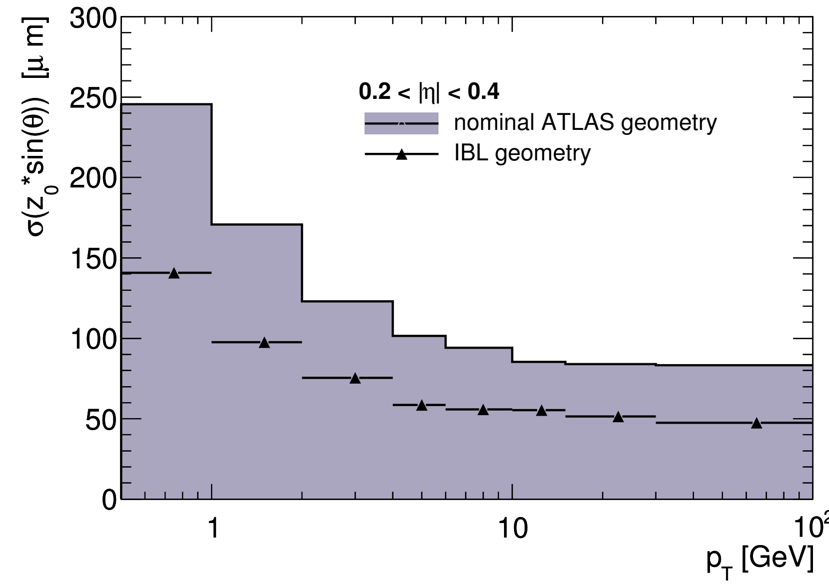


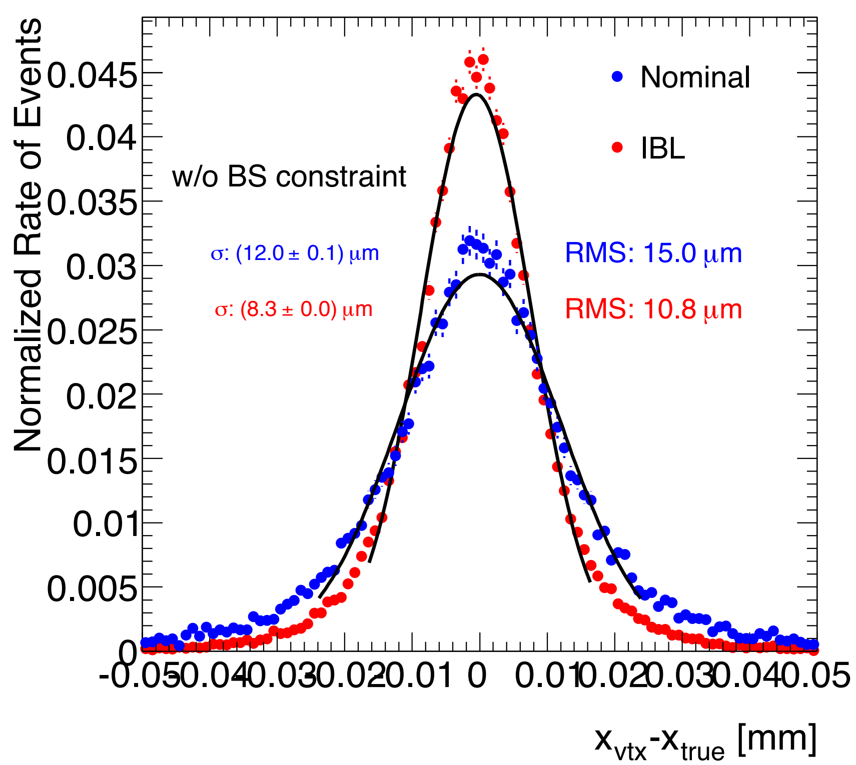
b tagging based on Impact parameter and secondary vtx

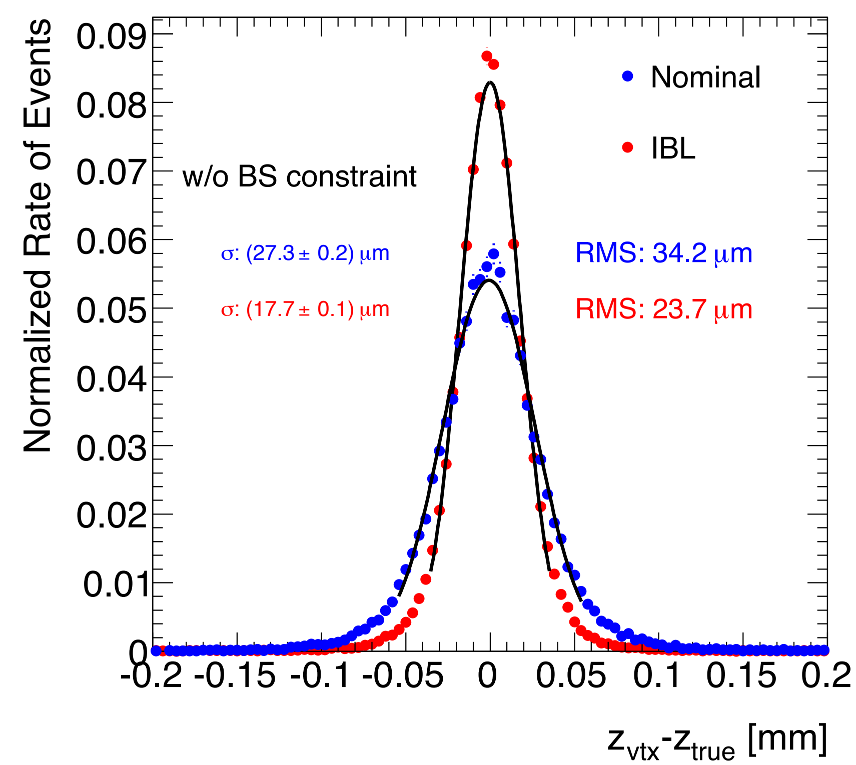
IBL in ATLAS/II

- improvement on impact parameters d_0 and z_0
  - as a function of pT
  - the effect of a smaller z pitch
- improvement on vertex resolution in ttbar events
  - in transverse coord 15μm→11μm, in z 34μm→24μm
  - the effect on x is smaller when BS constrained (9μm→8μm)









Summary

- very good understanding of performance of the detector and algorithms
  - well simulated by MC
- tracking and vertexing performance robust wrt increasing pileup
  - detectors and reconstruction algorithms maintain their performance
  - the effects of pile up carefully studied
- Run2 conditions even more challenging
  - increase of luminosity, initial LHC setup with 50ns bunch spacing
  - ATLAS - first detector upgrades over LS1 beneficial for tracking performance and B-physics programme