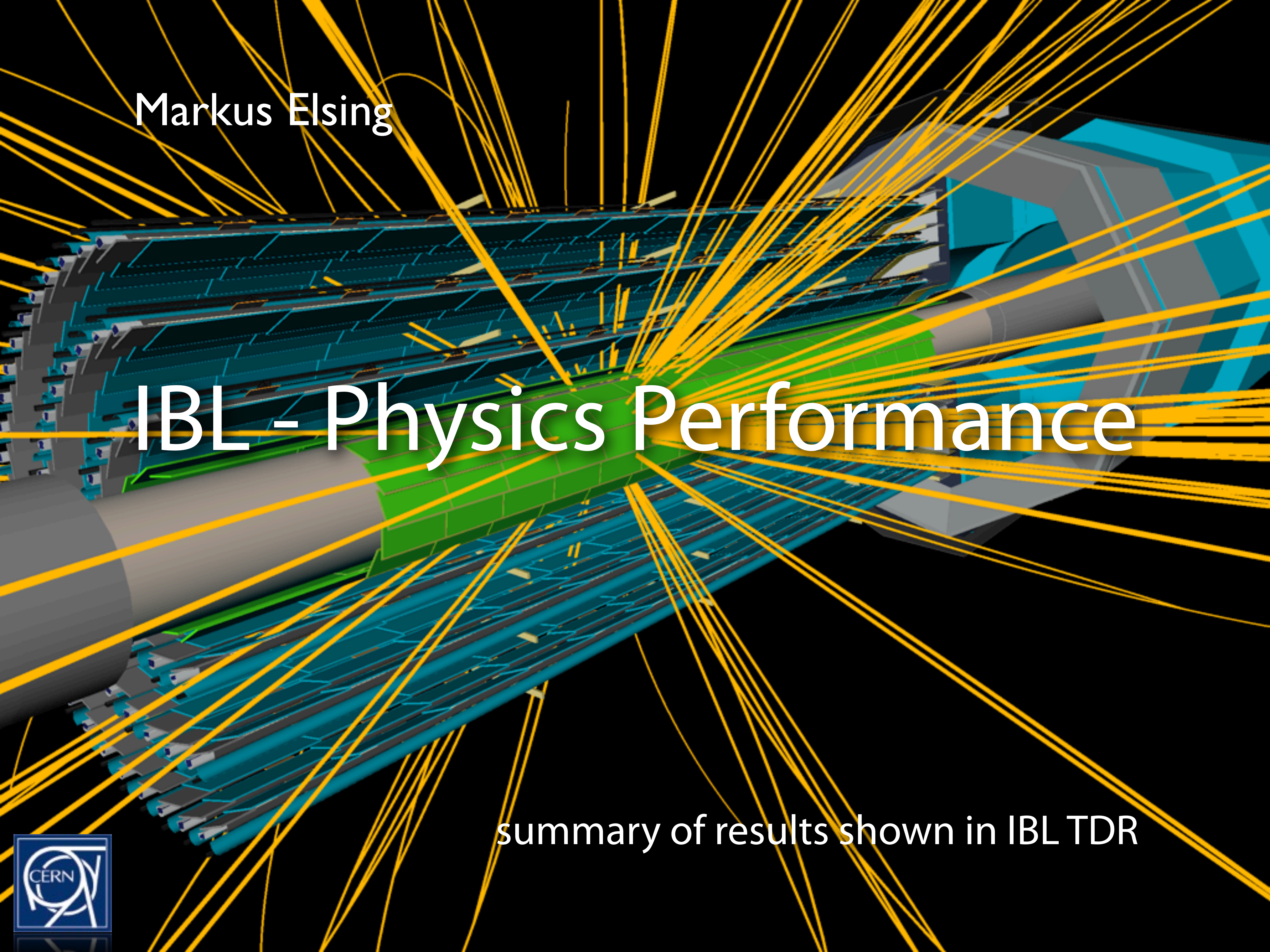


Markus Elsing

IBL - Physics Performance

summary of results shown in IBL TDR

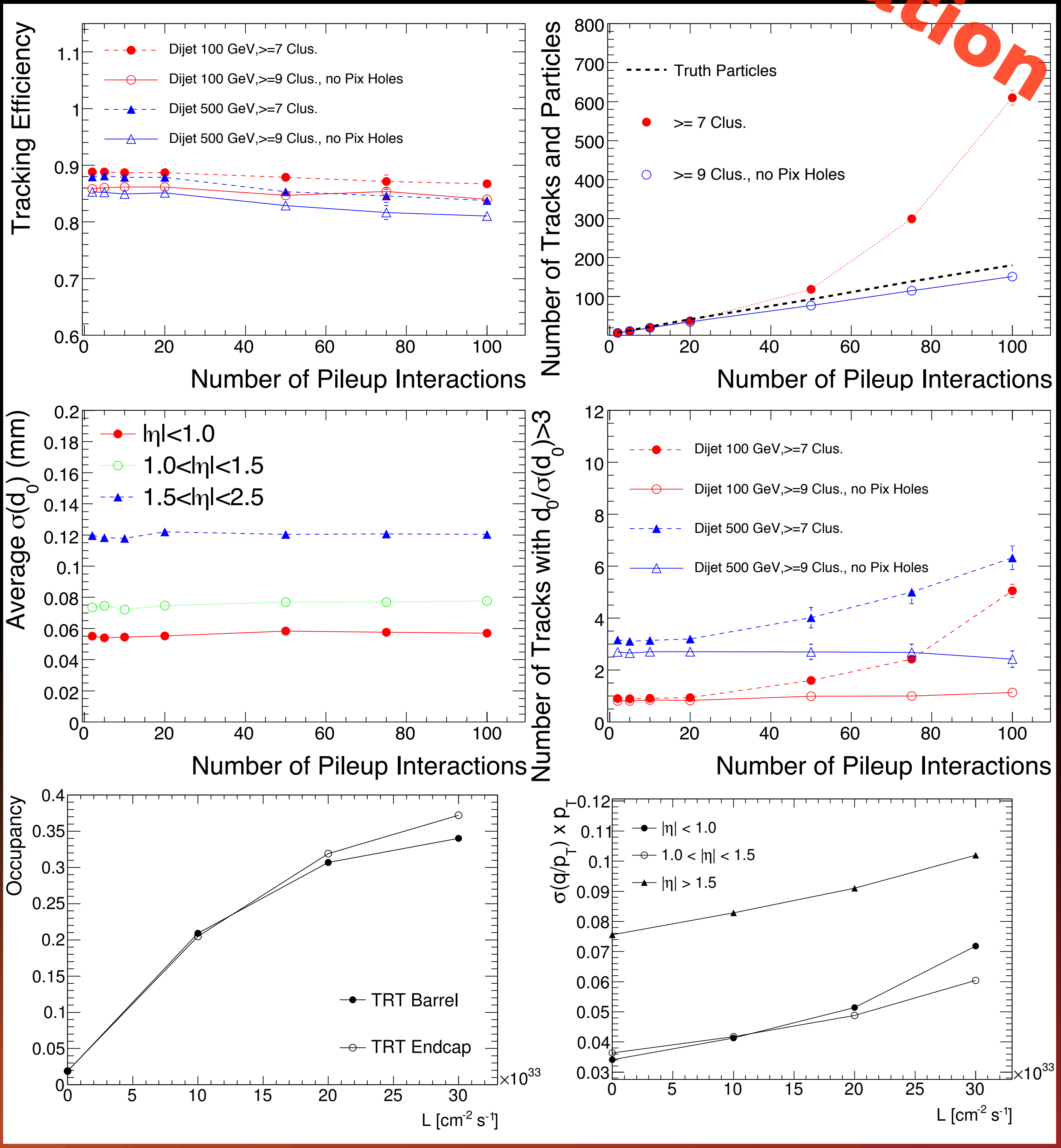
Physics at sLHC Phase-I

- ATLAS physics goals will remain the same before and after phase-I upgrade
  - ➡ exploration of new energy regime, advanced using 7 to 14 TeV data
- physics program evolves as first discoveries are made
  - ➡ physics signatures involving flavor jets tagging will remain central
  - ➡ e.g. low mass Higgs discovery in b-jets is difficult, but confirmation of observation is crucial to study Higgs coupling
- LHC phase-I
  - ➡ expect to have 66 fb^{-1} collected by 2016 and 340 fb^{-1} until end of phase-I
  - ➡ phase-I peak luminosities of $2*10^{34}\ cm^{-2}s^{-1}$
- IBL upgrade
  - ➡ improve tracking, vertexing and b-tagging in presence of very high luminosity pileup and recover eventual failures in present Pixel detector

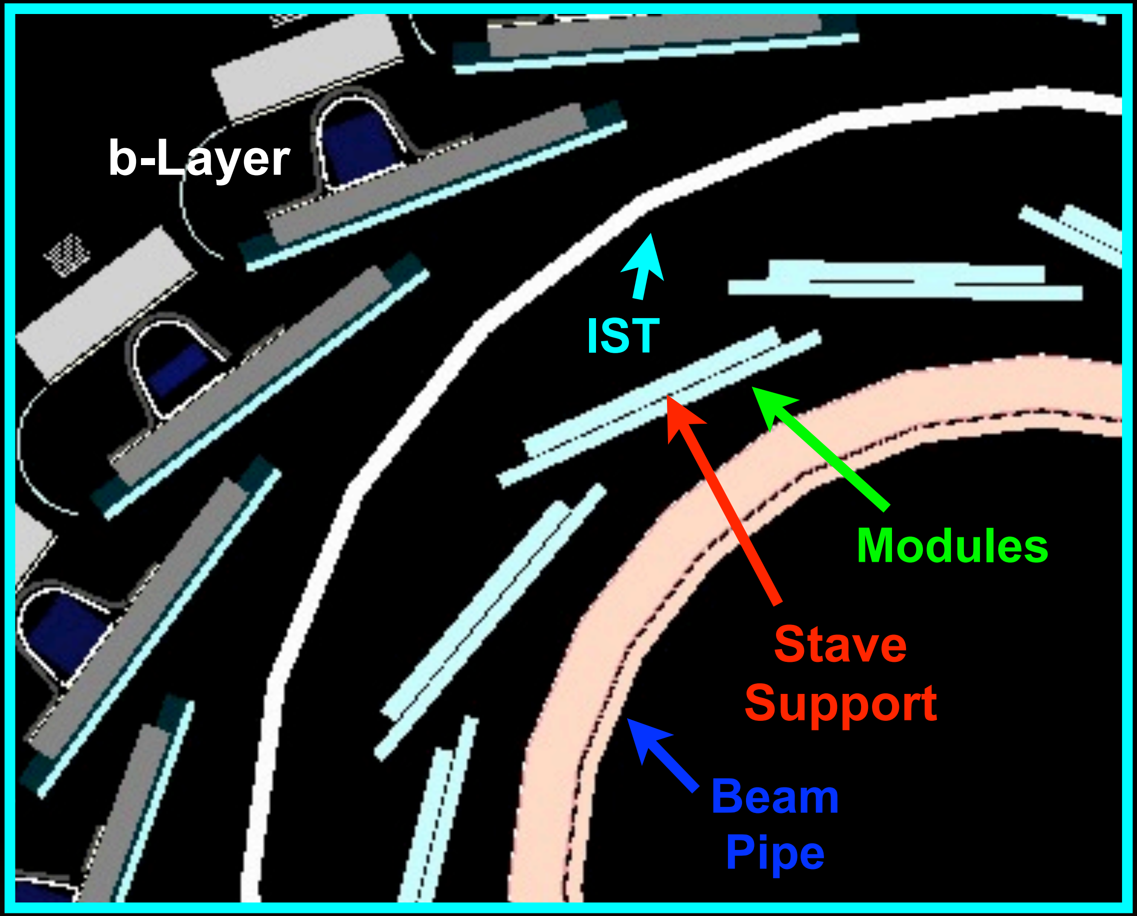
Phase I - Current Inner Detector

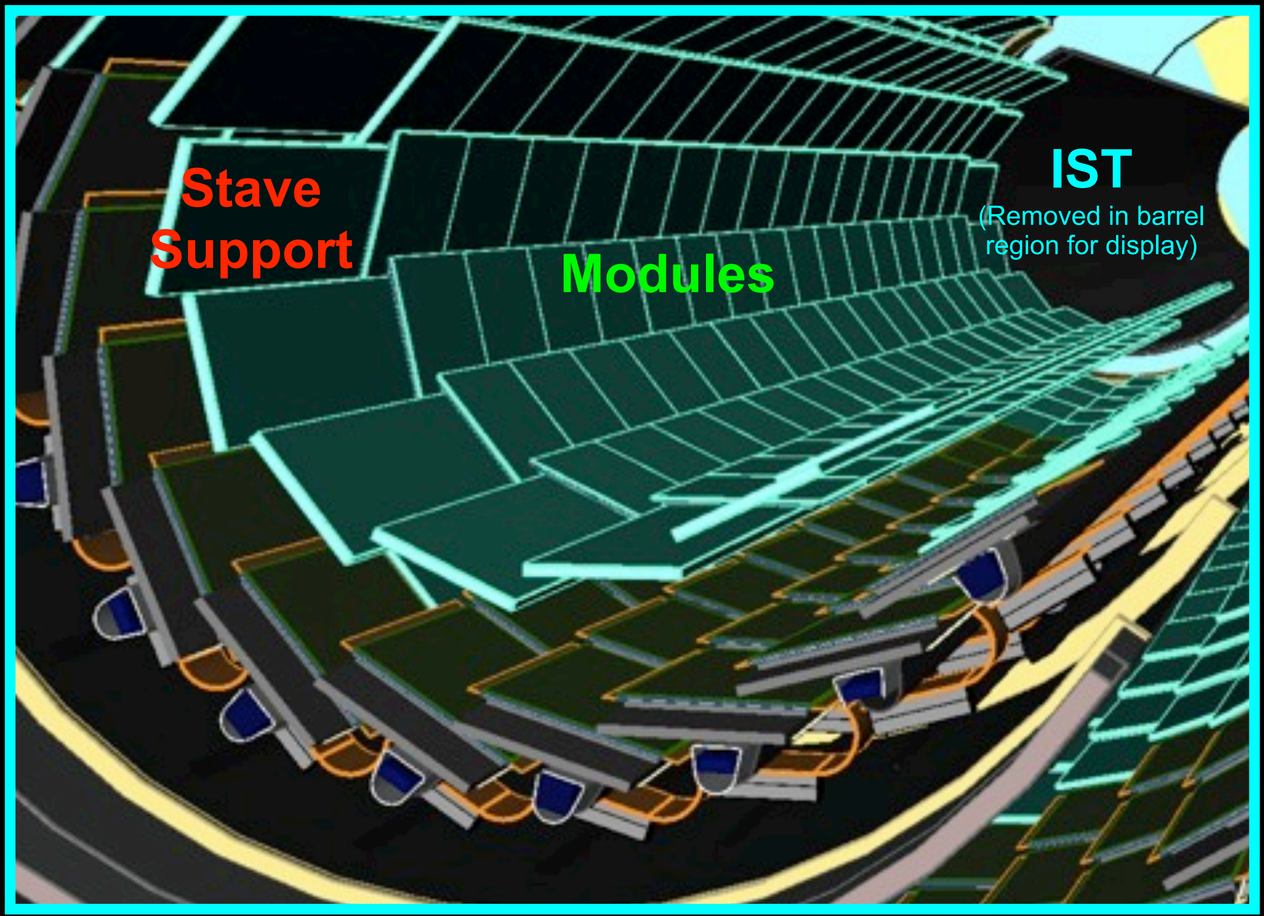
for information

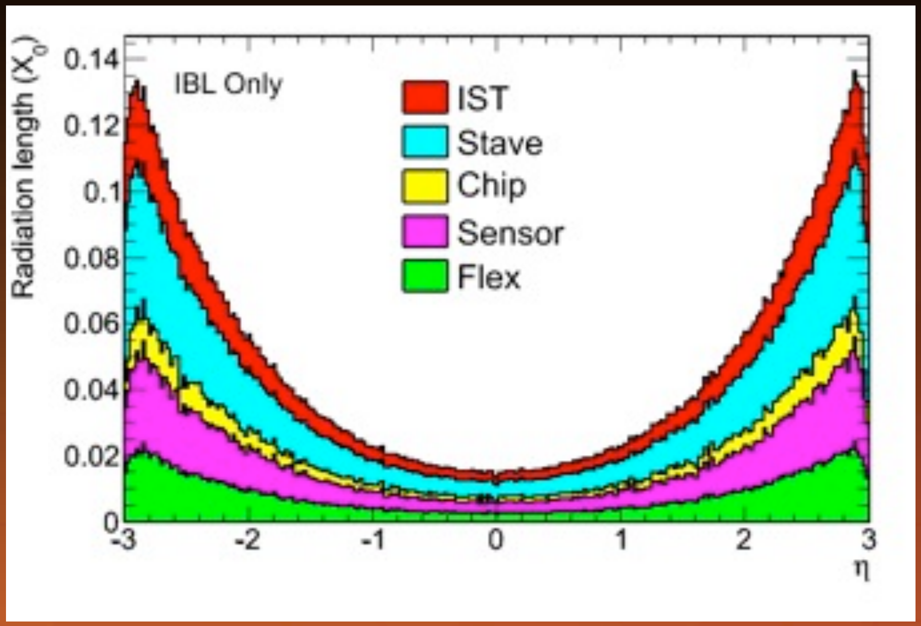
- occupancy
  - ➡ Pixel and SCT scales linearly
  - ➡ TRT good hit occupancy vs efficiency
- tracking in pileup
  - ➡ efficiency, most resolutions same
  - ➡ momentum resolution slowly deteriorates with TRT occupancy
  - ➡ rate of fake tracks and rate of significant impact parameters increases fast
- pileup track selection
  - ➡ suppresses fakes at expense of some efficiency
  - ➡ requiring 9 out of 11 hits - robust ?
  - ➡ cut on "no Pixel holes" ...



IBL in the ATLAS Simulation



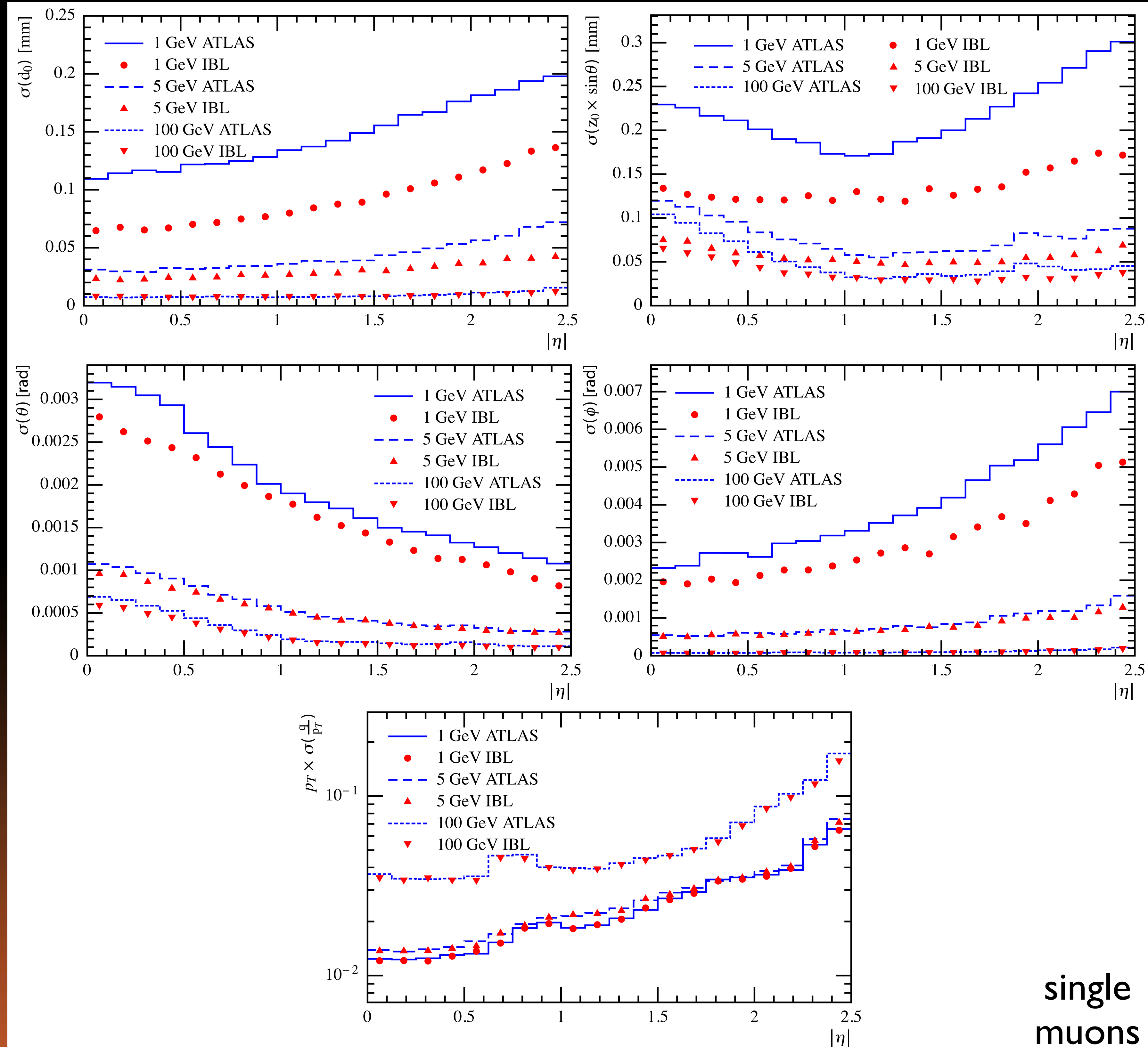




- IBL as 4th Pixel layer in G4
  - ➡ new beam pipe (R_{min} = 25 mm)
  - ➡ re-use Pixel digitization model
    - – similar to IBL planar sensors
    - – 8bit (FE-I3) instead of 4bit (FE-I4)
- IBL material adjusted to 1.5% X_0
  - ➡ reconstruction: 4 layer tracking geometry

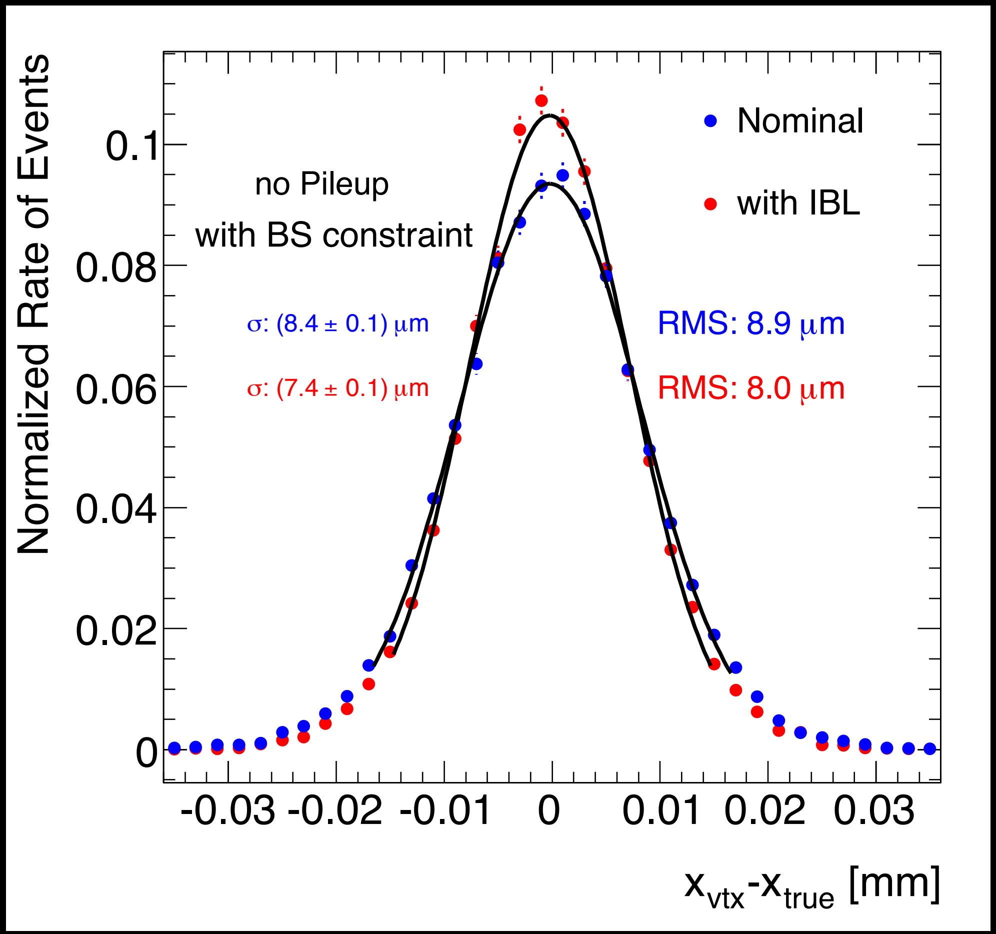
Tracking Performance with no Pileup

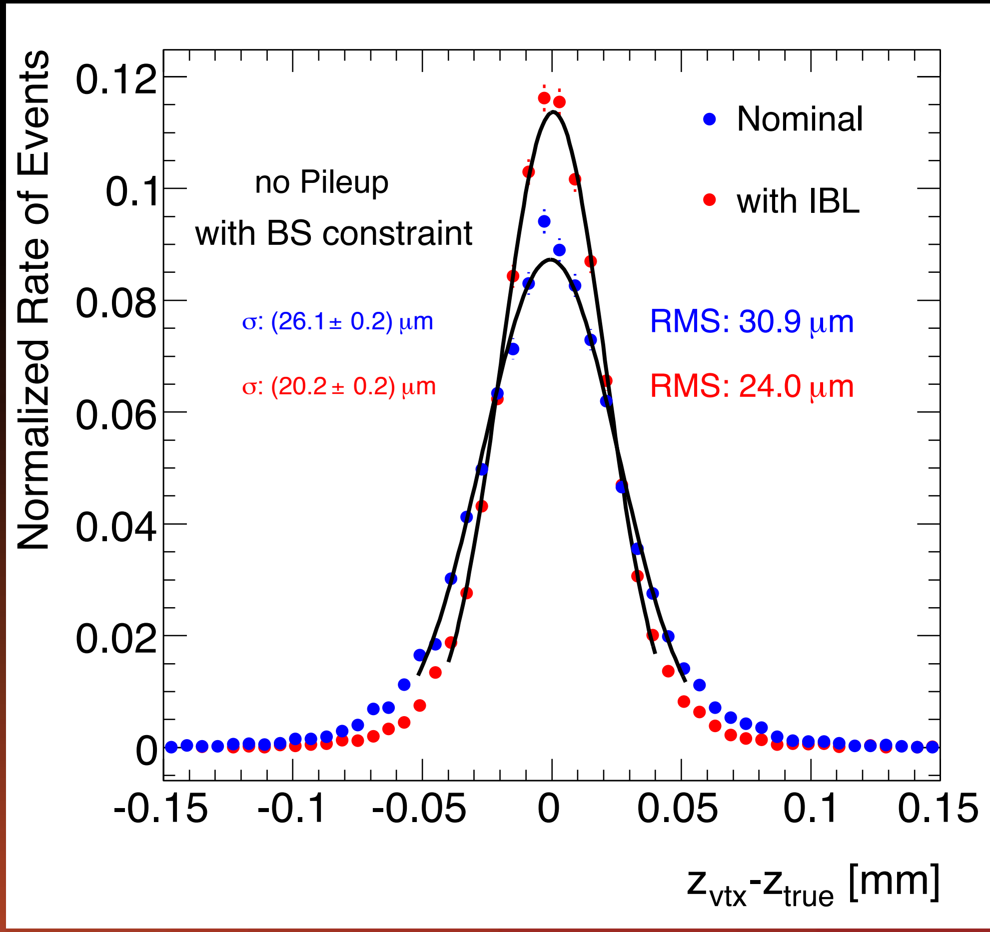
- expected results
  - ➡ smaller radius
  - ➡ small z pitch
  - ➡ less material between first and 2nd layer
  - ➡ track length ~ same
- improvements
  - ➡ better d_0 resolution
  - ➡ better z_0 resolution
  - ➡ θ and ϕ improved at low-pT
  - ➡ momentum resolution ~ unchanged



Primary Vertexing

- current vertex finder
  - ➡ "IterativeVertexFinder"
- d_0, z_0 resolution without pileup improved with IBL
  - ➡ as expected
- with beam spot constraint
  - ➡ IBL improvement mostly in z_0
  - ➡ ~ 20% better RMS or σ
- non Gaussian tails
  - ➡ especially without BS constraint

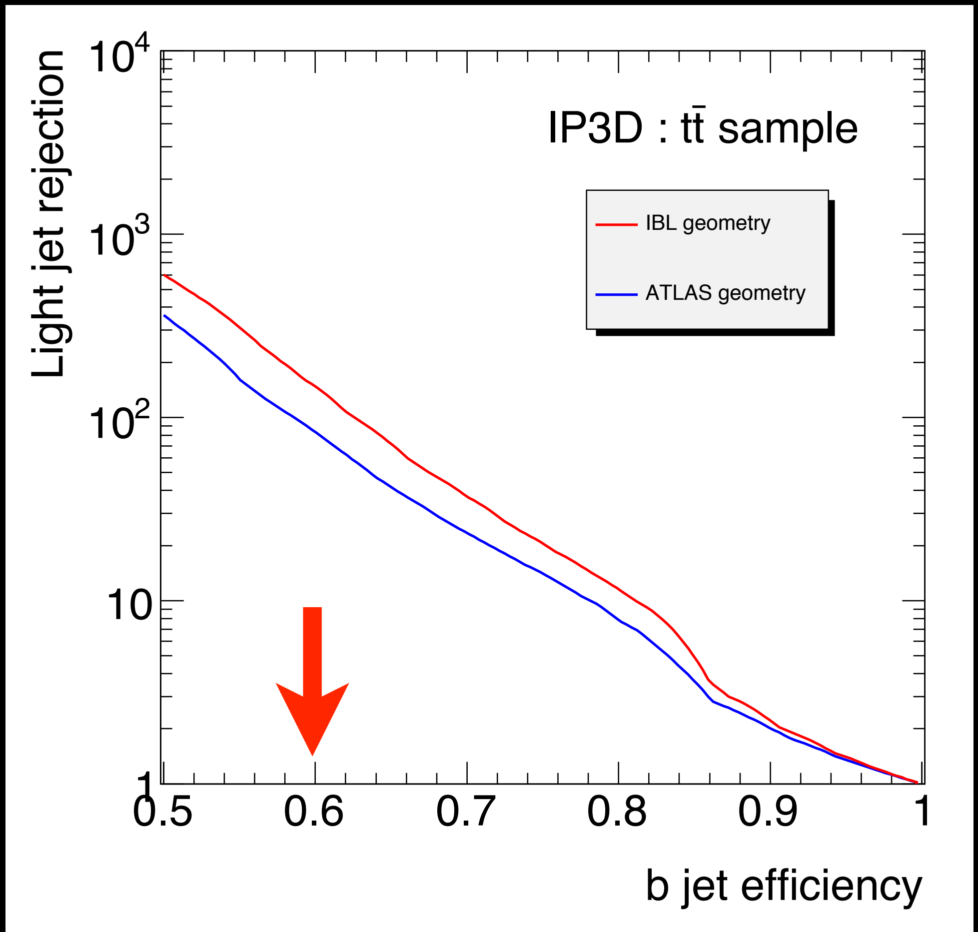


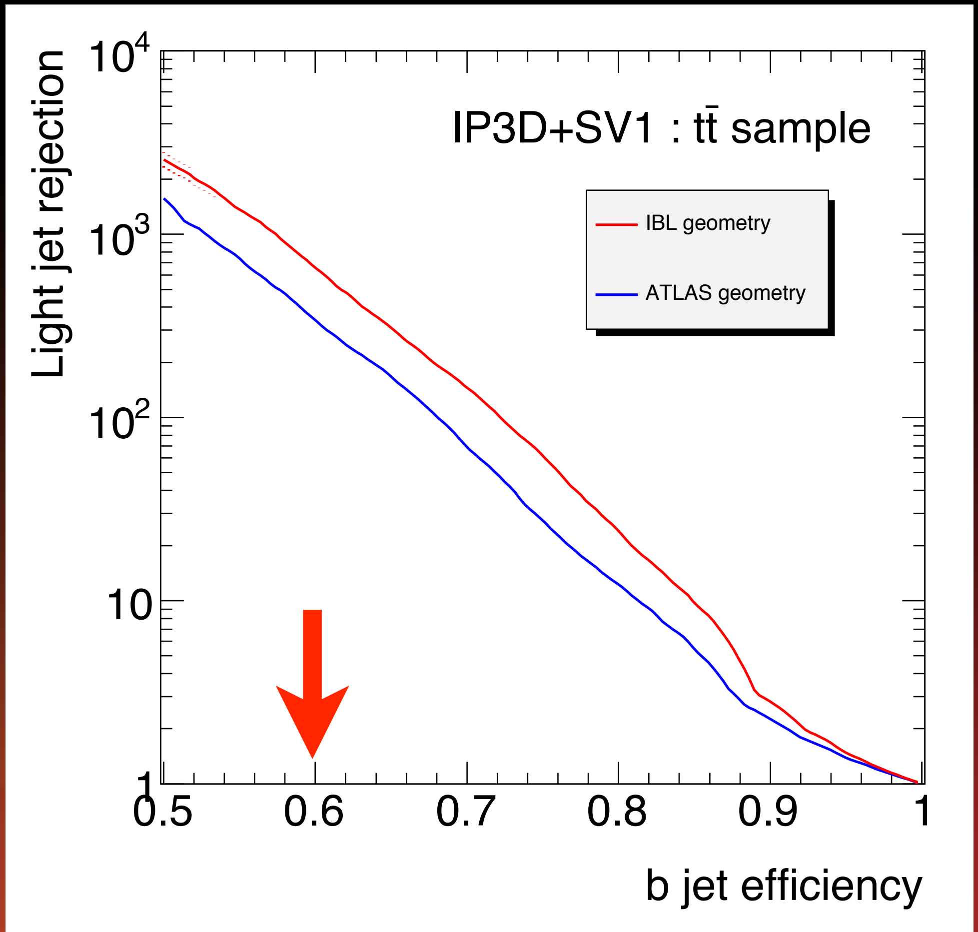


tt events

b-Tagging Performance

- state of the art ATLAS tagging code
  - ➡ "IP3D" ~ $d_0 \oplus z_0$ impact significance likelihood
  - ➡ "IP3D+SV1" ~ adding secondary vertex information
- likelihood taggers ~ re-calibration
- light rejection as function of b-jet efficiency in tt events
  - ➡ normalized to jets with p_T>15GeV, ≥1 b-tag track
- IBL without pileup:
  - ➡ ~ 10% more secondary vertices found
  - ➡ at 60% b-jet efficiency a
    - factor 1.8 in light rejection for IP3D
    - factor 1.9 in light rejection for IP3D+SV1

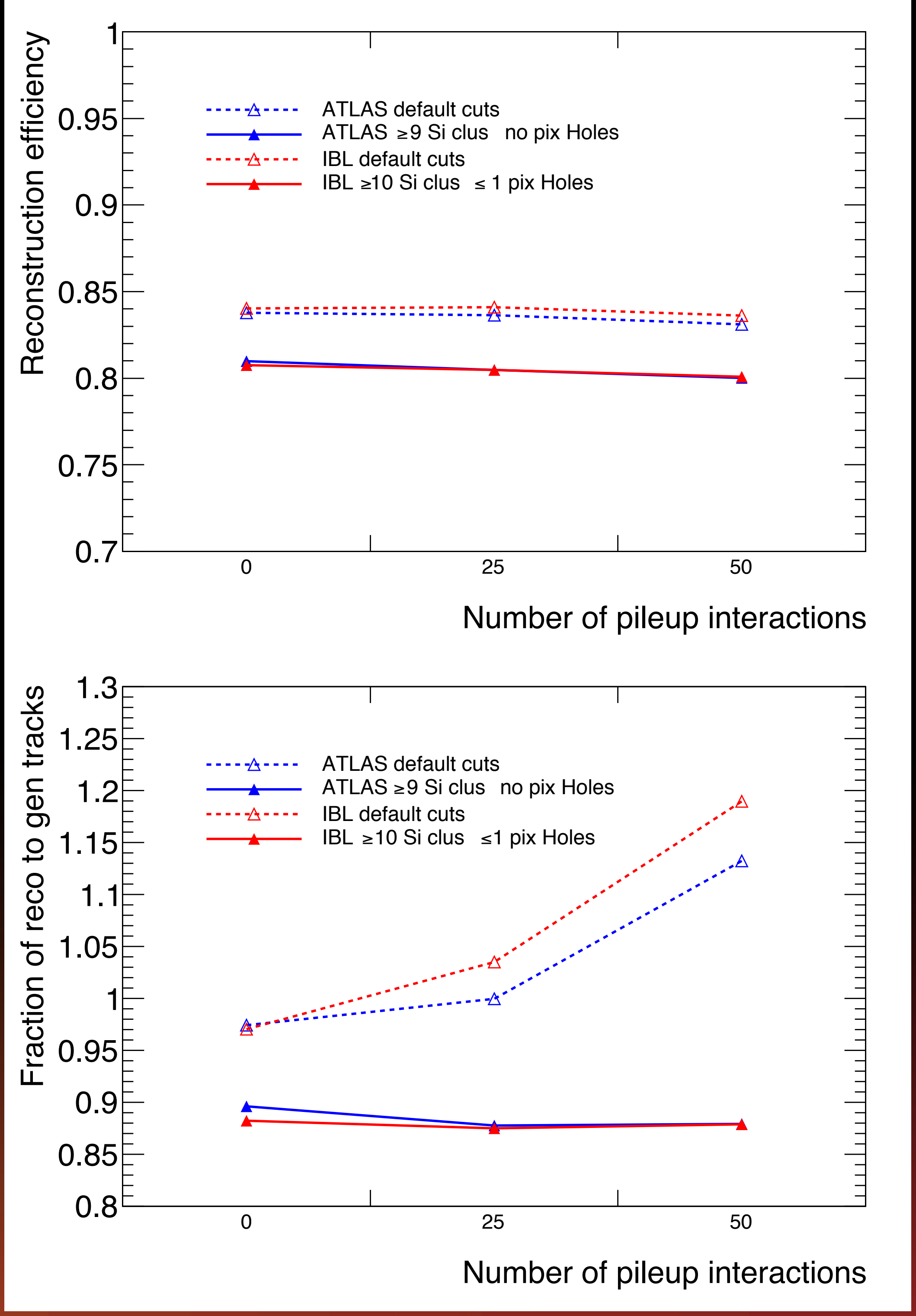




Robustness of Tracking with Pileup

- tracking efficiency rather constant with luminosity
  - ➡ with and without IBL
  - ➡ similarly, impact parameter resolutions not much affected
- with pileup
  - ➡ increased rate of secondaries and combinatorial fakes
  - ➡ especially at $2*10^{34}$ $cm^{-2}s^{-1}$
- pileup selection with IBL
  - ➡ ≥10 IBL+Pixel+SCT hits, ≤1 pixel hole
  - ➡ benefit from additional layer
  - ➡ leaves room for eventual inefficiencies in b-layer
  - ➡ following result shown with default and pileup selections

tt events

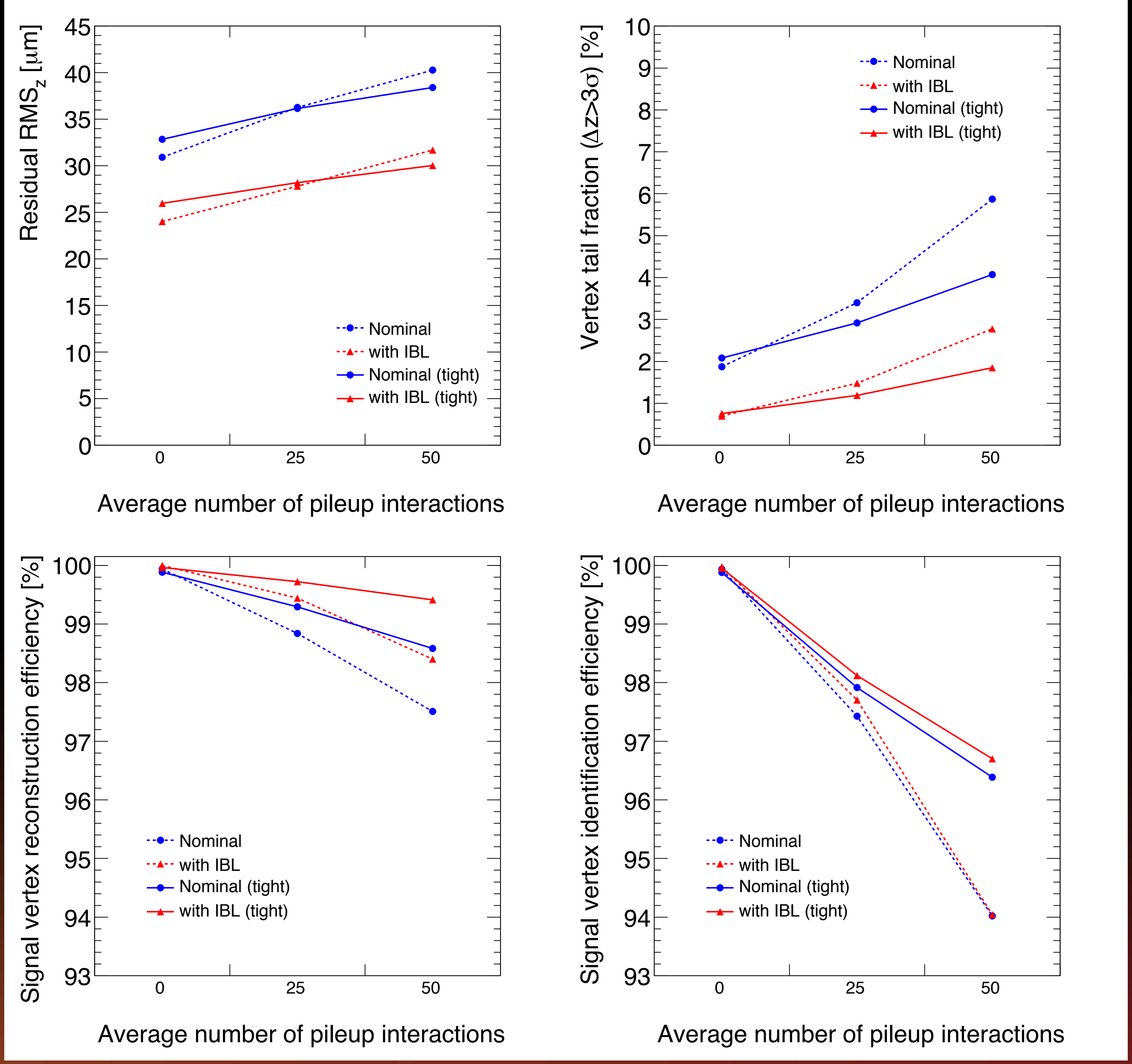


25(50) ⇔ 1(2) $*10^{34}$ $cm^{-2}s^{-1}$

Primary Vertexing with Pileup

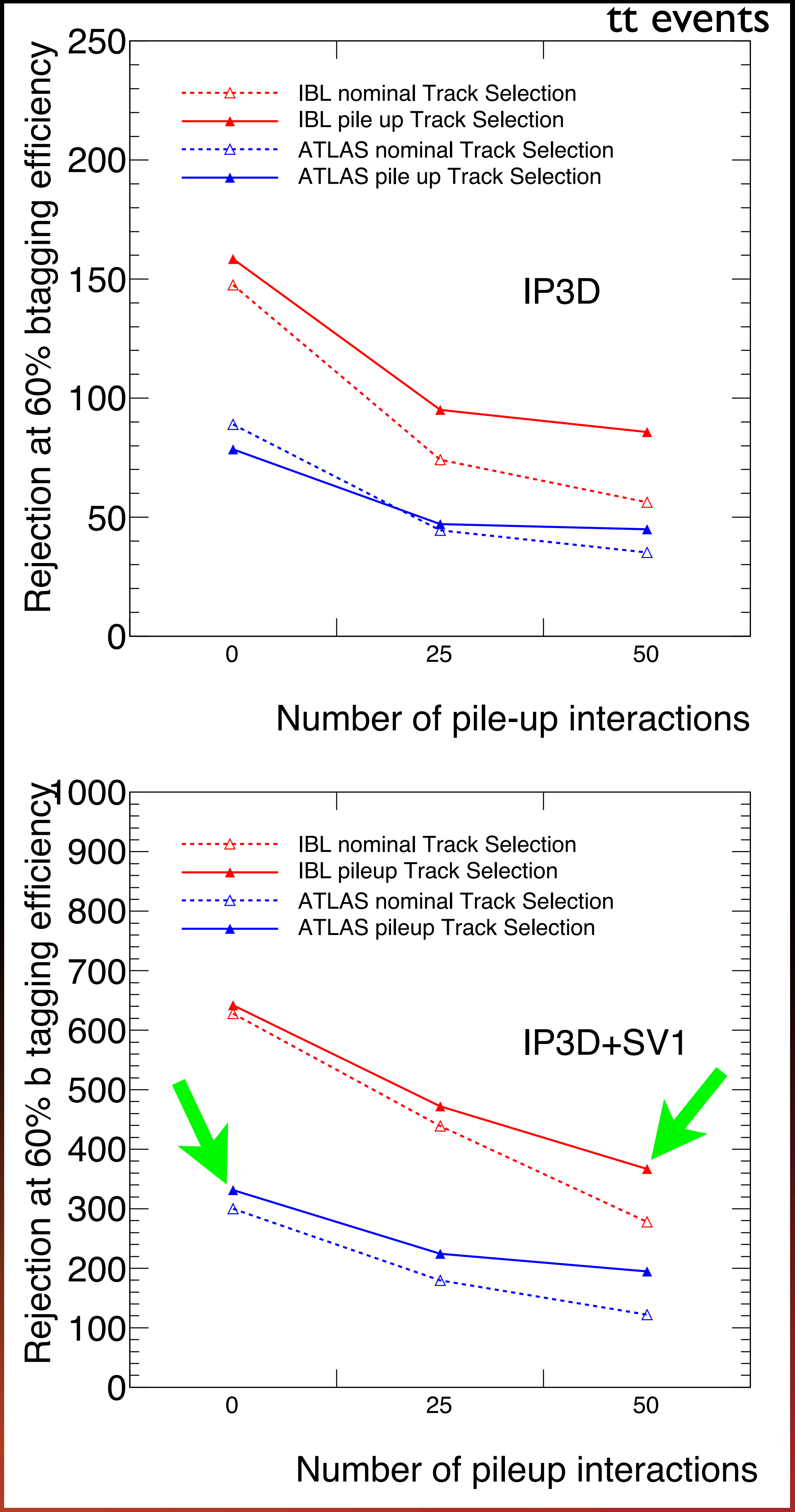
tt events

- "IterativeVertexFinder"
  - ➡ conservative 7σ before seeding new
- clear improvements with IBL
  - ➡ gains in resolution and vertex tail fraction as well with pileup
  - ➡ signal vertex efficiency better
  - ➡ Σp_T^2 identification of primary vtx ?
  - ➡ pileup selection better overall
- vertex identification is analysis level issue
  - ➡ use lepton+jets in tt
  - ➡ truth vertex identification used in the following



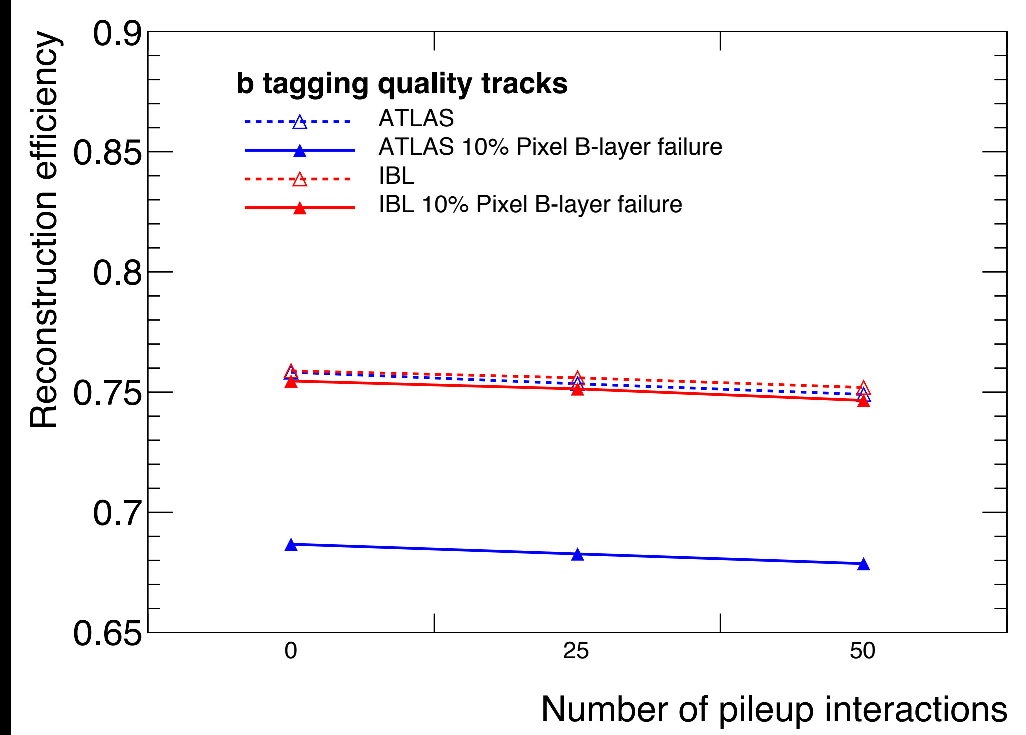
b-Tagging with Pileup

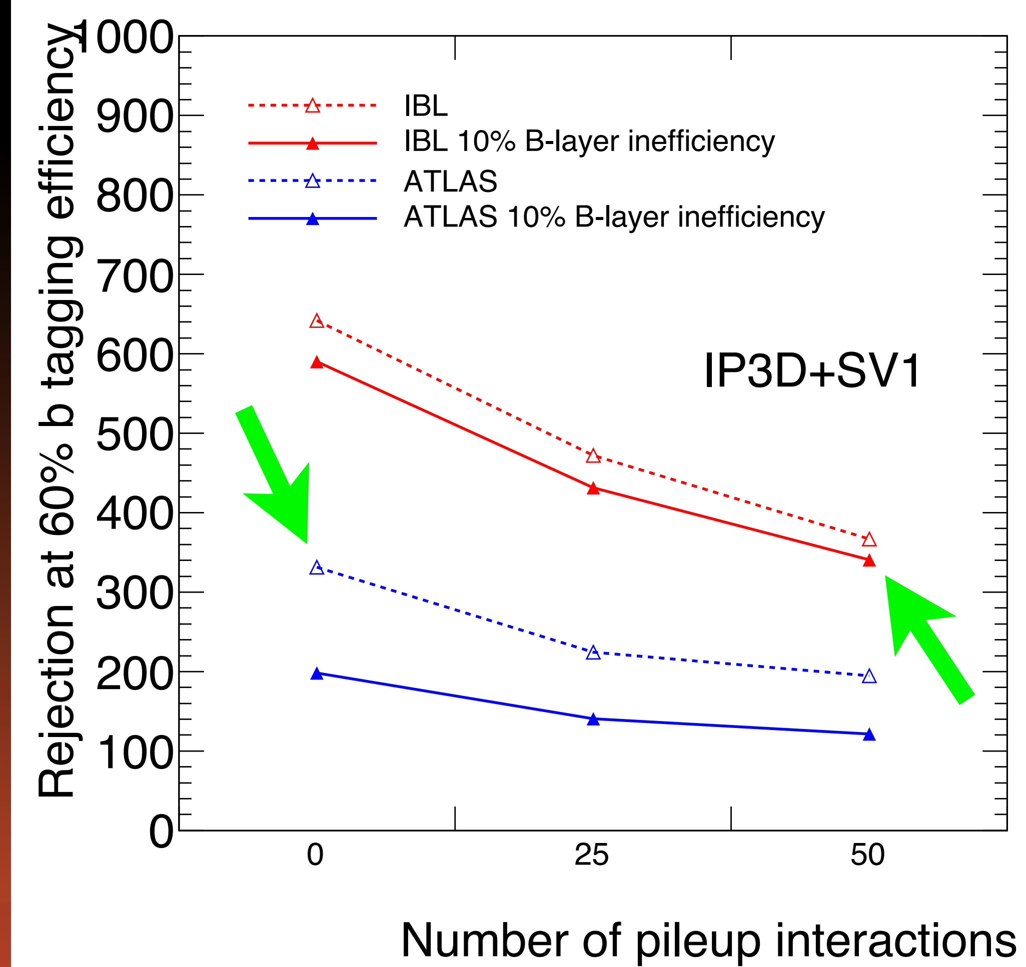
- pileup affects b-tagging in many ways
  - ➡ additional jets and fake jets from in/out of time pileup
    - restrict to truth jets to get comparable results
    - real data: can use e.g. Jet-Vertex-Fraction
  - ➡ close-by pileup vertices
    - additional b-tag tracks
    - lead to significant z_0 offsets affecting IP3D
- good performance with IBL and pileup
  - ➡ as good or better as for current ATLAS without pileup!
  - ➡ pileup selection is again better



Detector Defects: Scenario I

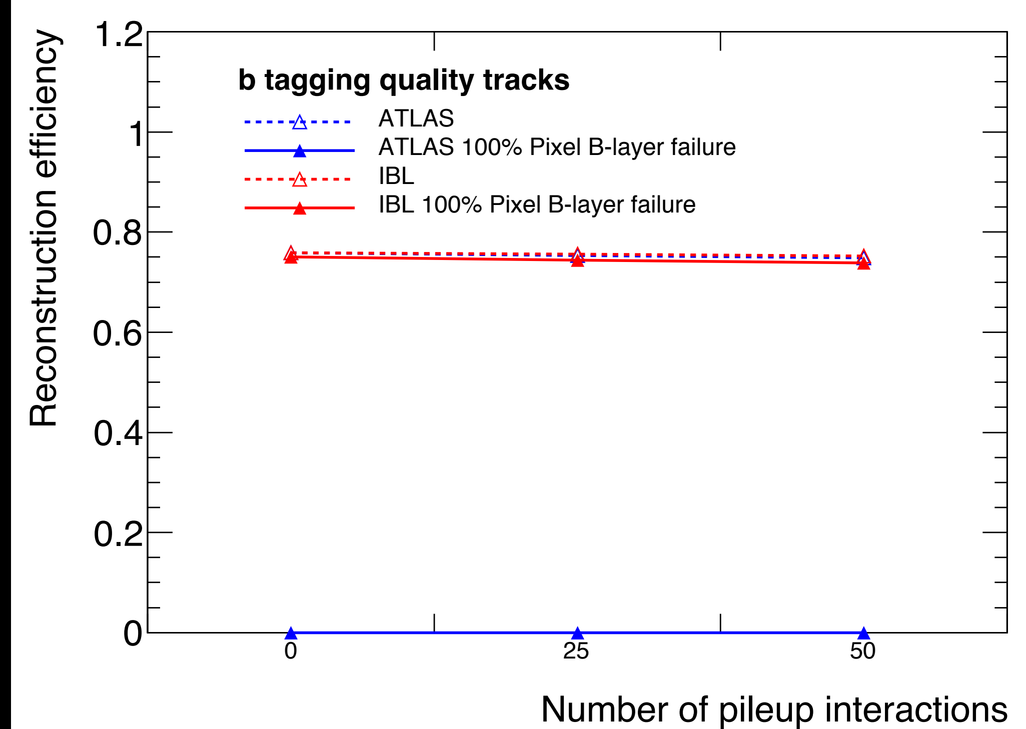
- 10% cluster inefficiency in b-layer
  - ➡ emulates e.g. so-called double column readout inefficiency
- IBL fully recovers tracking efficiency and impact resolution
- with IBL only small effects on b-tagging performance
  - ➡ even at high luminosity
  - ➡ with IBL even better than ATLAS without pileup and defects !

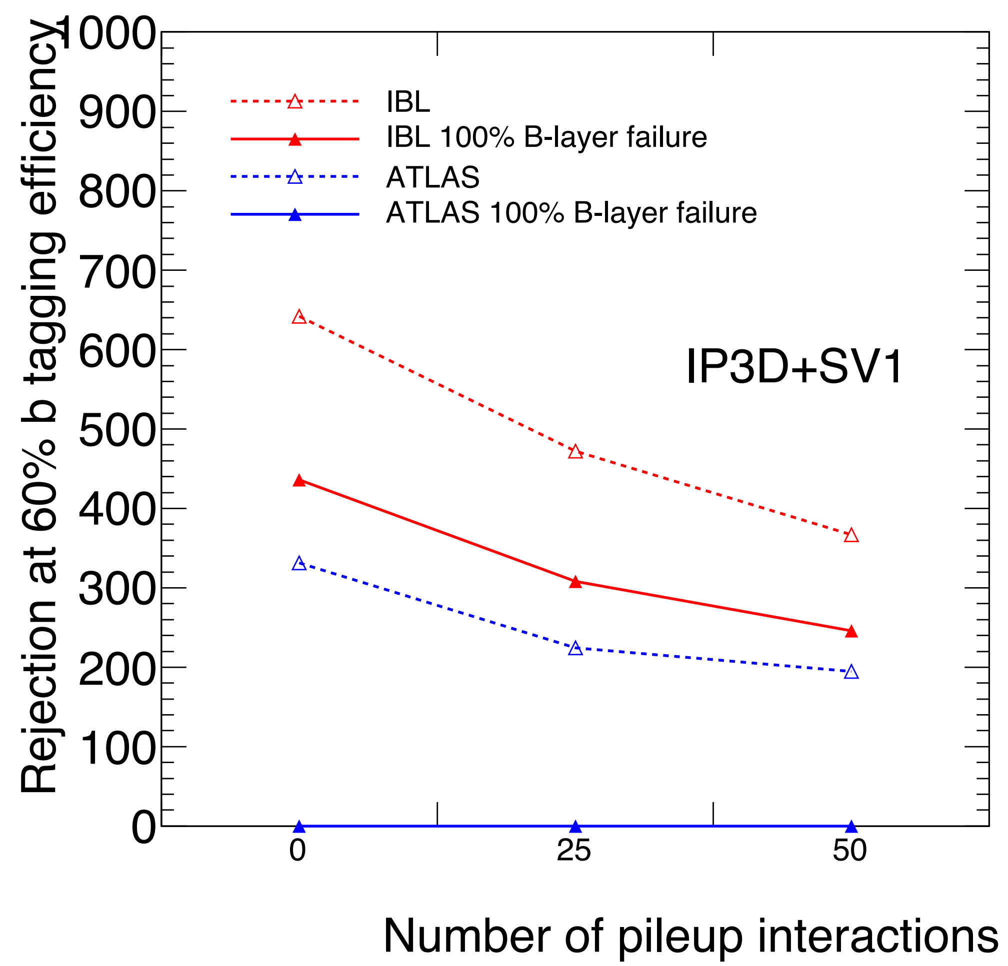




Detector Defects: Scenario II

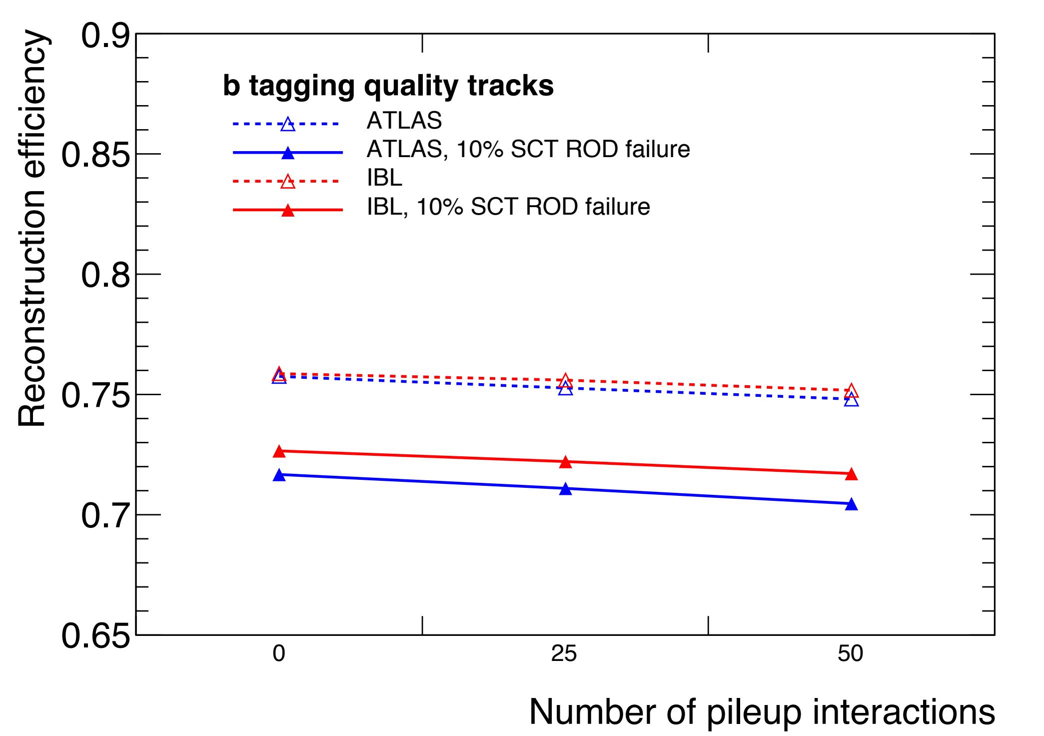
- catastrophic failure of b-layer
- again, IBL recovers tracking efficiency
  - ➡ without IBL, loosing the b-layer means loosing all tracks for b-tagging algorithms
- effect on b-tagging is bigger than for scenario I
  - ➡ loss of 1 layer reduces redundancy
  - ➡ more material between 1st and 2nd cluster
  - ➡ performance with IBL ⊕ lost b-layer ⊕ pileup equivalent to current ATLAS without pileup !

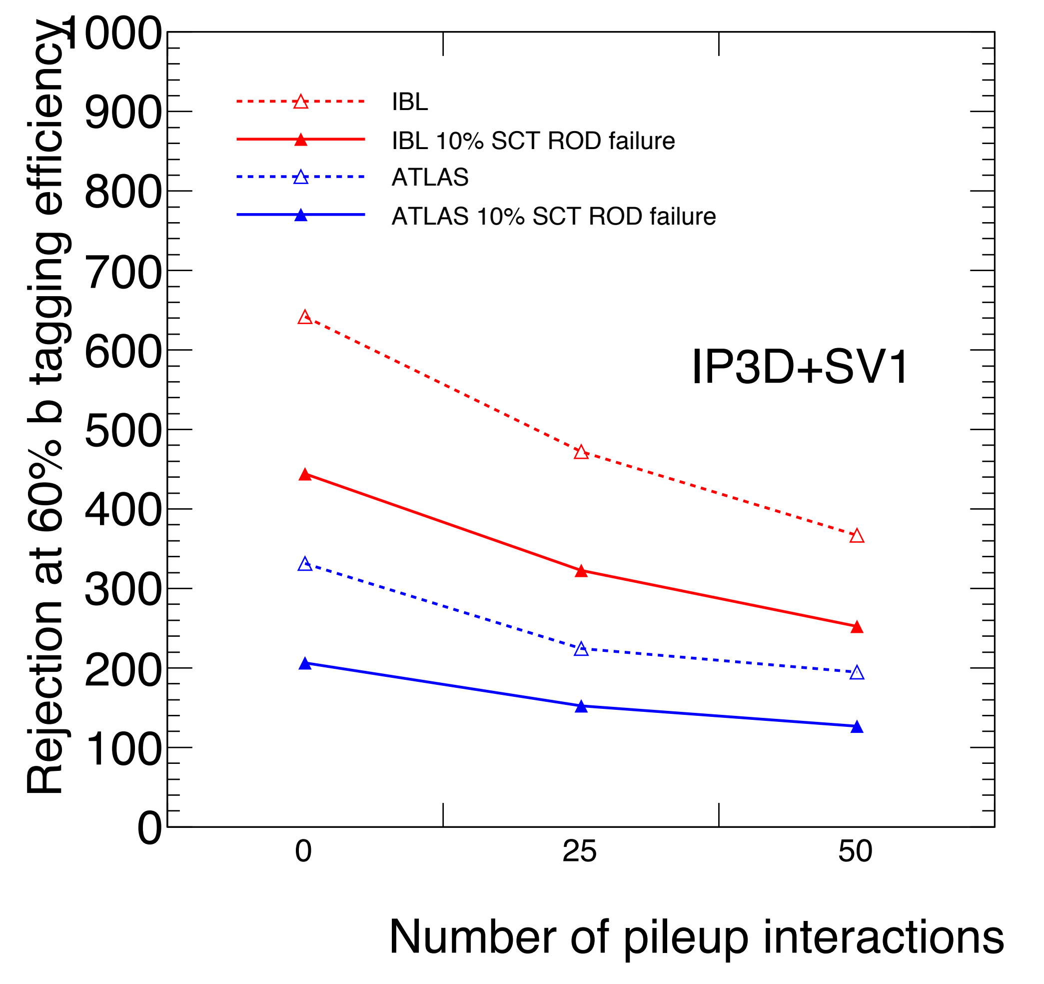




Detector Defects: Scenario III

- 10% ROD errors in the SCT
  - ➡ means loosing data in several layers (!) in certain η-ϕ regions
  - ➡ ROD errors are recorded in data, reconstruction tries to correct for it
- tracking efficiency loss with and without IBL
  - ➡ essentially not enough clusters to find tracks
  - ➡ additional layer helps, but distance between Pixels and TRT is big
- b-tagging performance with IBL still recovered !
  - ➡ compared to ATLAS without defects

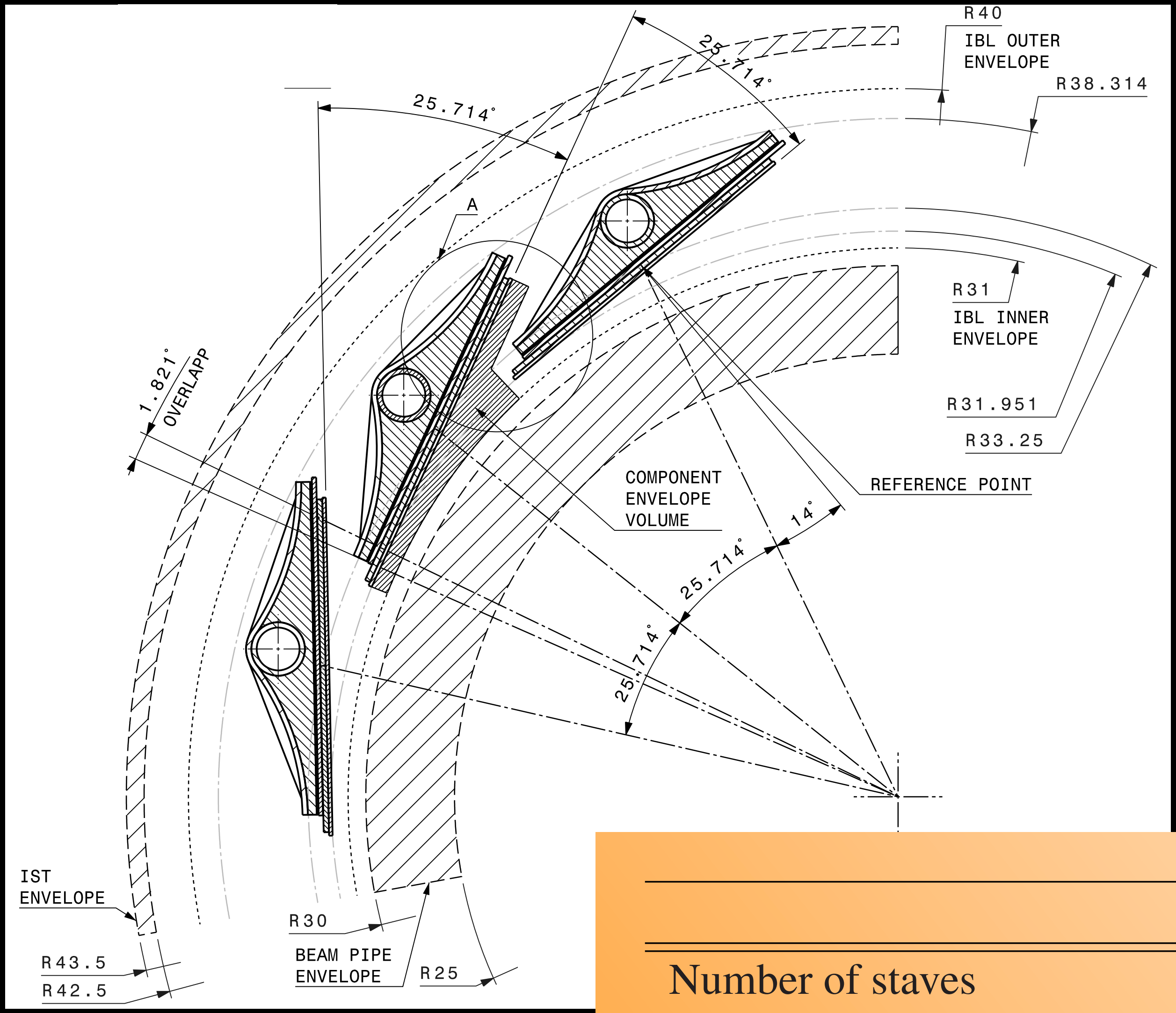




Summary

- IBL detector
  - ➡ additional low mass layer close to interaction point
- IBL improves impact parameter resolution, therefore improved vertex reconstruction and b-tagging
- b-tagging performance with IBL at $2*10^{34}$ $cm^{-2}s^{-1}$ is similar to current ATLAS without pileup
- in all studied scenarios with detector defects, the IBL recovers the tracking and b-tagging performance

BACKUP



	Value	Unit
Number of staves	14	
Number of modules per stave (single/double FE-I4)	32 / 16	
Pixel size (ϕ, z)	50, 250	μm
Module active size W×L (single/double FE-I4)	16.8×40.8 / 20.4	mm^2
Coverage in η, no vertex spread	$\lvert\eta\rvert < 3.0$	
Coverage in η, 2σ (=112 mm) vertex spread	$\lvert\eta\rvert < 2.58$	
Active z extent	330.15	mm
Geometrical acceptance in z (min, max)	97.4, 98.8	%
Stave tilt angle in ϕ (center of sensor, min, max)	14.00, −0.23, 27.77	degree
Overlap in ϕ	1.82	degree
Sensor thickness	230±15	μm
Radiation length at $z = 0$	1.5	% of X_0

Table 4. Main IBL layout parameters.

Digitization Model for IBL

BACKUP

- re-used Pixel digitization model
  - ➡ no radiation effects
  - ➡ model is closest to planar IBL modules
- 4bit (FE-I4) cluster calibration vs 8bit (FE-I3)
  - ➡ different dynamic range
    - FE-I4 different in handling overflow
  - ➡ average cluster size in IBL bigger than in b-layer
    - broader spectrum of incident angles
- IBL (FE-I4) and b-layer (FE-I3) resolutions
  - ➡ similar in X_{local}
  - ➡ pitch drives Z_{local}
  - ➡ used 8-bit for the following studies