



Early Minimum Bias physics at Atlas

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@Berkeley Workshop on Physics Opportunities with Early LHC Data



Overview

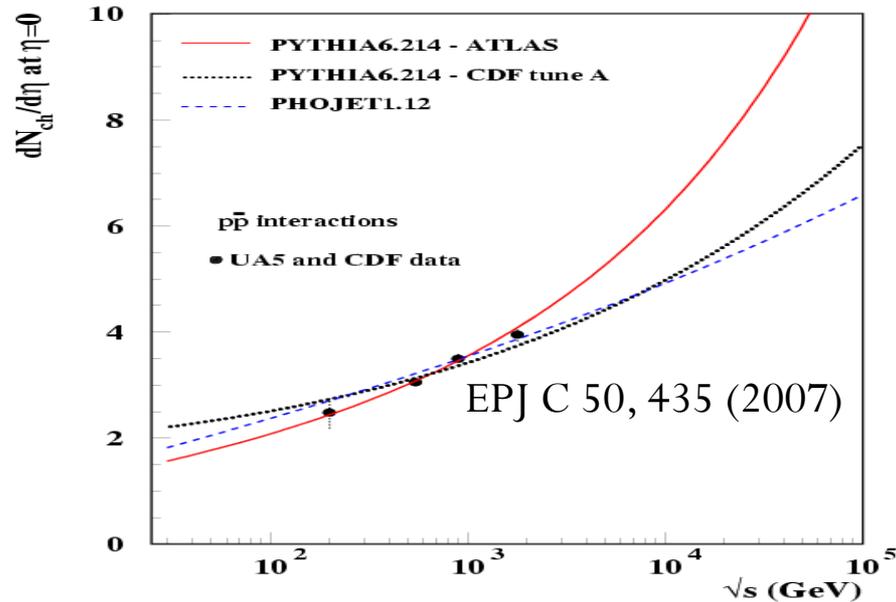
- ◆ Minimum Bias Events at ATLAS
- ◆ Analysis Goals at Start up
- ◆ Monte Carlo Analysis Studies
- ◆ Minimum bias Trigger
- ◆ Analysis strategy
- ◆ Conclusions and Outlook



Minimum bias event at ATLAS



◆ At the LHC, studies on minimum-bias **should be done early on**, at low luminosity to remove the effect of overlapping proton-proton collisions!



Process	Cross-section (mb)@14Tev	
	PHOJET	PYTHIA
Non-Diff.	69	55
Single Diff.	11	14
Double Diff.	4	10
Central Diff.	1	-
Inelastic	85	79
Elastic	35	23
Total	120	102

◆ Modeling of minimum bias pile-up **necessary tool for high p_T physics!**

- **Physics**: improve our understanding of QCD effects, total cross-section, saturation, jet cross-sections, mass reconstructions,...
- **Experiments**: occupancy, pile-up, backgrounds,...



Physics goal at Start up

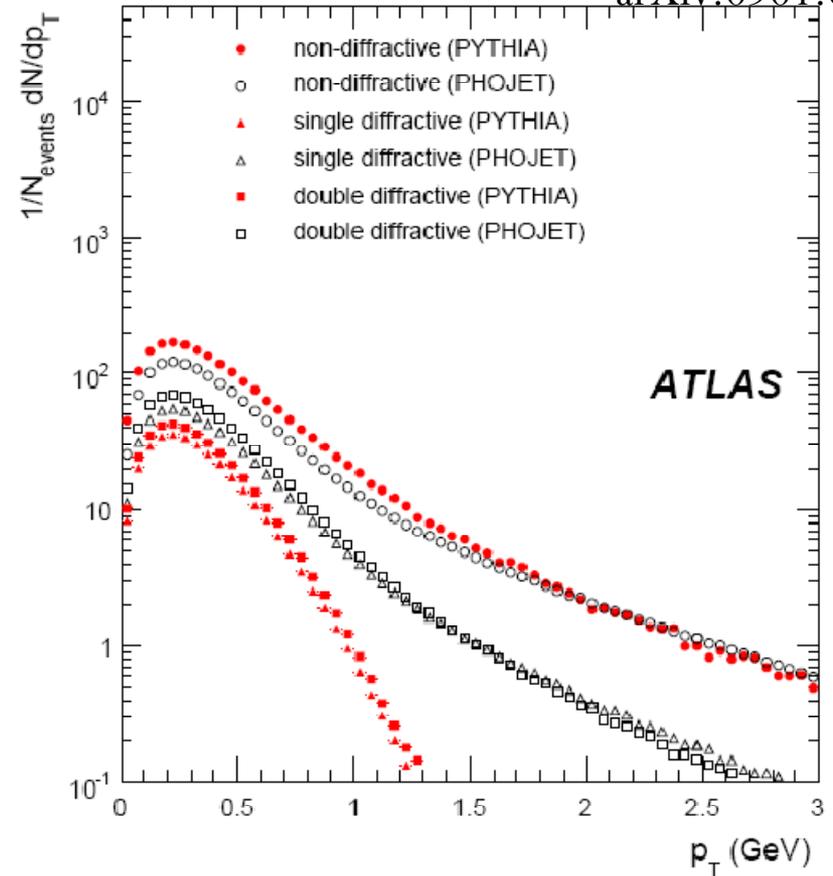
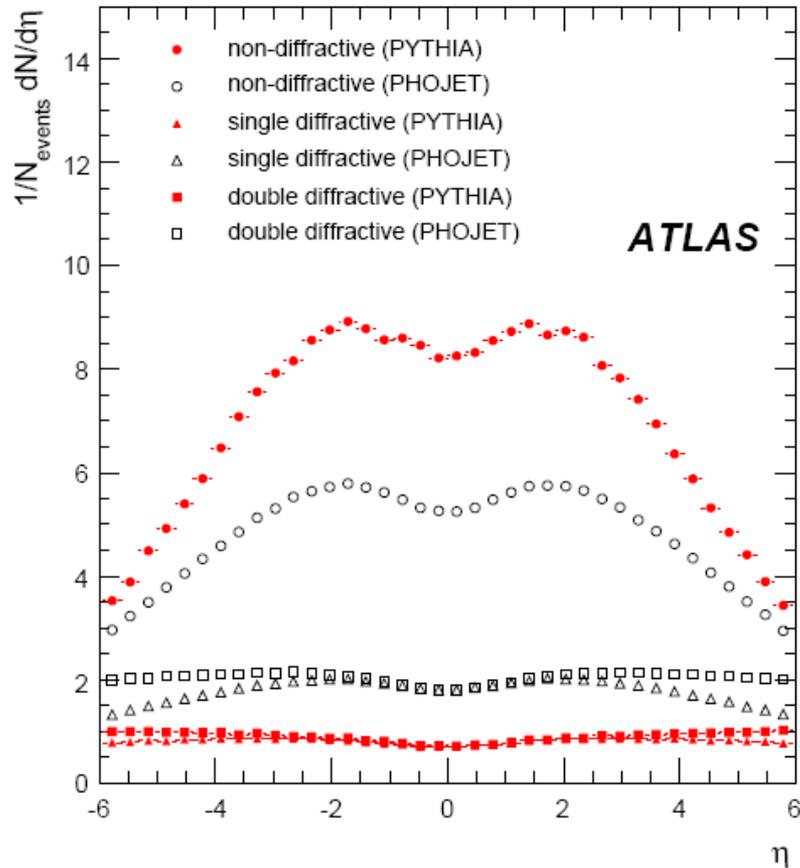
- ◆ Charged particle $dN/d\eta$, dN/dp_T ($\sim 10K$)
- ◆ Charged particle multiplicity (KNO) ($\sim 400K$)
- ◆ $\langle P_T \rangle$ vs N (1M)
- ◆ UE distributions (E_T up to 150GeV) (10M)
(Triggered event estimation based on statistical error.)
- ◆ Time needed to perform analysis is dependant on bandwidth allocated



Predicted Properties



arXiv:0901.0512



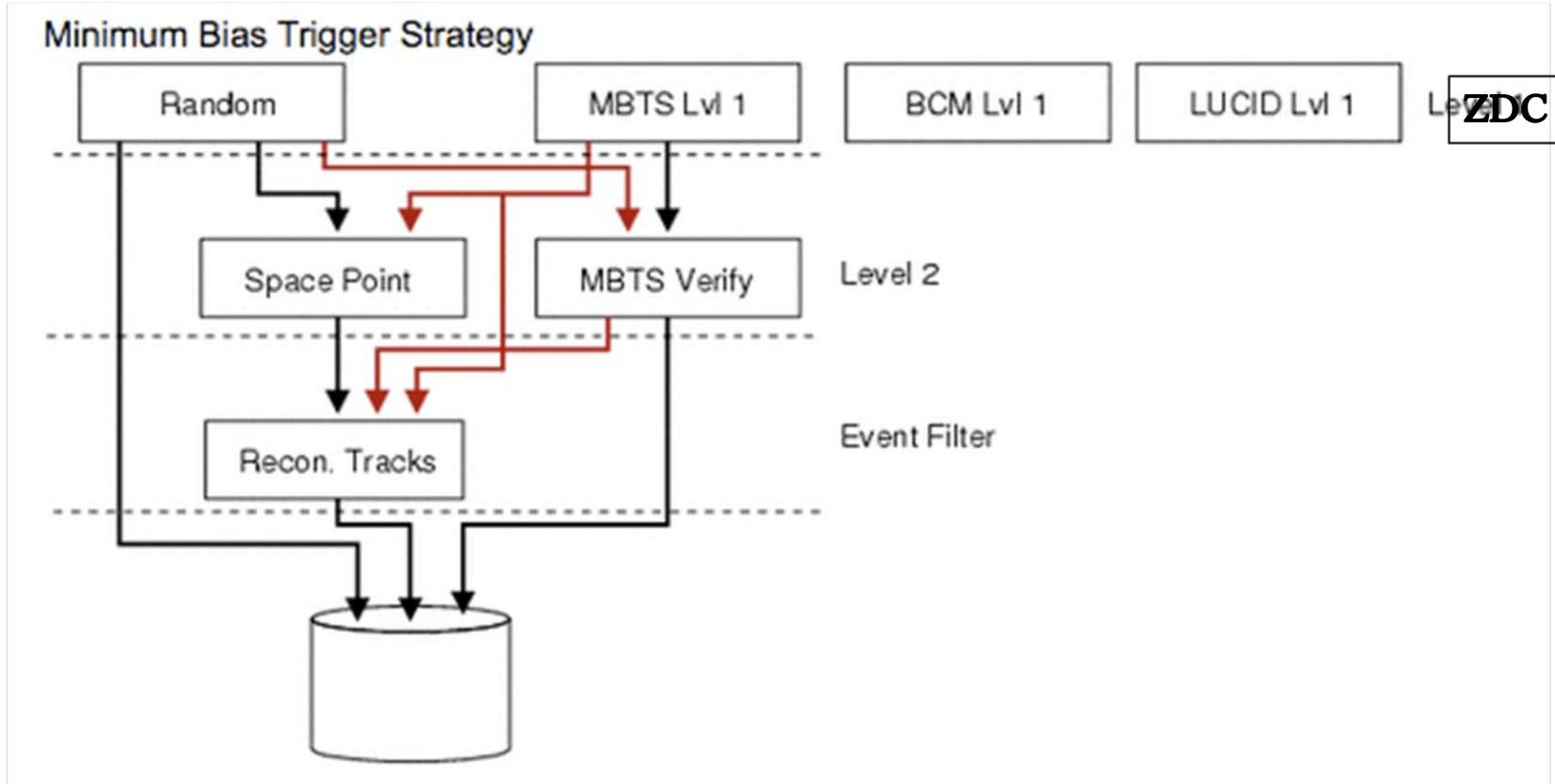


Minimum Bias Event

- ◆ What do we want in our final minimum bias event?
 - Non-single diffractive inelastic event.
- ◆ What are the backgrounds to be rejected?
 - Empty events (**trigger based on bunch crossings**);
 - Elastic events, Single-diffractive interactions;
 - Beam-gas;
 - Beam-halo (**interactions in the tertiary collimators in the accelerator**)
 - Pile-up (Not an issue early on but important for higher luminosity)



Triggering on Minimum bias





Triggering on Minimum Bias

Inner Detector Space Points

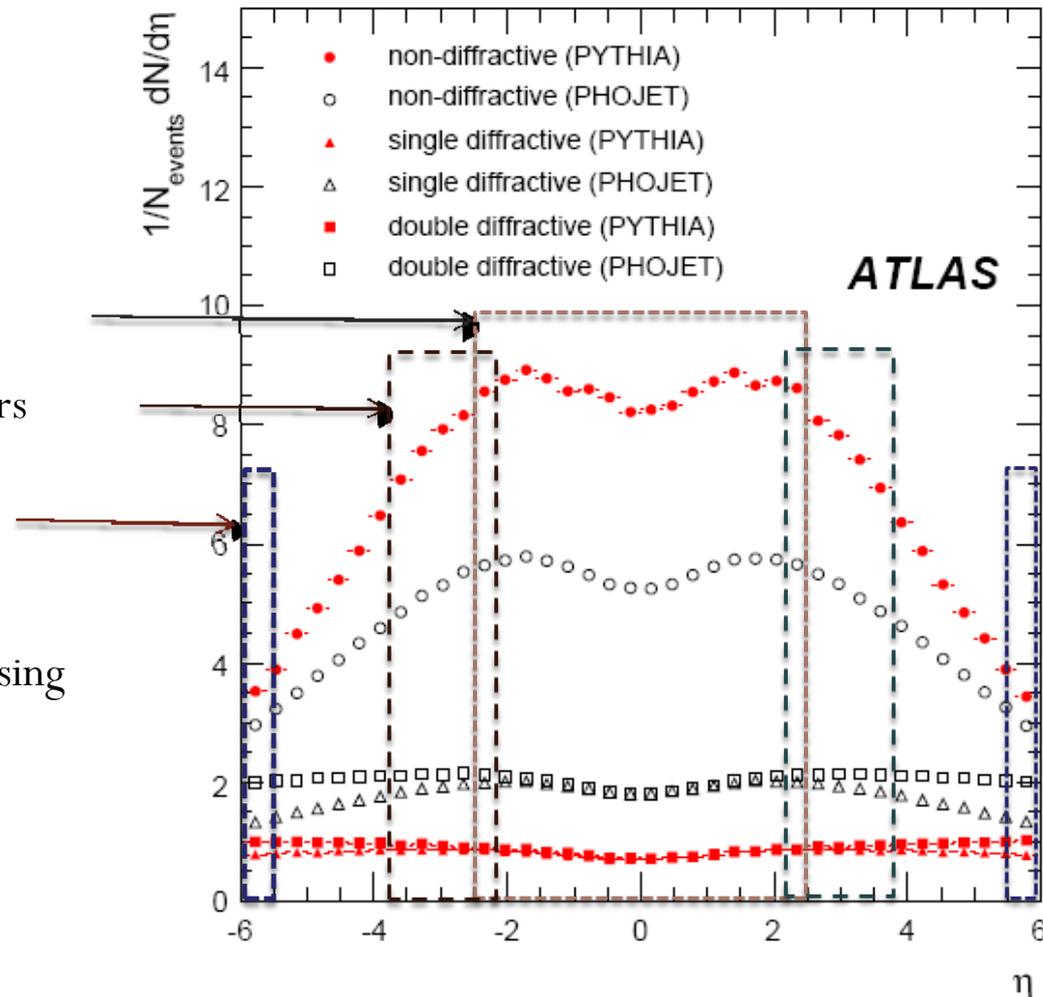
Minimum Bias Trigger Scintillators

Cerenkov Detector (LUCID)

Select events with minimal bias using level 1 and level 2 trigger items.

Zero degree calorimeter (ZDC)

8.3 $\rightarrow \infty$





Random trigger (initial runs)

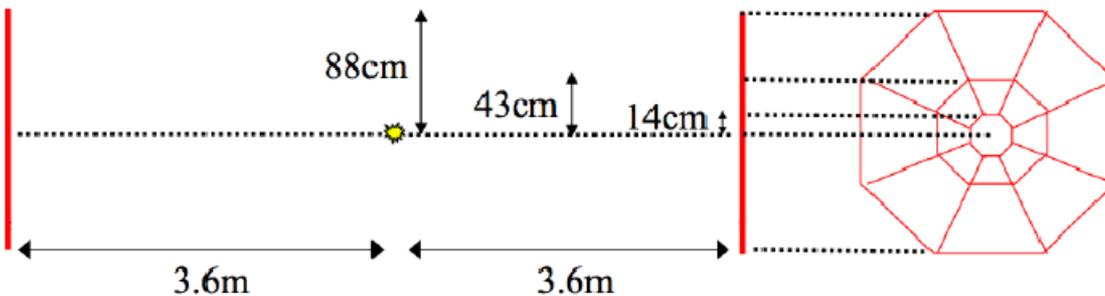
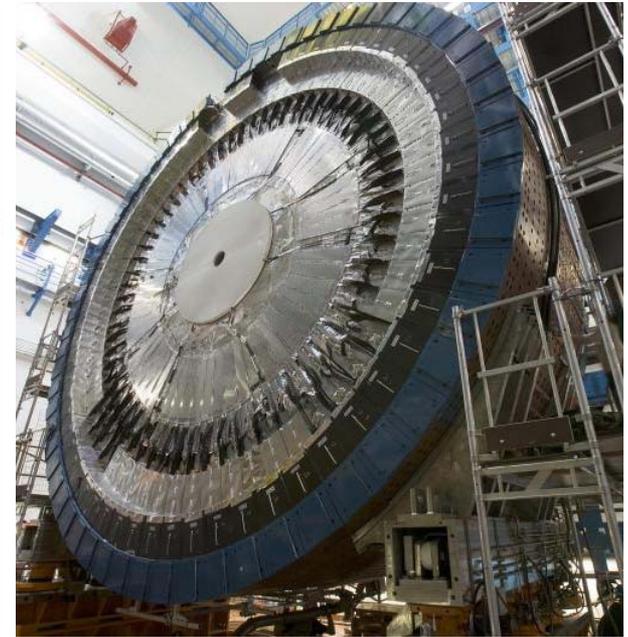
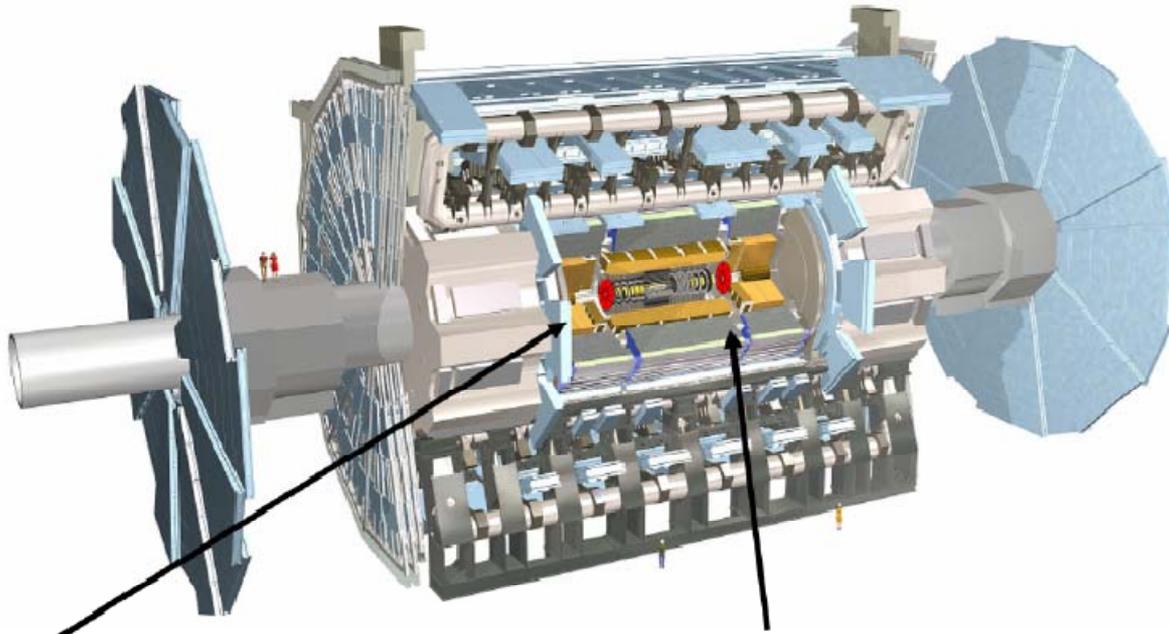
- ◆ 75ns bunch spacing at the start up.
 - ◆ Probability of 1pp event per bunch crossing ($\sim 10\%$).
 - ◆ Triggering on random bunch crossing at LVL1 and make the selection in the HLT.
 - ◆ Use Event Filter (EF) to remove empty events:
 - ◆ Eg. Pixel/Silicon hits, track reconstruction



Minimum Bias Trigger Scintillators



Minimum Bias Trigger Scintillators (MBTS)



$$2.12 < |\eta| < 2.83$$

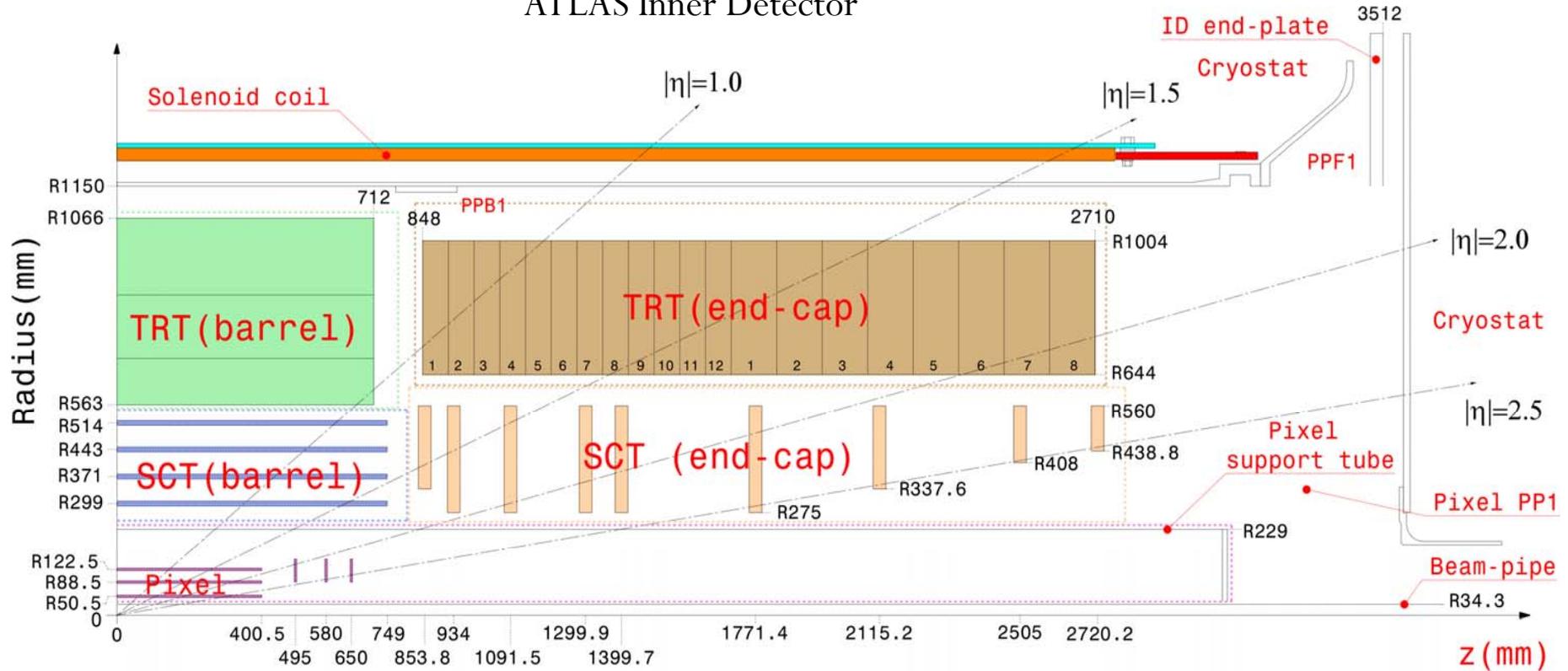
$$2.83 < |\eta| < 3.8$$



Space Points and Tracks

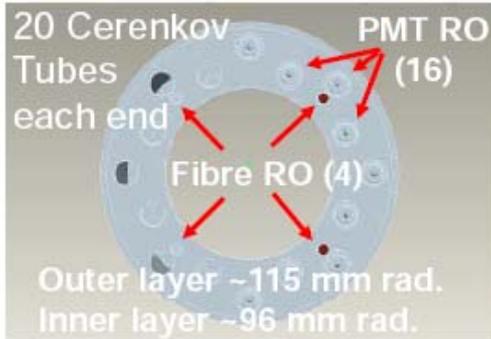
Pixel and silicon micro strip (SCT) detectors provide space points at level 2.

ATLAS Inner Detector





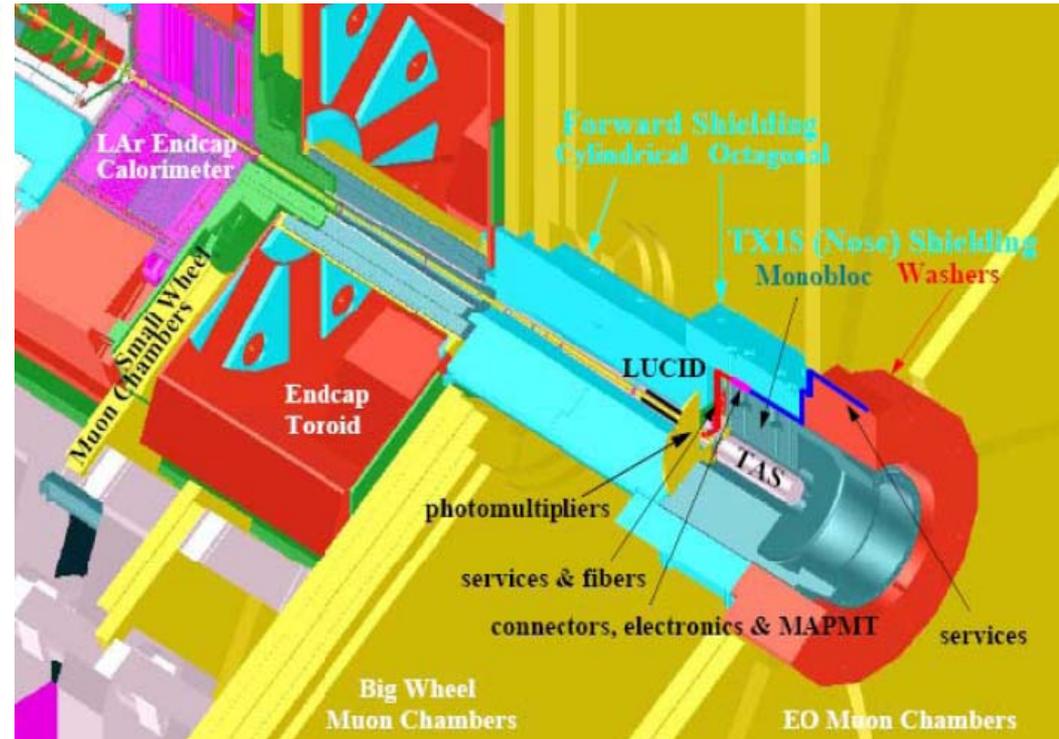
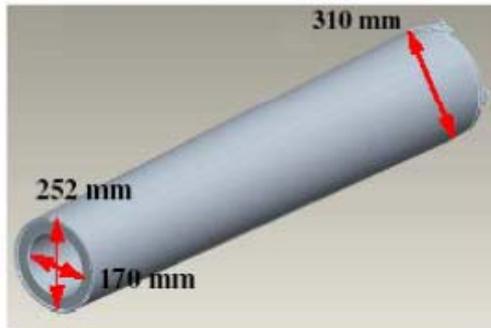
LUCID



Cerenkov Detector (LUCID)

+/-17m from IP

$$5.61 < |I| < 5.93$$



Require 1 or more tube one side



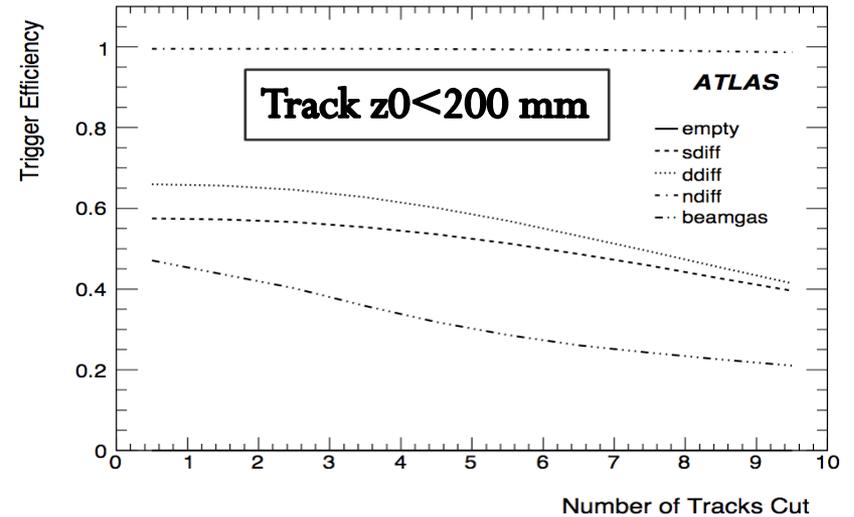
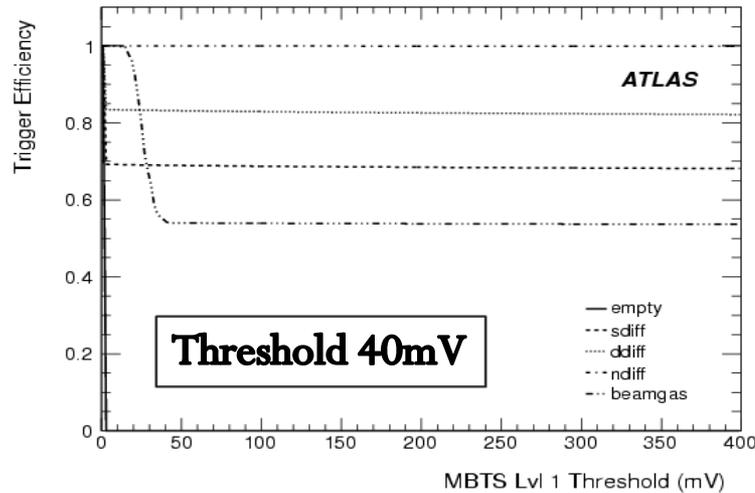
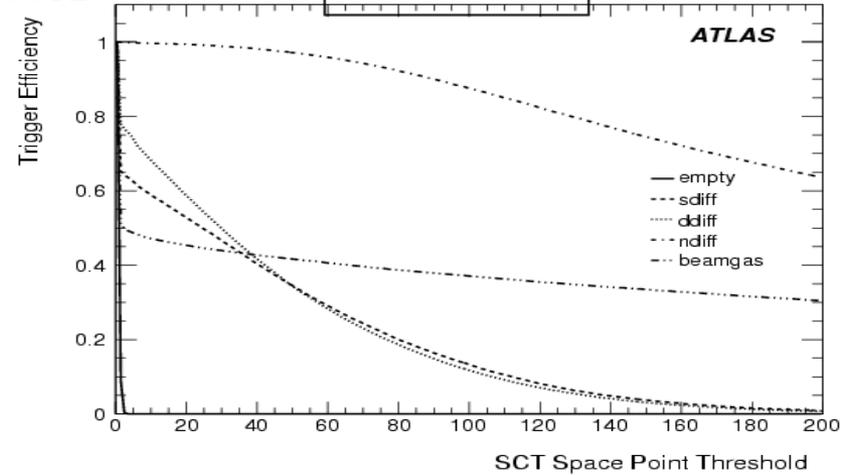
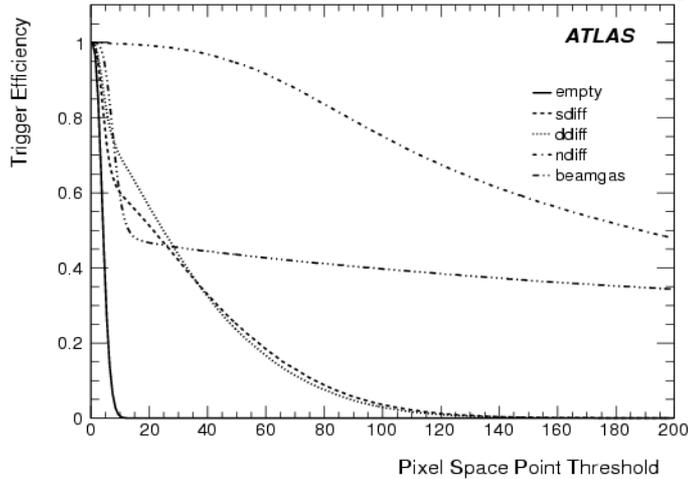
Trigger Efficiency



Pixel SP ≥ 12

arXiv:0901.0512

SCT SP ≥ 3





Trigger Efficiency

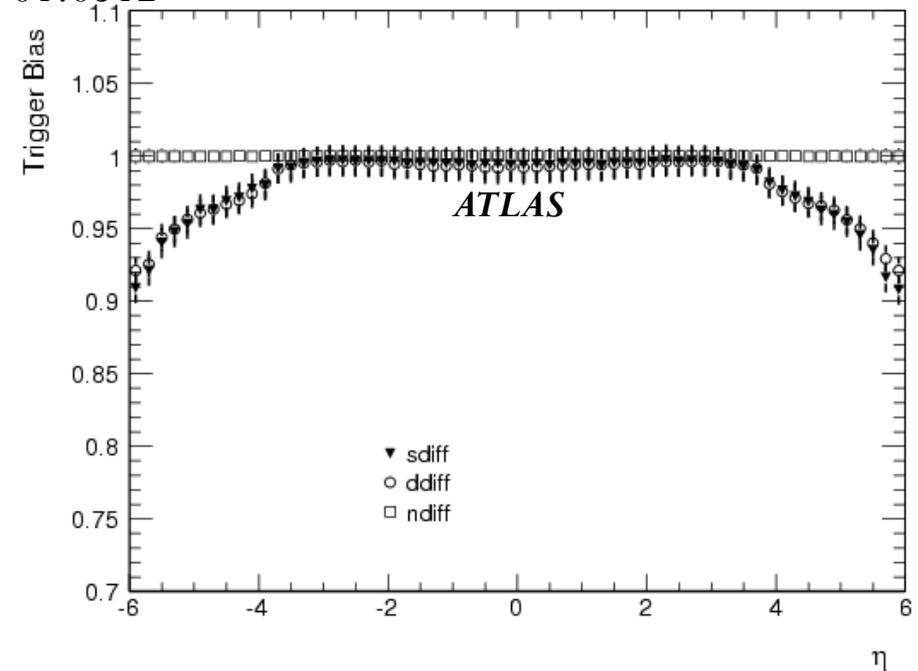
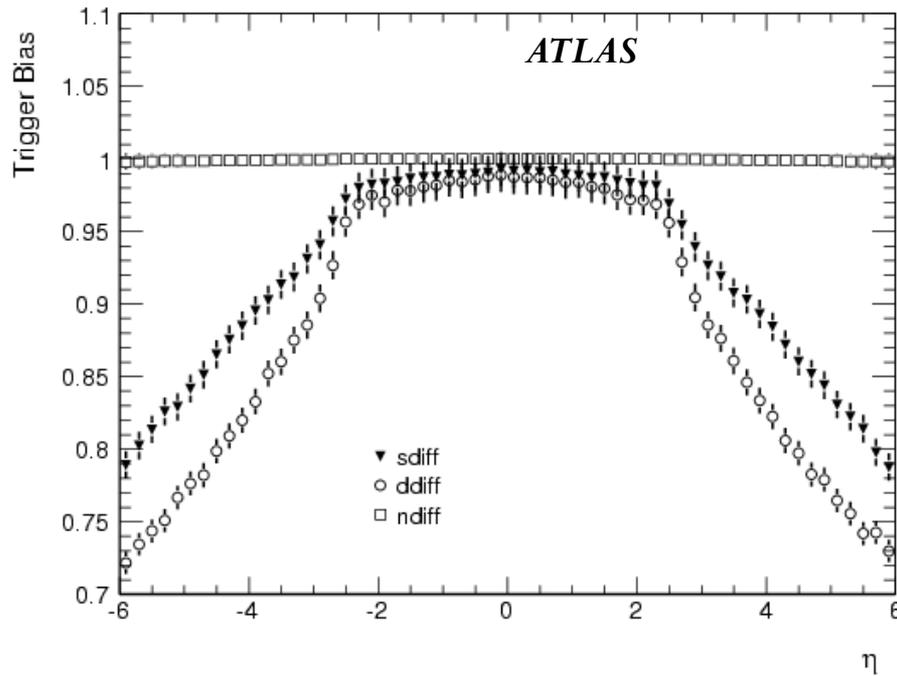
	MBTS_2	SP
Ndiff	100%	100%
Ddiff	83%	66%
Sdiff	69%	57%
B. Gas	54%	47%

- **MBTS** ≥ 2 (of 32), Threshold @ 40mV from cosmic data
- Space Point (SP) trigger SCT ≥ 3 & Pixel ≥ 12



Trigger Bias

arXiv:0901.0512



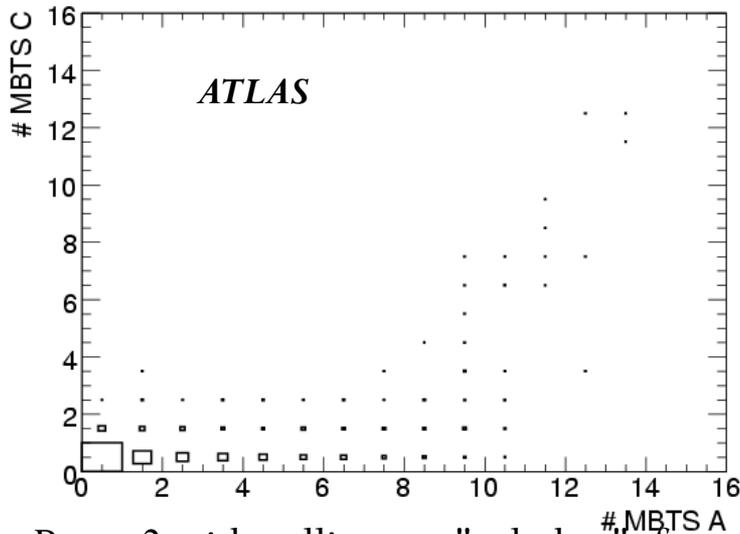
Space Point Trigger
SCT ≥ 3 & Pixel ≥ 12

MBTS ≥ 2 (of 32)
Threshold @ 40mV

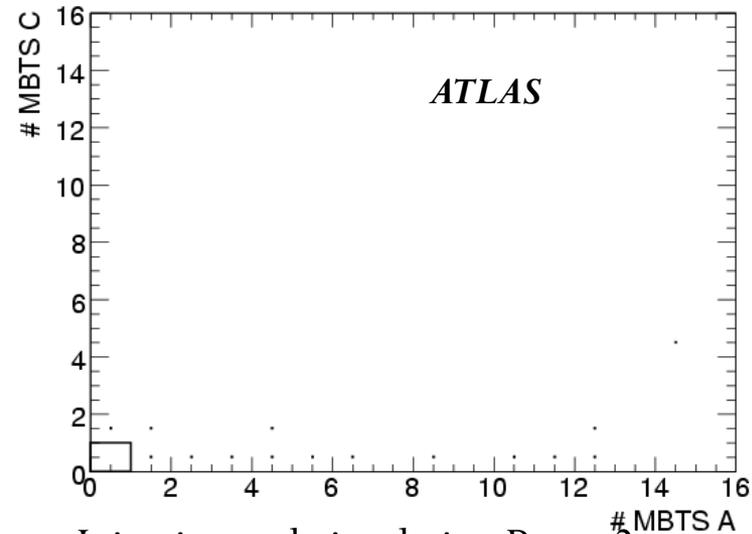


MBTS readiness

- During September ATLAS was triggering on beam pickups and MBTS
- Saw single beam collimator splashes and stable single beam
- MBTS A in time, MBTS C out of time.
- Plot MBTS A and C side multiplicities



Beam 2 with collimator "splashes", few turns only before being lost



Injecting and circulating Beam 2

MBTS provides a stable activity trigger

(Lvl1 MBTSA timed in with opposite side BPTX)



Analysis Strategy

$dN/d\eta$, dN/dp_T



- ◆ Record events with Minimum Bias trigger
 - ◆ Selection required while $N_{\text{inter}} \ll 1$
 - ◆ Combination of MBTS and Inner Detector space point
 - ◆ Comparisons with LUCID
 - ◆ Diffractive content estimation ZDC
- ◆ Measurement with tracks
 - ◆ Utilise low p_T tracking down to 100MeV
 - ◆ Efficiency studies with track insertion cross checked with $K_s \rightarrow \pi^+ \pi^-$
 - ◆ Sensitive to material model and misalignment



Track Selection

arXiv:0901.0512

- ◆ Using loose track cuts to
 - ◆ Remove fake and secondary tracks
 - ◆ Select tracks with reasonable fits

Quality cuts	No. of b-layer hits ≥ 1 No. of Silicon hits ≥ 5 $P(\chi^2) > 0.0$
Resolution cuts	$ \sigma_{d_0} < 1.6 \text{ mm}$ $ \sigma_{z_0} < 6.0 \text{ mm}$ $ \sigma_\phi < 0.03$ $ \sigma_\theta < 0.015$ $ \sigma_{q/p_T} < 0.0003 \text{ (GeV)}^{-1}$
Track-to-vertex cut	$N_\sigma < 3$

Using Gaussian fits to parameters, cuts are 3σ

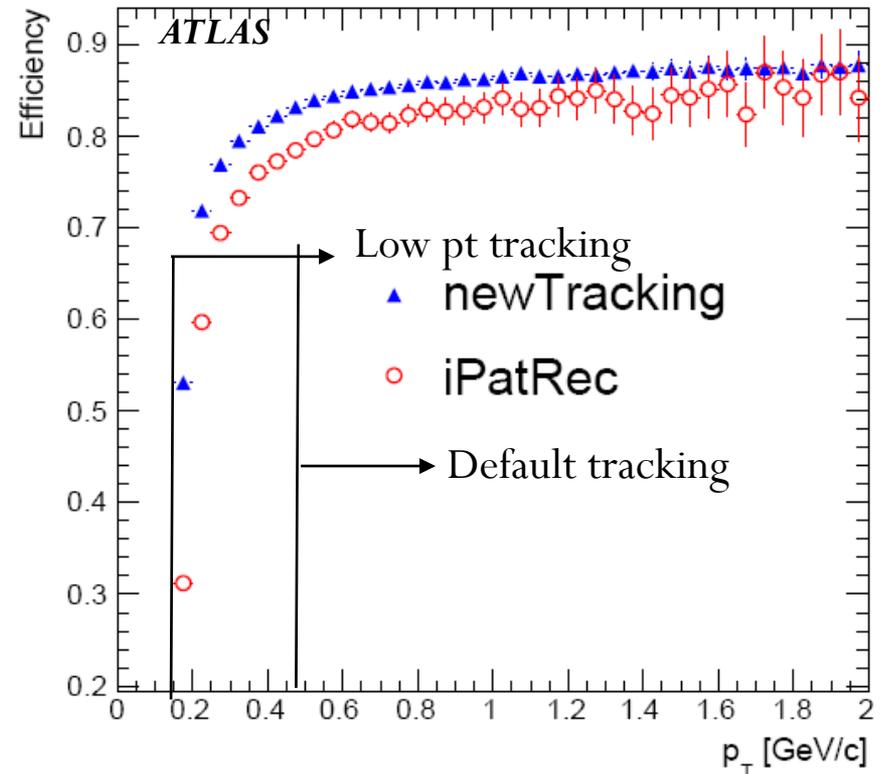
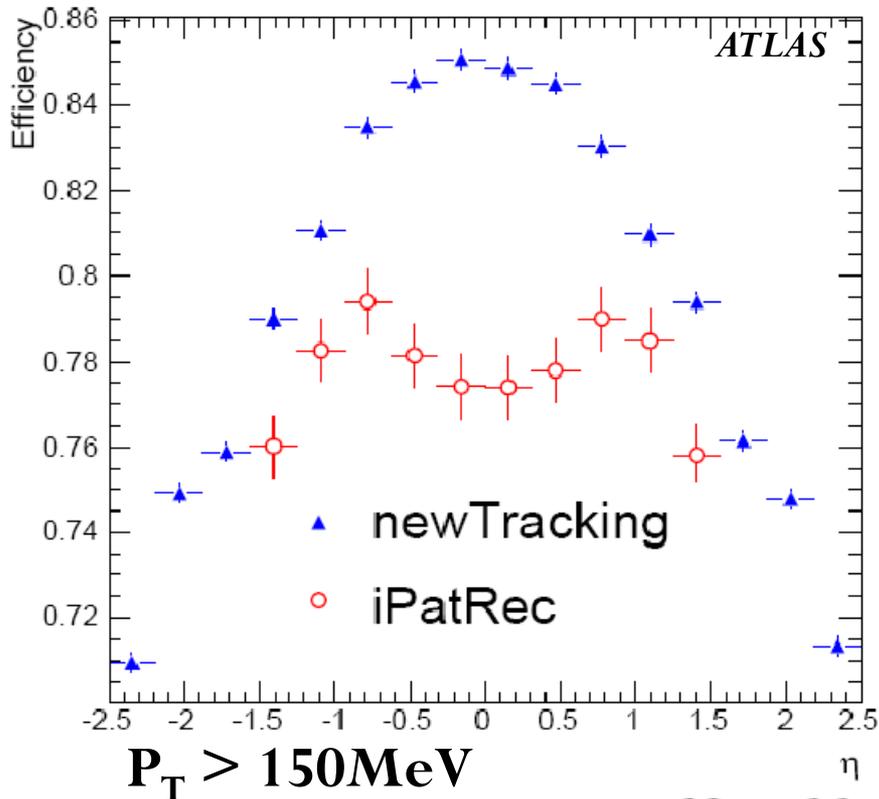


Tracking Efficiencies



$$\text{truth probability} \equiv \frac{\sum_{i=\text{subdetector}} w_i C_i}{\sum_{i=\text{subdetector}} w_i T_i}$$

Truth probability $\geq 50\%$ \Rightarrow Matched

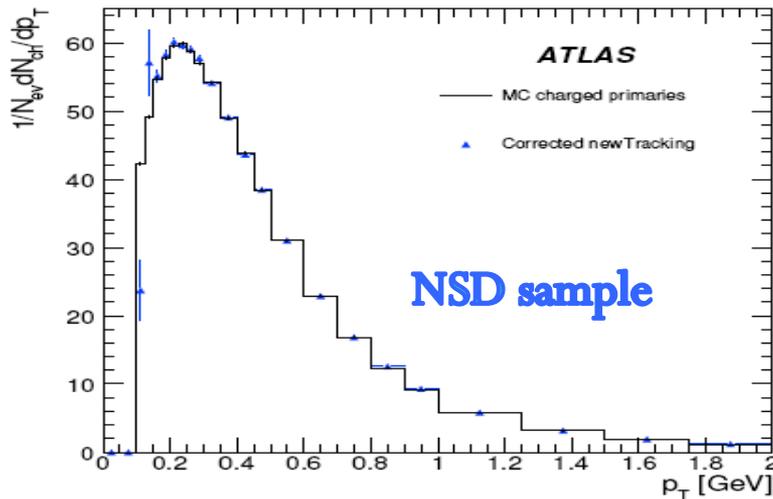
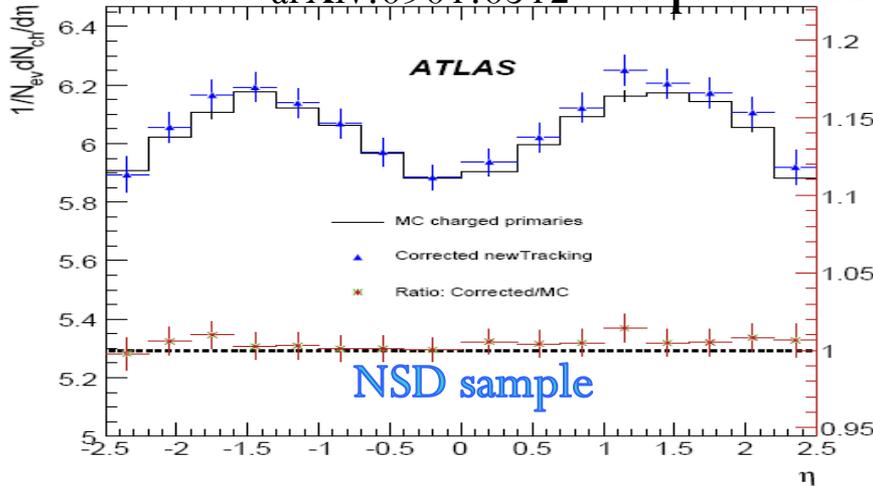


$$\mathcal{E}_{tr} \equiv \frac{\text{No. of found generated primaries}}{\text{No. of generated primaries}}$$



Results

arXiv:0901.0512 $P_T > 150\text{MeV}$



Name	Estimated Uncertainty
Track Selection Cuts	2%
Mis-estimate of Secondaries	1.5%
Vertex Reconstruction Bias	0.1%
Misalignment	6%
Beam-gas and pileup	1%
Particle Composition	2%
Diff. Cross Sections (NSD)	4%
Total	8%

Corrections: {

- Track-to-particle
- Vertex reconstruction
- Trigger bias



Summary and conclusions

- ◆ Trigger is ready for minimum bias measurement from early data.
- ◆ Single beam showed MBTS stability
- ◆ Last year cosmic data were used to tune the ID and expect better results from simulation.
- ◆ Early measurement can be done with as little as 10K minimum bias events.