Luminosity measurement from track counting in ATLAS

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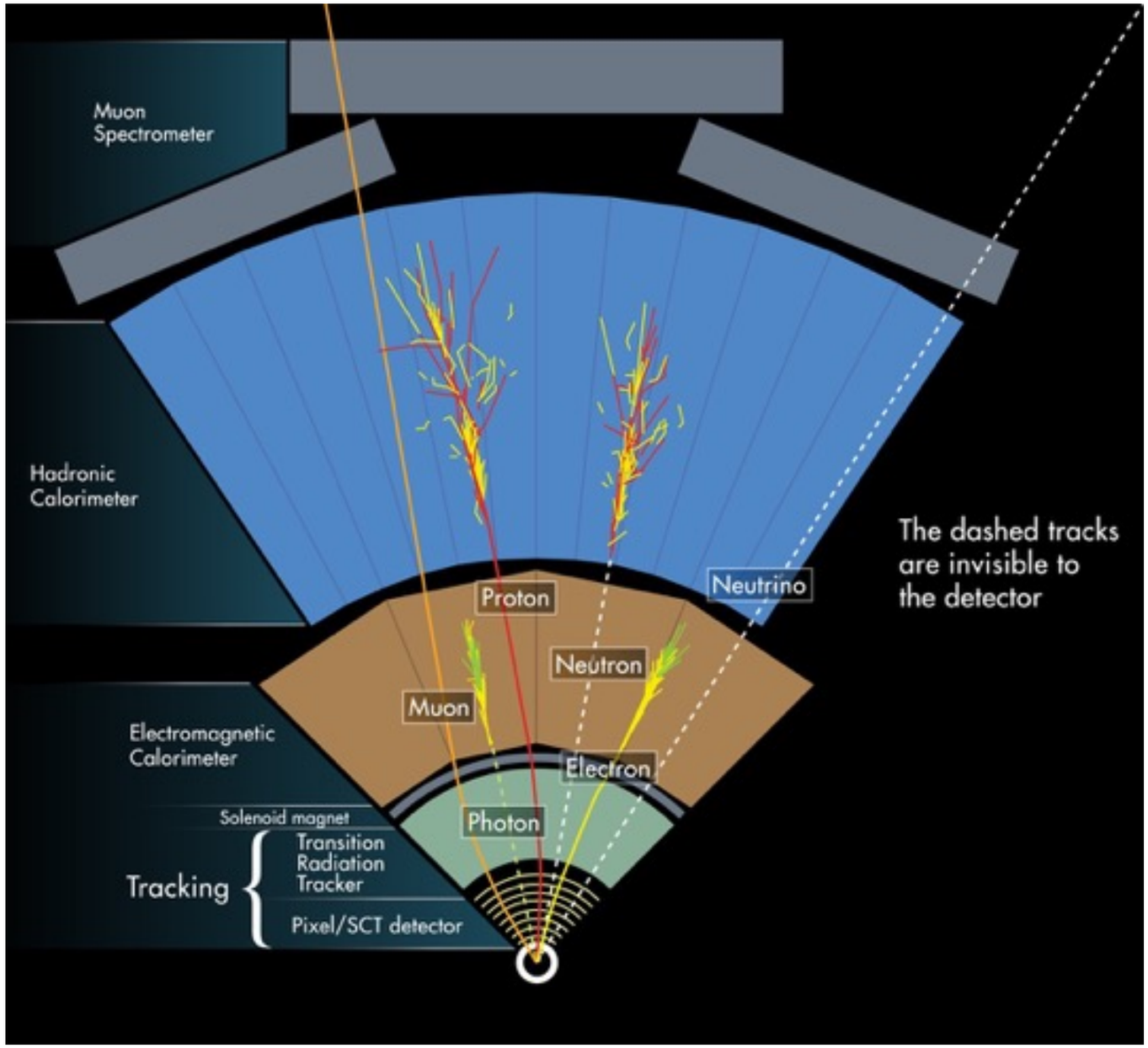
Outline

- The ATLAS detector
- Luminosity
  - Definition and formalism
  - Luminosity measurement in ATLAS
- Luminosity measurement from track counting
  - How it is performed
  - Preliminary results from 2016 and 2017 data

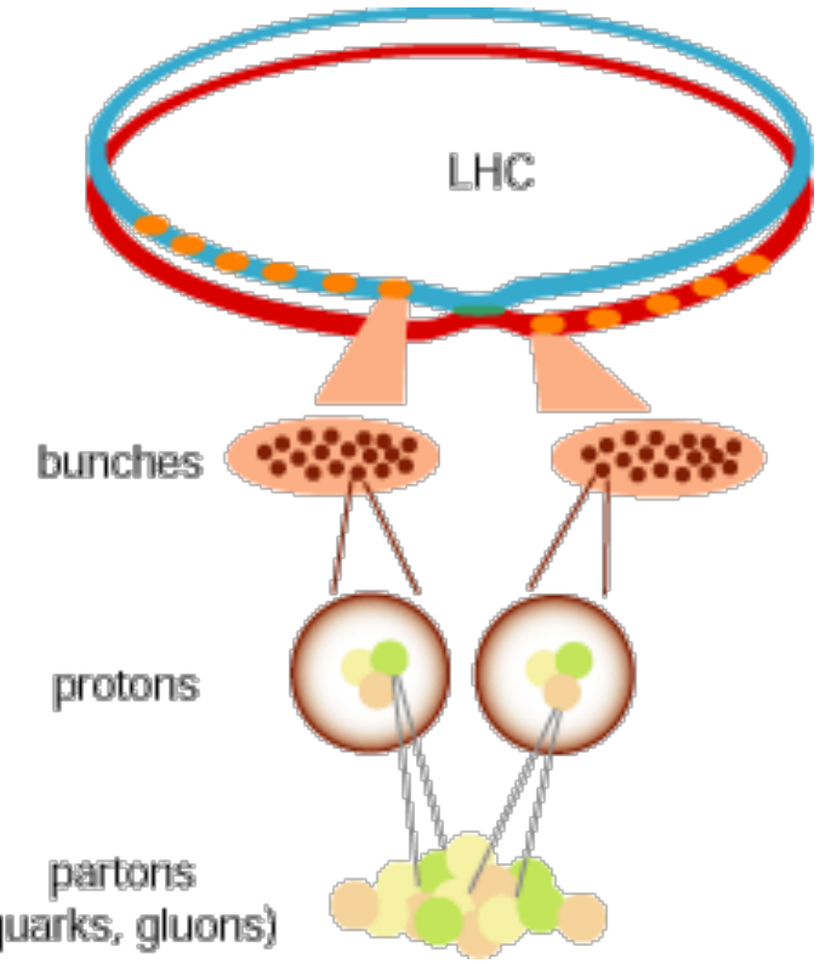
The ATLAS Detector



A cross sectional diagram of the ATLAS detector with various particle trajectories (photo from atlasexperiment.org/photos)

* ATLAS is one of the four main detectors of the LHC
* General purpose detector
* Inner Detector (ID)
  * Composed of silicon sensors and drift tubes
  * Charged-particle tracks identification
* ECAL where electrons and photons deposit energy
* HCAL where hadrons deposit energy
* Muon Spectrometer (MS) for muon detection

Luminosity



Proton bunches inside the LHC
(photo from lhcathome)

* Luminosity is a measurement of a number of inelastic pp collisions

Instantaneous luminosity per bunch crossing

$$\mathcal{L}_b = \frac{\mu f_r}{\sigma_{inel}} \quad [cm^{-2}s^{-1}]$$

* μ is the average number of inelastic pp collisions per bunch crossing (BC)
* f_r is the revolution frequency
* σ_{inel} is the cross-section of an inelastic pp collision
* The total instantaneous luminosity $\mathcal{L}$ can be obtained by

$$\mathcal{L} = \sum_{b=1}^{n_b} \mathcal{L}_b = n_b \langle \mathcal{L}_b \rangle = n_b \frac{< \mu > f_r}{\sigma_{inel}} \quad [cm^{-2}s^{-1}]$$

* n_b is the number of bunch pairs

Why measure luminosity?

* To measure a process cross-section

$$\sigma_{\text{proc}} = \frac{N_{\text{proc}}}{\int \mathcal{L} \mathrm{d}t} \quad ; \qquad \int \mathcal{L} \mathrm{d}t \text{ is the integrated luminosity}$$

  * The measured cross-section is used to compare to the value obtained from theory

* To predict a number of events from a given process

$$N_{\text{proc}} = \sigma_{\text{proc}} \cdot \int \mathcal{L} \mathrm{d}t$$

Track Counting Luminosity

* The average number of tracks per BC is linearly proportional to $<\mu>$

$$< N_{\text{tracks}} >= \alpha < \mu > \quad ; \quad \alpha \text{ is constant}$$

* $\mathcal{L}$ can be obtained by counting the number of tracks from charged particles inside the ID

$$\mathcal{L} = n_{\text{b}} \frac{< \mu > f_{\text{r}}}{\sigma_{\text{inel}}} = n_{\text{b}} \frac{< N_{\text{tracks}} > f_{\text{r}}}{\alpha \sigma_{\text{inel}}}$$

* $n_{\text{b}}, f_{\text{r}}, \alpha, \sigma_{\text{inel}}$ are constants that are either known or can be determined in special calibration runs

$$\therefore \quad \mathcal{L} = \beta < N_{\text{tracks}} > \quad ; \quad \beta = \frac{n_{\text{b}} f_{\text{r}}}{\alpha \sigma_{\text{inel}}}$$

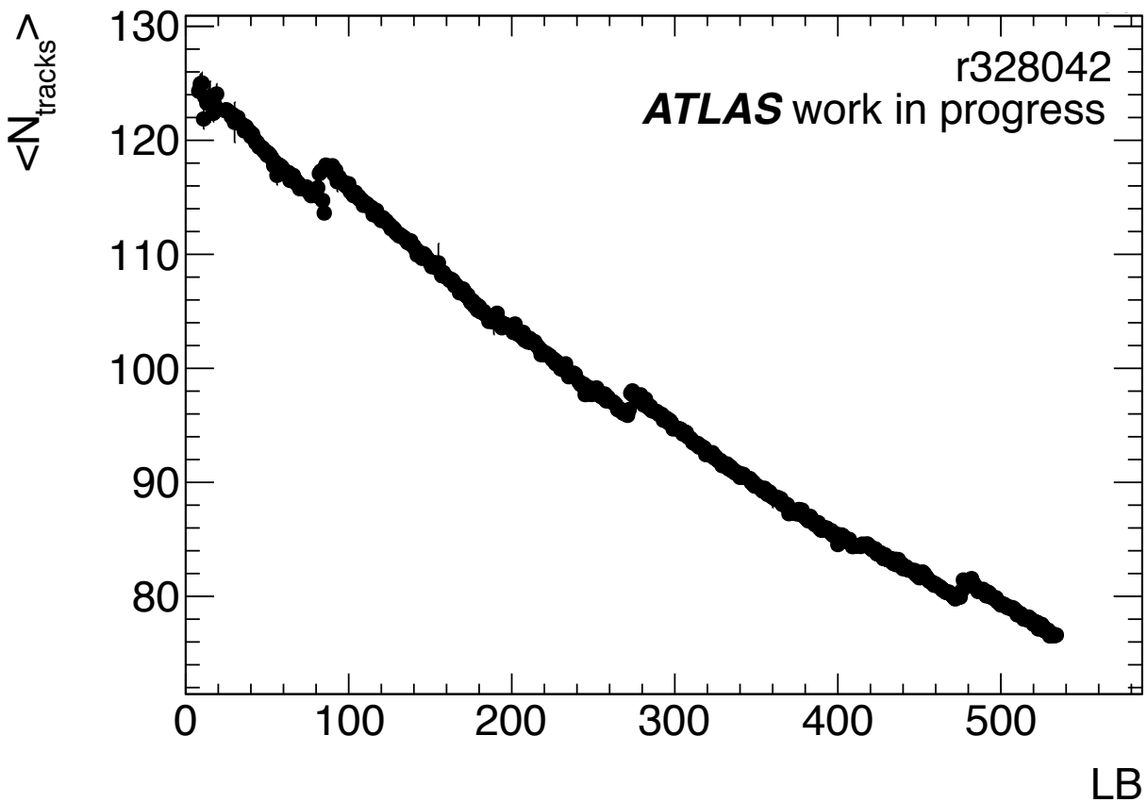
Track Reconstruction Efficiency

- Track reconstruction efficiency depends on μ and time
  - μ : more difficult to reconstruct the tracks when μ is high due to larger number of detector hits (larger occupancy)
  - Time: detector condition, e.g. dead modules
  - Measure the efficiency from Z—>$\mu^+\mu^-$ events
- The number of fake tracks also depend on μ as the probability of getting fake tracks increases with occupancy

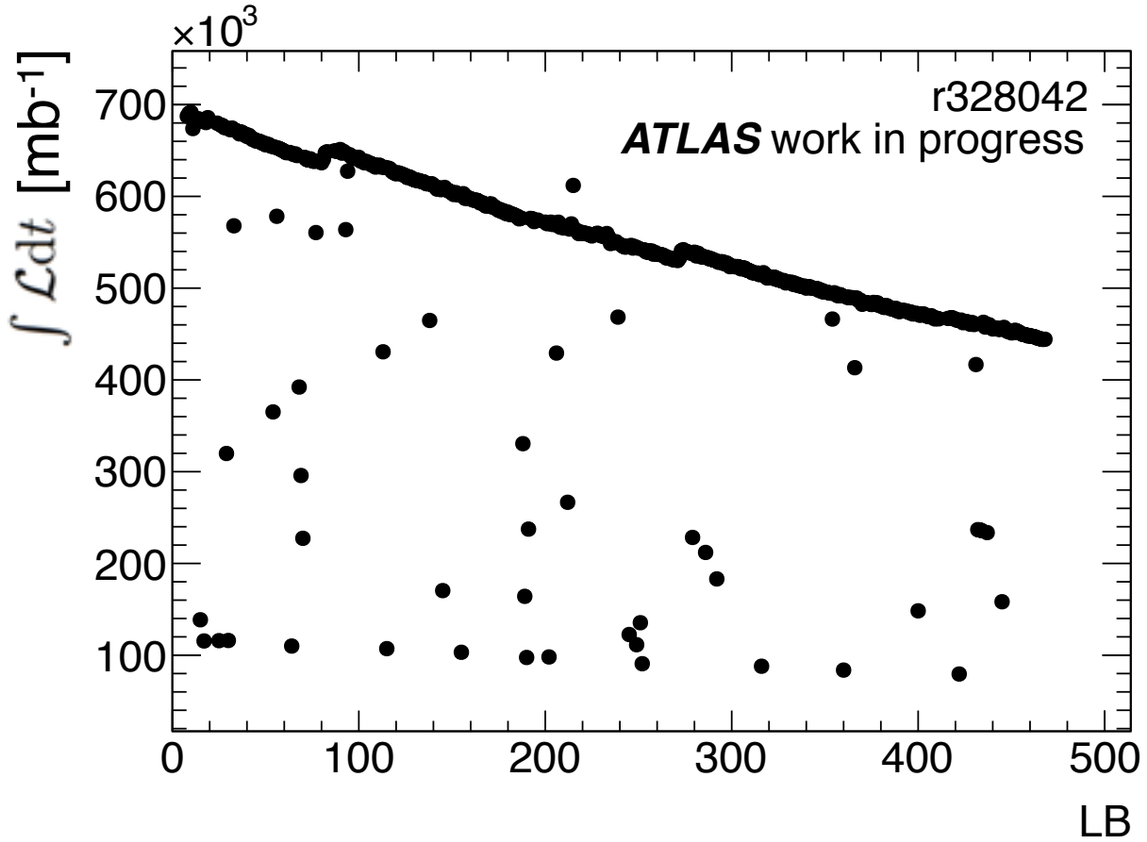
Track Counting in 2017 Data

* A luminosity block (LB) is a time interval over which the instantaneous luminosity is approximately constant

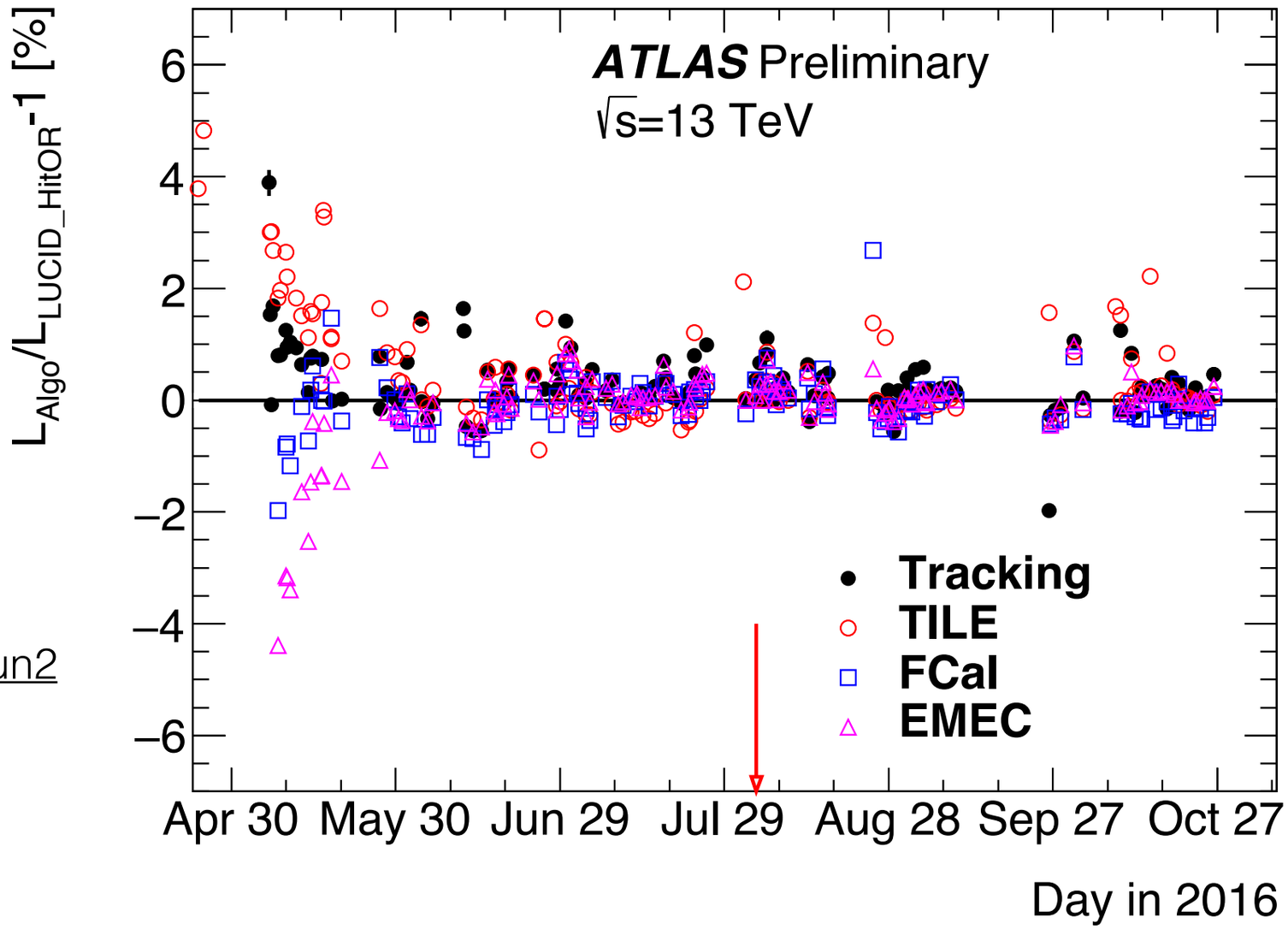
Average number of tracks per event per LB



Integrated luminosity per LB



Track Counting in 2016 Data



Taken from AtlasPublicResultsRun2

- Integrated luminosity from different algorithms from the runs in 2016, compared to LUCID — ATLAS's default online luminosity detector
- Work in progress to produce similar results for 2017 data

Summary

- The integrated luminosity of the data sample is an essential input to all physics analyses in ATLAS
  - Cross-section measurements
  - Predictions for number of instances of a given process
- One of the ways to measure luminosity in ATLAS is by counting the number of tracks in the ID
- The luminosity results in 2016 data from TC are presented and compared with results from LUCID
- Work in progress to produce results from 2017 data

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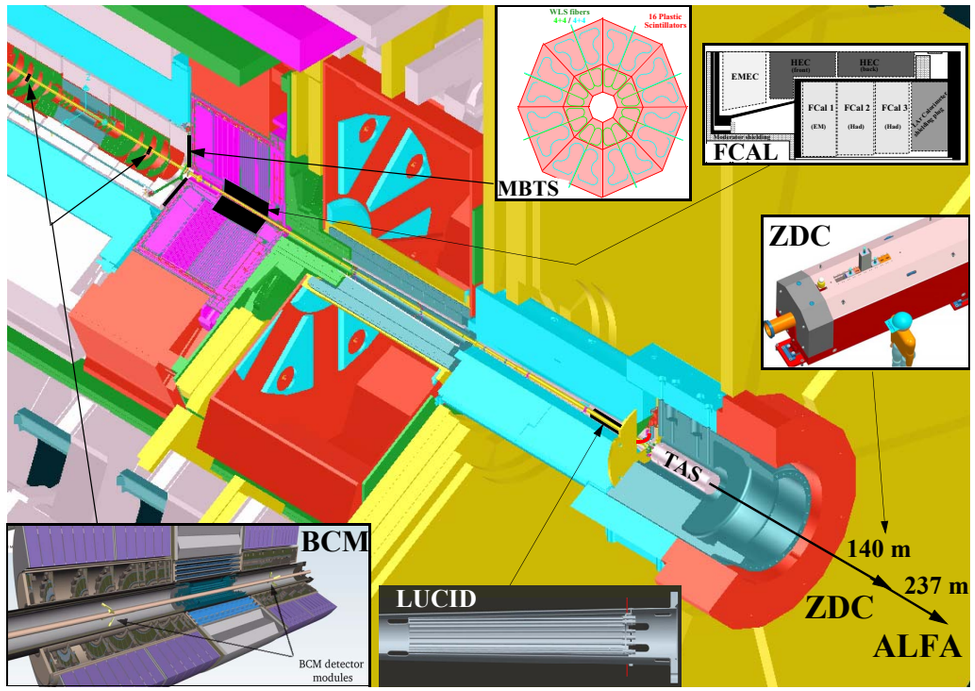
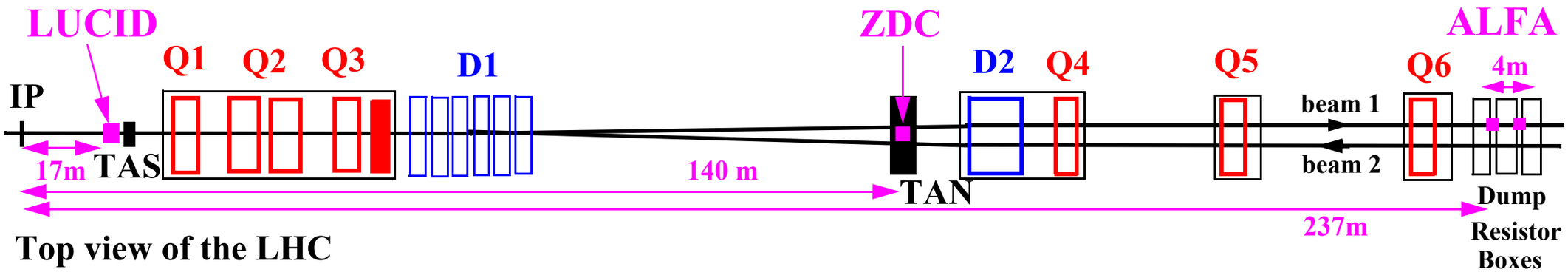
BACKUP

The ATLAS Detector

Photos from the ATLAS LMTF page

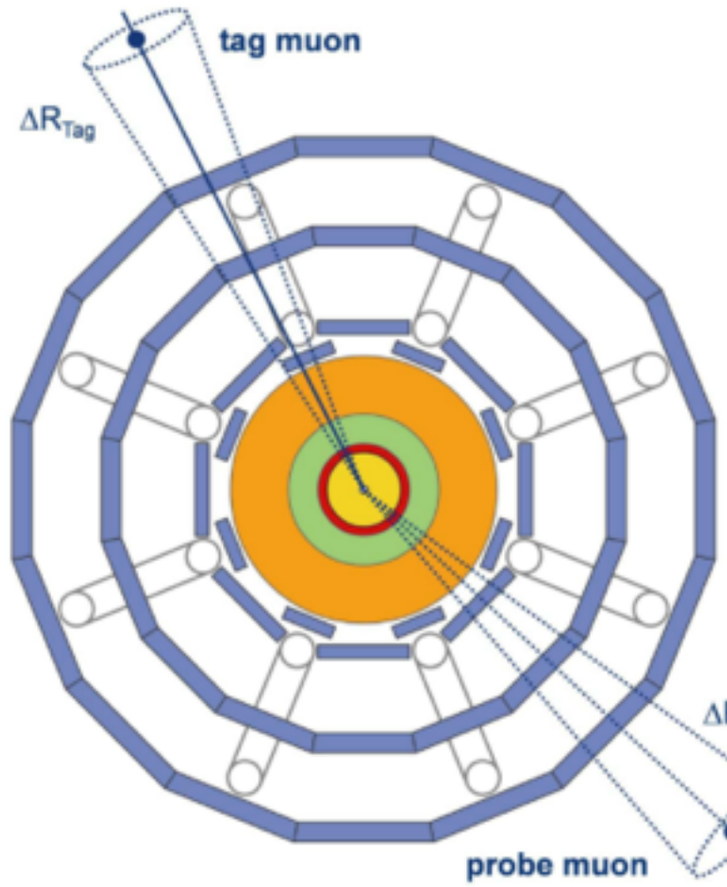


- ATLAS has subdetectors in the forward and backward regions
- For monitoring activity in high eta region
- All can be used to measure luminosity
- LUCID is currently the default online luminosity detector
- It is a Cherenkov detector

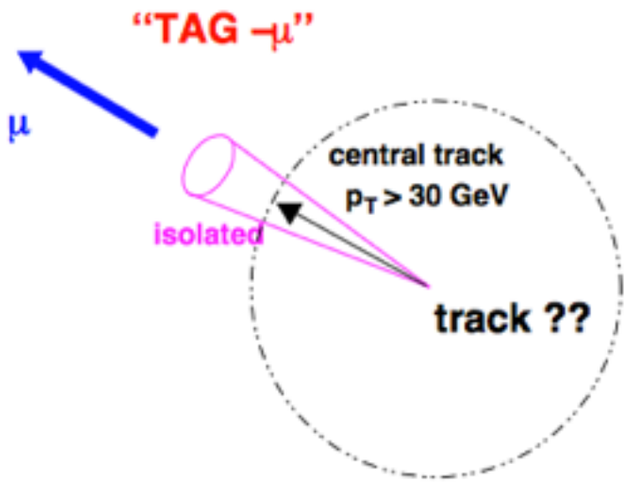


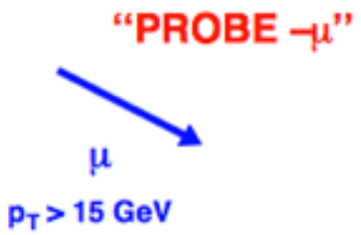
Track Counting Efficiency

Photo from arXiv:1204.0952



- Measure the efficiency by doing Z tag-and-probe
  - From Z—>$\mu^+\mu^-$ events, compare the ID tracks with the muon spectrometer tracks





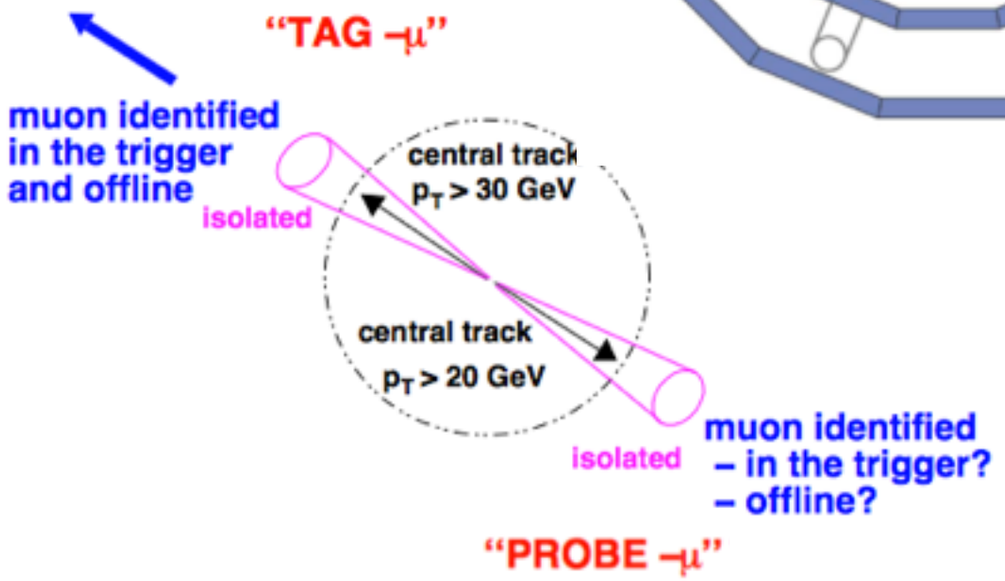
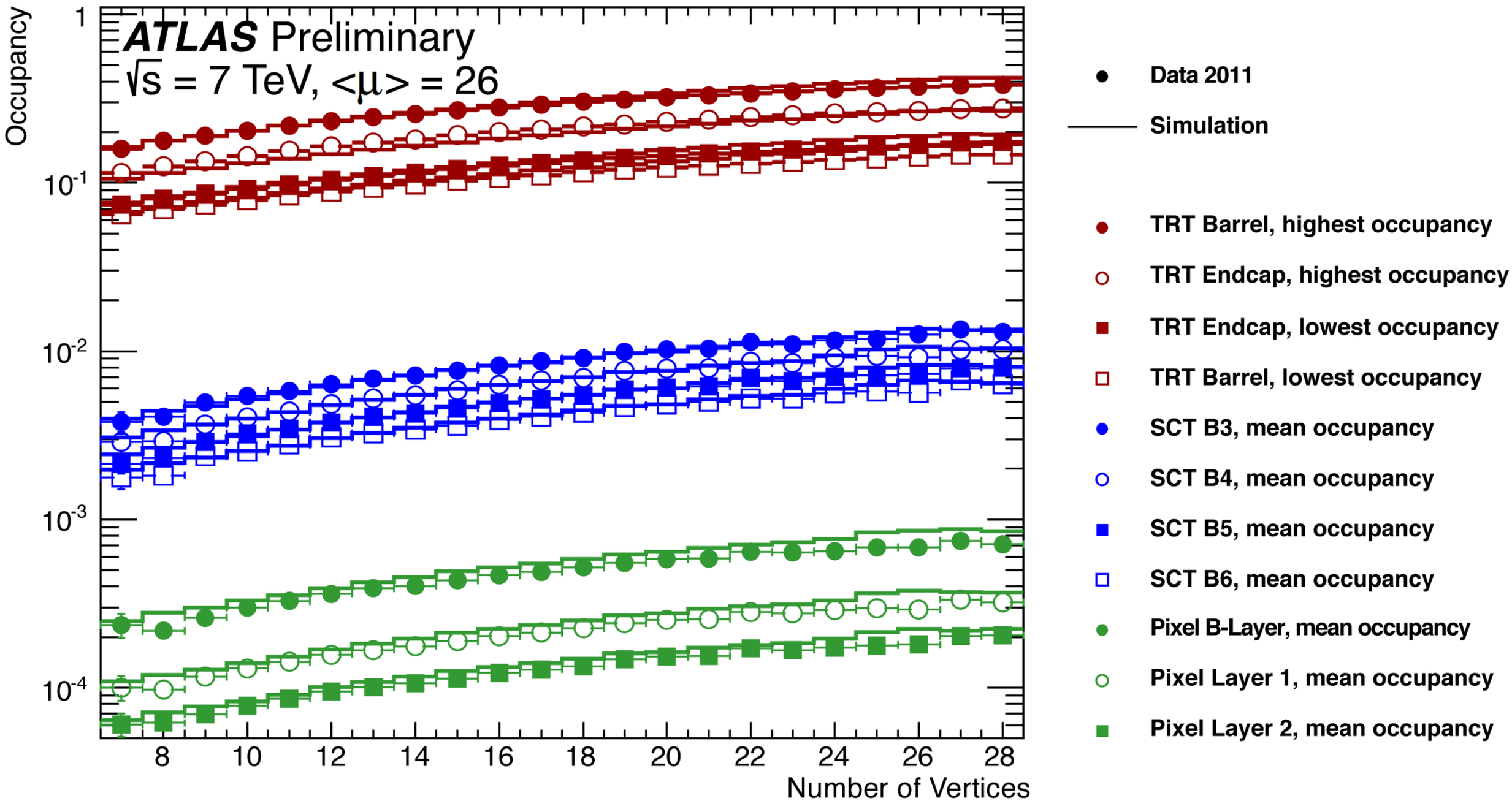


Photo from arXiv:1003.0521



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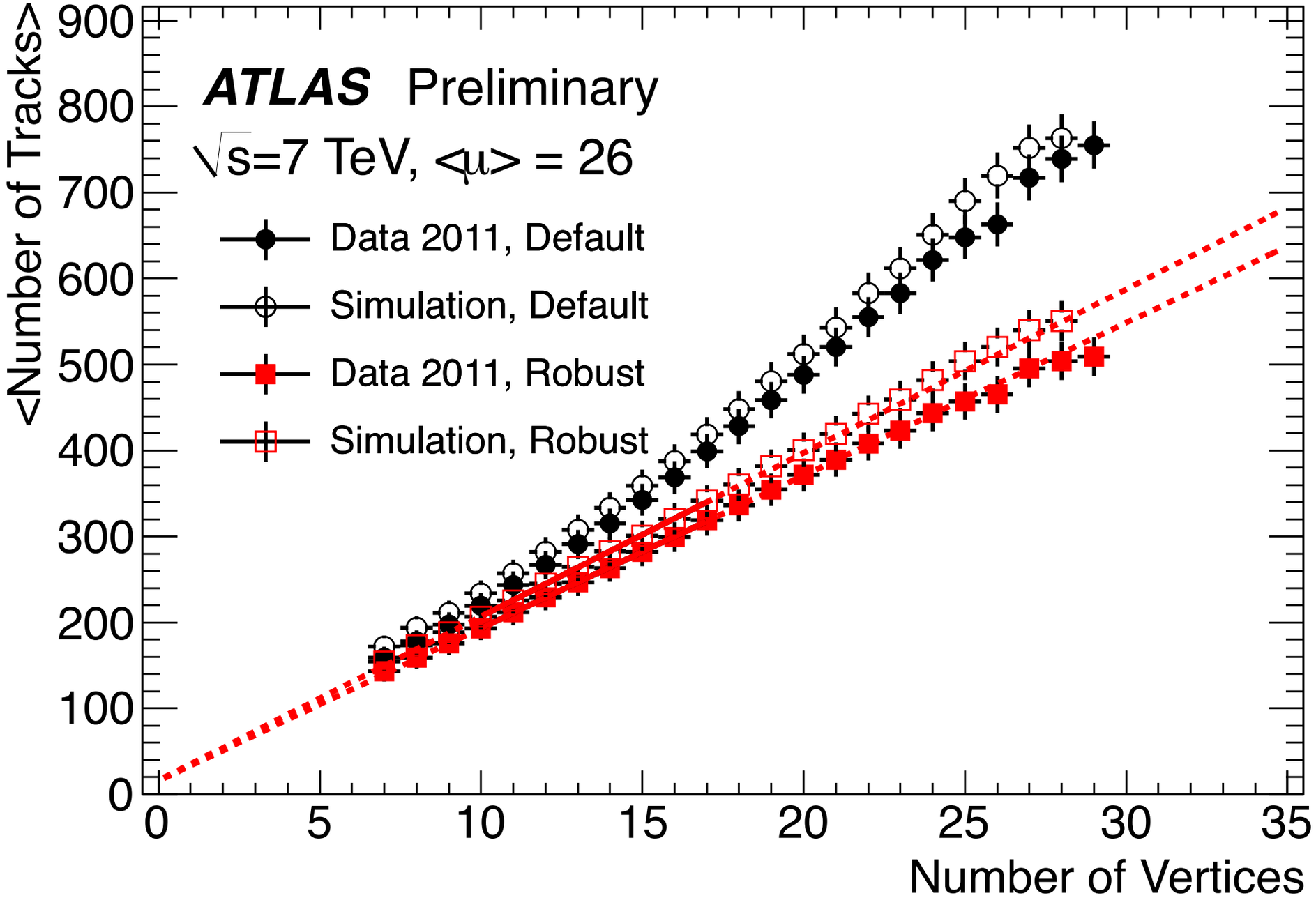

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