Measurement of charged particle multiplicities and densities in pp collisions at $\sqrt{s} = 7\,\text{TeV}$ in the forward region

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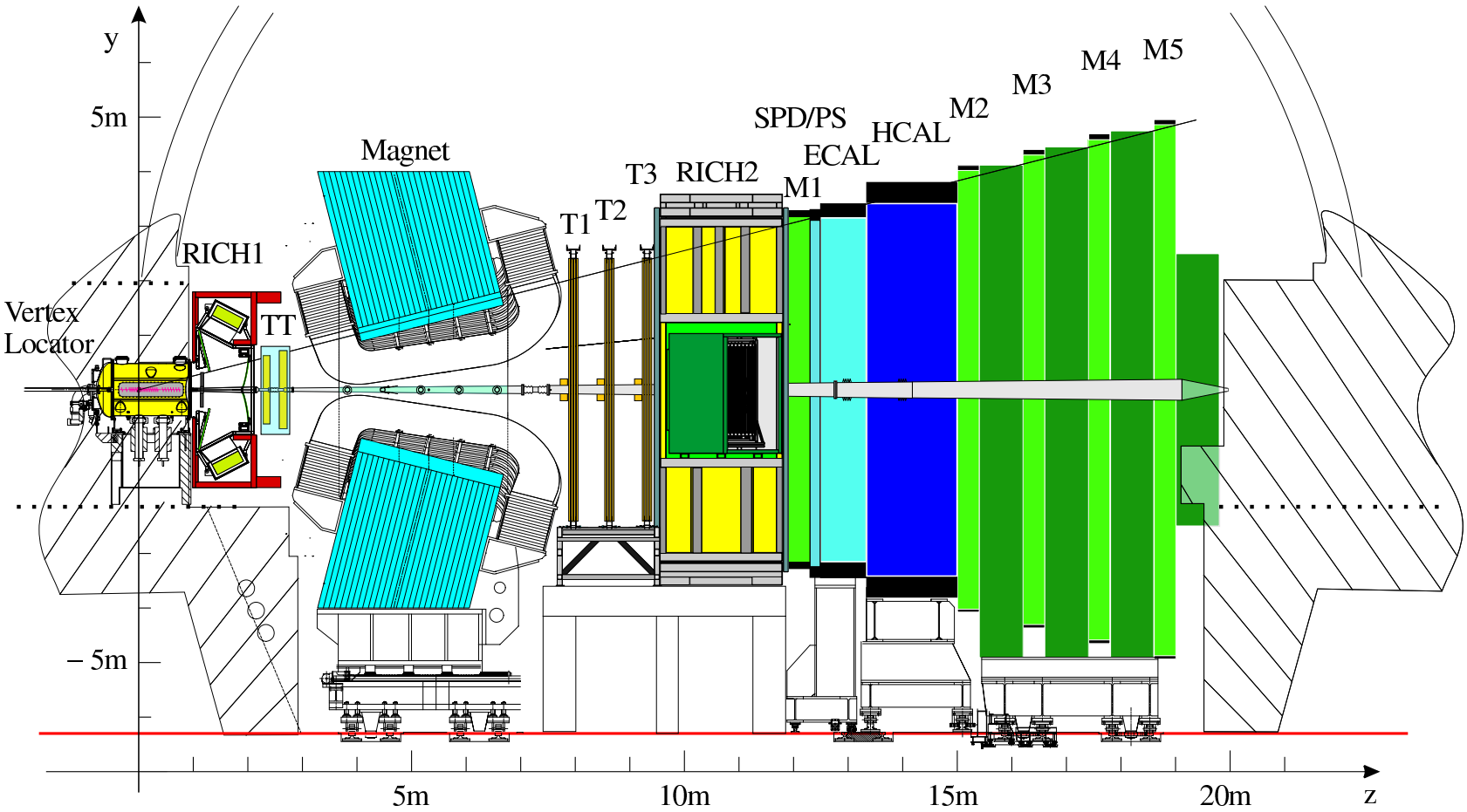
Outline

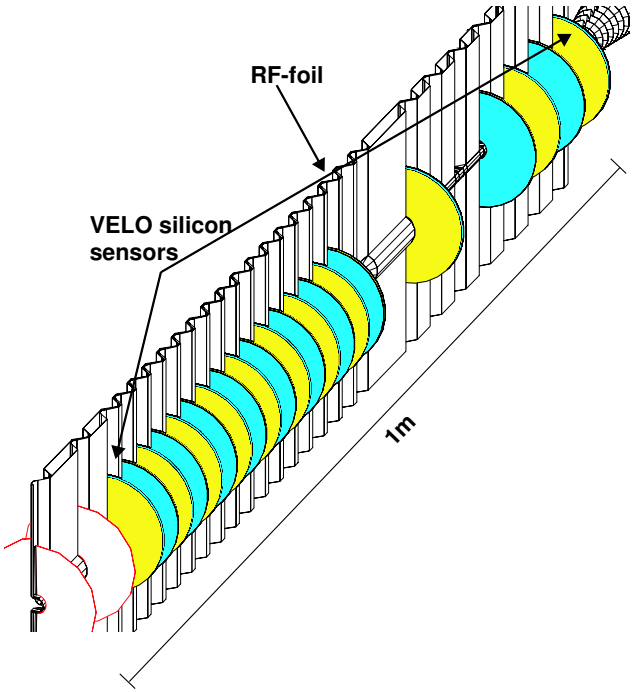
- This talk will cover the latest charged particle multiplicity measurements performed by the LHCb Collaboration.
- Builds upon previous multiplicity study by LHCb: arXiv::1112.4592.
- Accepted for publication in the European Physical Journal C.
- More details can be found in the arXiv paper: arXiv:1402.4430.

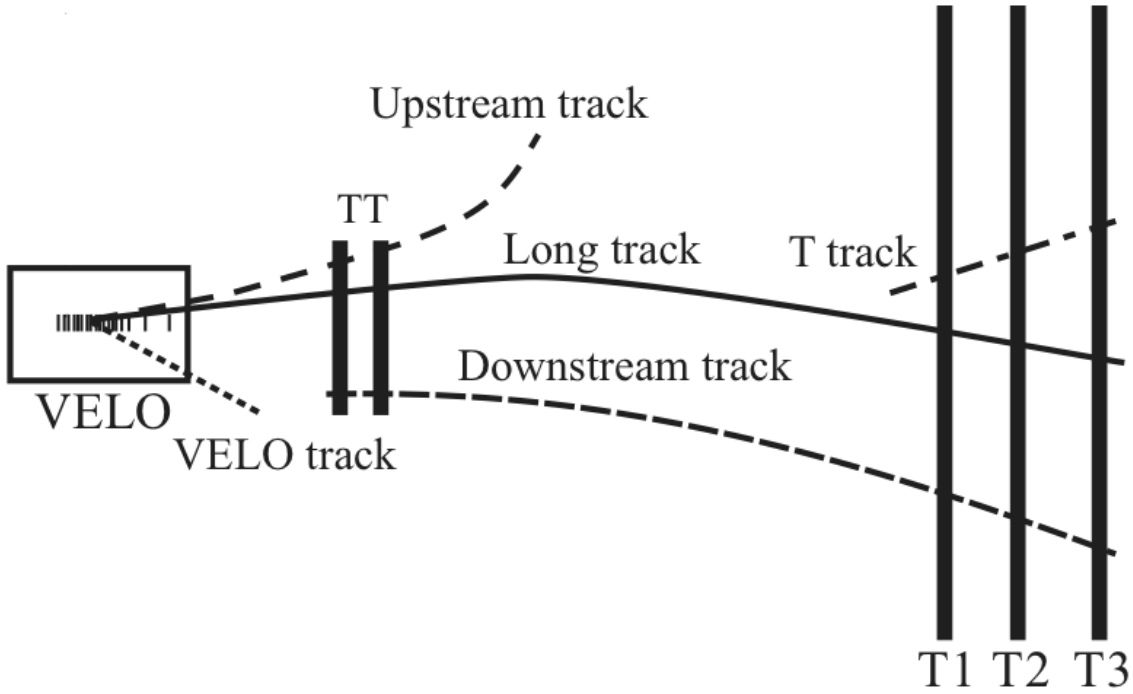
The LHCb Detector



LHCb is a single-arm forward spectrometer covering the rapidity range $2 < \eta < 5$.

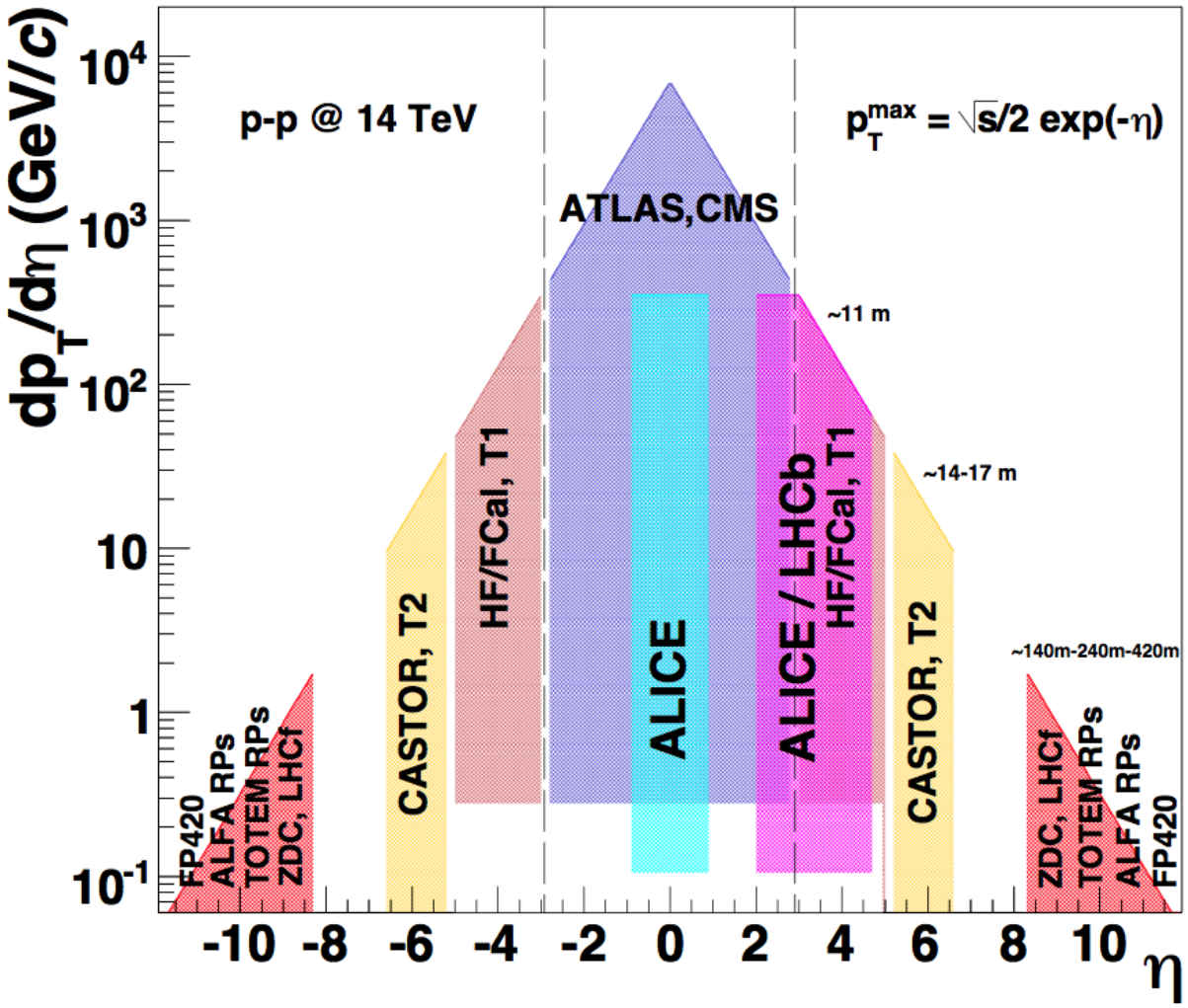
LHCb Tracking System





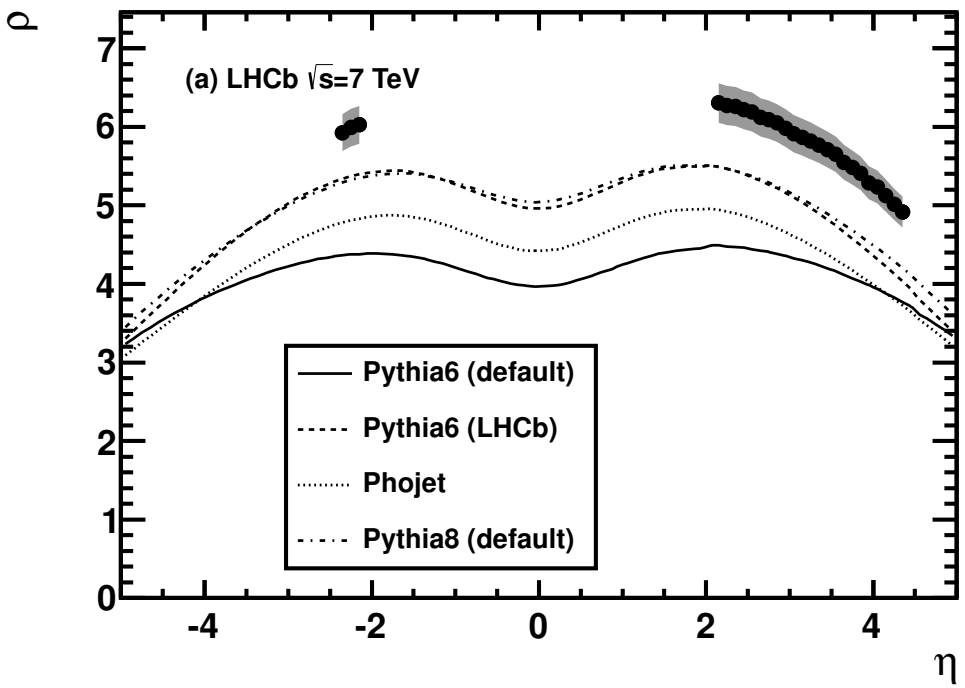
- VELO surrounds interaction point.
- Relative momentum uncertainty: 0.4-0.6%
- IP resolution: 20 μm for $p_T > 200$ MeV, $p > 2$ GeV

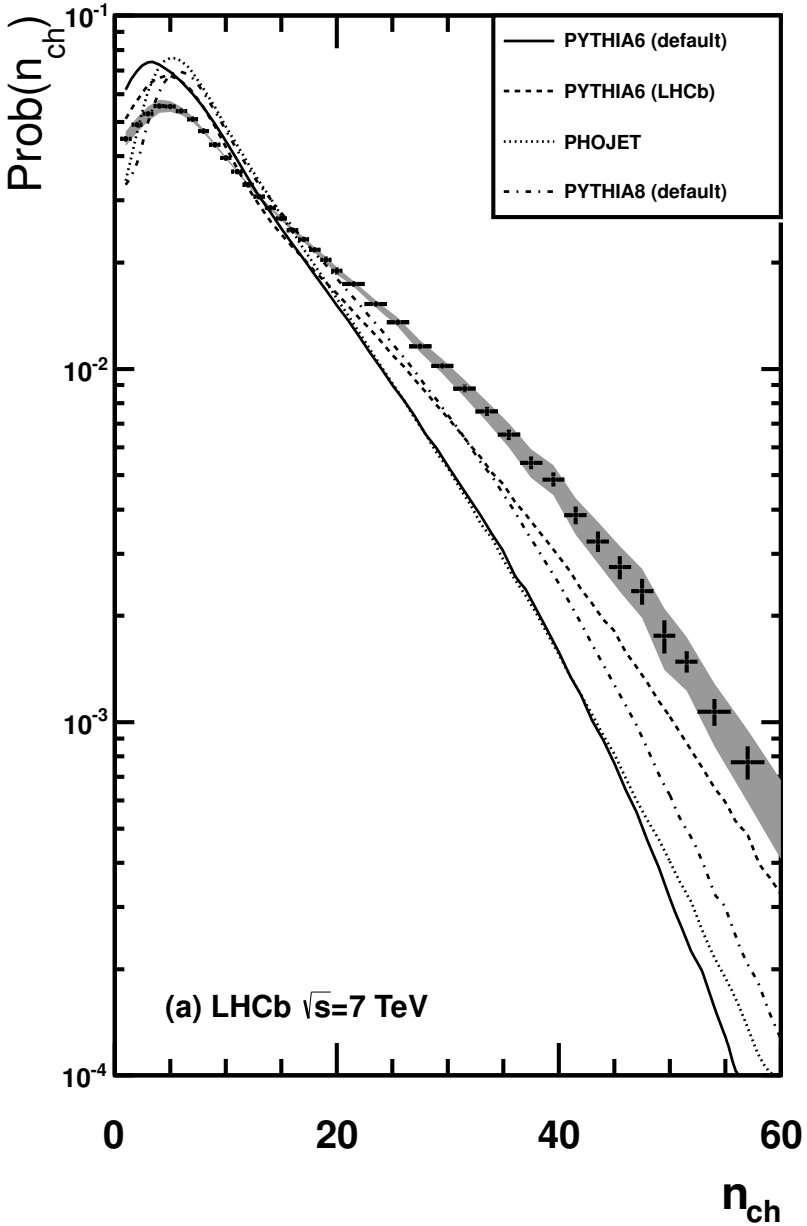
Acceptance



- LHCb's acceptance is complementary to ATLAS and CMS.

Previous Multiplicity Measurement (VELO Tracks)





- Asymmetry due to requirement of 1 track in forward acceptance.
- All models fail to describe mean charged multiplicity.
- arxiv.org/abs/1112.4592

Dataset and Simulation

The measurement was performed using a minimum-bias data sample of pp collisions at a centre of mass energy of $\sqrt{s} = 7$ TeV collected during 2010.

- Low-luminosity running period, the average number of interactions in the acceptance per bunch crossing was less than 0.1.
- Pile up events occurred in less than 4% of crossings.
- A total of 3 M events were recorded, split equally between magnet polarities.
- Events with at least one reconstructed track segment in the VELO were selected.

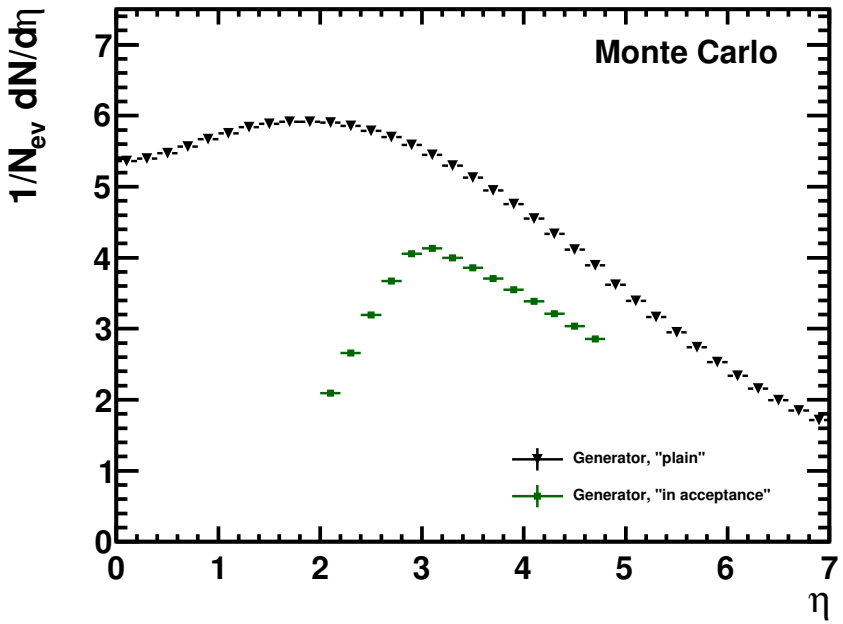
MC Sample

- Fully simulated minimum bias events.
- PYTHIA 6.4 using LHCb Tune and CTEQ6L parton density functions.
- Hadrons decayed by EVTGEN, final state radiation provided by PHOTOS.

Event Definition and Selection

In order to directly compare the data to MC generator predictions we define a *visible event* as containing at least one charged particle with:

- $2.0 < \eta < 4.8$
- $p > 2\,\mathrm{GeV}/c$
- $p_T > 0.2\,\mathrm{GeV}/c$
- the sum of parent's average lifetime $< 10\,\mathrm{ps}$



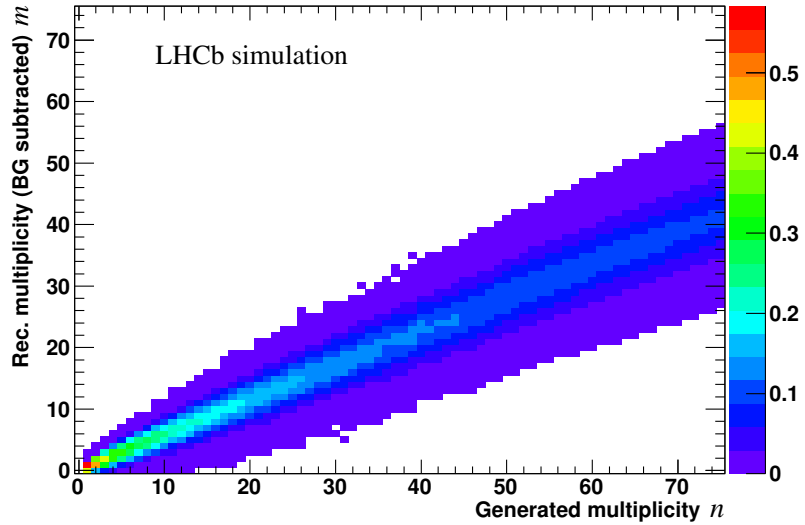
i.e. the typical kinematic requirements for particles which traverse the magnetic field and reach the downstream tracking stations.
This tracking requirement is responsible for the leading slope in the lower rapidity region.

General Method

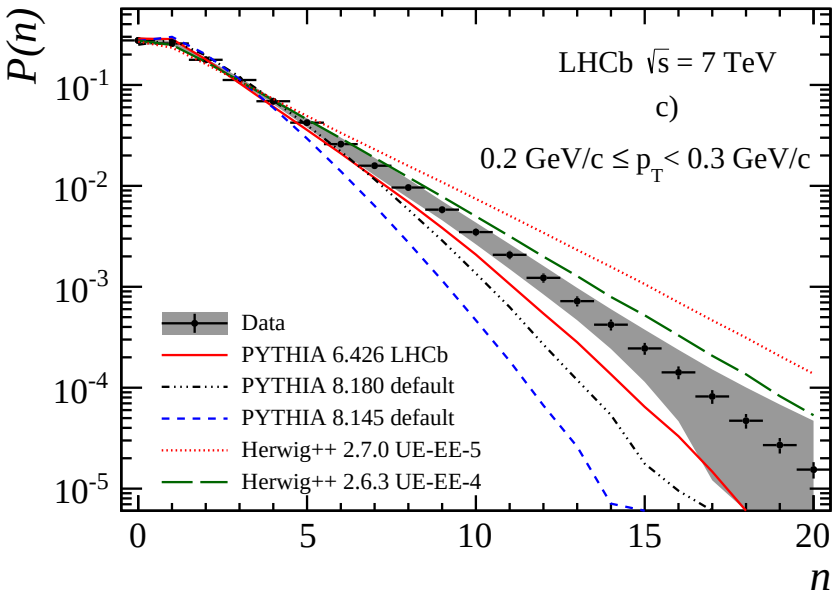
The raw measured multiplicity distribution and mean particle densities have corrections applied:

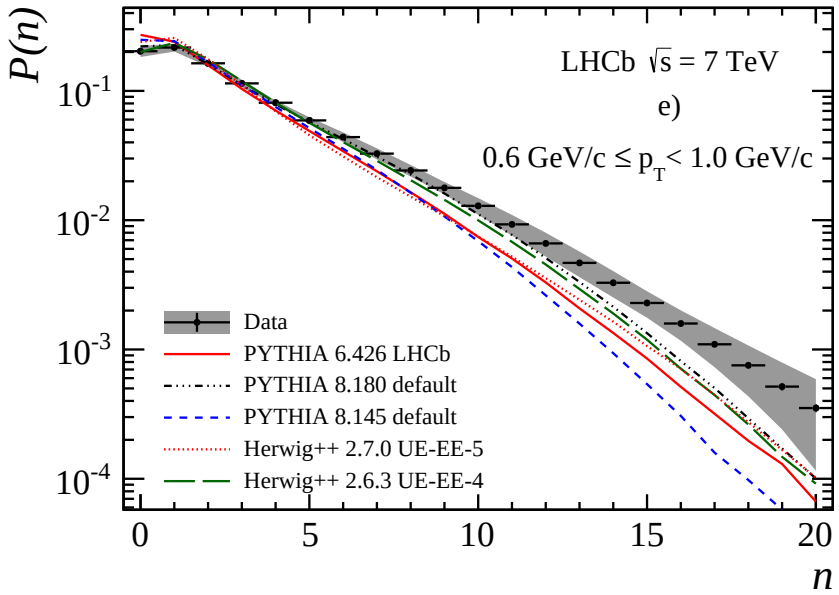
- Reconstruction artefacts and non-prompt particles (fake, clone, secondary tracks).
- Undetected "visible" events.
- Pile-up renormalisation.
- Detector acceptance and track efficiencies (unfolding).

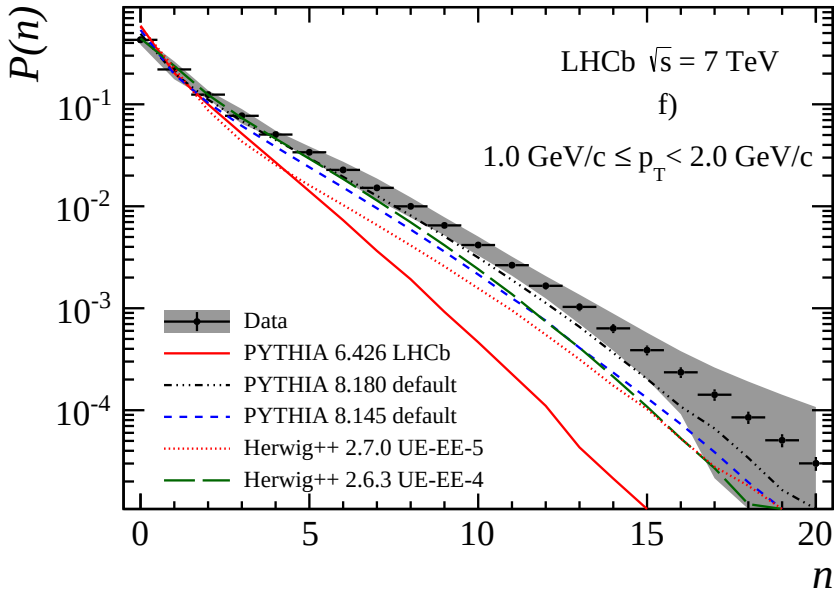
- Response matrix accounts for track reconstruction and detector efficiencies.
- Maps true particles to measured tracks.
- Smoothing applied to extend to very high multiplicity region.



Results - Multiplicity in bins of p_T

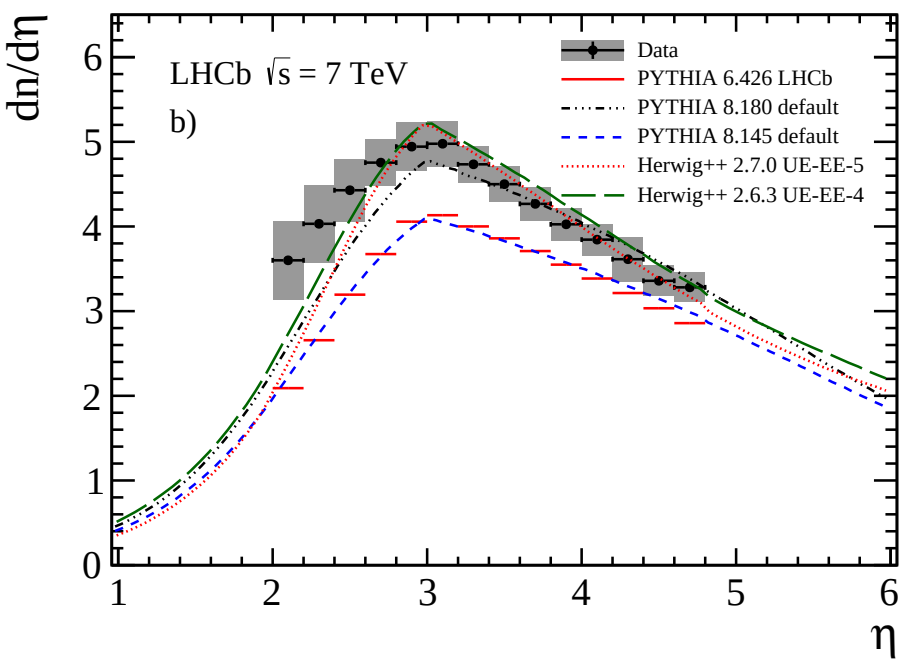


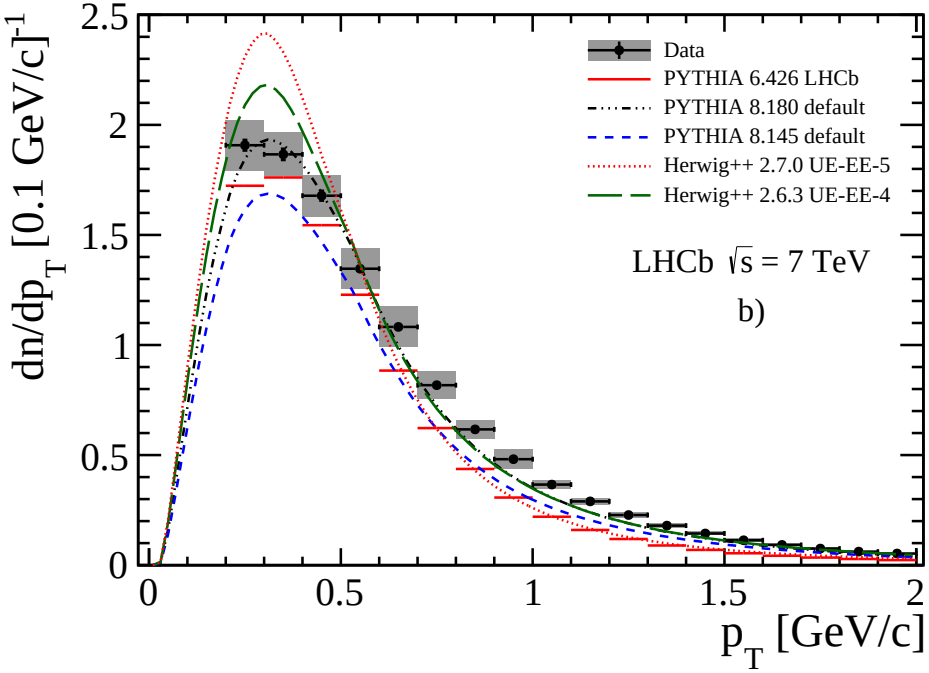




- Higher p_T bins more useful for probing the hard scatter.
- PYTHIA 8 underestimates at low p_T, HERWIG overestimates.
- PYTHIA 8 and HERWIG agrees well in the mid to high-p_T bins

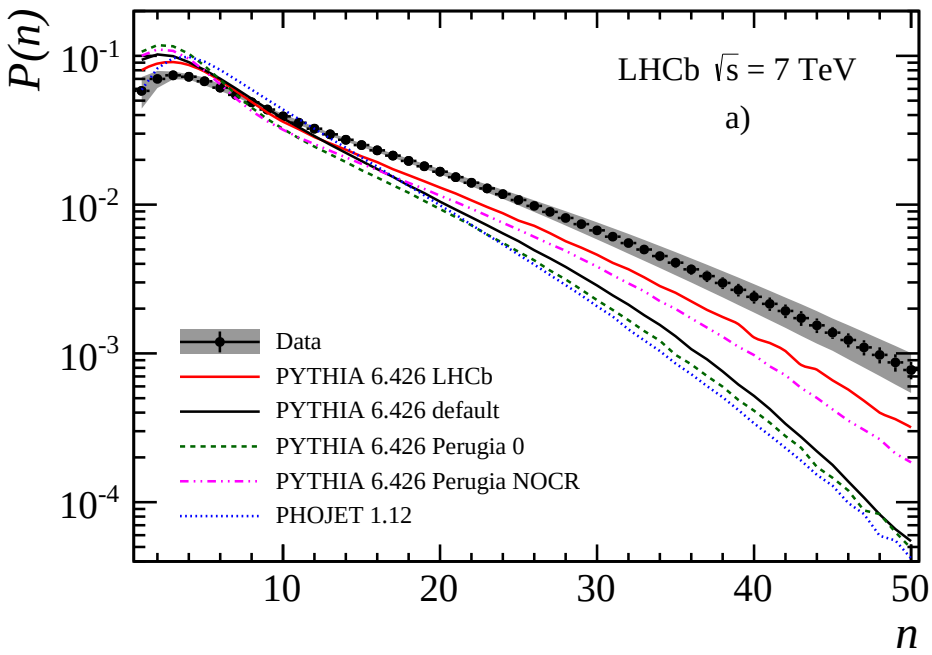
Results - Charged Particle Density

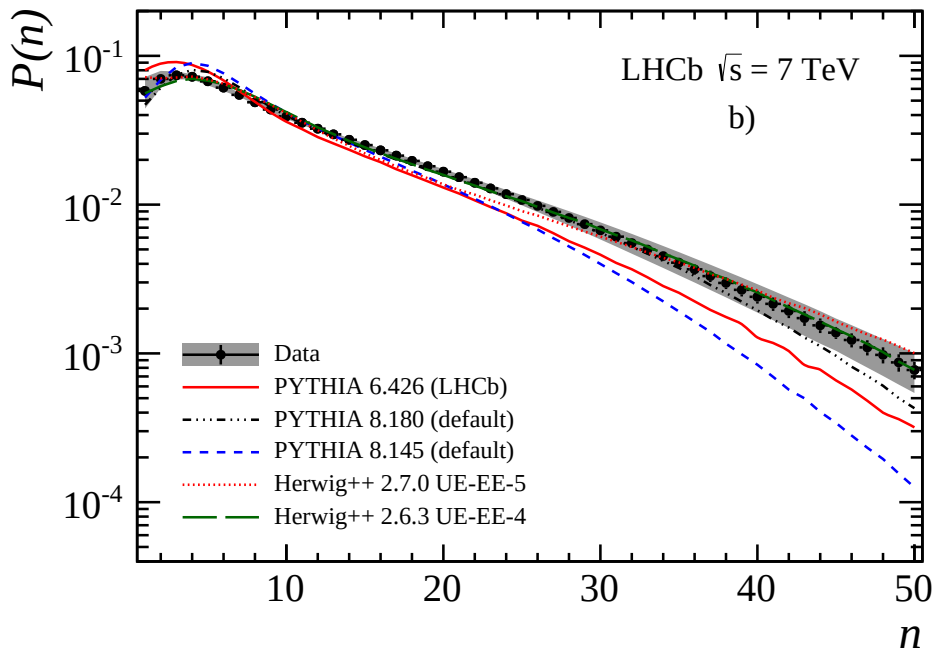




- Comparison of recent generators and LHCb PYTHIA to data.
- All generators underestimate the number of particles at low η.
- HERWIG++ 2.7.0 overestimates the data at low p_T and underestimates it at high p_T.

Results - Total Multiplicity





- In the range 1-50 particles, we measure:
  - Mean, $\mu = 11.304 \pm 0.008 \pm 0.091$
  - RMS, $\sigma = 9.496 \pm 0.006 \pm 0.021$
- In general, the MC predictions underestimate the data. PYTHIA 8.180 (tuned to LHC data) describes the data best.
- Of the non-LHC tuned MC, the LHCb tune agrees best, yet still underestimates the mean by 15%.

Measurement Systematics

systematic	rel uncert.	abs uncert.	corr
ghost rate	2%	$\pm 0.1\%$	yes
secondary part. rate	12%	$\pm 0.5\%$	(yes)
clone track rate	9%	$\pm 0.1\%$	
detector acceptance	3%	$\pm 0.9\%$	(yes)
track finding efficiency	4%	$\pm 0.8\%$	yes
response matrix param	5%	$\pm 2.2\%$	
pile-up	$<< 1\%$	negligible	
not-reconstructed events	$\sim 15\%$	$\sim 0.4\%$ (average)	

- Ghost rate and track finding efficiency conservatively assumed to be fully correlated.
- Detector acceptance partially correlated with the secondary rate through material interaction terms. This part is treated as fully correlated with the secondary rate.
- Systematic from not-reconstructed events has small impact on the results - only the first few multiplicity bins are affected.

Summary

- Total multiplicities and charged particle densities from inclusive single pp events at $\sqrt{s} = 7\,\text{TeV}$ were measured.
- Particle multiplicity distributions in bins of η and p_T are also provided. (Not all shown)
- Provides important input for generator tuning.
- Plan to release the results as a RIVET plugin.

Mean Particle Density Combined Correction

Each track is given a weight, ω, which represents it's average "purity":

$$\omega\left(\eta, p_T, \text{T-hits}, \text{Velotr.}\right) = 1 - R_{tot}\left(\eta, p_T, \text{T-hits}, \text{Velotr.}\right)$$

where $R_{tot} = R_{ghost} + R_{sec} + R_{clone}$.

- The same track-level procedure would result in non-integer event multiplicities when applied to the multiplicity distributions.
- R_{tot} used to calculate the mean number of mis-selected tracks per event. Poisson distribution assumed and statistical correction applied.