QCD Measurements in the forward acceptance at the LHC

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on behalf of the LHCb Collaboration

DIFFRACTION 2014

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LHCb

Outline

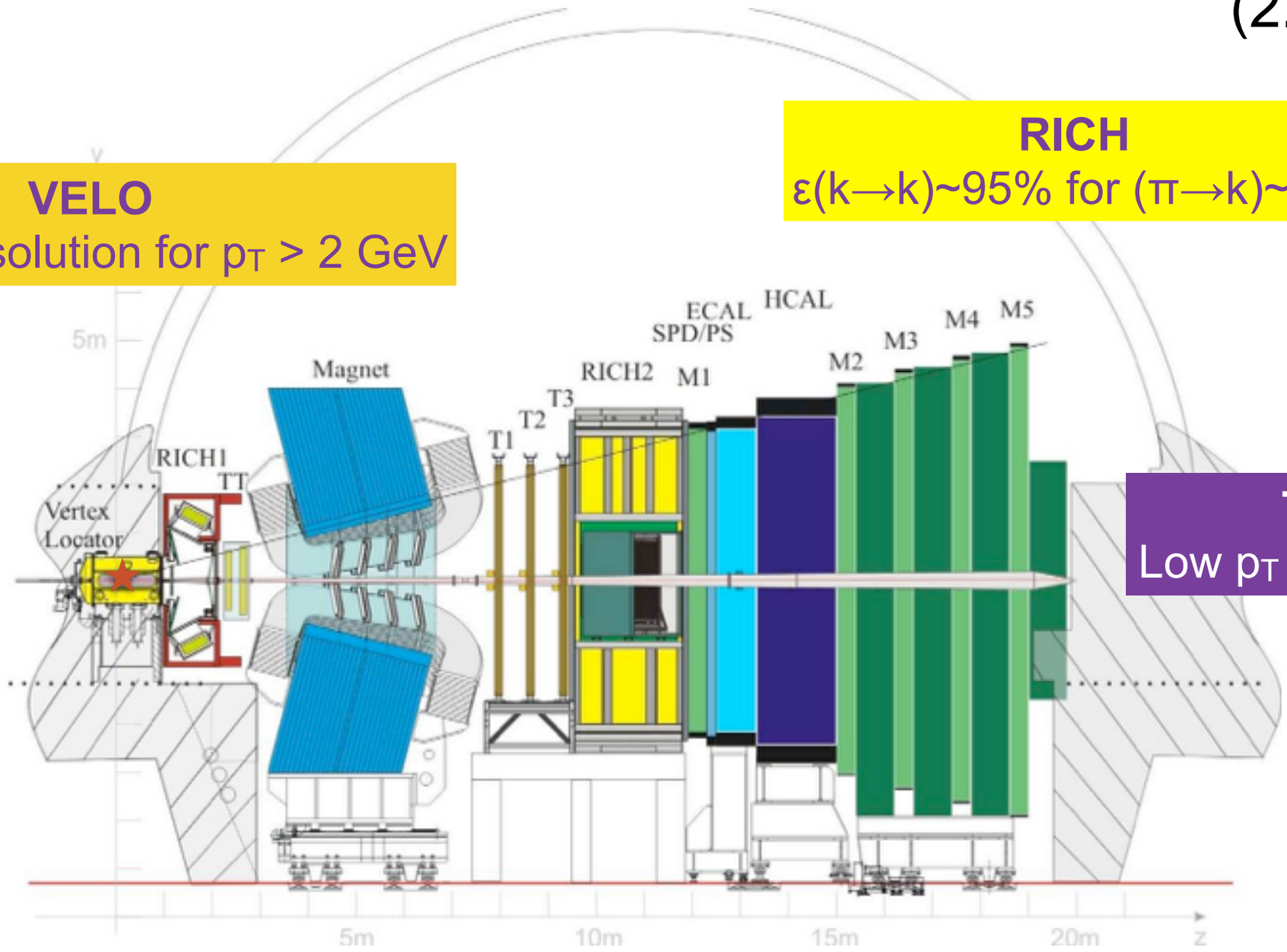
- **LHCb Experiment**
- **Measurements**
  - Charged Particle Multiplicity and Densities
  - Forward Energy Flow
- **Summary**

LHCb Experiment

LHCb is a single arm spectrometer fully instrumented in the forward region (2.0<η<5.0)

VELO
~20μm IP resolution for p_T > 2 GeV

RICH
ε(k→k)~95% for (π→k)~5%

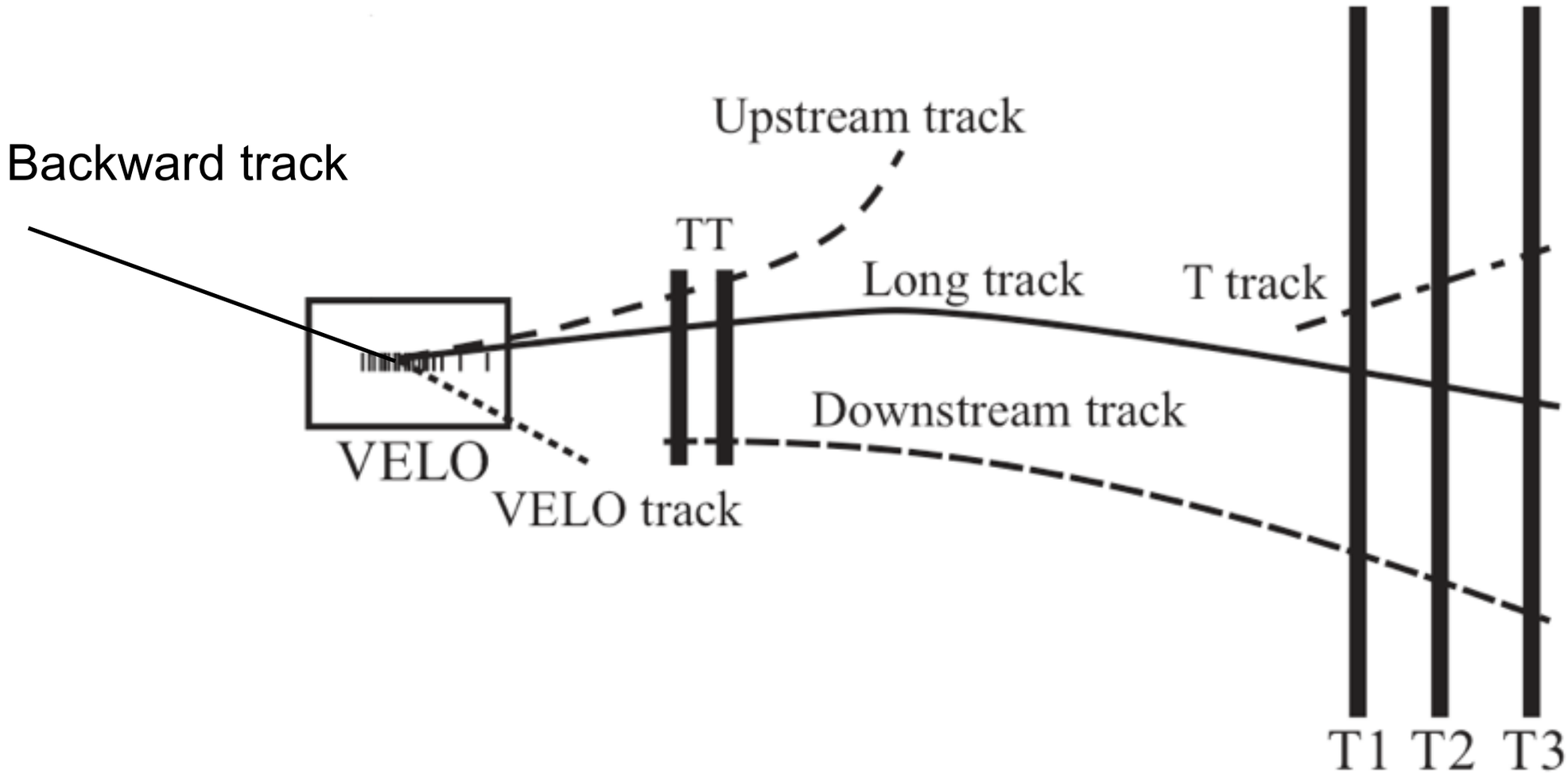


Trigger
Low p_T Minimum Bias

TRACK
0.4%-0.6% momentum resolution

MUON
Muon Identification ε~97% misID~2%

LHCb Tracking



VELO: surrounds the interaction point - high reconstruction efficiency
Long Tracks: Relative momentum uncertainty 0.4-0.6%
IP resolution: 20μm IP for p > 2 GeV, p_T > 200 MeV

Charged Particle Multiplicity and Densities

Motivation

EPJ C64 (2014) 2888

- hadronic final state characterization
- underlying event studies
- input for tuning phenomenological models
- extension of EPJ C72(2012) 1947

Data

- Low Multiplicity minimum-bias (MB) sample collected at $\sqrt{s}$=7 TeV during 2010
- Pile-up only present in less than 4% of bunch crossings
- Events triggered by at least one VELO track
- ~3M events split between magnet polarities

Analysis Strategy

- Tracks selection: p_T>0.2 GeV, p>2 GeV, 2.0<η<4.8
- Raw distributions corrected by:
  - o reconstruction artifacts (fake, duplicate and non-prompt)
  - o undetected “visible” events
  - o pile-up renormalization
- Final distributions after unfolding and efficiency reconstruction

Charged Particle Multiplicity and Densities

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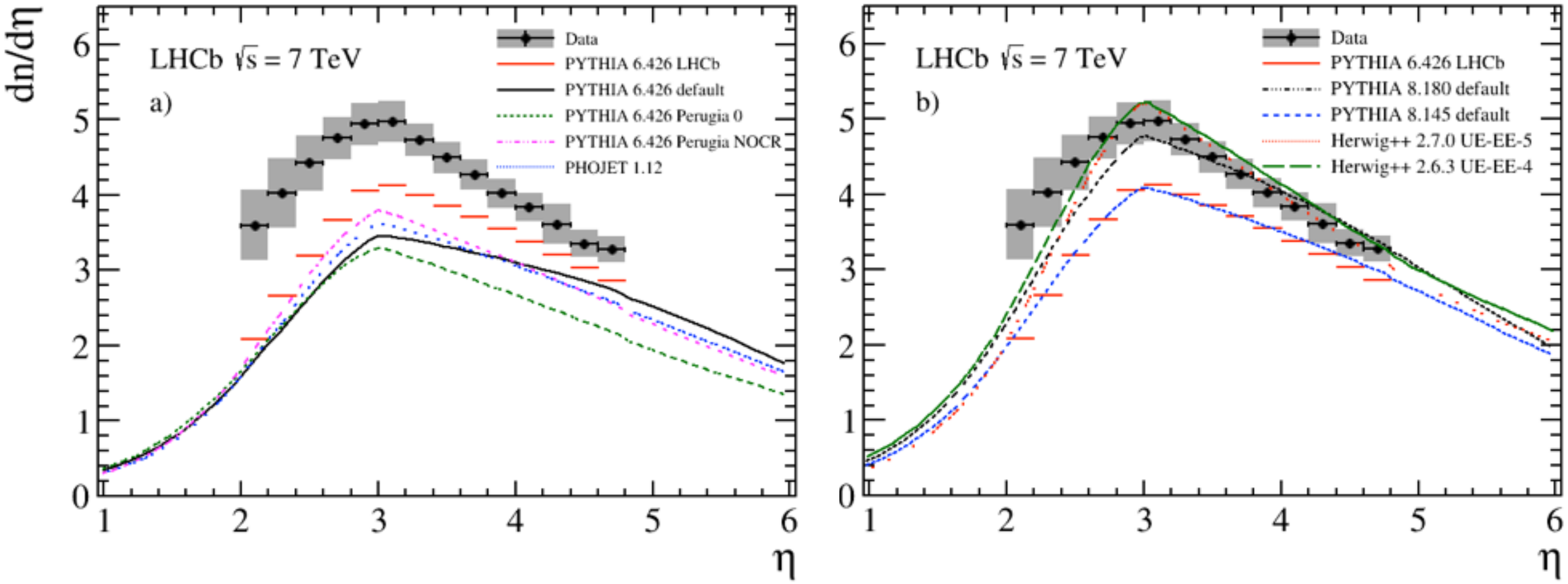

— Shapes are described qualitatively

— PYTHIA 6 and PHOJET (not tuned to LHC) underestimate particle density

— PYTHIA 8.180 (tuned to LHC) and HERWIG++ give best description

Charged Particle Multiplicity and Densities

All models fail for low η

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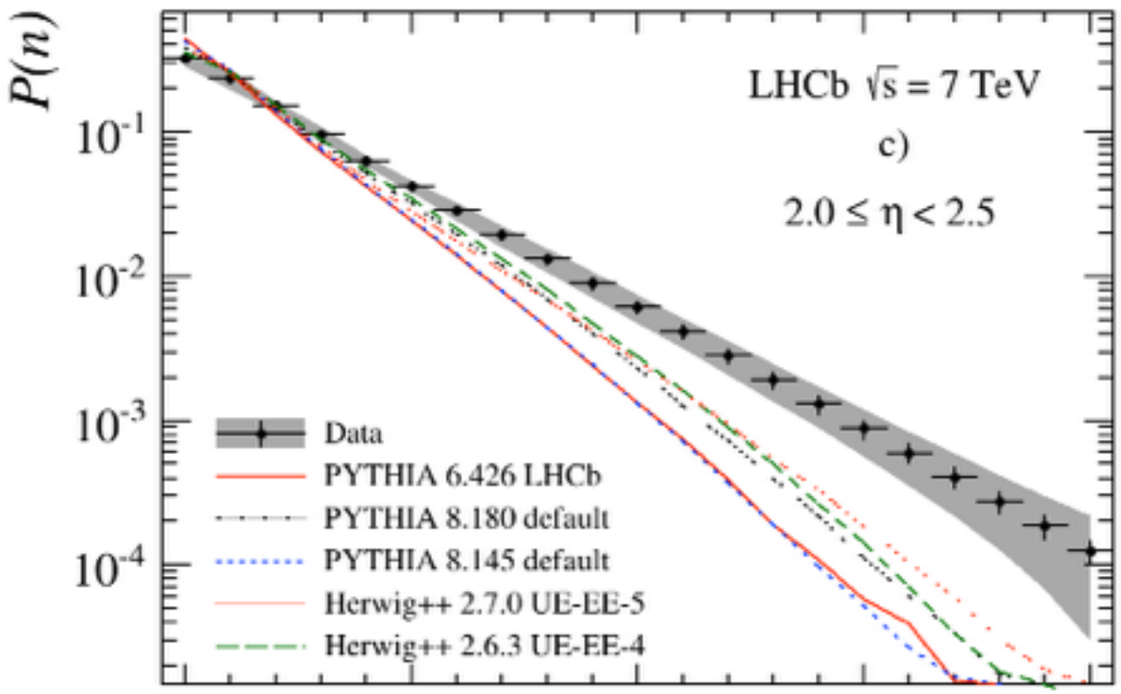

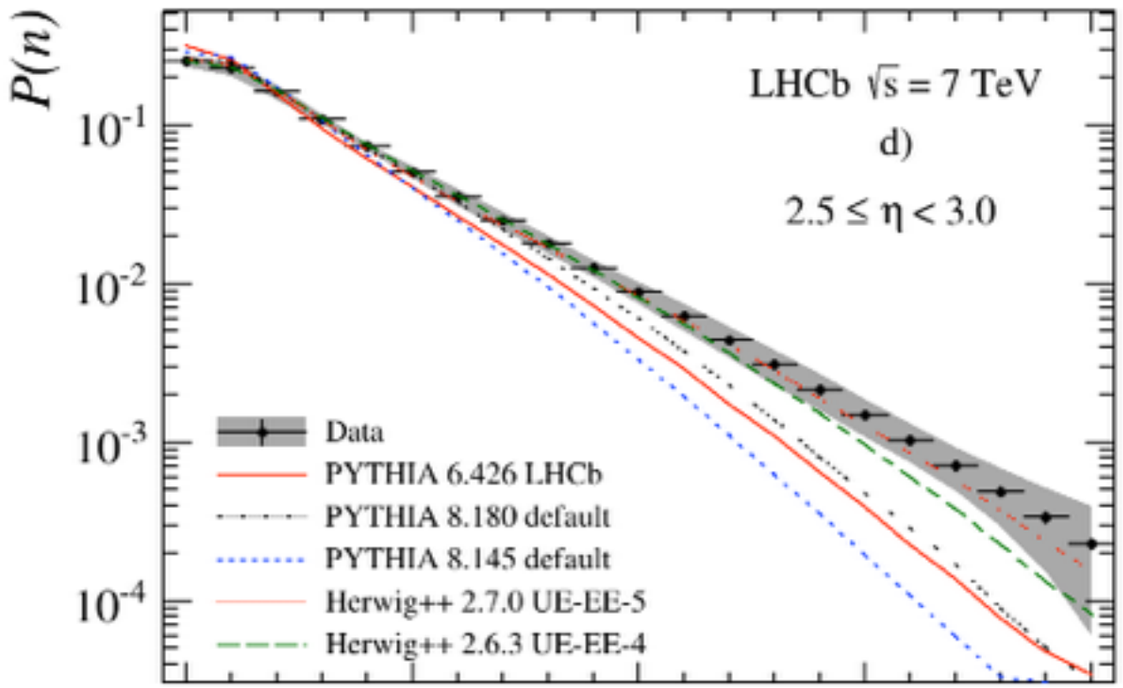

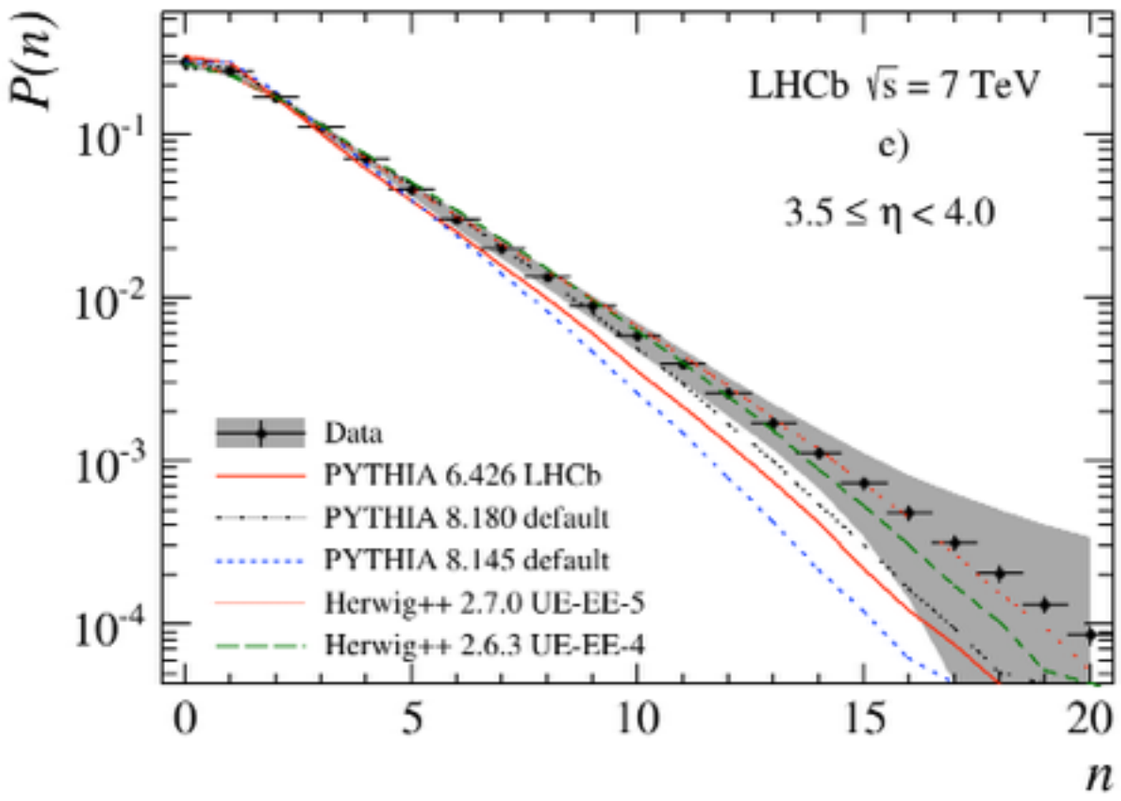

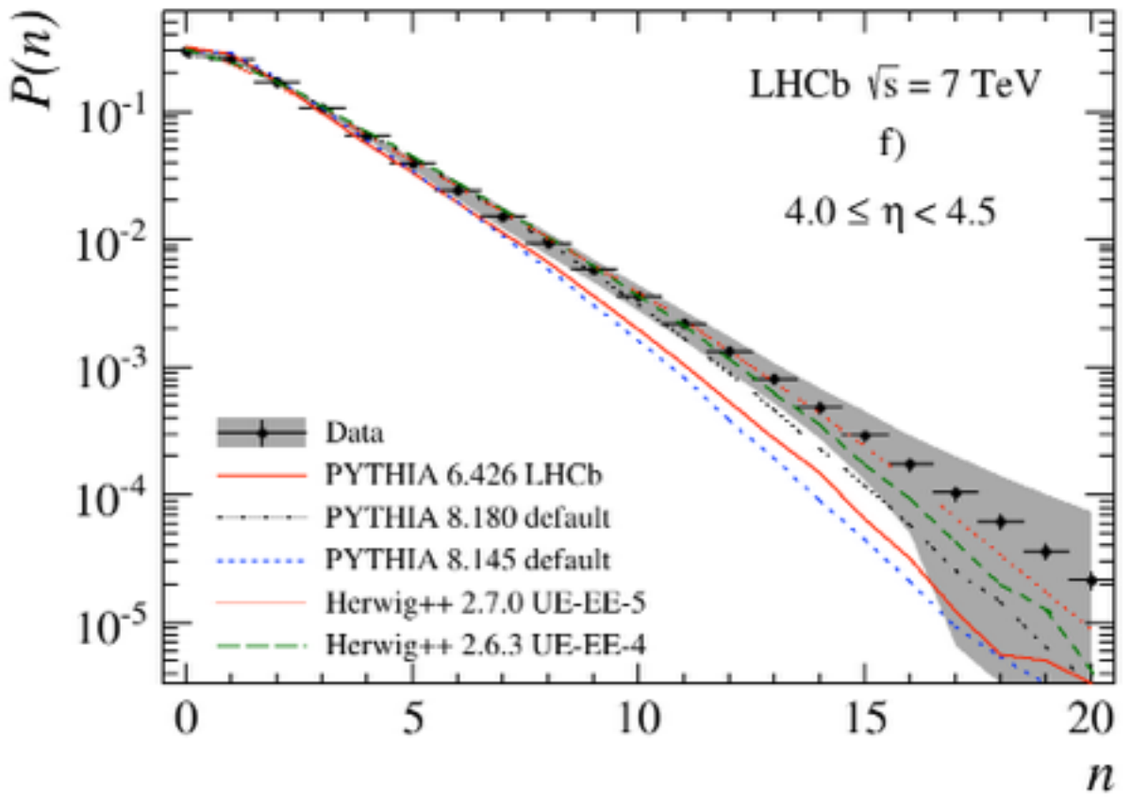

Charged Particle Multiplicity and Densities

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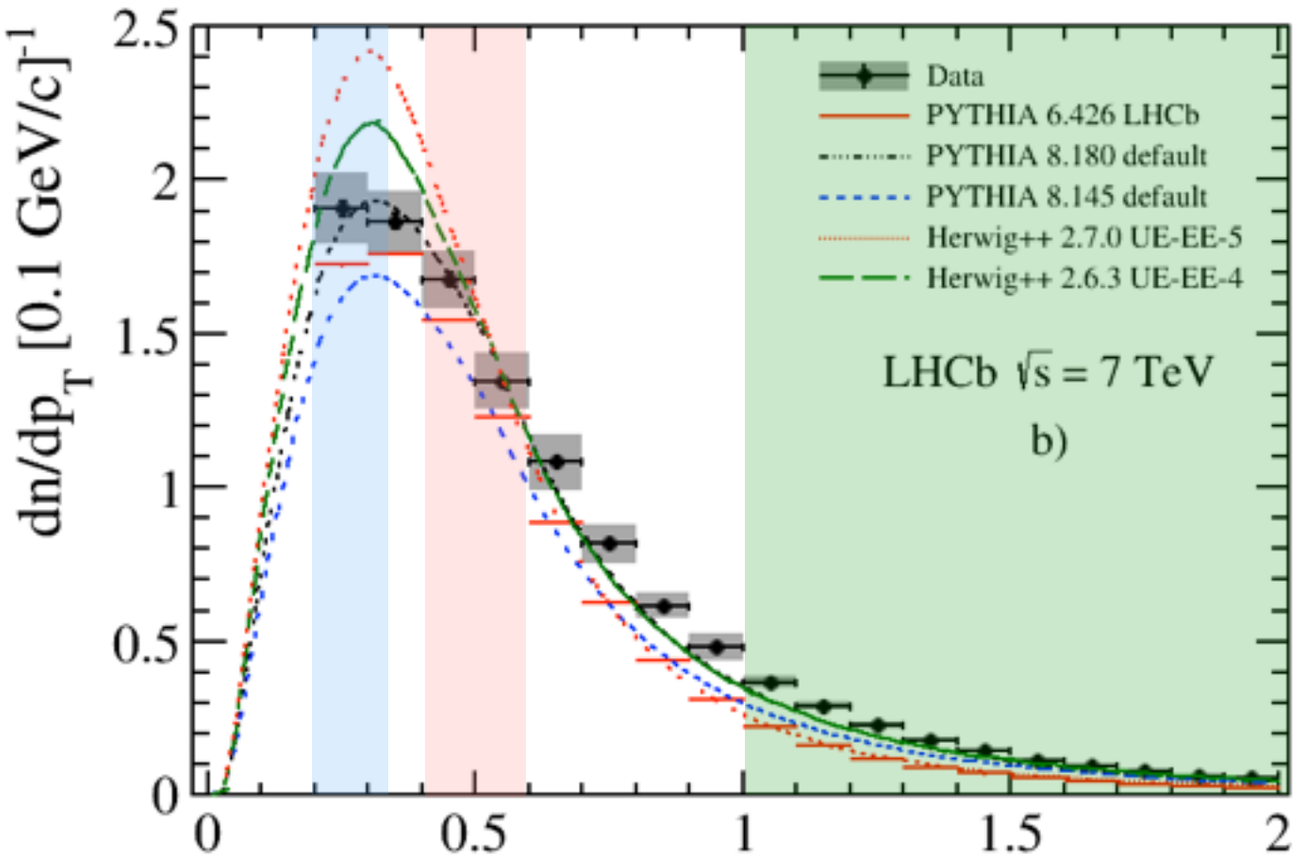
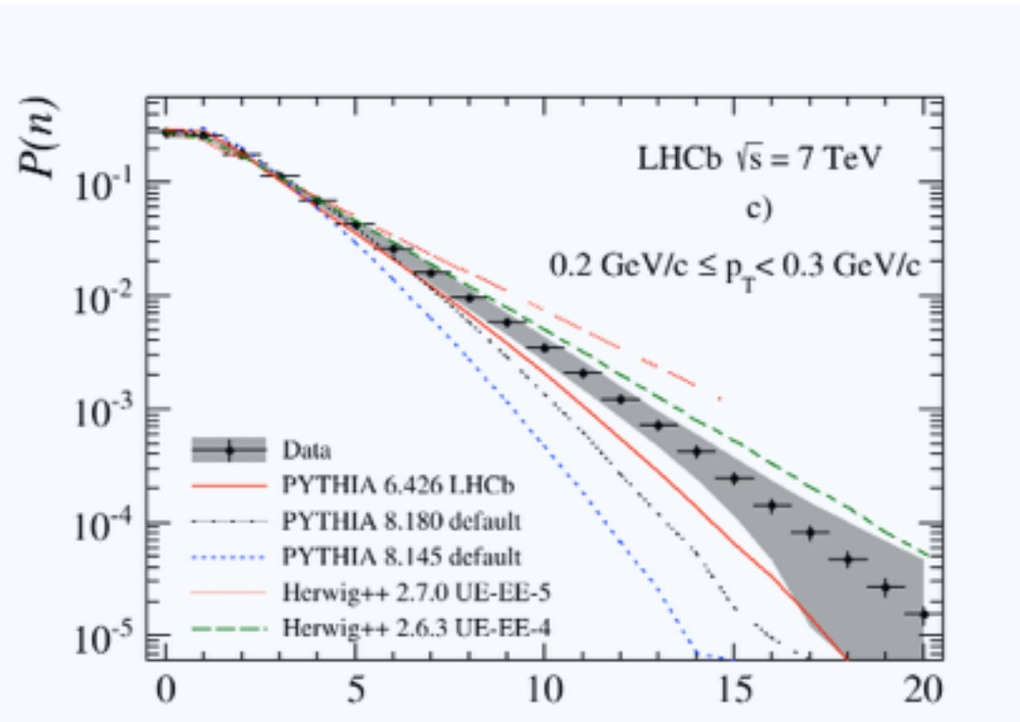
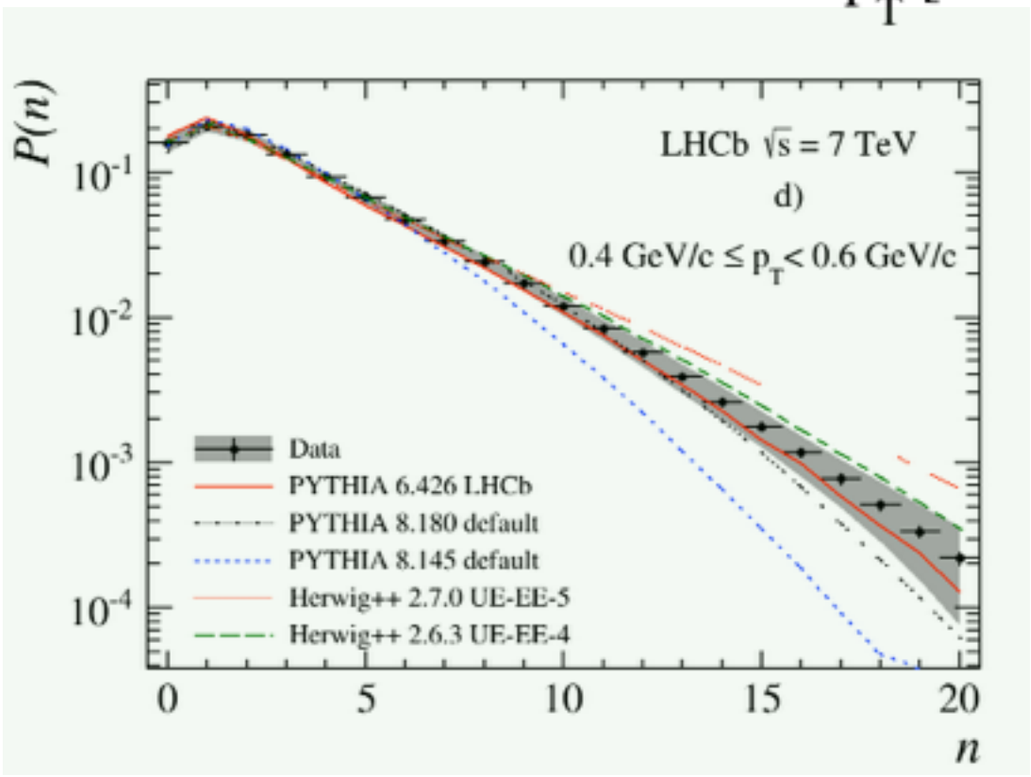
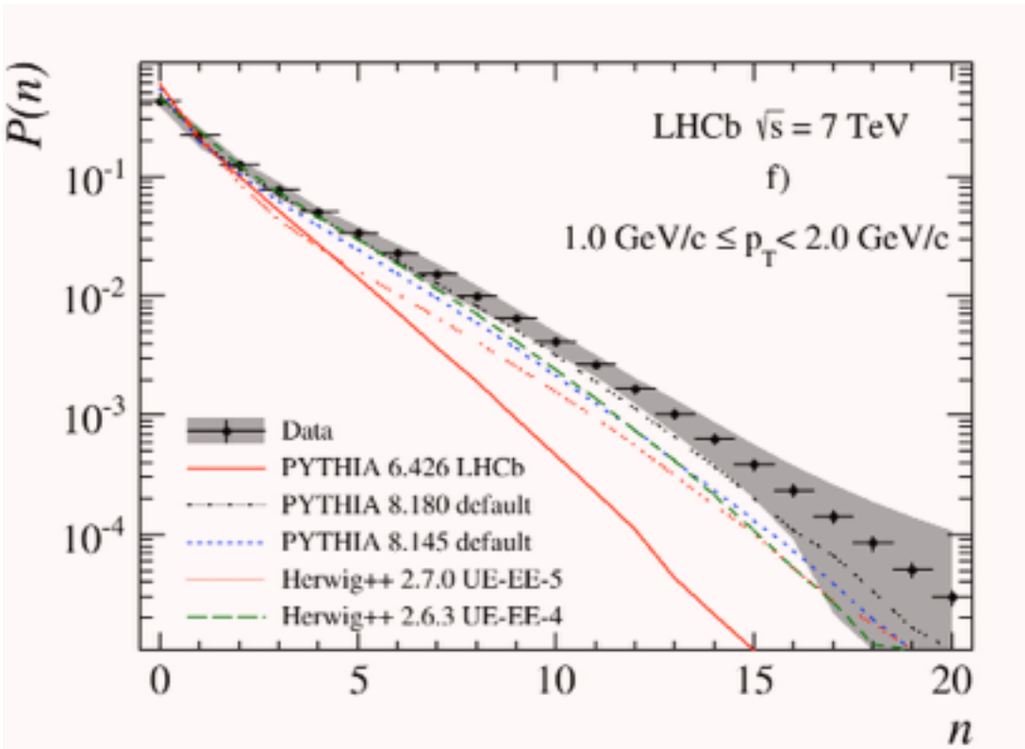








Forward Energy Flow Measurement

EPJ C73 (2013) 2421

Motivation

- Sensitive to parton radiation and multiple parton interaction
- Tests of event generators – collider and cosmic ray models

Data

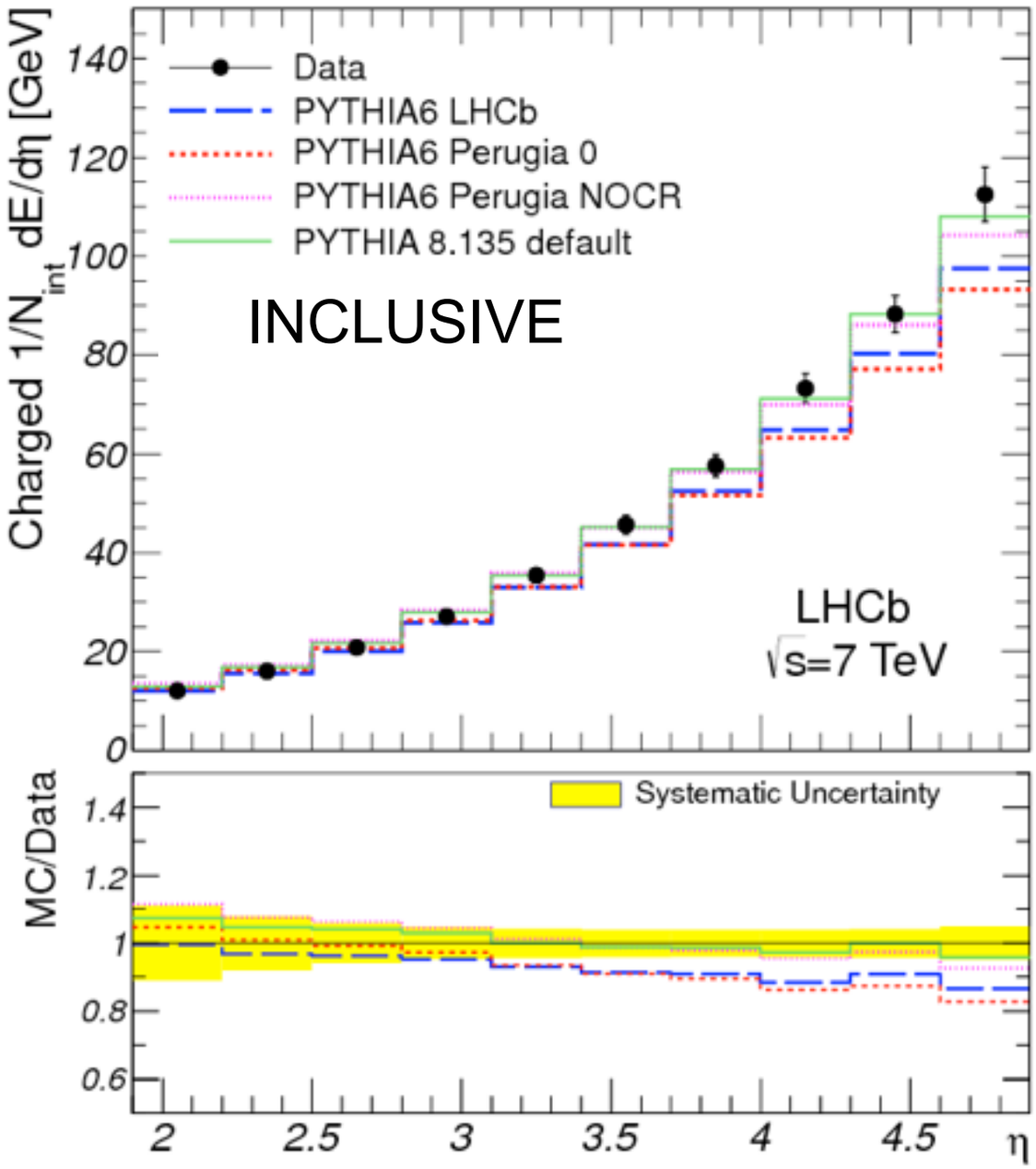
- Integrated Luminosity 0.1/nb – low pile-up data collected at $\sqrt{s}$=7 TeV (2010)
- At least one VELO track required in the trigger

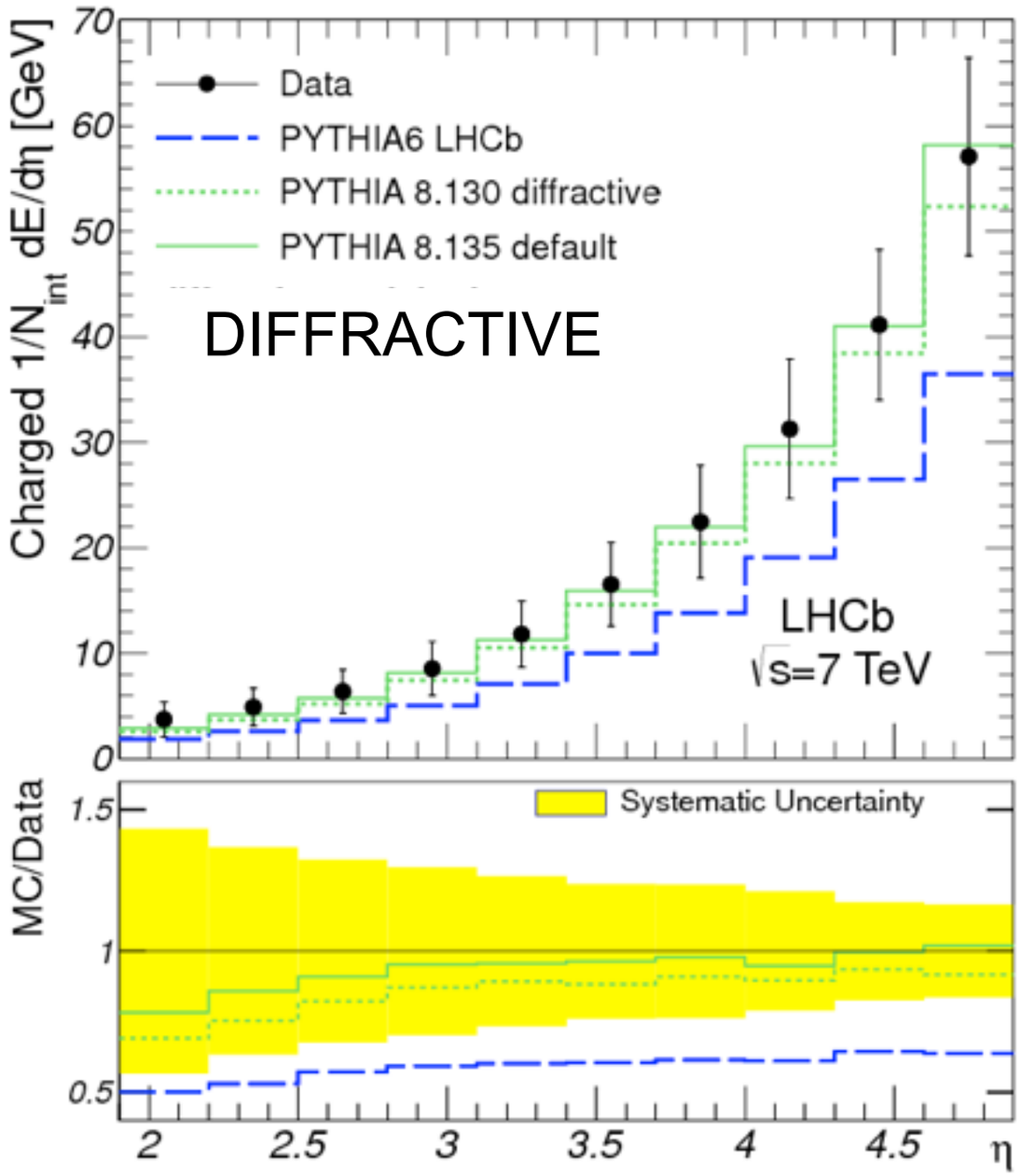
Analysis Strategy

- Four different samples
  - o Inclusive minimum bias
  - o Hard-scattering (pT>3 GeV)
  - o Diffractive enriched (no backward tracks)
  - o Non-diffractive enriched (at least one backward track)
- Measurement with tracks 2 GeV<p<1 TeV
- Corrected to particle level
  - o Charged Energy Flow
  - o Total Energy Flow
- Errors are dominated by model uncertainty and selection cuts

$$\frac{1}{N_{\text{int}}}\frac{dE_{\text{total}}}{d\eta} = \frac{1}{\Delta\eta}\left(\frac{1}{N_{\text{int}}}\sum_{i=1}^{N_{\text{part},\eta}} E_{i,\eta}\right)$$

Forward Energy Flow Measurement



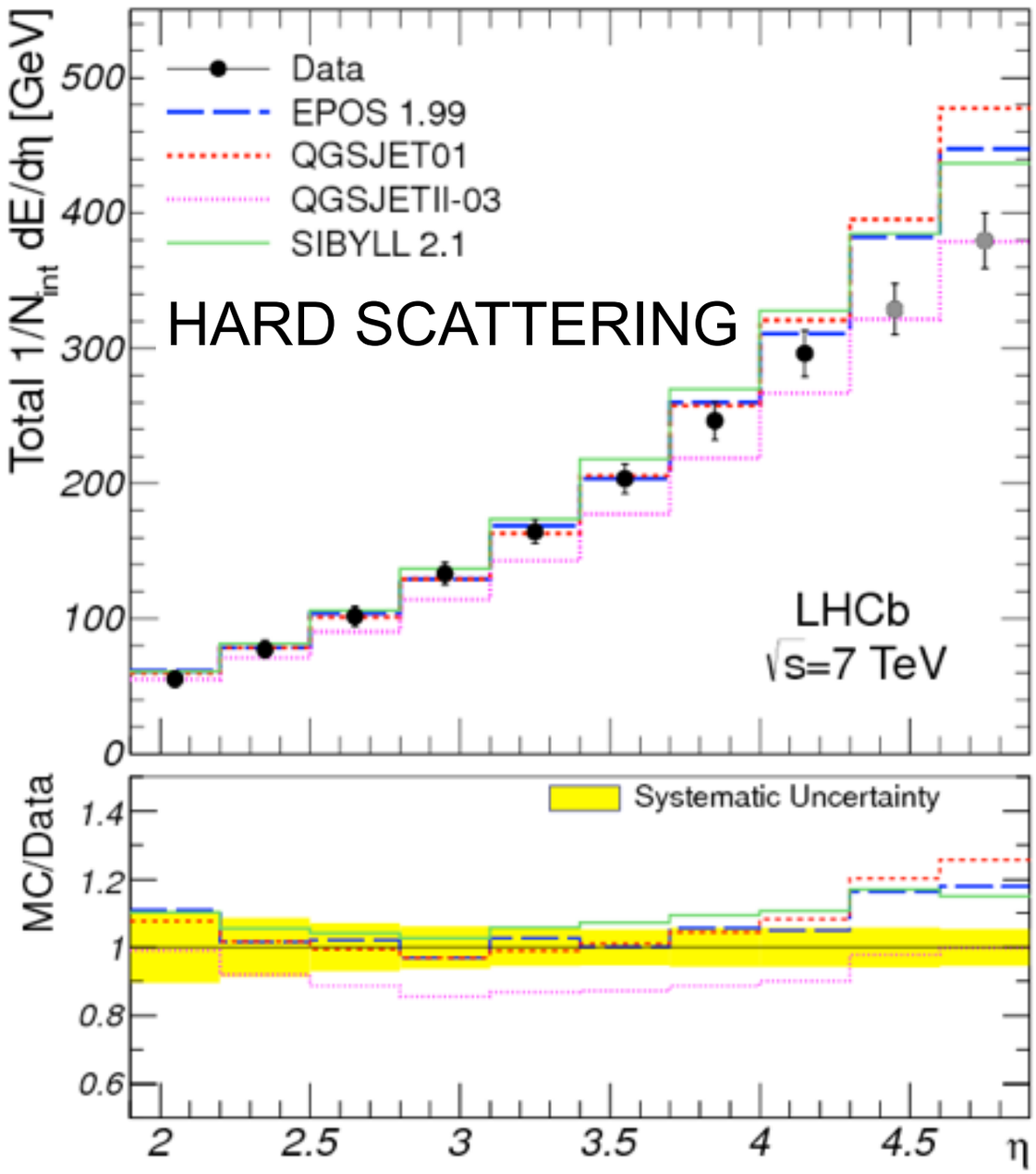


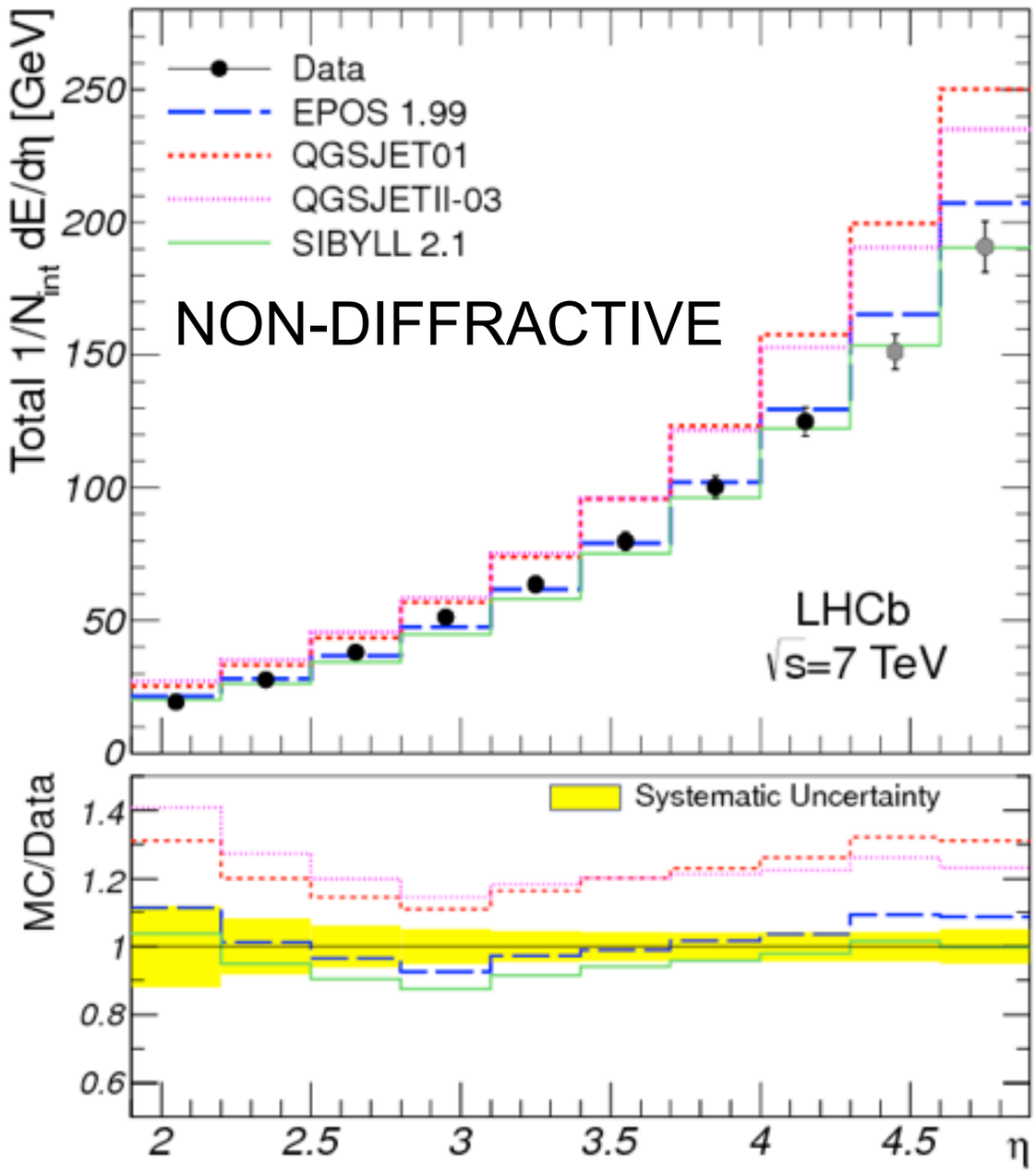
Charged particle multiplicity is measured in different samples

PYTHIA 6 tunes in all samples underestimate data

PYTHIA 8 give best overall description

Forward Energy Flow Measurement





Charged particle multiplicity is measured in different samples

EPOS and SIBYLL describe well minimum-bias and non-diffractive samples

QSJET01 give best description for hard scattering

Summary

- **LHCb has a unique coverage in η and low p_T at LHC**

- **Charged Particle Multiplicity and Densities**

  - o underestimated by older generators
  - o recent generators (optimized to LHC data in central rapidity region) show better agreement
  - o none of the generators describe all measurements

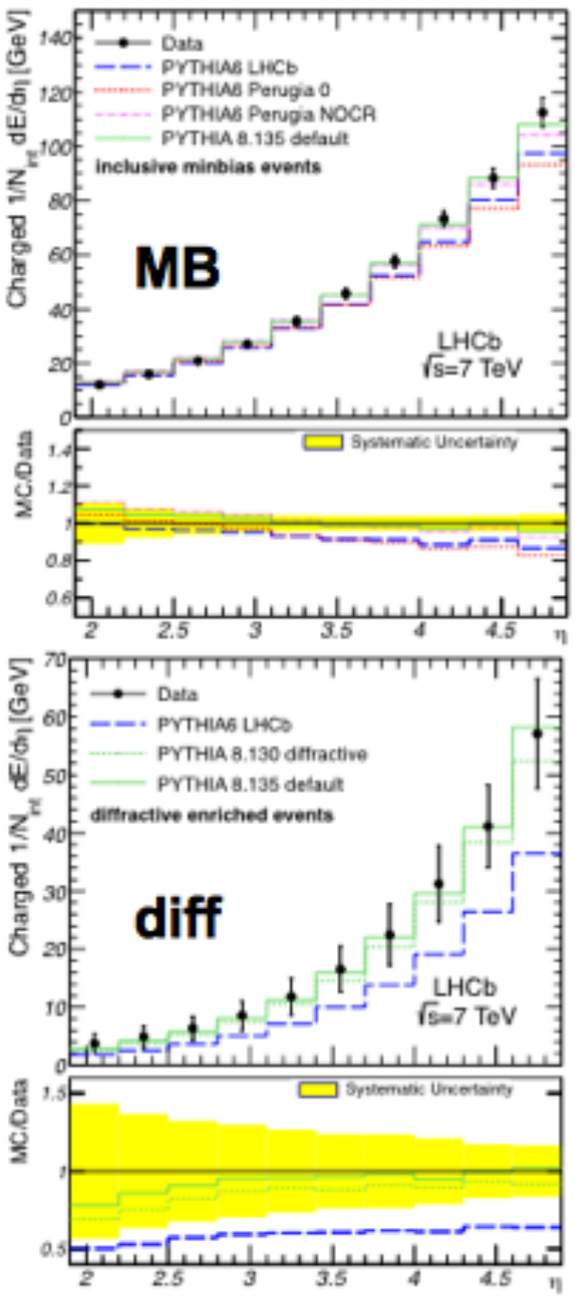
- **Forward Energy Flow**

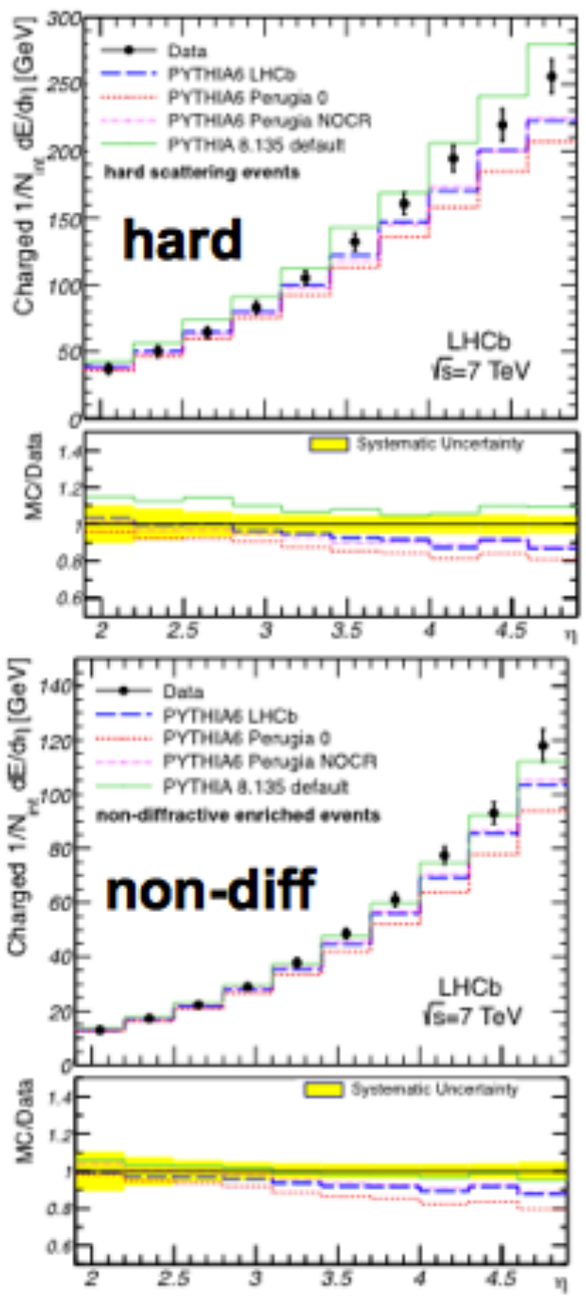
  - o measured for four different samples
  - o Pythia 8 gives better description than Pythia 6
  - o Cosmic-ray generators can also describe data
  - o none of the generators describe all measurements

- **Measurements are valuable input for generator tuning**

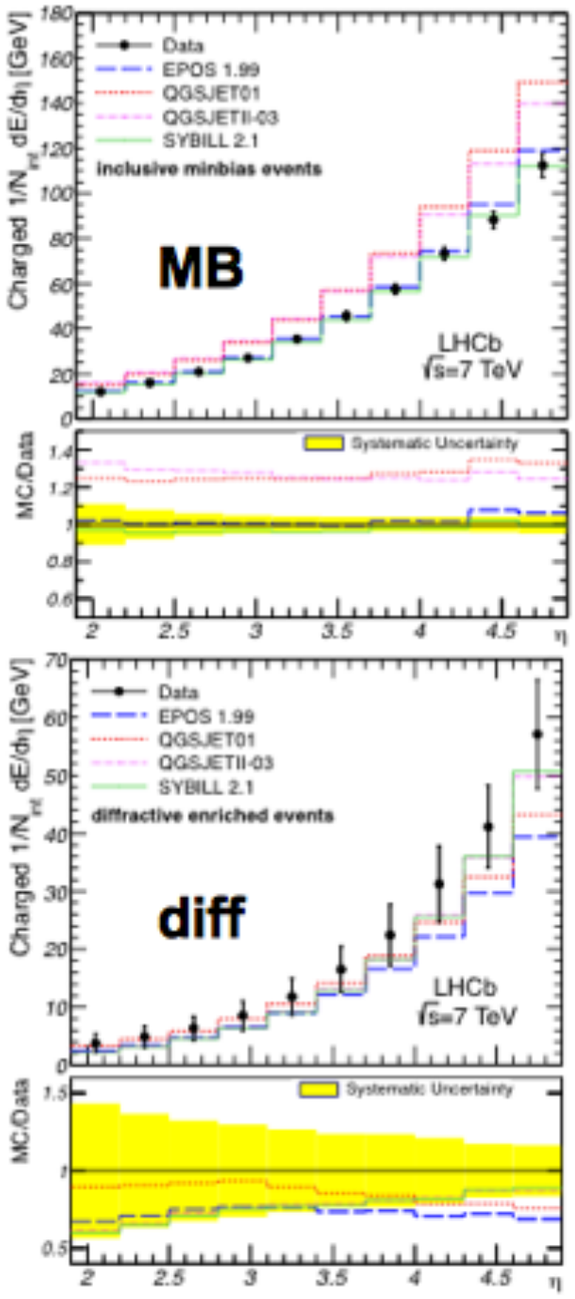
BACK UP

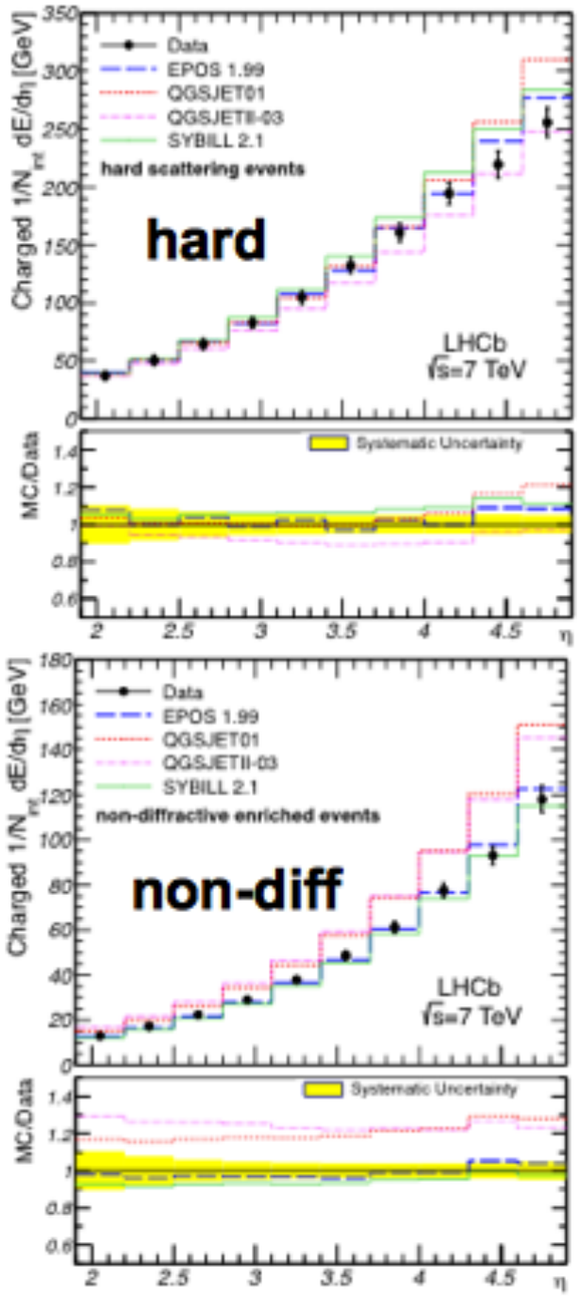
PYTHIA PREDICTIONS





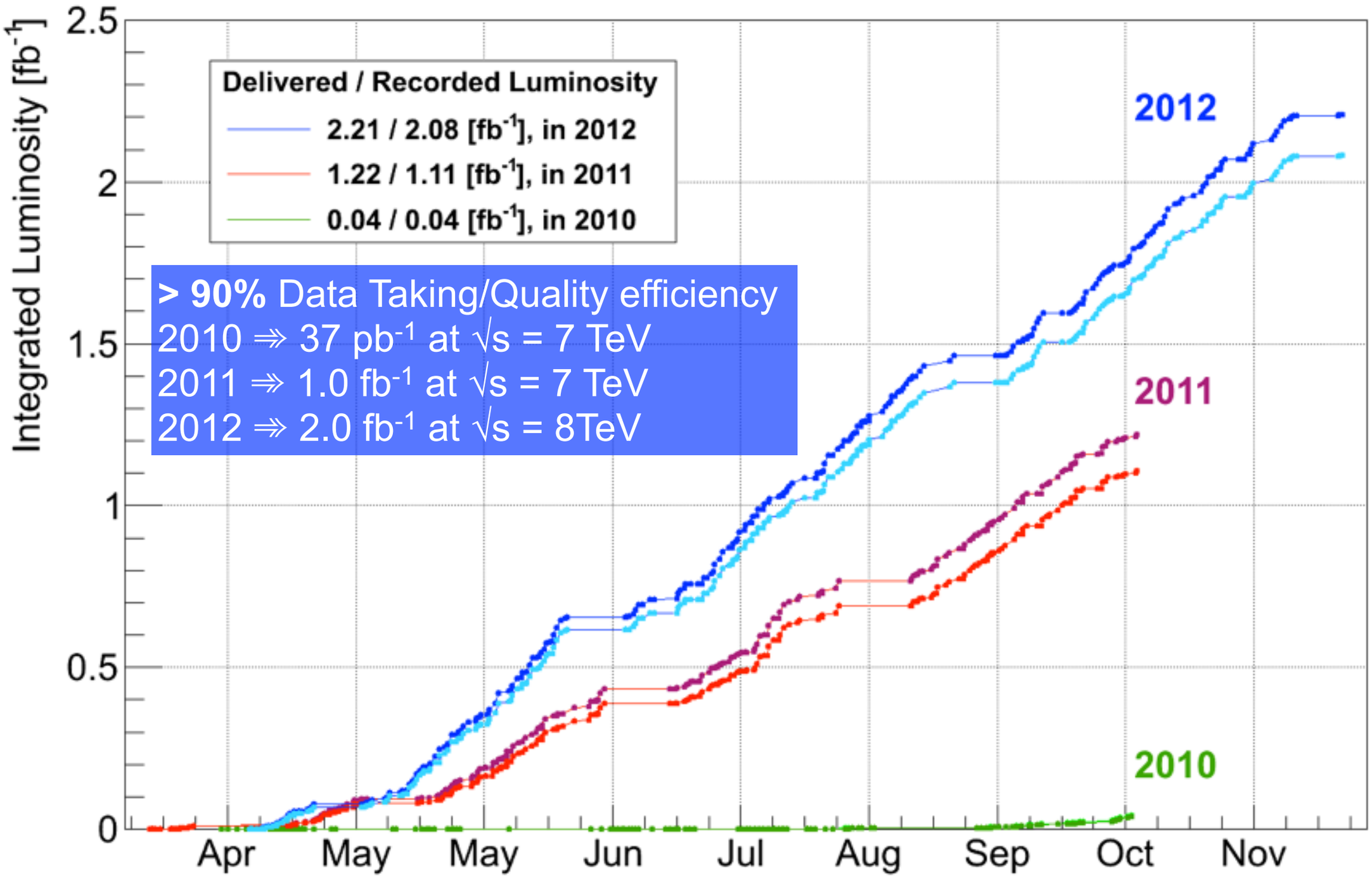
COSMIC RAY PREDICTIONS





$$\frac{1}{N_{\text{int}}}\frac{dE_{\text{total}}}{d\eta} = \frac{1}{\Delta\eta}\left(\frac{1}{N_{\text{int}}}\sum_{i=1}^{N_{\text{part},\eta}} E_{i,\eta}\right)$$

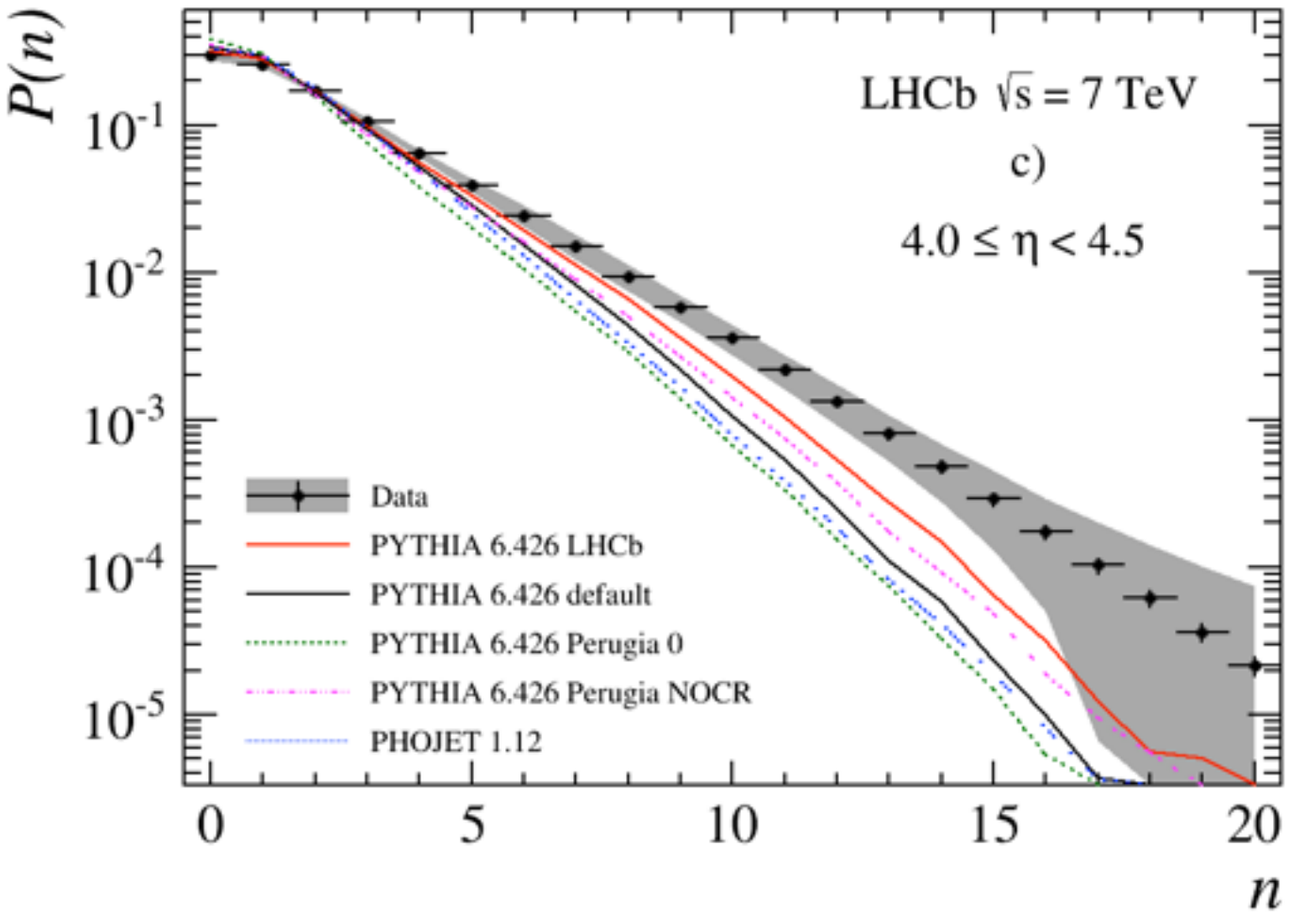
Collected Data

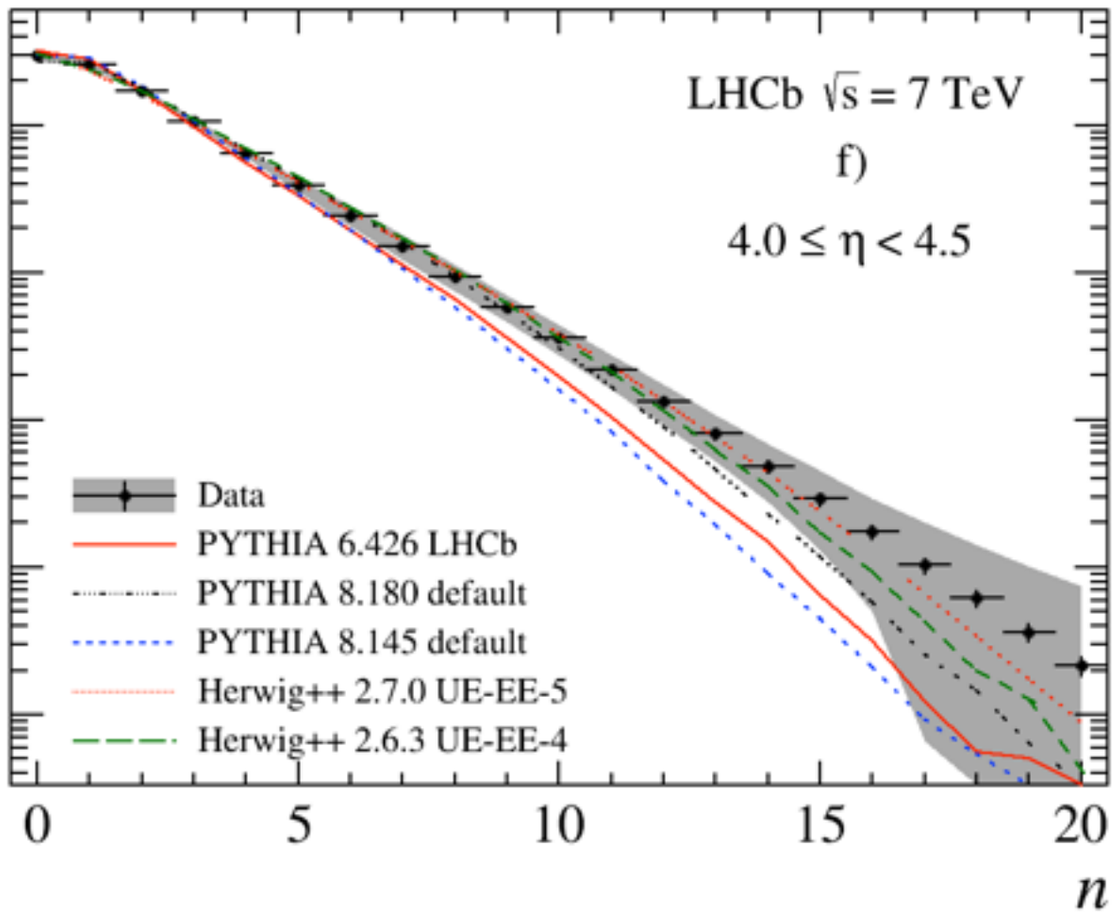


> 90% Data Taking/Quality efficiency
2010 ⇛ 37 pb^{-1} at $\sqrt{s}$ = 7 TeV
2011 ⇛ 1.0 fb^{-1} at $\sqrt{s}$ = 7 TeV
2012 ⇛ 2.0 fb^{-1} at $\sqrt{s}$ = 8TeV

Charged Particle Multiplicity and Densities

EPJ C64 (2014) 2888





Charged particle multiplicity is measured in bins of η and p_T

PYTHIA 8.180 (tuned to LHC) and HERWIG++ give best description for high η