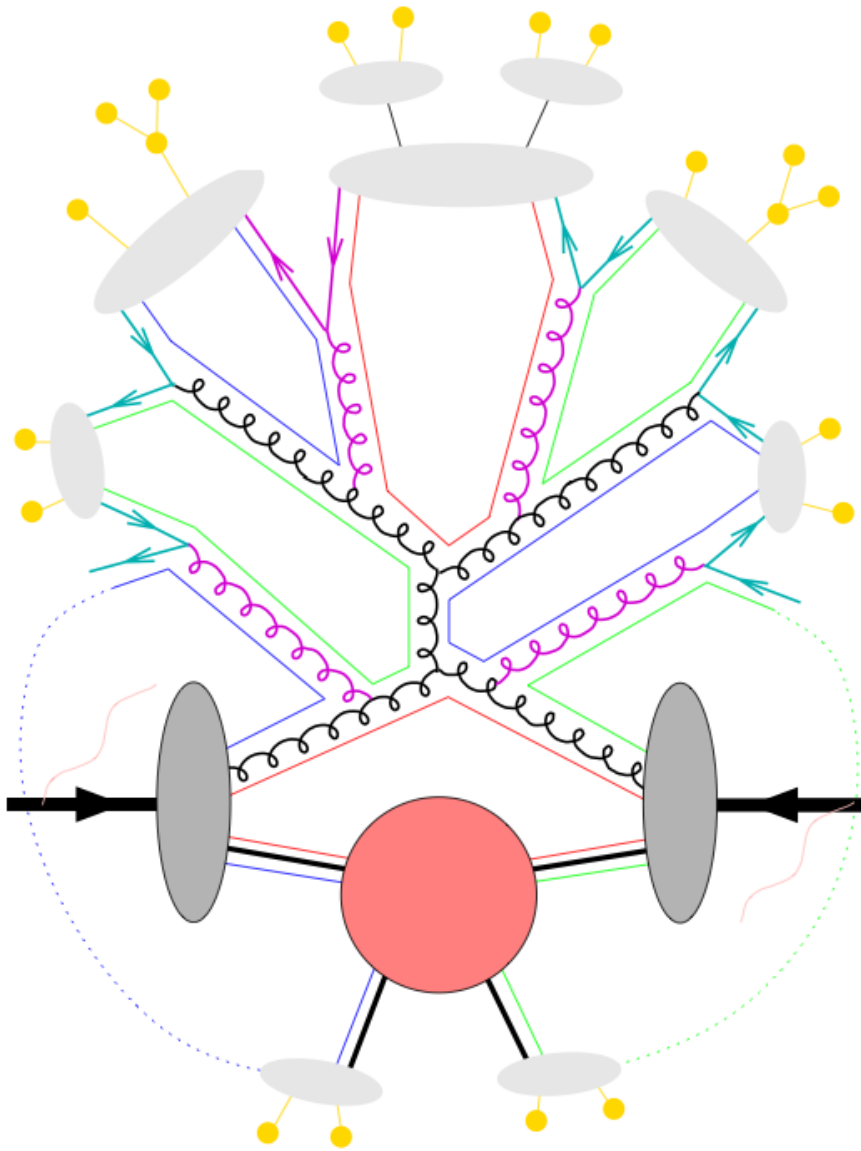


# Particle Production & Minimum Bias Distributions at the LHC

Nick Brook



# Motivation

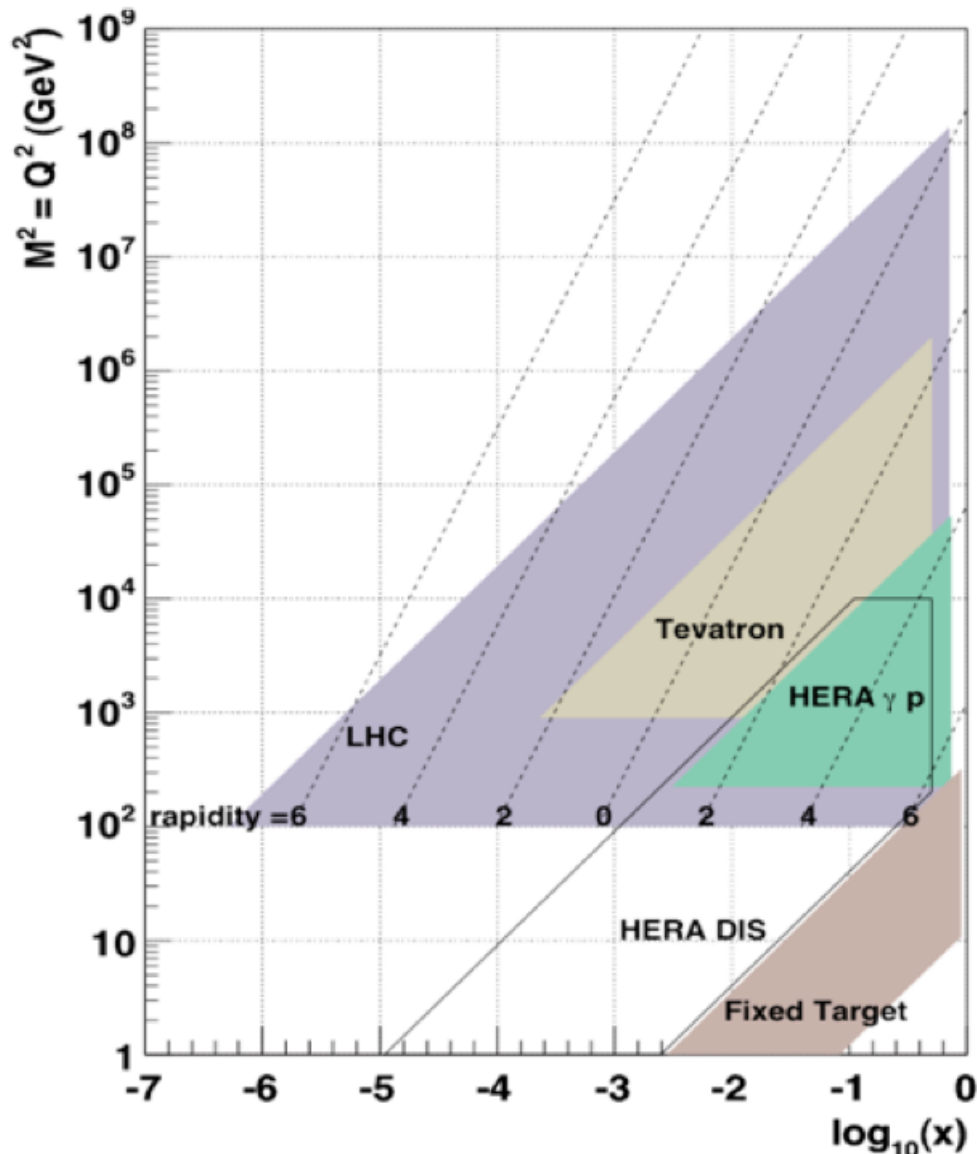


p-p collision reveal rich structure of QCD

- Parton densities
- Parton showers
- Hard scattering
- Multiple parton interactions
- Hadronisation

Not as clear cut but convenient process breakdown

# Motivation



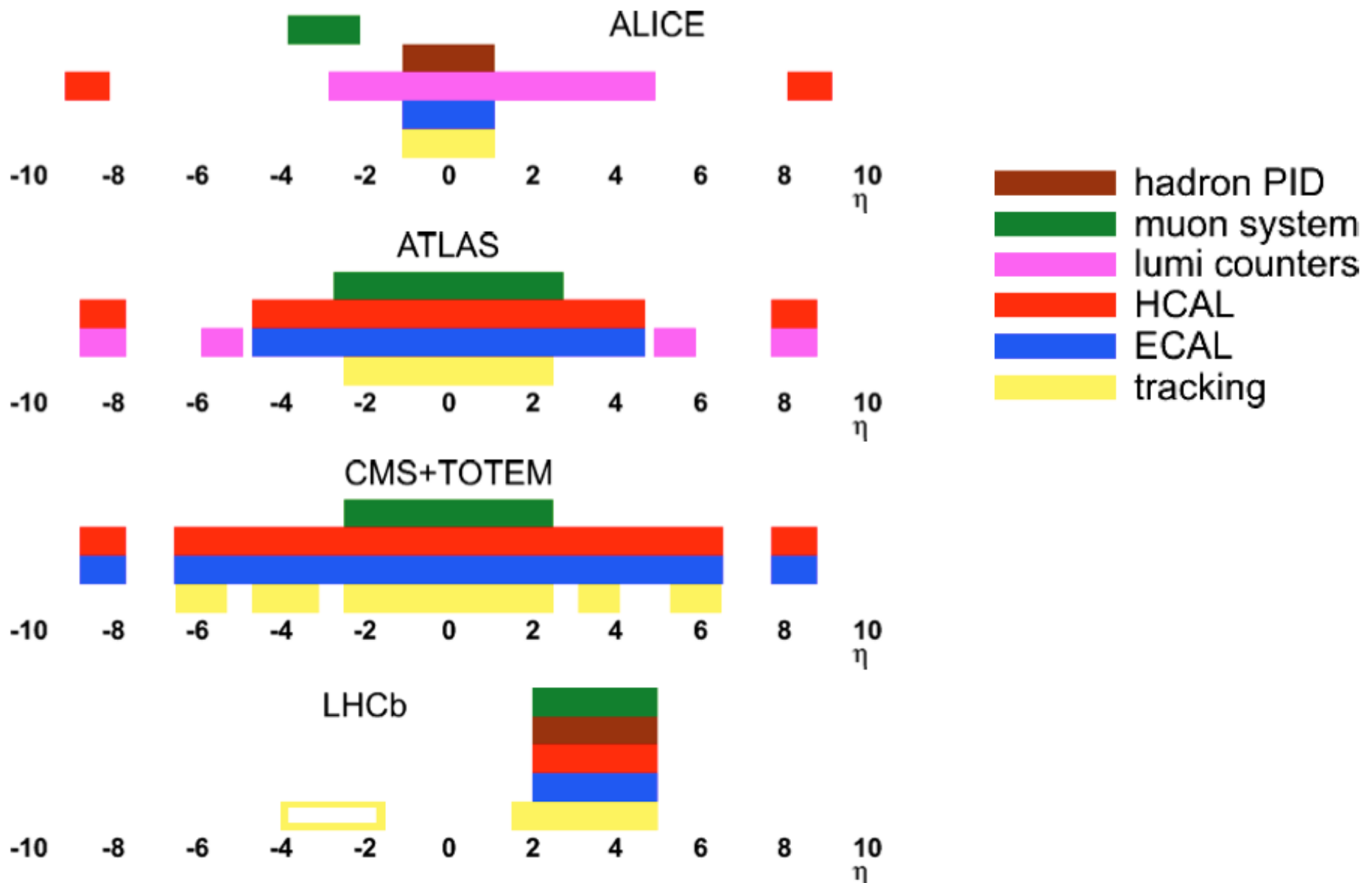
LHC opens up a brand new kinematic regime for QCD

- Soft particle production
- Improve event generators
- Multi-parton interactions
- pQCD calculations
- PDF constraints
- Multijet production

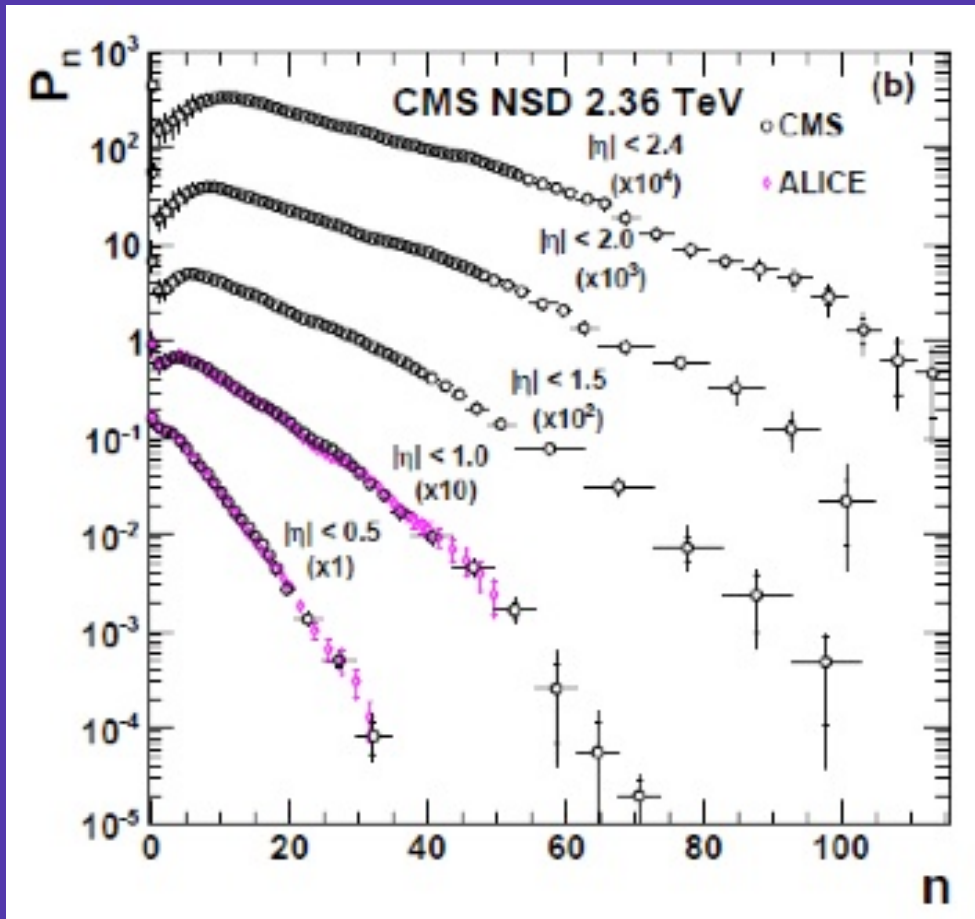
⋮

⋮

# Acceptance of LHC Expts

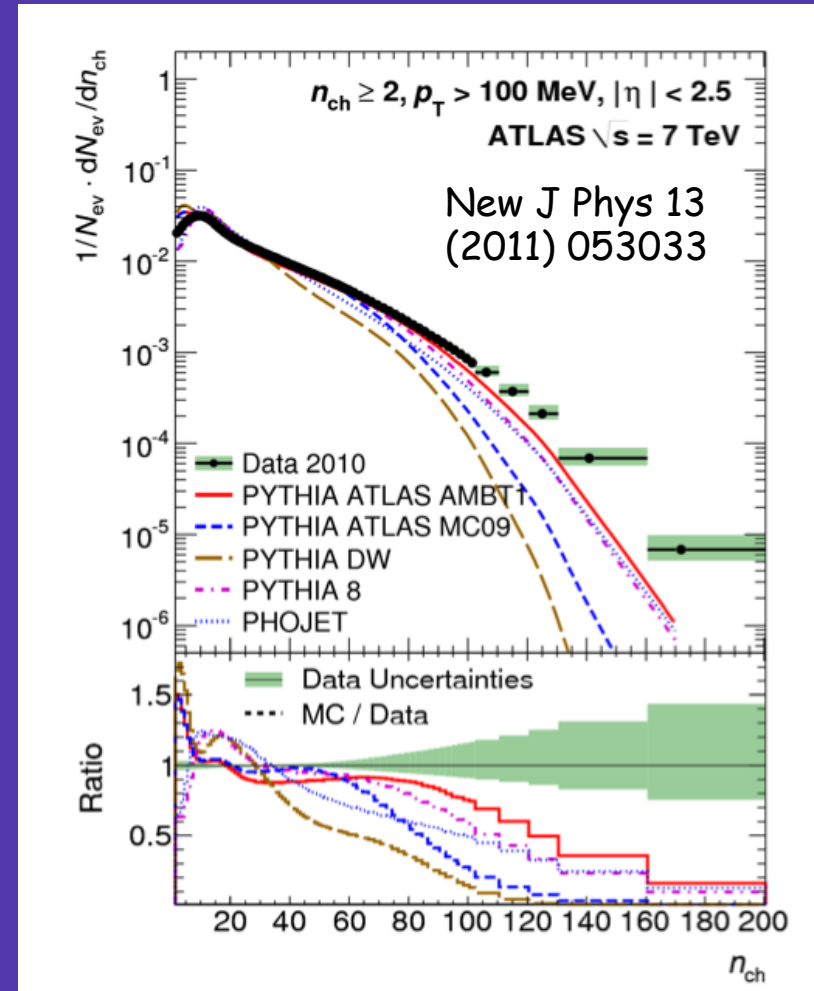


# Multiplicity distributions - central region



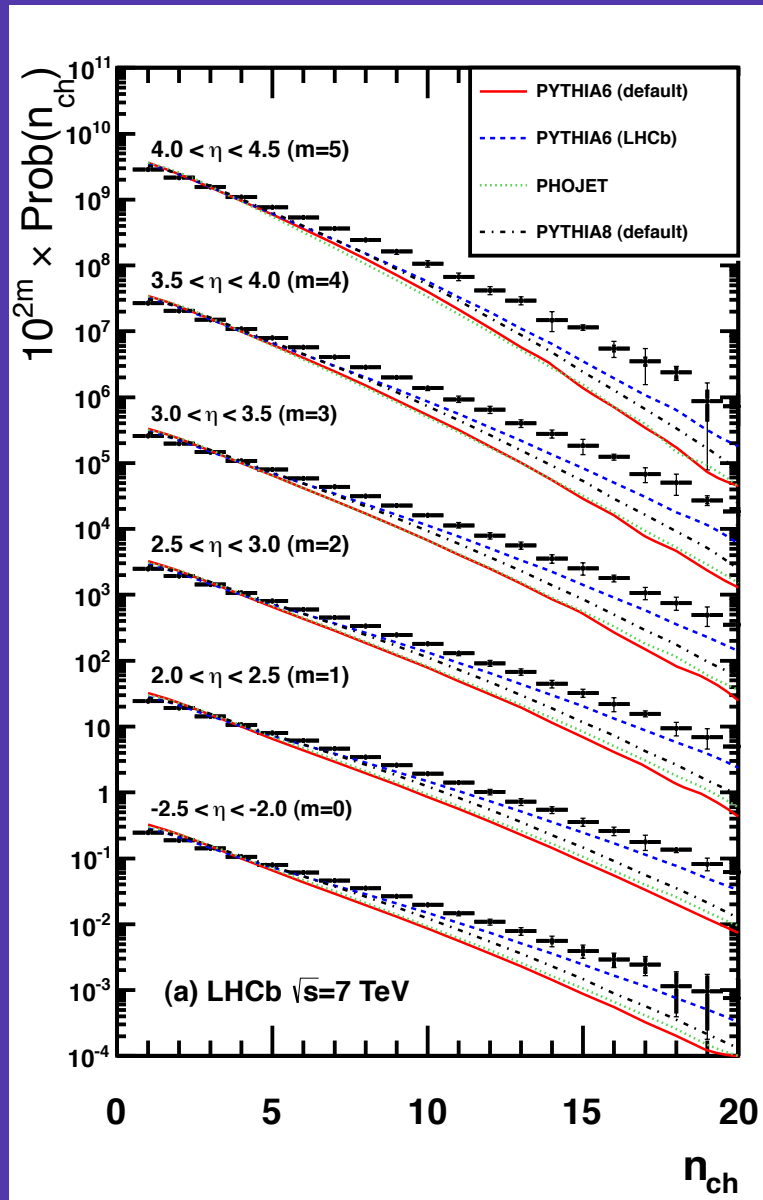
Good agreement between ALICE & CMS

(JHEP 01 (2011) 079 & Eur Phys J C68 (2010) 89)



Pre-LHC MC tune fail to describe high  $n_{ch}$  tails

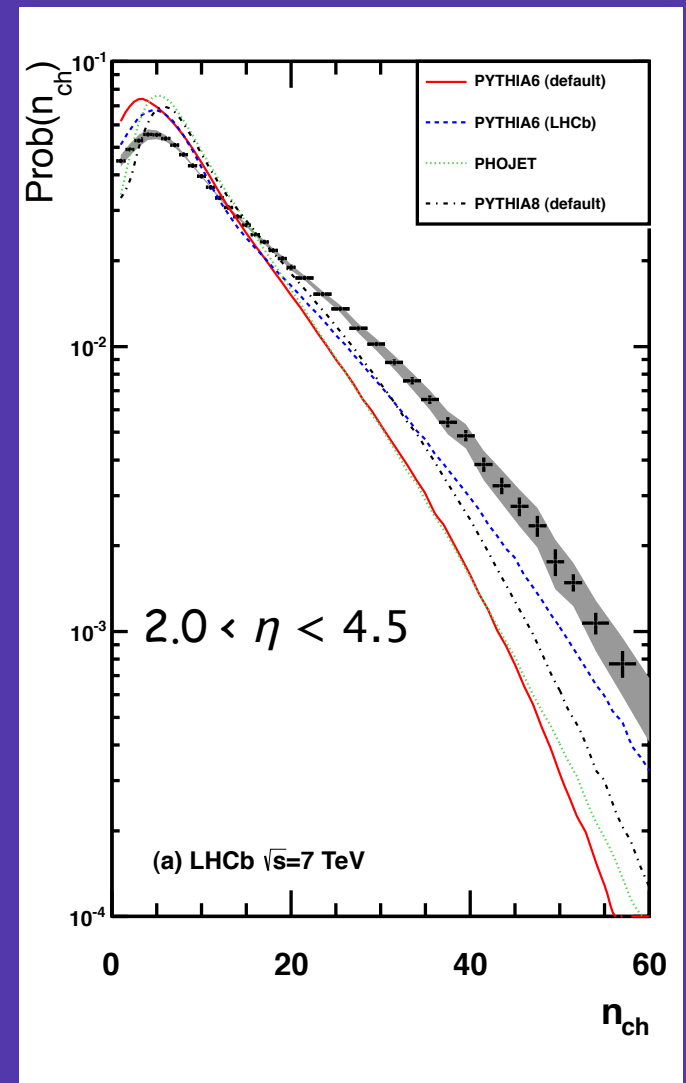
# Multiplicity distributions - forward region



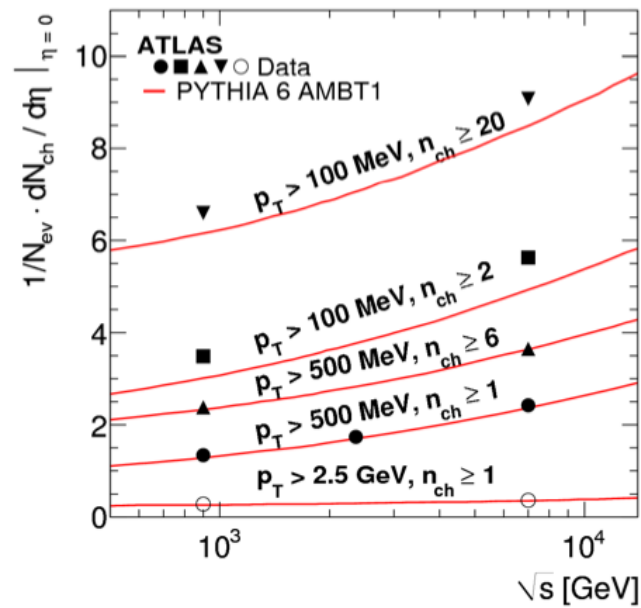
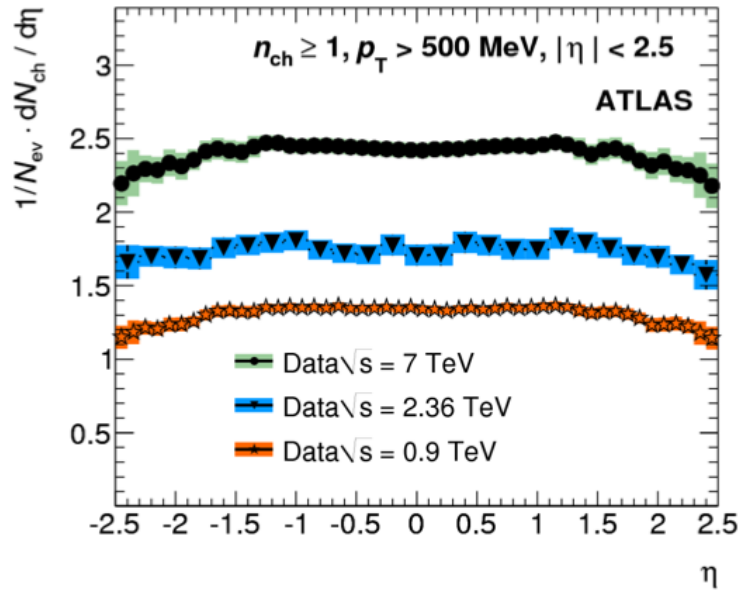
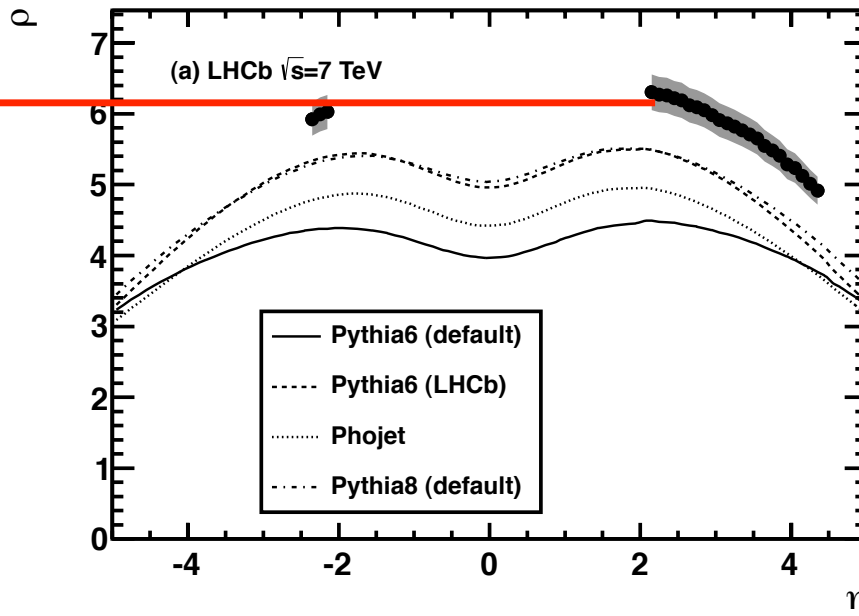
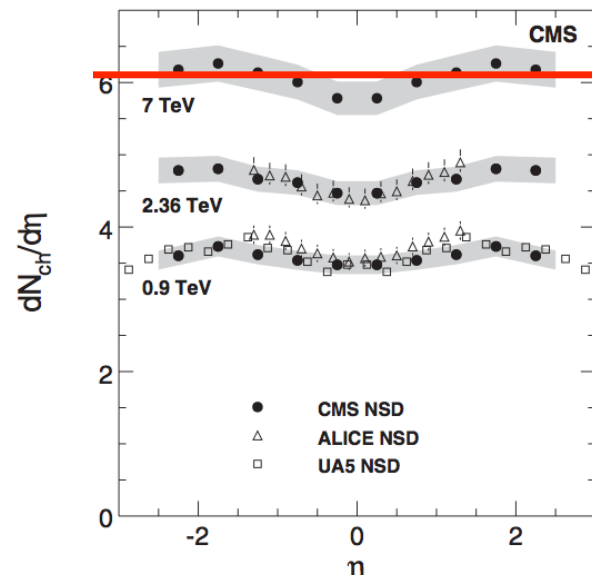
CERN-PH-EP-2011-209

At least 1 track in  $\eta$  range under study

Same trends observed as in central production

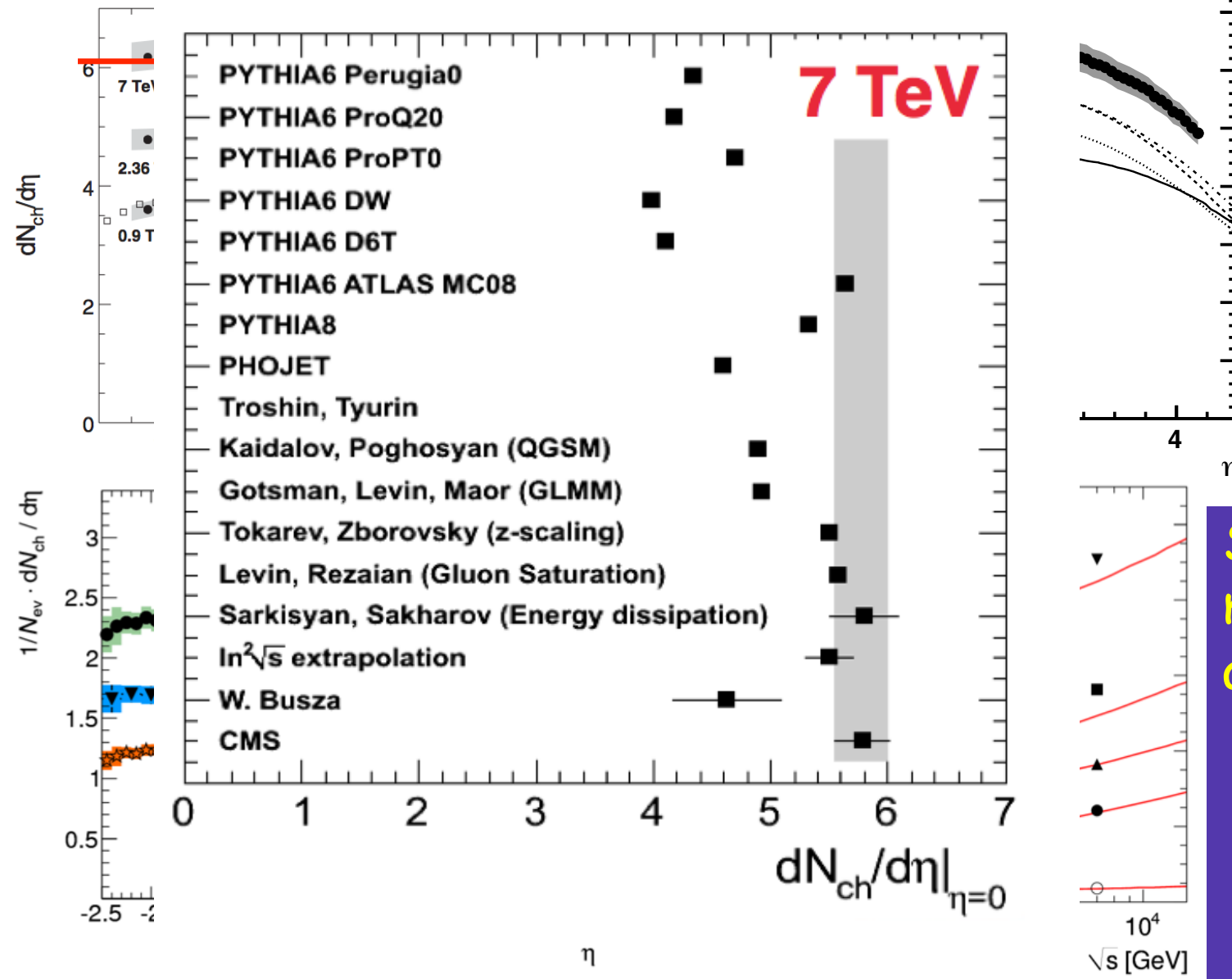


# Charged particle pseudorapidity distributions



Expts in agreement  
Generator tunes improve without low  $p_T$  region

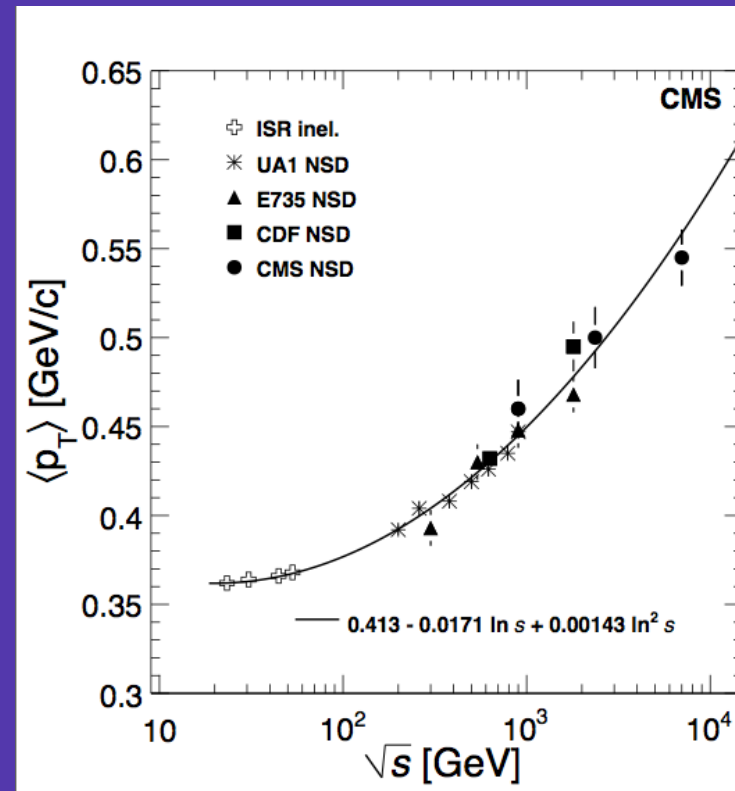
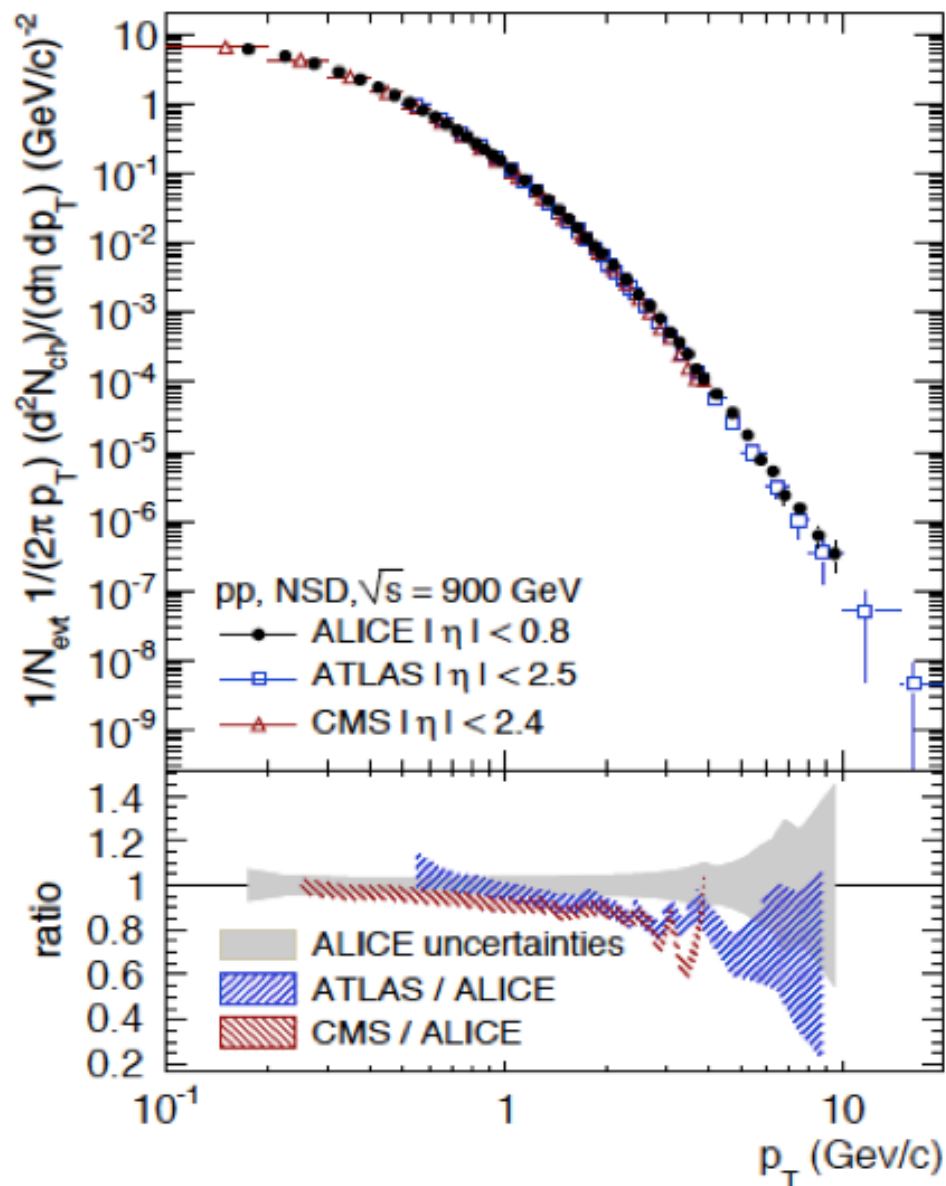
# Charged particle pseudorapidity distributions



Same analytic models in good agreement



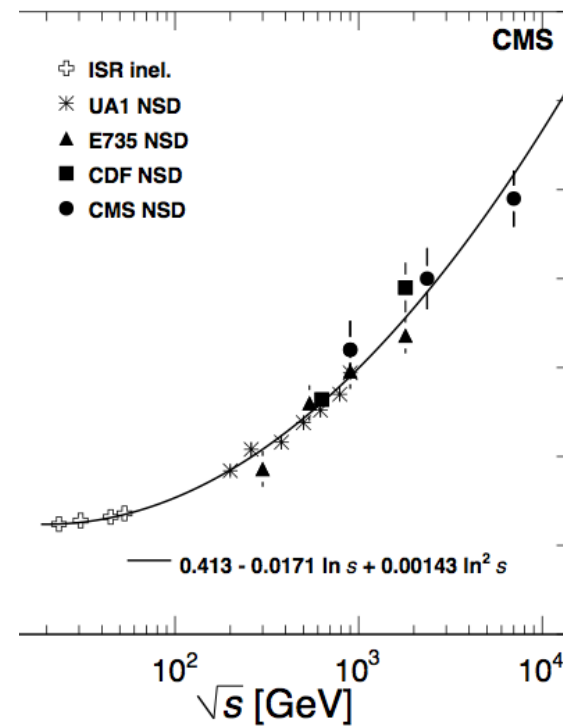
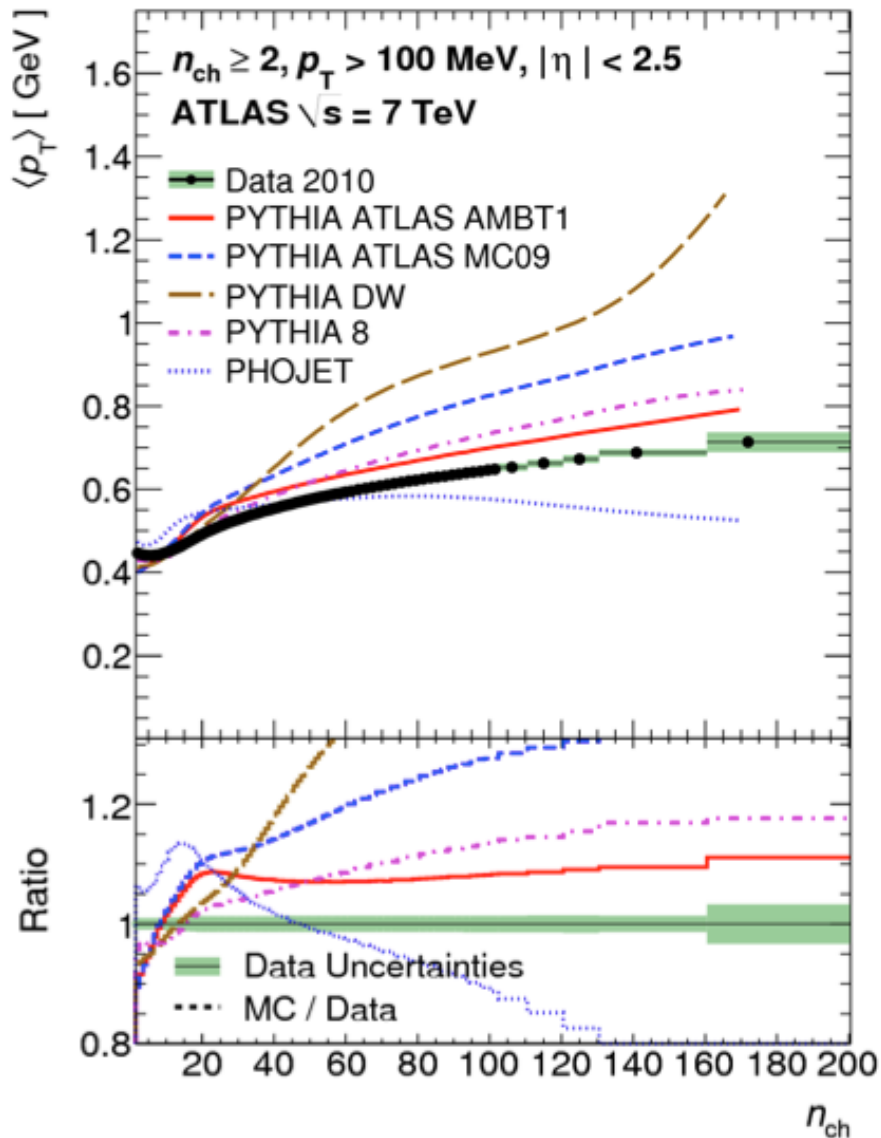
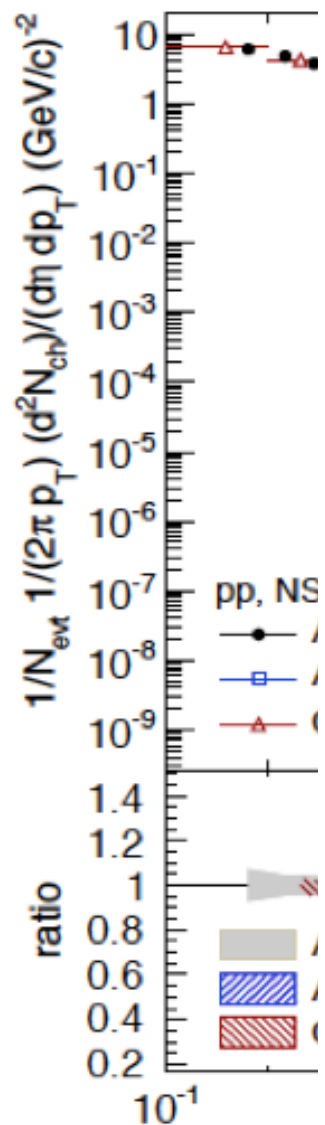
# Charged Particle Transverse Momentum



Mean  $p_T$  grows with CoM energy

LHC measurement in line with lower energy data

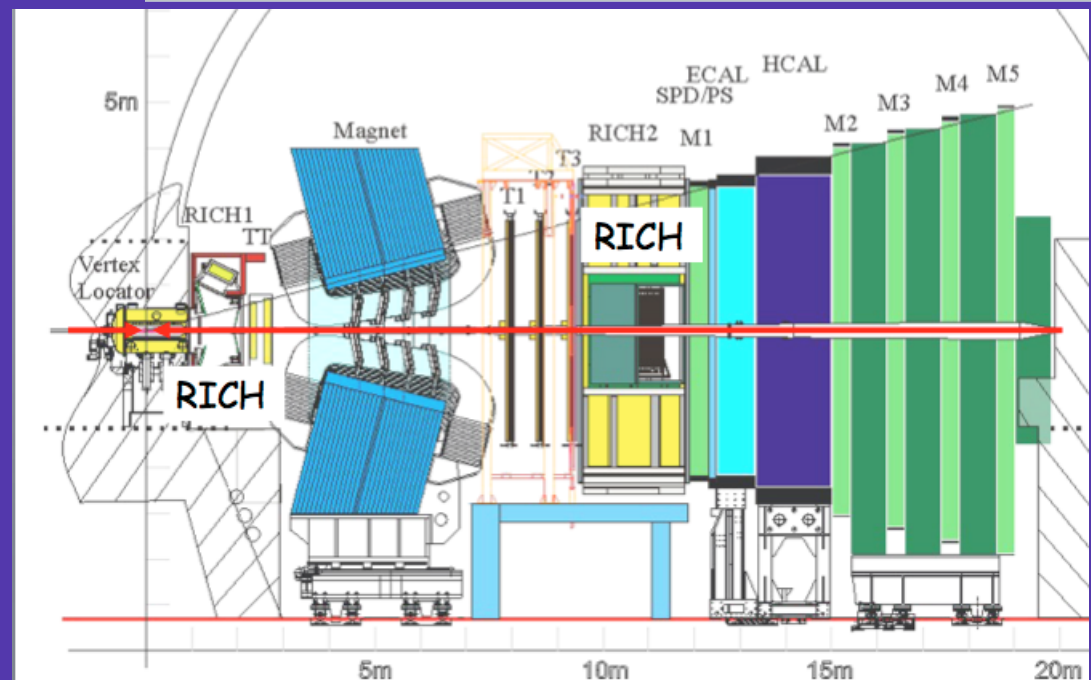
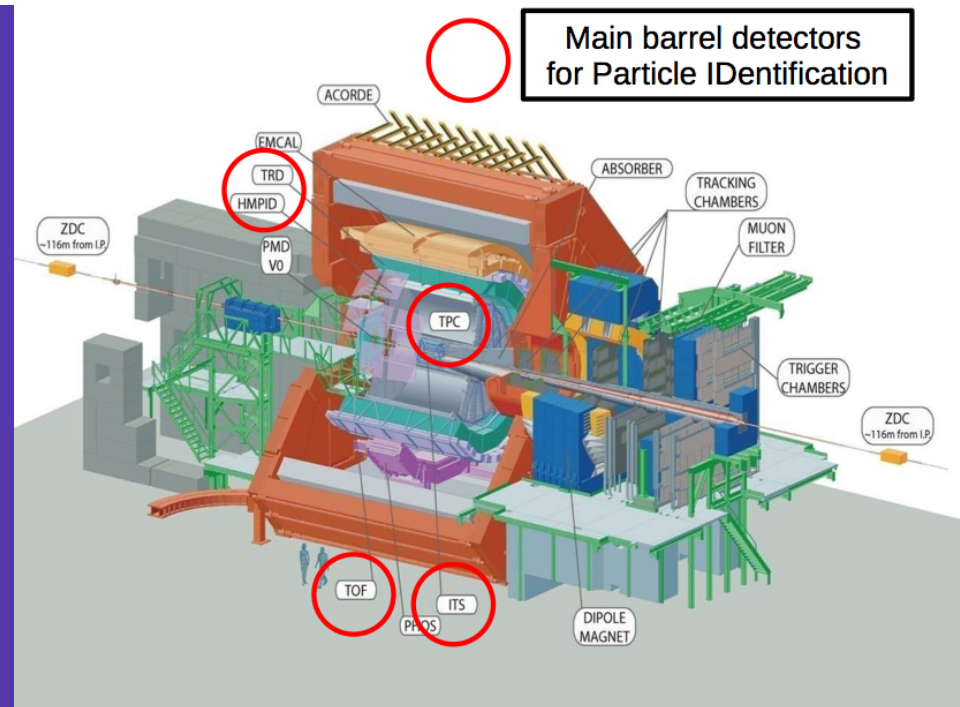
# Charged Particle Transverse Momentum



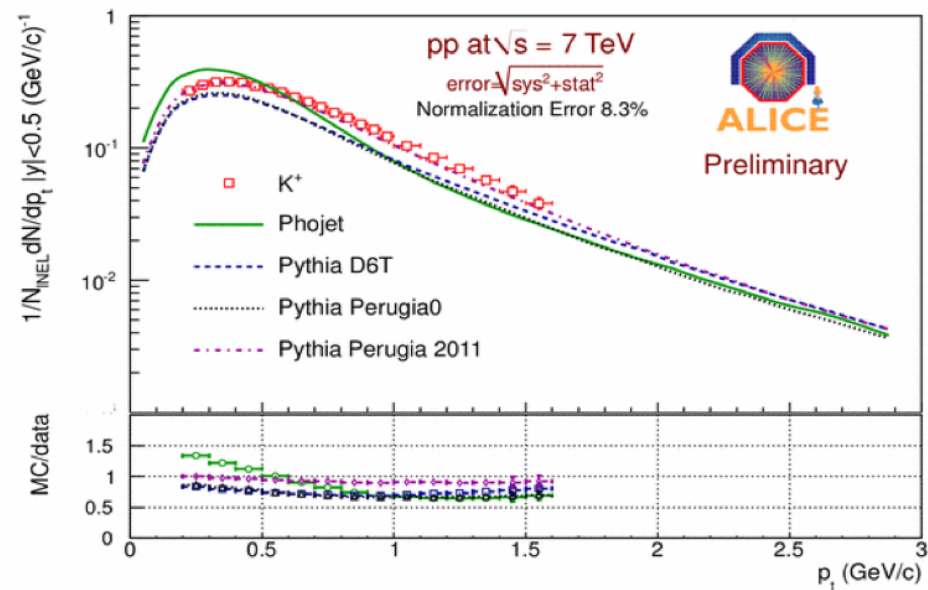
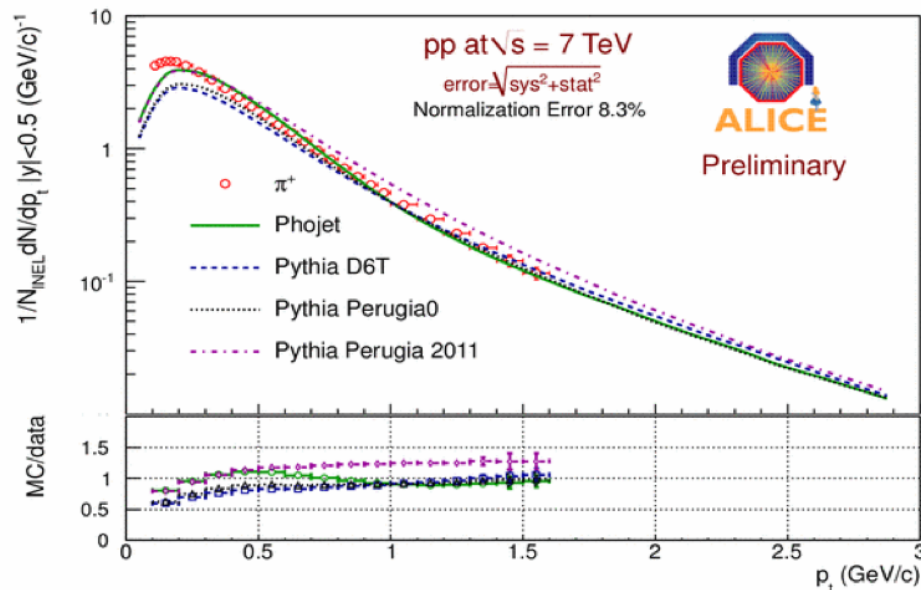
Event generator  
 predictions  
 expected a greater  
 $\langle p_T \rangle$

# Identified Charged Particles

- ALICE has several barrel detectors dedicated to PID
  - $dE/dx$ , transition radiation, ToF, Cherenkov radiation
- LHCb has dedicated PID detectors
  - 2 RICH detectors

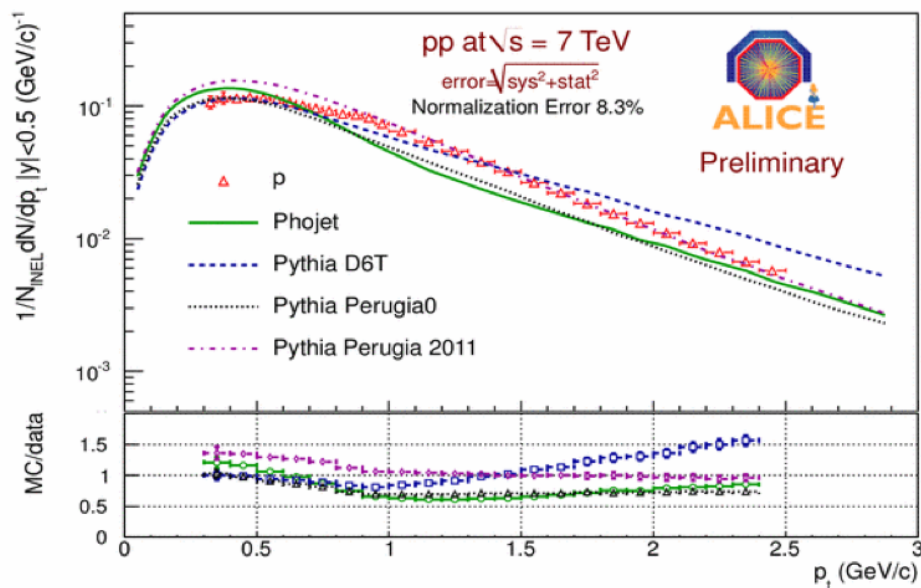


# Identified Charged Particles



ALI-PREL-10373

ALI-PREL-10385

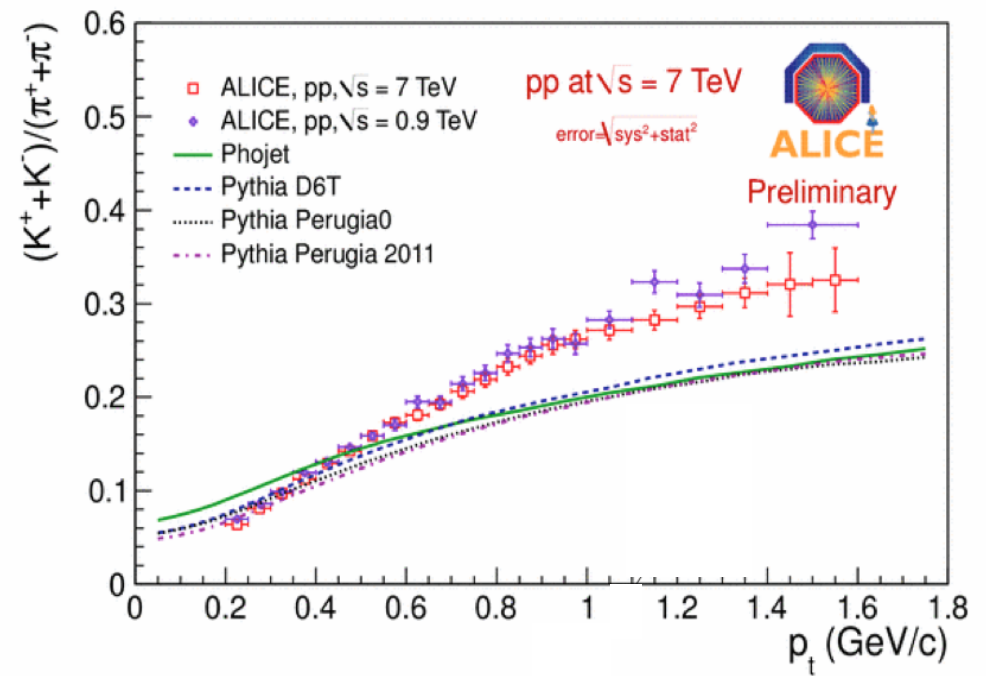


ALI-PREL-10393

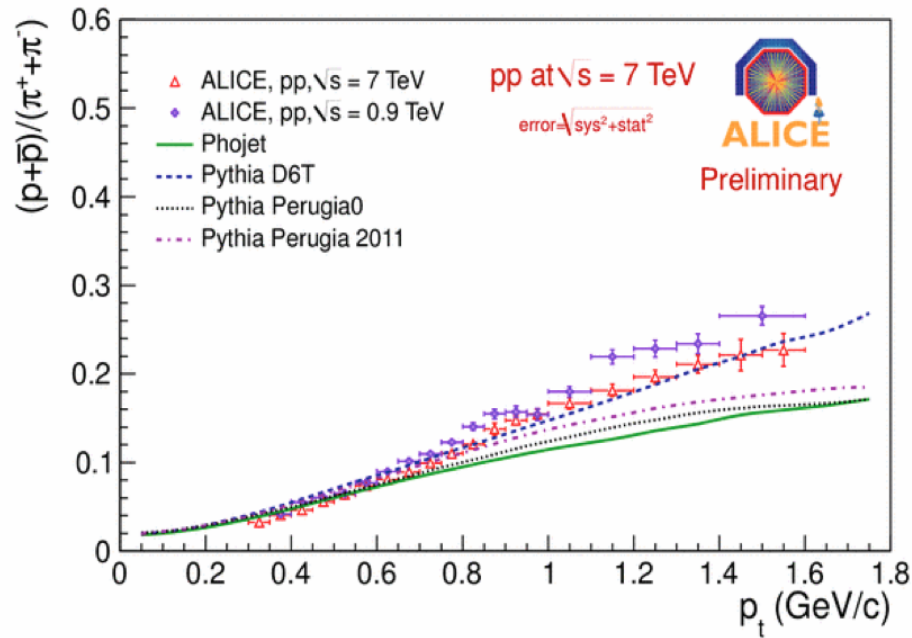
MC models do not describe detail of particle spectra at low  $p_T$

# Charged Particle Ratios

## ALICE results



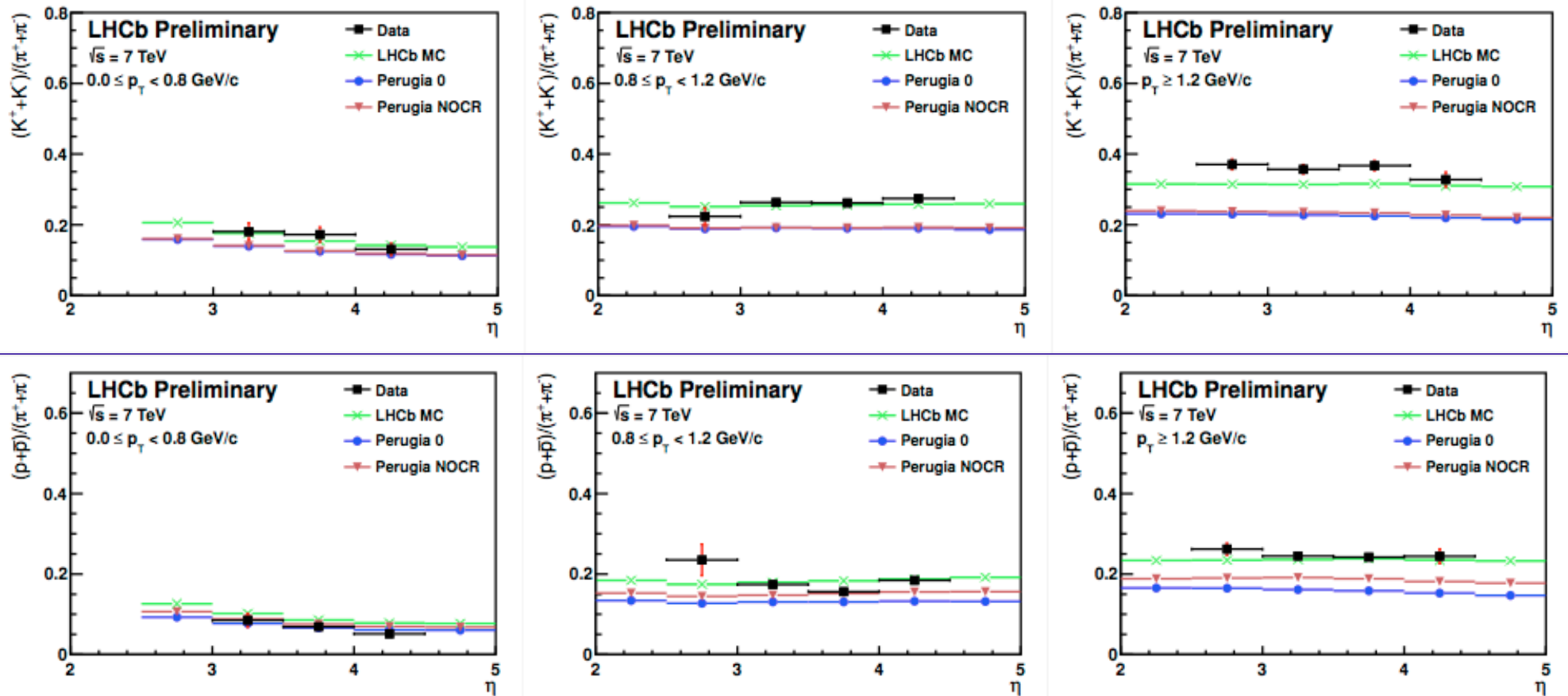
ALI-PREL-5407



ALI-PREL-5410

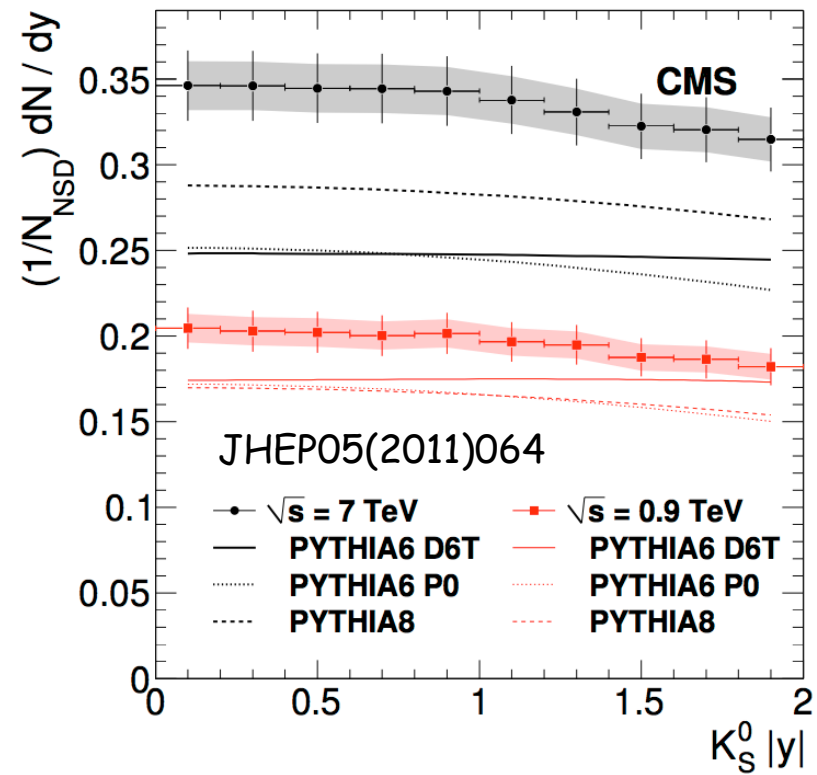
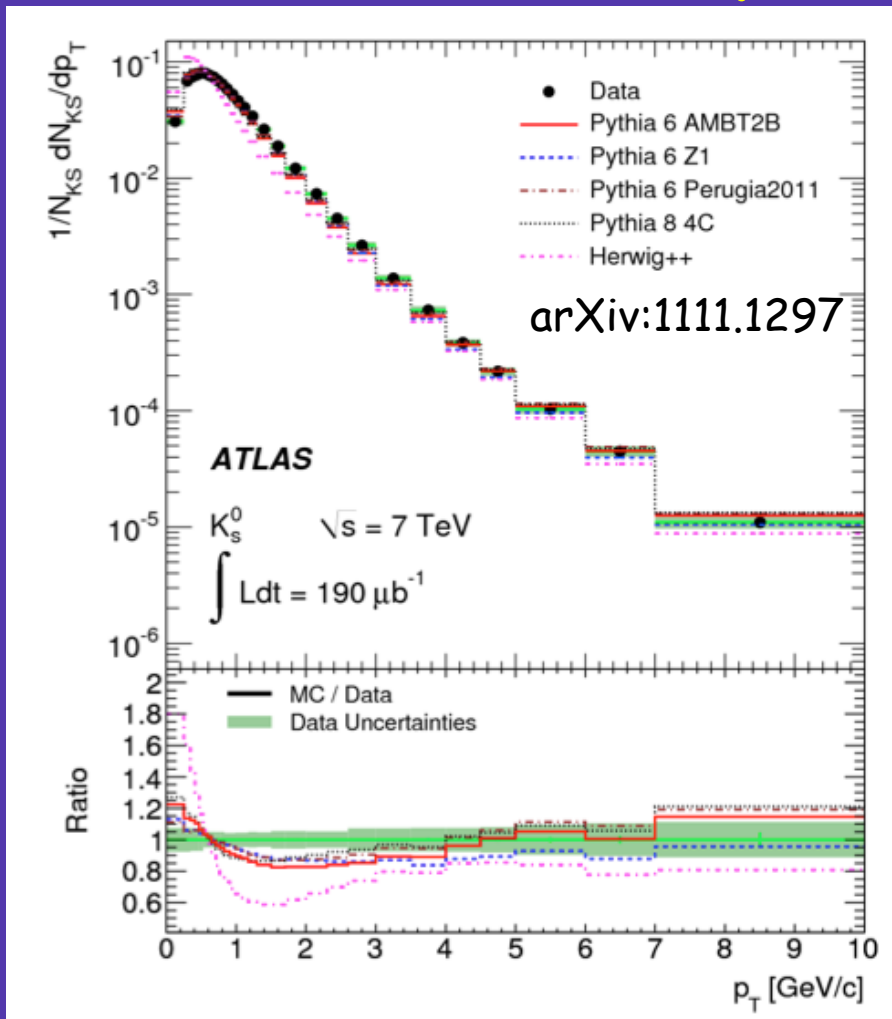


# Charged Particle Ratios



$P/\pi, K/\pi$  ratio underestimated by models at high  $p_T$   
 LHCb tune – specifically looked at species production

# $K_S^0$ production

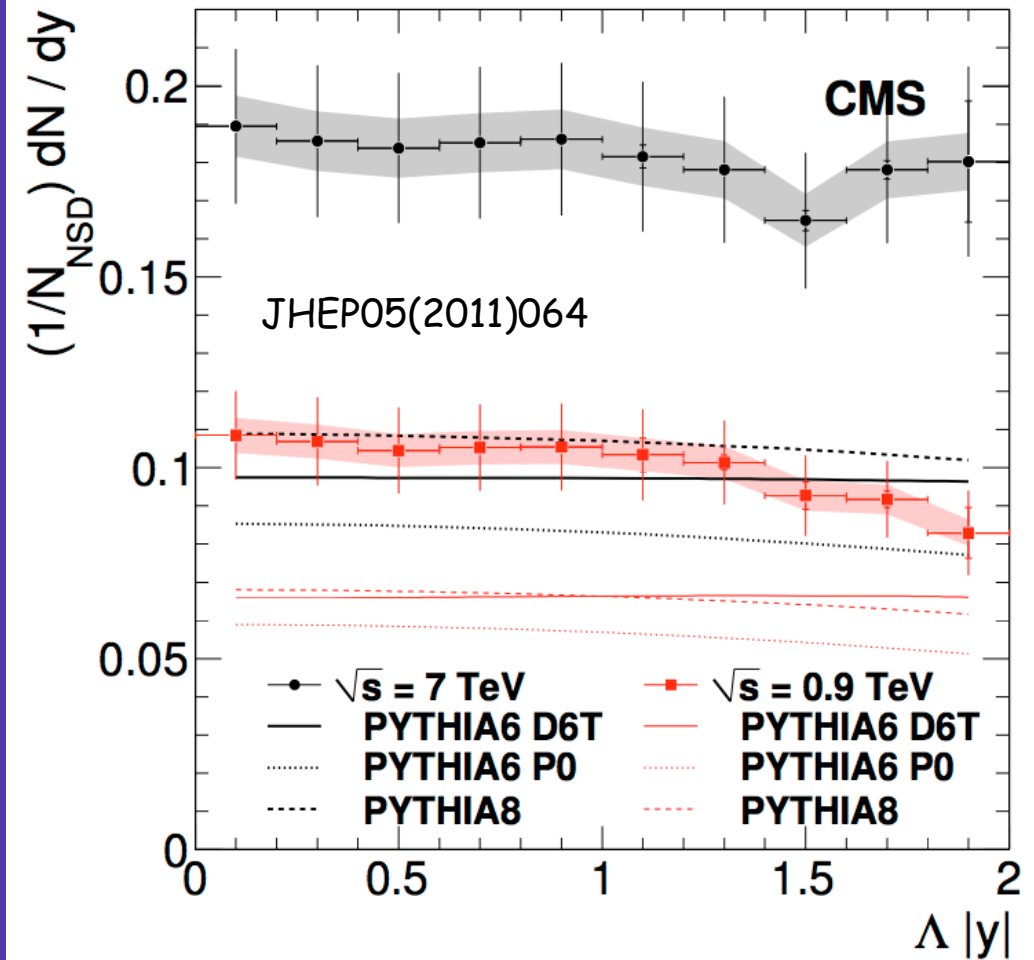
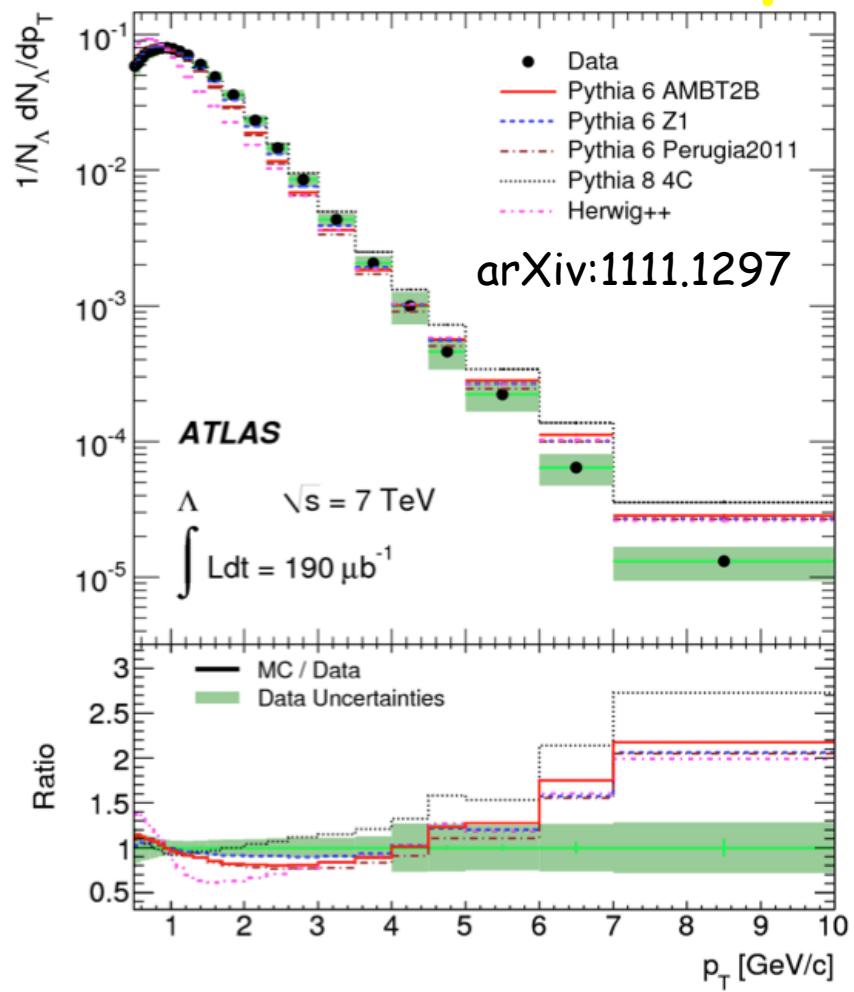


Not too surprising given  $n_{ch}$  results -  $K_S^0$  is also underestimated

Rapidity shape is well described

$p_T > 2 \text{ GeV}/c$  - MC falls more slowly than data

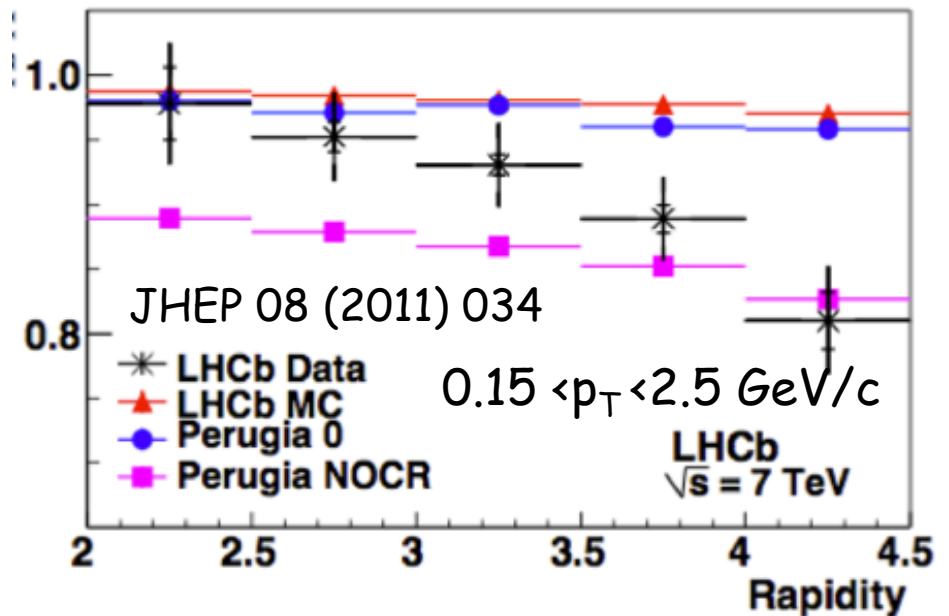
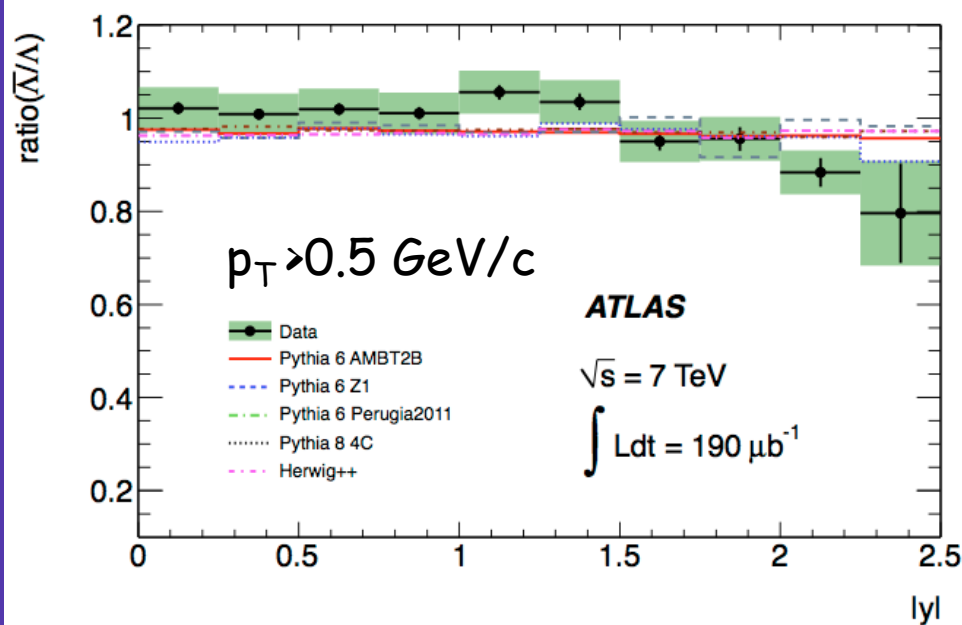
# $\Lambda$ production



$\Lambda$  production not as well described as  $K_S^0$



# $\Lambda$ production ratios

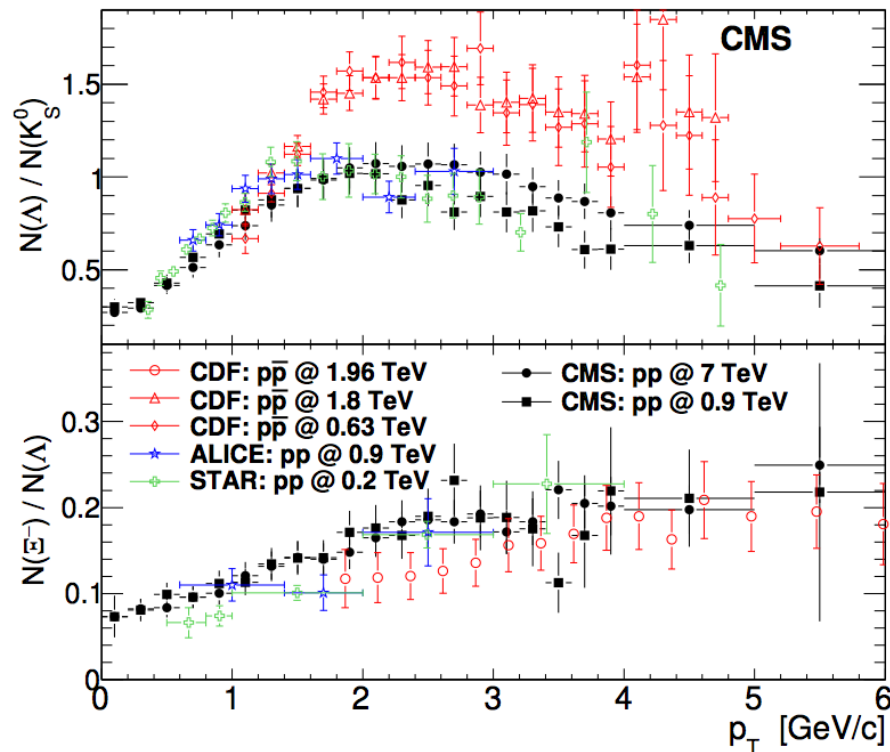


AntiParticle/particle ratio flat ( $\sim 1$ ) in central region

Ratio falls off go to forward region

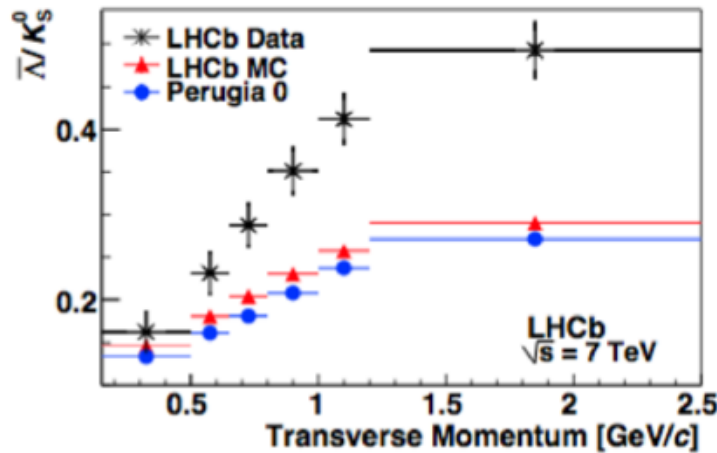
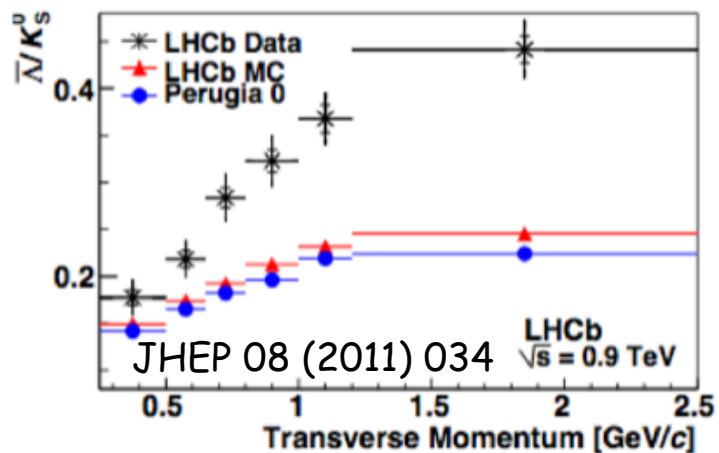
MC predictions remain essentially flat

# $\Lambda(\bar{\Lambda})/K_S^0$ production ratios



Ratio rises at  $p_T$  raises as expected

Rise in forward region greater than MC predictions

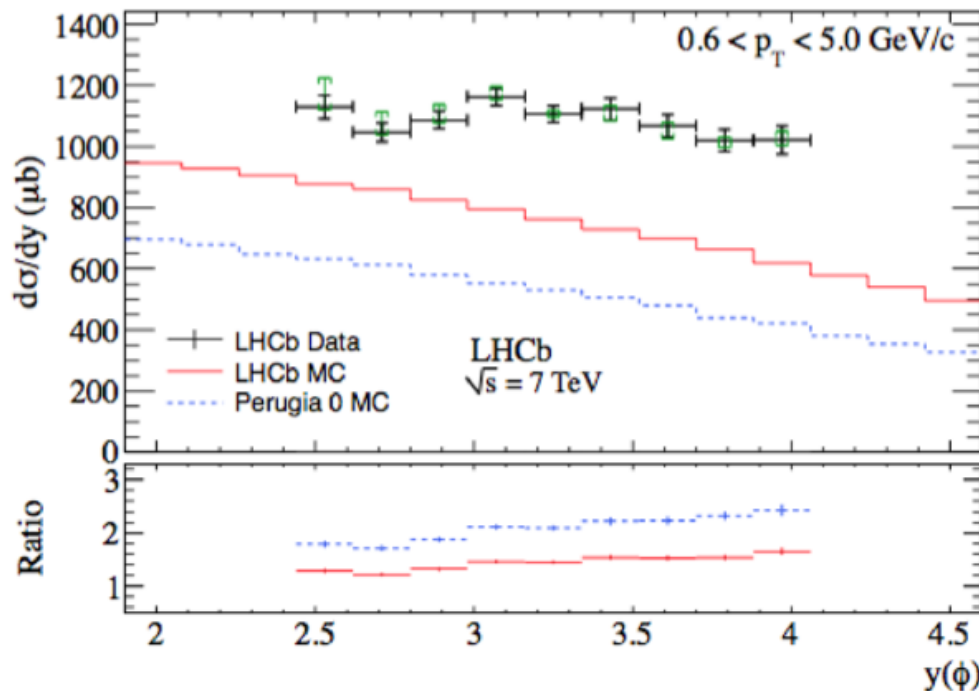
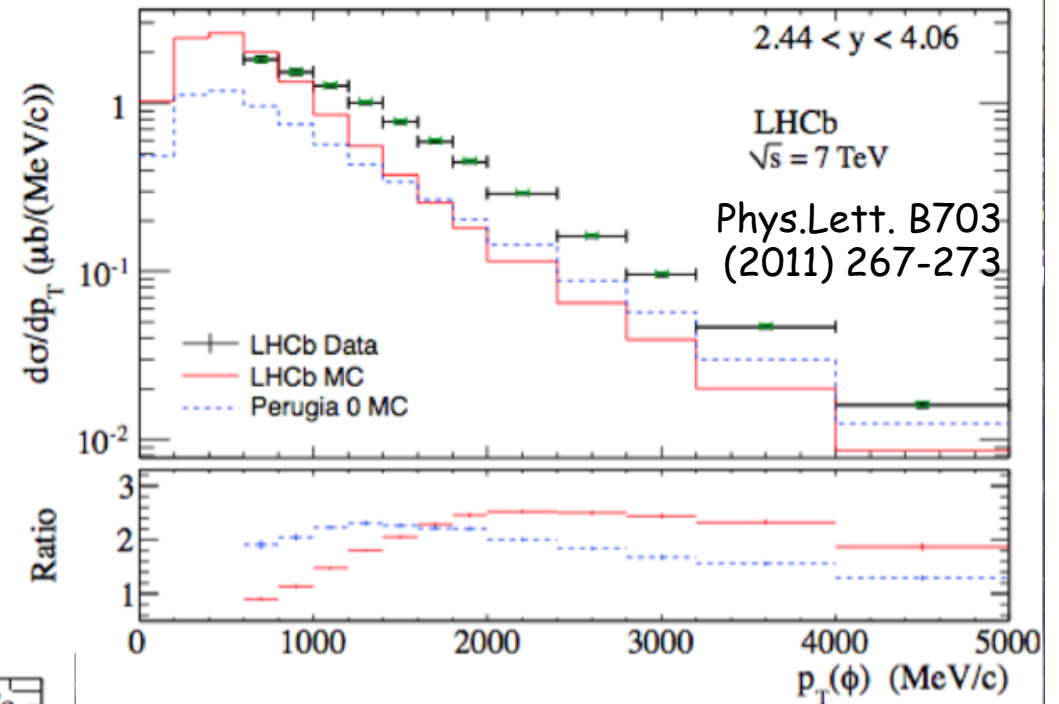


# $\phi$ production

X-section underestimated  
by MC

Flatter rapidity distribution  
than MC

$p_T$  spectra closer to P0 tune



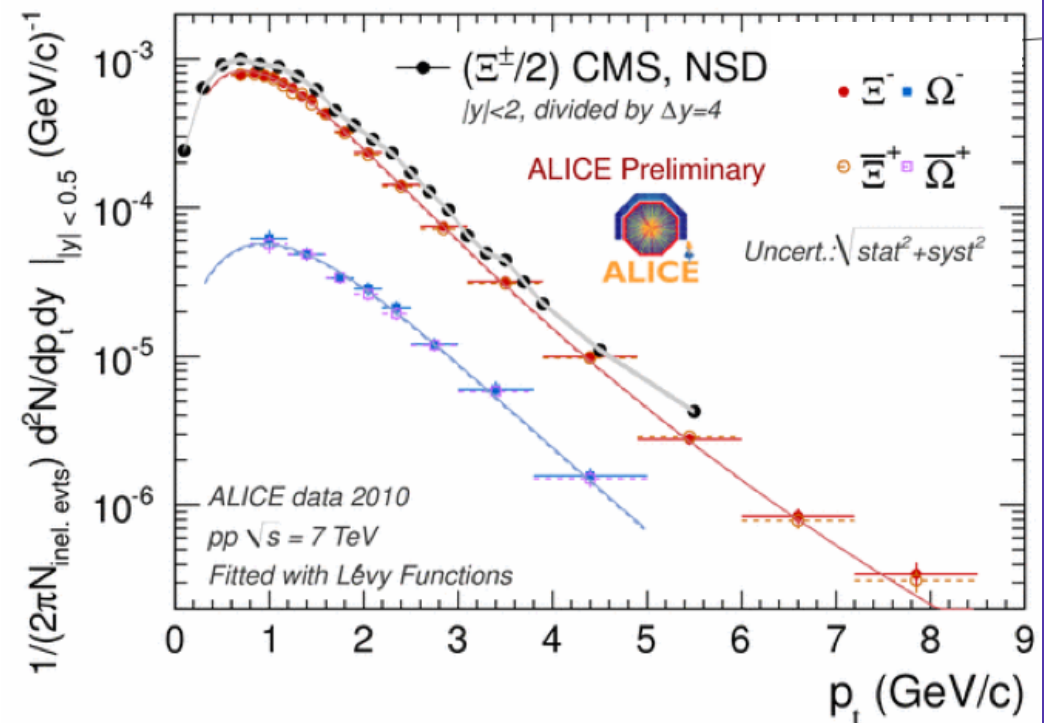
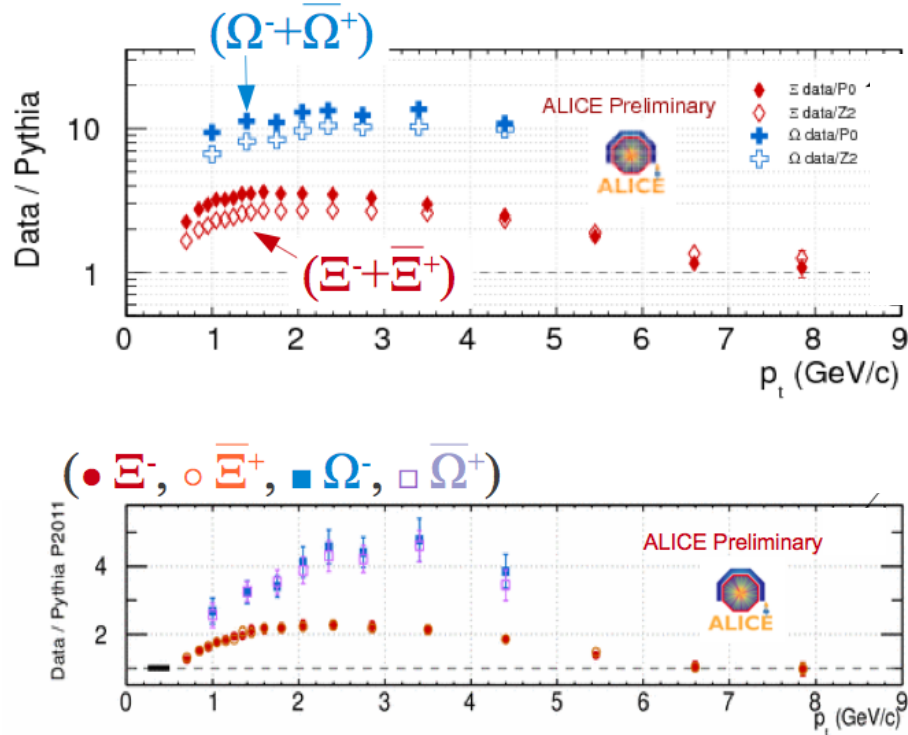
$$\sigma_{pp \rightarrow \phi X} = 1758 \pm 19(\text{stat})$$

$$+43(\text{syst}) \pm 182(\text{scale}) \mu\text{b}$$

$$p_T \in [0.6, 5.0 \text{ GeV}/c]$$

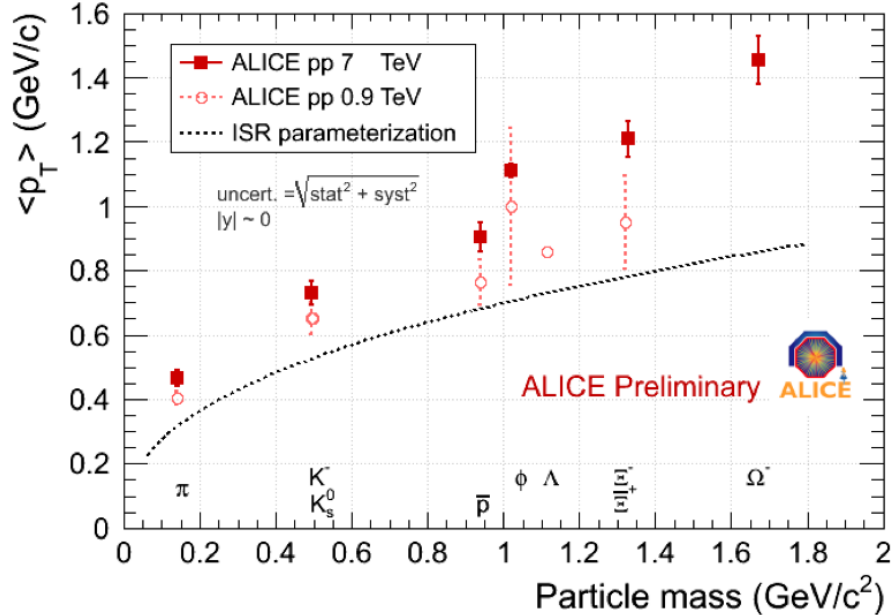
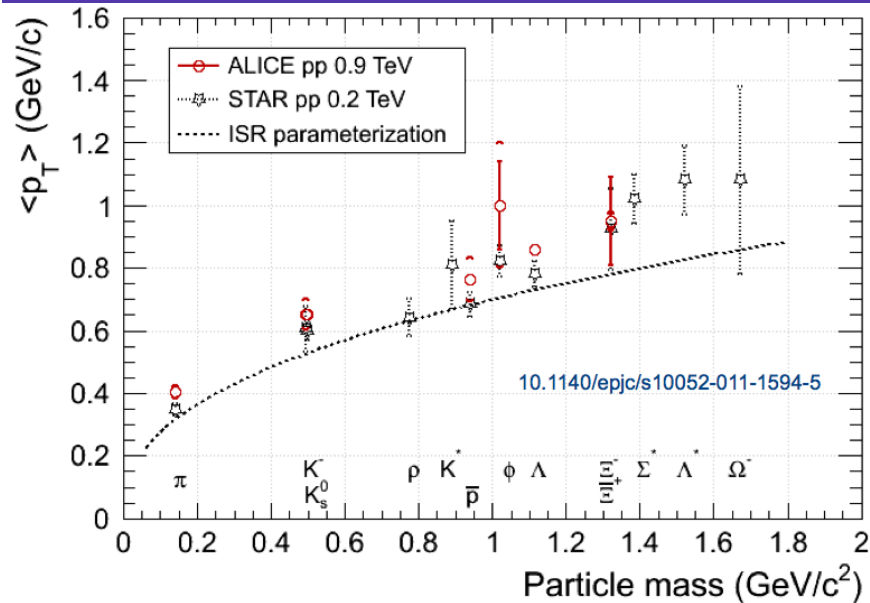
$$y \in [2.44, 4.06]$$

# $\Xi, \Omega$ production



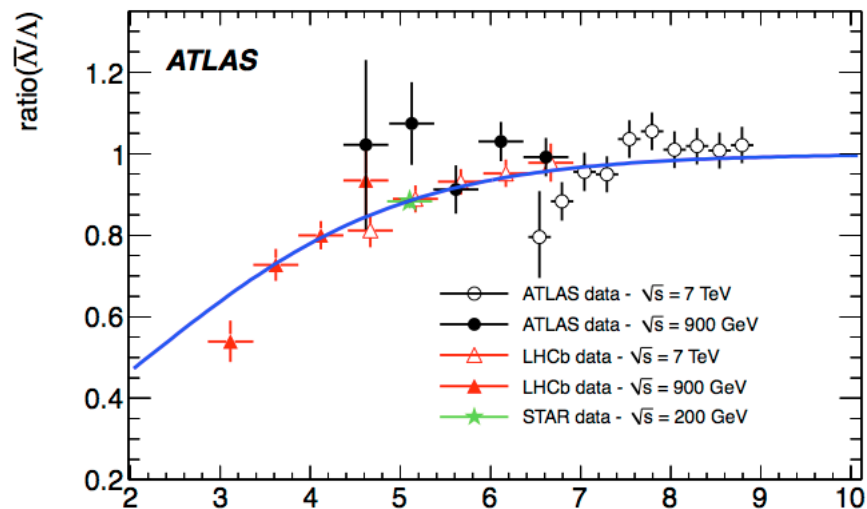
- Agreement between ALICE & CMS
  - Slightly different samples inelastic vs NSD
- MC yields greatly underestimate data

# $\langle p_T \rangle$ versus mass



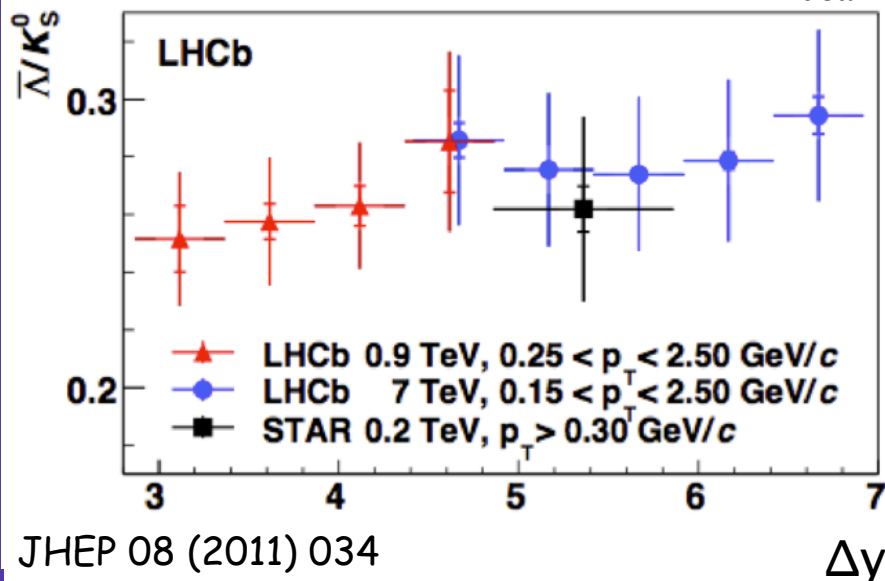
- $\langle p_T \rangle$  increases with mass as expected
- ISR parameterisation significantly below data @ 7 TeV
  - Nucl.Phys. B114 (1976) 334

# Baryon transport



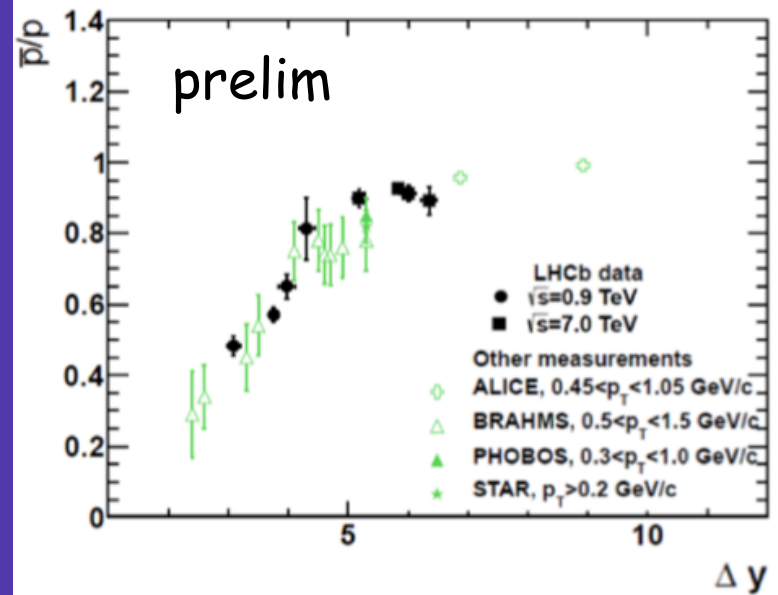
arXiv:1111.1297

$\Delta y = y - y_{\text{beam}}$



JHEP 08 (2011) 034

$\Delta y$



Motivated by string-junction  
& Pomeron models

$$\frac{1}{\text{ratio}} = 1 + C \times e^{(\alpha_J - \alpha_P)\Delta y}$$

$\alpha$  parameters fixed  
( $\alpha_J = 0.5$ ,  $\alpha_P = 1.2$ )

LHC data consistent with  
lower energy data

# Summary

- Plethora of soft QCD measurements coming from the LHC
  - Many papers from all 4 experiments
  - Consistency across the experiments + complementarity
- Overall MC generators need further tuning
  - Pre-LHC tunes struggle to describe data
  - Strangeness & baryon production problematic
- Further measurements to come

# Backup slides



# LHCb consistency check

