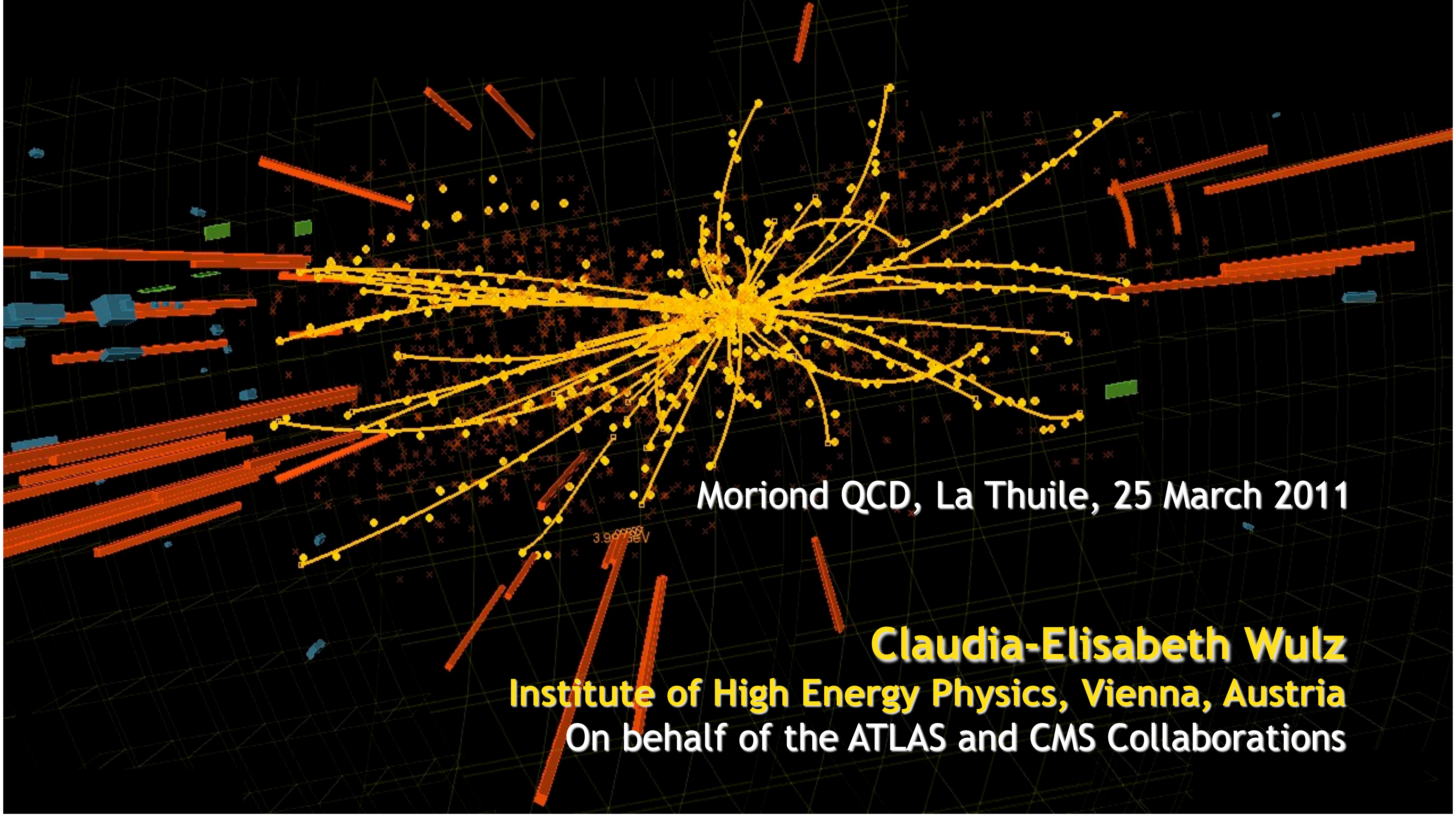
Soft QCD Results from ATLAS and CMS



Moriond QCD, La Thuile, 25 March 2011

Claudia-Elisabeth Wulz
Institute of High Energy Physics, Vienna, Austria
On behalf of the ATLAS and CMS Collaborations

Topics

Properties of minimum bias events

- transverse momentum, pseudorapidity and event-by-event multiplicity distributions of charged particles

Underlying event characteristics

- from charged particle tracks (ATLAS, CMS)
- from calorimeter information (recent ATLAS analysis, not part of talk)

Studied observables (non-exhaustive):

charged particle multiplicity density
charged particle scalar p_T density
charged particle mean p_T
angular distributions

Strangeness production

Particle correlations

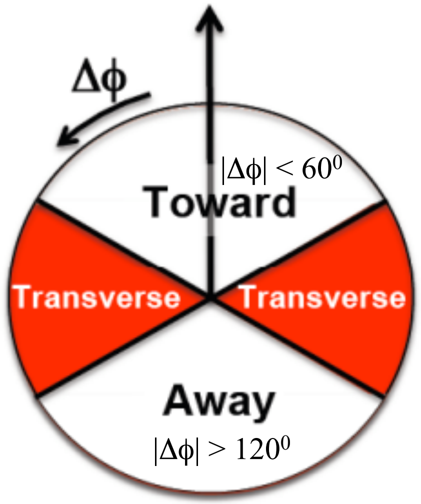
- Bose-Einstein correlations
- short-range and long-range angular correlations in pp and Pb-Pb events

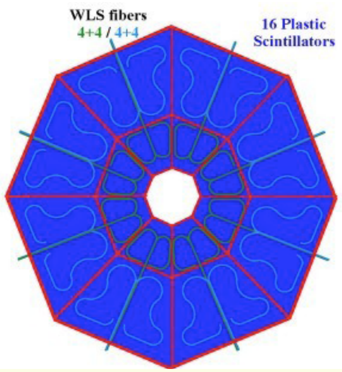
Minimum Bias, Underlying Event

Ideally Minimum Bias events are those recorded with a totally inclusive trigger. The exact definition depends on the experiment, in particular the trigger. Usually Minimum Bias only refers to non-single diffractive (NSD) events.

Underlying event comprises all particles except the (hard) process of interest. It has components from multiple semi-hard parton scattering processes and soft components from beam-beam remnants. The region transverse to the dominant momentum flow is most sensitive to the underlying event.

Leading track or (track) jet direction



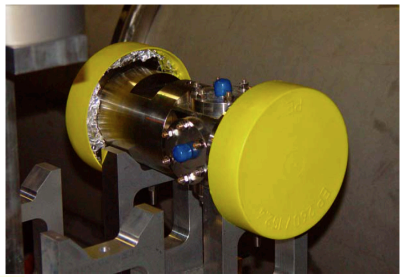


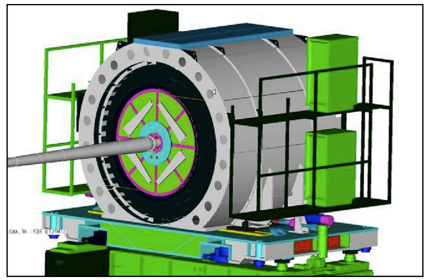
ATLAS Min. Bias Trigger Scintillators (MBTS)

2 stations at $z = \pm 3.56$ m, $2.09 < |\eta| < 2.82$, $2.82 < |\eta| < 3.84$

Beam Pickup Timing for experiments (BPTX)

$z = \pm 175$ m, time resolution 0.2 ns



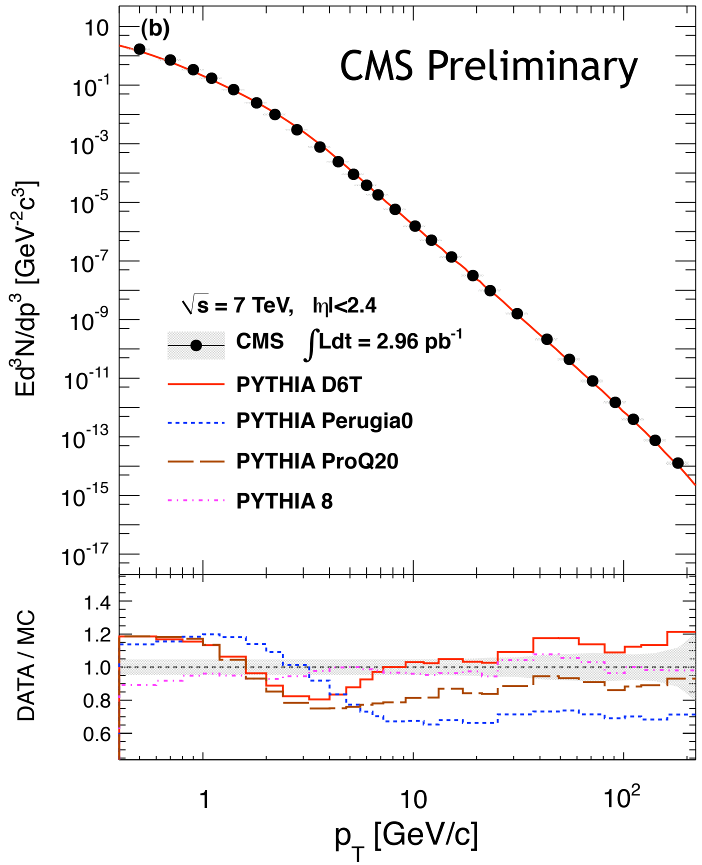


CMS Beam Scintillator Counters (BSC)

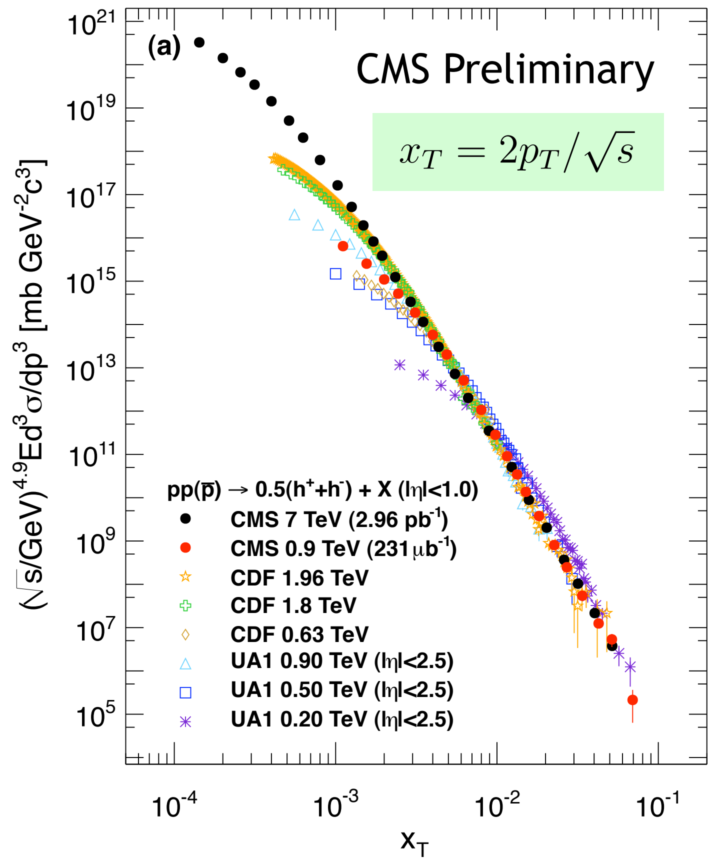
$z = \pm 10.86$ m, $3.23 < |\eta| < 4.65$

Transverse momentum spectra

Inclusive invariant cross-section



x_T scaling curve

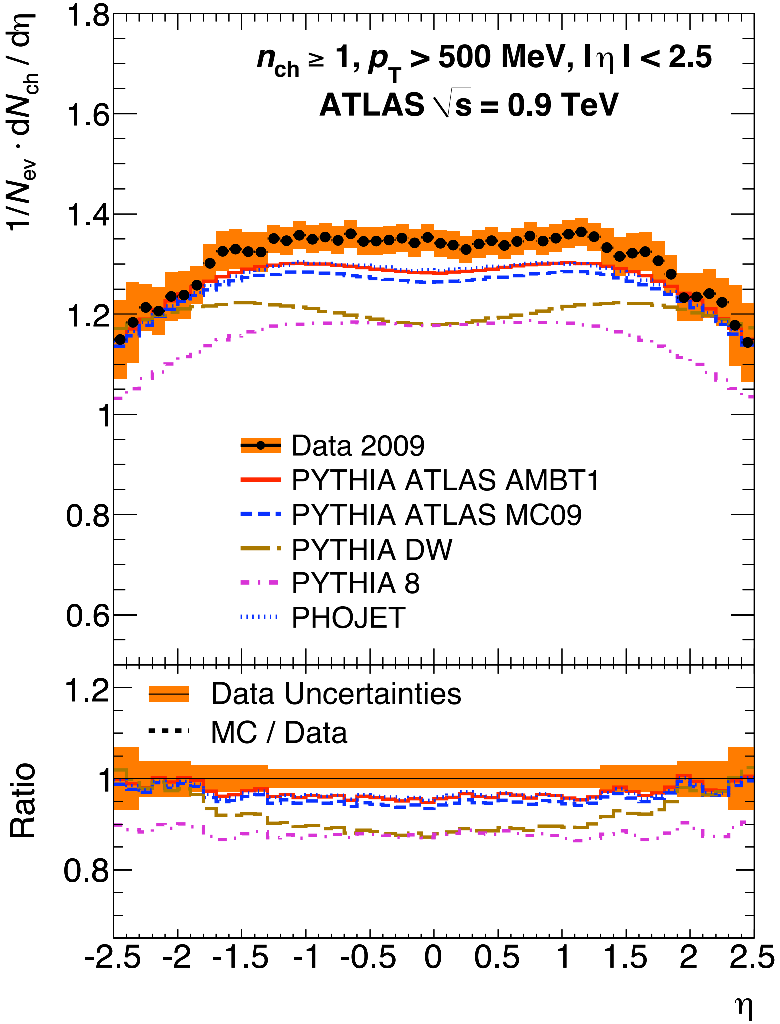


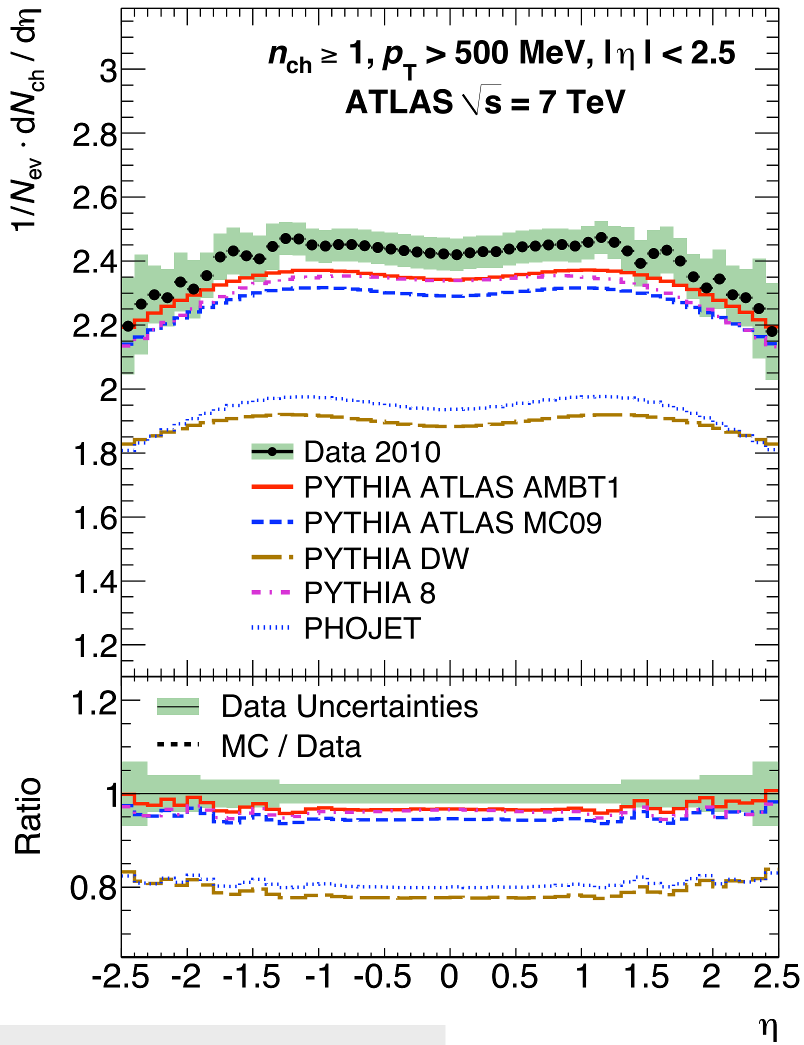
CMS PAS QCD-10-008

$$E\frac{d^3\sigma}{dp^3} = F(x_T)/p_T^{n(x_T,\sqrt{s})} = F'(x_T)/\sqrt{s}^{n(x_T,\sqrt{s})}$$

Minimum Bias pseudorapidity distributions

Charged particle multiplicities versus pseudorapidity at 900 GeV and 7 TeV



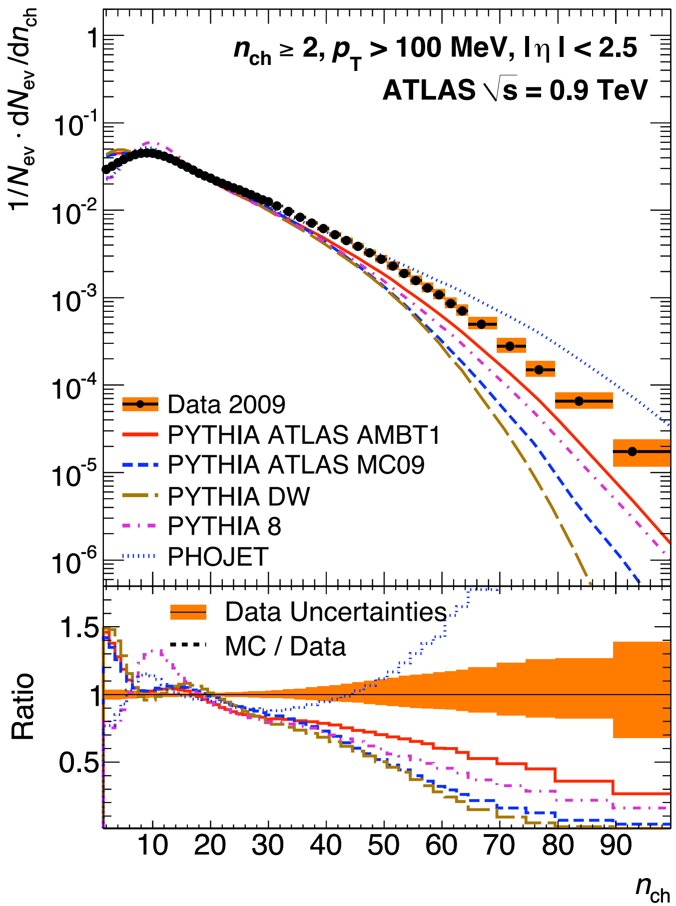


hep-ex 1012.5104v2, accepted by New J. Physics

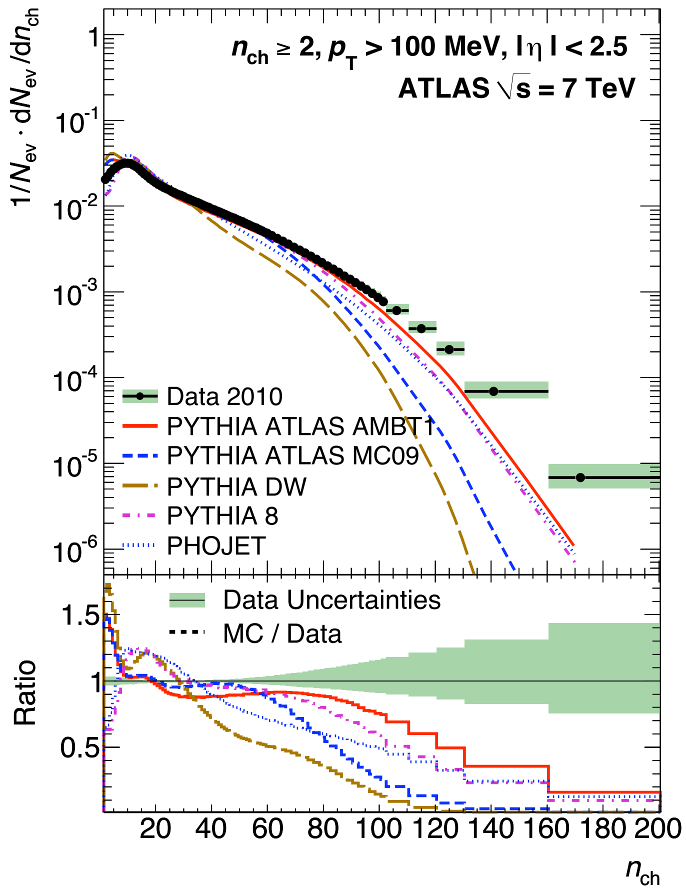
Minimum Bias multiplicity distributions

$n_{ch} \geq 2$, $p_T > 100$ MeV, $|\eta| \leq 2.5$

900 GeV

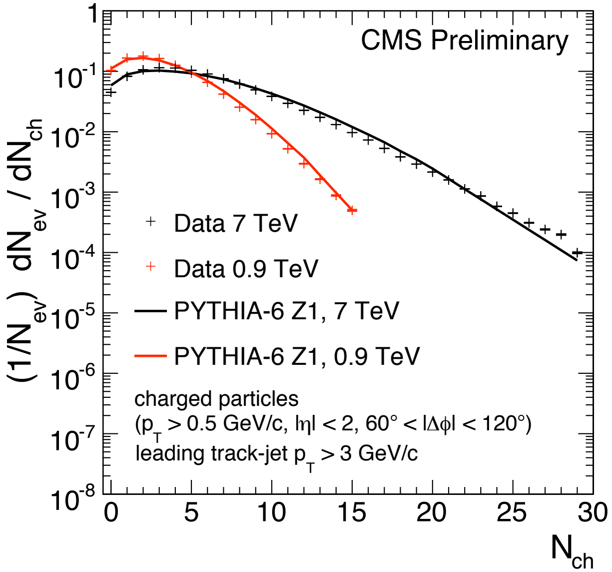


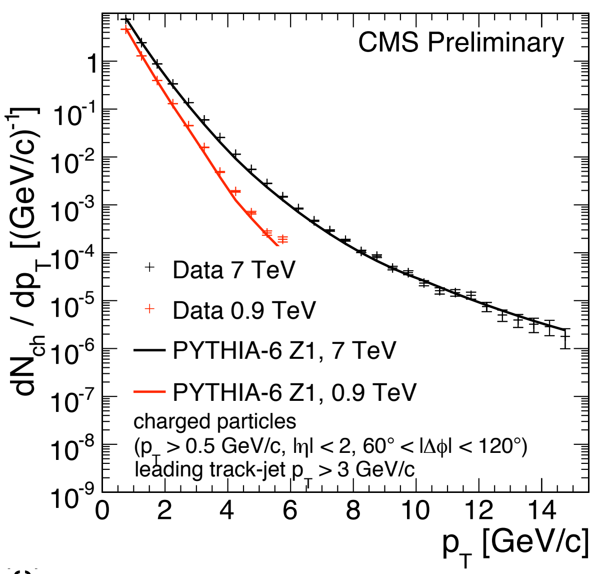
7 TeV

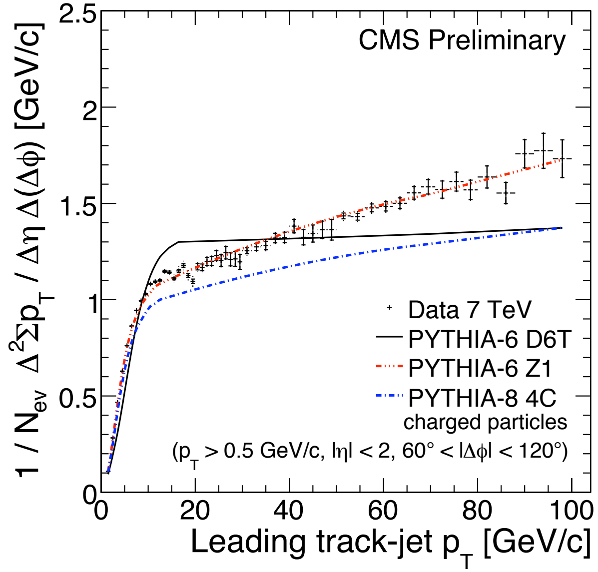


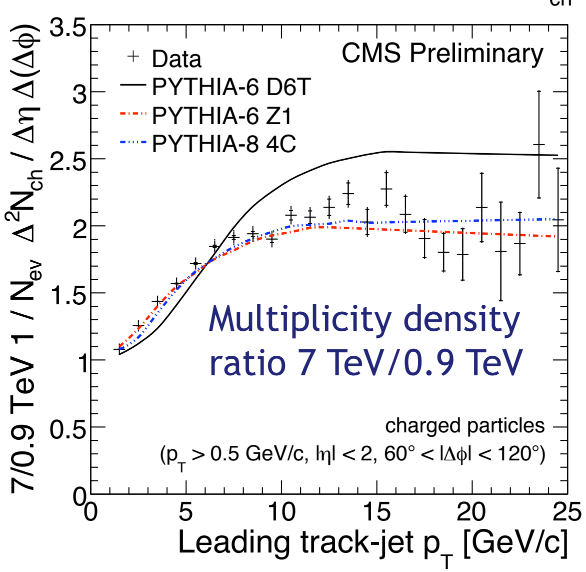
hep-ex 1012.5104v2, accepted by New J. Physics

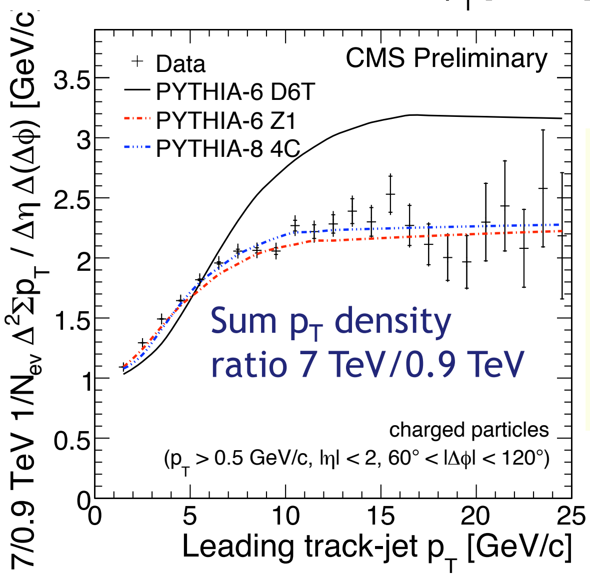
Charged particle distributions











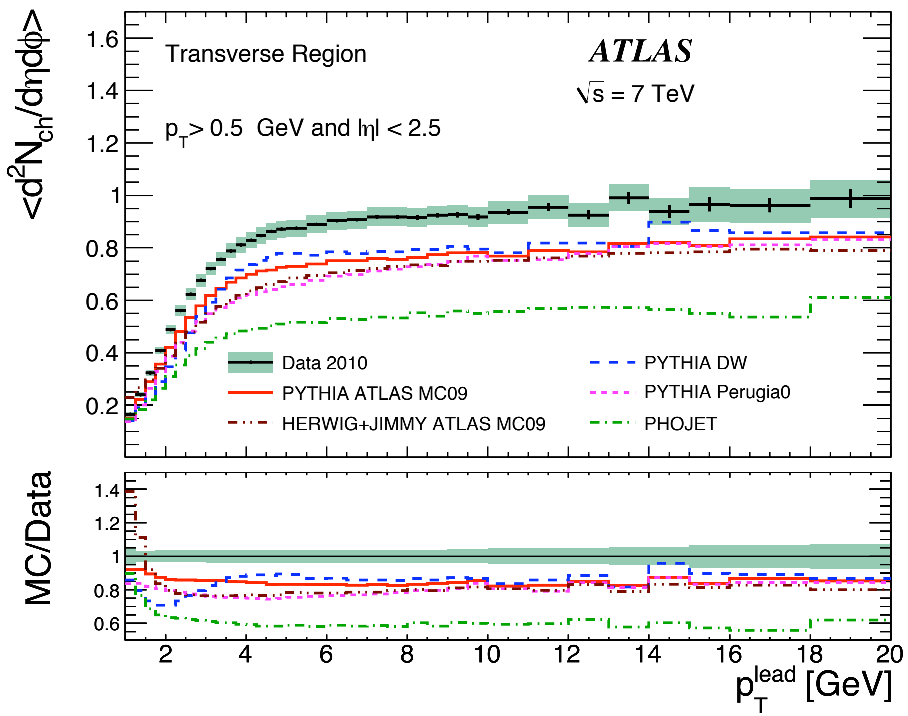
Transverse regions

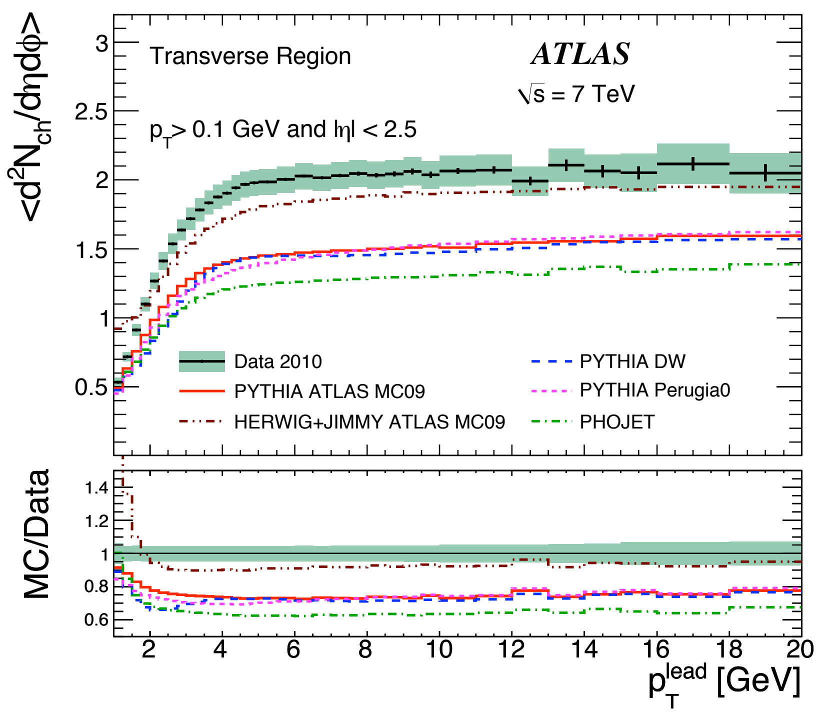
Strong growth of underlying event activity with √s. PYTHIA Z1 describes the distributions and the √s dependence well.

CMS PAS QCD-10-010

Charged particle multiplicity density

Transverse region





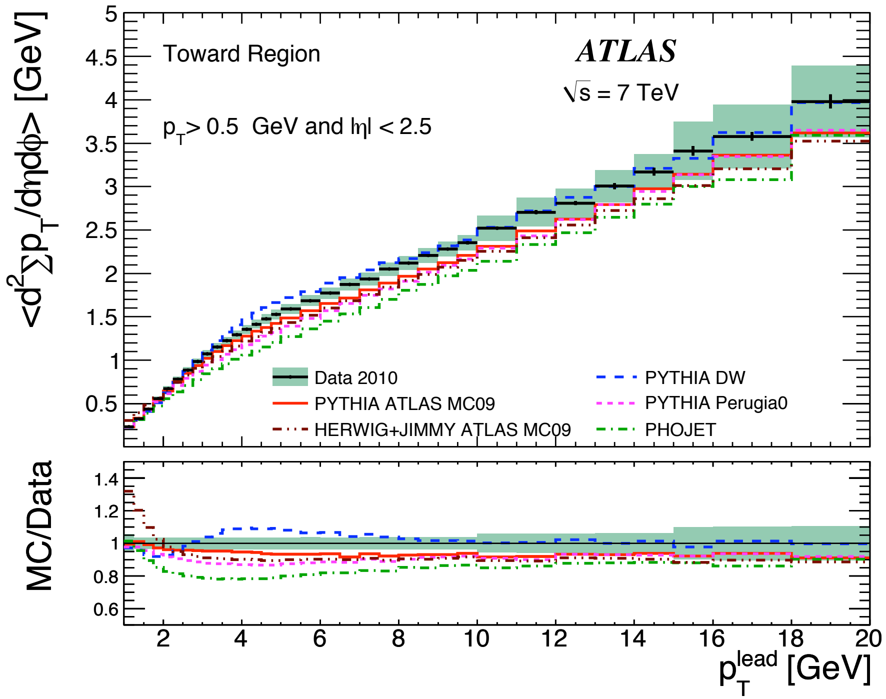
Two-fold increase in multiplicity for p_T > 0.1 GeV compared to p_T > 0.5 GeV

All models underestimate the multiplicity by at least 10-15%, but PYTHIA DW comes closest for p_T > 0.5 GeV. HERWIG/JIMMY produce more particles between 100 MeV and 500 MeV than other models.

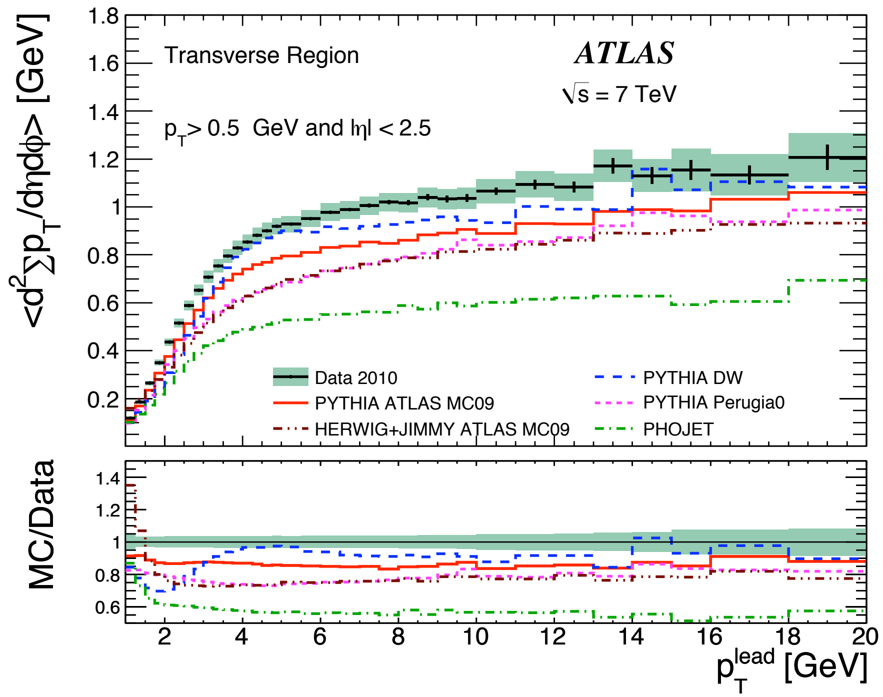
hep-ex 1012.0791v2, submitted to Phys. Rev. D

Charged particle scalar p_T sum density

Toward region



Transverse region

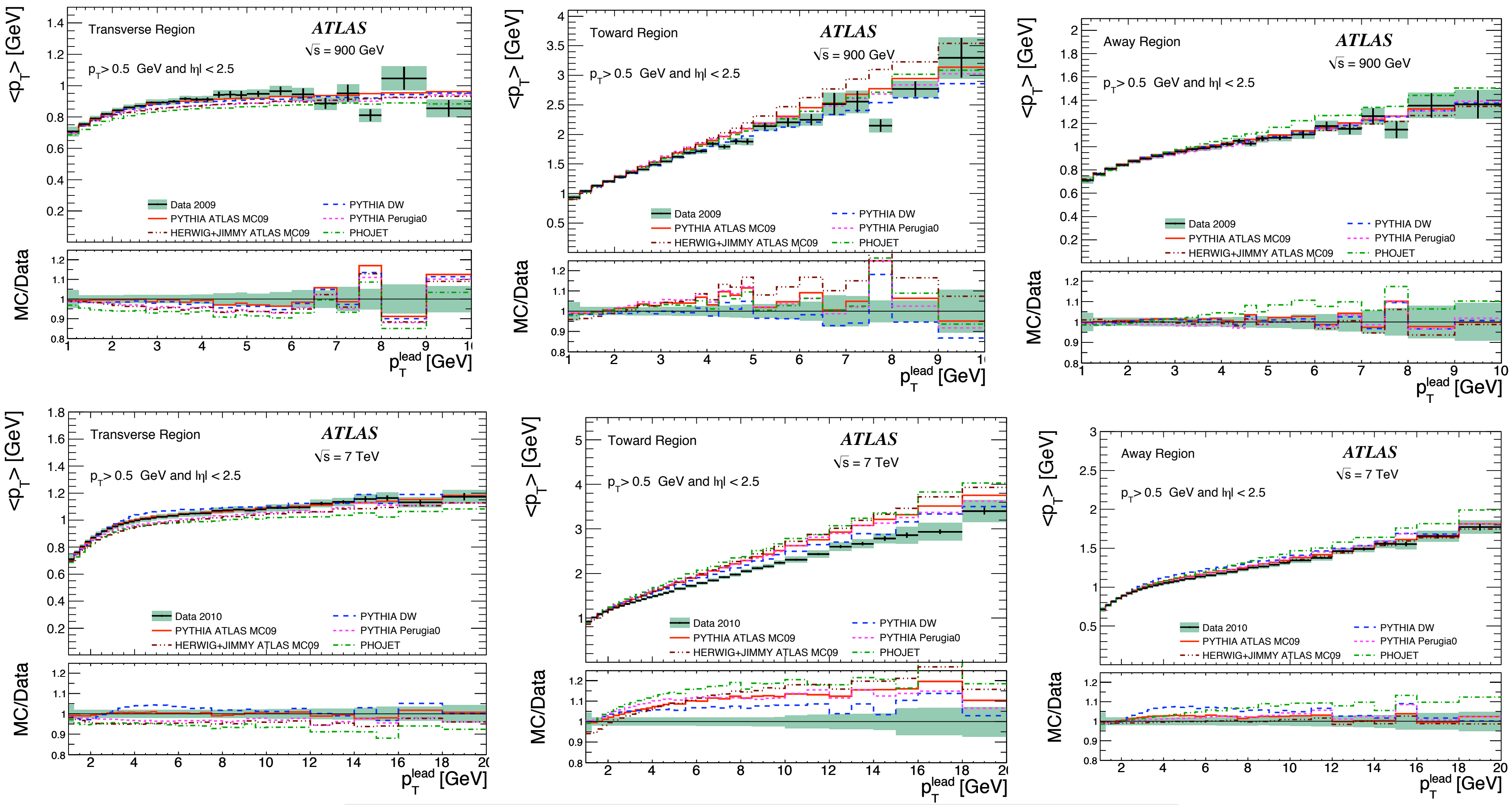


The transverse region plateau characterizes the mean contribution of the underlying event to jet energies, whereas in the toward and away regions jet-like profiles are present. PYTHIA DW describes both regions best. Other Monte Carlo programs describe the transverse region in particular quite poorly.

hep-ex 1012.0791v2, submitted to Phys. Rev. D

Charged particle mean p_T at 900 GeV and 7 TeV

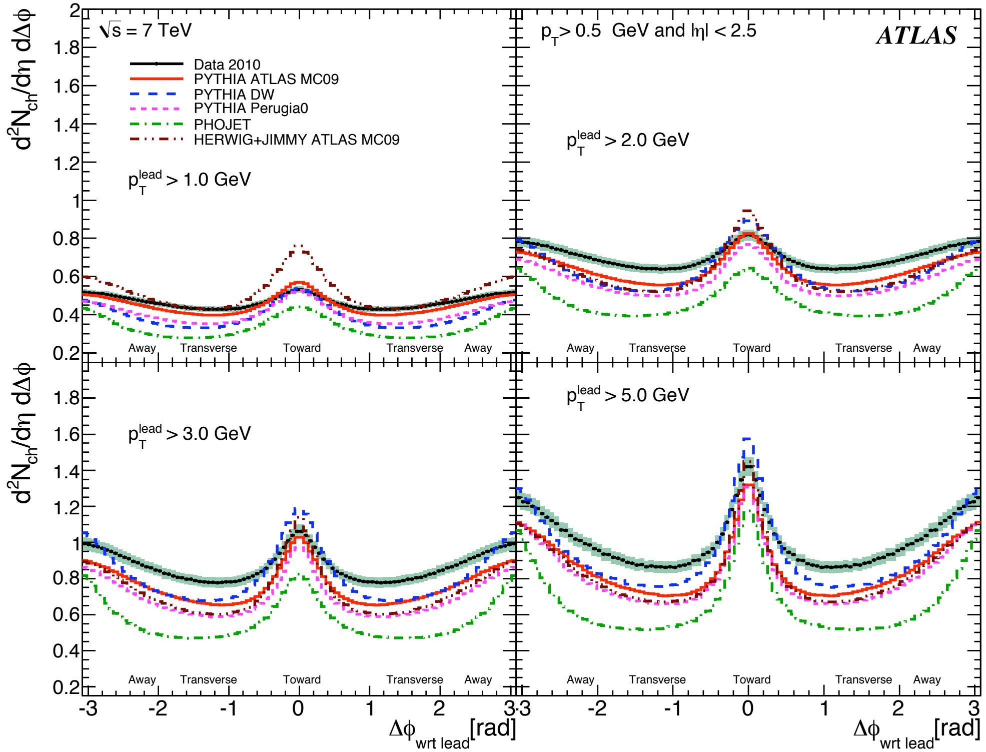
Increase of underlying event $<p_T>$ by about 20% from $\sqrt{s}$ = 900 GeV to $\sqrt{s}$ = 7 TeV.



hep-ex 1012.0791v2, submitted to Phys. Rev. D

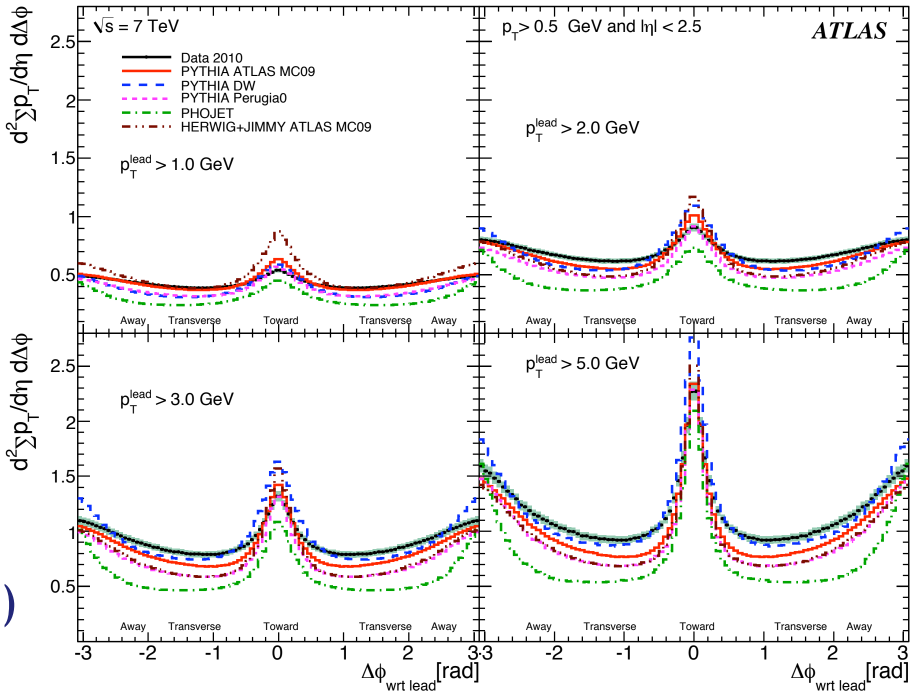
Angular distributions

p_T > 0.5 GeV, leading particle excluded



ϕ distribution (Δϕ wrt to the leading particle) of charged particle multiplicity densities

Significant shape difference between data and MC. With increasing p_T^{lead} jet-like structure develops. PYTHIA tunes predict stronger correlation in toward region.

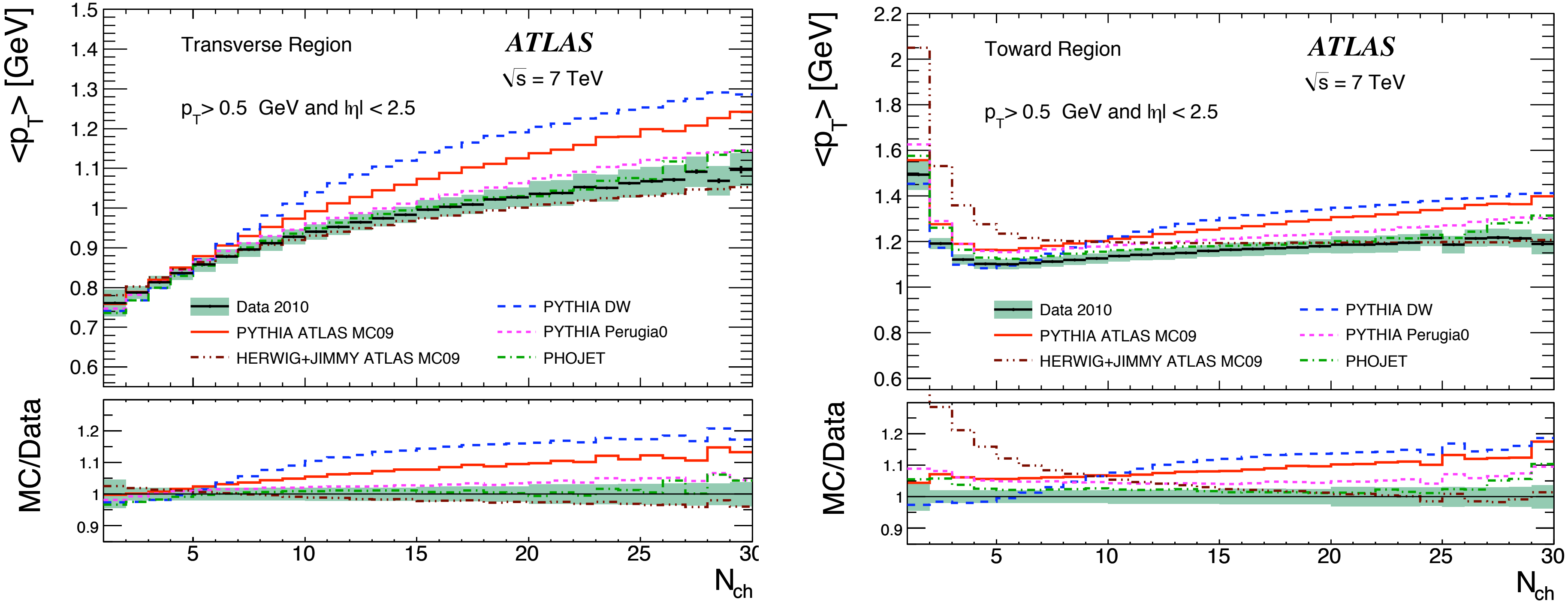


ϕ distribution (Δϕ wrt to the leading particle) of p_T sum densities

hep-ex 1012.0791v2, submitted to Phys. Rev. D

Correlations

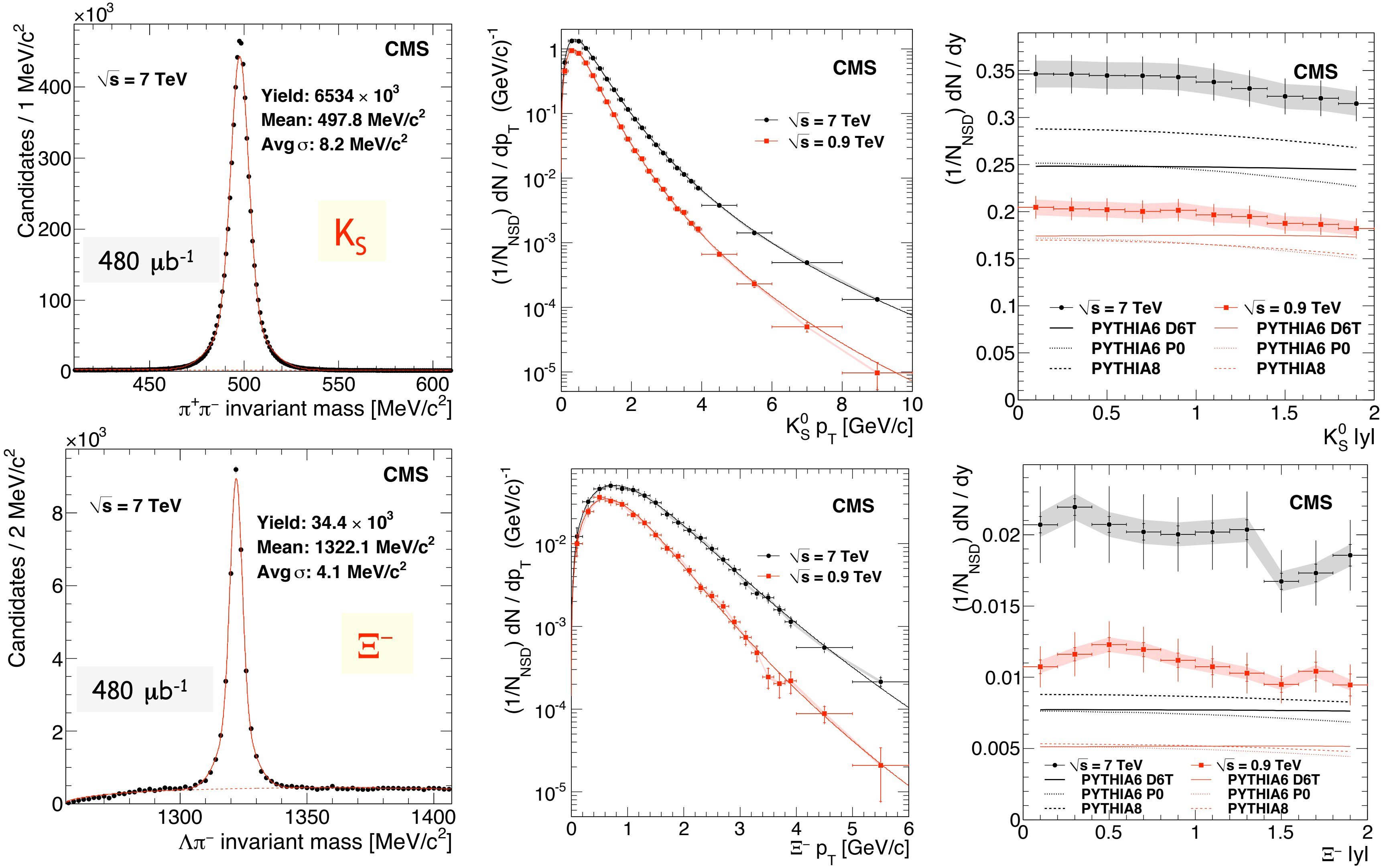
Charged particle mean p_T versus multiplicity



Monotonic increase of $<p_T>$ with N_{ch} in transverse and away regions. In the toward region, for $N_{ch} > 5$ a jet-like structure forms and $<p_T>$ rises weakly. PHOJET gives best description at 7 TeV.

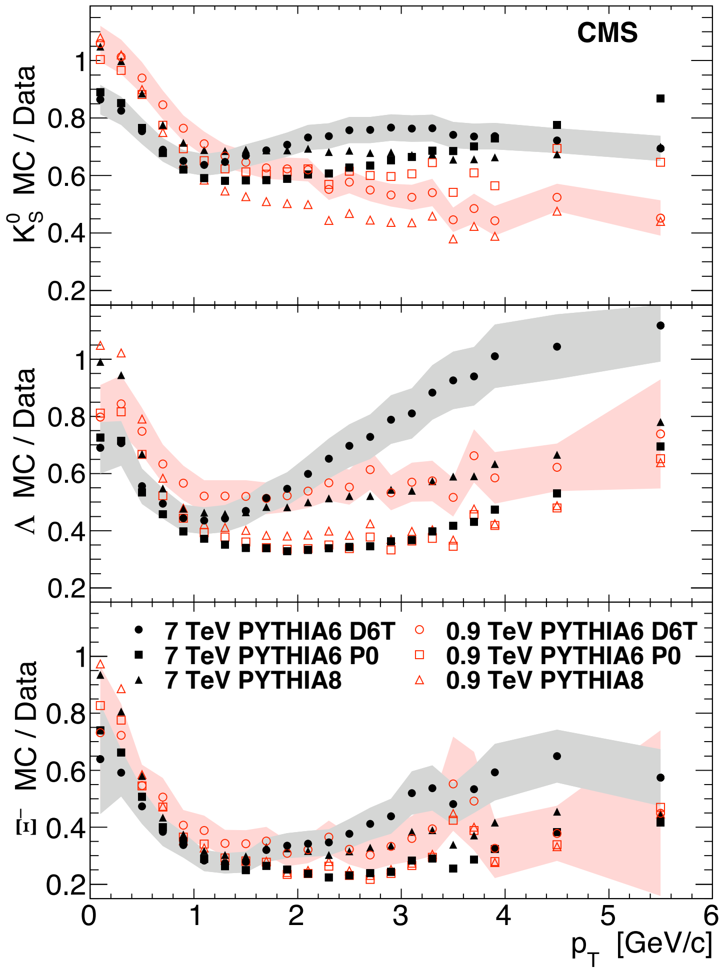
hep-ex 1012.0791v2, submitted to Phys. Rev. D

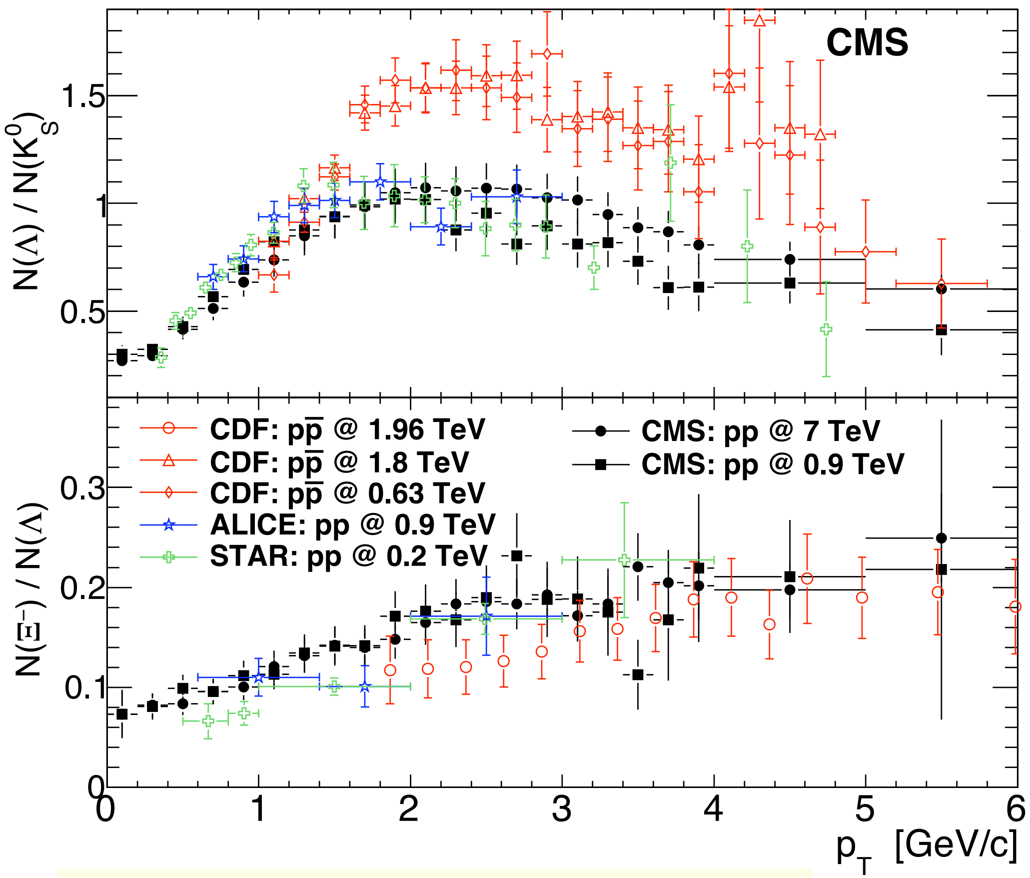
Strangeness production (K_S, Λ, Ξ)



hep-ex 1102.4282v1, submitted to JHEP

Strangeness production (K_S, Λ, Ξ)



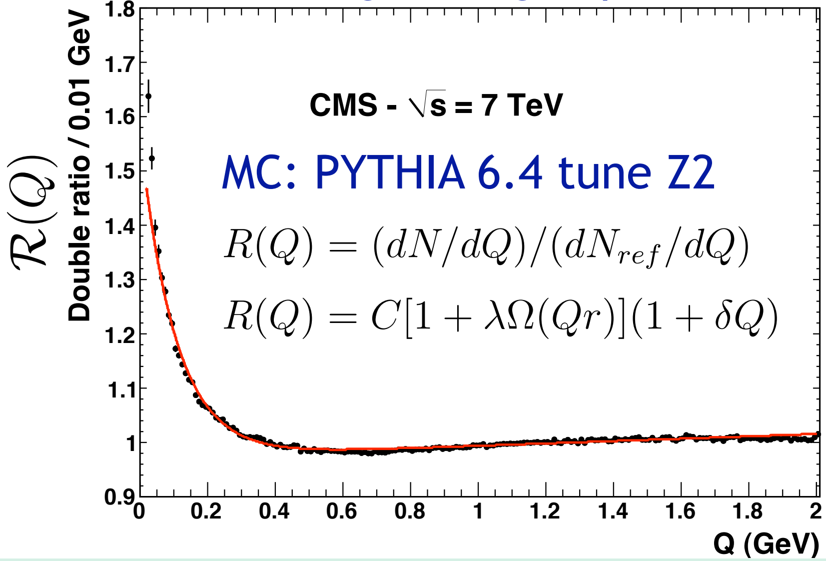


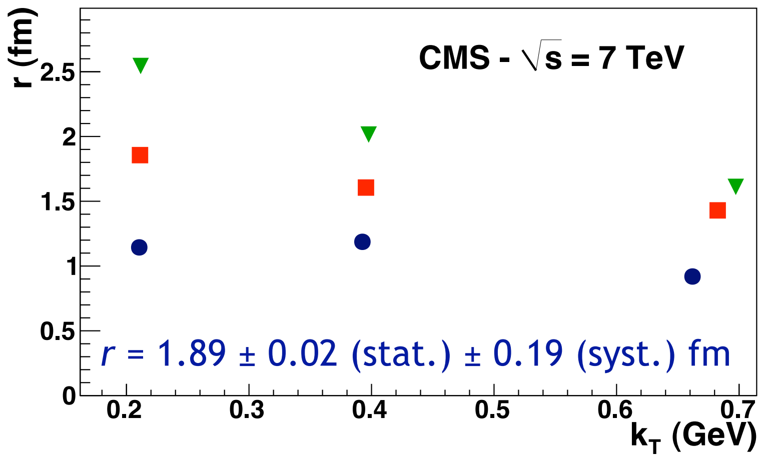
N stays approximately constant for both centre-of-mass energies.

hep-ex 1102.4282v1, submitted to JHEP

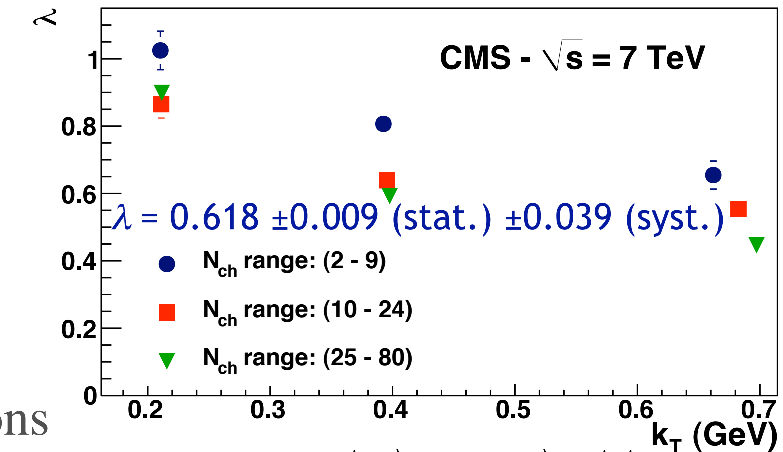
Bose-Einstein correlations

Pairs of same-sign charged particles with 0.02 GeV < Q < 2 GeV are studied.





$$\mathcal{R}(Q) = \frac{R}{R_{MC}} = \left(\frac{dN/dQ}{dN_{ref}/dQ}\right)/\left(\frac{dN_{MC}/dQ}{dN_{MC,ref}/dQ}\right)$$



Reference sample: opposite-sign pairs, mixed events etc.

λ … correlation strength

r …. radius of effective space-time region emitting bosons with overlapping wave functions

Ω … Fourier transform of the region defined by r

$$k_T = |\vec{p}_{T1} + \vec{p}_{T2}|/2$$

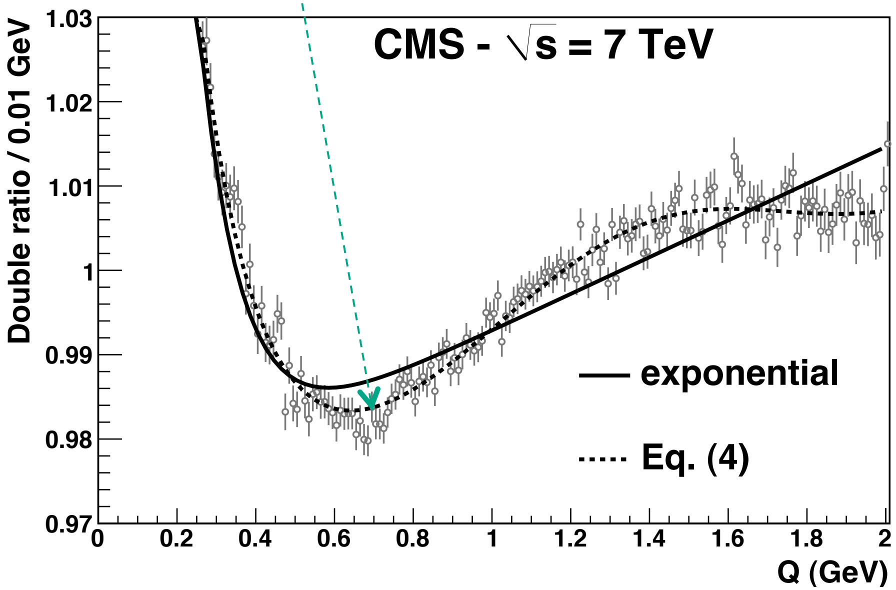
$$Q = \sqrt{-(p_1 - p_2)^2}$$

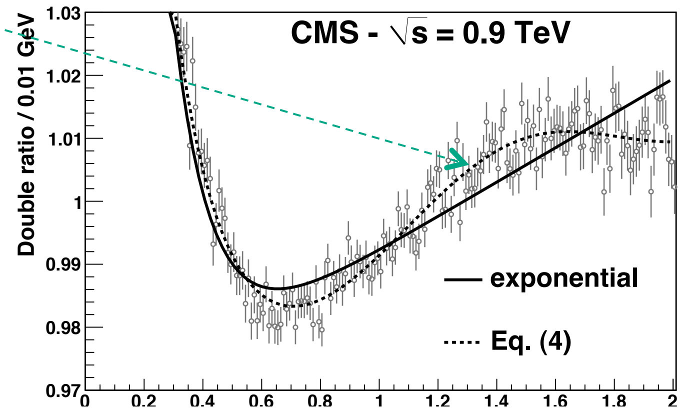
hep-ex 1101.3518v1, submitted to JHEP

Anticorrelations

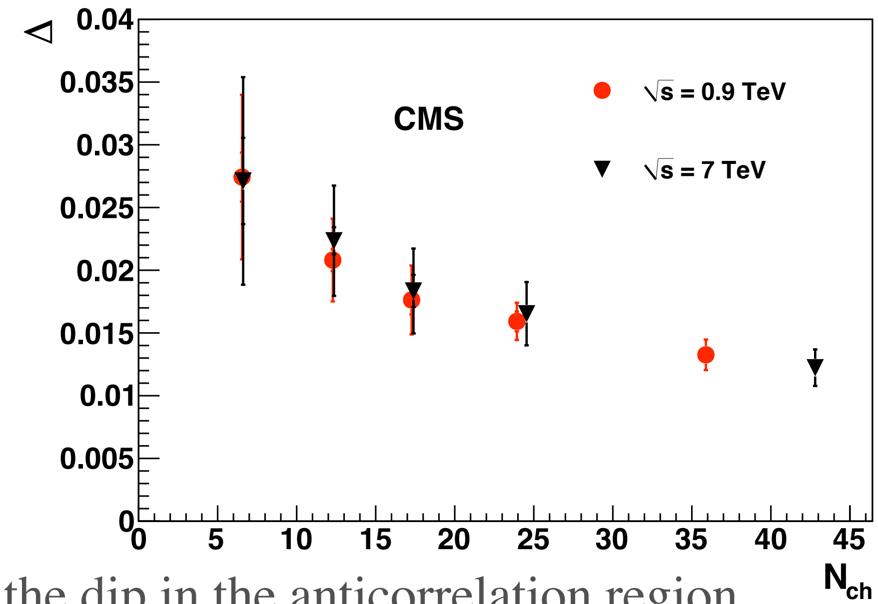
$$R(Q) = C[1 + \lambda(\cos[(r_0 Q)^2 + \tan(\alpha\pi/4)(Qr)^\alpha]e^{-(Qr)^\alpha})](1 + \delta Q)$$

PLB 663 (2008214)





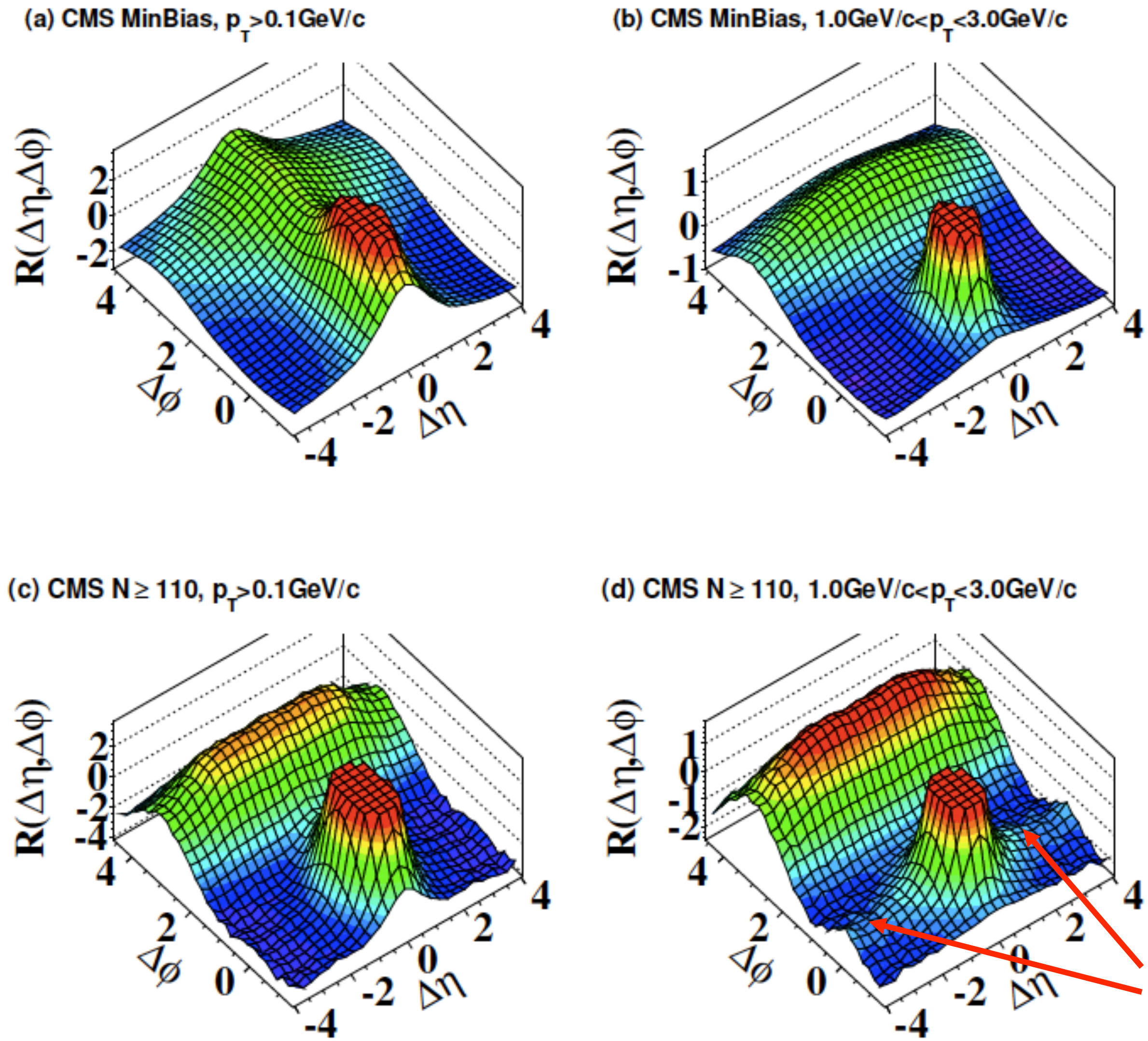
Anticorrelations between same-sign charged particles are observed for *Q* values above the signal region.



hep-ex 1101.3518v1, submitted to JHEP

Δ … depth of the dip in the anticorrelation region

Near-side long-range correlations in pp data



JHEP 09 (2010) 091

First surprise in LHC data!

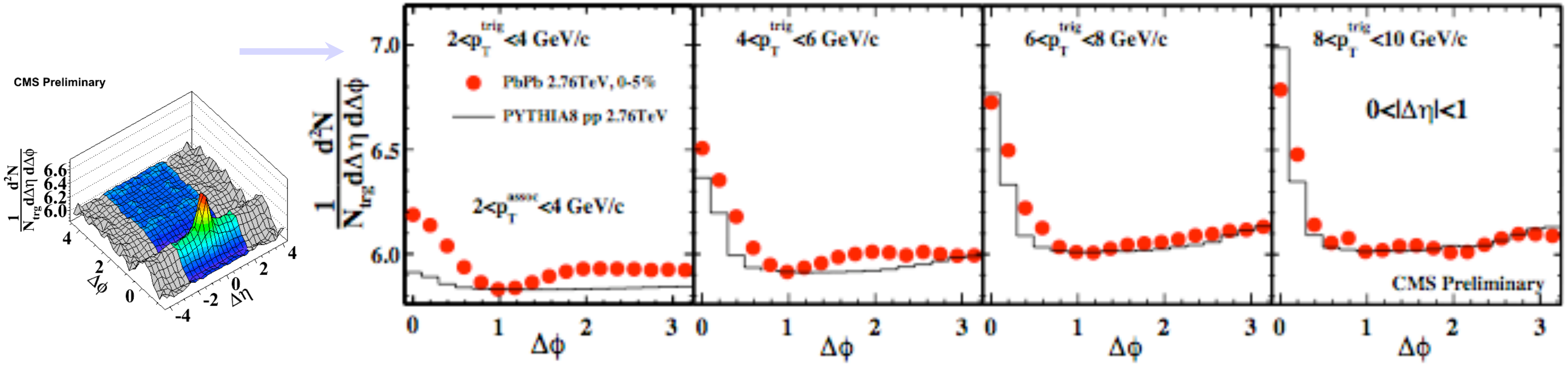
CMS pp 7 TeV

Ridge does not come from short range correlations such as resonances, near-side jet peaks, away side correlations of particles between back-to-back jets or Bose-Einstein correlations.

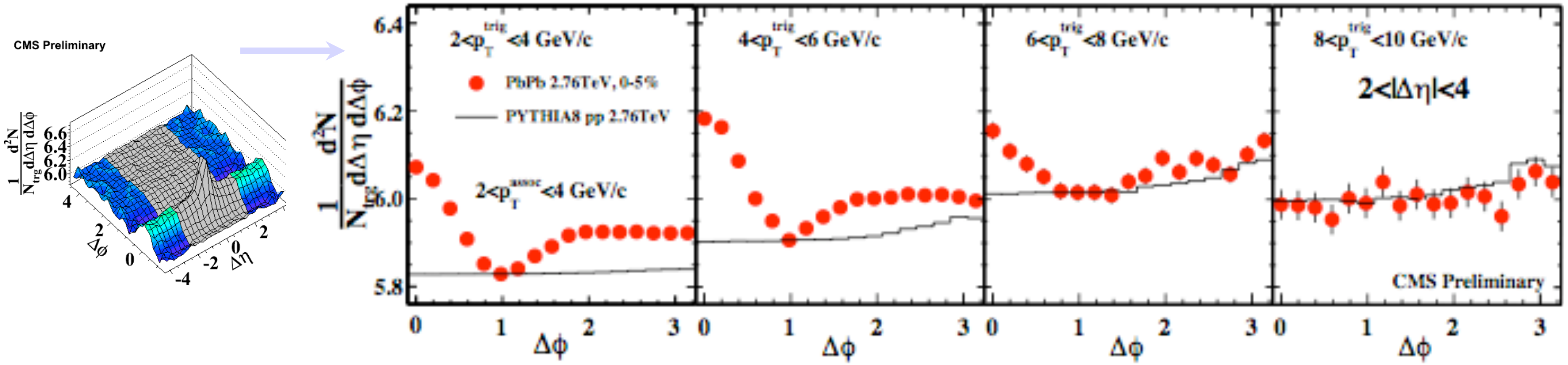
Pronounced structure (ridge) in high-multiplicity events for $2.0 < |\Delta\eta| < 4.8$ and $\Delta\phi \approx 0$

Long- and short-range correlations in ion data

Short-range ($0<|\Delta\eta|<1$): **Jet + Ridge**



Long-range ($2<|\Delta\eta|<4$): **Ridge**



Ridge most evident for 2 GeV < p_T^{trig} < 6 GeV, but disappears at high p_T

Conclusions

- Understanding of soft QCD contributions is crucial for new physics searches and precision measurements of Standard Model processes.

- Pre-LHC Monte Carlo tunes do not describe the data well in all aspects. Much more tuning is needed.

- Strangeness production has been investigated and Bose-Einstein correlations have been studied in detail.

- Interesting long-range correlations have been observed, both in proton and heavy ion data.