ATLAS measurements of soft particle production and diffraction

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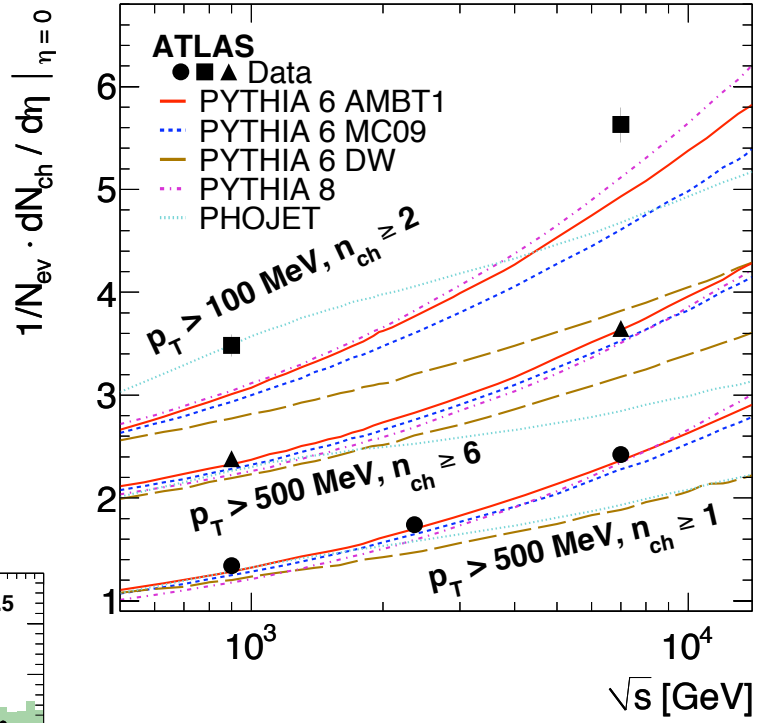
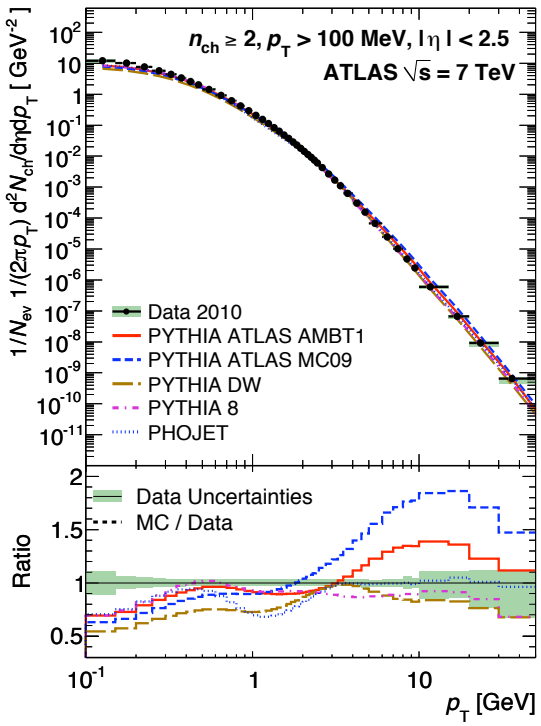
on behalf of the ATLAS Collaboration

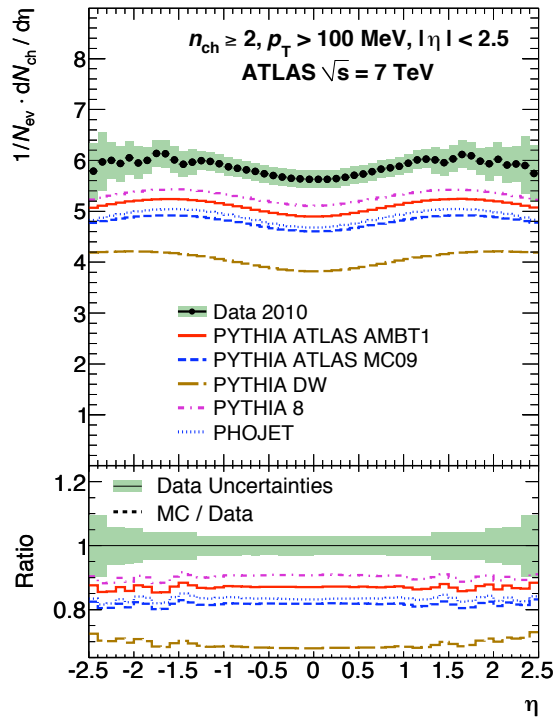
Inclusive particle production

dominated by soft QCD processes (p_T <≈ 1-2 GeV)

Not necessarily well described by models,
in particular for very low p_T region
(ATLAS tracking : p_T> 100 MeV , |η|<2.5)







Most of presented results based on 2010 data (low luminosity sample, no pile-up)
All results fully corrected for detector effects

New J. Phys. 13 (2011) 053033

Experimentally demanding

(low pT, forward region)

Nonperturbative region

PHENOMENOLOGY

A vast experimental field

SOFT QCD

with MANY uncertainties

Inelastic pp x-section

Nature Commun. 2 (2011) 463

DIFFRACTION

Rapidity gaps

Eur. Phys. J. C72 (2012) 1926

Azimuthal ordering

arXiv:1203.0419

Modelling

Multiple parton interaction

Inclusive angular correlations

arXiv:1203.3549

Particle correlations

Hadron spectroscopy

Underlying event

CERN-PH-EP-2012-148

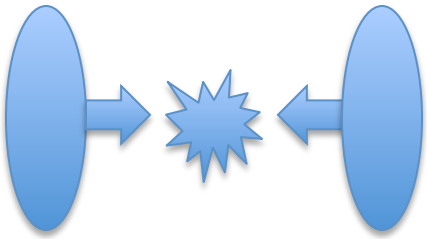
K_S^0, Λ production

Phys.Rev. D85 (2012) 012001

Forward-backward correlations & azimuthal particle distributions

arXiv:1203.3100

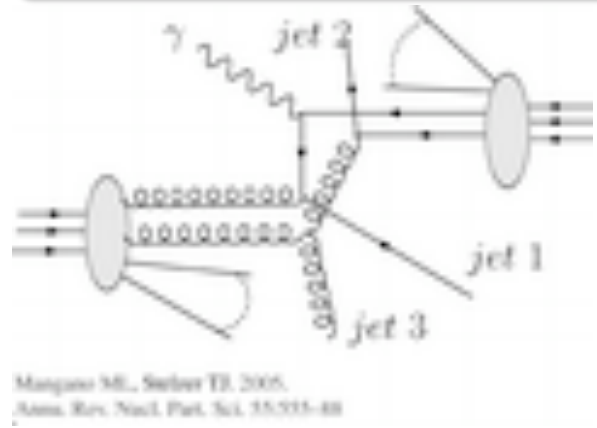
Physics content



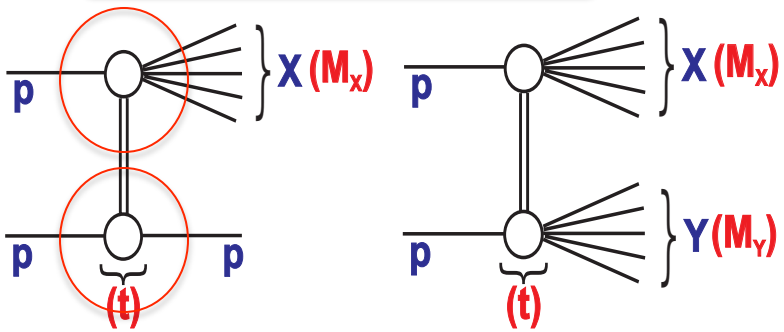
Parton density functions

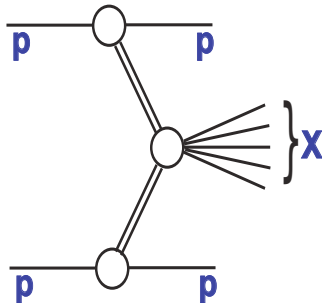
Non-diffractive scattering

Multiparton interaction

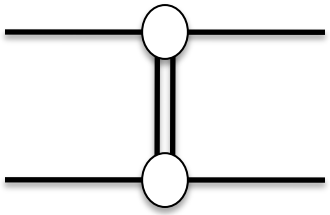


Diffractive scattering

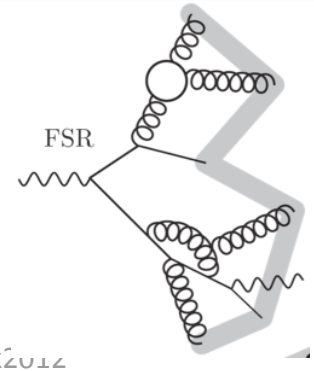




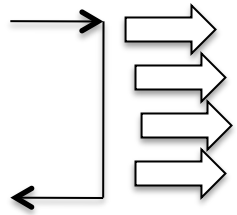
Elastic scattering



Parton shower (ISR,FSR)



Hadronization

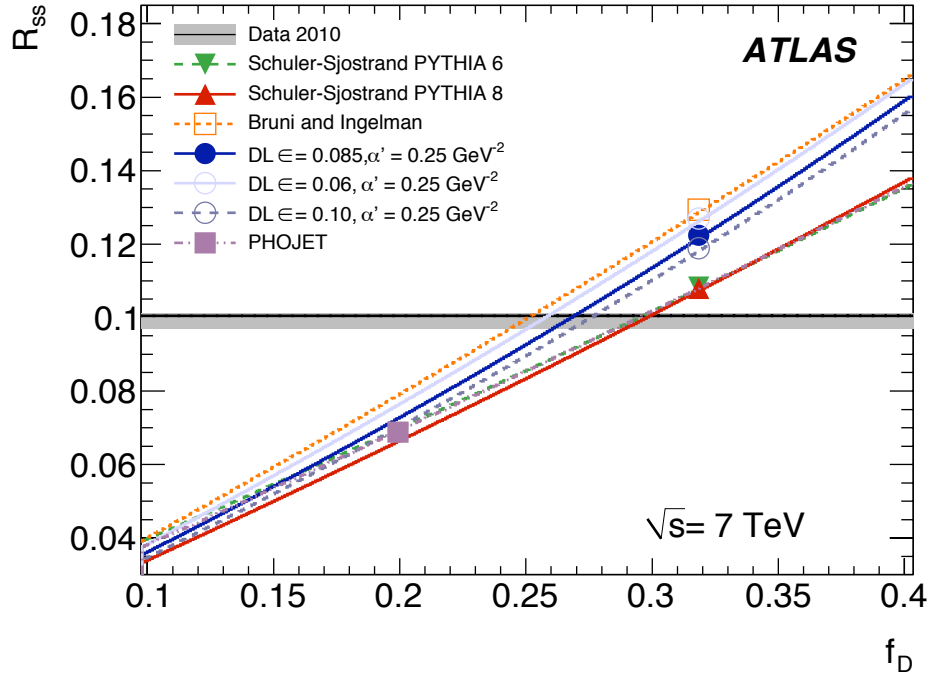


Diffraction

Diffractive scattering

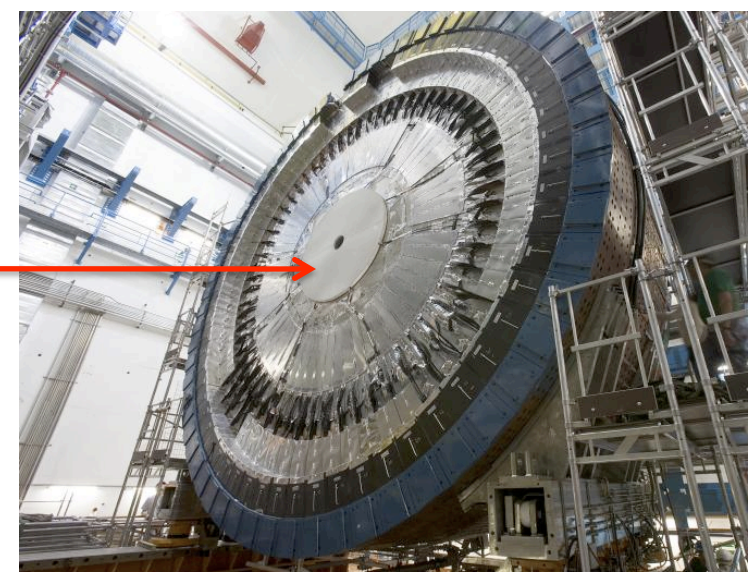
Large theoretical and experimental uncertainties (often, at least part of diffractive hadron system escapes undetected)

$$f_D = \frac{\sigma_{SD} + \sigma_{DD} + \sigma_{CD}}{\sigma_{inelastic}}$$



measured with help of relative rate of single-side triggered events R_{SS} and model predictions

MBTS trigger



acceptance 2.09<|η|<3.84

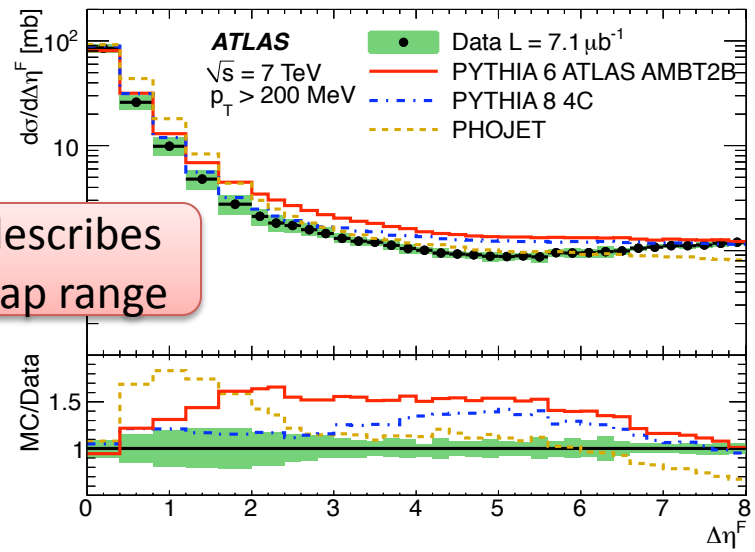
[Nature Commun. 2 (2011) 463]

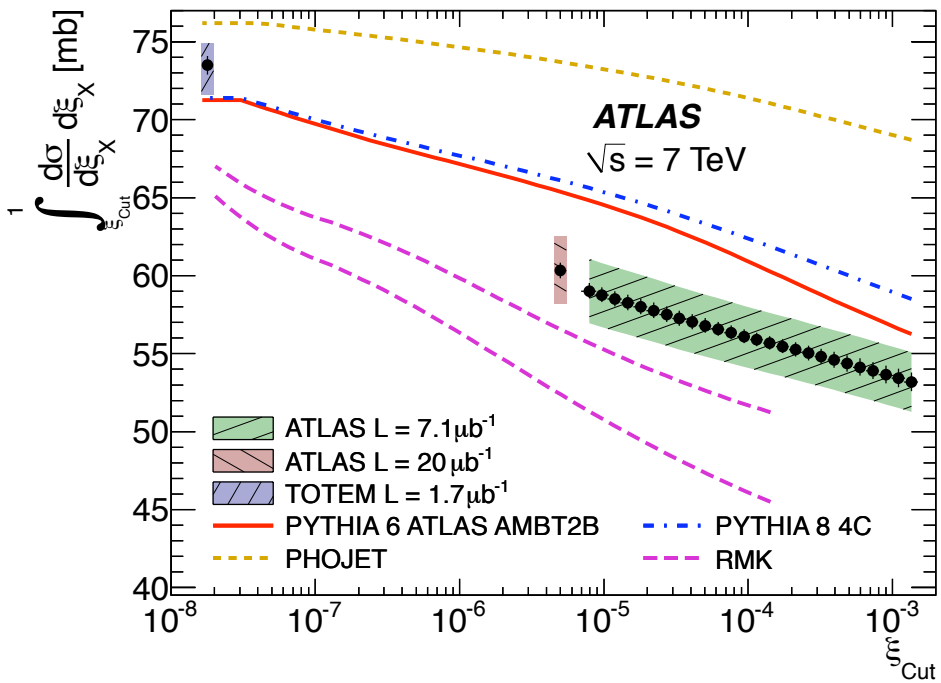
Diffractive scattering

Rapidity gaps [Eur. Phys. J. C72 (2012) 1926]

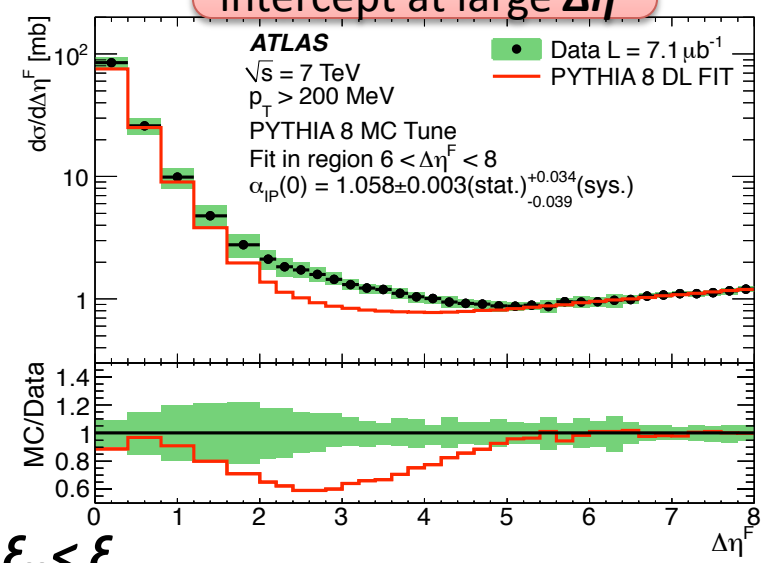
Characteristic for diffractive particle production: $\Delta\eta^F$ largest forward empty region

No model describes the whole gap range





Fit of Pomeron intercept at large $\Delta\eta^F$



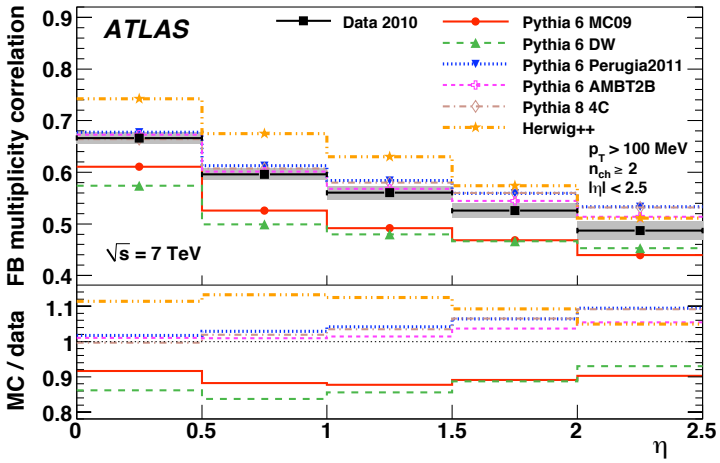
$\xi_X = M_X^2/s$; $\Delta\eta \cong -\ln \xi_X$

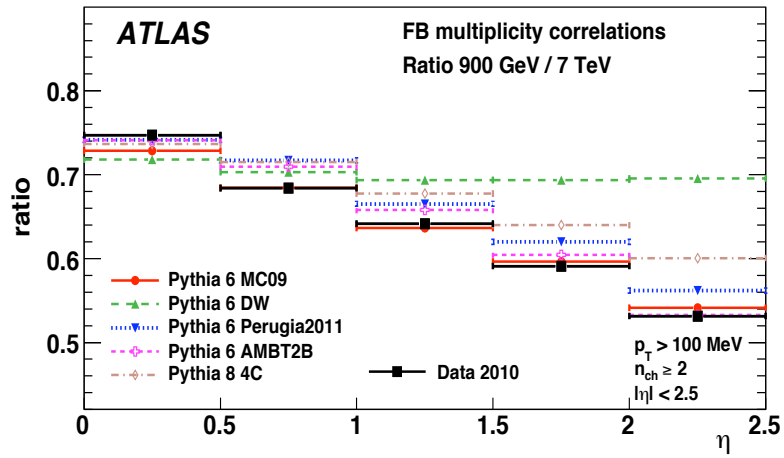
Inelastic x-section excluding diffraction with $\xi_X < \xi_{cut}$

$|\eta| < 4.9$ (calorimeter)

Minimum bias : Forward-backward correlations *[arXiv:1203.3100]*

Particle density, underlying event



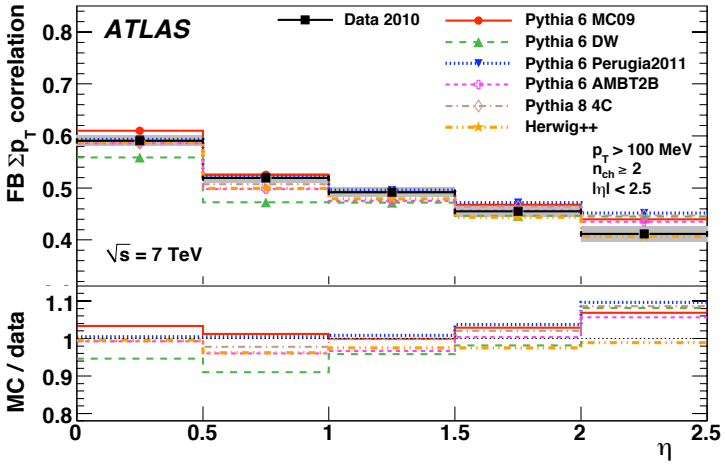


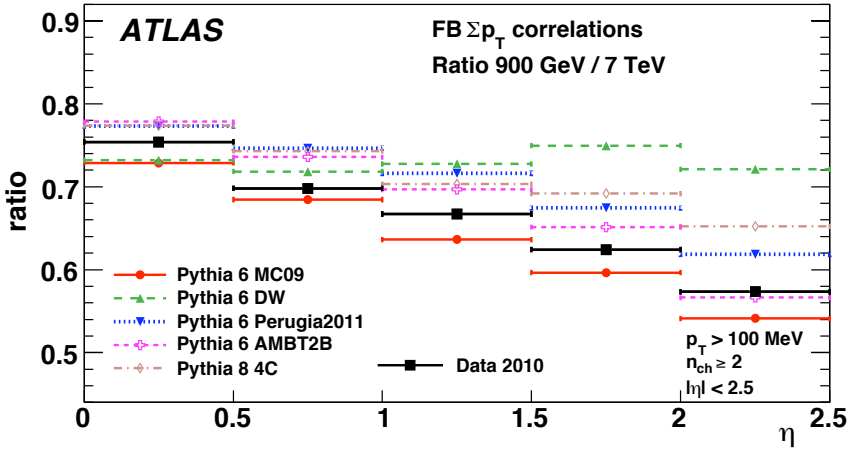
Multiplicity correlations in symmetrically opposite η intervals

-> described by models with 15% precision

-> long range correlation higher at 7TeV compared to 900 GeV data

Idem for summed p_T

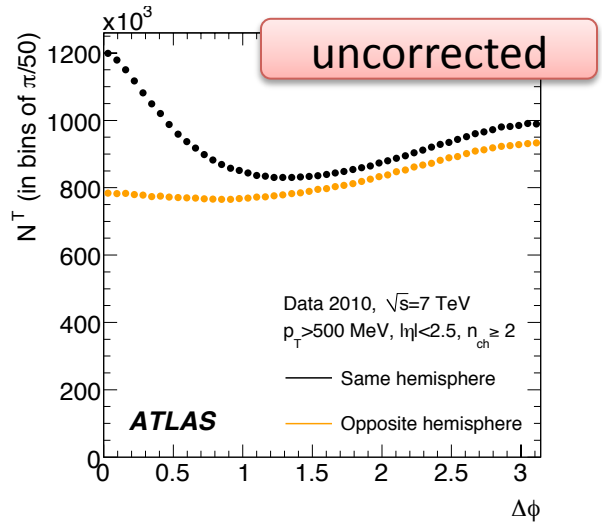




Minimum bias : Azimuthal correlations *[arXiv:1203.3100]*

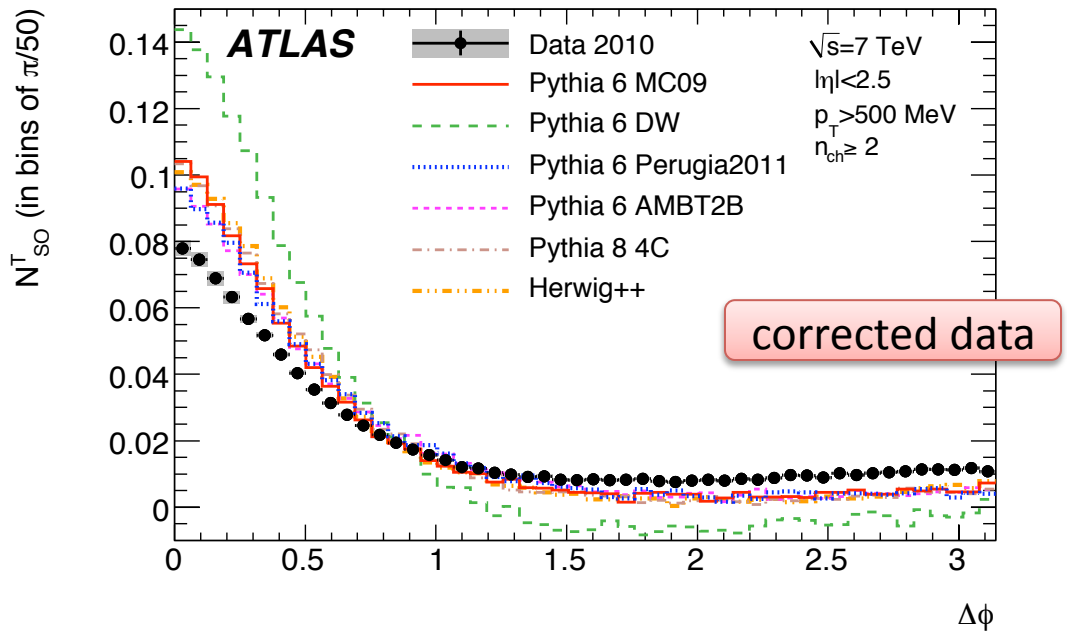
Particle density, underlying event

A variant of study of properties of the underlying event :
-> particle density wrt leading track (highest pT)
-> same and opposite hemisphere normalized & subtracted



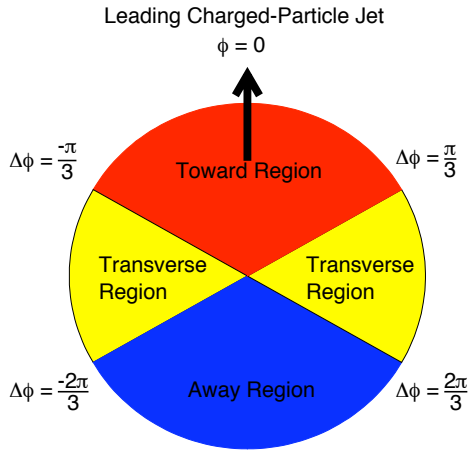
Models tend to overestimate the 'leading jet' structure
-> other regions underpopulated

Re-tune of models clashes with the description of inclusive single particle spectra (more later)



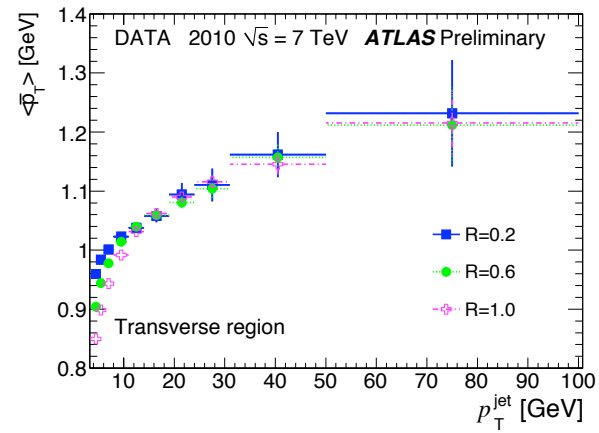
Study of underlying event : dependence on the leading jet

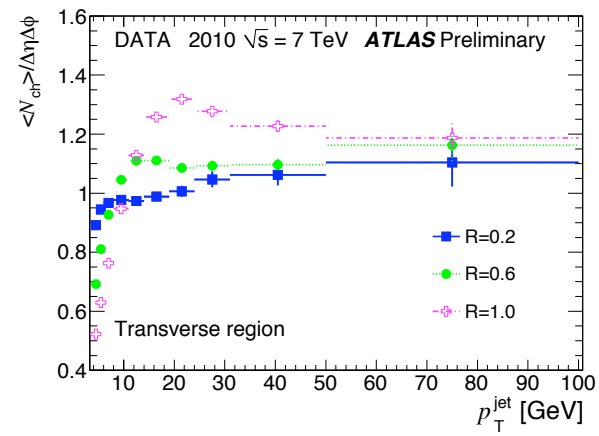
Particle density, underlying event



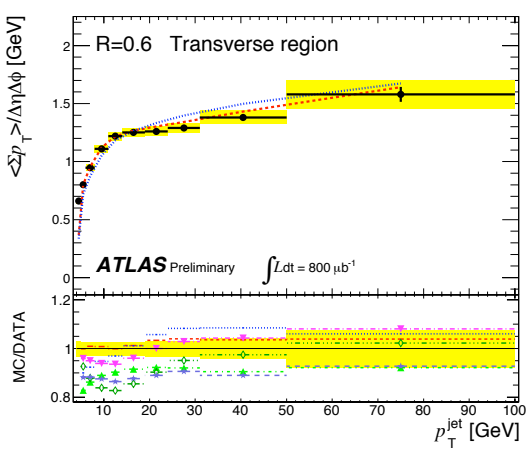
Leading jet = jet with highest p_T

Dependence of particle density in transverse/away regions on leading jet p_T, R parameter (anti-k_T jet algorithm)



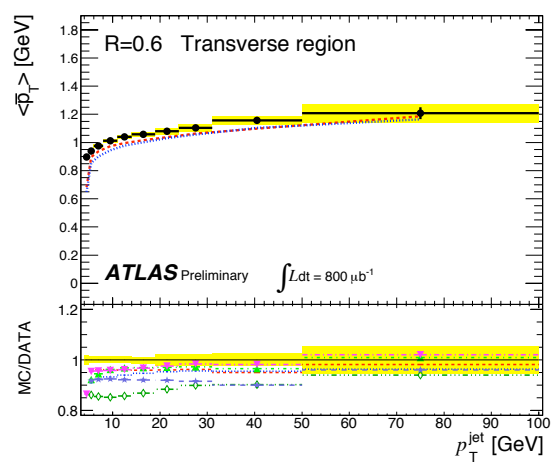


Intended for development of MC tunes
Data reasonably well (10-20%) described by tunes based on LHC data



- DATA 2010 √s = 7 TeV
- PYTHIA (Z1)
- PYTHIA (AUET2B)
- HERWIG++ (UE7-2)
- PYTHIA (Perugia2011)
- PYTHIA (Perugia2011 NOCR)
- PYTHIA 8.145 (4C)

$p_T^{track} \geq 0.5$ GeV $|\eta^{track}| \leq 1.5$
anti-k_t jets: $|\eta^{jet}| \leq 1.5$



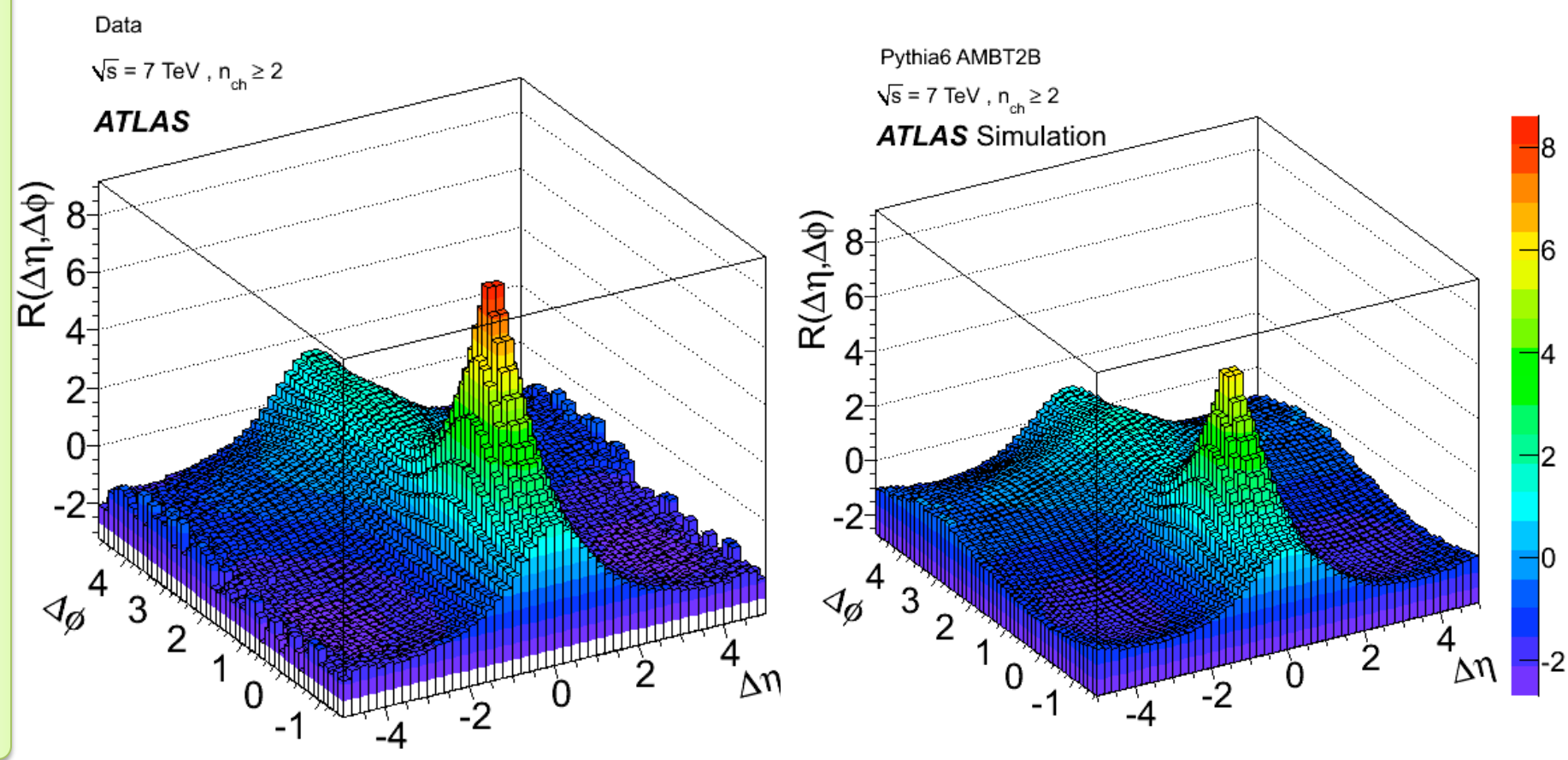
Minimum Bias: Inclusive angular correlations *[arXiv:1203.3549]*

Inclusive particle correlations

$$R(\Delta\eta,\Delta\Phi) = \langle (n_{ch}-1)F(n_{ch}, \Delta\eta,\Delta\phi)\rangle_{ch} / B(\Delta\eta,\Delta\Phi) - \langle n_{ch}-1\rangle_{ch}$$

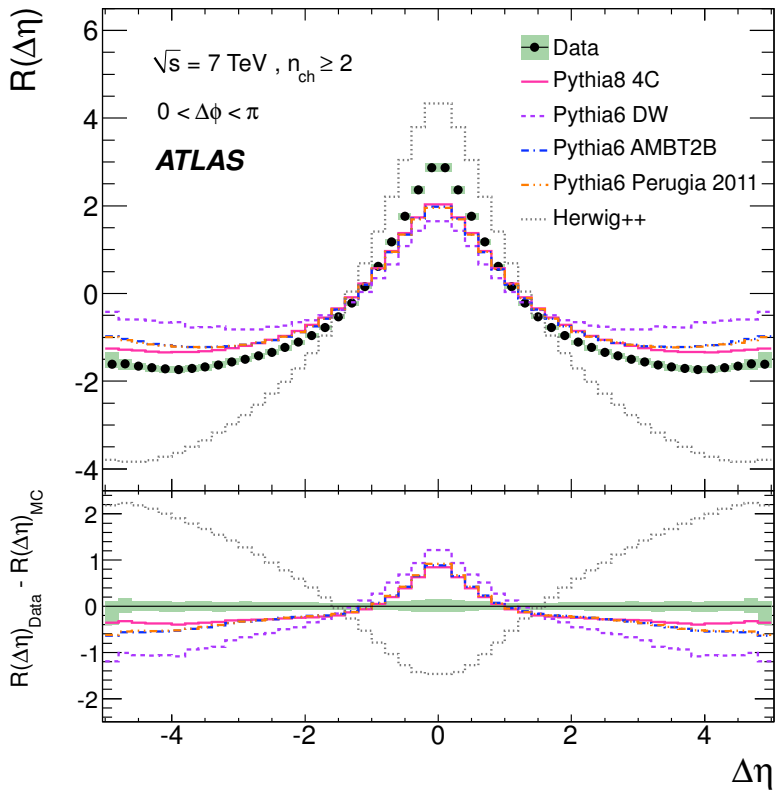
multiplicity independent correlation function

F normalised 2-particle density ; B random event-event combination



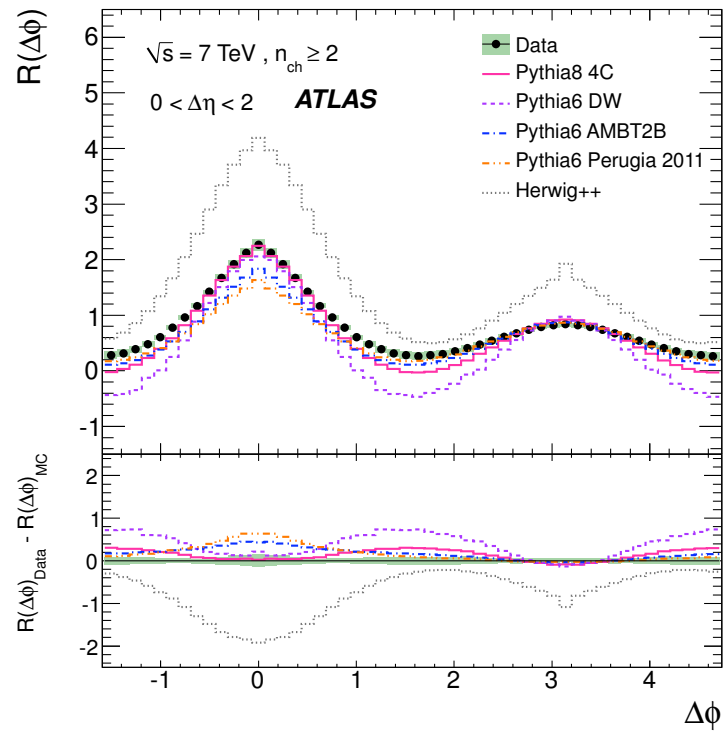
Inclusive particle correlations

[arXiv:1203.3549]



Projections taken separately
(F,B integrated before taking ratio)

Results is good agreement with previously published CMS results after correction for differences in the analysis *[JHEP09(2010)091]*



-> poor description by Herwig
-> best described with Pythia8 4C and Pythia6 AMBT2B
but no model gives a satisfactory description of strength of correlations

Hadron spectroscopy

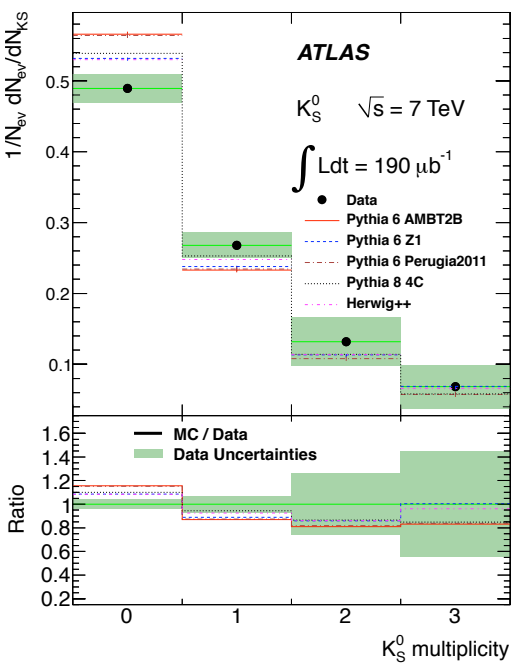
K_S^0, Λ production [Phys.Rev. D85 (2012) 012001]

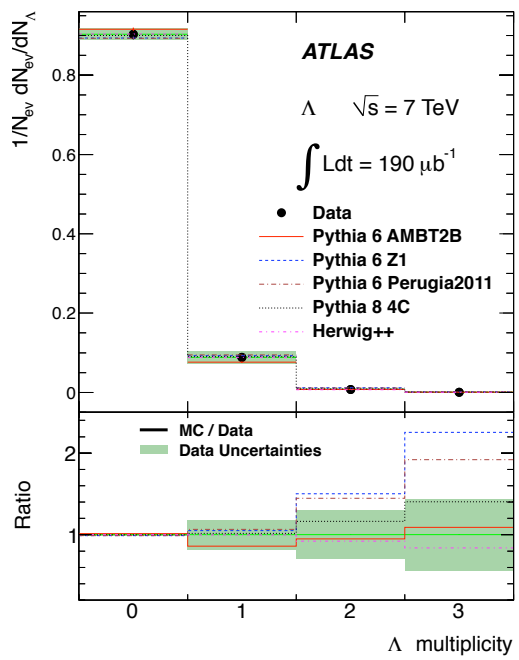
Selection -> pairs of opposite sign tracks pointing to a common secondary vertex

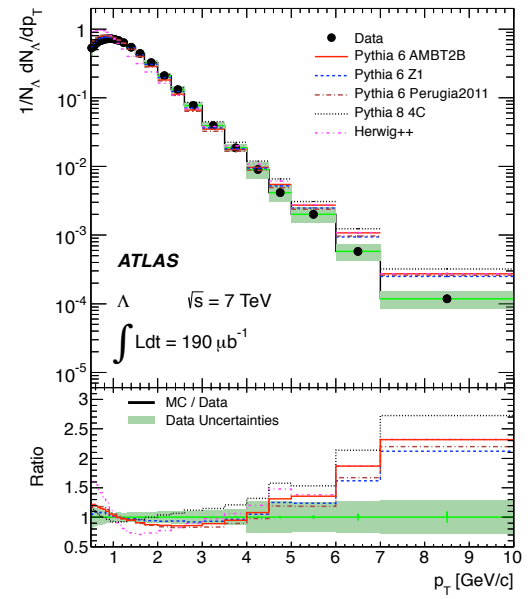
-> cut on the transverse flight distance (primary vs secondary vertex)

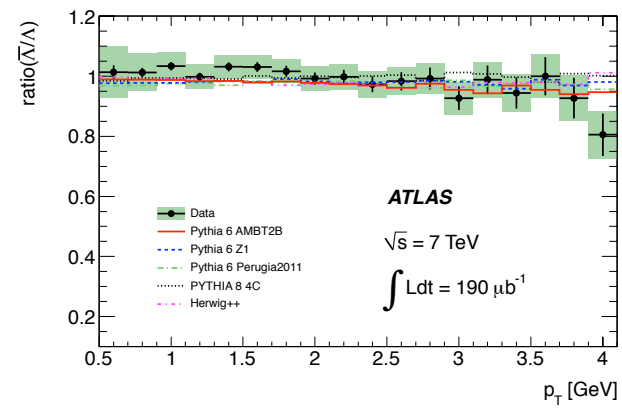
-> cut on the pointing angle (<1.15°)

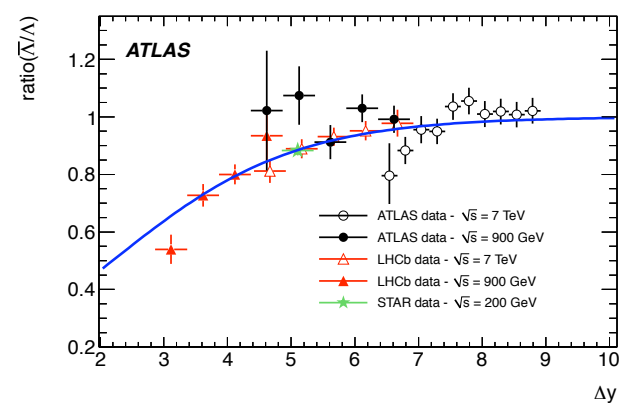
K_S^0 production slightly underestimated by models, Λ significantly overestimated











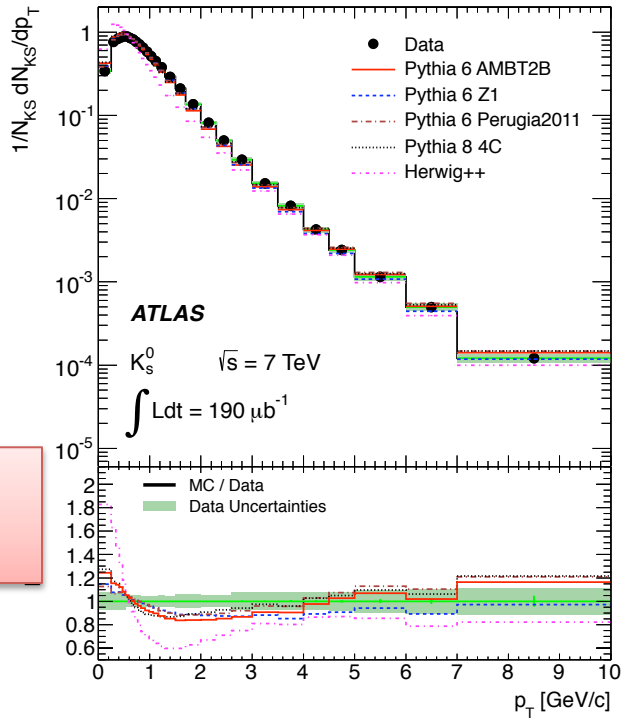
Modelling

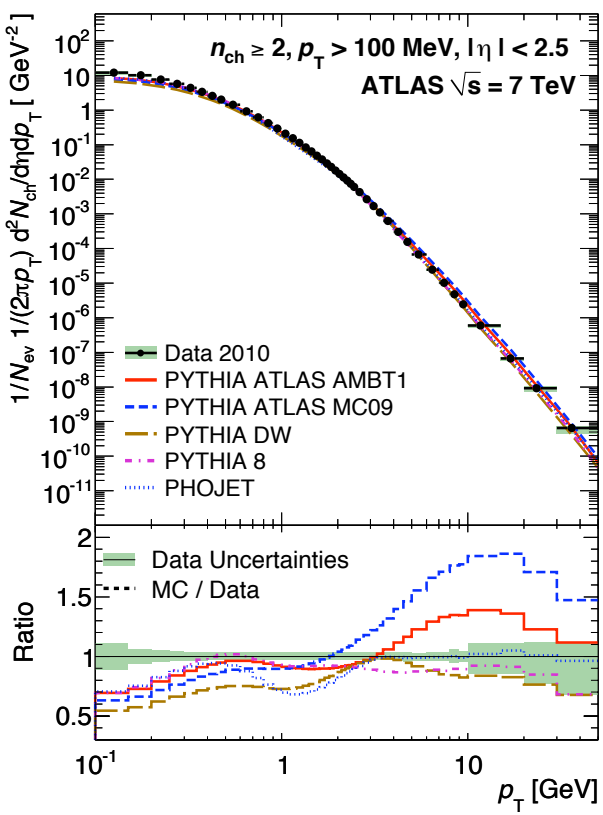
Problems in the description of … inclusive pT spectrum

… inclusive charged multiplicity

… particle flow (underlying events)

… size of particle correlations





HADRONISATION: is the intrisic p_T modelling adequate ?

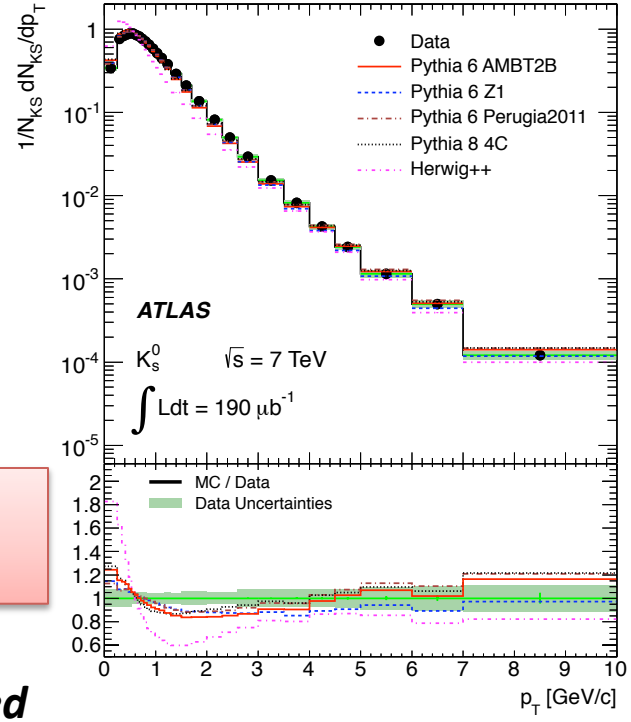
Modelling

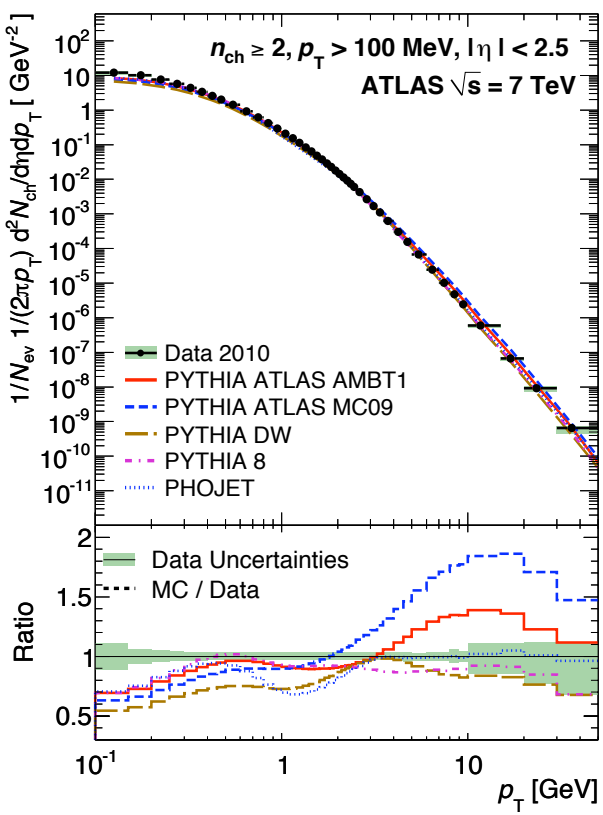
Problems in the description of … inclusive pT spectrum

… inclusive charged multiplicity

… particle flow (underlying events)

… size of particle correlations





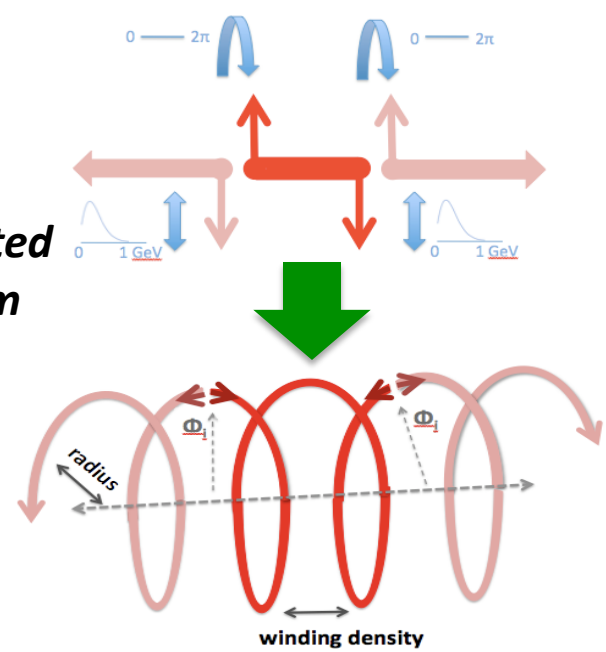
HADRONISATION: is the intrisic p_T modelling adequate ?

The idea : replace uncorrelated string break-up vertices and random pt sampling in the vacuum tunneling by helix-like shaped string

-> hadron pT strongly correlated with its longitudinal momentum (2 degrees of freedom removed from fragmentation)

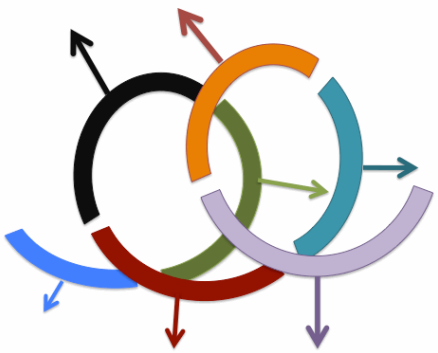
JHEP09(1998)14

arXiv:1204.2655



Minimum bias: Azimuthal ordering of hadrons *[arXiv:1203.0419]*

Particle correlations



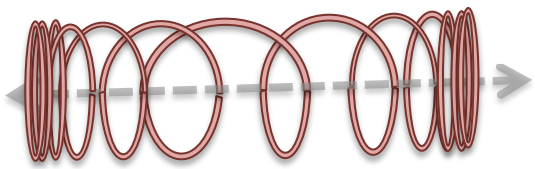
The helix-like shape structure of the QCD field should be visible in the azimuthal ordering of hadrons along the string

The exact form of the helix structure not predicted.

With the help of power spectra, we test two (weakly correlated) hypotheses

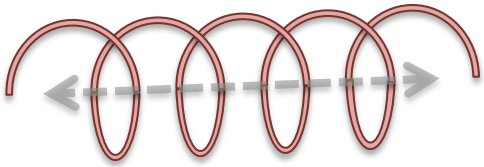
A/ ΔΦ ~ Δη

$$S_\eta(\xi) = \frac{1}{N_{ev}} \sum_{event} \frac{1}{n_{ch}} \left| \sum_j \exp(i(\xi \eta_j - \phi_j)) \right|^2$$



B/ ΔΦ ~ ΔX (energy-distance - amount of energy stored in the string/ ordered hadron chain - experimentally : ordered in pseudorapidity)

$$S_E(\omega) = \frac{1}{N_{ev}} \sum_{event} \frac{1}{n_{ch}} \left| \sum_j \exp(i(\omega X_j - \phi_j)) \right|^2$$



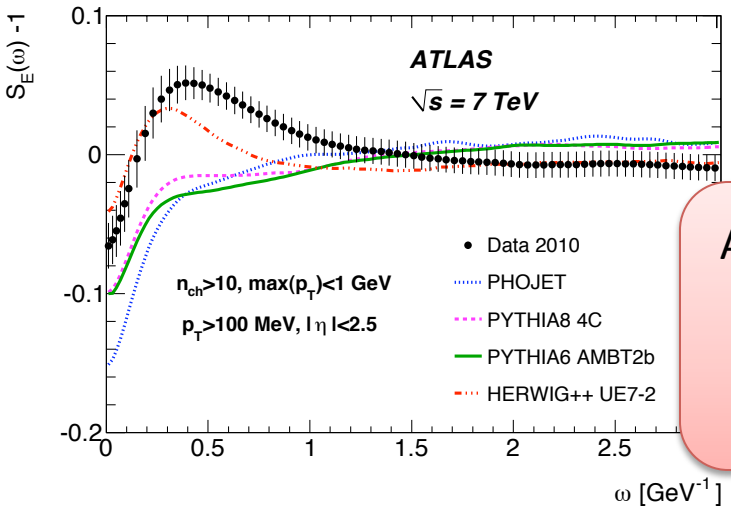
Search for resonant behaviour -> density of helix winding

Azimuthal ordering of hadrons *[arXiv:1203.0419]*

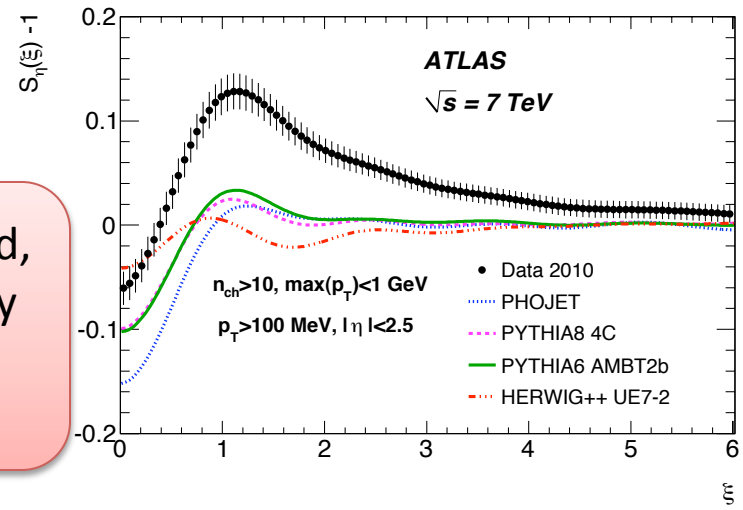
Particle correlations

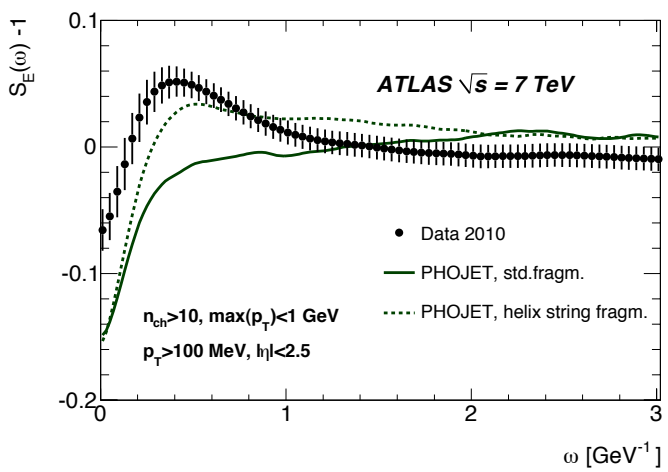
- ***Soft event selection to limit contribution from high-pT jets***

max(pT) < 1 GeV -> higher sensitivity to fragmentation effects

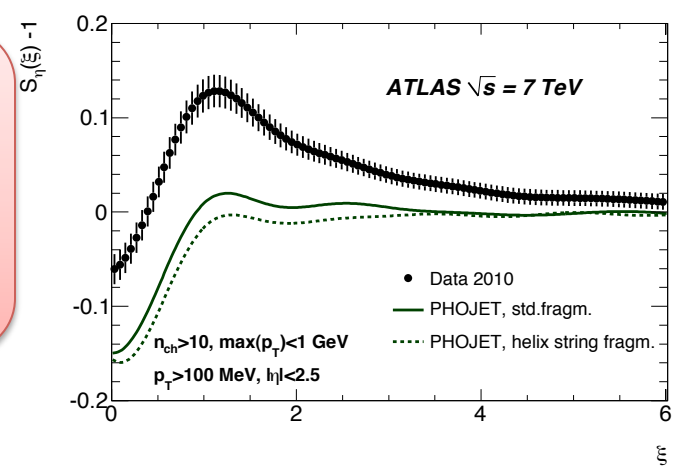


A signal observed, not described by conventional models ..





.. showing similarities with the signature of a helix-shaped string



Summary

SUMMARY

This is a short talk only – apologies for not showing older measurements !

ATLAS has potential to say more about soft QCD :

- ongoing correlations studies (Bose-Einstein effect)

- forward physics: ongoing measurements with new ALFA detectors

-> ATLAS upgrade : Atlas Forward Program (AFP)

ATLAS measurements have large impact on development of better model tunes – but there is still a lot to do

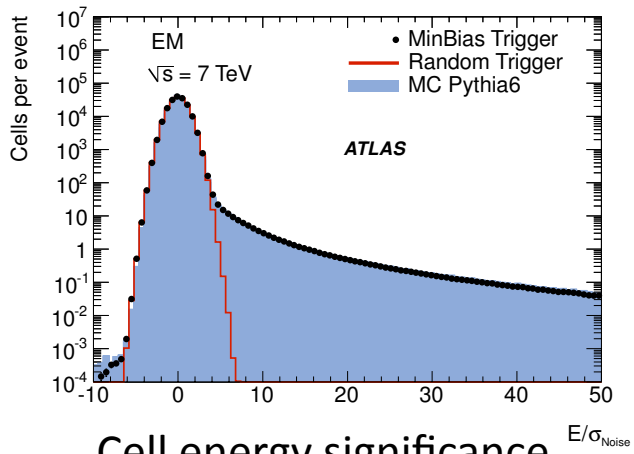
We have plenty of data to test alternative models !

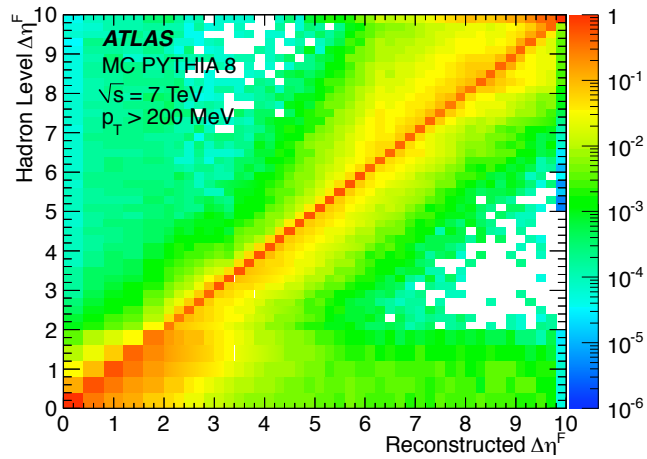
Our soft QCD measurements are sensitive to the structure of the confinment field

THANKS & STAY TUNED

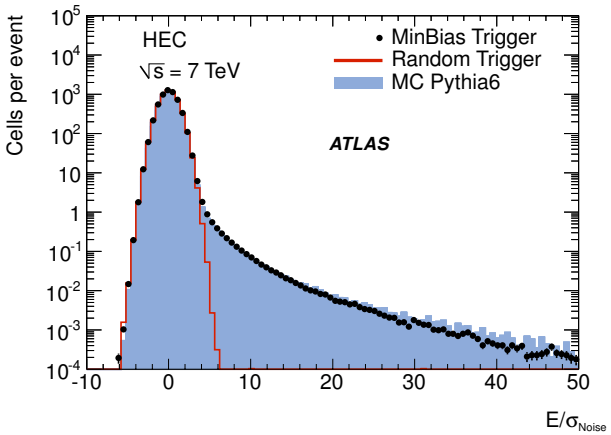
backup slides

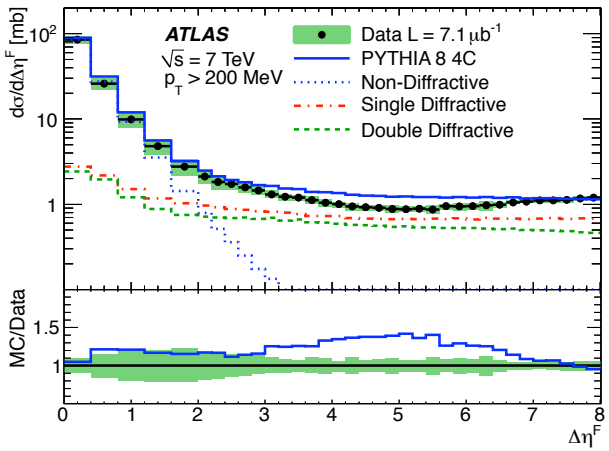
Diffraction (rapidity gaps)

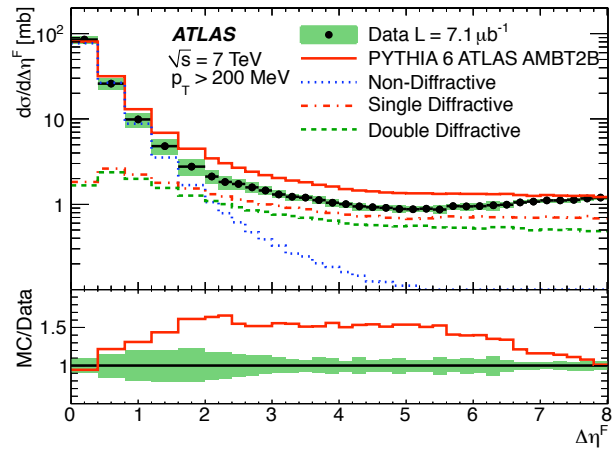


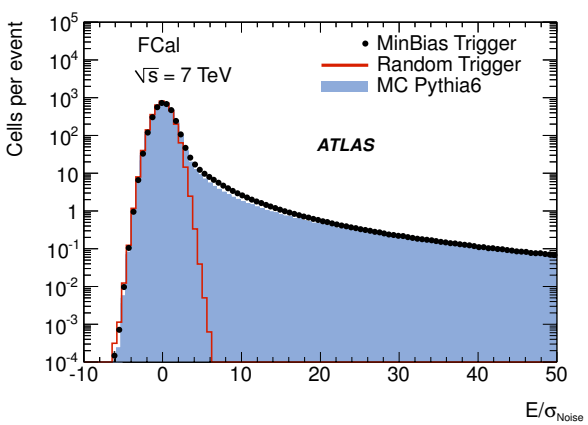


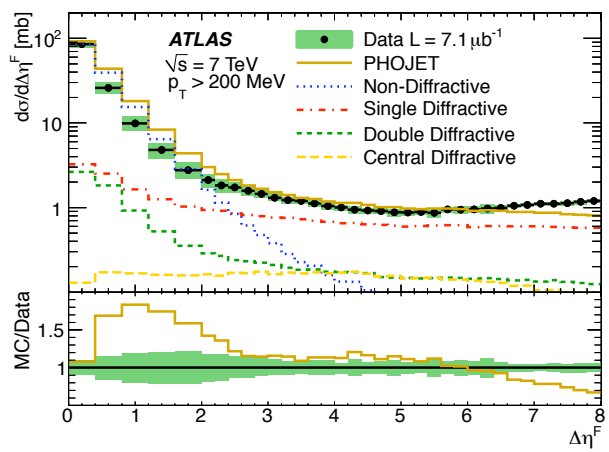
Cell energy significance

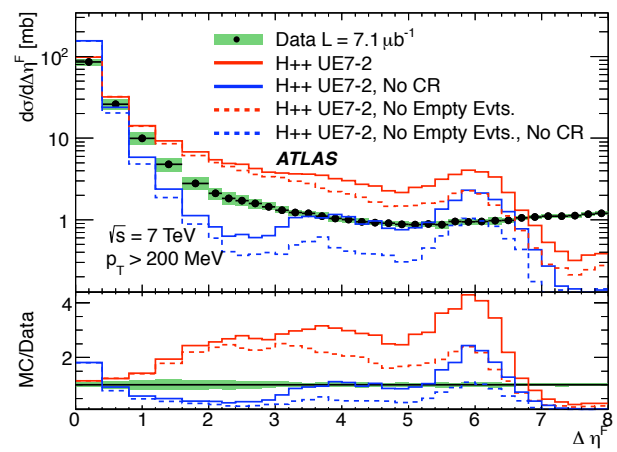






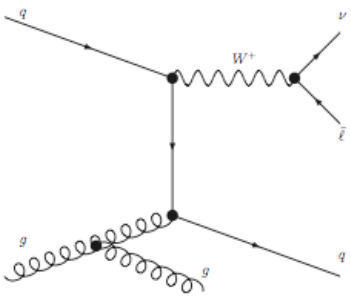




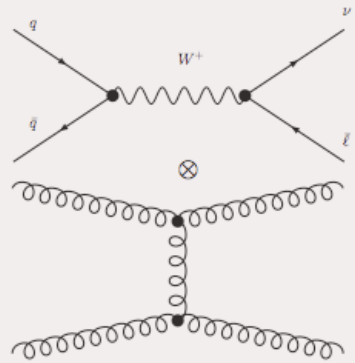


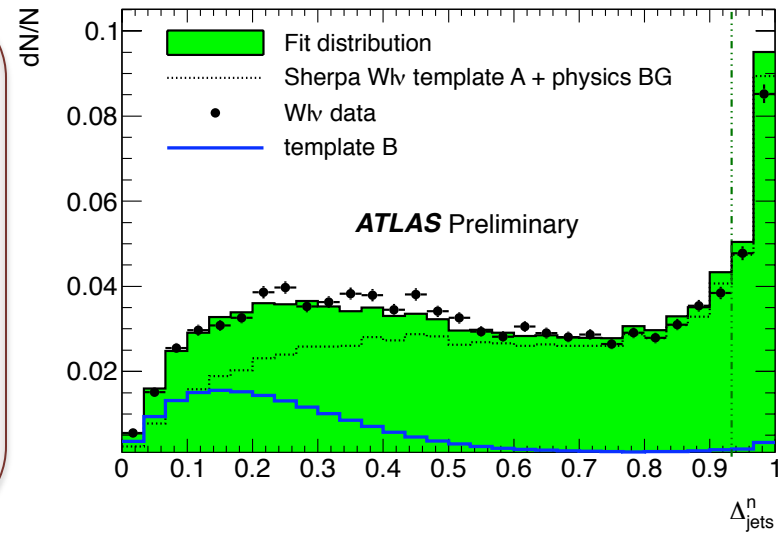
Double parton scattering

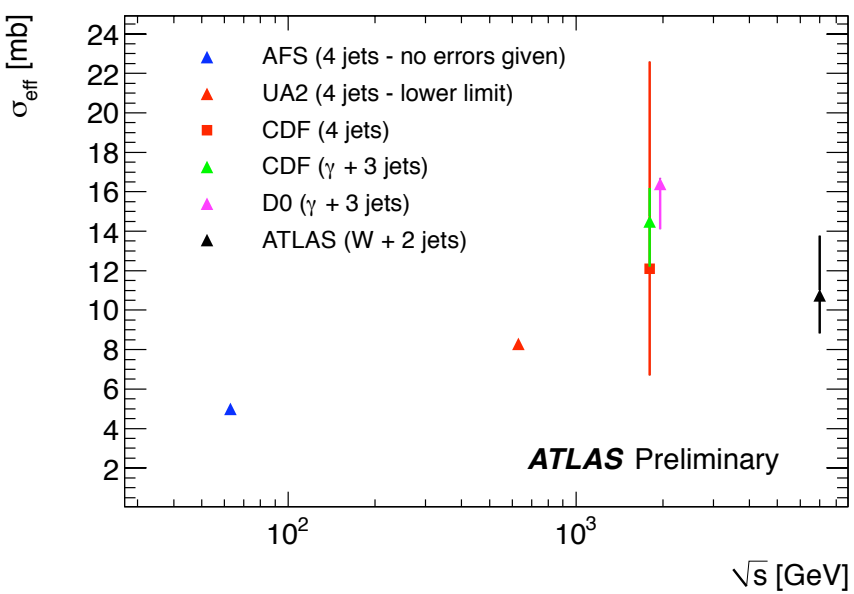
W+2jets :
direct

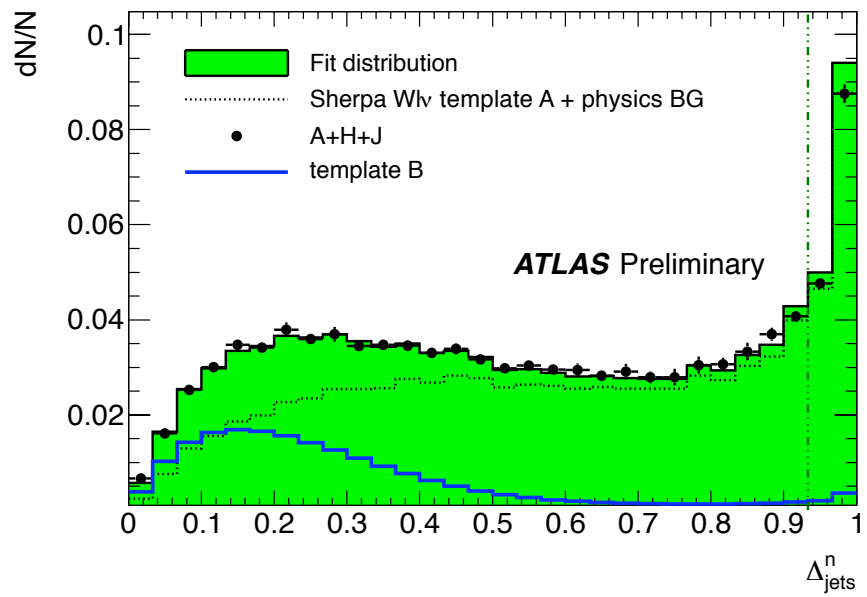


2-parton scattering

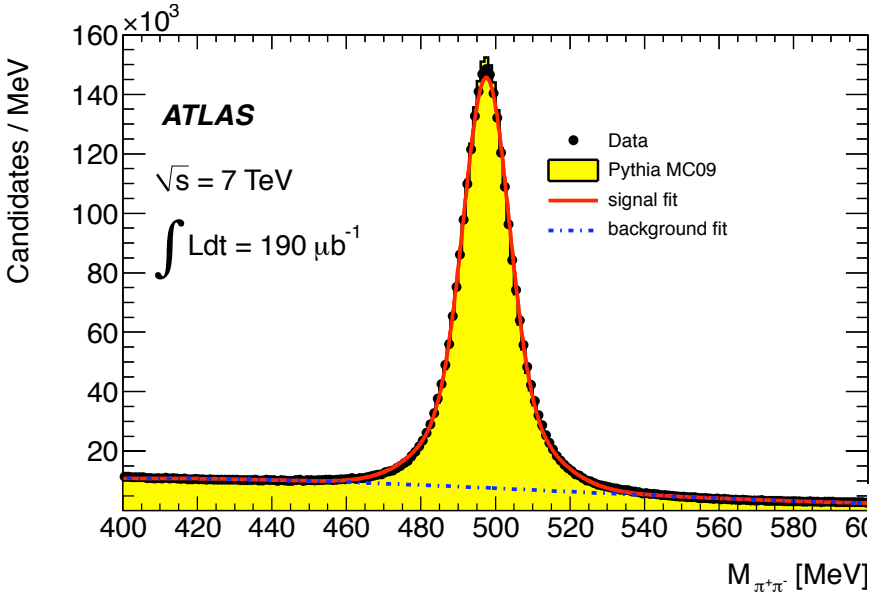


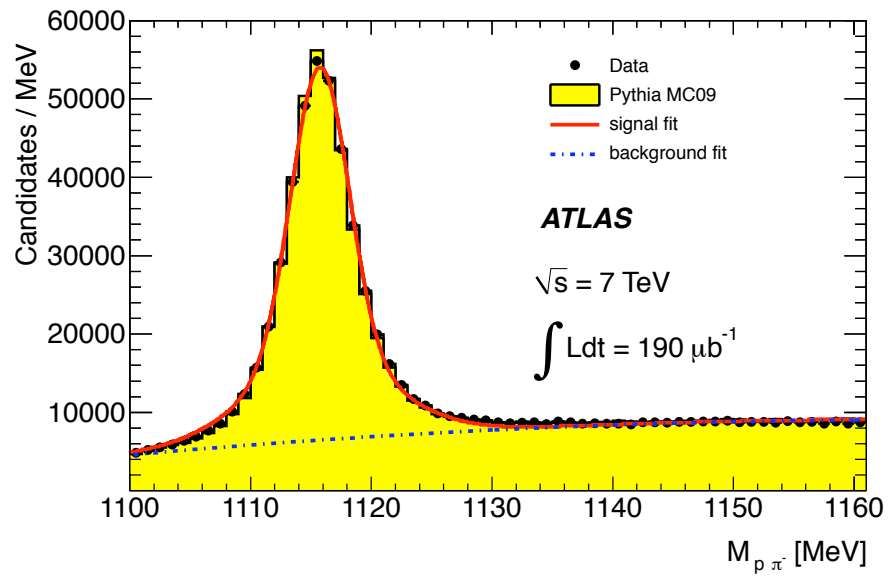






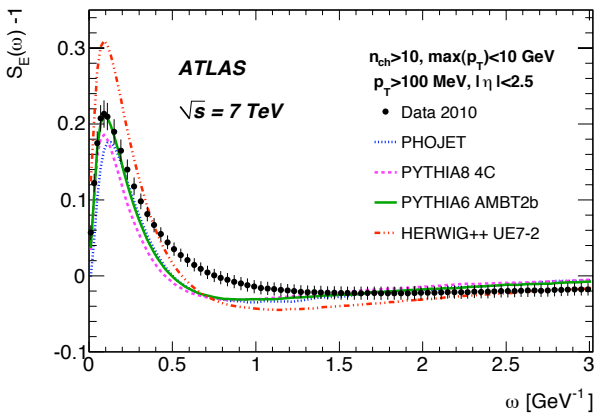
K_S, Λ production





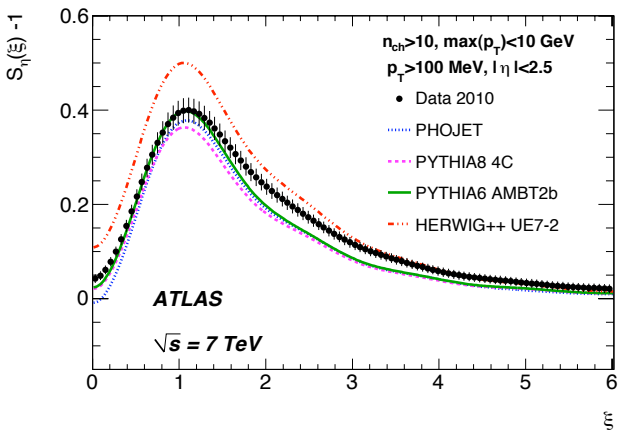
Azimuthal ordering

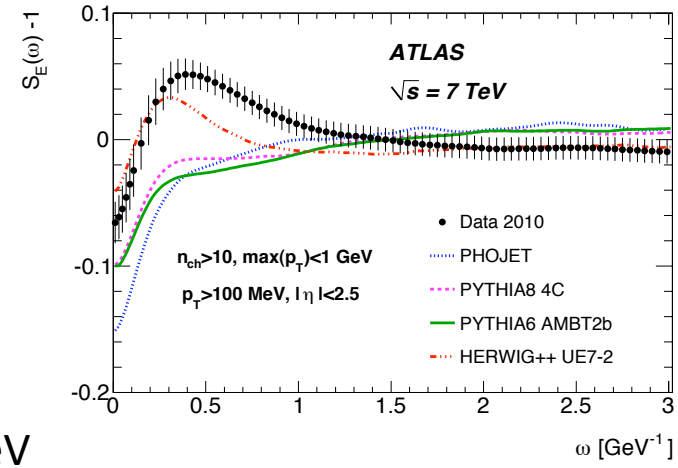
n_{ch} >10



Inclusive selection

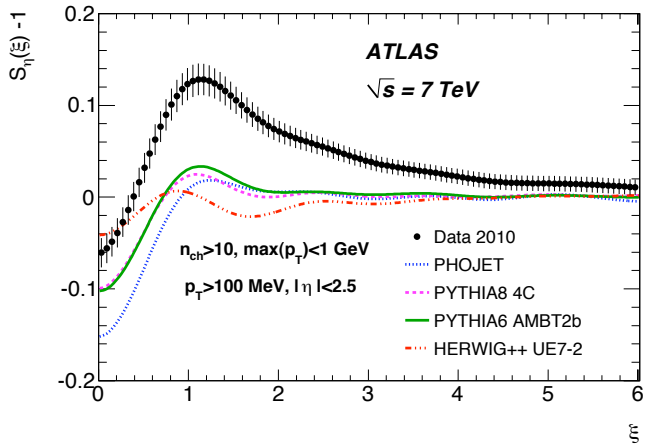
p_T >100 MeV, max(p_T)<10 GeV

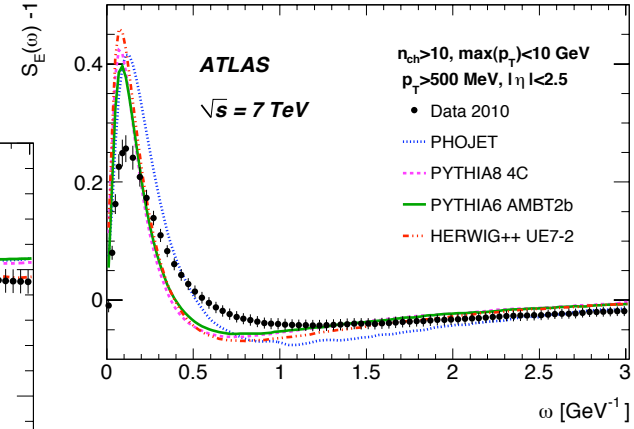




Low-p_T enhanced selection

p_T >100 MeV, max(p_T)<1 GeV





Low-p_T depleted selection

p_T >500 MeV, max(p_T)<10 GeV