UNIVERDIDAD TECNICA
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ATLAS

Forward Physics with ATLAS

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(On behalf of the ATLAS collaboration)

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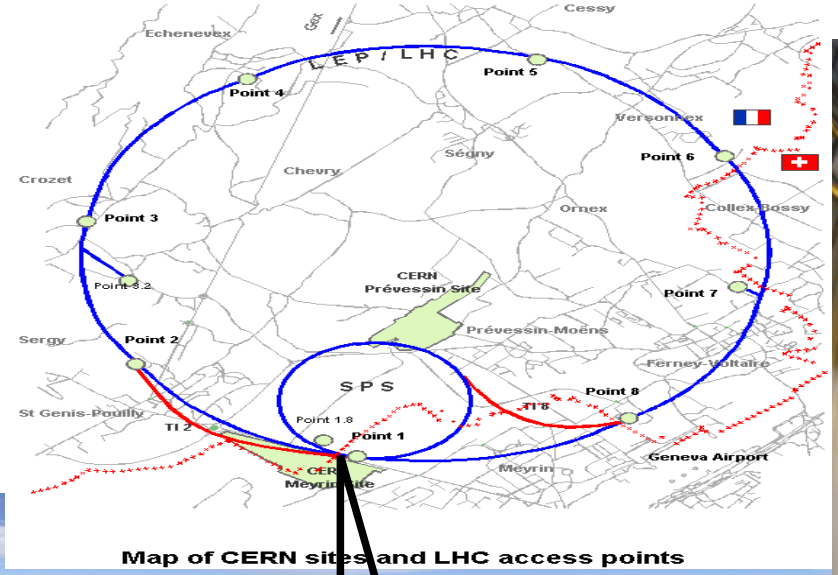
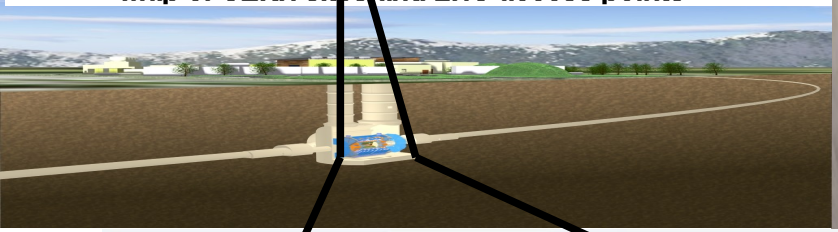
Outline

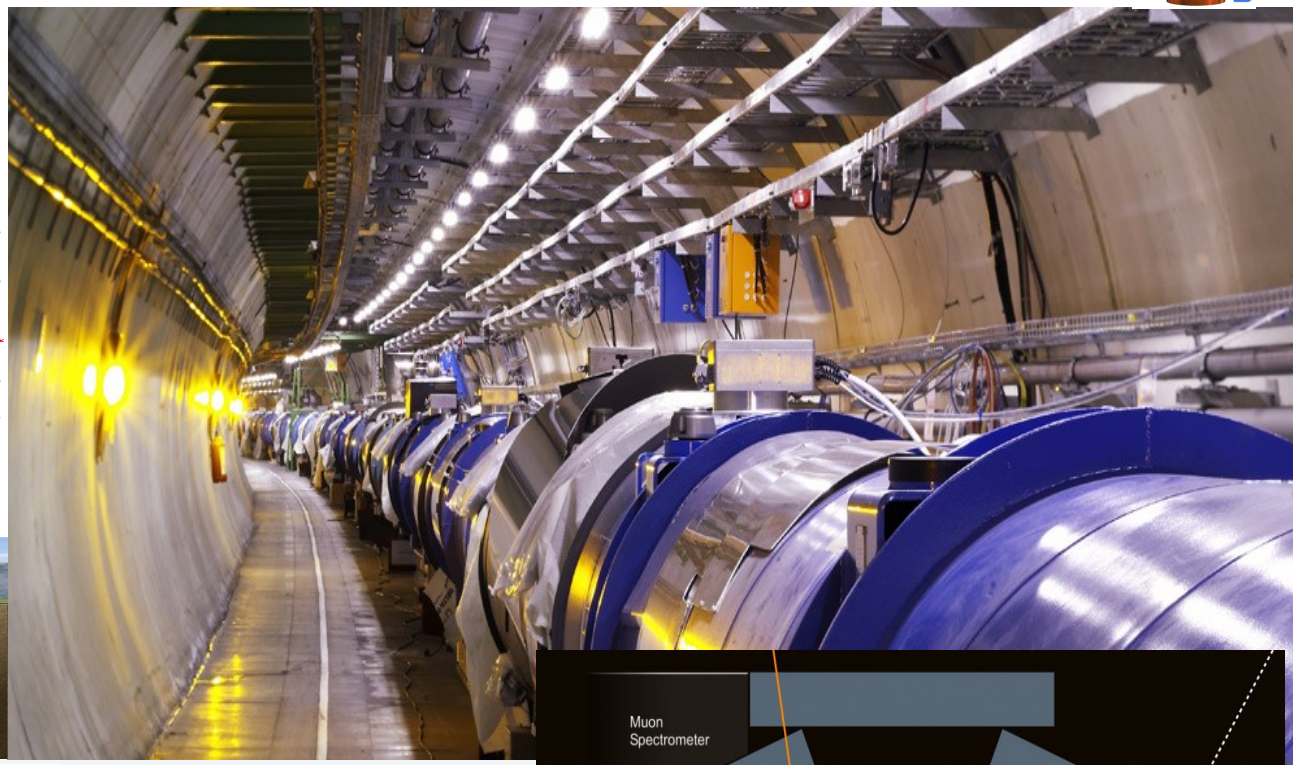
- *ATLAS and forward detectors.*
- *Forward rapidity gap measurements [Eur. Phys. J. C72 (2012) 1926] [arXiv:1104.0326].*
- *Total inelastic cross section [Nature Commun. 2 (2011) 463] [arXiv:1104.0326].*
- *Inclusive (forward) jet cross section at 7 TeV [Phys.Rev. D86 (2012) 014022][arXiv:1112.6297].*
- *Inclusive (forward) jet cross section at 2.76 TeV and a comparison with the cross section at 7TeV [ATLAS-CONF-2012-128].*
- **Dijet production with a veto on additional jet activity** *[JHEP 1109 (2011) 053]*
- *Forward energy flow [JHEP11(2012)033][arXiv:1208.6256].*
- *ZDC measurements in pp collisions at 7 TeV (performance).*
- *Electromagnetic dissociation in HI collisions, peripheral interactions (performance).*
- *Summary.*

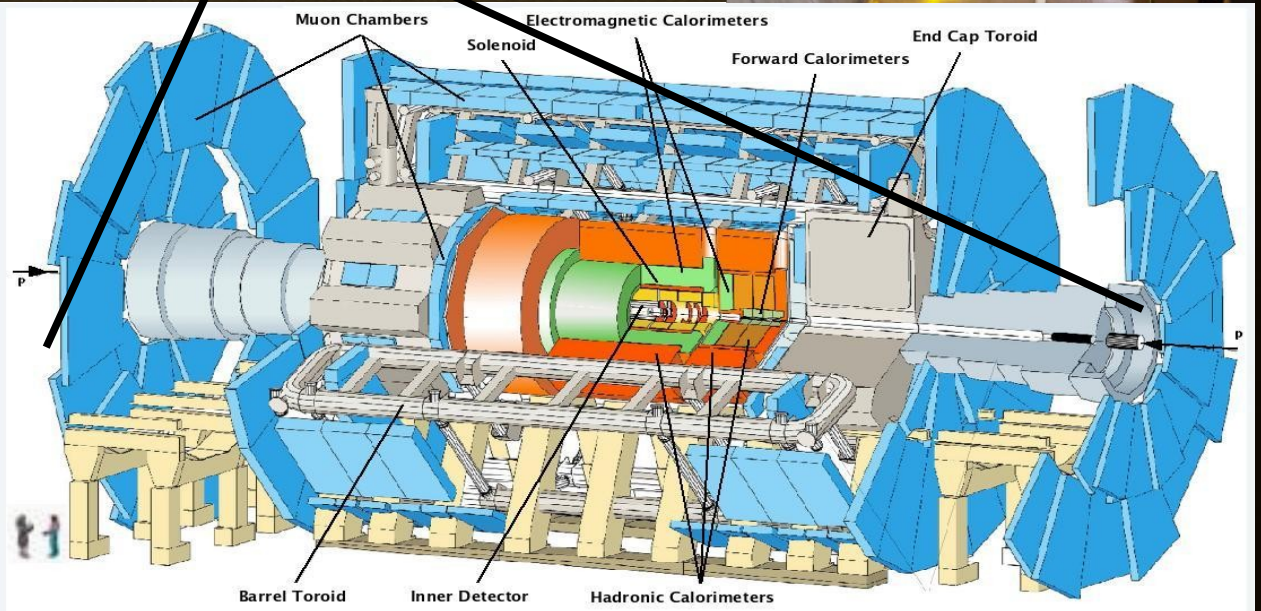
The ATLAS detector al LHC

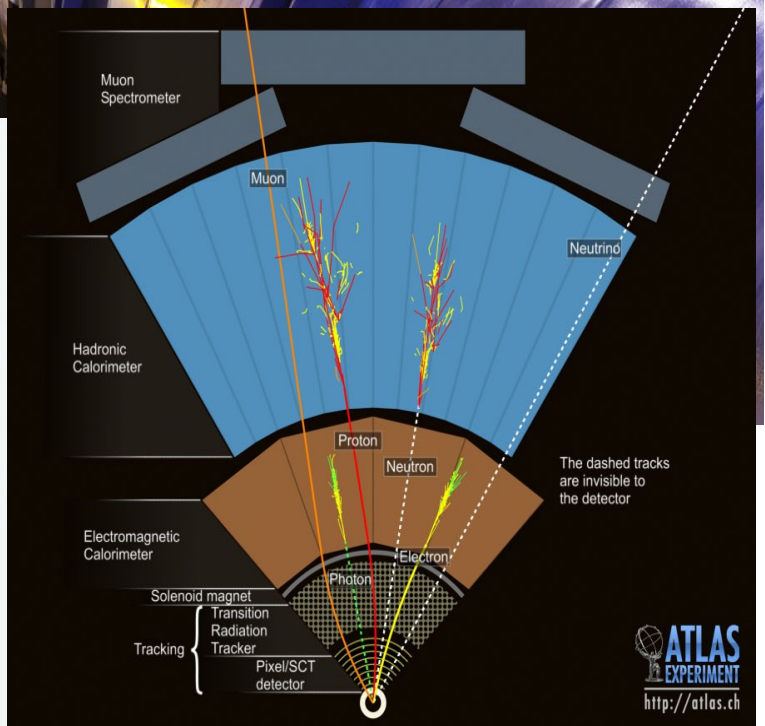


Map of CERN sites and LHC access points



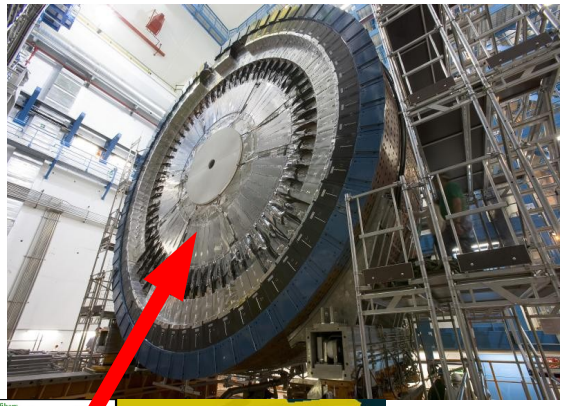




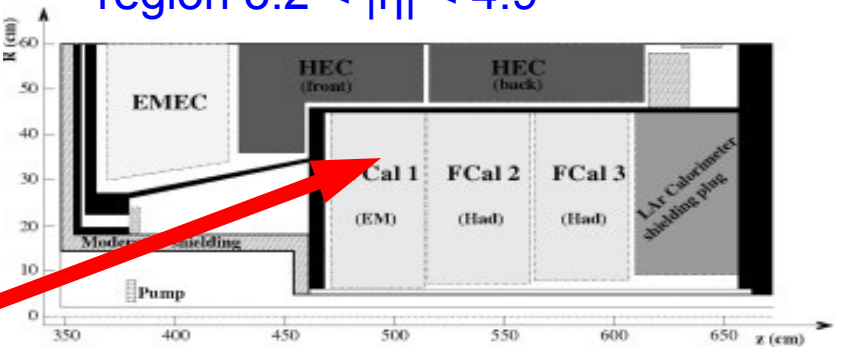


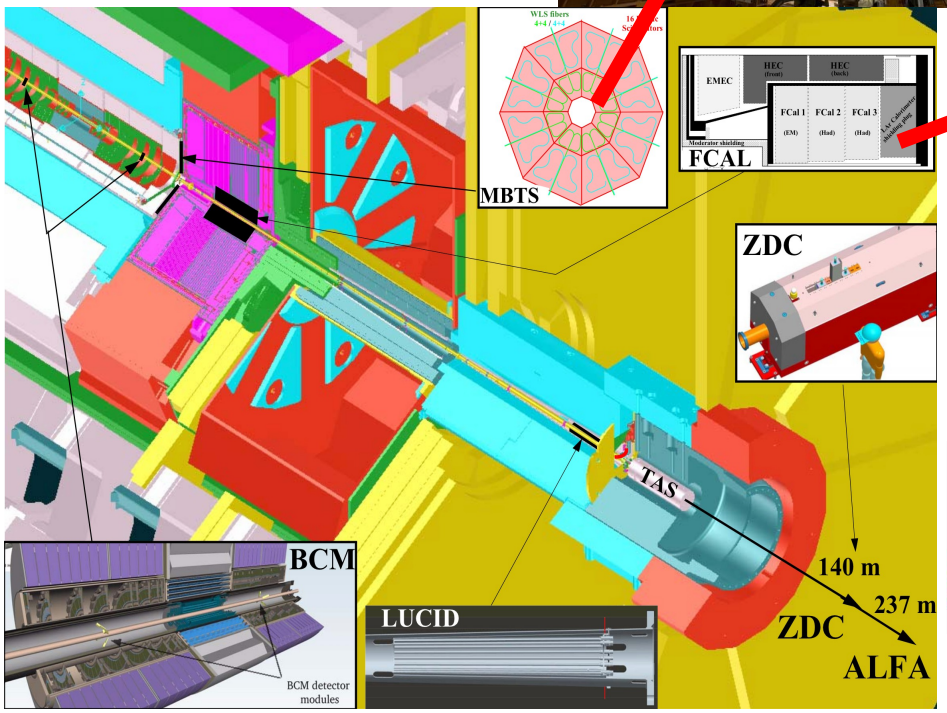
ATLAS forward detectors

MBTS, main trigger for selecting inelastic interactions
2.1<|η| < 3.8

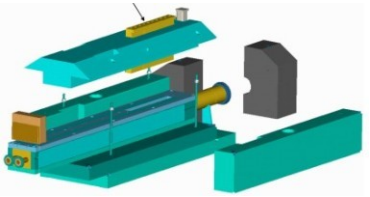


The ATLAS forward calorimeter , FCAL cover the region 3.2 < |η| < 4.9

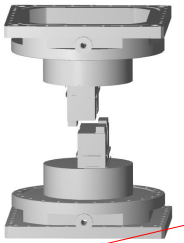




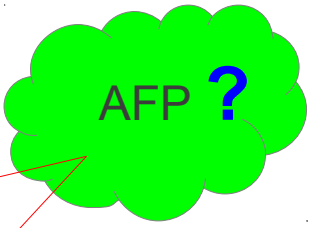
The ZDC detectors are sensitive to neutral particles with |η| > 8.3

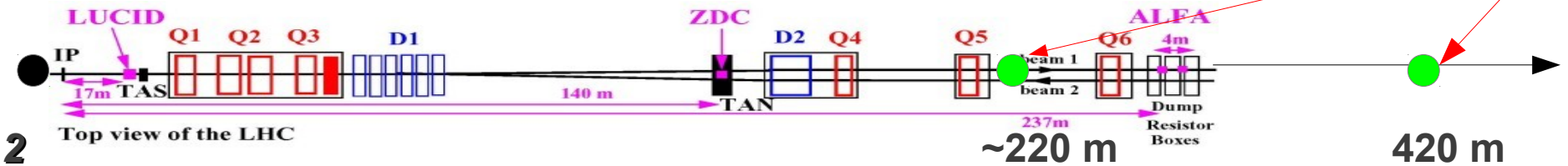


ALFA, roman pots for tagging intact protons



AFP **still under approval**, will tag intact protons in high lumi runs



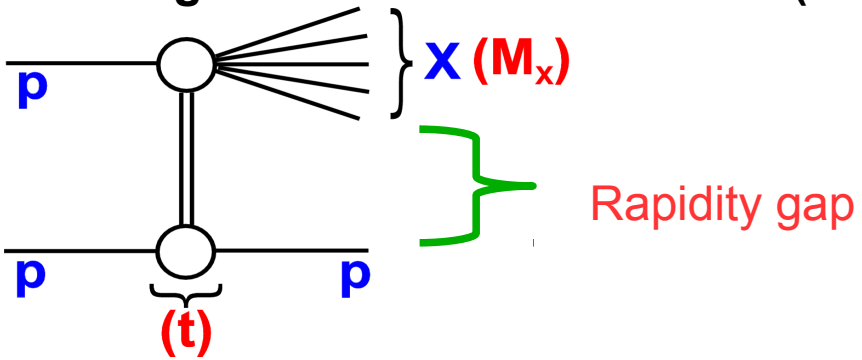


Rapidity Gap Cross Sections in pp Interactions at sqrt(s) = 7 TeV measured with the ATLAS detector.

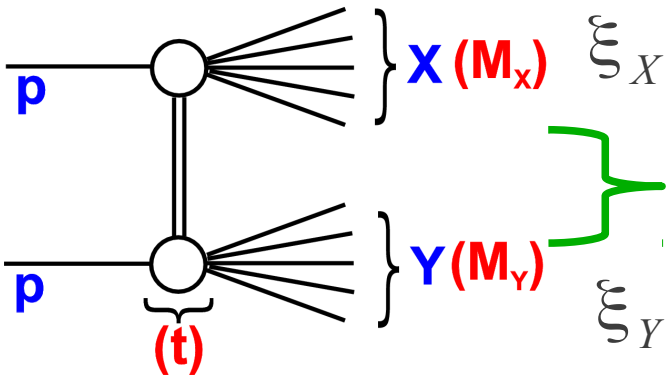
Eur. Phys. J. C72 (2012) 1926.

Forward physics, gap signatures and soft interactions.

Single diffractive dissociation (SD)



Double diffractive dissociation (DD)

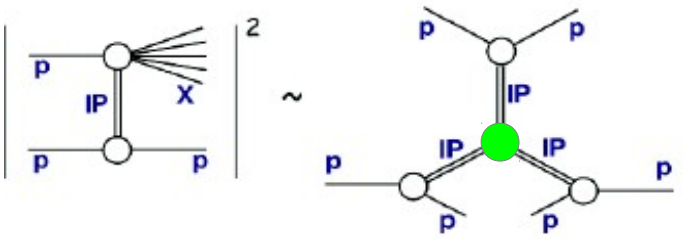


$$\xi_X = \frac{M_X^2}{s}$$

$$\xi_Y = \frac{M_X^2}{s}$$

Where $\xi_Y = M_P$ for single diffraction

Single diffraction test the triple pomeron vertex.



$$\frac{d\sigma}{d\xi\, dt} \propto \left(\frac{1}{\xi_X}\right)^{2\alpha(t)-\alpha(0)} e^{bt} \quad \text{(fixed s)}$$

$$[\alpha(t) = \alpha(0) + \alpha' t]$$

i.e approx: $\frac{d\sigma}{d\xi_X} \propto \frac{1}{\xi_X}$

And since: $\Delta\eta \sim -\log\xi$

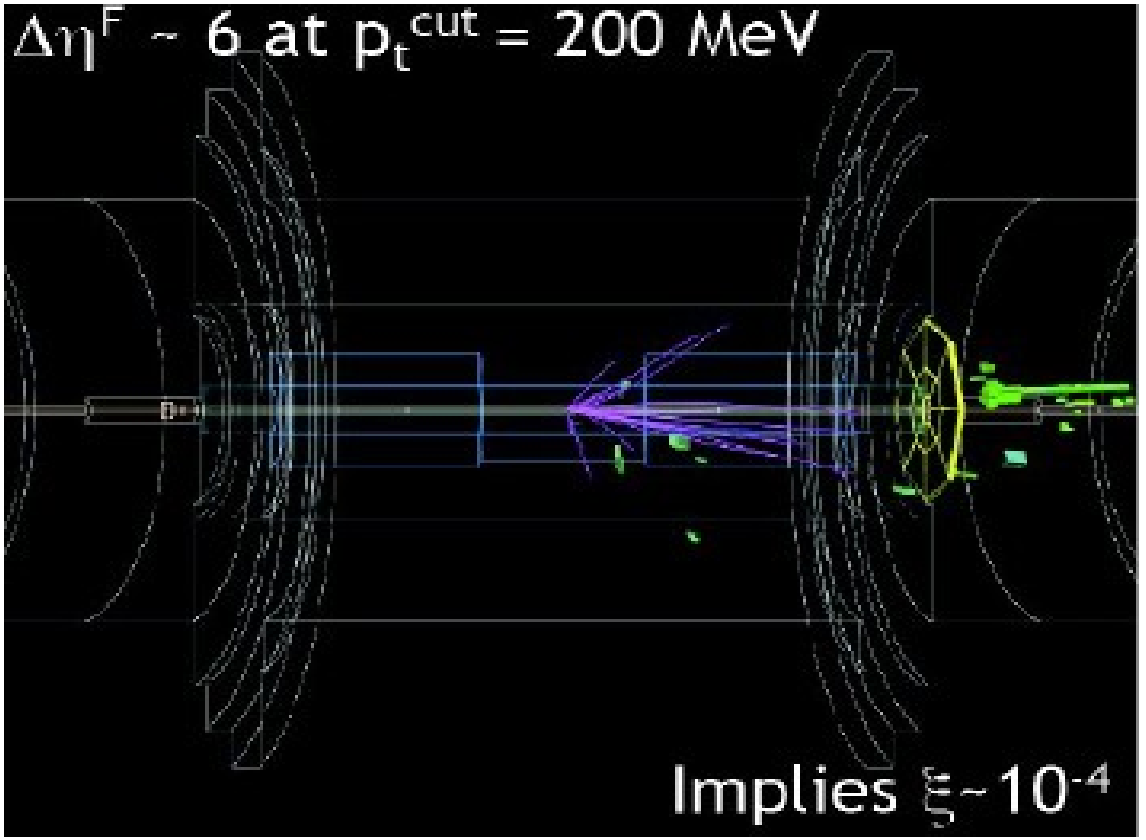
$$\frac{d\sigma}{d\Delta\eta} \sim flat$$

At the LHC energy the dissociated masses can vary between m_p+m_π and ~ 1 TeV.

Rapidity gap definition

A rapidity gap is a region of the detector where no particles are detected (an "empty" region), between the border of the detector acceptance at |η| =4.9 and the first particle with pT>

200,400,600,800 (MeV)

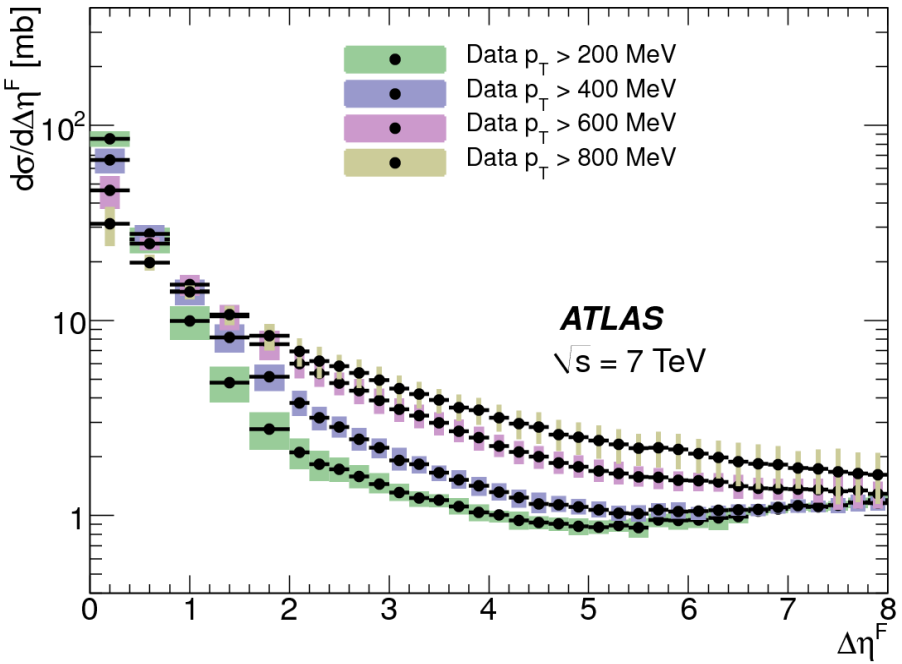


A particle is detected when a good quality track is found in |η| < 2.5 or a calorimeter cluster with energy above threshold with $E/\sigma > S_{th}$ is found outside the tracking region

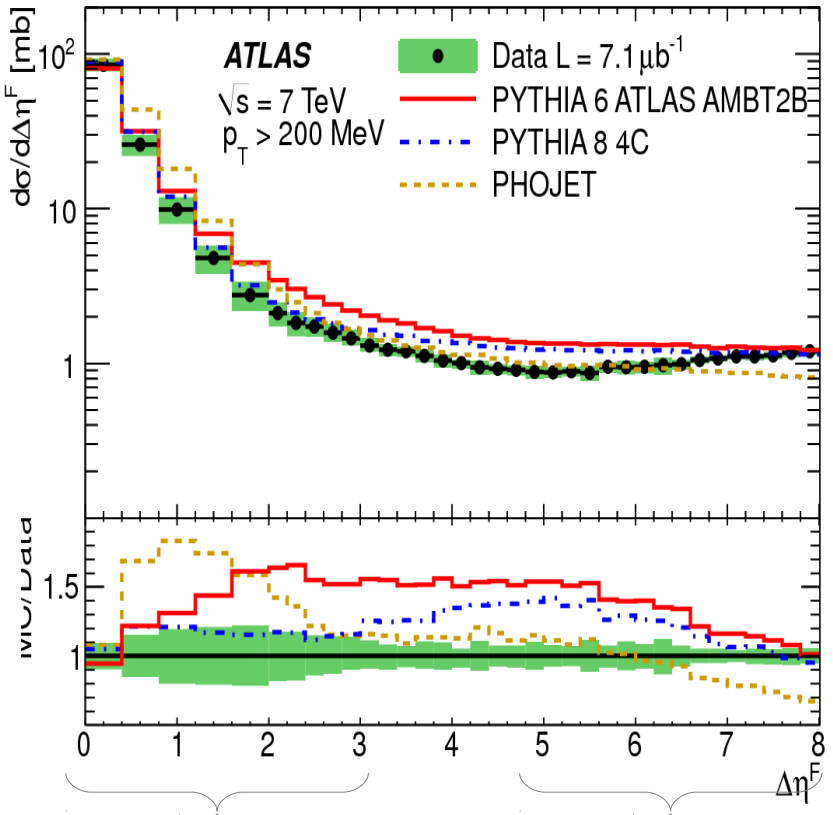
- ***ATLAS Acceptance alows to investigate diffractive systems with M_X >~ 7GeV and M_Y <~ 7GeV in the case of DD.***
- **Maximum gap size studied by ATLAS Δη = 8.**

Rapidity gap measurements

No model is able to describe the data In the whole interval !, not even the rise with rapidity gap size at the largest Δη.



Rise in the p_T cut increases the rapidity gap size but the diffractive plateau dissapear at mid rapidities.



20 %

Color octet dominated

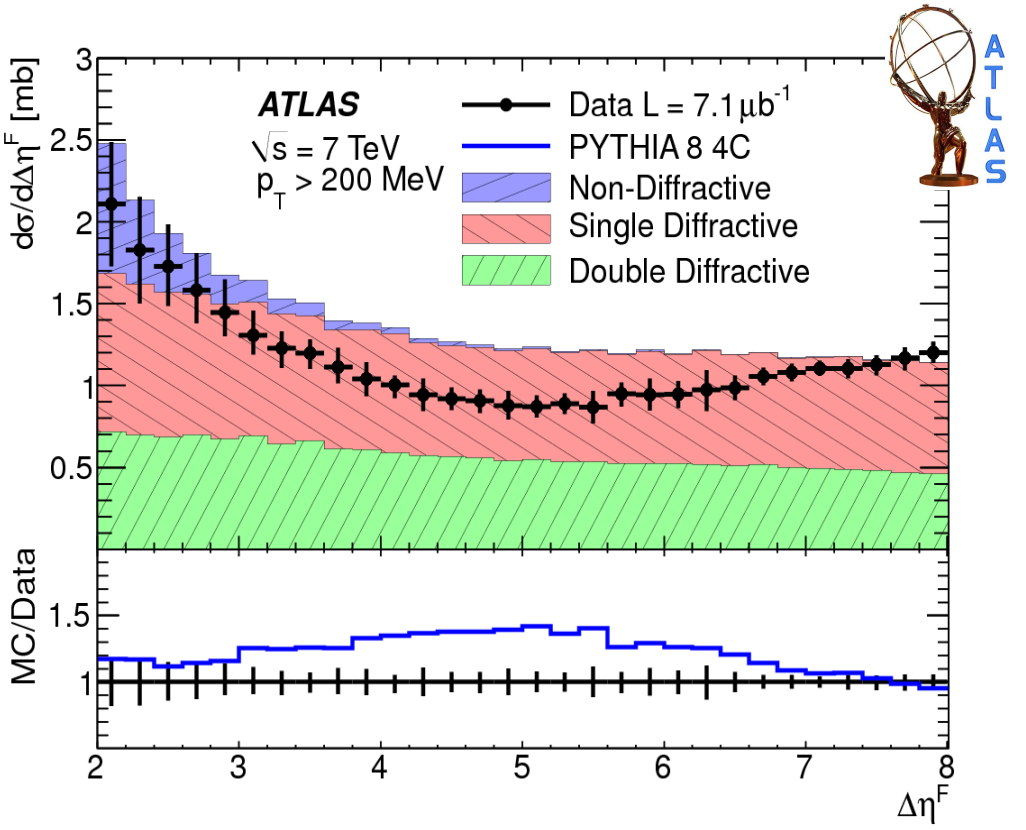
No diffractive

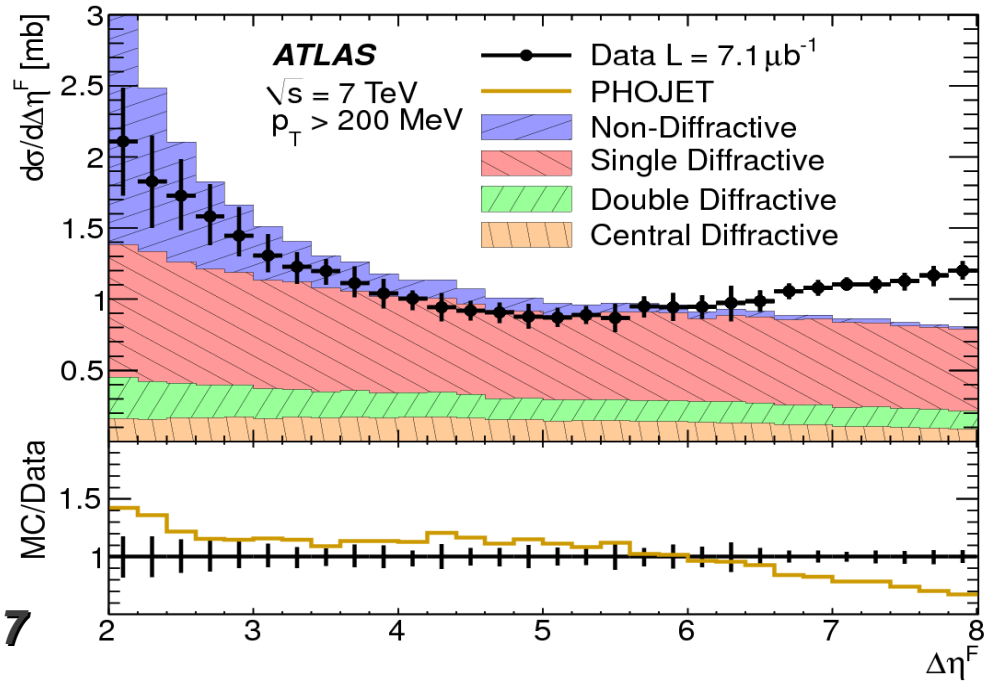
~8 % Uncertainty

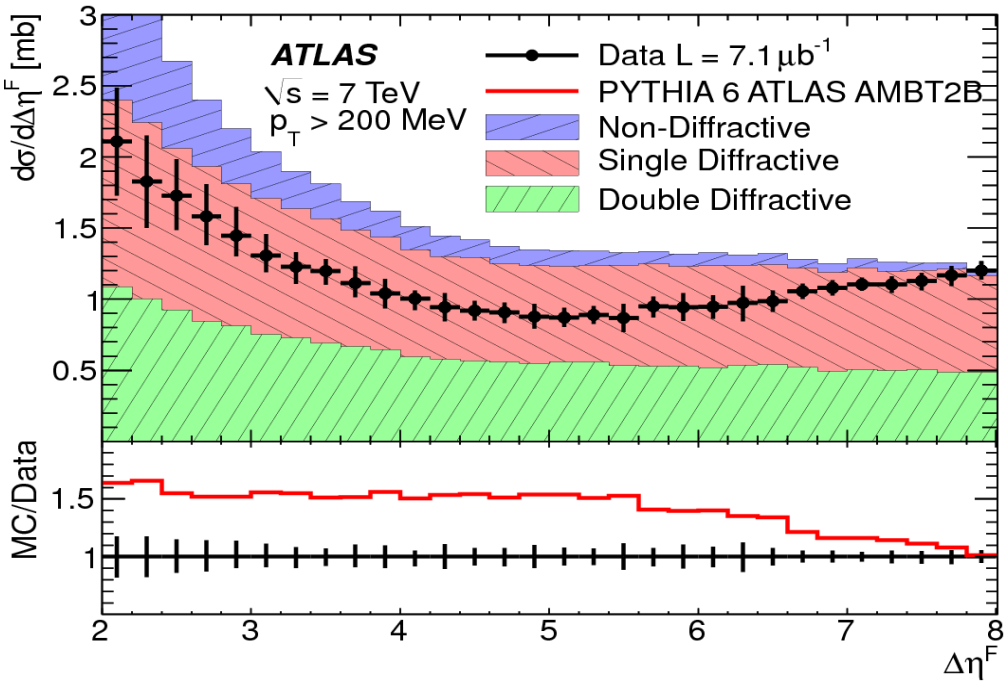
Color singlet dominated

single diffractive

- All models exhibit different admixtures of diffractive and non-diffractive contributions.
- Diffractive plateau with ~ 1 mb per unit of rapidity gap size for $\Delta\eta > 3$, broadly described by the models.

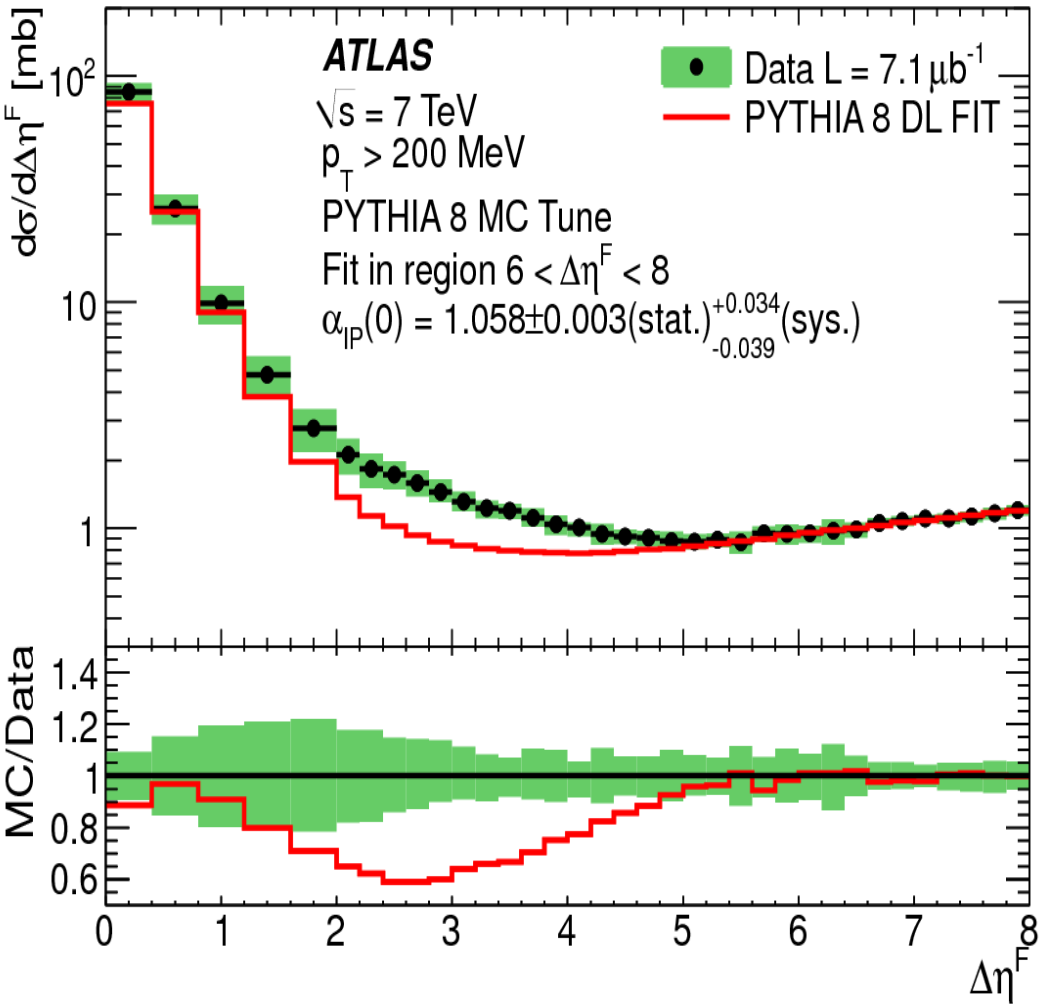






Extracting the pomeron intercept value $\alpha_P(0)$ from LHC data.

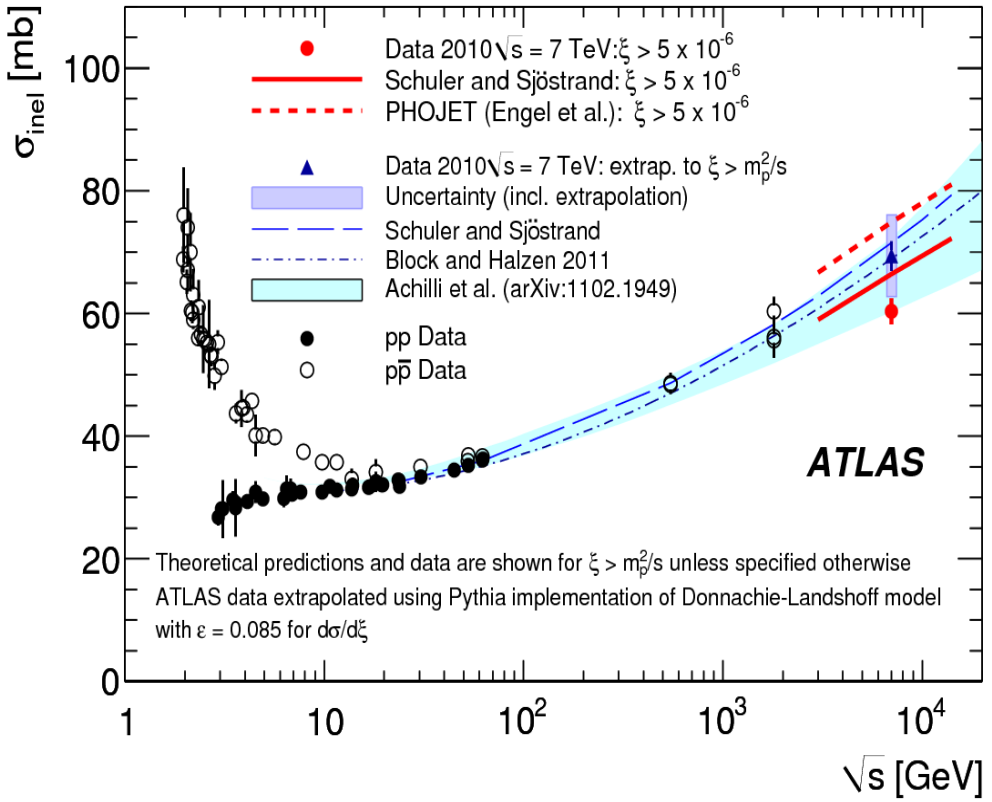
- *A PYTHIA 8 model with the Donnachie-Landshoff flux parametrization was fitted to the data.*
- *At large rapidity gaps it shows a very good agreement, while large differences are found at gaps of 2-4 units.*
- *Maybe due to large diffractive mass effects, large hadronization fluctuations in the ND models, the contribution from sub-leading trajectory exchange or to the lack of correctly modelling the background processes contributiong with gap signatures as central diffraction, photoproduction or gamma-gamma interactions.*



Measurement of the Inelastic Proton-Proton Cross-Section at sqrt(s) = 7 TeV with the ATLAS Detector

Nature Commun. 2 (2011) 463

Total inelastic cross-section measured by ATLAS

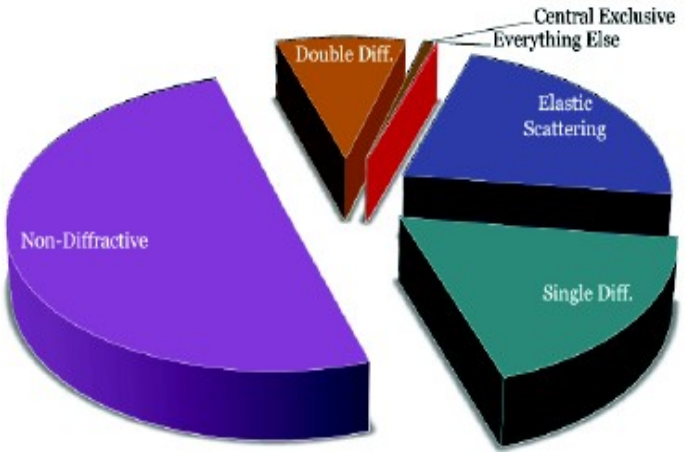


- Extrapolated value:

$$69.4 \pm 2.4\,(exp.) \pm 6.9\,(extr.)\,mb$$

- Fiducial cross section:

$$60.33 \pm 2.10\,(exp.)\,mb$$



- Extrapolated value in good agreement with models.

- Diffractive processes togheter account for ~ 30 % of the total inelastic cross section at the LHC.

Forward jet measurements

- Measurement of inclusive jet and dijet cross sections in proton-proton collisions at 7 TeV centre-of-mass energy with the ATLAS detector

Phys.Rev. D86 (2012) 014022

- Measurement of the inclusive jet cross section in pp collisions at sqrt(s) = 2.76 TeV and comparison to the inclusive jet cross section at sqrt(s) = 7 TeV using the ATLAS detector

(Preliminary)

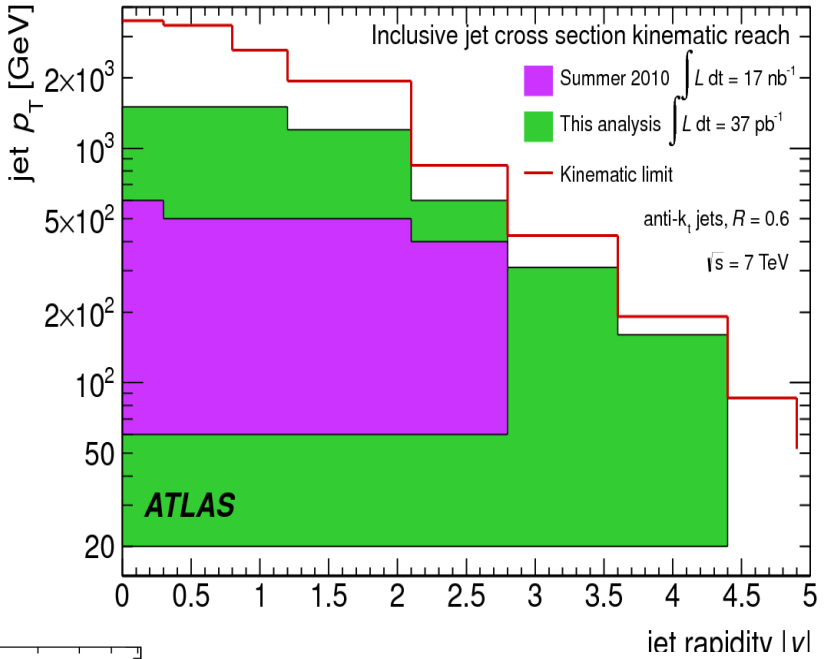
ATLAS-CONF-2012-128

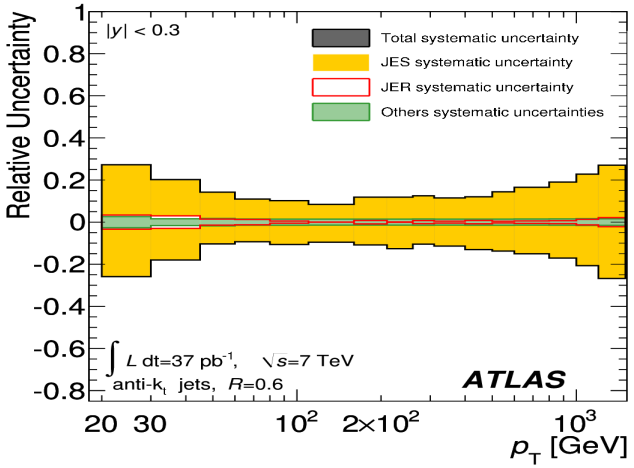
- Measurement of dijet production with a veto on additional central jet activity in pp collisions at sqrt(s) = 7 TeV using the ATLAS detector

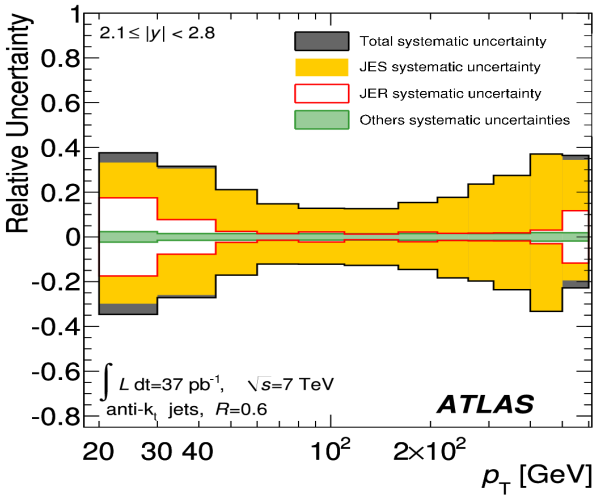
JHEP 1109 (2011) 053

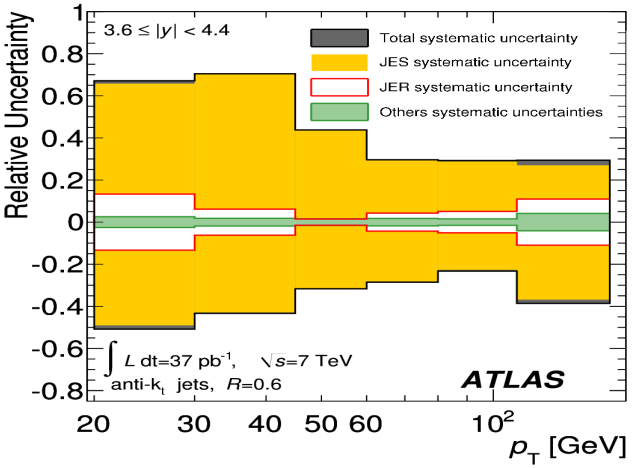
Inclusive forward jet measurements

- Kinematic reach of the inclusive jet analysis increased to include the forward region, compared to previous measurement.
- To measure in the forward region is challenging due to increased JES sys. uncertainty.





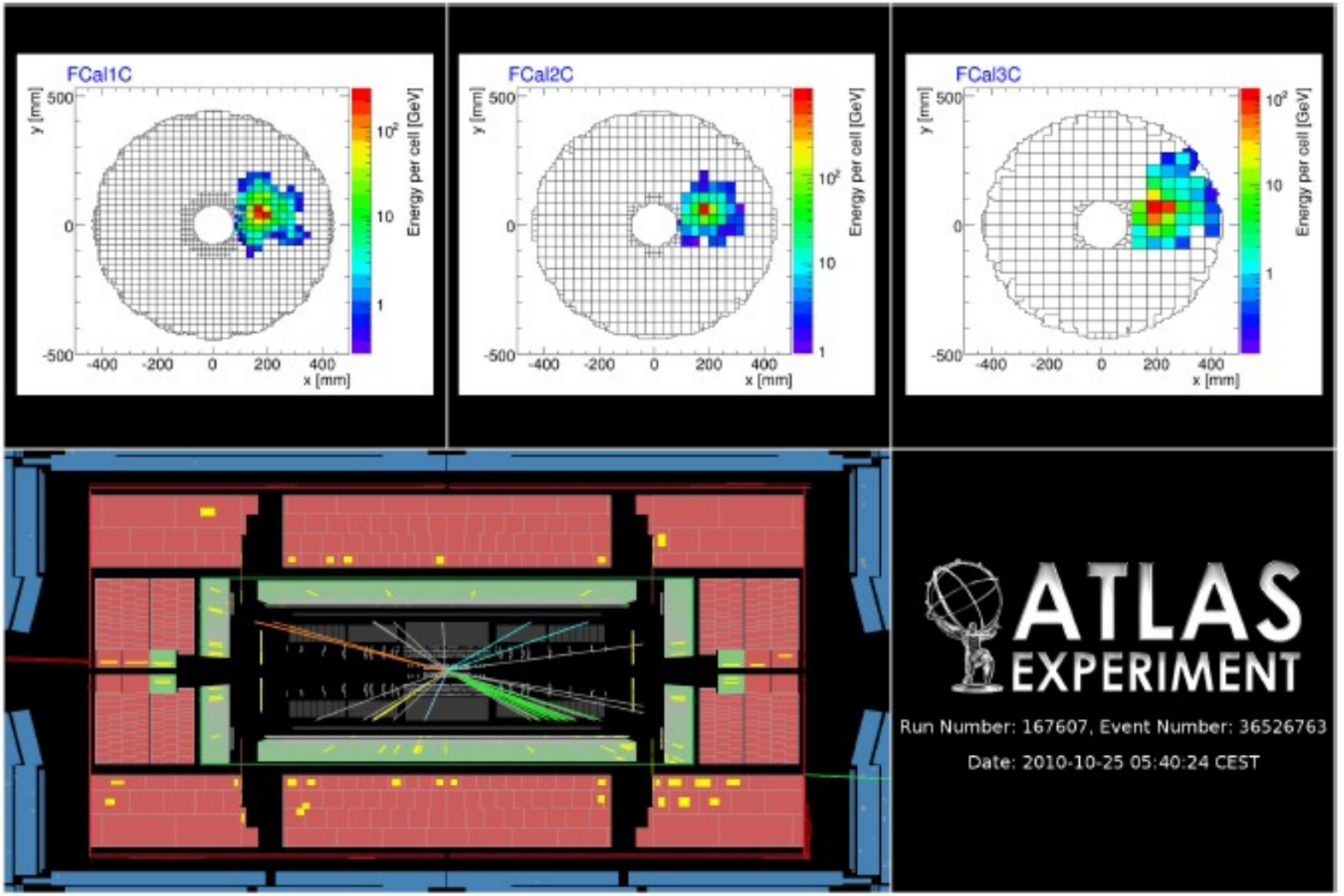




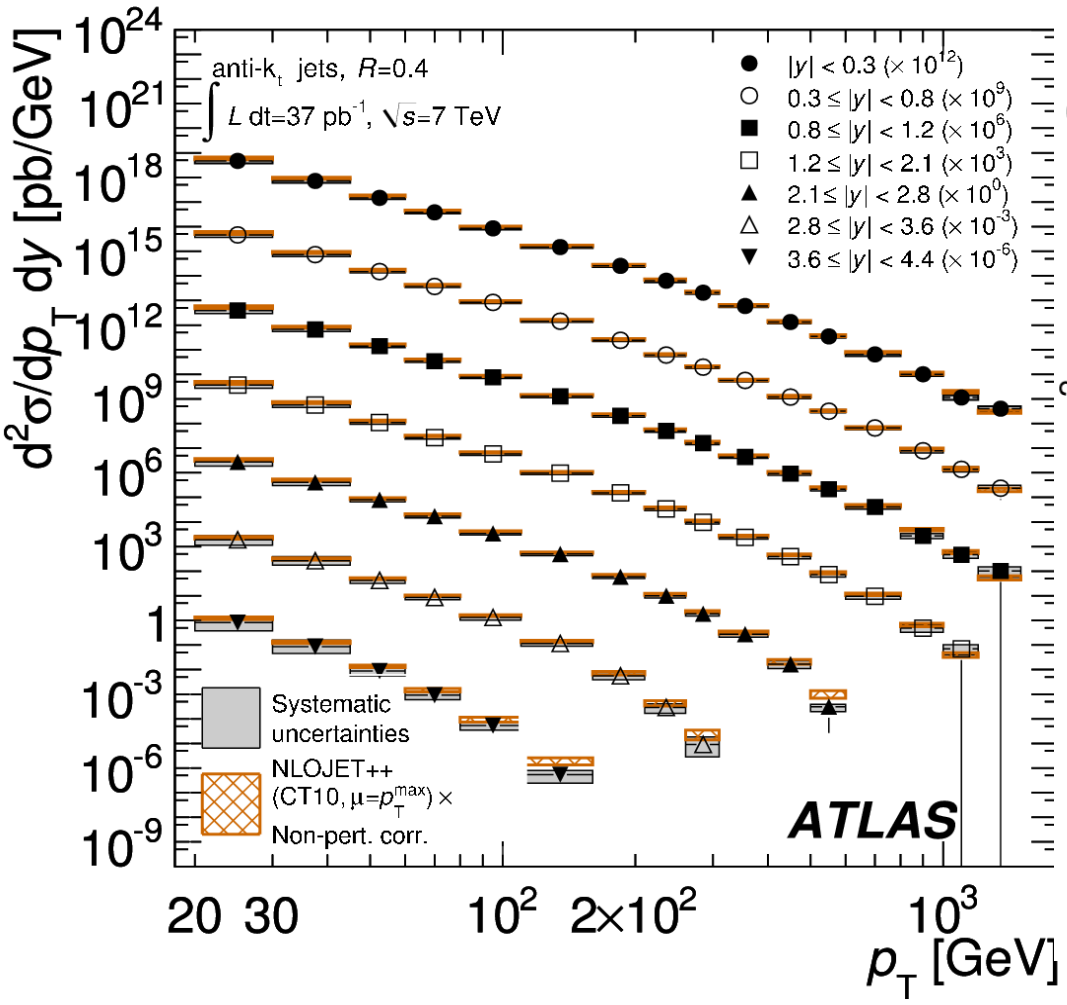
CENTRAL FORWARD

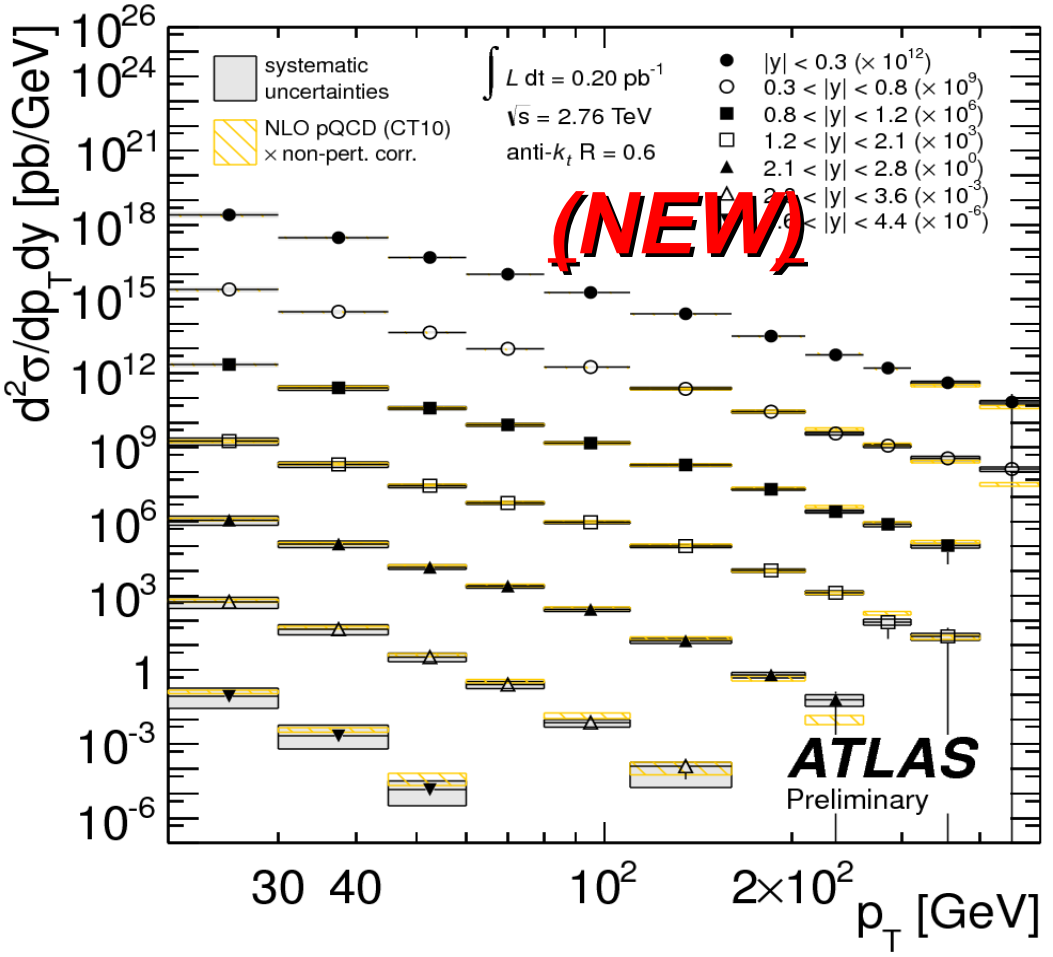
Forward jet event at 7TeV

- Jet (p_T = 3.37 TeV, y = -4) reconstructed in the forward calorimeter.



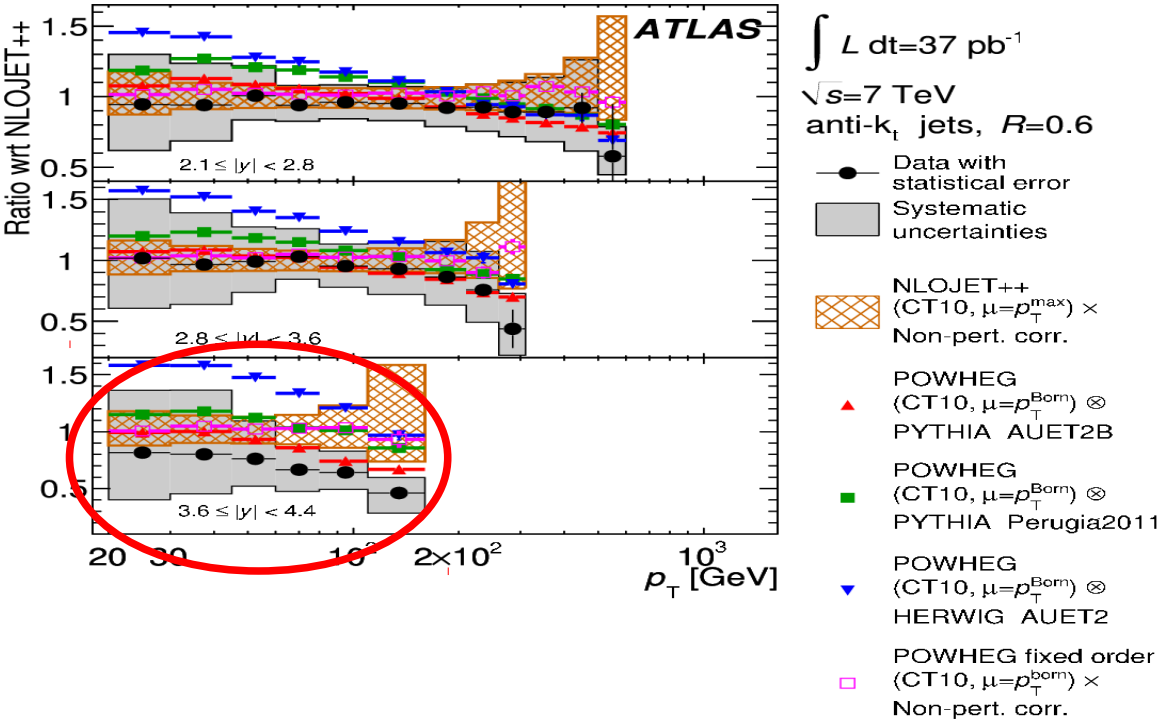
Comparisons with NLO predictions

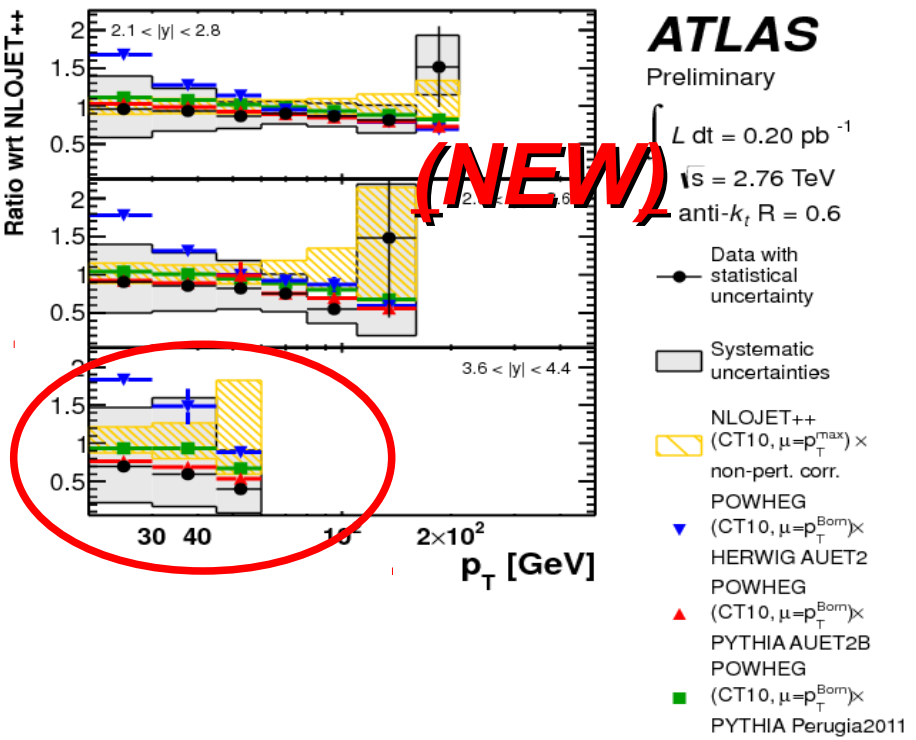




- Large kinematic regime covered in this measurements.
- In general quite good description of the data.

Inclusive (forward) jets

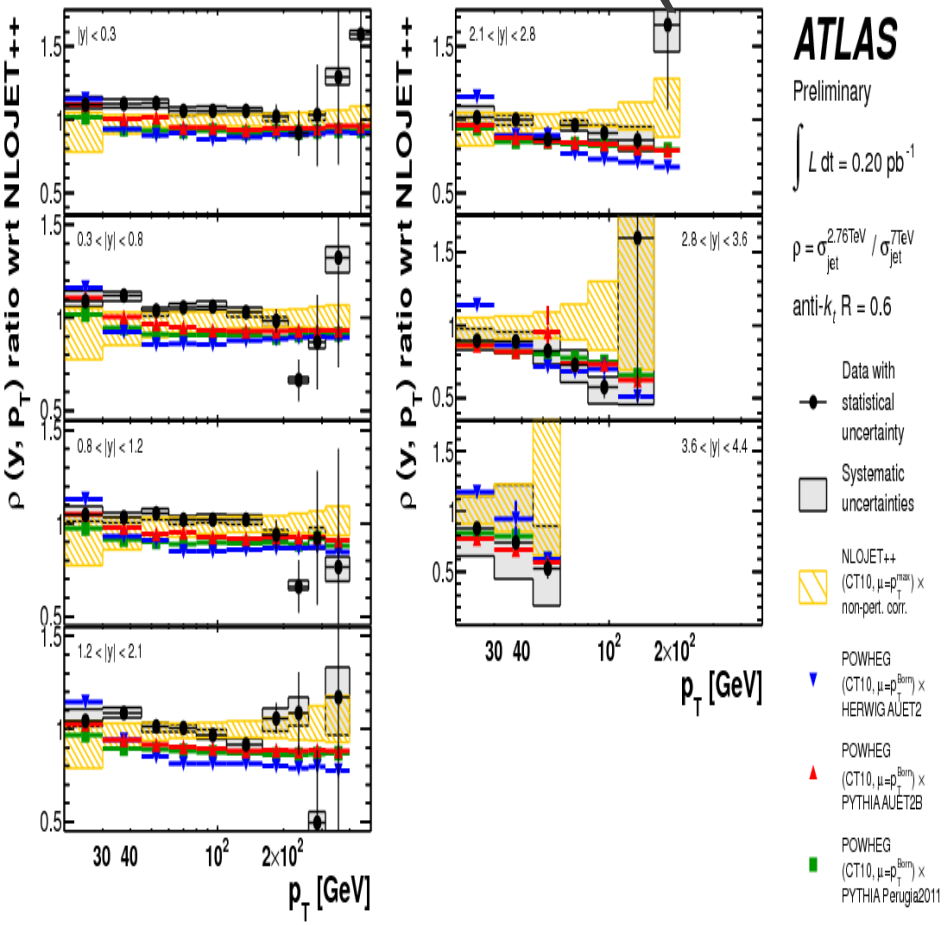




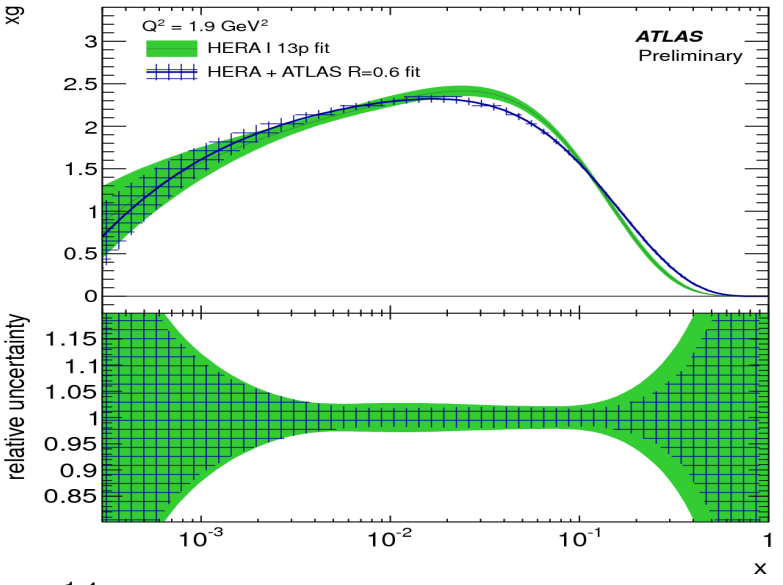
- *In the forward region, at **sqrt(s)=7TeV**, tension between **NLO** predictions and data.*

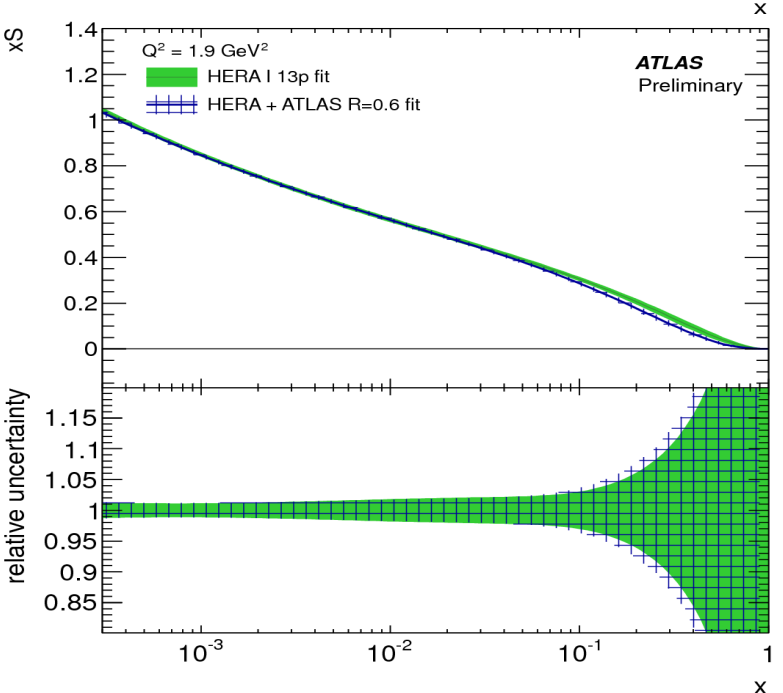
- Agreement between data and theory (***POWHEG+PYTHIA***) restored at lower c.m. energy in the forward region (softer jet p_T spectrum).

Inclusive jet cross section ratio (2.76 TeV/ 7TeV) **(NEW)**



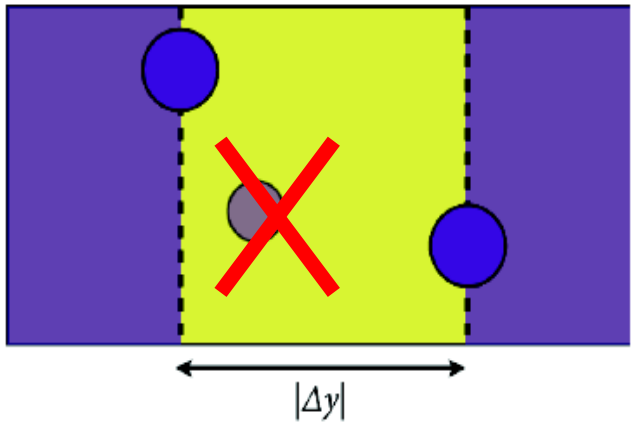
- Combined ATLAS + HERA 1 data used in the PDF fit.
- Harder xg and softer xS at large x found after the inclusion of the ATLAS data in the fit.
- Reduction of the uncertainty in the gluon distribution.

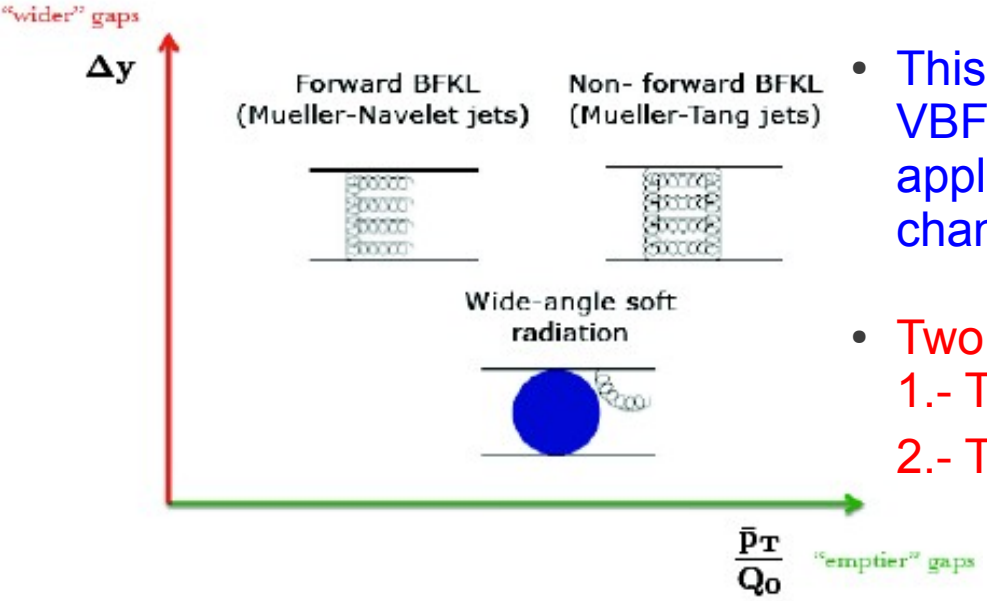




- Good agreement in the forward region for the cross section ratio given with the POWHEG predictions.

Dijet production with a central (jet) veto.





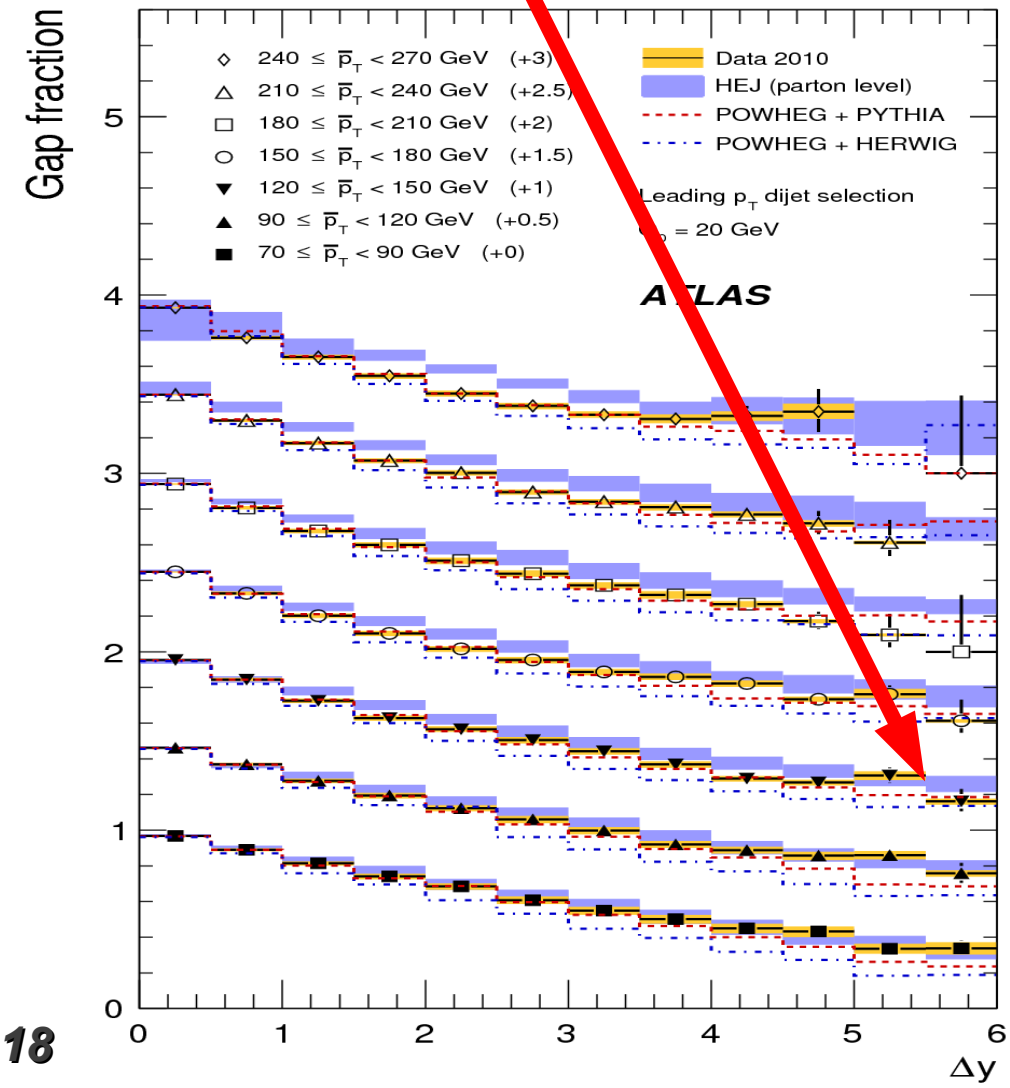
- BFKL dynamics is expected to be increasingly important for large rapidity intervals.
- Effects of the wide angle soft gluon radiation can be studied in the limit $\langle p_T \rangle / Q_0 >> 1$
- Color singlet exchange is expected to become important if both conditions are satisfied at the same time.
- This process is also important in Higgs searches in the VBF production mechanism where a central jet veto is applied to reject background, in the Higgs plus 2 jets channel.
- Two different ways to define the Dijet system:
  1.- The Dijet system two leading p_T jets.
  2.- The Dijet system the most forward and the most backward jet.

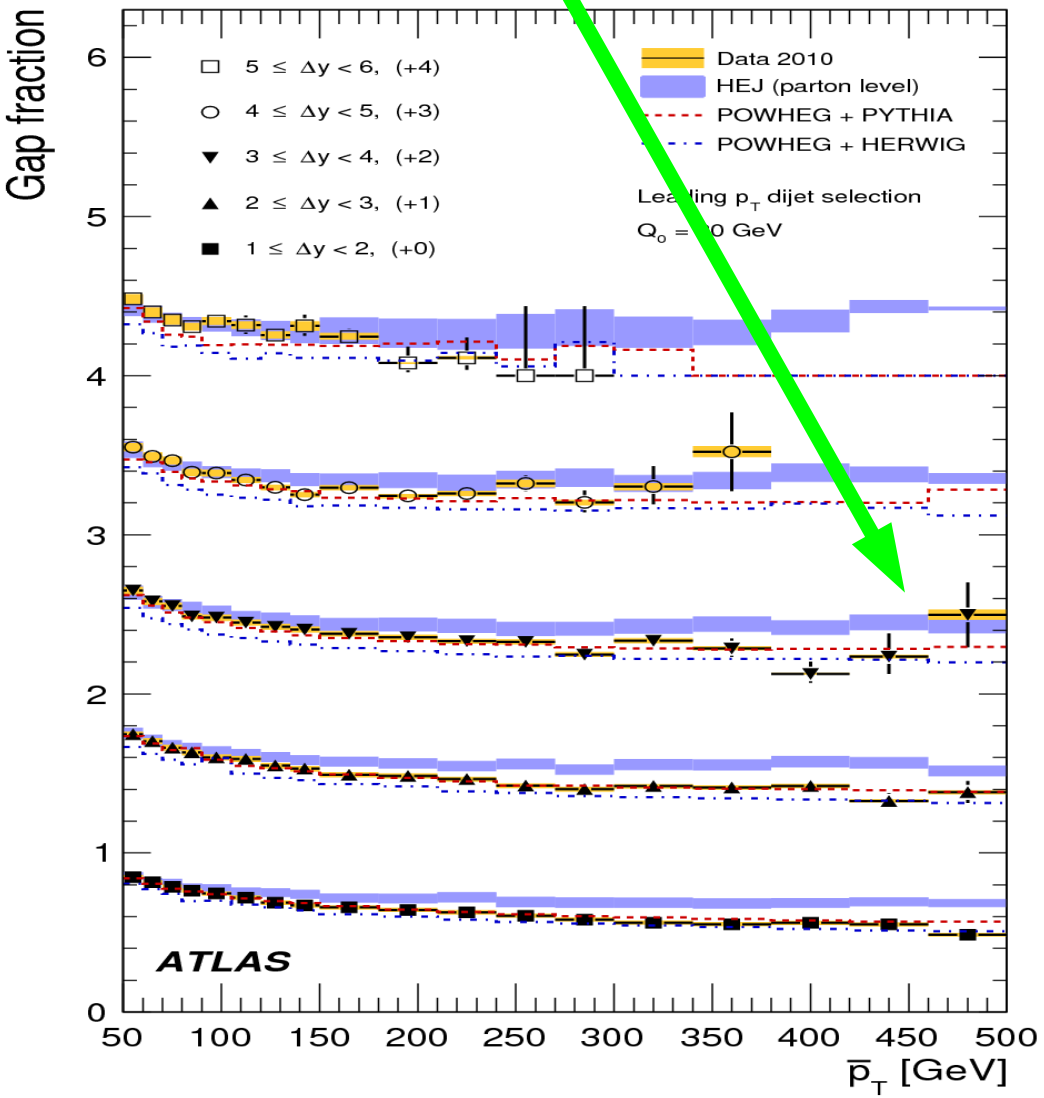
- **Gap fraction: Fraction of dijet events that not have an additional jet with a $p_T > Q_0$.**

Dijet production with a central (jet) veto

Dissagreement between data and NLO predictions at large Δy, lack of a fully comprehensive QCD picture in this limit.

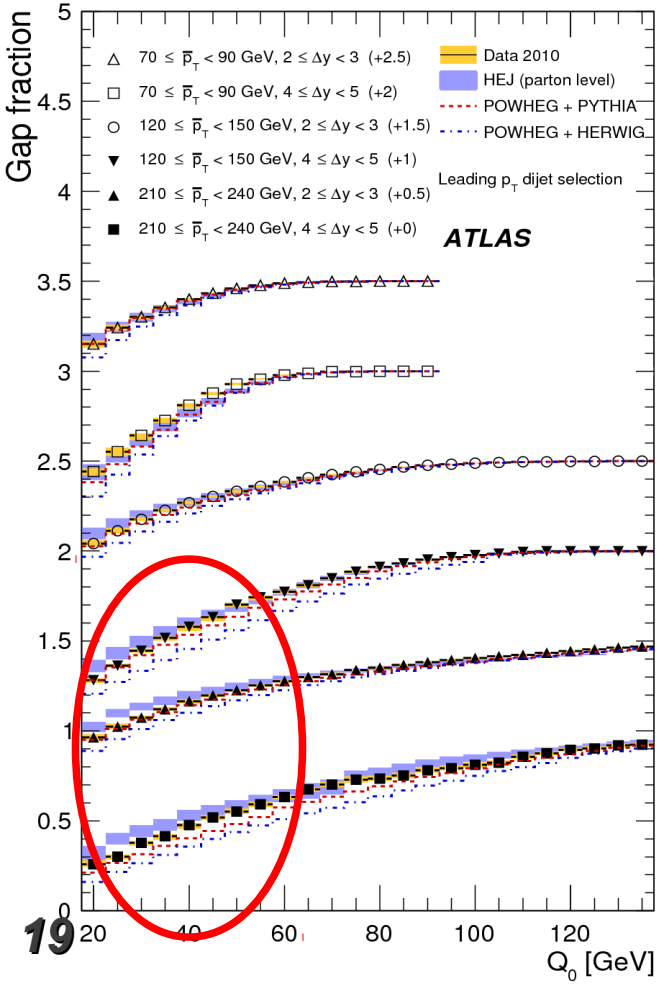
As function of $\langle p_T \rangle$, HEJ predict a larger fraction of gap events at larger $\langle p_T \rangle$. While POWHEG gives the best description to the data.

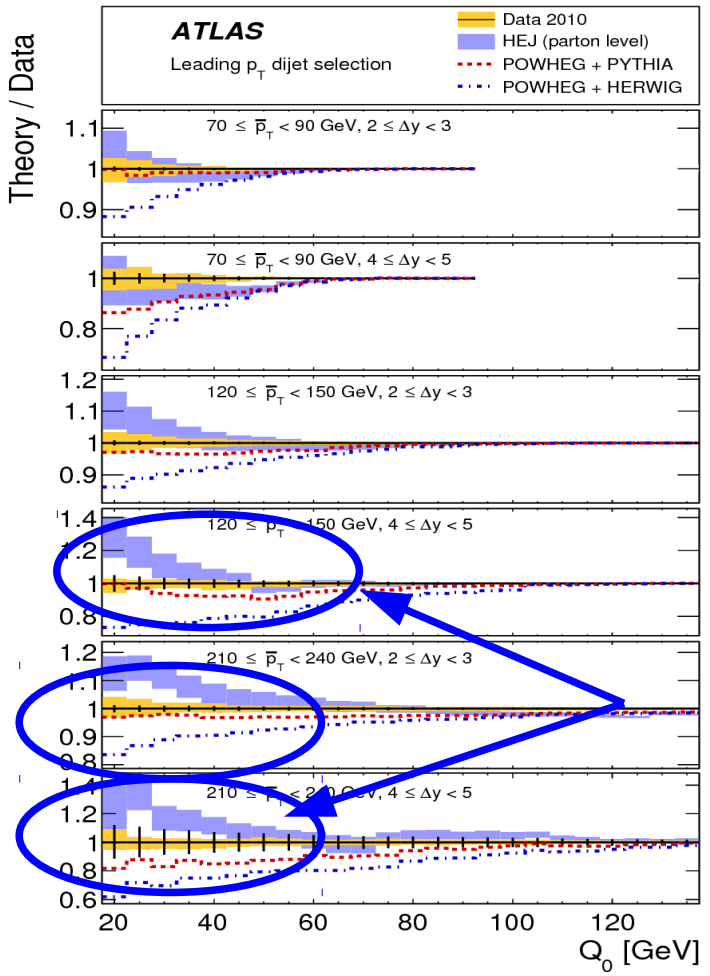




Dijet production with a central (jet) veto

- Gap fraction as a function of the veto on the energy scale (Q_0).





$$\bar{p}_T \gg Q^0 \gg \Lambda_{QCD}$$
$$\Delta y \sim large$$

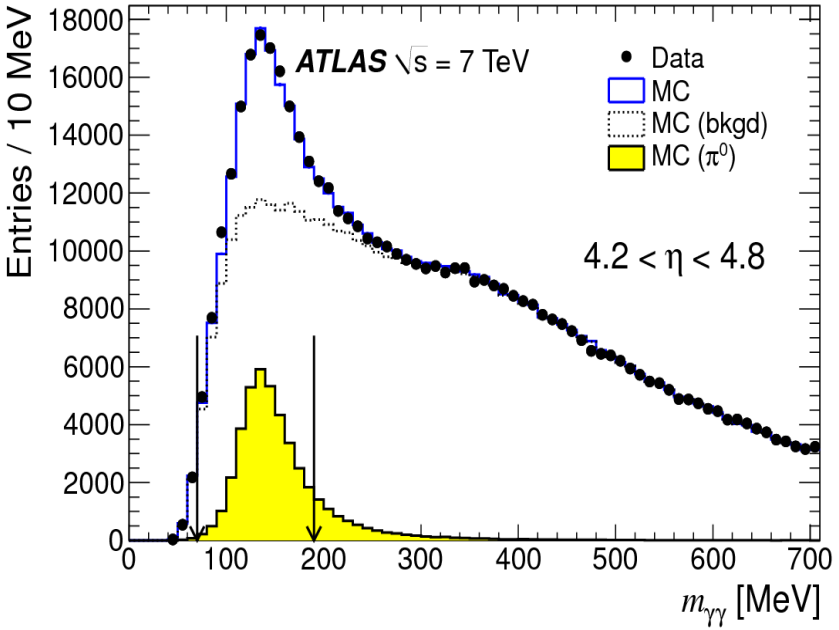
Regions dominated by color siglet exchange, not well described by NLO models

Measurements of the pseudorapidity dependence of the total transverse energy in proton-proton collisions at sqrt(s)=7 TeV with ATLAS

JHEP11(2012)033

(Forward) Transverse Energy Flow

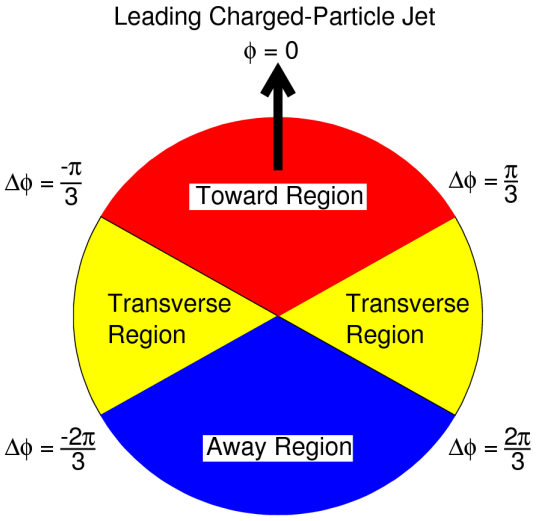
- Measured in two different event samples MinBias and Dijet
- Electromagnetic scale determined with $\pi_0 \rightarrow \gamma\gamma$ decays in the forward detector.



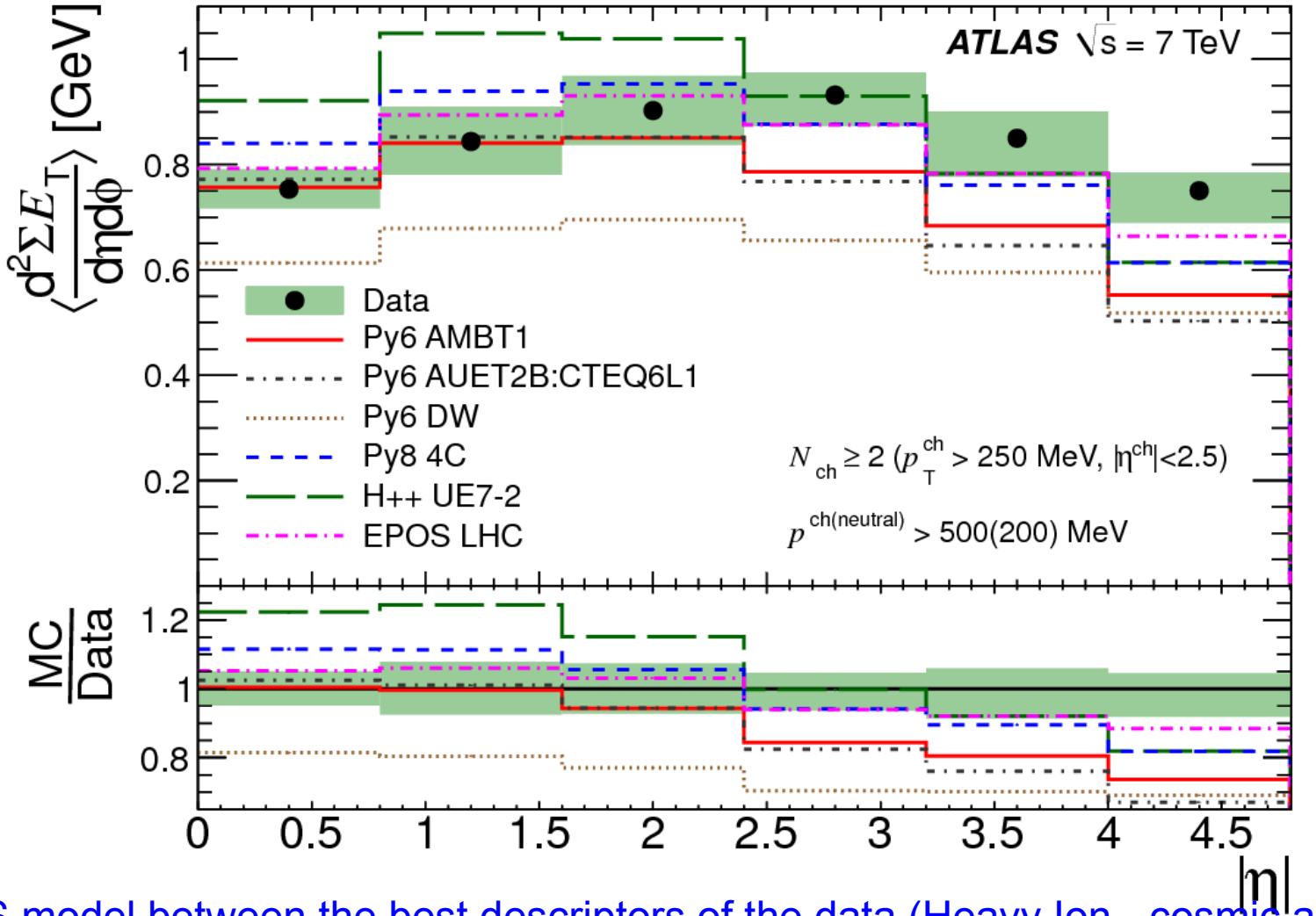
- Track and topological cluster based ΣE_T algorithm with $|\eta| < 4.8$, $p_T > 500$ MeV (charged), $p_T > 200$ MeV (neutrals).

1.- Summed over all φ in the MinBias sample

2.- For transverse (yellow) region in events with a central Dijet system (sensitive to the underlying event).

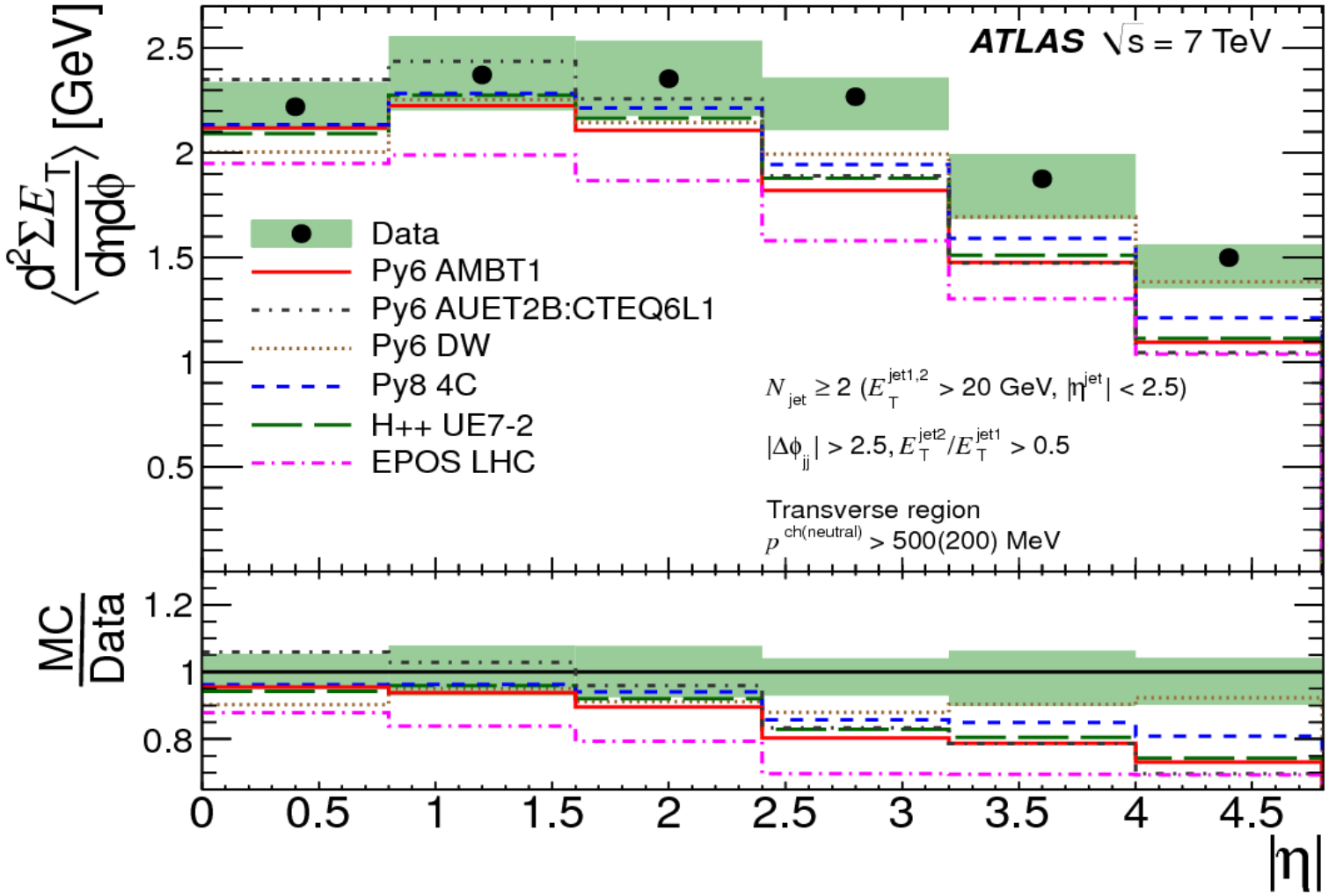


Energy density distribution (MinBias)



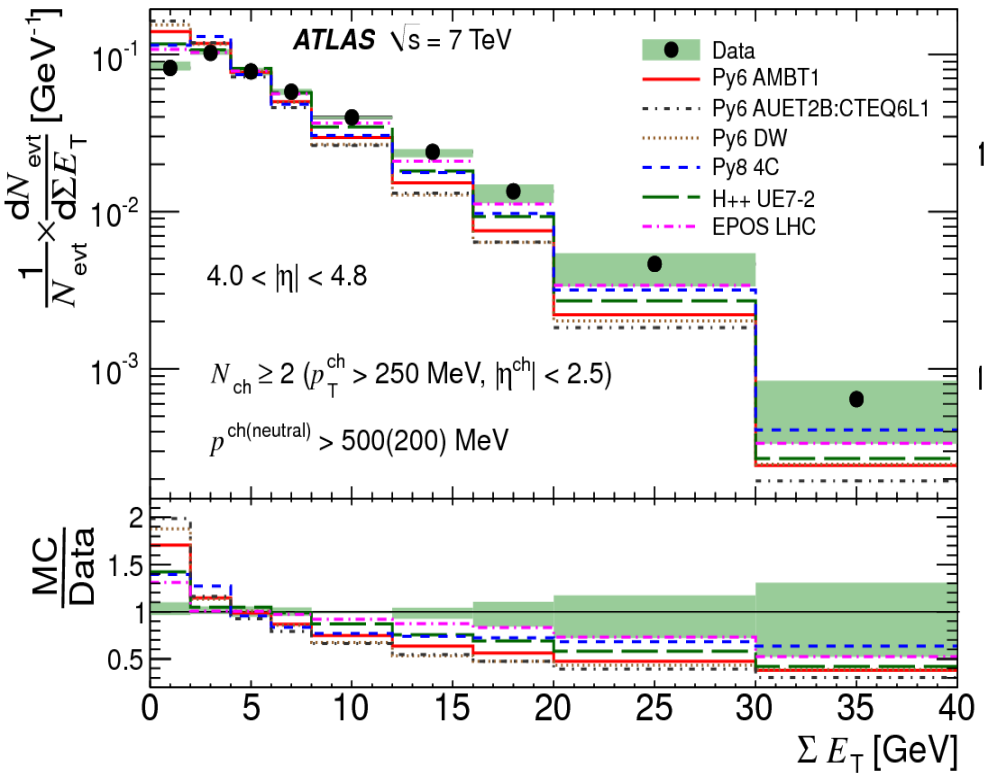
- EPOS model between the best descriptors of the data (Heavy Ion - cosmic air shower generator).
- Energy density underestimated in the forward region by all the models.

Energy density distribution (Dijet)

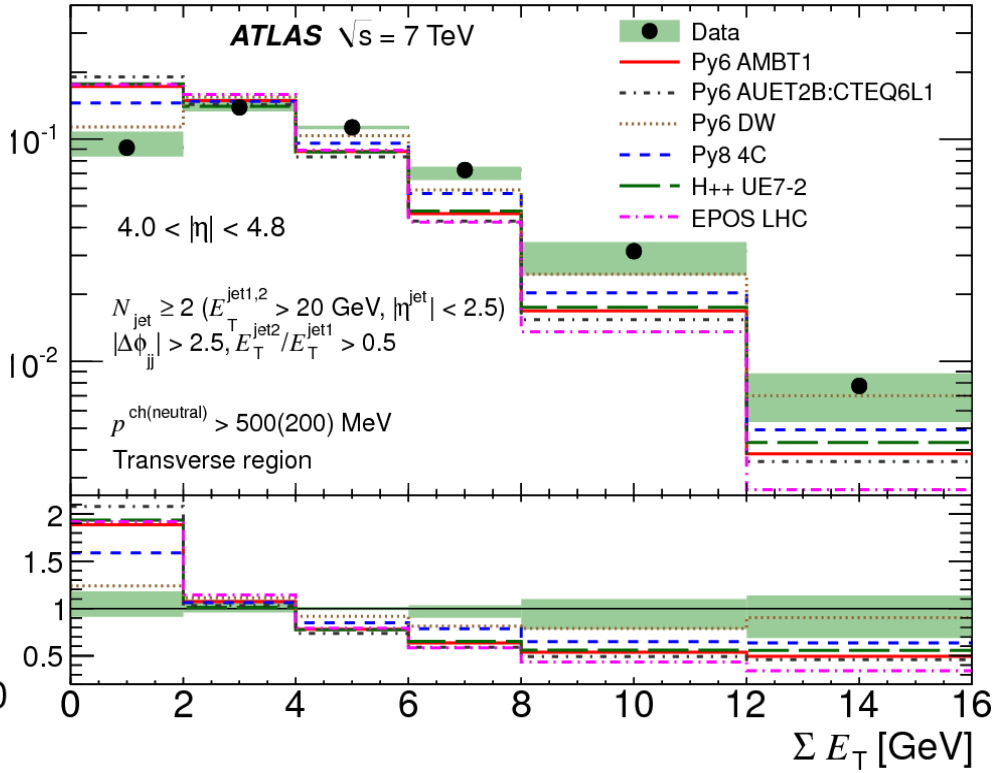


- Spectrum ~3 times harder in the central region, ~2 times in the forward region, compared to the MinBias selection.
- Similar conclusions as for MinBias selection, although better description of Herwig++.
- EPOS tune to the LHC data not based in underlying event measurements.

Total Forward Transverse Energy



MinBias

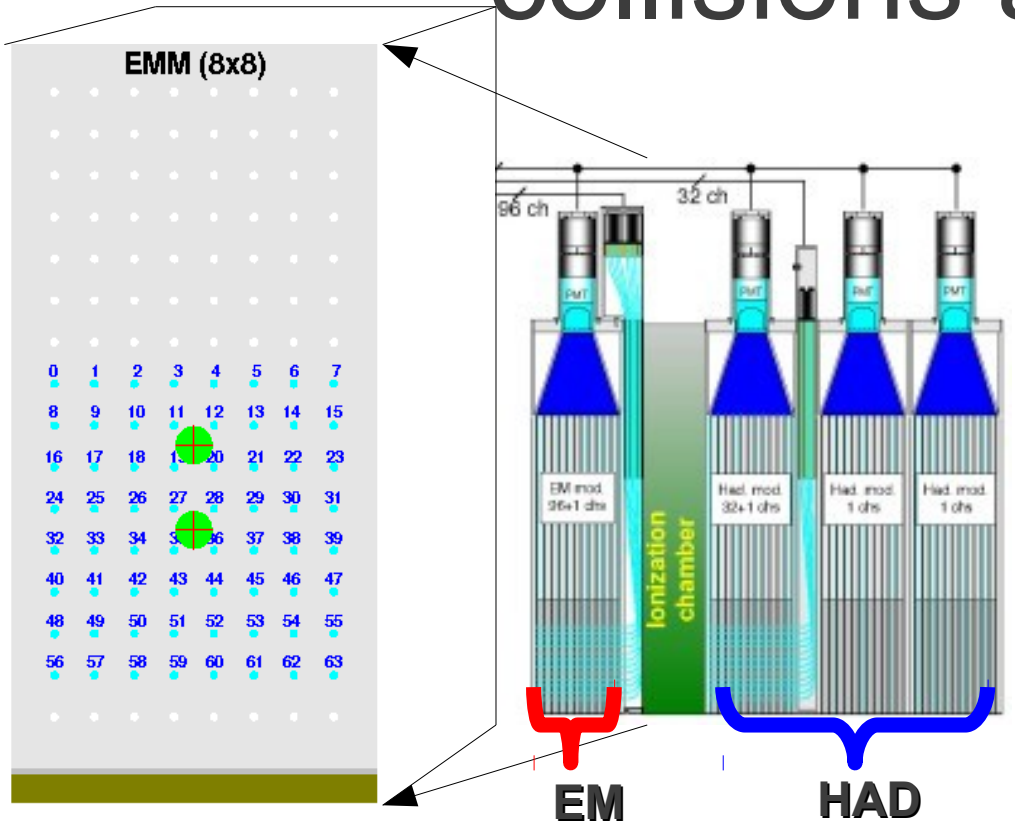


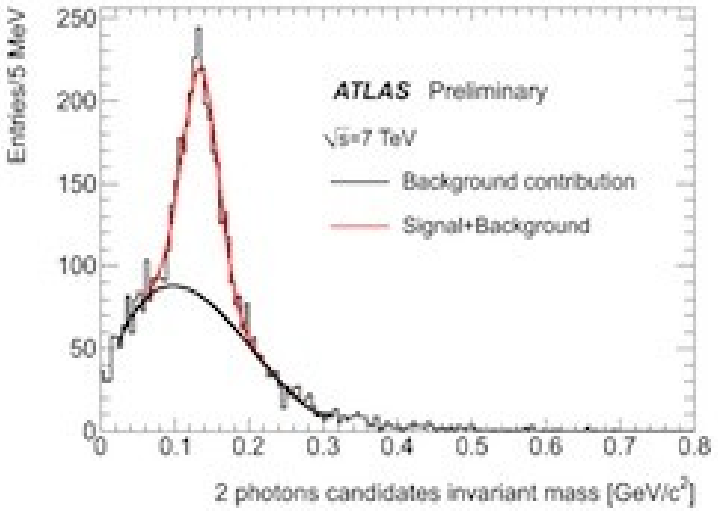
DiJET

- ***Distribution is overestimated in the low E_T region while it is underestimated in the high energy tail.***

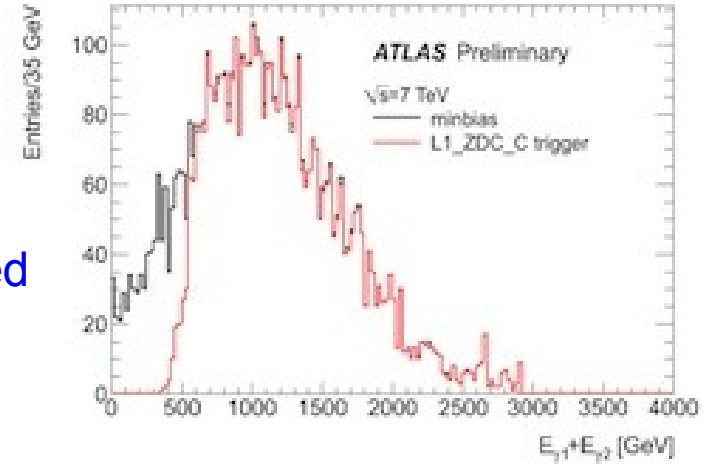
Performance of the ZDC detector in pp (at 7TeV) and HI (at 2.76 TeV) collisions and its potential to study peripheral interactions.

ZDC measurements in pp collisions at 7 TeV



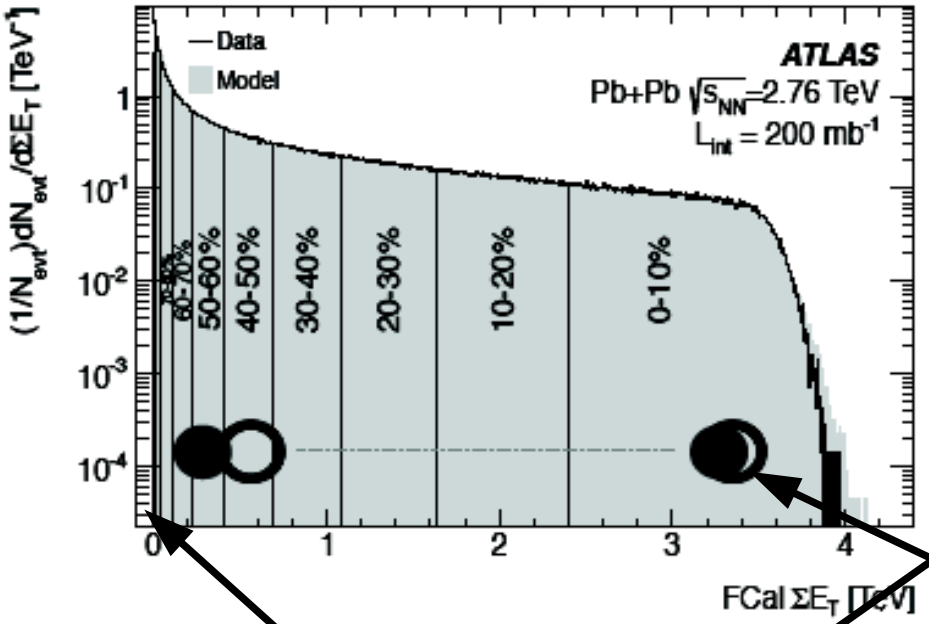


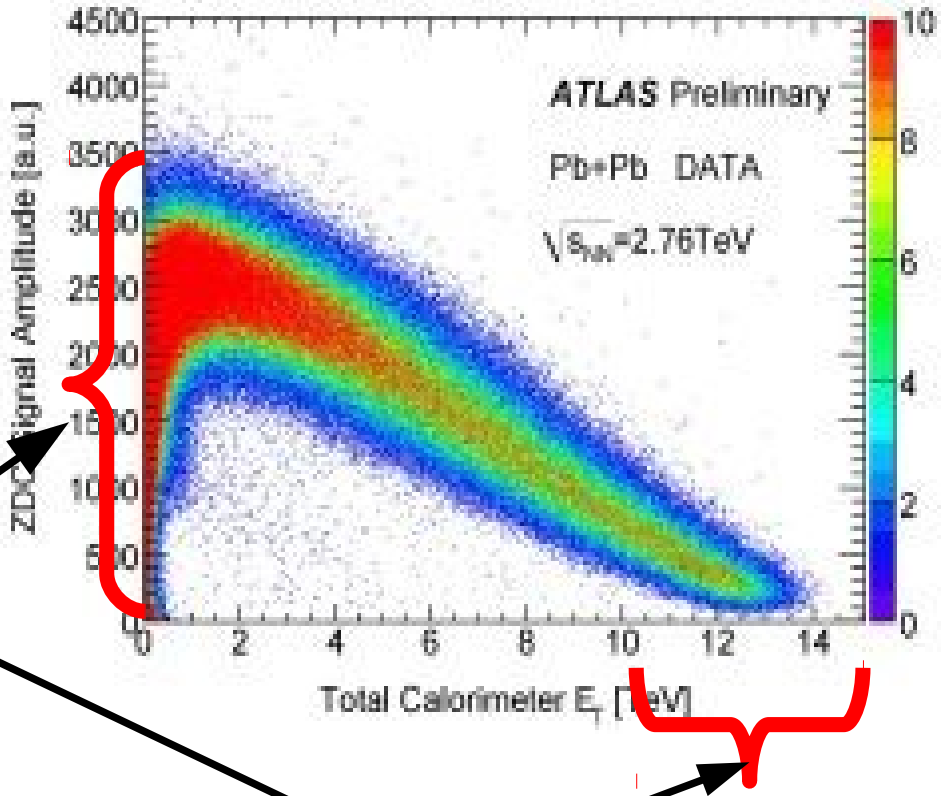
- Reconstruction of the inv. mass of two photon events, π_0 peak used for calibrating the EM module



- ZDC segmented module, sensitive to photon positions (transverse view) present only on one side respect to the ATLAS interaction point **!**.
- The impact point of a photon into the ZDC is found by a cluster reconstruction algorithm using the EM segmented module (which is equiped with a readout of 8x8 pixels).
- Two photons energy sum distribution extracted from the invariant mass plot

Peripheral HI physics with ATLAS





Peripheral

(Few particles)

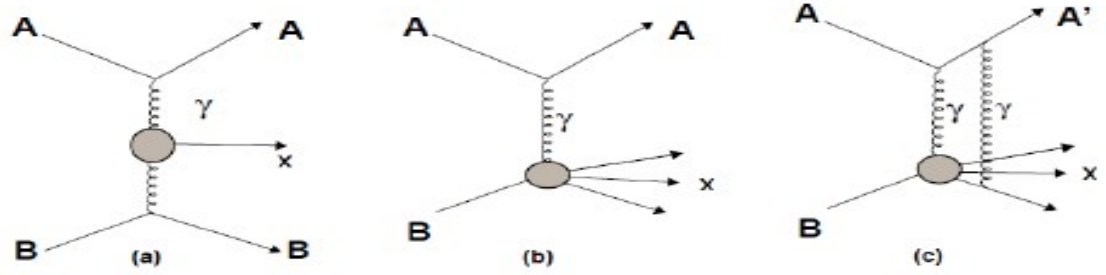
Dominated by electromagnetic and soft QCD interactions (Pomeron echange)

Head-on

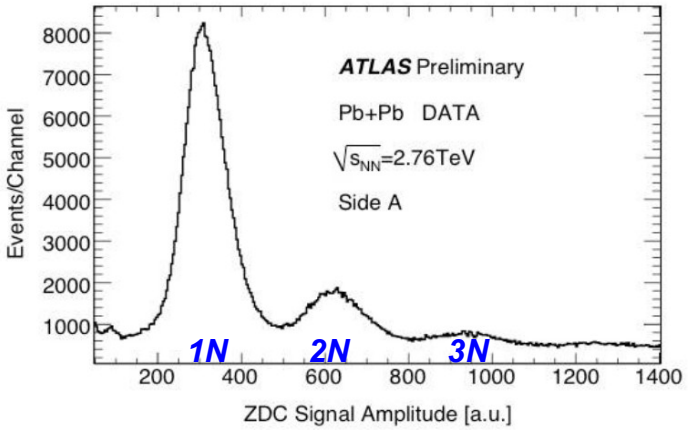
(Thousands of particles)

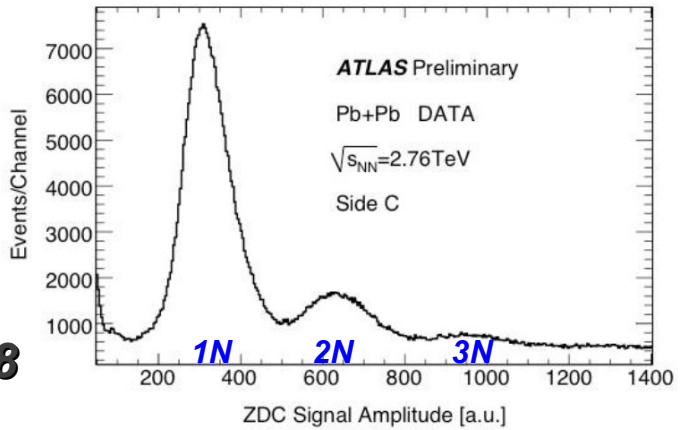
Dominated by hot QCD interactions, collective phenomena

ElectroMagnetic Dissociation (EMD)



Huge cross sections: $\sigma_{single\text{-}EMD}$~185 b, $\sigma_{mutual\text{-}EMD}$~5.5 b (Reldis)





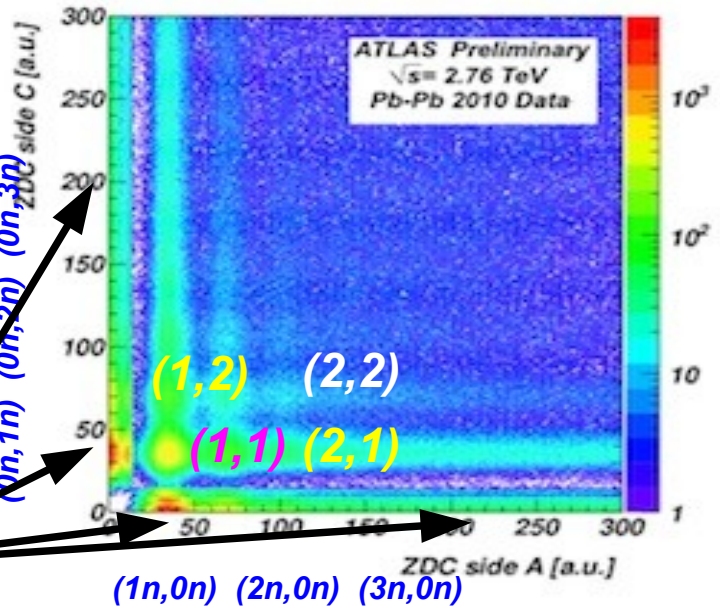
ZDC acceptance ~100% to forward neutron emission from EMD

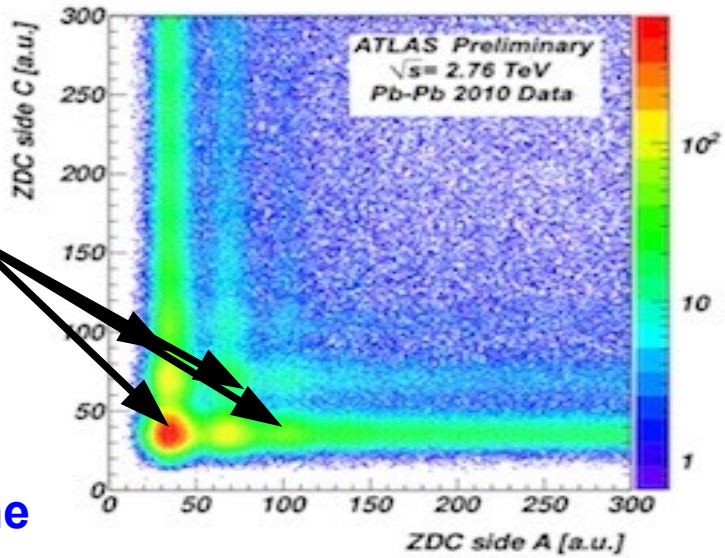
SINGLE DISSOCIATION

MUTUAL DISSOCIATION

The electromagnetically excited nuclei decays through neutron emission (with the beam energy) to the ground state.

(ZDC OR Trigger)



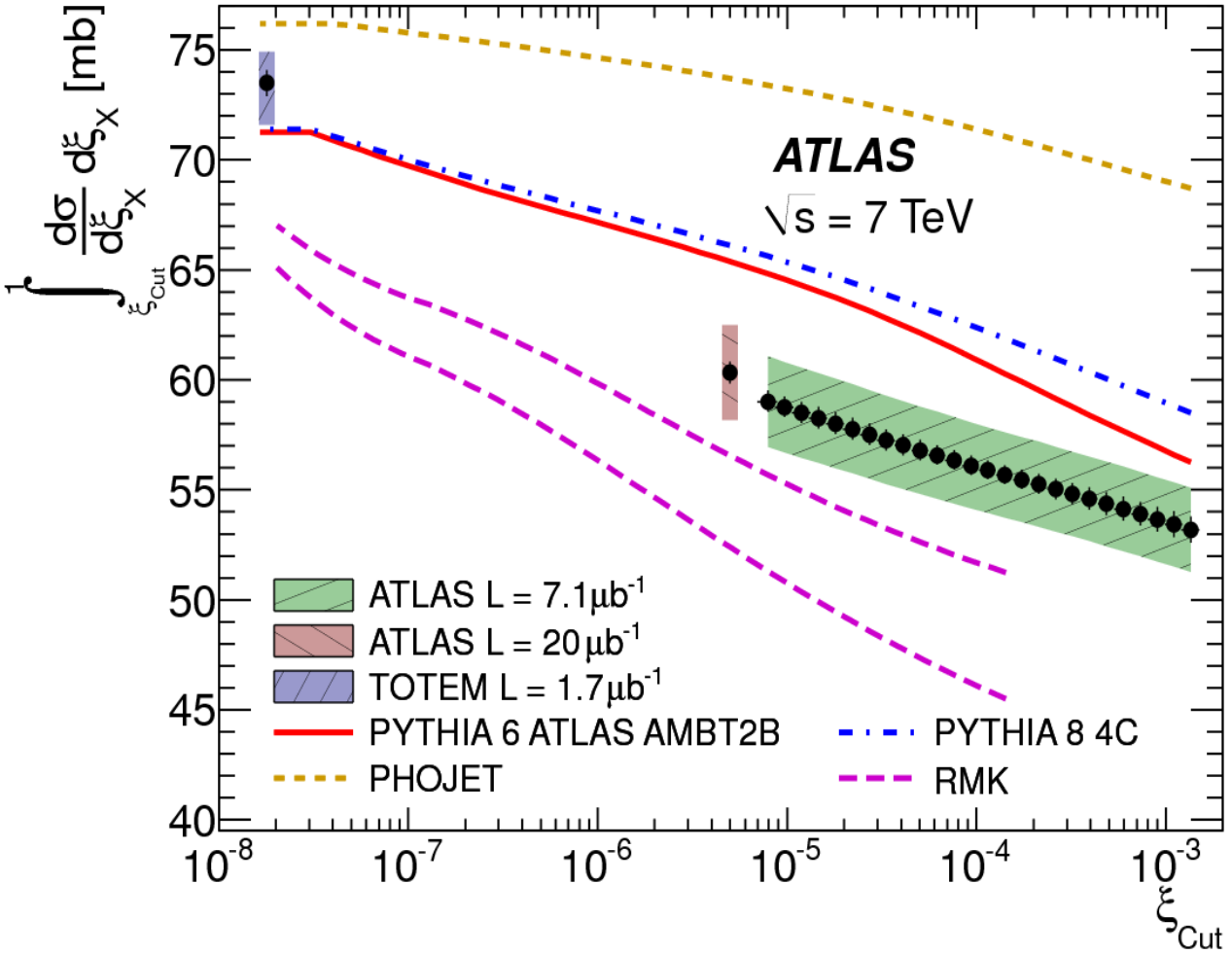


(ZDC AND Trigger)

Summary

- *Rapidity gaps have been measured up to $\Delta\eta_F$=8 from the FCal edge.*
- *Soft diffraction broadly described by single soft pomeron with intercept as expected.*
- *Low mass diffraction beyond the current experimental acceptance (ALFA data analysis on elastic and single diffraction are ongoing in runs with special optics).*
- *Inclusive jet cross section measured for jets up to rapidities of 4.4 (for the first time – in hadron-hadron collisions) – Tension between the NLO predictions and/or PDFs in the forward region, but in general good agreement with NLO predictions.*
- *Dijet measurement with a veto on additional jet activity show depart from the NLO predictions in the large Δy regime, need improved description of the soft activity and color singlet echange processes.*
- *Energy flow not well described in the forward region by current models.*
- *Good performance of ZDC in (low lumi) pp and HI collisions, specially useful for tagging UPCs with nuclear break-up.*

Total inelastic integrated cross down to ξ_{Cut}



- The integrated inelastic cross section results compared to TOTEM result shows that small ξ region is underestimated in PYTHIA and PHOJET.

- All diffractive interactions excluded below

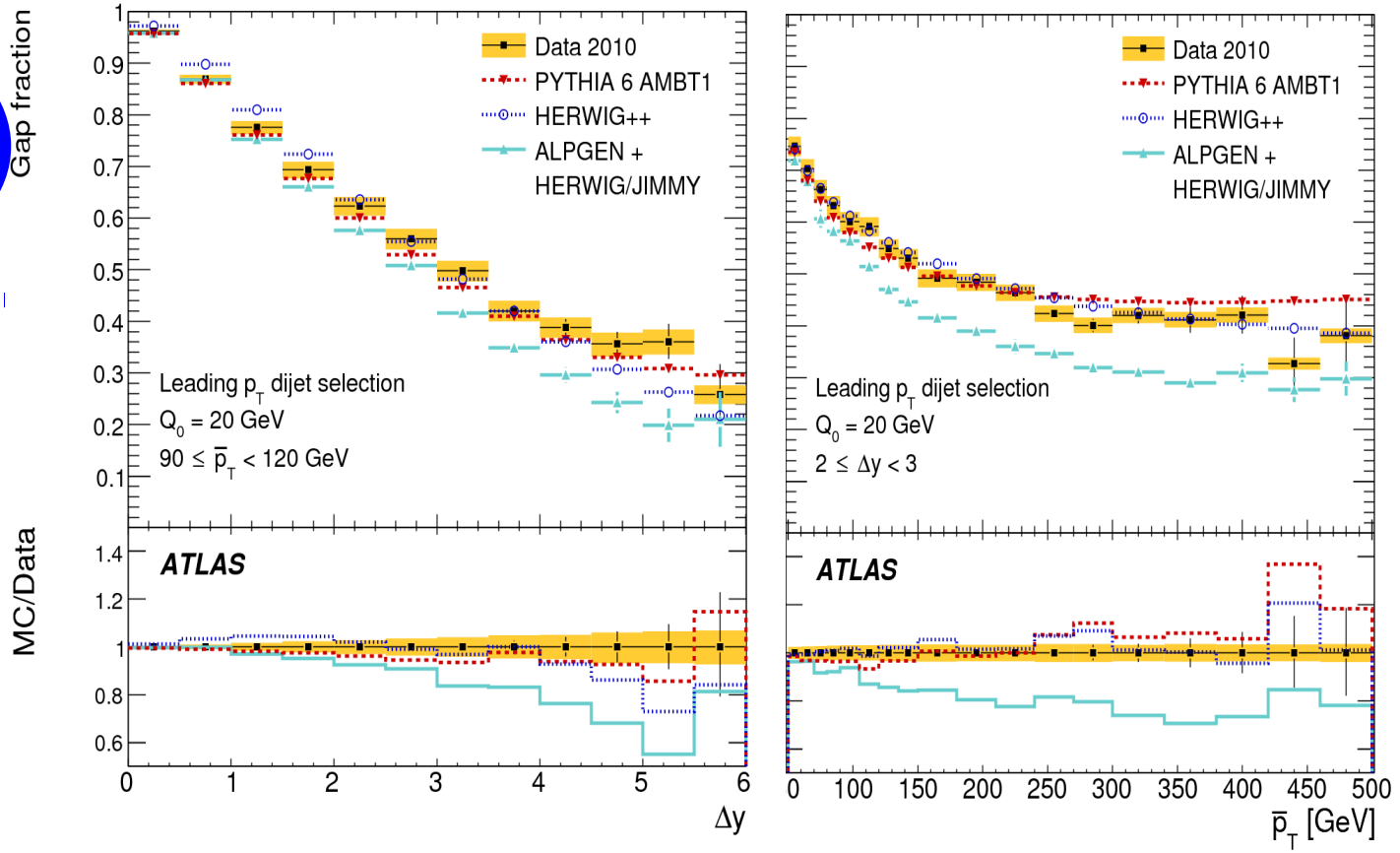
$$\xi < \xi_{CUT}$$

Dijet production with a central (jet) veto.

To quantify the additional radiation in the region defined by the two jets system, we use:

- Gap fraction: Fraction of dijet events that not have an additional jet with a $p_T > Q_0$.

- The mean number of jets with pT > Q_0 in the rapidity interval bounded by the dijet system.



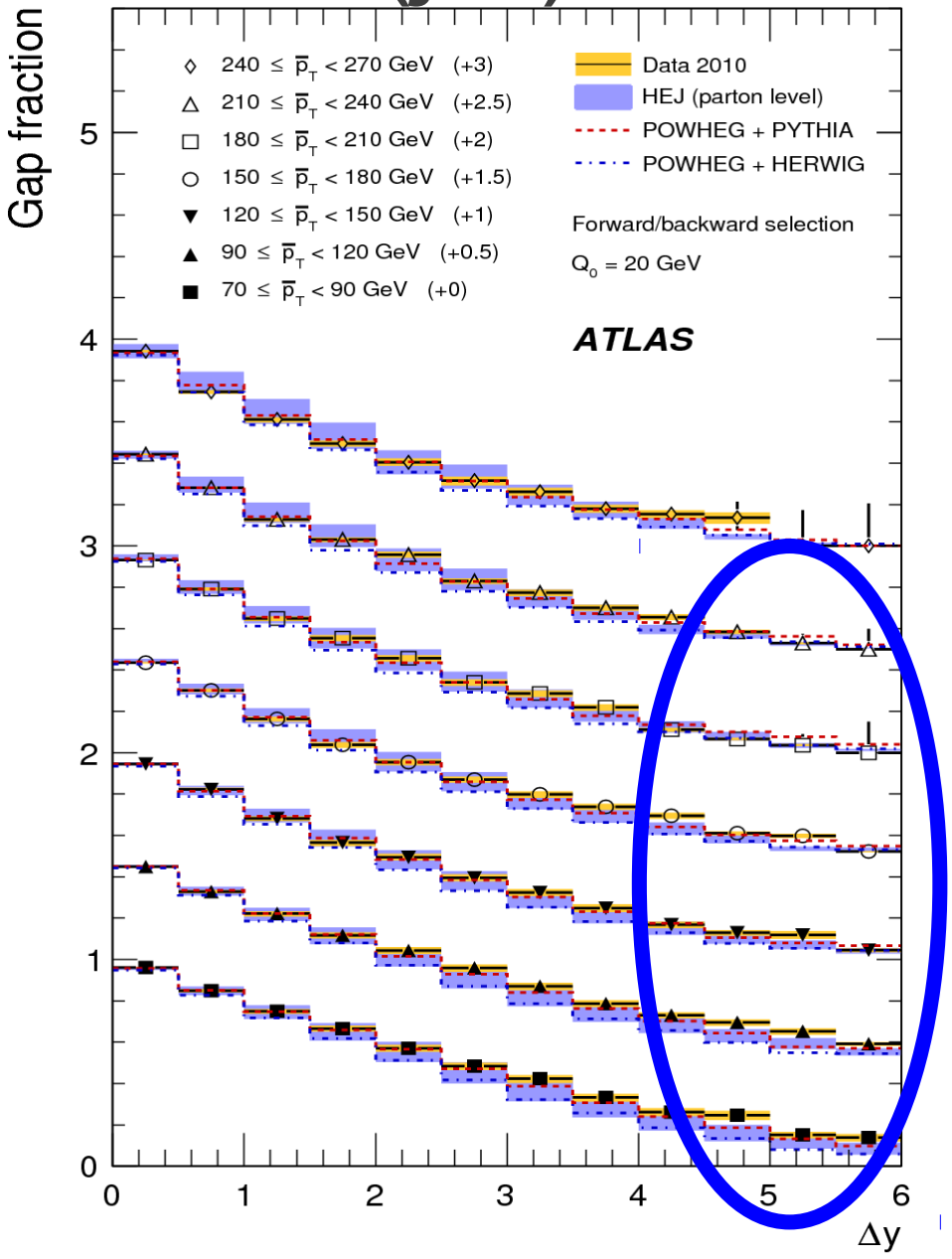
- ALPGEN + HERWIG+JIMMY show the largest deviation from the data.

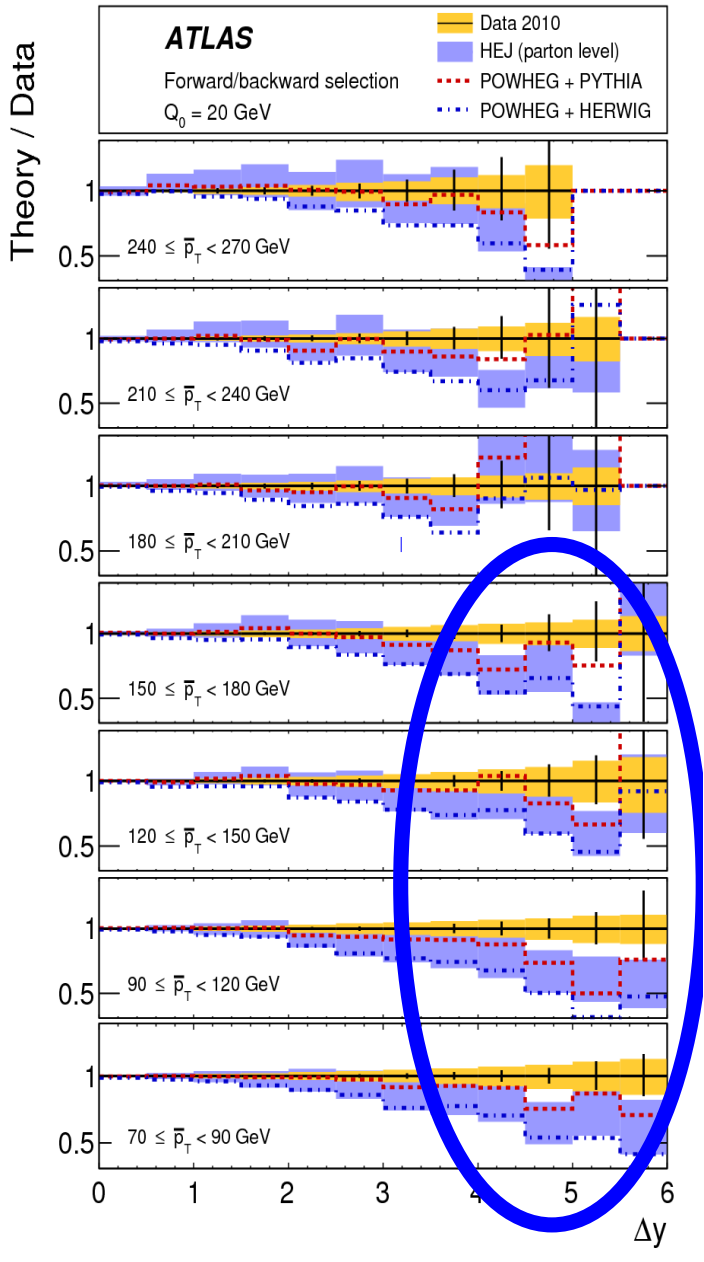
Dijet production with a central (jet) veto

Most forward and most backward Dijet selection (Sensitive to BFKL dynamics).

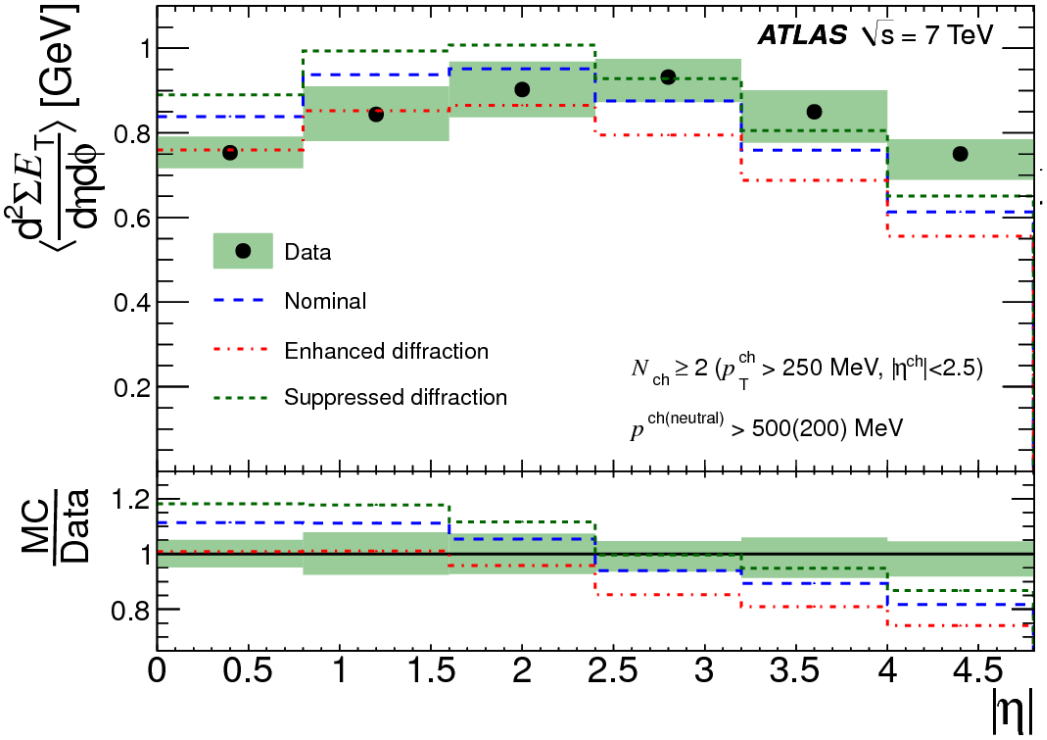
Data is not well described by HEJ and POWHEG at low values of $\langle p_T \rangle$ and large Δy, both models predict a smaller value for the gap fraction.

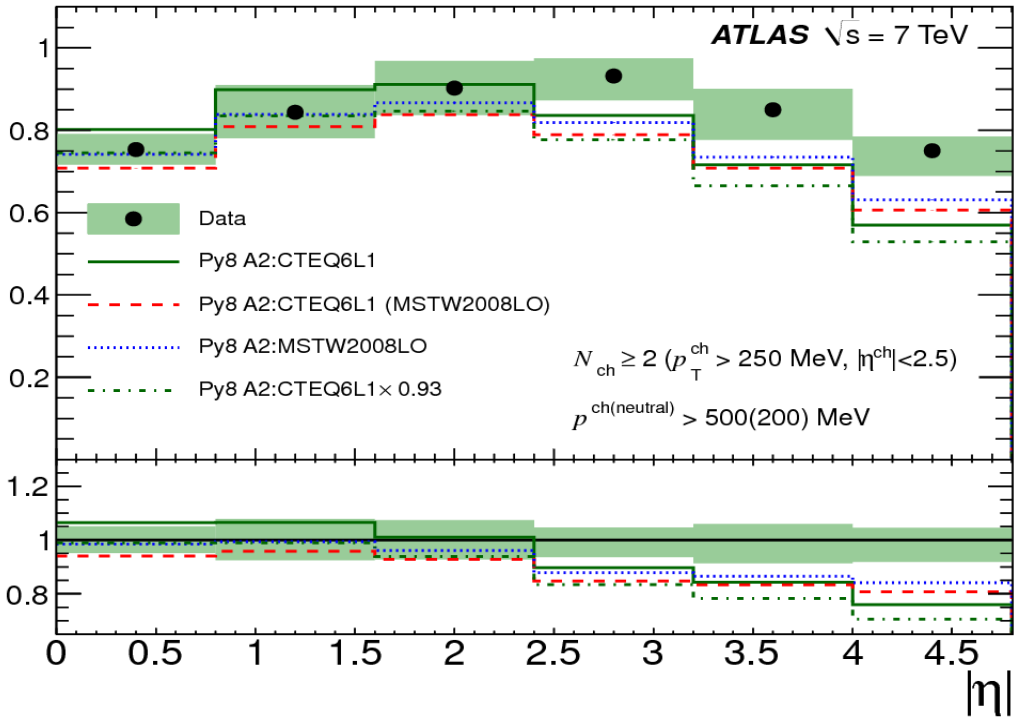
The resummation of soft emmisions could be important for this configuration.





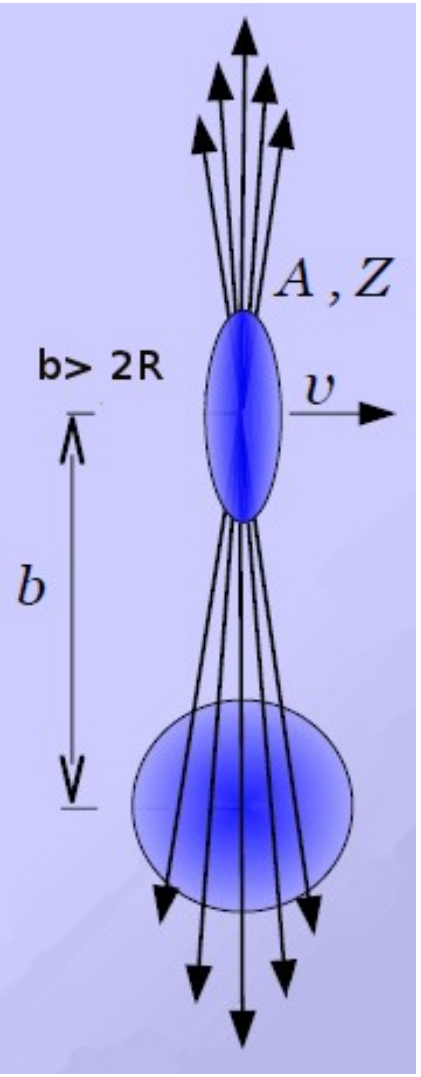
Diffractive modelling and PDFs tunes (minbias)



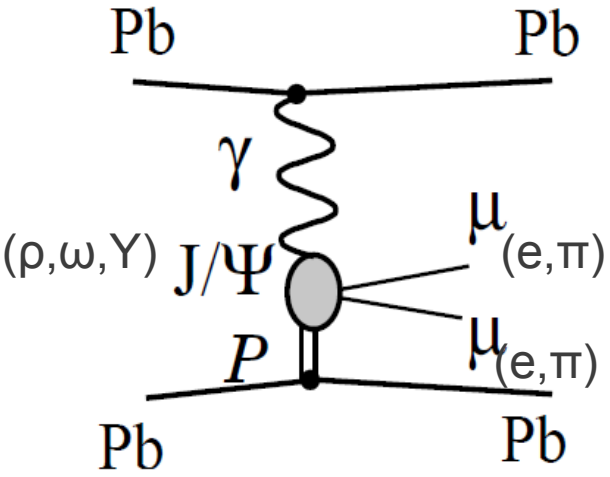


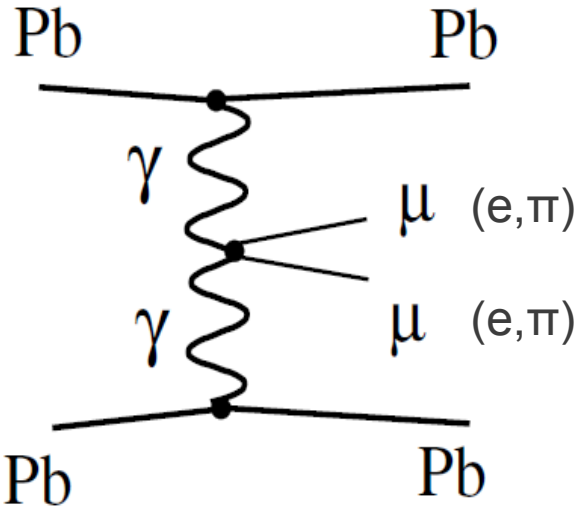
- Distributions reveal dependent on the role of diffractive processes.
- Several PDFs and tunes used in Pythia8, specially sensitive to the high and low-x gluon PDF, where uncertainties are larger in the PDF fits.
- When going from the CTEQ 6L1 to the MSTW2008 LO PDFs, decreases the amount of energy in the central region while it increases in the forward region.

Photoproduction of vector mesons with ATLAS



- Photon fluxes larger than in pp collisions by a factor of Z^2.
- The LHC acting as an effective γγ and γP collider.





- Specific triggers for ultraperipheral collisions (UPCs) were defined on 2011 PbPb and pPb 2013 runs, several analyses are ongoing.
- UPC provides unique oportunities to study low-x physics in PbPb and pPb collisions.
- Systems with masses of the order

$$2\gamma\hbar c/R \approx 100\,GeV$$

can be produced in PbPb collisions.