ATLAS results on diffraction

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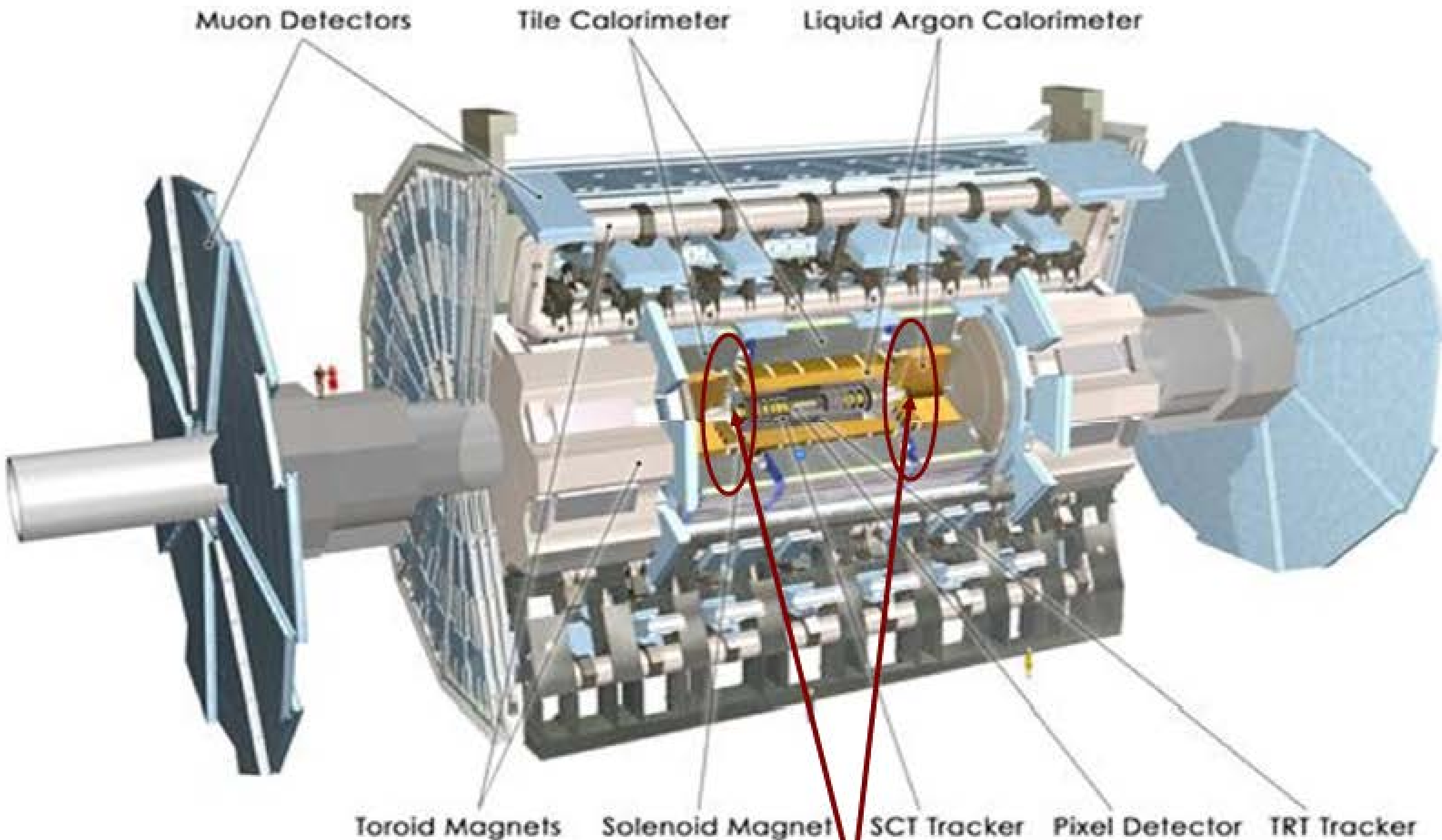
On behalf of the ATLAS collaboration

Diffraction 2012, Lanzarote, Spain - 13/09 2012

Diffraction results

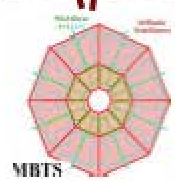
Future measurements

The ATLAS Detector



Trackers: |η|<2.5

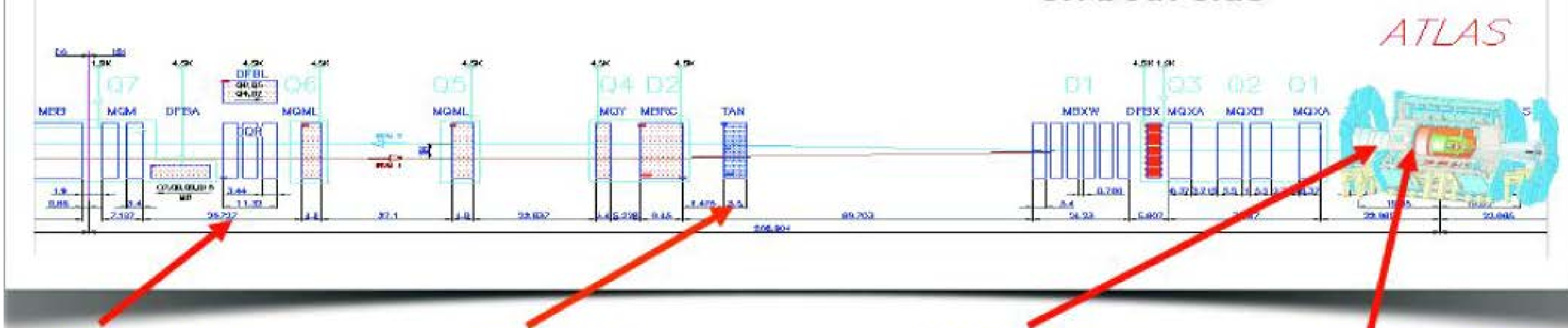
Calorimeters: |η|<4.9



Minimum Bias
Trigger Scintillator
2.1< |η|<3.8

ATLAS Forward detectors

on both side



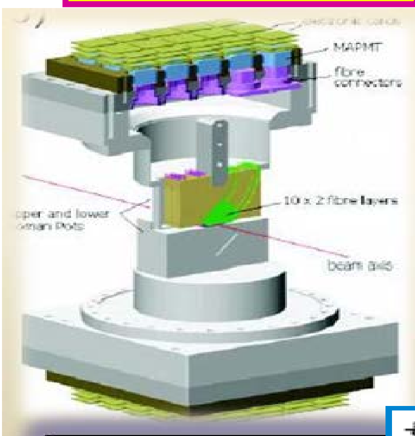
ALFA at 240 m

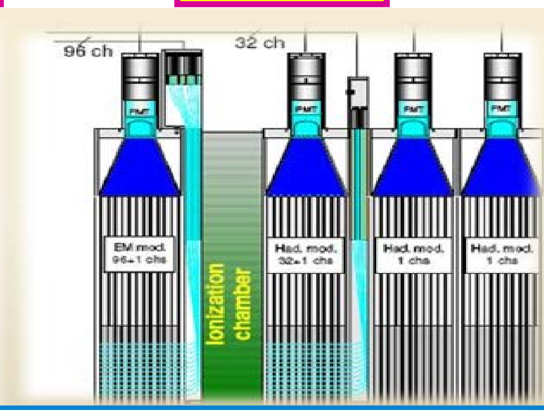
ZDC at 140 m

LUCID at 17 m

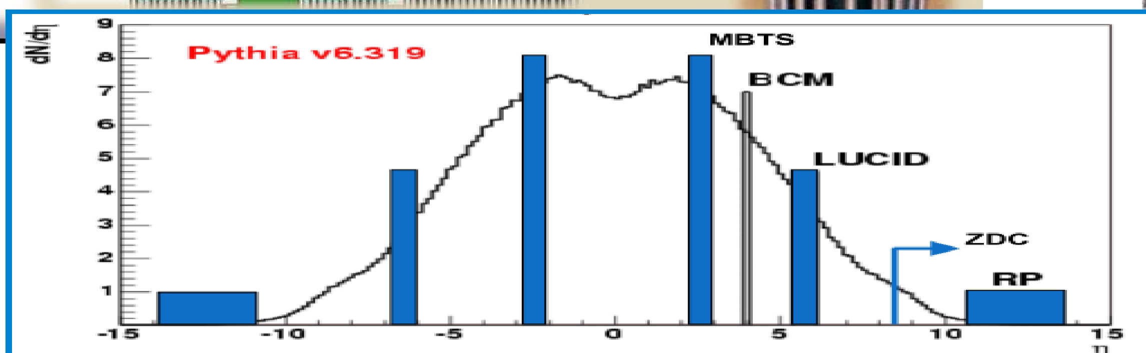
MBTS at 3.6 m

10.6 < | η | < 13.5	| η | > 8.3	5.6 < | η | < 5.9	2.1 < | η | < 3.8

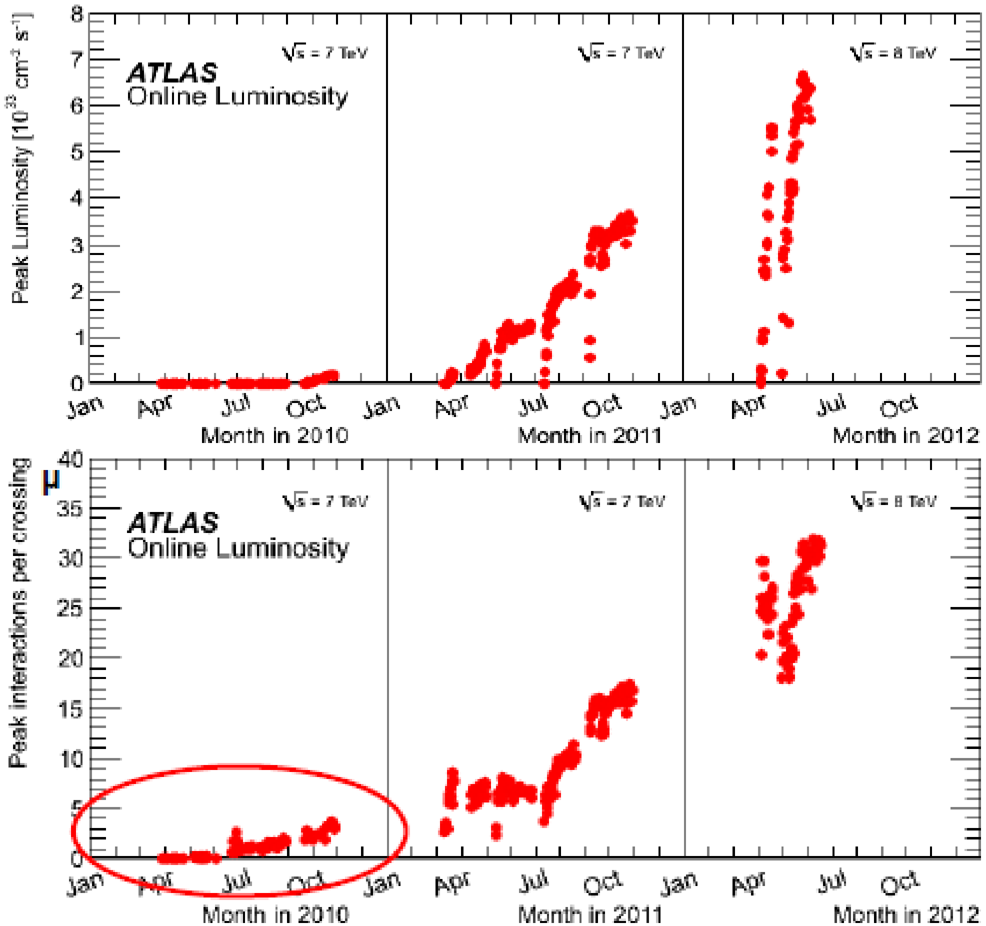


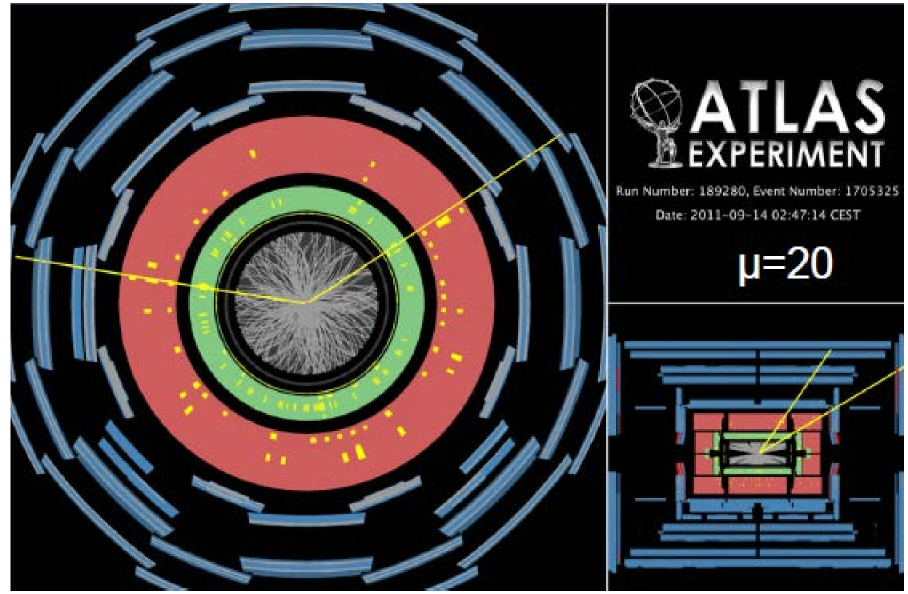


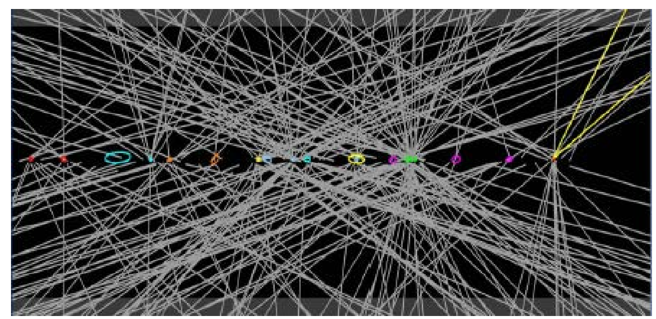
In operation since 2011



Diffraction needs very low Pile-up



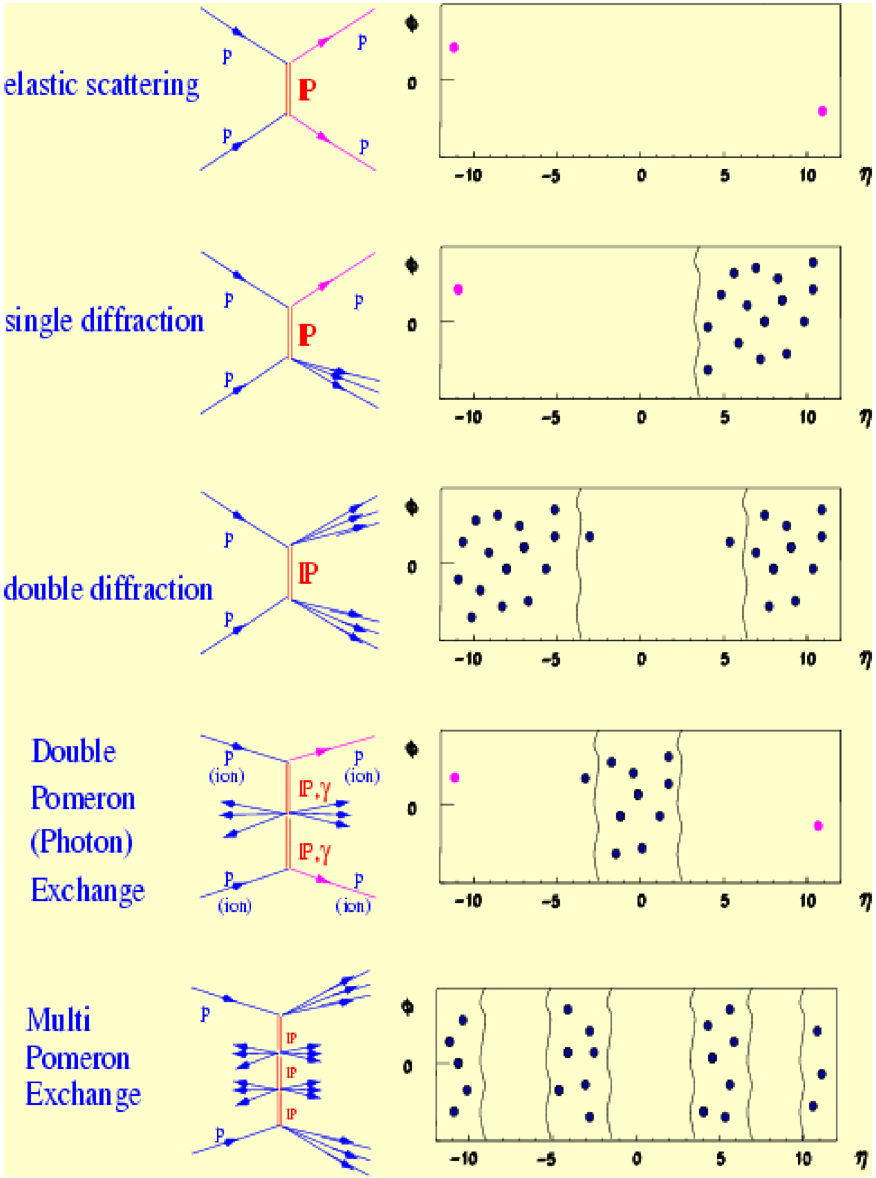




Pile-up = soft particles sitting on top of the hard-scale event, influencing efficiencies of various finding algorithms (Primary vertex, triggers, jets and other usual objects).

Diffractive signature: in the absence of forward proton detectors we have to rely on gaps. Gaps are easily seen only when Pile-up is low → concentrate on data 2010.

Diffraction at LHC:



- Forward proton tagging in special runs with ALFA

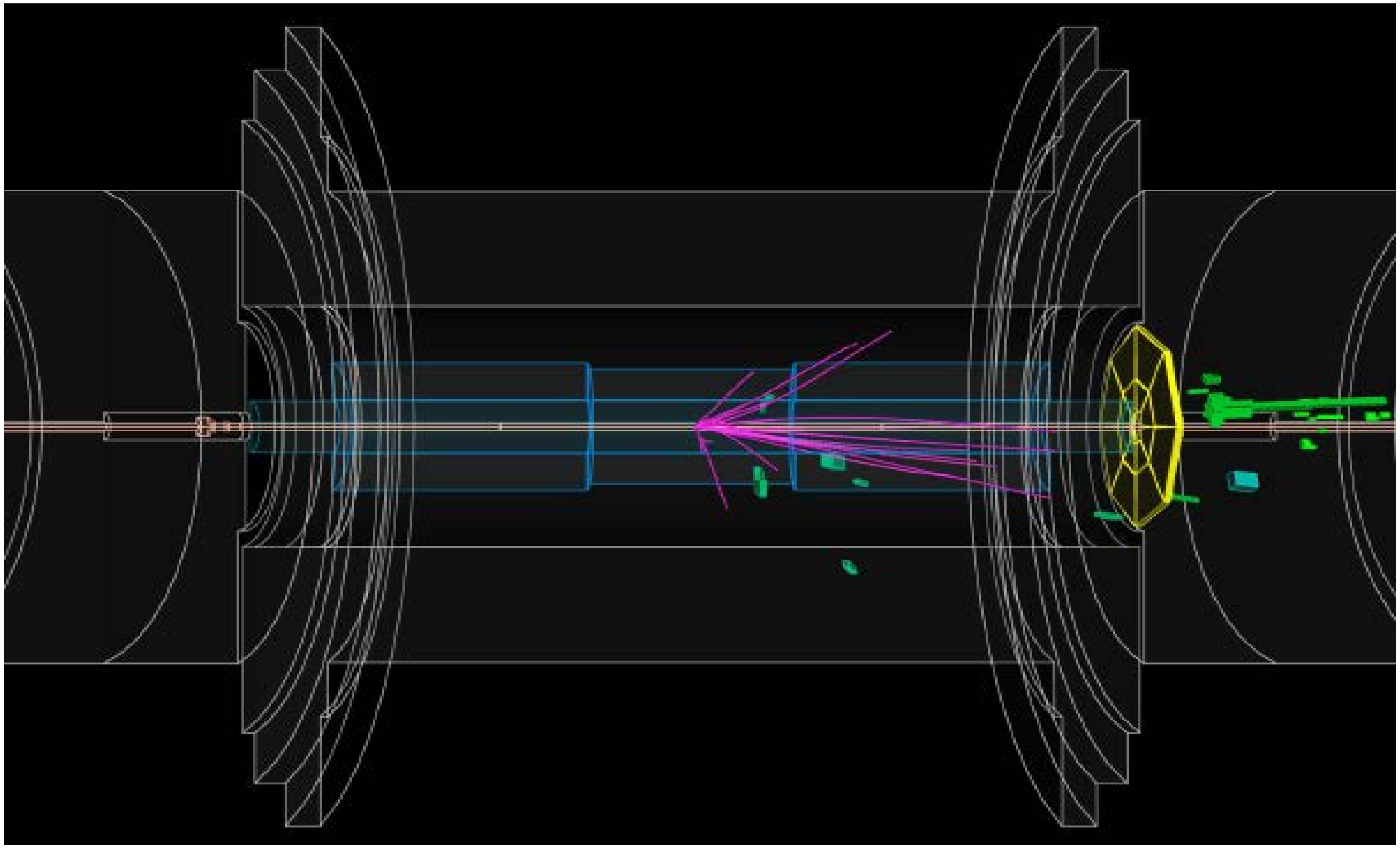
- Combined tag of proton in ALFA on one side and remnants of dissociated proton in MBTS/Calorimeter on the other side

- Central rapidity gap in EM/HAD calorimeters (|η|<4.9) and inner detector (|η|<2.5)

- Rapidity gaps on both sides of IP:
Double Pomeron Exchange: parton from Pomeron brings a fraction β out of ξ into the hard subprocess → Pomeron remnants spoil the gaps
Central exclusive production: β = 1 → no Pomeron remnants

Gaps in the detector

Typical Single-Diffraction event: activity on one side (proton remnants + possibly hard scatter), the other part of detector empty.



Measure $R_{SS} = \frac{N_{SS}}{(N_{SS}+N_{DS})}$, where N_{SS} = single-sided, N_{DS} = double-sided

Diffraction enhanced MinBias events

"Measurement of the inelastic pp cross section at $\sqrt{s}$ = 7 TeV with the ATLAS detector"

Nature Comm 2 (2011) 1926

L= 20 μb^{-1}, single fill in March 2010, $\mu = 0.01$

Event selection:

1) Veto activity in MBTS on one side of IP
2) $N_{trk} \geq 1$ ($p_T > 0.5$ GeV, $|\eta| < 2.5$)

Study:

1) Ratio of diffraction enhanced to inclusive events
2) Inelastic cross section

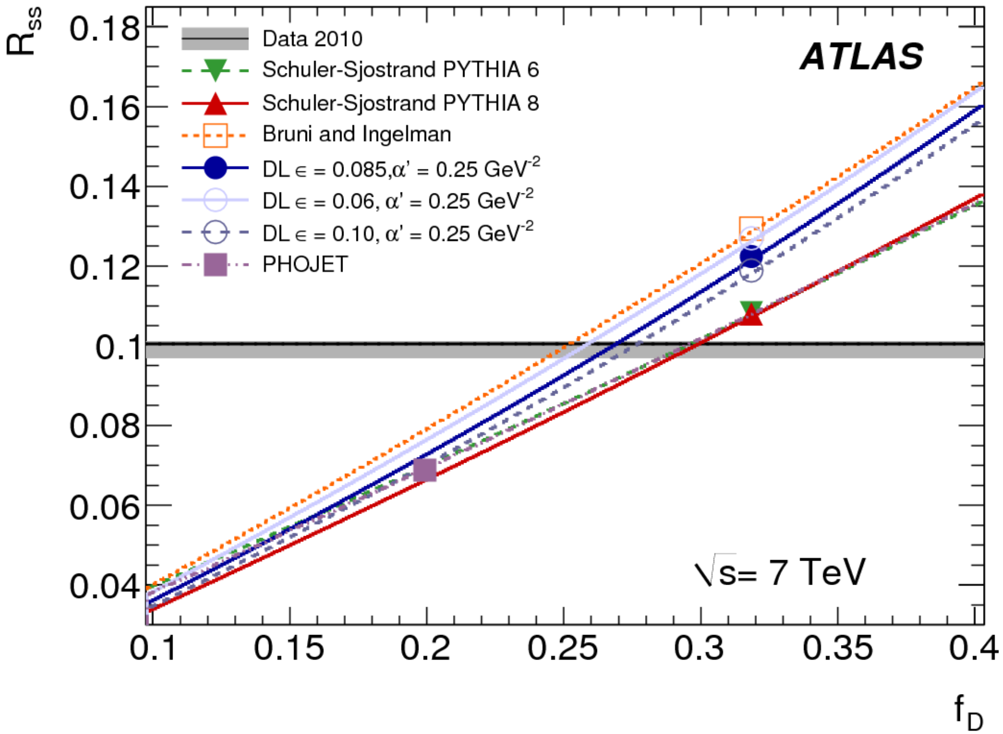
Diffraction enhanced MinBias events

Measure $R_{SS} = \frac{N_{SS}}{(N_{SS}+N_{DS})}$, where N_{SS} = single-sided, N_{DS} = double-sided

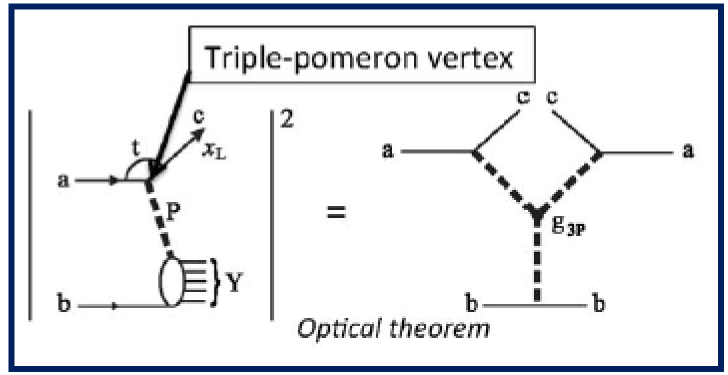
R_{SS} as a function of f_D - fraction of diffractive to inelastic events

$$f_D = {}^{(\sigma_{SD}+\sigma_{DD})}/_{(\sigma_{SD}+\sigma_{DD}+\sigma_{ND})}$$

Details on the analysis in the talk by T. Zenis



MC generators based on triple Pomeron exchange:



$$\frac{d\sigma}{d\xi} \sim \frac{1}{\xi^{1+\epsilon}}, \ \varepsilon = \alpha_{IP} - 1$$

Data: R_{SS} **= 10.0 ± 0.4 %** - requires f_D to be around 25-30% (depending on model)

Rapidity gaps in soft processes

"Rapidity gap cross section in pp interactions at $\sqrt{s}$ = 7 TeV"

Eur. Phys. J. C72 (2012) 1926

L= 7.1 μb^{-1}, taken in March 2010, μ < 0.005

Event selection:

1) Only good tracks with p_T > 200 MeV
2) Only calorimeter cells with E > noise (~5σ_{noise})
3) Look for empty η-rings starting from the edge of calorimeter (|η| < 4.9)

Study:

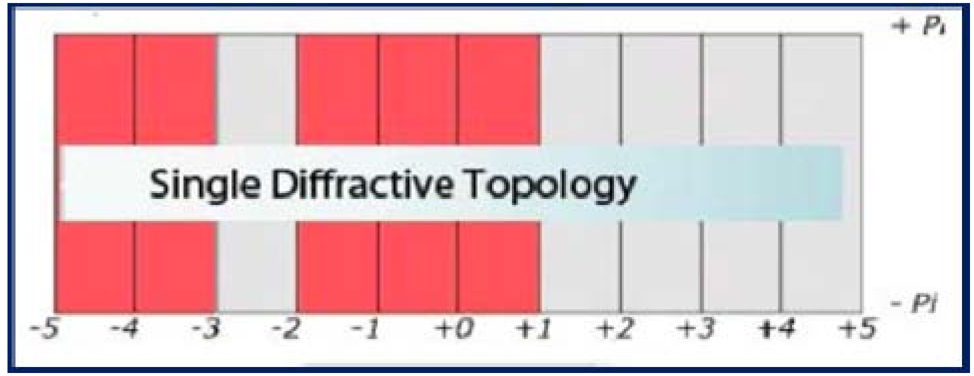
1) Gap spectrum
2) Predictions of various MC models
3) Diffraction dynamics

Rapidity gaps in soft processes

Definitions of gaps

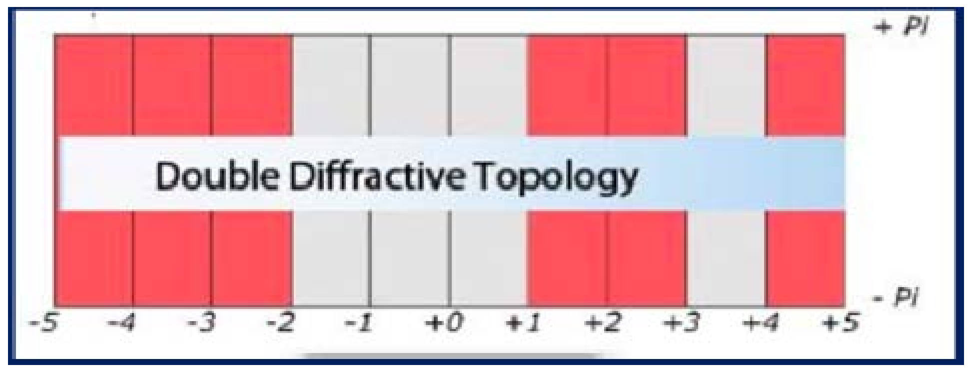
Detector level:

Detector divided into η-rings of size 0.1
in the calorimeter (|η|<4.9)
Ring is considered empty if
- No track with p_T > 200 MeV (|η|<2.5)
- No calo cell with E > 4.5-5.5 σ_{noise}(η) (|η|<4.9)



Hadron level:

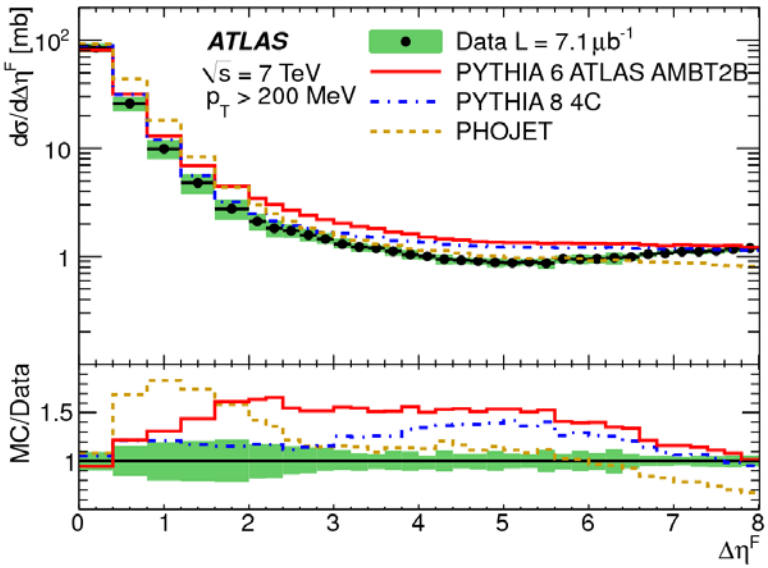
Phase space divided into η-rings of size 0.1
Ring is considered empty if
- No stable particle with p_T > 200 MeV

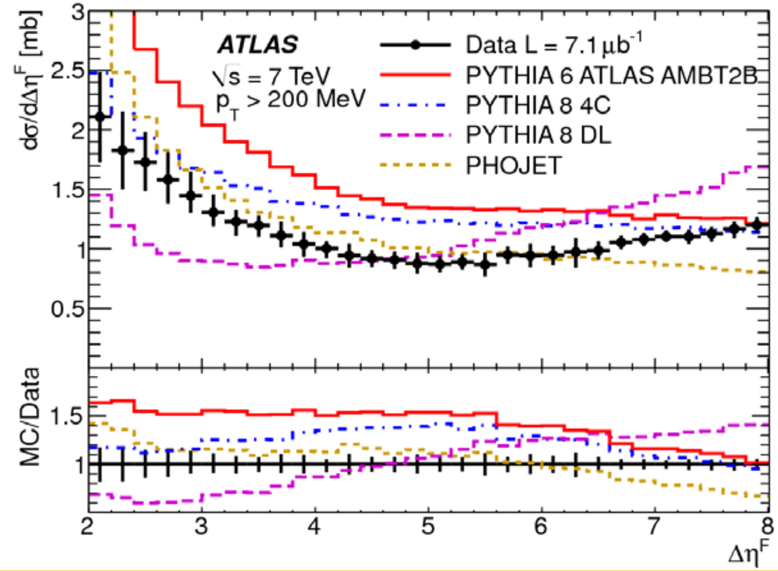


Observable: Forward gap
- **The largest consecutive set of empty rings starting from the edge of the calorimeter**

Rapidity gaps in soft processes

General properties of the gap spectrum

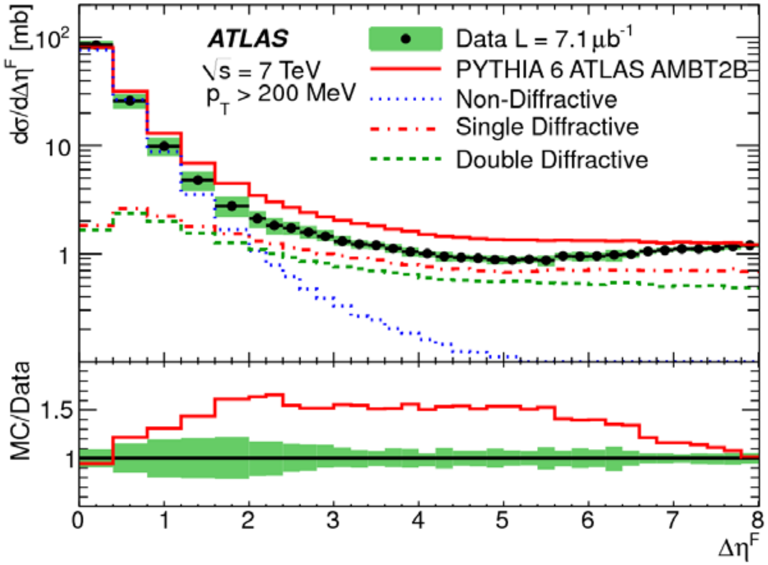


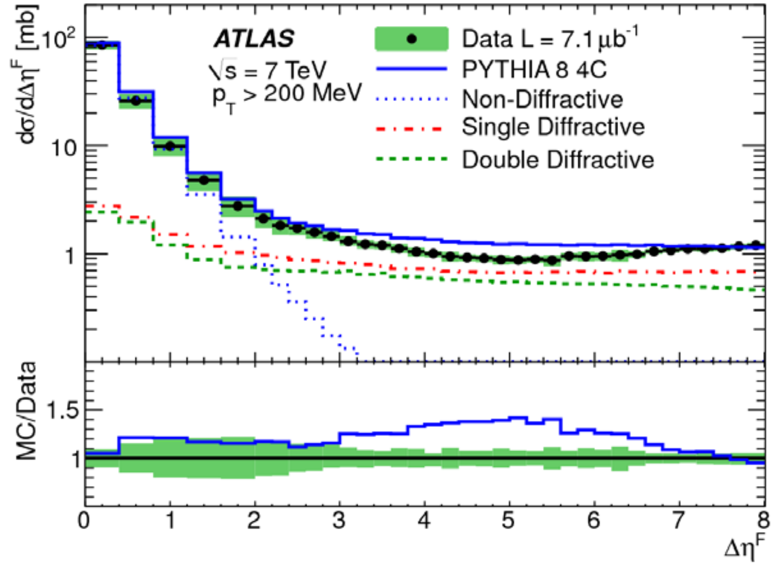


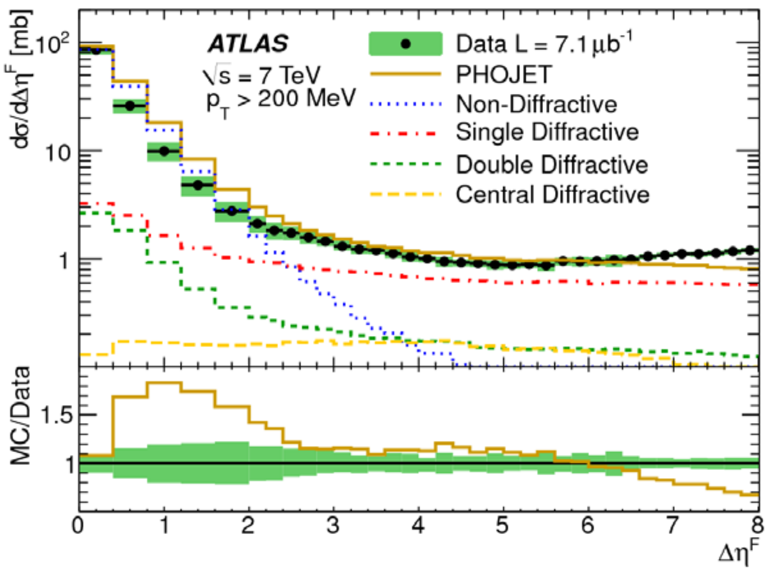
- Data precision: between 8% at large $\Delta\eta_F$ and 20% at $\Delta\eta_F \sim 1.5$
- Data show an exponential decrease at low $\Delta\eta_F$ (dominance of ND) and a plateau at large $\Delta\eta_F$ (dominance of diffractive processes) – as expected from previous HERA and Tevatron results

- This general feature is followed by all MC models.
- Details are not described by any of the models. But note: this is one of very first LHC analyses dealing with diffractive processes – these data should serve to tune MC generators
- Data lie in between the DL slope and slope of the other models

Rapidity gaps in soft processes





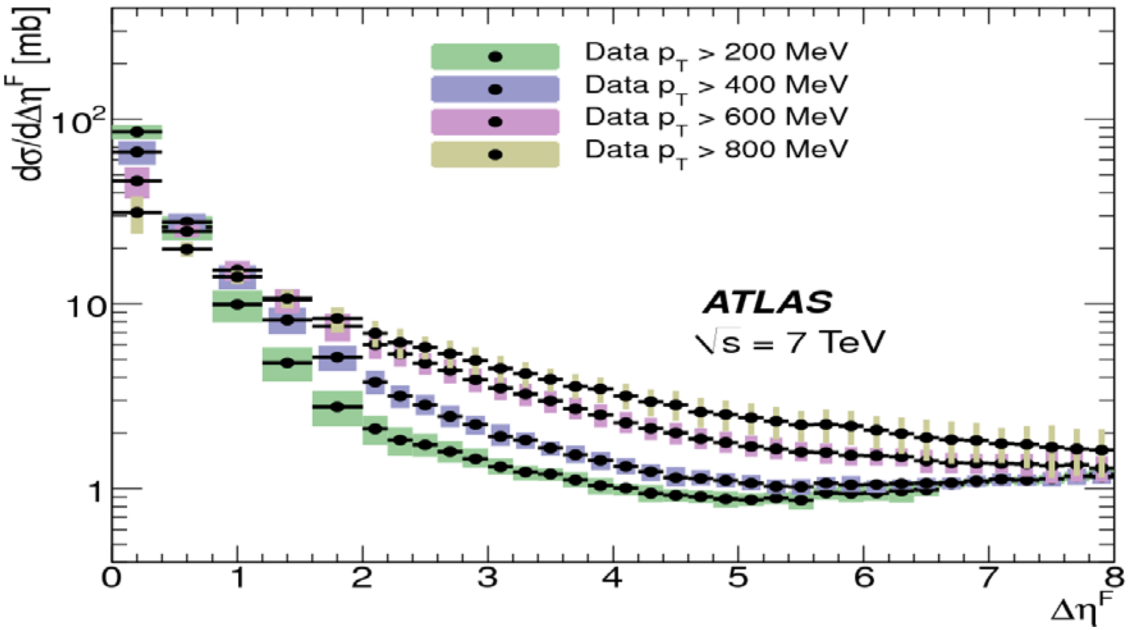


Details about composition and components in PYTHIA 6, PYTHIA 8 and PHOJET

- All models overshoot the data (i.e. overshoot σ_{inel})
- PYTHIA 6, 8: unexpectedly large DD
- PHOJET: much smaller DD but contribution of CD

Rapidity gaps in soft processes

Study of the effect of $p_{T,min}$ of clusters and tracks

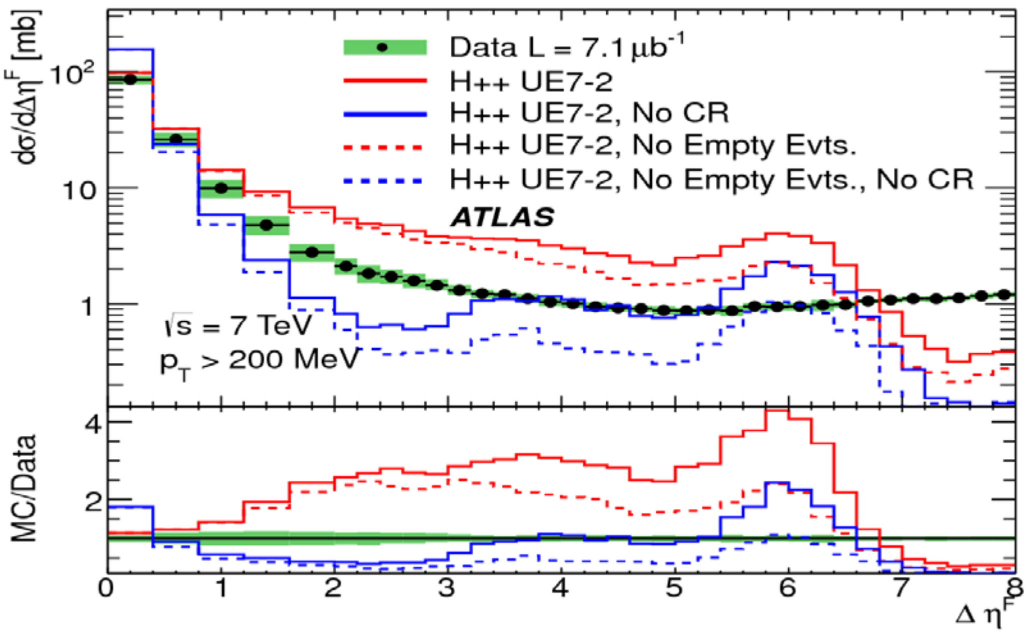


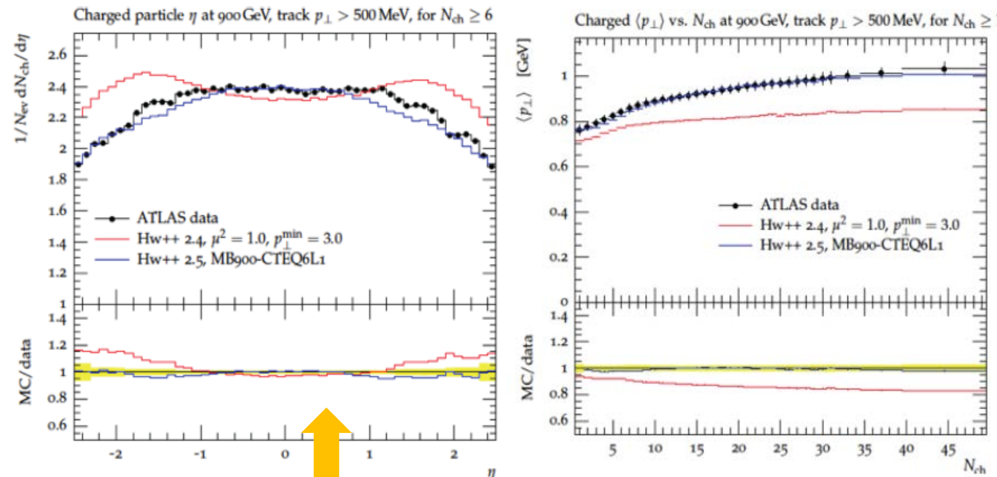
- ❑ Too much large $p_{T,min}$ produces artificial gaps

- ❑ $p_{T,min}$ = 200 MeV seems to be optimum:
- Tracks are within the acceptance of inner tracker
- Selection efficiency of calorimeter clusters > 50%
- Above noise threshold in any part of calorimeter

Rapidity gaps in soft processes

Special behaviour of HERWIG++ 2.5.1 UE7-2 which describes ATLAS MinBias data





ATLAS MinBias data [New J. Phys. 13 (2011) 053033]
Effect of CR studied by Gieseke et al., arXiv:1206.0041

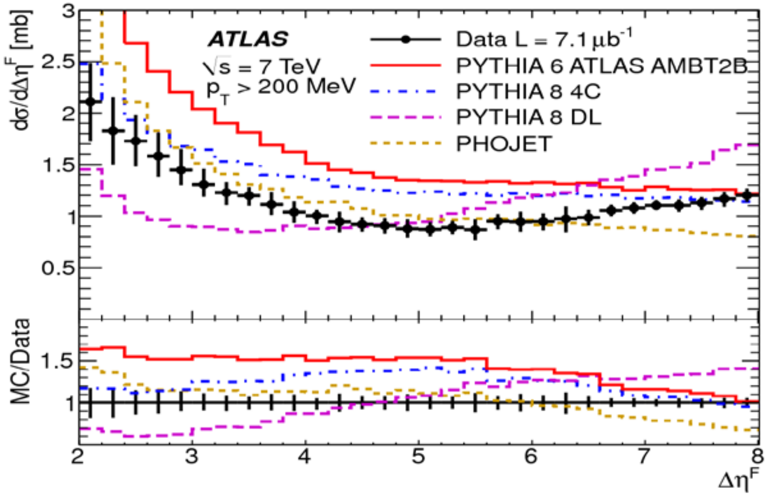
- ❑ HERWIG++ 2.5.1 MinBias UE7-2 does not contain diffractive processes, yet it produces very large gaps
- ❑ Different models of hadronization:

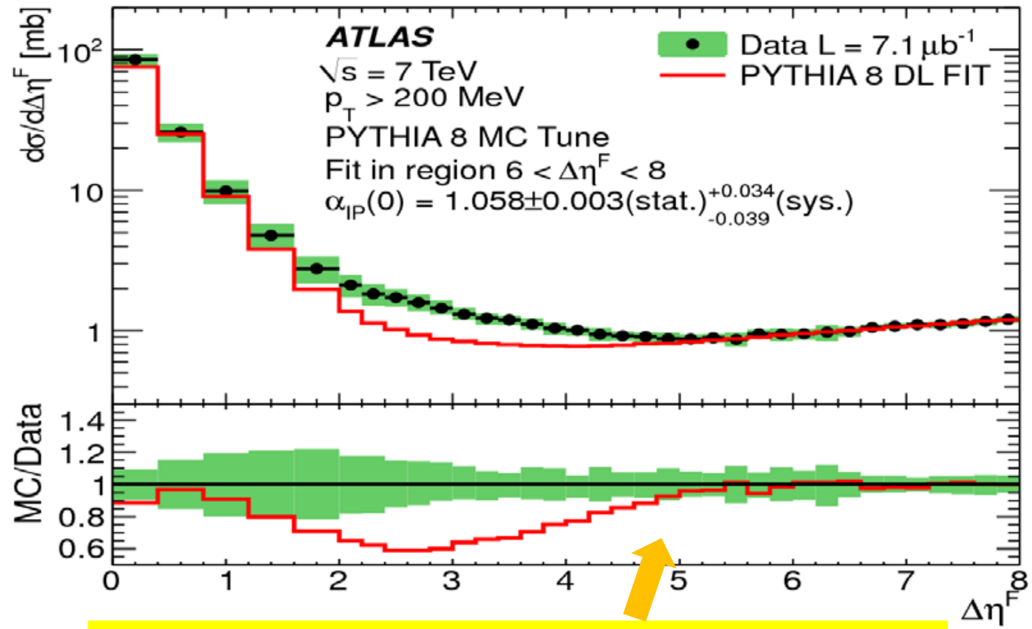
- No Empty Evts = excludes soft events
- No CR = excludes Color Reconnection

- ❑ HERWIG++ 2.5.1 MinBias UE7-2 fails to describe the shape for any of the tunings

Rapidity gaps in soft processes

Estimate of Pomeron intercept $\alpha_{IP}(0)$ in Donnachie-Landshoff model





Default DL:

$$\frac{d\sigma^{SD}}{d\zeta dt} \propto \zeta^{1-2\alpha_{IP}(t)} e^{bt} \qquad \alpha_{IP}(t) = \alpha_{IP}(0) + \alpha_{IP}' t$$

$$\alpha_{IP}(0) = 1.085$$

$$\alpha_{IP}' = 0.25$$

Improved description of the data by PYTHIA 8 DL with the fitted $\alpha_{IP}(0)$ = 1.058

- ❑ Implement DL model in PYTHIA 8
- ❑ Fit data in the region 6 < $\Delta\eta_F$ < 8 where ND is absent:

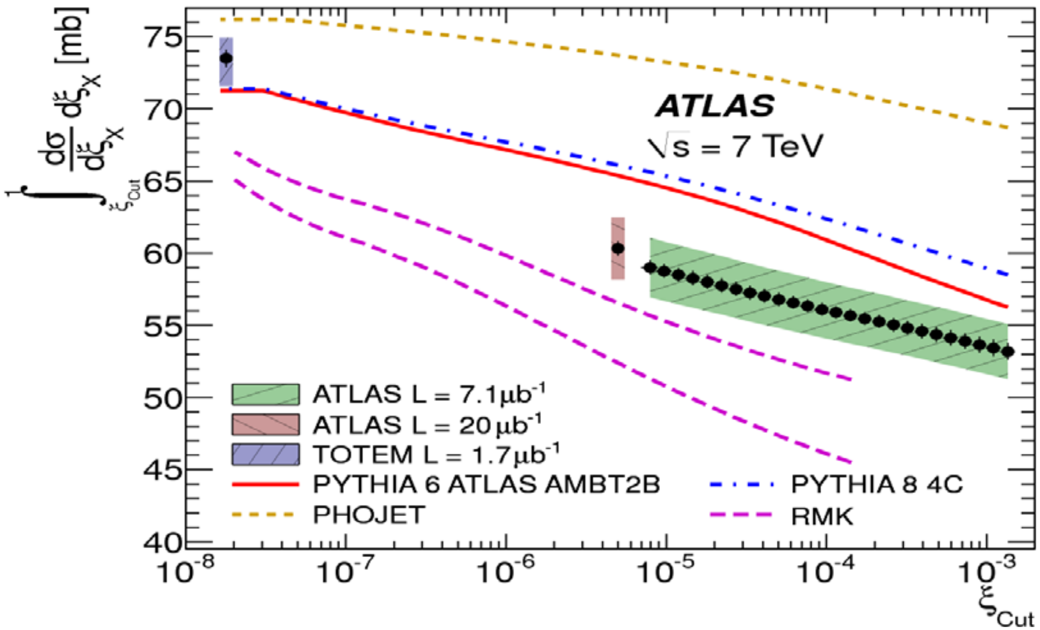
($\alpha_{IP}(0)$ governs the slope at large $\Delta\eta_F$: Flatness → $\alpha_{IP}(0)$ = 1, Increase → $\alpha_{IP}(0)$ > 1)

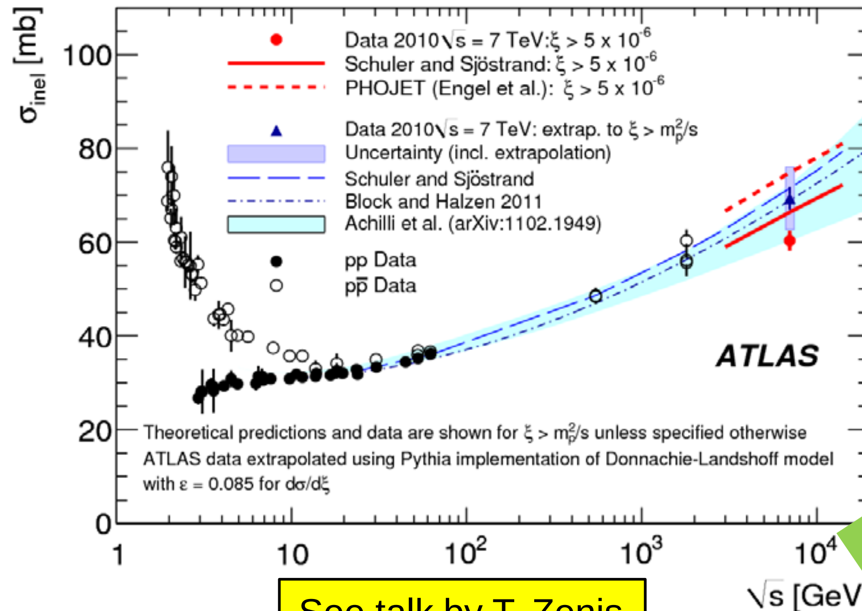
Best fit: $\alpha_{IP}(t=0) = 1.058 \pm 0.003(\mathrm{stat})^{+0.034}_{-0.039}(\mathrm{syst})$ ← due to large model uncert. still compatible with default DL $\alpha_{IP}(0)$

Cross section of ~ 1mb per unit of rapidity (see KMR, arXiv:1102.2844)

Rapidity gaps in soft processes

Estimate of the inelastic cross section

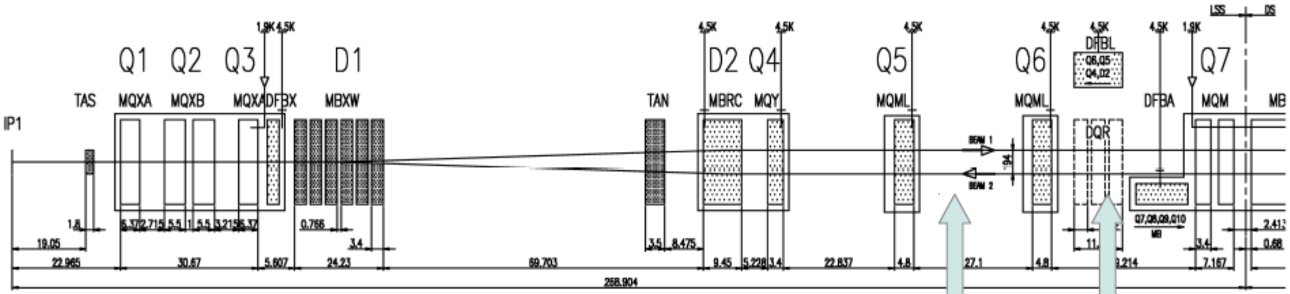


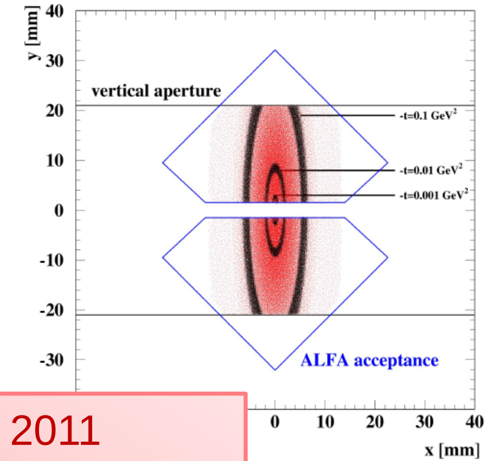


See talk by T. Zenis

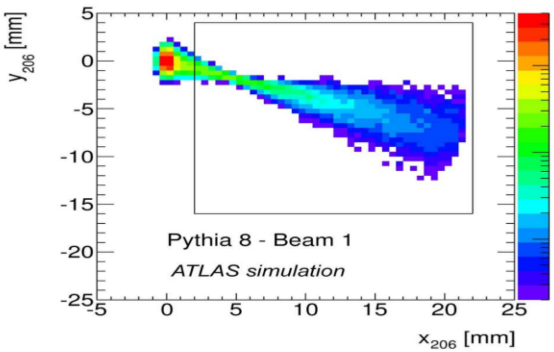
- Inelastic cross section obtained for $\xi > \xi_{cut}$ from MC thanks to strong correlation $\Delta\eta_F \sim -\ln\xi$
- Small corrections (~2%) applied to include particles with p_T < 200 MeV and to account for hadronization fluctuations
- Total uncertainty dominated by uncertainty on luminosity
- Comparison with Totem result and with previous ATLAS analysis ("Measurement of σ_{inel}(7 TeV)")
- Models fail to describe the evolution from low ξ (Totem) to large ξ (ATLAS) but RMK better in describing the slope (thanks to adding IP IP IR terms to IP IP IP terms)

Prospects: proton tagging





AFP ALFA



- ❑ Upgrade project
- ❑ High lumi
- ❑ Normal runs, Low β^*
- ❑ 210 m from IP
- ❑ Movable beam pipes
- ❑ 3D Si pixels
- ❑ Quartic timing detector

- ❑ Taking data since 2011
- ❑ Low lumi
- ❑ Mainly special runs, Large β^*
- ❑ 240 m from IP
- ❑ Roman Pots
- ❑ Scintilating fibre

QCD physics:
- ➢ Hard Single Diffr. (jj, W/Z)
- ➢ Hard Double Pomeron (jj, W/Z)
- ➢ Hard Central Exclusive (jj, γγ)

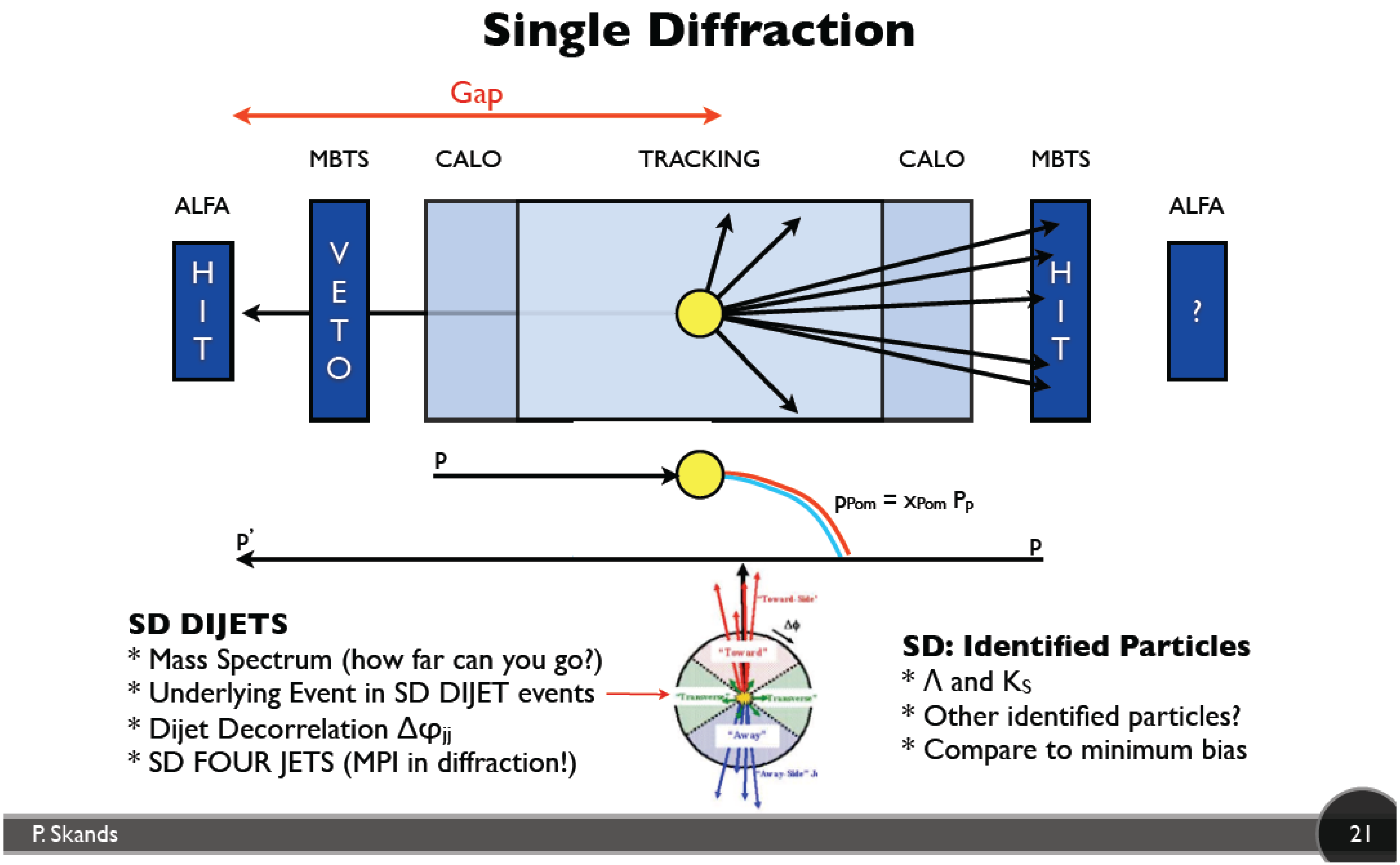
Exploratory physics:
- ➢ γγ physics (anomalous quartic couplings)
- ➢ SUSY
- ➢ Magnetic monopoles

More details by L. Chytka

See the next slide

ALFA + ATLAS

❖ **Peter Skand's view on what can be measured with ALFA + ATLAS**
[ALFA collaboration meeting 23.08.2011]



Summary

Details about the ATLAS analysis

"Rapidity gap cross section in pp interactions at √s=7 TeV"

given. The other diffractive analysis ("Measurement of $\sigma_{inel}(7\ \mathrm{TeV})$") detailed by T. Zenis

- Forward gap distribution measured for different $p_{T,min}$ cuts (200, 400, 600, 800 MeV)
- Plateau observed for large gaps suggests presence of diffractive processes
- None of the models able to describe the details of the gap spectrum
- σ_{inel} measured for various ξ values. Models not able to describe the ξ-evolution
- Pomeron intercept in DL model measured from fit to spectrum at large gaps. It is compatible with the default DL value ($\alpha_{IP}(0)$ = 1.085).

- First ATLAS analyses dealing with diffraction signal provide some material to think about
- Data compared to various models of hadronization and underlying event.
- PYTHIA maybe too much DD? HERWIG++2.5 ND too many big gaps

Possible future topics:

- **Soft and hard diffraction using protons tagged by ALFA**
- **Diffractive and Photon-induced processes using protons tagged by AFP**