Diffractive measurements in ATLAS

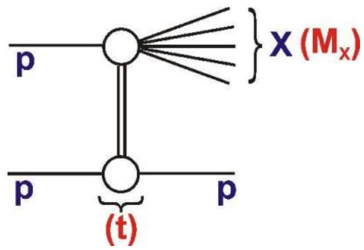
PER GRAFSTROM
CERN

ON BEHALF OF THE
ATLAS COLLABORATION

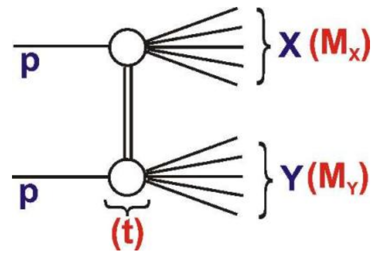
LOW-X MEETING

SANTIAGO DE COMPOSTELA
GALICIA,SPAIN
JUNE 3-7 2011

Immediate caveat



Single diffraction



Double diffraction

There is no unique way of defining diffraction

Theoretically:

Exchange of the quantum numbers of the vacuum

t-channel Pomeron exchange

Experimentally:

Large rapidity gaps and intact protons (Single Diffraction)

Mapping is not one to one ……

Not clear to what extent one can always disentangle non-diffractive and diffractive processes !

More caveat

ATLAS central detector sensitive to high mass diffraction.

($|\eta| < 4.9 \Rightarrow M_x > 7$ GeV)

Is there a theoretically solid way to extrapolate from high mass diffraction to low mass diffraction ?

How many "mb " disappear in the beam pipe.... ?

Is there consensus in the theoretical community...... ?

May be there is a demon in the beam pipe ?

Come back later on how to find out!

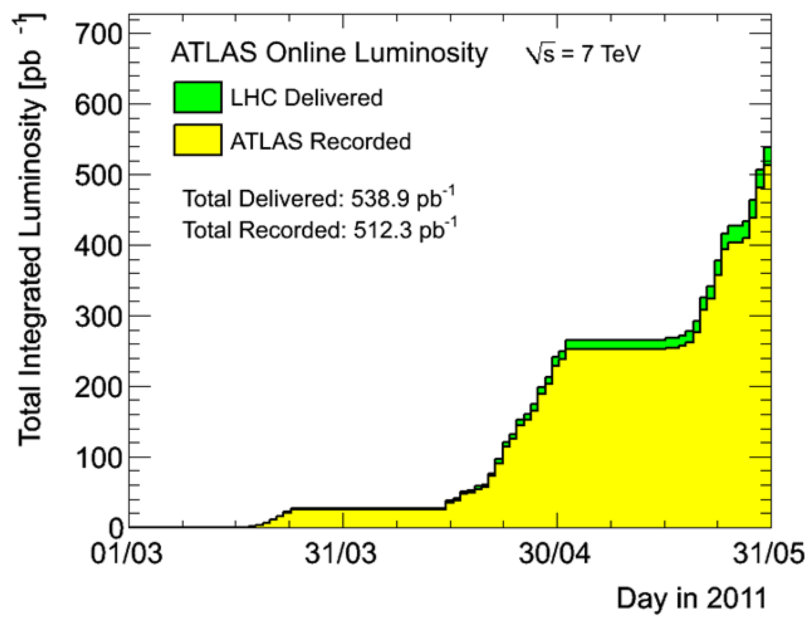
Two separate ATLAS studies will be reported today

- A first look at sensitivities to diffractive channels using a diffraction enhanced sample
  (arXiv:1104.0326;CERN-PH-EP-2011-047)

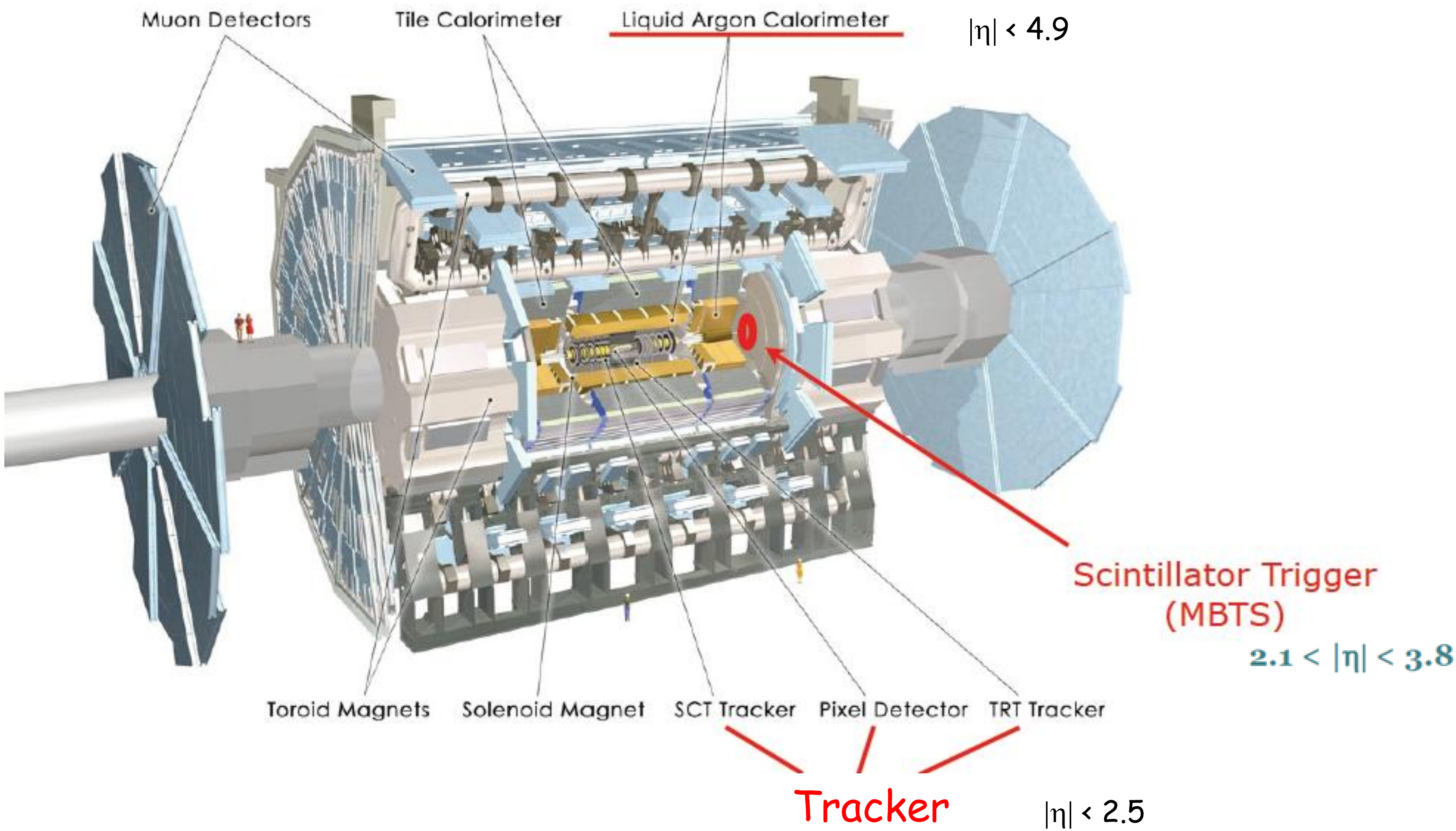
- Rapidity gap studies
  (ATLAS-CONF-2011-059)

20.1 μb^{-1} and 7.1 μb^{-1}

Important: no pile up

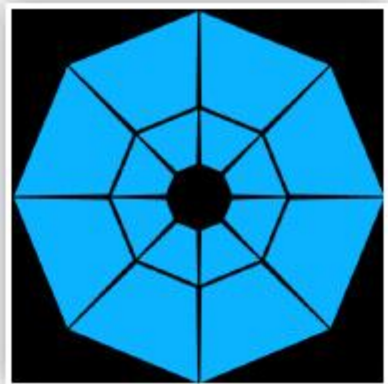


The ATLAS Detector

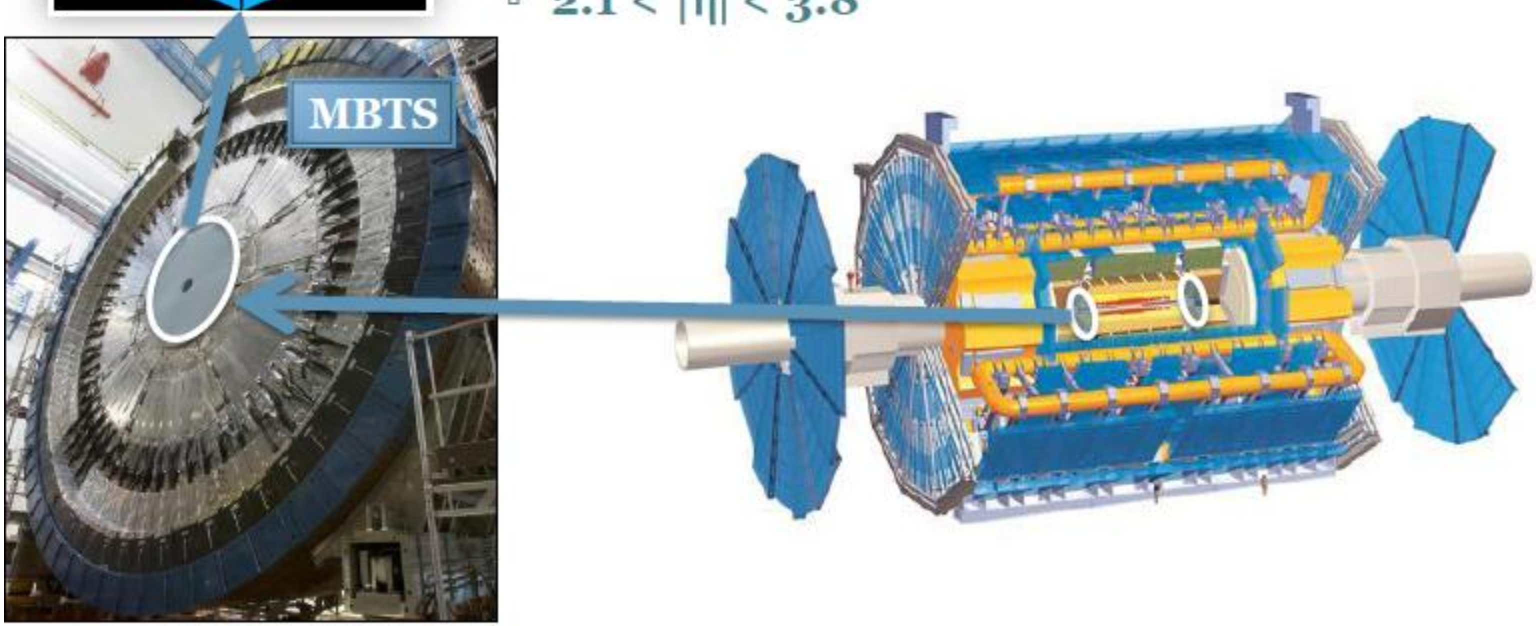


More about the MBTS

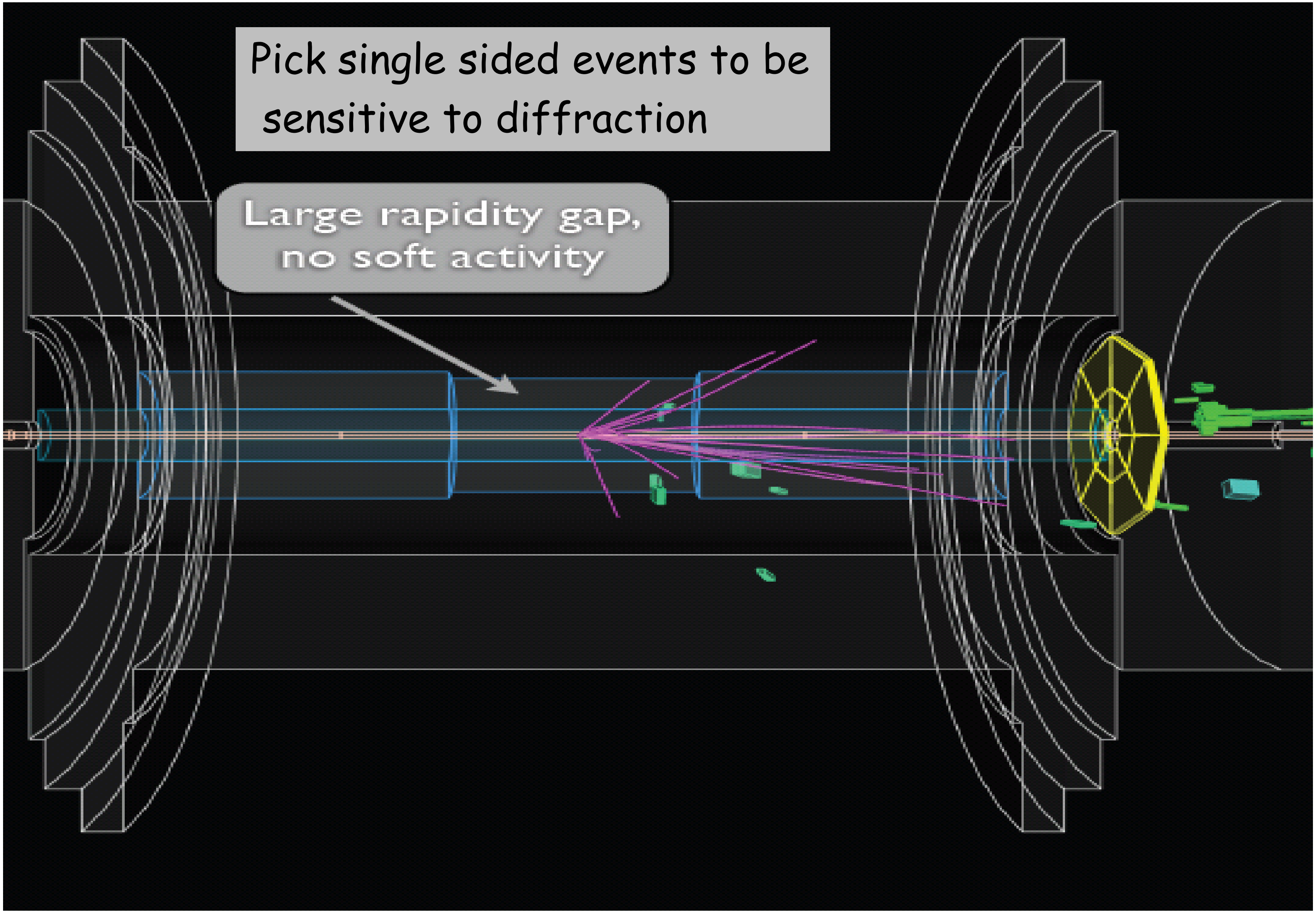
MBTS Trigger



- **Segmented** into **16 counters** on **each side.**
- Plastic scintillator planes connected to photomultiplier tubes via wavelength shifting fiber.
- Highly efficient trigger on charged particles.
- Generally trigger on the **Inclusive Or** of both sided.
- **MBTS** is **the primary** Minimum Bias trigger.
  - **$2.1 < |\eta| < 3.8$**

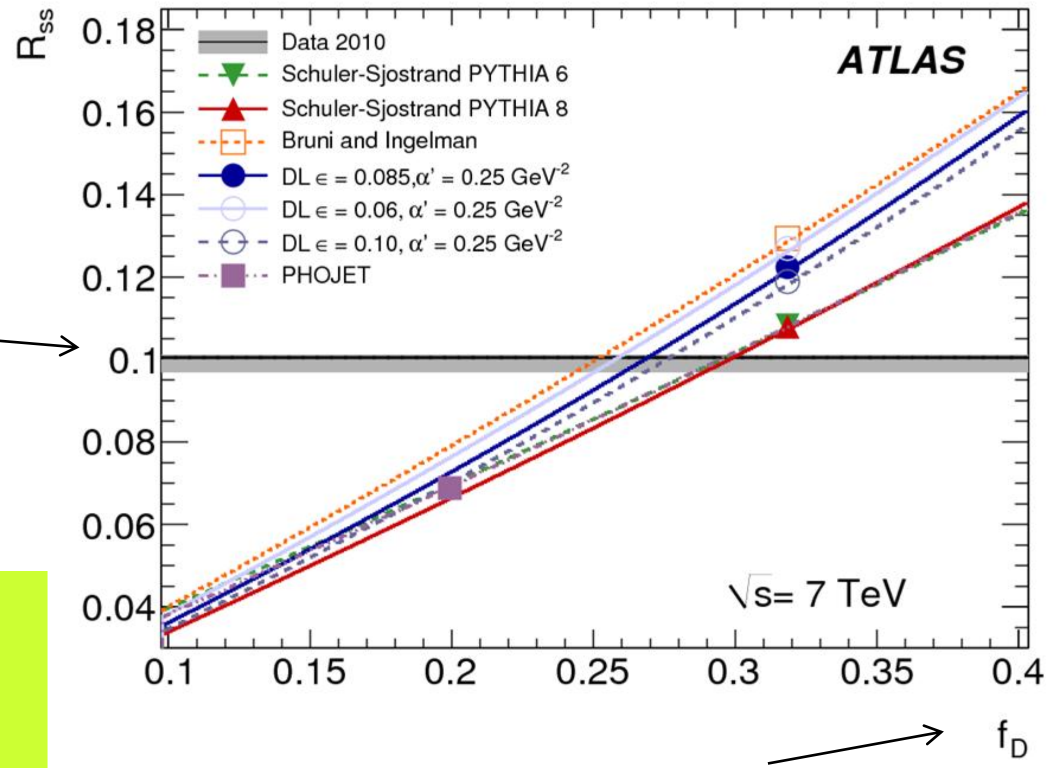


Diffractive enhanced sample using MBTS



R_{ss} =ratio of single-sided to inclusive event sample

R_{ss} = 10.02±0.03 (stat.) $^{+.1}_{-.4}$ (syst.) %



Fractional contribution of diffraction to the inelastic cross section

Generator used :

1. PYTHIA6 and PYTHIA8 based on Schuler and Sjöstrand model

2. PHOJET based on Dual Parton Model

In addition different ξ-dependence in PYTHIA8 ($\xi = M_x^2/s$).

More about all this in the talk by Sebastian Eckweiler:" Measurement of the Inelastic Proton-proton Cross Section at √s = 7 TeV with the ATLAS Detector"

Rapidity gap studies

Gap finding algorithm

Divide the detector in rings of $\Delta\eta$ and look for activity.
Activity in a ring is either:

- $\geq$ 1 track with p_t > 200 MeV ($|\eta|$< 2.5)
- $\geq$ 1 calorimeter cell above threshold ($|\eta|$< 4.9)

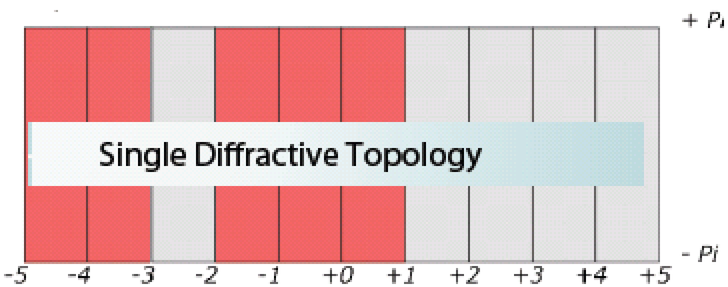
Two different $\Delta\eta$ definitions in the analysis:

For MC optimization

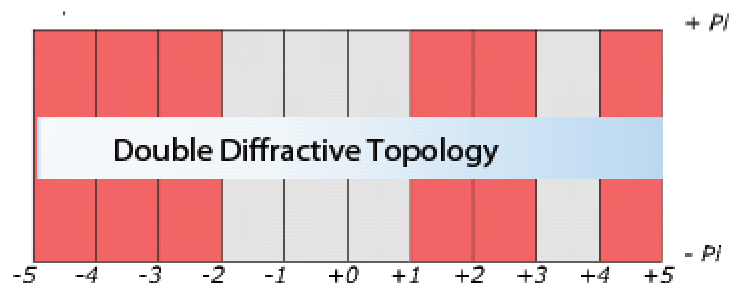
- **Floating gap**: Largest s consecutive set of empty rings parameterised by its size $\Delta\eta$ and start η_{start}

For cross section determination

- **Forward gap:** Largest consecutive set of empty rings starting from the edge of the acceptance (η = + - 4.9) and size $\Delta\eta^F$

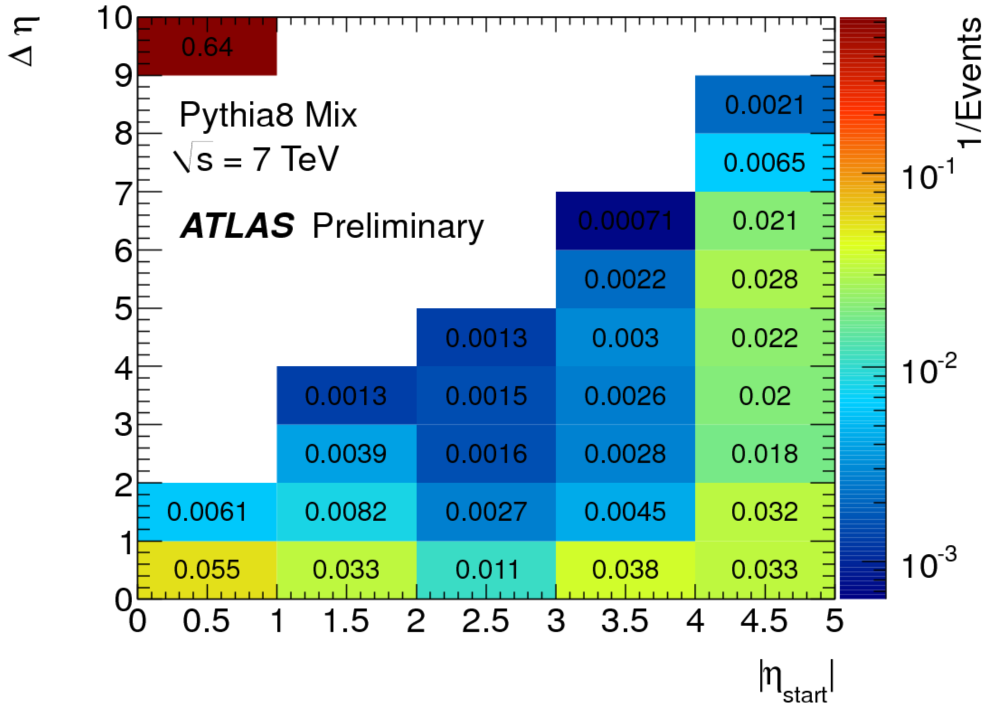


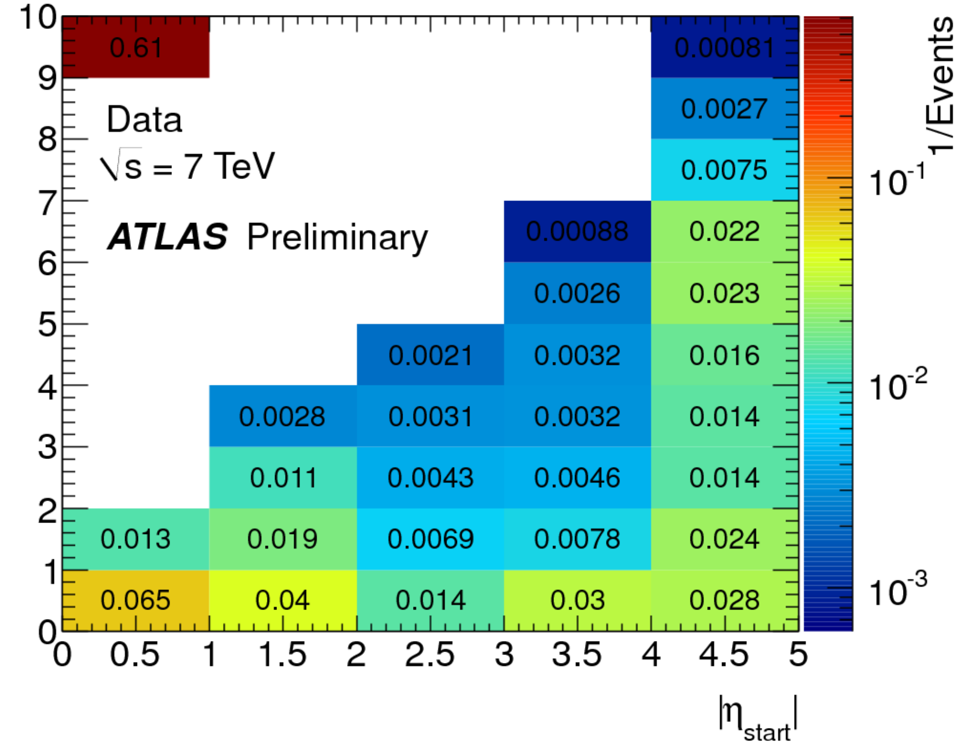
$\Delta\eta$ = 4
$\Delta\eta^F$ = 4
η_{start} = 5



$\Delta\eta$ = 3
$\Delta\eta^F$ = 0
η_{start} = 2

Compare MC with data



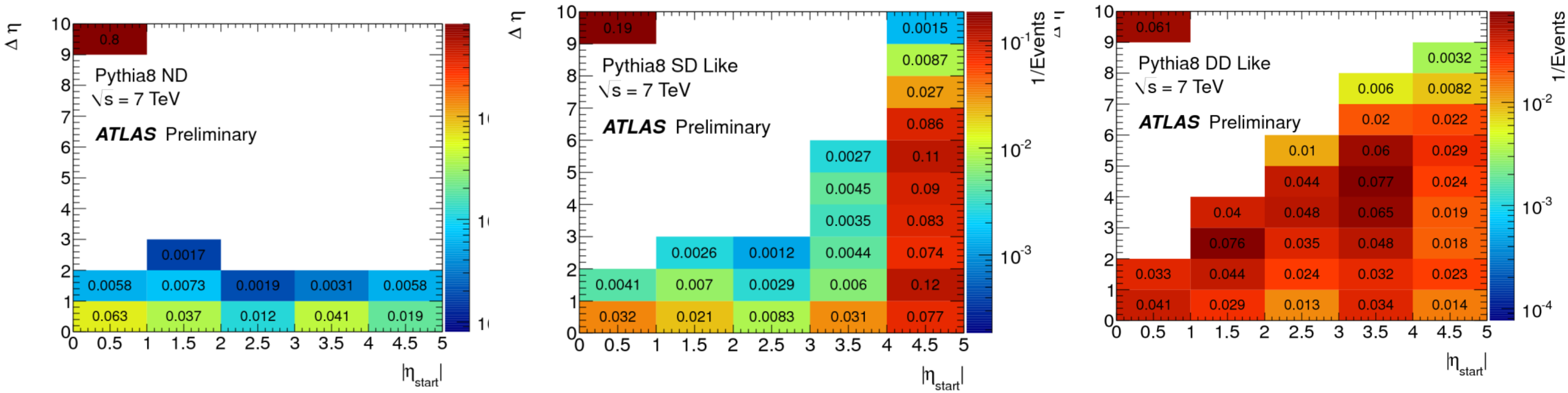


The generator here is PYTHIA8 with default mix of single , double diffraction and non diffractive events

In the same manner as we did for R_{ss} we can try to see if we get better agreement for a different mix….

Optimize the mix

Construct templates for non diffractive,
single diffraction -like and double diffraction -like .



Fit the fraction for each template to the data from a log-likelihood fit

Measured diffractive fraction (Pythia8)

f_D = 30.2 ± 0.3 (stat) ± 3.8 (syst) %

Several control distributions shows reasonable agreement with MC using the optimized mix.
IMPORTANT for unfolding of the instrumental effects

Unfolding

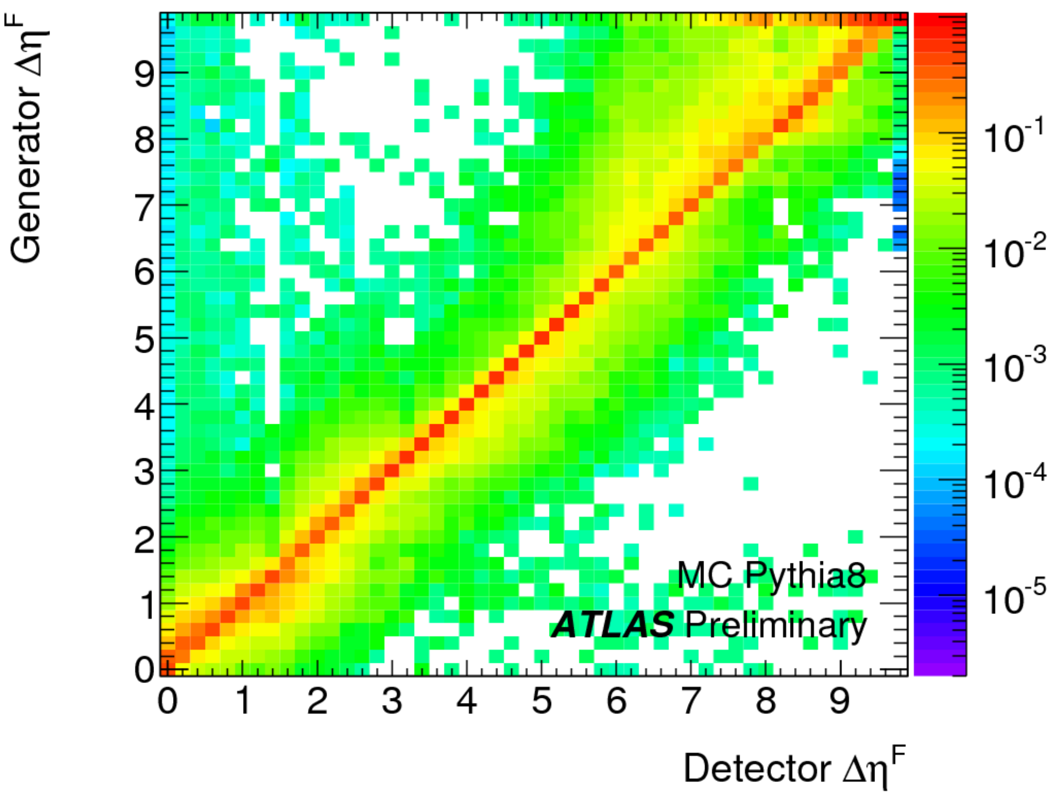
$$\frac{d\sigma(\Delta\eta^{\mathrm{F}})}{d\Delta\eta^{\mathrm{F}}} = \frac{A(\Delta\eta^{\mathrm{F}})}{\Delta\eta_{\mathrm{ring}}} \frac{N(\Delta\eta^{\mathrm{F}}) - N_{\mathrm{BG}}(\Delta\eta^{\mathrm{F}})}{\epsilon(\Delta\eta^{\mathrm{F}}) \times \mathcal{L}}$$

Beam gas ~ 0.2 %

Migration correction factor

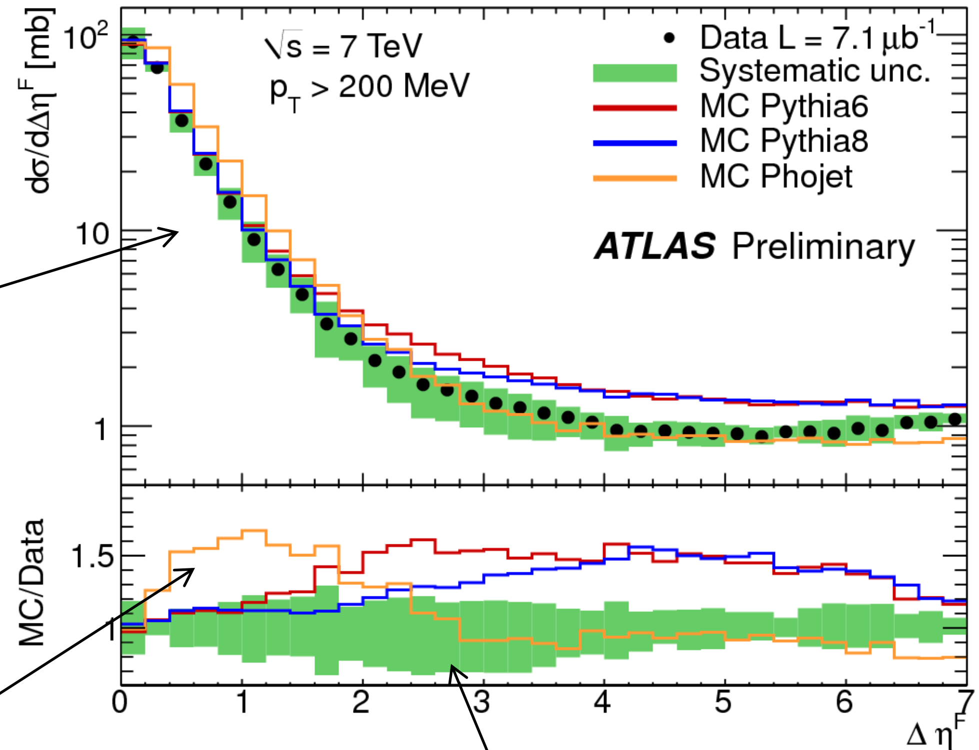
Δ L ~ 3.4 %

> 95 %



Migration matrix between the hadron and detector level for PYTHIA8.

Cross sections

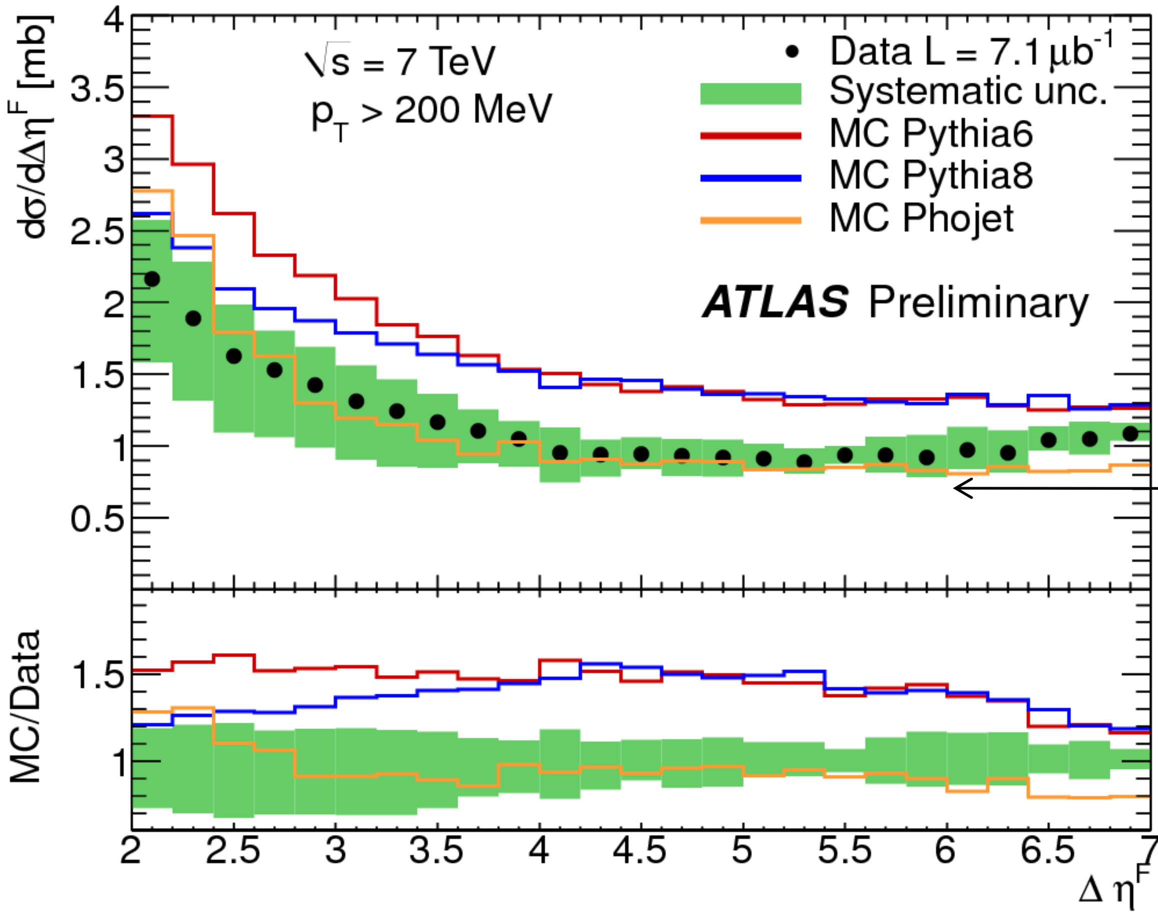


Expected exponential decrease for ND events

PHOJET 50 % excess

Data uncertainty typically ~ 20%

Zoom in on large $\Delta\eta^F$



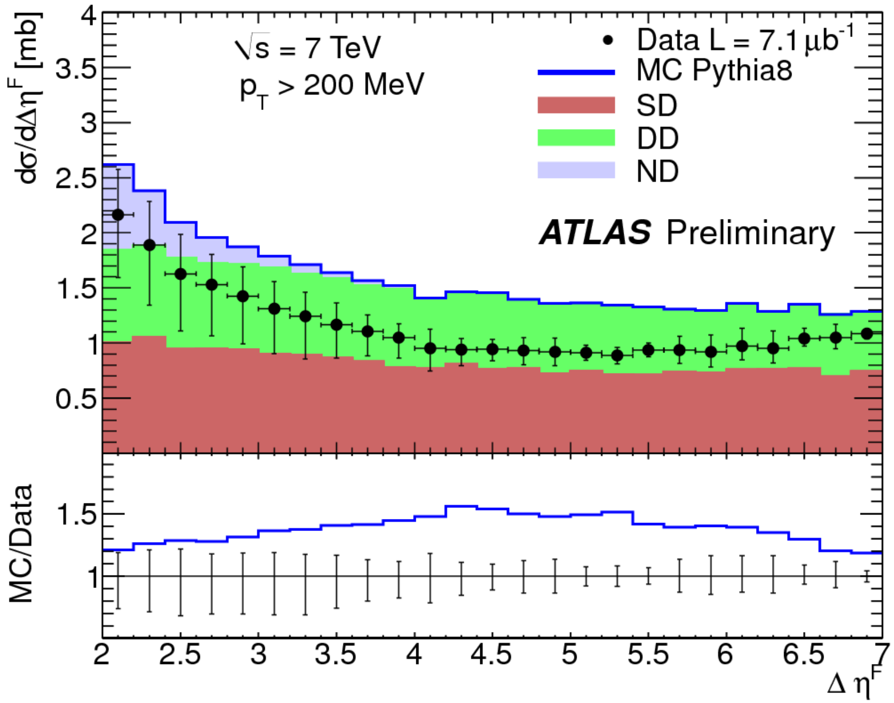
ND events supposed to be negligible for $\Delta\eta^F > 3$

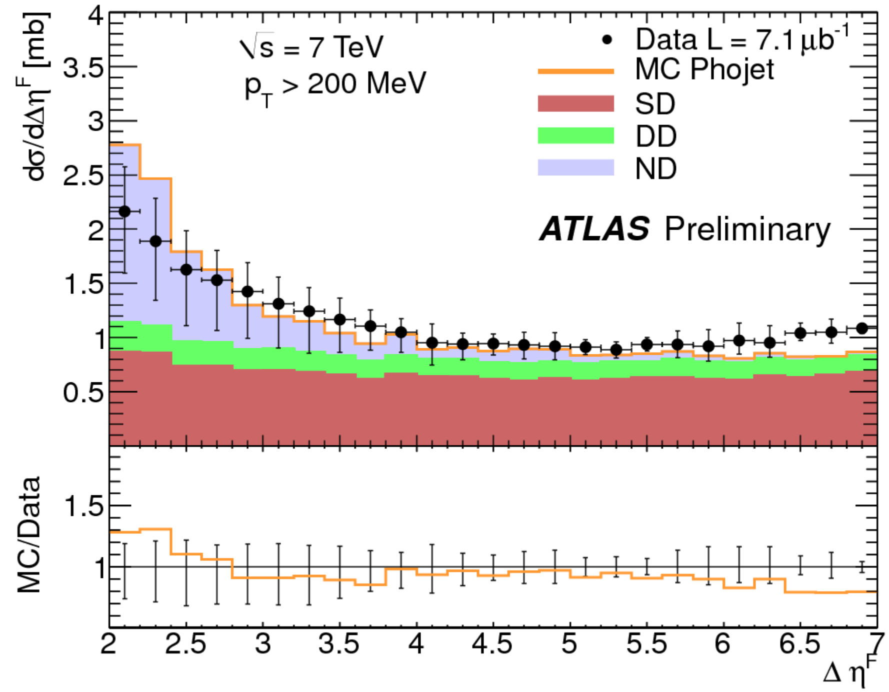
Plateau at large $\Delta\eta^F$

Roughly 1 mb per unit of gap size

Flatness indicates that the Pomeron intercept close to 1.

Zoom in on large $\Delta\eta^F$ and SD/DD breakdown





The difference is in Double Diffraction

How to measure the « mb » hiding in the forward direction and in the beam pipe?

ATLAS has measured σ_{inel} for $\xi > 5{\cdot}10^{-6}$

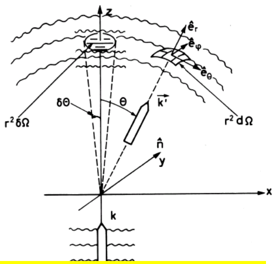
How to measure the remaining cross section i.e. σ_{inel} for $\xi < 5{\cdot}10^{-6}$?

We need three ingredients !

see next slide

1 **Optical theorem**

$\sigma_{tot} \propto \mathrm{Im}\, f_{el}(t=0)$



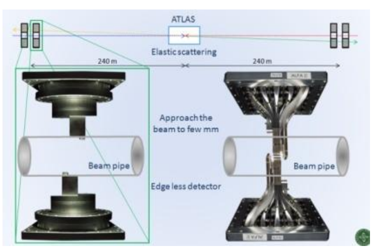
$\Rightarrow$ **The forward direction of elastic scattering is sensitive to all inelastic channels**

(the very existence of scattering requires scattering in the forward direction in order to interfere with the incident wave, and thereby reduce the probability current in this direction)

2 **VDM scans**

$\Rightarrow$ **Luminosity to ~3 %**

3 **ATLAS Roman Pots: ALFA**



$\Rightarrow$

a) σ_{el} from integrating $d\sigma_{el}/dt$

b) Extrapolation to t=0 i.e optical point

$$\sigma_{inel}\ (\xi < 5\cdot10^{-6}) = \sigma_{tot} - \sigma_{el} - \sigma_{inel}\ (\xi > 5\cdot10^{-6})$$

Conclusions

- An enhanced sample of diffractive events based on absence of activity on one side of the MBTS detector gives a fractional contribution to the inelastic cross section in the range 25% to 30% depending on which generator is used.

- Rapidity gap studies gives a diffractive fraction f_d

  $f_d = 30.2 \pm 0.3\ (\text{stat}) \pm 3.8\ (\text{syst})\ \%$

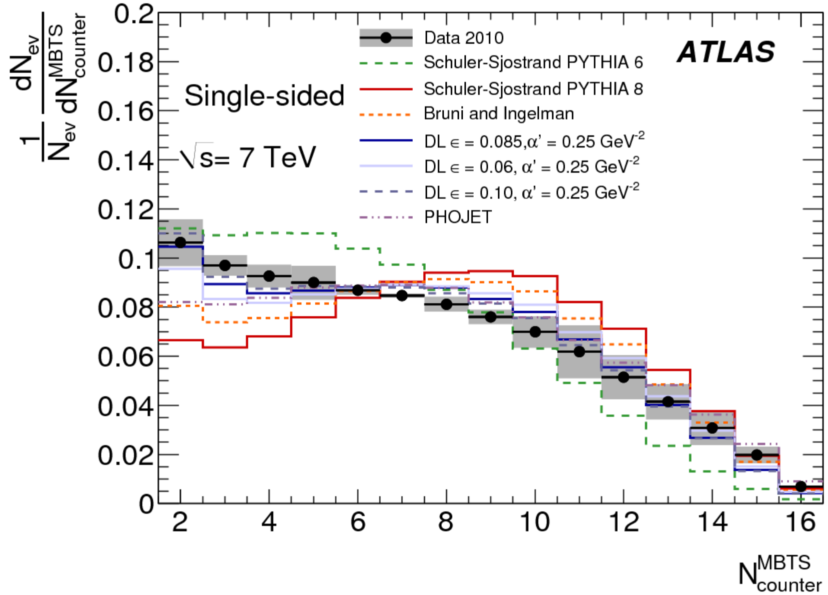
- In both cases the PYTHIA8 generator describes better the non-diffractive part while PHOJET gives better agreement for the diffractive part

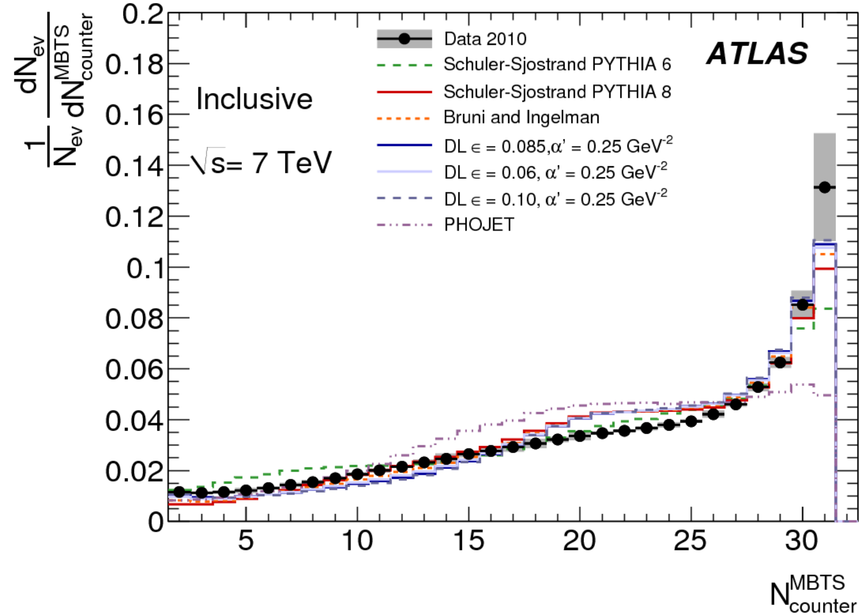
- Diffractive cross section $d\sigma/\Delta\eta^F \sim 1.0 \pm 0.2$ mb per unit of $\Delta\eta^F$ for $\Delta\eta^F > 3.5$

- The ALFA detector will give more information on the small ξ part of the inelastic cross section

Back up

MBTS multiplicity for single sided and inclusive sample



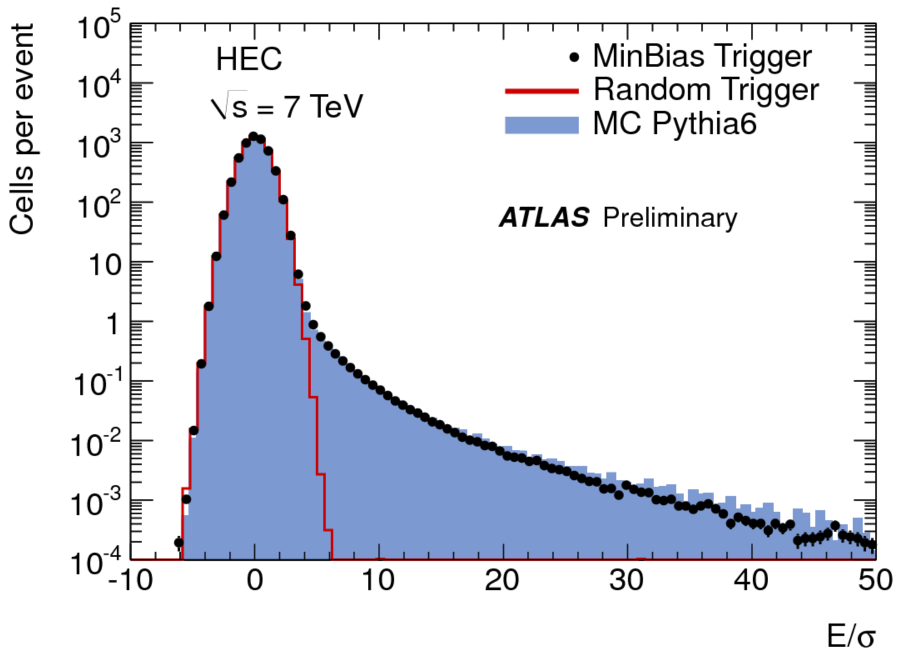


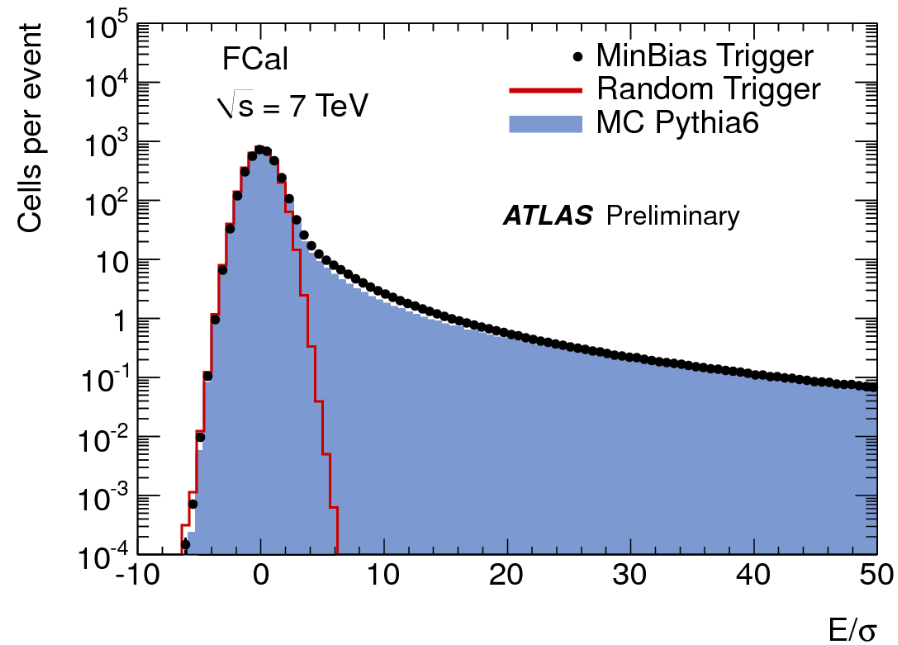
The different generators used the corresponding f_d values which agree with the R_{ss} data measured .

More about all this in the talk by Sebastian Eckweiler:
" Measurement of the Inelastic Proton-proton Cross Section at $\sqrt{s}$ = 7 TeV with the ATLAS Detector"

Understanding of noise

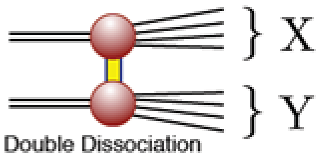
Compare MBTS triggers with random triggers triggered on empty bunches





Require $S = E/\sigma_{noise} > S_{th}$ with $S_{th} \sim 5$ (4.8-5.8 depending on η-ring)
One cell or more in one ring above threshold and the ring is not empty

Convenient reclassification of events



Use convention $M_y < M_x$

For events with $\xi_y = M_y^2/s < 10^{-6}$ the Y system is produced entirely outside the acceptance of the calorimeters (corresponds to $M_y < 7$ GeV)

Reclassify events:

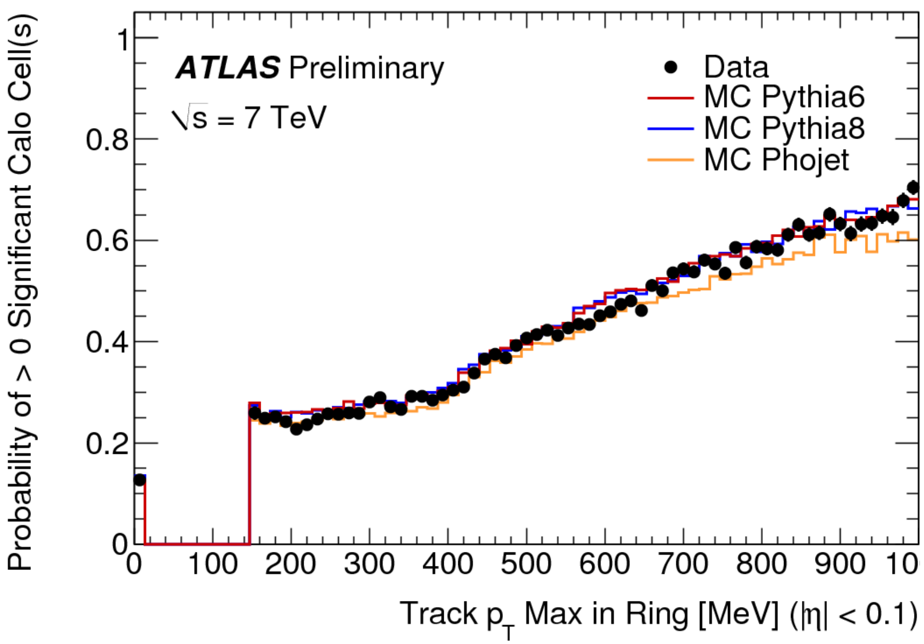
DD- like events are events with both $\xi_{x,y} > 10^{-6}$

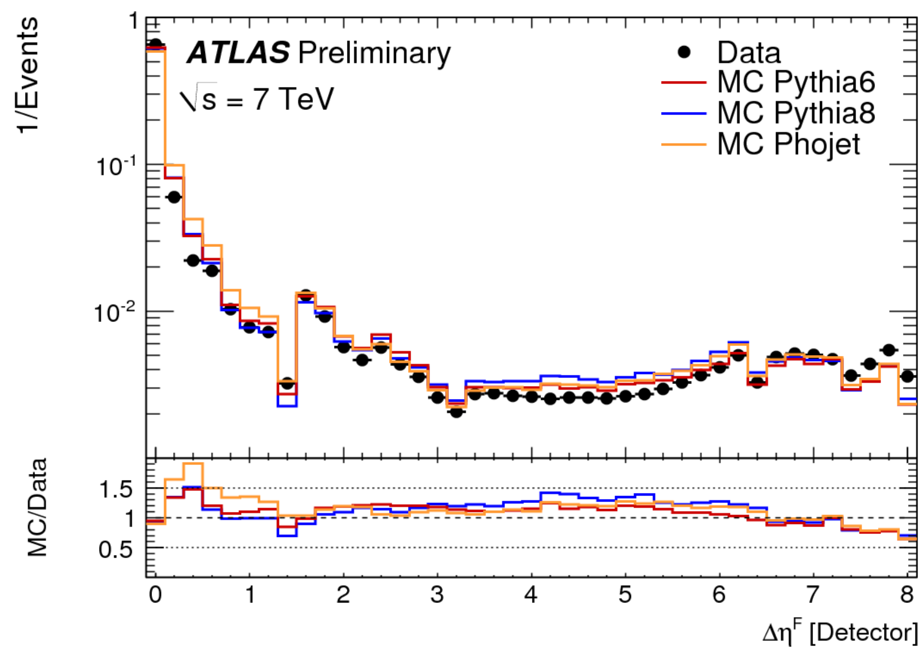
SD- like events are events with $\xi_x > 10^{-6}$ and $\xi_y < 10^{-6}$

Contribution	PYTHIA6	PYTHIA8	PHOJET
Predicted			
ND (%)	67.9	67.9	80.8
SD-like (%)	28.8	29.4	17.0
DD-like (%)	3.3	2.7	1.9

Control distributions

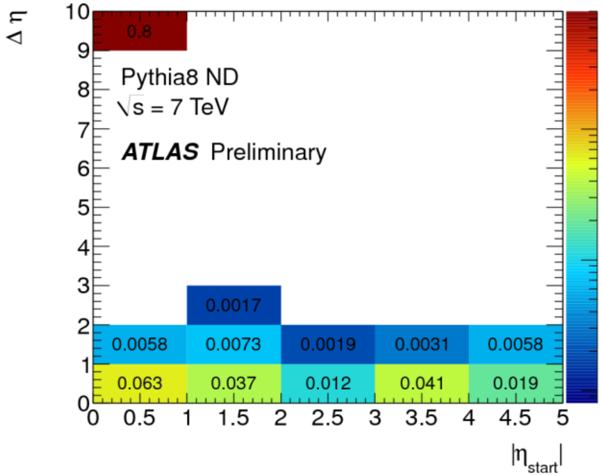
Before proceeding to unfolding to get the cross section compare f_d optimized Monte Carlo with control distributions

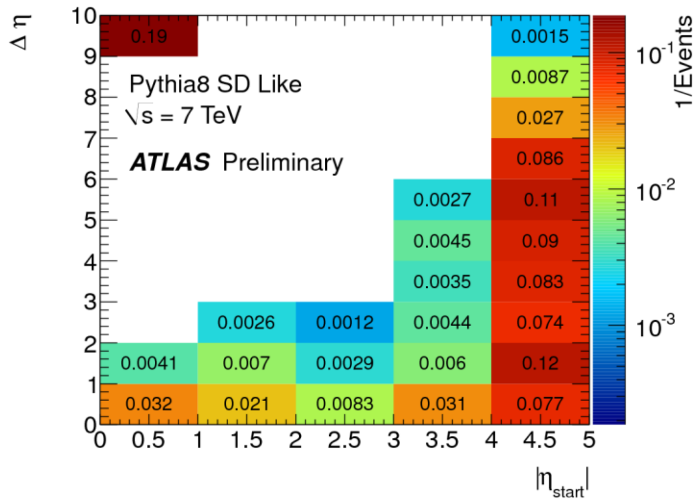


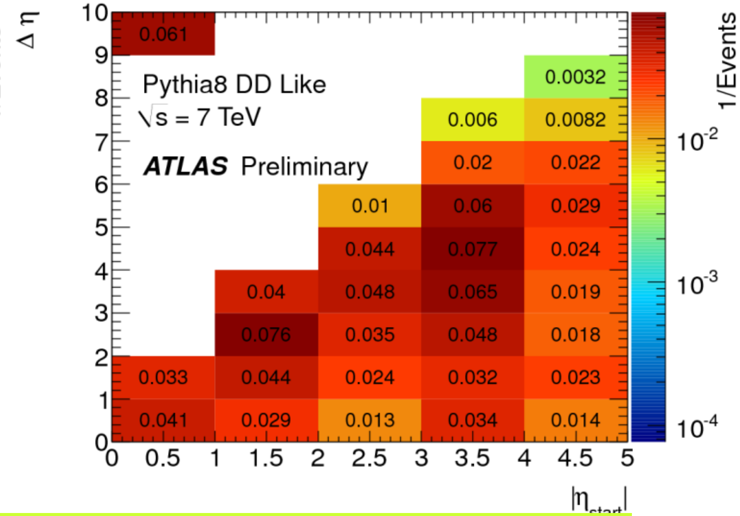


Optimize the mix

Construct templates for ND, SD-like and DD -like .







Fit the fraction for each template to the data from a log-likelihood fit

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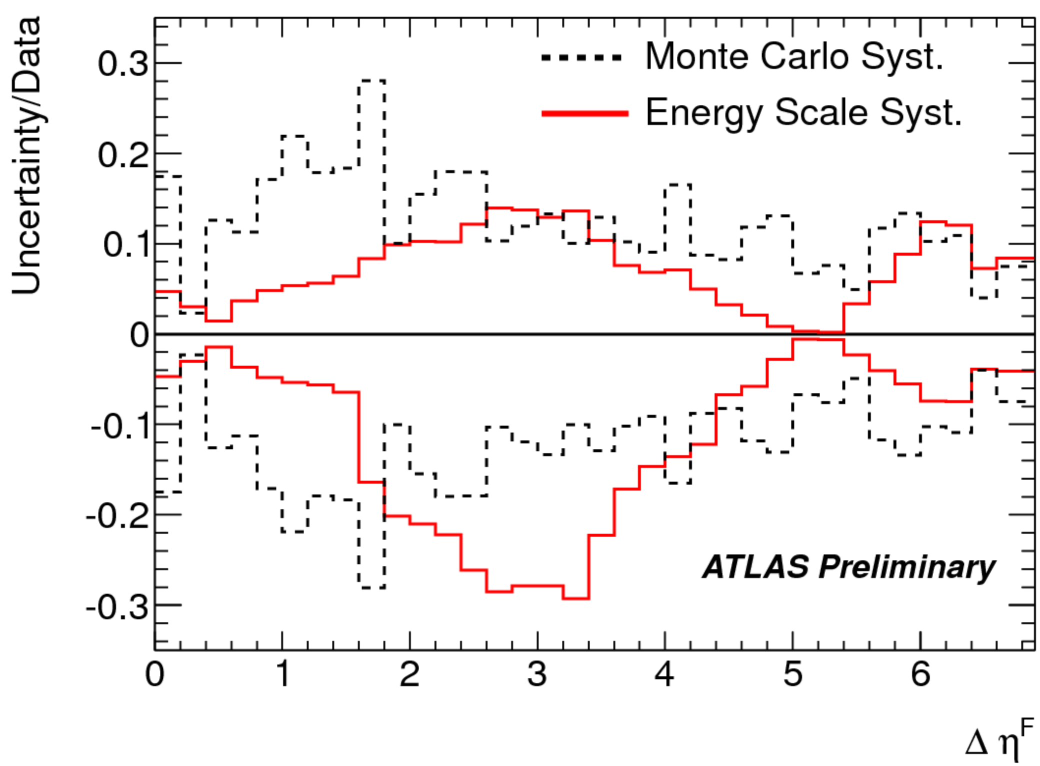
Predicted			
ND (%)	67.9	67.9	80.8
SD-like (%)	28.8	29.4	17.0
DD-like (%)	3.3	2.7	1.9
Optimised			
ND (%)	72.0 ± 0.3	69.8 ± 0.3	70.3 ± 0.4
SD-like (%)	25.2 ± 0.2	21.3 ± 0.2	23.5 ± 0.2
DD-like (%)	2.9 ± 0.1	8.9 ± 0.2	6.2 ± 0.1

Measured diffractive fraction (Pythia8)

f_D = 30.2 ± 0.3 (stat) ± 3.8 (syst) %

Systematic uncertainties



Unfolding :
Difference of PYTHIA6 and PHOJET relative PYTHIA8 gives indication

Energy scale: ± 25%

Bayesian method for unfolding:
G.D'Agostini, NIM A362 (1995) 487

Others small:
Threshold cut,
MBTS efficiency
Tracking efficiency
……