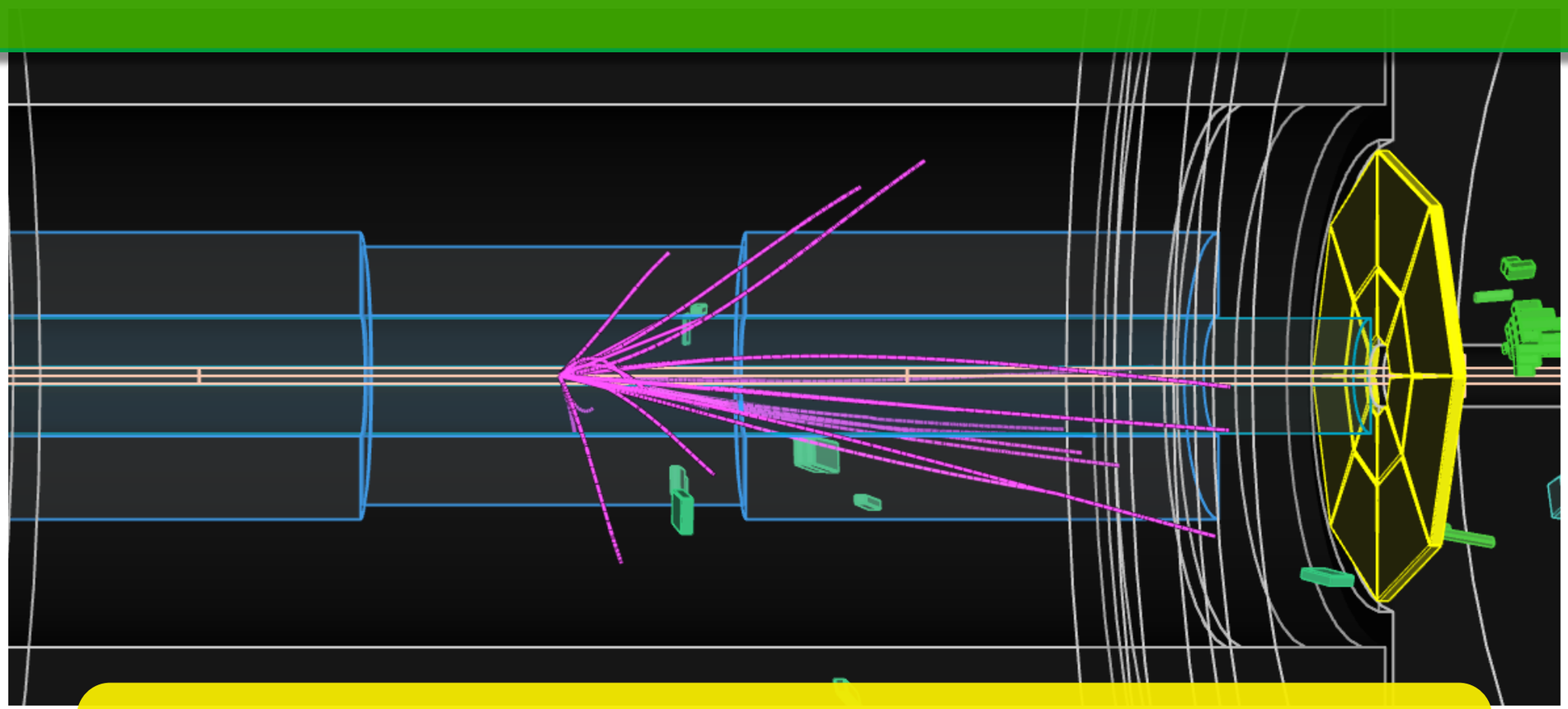
Diffractive measurement(s) in ATLAS

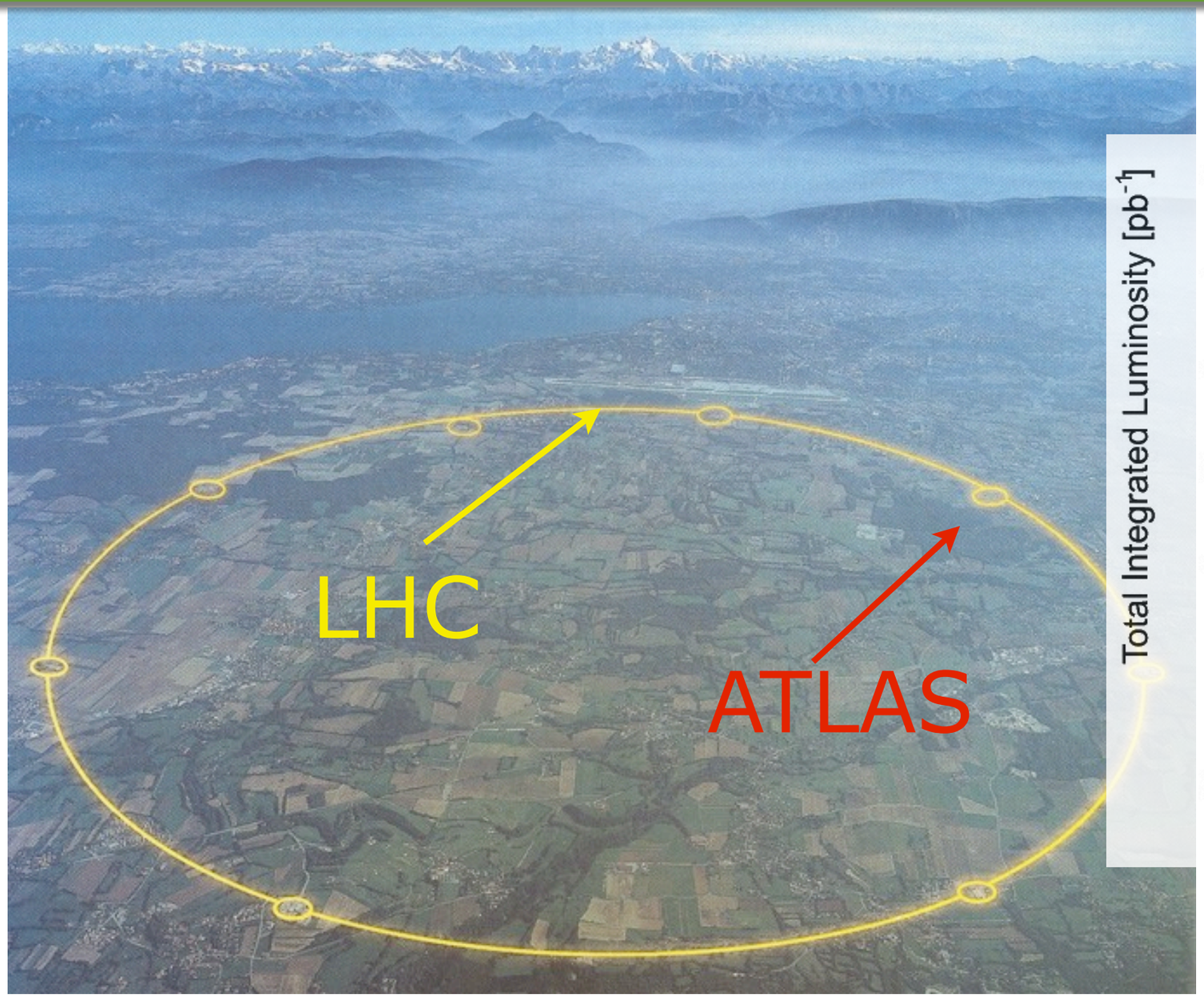


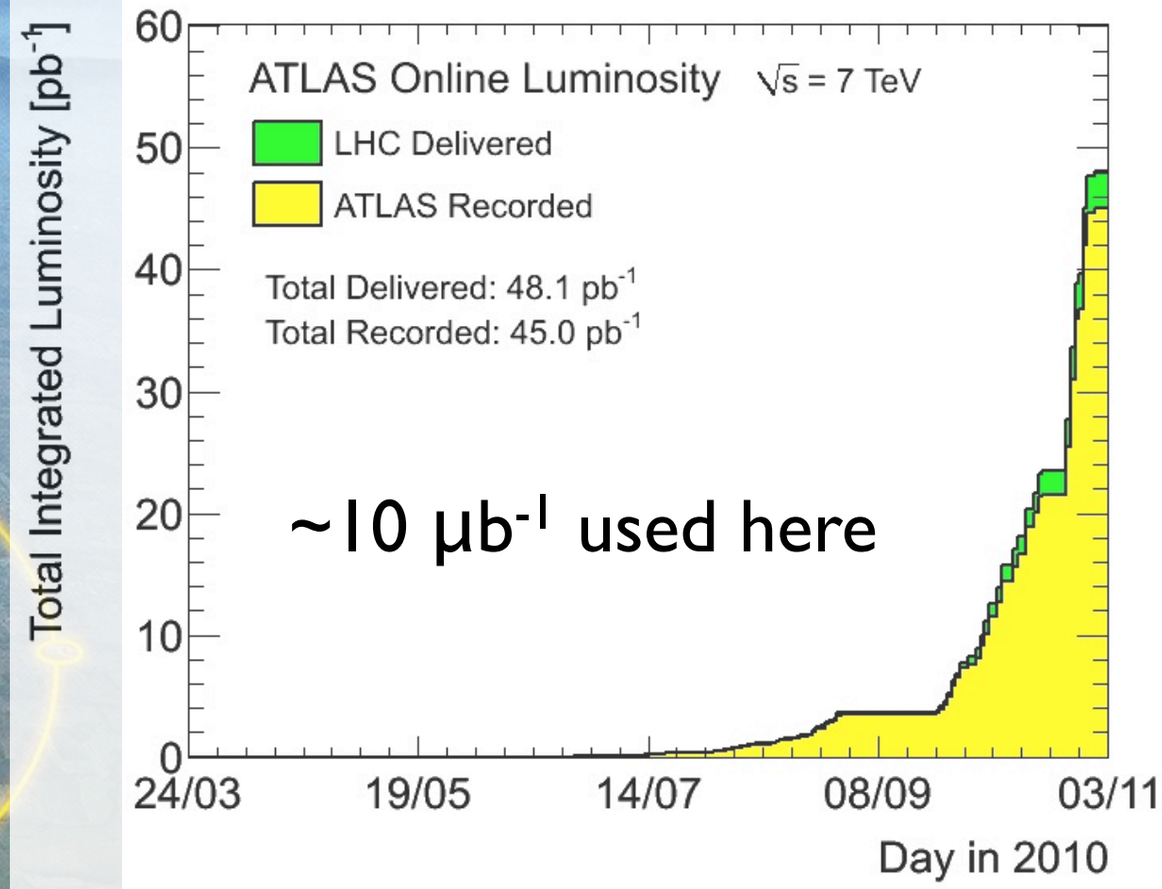
DIS 2011, Newport News, Va
April 13, 2010

Manuel Kayl
on behalf of the ATLAS Collaboration

NIKHEF

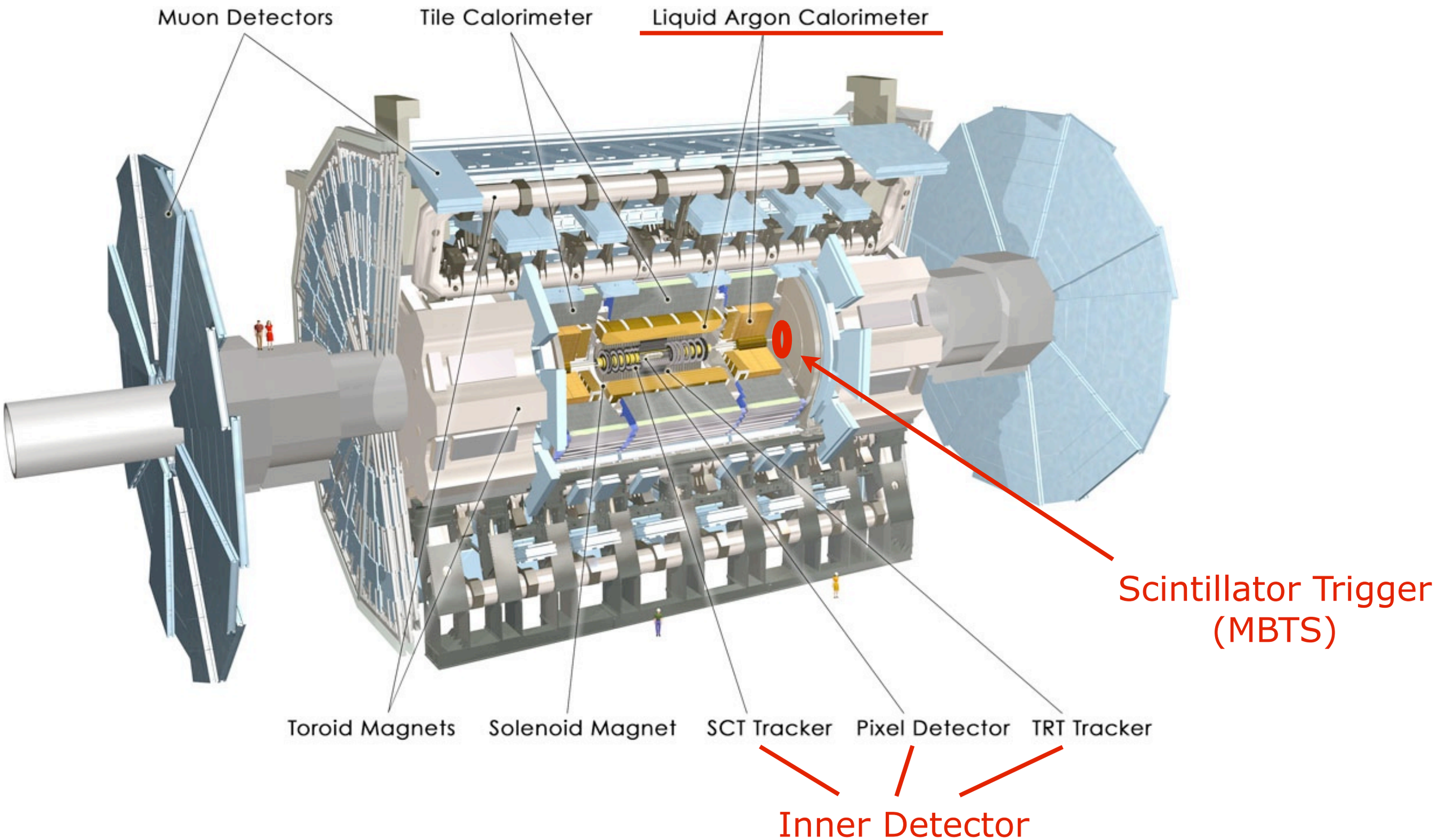
The LHC



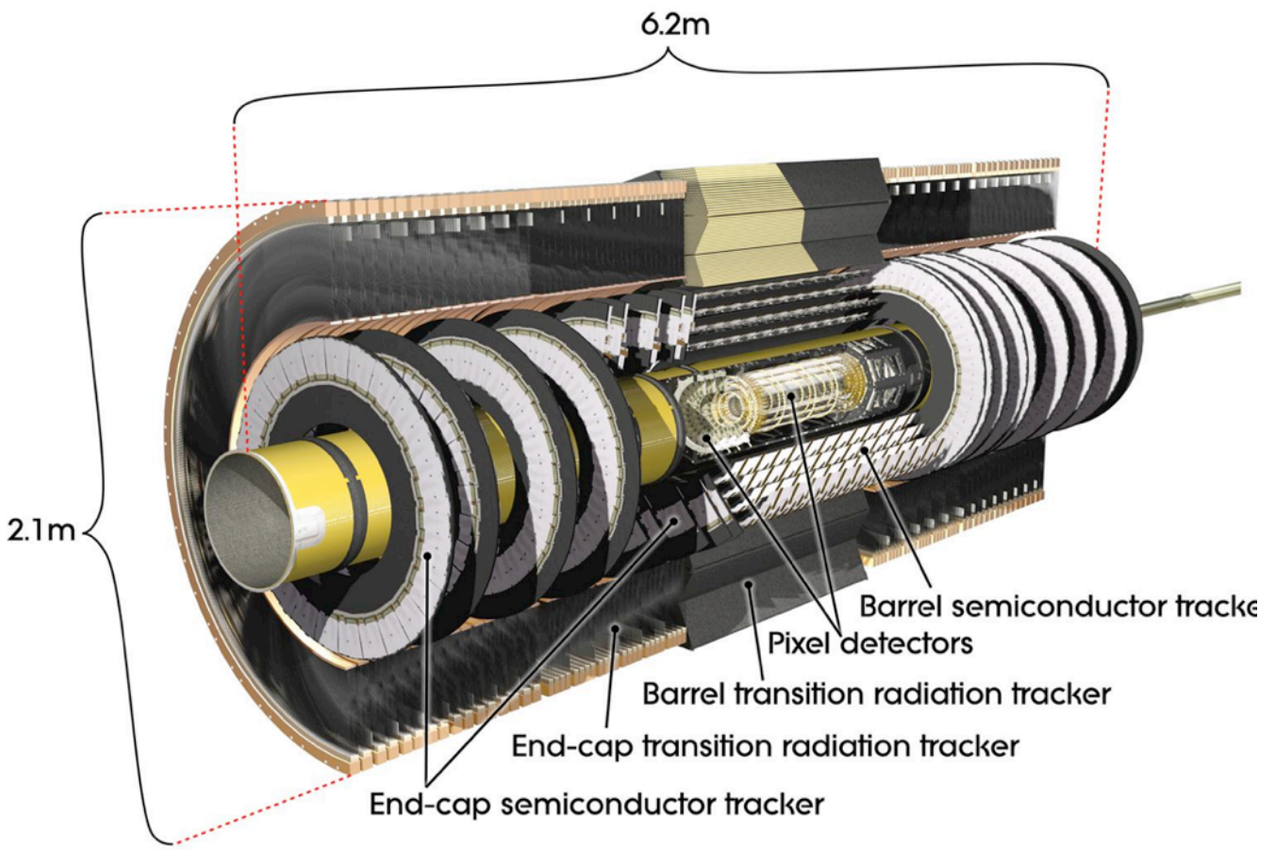


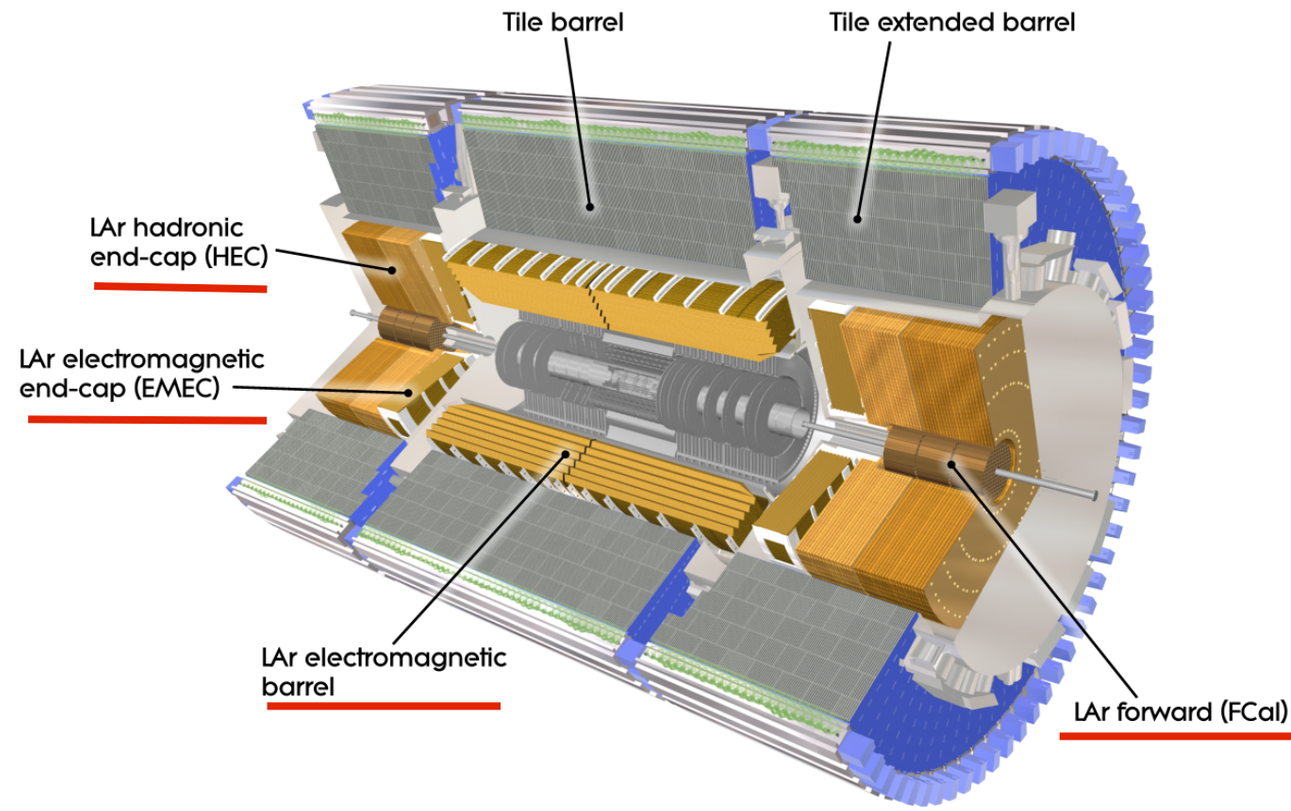
- pp collider with nominal center of mass energy $\sqrt{s}$ = 14 TeV
- design luminosity of $\mathscr{L} = 10^{34}\ cm^{-2}\ s^{-1}$ (collision rate of 40 MHz)
- design to collect data set of ~10 fb^{-1} per year (Tevatron: total of ~8 fb^{-1})

The ATLAS detector



The ATLAS inner detector / calorimeter

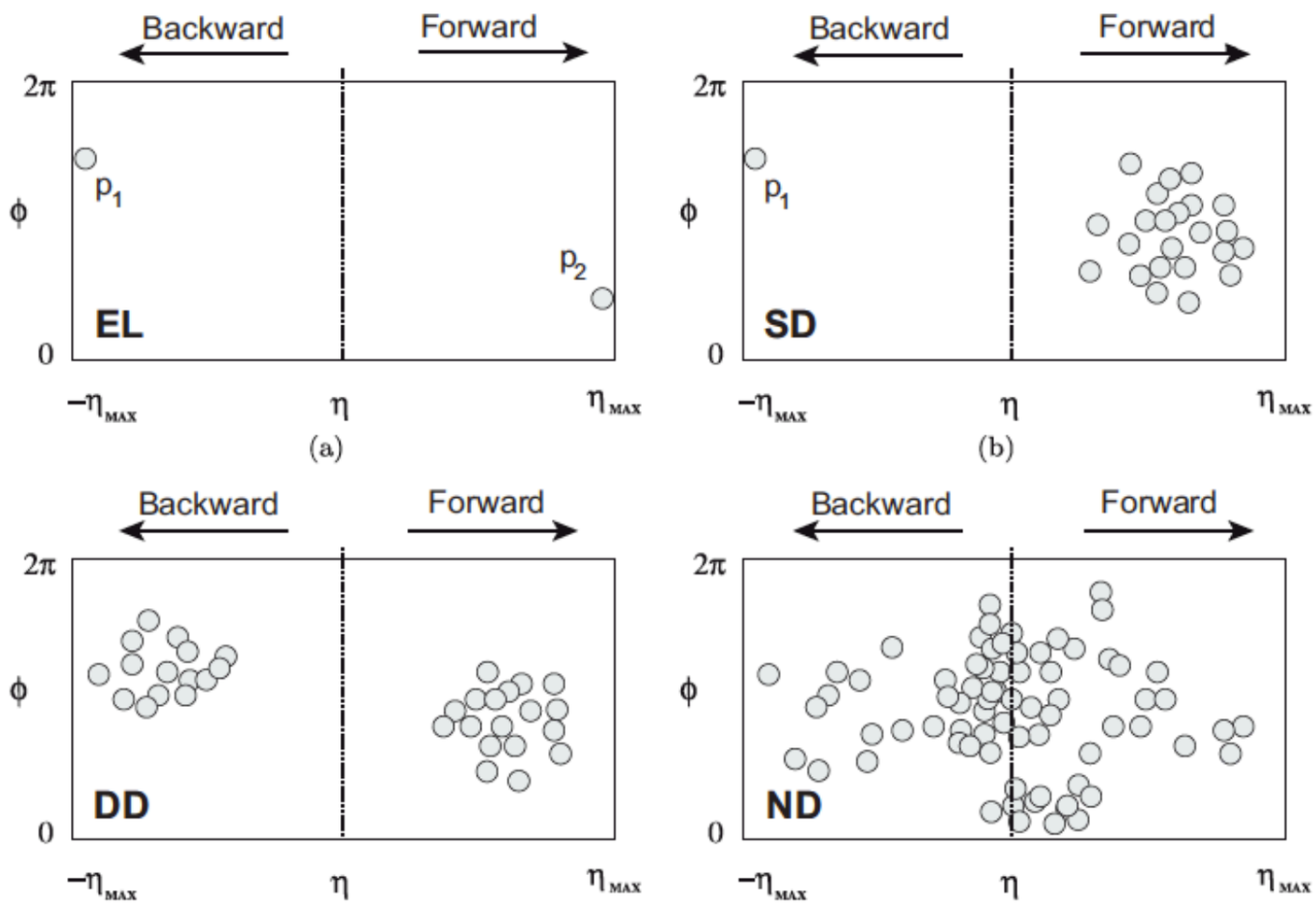


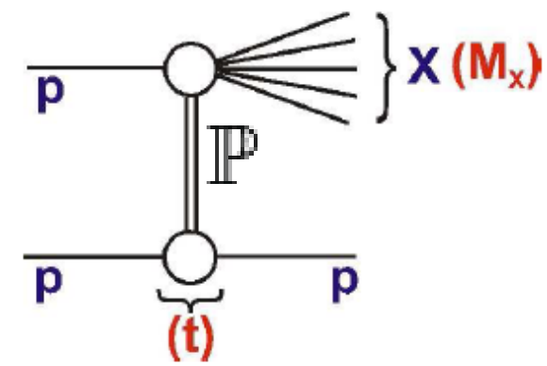


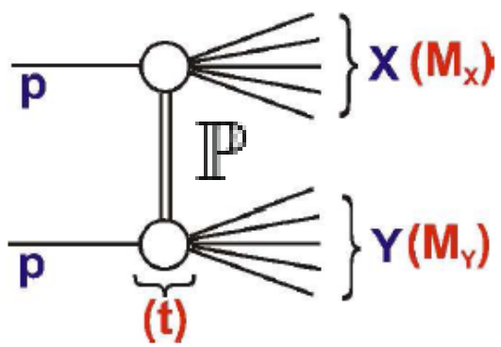
- Inner detector composed of silicon pixel detector, silicon strip detector (SCT), transition radiation tracker (TRT) (coverage $|\eta| < 2.5$)
- Calorimeter components used : LAr EM, LAr HEC, LAr FCAL (coverage $|\eta| < 4.9$)
- Study energy deposits per readout cell (no jets)

→ Identify rapidity gaps (coverage $|\eta| < 4.9$)

Proton proton collisions

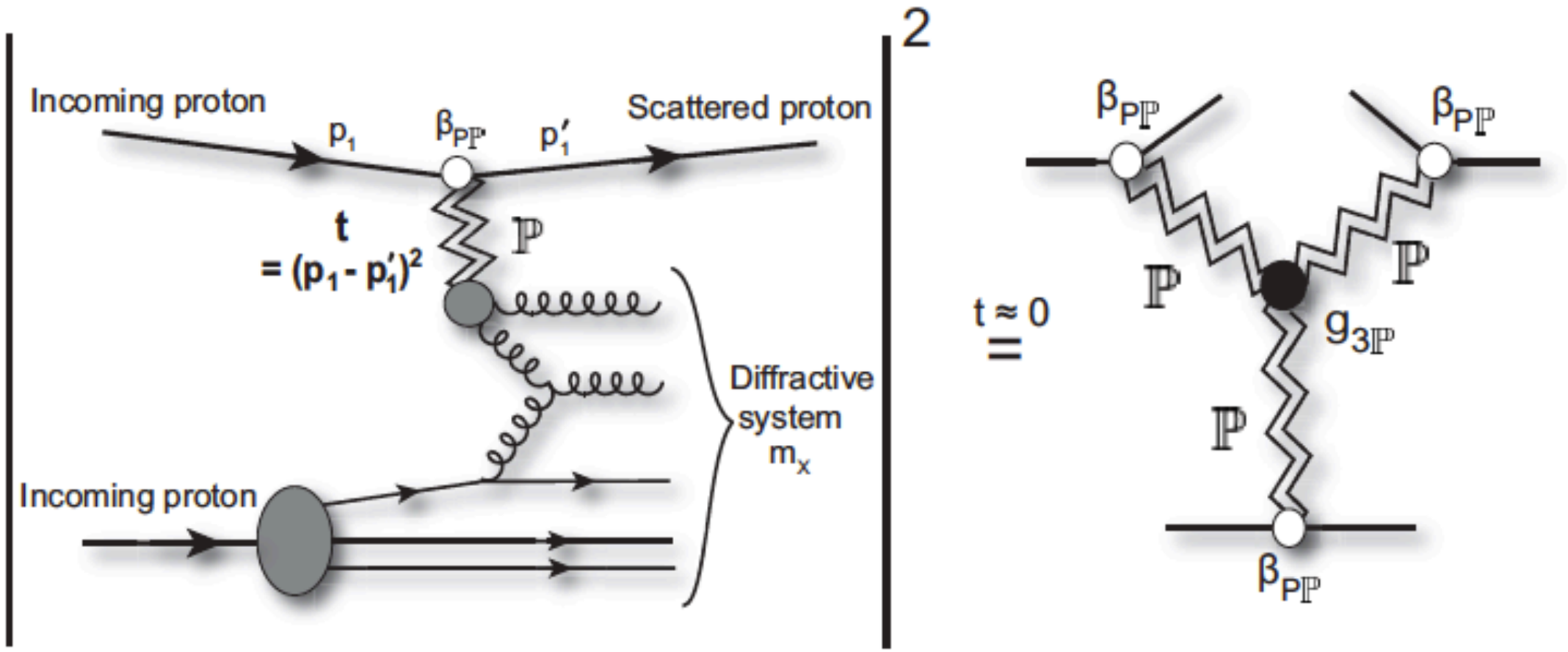






- Proton proton collisions divided in elastic (EL) events, single diffractive (SD) dissociation, double diffractive (DD) dissociation and non-diffractive (ND) events
- Diffraction (~30% of total): no exchange of quantum numbers, proton (s) get excited and dissociate into multiple particles
- Important for total cross-section, pile-up, luminosity monitoring, ...

Modeling of diffractive events

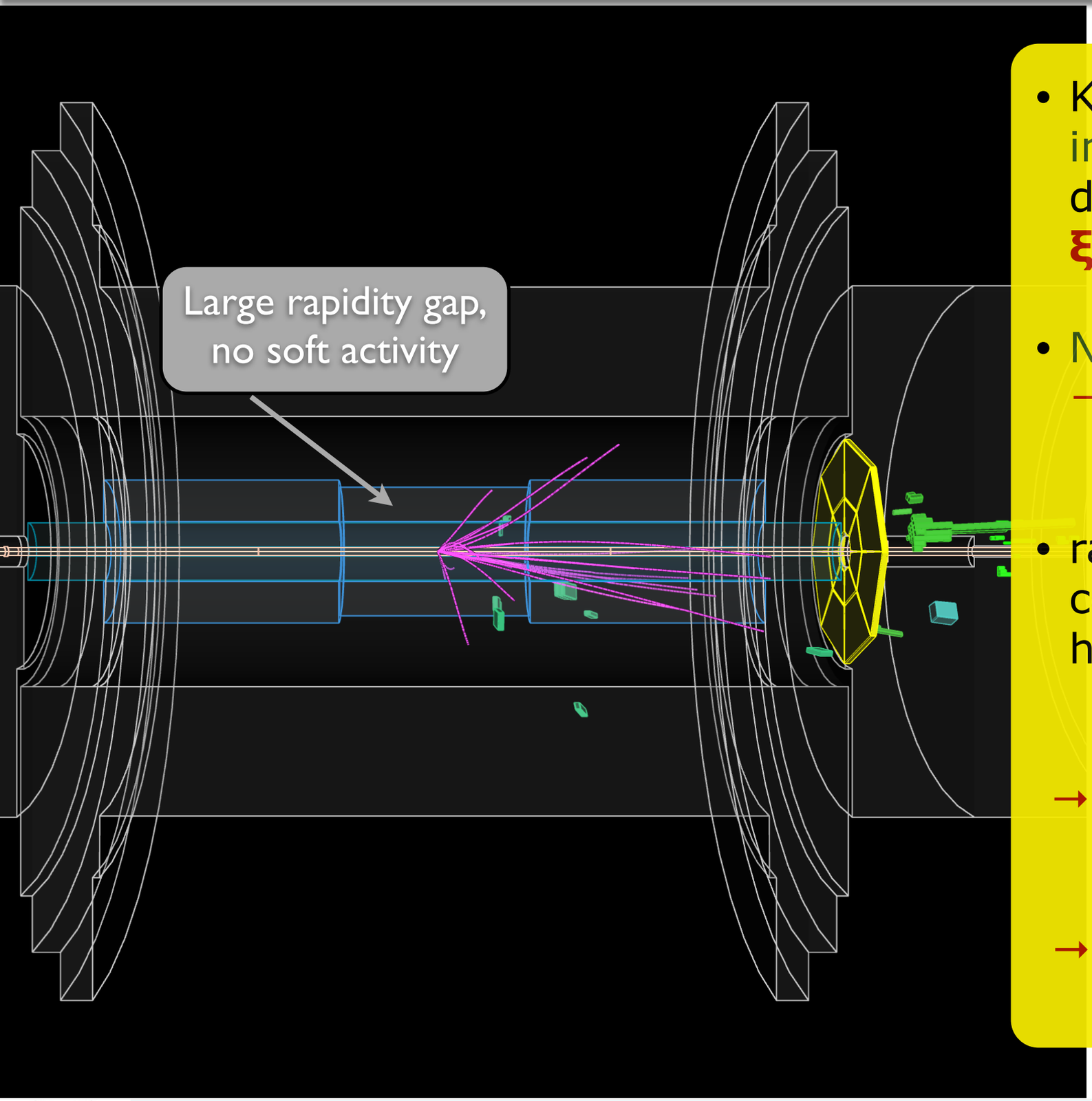


- Soft interactions → realm of non-perturbative QCD
- Generally described in Regge theory by exchange of Pomerons
- Cross sections described by triple Pomeron coupling g_{3P} with correction factors (partly empirical)
- Three models: Pythia6, Pythia8 and Phojet (Dual Parton Model)
- New approach by Pythia8: use of diffractive PDFs and calculation of 'partonic' cross sections
  → includes hard and soft diffractive component

Identifying diffraction:

Rapidity gap cross sections at $\sqrt{s}$ = 7 TeV

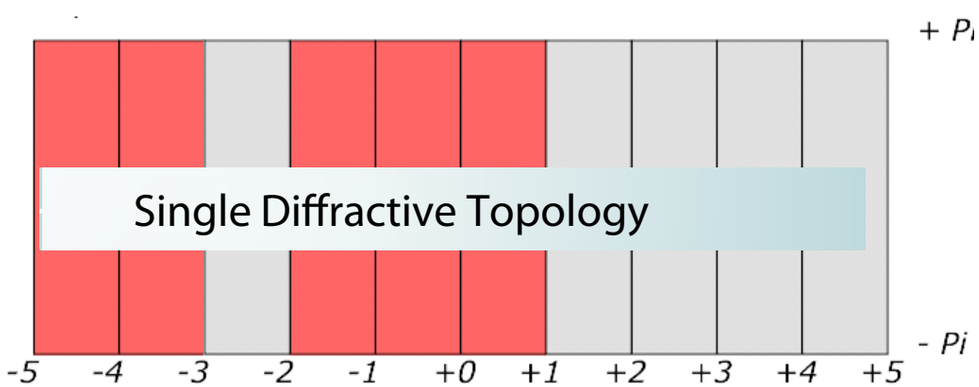
Overview of rapidity gap analysis



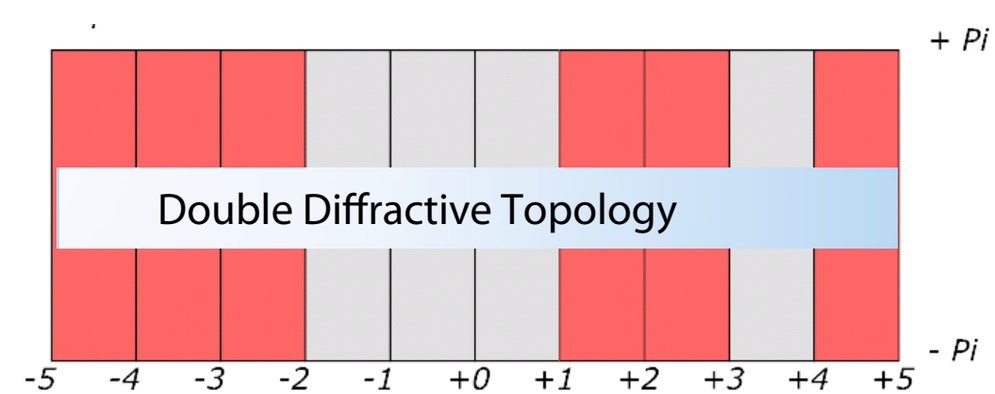
- Kinematics described by invariant masses M_X, M_Y of diffractive systems:
  $\xi_X = M_X^2/s$ $\xi_Y = M_Y^2/s$
- No colour flow in diffraction
  → Large rapidity gaps (LRG) $\Delta\eta$ between diffractive systems
- rapidity gap $\Delta\eta$ and ξ are connected via (for SD before hadronisation):
  $$\Delta\eta = -\ln \xi_X$$
  → Optimise fraction of diffractive dissociation in Monte Carlo
  → Measure cross section as function of $\Delta\eta$

Gap finding algorithm

- Divide 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 analysis:
  - *Floating gap* : Largest consecutive run of empty rings, parameterised by its size $\Delta\eta$ and start η_{start}
  - ***Forward gap***: Largest consecutive run of empty rings, starting from edge of acceptance (η=±4.9) and size $\Delta\eta^F$

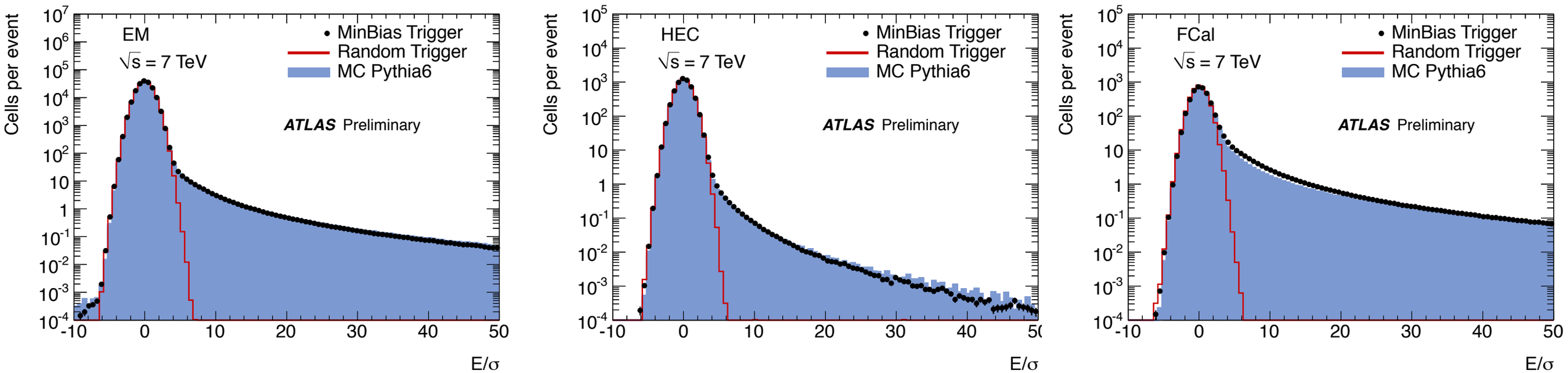


$\Delta\eta$ = 4
$\Delta\eta^F$ = 4
η_{start} = 5



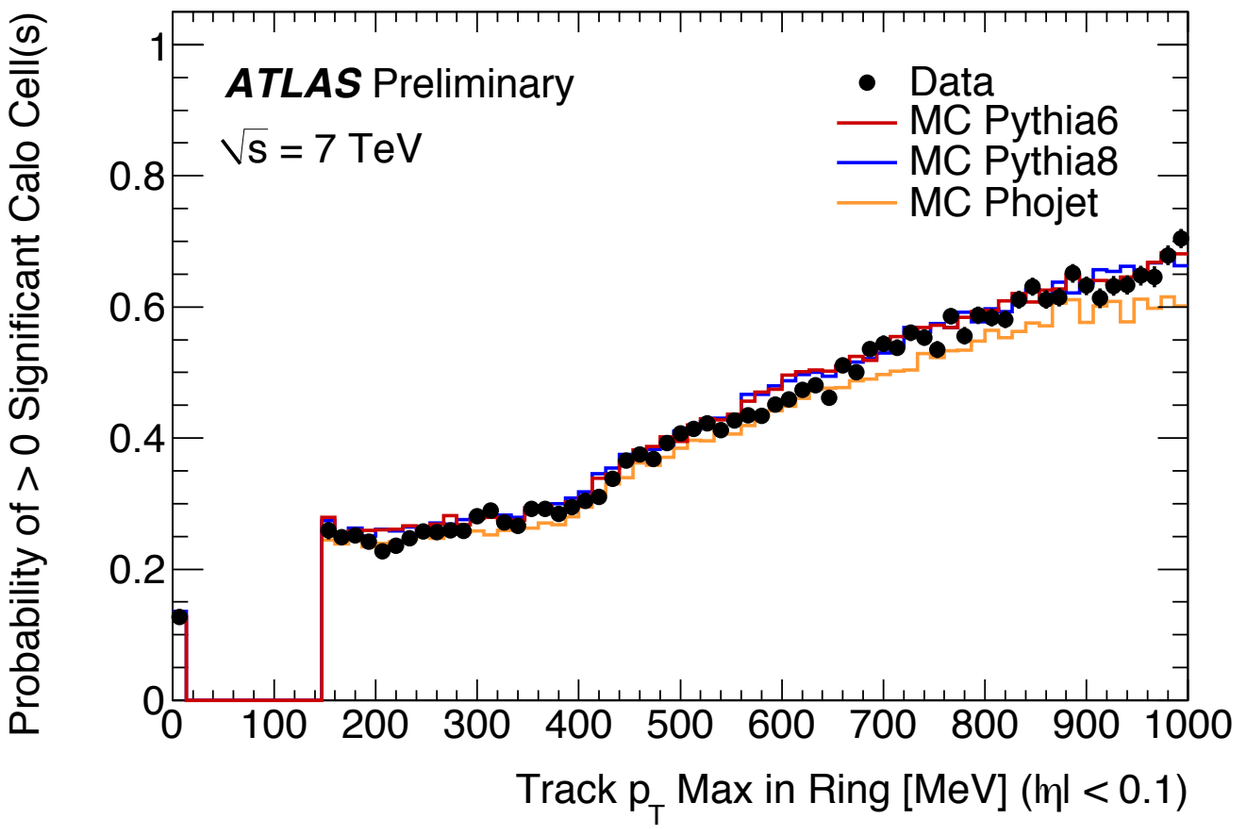
$\Delta\eta$ = 3
$\Delta\eta^F$ = 0
η_{start} = 2

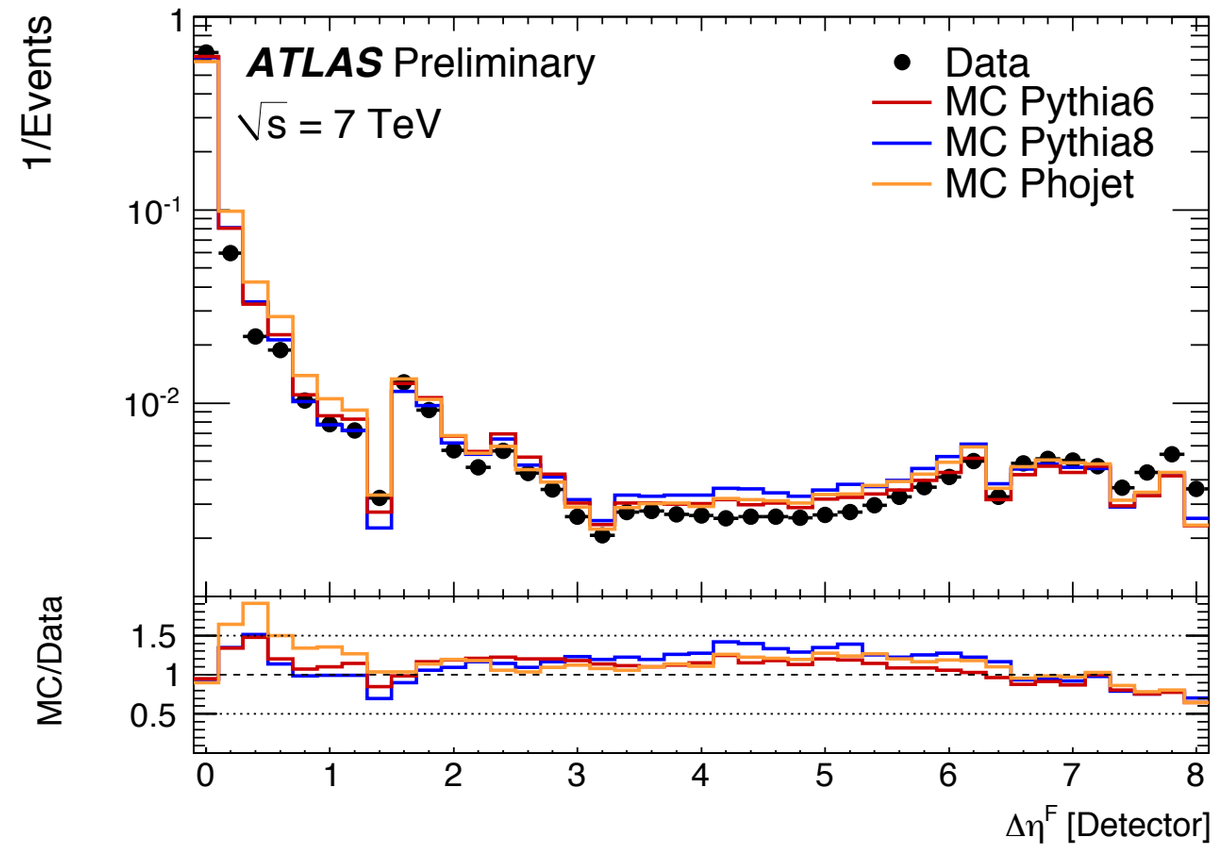
Energy deposit in calorimeters



- Energy significance in data with MinBias/Random trigger and MC
- Three calorimeters shown: electromagnetic, hadronic end-cap, forward
- Noise is well modeled by MC over many orders of magnitude, gaussian profile
- Selection based on significance of energy per cell $E/\sigma_{noise} > 5.5$ and at least one cell above threshold

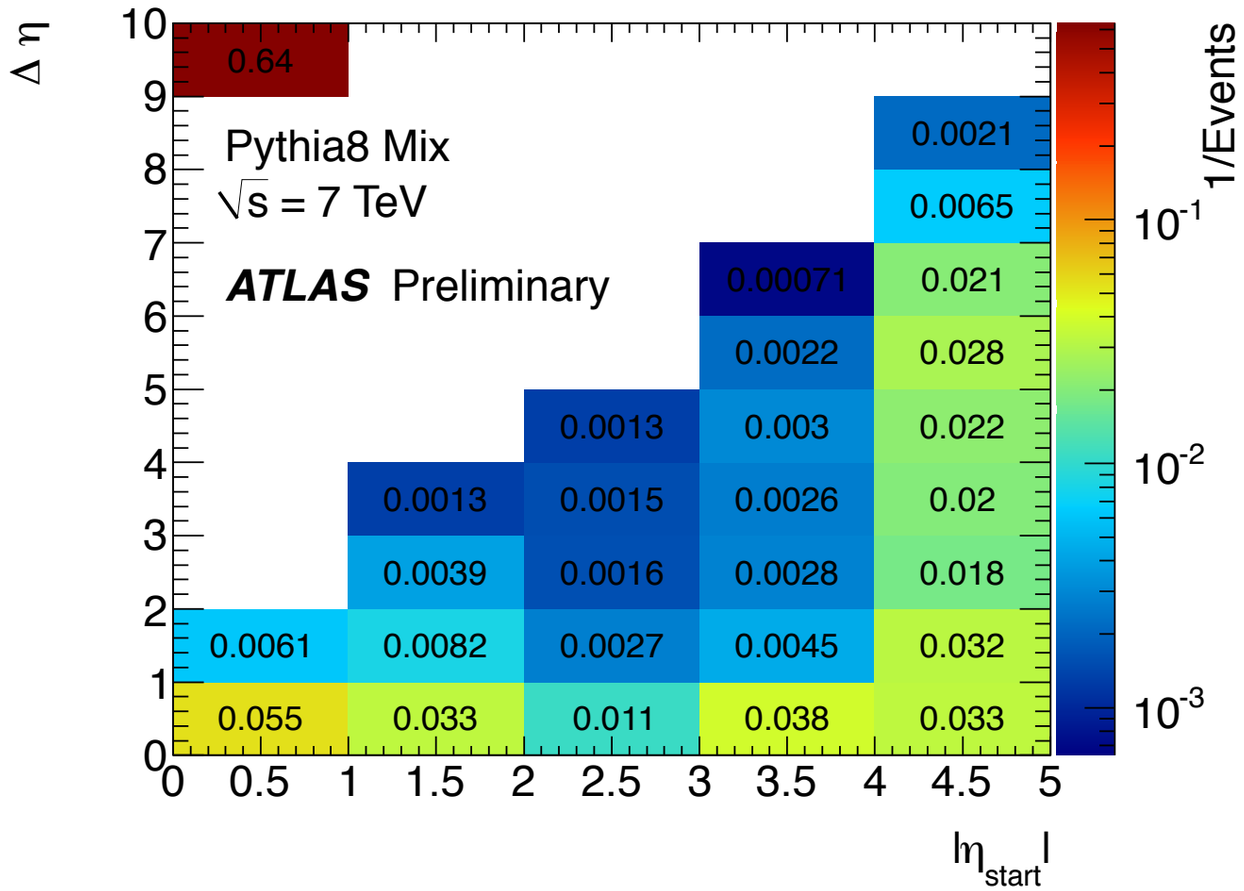
Control distributions

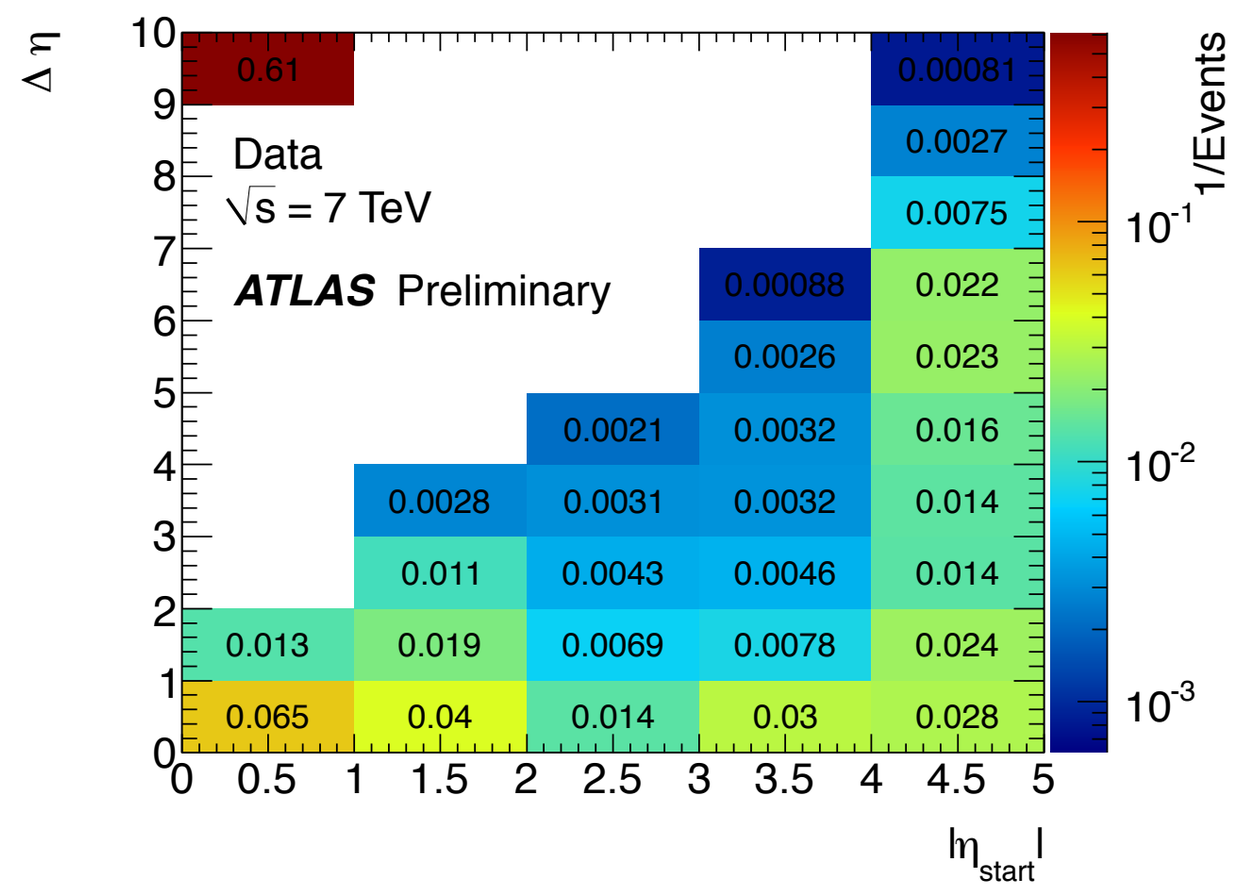




- Check quality of MC description for unfolding procedure
- Probability to a select a cell as a function of maximum track p_T in central η region (left)
- Forward rapidity gap distribution in data and MC (right)

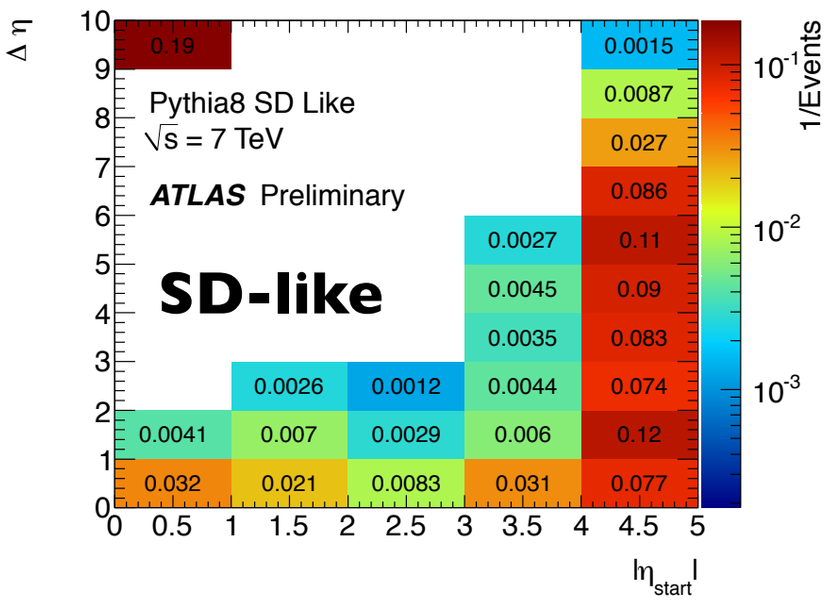
Optimisation of diffractive fractions in MC

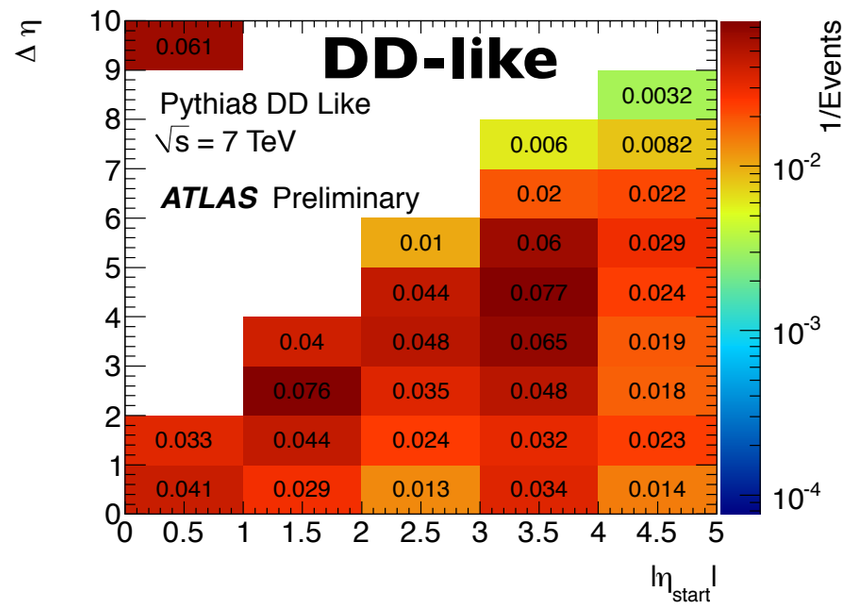


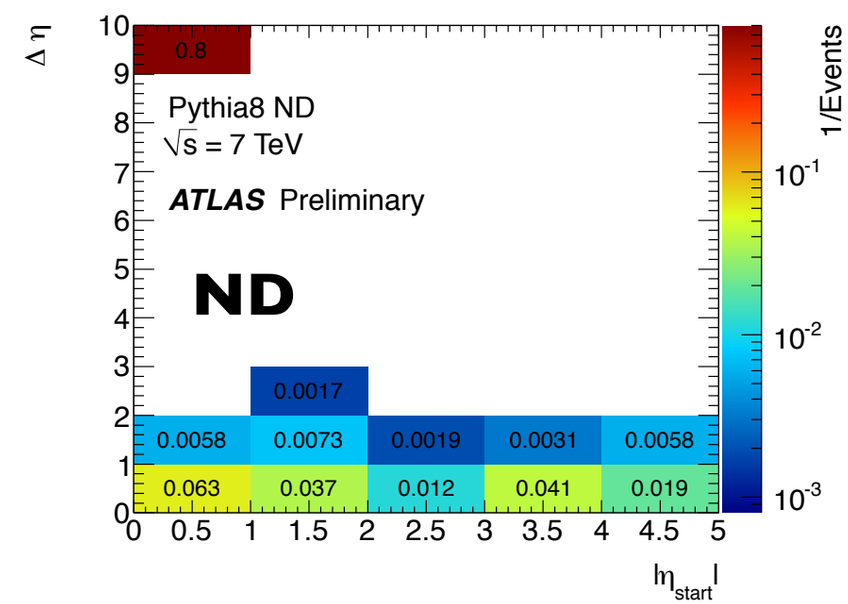


- Measure rapidity gap $\Delta\eta$ versus first ring with activity η_{start}
- Discrepancies between data (left) and default Pythia8 (right) found
- Expect improvement if diffractive and non-diffractive component are mixed differently

Optimisation of diffractive fractions in MC







- Construct templates for SD-like (SD and DD events with $\xi_X \leq 10^{-6}$), DD-like (remaining diffractive events) and ND events
- Fractional fit of templates to data using log-likelyhood

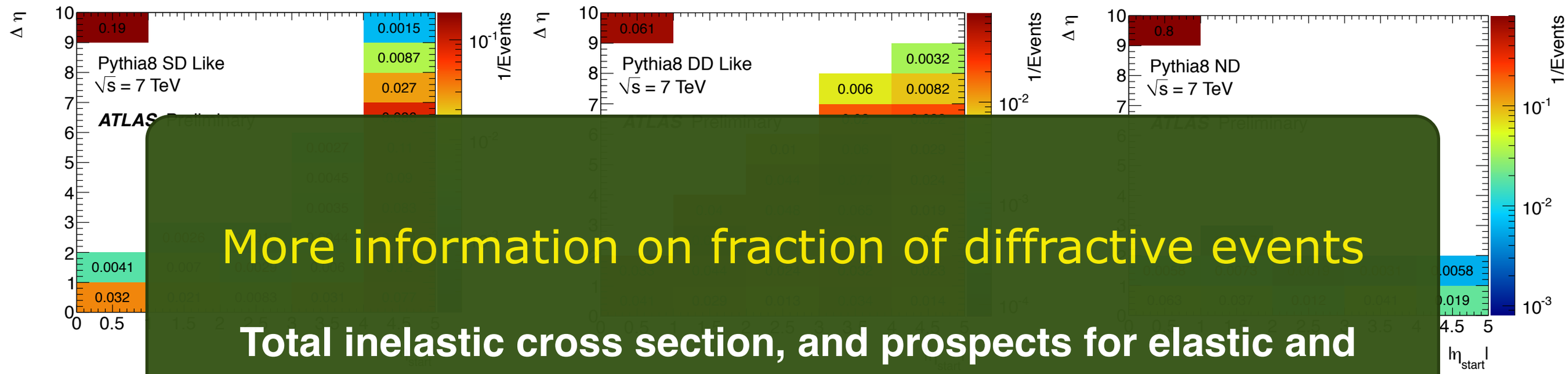
$M_Y \leq 7$ GeV

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
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) %

Optimisation of diffractive fractions in MC



More information on fraction of diffractive events

Total inelastic cross section, and prospects for elastic and central-exclusive measurements in ATLAS
by
Lauren Tompkins

Thursday 14th April 2011 - Grand Ballroom - Salon I
11:35 hrs

- Construct templates for SD-like (SD and DD events with $\xi \leq 10^{-3}$), DD-like (remaining diffractive events) and ND events
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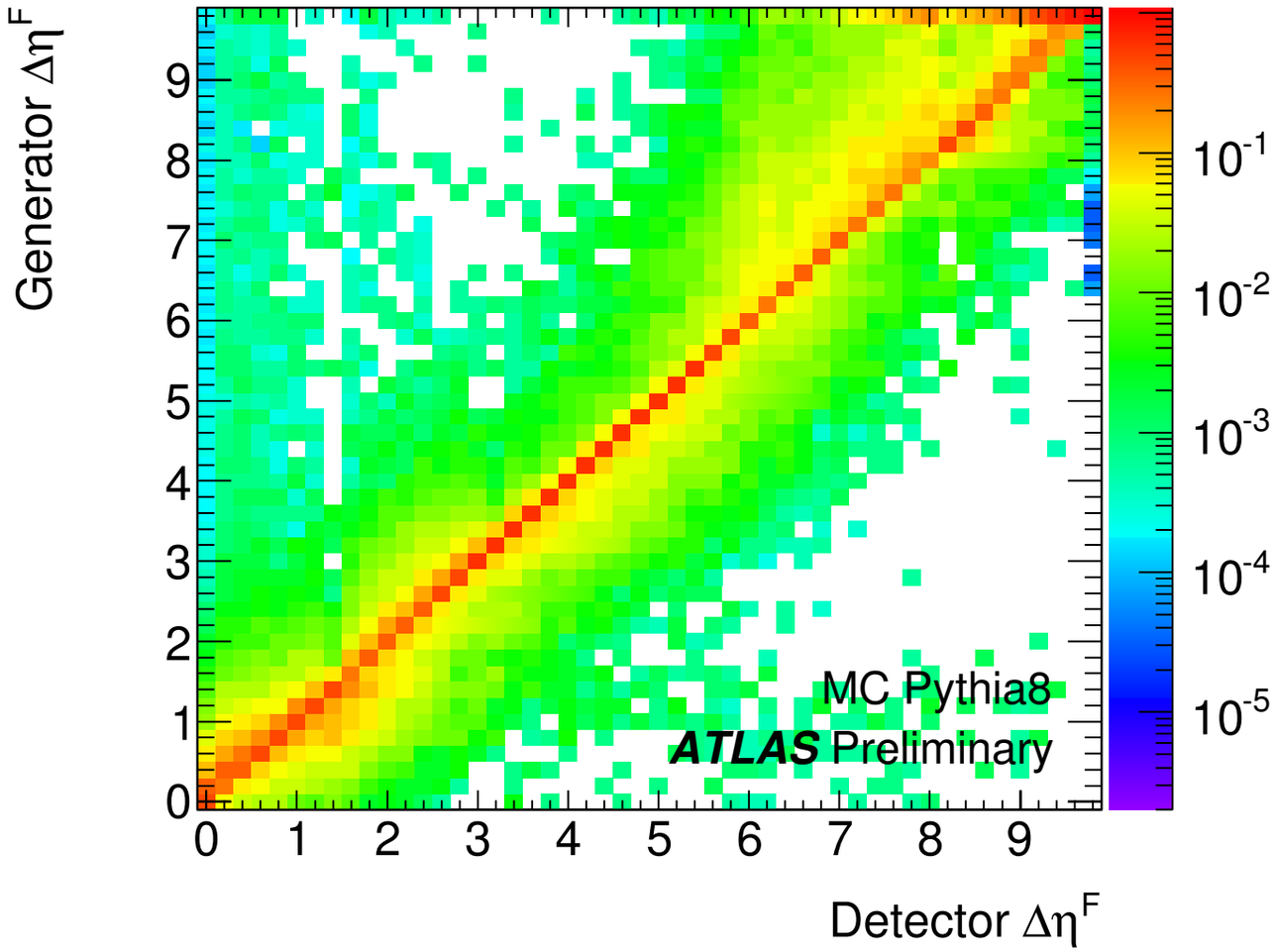
Unfolding for cross section measurement

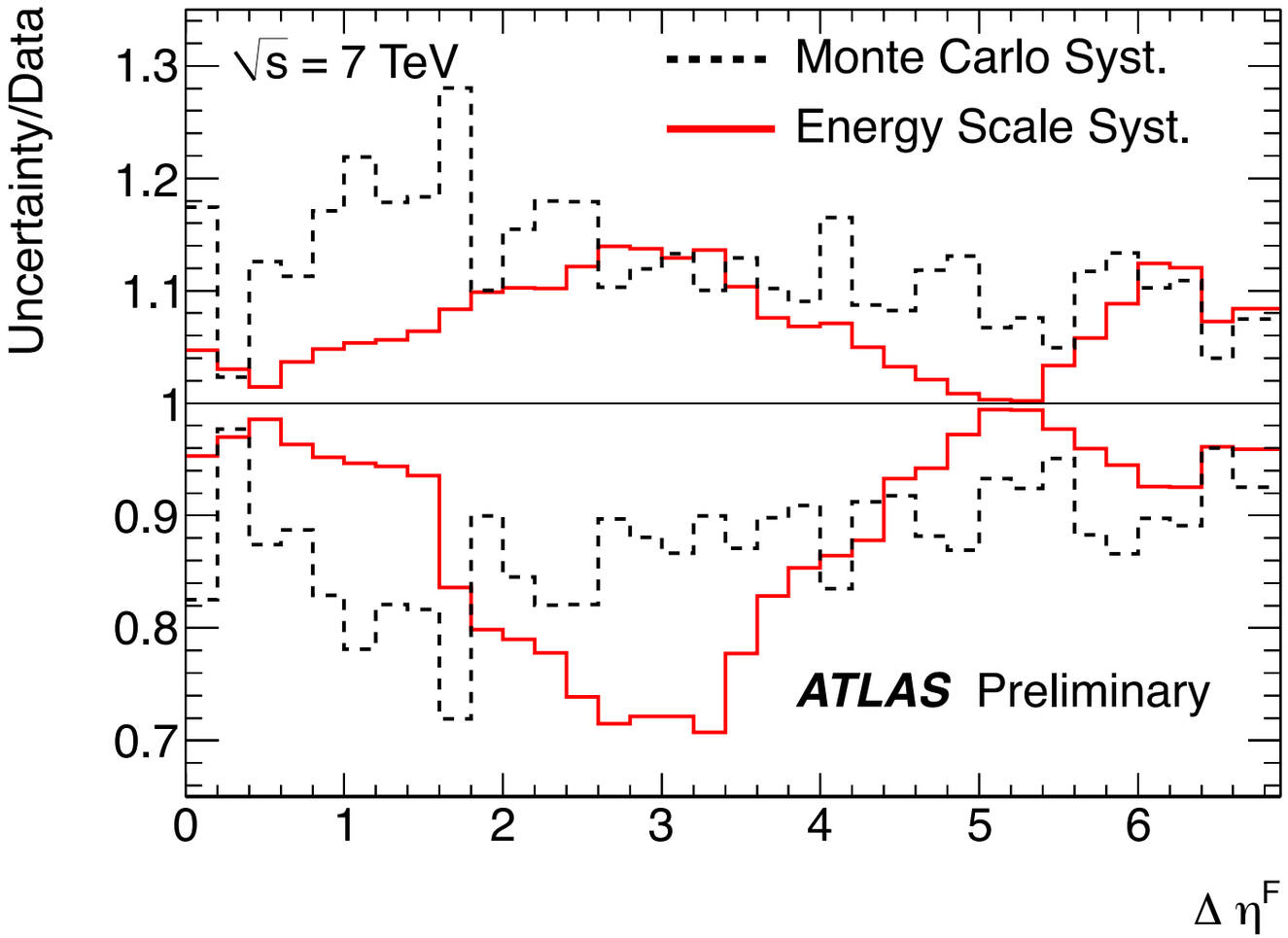


- Migration matrix between hadron and detector level to obtain correction factors $A(\Delta\eta^F)$
- Cross section as function of rapidity gap obtained as

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

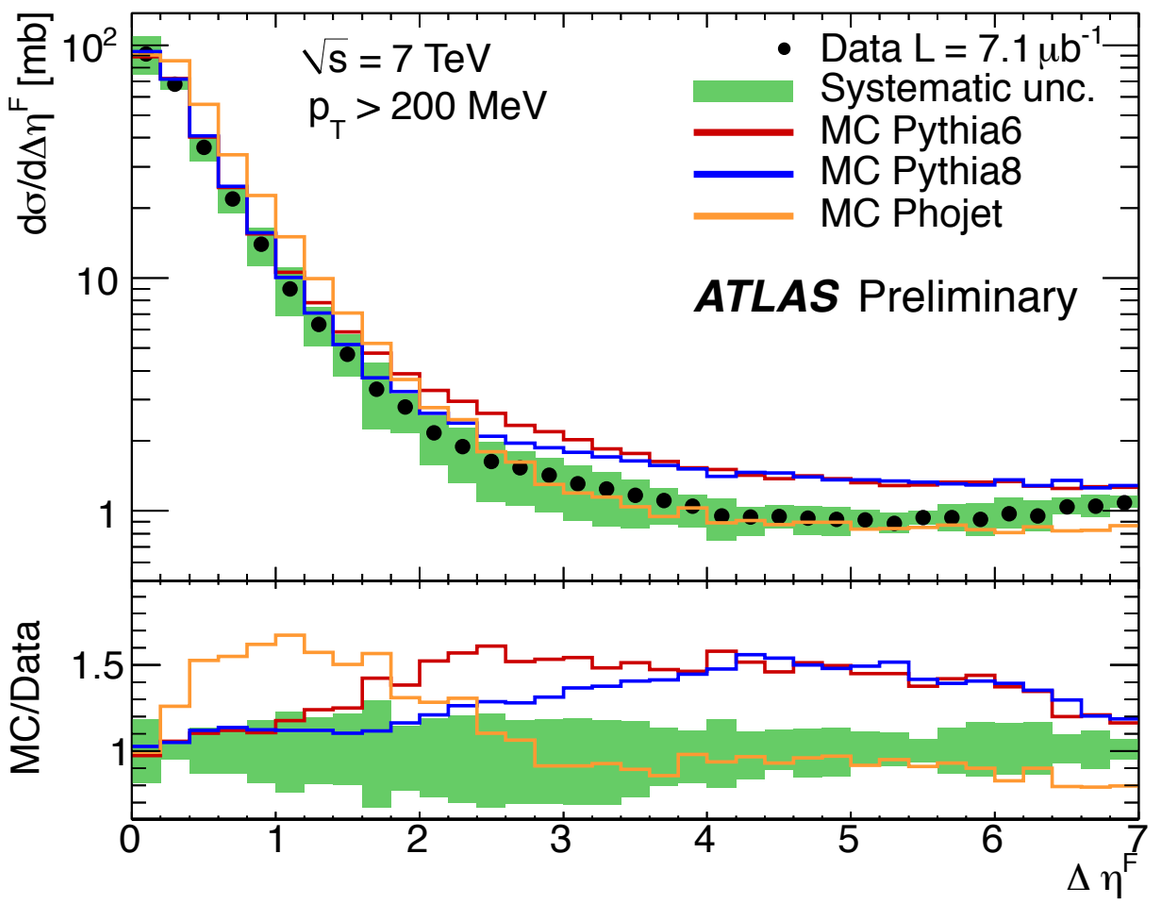
Systematic uncertainties

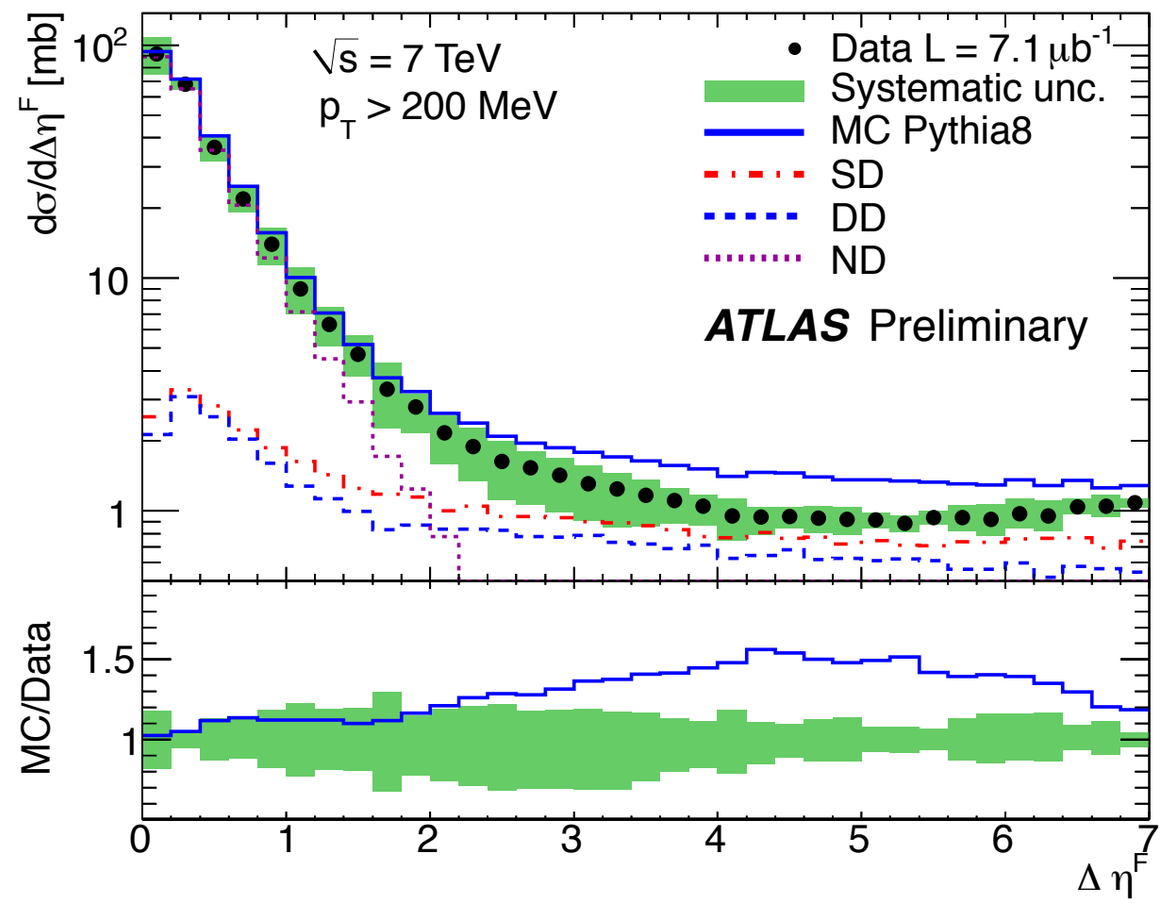
- *Energy Scale*:
  - 25% uncertainty on all measured cell depositions
  - derived from comparison of tracking/calo in central part
  - derived from test beam in forward region
- *Model dependence*: Deviation of correction procedure using Pythia6 and Phojet instead of Pythia8 (default)



- Various other sources considered: Cell threshold cut, track reconstruction efficiency, additional material in the detector, variations of the trigger efficiency, luminosity (3.4%)
- All negligible compared to the ones above

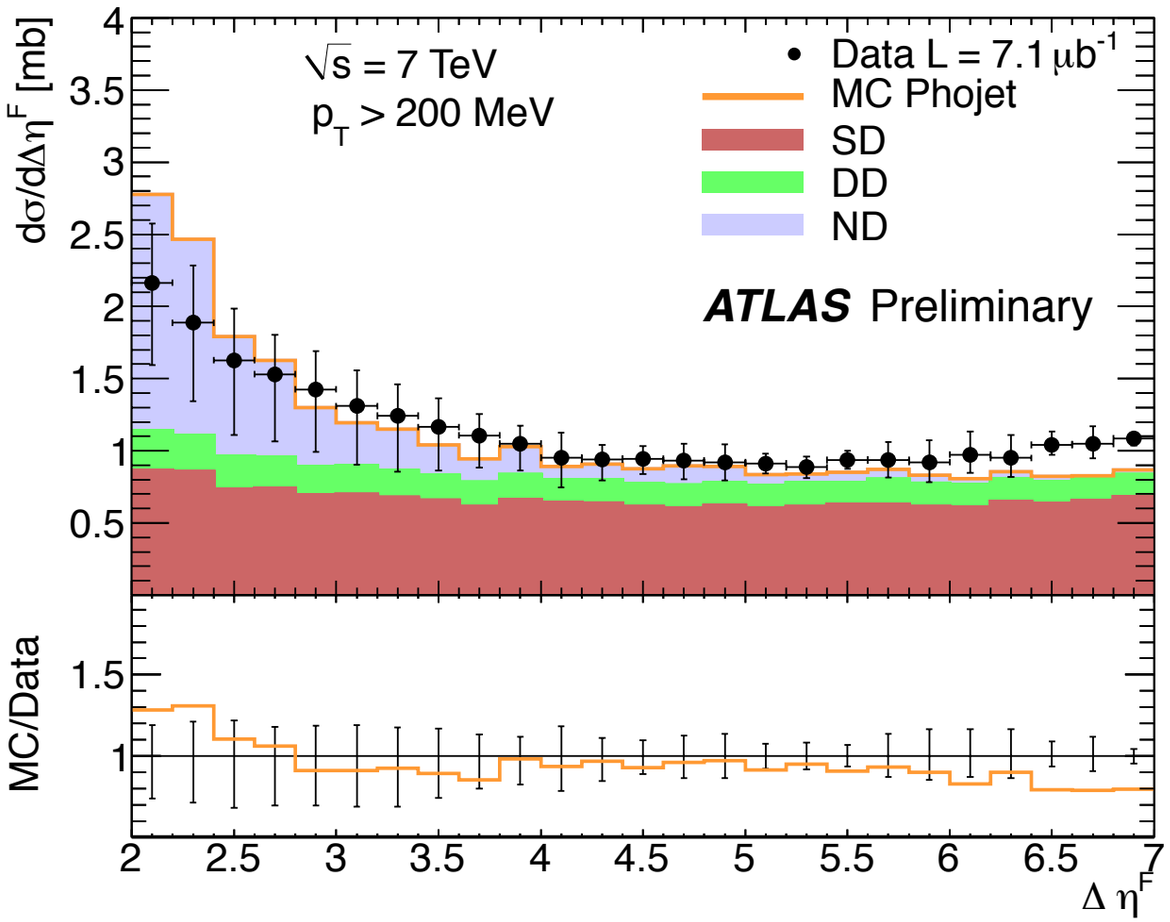
Diffractive cross section

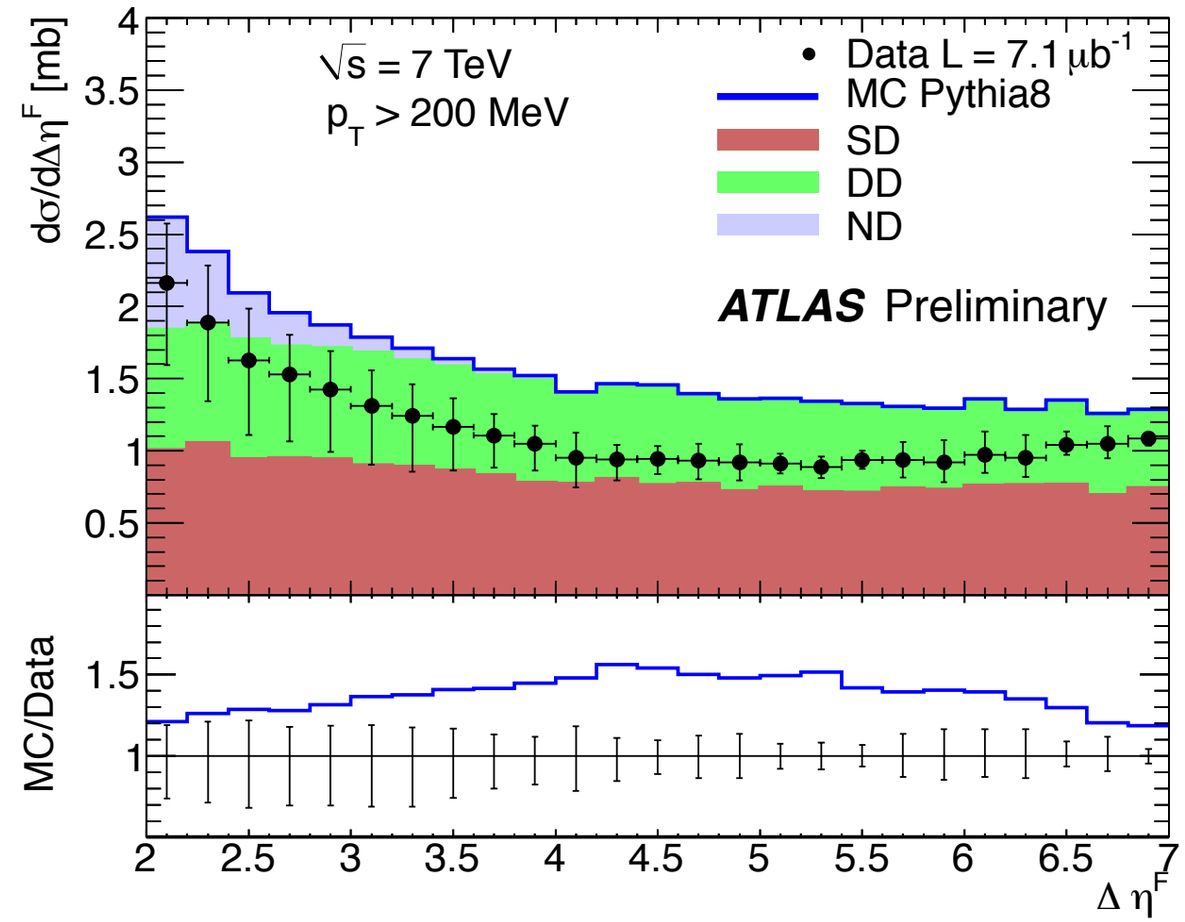




- Cross section as function of forward rapidity gap $\Delta\eta^F$
- Pythia 8 describes data best at low $\Delta\eta^F$, Phojet at high $\Delta\eta^F$
- Evidence of diffraction at high $\Delta\eta^F$: MC predicts exponential fall off of ND events, plateau from SD/DD dissociation
- Diffractive cross section ~ 1mb per unit of $\Delta\eta^F$ at high $\Delta\eta^F$

Diffractive cross section

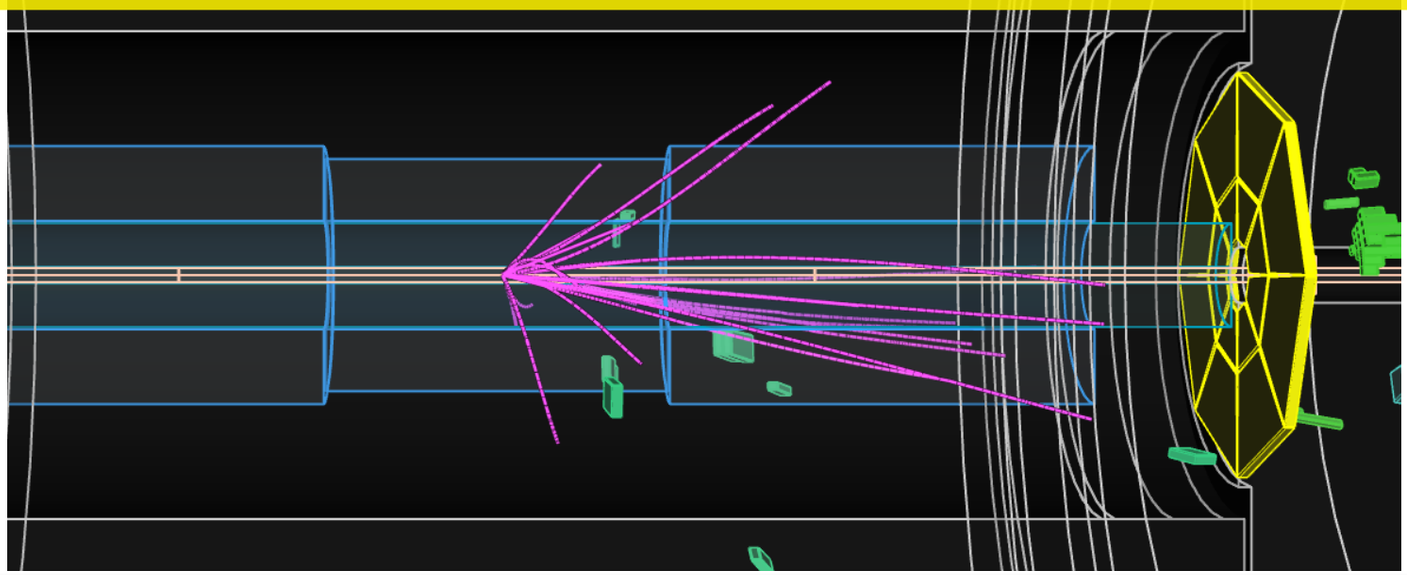


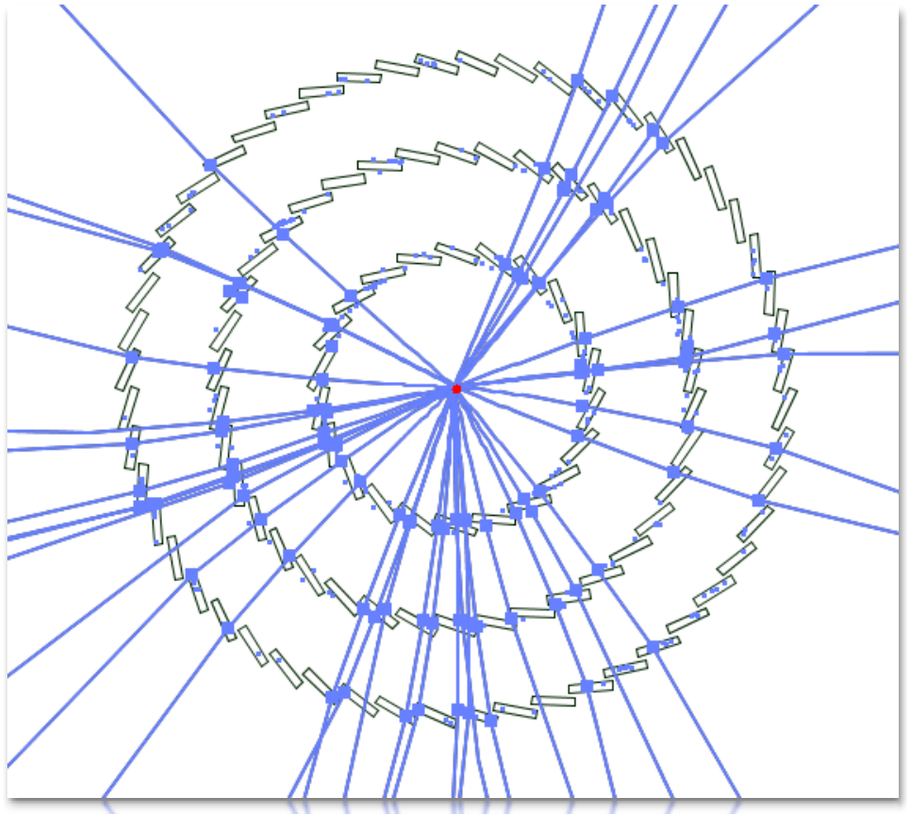


- Zoomed in view of cross section at high $\Delta\eta^F$
- Normalisation obtained by Phojet fits data points better than the one from Pythia 8
- Pythia 8 overestimates contribution of diffractive dissociation

Conclusions

- Rapidity gap cross section analysis measures the diffractive component in proton proton collisions
- Comparisons with various Monte Carlo models
  - Pythia6
  - Phojet (Dual Parton Model)
  - Pythia8 (Hard diffractive component)
- Key results
  - Non-diffractive part best modeled by Pythia8
  - Diffractive cross section best modeled by Phojet
  - Fraction of diffractive events
    f_D = 30.2 ± 0.3 (stat) ± 3.8 (syst) %
  - Diffractive cross section
    $d\sigma/d\Delta\eta F \sim 1.0 \pm 0.2$ mb per unit $\Delta\eta^F$ for **$\Delta\eta F > 3.5$**

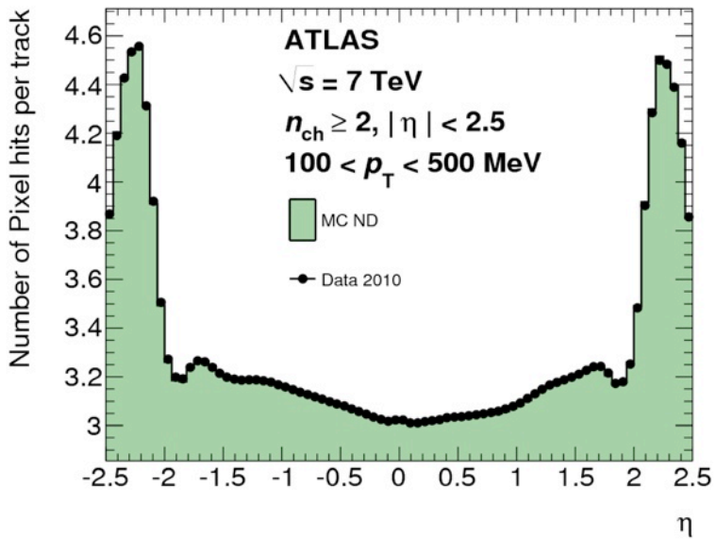




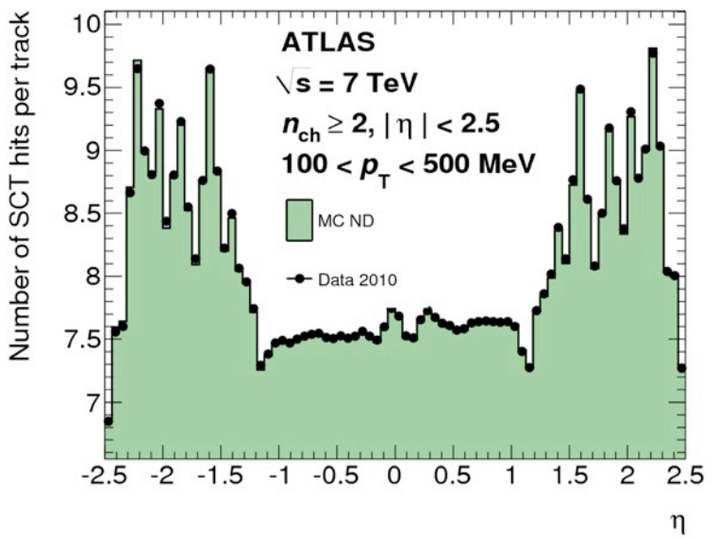
BACKUP

Validation of Tracking

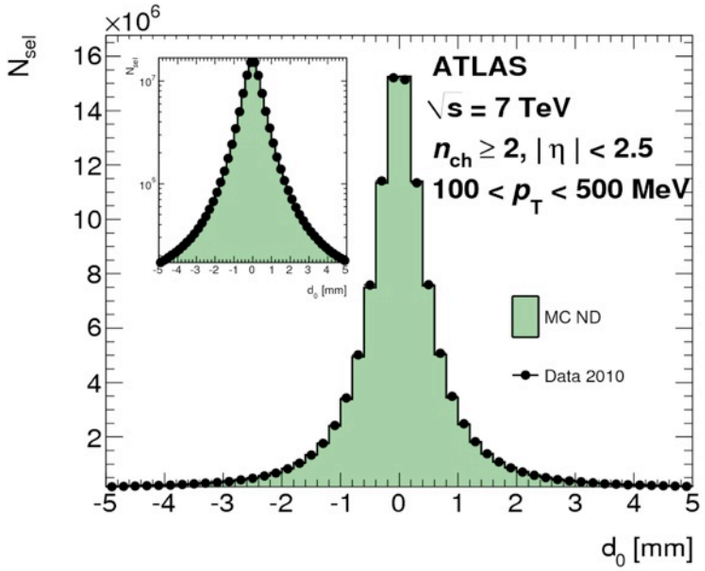
- **Main ingredient:** tracks from charged particles in the inner detector
- Validate performance by comparing data to simulation
  (100 MeV < p_T < 500 MeV)



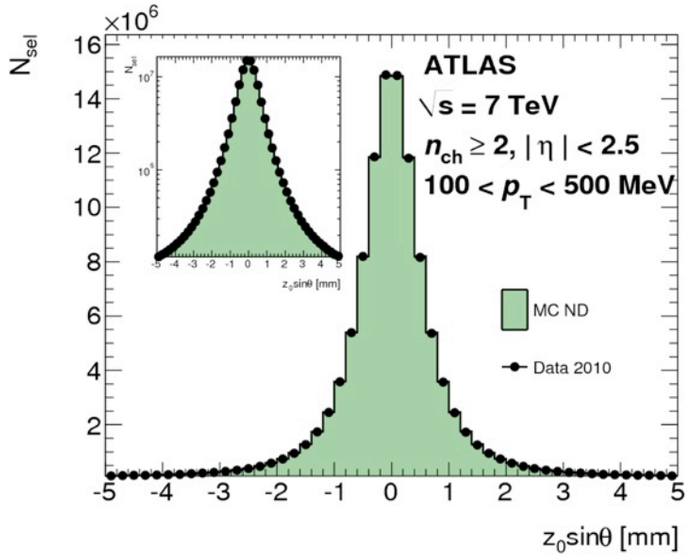
average number of pixel hits



average number of SCT hits



transverse impact parameter



longitudinal impact parameter