Soft-diffraction with AFP

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Program of AFP

- 1) High luminosity
  - Hundreds of fb^{-1}, interactions / crossing = 50 – 100
- 2) Medium luminosity
  - Hundreds of pb^{-1} (1-3 weeks of special running), interactions / crossing = up to 1
- 3) Low luminosities
  - < 1 pb^{-1} (~1 day of special running) – 10pb^{-1} (3-4days*), interactions / crossing < 0.5

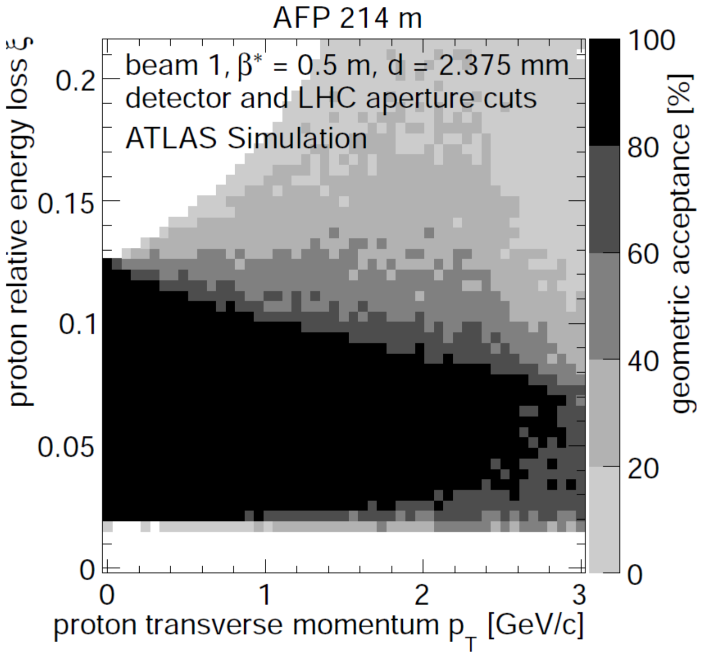
- 1) Exclusive production
- 2) Hard diffraction DPE, pomeron structure – double tag - timing needed
- 3) Soft diffraction, pA runs, SD (dijets/W/...) – particle production, correlation, etc. (never discussed in much detail, assuming that AFP will join dedicated special runs together with other experiments)

* 2013 run– 600nb^{-1} in 5hours @ 2.76TeV

- beta*=11, bunch intensity 1.5E11 ppb, 50ns bunch spacing, crossing angle 170 urad, mu=0.6

Low-mu program

- Luminosity of ~100nb^{-1}: millions of single tag and double tagged events
- Due to AFP acceptance, essentially high mass diffraction $0.015 < \xi < 0.13$
  - The low mass diffraction interesting (TOTEM shows 3 times higher cross section then models predict for $\xi < 10^{-7}$), but not in the acceptance
- Proton tagging information correlation with rapidity gaps in central detector
  - Limited, but some separation between single and double diffraction possible
- Essentially all the measurements of the soft particle activity that were done in ATLAS/CMS can be repeated after adding a proton tag requirement



Hard soft diffraction

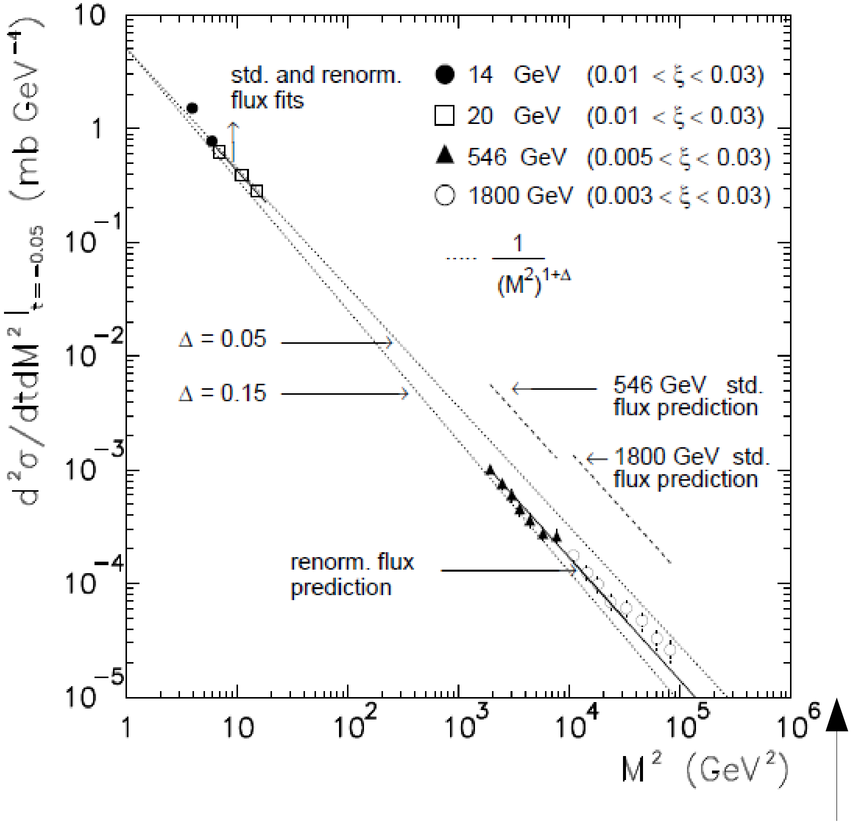
- Hard diffraction described by Gribov-Regge theory – triple-pomeron interactions
  - Super critical pomeron $\alpha(0) > 1$ has problems in high energy limit – amplitudes violate unitary
  - Predicted diffractive cross section grows faster than Tevatron data

- Many theoretical approaches to resolve this
  - Modification of Pomeron-hadron vertex, renormalization or dumping of pomeron flux, resumation of enhanced Pomeron diagrams decrease pomeron intercept wrt to bare pomeron

- Measurement of diffractive cross section as a function of ξ and t will help to resolve this issue

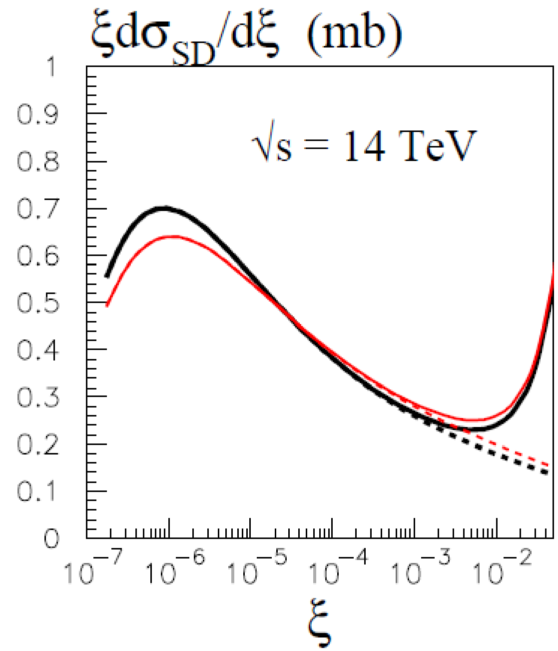
Soft Diffractive Measurements

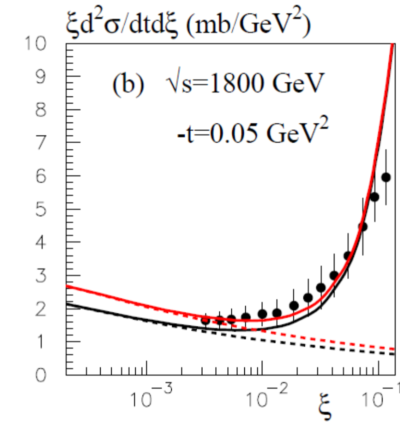
K. Goulianos, hep-ph/0407035



AFP acceptance: $M^2 > 4\times10^6$ GeV^2

- AFP 210 can resolve the problem of mass spectrum at large M_X





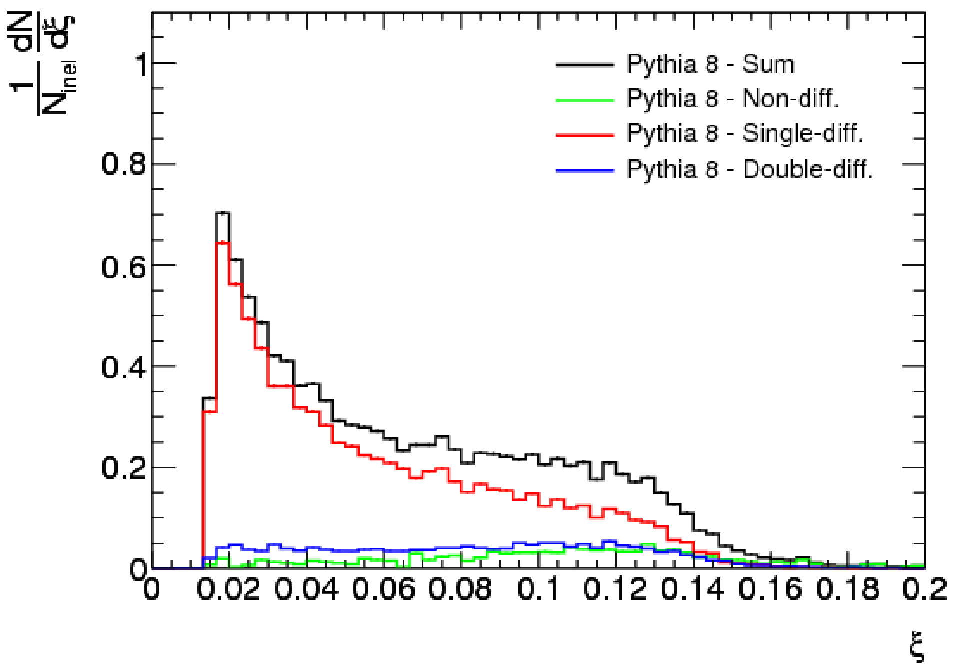
- Unifying the description of 'soft' and 'hard' physics
- Need to run at different energies?

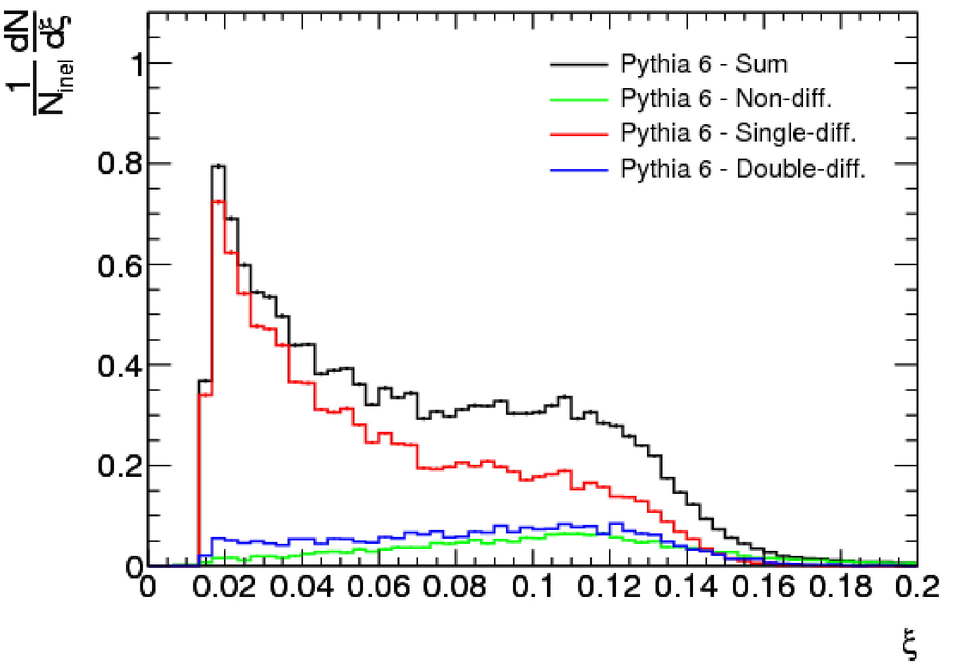
M.G Ryskin *et al.* arXiv:1102.2844v1

S. Ostapchenko, Phys.Rev.D81:114028,2010

Pythia 6 / 8

- Differences in the modeling of high xi region – uncertainty ~ 30%
- Significant contribution of the non-diffractive and double diffractive events
- Forward physics community should aim at constraining the prediction (ALFA/TOTEM/AFP)
  - Particularly important to predict pile-up in forward detectors

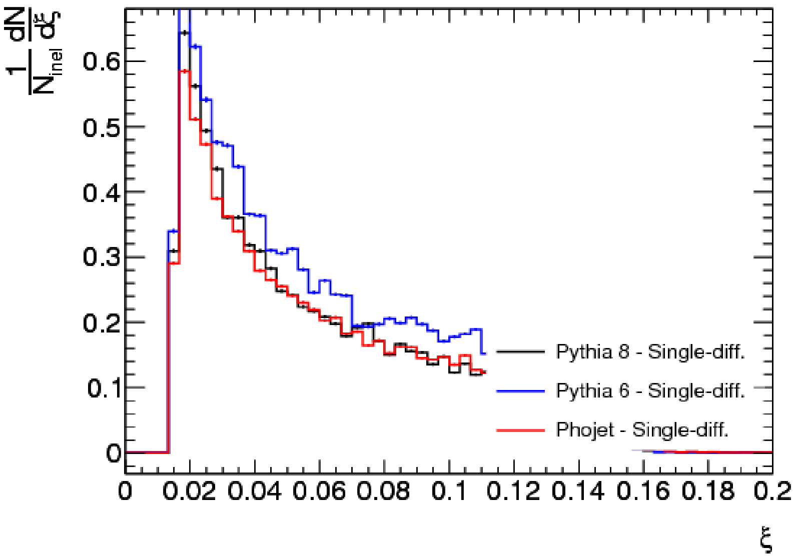


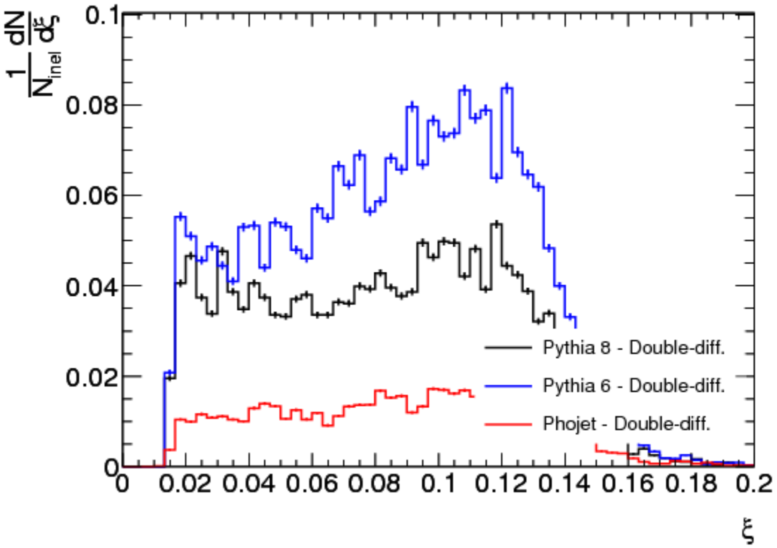


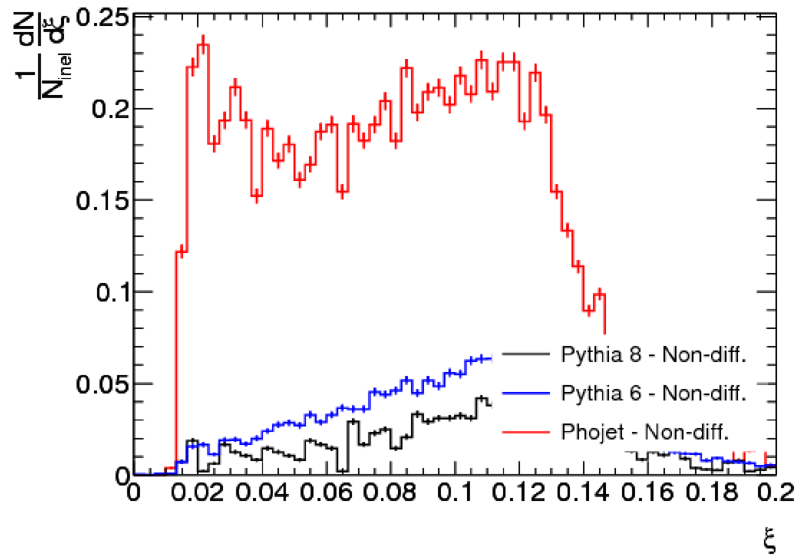
Comparison of various contributions

- SD event with intrinsic intact protons tend to agree

- Big differences between the generators for DD and ND

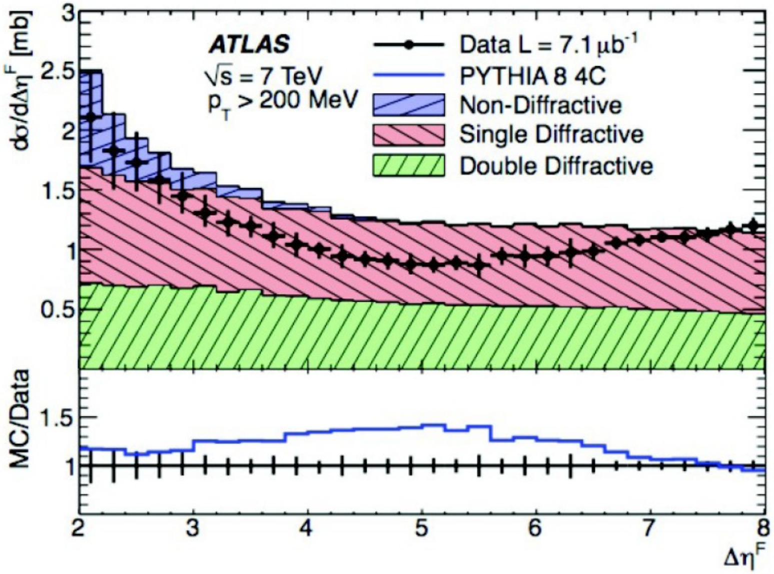


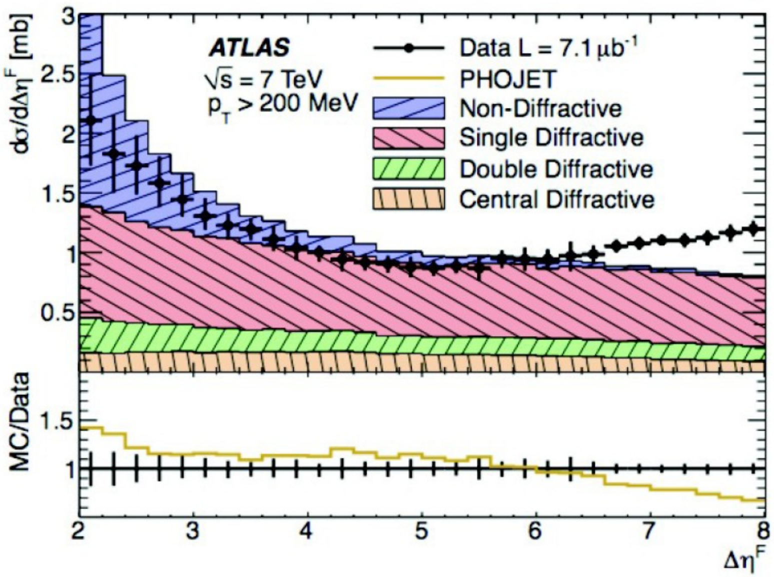




Rapidity gaps

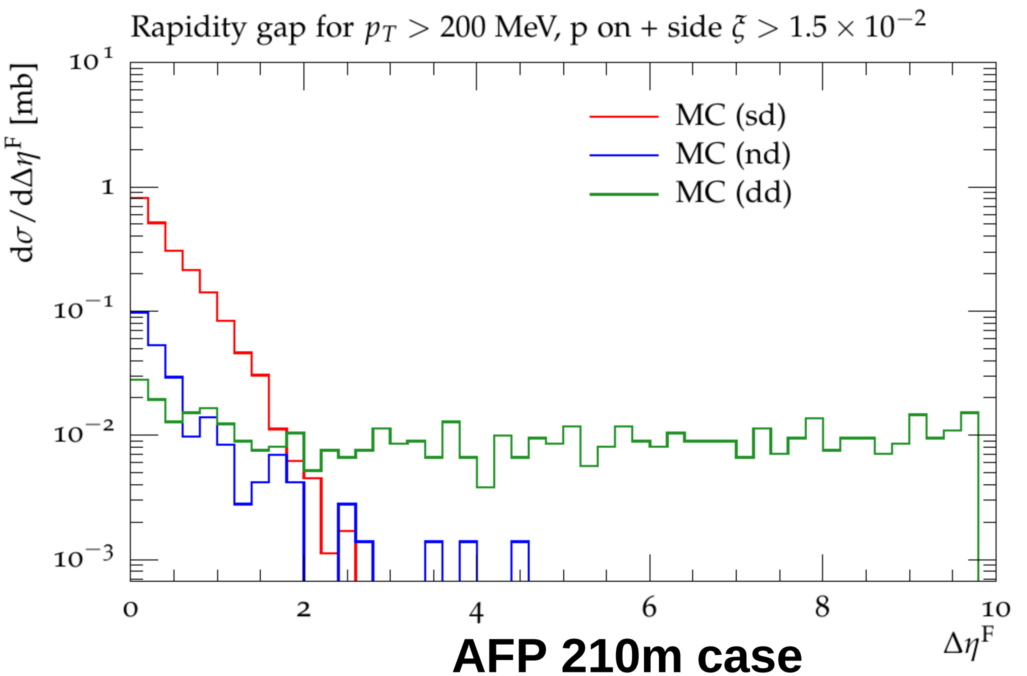
- A flat cross section as a function of rapidity gap size is the standard signature for diffraction.
- ATLAS measurement EPJC 72 (2012) 1926 exposed a likely too-large contribution from double diffractive events in PYTHIA.
- Repeated measurement + single proton-tagged data will unambiguously determine whether that was indeed the case.
  - One proton tag on same side as gap = SD
  - Two proton tags + gap = CD



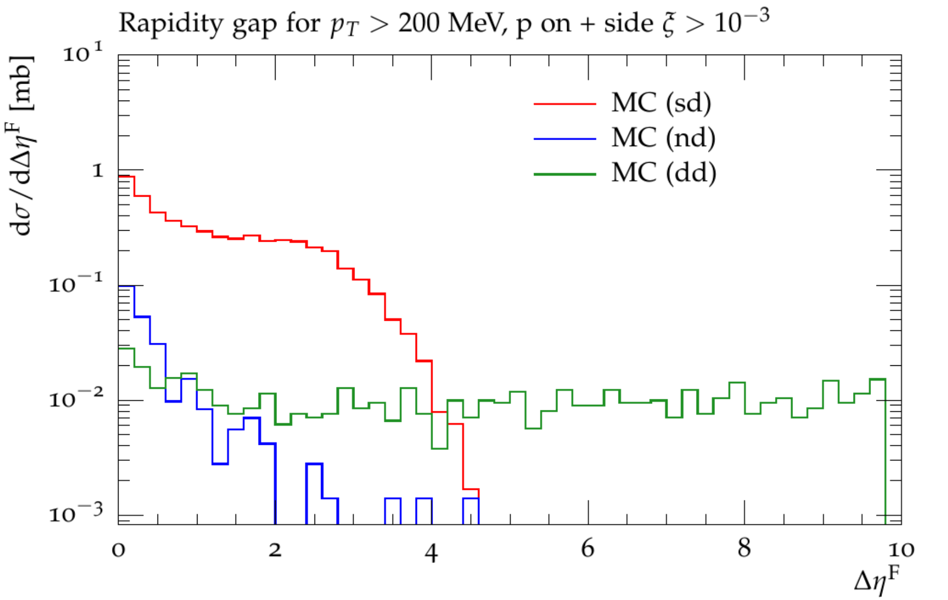


Rapidity gaps in tagged events

- AFP restricts diffractive masses to be large Mx>1.7 TeV
- Consequently there is limited correlation seen for SD, gaps measured on the same side as intact proton
- Tagging suppresses ND contribution and DD contribution can be estimated, it has completely different shape



AFP 210m case

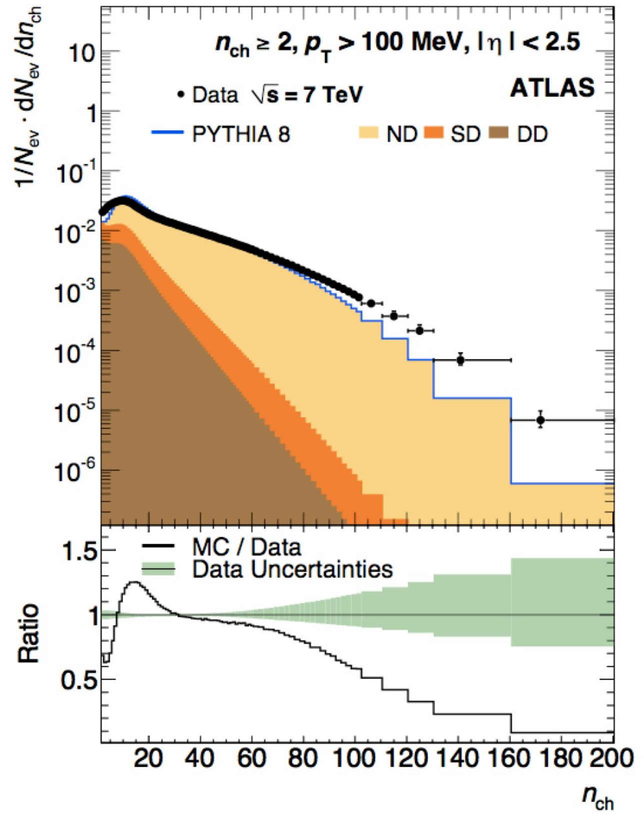


AFP 210+420m case

Charged particles in min-bias collision

- Repeat basic density measurements from the minbias studies in NJP. 13 (2011) 053033

$$\frac{1}{N_{\mathrm{ev}}} \cdot \frac{\mathrm{d}N_{\mathrm{ch}}}{\mathrm{d}\eta}, \quad \frac{1}{N_{\mathrm{ev}}} \cdot \frac{1}{2\pi p_{\mathrm{T}}} \cdot \frac{\mathrm{d}^2 N_{\mathrm{ch}}}{\mathrm{d}\eta \mathrm{d}p_{\mathrm{T}}}, \quad \frac{1}{N_{\mathrm{ev}}} \cdot \frac{\mathrm{d}N_{\mathrm{ev}}}{\mathrm{d}n_{\mathrm{ch}}}$$



- Less activity due to reduced number of partonic interactions in proton

- Allows the first ever tune of the diffractive components in MC
  - Pythia 6 has an incorrect model of diffraction and will fail
  - Same tune parameters in Pythia 8 for proton tagged and non-proton tagged events?
  - Can an 'inclusive' model of inelastic scattering (SHRiMPS/QGSJET ..) be able to describe both datasets?

- Strangeness production in SD: Λ, Ks, other identified final state particles?

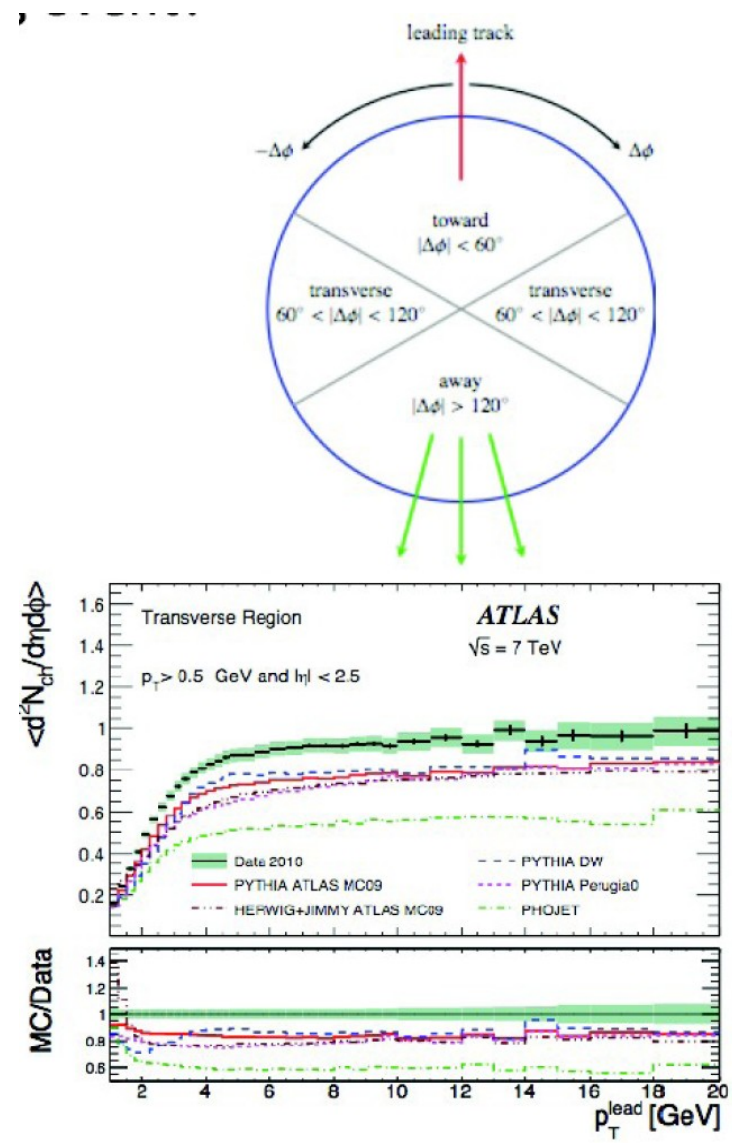
Underlying event

- The classic Rick Field measurements:
  charged particle density perpendicular in azimuth to a hard object in the event. Most of the activity comes from multiple parton-parton scattering between spectator quarks/gluons in the protons

- If there is a forward proton, MPI must be reduced because an interaction would remove color from the proton and it would break up (soft-survival prob.)

  - Can have scattering between spectator partons in the pomeron
  - One proton tag will test MPI for pomeron-proton Interactions
  - Two tagged protons tests MPI in pomeron-pomeron interactions

- With more luminosity:
  - SD/CD: Dijet decorrelation in Δφjj
  - SD/CD: Four jets (MPI in diffraction)



Conclusion

- AFP is clearly as significant add-on for understanding QCD for ATLAS
  - On CMS side – situation a bit more optimistic, TOTEM has already horizontal detectors, CMS is installing FWD shower counters $6<|\eta|<8$

- Data taking will be performed during low-mu runs where trigger prescales are not an issue

- Diffraction not so relevant for the central physics program (non-diffraction)
- But it is relevant for fwd physics and MC development (Pytha8, Herwig++, KMR in Sherpa, QGSJET, etc.)

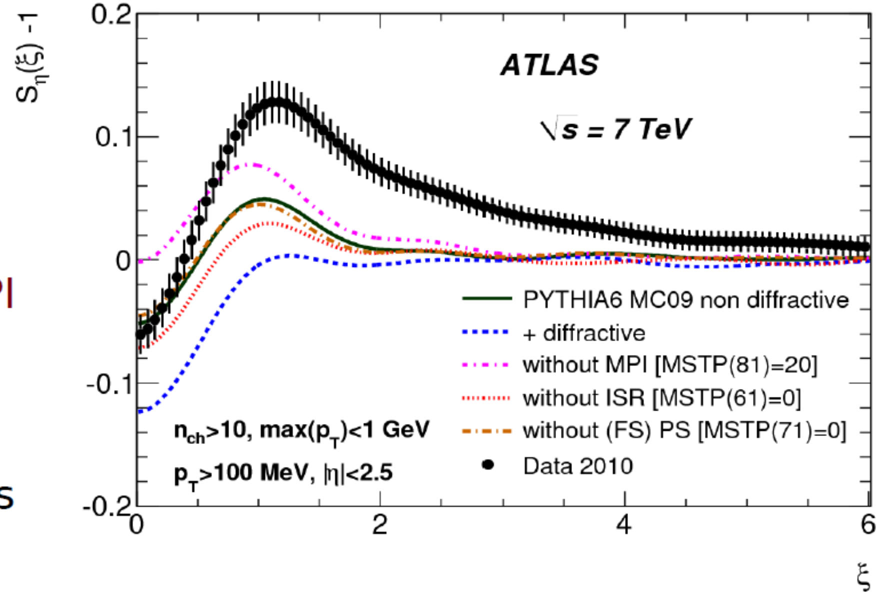
- Measurements of hard diffraction will improve understanding of multiple scattering and merging description of 'soft' and 'hard' phenomena

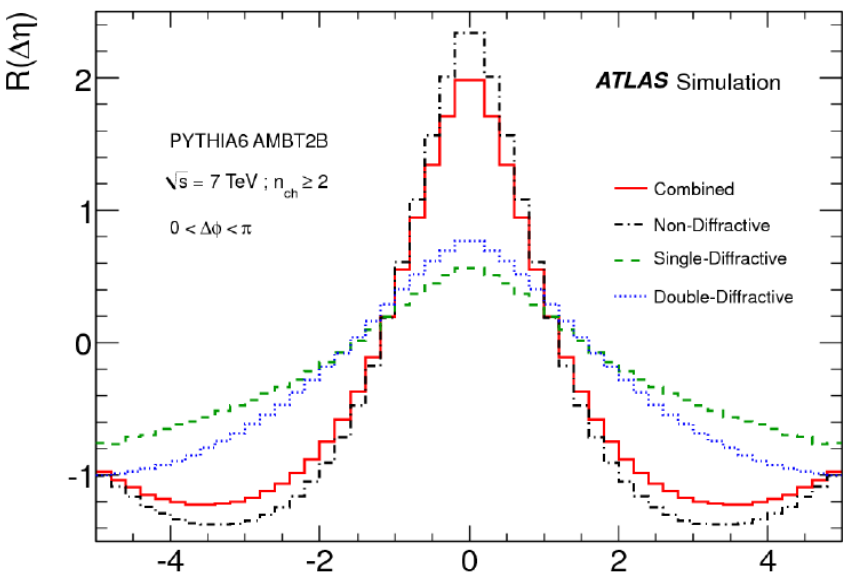
- To theorists: Please help us, the experimentalists, to identify why it is important to make these measurements. Persuading the large LHC experiments to do these measurement is not easy.

Backup

Correlation analyses

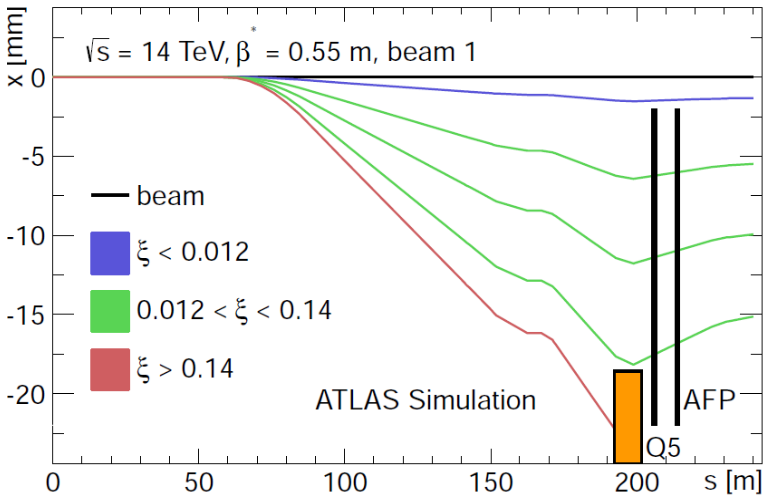
- Azimuthal ordering of charged hadrons is sensitive to structure of hadronisation model
  - Diffractive events are less-hard and have less MPI
- Two particle correlations and forward/backward correlations are sensitive to long-range correlations
  - Diffractive processes has typically longer range correlations
- Events with one/two proton tags can provide even more data to investigate these correlations
- Bose-Einstein correlations have never been measured in diffractive events, but the BEC radius may be a factor of two smaller for DPE than ND



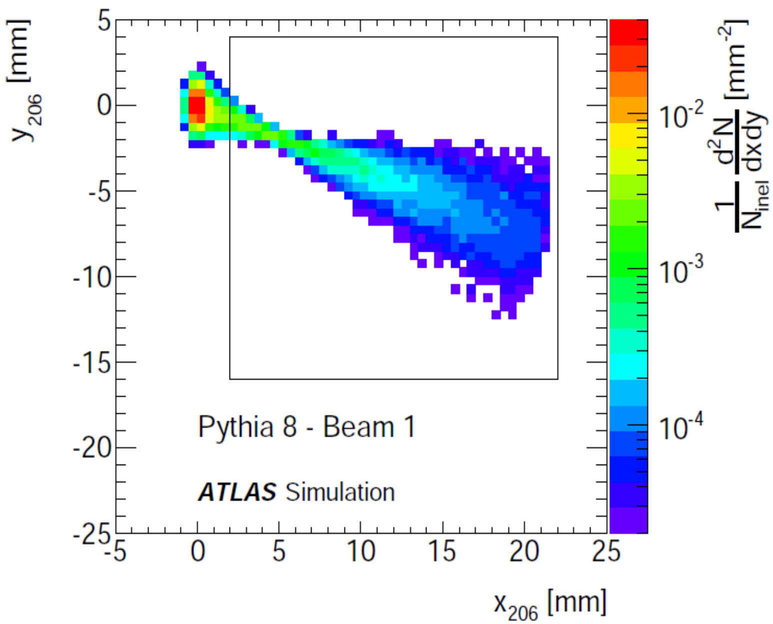


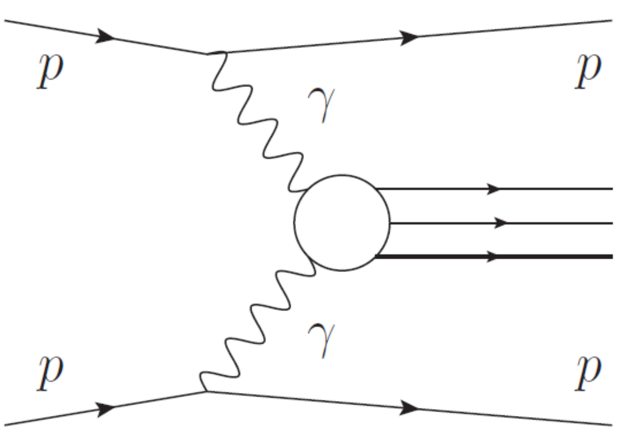
Forward protons

- AFP – proton taggers (206/214m) to measure position and time of arriving protons



- For increasing relative proton momentum loss $\xi \simeq (1-E/E_0)$ protons scatter outside the ring
- Acceptance large for $0.012 < \xi < 0.14$
- d at 15σ: 2.3mm = 0.13x15 + 0.3 mm

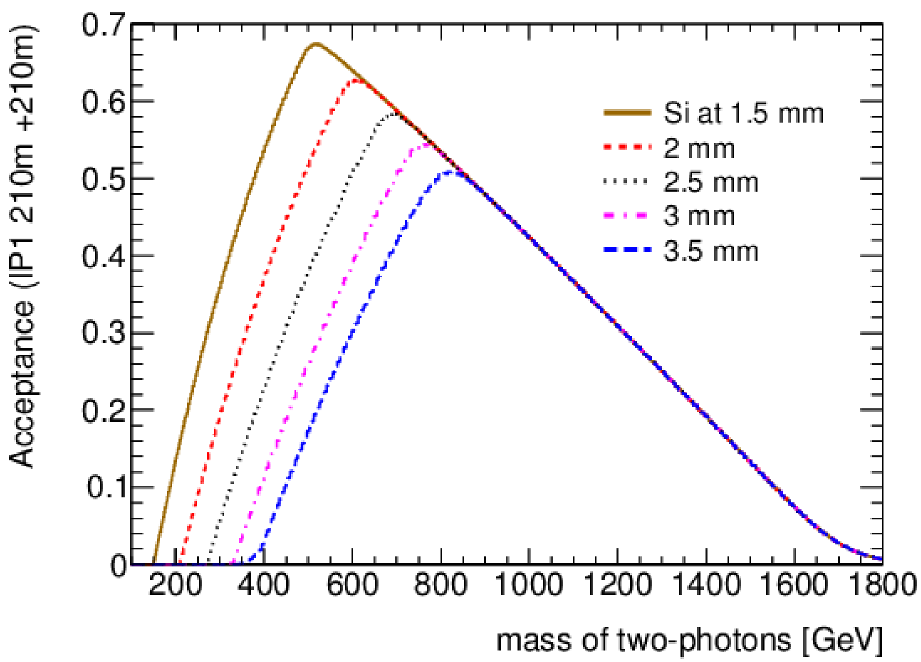


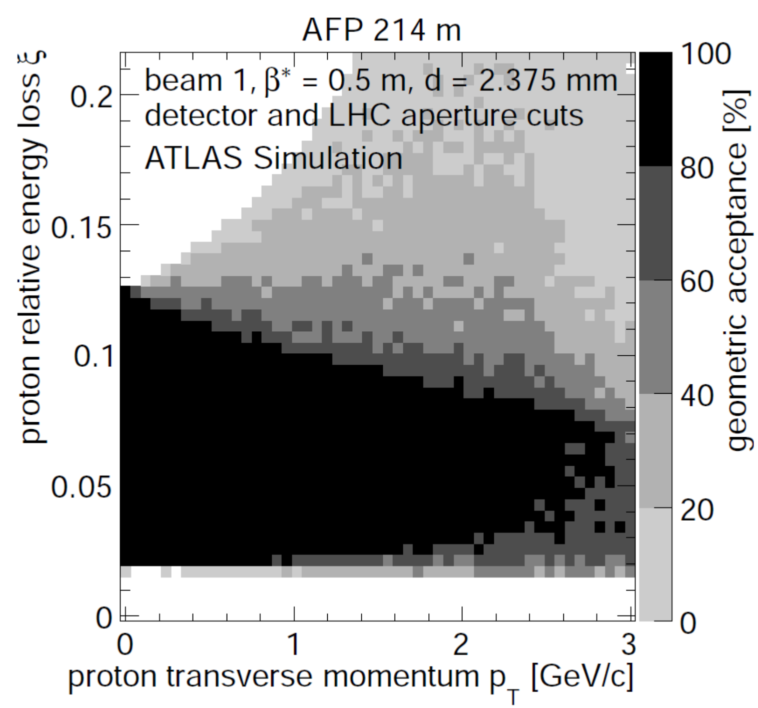


Also Pomeron exchanges, exclusive gluon exchange, Pomeron-photon

Kinematics

- Acceptance large for $0.015 < \xi < 0.13$
- Good resolution in ξ, not so great resolution in p_T
- Tag protons in both stations to reconstruct mass (resolution ~ 1-2% depending on mass)
- Timing detectors, mass trigger at L1 from course bars (quart/diamonds)





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