



**6th International Conference on New Frontiers in
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Kolymbari, Crete, Greece
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Measurements of low energy observables, elastic pp interactions and exclusive production in proton-proton collisions with the ATLAS Detector

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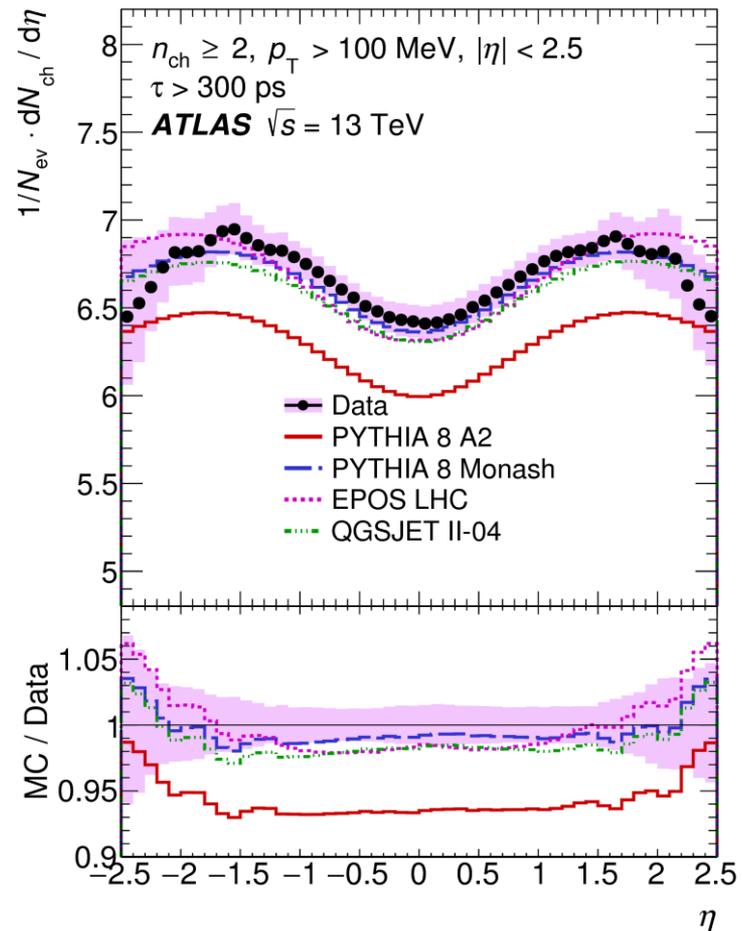
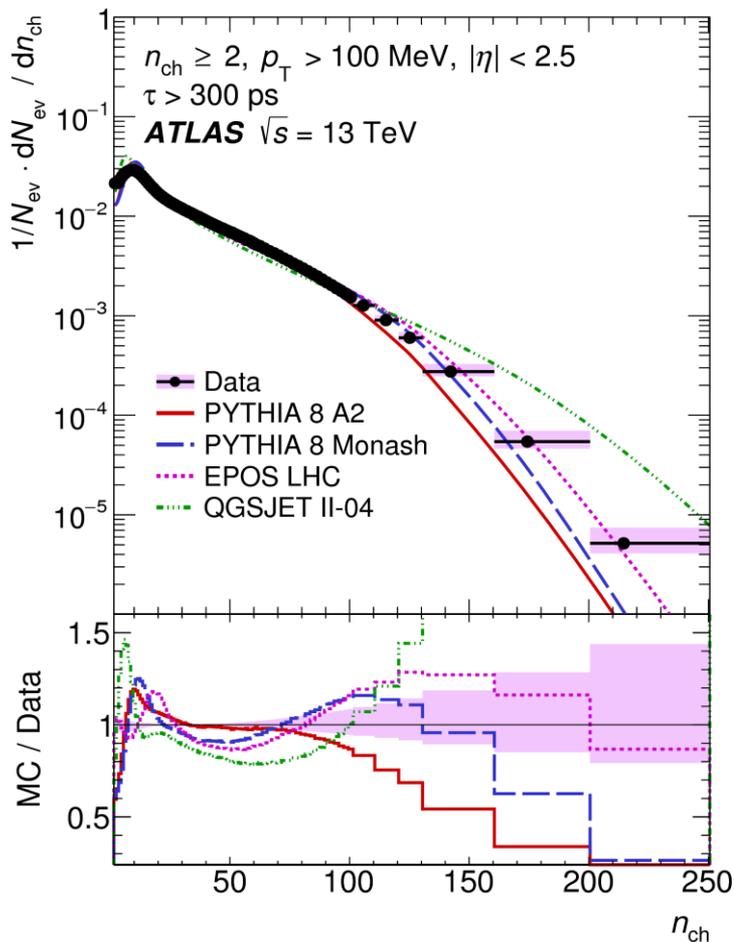
Contents:

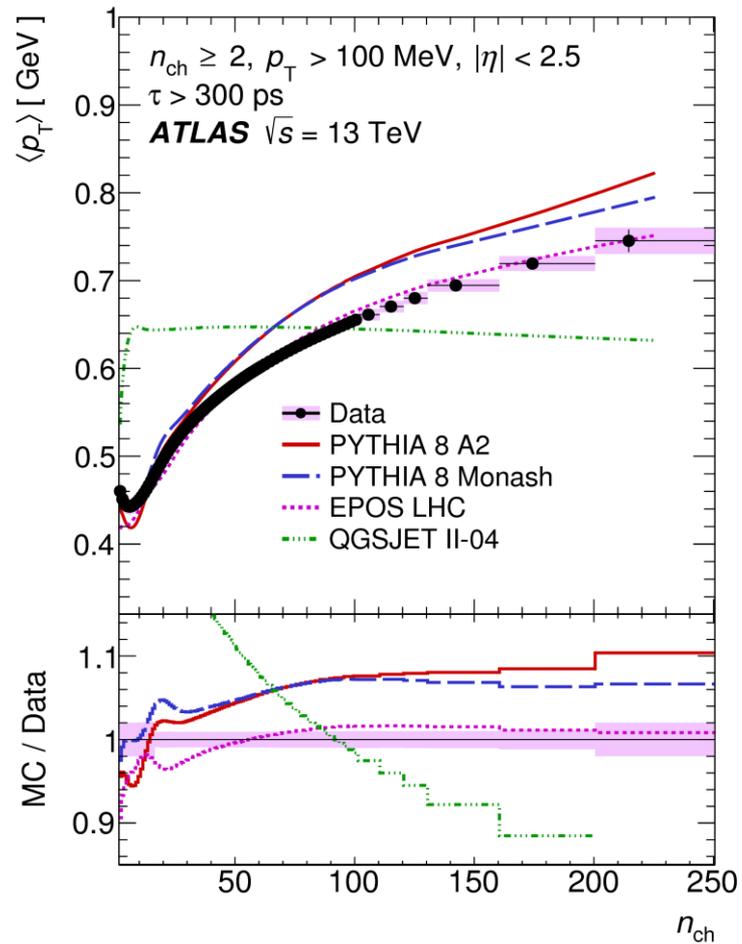
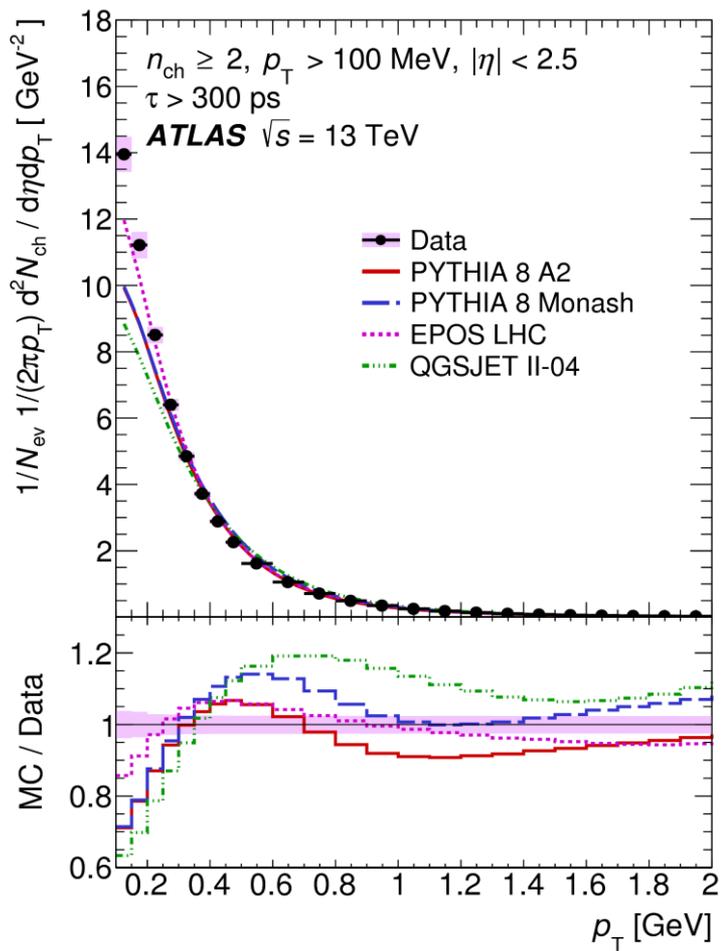
- 1) Study of charged-particle distributions at low transverse momentum.
($\sqrt{s} = 13$ TeV)
- 2) Study of charged-particle distributions sensitive to the underlying event.
(13 TeV)
- 3) Study of ordered hadron chains (7 TeV)
- 4) Exclusive $\mu^+\mu^-$ production (13 TeV)
- 5) Total p-p cross section from elastic scattering (8 TeV)
- 6) First look at forward proton tagging (13 TeV)

1) Study of charged-particle distributions at low transverse momentum.

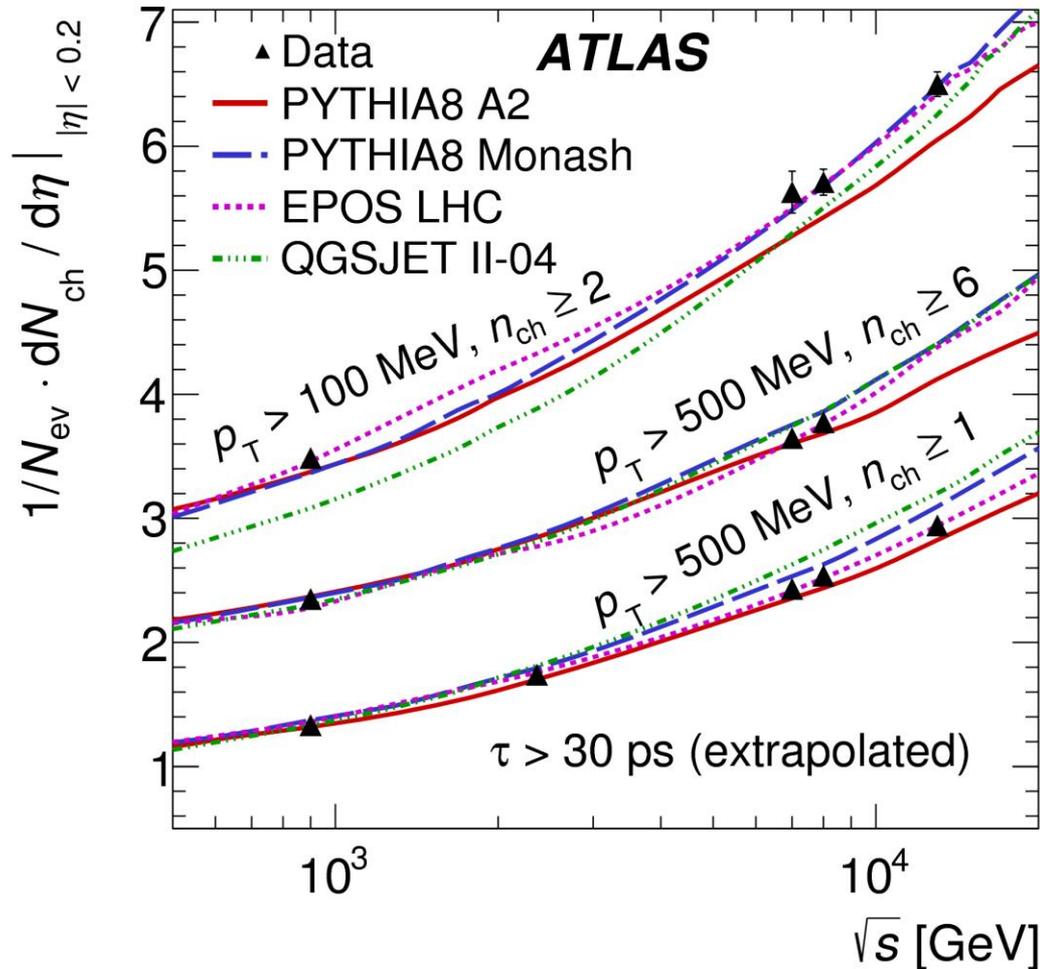
Eur. Phys. J. C 76 (2016) 502

Study charged particles with $p_T > 100$ MeV/c and pseudorapidity $|\eta| < 2.5$





Collate results of this measurement with others at different \sqrt{s} values



QGSJET is not so good as the other tunes and models.

Overall a reasonable description from most of them.

Perhaps PYTHIA8 A2 should be updated.

EPOS is good.

2) Underlying event (UL, i.e. whatever does not emerge in the hard parton scatter)

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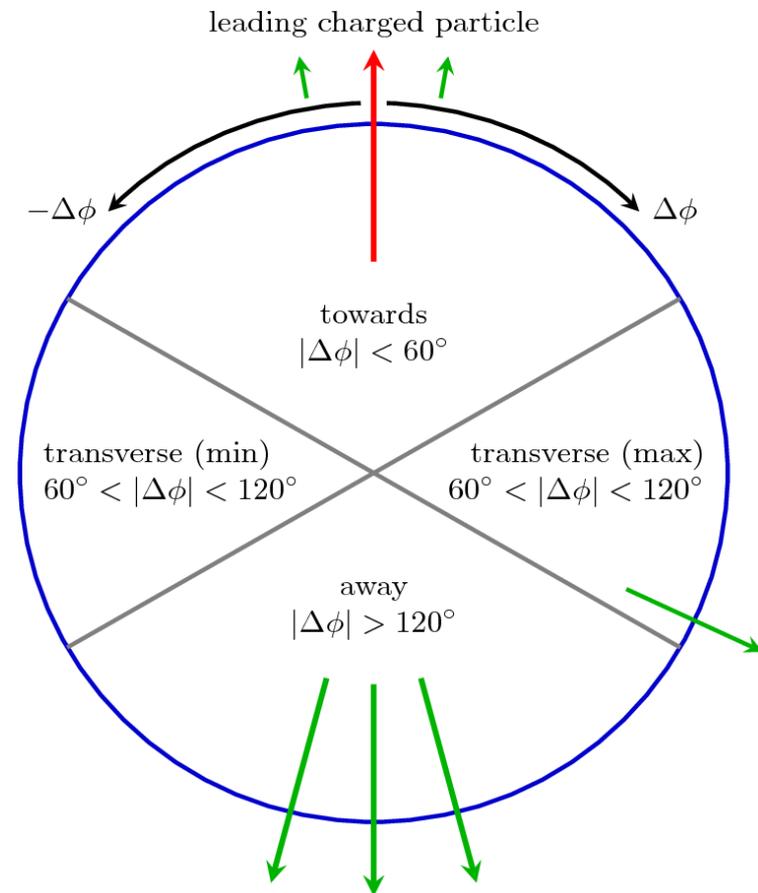
Aim is to study various parameters so that the UL can be well modelled, since it is present in all hard parton scatters at the LHC.

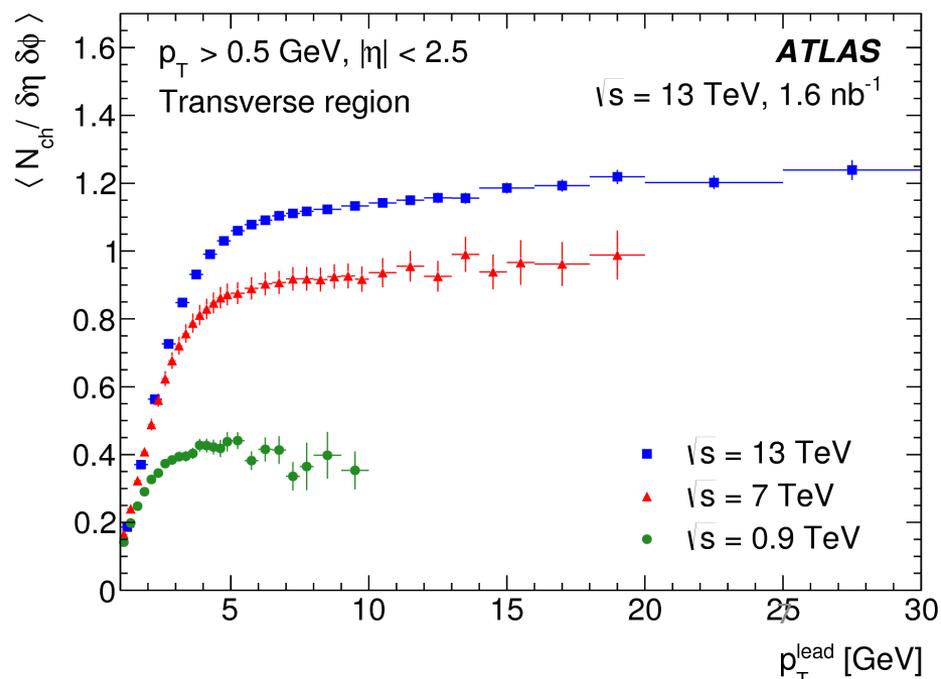
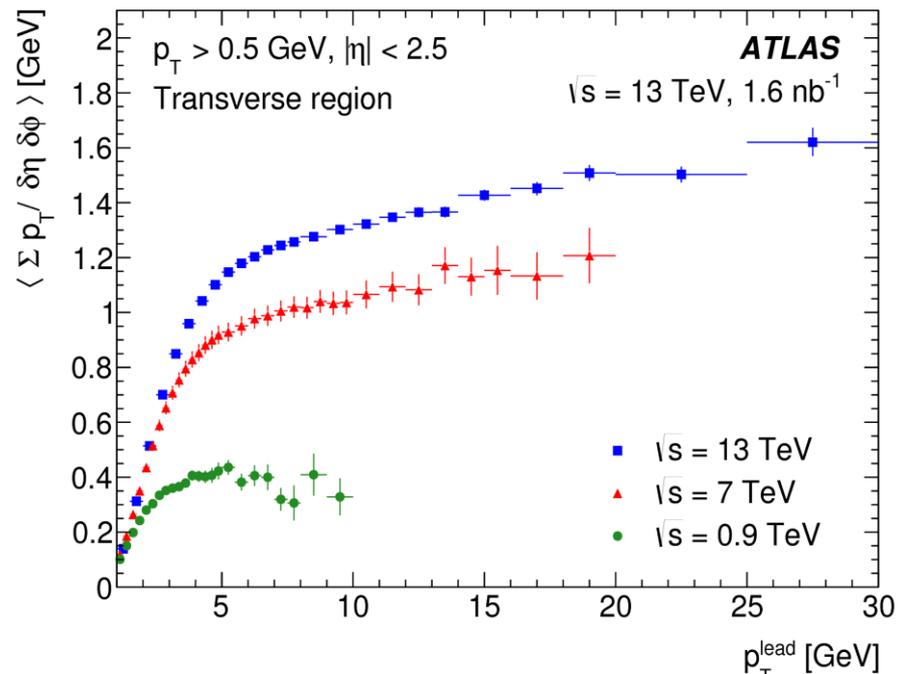
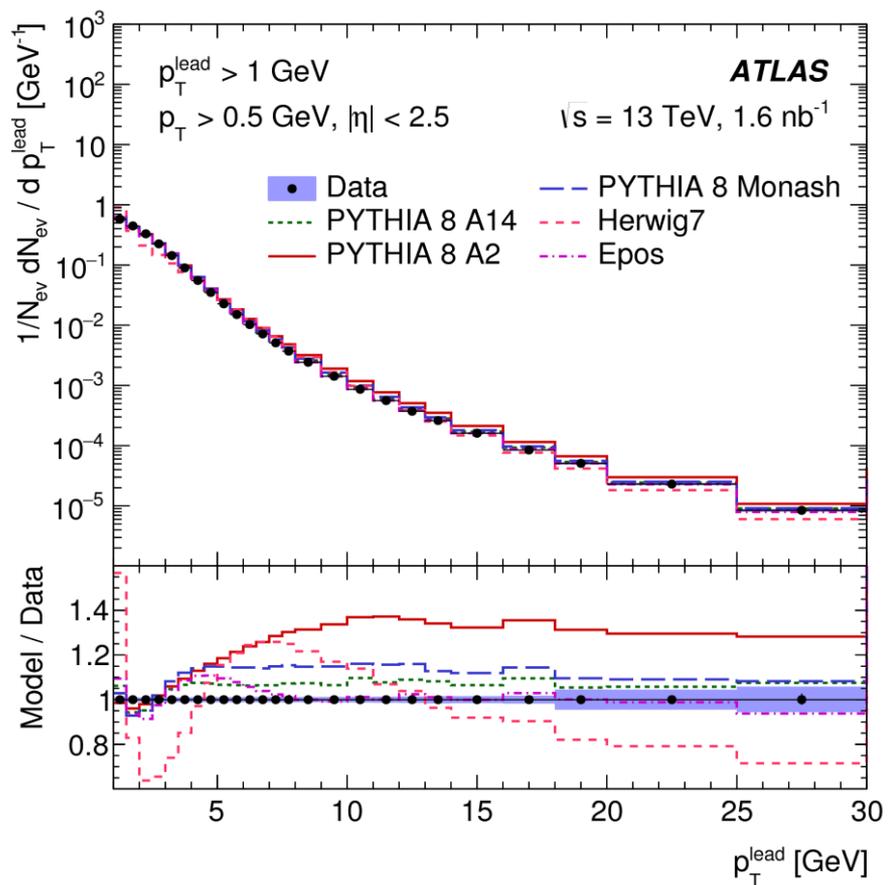
Study distributions using charged tracks with $p_T > 500 \text{ MeV}/c$ and $|\eta| < 2.5$

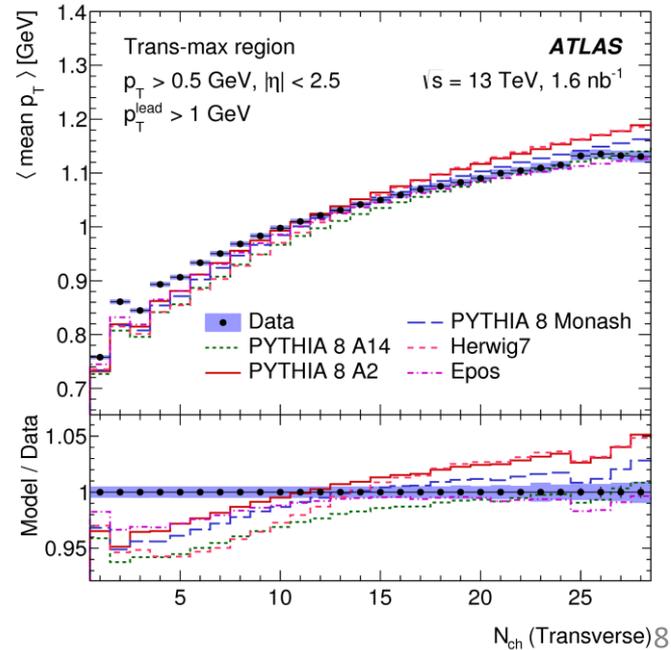
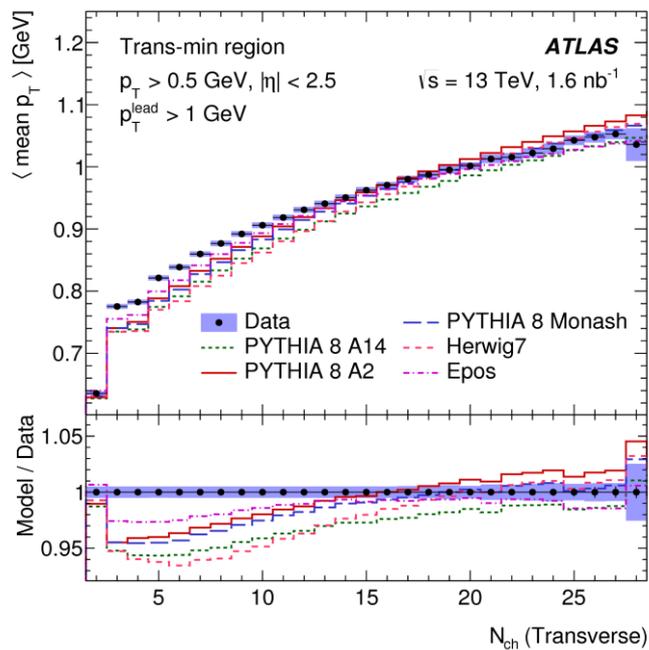
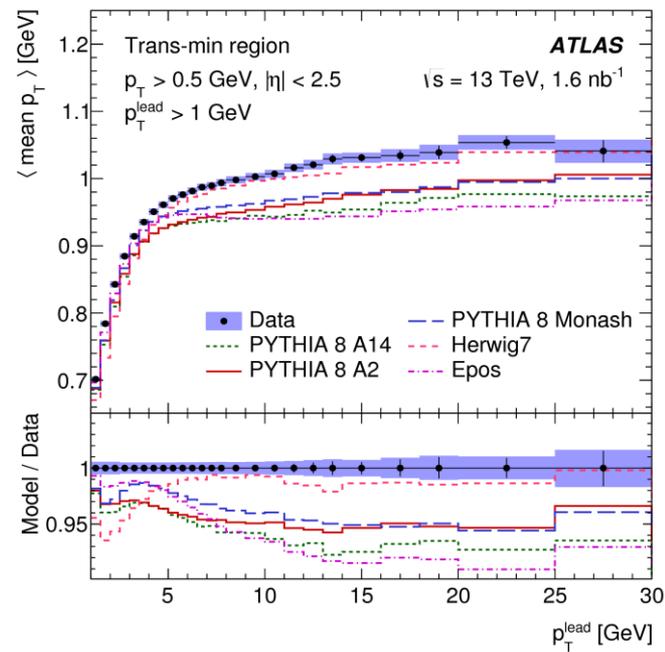
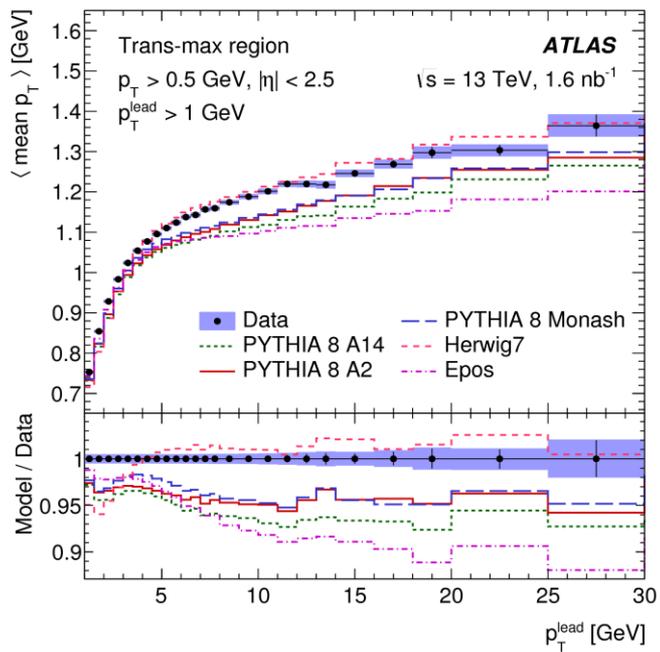
Define azimuth $\Delta\phi$
relative to leading charged particle.

No jets used.

Study “transverse” region with $|\Delta\phi|$ between 60° and 120°







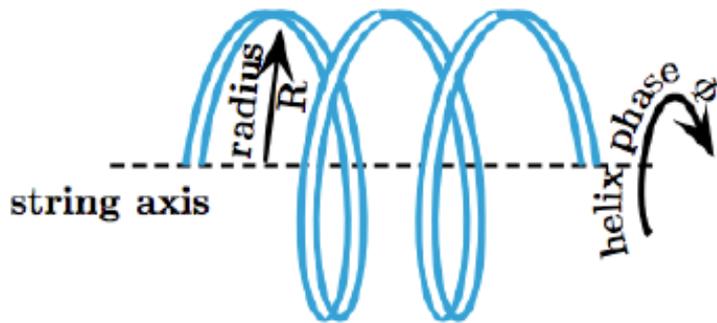
3) Study of ordered hadron chains with the ATLAS detector

Lund-model QCD strings are 1-D objects that fragment along their length.

Other models can incorporate 3-D structure in a QCD string that can be reflected in correlations between final-state particles.

A helical structure has been proposed.

S. Todorova, Quantization of the QCD string with a helical structure
Phys.Rev. D89 (2014) 015002.

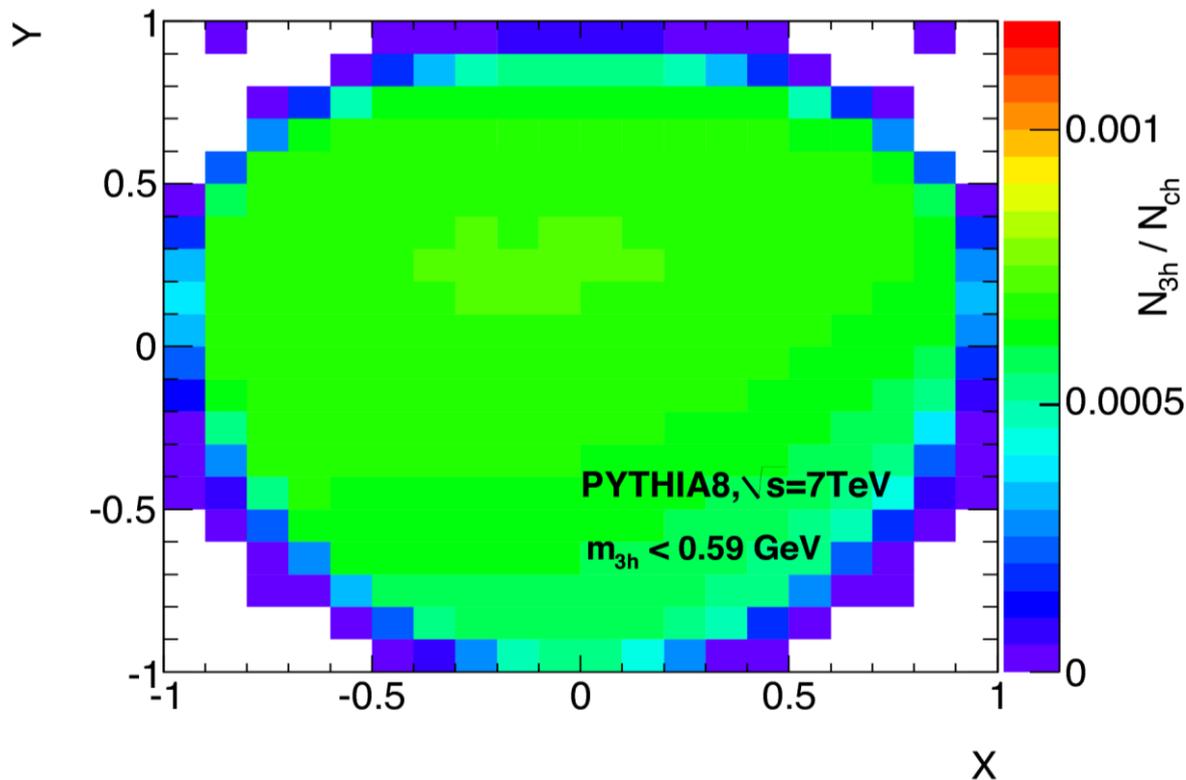


We try to test this idea.

Method: in minimum-bias multihadronic events, select triplets of tracks that have a small relative mass.

Plot Dalitz plot parameters, compare with models.

$$X = \sqrt{3} \frac{T_0 - T_2}{\Sigma T}, \quad Y = \frac{3T_1}{\Sigma T} - 1$$

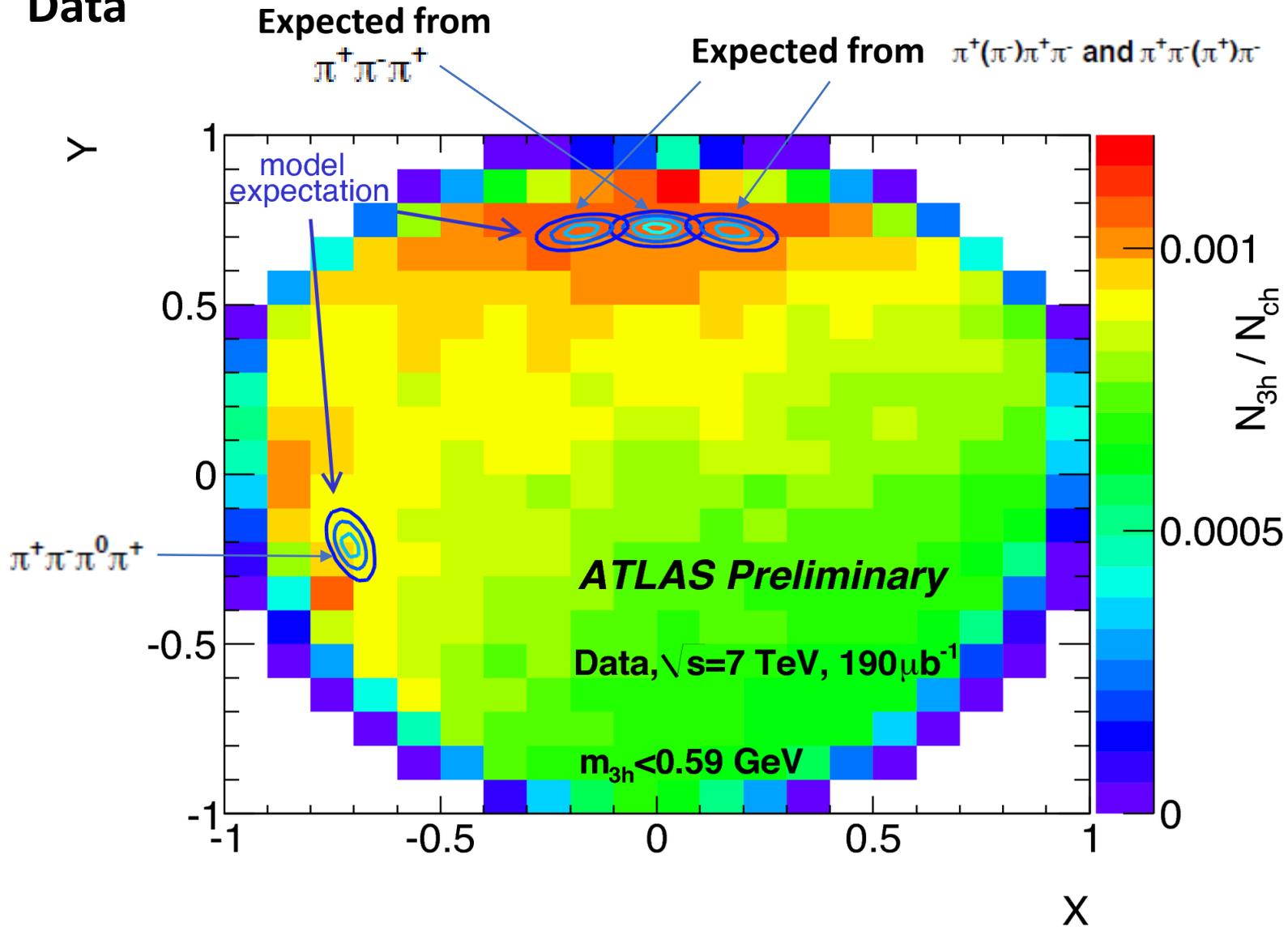


T = K.E.

Particles 0, 2
form a like-sign
pair.

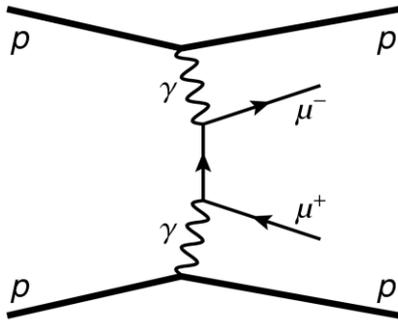
Other standard
models give
Dalitz plots with
similar broad
features.

Data

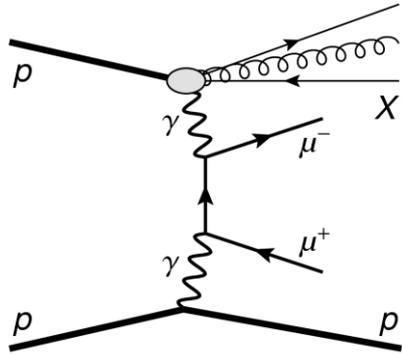


Excesses that support a helical string interpretation . (Bose-Einstein??)

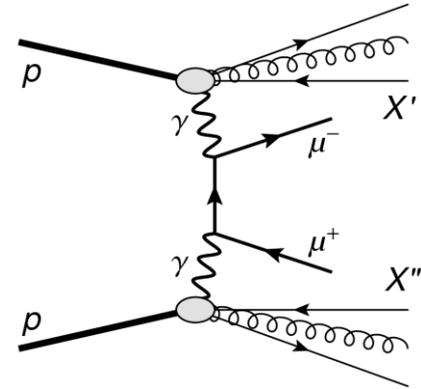
4) Measurement of exclusive two-photon production of muon pairs with ATLAS. arXiv 1708.04053



No proton dissociation



Single dissociation (S)

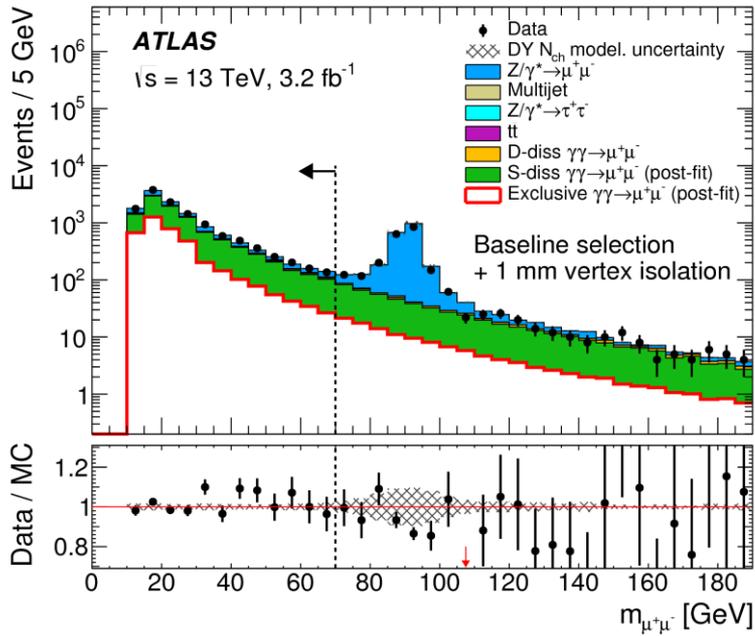


Double dissociation (D)

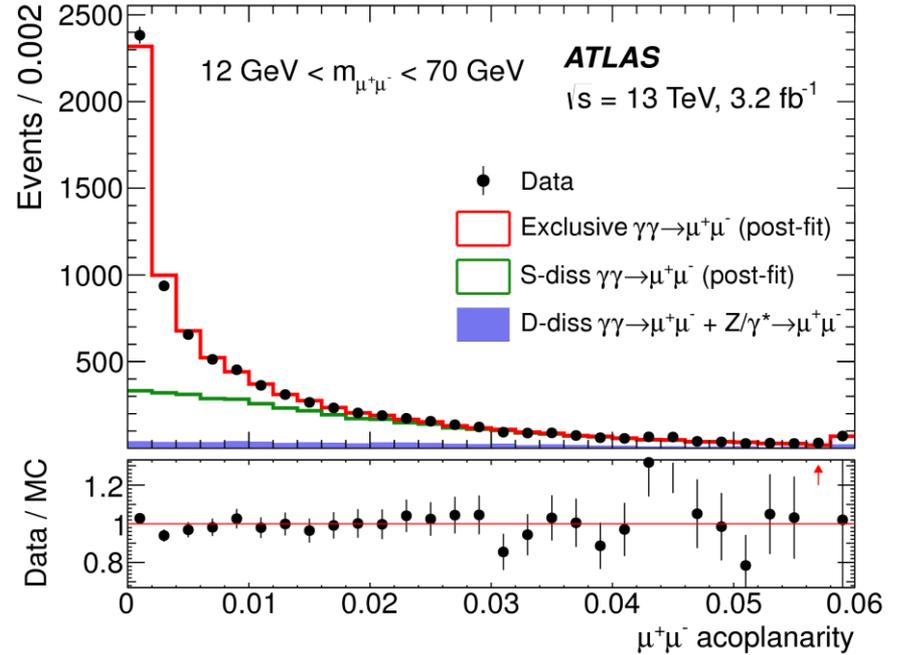
Select events with just two tracks at an isolated vertex, both identified as muons.

p_T of the pair < 1.5 GeV/c to reduce proton dissociation contribution.

Distributions after baseline cuts.

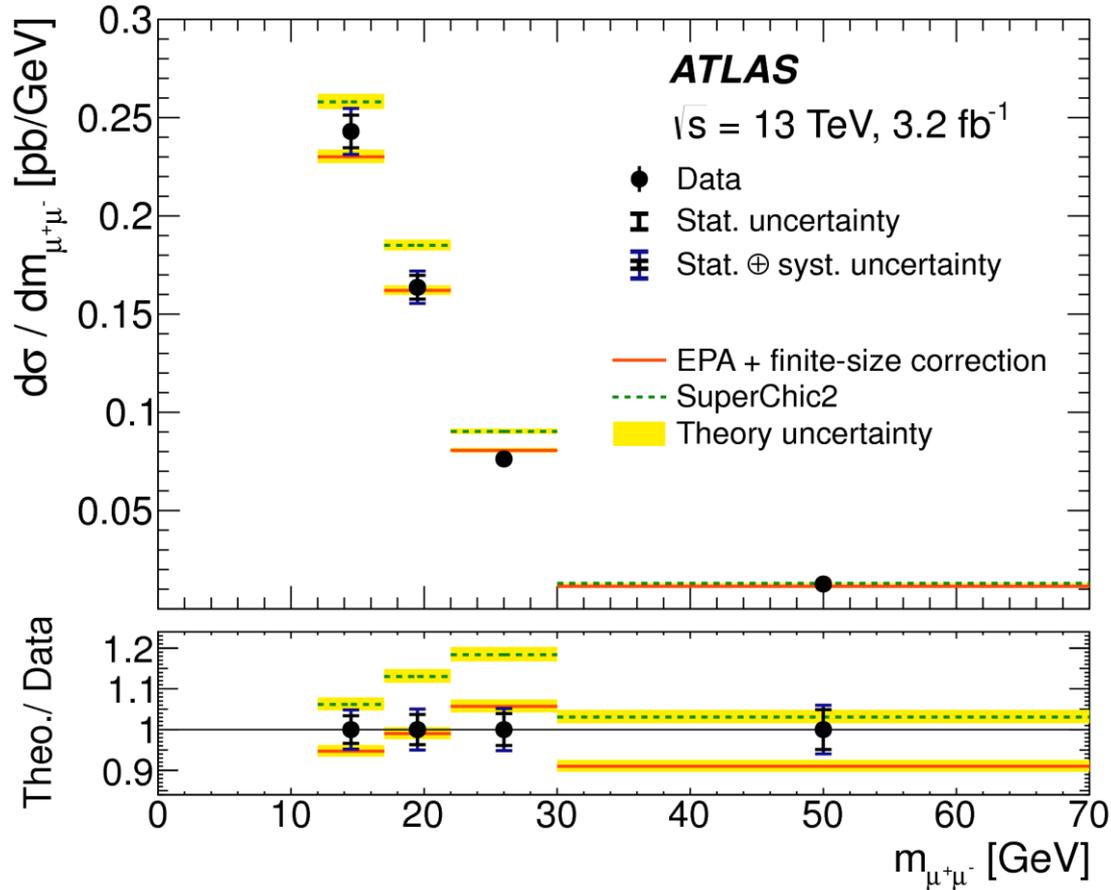


Dimuon mass before pT cut



Acoplanarity after pT cut.

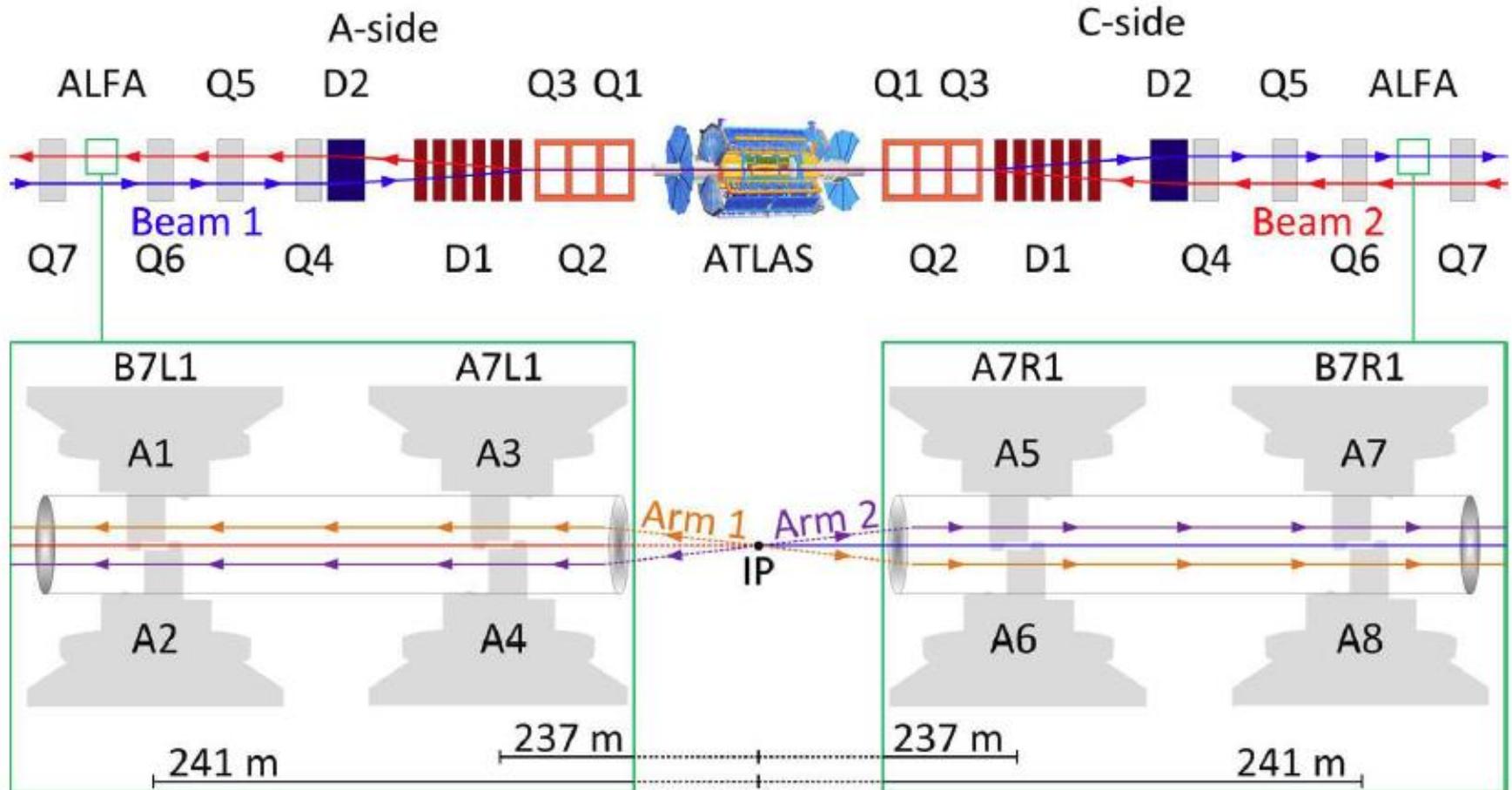
Final cross sections

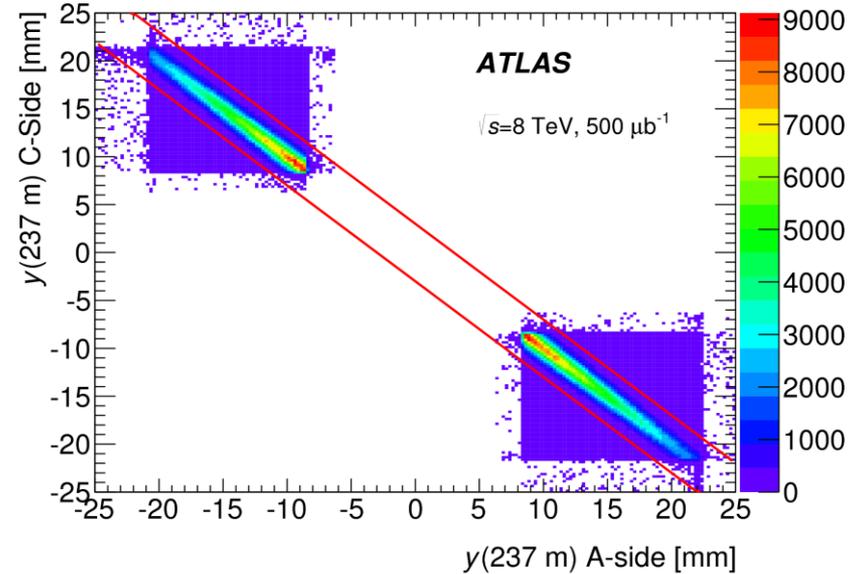
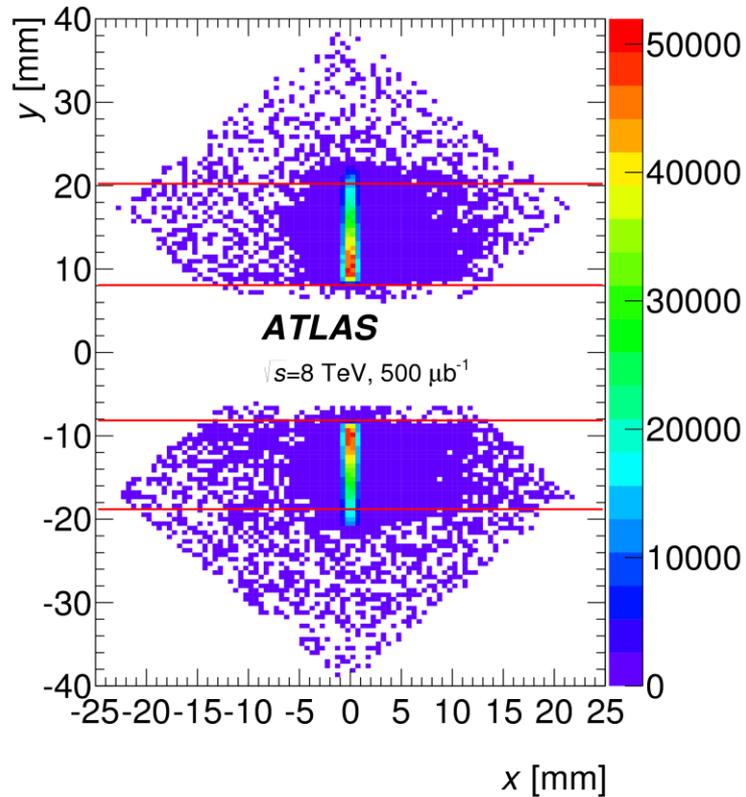


Equivalent photon approximation (EPA) model gives good description.
SuperChic2 (different treatment of absorptive effects) slightly less good.

5) Measurement of proton-proton total cross section at $\sqrt{s} = 8$ TeV with ATLAS.

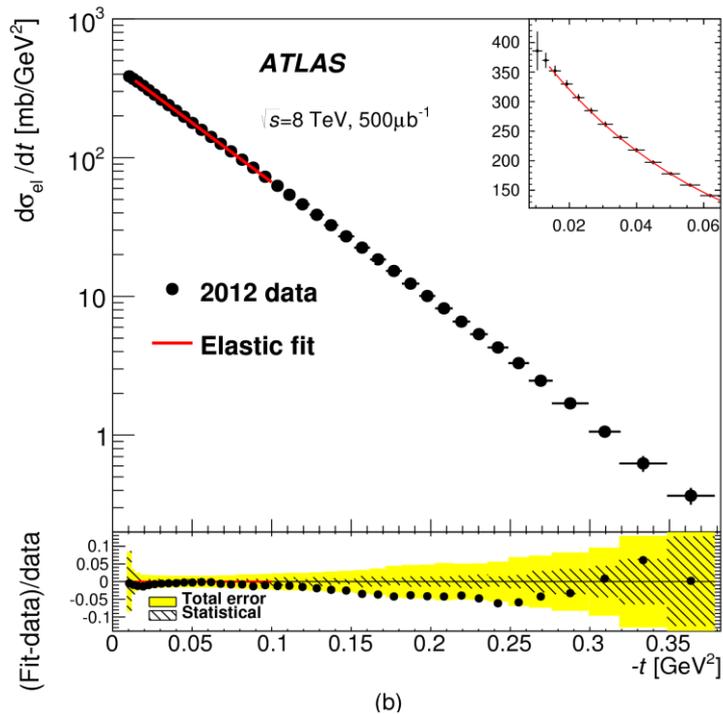
ALFA is a system of Roman Pots and associated detectors downstream of ATLAS in both directions. Scintillating fibres are used.





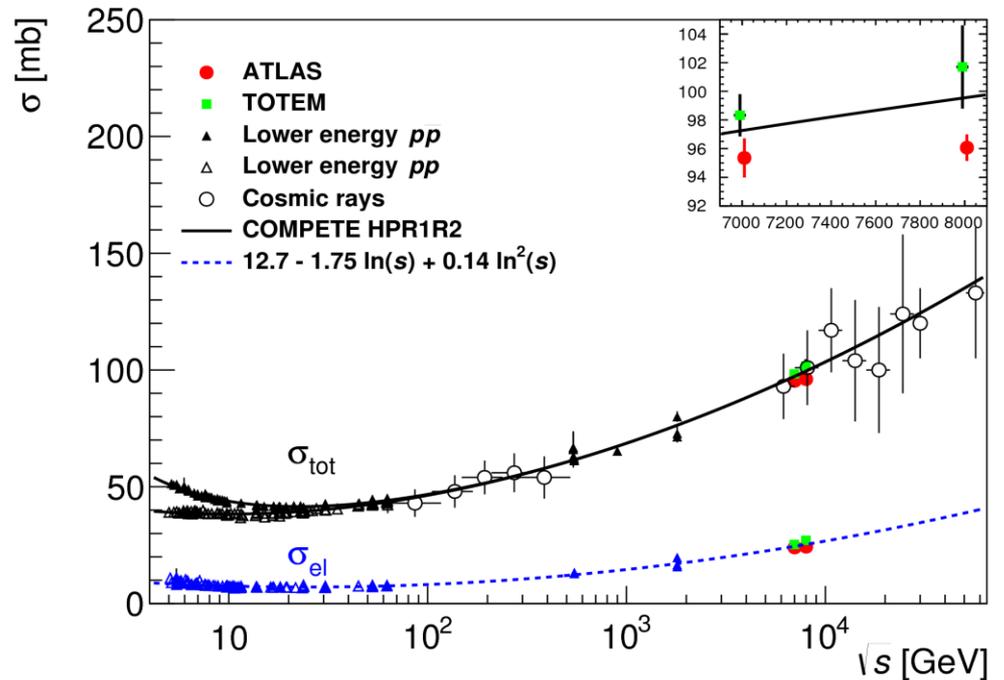
(Left) distribution of hits in Main Detector after basic selection but before background rejection.

(Right) Correlation between y coordinate in track pairs in A and C.



Optical theorem:

$$\sigma_{\text{tot}}^2 = \frac{16\pi(\hbar c)^2}{1 + \rho^2} \left. \frac{d\sigma_{\text{el}}}{dt} \right|_{t \rightarrow 0}$$



$$\frac{d\sigma}{dt} = \frac{1}{16\pi} |f_N(t) + f_C(t)e^{i\alpha\phi(t)}|^2$$

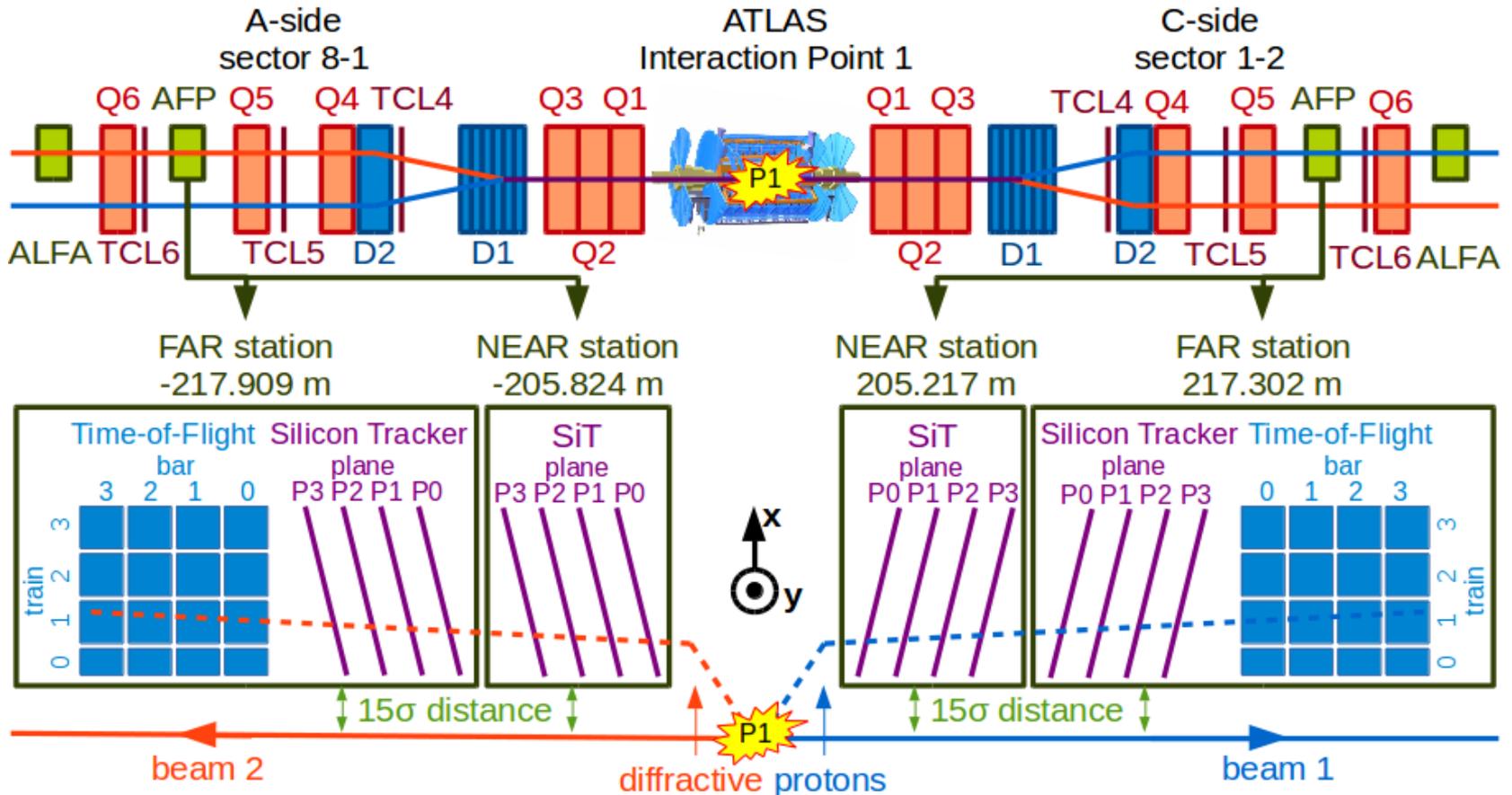
$$f_C(t) = -8\pi\alpha\hbar c \frac{G^2(t)}{|t|},$$

$$f_N(t) = (\rho + i) \frac{\sigma_{\text{tot}}}{\hbar c} e^{-B|t|/2},$$

$$\sigma_{\text{el}} = \frac{\sigma_{\text{tot}}^2}{B} \frac{1 + \rho^2}{16\pi(\hbar c)^2}$$

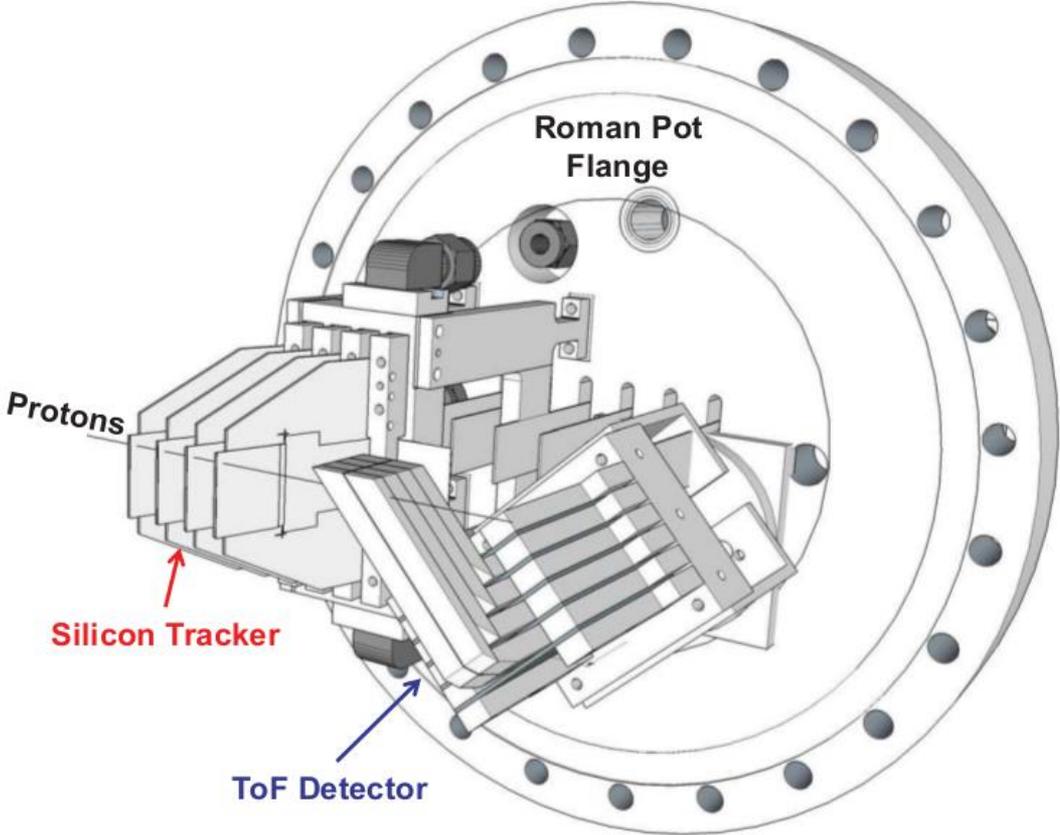
By subtraction, a good way to measure σ_{inel}

6) First results for forward proton tagging in the AFP (ATLAS Forward Proton) system.

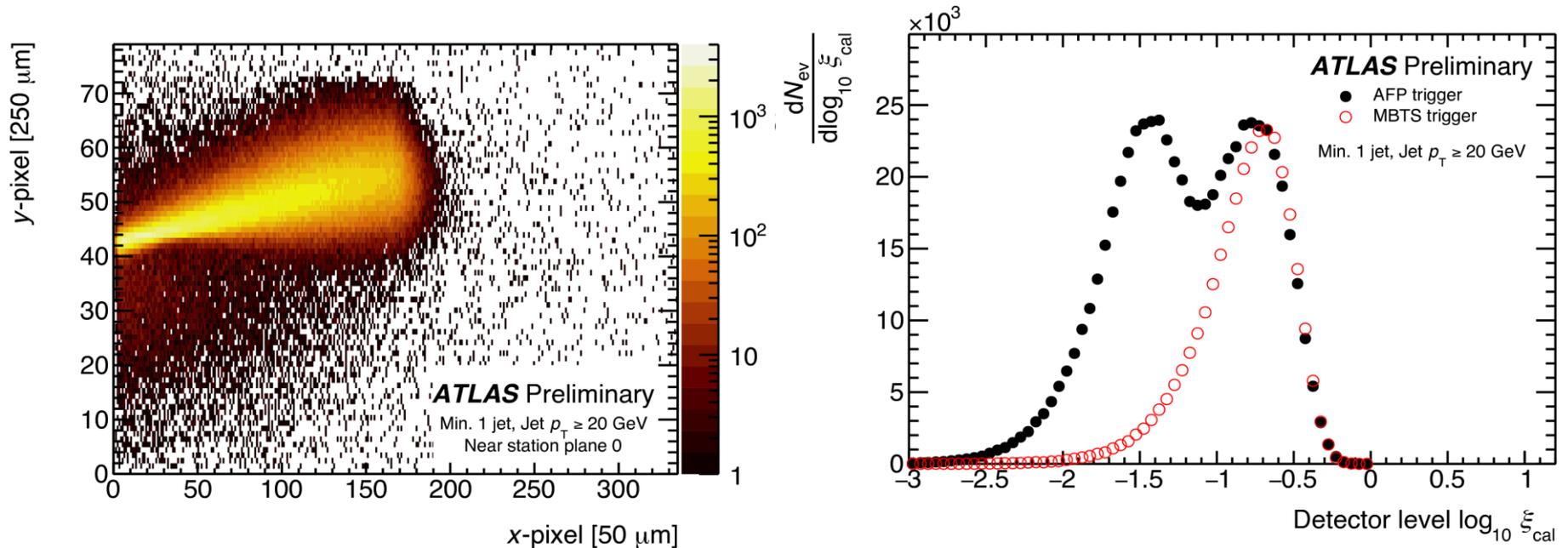


Installation is in regions $\sim \pm 210\text{m}$ from Interaction Point.

Sketch of AFP detector



For a preliminary study, trigger events on the AFP,
 compare ξ_{CAL} of these events with minimum bias events.
 i.e. fraction of proton energy lost in forming hadrons
 (a jet with transverse energy > 20 GeV was demanded)



Distribution of protons in AFP
 for events with a jet > 20 GeV p_T
 ("A" side only)

Red: Min bias trigger

Black: AFP trigger.

Upper peak: proton in random
 coincidence with min bias event

Lower peak: proton tags a low- ξ_{CAL}
 event.

Summary

ATLAS has a varied and forward-looking programme of measurements in “soft” physics, of which we have seen a small selection here.

Look forward to more developments in coming years, with AFP being brought into full operation.