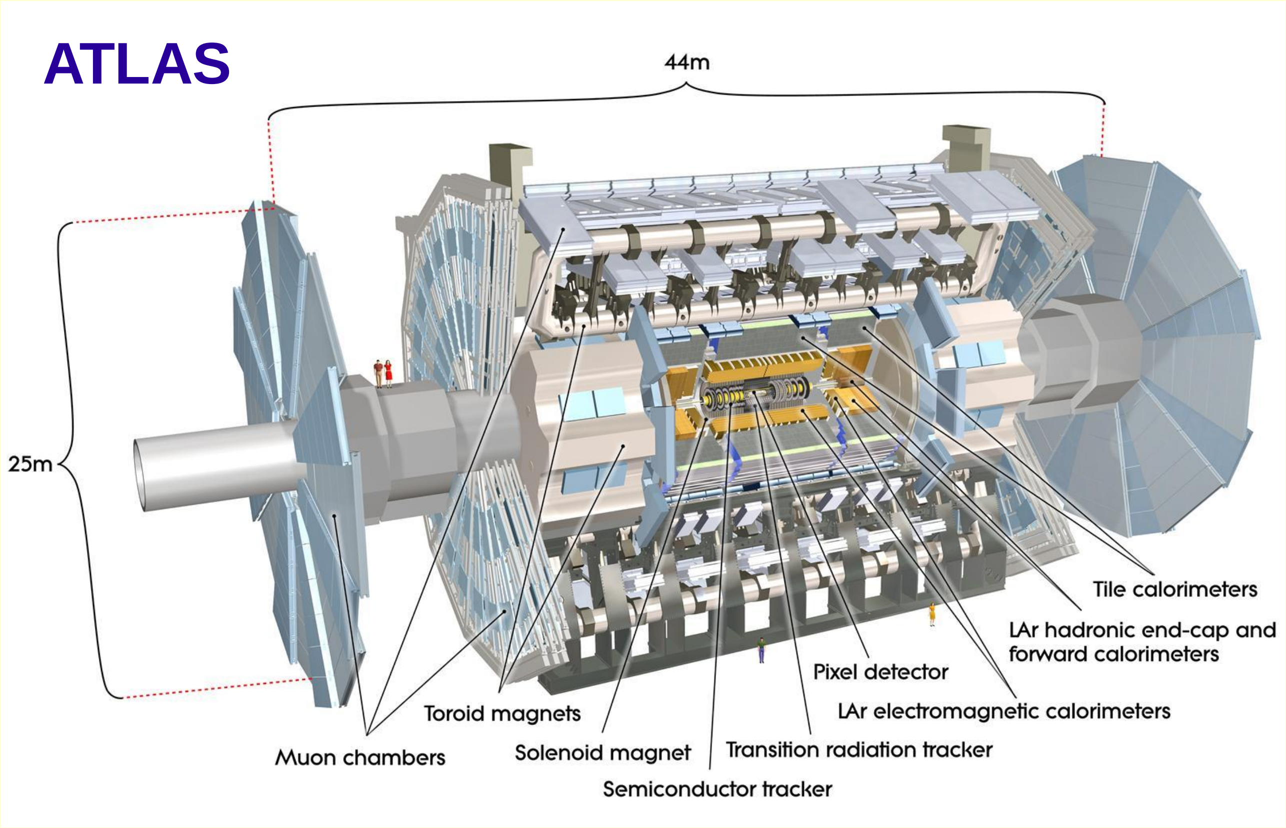
Soft-QCD and diffractive processes at ATLAS

Peter Bussey
University of Glasgow

for the ATLAS Collaboration

LHCP2020 **Paris-Virtual** May 2020

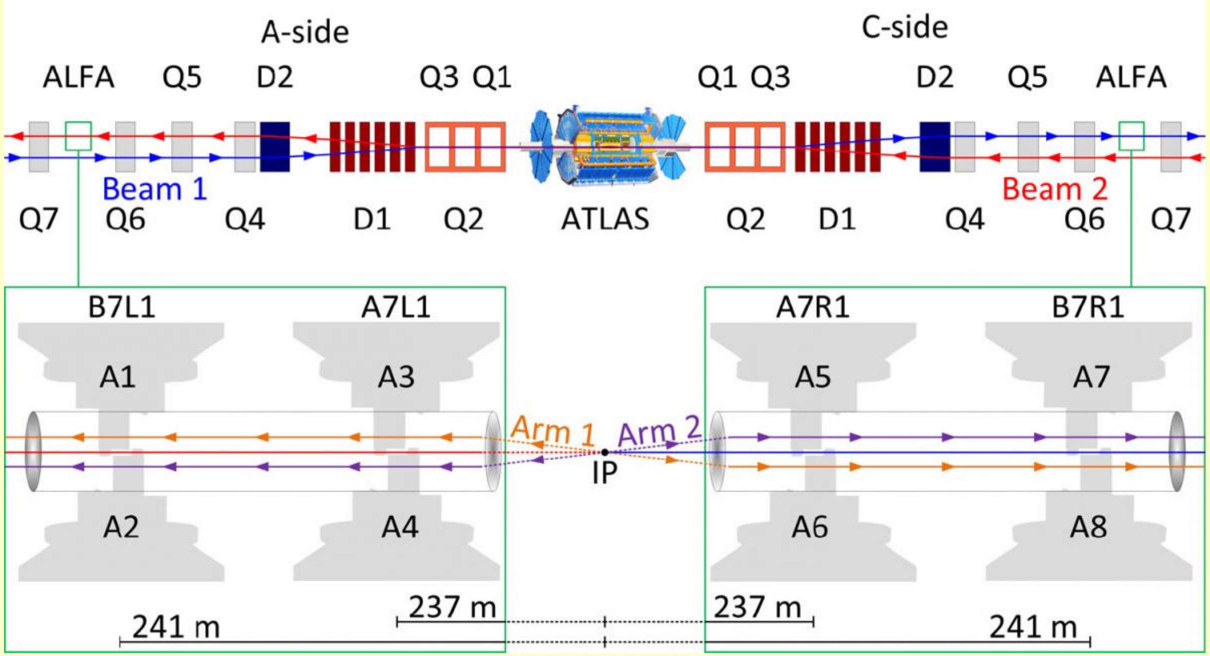


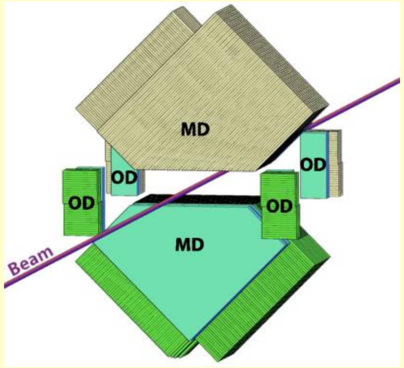
Subjects of talk

1) Single diffractive-dissociation using ALFA
2) Underlying event studies in Z + jet production
3) Strange particle production
4) Update on AFP

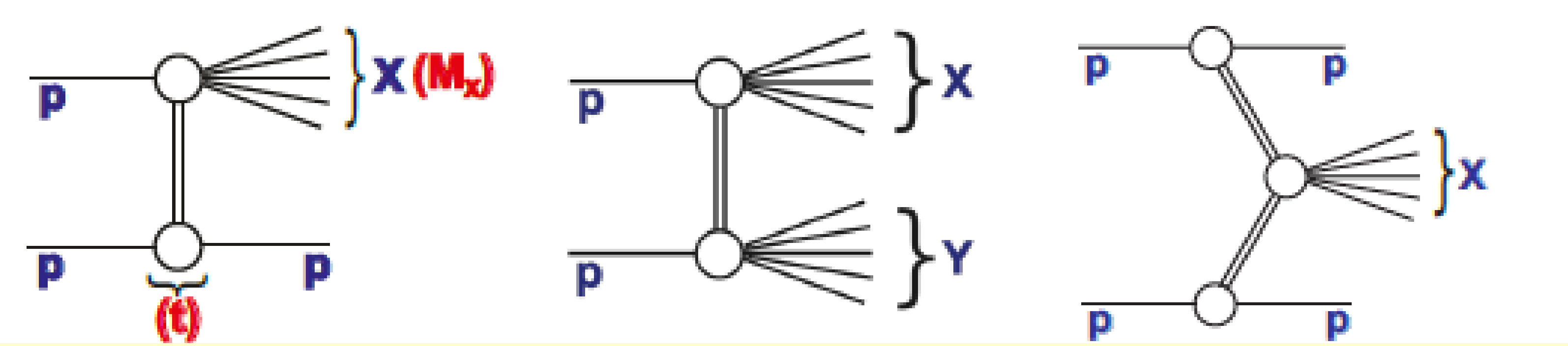
Measurement of differential cross sections for single diffractive dissociation in $\sqrt{s} = 8$ TeV pp collisions using the ATLAS ALFA spectrometer

JHEP 02 (2020) 042





ALFA consists of pairs of Roman-Pot mounted scintillating-fibre detectors that approach the beam vertically.
Positioned at 237m and 241m either side of the Interaction Point.



Single diffractive dissociation (SD)

Double diffractive dissociation (DD)

Central diffraction (CD)

Data taken during a special low-lumi run in 2012
Pile-up factor $\mu \leq 0.08$
Parallel-to-point vertical beam focus enables small-angle scattered protons to be detected

SD events are selected with a primary tracking vertex and one well-reconstructed proton in ALFA.

PYTHIA8 used for simulations, Donnachie-Landshoff Pomeron model.

Analysis method

Scattered proton angle and momentum are determined from ALFA measurements and beam optics.
Use to calculate squared momentum transfer t .

Charged particles with $p_T > 200$ MeV are used to measure:
- visible rapidity gap $\Delta\eta$ from $|\eta| = 2.5$ towards zero
- mass M_X of the central diffractively produced system X.

Fractional proton energy loss ξ given by $\xi = M_X{}^2 / s$.
A formula is which reduces effects of undetected forward particles
is $\xi = \Sigma\,(E \pm p_Z)/\sqrt{s}$, summing over charged particles with $p_T > 100$ MeV.
A MC-based correction term is applied to compensate missing neutrals.

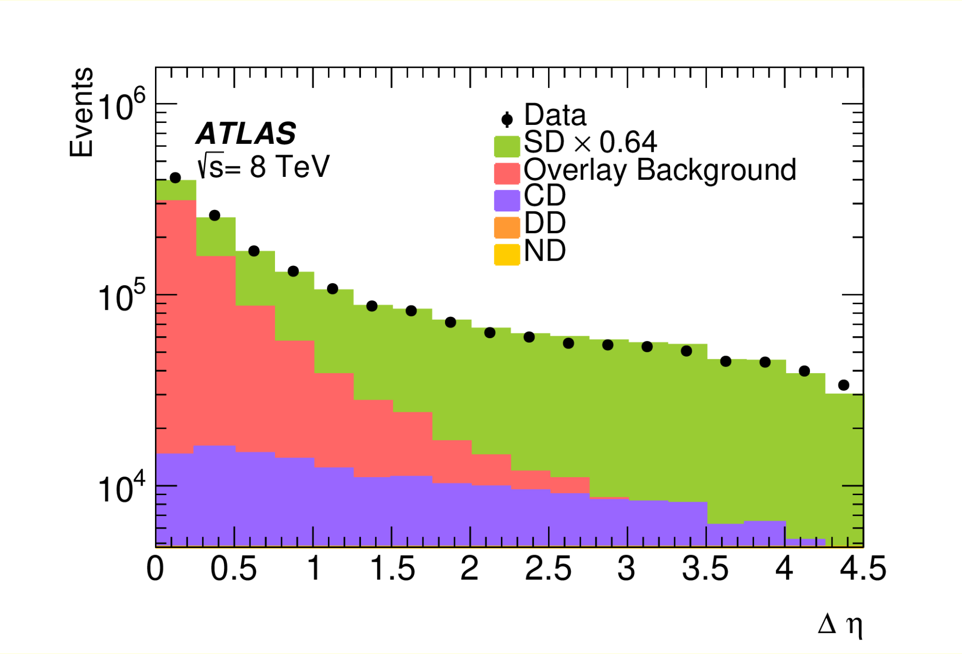
Fiducial range with acceptance > 10% is chosen as

$$-4 < \log_{10} \xi < -1.6$$

$$0.016 < -t < 0.43\ \text{GeV}^2$$

After acceptance and measurement corrections,
unfold in t , $\Delta\eta$ and ξ using iterative Bayesian algorithm (D'Agostini)
- response matrices are diagonal to good approximation.

Backgrounds.



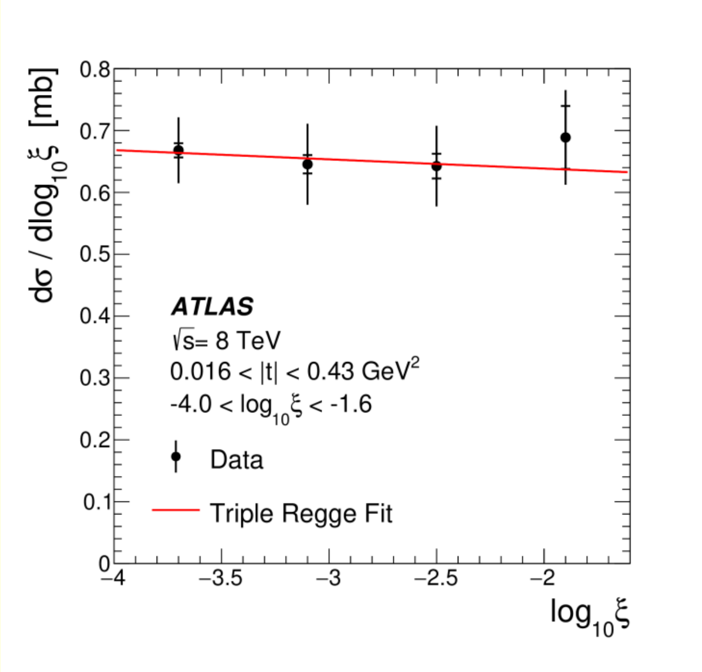
SD signal is accompanied by

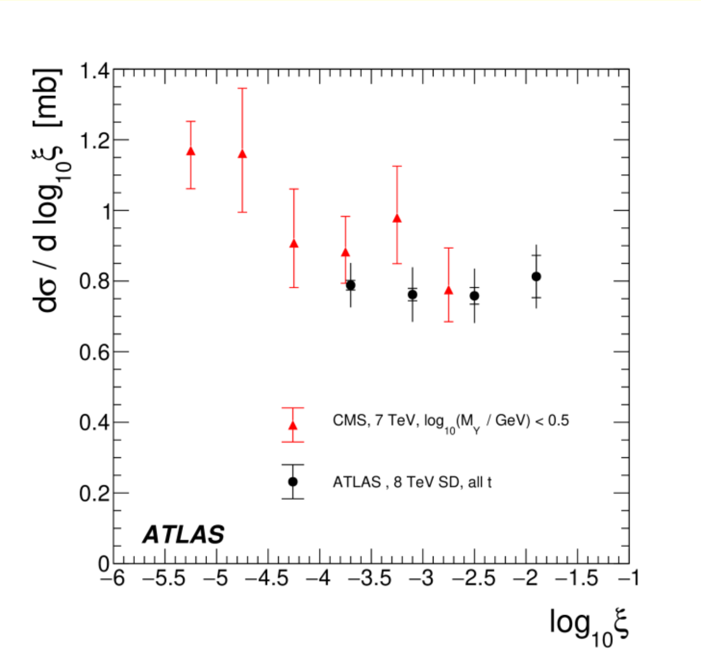
- single-process backgrounds (CD, DD, non-diffr. ND)
- central-detector events with random ALFA count. ("Overlay Background")

ND and DD backgrounds are negligible
CD modelled with PYTHIA and scaled to fit control region
Overlay evaluated from non-diffractive topologies accompanied by non-matching ALFA track.

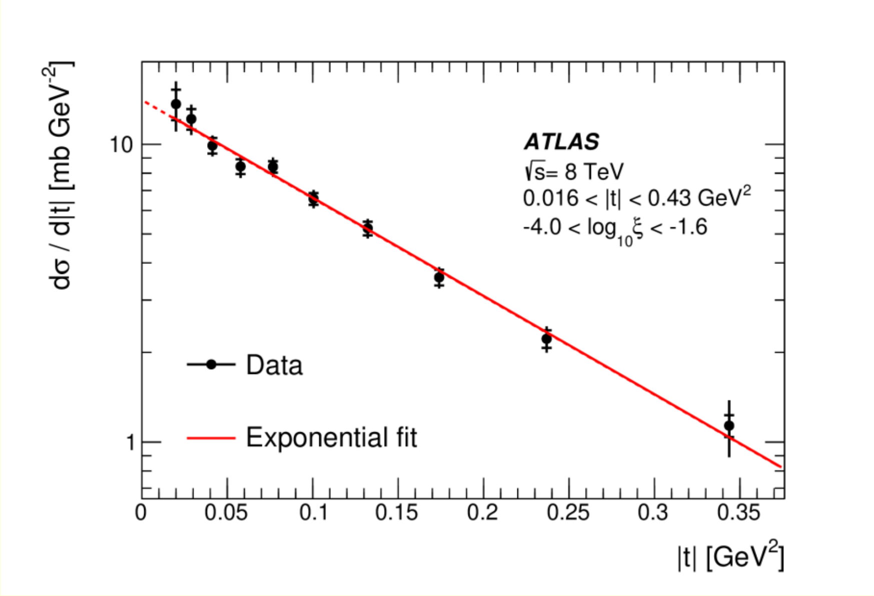
Overlay background contributes dominant **systematic uncertainty**
(typically 5% increasing to 20% at lowest t)

Results

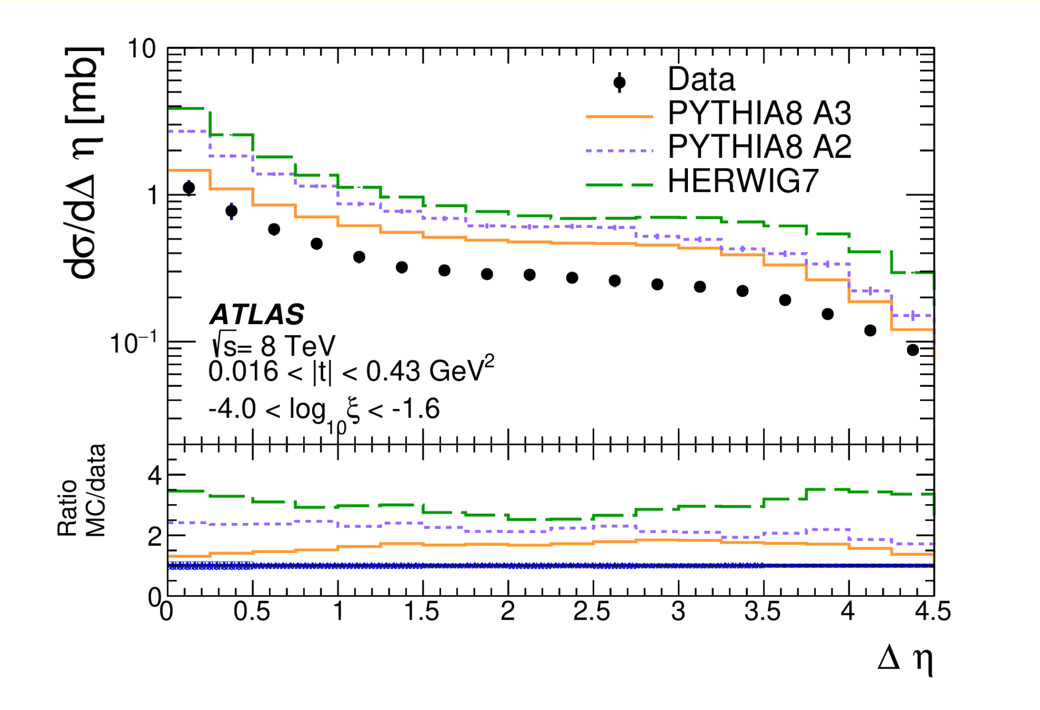




Flat distribution in log ξ , within fiducial range, consistent with CMS.
Curve is based on triple-Pomeron model.



Standard exponential fall-off in t



Cross sections are lower than PYTHIA/HERWIG models (as has been found before)

Similar shape in $\Delta\eta$, with "plateau".

PYTHIA – perhaps incorrect modelling of Pomeron intercept.

HERWIG – perhaps influenced by use of clusters rather than strings, or inaccurate use of data input to model?

Distribution	$\sigma_{SD}^{\text{fiducial}(\xi,t)}$ [mb]	$\sigma_{SD}^{t\text{-extrap}}$ [mb]
Data	1.59 ± 0.13	1.88 ± 0.15
PYTHIA8 A2 (Schuler–Sjöstrand)	3.69	4.35
PYTHIA8 A3 (Donnachie–Landshoff)	2.52	2.98
HERWIG7	4.96	6.11

Summary:

General features of diffractive production confirmed.

Disagreement with existing LO Pomeron models.

Measurement of distributions sensitive to the underlying event in inclusive Z boson production in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector

Eur. Phys. J. C (2019) 79:666

Drell-Yan processes provide a clean hard environment for studying soft accompanying QCD processes: the **Underlying Event** (UE)

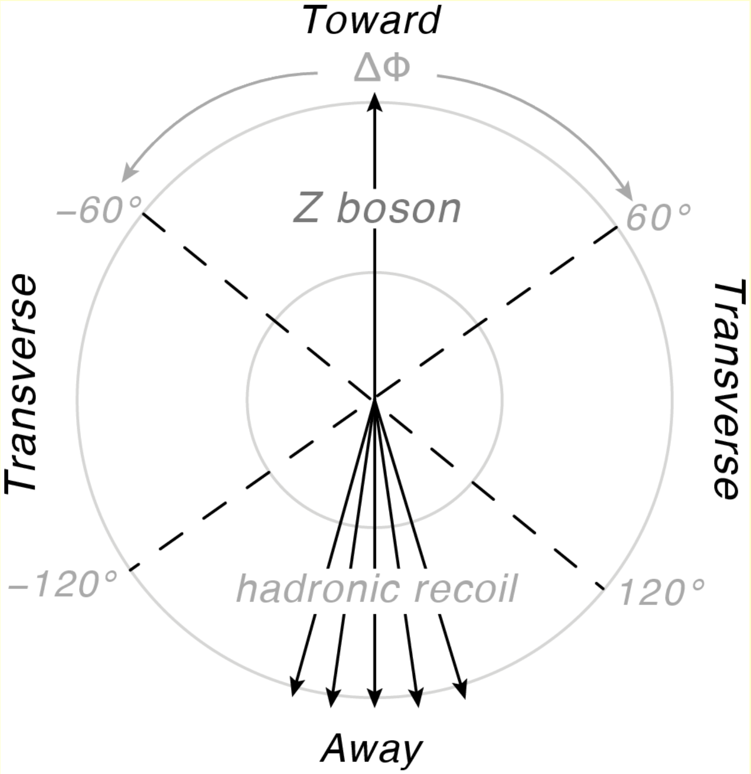
The hard process studied here comprises

$q \bar{q} \rightarrow Z \rightarrow \mu^+\mu^-$

with initial-state radiation (ISR) to give a balancing jet. No final-state radiation.

Kinematic distributions in the transverse regions enable soft production models to be tested.

Principal MC was POWHEG + PYTHIA 8.180 +PHOTOS (final-state e/m radiation)



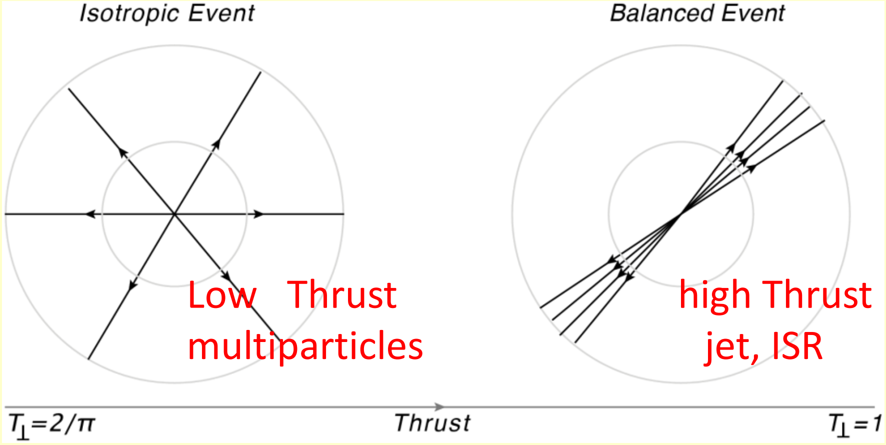
Analysis method

Four regions: Toward (Z direction),
Away (jet direction),
Transverse max./min with greater/lesser $\Sigma\, p_T$.

Four observables are studied, normalised to angular width of each region:

- p_T^{ch} (selected charged particles)
- N^{ch} (in an event)
- $\Sigma\, p_T^{ch}$ (in an event)
- mean p_T^{ch} (in an event)

Studied in 8 bins of $p_T(Z)$
and two bins of transverse thrust $T_\perp$
(using all particles in event except muons.)

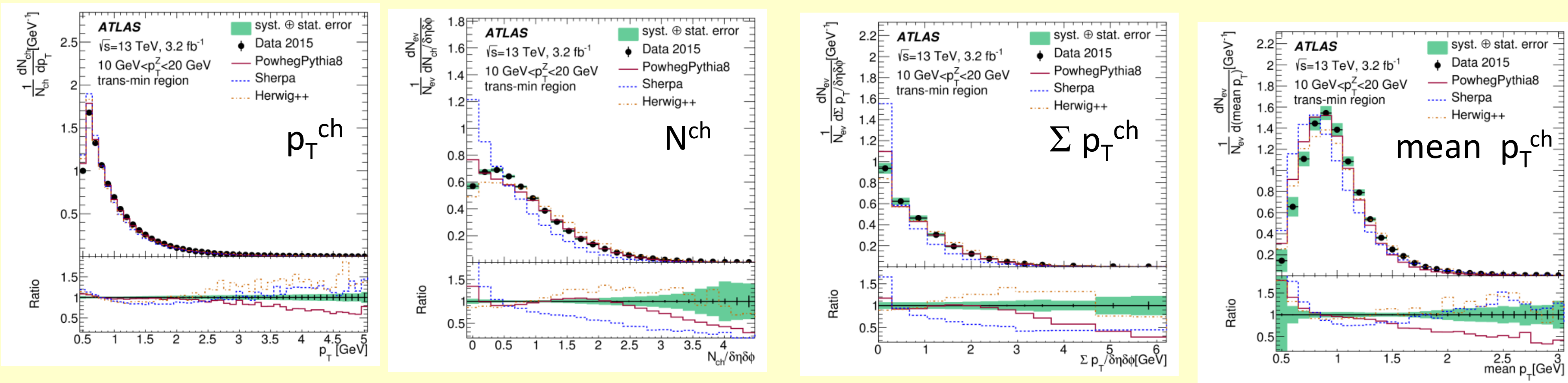


Track selection:
Muons: $p_T > 25$ GeV, $|\eta| < 2.4$,
$66 < m^{\mu\mu} < 116$ GeV.
Charged particles: $p_T > 0.5$ GeV, $|\eta| < 2.5$

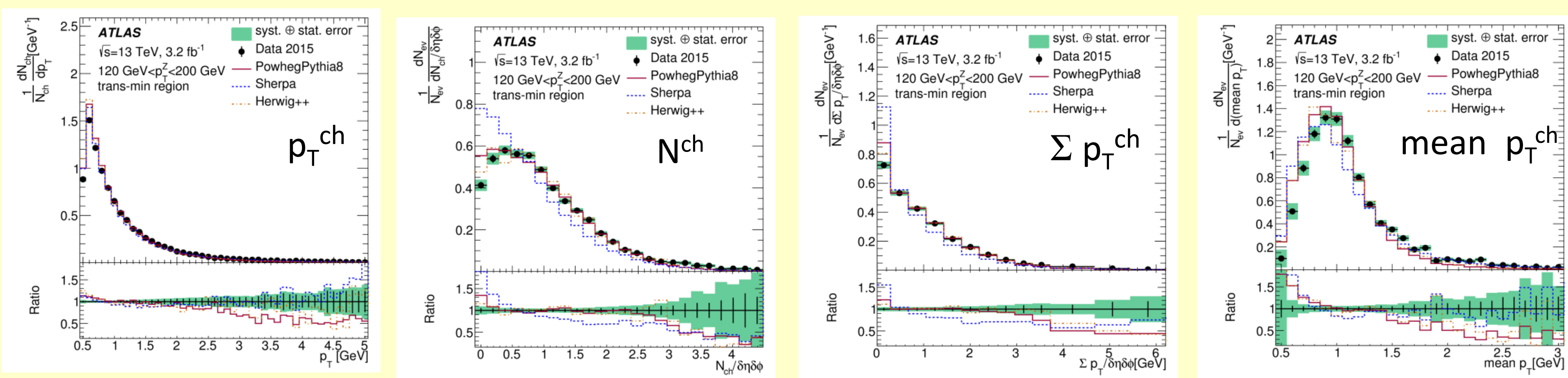
Unfold using an iterative Bayesian technique
and POWHEG+PYTHIA

Selected results (1)

10 < pT(Z) < 20 GeV

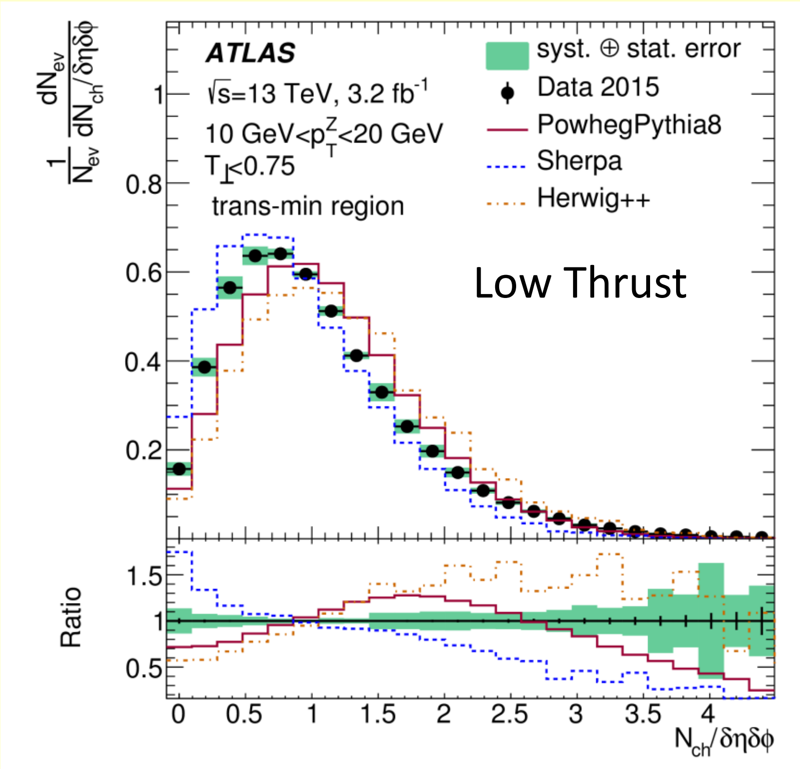


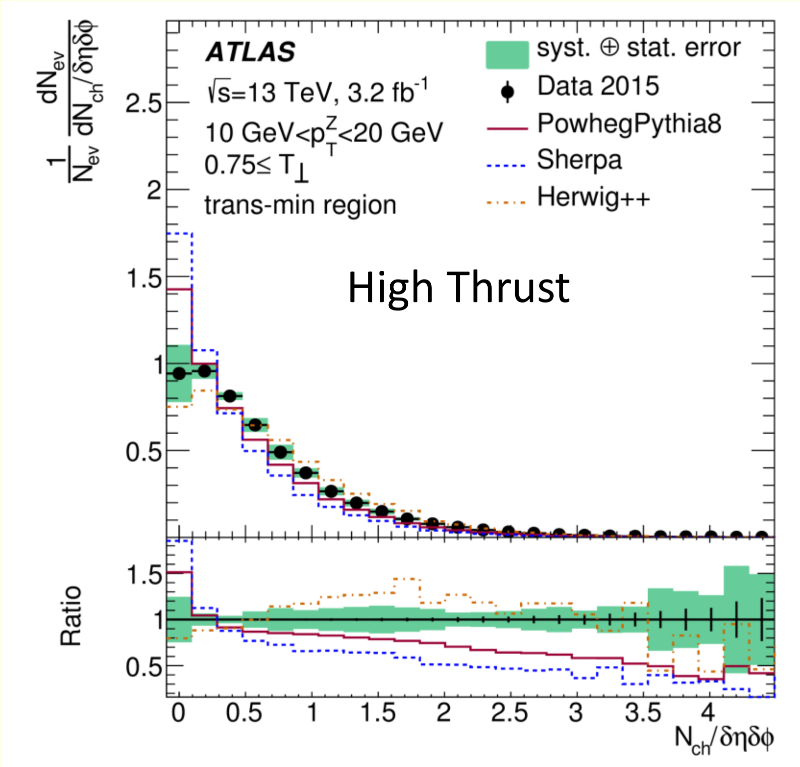
100 < p_T(Z) < 120 GeV



Systematic uncertainties are small and mainly detector-related.
Fair agreement with most models.

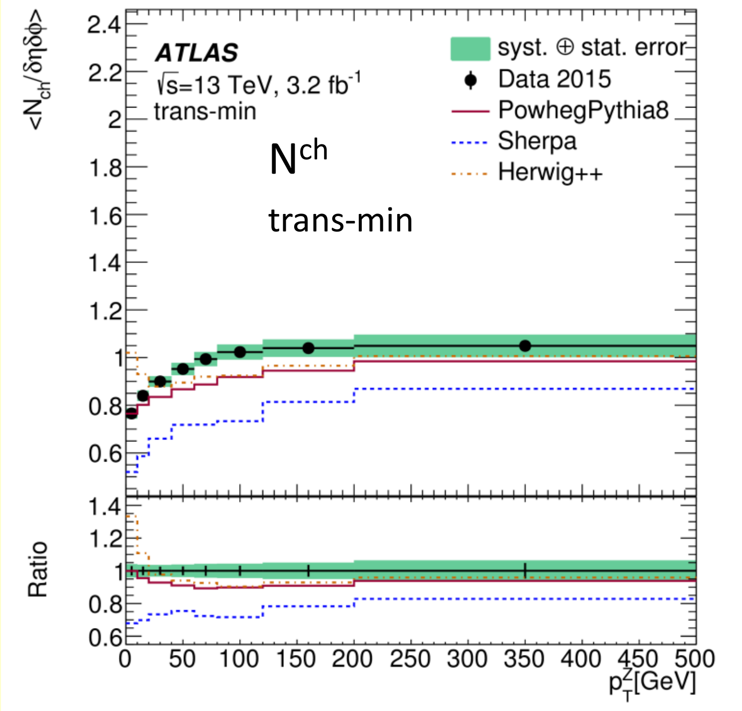
Selected results (2)

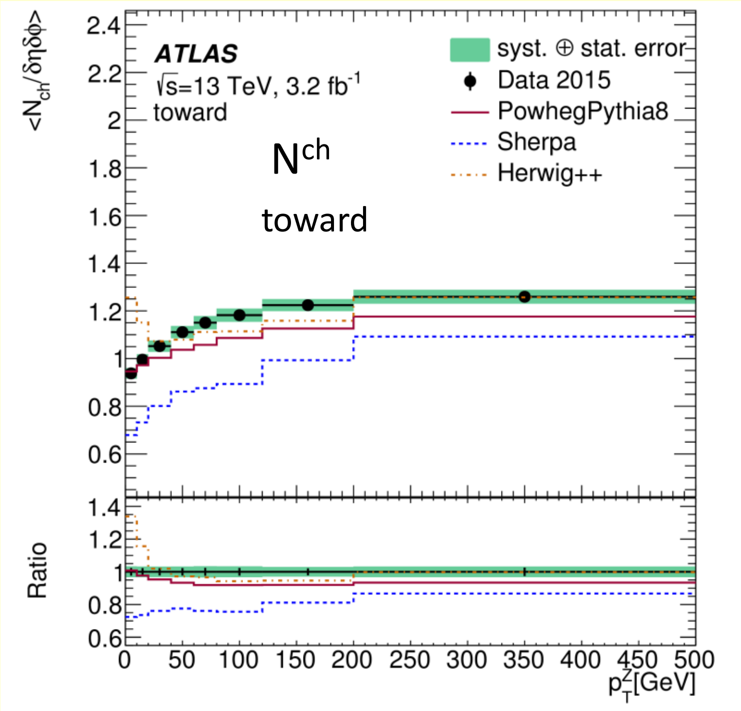




Distribution of N^{ch} in trans-min for low Thrust, high Thrust is poorly described.

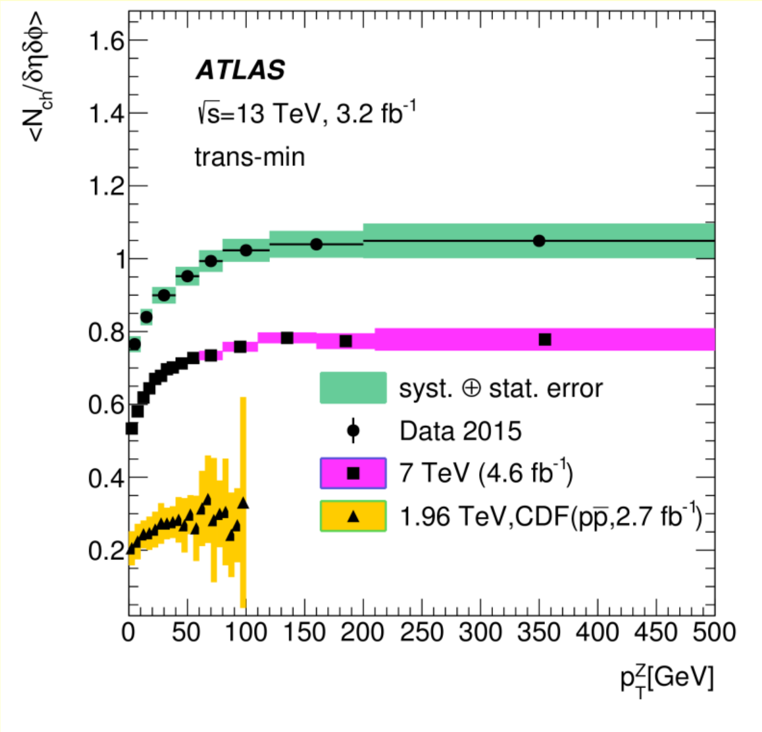
Selected results (3)

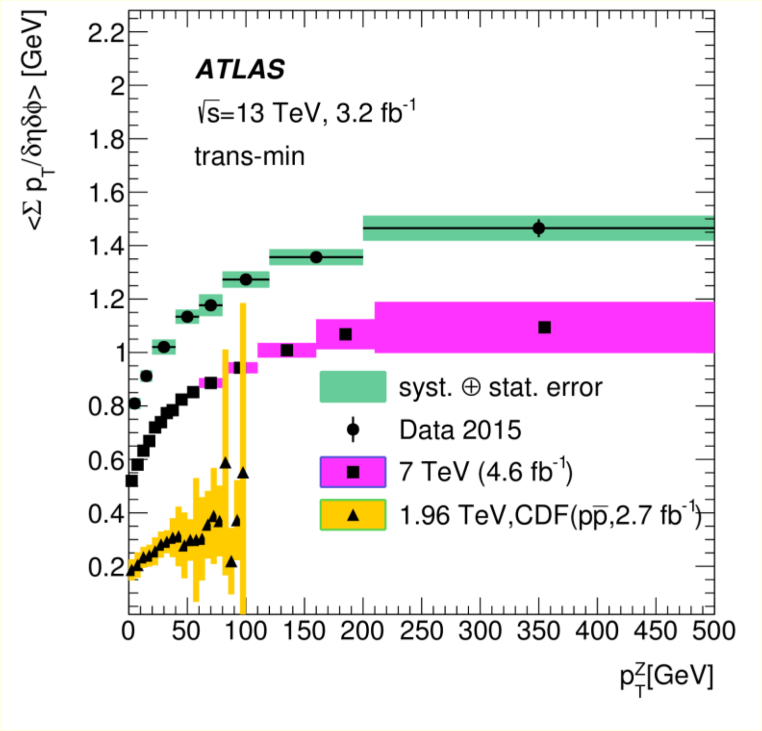




N^{ch} is poorly described.

Selected results (4)





Comparison with lower energy measurements

Measurement of K_S^0 and Λ^0 production in $t\bar{t}$ dileptonic events in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

Eur. Phys. J. C (2019) 79:1017

Physics goals

- The t quark decays mainly into *Wb,* rarely into *Ws*, governed by the WKB matrix element V_{ts}. A step towards the measurement of V_{ts}.
- In jet fragmentation via strings, a strangeness suppression factor γ_s is observed. Nearer unity going from e+e- collisions to pp and heavy-ions ("ropes"?). Good to study this.

Measurement aims

Properties of strange particles:

- In b-tagged jets
- In non-b-tagged jets
- Outside jets

Event selections

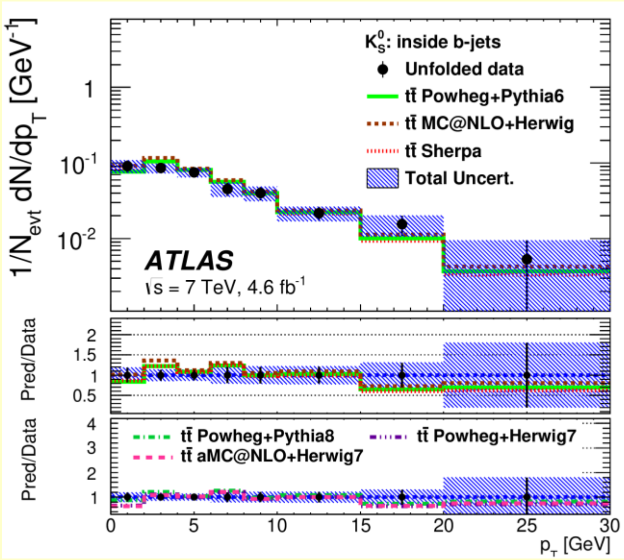
Selection	ee	$\mu\mu$	$e\mu$
Leptons	Exactly 2 leptons, opposite-sign charge, isolated		
Electrons	$E_T > 25$ GeV, $\|\eta\| < 2.47$, excluding $1.37 < \|\eta\| < 1.52$		
Muons	$p_T > 20$ GeV, $\|\eta\| < 2.5$		
Jets	≥ 2 jets, $p_T > 25$ GeV, $\|\eta\| < 2.5$		
b-tagging	≥ 1 b-tagged jet at $\epsilon_b = 70\%$ with MV1		
m_{ll}	$\|m_{ll} - 91\text{ GeV}\| > 10$ GeV, $m_{ll} > 15$ GeV		None
E_T^{miss} or H_T	$E_T^{miss} > 60$ GeV		$H_T > 130$ GeV

MC generator settings

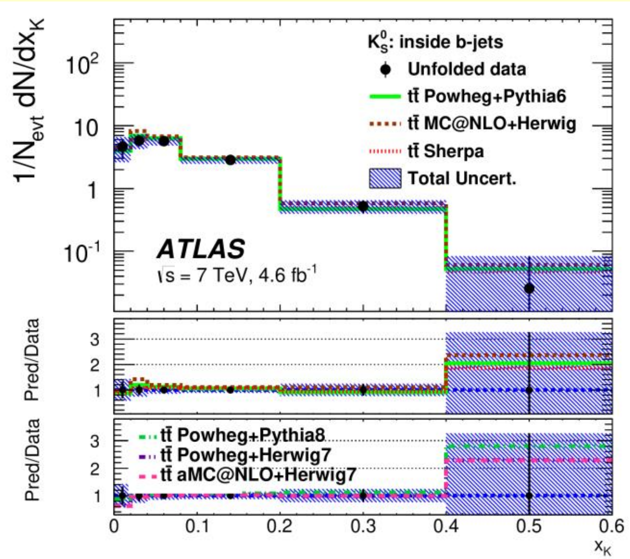
MC generator	ME order	PDF	UE tune
Powheg+Pythia6	NLO	CTEQ66 NLO	Perugia2011c
MC@NLO+Herwig	NLO	CT10 NLO	Jimmy-AUET2
Sherpa 2.1.1	NLO	CT10 NLO	Sherpa
Powheg+Pythia8	NLO	NNPDF3.0 NLO	A14
Powheg+Herwig7	NLO	NNPDF3.0 NLO	H7UE
aMC@NLO+Herwig7	NLO	NNPDF3.0 NLO	H7UE
AcerMC+Pythia6	LO	CTEQ6L	Perugia/TuneAPro (with and w/o CR)

Most corrections were simple bin-by-bin efficiencies, but particle multiplicities needed Bayesian unfolding. Systematic uncertainties are mainly due to the choice of MC.

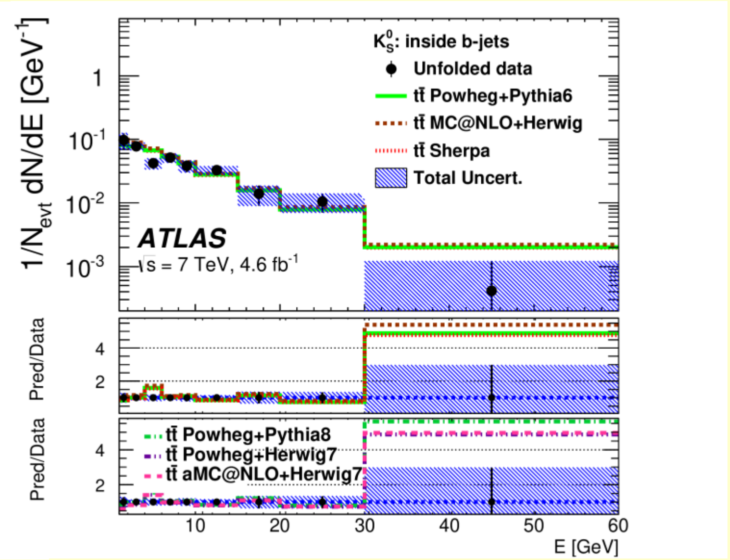
Results (1) Unfolded particle-level distributions.



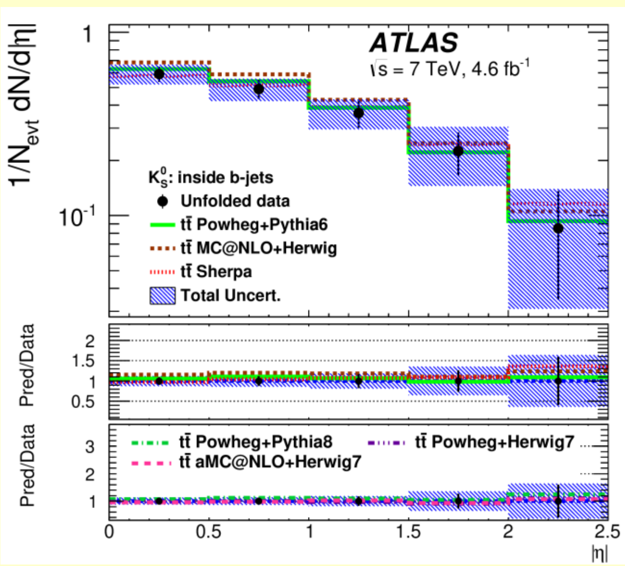
P_T



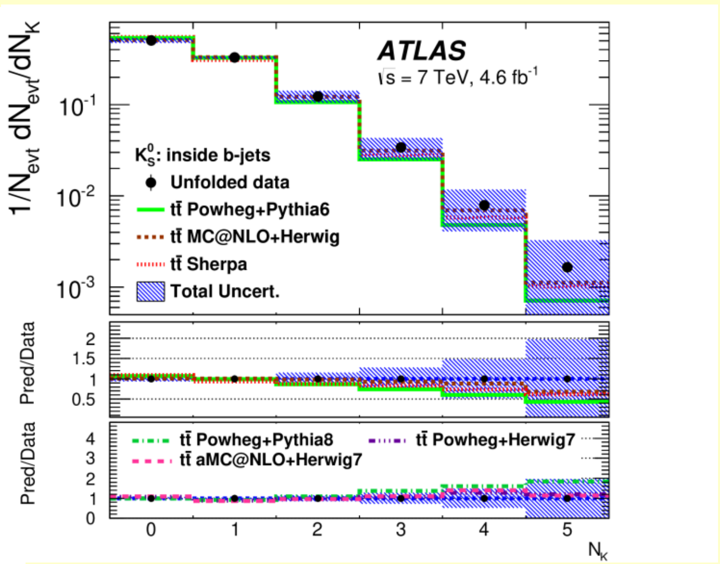
x_K



E



$|\eta|$

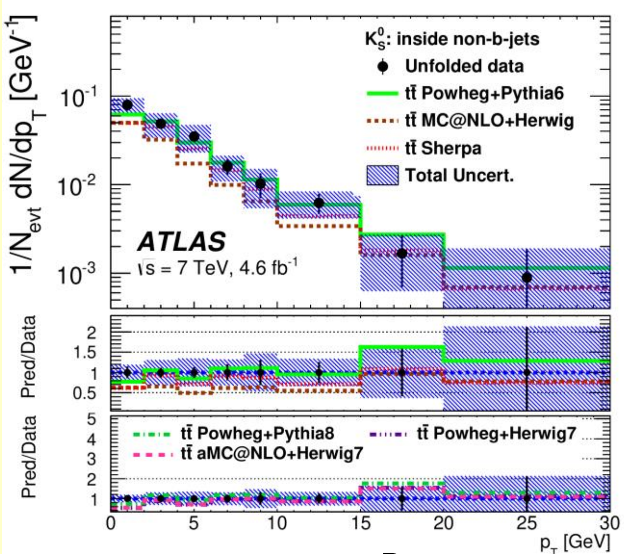


N_K

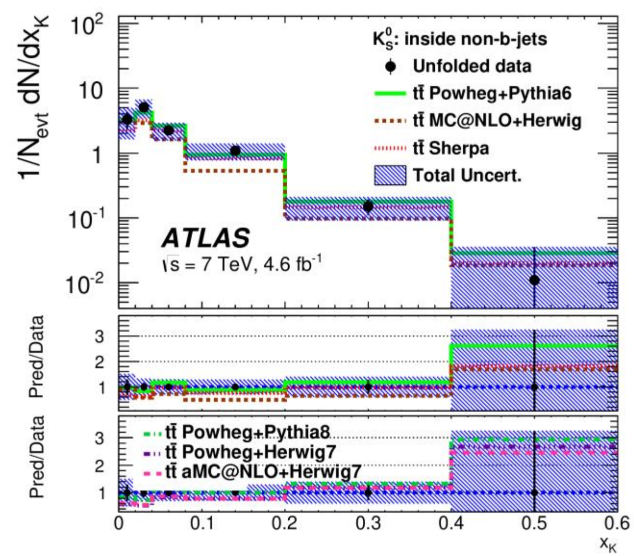
K^0 inside b-jets

Agreement with theory models.

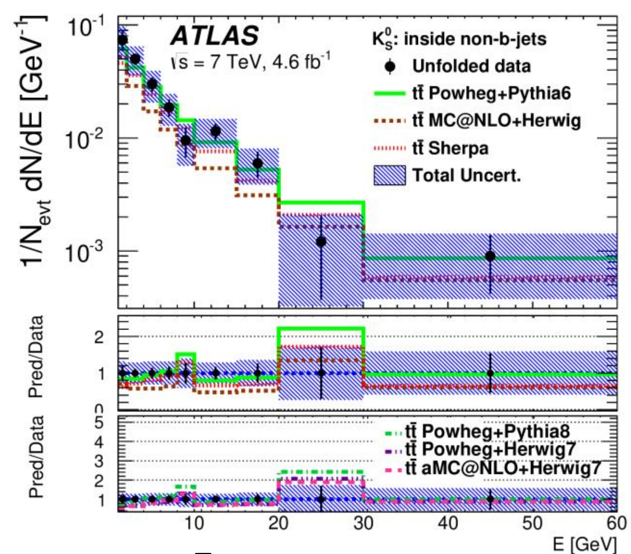
Results (2)



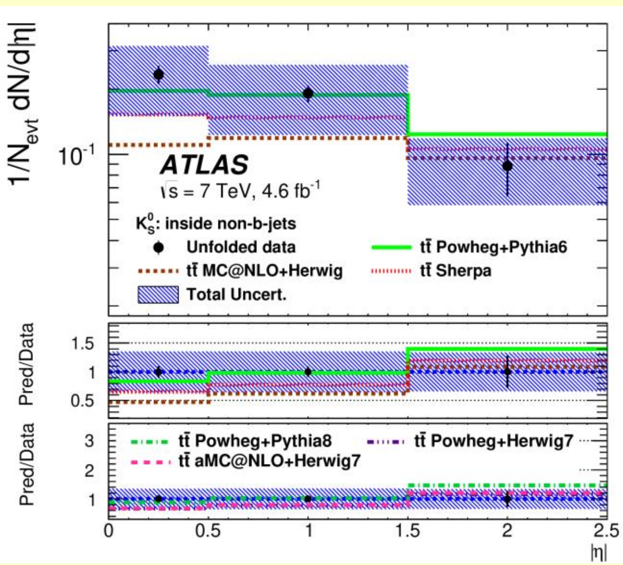
P_T



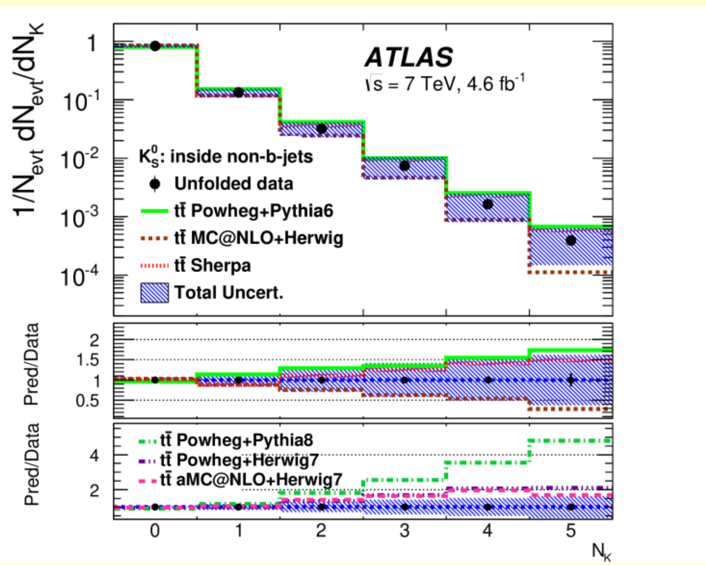
x_K



E



|η|

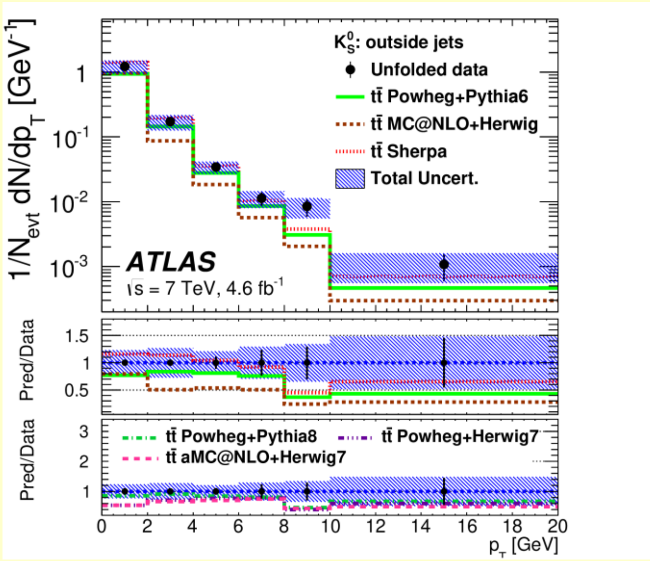


N_K

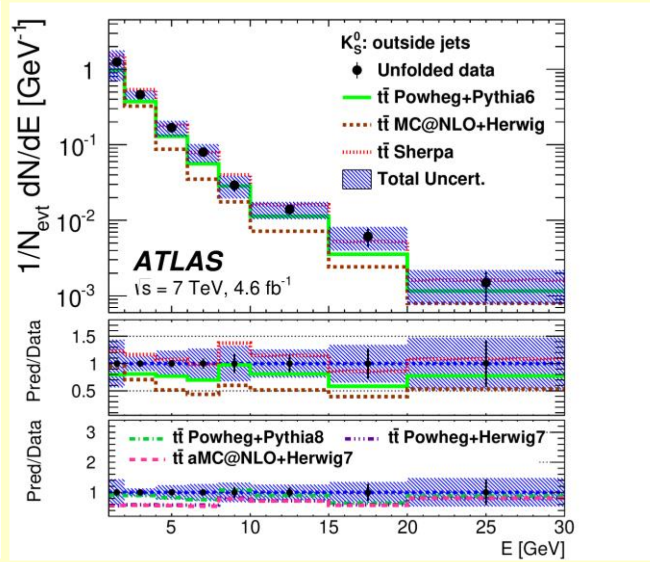
K^0 inside non-b-jets

Agreement with theory models
Except for N_K

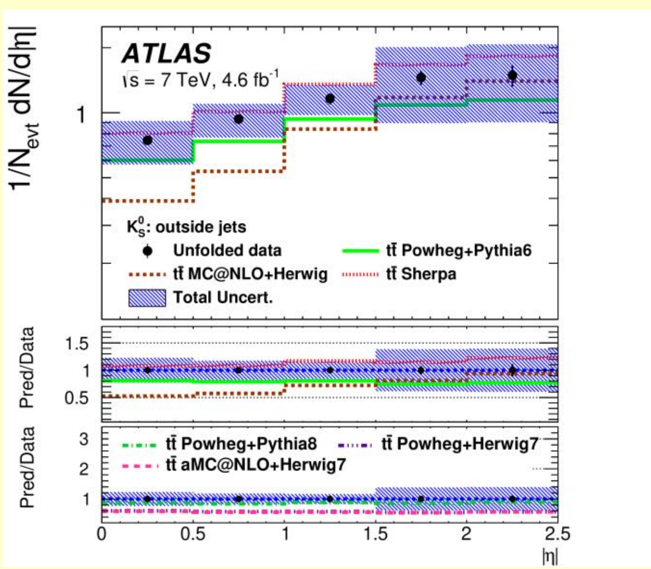
Results (3)



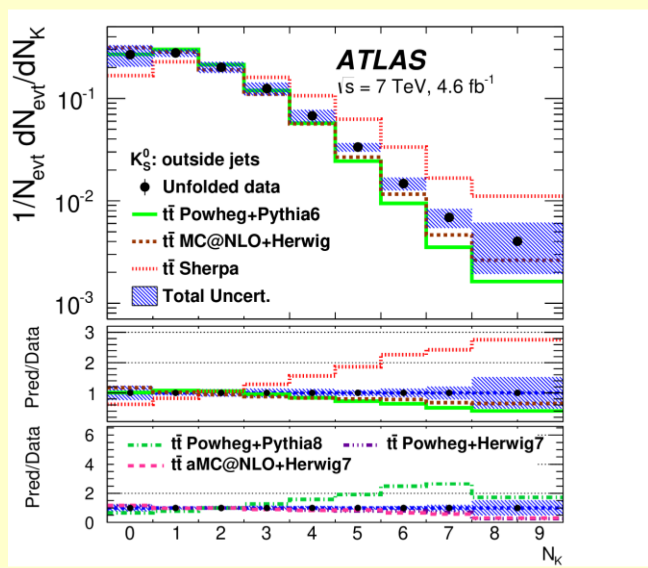
P_T



E



$|\eta|$



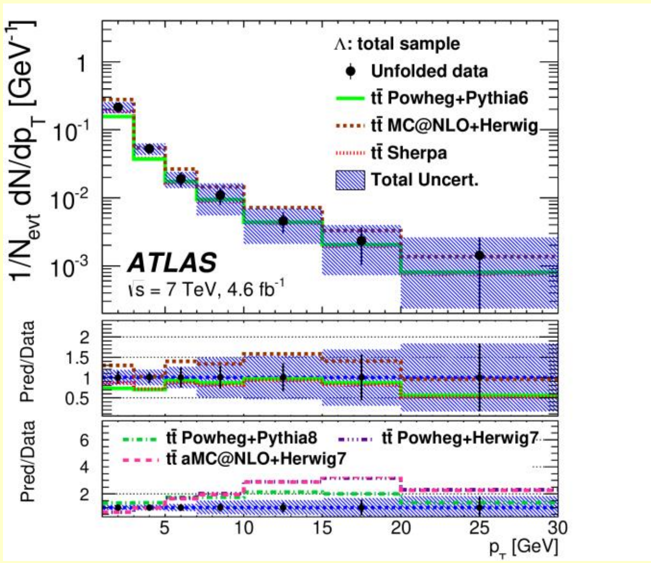
N_K

K^0 outside jets

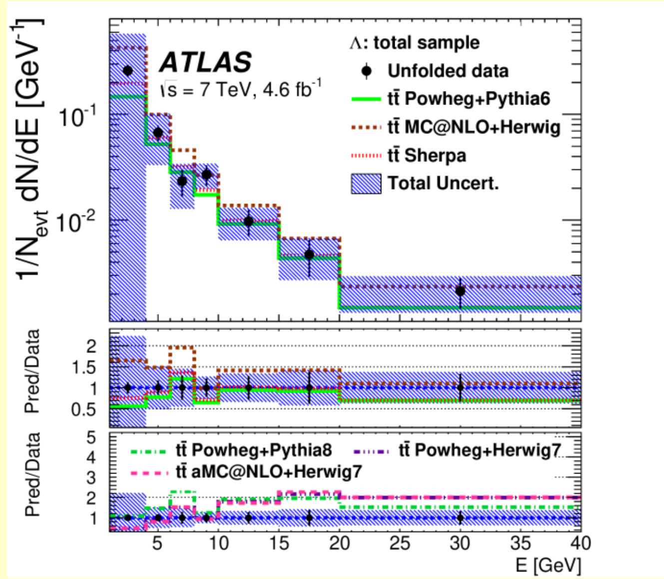
Agreement with most theory models.

Some predict too much production.

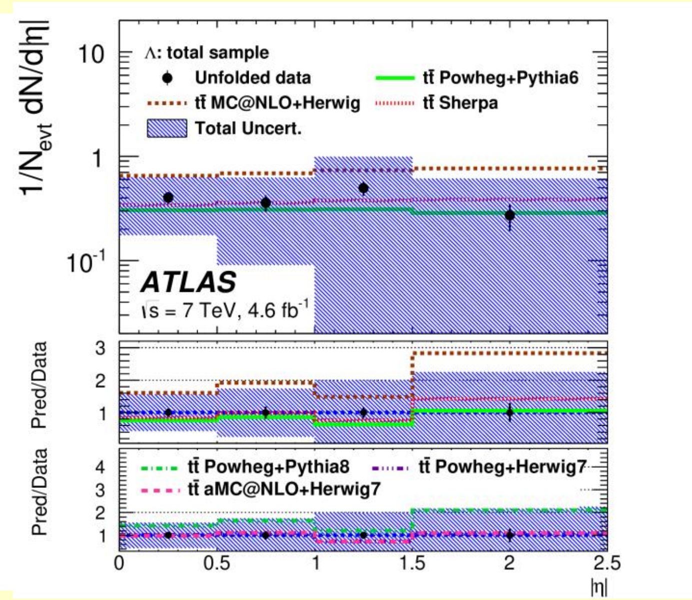
Results (4)



P_T



E



$|\eta|$

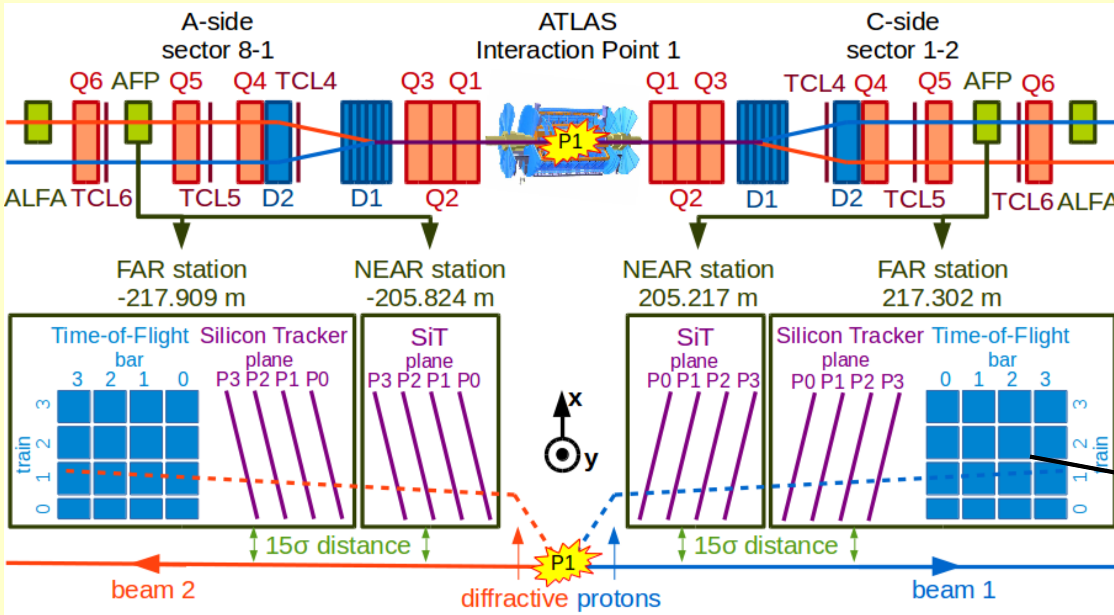
Λ^0 all.

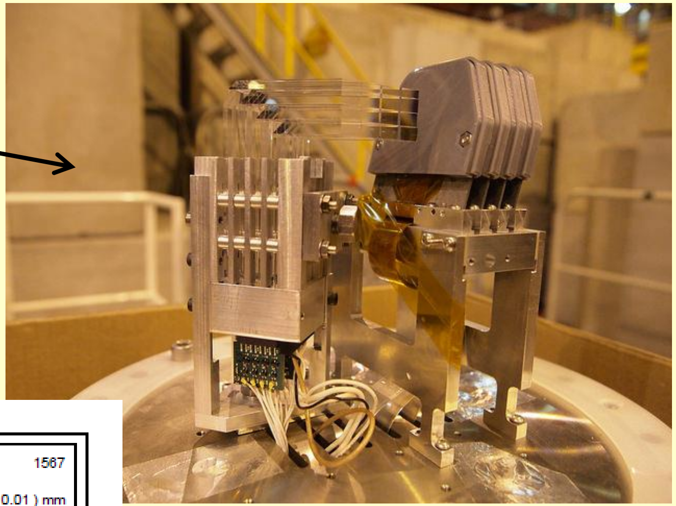
Agreement with most theory models.

Conclusions from this analysis

- Strange baryon production suppressed everywhere relative to strange meson production.
- Neutral strange particle production is much softer outside jets
- Neutral strange particle multiplicities are higher outside jets
- Current MC models give a fair description inside jets
- Outside jets, most models underestimate the production,
  suggesting a need for less strangeness suppression.
  - Most of the models use a factor γ_s = 0.217.
  - A value ~30% higher outside jets might be better.
  - However in SHERPA 2.2.1, a value 0.4 is too high.

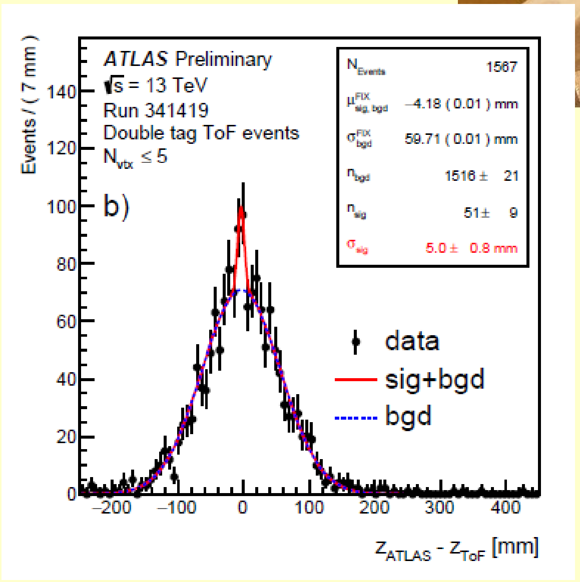
AFP – Progress Report





Silicon detector system is calibrated and analyses are progressing.

TOF is being prepared.



TOF:

$Z_{ATLAS} - Z_{TOF}$ (mm)

$N_{vtx} \leq 5$

Summary

Results from ATLAS have been presented on:

1) Single diffractive-dissociation using ALFA
   General diffractive properties confirmed, existing Pomeron models fail.

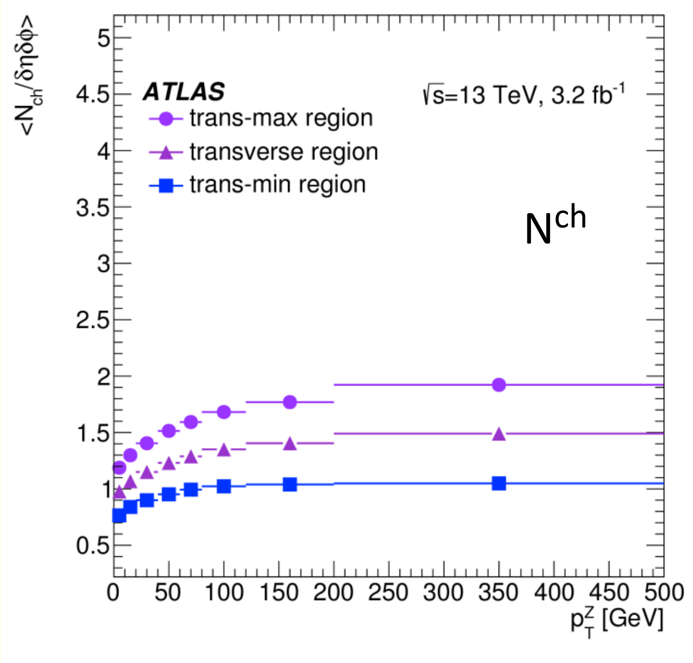
2) Underlying event studies in Z + jet production
   Mixed agreement with theories in underlying event.

3) Strange particle production
   Fair agreement with theories, better inside jets than outside

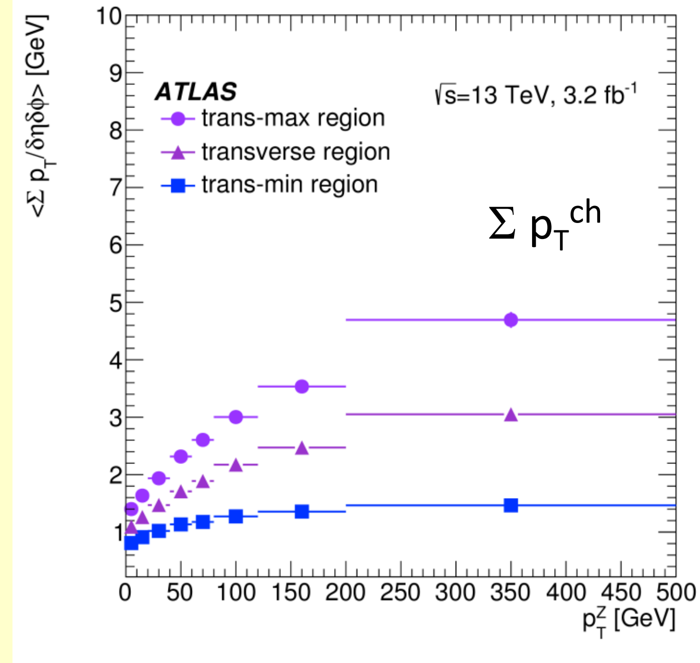
4) Update on AFP
   Progress in analysis and in TOF system development.

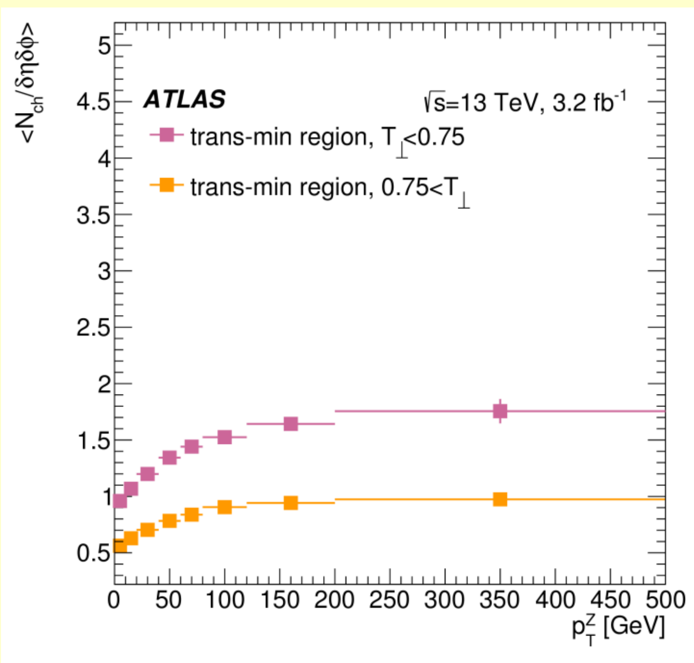
Backups

Selected results

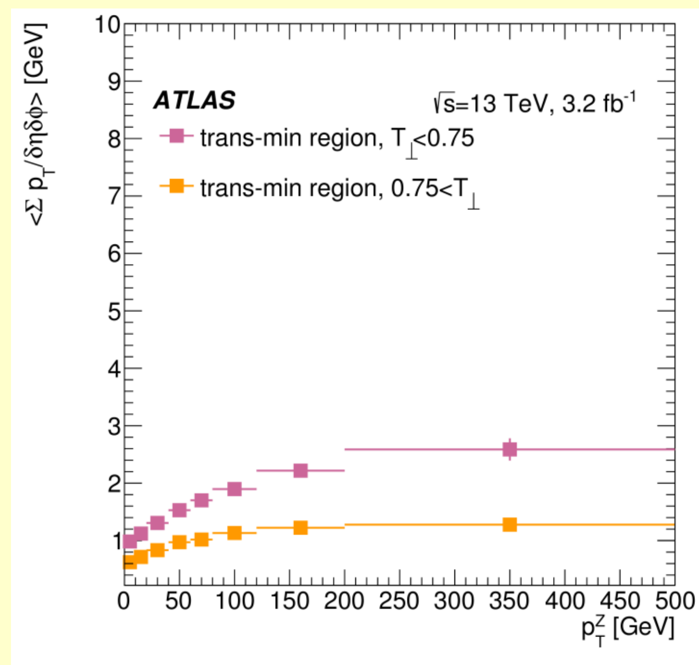


Various comparisons

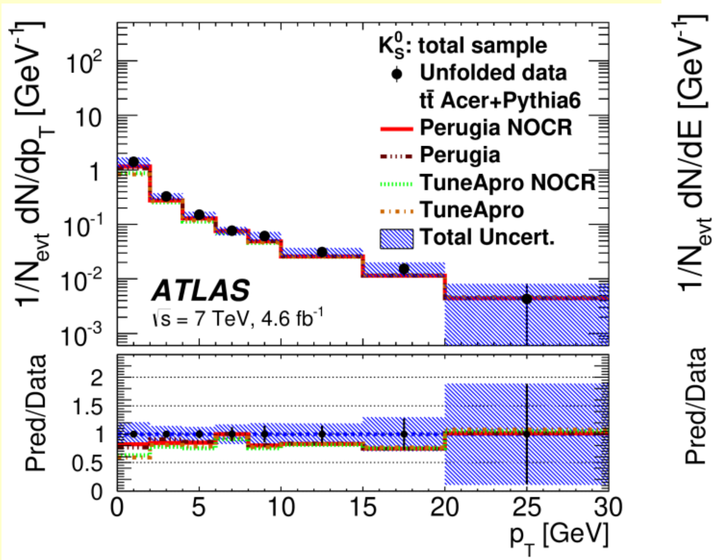




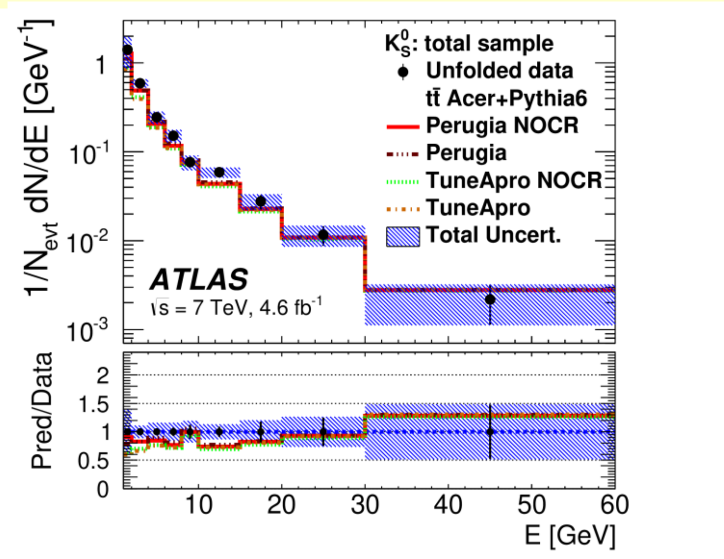
N^{ch} and $\Sigma\, p_T^{ch}$ mean values in different Thrust regions



Results (5)



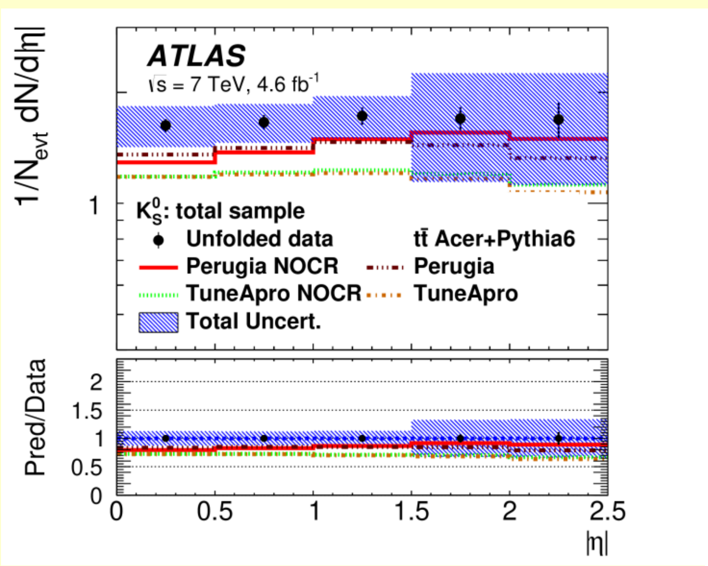
P_T



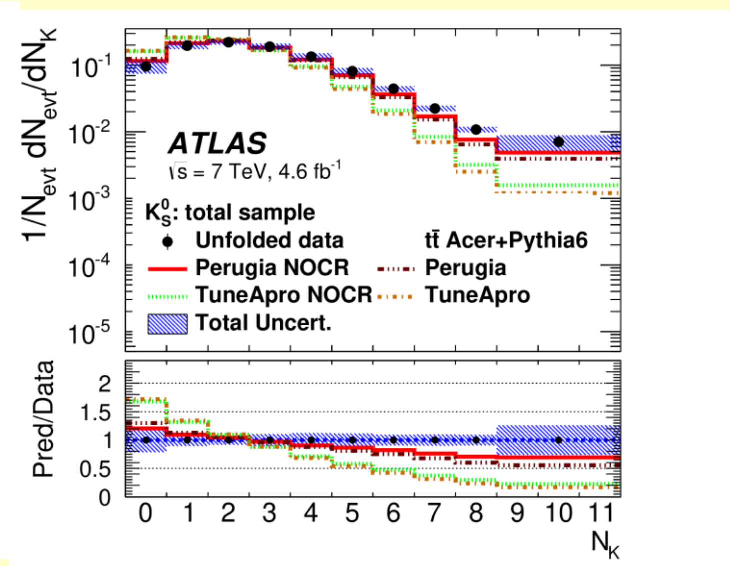
E

K^0 all

Comparison with ACER + Pythia6, different tunes.



$|\eta|$



N_K