Soft Physics with a Proton Tag, Analysis report
LPCC Forward Physics, Trento

Tim Martin

University of Warwick

April 15, 2014

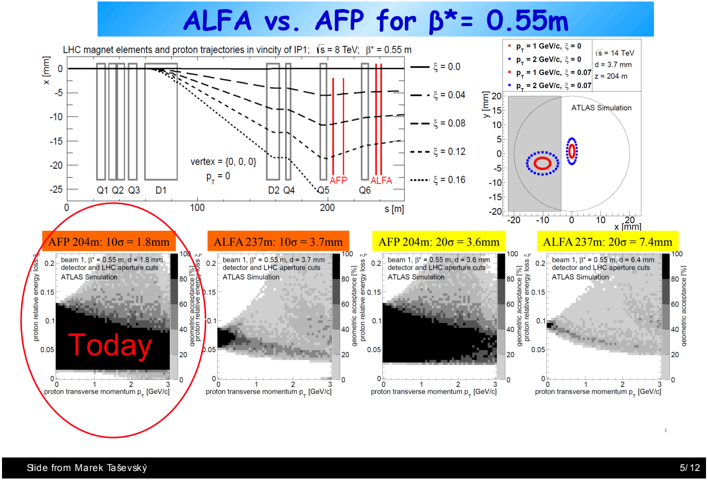
Introduction

- Aim of this contribution is to investigate the possibility for using the AFP and ALFA forward detectors to obtain:
  - A diffractive enhanced ‘minimum bias’ physics sample. High mass dissociations through direct AFP sensitivity to high ξ protons and low mass dissociations through tagging of forward resonant decay.
  - Phase space regions in which current MC models have greatly fluctuating predictions.
  - Better MC tunes for Pomeron-proton initiated fragmentation or tensions which highlight model inadequacies.
- Draft one of the contribution is written up for the report, expect 15 pages on three MC models (specific details) and studies of diffractive rapidity gaps, energy flow and charged particle spectra.

MC Choice and tunes

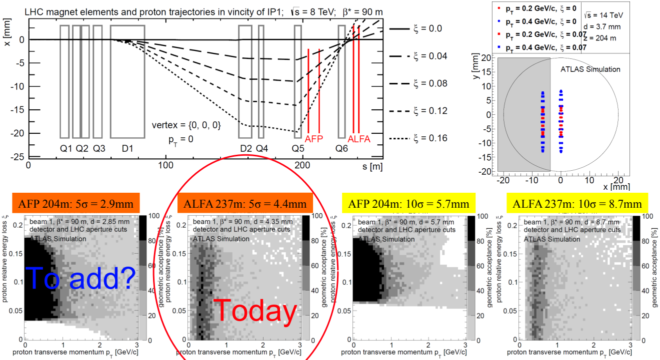
- Reminder, using three different generators to get a spread of predictions.
  - `PYTHIA 8 A2 MSTW2008LO` [ATL-PHYS-PUB-2012-003]
    - ATLAS tune of PYTHIA to 900 GeV and 7 TeV data, based on 4C but with x-dependent matter profile and without rapidity-ordered spacelike emissions. Past analyses [arXiv:1208.6256] have shown the dependence on the choice of PDF, this is not investigated as the effect is relativly small.
    - Explicit diffractive classifications.
  - `HERWIG++ UE-EE-4-CTEQ6L1`
    - https://herwig.hepforge.org/trac/wiki/MB_UE_tunes
    - With automatic evolution of minimum $p_{\mathrm{T}}^{\mathrm{min}}(s) = p_{\mathrm{T},0}^{\mathrm{min}}(\sqrt{s}/E_0)^b$ and cluster hadronisation.
  - `EPOS LHC` [Phys. Rev. C 83 (2011) 044915]
    - Parametrised approximation to hydrodynamic evolution of initial state using a parton based Gribov-Regge theory tuned to LHC data.

R. Staszewski, M. Taševský, M. Trzebiński



R. Staszewski, M. Taševský, M. Trzebiński

ALFA vs. AFP for β*= 90m



AFP concentrated around higher xi, while ALFA gives access to very low xi – common data taking would be best!
ALFA upgrades its dead time, radhardness and trigger. BUT: 1) Still there will be some dead time and 2) no timing det.
3) In the overlap regions, the ALFA acceptance is 10% of the AFP acceptance ;4) Below xi<10-3 resolution bad

Slide from Marek Taševský 6/12

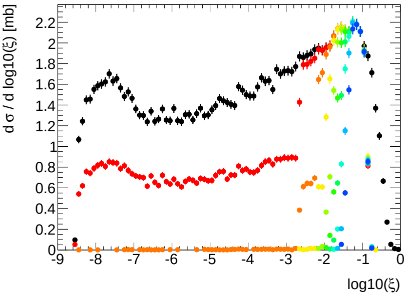
Running Conditions

- For these studies, require a minimum bias sample with the inclusion of forward detectors and appropriate optics.
- Inelastic cross section will be around 20% larger than experienced so far at ~ 85 mb.
- Roughly 2–3% of inelastic events will have a single proton tag.
  - Low pileup desirable, $\mu < 0.01$. Pileup is a a background, which is irreducible at some level. May be an issue for low β^* (AFP).
  - Well separated bunches, 200 ns or greater.
  - Integrated luminosity of 200 - 1000 μb^{-1} ($\sim 10 - 50$ million events, $\sim$300 – 1500 thousand with proton tag).

ATLAS experience from 8 TeV minimum bias run: 200 μb^{-1} collected from 10 bunches with $<\mu>= 0.003, \beta^* = 0.8$ m in 3 hours by reading out ATLAS at up to 1.2 kHz. No forward detectors.

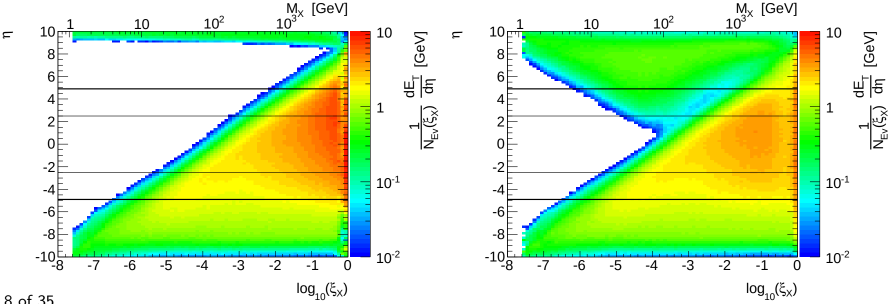
AFP ξ Acceptance - Truth

- `Pythia 8 4C Single Diffractive` at $\sqrt{s}$ 14 TeV.
- For Single Diff: $\xi_X = M_X^2/s = (B_E - p_E)/B_E$. B_E is beam energy.
- For Double Diff: $\xi_X = M_X^2/s, \xi_Y = M_Y^2/s$. Define $M_X > M_Y$.
- Black, generated. Red, 0mm from beam - Blue, 4mm from beam.
- At $\sqrt{s} = 14$ TeV, we can in principal probe over 9 orders of magnitude in ξ.



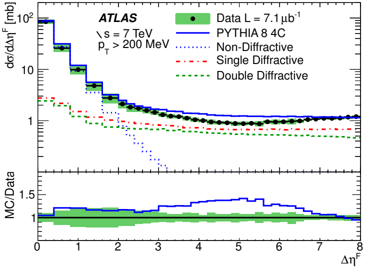
Diffractive Kinematics: Generator Energy Flow

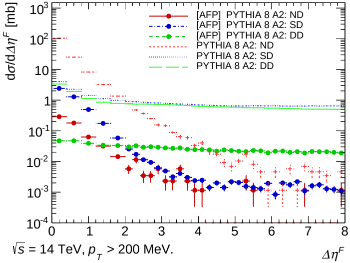
- These events have no colour flow between the protons. This results in a pseudorapidity gap between the dissociating system and intact proton, or both dissociating systems.
- The size of the gap, measuring inwards from the edge of the detector can be used as a classifier of these events.



Predictions for PY8 [Eur. Phys. J. C72 (2012) 1926]

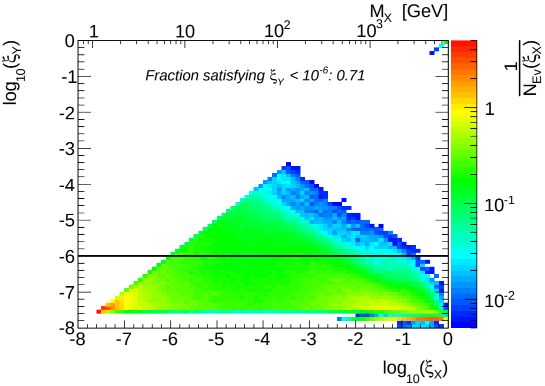
- For inclusive minimum bias, gap size in ND events falls exponentially (hadronisation). Diffractive cross sections are $\sim$ flat.
- With AFP single-tag, SD events also fall exponentially as only high mass events trigger (no gap within ATLAS).
- $\sim$ flat distribution preserved for DD events. What drives this?



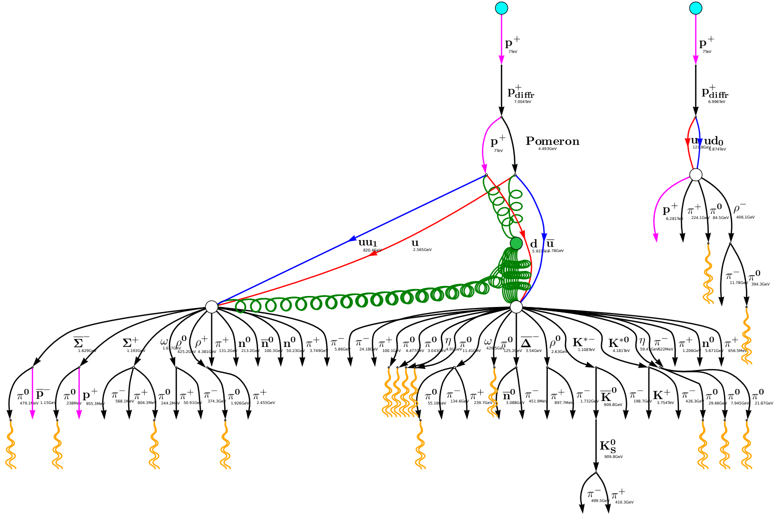


Raw Pythia 8 Double Diffractive Kinematics

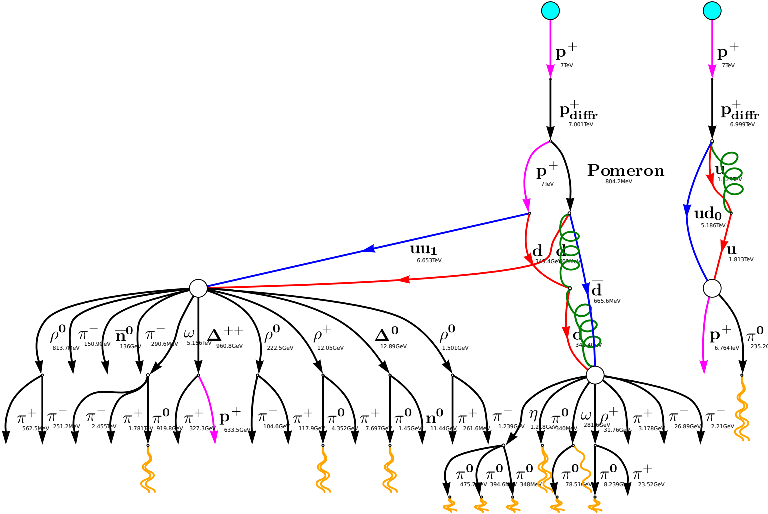
- Correlation of larger (ξ_X) and smaller (ξ_Y) diffractive systems as simulated by Pythia 8. Very little correlation.
- Normalised in columns of ξ_X.
- This is for all DD events, what about ones which tag AFP?



PYTHIA 8: Gap 4.12772

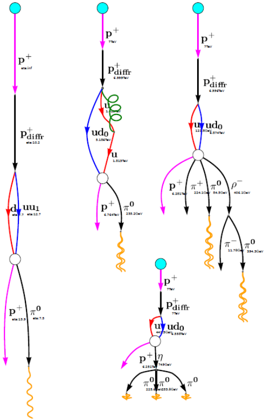


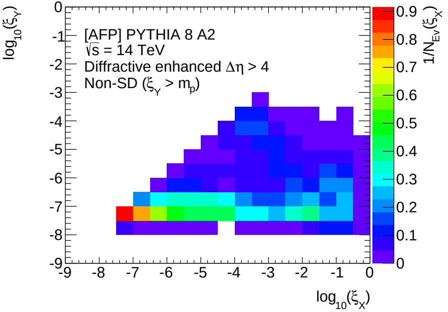
PYTHIA 8: Gap 6.61757



PYTHIA 8

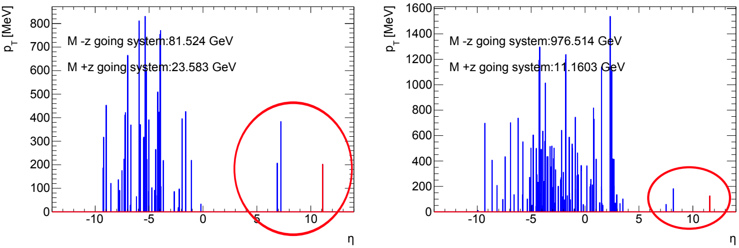
Examples of forward low mass diffractive excitations in Pythia 8 resulting in a proton within AFP acceptance.



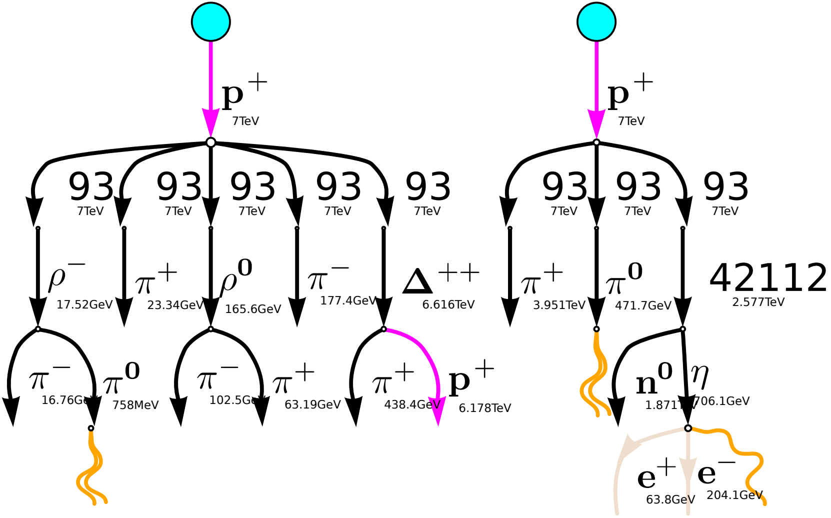


Soft Diffraction with *p*-tag.

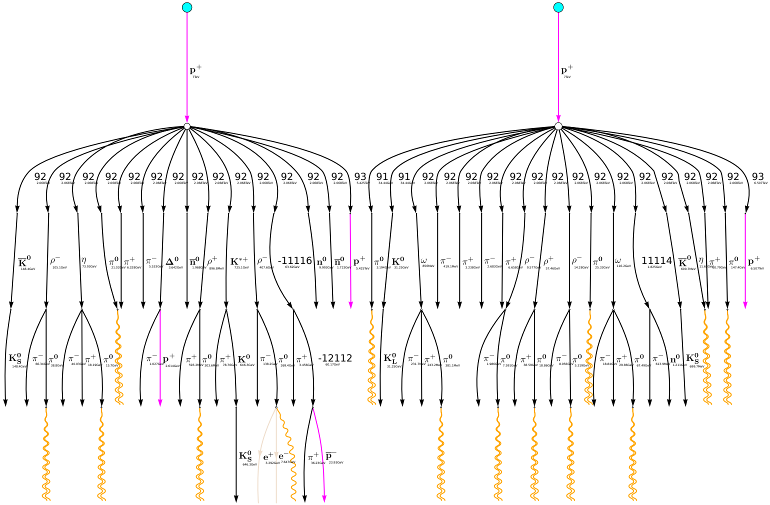
- Double-dissociative diffraction with a forward proton through a baryonic resonance may allow for lower, otherwise inaccessible diffractive masses to be enhanced.
- In Pythia 8, the majority of DD events passing the AFP selection come from this mechanism.



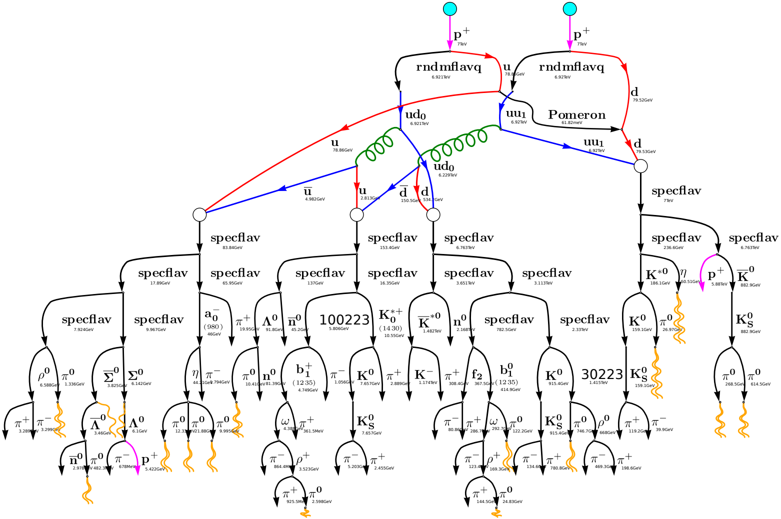
EPOS: Gap 8.95314



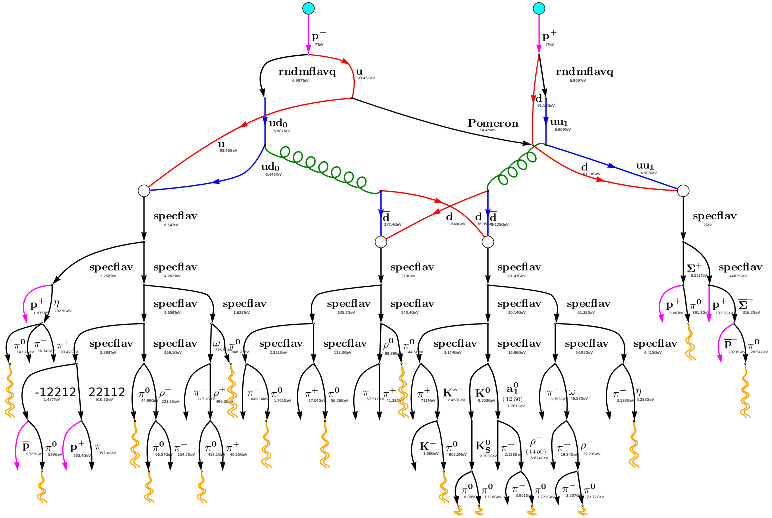
EPOS: Gap 3.00979



H++: Gap 5.15123

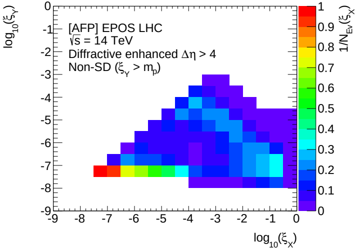

p+
7TeV
rndmflavq
6.921TeV
6.92TeV
u
d
79.52GeV
ud0
6.921TeV
uu1
6.92TeV
Pomeron
61.82meV
d
79.53GeV
ud0
6.229TeV
specflav
7TeV
specflav
83.84GeV
specflav
153.4GeV
specflav
6.763TeV
specflav
236.6GeV
specflav
17.89GeV
specflav
65.95GeV
specflav
137GeV
specflav
16.35GeV
specflav
3.651TeV
specflav
3.113TeV
specflav
7.924GeV
specflav
9.967GeV
100223
5.806GeV
specflav
782.5GeV
specflav
2.33TeV
30223
1.415TeV

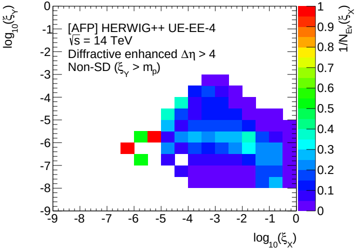
H++: Gap 6.40241



Forward resonances with H++ and EPOS

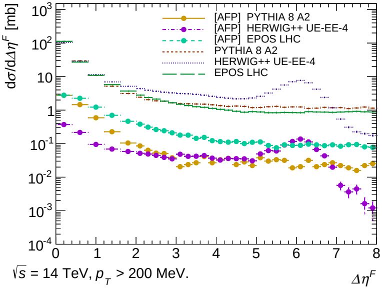
- EPOS agrees with Pythia for $\xi_X < 10^{-4}$, however - ξ_X and ξ_Y are correlated for large systems.
- This could be driven in part by picking up gap fluctuations in non-diffractive events.
- No clear pattern visible in H++, looks similar to higer ξ_X EPOS, no explicit diffractive component visible.

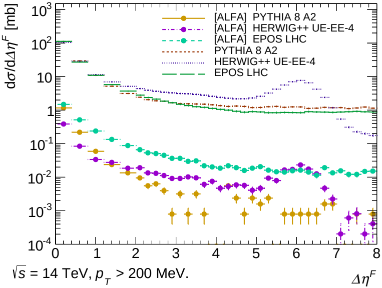




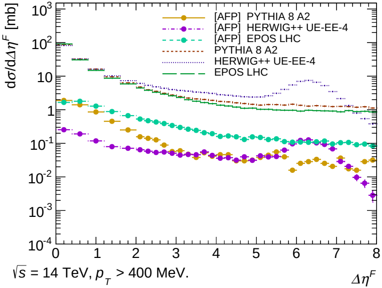
Forward Diffractive Gaps PY8/H++/EPOS

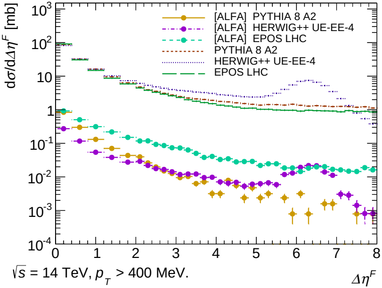
- The HERWIG++ bump is known, due to clustering of beam remnants.
- All models continue to predict the existence of a flat tail with p-tag.
- Significant variation of the expected magnitude of this tail.





Forward Diffractive Gaps PY8/H++/EPOS

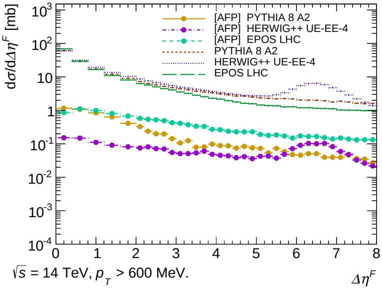


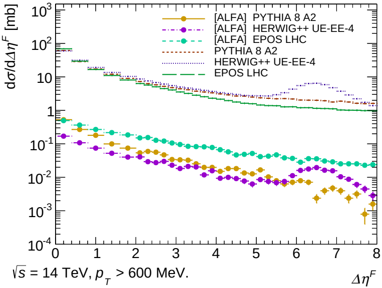


$p_T > 400$ MeV

- Increasing the threshold p_T cut defining the gap tends to enlarge gaps. Allows more SD at larger gap sizes.
- **Proton tag enlarges the discrimination possible between hadronisation models.**

Forward Diffractive Gaps PY8/H++/EPOS

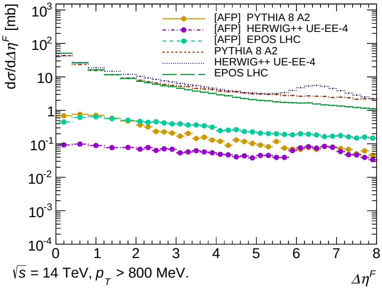


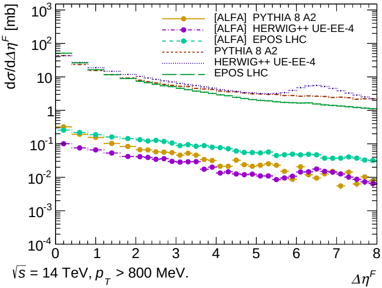


$p_T > 600$ MeV

- Increasing the threshold p_T cut defining the gap tends to enlarge gaps. Allows more SD at larger gap sizes.
- **Proton tag enlarges the discrimination possible between hadronisation models.**

Forward Diffractive Gaps PY8/H++/EPOS

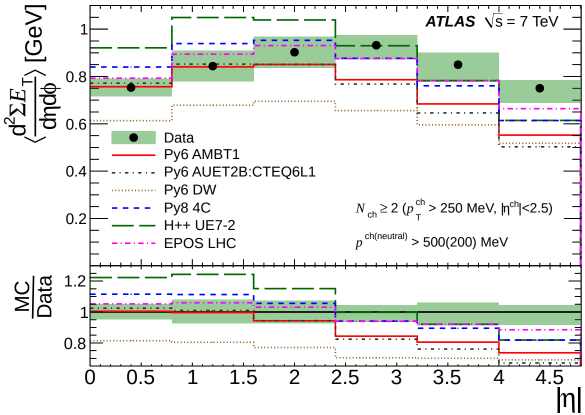




$p_T > 800$ MeV

- Increasing the threshold p_T cut defining the gap tends to enlarge gaps. Allows more SD at larger gap sizes.
- **Proton tag enlarges the discrimination possible between hadronisation models.**

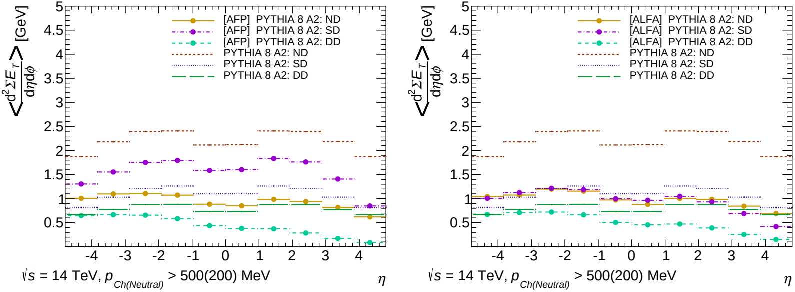
Energy Flow



ATLAS √s = 7 TeV
⟨d²ΣE_T/dηdφ⟩ [GeV]
MC/Data
Data
Py6 AMBT1
Py6 AUET2B:CTEQ6L1
Py6 DW
Py8 4C
H++ UE7-2
EPOS LHC
N_ch ≥ 2 (p_T^ch > 250 MeV, |η^ch|<2.5)
p^ch(neutral) > 500(200) MeV
|η|

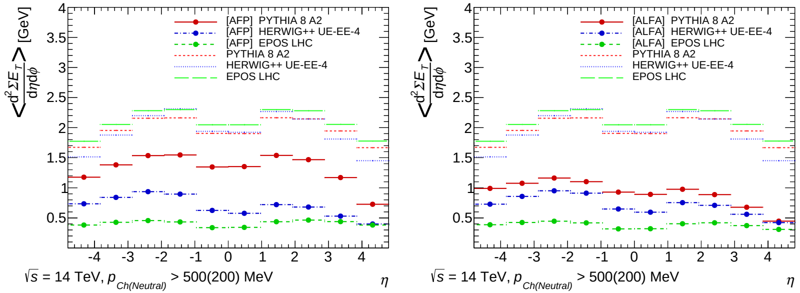
Energy Flow ND/SD/DD

- Charged and neutral energy flow for $p_{\text{ch(neutral)}} > 500(200)$ MeV in events $N_{\text{Ch}} \geq 2(p_{\text{T}} > 250 \text{ MeV}, |\eta| < 2.5)$. Proton tag at $+$ve z.
- PYTHIA asymmetry in energy flow greatest % change in double-dissociation.
- Only magnitude of single dissociative component strongly affected by acceptance of AFP vs. ALFA.



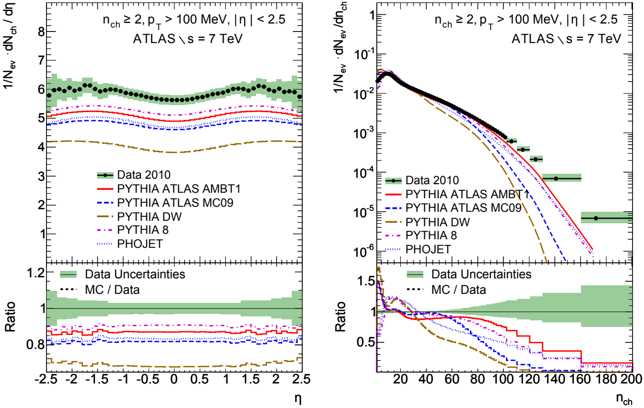
Energy Flow PY8/H++/EPSO

- Forward tag greatly enhances spread of model predictions.
- `EPOS` plus proton tag does not predict a notable asymmetry between the tag (+ve) and away (-ve) sides. The others do, notably `PYTHIA 8`.
- `PYTHIA 8` exhibits a much greater sensitivity to the differences in acceptance between AFP and ALFA.



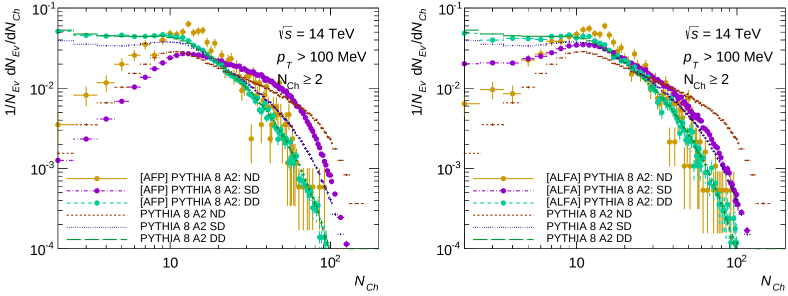
New J. Phys. 13 (2011) 053033

Charged Particle Spectra



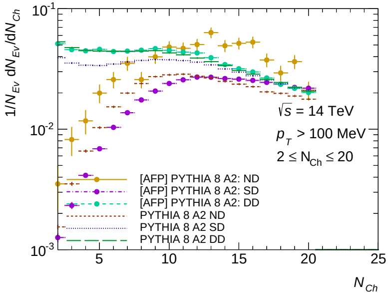
Charged Particle: N_{Ch} ND/SD/DD

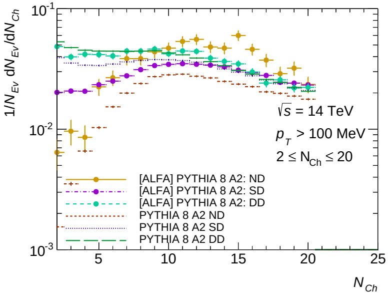
- The enhancement of double dissociation in AFP tagged events with PYTHIA 8 is nicely contained at low overall charged particle multiplicity ($|\eta| < 2.5$).
- Also seen in AFLA, but to a lesser extent as more single diffraction is accessible.



Charged Particle: N_{Ch} ND/SD/DD

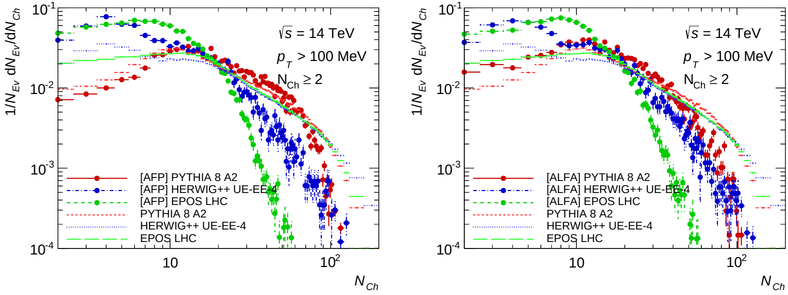
- On some following slides an explicit upper cut of 20 charged particles will be applied to observe the effects of this enrichment.





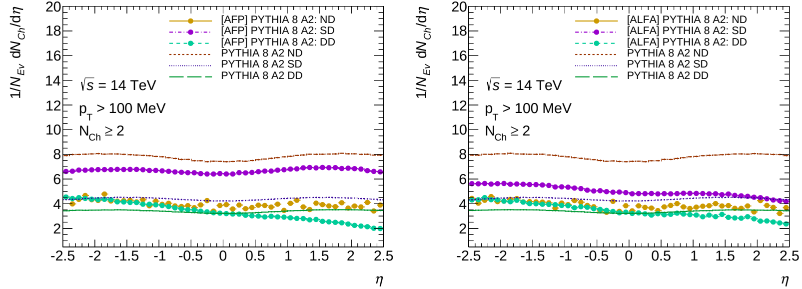
Charged Particle: N_{Ch} PY8/H++/EPOS

- When comparing between the generators, only `PYTHIA 8` is observed to have (overall) reduced activity at low N_{Ch} with a proton tag. `HERWIG++` and `EPOS` are both observed to rise.
- Similar stories for AFP and ALFA for this variable.



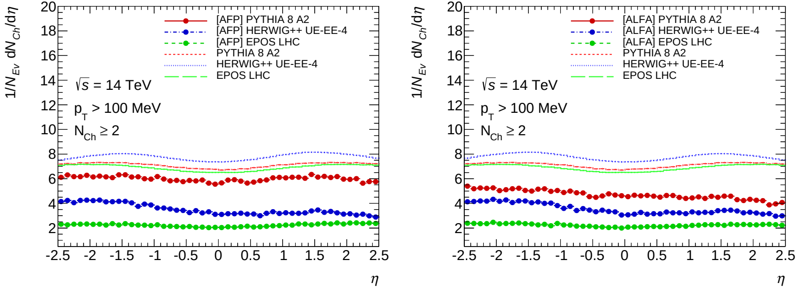
Charged Particle: η ND/SD/DD

- As seen before, asymmetry in particle flow for `PYTHIA 8` with AFP tag driven by double diffractive component.
- For ALFA tag, the single diffracive plays a role too.



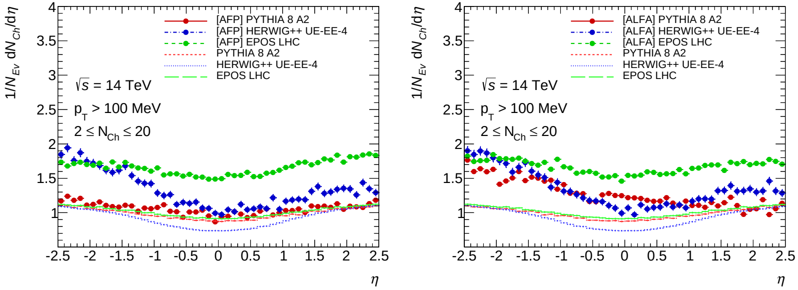
Charged Particle: η PY8/H++/EPOS

- Good degree of model separation observed when comparing the generators.
- Like with the energy flow, EPOS shows no sign of any asymmetry in flow.



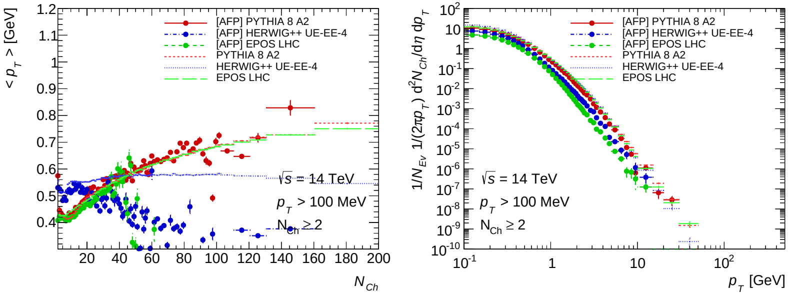
Charged Particle: η PY8/H++/EPOS

- By applying the upper multiplicity cut, these differences are nicely enhanced.
- AFP and ALFA show good promise for model discrimination here.
- HERWIG++ has the largest asymmetry in this phase space.



Charged Particle: p_T PY8/H++/EPOS

- p_T based variables displayed less sensitivity to an explicit upper cut on charged particle multiplicity.
- The long, steeply falling tail of the inclusive charged particle p_T distribution could prove useful too in modelling these interactions.



Conclusion

Good descriptions of minimum bias pp interactions at $\sqrt{s} = 13$ or 14 TeV yields higher precision physics at the LHC through better modelling of the increasingly fierce pileup conditions.

Use of the forward detectors will allow for the soft diffractive component of the cross section to be enhanced in interesting phase spaces, yielding a greater handle on the physics of the $p - IP$ interaction.

ALFA is shown to select events of all ξ though at larger $|t|$, AFP selects events only at larger ξ but may also be sensitive to low mass diffractive systems through forward baryonic excitation and subsequent decay to a proton within AFP acceptance.