ALFA and AFP influence on diffractive dijet measurements

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LHC WG on Forward Physics and Diffraction

Introduction

- **The goal**

  Measurement of the hard scale diffraction in the ATLAS at $\sqrt{s}$ = 14 TeV

- **Means**

  Using calorimeters for forward rapidity gap definition and relative momentum transfer of the diffractive proton calculation

- **How the AFP & ALFA can help?**

  Tagging of the scattered protons to clean-up the single diffractive signal

- **Purpose of this Monte Carlo study?**

  To estimate the AFP's & ALFA's influence on gap and ξ spectra for different optics and beam-distance scenarios

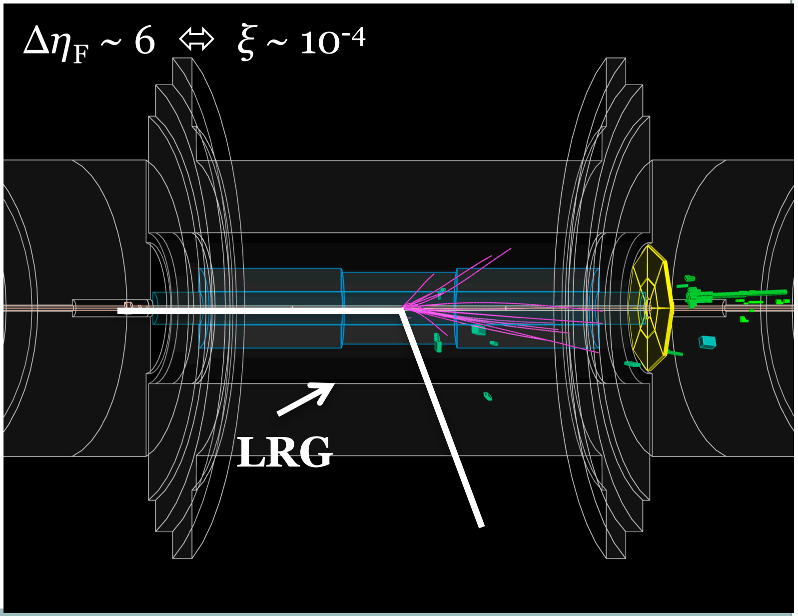
  &

  Take advantage of the acquired knowledge of the ATLAS sensitivity to diffraction

  (hard diffraction measurement in final stage)

Rapidity gaps in the ATLAS experiment

- **<u>Large Rapidity Gap (LRG)</u>** … **$\Delta\eta$ ~ -log ξ_X** … smaller ξ_X (M_X) => bigger gap
  Region in η devoid of hadronic activity due to the exchange of colorless object (Pomeron)
- **Detector-level LRG definition … $\Delta\eta^F$**
  Biggest region in η (starting at the edge of the detector η=±4.9) absent of clusters and tracks complying selection:
  - no tracks with p_T>200MeV
  - no clusters; noise suppression …
    - most significant cell in the cluster: $E_{cell}/\sigma_{noise} > S_{threshold}$
- Non-pileup environment necessary - could fill the gap
  - events from early runs of 2010 (A-B)
  - later periods with correction for pile-up effects



Event selection criteria & definitions

- Basic kinematic cuts
  - at least **2 jets** per event
  - $\boldsymbol{p_T^{jets} > 20}$ **GeV,** $\boldsymbol{k_T = 0.6}$
  - $\boldsymbol{|\eta^{jets}| < 4.4}$
- Forward rapidity gap definition ($\Delta\eta^F$)
  - ATLAS acceptance: calorimeters … $\boldsymbol{|\eta| < 4.8}$

    particles with $p^{charged\ (neutral)} < 500\ (200)$ MeV <u>not visible</u> in calorimeters
  - therefore: $\Delta\eta^F$ = η-region starting either at η=-4.8 or η=+4.8 with no particles with …
    - particle-level definition: $\boldsymbol{p_{charged\ (neutral)}^{particle} > 500\ (200)}$ **MeV**
- Relative momentum loss of the scattered proton

$$\xi = (7\ \text{TeV} - p_Z^{proton})\ /\ 7\ \text{TeV} \quad \text{-> (approximation)} \quad \boldsymbol{\xi^{\pm} = \Sigma_i(E_i \pm p_{Z,\,i})\sqrt{s}}$$

  - in ATLAS' calorimeters: summing over all clusters within $|\eta| < 4.8$ (noise symmetric around 0 => summing cancels it)
  - on a generator level: summing over all particles within $|\eta| < 4.8$

Monte Carlos and AFP & ALFA set-ups

CMS energy: 14 TeV

Monte Carlo samples:

Pythia 8 AU2 CT10 tune: ND, SD, DD

Pomwig 2.0 H1 2006 Fit B: SD

(many thanks to Hardeep Bansil for Pomwig generation)

The default AFP & ALFA set-up:

$\beta^* = 0.55$ m	…	AFP:	$d = 2$ mm	$\sim 11.1\ \sigma$
$\beta^* = 90$ m	…	AFP:	$d = 3$ mm	$\sim 5.2\ \sigma$
	…	ALFA:	$d = 4.5$ mm	$\sim 5.1\ \sigma$

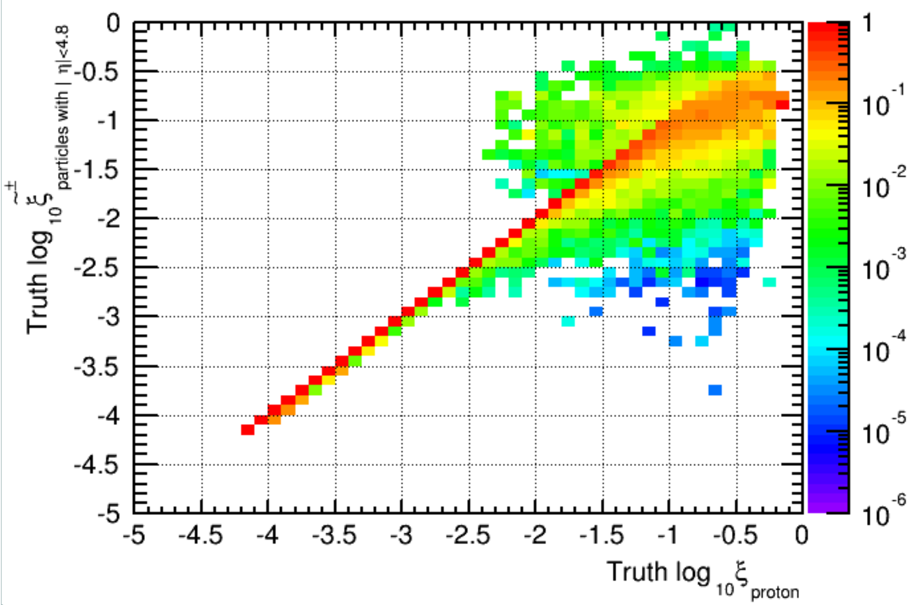
Alternative (more conservative) set-up:

$\beta^* = 0.55$ m	…	AFP:	$d = 2.5$ mm	$\sim 13.9\ \sigma$

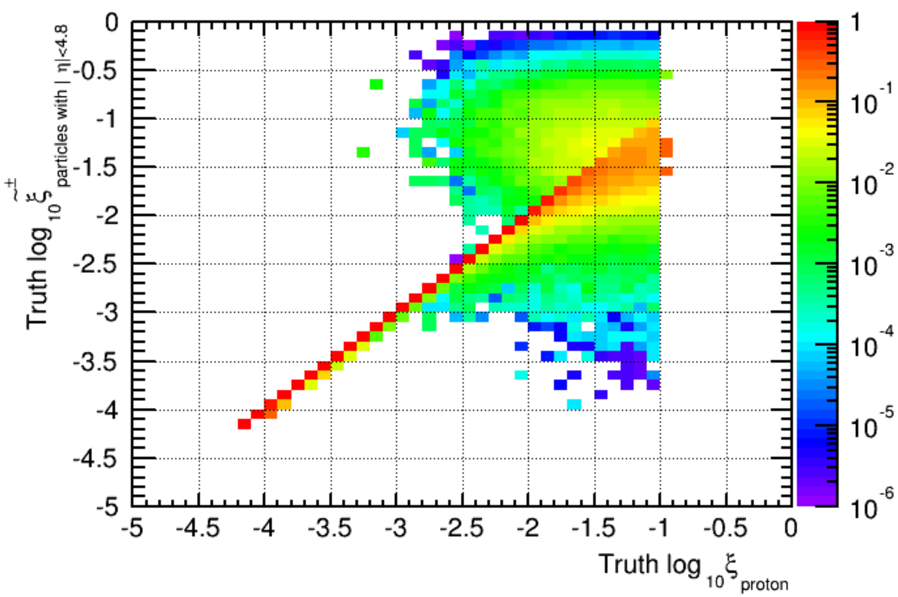
(many thanks to Maciej Trzebinski for providing acceptance maps)

xi: E+-pz method validation

Pythia 8 SD



Pomwig SD



Validation of $\xi^{\pm}$ calculation with respect to ξ^{proton}

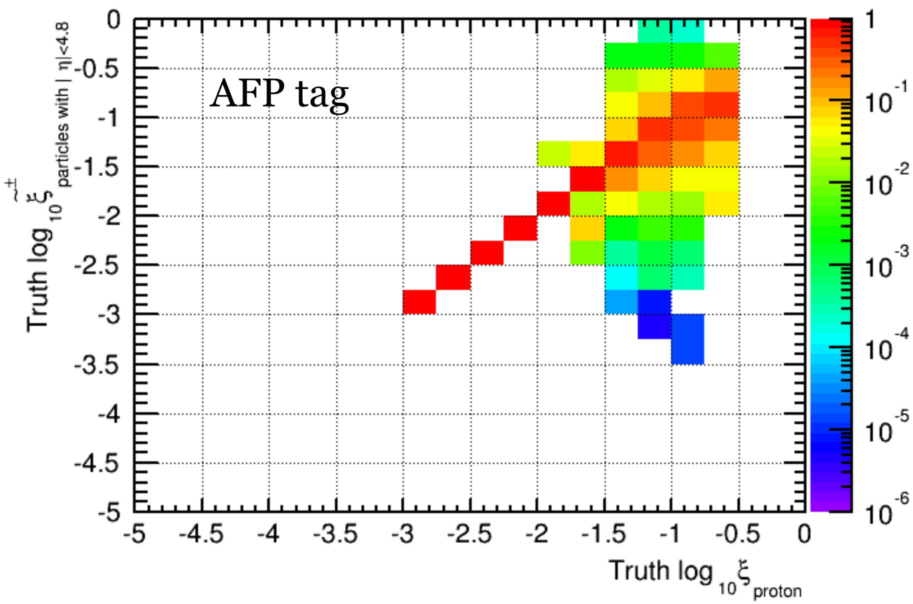
$\xi^{\pm}$ method reliability:

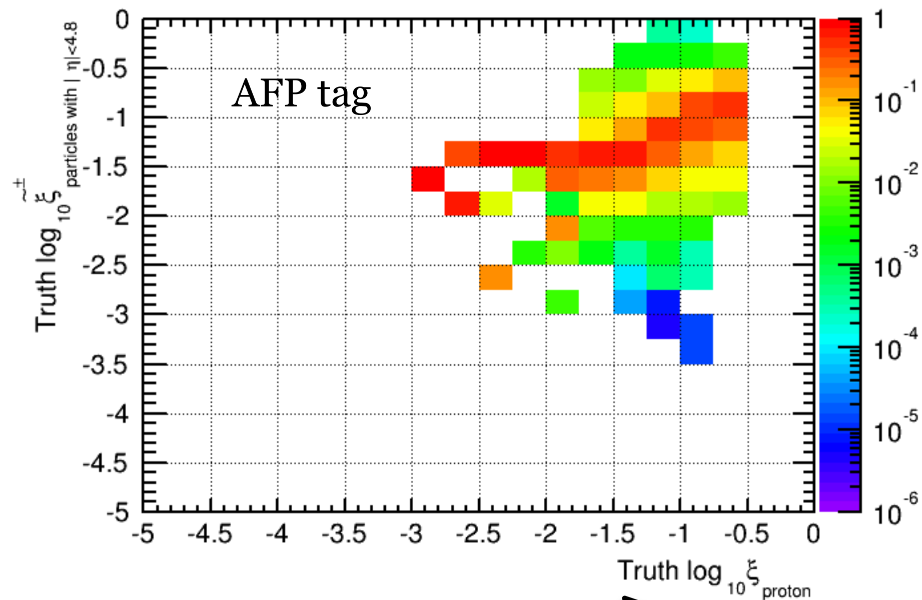
Pythia 8: $\xi^{\text{proton}} < 0.1$

Pomwig: $\xi^{\text{proton}} < 0.03$

Influence of ξ resolution in AFP

Pythia 8 SD





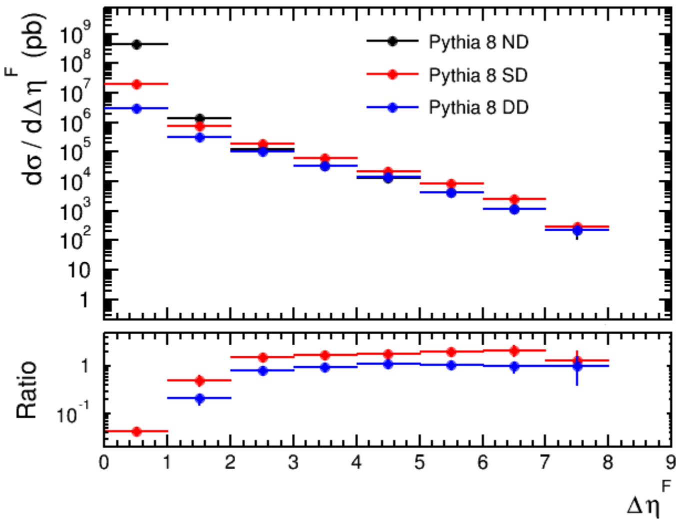
Proton's ξ smeared

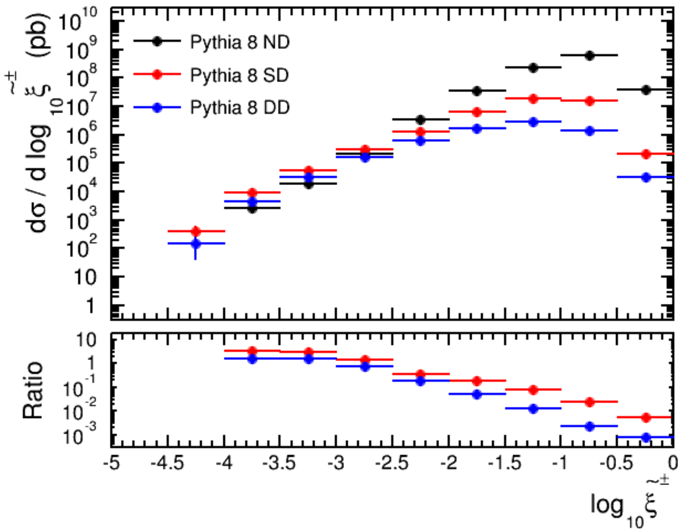
The effect of the AFP's ξ-resolution.

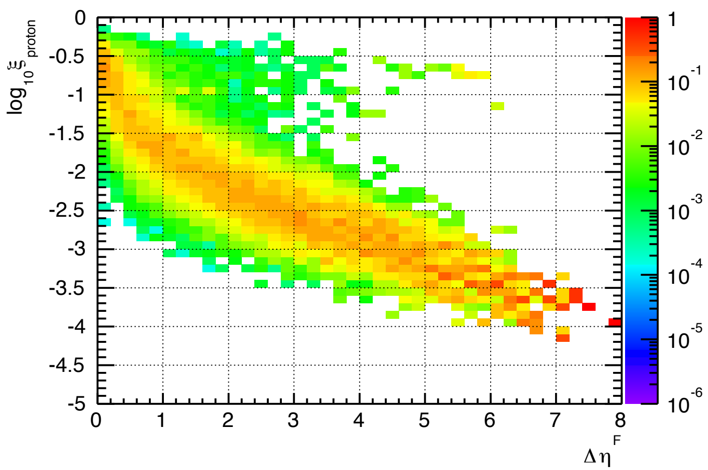
-> as expected (energy resol. ~5 GeV, biggest effect expected for small ξ)

Distributions without tagging

ND vs. SD vs. DD





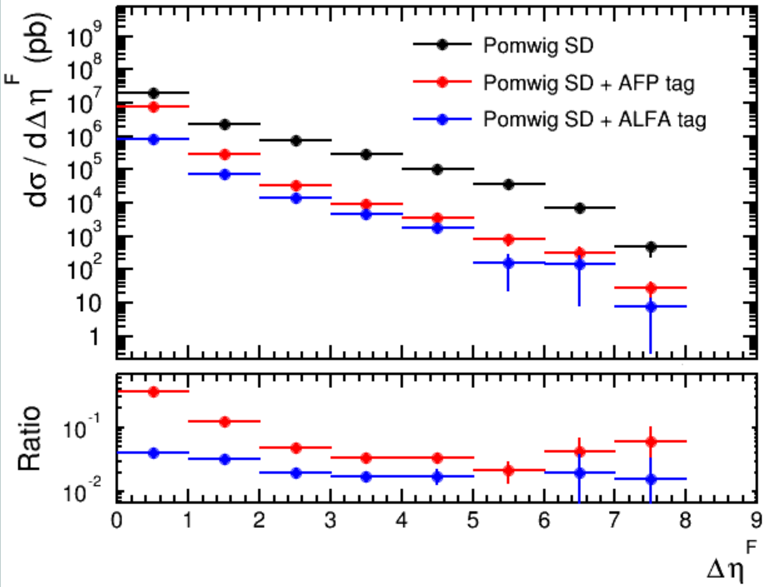


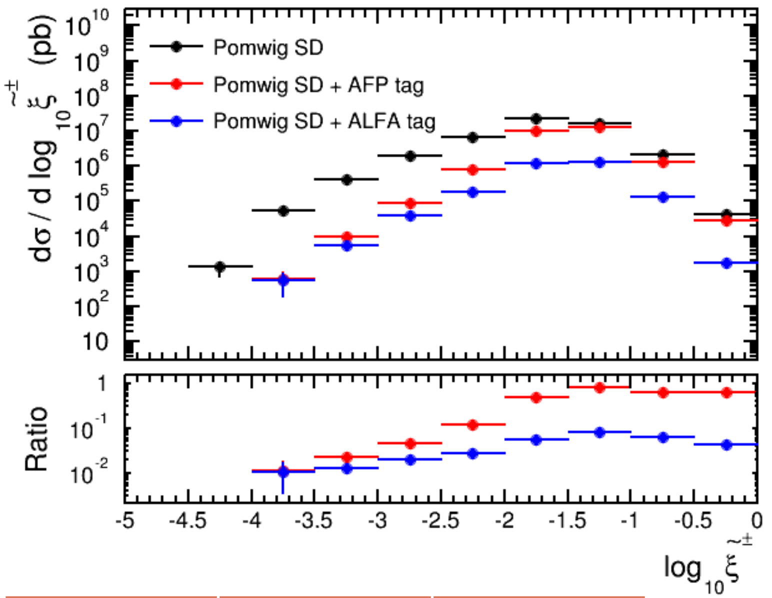
No surprises:

- small $\Delta\eta^{F}$ & large ξ -> dominated by ND
- large $\Delta\eta^{F}$ & small ξ -> SD dominant (ND≈DD)
- $\Delta\eta^{F} \sim -\log\xi$
  $\Delta\eta^{F} = 3 \Leftrightarrow \xi = 0.001 - 0.01$

Pomwig SD + proton tagging

$\beta^* = 90$ m: AFP $d = 3$ mm
ALFA $d = 4.5$ mm





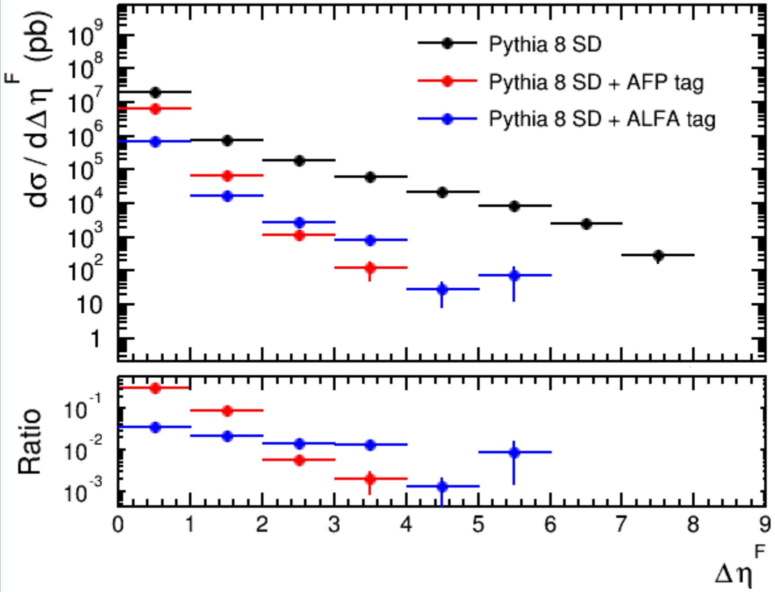
$\Delta\eta^F$	AFP Eff.	ALFA Eff.
1 – 2	12.3 %	3.1 %
2 – 3	4.8 %	2 %
3 – 4	3.3 %	1.7 %
4 – 5	3.4 %	1.7 %

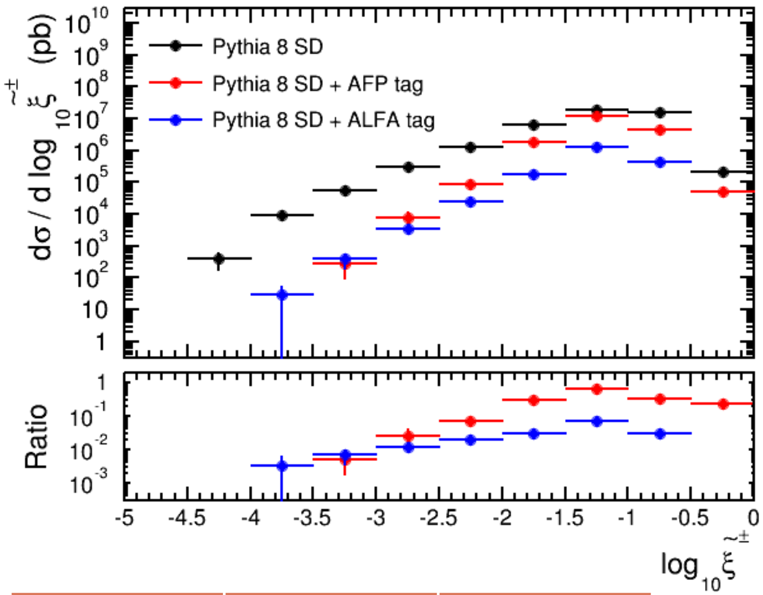
- log ξ	AFP Eff.	ALFA Eff.
3 – 2.5	4.5 %	2 %
2.5 – 2	11.9 %	2.8 %
2 – 1.5	47.5 %	5.5 %
1.5 – 1	81.9 %	7.9 %

AFP -> better high ξ coverage - ALFA ~10x below

Pythia 8 SD: tagging influence

$\beta^* = 90$ m: AFP $d = 3$ mm
ALFA $d = 4.5$ mm





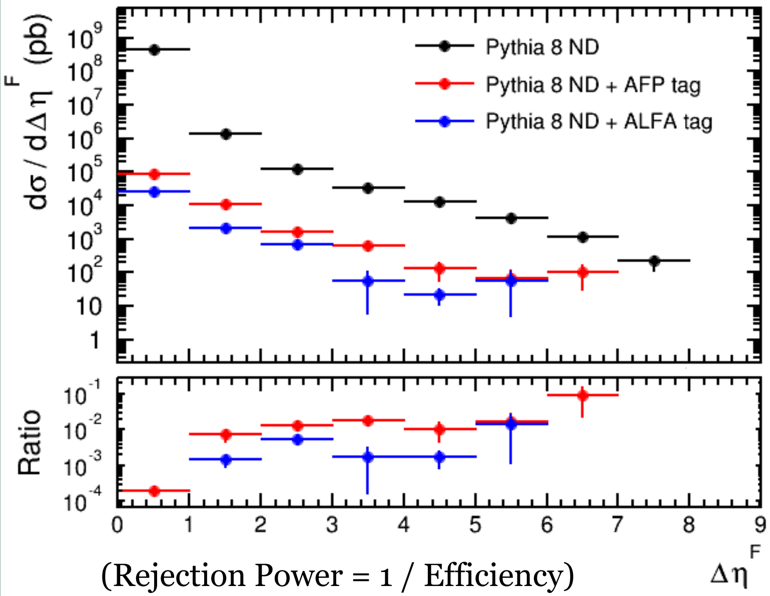
$\Delta\eta^F$	AFP Eff.	ALFA Eff.
1 – 2	8.9 %	2.2 %
2 – 3	0.6 %	1.4 %
3 – 4	0.2 %	1.3 %
4 – 5	0 %	0.1 %

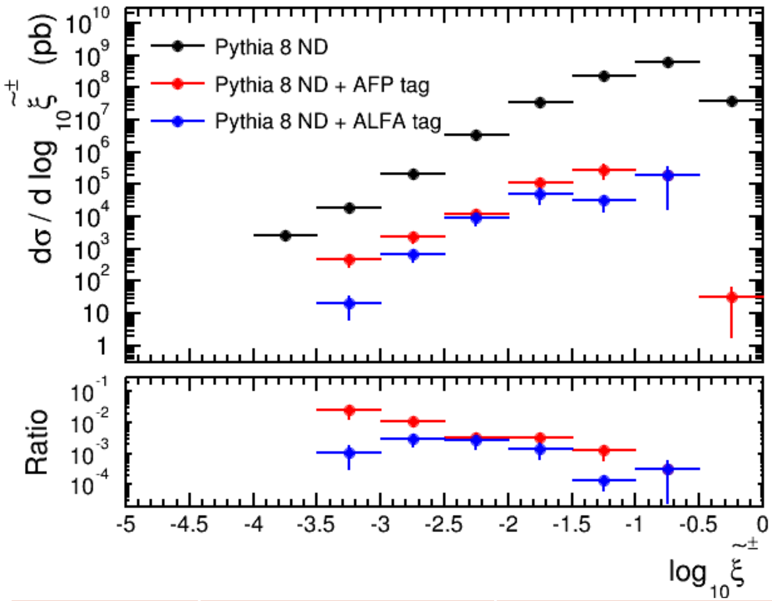
- log ξ	AFP Eff.	ALFA Eff.
3 – 2.5	2.5 %	1.1 %
2.5 – 2	7 %	2 %
2 – 1.5	29.3 %	2.9 %
1.5 – 1	64.6 %	6.7 %

AFP -> better high ξ coverage - ALFA ~10x below

Pythia 8 ND: tagging influence

$\beta^* = 90$ m: AFP $d = 3$ mm
ALFA $d = 4.5$ mm





(Rejection Power = 1 / Efficiency)

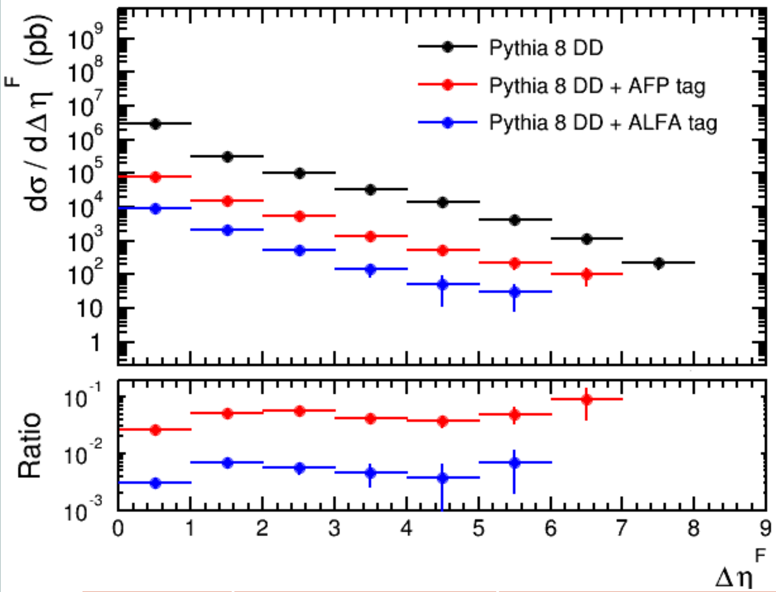
$\Delta\eta^F$	AFP Reject. Power	ALFA Reject. Power
1 – 2	134	656
2 – 3	73	185
3 – 4	54	585
4 – 5	95	577

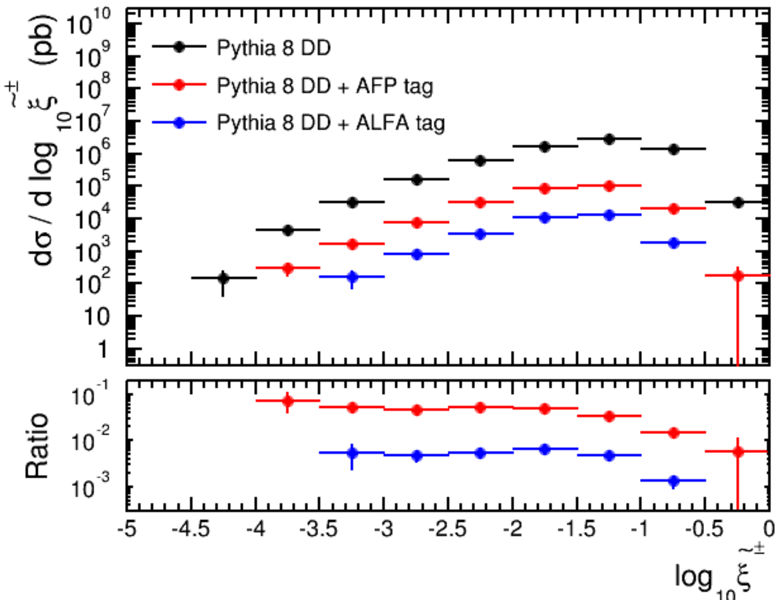
- log ξ	AFP Reject. Power	ALFA Reject. Power
3 – 2.5	93	330
2.5 – 2	302	378
2 – 1.5	292	673
1.5 – 1	808	7475

=> $\Delta\eta^F$ … ALFA -> better rejection power | => ξ distr. -> significantly better rejection

Pythia 8 DD: tagging influence

$\beta^* = 90$ m: AFP $d = 3$ mm
ALFA $d = 4.5$ mm





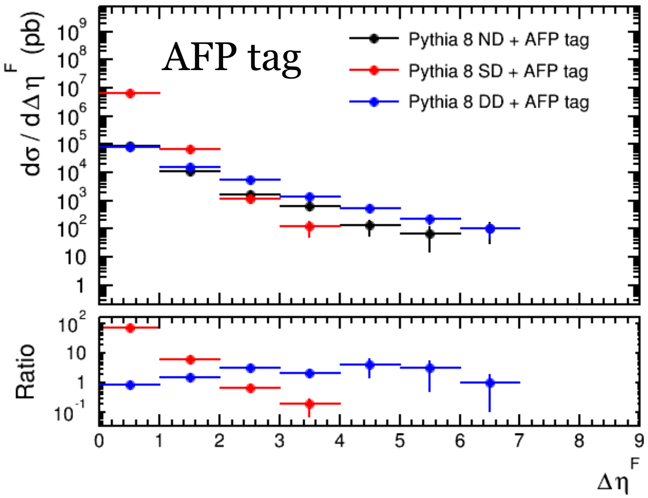
$\Delta\eta^F$	AFP Reject. Power	ALFA Reject. Power
1 – 2	19	14
2 – 3	18	180
3 – 4	24	219
4 – 5	26	266

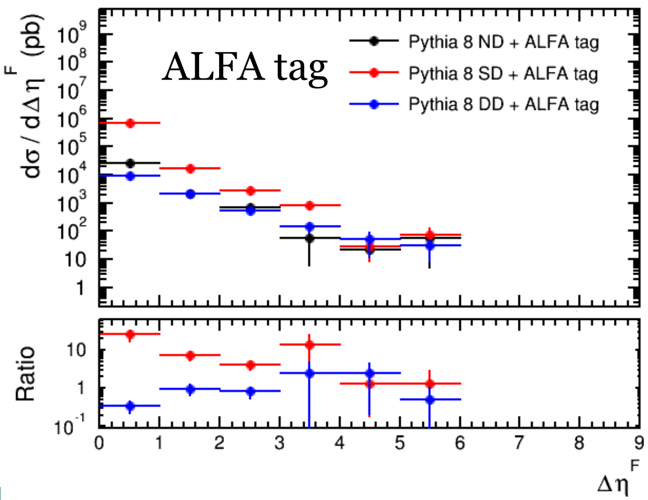
- log ξ	AFP Reject. Power	ALFA Reject. Power
3 – 2.5	22	206
2.5 – 2	19	185
2 – 1.5	20	151
1.5 – 1	29	214

=> $\Delta\eta^F$ & ξ -> comparable rejection powers for double diffractive dissociation

Final yields for $\Delta\eta^F$ distribution

β^* = 90 m: AFP d = 3 mm
ALFA d = 4.5 mm





Pythia 8 SD – signal
Pythia 8 ND & DD – main background

=> tagging effect on extracting signal …

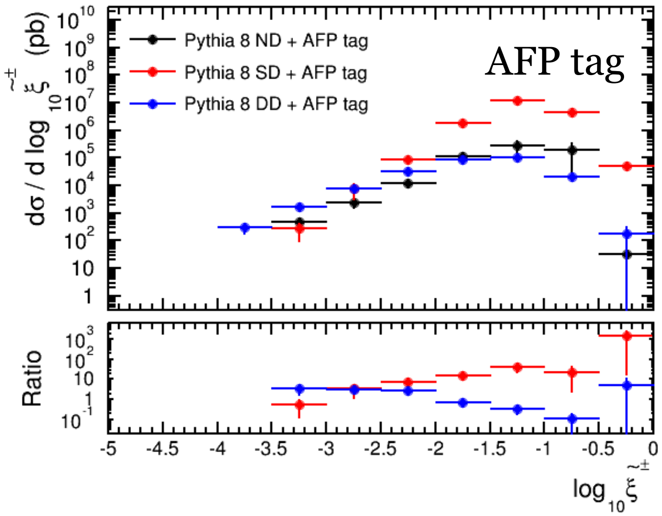
$\Delta\eta^F$	**No tagging: SD / (ND+DD)**	**AFP: SD / (ND+DD)**	**ALFA: SD / (ND+DD)**
1 – 2	0.4	2.5	3.8
2 – 3	0.9	0.2	2.3
3 – 4	0.9	0.06	3.9
4 – 5	0.9	0	0.4

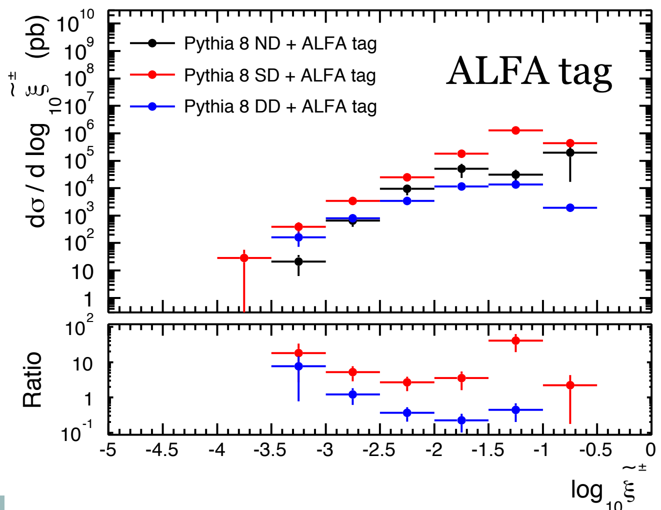
Generally –> unsatisfactory coverage of large gaps by AFP

ALFA -> better signal/bcg. ratios for β^* = 90 m

Final yields for $\xi^{\pm}$ distribution

β^{*} = 90 m: AFP d = 3 mm
ALFA d = 4.5 mm





Pythia 8 SD – signal
Pythia 8 ND & DD – main background

=> tagging effect on extracting signal ...

- log ξ	No tagging: SD / (ND+DD)	AFP: SD / (ND+DD)	ALFA: SD / (ND+DD)
3 – 2.5	0.8	0.8	2.4
2.5 – 2	0.3	2	2
2 – 1.5	0.2	9	3
1.5 – 1	0.1	32	28

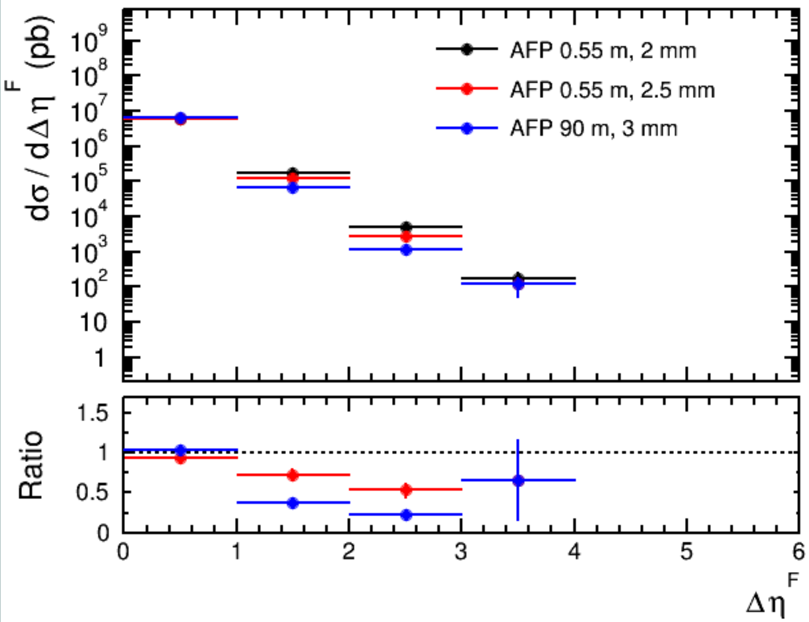
The most promising ξ range: 0.1 – 0.01

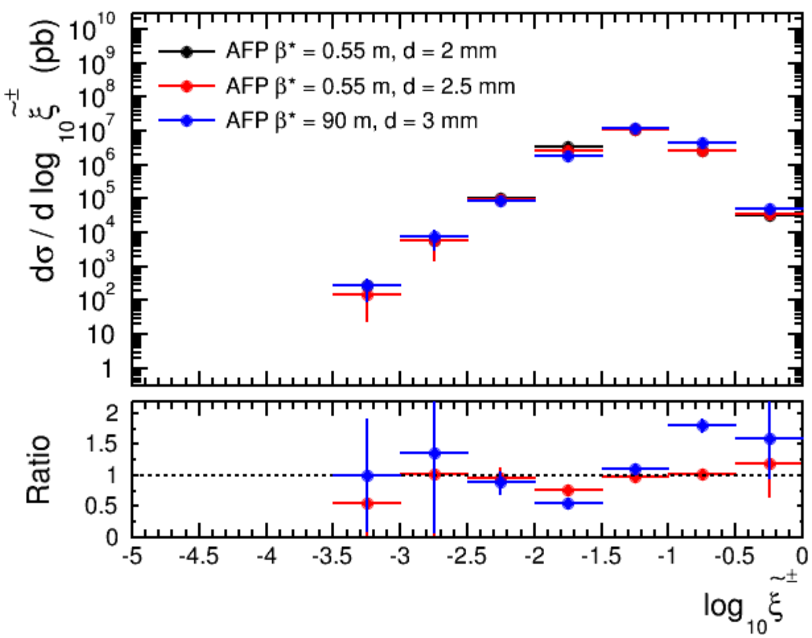
AFP -> gaining us up to 200% of statistics

ξ -> more sensitive to tagging than $\Delta\eta^{F}$

Other AFP installations

Pythia 8 SD





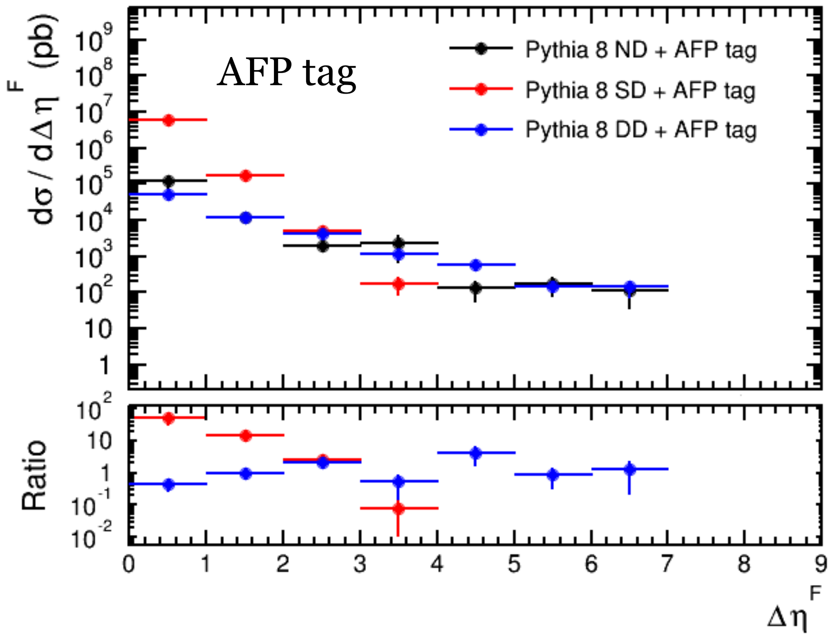
Different optics scenarios:

$\beta^* = 0.55$ m	...	AFP:	$d = 2$ mm $\sim 11.1\ \sigma$
$\beta^* = 0.55$ m	...	AFP:	$d = 2.5$ mm $\sim 13.9\ \sigma$
$\beta^* = 90$ m	...	AFP:	$d = 3$ mm $\sim 5.2\ \sigma$

-> gap distributions very sensitive, ξ generally less influenced

Final yields for $\Delta\eta^F$ distribution

$\beta^* = 0.55$ m: AFP $d = 2$ mm



$\beta^* = 90$ m
$d = 3$ mm ($\sim 5\sigma$)

$\beta^* = 0.55$ m
$d = 2$ mm ($\sim 10\sigma$)

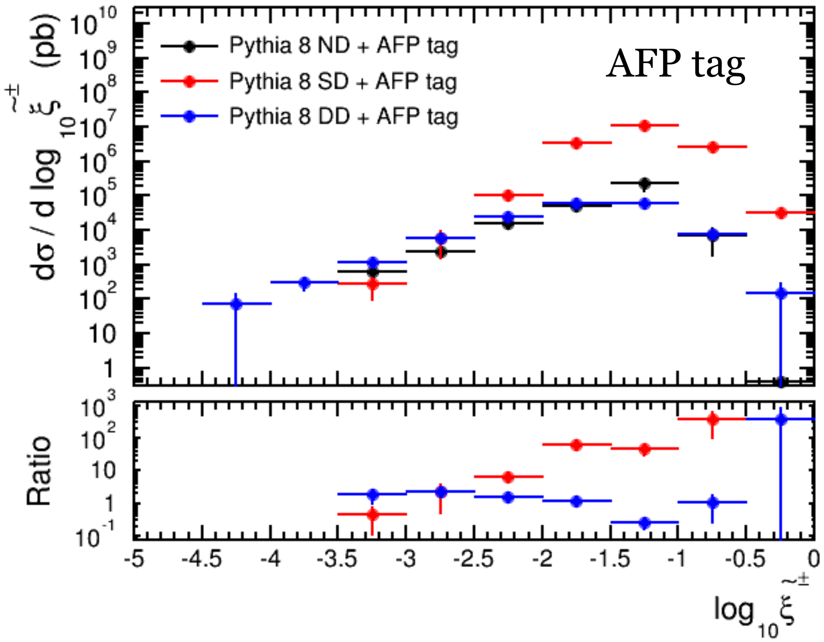
$\Delta\eta^F$	AFP (90m): SD / (ND+DD)	AFP (0.55m): SD / (ND+DD)
1 – 2	2.5	7.7
2 – 3	0.2	0.8
3 – 4	0.06	0.05
4 – 5	0	0

AFP not sensitive for large $\Delta\eta^F$

$\Delta\eta^F < 3$ -> ~3x better performance for β^*=0.55m than 90m

Final yields for $\xi^{\pm}$ distribution

β^{*} = 0.55 m: AFP d = 2 mm



β^{*} = 90 m
d = 3 mm (~5σ)

β^{*} = 0.55 m
d = 2 mm (~10σ)

- log ξ	**AFP (90m): SD / (ND+DD)**	**AFP (0.55m): SD / (ND+DD)**
3 – 2.5	0.8	0.7
2.5 – 2	2.0	2.5
2 – 1.5	9.0	29.4
1.5 – 1	31.6	38.1

=> AFP at β^{*}=0.55m performs **tens of % better** than β^{*}=90m

Conclusions

- Scenarios studied

$\beta^* = 0.55$ m	…	AFP:	$d = 2$ mm ~ 11.1 σ
	…	AFP:	$d = 2.5$ mm ~ 13.9 σ
$\beta^* = 90$ m	…	AFP:	$d = 3$ mm ~ 5.2 σ
	…	ALFA:	$d = 4.5$ mm ~ 5.1 σ

- Efficiency of AFP & ALFA tagging dependent on the distance
  - ξ -> improvement in the order of tens percent
  - $\Delta\eta^F < 3$ -> improvement by ~3x (0.55m vs. 90m)
- ξ variable more stable between generators
  - -> more stable between generators
- AFP -> ~10x better SD event yields for **0.01 < ξ < 0.1** than ALFA
- Similar yields for AFP with $\beta^* = 0.55$ m and $\beta^* = 90$ m