

Exclusive Jet Measurement in Special LHC Runs Feasibility Studies

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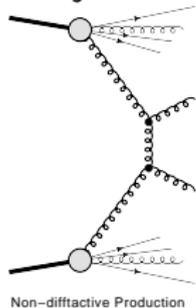


XXII Cracow Epiphany Conference

8th January 2016

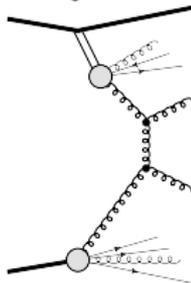
Introduction

non-diffractive jets



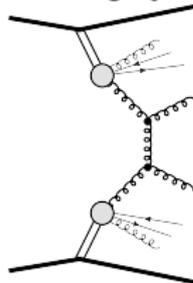
- two jets
- proton remnants

single-diffractive jets



- two jets
- intact proton
- proton and Pomeron remnants

double Pomeron exchange jets



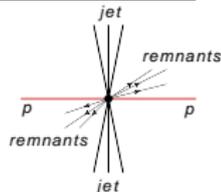
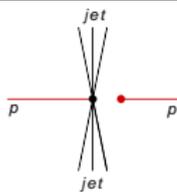
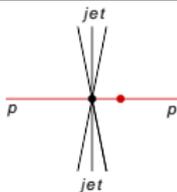
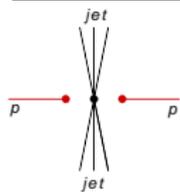
- two jets
- intact protons
- Pomeron remnants

exclusive jets



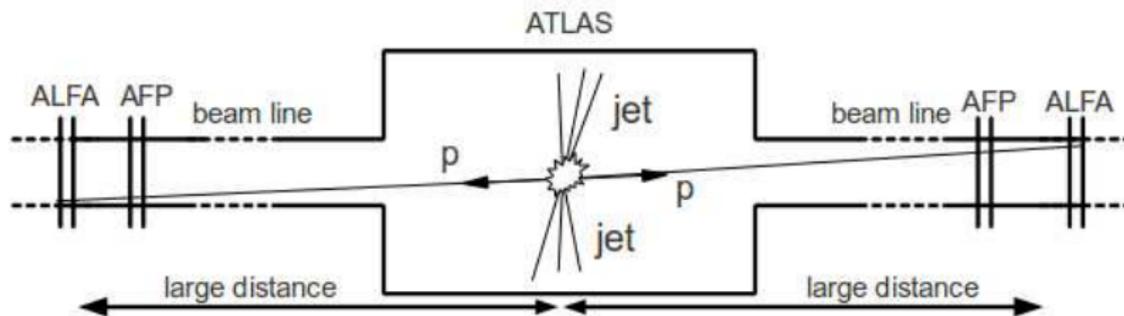
- two jets
- intact protons
- no remnants

Backgrounds



Measurement Idea

Signature: two jets measured in ATLAS and two protons in forward detectors.



ALFA

- 240 m from ATLAS IP
- elastic scattering
- special runs (high β^* optics)
- position detectors
- vertically inserted Roman Pots
- soft events, pile-up background

AFP

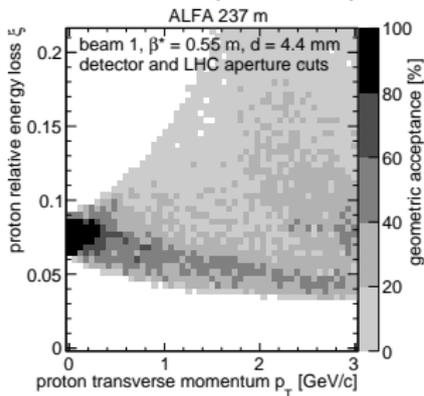
- 210 m from ATLAS IP
- hard diffraction
- nominal runs (collision optics)
- position and timing detectors
- horizontally inserted RP
- proton detector for hard events

Geometric Acceptance

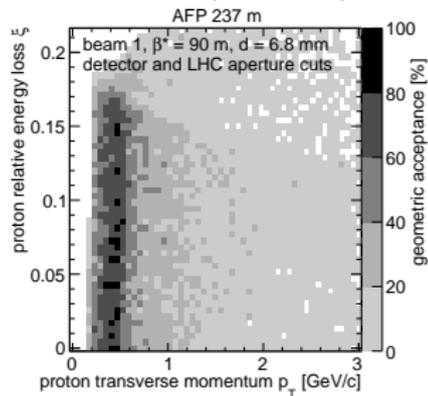
optics

ALFA

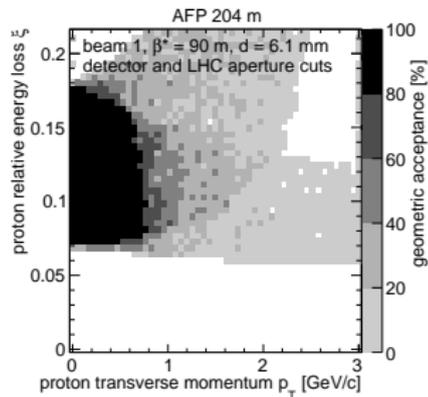
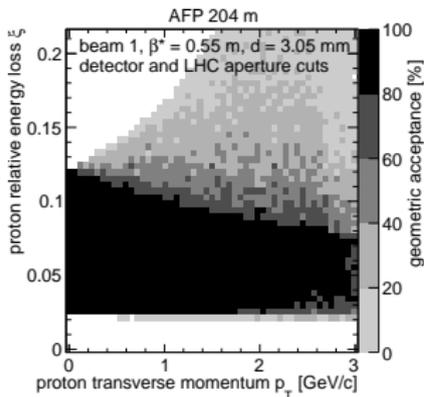
$\beta^* = 0.55$ m
nominal (*collision*)



$\beta^* = 90$ m
special (*high- β^**)



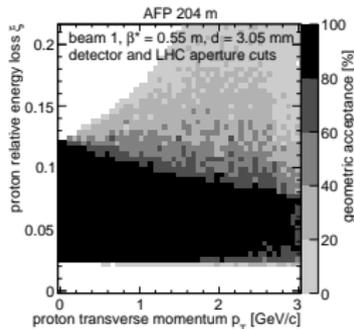
AFP



Double Tag Events

high- p_T jets (> 150 GeV)

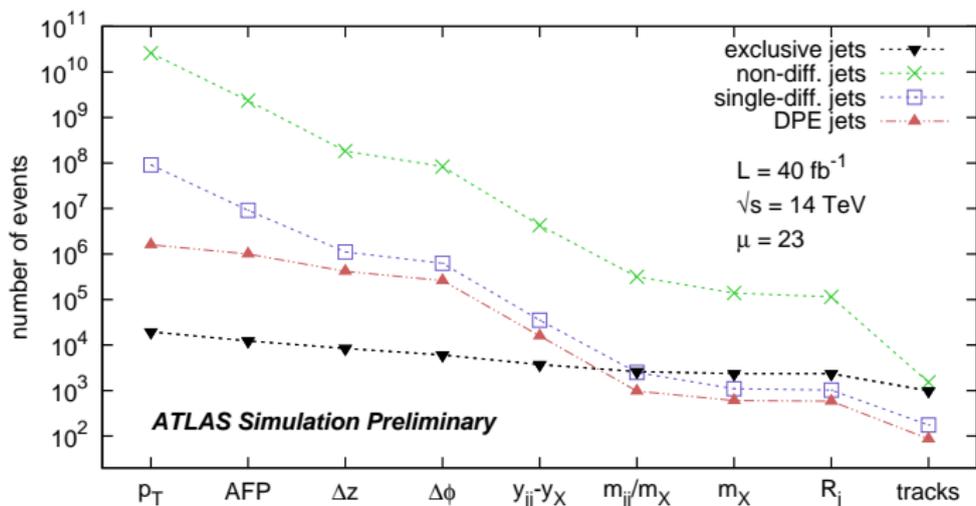
Exclusive Jet Production with Forward Proton Tagging
ATL-PHYS-PUB-2015-003



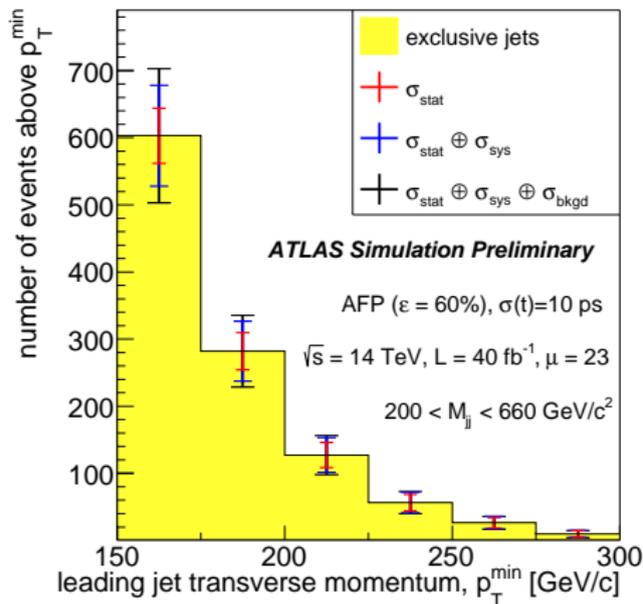
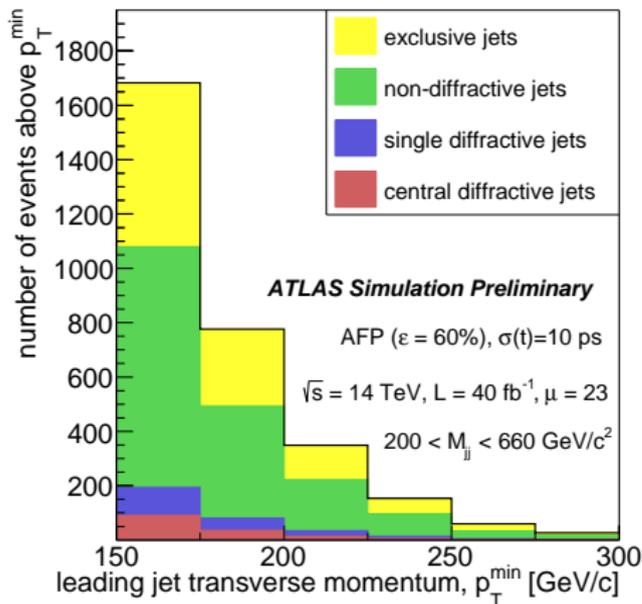
high ξ \rightarrow large mass \rightarrow high jet p_T \rightarrow rare events \rightarrow large luminosity \rightarrow
high pile-up

Signal Selection

- high- p_T jets,
- proton in each AFP station,
- position of vertex from proton ToF in agreement with the hard one (20 ps resolution!),
- proton-jet correlations: rapidity fraction, mass fraction,
- tracks pointing to hard vertex.



Expected Significance ($\mu = 23$)



- very challenging measurement,
- feasible with pileup of about 23 and 40 fb $^{-1}$ of data,
- improvement w.r.t. Tevatron data,
- impossible without AFP detectors.

Single Tag Events

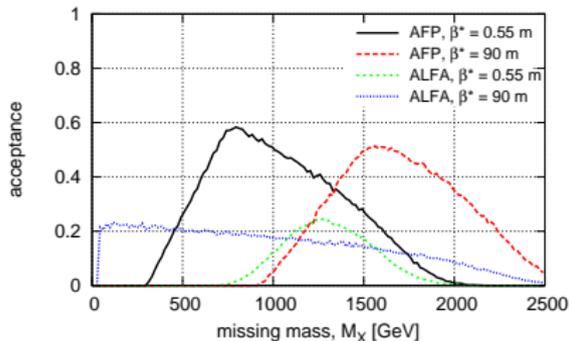
low- p_T jets (> 20 GeV)

*On the Possibility of Measuring the Single-tagged Exclusive Jets at the
LHC*

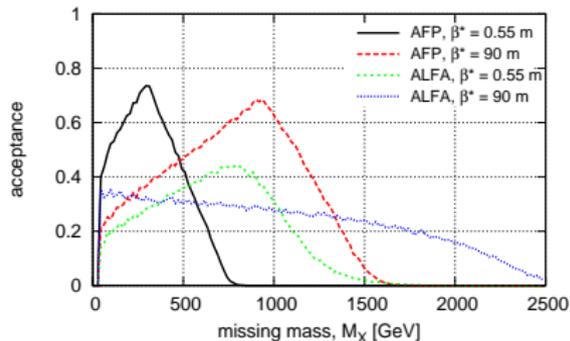
Eur. Phys. J. C **75** (2015) 320, arXiv:1503.00699

Motivation

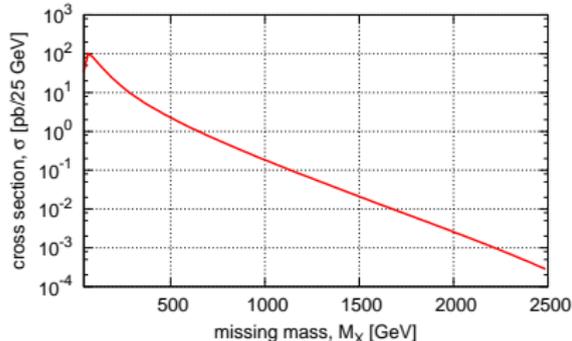
Exclusive jet production - acceptance for double tag events



Exclusive jet production - acceptance for single tag events



Exclusive jet production - cross section



smaller ξ (one proton outside acceptance)

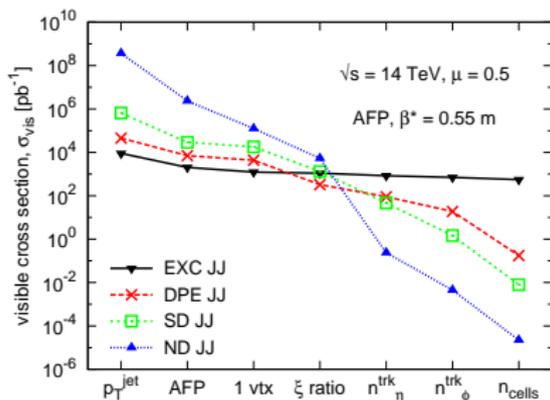
↓
lower central mass

↓
smaller jet p_T

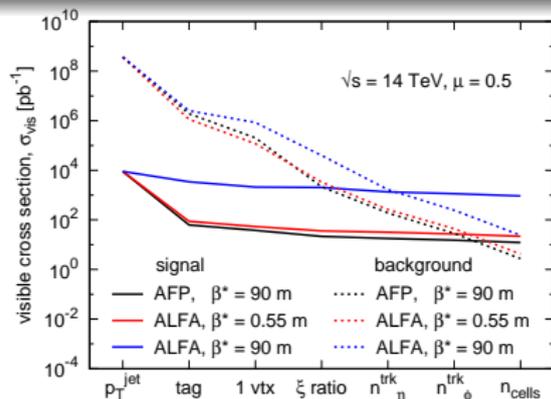
↓
higher cross-sections

↓
smaller luminosity

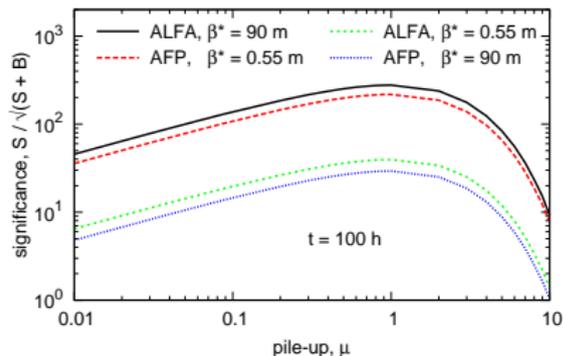
Results



- low- p_T jets,
- proton in forward detector,
- one reconstructed vertex,
- proton-jet correlation: relative energy loss,
- number of tracks outside the jet system,
- amount of energy in forward calorimeters.



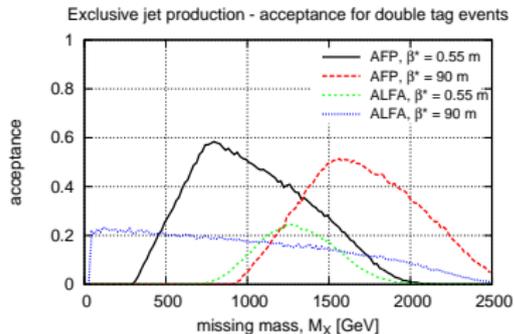
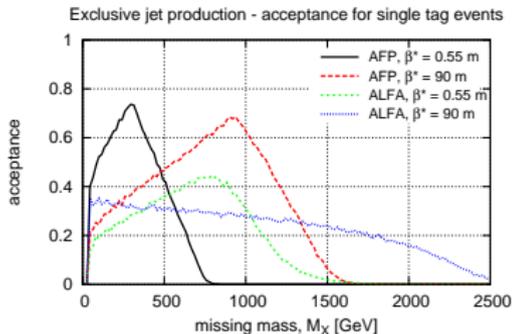
Exclusive jets (single tagged)



Conclusion: pure samples and statistically significant measurements.

Double Tag Events

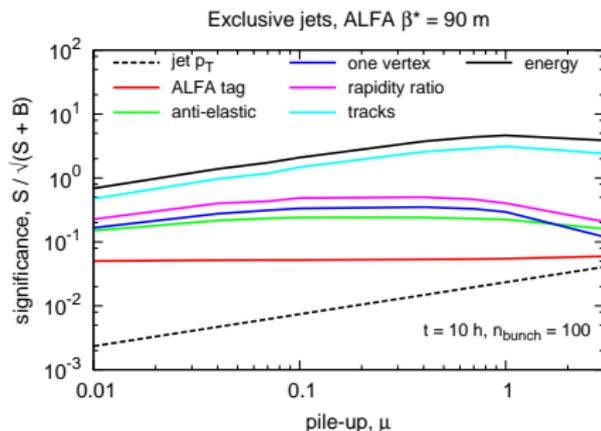
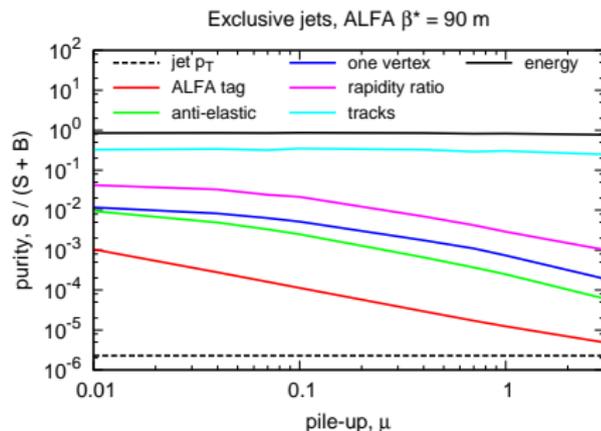
low- p_T jets (> 20 GeV)



Results

- low- p_T jets,
- double tag in ALFA,
- anti-elastic cut,
- one reconstructed vertex,
- proton-jet correlation: relative energy loss,
- number of tracks outside the jet system,
- amount of energy in forward calorimeters.

Pure ($> 90\%$) and statistically significant measurement should be feasible with data collected by ALFA during Run II.



High- p_T jets (double tag)

- Measurement of the exclusive jet production will be possible in the ATLAS detector during normal runs (low beta, high pile-up) using the AFP detectors.
- Very challenging measurement – difference of six orders of magnitude between signal and background cross-sections (impossible to measure without AFP)!
- Results published in: ATL-PHY-PUB-2015-003

Low- p_T jets (single tag)

- Smaller masses \rightarrow larger cross-sections \rightarrow smaller pile-up \rightarrow cleaner events.
- High signal-to-background ratio.
- High statistical significance.
- Results published in: Eur. Phys. J. C **75** (2015) 320.

Low- p_T jets (double tag)

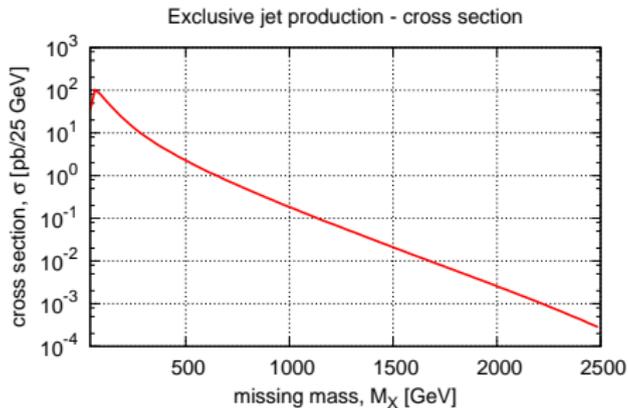
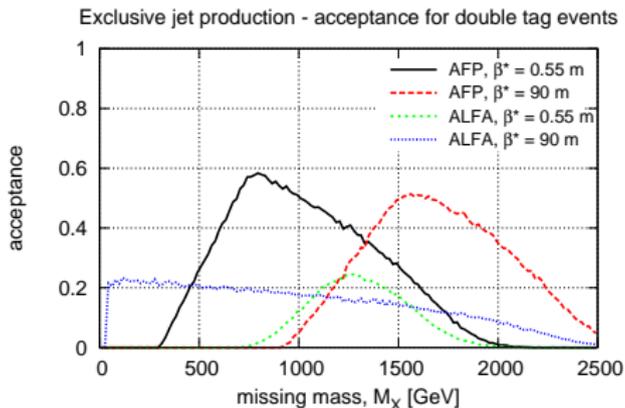
- Pure ($> 90\%$) and statistically significant measurement should be feasible with data collected by ALFA during Run II.

This work was supported by Polish Ministry of Science and Higher Education under the Mobility

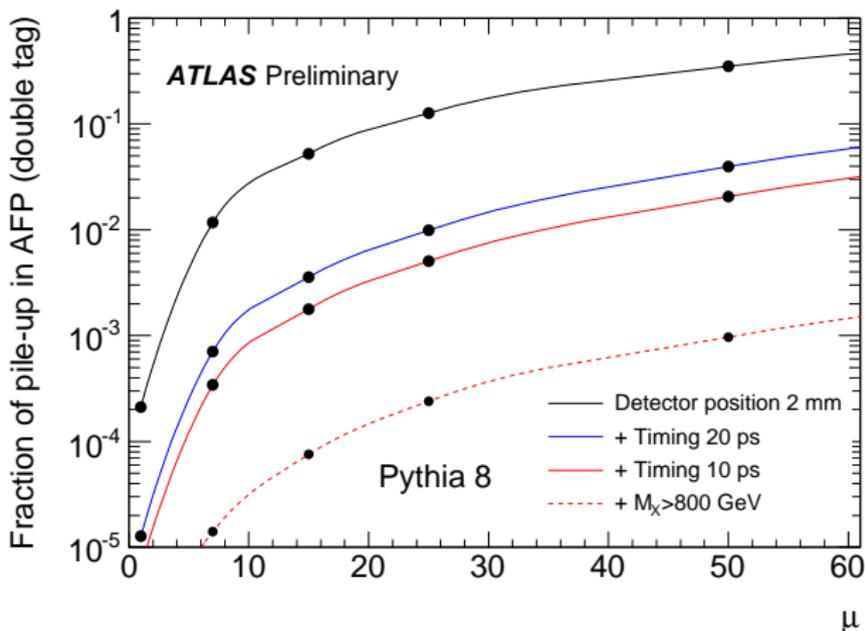
Plus programme (1285/MOB/IV/2015/0).

Backup

Mass Acceptance



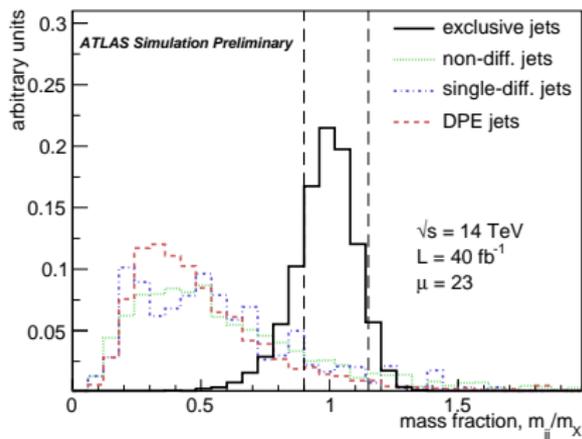
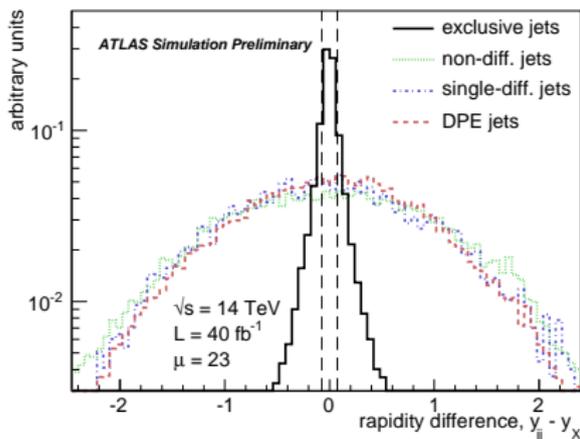
Cuts – AFP Acceptance



Fraction of pile-up events in AFP (double tagged events) as a function of the average number of interactions with a timing resolution of 20, 10 ps, and for a diffractive mass greater than 800 GeV.
Exclusive jet studies for pile-up $\mu = 23$ end $\mu = 46$.

Signal Selection

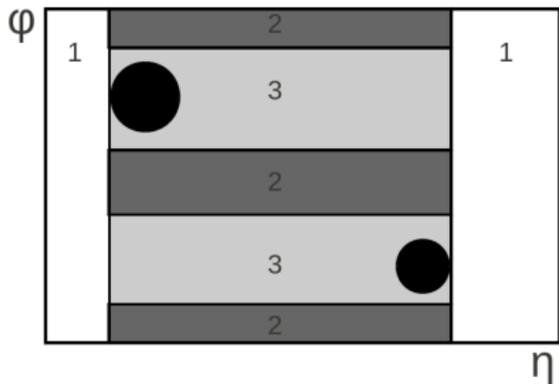
- proton in each AFP station,
- position of vertex from proton ToF in agreement with the hard one,
- rapidity fraction,
- mass fraction



Left: Difference, $y_{jj} - y_X$, of the rapidity of the jet system (y_{jj}) and the rapidity of the proton system $y_X = 0.5 \cdot \ln\left(\frac{\xi_1}{\xi_2}\right)$, where ξ_1 and ξ_2 are relative energy losses of the tagged in the AFP C and A stations.

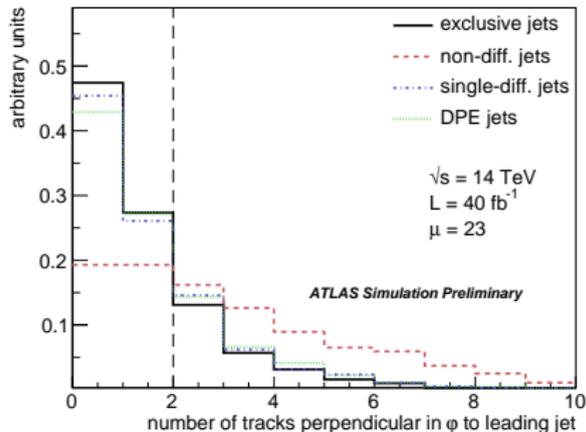
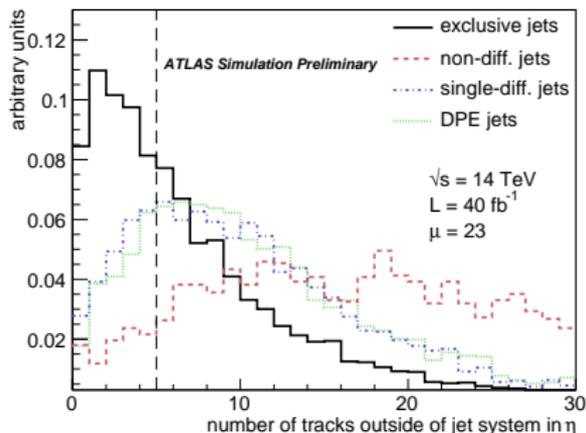
Right: The ratio of the jet system mass to the missing mass $M_X = \sqrt{s \cdot \xi_1 \cdot \xi_2}$.

Signal Selection – Tracks Outside Jets

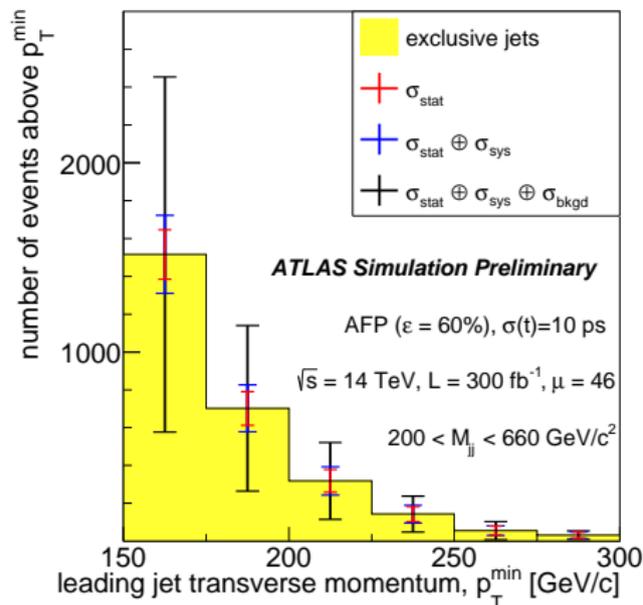
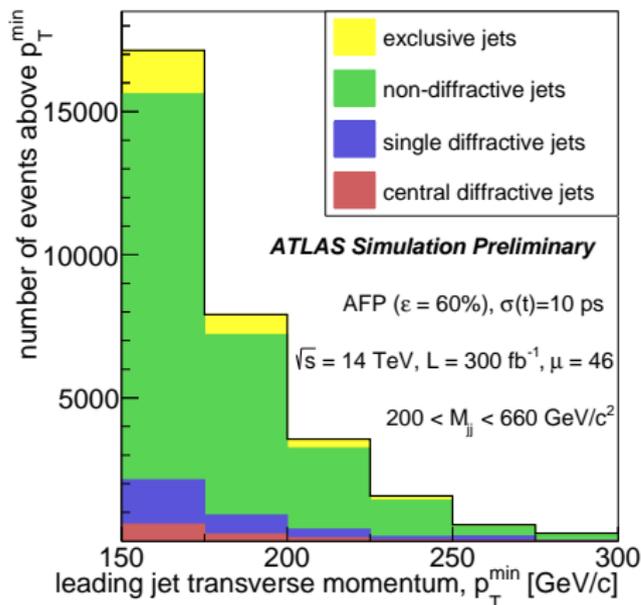


The number of tracks (fitted to the primary vertex) outside the jet system in η (region 1, top) and the number of tracks perpendicular to the leading jet in ϕ (region 2, bottom) for the signal and background events at pile-up $\mu = 23$.

The dashed line represents the value of the applied cut.



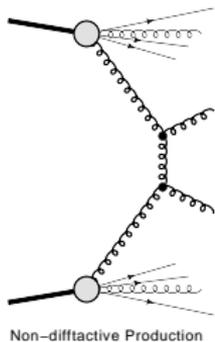
Expected Significance ($\mu = 46$)



Left: The number of accepted events as a function of the leading jet p_T threshold for the integrated luminosity $L = 300$ fb $^{-1}$ and average number of interactions of $\mu = 46$.

Right: the number of signal events, marked as yellow bar, with statistical (σ_{stat}), systematic (σ_{sys}) and background (σ_{bkgd}) uncertainties. The \oplus sign means that given errors are added in quadrature.

Non-diffractive jets + pile-up

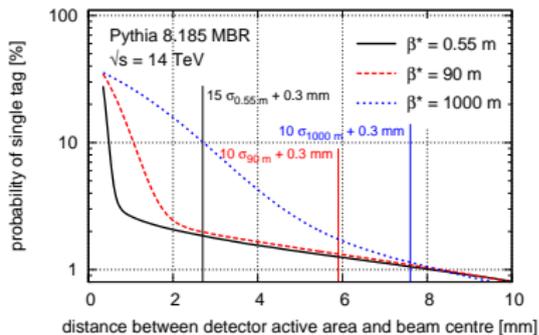


Cuts:

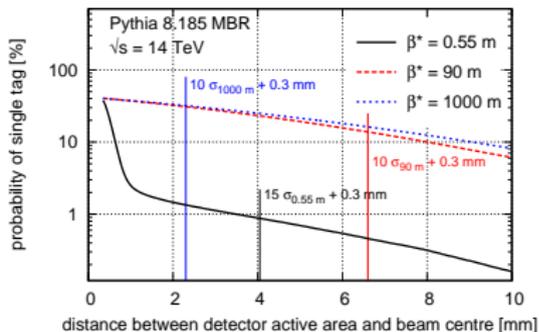
- proton in AFP/ALFA,
- one reconstructed vertex.

Soft single tag probability

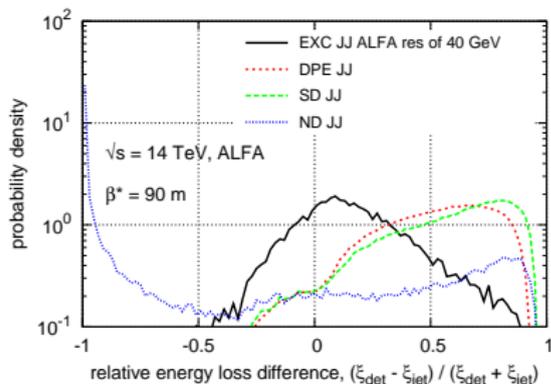
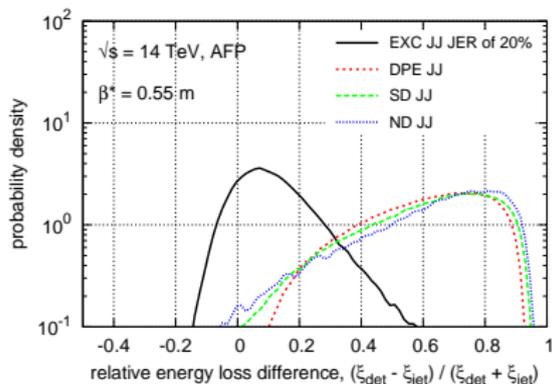
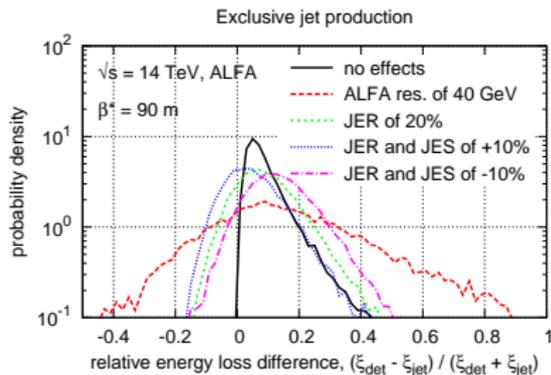
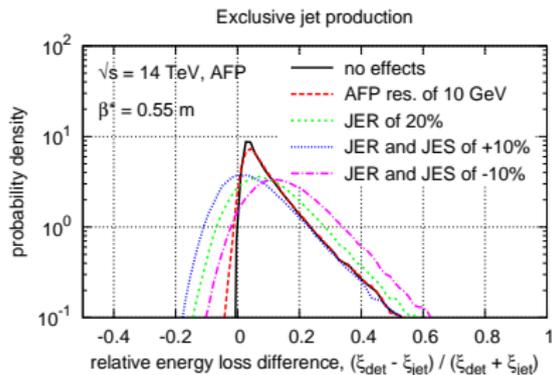
Minimum-bias and elastic protons in AFP station at 204 m



Minimum-bias and elastic protons in ALFA station at 237 m

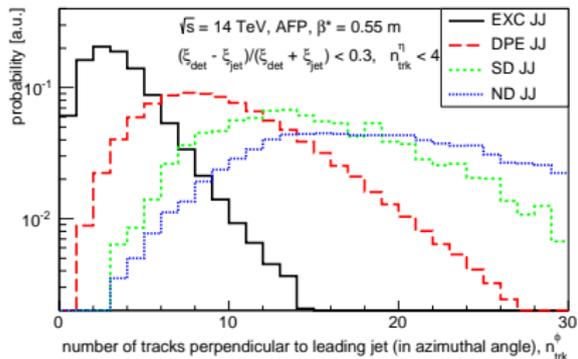
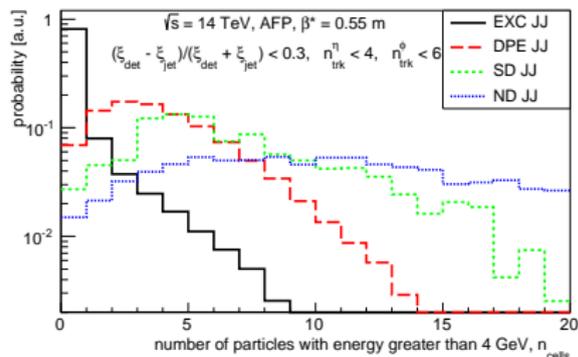
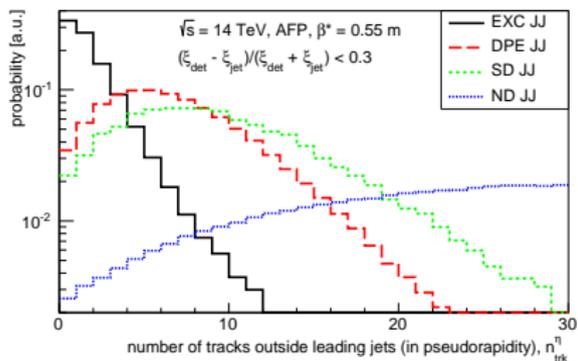


Relative Energy Loss Difference



$$\xi^{\text{jet}} = \exp(\pm y_{jj}) \frac{M_{jj}}{\sqrt{s}}$$

Veto on Additional Activity



- number of tracks outside jet system (in η): $n_{\text{trk}} < 4$,
- number of tracks perpendicular to the leading jet (in ϕ): $n_{\text{phi}} < 6$,
- number of particles with energy greater than 4 GeV, $n_{\text{cells}} < 2$.

Anti-elastic Cut

