Exclusive Jet Production at the LHC
Feasibility Studies

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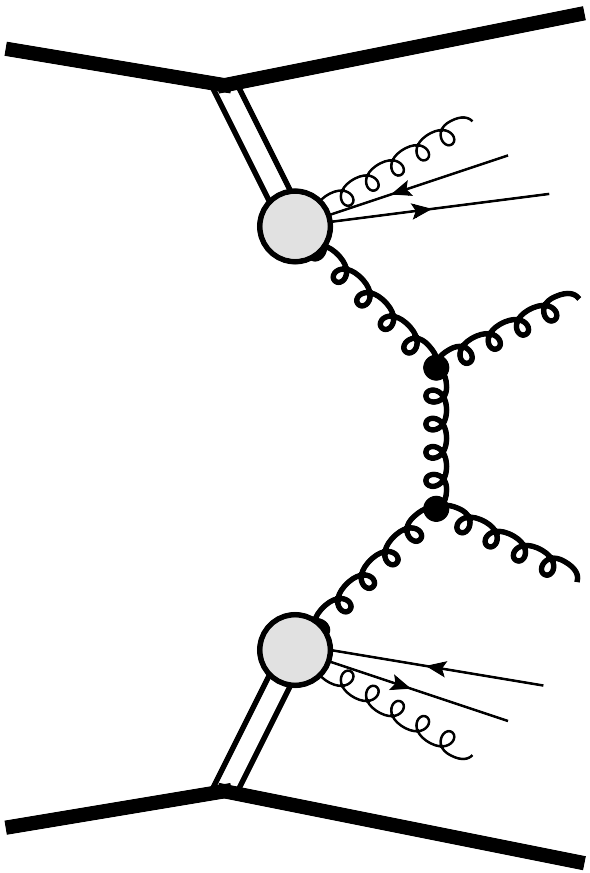
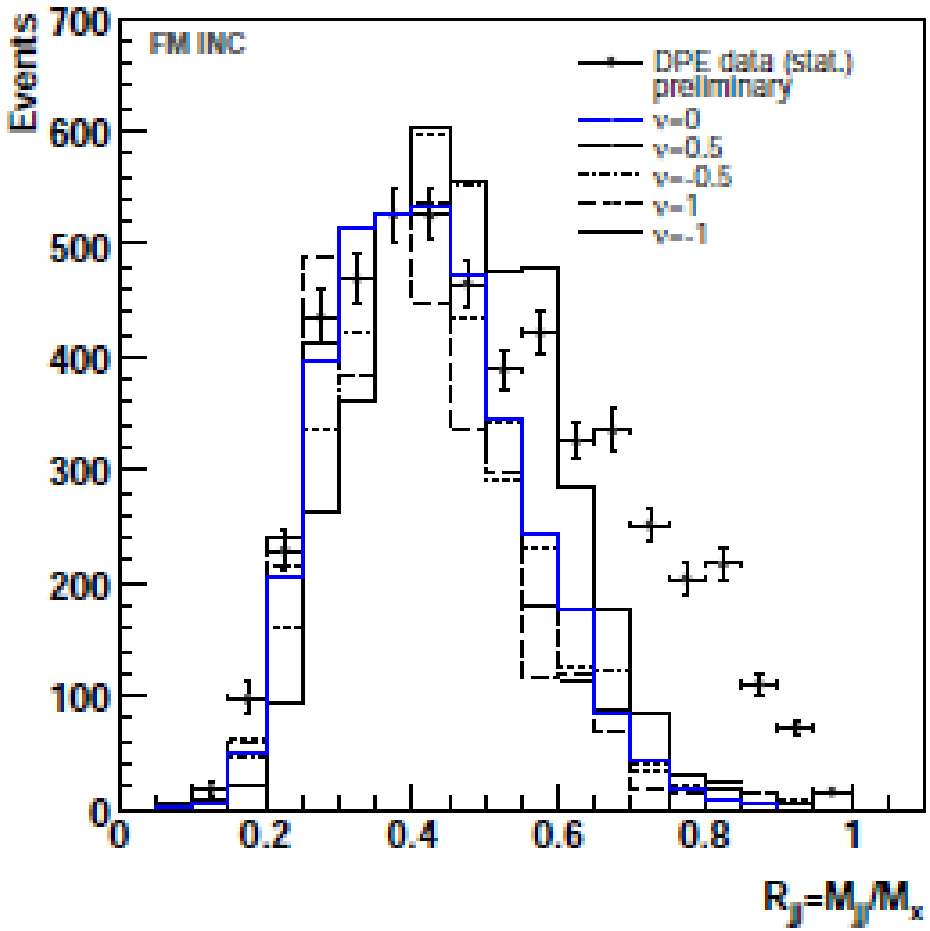
DPE – Double Pomeron Exchange

Signature: two jets in central region + two intact protons.





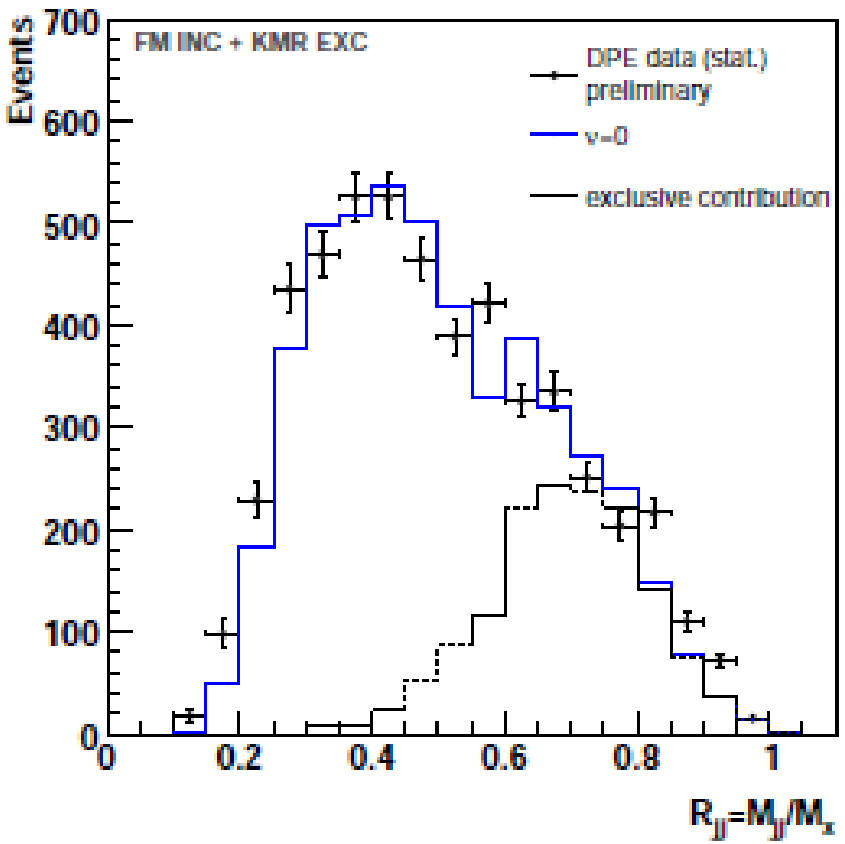
Goal: to probe the Pomeron Density Function.

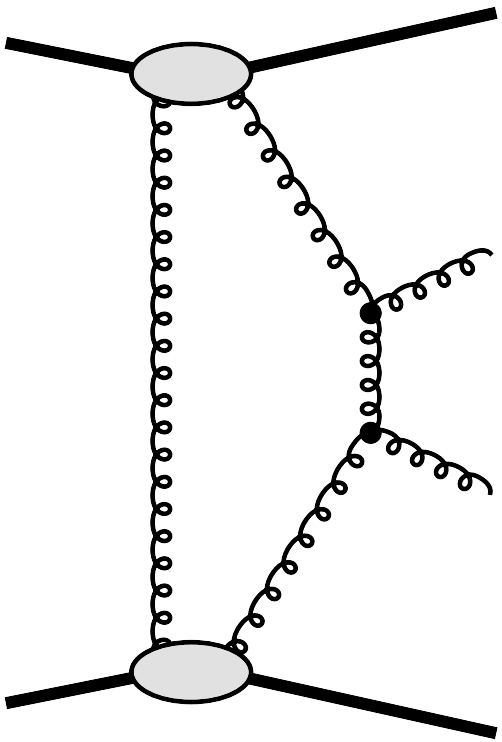
Too much events in the high mass ratio (M_{jj}) region.

Mass ratio is defined as the ratio of mass of the dijet system to missing mass.

Exclusive Jet Production at the Tevatron

Signature: two jets in central region + two intact protons
+ **gap in rapidity between jet and proton** (no remnants).

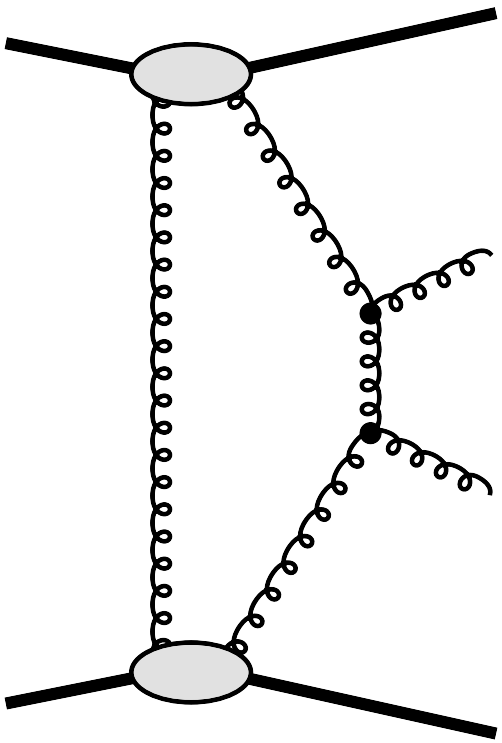




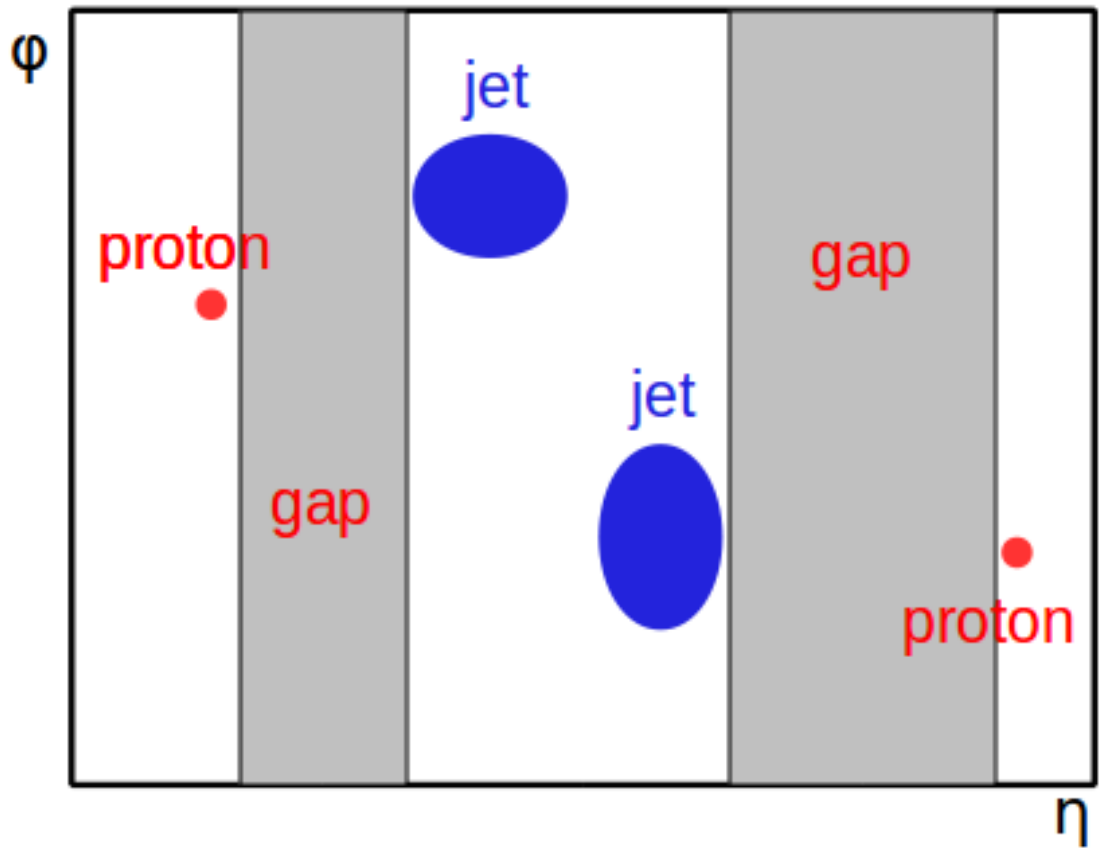
Exclusive Production

KMR model explains additional contribution in high mass ratio region. In such process there are no Pomeron remnants (in theory ratio = 1, smearing due to the detector effects).

Detection Methods



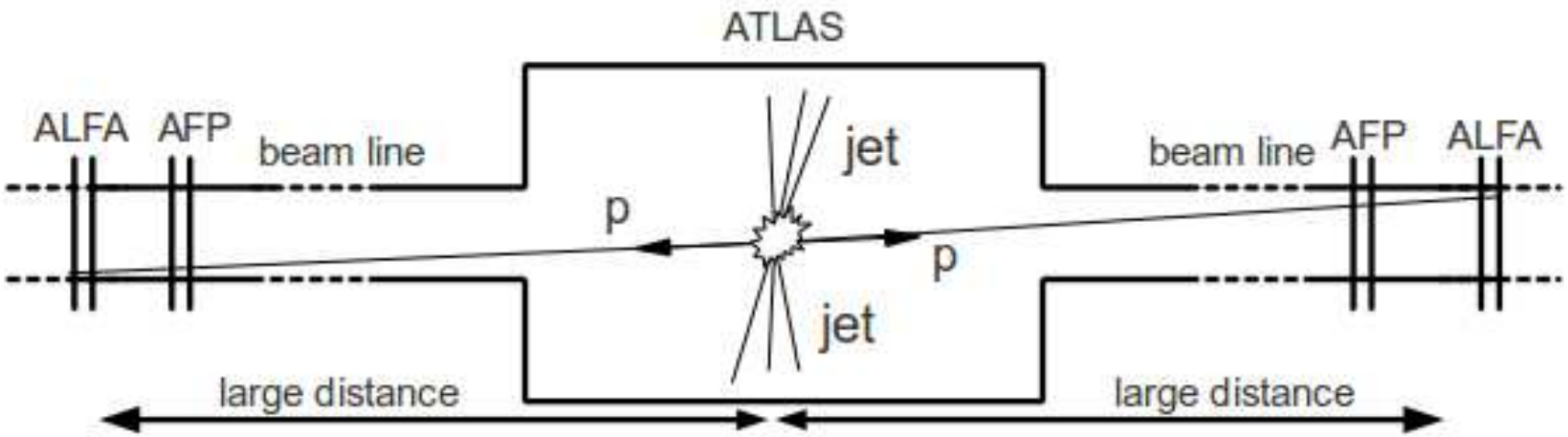
Exclusive Production



1. Gaps between jets and outgoing protons.
2. Intact proton tagging.

Forward Detectors

Intact protons – natural diffractive signature.



ALFA

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

- soft events, pile-up background

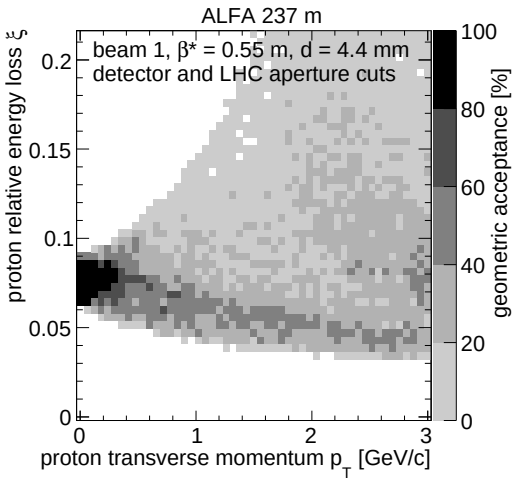
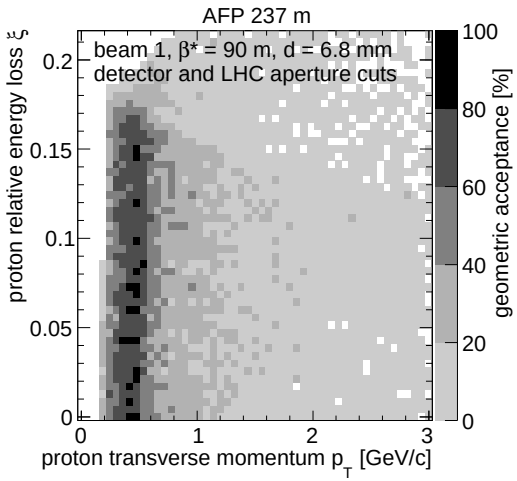
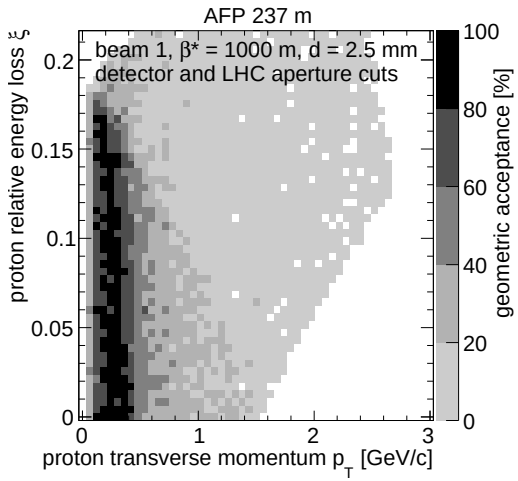
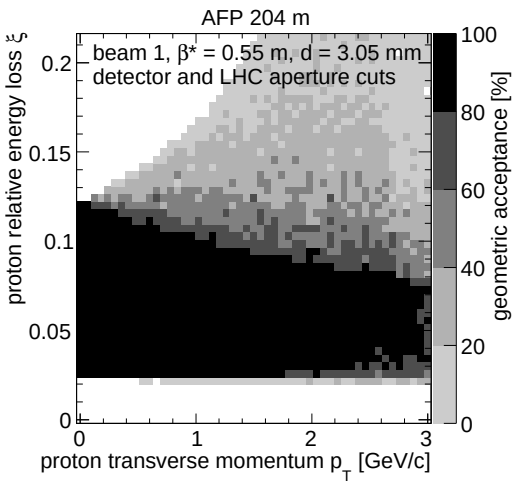
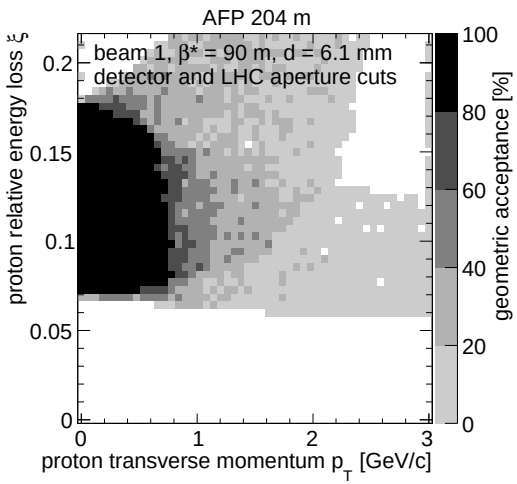
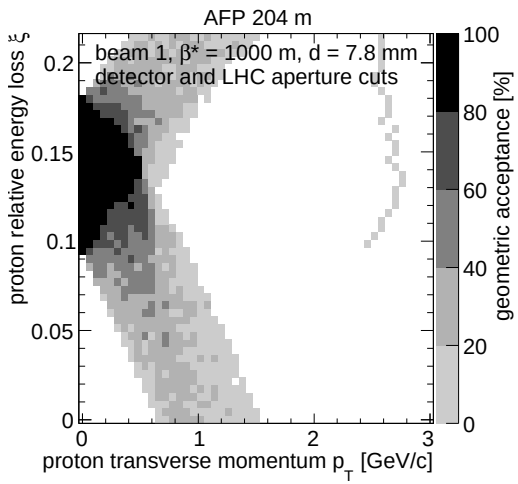
AFP

- planned, 210 m from ATLAS IP
- hard diffraction
- nominal runs (collision optics)
- position and timing detectors
- horizontally inserted RP

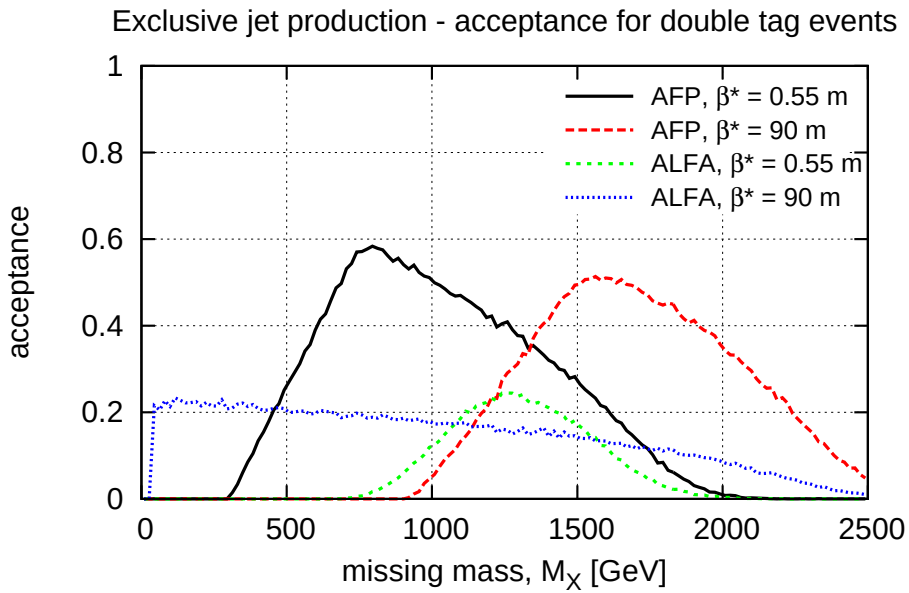
- proton detector for hard events

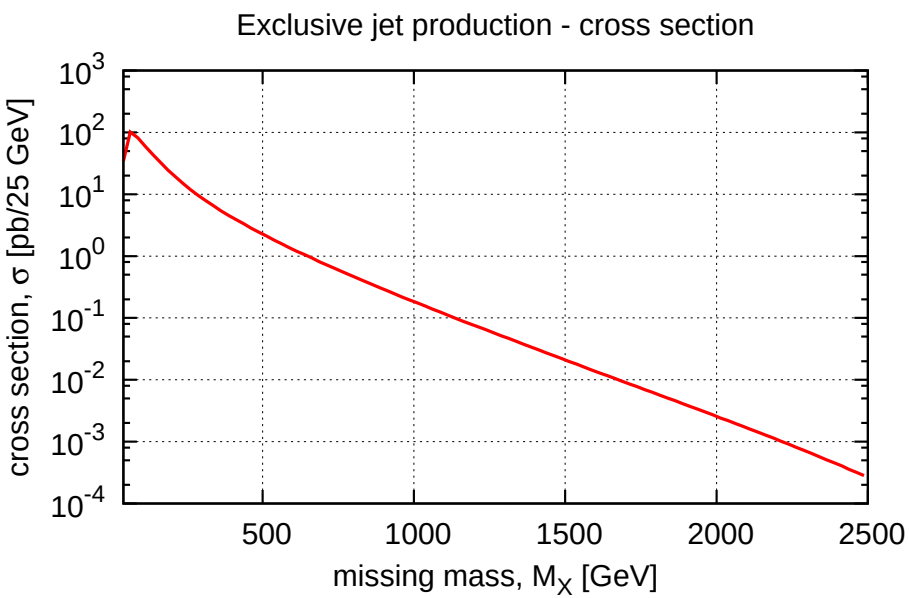
Geometric Acceptance

optics

	$\beta^* = 0.55$ m nominal (*collision*)	$\beta^* = 90$ m special (*high-β^**)	$\beta^* = 1000$ m special (*high-β^**)
ALFA			
AFP			

Mass Acceptance

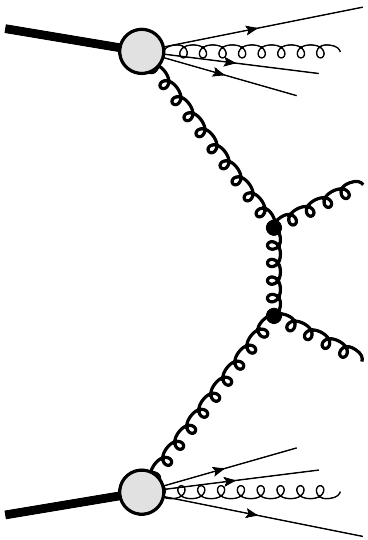


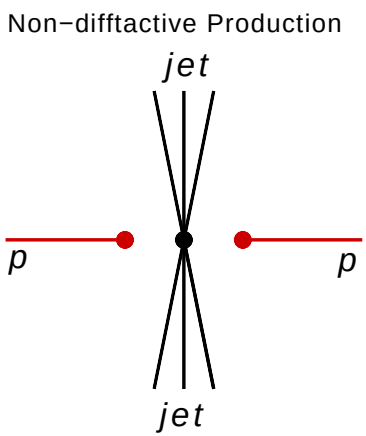


Background

Pile-up – multiple collisions during one bunch crossing (mostly min-bias).

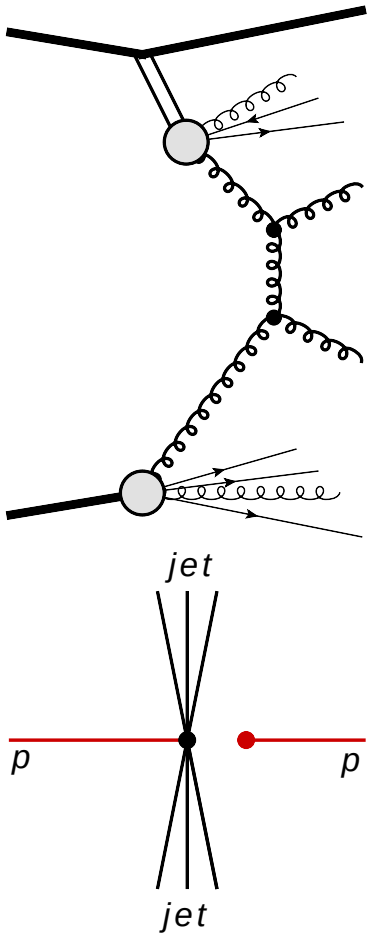
Non-diffractive jets + pile-up.





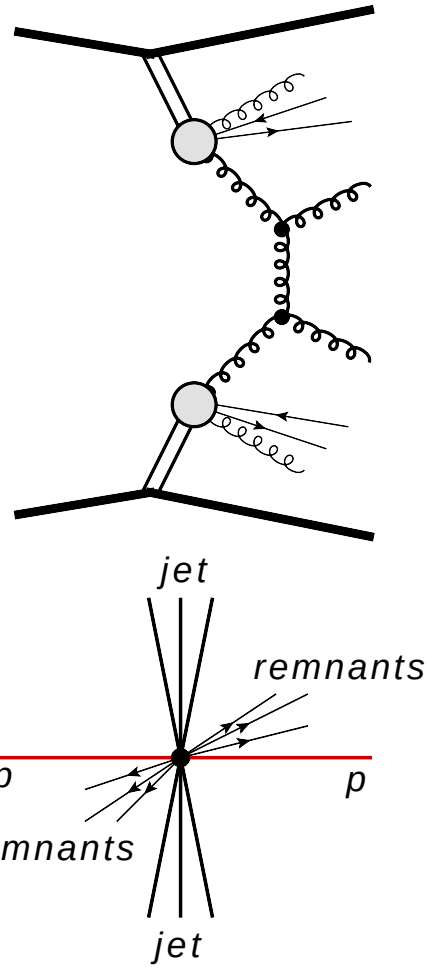
CS ($p_T > 150$ GeV):
645 nb

Single-diffractive jets + pile-up.



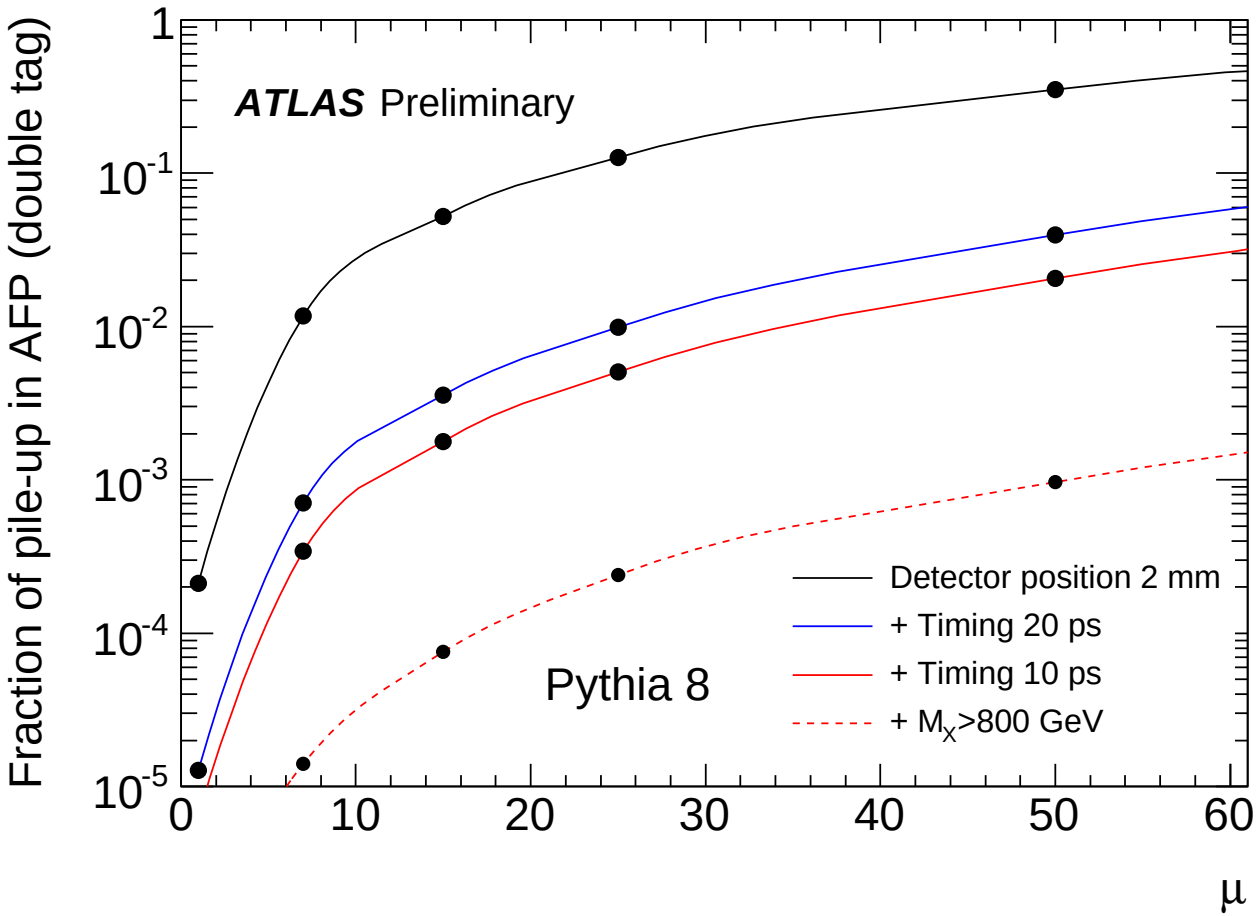
CS ($p_T > 150$ GeV):
2.26 nb

DPE jets + pile-up.



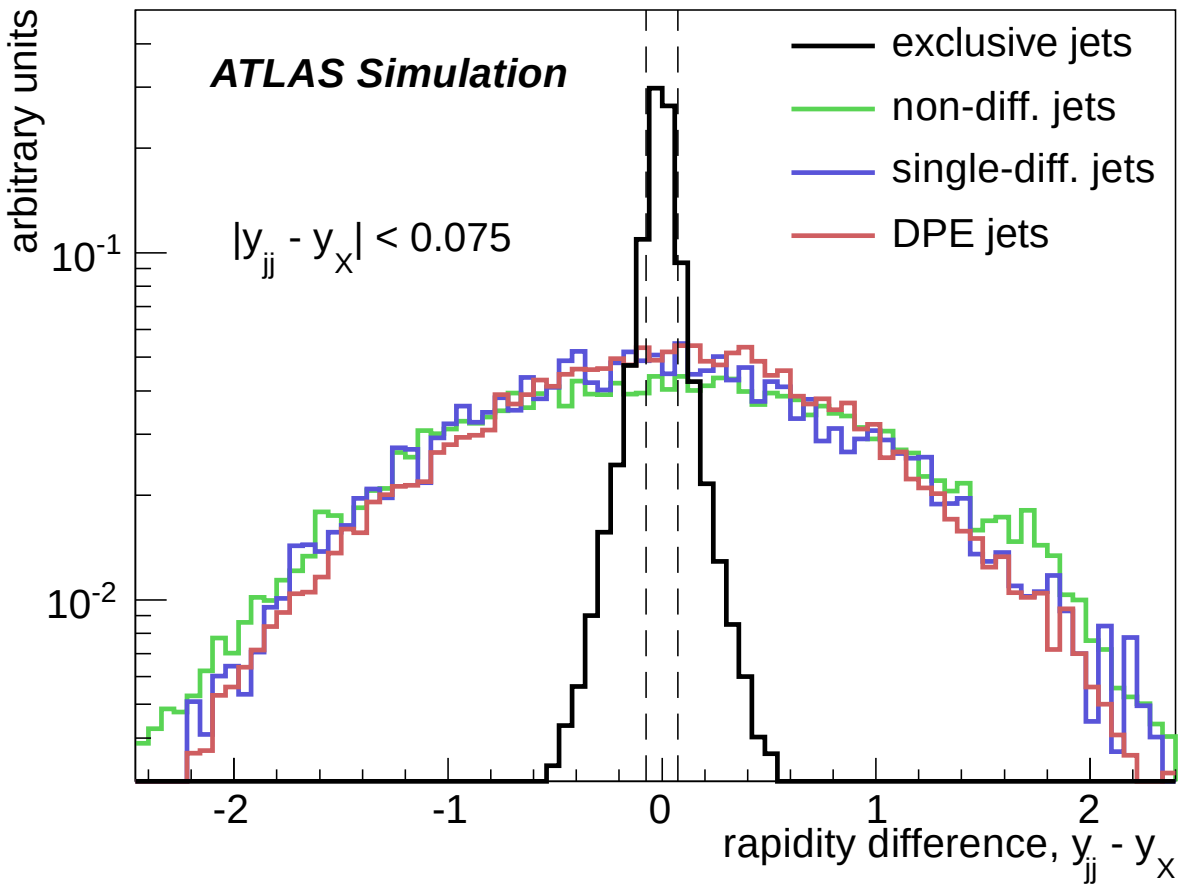
CS ($p_T > 150$ GeV):
40 pb

Cuts – AFP Acceptance



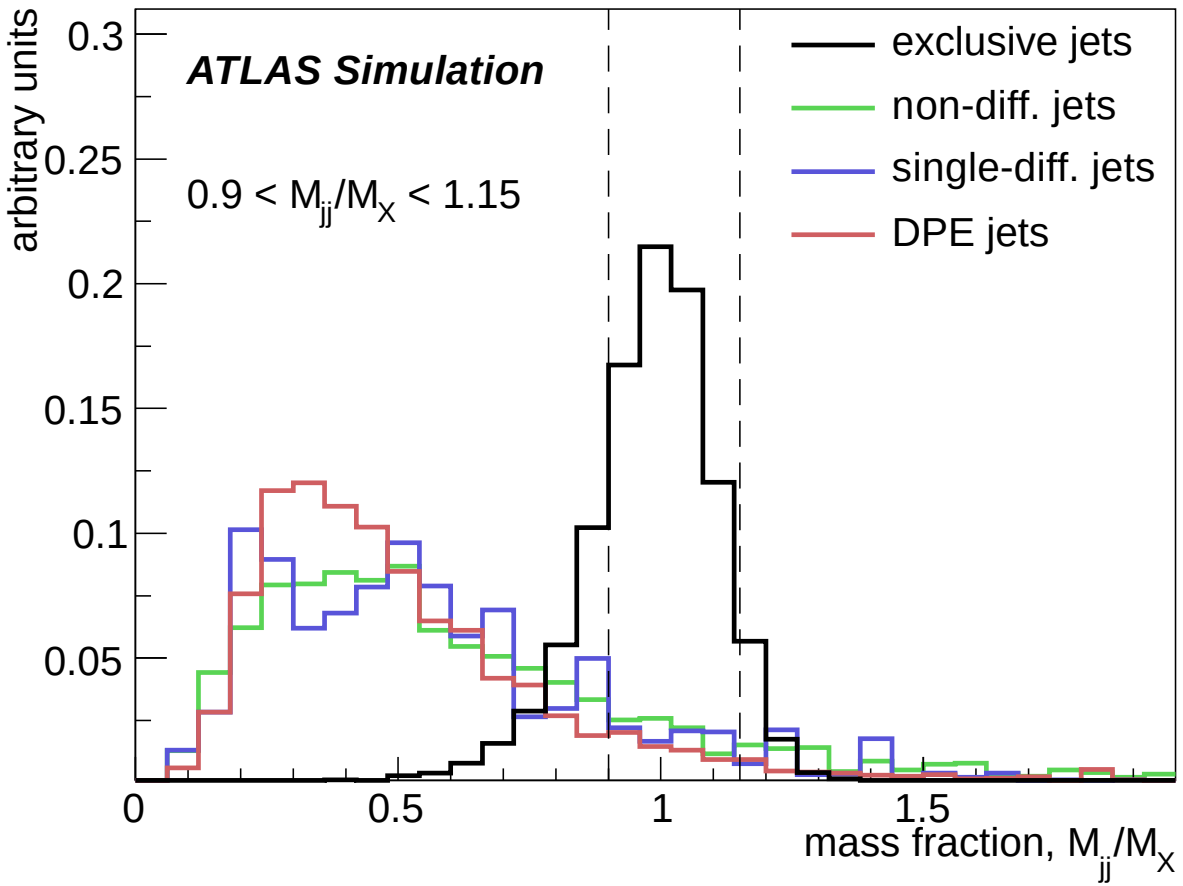
Fraction of pile-up events in AFP (double tagged events) as a function of the average number of interactions with a timing resolution of 20, 10 ps, and for a diffractive mass greater than 800 GeV.
Exclusive jet studies for pile-up $< \mu >= 23$ end $< \mu >= 46$.

Cuts – Rapidity Difference



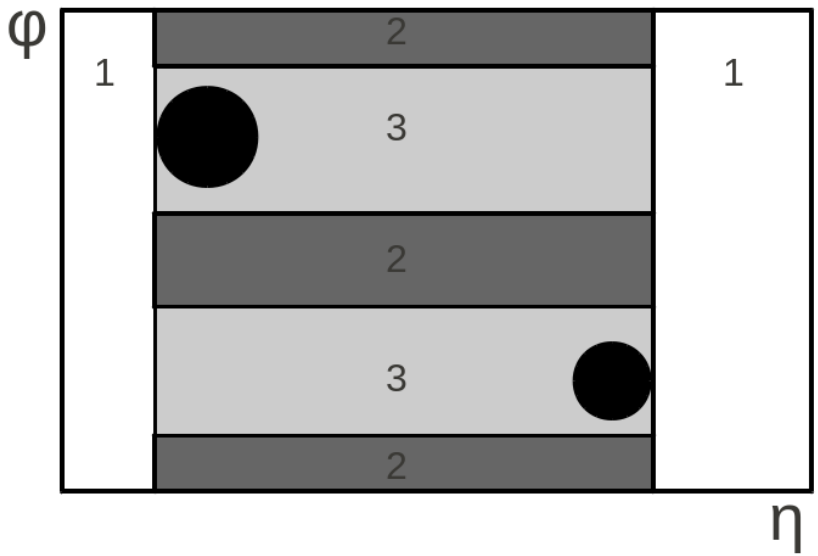
Difference, $y_{jj} - y_X$, of the rapidity of the jet system (y_{jj}) and the rapidity of the proton system $y_X = 0.5 \cdot \ln\left(\frac{\xi_1}{\xi_2}\right)$, where ξ_1 and ξ_2 are relative energy losses of the tagged in the AFP C and A stations. The dashed line represents the value of the applied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

Cuts – Mass Fraction

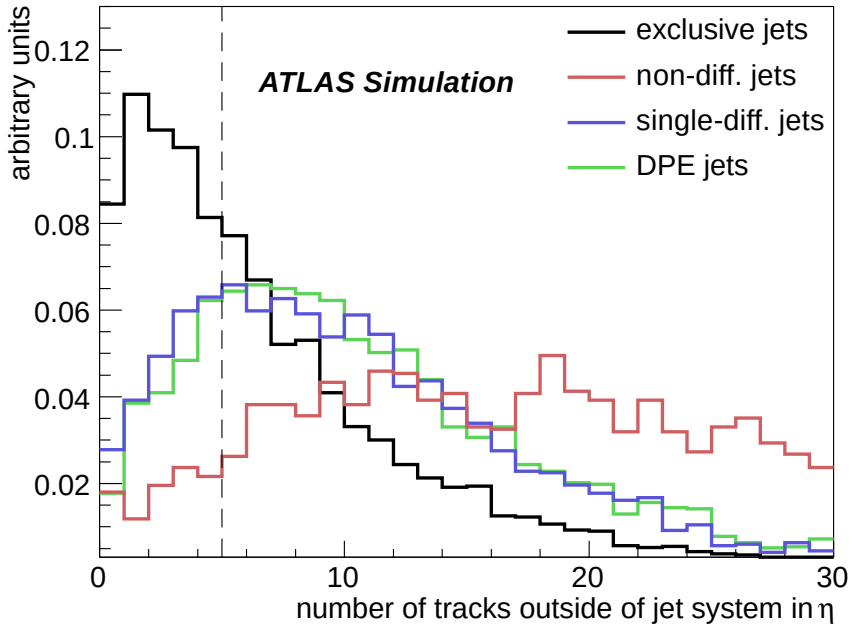


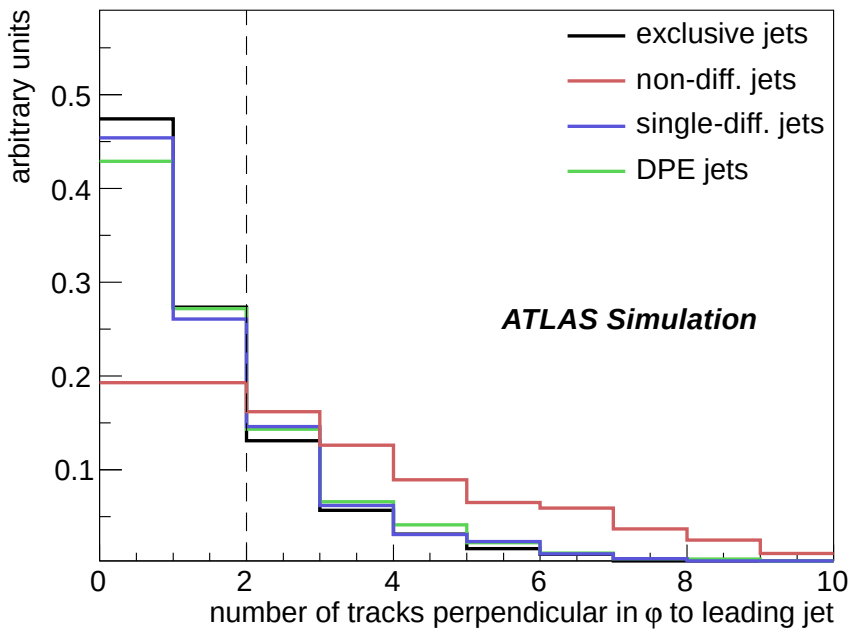
The ratio of the jet system mass to the missing mass $M_X = \sqrt{s \cdot \xi_1 \cdot \xi_2}$, where ξ_1 and ξ_2 are relative energy losses of the tagged in the AFP C and A stations. The dashed line represents the value of the applied cut.

Cuts – 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.

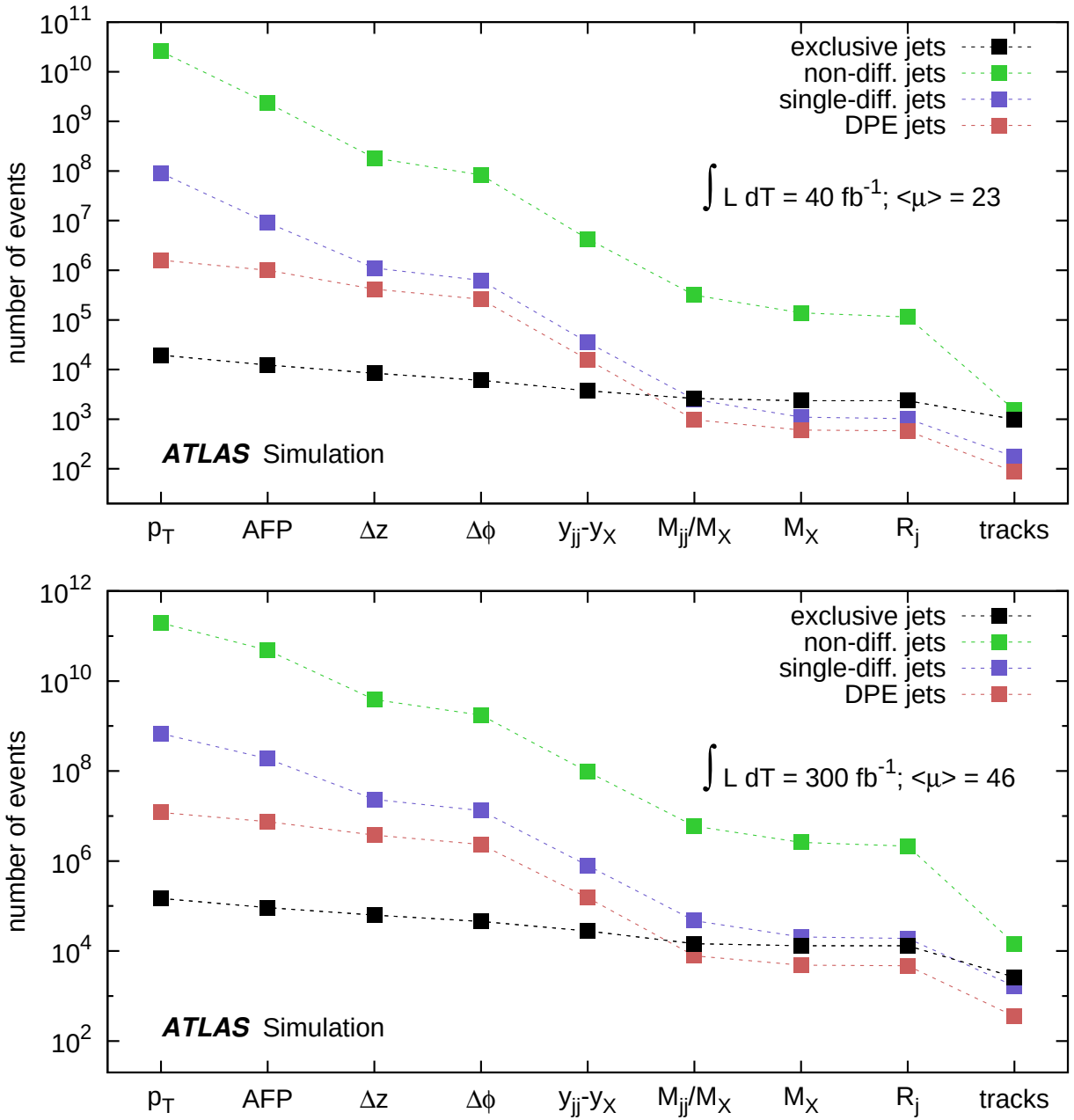




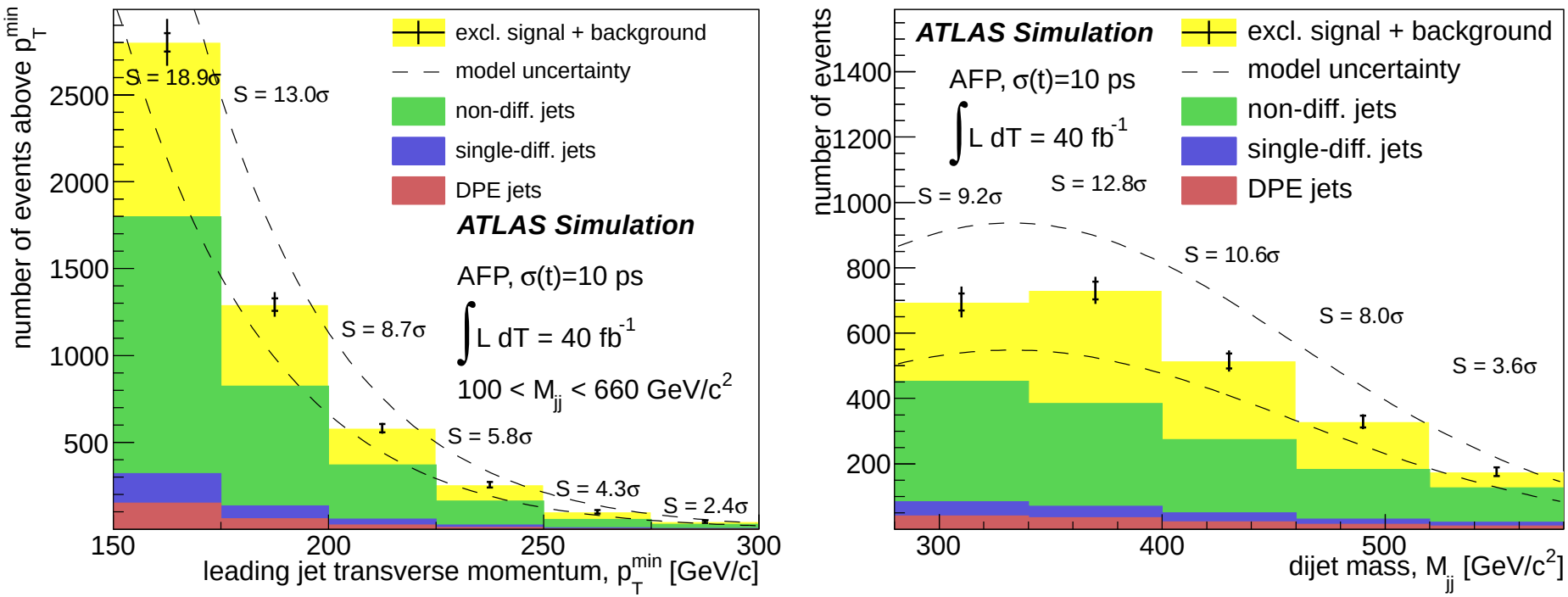
Discriminating Power

The number of events accepted after a particular cut for signal and background processes for the integrated luminosity of 40(300) fb^{-1} at pile-up $\mu = 23(46)$ as a function of the applied consecutive cuts.

The AFP time resolution of 10(5) ps has been assumed for background rejection.



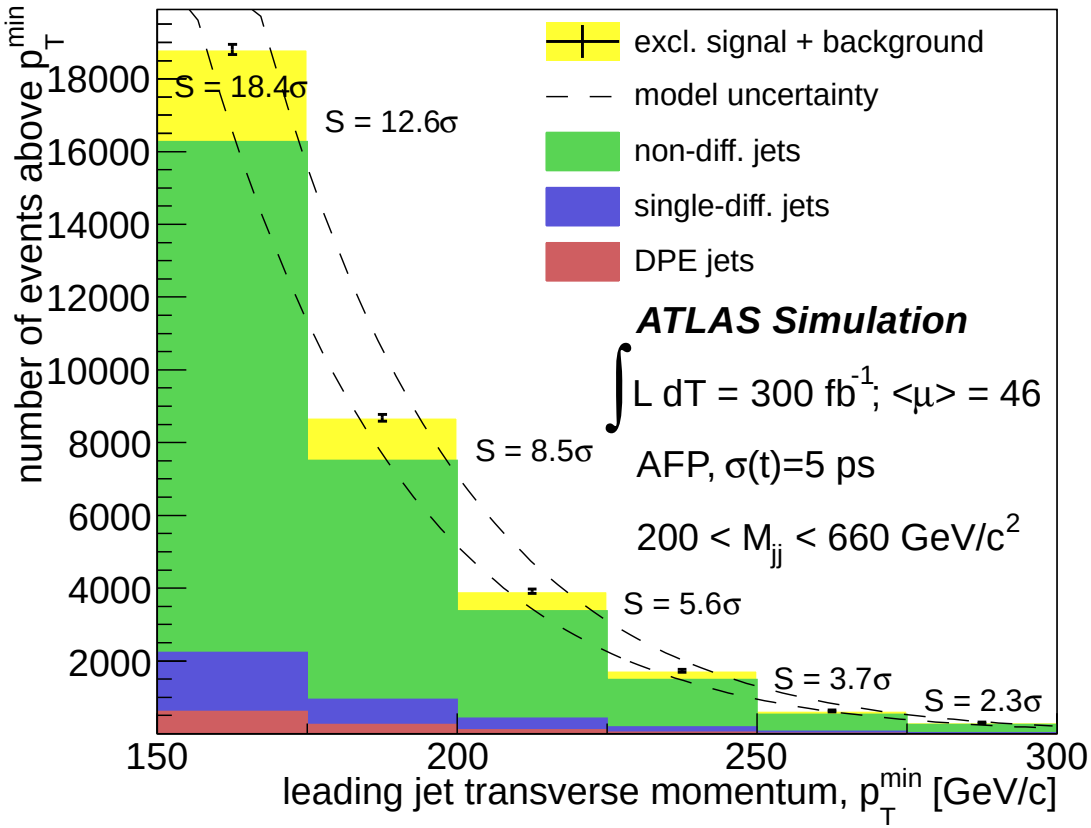
Number of Events ($< \mu >= 23$)



The leading jet transverse momentum distribution above a given threshold (left) and mass of the jet system distribution (right) for the accepted signal and background events for the integrated luminosity $L = 40$ fb^{-1} at pile-up $\mu = 23$.
The error bars show the statistical and systematic uncertainties.
The dashed line represents the theoretical model uncertainty (best constraints on parameters from the Tevtatron data).

For each bin the significance (S) is presented.

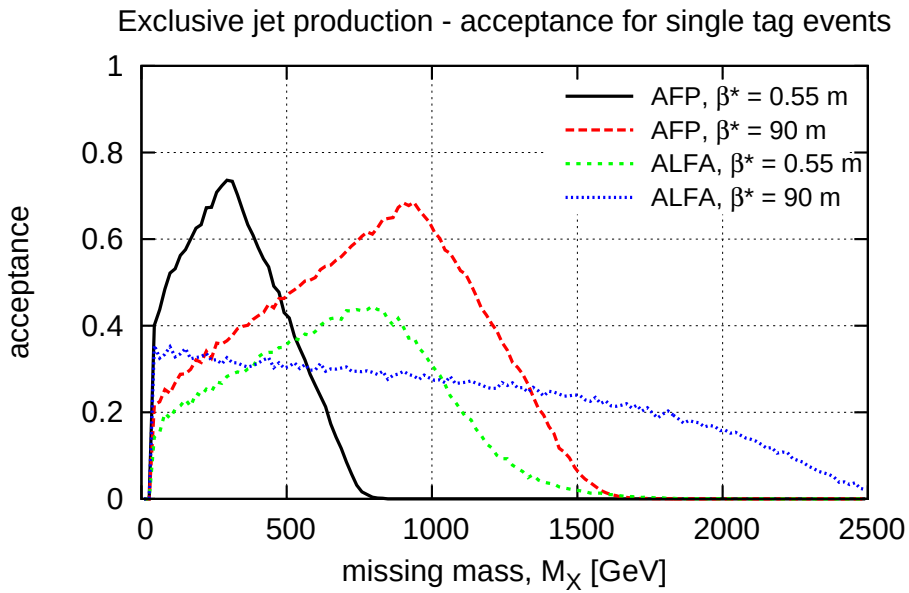
Number of Events ($< \mu >= 46$)

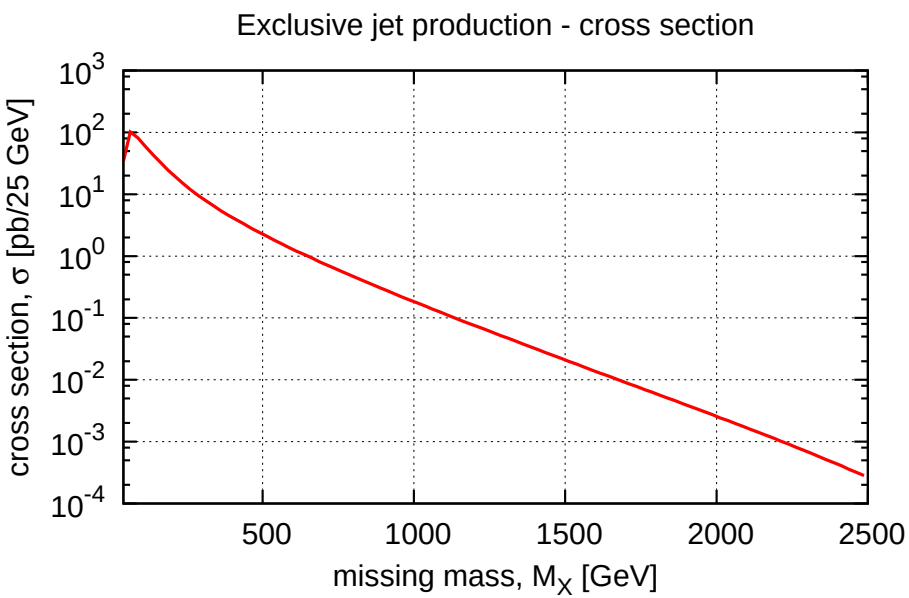


The leading jet transverse momentum distribution above a given threshold for the accepted signal and background events for the integrated luminosity $L = 300$ fb^{-1} at pile-up $\mu = 46$.
The error bars show the statistical uncertainty.
The dashed line represents the theoretical model uncertainty (best constraints on parameters from the Tevtatron data).

For each bin the significance (S) is presented.

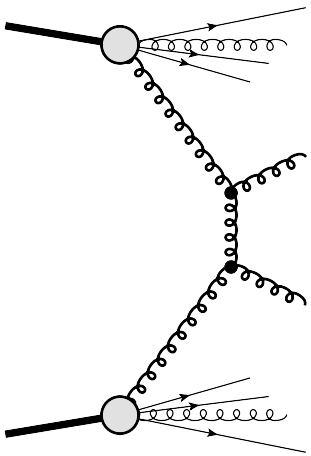
One Tag Approach





Non-diffractive Backgrounds

Non-diffractive jets
+ pile-up



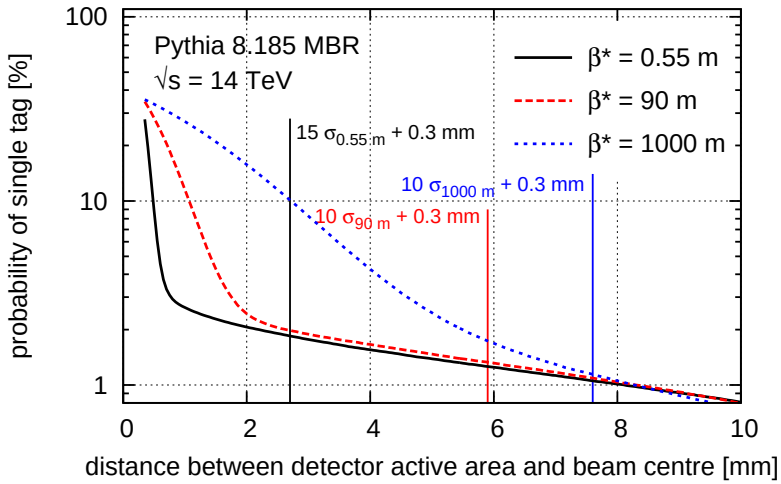
Non−difftactive Production

Cuts:

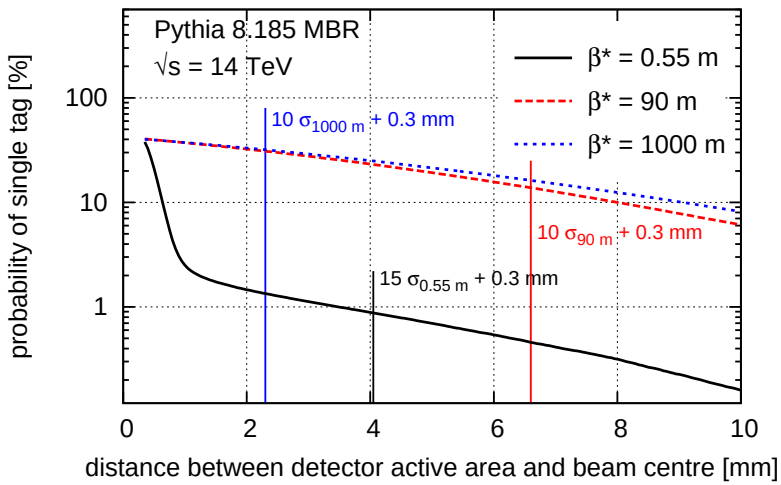
- proton in AFP/ALFA,
- one reconstructed vertex,
- ξ correlation,
- number of tracks to hard vertex,
- veto on energy in forward calorimeter.

Soft single tag probability

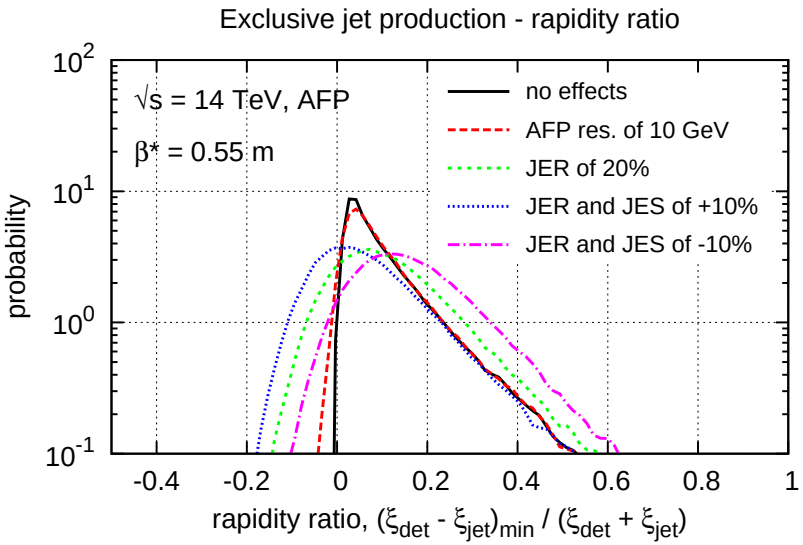
Minimum-bias and elastic protons in AFP station at 204 m

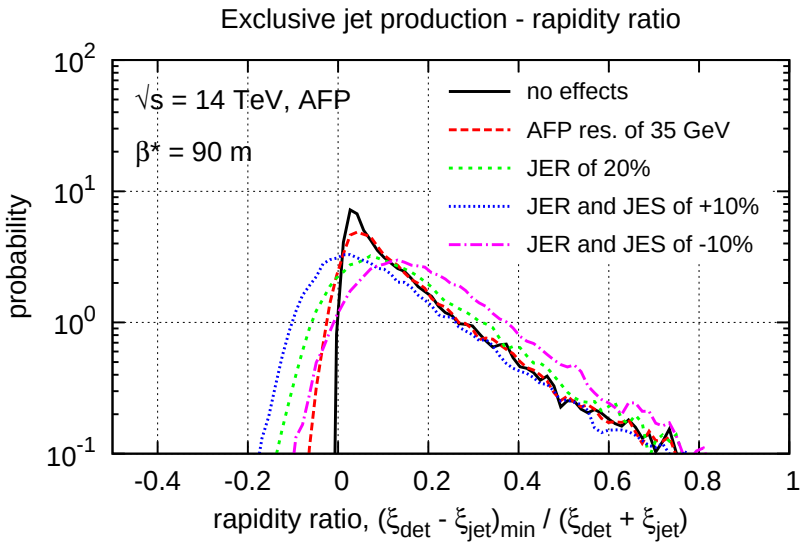


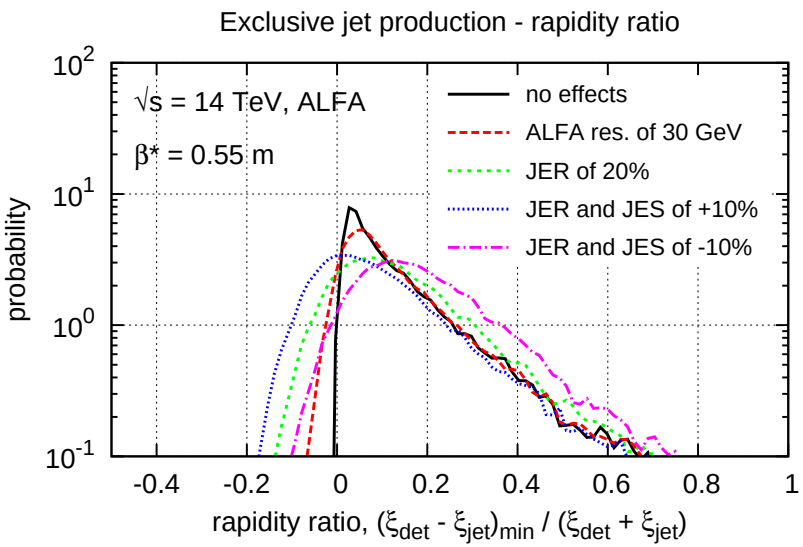
Minimum-bias and elastic protons in ALFA station at 237 m

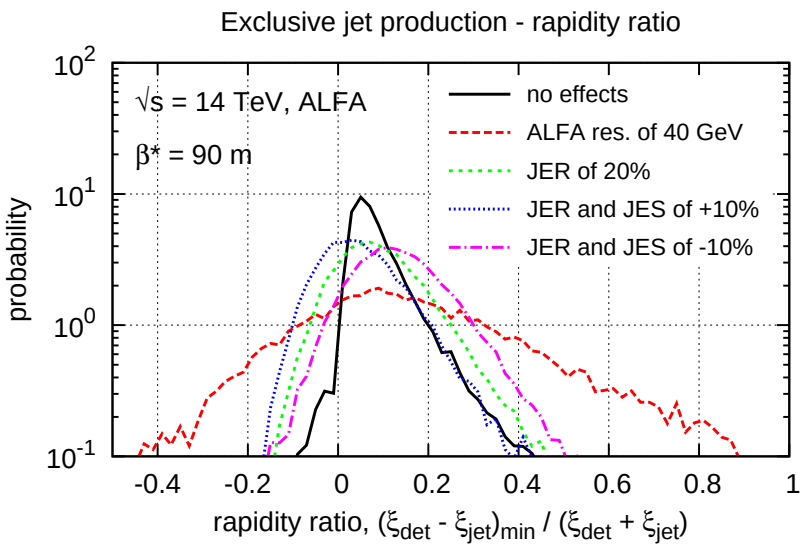


Exclusive Jets – Reconstruction Issues



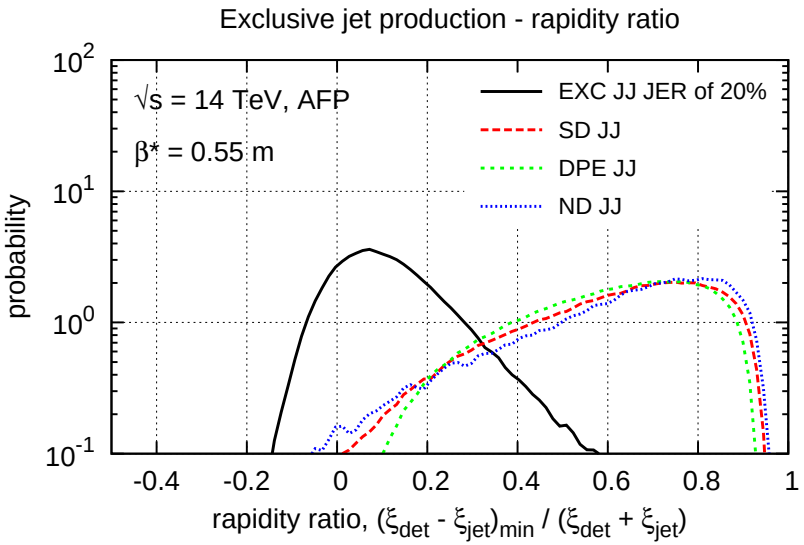


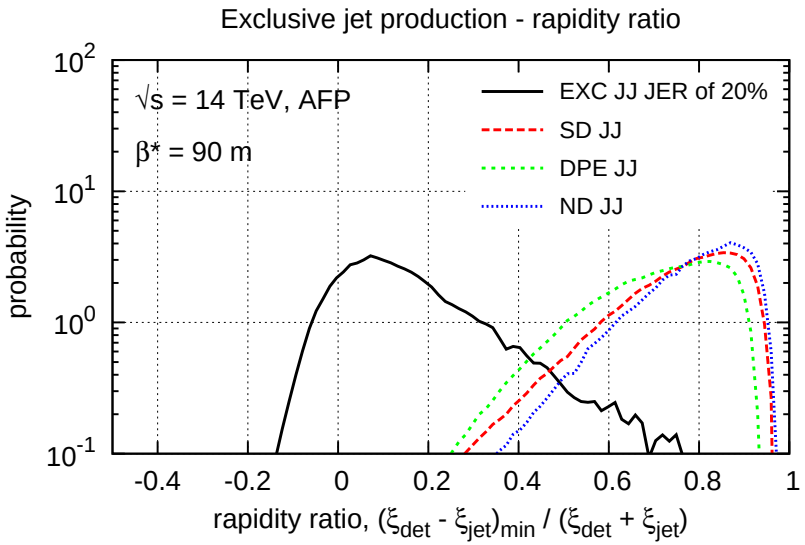


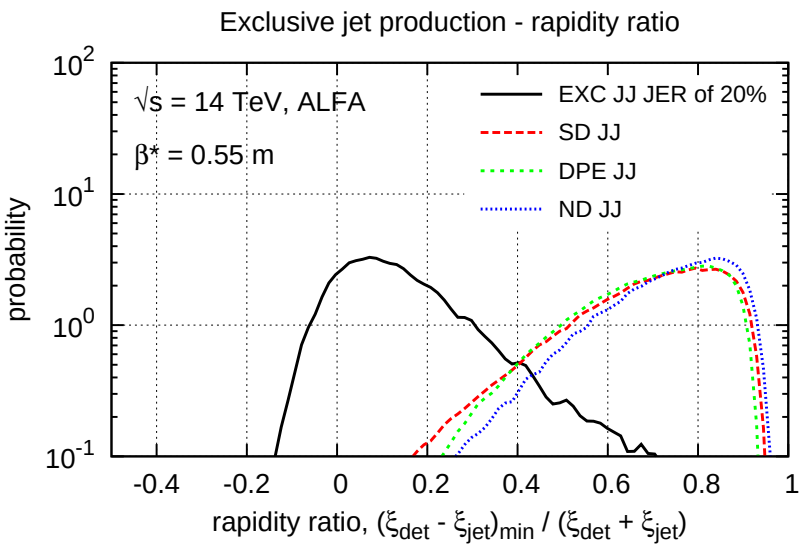


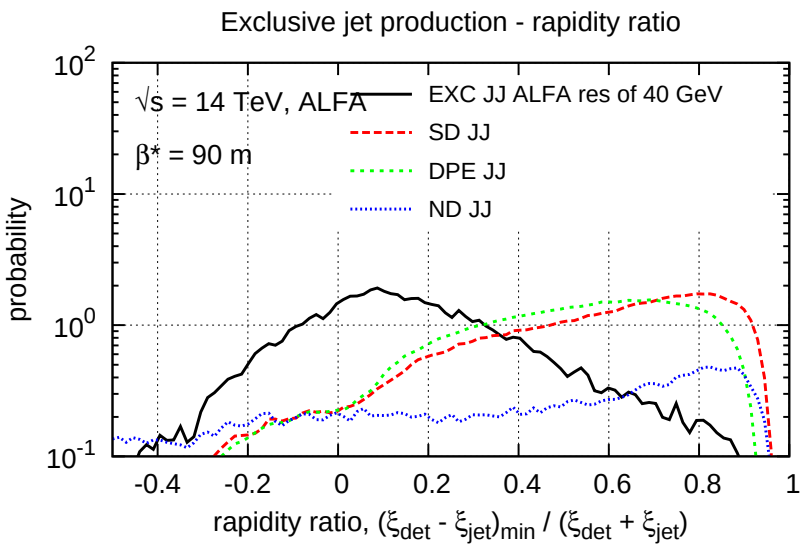
$$\xi_1^{jet} = \exp(y_{jj})\frac{M_{jj}}{\sqrt{s}} \qquad \xi_2^{jet} = \exp(-y_{jj})\frac{M_{jj}}{\sqrt{s}}$$

ξ Requirement









$$\xi_1^{jet} = \exp(y_{jj})\frac{M_{jj}}{\sqrt{s}} \qquad \xi_2^{jet} = \exp(-y_{jj})\frac{M_{jj}}{\sqrt{s}}$$

Summary

Double tagged events.

- 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)!
- Up to 18.9σ significance for the exclusive signal could be achieved.
- Improvement of uncertainties coming from the Tevatron CDF measurements using pbar tagging by about one order of magnitude.

Single tagged events.

- Smaller masses $\rightarrow$ larger cross sections $\rightarrow$ smaller pile-up $\rightarrow$ cleaner events.
- Very promising initial results.
- Studies ongoing...

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