Impact of multiple pp interactions on proton tagging

Oldřich Kepka
Institute of Physics, Academy of Sciences, Prague
On Behalf of AFP Working Group

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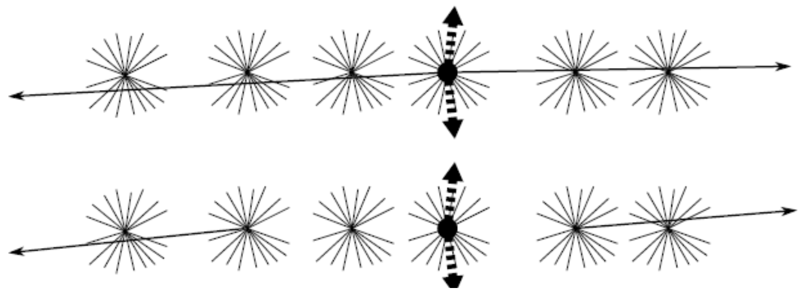
Outline

- Summary of pile-up studies for AFP 220m
- Rates as predicted by MC
  - Only using the intact leading protons, debris coming from the interactions hitting the forward detectors is another story

Pile-up is problematic

- Minimum bias events can fake hard diffractive or two-photon signature when overlayed with non-diffractive background (has orders of magnitude higher cross section)



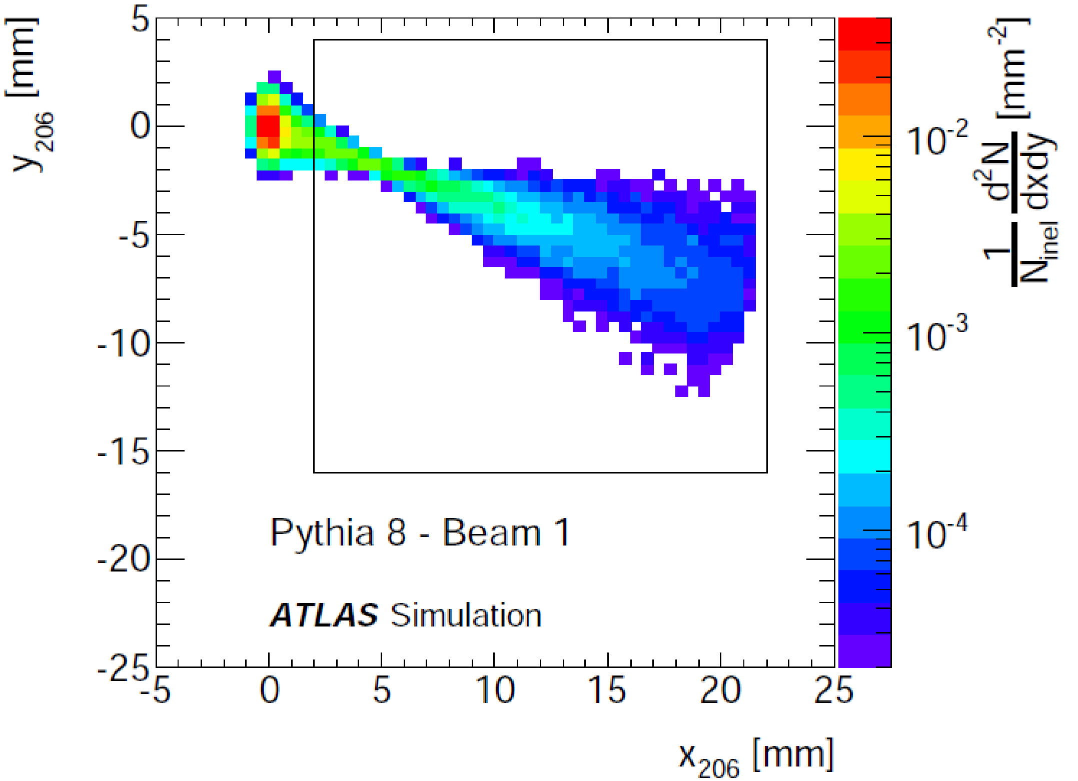
- Two-solutions:
  - SD diffractive cross section falls as $1/\xi \rightarrow$ study processes at sufficiently high mass
  - Reject combinatorial pairs require time arrival to be compatible with primary vertex in central detector $|z_0(\mathrm{AFP}) - z_0(\mathrm{PV})| < 1\sigma$

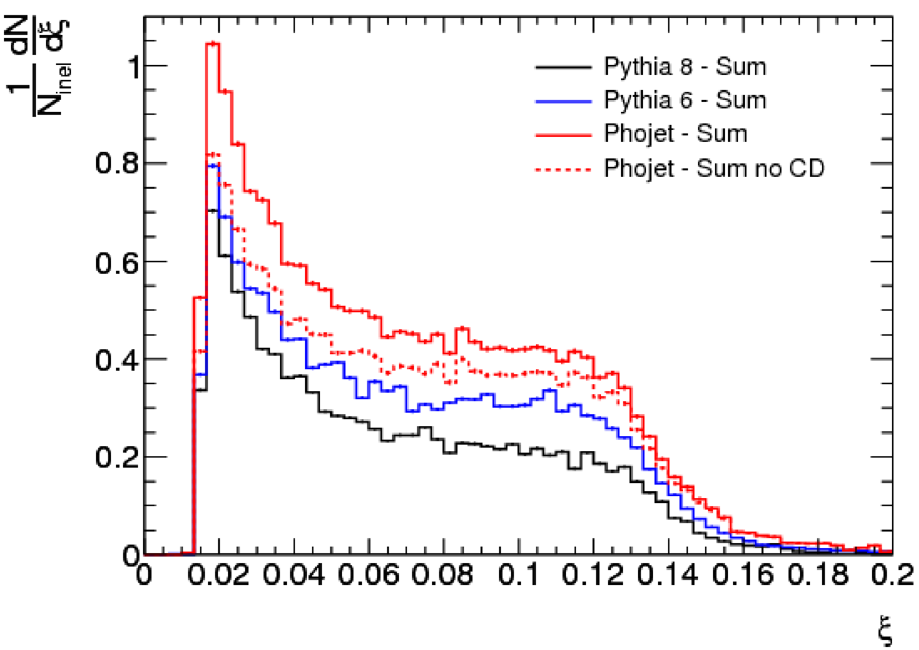
$$z_0 = \frac{c}{2}(t_1 - t_2) \qquad \Delta t_{1,2} = 10\,\mathrm{ps} \rightarrow \Delta z_0 = 2.1\,\mathrm{mm}$$

  - … or combination of the two

Properties of pile-up

- Acceptance large for $0.012 < \xi < 0.14$
- d at 15σ: 2.3mm = 0.13x15 + 0.3 mm
- High rates close to the beam
- Irradiation of small area
  a detector (lifetime issues?)





- Factor 2 difference in the rates predicted by PYTHIA8/PHOJET

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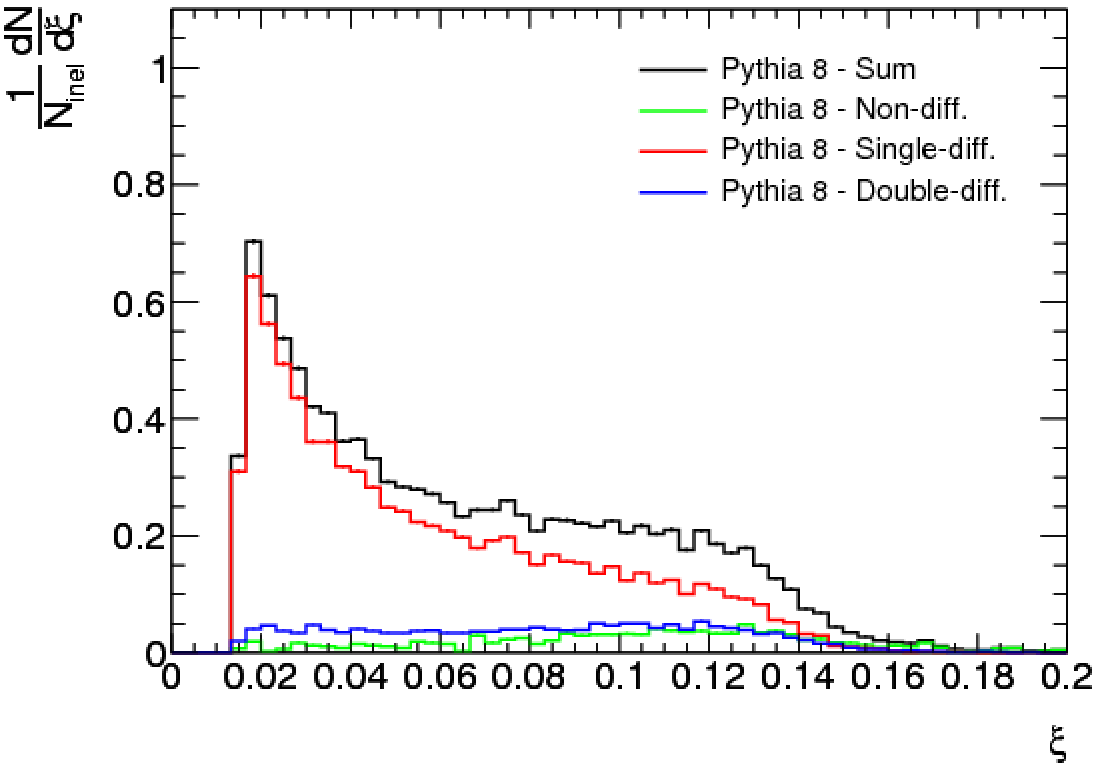
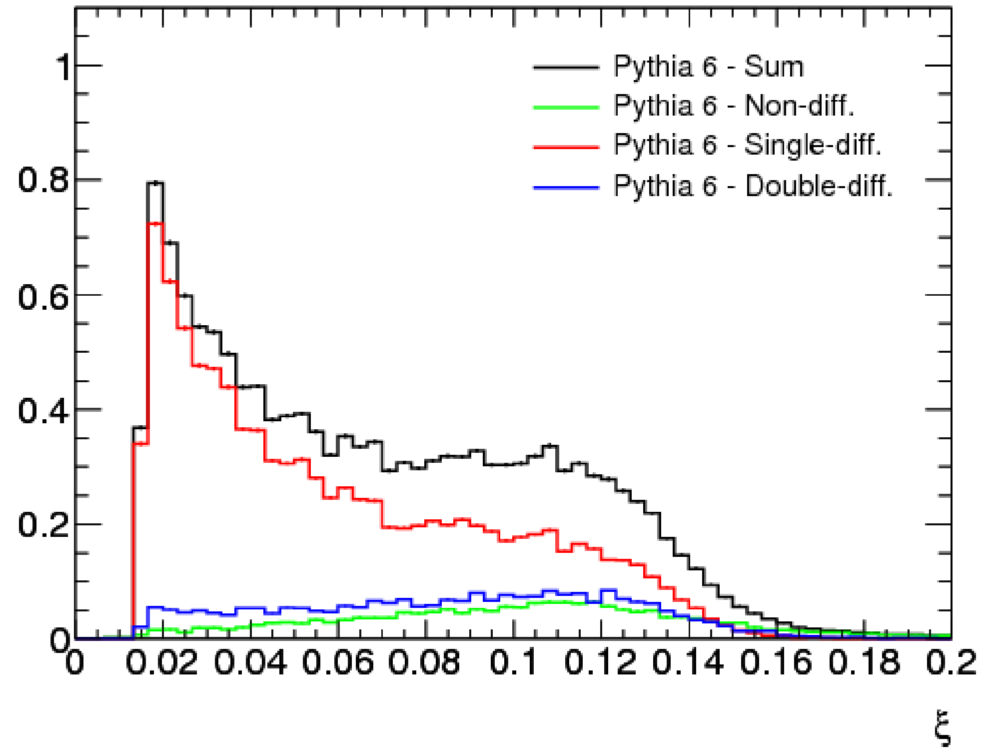
Pythia 6 / 8

- Differences in the modeling of large xi region – uncertainty ~ 30%
- Significant contribution of the non-diffractive and double diffractive events
- Forward physics community should aim at constraining the prediction (ALFA/TOTEM)





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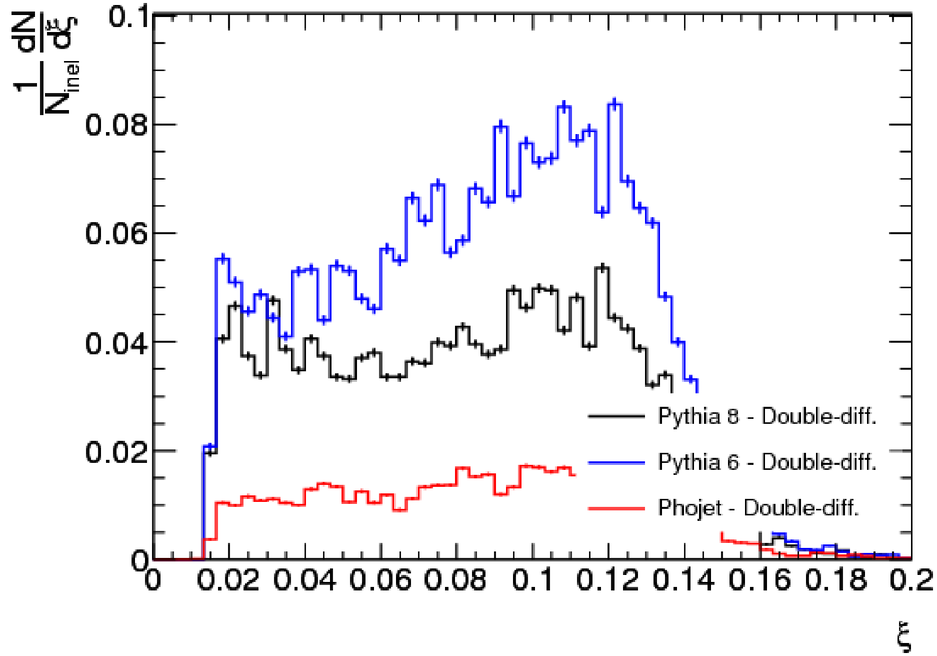
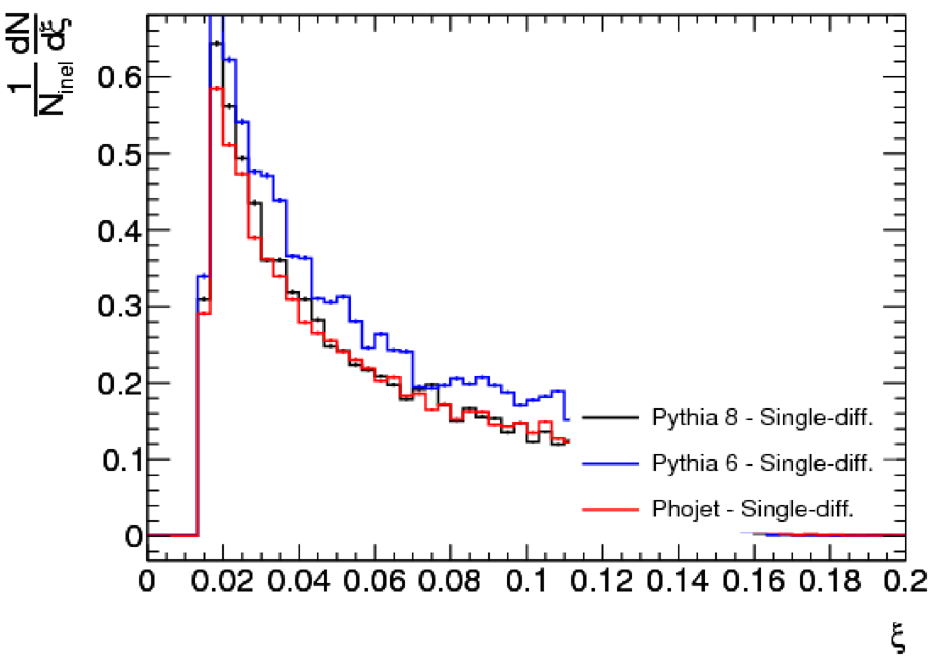
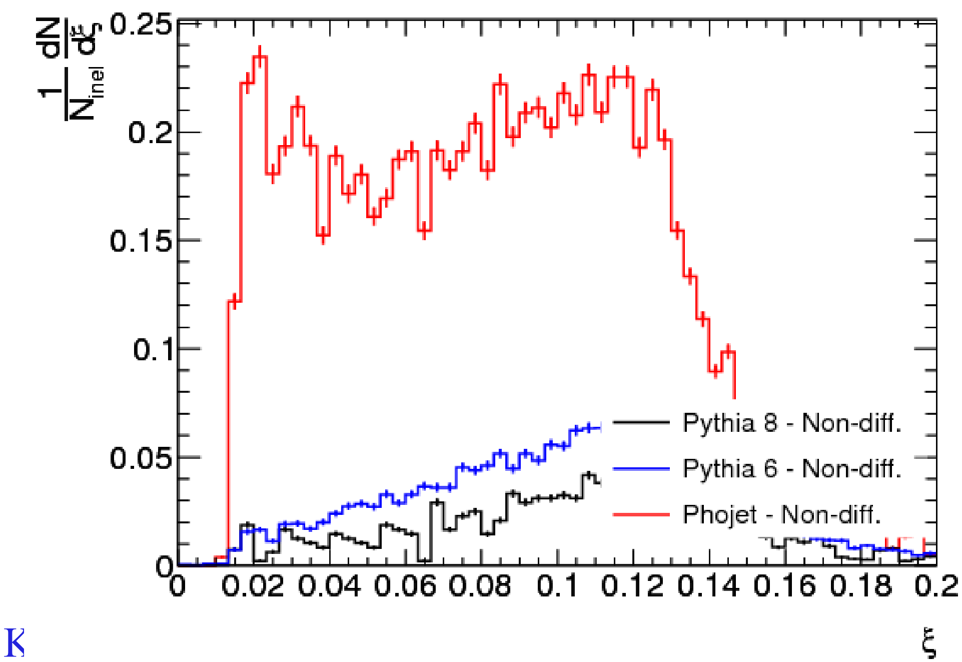
Comparison of various contributions

- While SD event with intrinsic intact protons tend to agree, there are big differences between the generators for DD and ND

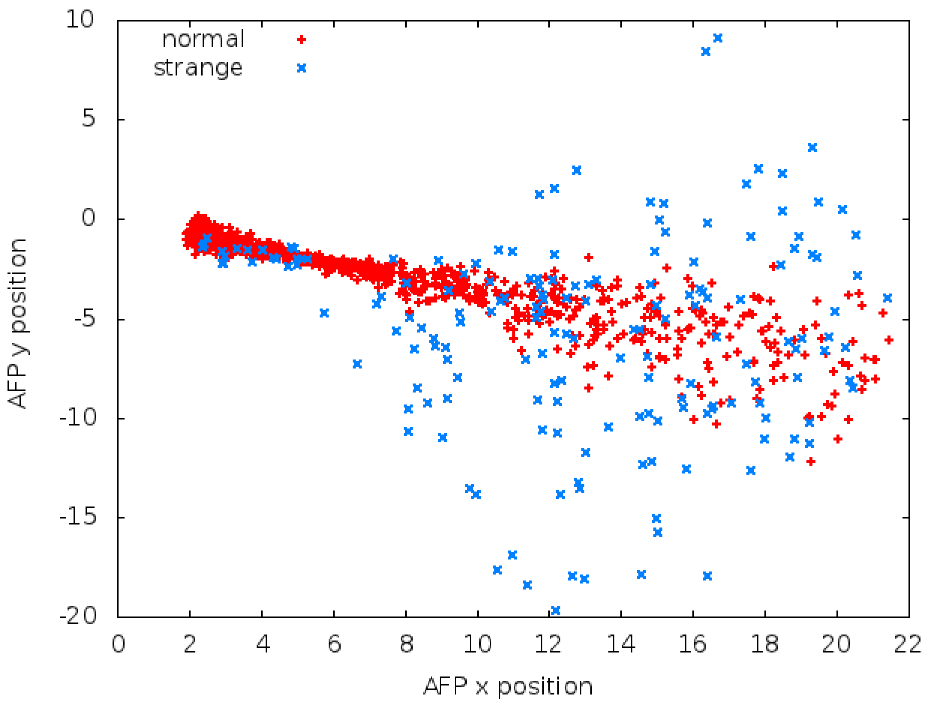






Momentum fraction loss profiles

- Single diffractive events
  - Comparing side with forward proton and the side with dissociated system
  - Rejection power could be increased by cutting on particular XxY pattern
  - Could be used to reject background in offline analysis, but affects trigger rates/inefficiencies in timing detectors



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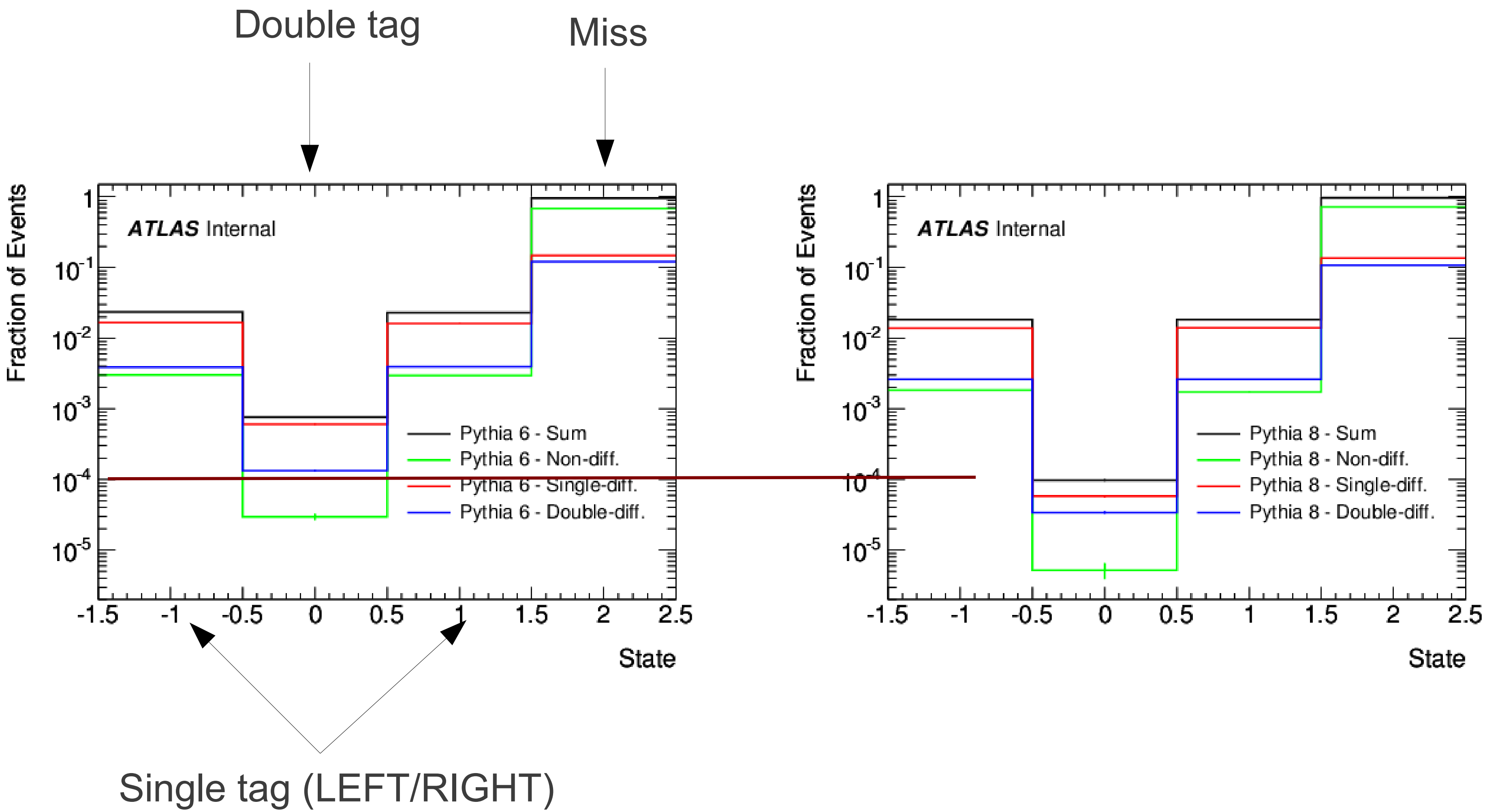
Rates of double taggs

- MB interaction hits one detector in 2% cases
- Fake double tag in 0.01% cases
- Pythia 6 predicts by about factor 10 higher rates then Pythia8



Suppression of pile-up

- Require difference between proton arrival times compatible with primary vertex

$$z_0 = \frac{c}{2}(t_1 - t_2) \qquad \Delta t_{1,2} = 10\,\mathrm{ps} \rightarrow \Delta z_0 = 2.1\,\mathrm{mm}$$

- Smearing both in time and position - rejection at 1σ level (2.1mm)

Summary:

- Acceptance

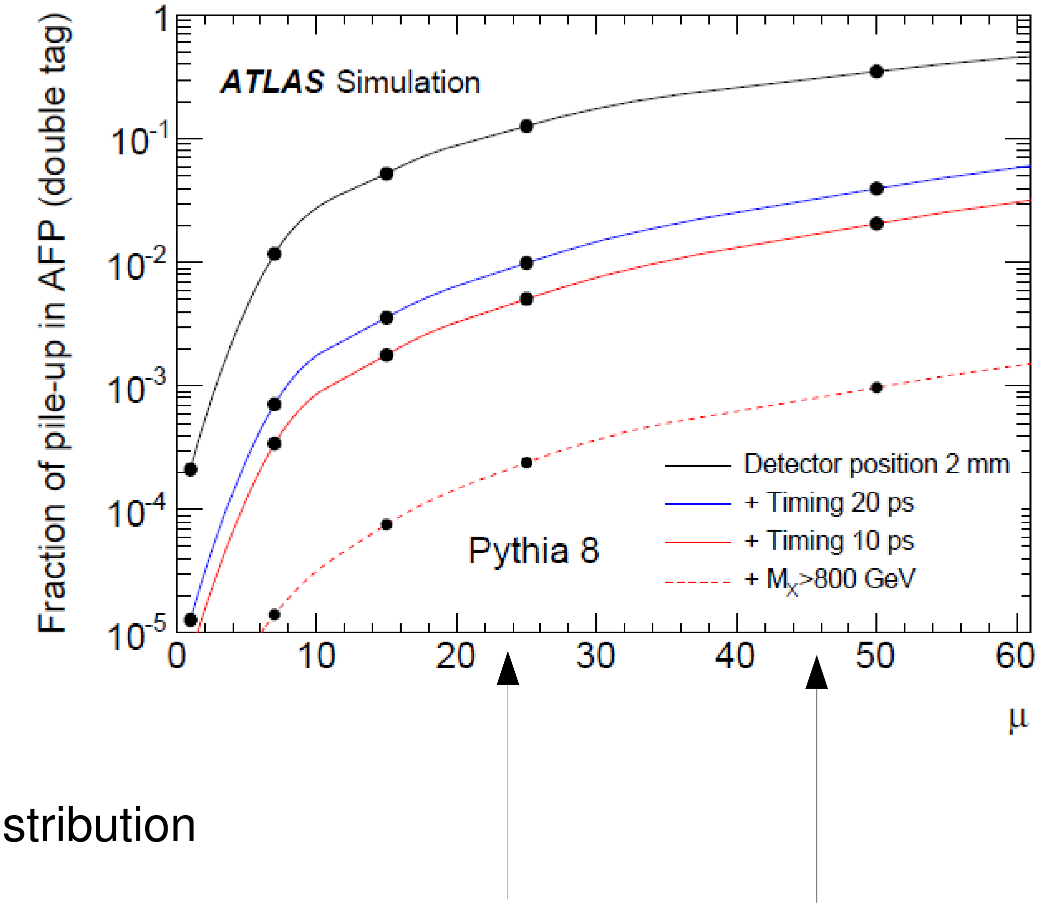
  μ = 23: 10^{-1} μ = 46: $3\mathrm{x}10^{-1}$

- +10ps timing

  μ = 23: $4\mathrm{x}10^{-3}$ μ = 46: $2\mathrm{x}10^{-2}$

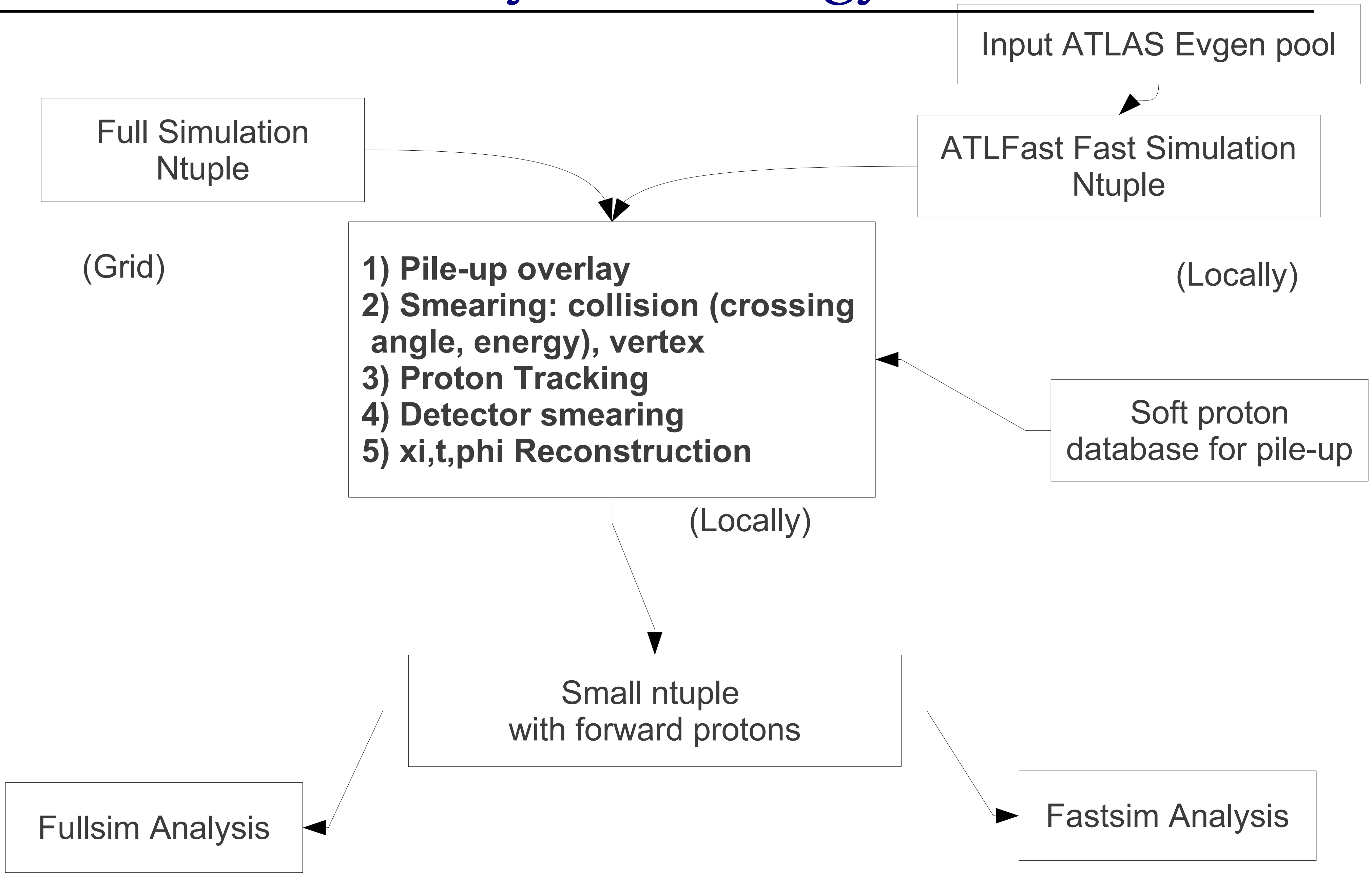
- +High mass W>800GeV

  μ = 23: $2\mathrm{x}10^{-4}$ μ = 46: 10^{-3}



- Can be parametrized using multinomial distribution

Simulation/Analysis Strategy



Overlay-Tracking Package

1) Pile-up overlay
2) Smearing: collision (crossing angle, energy), vertex
3) Proton Tracking
4) Detector smearing
5) xi,t,phi Reconstruction

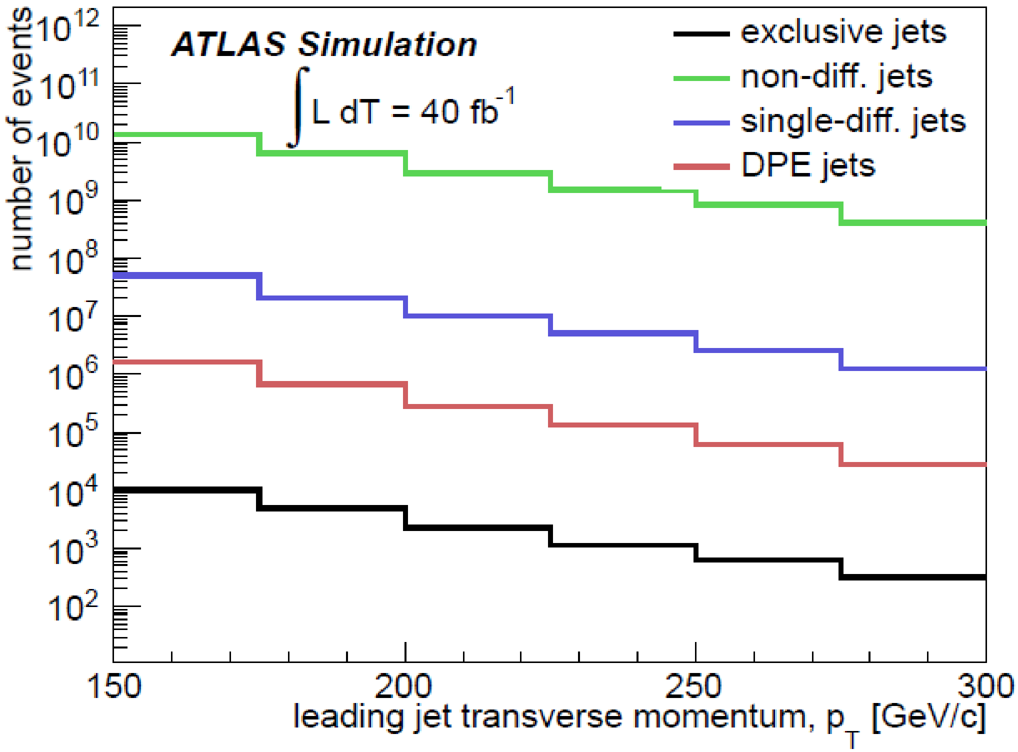
- Pre-selection of forward protons used for pile-up
  - Each background event has protons in AFP
  - Filter to have >=2 two protons in AFP
  - We do not loose events in analysis due to high mass W cut. Get the signal/background pile-up normalization right from efficiencies of these filters

- Smearing only protons, nothing done to objects in the cental detector
- Using FPTracker (P. Bussey) to transport protons, cross-checked with MadX

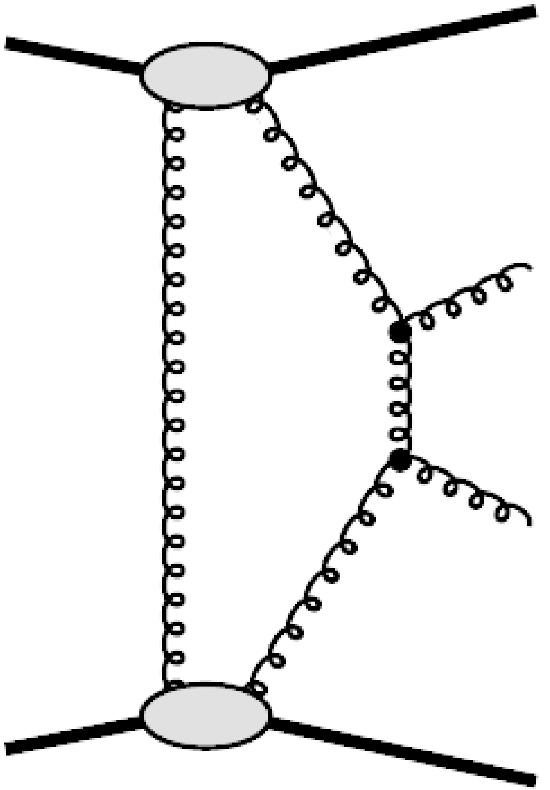
- Reconstruction xi, t, phi
  - Polynomial parameterization of the transport => inversion
  - Allows to study the impact of detector imperfections

Exclusive dijets

- Just one example where this simulation framework was used
  - Exploit the complete kinematic correlation between central detector and AFP



Six orders of magnitude to gain!



Exclusive Production

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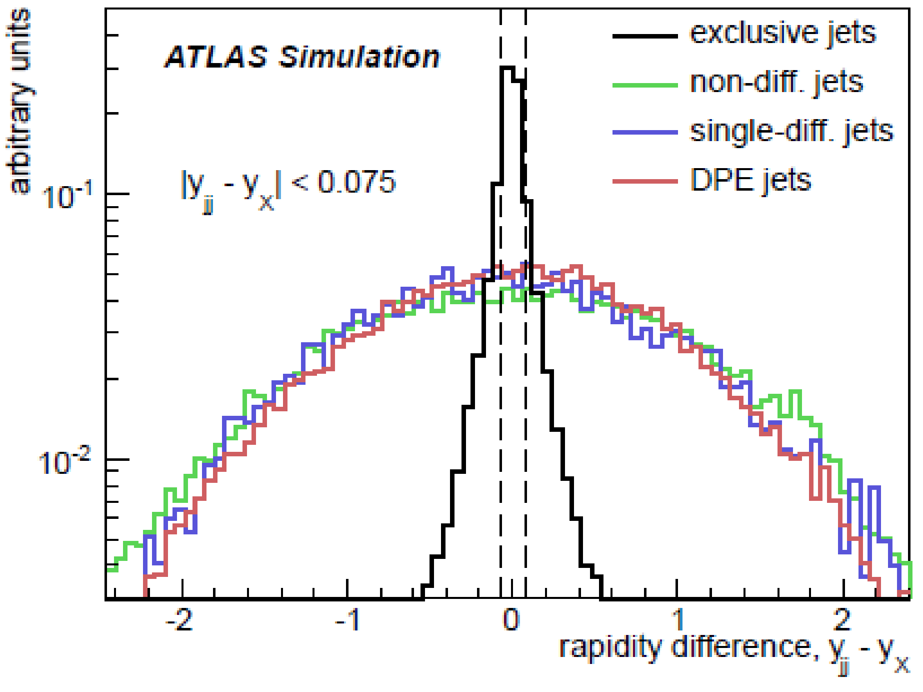
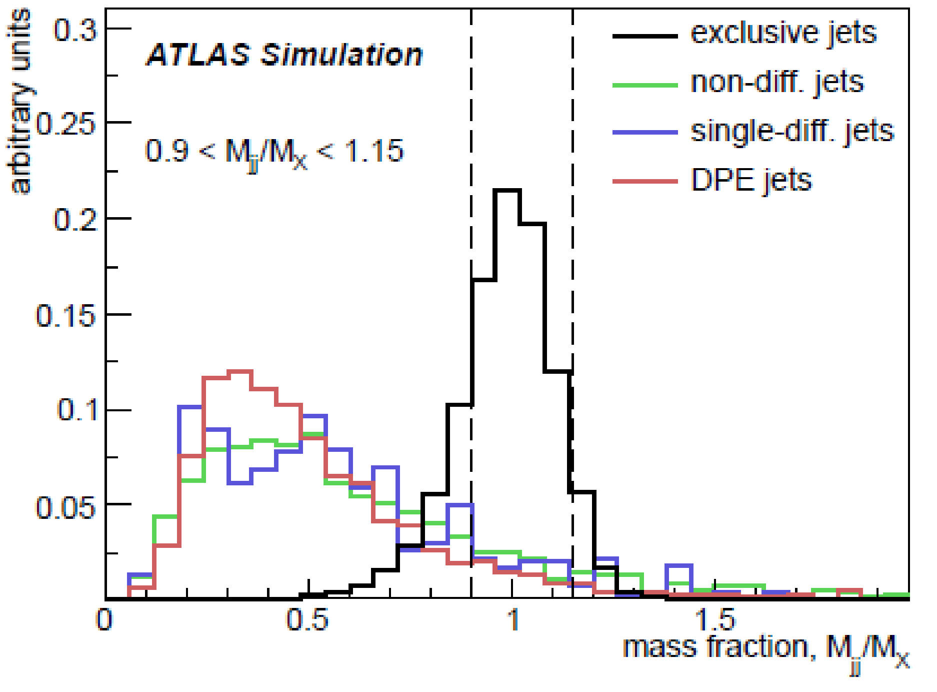
Exploiting the exclusive kinematics





Difference, $y_{jj} - y_X$, of the rapidity of the jet system (y_{jj}) and the rapidity of the proton system $y_X = 0.5 \cdot \ln\left(\frac{\xi_1}{\xi_2}\right)$

Ratio of the jet system mass to the missing mass $M_X = \sqrt{s \cdot \xi_1 \cdot \xi_2}$

Segmentation of timing detector

- At high pile-up the timing detector suffers from inefficiencies
  - In events in which two protons hit the same bar – the time measurement is lost

- 10 bars detector, 2mm width for all bars

Inefficiencies - Scenario 2										
Bar	1	2	3	4	5	6	7	8	9	10
$\mu = 50$	0.129	0.085	0.067	0.057	0.049	0.046	0.043	0.040	0.036	0.011
$\mu = 100$	0.185	0.122	0.097	0.082	0.071	0.066	0.062	0.057	0.051	0.016
$\mu = 300$	0.226	0.149	0.118	0.100	0.087	0.081	0.077	0.071	0.063	0.020

- Rates of multiple protons / bar large close to the beam
- Should be kept in mind for a design for high-luminosity (pixelisation?)

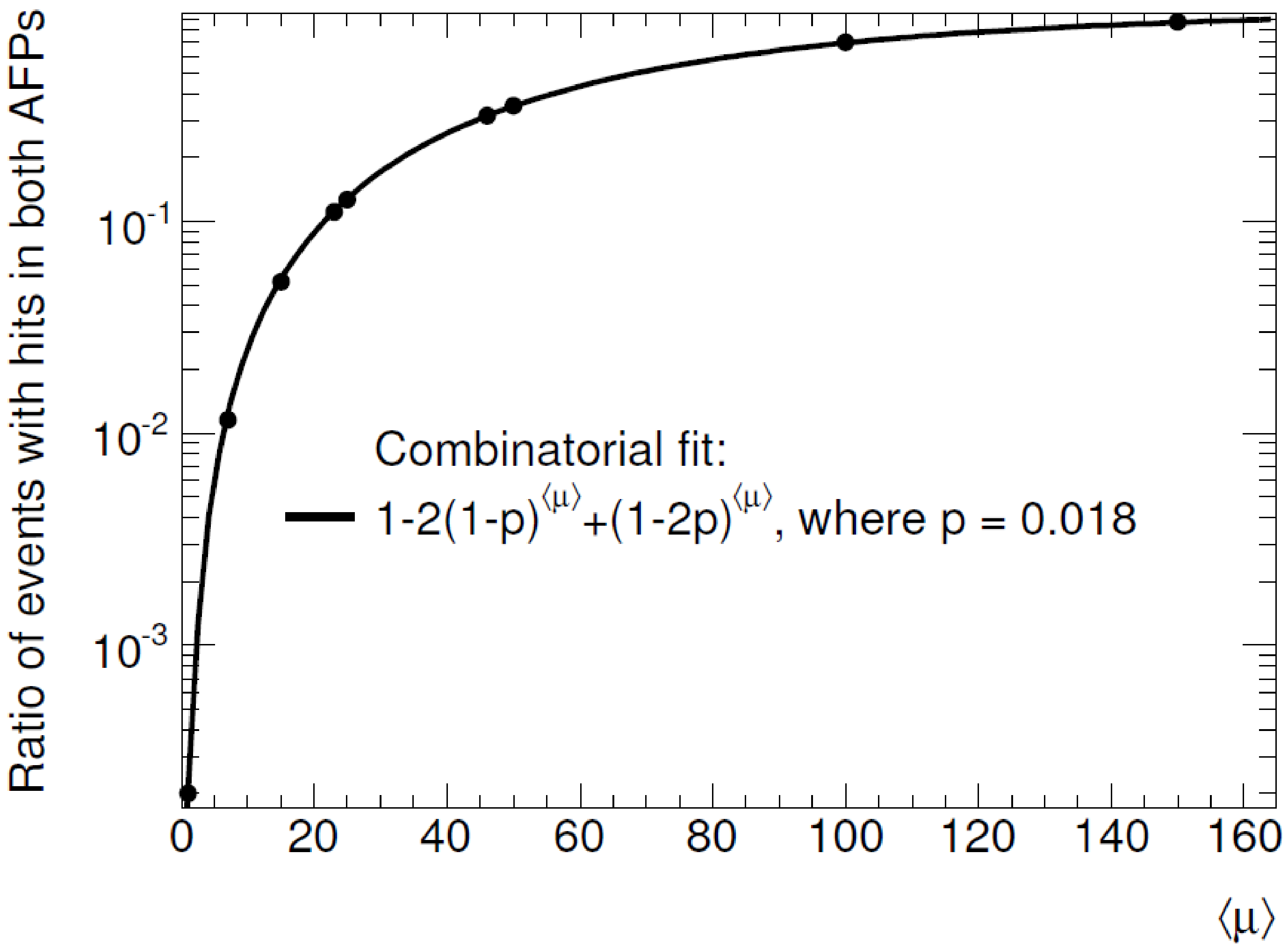
Summary

- Within AFP we have a working setup to analyze impact of pile-up in physics analysis

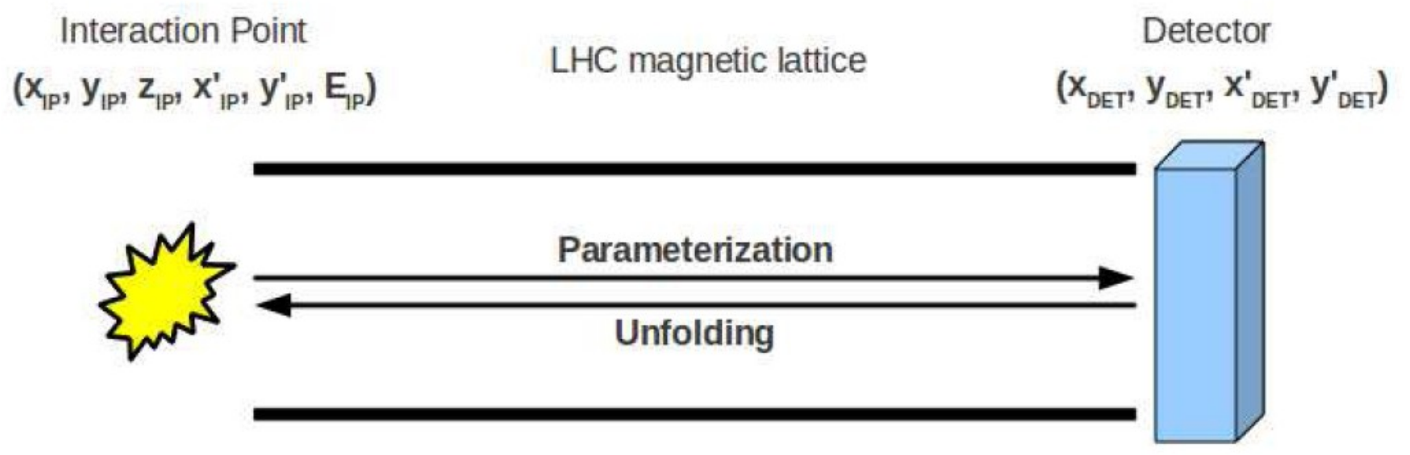
- Not depending on ATLAS Software, though using interface
- Can be adjusted to work on general HepMC format, and shared if needed

Backup

Combinatorics

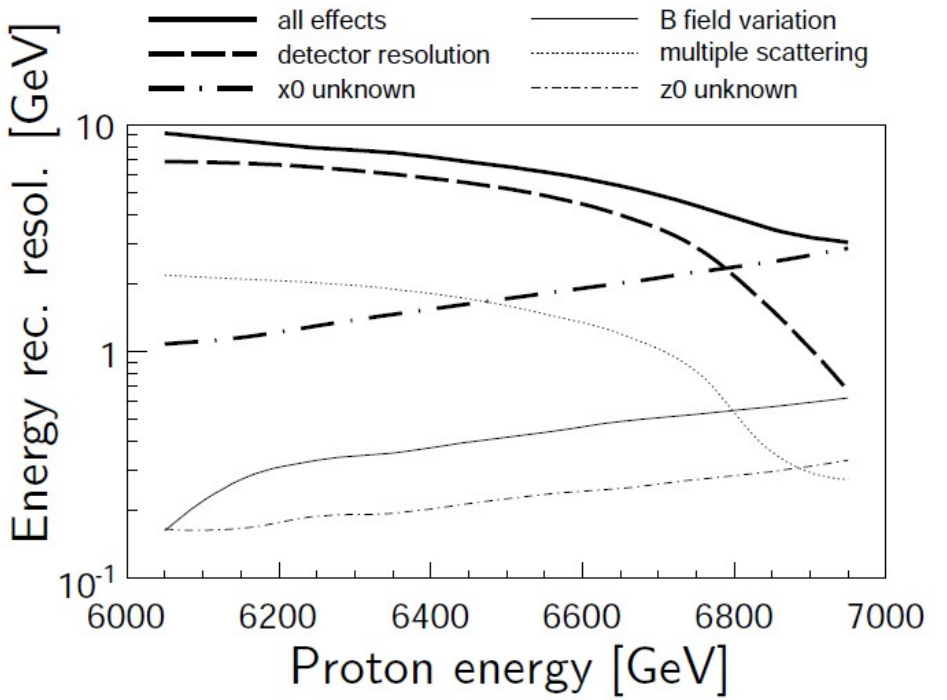


Proton kinematic reconstruction



Knowing proton position at both AFP stations one can reconstruct energy and momentum at the Interaction Point.

The energy reconstruction resolution is **better than 10 GeV**!



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Kinematics

- Acceptance large for 0.012 < ξ< 0.14
- Good resolution in ξ, not so great resolution in p_T
- Tag protons in both stations to reconstruct mass (resolution ~ 1-2% depending on mass)
- Timing detectors, mass trigger at L1 from course bars (quart/diamonds)