Double Pomeron Exchange Jet Production Feasibility Studies

Maciej Trzebiński

Institute of Nuclear Physics
Polish Academy of Sciences

Service de Physique des Particules
Institut de Recherche Fondamentale sur l'Univers
CEA Saclay

LHC Working Group on Forward Physics and Diffraction

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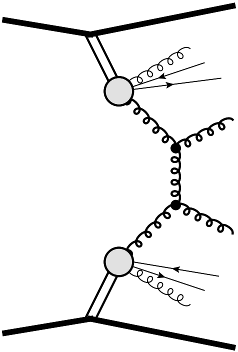
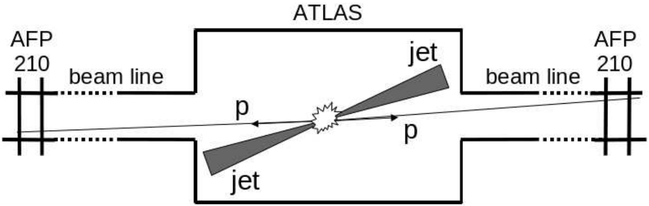
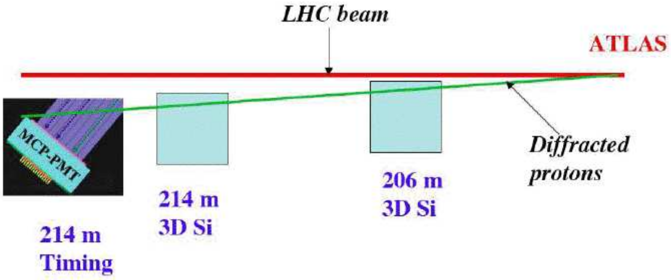
DPE Jet Production

DPE – Double Pomeron Exchange
Signature: two jets in central region + two intact protons.



Studies performed at high values of pile-up ($\mu \sim 23$) reveal that the purity was very small.
How the situation looks at low μ?



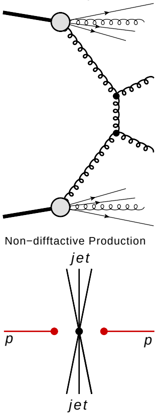


- Detector located close to the beam – Movable Beam Pipe.
- Proton position measurement (3-D Pixel detectors).
- Precise time of flight measurement (QUARTIC timing detector).

Background

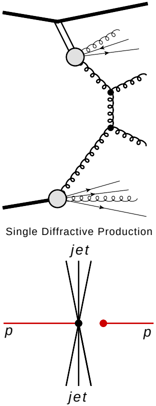
- highest cross section among all hard DPE processes – no other DPE process that is a background,
- background due to non-diffractive (ND) and single diffractive (SD) jets overlaid with pile-up protons

non-diffractive jets + pile-up



CS $\sim 10^4$ times higher than DPE

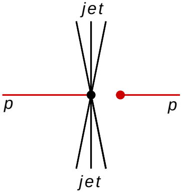
single diffractive jets + pile-up



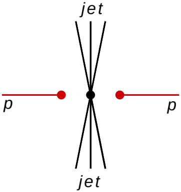
CS $\sim 10^2$ times higher than DPE

Probability of Single and Double Tag

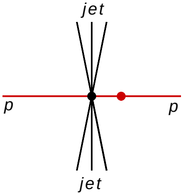
Single Tagged Soft Interaction(ST) Double Tagged Soft Interaction(DT)



SD JJ + ST



ND JJ + ST + ST



ND JJ + DT

Single Tag (ST) Interactions					
probability					
default	0.18	0.045	–	0.0055	0.038
MBR	0.12	0.040	0.42	0.0054	0.030
cross section [mb]					
default	2.3	0.40	–	0.32	3.0
MBR	1.3	0.38	0.34	0.30	2.3
	SD	DD	CD	ND	MB

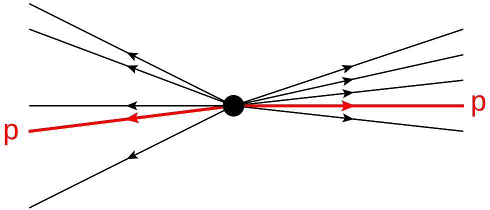
Double Tag (DT) Interactions					
probability [10^{-3}]					
default	0.47	0.37	–	0.014	0.13
MBR	0.31	0.36	26.0	0.012	0.37
cross section [μb]					
default	6.1	3.3	–	0.81	10
MBR	3.5	3.4	21	0.67	28
	SD	DD	CD	ND	MB

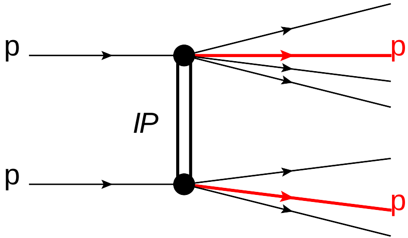
default – Schuler and Sjöstrand (PomFlux $= 1$)

MBR (PomFlux $= 5$)

Double Tagged Soft Interaction(DT)

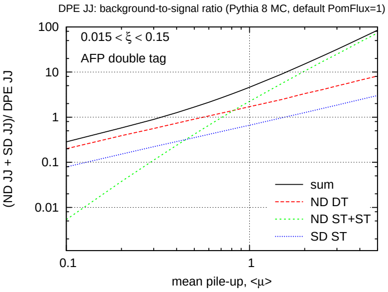
E.g. Double Diffractive Dissociation with protons from hadronisation propagating in forward direction.

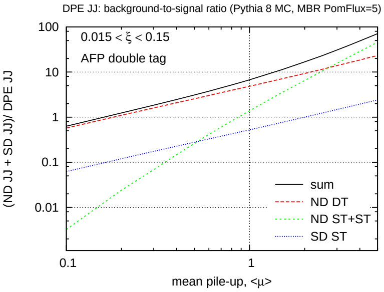




Large differences between MC generators and tunes!

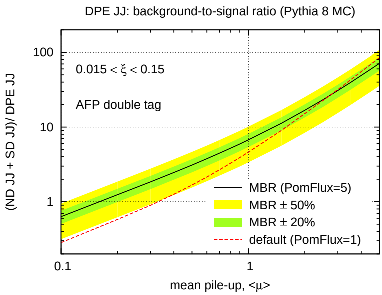
Background to Signal Ratio (I)

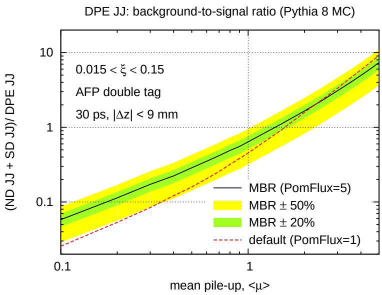




- generator: PYTHIA 8.165,
- **left**: Schuler and Sjöstrand (POMFLUX $= 1$),
- **right**: MBR (POMFLUX $= 5$),
- three main backgrounds:
  - Non-Diffractive Jets + soft event with two protons (red line), **dominates at $\mu < 1$**
  - Non-Diffractive Jets + two soft events with proton (green line), **dominates at $\mu > 1$**
  - Single Diffractive Jets + one proton (blue line),
- differences between tunes and various generators (not shown here)

Background to Signal Ratio (II)

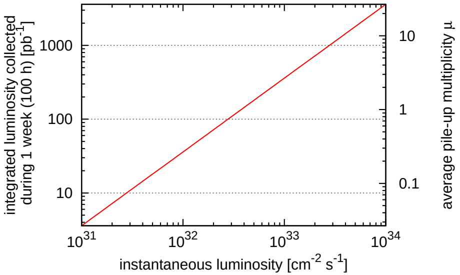


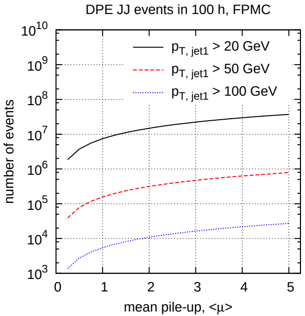


- **left**: B/S ratio **without** AFP timing cut,
- **right**: B/S ratio **with** AFP timing cut,
- 30 ps timing resolution, $|\Delta z| < 9$ mm,
- gain of one order of magnitude in B/S ratio

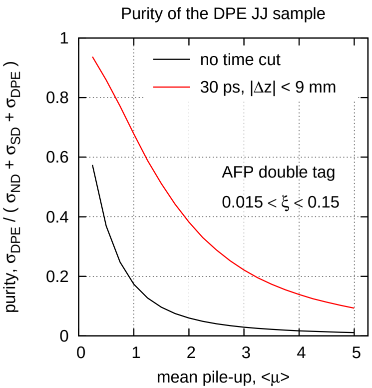
- **green** band – **20%** difference of having Single Tag event,
- **yellow** band – **50%** difference of having Double Tag event

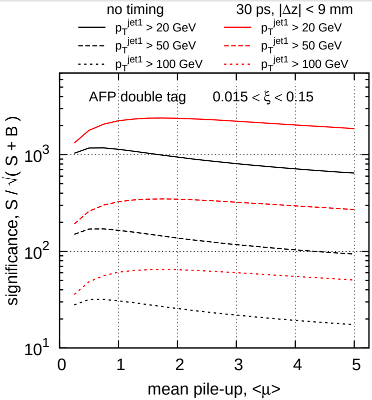
LHC Run Conditions





- **left**: dependence between the instantaneous luminosity of the machine, the average pile-up multiplicity and the integrated luminosity collected in 100 hour of data taking,
- **right**: number of signal events after the AFP double tag and timing requirements,
- for $\mu = 1$:
  - $\sim 8 \cdot 10^6$ for $p_{T,jet1} > 20$ GeV,
  - $\sim 2 \cdot 10^5$ for $p_{T,jet1} > 50$ GeV,
  - $\sim 5 \cdot 10^3$ for $p_{T,jet1} > 100$ GeV.





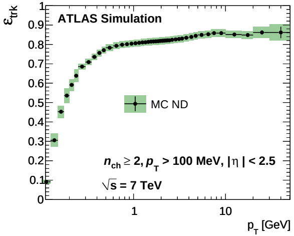
- **left**: purity of DPE sample $(S/(S+B))$:
  - without timing detectors: 0.2 for $\mu = 1$, 0.05 for $\mu = 3$,
  - with timing detectors: 0.7 for $\mu = 1$, 0.2 for $\mu = 3$,
- **right**: significance of DPE sample $(S/\sqrt{S+B})$:
  - without timing detectors maximum around $\mu = 0.5$,
  - with timing detectors wide maximum around $\mu = 1.5$.

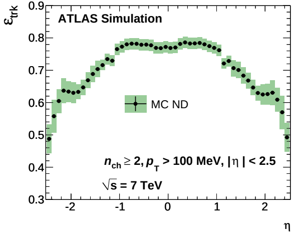
Purity Improvement – One Vertex Requirement

- significant measurement can be done only using the AFP double tag and timing requirements,
- purity can be increased by the requirement of exactly one reconstructed vertex in the event,
- background removed due to the presence of (at least) one additional soft interaction,
- signal events accompanied by pile-up will also be rejected,
- this cut works optimally when the mean pile-up is about 1,
- two inefficiency sources:
    - soft vertex is merged with a hard one ($\Delta z = 1$ mm, $\Delta z = 2$ mm),
    - not enough reconstructed tracks pointing to the soft vertex ($n_{trk} = 2$, $n_{trk} = 4$).

One Vertex Requirement

- ATLAS track reconstruction efficiency:

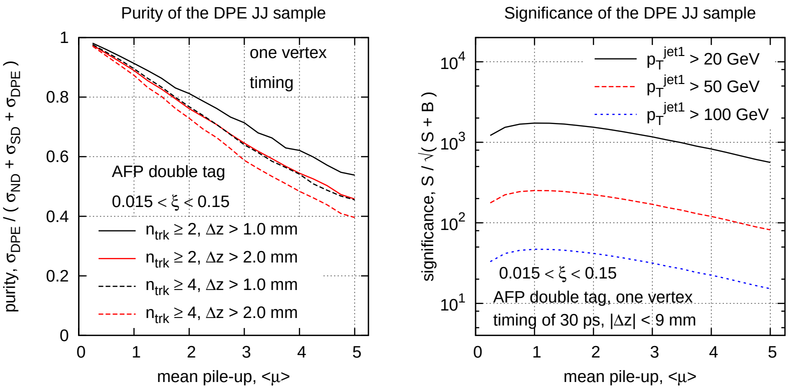




- **table**: prob. of the vertex reco. for a given number of tracks,
- last column contains a weighted sum of all listed processes,
- weight considers cross sections and probabilities of having a proton with $0.015 < \xi < 0.15$

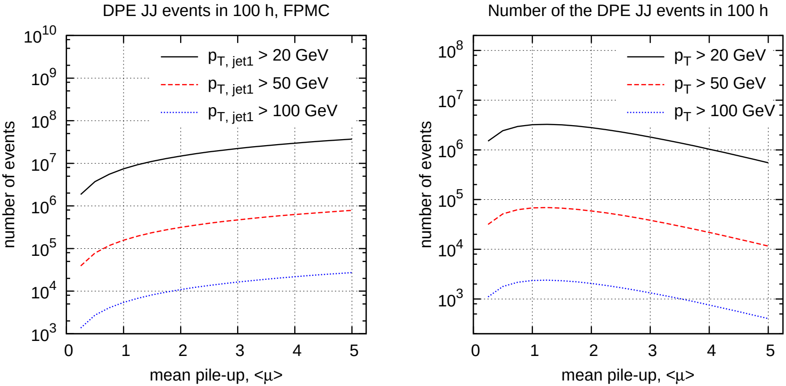
Min. number of tracks	Probability SD	DD	ND	min-bias
2	0.917	0.546	0.987	0.870
3	0.909	0.498	0.967	0.855
4	0.894	0.450	0.932	0.833
5	0.870	0.404	0.881	0.803

One Vertex Requirement – Purity and Significance



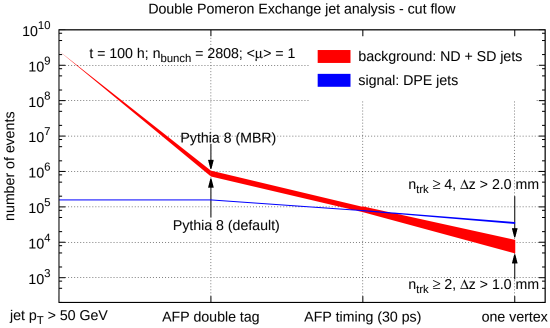
- **left**: purity of DPE sample
  - about 0.9 for $\mu = 1$,
  - small impact of minimal number of tracks and vertex merging effect,
- **right**: significance of DPE sample

Number of Events



- **left**: AFP double tag and timing requirement
- **right**: additional requirement of one reconstructed vertex

Cut Flow



- number of bunches, $n_{bunch} = 2808$, $\mu = 1$, 100 h of data collecting,
- **process possible to be measured using AFP detectors**,
- requirement of one vertex results in high purity,
- colour bands represents different cut possibilities rather than uncertainty,
- at the time of the DPE measurement, the probability of having forward proton in the AFP acceptance will be measured by CMS/TOTEM or AFP detectors

Experimental Effects – Summary

- Discussed:
  - minimum bias protons – uncertainty on single and double tag probability,
  - vertex merging,
  - track reconstruction efficiency.
- Not covered in this talk:
  - trigger,
  - jet reconstruction,
  - particle showers from collimators/LHC apertures,
  - silicon and timing detectors inefficiency.

Summary

- **DPE process possible to be measured using AFP detectors!**
- Large differences in ST and DT predictions between MC generators and tunes.
- AFP double tag and timing requirements enable a significant measurement.
- One vertex requirement increases purity to ~ 0.9 for $\mu = 1$.