On the possibility to study multiple parton scattering in ATLAS experiment

О возможности изучения многопартонных взаимодействий в эксперименте АТЛАС

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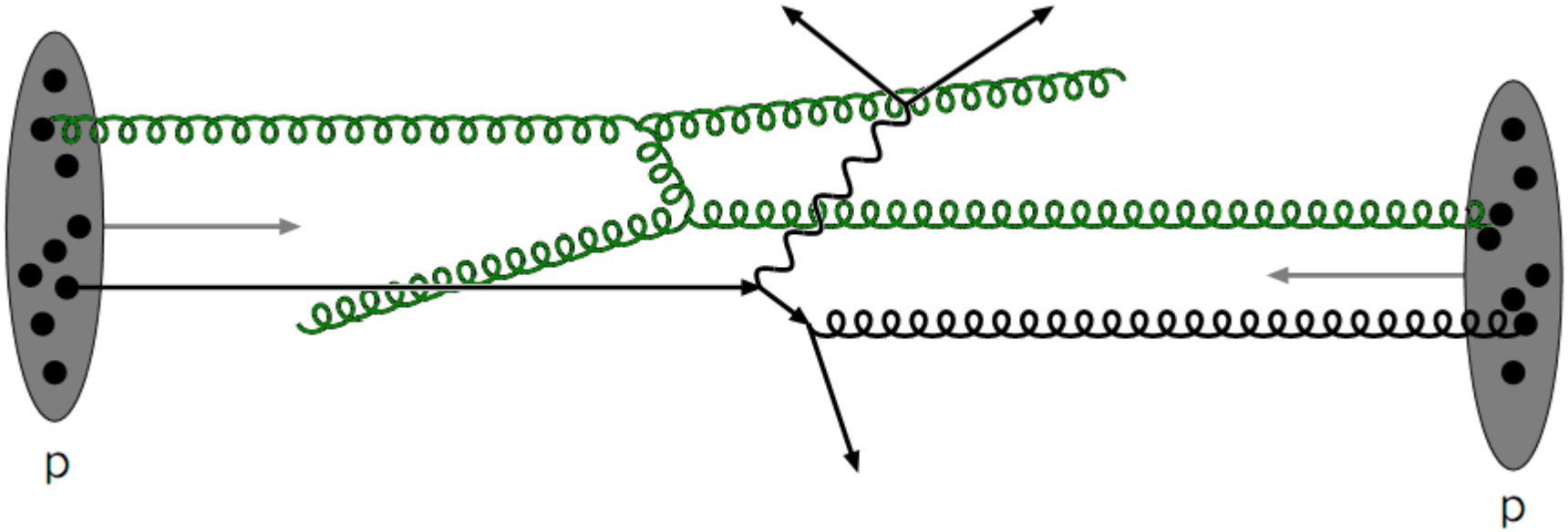
Introducion

- Double (multiple) parton scattering (DPS (MPS)) = process where two (more) parton scatterings occur in one hadron-hadron interaction.
- The impact parameter is the source of the spatial correlations of partons.
- The connecting gluons are the source of process correlations.
- The MPS provides information on spatial distribution of partons within the proton as well as other parton-parton correlations.



Cross section of DPS

- In the simplest model, DPS is a combination of two independent scatterings. For the DPS process comprised of scatterings A and B

$$\sigma_{\mathrm{DPS}} = \frac{\sigma_A \sigma_B}{\sigma_{\mathrm{eff}}}$$

- An additional factor of one-half is needed if A and B are indistinguishable scatterings.
- σ_{eff} contains all information about the non-perturbative structure of proton, in simplest approximation: $\sigma_{eff} \sim$ *size of proton* $= \pi R^2 \sim 40$ *mb*.
- This value differs significantly from the measured values.

Effective cross section measurements

- AFS Collaboration: [T.Akesson et al., Z.Phys.C34 (1987) 163]
  - pp interactions at $\sqrt{s} = 63\ GeV$
  - Search for 4 jet events; Result: $\sigma_{eff} = 5\ mb$
- UA2 Collaboration: [J.Alitti et al. [UA2 Collaboration], Phys.Lett. B268 (1991) 145]
  - pp(bar) interactions at $\sqrt{s} = 630\ GeV$
  - Search for 4 jet events; Result: $\sigma_{eff} > 8.3\ mb$ at 95% C.L.
- CDF Collaboration:
  - pp(bar) interactions at $\sqrt{s} = 1.8\ TeV$
  - Search for 4 jet events; Result: $\sigma_{eff} = 12.1\ mb$
    [F.Abe at al. [CDF Collaboration], Phys.Rev. D47 (1993) 4857]
  - Search for 3 jets+direct photon; Result: $\sigma_{eff} = 14.5 \pm 1.7\ mb$
    [F.Abe at al. [CDF Collaboration], Phys.Rev.Lett. 79 (1997) 584]

The final states

- Ways to obtain the same final state:
  - Perturbative corrections to the single parton scattering (the leading QCD process)
  - Multiple parton scattering

- Competitive final states of DPS:
  - 4 b-jets / $H \rightarrow bb'$
  - 3 jets + γ / direct photon production
  - Same-sign W pair production
  - Vector boson + 2 jets
  - Double Drell – Yan

Generation of MPS with *pythia8*

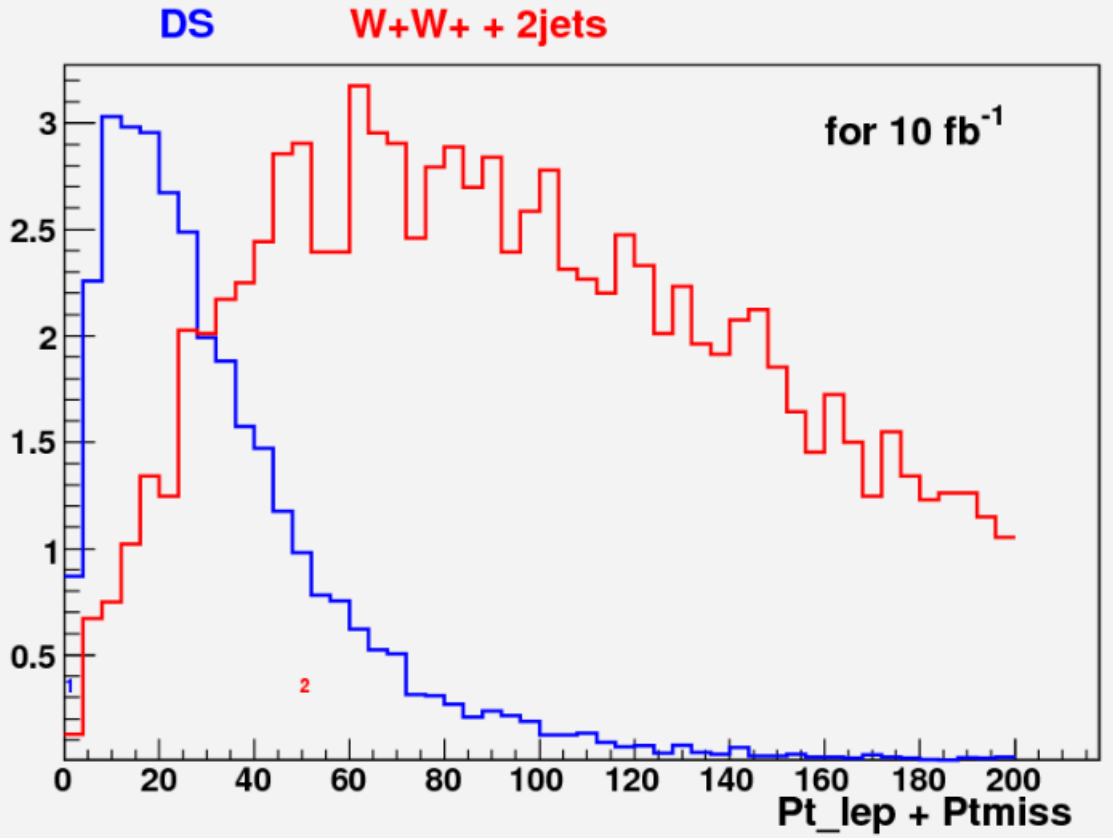
- Model assumptions:
  - Central collisions are likely to have more activity, peripheral – less.
    Impact factor *f_impact* is chosen event-by-event and can be averaged during the course of the run.
  - The double Gaussian form of matter overlap profile, used in the Tune A (default), gives approximately $\langle f\_impact \rangle = 2.5$,

$$\sigma_{eff} = \sigma_{ND} / \langle f\_impact \rangle$$

where σ_{ND} is the total non-diffractive cross section.

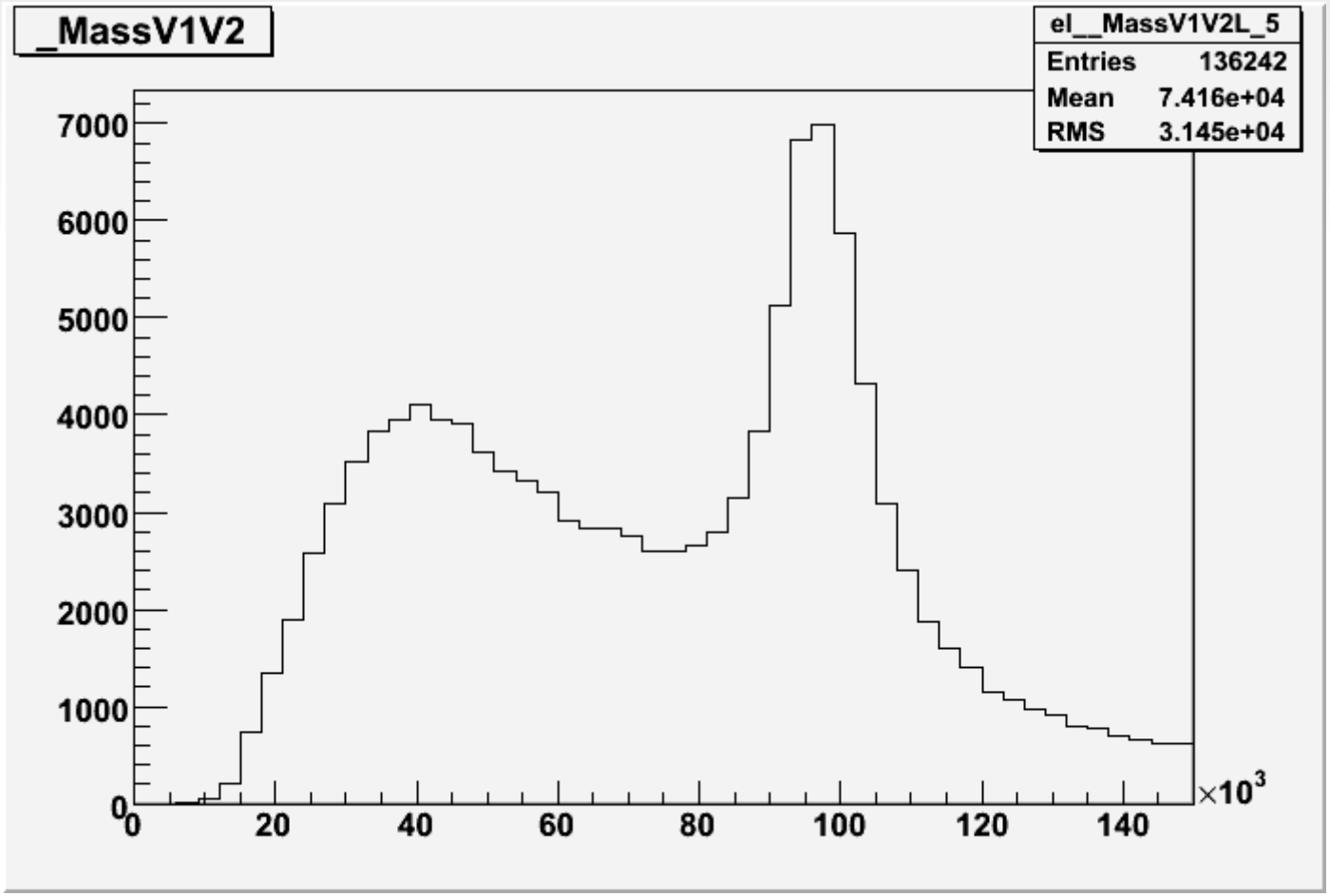
Same-sign *W* pair production

- $\sigma_{W+W+\,(DS)} = 0.30\ pb$ $\sigma_{W-W-\,(DS)} = 0.16\ pb$ *(pythia8)*
- $\sigma_{W+W+\,\&\,2j} = 0.54\ pb$ $\sigma_{W-W-\,\&\,2j} = 0.27\ pb$ *(MadGraph)*
- Reducible backgrounds:
  - *WZ* production with further loss of 1 lepton from *Z*,
  - Wrong lepton sign reconstruction,
  - Photons identified as electrons.



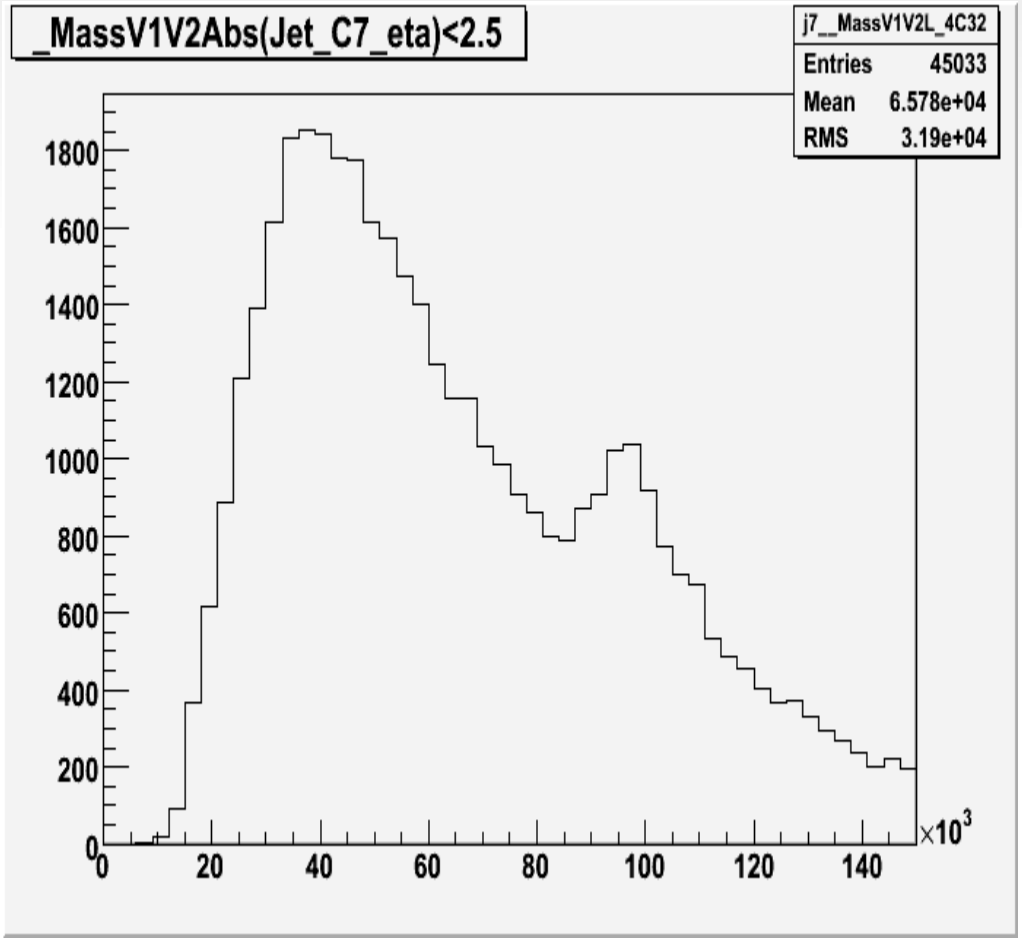
Reducible BG – WZ

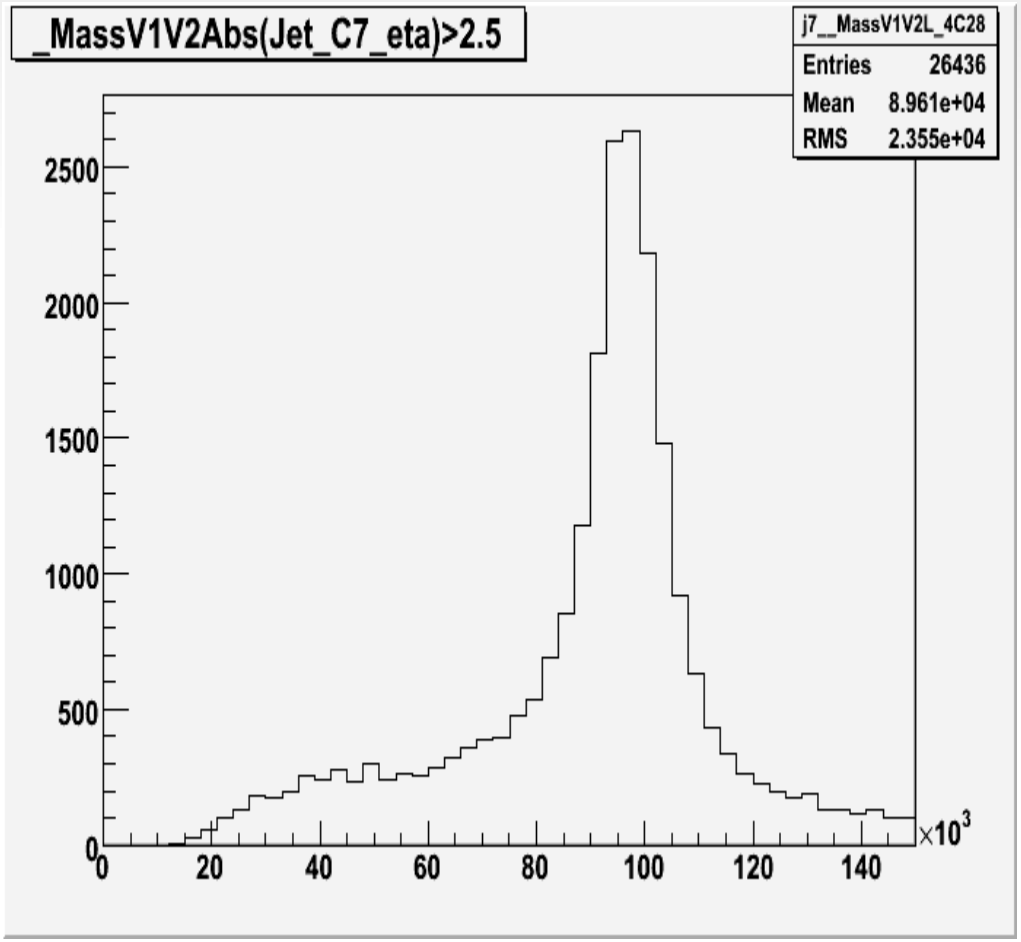
- Inv. mass of *(e + jet)* for events with $N_e = 1$



Reducible BG – *WZ*

- Jet in barrel vs. jet out barrel





Reducible BG – wrong lepton sign reconstruction

- $\frac{\sigma_{W+W-}}{\sigma_{W+W+(DS)}} \sim 40$
- Probability of sign misidentification can be obtained from the real data on the decays of *Z-candidates*. The expected value is ~ 2-3% => $\frac{signal}{backgound} \sim 0.8$
- For detector there is no difference between *e* from *Z* decay and from *W* decay.
- So, this BG can be measured precisely and subtracted.

Single *Z* plus 2 jets

- $Z(\rightarrow e^+e^-, \mu^+\mu^-)$ plus 2 jets production:
  - $\sigma_{Z+2j\ (DS)} = 0.57\ nb$ *(pythia8)*
  - $\sigma_{Z+j} = 1.5\ nb$ *(MadGraph + pythia)*
  - $\sigma_{Z+2j} = 1.1\ nb$ *(MadGraph + pythia)*
  - $\sigma_{Z+3j} = 0.74\ nb$ *(MadGraph + pythia)*

Single *W* plus 2 jets

- $W(\rightarrow ev, \mu\nu)$ plus 2 jets production:
  - $\sigma_{W+2j\ (DS)} = 6.1\ nb$ *(pythia8)*
  - $\sigma_{W+j} = 8.0\ nb$ *(MadGraph + pythia)*
  - $\sigma_{W+2j} = 5.8\ nb$ *(MadGraph + pythia)*
  - $\sigma_{W+3j} = 4.1\ nb$ *(MadGraph + pythia)*

Conclusion

- MPS will contribute to many important processes, like a Higgs boson production.
- The precise measurement of the MPS cross sections can bring a more accurate picture of hadron structure.
- Cross-sections of DPS processes are sufficient for DPS to be observed at LHC luminosities.
- ATLAS detector provides effective means of DPS investigation.