A Parton-Level Simulation of DPS

Baptiste Cabouat

In collaboration with J. R. Gaunt and K. Ostrolenk
School of Physics and Astronomy, Schuster Building, University of Manchester
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Outline[1]

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2. Combining parton showers and dPDFs
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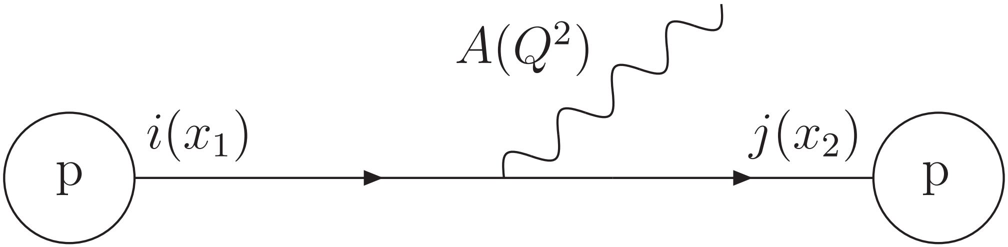
Double vs. single parton scattering

- Single parton scattering (SPS):

$$\sigma_A^{\mathrm{SPS}} = \sum_{i,j} \int \mathrm{d}x_1 \mathrm{d}x_2 \, \hat{\sigma}_{ij \to A}(\hat{s} = x_1 x_2 s, Q^2) \, f_i(x_1, Q^2) \, f_j(x_2, Q^2).$$

- $f_i(x, Q^2)$: Parton Distribution Functions (PDFs).



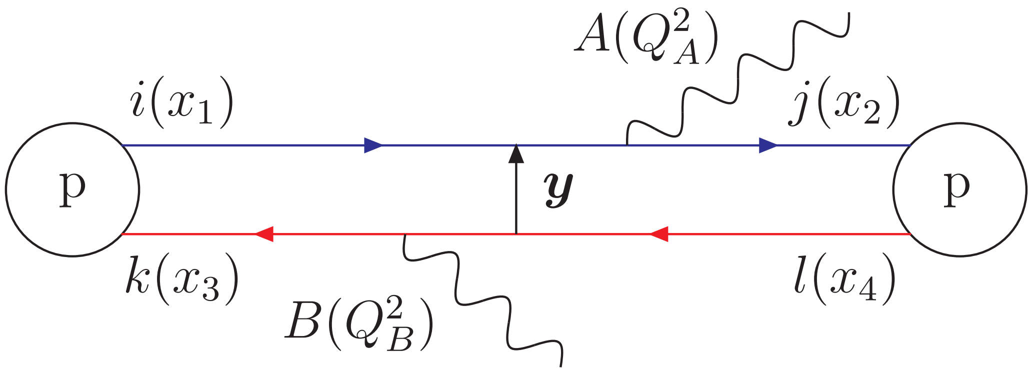
Double vs. single parton scattering

- Double parton scattering (DPS) [1710.04408]:

$$\sigma^{\text{DPS}}_{(A,B)} = \sum_{i,j,k,l} \int \mathrm{d}x_1\, \mathrm{d}x_2\, \mathrm{d}x_3\, \mathrm{d}x_4\, \hat{\sigma}_{ij\to A}(x_1 x_2 s, Q_A^2)\, \hat{\sigma}_{kl\to B}(x_3 x_4 s, Q_B^2)$$

$$\int \mathrm{d}^2\boldsymbol{y}\, F_{ik}(x_1, x_3, \boldsymbol{y}, Q_A^2, Q_B^2) F_{jl}(x_2, x_4, \boldsymbol{y}, Q_A^2, Q_B^2).$$

- $F_{ij}(x_1, x_2, \boldsymbol{y}, Q_A^2, Q_B^2)$: dPDFs.



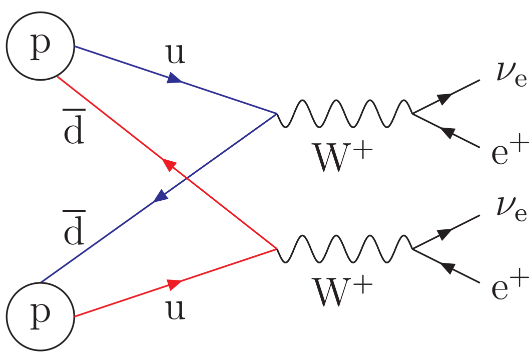
Why do we consider double parton scattering?

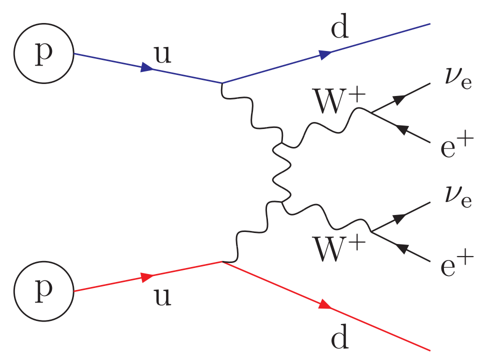
$\sigma^{\mathrm{DPS}}_{(A,B)}/\sigma^{\mathrm{SPS}}_{A+B} \sim \Lambda^2/Q^2$. But:

- For bosons with small transverse momenta [1111.0910]:

$$\frac{\mathrm{d}\sigma^{\mathrm{DPS}}_{(A,B)}}{\mathrm{d}^2\boldsymbol{q}_A \mathrm{d}^2\boldsymbol{q}_B} \sim \frac{\mathrm{d}\sigma^{\mathrm{SPS}}_{A+B}}{\mathrm{d}^2\boldsymbol{q}_A \mathrm{d}^2\boldsymbol{q}_B}$$

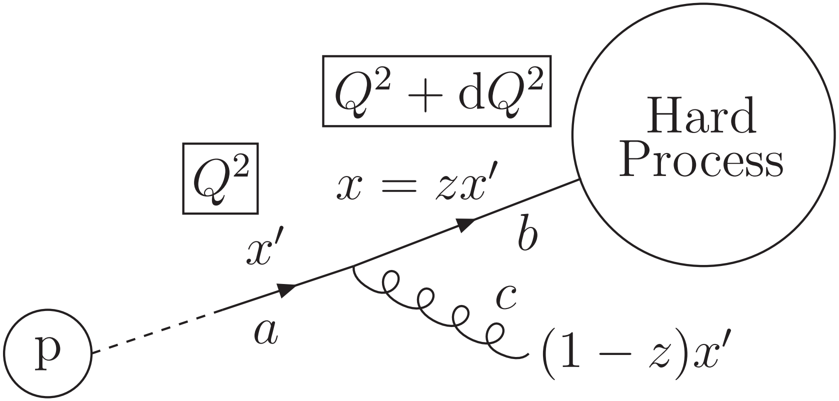
- SPS might be suppressed by a high multiplicity of couplings:





Parton shower

- Define the probability $\mathrm{d}\mathcal{P}_b = \mathrm{d}f_b(x, Q^2)/f_b(x, Q^2)$.



- Evolve downwards in Q^2 according to DGLAP equations:

$$\mathrm{d}f_b(x, Q^2) = \frac{\mathrm{d}Q^2}{Q^2} \sum_a P_{a\to bc}\left(\frac{x}{x'}\right) \otimes f_a(x', Q^2)$$

dDGLAP equations

- Homogeneous equal-scale dDGLAP equations [1702.06486]:

$$\mathrm{d}F_{ij}(x_1, x_2, \boldsymbol{y}, Q^2) = \frac{\mathrm{d}Q^2}{Q^2} \left(\sum_{i'} P_{i' \to i} \left(\frac{x_1}{x_1'} \right) \otimes F_{i'j}(x_1', x_2, \boldsymbol{y}, Q^2) + \sum_{j'} P_{j' \to j} \left(\frac{x_2}{x_2'} \right) \otimes F_{ij'}(x_1, x_2', \boldsymbol{y}, Q^2) \right)$$

- Inhomogeneous term included inside $F_{ij}(x_1, x_2, \boldsymbol{y}, Q^2)$ ($1/\boldsymbol{y}^2$ behaviour).

The simualtion

- Algorithm:

    1. Select two separate hard processes with the DPS cross section. A value for $\boldsymbol{y}$ is also selected.

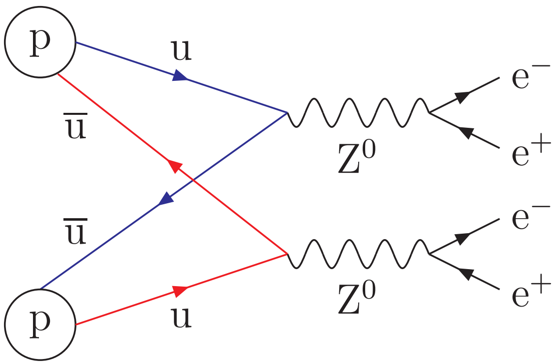
    2. Define the branching probability as $\mathrm{d}\mathcal{P}_{ij} = \mathrm{d}F_{ij}(x_1, x_2, \boldsymbol{y}, Q^2)/F_{ij}(x_1, x_2, \boldsymbol{y}, Q^2)$ [0408302].

    3. Shower simultaneously the two hard processes with an angular-ordered shower.

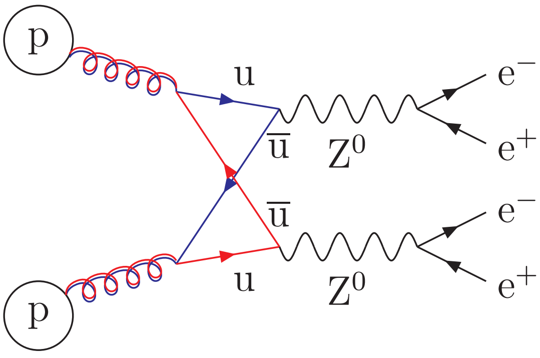
- The set of $\boldsymbol{y}$-dependent dPDFs has been developed in [1702.06486].

Merging

- The possibility to have mergings is included in the simulation:



Before merging

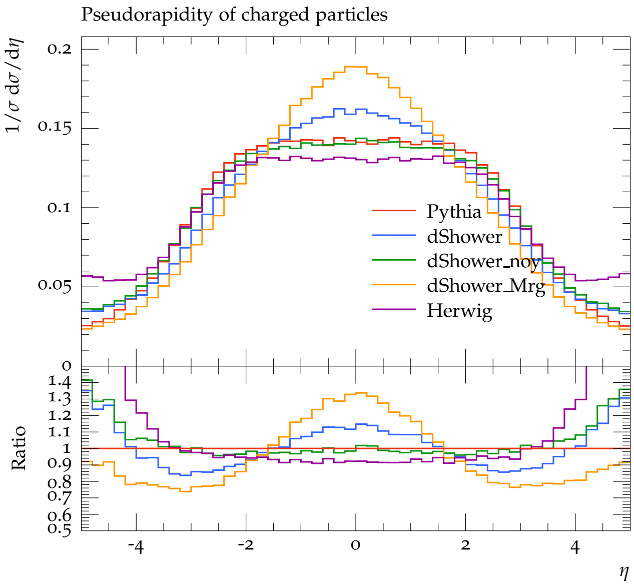


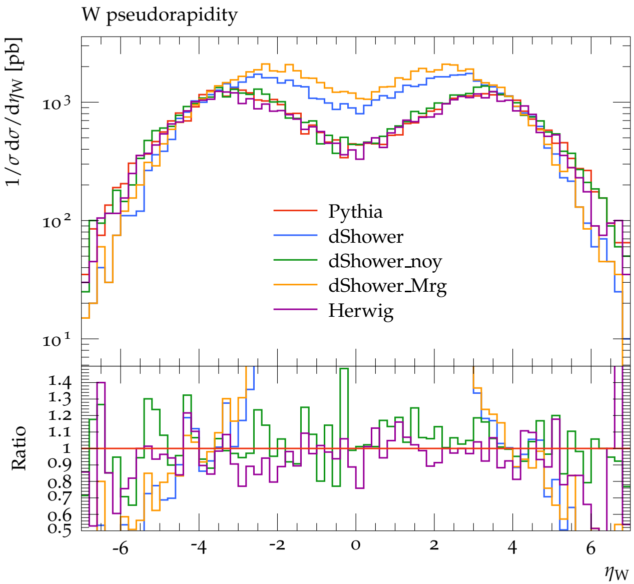
After merging

- But far from perfect (kinematics very difficult): still some problems and requires further work!

Results – W^+W^+

- DPS: $W^+ \to e^+\nu_e \oplus W^+ \to \mu^+\nu_\mu$ (no SPS channel).





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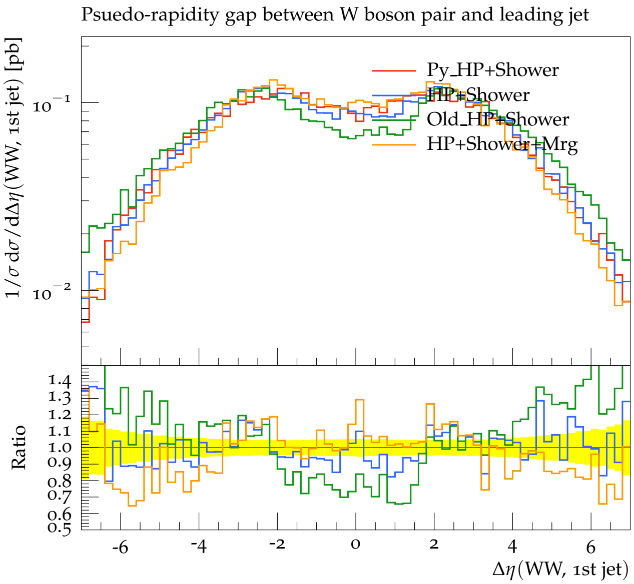

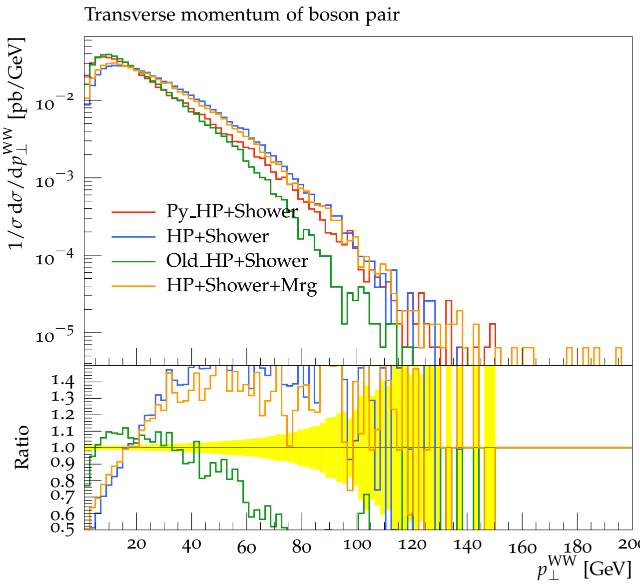

Summary

- Double parton scattering must be included to improve the precision of event generators. Combine dPDFs and parton showers.
- Use the $\boldsymbol{y}$-dependent dPDFs $F_{ij}(x_1, x_2, \boldsymbol{y}, Q^2)$.
- Extension to two different scales Q_A^2 and Q_B^2?
- MPI models might benefit from a parton shower based on dPDFs.

Thanks

Thanks for your attention!