Generic hadron–hadron and hadron–ion collisions in Pythia/Angantyr

Marius Utheim

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Objective and motivation

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Hadronic cascades

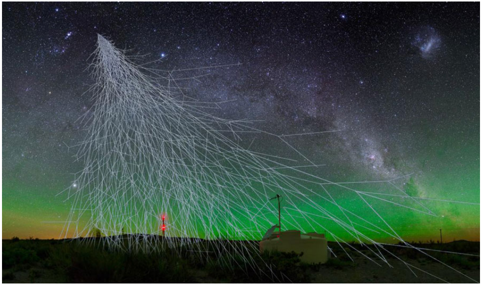

Image credit: A. Chantelauze, S. Staffi, L. Bret

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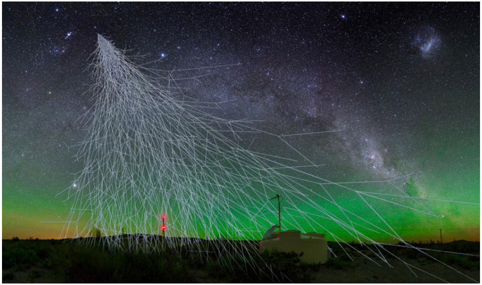

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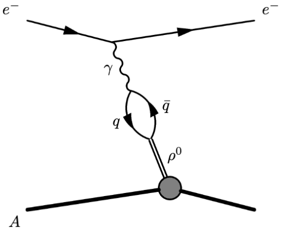
Electron–ion collisions



Outline

Generic hadron collisions

In the context of PYTHIA, going from *pp* collisions to generic hadron–hadron collisions requires three things:

1. Different total cross sections
2. Different partial cross sections
3. Different PDFs

Main reference: T. Sjöstrand and M. Utheim,
`https://doi.org/10.1140/epjc/s10052-021-09953-5`

Total cross sections

For high energy total cross sections, we use the Donnachie-Landshoff model:

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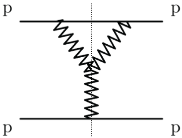
The coefficients X and Y are dependent on the hadron species. Before our work, these were defined in PYTHIA for only a few beam combinations. We define further coefficients by rescaling the coefficients of existing combinations, using e.g. the Additive Quark Model (AQM).

Partial cross sections

Elastic and diffractive cross sections are based on parameterizations by SaS, e.g.



$$d\sigma = \frac{g_{3\mathbb{P}}\beta_{A\mathbb{P}}\beta_{B\mathbb{P}}^2}{16\pi} \frac{dM_X^2}{M_X^2} (e^{B_{XB}t} dt)\, F_{\mathrm{SD}}(M_X^2, s)$$

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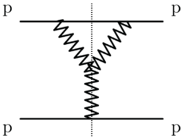

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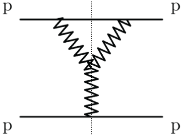

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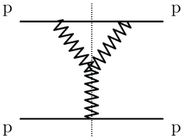

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- $B_{XB} = 2b_B + 2\alpha'_{\mathbb{P}}\log(s/M_X^2)$ with $b = 1.4$ for mesons and 2.3 for baryons
- F_{SD} is a fudge factor (out of scope for this talk)

Parton distribution functions

PDF data exists only for the most common hadron species. For other species, we base our valence distributions on an ansatz by Glück, Reya et al.:

$$f(x, Q_0^2 = 0.26\ \mathrm{GeV}^2) = Nx^a(1-x)^b(1 + A\sqrt{x} + Bx)$$

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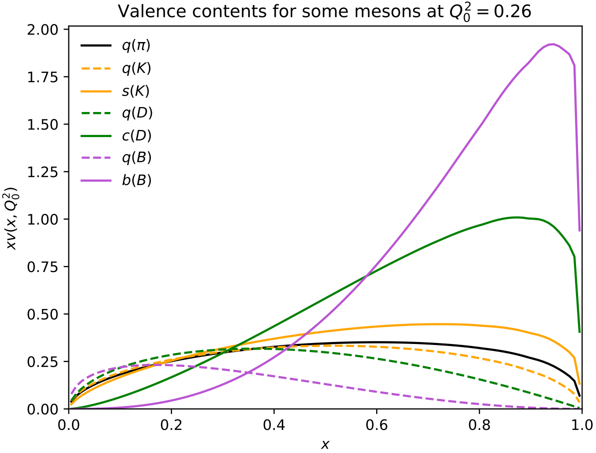
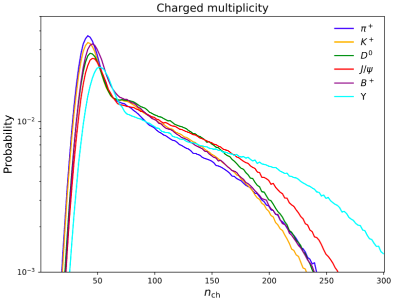
- a is fixed by b and $\langle x \rangle$, N is fixed by flavour sum relations.
- Sea and gluon distributions are given by $f_h(x) \propto x^d f_\pi(x)$, normalized to satisfy the momentum sum relations.

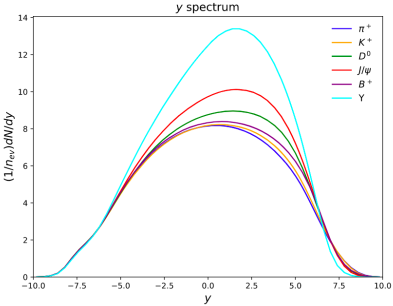
Parton distribution functions



- $\langle x \rangle$ is higher for heavy valence content, and correspondingly lower for light content.

Model tests





- Hadrons with heavier valence content generally lead to harder interactions and more activity
- Effect is particularly pronounced for J/ψ and Υ, which have no light valence.

Outline

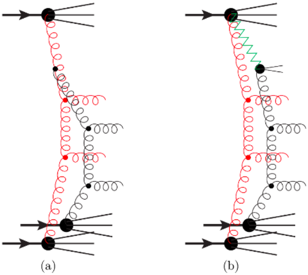
Generic hadron–hadron collisions

Angantyr and generic hadron–ion collisions

Outlook

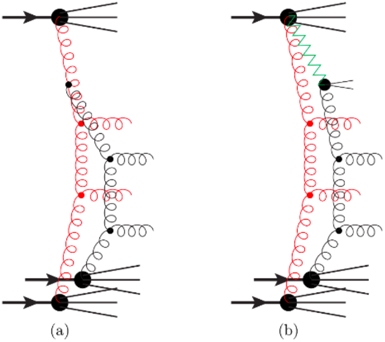
Angantyr overview

- Glauber model gives nuclear geometry. Each subcollision is assigned a type based on the impact parameter b_{NN}.
- Perform absorptive subcollisions with smallest b_{NN} first. Generate events to parton level.
- Secondary absorptive collisions are modelled like diffractive interactions.
- Combine partons from all subevents, then do color reconnection, string interactions, string hadronization, etc.



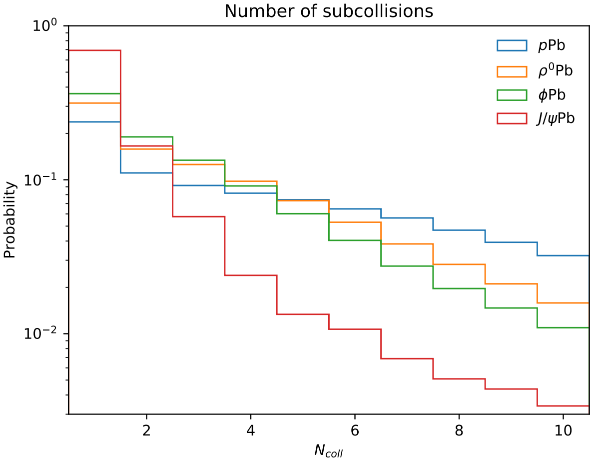
arXiv:1806.10820

Generic hadron–ion collisions in Angantyr



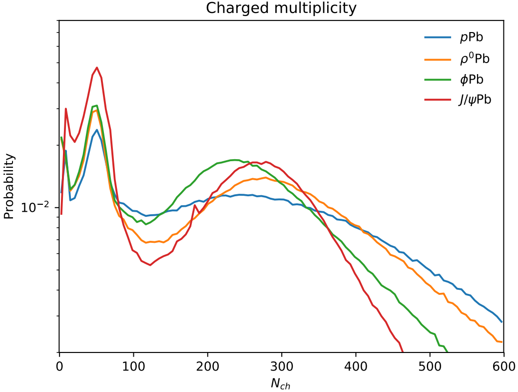
- Angantyr needs cross sections and process simulations. We already have those, so implementing *hA* is trivial – almost too good to be true!
- The only thing missing for hadronic cascade simulations is variable energies.

Model tests



- Heavier quark content implies fewer subcollisions, but more activity per subcollision.

Model tests



- In *hA*, there is one or zero absorptive interactions.
- Peaks are especially narrow for J/ψ
- Note that ϕ peak is not between ρ^0 and J/ψ.

Outline

Outlook

- Generic hadron–hadron collisions were implemented in PYTHIA 8.307. Expect to see hadron–ion in 8.308.
- The main thing missing before Angantyr can be fully used in hadronic cascades is variable energy.
- Having implemented hA, we can give a detailed description of γA. Our ultimate goal is a detailed minimum-bias simulation of $e^{-}A$.