Hard diffraction in PYTHIA8

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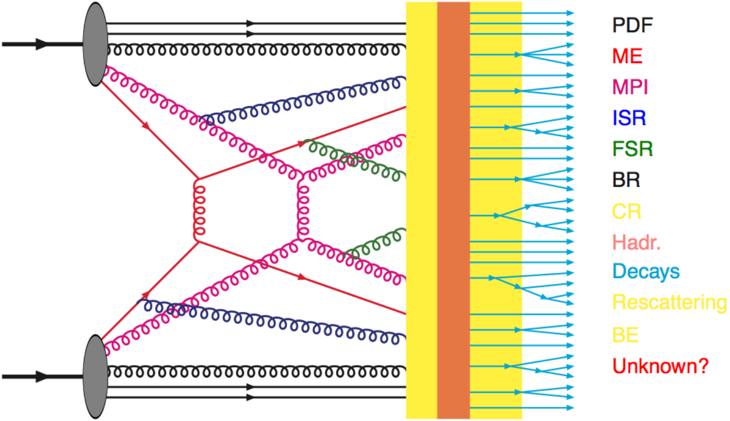
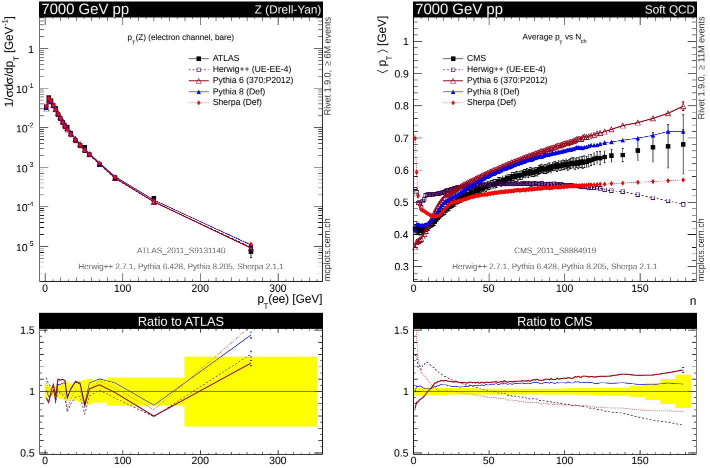
- PYTHIA8
- Soft diffraction
- Hard diffraction
- Preliminary results
- Conclusion and outlook

PYTHIA8 is a general purpose event generator for high-energy collisions.



It attempts to describe all parts.
[Figure: T. Sjöstrand]

And does a fairly good job for most of the physics:



Figures from MCPlots: [mcplots.cern.ch]

PYTHIA8

Currently 8 authors (incl. 3 post-docs and 2 PhD students).

New main features as of version 8.2:

- New models of colour reconnections
  (J. Christiansen, P. Skands + T. Sjöstrand)
- Variety of matching and merging schemes
  (S. Prestel + L. Lönnblad)

Ongoing work:

- New PDF for photons for e^+e^- studies
  (I. Helenius + T. Sjöstrand)
- New model for hard diffraction
  (C. Rasmussen + T. Sjöstrand)

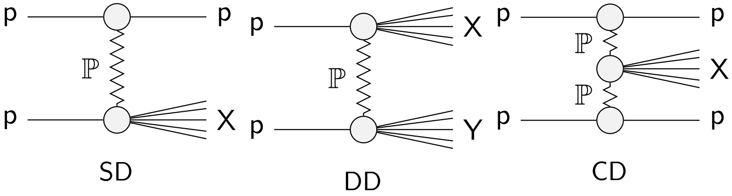
An Introduction to PYTHIA8.2
[Comput.Phys.Commun. 191 (2015) 159]

Soft diffraction

The soft diffractive PYTHIA8 machinery is based on the Ingelman-Schlein picture of a Pomeron as a hadronlike state.

$\mathbb{P}$p and $\mathbb{P}\mathbb{P}$ collisions are here developed to also include the interleaved parton evolution of MPI, ISR and FSR.

MPI gives a smooth merging of hard jets and soft events.



Soft diffraction

Low-mass region:
$M_{\mathrm{X}} \leq 10$ GeV.

- Represent M_{X} as longitudinal string
- Probability to take out a gluon or quark from Pomeron: $\frac{P(\mathrm{q})}{P(\mathrm{g})} = \frac{N}{M^p}$, p tunable
- Quark $=$ 1 string, gluon $=$ 2 strings
- No ISR, FSR, MPI
- Fragment with Lund String fragmentation model

High mass region:
$M_{\mathrm{X}} > 10$ GeV.

- Based on Ingelman-Schlein approach
- Set up $\mathbb{P}\mathrm{p}$ system
- MPI machinery decide interactions
- Includes interleaved MPI, ISR, FSR evolution in $\mathbb{P}\mathrm{p}$ system
- Now includes 7 models for Pomeron flux and 5 for Pomeron PDF

Soft diffraction

σ_{SD} with Pomeron-based parametrisation of Schuler-Sjöstrand:

$$\frac{\mathrm{d}^2\sigma_{\mathrm{SD}}}{\mathrm{d}t\,\mathrm{d}M^2} = \frac{g_{3\mathbb{P}}}{16\pi}\beta_{A\mathbb{P}}\beta_{B\mathbb{P}}^2\frac{1}{M^2}\exp(B_{\mathrm{SD}}t)F_{\mathrm{SD}}$$

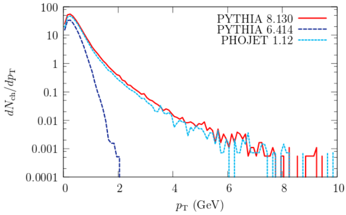
MPI activity in SD tuned to give approximately same amount as in ND:

$$\langle n_{\mathrm{MPI}}\rangle(\mathrm{ND}) \sim \frac{\sigma_{\mathrm{hard}}}{\sigma_{\mathrm{ND}}} \Rightarrow$$

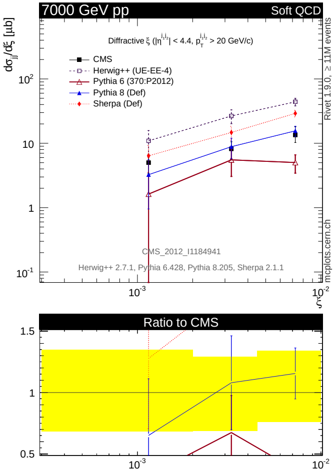
$$\langle n_{\mathrm{MPI}}\rangle(\mathrm{SD}) \sim \frac{\sigma_{\mathrm{hard}}(\mathrm{No\,gap\,survival})}{\sigma_{\mathbb{P}\mathrm{p}}(\mathrm{No\,gap\,survival})} = \frac{\sigma_{\mathrm{hard}}}{\sigma_{\mathbb{P}\mathrm{p}}^{\mathrm{eff}}}$$

with $\sigma_{\mathbb{P}\mathrm{p}}^{\mathrm{eff}} = 10$ mb, tunable.
Gap always survives, as MPI not allowed between Pomerons hadron-remnant and other hadronic remnant.

Soft diffraction



p_T distribution for SD events at 7 TeV. From S. Navin [arXiv:1005.3894[hep-ph]].



From MCPlots [mcplots.cern.ch]

Hard diffraction

Objective: Given a hard scattering, $ab \to cd$, what is the probability for this to have been created in a diffractive process?

Available: Parton id, x and Q^2.

Method: Evaluate the diffractive structure function and use dynamical gap survival.

Assumption 1: The hadronic PDFs can be split into non-diffractive and diffractive.

$$f_i(x, Q^2) = f_i^{\mathrm{ND}}(x, Q^2) + F_i^{\mathrm{D}}(x, Q^2)$$

Assumption 2: The diffractive structure function factorises.

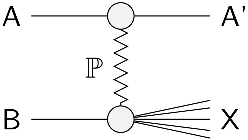
$$F_i^{\mathrm{D}}(x, Q^2) = \int_x^1 \frac{\mathrm{d}\xi}{\xi} \int_{t_{\min}}^{t_{\max}} \mathrm{d}t \, f_{\mathbb{P}/p}(\xi, t) \, f_{i/\mathbb{P}}(x/\xi, Q^2)$$

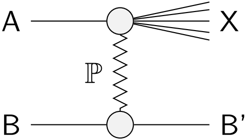
Hard diffraction

Only flux is t-dependent, hence we integrate t out:

$$f_{\mathbb{P}/\mathrm{p}}(\xi) = \int_{t_{min}}^{t_{max}} \mathrm{d}t\, f_{\mathbb{P}/\mathrm{p}}(\xi, t)$$

with mass-dependent limits, $t = t(m^2_{\mathrm{A}}, m^2_{\mathrm{B}}, m^2_{\mathrm{A}'(\mathrm{X})}, m^2_{\mathrm{X}(\mathrm{B}')})$.

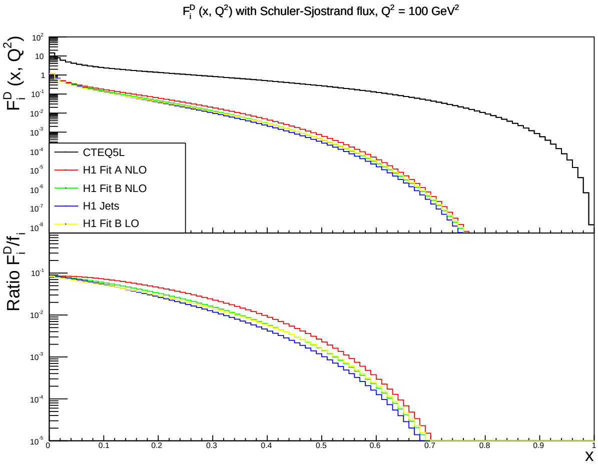




The probabilities for either sides to be diffractive are

$$P_{\mathrm{B}} = F^{\mathrm{D}}(x_a, Q^2)/f_{\mathrm{p}}(x_a, Q^2)$$
$$P_{\mathrm{A}} = F^{\mathrm{D}}(x_b, Q^2)/f_{\mathrm{p}}(x_b, Q^2)$$

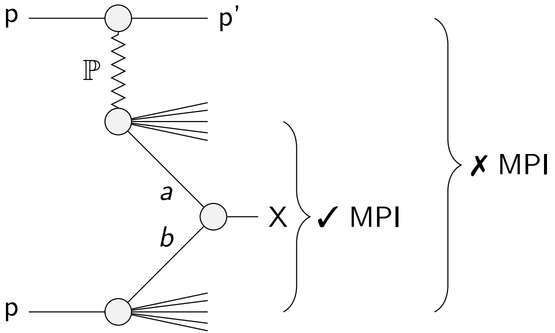
Hard diffraction



The diffractive structure function.

Hard diffraction

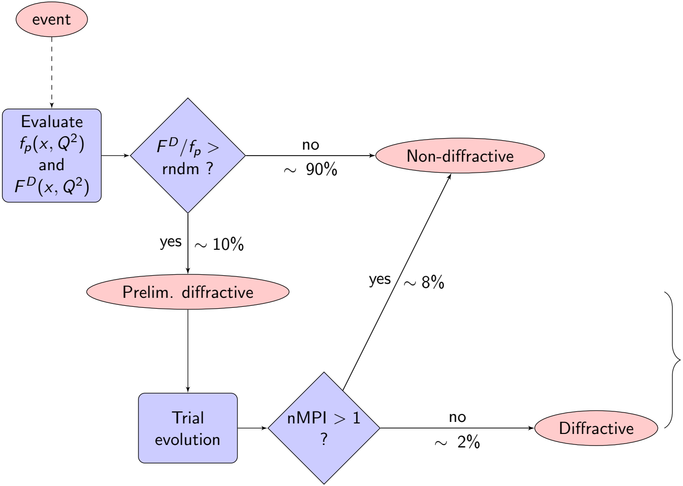
Dynamical gap survival:



SD $ab \to X$ process with beam remnants from both proton and Pomeron.

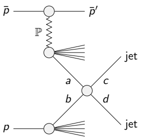
Hard diffraction

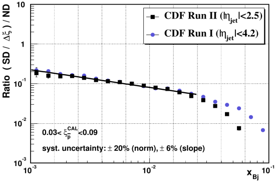
Dynamical gap survival:



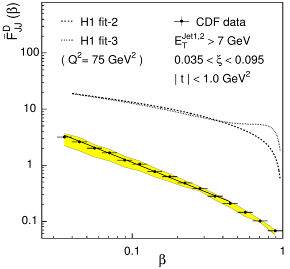
Additional suppression factor. Can this explain discrepancies btw. HERA and Tevatron?

Diffractive dijet production at the Tevatron.





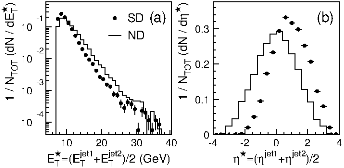
(a)

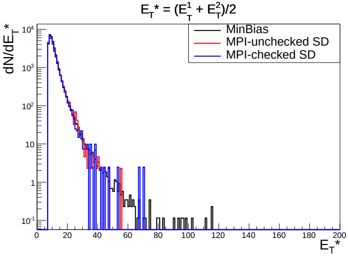


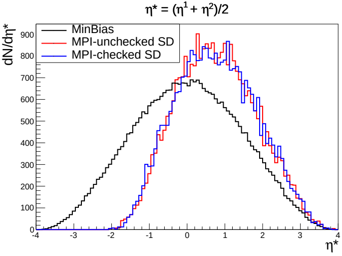
(b)

(a) The ratio SD/ND dijet events at $\sqrt{s} = 1.8$ and $\sqrt{s} = 1.96$ TeV from CDF [Phys.Rev.D86.(2012) 032009].
(b) The diffractive structure function measured at $\sqrt{s} = 1.8$ TeV from CDF [Phys.Rev.Lett.84.(2000) 5043]

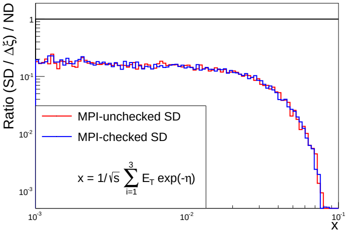
Preliminary studies

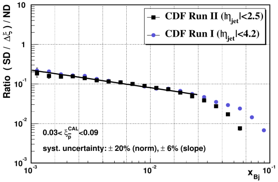






Preliminary studies



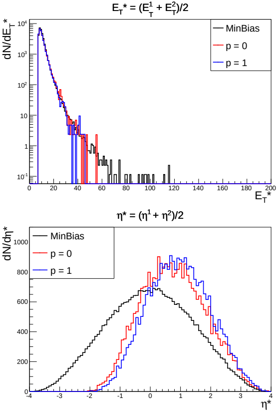


Events too hard ⇒ ratio not steep enough.
We need to suppress hardest events.

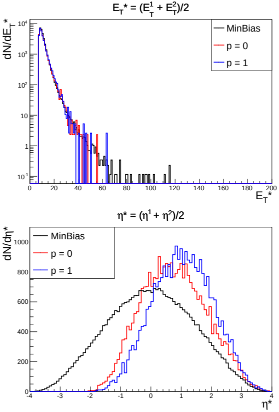
Preliminary studies

Solutions: New Pomeron fluxes and/or PDFs.

Test: Suppress Pomeron PDFs.



Suppression with $(1-x)^p$



Suppression with x^{-p}

Preliminary studies

D0	$p\bar{p} \rightarrow Gap + W$ $(0.89^{+0.19}_{-0.17})$ %	$p\bar{p} \rightarrow Gap + Z$ $(1.44^{+0.61}_{-0.52})$ %
CDF	$p\bar{p} \rightarrow \bar{p}' + W$ (1.0 ± 0.11) %	$p\bar{p} \rightarrow \bar{p}' + Z$ (0.88 ± 0.22) %
PYTHIA8 MPI-checked	$p\bar{p} \rightarrow \bar{p}' + W$ $\sim 1.7\%$	$p\bar{p} \rightarrow \bar{p}' + Z$ $\sim 2\%$

Fractions are too large.
D0:[Phys.Lett.B574(2003)169]
CDF:[Phys.Rev.D82(2010)112004]

Conclusion

- We have developed a new model for hard diffraction with dynamical gap survival
- Model is implemented in PYTHIA8, publicly available (but still being tested)
- Model gives a factor ~ 2 larger fractions for diffractive W/Z than observed
- Kinematical distributions disagree with CDF data - we obtain too hard events
- Development of new Pomeron flux and/or PDF might solve the problems. On to-do list for Autumn
- LHC studies on to-do list. Comparison to eg. CMS feasibility studies [CMS PAS DIF-07-002].