Hard diffraction in PYTHIA 8

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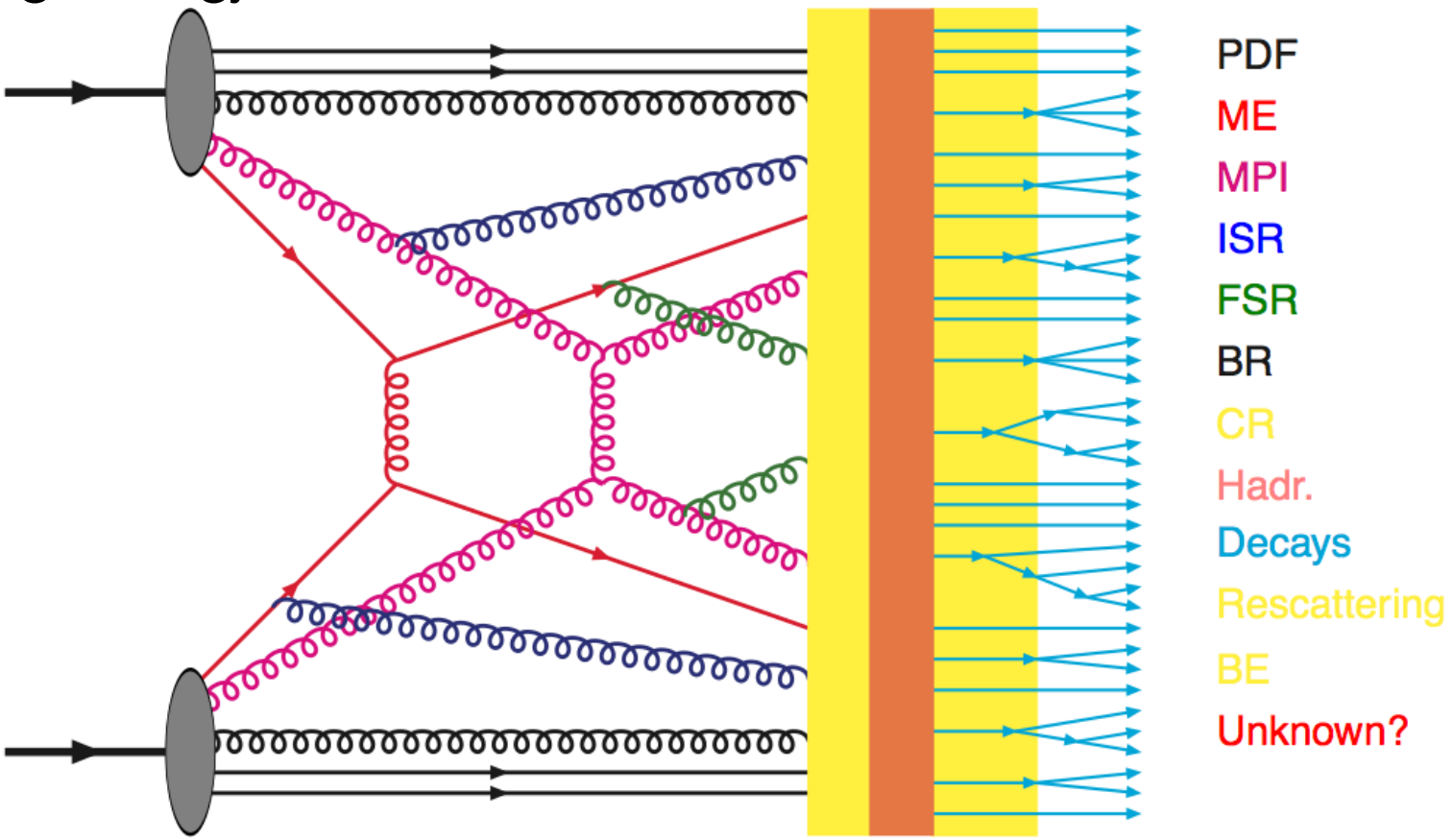
- PYTHIA 8
- Soft diffraction
- Hard diffraction
- Preliminary results
- Conclusion and outlook

PYTHIA 8 is a general purpose event generator for high-energy collisions.



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

PYTHIA 8

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

New main features as of version 8.2:

- New models of colour reconnections
  (S. Argyropoulos, J. Christiansen, P. Skands + T. Sjöstrand)
- Variety of matching and merging schemes
  (S. Prestel + L. Lönnblad)
- Weak showers, matching and merging with weak showers
  (J. Christiansen, S. Prestel + T. Sjöstrand)
- Many new tunes - default Monash 2013 tune
  (P. Skands et. al)

Ongoing work:

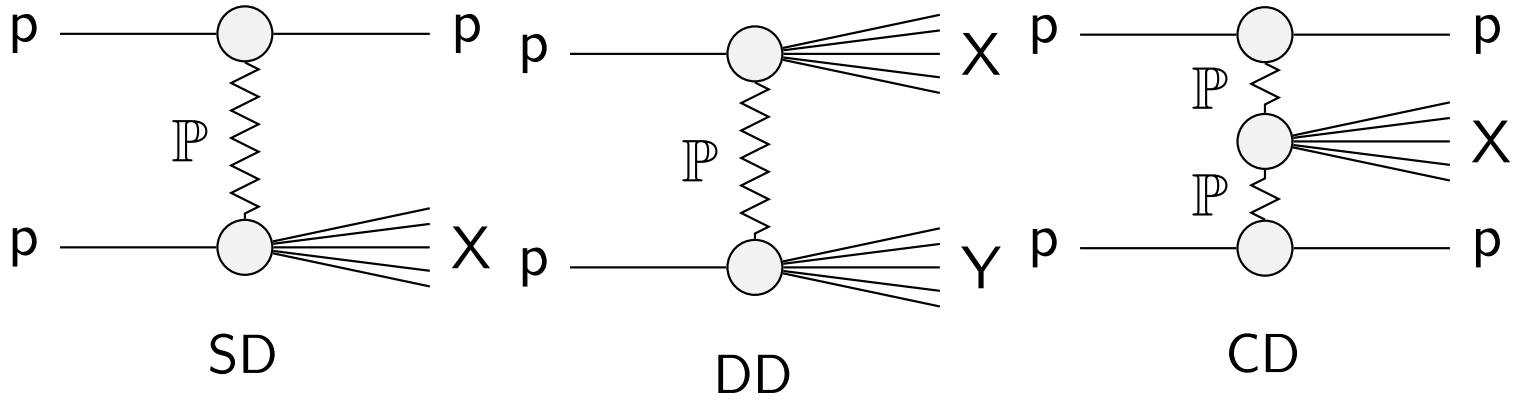
- Model for hard $\gamma\gamma$ events
  (I. Helenius + T. Sjöstrand)
- New model for hard diffraction
  (C. Rasmussen + T. Sjöstrand)
- Exclusive processes
  (R. Zlebic + L. Lönnblad)

An Introduction to PYTHIA 8.2 [Comput.Phys.Commun. 191 (2015) 159]

Soft diffraction

σ_{tot} calculated using Donnachie-Landshoff parametrisation.

Diffractive and elastic topologies calculated with Pomeron-based parametrisation of Schuler-Sjöstrand.



Nondiffractive (ND) cross section inferred from the above,

$$\sigma_{\mathrm{ND}} = \sigma_{\mathrm{tot}} - \sigma_{\mathrm{el}} - \sum_{\mathrm{X=S,C,D}} \sigma_{\mathrm{XD}}$$

Soft diffraction

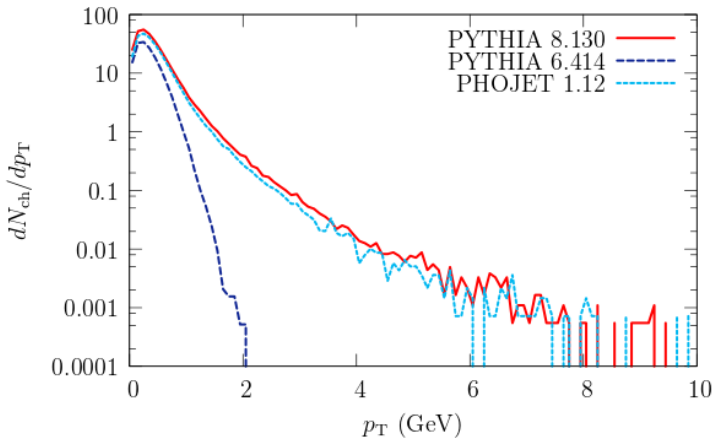
Low-mass region:
$M_{\mathrm{X}} \leq 10$ GeV.

- Represent M_{X} as longitudinal string
- Quark $=$ 1 string, gluon $=$ 2 strings
- Probability to kick out a gluon or quark from proton: $\frac{P(\mathrm{q})}{P(\mathrm{g})} = \frac{N}{M^p}$
- 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



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

Gap always survives, as MPI not allowed in hadron-hadron system.

[S. Navin: arXiv:1005.3894[hep-ph]]

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

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

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

with $\sigma_{\mathbb{P}\mathrm{p}}^{\mathrm{eff}} = 10$ mb, tunable.

Hard diffraction

Objective: Allow for truly hard diffractive processes, e.g. high-$p_\perp$ QCD, electroweak etc.

Question: Given a hard scattering, 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 PDF and use dynamical gap survival.

Assumption 1: The hadronic PDFs can be split into nondiffractive 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 PDF factorises,

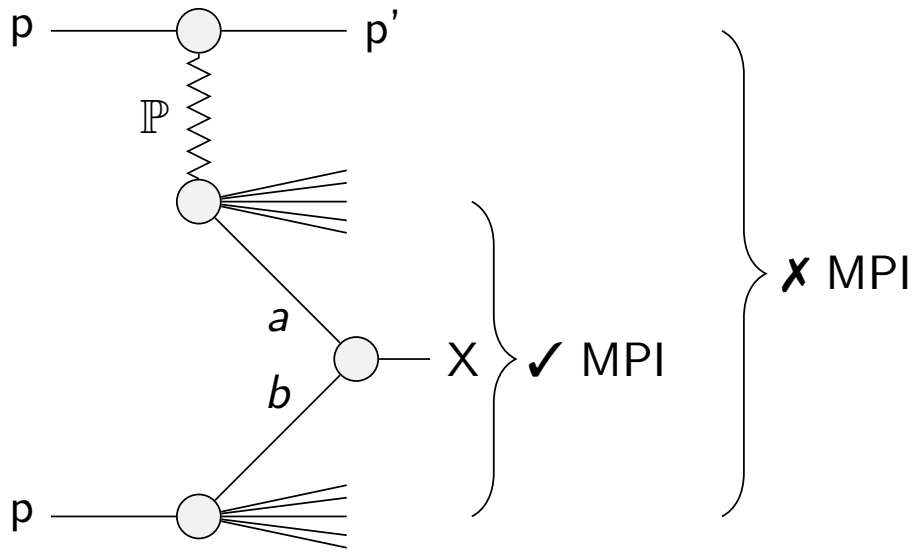
$$f_i^{\mathrm{D}}(x, Q^2) = \int_x^1 \frac{\mathrm{d}x_{\mathbb{P}}}{x_{\mathbb{P}}} \int_{t_{\min}}^{t_{\max}} \mathrm{d}t \, f_{\mathbb{P}/p}(x_{\mathbb{P}}, t) \, f_{i/\mathbb{P}}(x/x_{\mathbb{P}}, Q^2)$$

Hard diffraction

The probabilities for either sides to be diffractive are

$$\mathcal{P}_{\mathrm{B}} = f_i^{\mathrm{D}}(x_a, Q^2)/f_i(x_a, Q^2)$$
$$\mathcal{P}_{\mathrm{A}} = f_i^{\mathrm{D}}(x_b, Q^2)/f_i(x_b, Q^2)$$

Dynamical gap survival:



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

Hard diffraction

Dynamical gap survival introduces additional suppression.

	$p\bar{p} \to Gap + W$	$p\bar{p} \to Gap + Z$
D0 [Phys.Lett.B574(2003)169]	$(0.89^{+0.19}_{-0.17})$ %	$(1.44^{+0.61}_{-0.52})$ %
CDF [Phys.Rev.D82(2010)112004]	$(p\bar{p} \to \bar{p}' + W) \times 2$ (1.0 ± 0.11) %	$(p\bar{p} \to \bar{p}' + Z) \times 2$ (0.88 ± 0.22) %
PYTHIA 8 CDF cuts	$(p\bar{p} \to \bar{p}' + W) \times 2$ (0.37 ± 0.02) %	$(p\bar{p} \to \bar{p}' + Z) \times 2$ (0.28 ± 0.01) %

PYTHIA 8 too suppressed.
Fractions are sensitive to variations of model parameters:
$\mathbb{P}$ PDF and flux, free parameters of MPI model.

Hard diffraction

How are these fractions and the particle distributions affected when we change

- the Pomeron parametrisations,
- the regulator $p_{\perp 0}^{\mathrm{ref}}$,
- the impact-parameter dependence of the MPI model?

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Will affect the chosen value of $x_{\mathbb{P}}$ and connected variables such as the mass of the diffractive system, the size of the rapidity gap, the squared momentum transfer and the angle at which the proton is bent.

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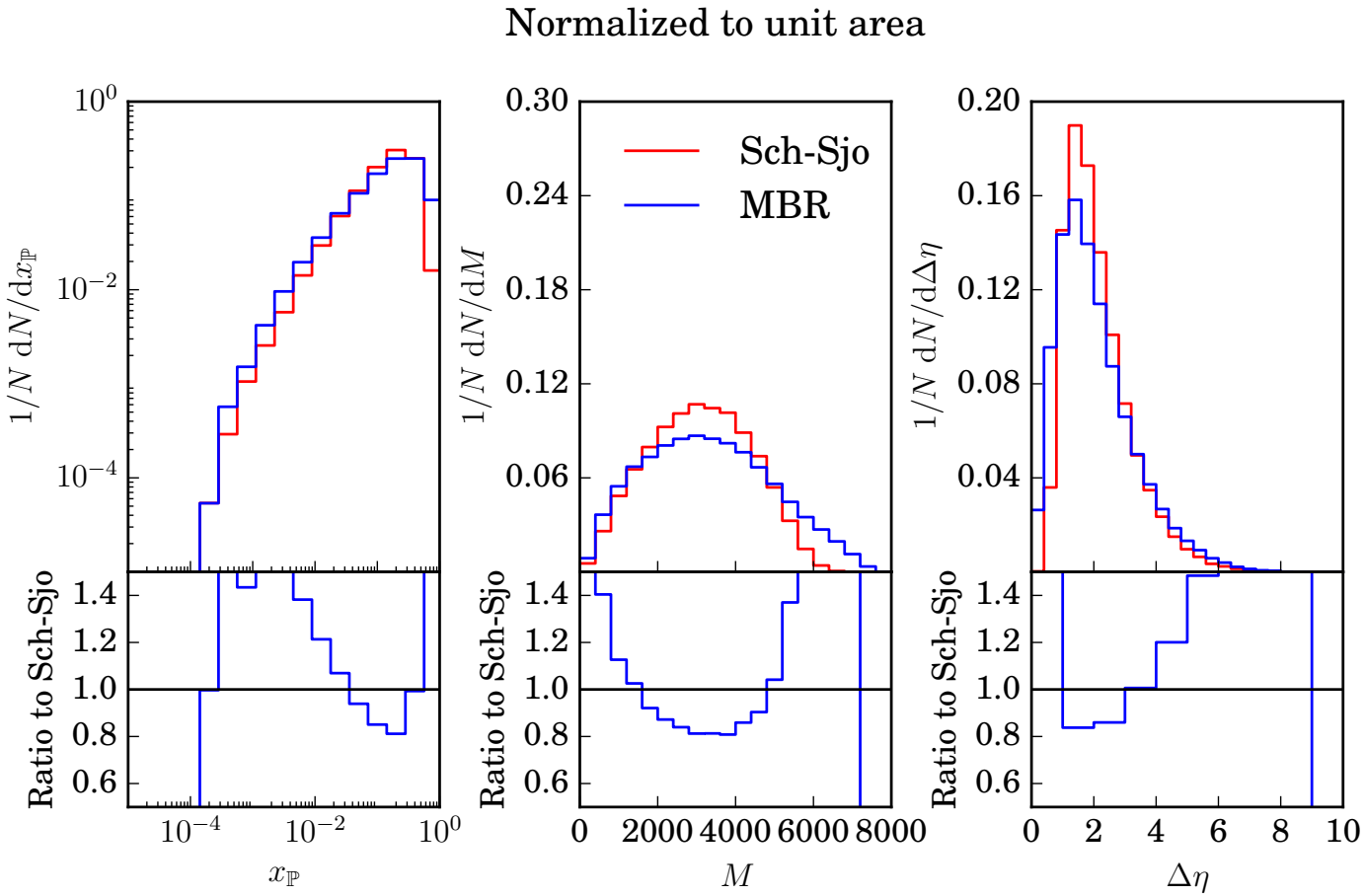
Will affect the rapidity gap survival rate, the charged particle spectrum and the underlying event.

Hard diffraction

QCD $2 \to 2$ processes with $p_\perp > 20$ GeV
at $\sqrt{s} = 8$ TeV pp collider



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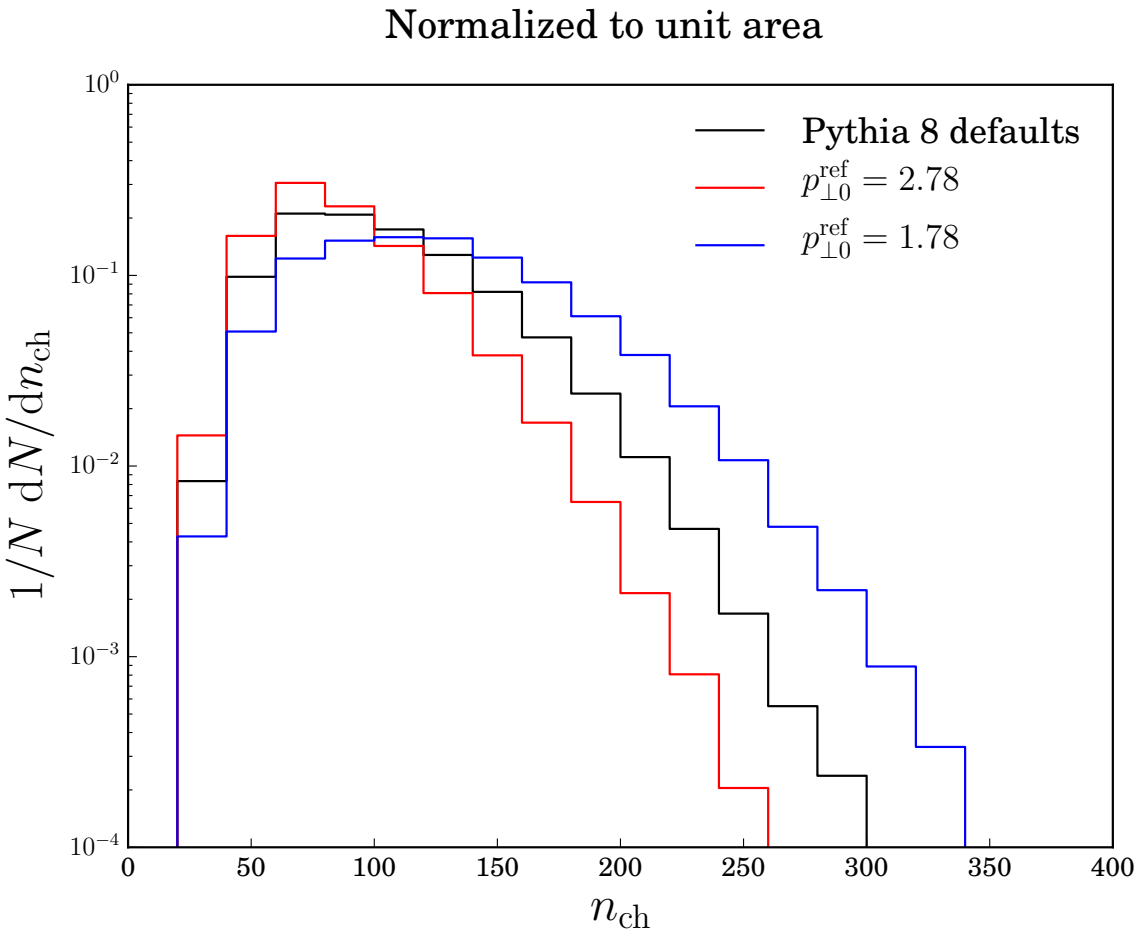


Hard diffraction

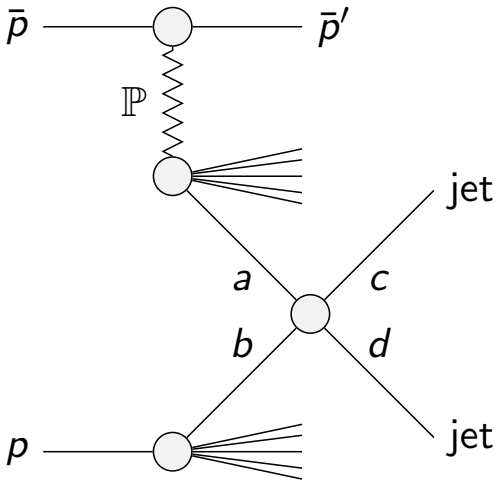
Changing the $p_{\perp 0}^{\mathrm{ref}}$ increases the diffractive fraction, as a higher value gives less MPIs.

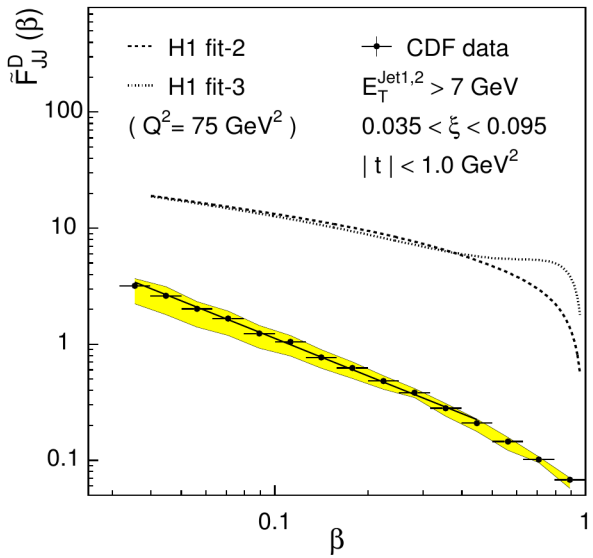
	$p\bar{p} \to Gap + W$	$p\bar{p} \to Gap + Z$
D0 [Phys.Lett.B574(2003)169]	$(0.89^{+0.19}_{-0.17})$ %	$(1.44^{+0.61}_{-0.52})$ %
CDF [Phys.Rev.D82(2010)112004]	$(p\bar{p} \to \bar{p}' + W) \times 2$ (1.0 ± 0.11) %	$(p\bar{p} \to \bar{p}' + Z) \times 2$ (0.88 ± 0.22) %
PYTHIA 8 CDF cuts $p_{\perp 0}^{\mathrm{ref}} = 2.28$	$(p\bar{p} \to \bar{p}' + W) \times 2$ (0.37 ± 0.02) %	$(p\bar{p} \to \bar{p}' + Z) \times 2$ (0.28 ± 0.01) %
PYTHIA 8 CDF cuts $p_{\perp 0}^{\mathrm{ref}} = 2.78$	(0.61 ± 0.02) %	(0.48 ± 0.01) %

Diffractive dijet production at the Tevatron.

SD dijets: $\mathrm{p\bar{p}} \to X\bar{\mathrm{p}}, [X \to X' + jet + jet]$

$E_T^{jet} > 7$ GeV, $|\eta|^{jet} < 4.2$



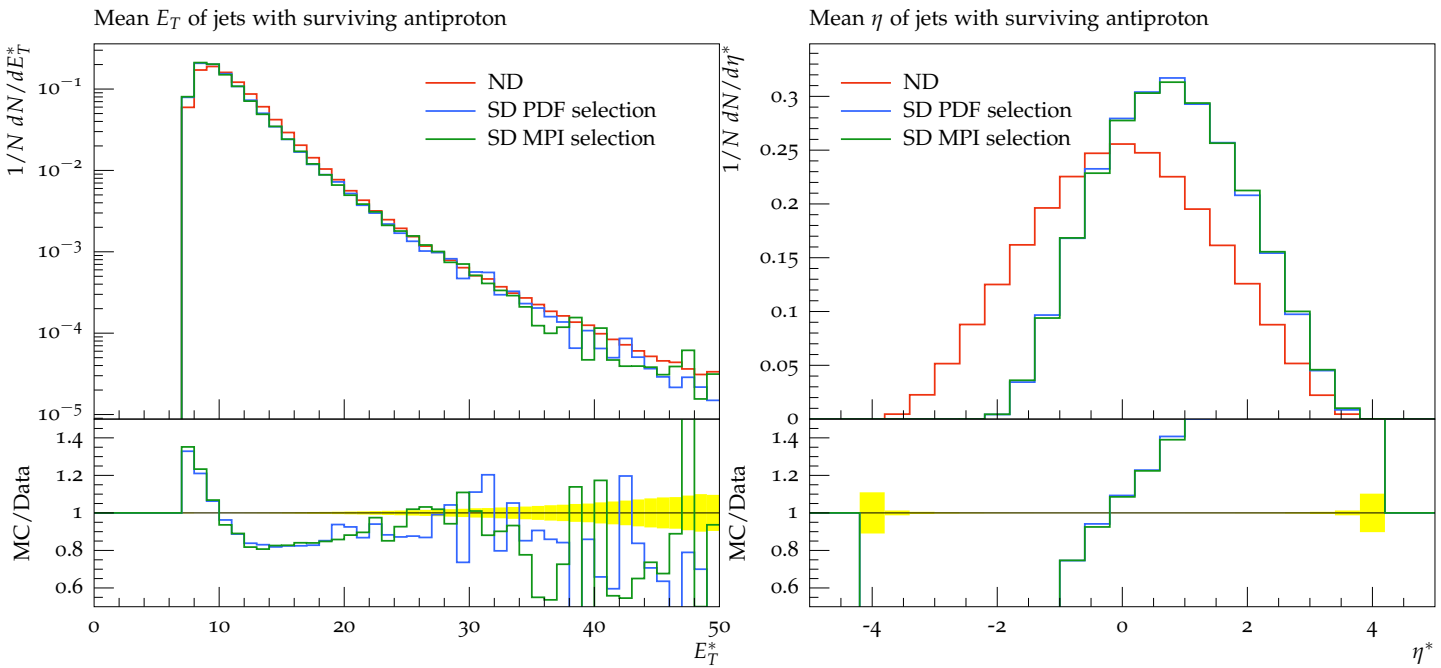


[Phys.Rev.Lett.84.(2000) 5043]

HERA parametrisations does not describe CDF data

Preliminary results

Kinematical distributions of SD jets



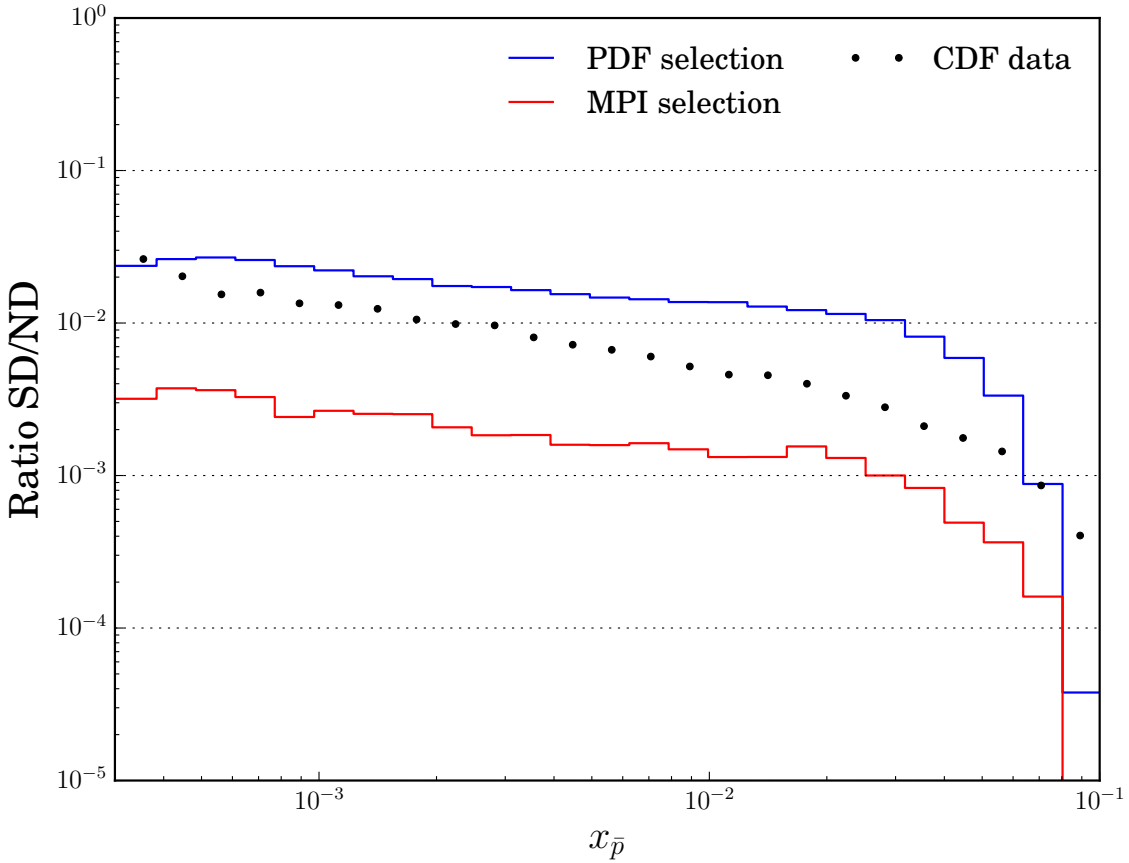
E_T^* not steep enough

Notation:

Setup $\mathbb{P}$p system after probabilistic criterion = PDF selection

Setup $\mathbb{P}$p system after MPI criterion = MPI selection

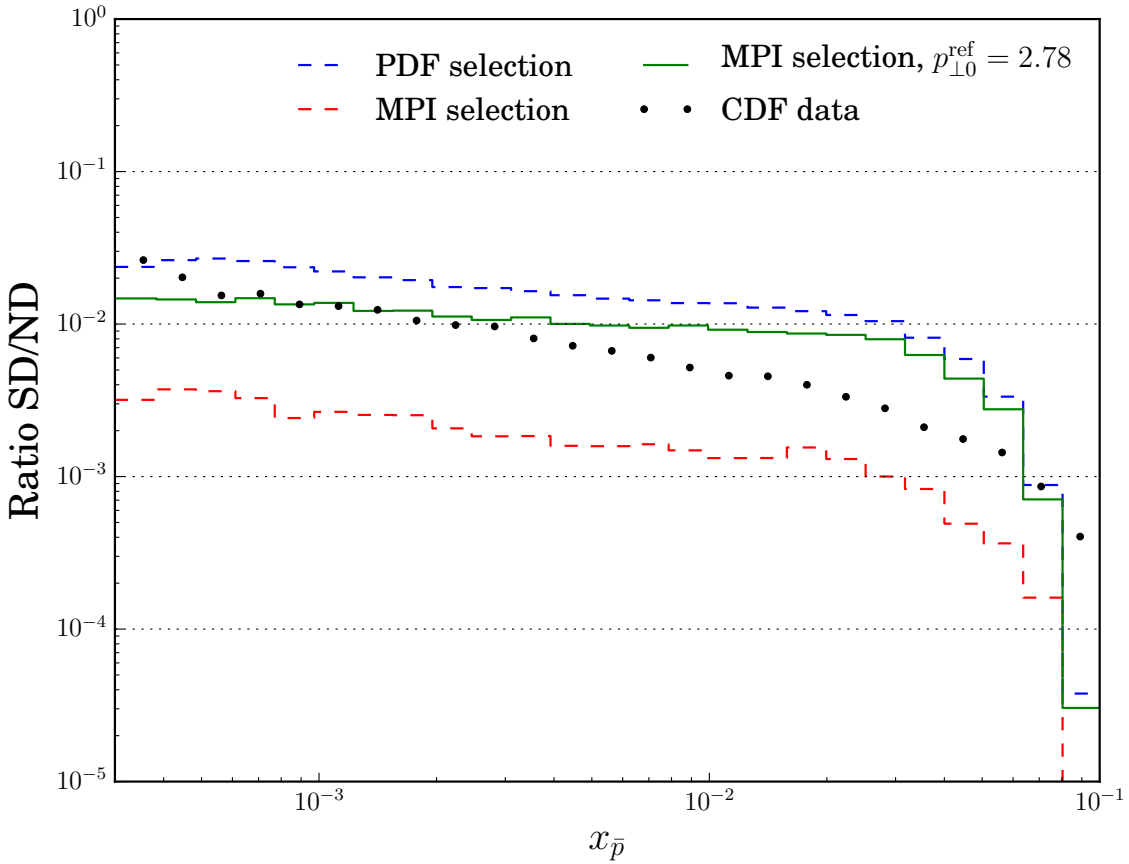
Preliminary results



[Phys.Rev.D86.(2012) 032009]

PYTHIA 8 not as steep as data.

Preliminary results



[Phys.Rev.D86.(2012) 032009]

Tweaking $p_{\perp 0}^{\mathrm{ref}}$ helps, but still too flat

Conclusion and outlook

- We have developed a new model for hard diffraction with dynamical gap survival
- Model is implemented in PYTHIA 8, publicly available
- Some kinematical distributions disagree with CDF data - we obtain too hard events
- Tuning MPI parameters could improve distributions
- Development of new Pomeron flux (and PDF?)
- Retuning of the soft diffractive machinery