LUND UNIVERSITY

HERA and the LHC
CERN
11 October 2004

New $p_\perp$-ordered showers
and
Interleaved Multiple Interactions

Torbjörn Sjöstrand[1] + Peter Skands[2]

Department of Theoretical Physics, Lund University

[1] now at CERN

[2] at FNAL from 1 Nov.

hep-ph/0408302

also **JHEP 03 (2004) 053 [hep-ph/0402078]**

Transverse-momentum-ordered showers

1) *Define*
$$\mathrm{p}_{\perp\mathrm{evol}}^2 = z(1-z)Q^2 = z(1-z)M^2 \text{ for FSR}$$
$$\mathrm{p}_{\perp\mathrm{evol}}^2 = (1-z)Q^2 = (1-z)(-M^2) \text{ for ISR}$$

2) *Evolve* all partons *downwards* in $\mathrm{p}_{\perp\mathrm{evol}}$ from common $p_{\perp\mathrm{max}}$

$$\mathrm{d}\mathcal{P}_a = \frac{\mathrm{dp}_{\perp\mathrm{evol}}^2}{\mathrm{p}_{\perp\mathrm{evol}}^2} \frac{\alpha_{\mathrm{s}}(\mathrm{p}_{\perp\mathrm{evol}}^2)}{2\pi} P_{a\to bc}(z)\,\mathrm{d}z\, \exp\left(-\int_{\mathrm{p}_{\perp\mathrm{evol}}^2}^{p_{\perp\mathrm{max}}^2} \cdots\right)$$

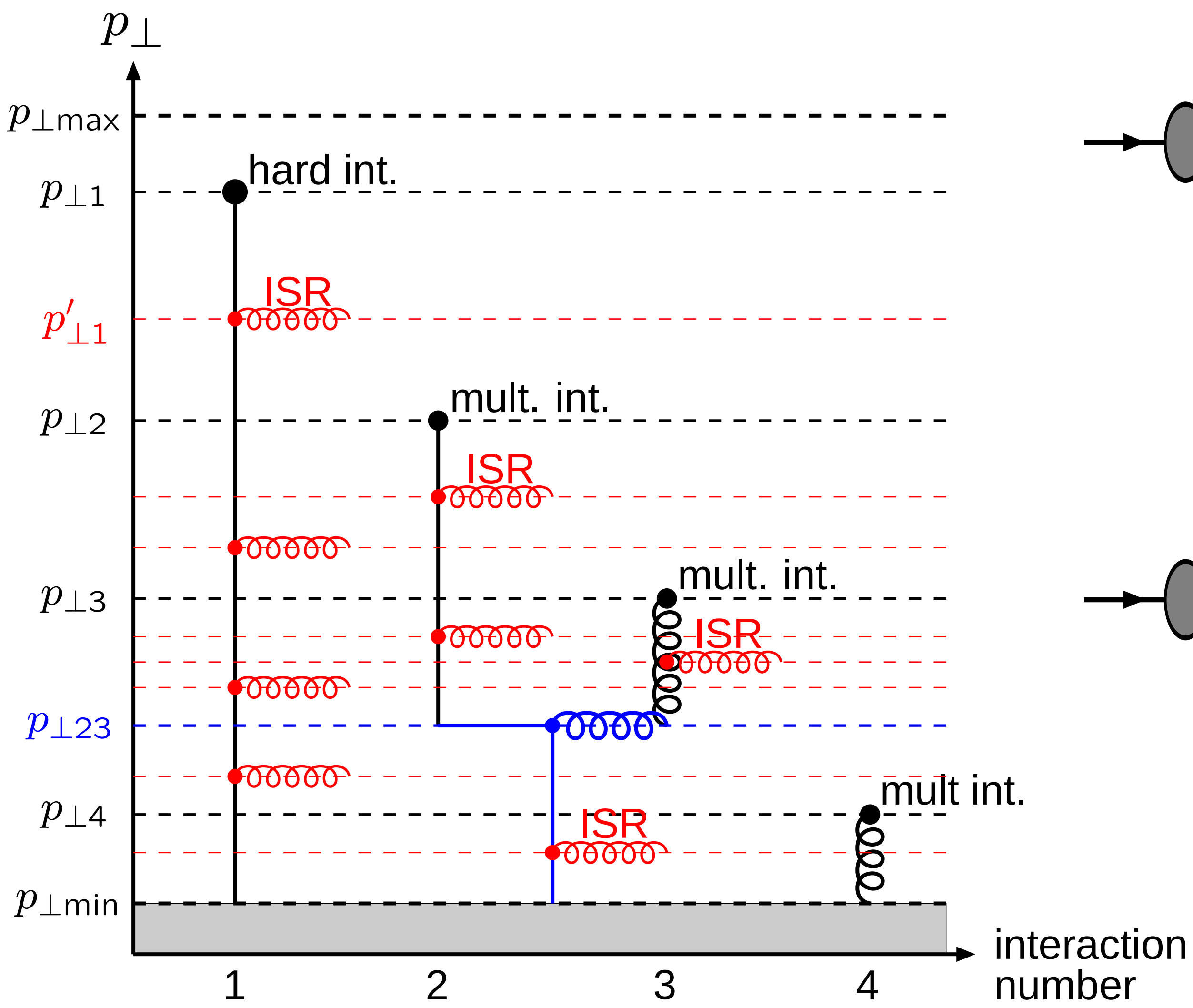
$$\mathrm{d}\mathcal{P}_b = \frac{\mathrm{dp}_{\perp\mathrm{evol}}^2}{\mathrm{p}_{\perp\mathrm{evol}}^2} \frac{\alpha_{\mathrm{s}}(\mathrm{p}_{\perp\mathrm{evol}}^2)}{2\pi} \frac{x' f_a(x', \mathrm{p}_{\perp\mathrm{evol}}^2)}{x f_b(x, \mathrm{p}_{\perp\mathrm{evol}}^2)} P_{a\to bc}(z)\,\mathrm{d}z\, \exp\left(-\cdots\right)$$

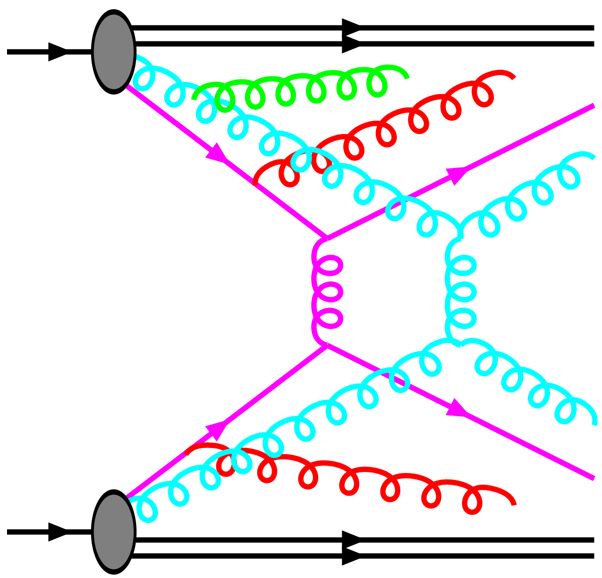
Pick the one with *largest* $\mathrm{p}_{\perp\mathrm{evol}}$ to undergo branching; also gives z.

3) Kinematics: *Derive* $Q^2 = \pm M^2$ by inversion of 1), but then interpret z as *energy fraction* (not lightcone) in "dipole" rest frame, so that *Lorentz invariant* and matched to matrix elements.
Assume yet unbranched partons on-shell and shuffle $(E, \mathbf{p})$ inside dipole.

4)*Iterate* $\Rightarrow$ combined sequence $p_{\perp\mathrm{max}} > p_{\perp 1} > p_{\perp 2} > \ldots > p_{\perp\mathrm{min}}$.

Interleaved Multiple Interactions





• **Competition:** (for PDF and phase space)

$$\frac{\mathrm{d}\mathcal{P}}{\mathrm{d}p_\perp} = \left(\frac{\mathrm{d}\mathcal{P}_{\mathrm{MI}}}{\mathrm{d}p_\perp} + \sum \frac{\mathrm{d}\mathcal{P}_{\mathrm{ISR}}}{\mathrm{d}p_\perp} \right) \exp\left(- \int_{p_\perp}^{p_{\perp i-1}} \left(\frac{\mathrm{d}\mathcal{P}_{\mathrm{MI}}}{\mathrm{d}p'_\perp} + \sum \frac{\mathrm{d}\mathcal{P}_{\mathrm{ISR}}}{\mathrm{d}p'_\perp} \right) \mathrm{d}p'_\perp \right)$$

$\Rightarrow$ one interleaved sequence of MI and ISR

FSR: no competition so not required (but nice for ME merging)

• **Regularization procedure:**

$$\alpha_{\mathrm{s}}(p_\perp^2) \frac{\mathrm{d}p_\perp^2}{p_\perp^2} \to \alpha_{\mathrm{s}}(p_{\perp 0}^2 + p_\perp^2) \frac{\mathrm{d}p_\perp^2}{p_{\perp 0}^2 + p_\perp^2}$$

common for MI (quadratically) and ISR by colour neutralization

$p_{\perp 0} \approx$ 2–3 GeV energy-dependent (Tune A)

• **Availability:**

in PYTHIA 6.312 on www.thep.lu.se/~torbjorn/Pythia.html

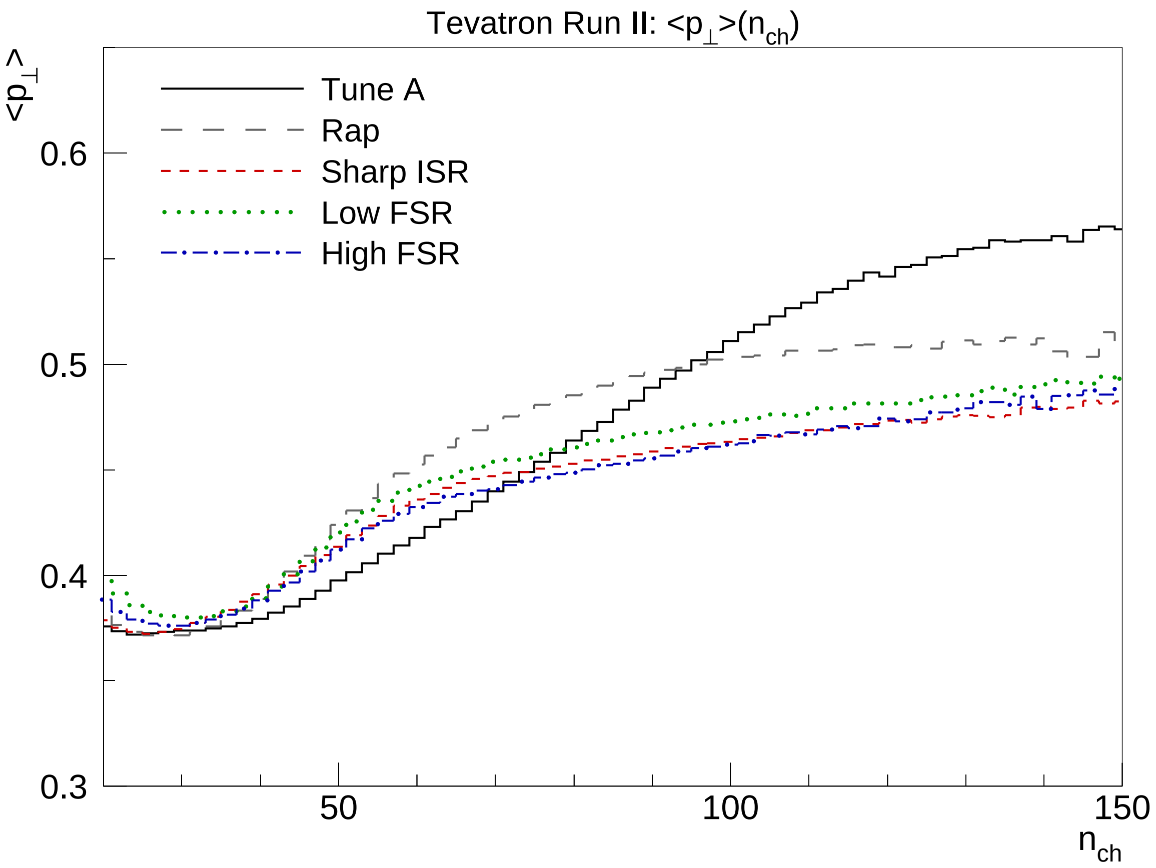
but $\mathrm{pp}/\mathrm{p\overline{p}}$ only (technical + physics reasons)

• **Data comparisons:**

usually comparable with Tune A (for better or worse), but

still in need of good tuning and detailed tests, and . . .

$\ldots\langle p_\perp\rangle(n_{\text{ch}})$ problematical



$\Rightarrow$ how are final-state colours correlated?

- **Next steps:**

test and tune, especially colour flow

interleave FSR

intertwine = (3 $\rightarrow$ 3) + 2 interacting partons with same ancestry