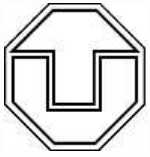
Simulation of Multiple Interactions in the Sherpa Framework



Stefan Höche
Dresden University of Technology

- The Basics
- Simple Model: SHERPA 1.0 vs. PYTHIA 6.2
- Impact Parameters
- Implementation Issues

The Basics

hadronic xs in parton model

$$\sigma_{\rm hard} = \int {\rm d}x_1 \int {\rm d}x_2 \cdot f_1(x_1, Q^2) f_2(x_2, Q^2)\, \hat{\sigma}_{12}$$

$\frac{\hat{\sigma}}{{\rm d}\hat{t}}$ to LO divergent for $\hat{t} \to 0$

- $\sigma_{\rm hard}$ comparable with $\sigma_{\rm ND}$ (non-diffractive xs) for $\hat{t}_{\rm min} \approx 2 - 4\,{\rm GeV}^2$

$\sigma_{\rm hard}$ must not exceed $\sigma_{\rm ND}$

➡ need multiple scatterings mean multiplicity:

$$\langle n \rangle = \frac{\sigma_{\rm hard}}{\sigma_{\rm ND}}$$

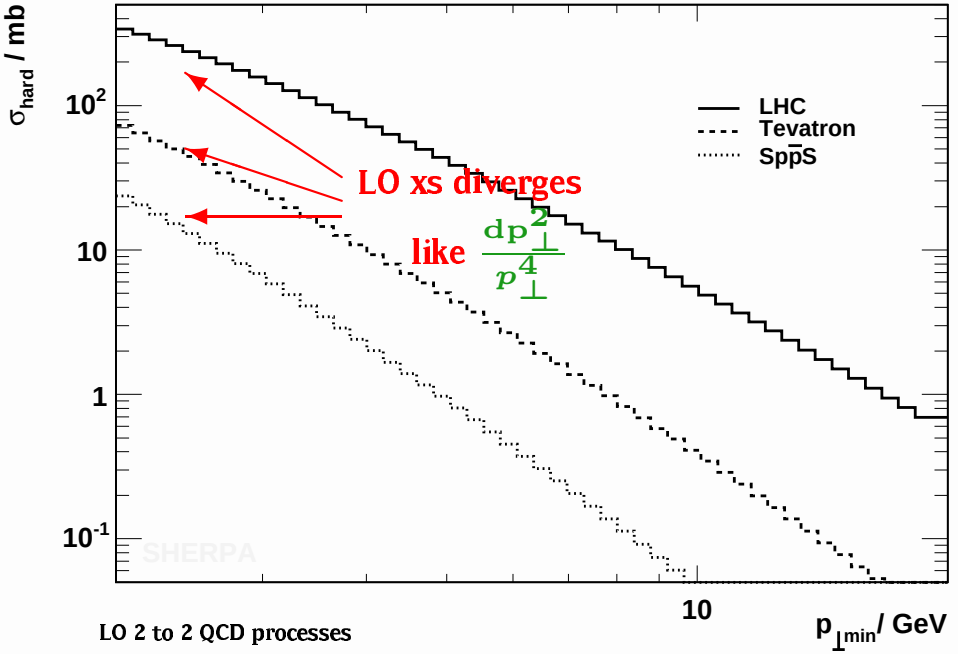
Sjöstrand and Zijl, Phys. Rev. **D36** (1987)

Monte Carlo method:

distribute hard interactions like

$$f(p_\perp) = \frac{1}{\sigma_{\rm ND}} \frac{d\sigma_{\rm hard}(p_\perp)}{dp_\perp}$$

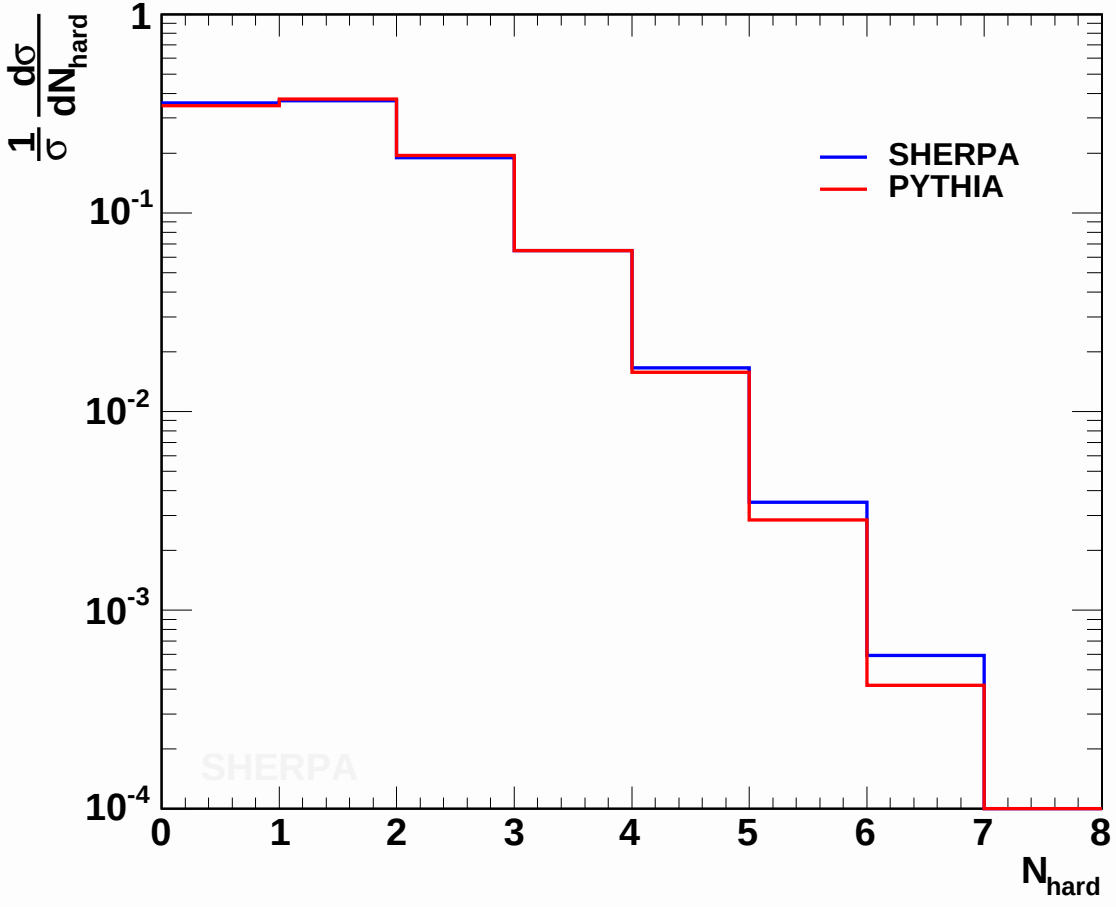
related problem:



⇒ σ_{hard} **requires regularization!**

Simple Model: SHERPA 1.0 vs. PYTHIA 6.2

- sample setup: $\mathrm{p\bar{p}}$, $E_{\mathrm{cms}} = 1.8\,\mathrm{TeV}$,
  seed: QCD jet, $P_T \geq 10\,\mathrm{GeV}$



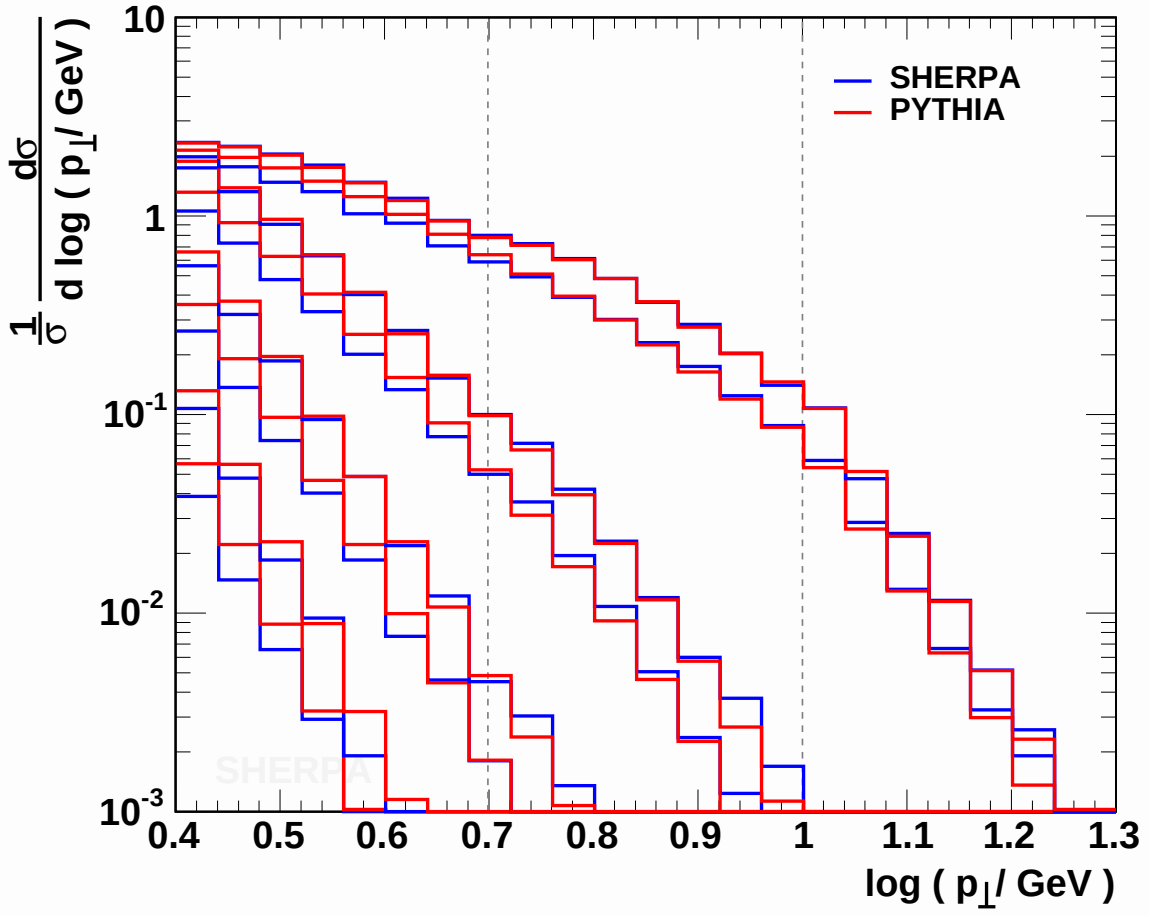
- compare multiplicity of hard scatterings in underlying event

→ multiplicity agrees with PYTHIA result

Simple Model: SHERPA 1.0 vs. PYTHIA 6.2

- sample setup: $p\bar{p}$, $E_{cms} = 1.8\,\mathrm{TeV}$,
  K_T clustering algorithm

  seed: QCD jet, $P_T \geq 10\,\mathrm{GeV}$



- compare shapes of “jets” from underlying event at ME level

→ shapes agree with PYTHIA results

Impact Parameters

- assume extended hadrons

  → profile function $\rho(\mathbf{x})$

  overlap of two colliding hadrons at impact parameter $\mathbf{b}$

$$\mathcal{O}(\mathbf{b}) = \int \mathrm{d}t\, \mathrm{d}^3\mathbf{x}\, \rho_1(\mathbf{x_1})\, \rho_2(\mathbf{x_2})$$

→ mean multiplicity:

$$\langle n(\mathbf{b}) \rangle = k\mathcal{O}(\mathbf{b})$$

$n(\mathbf{b})$ Poissonian distributed for each $\mathbf{b}$

total interaction probability $P_{\mathrm{int}}(\mathbf{b})$ given by Poissonian

→ determine k from constraint

$$\frac{\sigma_{\mathrm{hard}}}{\sigma_{\mathrm{ND}}} = \frac{\int \mathrm{d}^2\mathbf{b}\, \langle n(\mathbf{b}) \rangle\, P_{\mathrm{int}}(\mathbf{b})}{\int \mathrm{d}^2\mathbf{b}\, P_{\mathrm{int}}(\mathbf{b})}$$

Monte Carlo method:

- distribute interactions like

$$f(p_\perp, b) = f_c f(b)\, \frac{1}{\sigma_{\mathrm{ND}}}\, \frac{d\sigma_{\mathrm{hard}}(p_\perp)}{dp_\perp}$$

apply veto algorithm
for profiles with tail to infinity
(e.g. Gaussian)

- regularize σ_{hard}:

naive:
- remove singularity via

$$\sigma_{\mathrm{hard}} \to \sigma_{\mathrm{hard}} \cdot \frac{p_\perp^4}{(p_\perp^2 + p_{\perp 0}^2)^2}$$

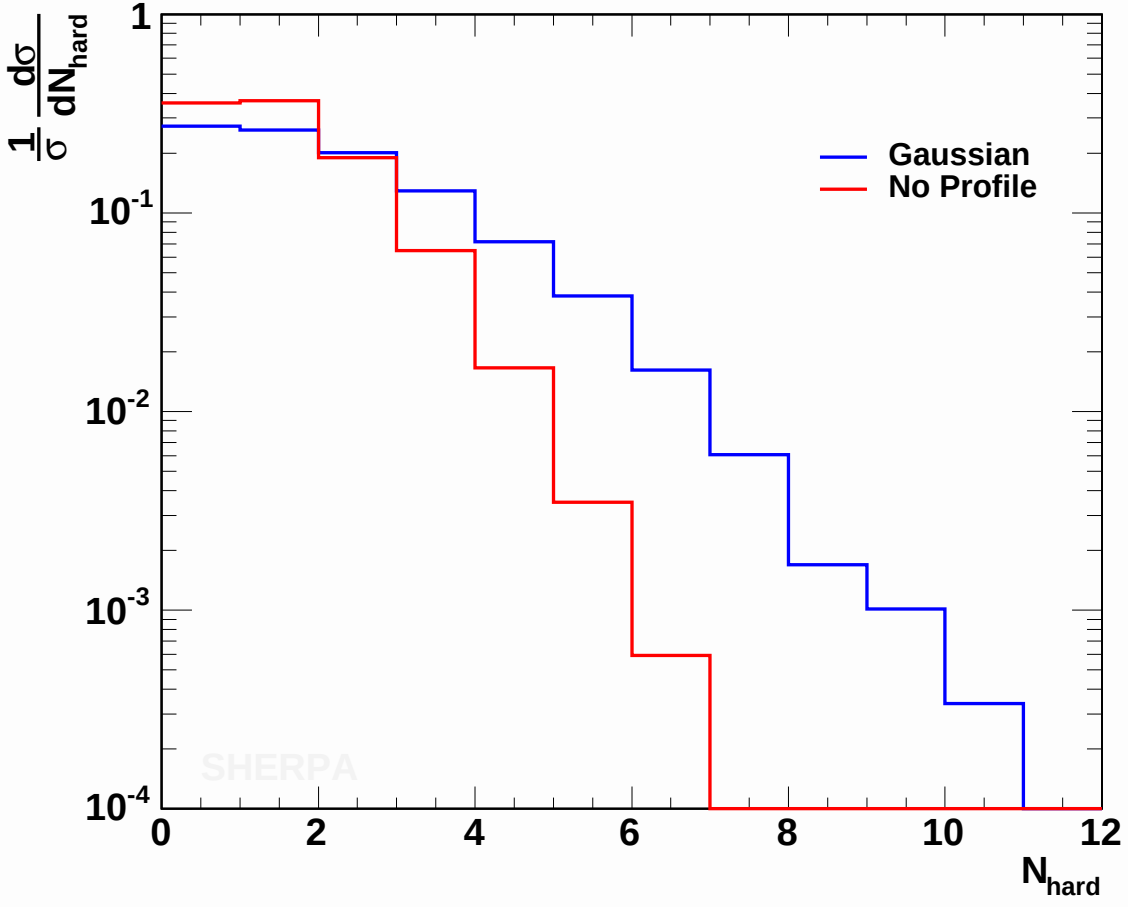
- adjust hard scale

$$\alpha_s^2(p_\perp^2) \to \alpha_s^2(p_\perp^2 + p_{\perp 0}^2)$$

Impact Parameters

- sample setup: $\mathrm{p\bar{p}}$, $E_{\mathrm{cms}} = 1.8\,\mathrm{TeV}$,
  Gaussian profile

  seed: QCD jet, $P_T \geq 10\,\mathrm{GeV}$



- compare multiplicity of hard interactions in underlying event

→ enhanced multiplicity (agrees with PYTHIA)

Implementation Issues

SHERPA implementation of the multiple interaction formalism

- all $2 \to 2$ QCD processes included
- color flow adjusted such that string length is minimized in partonic final state
- showering allowed for partons from hard underlying event

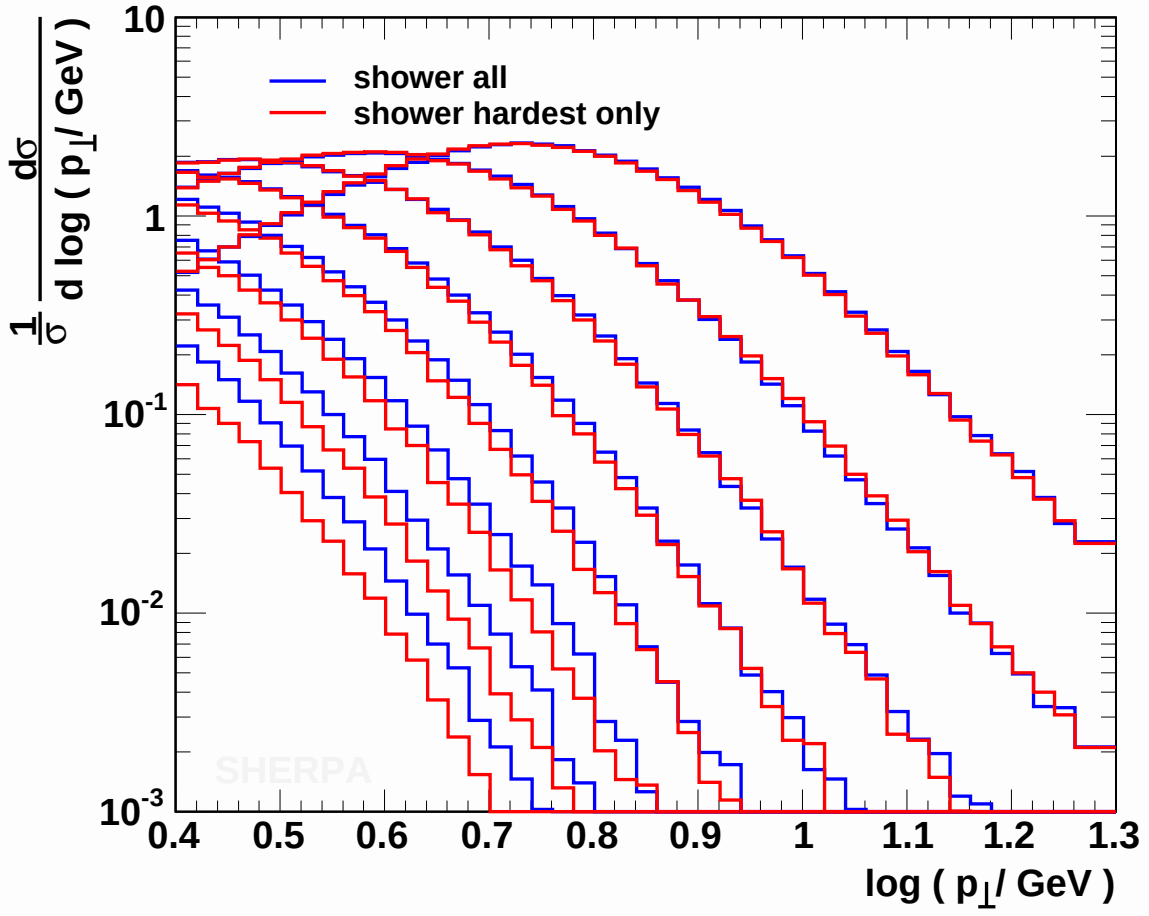
➡ New SHERPA module AMISIC++

(A Multiple Interaction Simulation In C++)

Implementation Issues

- sample setup: $\mathrm{p\bar{p}}$, $E_{\mathrm{cms}} = 1.8\,\mathrm{TeV}$,
  Gaussian, K_T clustering

  seed: QCD jet, $P_T \geq 10\,\mathrm{GeV}$



- compare jet shapes
  (excluding the
  2 hardest jets)
  with / without shower

- harder jets
  from underlying event

Outlook

Done:

- Multiple interaction treatment included in SHERPA 1.0
  - Impact parameter independent model
  - Impact parameter dependent model
  - Parton showering for multiple interactions
  - Colour flow adjustment

Missing:

- Tune
- Model for soft underlying event