Underlying Event Simulation in Sherpa

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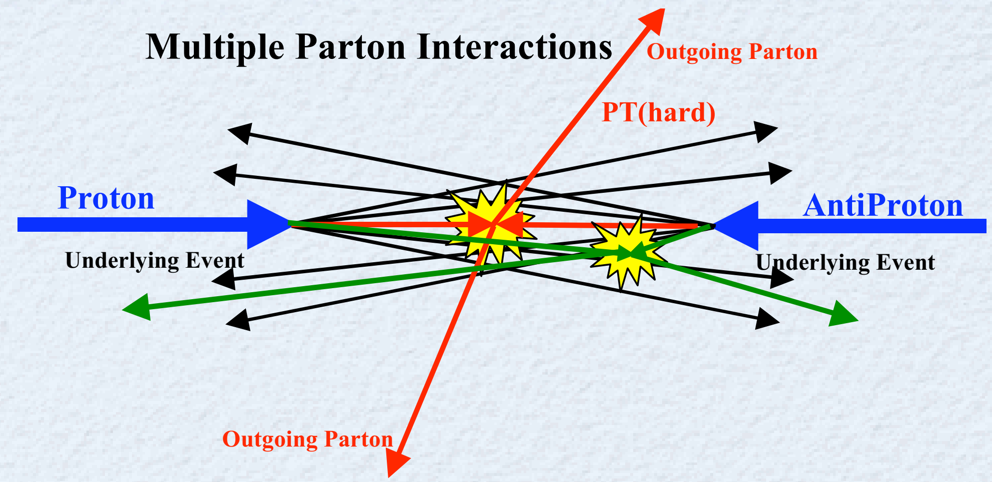
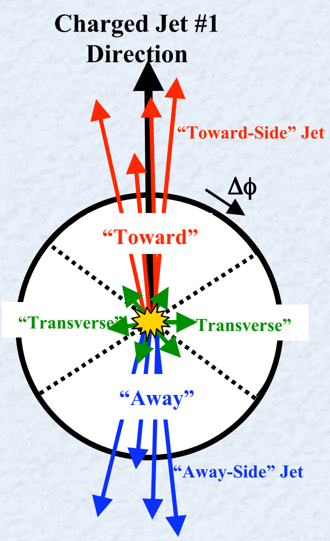
Experimental Evidence

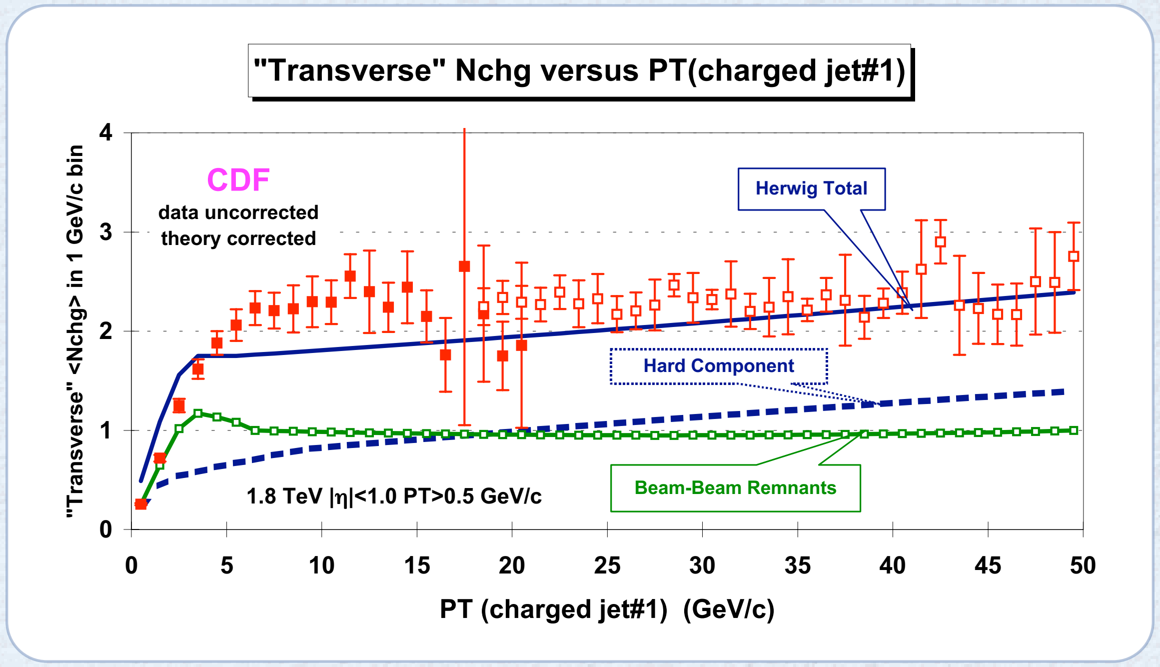
- Ongoing dedicated CDF analysis (R. Field) to investigate structure of multiple parton scatterings





- Defines leading charged particle jet
- Examines charged multiplicity in different azimuthal regions w.r.t. leading jet

- Standard event generation
  - Too few charged particles in low-$p_{T,\mathrm{jet1}}$ region ⟶
  - Too steep $dN_{\mathrm{charged}}\,/\,dp_T$ spectra
  - **Multiple scattering assumption solves this problem**

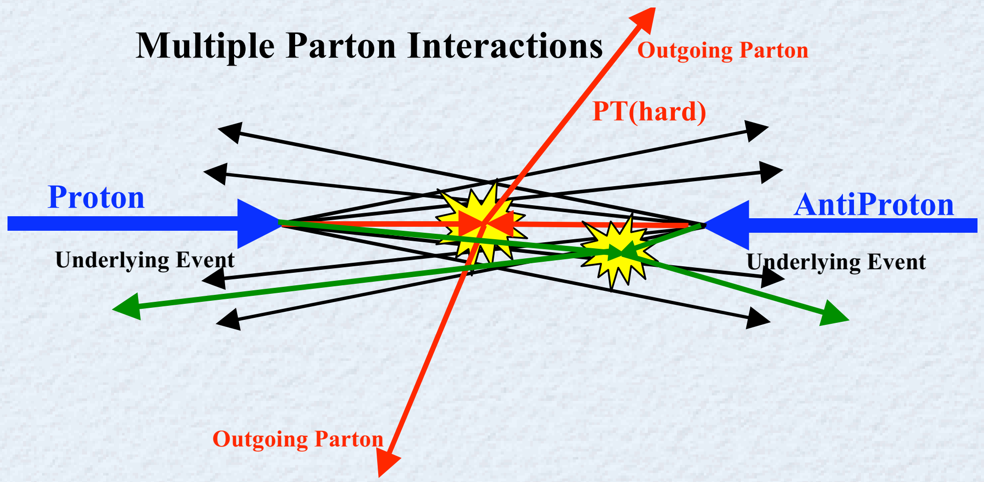


Simulation in Sherpa

hep-ph/0601012

Sherpas current multiple parton interaction (MPI) module

- Based on the PYTHIA model
  T. Sjöstrand & M. van Zijl, PRD36(1987)2019
- Parton showers (PS) attached to secondary interactions



Combination of MPI's with hard processes and CKKW matching

- Hard processes with final state multiplicity different from two require unique definition of starting scale for MI evolution, μ_{MI}
- Sherpa algorithm (works for arbitrary n-jet ME):
  - Employ K_T-algorithm to define 2→2 core process
  - Set starting scale μ_{MI} to p_T of final state QCD parton(s) from this process and veto partons harder than μ_{MI} (from PS) in secondary interactions

Results from Sherpa

hep-ph/0601012

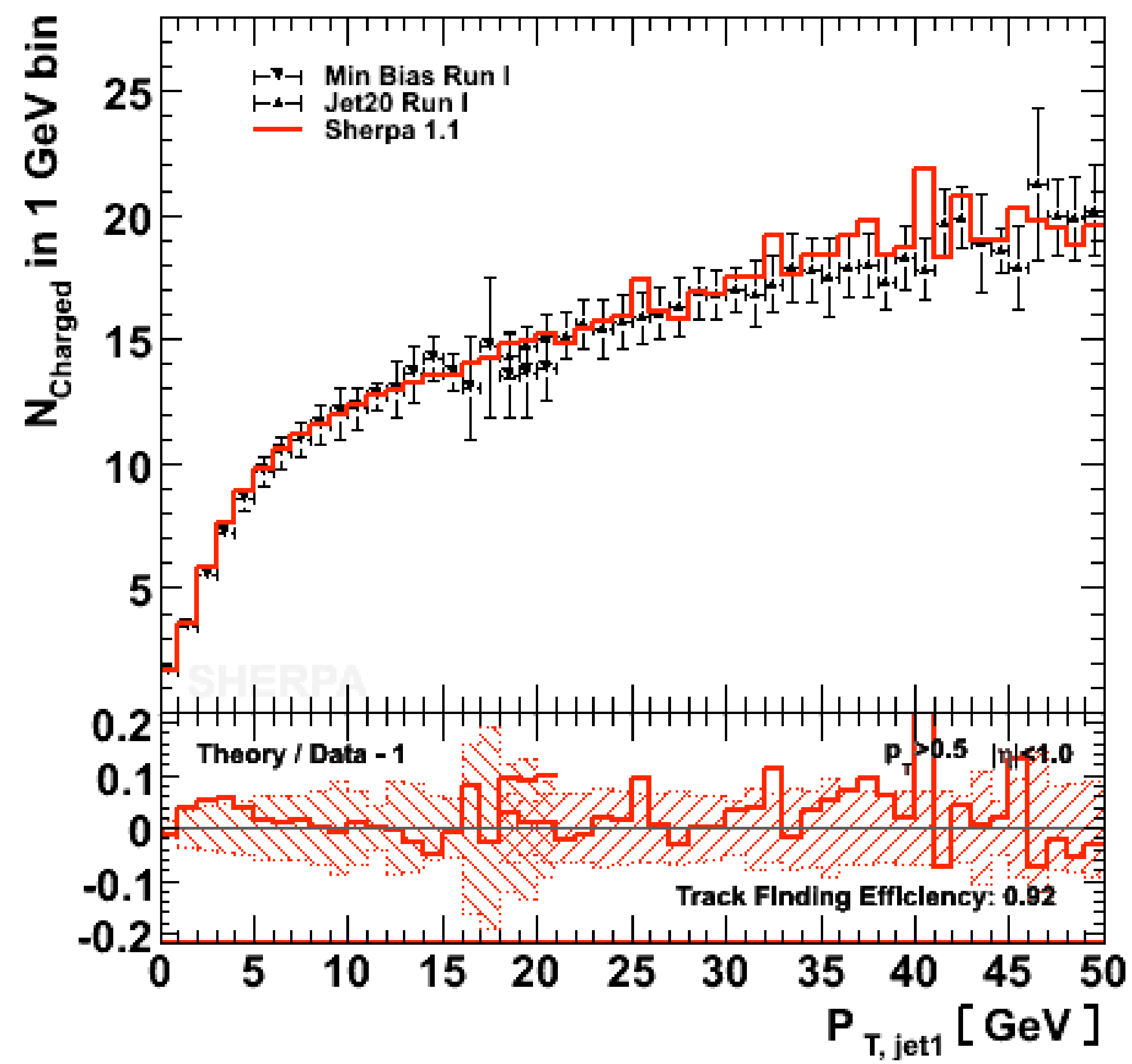
Our current "best fit" for CDF

- Lower p_T - cutoff
  - ➡ $\mathbf{p}_{T,\min} \approx \mathbf{2.4}$ GeV
- Moderate interaction number due to additional multiplicity from PS
  - ➡ $< \mathbf{N}^{\mathbf{2\to2}}_{\text{hard}} > \approx \mathbf{2.08}$

To take home ...

- Highly dependent on $p_{T,min}$ and PDF
- Does not give any prediction for the LHC (naive scaling)

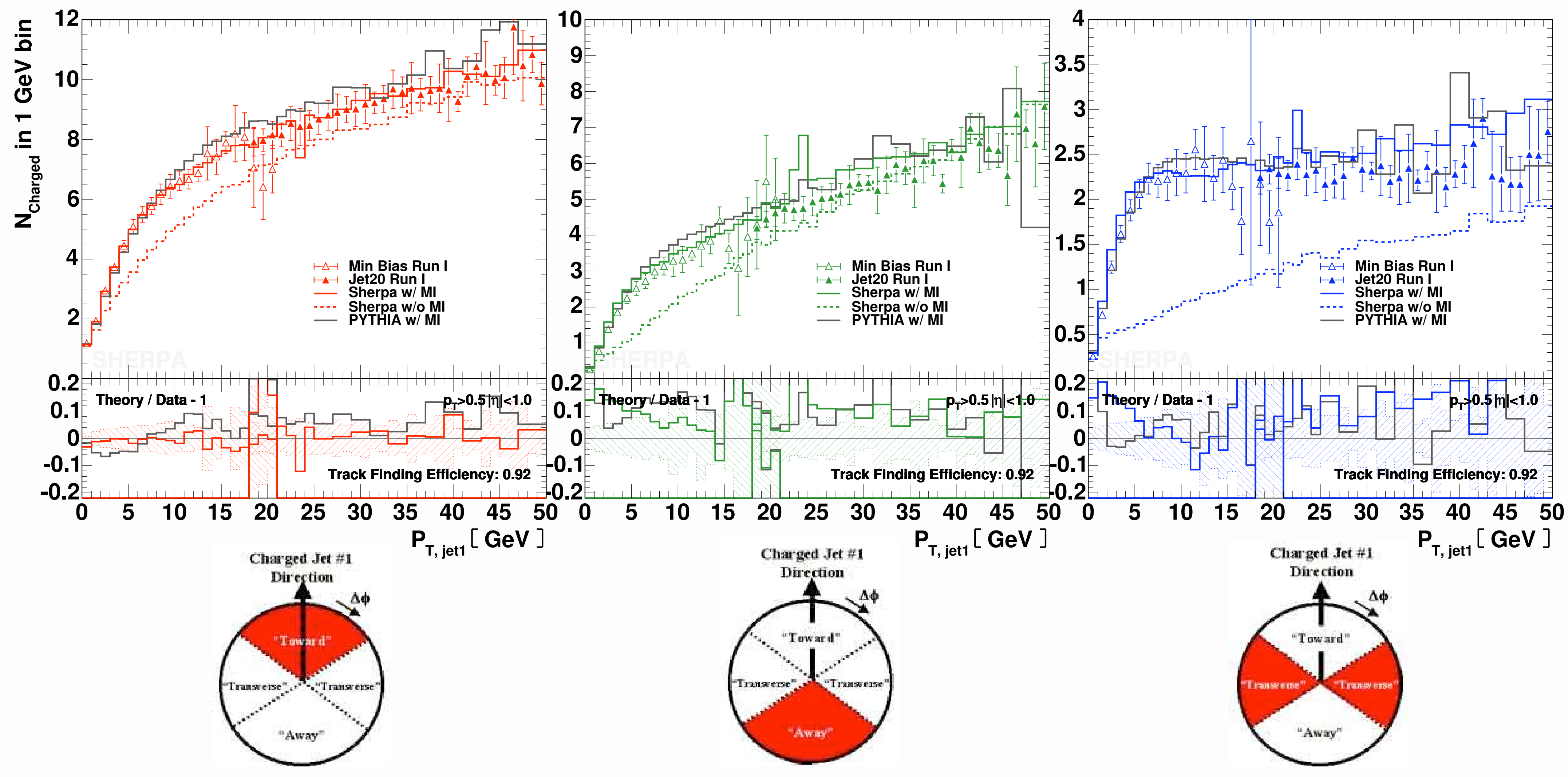
- N_{Charged} vs. $p_{T,\text{jet1}}$ in CTC



Results from Sherpa

hep-ph/0601012

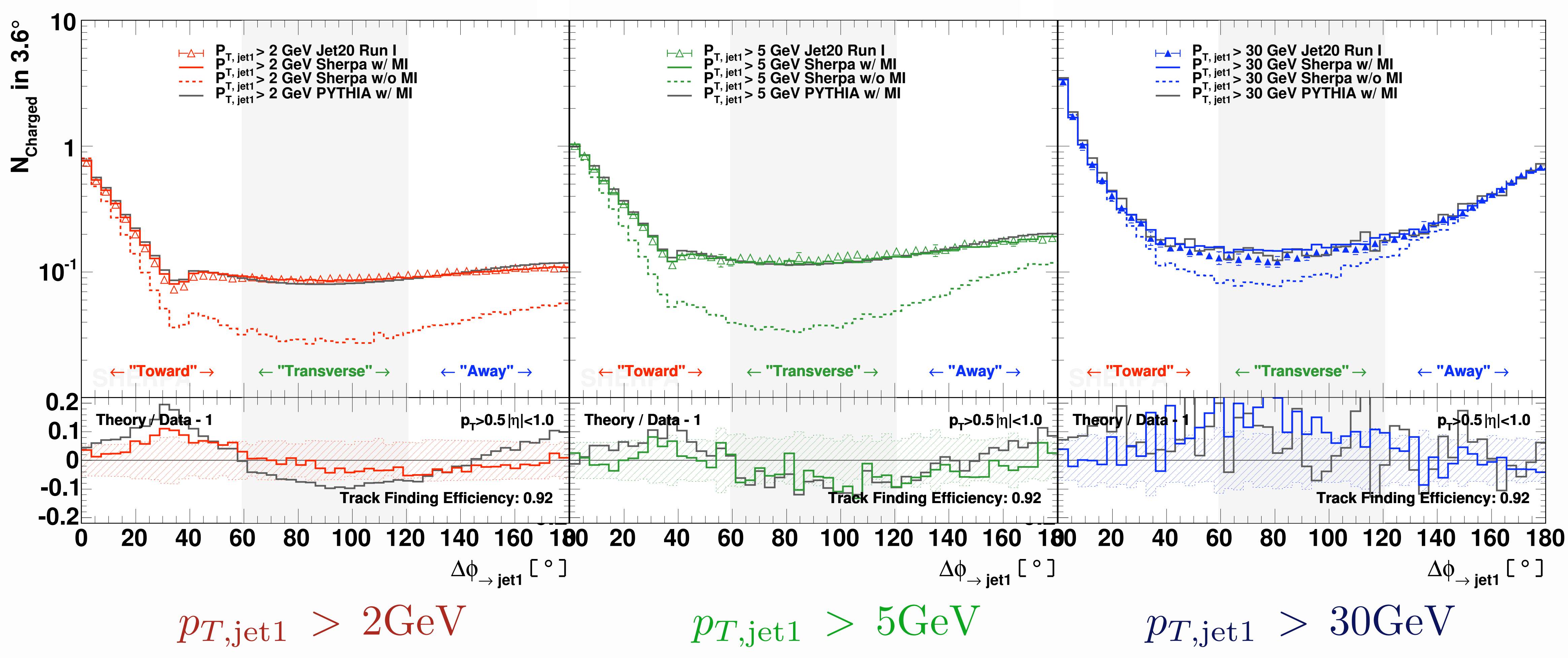
- $N_{Charged}$ vs. $p_{T,jet1}$ in CTC
  in different regions w.r.t. leading charged particle jet



Results from Sherpa

hep-ph/0601012

- N_{Charged} vs. $\Delta\varphi_{\text{jet1}}$ in CTC
  for different p_T of leading charged particle jet



Towards a new MPI model

Drawbacks of the current MPI model

- Lower p_T - cutoff defines total cross section
- Energy extrapolation depends on tuning parameter

We try to solve part of this by ...

- Definiton of hard cross section through BFKL kernel convoluted with DUPDF's
  ➔ can be extended into diffractive region
- Distribution of interactions according to a Poissonian in the spirit of JIMMY (Z.Phys.C72(1996)637)
  - Hard scatters unordered in p_T
  - Multiplicity determined by impact parameter

This is work in progress ...

Jets & k_T- Factorisation

BFKL describes "just another type of shower"

- BFKL evolution can be rewritten in terms of Sudakov-like factors and vertex factors (PRL 78(1997)4531, PRD56(1997)5875)

DUPDF's can be inferred from DGLAP PDF's (KMRW)

- Undoing the last evolution step yields a well-defined quantity Inputs from data can be used (EPJC31(2003)73, PRD70(2004)014012)

➜ Combine the two methods, employ that DGLAP and BFKL are essentially equivalent to angular ordered parton evolution (Integrated branching probabilities agree to leading log)

$$\mathbf{\Gamma}_{\mathbf{gg}}^{(\mathbf{LL})}(\mu^{\mathbf{2}},\tilde{\mu}^{\mathbf{2}}) = \int_{\ln\mu^{\mathbf{2}}}^{\ln\tilde{\mu}^{\mathbf{2}}} \mathrm{d}\ln \mathrm{k}_\perp^{\mathbf{2}} \int_{\mathbf{y}(\mathbf{z}_{\max})}^{\mathbf{y}(\mathbf{z}_{\min})} \mathrm{d}\mathbf{y}\;\tilde{\alpha}_{\mathbf{s}}$$

$$\bar{\mathbf{\Gamma}}_{\mathbf{g}}^{(\mathbf{LL})}(\mathbf{y},\tilde{\mathbf{y}}) = \int_{\mathbf{y}}^{\tilde{\mathbf{y}}} \mathrm{d}\mathbf{y}' \int_{\mathbf{0}}^{\ln \mathrm{q}_\perp^{\mathbf{2}}/\mu_{\mathbf{0}}^{\mathbf{2}}} \mathrm{d}\ln\frac{\mathrm{q}_\perp^{\mathbf{2}}}{\mathrm{k}_\perp^{\mathbf{2}}}\;\bar{\alpha}_{\mathbf{s}}$$

This allows to generate scatterings using BFKL for IS evolution

Jets & k_T- Factorisation

Factorisation of the cross section

- gg→gg matrix element in high-energy limit

$$|\mathrm{M_{gg}}|^2 = (4\pi\alpha_s)^2 \frac{C_A^2}{2}\left(3 - \frac{tu}{s^2} - \frac{us}{t^2} - \frac{st}{u^2}\right) \Rightarrow (4\pi\alpha_s)^2 \frac{1}{8}\left[\,P_{gg}(z)\,\right]^2 \left\{1 + \mathcal{O}(z)\right\}$$

- Rewrite two-particle FS phase space & IS integration ⇒

$$\sigma = \frac{\pi^2}{2S}\int dy_1 \int dk_{1\perp}^2 \int d\phi_1 \int dy_2$$
$$\times\ \bar{f}_g(x^{(1)}, z, k_\perp^2, \bar{k}_\perp^2)\, \bar{f}_g(x^{(2)}, z, k_\perp^2, \bar{k}_\perp^2)\, \frac{1}{2\,\xi^{(1)\,2}\xi^{(2)\,2} S}\, \frac{1}{\bar{\Delta}_g(y_1, y_2)}$$

What about quarks ?

- No LO effective vertices for quark production & decay
  ⇒ employ leading term of DGLAP kernel for z→0

$$C_{qg} = C_F\ , \quad C_{qq}(z_i) = \frac{1}{2} C_F\, z_i\ , \quad C_{gq}(z_i) = \frac{1}{2} T_R\, z_i$$

Jets & k_T- Factorisation

arXiv0705.4577

General BFKL cascade

$$\sigma = \frac{\pi^2}{2S} \sum_{a^{(1)}} \int \mathrm{d}y_1 \int \mathrm{d}k_{1\perp}^2 \int \mathrm{d}\phi_1 \int \mathrm{d}y_n$$

$$\times\; f^{(1)}(x^{(1)}, z^{(1)}, k_{1\perp}^2, \bar{k}_{2\perp}^{(1)2})\, f^{(2)}(x^{(2)}, z^{(2)}, k_{n\perp}^2, \bar{k}_{n-1\perp}^{(2)2})\, \frac{1}{2\xi^{(1)\,2}\xi^{(2)\,2}S}\, \frac{1}{\Delta_{a_1}(y_1, y_2)}$$

$$\times \left[\prod_{i=2}^{n} \int \frac{\mathrm{d}\phi_i}{2\pi} \int \mathrm{d}y_i \int \frac{\mathrm{d}k_{i\perp}^2}{k_{i\perp}^2} \frac{\alpha_s(k_{i\perp}^2)}{\pi} \sum_{a_i} C_{a_{i-1}a_i}(q_{i-1}, k_i)\, \Delta_{a_i}(y_i, y_{i-1}) \right]$$

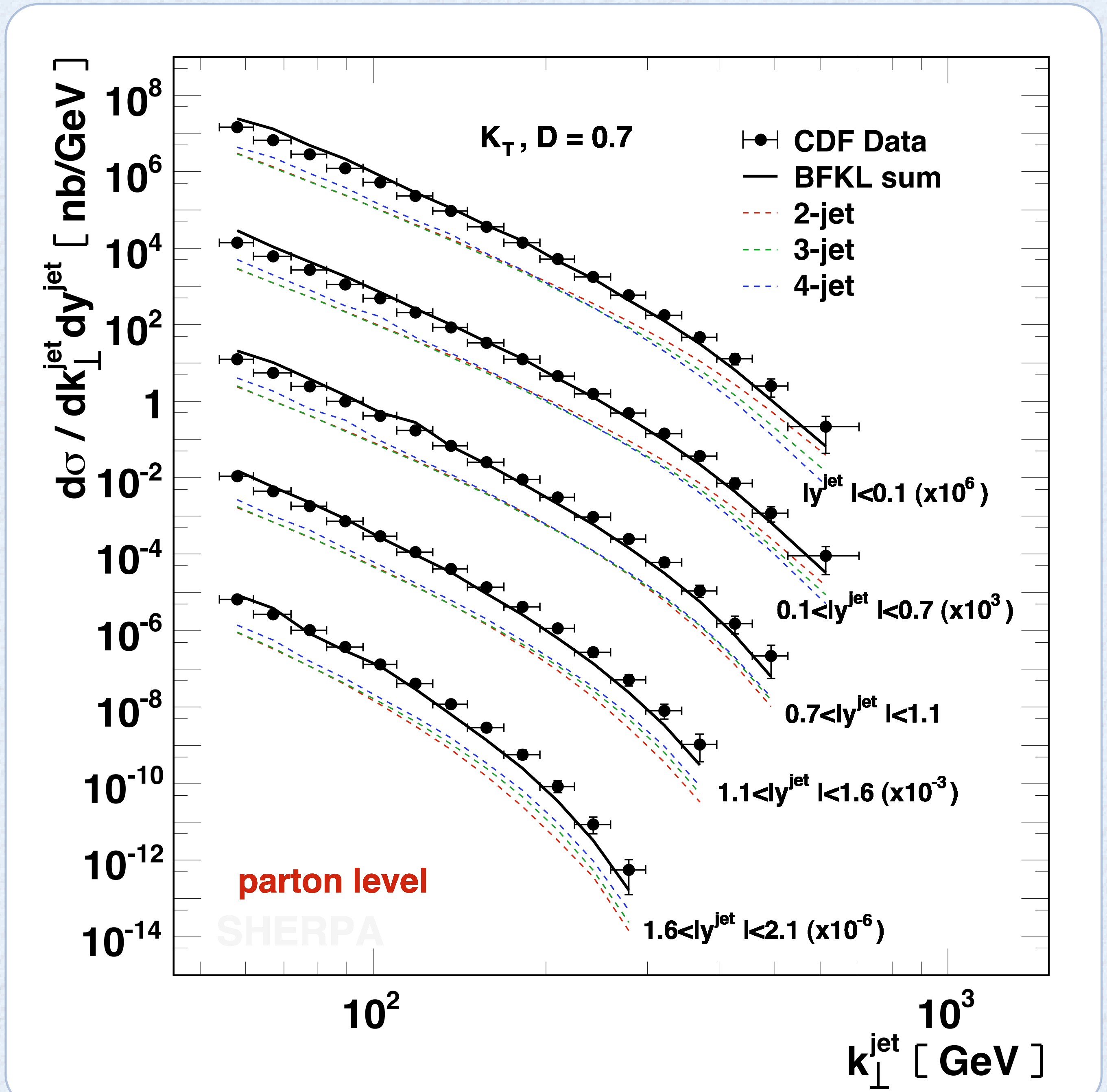
Monte Carlo method

- Markovian algorithm to generate splittings from $\Delta_{a_i}(y_i, y_{i-1})$ in the spirit of a parton shower
  ➡ number of emissions determined on the flight
- Strong coupling taken at p_T of each emitted parton as suggested in PRD56(1996)5875

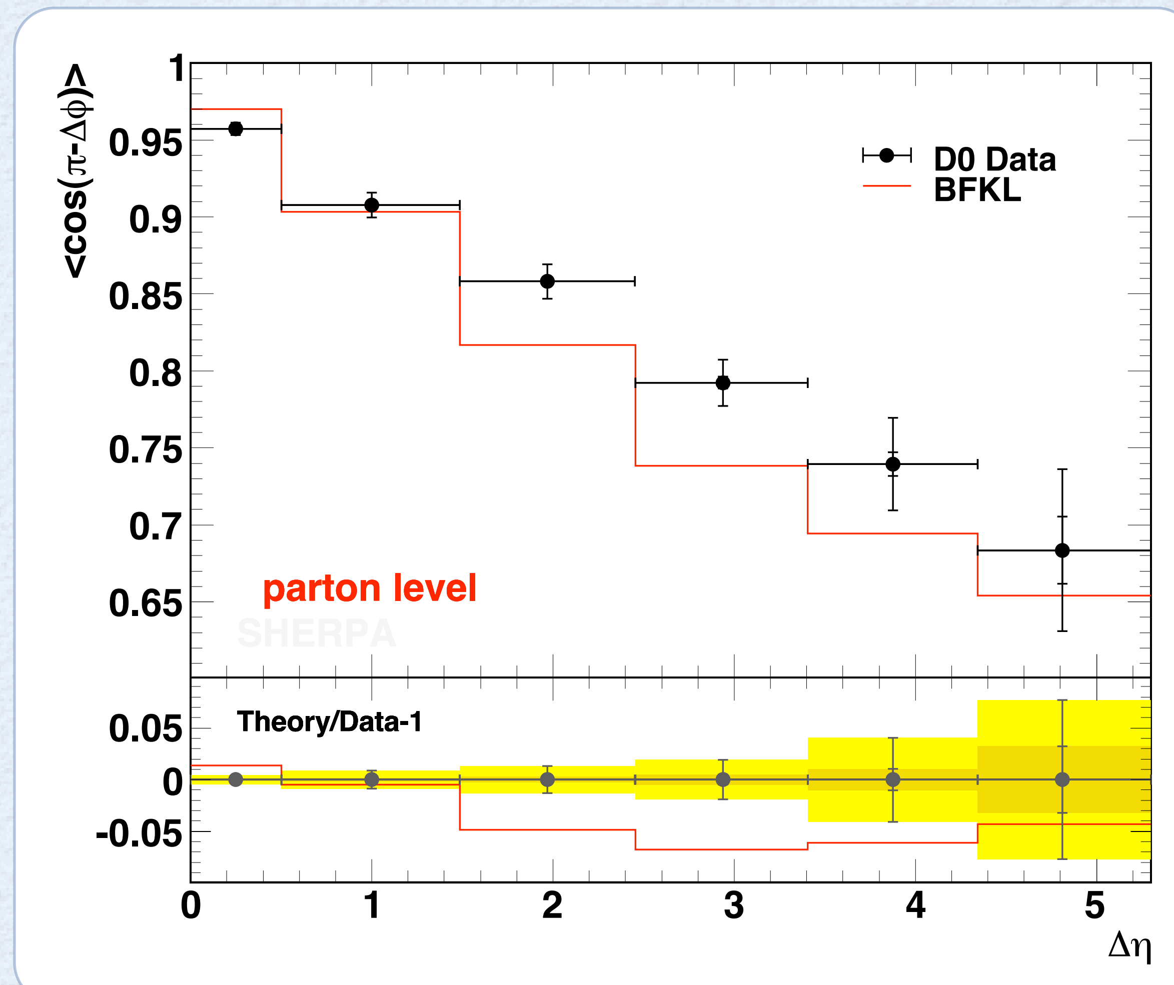
Jets & K_T- Factorisation

arXiv0705.4577

- Jet - p_T spectra PRD75(2007)092006



- Azimuthal decorrelation of widely separated jets PRL77(1996)595



Summary and Outlook

So far ...

- Monte Carlo for jet production in K_T - factorisation

To be done ...

- Simulation of exchange of multiple ladders
- Interplay with hard process and CKKW

Prospects ...

- Simulation of diffractive and mixed events possible
- Might give a handle on min-bias events