Workshop Summary

▸ **Objectives:**

- raise the profile of MPI studies
- summarize legacy from older phenomenology
- favour contacts between theory and experimental communities

MPI@LHC Agenda

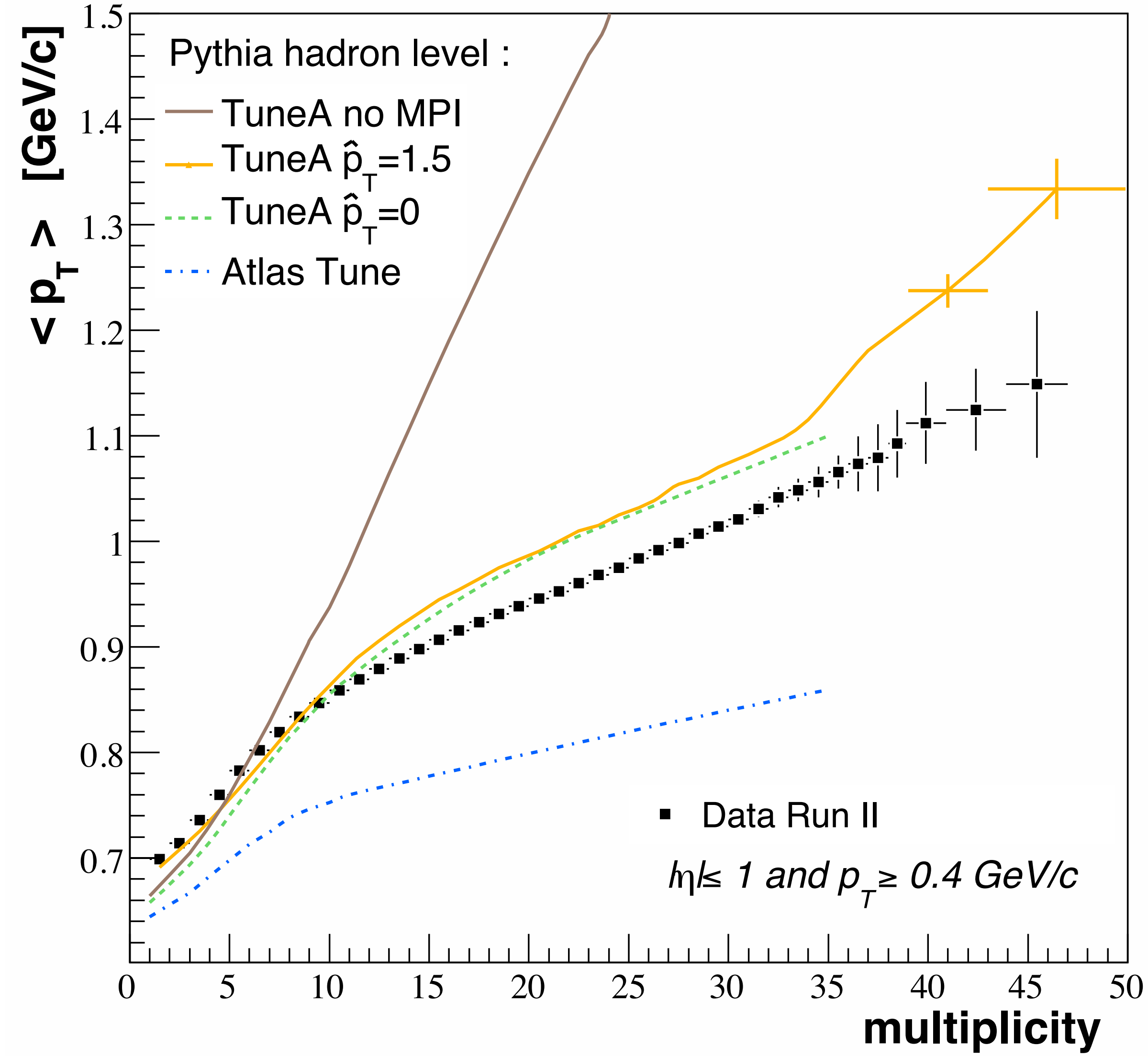
- **Hot Topics**
  - Higgs searches, Total LHC cross-sections, Progress in Jet algorithms
- **Soft & Hard Multiple Parton Interactions**
  - Double-parton-scattering, Multijet production, **Minimum bias, Underlying Event**
- **Small x physics and diffraction**
  - Gap survival probability, Rescattering
- **Monte Carlo Models**
  - **Herwig++, Pythia 8, Sherpa, Vincia, “Foundations”, Tunes**
- **Heavy Ions**
  - Saturation, Quarkonia, Jets

https://agenda.infn.it/conferenceDisplay.py?confId=599

$<p_T> (N_{ch})$

N. Moggi

- Merged data at high N_{ch} from a dedicated "high-multiplicity" trigger
  - ToF at L1
  - Track reconstruction at L3
  - Double the stat in N_{ch}>24
  - Total uncertainty ~2% (6% for Nch>40)



- TuneA: fairly good

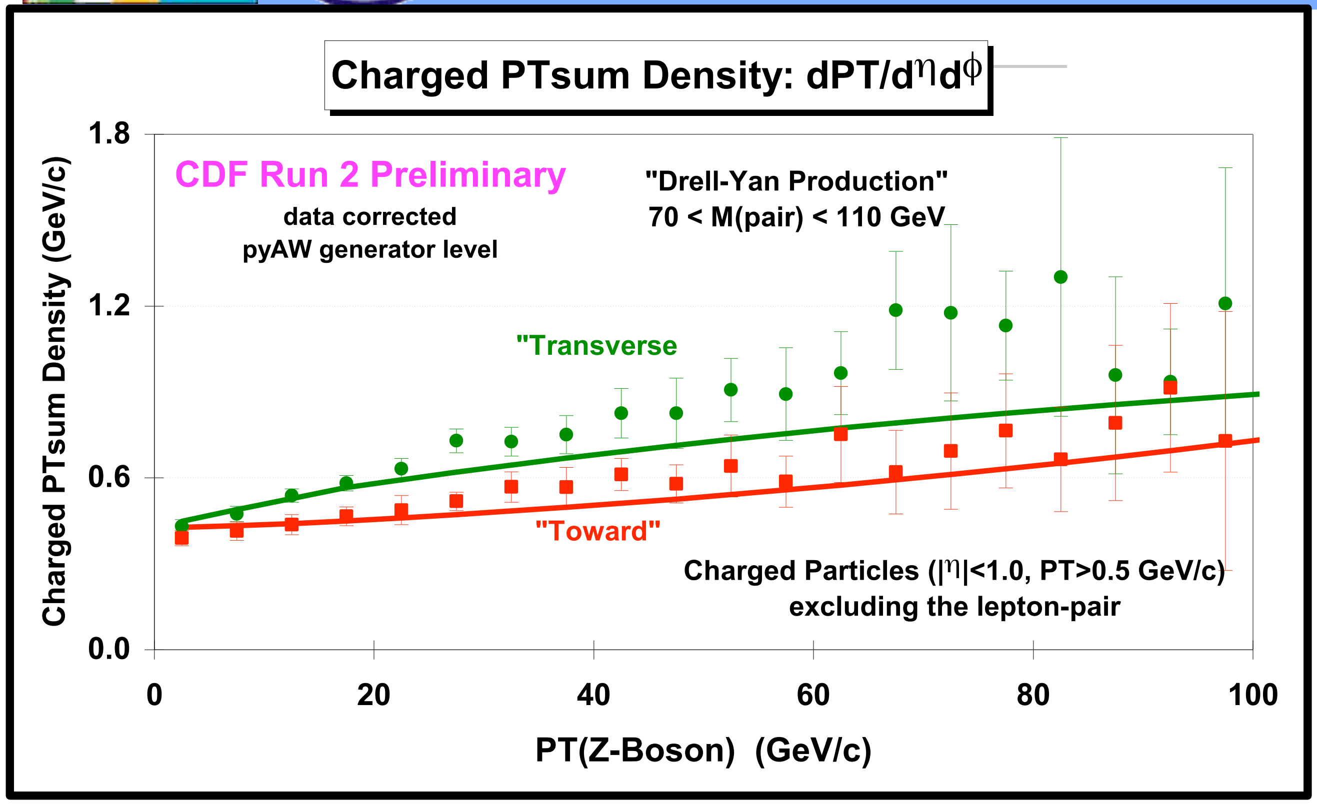
  TuneA no MPI: too hard

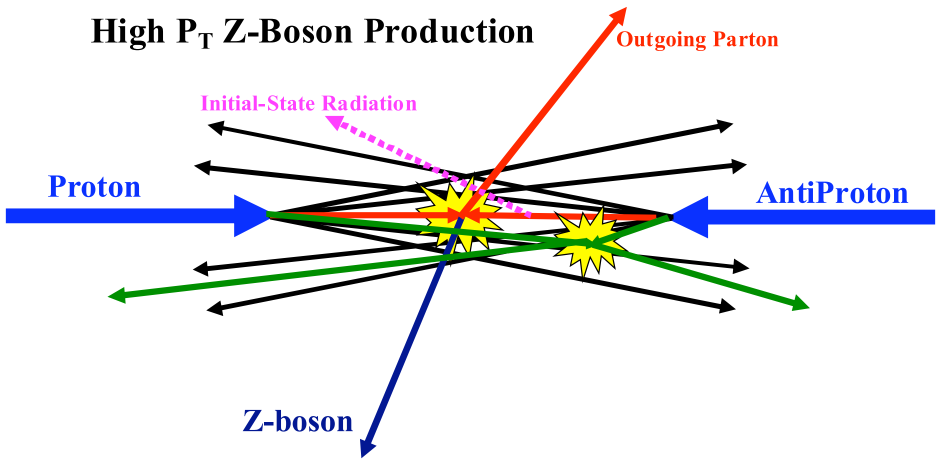
  Atlas tune: too soft

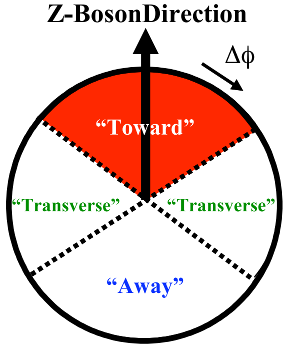
  (tunes by courtesy of R.Field)
- MPI mechanism necessary to reproduce $<p_T>(N_{ch})$
- $<p_T>(N_{ch})$ useful to tune MPI

R. Field

Z-Boson: “Towards”, Transverse”,







- Data at 1.96 TeV on the charged *scalar* PTsum density, dPT/dηdφ, with $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “Z-Boson” events as a function of $P_T(Z)$ for the “toward” and “transverse” regions. The data are corrected to the particle level (*with errors that include both the statistical error and the systematic uncertainty*) and are compared with PYTHIA Tune AW and HERWIG (without MPI) at the particle level (*i.e.* generator level).

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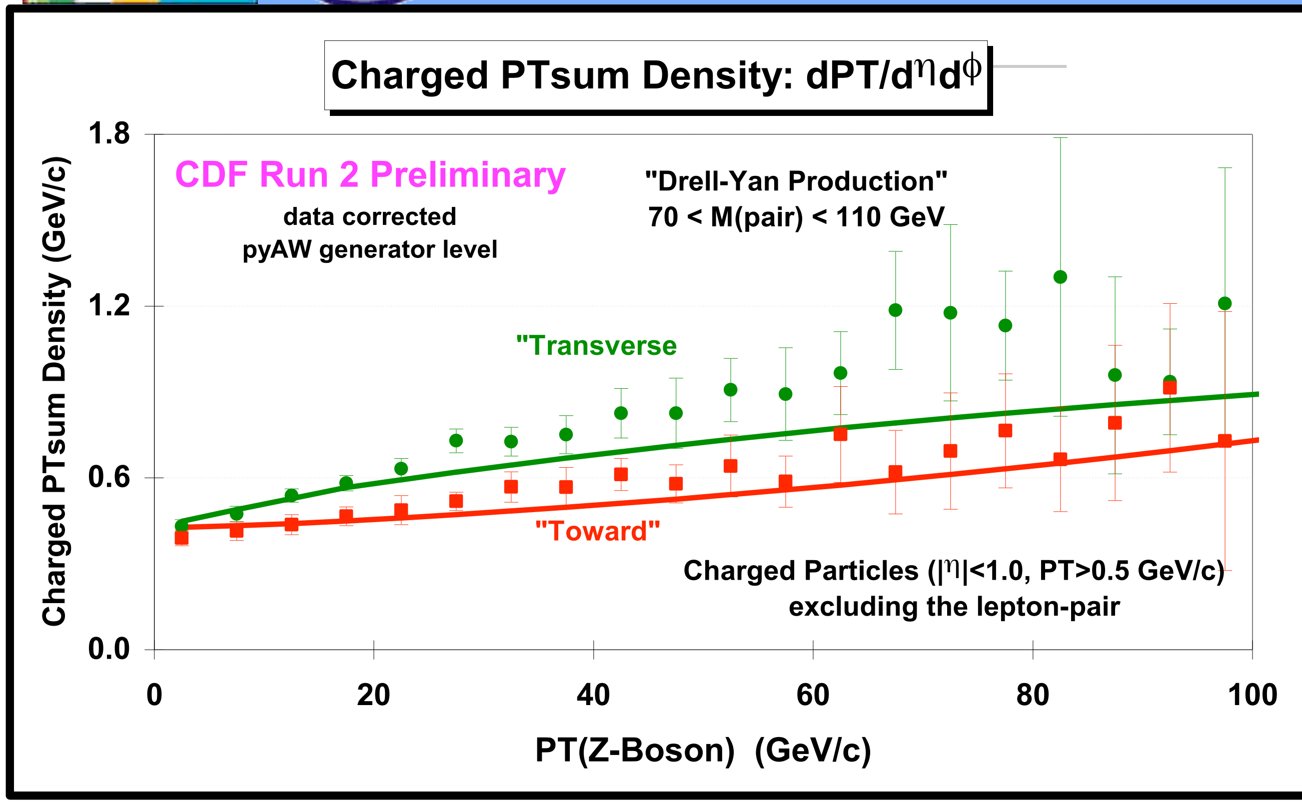

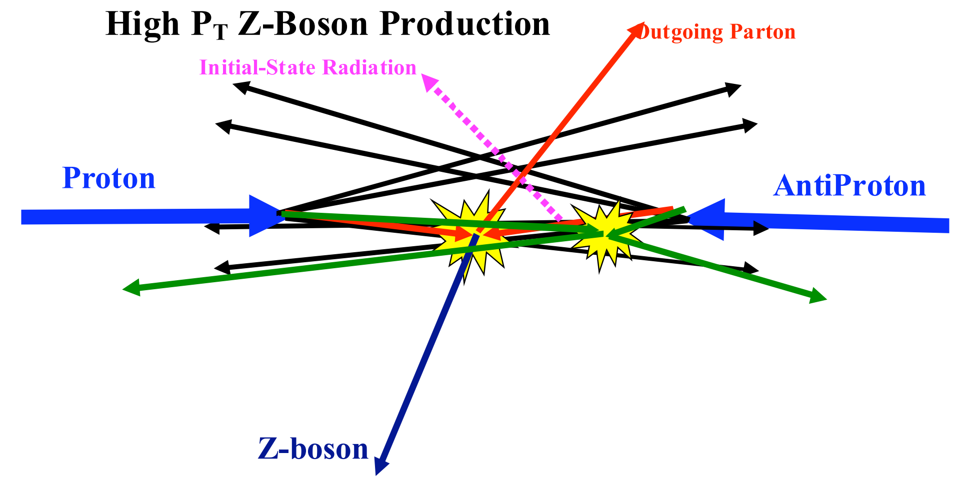

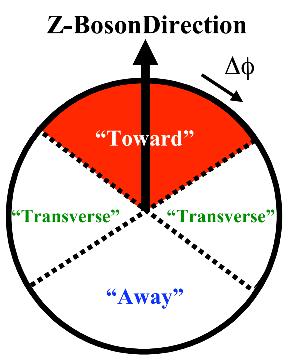

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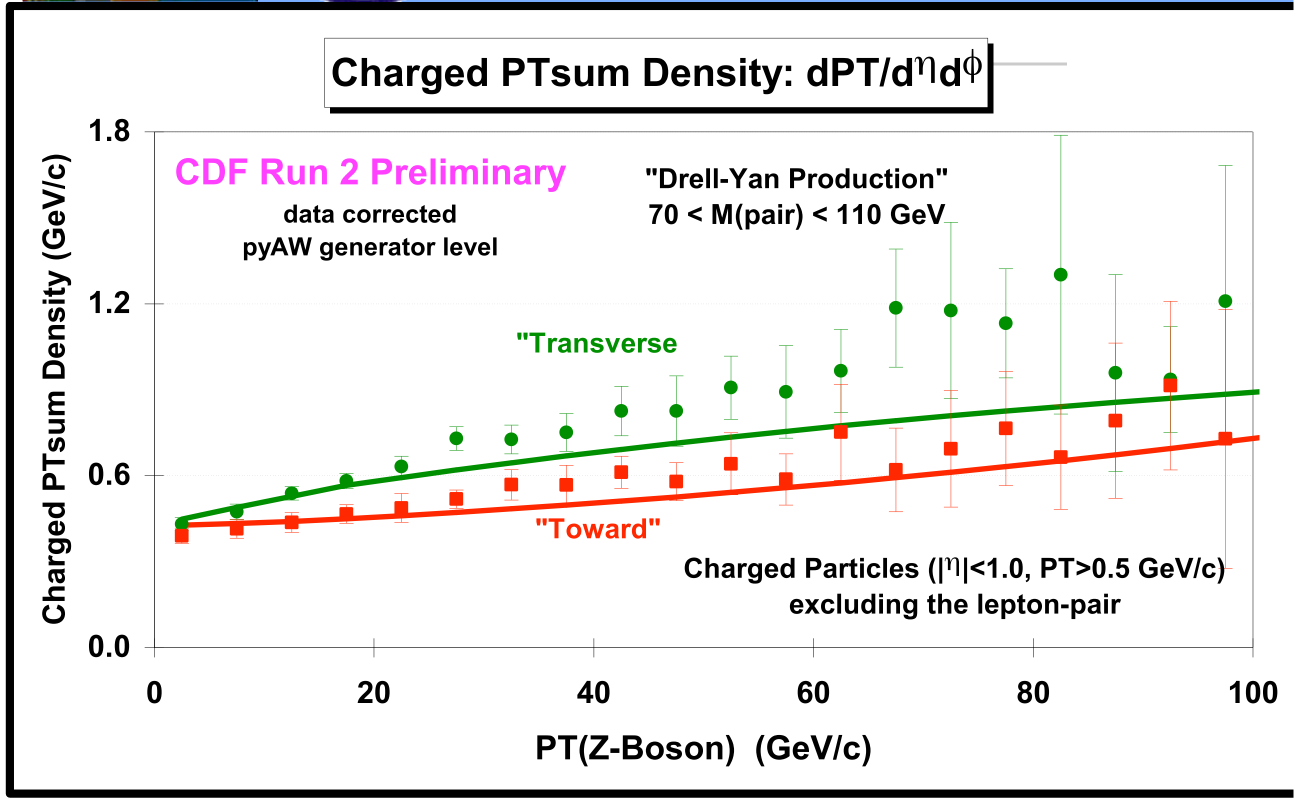

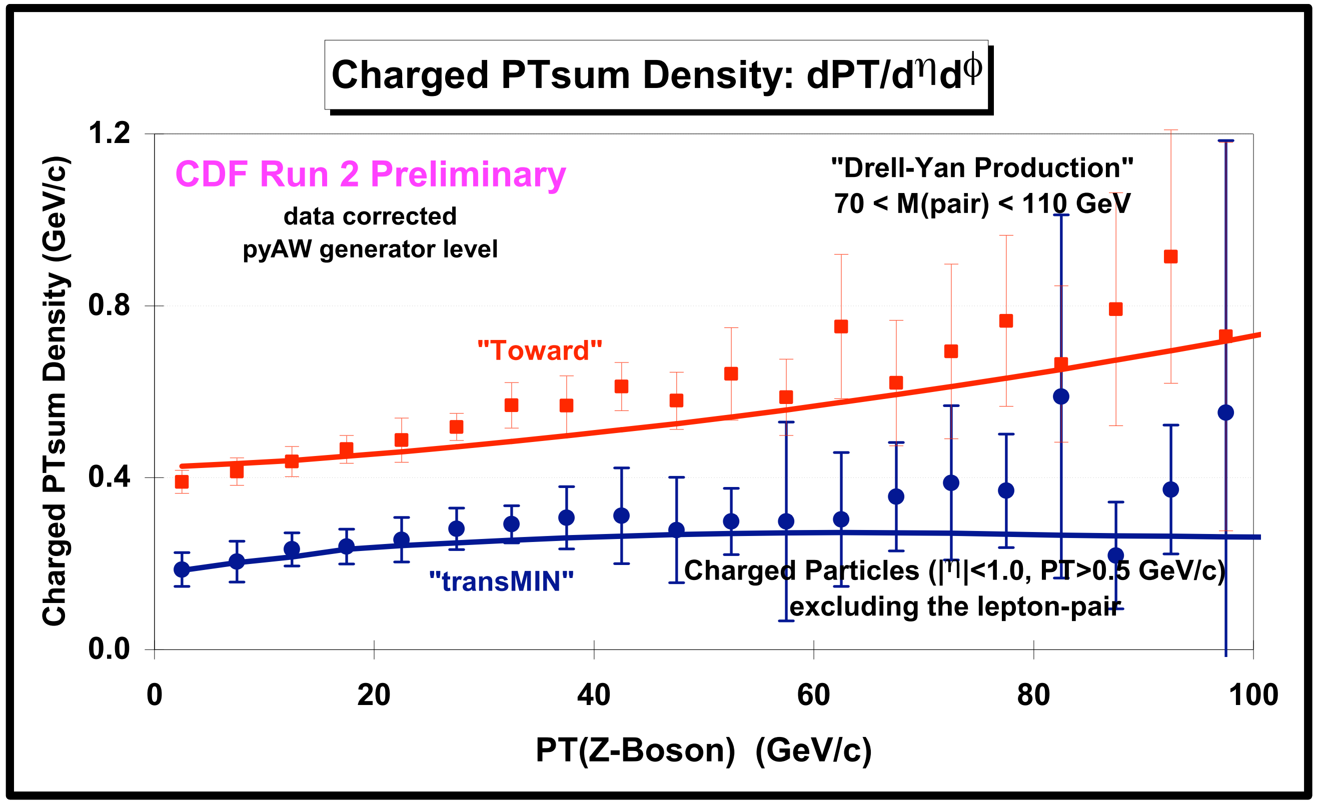

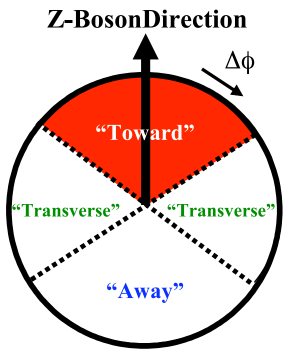

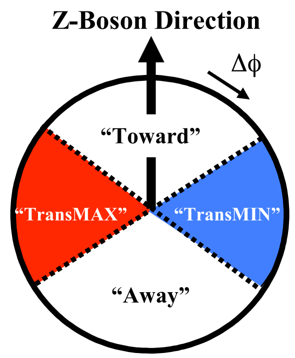

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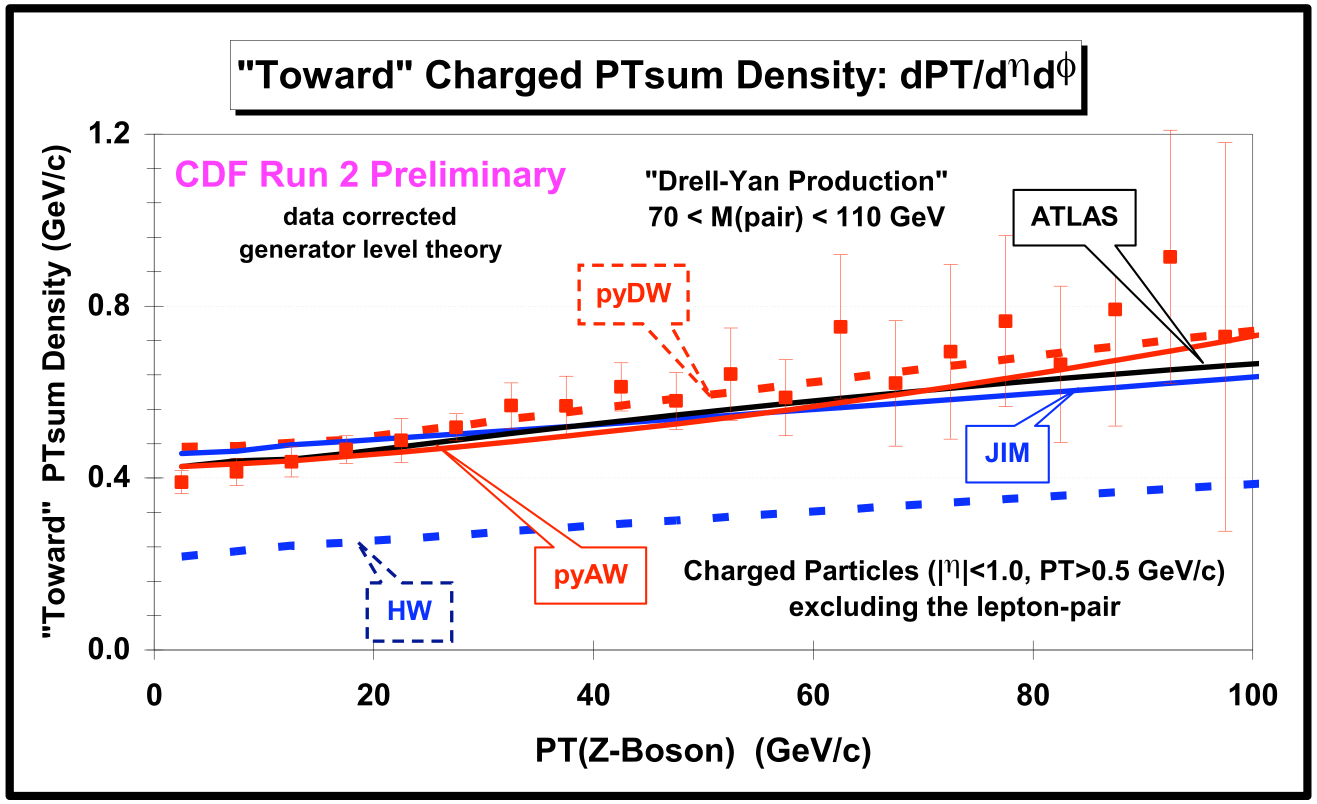

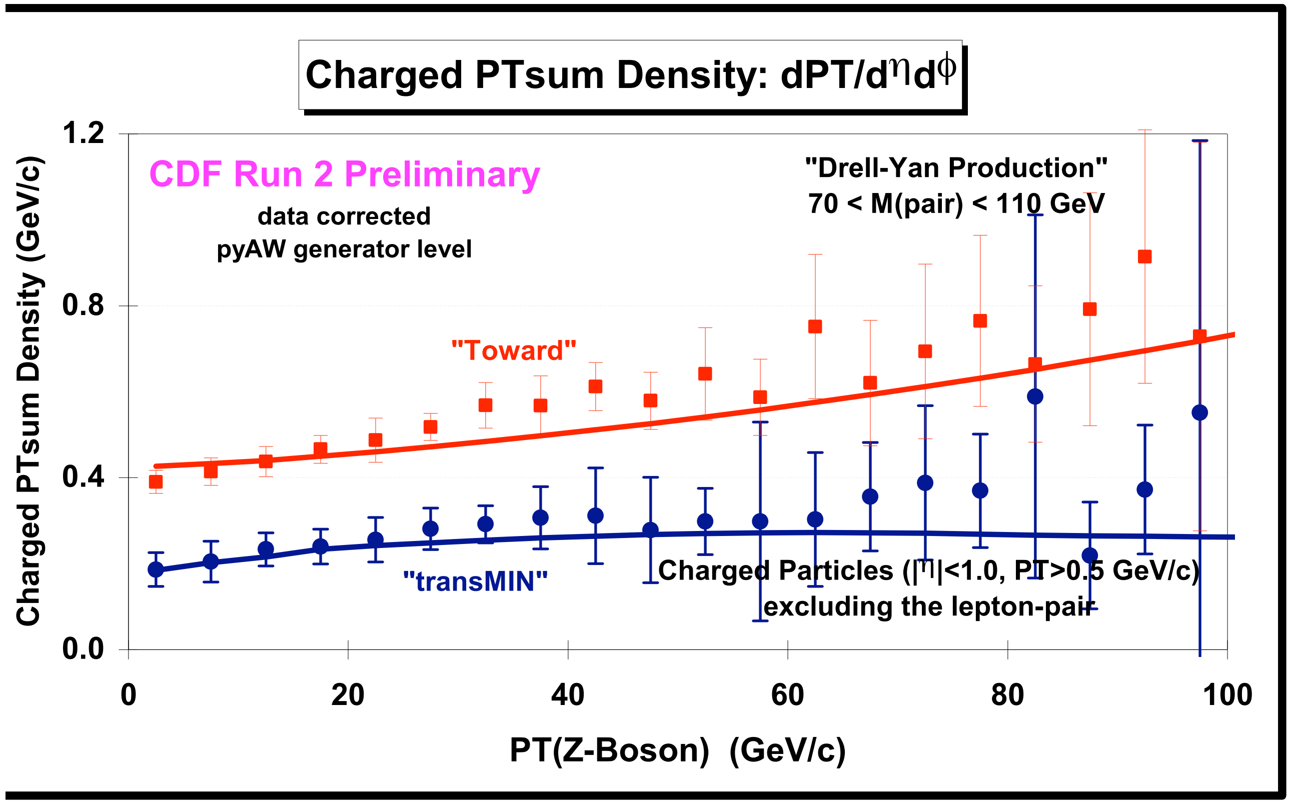

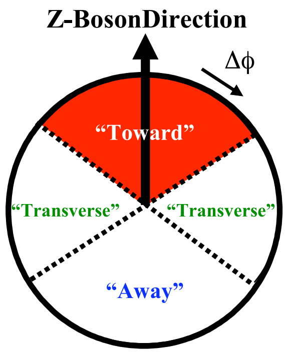

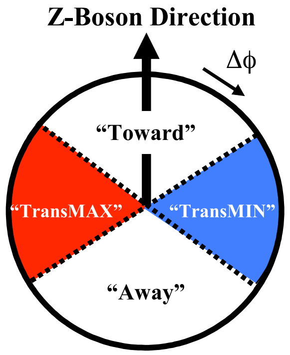

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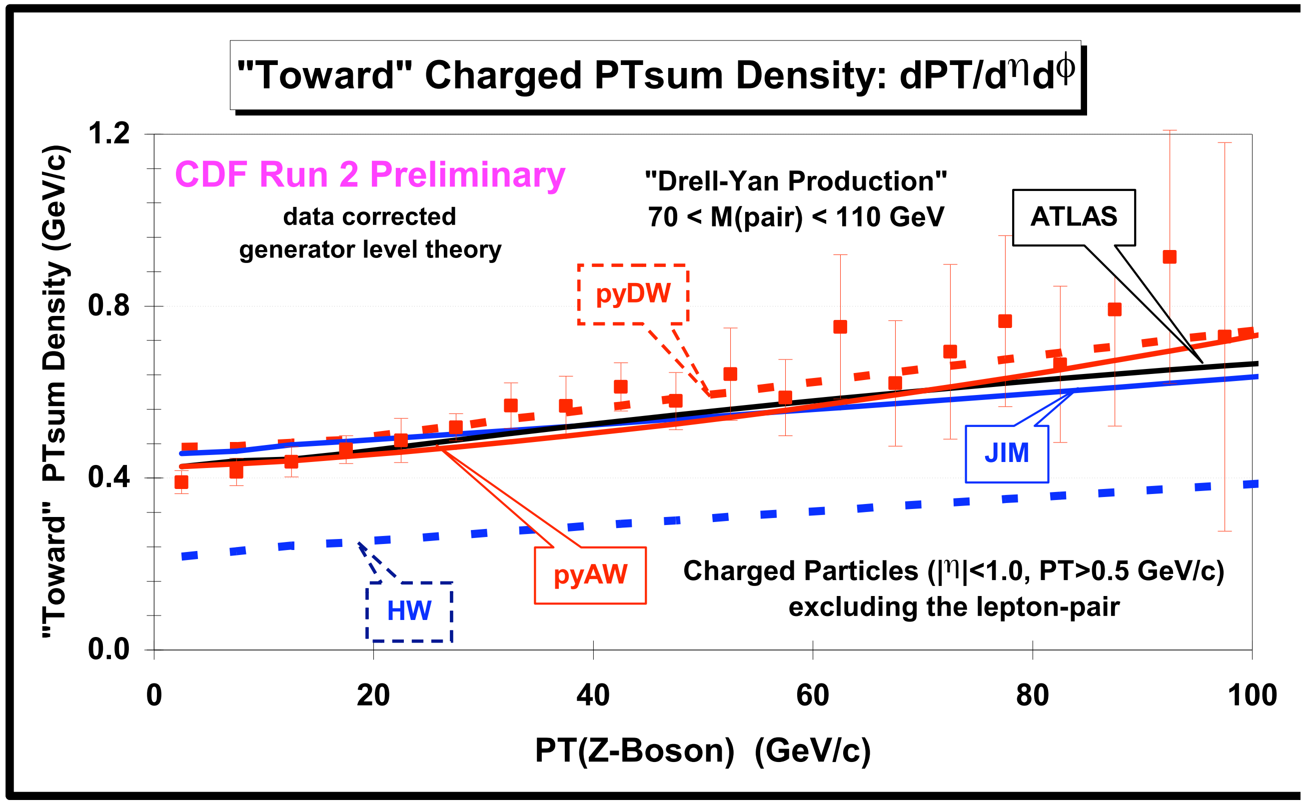

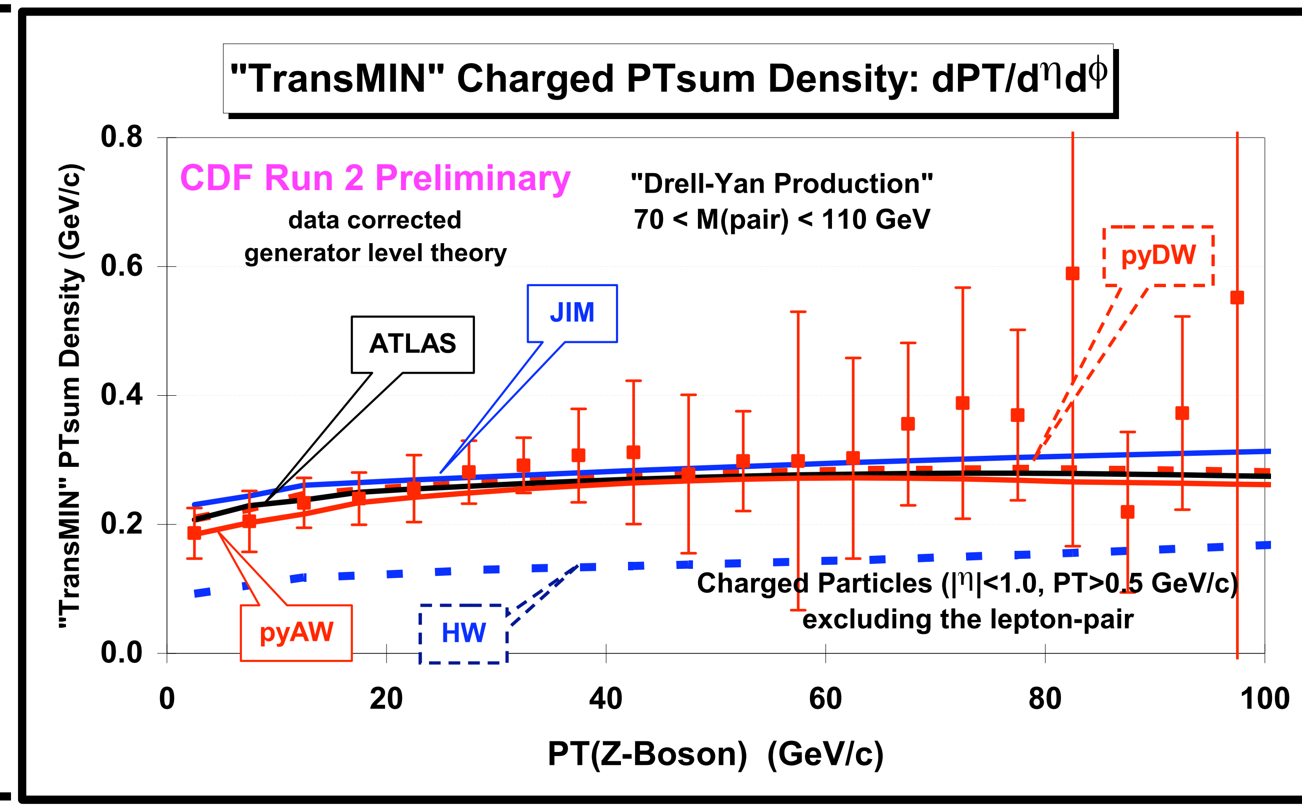

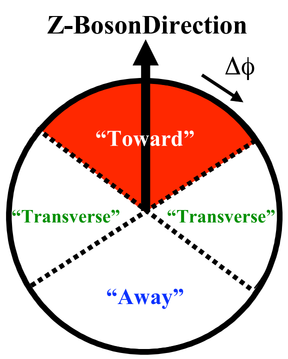

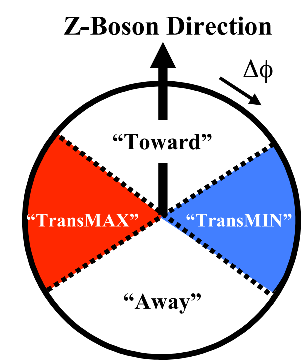

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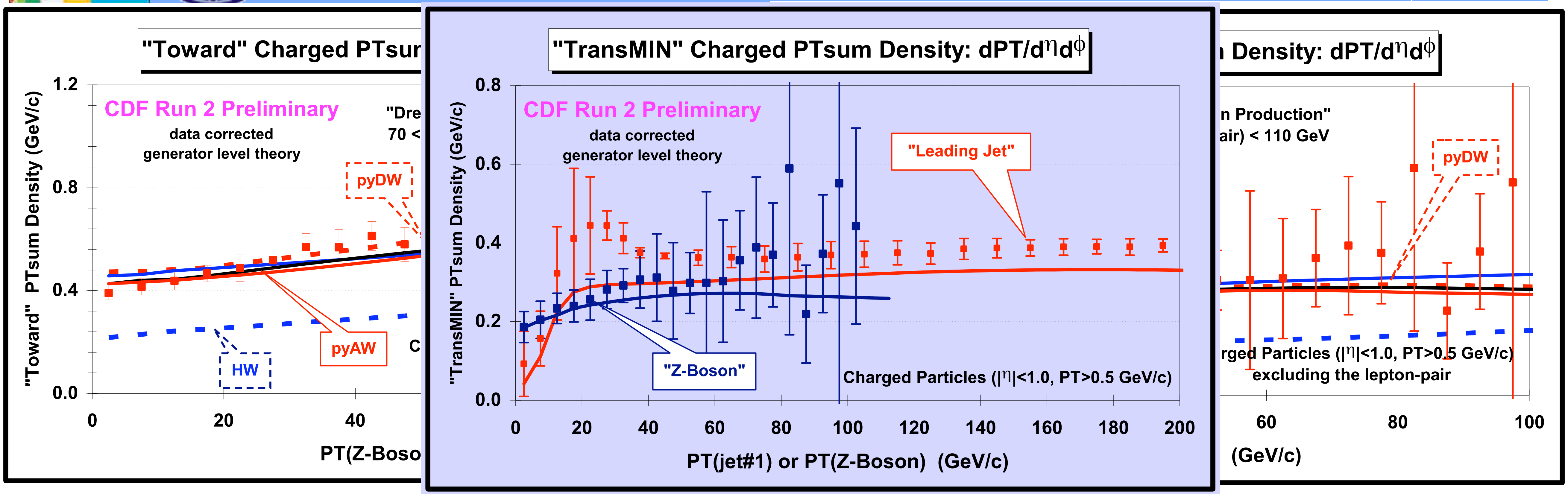

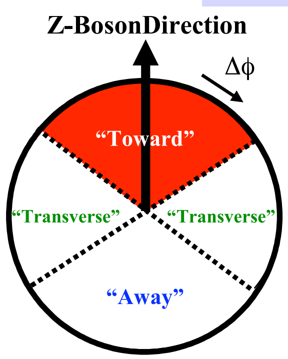

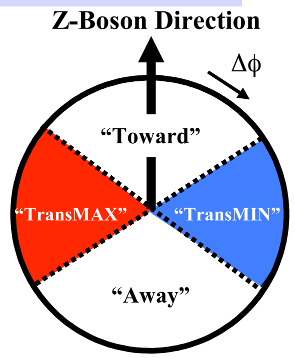

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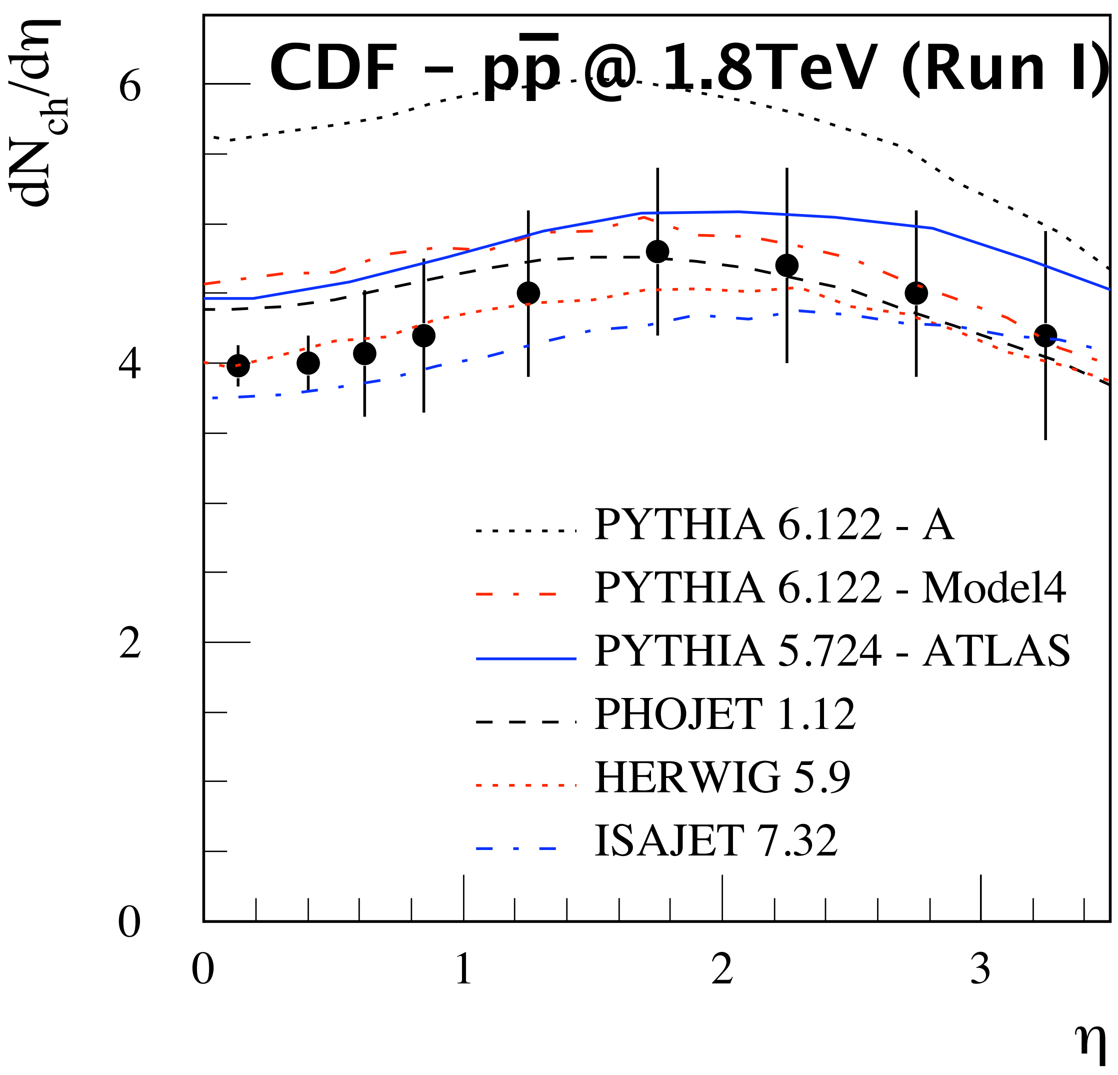
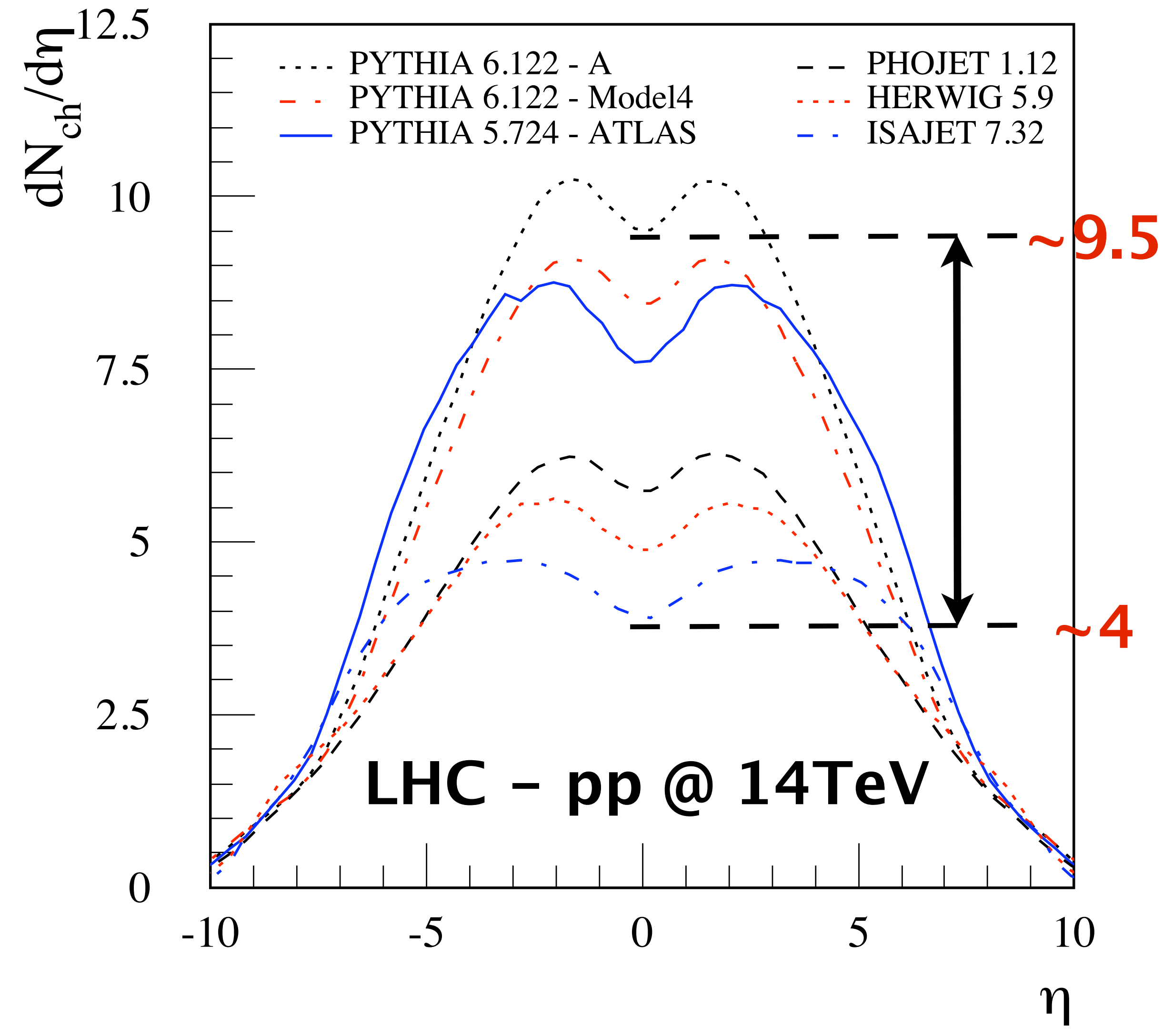
Introduction:

- ATLAS studies on the calibration of MC models have evolved considerably from the time of the ATLAS Detector & Physics Performance TDR (1999...).

- Minimum bias distributions:





ATL-PHYS-99-019

Updating the UE prediction/tuning for ATLAS.

University of Glasgow

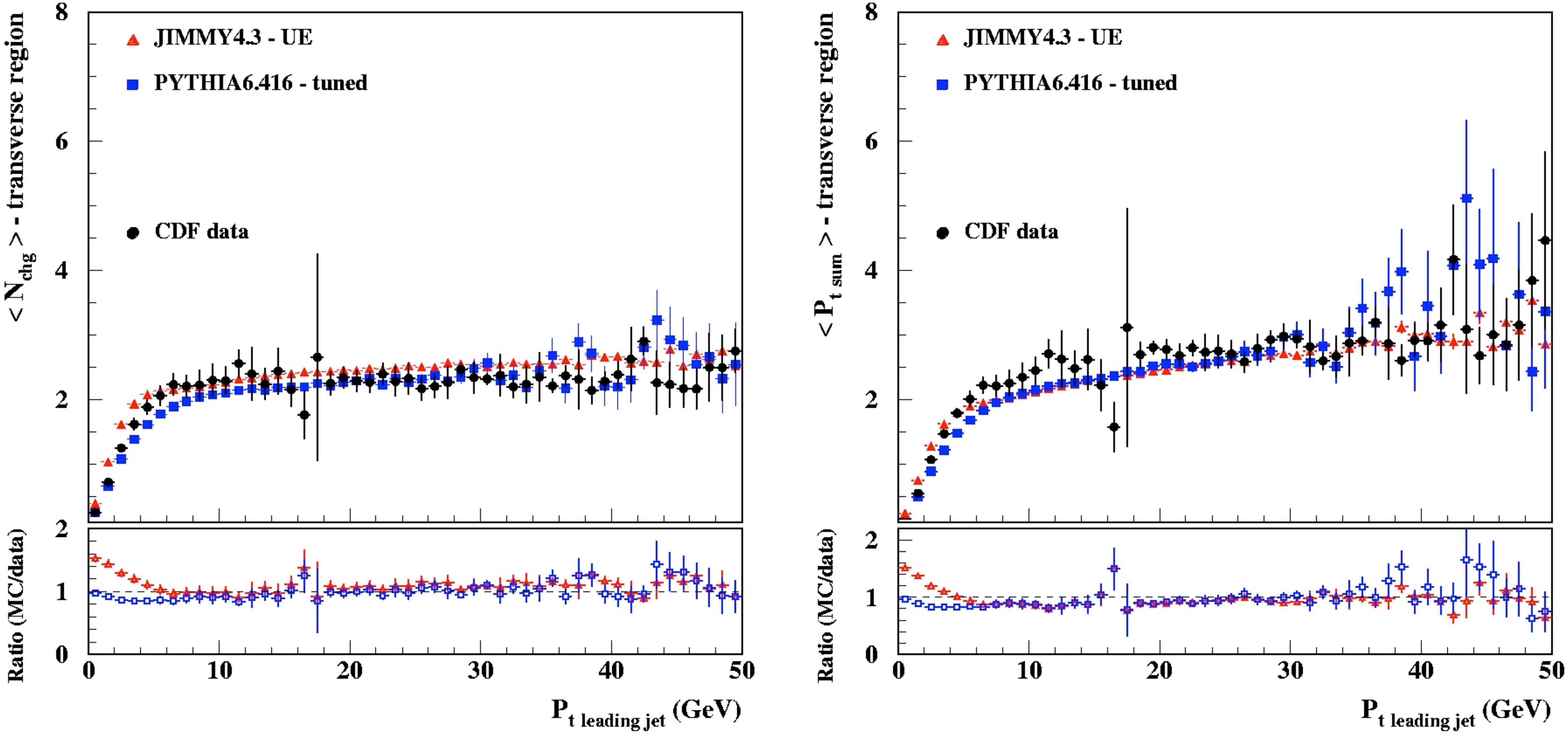
- JIMMY: no immediate need to update the tune currently used by ATLAS. **hep-ph/0604120 – LH2005: SM & Higgs WG report**

- Data distributions used to check model predictions:
  - $<N_{chg}>$ and $<P_T^{sum}>$ in the region transverse to the leading jet (CDF Run I data @ $\sqrt{s}$ = 1.8 TeV). **Phys. Rev. D65, 092002 (2002)**
  - dN_{chg}/dp_T spectrum of particles in the underlying event (same CDF data as above). **Phys. Rev. D65, 092002 (2002)**
  - MAX/MIN cones transverse to the leading jet (CDF Run I data @ $\sqrt{s}$ = 630 GeV and $\sqrt{s}$ = 1.8 TeV) **Phys. Rev. D70, 072002 (2004)**

A. Moraes

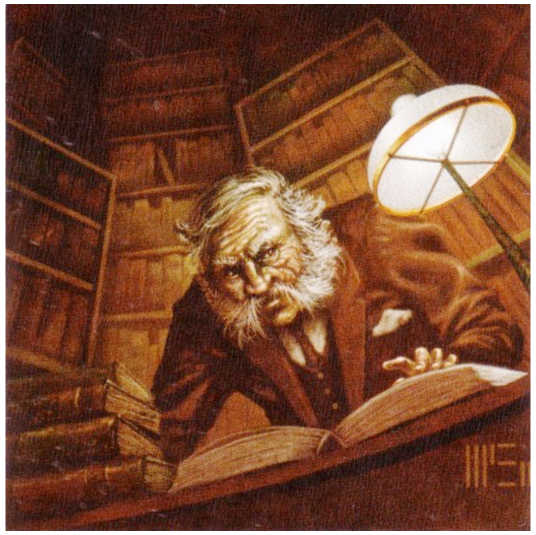
PYTHIA6.416 – tuned vs. JIMMY4.3

A. Moraes



Professor and Rivet

H. Hoeth



Tools for MC tuning have been developed and tested as part of the MCnet programme.

Rivet/Rivetgun: A general tool to steer different MC generators in a common way and to run analyses on generator level. Lots of published analyses are implemented, direct data/MC comparison is very easy. (http://projects.hepforge.org/rivet/)

Professor: Implementation of the tuning procedure. Uses Rivet to fill histograms. (http://projects.hepforge.org/professor/)

A strategy

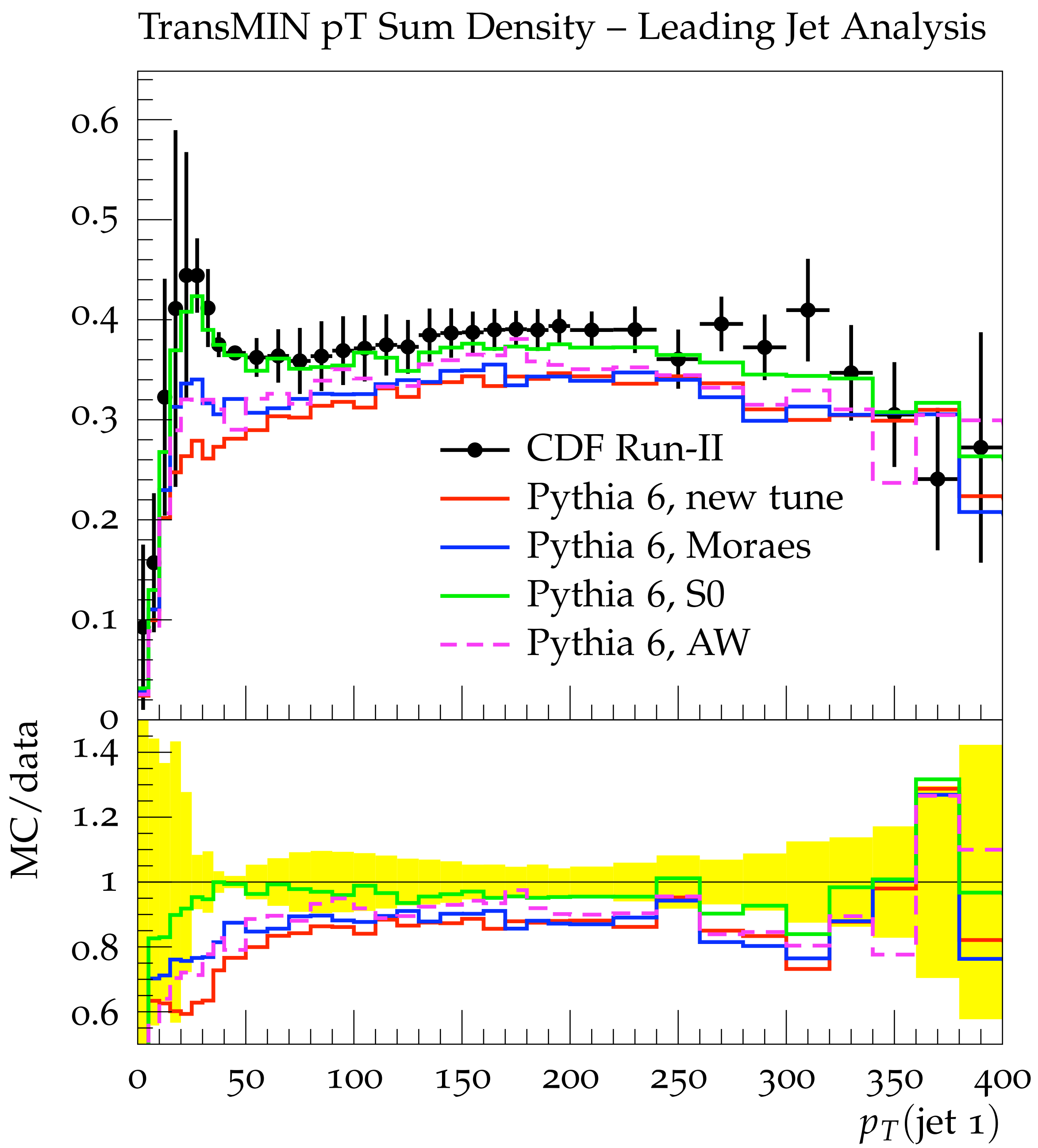
H. Hoeth

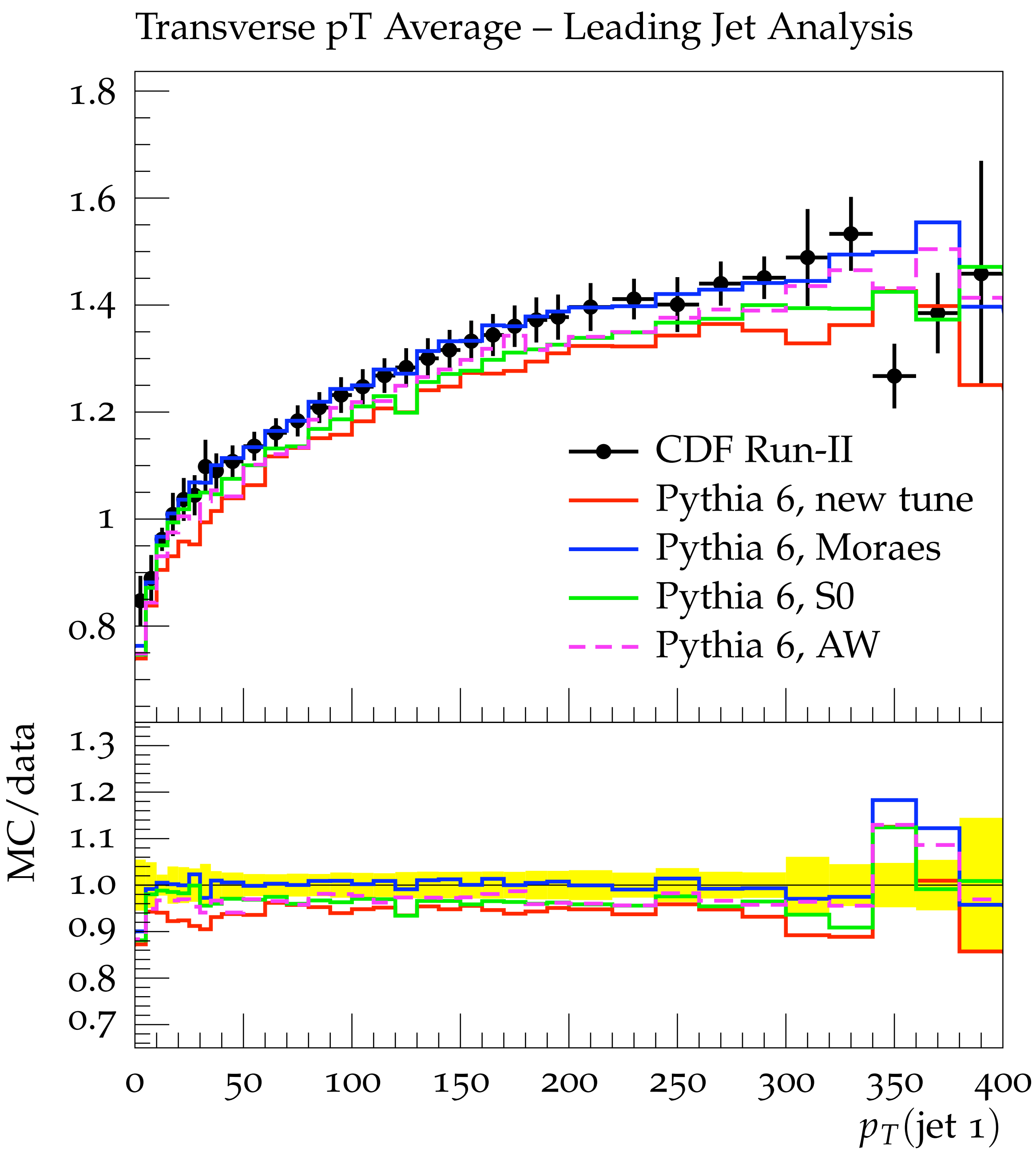
1. Choose a tuning interval for the parameters, then pick random points in parameter space and run the generator with these settings.
2. Interpolate between points $\Rightarrow$ prediction of the MC output at any specific parameter setting.
3. Fit this prediction to data (minimal χ^2).
4. Repeat the fit for different combinations of observables.
5. Choose the nicest set of parameters.

(already described and used in Z. Phys., C 73 (1996) 11–59)

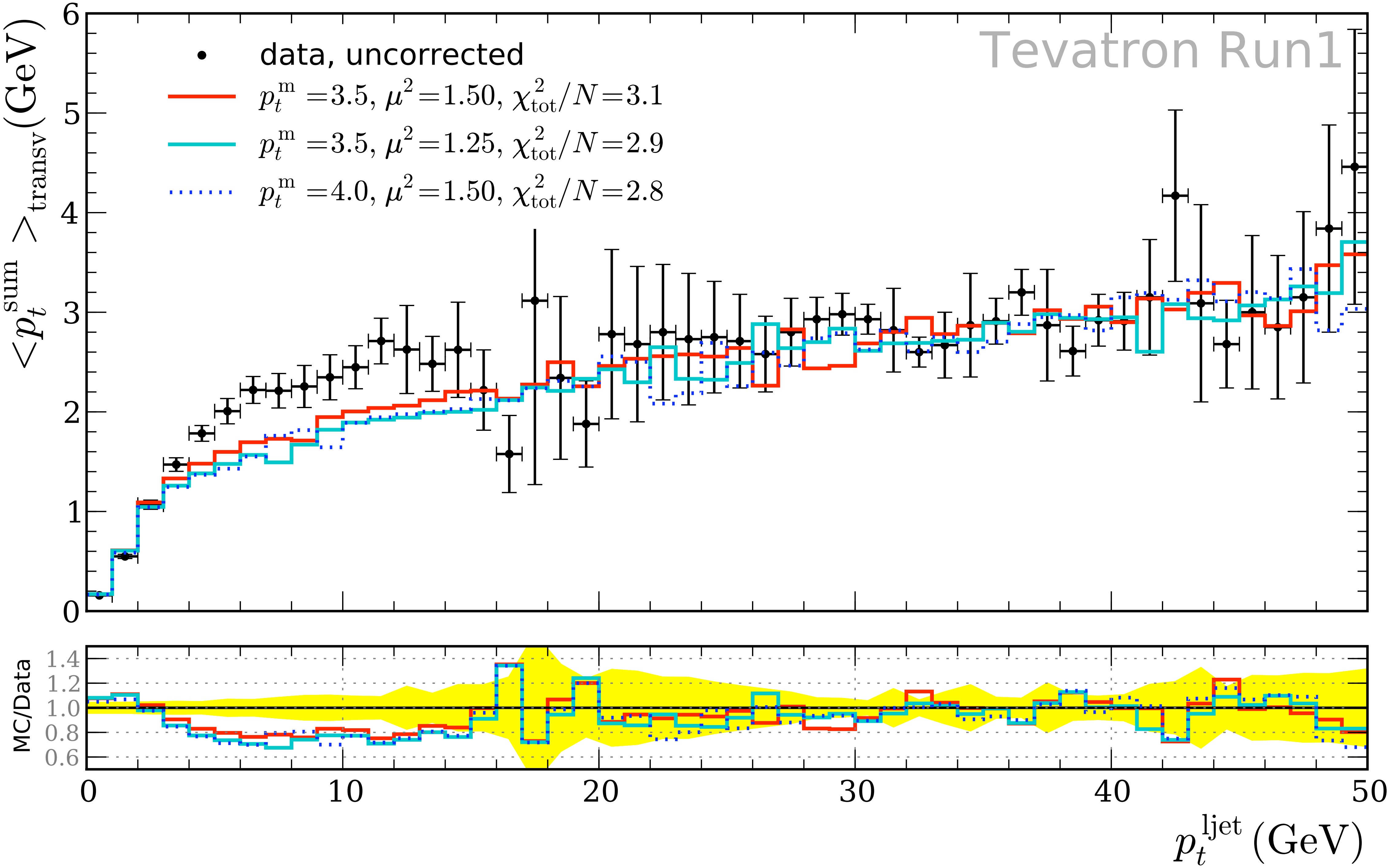
Pythia 6 – Tevatron Comparisons

H. Hoeth





Detailed look at observables: Transverse Region



Conclusions

- We extended the existing model to soft partonic interactions. First time MinBias is available in Herwig ever!
- The ue activity is directly coupled to the total and elastic cross section
  - Large impact of first measurements of these quantities at LHC
  - Extrapolation to larger energies constraint by predictions for these quantities
- Hot-Spot model to describe inconsistency between $\sigma_{\rm eff}$ and $b_{\rm el}$
- Fully exclusive simulation of multiple hard scatterings + low p_t jets possible (again no time to talk about it), e.g. $\gamma j + jj$, like sign W's, several b-jet pairs (... you name it) with arbitrary and independent cuts.

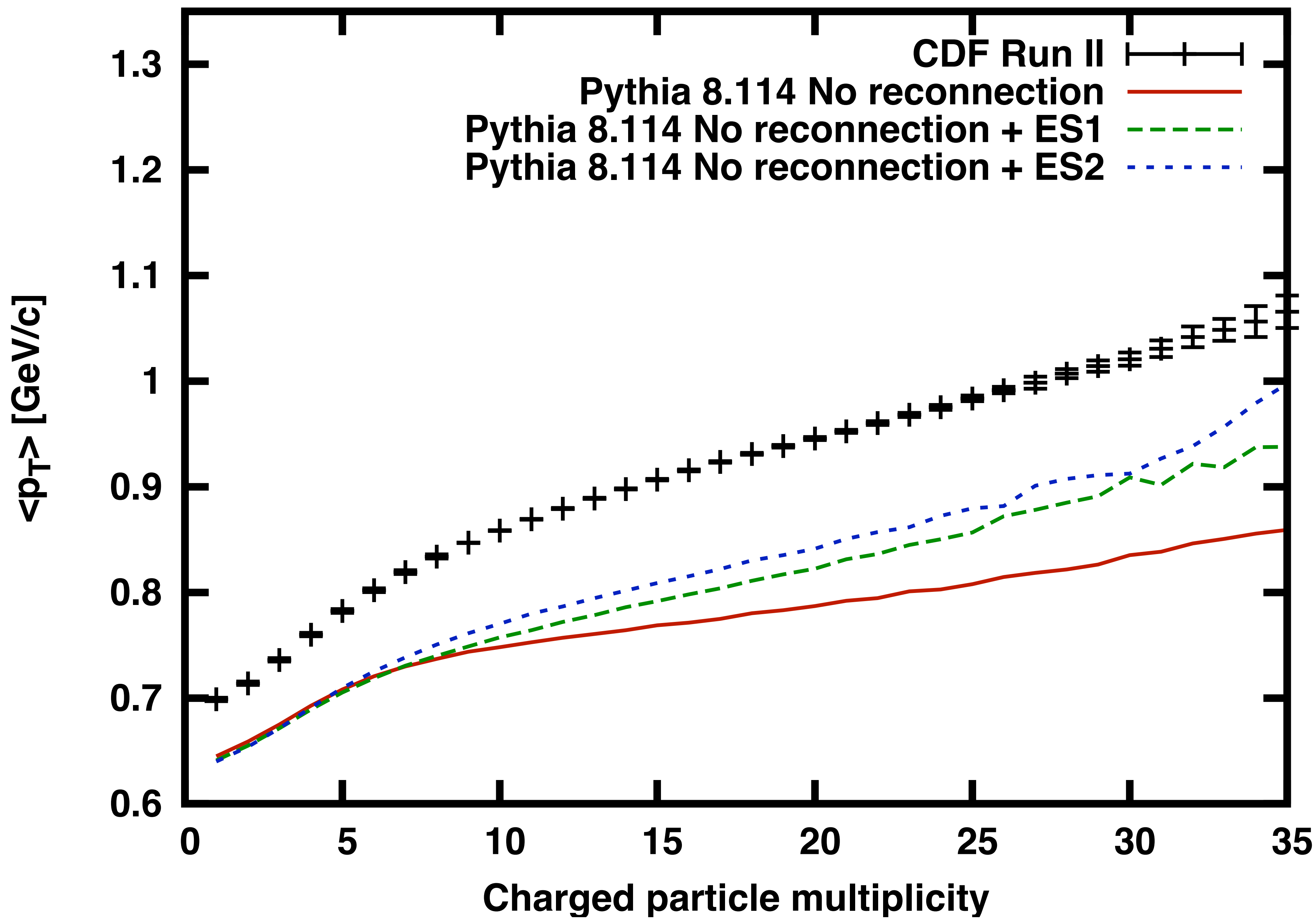
Enhanced Screening

R. Corke

Enhanced Screening in PYTHIA

$$\frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}p_\perp^2} \propto \frac{\alpha_S^2(p_{\perp 0}^2 + p_\perp^2)}{(p_{\perp 0}^2 + p_\perp^2)^2} \to \frac{\alpha_S^2(p_{\perp 0}^2 + p_\perp^2)}{(n\,p_{\perp 0}^2 + p_\perp^2)^2}$$

ES1: n = no. of MI
ES2: n = no. of MI + ISR



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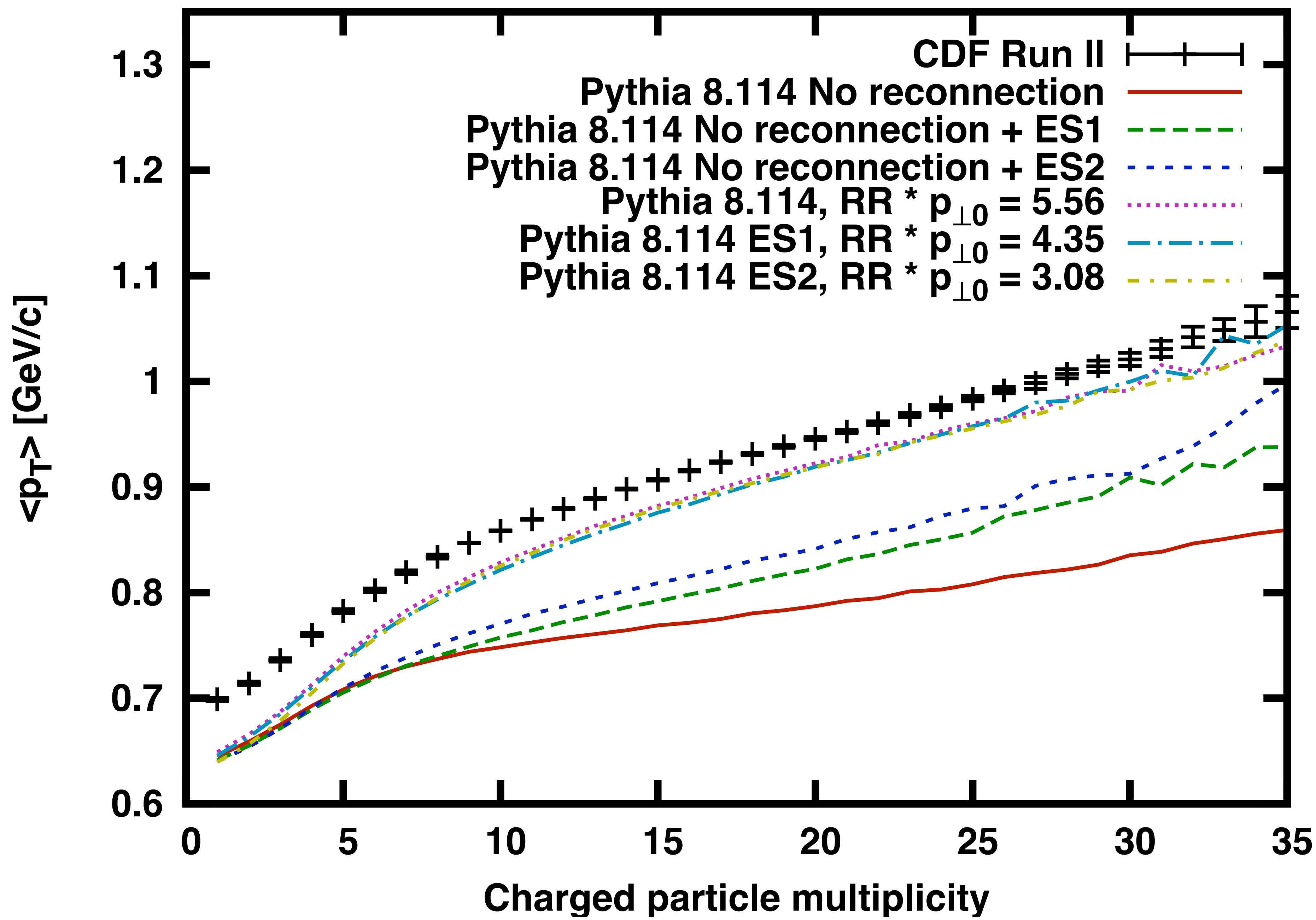


S. Höche

MPI results from Sherpa

in hep-ph/0601012

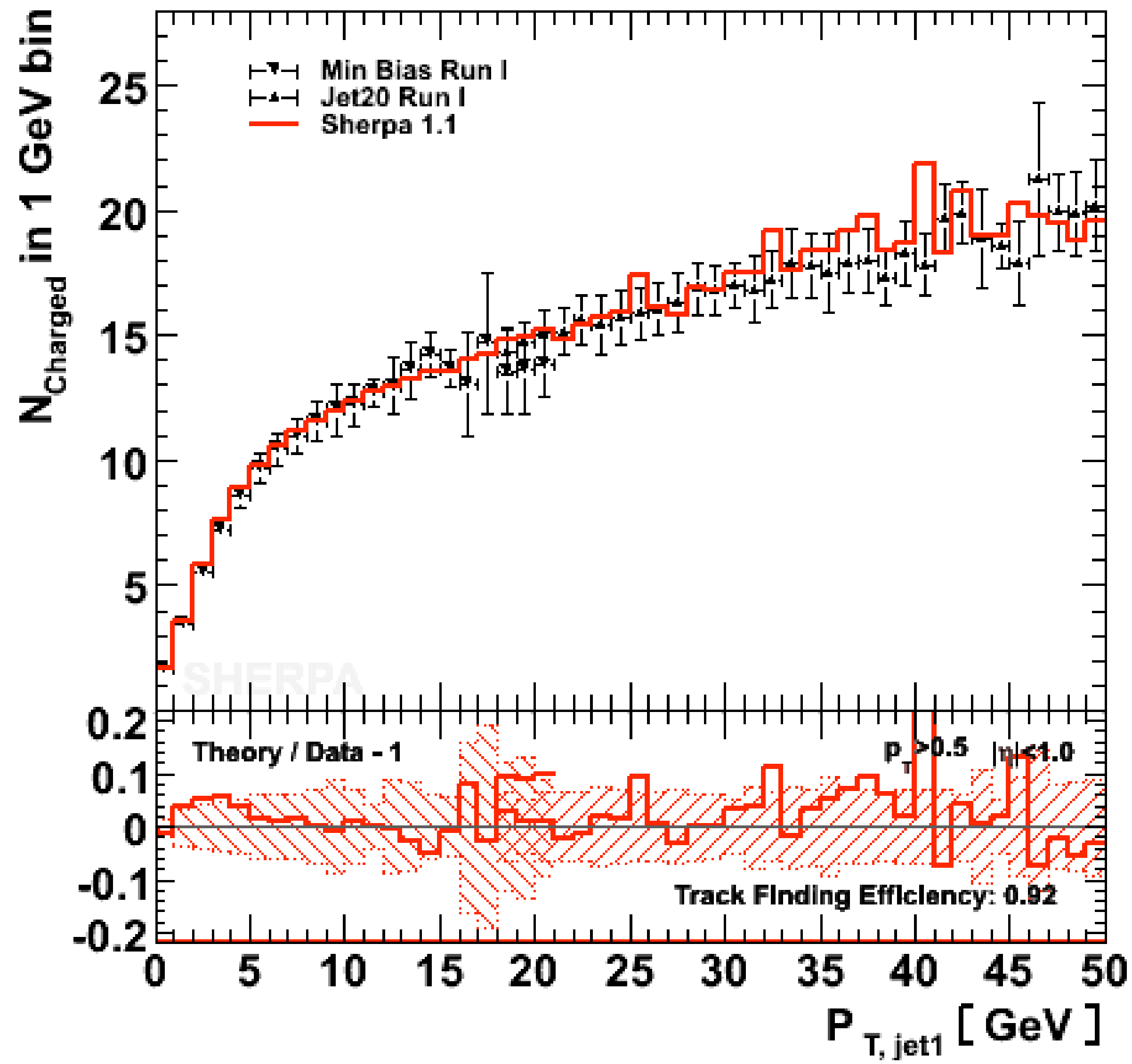
Our current "best fit" for CDF

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

To take home ...

- Highly dependent on $p_{T,\min}$ and PDF
- Does not give a prediction for LHC energies

- N_{Charged} vs. $p_{T,\mathrm{jet1}}$ in CTC, Run I



S. Höche

Towards a new MPI model

SH, F. Krauss, T. Teubner; arXiv: 0705.4577 [hep-ph]

Shortcomings 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

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

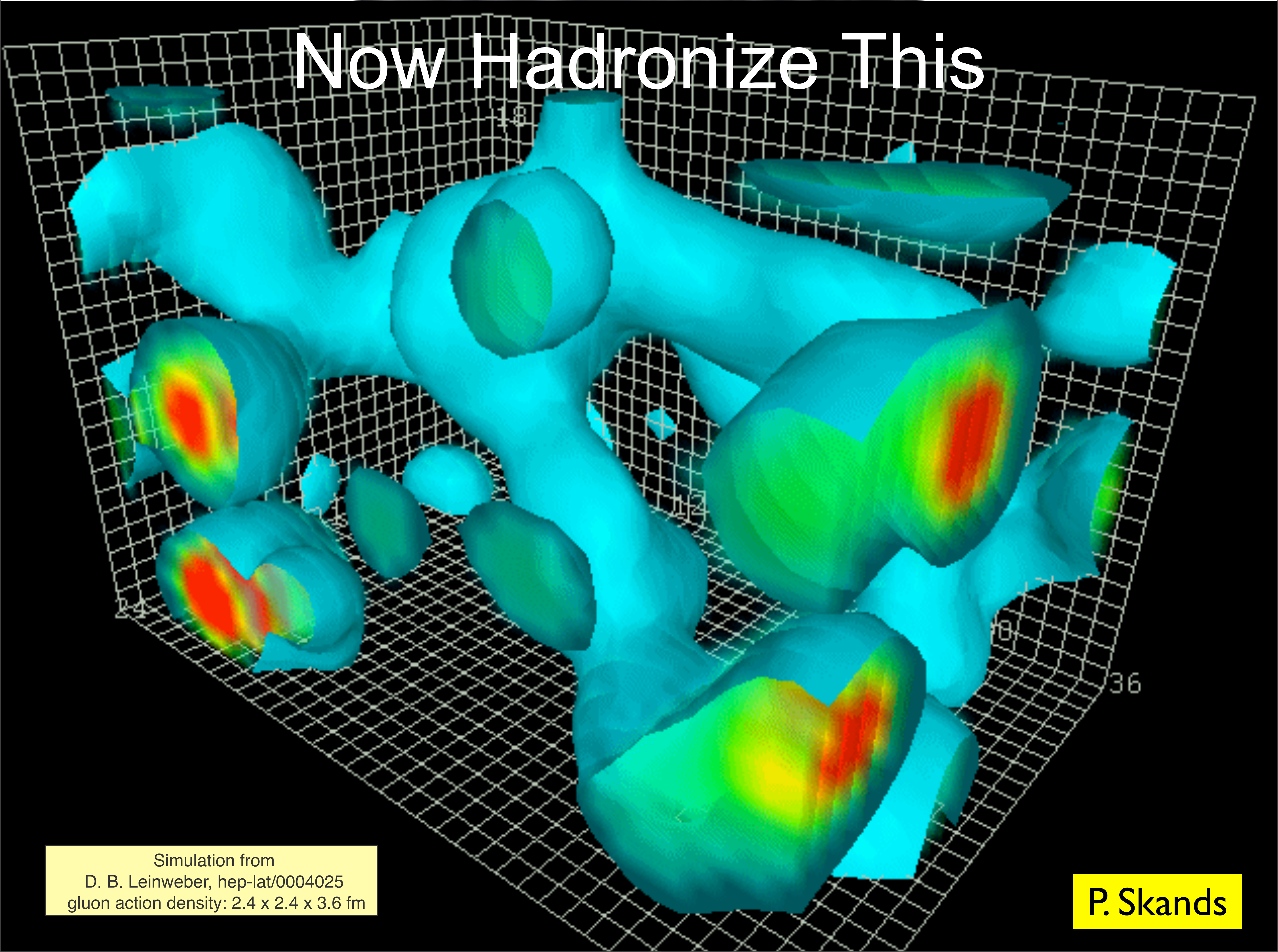
$$\times\ f^{(1)}(x^{(1)}, z^{(1)}, \mathrm{k}^2_{1\perp}, \bar{\mathrm{k}}^{(1)2}_{2\perp})\, f^{(2)}(x^{(2)}, z^{(2)}, \mathrm{k}^2_{n\perp}, \bar{\mathrm{k}}^{(2)2}_{n-1\perp})\, \frac{1}{2\xi^{(1)\,2}\xi^{(2)\,2}S}\, \frac{1}{\Delta_{a_1}(y_1, y_2)}$$

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

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

Now Hadronize This



Simulation from
D. B. Leinweber, hep-lat/0004025
gluon action density: 2.4 x 2.4 x 3.6 fm

P. Skands

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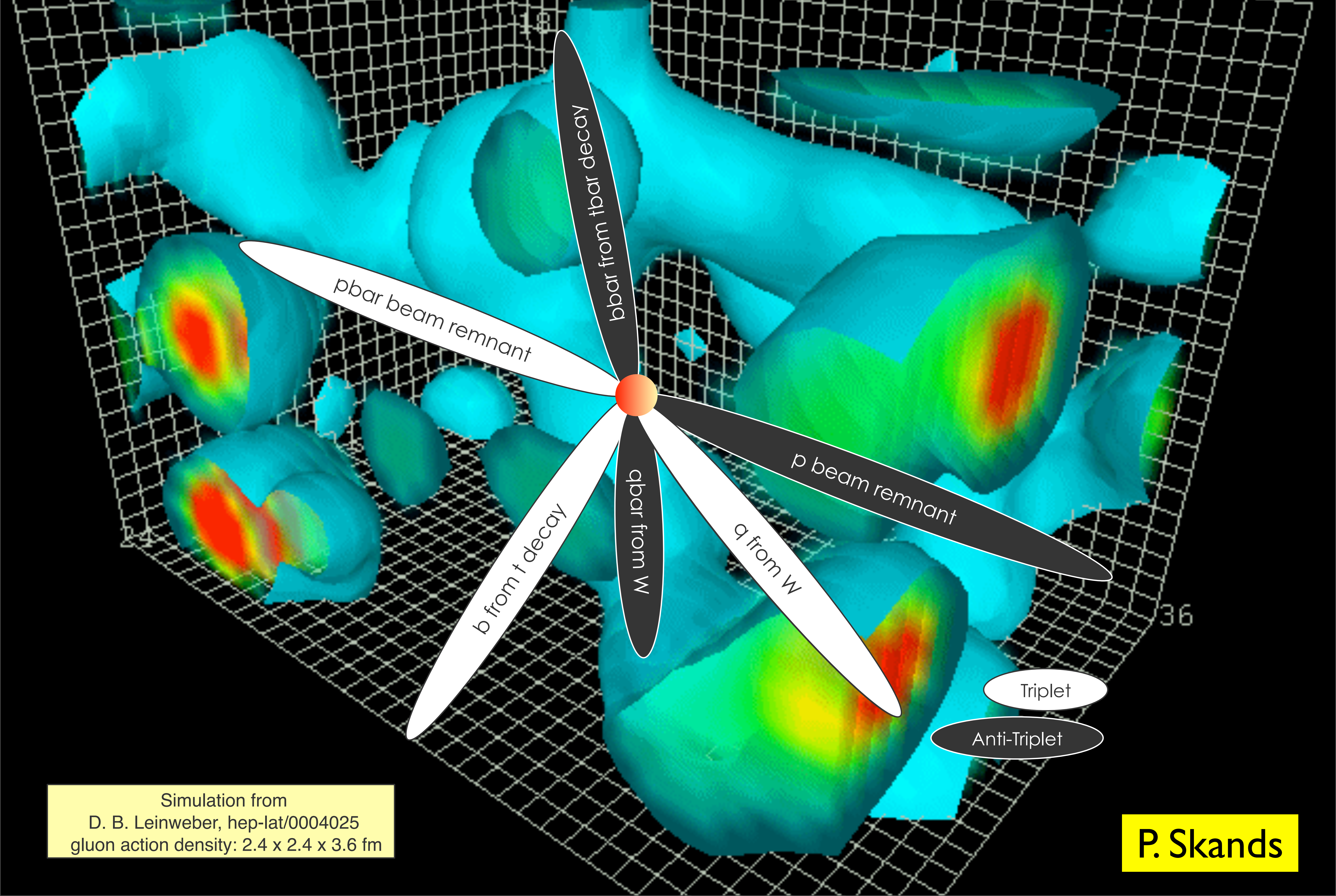

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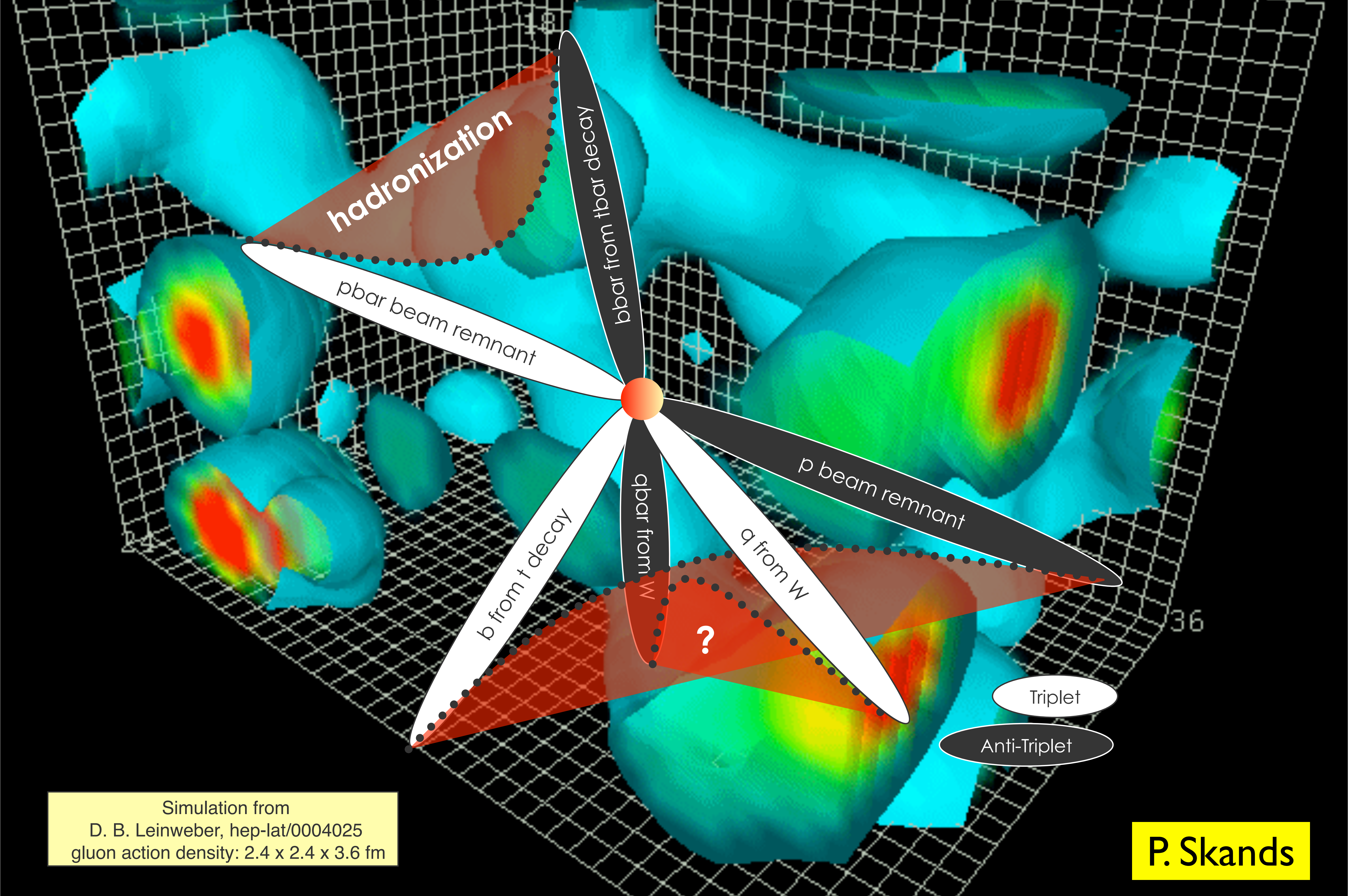

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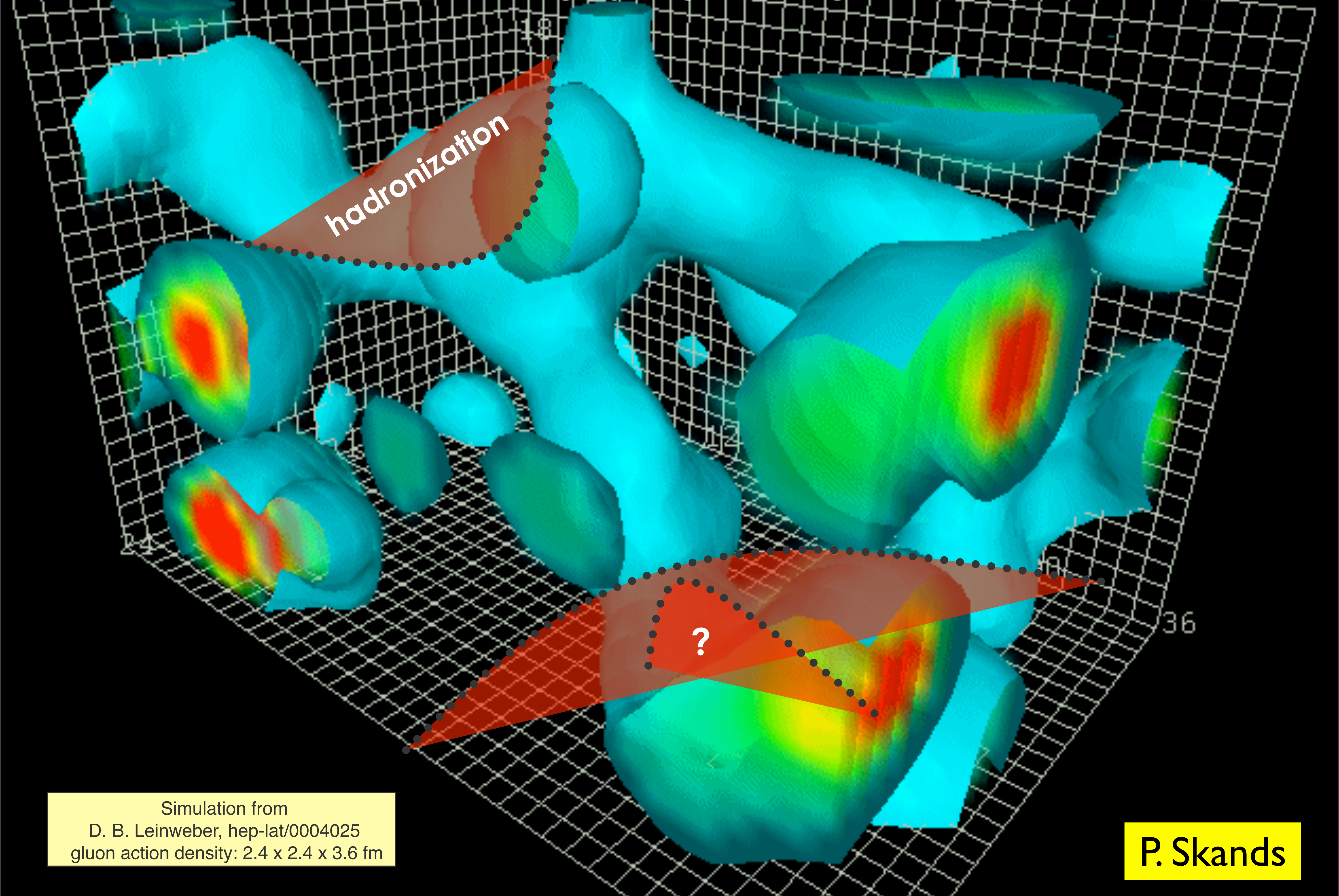

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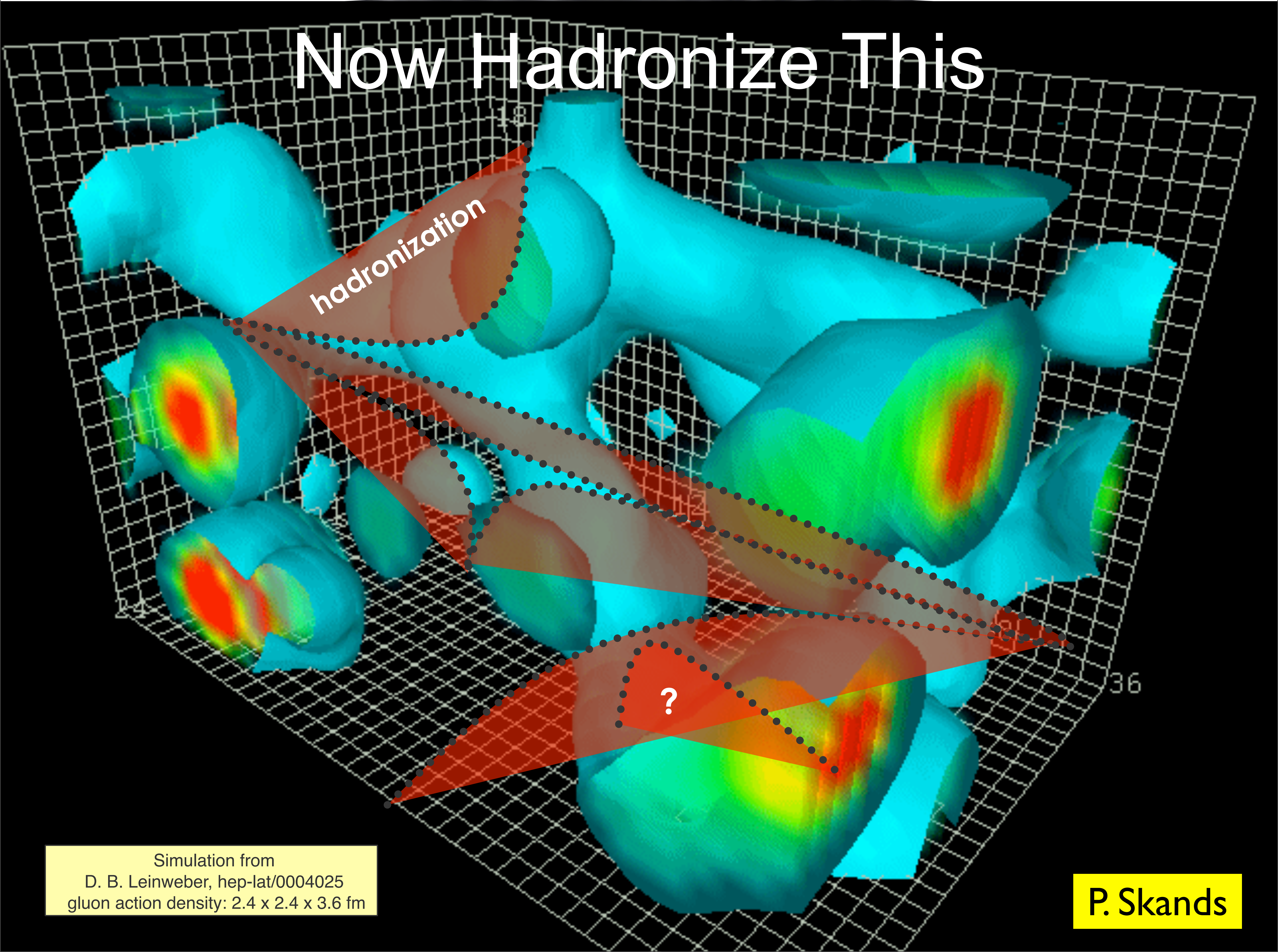

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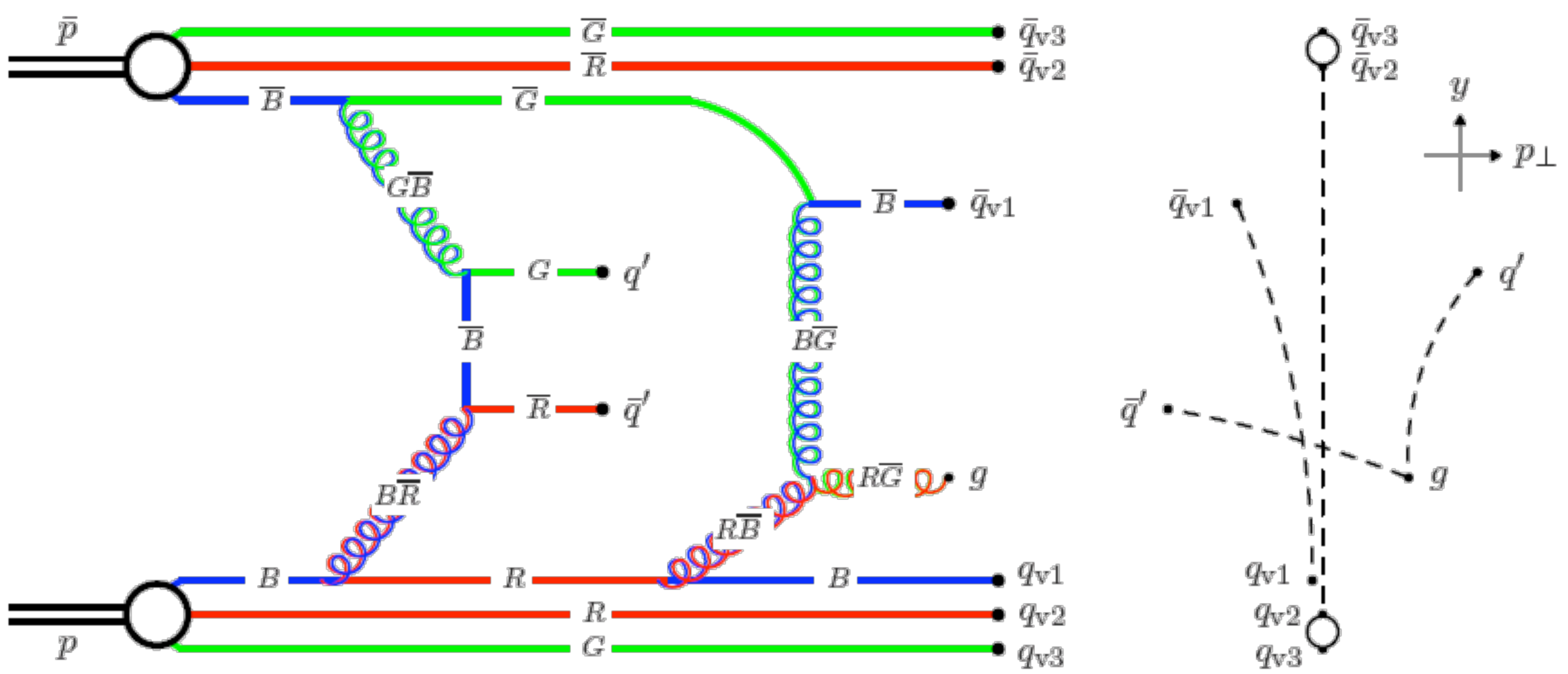
P. Skands

The Underlying Event and Color

► The colour flow determines the hadronizing string topology

- Each MPI, even when soft, is a color spark
- Final distributions <u>crucially</u> depend on color space



Note: this just color **connections**, then there may be color **reconnections** too

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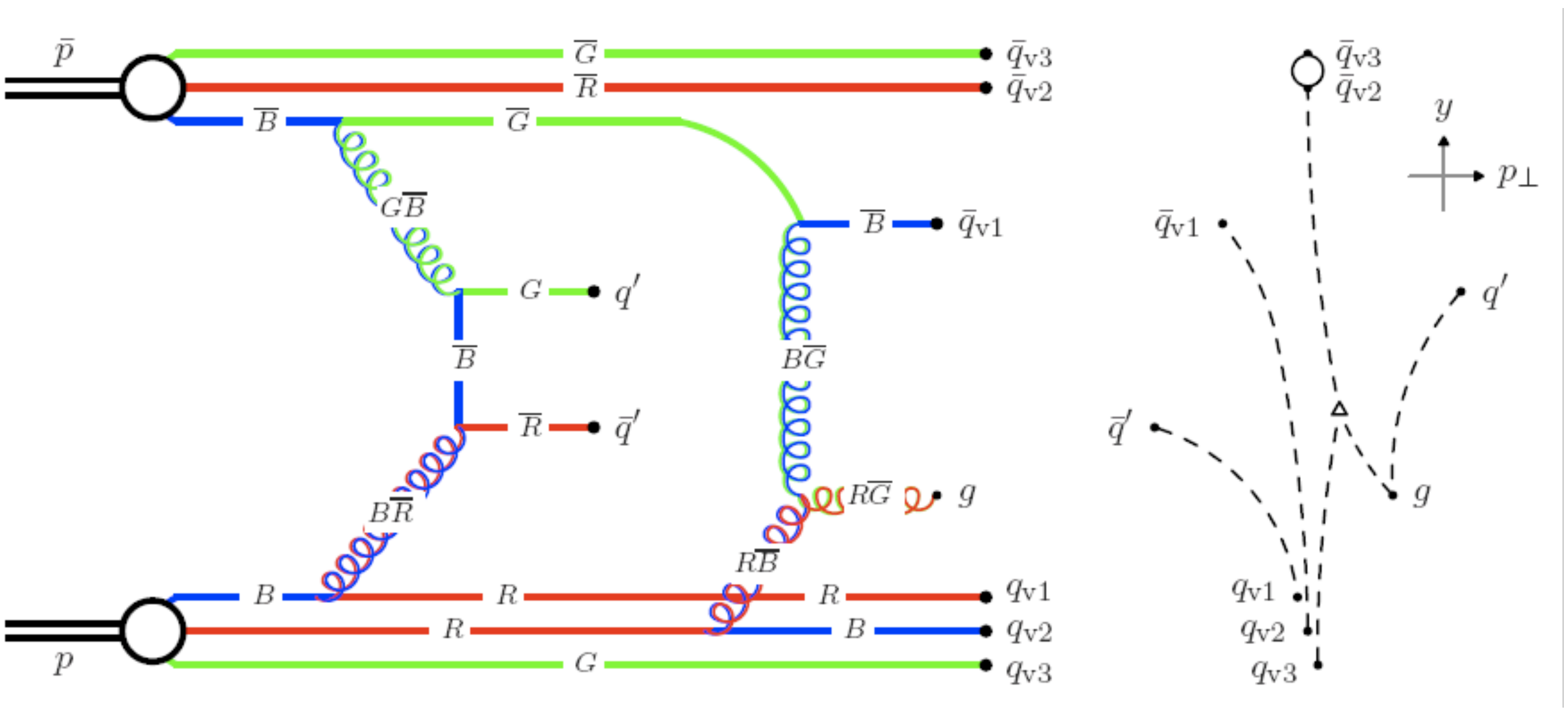

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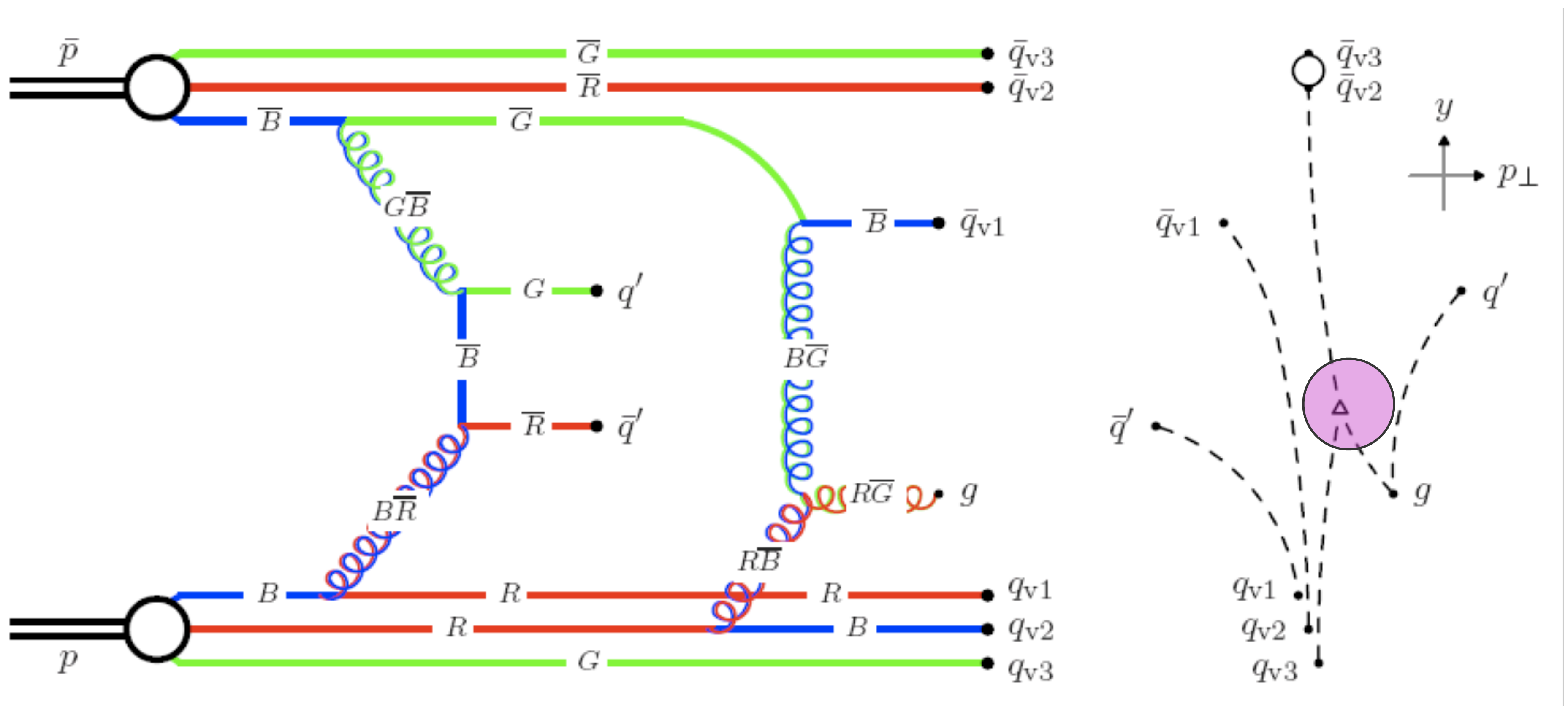

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Factorization Theorem

Deep inselastic scattering we can proof the factorization of the cross section:

$$\sigma[F] = \sum_a \int_0^1 d\eta f_{a/H}(\eta, \mu) \int d\hat{\sigma}_a[F]$$

In hadro-hadron collision we cannot proof the factorization in general. It is understood only for some simple quantity, like Drell-Yan cross section. For other (more exclusive quantities) we can assume and check it by order by order.

$$\sigma[F] = \sum_{ab} \int_0^1 d\eta_a f_{a/H}(\eta_a, \mu) \int_0^1 d\eta_b f_{b/H}(\eta_b, \mu) \int d\hat{\sigma}_{ab}[F]$$

Now the questions:

- If now factorization at hard level, what can we expect in the multiple interaction case?
- Can we understand something at least order-by-order basis?

Z. Nagy

Summary

- **Exciting times: Minimum-bias and Underlying Event will be the first measurements at LHC**
  - Multiple interactions vital in phenomenology

- **Much work done (and remains to be done) on theoretical and experimental side**

- **Common terminology?**

- **Common model? (HEP - HI - Diffraction)**