Summary WG2
Multi-jet Final Sates and Energy Flows
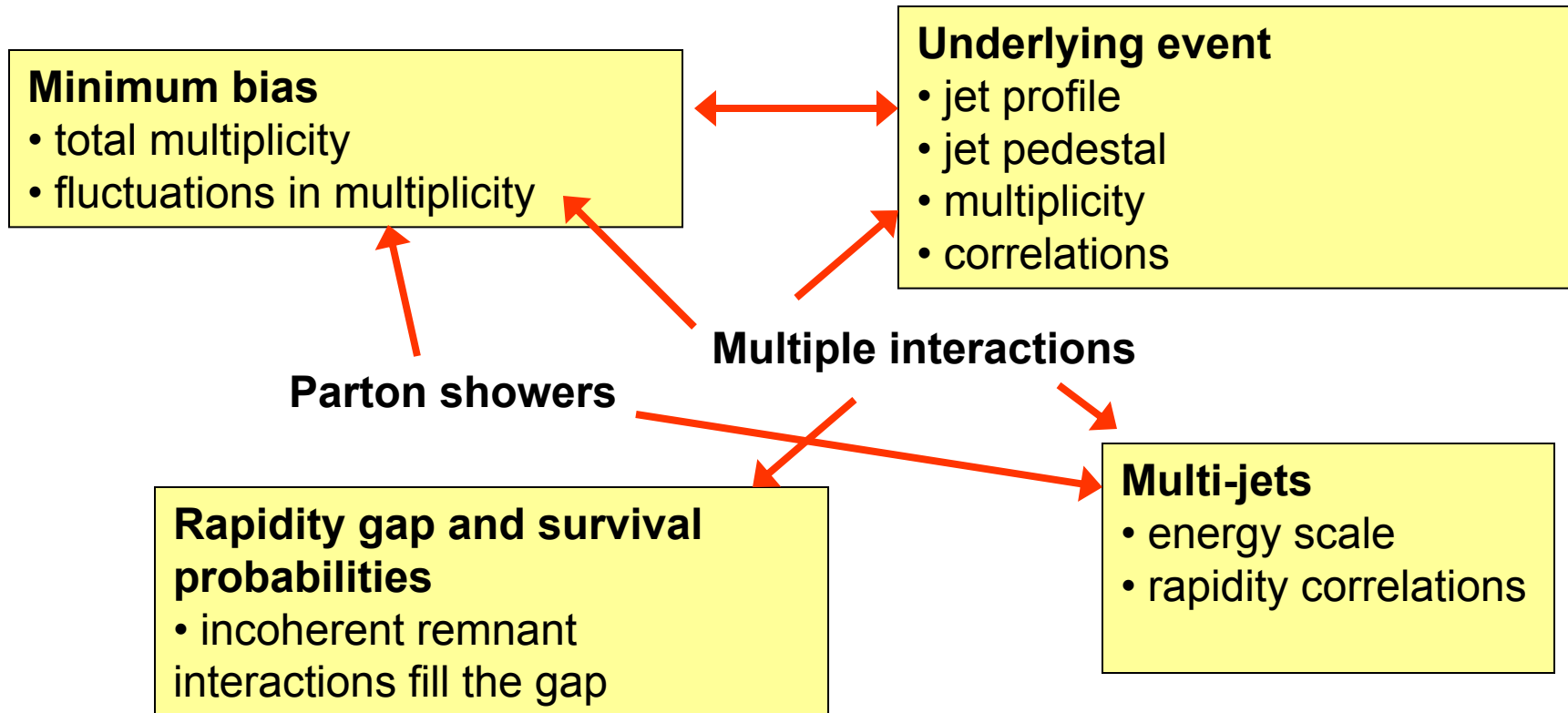
(Mid-term meeting at CERN 11-13 October 2004)

List of main topics discussed

- **Underlying event and minimum bias**
- **Rapidity gaps and survival probabilities**
- **Multi-jet topologies and multi-scale QCD**
- **Parton shower/ ME matching**

Conveners: Leif Lönnblad (Lund), Valery Khoze (Durham), Niels Tuning (LHCb), Craig Buttar (ATLAS), Jon Butterworth (ZEUS)

Final State Issues:

Minimum bias
- total multiplicity
- fluctuations in multiplicity

Underlying event
- jet profile
- jet pedestal
- multiplicity
- correlations

Multiple interactions

Parton showers

Rapidity gap and survival probabilities
- incoherent remnant interactions fill the gap

Multi-jets
- energy scale
- rapidity correlations

Much of this can be measured at HERA

Monday: Min. Bias and Und. Event

09:00	General Discussion: Where are we now? (30')	
09:30	**Minimum bias and underlying events (in common with WG5) (1h00')**	

- Tuning at the tevatron (25') (📄 transparencies) — **Rick Field**
- Jimmy tuning (15') — **Arthur Moraes**
- Discussion (20')

10:30	Coffee

11:00	**Minimum bias and underlying events (in common with WG5) (1h30')**

- Photoproduction UE/MB in HZTool (15') (📄 transparencies) — **Victor Lendermann**
- Use of generators in LHCb (15') (📄 transparencies) — **Paul Szczypka**
- Underlying events in Sherpa (10') (📄 transparencies) — **Stefan Hoeche**
- News in Pythia 6.3 (10') (📄 transparencies) — **Torbjörn Sjöstrand**
- Discussion: Tuning Tevatron vs. HERA (40')

12:30	Lunch
14:00	Common sessions with WG4 and WG5 (1h30')

15:30	Coffee

16:00	**Rapidity gaps and survival probabilities (in common with WG4) (2h00')**

- Rapgap survival as a probe of unitarity (25') — **Uri Maor**
- Diffractive photoproduction to NLO (15') (📄 transparencies) — **Michael Klasen**
- Diffractive photoproduction at H1 (15') (📄 transparencies) — **Frank-Peter Schilling**
- Diffractive photoproduction at ZEUS (15') (📄 transparencies) — **Alessia Bruni**
- Discussion: What can we learn from HERA (50')

Tuesday: Multi-jets and Multi-scale QCD

10:00	**Multi-jet topologies and multi-scale QCD (in common with WG5)** (1h00')	**Common session with WG5 (MC)**

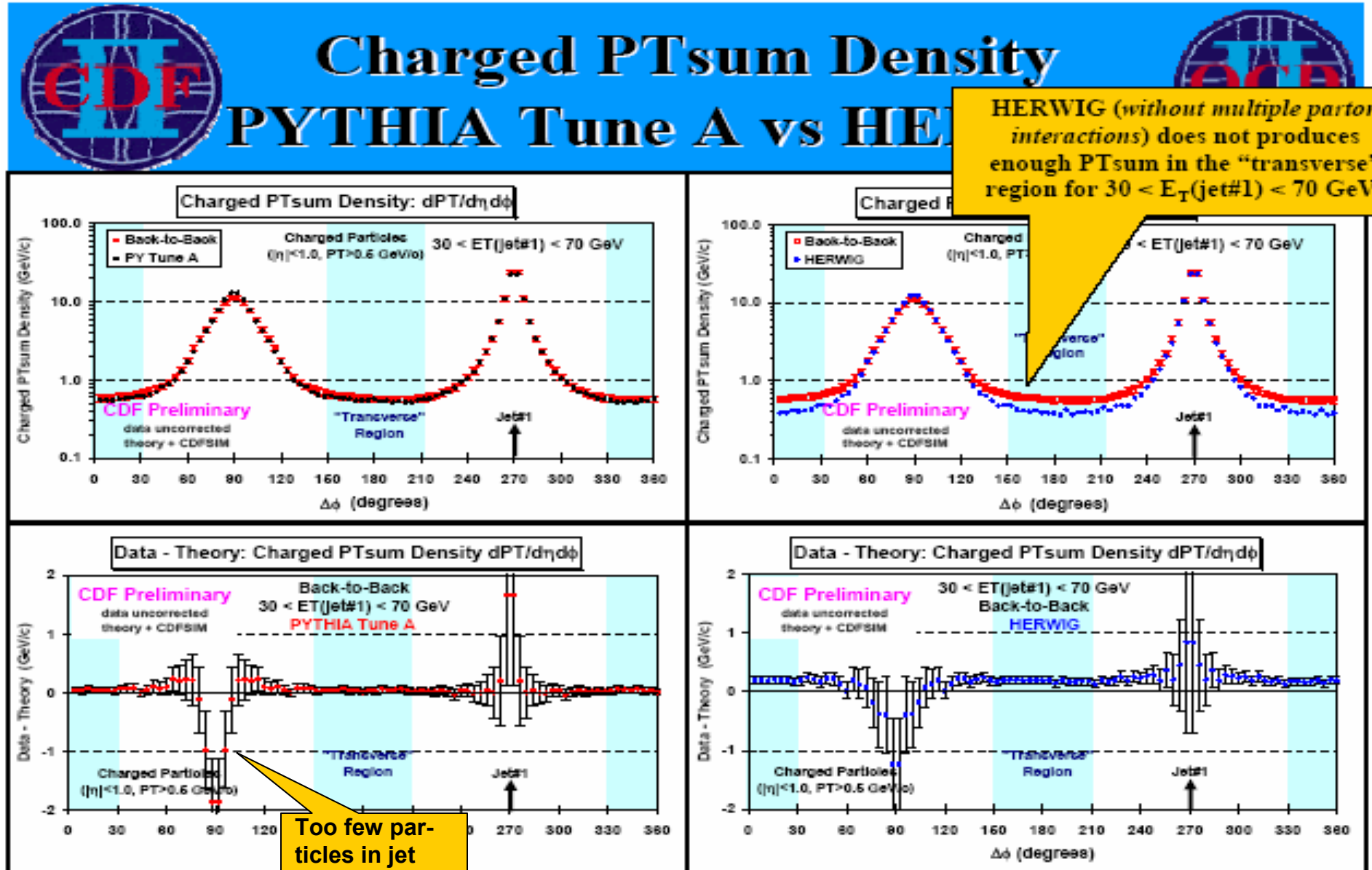| 10:00	**Multi-jet topologies and multi-scale QCD (in common with WG5)** (1h00')	
	• Jet veto on MCs for gg->h at LHC (15') (📄 transparencies)	Giovanna Davatz
	• General Search for new phenomena (15')	Sascha Caron
	• Discussion (30')	
11:00	Coffee	
11:30	**Parton shower/ME matching (in common with WG5)** (1h00')	
	• Non-Markovian Monte Carlo algorithm for QCD evolution (15') (📄 transparencies)	Stanislaw Jadach
	• W+jets in Sherpa (15')	Steffen Schumann
	• Discussion (30')	
12:30	Lunch	
14:00	**Multi-jet topologies and multi-scale QCD** (45')	
	• Forward jets and pions (15')	Jacek Turnau
	• Jet ET spectra at LHC (15')	Steve Magill
	• Discussion (15')	
14:45	**Discussion: What will go in tomorrows summary? What will go in the proceedings?** (45')	
15:30	Coffee	**Common session with WG1 (Struc.Fun)**
16:00	**Unintegrated parton densities (in common with WG1)** (50')	
	• Unintegrated PDFs (20')	Hannes Jung
	• Discussion: How to constrain the unintegrated gluon at HERA. (30')	

List of topics discussed

- **Underlying event and minimum bias**
  - **Tuning of PYTHIA at Tevatron**
  - **Tuning of Jimmy**
  - **Tuning of PYTHIA for LHCb**
  - **News in PYTHIA 6.3**

- **Rapidity gaps and survival probabilities**

- **Multi-jet topologies and multi-scale QCD**

- **Parton shower/ ME matching**
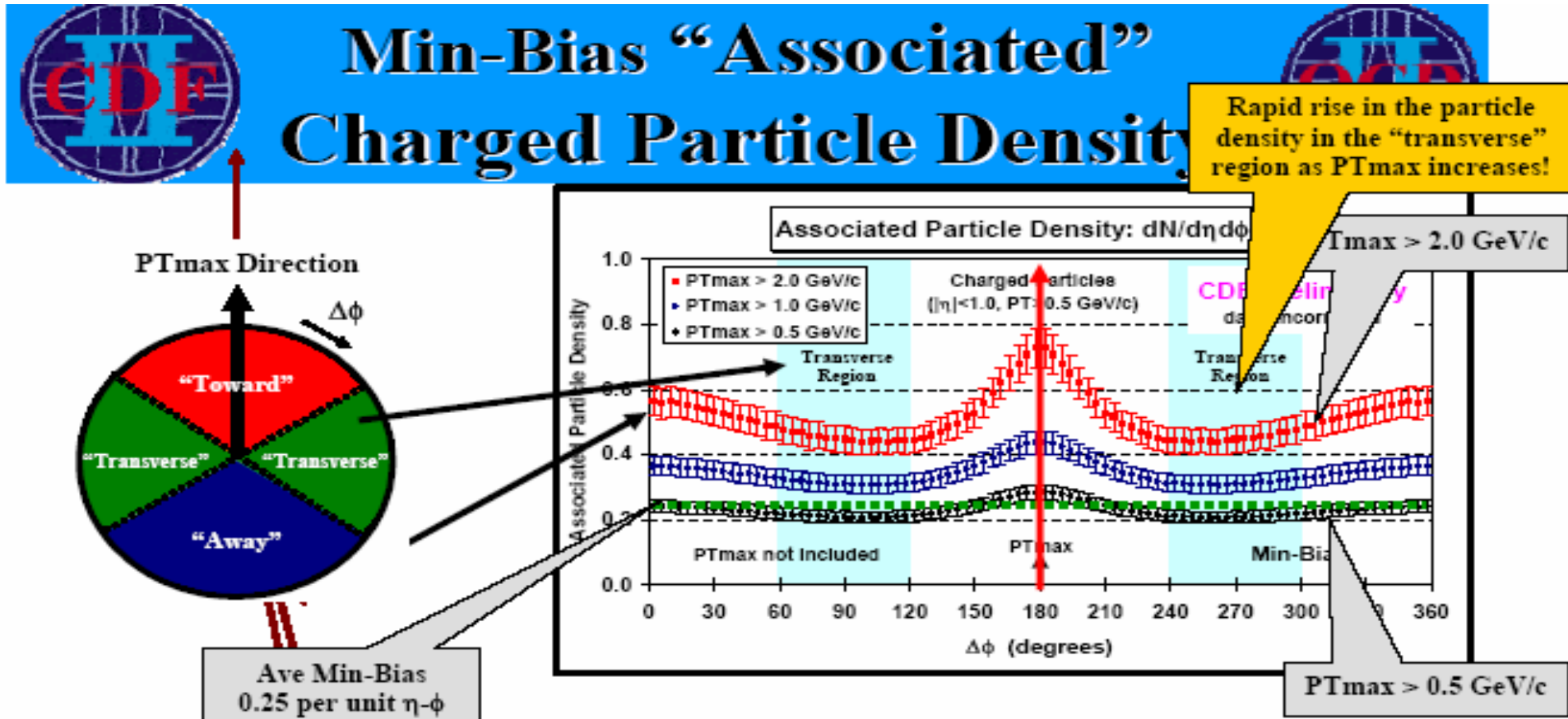
UE at the Tevatron – PYTHIA and HERWIG

Charged PTsum Density
PYTHIA Tune A vs HERWIG

HERWIG (*without multiple parton interactions*) does not produces enough PTsum in the "transverse" region for $30 < E_T(jet\#1) < 70$ GeV!

Too few particles in jet

Courtesy of Rick Field

Min-Bias "Associated" Charged Particle Density

PTmax Direction

$\Delta\phi$

"Toward"

"Transverse" "Transverse"

"Away"

Ave Min-Bias 0.25 per unit η-ϕ

Rapid rise in the particle density in the "transverse" region as PTmax increases!

Associated Particle Density: dN/dηdϕ

PTmax > 2.0 GeV/c

- ■ PTmax > 2.0 GeV/c
- ▶ PTmax > 1.0 GeV/c
- ◆ PTmax > 0.5 GeV/c

Charged particles ($|\eta|$<1.0, PT>0.5 GeV/c)

Transverse Region

Transverse Region

CDF Preliminary data uncorrected

Associated Particle Density

PTmax not Included

PTmax

Min-Bias

$\Delta\phi$ (degrees)

PTmax > 0.5 GeV/c

➡ Shows the data on the $\Delta\phi$ dependence of the "associated" charged particle density, dNchg/dηdϕ, for charged particles (p_T > 0.5 GeV/c, $|\eta|$ < 1, *not including PTmax*) relative to PTmax (rotated to 180°) for "min-bias" events with PTmax > 0.5, 1.0, and 2.0 GeV/c.

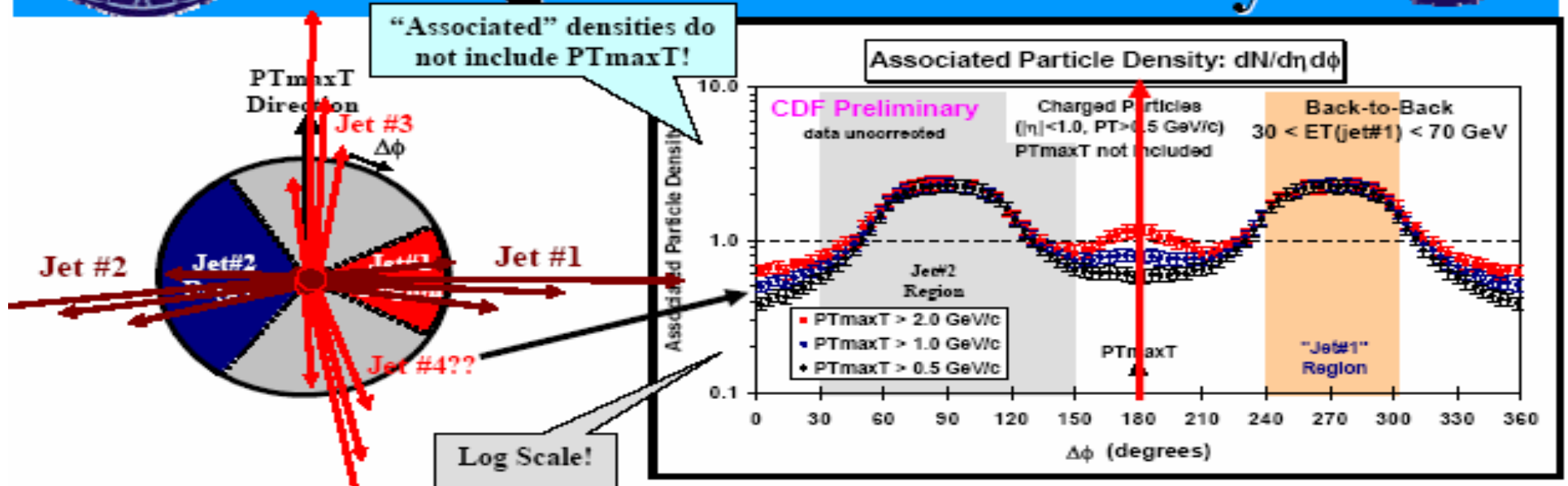➡ Shows "jet structure" in "min-bias" collisions (*i.e.* the "birth" of the leading two jets!).

Look at the $\Delta\phi$ dependence of the "associated" charged particle density, $dN_{chg}/d\eta\,d\phi$ for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$, *not including PTmaxT*) relative to PTmaxT (rotated to 180°) for PTmaxT > 0.5 GeV/c, PTmaxT > 1.0 GeV/c and PTmaxT > 2.0 GeV/c, for "back-to-back" events with $30 < E_T(jet\#1) < 70$ GeV .

Shows "jet structure" in the "transverse" region (*i.e.* the "birth" of the 3rd & 4th jet).
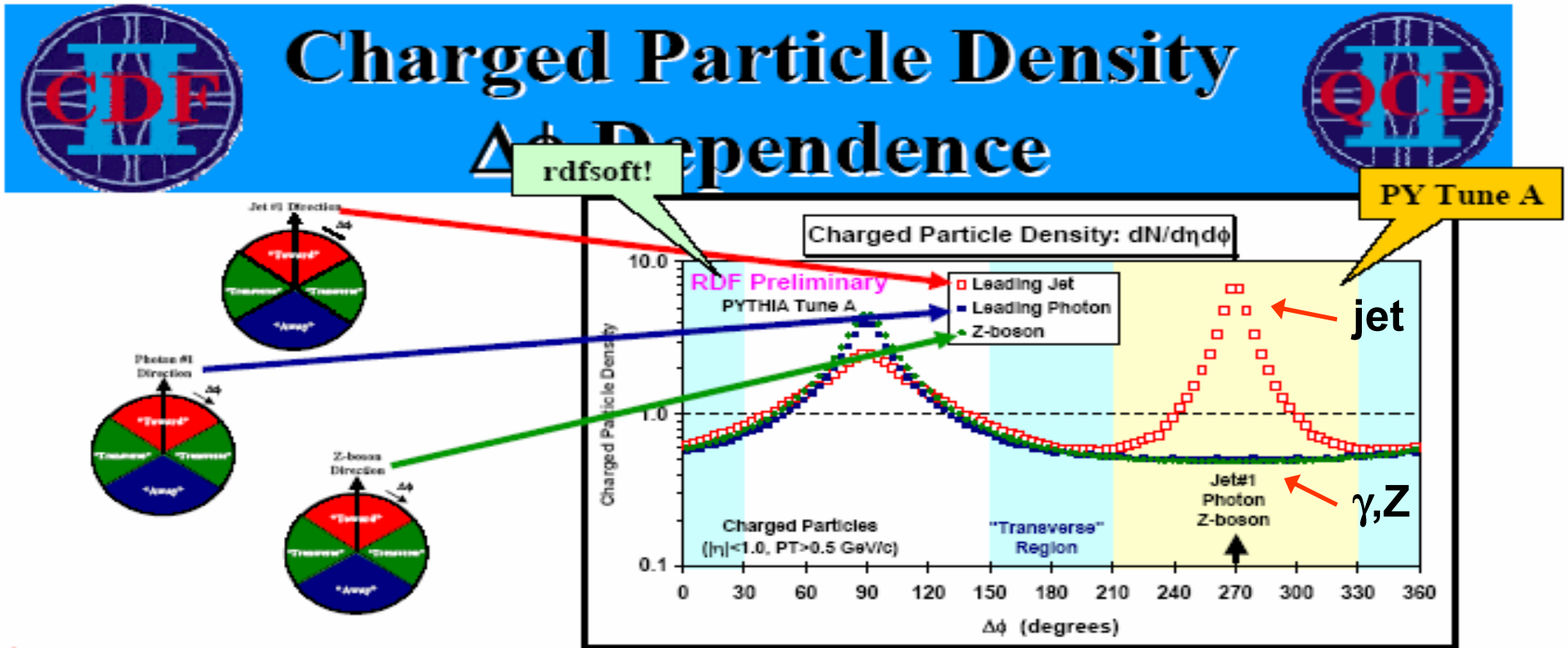
Is Tune A universal ?

Charged Particle Density Δφ Dependence

➡️ Shows the Δφ dependence of the density, $dN_{chg}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to jet#1 (rotated to 270°) for E_T(jet#1) > 30 GeV for "Leading Jet" events from PYTHIA Tune A.

➡️ Shows the Δφ dependence of the density, $dN_{chg}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to pho#1 (rotated to 270°) for P_T(pho#1) > 30 GeV for "Leading Photon" events from PYTHIA Tune A.

➡️ Shows the Δφ dependence of the density, $dN_{chg}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to the Z (rotated to 270°) for P_T(Z) > 30 GeV for "Z-boson" events from PYTHIA Tune A.
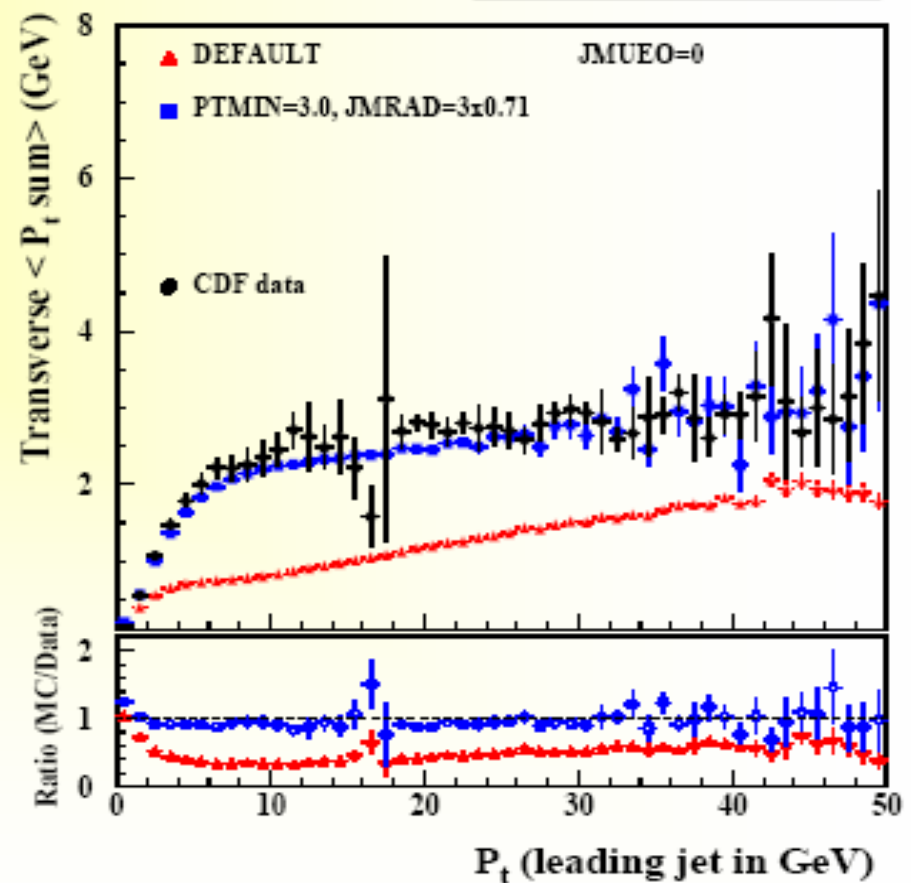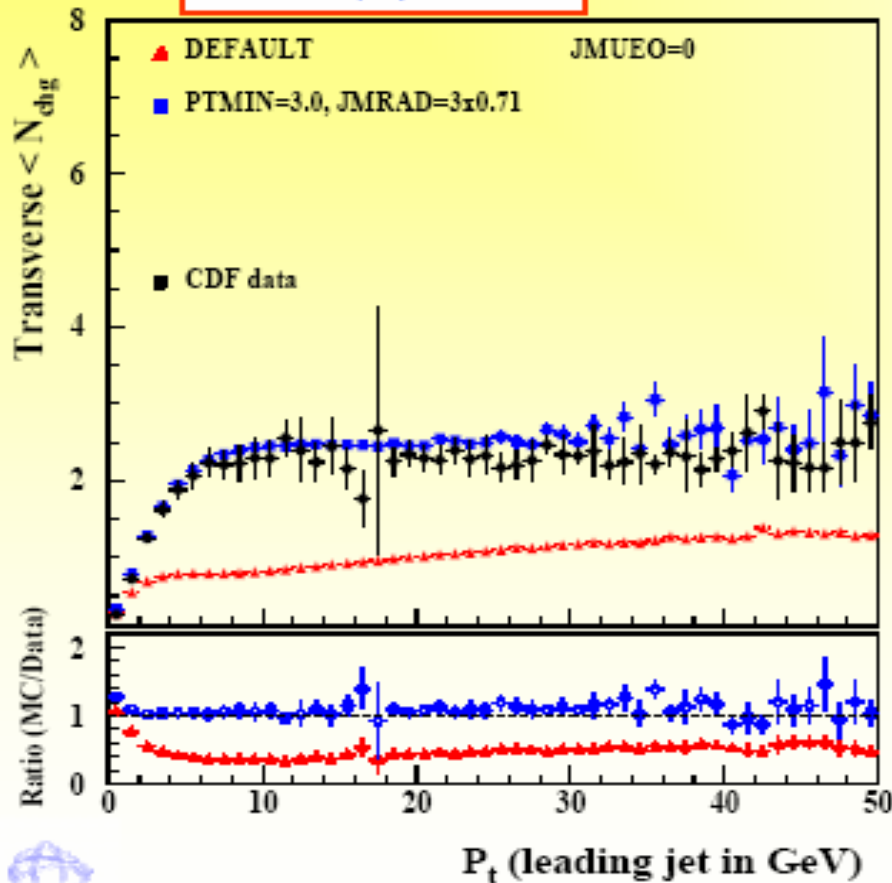
Jimmy Tuning – Tevatron

JIMMY4.1 – Tuning A

JIMMY – Tuning A
JMUEO=0
PTMIN=3.0
JMRAD(73)=3x0.71

Proton radius shrunk by 1.73

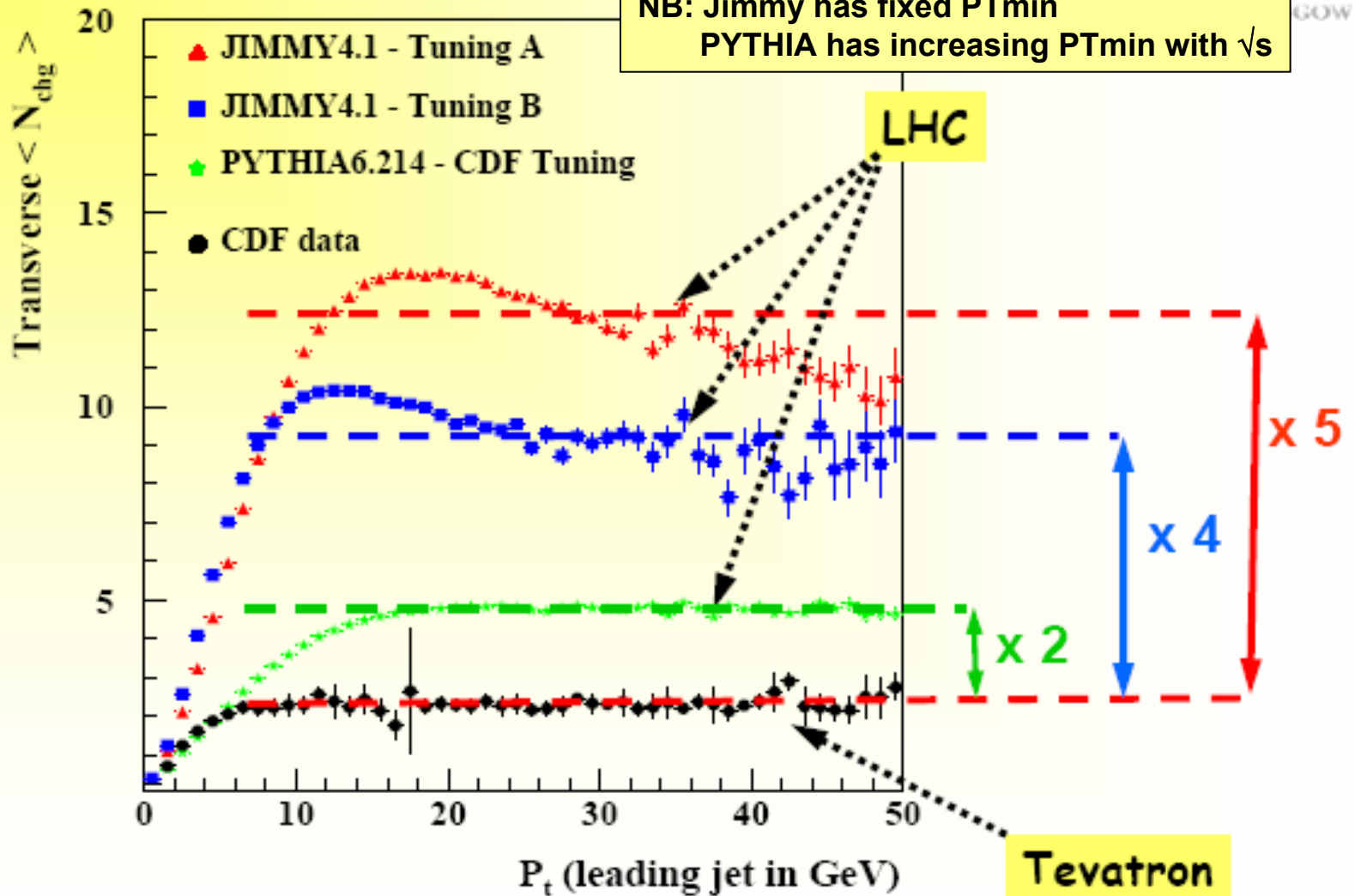Motivated by I. Borozan's work (CDF Data!). See JetWeb Fit 493

Left plot:
- DEFAULT   JMUEO=0
- PTMIN=3.0, JMRAD=3x0.71
- CDF data

y-axis (top): Transverse $< N_{chg} >$
y-axis (bottom): Ratio (MC/Data)
x-axis: P_t (leading jet in GeV)

Right plot:
- DEFAULT   JMUEO=0
- PTMIN=3.0, JMRAD=3x0.71
- CDF data

y-axis (top): Transverse $< P_t$ sum$>$ (GeV)
y-axis (bottom): Ratio (MC/Data)
x-axis: P_t (leading jet in GeV)

A. M. Moraes   Describing the UE at the LHC   CERN, 11th October 2004

Jimmy Tuning – LHC

Courtesy of Arthur Moraes

LHC predictions: JIMMY4.1 Tunings A and B vs.
.214 – CDF Tuning

Tuning A: prot. radius=3x0.73 PTmin=3.0
Tuning B: prot. radius=   0.73 PTmin=2.0

NB: Jimmy has fixed PTmin
    PYTHIA has increasing PTmin with √s

UNIVERSITY
GOW

LHC

▲ JIMMY4.1 - Tuning A
■ JIMMY4.1 - Tuning B
★ PYTHIA6.214 - CDF Tuning
● CDF data

x 5
x 4
x 2

Tevatron

Min bias plots of DC04 settings compared to LHCb tune

New settings:

PARJ(1)=0.1
PARJ(2)=0.3
PARJ(13)=0.75
PARJ(14)=0.162
PARJ(15)=0.018
PARJ(16)=0.054
PARJ(17)=0.09
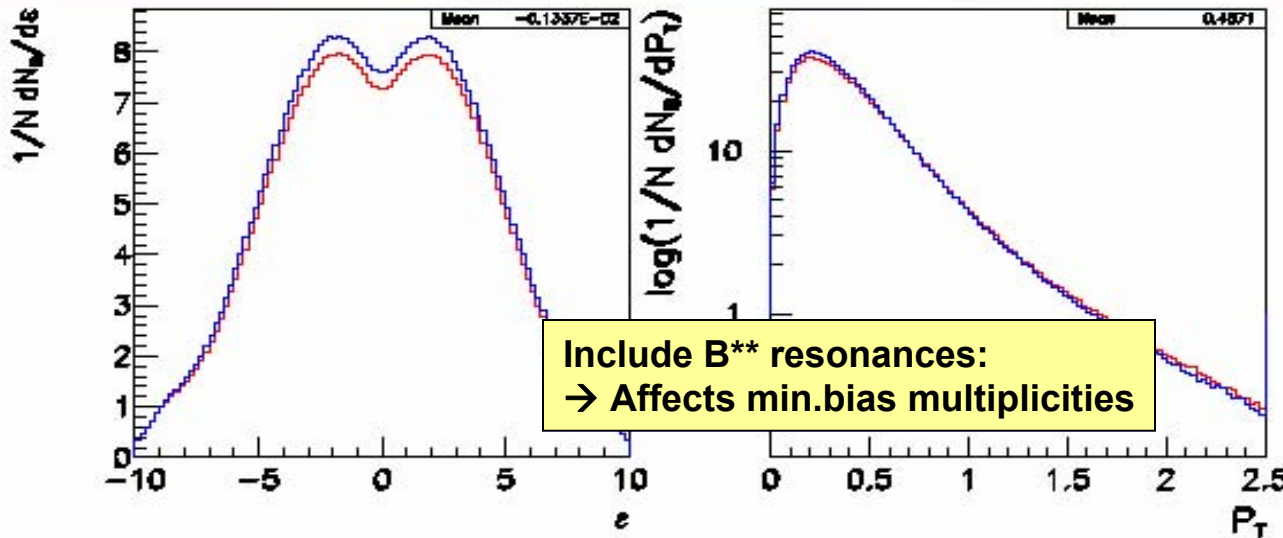
Include B** resonances:
→ Affects min.bias multiplicities

$<n>$ = 22.70
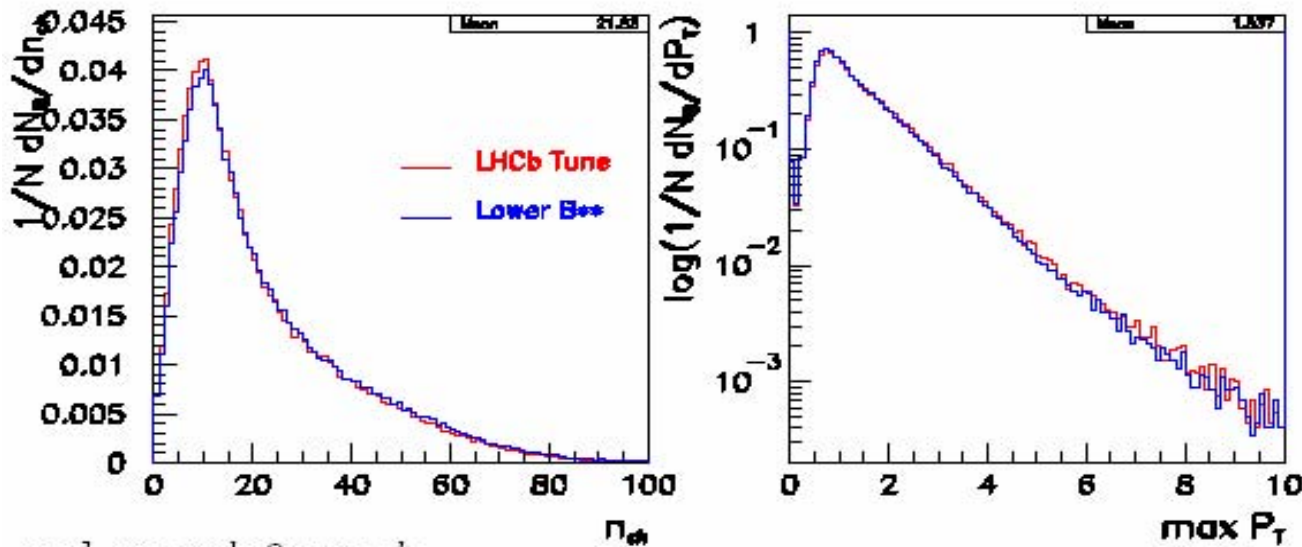
LHCb tune:

$<n>$ = 21.83

Re-tune required

LHCb Tune
Lower B**

paul.szczypka@cern.ch

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News in Pythia 6.3

Interleaved Multiple Interactions

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

Tevatron Run II: $\langle p_\perp \rangle (n_{ch})$

- Tune A
- Rap
- Sharp ISR
- Low FSR
- High FSR
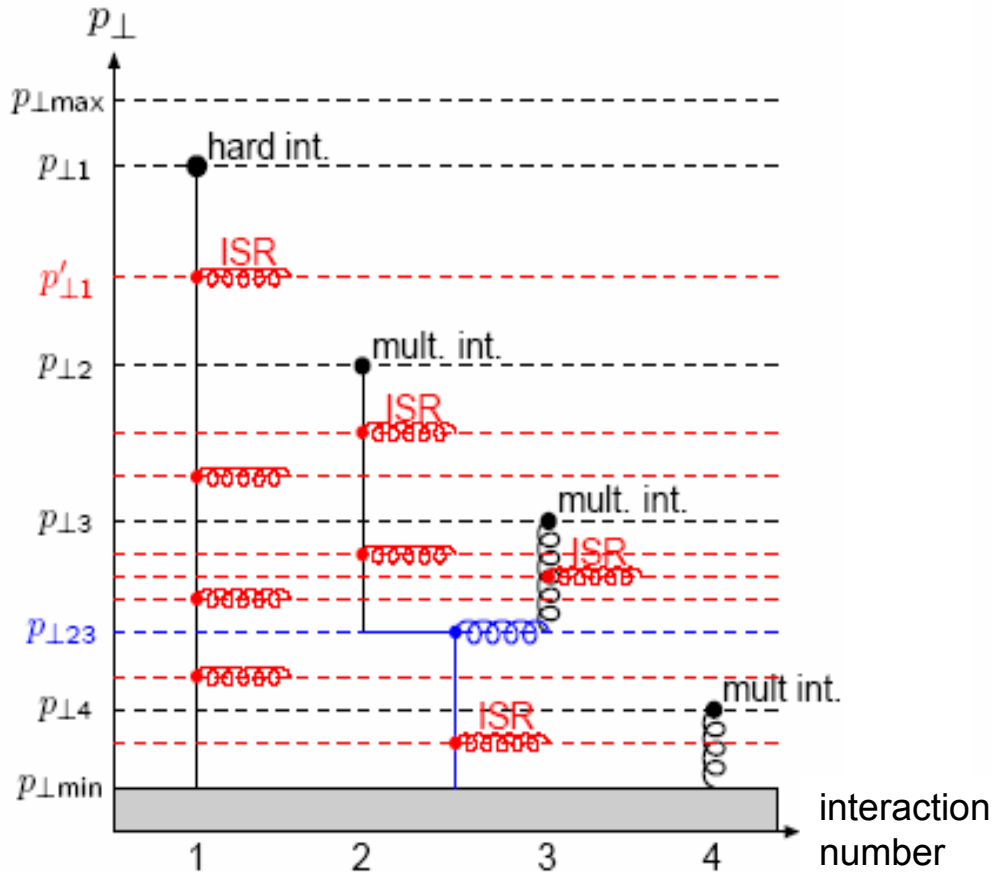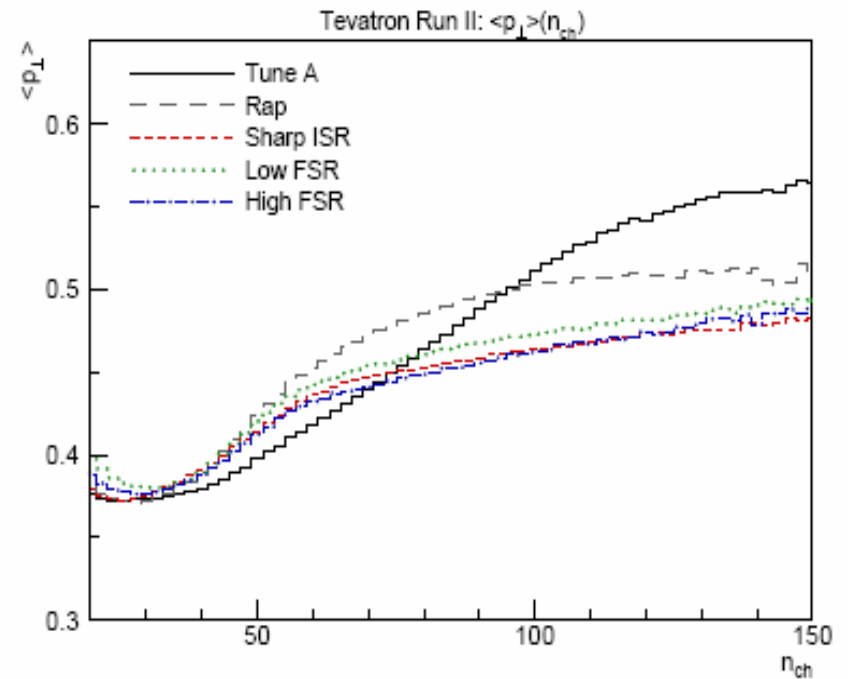
$\Rightarrow$ how are final-state colours correlated?

- **Next steps:**

test and tune, especially colour flow

interleave FSR

intertwine = $(3 \to 3)$ + 2 interacting partons with same
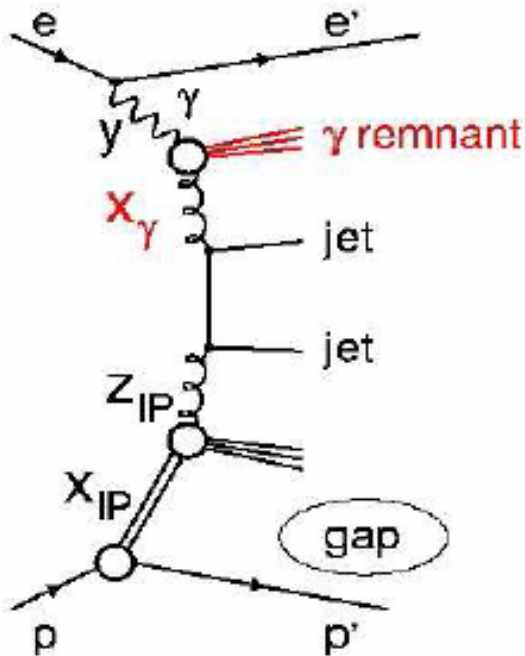
List of topics discussed

- **Underlying event and minimum bias**
- **Rapidity gaps and survival probabilities**
  - **Diffractive γp at HERA**
- **Multi-jet topologies and multi-scale QCD**
- **Parton shower/ ME matching**
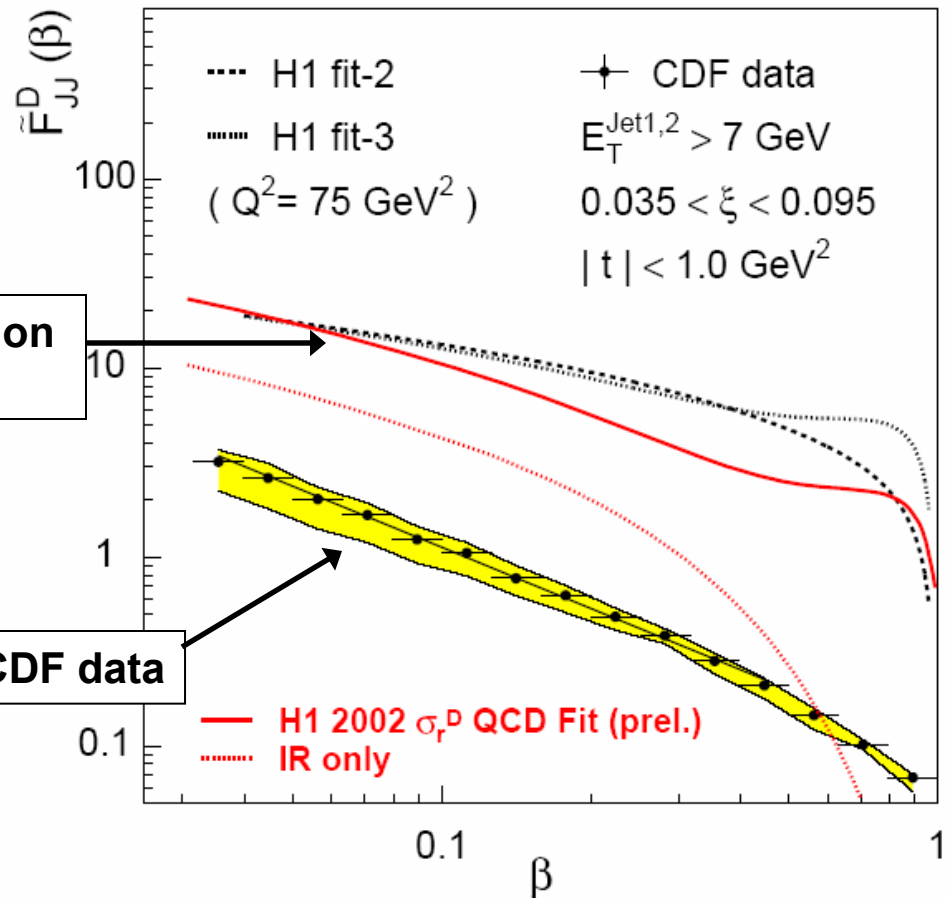
Rapidity Gaps and Survival Probabilities

Gap filled by remant interactions?

HERA prediction for dijet rate in diffraction exceeds Tevatron data by factor 10:

H1 predicition from fit

CDF data

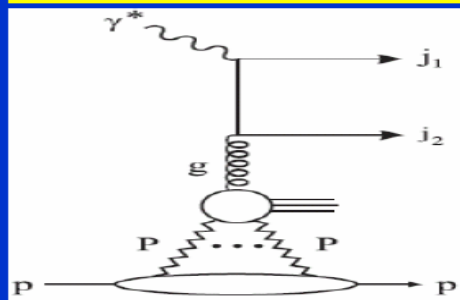NB: Resolved **photon** at HERA is similar to **proton** at LHC

Diffractive γp to NLO
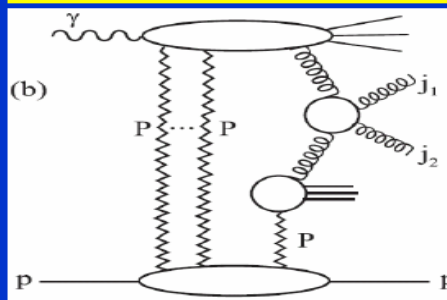
Multi-Pomeron Exchanges

Direct photoproduction:

Resolved photoproduction:

→ Modification of the Regge trajectory

→ Factorization breaking

11 october 2004   Michael Klasen - LPSC Grenoble   2

High- to Low-Q^2 Transition in DIS: From Factorization to its Breaking

Theory predicts suppression of resolved component by x 0.34

$ep \rightarrow e' + 2jets + X' + Y$

- H1 Data
- NLO, R=1
- NLO, R=0.34
- NLO, R=0
- LO, R=0

$ep \rightarrow e' + 2jets + X' + Y$

$Q^2 + p_T^2 > 60$ GeV^2

$Q^2 + p_T^2 \in [45 ; 60]$ GeV^2

$Q^2 + p_T^2 \in [35 ; 45]$ GeV^2

$Q^2 + p_T^2 \in [20 ; 35]$ GeV^2

$\log_{10} x_{IP} \in [-1.5 ; -1]$

$\log_{10} x_{IP} \in [-1.75 ; -1.5]$

$\log_{10} x_{IP} \in [-2.0 ; -1.75]$

$\log_{10} x_{IP} < -2.0$

H1 Data
NLO, R=1
NLO, R=0.34
NLO, R=0
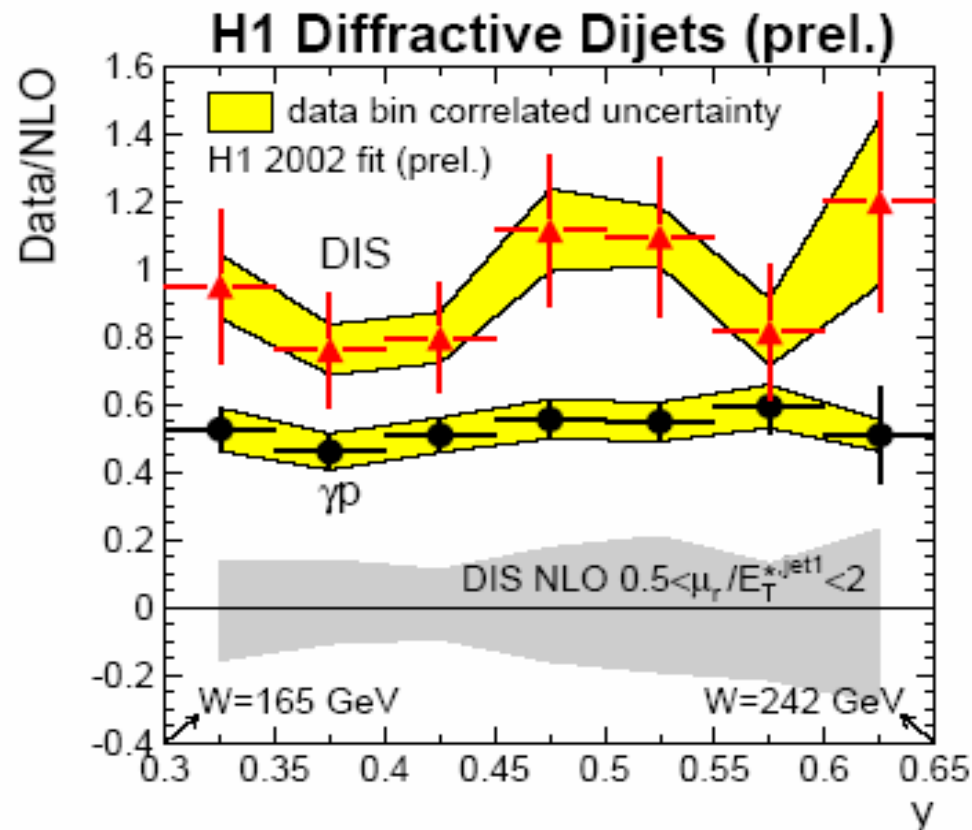LO, R=0
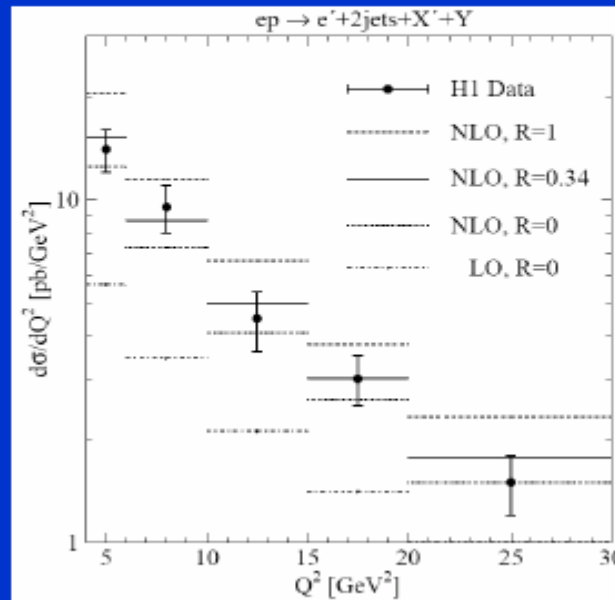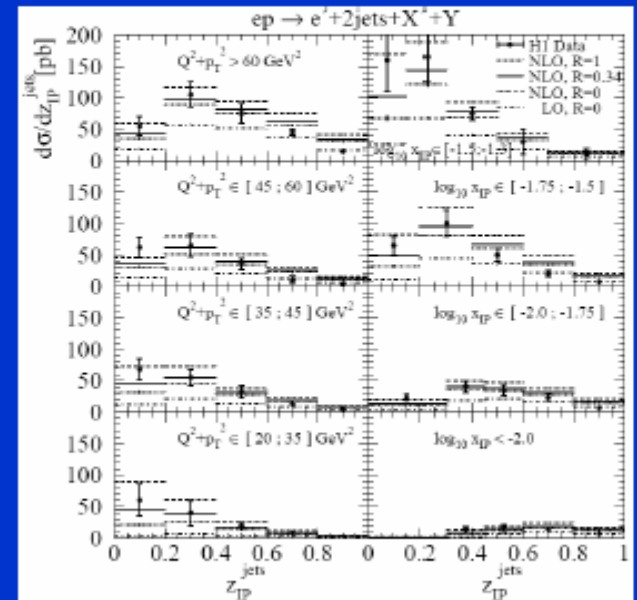
11 october 2004   Michael Klasen - LPSC Grenoble   9

Comparison of DIS and Photoproduction

Exp. measures suppression of resolved+direct component by x 0.5

- Ratio Data/NLO for **DIS** compatible with **one**!
- Ratio Data/NLO for **photoproduction** around 0.5
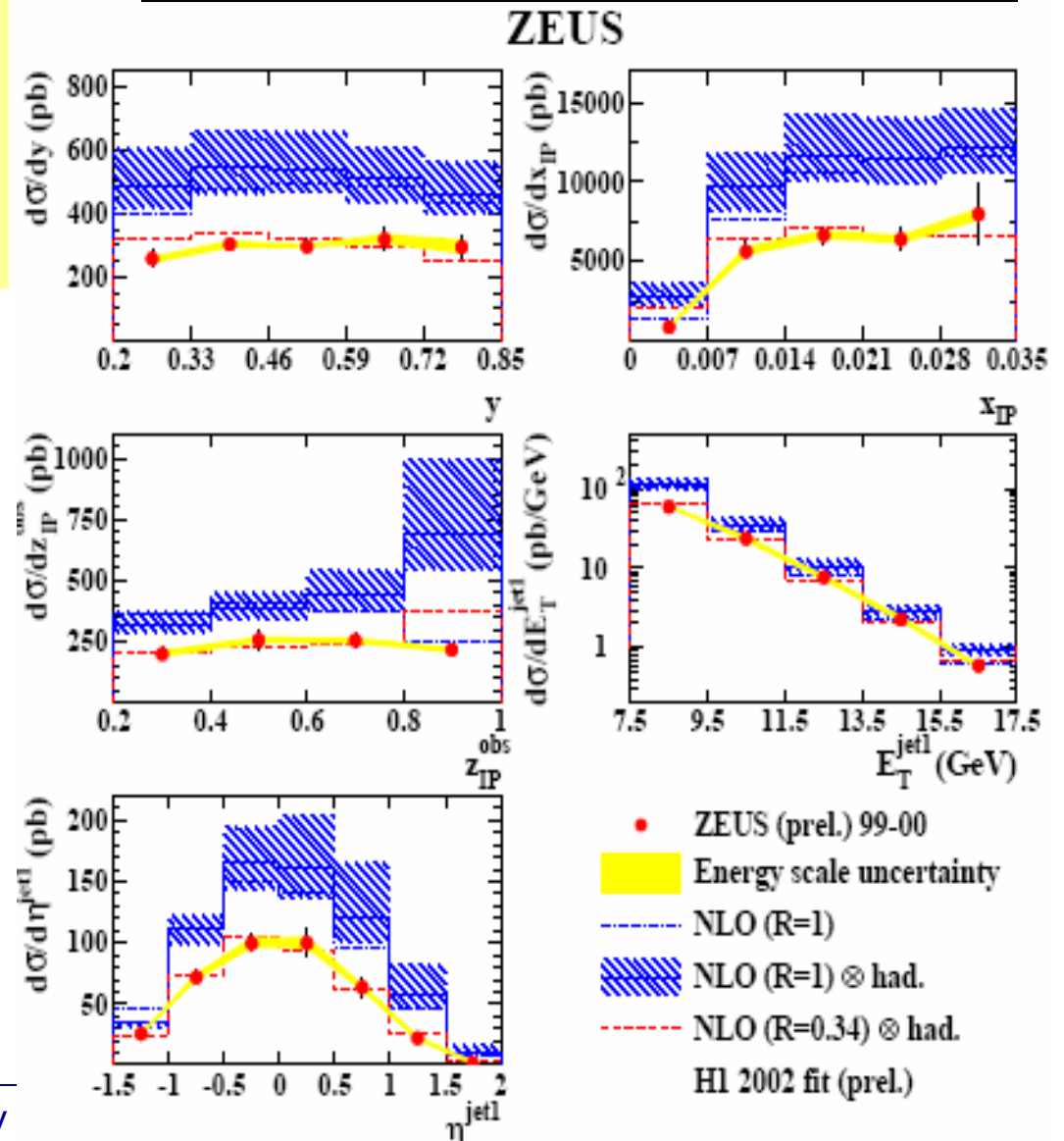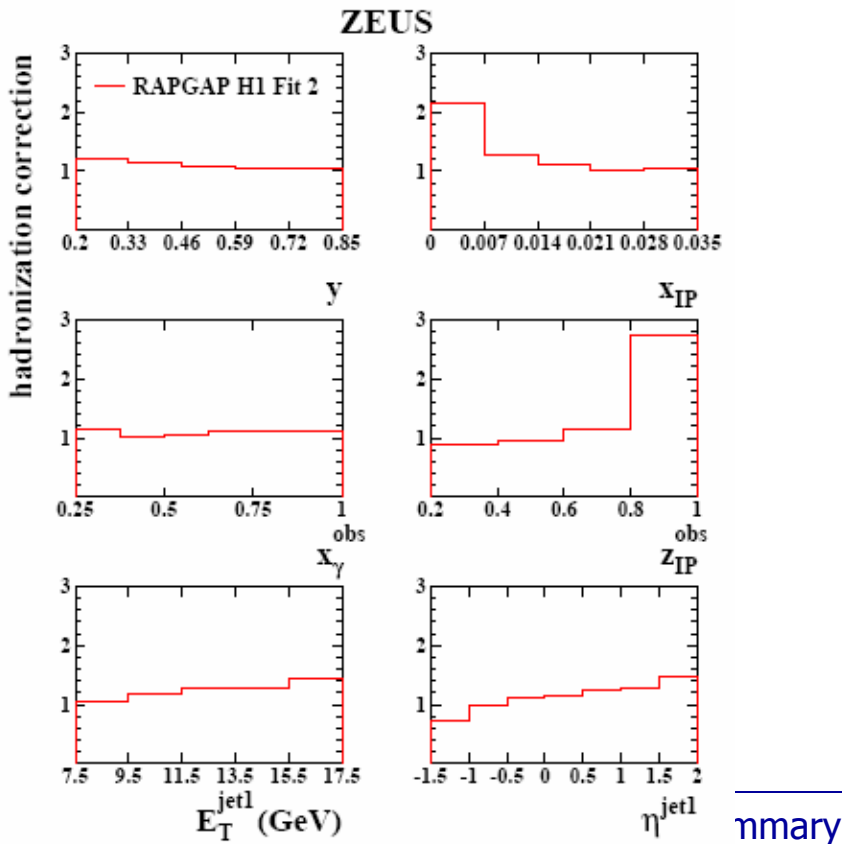- No significant $W^2 = ys$ dependence observed!

Diffractive γp at ZEUS

Hadronization corrections
- **Parton → jet**
- **Filling of the gap**
  - **alternative ways to define gap by looking at kT mini-jets?**

Data and NL0 calculation off by ~0.5 :

ZEUS

- ZEUS (prel.) 99-00
- Energy scale uncertainty
- NLO (R=1)
- NLO (R=1) ⊗ had.
- NLO (R=0.34) ⊗ had.
- H1 2002 fit (prel.)

Summary

List of topics discussed

- **Underlying event and minimum bias**
- **Rapidity gaps and survival probabilities**
- **Multi-jet topologies and multi-scale QCD**
  - **Forward jets at HERA**
  - **Jet ET spectra with CASCADE and PYTHIA**
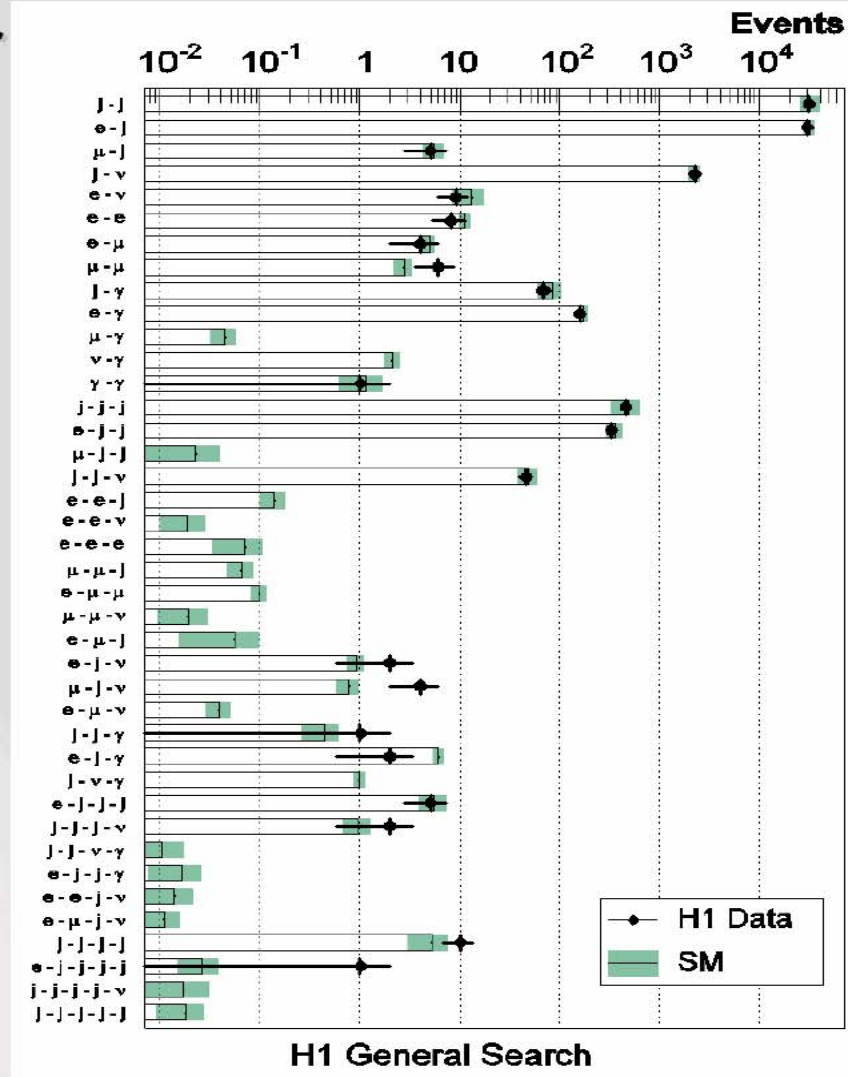- **Parton shower/ ME matching**

Forward jets and pions, with multiple interactions

Large x_{jet}/x_{bj} to enhance phase space for BFKL evolution

$$p_{tjet}^2 \approx Q^2$$

to supress DGLAP evolution

x_{bj}

x_{bj} small

evolution from large to small x

Not kT ordered

'forward' jet

$$x_{jet} - \frac{E_{jet}}{E_{proton}} - large$$

γ structure

Forward jet

p structure

electron   proton

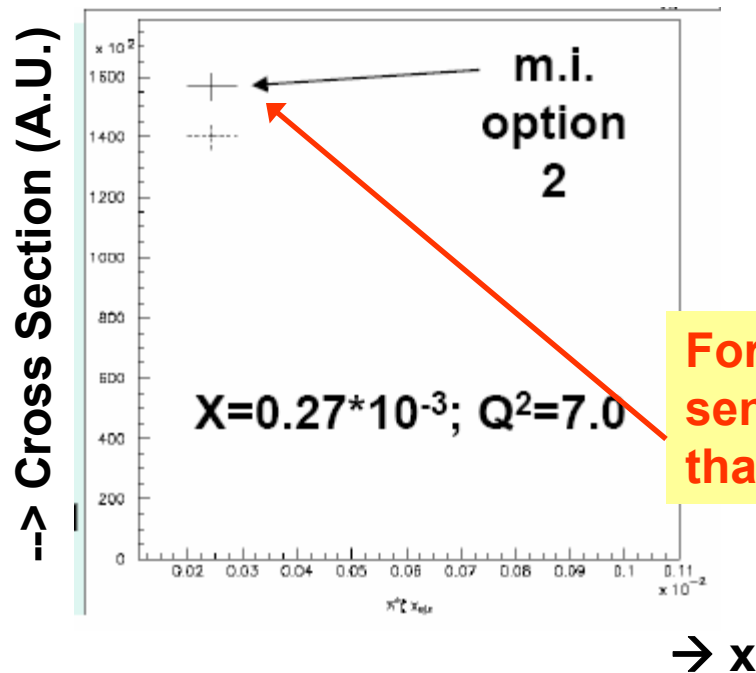| -1.5 | 0 | 1.5 | 2.8 | η_{lab} |
| $155°$ | $90°$ | $25°$ | $7°$ | Θ |

10/12/2004

j.turnau forward jets with m.i.
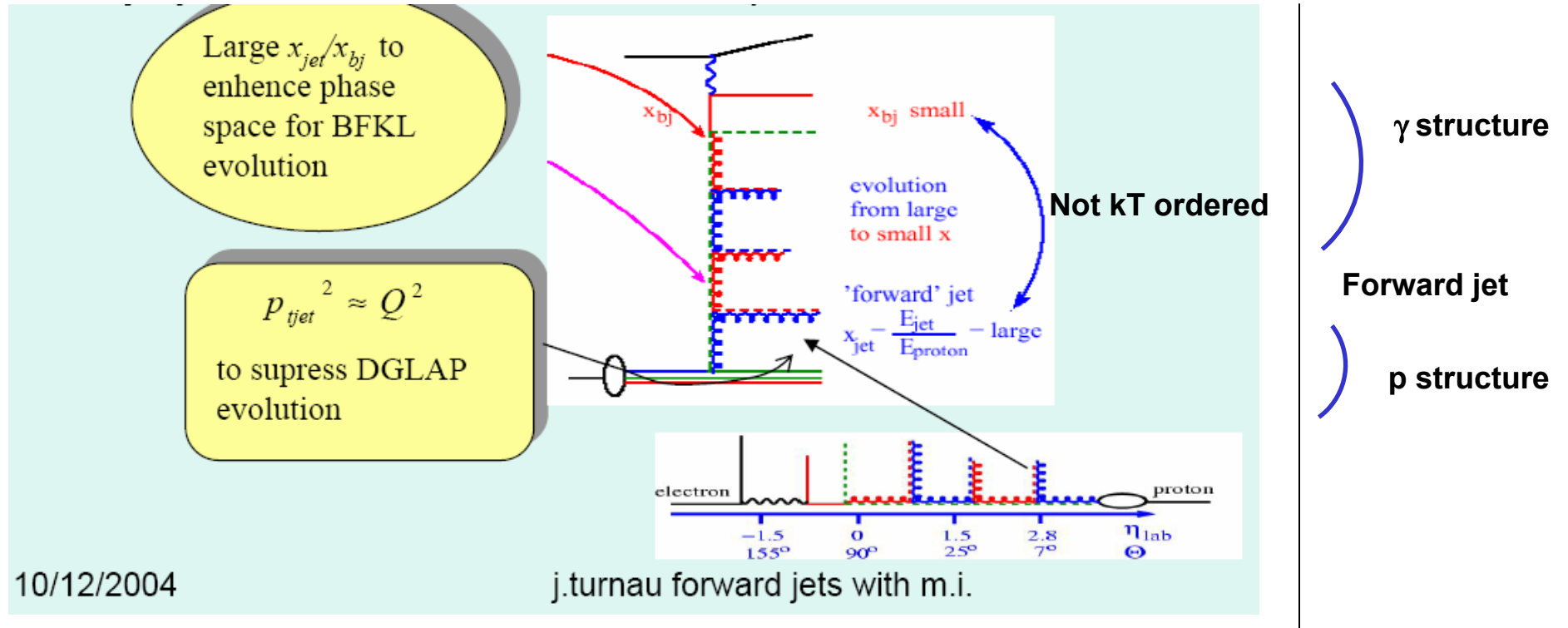
- Multiple Interactions can affect these small-PT measurements substantially
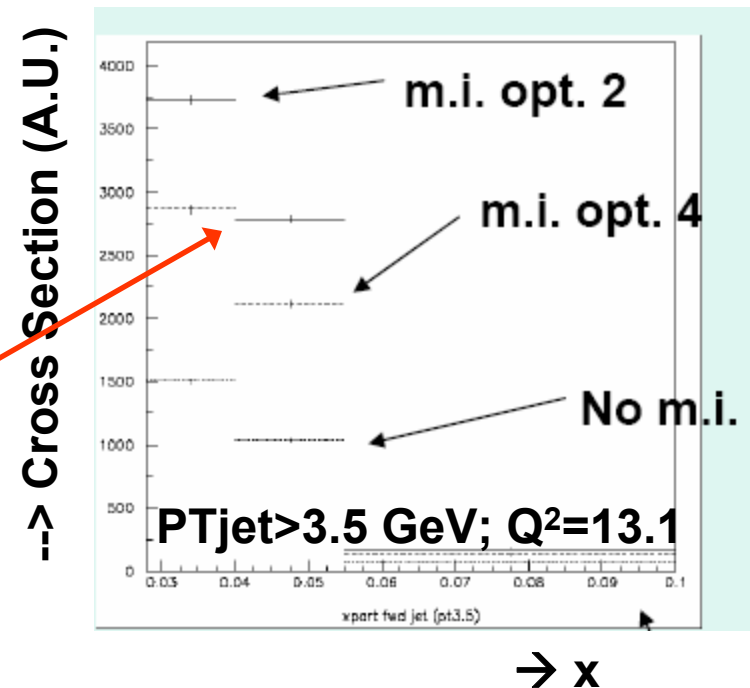- Large x_{Jet}/x_{Bj} enhances BFKL
- $p_T^2 \sim Q^2$ suppresses DGLAP

Forward jets and pions, with multiple interactions

Forward π^0 w/o multiple interactions:

Forward **jets** w/o multiple interactions:

m.i. option 2

$X=0.27*10^{-3}$; $Q^2=7.0$

Forward jet more sensitive to MI than forward π^0

m.i. opt. 2

m.i. opt. 4

No m.i.

PTjet>3.5 GeV; $Q^2=13.1$

➔ By measuring forward jet and π^0 cross sections, HERA is sensitive to Multiple Interactions
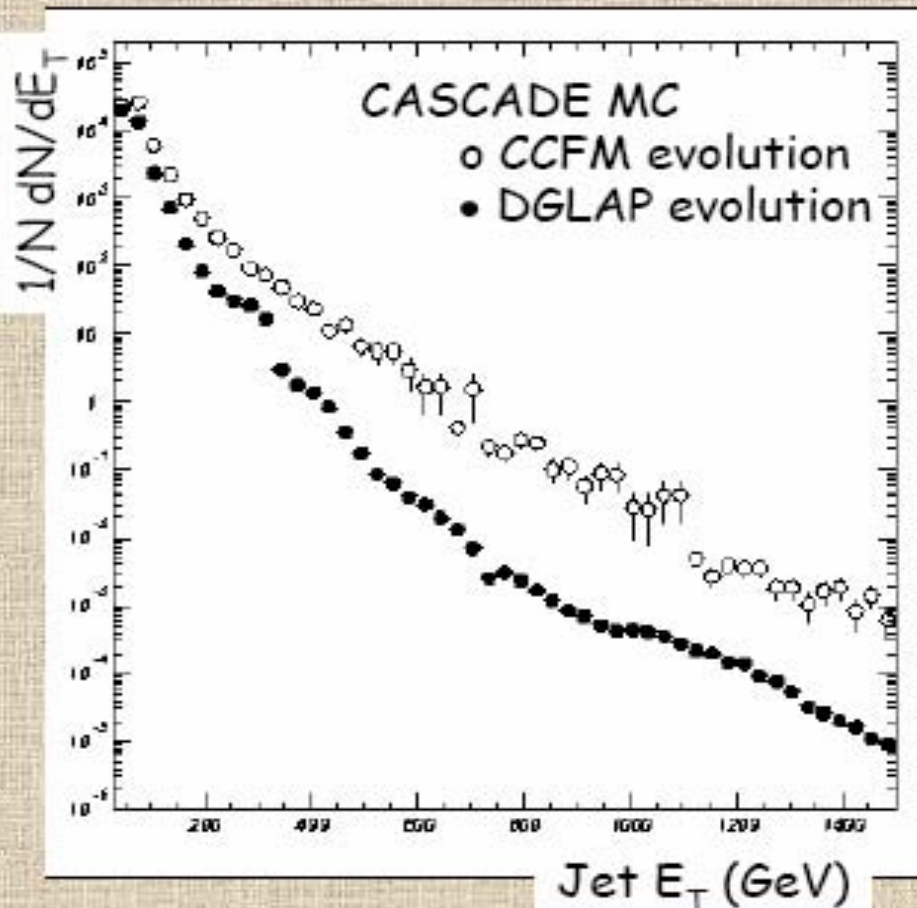(Problem: Multiple Interactions in PYTHIA at fixed √s (γp))

Parton Evolution Comparison

CASCADE MC
o CCFM evolution
• DGLAP evolution

$1/N \, dN/dE_T$

Jet E_T (GeV)

Shape :
CCFM (BFKL) harder than DGLAP

Cross Sections (not shown) :
CCFM ~ 6 X DGLAP

Issues :
1) Is this comparison fair? gg -> qq only in DGLAP?
2) DGLAP CASCADE ≡ gg -> qq in PYTHIA?

List of topics discussed

- **Underlying event and minimum bias**
- **Rapidity gaps and survival probabilities**
- **Multi-jet topologies and multi-scale QCD**
- **Parton shower/ ME matching**
  - **Monte Carlo modelling of the evolution equations**
  - **W+ jets in Sherpa (+ underlying events)**

Summarized by Victor Lendermann, on behalf of WG5

Topics for further work in the next 6 months (1)

- ## <u>Underlying Event</u>

  - Tuning a la Rick Field. Come up with PYTHIA settings from HERA.

  - Multiple interactions to be implemented in γp in PYTHIA

L.Lönnblad, J.Butterworth

  - Tuning of Jimmy

A.Moraes, C.Buttar, J.Butterworth

- ## <u>Survival Probabilities</u>

  - Can we use forward neutron data to test models of absorbtion, rescattering?

V.Khoze et al.

  - Diffractive γp

M.Klasen, H1, ZEUS

Topics for further work in the next 6 months (2)

- ## Compare different evolutions

  - DGLAP vs CCFM/BFKL (CASCADE)

  - Ariadne vs PS

  - ➔ Effect on jet ET, forward jets, multiplicities in forward direction, …

- ## Fragmentation

  - Core of the jet, too many particles in light-quark jets?

  - Fraction of strange; 20% at LEP, 30% at HERA?

  - Jet fragmentation properties, jet energy profile very large contribution to m_t measurement.

S.Magill, H.Jung, L.Lönnblad, E.Rodrigues, N.Tuning, J.Turnau, …