Multi-parton interactions and underlying events from Tevatron to LHC

Outline

1) Multiple Parton Interactions (MPI) Models
2) Review of the older Min Bias (MB) & Underlying Event (UE) Phenomenology
3) MB&UE Feasibility Studies for the LHC
4) New ideas, generator level studies
   - Double Parton Scattering
   - The mini-jet structure of the MB
   - Central-Forward correlations
   - Multiple Parton Interactions & Diffraction

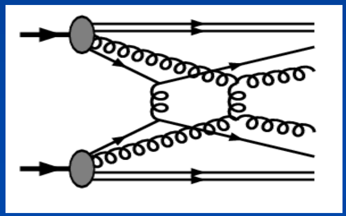
pQCD Models

ISR, FSR, SPECTATORS…
Not enough to account for the observed multiplicities & P_T spectra

→

The Pythia solution:
[T. Sjöstrand et al. PRD 36 (1987) 2019]
Multiple Parton Interactions (MPI)
(now available in other general purpose MCs: Herwig/Jimmy, Sherpa, etc.)

Inspired by observations of double high P_T scatterings



Main Parameter: P_T cut-off P_{T0}

$$\sigma(\widehat{P}_T) \rightarrow \sigma(\widehat{P}_T) \cdot \frac{(\widehat{P}_T)^4}{((\widehat{P}_{T0})^2 + (\widehat{P}_T)^2)^2}$$

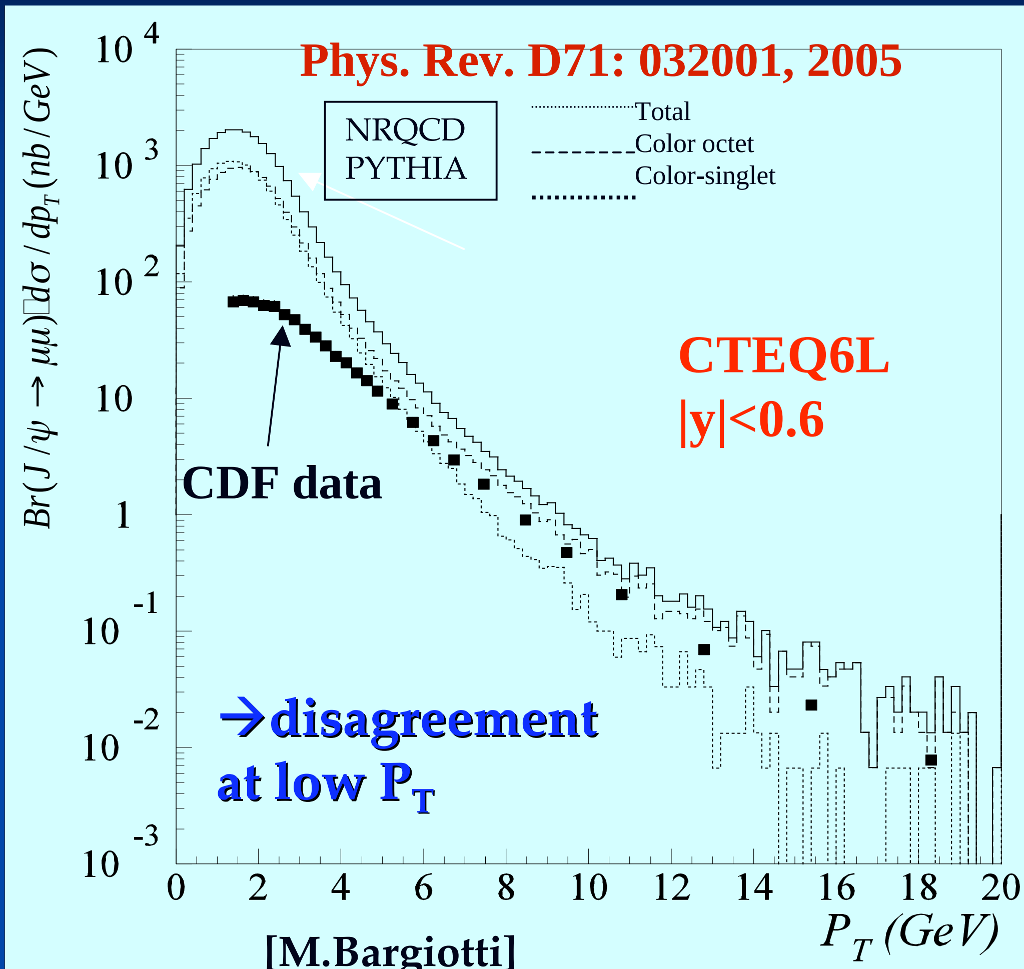
(dampening)

- ✓ **Cross Section Regularization for $P_T \rightarrow 0$**
- ✓ **P_{T0} can be interpreted as inverse of effective colour screening length**
- ✓ **Controls the number of interactions hence the Multiplicity:**

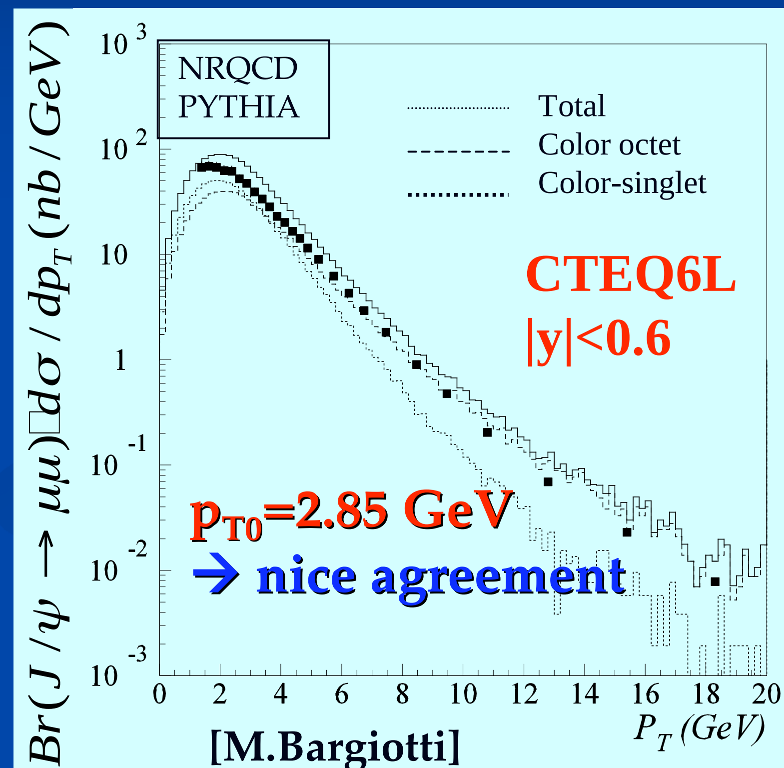
$$< N_{int} > = \sigma_{parton-parton} / \sigma_{proton-proton}$$

Tuning for the LHC:
Emphasis on the Energy-dependence of the parameters.

Quarkonia also prefers dampening



$$\sigma(\widehat{P}_T) \to \sigma(\widehat{P}_T) \cdot \frac{(\widehat{P}_T)^4}{((\widehat{P}_{T0})^2 + (\widehat{P}_T)^2)^2}$$



Regularization natural: gluon exchange in the t channel $d\sigma/dP_T^2 \sim 1/dP_T^4$

P_{T0} very much along the lines of the one adopted in MPI MB & UE Tunes

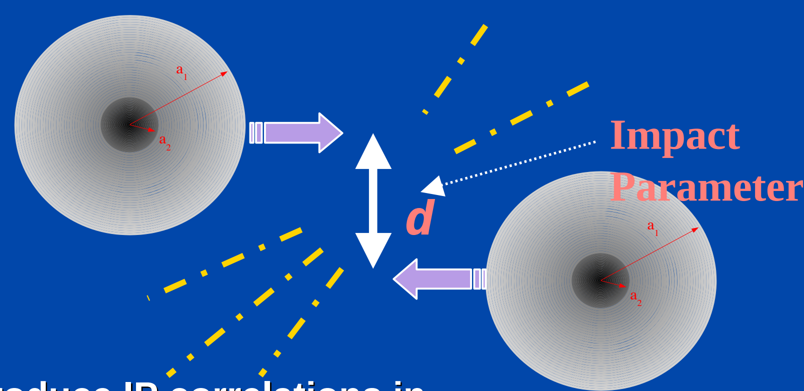
MB: Charged Multiplicity vs MPI models

- "post Hera" PDFs have increased color screening at low x ?

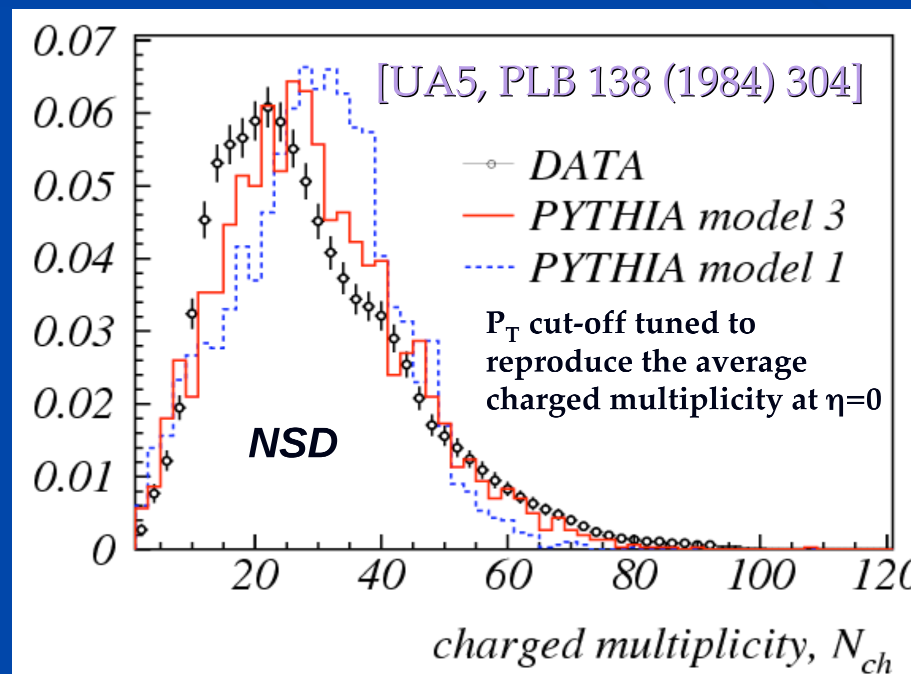
$$x\,g(x,Q^2) \rightarrow x^{-\varepsilon} \text{ for } x \rightarrow 0$$

- $P_T(s)$ cut-off fitted with exponential function using the average charged multiplicity in the central region from SPS & Tevatron [CERN 2000-004, pgg 293-300]
- G.Gustafson & G.Miu rather suggest energy independency of the P_T cut-off [Phys.Rev.D63:034004,2001 and Phys.Rev.D67:034020,2003]

Pythia MPI Model with Varying impact parameter between the colliding hadrons: hadronic matter is described by Gaussians



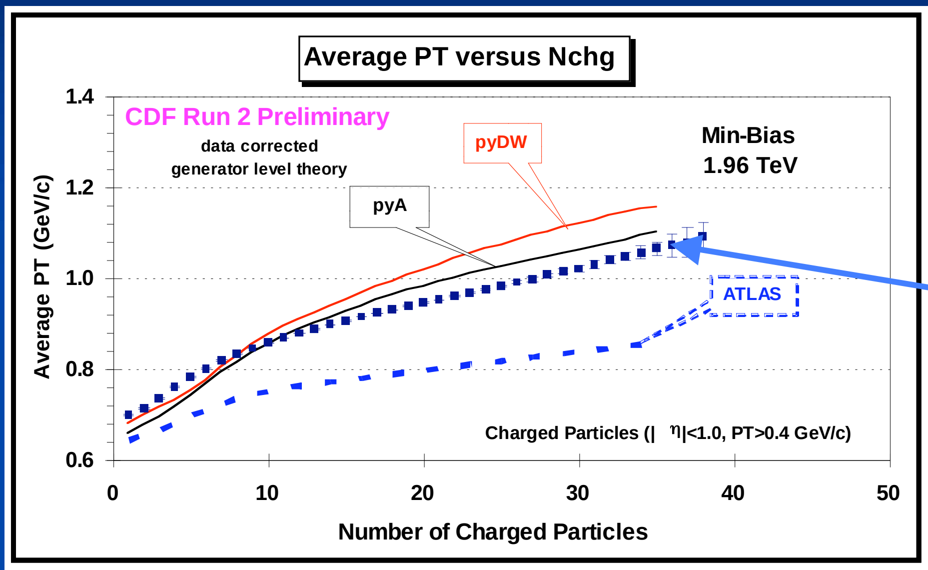
Introduce IP correlations in Multiple Parton Interactions → Describe Tails!

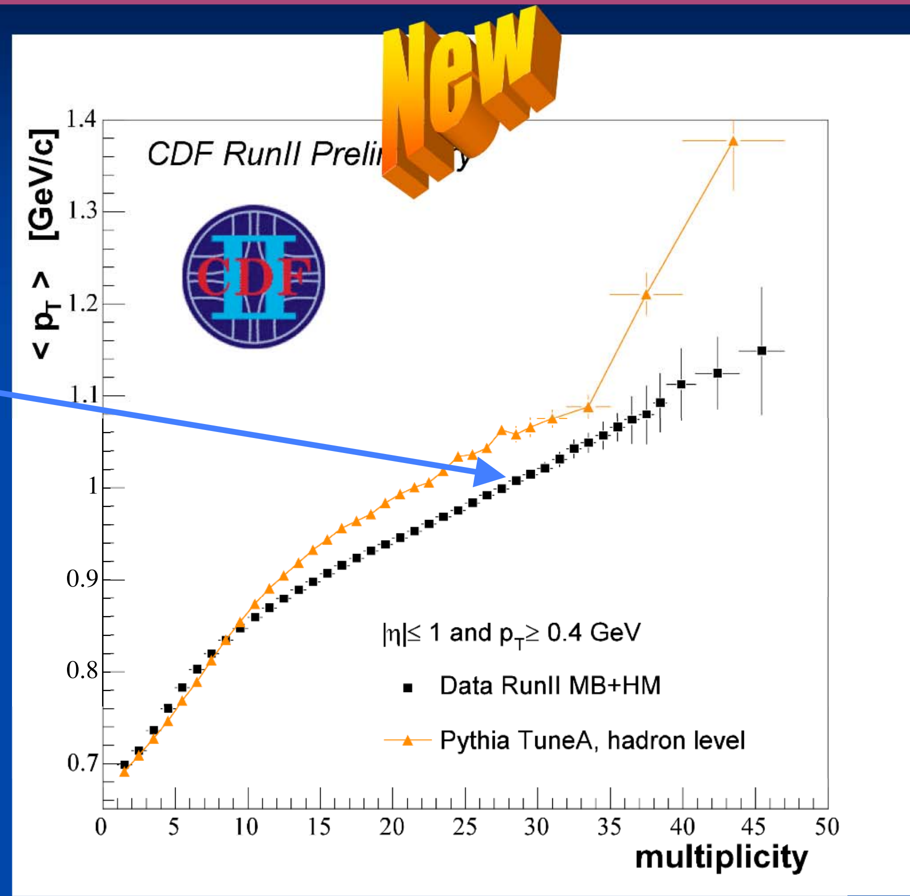


Further correlations introduced in new Pythia MPI [Eur.Phys.J.C39(2005)129 + JHEP03(2004)053]

$\langle P_T \rangle$ vs Multiplicity: see [hep/ph 0703081]

MB Correlations: Average P_T vs Charged Multiplicity





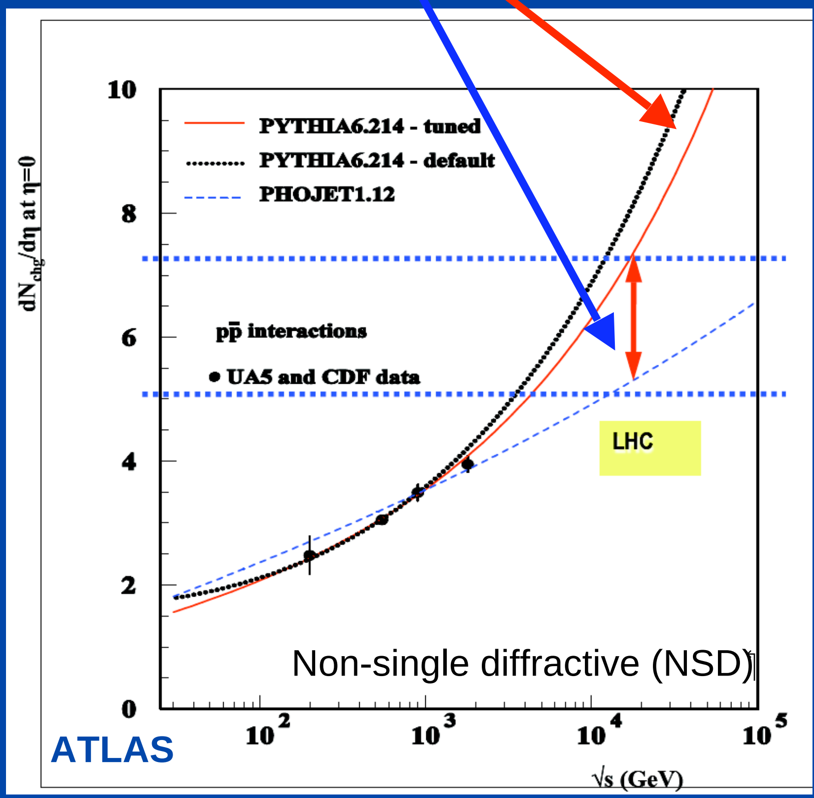
[Rick Field, HERA/LHC, May 08]

- Data at 1.96 TeV on the average p_T of charged particles versus the number of charged particles ($p_T > 0.4$ GeV/c, $|\eta| < 1$) for "min-bias" collisions at CDF Run 2. The data are corrected to the particle level and are compared with PYTHIA Tune A at the particle level (*i.e.* generator level).

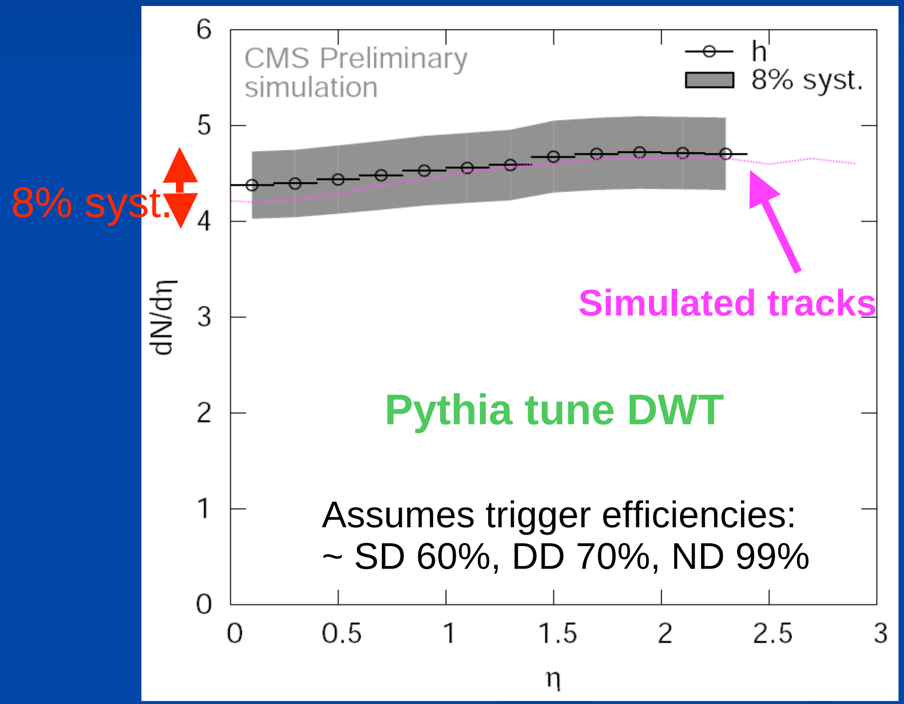
MB: Charged Multiplicity at the LHC

Model expectations for charged particles at |η| = 0 vs. √s:

- Pythia: ~ $\ln^2(s)$
- Phojet: ~ $\ln(s)$



CMS:
Tracklets, i.e. Only pixel triplets
down to 75 MeV !



CMS Physics Analysis Summary QCD-07-001

Reference for trigger performances:
CMS Physics Analysis Summary QCD-07-002

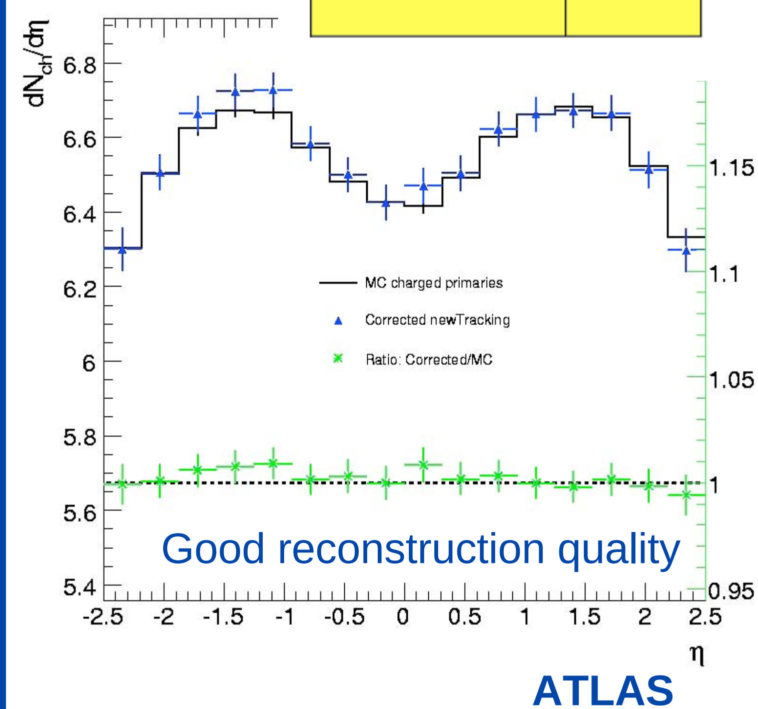
Tunes & Trigger performances -> backup slides

MB: Hadron spectra at the LHC

ATLAS Track Reco

Summary of systematic uncertainties

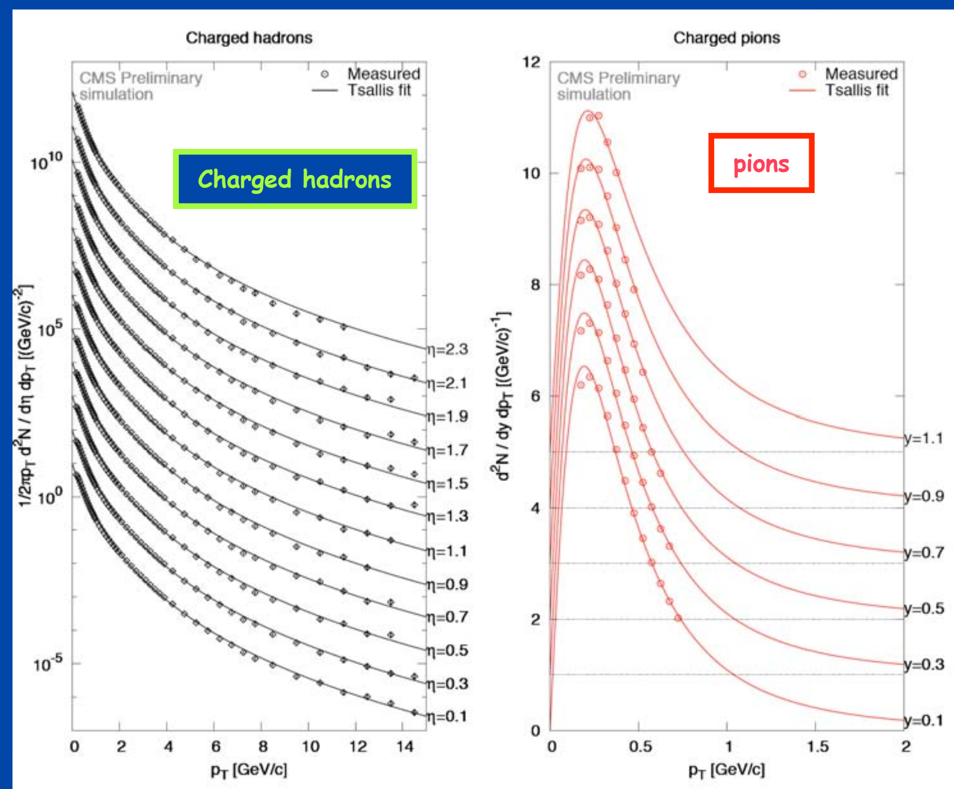
Track selection cuts	2%
Mis-estimate of secondaries	1.5%
Vertex reconstruction	0.1%
Mis-alignment	6%
Beam-gas & pile-up	1%
Particle composition	2%
Diffractive cross-sections	0.1%
Total:	**6.9%**



CMS:
Tracklets:
Only pixel triplets
down to 75 MeV !

Systematic:
Trigger, feed-down, geom. acceptance, alg. efficiency

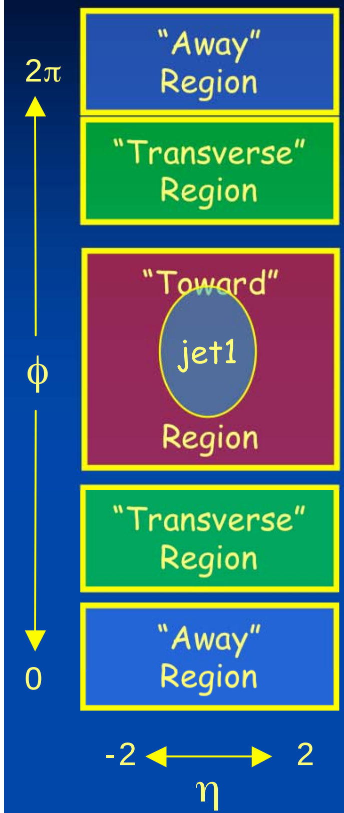
Diff. yields of identified $\pi^{\pm}$, $K^{\pm}$, $p/\bar{p}$ together with *Tsallis*-function fits (inverse slope T = 0.2 GeV/c, high p_T exponent n = 7.2)

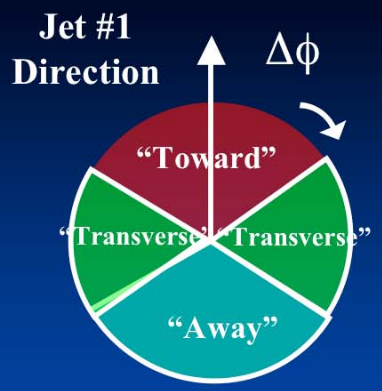


CMS Physics Analysis Summary QCD-07-001

Tunes & Trigger performances -> backup slides

UE: Observables





MB and Jet events

The Calo jet (or Charged jet) provides a scale and defines a direction in the ϕ plane

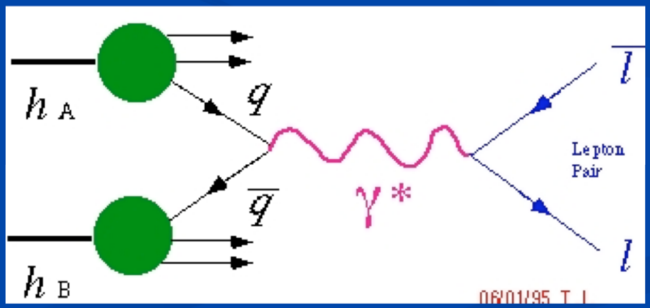
The transverse region is expected to be particularly sensitive to the UE

Several Jet topologies can be tested to increase the sensitiveness to the MPI component of the UE

Main observables built from charged tracks:
- + $dN/d\eta d\phi$, charged density
- + $d(PT_{sum})/d\eta d\phi$, energy density

LHC experiments have a much wider $\Delta\eta$ region with respect to the Tevatron ones

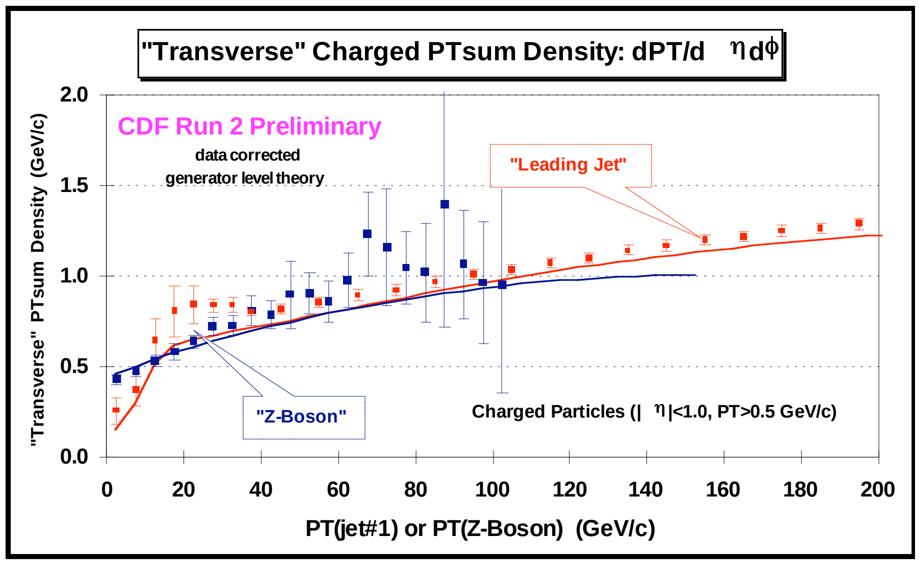
DY events

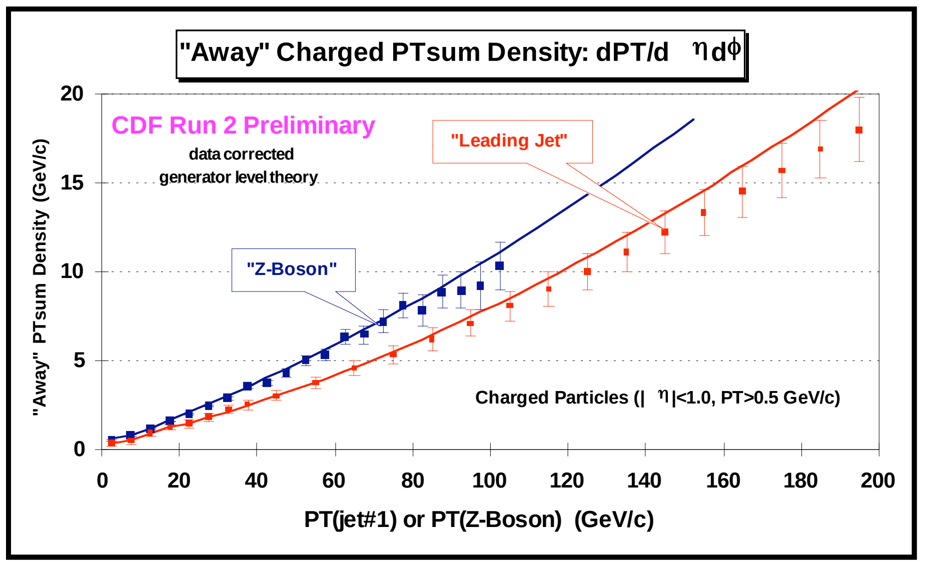


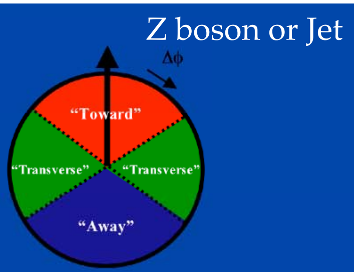
observables are the same

The PT of the boson is used to define a direction

CDF: UE in Jet and Z topologies





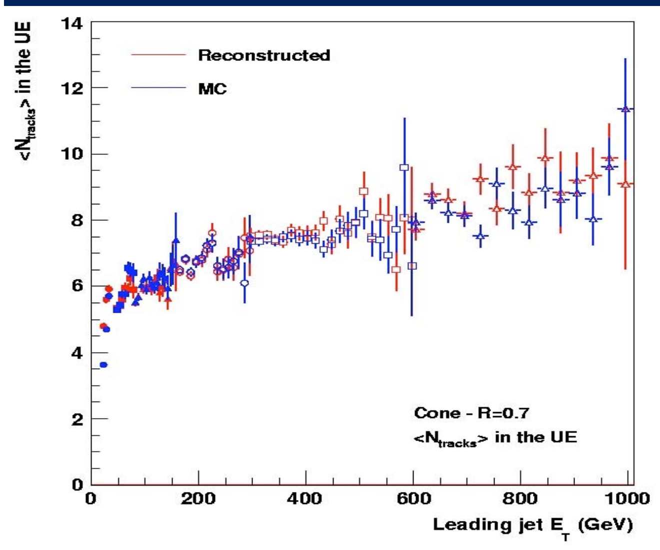


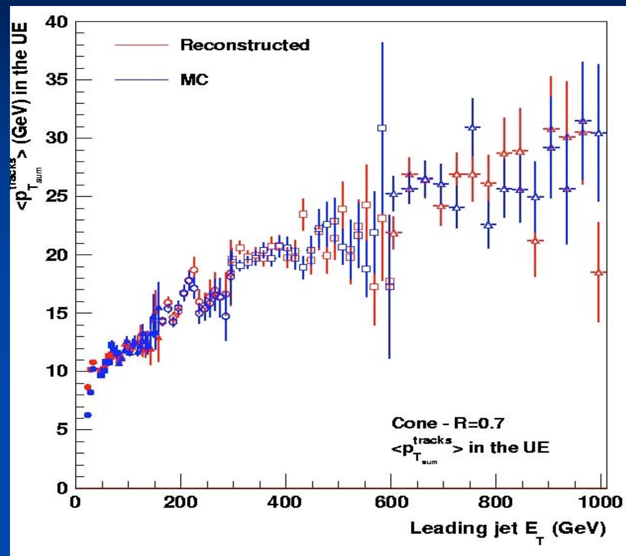
[Rick Field, HERA/LHC, May 08]

- 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" and "Leading Jet" events as a function of the leading jet p_T or $P_T(Z)$ for the "toward", "away", 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 Tune A, respectively, at the particle level (*i.e.* generator level).

Further details in next talk (from D. Kar)

ATLAS: UE in the transverse region





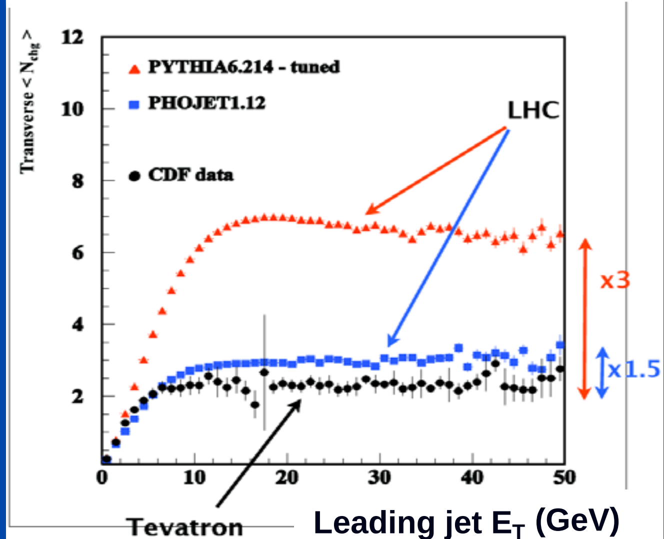
Up to 1 TeV in few pb^{-1}

$N_{jets} > 1$,
$|\eta_{jet}| < 2.5$,
$E_T^{jet} > 10$ GeV,

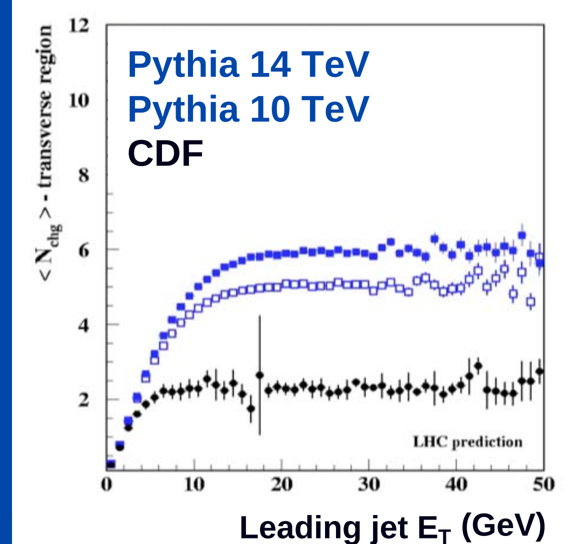
$|\eta_{track}| < 2.5$,
$p_T^{track} > 1.0$ GeV/c

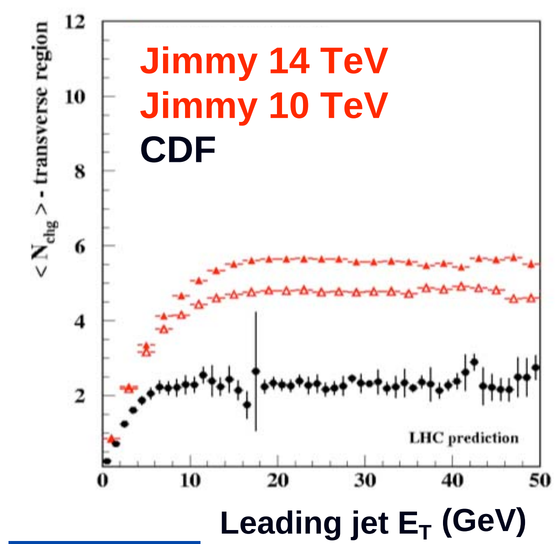
Good RECO/MC agreement

LHC / Tevatron ~ 1.5 - 3



Tune of the energy dependent MPI parameters (run at 900 GeV coming!)



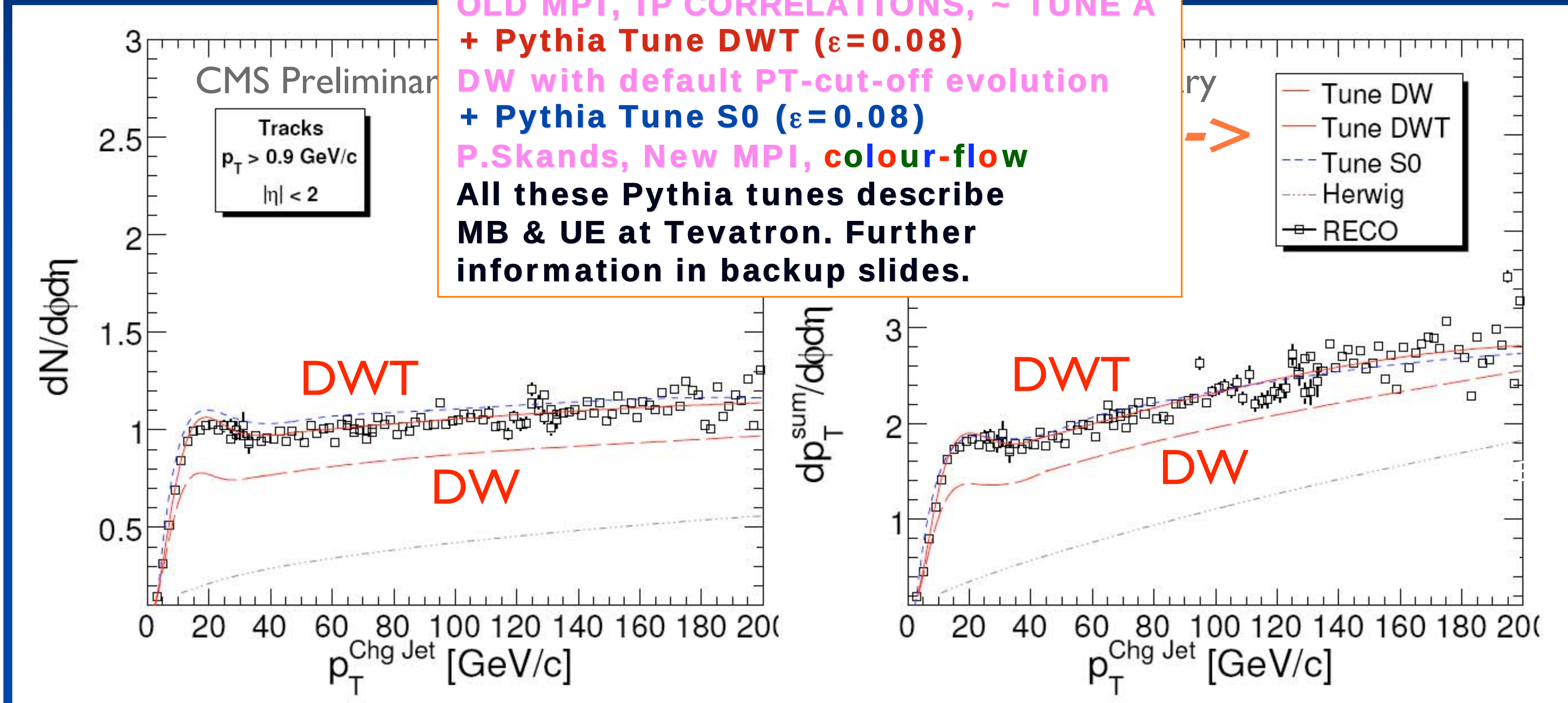


Tunes -> backup slides

CMS: UE in the transverse region (I)

Select c… .9 GeV/c

+ Pythia Tune DW (ε=.125)
OLD MPI, IP CORRELATIONS, ~ TUNE A
+ Pythia Tune DWT (ε=0.08)
DW with default PT-cut-off evolution
+ Pythia Tune S0 (ε=0.08)
P.Skands, New MPI, colour-flow
All these Pythia tunes describe MB & UE at Tevatron. Further information in backup slides.



CMS Physics Analysis Summary QCD-07-003

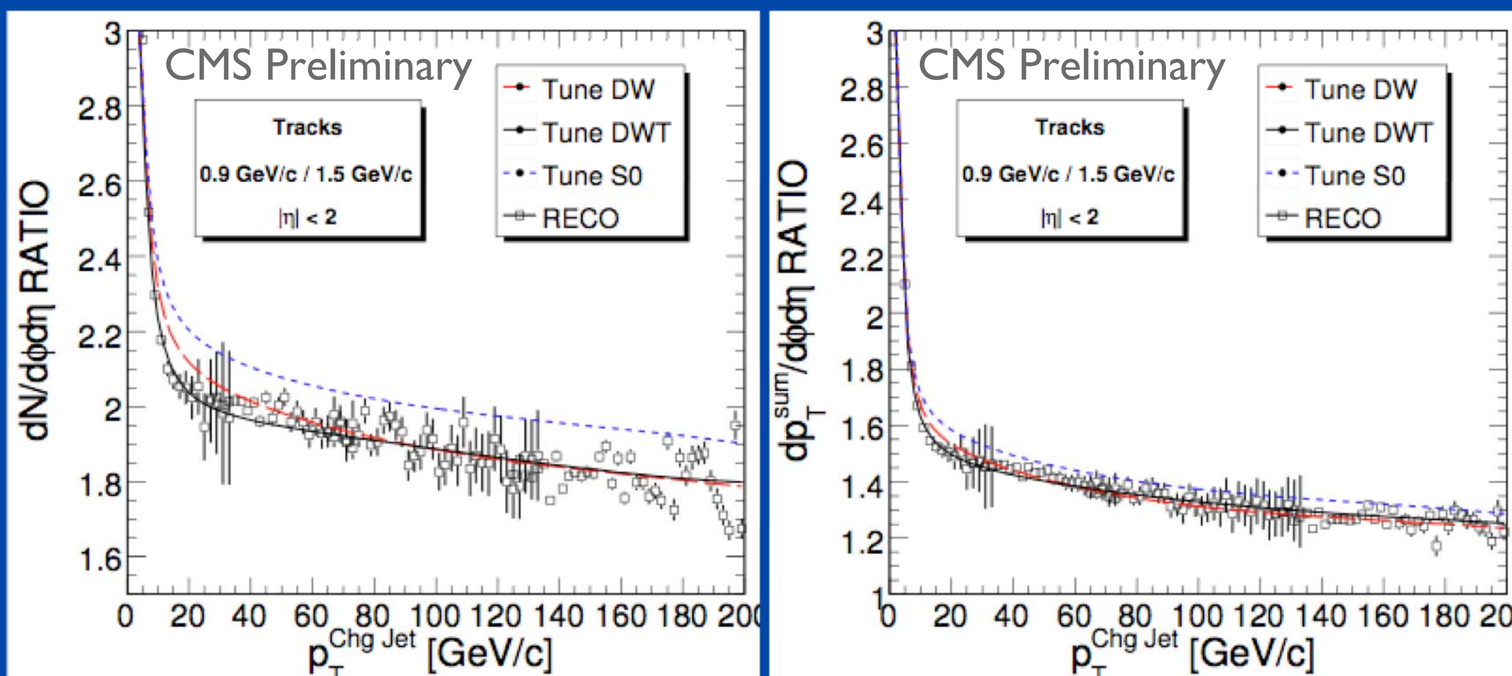
→ discriminate DW against DWT

(no pile-up included)

UE in jets: Ratios in the transverse region

- **Ratios between uncorrected UE-observables:**
  - UE-density(p_T(track) > 0.9 GeV/c) / UE-density(p_T(track) > 1.5 GeV/c)

- **No additional track reconstruction corrections needed!**
  - track reconstruction performance uniform in p_T for p_T > 0.9 GeV/c



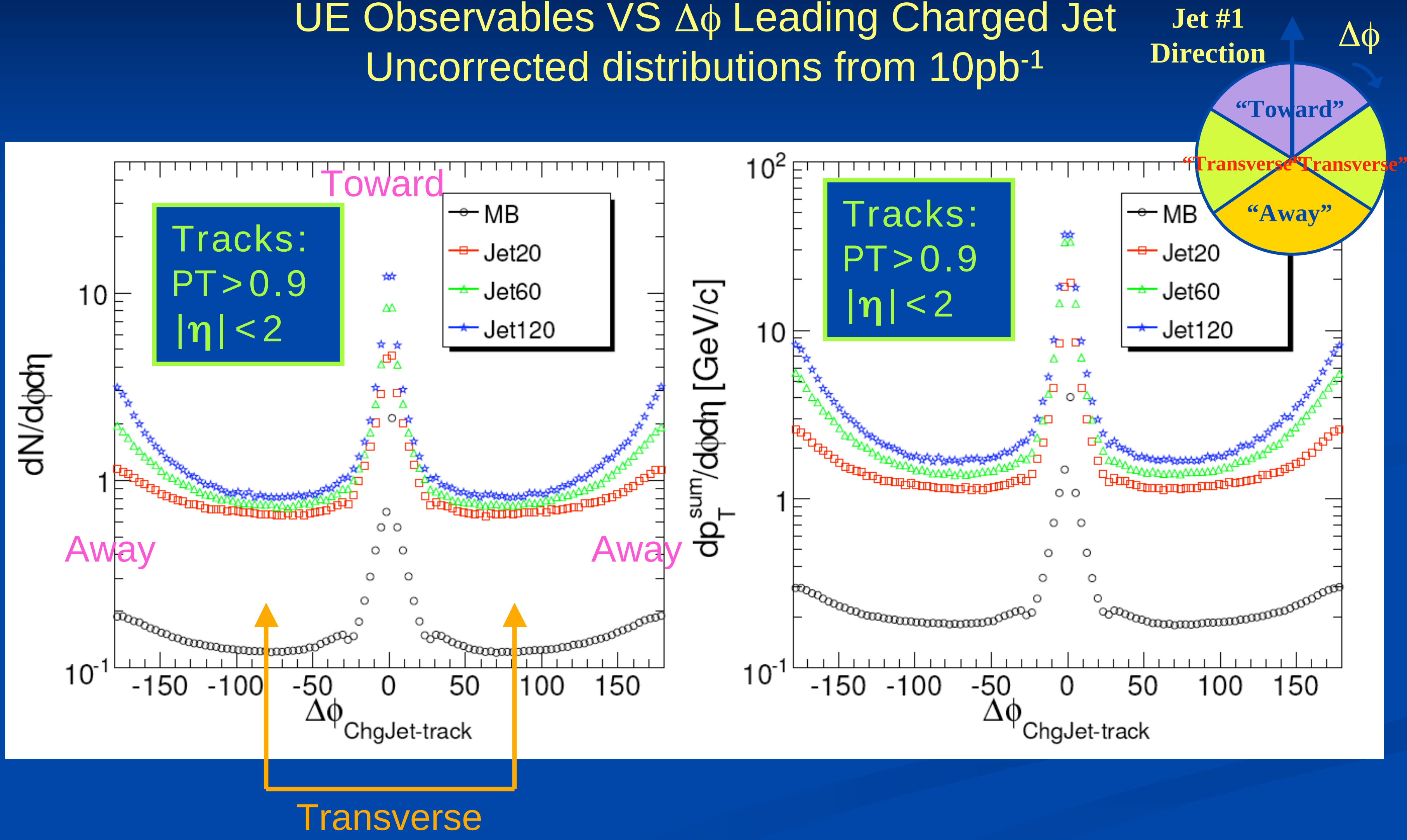
(input to RECO is DWT)

CMS Physics Analysis Summary QCD-07-003

→ **discriminate DW/DWT against S_0**

CMS: Activity vs distance to charged jet

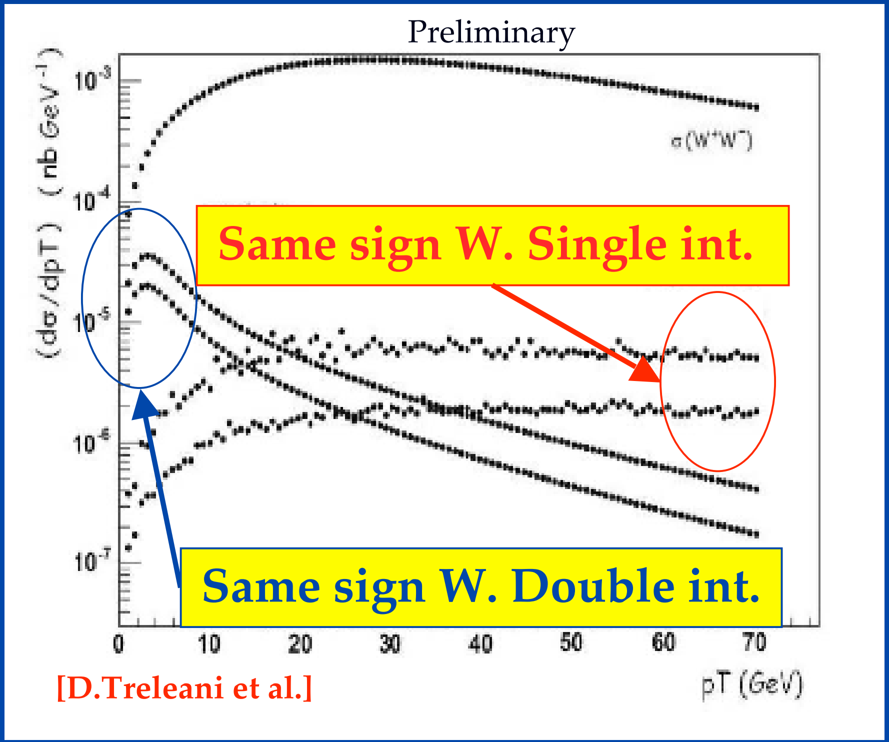
UE Observables VS $\Delta\phi$ Leading Charged Jet
Uncorrected distributions from $10pb^{-1}$



CMS Physics Analysis Summary QCD-07-003

The MPI Challenge for the LHC

THE ULTIMATE GOAL WOULD BE TO ACHIEVE A UNIFORM DESCRIPTION FOR **HIGH P_T** AND **LOW P_T** MPI



HOW?

- **3j + γ**
- **Standard MB & UE measurements (along the lines of the CDF experience)**
- **Counting pairs of same sign W** NEW
- **Counting pairs of mini-charged jets in MB interactions** NEW

[Treleani et al. Int.J.Mod.Phys.A20:4462-4468 (2005). Phys. Rev. D 72, 034022 (2005).]

CDF: Double Parton Scattering in 3jet + γ

Double high P_T interactions observed by AFS, UA2, CDF

3jet+γ:
[CDF Collab, Phys. Rev. Lett. 79, 584 (1997)]

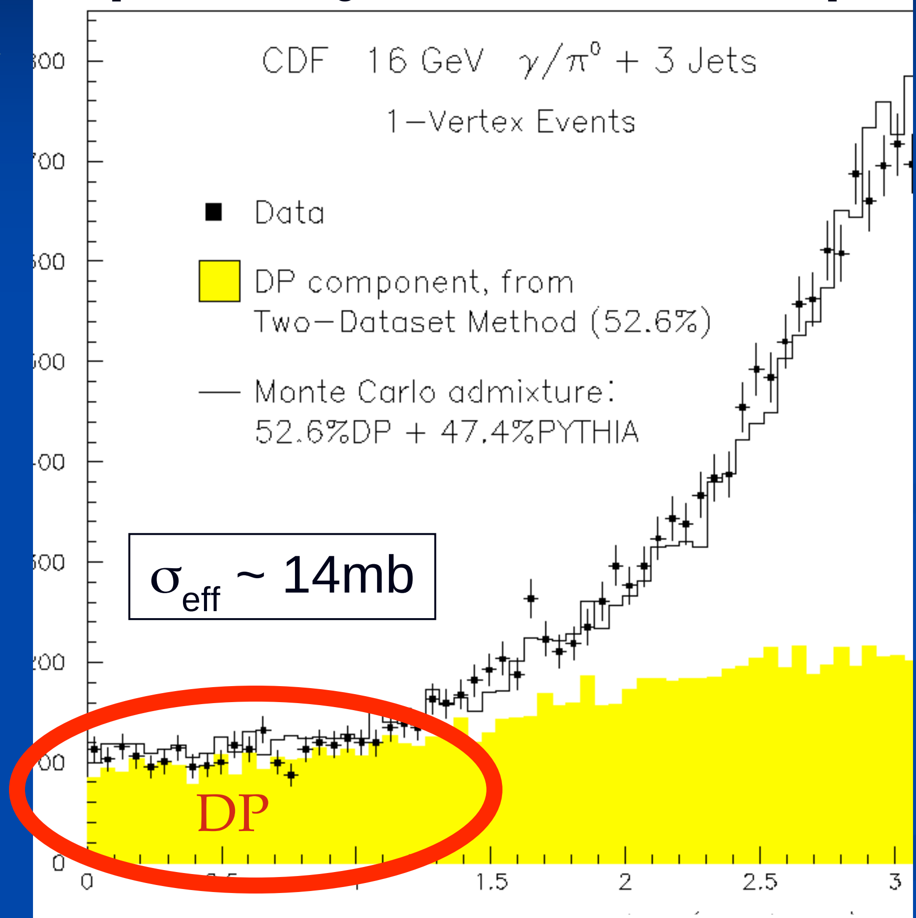
In the simplest model, DPS produces a final state that mimics a combination of two independent scatterings.

$$\sigma_{DP} \equiv m \frac{\sigma_A \sigma_B}{2\sigma_{\rm eff}}.$$

m=2 for distinguishable scatterings
m=1 for indistinguishable scatterings

$\sigma_B/(2\sigma_{\rm eff})$ is the probability of hard scattering B taking place given A, and this will be larger or smaller depending on the parton spatial density. $\sigma_{\rm eff}$ contains the information on the spatial distribution of partons

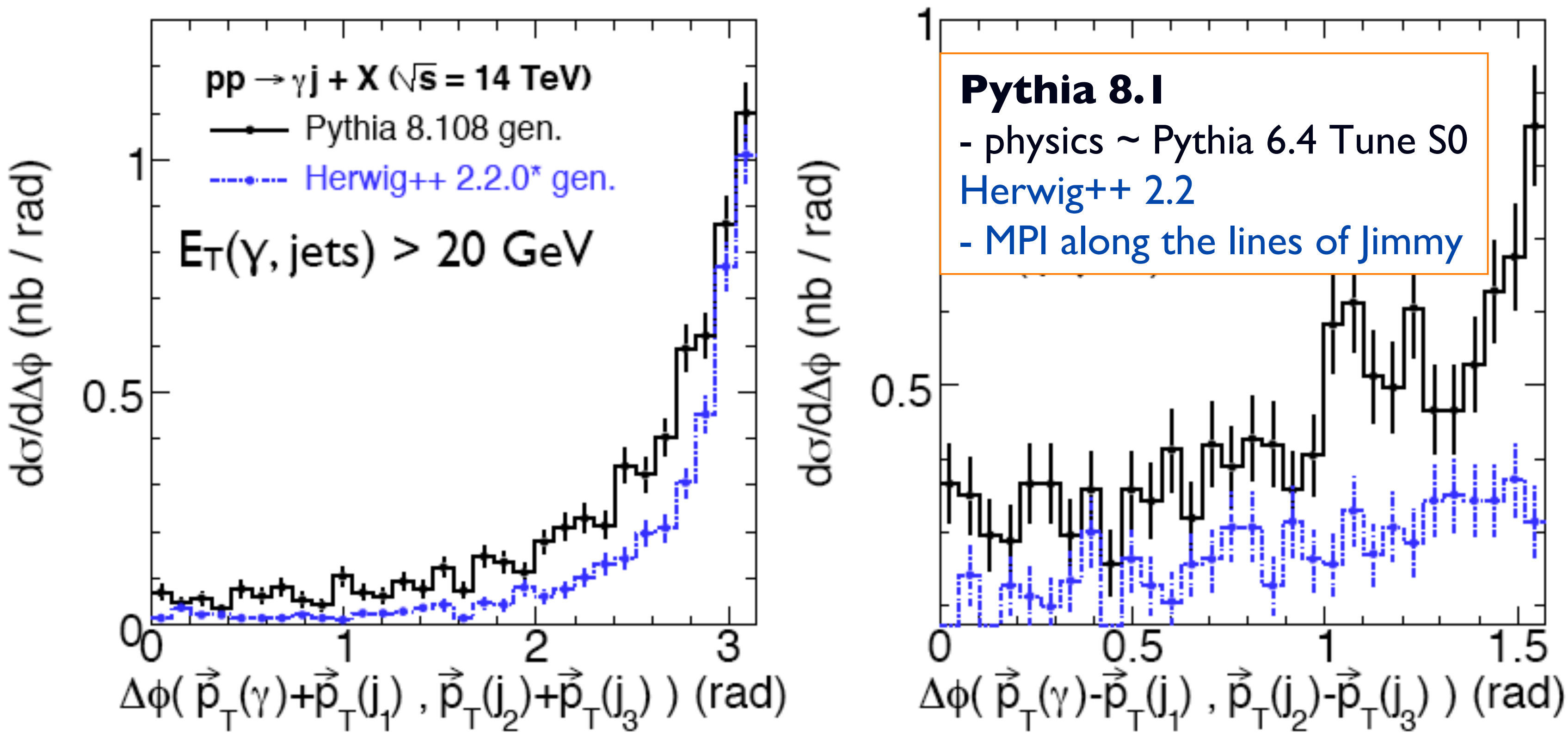
[Paoti Chang Fermilab Conf-97-175-E]



$\Delta\varphi$ between $\mathbf{p_{Tj}} + \mathbf{p_{Tj}}$ and $\mathbf{p_{Tj}} + \mathbf{p_{T\gamma}}$

Treleani corrects to $\sigma_{\rm eff}$ ~ 10mb
[Phys.Rev.D76:076006,2007]

Model comparison @ LHC



→ More statistics underway to clear potential disagreement

→ Default PDFs used: CTEQ5L (Pythia) and MRST98 (Herwig)

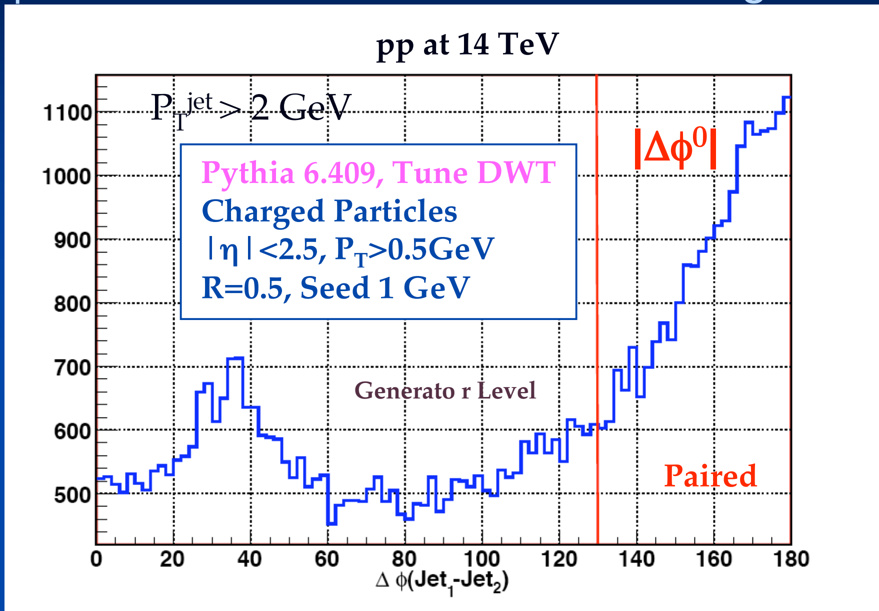
Further information on the models in backup slides

LHC: Quoting MPIs with paired charged MiniJets

Generator Level Studies with Pythia 6.4x

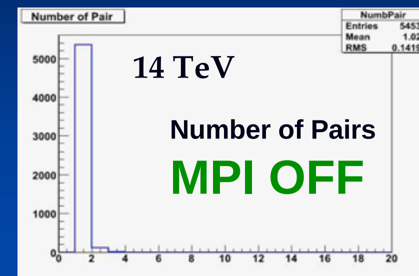
[F. Ambroglini et al.]

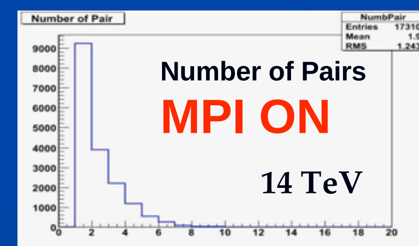
$\Delta\phi$ distribution for the two most energetic charged Mini-Jets of the events

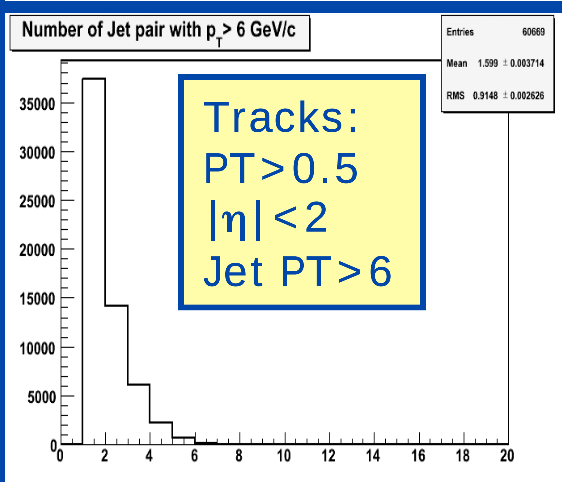


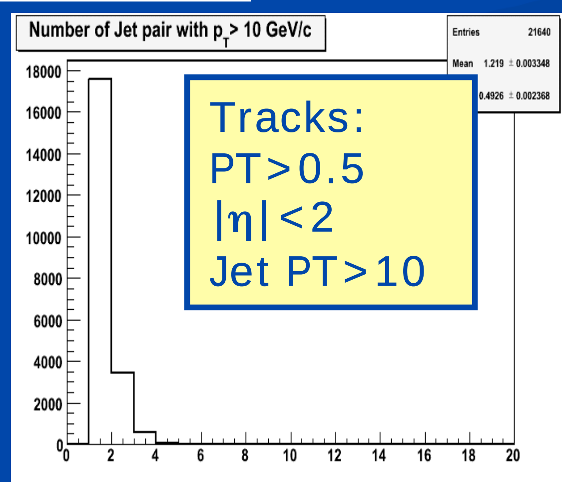
Pairing Algorithm:

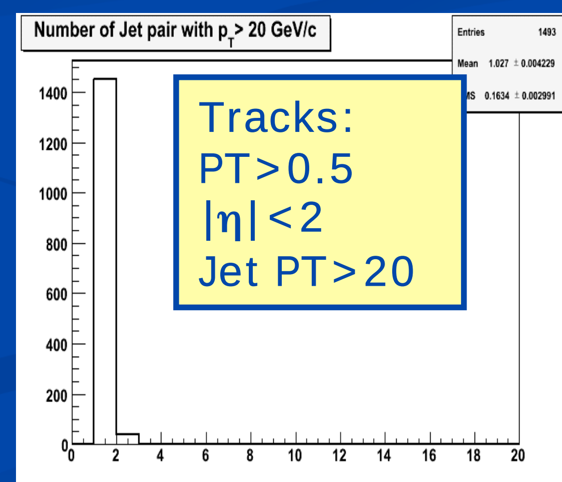
- MiniJets ordered in decreasing P_T
- Start from the first
- Paired = jet with closest PT that satisfies the condition $|\Delta\phi^0|<|\Delta\phi|$











The Number of pairs deeply depends on jet PT and acceptance

LHC: Quoting MPIs with paired MiniJets

Generator Level Studies with Pythia 6.4x

[F. Ambroglini et al.]

The idea of the measurement (D. Treleani) is to study the Rates for a given number N of Mini-Jet Pairs above a given P_T threshold -> Infrared Safe Quantity

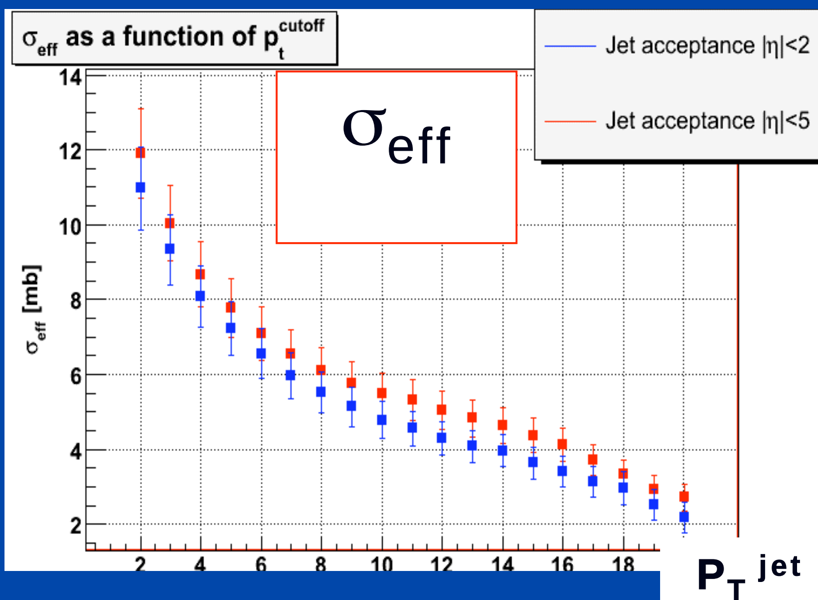
$$\langle N\rangle\sigma_H = \sigma_S \quad \text{and} \quad \frac{1}{2}\langle N(N-1)\rangle\sigma_H = \sigma_D \qquad \langle N(N-1)\rangle = \langle N\rangle^2 \frac{\sigma_H}{\sigma_{eff}}$$

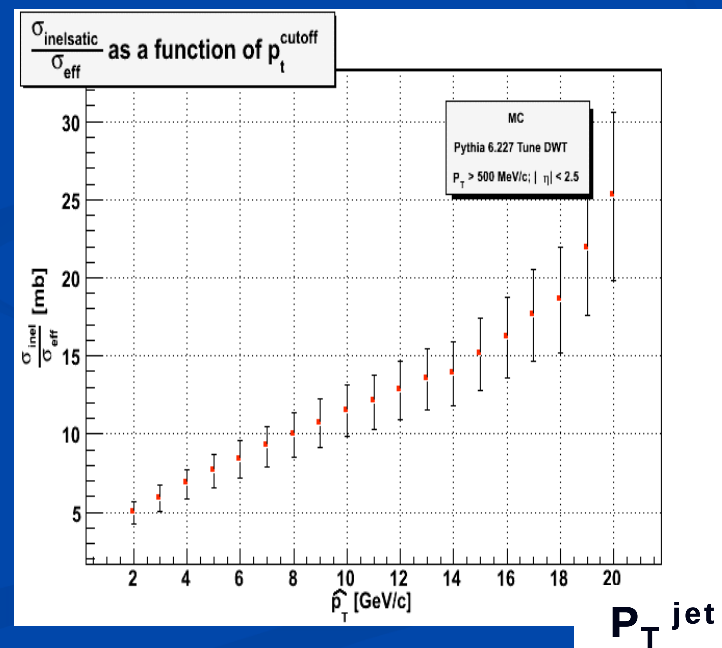
Where $\sigma_{inel} = \sigma_{soft} + \sigma_H$

"S" = Single Interactions, "D" = Double Interactions, "H" = Hard

$\sigma_{eff}(P_T)$ contains the information on the spatial distribution of partons

Enhancement in the probability of additional interactions

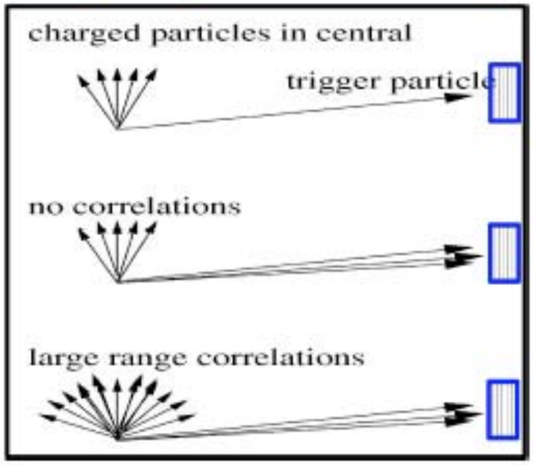




σ_{eff} ~ independent from acceptance & efficiency (also from theory)

UE & Long Range Correlations

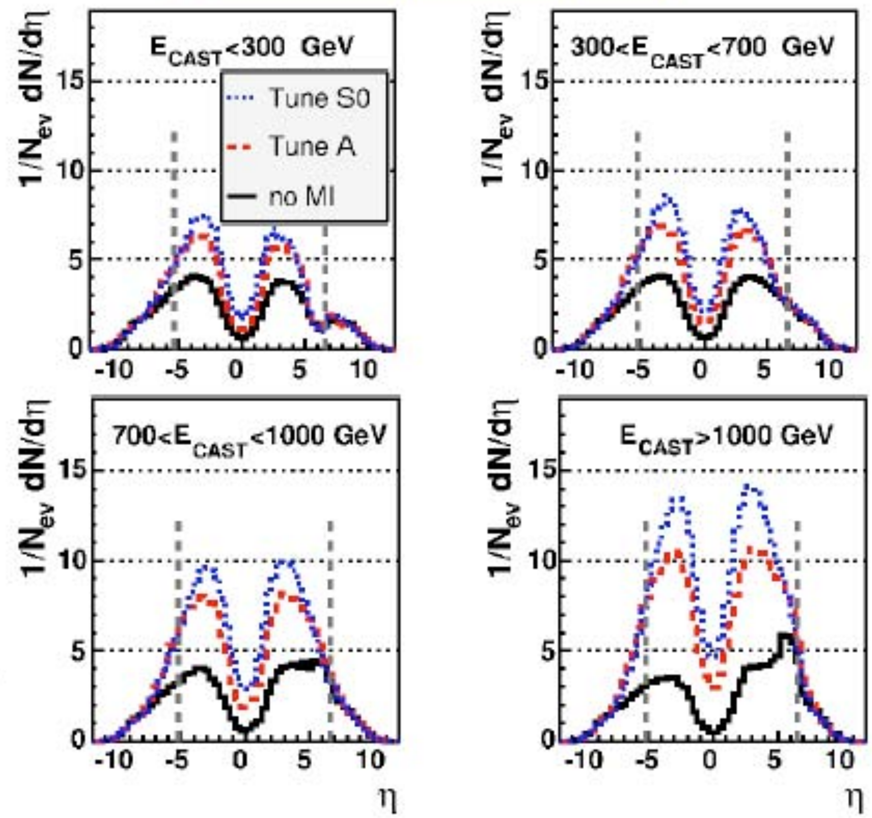
Long range Correlations:



- **Without MI:** no correlations
- **With MI:** large trigger E in Castor --> high particle multiplicities in central region
- **Triggering on CASTOR calorimeter enhances differences between various UE tunes**

Charged particle multiplicities (E_{part}>1GeV) in Pythia:

$E_{CASTOR} = \sum E_{part}$, $5.2 < \eta_{part} < 6.6$



[Z.Rurikova, HERA/LHC, May08]

Conclusions

- LHC ready to go with the standard reference MB and UE measurements relying on soft track reconstruction
  - New ideas, synergies with the Tevatron measurements in ongoing w/s
- Tevatron keeps providing progress/refinements
  - Rich set of particle level observables (directly comparable with the predictions of the QCD models)
  - New measurements (UE in Drell-Yan, MB Correlations)
  - Recent progress also from HERA (see backup slides)
- Progress of the MPI models
  - "New" MPI model in Pythia (comparisons with data needed)
  - MPI now in most of the new reference MCs: Pythia 8, Herwig++, Sherpa.
  - New ideas: dynamical structure of the hadrons, connection to diffraction
- LHC: TH progress & generator level studies prepare the ground for a uniform description of high P_T and low P_T MPIs
  - Same sign W, 3jet+γ, mini-jets, long distance correlations, connection to diffraction (i.e. hard factorization breaking, survival of rapidity gaps)

Credits:

Filippo Ambroglini,
Manuel Bähr,
Florian Bechtel,
Jon Butterworth,
Livio Fanò,
Rick Field,
David Hofman,
Lluis Marti,
Arthur Moraes,
Klaus Rabbertz,
Zuzana Rurikova,
Ferenc Siklér,
Torbjörn Sjöstrand,
Daniele Treleani,

etc…

Backup

Pythia Tunes

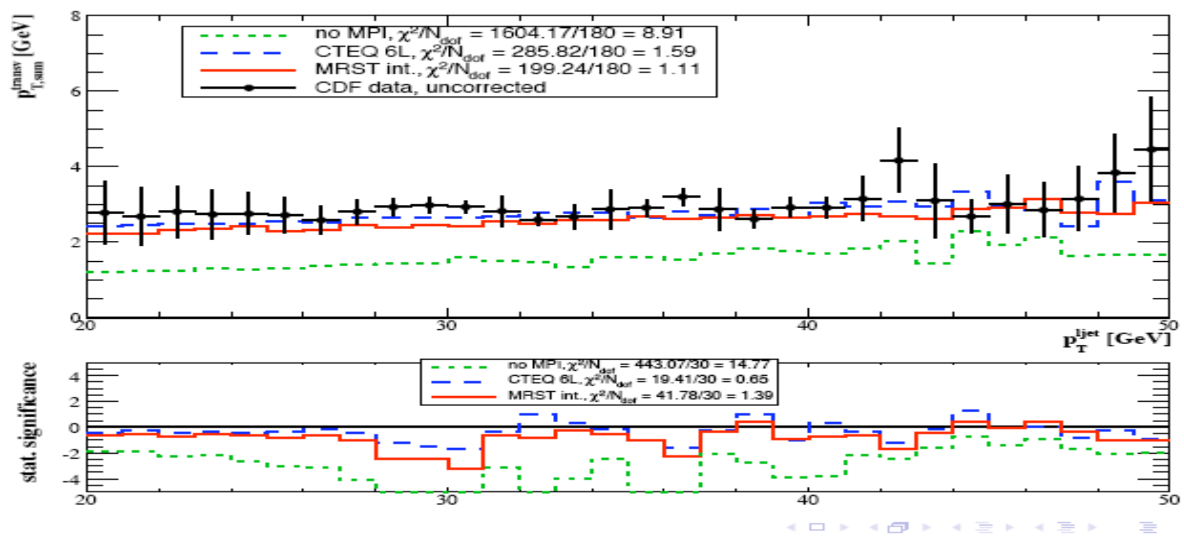
Parameter (PYTHIA v.6412+)	A	ATLAS	DW	DWT	S0
UE model MSTP(81)	1	1	1	1	21
UE infrared regularisation scale PARP(82)	2.0	1.8	1.9	1.9409	1.85
UE scaling power with $\sqrt{s}$ PARP(90)	0.25	0.16	0.25	0.16	0.16
UE hadron transverse mass distribution MSTP(82)	4	4	4	4	5
UE parameter 1 PARP(83)	0.5	0.5	0.5	0.5	1.6
UE parameter 2 PARP(84)	0.4	0.5	0.4	0.4	n/a
UE total gg fraction PARP(86)	0.95	0.66	1.0	1.0	n/a
ISR infrared cutoff PARP(62)	1.0	1.0	1.25	1.25	(= PARP(82))
ISR renormalisation scale prefactor PARP(64)	1.0	1.0	0.2	0.2	1.0
ISR Q^2_{max} factor PARP(67)	4.0	1.0	2.5	2.5	n/a
ISR infrared regularisation scheme MSTP(70)	n/a	n/a	n/a	n/a	2
ISR FSR off ISR scheme MSTP(72)	n/a	n/a	n/a	n/a	0
FSR model MSTJ(41)	2	2	2	2	$(p_T - ordered)$
FSR Λ_{QCD} PARJ(81)	0.29	0.29	0.29	0.29	0.14
BR colour scheme MSTP(89)	n/a	n/a	n/a	n/a	1
BR composite x enhancement factor PARP(79)	n/a	n/a	n/a	n/a	2
BR primordial k_T width $< \lvert k_T \rvert >$ PARP(91)	1.0	1.0	2.1	2.1	n/a
BR primordial k_T UV cutoff PARP(93)	5.0	5.0	15.0	15.0	5.0
CR model MSTP(95)	n/a	n/a	n/a	n/a	6
CR strength ξ_R PARP(78)	n/a	n/a	n/a	n/a	0.2
CR gg fraction (old model) PARP(85)	0.9	0.33	1.0	1.0	n/a

Table 3.1: PYTHIA parameters, divided into main categories: UE (underlying event), ISR (initial state radiation), FSR (final state radiation), BR (beam remnants), and CR (colour reconnections). The UE reference energy for all models is PARP(89)=1800GeV, and all dimensionful parameters are given in units of GeV.

PT0= PT0(Ecm/E0)$^{PARP(90)}$

New UE Model in Herwig++ [M.Bähr]

- Fully working model included from `Herwig++ 2.1` onwards. It allows for the simulation of multiple partonic interactions (MPI) to describe the underlying event (UE). Same functionality and physics than `JIMMY`.
- Overview available in *Herwig++ Physics and Manual* [arXiv:0803.0883]
- A more detailed description including tuning results: [arXiv:0803.3633, MB, S. Gieseke and M. H. Seymour]



Description of Tevatron UE truly satisfactory

Similar predictions with respect to the Pythia tunes at the LHC (constant cut-offs)

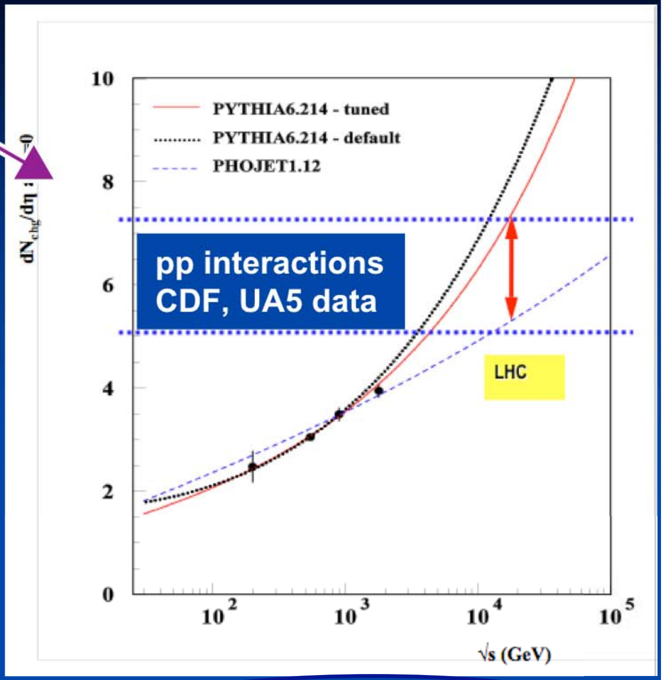
Soft interactions (minimum-bias) will be available in the next release.

Low-pT QCD - Minimum Bias - Trigger

[Livio Fano', ICHEP08]

$dN/d\eta_{\eta=0}$: **large uncertainty on LHC extrapolation**

The study of MB events depends on:
+ Constraining QCD models at 14 TeV
+ Calibrating detectors and main physics tools



MB is defined by the trigger - usually *Not Single Diffractive*

σ_{tot}	$= \sigma_{Elastic}$	$+ \sigma_{SD}$	$+ \sigma_{DD}$	$+ \sigma_{HardCore}$	
(14 TeV)	~20 mb	~15 mb	~10 mb	~55 mb	= ~100 mb

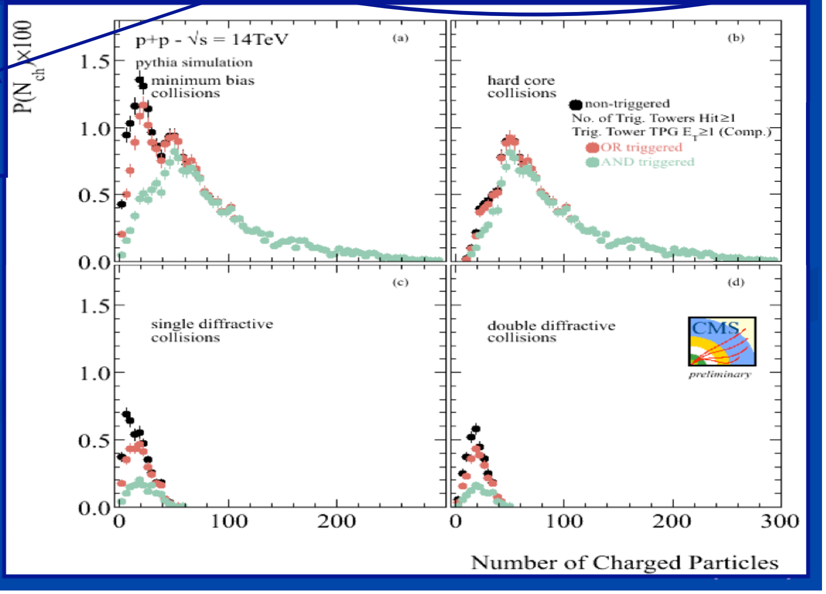
from Pythia (CMS tune)

Triggering

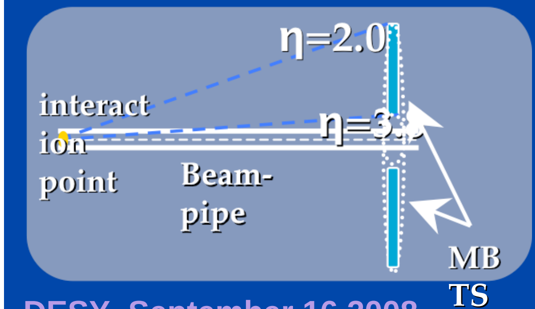
Issues:
Keep as much inelastic
Reject beam/halo,beam/gas, empty or pile-up events (low or high luminosity)

CMS - based on forward H-CAL towers

All events
+ OR -
+ AND -



ATLAS - MBTS



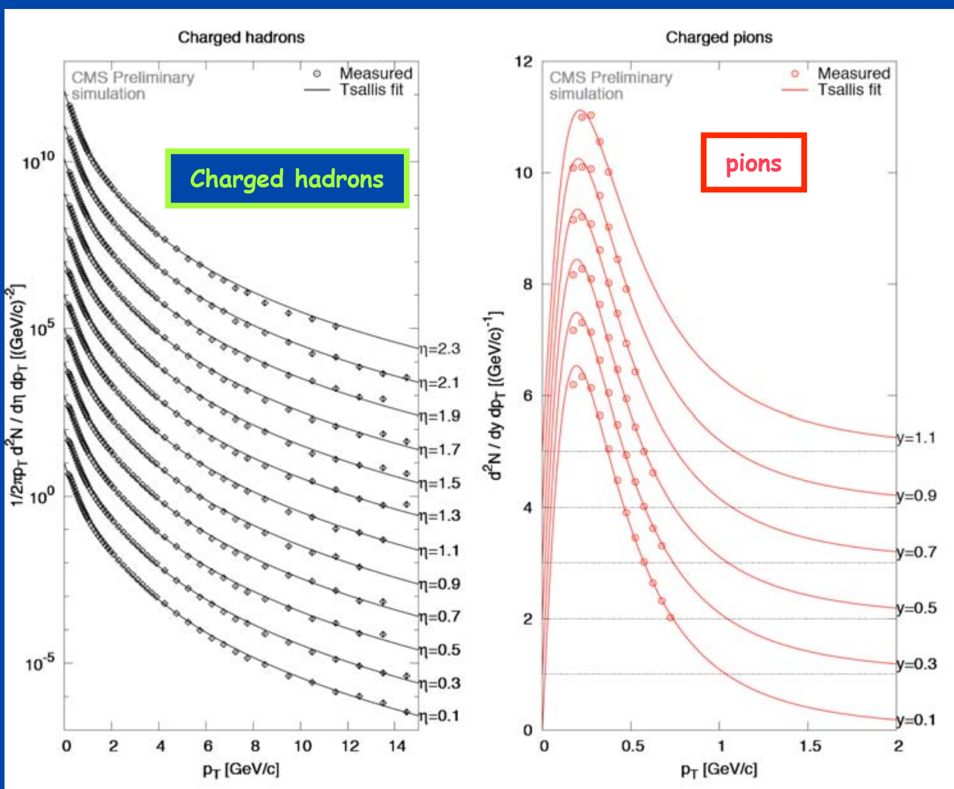
Accidental rate from noise must be suppressed to ~Hz, limited by trigger output-rate of 100Hz

MB: Charged hadron spectra at the LHC

CMS:
Tracklets:
Only pixel triplets
down to 75 MeV !

Systematic:
Trigger, feed-down,
geom. acceptance,
alg. efficiency

Diff. yields of identified $\pi^{\pm}$, $K^{\pm}$, $p/\bar{p}$ together with *Tsallis*-function fits
(inverse slope T = 0.2 GeV/c, high p_T exponent n = 7.2)

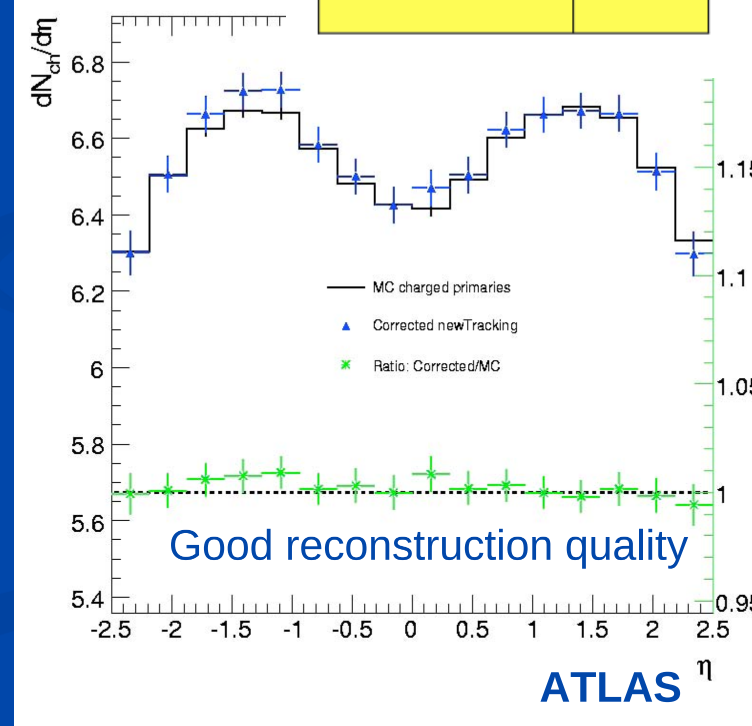


CMS Physics Analysis Summary QCD-07-001

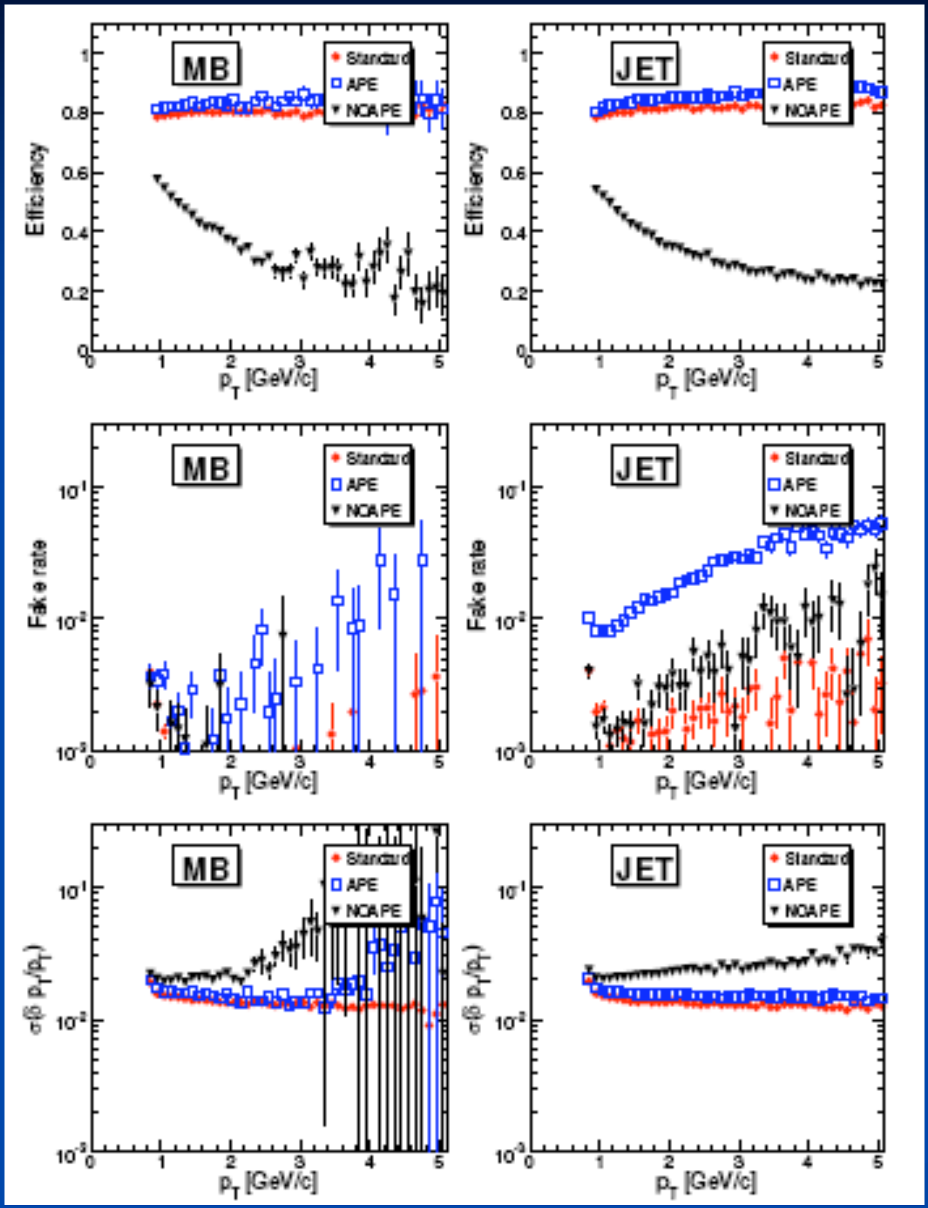
ATLAS
Track
Reco

Summary of systematic uncertainties

Track selection cuts	2%
Mis-estimate of secondaries	1.5%
Vertex reconstruction	0.1%
Mis-alignment	6%
Beam-gas & pile-up	1%
Particle composition	2%
Diffractive cross-sections	0.1%
Total:	**6.9%**



CMS Tracking performances



MB and Jet events

1 pb^{-1}

Efficiency and fake performances at the LHC start-up are recovered using APE (error to the hits taking into account alignment precision)

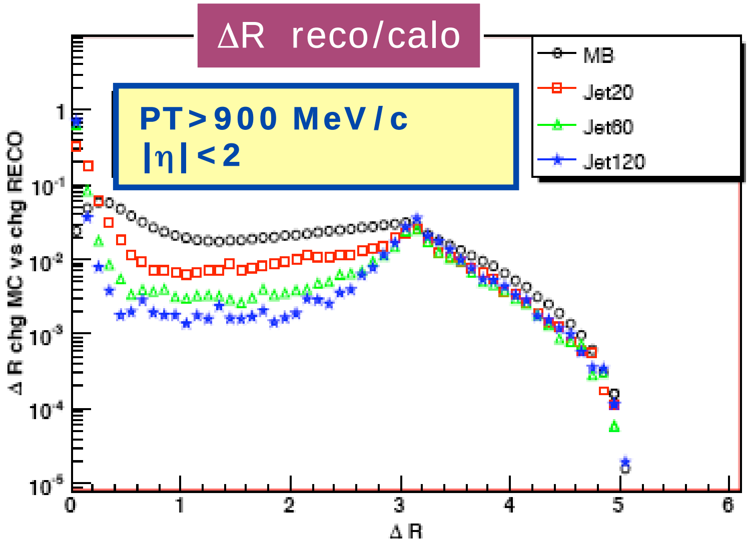
Ideal aligned detector
Misaligned + APE
Misaligned

The CMS tracking is optimized for P_T>900 MeV

Seeding and tracking from 500 MeV is also possible with sufficient high efficiency (>70%) and fakes under control (<2%)

Tracking from 500 MeV is used to enhance discriminative power of the UE observables in the transverse region

The Charged Jet



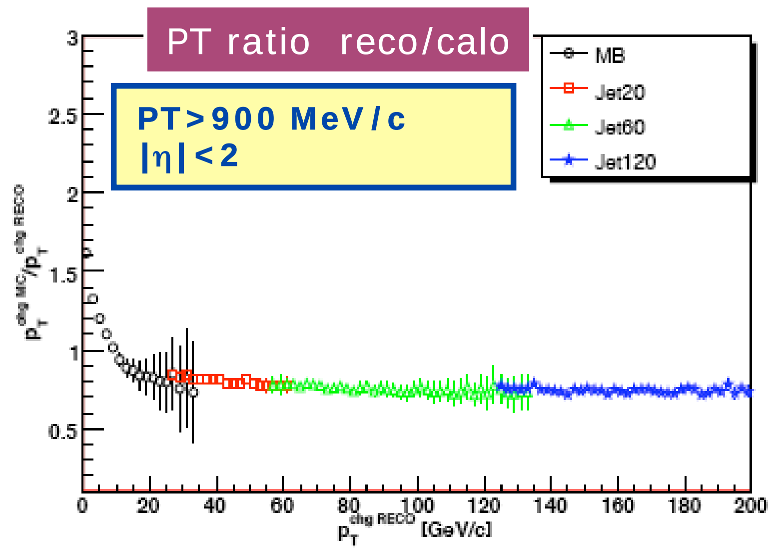


Figure 1: Charged Jet performances. *Left:* $\Delta R\,(=\sqrt{\Delta\phi+\Delta\eta})$ between the charged and the calorimetric leading jets. *Right:* charged jet response function $(P_T^{charged}/P_T^{calorimetric})$.

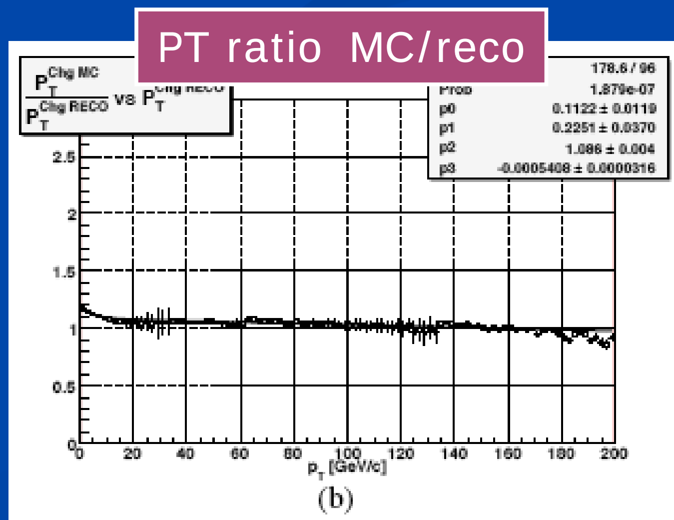
CMS Physics Analysis Summary QCD-07-003

Charged jet instead of calorimetric:

+ access to low PT region

+ intrinsically free from pile up

+ better control of systematic effects at startup

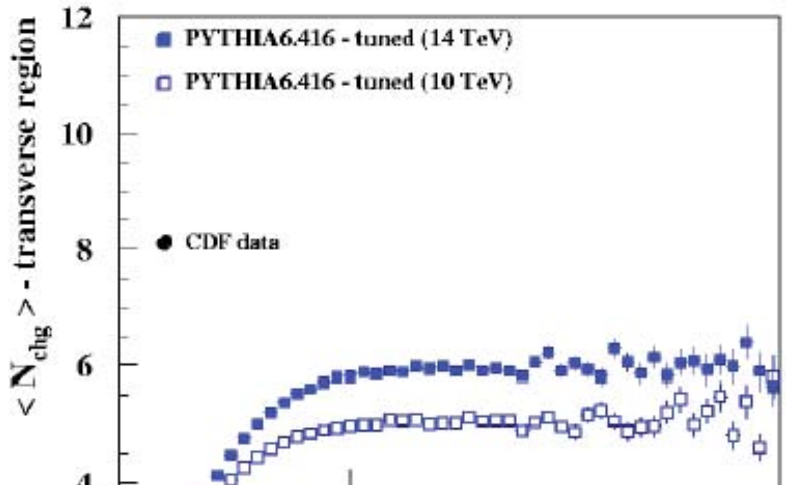


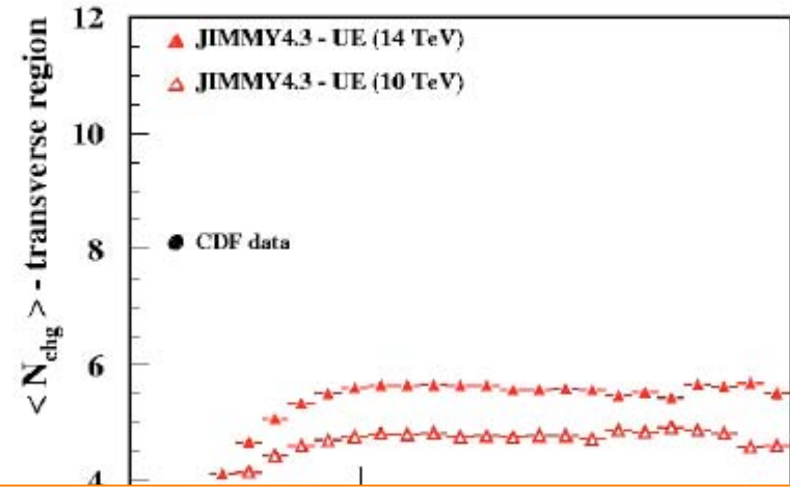
MC/RECO energy calibration of the leading charged jet

LHC Predictions: describing the region transverse to the leading jet

University of Glasgow

Jimmy Tune:
Charged Multiplicity OK, Softer PT spectrum





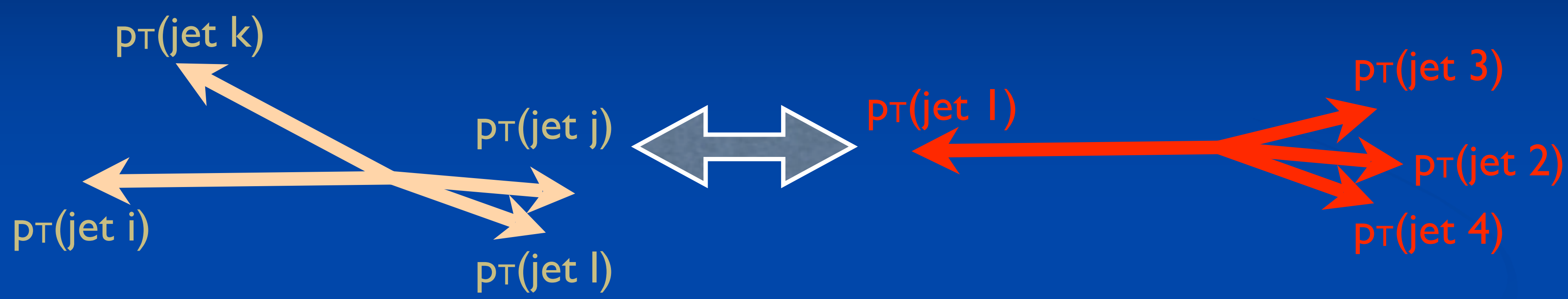
- PYTHIA6.416 (CTEQ6lI) parameters tuned to the UE:
- Results are comparable to those obtained with previous tunings.
- $<p_T>/N_{chg}$ has improved (requiring shorter strings and more connections to the hard scatter system).

mstp(81)=21
mstp(82)=4
mstp(84)=1
mstp(85)=1
mstp(86)=2
mstp(87)=4
mstp(88)=1
mstp(89)=1
mstp(90)=0
mstp(95)=2

PARP(78)=0.3
PARP(80)=0.1
PARP(82)=2.1
PARP(83)=0.8
PARP(84)=0.7
PARP(89)=1800
PARP(90)=0.16

Double Parton Scattering in 4jet topologies

Disentangle double-parton-scattering from bremsstrahlung



• No correlation (DPS) versus strong correlation **Make use of different correlations between jet pairs**

AFS solution:

• Study $\Delta\varphi$ between $\mathbf{p_{T1} - p_{T2}}$ and $\mathbf{p_{T3} - p_{T4}}$

CDF solution:

• Study $\Delta\varphi$ between $\mathbf{p_{T1} + p_{T2}}$ and $\mathbf{p_{T3} + p_{T4}}$ (CDF nomenclature: ΔS)

Double Parton Scattering in γ+3jet topologies

Generator-level analysis

- Combine γ (MC truth) with 3 jets (Midpoint-Cone, R=0.7) where $\Delta R_{ij} > 0.8$
- assign jets following UA2/CDF method (minimize imbalance)

pp → γ j + X

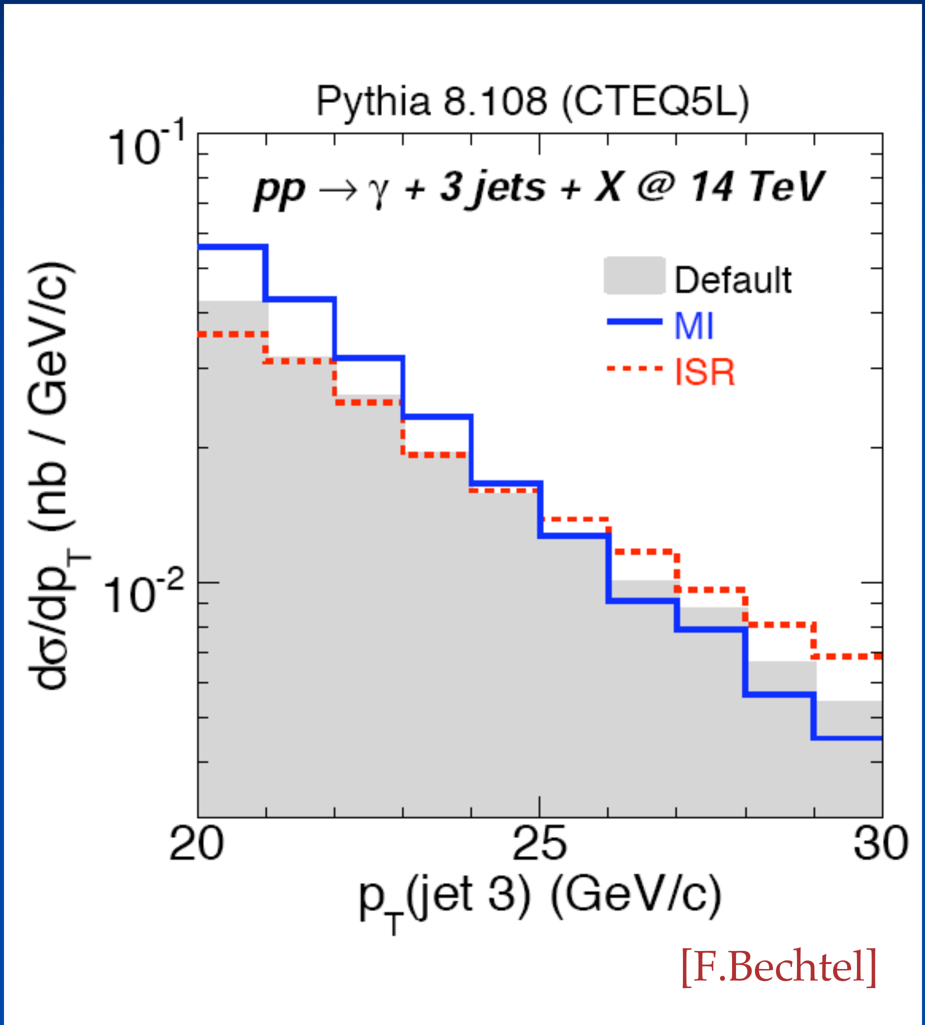
Pythia 6.413 $\hat{p}_T > 20$ GeV/c
- DWT (CMS default)
- S0 (→ *colour reconnection*)

Pythia 8.1 $\hat{p}_T > 20$ GeV/c
- default (physics ~ Pythia 6.4 S0)
- multiple parton-parton interactions switched off

+ simulate two hard jets (in addition to γ j)

Herwig 6.510 $\hat{p}_T > 20$ GeV/c
- soft underlying event
- Jimmy 4.2

LHC: Prediction for the 3rd jet PT in 3jet + γ events MPI vs radiation: generator level results

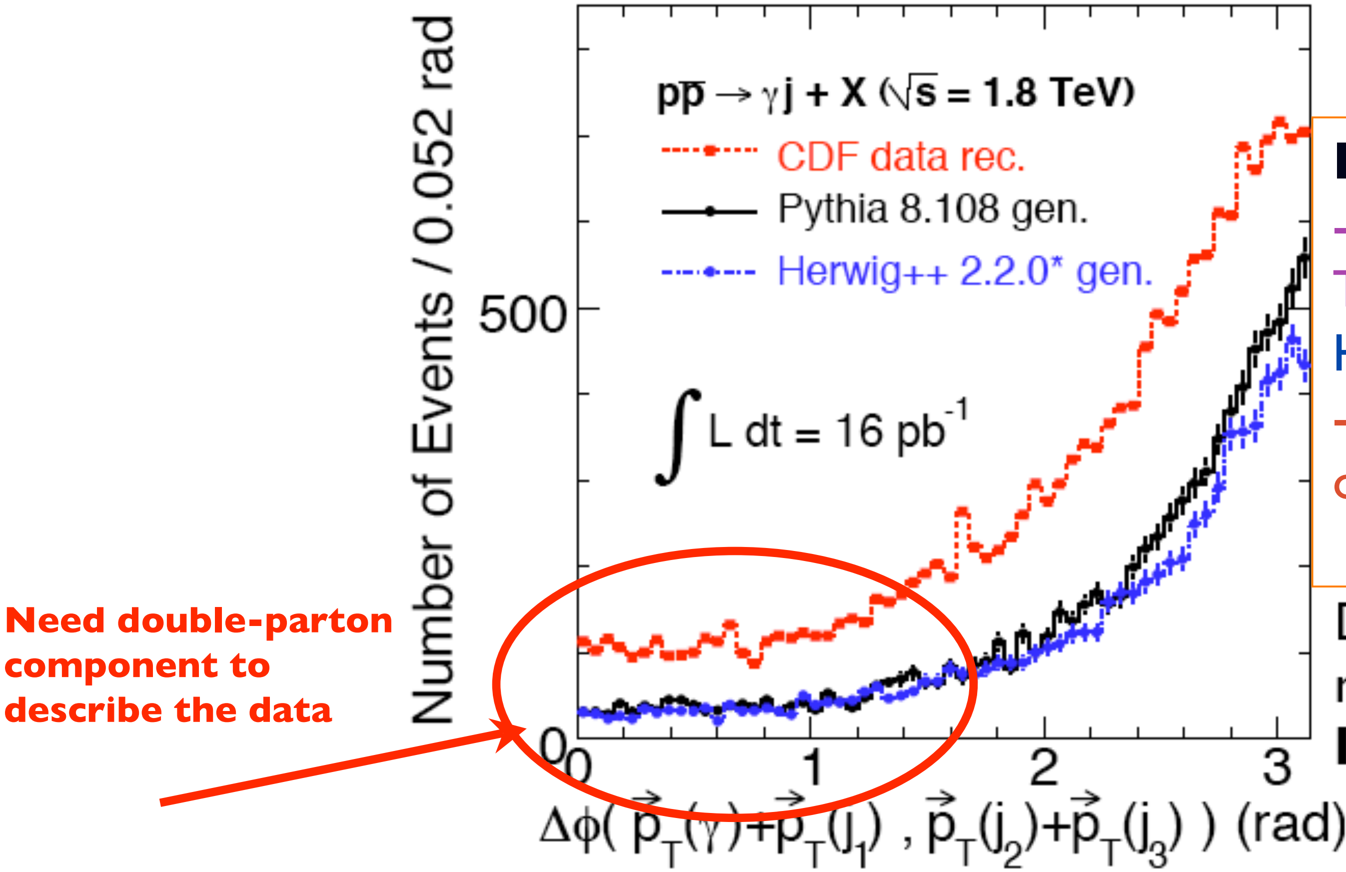


Comparison between the reference selection cuts: LHC vs Tevatron

- **Photon:**
  - $|\eta| < 1.1$ (CMS: $|\eta| < 2.5$)
  - $E_T > 16$ GeV (CMS HLT thresholds: $E_T > 10, \ldots, 40$ GeV)
- **Jets:**
  - $|\eta| < 4.2$ (CMS: $|\eta| < 5$)
  - $E_T > 5$ GeV (CMS: $E_T > 30$ GeV)
  - ~~exactly~~ **at least** three jets
  - ~~two lowest E_T-jets: $E_T < 7$ GeV~~

→ "Performance of Jet Reconstruction at CMS" (C. Sander)

Model comparison @ TVT



Pythia 8.1
- physics ~ Pythia 6.4
Tune S0

Herwig++ 2.2
- MPI along the lines of Jimmy

Distributions normalized to **luminosity**

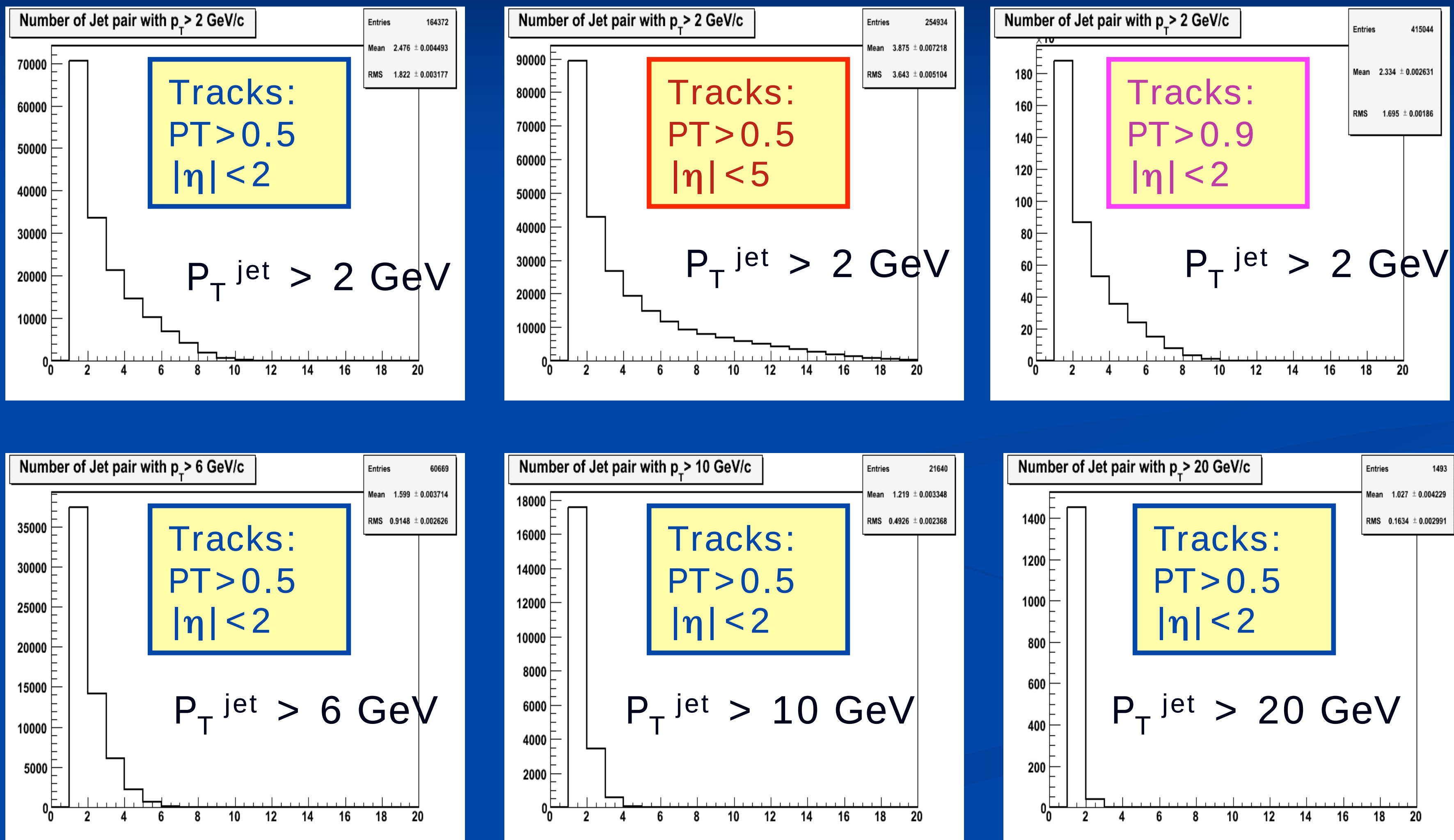
→ Pythia and Herwig predictions for **$p\bar{p} \to \gamma j + X$** agree

→ Next: Simulate **$p\bar{p} \to jj + X$** to compare with CDF rates

LHC: Quoting MPIs with paired MiniJets

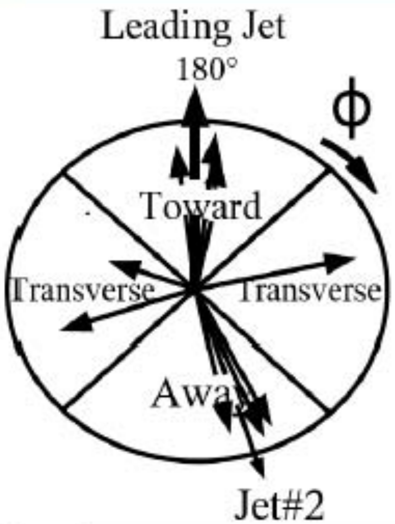
Generator Level Studies
with Pythia 6.4x

N = Number of jet pairs for different η, P_T^{track}, $P_T^{\ jet}$

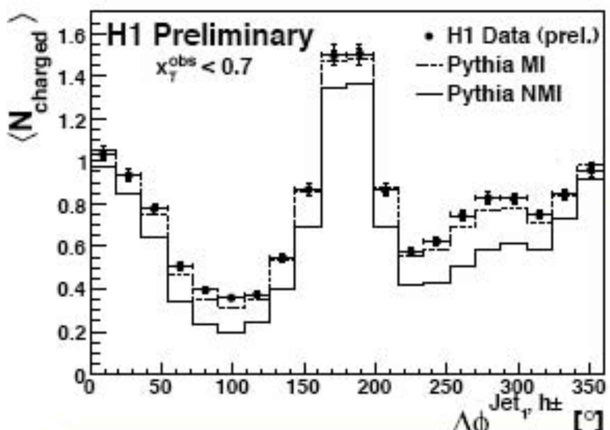


N deeply depends on PT-jet and acceptance

Study of multi-parton interactions using dijet photoproduction



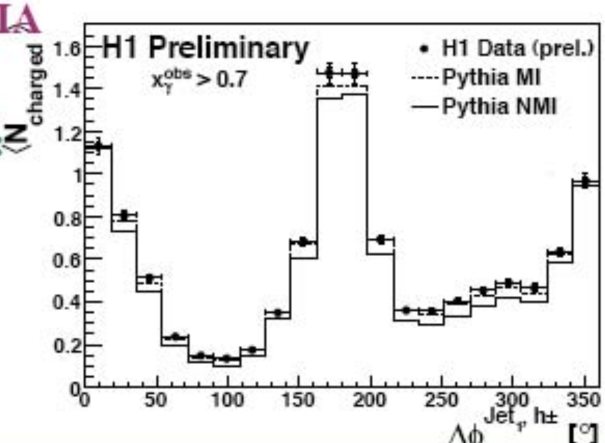
- Study of multi-parton interactions in photoproduction by measuring the charged-particle multiplicity in dijet events $P_T^{jet} > 5$ GeV and $-1.5 < \eta_{lab}^{jet} < 1.5$
- Kinematic region: $Q^2 < 0.01$ GeV^2, $0.3 < y < 0.65$
- Jets are reconstructed using the k_T-cluster algorithm in the LAB frame: leading jet at $\phi = 180°$
- Measurement of $\langle N_{charged} \rangle$ in four regions: "Toward", "Away", "High-activity" and "Low-activity"



Comparison to PYTHIA with/without MI in two regions in x_γ^{obs}:

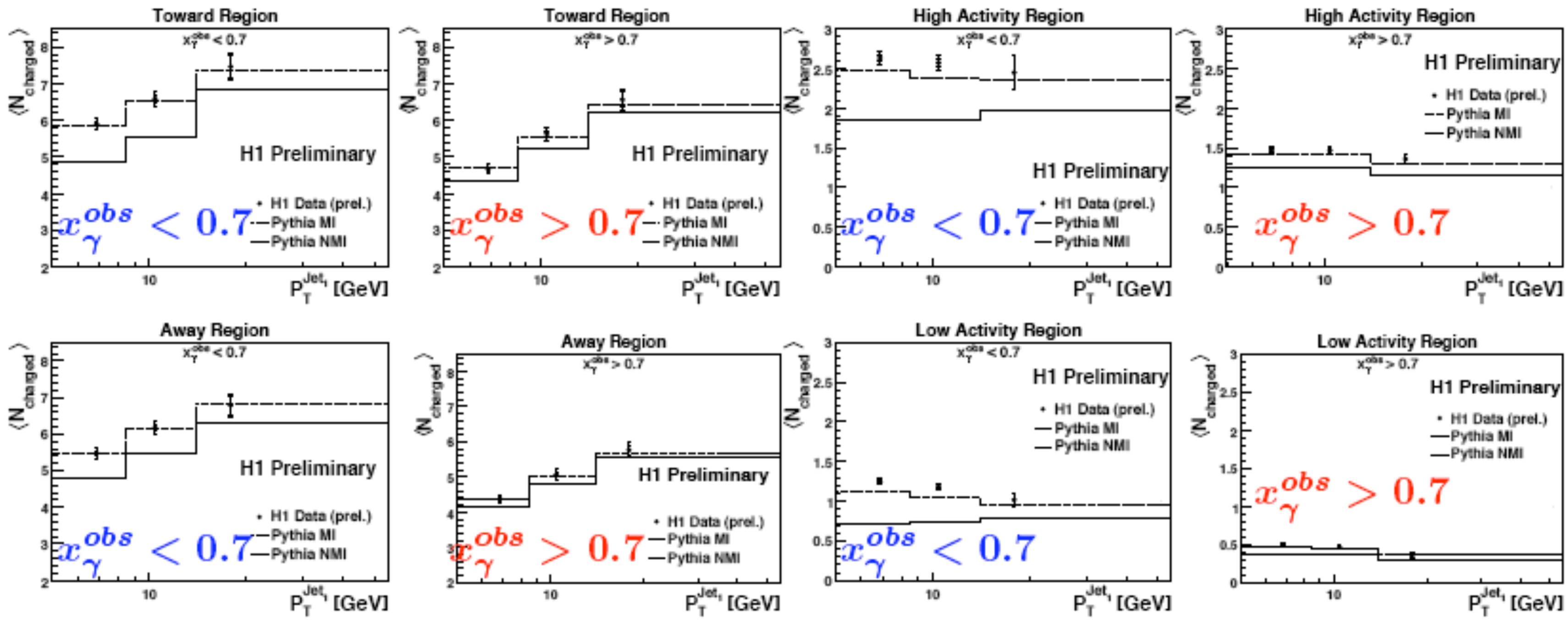
← resolved-photon $x_\gamma^{obs} < 0.7$

direct-photon → $x_\gamma^{obs} > 0.7$



See also [L. Marti, HERA/LHC - May08]

Study of multi-parton interactions using dijet photoproduction



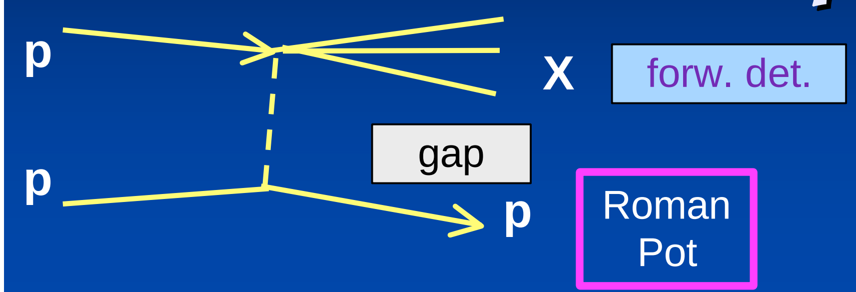
- Direct-photon: reasonably well described by PYTHIA with parton showers and no MI
- Resolved-photon: excess observed in the data with respect to PYTHIA without MI

$\longrightarrow$ inclusion of multi-parton interactions describes the data well

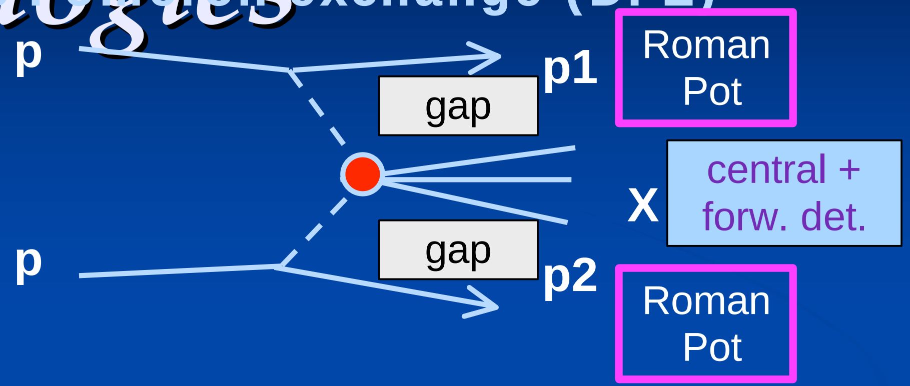
See also [L. Marti, HERA/LHC - May08]

UE in Hard Diffractive Topologies

Single diffraction (SD)



Double Pomeron exchange (DPE)



Scale given by **X** → Study UE(M_X)

MPI in diffractive events are strongly suppressed

The **Beam Remnant** component is also strongly suppressed
(at least in the hemispheres with surviving protons)

→ **Comparing with corresponding not diffractive topologies may allow to better disentangle the different UE components**

→ Optimize LRG definition

Interplays Between Multiple Interactions and Hard Diffraction at the LHC

- Handle on soft multiple parton-parton interactions in hard diffractive events
  - Breaking of factorization in hard diffraction
    - Survival probability of protons and LRGs ~ $e^{-<N_{int}>}$

Where $< N_{int} > = \sigma_{parton\text{-}parton} / \sigma_{inel\ proton\text{-}proton}$

[R.Field]	$\sigma_{parton\text{-}parton}$ at 1.96 TeV	$\sigma_{parton\text{-}parton}$ at 14 TeV
Tune A	309.7 mb	484.0 mb
Tune DW	351.7 mb	549.2 mb
Tune DWT	351.7 mb	829.1 mb

~ 80 mb

Our goal would be to give a more “concrete” meaning to the $\sigma_{parton\text{-}parton}$ (P_T) numbers for example through the mini-jet pair counting method

- On the other hand there’s a well consolidated experimental methodology to measure hard diffraction from data
  - Extrapolate the dPDFs measured at HERA and Tevatron and compare the resulting cross section predictions for the LHC with the cross sections measured at the LHC
  - Measure F_2^D, via e.g. dijet production, in SD and DPE and compare