Matrix Element/Monte Carlo tuning Workshop
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On Minimum Bias Events

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- Introduction
- Minimum bias data
- Comparison with PYTHIA
  - Charge particles density
  - Average p_T vs multiplicity
- First look at DØ fiber tracker data
- Summary

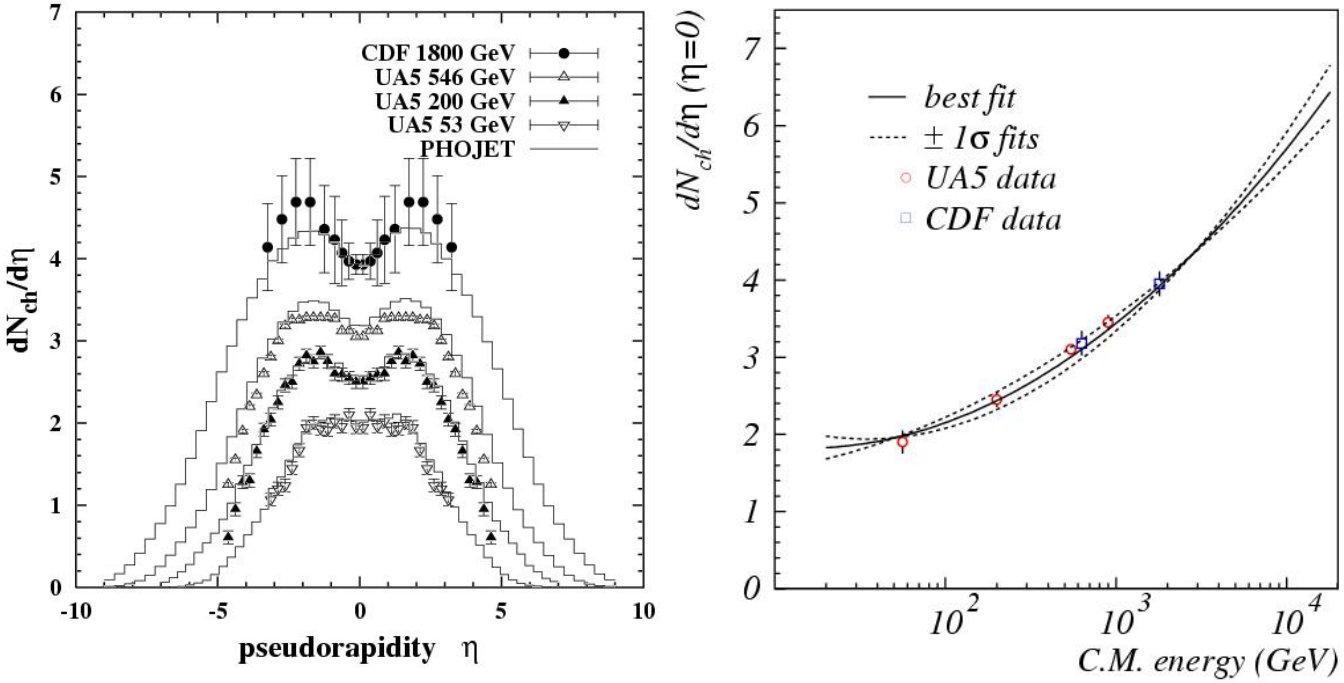
Introduction

- There is no clear success in describing soft processes in hadronic collisions
  - This is especially true for general purpose MC event generators
- Essential for proper simulation of multiple interactions as the instantaneous lumi increases
- Closely related issue is to understand the underlying event structure in hard scattering
  - Multiple parton interactions
  - Beam remnants
  - Process dependence
- Impacts, e.g., precision measurements with jets
  - Top mass, Higgs searches, etc.
- There are attempts to address these issues with, e.g., PYTHIA MC event generator
  - Has many parameters for tuning
- Goal of the current analysis is to confront various PYTHIA tunings to data
  - Eventually will choose or devise one

Minimum Bias data

- CDF's measurements, Phys.Rev. D41 (1990) 2330
- Minimum Bias (MB) events selection
  - Trigger on ≥1 hit in each set of BBC, $3.2<|\eta|<5.9$
  - Require ≥4 tracks in VTPC, $|\eta|<5.9$, or ≥2 track vertex be within 16 cm measured by BBC TOF
- Unfold for acceptance/inefficiencies/etc.

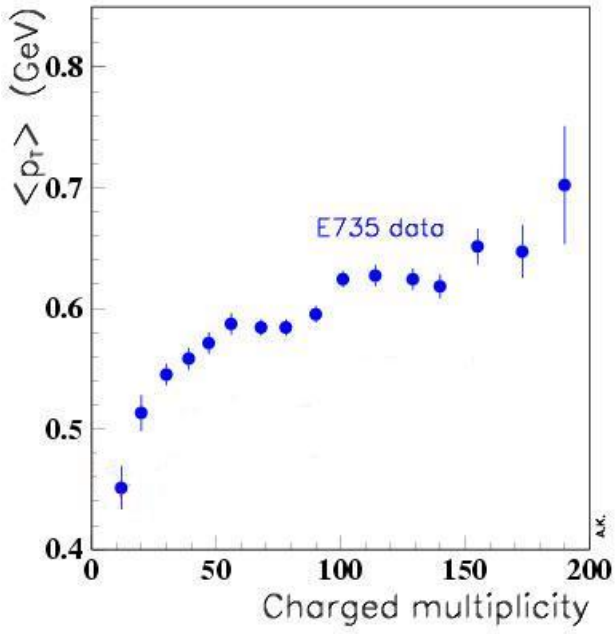
Charged particles density at various energies



- Observe $dN_{ch}/d\eta\,|_{\eta=0} \approx 4$ at sqrt(s)=1.8 TeV
- Density at $\eta \sim 0$ increases like $\ln^2(s)$

E735 data

- Average p_T vs charged particles multiplicity at 1.8 TeV, T.Alexopoulos et al., PRL 60 (1988) 1622
- MB trigger
  - Require ≥1 hit in both, up- and downstream hodoscopes covering $3<|\eta|<4.5$
- High multipl. evts enhanced w/ on-line trigger
- Average p_T in $0.15<p_T<3$ GeV and $|\eta|<4.5$
- Correct for overall acceptance/conversions/etc.



- Did not receive much attention in literature?

PYTHIA soft and hard QCD processes

- Parameterizations for soft processes include

PYTHIA #	Process
91	Elastic scattering
92, 93	Single diffraction
94	Double diffraction
95	Low-p_T production

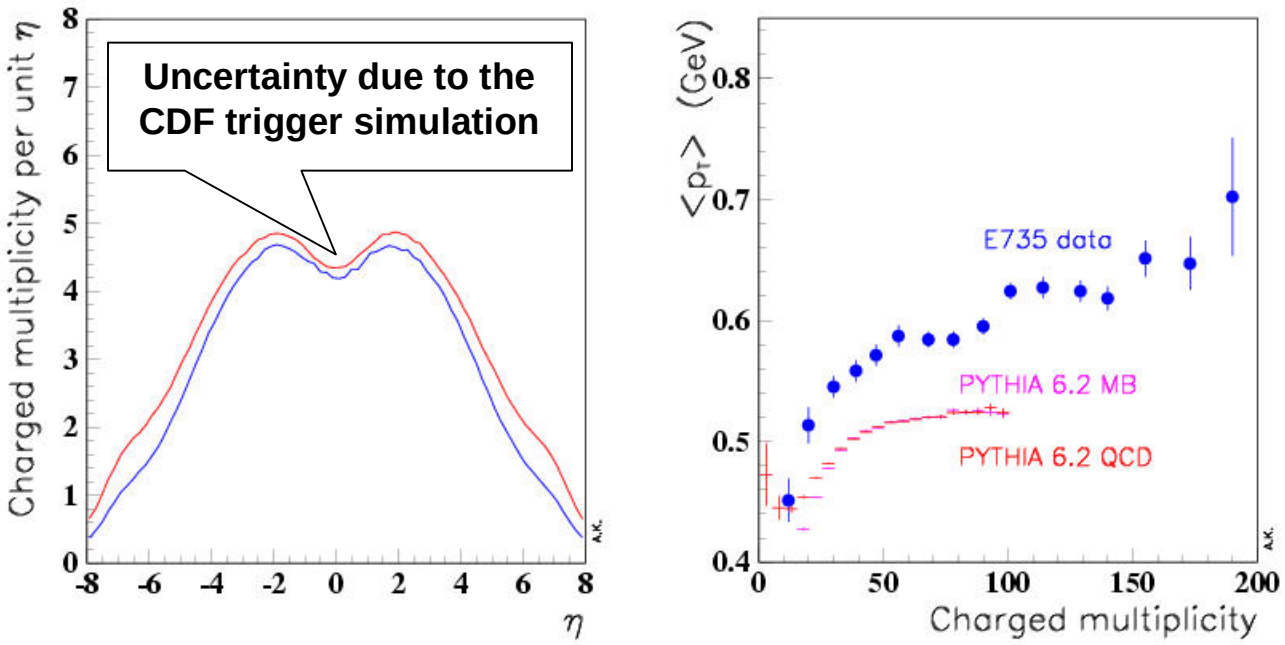
- DØ MB = sum of 92, 93, 94 and 95
  - Gives cross-section of ~60 mb
- Hard QCD procs. with massless MEs (MSEL=1)

PYTHIA #	Process
11	$q_i\ q_j \rightarrow q_i\ q_j$
12	$q_i\ \bar{q}_i \rightarrow q_k\ q_k$
13	$q_i\ \bar{q}_i \rightarrow g\ g$
28	$q_i\ g \rightarrow q_i\ g$
53	$g\ g \rightarrow q_k\ q_k$
68	$g\ g \rightarrow g\ g$
(95	Low-p_T production)

- Cross-section diverges $\Rightarrow$ a p_T cut is required
  - $p_T \gtrsim 2$ GeV gives $\sigma \approx 40$ mb
- Compare these two PYTHIA options with data

PYTHIA 6.2 default settings

- Comparison with the Tevatron data



- Default PYTHIA 6.2 setting slightly overestimates the particles density
  - Can't attribute, e.g., to details of the CDF MB trigger simulation
- Average p_T vs charged particles multiplicity is not reproduced
  - At large multiplicities (≳25) both PYTHIA processes, soft and hard, yield similar results

Various settings of PYTHIA

- CDF tuning 1 to $b\bar{b}$ data, PR D59 (1999) 032001
  - PYTHIA 5.7, MSEL=1, CTEQ2L structure functions

Parameter	Default	Tuned	Comment
MSTP(82)	1	3	Model of multiple interactions
PARP(85)	0.33	1.0	Fraction of color-connected *gg* multiple interactions
PARP(86)	0.66	1.0	Total fraction of *gg* multiple interactions
MSTP(33)	No	Yes	Multiply cross-section by PARP(31)
PARP(31)	1.50	1.69	Increase cross-section by 69%
PARJ(21)	0.36	0.613	σ fragmentation p_T
MSTJ(11)	4	3	Use Peterson fragmentation for *b, c*
PARJ(55)	0.005	0.0063	ε_b

- CDF tuning 2 to di-jet data, R.Field, D.Stuart, R.Haas
  - PYTHIA 6.1, MSEL=1, CTEQ4L str. functions

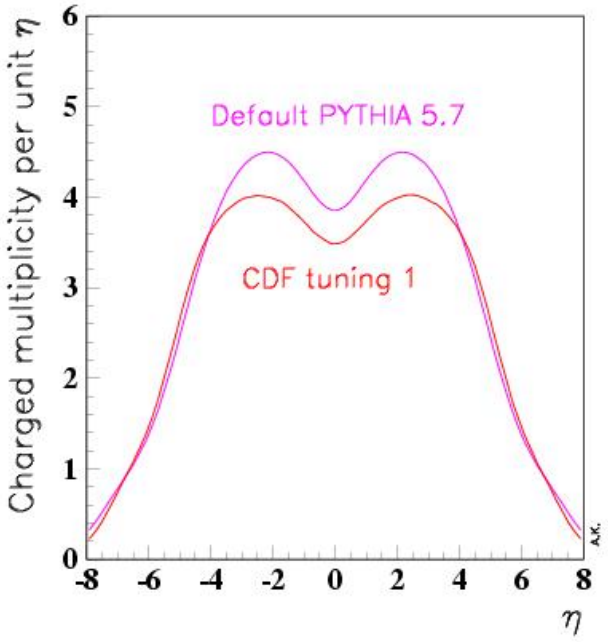
    MSTP(82) = 4

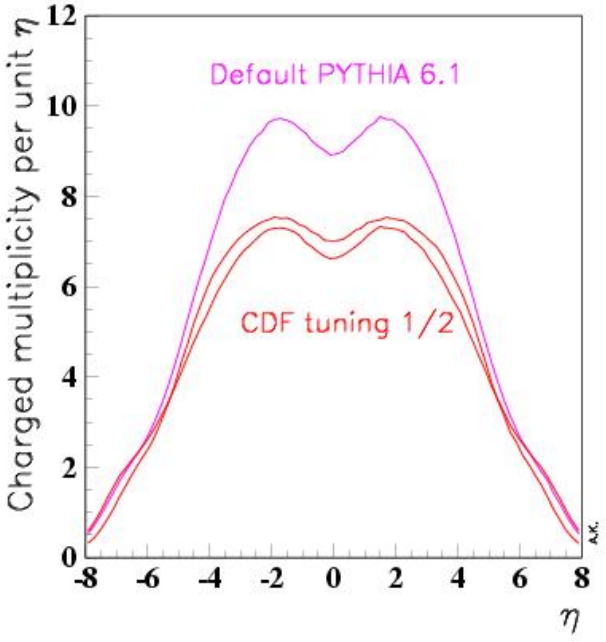
    PARP(82) = 2.4 GeV (regularization scale of the p_T spectrum for multiple interactions)
  - The rest is default
  - **This set is currently used in DØ**

- NB: tunings are not necessarily valid across various versions and depend on PDF set, default cuts, etc.

Hard QCD processes (1)

- Charged particles density

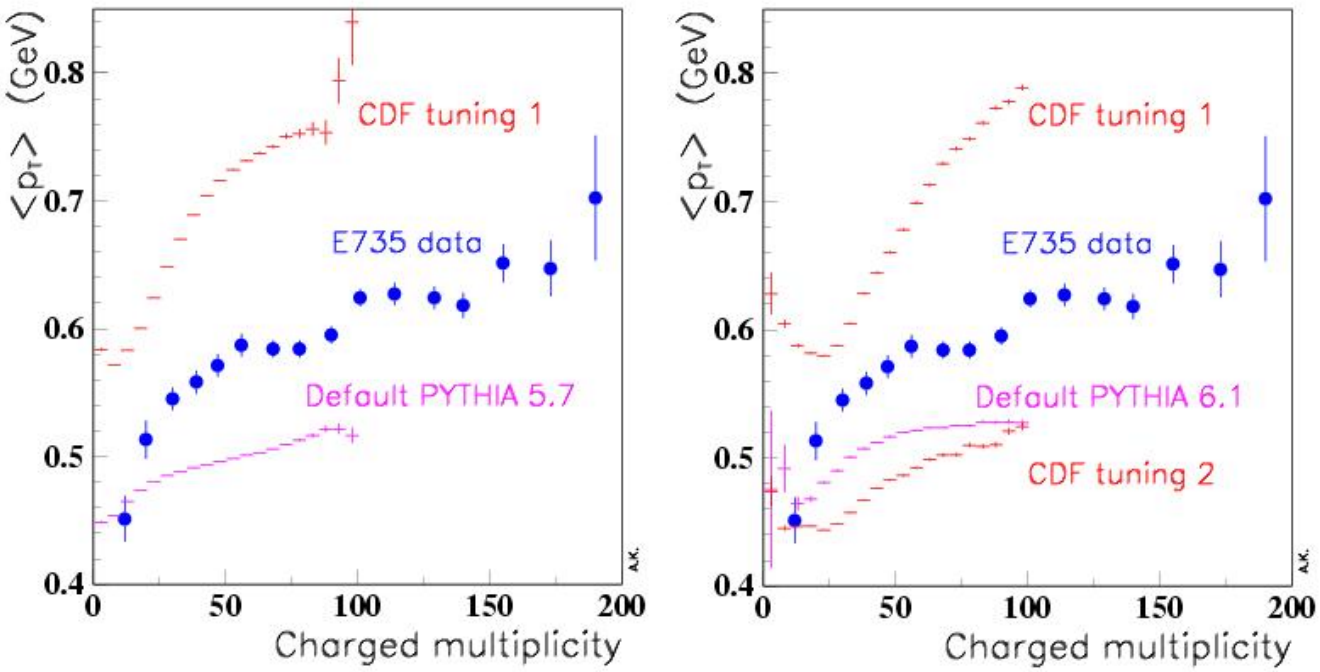




- PYTHIA 5.7, default or CDF tuning 1, reproduce the data
- PYTHIA 6.1 overestimate the particles density

Hard QCD processes (2)

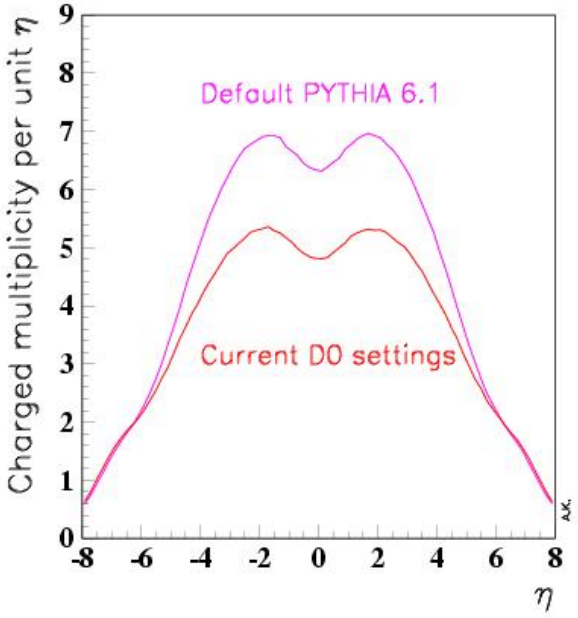
- Average p_T vs charged particles multiplicity

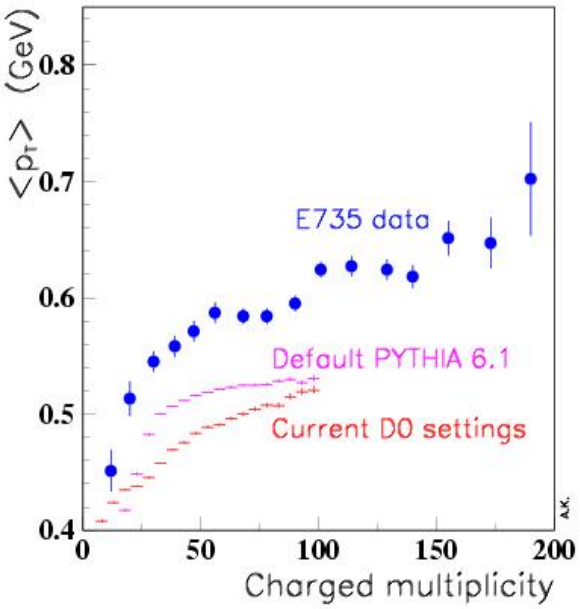


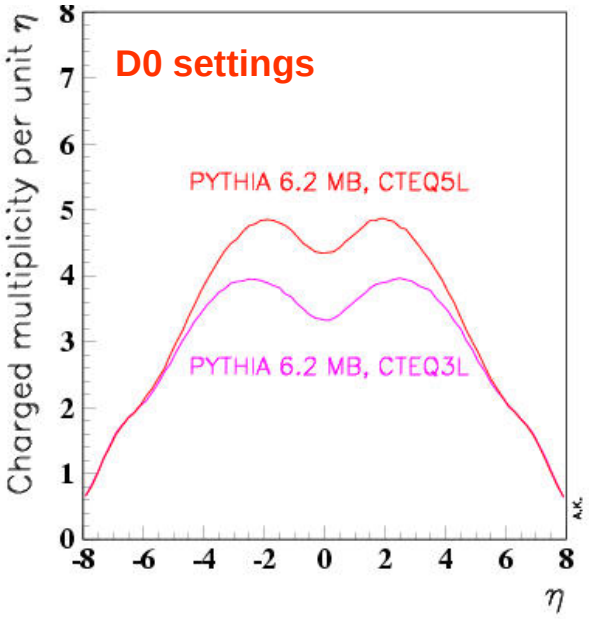
- None of the PYTHIA settings describe the data

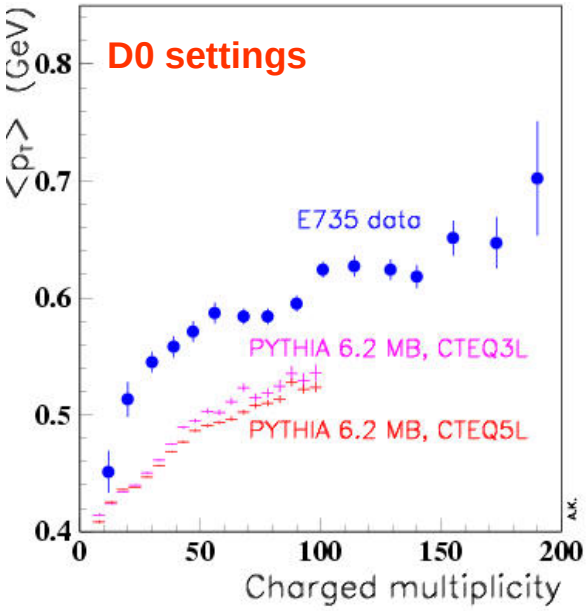
Soft processes

- Comparison of PYTHIA soft processes with data









- None of the PYTHIA settings reproduce the data

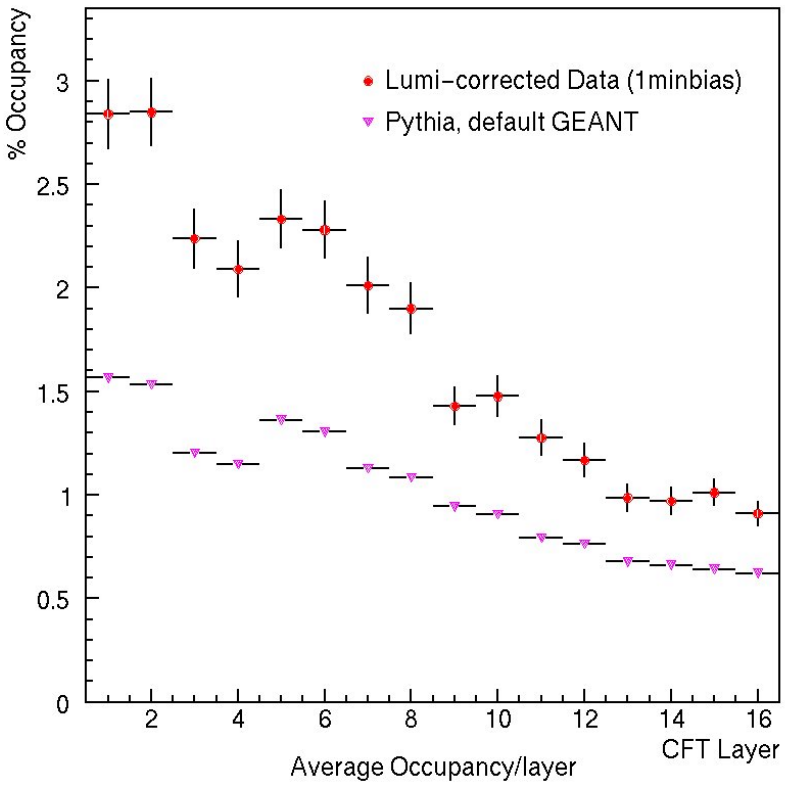
Data/MC comparison for DØ tracker (1)

- Occupancy for a single MB event determined by appropriate subtraction of
  - "Zero-bias" triggers, corrected for physics occupancy (account for detector noise)

  from
  - "Min-bias" triggers, corrected for multiple interactions to 1 minimum bias occupancy
- PYTHIA 6.1 events subjected to the same trigger constraints as data, particles in both ends of the luminosity monitor, $2.7<|\eta|<4.4$
  - Not "unfolded"
- Overall tracker occupancy in MC depends on GEANT thresholds for δ-ray generation and propagation
  - some 30% or so uncertainty there
- Tracker simulation includes no noise, detector inefficiencies

Data/MC comparison for DØ tracker (2)

- Hit occupancies at various radii, ~20 to 52 cm
  - MC disagrees with data



- Occupancy depends on details of simulation, however, these do not change the shape of the distribution
  - still disagreement at low radii = low p_T
  - no way to “scale up” MC to match data
- More studies needed, e.g., with charged tracks

Summary

- PYTHIA reproduces the charged particles density in the central rapidity region quite satisfactorily

- However, the Tevatron data on average p_T vs multiplicity is not reproduced by soft or hard QCD processes from PYTHIA

- Dedicated studies/tunings are necessary to describe the data and the current Workshop is probably the right forum for achieving this goal