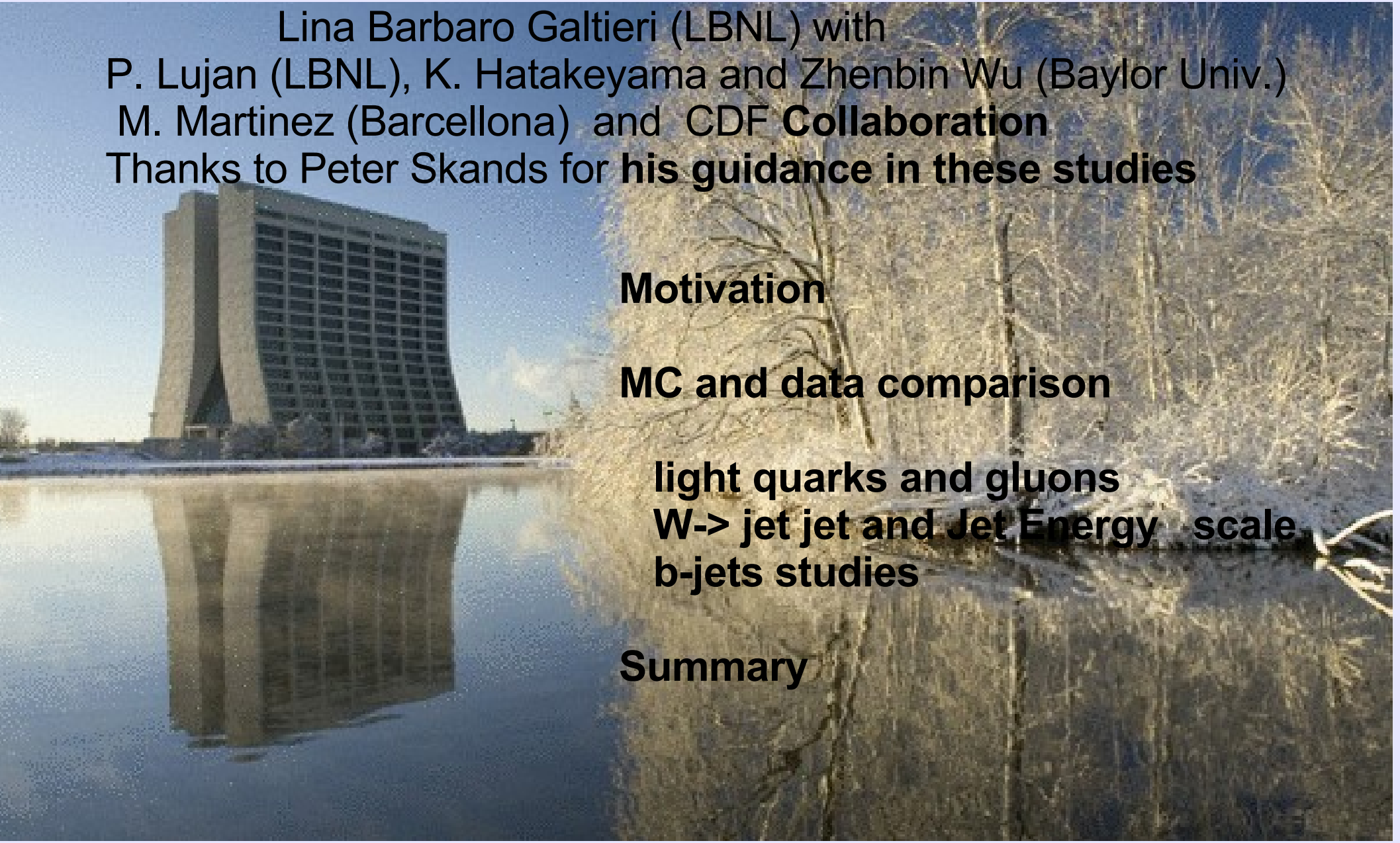
# STUDY of PYTHIA TUNES with CDF JET SHAPES

Lina Barbaro Galtieri (LBNL) with
P. Lujan (LBNL), K. Hatakeyama and Zhenbin Wu (Baylor Univ.)
M. Martinez (Barcellona) and CDF **Collaboration**
Thanks to Peter Skands for **his guidance in these studies**



**Motivation**

**MC and data comparison**

**light quarks and gluons**
**W-> jet jet and Jet Energy scale**
**b-jets studies**

**Summary**

# Motivation of this study: Systematic uncertainties from MC

Precision measurements which have low statistical error, are dominated by systematic uncertainties with large contributions from Monte Carlo modeling. This is the case for the top mass measurement at the Tevatron

.

World Average

$M_{top}$=173.1± 0.6(stat) ± 1.1(syst) = 173.1± 1.3 GeV

New CDF result (MTM, to be included in the world average)

$M_{top}$=172.8± 0.7(stat) ± 0.7 (MC sys) ± 0.8 (syst) = 172.8±1.3 GeV

Statistical uncertainties can be reduced with more data

Other systematics come from detector effects, background uncertainties, analysis methodology

MC systematics: this is the subject of this workshop

# PYTHIA V6.4.20 versus V6.2.16

CDF analyses (including the top mass analysis) are done mostly using PYTHIA V6.2.16

Changes in V6.4.20 with respect to V6.2.16

- Parton shower uses $P_T$ ordering rather then mass ordering
- Multiparton (MPI) interactions are part of the parton shower
- ISR and FSR also use $P_T$ ordering algorithm
- New model for beam renmants, including baryon junctions
- Model interleaves MPI process with ISR evolution off the hard process
- Color reconnection added with an "annealing model" by M. Sandhoff and P. Skands

# Compare PYTHIA V6.2 and V 6.4

All of the above changes are expected to have an effect on the top mass measurement of the order of 1 GeV. See references below

P. Skands and D. Wicke hep-ph/0703081v1 (March 2007)
D. Wicke and P. Skands hep-ph/0807.3248 v1 (July 2008)
D. Wicke and P. Skands TOP08 (May 2008)

- Color Reconnection (CR) expected to contribute to top mass shift
- Jet Shapes expected to be different
- Tunes being investigated (used for the top mass analysis)

A-pro : Rick Field's tune A (just submitted to PRD) retuned with the "professor" tools

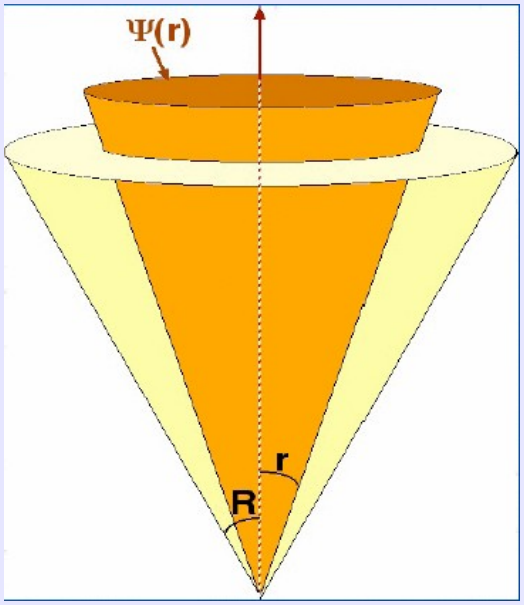
ACR-pro : as above with color reconnection added

Perugia0 : includes the new parton shower+ CR Peter Skands tune 320, includes TeV min bias info +$P_T(Z)$

NOCR : as Perugia0 without CR

# JET Shapes Studies (1)

CDF has published jet shapes, obtained in pp collision at 1.96 TeV. Jets are reconstructed using a cone-based midpoint algorithm with a cone of 0.7. The jet shapes are corrected to the hadron level (PRD 71, 112002, 2005 ).




Evaluate fractional $P_T$ in subsequent annuli as a function of the radius

Integrate over a radius r in different $P_T$(jet) bins

$$\Psi(r) = \int_0^r \frac{p_T(r')}{p_T^{jet}} dr' = \frac{1}{N_{jets}} \sum_{jets} \frac{p_T(0,r)}{p_T(0,R)}$$

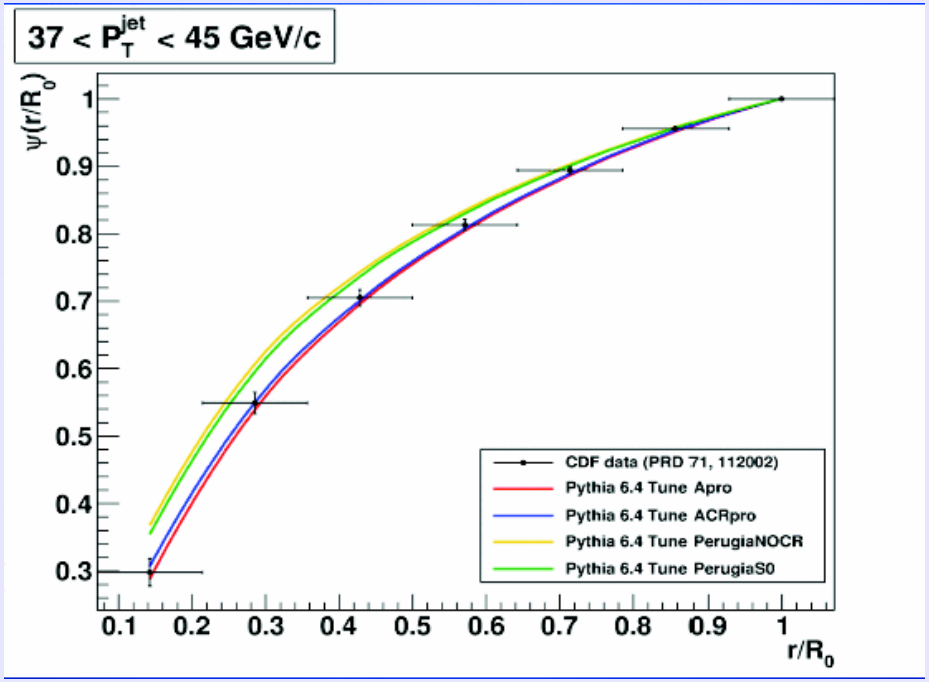
Jets Composition: ~30% quarks at low $P_T$, ~80% quarks at high $P_T$

# QCD JET SHAPES (2)

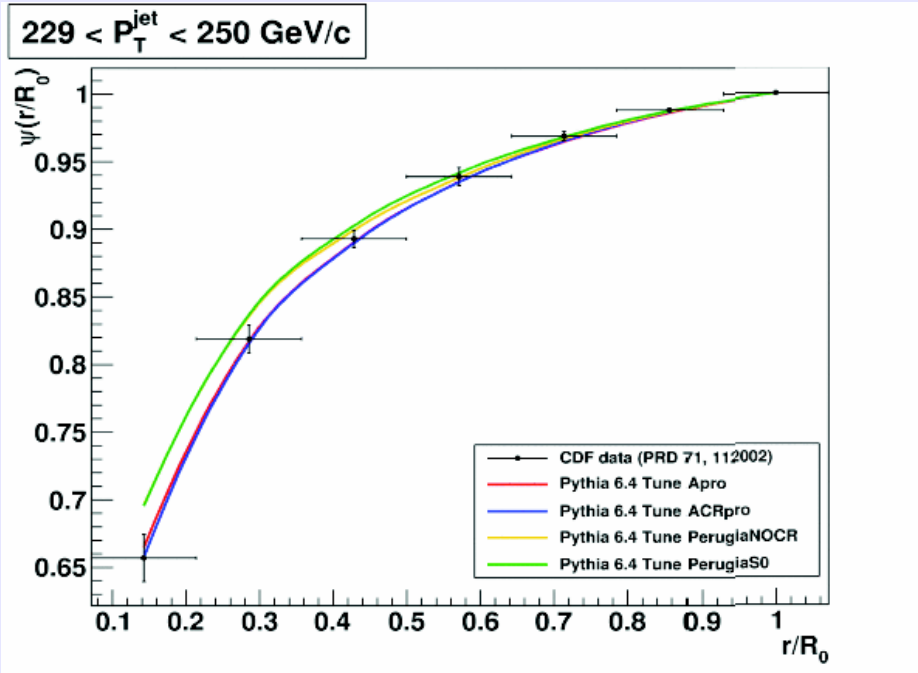
We compare here data with 4 tunes of PYTHIA V6.4.20

Tune A-pro and Tune ACR-pro fit the data very well
Tune Perugia0 and Tune Pg0-NOCR have narrower jets

$P_T$ = 37-45 GeV/c



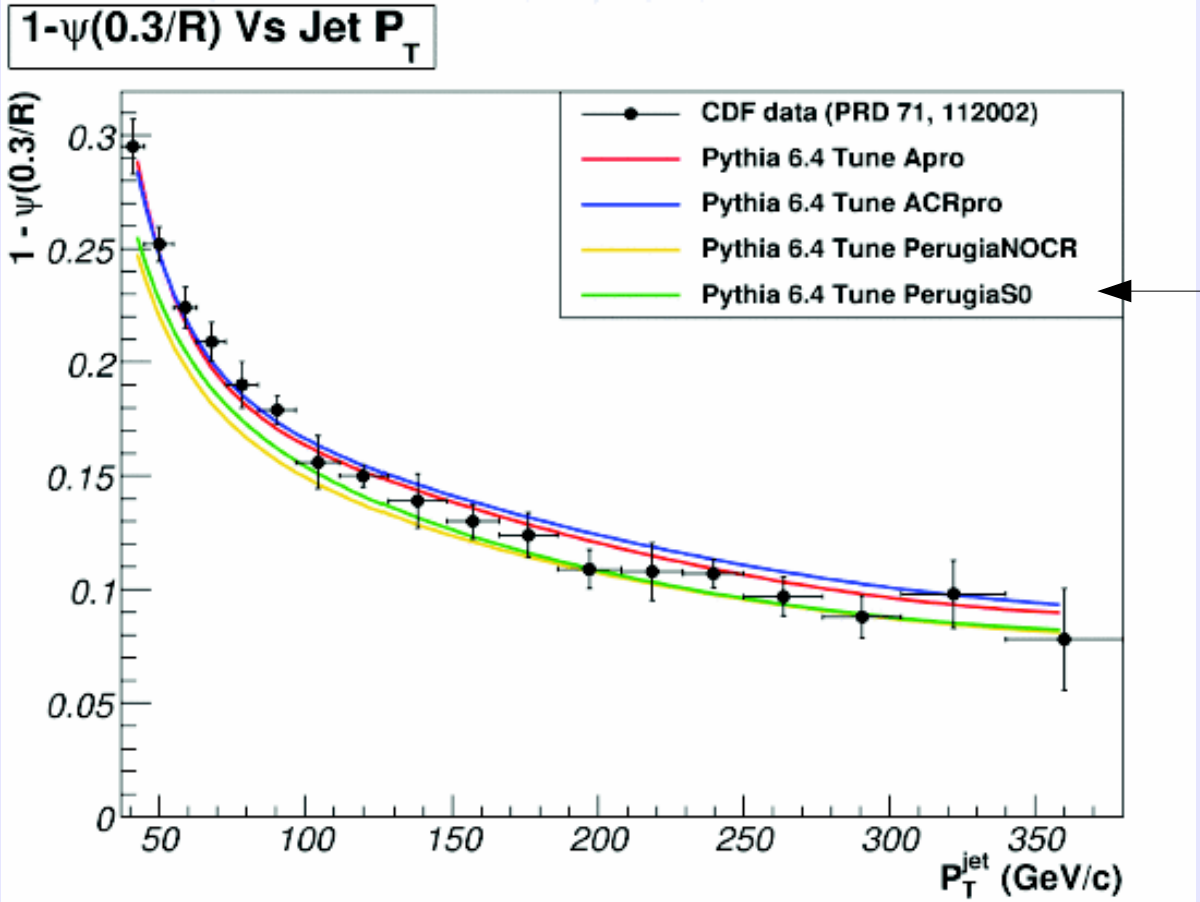

$P_T$ = 229-250 GeV/c



# QCD Jet Shapes (3)

Jet $P_T$ dependence of F(OOC)=1-ψ(r) for r=0.3.

F( OOC) = $P_T$ fraction outside of cone of 0.3



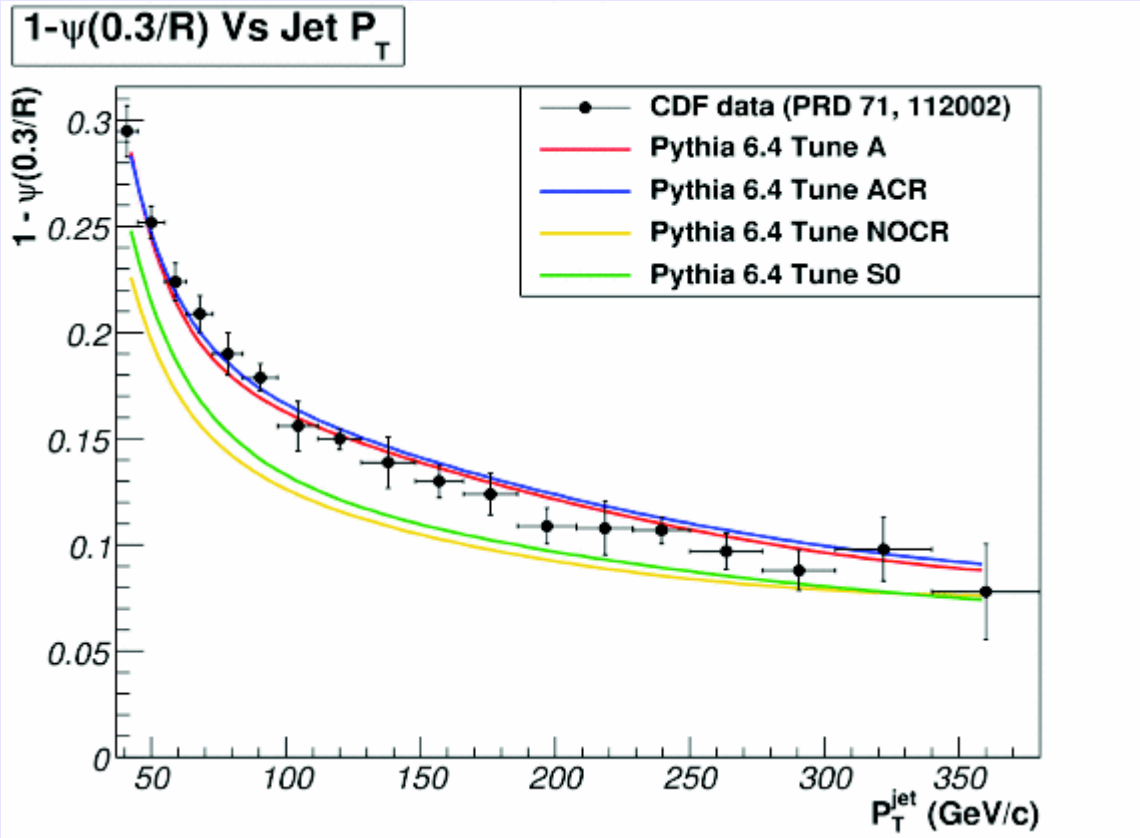

This should be Perugia0

Perugia0 has narrower jets for $P_T$ <100 Gev/c

The color reconnection term has negligible effect on jet shapes

# QCD Jet Shapes (4)

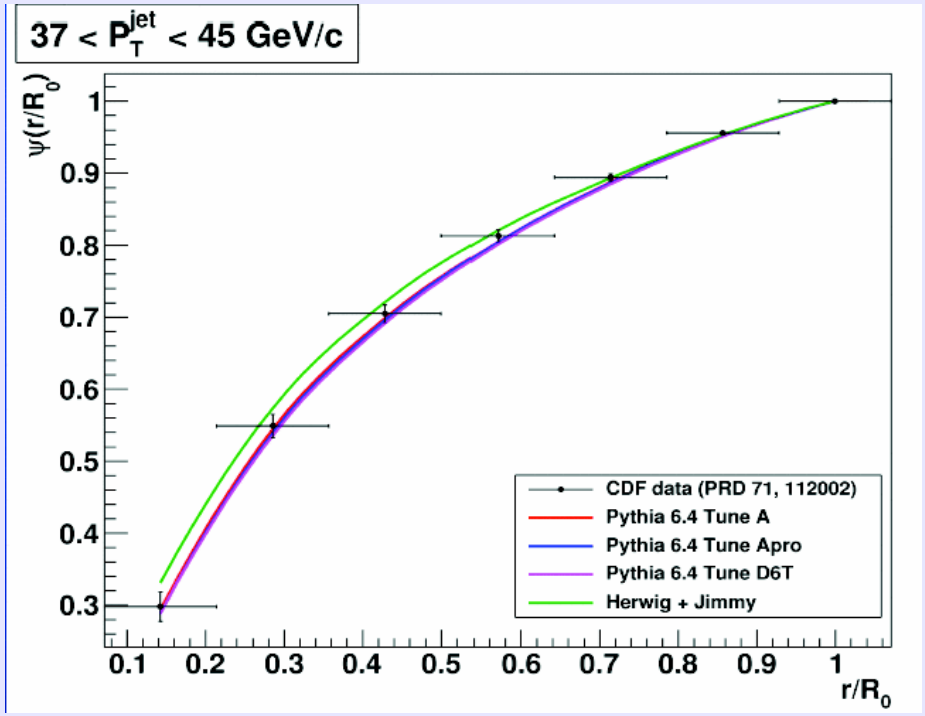
Comparison of older tunes with data
Tune S0-pro and corresponding NOCR show larger discrepancy with the data. Minbias data added for the Perugia0 tune



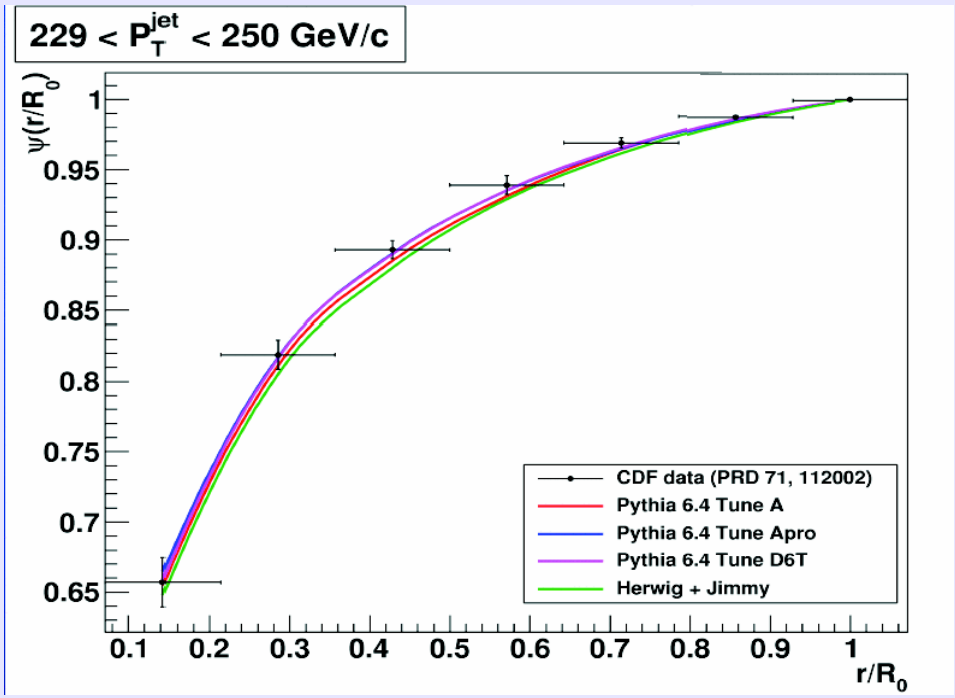
# QCD JET SHAPES: MORE TUNES

PYTHIA V6.4 tune A
PYTHIA V6.4 tune A-pro
PYTHIA V6.4 tune D6T: Rick Field's tune (less ISR, more MPI)
HERWIG with Jimmy

$P_T$= 37-45 GeV/c



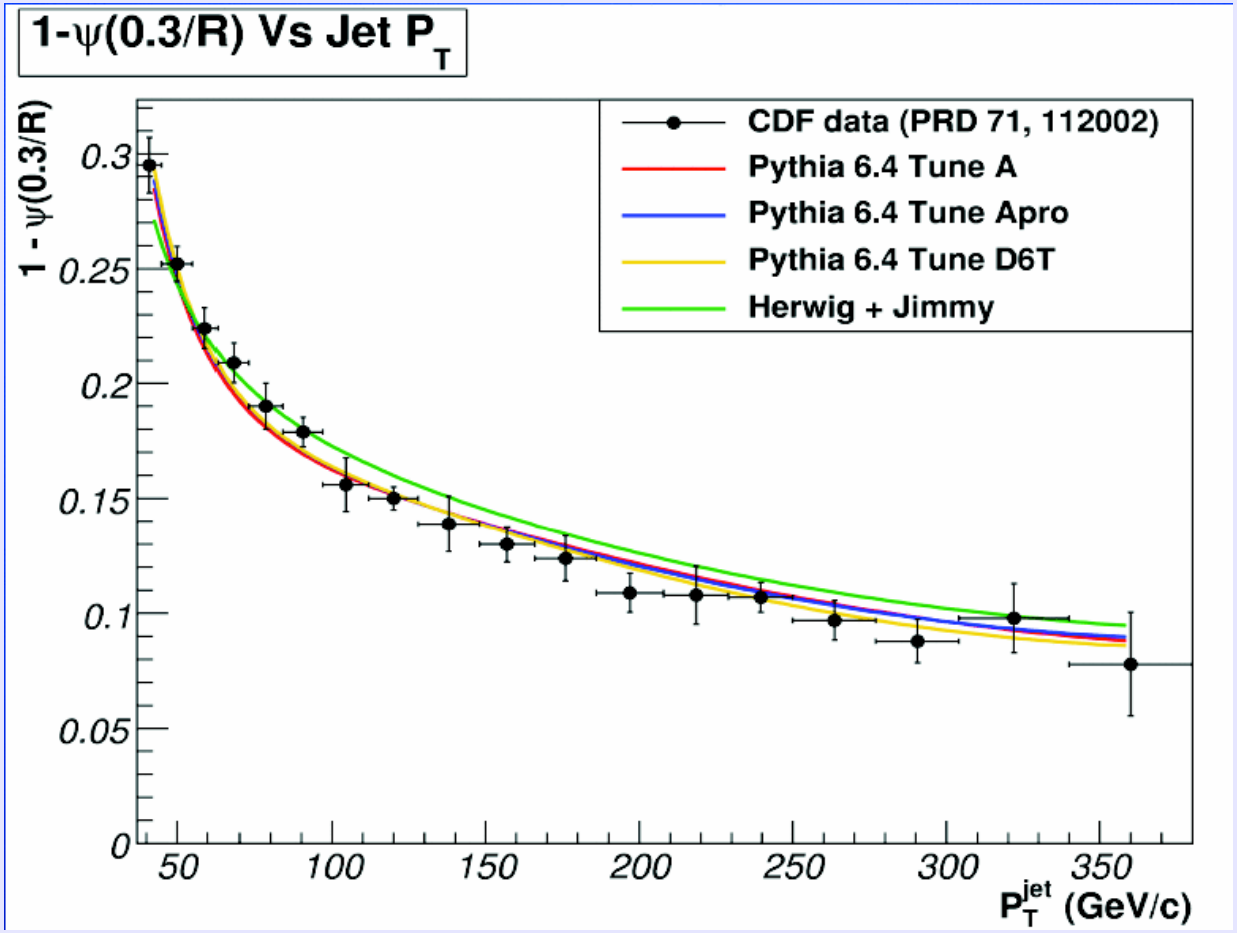

PT= 229-250 GeV/c




Difference between these tunes are very small

# More PYTHIA tunes and HERWIG

- None of the tunes fits the data perfectly
- HERWIG seems to fit the data better below 100 GeV, where most of the jets in top events are.



# Summary of QCD jet studies

- The latest PYTHIA V6.4 tunes have been compared with CDF data, i.e., jets with radius=0.7 obtained with a cone based mid-point algorithm
- Integrated jet shapes as a function of radius are compared to new and old PYTHIA tunes and with HERWIG+Jimmy
- Tune Perugia0 ( which uses $P_T$ ordered showers) predicts narrower jets below 100 GeV/c
- Effects of Color reconnection are negligible

Plan:

Study jets in e+e- to separate the effects of UE, MPI, CR, ISR, from effect due to the new parton shower

Include these data in future tuning

# Studies of New Tunes in Top events

$t\,\bar{t} \rightarrow W^{+}\, b\, W^{-}\, \bar{b}$ sample used to measure the top mass

$W \rightarrow l\ \nu$

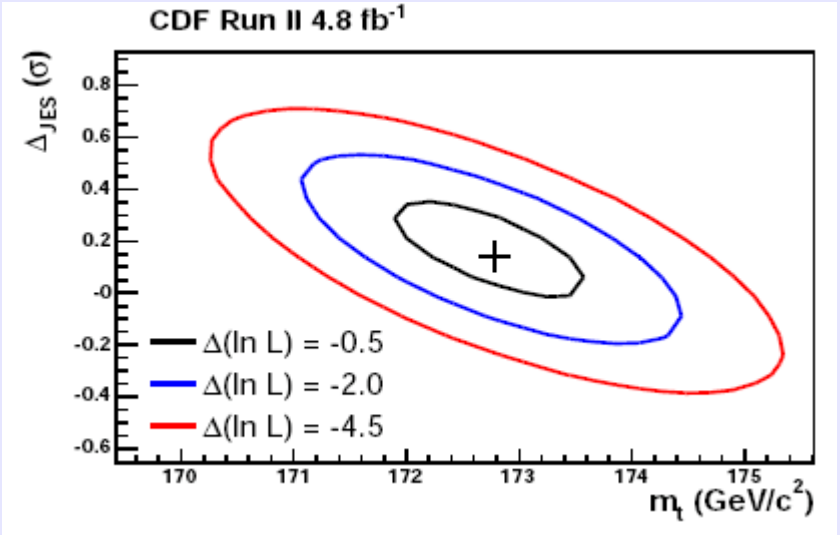
$W \rightarrow q\ \bar{q}'$

- Events in the lepton + jets topology (832 events)
  4 jets with $P_T$>20 GeV , ≥ 1 b-tag (1000 b-jets)
  Background: 21%

- 2D likelihood with top mass and jet energy scale as variables.
- JES calibration in "situ", constraint of $M_{jj}$ to $M_w$

- Is the event topology with PYTHIA V6.4 different from that of V6.2?
- What do we learn about jets?

Result of the MTM analysis



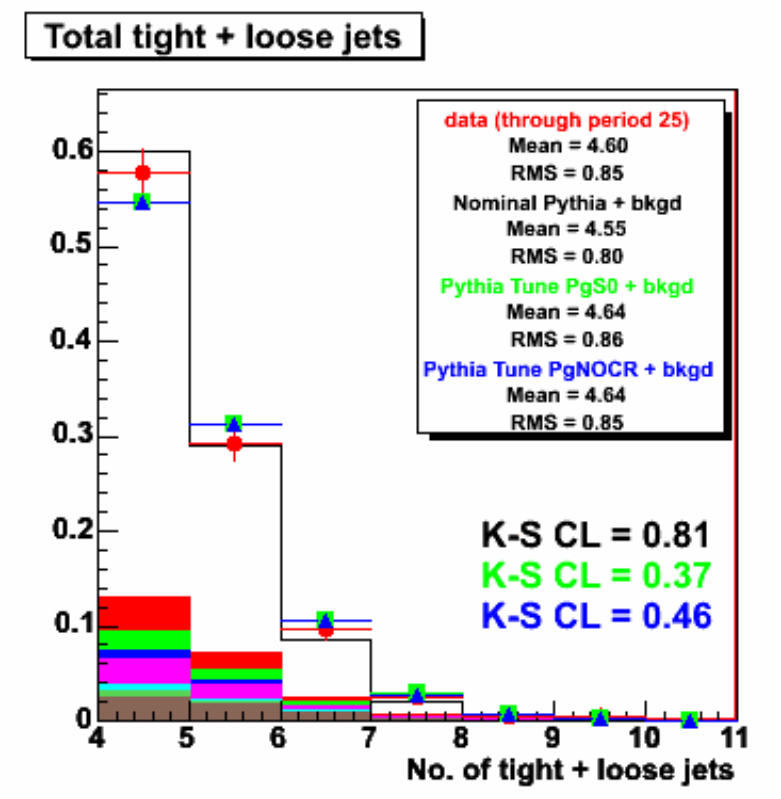
# Comparison of PYTHIA V6.2-V6.4

## Comparison at the event level

Given a MC sample of lepton +jets top events, we can match the simulated jets with the initial partons. The algorithm uses only the $\Delta R$ between the parton and the jets, calculates an overall $\chi^2$ for the event and applies some $\chi^2$ cut. (Used by the MTM mass analysis).

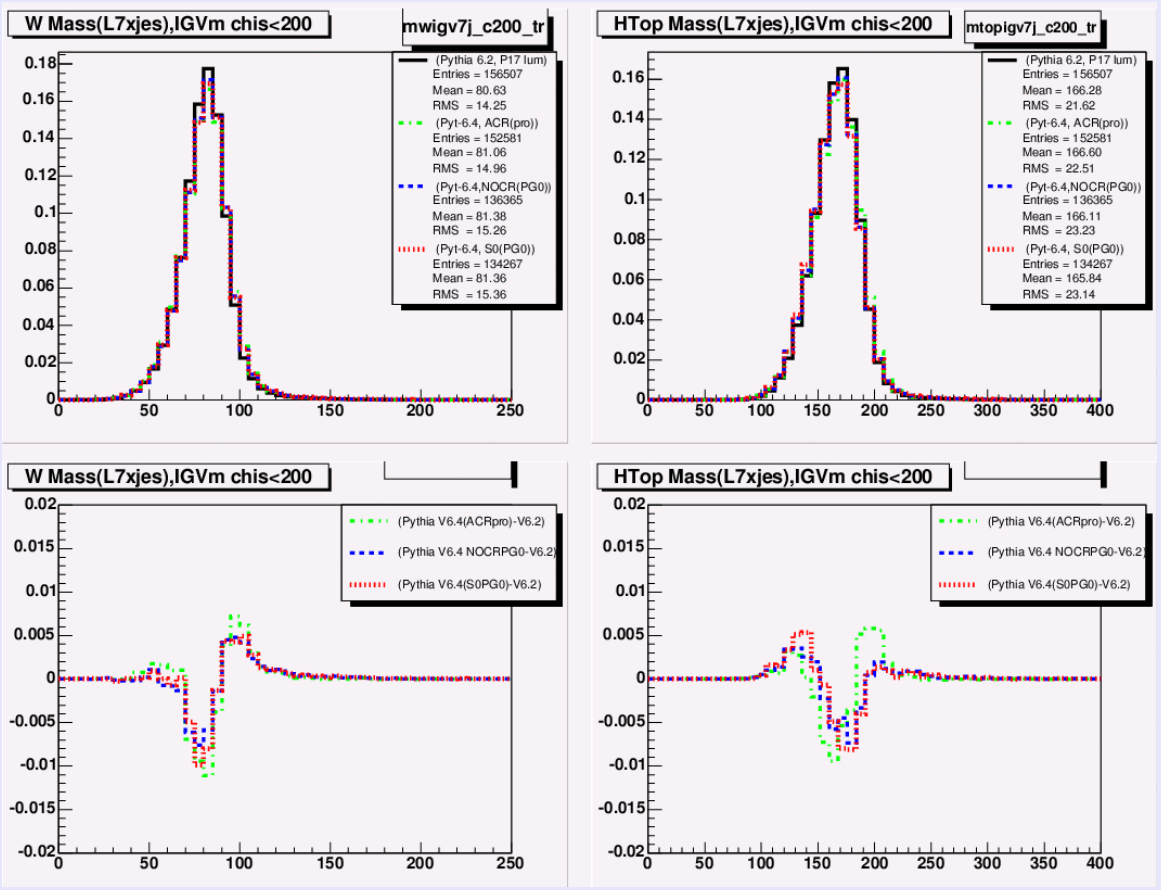
- For "good match" we find:
  - V6.2 (tune A) 68%
  - V6.4 ACR 68%
  - V6.4 NOCR-Pg0 59%
  - V6.4 Perugia0 59%

- The N(jet) distribution is not very different, but the topology for the new tunes is different. More ISR/FSR?



# Perugia0: W and Top mass shifts

## Reconstructed $M_W$ and M(top) using the matched jets




172.5 GeV(6M ev.)
Perugia0 -Nominal

$\Delta M_w = +0.73 \pm 0.05$

$\Delta M_{top} = -0.44 \pm 0.08$

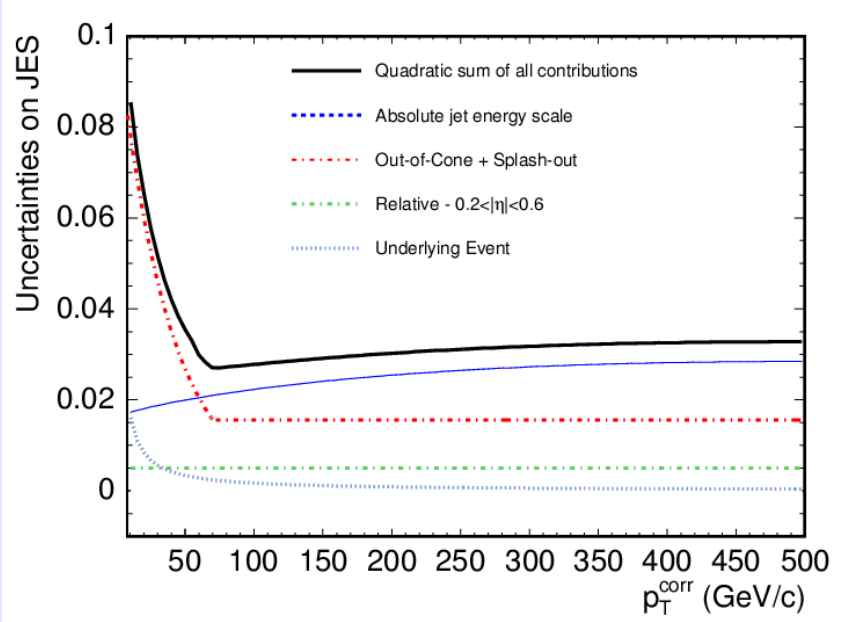
The quark jets of the Perugia0 tune have too much energy in the cone, which confirms our earlier observation

The b-jets have less energy in the cone than PYTHIA V6.2

# Determination of $\Delta_{JES}$

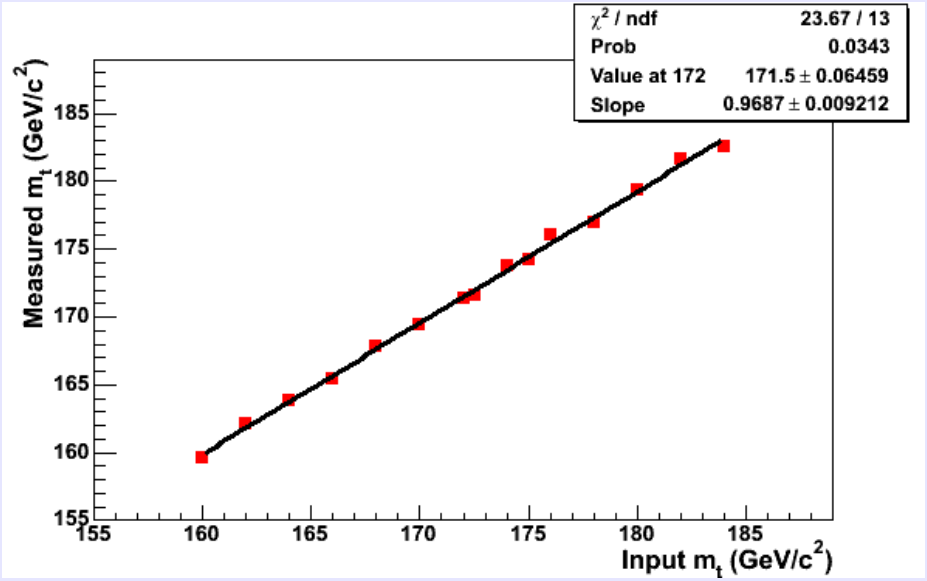
2D likelihood determination of the top mass, provides a value for $\Delta_{JES}$. This is related to the systematic uncertainty of the jet Energy Scale . Each jet is divided by a factor

$$F = 1 + \Delta_{JES} \cdot \sigma(P_T)$$




Note that the OOC systematic is ~50% of $\sigma(P_T)$. It comes from MC

Calibration of the method uses PYTHIA V6.2




Linear relationship between input and reconstructed mass

# Top mass measured by MTM

- Using the methodology of the MTM analysis the constraint imposed on $M_{jj}$ requires a $\Delta_{JES}$ of 0.32 for the new tunes, but also 0.26 for ACR-pro

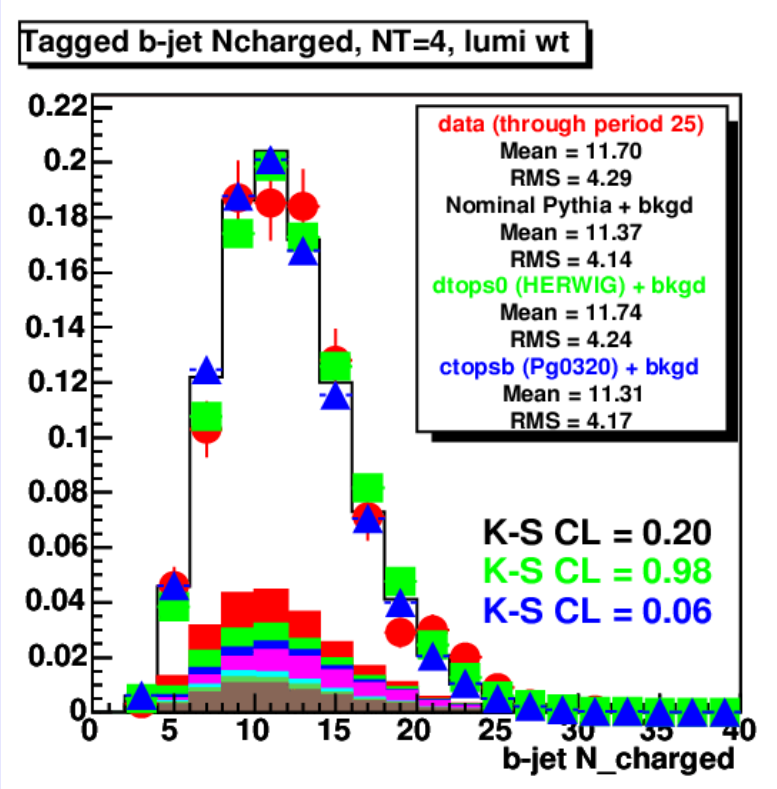
| Sample | $\Delta m_t$ (GeV/$c^2$) | $\Delta_{JES}$ $\sigma$ |
|---|---|---|
| | MTM Pseudo-Experiments | |
| V6.2 (nominal) | – | 0.11±0.03 |
| V6.4 A-pro | -0.02±0.18 | 0.08±0.03 |
| V6.4 ACR-pro | -0.39±0.18 | 0.26±0.03 |
| V6.4 NOCR-pro | -1.36±0.23 | 0.33±0.04 |
| V6.4 Perugia0 | -1.29±0.23 | 0.32±0.04 |

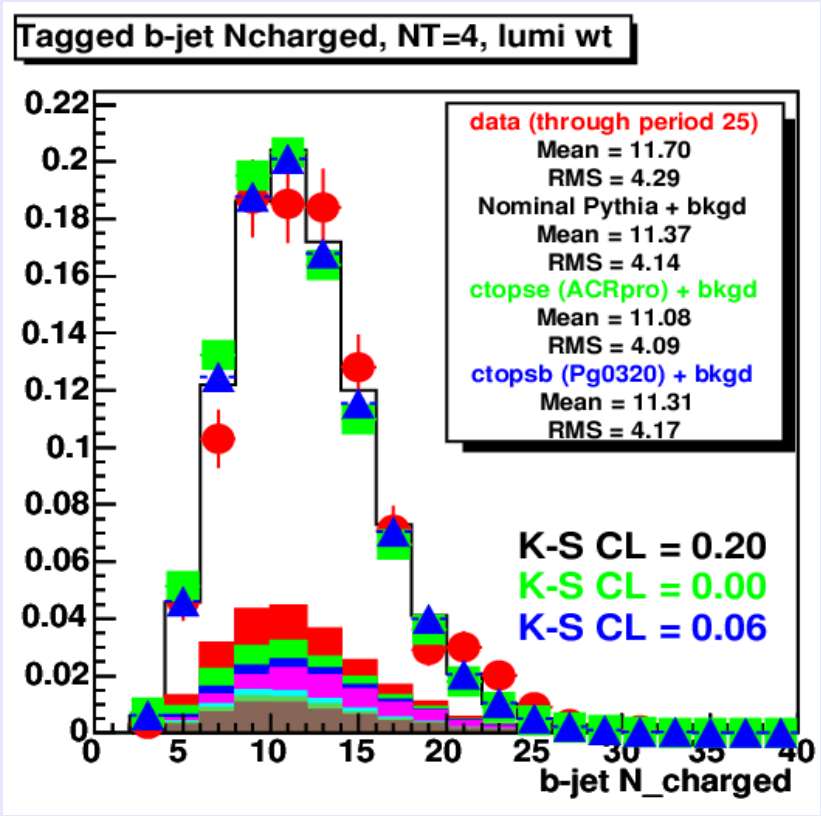
- All jet momenta are reduced by a factor 1.32 in the Perugia0 tune. This gives a top mass shift in excess of the 0.44 GeV seen earlier.
- Other component is the fact that the topology has changed, less events with parton-jets matching

- Systematics from color reconnection is taken to be (ACR(pro)-A(pro))=0.37 +-0.25 GeV

# b jets: compare N(charged)

- What can we learn from b-jets in top events?
  Compare Number of charged tracks in a cone of 0.4 .




- PYTHIA V6.2 compared with ACR-pro, Perugia0, HERWIG.
  Tune ACR and Perugia0 have less charged particles in the cone than tune A in PYTHIA V6.2 (as expected from the $\Delta_{JES}$ result)
- We need more information on b-jets at hadron colliders

# Summary

- We have compared jet shapes obtained in di-jet events (quark and gluon jets) with some PYTHIA V6.4 tunes expectations.
- We find that the Perugia0 tune does not fit the data as well as tune A
  Jets have more energy in the cone of 0.4, i.e., they are narrower.
  A small change in the parameters moves the jet shapes considerably
- Precision measurements like the top mass measurement are now limited by systematic uncertainties. The contribution from MC is quite large (0.73 out of 1.05)
- Constraining the $M_{jj}$ to the W mass helps reducing the systematics
  This constraint requires reducing the jet energies in Perugia0 by 1%
- Color Reconnection effects contribute 0.37 GeV
- The Perugia0 tune results in a large negative shift of the top mass.
  N(charged) in the cone for Perugia0 are less than for default PYTHIA and HERWIG, as expected from the mass shift

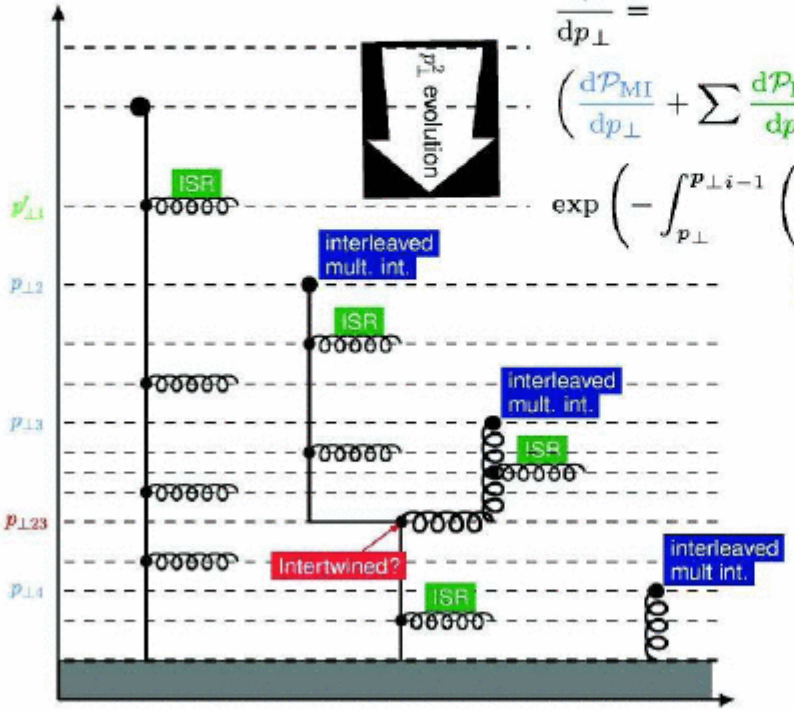
# Top Mass Measurement and CR

Backup slides

# New PYTHIA model (P. Skands etc)

## Pythias Underlying Event Models

- Old: UE generated after the ISR is done, i.e. uncorrelated.
- New: Parton showers interleaved with UE. (Requires $p_T$ ordered shower).




$$\frac{d\mathcal{P}}{dp_\perp} = \left(\frac{d\mathcal{P}_{MI}}{dp_\perp} + \sum \frac{d\mathcal{P}_{ISR}}{dp_\perp} + \sum \frac{d\mathcal{P}_{JI}}{dp_\perp}\right) \times \exp\left(-\int_{p_\perp}^{p_{\perp i-1}} \left(\frac{d\mathcal{P}_{MI}}{dp'_\perp} + \sum \frac{d\mathcal{P}_{ISR}}{dp'_\perp} + \sum \frac{d\mathcal{P}_{JI}}{dp'_\perp}\right) dp'_\perp\right)$$

⇨ successive "finegraining" of all perturbative activity

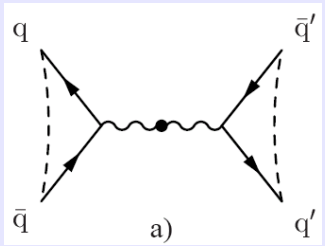
+ correlated multiparton pdfs (with flavour/momentum cons)
+ Impact parameter dependence
+ String fragmentation developed for baryonic colour topologies ⇨ improved description of beam remn.

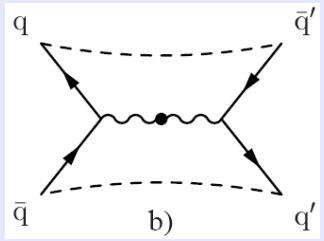
# Color Reconnection Systematics

Strong color correlations between the hard process and the underlying event are implied by tune A and similar tunes. These effects may be interpreted as sign for color reconnection.

The issue has been studied at LEP for the W mass measurement

## LEP




CR effects on the $M_W$ measurement at LEP contribute to systematics

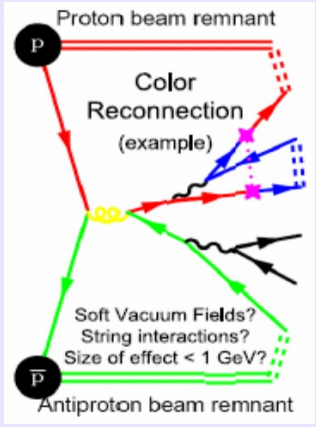
CR(sys) = 8 MeV

out of 22 MeV (total sys)

(LEPEWWG hep-ex/061203)

## Tevatron

Preliminary MC studies have indicated possible contributions




to the top mass systematics of order

CR(sys)≈ 0.5 GeV

D. Wicke and P. Skands arXiv:0807.3248V1

# Systematics from generators

- We find the following Color Reconnection values :
  -0.37 ± 0.18 GeV from A-pro - CR
  +0.07 ± 0.27 GeV from Pg0 - NOCR

- The Perugia0 tune gives $\Delta M_{top}$ = -1.3 GeV
  this is related to different jet shapes, i.e., different p-shower and different topology (more ISR)

- Present systematics from MC
  generator : $\Delta(m_t)$ = 0.25 GeV (HERWIG-PYTHIA)
  ISR/FSR : $\Delta(m_t)$ = 0.15 GeV
  Jets (OOC+JES) : $\Delta(m_t)$ = 0.43 GeV
  b-jets : $\Delta(m_t)$ = 0.16 GeV
  Color reconnection: $\Delta(m_t)$ = 0.37 GeV

- that is, MC related systematics (0.73 GeV)