Color Reconnection Systematics

This systematic uncertainty has not been included as yet, although we heard talks about this for many years now.

We are now trying to understand how to include it, with the help of our PYTHIA friends.

In recent months in CDF many samples have been generated and some effort is being made to study this effect.

We have a better understanding of the issues, but no concrete proposal on how to proceed yet.

Thanks to all that are contributing to this effort:
Sasha Golossanov, Nathan Goldschmidt
A. Castro, P. Lujan, P. Mehtala, Jian Tang, Marco Trovato, et al.
Top mass conveners, top conveners
Peter Skands for his availability and continuous help.

PYTHIA V6.416 versus V6.216

Our top mass measurements have been done using V6.216 (2003)
Color reconnection effects are included in PYTHIA V6.416

Changes in V6.416

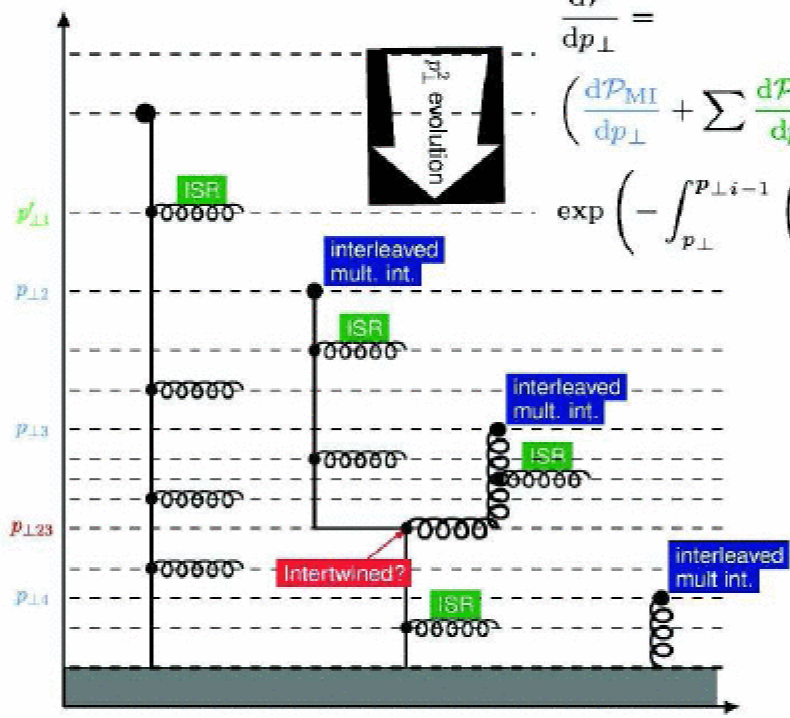
- Parton shower uses pt ordering rather then mass ordering
- Multiparton (MPI) interactions have been added
- ISR and FSR are also uses PT ordering algorithm
- New model for beam renmants, including baryon junctions
- Model interleaves MPI process with ISR evolution off the hard process
- Color reconnection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

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

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).



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

⇨ 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.

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Top2008, La Biodola, Elba, 18–24 May 2008 5

Effects on top mass

The complete set of changes is included in tune S0 of PYTHIA V6.416
Wicke + Skands analysis (toy MC for top mass) , conclude:

$\Delta(m_t)$ ~ 0.7 from new shower effects
~ 0.5 from color reconnection effects

- Tune S0 includes systematics that we are already taking into account
- We (MTM3 as an example) have the following systematics:
  generator: $\Delta(m_t)$ = 0.51 +- 0.37 GeV
  ISR/FSR: $\Delta(m_t)$ = 0.29 +- 0.26 GeV
- Using V6.416 (S0) to estimate systematics should cover most of these systematics, in addition to color reconnection.
- We have to avoid double counting, so we should try to separate the two effects . Not clear how to do this.

MC Studies of Color Reconnection

PYTHIA V6.416 includes color reconnection effects

We now have many top samples to work with at M=170 and 175 GeV (thanks Sasha and Nathan).

Pythia V6.4 has new features available:

New parton shower model
New underlying event model
Inclusion of color reconnection with Skand's et al model

Can we use them to extract the CR systematics ?

- How do these samples differ from V6.216 ?
- Is there a difference between the new (175) and old (170) samples?
- Are the jet shapes different?

Are the jets different?

So far the model has been tuned on Minbias events

We need to look at other samples to see if the new model fits the data: dijet, gam+jet. Compare jet shapes with data.

In the mean time many of us are applying the top mass machinary to evaluate mass shifts obtained with the new samples.

We are also looking at jets in top sample:

- usual cuts : PT>20 GeV , jet corrected at L5
- P lot: fraction of P_T(jet)/P_T(parton) in cone of DR=0.4
- DE (parton-jet at level 5)
- Compare old and new PYTHIA for jets from W-jets and b- jets.
- Compare V6.216 (tune A) and V6.416 (S0, tune ACR, NOCR)

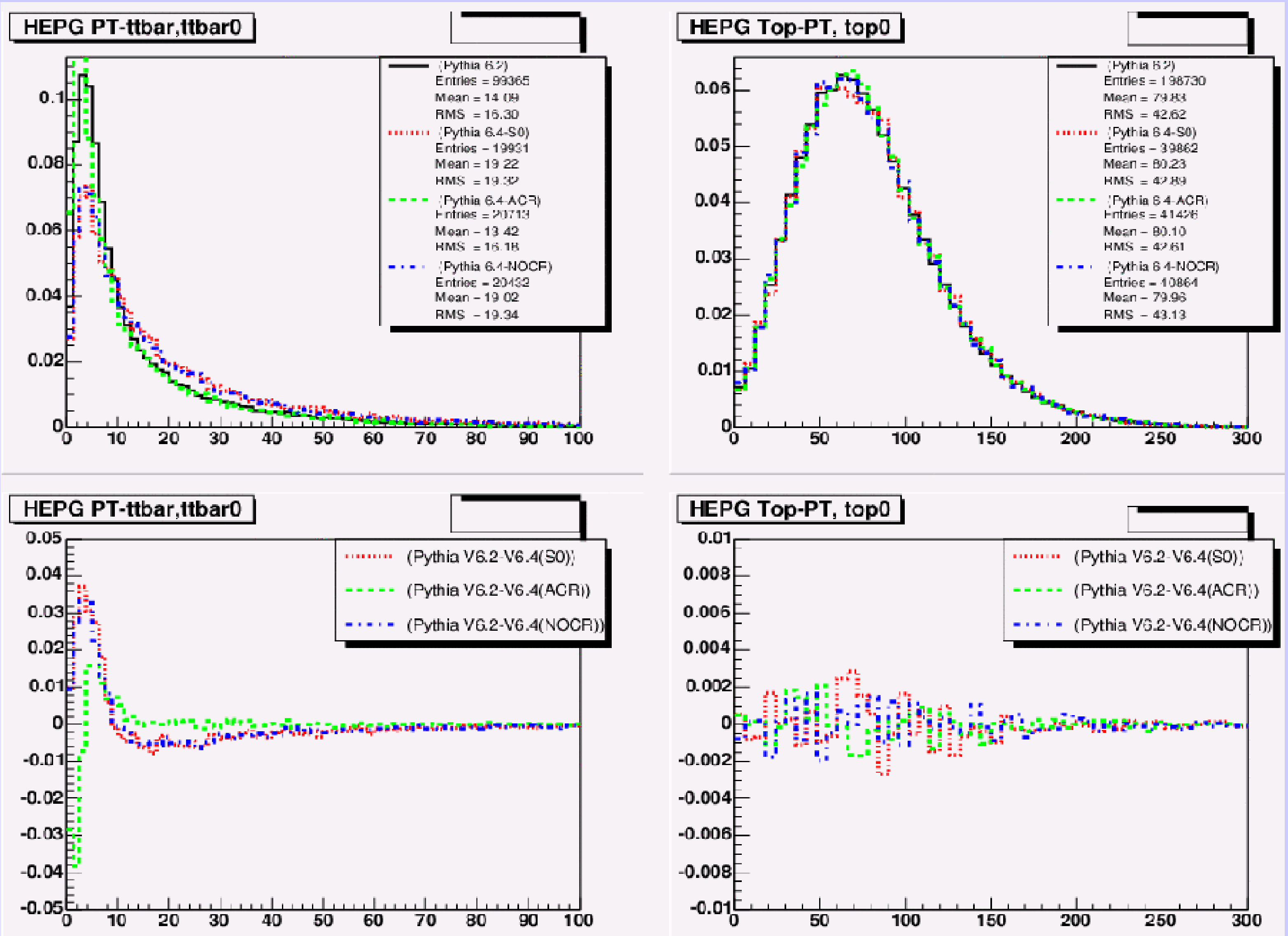
Procedures

A. Given a MC sample, for each event we match the partons from top decays to the observed jets (Ntight = 4) We then know which jet is light quark jet and which ones are b-jets. We correct the jets at L5 (no out of cone cor.)

- Compare pt5/pt0 and/or dE in cone of R=0.4
- We calculate M(W) and M(top) using the matched jets

B. We apply to each sample the top mass measurement analysis to obtain a mass and an unceratainty. Compare the values to estimate a systematics

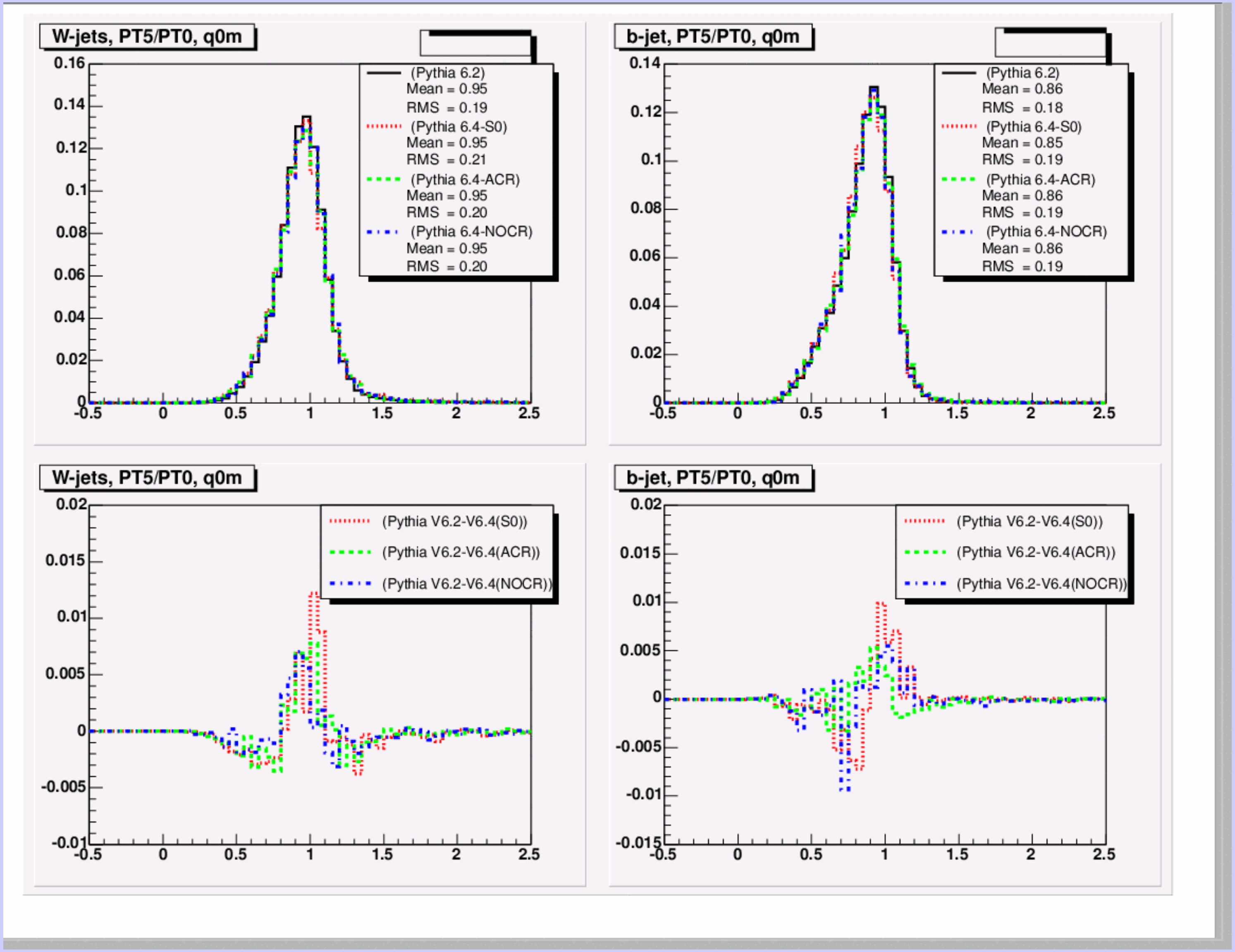
PT(ttbar) and top PT for 4 tunes



M=175 GeV
V6.2 (tune A)
V6.4 ACR
V6.4 NOCR
v6.4 S0

ACR case has PT(ttbar) similar to V6.216

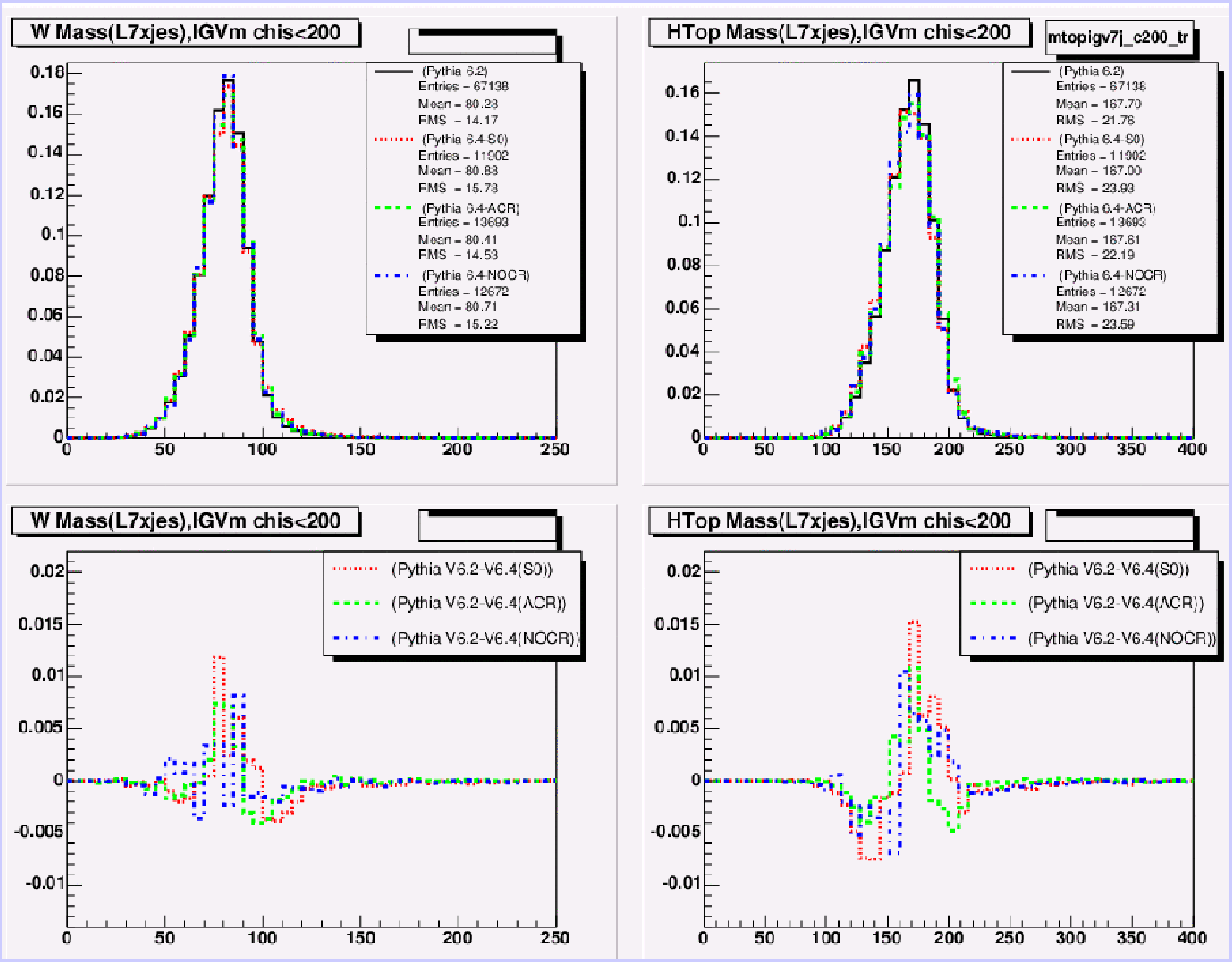
PT(jet)/PT(parton) for q and b jets



M=175GeV
V6.2 (tune A)
V6.4 ACR
V6.4 NOCR
v6.4 S0

Jets look wider for q-jets, shifted for b-jets

Reconstructed W and top mass at L7



M=175 GeV
V6.2 (tune A)
V6.4 ACR
V6.4 NOCR
v6.4 S0

MW shifted by 0.5 GeV, and M(top) shifted for S0

Sample comparison: A. and B.

Comparing 175 GeV samples

	MC event matching		MTM3 Pseudo-Exp		
Sample	Δm_W (GeV/c^2)	Δm_t (GeV/c^2)	m_t (GeV/c^2)	Δm_t (GeV/c^2)	Δ_{JES} (σ)
	MC samples at M = 175 GeV/c^2				
V6.2 (nominal) (ttkt75)	–	–	175.27±0.21	-	-0.12±0.04
V6.4 tune A (otop3u)	-0.28±0.13	-0.10±0.20	175.88±0.28	+0.61±0.35	-0.31±0.06
V6.4 ACR (otop3v)	+0.33±0.12	-0.01±0.20	174.99±0.28	-0.28±0.35	-0.03±0.06
V6.4 NOCR (otop3w)	+0.43±0.14	-0.29±0.21	174.46±0.31	-0.81±0.37	-0.08±0.06
V6.4 S0 (otop3t)	+0.60±0.14	-0.60±0.22	174.61±0.30	-0.46±0.37	-0.11±0.06

What do we learn?

	MC samples at M = 175 GeV L+JETS					
Sample	m_t (GeV)	Δm_t (GeV)	Δ_{JES} (σ)	m_t (GeV)	Δm_t (GeV)	Δ_{JES} (σ)
	Lepton+Jets, TMT			Lepton+Jets, MTM3		
V6.2 (nom)	175.11±0.13	–	0.020	175.03±0.22	-	+0.01±0.05
V6.4 tuneA	175.35±0.24	+0.24±0.27	0.047	175.73±0.31	+0.73±0.42	-0.19±0.07
V6.4 ACR	174.63±0.24	-0.48±0.27	0.047	174.62±0.31	-0.38±0.42	+0.11±0.07
V6.4 NOCR	173.46±0.24	-1.65±0.27	0.047	174.11±0.35	-0.89±0.42	-0.05±0.07
V6.4 S0	173.78±0.22	-1.33±0.27	0.047	174.24±0.34	-0.76±0.43	+0.02±0.07
	di-Lepton, TMT			All Hadronic, Hist		
V6.2 (nom)	175.40±0.17	–	0.020	174.4±0.6	-	+0.07±0.06
V6.4 tuneA	175.19±0.42	-0.21±0.45	0.047	175.6±0.6	+1.2±0.8	-0.12±0.06
V6.4 ACR	175.56±0.42	+0.16±0.45	0.047	176.1±0.7	+1.7±0.9	-0.17±0.07
V6.4 NOCR	176.32±0.42	+0.92±0.45	0.047	173.4±0.7	-1.0±0.9	+0.02±0.07
V6.4 S0	175.77±0.42	+0.37±0.45	0.047	173.9±0.7	-0.5±0.9	+0.10±0.07

- ACR should be directly comparable to tune A, the difference being due to Color Reconnection.
- NOCR and S0 are expected to have larger DM

Summary and Conclusions

First studies indicate that jets in PYTHIA V6.416 are different than for V6.216

Expect to compare the new PYTHIA with d-ijet and gam+jet data, to see if it fits the data

Using ACR to evaluate the systematics could be the simpler thing to do, but we have to look at di-jet and gam-jet first

Color reconnection in PYTHIA

Current Tunes

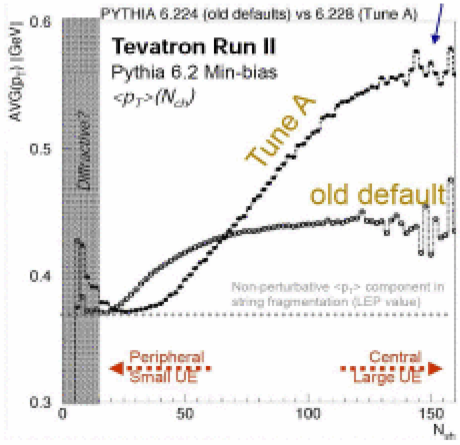
Tuning to min. bias data gave significant improvements

Several pythia tunes to min. bias data available

Tune A, Tune DW, Tune BW, ... (Rick Field)

These implicitly allow CR within UE to a high level:

PARP(85)	$0.33 \to 1.0$	Prob. for MPI w/ colour connection
PARP(86)	$0.66 \to 1.0$	to neighbours/ closed loop



Colour Reconnection

Is the colour-flow of the hard interaction preserved?

Proton remnants provide lots of (soft) gluons to interact with.

Most models were only available for $e^+e^- \to WW$

New Models by M. Sandhoff and P. Skands in Pythia 6.326+
Alternative models by Uppsala group / Webber not yet explored in this context.

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Color reconnection in PYTHIA V6.4

New CR Models: Colour Annealing

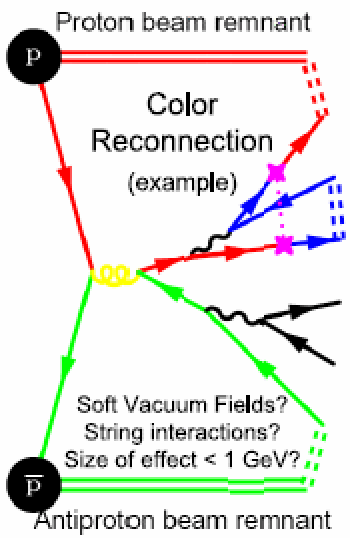
Allow CR also within the hard interaction.

- At hadronisation strings pieces may reconnect

$$P_{\text{reconnect}} = 1 - (1 - \chi)^n$$

χ — strength parameter
n — number of interactions
(counts number of possible interactions)

- New connection chosen to minimise string length, i.e. minimise potential energy in strings
- Model variations: $S0$, $S1$, $S2$ differ in suppression of gluon only string loops



These models of colour reconnection are applicable to any final state.

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