PHYSICS AT THE TERA SCALE
Helmholtz Alliance

DESY

CMS related tuning activities

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Tunes to UE and forward energy flow data from CMS.

- **Pythia 6 – the Z2* and Z2f tune**
- **Pythia 8 – the 4C* and 4Cf tune**
- **Status of CMS Rivet Routines**

Preliminary tuning results!
(Not CMS approved.)
Work in progress...

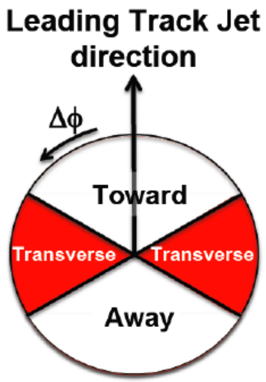
Introduction

- Rivet and PROFESSOR have been implemented in the CMS software environment.

- Start to gain experience.
  First steps towards tuning activities in CMS:
  We remake the Pythia 6 tune Z2 and Pythia 8 tune 4C.

- **Data for Z2* and 4C*:**
  The **traditional UE measurement** (a la Tevatron), in the central region by CMS at 0.9 and 7 TeV. *(CMS-QCD-10-010)*

  Measurement of activity transverse to the leading charged particle jet.



- **Data for Z2f and 4Cf:**
  The **energy flow in the forward region**, $3.15<|\eta|<4.9$, measured by CMS at s=0.9 and 7 TeV. *(CMS-FWD-10-011)*

  Measured in both MB and di-jet events.

The Z2, Z2* and Z2f Tunes

- **Z1 – CTEQ5L**
  Based on Professor tunes with ATLAS MB data.
  Manual retune of MI parameters by Rick Field.

- **Z2 – CTEQ6L**
  Manual retune of Z1 for CTEQ6L. By Rick Field.

- **Z2* and Z2f (in this talk) – use PROFESSOR to retune:**

  PARP(82) – Cut off for MPI

  PARP(90) – Extrapolation of energy dependence

$$p_T^{min}(E_{CM}) = PARP(82) \cdot \left(\frac{E_{CM}}{E_{ref}}\right)^{PARP(90)}$$

The Pythia 8 – Tune 4C* and 4Cf

- **Tune 2C: Tune to CDF data. Mix of manual tuning and automated tuning.**

- **Tune 4C: Based on 2C, but with SD reduced data from ATLAS included.**
  [Cork, Sjöstrand, arXiv:1011.1759]

- **Tune 4C*/f (this talk).**
  We use CTEQ6L and CMS data, and retune the following parameters:

- **`MultipleInteractions:pT0Ref`**
  Cut off for MPI (analog to PARP(82) in Py6 Z2* tune)

- **`MultipleInteractions:ecmPow`**
  Extrapolation of energy dependence (analog to PARP(90) in Py6 Z2* tune)

$$p_T^{min} = pT0Ref \cdot \left(\frac{E_{CM}}{E_{ref}}\right)^{ecmPow}$$

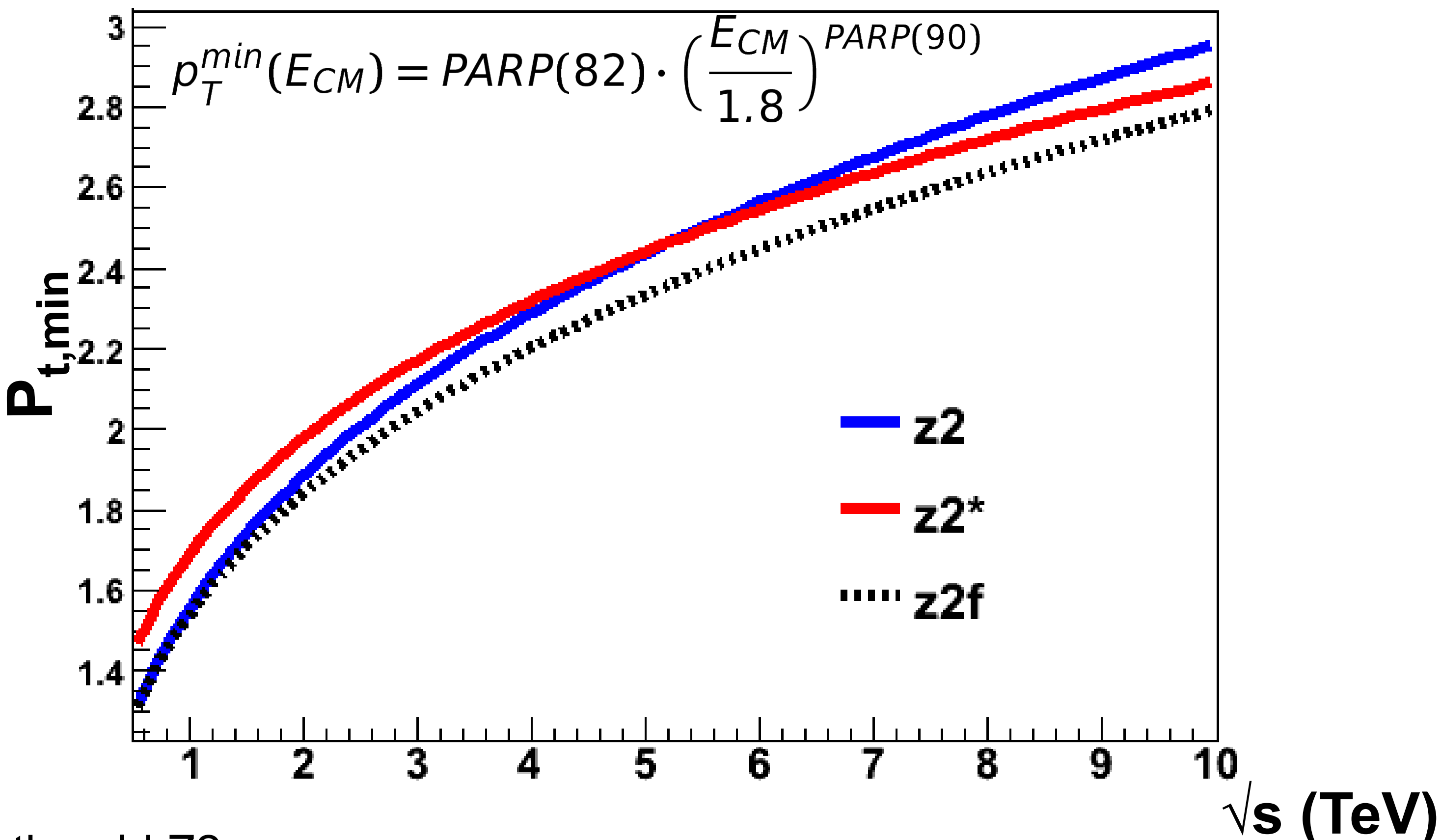
- **`MultipleInteractions:expPow`**
  Matter distribution
  Gives the matter overlap between colliding protons. exp(- b^expPow)

- **`BeamRemnants:reconnectRange`**
  Gives the color reconnection probability
  for a system with pT to be merged with a higher pT system
  (probability according to pT0_Rec^2 / (pT0_Rec^2 + pT^2)
  where pT0_Rec = reconnectRange * pTmin)

Results Z2 and Z2f*

Results – Z2* and Z2f

	Tuning Range	Z2	Z2* (UE)	Z2f (Forward)
PARP(82)	1.0 - 3.0	1.83	1.93	1.79
PARP(90)	0.0 - 0.4	0.28	0.23	0.26



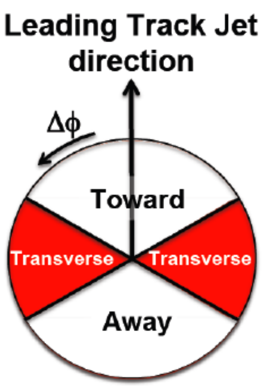
Compared to the old Z2:

- Z2* will increase the activity at 7 TeV (lower pt-cut)
  Z2* will decrease the activity at 0.9 TeV (higher pt-cut)

- Z2f will not do much at 0.9 TeV, but will increase the activity at 7 TeV.

Transverse Particle Distributions – 0.9 TeV

Comparisons ot data used in the Z2* tune....



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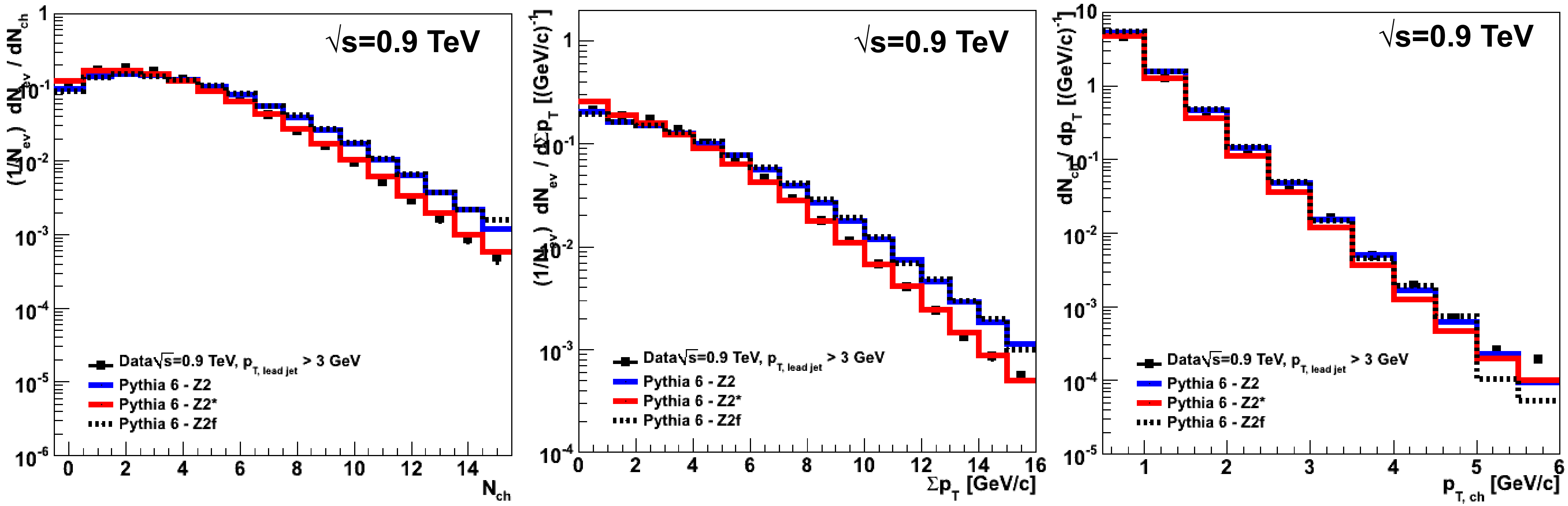


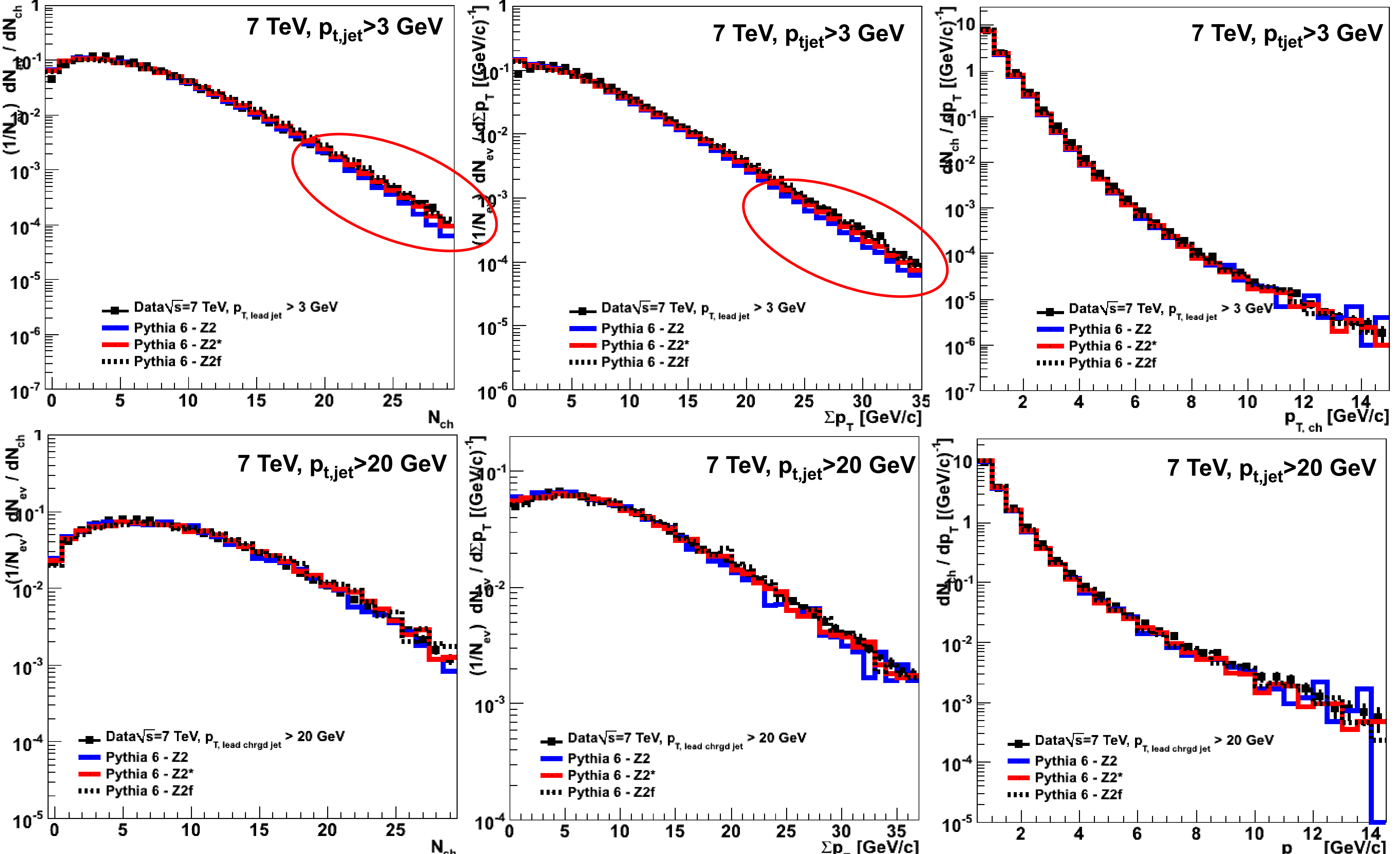
Z2*: Big improvement in the tails of N_{ch} and $\sum p_t$.

Z2f: No big difference to original Z2.

Blue: Z2
Red dashed: Z2*
Black dashed: Z2f

Transverse Particle Distributions – 7 TeV

Blue: Z2 Red dashed: Z2* Black dashed: Z2f



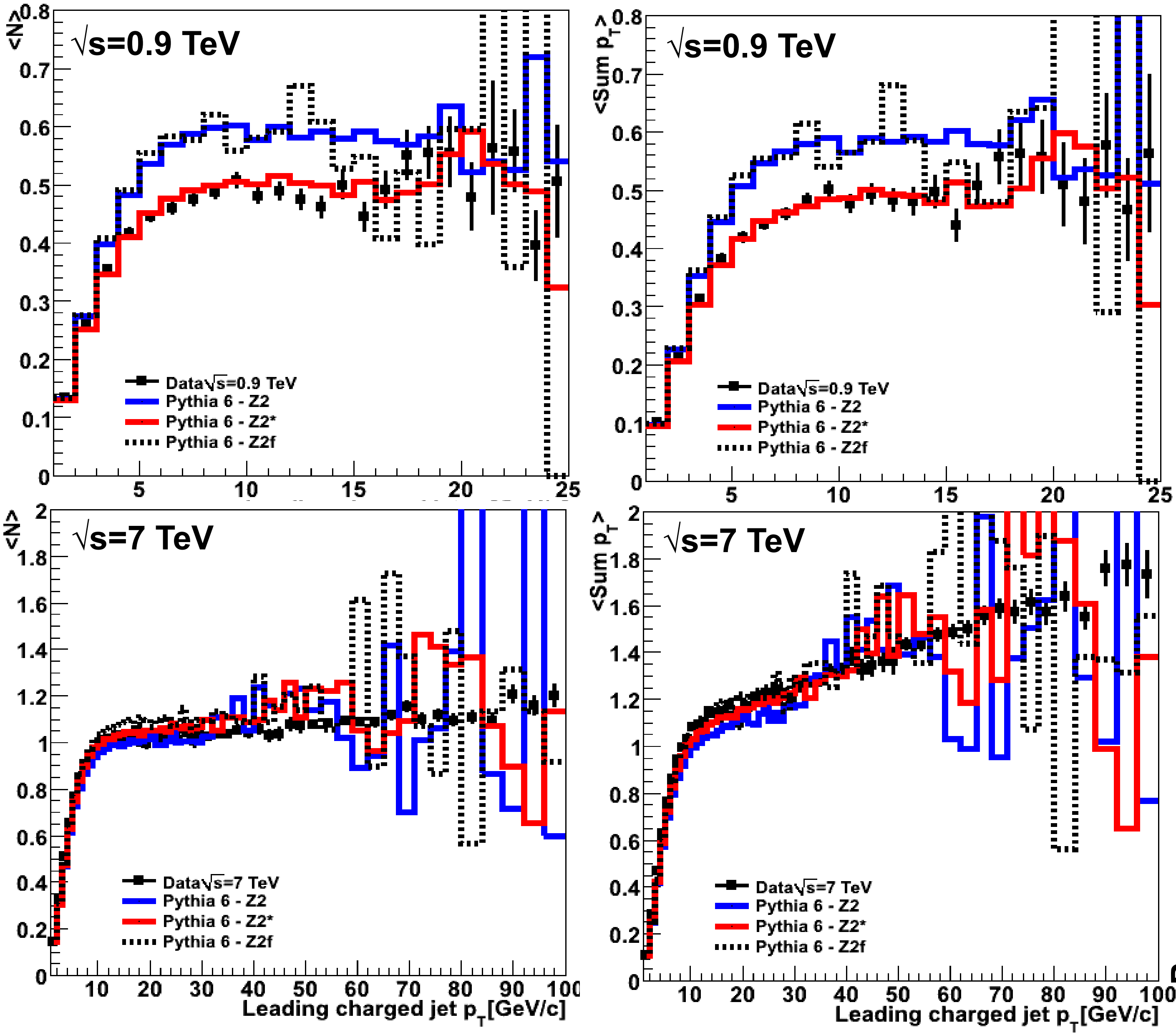
Z2*: Improvement in the tails for the $P_{t,jet}$>3 GeV events.

Z2f: Somewhat higher activity in the tails comp Z2.

Higher activity = lower P_T cut.

Compare 0.9 TeV: Energy dependence...

<N> and Σp_t vs $P_{t,lead}$ – Z2* and Z2f



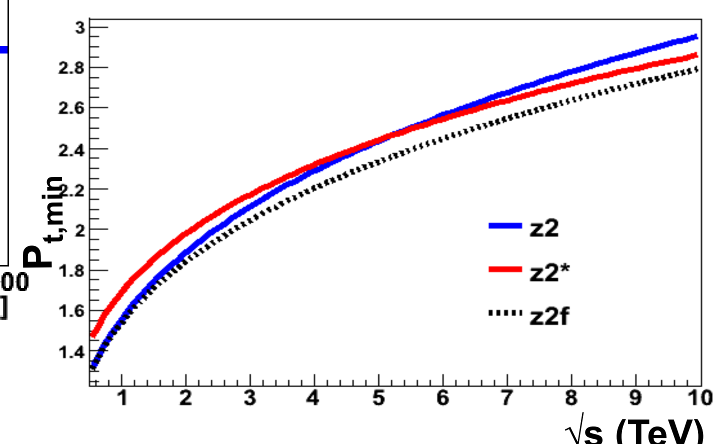
Z2*:
Significant improvement, especially for the 0.9 TeV data.

More activity in the 0.9 TeV data. Somewhat lower activity in the 7 TeV.

Z2f:
No difference for the 0.9 TeV data.

Too much <N> at 7 TeV.
Good for Σp_t at 7 TeV.

(Sorry for the low stat, we are working on that.)



Blue: Z2 **Red dashed: Z2*** **Black dashed: Z2f**

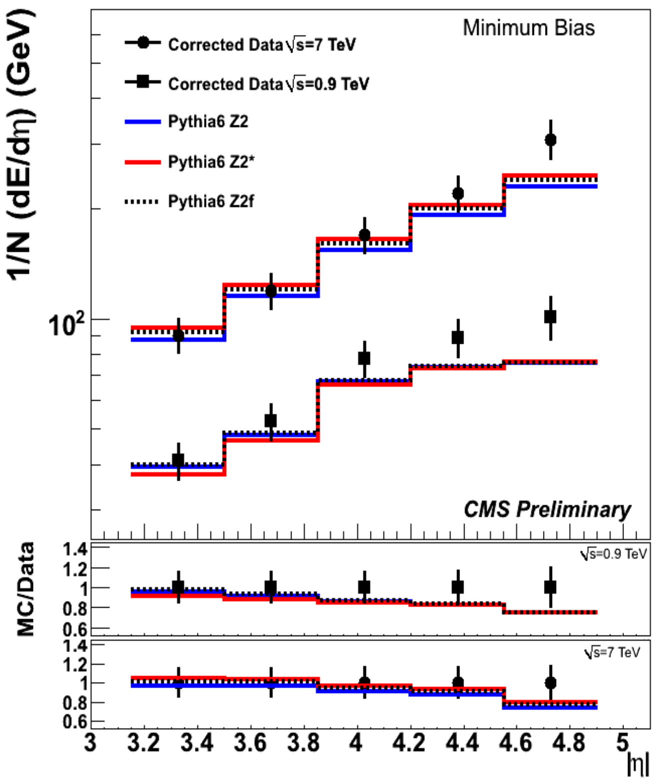
Forward Energy Flow – Z2* and Z2f

Comparison to data used in the Z2f tune.
Energy flow in the forward region (3.14 < |η| < 4.9)

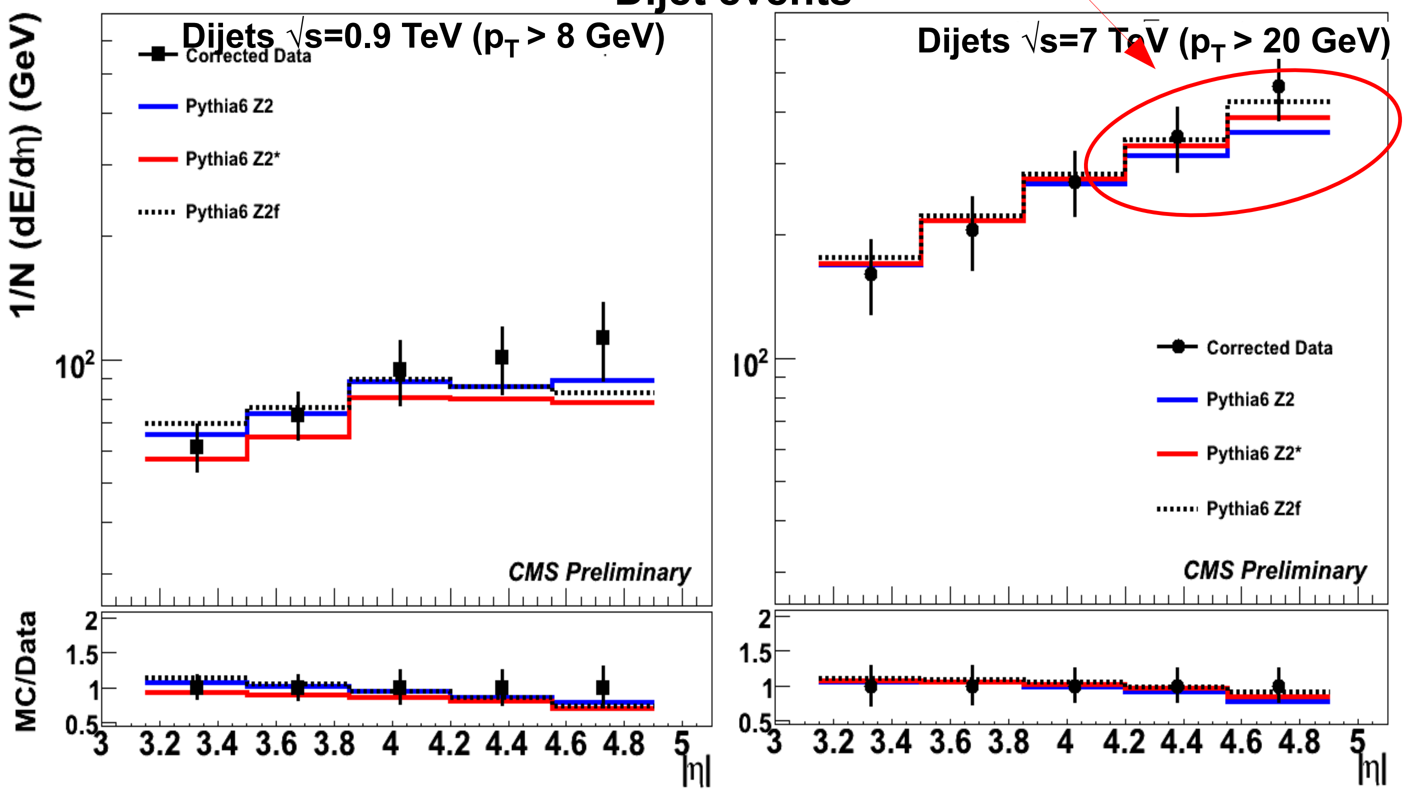
Very little differerence between tunes.

- MB: No difference between Z2, Z2* and Z2f
- Dijets@0.9TeV: Tiny difference between Z2 and Z2f. Z2* somewhat worse.
- Dijets@7TeV: Z2f and Z2* improve data description *little* at high |η|.

MB events



Dijet events



Results - 4C and 4Cf*

Results – 4C* and 4Cf

parameter	tuning range	4C	4C* (UE)	4Cf (Forward)
pT0Ref	1.0 - 3.0	2.09	1.95	1.99
ecmPow	0.0 - 0.4	0.19	0.17	0.21
expPow	0.4 - 10.0	2.0	3.2	3.0
reconnectRange	0.0 - 9.0	1.5	4.7	3.05

Somewhat different P_t-cut, but

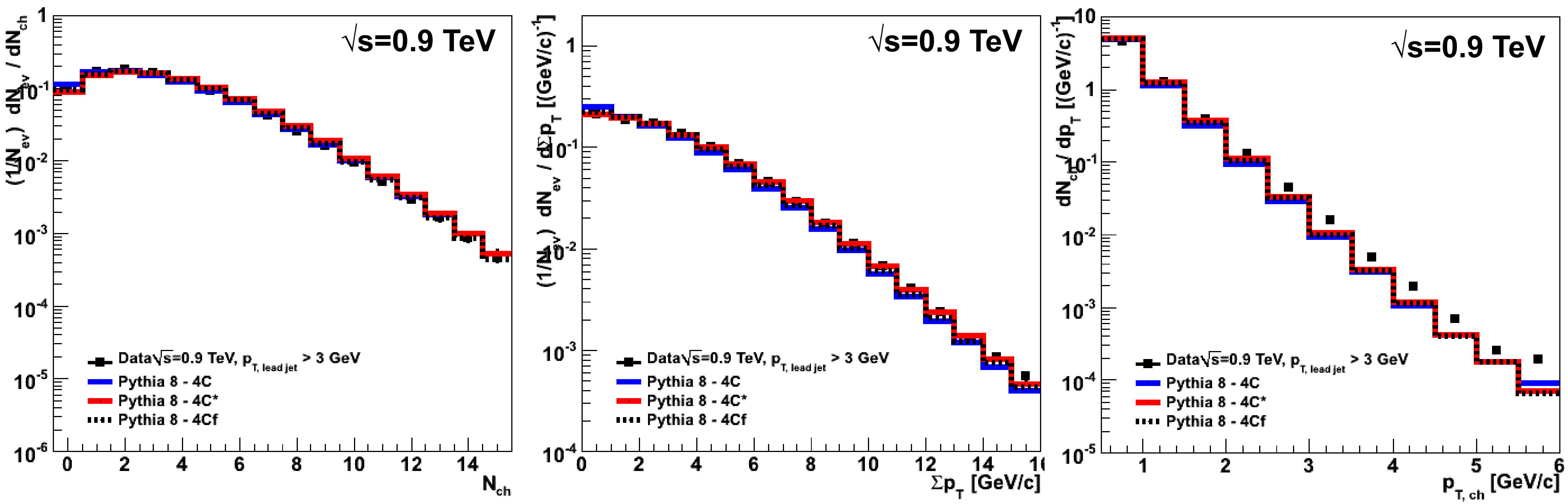
biggest change is compared to original 4C is

the matter overlap and the color reconnection.

Results – Particle Distributions – 0.9 TeV

parameter	tuning range	4C	4C*	4Cf
pT0Ref	1.0 - 3.0	2.09	1.95	1.99
ecmPow	0.0 - 0.4	0.19	0.17	0.21
expPow	0.4 - 10.0	2.0	3.2	3.0
reconnectRange	0.0 - 9.0	1.5	4.7	3.05

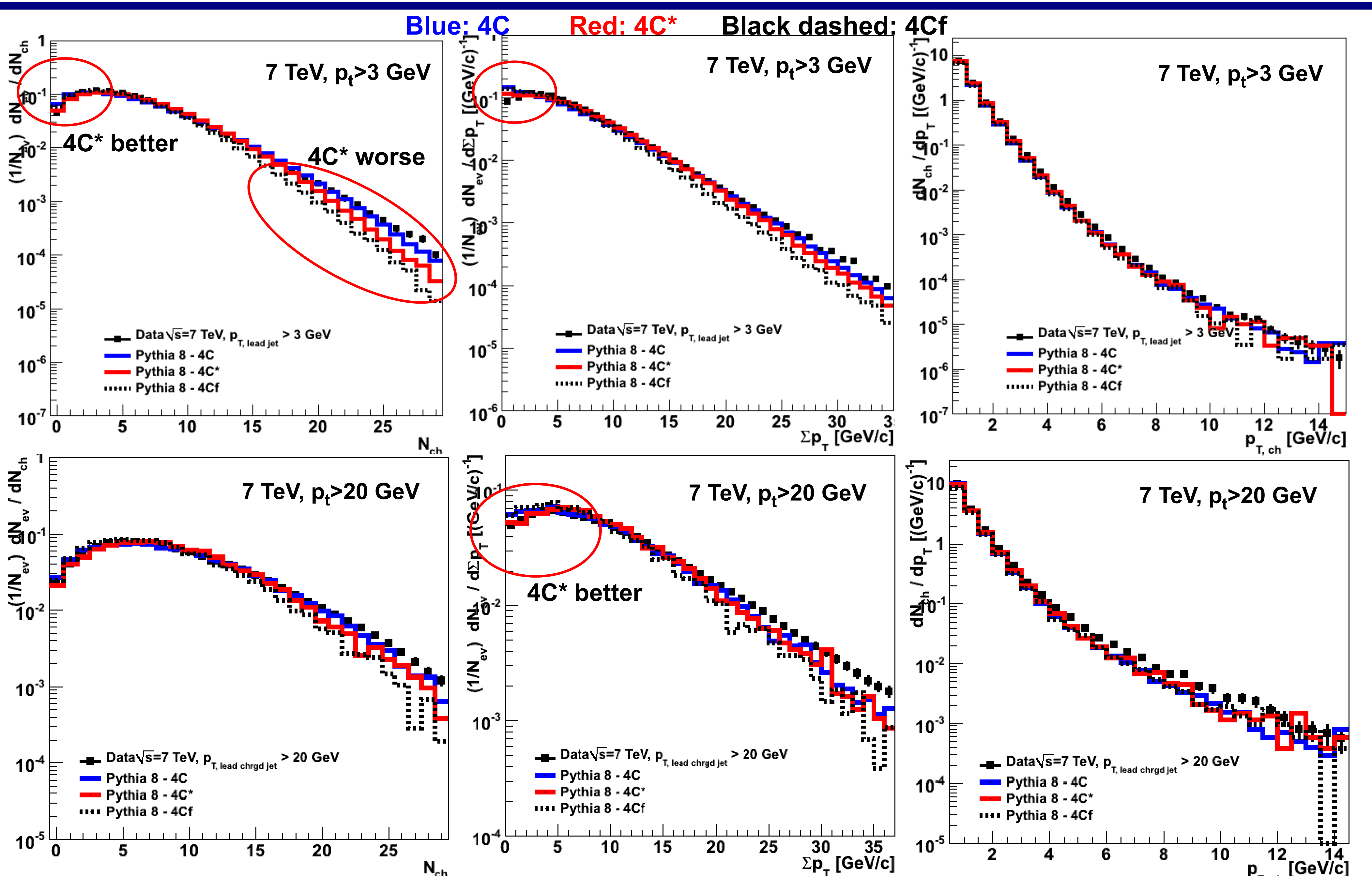
Particle distributions in the regions transverse to the leading track jet.



4C* seems to be somewhat better in the tail of $\sum p_t$.
Visually, very small difference between the tunes.

Blue: 4C
Red: 4C*
Black dashed: 4Cf

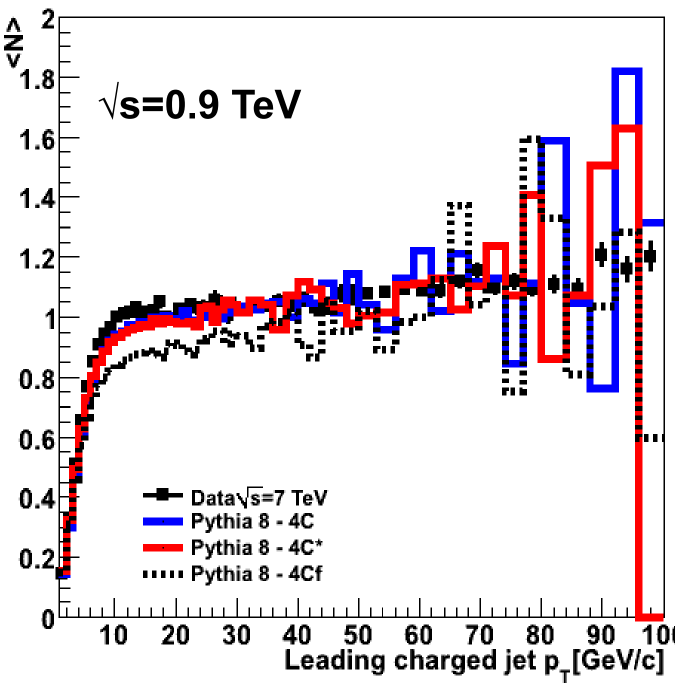
Results – Particle Distributions – 7 TeV

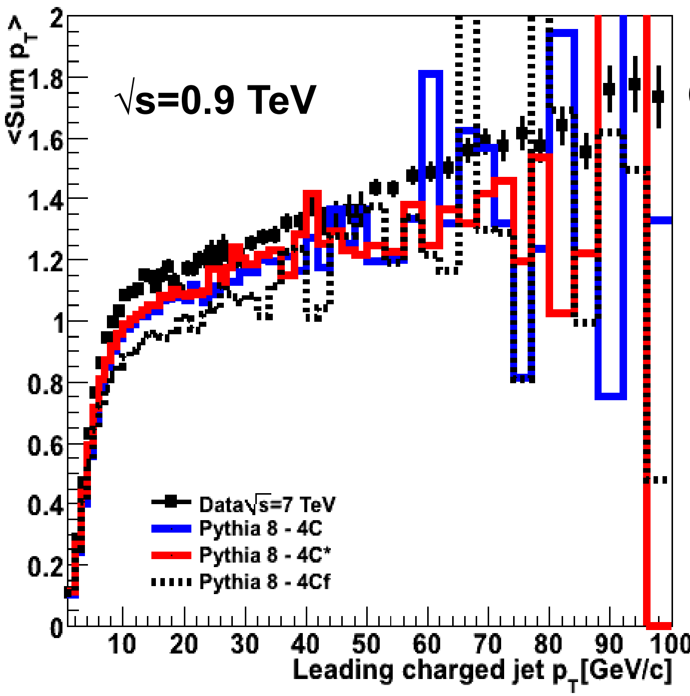


Most significant change is in N_{ch} for low pt jet events. Also at low $\sum p_t$ 4C* makes a difference.

<N> and Σp_t vs $P_{t,lead}$ – Z2* and Z2f

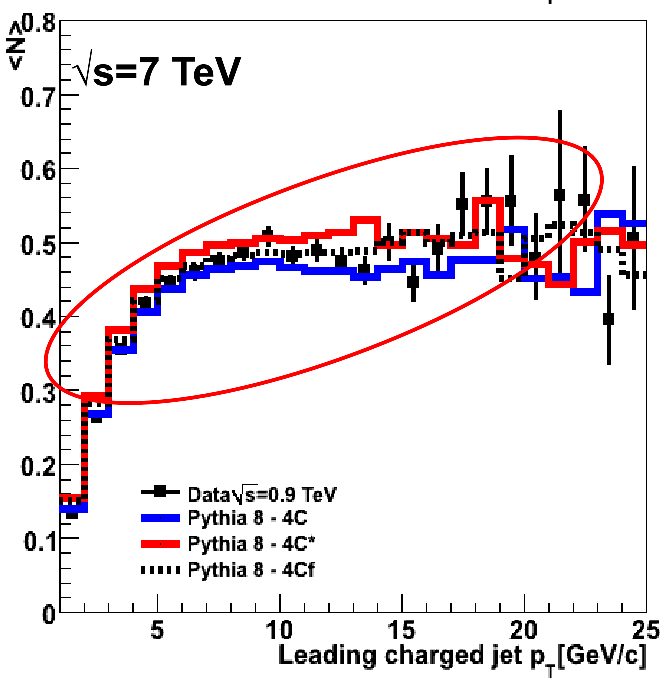
Blue: 4C Red: 4C* Black dashed: 4Cf

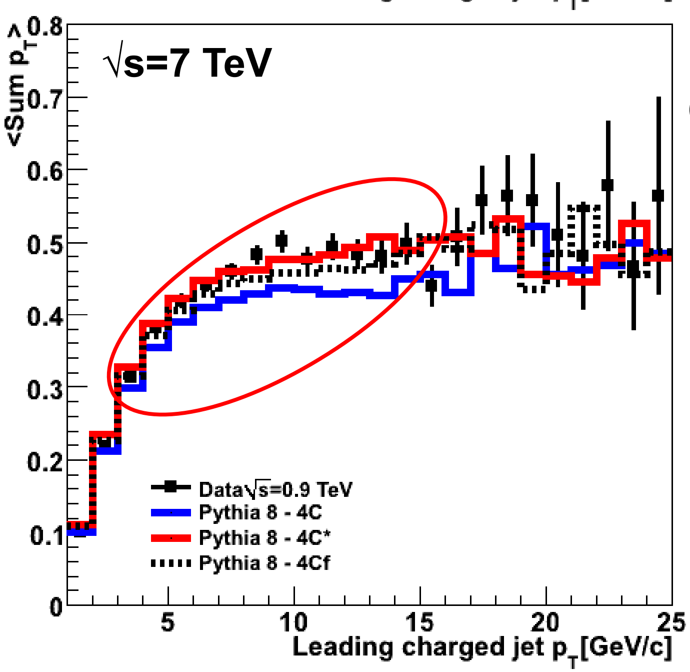




@0.9 TeV:

4C* – no improvement over 4C.
4Cf – too low activity.





@7TeV:

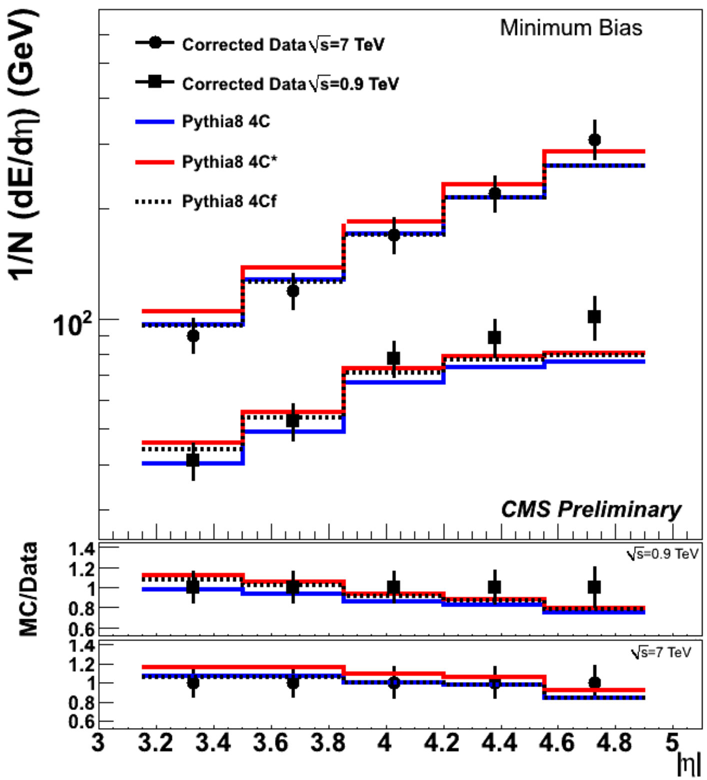
4C* and 4Cf both give increased activity compared to 4C.
This is what we need, but N_{ch} too high in 4C*.

Comparison to the Forward E-flow

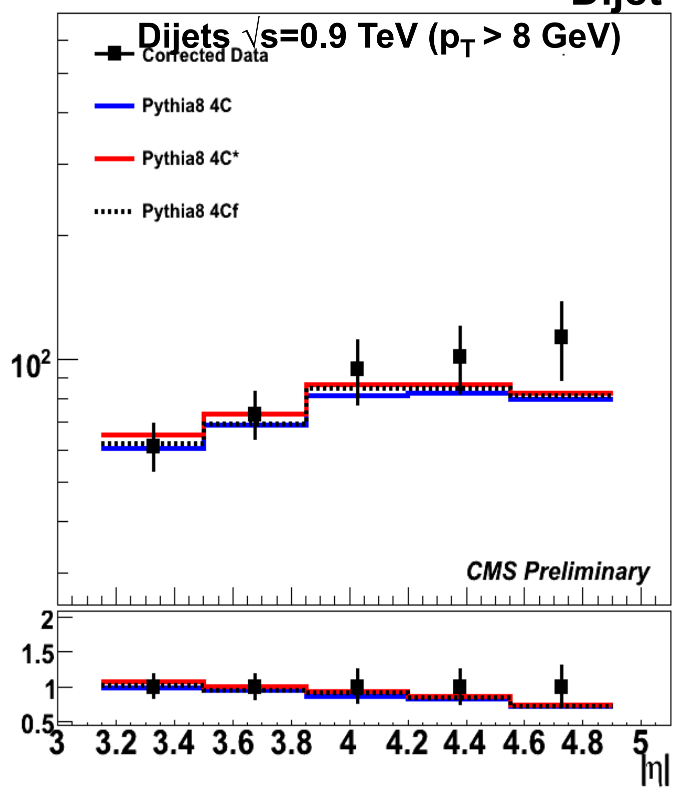
parameter	tuning range	4C	4C*	4Cf
pT0Ref	1.0 - 3.0	2.09	1.95	1.99
ecmPow	0.0 - 0.4	0.19	0.17	0.21
expPow	0.4 - 10.0	2.0	3.2	3.0
reconnectRange	0.0 - 9.0	1.5	4.7	3.05

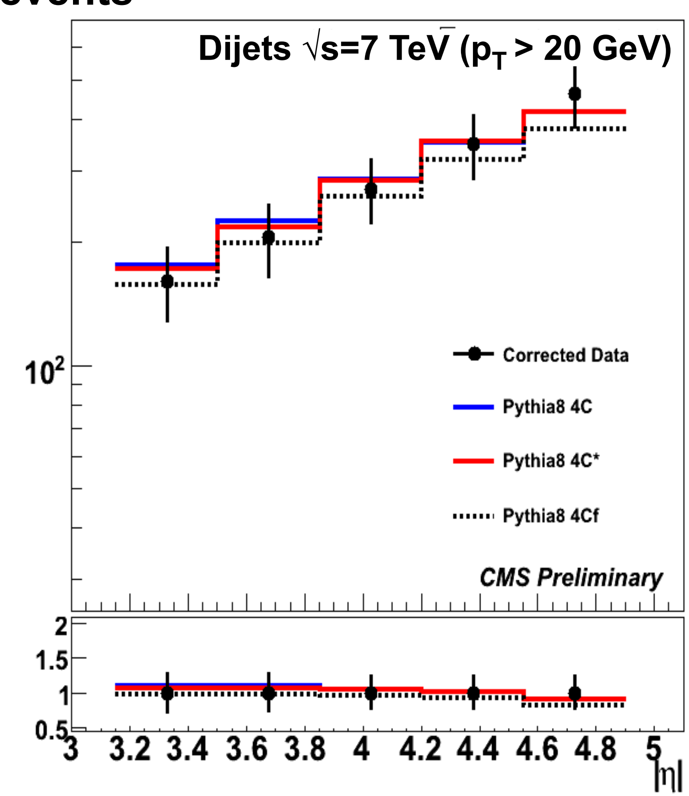
Very little sensitivity, compard to the UE measurement.
No significant difference.
Only difference comparing 4Cf to 4C is for 7 TeV dijet events.

MB events



Dijet events





Status of CMS Rivet analyses

CMS Rivet Analyses

The following Rivet analyses have been sent to the Rivet developers, and are soon officially available.
(We are currently iterating some details with the Rivet team.)

- **P_t and η distributions of charged hadrons in pp collisions at √s = 0.9 and 2.36 TeV.**
  JHEP 1002:041,2010, arXiv:1002.0621 (CMS-QCD-09-010)

- **P_t and η distributions of charged hadrons in pp collisions at √s = 7 TeV.**
  Phys.Rev.Lett.105:022002,2010, arXiv:1005.3299 (CSM-QCD-10-006)

- **Charged particle multiplicities in pp interactions at √s = 0.9, 2.36, and 7 TeV.**
  JHEP 1101:079,2011, arXiv:1011.5531 (CSM-QCD-10-004)

- **Strange Particle Production in pp Collisions at √s = 0.9 and 7 TeV**
  JHEP 1105:064,2011,arXiv:1102.4282 (CMS-QCD-10-007)

- **Dijet Angular Distributions and Search for Quark Compositeness at √s = 7 TeV**
  Phys.Rev.Lett.106:201804,201, arXiv:1102.2020 (CMS-QCD-10-016)

More to come...

Summary

- **Tuning activity "within" CMS has started.** (Results not CMS approved.)

- **Z2* tune to UE measumrent.**
  Clear improvement over the old Z2 tune.
  New energy dependence: Just what we needed (for the UE).
  Less transverse activity for the 0.9 TeV data, more activity for the 7 TeV data.

- **4C* tune to UE measurement.**
  Improved description of data at low p_t (compared to 4C).
  But improvements not as obvious for the Z2* tune.

- **Z2f and 4Cf tunes to the forward energy flow measurement.**
  Little difference in forward energy flow between new and old tunes.
  Although, Z2f somewhat better description
  of the energy flow data at 7 TeV.

- **CMS Rivet Routines.**
  First 5 routines sent to developers yesterday.
  More to come.

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Back-up

The Pythia 8 – Tune 4C

Parameter	Tune 2C	Tune 2M	Tune 4C
SigmaProcess:alphaSvalue	0.135	0.1265	0.135
SpaceShower:rapidityOrder	on	on	on
SpaceShower:alphaSvalue	0.137	0.130	0.137
SpaceShower:pT0Ref	2.0	2.0	2.0
MultipleInteractions:alphaSvalue	0.135	0.127	0.135
MultipleInteractions:pT0Ref	2.320	2.455	2.085
MultipleInteractions:ecmPow	0.21	0.26	0.19
MultipleInteractions:bProfile	3	3	3
MultipleInteractions:expPow	1.60	1.15	2.00
BeamRemnants:reconnectRange	3.0	3.0	1.5
SigmaDiffractive:dampen	off	off	on
SigmaDiffractive:maxXB	N/A	N/A	65
SigmaDiffractive:maxAX	N/A	N/A	65
SigmaDiffractive:maxXX	N/A	N/A	65

Pythia 6 – Tune Z2

PYTHIA Tune Z2

My guess!

Parameter	Tune Z1 (R. Field CMS)	Tune Z2 (R. Field CMS)
Parton Distribution Function	CTEQ5L	CTEQ6L
PARP(82) – MPI Cut-off	1.932	1.832
PARP(89) – Reference energy, E0	1800.0	1800.0
PARP(90) – MPI Energy Extrapolation	0.275	0.275
PARP(77) – CR Suppression	1.016	1.016
PARP(78) – CR Strength	0.538	0.538
PARP(80) – Probability colored parton from BBR	0.1	0.1
PARP(83) – Matter fraction in core	0.356	0.356
PARP(84) – Core of matter overlap	0.651	0.651
PARP(62) – ISR Cut-off	1.025	1.025
PARP(93) – primordial kT-max	10.0	10.0
MSTP(81) – MPI, ISR, FSR, BBR model	21	21
MSTP(82) – Double gaussion matter distribution	4	4
MSTP(91) – Gaussian primordial kT	1	1
MSTP(95) – strategy for color reconnection	6	6

Reduce PARP(82) by factor of 1.83/1.93 = 0.95
Everything else the same!

PARP(90) same
For Z1 and Z2!