

The Status of Event Generator Tuning in CMS

Stephen Mrenna

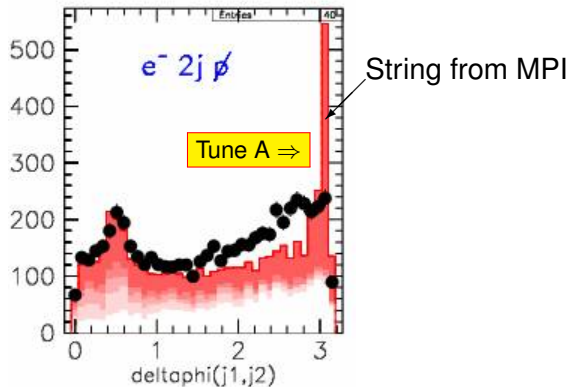
Fermilab
for the CMS Collaboration

November 14, 2013

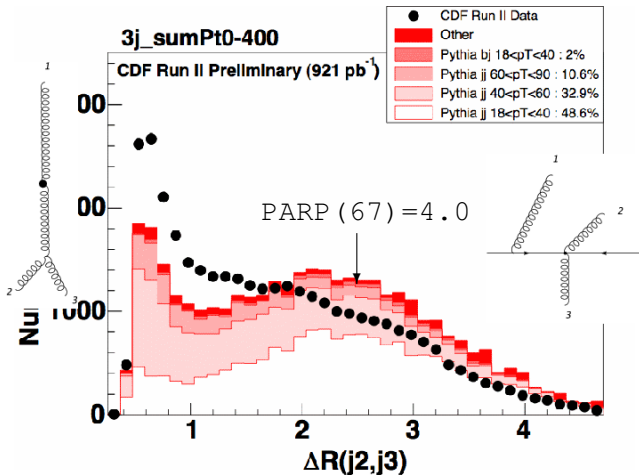
- 1 The Past
 - Z2* and 4C/4C*
 - How did these tunes come about?
 - What data was used, RIVET
- 2 Comparisons
 - Totem data
 - UE in hard events, ...
- 3 Tuning Strategy
 - Basics
 - CDF energy scan data, ...
- 4 Open Issues
 - Powheg+Pythia
 - b-fragmentation
- 5 Conclusions

History of Tunes A-D

- 1 Theorist [R. Field] joins CDF
- 2 He can look at charged tracks, because he can't screw that up
- 3 Uses this as a vehicle to study UE
- 4 Finds the "best" tune is one that enhances ISR and has decreased MI interaction
- 5 Side note: I express concerns about best fit, but cannot quantify the size of an effect. Concerns are dismissed.
- 6 Tune A is almost exclusively adopted by the experiments and used for LHC extrapolations (with caveats)
- 7 Lots of good physics ensues

High- p_T observables are sensitive to UE

Need to allow FSR for multiple parton interactions



Don't increase starting scale for ISR

- Some theorists should join the experiments
- Theorists should check theorists
- UE tunes are **Event** tunes – impact on more than properties of low pT charged tracks
- Trust, but verify your tunes

Pythia6.4 Tunes

Z1 : First CMS tune including 7-TeV LHC data

Many features of AMBT1 (ATL-PHY-PUB-2011-008)

Based on CTEQ5L

Manual retune of MPI parameters by RF

Lower pT0 at the Tevatron, faster scaling with energy

Z1-LEP : Z1 + improved LEP parameters from Prof/Perguia by PS

Z2 : Z1 + CTEQ6L by RF

Forgot to change energy dependence (did not fit 900 GeV data)

Z2-LEP : Z2 + improved LEP parameters from Prof/Perugia

Z2* : Professor-based by Knutsson and Zakaria

CMS leading charged jet “transAVE” UE data at 900 GeV/7 TeV

Fixed energy dependence

Pythia8 Tunes

Internal Pythia8 Tunes

2C CTEQ 6L1: agrees with much of the published CDF data

4C 2C + reduced SD + modified MPI parameters to give a higher and more rapidly increasing charged pseudorapidity plateau

CMS Tunes

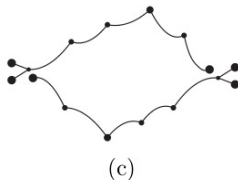
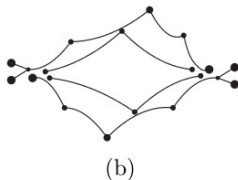
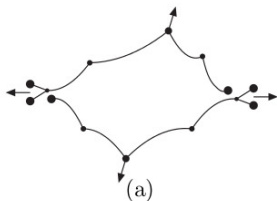
4C* CMS leading chgjet “transAVE” data at 900 GeV and 7 TeV

4Cf CMS energy flow in $3.15 < |\eta| < 4.9$ from MB and dijet data

parameter	4C	4C*	4Cf	Explanation
pT0ref	2.09	1.95	1.99	color screening
ecmPow	0.19	0.17	0.21	rise with \sqrt{S}
expPow	2.0	3.2	3.0	b profile
reconnect range	1.5	4.7	3.05	prob. for CR

$$pT0 = pT0(\text{ecmNow}) = pT0\text{Ref} * (\text{ecmNow}/\text{ecmRef})^{\text{ecmPow}}$$

Cartoon of color reconnection of low pT subscattering



Overview of 2011 Tuning Efforts

4 CMS Tunes: Z2*, Z2f, 4C*, 4Cf

- **Z2***: improved energy dependence – CMS default
- **4C***: little advantage over 4C
- **Z2f, 4Cf**: data not constraining enough
- Best results from manual tuning!

A good tuner plays well with others

We have benefited from ATLAS data, tuning efforts

About 22 CMS Analyses in Public Rivet

- Traditional UE, UE in DY, Strangeness, Forward Energy Flow, . . .

About 16 in CMS Rivet or under construction

- “The ridge,” Color Coherence, Substructure, . . .

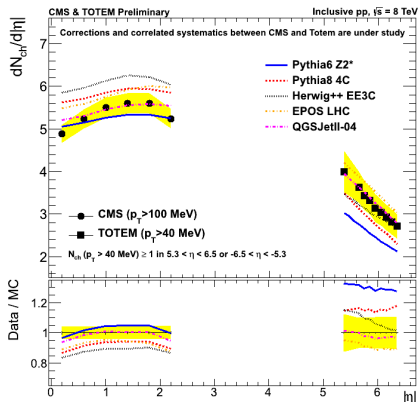
Exciting possibilities to better describe the collider data!

- Lots of material to work with
- Many tests and comparisons of data and current tunes
- But no official tuning results yet for 2013

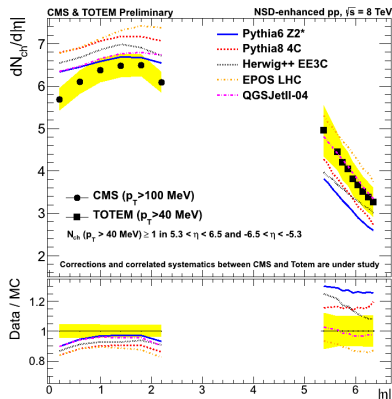
- Pythia8 is a priority (because of its general utility)

- Some comparisons . . .

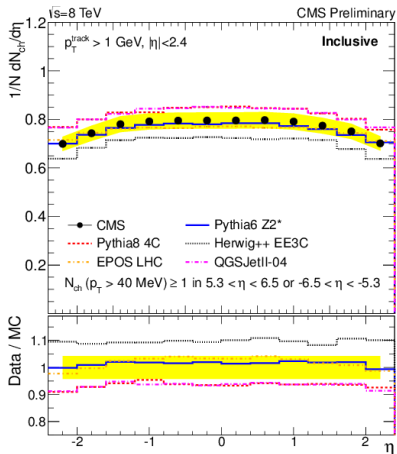
$dN_{ch}/d|\eta|$ at 8 TeV for tracks in $|\eta| < 2.4$ with $p_T > 100$ MeV as measured from CMS
and for tracks in $5.3 < |\eta| < 6.5$ with $p_T > 40$ MeV as measured by the TOTEM T2



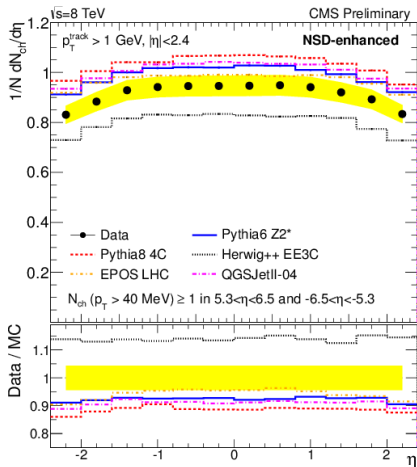
Tracks in either hemisphere



Tracks in both hemispheres

Charged particle eta distributions at 8 TeV for tracks in $|\eta| < 2.4$ with $p_T > 1$ GeV.

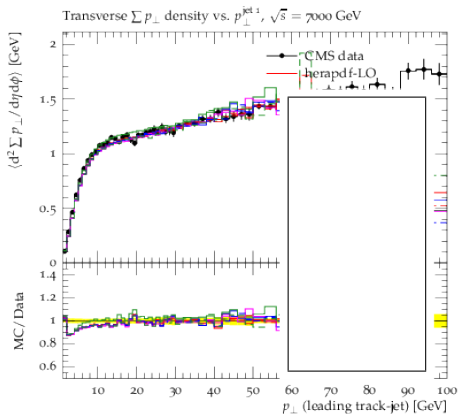
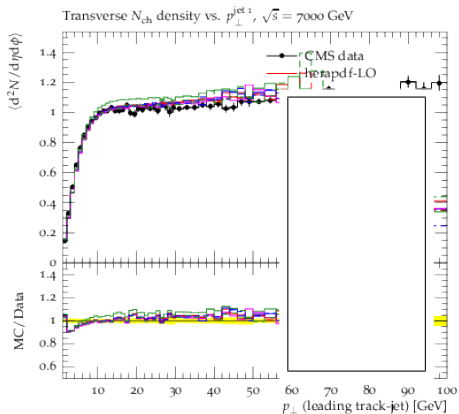
Tracks in either hemisphere

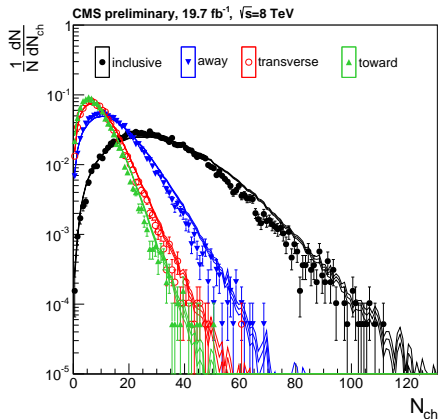


Tracks in both hemispheres

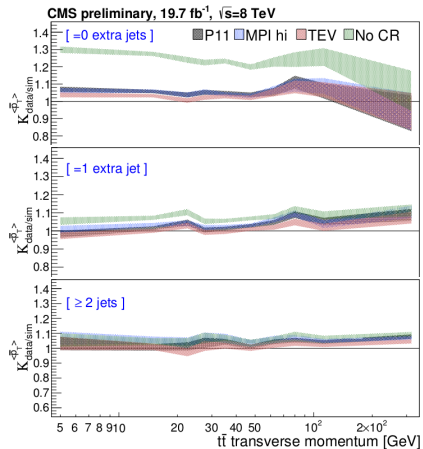
HERAPDFs use only HERA NC and CC data
 Comparisons to CMS UE at 0.9 and 7 TeV with $p_T > 500$ MeV.

First LO-error results





“Traditional” Charged Track Counting
 but in $t\bar{t}$ events ($e\mu$)
 Pythia6 Tune Z2*

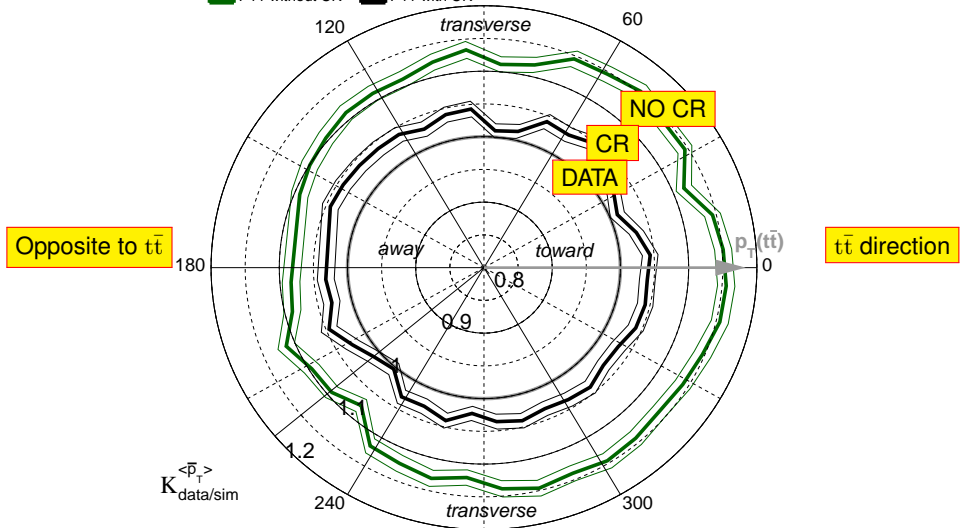


Data-to-simulation ratio for the
 average p_T of the charged particles.

$N_{\text{extra-jets}} = 0, 1, 2$

CMS preliminary, 19.7 fb^{-1} , $\sqrt{s}=8 \text{ TeV}$

[inclusive]

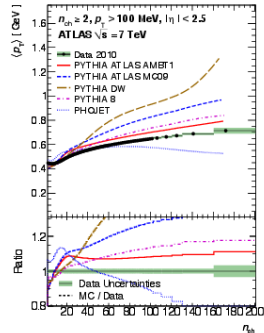
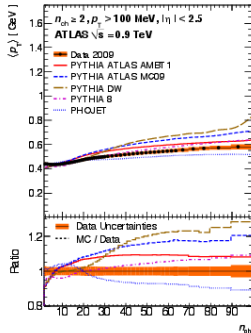
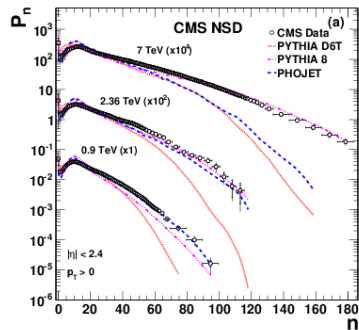
■ P11 without CR ■ P11 with CR


Phase I Tune energy dependence with as many points as possible

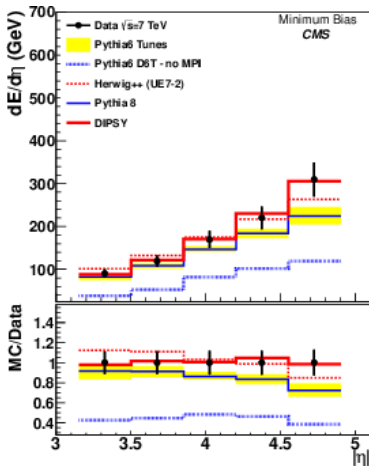
- $dN_{ch}/d\eta$ (CMS, ATLAS, others)
- $\langle p_T \rangle, \langle n_{ch} \rangle$ vs. \sqrt{s} (CMS)

Phase II Include correlations

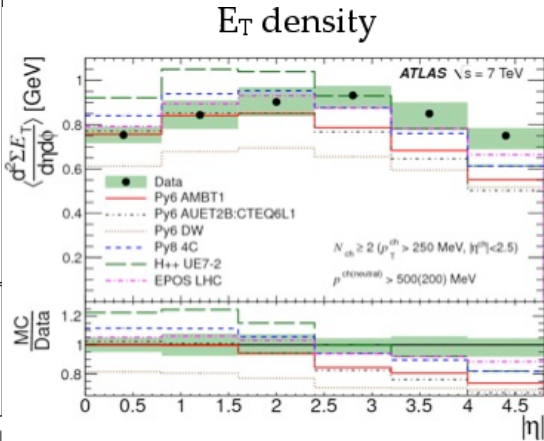
- $\langle p_T \rangle$ vs n_{ch} for various \sqrt{s}



Phase III Add E-flow (CMS/ATLAS) – info on neutrals



CMS_2011_S9215166



ATLAS_2012_I1183818

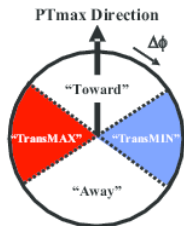
Phase IV Review and choose weights for data



PTmax UE Data

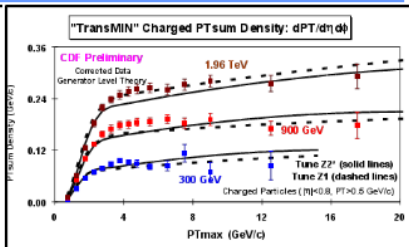
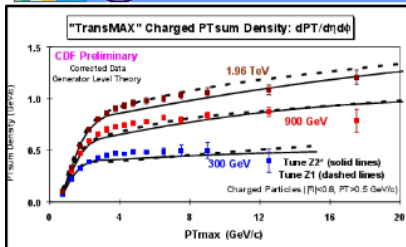


- **CDF PTmax UE Analysis:** “transMAX”, “transMIN”, “transAVE”, and “transDIF” charged particle and PTsum densities ($p_T > 0.5$ GeV/c, $|\eta| < 0.8$) in proton-antiproton collisions at 300 GeV, 900 GeV, and 1.96 TeV (R. Field analysis).
- **CMS PTmax UE Analysis:** “transMAX”, “transMIN”, “transAVE”, and “transDIF” charged particle and PTsum densities ($p_T > 0.5$ GeV/c, $|\eta| < 0.8$) in proton-proton collisions at 900 GeV and 7 TeV (M. Zakaria analysis). The “transMAX”, “transMIN”, and “transDIF” are not yet approved so I can only show “transAVE” which is approved.
- **CMS UE Tunes:** PYTHIA 6.4 Tune Z1 (CTEQ5L) and PYTHIA 6.4 Tune Z2* (CTEQ6L). Both were tuned to the CMS leading chgjet “transAVE” UE data at 900 GeV and 7 TeV.
- **PYTHIA 8:** Some comparisons with PYTHIA 8 Tune 4C (CTEQ6L), Richard Corke and Torbjörn Sjöstrand, JHEP 1103:032 (2011), arXiv:1011.1759.

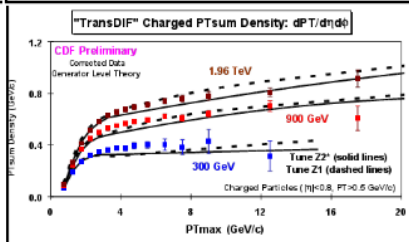




“transMAX/MIN” PTsumDen



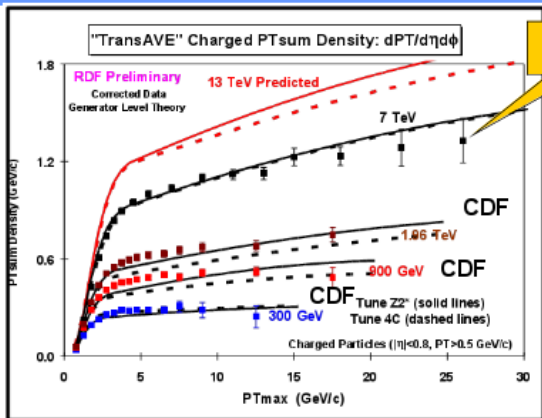
→ Corrected CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged PTsum density in the “transMAX”, “transMIN”, and “transDIF” regions as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty. The data are compared with PYTHIA 6.4 Tune Z1 and Tune Z2*.



Rick Field – Florida/CDF/CMS Page 25



“Tevatron” to the LHC



PYTHIA 8 Tune 4C (dashed lines) - Corke & Sjöstrand



Next CMS UE Tune

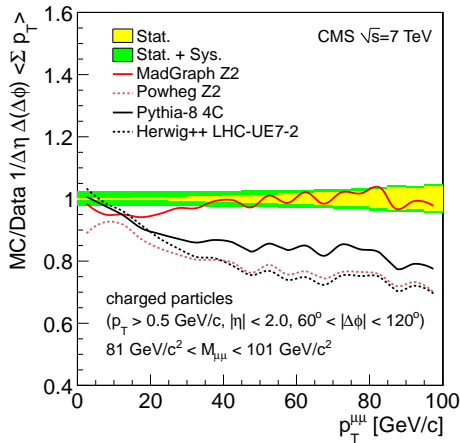
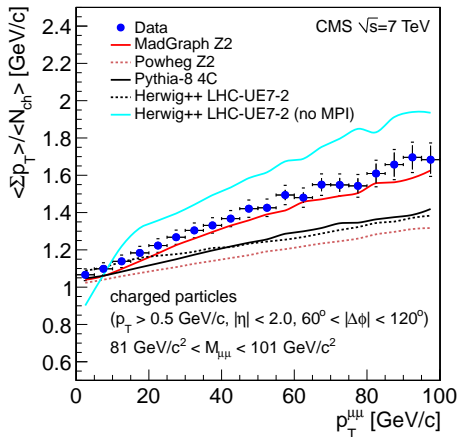


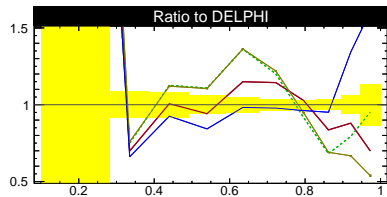
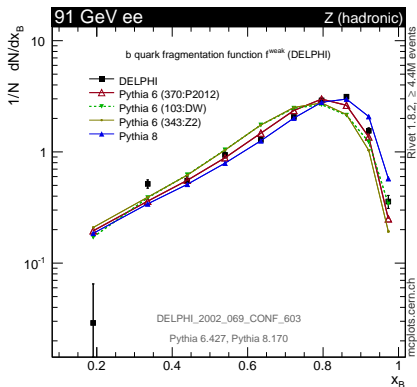
PYTHIA 8: Improved Version of Tune 4C*

- ➔ **CDF Data (1.96 TeV, 900 GeV, 300 GeV??)** – **PTmax UE Observables:** “transMAX” & “transMIN” charged particle and PTsum densities.
- ➔ **CMS Data (7 TeV)** – **PTmax UE Observables:** “transMAX” & “transMIN” charged particle and PTsum densities.
- ➔ **CMS Data (900 GeV & 7 TeV)** – **ChgJet UE Observables:** “transAVE” charged particle and PTsum densities.

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

Powheg + Pythia does not describe DY data

<http://arxiv.org/abs/arXiv:1204.1411>




Given the experimental precision of $t\bar{t}$ measurements, it is worth reevaluating the theory inputs

From the mcplots repository, we find that b-fragmentation measurements are not well-described by current tunes

We find mcplots so useful, that we want an internal version for CMS

- CMS started off Run I with Tune Z2* (Pythia6) and 4C* (Pythia8)
- For Run II, a new subgroup to organize tuning efforts (chaired by R.D. Field and H. Jung)
- 20-ish datasets in Rivet, more coming
- Starting on two separate tunes (UE, MB)
- First results on tuning ME+PS calculations
- Many other “discrepancies” to investigate

OVERFLOW

Analysis code	Short description	Rivet Name	Validation plots	Responsible	Status / Notes / To Do
QCD-10-013	Hadron even shapes	CMS_2011_S8957746	-	Rivet	Official Rivet 1.5 <input checked="" type="checkbox"/>
QCD-09-010	Charged hadrons dn/deta (0.9 and 2.36 TeV)	CMS_2010_S8547297	dndeta_d6t_900 dndeta_d6t_2360	Kevin Stenson	CMS approved. Accepted by Rivet (1.5.1b) <input checked="" type="checkbox"/>
QCD-10-006	Charged hadrons dn/deta (7 TeV)	CMS_2010_S8656010	dndeta_d6t_7000	Kevin Stenson	CMS approved. Accepted by Rivet (v1.5.1b) <input checked="" type="checkbox"/>
QCD-10-007	Strangeness	CMS_2011_S8978280	d6t_900 d6t_7000	Kevin Stenson	CMS approved. Accepted by Rivet (v1.5.1b) <input checked="" type="checkbox"/>
QCD-10-004	Charged particles multiplicities	CMS_2011_S8884919	KNO	Romain Roughy	CMS approved. Accepted by Rivet (v1.5.1b) <input checked="" type="checkbox"/>
QCD-10-016	Dijet angular ... and quark comp.	CMS_2011_S8968497	DijetAngular	Andreas Hinzmann	CMS approved. Accepted by Rivet (v1.5.1b) <input checked="" type="checkbox"/>
QCD-10-010	Traditional UE	CMS_2011_S9120041	UE7TeV	Mohammed Zakaria	CMS approved. Accepted by Rivet <input checked="" type="checkbox"/>
QCD-10-026	Di-jet azimuthal decorrelations	CMS_2011_S8950903	val-plots	Tomo Umer Cosmin Dragoiu	CMS approved. Accepted by Rivet <input checked="" type="checkbox"/>
QCD-10-012	3- and 2-jet ratios	CMS_2011_S9088458	val-plots	Tomo Umer	CMS approved. Accepted by Rivet <input checked="" type="checkbox"/>
QCD-10-011	Inclusive jet cross-sections	CMS_2011_S9086218	val-plots	Rasmus S Hansen / Paolo Gunnellini	CMS approved. Accepted by Rivet <input checked="" type="checkbox"/>
QCD-10-024	Pseudorapidity of charged hadrons	CMS_QCD_10_024	val plots	Panos Katsas	CMS approved. Accepted by Rivet <input checked="" type="checkbox"/>
QCD-11-012	UE in DY	CMS_2012_I1107658	val plots	Sunil Bansal	CMS Approved. Accepted by Rivet <input checked="" type="checkbox"/>

FWD-10-011	Forward E Flow	CMS_2011_S9215166	val-plots	Albert Knutsson	CMS approved. Accepted by Rivet
FWD-10-003 FWD-10-006	Forward and Forward+Central Jets	CMS_2012_I1087342	val-plots	Albert Knutsson	CMS approved. Accepted by Rivet
FWD-10-014	Dijet k-factor	CMS_2012_I1102908	twiki	Vadim Oreshkin	CMS approved. Accepted by Rivet
FWD-10-004	Diffractive Di-jets	CMS_2012_I1184941	val-plots	Sercan Sen	CMS approved. Accepted by Rivet
QCD-11-010	Strangeness UE	CMS_2012_PAS_QCD_11_010	val-plots	Sercan Sen	PAS-version CMS approved. PAS-version accepted by Rivet
FWD-11-001 and QCD-11-002	Inelastic cross-section	CMS_2012_I1193338	val-plots	Sercan Sen	CMS approved. Accepted by Rivet
FWD-10-005	excl. diphoton production of muon pairs	CMS_2011_I954992	val-plots	Sercan Sen	CMS approved. Accepted by Rivet
FWD-11-003	UE in CASTOR	CMS_2012_PAS_FWD_11_003	to be added	Samantha Dooling	PAS-version CMS approved. PAS-version accepted by Rivet
BPH-10-007	Open beauty production cross section with muons	CMS_2011_S8941262	val-plots	Wolfram Erdmann	CMS approved. Accepted by Rivet
BPH-10-010	B Bbar angular correlations	CMS_2011_S8973270	val-plots	Lukas Wherli	CMS approved, with normalization as in paper. Accepted by Rivet

Status of ongoing Rivet plugins NEW

Analysis code	Short description	Rivet Name	Validation plots	Responsible	Status / Notes / To Do	In GIT ?
SMP-12-004	Z+jets and gamma+jets	CMS_2013_I1258128	zjets gammajets	Yu-hsiang Chang / Shin-Shan Yu	Approved by CMS. Submitted to Rivet developers (18/10 AK)	
SMP-13-007	Z+jets differential x-secs	CMS_SMP_13_007		Bhawandeep Bhawandeep	Close to done. Need to correctly book aida histos. Fix plot file etc. (10/10 AK) Ping (5/11 AK)	
SMP-12-019	Jet mass and substructure in dijet and V+jets events at 7 TeV	CMS_2013_I1224539	Dijets Z+jets W+jets	Salvatore Rappoccio	Sent to Rivet forum for feedback by Nhan 28/9 (10/10, AK).	
SMP-12-010	Color Coherence Measurement	CMS_SMP_12_010	Attached in mail.	Maxime Gouzevitch	Ready for submission once paper published. (23/8 LS).	
EWK-10-012	V+Jets ratios	CMS_EWK_10_012	V+jets	Lovedeep Saini	Feedback from CMS approval: Full published measurement needs to be included. Lovedeep in between contracts - will resume work asap.	Y
EWK-10-010	Pt and eta spectra of Z	CMS_EWK_10_010	Zpt	Justin Hugon	Approved by CMS. Need bugfix for external Rivet version.	Y
EWK-11-021	Azimuthal Correlations and Event Shapes Distributions in Z+jets Production	CMS_EWK_11_021	val-plots	Piergiulio Lenzi	Version in GIT, needs to be checked. Mail received (6/10, AK)	Y
QCD-11-005	Photon+jets differential cross section at 7 TeV	CMS_QCD_11_005		Chuanzhe Lin	Action of authors required; responsible have been contacted. Reminder and request for most recent files (12/8, AK)	

QCD-11-010	Strangeness Production in the Underlying Event	CMS_QCD_11_010		Tomas Hreus	New validation plots requested. 2/8 (AK)	
FSQ-12-020	Underlying Event Activity at the LHC at 7 TeV and Comparison with 0.9 TeV	CMS_FSQ_12_020		Mohammed Zakaria, Piergiulio Lenzi	Ongoing. Working on data analysis. (13/8, AK)	Y
FSQ-12-022	Properties of jets and underlying event as a function of particle multiplicity in p-p collisions at $\sqrt{s} = 7$ TeV	CMS_FSQ_12_022		Maxim Azarkin, Sercan Sen	Ongoing. Status requested (13/8, AK).	
FSQ-12-028	Double Parton Scattering via W + di-jet	CMS_2012_PAS_FSQ_12_028	validation plots	Sunil Bansal	Final details, then internal validation. Will be updated withiin short. (13/8 AK)	
FWD-11-003	UE in CASTOR	CMS_2012_PAS_FWD_11_003	to be added	Samantha Dooling	PAS-version accepted by Rivet. Need to rename files and correct one typo in the aida.	
SMP-12-027	3-jet mass cross section at 7 TeV and alphas	CMS_PAS_SMP_12_027	val plots	Klaus Rabbertz / Corinna GuentH	Iterating with authors. (28/8, AK)	
SMP-12-004	Rapidity distributions in Z+1jet and gamma+1jet	SMP_12_004	val plots	Yu-Hsiang	Feedback to authors (13/8, AK). Need to combine analyses into one plugin.	
QCD-10-002	Long-Range Near-Side Angular Correlations, "the ridge"	CMS_2010_S8808686	-	Albert Knutson	Root based analysis not accepted by Rivet, but 2D histogramming not possible in Rivet	Y