“Approval Talk”
Jet Shapes Analysis
AN-10-463 & QCD-10-029

Transverse Momentum Distributions within Jets in pp Collisions at $\sqrt{s}$=7 TeV at CMS

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Presentation of the Paper

- ☑ The paper was prepared by combining two individual analyses.
  - **Classical Jet Shapes** (AN-10-463 & QCD-10-029)
  - Mean Charged Particle Multiplicity (QCD-10-014)
    - Combined paper has 62 pages, 10 figures and 43 tables.
- ☑ We also would like to make the results in this link public as well.
  https://twiki.cern.ch/twiki/bin/viewauth/CMS/JetShapesResults

Other Twiki's :

- Analysis twiki page
  https://twiki.cern.ch/twiki/bin/view/CMS/JetShapes
- Dedicated twiki page for Preapproval Q&A:
  https://twiki.cern.ch/twiki/bin/viewauth/CMS/JetShapeClassicPreapprovalQandA
- Dedicated twiki page for ARC Review:
  https://twiki.cern.ch/twiki/bin/viewauth/CMS/JetShapes#ARC_Review

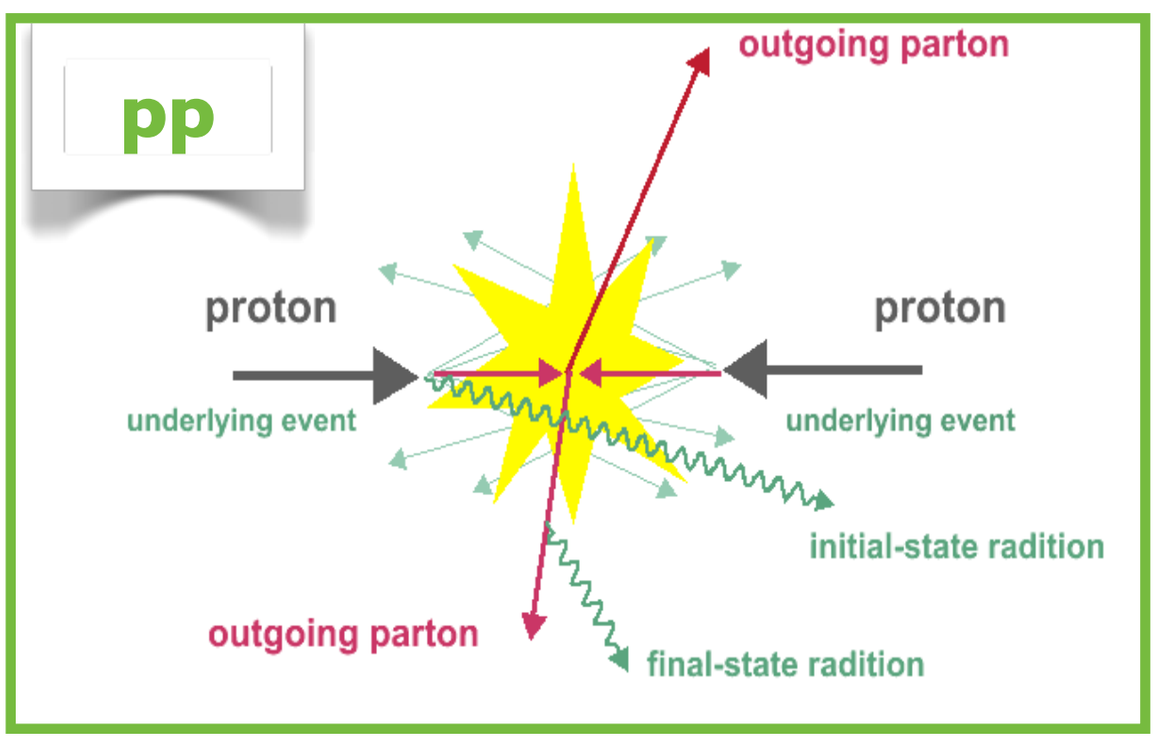
Outline

- ☑ Motivation
- ☑ Jet Shapes
- ☑ Systematics and Sensitivities
- ☑ Results

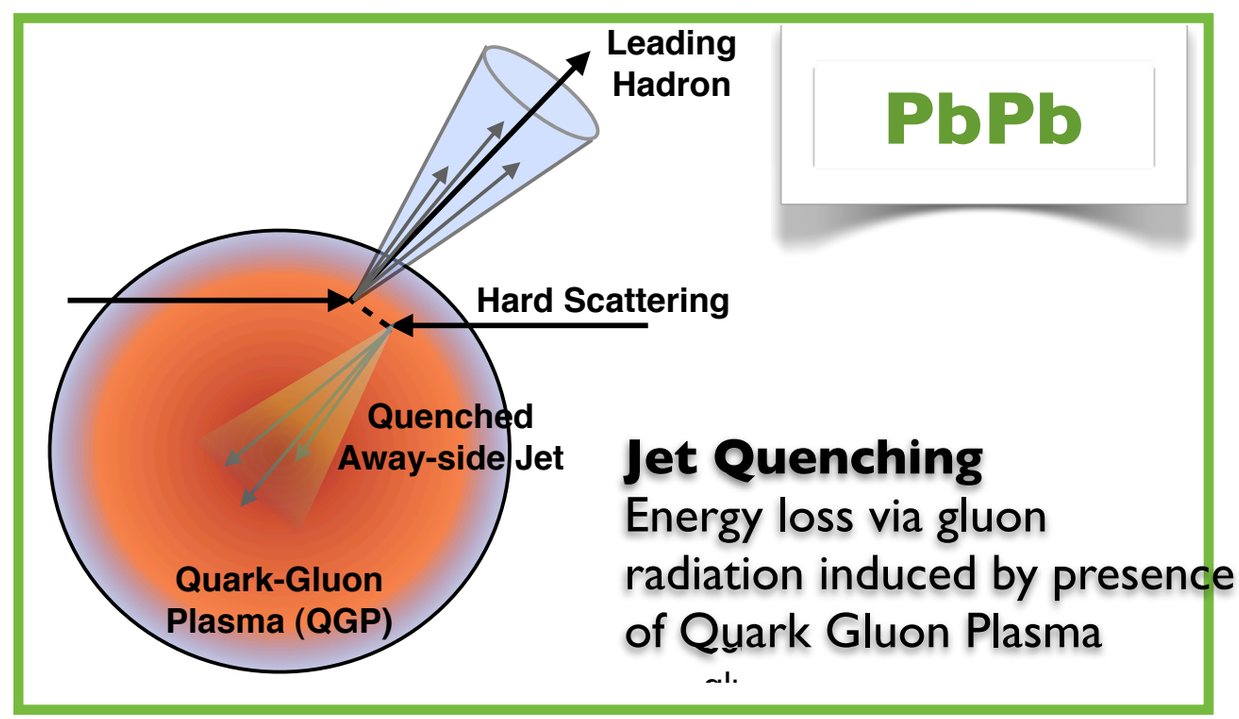
Motivation

Jet Shapes measure the average distribution of energy flow as a function of the distance away from the jet axis:

- ☑ Test showering models in Monte Carlo generators.
- ☑ Discriminate between different underlying event models.
- ☑ Sensitive to the quark/gluon jet mixture.
- ☑ Jet shapes can discriminate between competing models of jet quenching which have allsuccessfully described leading particle suppression in Relativistic Heavy Ion Collider (RHIC) data.

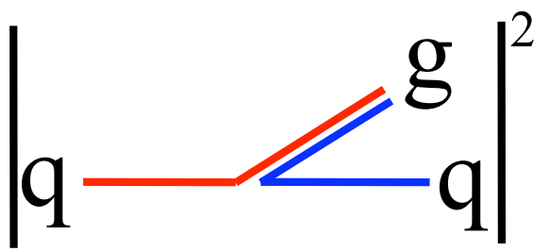


arXiv:0810.2807 (Ivan Vitev (LANL) and et. al)

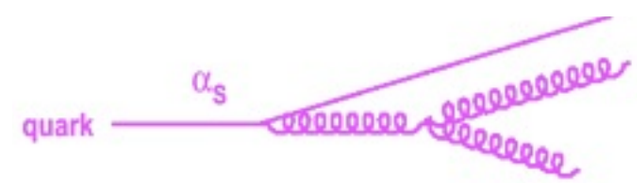


Quark and Gluon Jets

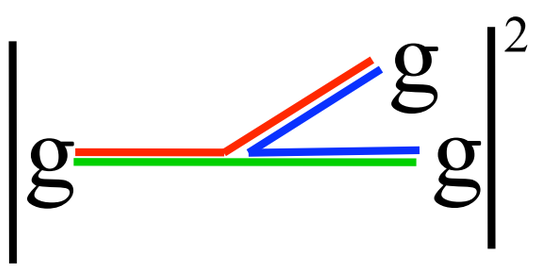
- ☑ Jet Shapes are sensitive to quark/gluon jet mixture
  - Can separate quark and gluon jets in a statistical way
- ☑ Quark and Gluon jets radiate proportionally to their color factors
  - CF : strength of gluon coupling to quarks
  - CA : strength of gluon self coupling



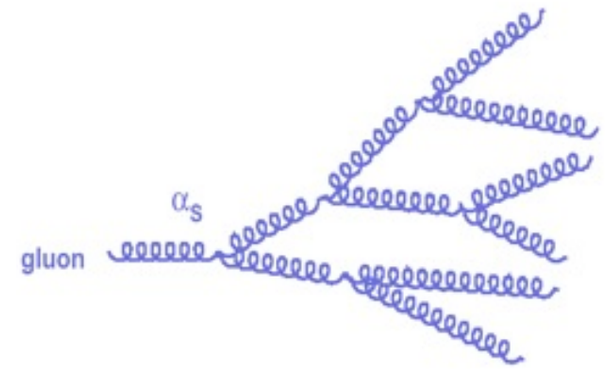
$$\sim C_F = 4/3$$



quark jets



$$\sim C_A = 3$$



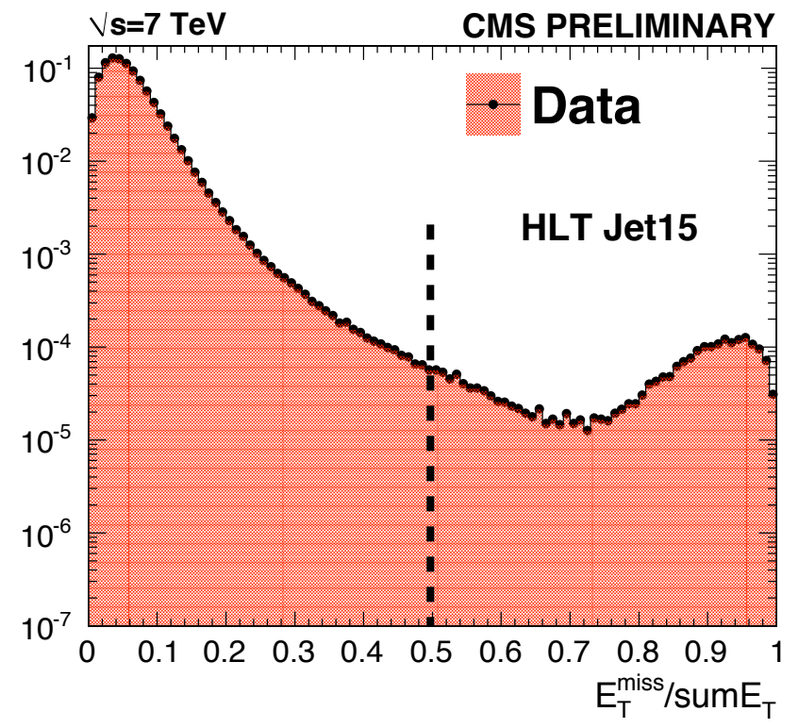
gluon jets

- ☑ In QCD, quark jets are expected to be narrower than gluon jets.
- ☑ Jets initiated by quarks and gluons are also expected to have different average multiplicities and p_T spectra of constituents.

Event Selection

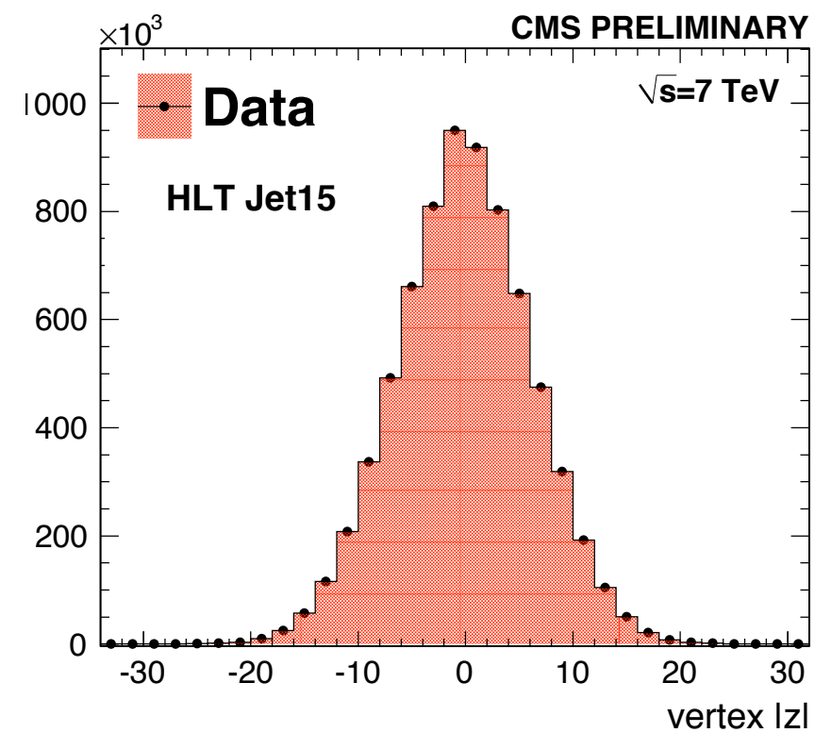
Cleaning

- HBHENoiseFilter to remove the non physics events
- $\not{E}_T / \sum E_T$ < 0.5 to remove fake jets
- Loose PFJetID cuts (AN2010-439) to remove jet which contain fake energy



Vertex Selection Criteria

- Number Of Degrees of freedom (ndof > 4)
- z position of the vertex (|z|<24 cm)
- Radial position of the vertex (|rho| < 2 cm)



Jet Selection

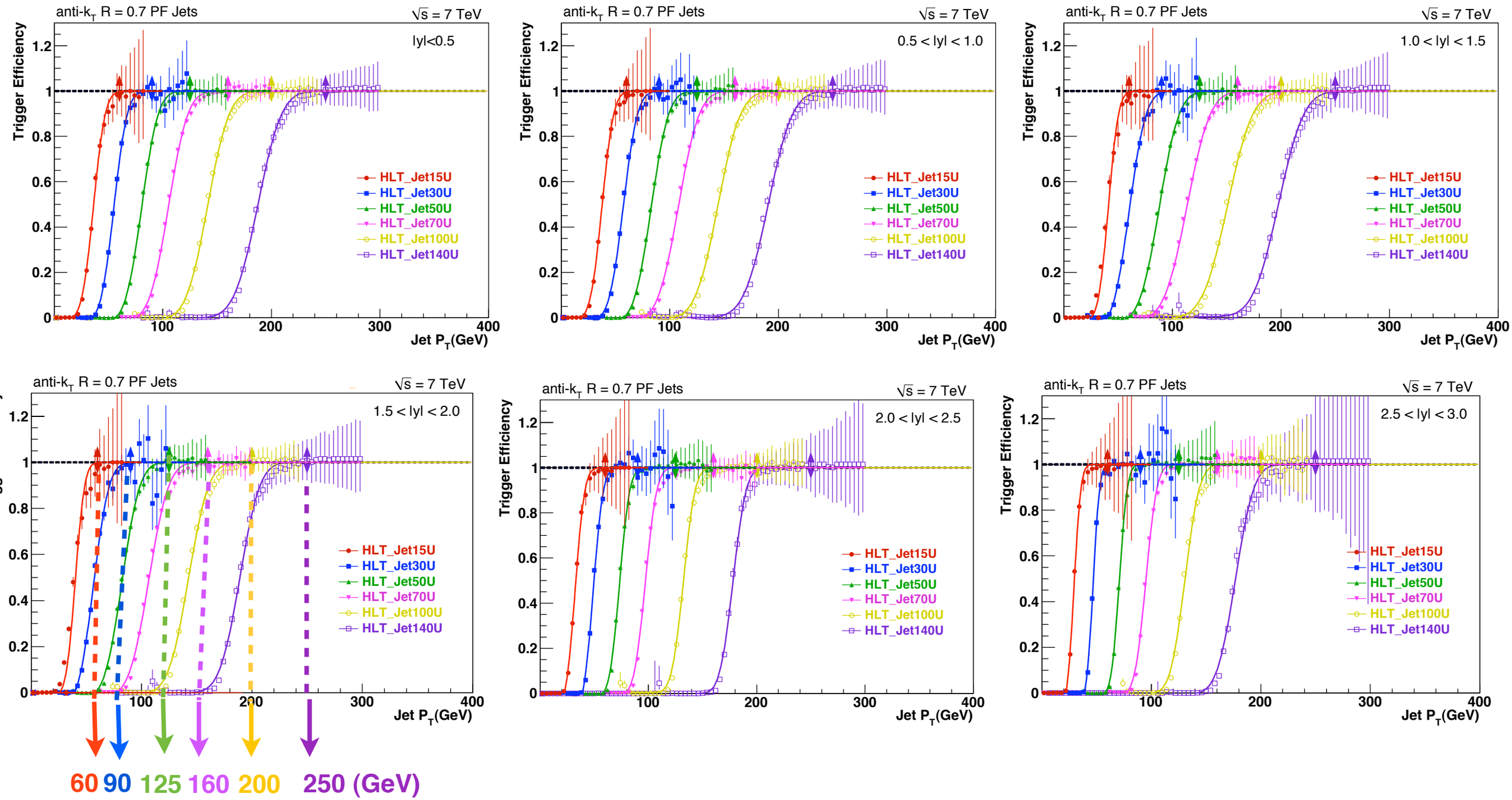
- Antik$_T$ PFJets are reconstructed with R=0.7 size with CMSSW_3_8_7
- All inclusive jets (require PFJetID and corr. p_T > 8GeV)
- All PF candidates are used in ΔR<0.7 from the jet axis
- Jet Energy Correction including residual corrections
- Central Rapidity bin: 0.0-1.0
  Fine rapidity bins : 0.0-0.5 , 0.5-1.0, 1.0-1.5, 1.5-2.0, 2.0-2.5, 2.5-3.0

Data Sets

- ☑ Monte Carlo Data (Fall10-START38-V12-v1)
  - Pythia6 (Tune Z2) [p_T hat bin : 0-1000GeV]
  - Pythia6 (Tune D6T) [p_T hat bin : 0-300GeV]
  - Pythia8 [p_T hat bin : 0-1000GeV]
  - Herwig++ (Tune 23) Flat : [p_T hat bin : 15GeV-3000GeV]
- ☑ Collider Data
  - JetRun2010B-Nov4ReReco-v1RECO
  - JetMETRun2010A-Nov4ReRec0-v1RECO
  - JetMETTauRun2010A-Nov4ReRec0-v1RECO
  - MinimumBiasCommissioning10-GOODCOLL-Jun14thSkim-v1RECO

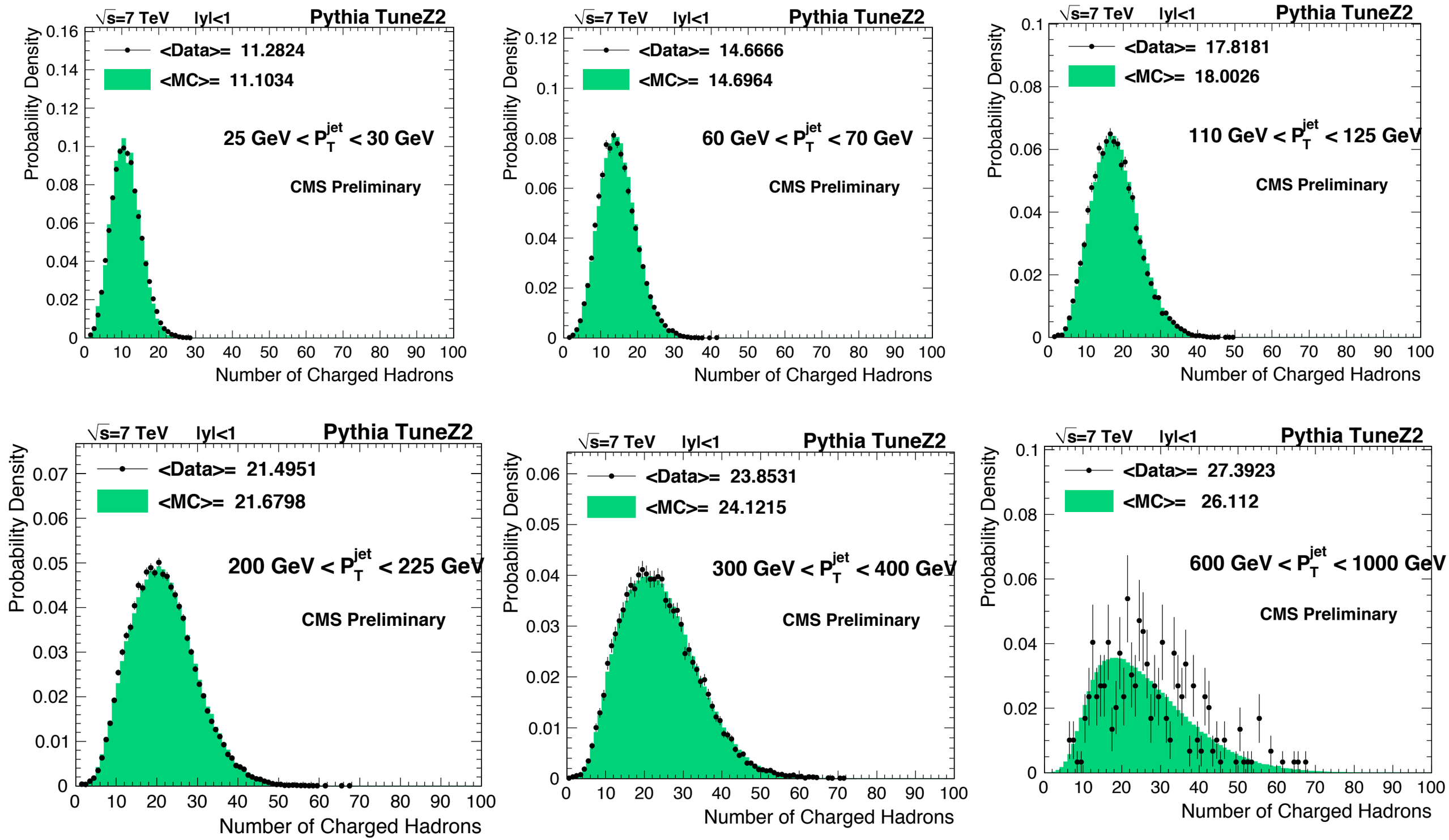
  Cert 136033-149442 7TeV Nov4ReReco Collisions10 JSON.txt (36 pb^{-1})
- ☑ Jet Triggers
  - HLT BscMinBiasOR-BptxPlusORMinus
  - HLT Jet15U
  - HLT Jet30U
  - HLT Jet50U
  - HLT Jet70U
  - HLT Jet100U
  - HLT Jet140U

Trigger Turn-on Curves



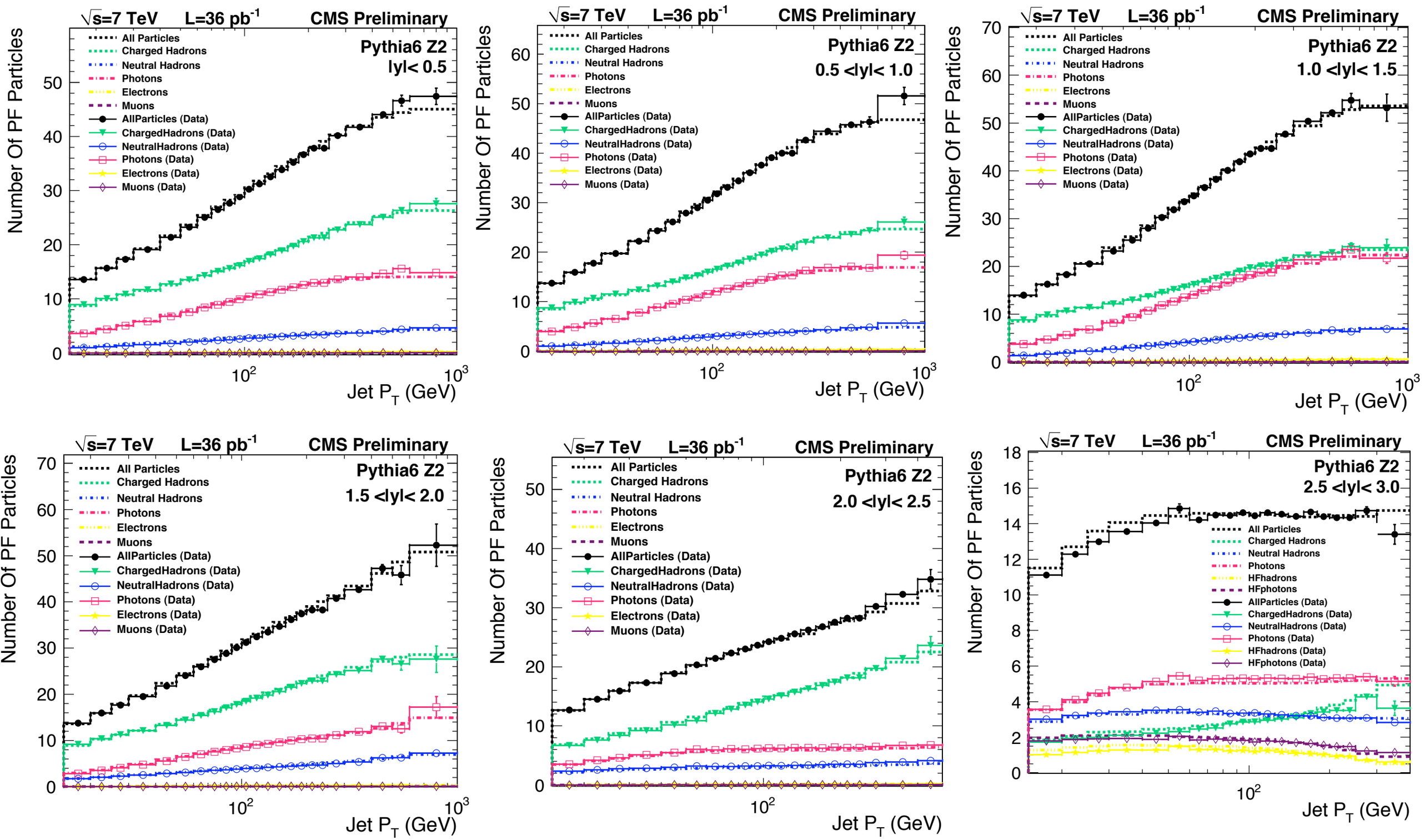
Trigger efficiencies look nicely plateauing at unity at high p_T's.

Multiplicity (Tune Z2)



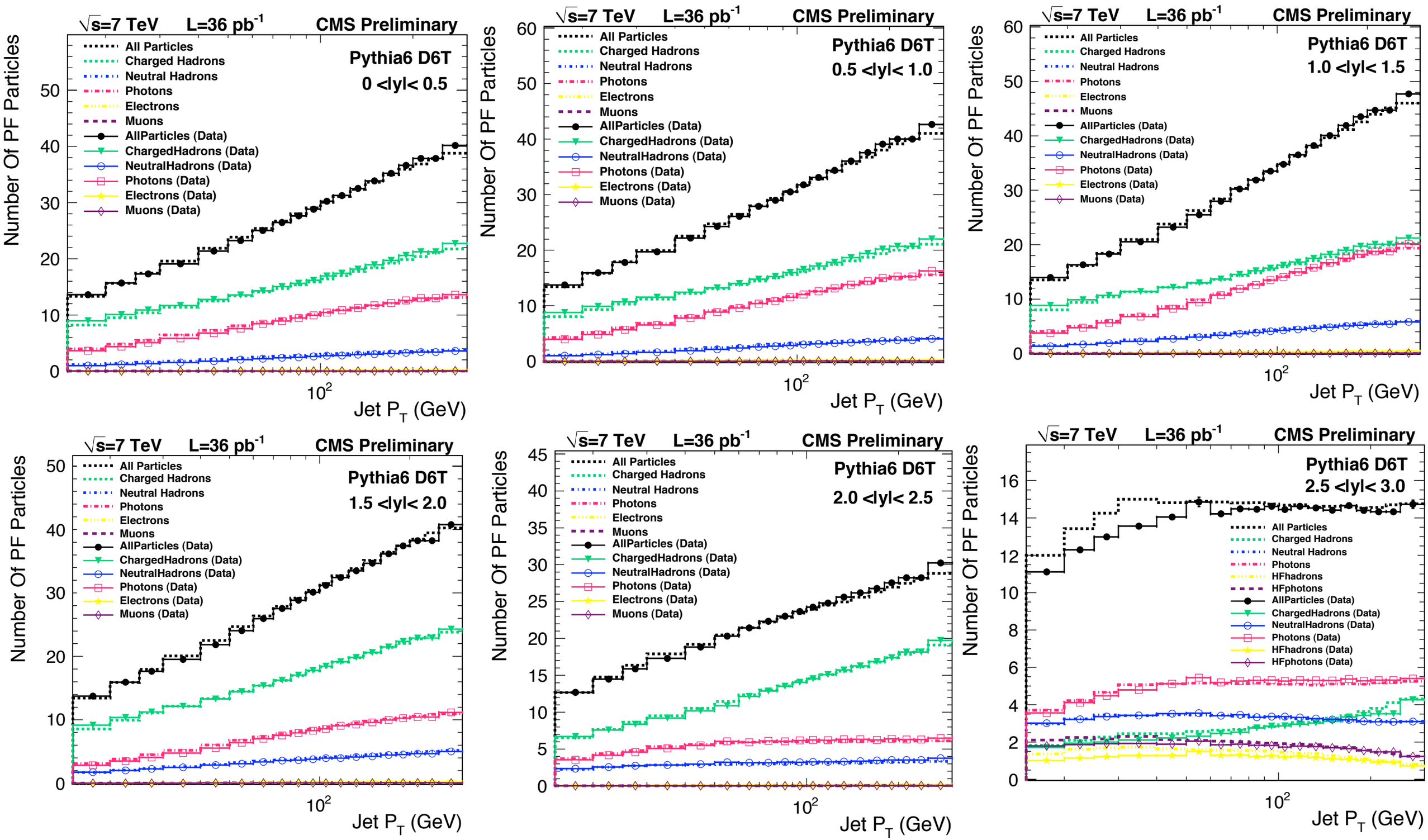
Multiplicity in a jet increases as a function of jet p_T.

Multiplicity vs P_T (Tune Z2)



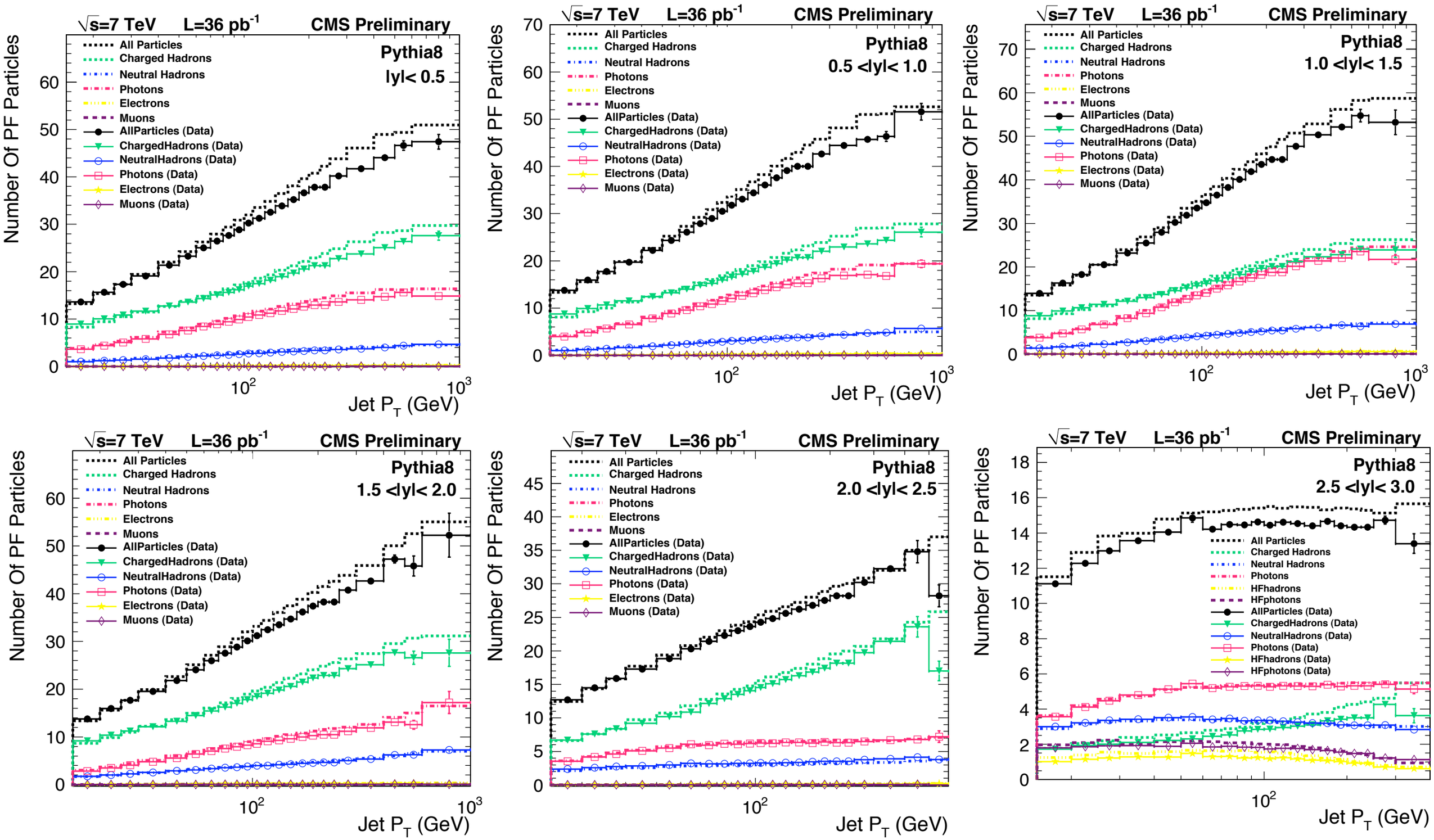
Multiplicity in a jet increases as a function of jet p_T for Pythia6 Tune Z2.

Multiplicity vs P_T (Pythia Tune D6T)



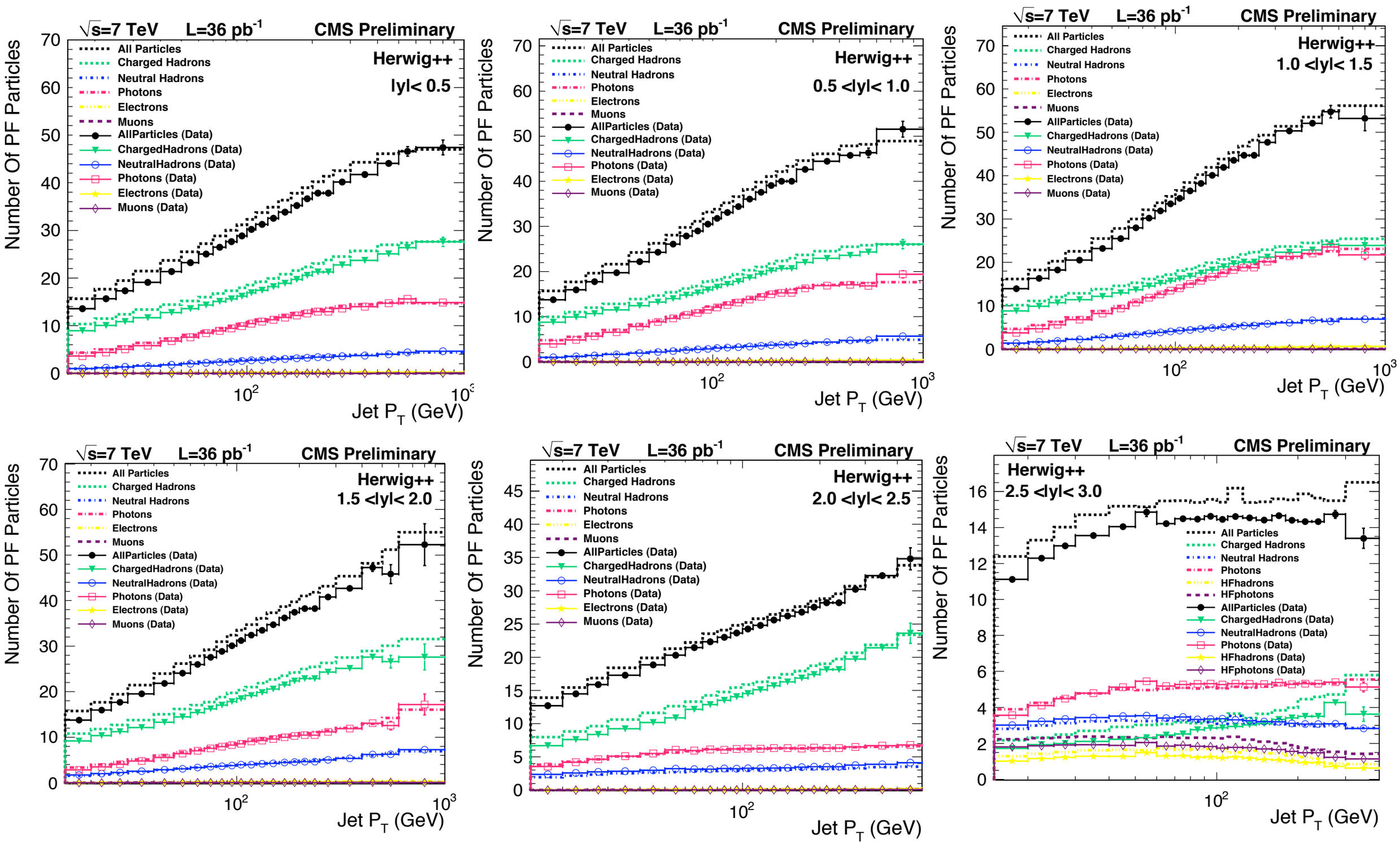
Similar trend is observed for Pythia6 Tune D6T as well.

Multiplicity vs P_T (Pythia8)



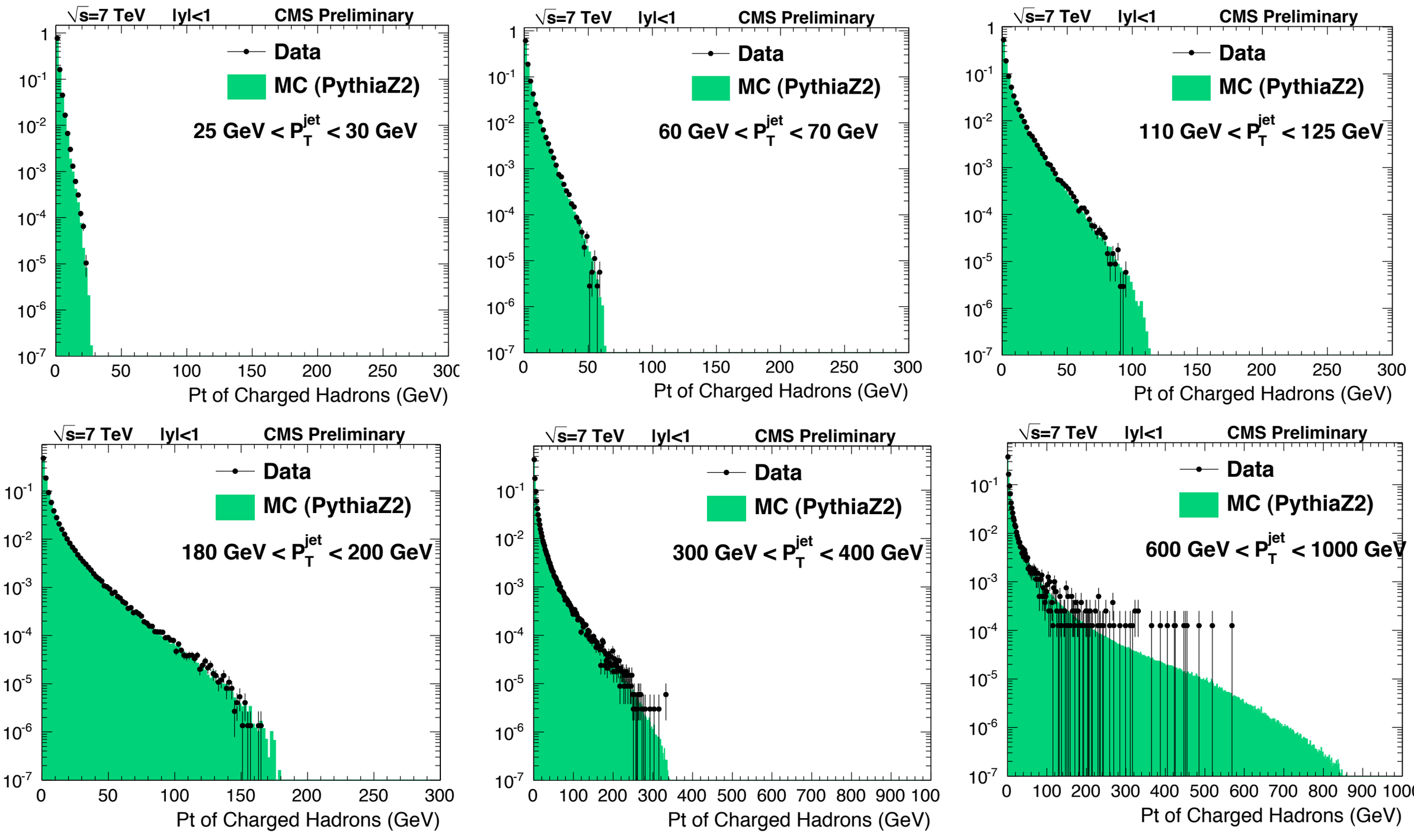
Similar trend is observed for Pythia8 as well.

Multiplicity vs P_T (Herwig++)



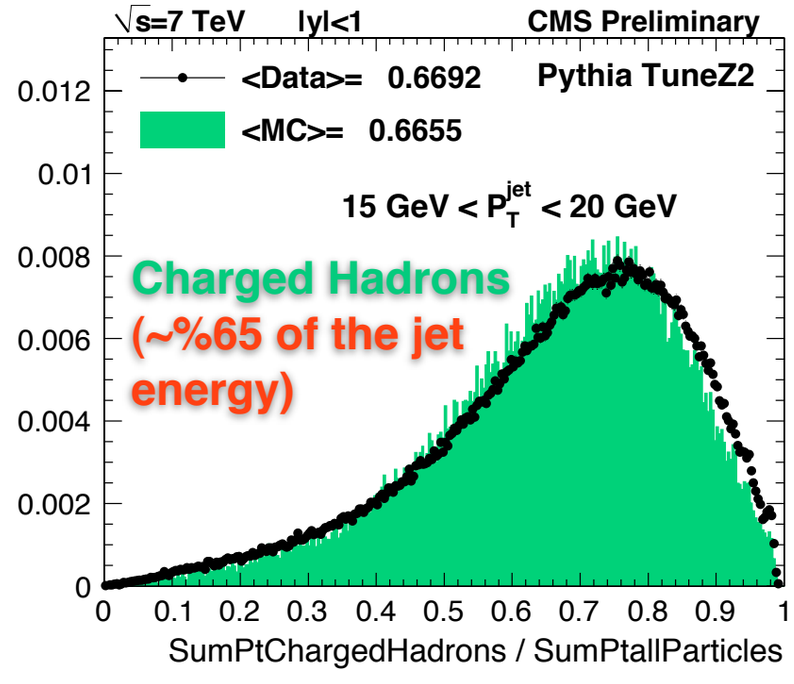
Similar trend is observed for Herwig++ as well.

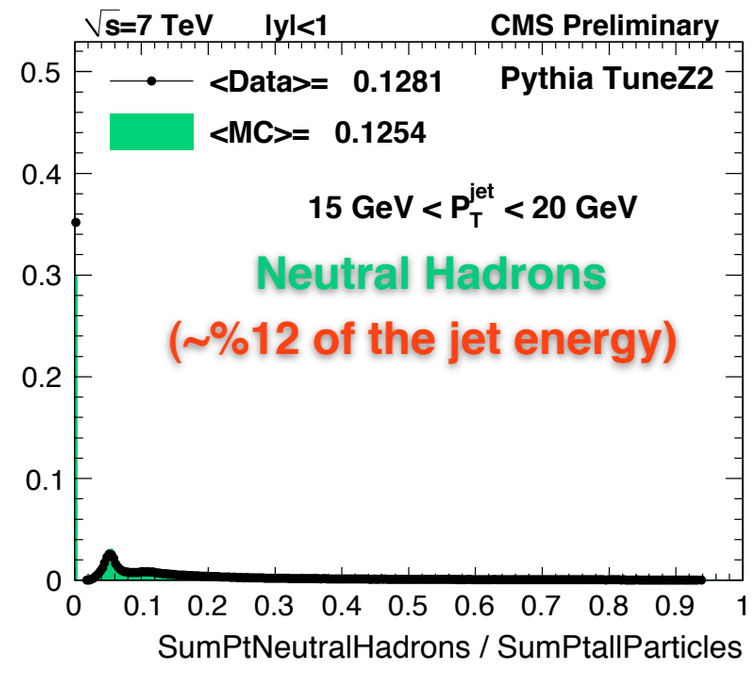
P_T Spectrums for Charged Hadrons (Tune Z2)

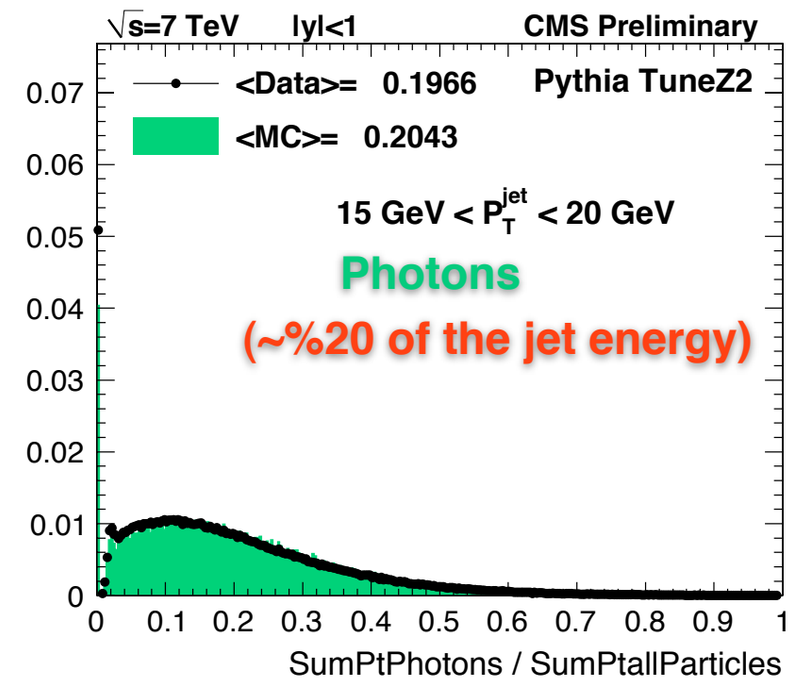


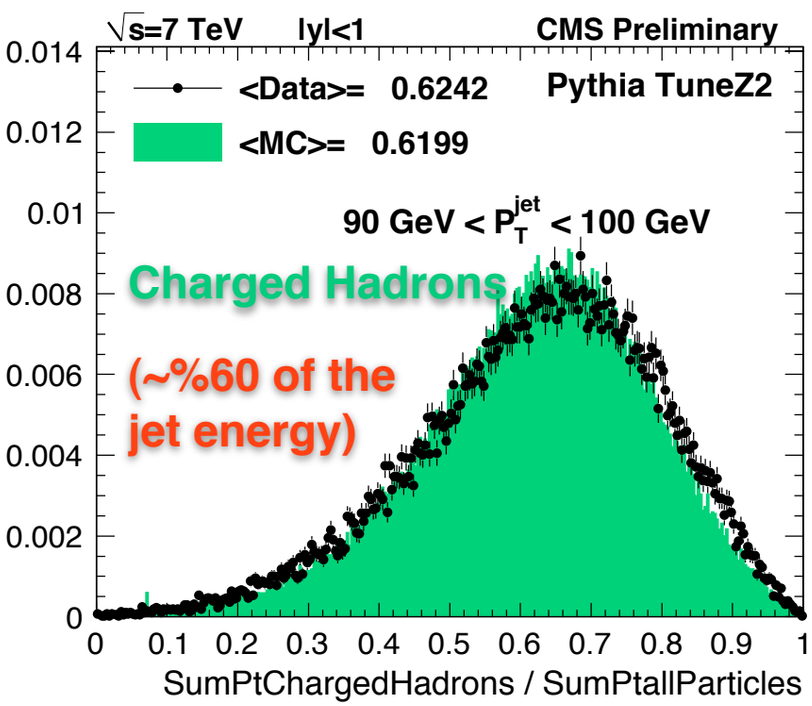
Charged Hadron p_T spectrums reach to very high p_T in both MC/Data and get harder with the increasing jet p_T.

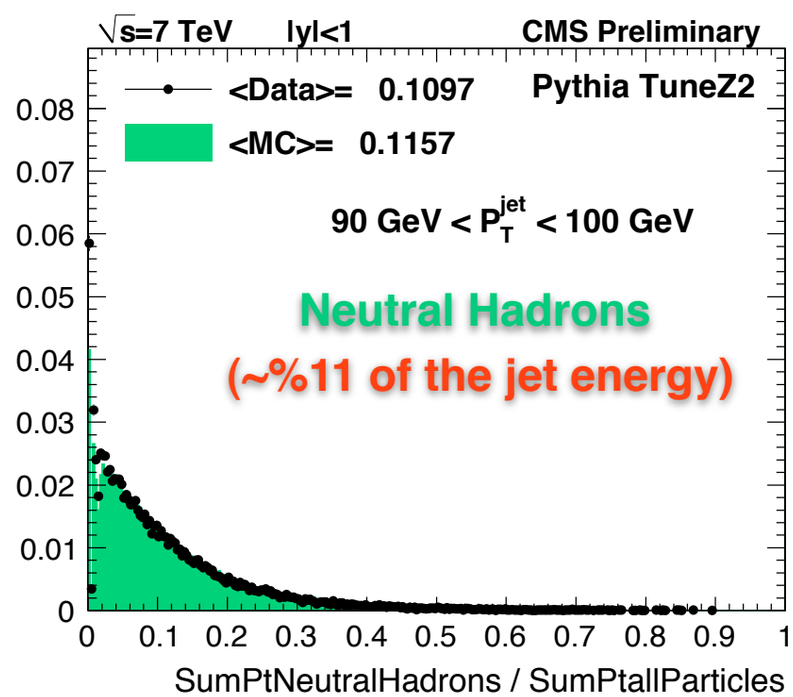
Sum P_T fraction for Charged, Neutral Hadrons and Photons

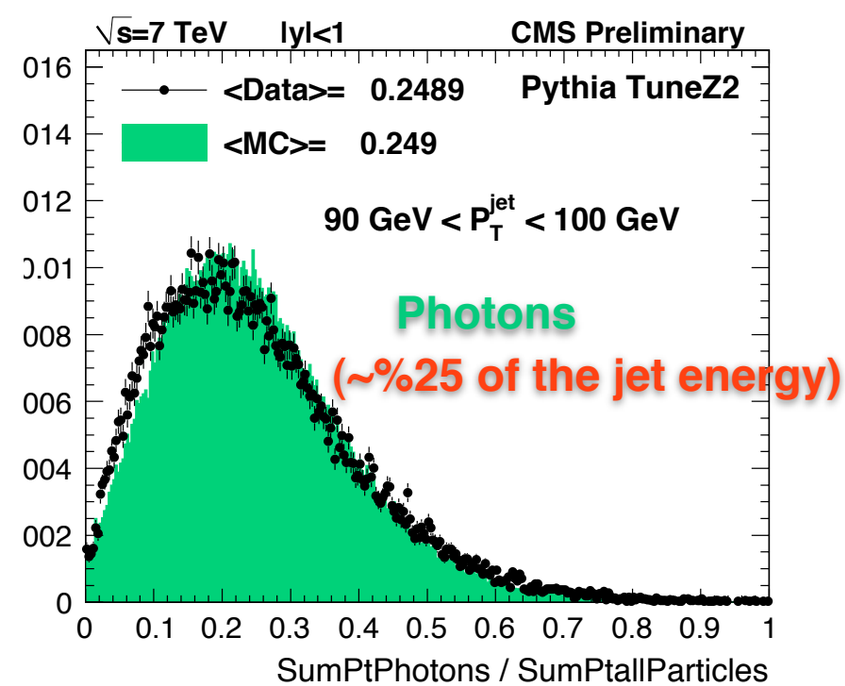












Reconstructed PF objects carry expected fraction of the jet energy for high p_T jets.

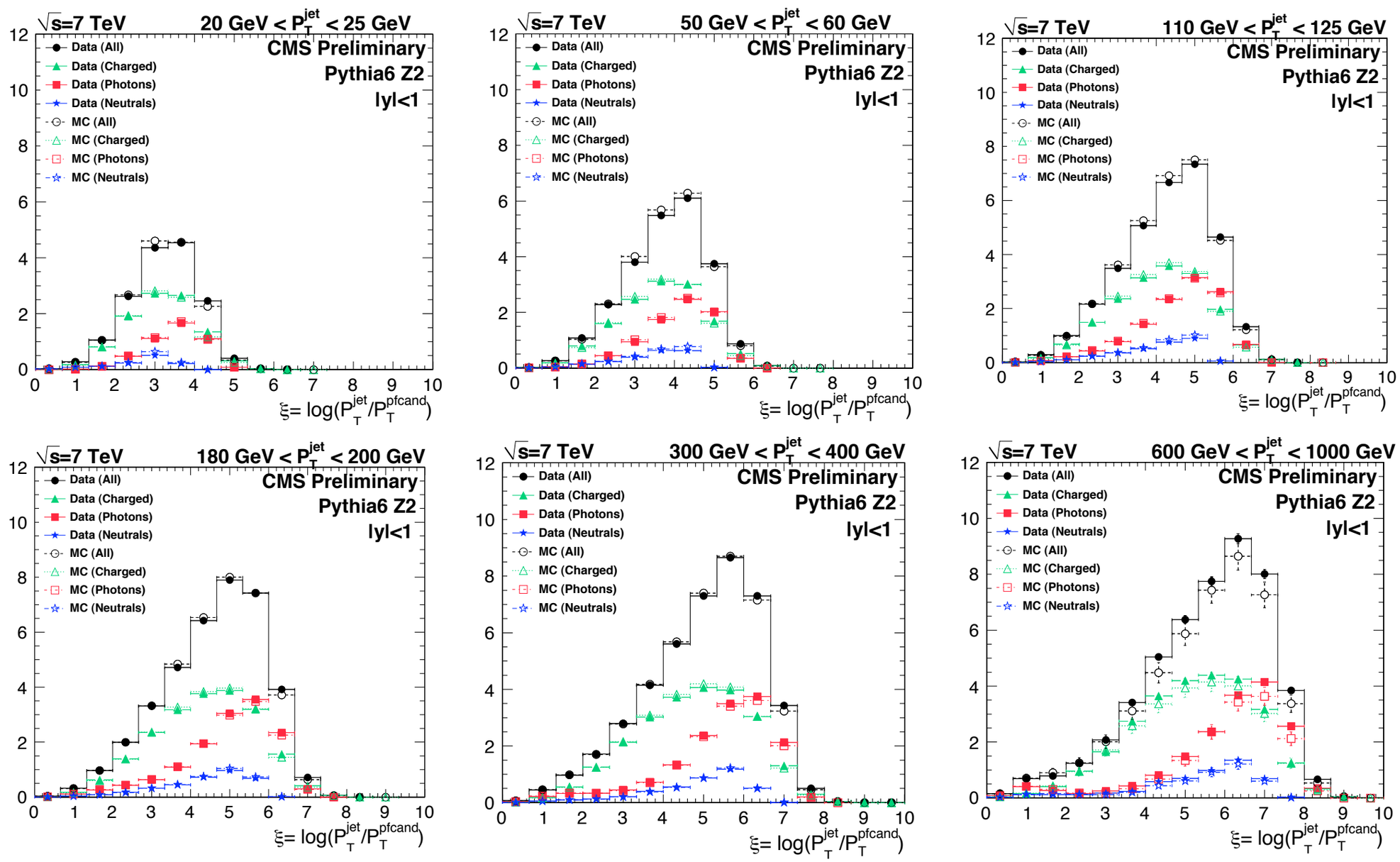
Low reconstruction efficiency is seen at the low p_T for both MC and Data.

Jet Fragmentation Functions

- Jet fragmentation functions (ξ) defined as *log(1/z)*, where *z* is the momentum fraction of the jet carried by an individual particle:

$$\xi = log\frac{1}{z}$$

$$z = \frac{P_T^{particle}}{P_T^{Jet}}$$



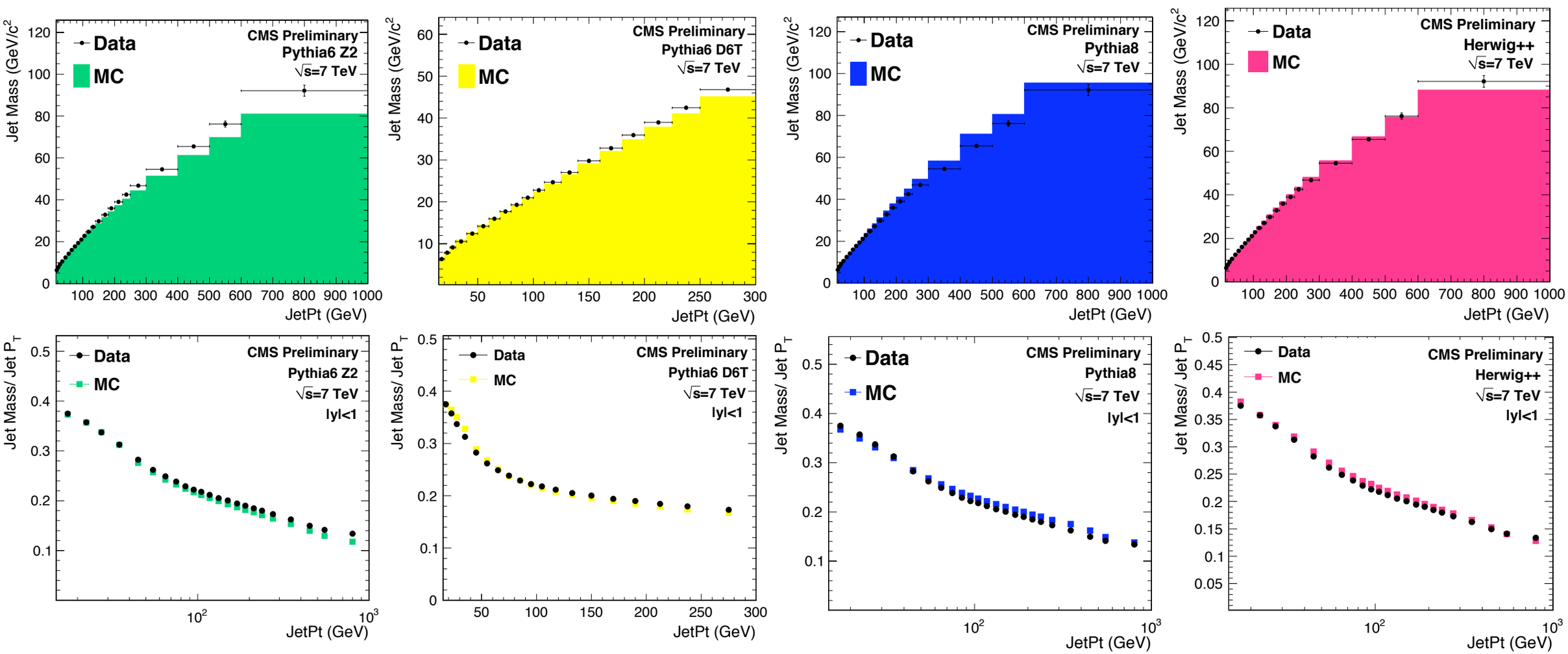
Jet fragmentation gets harder with the increasing jet p_T for all PF candidates.

Jet Mass

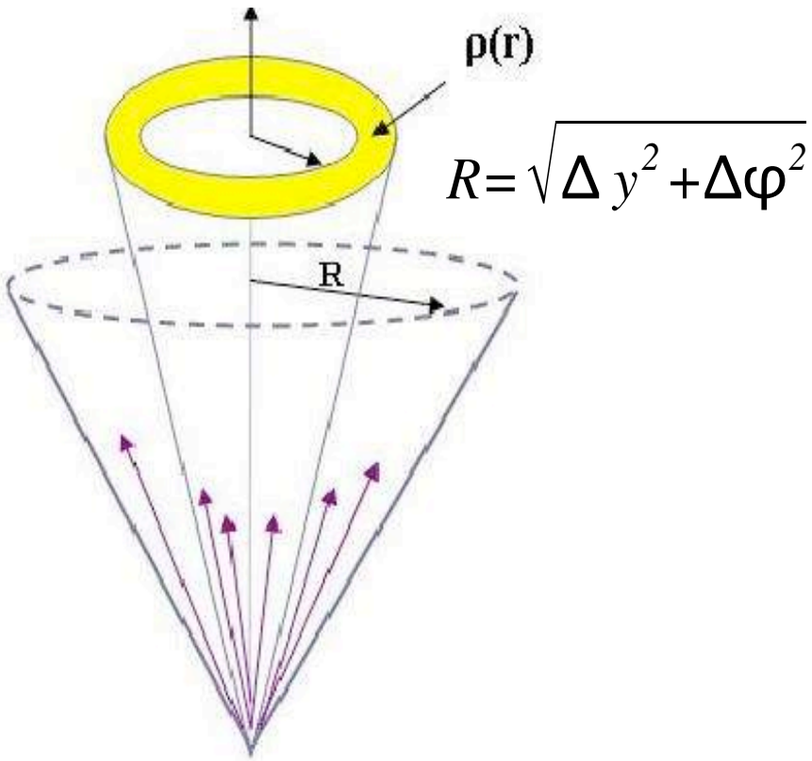
- Sensitive to parton showering and underlying event
- Mass of jets is sensitive to boosted resonances like Higgs, top and new particles
- Lots of activity to determine internal structure of jets (pruning, subjects, ...)
- Test analytical QCD predictions of jet mass

$$\frac{d\sigma(R)}{dp_T dm_J} = \sum_{q,G} J^{q,G}(m_J, p_T, R) \frac{d\hat{\sigma}^{q,G}(R)}{dp_T}$$

$$J(m_J, p_T, R) \simeq \alpha_s(p_T) \frac{4C_{q,G}}{\pi m_J} \log\left(\frac{R\, p_T}{m_J}\right)$$



Jet Shapes



$$R=\sqrt{\Delta y^2+\Delta\varphi^2}$$

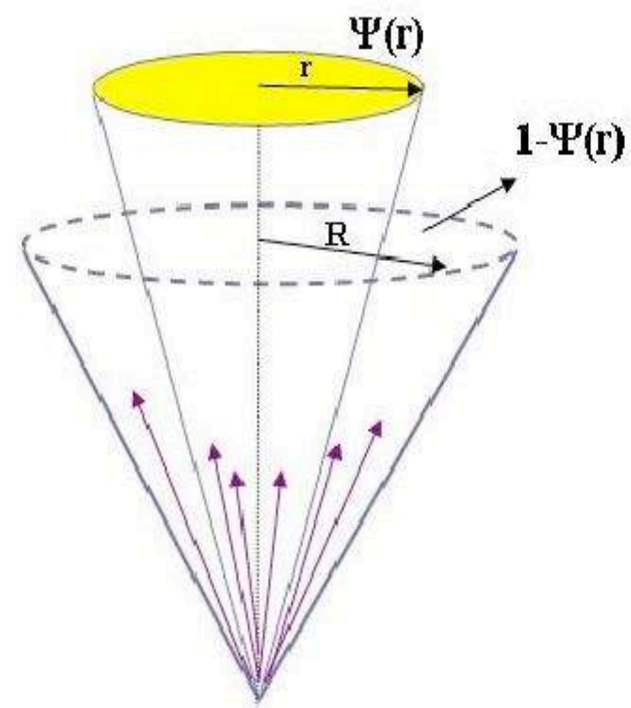
Differential Jet Shape

Definition: The average fraction of the jet transverse momentum inside an <u>annulus</u> in the y-ϕ plane of inner (outer) radius r-Δr/2 (r+Δr/2) concentric to the jet axis.

$$\rho(r) = \frac{1}{\delta r}\frac{1}{N_{jet}}\sum_{jets}\frac{P_T(r-\delta r/2, r+\delta r/2)}{P_T(0,R)}$$

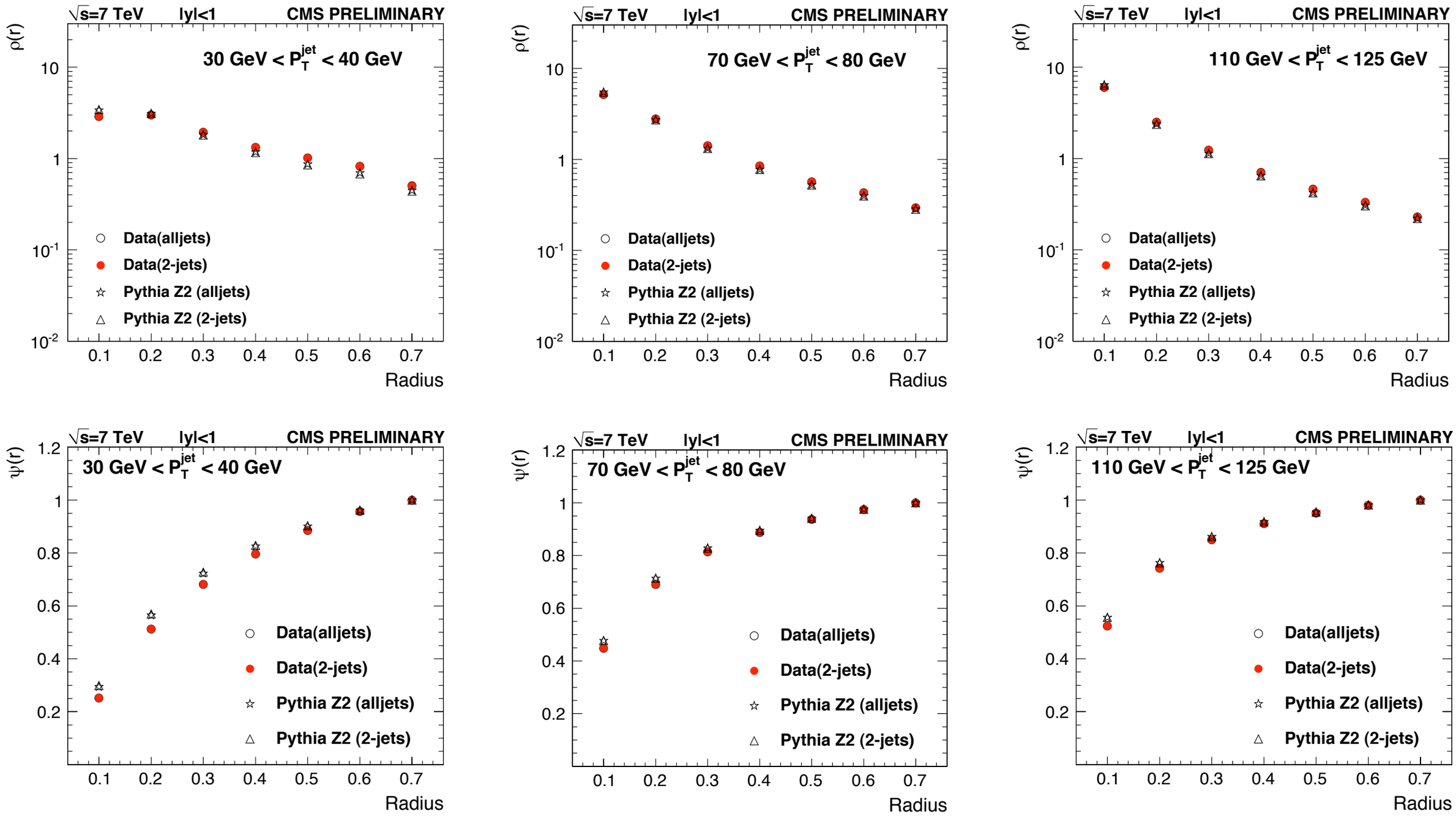
Definition: Integrated jet shape is defined as the average fraction of jet transverse momentum inside a cone of radius *r* concentric to the jet axis.

$$\Psi(r) = \frac{1}{N_{jets}}\sum_{jets}\frac{P_T(0;r)}{P_T^{jet}(0,R)}$$



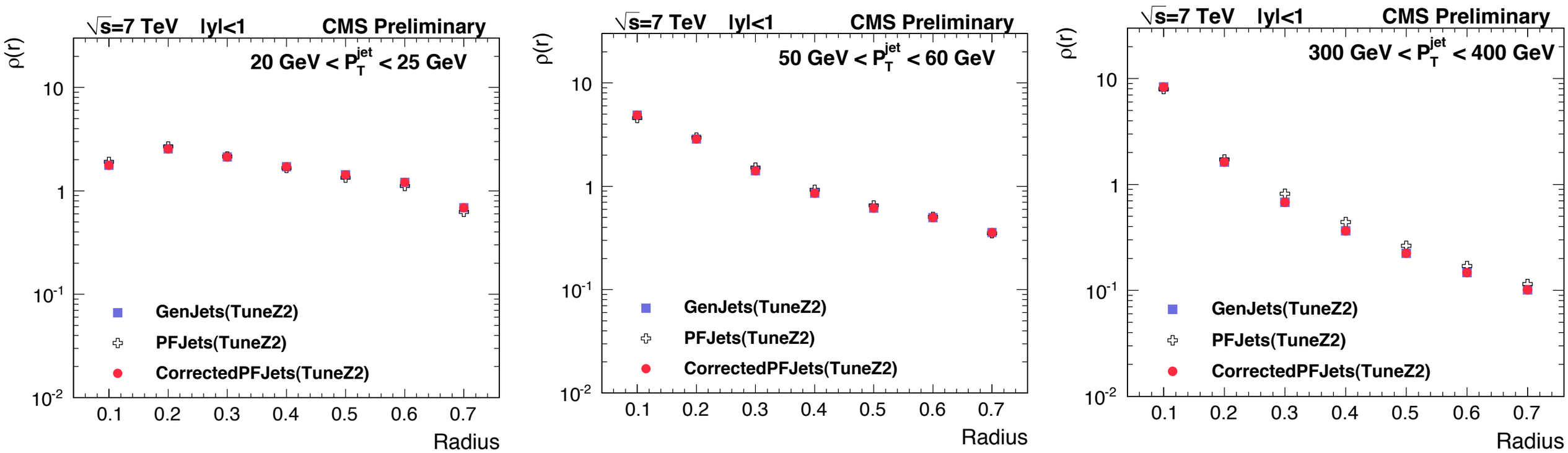
Integrated Jet Shape

Comparison of Jet Shapes



All Inclusive jets involve more gluons than the 2-leading inclusive jets so one would expect broader shapes. It is hard to see the difference since it is on the scale of 0.1% in general.

Gen and Reconstructed Jet Shapes



The Corrected and Gen distributions should agree by definition.

The difference between Gen-Reco level is due to:

- Smearing of jets in and out of a given p_T bin
  Detector not perfect, so reconstructed energy is smeared => broader shapes after reco
- Difference in the reconstruction of particles
  Low p_T particles are not reconstructed, but Gen level jets include particles of all p_Ts.
- Smearing of the reconstructed jet axis
- Smearing of the particles along the distance from the jet axis

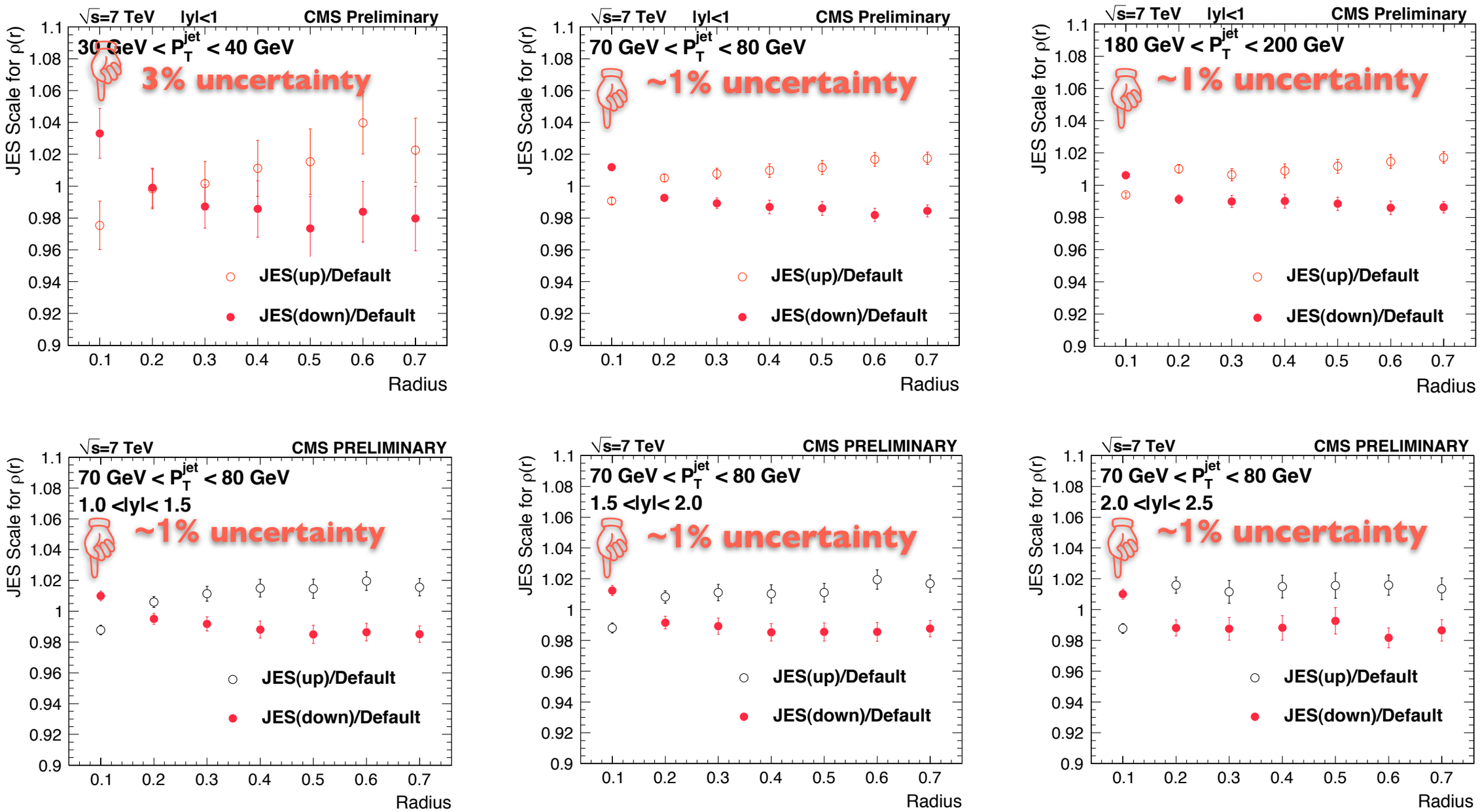
Gen/PF ratios are used to correct the reconstructed data!

Systematics

1. - Jet Energy Scale
2. - Unfolding Based Systematics
3. - Single Particle Calibration

Jet Energy Scale

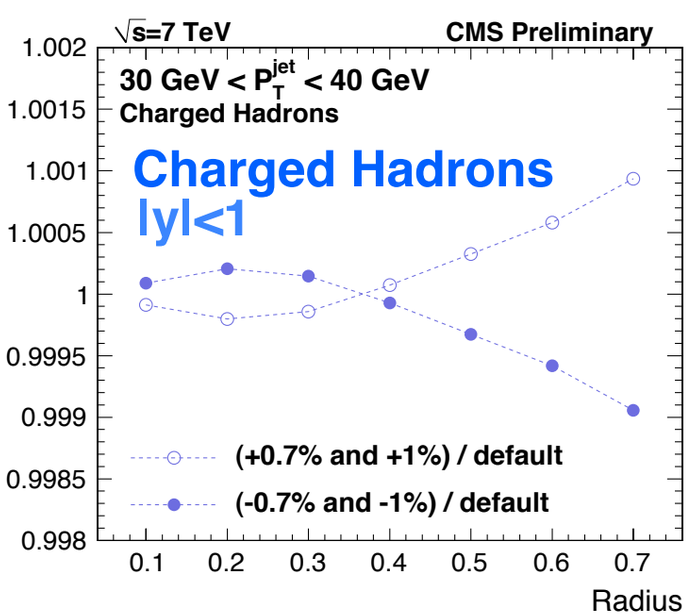
The jet shapes in bins of corrected p_T of the jets and jet can move in an out of the bin if the jet energy scale changes. We used official JES uncertainty which depends on the p_T and η.

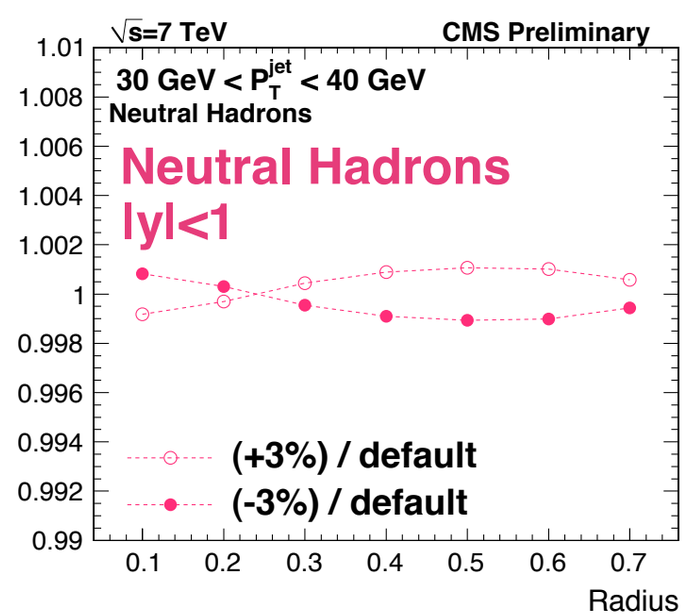


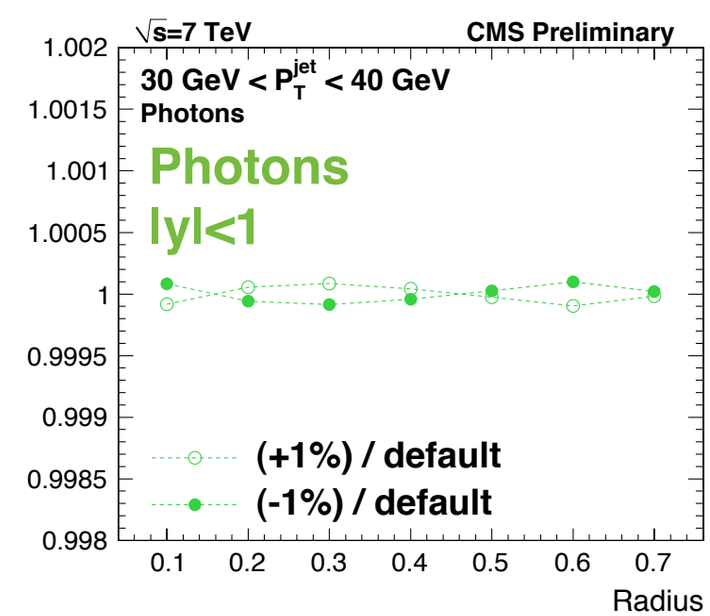
This uncertainty results in a maximum uncertainty of 3-5% for differential jet shapes variable at the very low p_T.

Single Particle Response

- Charged Hadrons are scaled to simulate impact of changing tracking efficiency
  - $|\eta| < 2.3$: scale by ±1% if p_T <1.5 GeV and ±0.7% if p_T >1.5 GeV
  - $|\eta| \geq 2.3$: scale by ±5%
- Neutral Hadrons are scaled to simulate impact of changing HCAL+ECAL scale
  - $|\eta| < 1.3$: scale by ±1%
  - $|\eta| \geq 1.3$: scale by ±5%
- Photons to simulate impact of changing ECAL scale (to photons)
  - $|\eta| < 1.3$: scale by ±1%
  - $|\eta| \geq 1.3$: scale by ±3%



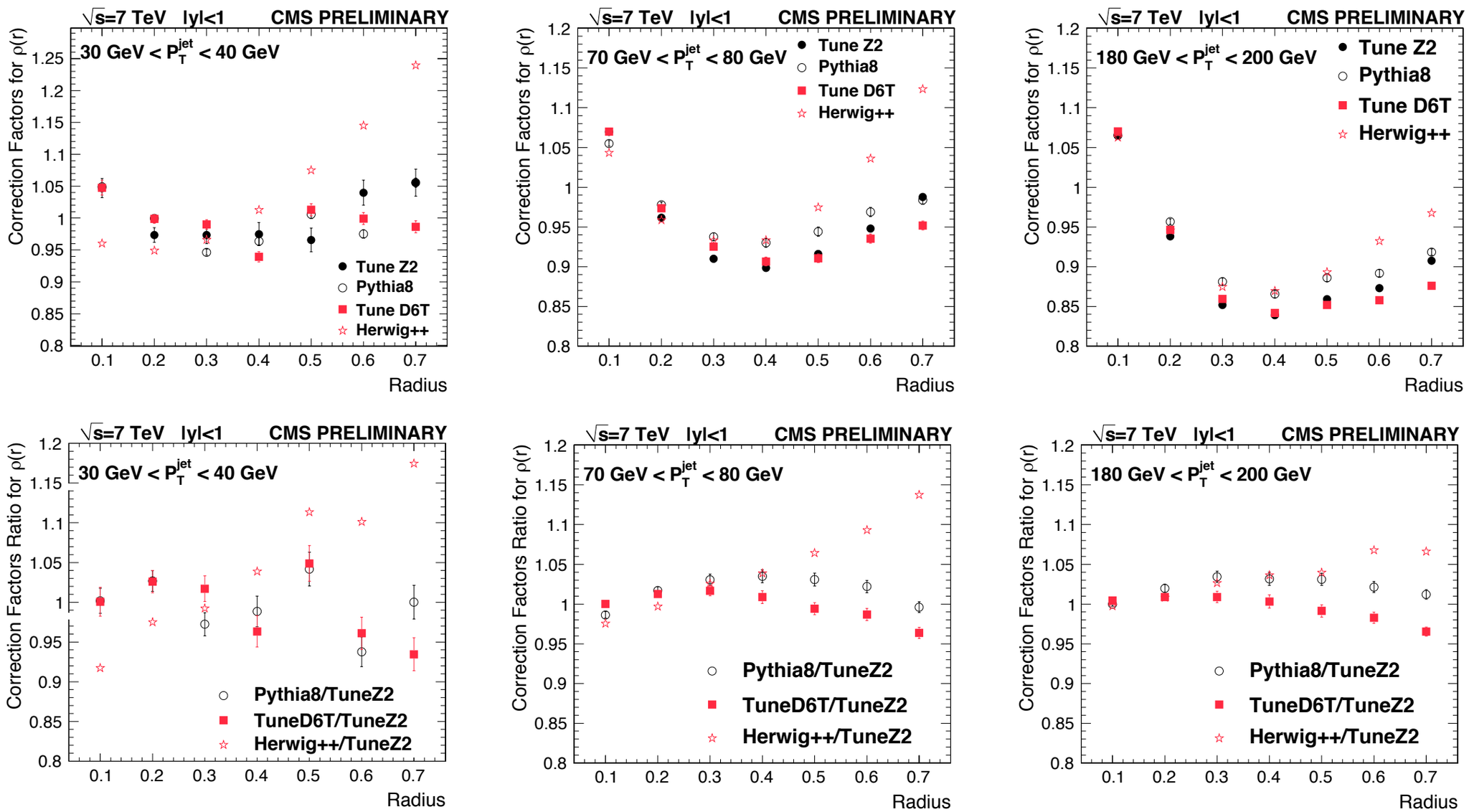




The effect of these uncertainties on jet shapes is minimal as change in the energy deposition versus radius for the central value is the same and thus largely cancel out.

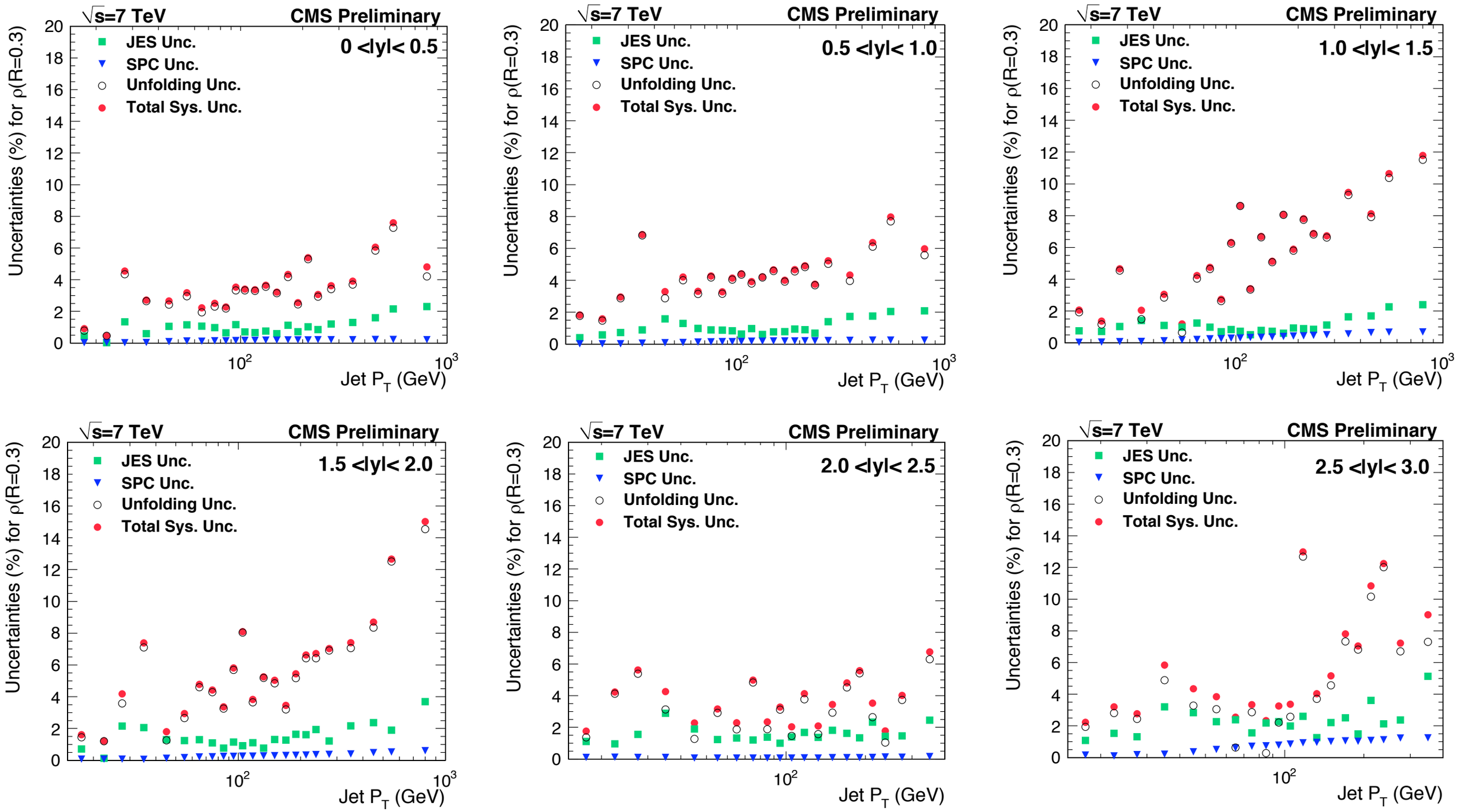
Unfolding Correction Factors

The unfolding corrections were determined using Pythia6 (Tune Z2). We compare the correction factors obtained using other event generators and assign the largest difference from Tune Z2 in the correction factors as systematic uncertainty.



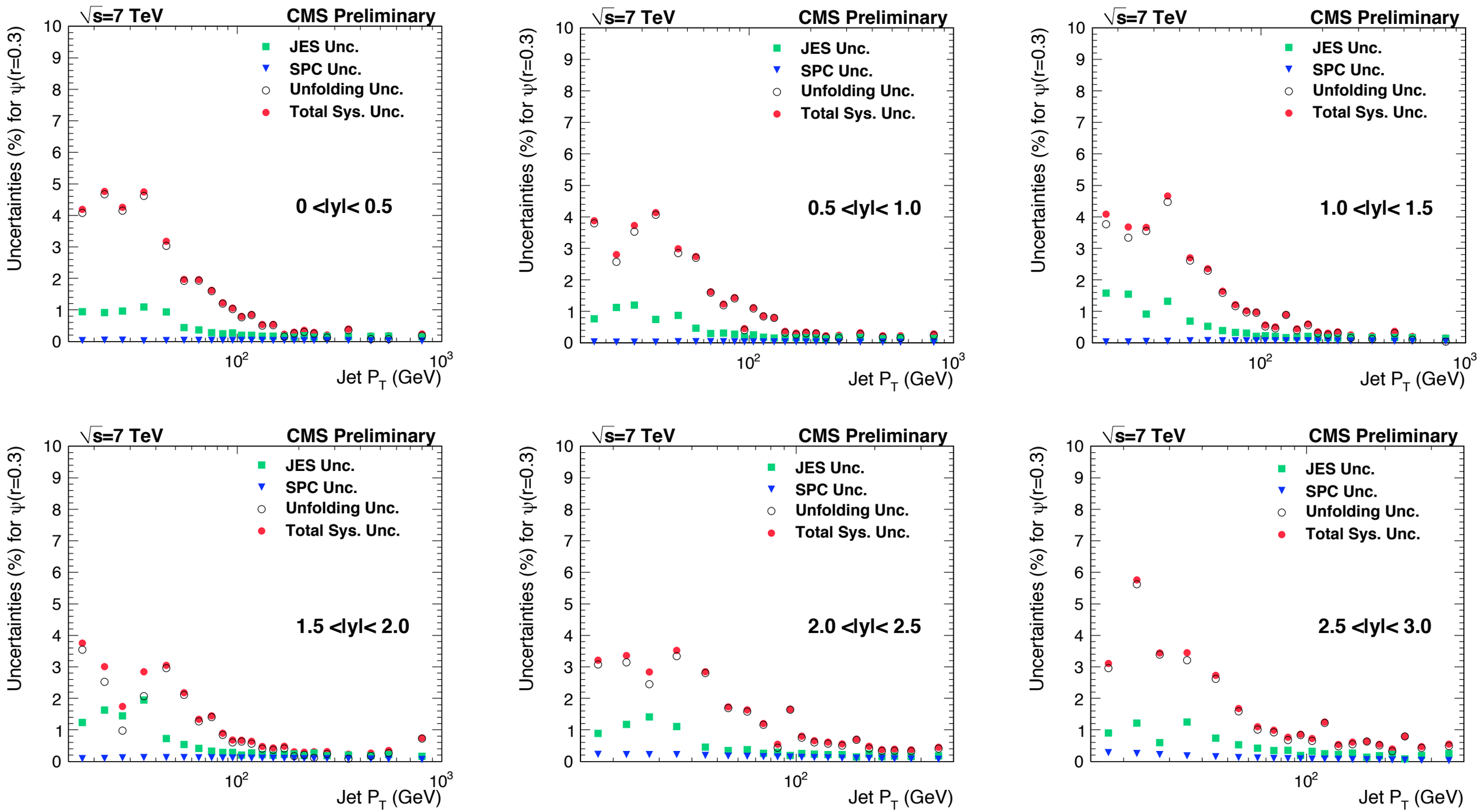
- The uncertainty is typically about 5% except for the lowest p_T bins where it reaches as high as 15%.
- The ratios show the sensitivity of unfolding corrections to the modeling of the jet shape

Uncertainty vs P_T for ρ(R=0.3)



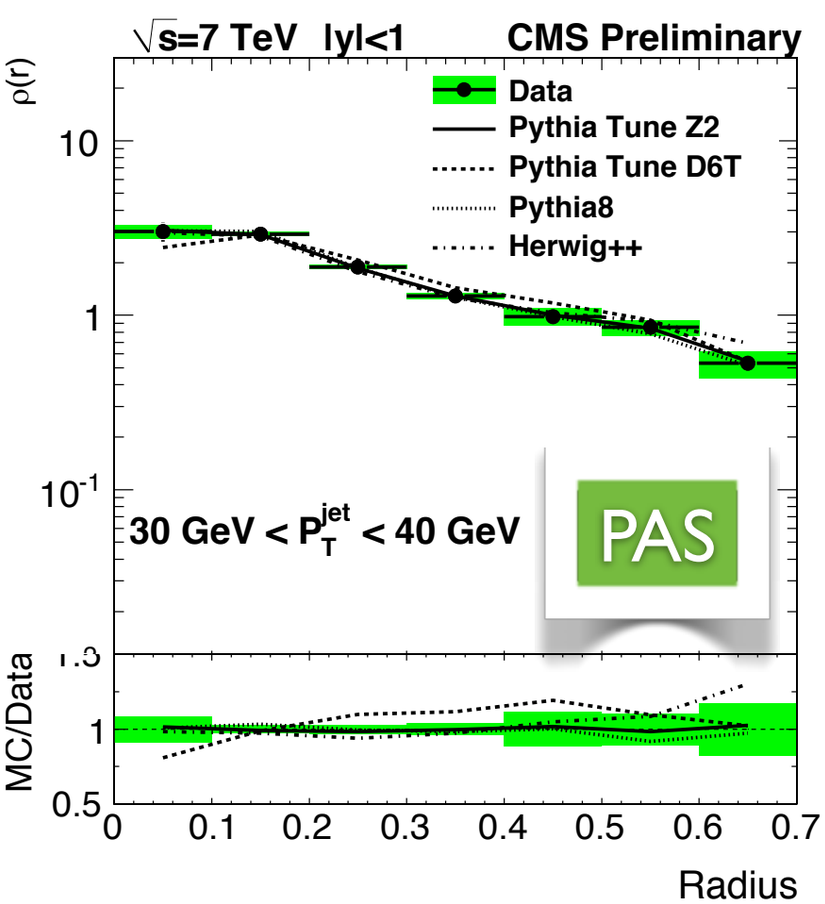
The total systematic is dominated by **Unfolding** and **JES** uncertainties for all rapidity bins.

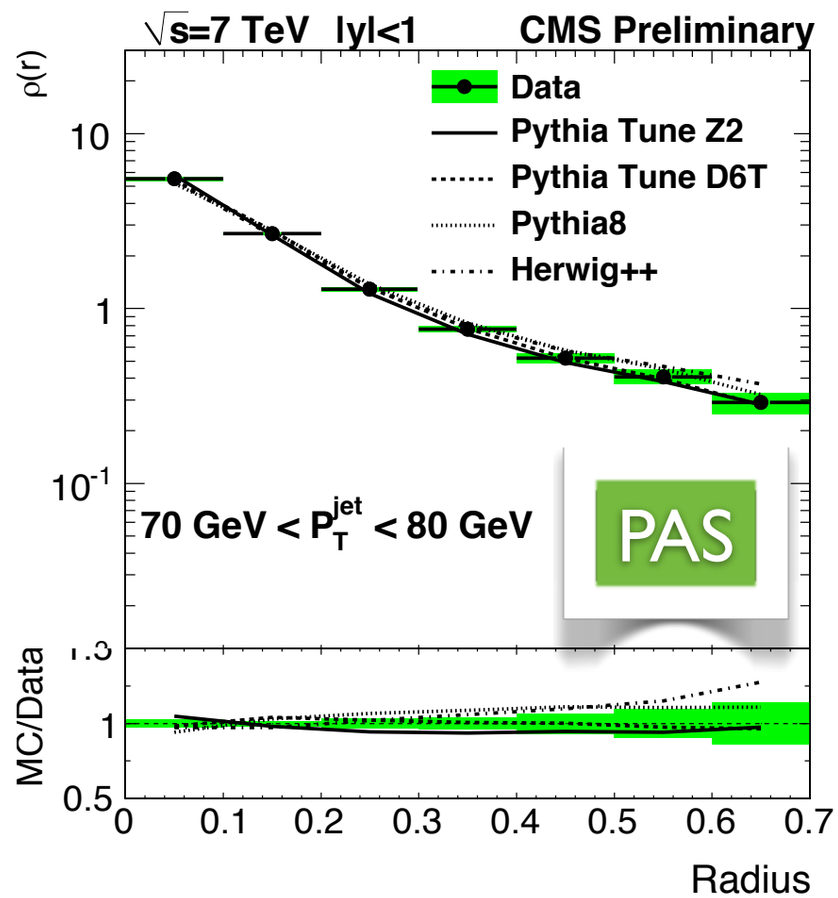
Uncertainty vs P_T for Ψ(R=0.3)

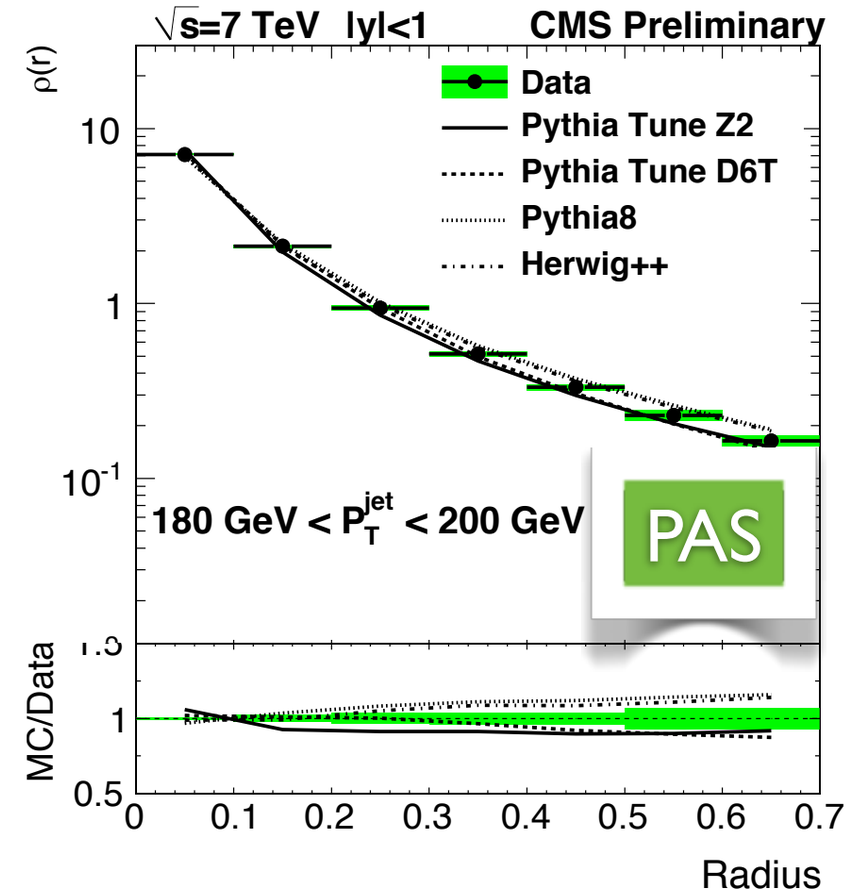


The total systematic is dominated by **JES** and **Unfolding** uncertainties for all rapidity bins.

Final Differential Jet Shapes



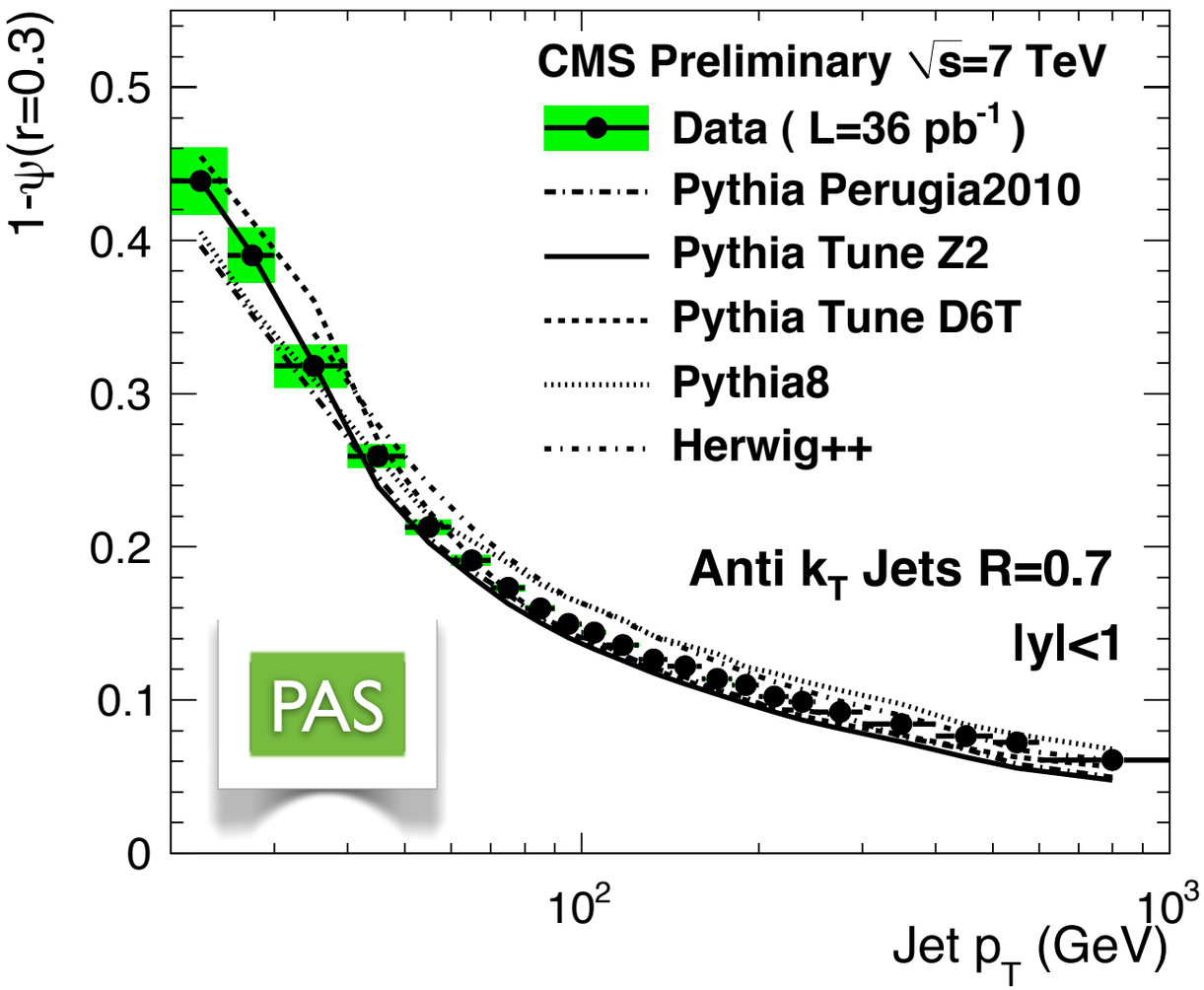




The differential jet shapes from data and different MC generators are compared.

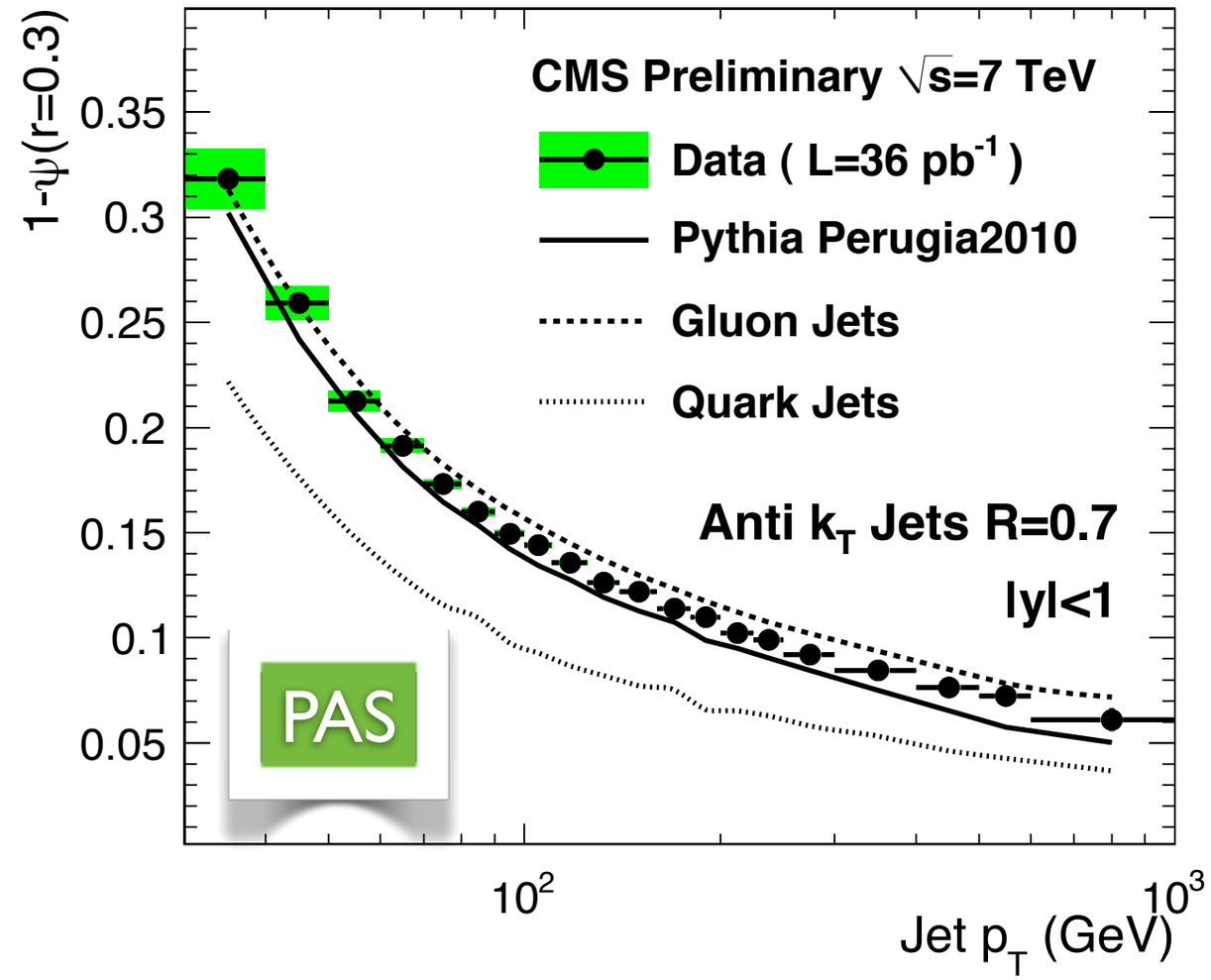
- As expected jets become more collimated with increasing jet p_T .
- At the low p_T event generators differ from each other.
- The Data/MC agreement is better at the high p_T.

1-Ψ(R=0.3) for Different Tunes and Sensitivity to qg Mixture



Out of cone energy outside the cone size R=0.3 is shown for unfolded data and compared with different MC event generators for the central region.

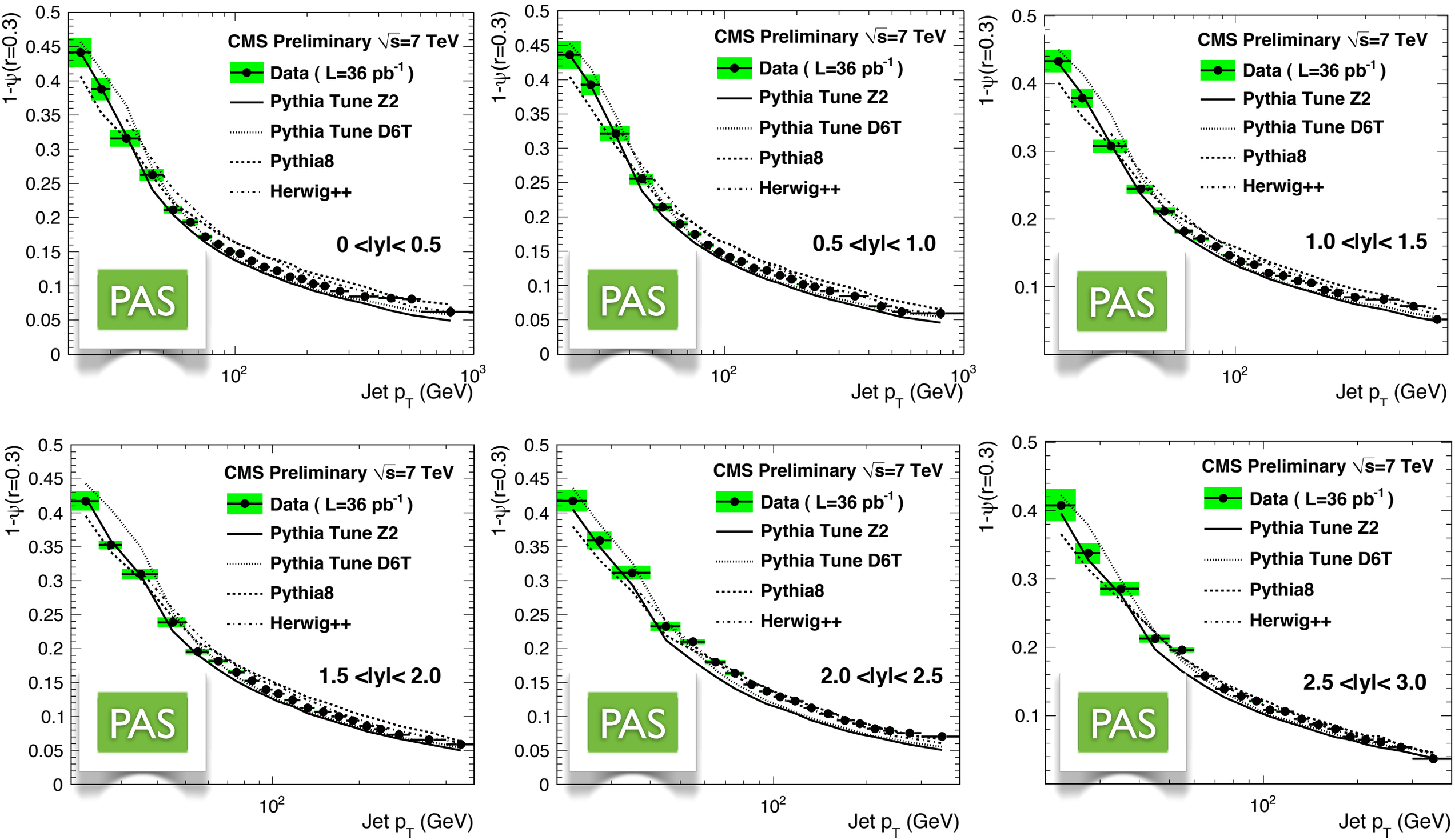
- Perugia 2010 gives a better description of data.



qg sensitivity was investigated by matching outgoing partons with jets within **ΔR<0.7.**

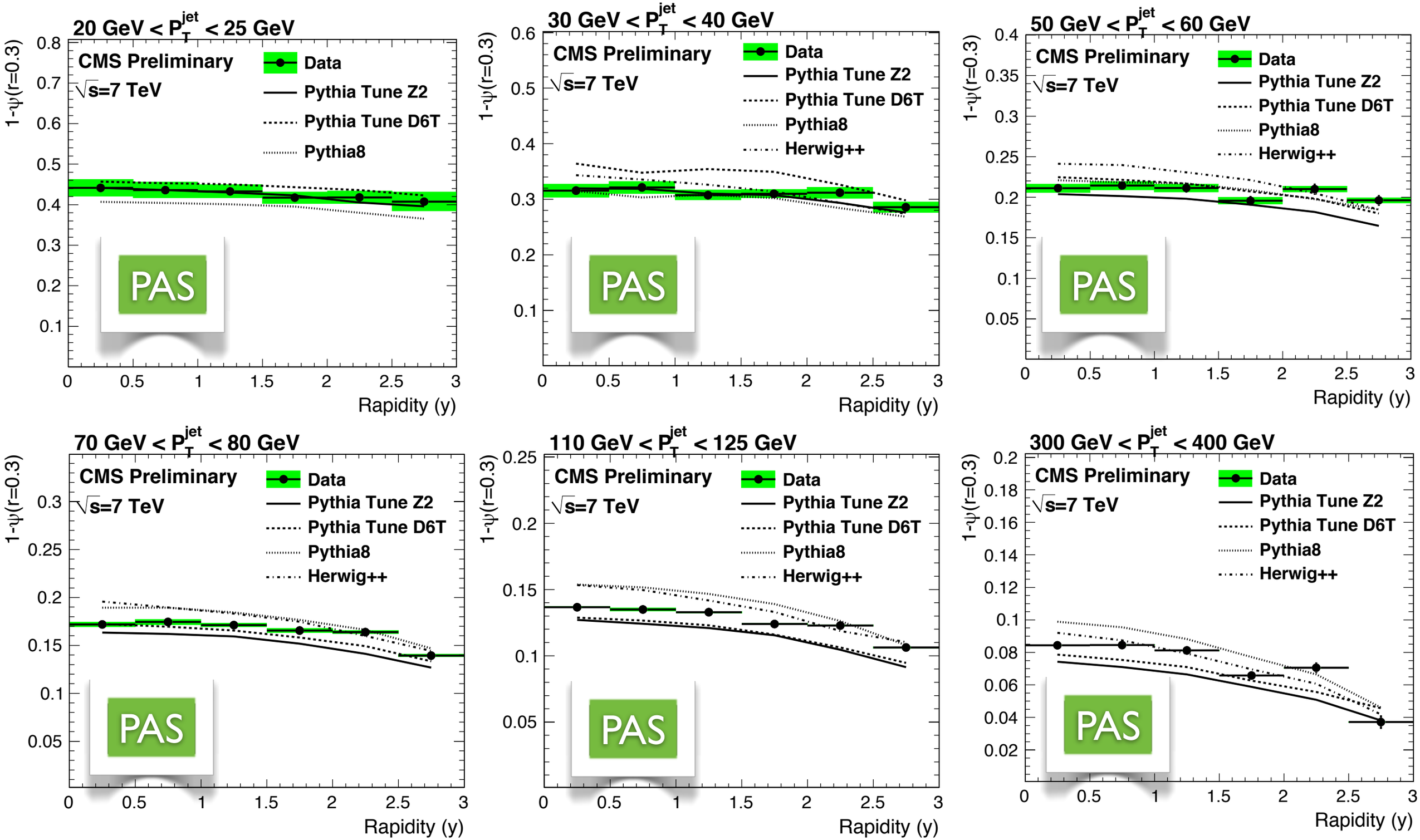
- Quark jets are narrower than the gluon jets.
- Fraction of gluon initiated jets decreases with the increasing jet p_T

1-Ψ(R=0.3) for Different Tunes and Kinematic Regions



Strong dependence of the amount of jet energy deposited outside a cone of R=0.3, 1-Ψ(R=0.3), as a function of p_T for different rapidity regions.

1-Ψ(R=0.3) vs Rapidity



Classical Jet Shapes Tables in the PAS

Pt bins	Mean Pt	corr. fact.	Data	Stat Error	Systematics			Total Sys.
p_T bin	Mean p_T	CF(Z2)	$\rho(r=0.3)$	Stat Error	JES Sys	Frag Sys	SPC Sys	Total Sys
15 - 20	17.0	0.996	2.199	0.015	0.004	0.008	0.0002	0.009
20 - 25	22.0	0.999	2.133	0.028	0.000	0.005	0.0004	0.005
25 - 30	27.1	0.988	2.044	0.040	0.013	0.043	0.0003	0.045
30 - 40	33.7	0.959	1.879	0.039	0.006	0.027	0.0004	0.027
40 - 50	44.1	0.943	1.611	0.035	0.011	0.024	0.0009	0.027
50 - 60	54.2	0.932	1.482	0.041	0.012	0.030	0.0013	0.032
60 - 70	64.3	0.928	1.390	0.013	0.011	0.019	0.0012	0.022
70 - 80	74.4	0.913	1.302	0.017	0.010	0.023	0.0014	0.025
80 - 90	84.4	0.912	1.229	0.022	0.006	0.022	0.0015	0.023
90 - 100	94.6	0.907	1.162	0.010	0.012	0.033	0.0016	0.035
100 - 110	104.6	0.903	1.145	0.012	0.007	0.033	0.0017	0.034
110 - 125	116.6	0.892	1.101	0.013	0.007	0.033	0.0017	0.034
125 - 140	131.7	0.884	1.043	0.008	0.008	0.036	0.0019	0.036
140 - 160	148.7	0.874	1.009	0.008	0.006	0.032	0.0019	0.032
160 - 180	169.0	0.864	0.967	0.008	0.011	0.042	0.0019	0.043
180 - 200	189.1	0.864	0.949	0.010	0.007	0.024	0.0020	0.026
200 - 225	211.0	0.844	0.898	0.008	0.010	0.053	0.0020	0.054
225 - 250	236.2	0.851	0.889	0.011	0.009	0.029	0.0021	0.031
250 - 300	270.5	0.842	0.827	0.010	0.012	0.034	0.0021	0.036
300 - 400	335.7	0.845	0.778	0.014	0.013	0.037	0.0022	0.039
400 - 500	438.1	0.852	0.698	0.029	0.016	0.058	0.0023	0.061
500 - 600	540.2	0.881	0.684	0.057	0.022	0.073	0.0023	0.076
600 - 1000	689.2	0.893	0.640	0.105	0.023	0.042	0.0022	0.048

- In order to summary the data points and systematic sources we prepared **42 tables** for each radius and rapidity bin. The table is shown here for R=0.3 and 0<|y|<0.5 region.
- No tables included for the integrated jet shapes since the data points can be extracted from the differential jet shapes.

We would like to make these tables public! PAS

Summary

1. We presented the first measurement of jet shapes in pp collisions at $\sqrt{s}$ =7 TeV using 36 pb^{-1} of data collected during 2010 with PF jets.

2. Jet shape measurements are observed to follow the trends expected from QCD as a function of the jet transverse momentum.

3. We observe that Pythia6 with Perugia 2010 tune best describes the data.
   - Several QCD inspired Monte Carlo event generators and tunes were compared with data.
   - The Tune Z2 (Pythia6) describes the initial CMS soft p_T data very well but predicts slightly narrower jets than those in data at high transverse momenta

Many Thanks to our QCD conveners and ARC members for their collaboration and support for the preparations of this paper !!!

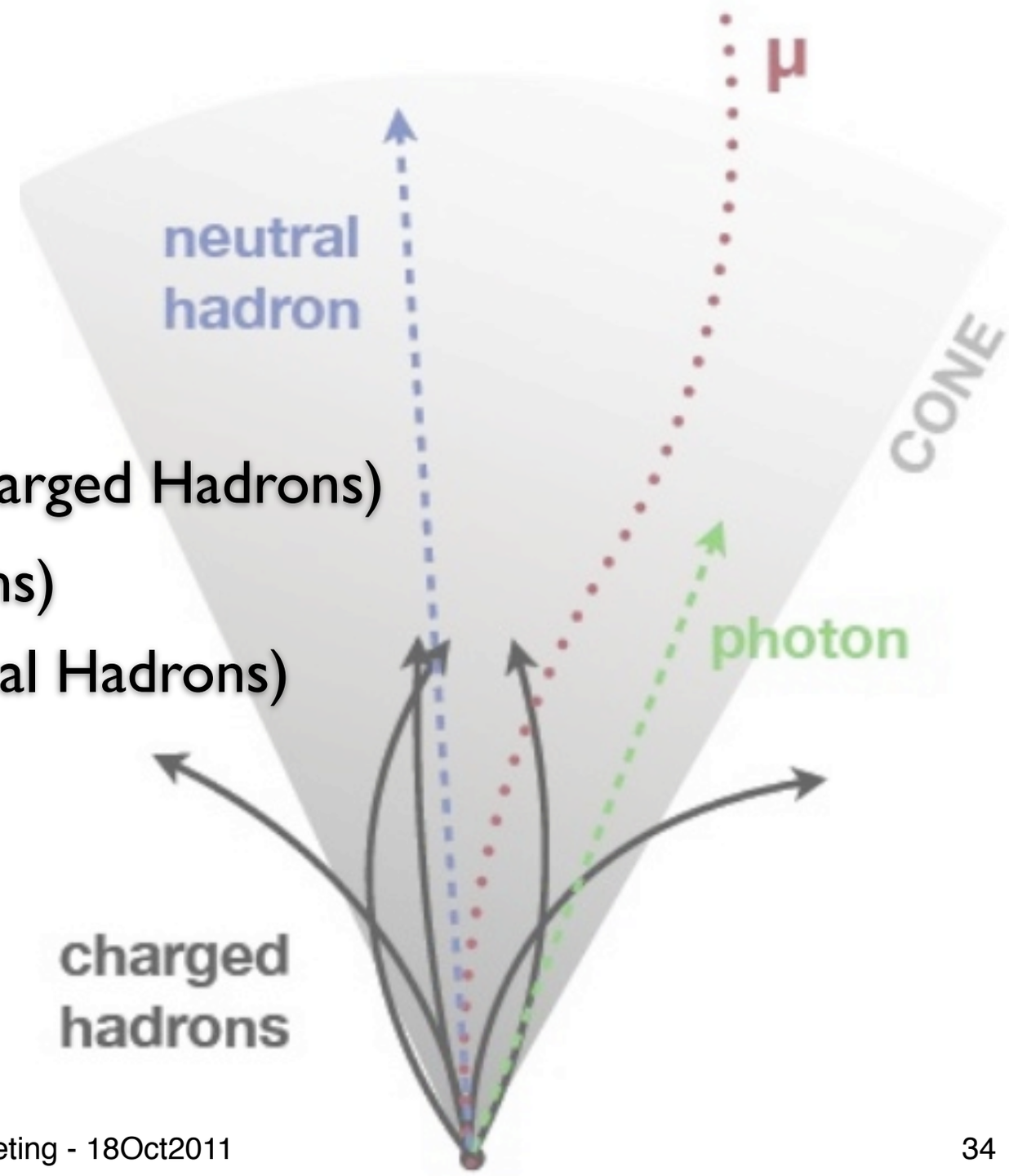
Extra Slides

PF Jet Reconstruction in CMS

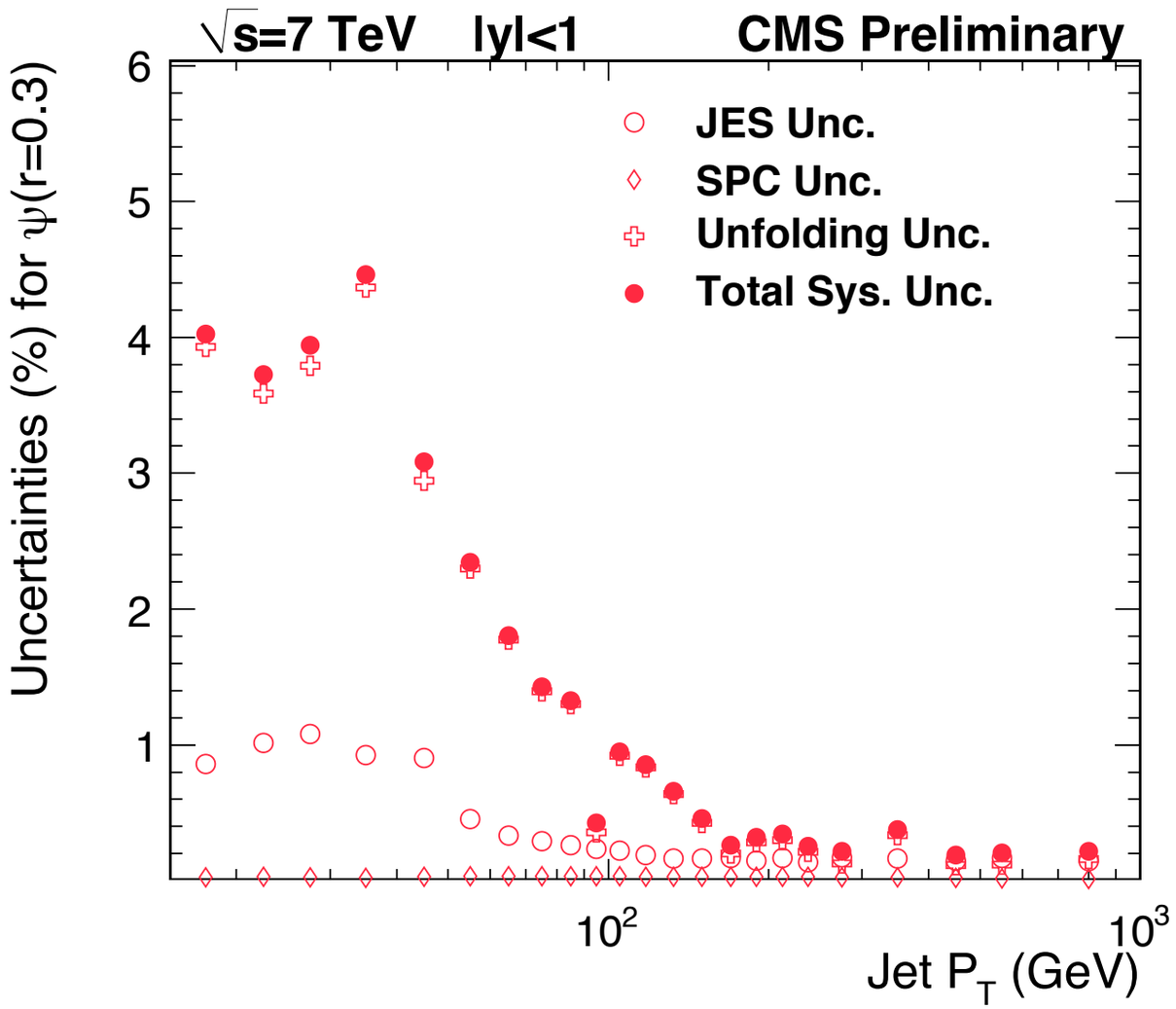
PF candidate combines information from various detectors to make the best combined estimation of particle properties.

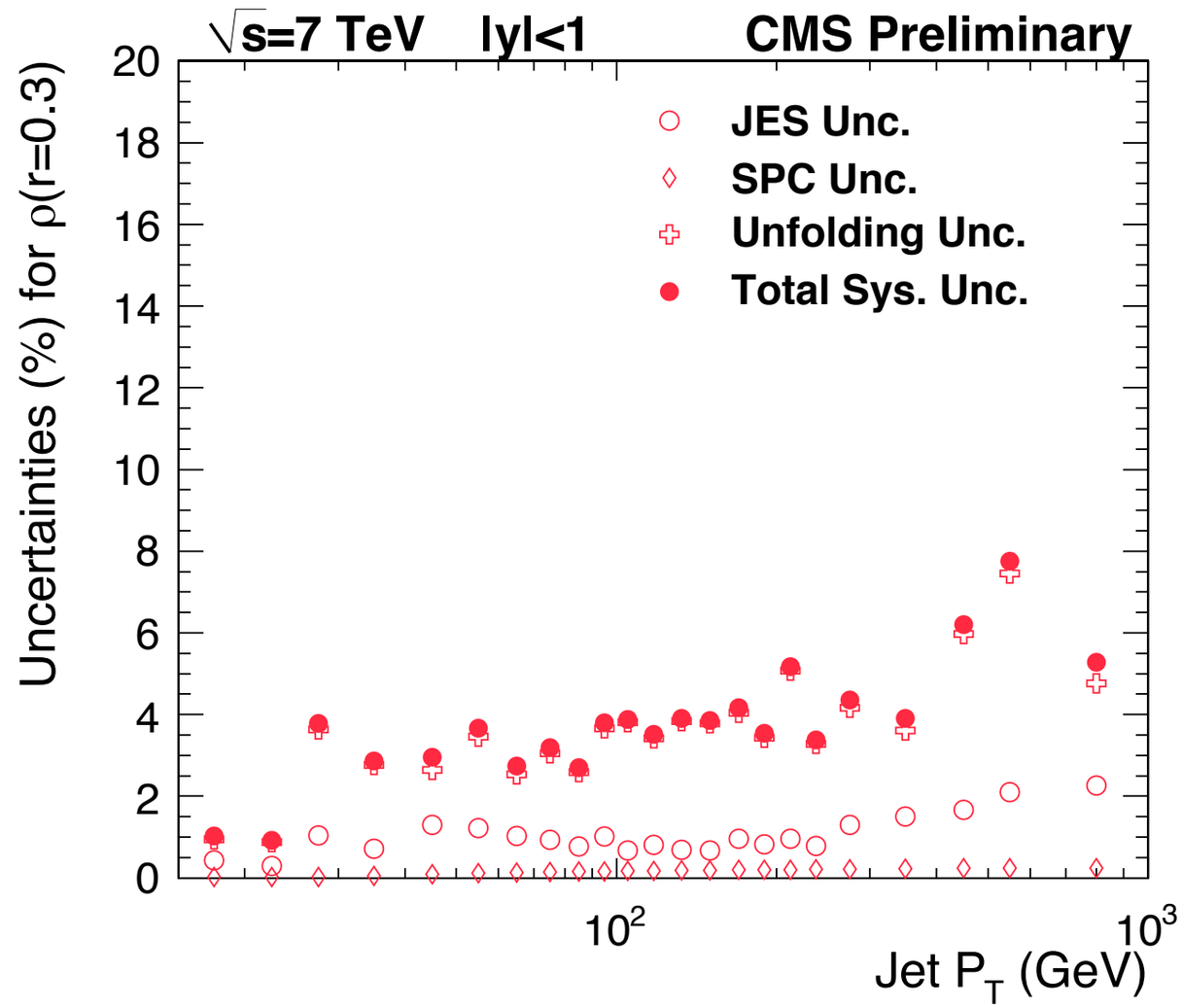
- ECAL clusters
- HCAL clusters
- Propogate track to clusters

- Both EM and HAD clusters (Charged Hadrons)
- ECAL clusters, no track (Photons)
- HCAL clusters, no track (Neutral Hadrons)



Systematics vs P_T for Central Region





Number Of Reconstructed Jets

All inclusive jets

Table 3: Number of jets are shown for different rapidity bins as a function of jet p_T.

p_T (GeV)	$0-0.5$	$0.5-1.0$	$1.0-1.5$	$1.5-2.0$	$2.0-2.5$	$2.5-3.0$
$15 < P_T^{jet} < 20$	182797	169643	161015	147364	113541	97836
$20 < P_T^{jet} < 25$	53914	48973	45223	40216	30927	26257
$25 < P_T^{jet} < 30$	18693	17016	15421	13472	10539	8891
$30 < P_T^{jet} < 40$	11247	10181	9229	7848	6308	5196
$40 < P_T^{jet} < 50$	2776	2534	2267	1966	1580	1247
$50 < P_T^{jet} < 60$	952	886	737	674	498	411
$60 < P_T^{jet} < 70$	12885	12284	10756	8762	6879	5558
$70 < P_T^{jet} < 80$	6005	5645	5106	3805	3023	2381
$80 < P_T^{jet} < 90$	3109	2913	2526	1942	1501	1164
$90 < P_T^{jet} < 100$	21103	19836	16927	13001	10095	7689
$100 < P_T^{jet} < 110$	12644	11722	9717	7387	5637	4228
$110 < P_T^{jet} < 125$	10231	9564	8131	6098	4581	3211
$125 < P_T^{jet} < 140$	50803	47268	38781	29022	20909	14578
$140 < P_T^{jet} < 160$	34099	32080	25915	19057	13686	8703
$160 < P_T^{jet} < 180$	36950	33513	26718	19624	13044	7538
$180 < P_T^{jet} < 200$	19423	17186	14018	10033	6512	3340
$200 < P_T^{jet} < 225$	25907	22744	17460	12676	7492	3126
$225 < P_T^{jet} < 250$	13480	11897	8782	6313	3475	1198
$250 < P_T^{jet} < 300$	15656	13539	10305	6992	3143	832
$300 < P_T^{jet} < 400$	7758	6702	4748	3118	885	108
$400 < P_T^{jet} < 500$	1559	1260	849	405	45	0
$500 < P_T^{jet} < 600$	386	305	197	78	5	0
$600 < P_T^{jet} < 1000$	158	139	49	15	0	0

2-leading jets

Table 1: The number of jets for various rapidity bins for the 2-leading jet selected events.

Jet p_T	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0
15 GeV $< P_T^{jet} <$ 20 GeV	153877	142811	134840	123433	94849	80703
20 GeV $< P_T^{jet} <$ 25 GeV	50776	46282	42829	37959	29212	24540
25 GeV $< P_T^{jet} <$ 30 GeV	18322	16753	15245	13279	10374	8680
30 GeV $< P_T^{jet} <$ 40 GeV	11276	10198	9282	7988	6326	5199
40 GeV $< P_T^{jet} <$ 50 GeV	2824	2580	2322	1988	1584	1260
50 GeV $< P_T^{jet} <$ 60 GeV	969	934	755	688	507	418
60 GeV $< P_T^{jet} <$ 70 GeV	12711	12087	10582	8654	6793	5491
70 GeV $< P_T^{jet} <$ 80 GeV	5932	5581	5042	3754	2996	2359
80 GeV $< P_T^{jet} <$ 90 GeV	3052	2885	2497	1920	1486	1153
90 GeV $< P_T^{jet} <$ 100 GeV	20910	19635	16761	12877	10005	7631
100 GeV $< P_T^{jet} <$ 110 GeV	12529	11619	9627	7325	5596	4214
110 GeV $< P_T^{jet} <$ 125 GeV	10150	9495	8076	6047	4562	3186
125 GeV $< P_T^{jet} <$ 140 GeV	50447	46934	38523	28842	20806	14504
140 GeV $< P_T^{jet} <$ 160 GeV	33891	31879	25766	18965	13653	8670
160 GeV $< P_T^{jet} <$ 180 GeV	36754	33336	26566	19554	13030	7509
180 GeV $< P_T^{jet} <$ 200 GeV	19336	17110	13948	9987	6501	3330
200 GeV $< P_T^{jet} <$ 225 GeV	25782	22639	17399	12629	7472	3117
225 GeV $< P_T^{jet} <$ 250 GeV	13431	11851	8770	6304	3469	1195
250 GeV $< P_T^{jet} <$ 300 GeV	17753	15417	11664	7949	3540	924
300 GeV $< P_T^{jet} <$ 400 GeV	8785	7569	5430	3500	976	133
400 GeV $< P_T^{jet} <$ 500 GeV	1774	1408	956	465	53	4
500 GeV $< P_T^{jet} <$ 600 GeV	435	339	214	81	6	0
600 GeV $< P_T^{jet} <$ 1000 GeV	168	165	62	15	0	0

Number of jets increased as expected when we use all inclusive jets due to gluon jet contribution up to 250GeV.

Systematics Table for ρ(R=0.3)

Table 1: The p_T dependence of differential jet shapes for radius 0.3 for rapidity bin $0 < |y| < 0.5$. All systematic unceratinties are added in quadrature to get the total systematic uncertainty. Statistical uncertainty is not added to total uncertainty.

p_T Min (GeV)	p_T Max (GeV)	Mean p_T (GeV)	CorrFactor (Tune Z2)	$\rho(r = 0.3)$	Stat Error	JES Sys	Frag Sys	SPC Sys	Total Sys
15	20	17.0	0.996	2.199	0.015	0.004	0.008	0.0002	0.009
20	25	22.0	0.999	2.133	0.028	0.000	0.005	0.0004	0.005
25	30	27.1	0.988	2.044	0.040	0.013	0.043	0.0003	0.045
30	40	33.7	0.959	1.879	0.039	0.006	0.027	0.0004	0.027
40	50	44.1	0.943	1.611	0.035	0.011	0.024	0.0009	0.027
50	60	54.2	0.932	1.482	0.041	0.012	0.030	0.0013	0.032
60	70	64.3	0.928	1.390	0.013	0.011	0.019	0.0012	0.022
70	80	74.4	0.913	1.302	0.017	0.010	0.023	0.0014	0.025
80	90	84.4	0.912	1.229	0.022	0.006	0.022	0.0015	0.023
90	100	94.6	0.907	1.162	0.010	0.012	0.033	0.0016	0.035
100	110	104.6	0.903	1.145	0.012	0.007	0.033	0.0017	0.034
110	125	116.6	0.892	1.101	0.013	0.007	0.033	0.0017	0.034
125	140	131.7	0.884	1.043	0.008	0.008	0.036	0.0019	0.036
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160	180	169.0	0.864	0.967	0.008	0.011	0.042	0.0019	0.043
180	200	189.1	0.864	0.949	0.010	0.007	0.024	0.0020	0.026
200	225	211.0	0.844	0.898	0.008	0.010	0.053	0.0020	0.054
225	250	236.2	0.851	0.889	0.011	0.009	0.029	0.0021	0.031
250	300	270.5	0.842	0.827	0.010	0.012	0.034	0.0021	0.036
300	400	335.7	0.845	0.778	0.014	0.013	0.037	0.0022	0.039
400	500	438.1	0.852	0.698	0.029	0.016	0.058	0.0023	0.061
500	600	540.2	0.881	0.684	0.057	0.022	0.073	0.0023	0.076
600	1000	689.2	0.893	0.640	0.105	0.023	0.042	0.0022	0.048

Scaling Factors for Data

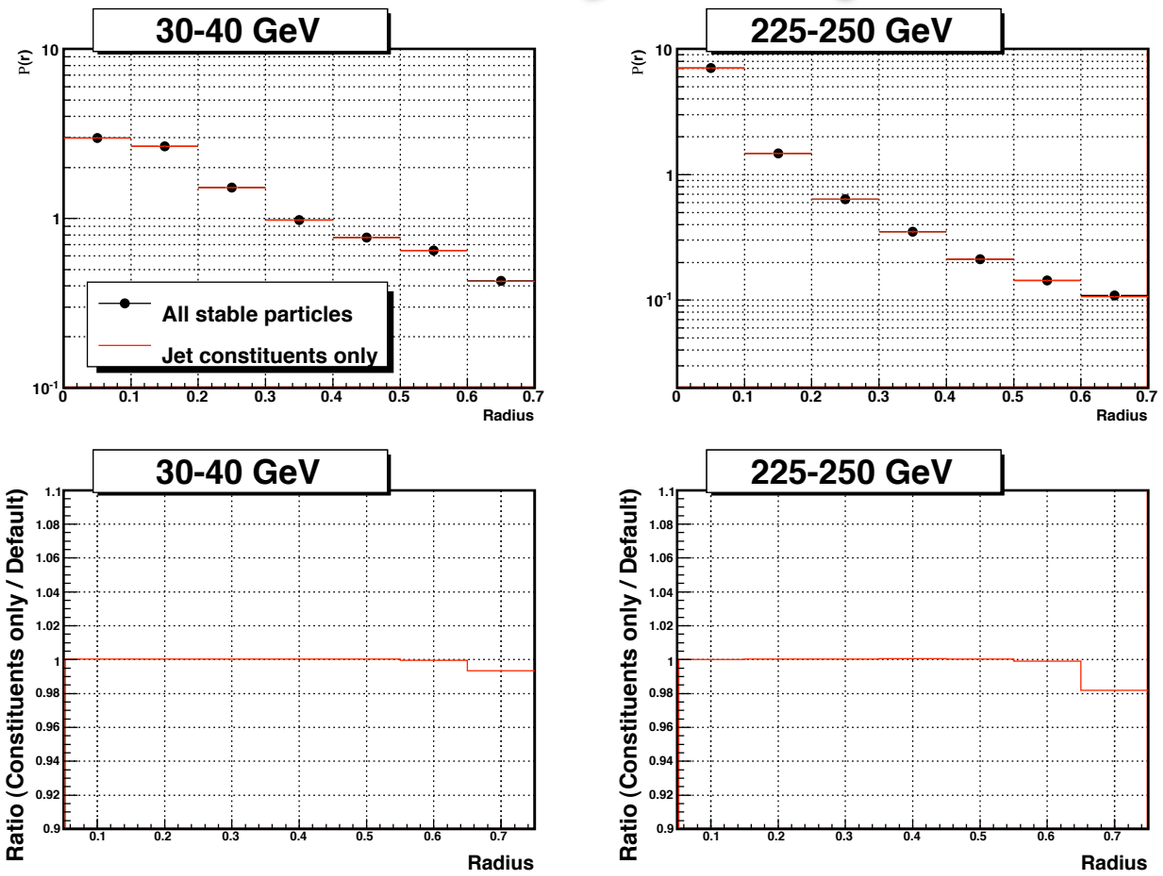
Table 3: Transverse momentum scaling factors for reconstructed PF particles

η_{min}	η_{max}	Residual JES	Photons	Neutral hadrons	Charged hadrons
-5.0	-5.0	0.999	1.027	0.9897	0.9897
-3.5	-5.0	0.982	1.027	0.967	0.967
-3.2	-3.5	1.005	1.027	0.9977	0.9977
-3.0	-3.2	0.9	1.027	0.8577	0.8577
-2.9	-3.0	0.93	1.027	0.8977	0.8977
-2.5	-2.9	0.948	1.027	0.9217	0.9217
-2.4	-2.5	0.972	1.027	0.9537	0.9537
-2.3	-2.4	0.988	1.027	0.975	0.975
-1.9	-2.3	0.999	1.027	0.9295	1
-1.5	-1.9	1.03	1.027	1.211	1
-1.3	-1.5	1.01	1.027	1.03	1
1.3	1.5	1.03	1.027	1.211	1
1.5	1.9	1.005	1.027	0.9841	1
1.9	2.3	1.002	1.027	0.9568	1
2.3	2.4	1.002	1.027	0.9937	0.9937
2.4	2.5	0.992	1.027	0.9803	0.9803
2.5	2.9	0.97	1.027	0.951	0.951
2.9	3.0	0.955	1.027	0.931	0.931
3.0	3.2	0.93	1.027	0.8977	0.8977
3.2	3.5	1.001	1.027	0.9923	0.9923
3.5	5.0	0.975	1.027	0.9577	0.9577
5.0	5.0	0.992	1.027	0.9803	0.9803

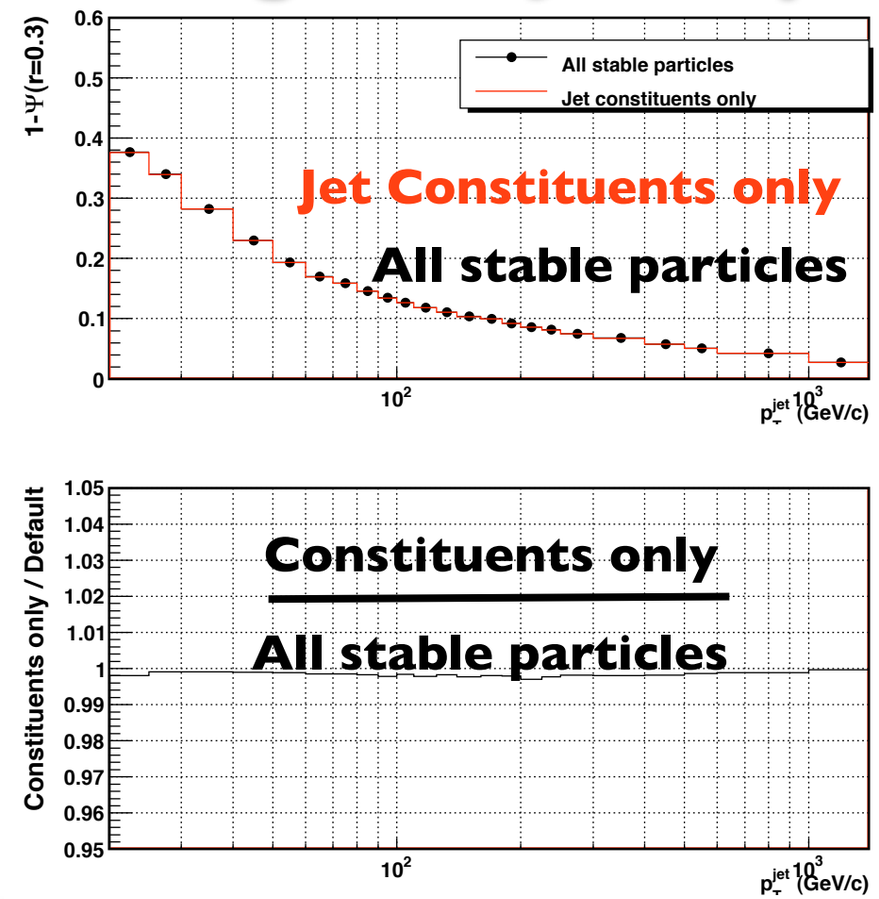
DRAFT

Why a fixed cone?

"Differential JetShapes"



"Integrated JetShapes"

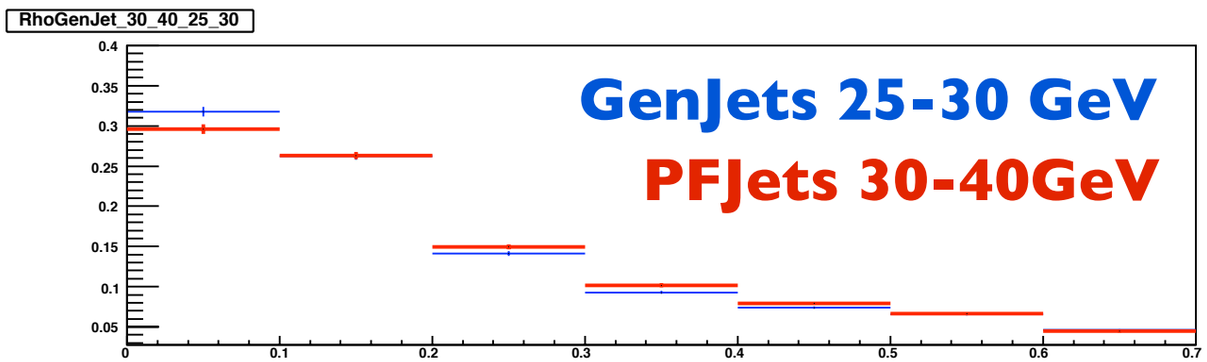


- This definition does not have any theory problems, is easy to understand, is normalized such that integrated jet shape at R=r=0.7(or =1.0) where R is the radius of the big cone we sum over and had been previously used in **AN2008-024, QCD-08-005** and for **2010 ICHEP** analysis.
- **CDF** and **ATLAS** has used the same definitions.
- We consulted on this choice with the theorists: Gavin Salam and Steve Ellis. Both did not find anything wrong with this definition.
- As can be seen from the figures, both definition give quite similar shapes of jets.

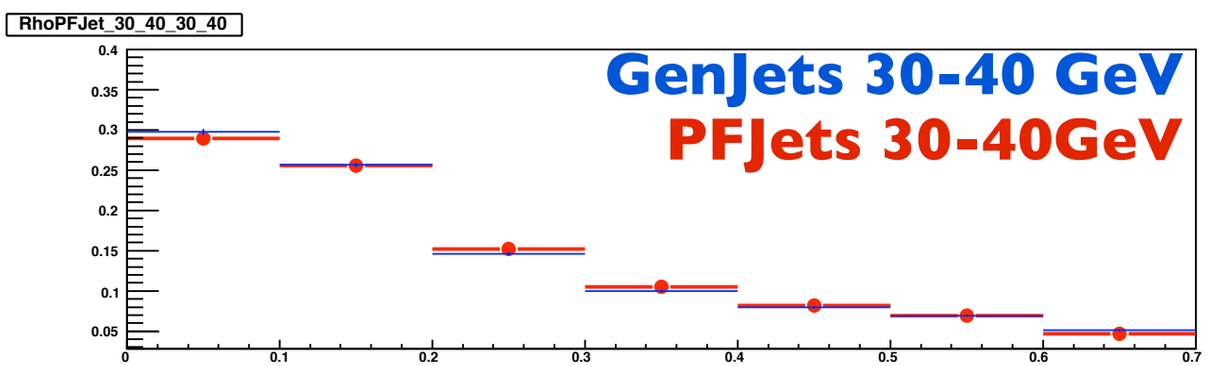
Understanding of Systematics - I

❶ - Understanding of shape of unsmearing correction factors (II)

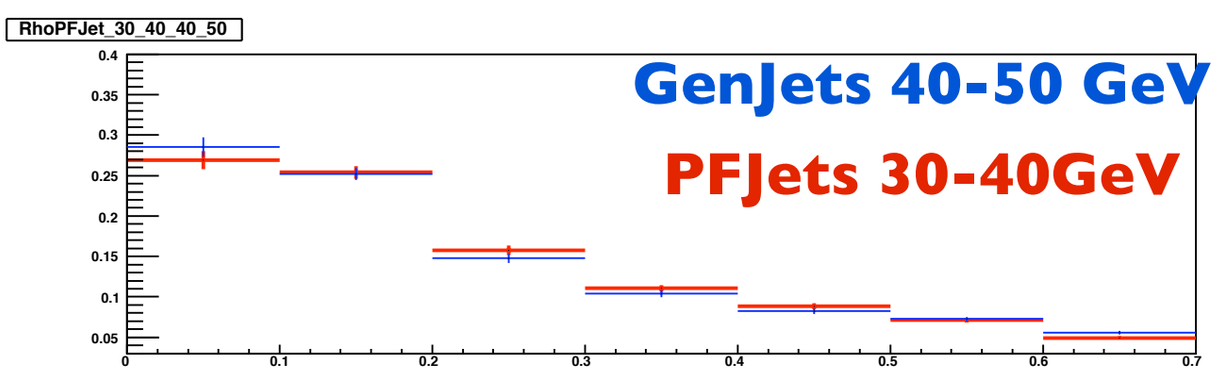
The GenJets are required to match PFJets with dR<0.7 requirement ...



- The plot shows the comparison of GenJetShapes with PFJetShapes for PFJet 30-40 GeV and GenJet 25-30GeV. PFJets are wider due to smearing.



- When both GenJet and PFJets are in the same bin (30-40GeV), there is no migration.

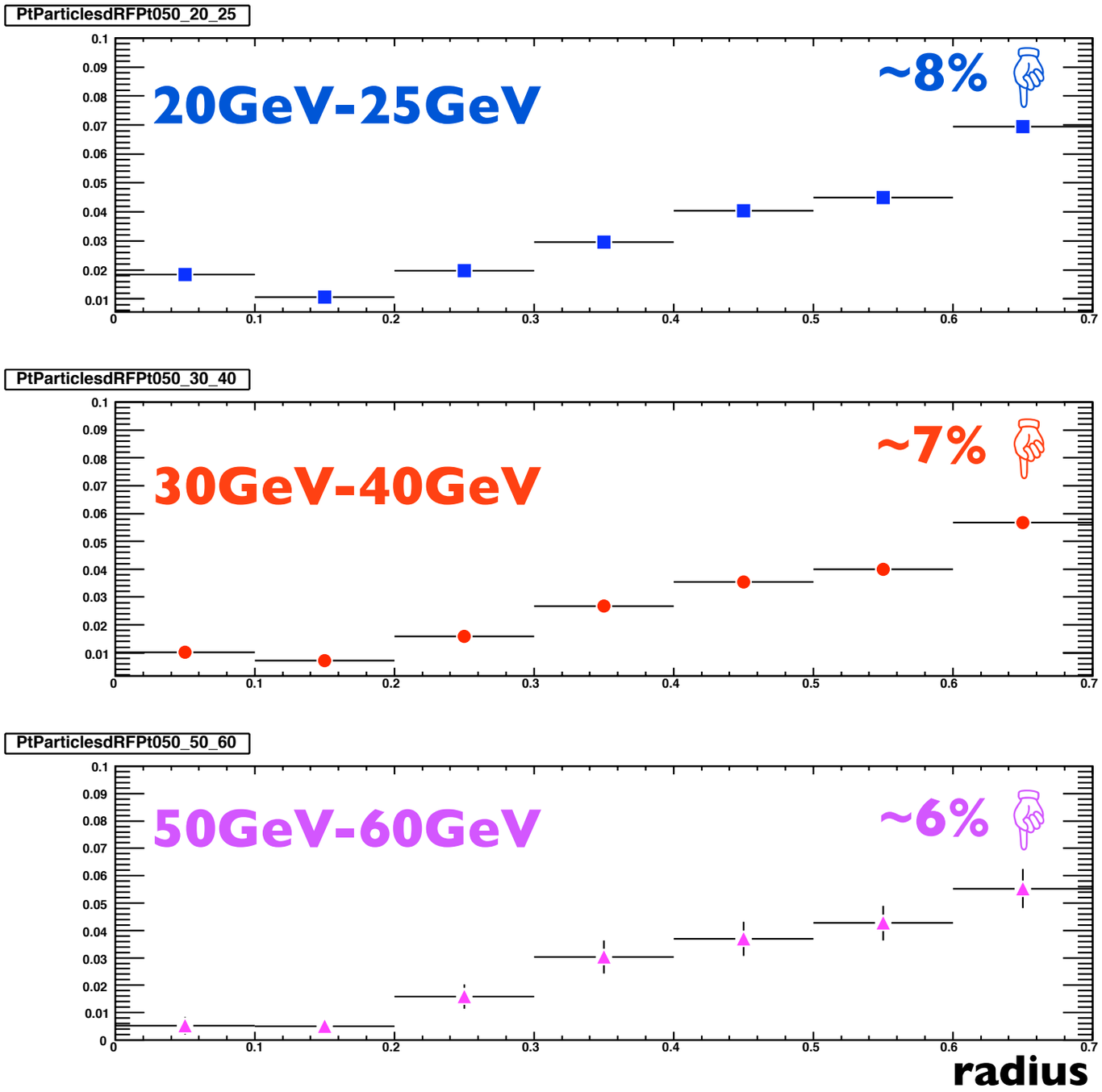


- Bottom plot shows when higher pt GenJets smear into lower pT PFJets.
- In all three cases the GenJets are narrower than the PFJets and correction in bin r=0.1 is higher than >1.

Understanding of Systematics - II

❷ - Understanding of shape of unsmearing correction factors (III)

The GenJets are required to match PFJets with dR<0.7 requirement ...



- This figure shows the fraction of a jet's energy that will be lost because it is too soft (< 50 MeV)

Assume we dont detect particles below 50MeV, this will be the correction in that bin. So we need to correct up the r=0.7 bin by ~8% for this effect for 20-25GeV bin.