First UE Results from CMS at 900 GeV

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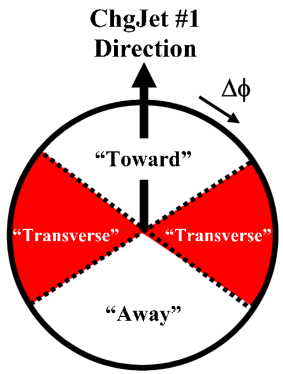
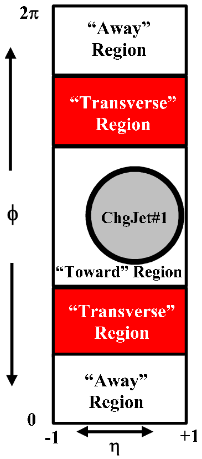
for the CMS Collaboration

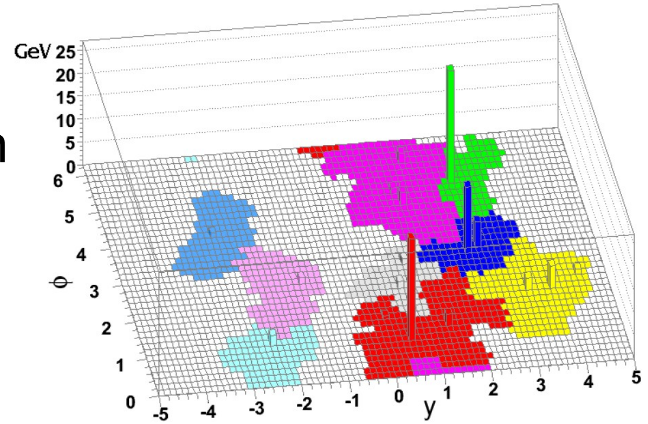
Outline

1. CMS UE measurement at 900 GeV in traditional approach:
   - CMS Physics Analysis Summary QCD-10-001 (public)
   - Soon to be released improved figures with basically the same content included (small formatting/labelling changes possible!)

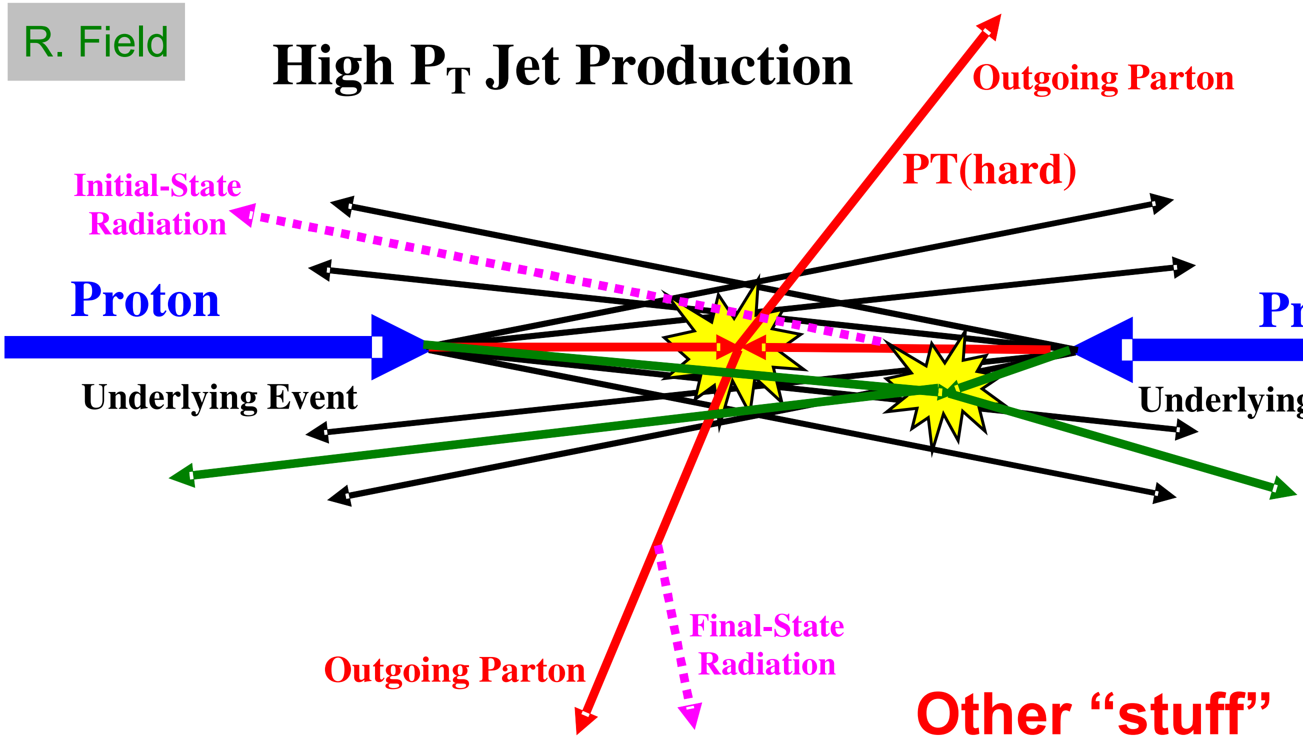




2. CMS UE study at 900 GeV in jet area/median approach:
   - Theory paper: "On the characterisation of the underlyin event"; JHEP04(2010)065; M. Cacciari, G. Salam, S. Sapeta
   - QCD-10-005 in progress

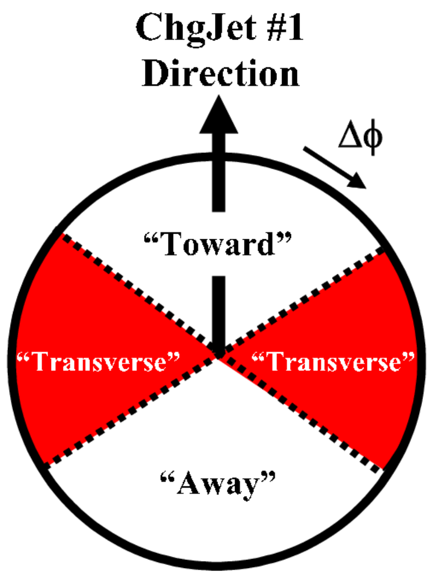


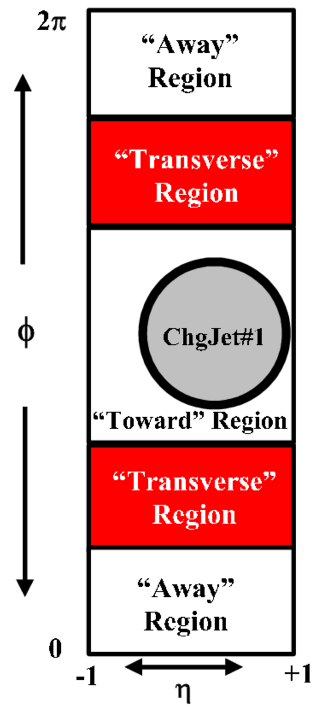
Traditional Approach



MPI, BBR, ISR and FSR not uniquely differentiable

Leading jet





Balancing jet

Other "stuff" but the hard scatter

Measurement possibility:

- Charged particle and p_T sum densities in transverse region of leading jet of charged particles

Trigger & Event Selection

Triggering:

- Beam Pick-up Timing for eXperiments (BPTX) signalling both beams
- Coincidence with signal of both Beam Scintillator Counters (BSC)
- ZeroBias events used for cross-checking efficiencies in data and MC

Event Selection:

Event selection	Data (nb. events)	Data [%]	MC [%]
triggered	255122	100	100
+ 1 real vertex	239038	93.7	92.9
+ 15 cm vertex z window	238977	93.6	92.8
+ 3 tracks associated	230611	90.4	88.7

900 GeV data from December

Track Selection

Tracks from iterative tracking of combinatorial track finder with loose cuts ...

Track selection	Data (nb. tracks)	Data [%]	MC [%]
no requirement	4826701	100	100
$+\ p_T > 0.5$ GeV/c	1986805	41.2	42.0
$+\ \lvert\eta\rvert < 2.5$	1950269	98.2	98.1
$+\ \lvert\eta\rvert < 2$	1588177	81.4	81.1
$+\ d_{xy}/\sigma(d_{xy}) < 5$	1376042	86.6	87.5
$+\ d_z/\sigma(d_z) < 5$	1260249	91.6	94.2
$+\ \sigma(p_T)/p_T < 5\%$	1201941	95.4	95.2
+ high purity algorithm	1168530	97.2	97.4
Total	1168530	24.2	25.5

Iterative tracking with tight cuts

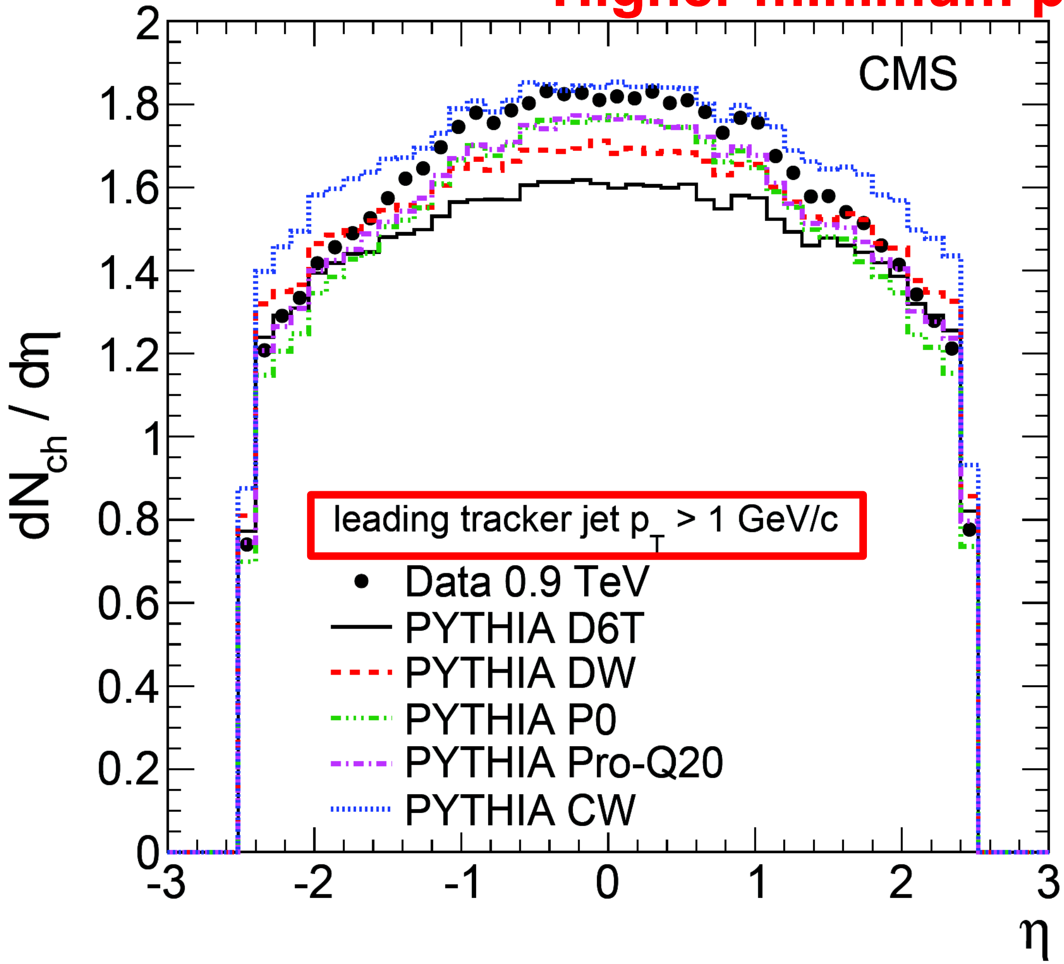
Final efficiency ~ 90%, fake rates ~ 2% at central rapidity (from Simulation)

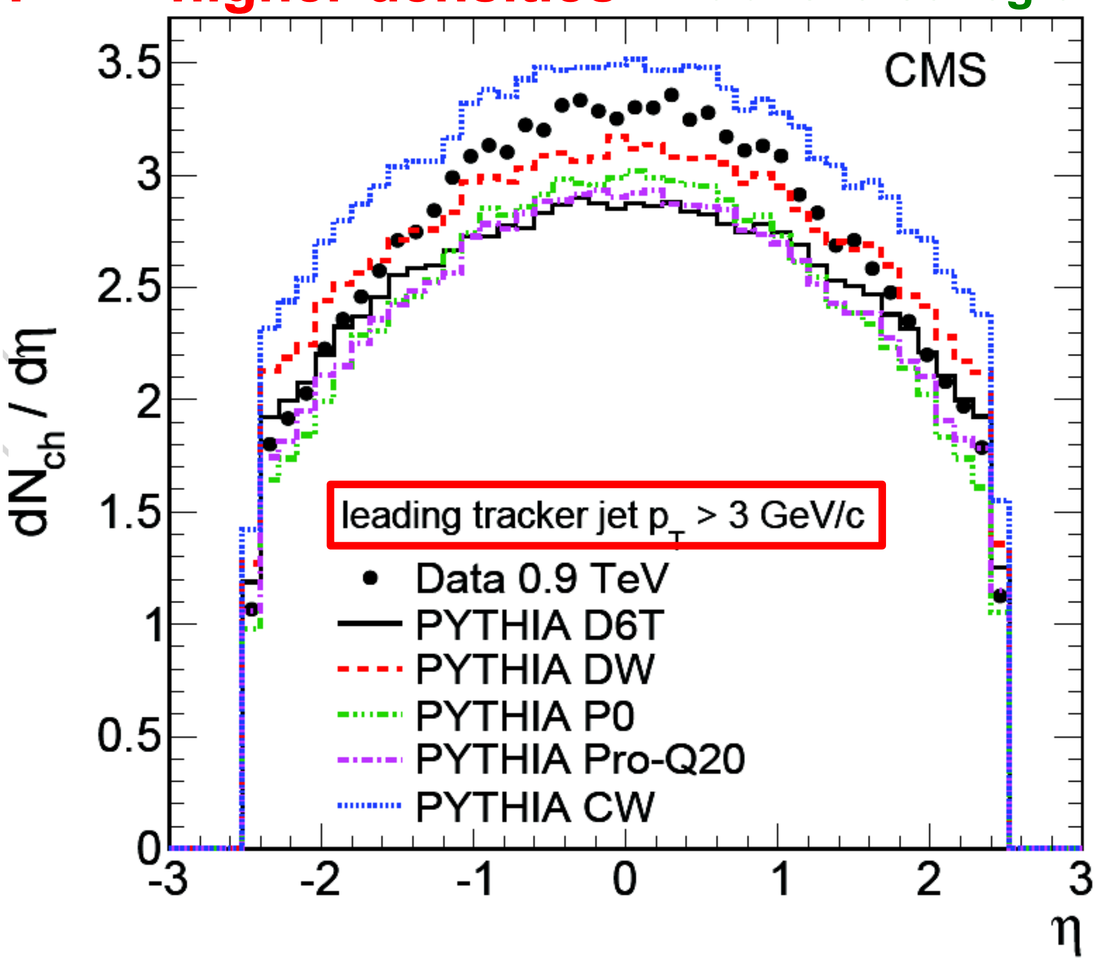
Charged Particle Density

Charged particle density versus pseudorapidity

All tracks! Not only transverse region.

Higher minimum pT ==> higher densities





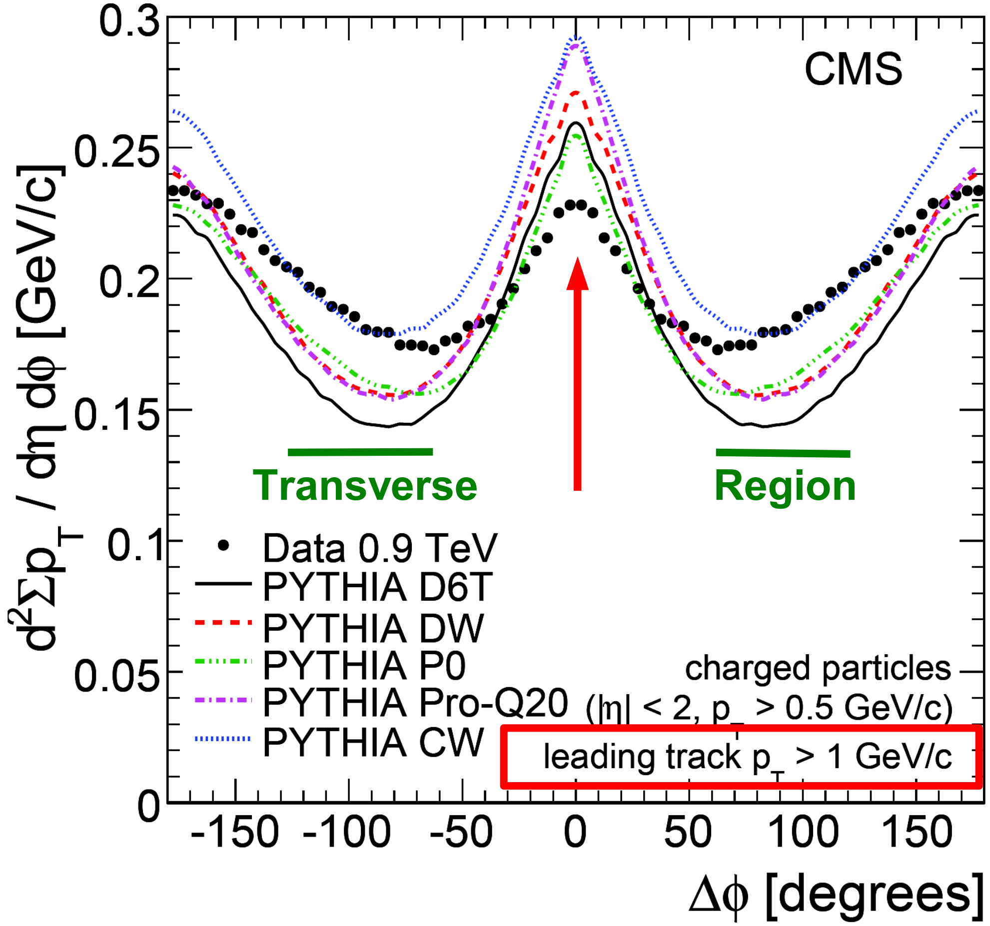
Distribution in ΔΦ

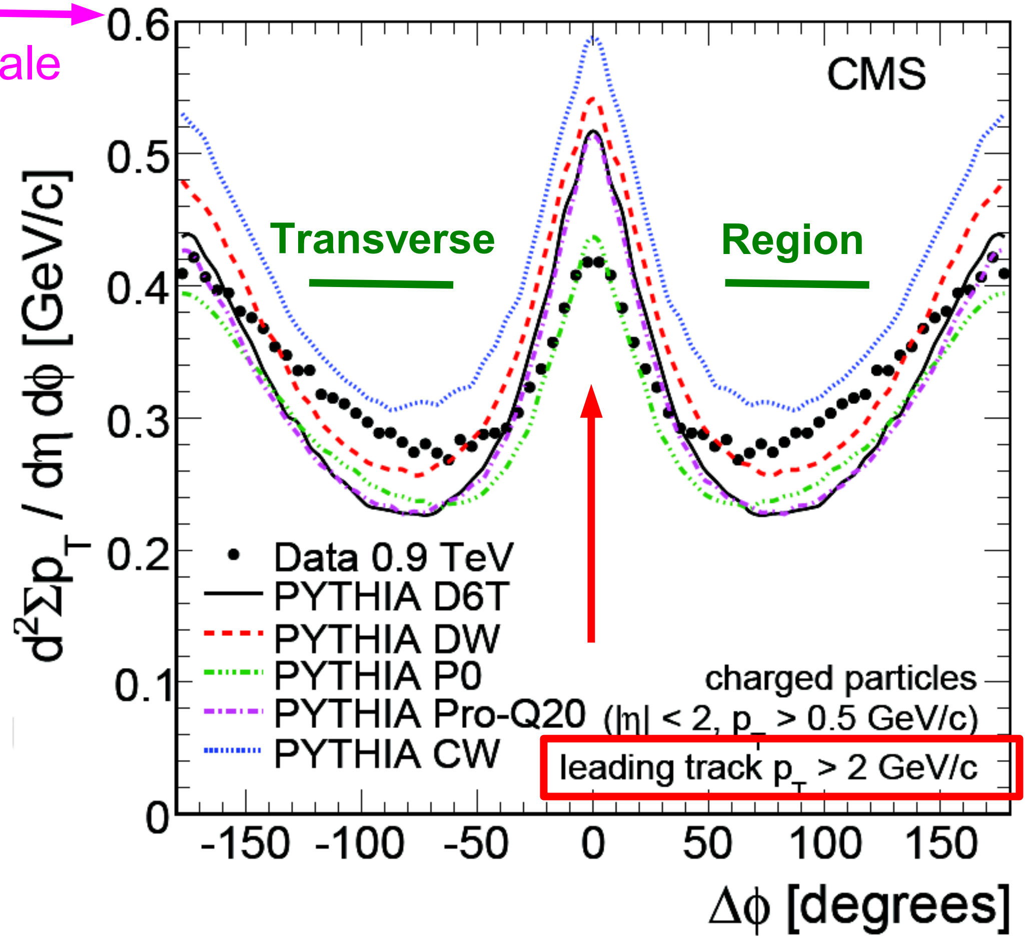
Sum pT density versus azimuthal angle with respect to leading object

Leading track or jet not included!

All tracks! Not only transverse region.

Scale





Systematic Uncertainties

All results/distributions are UNCORRECTED for detector effects

==>

- Cannot be used directly for MC tuning by people external to CMS
- Provide ratios of MC versus data which can be compared
- Show level of compatibility of physics models with our data
- No uncertainties for detector corrections
- Uncertainties here reflect potential differences in detector or beam condition modelling compared to the real measurement

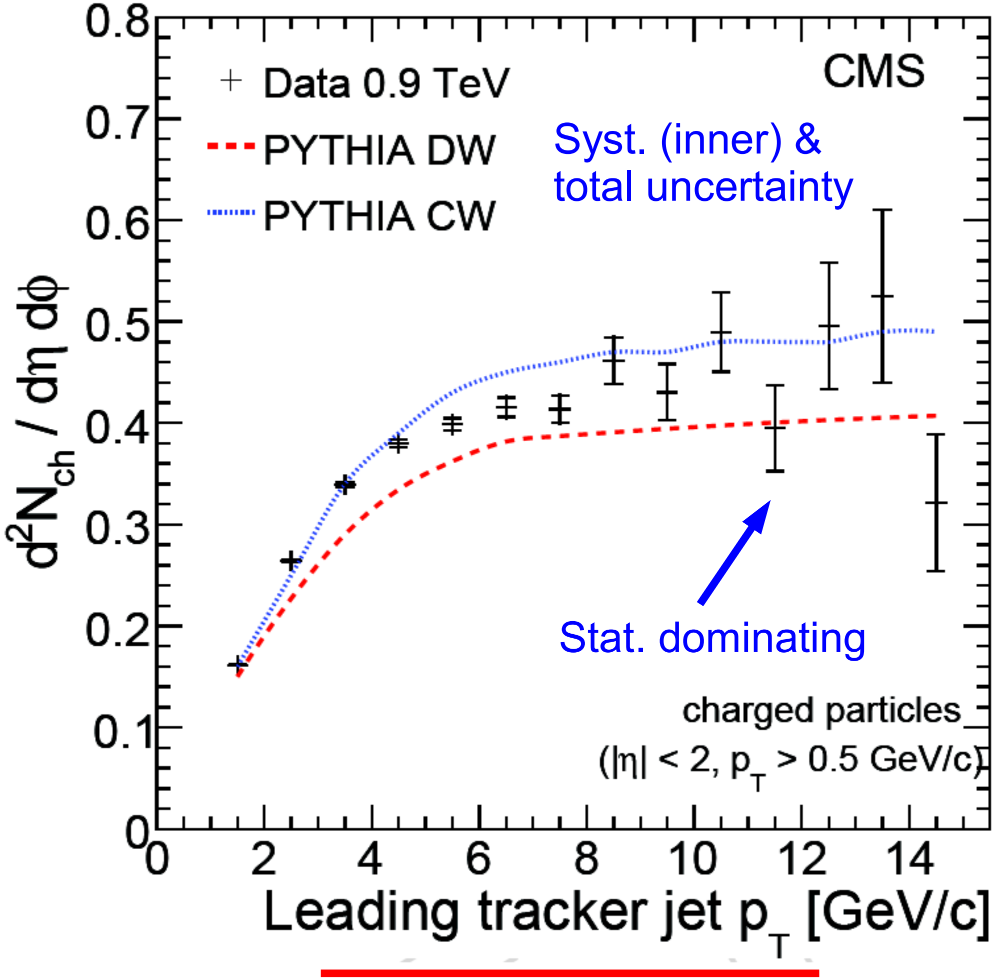
	Track sel.	Align.	Mat. budget	Bg. cont.	Trigger	Dead ch.	Beam spot	Total
$d^2N_{ch}/d\eta d\phi$ ($p_T = 3.5$ GeV/c)	0.3	0.3	1.0	0.8	0.6	0.1	0.5	1.8
$d^2\Sigma p_T/d\eta d\phi$ ($p_T = 3.5$ GeV/c)	0.4	0.3	1.0	0.8	1.1	0.1	0.5	1.8
dN/dN_{ch} ($N_{ch} = 4$)	0.6	0.6	1.2	1.0	1.2	0.2	0.6	2.3
$dN/d\Sigma p_T$ ($\Sigma p_T = 4.5$ GeV/c)	0.5	0.2	0.6	0.5	1.2	0.2	0.4	1.6
dN/dp_T ($p_T = 1$ GeV/c)	0.8	0.6	1.0	0.8	1.0	0.2	0.5	2.0

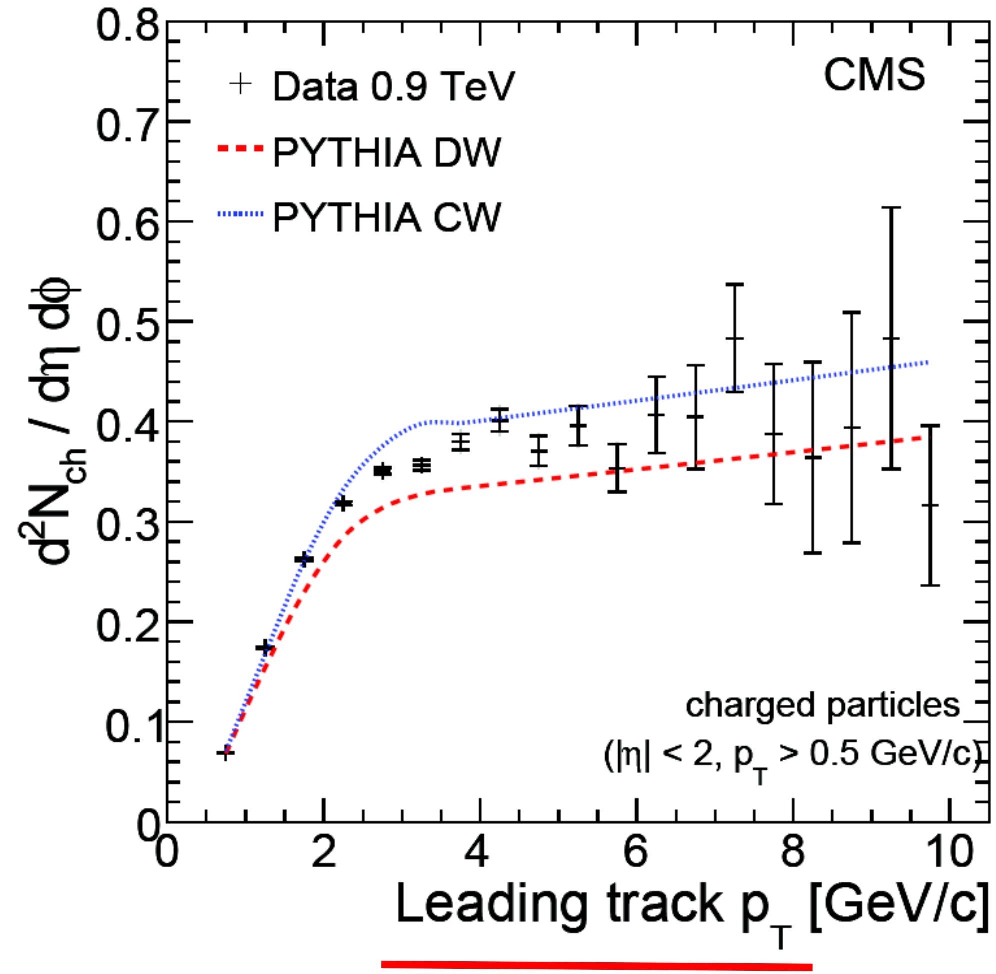
Charged Particle Density

Charged particle density in transverse region versus event pT scale

Note different x axis

Here and in the following: Tracks in transverse region

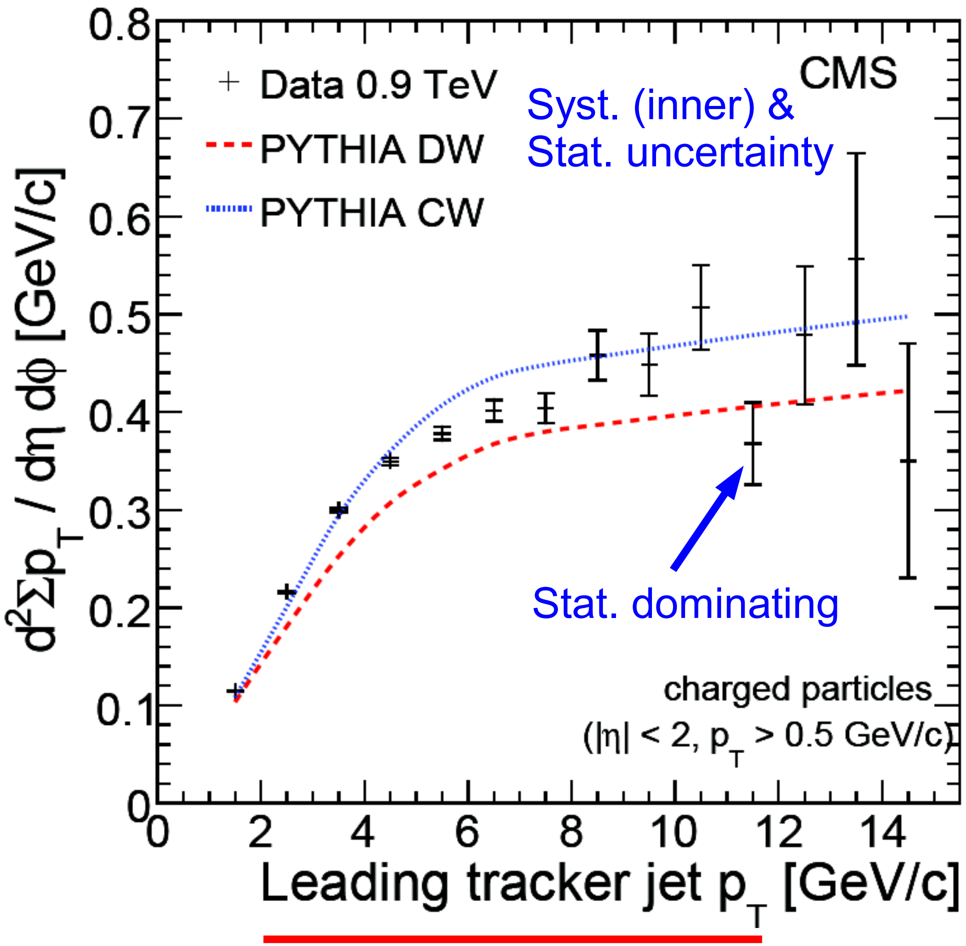


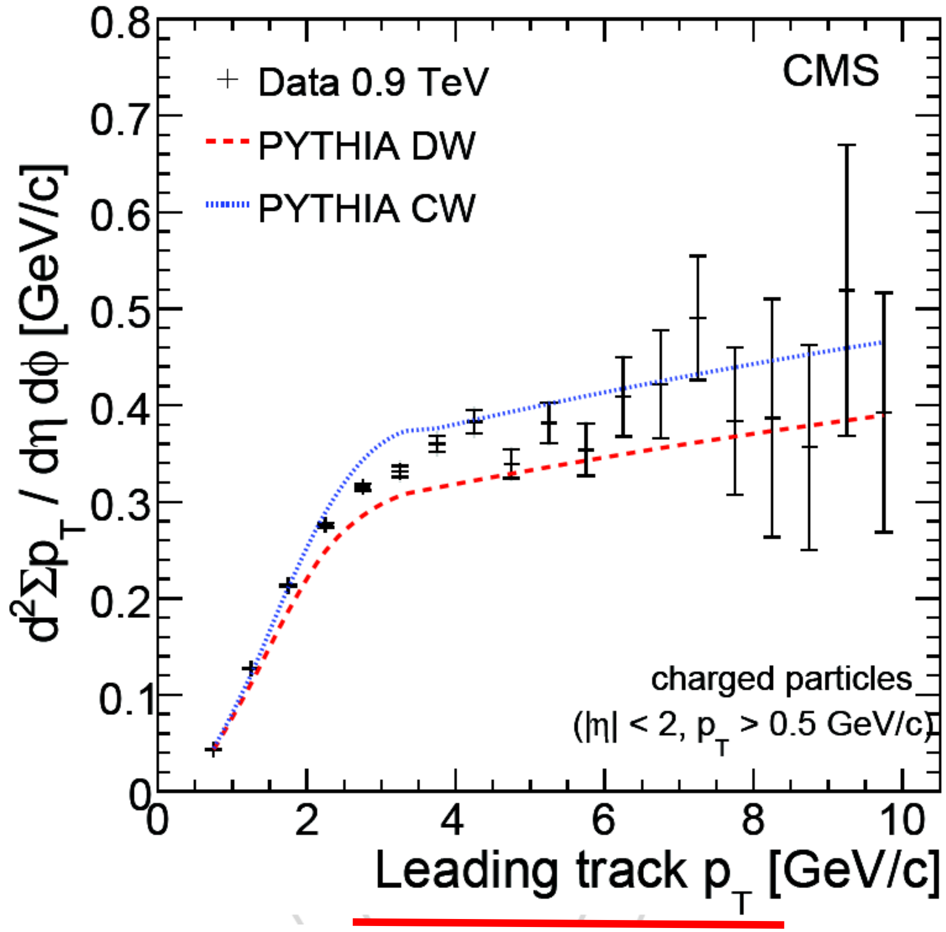


Sum pT Density

Sum pT density in transverse region versus event pT scale

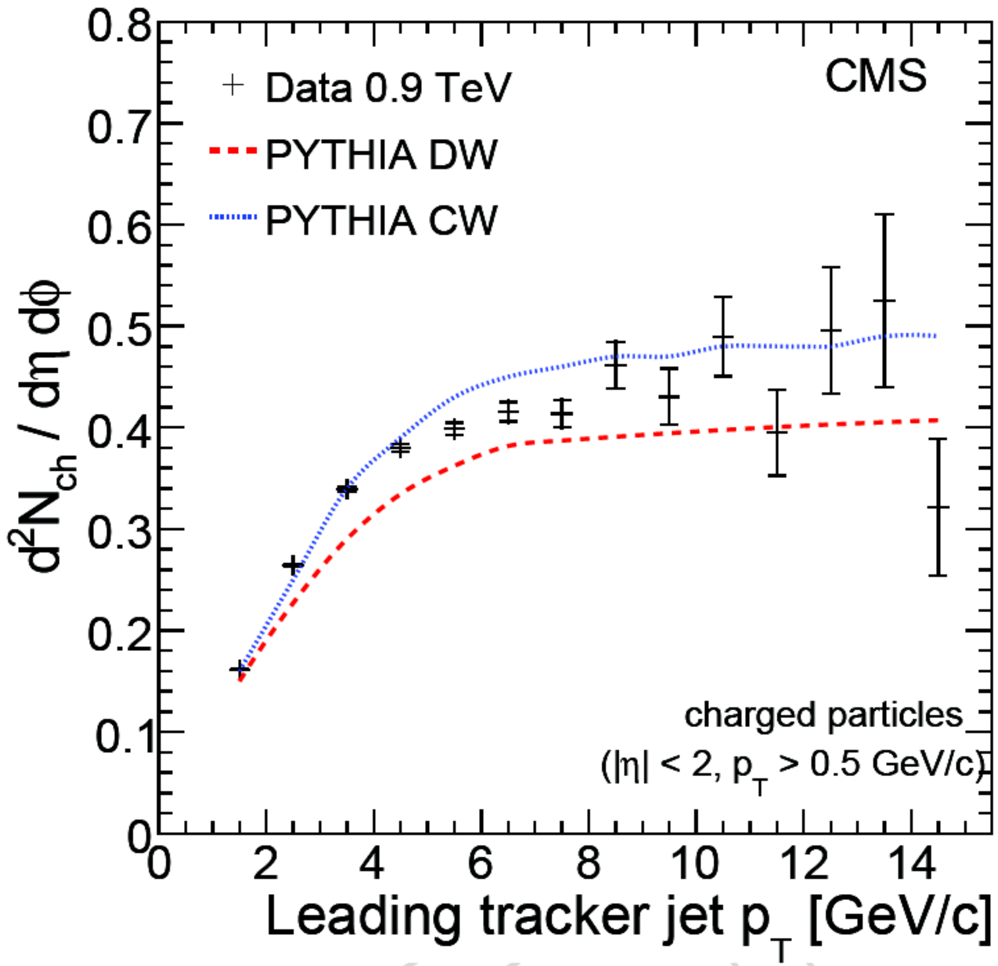
Note different x axis

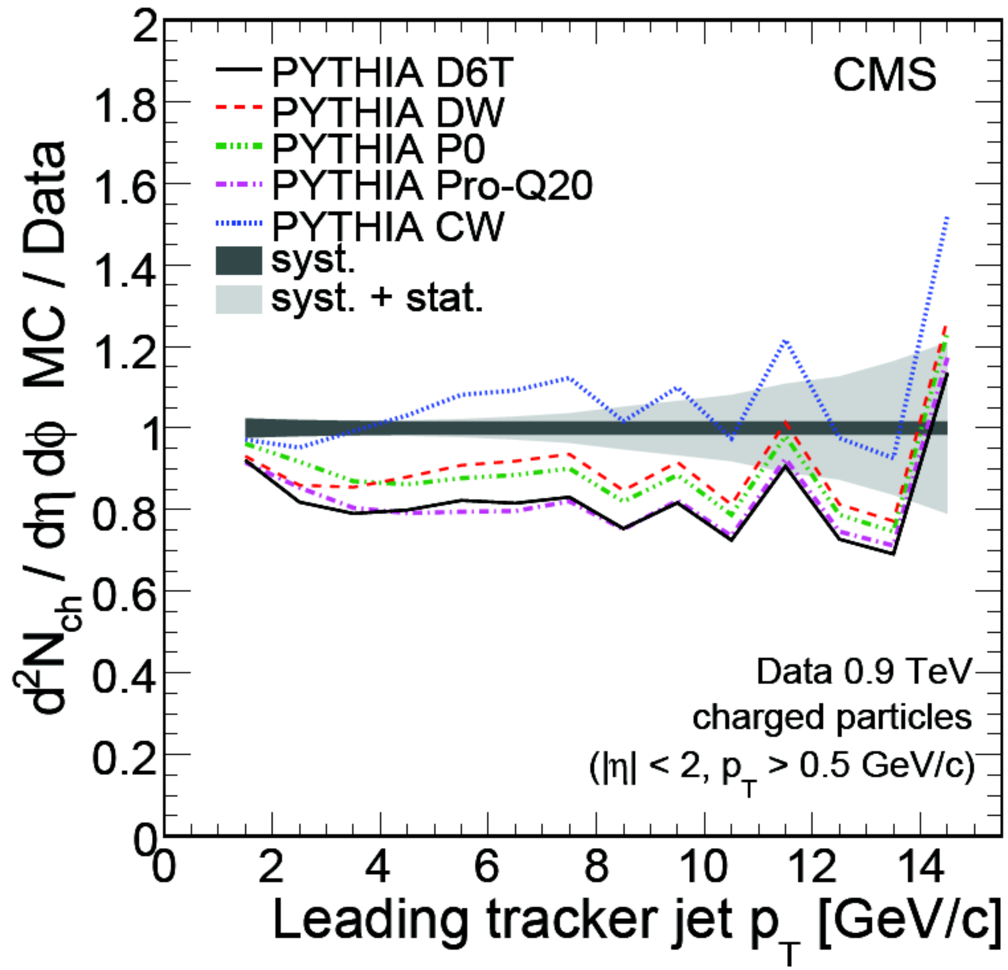




Ratio Data/MC 1/4

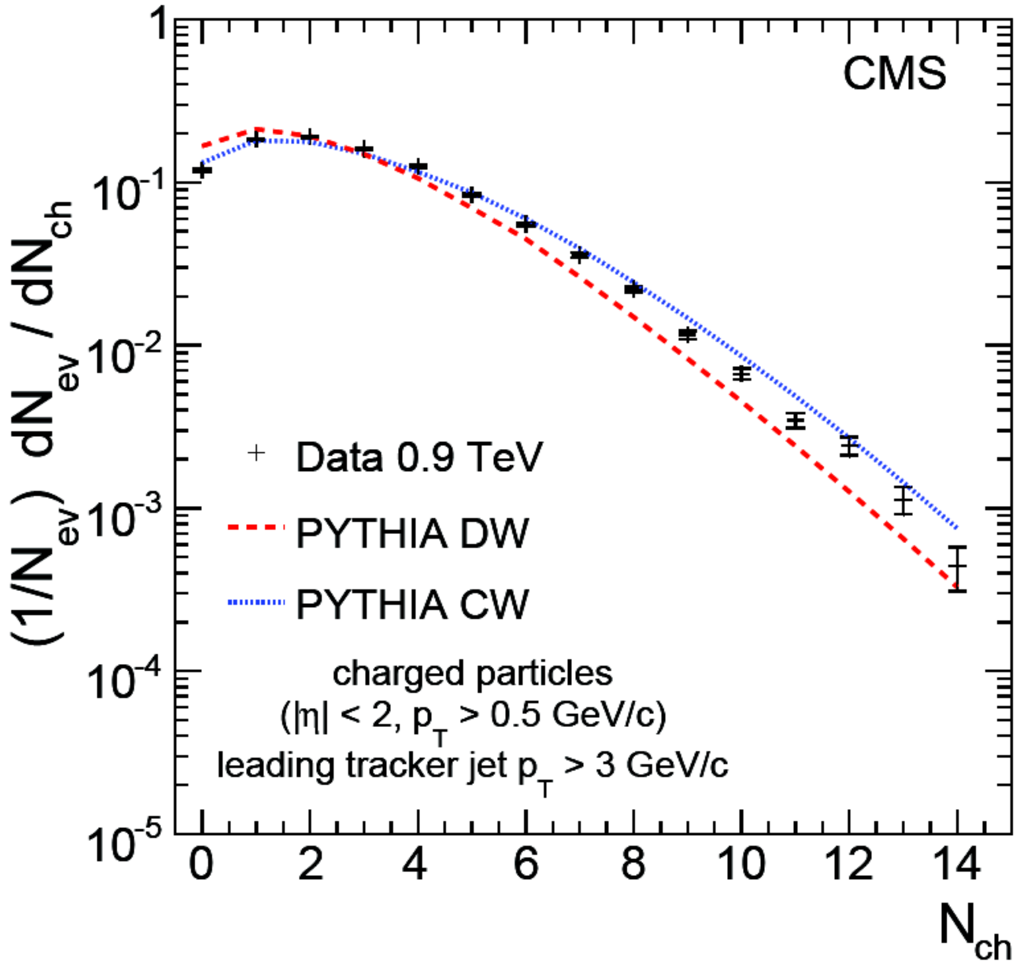
Charged particle density in transverse region versus event pT scale

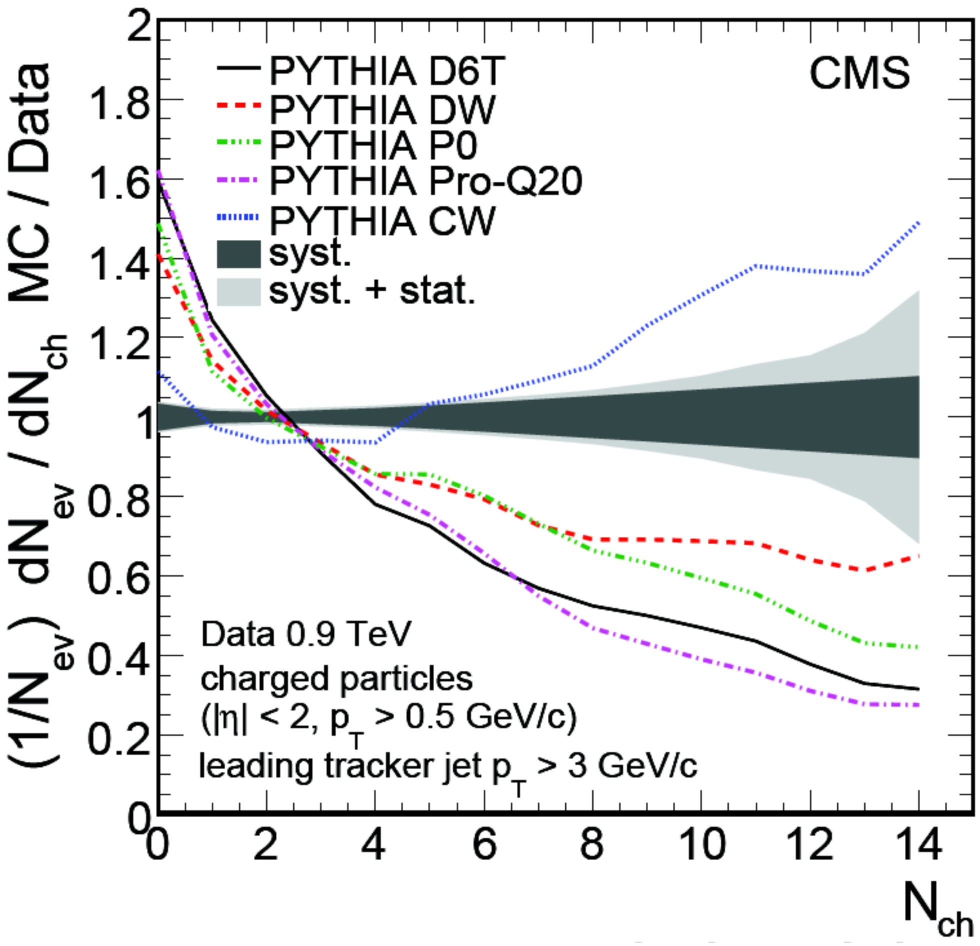




Ratio Data/MC 2/4

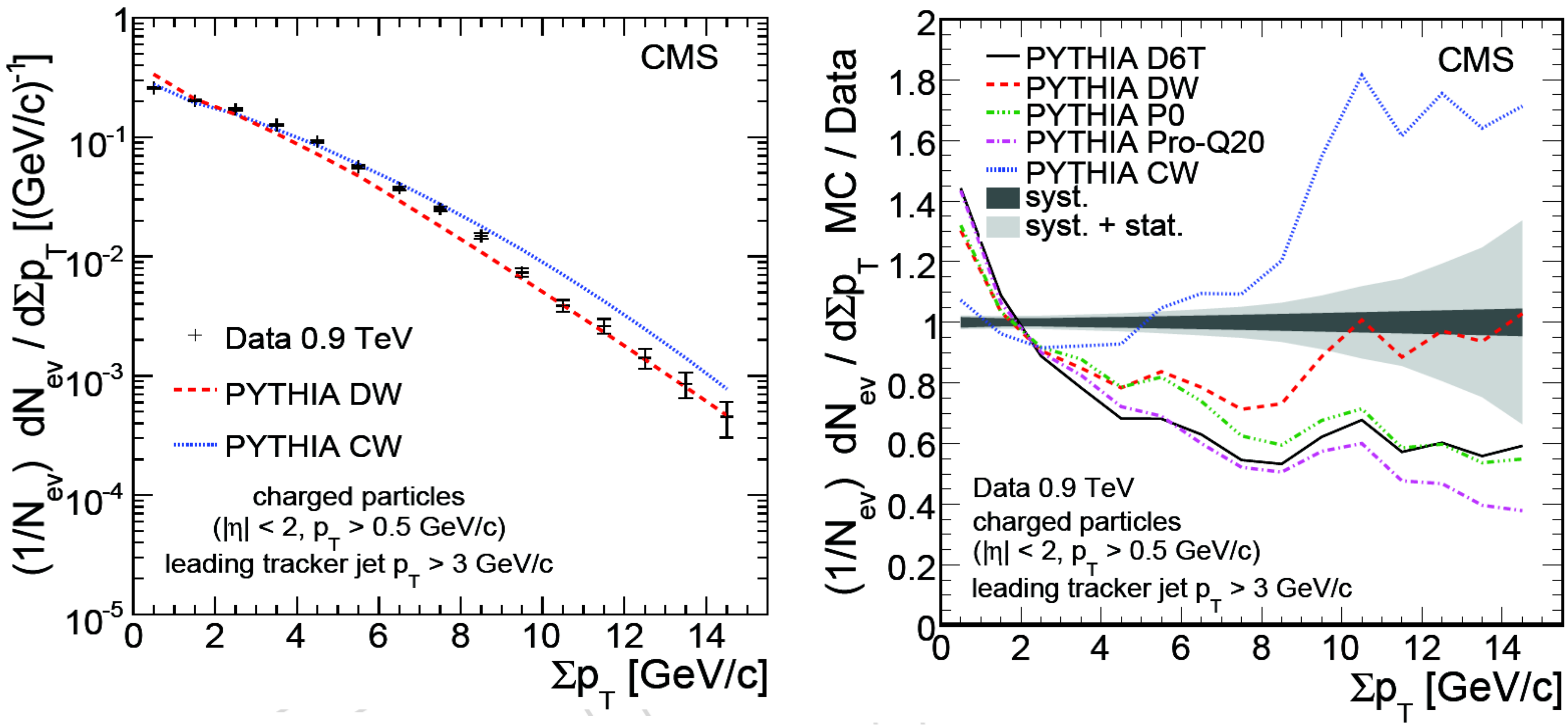
Multiplicity of charged particles in transverse region





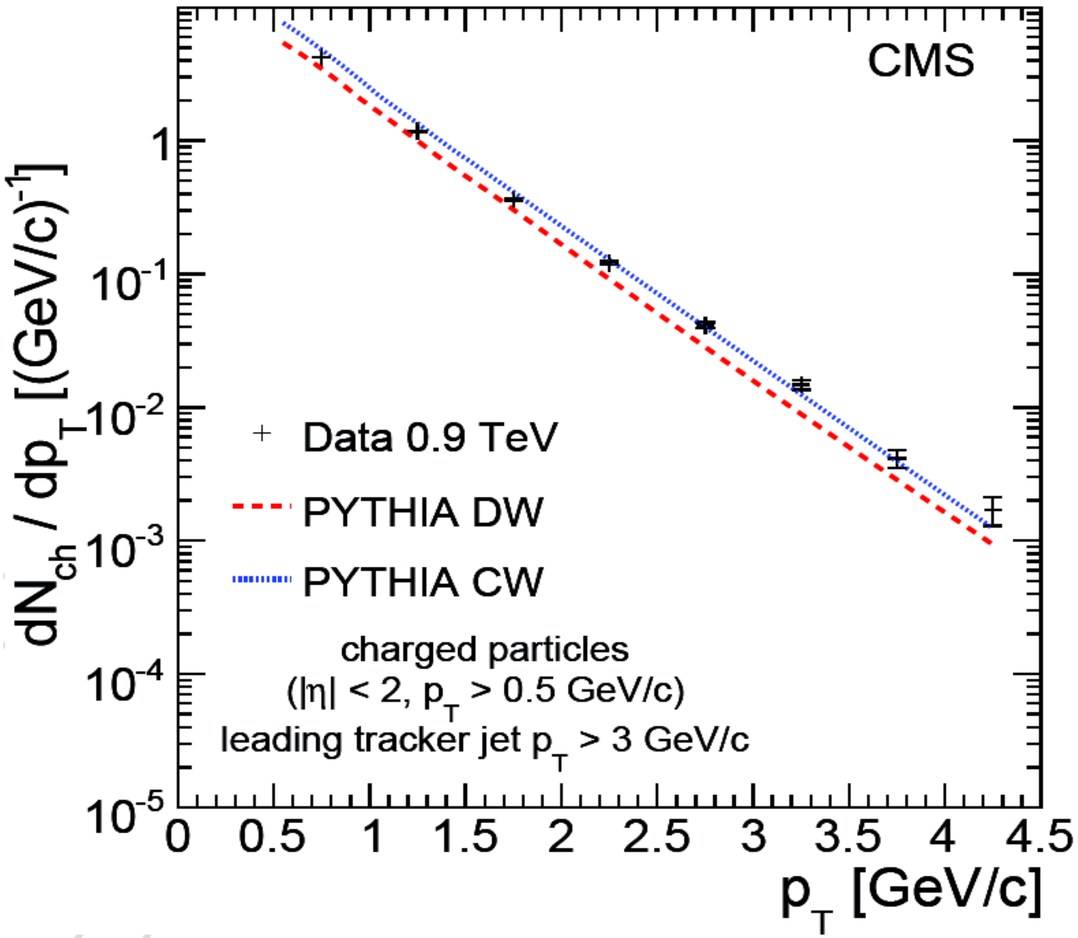
Ratio Data/MC 3/4

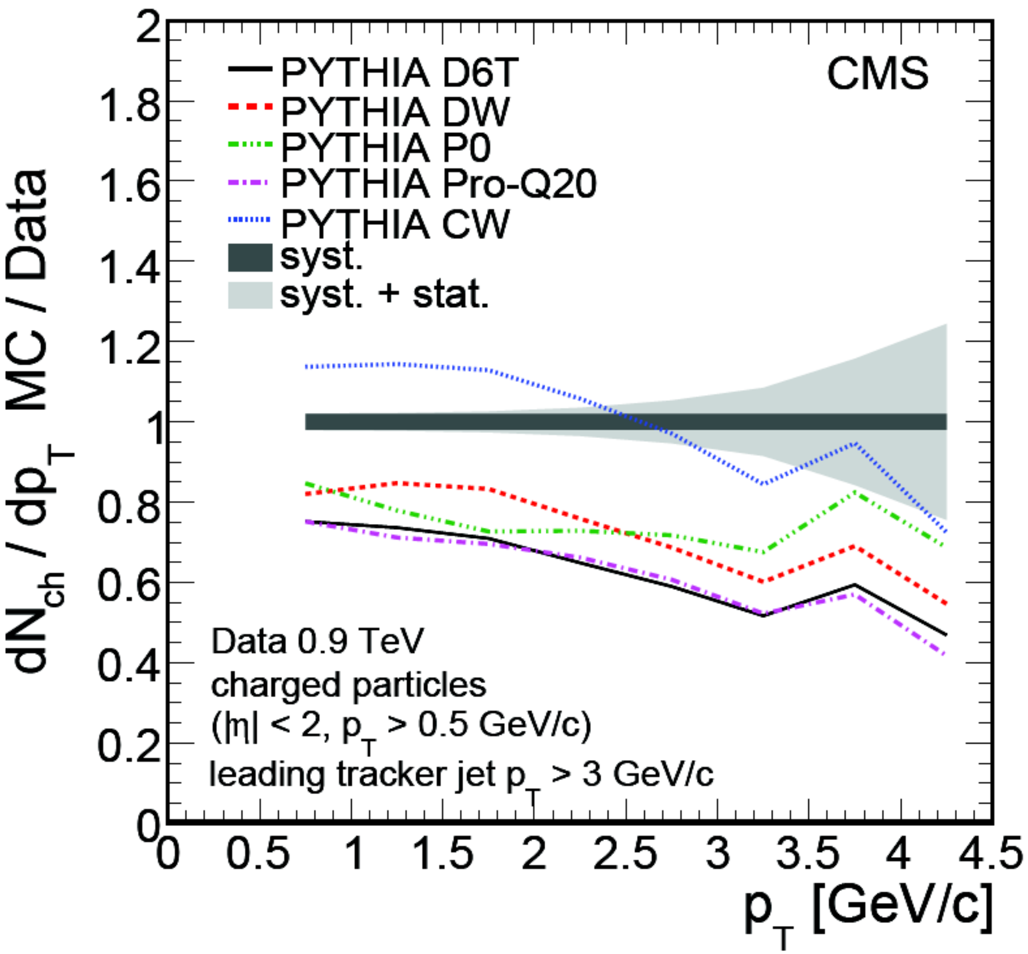
Sum pT distribution of charged particles in transverse region



Ratio Data/MC 4/4

PT distribution of charged particles in transverse region





Jet Area/Median Approach

Jet Areas:

Jet area is determined with **active area clustering**

- See “The Catchment Area of Jets”, JHEP04(2008)005, M. Cacciari et al.

pT infinitesimally small

A uniform grid of extremely soft “ghost particles” is clustered with the physical input particles

- Number of ghosts in a jet determines its area
- Requires a fast infrared & collinear safe jet algorithm
- Cambridge-Aachen, kT, anti-kT
- Empty regions are covered with **ghost jets**

physical jets

$$A_j = \frac{N_j^{\mathrm{ghosts}}}{\rho^{\mathrm{ghosts}}} = \frac{N_j^{\mathrm{ghosts}}}{N_{\mathrm{tot}}^{\mathrm{ghosts}}} A_{\mathrm{tot}}$$

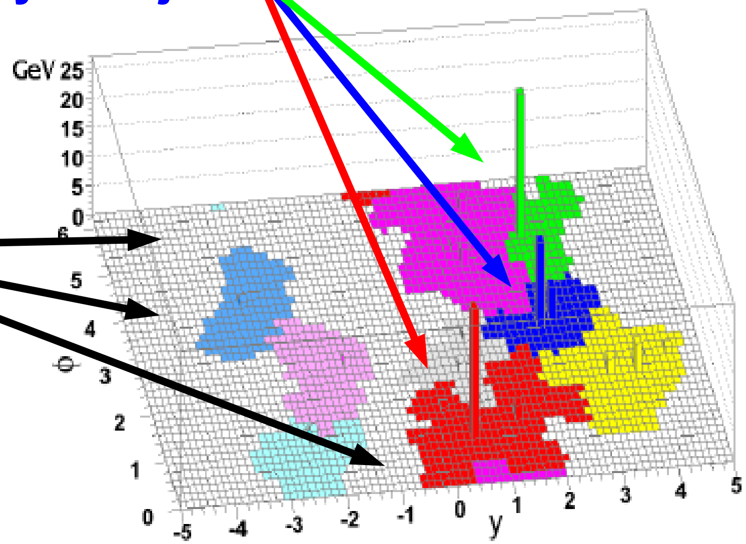
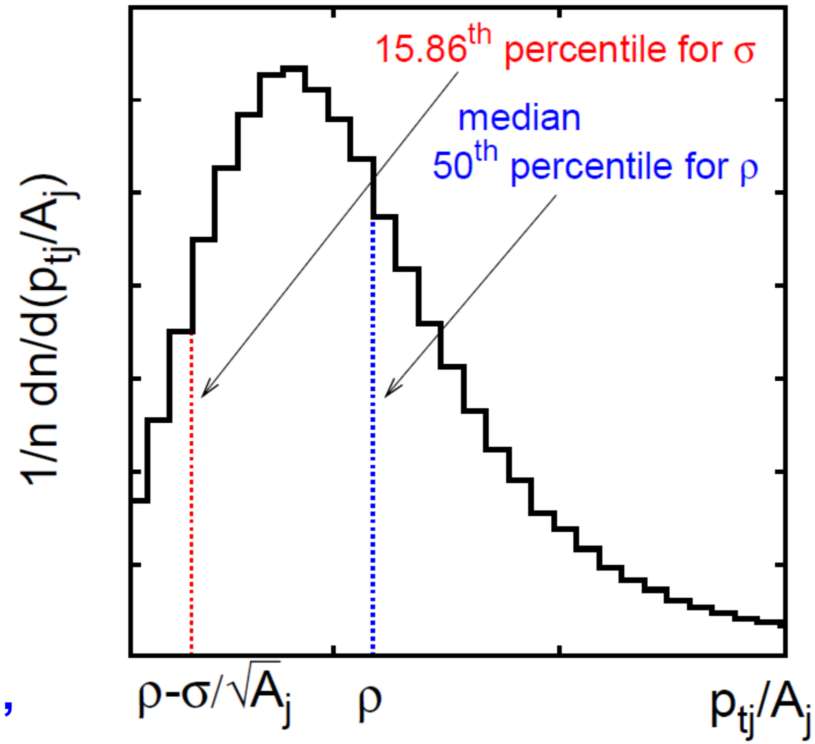


Figure 4: Active area for the same event as in figure 3, once again clustered with the k_t algorithm and $R = 1$. Only the areas of the hard jets have been shaded — the pure ‘ghost’ jets are not shown.

Jet Area/Median Approach

New Observable:

- **ρ = median(pt/area) of all jets in an event**
- **Determination of leading objects (jets) inherent**
- **Suited for different event topologies**
- **Looks into complete region in η, Φ**
- **Has never been used in tuning**



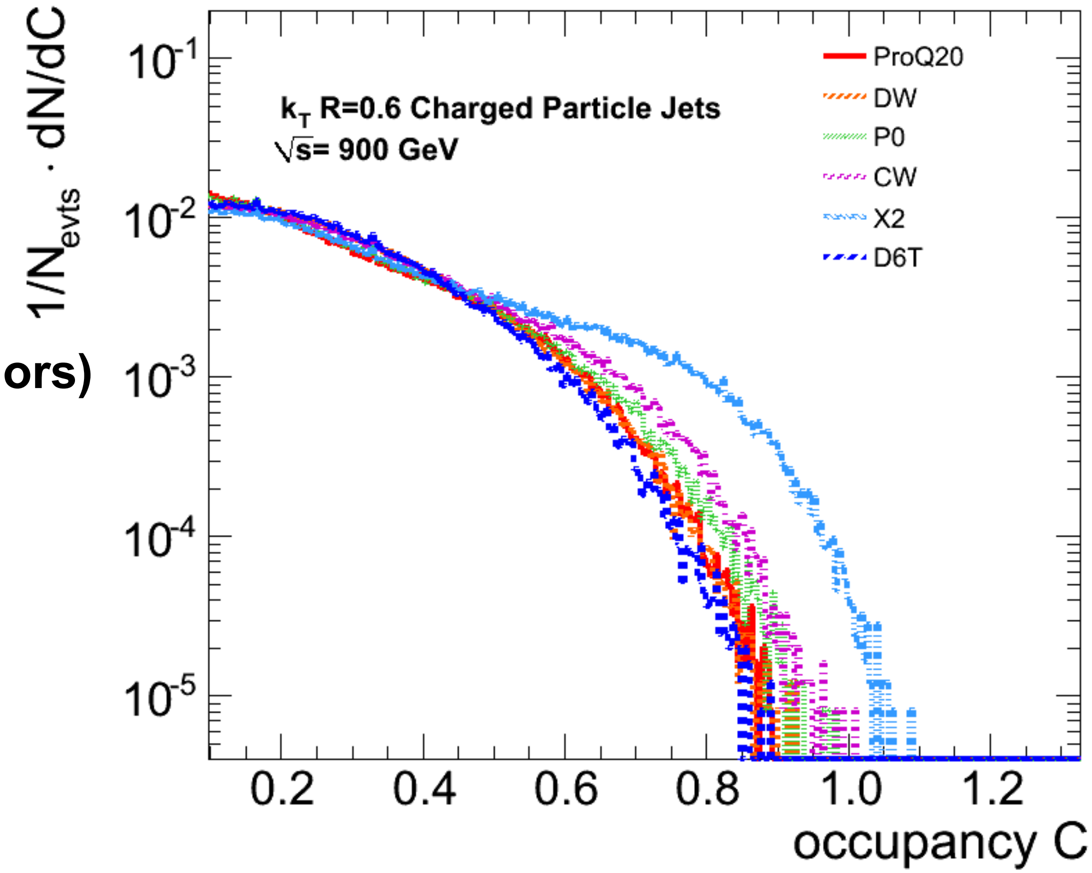
Event and Track Selection identical to previous one, only differences:

- **pT track > 0.3 GeV instead of 0.5 GeV**
- **$|\eta|$ track < 2.3**
- **$|\eta|$ track-jet < 1.8**

Event Occupancy

Define event occupancy **as sum of all jet areas in an event divided by overall considered detector area (defined to be 4 * 2π = 8π).**

- **If occupancy is smaller than 0.5 most of the detector is covered with ghost jets**
  → Median(pt/area) = 0 in this case
- **Adjustment of ρ (discussed with authors) is necessary**



Adjusted observable:

$$\rho' = \underset{j \in physical\ jets}{median}\left[\left\{\frac{p_{T,j}}{A_j}\right\}\right] * C$$

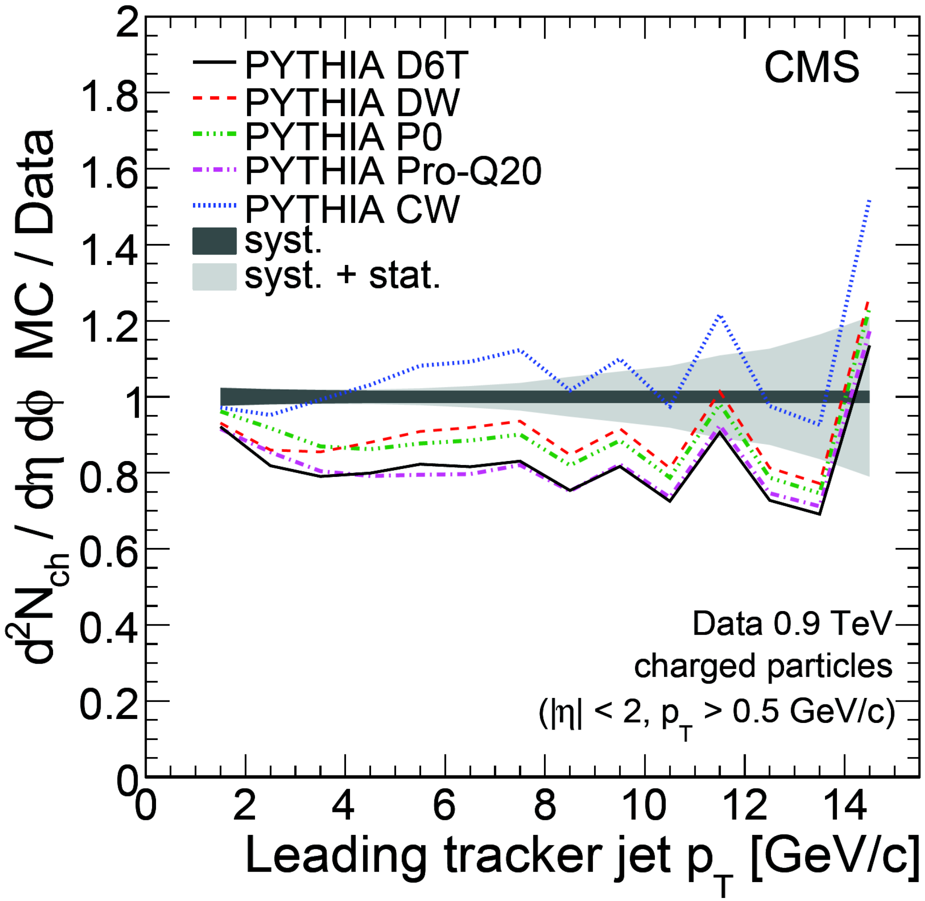
$$C = \frac{\Sigma_j A_j}{A_{tot}}$$

takes into account only physical jets

Jet areas extending beyond |η|=2 may give values > 1 with the definition above

Traditional and New

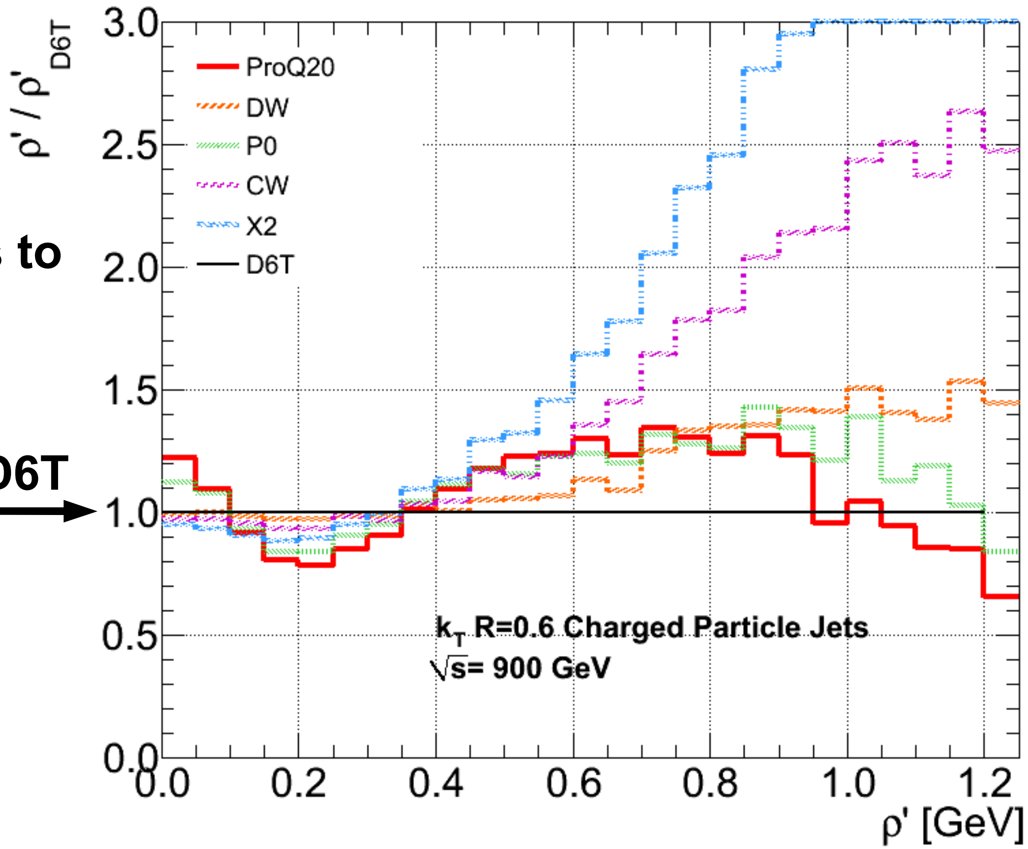
Traditional Method



Ratios to Data

D6T

Jet Area/Median Method



Charged generator particles only
Data analysis ongoing

Conclusions & Outlook

- No tune describes all features of the data at 900 GeV
- In the transverse region they predict generally not enough hadronic activity
- Agreement gets better at higher minimal transverse momenta
- The measurements exhibit a preference for higher values of the energy dependence, i.e. $\varepsilon = 0.25$ (as in tune DW) or 0.30 (as in tune CW)
- Lower values of 0.16 as in tune D6T are disfavoured
- The analysis on 7 TeV data as well as corrections for detector effects are ongoing
- An investigation of the UE with the new jet area/median approach is in progress

Acknowledgements

Many thanks for all the dedicated work go to:

The "traditional" UE Group:
D. Acosta, S. Bansal, P. Bartalini, G. Cerati, Y. Chao, D. Dobur, L. Fanó, R. Field, I.K. Furic, K. Kotov, T.N. Kypreos, A. Lucaroni, D. Majumder, K. Mazumdar, L. Mucibello, G. Sguazzoni, M. Zakaria

The "jet area/median" UE Group:
J. Berger, V. Büge, C. Hackstein, M. Heinrich, O. Oberst, A. Oehler, D. Piparo, G. Quast, KR, F. Stober, M. Zeise

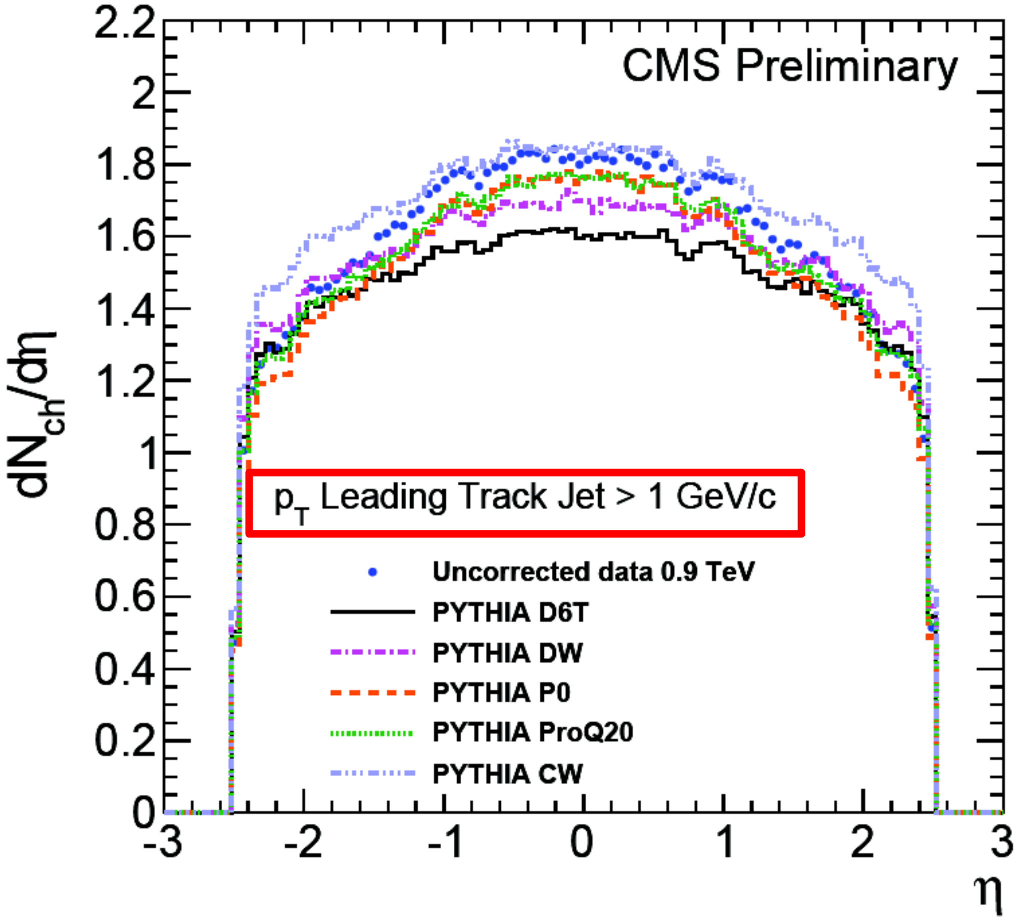
Backup

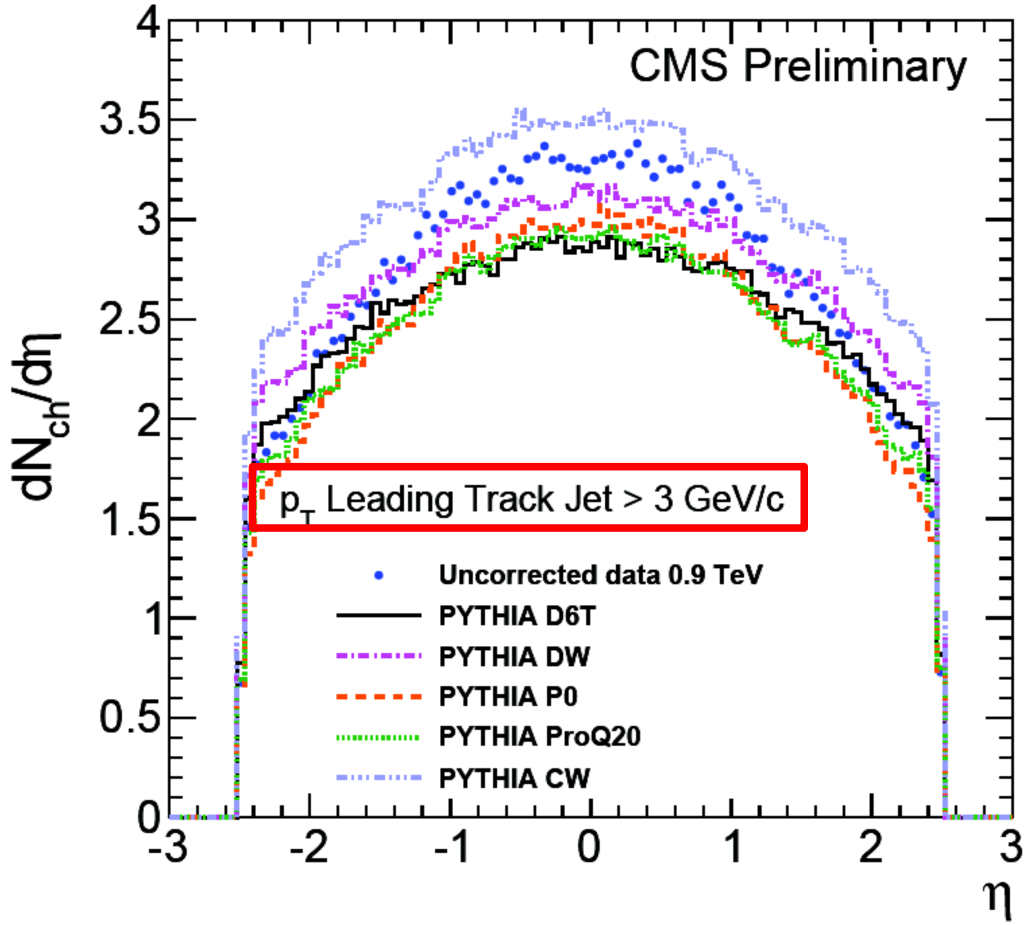
Charged Particle Density

Charged particle density versus pseudorapidity

Higher minimum pT ==> higher densities

All tracks! Not only transverse region.





Distribution in ΔΦ

Sum pT density versus azimuthal angle with respect to leading object

Leading track or jet not included!

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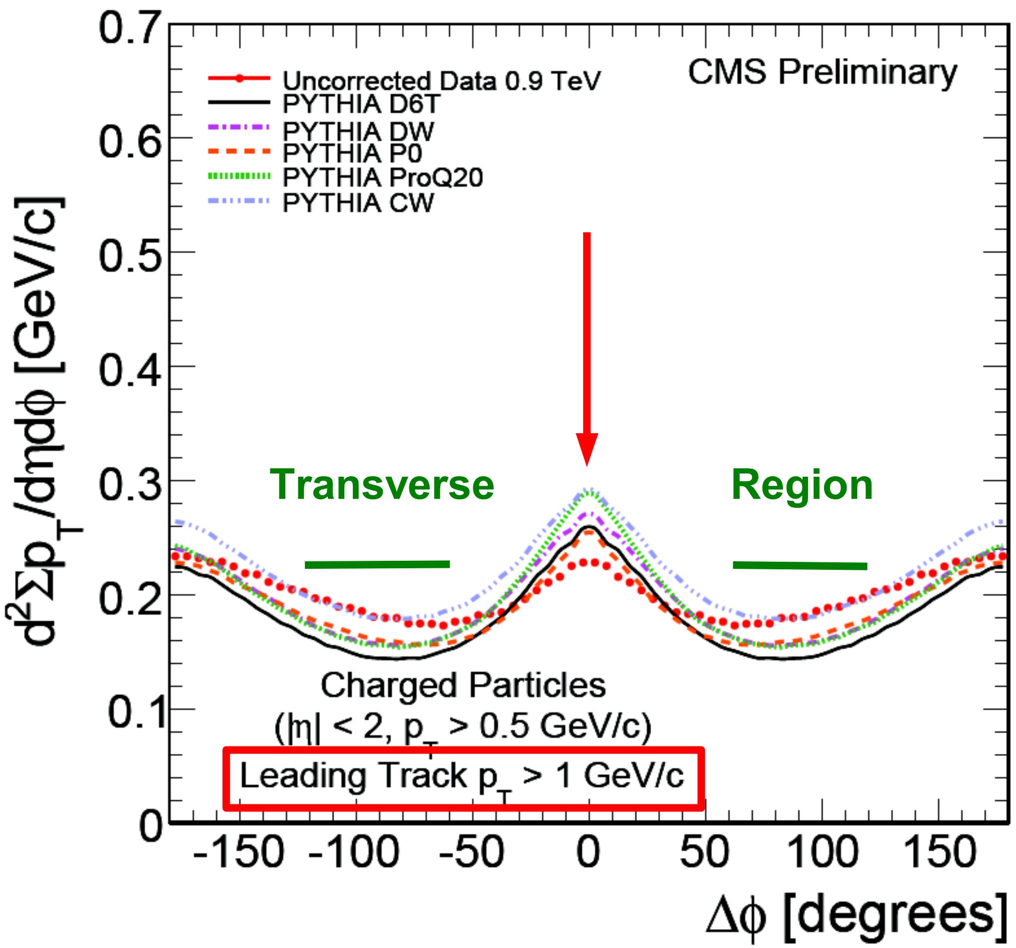
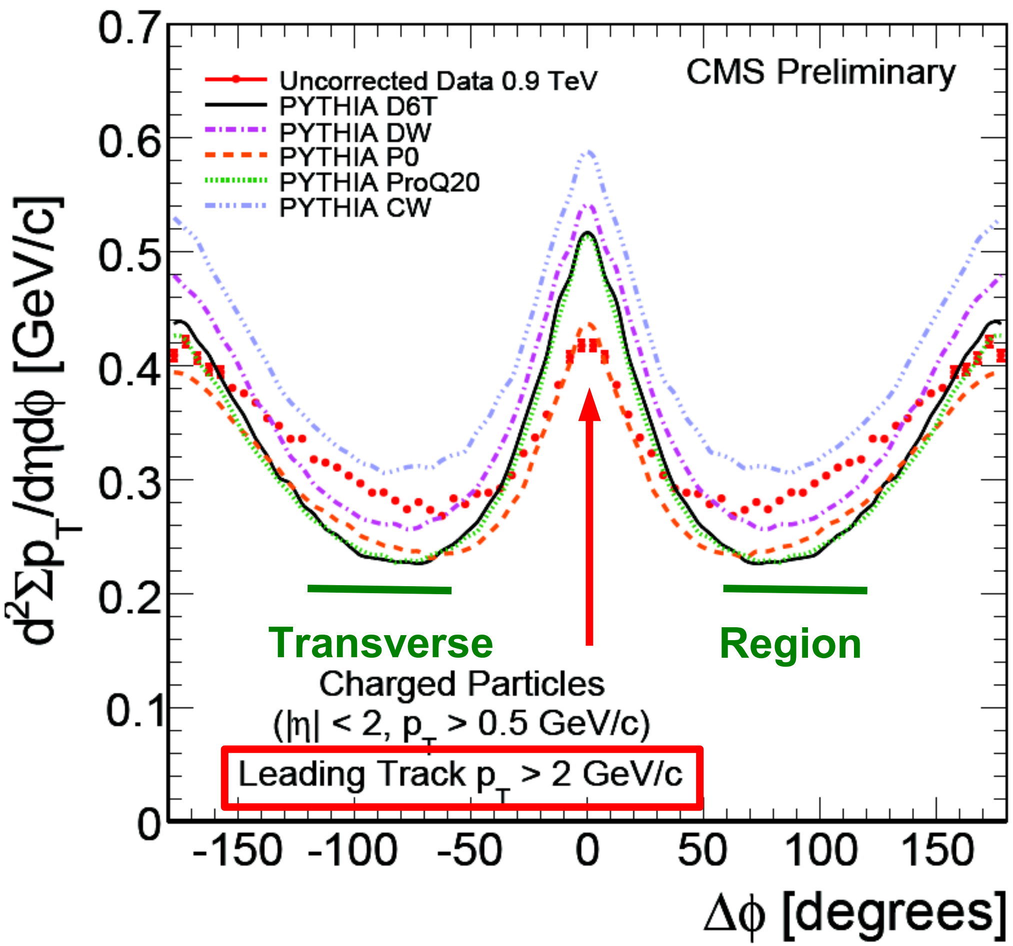
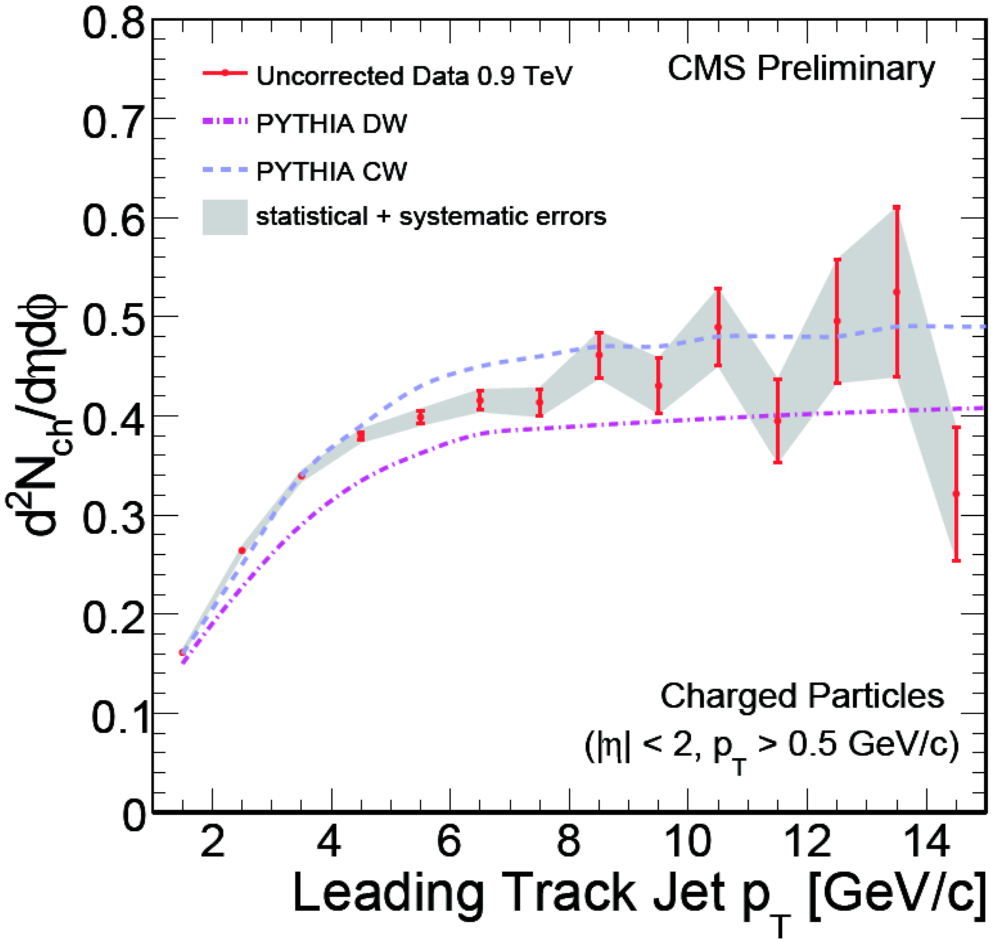
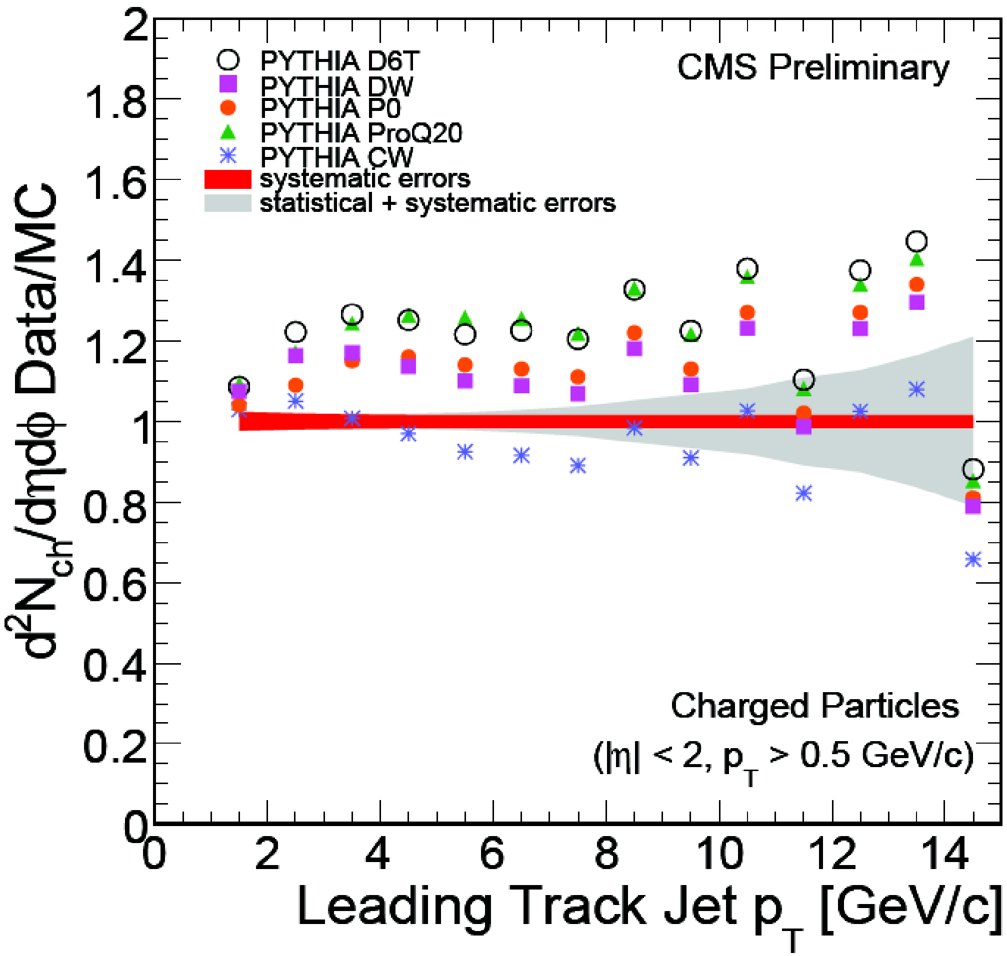




Ratio Data/MC 1/4

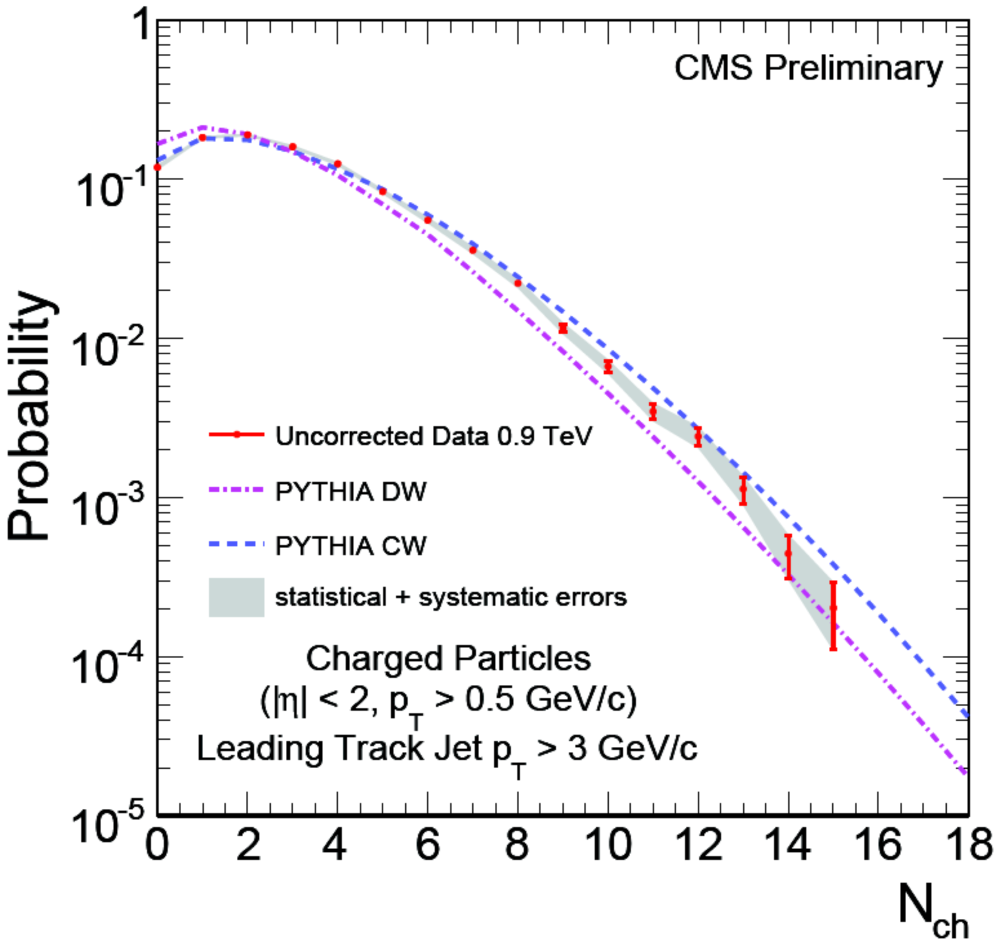
Charged particle density in transverse region versus event pT scale

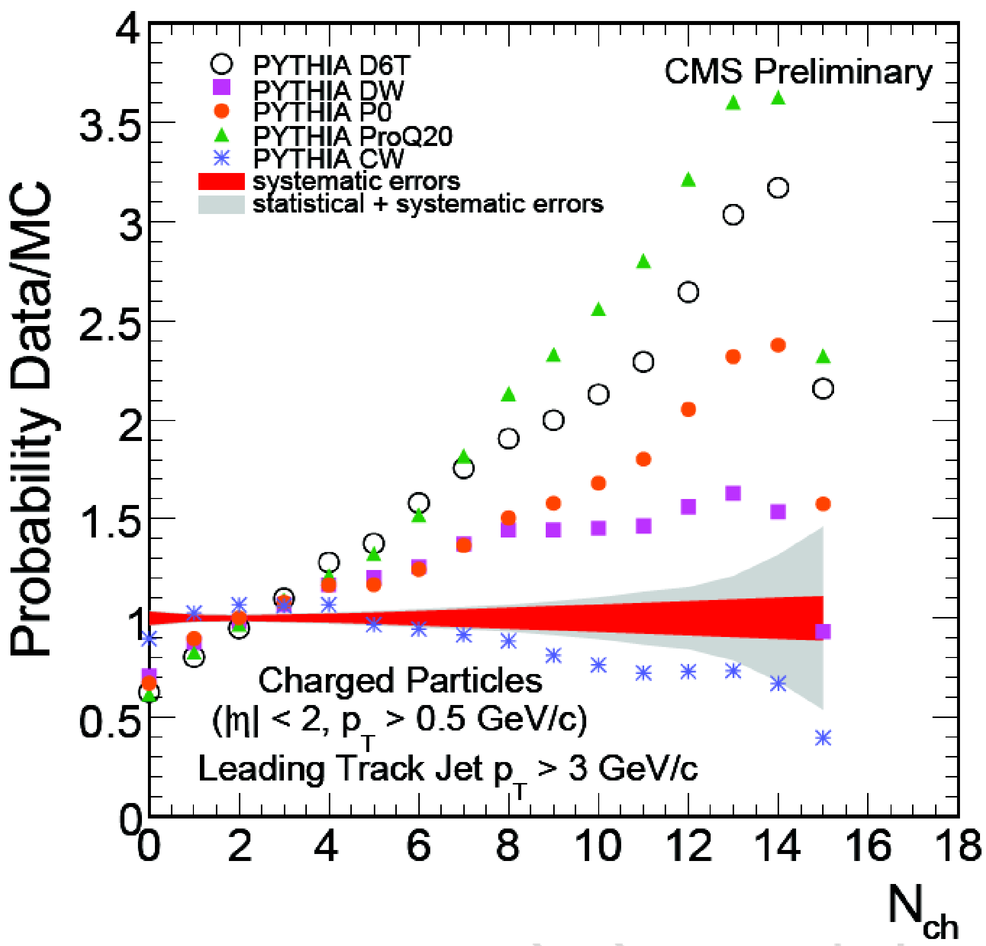




Ratio Data/MC 2/4

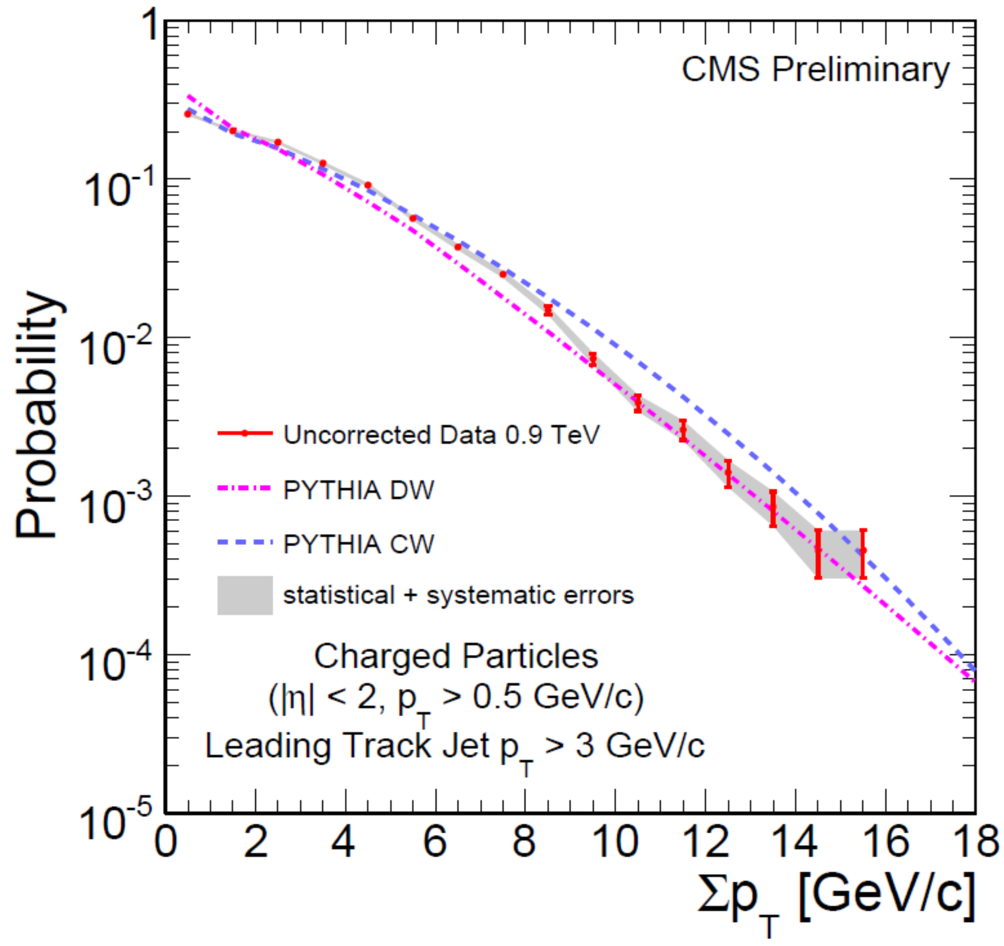
Multiplicity of charged particles in transverse region

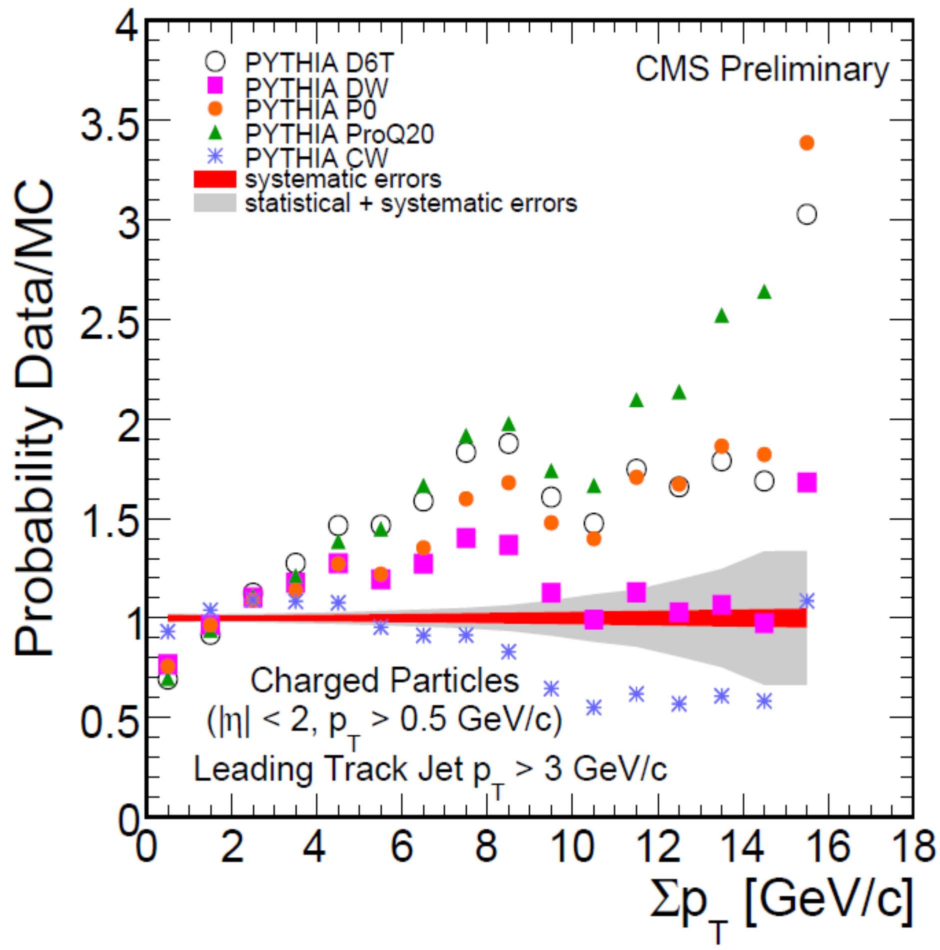




Ratio Data/MC 3/4

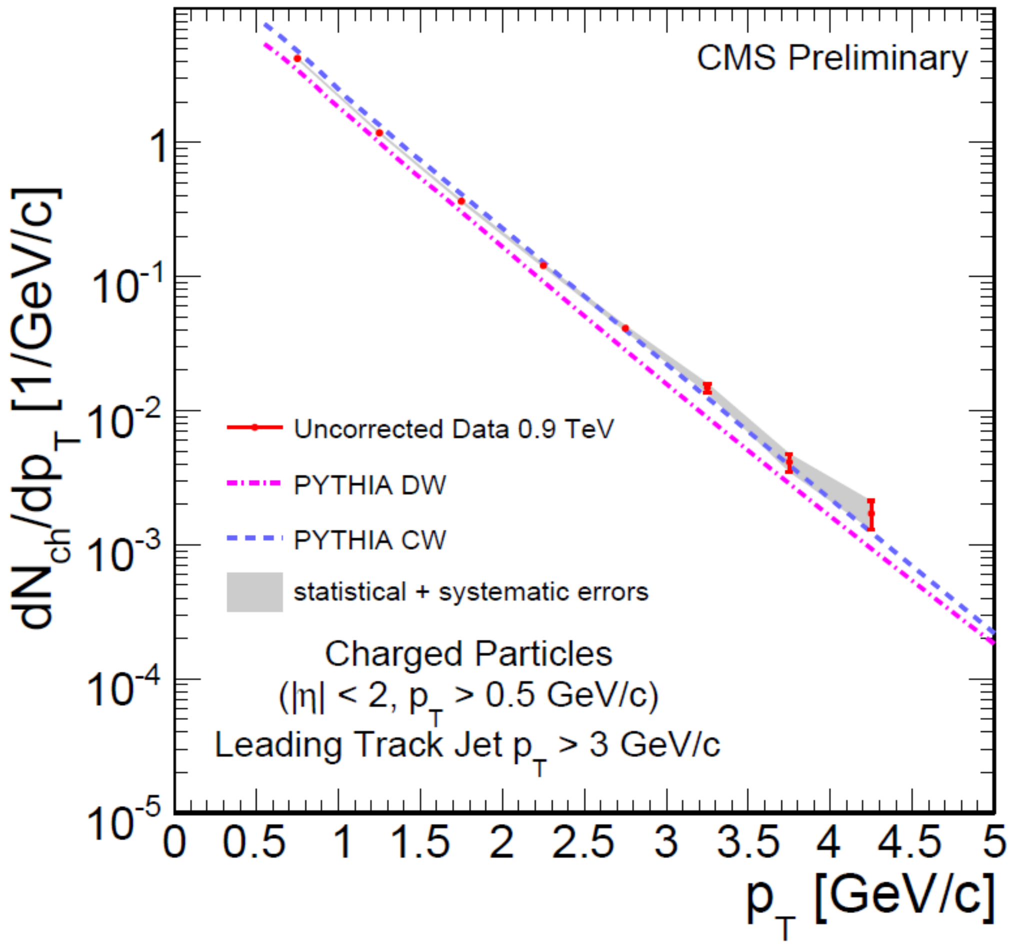
Sum pT distribution of charged particles in transverse region

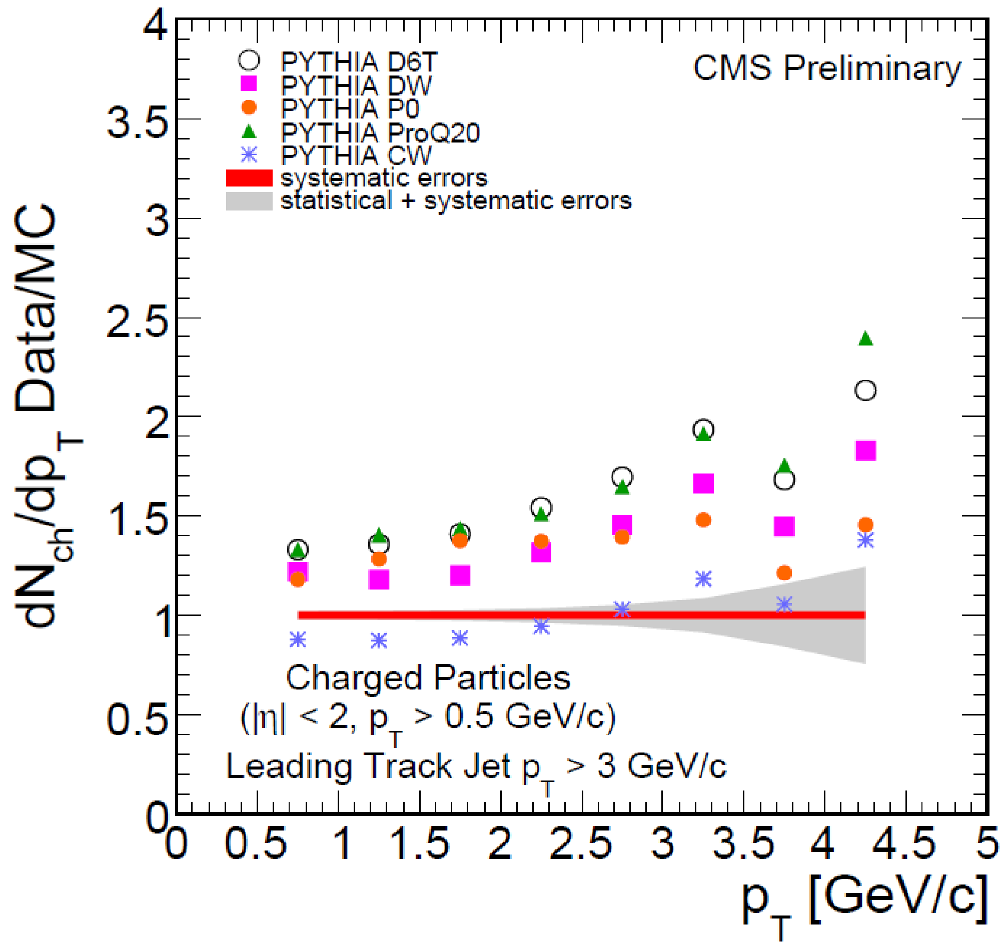




Ratio Data/MC 4/4

PT distribution of charged particles in transverse region





Ratio Data/MC 5/4

Sum pT density in transverse region versus event pT scale