CMS Update on Minimum Bias results
dNdEta Common Plots

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MBUEWG Common Plots

Status of Common Plots

- $dN_{chg}/d\eta$ - Done. Presenting today.
  - Public Document: QCD-10-024 (will be available within 2-3 weeks)
- dN_{chg}/dp_T; $dN/\Delta N_{chg}$ and $< p_T >$ vs N_{chg} - all in progress. Expected by Summer.

- This talk is concentrated on dNdEta analysis details.

dNdEta. Analysis Description and Motivation

- Require at least One charged particle in a given eta range with a minimum P_T threshold for an event to be selected
- No special effort to reject diffractive events
- Good observable to compare between experiments and tune MC generators.

1. 1 track in $|\eta| < 0.8$ with 0.5 GeV (1 GeV) p_T threshold
   - Direct comparison with ALICE & ATLAS
     - ALICE tracking limited to $|\eta| < 0.8$
     - Include data for $0.8 < |\eta| < 2.4$ to compare with ATLAS
2. 1 track in $|\eta| < 2.4$ with 0.5 GeV (1 GeV) p_T threshold
   - Direct comparison with ATLAS

Samples Used

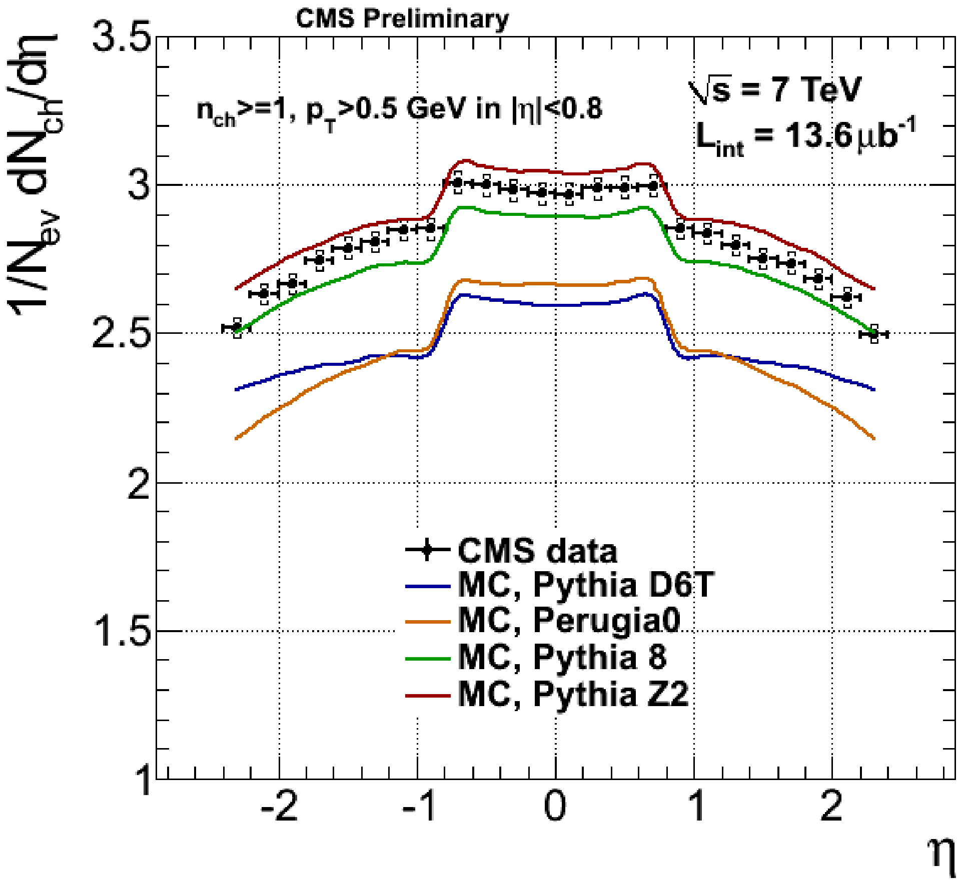
Monte Carlo

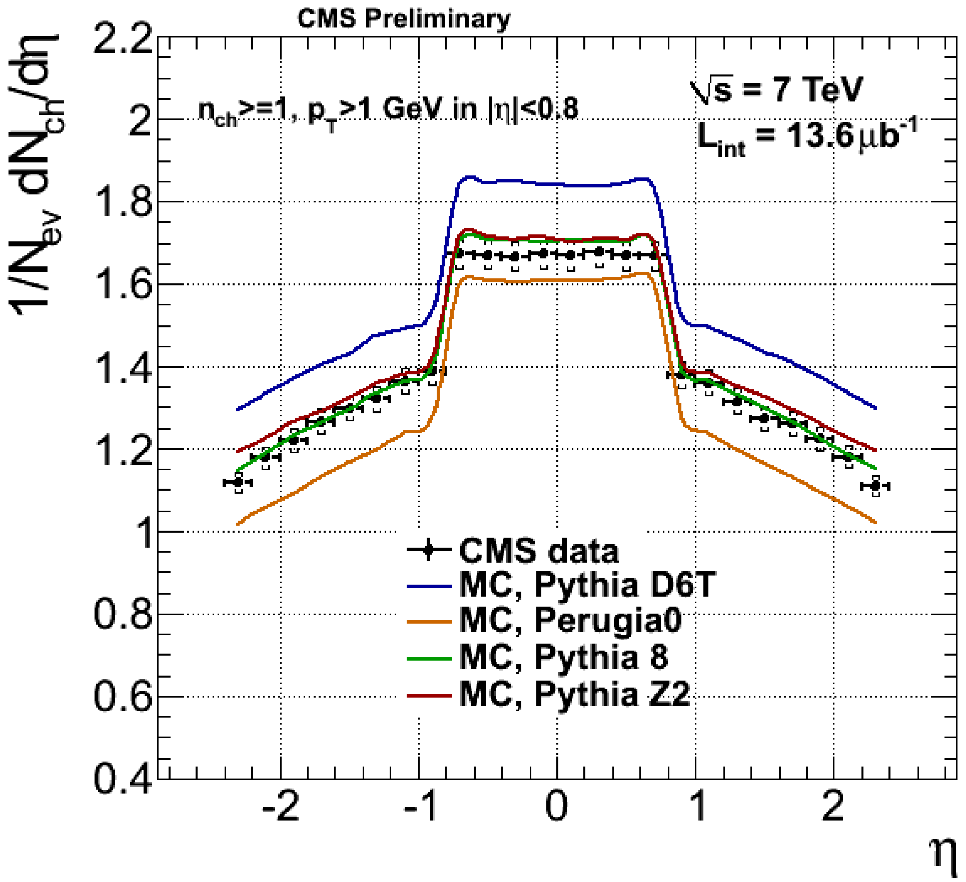
- 7 TeV. Pythia6: Z2, D6T, Perugia0; Pythia8
- 0.9 GeV. Pythia6: Z2, D6T
- We use Z2 tune as our main MC for corrections. Other MC are used for systematics.

Data

- Use Spring'10 Minimum Bias Data taken with low-luminosity
- This is early data with $\sim 1\%$ of pile-up.
- Select events with BSC MinimumBias trigger.

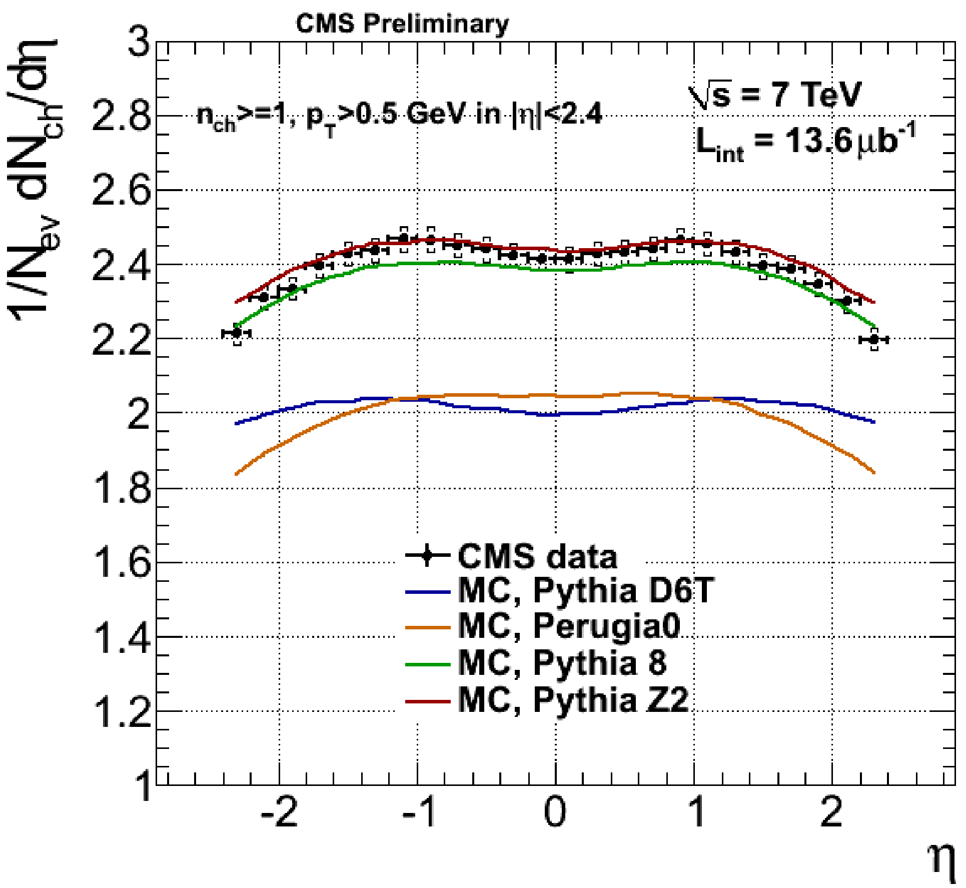
@7 TeV. Result 1a, 1b. Track in $|\eta| < 0.8$

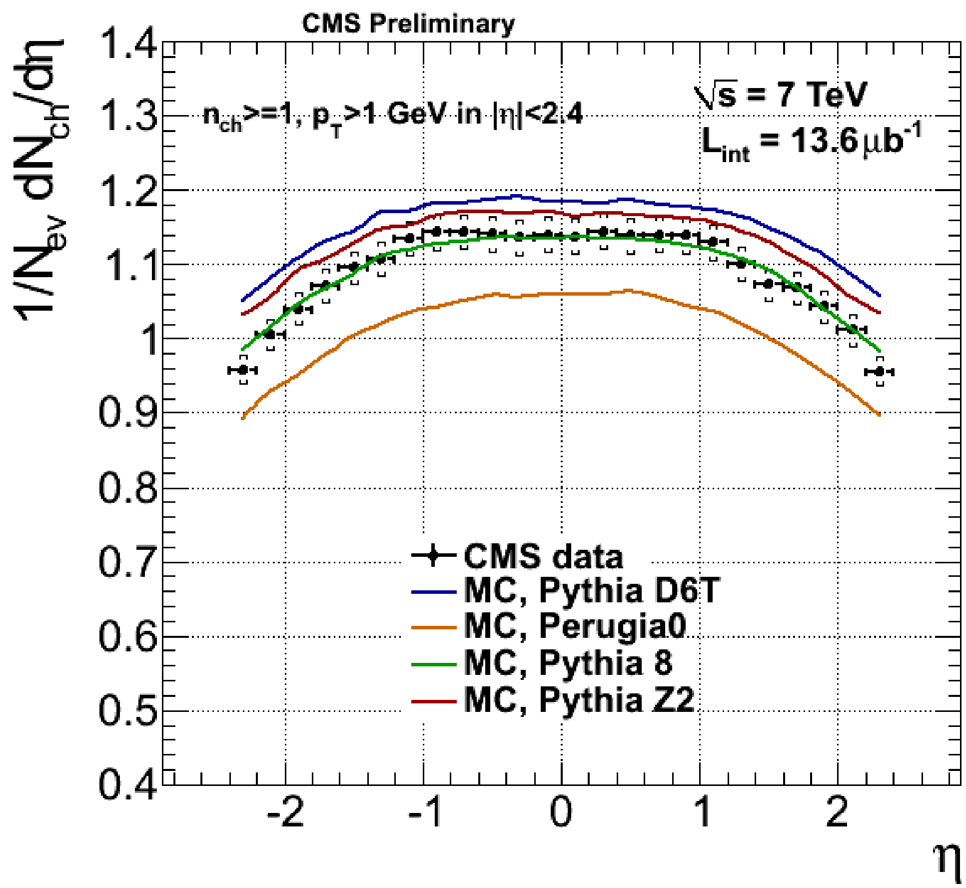




- These are the main results requested by MBUEWG ($|\eta| < 0.8$ region).
- Z2 and PY8 tunes show better agreement with data points.
- Include data for $0.8 < |\eta| < 2.4$ - useful for fine tuning of generators (see the shape of PY8 vs Z2 on the right plot)

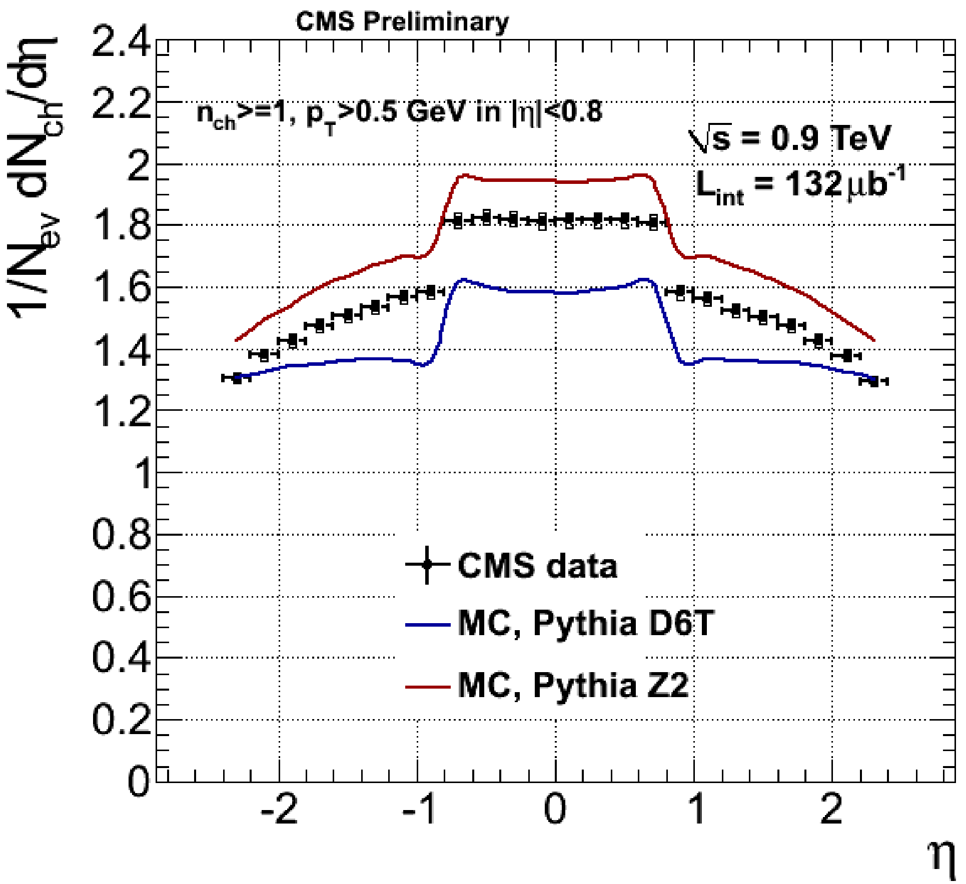
@7 TeV. Result 2a, 2b. Track in $|\eta| < 2.4$

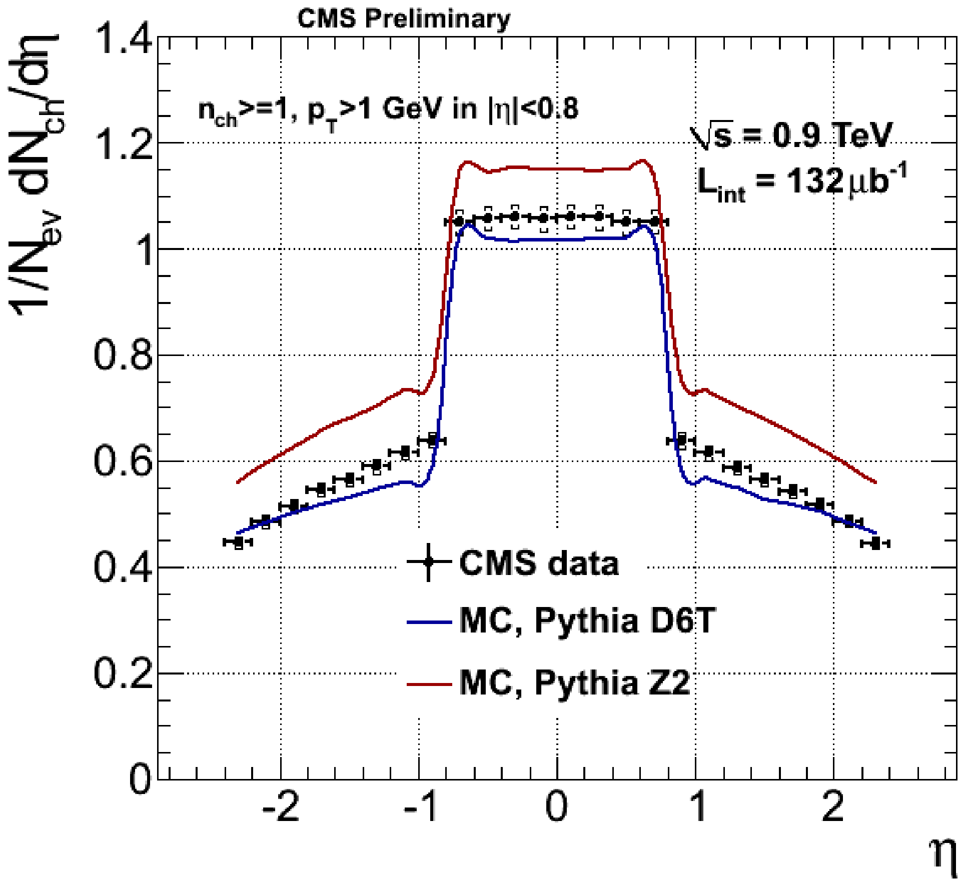




- Second set of results. (Particle in $|\eta| < 2.4$)
- Comparable with public Atlas result (left).
- Z2 and PY8 do a good job here. PY8 does better for 1 GeV tracks.

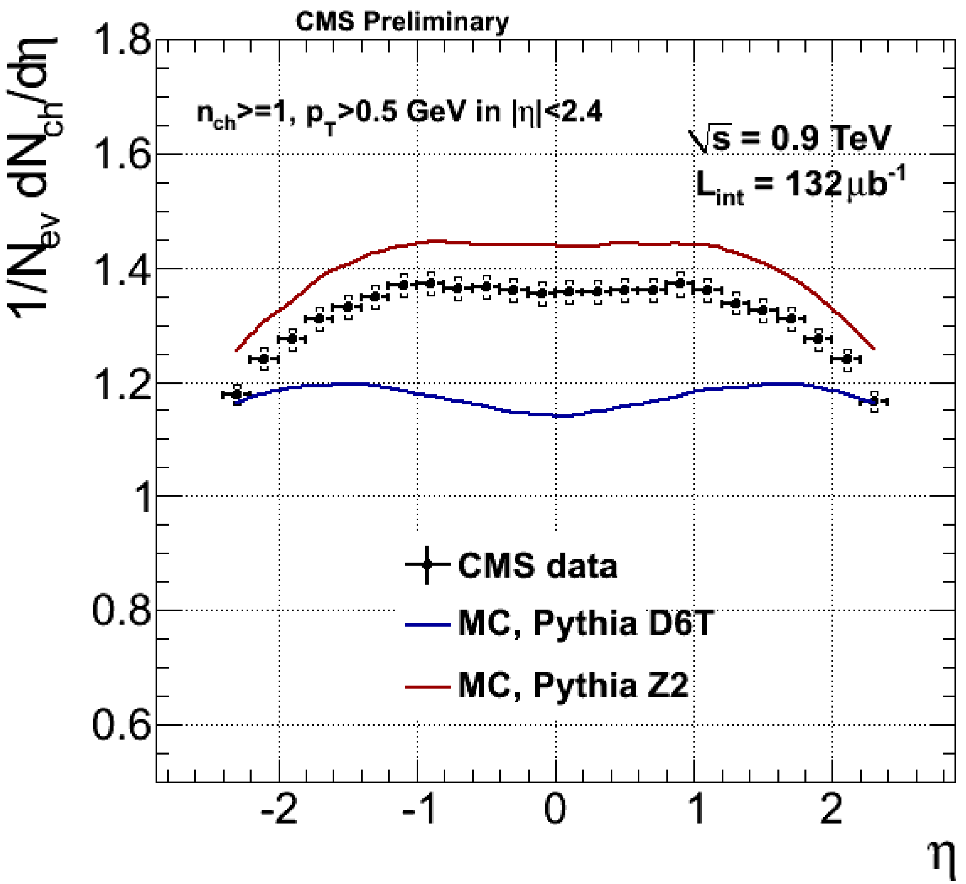
@0.9 TeV. Result 1a, 1b. Track in $|\eta| < 0.8$

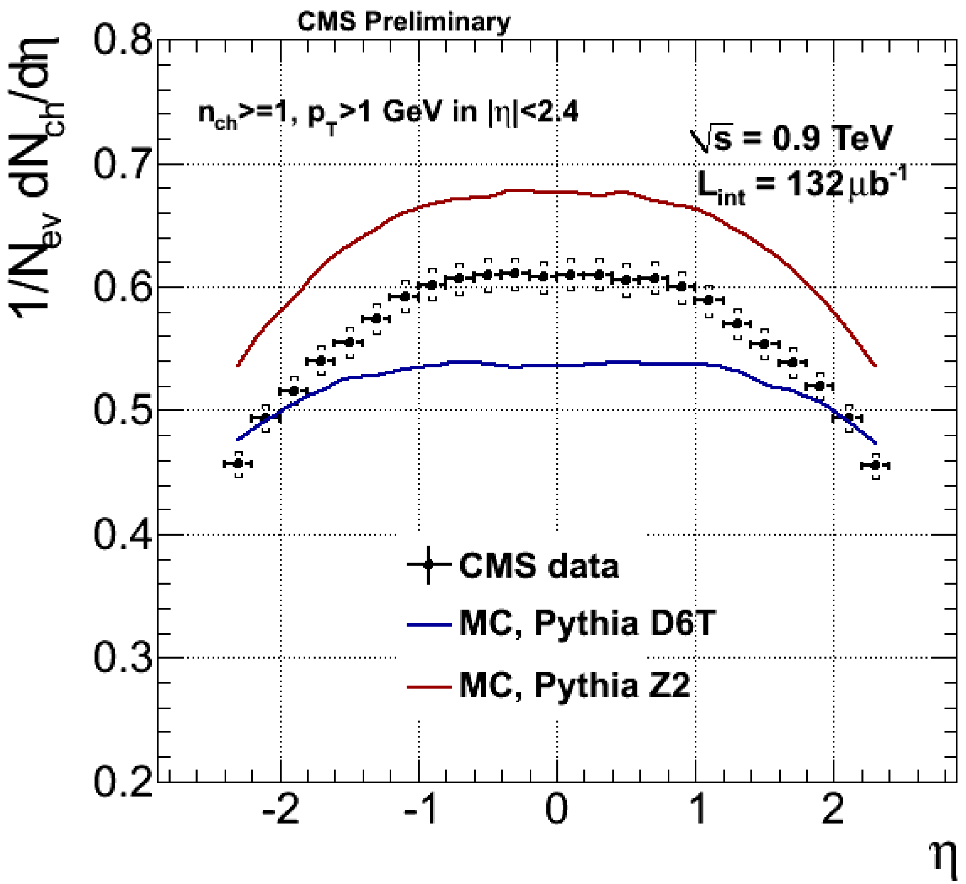




- Main results for 900 GeV
- Z2 is not that good for 900 GeV(?)

@0.9 TeV. Result 2a, 2b. Track in $|\eta| < 2.4$





- Second set of results. (Particle in $|\eta| < 2.4$)
- Comparable with public Atlas result (left).

Analysis

dNdEta analysis. Outline

- Formalism for dNdEta
- Preface. Multiplicity Bin
- Primary Vertex filter efficiency
- Central Track Requirement efficiency
- Tracking correction, fakes, MC truth matching.
- In back-up
  - Primary, non-primary tracks.
  - Pile-up
  - Effect of diffractive events

Formalism

$$\frac{1}{N_{EV}}\frac{dN_{CH}}{d\eta} = \frac{\sum_M \sum_{P_T} \mathbf{N^{raw}_{tracks}}(M, P_T, \eta)\, \omega_{track}(M, P_T, \eta)\, \omega_{event}(M)}{\Delta\eta(1 + f_{MV}) \sum_M \mathbf{N^{sel}_{evts}}(M)\, \omega_{event}(M)} \quad (1)$$

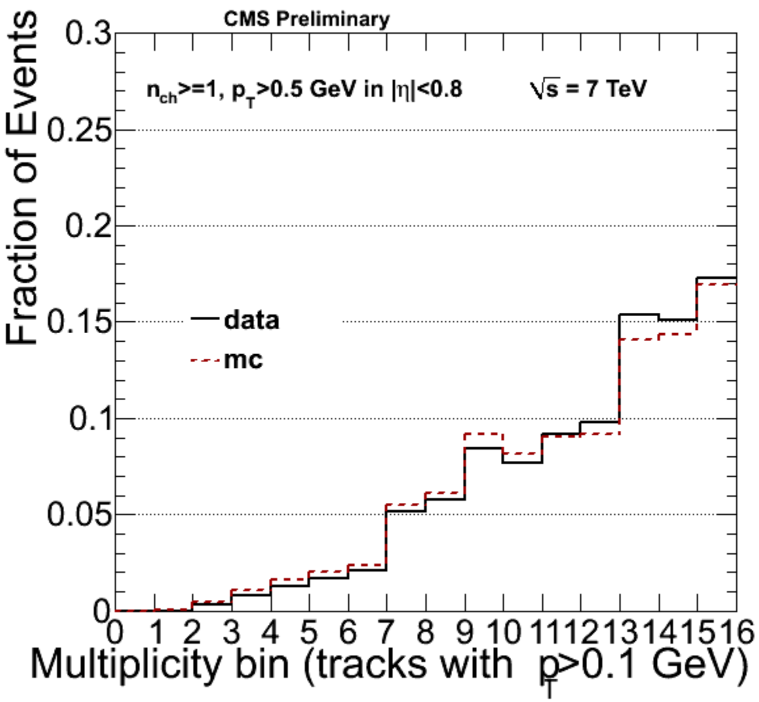
- $N^{sel}_{evt}(M)$: raw number of selected events with a 'trigger'-track
- $N^{raw}_{tracks}(M, p_T, \eta)$: raw number of tracks found in a bin
- M: event multiplicity bin (see definition on the next slide)
- p_T, η: bins in p_T and η of the track. (η=0.2 and P_T is variational)
- $\omega_{event}(M)$: correction for event losses;
- $\omega_{track}(M, p_T, \eta)$: corrections for N_{tracks}
- f_{MV}: 'multiple vertex' – pile-up correction
- $\Delta\eta$: eta- bin size. Constant, chosen to be 0.2

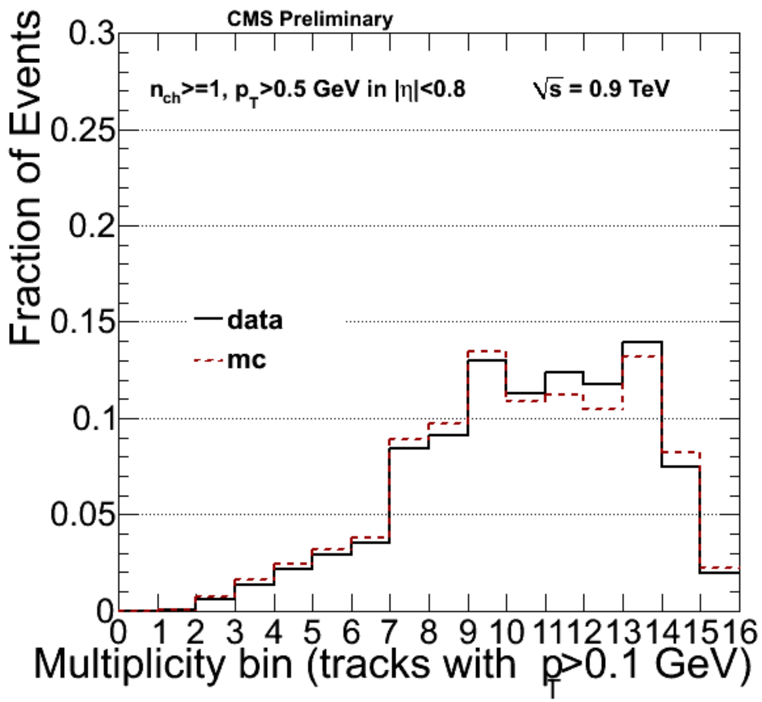
Preface. Multiplicity Bin

M is a multiplicity bin for *highPurity* tracks with $p_T > 100$ MeV, $|\eta| < 2.4$ and $\delta p_T/p_T < 0.1$

- We split a sample in bins of M and obtain corrections in each subsample, see formula 1.
- The main purpose of this is to properly account for Primary Vertex reconstruction inefficiency.

M	N_{trk}
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7-8
8	9-10
9	11-13
10	14-16
11	17-20
12	21-25
13	26-35
14	36-50
15	>51





Event Selection Corrections

$$\omega_{event}(M) = \frac{1}{\epsilon_{trig}(M)\ \epsilon_{PV}(M)\ \epsilon_{central}(M)} \quad (2)$$

- $\epsilon_{trig}(M)$: trigger efficiency as a function of the track multiplicity in the event. Includes the efficiency due to beam halo inclusion in the offline selection. $\epsilon_{trig} \simeq 99.9\%$ for low-M events and around 100% for high-M events.
- $\epsilon_{PV}(M)$: Primary Vertex Filter efficiency as a function of the track multiplicity in the event. $(ndof > 0, |z| <= 15cm, |d_0| <= 2cm)$. From MC,$\epsilon_{PV} = \frac{N_{ev}^{passed}}{N_{ev}^{all}}$.
- $\epsilon_{central}(M)$: efficiency of selecting an event with a 'trigger'-track, e.g. a track in central region with $p_T > 0.5 GeV$ From MC, $\epsilon_{central} = \frac{N_{evts\ reco}^{central\ track}}{N_{evts\ gen}^{central\ part}}$. It is calculated or events that already passed the PV-filter.

Tracks Selection, Quality Cuts

RECO tracks (both in Data and MC)

- highPurity tracks (as a standard in CMSSW)
- numLayersWithMeasurements $>= 4$
- $|dxy| < 0.2\,\text{cm}$, $|dz| < 0.6\,\text{cm}$ wrt Primary Vertex.
  (In case of two PV reconstructed, higher nTracks() is used.)
- ptErrorTrack/Pt < 0.1

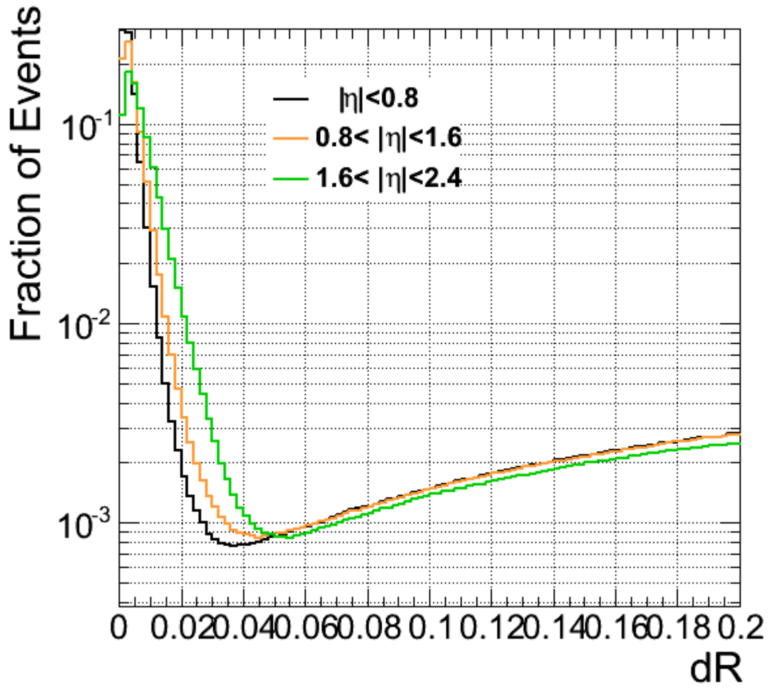
Gen particles

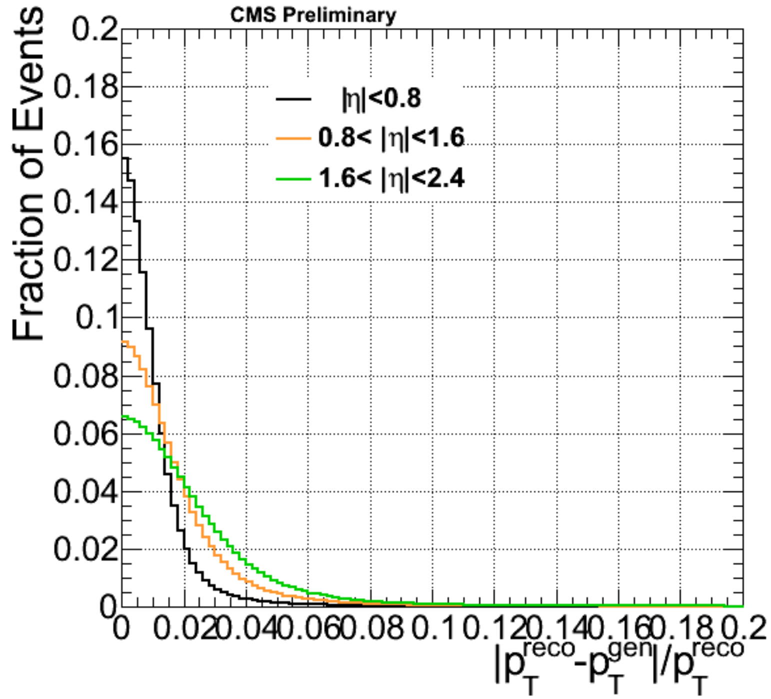
- Pythia status 1 (stable), charged particles. Leptons included.
- Definition of stable particles in Pythia CMS: above 1cm proper lifetime.
- E.g. for the process $pp \to A^+ \to b^+ c^+ d^-$
  if $c\tau_{A^+} < 1\text{cm}$: b, c and d are used for dNdEta

Reconstructed Tracks Matching to Gen Particles

- Tracks are matched to gen particles using dR cone and dPt $= |p_T^{track} - p_T^{gen}|/p_T^{track}$ cuts.
- $dR(\eta, \phi) < 0.04$ for any η
-

eta	$|\eta| < 0.8$	$0.8 < |\eta| < 1.6$	$1.6 < |\eta| < 2.4$
dPt cut	0.05	0.06	0.07





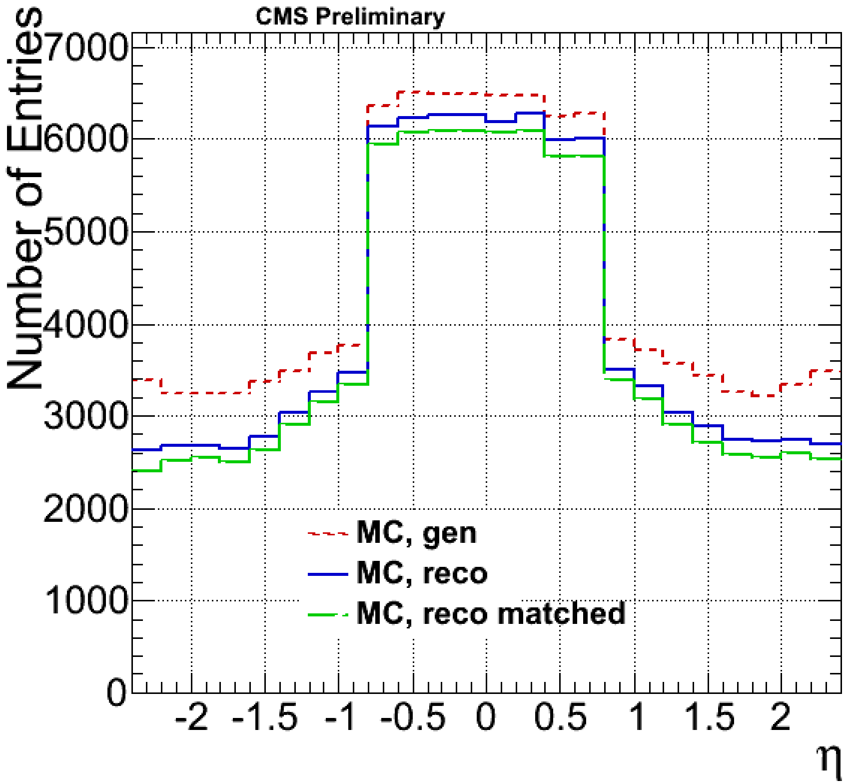
Track Corrections

$$\omega_{track}(M, P_T, \eta) = \frac{(1-T)}{\epsilon_{bin}(1+D)}$$

- $\epsilon_{bin}(M, P_T, \eta) = \frac{N_{reco}^{matched\ track}(M, p_T, \eta)}{N_{gen}^{particle}(M, p_T, \eta)}$
- T: fraction of non-primary and fake tracks (not matched to gen truth).
- D: fraction of tracks associated to the multiple gen particles (very small number, < 0.001)

All above are the conditional quantities (after passing the PV and selecting an event with a central track). Therefore they are different when obtained for different event selections.

Illustration: tracks to particles correction



On the plot

- Top (red) curve - generated particles
- Middle (blue) curve - reconstructed tracks
- Bottom (green) curve - reconstructed tracks matched to generated particles.

generally speaking

- Eff. correction (ϵ_{bin}) will take green curve (bottom) to the red (top).
- Non-primary (T): (blue-green)/blue.
- All corrections are done in bins of p_T and M for each η.

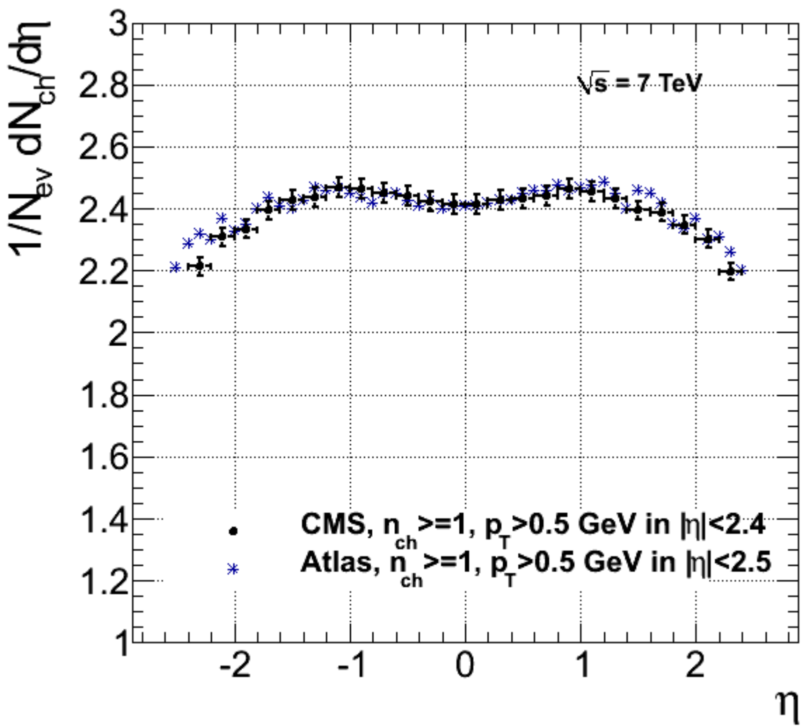
Uncertainties

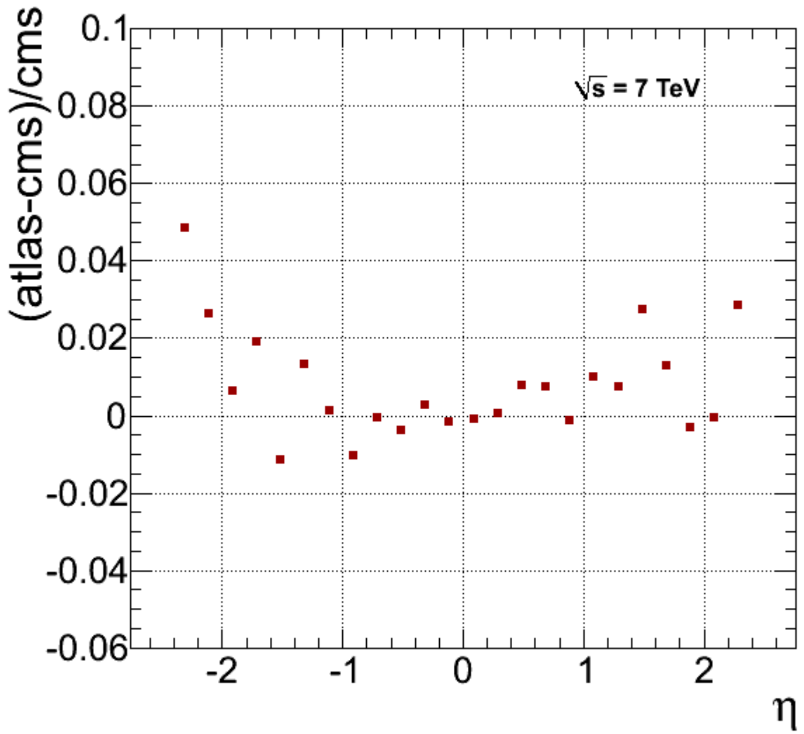
Table 3: Summary of uncertainties for $(1/N_{EV})\,(dN_{ch}/d\eta)$. See details in section 4.1.

Selection	$p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 0.8$		$p_T > 1$ GeV/c, $\lvert\eta\rvert < 0.8$		$p_T > 0.5$ GeV/c, $\lvert\eta\rvert < 2.4$		$p_T > 1$ GeV/c, $\lvert\eta\rvert < 2.4$	
Center of mass energy	7 TeV	0.9 TeV	7 TeV	0.9 TeV	7 TeV	0.9 TeV	7 TeV	0.9 TeV
Corrections	Uncertainty %							
Based on simulation								
- $\epsilon_{central}$ (tune dependence)	0.65	0.01	1.00	0.01	0.37	0.03	0.94	0.04
- ϵ_{PV} (tune dependence)	0.03	0.05	0.01	0.02	0.10	0.14	0.03	0.01
- Losses in the "zero" multiplicity bin (based on PYTHIA-6 Z2 tune)	0.02	0.02	0.01	0.01	0.14	0.14	0.03	0.03
- ω_{track}, additional uncertainty of 3.9% to take into account differences between track reconstruction efficiencies obtained with data and simulated events [11]	0.9	0.75-0.82	1.70-1.90	1.45-1.80	0.90	0.75-0.78	1.60	1.44-1.50
- ω_{track}, MC statistics	0.14-0.17	0.40-0.42	0.25-0.31	0.60-1.00	0.15-0.17	0.30-0.40	0.25-0.30	0.60-0.80
Based on data								
- f_{MV}	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
- ϵ_{trig}	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Statistical	0.25	0.13	0.34-0.40	0.25-0.30	0.23	0.12	0.33-0.40	0.20-0.25
Total	1.00-1.20	0.76-0.84	1.80-2.20	1.45-1.81	1.00-1.20	0.79-0.81	1.80-1.90	1.45-1.51

- 3.9% uncertainty is taken from TRK-10-002 PAS.
- The uncertainties on ε_{PV}, $\varepsilon_{central}$ include model dependence in them.
- To be updated in the final version of PAS

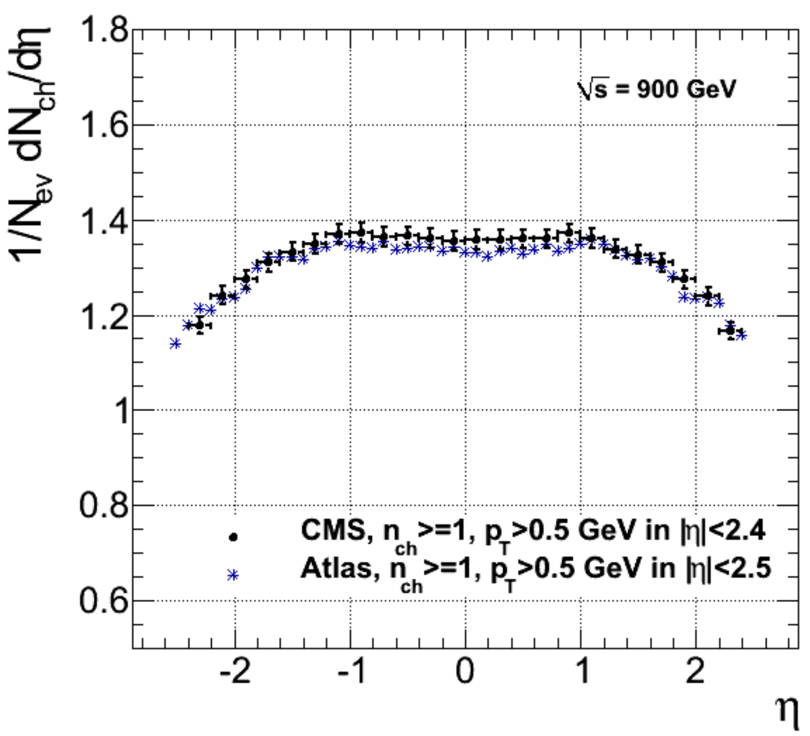
Atlas vs CMS, 7TeV

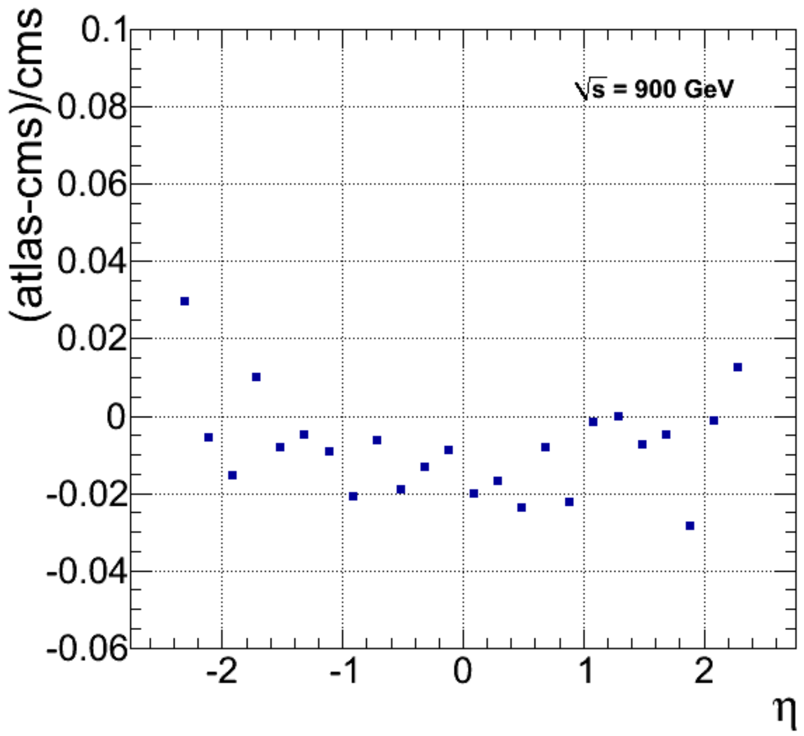




- Atlas data points are taken from ATLAS-CONF-2010-024
- Note: CMS: $|\eta| < 2.4$ and Atlas: $|\eta| < 2.5$.
  This makes $\sim 0.8\%$ difference based on MC studies.

Atlas vs CMS, 0.9 TeV





- Atlas point are taken from HEP data.
- Note: CMS: $|\eta| < 2.4$ and Atlas: $|\eta| < 2.5$.

Conclusions

- New set of dNdEta distributions obtained both for 7 and 0.9 TeV data.
- This information is useful for MC tuning and comparisons between experiments.

Back Up

Back up slides

Event Selection

Table 1: Number of events satisfying the trigger and event selection for the 7 TeV and 0.9 TeV data samples. The selection criteria are applied in sequence.

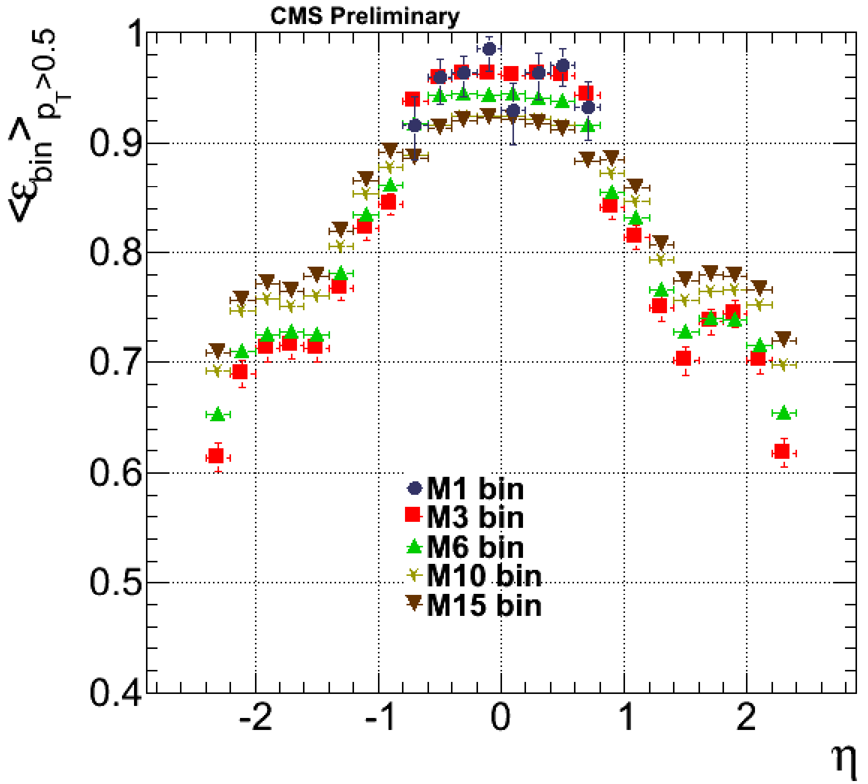
Selection	Number of events (Data) 7 TeV	Fraction 7 TeV	Number of events (MC) 7 TeV	Fraction 7 TeV	Number of events (Data) 0.9 TeV	Fraction 0.9 TeV	Number of events (MC) 0.9 TeV	Fraction 0.9 TeV
Colliding bunches bit0 (only in Data)	858344	1.000	5400000	1.000	6129869	1.000	1944000	1.000
MinimumBias trigger (in Data)	845521	0.985	5400000	1.000	5924682	0.967	1944000	1.000
Beam-halo rejection (only in Data)	843647	0.983	5400000	1.000	5898950	0.962	1944000	1.000
Other beam-background rejection (only in Data)	842778	0.982	5400000	1.000	5891966	0.961	1944000	1.000
Reconstructed primary vertex	739414	0.861	4405382	0.816	4754633	0.776	1511145	0.777
Events with selection:								
A primary track in $\|\eta\| < 2.4$ with $p_T > 0.5$ GeV/c	708543	0.825	4121169	0.763	4464782	0.728	1385313	0.713
A primary track in $\|\eta\| < 2.4$ with $p_T > 1$ GeV/c	516668	0.602	2829981	0.524	2680980	0.437	790116	0.406
A primary track in $\|\eta\| < 0.8$ with $p_T > 0.5$ GeV/c	585027	0.682	3354190	0.621	3403579	0.555	1045933	0.538
A primary track in $\|\eta\| < 0.8$ with $p_T > 1$ GeV/c	355439	0.414	1948341	0.361	1549737	0.253	470903	0.242

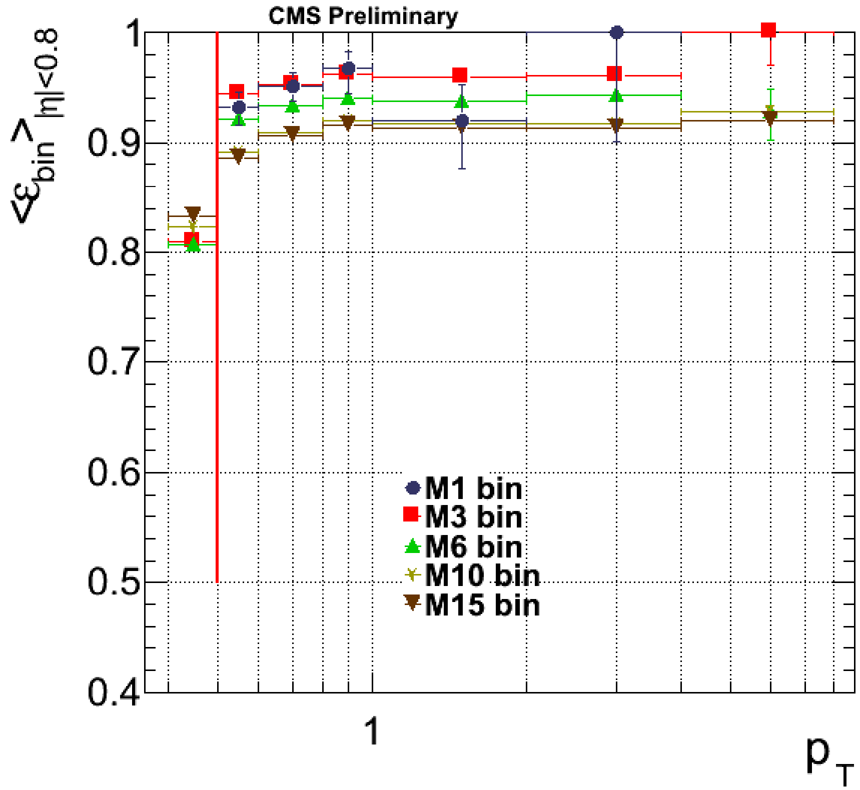
- Data Statistics high enough to avoid stat uncertainties, the uncertainty are dominated by systematics
- MC statistics is high enough to avoid MC stat uncertainties

Binning

- η is binned in 0.2 from -2.4 to 2.4
- p_T bins are:
  0, 0.2, 0.3, 0.4, **0.5, 0.6, 0.8, 1.0, 2.0, 4.0, 8.0, 16.0, 64.0**;
- The sample is binned in events multiplicity M (shown before). Important for reconstruction corrections.

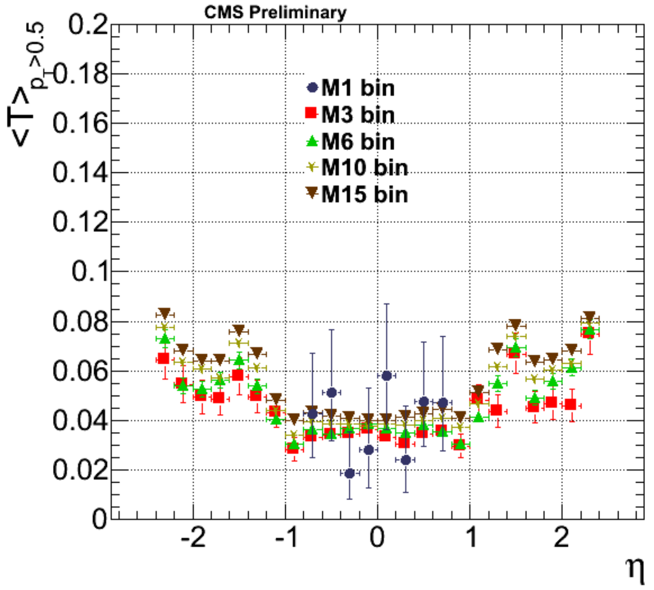
ϵ_{bin} M = 1,3,6,10,15

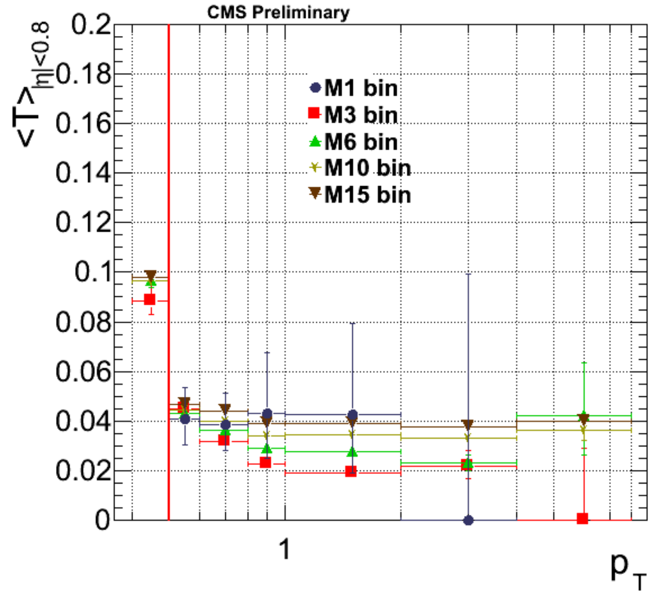


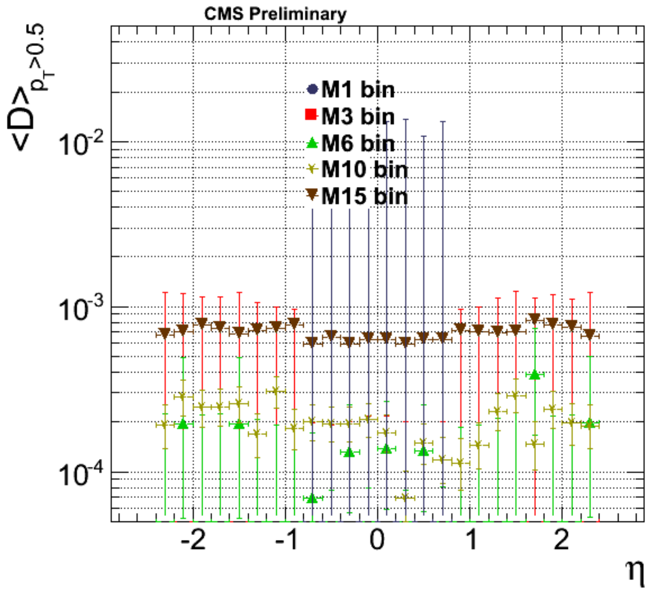


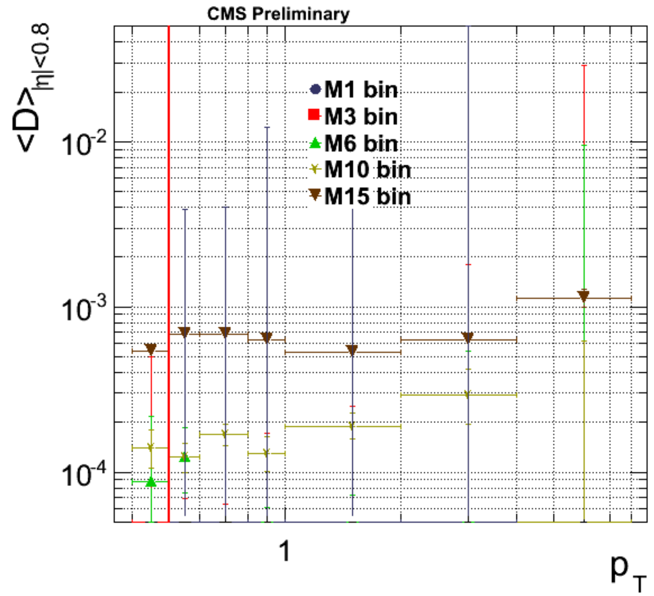
- There is always a track with $p_T > 0.5$ GeV in $|\eta| < 0.8$ (high efficiency in that eta-region)

T - fraction of non-primaries; M = 1,3,6,10,15

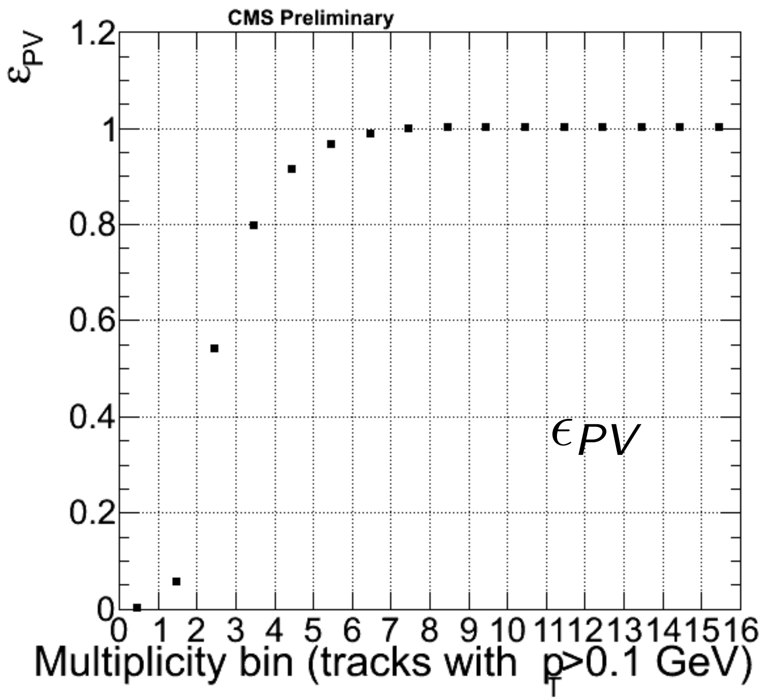


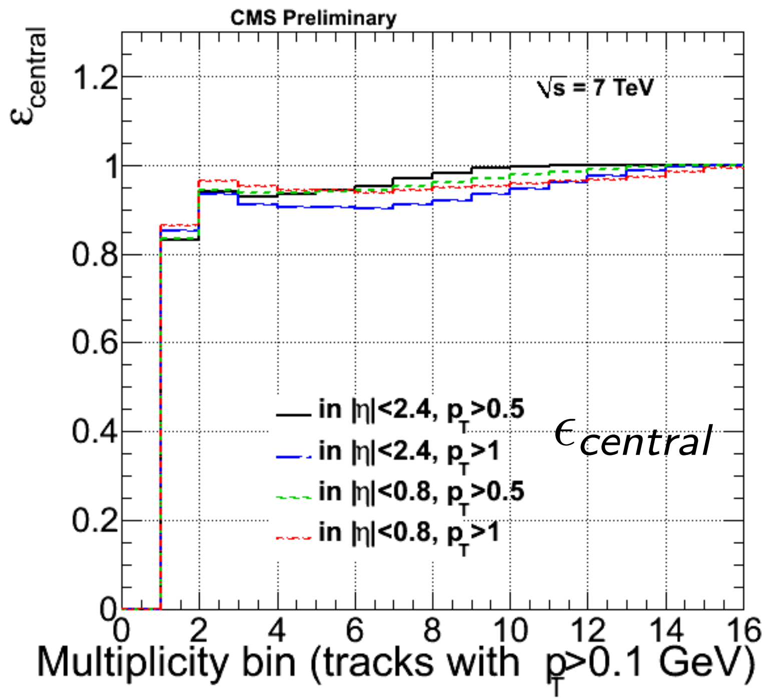




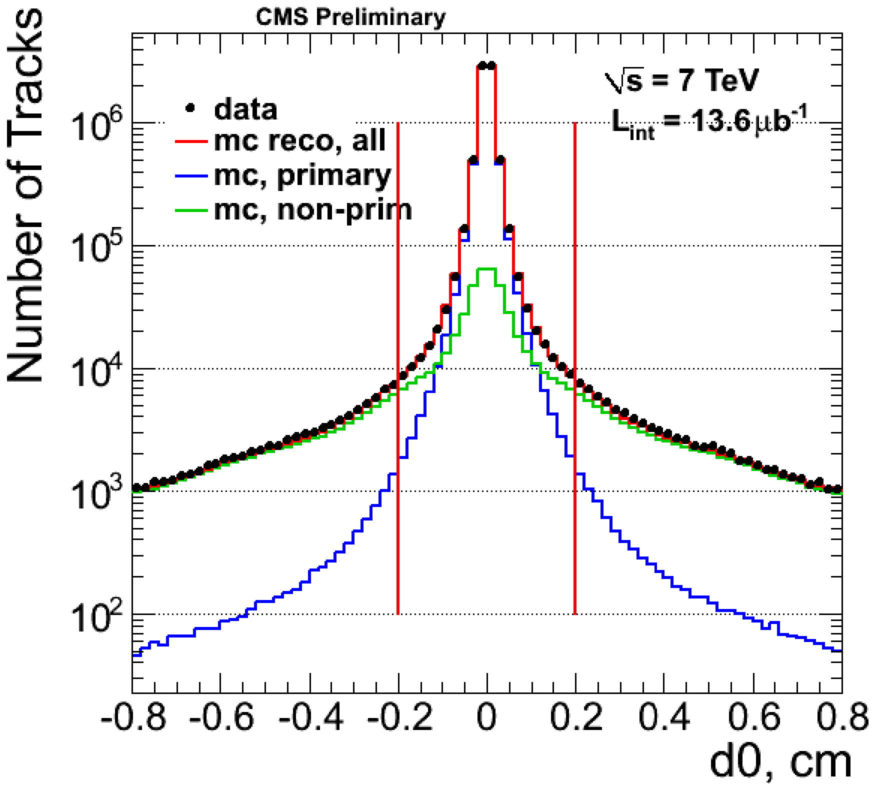


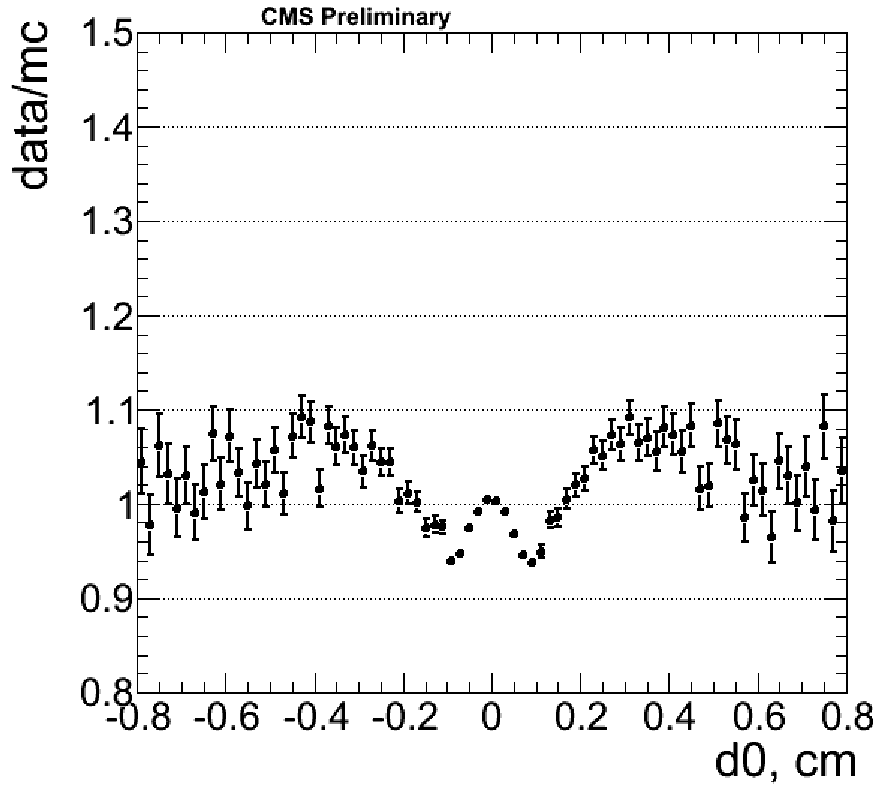
- ε_{PV} and $\varepsilon_{central}$ plots.





d0. Data and Monte Carlo

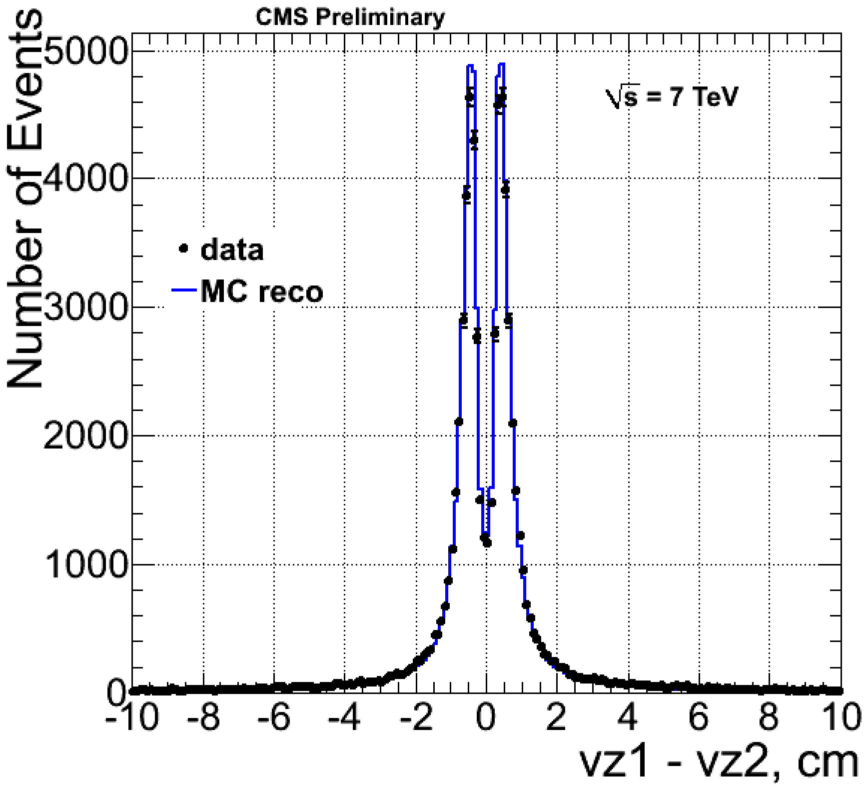




- This is dxy distribution of tracks with $p_T > 0.5$ GeV in $|\eta| < 2.4$ and $|dz(vtx)| < 0.6$
- Data/MC considered good enough for our needs. No need to make further corrections or add extra uncertainties.

f_{MV} correction - correction for the pile-up

Pile-up would result to a second good PV reconstructed. We are fine with that since take only one good PV. Unless the two PVs are so close that we don't resolve them. We correct for that.

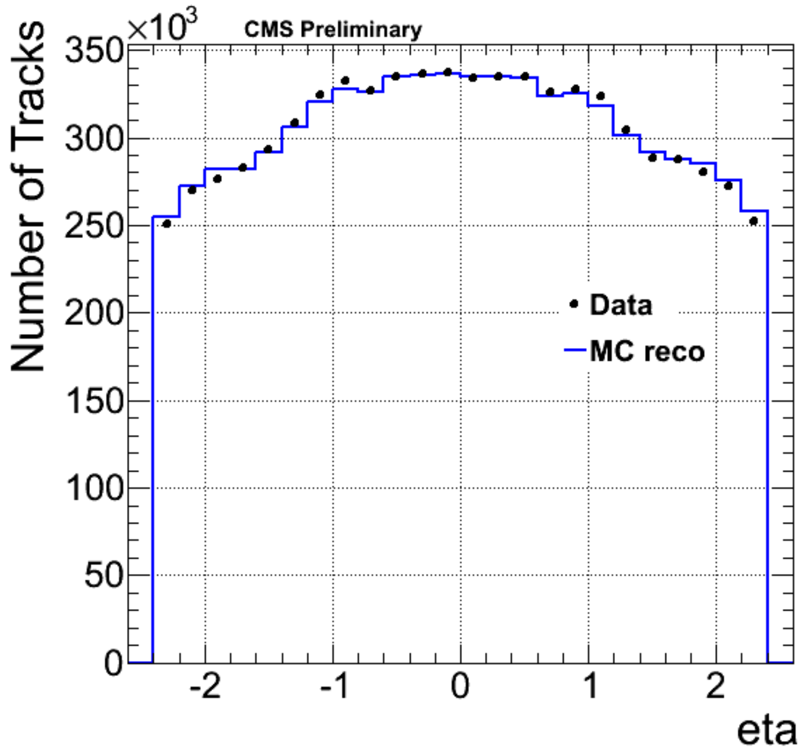


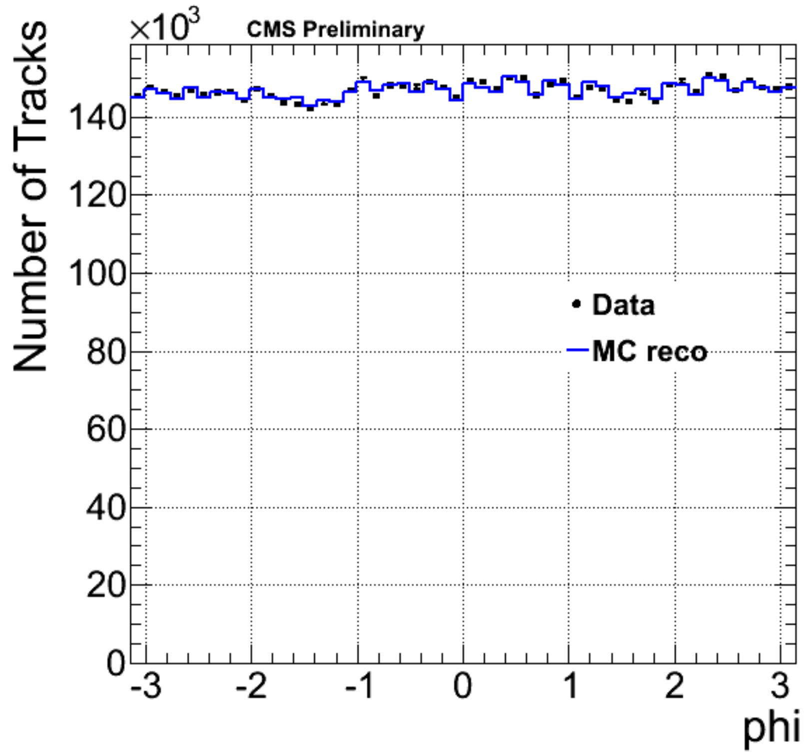
- Fraction of Events with multiple PV:

MC	0.085 ± 0.02
Data	0.097

- How many of those events we do not resolve two PVs? On the plot: if two or more Primary Vertices reconstructed we pick two best and plot z1-z2.
- The fraction of events in the dip of the distribution is what we don't resolve as potential two vertices. The fraction of them is ~ 0.4
- While in MC most of the extra vertices are fakes (splitted single vertices), in the Data, however, we have pile-up events.
- Pile-up is $\sim 1\%$. Consistent with $\sim 1.2\%$ more events with two PVs in data than in MC.
- So we use 0.01 as a pile-up fraction and multiply by 0.4 as a fraction of those events when we don't resolve PVs. Therefore:
  $f_{MV} = 0.4 \cdot 0.01 = 0.0040 \pm 0.0005$
- We only need to correct for the pile-up part, not for fakes.

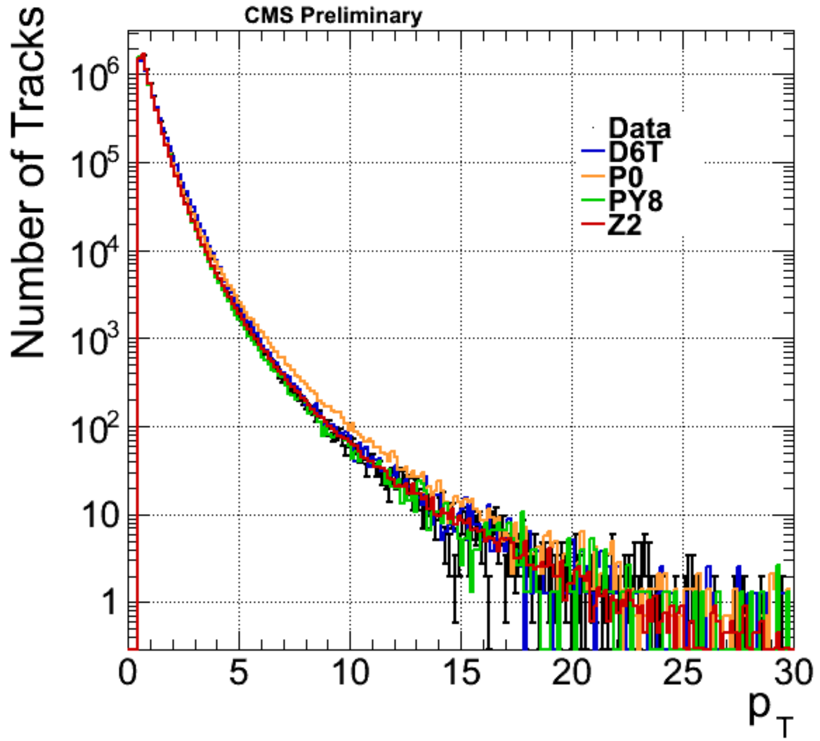
Eta and phi

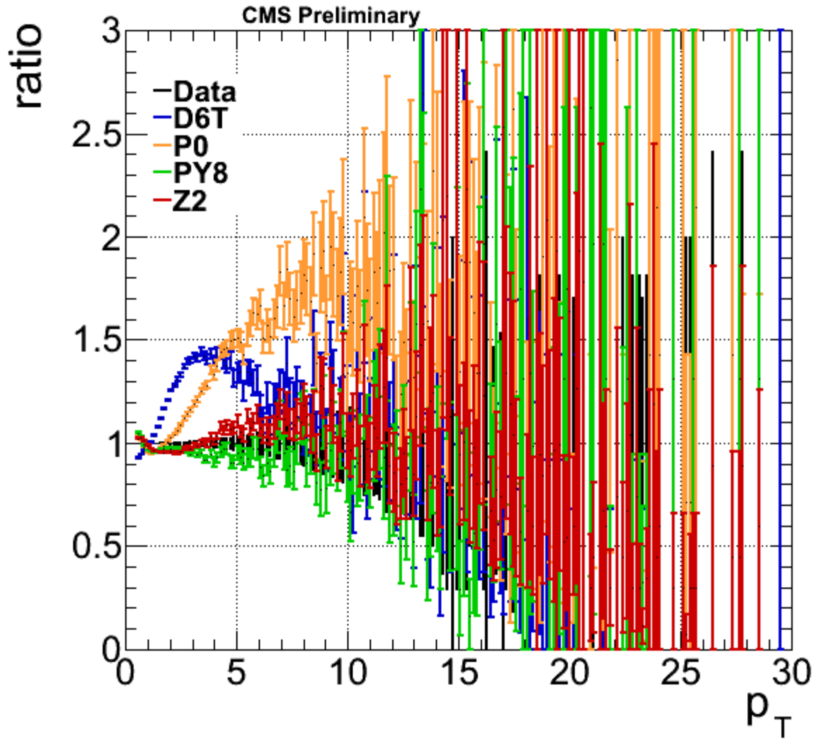




- All the tracks with $p_T > 0.5$ GeV in $|\eta| < 2.4$ that are passed the quality cuts and dzy(vtx), d0(vtx) cuts.

Pt distributions



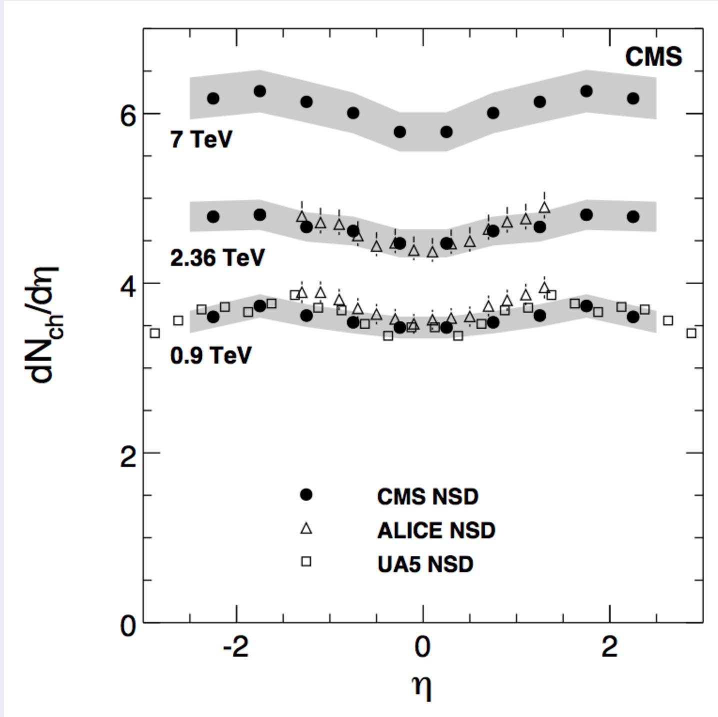


- All the tracks with $p_T > 0.5$ GeV in $|\eta| < 2.4$ that are passed the quality cuts and dzy(vtx), d0(vtx) cuts.
- On the left plot - pt spectra. MC are normalized to Data
- On the right plot - ratio to Data distribution

Usual dNdEta

Main differences with respect to previous dNdEta analysis

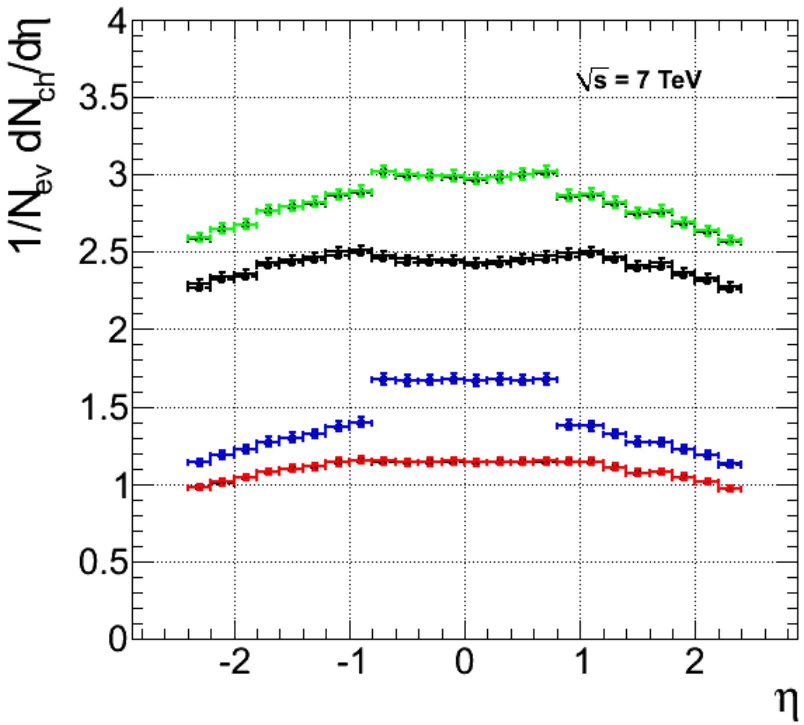
- Only tracks with $p_T > 0.5$ GeV, 1 GeV are plotted. (No extrapolation to $p_T \to 0$)
- No minimum energy requirement in HF (Applied in CMS-QCD-10-006 to reject SD)
- Standard tracking and vertex reconstruction is used.

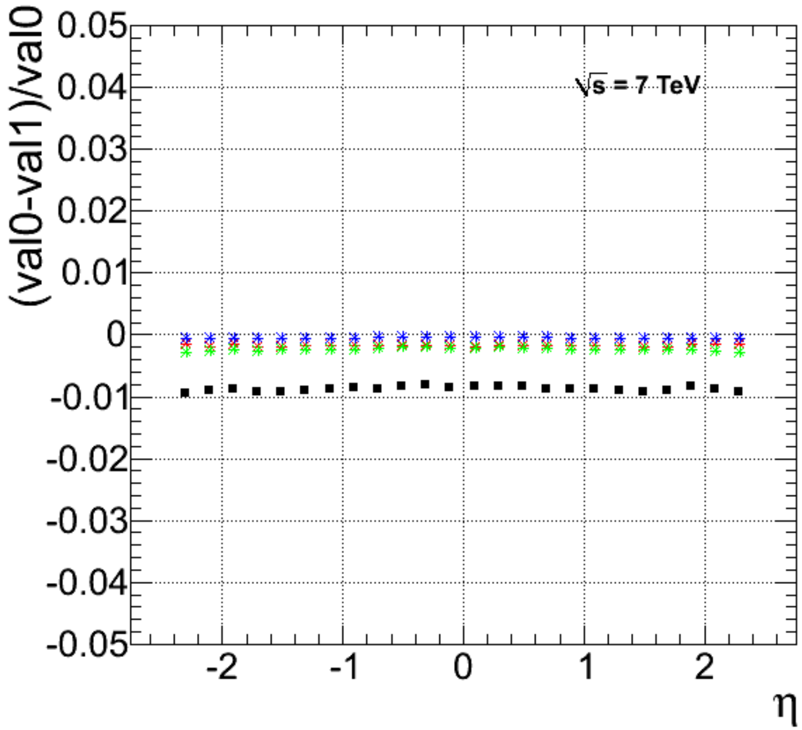


Diffractive events

	Z2 Before PV filter	after PV filter	D6T Before PV filter	after PV filter
SD1	0.0954	0.0529	0.0963	0.0540
SD2	0.0967	0.0538	0.0955	0.0531
DD	0.1299	0.0771	0.1301	0.0780
total	0.3220	0.1838	0.3219	0.1851

Q: Does the ε_{PV} and $\varepsilon_{central}$ efficiencies depend on the fraction of diffractive events?
A: Yes, they do. Does the result depend on this? What we can do to switch off the Diffractive component in MC. and obtain ε_{PV} and $\varepsilon_{central}$ from that. The effect on dNdEta plots are as max as 1%. We do not apply any systematics from that.





BeamSpot in MC: re-weighting

- BeamSpot position in MC is different than it is in Data.
- Based on z-plot of primary main vertex we can reweight MC events.