Measurement of the Underlying Event using the Drell-Yan process at the LHC with √s = 7 TeV

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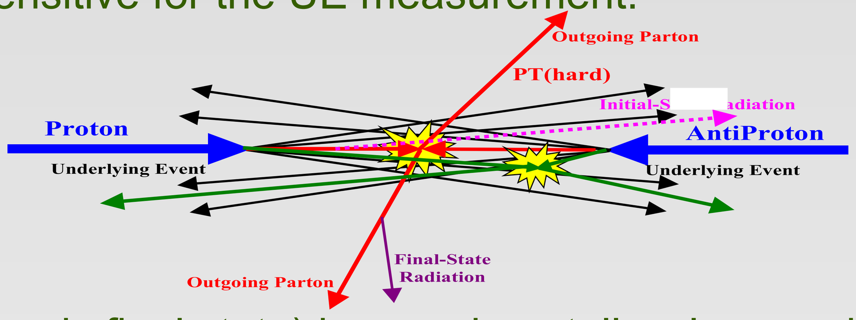
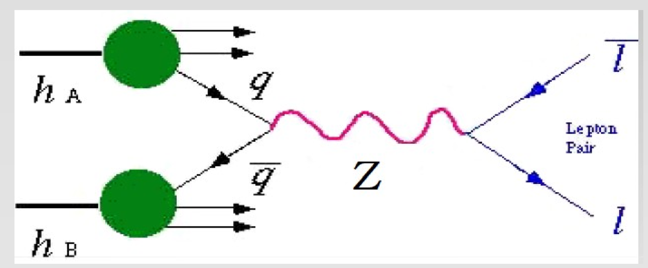
Introduction

- Multiple Parton Interaction (MPI) and Beam-Beam Remnants (BBR) are collectively known as Underlying events. It also includes ISR and FSR which are not possible to separate experimentally. In other words excluding the final state particles of collision, everything else contributes as Underlying events

- Hard interaction can be identified by the presence of particles with large mass or large transverse momentum i.e. Dijet or Drell-Yan. With reference to this *leading object*, regions can be defined which are sensitive for the UE measurement.

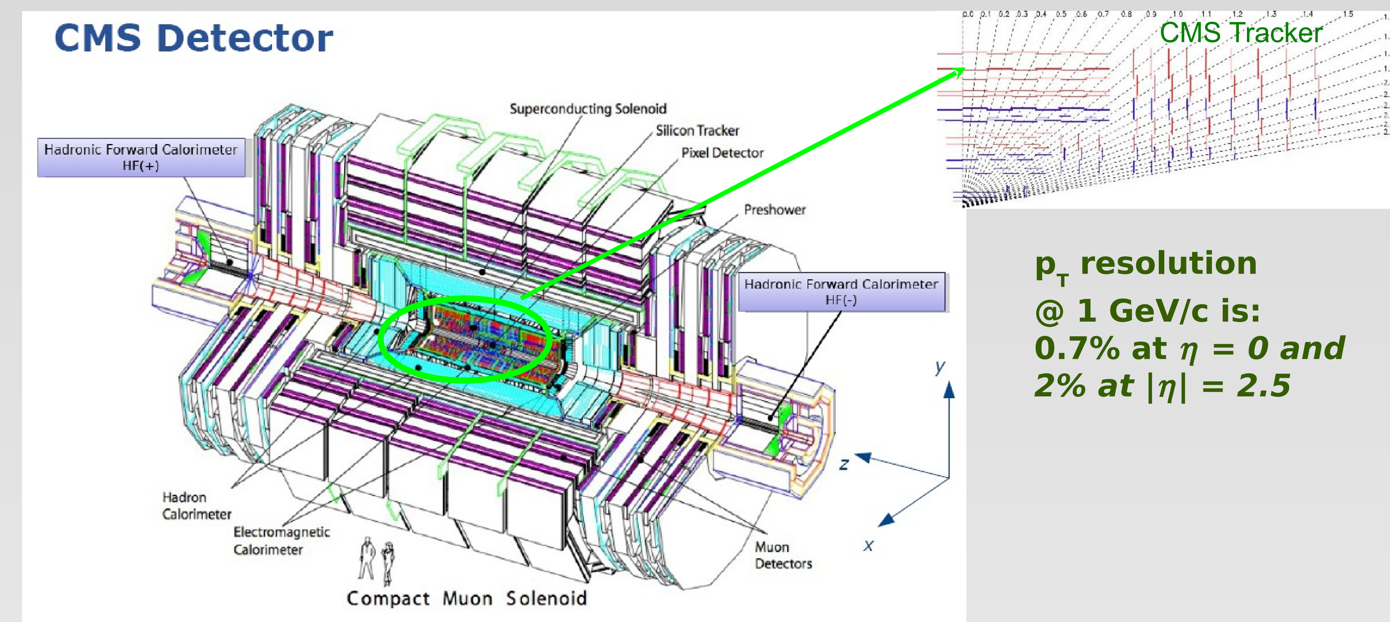




- Drell-Yan (muonic final state) is experimentally clean and theoretically well understood process. It is easy to separate the final state in Drell-Yan by identifying two muons with large transverse momentum.
- No QCD final state radiation and low probability of muons to radiate.

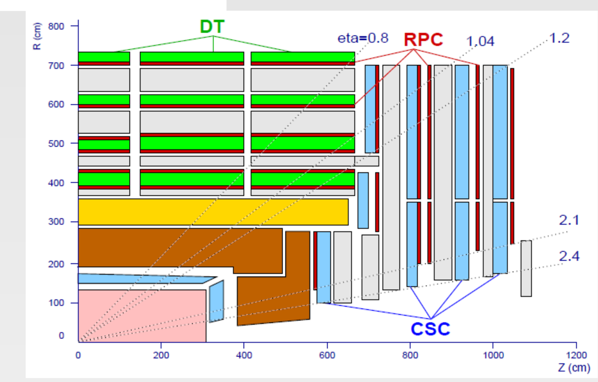
- *Transverse* and *towards* regions are sensitive for UE measurement.
- UE dynamics can be studied both as function invariant mass and transverse momentum of di-muon system.

CMS Experiment



p_T resolution @ 1 GeV/c is: 0.7% at $\eta = 0$ and 2% at $|\eta| = 2.5$

p_T resolution:
Muon chambers: 8%-15% at 10GeV/c & 20%-40% at 1 TeV/c
Tracker: 1%-1.5% at 10 GeV/c and 6-17% at 1 TeV/c

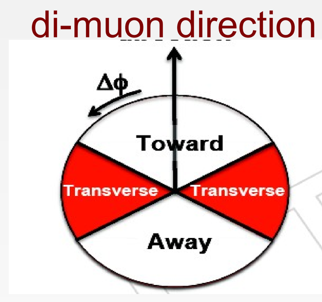


Analysis Strategy

– Event with two leading, well identified, muons having invariant mass: $60 < M_{\mu\mu} < 120$ GeV/c^2
– High quality tracks with $p_T > 0.5$ GeV/c, $|\eta| < 2$

Three topological regions:
Towards; $|\Delta\Phi| < 60^o$
Transverse; $60^o < |\Delta\Phi| < 120^o$
Away; $|\Delta\Phi| > 120^o$

di-muon direction



Observables:
– Average scalar sum of transverse momenta of charged particles per unit pseudo-rapidity per unit azimuth.
– Average number of charged particles per unit pseudo-rapidity per unit azimuth.
– Dependence of these observables on resultant transverse momentum ($p_T^{\mu\mu}$) and invariant mass ($M_{\mu\mu}$) has been studied. While performing study as function of $M_{\mu\mu}$, transverse momentum of di-muon pair $p_T^{\mu\mu}$ is required to be less than 10 GeV/c to reduce the radiation contributions.

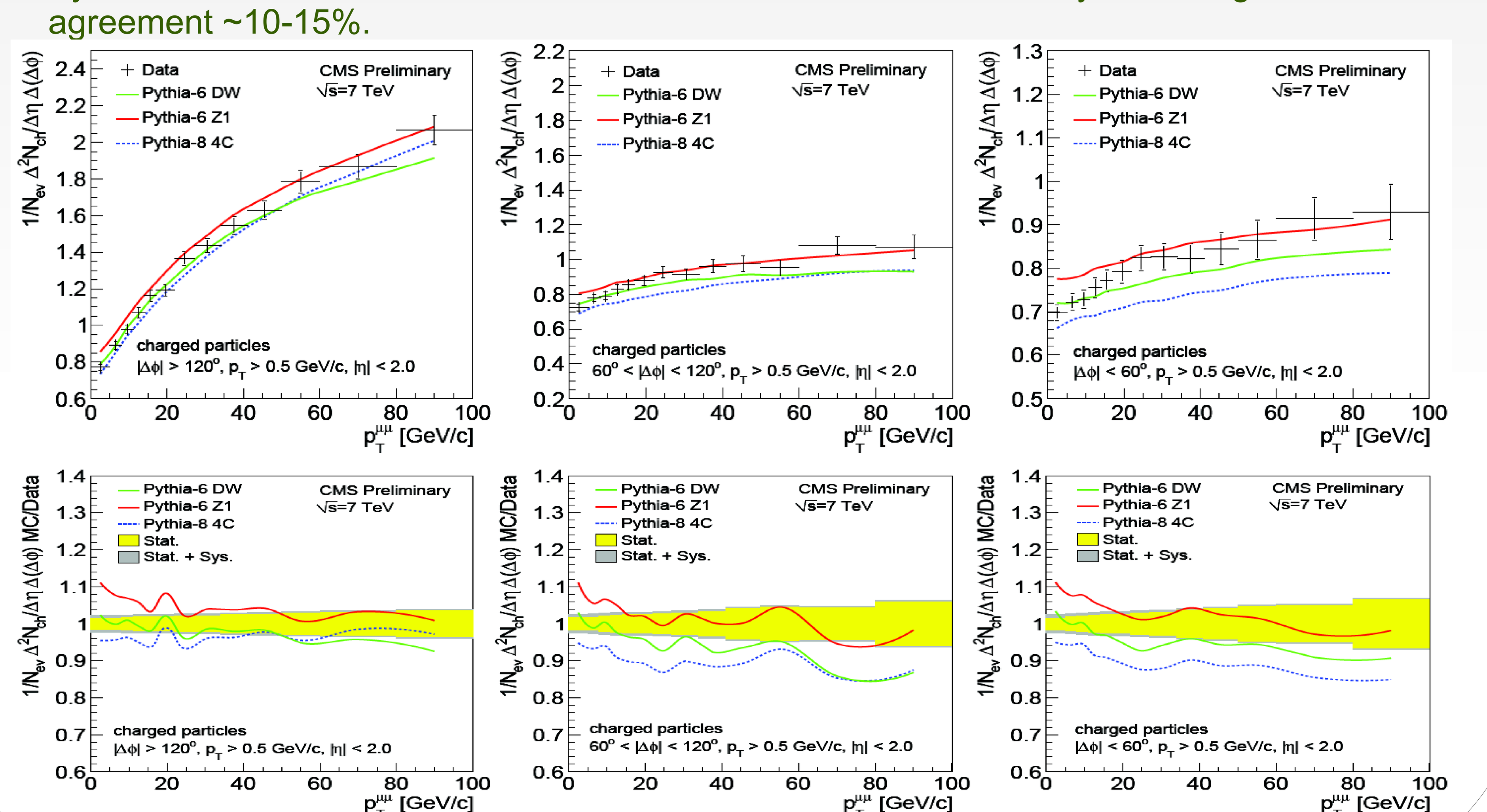
– Measurements in data are corrected for detector effects.

Systematic uncertainties

Observable	Trigger	Isolation	Track Sel.	Fake	Pile-up	QCD Model	Bkg. Process
$1/N_{ev}\ \Delta^2\Sigma p_T/\Delta\eta\ \Delta(\Delta\phi)$ (towards)	0.4 (0.4)	1.0 (1.1)	0.7 (0.8)	0.7 (0.7)	1.0 (1.2)	0.7 (1.5)	1.9 (0.2)
$1/N_{ev}\ \Delta^2\Sigma p_T/\Delta\eta\ \Delta(\Delta\phi)$ (transverse)	0.4 (0.4)	0.8 (1.3)	0.6 (1.1)	0.7 (0.7)	0.9 (1.2)	0.4 (1.7)	2.0 (0.2)
$1/N_{ev}\ \Delta^2\Sigma p_T/\Delta\eta\ \Delta(\Delta\phi)$ (away)	0.4 (0.4)	0.6 (0.8)	0.8 (0.8)	0.7 (0.6)	0.6 (1.1)	1.0 (1.4)	0.2 (0.2)
$1/N_{ev}\ \Delta^2 N_{chg}/\Delta\eta\ \Delta(\Delta\phi)$ (towards)	0.4 (0.4)	0.8 (0.9)	0.8 (0.8)	0.9 (0.8)	1.2 (1.5)	0.7 (1.0)	0.7 (0.2)
$1/N_{ev}\ \Delta^2 N_{chg}/\Delta\eta\ \Delta(\Delta\phi)$ (transverse)	0.4 (0.4)	0.7 (1.1)	0.9 (1.0)	0.9 (0.8)	1.1 (1.4)	0.7 (1.1)	0.7 (0.2)
$1/N_{ev}\ \Delta^2 N_{chg}/\Delta\eta\ \Delta(\Delta\phi)$ (away)	0.4 (0.4)	0.5 (0.7)	0.8 (0.8)	0.9 (0.6)	0.7 (1.3)	0.7 (1.1)	0.2 (0.2)

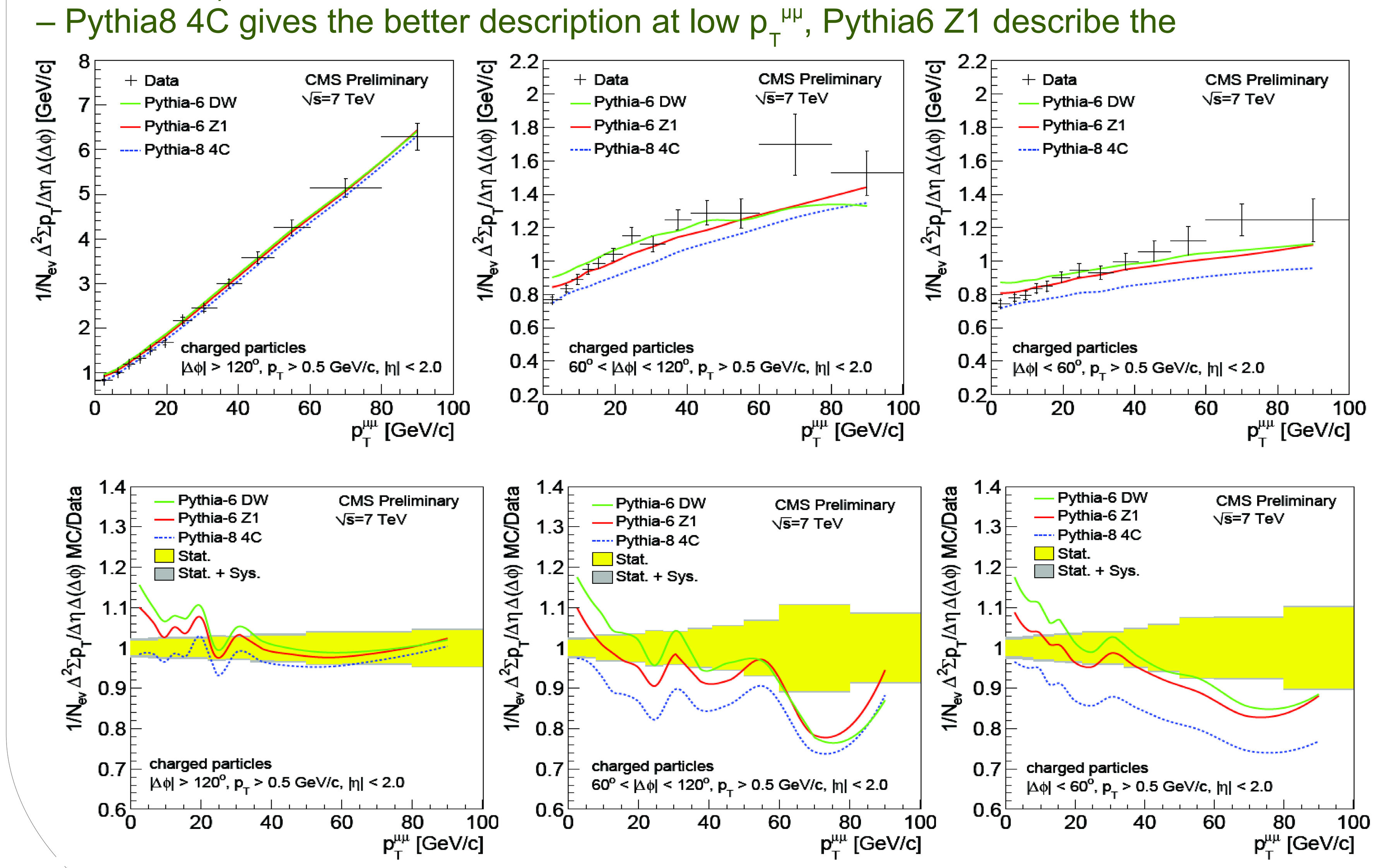
Average N_{chg} density as function of $p_T^{\mu\mu}$

– Increase in average N_{chg} density with $p_T^{\mu\mu}$ is mainly due to increase in contribution from ISR as energy scale of event is high enough to lie in MPI saturation region ($M_{\mu\mu} > 60$ GeV/c^2).
– Pythia6 DW and Z1 describe measurement within ~10% whereas Pythia8 4C give agreement ~10-15%.



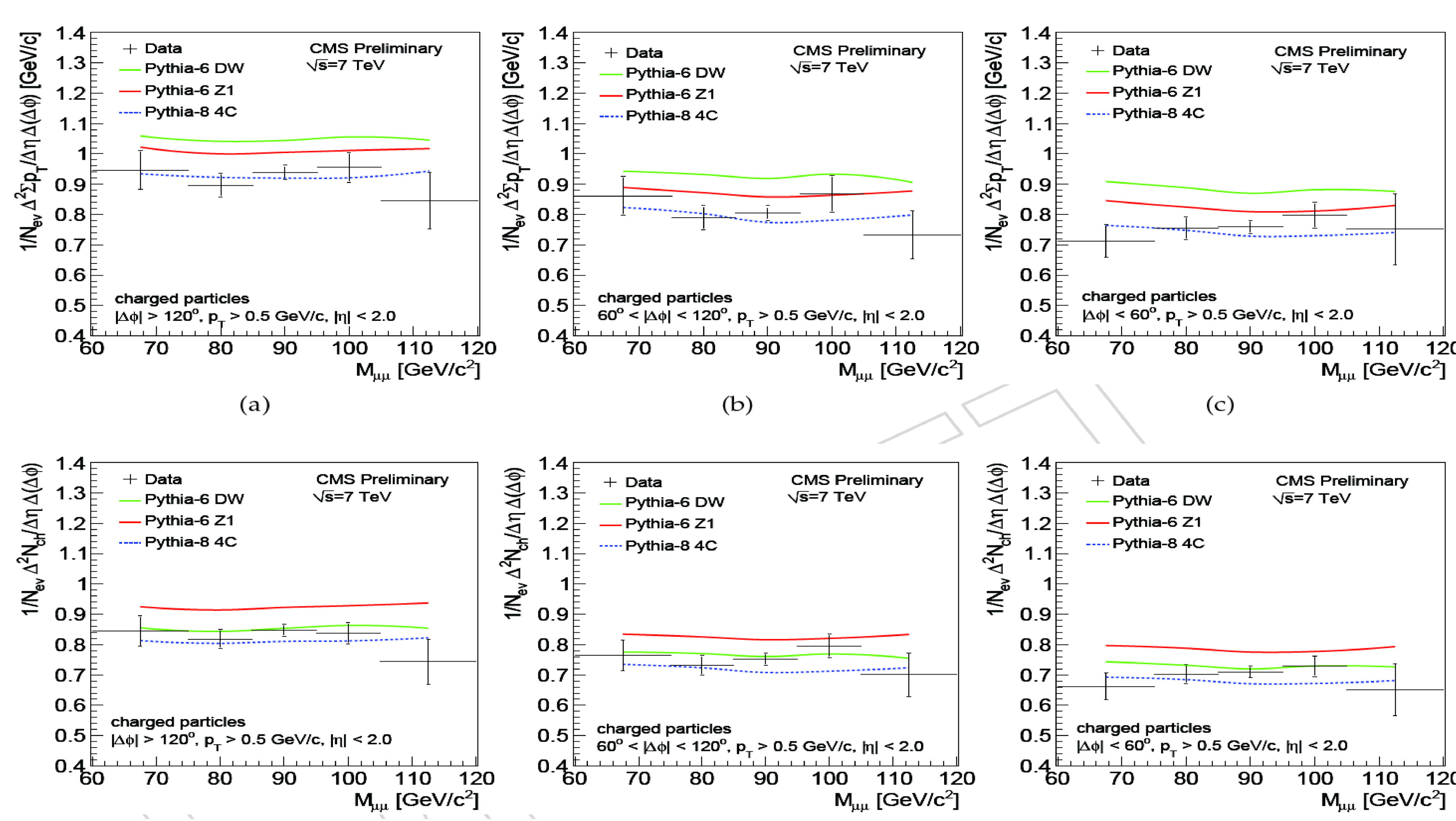
Average $\sum p_T$ Density as function of $p_T^{\mu\mu}$

– Increase in average $\sum p_T$ density with $p_T^{\mu\mu}$ is mainly due to increase in contribution from ISR as energy scale of event is high enough to lie in MPI saturation region ($M_{\mu\mu} > 60$ GeV/c^2).
– Pythia8 4C gives the better description at low $p_T^{\mu\mu}$, Pythia6 Z1 describe the



Average N_{chg} and $\sum p_T$ density as function of $M_{\mu\mu}$

– Contribution of radiation is minimized by requiring $p_T^{\mu\mu} < 10$ GeV/c
– Average N_{chg} and $\sum p_T$ densities are flat as function of $M_{\mu\mu}$: confirm the hypothesis that MPI gets saturated at high energy scale.
– Pythia-8 4C and Pythia-6 Z1 give good description of average ∑pT density whereas average N_{chg} density is well described by Pythia-8 4C and Pythia-6 DW predictions.



References:

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