Drell-Yan study in CMS for 100 pb^{-1} at 10 TeV

Monika Jindal

K.Mazumdar, D. Bourilkov , J.B. Singh

Motivation to study Drell-Yan process ($pp \rightarrow Z/\gamma^* \rightarrow l^+l^-$)

- LEP and Tevatron experiments have established Electroweak part of Standard Model (SM) very well.

- Confirmation of SM will be done at LHC using theoretically well- understood processes like, Drell-Yan events .

- Study of the new Physics at LHC requires the accurate measurement of Standard Model processes (like DY) which pose as background to many new physics searches e.g *Z'* ➔ resonance structure at high invariant mass , so needs to be estimated correctly.

- Lepton pair + missing energy is also signature of new physics.

Generation Information of data samples analyzed

Data	Events	Production cross-section(pb)	Filter Efficiency	effective cross-section(pb)	Scaling Factor
Z→ $\mu^+\mu^-$(Mll > 20.)	1296192	1944.0	1.0	1944.0	0.15
DY (6 < Mll < 40.)	230582	12900	0.309	2339.8	1.73
W+Jets	9494588	40000.0	0.45	40000	0.43
TTbar+Jets	927345	317.0	0.33	317.0	0.03
Z→ $\tau\tau$	1014480	1944.0	1.0	1944.0	0.19
InclusiveMuPt15	6246161	5.091×10^8	0.000239	121675.0	1.95 X
InclusivePPMuX	5279540	5.156×10^7	0.002305	11884.58×10^4	2251.1 X
QCD20-30	11377053	4.97×10^8	0.0041	2.0377×10^6	17.8
QCD30-50	11229012	9.177×10^7	0.0061	5.6×10^5	5.1
QCD50-80	12905363	1.165×10^7	0.014	1.63×10^5	5.6
QCD80-120	840244	1.547×10^6	0.0227	3.51×10^4	4.14
QCD120-170	328590	2.492×10^5	0.0282	7.03×10^3	2.2
QCD170	464357	6.203×10^4	0.58	22.0×10^4	0.47
WW	204305	44.8	1.0	44.8	0.022
ZZ	199455	7.1	1.0	7.1	0.004
WZ	248236	32.4	1.0	32.4	0.013

→ InclusivePPMuX has large scaling factor for 100 pb $^{-1}$ and InclusiveMuPt15 has large pt cut on muons (pt > 15 GeV).

➢ QCD samples in different pt hat bins have been merged after normalization

- Filter (implemented in PAT) used to select events with atleast two muons:
- ✓ Module used to select two muon events

```
minLayer1Muons = cms.EDFilter("PATMuonMinFilter",
src = cms.InputTag("selectedLayer1Muons"),
minNumber = cms.uint32(2)
```

Data	Events passing 2 muon filter	ϵ
Z$\rightarrow \mu^+\mu^-$ with CKIN(1) > 20.	627642	0.484
DY with 6 < Mll < 40	135445	0.587
W+Jets	404720	0.043
TTbar+Jets	283465	0.306
Z$\rightarrow \tau\tau$	45781	0.045
QCD20-30	1224066	0.138
QCD30-50	3240014	0.30
QCD50-80	1116309	0.37
QCD80-120	371973	0.44
QCD120-170	166858	0.51
QCD170-up	271024	0.58
WW	22065	0.108
ZZ	30716	0.154
WZ	21968	0.123

Online Selection:

- Single Muon Trigger : HLT_Mu9 (single muon with pt > 9 GeV)

- Double Muon Trigger : HLT_DoubleMu3 (2 muons pT > 3 GeV)

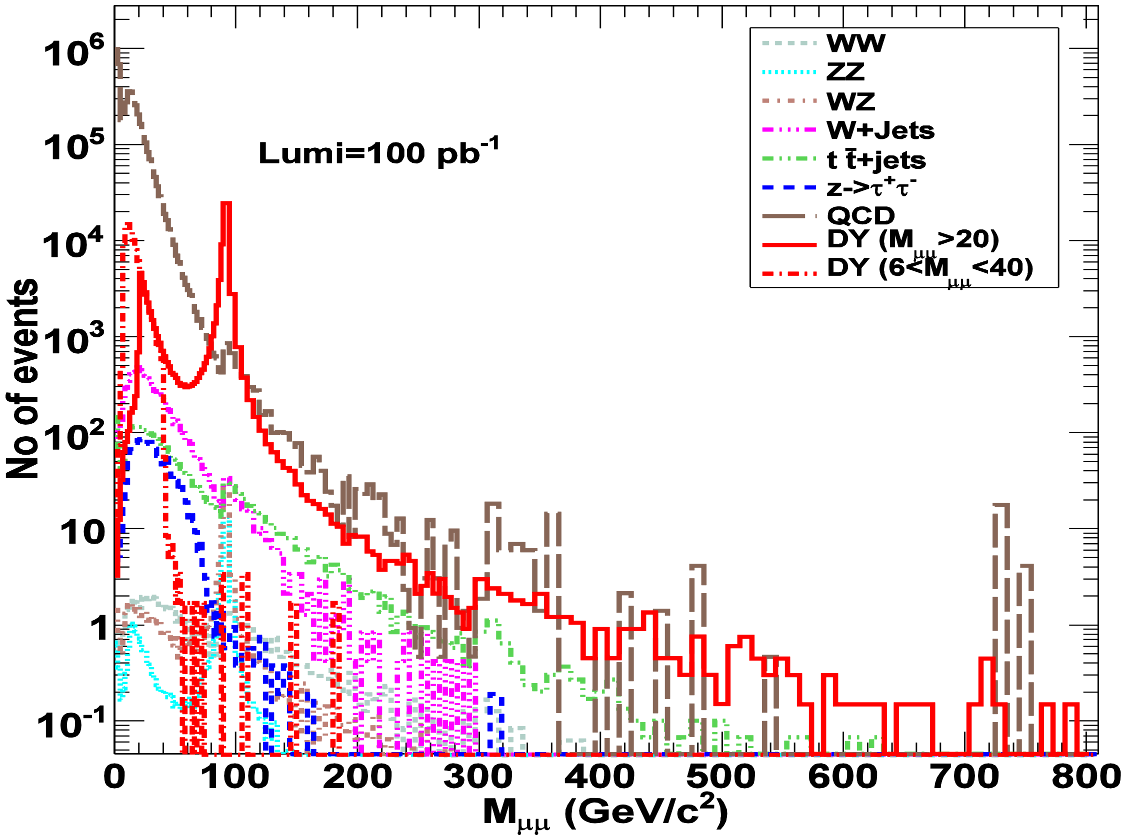
- ***OR of single muon and dimuon trigger has better signal efficiency rather than individual one.***

- Events passing OR of two triggers have been selected.

Efficiency:
Signal = 91%, Ztautau = 34%, Wjets=46%,   ttjets = 54%, QCD = 23%

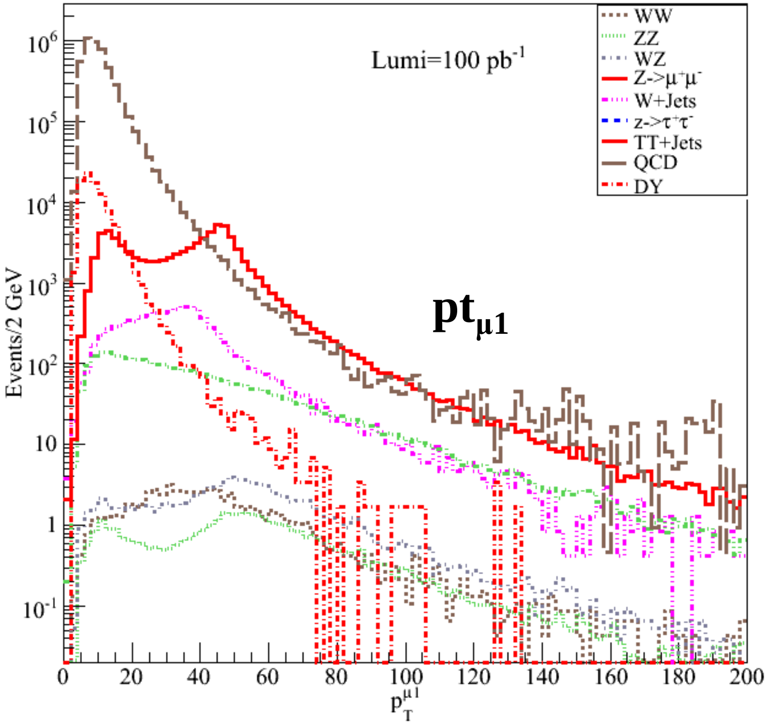
Offline Selections:

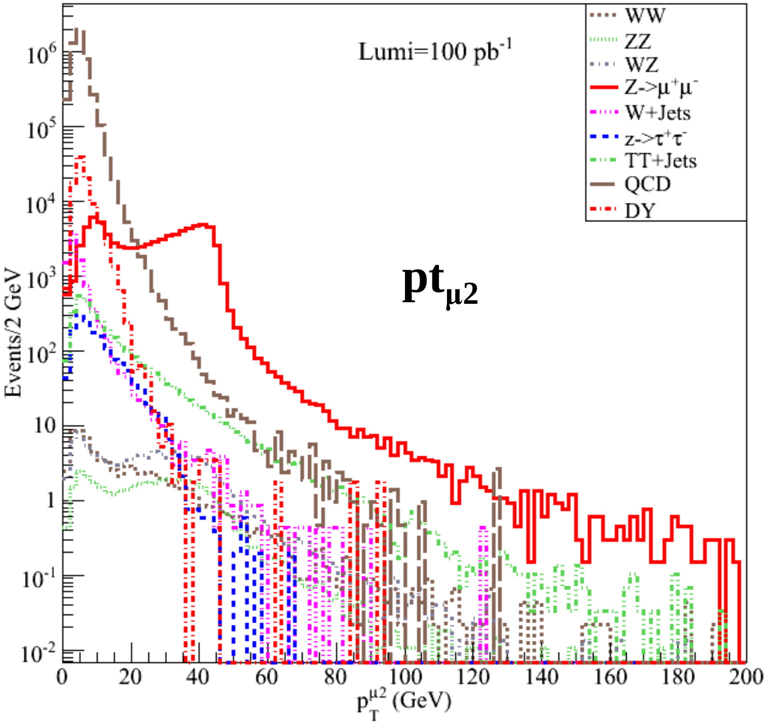
1. There must be atleast two global muons in the event.



Invariant mass of dimuon system after trigger and 2 muon selection. QCD is very dominating in the low mass region.

➢ pt of both leading muons > 10 GeV and both muons should be in detector acceptance region |η| < 2.4



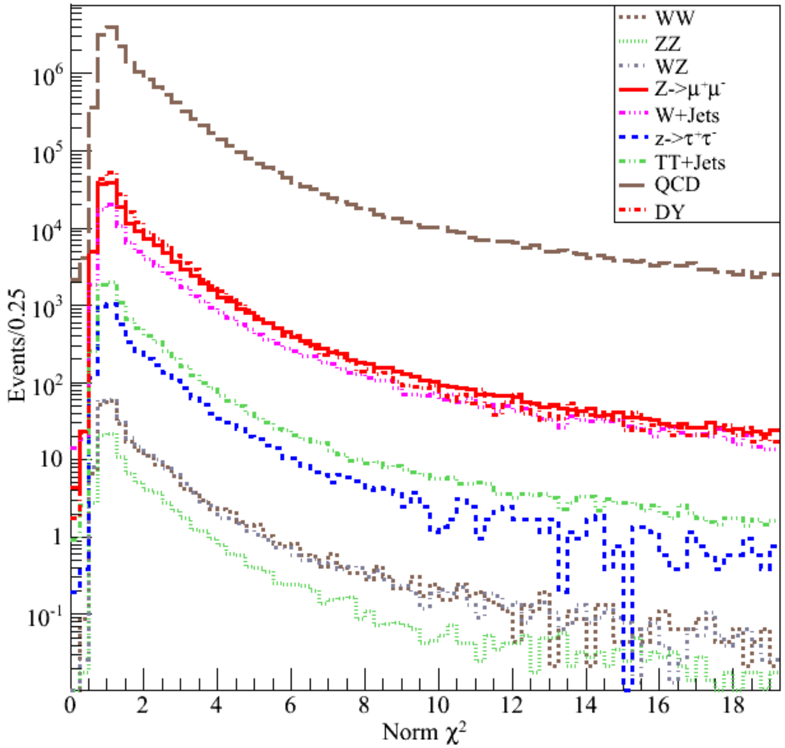


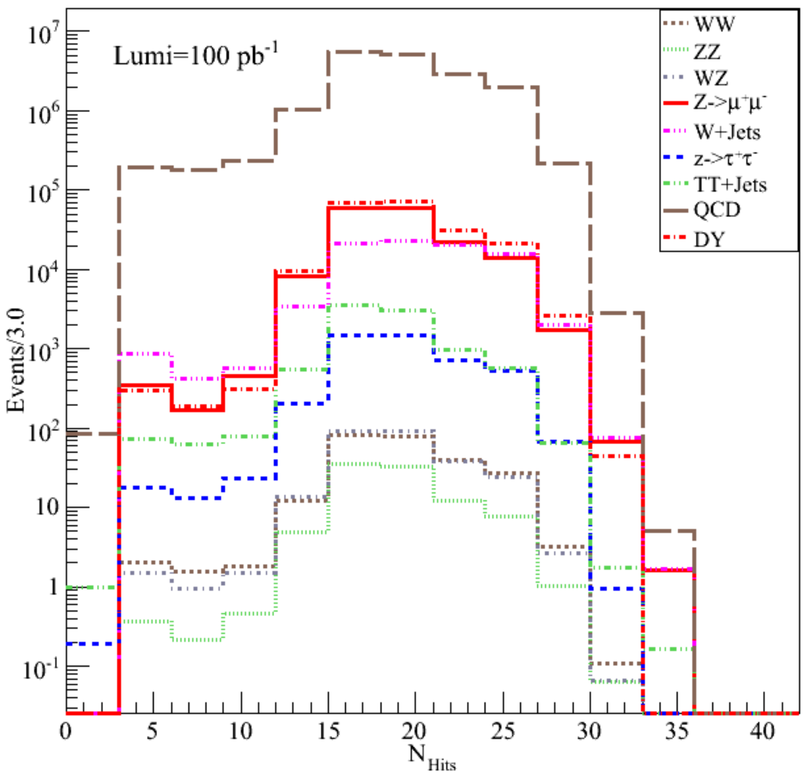
Since the muons coming from heavy meson decays in QCD will be relatively soft. so a pt cut > 10 GeV is quite effective in reducing a large fraction of QCD

Efficiency of pt > 10 GeV and **|η| < 2.4 cut** : Signal = 81% , QCD = 4% , Wjets = 8%

➢ Muon ID selection : (recommended by Muon POG for selecting good muon tracks)

- ✓ Normalized chi2 of both leading muons < 10.
- ✓ Number of valid hits > 11.

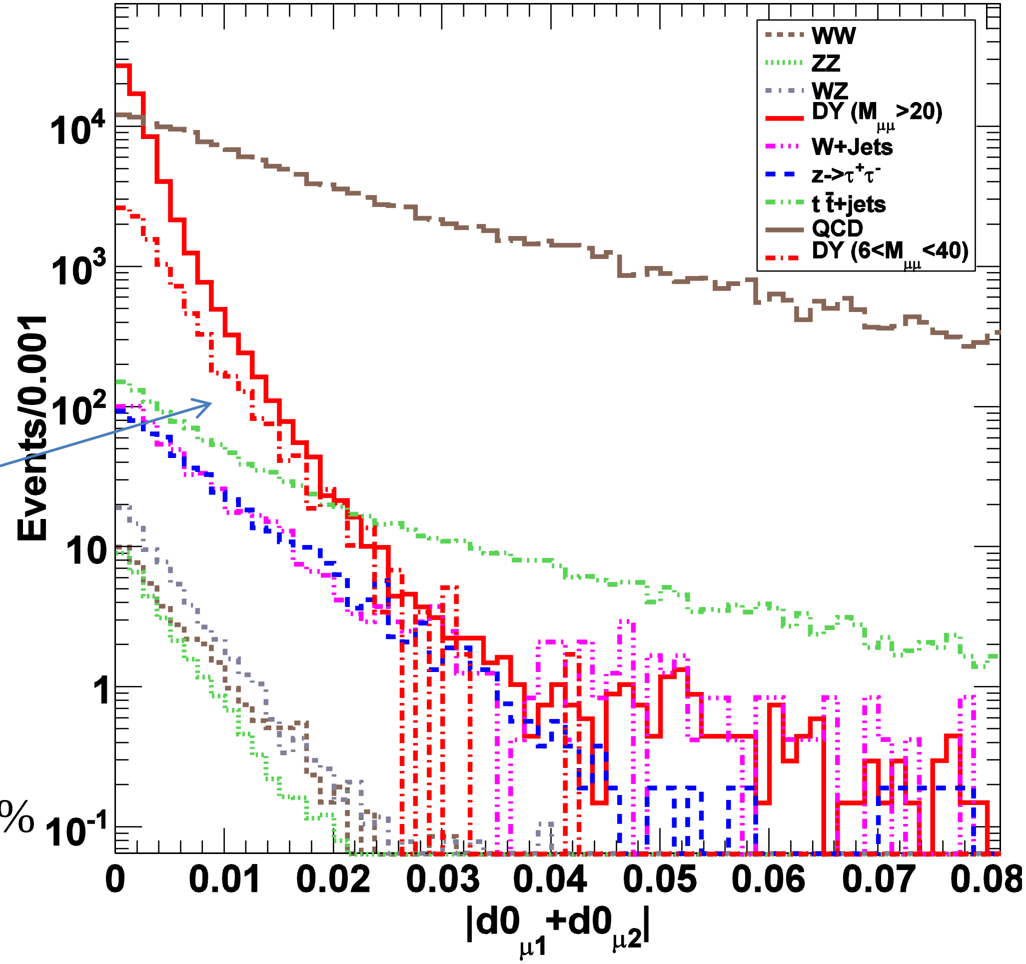




- For muons coming from signal , the transverse impact parameter is expected to be very small whereas for the muons coming from decays in flight muons in QCD , it will be quite large.

- |d0μ1+ d0μ2| < 0.01 cm for both leading muons.

✓ d0 is the transverse impact parameter of muon.

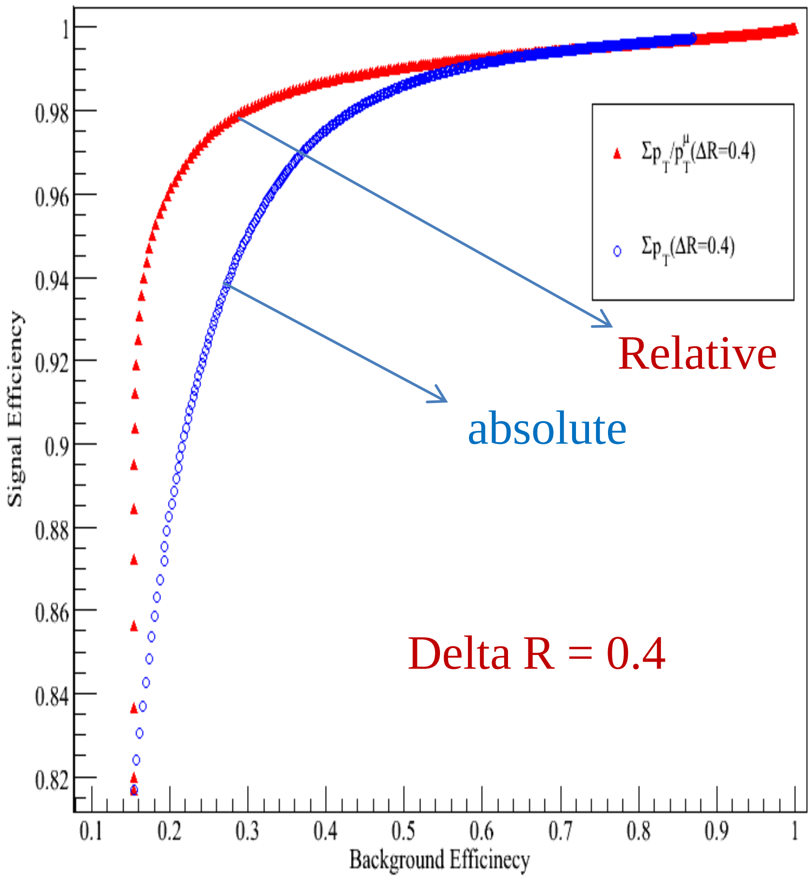


$|d0_{\mu1} + d0_{\mu2}|$ for two leading global muons in the event.

Efficiency of MuonID selection :
Signal = 94%, QCD = 36% , W+jets = 58%
ttbar+jets = 50%

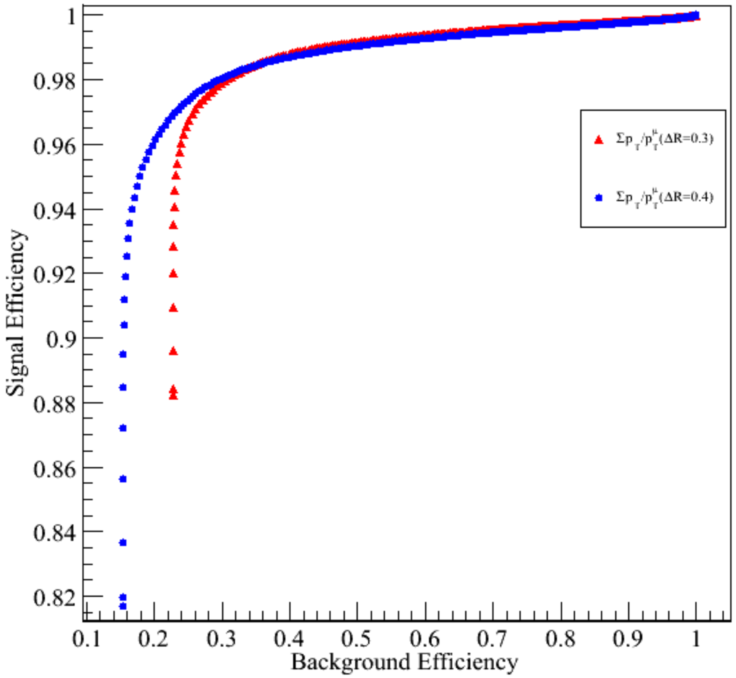
Isolation Condition (Tracker based)

- Comparison of Relative and absolute tracker isolation variable in two different cone sizes 0.3 and 0.4



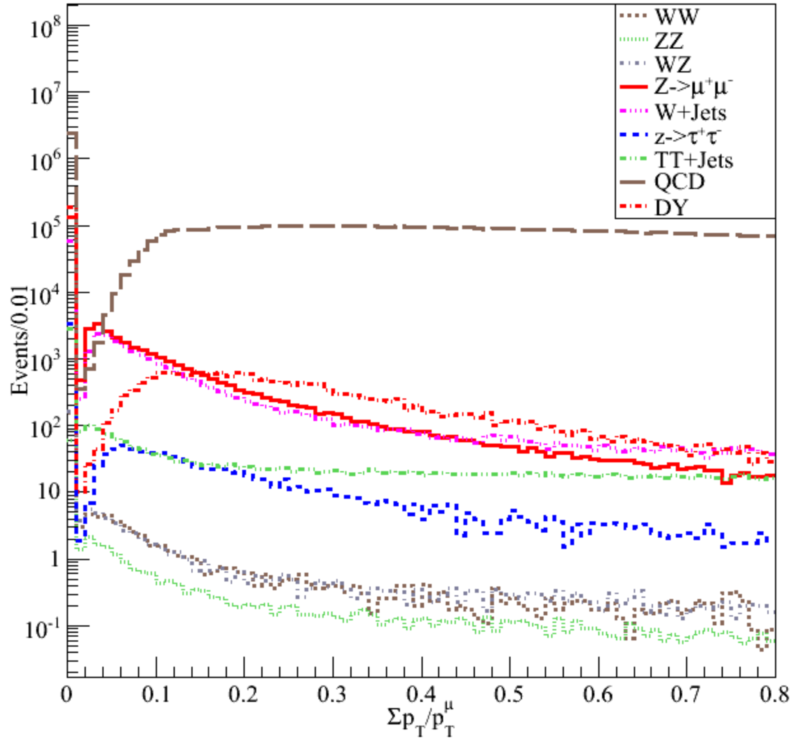
- **Relative Isolation variable** is defined as $\sum pt/pt_{\mu}$ and **absolute isolation variable** is $\sum pt$ of tracks in a given cone.

- For a given signal efficiency, relative isolation variable has more background rejection as compared to absolute one.



- Comparison of relative Isolation variable in two cone sizes 0.3 & 0.4
- Relative Isolation variable gives more background rejection for a given signal efficiency in cone size 0.4

Isolation Variable $\sum p^T/p^T_\mu < 0.1$
in cone of deltaR = 0.4(optimized)

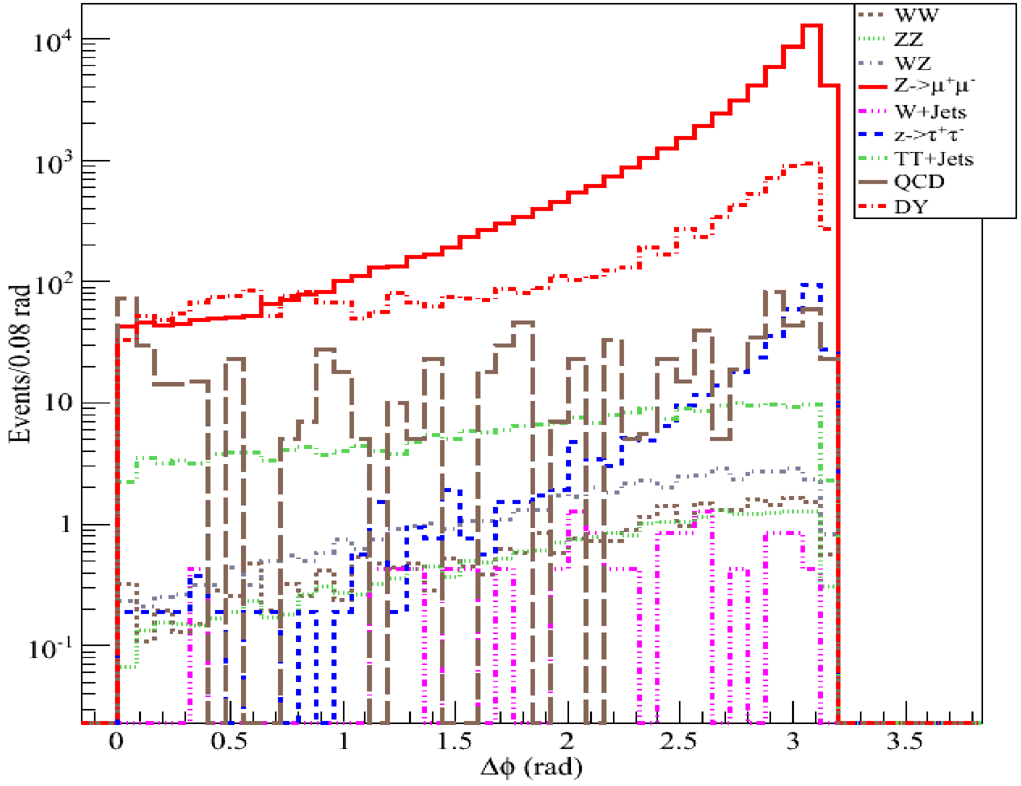


Veto cone of 0.01 to exclude muon tracks
Only tracks with pT > 1 GeV

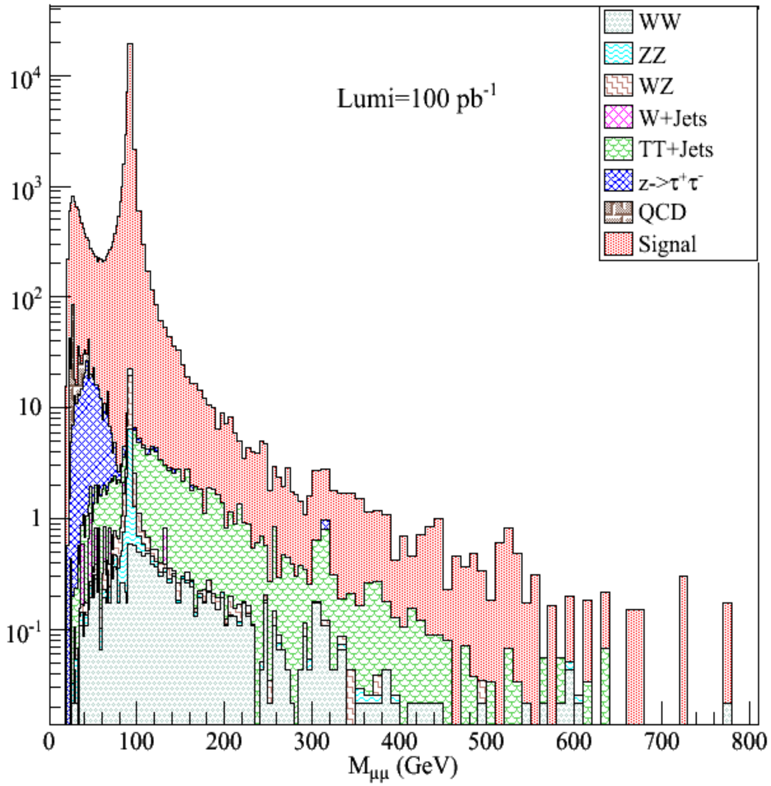
Efficiency:
Signal = 90% , QCD= 1%, Wjets=3% , ttbar+jets = 35%

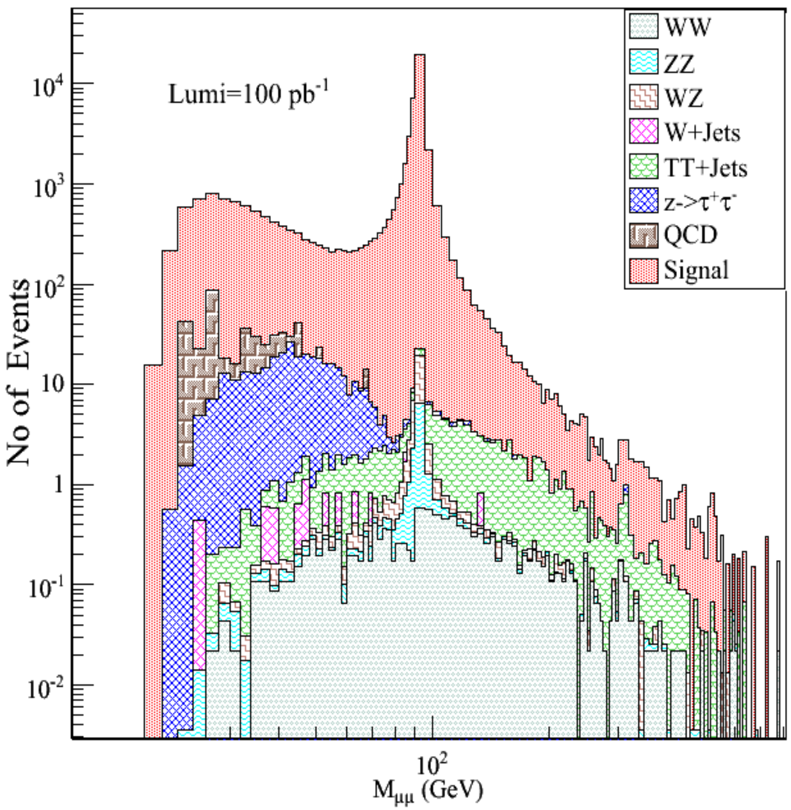
Angle between two muons

- Signal muons most of the time will be back to back. So the value for the angle between two muons has been optmized to be > 2.25 rad.



Invariant mass of dimuon system after all selection cuts





All the backgrounds have been reduced to a good extent. QCD and Z-> τ+τ- are now mainly contributing in the low mass region 20-60 GeV, however ttbar+jets is dominating in the higher mass region.

Cumulative efficiencies of all selection cuts

Selection	$Z\to\mu^+\mu^-$	DY (6<M_ll40)	Wjets	$Z\to\tau^+\tau^-$	$t\bar{t}$+jets	WW	ZZ	WZ	QCD
HLT_DoubleMu3 OR HLT_Mu9	0.91 ±3.7e-05	0.47 ±1.4e-03	0.46 ±7.8e-04	0.34 ±2.2e-03	0.54 ±1.0e-03	0.37 ±3.0e-03	0.45 ±2.8e-03	0.39 ±2.8e-03	0.23 1.9e-04
Global muons >=2	0.83 ±4.7e-04	0.41 ±1.3e-04	0.05 ±3.4e-04	0.18 ±1.8e-03	0.32 ±8.7e-04	0.15 ±2.4e-03	0.37 ±2.8e-03	0.25 ±2.5e-03	0.09 ±1.3e-04
p_T^μ > 10.0 GeV and $\lvert\eta_\mu\rvert < 2.4$	0.67 ±5.9e-04	0.04 ± 5.5e-04	0.004 ±9.6e-05	0.07 ±1.1e-03	0.14 ±6.5e-04	0.09 ±2.0e-03	0.30 ±2.6e-03	0.18 ±2.2e-03	0.004 ±2.18e-05
Muon ID	0.63 ±6.1e-04	0.04 ±5.2e-04	0.002 ±7.2e-05	0.05 ±1.0e-03	0.07 ±4.8e-04	0.07 ±1.7e-03	0.25 ±2.5e-03	0.15 ±2.1e-03	0.0013 ±1.3e-05
$\sum p_T^i / p_T^\mu$ < 0.1 ($\Delta R = 0.4$)	0.57 ±6.3e-04	0.03 ±4.7e-04	6.9e-05 ±1.31e-05	0.04 ±1.0e-03	0.02 ±3.0e-04	0.06 ±1.6e-03	0.22 ±2.3e-03	0.13 ±1.9e-03	1.48e-05 ± 1.83e-06
Opp Charge	0.57 ±6.3e-04	0.03 ±4.7e-04	5.9e-05 ± 1.2e-05	0.04 ±1.0e-03	0.02 ±3e-04	0.06 ±1.6e-03	0.21 ±2.3e-03	0.12 ±1.9e-03	1.17e-05 ±1.63e-06
$\Delta\phi > 2.25$	0.51 ±6.3e-04	0.02 ±4.0e-04	2.97e-05 ±8.6e-06	0.04 ±8.6e-04	0.01 ±2.0e-04	0.03 ±1.2e-03	0.12 ±1.8e-03	0.07 ±1.4e-03	4.91e-06 ±1.11e-06

No of events expected in each mass bin for 100 pb -1

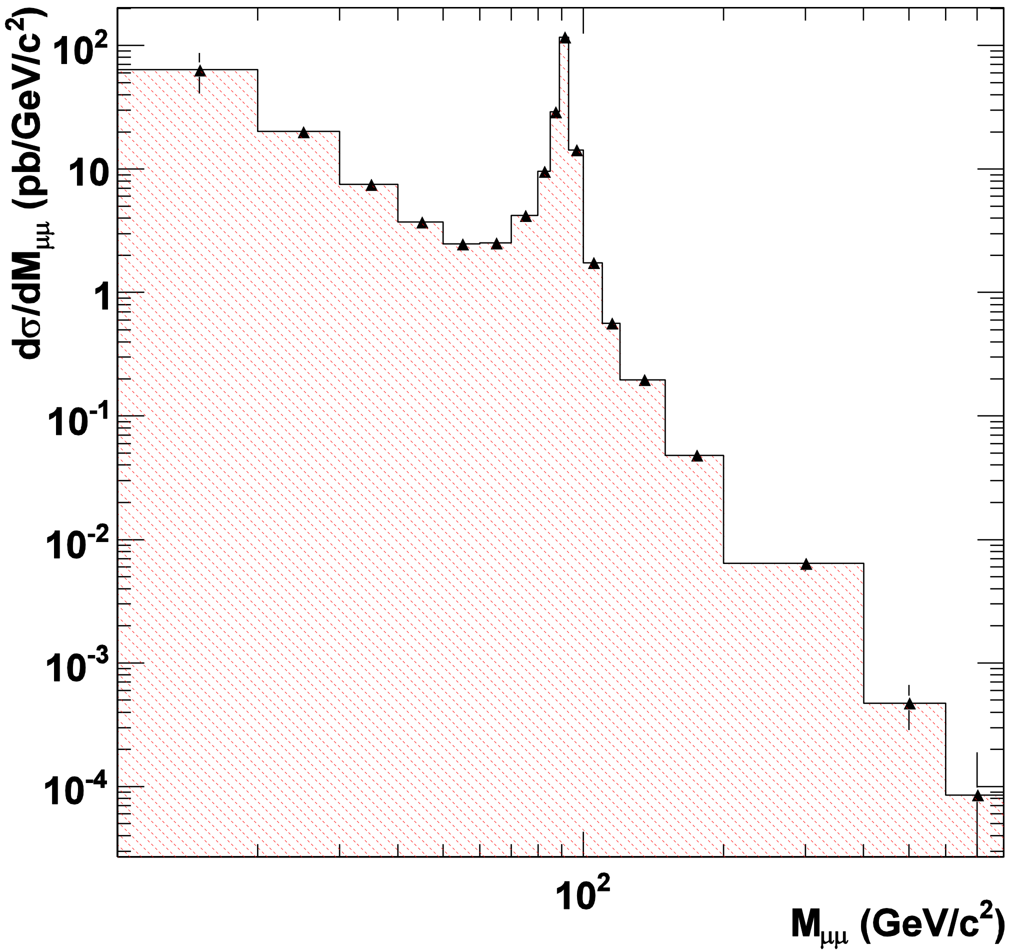
Mass window	Signal	Wjets	$Z\rightarrow \tau^{+}\tau^{-}$	ttjets	WW	ZZ	WZ	QCD
10-20	15.55±5.18	0±0	0±0	0±0	0±0	0.0±0.0	0±0	0±0
20-30	2881.43 ±20.46	0.43± 0.43	26.0±2.23	0.30±0.10	0.07±0.04	0.05±0.01	0.04±0.02	142.30±11.93
30-40	2550.84±19.29	0.85 ±0.60	67.3±3.57	1.71±0.24	0.33±0.08	0.12±0.02	0.14±0.04	67.24±8.2
40-50	1429.85± 14.53	1.27 ±0.74	98.41±4.31	3.42±0.34	0.85±0.14	0.18±0.03	0.18±0.05	39.12±6.25
50-60	1046.93±12.46	0.85±0.60	68.79±3.61	5.93±0.45	1.04±0.15	0.17±0.02	0.35±0.07	5.06±2.25
60-70	1117.4± 12.87	0.85±0.60	33.63±2.53	6.7±0.47	1.04±0.15	0.22±0.03	0.59 ±0.09	5.53±2.35
70-80	1931.95 ±16.84	0±0	9.17±1.32	7.8±0.51	1.59±0.19	0.55±0.04	1.24±0.13	0±0
80-85	2417.11±18.79	0.43±0.43	1.53±0.54	3.89±0.36	0.61±0.12	0.66±0.05	1.26±1.13	0±0
85-89	6590.76 ±30.31	0±0	1.34±0.51	2.71±0.30	0.48±0.10	2.0±0.08	4.06±0.23	0±0
89-93	20136.9 ±48.71	0±0	0.57±0.33	2.28±0.28	0.48±0.10	6.07±0.14	13.27±0.41	0±0
93-100	5779.81 ±28.52	0±0	0.38±0.27	5.16±0.42	0.76±0.13	1.84±0.08	3.63±0.22	0±0
100-110	885.76±11.47	0±0	0.57±0.33	7.44±0.50	0.96±0.14	0.33±0.03	0.6±0.09	0±0
110-120	279.61 ±6.47	0±0	0.57±0.33	6.87±0.48	0.87±0.14	0.1±0.02	0.24±0.06	0±0
120-150	296.40±6.66	0.43±0.43	0.76±0.38	15.79±0.73	1.74±0.19	0.16±0.02	0.37±0.07	0±0
150-200	120.54±4.25	0±0	0.19±0.19	16.02±0.73	2.02±0.21	0.12±0.02	0.28±0.06	0±0
200-400	71.51±3.27	0±0	0.19±0.19	13.00±0.66	2.13±0.22	0.1±0.02	0.38±0.07	0±0
400-600	7.5±1.06	0±0	0±0	0.84±0.17	0.22±0.07	0.02±0.001	0.05±0.03	0±0
600-800	0± 0	0±0	0±0	0±0	0.02±0.02	0.004±0.004	0±0	0±0

➔ Total signal events ~ 47500 and total background expected after all cuts for 100 pb^{-1} ~ 750

Drell-Yan differential cross section

- **Calculated using the formula :**

$$\left(\frac{d\sigma}{dM_{\mu\mu}}\right)_i = \frac{N_{obs.} - N_{bkd.}}{\varepsilon_i \beta_i \Delta M L}$$



ε = Correction factor for the selection efficiencies in each mass bin.

β = Correction factor for the detector acceptance in each dimuon mass bin

Points ➔ Measurements for 100 pb -1
Solid histogram ➔ SM prediction

Table shows the Drell-Yan cross section in each mass bin of dimuon pair for 100 pb -1

Mass window	Uncorrected xsec (pb)	cross section (pb)	SM prediction
10-20	0.16	638.87±229.03	638.87
20-30	28.75	201.84±5.13	201.84
30-40	25.48	75.28±1.92	75.28
40-50	14.35	37.22±1.25	37.22
50-60	10.45	24.88±0.97	24.88
60-70	11.19	25.27±0.94	25.27
70-80	19.29	42.12±1.19	42.12
80-85	24.15	48.38±1.21	48.38
85-89	65.90	116.57±1.72	116.57
89-93	201.47	472.33±4.17	472.33
93-100	57.82	100.29±1.57	100.29
100-110	8.82	17.55±0.72	17.55
110-120	2.80	5.68±0.42	5.68
120-150	2.97	5.96±0.42	5.96
150-200	1.20	2.42±0.27	2.42
200-400	0.72	1.29±0.18	1.29
400-600	0.08	0.1±0.04	0.1
600-800	0.01	0.02± 0.02	0.02

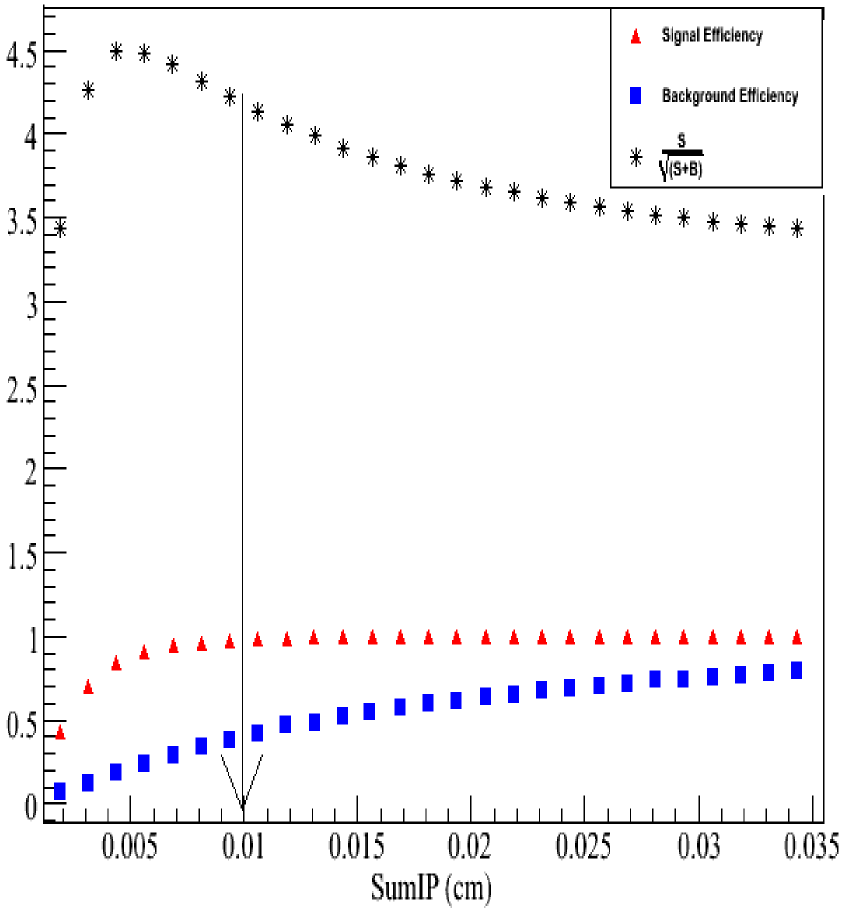
Since the corrections has been applied using the gen level info, so our measurements for 100 pb -1 are matching exactly with the SM predcition

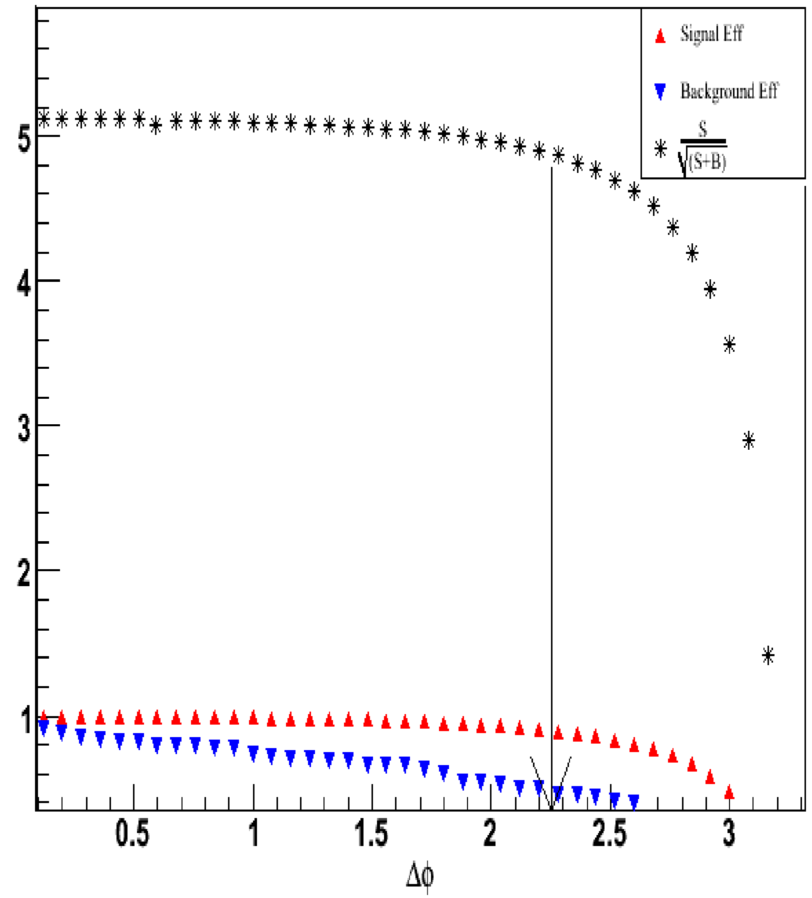
Conclusions/Plans

- Various selection cut has been optimized to reduce backgrounds to good extent.
- QCD mainly contributes to low dimuon mass region, in high mass region QCD is quite under control.
- This work has been done in 2_2_6 CMSSW version at 10 TeV, to redo this work in 3XY series using the new samples at 7 TeV
- To estimate the QCD , Z-> $\tau^+\tau^-$ and ttbar+jets background using data driven technique.

Back -up

Optimization plot for sum of transverse impact parameter and angle between of two leading muons





Relative efficiencies of all selection cuts

Selection	$Z\to\mu^+\mu^-$	DY (6<M$_{ll}$40)	Wjets	$Z\to\tau^+\tau^-$	$t\bar{t}$+jets	WW	ZZ	WZ	QCD
HLT_DoubleMu3 OR HLT_Mu9	0.91 ±3.7e-04	0.47 ± 1.3e-03	0.46 ±7.8e-04	0.34 ±2.2e-03	0.54 ± 1.0e-03	0.37 ±3.2e-03	0.46 ±2.8e-03	0.39 ±2.7e-03	0.23 ±1.9e-04
Global muons >=2	0.92 ±3.4e-04	0.89 ±8.6e-04	0.11 ±4.9e-04	0.53 ±2.3e-03	0.60 ±1.0e-03	0.41 ±3.3e-03	0.82 ±2.2e-03	0.65 ±2.7e-03	0.39 ±4.6e-04
p_T^μ > 10.0 GeV and $\|\eta_\mu\| < 2.4$	0.81 ±5.0e-04	0.10 ±8.3e-04	0.08 ±4.2e-04	0.38 ±2.3e-03	0.44 ±1.0e-03	0.57 ±3.3e-03	0.79 ±2.3e-03	0.73 ±2.5e-03	0.04 ± 2.4e-04
Muon ID	0.94 ±3.1e-04	0.91 ±8.0e-04	0.58 ±7.8e-04	0.72 ±2.1e-03	0.50 ±1.0e-03	0.80 ±2.7e-03	0.86 ±2.0e-03	0.84 ±2.1e-03	0.36 ±3.0e-03
$\sum p_T^{i}/p_T^\mu$ < 0.1 ($\Delta R = 0.4$)	0.90 ±3.8e-04	0.80 ±1.1e-03	0.03 ±2.8e-04	0.80 ±2.0e-03	0.35 ±8.8e-04	0.82 ±2.6e-03	0.85 ±2.0e-03	0.84 ±2.1e-03	0.01 ±1.4e-03
Opp Charge	0.99 ±6.7e-06	0.99 ±4.2e-05	0.86 ±5.5e-04	0.99 ±1.1e-04	0.98 ±2.6e-04	0.99 ±3.3e-04	0.98 ±6.5e-04	0.95 ±1.3e-03	0.79 ±5.1e-02
$\Delta\phi > 2.25$	0.90 ±3.9e-04	0.71 ±1.2e-03	0.5 ±7.9e-04	0.92 ±1.3e-03	0.43 ±1.0e-03	0.56 ±3.3e-03	0.55 ±2.8e-03	0.55 ±2.8e-03	0.42 ±7.0e-02