# $Z^0$ studies in CMS:Status &Workplan

Dipanwita Dutta

NPD, BARC, Mumbai

# Outline

**Physics Motivation**

**Simulation for $Z^0$**

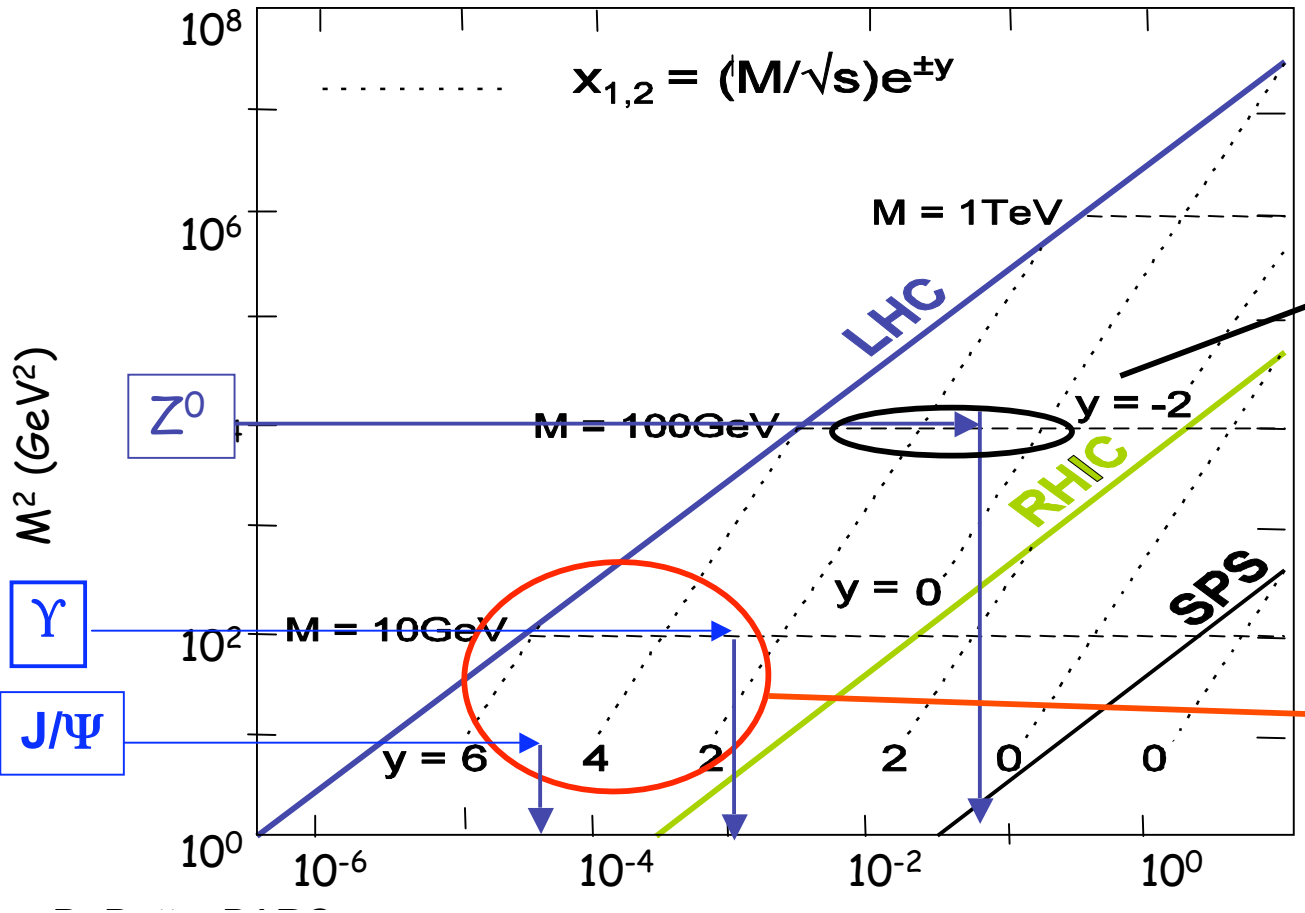
**Background Study**

**Results of background study**

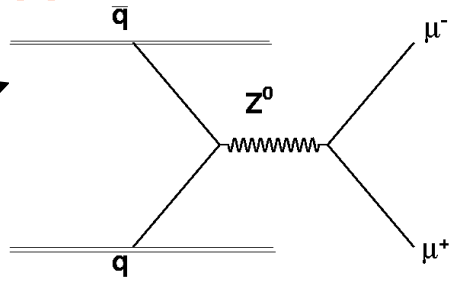
**Future plan**

# $Z^0$ :Physics Motivation

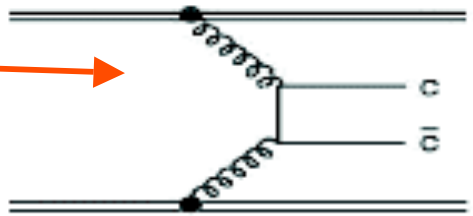
- $Z^0$ produced in large cross section at LHC (Pb+Pb@5.5TeV)
- Nuclear shadowing : Modification of PDF's in Nucleus
  - Novel Bjorken-x range ($10^{-2}$-$10^{-3}$) at Large $Q^2$
- Dominant Production : qq->$Z^0$ Shadowing of Quark PDI




$Z^0$ Production via $q\bar{q}$ annihilation




$Q\bar{Q}$ Production via gluon fusion




Gluon saturation; CC

# Expected Yield of $Z^0 \rightarrow \mu^+\mu^-$

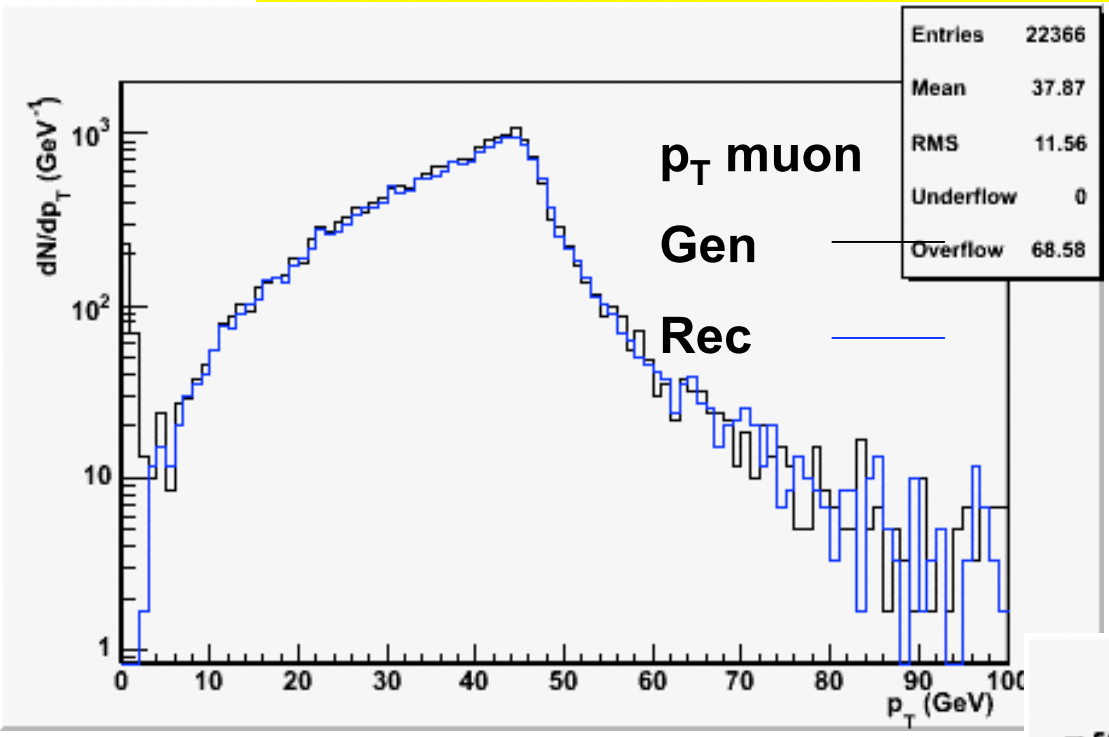
**Expected No. for one month LHC run, $L_{int}=0.5\ nb^{-1}$**

| Processes | Cross-section $\sigma_{pp}(Z^0)$ Pythia6.409 CTEQ5M | Cross-section $\sigma_{PbPb}(Z^0)=T_{AA}\times\sigma_{pp}(Z^0)$ 0-10% cent. (MB) | No. of $Z^0$ for 0-10% cent. (MB) collisions $N_{PbPb}=L_{int}\times\sigma_{PbPb}(Z^0)\times$Acc.(=0.51) |
|---|---|---|---|
| $Z^0$,$Z^0$+jet (MSUB=1,15,30) | 1.59 nb | 25.6 (69)μb | **$6.53\times10^3$ ($1.76\times10^4$)** |

**Signal Inclusive Z0: Z0, Z0+jet**
**PYTHIA 6.409 at $\sqrt{s}$=5.5 TeV**

**PYTHIA parameters**
**MSEL=0,**
**qq(bar)→Z0, MSUB=1**
**qq(bar)→Z0+jet, MSUB=15**
**q(qbar)+g→Z0+jet, MSUB=30**
MSTP(43)=2 (only Z0 , no $\gamma^*$)

# Simulation Results of $Z^0$: Single muon



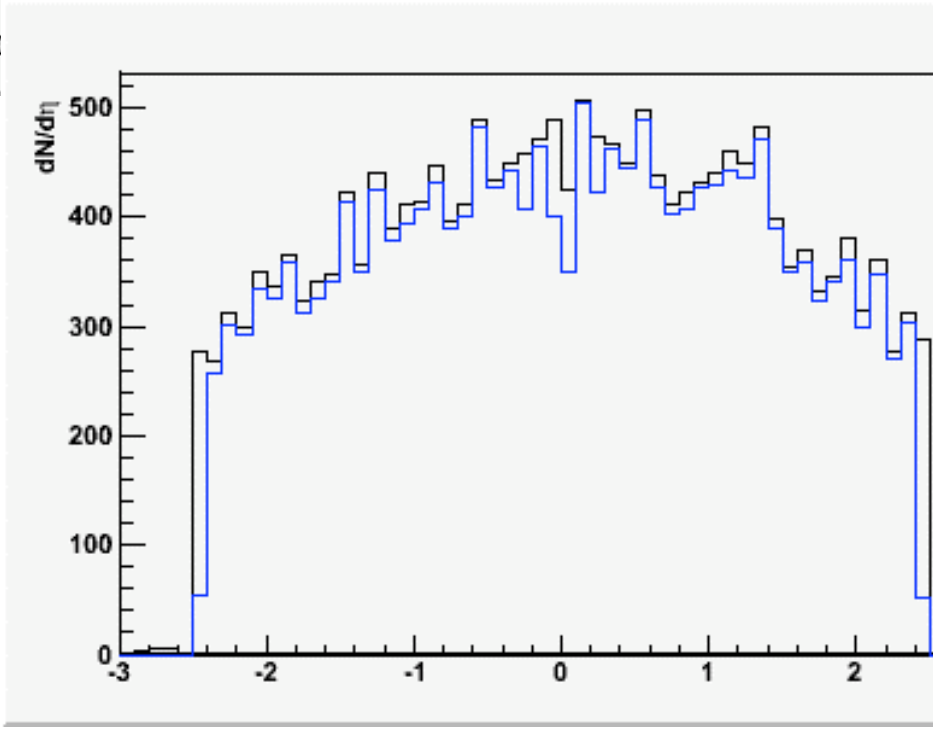

CMSSW_1_8_0_pre7

$dN_\mu/dp_T$ and $dN_\mu/d\eta$

for Integrated Luminosity

$L_{int}$= 0.5 $nb^{-1}$

( 1 month PbPb run at LHC)




No. of events gen.: 20,000

Pre selection: $p_T$ ($\mu$) >3.5 GeV

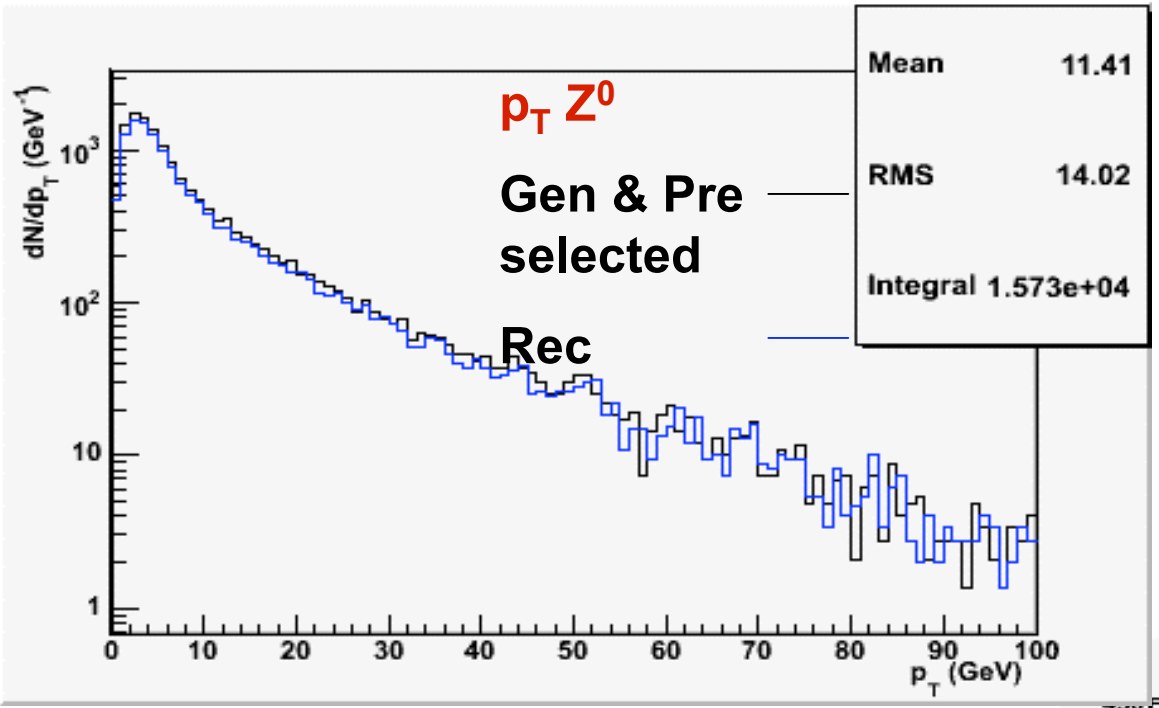
$|\eta\ (\mu)| < 2.5$

Pre selection Eff. : $\varepsilon_{pre}$=0.58

Reco. Eff. of single muon: $\varepsilon_{rec}$=0.94

Pre Sel Eff *Rec. Eff =0.58*0.94=0.54

# Simulation of $Z^0$: $p_T$ ($\mu$) >20 GeV




$dN_Z^0/dp_T$ and $dN_Z^0/d\eta$

for Integrated Luminosity

$L_{int}$= 0.5 nb$^{-1}$

( 1 month PbPb run at LHC)

Dimuons in the inv. mass windc

$M_z$-10GeV <$M_{\mu\mu}$ <$M_z$+10GeV

No. of $Z^0$ gen.: 50,000

**Pre selection: $p_T$ ($\mu$) >20 GeV**

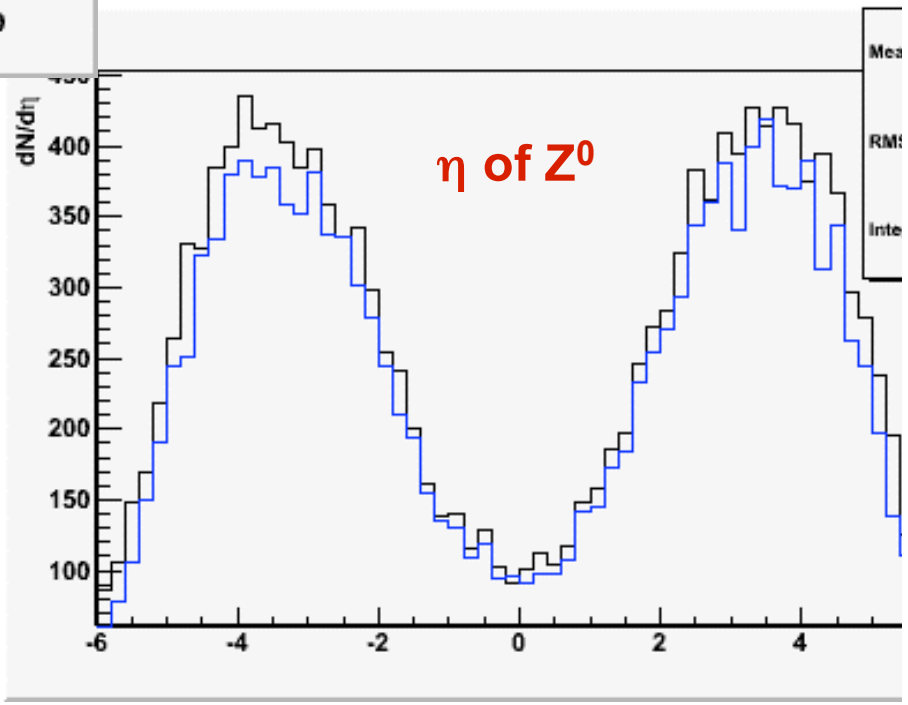
$|\eta\ (\mu)| < 2.5$

atleast two opp. sign muon

Pre selection Eff. : $\varepsilon_{pre}$=0.46

Reco. Eff. of single muon: $\varepsilon_{rec}$=0.91

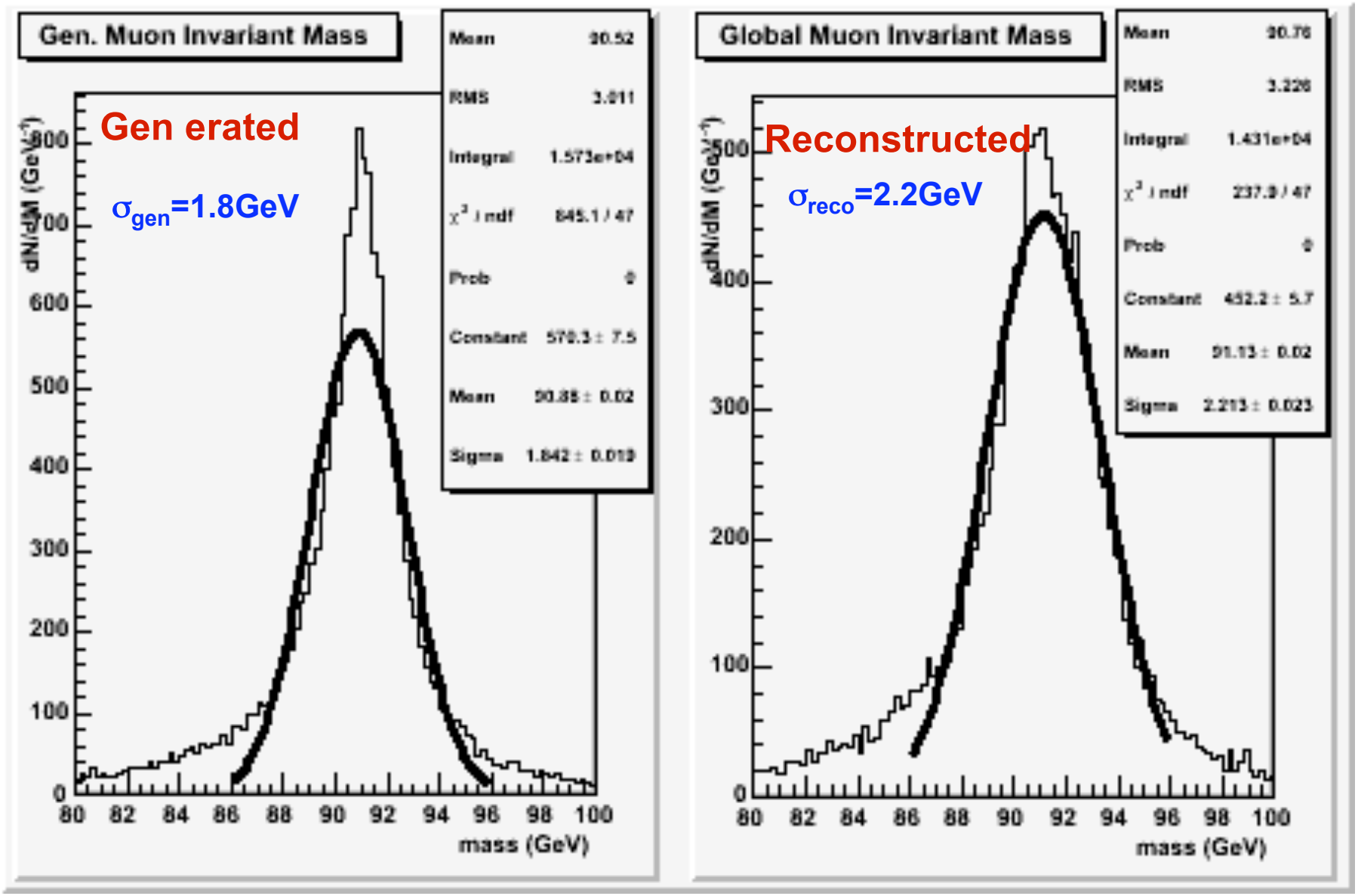
Pre Sel Eff *Rec. Eff =0.46*0.91=0.41



# Simulation Results of $Z^0$ : Inv Mass ($P_T(\mu)$>20GeV)

**No. of Reco. $Z^0$: $1.4\times10^4$ for one month LHC run $L_{int}=0.5\ nb^{-1}$**

**Reco. Eff×Acc.=0.41**



# Background for $Z^0$

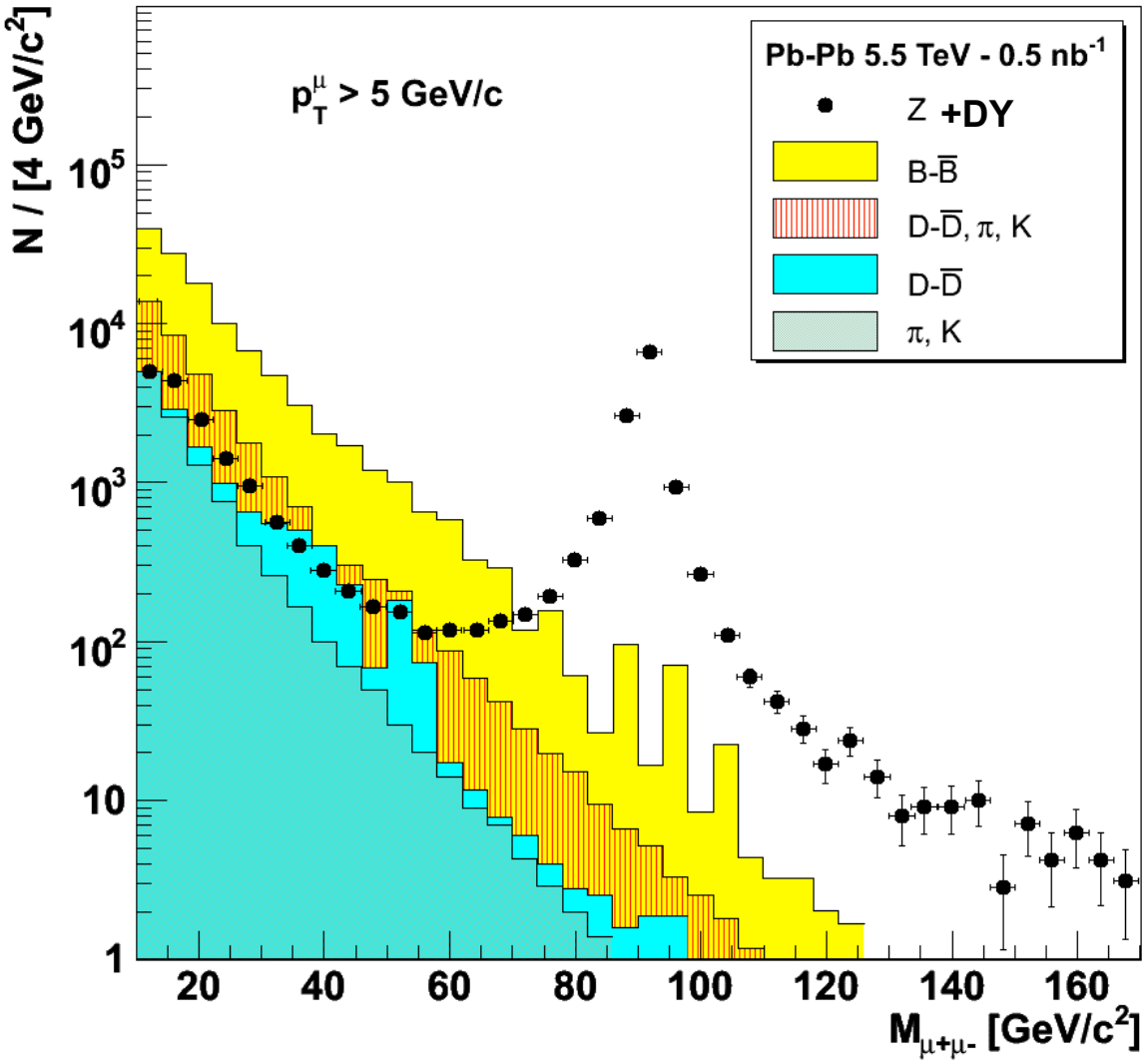
**Background Dimuons:**

- Decays from open c and b
- Decays from W

} PYTHIA-HARD, HYDJET

- Decays from $\pi$, K
  - Heavy Ion Background--HYDJET
- Mixed muon pairs

# Background of $Z^0 \rightarrow \mu^+\mu^-$: Gen. Level Study




CMS Physics TDR: Addendum to High Density QCD with Heavy Ions, J. Phys. G, Nucl. Part. Phys. 34 (2007) 2304

**Dimuons:**

- **bb(bar) fragmentation ~ dominant contribution**
- **Combinatorial backgrou b and π,K ~16%**
- **π,K and charm decay: 5**
- **Signal from $Z^0$: Clear pe ~11,000 events in $M_Z \pm 10$ GeV/c$^2$, Less than 5% background**

# Plan: Background Study for $Z^0$

- **Signal + High $p_T$ background generated with HYDJET**
  - with changing $p_T$ min (CKIN(3)) in HYDJET
  - HYDRO off
- **Soft + minijet background with normal HYDJET**
  - Important for reconstruction
- **Tracking code to be used for Reconstruction (signal+backgrd)**
  - Modified version of pp algorithm suitable for high $p_T$ muons + suitable vertex fit

# Results: Background Study with HYDJET

**Case I:** bool allowEmptyEvents =false

**Case II:** bool allowEmptyEvents =true

10000 event (10 min)

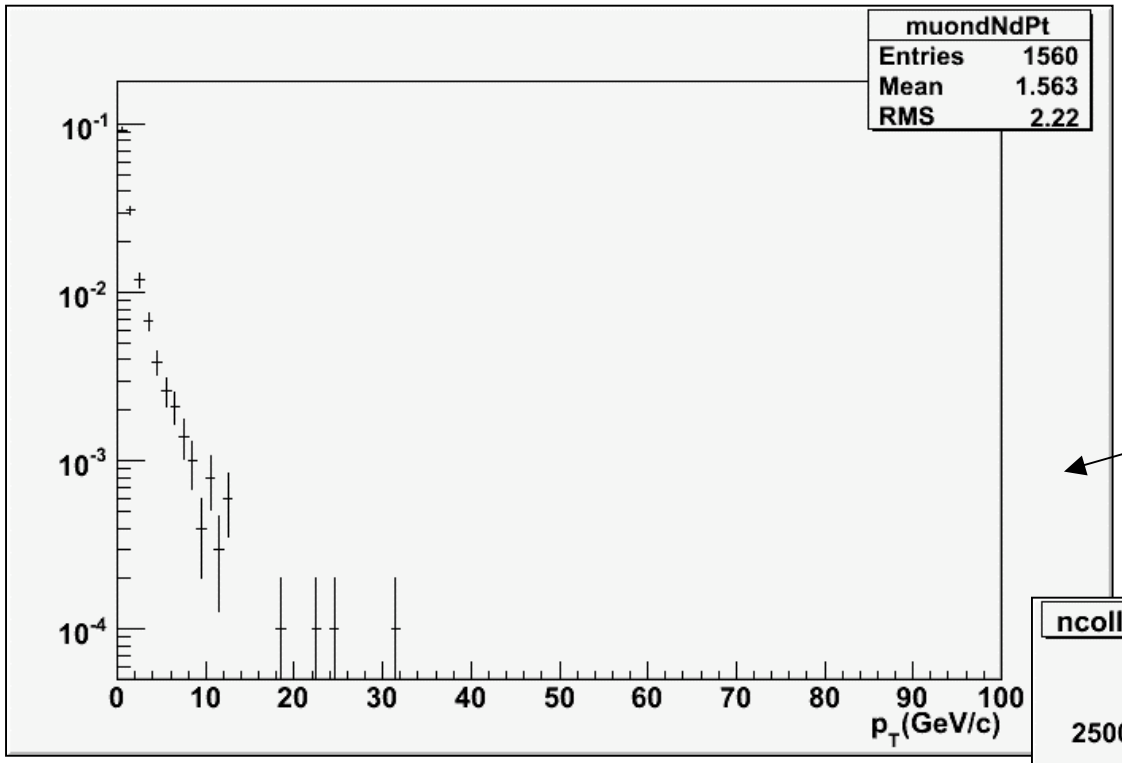
Study for 10.000 HYDJET events ,

(10% cent, MSEL=1)

CMSSW_2_1_0_pre

| CKIN(3) $p_T$ min. GeV | Av. No. of hard coll Ncoll_hard | Total No. of muons | No. of muons ($p_T$>20 GeV , $\|\eta\|$ <2.4) |
|---|---|---|---|
| 20 | 3.37 (3.26) | 1560 (1470) | 3 (1) |
| 30 | 1.83 (1.01) | 826 (363) | 3 (1) |
| 35 | 1.67 (0.8) | 760 (186) | 3 (0) |
| 40 | 1.58 (0.7) | 737 (116) | 8 (1) |
| 45 | 1.56 | 703 | 5 |

# Results: Background Study with HYDJET



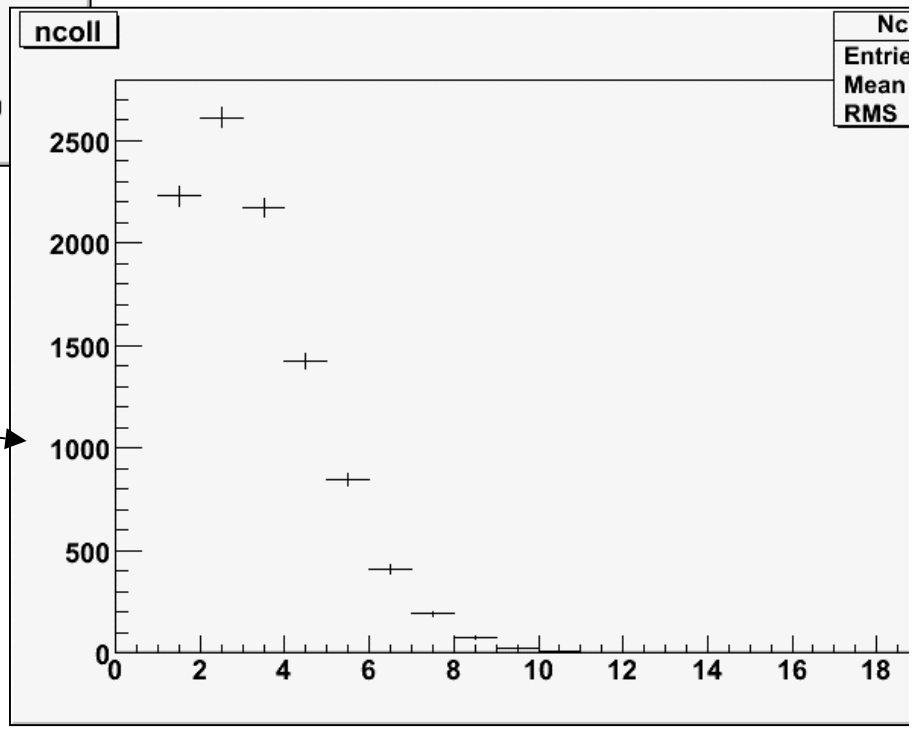

**CKIN(3)=20 GeV**

**$p_T$ distribution of generated muons**

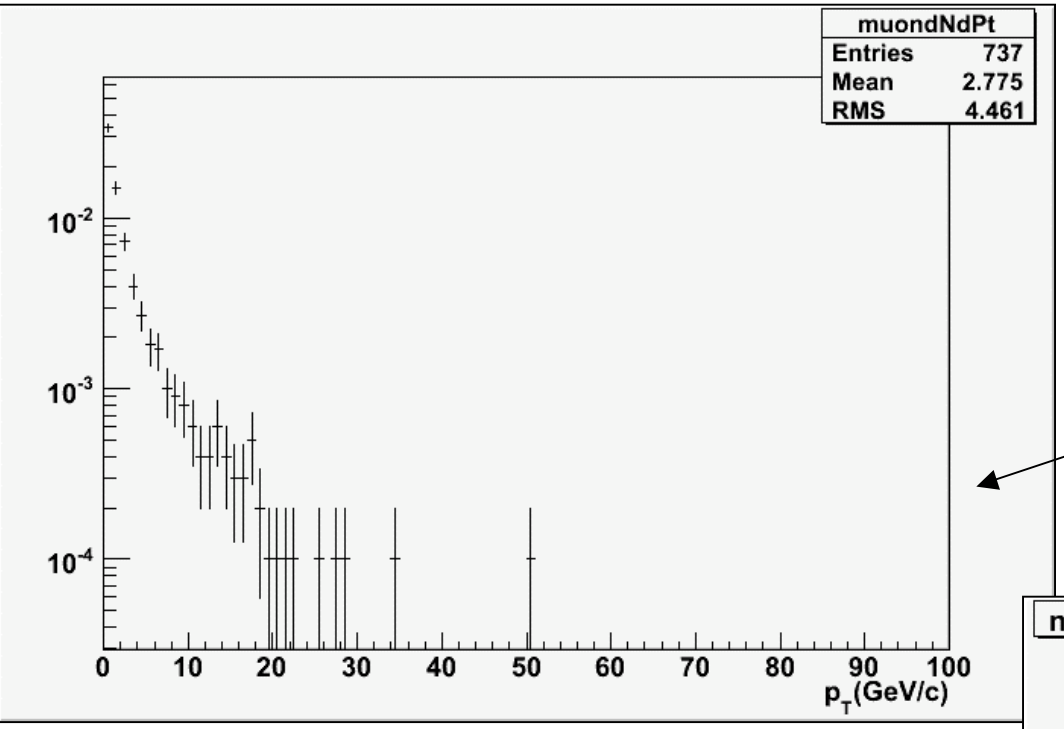
**CMSSW_2_1_0_pre4**

**Distribution for Ncoll_hard**

**Mean Ncoll_hard=3.35**



# Results: Background Study with HYDJET



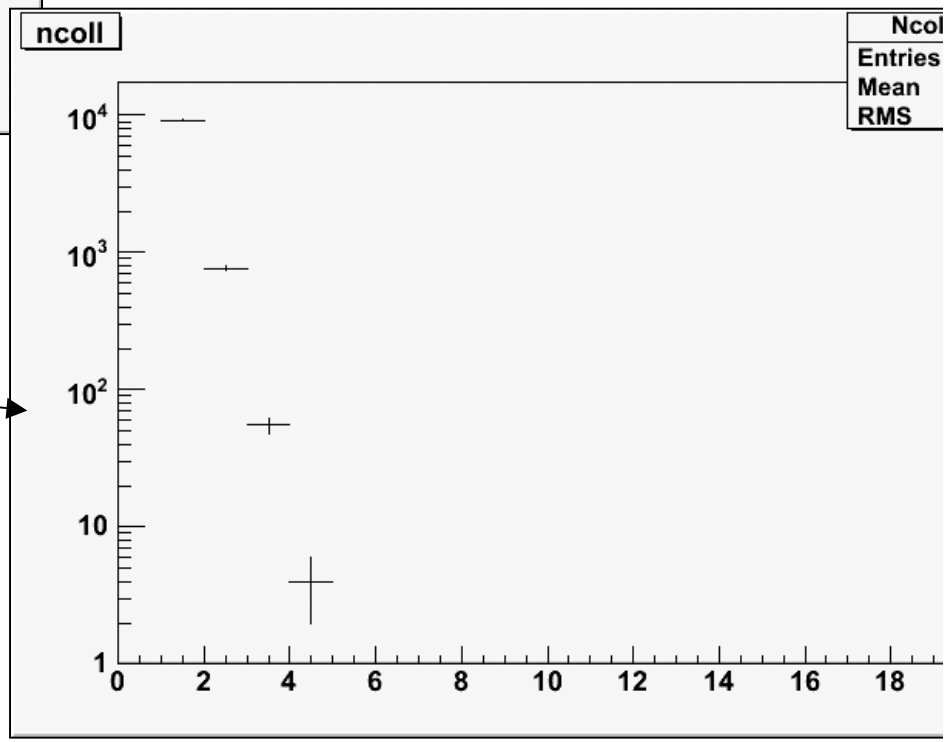

**CKIN(3)=40 GeV**

**$p_T$ distribution of generated muons**

**CMSSW_2_1_0_pre4**

**Distribution for Ncoll_hard**

**Mean Ncoll_hard=1.5**



# Study with PYTHIA

**PYTHIA (ccbar, bbbar, $Z^0$ and W) with CKIN(3)=20**

- **Cross-section for hard proc. = $1.93\times10^{-1}$ mb**
- **$N_{PbPb}$(hard-coll.)/per PbPb event = 4.4 (10% cent.)**
- **Study of $10^6$ PYHTIA events**

| | |
|---|---|
| Total No. of muons: | 107,046 |
| No. of muons from ccbar : | 36,650 |
| No. of muons from bbbar | 10,300 |
| No. of $Z^0$ generated: | 79 |
| No. of muons from $Z^0$ | 4 (79×0.03=2.3) |
| No. of muons from W | 31 |
| No of Muons ($p_T$>20 GeV, $\|\eta\|$ <2.4) | 95 |
| No. of dimuon in (80 Gev<Mμμ<90GeV) | 3 |

# Study with PYTHIA

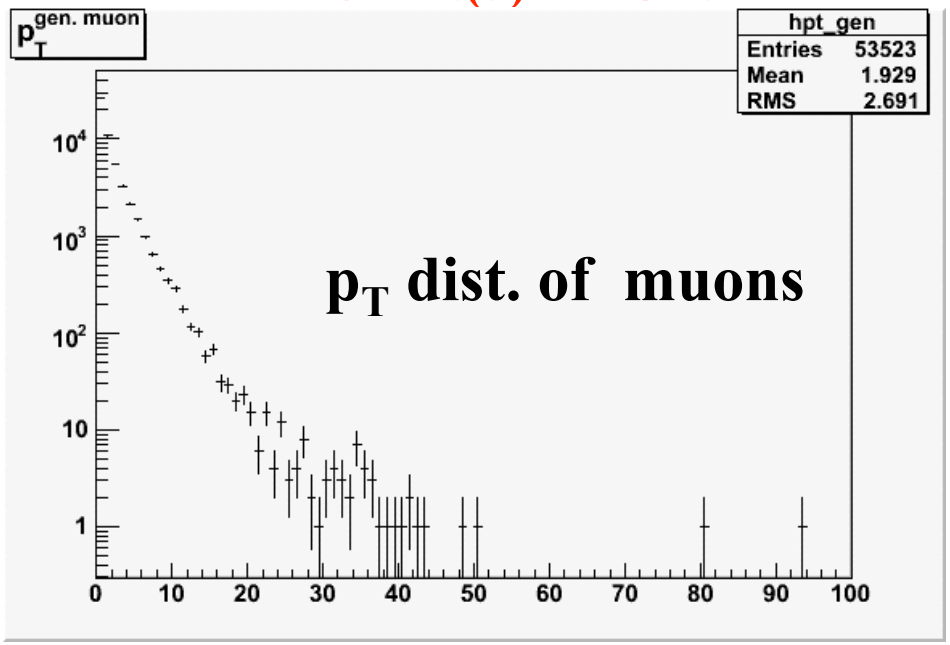
| N:o | Type | Generated | Tried | |
|---|---|---|---|---|
| 0 | All included subprocesses | 1000000 | 7018657 | 1.951E-01 |
| 1 | f + fbar -> gamma*/Z0 | 64 | 159 | 1.260E-05 |
| 2 | f + fbar' -> W+/- | 191 | 567 | 4.082E-05 |
| 11 | f + f' -> f + f' (QCD) | 48098 | 339912 | 9.378E-03 |
| 12 | f + fbar -> f' + fbar' | 692 | 1924 | 1.358E-04 |
| 13 | f + fbar -> g + g | 650 | 2508 | 1.232E-04 |
| 15 | f + fbar -> g + gamma*/Z0 | 7 | 58 | 1.132E-06 |
| 16 | f + fbar' -> g + W+/- | 12 | 62 | 2.936E-06 |
| 28 | f + g -> f + g | 395038 | 2983664 | 7.686E-02 |
| 30 | f + g -> f + gamma*/Z0 | 7 | 98 | 2.199E-06 |
| 31 | f + g -> f' + W+/- | 39 | 164 | 7.500E-06 |
| 53 | g + g -> f + fbar | 19091 | 68193 | 3.678E-03 |
| 68 | g + g -> g + g | 536111 | 3621348 | 1.048E-01 |

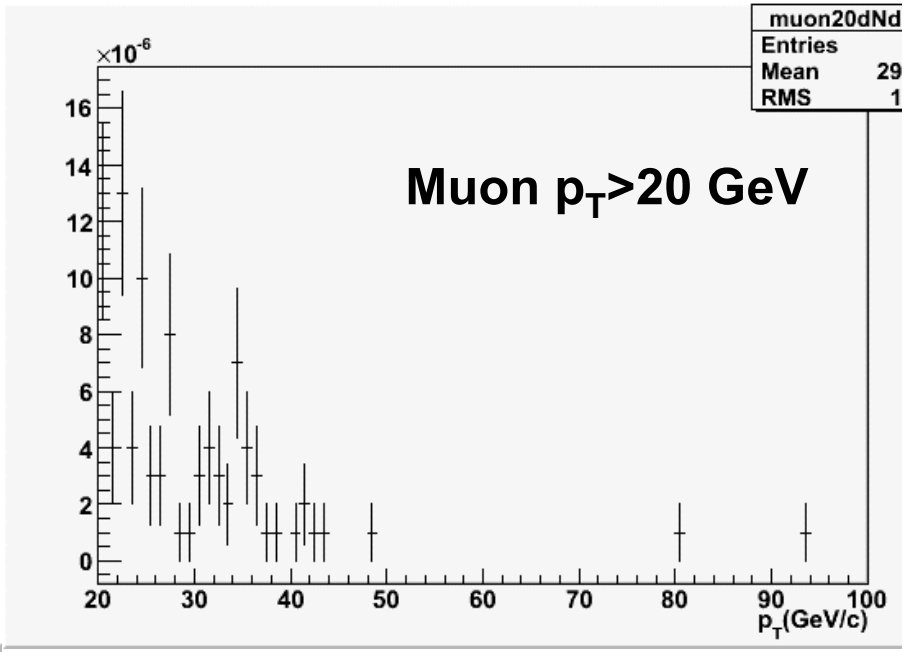
**Cross- section of Inclusive $Z^0$ ~ 16 nb (??)**

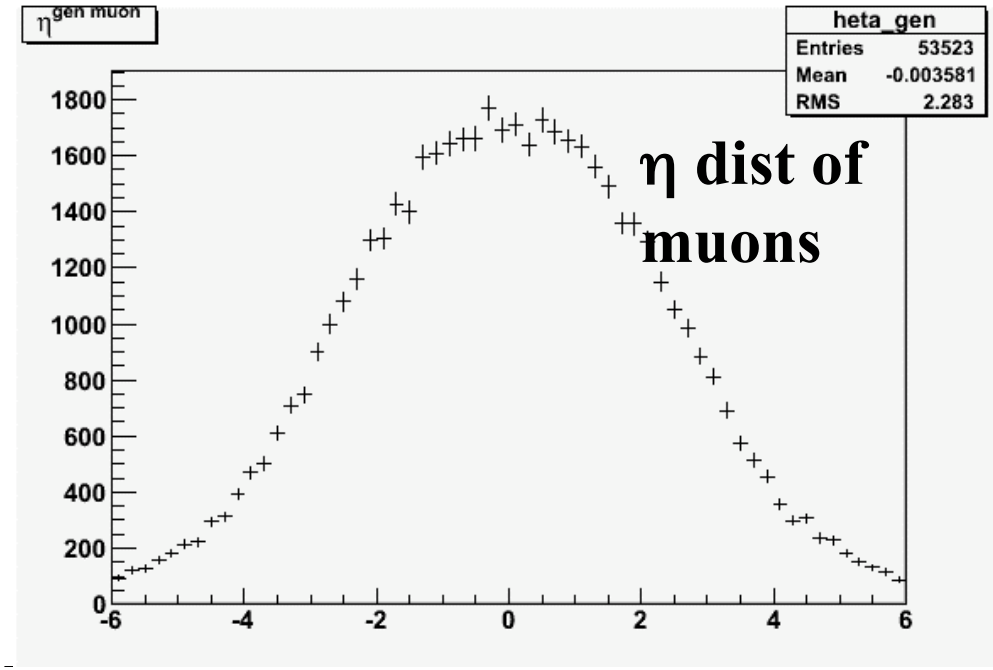
# Results: Background Study with PYTHIA

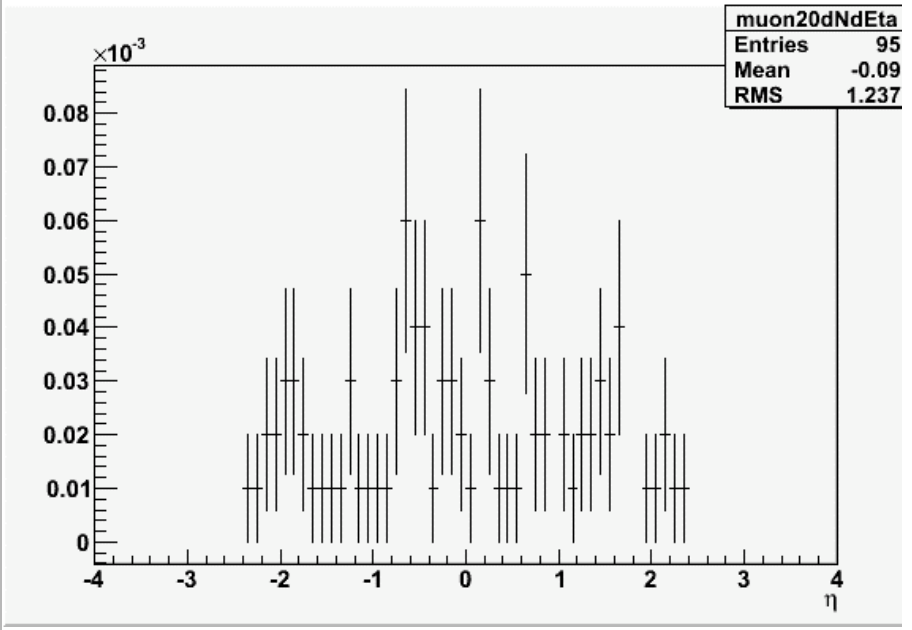
CKIN(3)=20 GeV

CMSSW_2_1_0_pre4



# Summary: PYTHIA

- 2 $Z^0 \rightarrow \mu^+\mu^-$ in $10^6$ events from PYTHIA study
- $10^3(10^4)$ $Z^0$ expected for 0-10% (MB) for $L_{int}$=0.5 $nb^{-1}$
- No. of HYDJET events required ~$10^9(10^{10})$
- No. of muon **($p_T$>20 GeV, $|\eta|$ <2.4)** ~$10^5$
- No. of Triggered HYDJET event : $10^5$

(at least one muon **pT>20 GeV, $|\eta|$ <2.4**)

- $10^5$ Triggered HYDJET events should have $10^3$ $Z^0$ +background muons
- To be confirmed using HYDJET

# Reconstruction of High $p_T$ muons

- **Started with**

RecoPixelVertexing/PixelLowPtUtilities/test/reconstruct_PbPb.cfg

- **Put the Muon reco modules and changed the generalTracks to globalPrimTracks**

  (Thanks to Camelia for providing all the codes)

- **High $p_T$ muon reco working with signal events**

  (study with more statistics has to be done)

- **Mixing of two signal events and GlobalMuon rec tested with small sample**

- **Signal+Background (HYDJET) +muon reco–**

- **to be done at MIT Cluster**

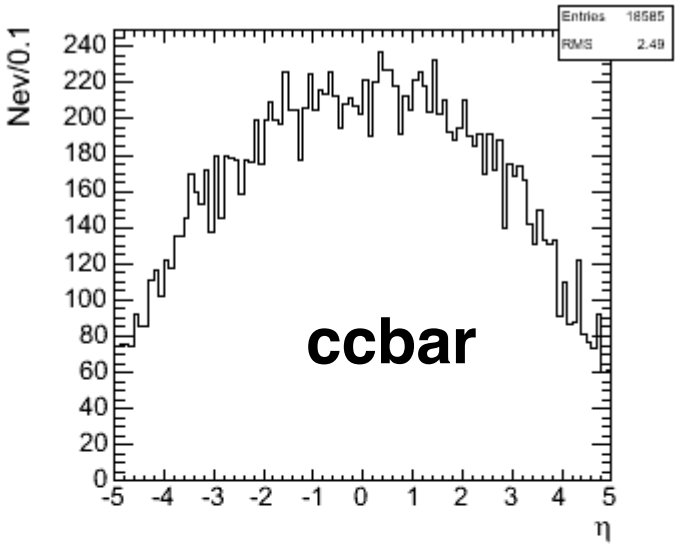
# Future Plan

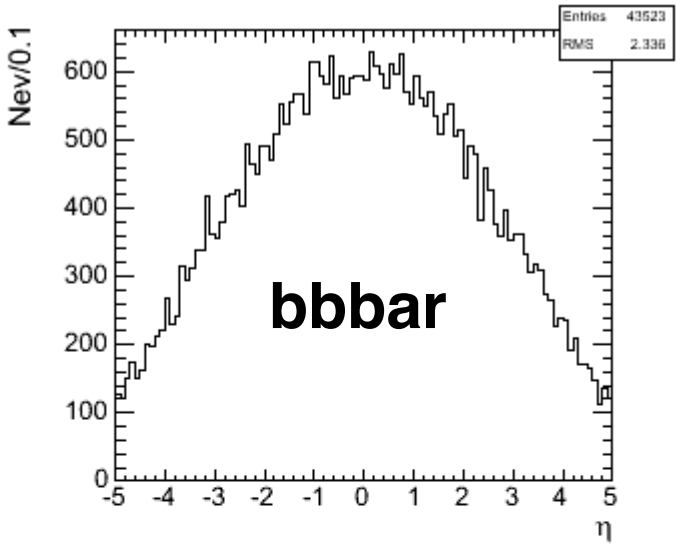
- Feasibility study HYDJET with the high pt muon paramters used in PYTHIA
- Generate background sample for $Z^0$ with HYDJET
- Consideration of Proper Impact parameter in HYDJE
- Generator level mixing with HYDJET soft backgrou
- L1, L2, L3 Trigger level study
- Reconstruction with background : Efficiency, Purity

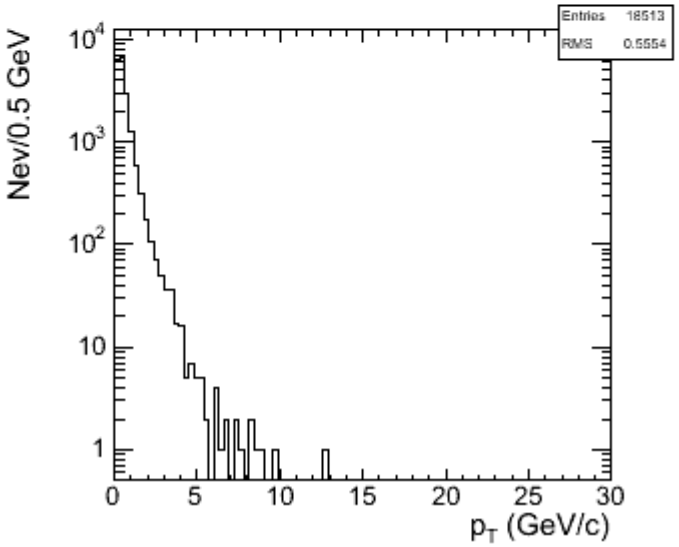
# Back Up Slides

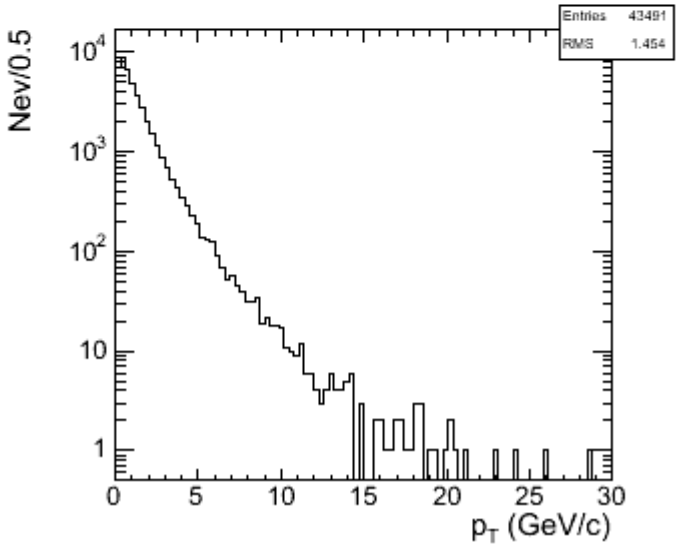
# Heavy quark pairs production: kinematical spectra

## $p_T$ and $\eta$ according to Yellow Report, CERN-2004-009, hep-ph/03110



# J/ψ and Υ trigger strategy

**L1 Trigger: single muon trigger with no momentum cuts optimized for HI run conditions**

**L2 and L3: run on online farm**

**L2 trigger condition:**

**either opposite(like) sign dimuon candidate at L1 trigger c opposite(like) sign dimuon candidate at L2 trigger**

**L3 includes regional track finder starting from the muon statio primary vertex finder with pixel detectors and dimuon verte constraints**

# Dimuon Sources at LHC : Signal and Backgrou

- Light mesons decays: $\pi, K, \ldots$
  - $\pi^+ \xrightarrow{99.9\%} \mu^+ \nu_\mu$ ; ...
  - $K^+ \xrightarrow{63.4\%} \mu^+ \nu_\mu$ ; ...
- Charm decays: $D$ , $c\bar{c}$ mesons
  - $D^0 \xrightarrow{6.5\%} \mu^+$ anything ; $D^\pm \xrightarrow{17\%} l^\pm$ anything ; $D_s^\pm \xrightarrow{8\%} l^\pm$ anything ;
  - $J/\psi \xrightarrow{5.9\%} \mu^+\mu^-$; ... Eur.Phys.J.C8, 573('99) : c $\xrightarrow{9.0\%}$ $\mu$ anything
- Beauty decays: $B$, $b\bar{b}$ mesons
  - $B^{0\pm} \xrightarrow{10.7\%} l\,\nu_l$ anything ; $B^{0\pm} \xrightarrow{24\%} D^\pm$ anything ;
    $B^{0\pm} \xrightarrow{64\%} D^0/\bar{D}^0$ anything ; $B^{0\pm} \xrightarrow{1.1\%} J/\psi$ anything ; ...
  - $\Upsilon \xrightarrow{2.5\%} \mu^+\mu^-$ ; ... PDG : b $\xrightarrow{10.7\%}$ l anything
- W / Z decays
  - $W^+ \xrightarrow{10.6\%} \mu^+ \nu_\mu$ ; $W^- \xrightarrow{10.6\%} \mu^- \bar{\nu}_\mu$;
  - $Z^0 \xrightarrow{3.4\%} \mu^+\mu^-$ ; ...

**Signal Dimuon Resonances**:

- **Quarkonia: J/Ψ (BR: 5.9%), Υ (BR 2.5%)**
- **$Z^0$: (BR: 3.4%)**

**Background Dimuons**:

- **Decays from open c and b**
- **Decays from π, K**
- **Decays from W**
- **Mixed muon pairs**