Cross section of $pp \to Zb\bar{b}$, $Z \to \mu^+\mu^-$ at LHC with CMS detector

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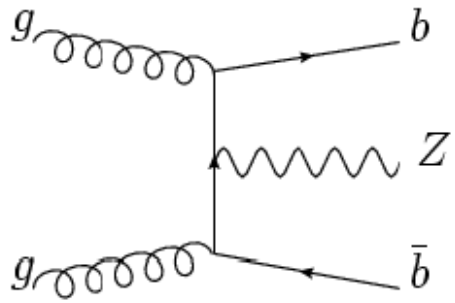
- Motivation
- Events selection
- Efficiencies of different cuts
- Cross section
- Conclusions and Outlook

Motivation

Standard Model process:

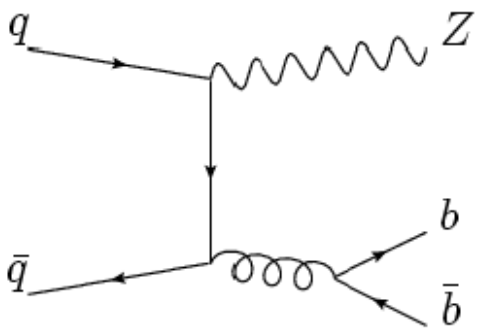
- $Z + 1$ bjet first observed and measured at CDF and D0 $(hep - ex/0605099)$
- $Z + 2$-bjet may be observed for the 1st time
- Potential help to new physics



Dominant at LHC

Background process to:

- SUSY (MSSM) Higgs discovery channels $b\bar{b}\Phi$ where Φ is h^0, H^0, A^0
- Standard Model Higgs discovery channel $H \to ZZ \to 4\ell$



~ 15% of bbZ total

Background processes

Cross section measurement $\Longrightarrow$ Identification of signal events and background processes

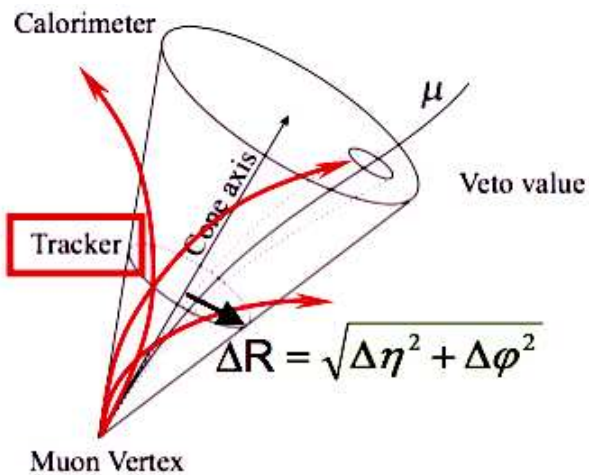
- **Signal:**
  - $Z^0 b\bar{b}$
- **Backgrounds:**
  - Drell-Yan $Z/\gamma^* \rightarrow \mu\mu$ in association with:
    - $Z^0 q\bar{q}$ $(q = u, d, s)$
    - $Z^0 c\bar{c}$
  - $t\bar{t}$
  - $b\bar{b}$, tW, WW, WZ and ZZ $\Rightarrow$ negligible contribution (CMS Note 2006/099)

Process	$\sigma(pb)$
$Z^0 q\bar{q}$	714
$Z^0 c\bar{c}$	13.3
$t\bar{t}$	840

Physics Objects

- **Muons:**
  - Reconstructed from Tracker and Muon Chamber information
  - Muon Isolation against jets and clean muon identification

- **Isolation in Tracker:**
  Σp_T of the tracks within a cone around muon
  (Veto value: Muon deposit is extracted)

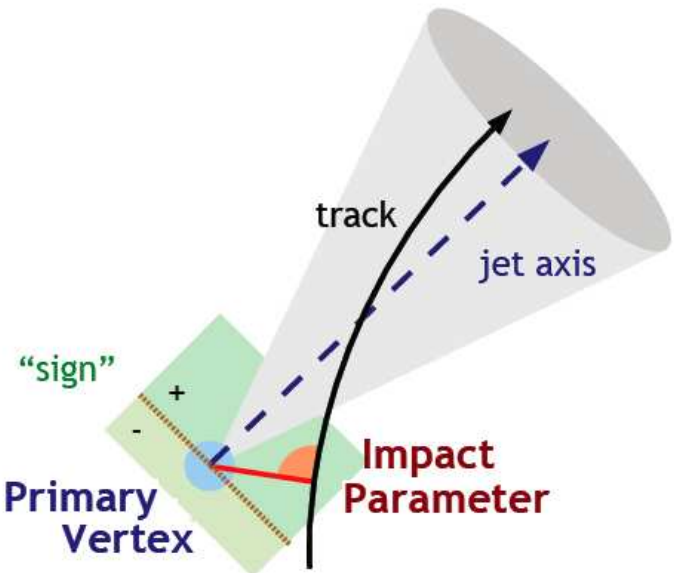


- **Jets:**
  Based on iterative cone jet algorithm with a cone size of $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.5$

b-jet Identification

b-jets:

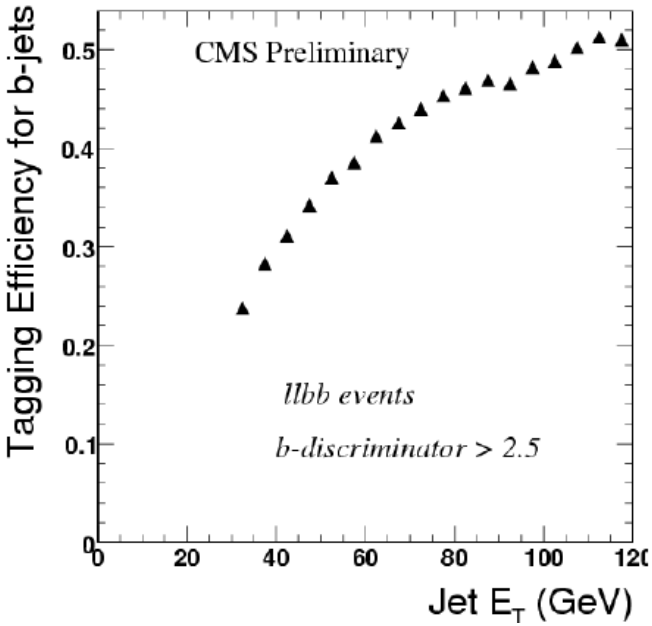
- part of many final states
- different properties from those of lighter flavour quarks (large lifetime & mass, high decay multiplicity etc)

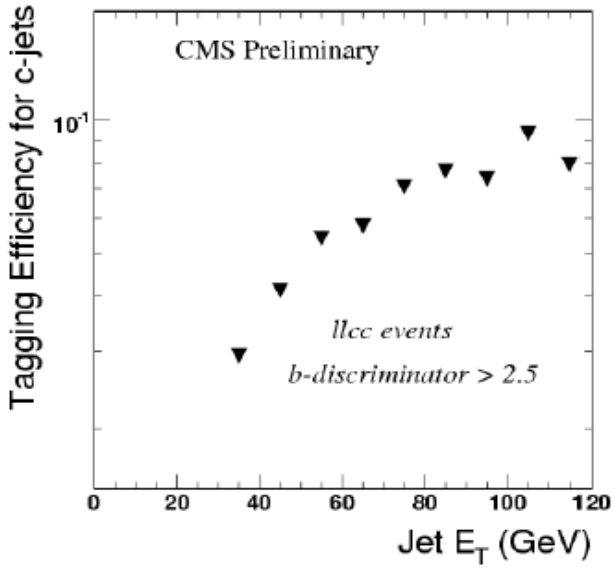


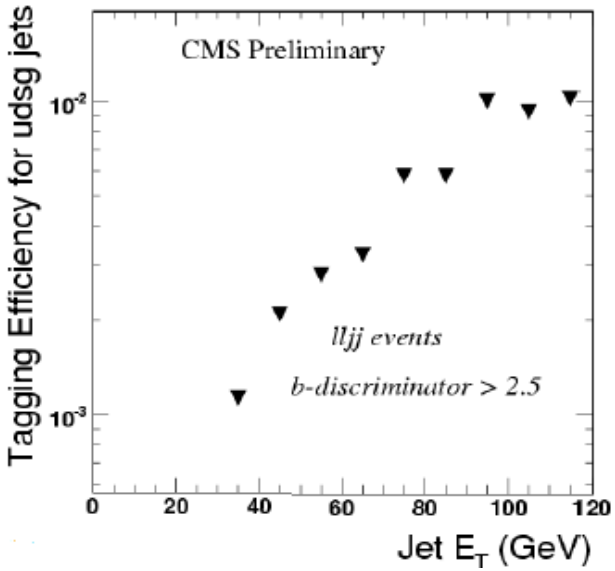
"TrackCounting" algorithm:

- Sort tracks in jet by descending Significance of the Signed Impact Parameter (SIP)
- Select n^{th} track:
  - 3^{rd} track $\rightarrow$ "high purity" tag
- Discriminator = SIP Significance of 3^{rd} track

b-tag Efficiency







- b, c and light jets after the dicriminator selection > 2.5 (CMS PAS EWK-08-001)

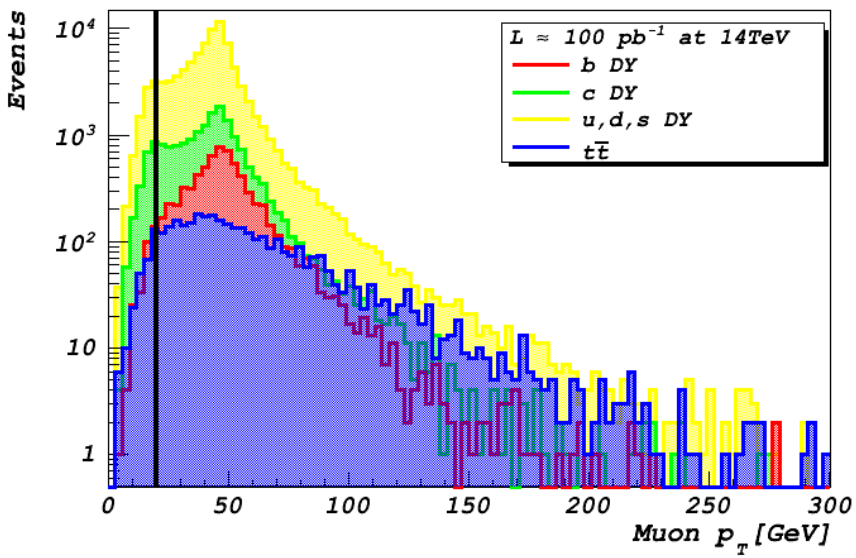
Event selection

- **Trigger Selection:**
  - at least one High-Level Trigger on
- **Muon Selection:**
  - two muons with highest p_T
  - $Q_{\mu_1}.Q_{\mu_2} < 0$
  - $p_{T\mu} > 20$ GeV
  - $|\eta_\mu| < 2.0$
  - muon Isolation
- **Jet Selection:**
  - at least two jets
  - $p_{T_{jet}} > 30 GeV$
  - $|\eta_{jet}| < 2.4$
- **b-jet Selection:**
  - Discriminator > 2.5
- **MET Selection:**
  - $E_T^{miss} < 50$ GeV

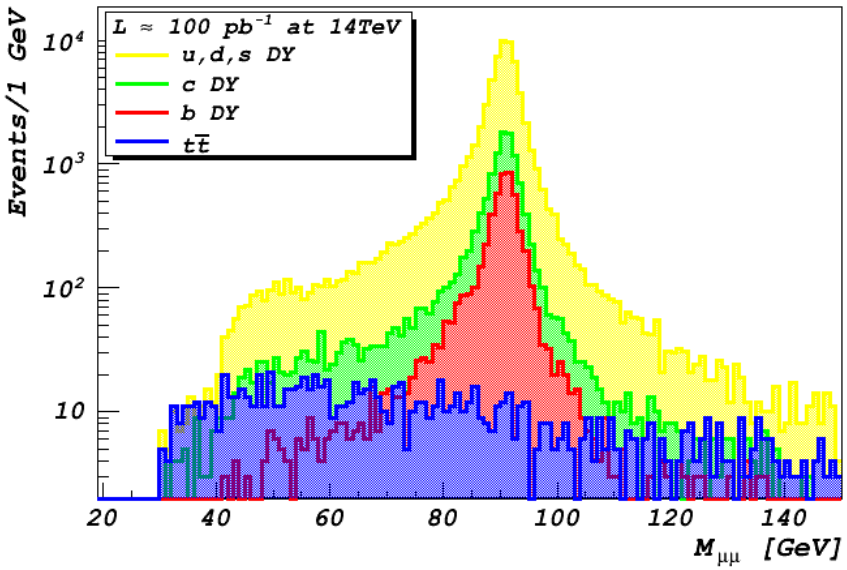
Muon Momentun p_T

- p_T **cut:** Reduce backgrounds with fake muon (e.g. QCD)

$p_{T\mu} > 20$ GeV



Invariant Mass



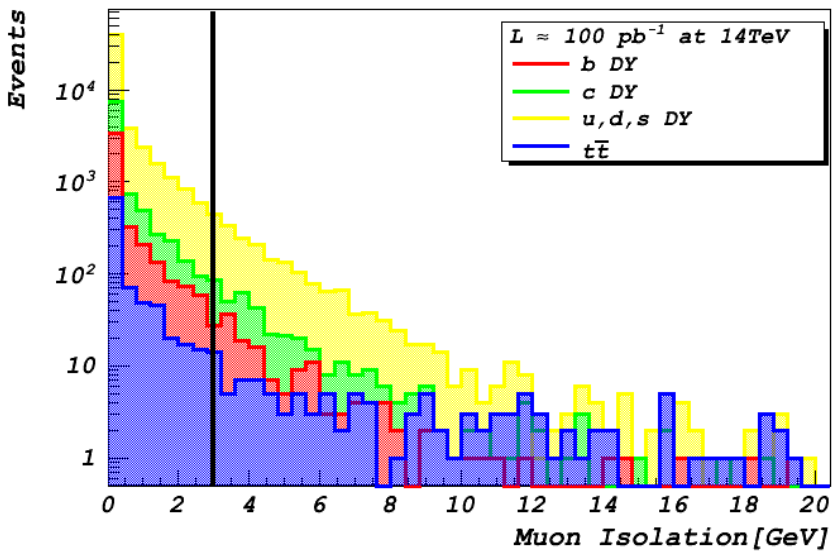
Efficiency ($Q_{\mu_1}.Q_{\mu_2} < 0$ and p_T):

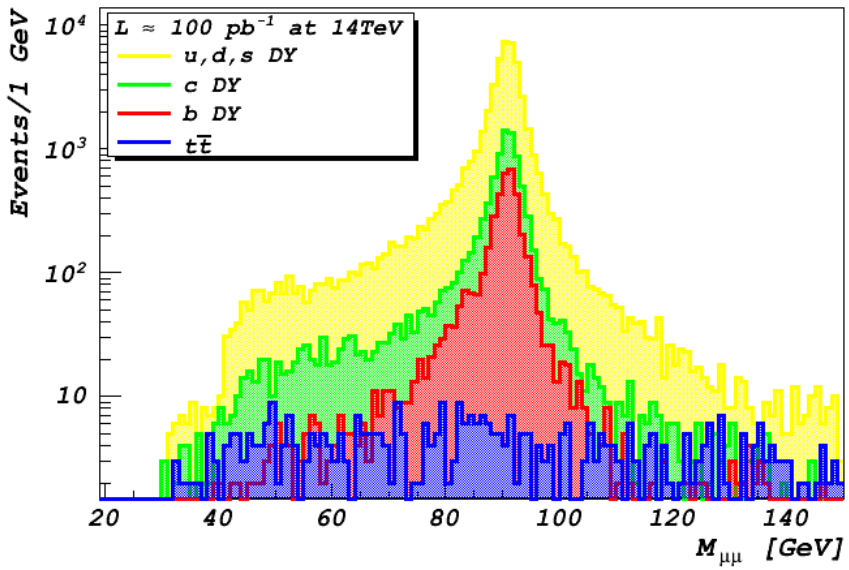
$b\bar{b}$DY: **75%**, $c\bar{c}$DY: **70%**, $q\bar{q}$DY: **78%**, $t\bar{t}$: **45%**

Muon Isolation

- $\Sigma p_{T_{tracks}} < 3$ GeV around μ within $\Delta R(\eta, \phi) = 0.3$

Invariant Mass





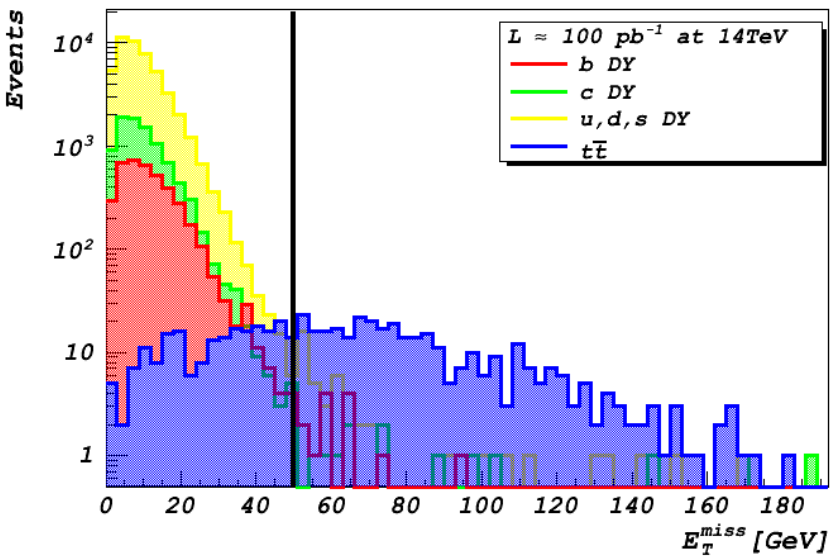
- Should look for better Isolation

Efficiency ($Q_{\mu_1}.Q_{\mu_2} < 0$, p_T, η and Isolation):

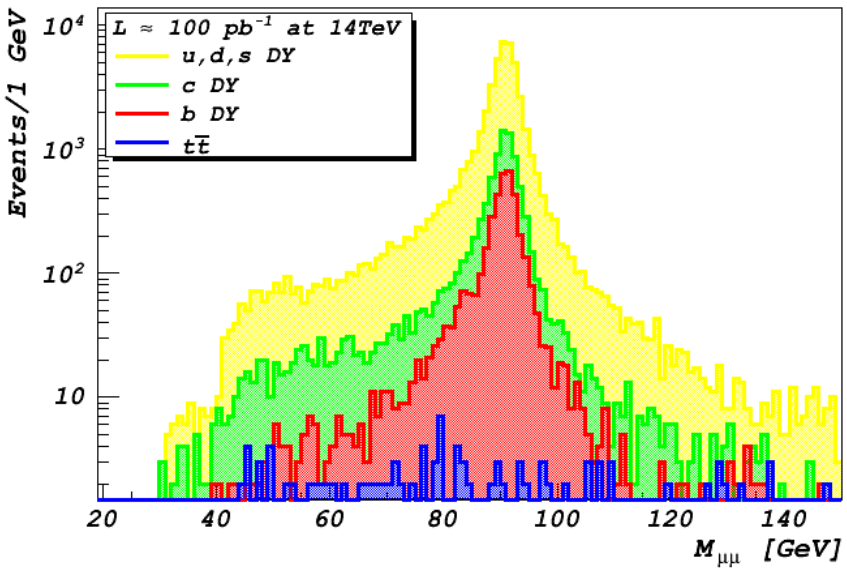
$b\bar{b}$DY: **56%**, $c\bar{c}$DY: **51%**, $q\bar{q}$DY: **56%**, $t\bar{t}$: **17%**

Missing E_T

- Reduce $t\bar{t}$ background



Invariant Mass

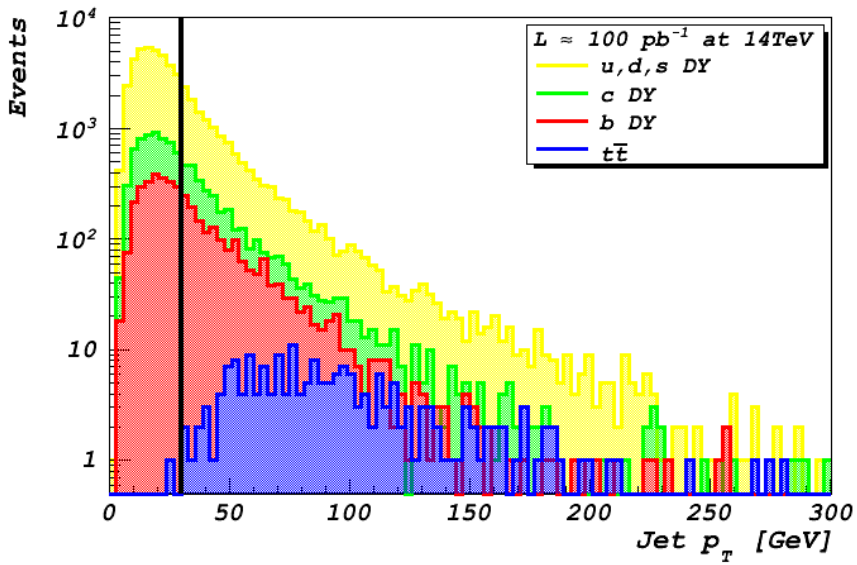


Efficiency (Muon Selection and MET):

$b\bar{b}$DY: **56%**, $c\bar{c}$DY: **51%**, $q\bar{q}$DY: **56%**, $t\bar{t}$: **5,9%**

Jet Selection

$p_{T_{jet}} > 30$ **GeV**

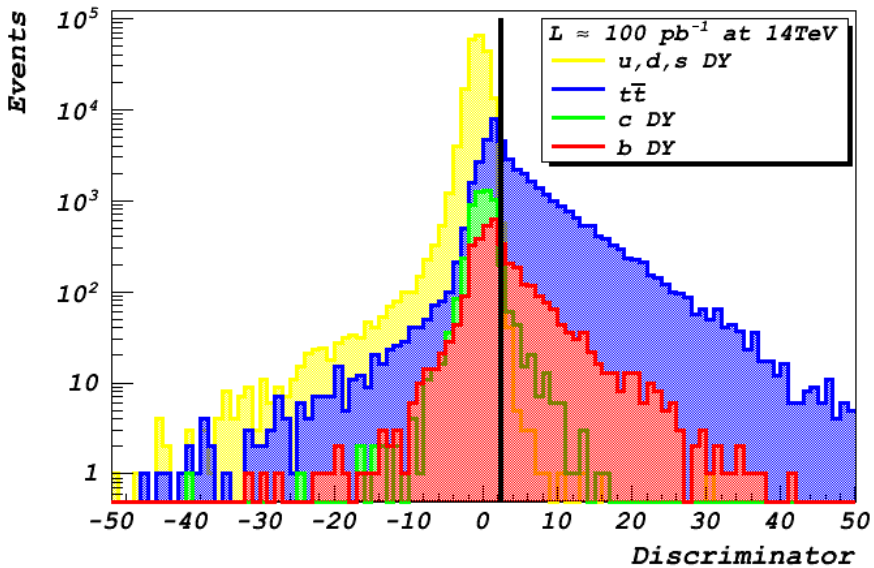


After:

- Muon Selection
- MET Selection

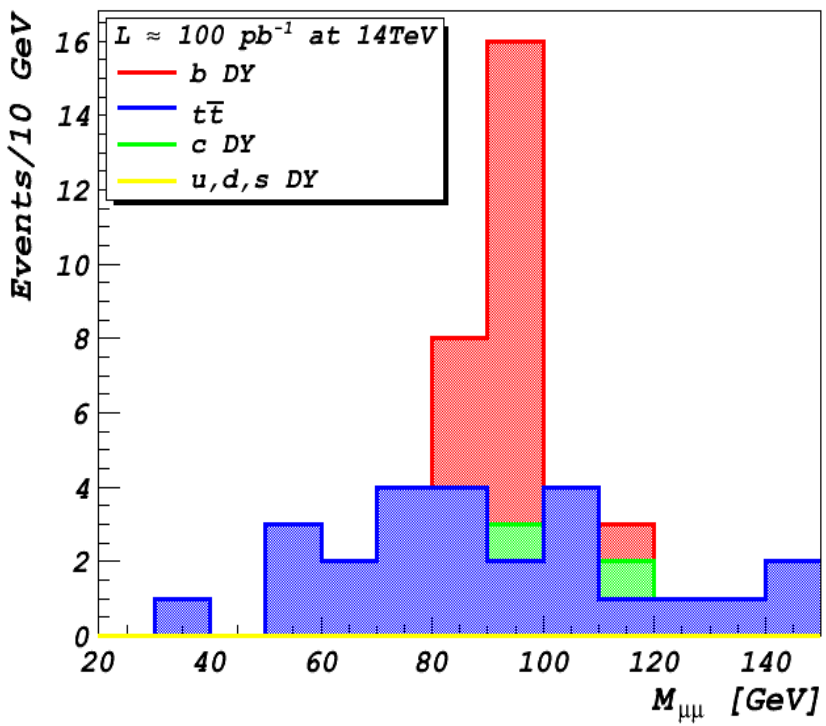
Discriminator before any cuts

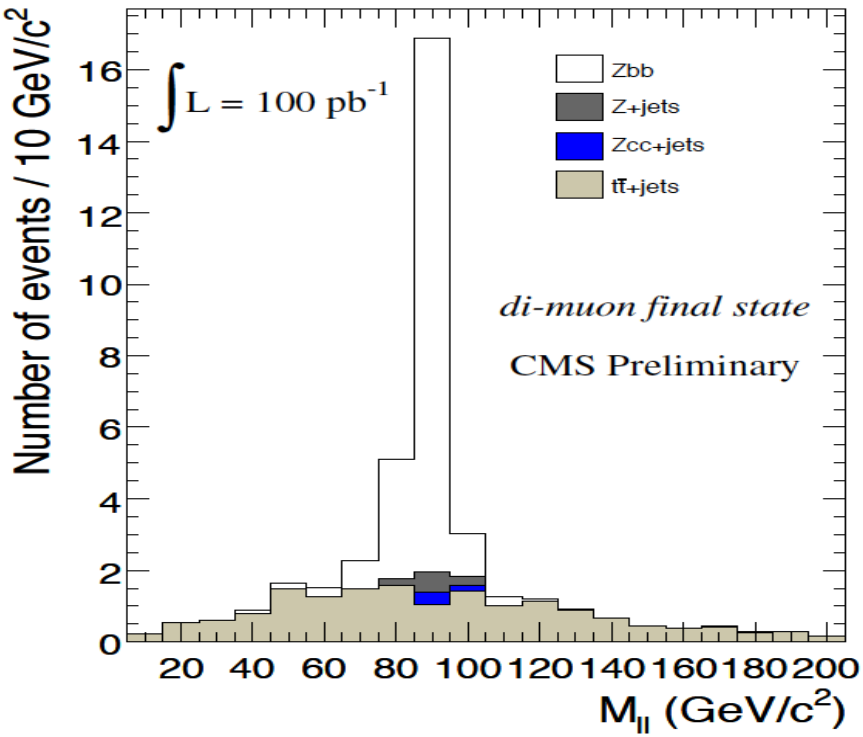
- b&t-jets have larger tail towards higher values
- Discriminator > 2.5 cuts off light quark background



Final Invariant Mass

- done with sample expected for 100 pb^{-1} [scale factor = 1]
- FastSim was used





- b-tagging reduces most of $\mathrm{u}, \mathrm{d}, \mathrm{s}, \mathrm{c}$ background

Conclusions and Outlook

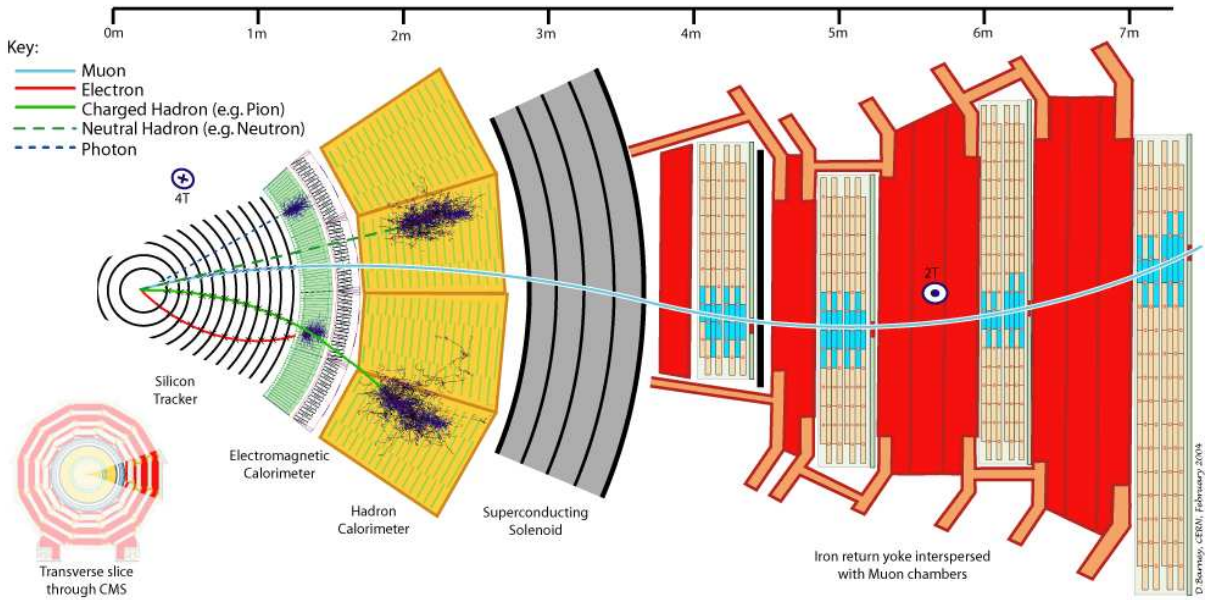
- A first attempt to reproduce the results published by CMS Collaboration (CMS PAS EWK-08-001) was made
- Cross section can be measured with first 100 pb^{-1} of data

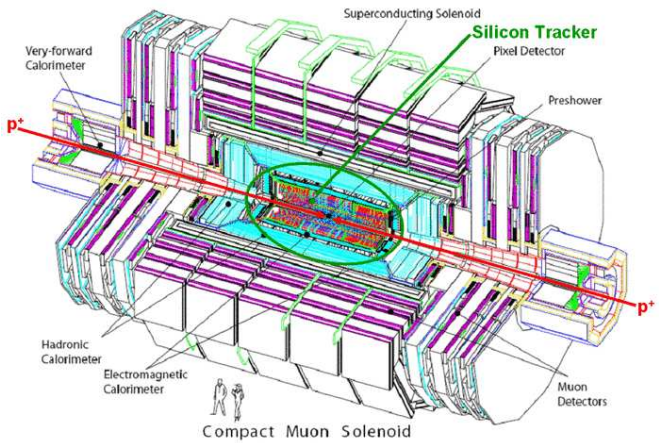
Process Name	σ NLO (pb)	Final σ (fb) (muon)
Zbb	46	212
$t\bar{t}$+jets	840	178
Z+jets	714	5.5
Zcc+jets	13.3	5.1

- Proceed with analysis
- Full scale simulation
- Estimation of systematic error for the cross section

Back-up

The CMS Detector



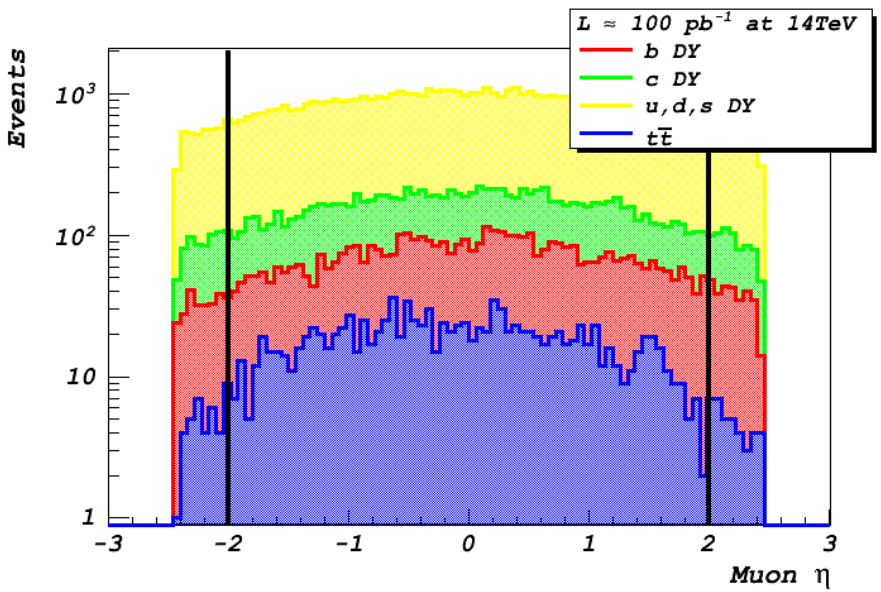


- Tracker:
  $\delta p_T/p_T \sim 4\%$ for p_T=100 GeV
- Muon Detection System
- Calorimeter: jets and missing transverse energy (MET)

Muon η

- **η cut:** Best Tracker acceptance

$|\eta_\mu| < 2.0$ GeV



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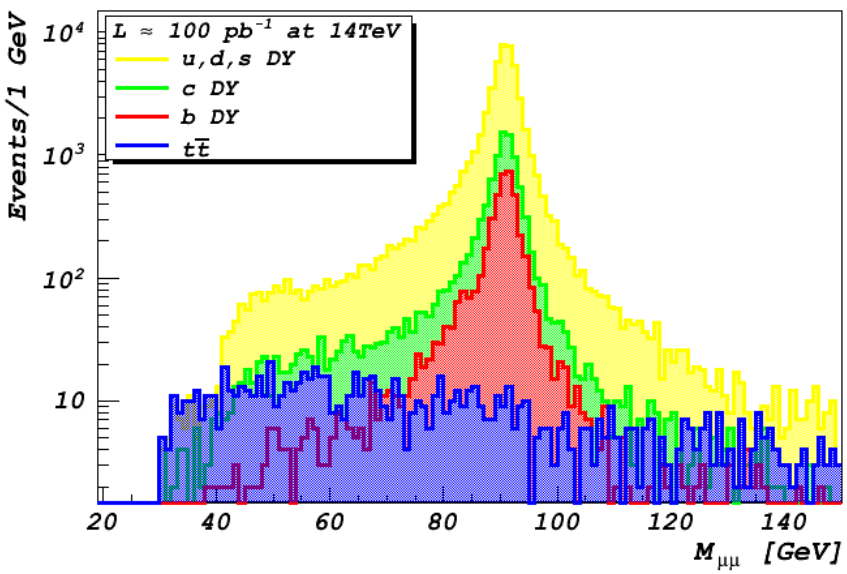


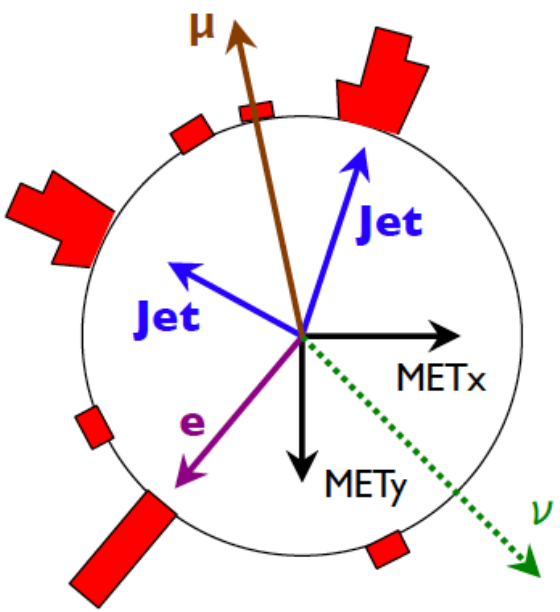
Efficiency ($Q_{\mu_1}.Q_{\mu_2} < 0$, p_T and η):

$b\bar{b}$DY: **62%**, $c\bar{c}$DY: **56%**, $q\bar{q}$DY: **61%**, $t\bar{t}$: **39%**

Missing Transverse Energy

Calculated from uncorrected energy deposits in Calorimeter Towers

$$\not\!\!E_T = \sqrt{\not\!\!E_{T\,x} + \not\!\!E_{T\,y}}, \quad \not\!\!E_{T\,x,y} = \sum_{i=1}^{tower} E_{T\,x,y}{}^{i}$$



- Unbalanced transverse energy in the event
- only non-interacting particles, e.g. neutrino

Corrections on MET:

- Jet Energy Scale Correction
- μ & τ Corrections

Cross section measurement

$$\sigma_{Z^0 b\bar{b}} = \frac{n_T - \sum_B n_B}{\mathcal{L}_{int} \epsilon_{Z^0 b\bar{b}}}$$

where,

- n_T is the total number of selected events
- $\sum_B n_B$ is the sum of the background events
- $\epsilon_{b\bar{b}Z^0}$ is the selection efficiency of the signal
- and $\mathcal{L}_{int}$ is the integrated luminosity

Jets

IterativeCone Jet Properties:

- Input: CaloTowers with $E_T > 1$ GeV
- Search for stable cones of radius ΔR
- Goal: Jet Energy and Direction

(CMS PAS JME-07-003)