Search for RS $G^* \rightarrow ZZ \rightarrow \mu^+\mu^- \mu^+\mu^-$ at sqrt(s) = 10 TeV

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26. Sep. 2009. CMS-KR Meeting

RS G signal sample

- **Winter09 Sample with CMSSW_2_2_6**
- **Fastsimulation with early 10 TeV condition**

- $G^* \rightarrow ZZ \rightarrow \mu^+\mu^- \mu^+\mu^-$
  16 mass: 500 -2000 GeV/c^2
  (100 GeV/c^2 difference)
  5 c constant: 0.01, 0.02, 0.05, 0.07, 0.1

- Total 16 x 5 = 80 “analysis point”
- 10000 events / analysis point

B.G.: ZZ and tt

- Both ZZ and tt samples were produced with Pythia6.416 embedded in CMSSW_2_2_3
- $p+p \rightarrow ZZ \rightarrow \mu^+\mu^- \mu^+\mu^-$
- $p+p \rightarrow t\bar{t} \rightarrow \mu^+\mu^- \mu^+\mu^-$

  ($t \rightarrow Wb \rightarrow \mu\nu b$, $b \rightarrow$ natural decays)

B.G. Channel	C.S. x B.R. (fb)	No. of Produced Event
ZZ	11.75	30000
$t\bar{t}$	2799	30000

B.G.: Zbb

- Zbb was produced with Comphep-4.5.1 + Pythia6 hardronization (CMSSW_2_2_9)
- There were many complex issues including Comphep cut, kinematics, regularization, output pev file format, LHEinterface+CRABbing for process.
- $p+p \rightarrow Zbb \rightarrow \mu^+\mu^- bb$ (b, b→ natural decays)

B.G. Channel	C.S. x B.R. (pb)	No. of Produced Event
Zbb	86.99	200000

B.G.: QCD and W_jet (Summer08)

- QCD sample is produced with Pythia 6.416 (CMSSW_2_2_7)
  W_jet sample is produced by Madgraph
- Skimmed with condition:
  N_{lepton}>2, 1st, 2nd highest lepton Pt > 10 GeV,
  3rd highest lepton Pt > 5 GeV
- QCD: CKIN(3) = 80 (minimum pt hat)

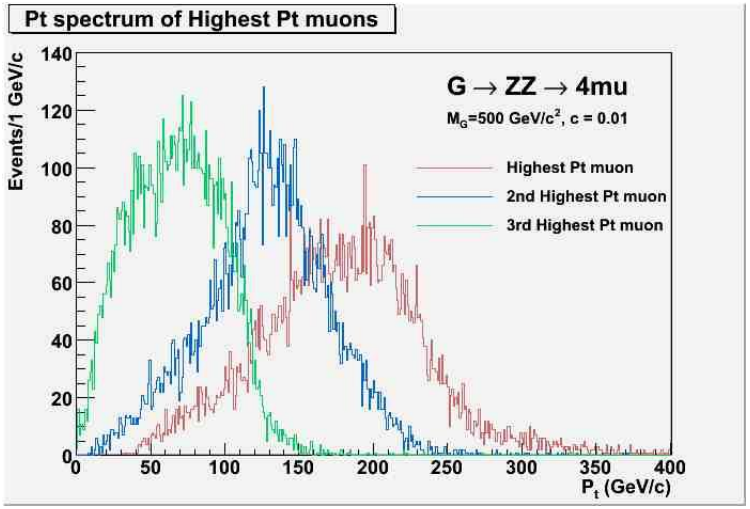
B.G. Channel	C.S. (pb)	No. of Produced Event	No. of final events (Skim Effi.)
QCD_pt80	1934639.567	3487680	6000 (0.00172)
W_jet	40000	9745661	16636 (0.00171)

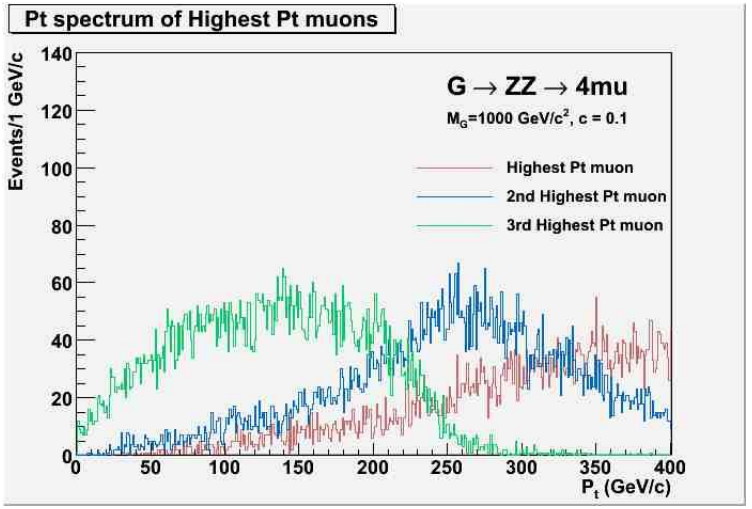
B.G.: Zmumu_jet (1)

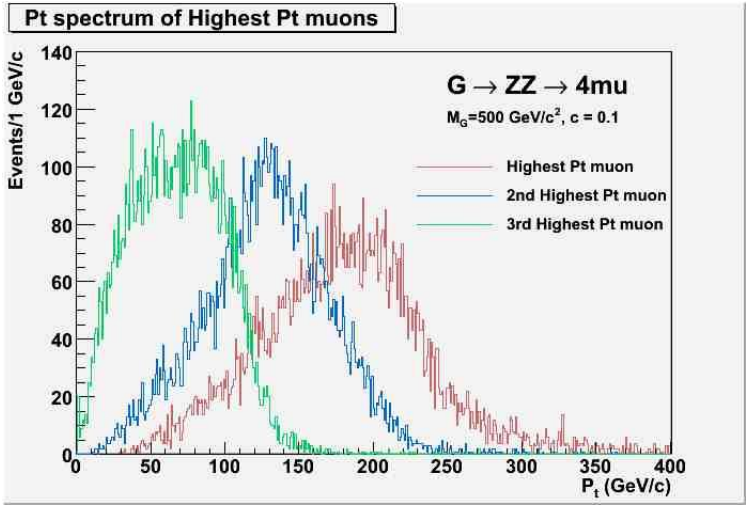
- Pythia6 (CMSSW_2_2_7)
- Produced with multiple section of different pt hat range. (details in the next page)
- $p+p \rightarrow Z+jet \rightarrow \mu^{+}\mu^{-} + jet$

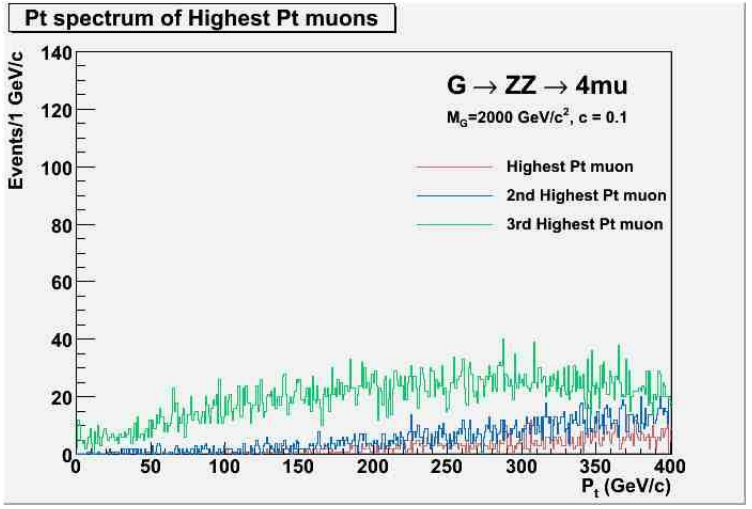
B.G. Channel	C.S. x B.R. (pb)	No. of Produced Event	No. of final events
Zmumu_jet	7096200	1544625	239139 (No weighted)

Muon Pt: Highest Order (1)

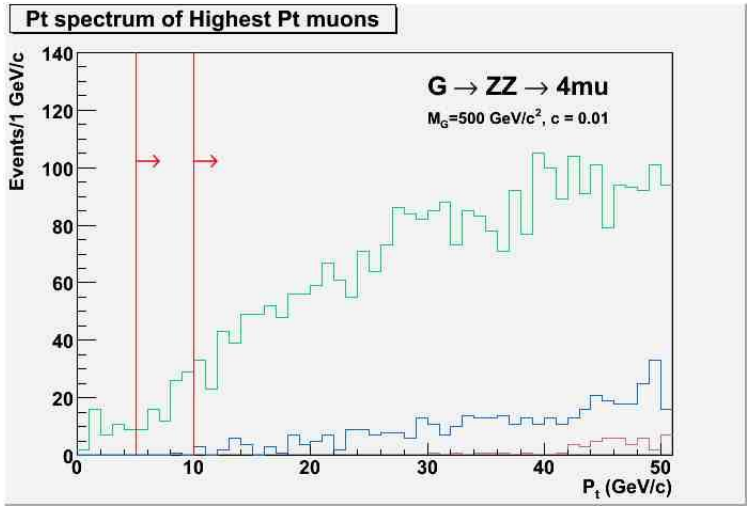


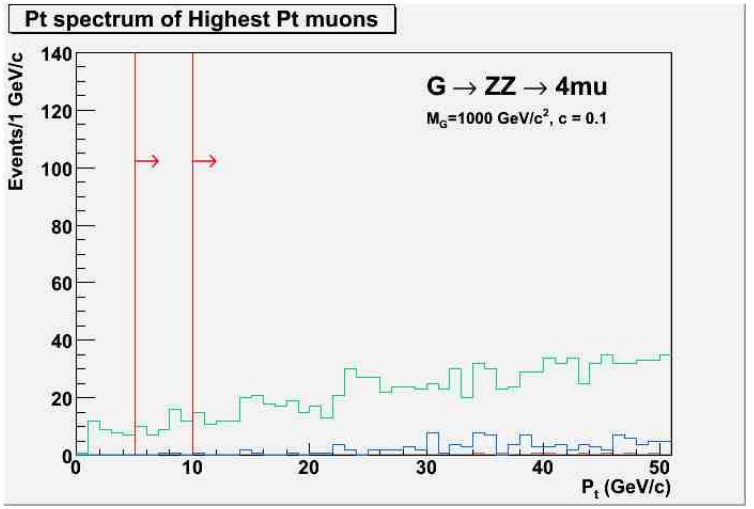


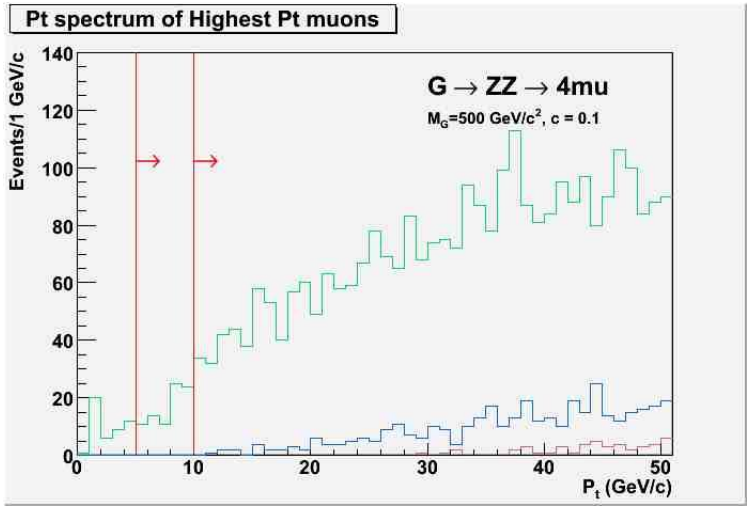


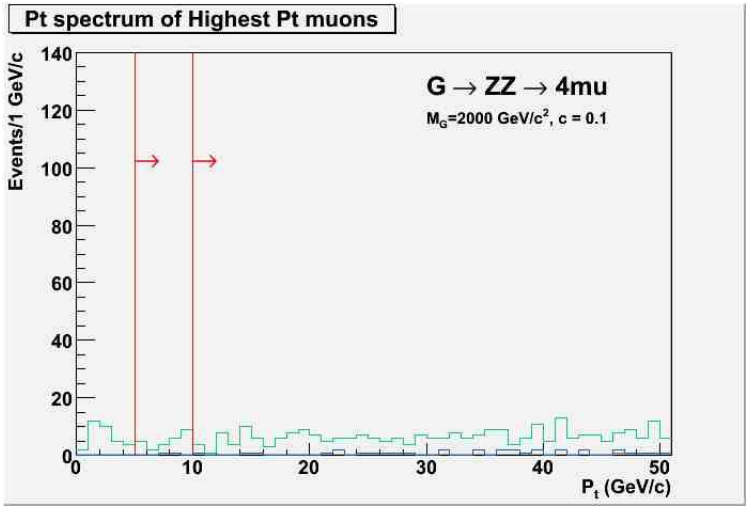


Muon Pt: Highest Order (2)









HLT study

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Sample	HLT pass ratio(%)					
	HLT_Mu3	HLT_Mu7	HLT_Mu15	HLT_ Double IsoMu3	HLT_ Double Mu3	HLT_ Double Mu7_Z
Graviton (c=0.1)	99.7	99.5	99.4	94.1	98.7	98.3
ZZ	95.3	91.5	87.2	80.3	84.6	69.5
Zbb	78.9	67.0	48.8	39.4	48.5	18.9
tt	98.3	96.1	93.7	58.7	82.2	48.4

- **HLT_DoubleMu7_Z was chosen for final HLT**

Selection Cut

0. Passing HLT_DoubleMu7_Z trigger

1. $P_T > 7.0$ GeV/c for each muon candidate

2. Muon's |pseudorapidity(η)| < 2.4

3. No. of $\mu^+ \geq 2$ & $\mu^- \geq 2$

4. $|M_z - M_{\mu^+\mu^-}| < 13.86$ GeV/c^2
   (3σ from M_z fitting)

5. $M_{4\mu} > 300$ GeV/c^2

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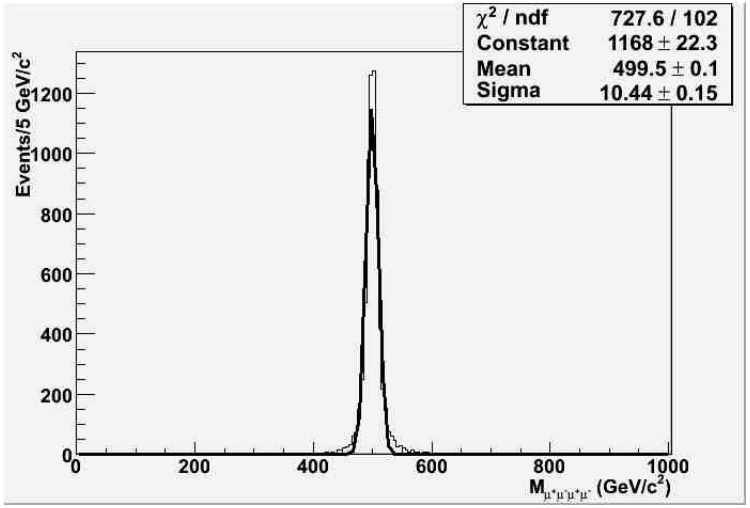
RS G : Selection Cut Efficiency (%)

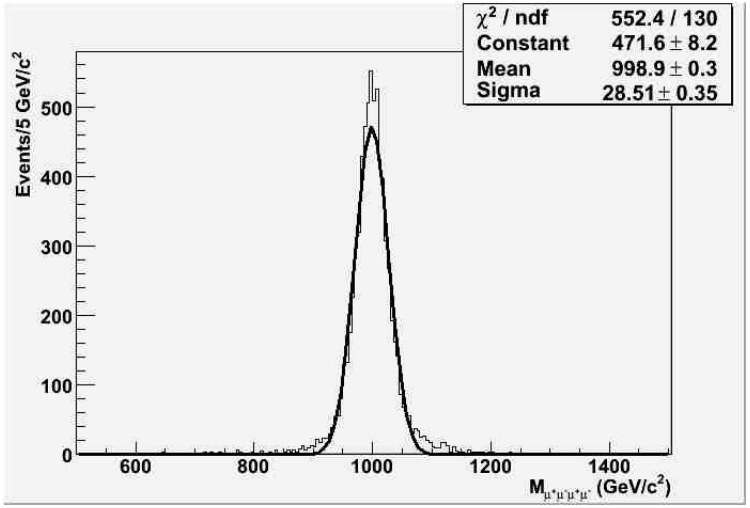
G* Mass (GeV/c^2)	Selection Cut Efficiency (c = 0.1)			
	Recon + (skim) + HLT	Pt > 7 + | Eta | < 2.4 + Mz >= 2	Mz Cut + MG > 300 GeV/c^2	3σ Fit
500	98.3	76.4	68.3	63.4
700	98.8	80.0	71.2	66.9
1000	98.7	83.3	73.6	68.9
1200	98.7	85.1	73.9	69.9
1500	98.3	86.3	72.8	69.6
2000	97.4	87.7	71.5	68.6

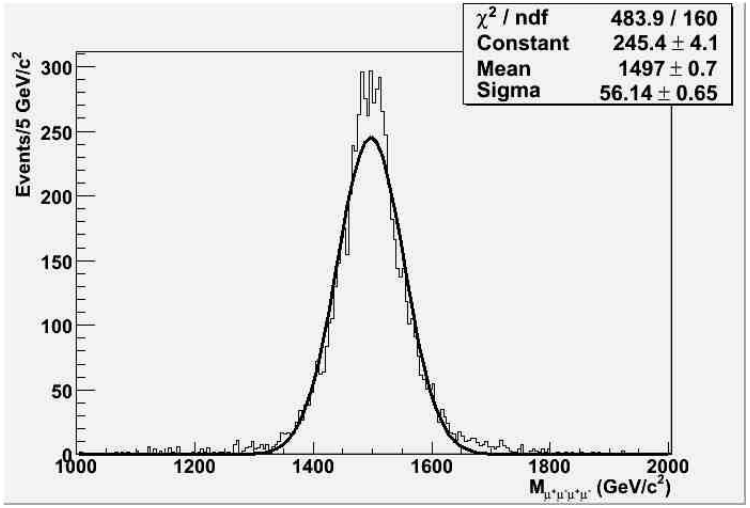
B.G. : Selection Cut Efficiency (%)

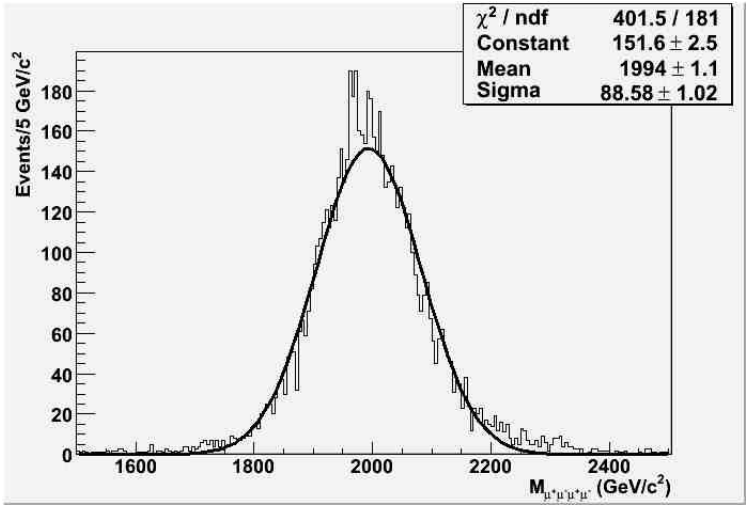
B.G.	Selection Cut Efficiency (%) (vs. MG=500 GeV/c^2 c = 0.1)			
	Recon + (skim) + HLT	Pt > 7 + | Eta | < 2.4 + Mz >= 2	Mz Cut + MG > 300 GeV/c^2	3σ Fit
ZZ	69.5	37.4	5.5	0.5
Zbb	18.9	0.1	0.001	0
Tt	48.4	0.9	0.007	0.003
QCD	0.0009	0	0	0
W_jet	0.0016	1.02e-5	0	0
Zmumu_jet	0.7	0.0009	2.0e-6	5.0e-8

Reconstructed RS Graviton (c=0.1)

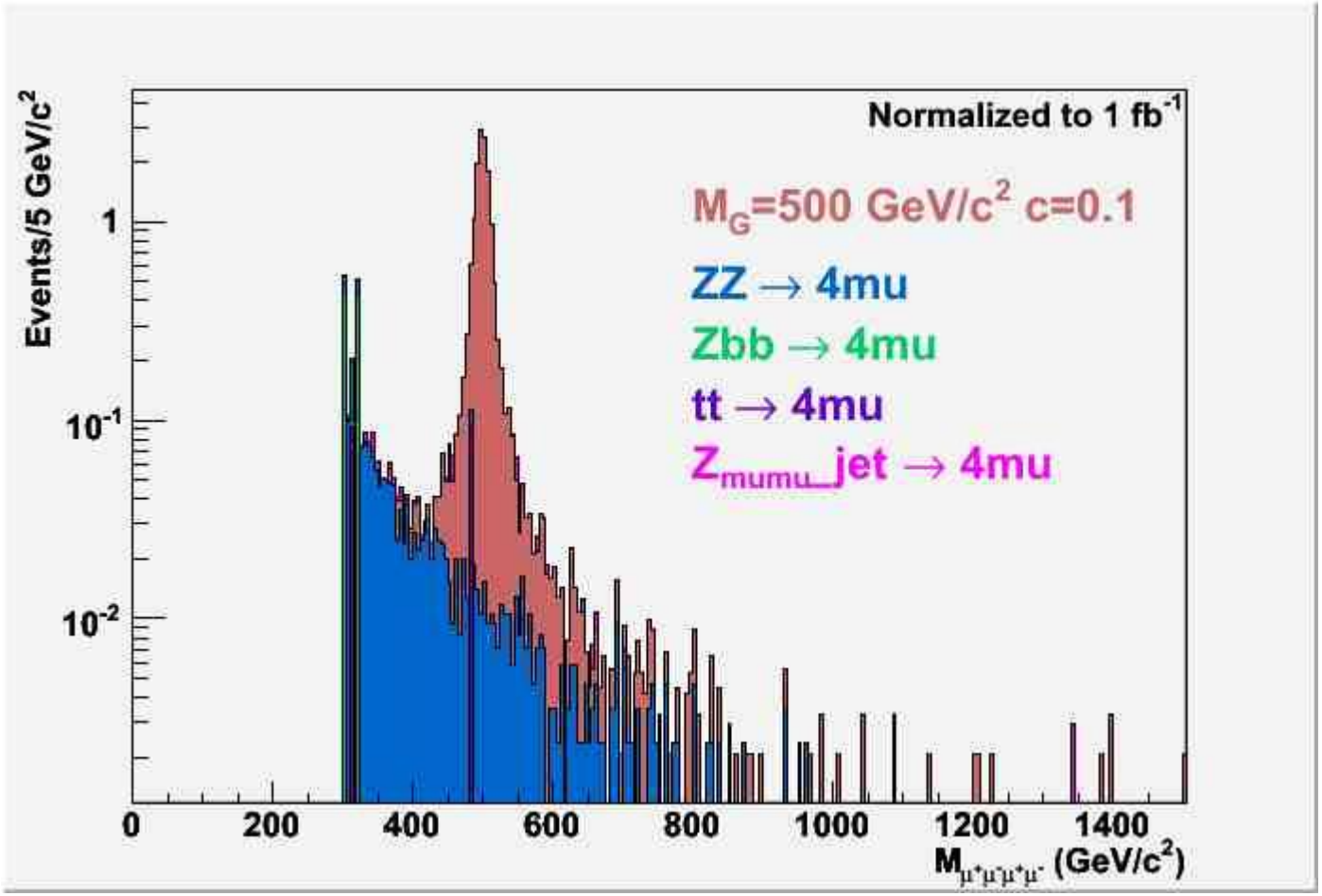




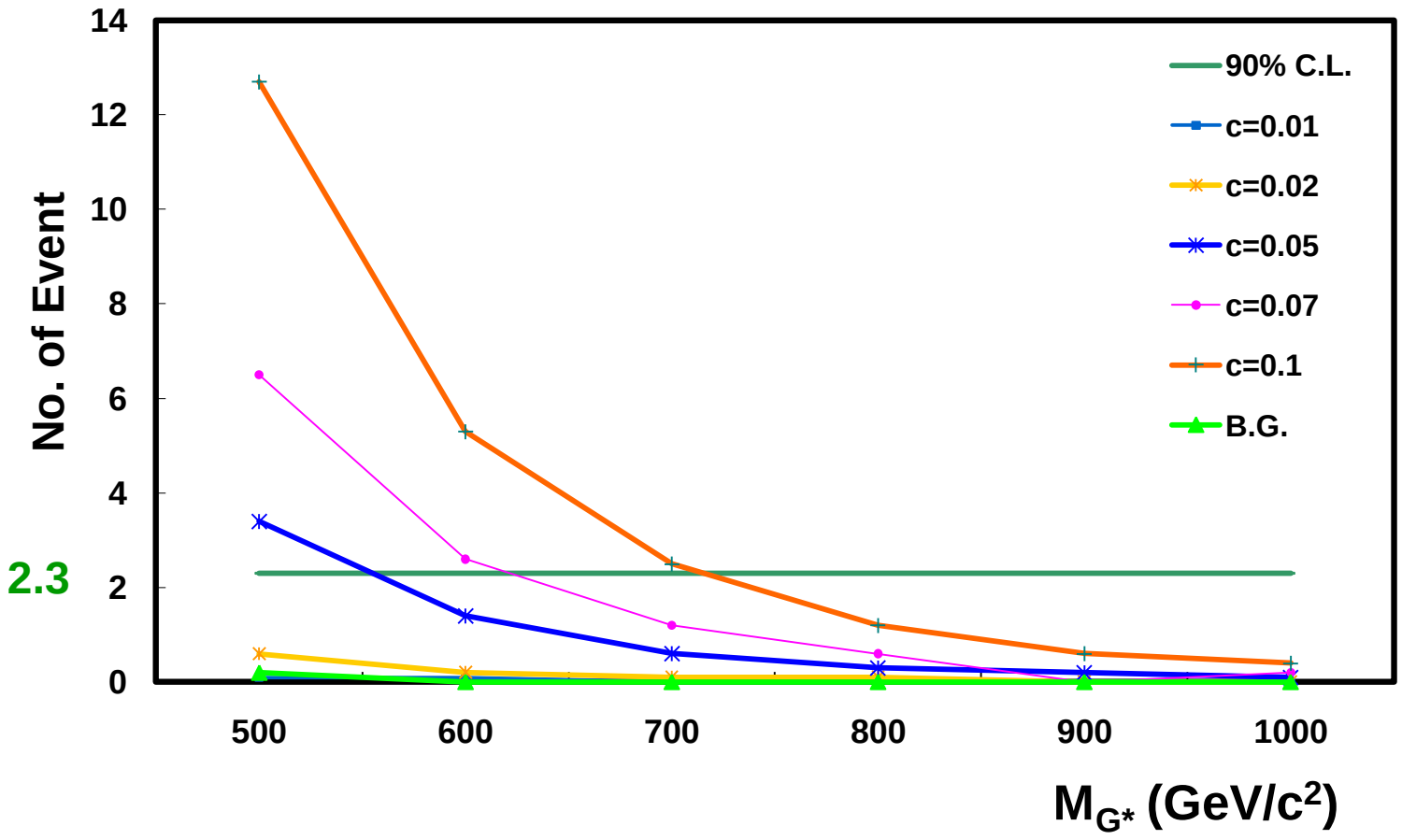




RS Graviton vs. Background in 1 fb^{-1}



Expected No. of Signal & Background at 1 fb^{-1}

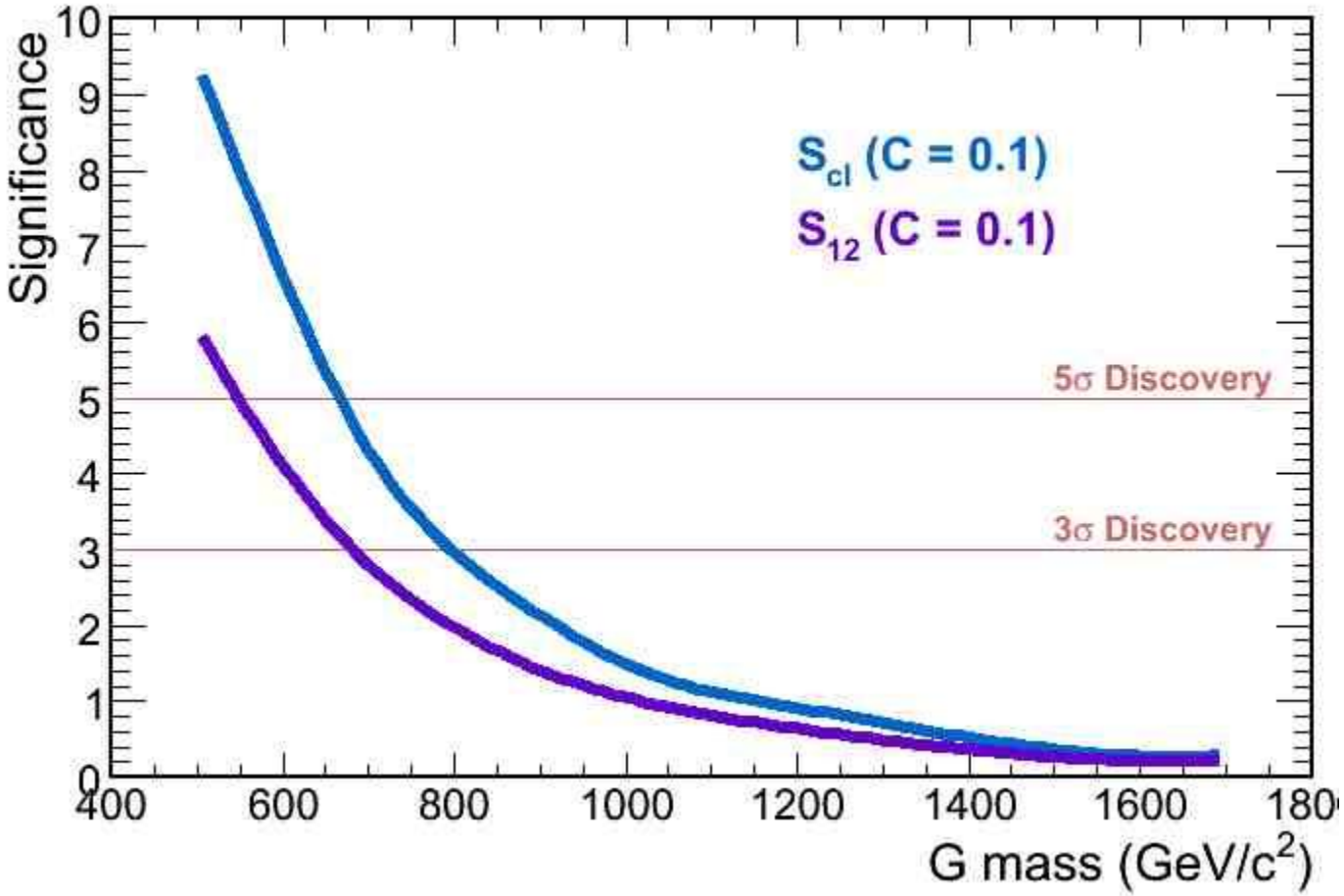


Systematic Uncertainty

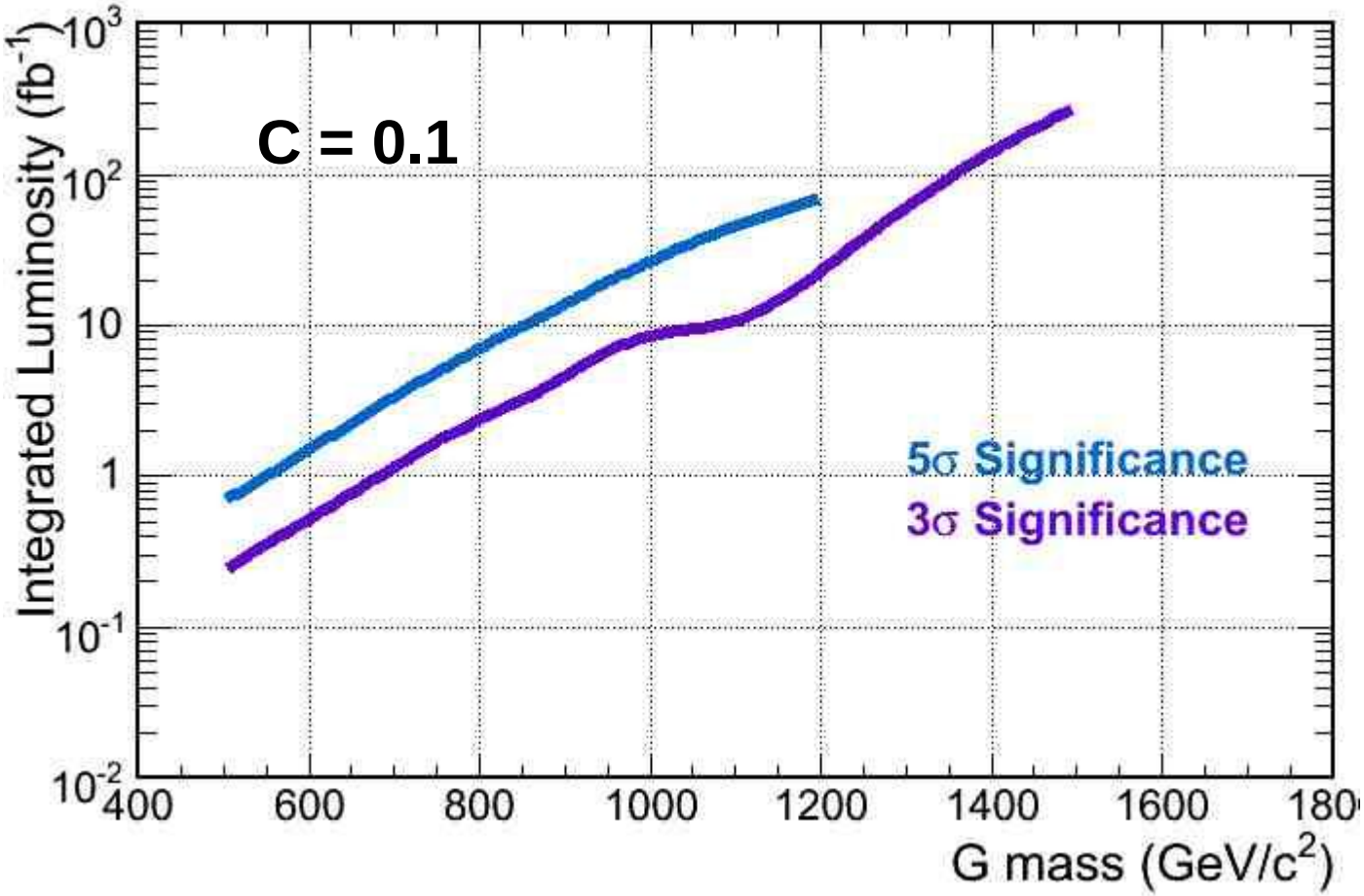
- There are already many studies on sources of systematic uncertainty. Especially Higgs and EWK studies were very helpful to understand them.

Source	Uncertainty (%)
PDF + QCD	6
Integrated Luminosity	10
Muon Reconstruction	4
Misalignment	2
MC Statistics	0.85
Statistical	100
Total	100.78

Expected Significance at 1 fb^{-1}



Required Int. luminosity for discovery (c=0.1)



Summary

- Prospective RS G* $\rightarrow$ZZ $\rightarrow\mu^+\mu^-\ \mu^+\mu^-$ in the mass range of 500 GeV/c^2 to 2 TeV/c^2 was analyzed.
- Including major BG: ZZ, Zbb, tt, additional QCD, Z+jet, W+jet background
  → could be highly reduced in the overall mass range
- Under the Systematic uncertainty effect, We could probe 5σ(3 σ) discovery in the mass range $M_{G^*} < 650(700)$ GeV/c^2 with 1 fb^{-1} int. lumi. with $c = 0.1$
- About 300 pb^{-1}(700 pb^{-1}) int. luminosity is expected to be required for 3σ(5σ) discovery of RS G with 500 GeV/c^2 mass with $c = 0.1$

Note AN-09-141 in Review Now

CMS AN AN-09-141

CMS Draft Analysis Note

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2009/09/23
Archive Id: 1.1
Archive Date: 2009/09/04 12:59:58

Search for Randall-Sundrum Graviton using the mode $G^* \to ZZ \to \mu^+\mu^-\mu^+\mu^-$ at $\sqrt{s} = 10$ TeV for the CMS Experiment

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Abstract

A search on Randall-Sundrum (RS) graviton using the mode $G^* \to ZZ \to \mu^+\mu^-\mu^+\mu^-$ is studied. Signal and background MC samples corresponding to an integrated luminosity of 1 fb^{-1} are used in this study. With the 10 TeV of center-of-mass energy at LHC, the potential of RS graviton discovery in CMS detector is probed, and 3σ observation of the RS graviton mass is less than 650 GeV/c^2 with the parameter c = 0.1.