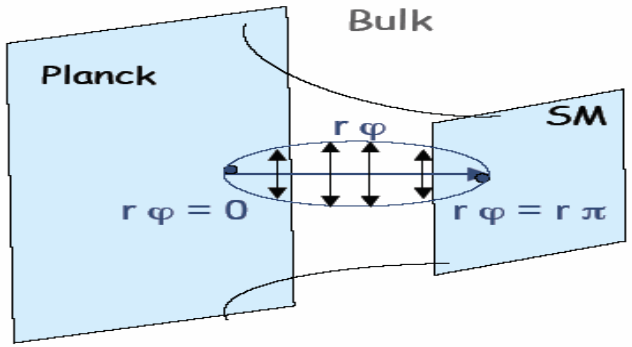
A first look into RS Gravitons at ATLAS

Tracey Berry
Royal Holloway

Randall Sundrum Model

Randall, Sundrum, Phys Rev Lett 83 (99)

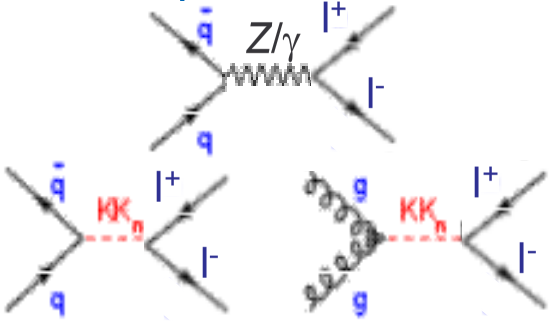


Signature:
Narrow, high-mass resonance states in dilepton/dijet/diboson channels

1 highly curved/warped extra dimension (ED)

Gravity localised in the ED

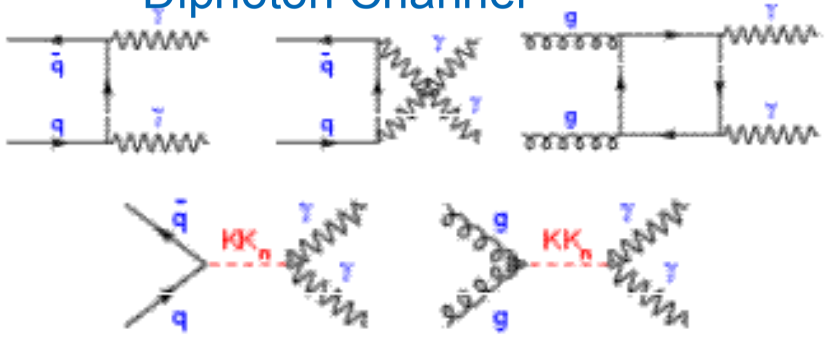
Dilepton Channel



SM

ED

Diphoton Channel



Randall Sundrum Model

Royal Holloway University of London

Randall, **S**undrum, Phys Rev Lett 83 (99)

Signature:

Narrow, high-mass resonance states in dilepton/dijet/diboson channels

Model parameters:

- Gravity Scale: $\Lambda_\pi = \overline{M}_{pl} e^{-kR_c\pi}$

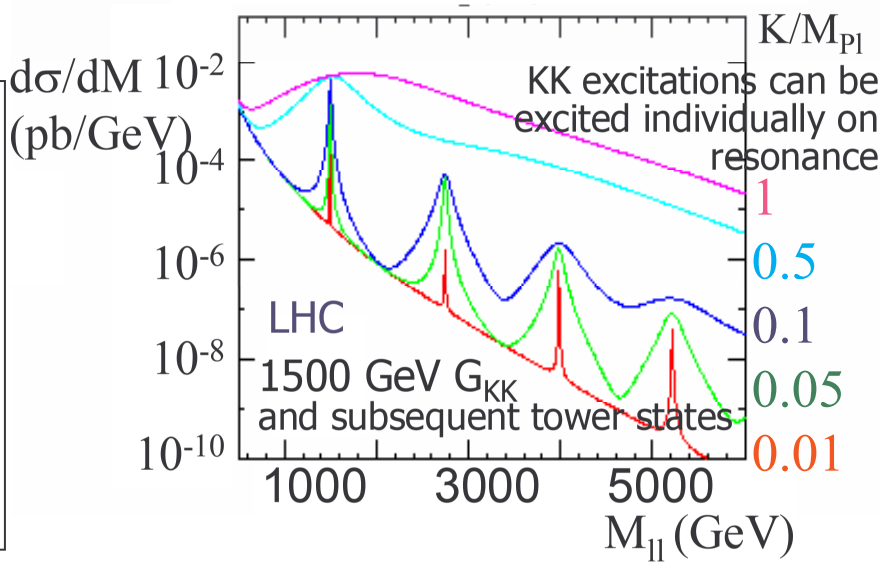
  Resonance

  1st graviton excitation mass: $m_1 \rightarrow$ position

  $\Lambda_\pi = m_1 \overline{M}_{pl}/kx_1$, & $m_n = kx_n e^{krc\pi}(J_1(x_n)=0)$
- Coupling constant: $c = k/M_{Pl}$

  $\Gamma_1 = \rho m_1 x_1^2 (k/\overline{M}_{pl})^2$ $\rightarrow$ width

k = curvature, R = compactification radius



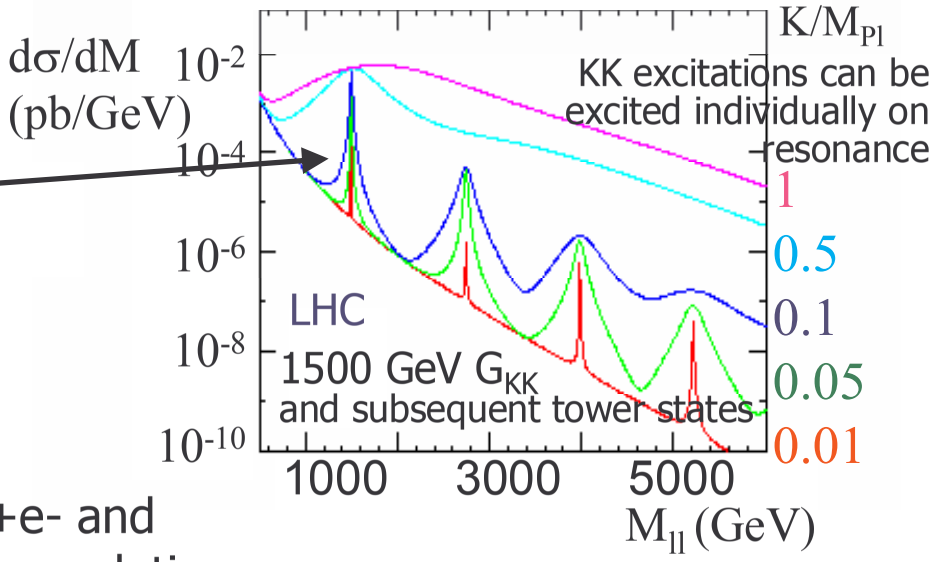
RS1 Discovery Limit

Royal Holloway University of London

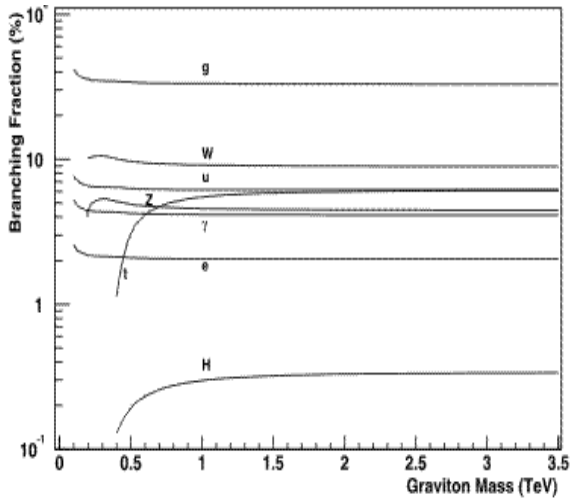
Davoudiasl, Hewett, Rizzo
hep-ph0006041

At the LHC only the 1st excitations are likely to be seen at the LHC, since the other modes are suppressed by the falling parton distribution functions.

Allenach et al, JHEP 9 19 (2000), JHEP 0212 39 (2002)



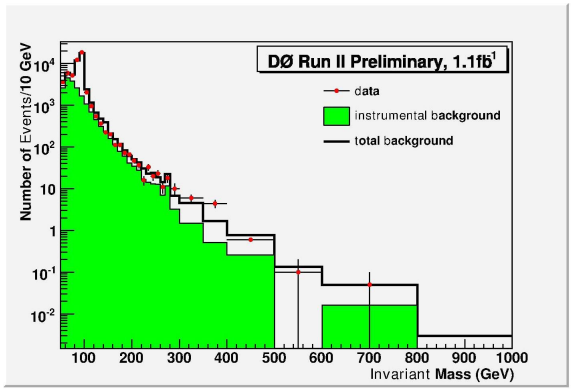
- Best channels to search in are G(1)→e+e- and G(1)→γγ due to the energy and angular resolutions of the LHC detectors
- G(1)→e+e- best chance of discovery due to relatively small bkdg, from Drell-Yan*



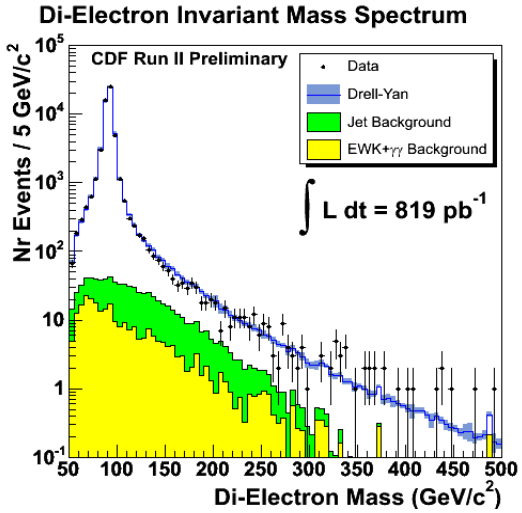
Allenach et al, hep-ph0006114

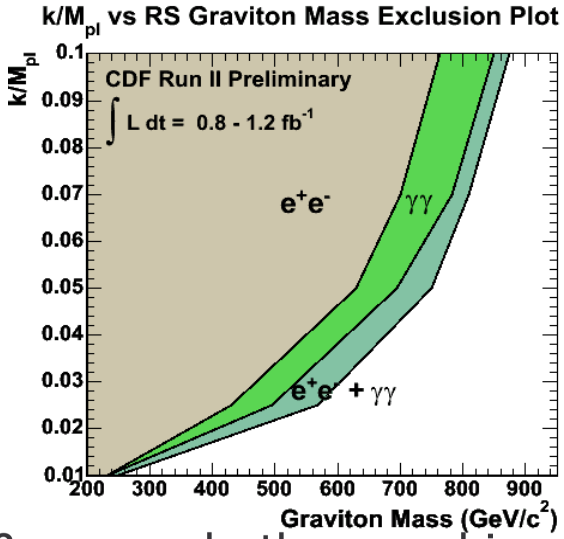
*Allenach et al, hep-ph0211205

Present RS Constraints

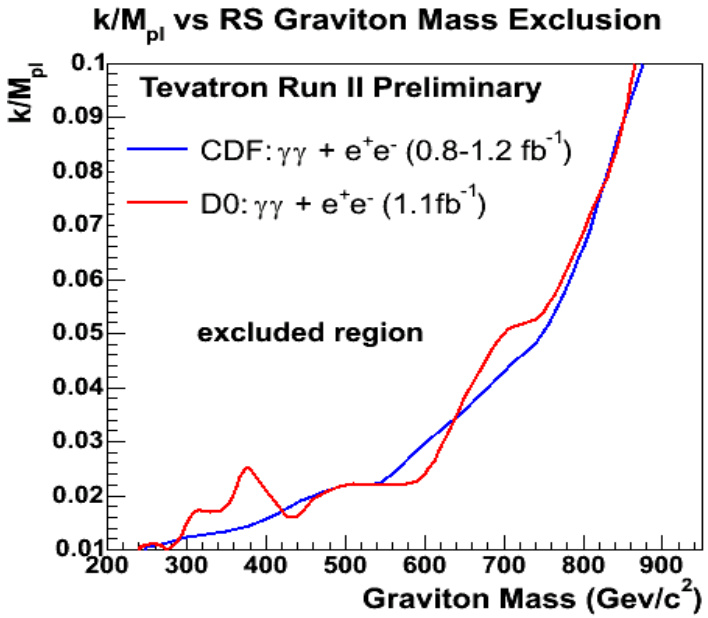


D0 performed combined ee+$\gamma\gamma$ (diem search)





CDF performed ee & $\gamma\gamma$ search, then combine



Present Experimental Limits

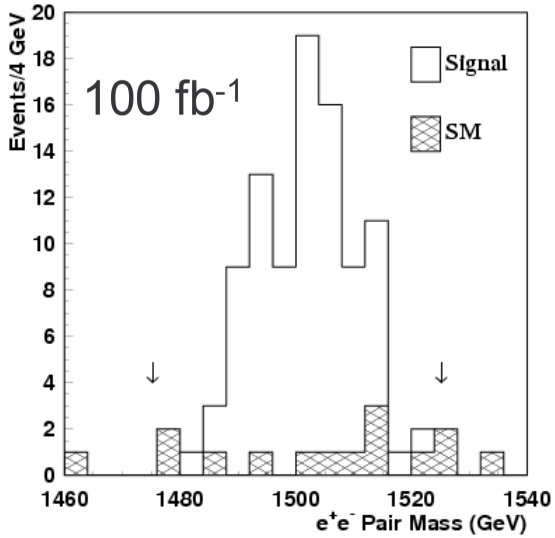
Theoretical Constraints

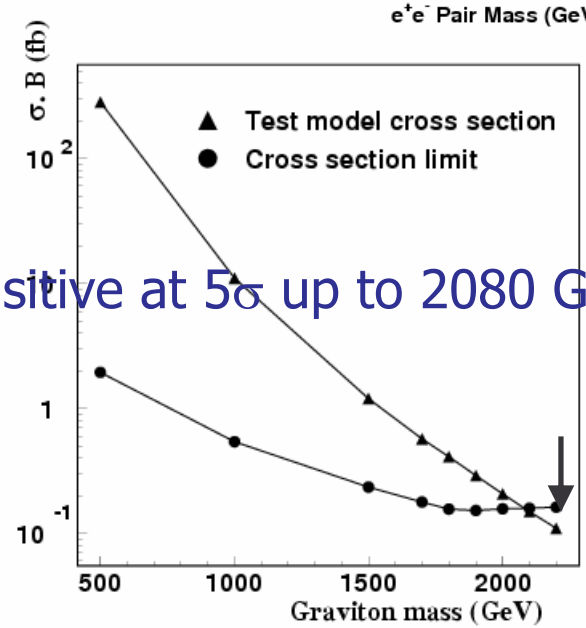
- c>0.1 disfavoured as bulk curvature becomes to large (larger than the 5-dim Planck scale)
- Theoretically preferred Λ_π<10TeV assures no new hierarchy appears between m_{EW} and Λ_π

RS1 Discovery Limit

Di-electron

- HERWIG
- Main Bkdg: Drell-Yan
- Model-independent analysis
- RS model with $k/M_{Pl}=0.01$ as a reference (pessimisitc scenario)
- Fast Simulation





*Reach goes up to 3.5 TeV for c=0.1 for a 20% measurement of the coupling.

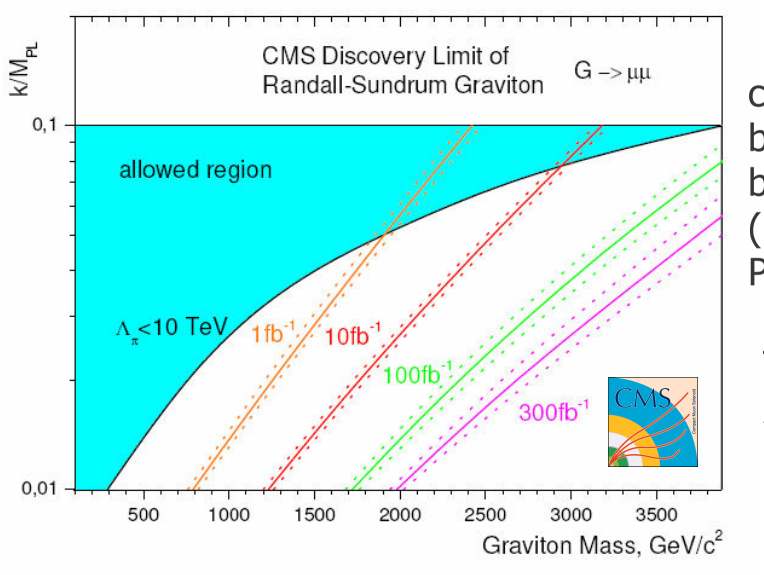
Sensitive at 5σ up to 2080 GeV

Allenach et al, hep-ph0006114

*Allenach et al, hep-ph0211205

CMS RS Discovery Limits

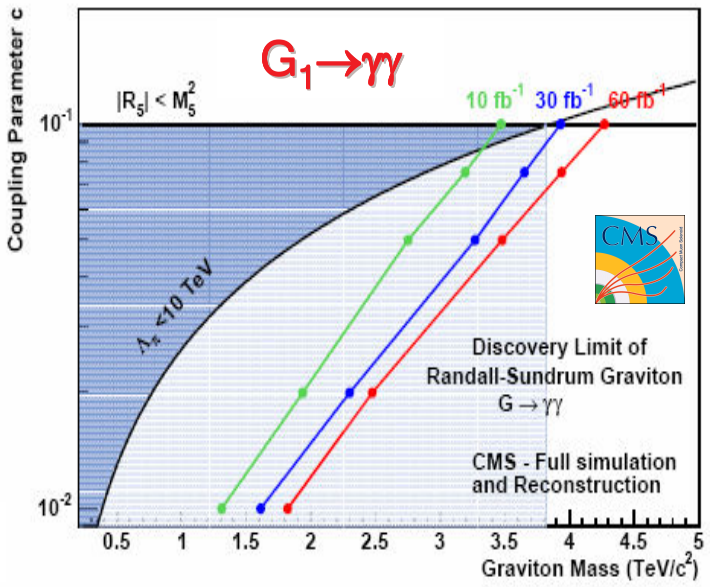
$G_1 \rightarrow \mu^+\mu^-$



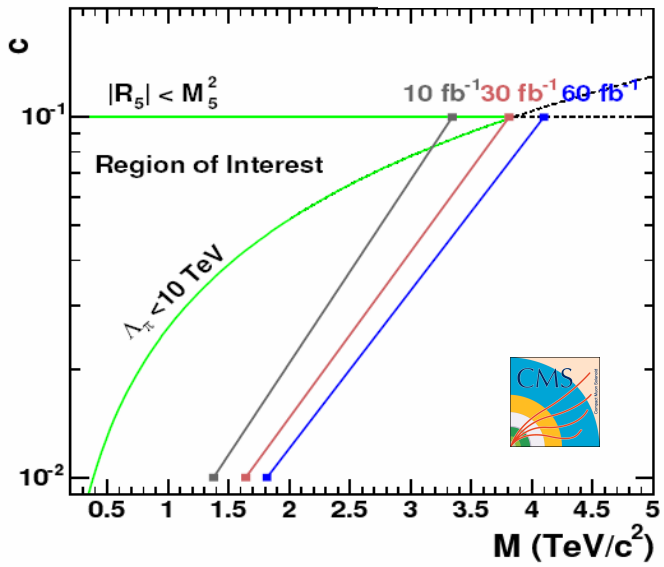
c>0.1 disfavoured as bulk curvature becomes to large (larger than the 5-dim Planck scale)

Theoretically preferred Λ_π<10TeV

$G_1 \rightarrow \gamma\gamma$



$G_1 \rightarrow e^+e^-$

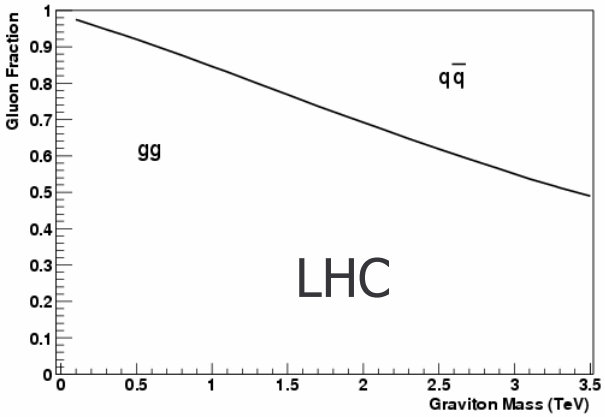


LHC completely covers the region of interest

RS1 Model Determination

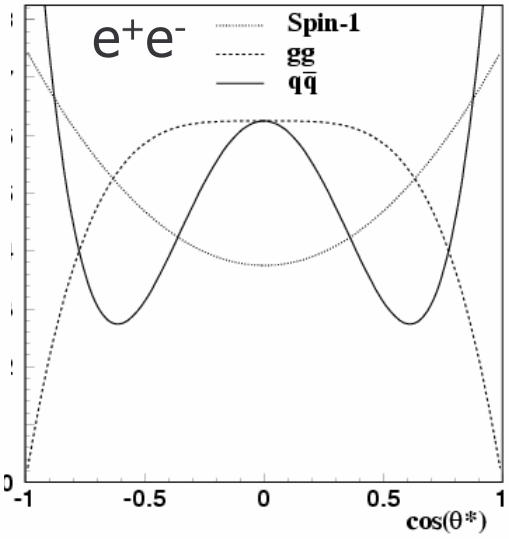
How could a RS G resonance be distinguished from a Z' resonance?
Potentially using Spin information:

G has spin 2: pp→G→ee has 2 components: gg→G→ee & $q\bar{q}$→G→ee: each with different angular distributions:

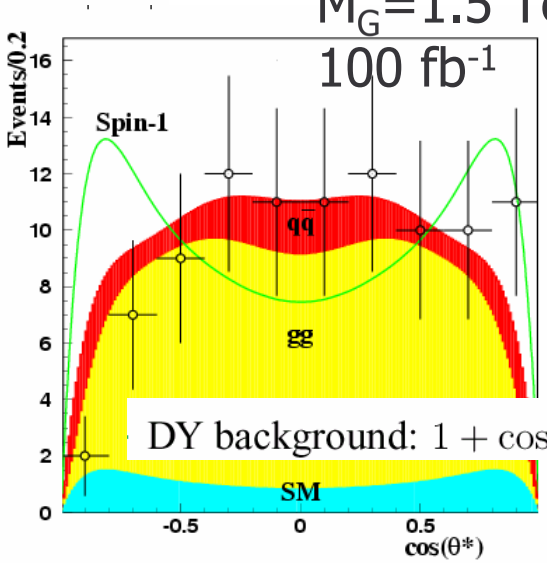


$qq \to G \to ff$: $1 - 3\cos^2\theta + 4\cos^4\theta$

$gg \to G \to ff$: $1 - \cos^4\theta$



M_G=1.5 TeV
100 fb^{-1}



Spin-2 could be determined (spin-1 ruled out) with 90% C.L. up to M_G = 1720 GeV with 100 fb^{-1}

Note: acceptance at large pseudo-rapidities is essential for spin discrimination (1.5<|eta|<2.5)

RS Gravitons Datasets

MC Dataset

- 3400 $G \rightarrow \gamma\gamma$ and 10200 $G \rightarrow ee$ Events:
- Generated with Mass = 1000 GeV $k/M_{pl}=0.1$
- Code version 11.0.42 and reconstructed with FullSim

Thanks to Barry King at Liverpool for generating the samples and producing ntuples.

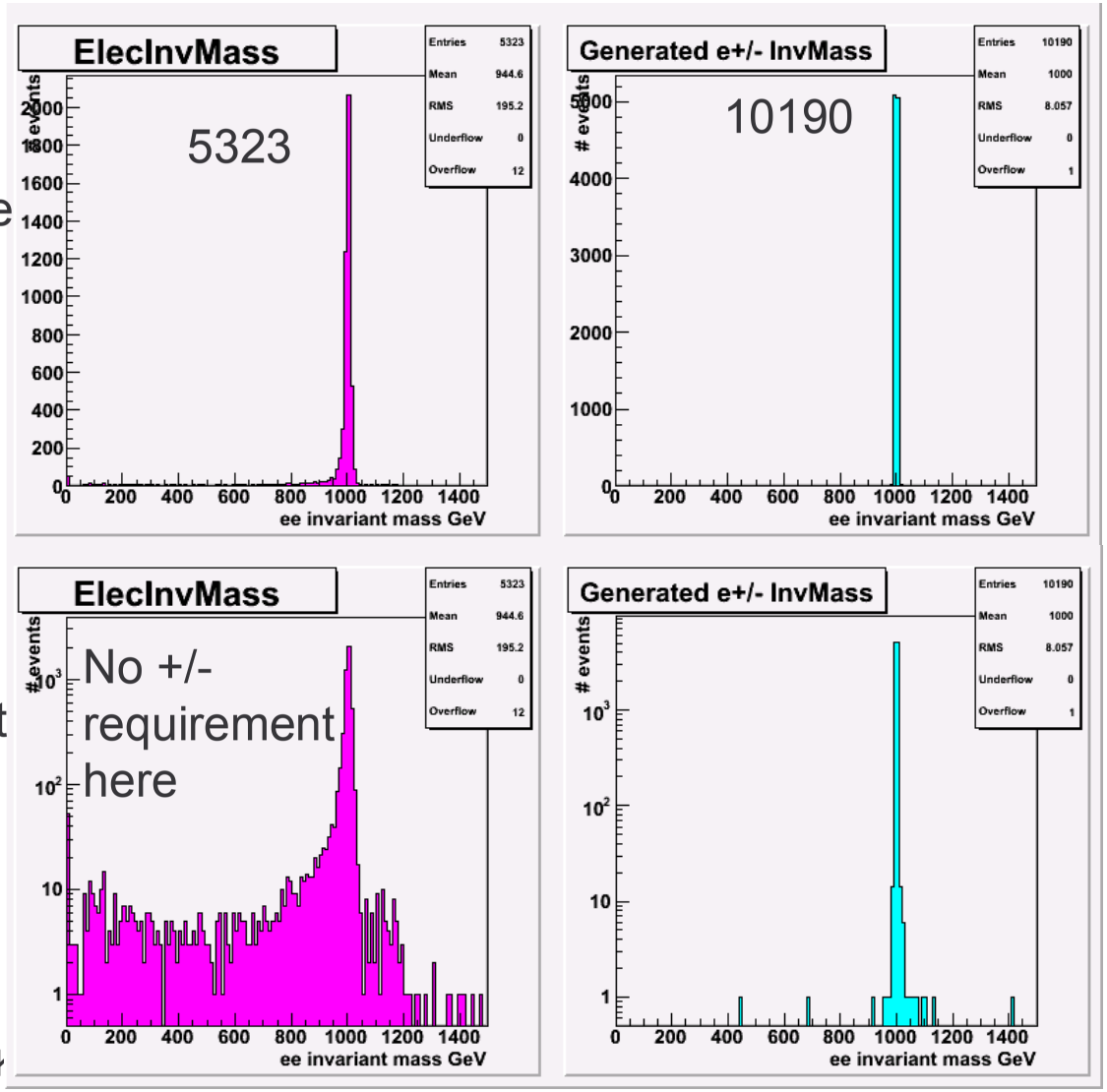
- Limited reconstruction information available. - can't trace mother/daughter - so just use the highest 2 Et e/photons in the event for now to look at distributions.

More detailed investigations to follow in future….

ee Invariant Mass

Generator level invariant mass:
first two e+/- with opposite charge and with E>100 GeV

Reconstructed mass:
highest energy 2 Et's in the event which pass the selection criteria

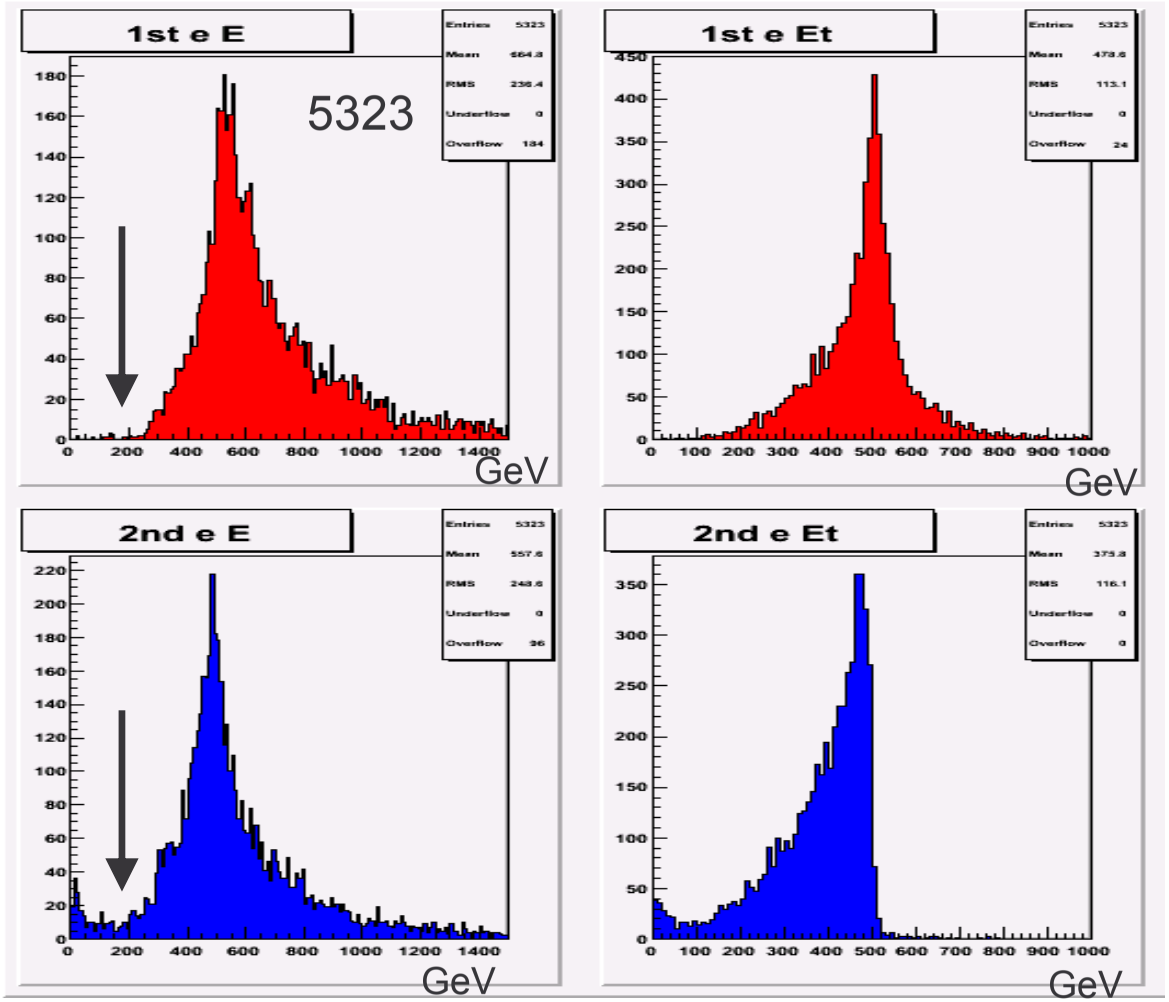


Reconstructed e/γ Selection Criteria

Electron:
Has a Track
IsEMel==0
Pt > 5.0
|Eta|<2.5
E/P>0.5
WeightRatio>0.6
NBel + NPixel>0
NHitsel = NBel + NPixel + ElecNSCTHits[i-1] + ElecNTRTHits[i-1]> 5

Photon:
isEMphot==0
Etphot>5.0
|Eta|<2.5
Charge photon==0

Reconstructed e variables

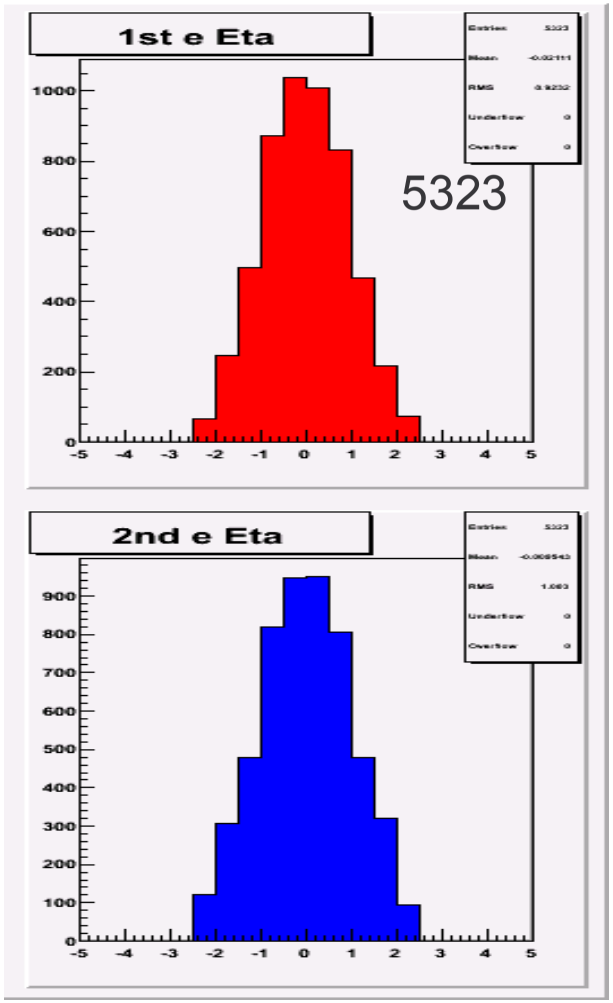


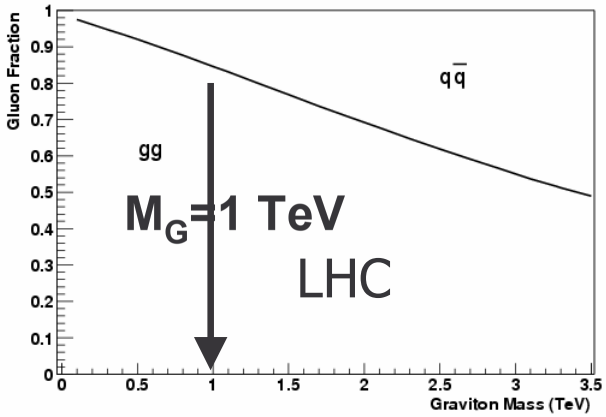
For G=1000 GeV

Interested in reconstructing e+/- with E above 200 GeV

And up to ~1.5-2 TeV

Reconstructed e variables



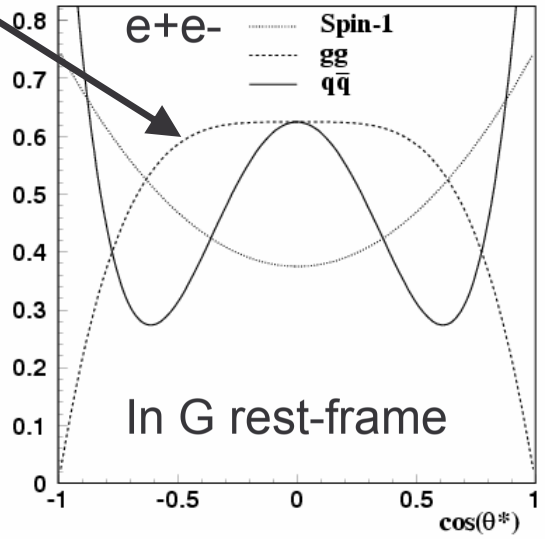


$qq \to G \to ff$: $1 - 3\cos^2\theta + 4\cos^4\theta$

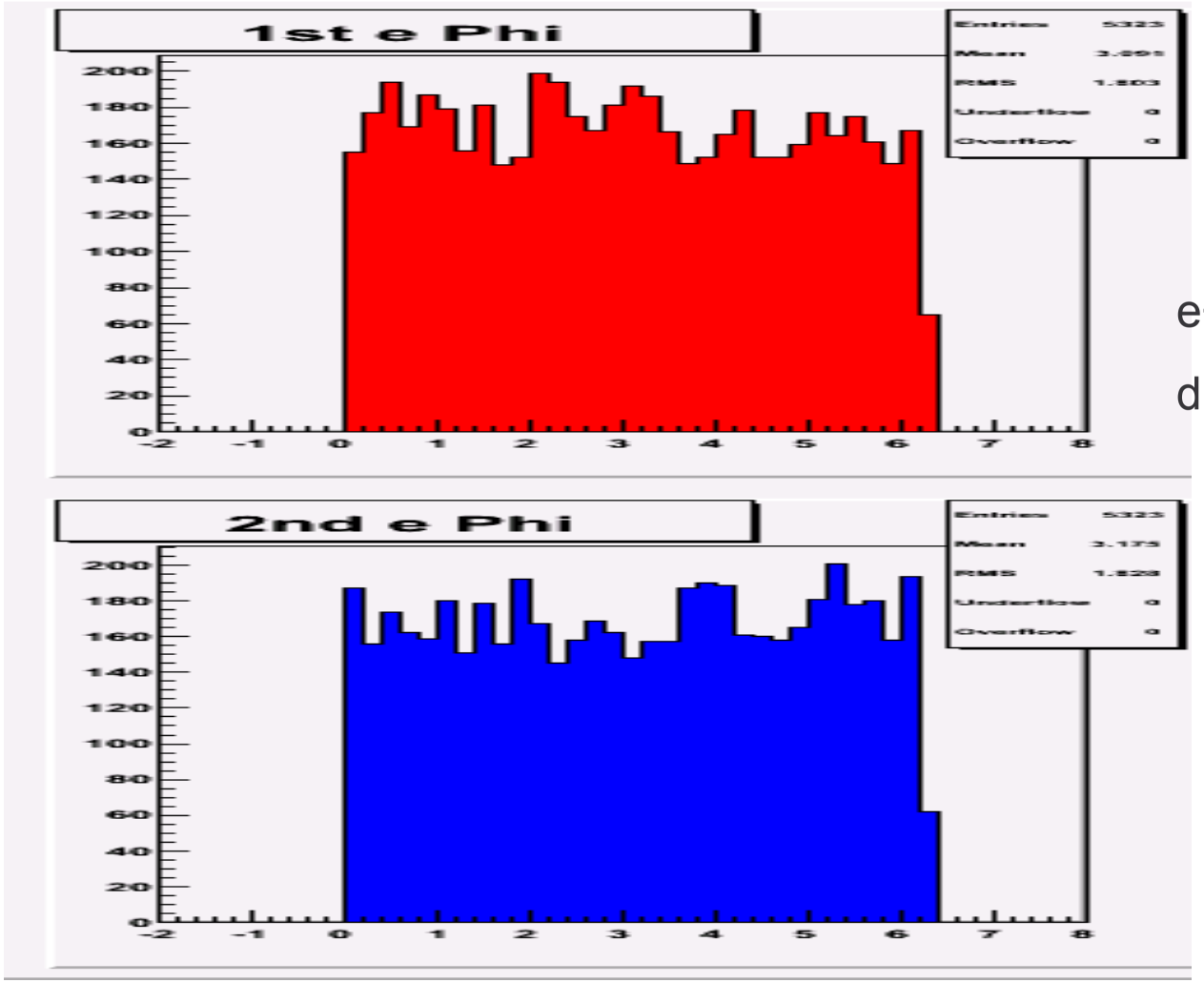
$gg \to G \to ff$: $1 - \cos^4\theta$

For M_G=1 TeV

Graviton production is mainly gg initiated

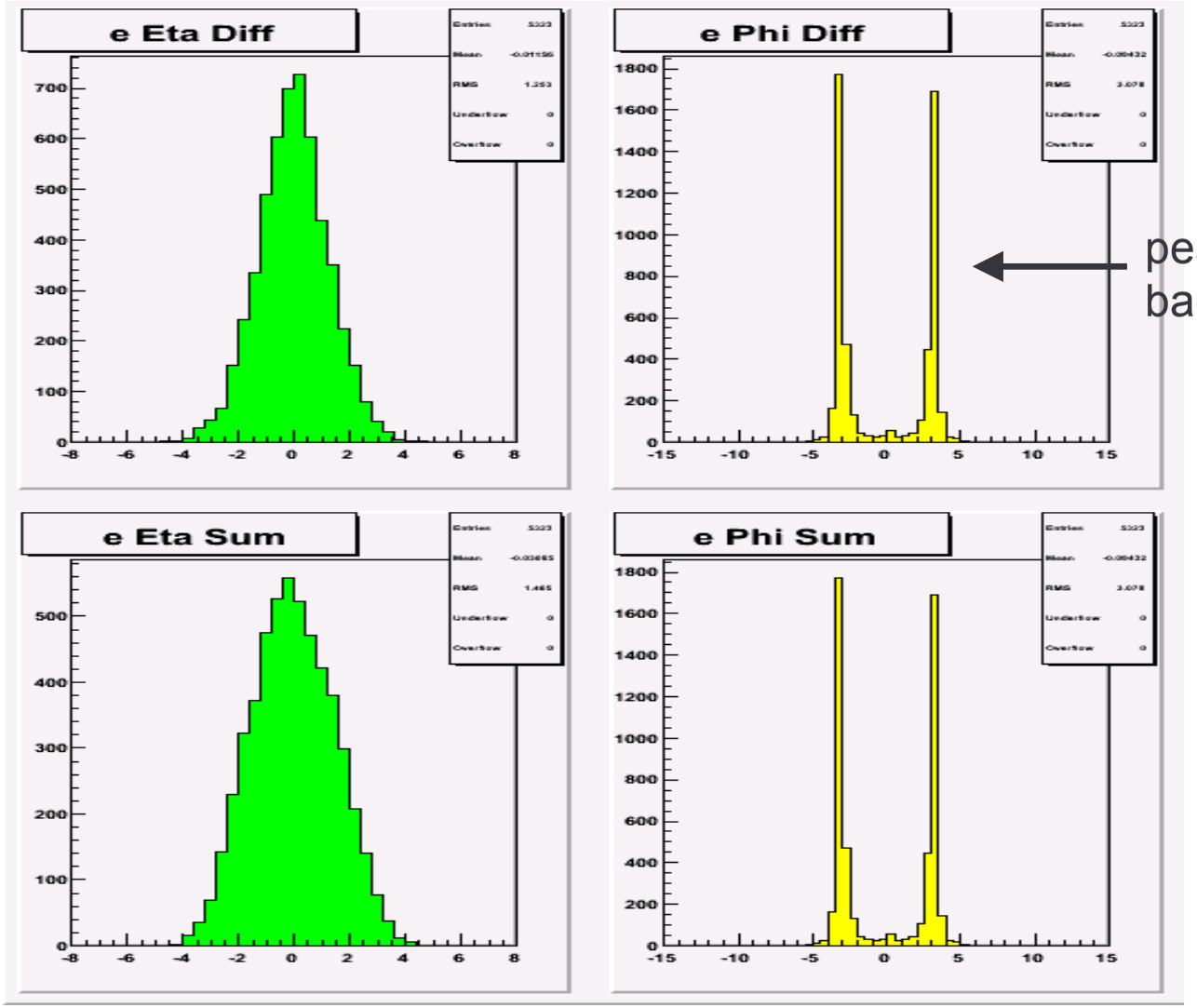


Reconstructed e variables



e+e- ~ uniformly distributed in phi

G→ee Distributions



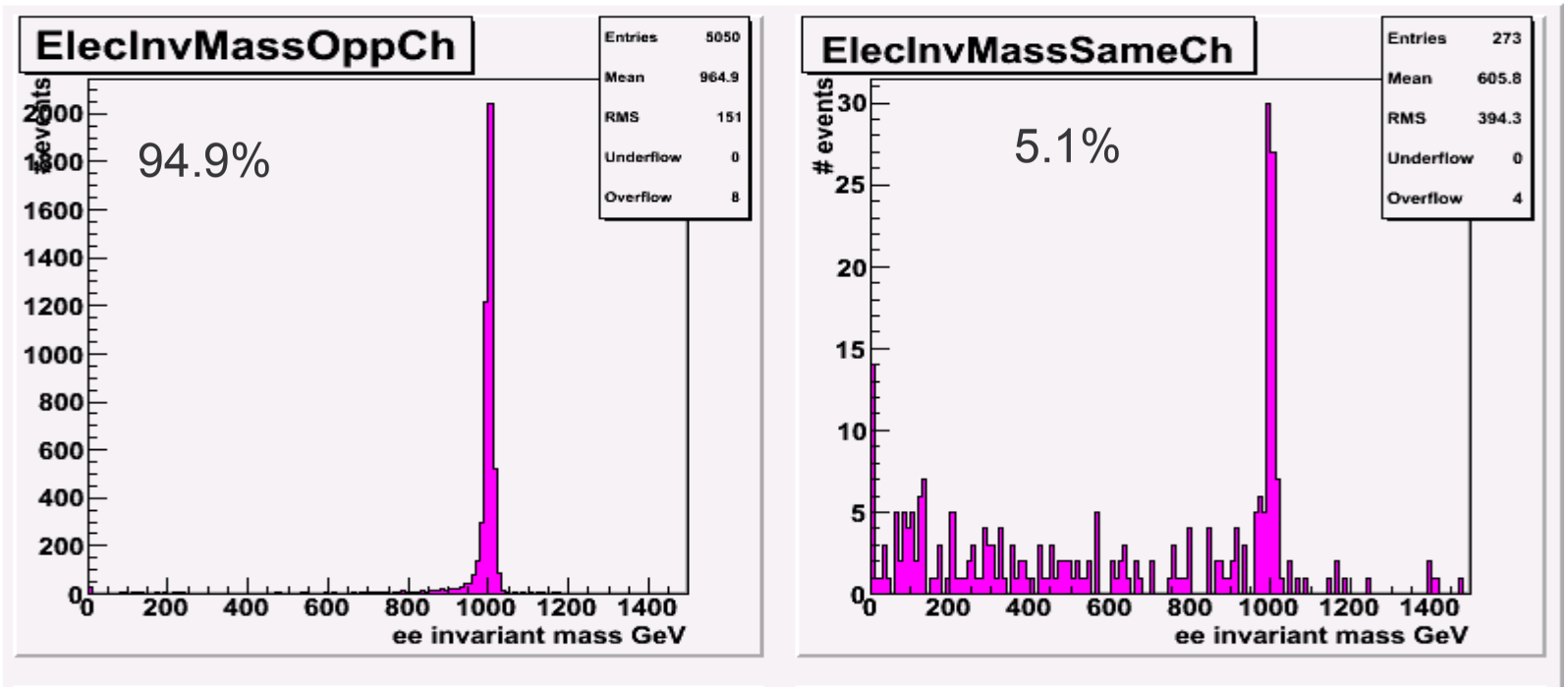
peaks at π implies e's back-to-back

Expect the ee to be back-to-back in the G rest frame

Charge Reconstruction

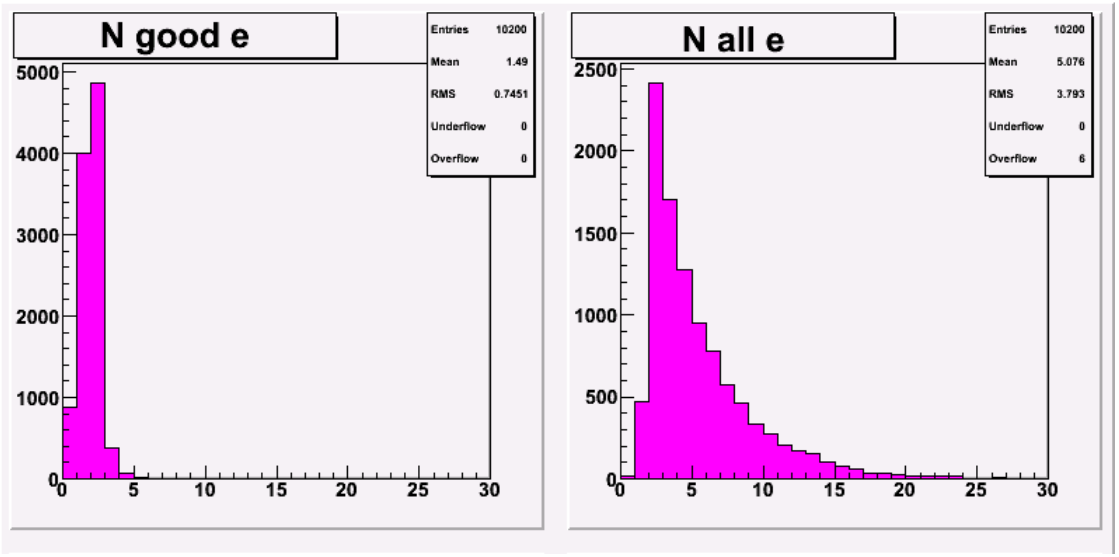
When more generator information available will match generated and reconstructed electrons

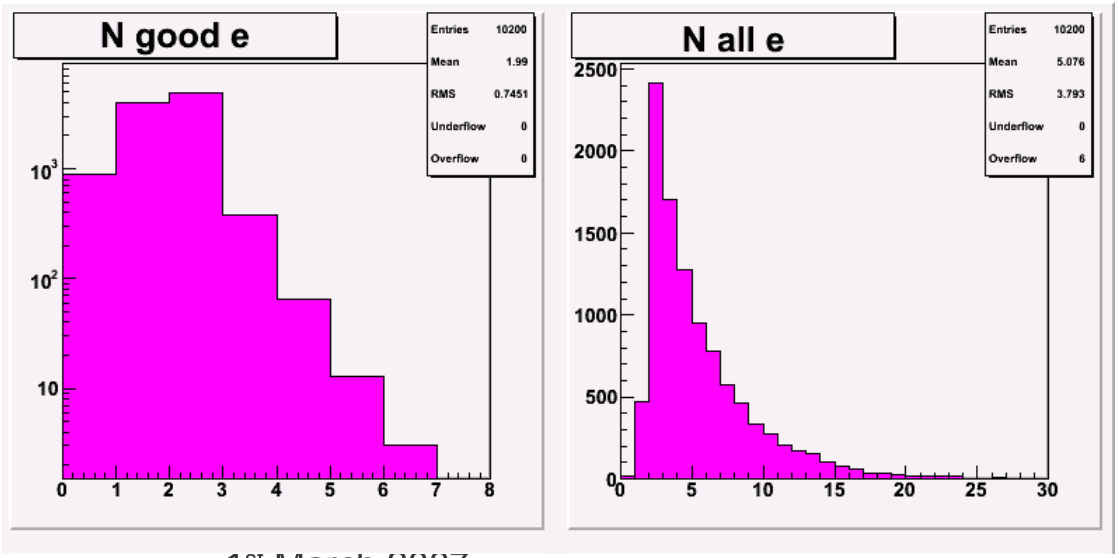
Reconstructed mass:
highest energy 2 e's in the event which pass the selection criteria



G→ee Events

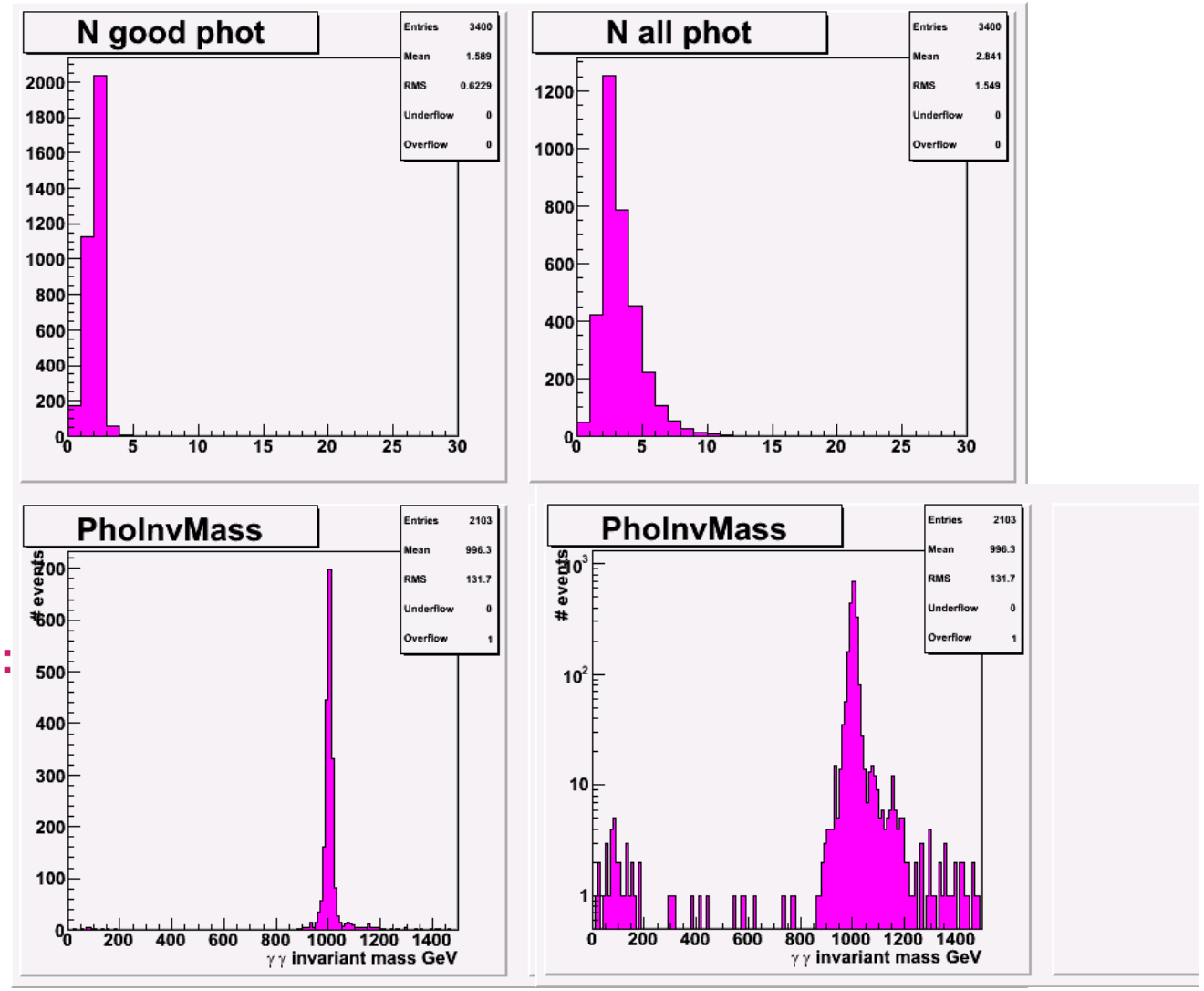
Most events have 1 or 2 “good” reconstructed electrons





G→γγ

Reconstructed mass: highest Et 2 γ's in the event which pass the selection criteria



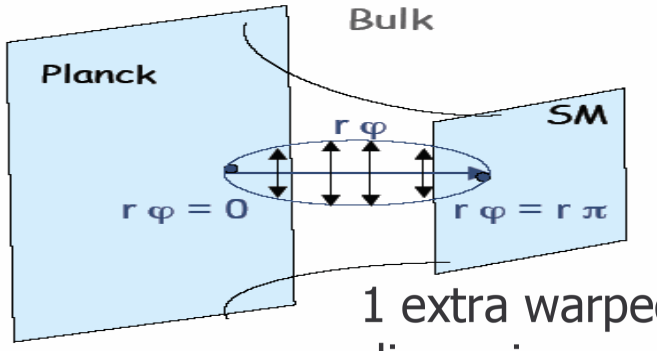
Future Plans

- Look at new samples which have more generator level information available.
- Look into reconstruction efficiency
- Investigate e/γ selection criteria

- Look into backgrounds

BACKUP….

Experimental Signature for RS Model



1 extra warped dimension

Model parameters:

- Gravity Scale: $\Lambda_\pi = \overline{M}_{pl} e^{-kR_c\pi}$
  1st graviton excitation mass: m_1 → position
  $\Lambda_\pi = m_1 \overline{M}_{pl}/kx_1$, & $m_n = kx_n e^{krc\pi}(J_1(x_n)=0)$
- Coupling constant: $c = k/M_{Pl}$
  $\Gamma_1 = \rho m_1 x_1^2 (k/\overline{M}_{pl})^2$ → width

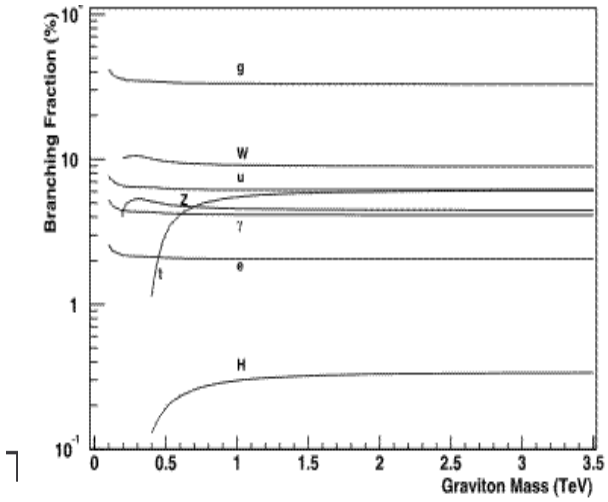
k = curvature, R = compactification radius

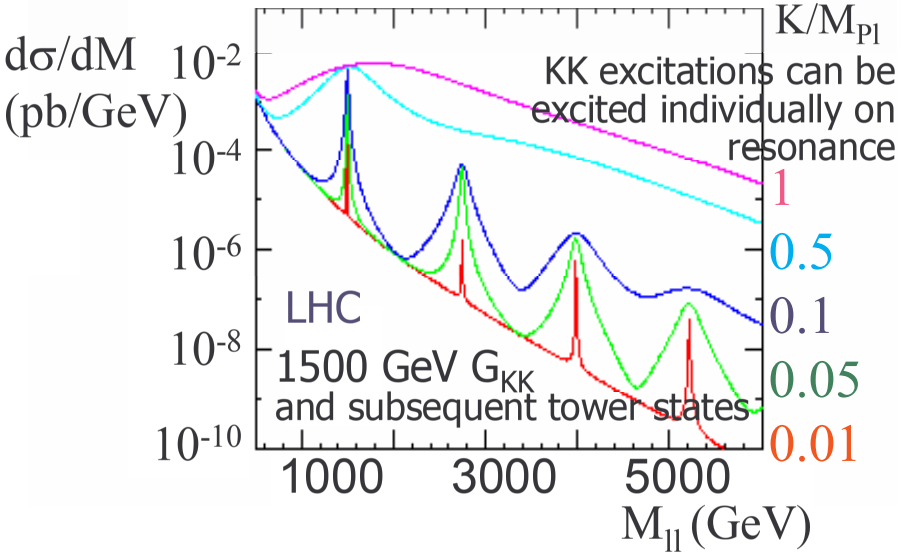
Resonance

Signature:

Narrow, high-mass resonance states in dilepton/dijet/diboson channels

$$qq, gg \rightarrow G_{KK} \rightarrow e^+e^-, \boldsymbol{\mu^+\mu^-}, \boldsymbol{\gamma\gamma}, jet + jet$$



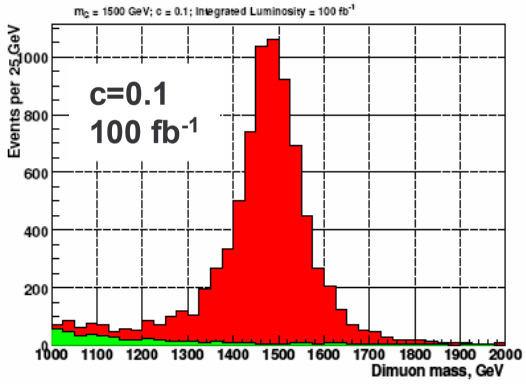


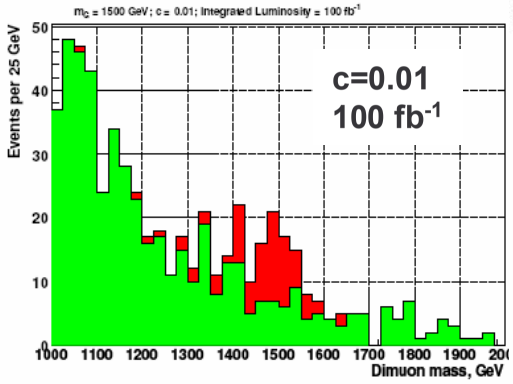
Davoudiasl, Hewett, Rizzo hep-ph0006041

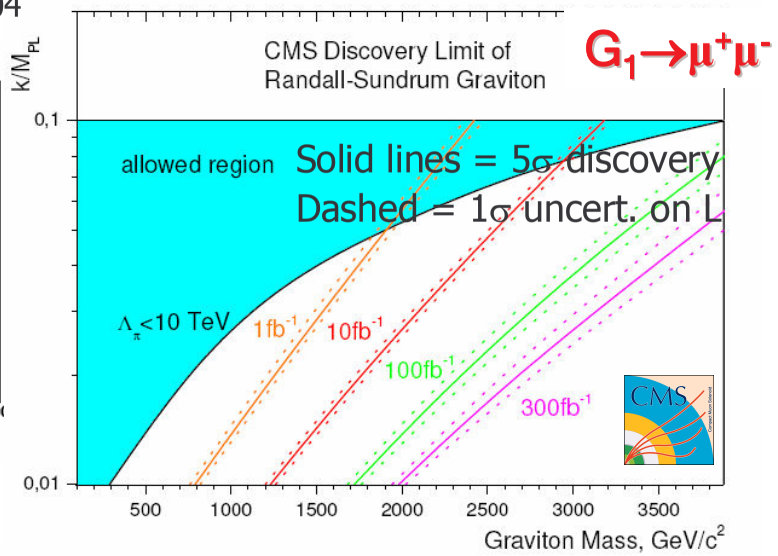
RS1 Discovery Limit

Di-lepton states

I. Belotelov et al.
CMS NOTE 2006/104
CMS PTDR 2006

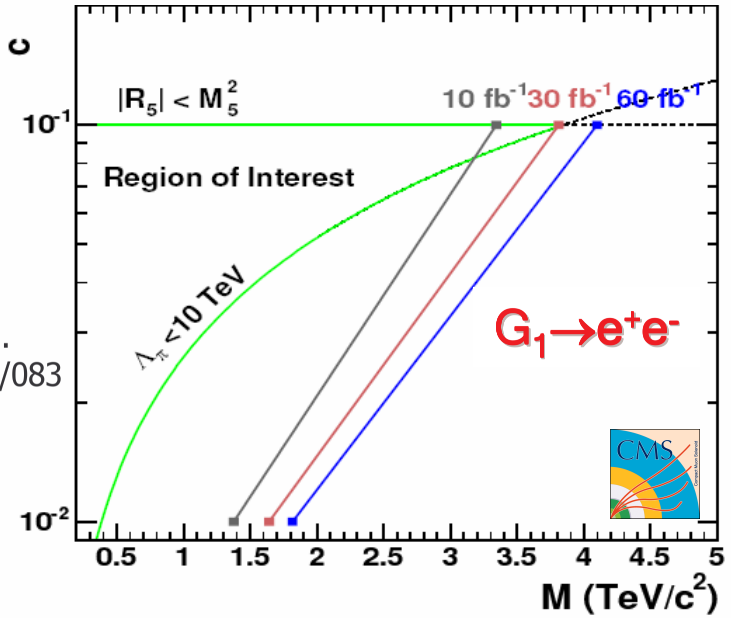






- Two muons/electrons in the final state
- Bckg: Drell-Yan/ZZ/WW/ZW/ttbar
- PYTHIA/CTEQ6L
- LO + K=1.30 both for signal and DY
- Full (GEANT-4) and fast simulation/reco
- Viable L1 + HLT(rigger) cuts
- Theoretical uncert.
- Misalignment, trigger and off-line reco inefficiency, pile-up

B. Clerbaux et al.
CMS NOTE 2006/083
CMS PTDR 2006

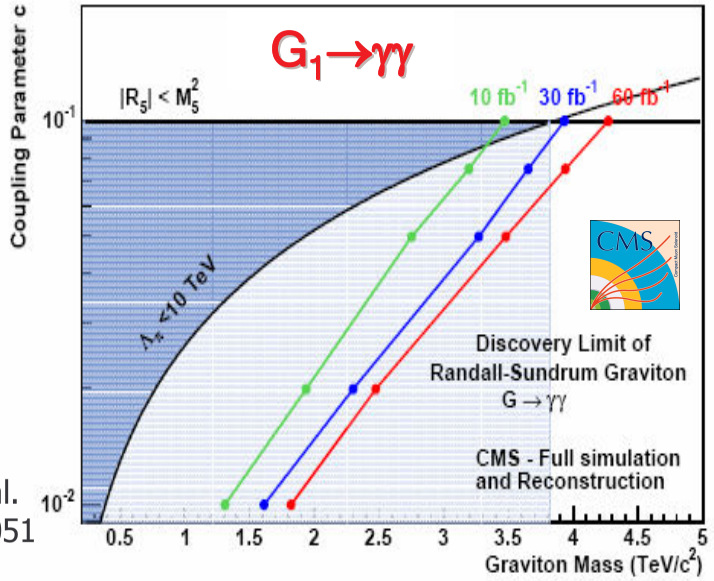


RS1 Discovery Limit

Di-photon states

- Two photons in the final state
- Bckg: prompt di-photons, QCD hadronic jets and gamma+jet events, Drell-Yan e^+e^-
- PYTHIA/CTEQ5L
- LO for signal, LO + K-factors for bckg.
- Fast simulation/reco + a few points with full GEANT-4 MC
- Viable L1 + HLT(rigger) cuts
- Theoretical uncert.
- Preselection inefficiency

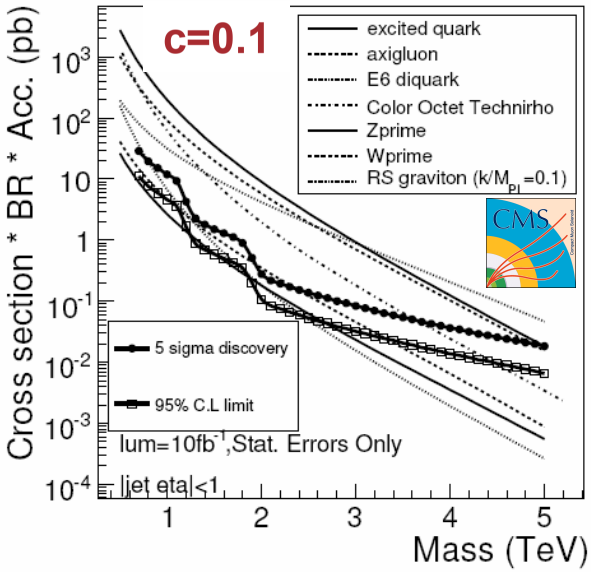
M.-C. Lemaire et al.
CMS NOTE 2006/051
CMS PTDR 2006



Di-jet states

- Bckg: QCD hadronic jets
- L1 + HLT(rigger) cuts

K. Gumus et al.
CMS NOTE 2006/070
CMS PTDR 2006



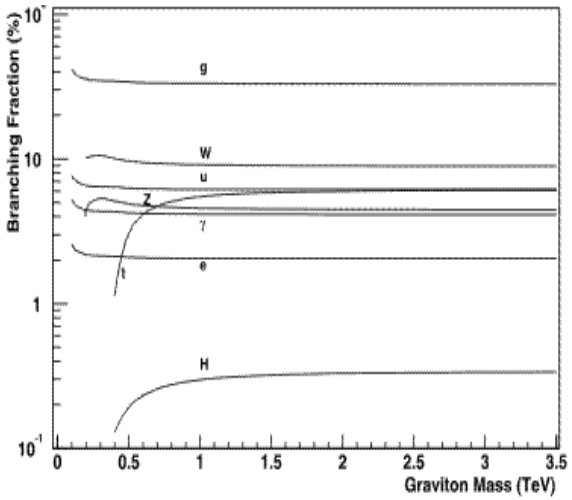
5σ Discovered Mass: 0.7-0.8 TeV/c^2

RS1 Model Parameters

A resonance could be seen in many other channels: μμ, γγ, jj, bbbar, ttbar, WW, ZZ, hence allowing to check universality of its couplings:

Channel	Point m_G, Λ_π (TeV)							
	1,10	1,20	1,30	2,10	2,20	2,30	3,10	3,20
e^+e^-	1.6	3.3	5.3	5.4	11.0	17.1	15.1	30.7
$\mu^+\mu^-$	1.9	4.5	8.2	6.2	15.2	28.2	15.1	32.7
$\gamma\gamma$	1.2	2.9	5.2	3.9	8.8	15.2	10.5	23.0
WW	11.6	44.9	-	38.2	-	-	-	-
ZZ	13.7	50.1	-	52.7	-	-	-	-
jj	19.0	77.0	-	31.0	-	-	59.0	-

Relative precision achievable (in %) for measurements of σ.B in each channel for fixed points in the M_G, Λ_π plane. Points with errors above 100% are not shown.



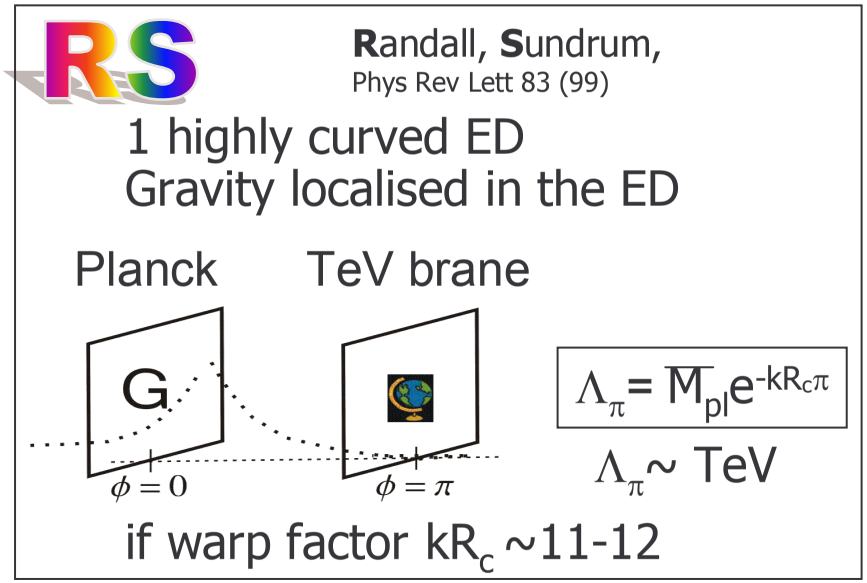
Also the size (R) of the ED could also be estimated from mass and cross-section measurements.

Allenach et al, hep-ph0211205

Allenach et al, JHEP 9 19 (2000), JHEP 0212 39 (2002)

Extra Dimensions: Motivations

M_{EW} (1 TeV) << M_{Planck} (10^{19} GeV)?



Some of these models can be/have been experimentally tested at high energy colliders