RS Graviton Searches in CMS

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The Randall-Sundrum Model

The CMS Detector

The e^+e^- Analysis

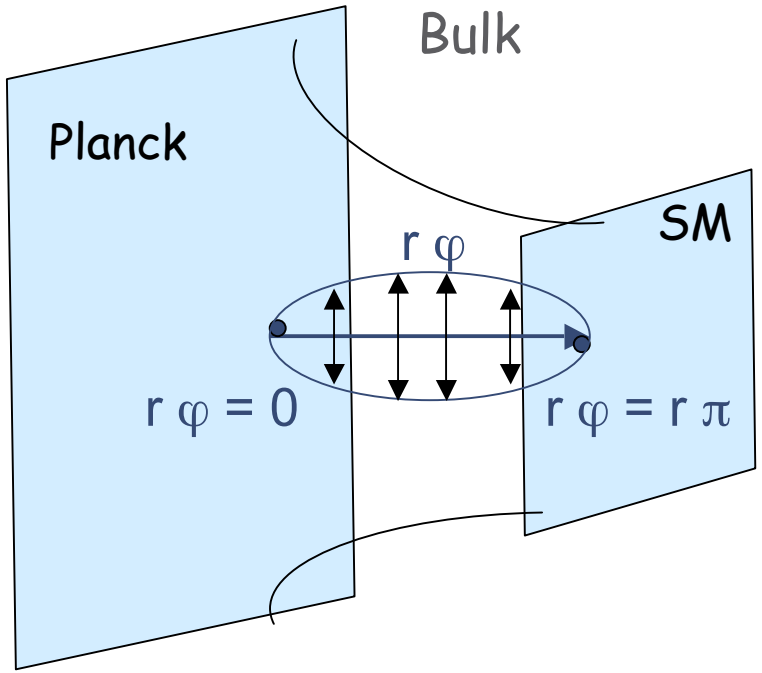
Correction for the electronics saturation

Search for massive resonances

Results & Conclusions

The Randall-Sundrum Model

One Warped Extra Dimension = Answer to the Hierarchy Problem



• 5D Anti-de-Sitter space-time with 2 branes of 4D:

Metric: $e^{-2kr\varphi}\,\eta_{\mu\nu}\,dx^{\mu}\,dx^{\nu} + r^2\,d\varphi^2$

Curvature: k ($\sim M_{PL}$)

Compactification radius: r

New coordinate: φ ($-\pi \le \varphi \le \pi$)

Traditional 4D coordinates: x^{μ}

• Gravity scale : $\Lambda_{\pi} = M_{PL}\,e^{-kr\pi}$

no new hierarchy with Λ_{π} ~1 TeV if $kr \approx 11\text{-}12$

The Randall-Sundrum Model

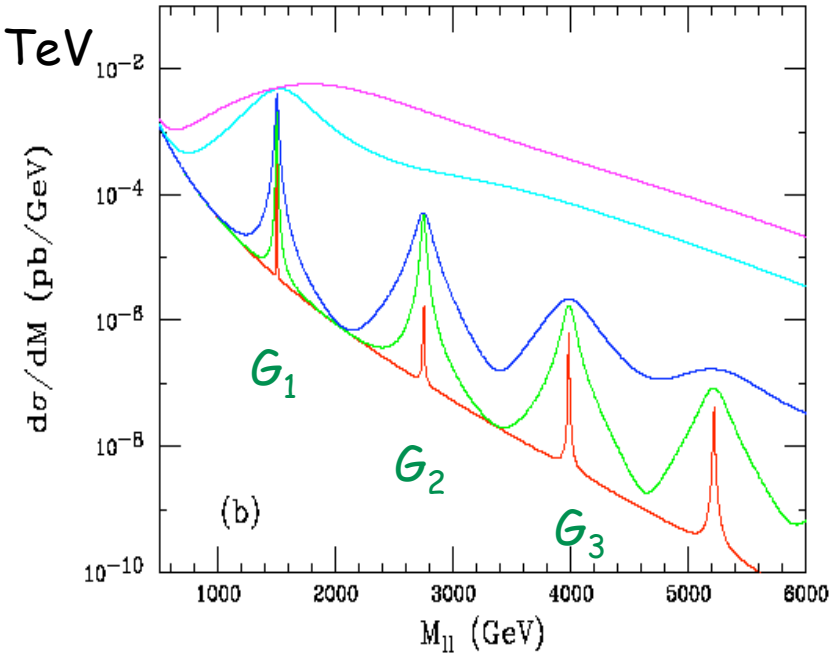
Only the graviton can propagate in 5D. On the 4D branes, Kaluza-Klein excitations of the graviton can be observed:

$$M_n = k\, x_n\, e^{-kr\pi} \quad \text{avec } J_1(x_n)=0$$

$$\Gamma_n = \rho\, M_n\, x_n^2\, c^2$$

with two free parameters in the model: $M_G=M_1$ and $c=k/M_{PL}$

Example: if M_1=1.5 TeV



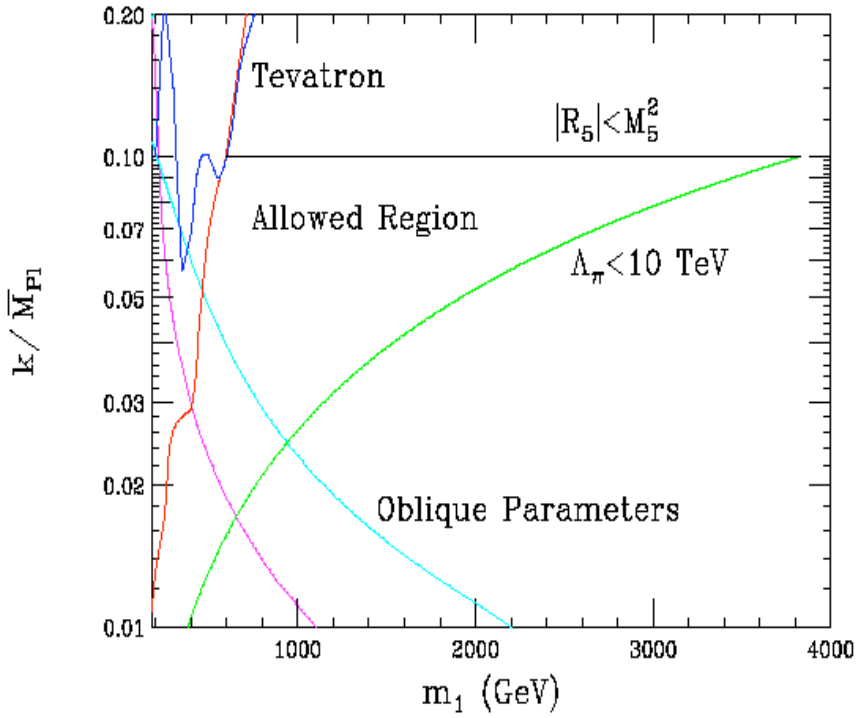
H.Davoudiasl, J.Hewett, T.Rizzo, hep-ph/0006041

c=1.
c=0.5
c=0.1
c=0.05
c=0.01

Look for the 1st KK graviton (resonance @ M_G~ TeV)

The Randall-Sundrum Model

Constraints on the two free parameters of the model: M_G and $c=k/M_{PL}$



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The Randall-Sundrum Model

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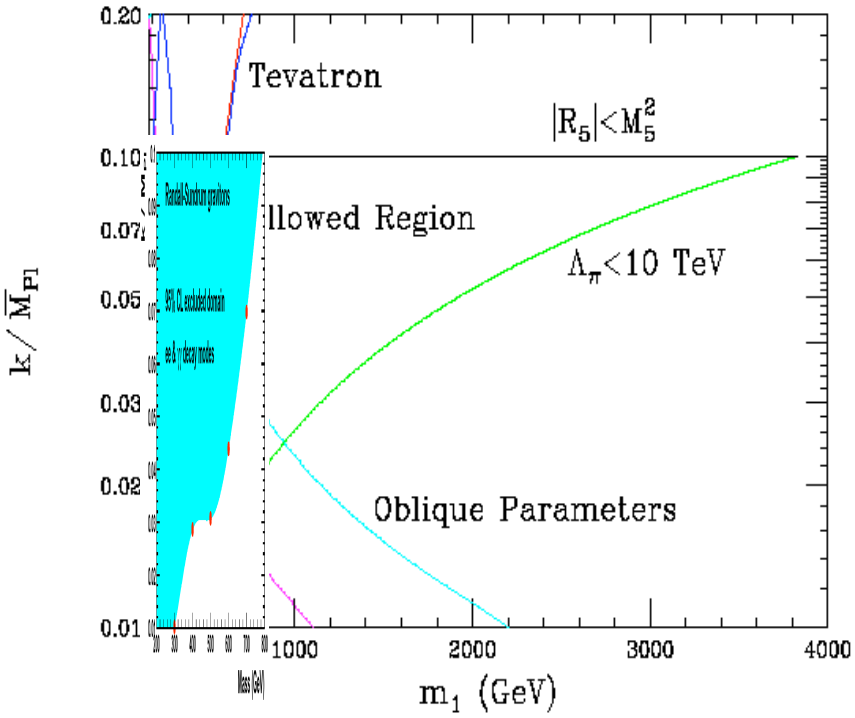

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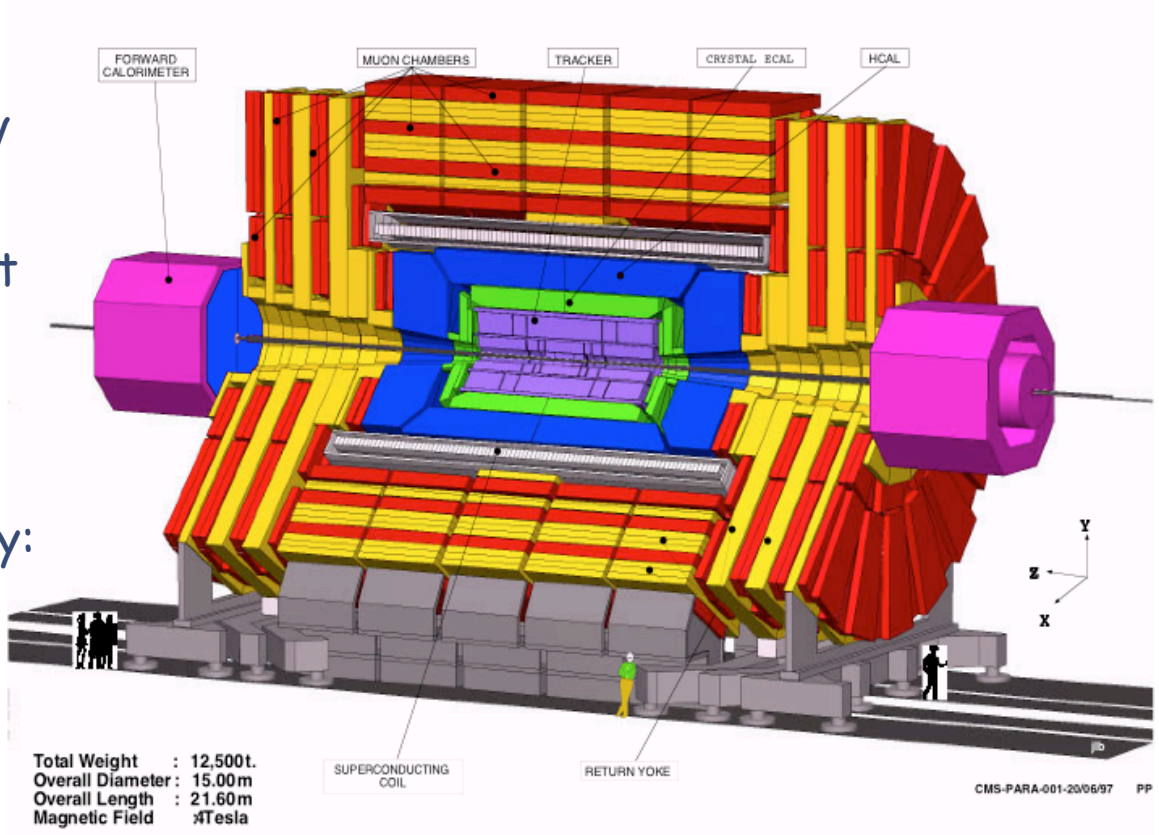
DO Run II Preliminary
95% CL excluded domain
ee & γγ modes

Which part of the plane can be access with CMS?

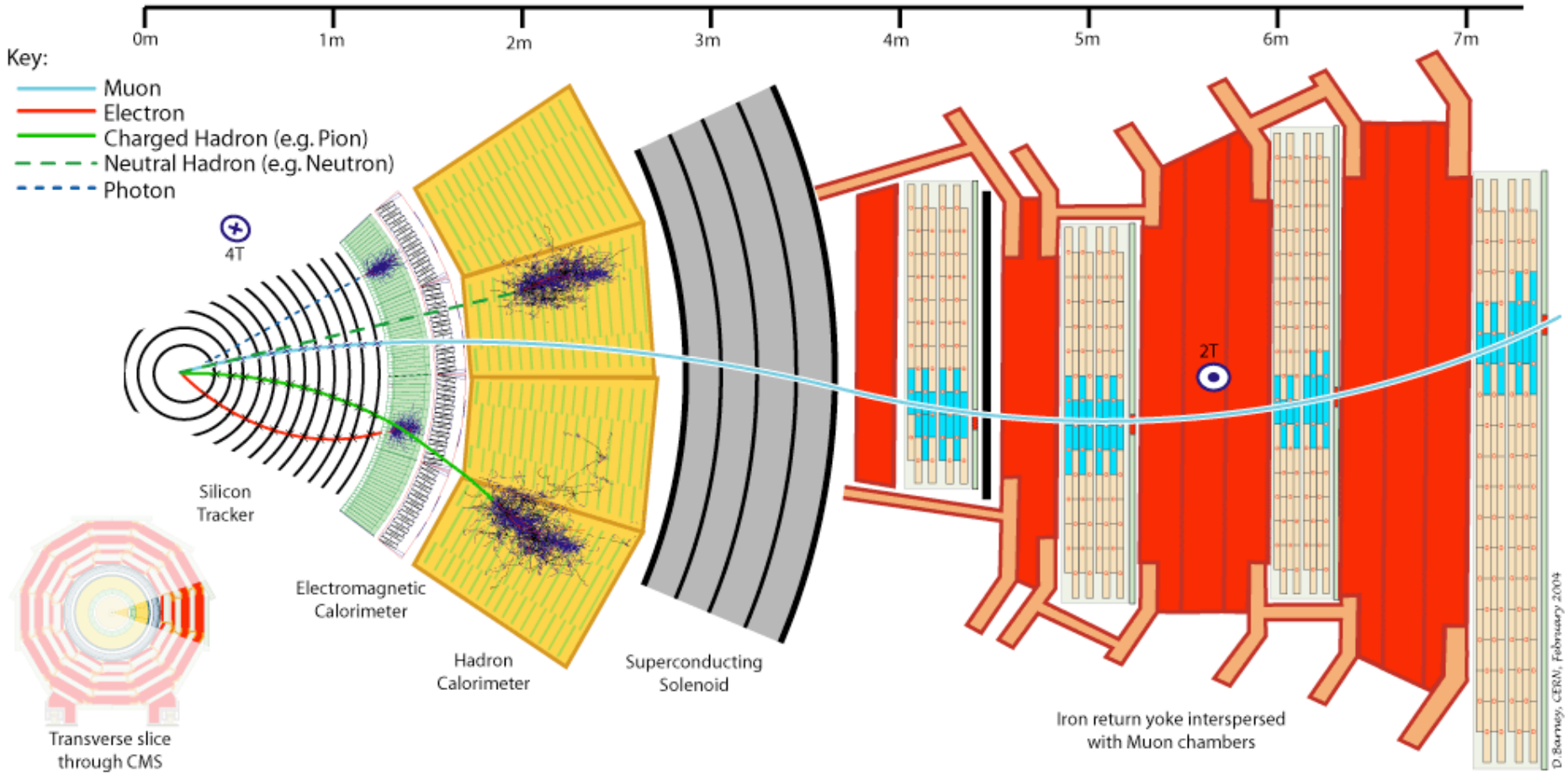
The CMS Detector

- pp collisions with 14 TeV in the centre of mass
- Start in 2007, with first physics run in 2008
- 1 year @ low luminosity: 10 fb^{-1}
- 1 year @ large luminosity: 100 fb^{-1}



⇨ Discovery of the Higgs Boson & Search for New Physics

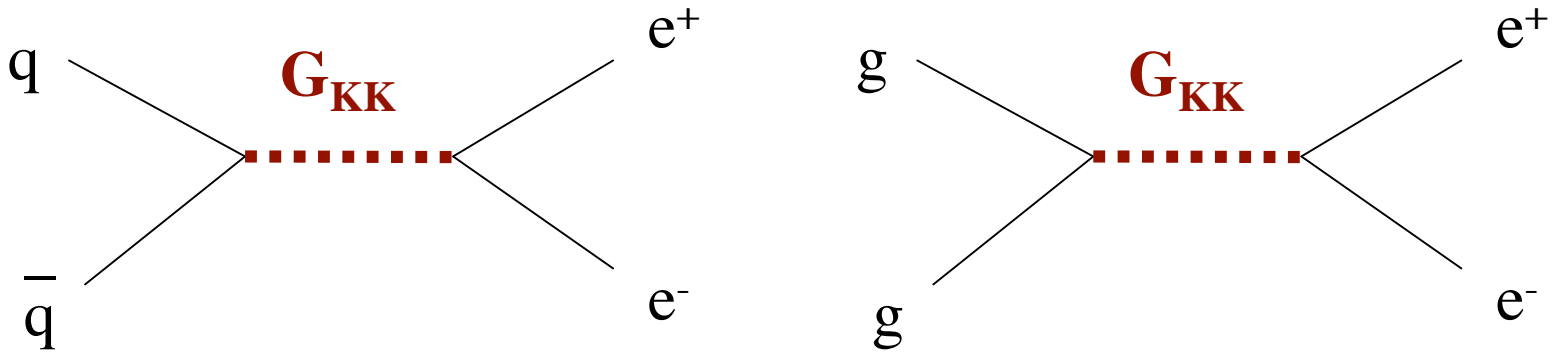
Particles in the CMS Detector



The e^+e^- channel

- **Signal:** $pp \rightarrow G \rightarrow e^+e^-$ (K Factor =1)

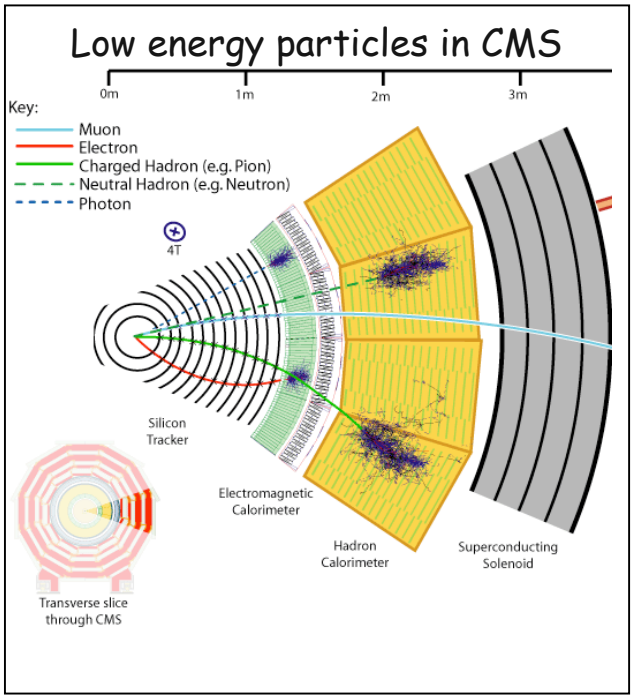
  The e^+e^- decay channel has a low branching ratio (BR=2%) but the clear signal in the electromagnetic calorimeter ECAL allows it to be the **discovery channel for Randall-Sundrum Gravitons**.



- **Background:** 2 electrons in the final state
  - Drell-Yan: $pp \rightarrow \gamma/Z \rightarrow e^+ e^-$ (K Factor=1.3)
  - [Jet faking an electron: Dijet, γ-jet, e-jet which is negligible in comparison to Drell-Yan after selection cuts]

Full Simulation & Reconstruction Analysis

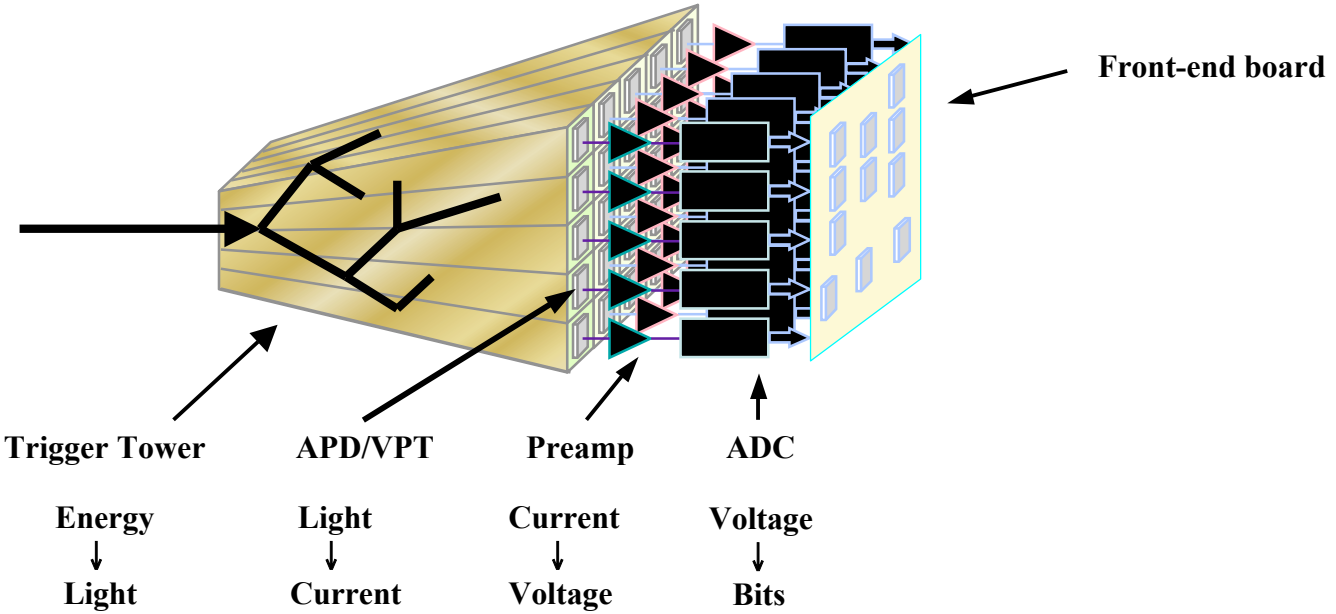
Generation with PYTHIA with a correct description of the energy evolution of the squared amplitude + inner Bremsstrahlung with PHOTOS



Full Simulation and Reconstruction chain of CMS (CMSIM & ORCA without pile-up):

- -Very high energetic electrons! Work on the electron reconstruction
- -Synchrotron radiation is included but found to be negligible in comparison to Bremsstrahlung in the tracker
- -Possible saturation of the ECAL electronics

Saturation of the ECAL electronics



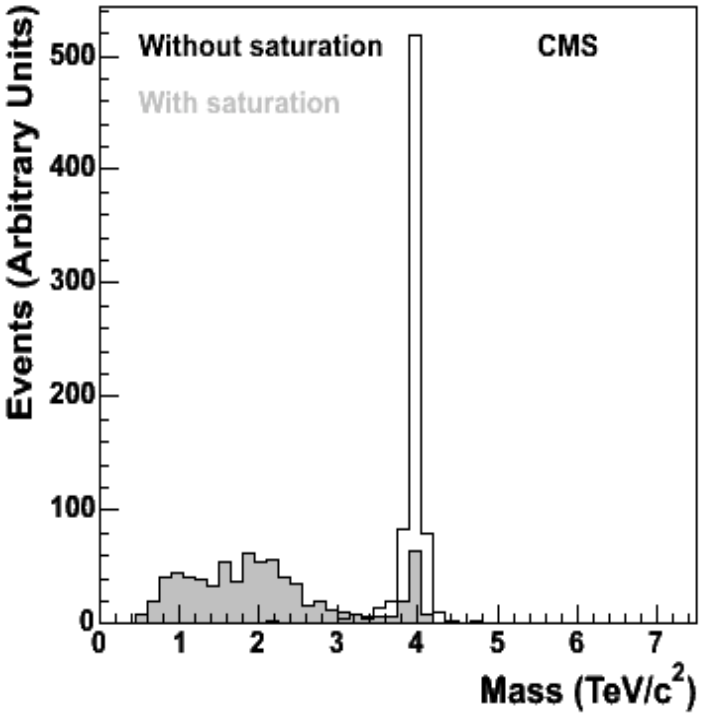
- Possible saturation of the ECAL electronics (pre-amplifiers in VFE cards) is studied:
  - Saturation expected at 1.7 TeV in the barrel with measured crystal light yield (4.5 photo-electrons/MeV)
  - Study here for saturation at 1.25 TeV (i.e. 6 p.e./MeV)
  - A simple correction is found.

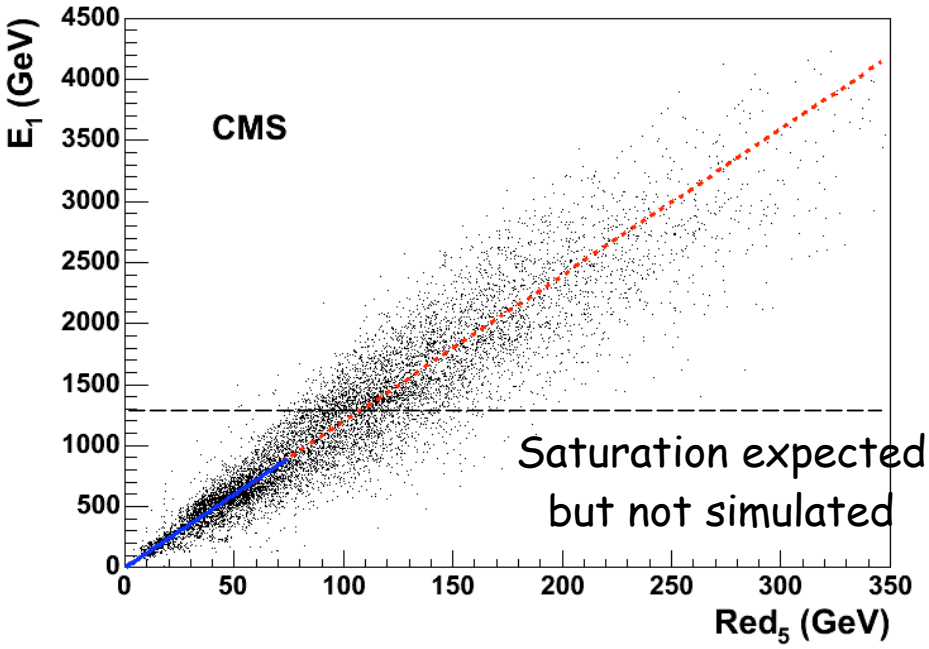
Saturation of the ECAL electronics

- The saturation has a big effect on the mass reconstruction of heavy resonances.

Idea for correction:
Correlation between
$Red_5 = E_9 - E_4$ and E_1

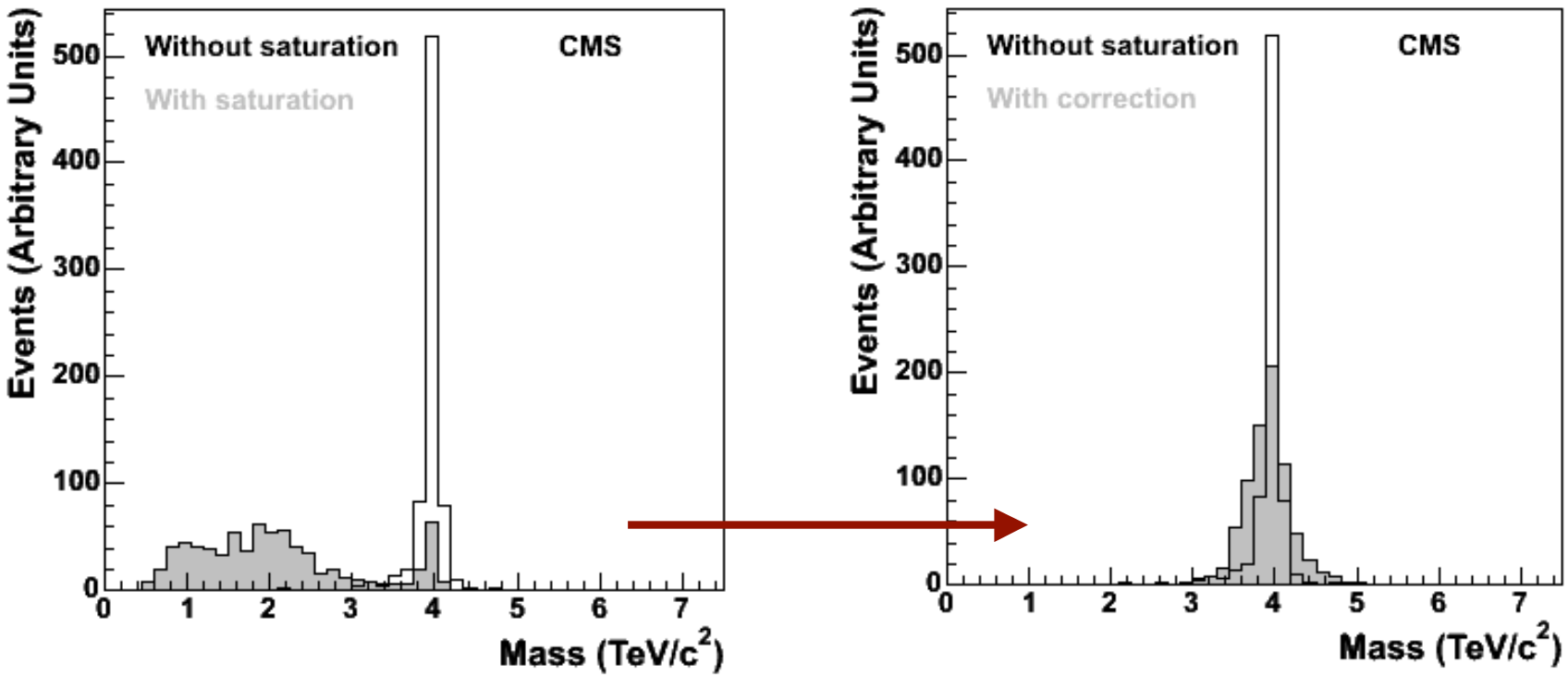
5x5 crystals





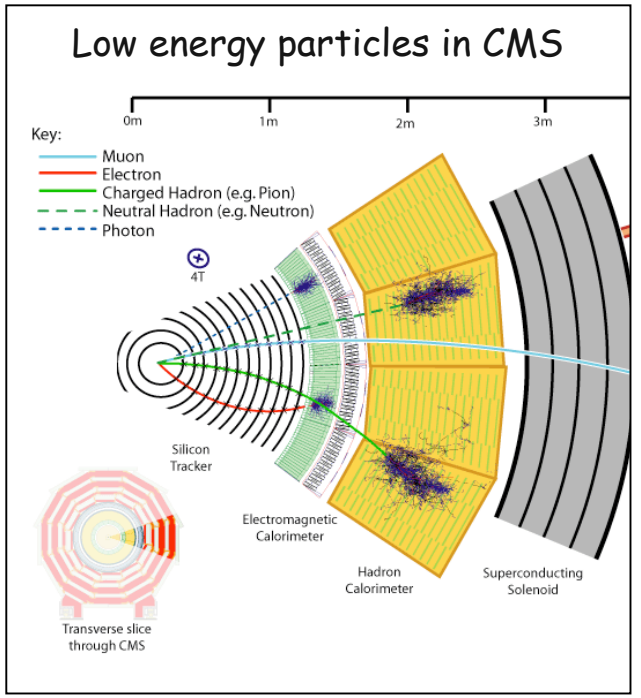
Saturation of the ECAL electronics

- This correction of the saturation allows to reconstruct heavy mass resonances.



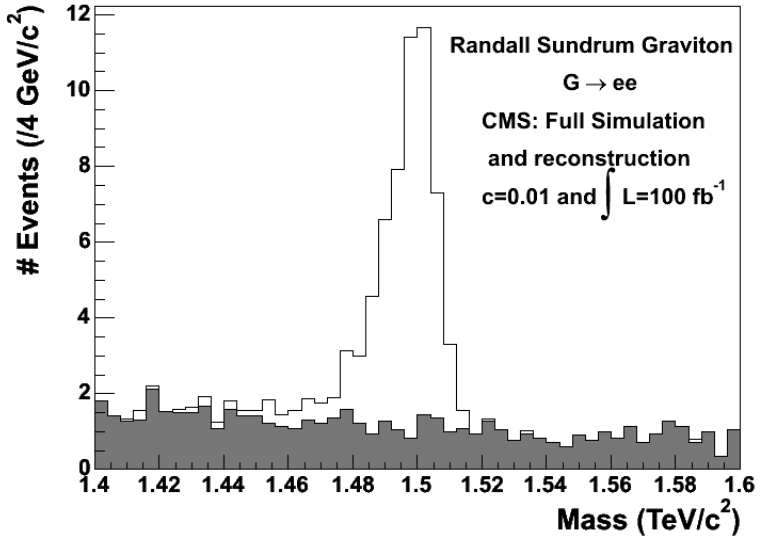
Selection Cuts

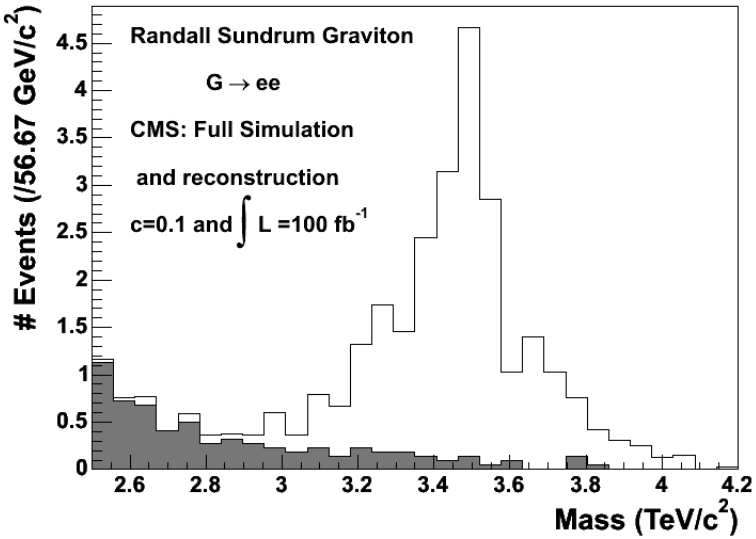
$pp \rightarrow G \rightarrow e^+e^-$



- Trigger up to Level 2.5
- 2 electrons
  - Super-Clusters:
    - $p_T > 100$ GeV,
    - $|\eta| < 1.4442$ (barrel)
      or $1.566 < |\eta| < 2.5$ (endcaps)
  - Isolated: $E_T^{cone} < 0.02\ E_T^{SC}$ in cone $\Delta r < 0.5$ (to kill big jets)
  - Electromagnetic: $H/E < 0.1$ (to kill π^+/π^-)
  - Charged: 2 tracks with at least 2 hits (to kill π^0/γ)

Search for a resonance

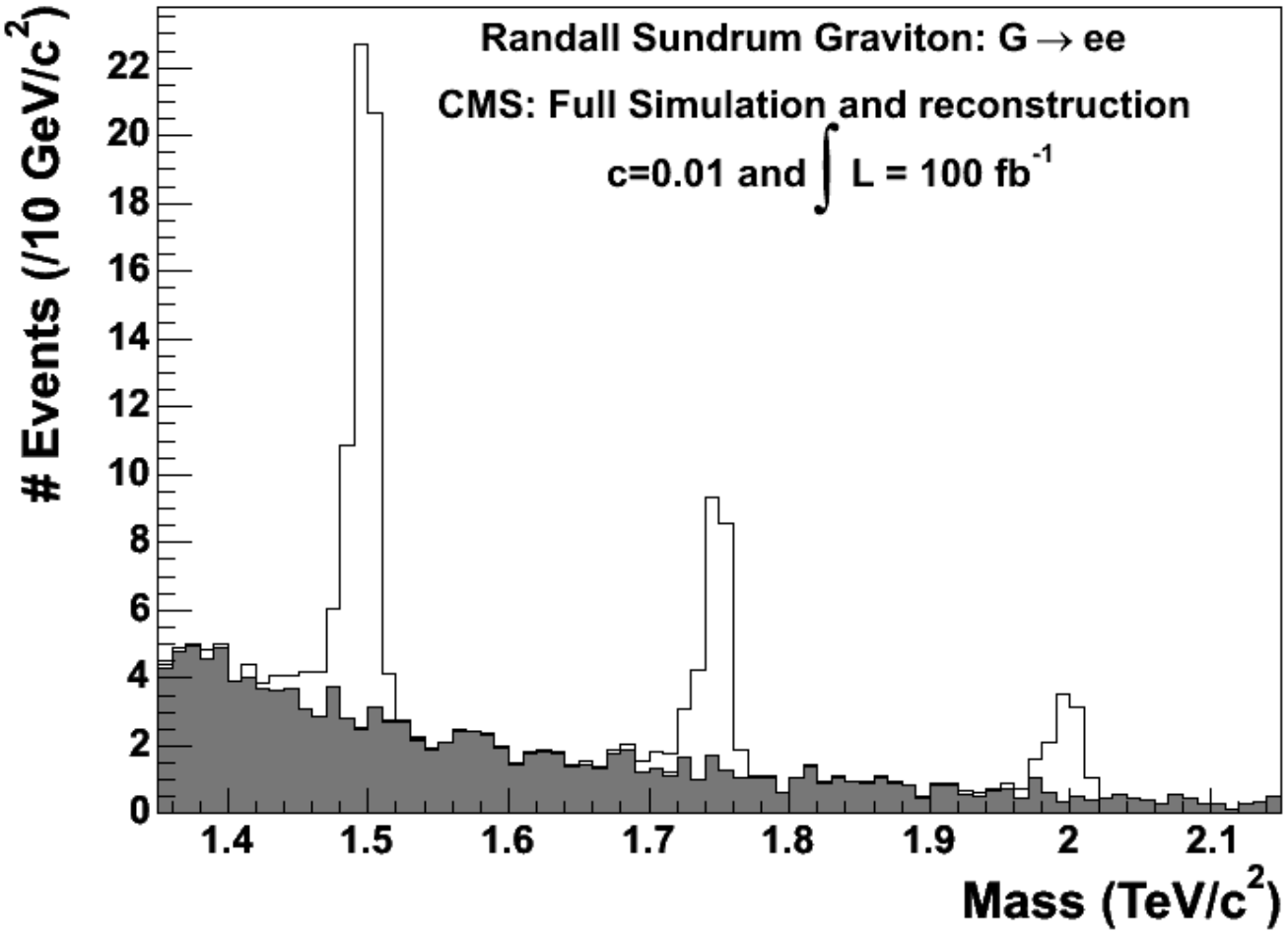




- Fit of a Gaussian to the signal distribution
- Mass window for N_S and N_B estimation: $\langle M \rangle \pm 3\sigma$

- For low coupling values: $E_1 < 1.25$ TeV (no saturation)
- For large coupling values: correction of the saturation coming from the ECAL electronics

Results for c=0.01



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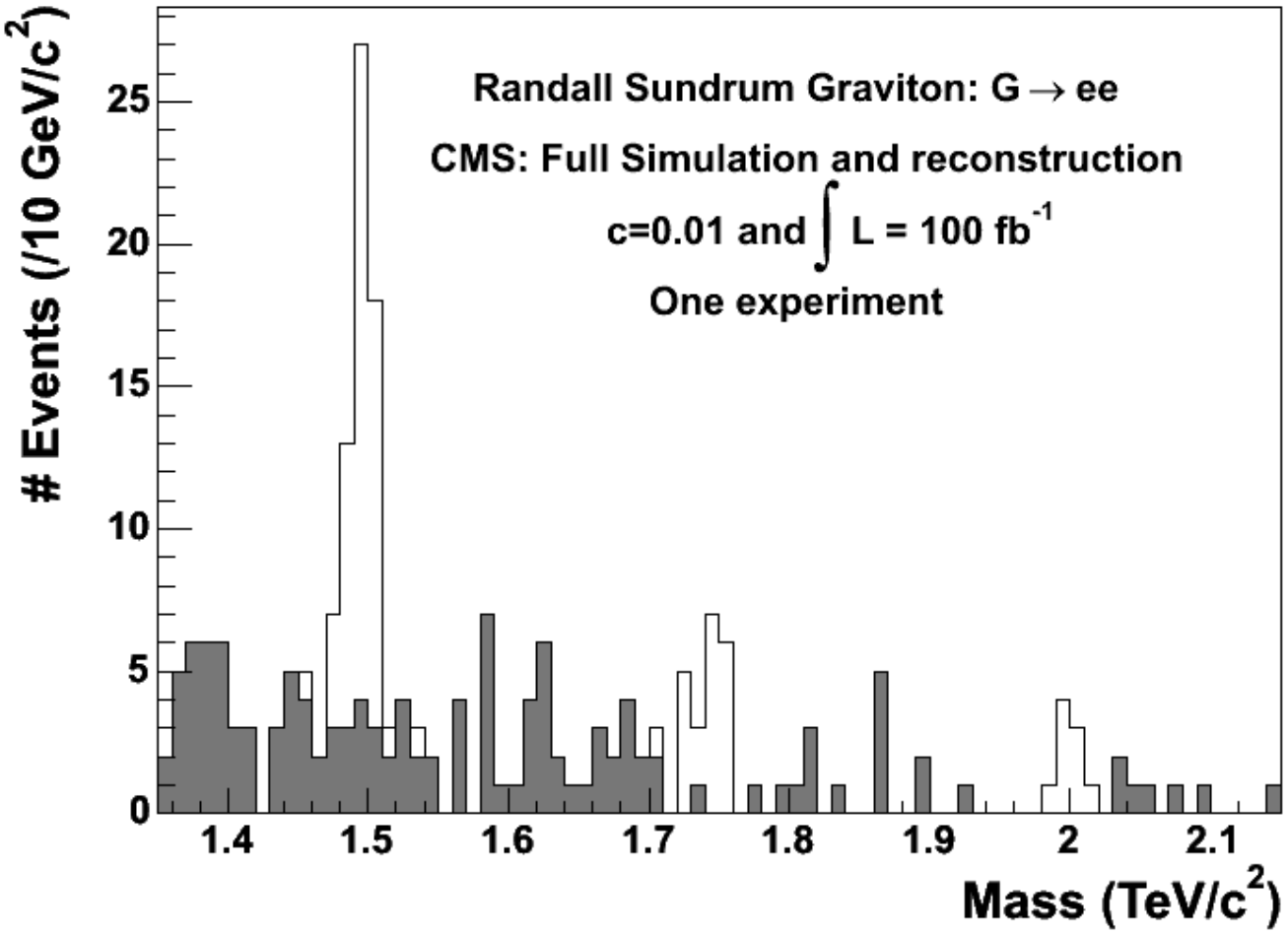
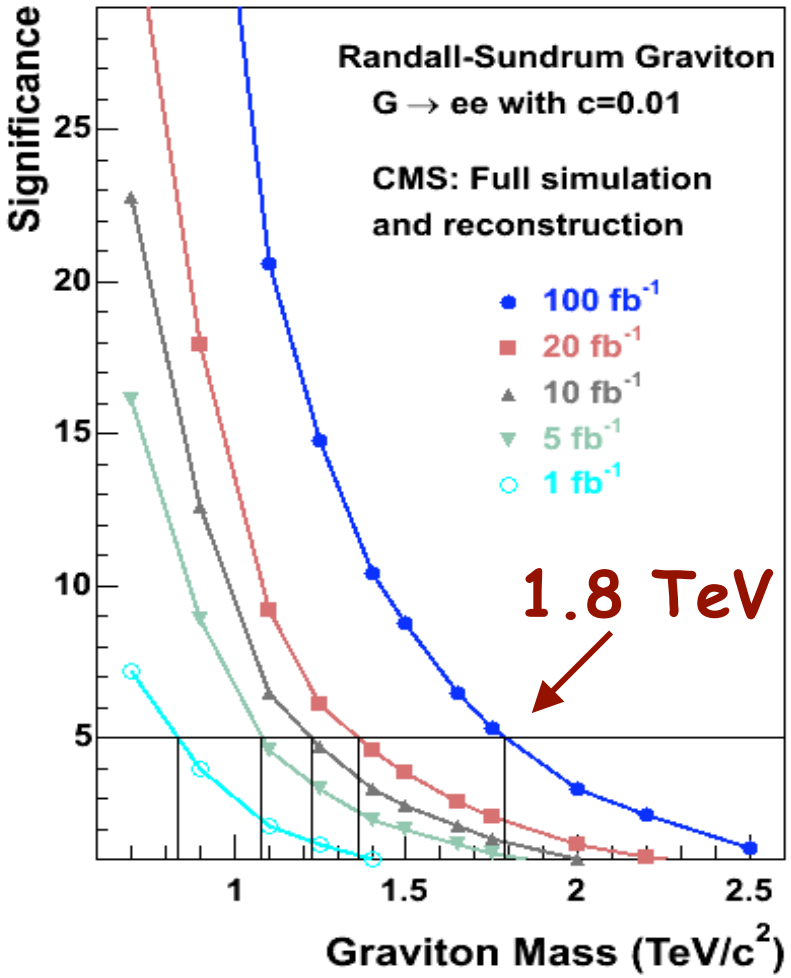
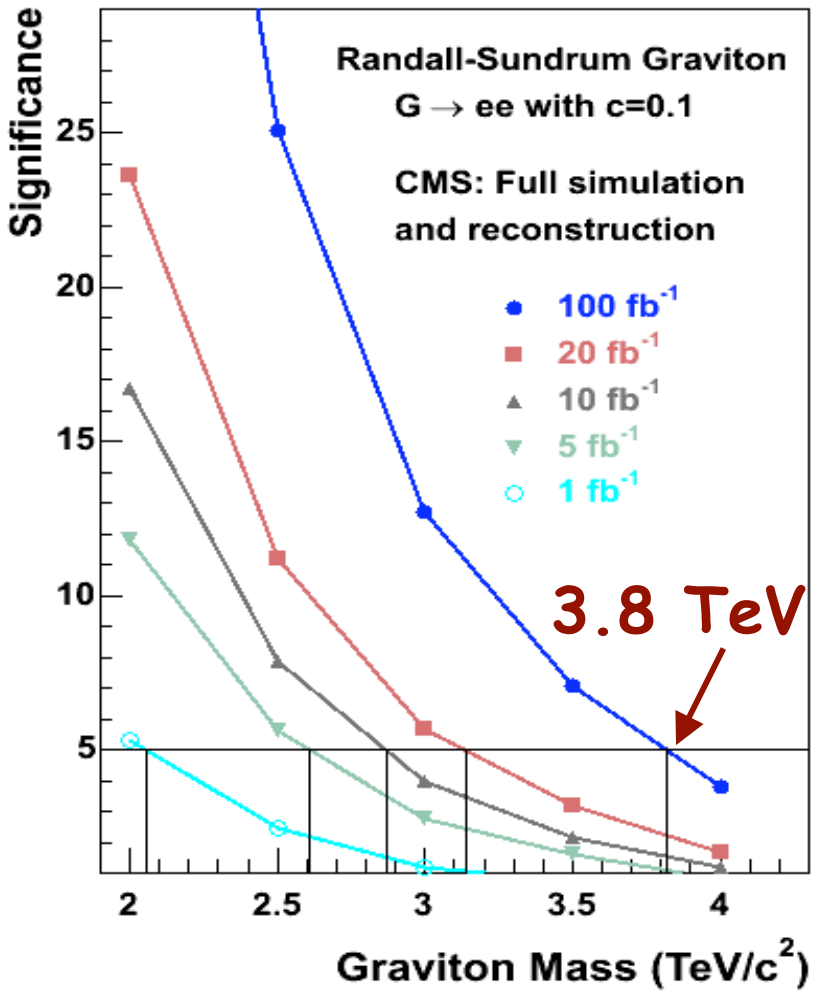


Significance

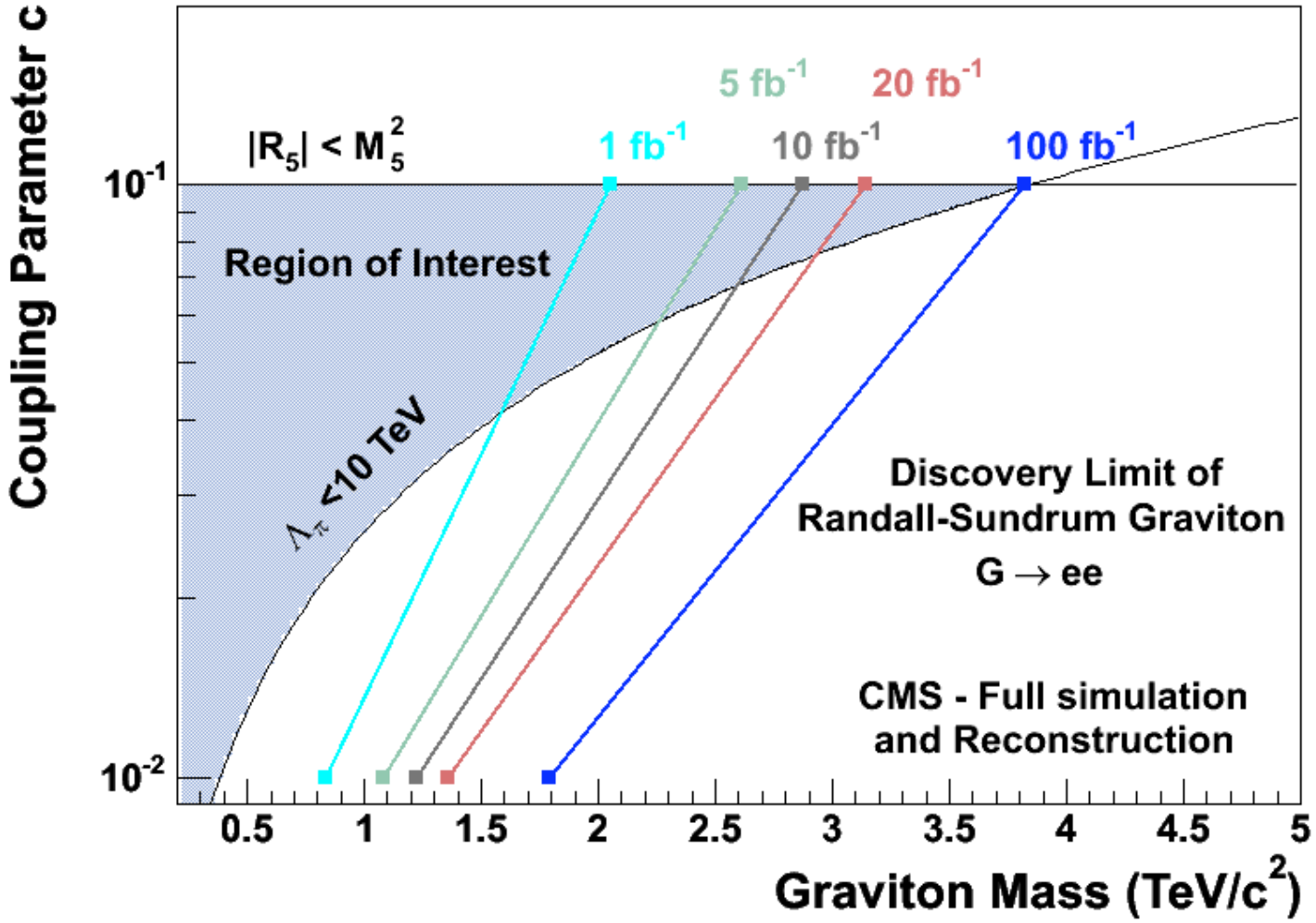
$$S = 2(\sqrt{N_S + N_B} - \sqrt{N_B}).$$





G→e⁺e⁻ : Discovery plane

CMS NOTE 2004-024



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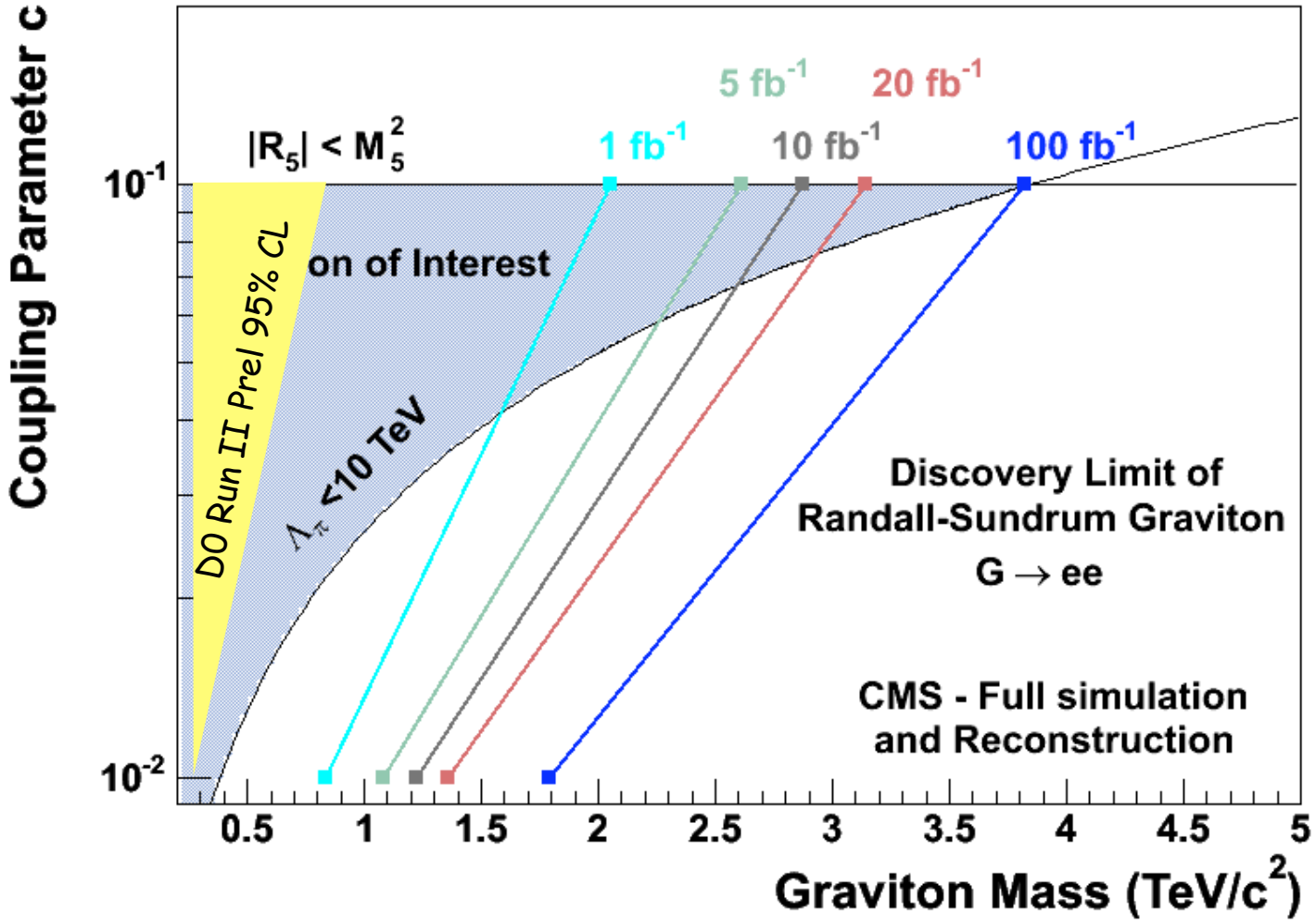
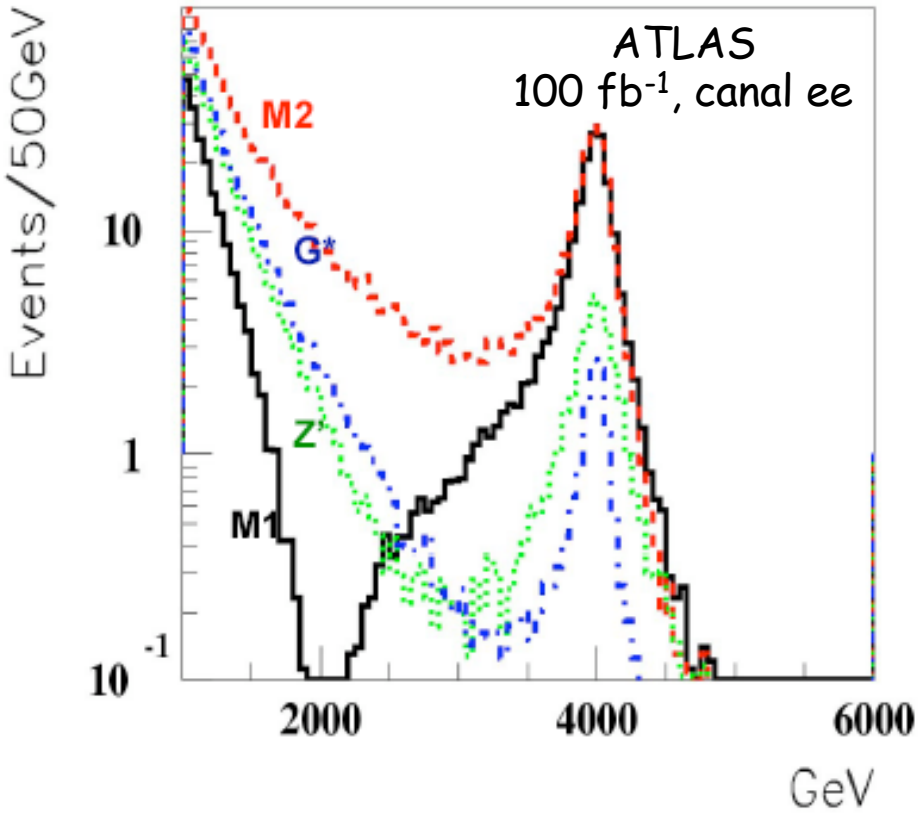
CMS NOTE 2004-024



Identification



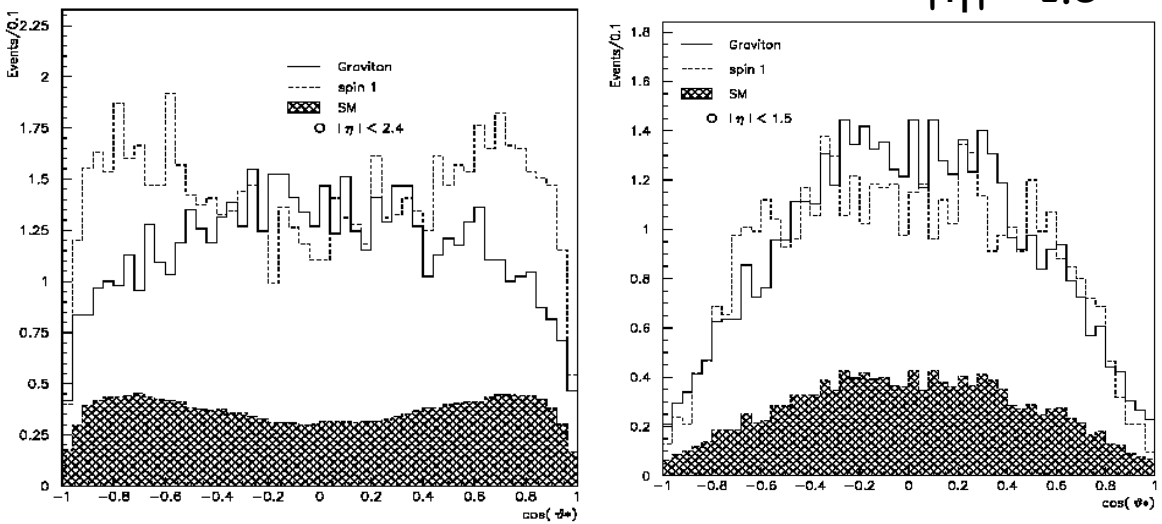
How to distinguish Gravitons from other particles?

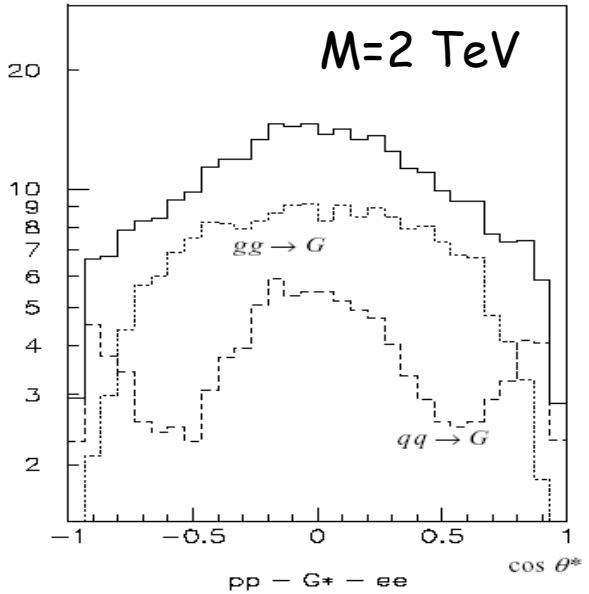
- Angular Distribution Study (Graviton is spin-2)
- Other Channel Study (Universal couplings of Graviton)

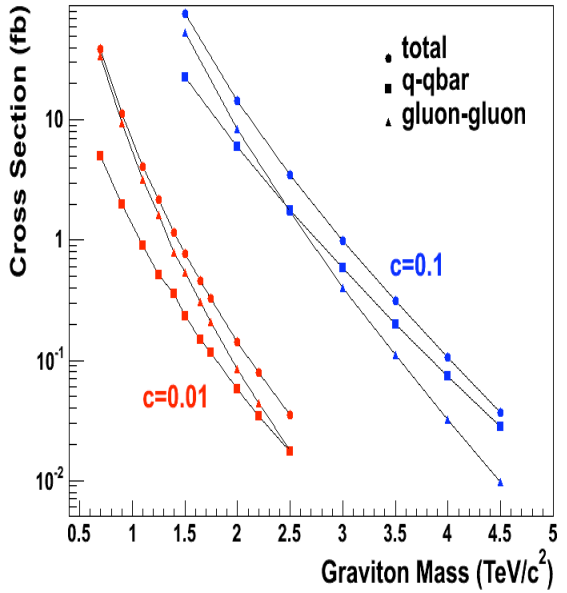
Angular Distribution

Analysis with fast simulation (CMSJET)

$|\eta| < 2.4$ M=1.5 TeV $|\eta| < 1.5$







- Need of the endcaps!
- Dependence on the Graviton mass

⇨ Need to do the study with the full simulation and reconstruction chain of CMS

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Conclusions

Full simulation & reconstruction analysis

- Study of very energetic electrons and search for massive resonances
- Discovery plane for the Randall-Sundrum gravitons $G \rightarrow e^+ e^-$:
  - With 100 fb^{-1}: the region of interest will be covered by CMS.
  - With 1 fb^{-1}: a large part of this region of interest will be accessible at the first beginning of the LHC running.
- For the Future: Work on the Identification of the Graviton nature
  - Angular Distribution (Graviton is spin 2)
  - Other channels:

    $G \rightarrow \gamma\gamma$ is allowed but not $Z' \rightarrow \gamma\gamma$.

    Test the universality of the Graviton couplings.