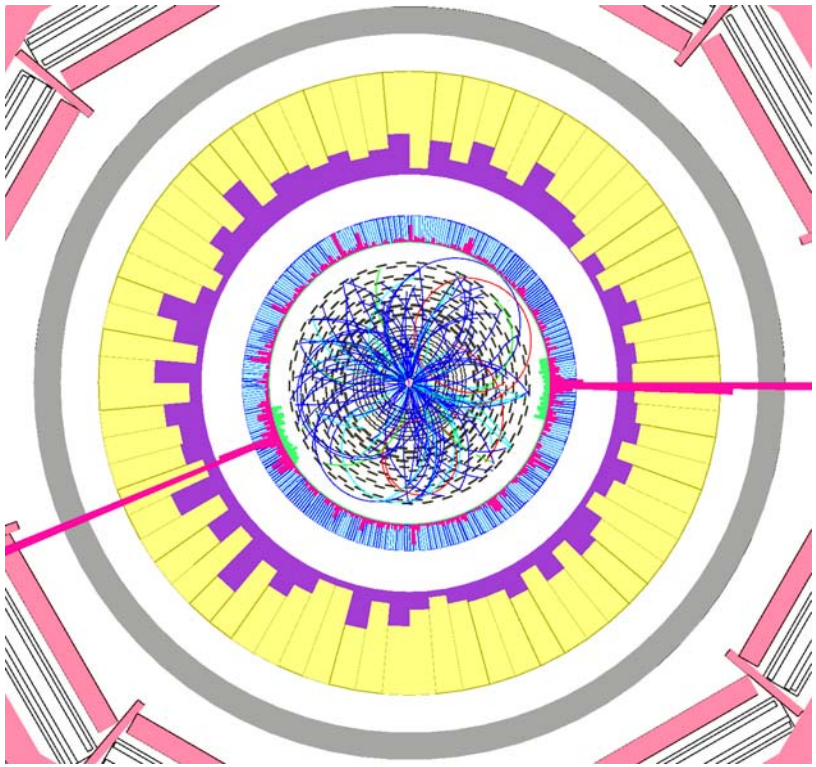
Searches for New Physics with Photons in CMS

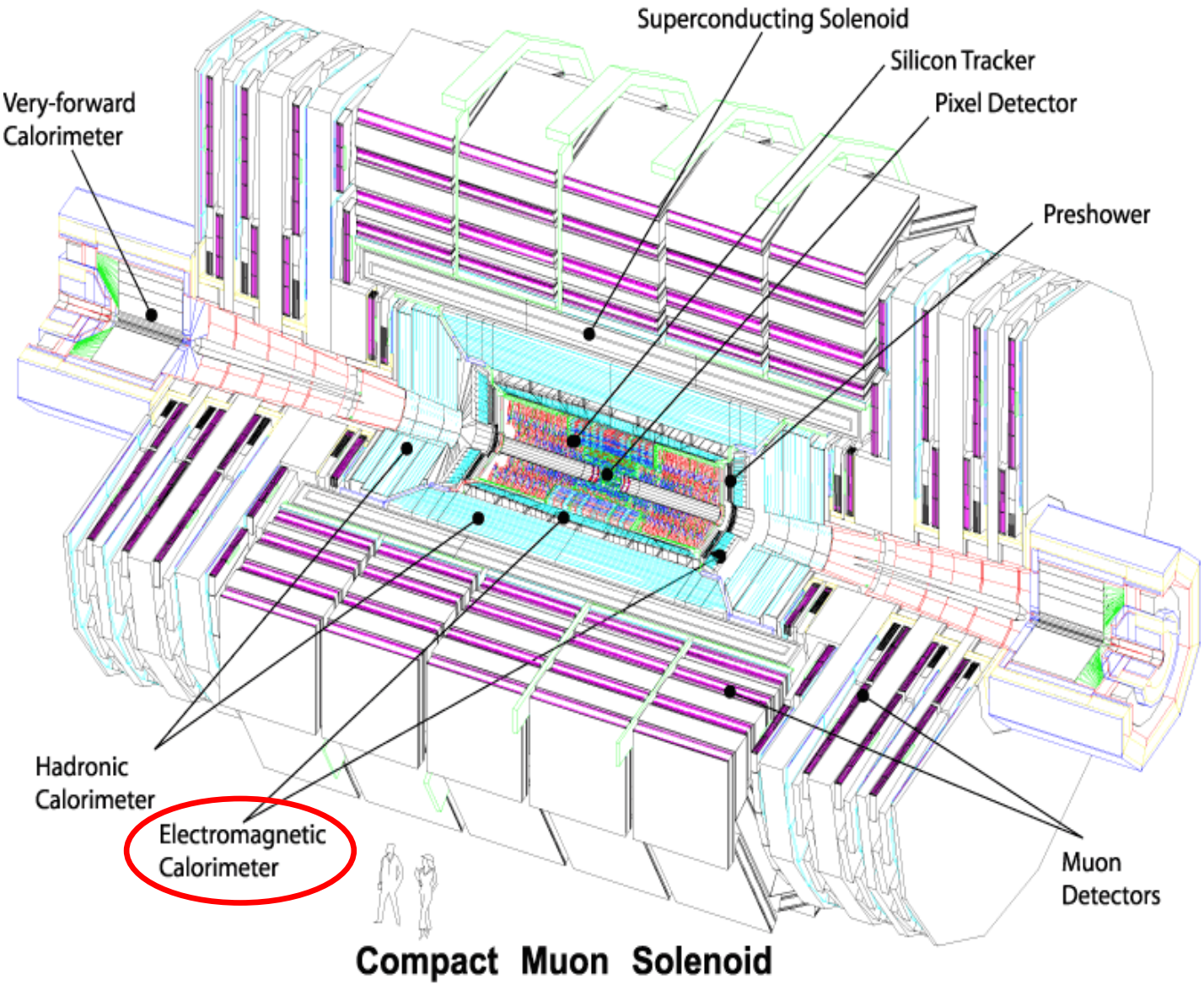
Marat Gataullin (Caltech/CMS)

LHC New Physics Signatures Workshop

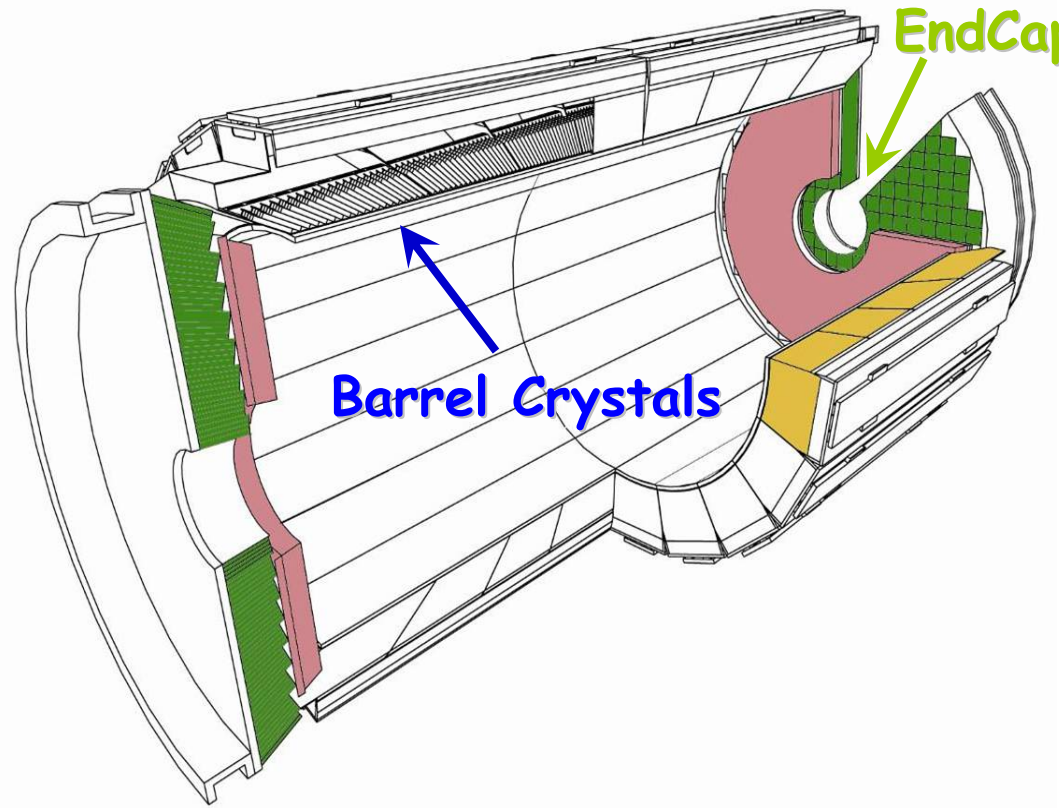
Ann Arbor, January 9 2008

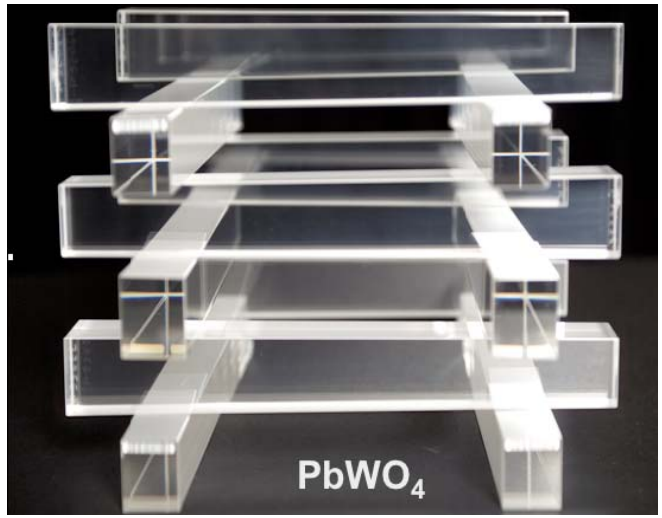


The CMS Detector



CMS ECAL: 76K $PbWO_4$ Crystals, 90 Tons





Barrel: 61,200 crystals in 170 φ-rings of 360 ($|\eta| < 1.48$)

Two Endcaps: 7,324 crystals each ($1.48 < |\eta| < 3$)

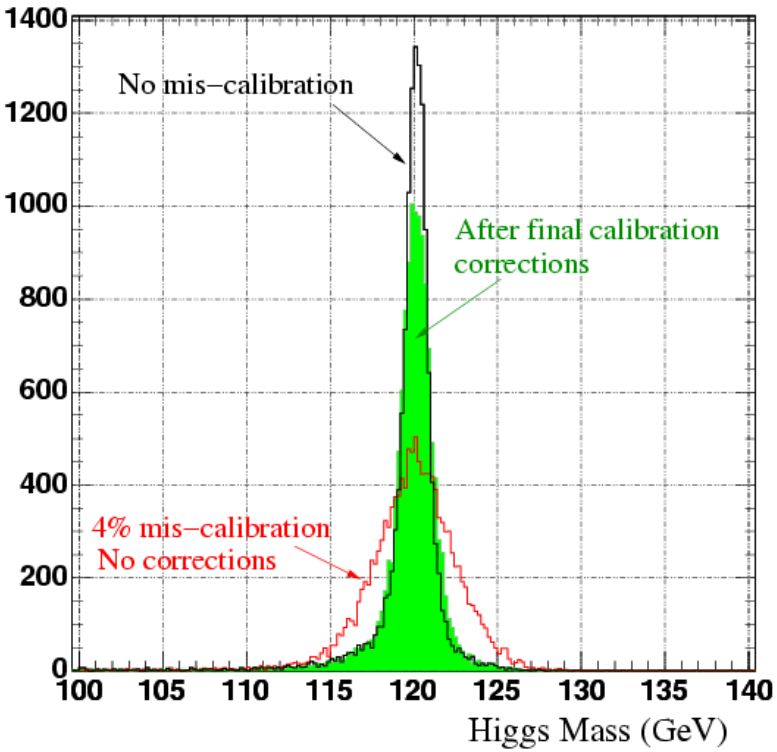
Test beams: energy resolution of <0.5% (~100 GeV e^-)

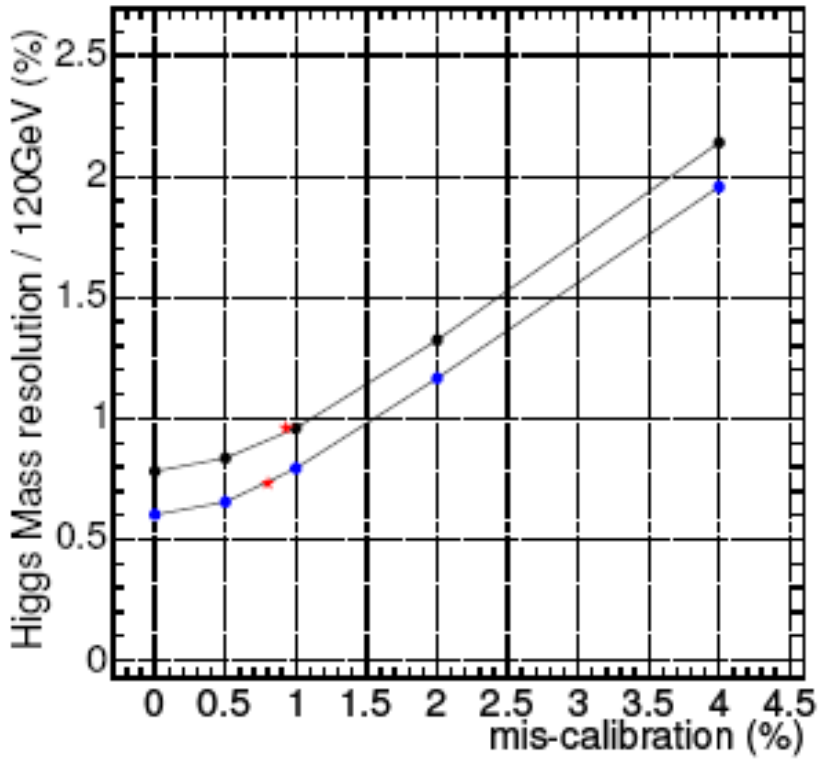
Goal: achieve and maintain it in situ at the LHC !

CMS ECAL Calibration

Crystals Pulse Amplitudes in a clustering algorithm → *Calibration* → **Particle Energy**

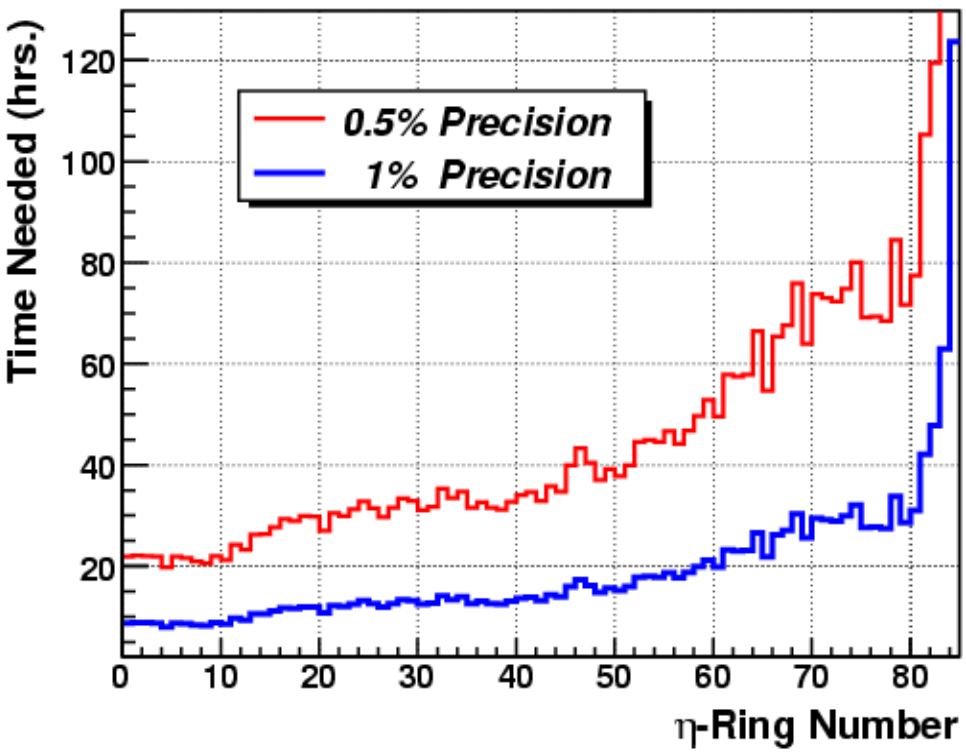
Achieving a precise in situ crystal-by-crystal calibration of the CMS ECAL will be crucial for the $H\rightarrow\gamma\gamma$ search (CMS NOTE-2006/021)



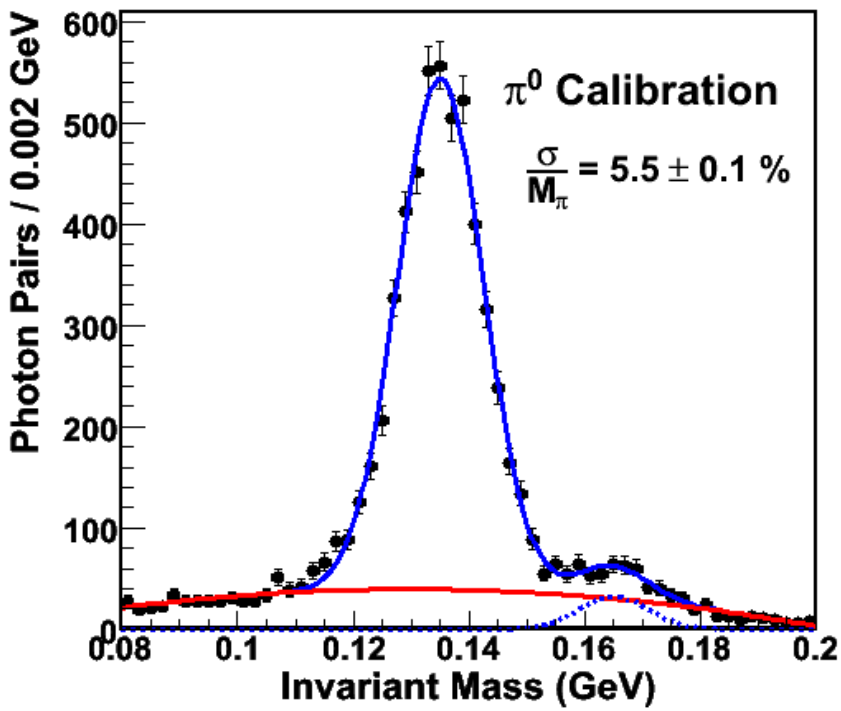


Calibration of CMS ECAL using $\pi^0 \rightarrow \gamma\gamma$ Decays

Barrel study at $L=2x10^{33}cm^{-2}s^{-1}$ gives average $\pi^0 \rightarrow \gamma\gamma$ rate of 1.5 kHz or 2,100 π^0/crystal/day with signal-to-background ≈ 2.0. Only 20 - 80 hours of running needed to calibrate 95% of barrel.

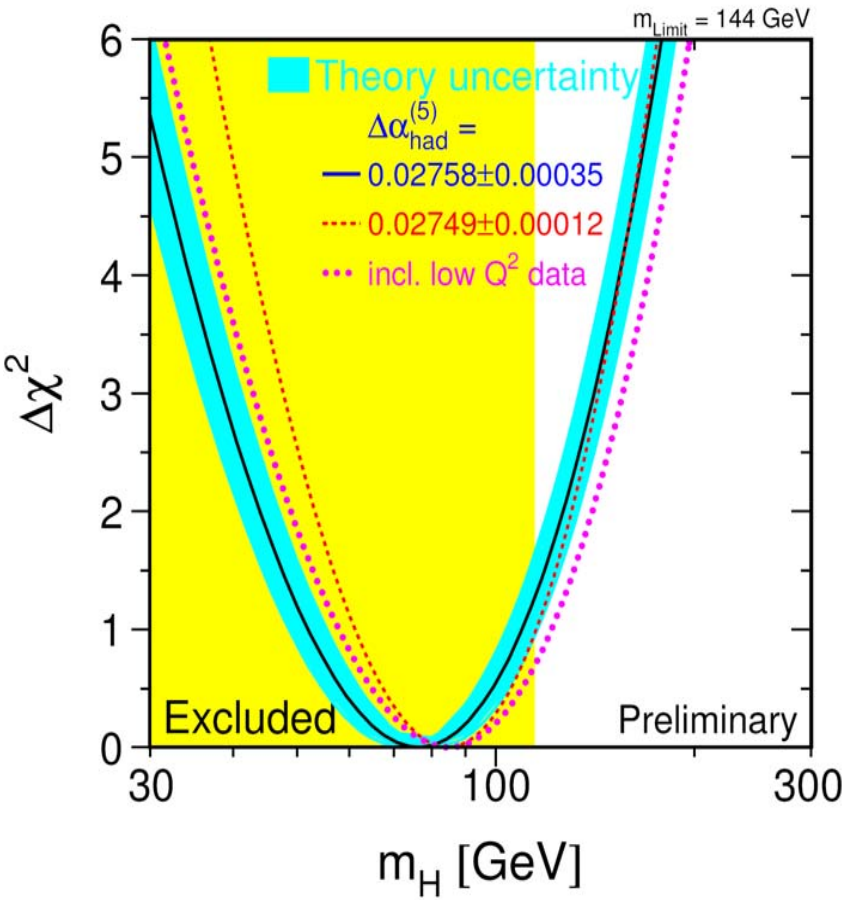


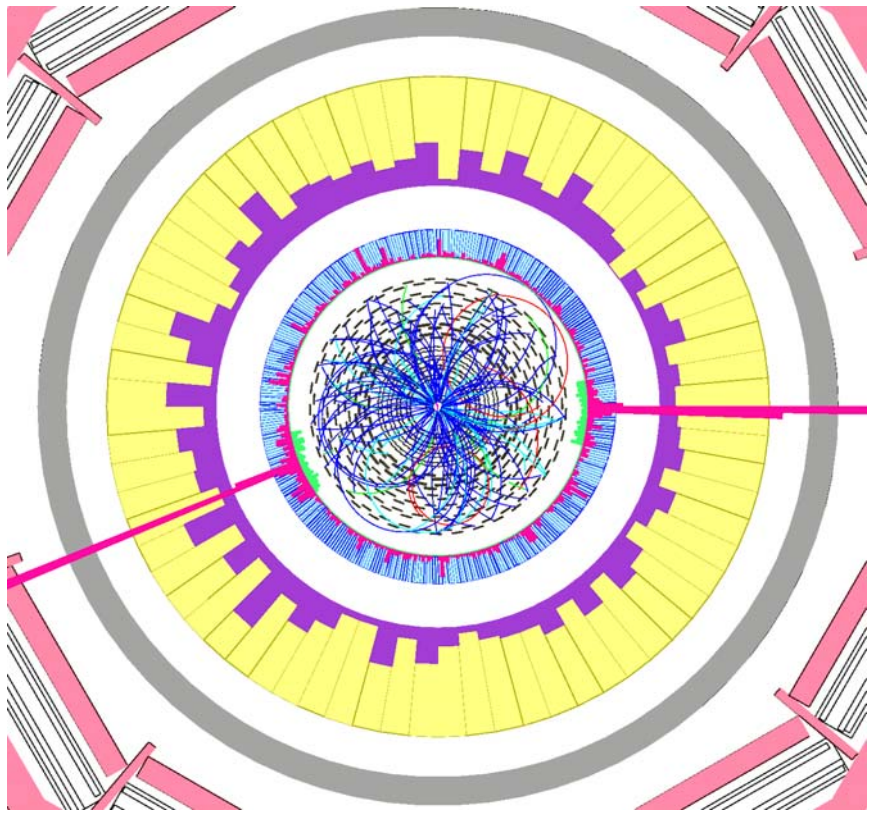
First Resonance Observed by CMS! (2006 Test beams)



Searching for Higgs at the LHC: according to the current collider data, $H \to \gamma\gamma$ decay channel is the place to look.

Summer 07: $M_{top} = 171.4 \pm 2.1$ GeV
$M_H < 144$ [182] GeV (95% CL)

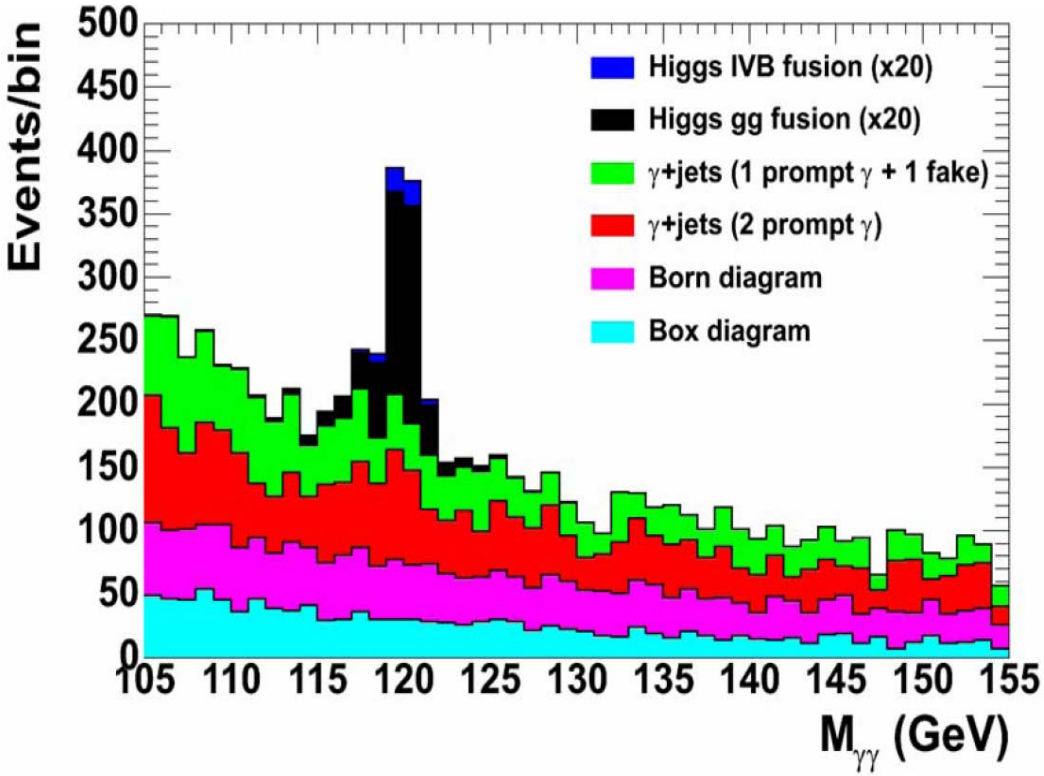




Optimized H→γγ Analysis

Integrated luminosity for 5σ discovery (CMS NOTE-2006/112)

Higgs Signal and Backgrounds

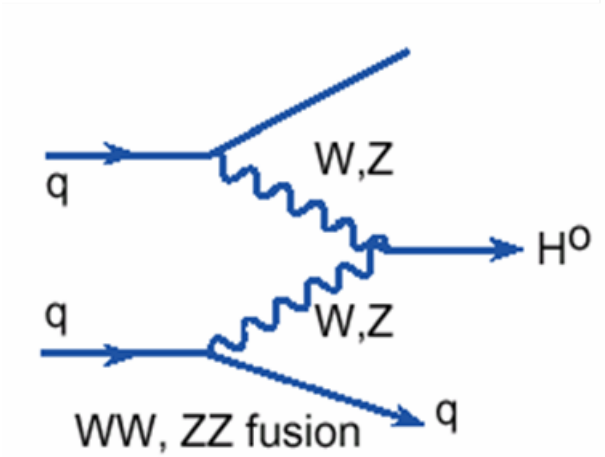


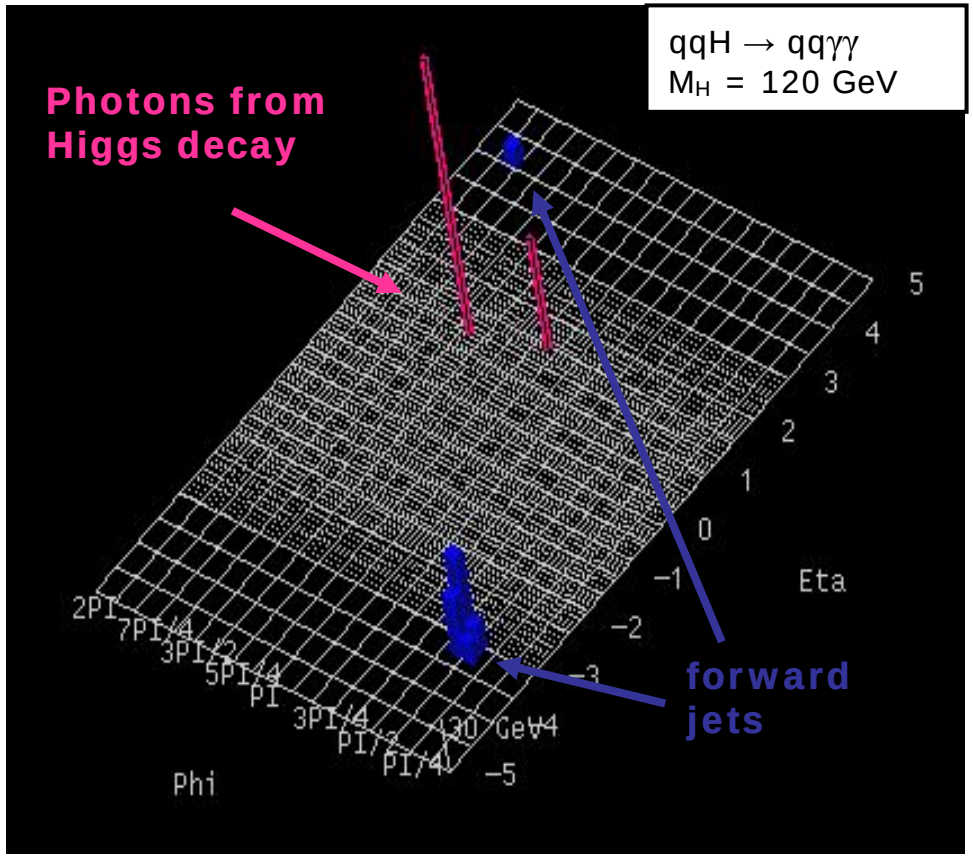
m_H (GeV)	L fb^{-1}
115	8.5
120	8
130	11
140	16
150	~30

- **Keys:** Clean Photon ID, 0.7% Mass Resolution.
- **Next Steps:** NLO MC Generators for Higgs & Backgrounds.

H→γγ: Vector Boson Fusion

CMS NOTE-2006/097





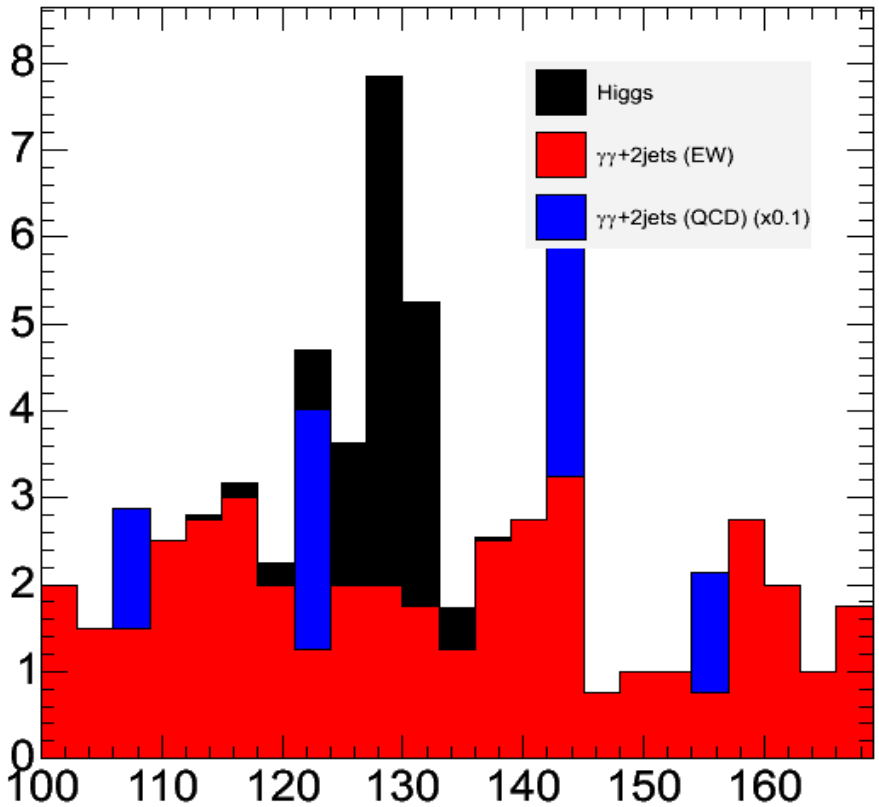
Jets from qq are at high rapidity and large Δη. Jet-tagging gives a background reduction of 95%

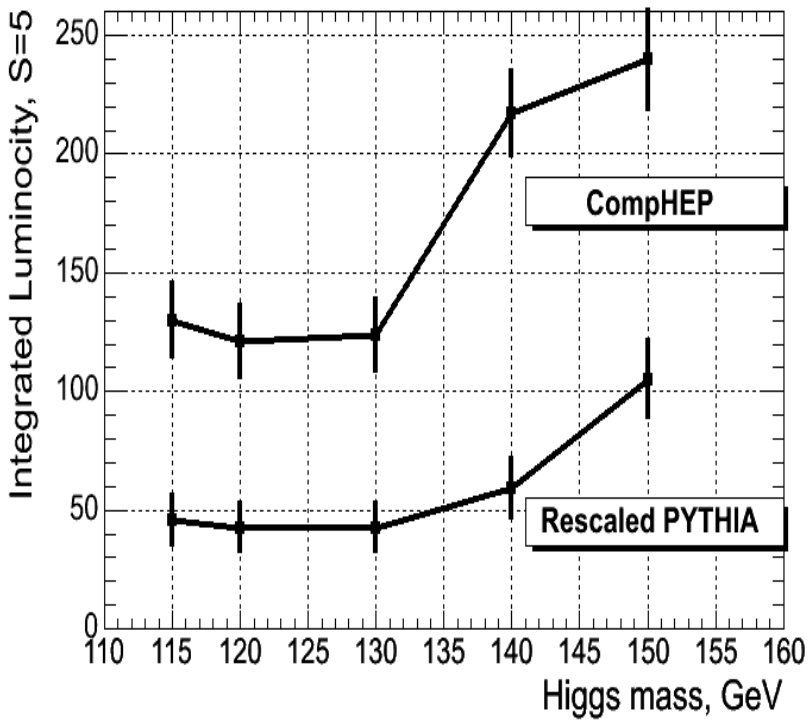
Selection Efficiency:

M_H	After photon selection	After Jet Tagging
120 GeV	37.1%	16%

H→γγ: Vector Boson Fusion

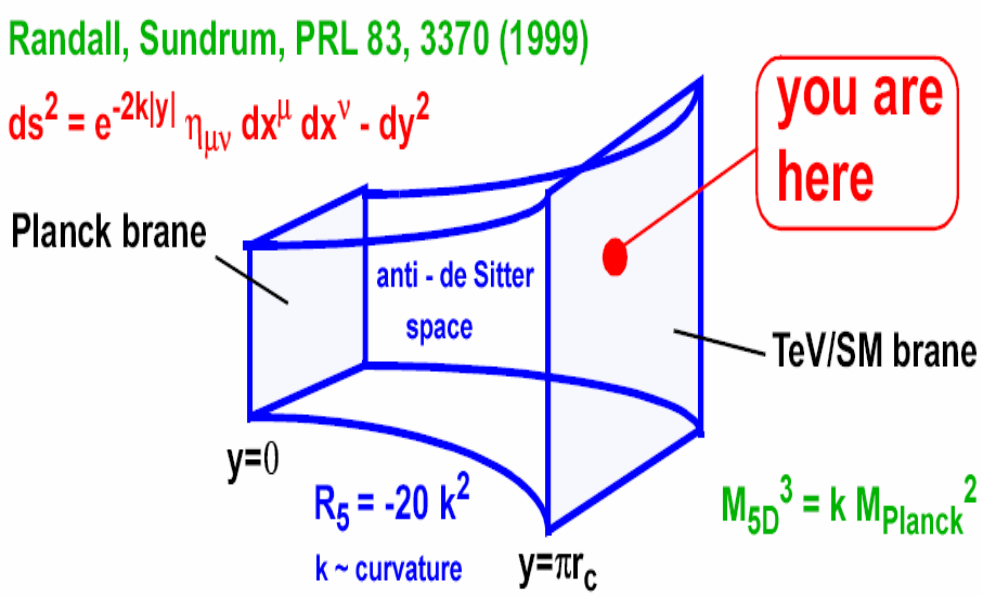
Two scenarios considered: PYTHIA and CompHEP





CompHEP includes the complete set of tree level (leading order) diagrams for the partonic subprocess ug→γγgu

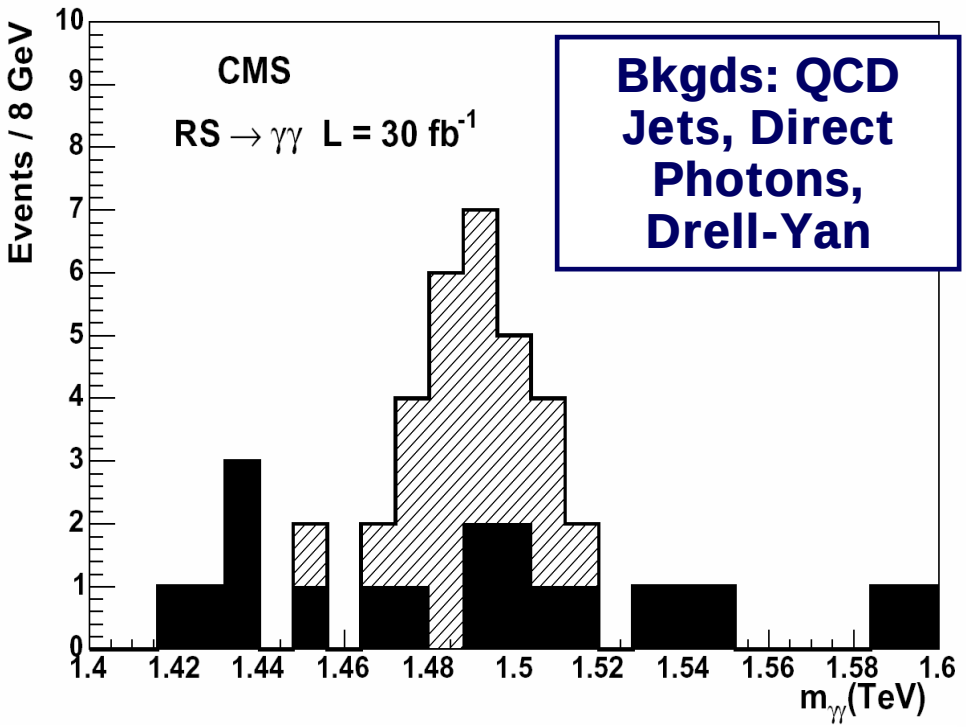
Search for RS Gravitons $G \rightarrow \gamma\gamma/e^+e^-$



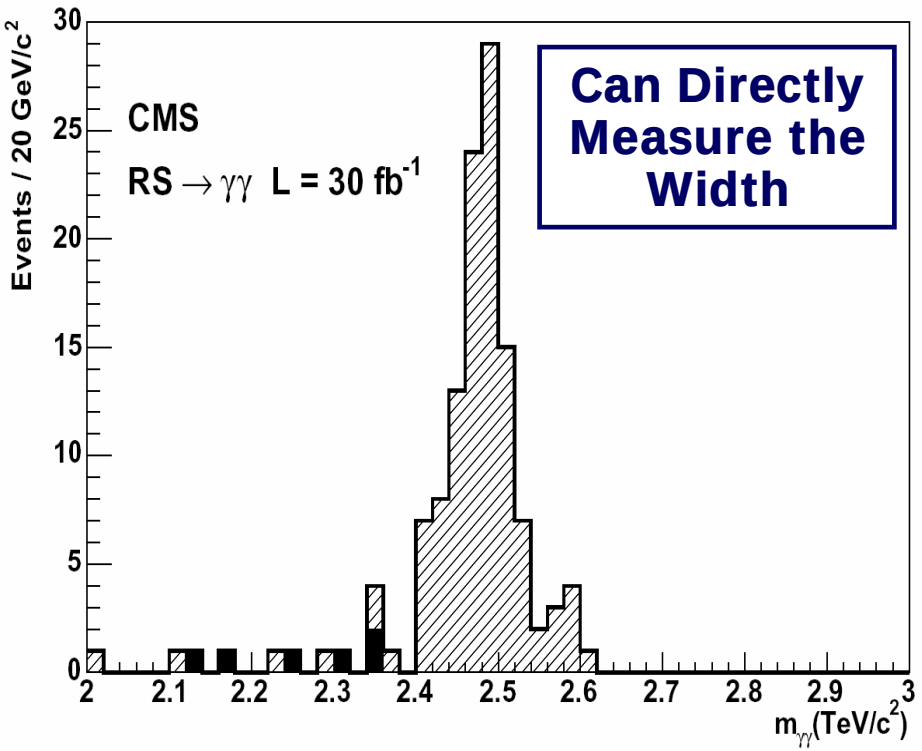
- Gravity scale = $M_{Pl}\ exp(-kr_c)$ ~TeV;
  for kr_c ~11-12, no hierarchy problem
- Graviton resonances $m_n = x_n\ k\ exp(-kr_c)$, $J_1(x_n)=0$
- Two parameters control graviton couplings and widths:
  mass m_G and constant $c=k/M_{Pl}$
- Signals: Narrow, high-mass resonance states in di-lepton and di-photon systems

RS Gravitons G→γγ

Fully Simulated with Backgrounds;
ECAL Saturation Corrected (for E_γ > 2 TeV)



Bkgds: QCD Jets, Direct Photons, Drell-Yan



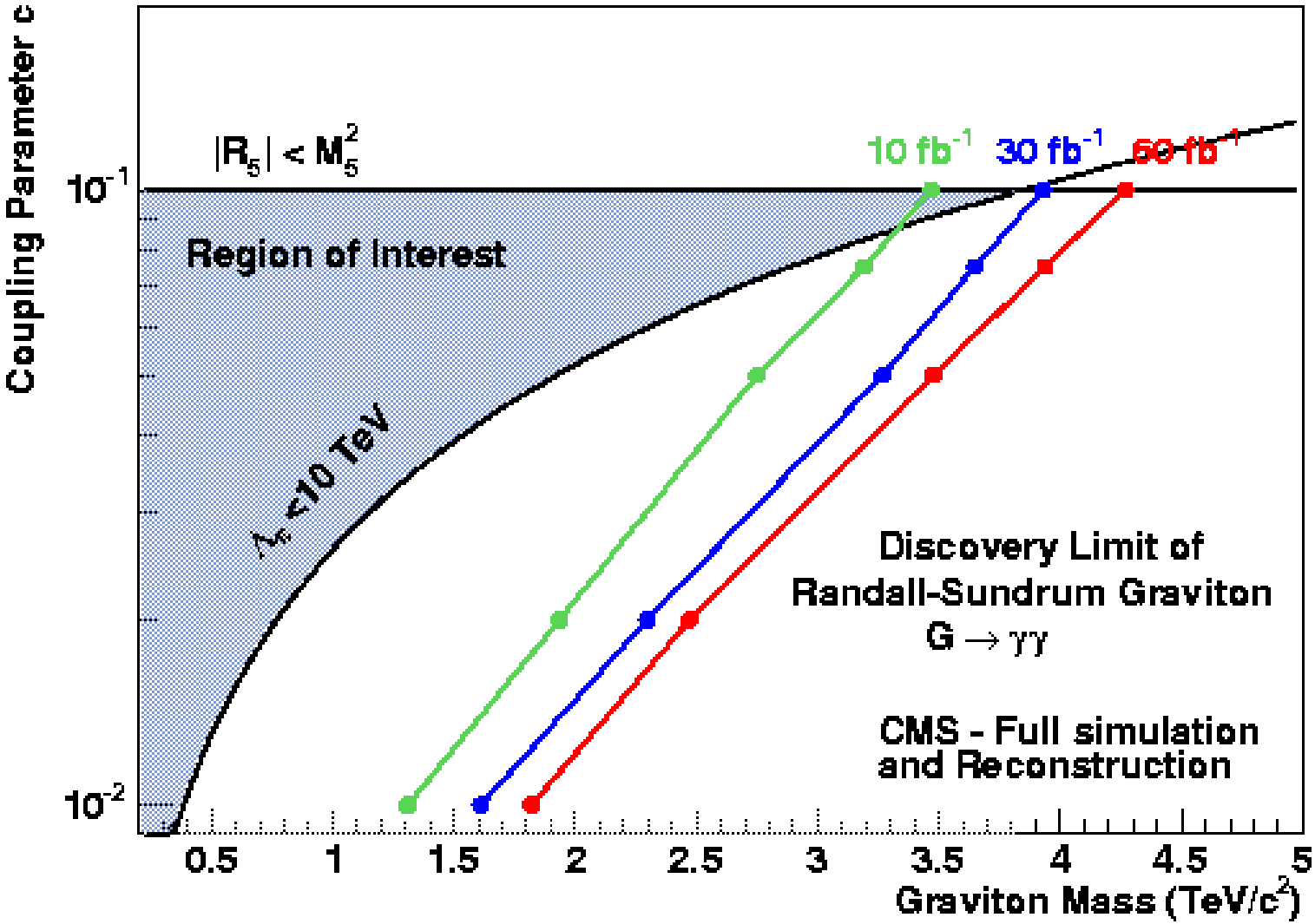
Can Directly Measure the Width

Discovery Reach

10 fb^{-1}: M_G > 3.14 TeV for c=0.1; M_G > 1.32 TeV for c=0.01
30 fb^{-1}: M_G > 3.54 TeV for c=0.1; M_G > 1.59 TeV for c=0.01

G→γγ Discovery Potential

CMS NOTE-2006/051



ADD Graviton Emission in γ+MET Channel

CMS NOTE-2006/129

Signature:

A single high-p_T photon in the central η region.

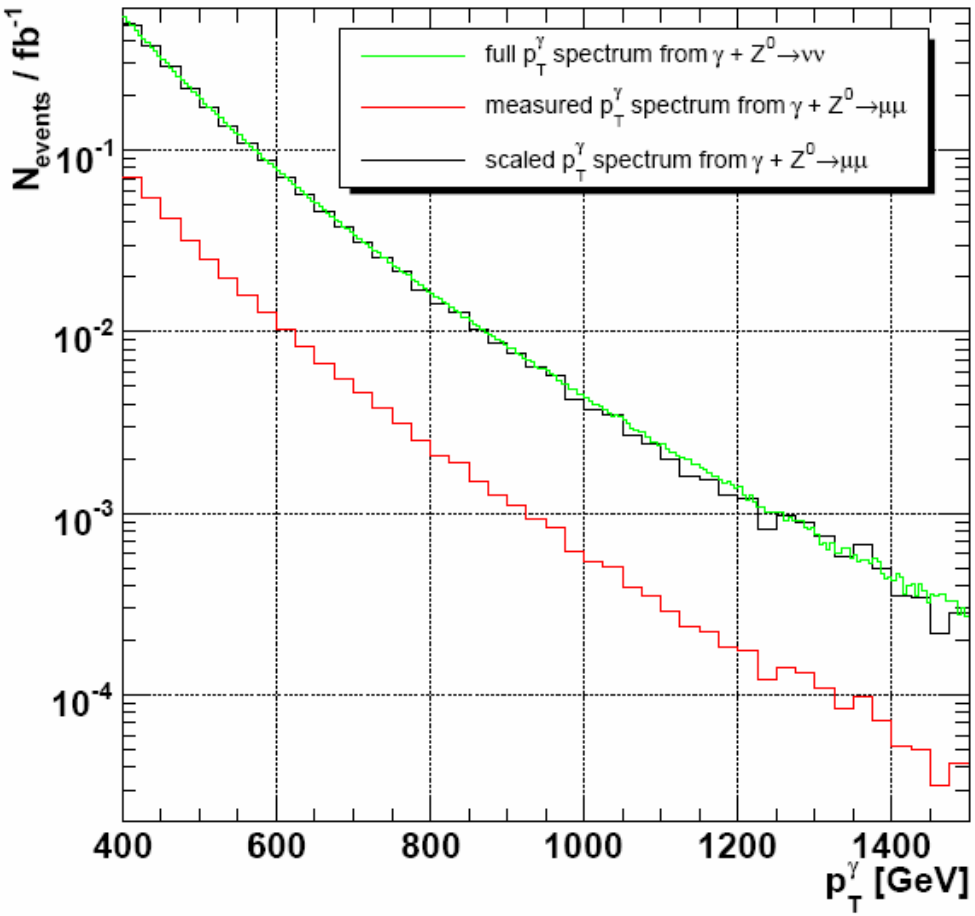
High missing p_T back-to-back with the photon in the azimuthal plane

Trigger: Single photon (L1+HLT), E > 80GeV, %100

Event selection:

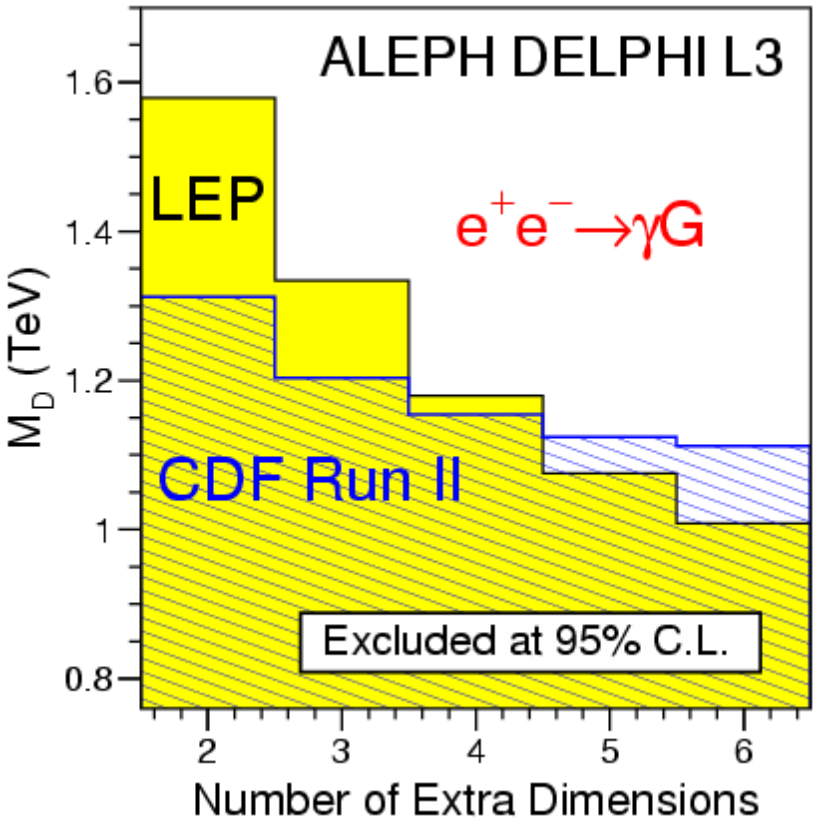
$E_{Tmiss} > 400$ GeV
$p_T > 400$ GeV
$\Delta\Phi(E_{Tmiss}, \gamma) > 2.5$
$|\eta| > 2.4$
Track veto > 40 GeV
γ likelihood > 0.2

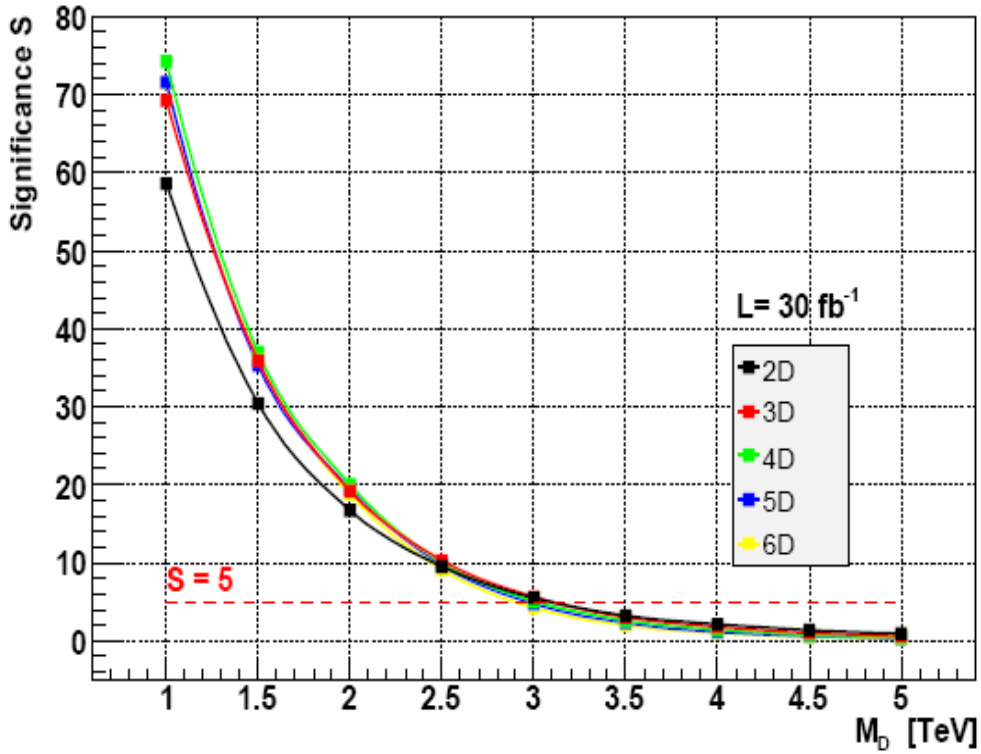
The $\gamma+(Z \rightarrow \nu\nu)$ background can be estimated by studying the $\gamma+(Z \rightarrow \mu\mu)$ process



ADD Graviton Emission in γ+MET Channel

M_D= 1 – 1.5 TeV for 1 fb^{-1}
2- 2.5 TeV for 10 fb^{-1}



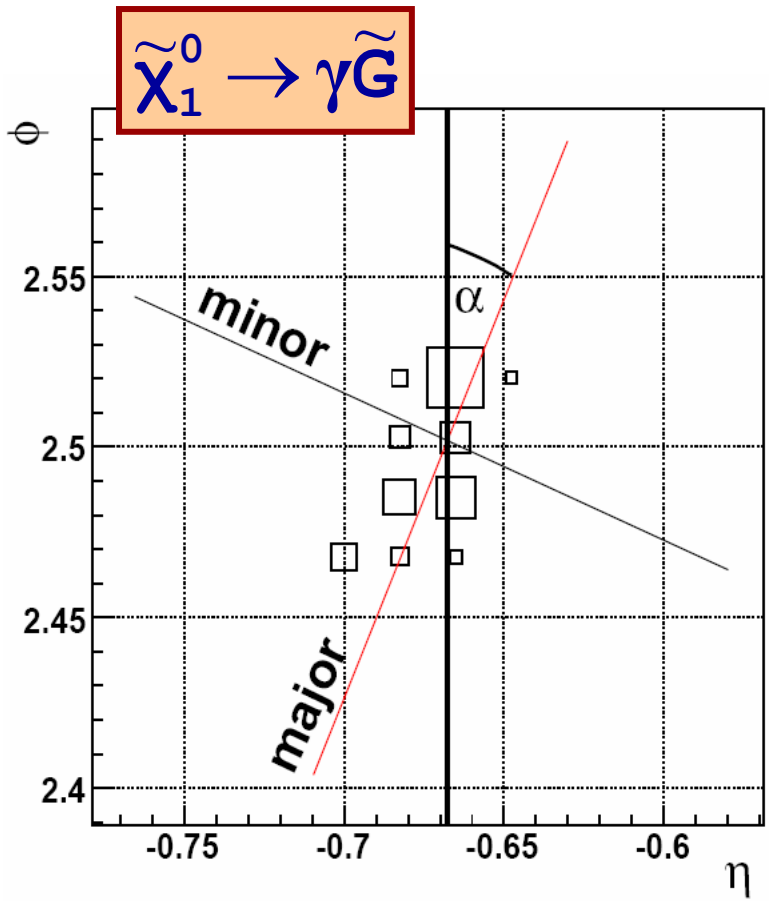


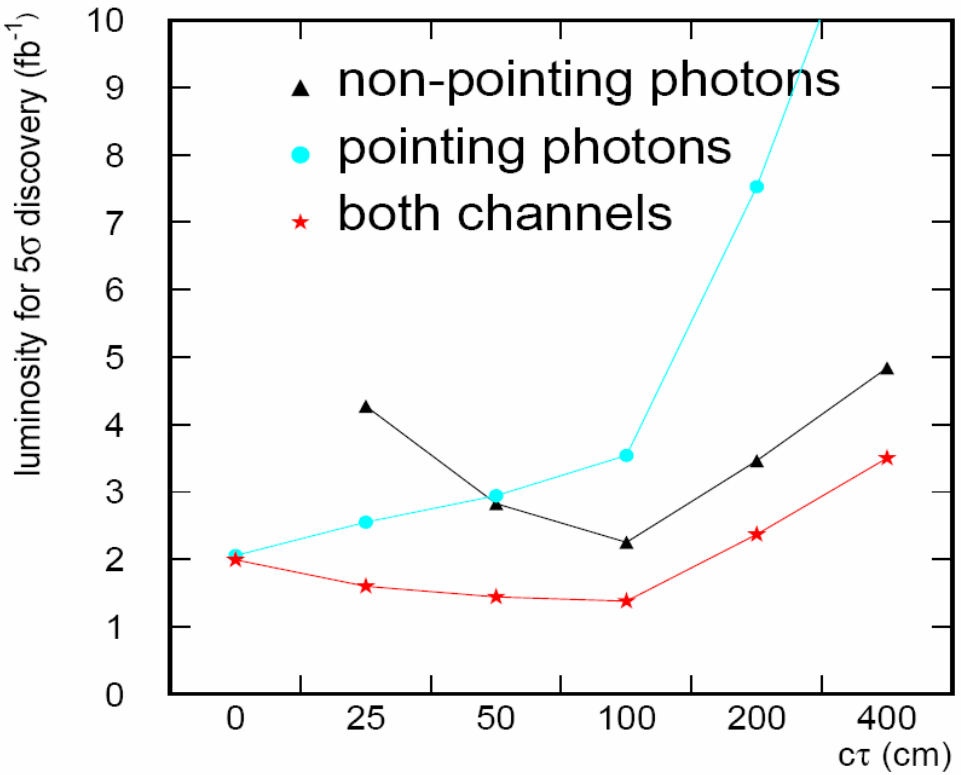
Search for Long-Lived Neutralinos

arXiv:0710.2647v1

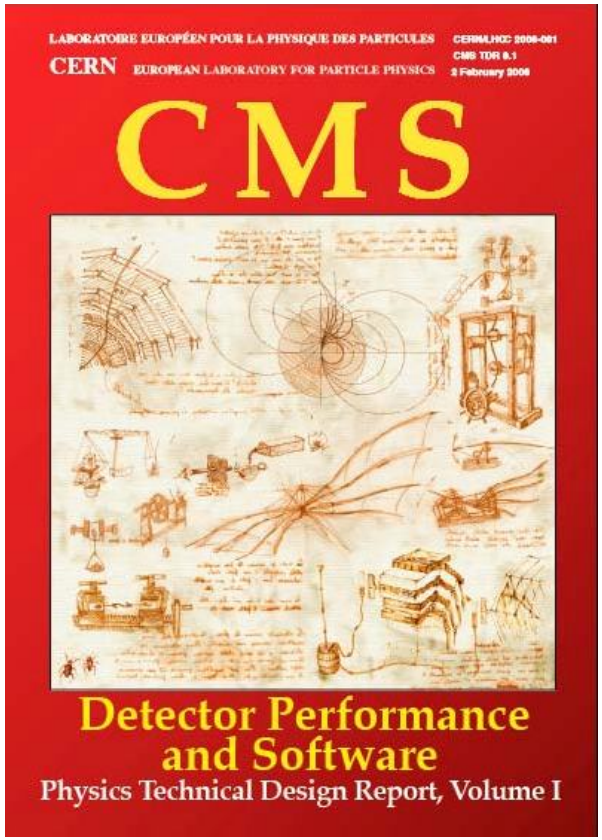
In GMSB SUSY neutralino decay length can be macrosopic

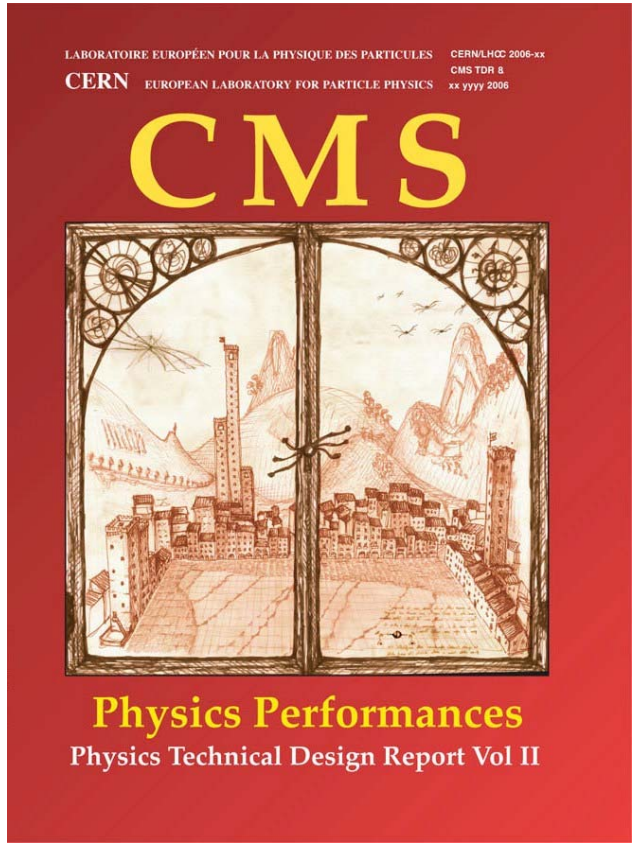
Experimental signature: assymmetric photon showers in ECAL





Main CMS Physics Results are in





http://cmsdoc.cern.ch/cms/cpt/tdr/

CERN/LHCC 2006-001 **CERN/LHCC 2006-021**

Summary

- Showed only a thin slice of CMS searches with photons in final state. Consult the CMS Physics TDRs and public CMS Notes for details.
- Good understanding of the detector performance and possible systematic effects will be crucial. This will have to be achieved in situ at the LHC, as soon as possible.
- The exciting times are just ahead!

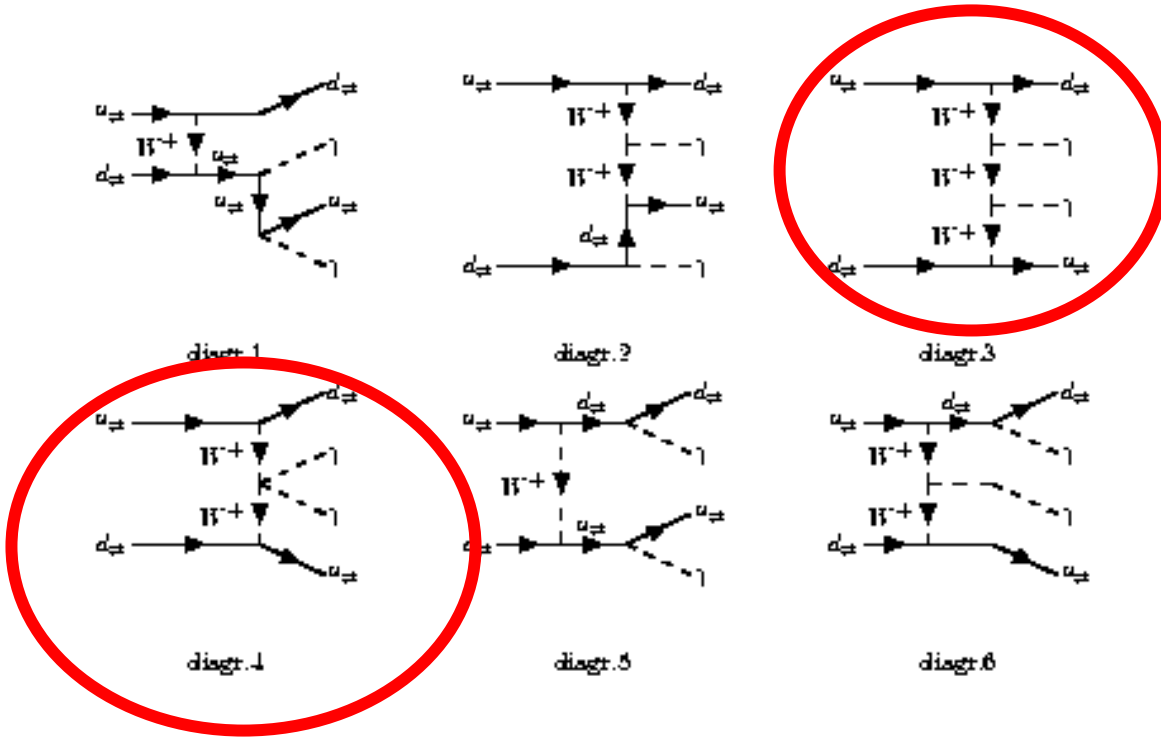
Extra Slides Follow

CompHEP EW background:

$ud \rightarrow \gamma\gamma du$

CompHEP EW 2γ+2jets background has smaller cross section compared to QCD 2γ+2jets background (300 fb vs 50 pb), but has long hard tails in p_T distributions and many photons at small η, from ladder diagrams, e.g. 3,4.

These tails are much harder than for the CompHEP QCD 2γ+2jets background sample…

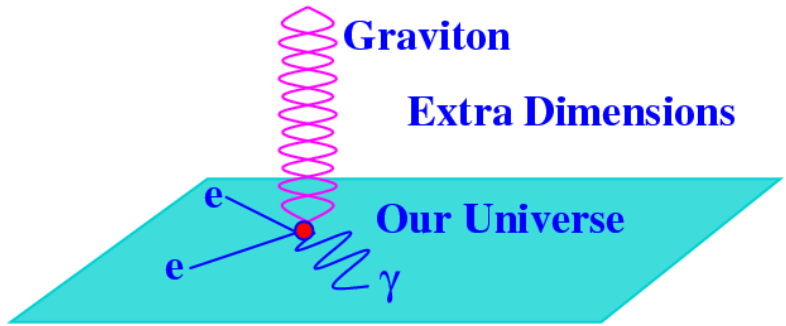


This background topology is very similar to the Higgs signal

LED with Single Photons at LEP

$$e^+e^- \to \gamma G$$

$$M_{\rm Pl}^2 \sim M_D^{2+n} R^n$$



- Gravity propagates in extra dimensions but the SM particles live on a 3D wall.
- Explains the weakness of the gravity force in our world and solves the hierarchy problem.
- LEP searches with single photon events produced the most stringent limits. Tevatron searches in the monojet channel reached comparable sensitivity.