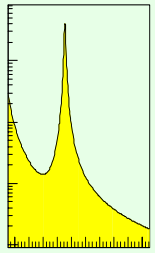
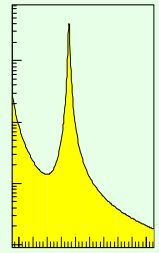




Event 4

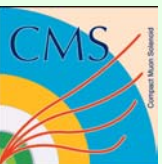
Alternatives: Beyond SUSY Searches in CMS

Dimitri Bourilkov

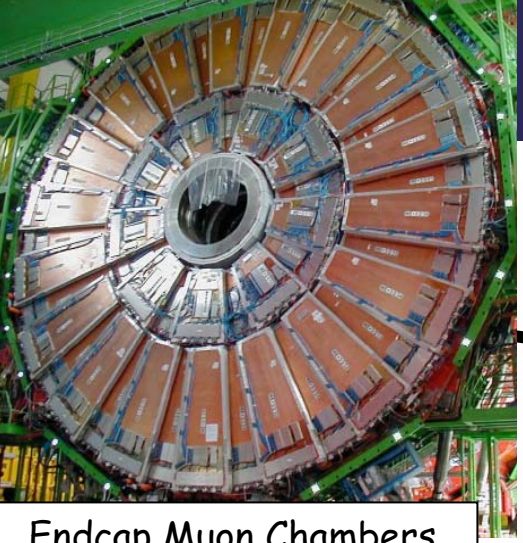
University of Florida

For the CMS Collaboration

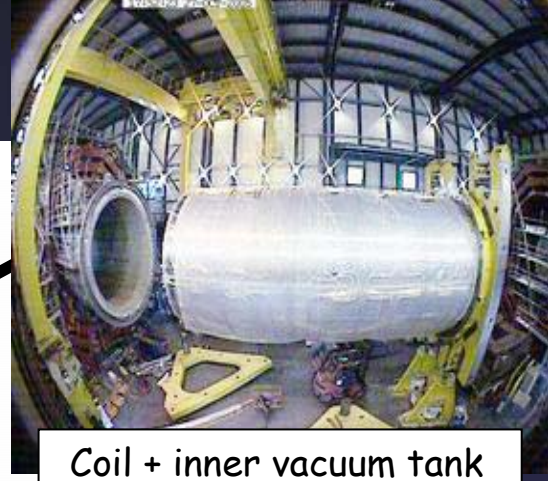
SUSY06, June 2006, Irvine, CA, USA



CMS

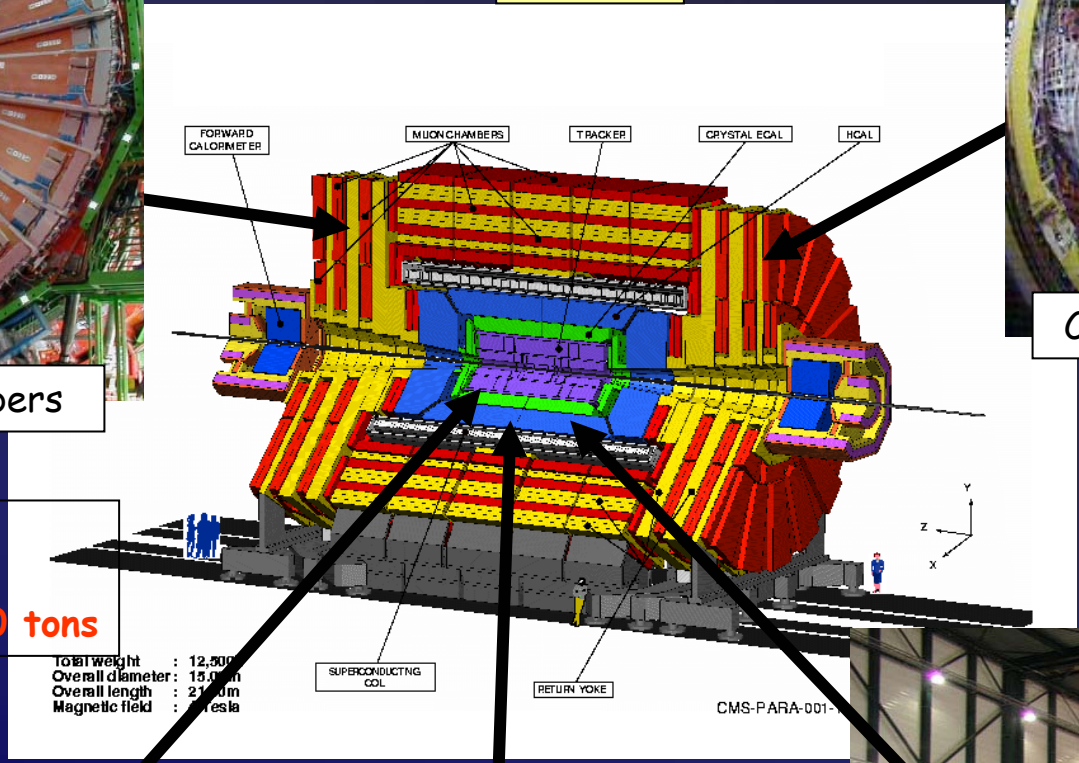


Endcap Muon Chambers



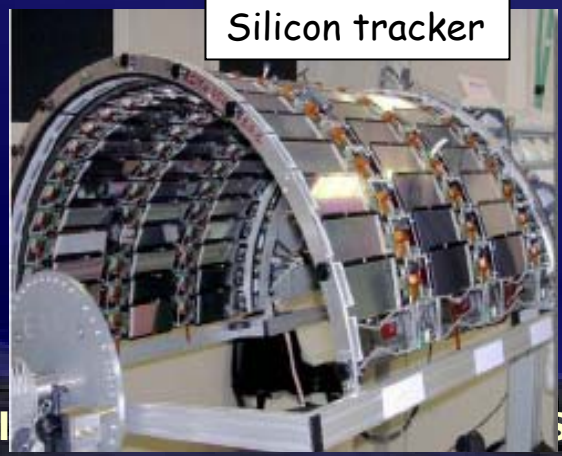
Coil + inner vacuum tank

Length : ~20 m
Radius : ~7 m
Weight : ~ 13000 tons

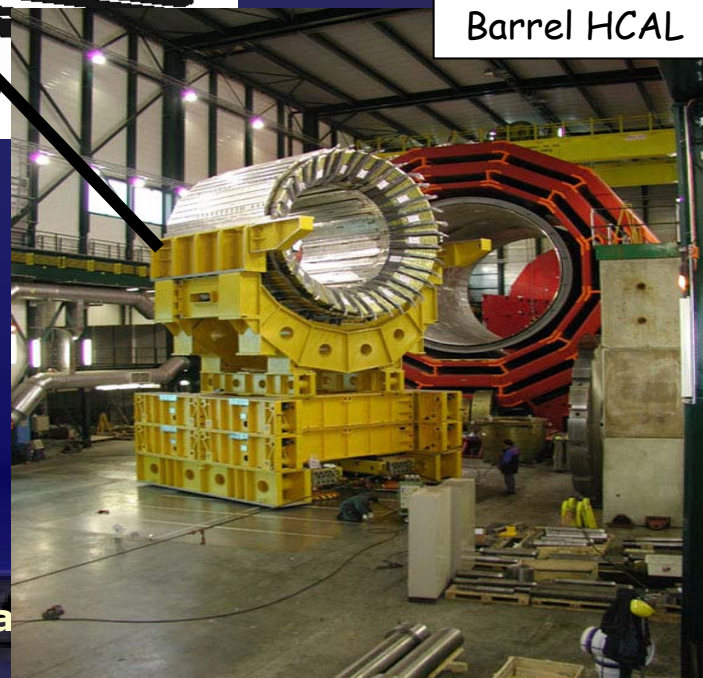


ECAL crystals

Silicon tracker



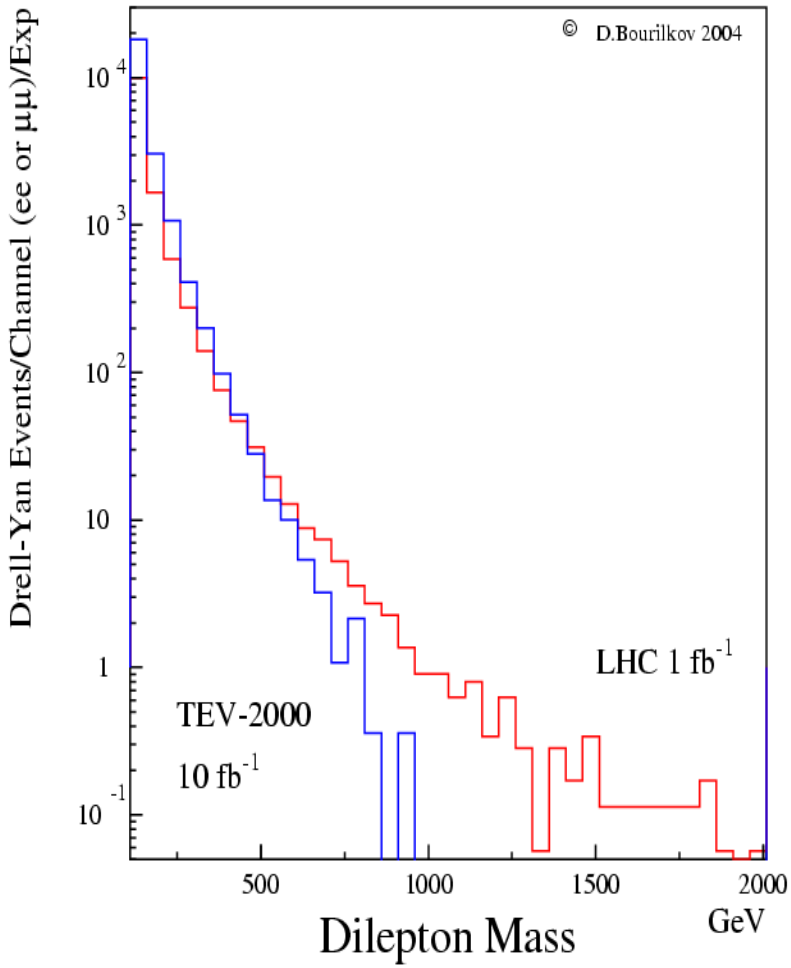
Barrel HCAL



D.Bourilkov Al Sea

Introduction

- Alternatives: simple final states with no missing energy; can reconstruct invariant mass
- Early discovery ?
  - "Easy" – resonances
  - "Not-so-easy" – non-resonant OR just a resonance tail
- LHC is a di-{lepton, photon, jet} factory
- Test Standard Model to highest momentum transfers
- Signals for many new physics scenarios: compositeness, Z', extra dimensions: Randall-Sundrum (RS) gravitons, ADD …



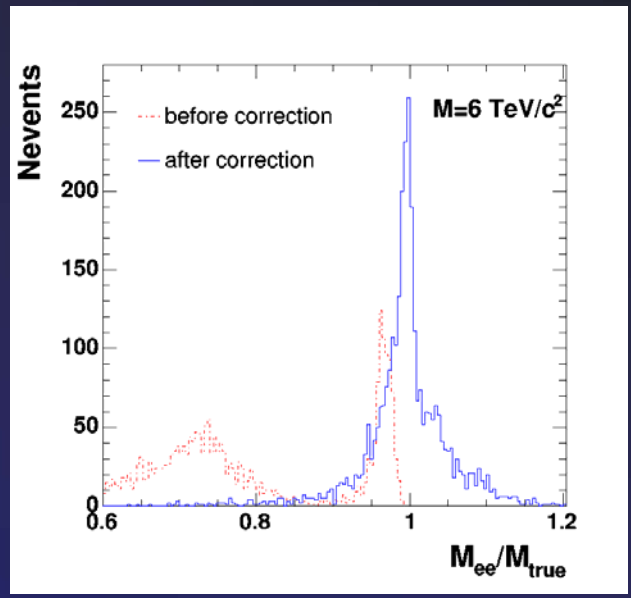
Dielectron Reconstruction

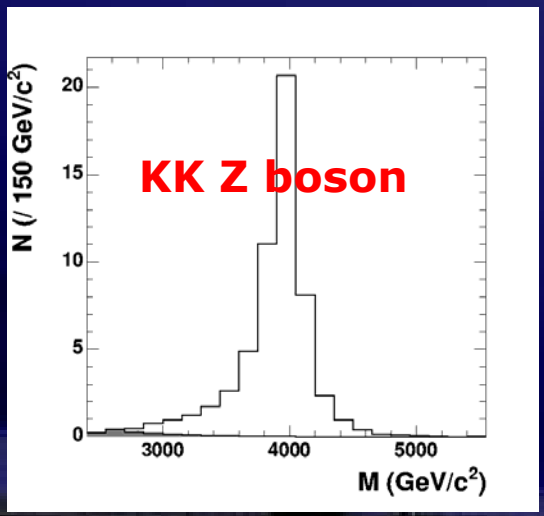
CMS Physics TDR:

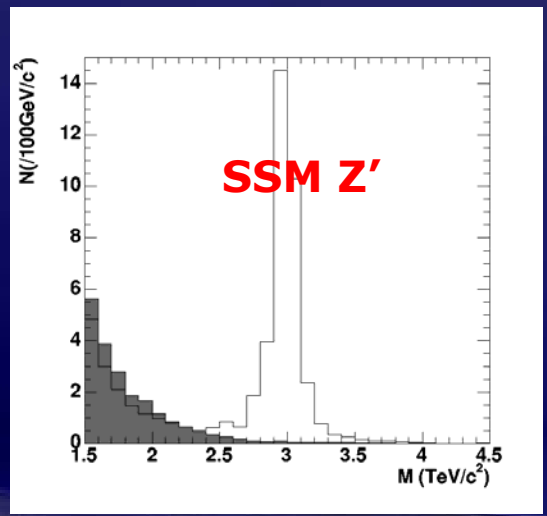
- Full detector simulation / reconstruction
- Detailed backgrounds & systematic uncertainties

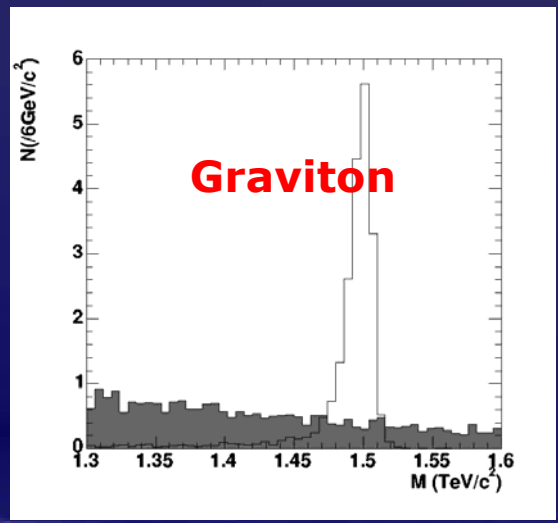
Saturation correction: above 1.7 TeV barrel, 3 TeV endcaps; mass resolution barrel 0.6 % (7%) without (with) saturation

Preshower, HCAL, energy corrections



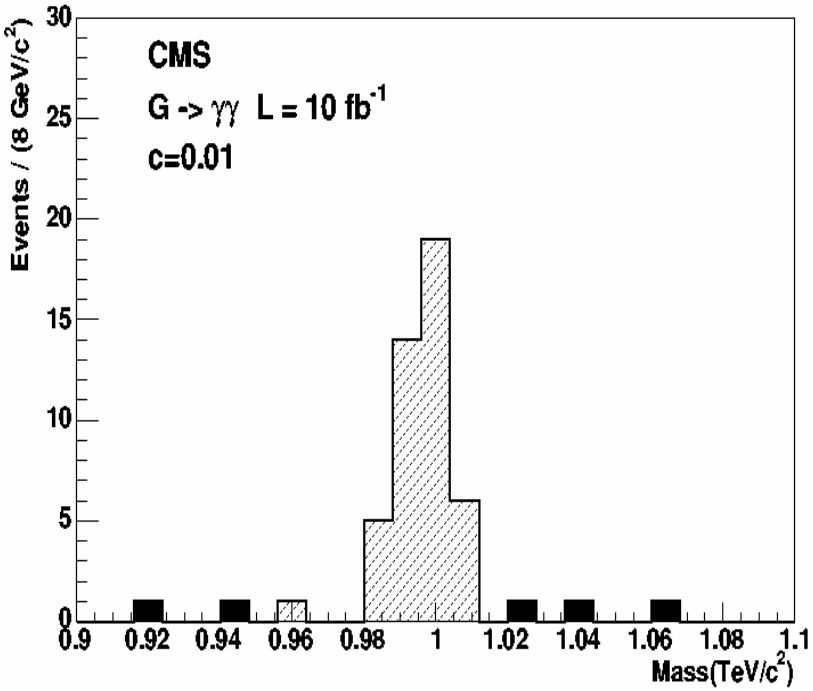


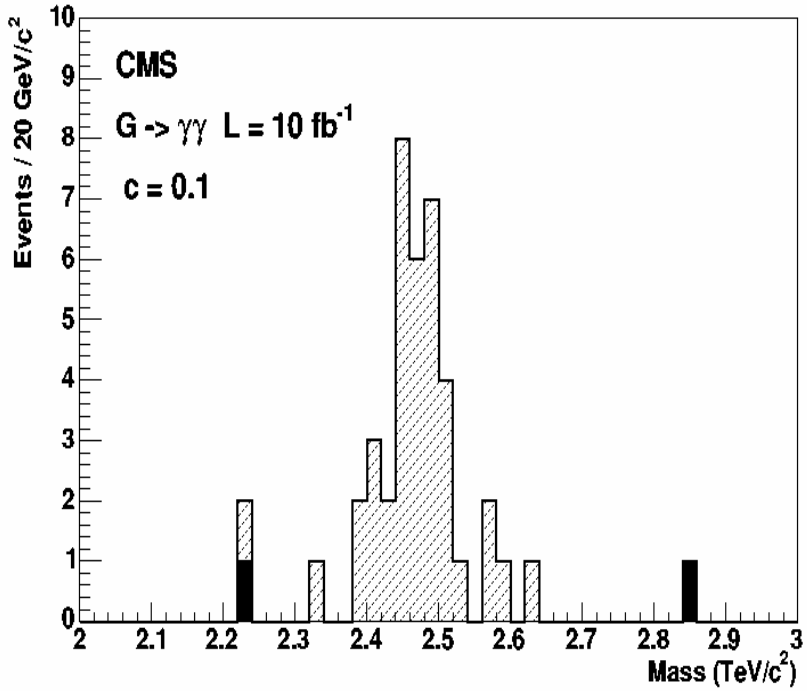




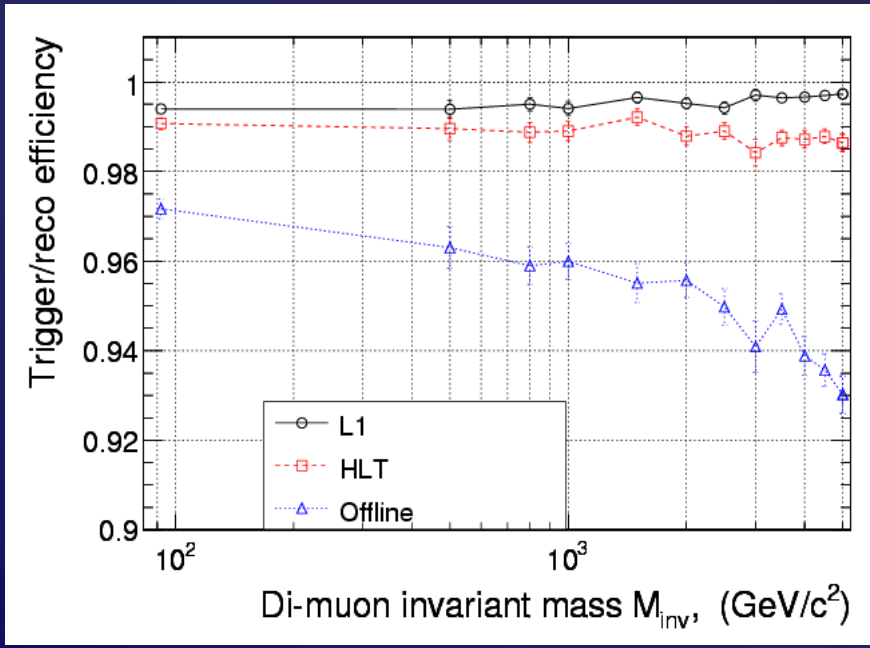
Diphoton Reconstruction

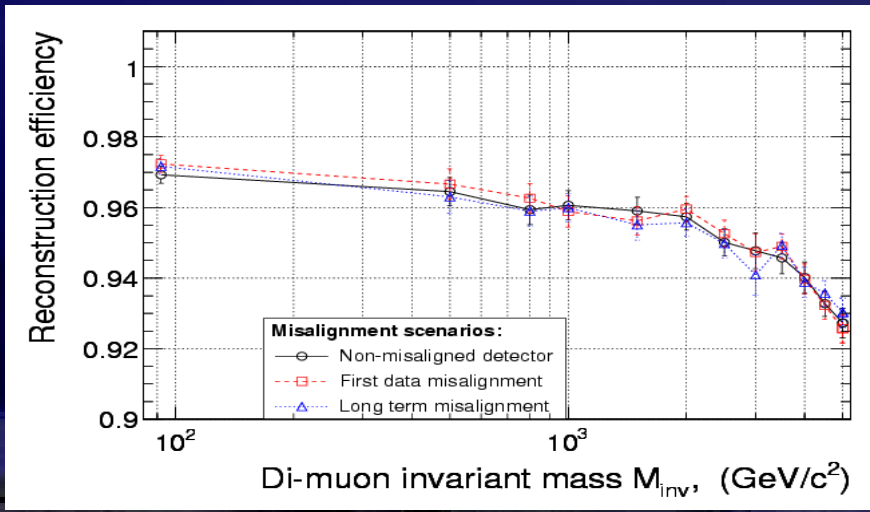
Photon energy corrections as for electrons





Dimuon Efficiency/Resolution

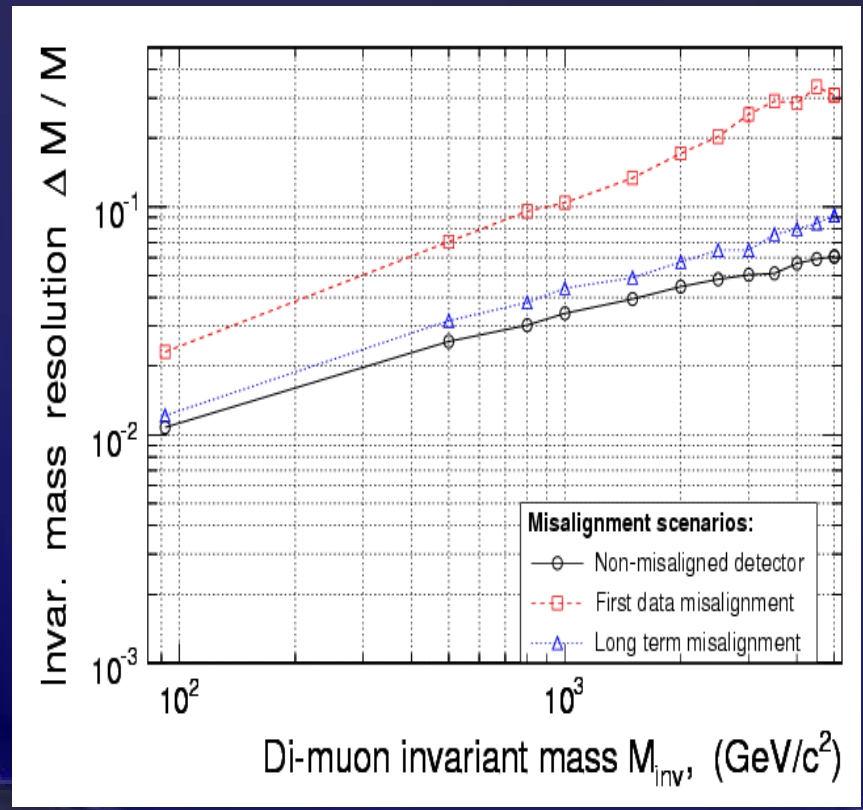




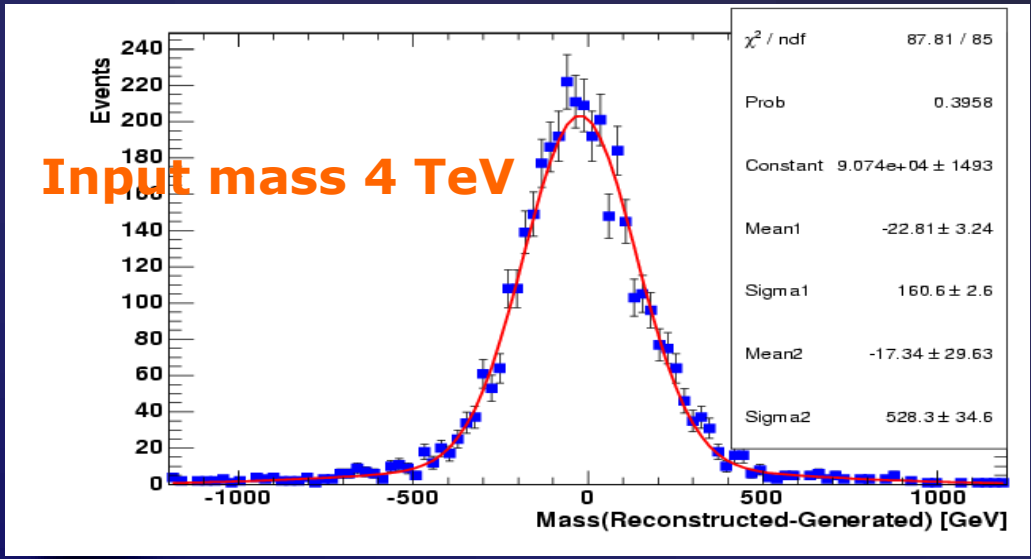
Most important - misalignment:

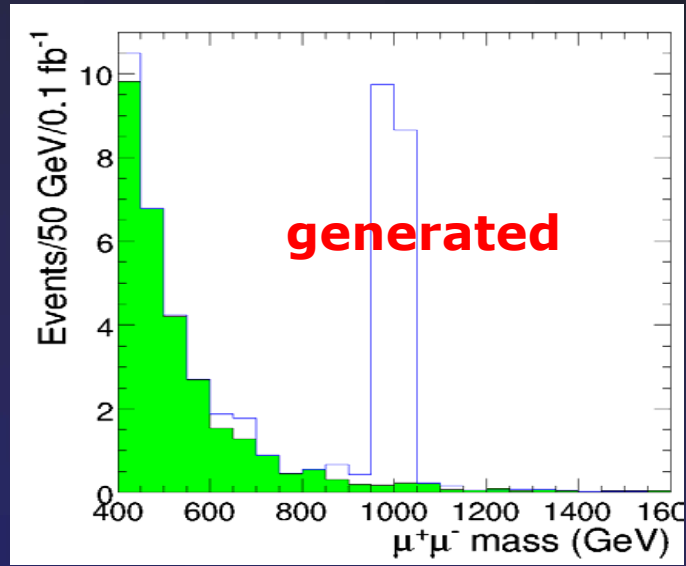
First data <~ 1 fb^{-1}

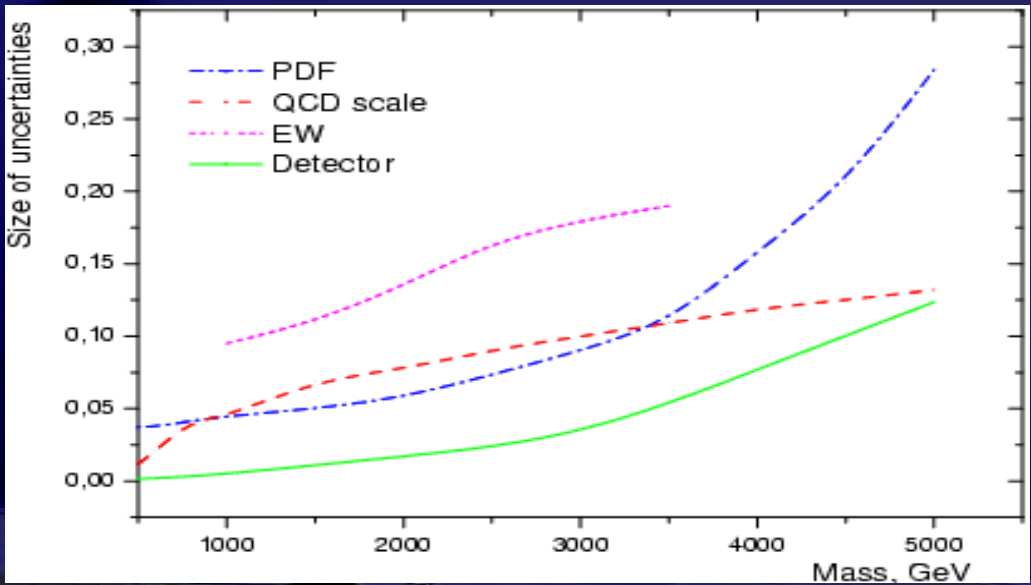
Long term (with more data)

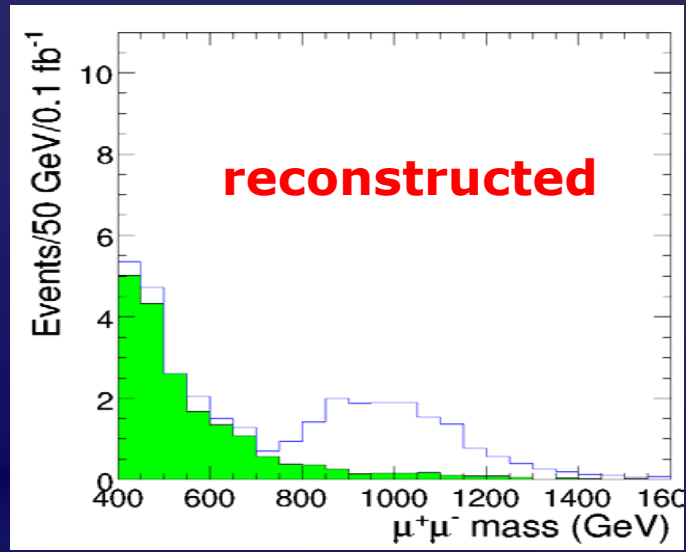


Dimuon Reconstruction



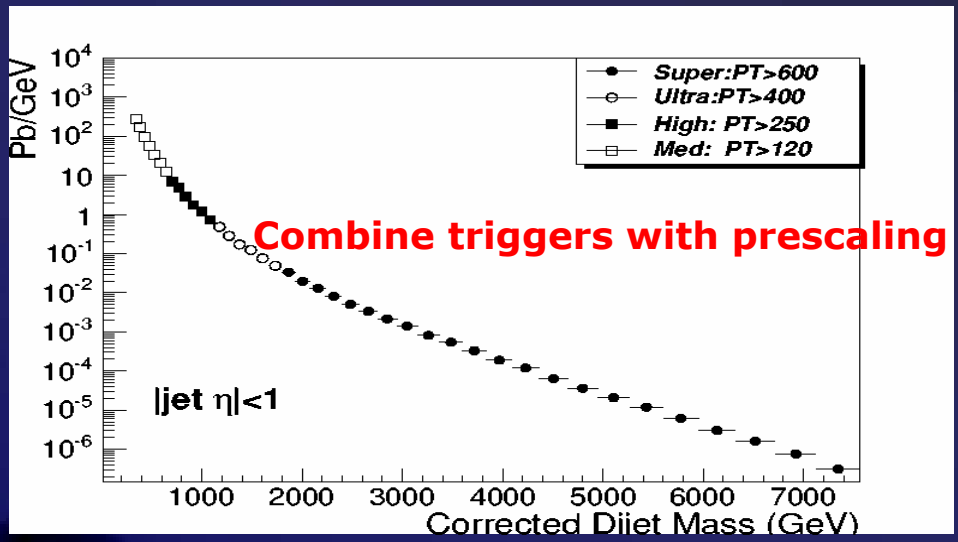


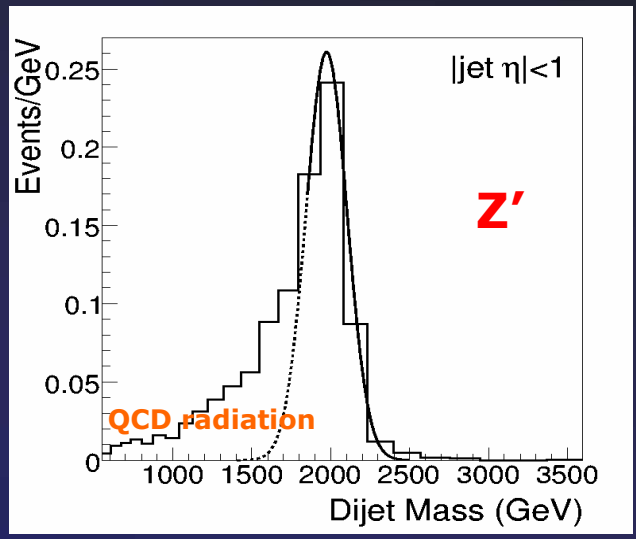


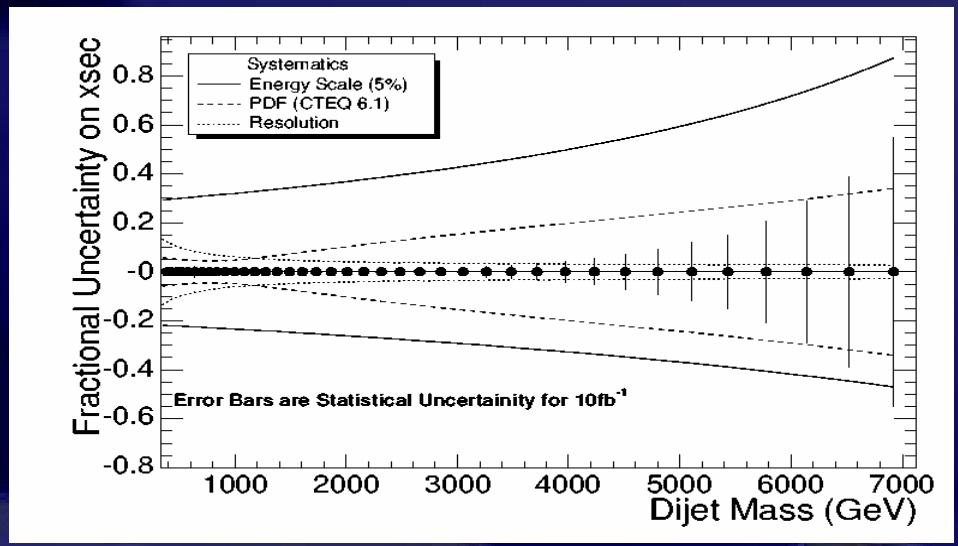


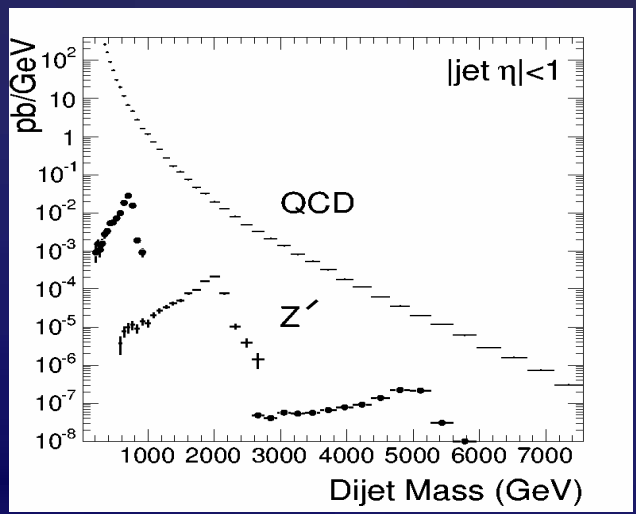
Dijet Reconstruction

$\sigma/M = 0.045 + 1.3/\sqrt{M}$



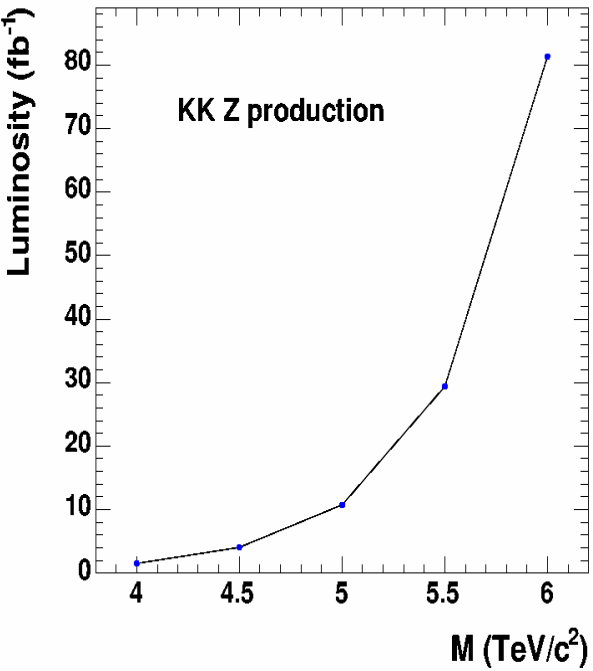


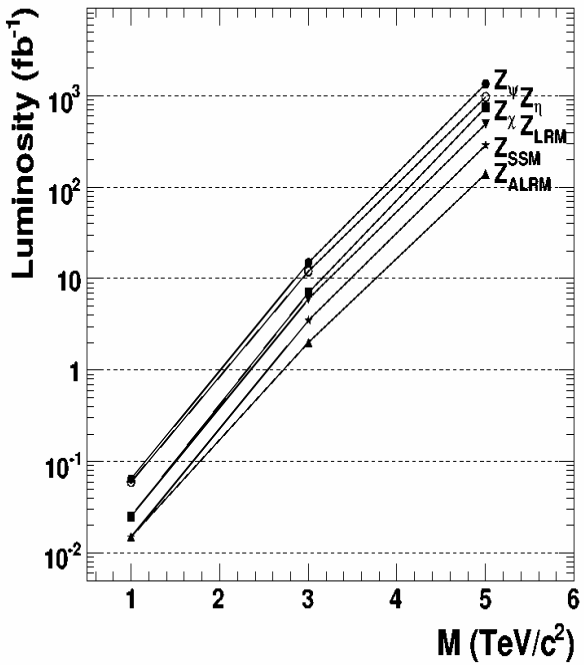


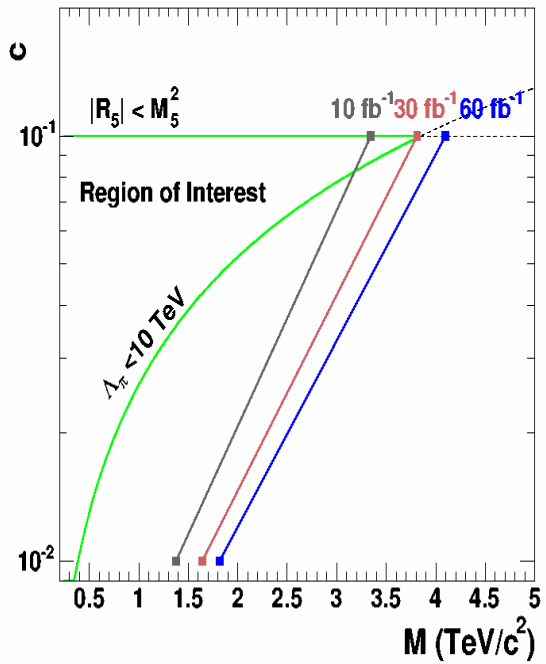


Resonance Hunting with Dielectrons

5 σ discovery reach for KK Z bosons, 6 Z' models, RS gravitons

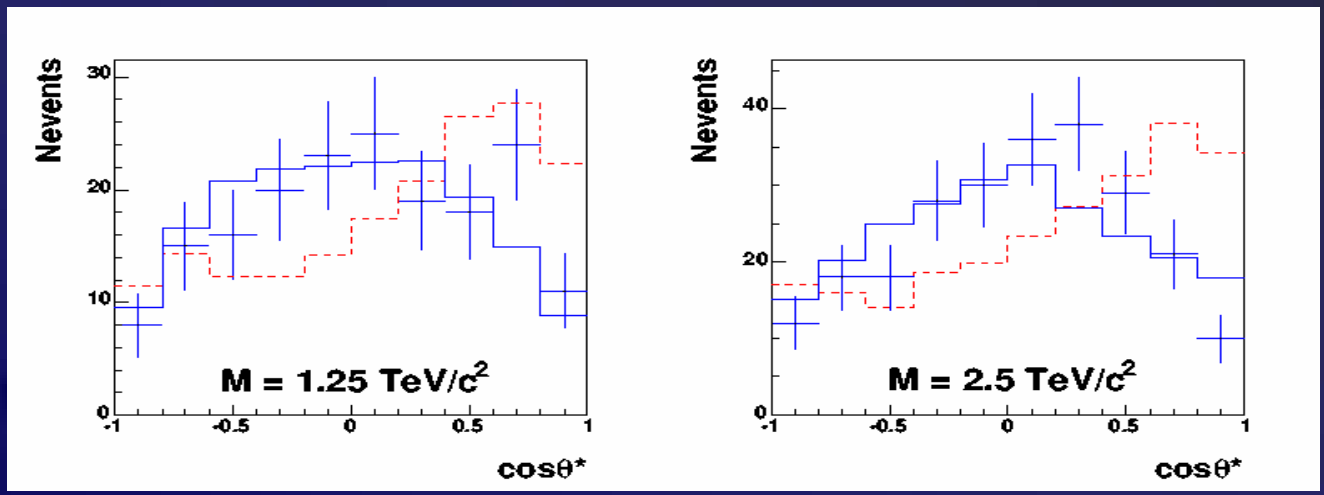






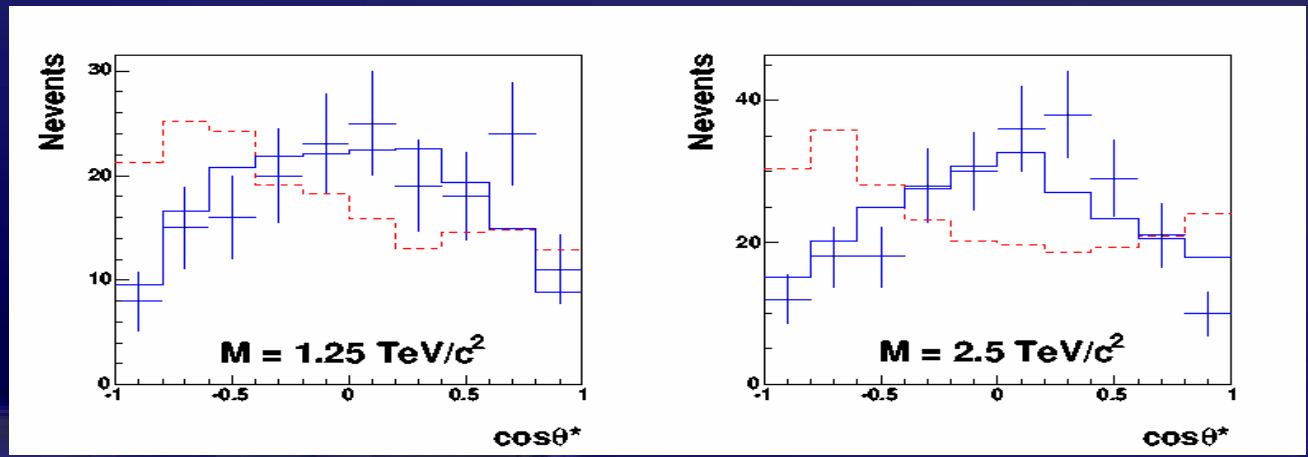
Resonance Identification for Dielectrons(muons)

Use angular distributions: identify spin/distinguish between Z′ models



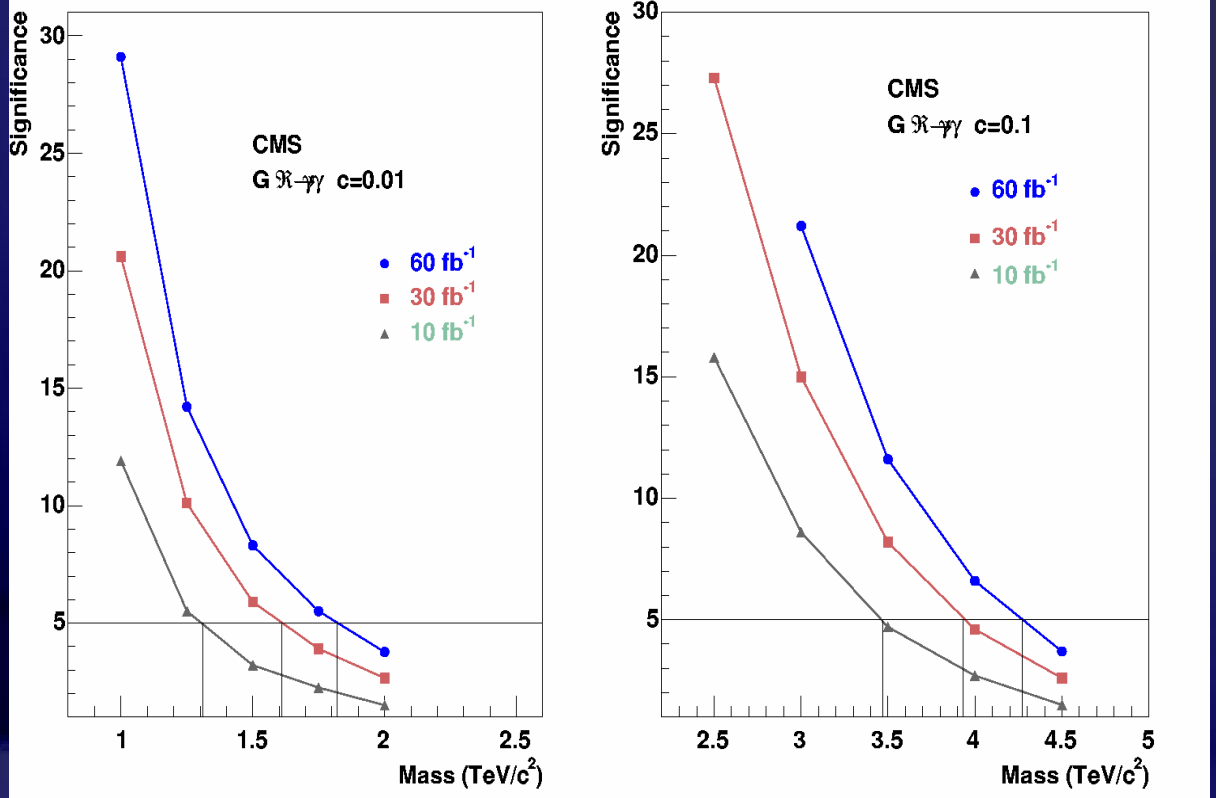
Graviton (blue); Drell-Yan (red)

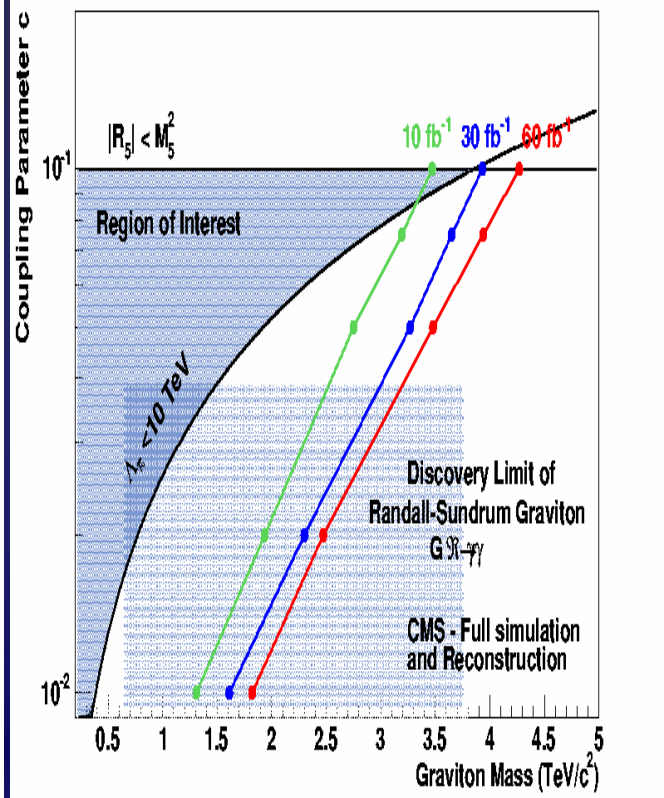
Z′ (LR) (red)



Resonance Hunting with Diphotons

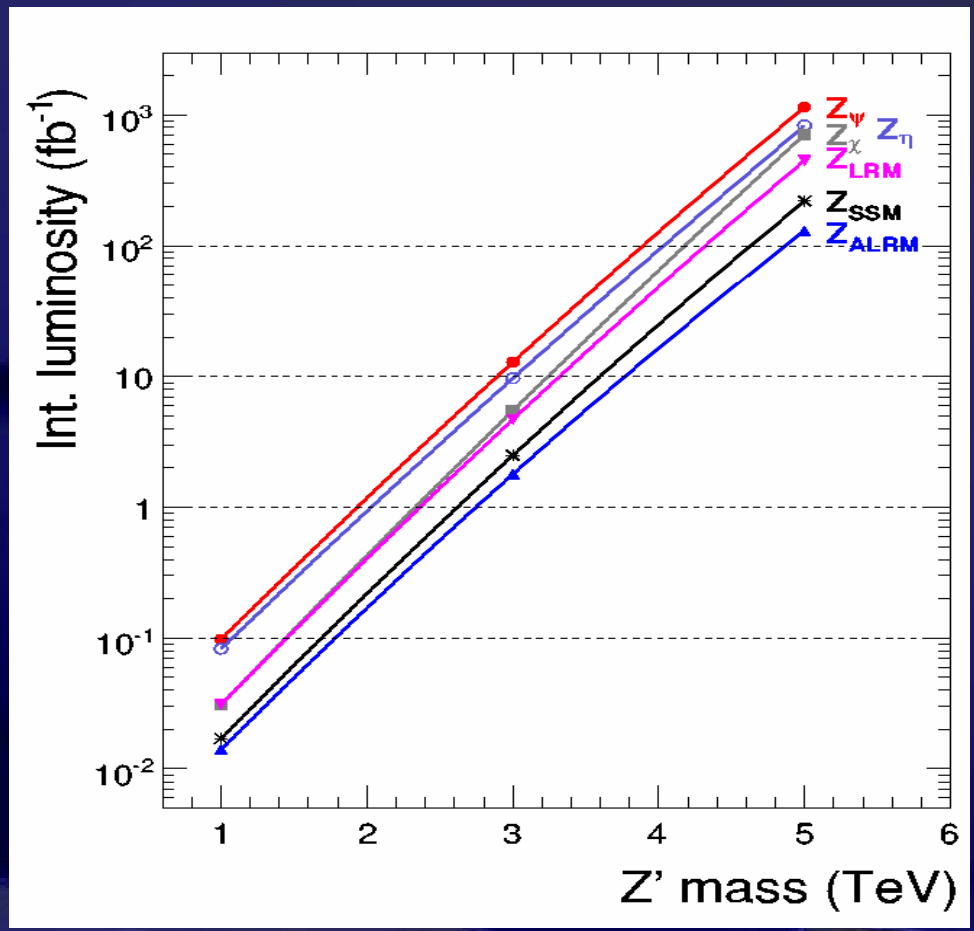
5 σ discovery reach for RS gravitons

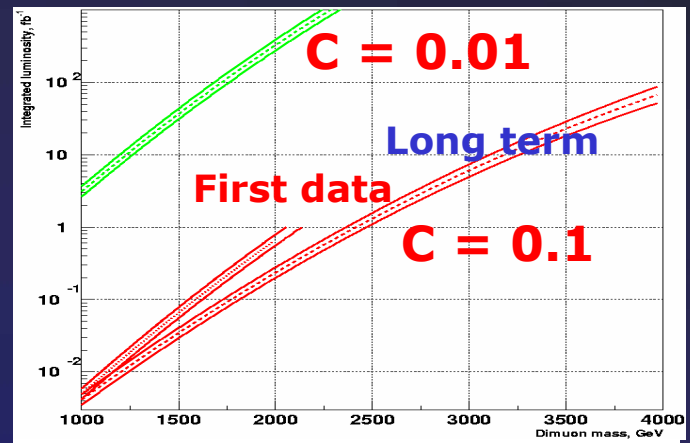


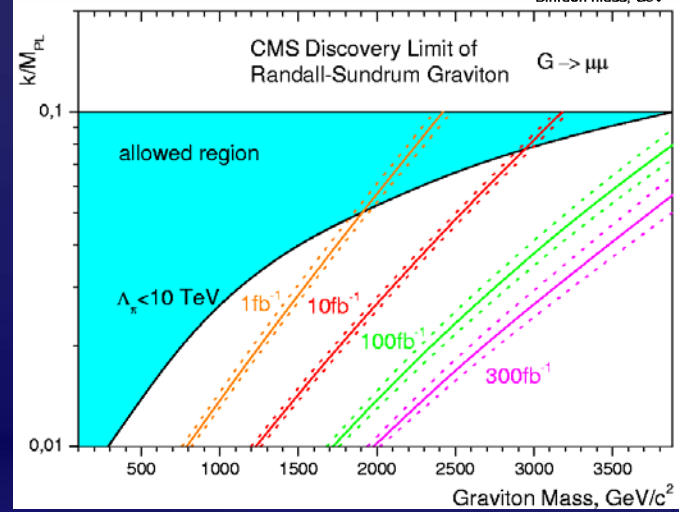


Resonance Hunting with Dimuons

5 σ discovery reach for 6 Z' models, RS gravitons (plots with systematic uncertainties e.g. misalignment)

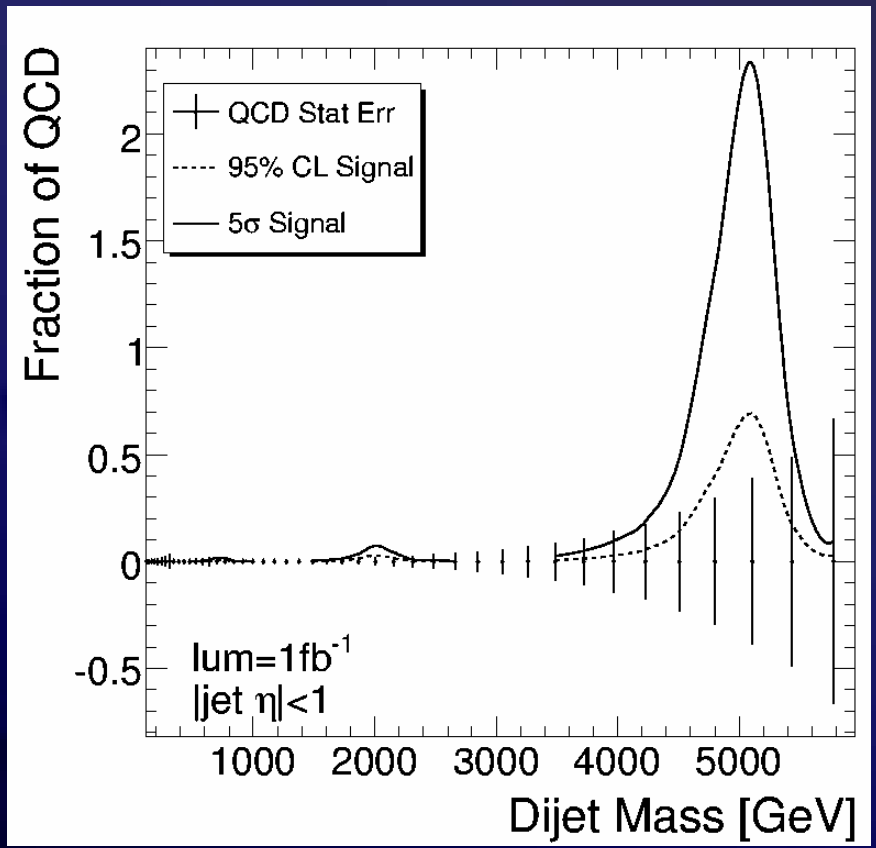


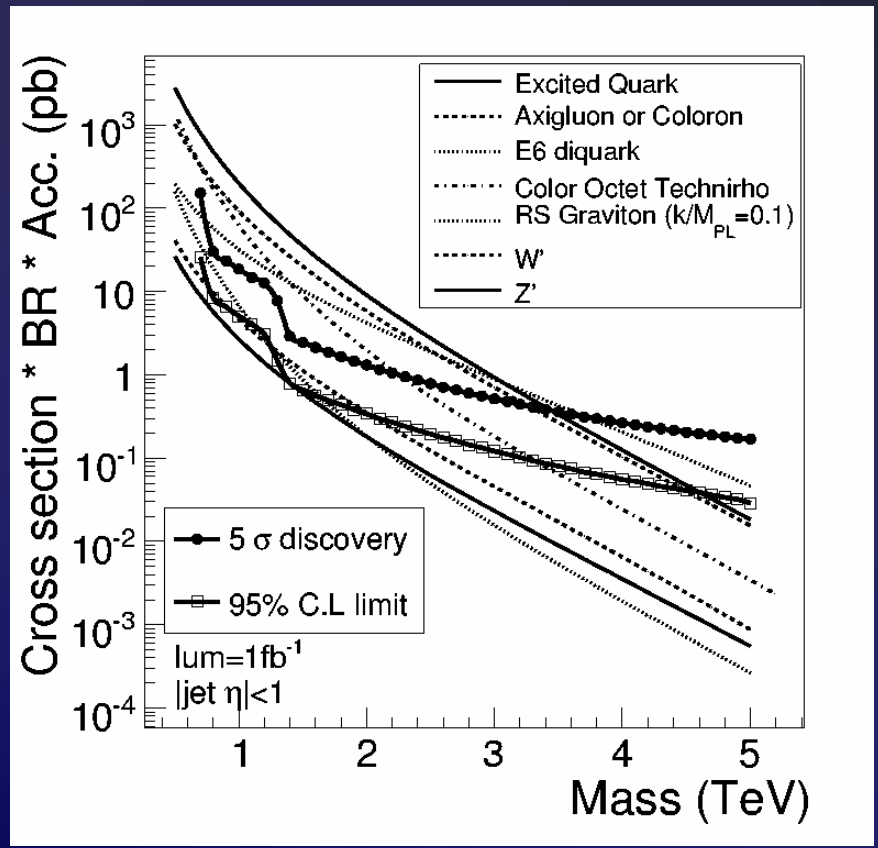




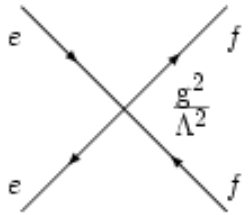
Resonance Hunting with Dijets

Exclusion / 5 σ discovery reach: resonance cross section compared to different models





Contact Interactions



$$\frac{d\sigma}{d\Omega} = SM(s,t) + \varepsilon \cdot C_{Int}(s,t) + \varepsilon^2 \cdot C_{NewPh}(s,t)$$

general framework for new interactions:

- **scale $\Lambda >> \sqrt{s}$ (virtual effects) or resonances if $\Lambda \approx \sqrt{s}$**
- **coupling g (convention $g^2 = 4\pi$)**
- **we constrain g / Λ**
- **operators with canonical dimension N > 4 $\Rightarrow$ terms ~ $1/\Lambda^{N-4}$**

Model	LL	RR	LR	RL	VV	AA	V0	A0
	Non-parity conserving				Parity conserving			
η_{LL}	±1	0	0	0	±1	±1	±1	0
η_{RR}	0	±1	0	0	±1	±1	±1	0
η_{LR}	0	0	±1	0	±1	∓1	0	±1
η_{RL}	0	0	0	±1	±1	∓1	0	±1

Double Ratio Method for Dileptons

- Observed events $N = L.\sigma.\varepsilon$
- Use e.g. mass bin 250-500 GeV for normalization (SM valid; Tevatron); prefer to use data above the Z due to the flavor composition / PDF
  - At Z peak 32.1% of initiating partons are heavier flavors (not u & d quarks) with their own PDF uncertainties; more d than u quarks
  - At 250-500 GeV u & d are "initiators" already in 85.6% of the cases
  - u & d are 96.3% above 1 TeV; the u / d ratio approaches 4:1
- For higher masses (bins 1 – n):

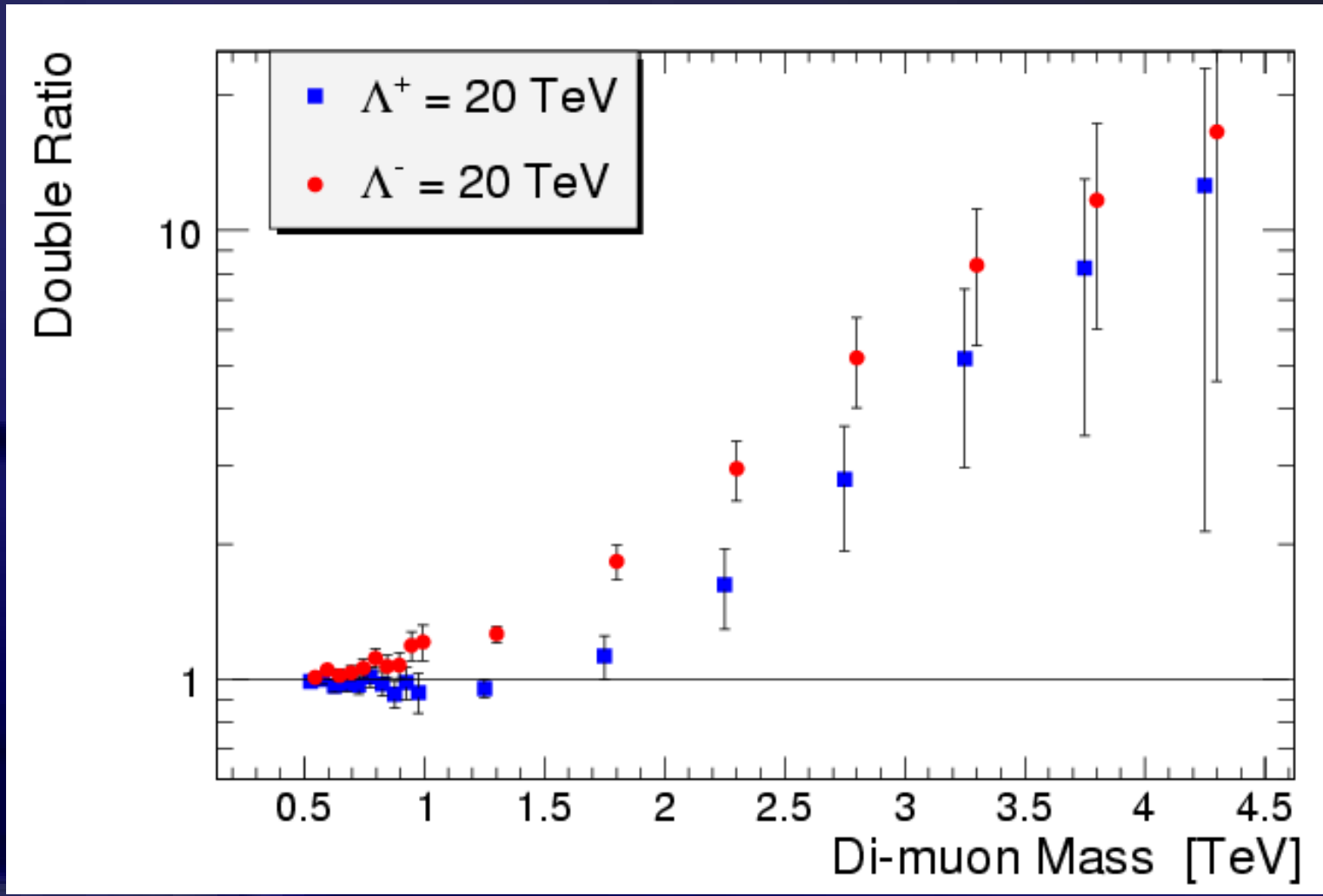
  $R_i^{DATA} = N_i^D/N_0^D = \sigma_i^D.\varepsilon_i^D \; / \; \sigma_0^D.\varepsilon_0^D$

  $R_i^{MC} = N_i^{MC}/N_0^{MC} = \sigma_i^{MC}.\varepsilon_i^{MC} \; / \; \sigma_0^{MC}.\varepsilon_0^{MC}$
- Many things cancel in the ratios: luminosity, absolute efficiency, K-factor etc.; absolute values are not important, only the ***shapes*** as function of mass
- Double ratio aka a pion/nucleon PDF study and aka SuperKamiokande

  $DR_i = R_i^{DATA} \; / \; R_i^{MC}$
- If theory understanding and detector modeling are both perfect

  $DR_i = 1$

Example of Double Ratios (100 fb^{-1})



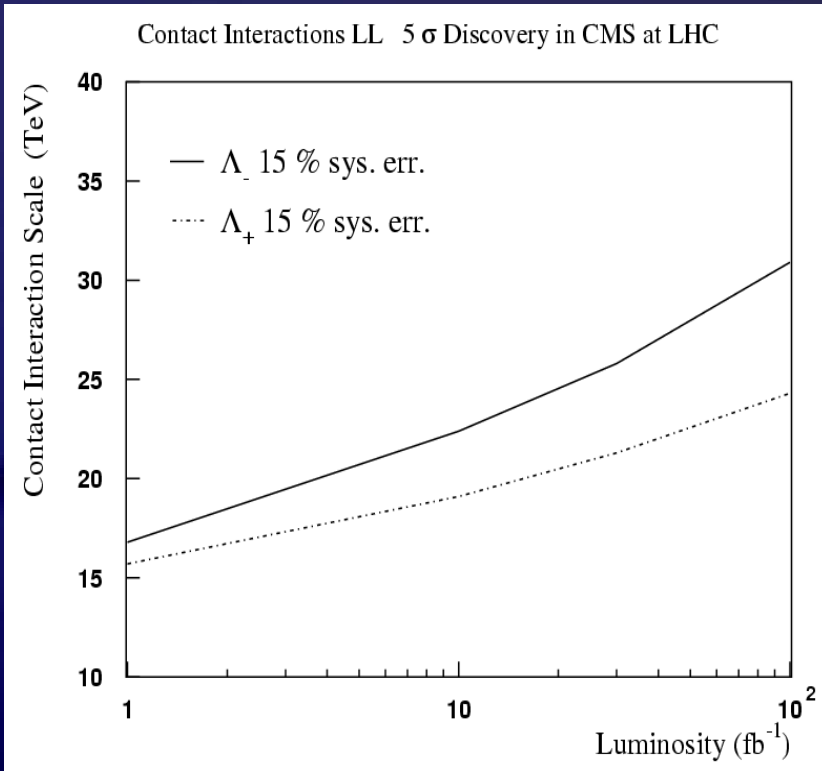
Systematic Effects for Dimuons

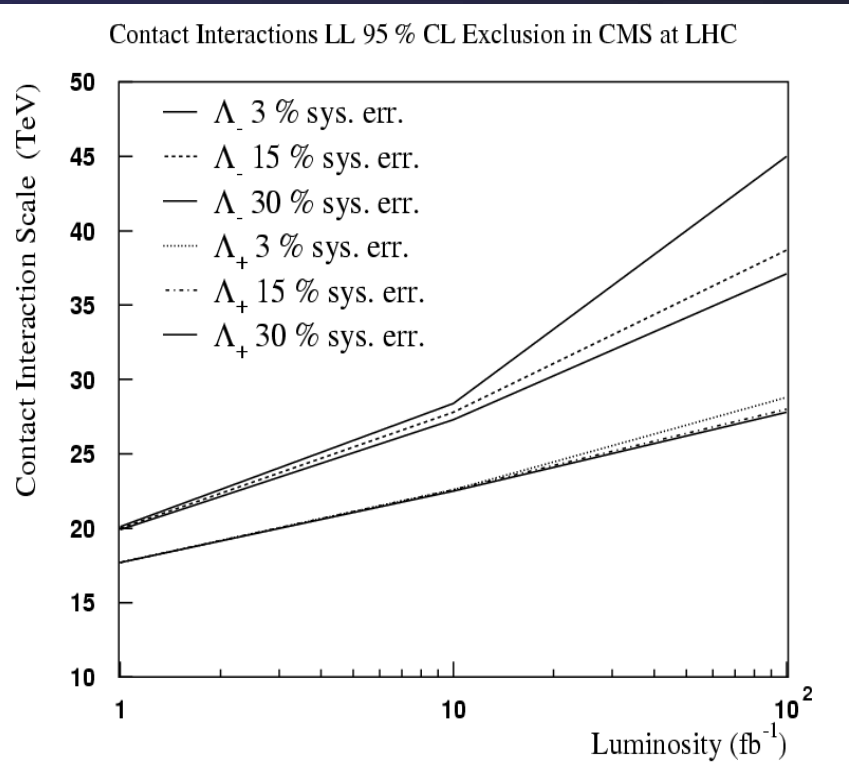
- PDF uncertainties (LHAPDF) on ratios

Mass	R(M/	250-500)	R(M/	Z)
[GeV]	PDF+	PDF-	PDF+	PDF-
500-600	+1.5%	-1.5%	+4.6%	-4.2%
1000+	+5.2%	-4.8%	+7.8%	-7.1%
2000+	+10.7%	-7.8%	+12.9%	-9.4%

- EW corrections change cross section by ~ 10 % (W.Hollik, U.Baur et al.); conservatively take ½ = 5 %
- QCD K-factors change cross section by ~ 8 %; conservatively take ½ = 4 % from K-functions
- In total < 11.5 % from theory
- Experiment+theory: nominal <12 %, start-up <15%

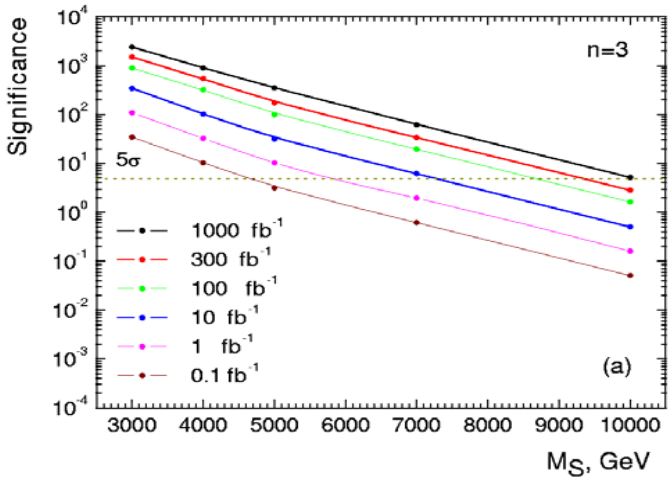
Contact Interactions with Dimuons

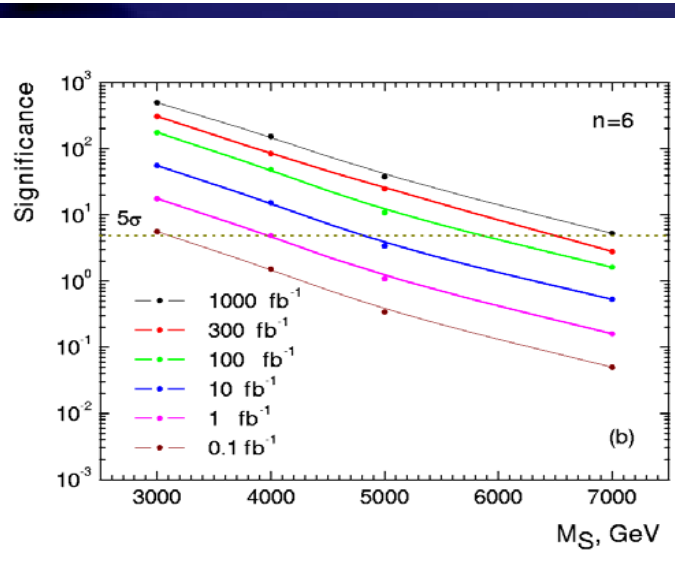


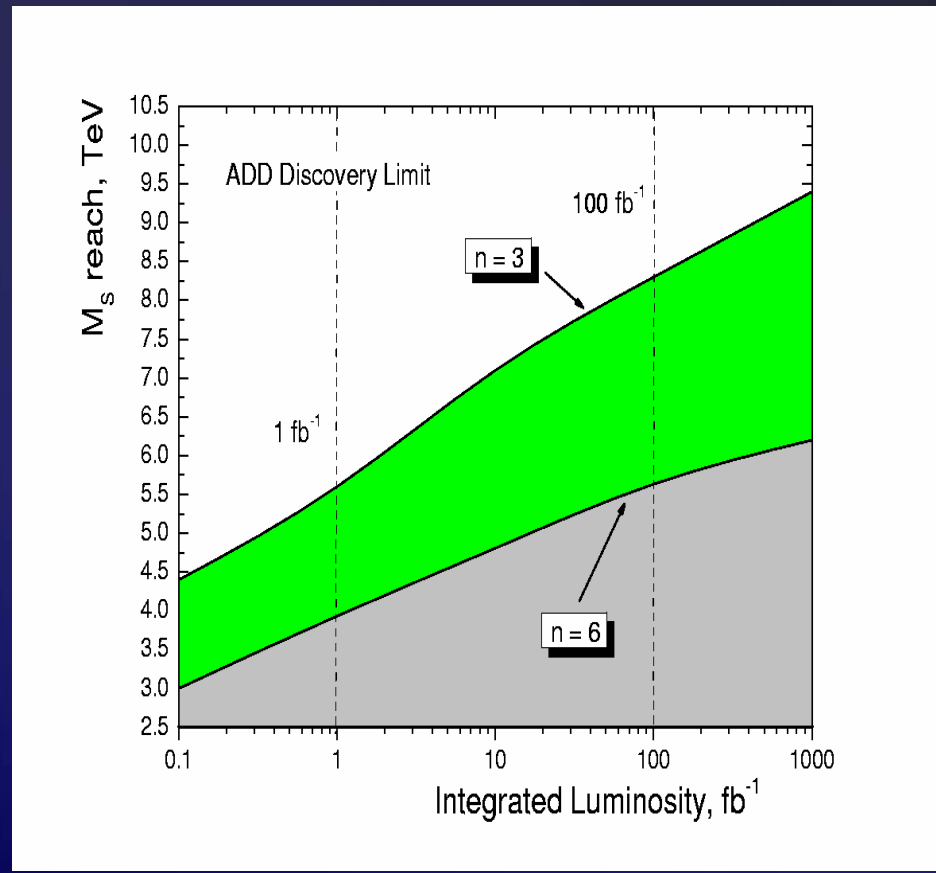


Up to 10 fb^{-1} (higher for Λ_+) we are dominated by statistical errors: even 30 % systematic errors have small impact

ADD Extra Dimensions with Dimuons

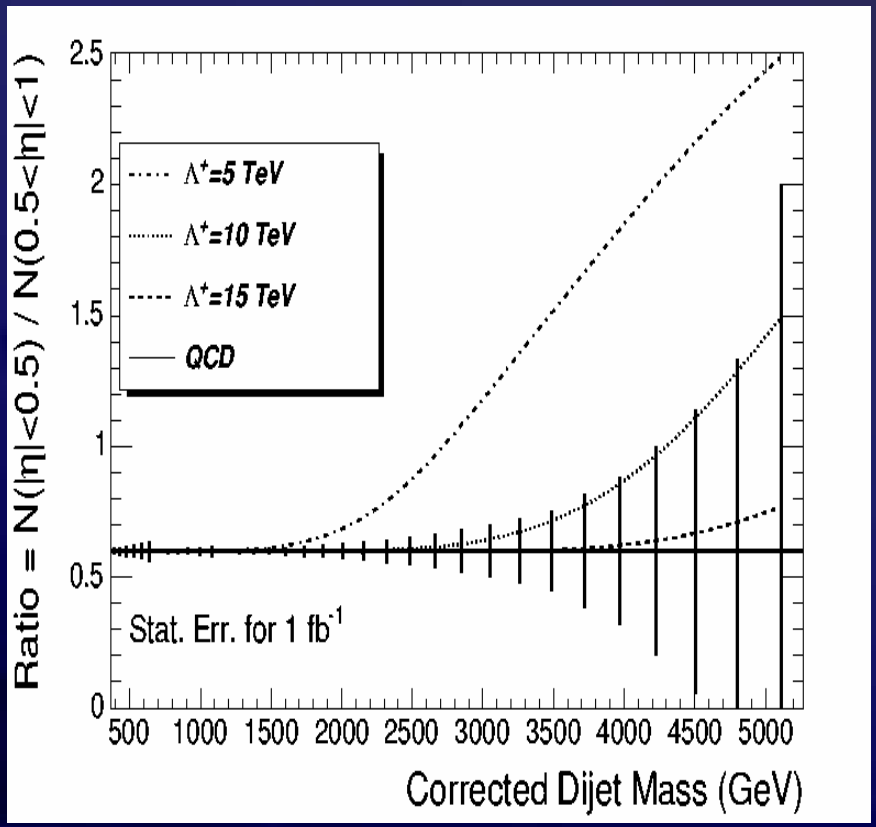


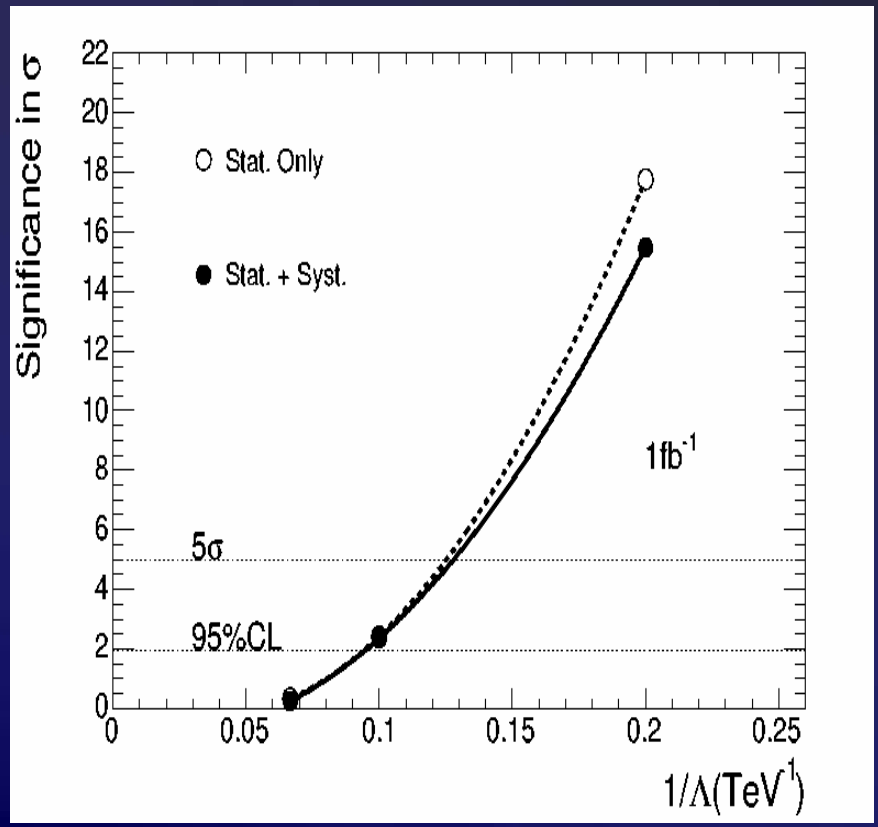




Contact Interactions with Dijets

Use dijet ratio N(|η| < 0.5) / N(0.5 < |η| < 1) as function of dijet mass





Outlook

- CMS can measure cross sections / forward-backward asymmetries for di-{electron, photon, muon, jet} to the highest masses @ LHC
- Rich search field for early discoveries at the multi-TeV scale: resonances first; fix scale for new physics?
- Ratio methods for non-resonant searches developed and well understood (reduced systematic uncertainties; dependence mainly on shapes as function of invariant mass, not on absolute values)
- Be ready for first data: detector, data acquisition, software
- Other alternatives studied by CMS: single leptons / photons, black holes, technicolor, heavy Majorana neutrinos and right-handed bosons, little Higgs, same sign top