Physics with Single, Multi- & Di-Photons at LEP

HEP2003, Aachen, July 17-23

Marat Gataullin (Caltech/L3) on behalf of LEP Collaborations

LEP 2: 650 pb^{-1}/Experiment at 189 - 208 GeV

Single and Multi-Photons
Missing Energy

Di-Photons
No Missing Energy

Direct Searches
Production of new particles

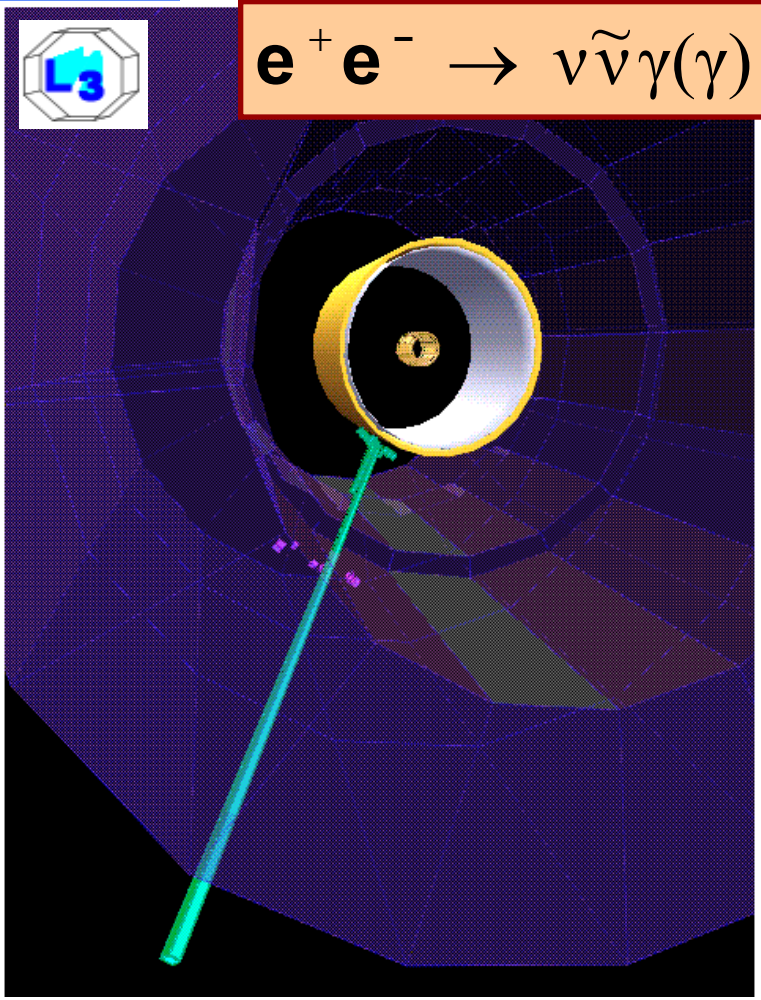
Indirect Searches: Deviations in differential distributions

- ❑ Additional Neutrino Flavors
- ❑ Extra Dimensions
- ❑ Different SUSY Scenarios
- ❑ Contact Interactions
- ❑ Anomalous Gauge Couplings

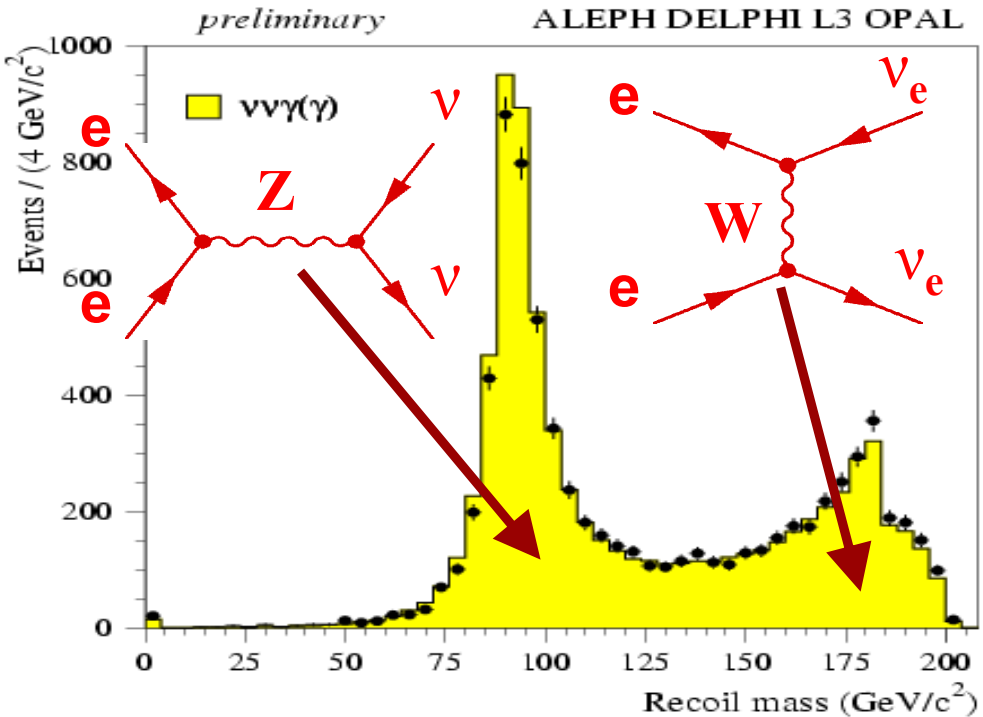
- ❑ Deviations from QED
- ❑ Contact Interactions
- ❑ Extra Dimensions
- ❑ Excited Electrons

Single & Multi Photons

$e^+e^- \rightarrow \nu\tilde{\nu}\gamma(\gamma)$



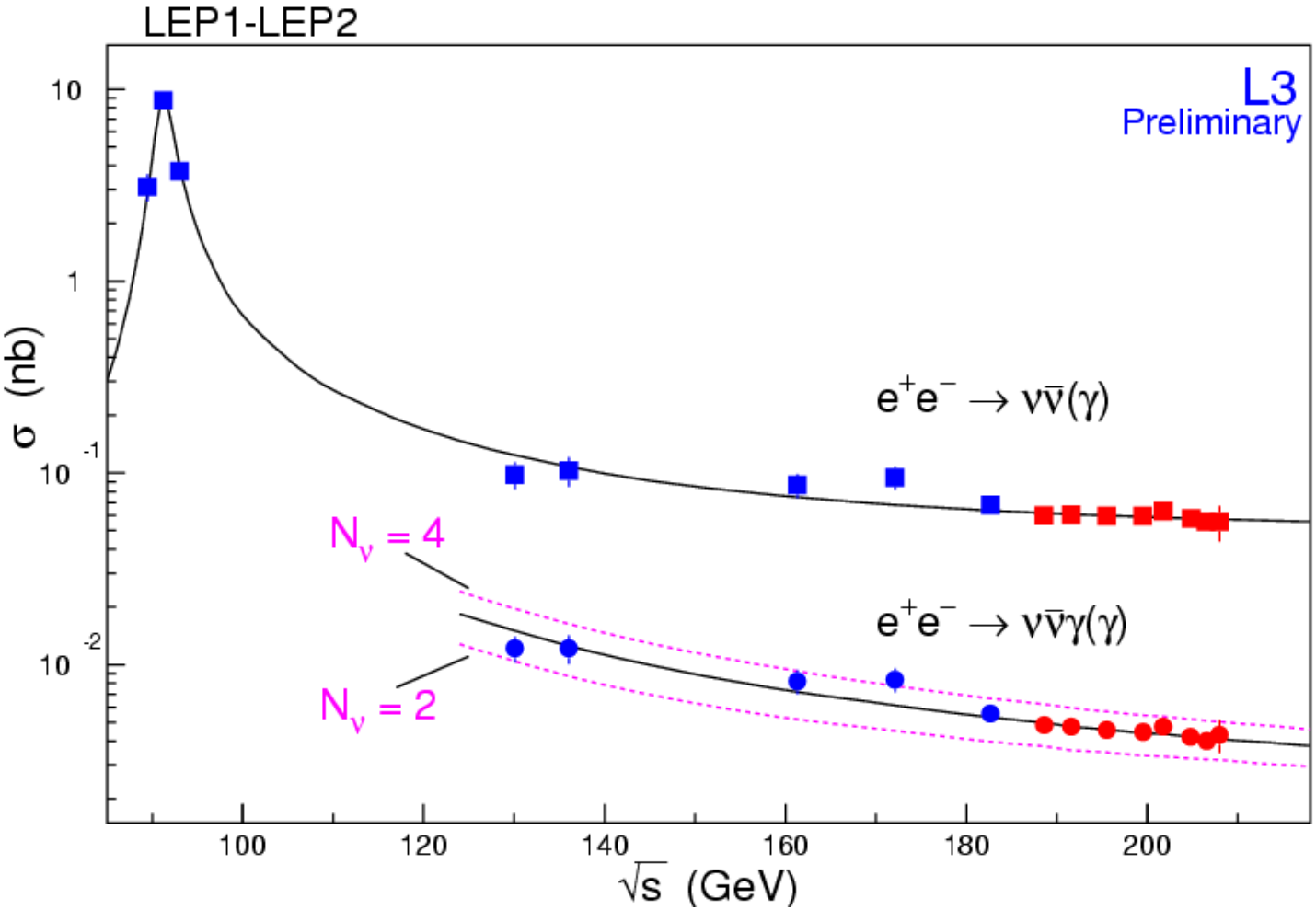
- Basic Selection (L3):
  $P_T > 0.04 * E_{BEAM}$ and Theta > 14 degrees
- Efficiency ~ 70-80% Purity ~ 99%
- ALEPH, DELPHI, L3 (updated)
  OPAL (combinations only)
  LEP combined (summer 2002)
- KK MC and NUNUGPV independent
  MC programs show good agreement
  Normalization Error (theory) 1%



- Tests detector hermeticity
- Selection challenges:

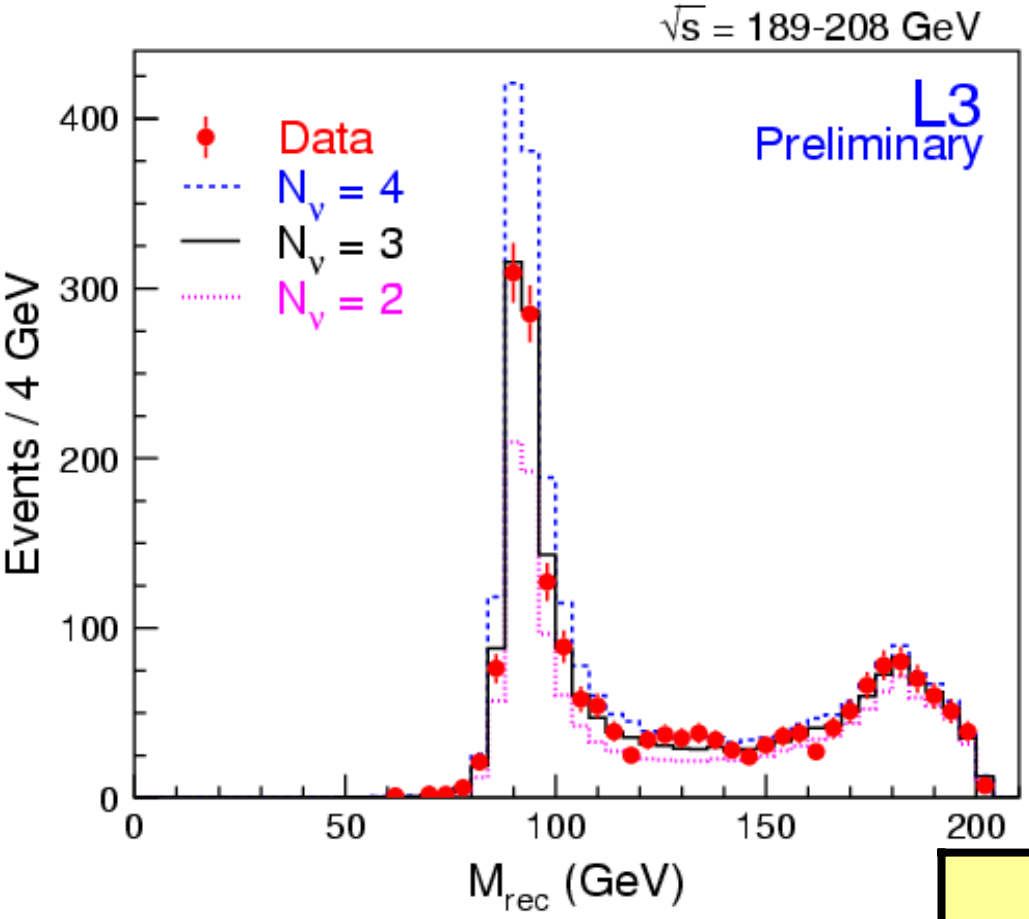
Trigger efficiency, Photon conversion, Dead channels

Single & Multi Photons



- Overall rates in good agreement for all experiments
- Some shape deviations in the missing mass spectrum

Direct Neutrino Counting



Total cross section & spectrum shape depend on the number of light neutrino families

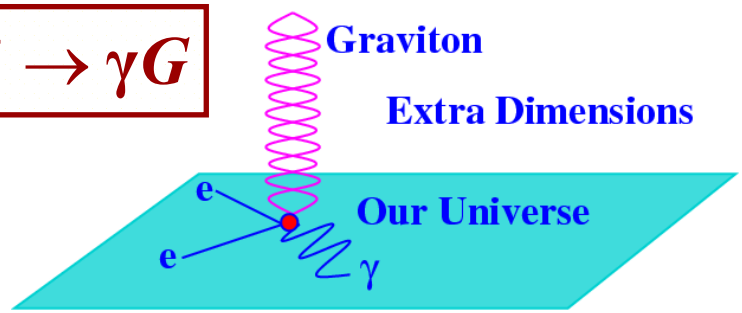
Good agreement with the SM expectation of three neutrino families

Number of Light Neutrinos	
DELPHI	2.80±0.10(*stat.*) ±0.14
ALEPH	2.86±0.09(*total*)
L3	2.95±0.08(*stat.*) ±0.03

Extra Dimensions with Single Photons

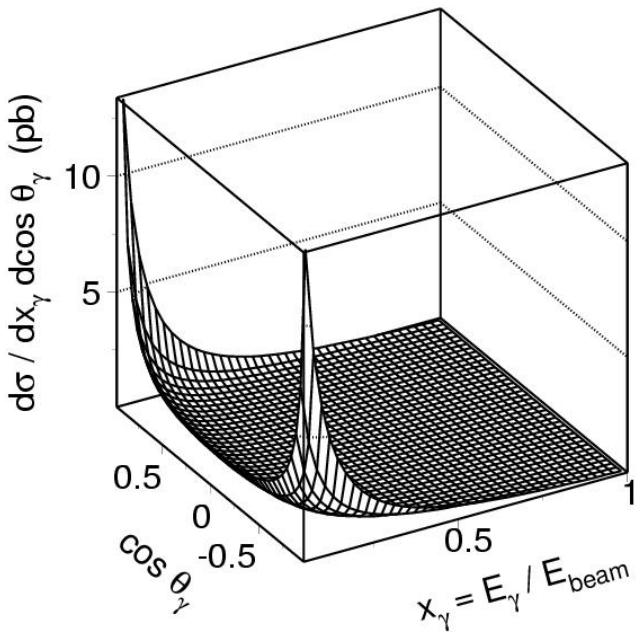
- Gravity propagates in extra dimensions but we (made of SM particles) live on a 3D wall
- Explains the weakness of the gravity force in our world and solves the hierarchy problem

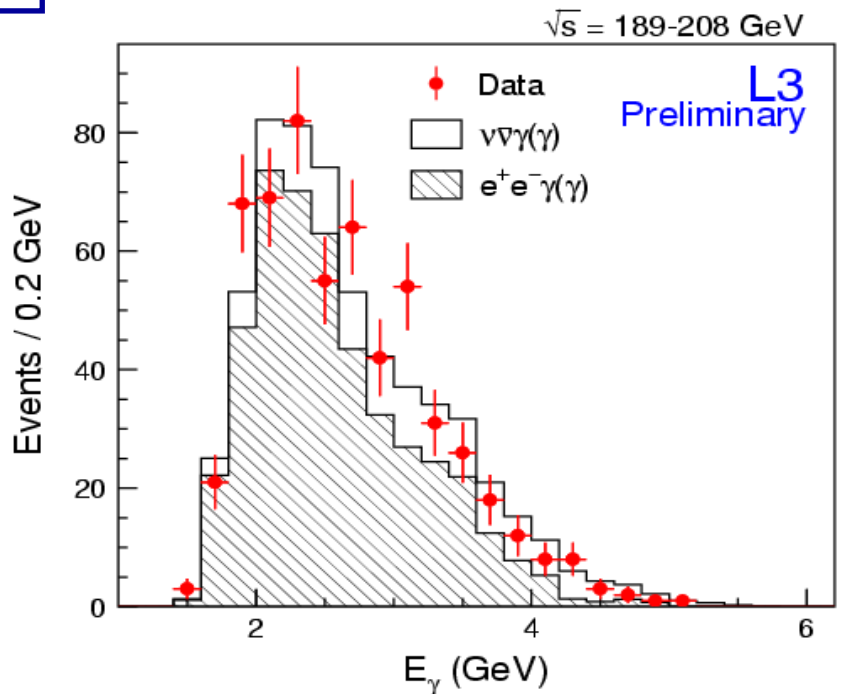
$$e^+e^- \to \gamma G$$



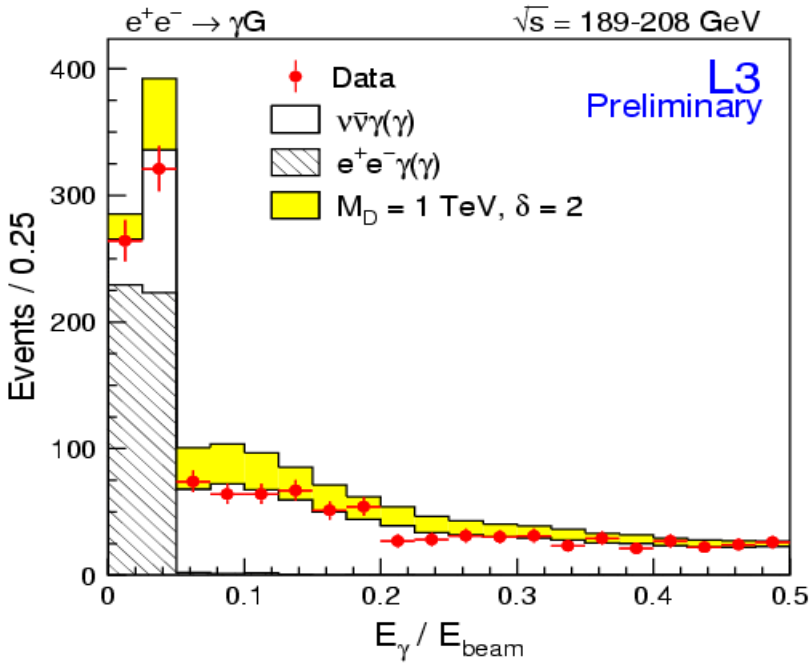
$$\frac{d^2\sigma}{dx_\gamma d\cos\theta_\gamma} = \frac{\alpha}{32s}\frac{\pi^{\delta/2}}{\Gamma(\delta/2)}\left(\frac{\sqrt{s}}{M_D}\right)^{\delta+2} f(x_\gamma, \cos\theta_\gamma)$$

Cross section peaks at low P_T
To improve sensitivity standard selection extended (L3)





Searches for Extra Dimensions



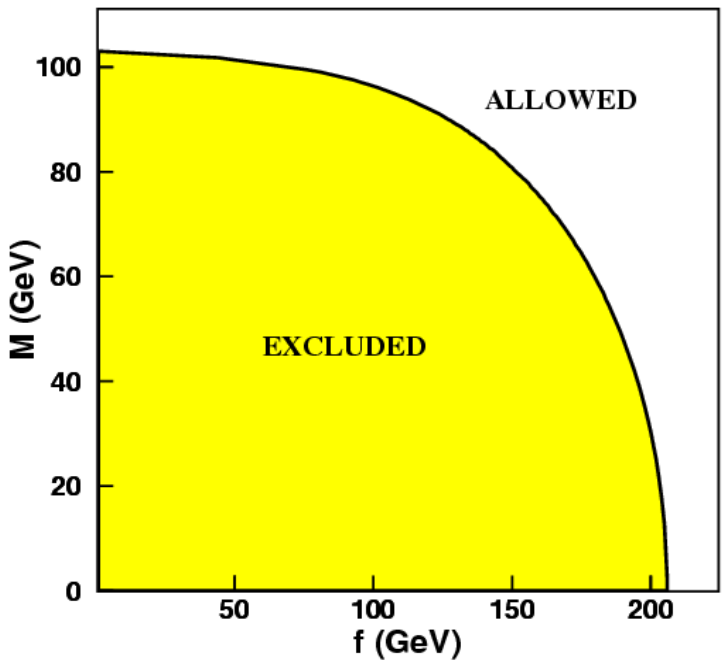
- Complementary search (L3)
  Brane excitations can lead to production of branons
- Parameters:
  Branon Mass and tension f
- Condition: f should be much less than M_D
- See hep-ph/0212269
- Same method as for γG

Limits on the fundamental scale

	M_D (TeV) > (at 95% CL)		
n	L3	ALEPH	DELPHI
2	1.50	1.26	1.36
4	0.91	0.77	0.84
6	0.65	0.57	0.59

Better than Tevatron for n < 7

L3 Limits on the Brane Tension

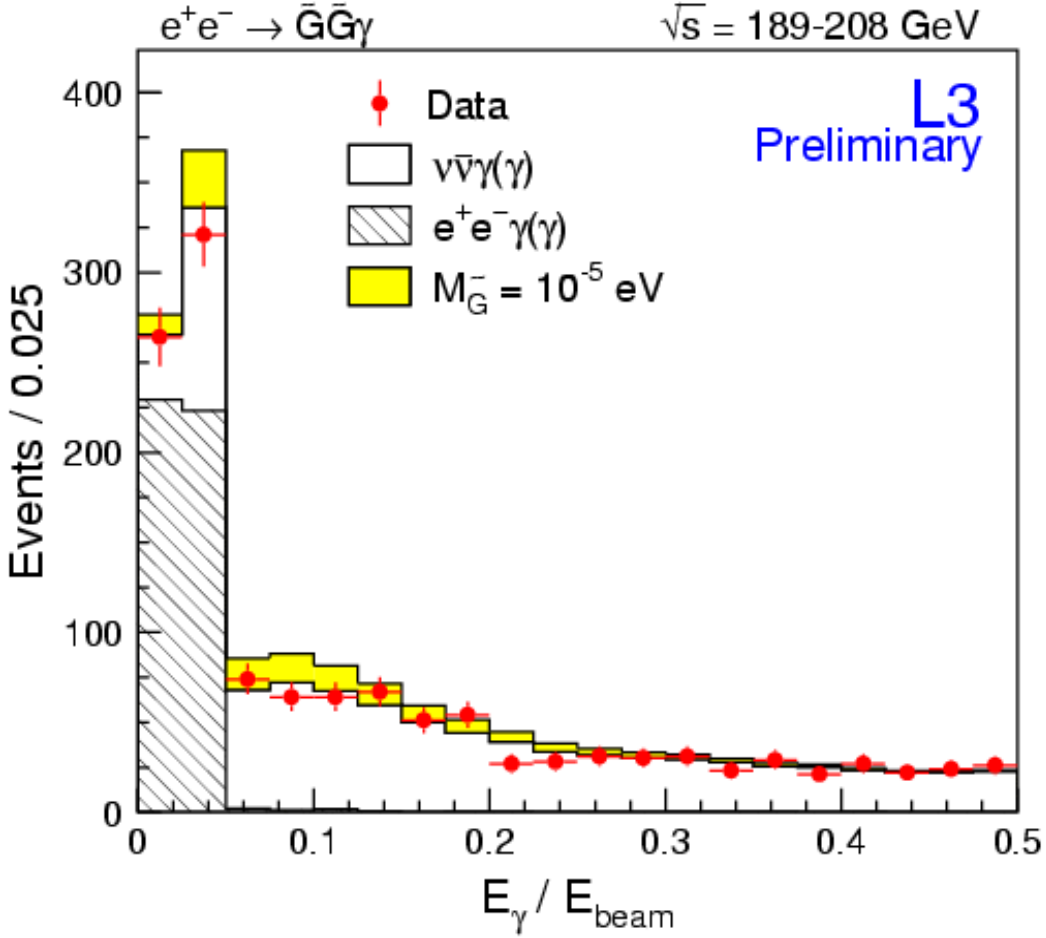


Search for Superlight Gravitinos

$$e^+e^- \to \gamma\tilde{G}\tilde{G}$$

- Gravitino is light and all other SUSY particles are too heavy to be observed at LEP
- Pair production of gravitinos with a photon (ISR) leads to a single photon signature
- Search strategy similar to to extra dim. and production cross section is ~ $1/M_{Gr}^4$

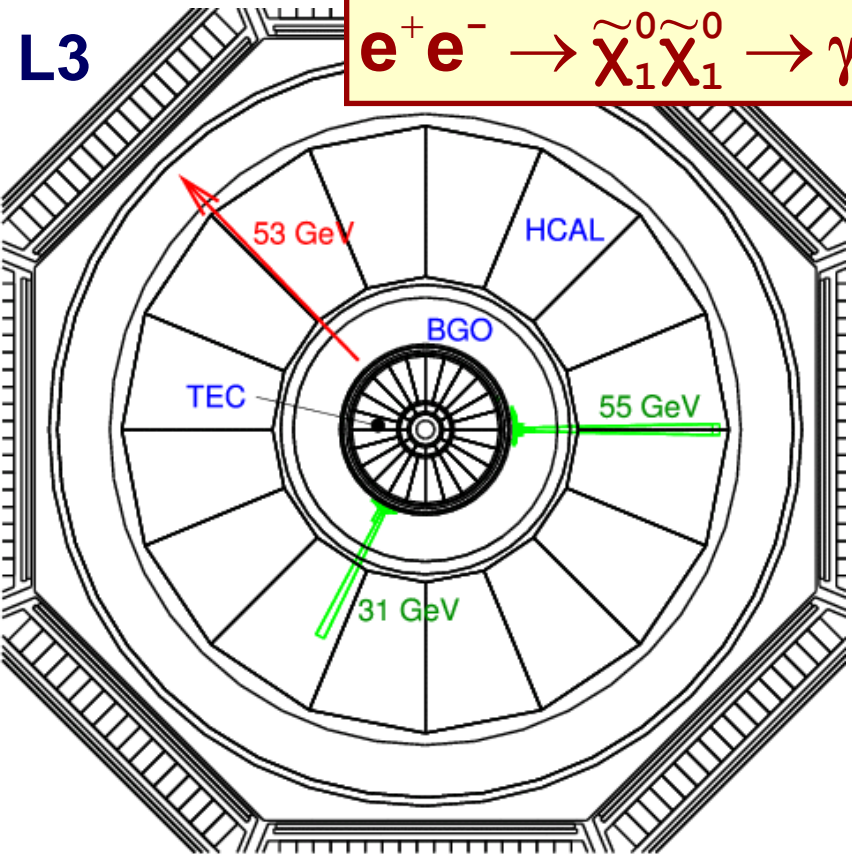
M_{Gr} (10^{-5} eV) > (at 95% CL)		
L3	ALEPH	DELPHI
1.35	1.3	1.12

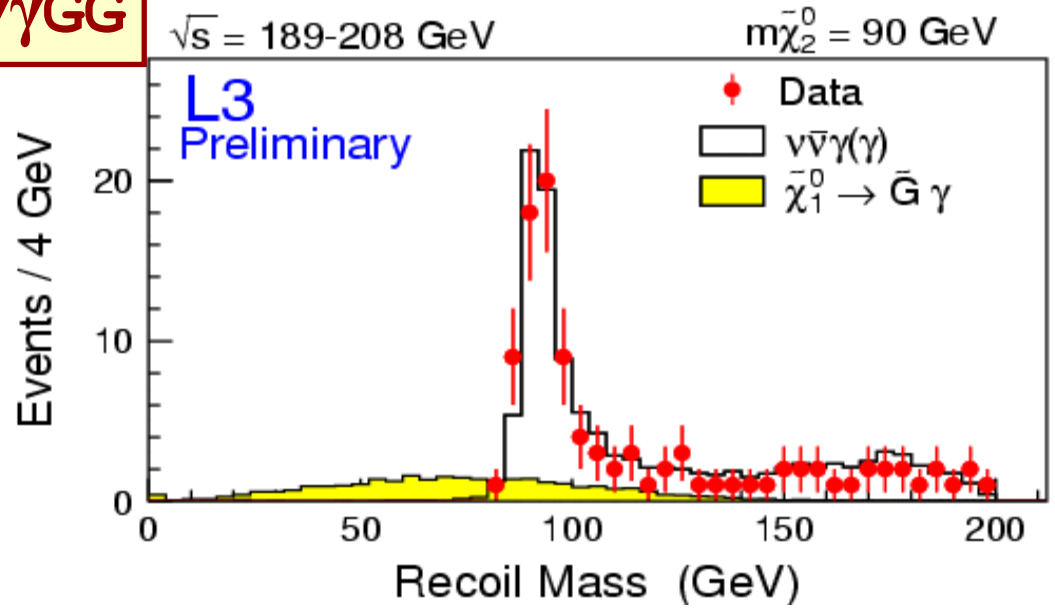


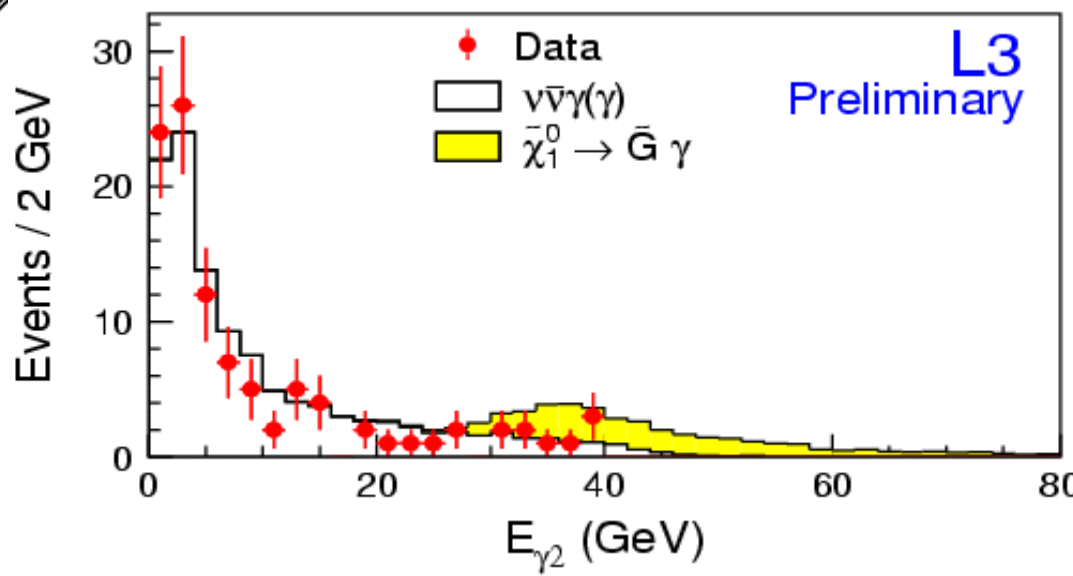
L3 limit on SUSY breaking scale

$$\sqrt{F} > 235 \text{ GeV}$$

Searches for GMSB Neutralinos



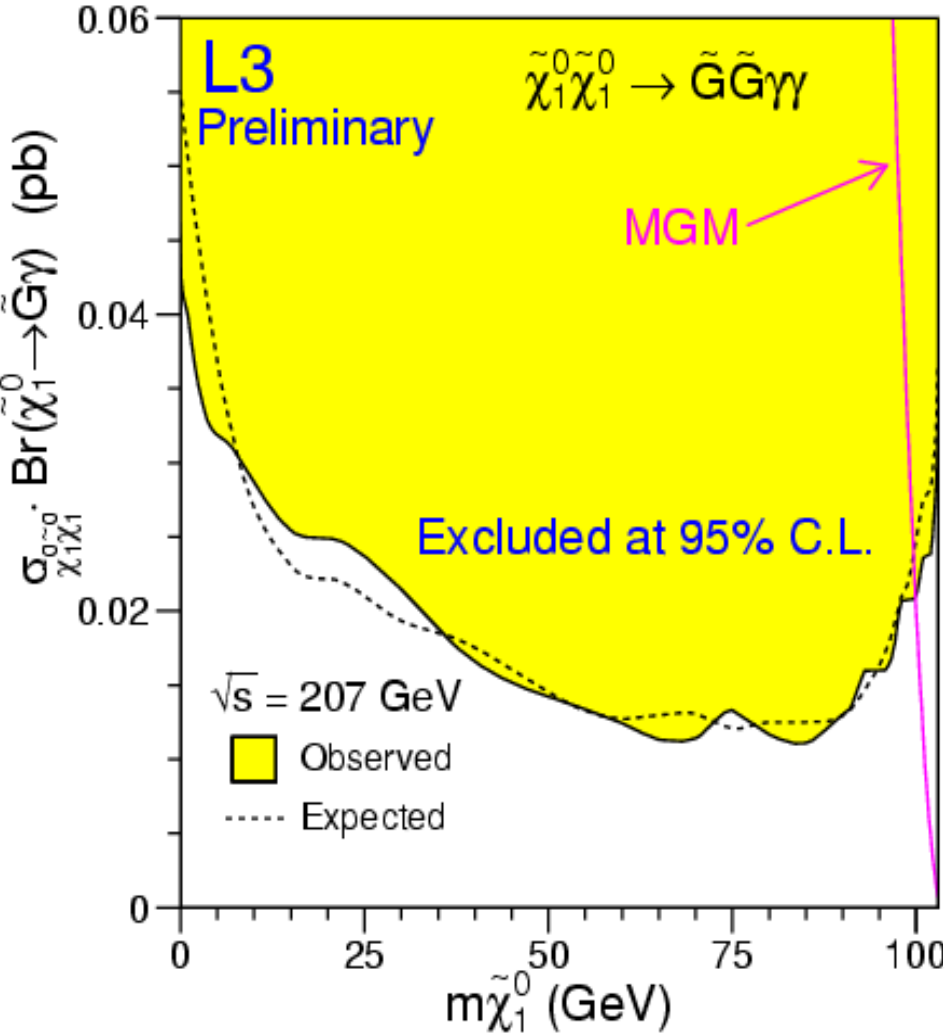




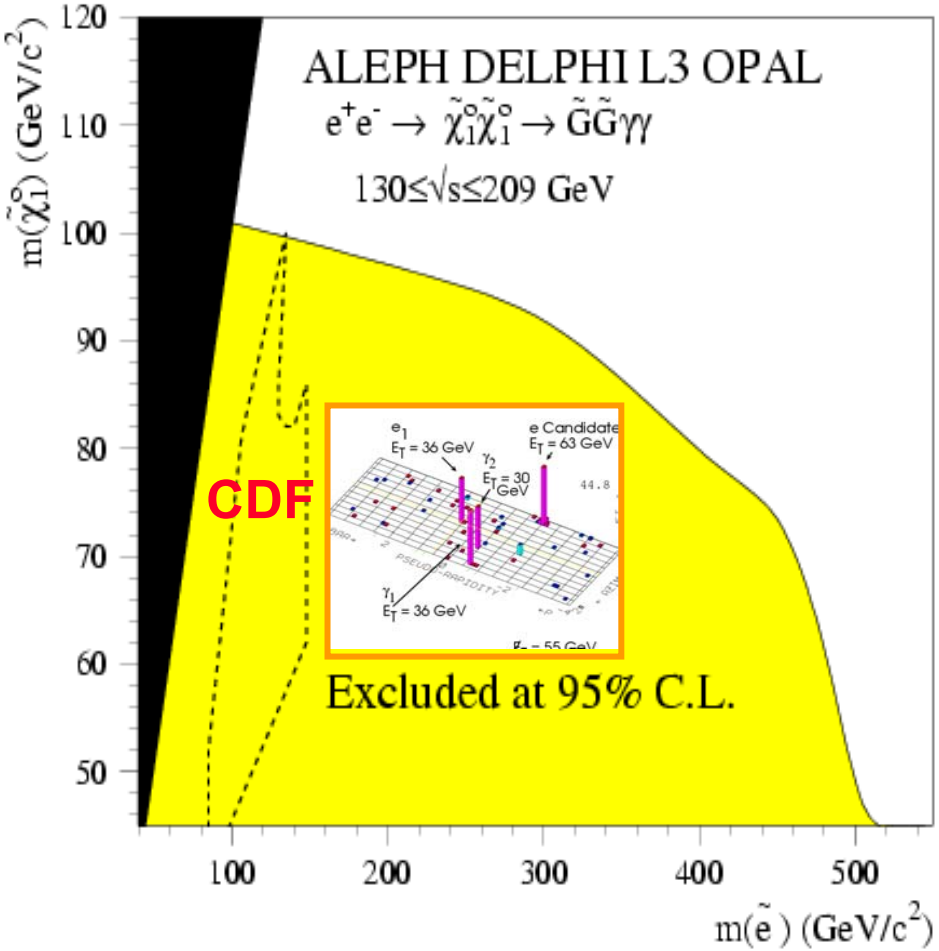
Signal is easy to separate
Efficiency ~ 60-70%

Searches for GMSB Neutralinos

Cross Section Limit



GMSB Interpretation



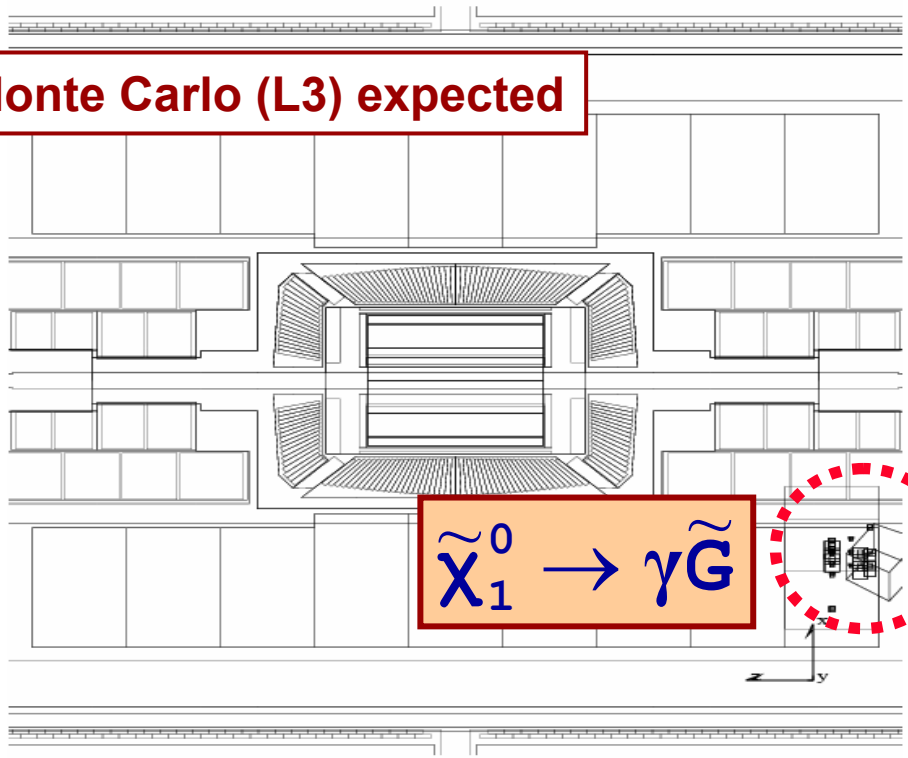
Searches for Long-lived Neutralinos

In GMSB SUSY depending on a gravitino mass neutralino decay length may be macroscopic

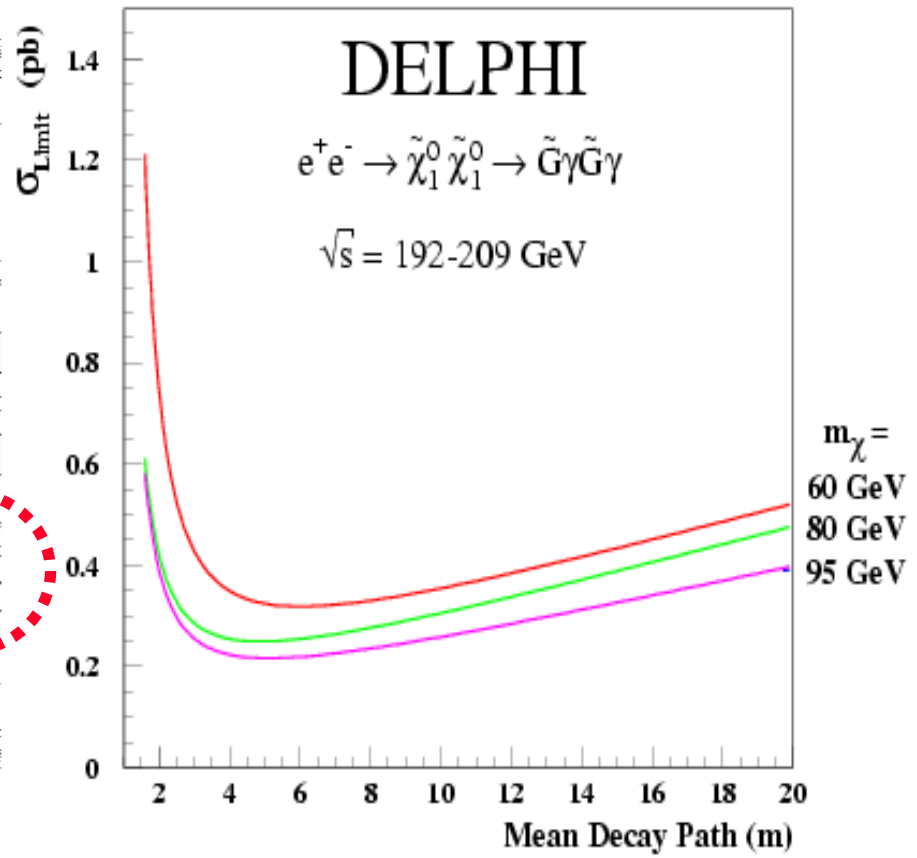
One or both neutralinos decay inside the detector

$$e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 \rightarrow \gamma\gamma\tilde{G}\tilde{G}$$

Monte Carlo (L3) expected

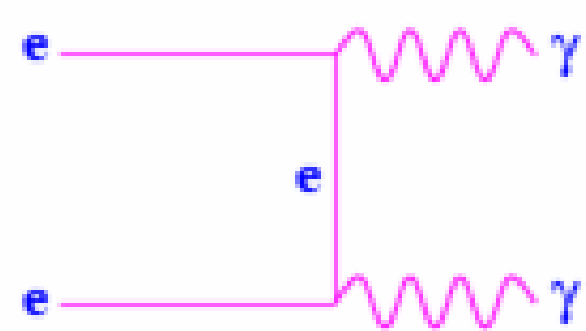


Limits from ALEPH, DELPHI, L3



Di-Photons at LEP

$e^+e^- \rightarrow \gamma\gamma$



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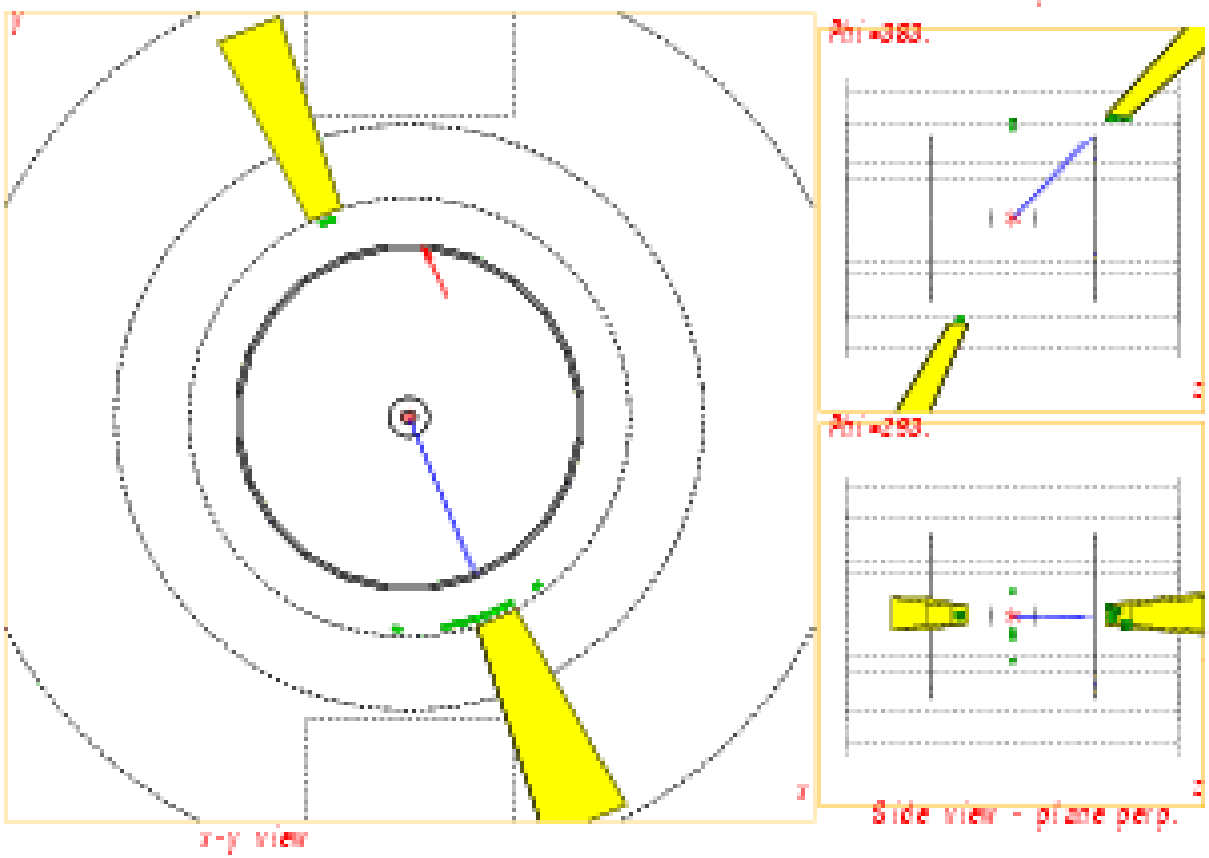
Date: 2 November 2000, Time: 07:57:38

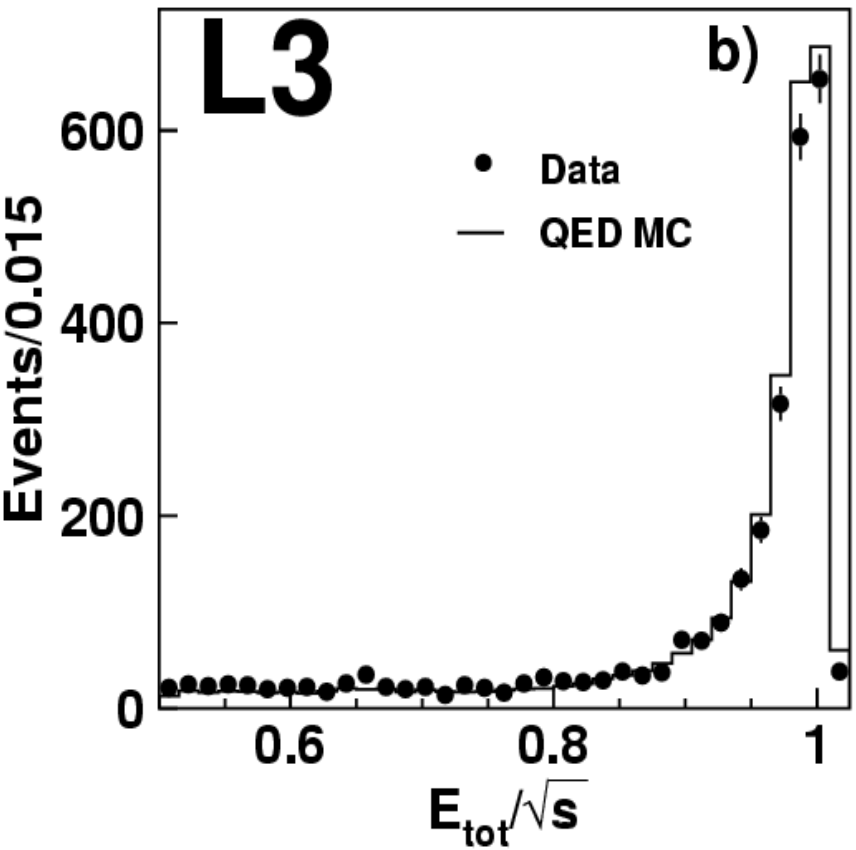


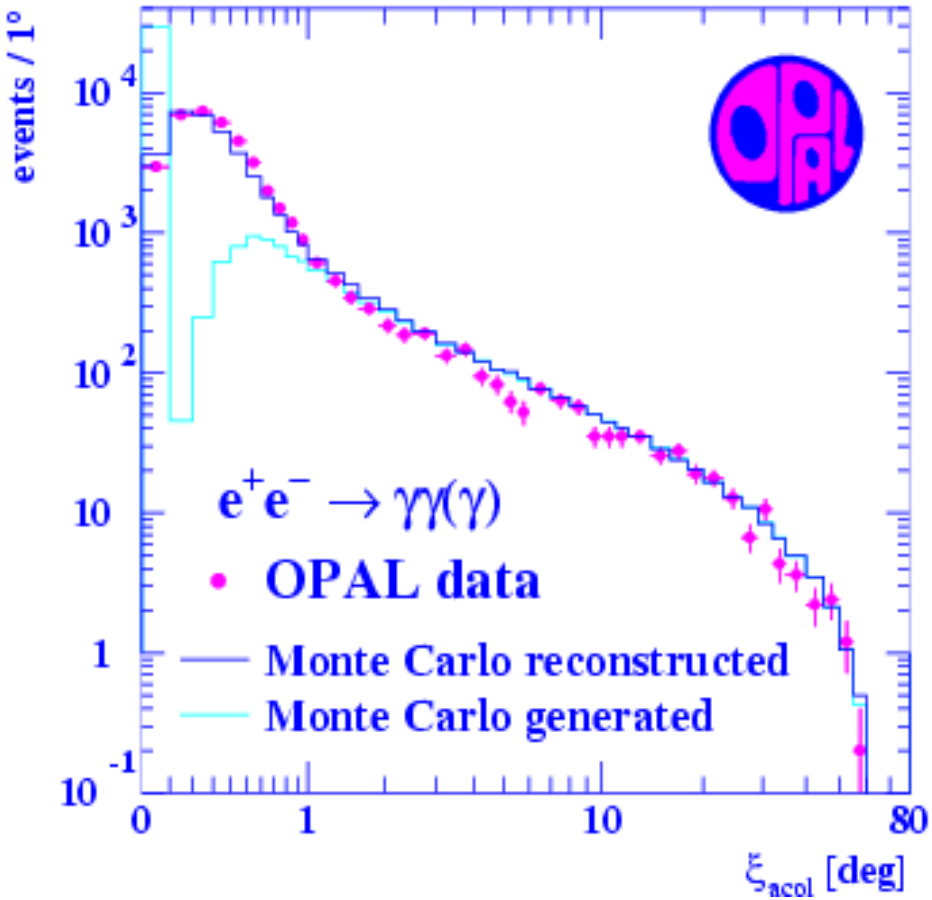
- **Selection (ALEPH):**
  Theta > 18 degrees
  $E_\gamma > 0.5 * E_{BEAM}$
  Back to back photons

- **ALEPH, OPAL, L3**
  DELPHI
  LEP combination
  (summer 2002)

Di-Photons at LEP

Good agreement with the QED

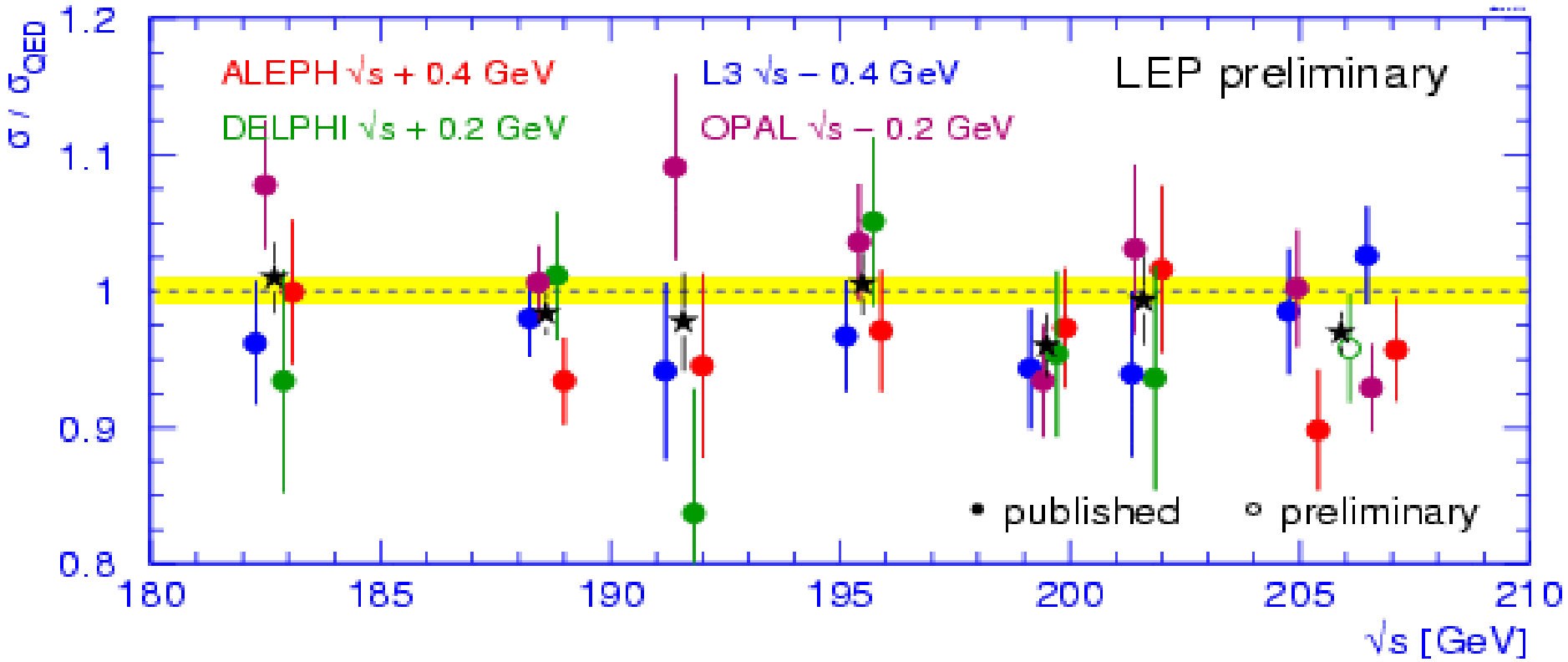




Di-Photons at LEP

$$\frac{\sigma_{\mathrm{LEP}}}{\sigma_{\mathrm{QED}}} = 0.982 \pm 0.010$$

Theoretical error is 1% as well



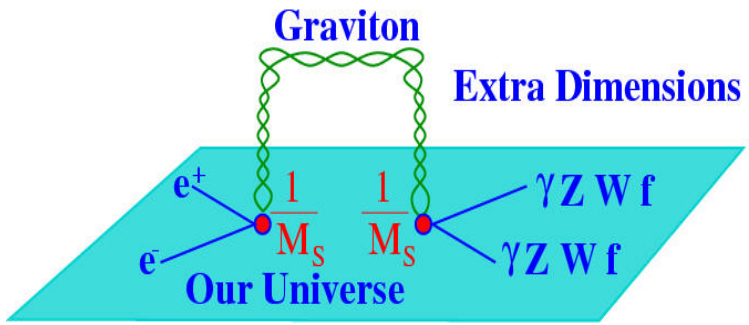
Searches for New Physics with Di-Photons

Deviations from QED predicted distributions expected in models with

- **Extra Dimensions**
- **Contact Interactions** (deviations from QED)
- **Excited Electrons** (see also talk by E.Sanchez)

SM cross section multiplied by
a model dependent factor

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{SM} \cdot \left(1 \pm \frac{s^2}{2(\Lambda_{\pm}^{QED})^4}\sin^2\theta\right)$$



$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{SM} \cdot \left(1 \mp \frac{s^2}{\pi\alpha} \cdot \frac{\lambda}{2M_S^4}\sin^2\theta + \ldots\right)$$

Searches for New Physics with Di-Photons

Event polar angle introduced to minimize effects due to ISR

$$\cos\theta = \left|\sin\left(\frac{\theta_1-\theta_2}{2}\right)\right| \Big/ \sin\left(\frac{\theta_1+\theta_2}{2}\right)$$

LEP Combined Limits (95% C.L.)

QED cut-off parameters

$\Lambda_+ > 392$ GeV

$\Lambda_- > 364$ GeV

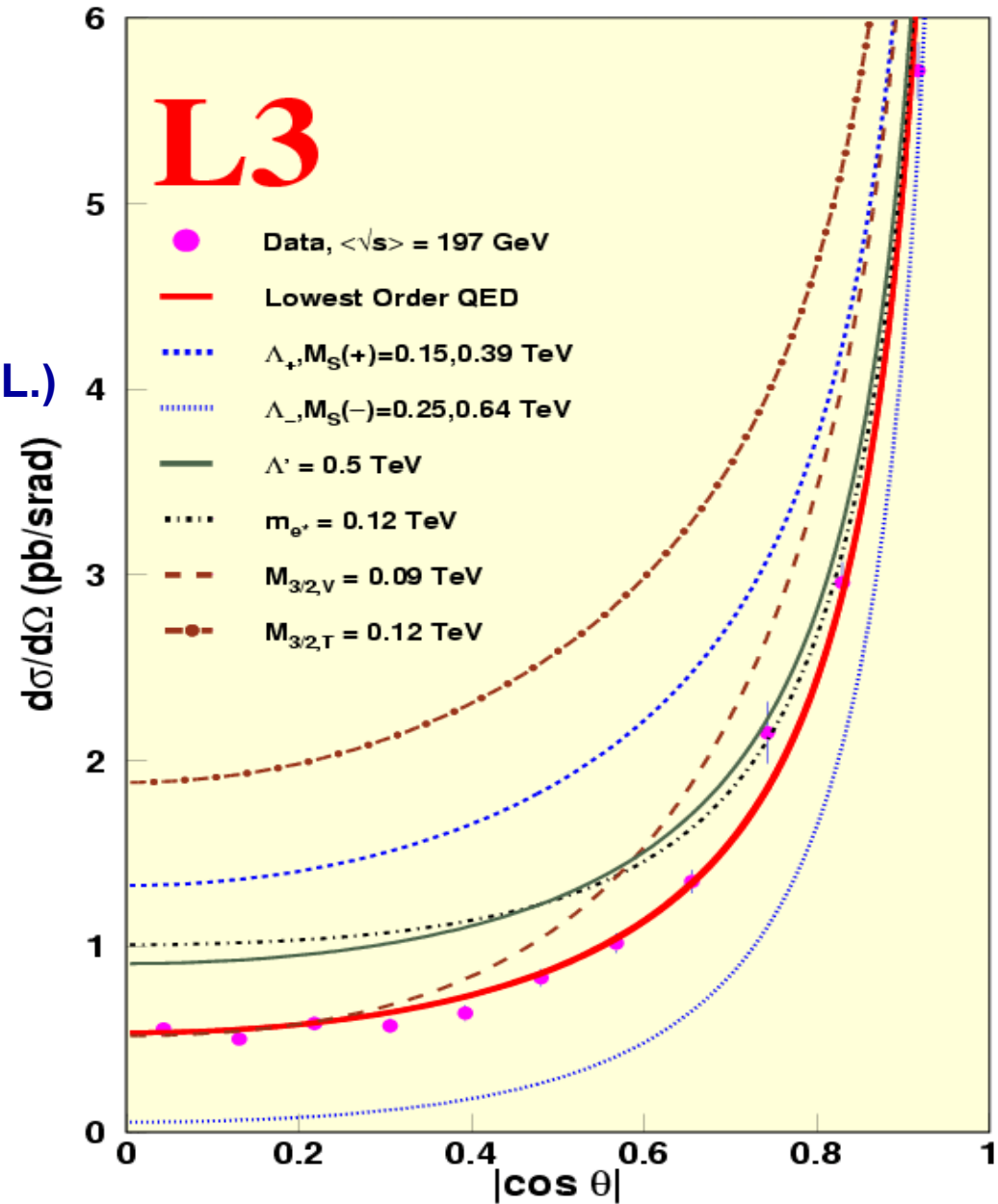
Contact Interactions

$\Lambda' > 831$ GeV

Low Scale Gravity

$M_S(\lambda = -1) > 0.99$ TeV

$M_S(\lambda = +1) > 0.84$ TeV



Summary

- Deviations from the Standard Model are searched for in a wide range of new physics scenarios (not all results covered in this talk)
- New effects are not found in differential and total cross section or in model dependent searches
- Thanks to S. Mele, J. Alcaraz, S. Ask, and authors of the KK MC and NUNUGPV, and all who provided their results
  Also thanks to the HEP2003 organizers; Professors Boehm, Fesefeldt and Newman for their support and help
- Final LEP combinations and papers are well under way

A LEP physicist after searching for new physics