

Searches at LEP



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On behalf of the LEP Collaborations

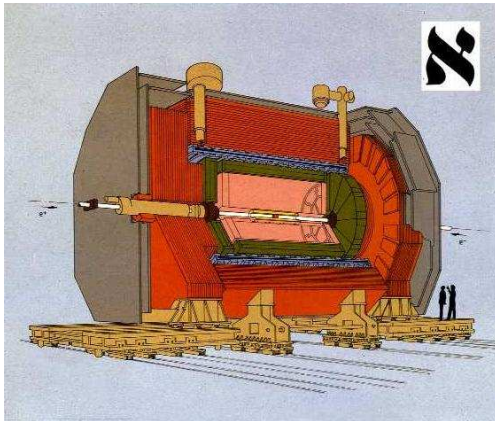
DIS Conference Strbske Pleso 2004

1. (Not so) New phenomena overview
2. SUSY as a model for new physics
3. Extra space dimension searches at LEP
4. Summary and outlook

New Physics

- Standard model still very healthy, but . . .
- Experimental facts:
 - Neutrino masses
 - Dark matter and dark energy
- Theoretical Problems:
 - Unification of the forces?
 - Mass hierarchy?
 - ⇒ Search for new massive particles
 - Substructure?
- Possible solutions: SUSY, extra dimensions, (Technicolour, Compositeness)
Two ideas to solve the problem, both based on new dimensions
 - SUSY: new fermionic dimension
 - E.D.: new space-time dimension

The LEP Experiments



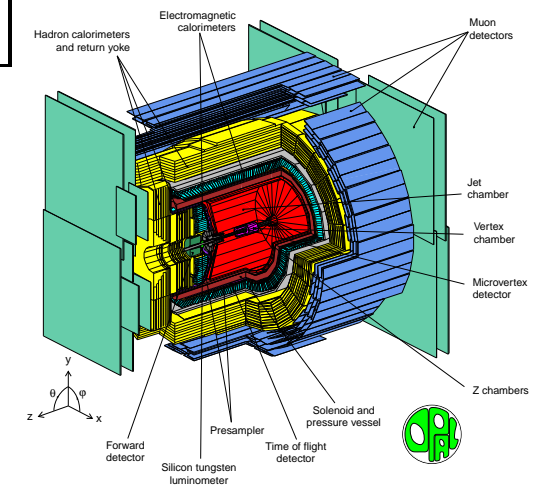
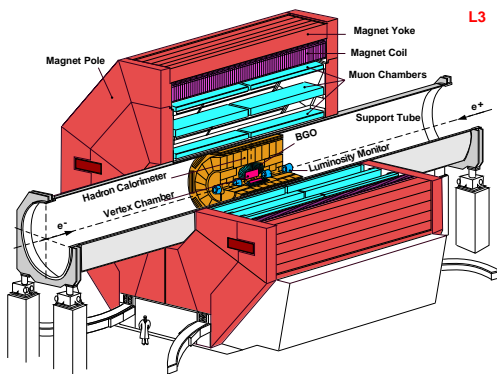
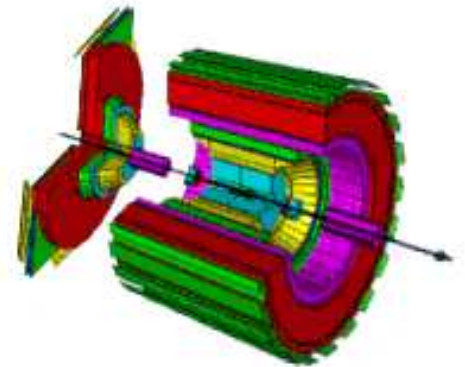
LEP data taking from 1989 to 2000

$$\sqrt{s} = 91 - 209 \text{ GeV}$$

$$\text{Overall } \mathcal{L} \approx 2600 \text{ pb}^{-1}$$

$> 20 \times 10^6$ Z on peak,

40000 W^\pm pairs, 1200 Z pairs



SUSY as a model for new Physics

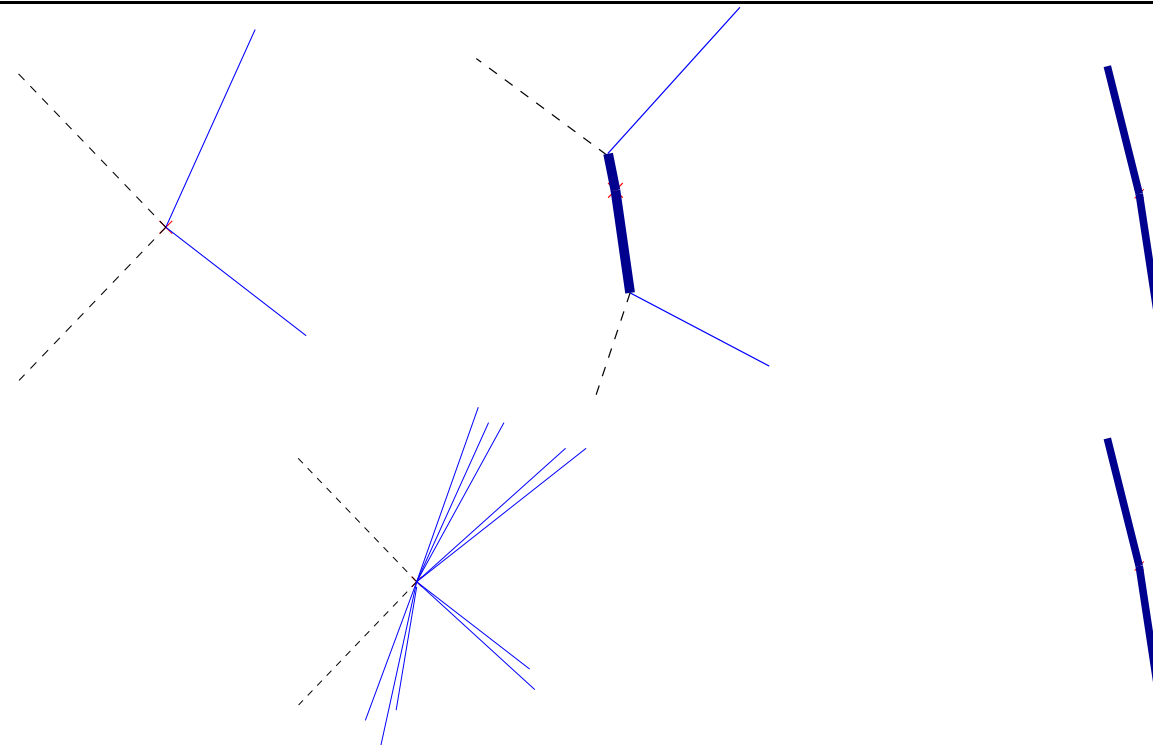
- Rich diversity, therefore good playground for **any** kind of new physics
- New **SUSY boson** for every SM fermion and new **SUSY fermion** for every SM boson

Particle

lifetime →

slepton
NLSP

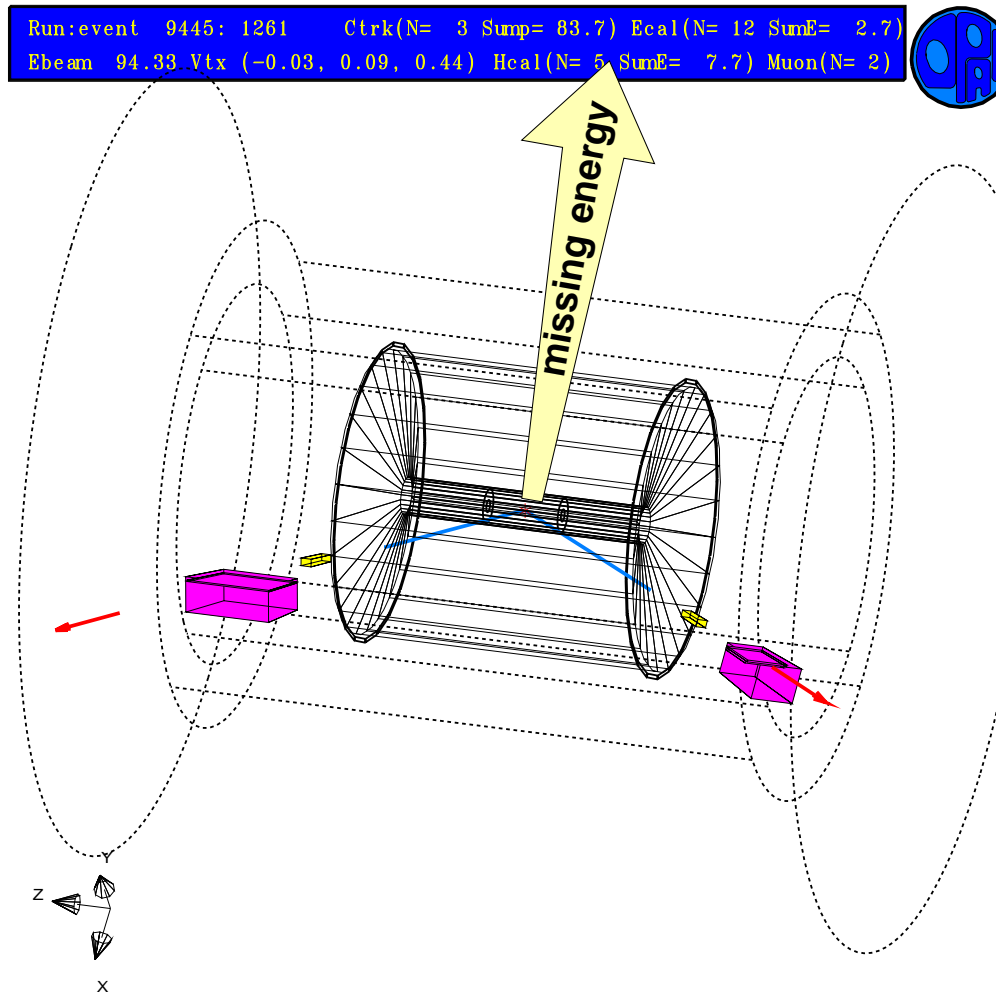
chargino
NLSP



- + R-parity violation, Higgs searches, etc.

A typical missing energy event

- A typical missing energy event, $e^+e^- \rightarrow \tilde{\ell}^+\tilde{\ell}^- \rightarrow \ell^+\chi_1^0\ell^-\chi_1^0$ (same flavour)



- ... or $e^+e^- \rightarrow W^+W^- \rightarrow \ell^+\nu\ell^-\bar{\nu}$ (possibly different flavour) background

: Something found at LEP?

No

... apart from lots of limits

Search Overview

- Sleptons

LEP combination, see

http://lepsusy.web.cern.ch/lepsusy/www/sleptons_summer02/slep_2002.html

- Neutralinos and Charginos

LEP combination, see

http://lepsusy.web.cern.ch/lepsusy/www/inos_moriond01/charginos_pub.html

and **ALEPH** [Phys.Lett.B583:247-263,2004]

- Long-lived stable particles

ALEPH [Eur.Phys.J.C31:327-342,2003]

- R-parity violation

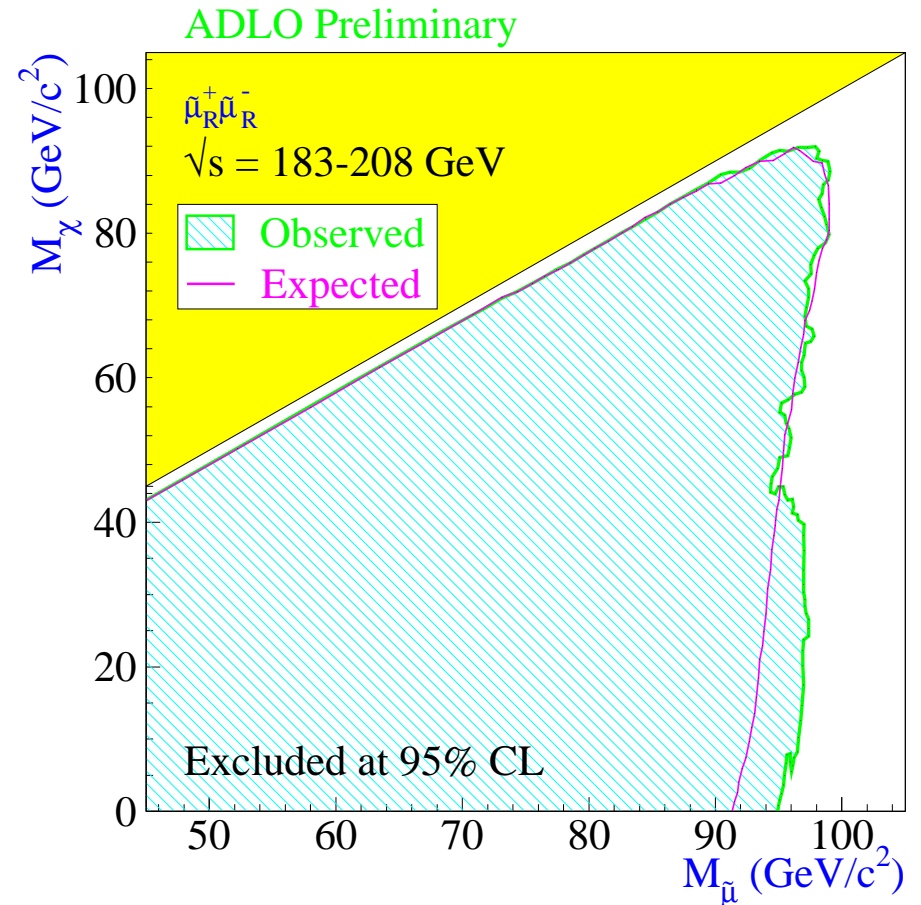
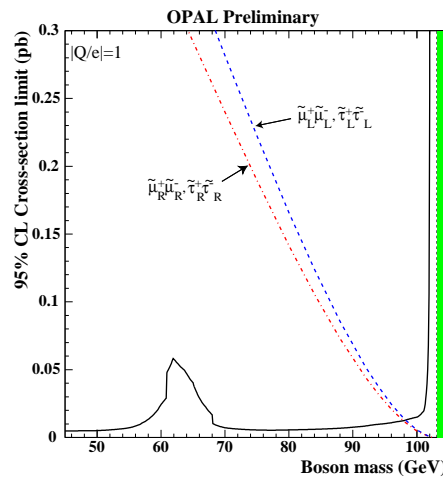
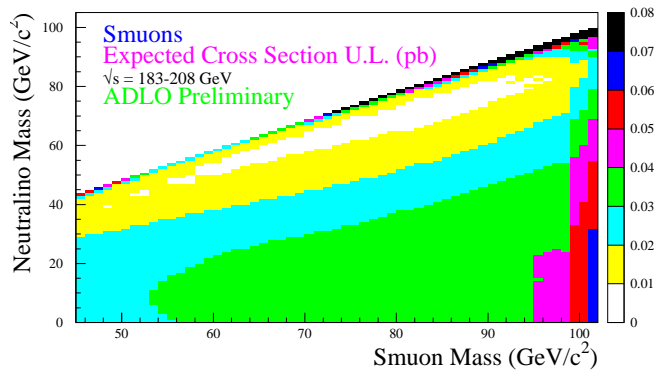
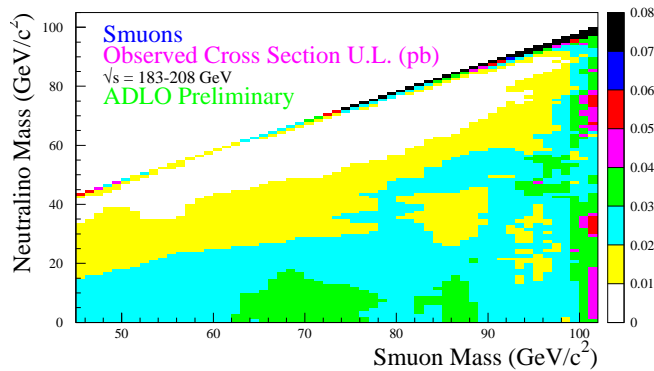
OPAL [CERN-EP-2003-036]

- Extra dimensions

DELPHI [DELPHI 2003-040 CONF 660] and **OPAL** [OPAL PN526]

Sfermion Searches

- No signal found, therefore calculate limit on σ

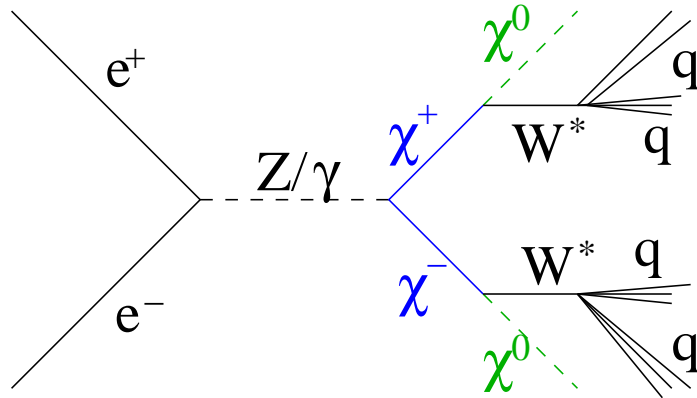


- Compare σ_{excl} with σ_{theo} , for $m_{\tilde{\mu}} = 80 \text{ GeV}$: 400 events expected, very hard to miss

- Exclusion up to the kinematic limit at around 100 GeV

Chargino Searches

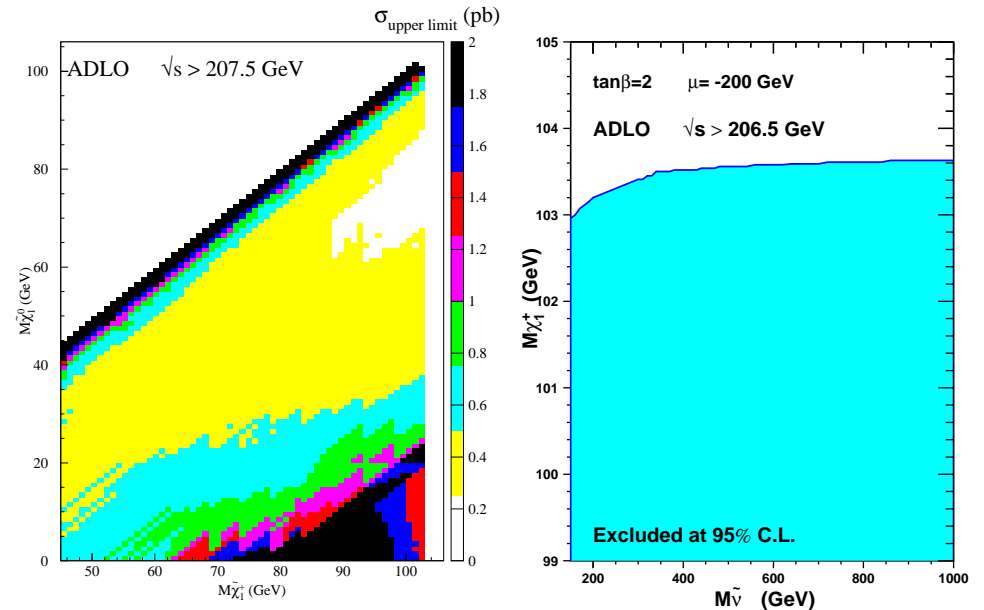
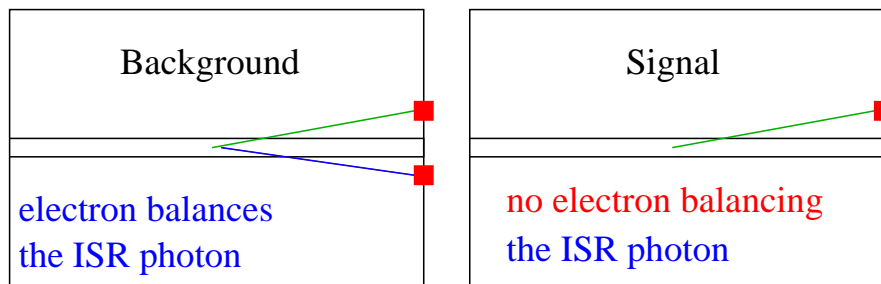
- Search for events like



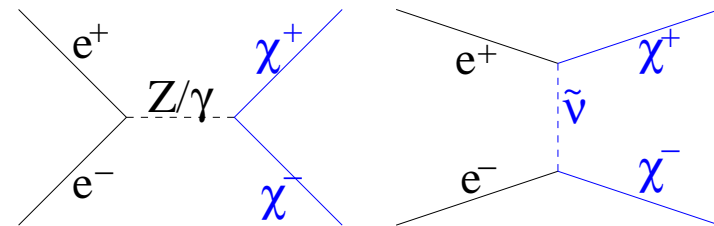
- Signature strongly depending on

$$\Delta m = m_{\chi_1^+} - m_{\chi_1^0}$$

- Fight low Δm background ($\gamma\gamma \rightarrow q\bar{q}$) with tagged photons

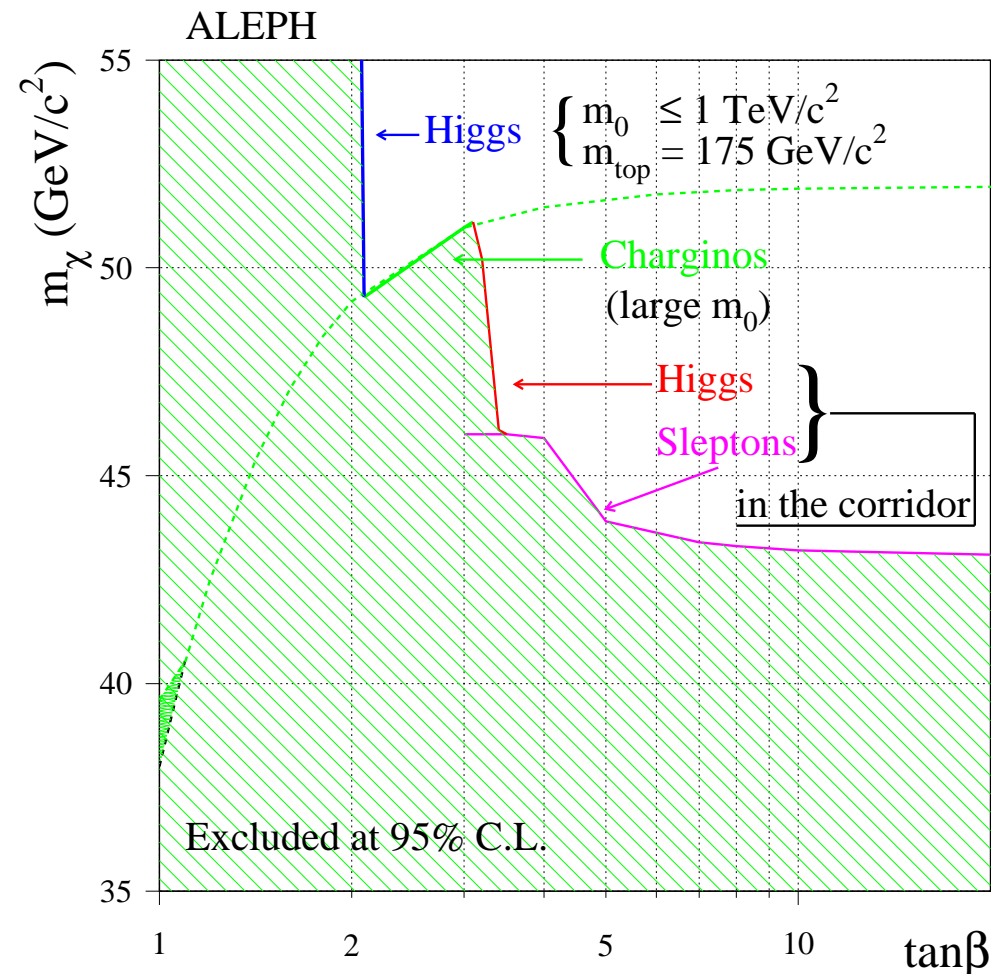


- Result also depends on the interference



Neutralino mass limits

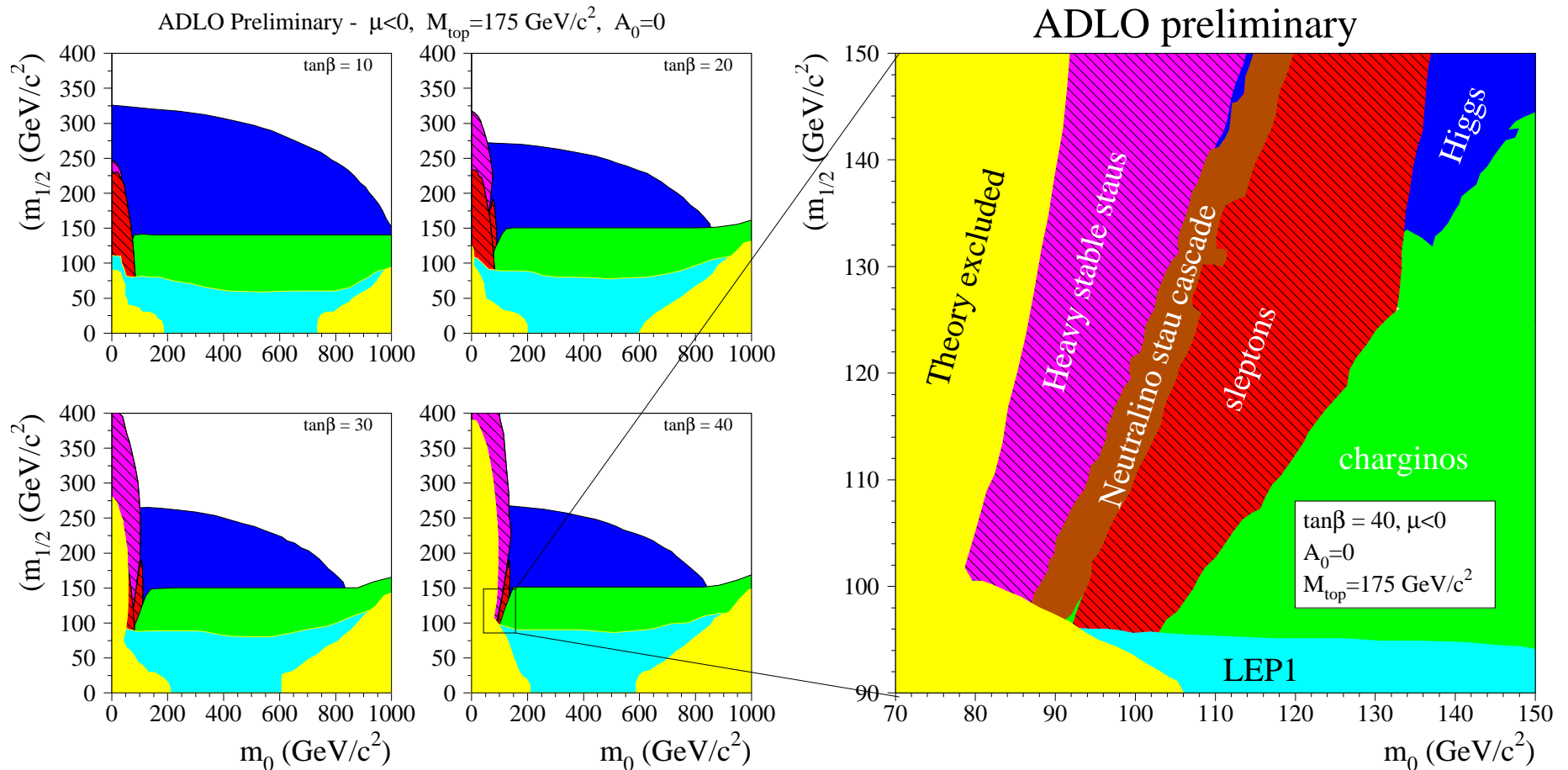
- Neutralino exclusion mainly depends on searches for Charginos and Higgs



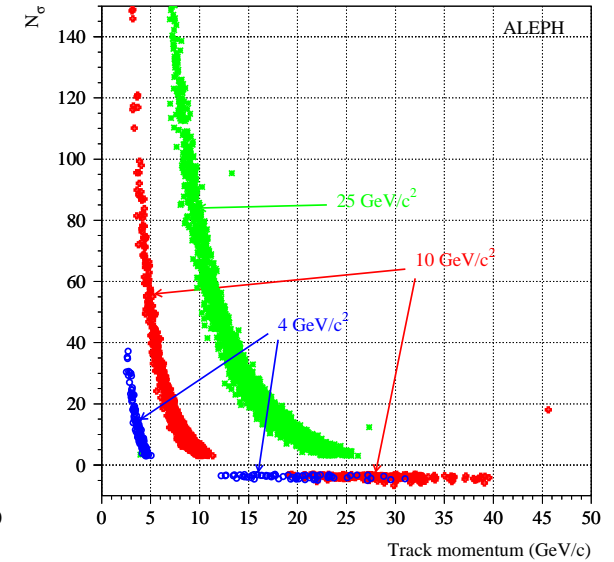
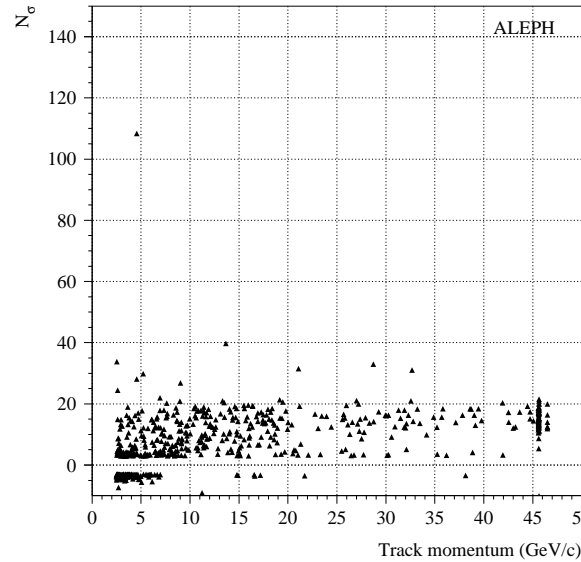
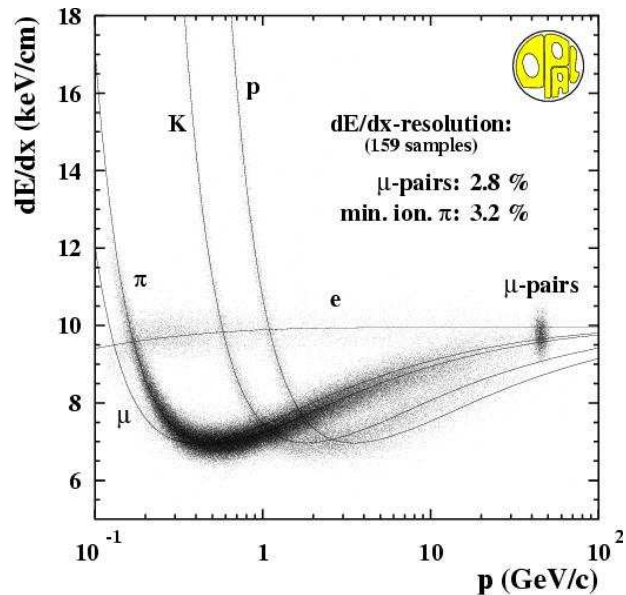
- Exclusion uses CMSSM GUT relation, **no** limit on m_{χ_0} without GUT relation

Combining the search results

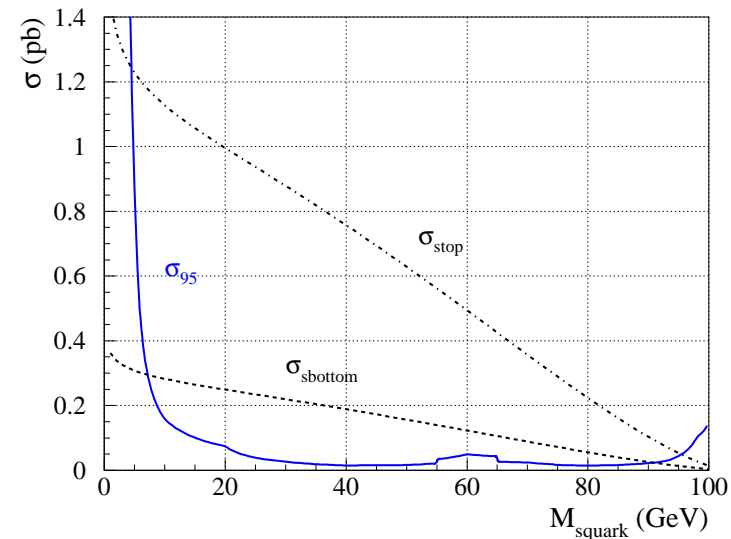
- Topological searches primarily independent of SUSY scenario
- Now combine searches to investigate given SUSY scenarios (e.g. MSUGRA)



Long lived stable particles

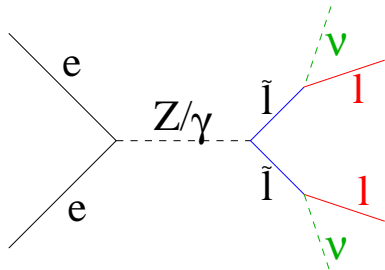


- Search for events with few very highly ionizing tracks
- Interpret search results in terms of stable \tilde{q} , $\tilde{\ell}$ or χ_1^+

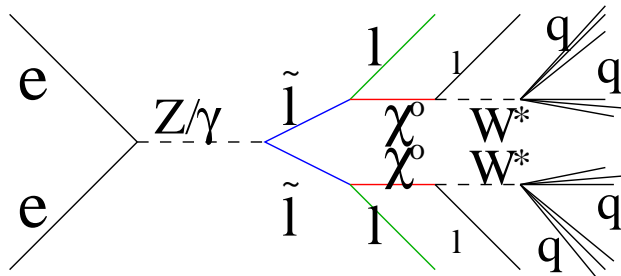


R-Parity Violation

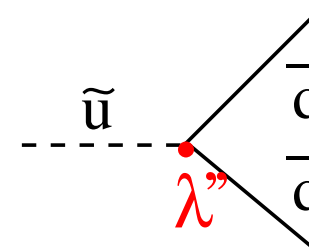
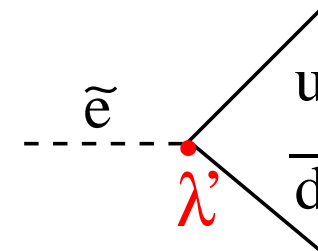
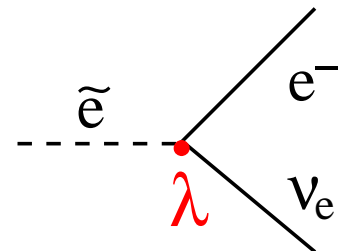
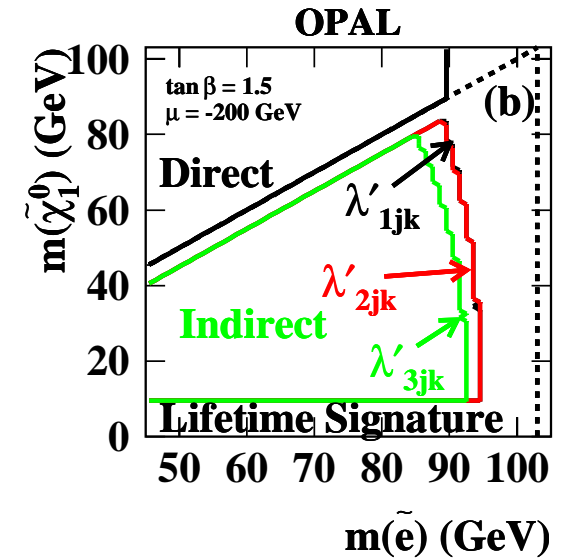
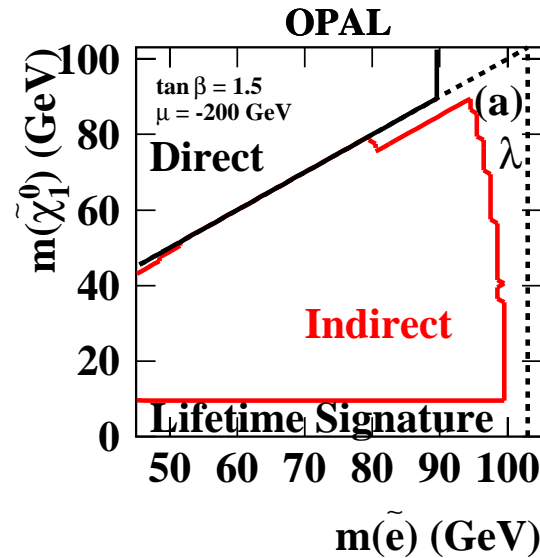
- Search for everything from 2 leptons



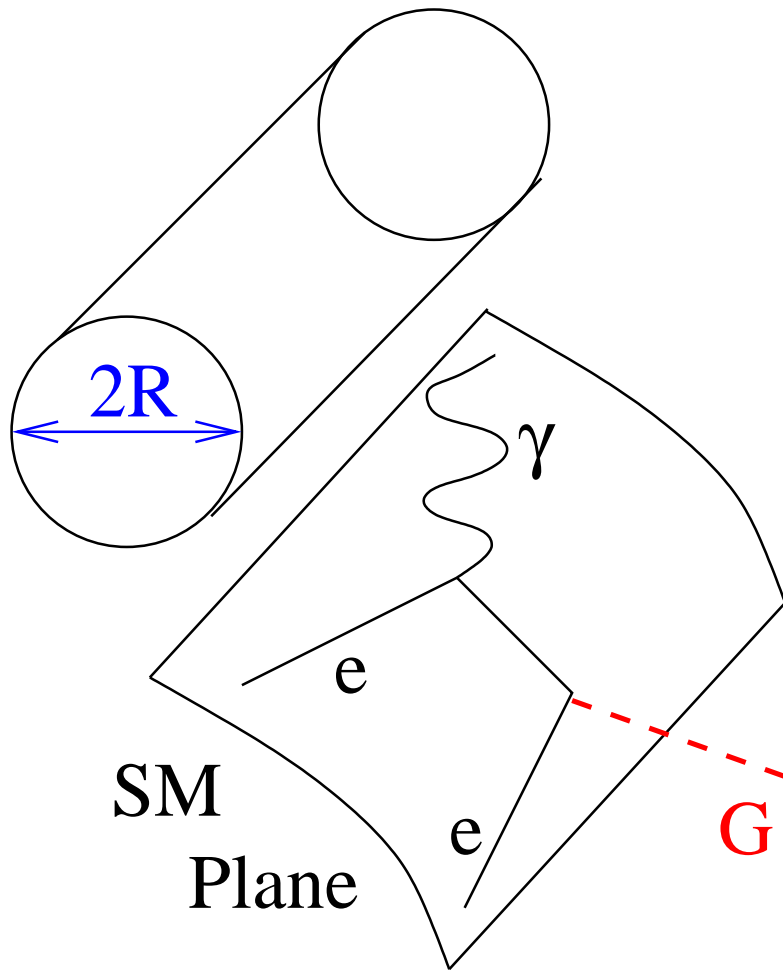
- to 4 leptons and 4 jets



- with and without missing energy (neutrinos)
- direct ($\tilde{\ell} \rightarrow lX$) or indirect ($\tilde{\ell} \rightarrow \chi X$)

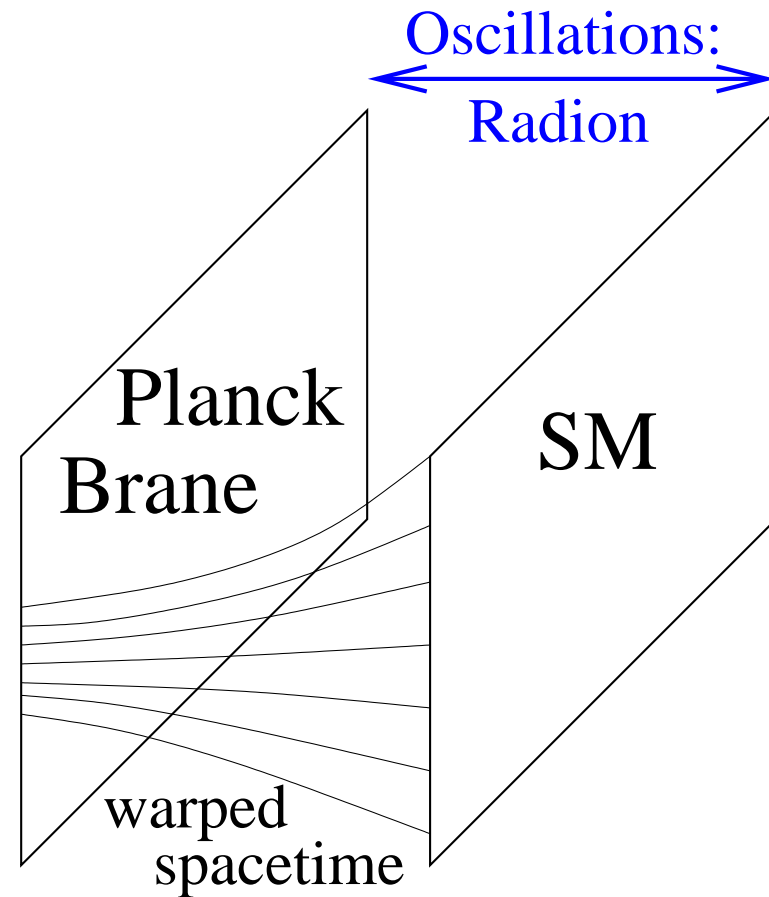


Extra space dimensions



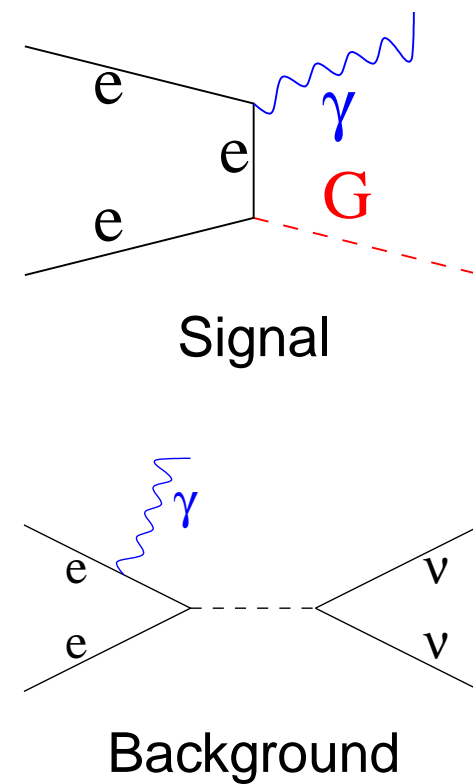
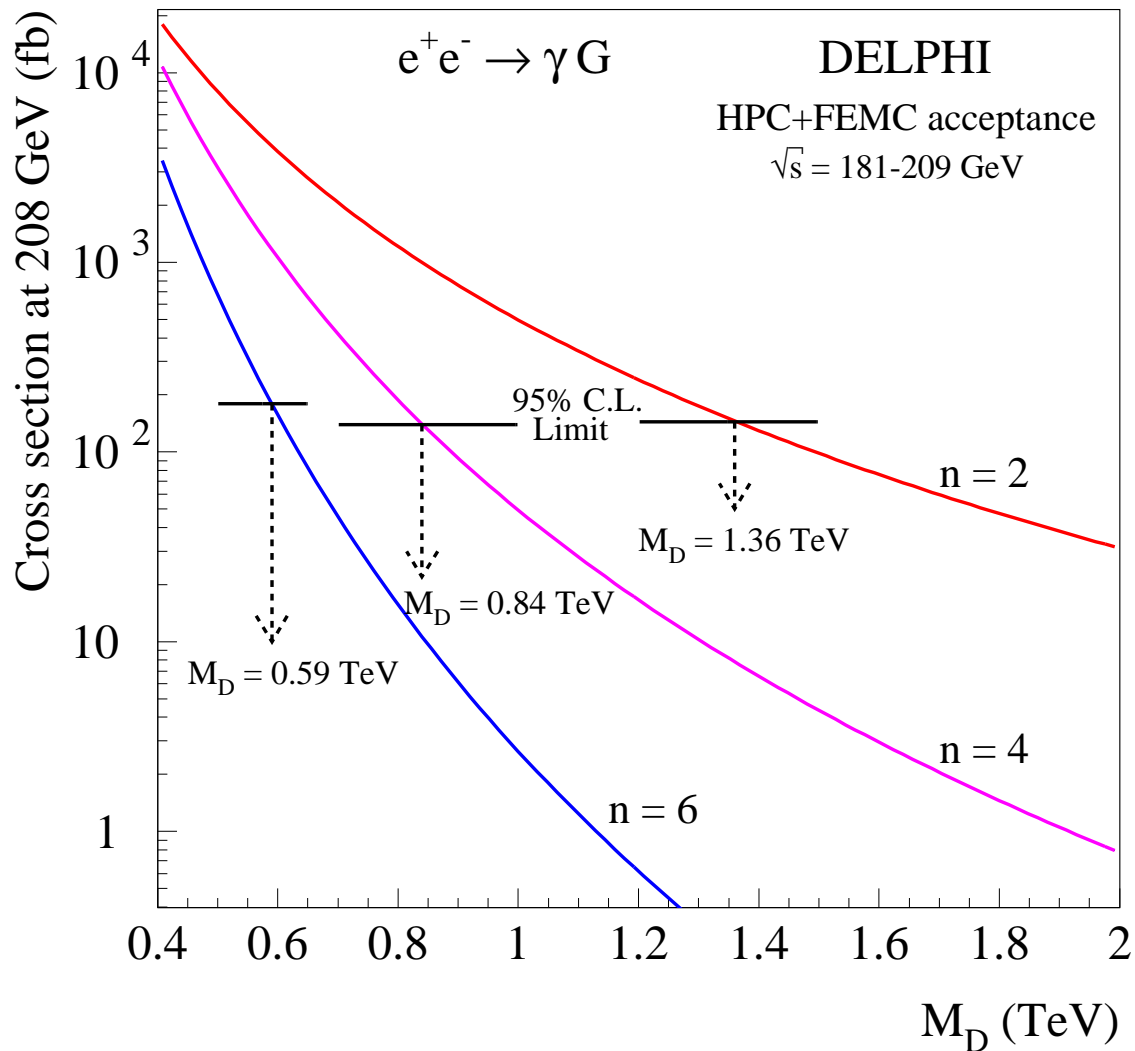
- Rolled extra dimensions

Randall–Sundrum–Model



- One extra dimension with fixed width

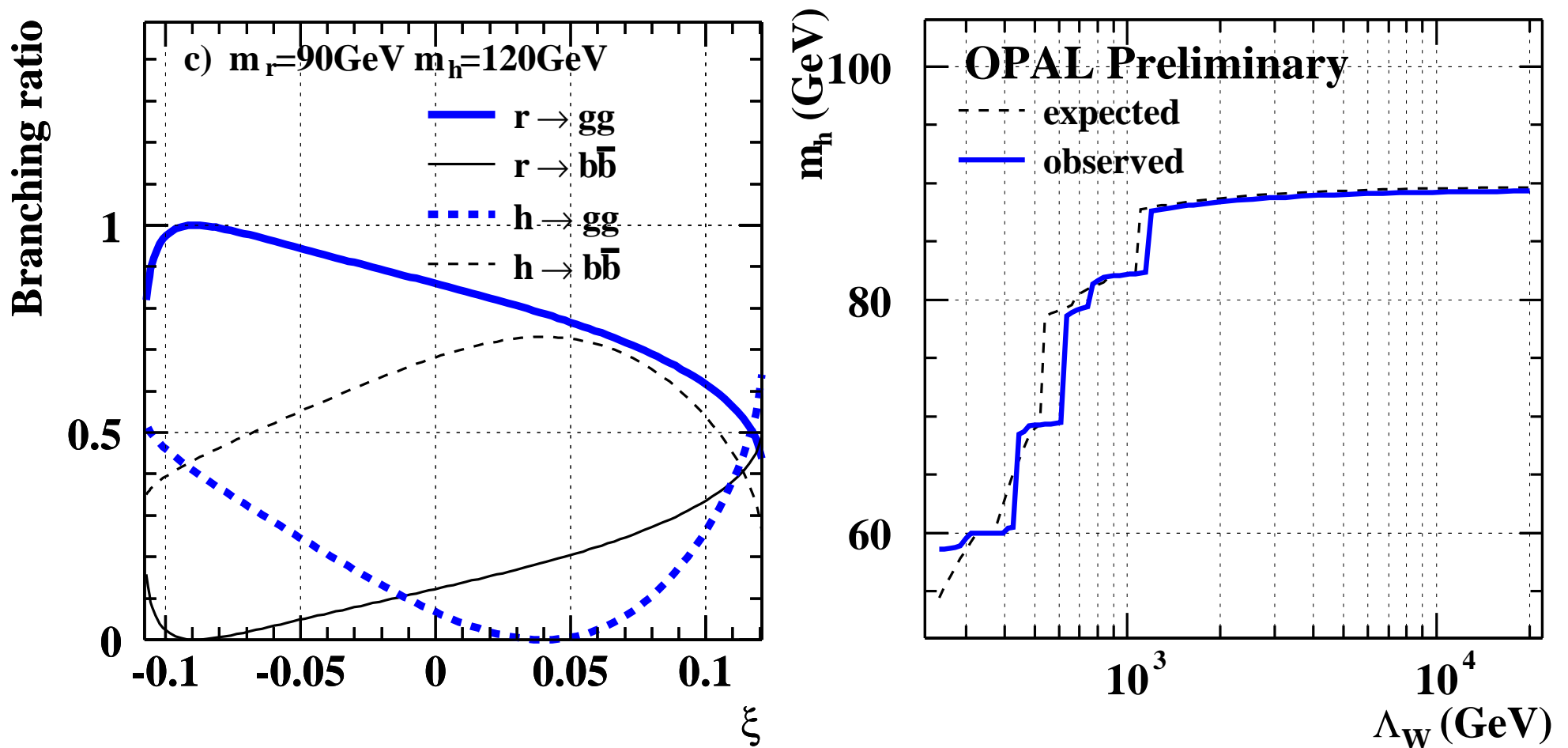
Photon searches



- Tighter limits for low number of extra dimensions

Randall-Sundrum Radions

- Higgs bosons and radions mix with mixing parameter ξ at scale Λ_W



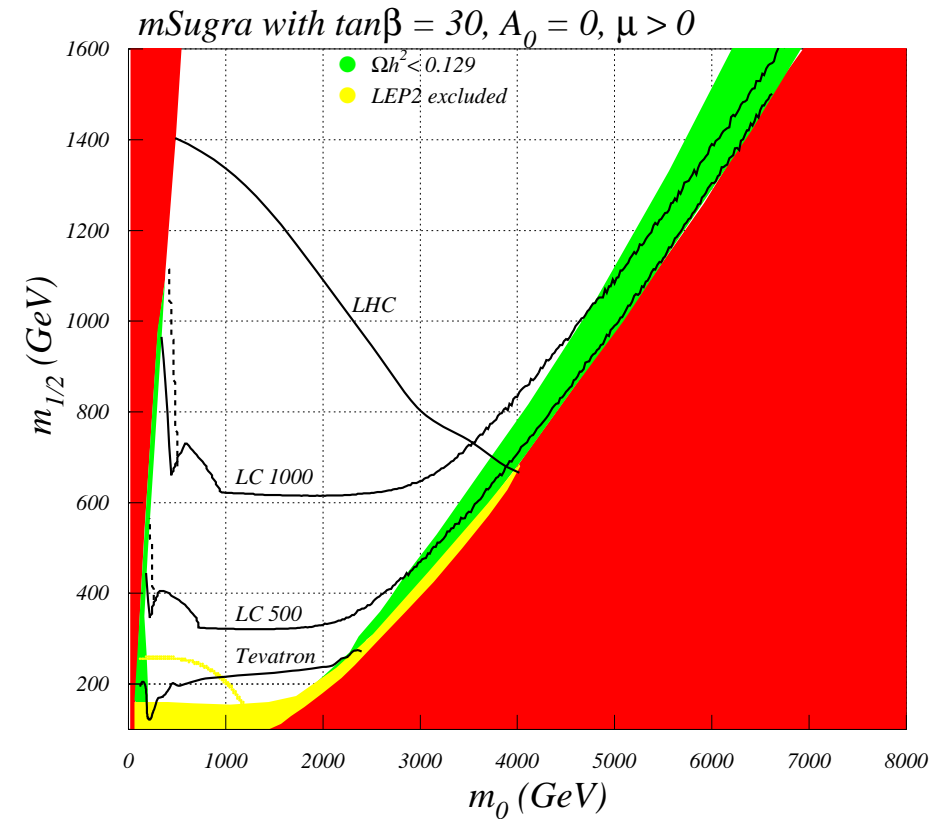
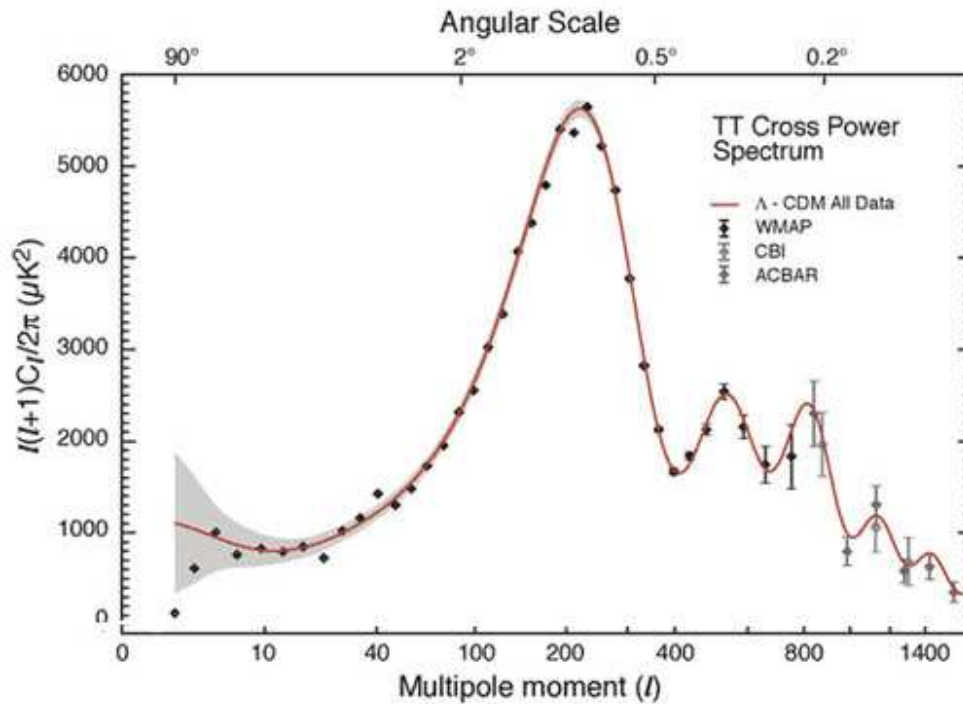
- Limits on scalar particles lowered down to 58 GeV

Summary and Outlook

- Large number of different phenomena investigated
 - R-parity conserving and violating SUSY
 - Compositeness
 - extra space dimensions
 - + Higgs etc. . . .
- Very few spaces for loopholes left
- Years of fruitful interaction with the theory community and the LEP machine group
- Still some searches and interpretations to come
- Precision data show clear sign of new phenomena, to be expected at the LHC and the LC

Outlook to LHC and LC

- Supersymmetry fits to WMAP and other cosmological data



- WMAP

- Allowed and excluded regions