The LEPSUSY working group status report

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CERN and LNF-INFN
on behalf the LEPSUSY-wg

A) Reminder:
Why, Who, What, How, Where ?

B) Combination of 183 GeV results:
χ **LSP,** $\tilde{G}$ **LSP**

C) Prospects for 189 GeV combination:
150 pb^{-1}/exp. still worth to combine ?

D) Conclusions:
Towards LEP200 combination

Why (to combine) ?

- Very simple: $\mathcal{L}_{combined} \sim 4 \times \mathcal{L}_{1-experiment}$
- Sensitivity in presence of a signal: $S/\sqrt{B} \sim \sqrt{\mathcal{L}} \sim 2$
- Cross-section Upper Limits:
  - Very small background $\sim 1/\mathcal{L} \sim 1/4$
  - Large background (subtracted) $\sim 1/\sqrt{\mathcal{L}} \sim 1/2$

Who (is combining) ?

- Members (2 per exp.):

  A L. Duflot and F.C.

  D A. De Min and L. Pape (convener)

  L A. Favara and S. Rosier-Lees

  O P. Giacomelli and S. Komamiya

- Other people doing the work at 183 GeV (many thanks):

  A V. Buescher, J. Dann, W. Orejudos, M. Schmitt, G. Taylor, P. Van Gemmeren

  D M. Berggren, A. Galloni, P. Gris, C. Matteuzzi, S. Navas, P. Kluit, U. Schwickerath

  L S. Bhattacharya, I. Iashvili, H. Nowak, R. McNeil

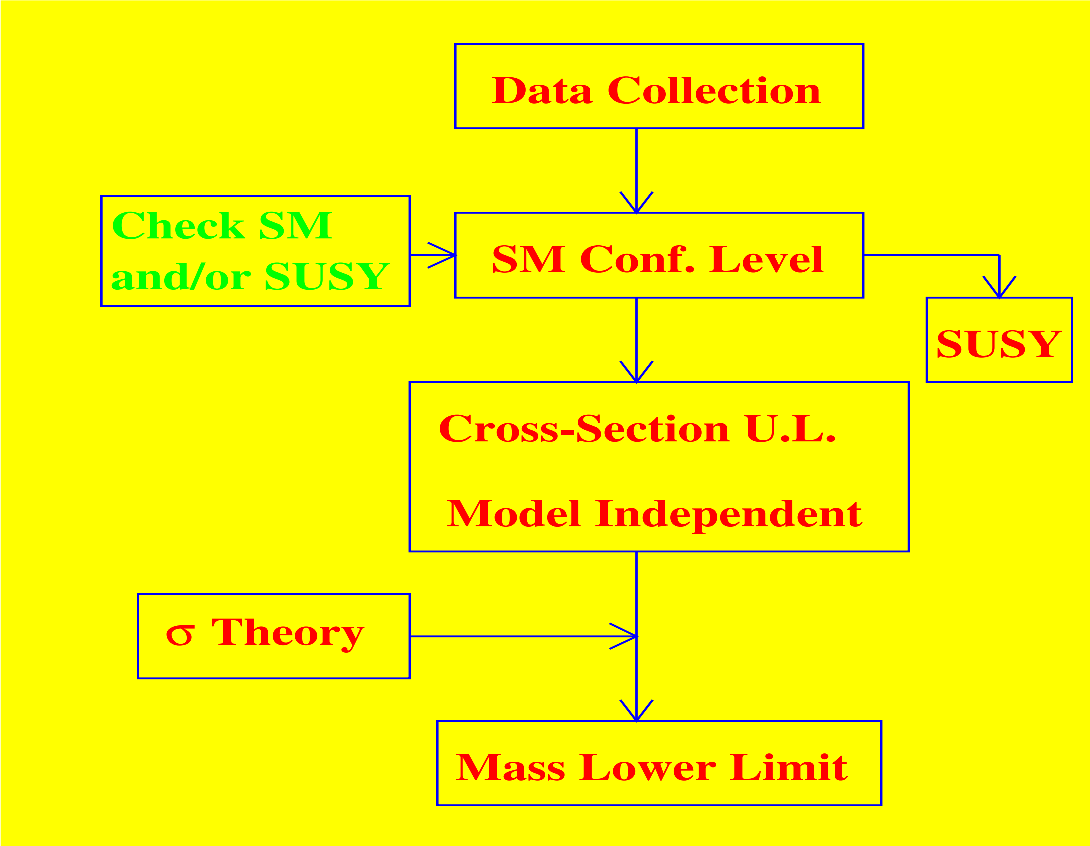
  O S. Asai, M. Fanti, D. Futyan, A. Honma, G. Long, P. Krieger , K. Roscoe, R. VanKooten, G.W. Wilson, T.R. Wyatt

- Support from theory: M. Mangano, P. Zerwas

What (to combine) ?

- Everything which is not excluded at kinematic limit by single LEP experiments
- Up to now this means all SUSY searches (but the $\tilde{\chi}^{\pm}$ at large m_0)

How (to combine) ?



How (to combine) ?

- Each exp. provides $\mathcal{L}$ and 2D matrices in the $M_{\tilde{P}} - M_{LSP}$ plane for:
  - Candidates
  - Efficiency
  - Background subtractable and unsubtractable (each exp. decides this classif.)

- Compatibility candidates vs SM expect. checked:
  - Look for excess (SUSY signal) or deficit (Bad bkg. description, stat. fluct.)
  - Up to know only deficits have been found and investigated: interpreted as stat. fluct.
  - Useful studies on MC generators have been performed for:

    a) 4-fermions: comparison on samples selected with loose $\tilde{\tau}$ selection

    b) $\gamma\gamma(\gamma)\nu\bar{\nu}$: comparison COMPHEP, GRACE, KORALZ

How (to combine) ?

- U.L. on σ_{sig} derived with three different methods (already reviewed by Luc Pape):
  - Extended PDG: based on Bayes theorem, do not account for different performance of comb. analyses
  - Obratzov: based on Bayes theorem, does account for different performance of comb. analyses
  - Modified Likelihood Ratio: based on frequentist approach, best stat. properties, chosen as default method

- Almost no differences when combined analyses have similar performance

- Expected limits compared with actual ones and made public

- Mass exclusions shown (usually) in the $M_{\tilde{P}} - M_{LSP}$ plane

Where (to find the results) ?

- Results posted on the web:

http://www.cern.ch/LEPSUSY/

- One page for each channel with a reference of the type: LEPSUSYWG/year-channel.version
- In addition to the σ_{95} and mass exclusion plots these pages contain other useful information:
  - Reference to the single experiment analyses
  - Candidates and SM expect. Bkg.
  - Confidence Level SM alone

- No LEPSUSY-wg paper for the moment because of:
  - Frequent updates: after each LEP energy upgrade single-exp. do not provide their data with the same time scale
  - Results become obsolete very quickly: chosen to combine results at a given energy only after single-exp. have shown them at least once
- Summary LEPSUSY-wg paper at the end of LEP2

183 GeV data combination

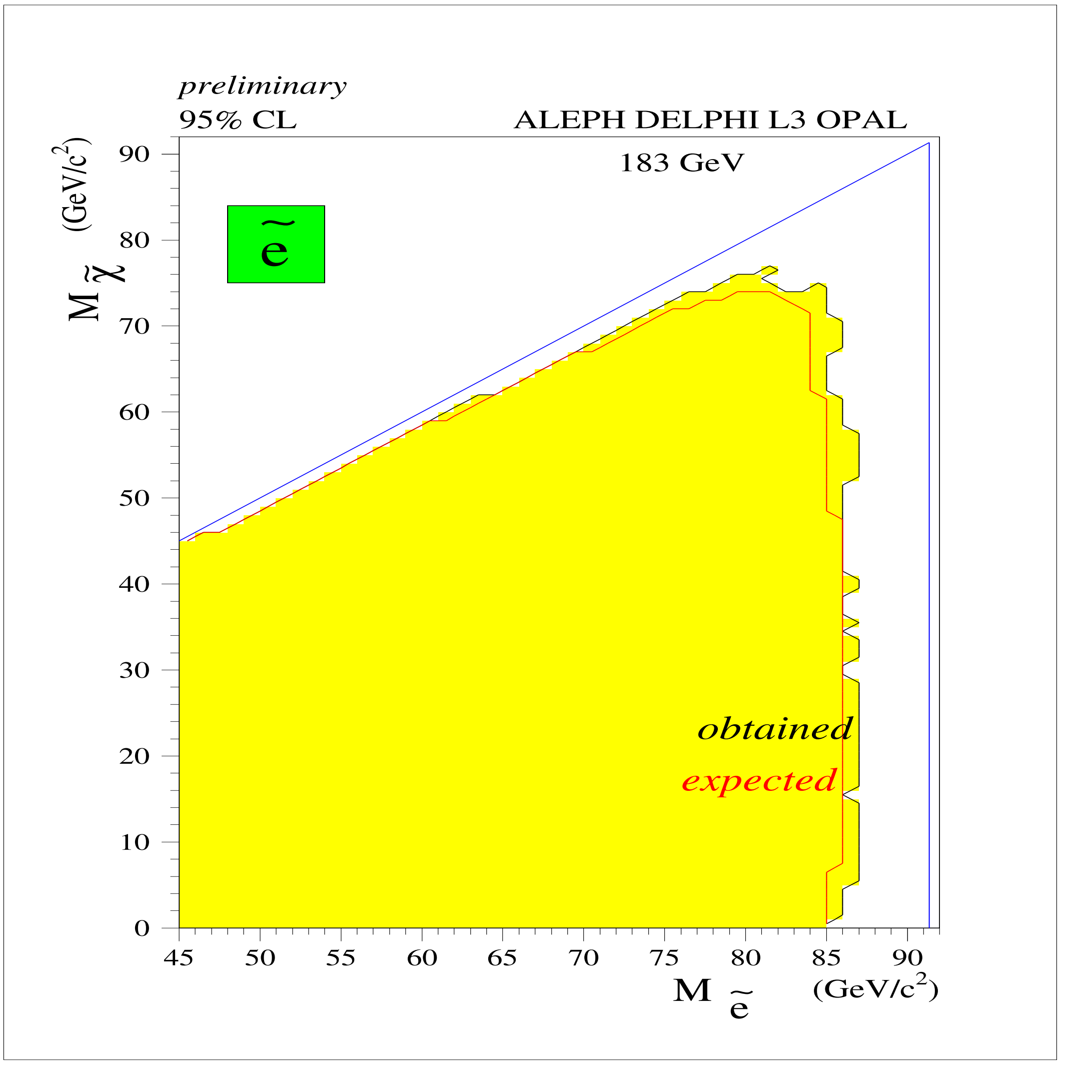
- All results are preliminary and the limits are at 95 % CL
- All LEP2 data up to 183 GeV are (usually) combined
- $\mathcal{L}$ per exp. (50-57) pb^{-1} at 183 GeV

Combined topologies

- $\tilde{\chi}$ LSP scenario (Gravity-MSB) with R$_P$ conserved:
  - Sleptons: $\tilde{e}$, $\tilde{\mu}$, $\tilde{\tau}$
  - Squarks: $\tilde{t} \to c\tilde{\chi}$, $\tilde{t} \to \ell\tilde{\nu}b$, $\tilde{b} \to b\tilde{\chi}$
  - Chargino: small ΔM at large m_0
- $\tilde{G}$ LSP scenario (GMSB) with R$_P$ conserved:
  - Photon: $\tilde{\chi}\tilde{G} \to \gamma\tilde{G}\tilde{G}$
  - Photons: $\tilde{\chi}\tilde{\chi} \to \gamma\tilde{G}\gamma\tilde{G}$
  - Stable $\tilde{\ell}$
- G. Kane scenario $\tilde{\chi} = \tilde{h}$ LSP with R$_P$ conserved:
  - Photons: $\tilde{\chi}_2\tilde{\chi}_2 \to \gamma\tilde{\chi}_1\gamma\tilde{\chi}_1$

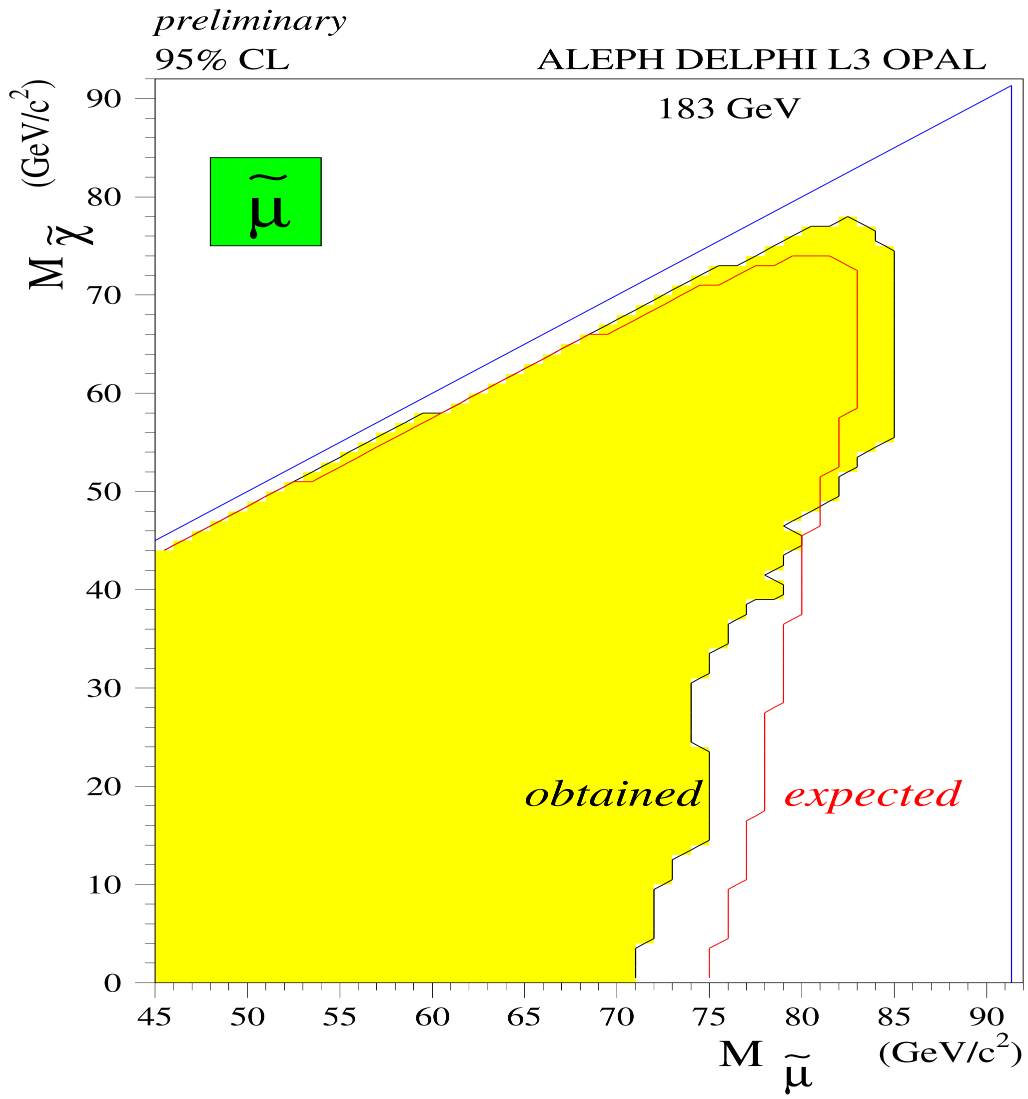
Sleptons at 183 GeV

- Good agreement Candidates vs SM expectation (for $\tilde{\tau}$ small deficit in large ΔM region)
- No Excess $\Rightarrow$ Limits on $\sigma_{\tilde{\ell}_R}$ and on $M_{\tilde{\ell}_R}$:



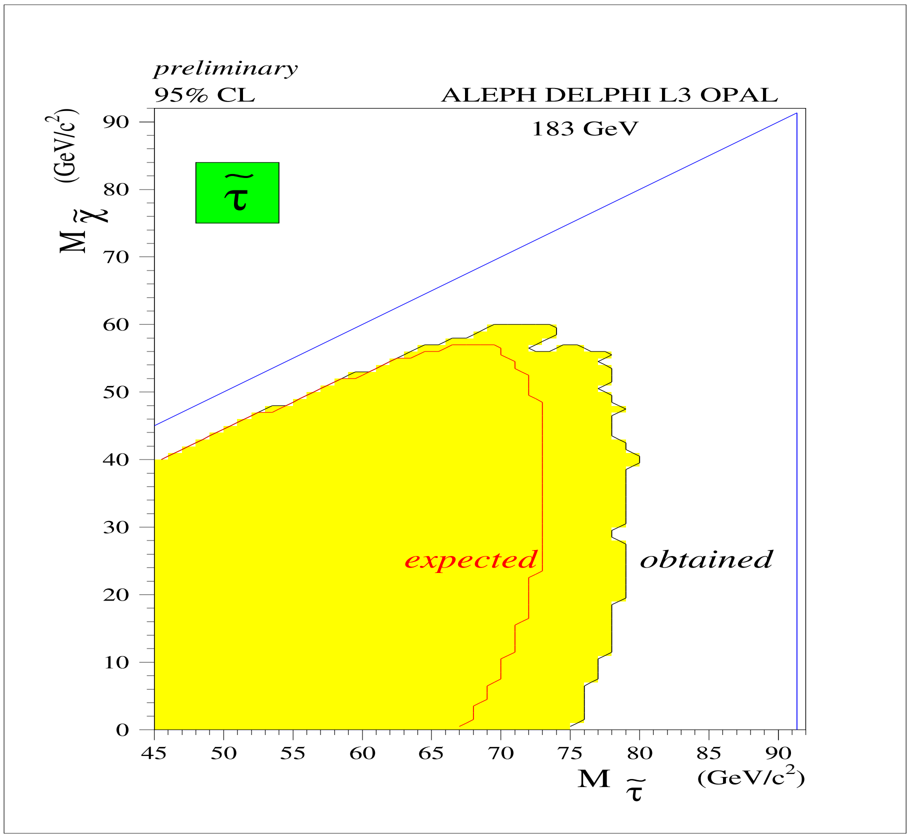
ADLO ($\tilde{e}_R$ $\tan\beta$=2 and $\mu = -200$; Eff. cascade dec. =0)

Sleptons at 183 GeV



ADLO ($\tilde{\mu}_R$ Eff. cascade dec. =0)

Sleptons at 183 GeV



ADLO ($\tilde{\tau}_R$ Eff. cascade dec. =0)

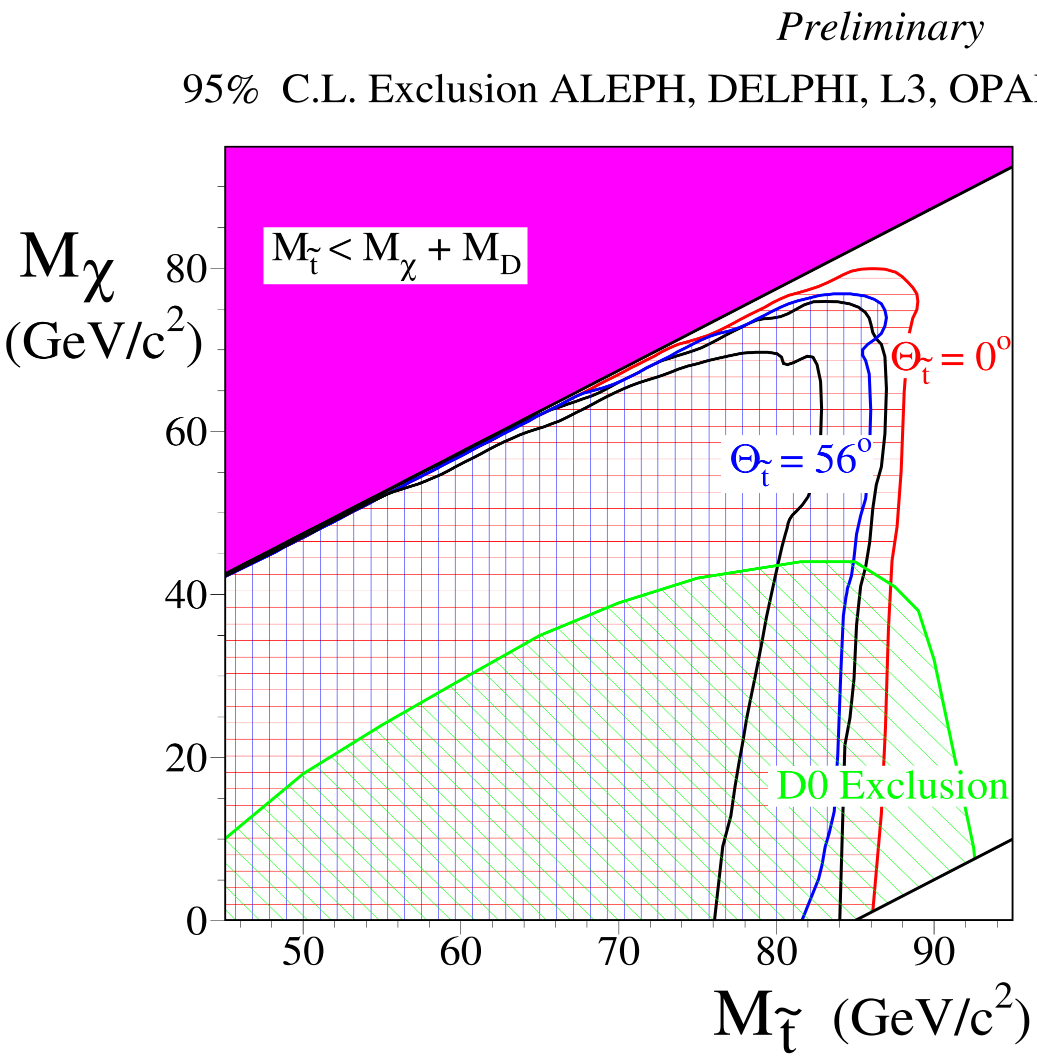
Improvement w.r.t. single experiments

Mass Lower Limit (GeV) for Large ΔM ($>$ 20)				
Channel	SE Expect.	Comb. Expect.	SE Act.	Comb. Act.
$\tilde{e}_R$	78-83	85	79-83	85
$\tilde{\mu}_R$	56-67	75	55-62	71
$\tilde{\tau}_R$	45-56	67	45-63	75

Stop and Sbottom at 183 GeV

$\tilde{t} \to c\tilde{\chi}$ **ADLO**

- Deficit of candidates in a region not relevant for the limit: ΔM=(10-25) GeV , $M_{\tilde{t}}$=(50-75) GeV

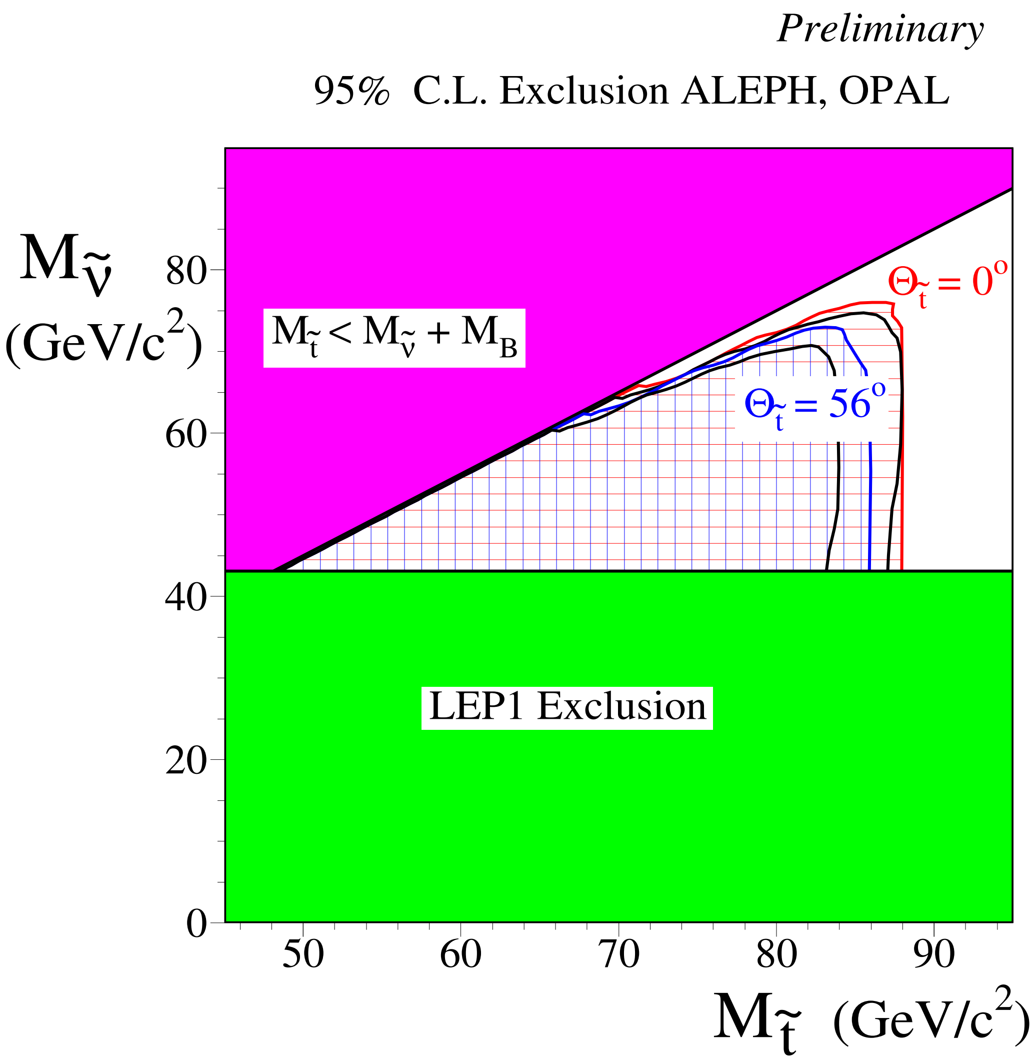


Black cont.=expect. limit ; Coloured cont.=Actual limit

Stop and Sbottom at 183 GeV

$\tilde{t} \rightarrow b\ell\tilde{\nu}$ **AO**

- Good agreement SM expect. vs data candidates

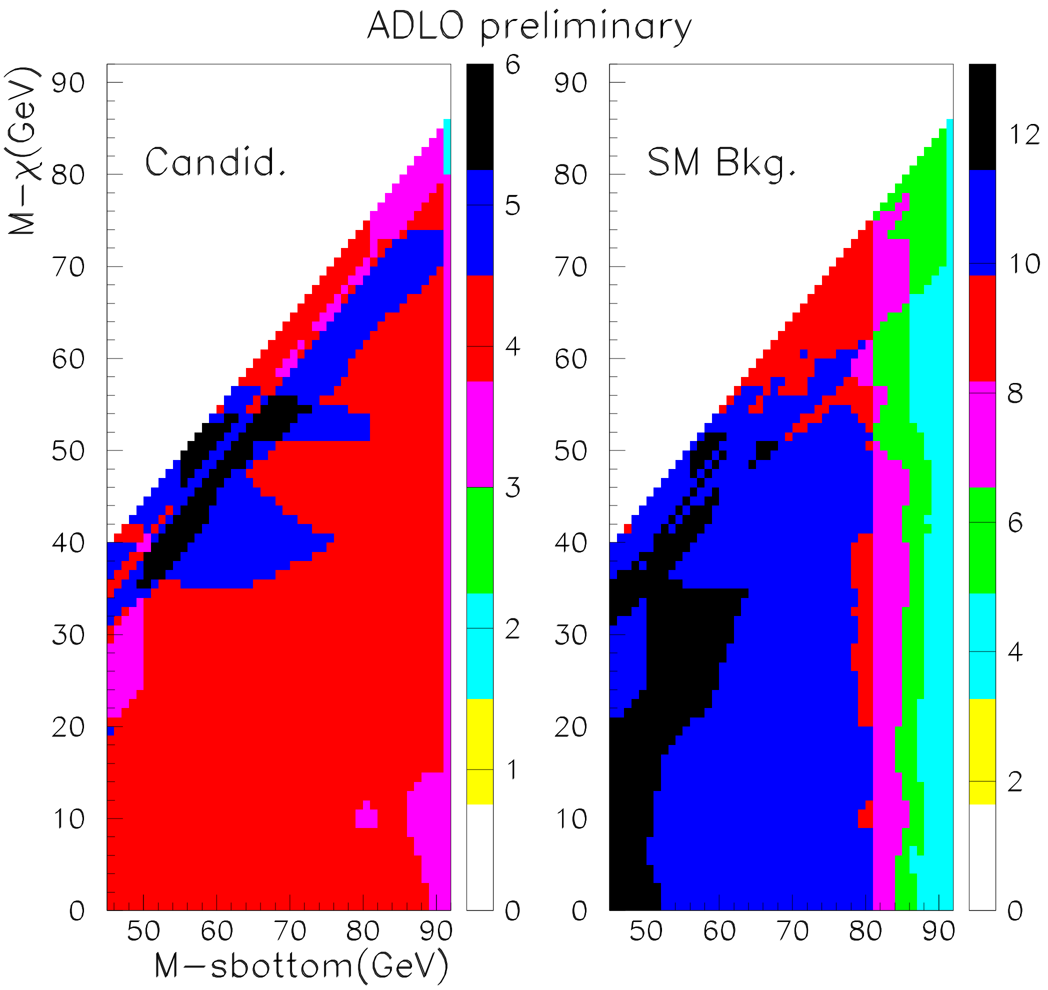


Black cont.=expect. limit ; Coloured cont.=Actual limit

Stop and Sbottom at 183 GeV

$\tilde{b} \rightarrow b\tilde{\chi}$ ADLO

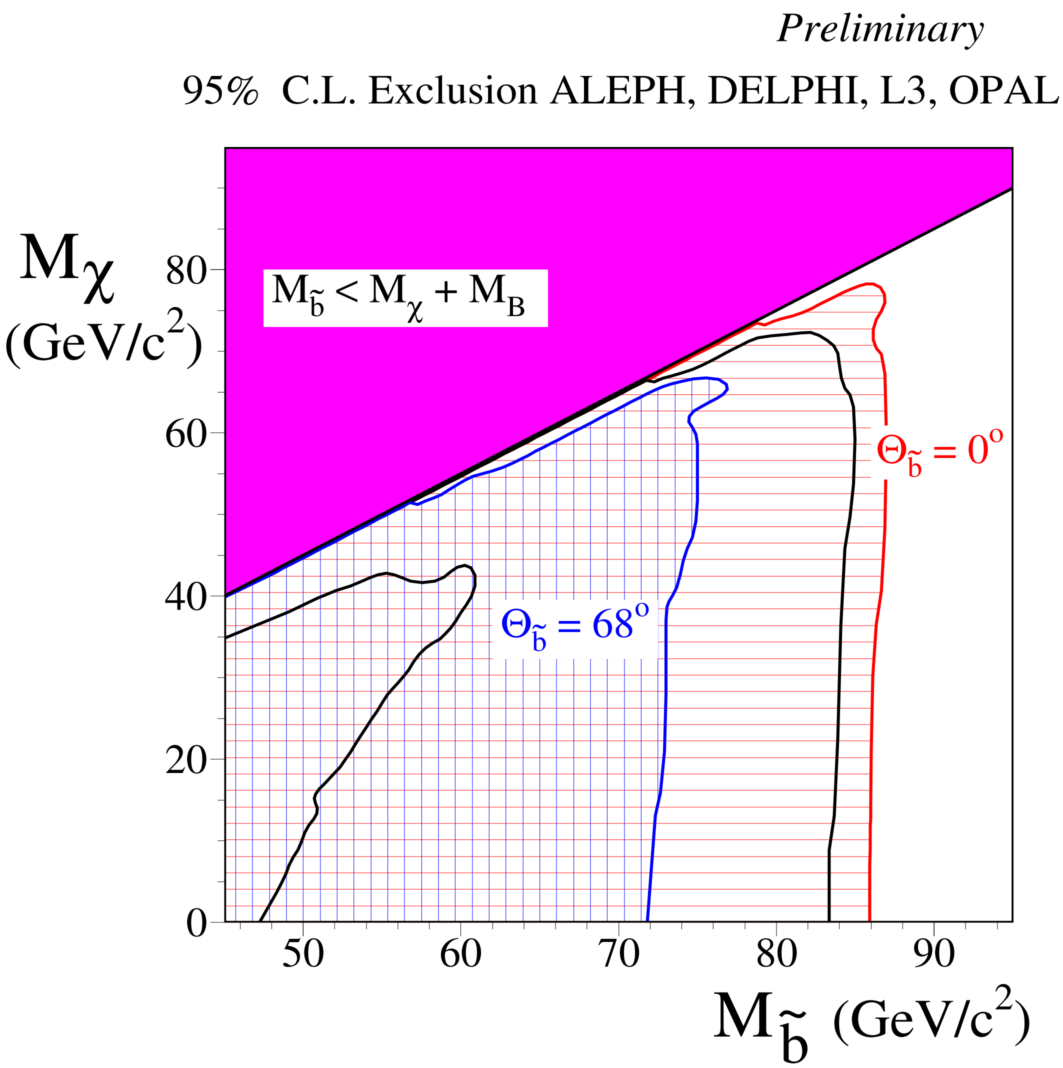
- Deficit of candidates in the region relevant for the limit: ΔM=(10-55) GeV , $M_{\tilde{b}}$=(50-80) GeV



Stop and Sbottom at 183 GeV

$\tilde{b} \to b\tilde{\chi}$ ADLO

- Under investigation: Limits derived without any bkg. subtraction (conservative)



Black cont.=expect. limit ; Coloured cont.=Actual limit

Stop and Sbottom at 183 GeV

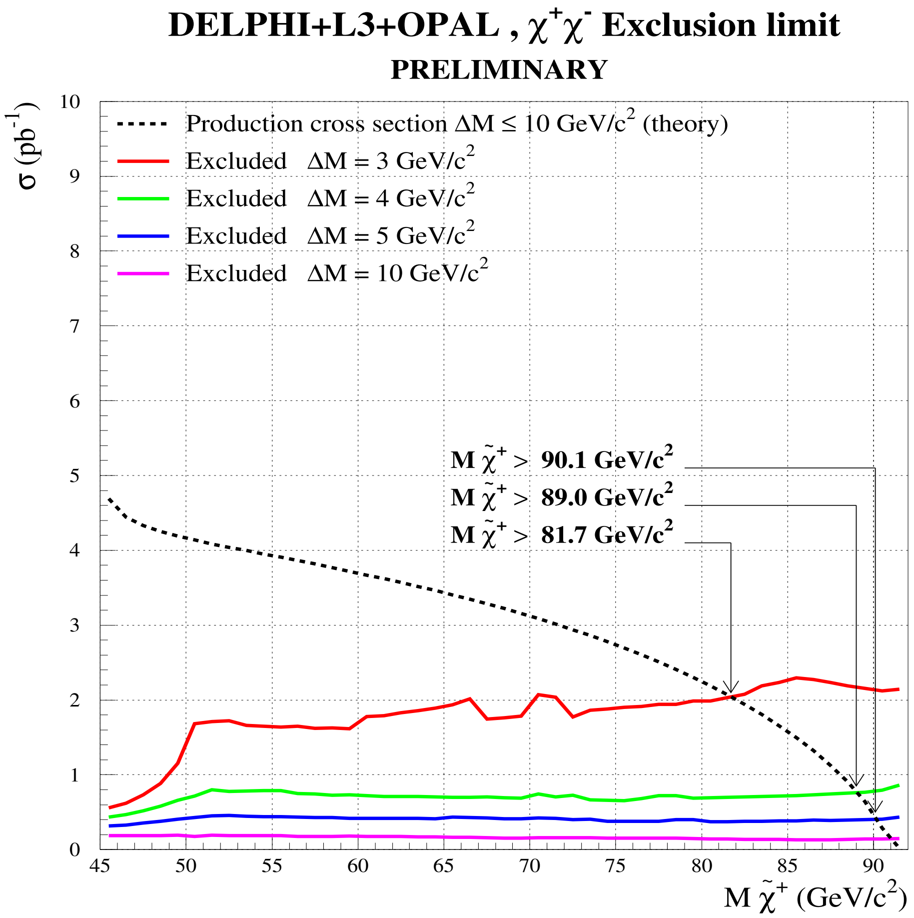
Improvement w.r.t. single experiments

Mass Lower Limit (GeV) for ΔM=15			
Channel	SE Act.	Comb. Act.	Comb. Expect.
$\tilde{t} \to c\tilde{\chi}$ (θ=0)	80-85	86	85
$\tilde{t} \to c\tilde{\chi}$ (θ=56)	72-81	83	80
$\tilde{t} \to b\ell\tilde{\nu}$ (θ=0)	84-85	87	86
$\tilde{t} \to b\ell\tilde{\nu}$ (θ=56)	80-82	85	84
$\tilde{b} \to b\tilde{\chi}$ (θ=0)	78-84	86	83
$\tilde{b} \to b\tilde{\chi}$ (θ =68)	45-68	75	60

- Improvements on actual limits for $\tilde{t} \to c\tilde{\chi}$ and for $\tilde{b} \to b\tilde{\chi}$ quite modest because 1 experiment has been quite lucky (it has the best limits)

Chargino at 183 GeV small-ΔM

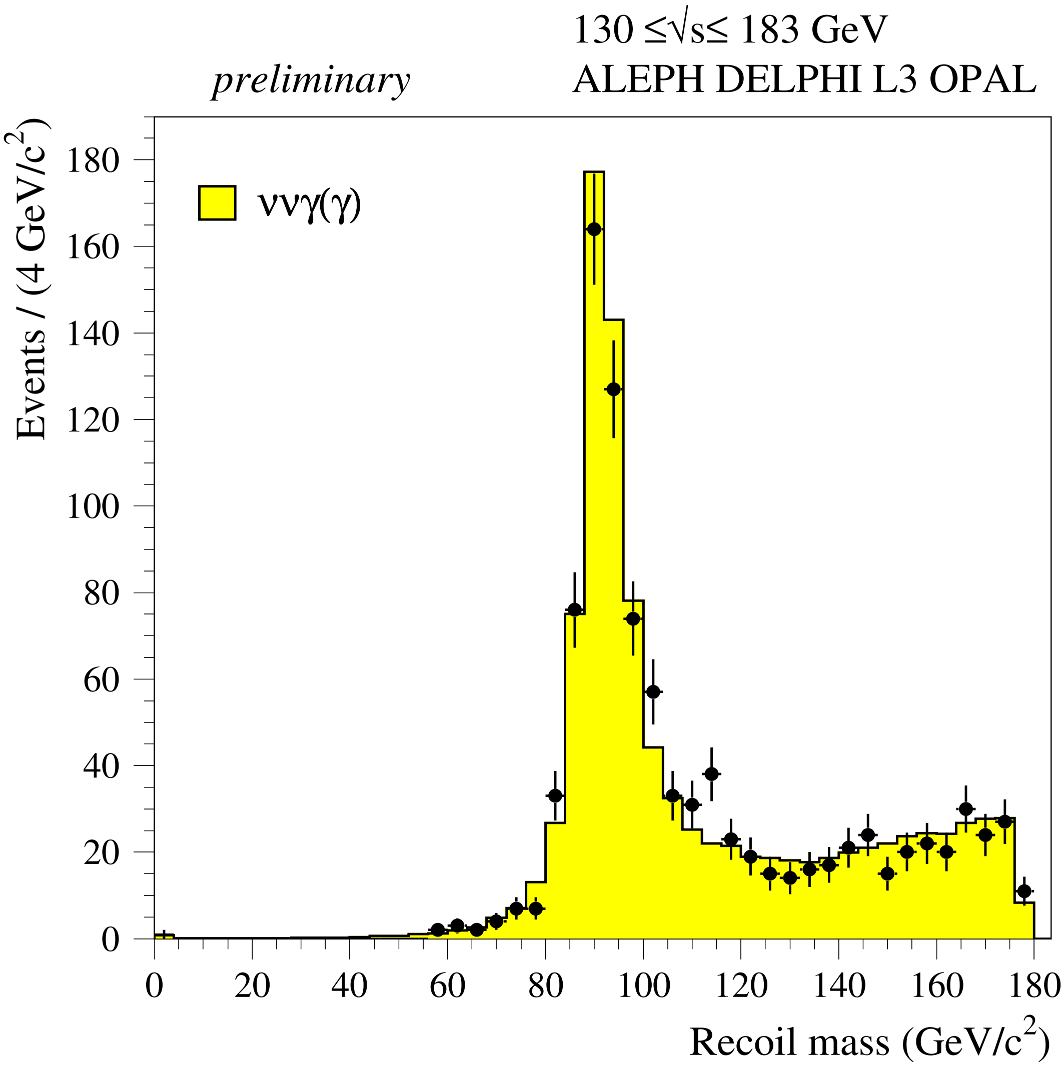
- Combination for small ΔM: deep Higgsino region
- Large $m_{\tilde{\ell}}$ assumed: $\tilde{\chi}^{\pm} \to \tilde{\chi} W^*$
- Combined DLO: good agreement SM expect. vs candidates
- For the same $M_{\tilde{\chi}^{\pm}}$ ($\Delta M \leq 5$ GeV) different cross-sect. are possible: chose the lowest one



- Improvement w.r.t. single experiments $\sim$ 1-4 GeV

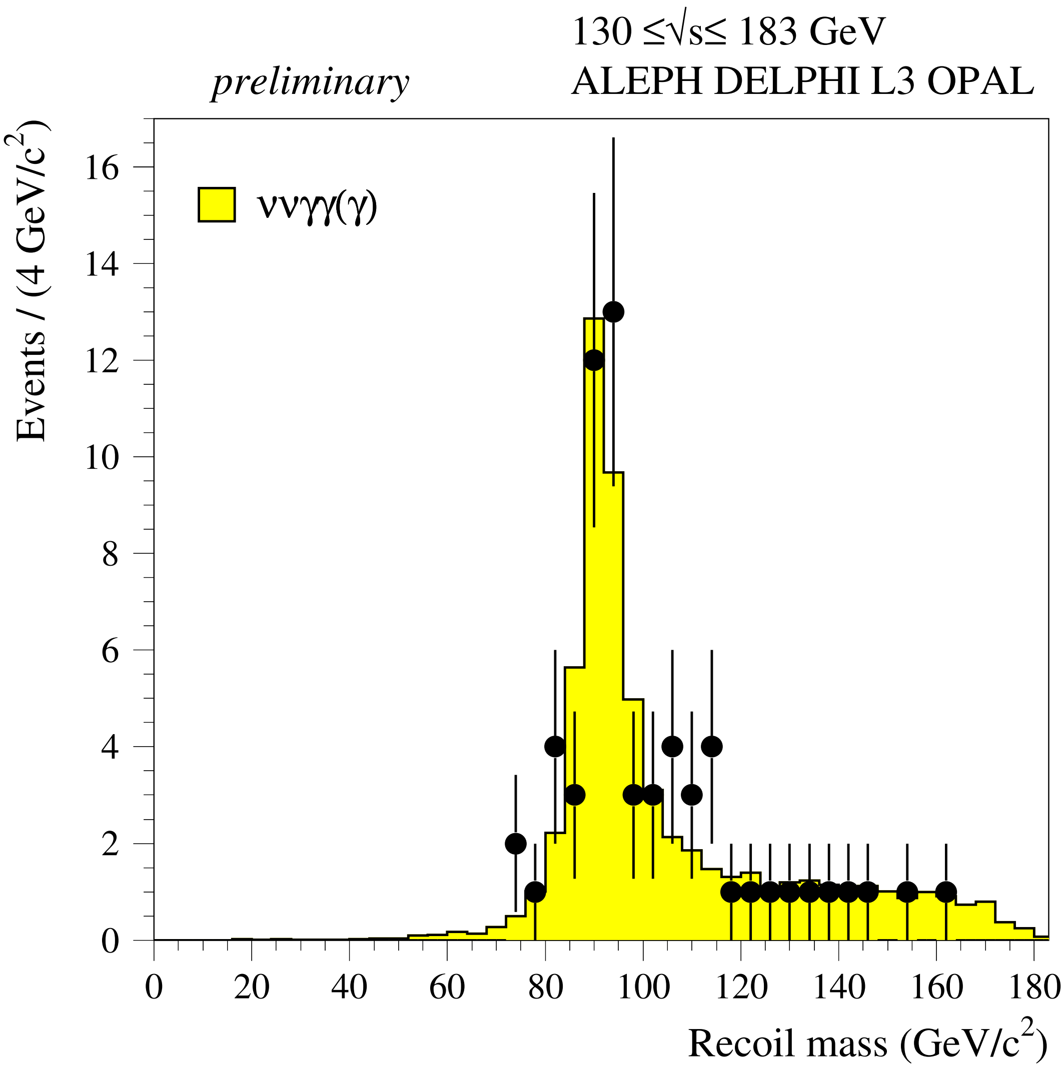
$\gamma(\gamma) + E_{miss}$

- The single-photon + E_{miss} topology is expect. in GMSB models and ultra-light $\tilde{G}$ scenarios
- Check recoil mass spectrum of $\gamma(\gamma) + E_{miss}$: good agreement of data with SM expect.



$\gamma\gamma + E_{miss}$

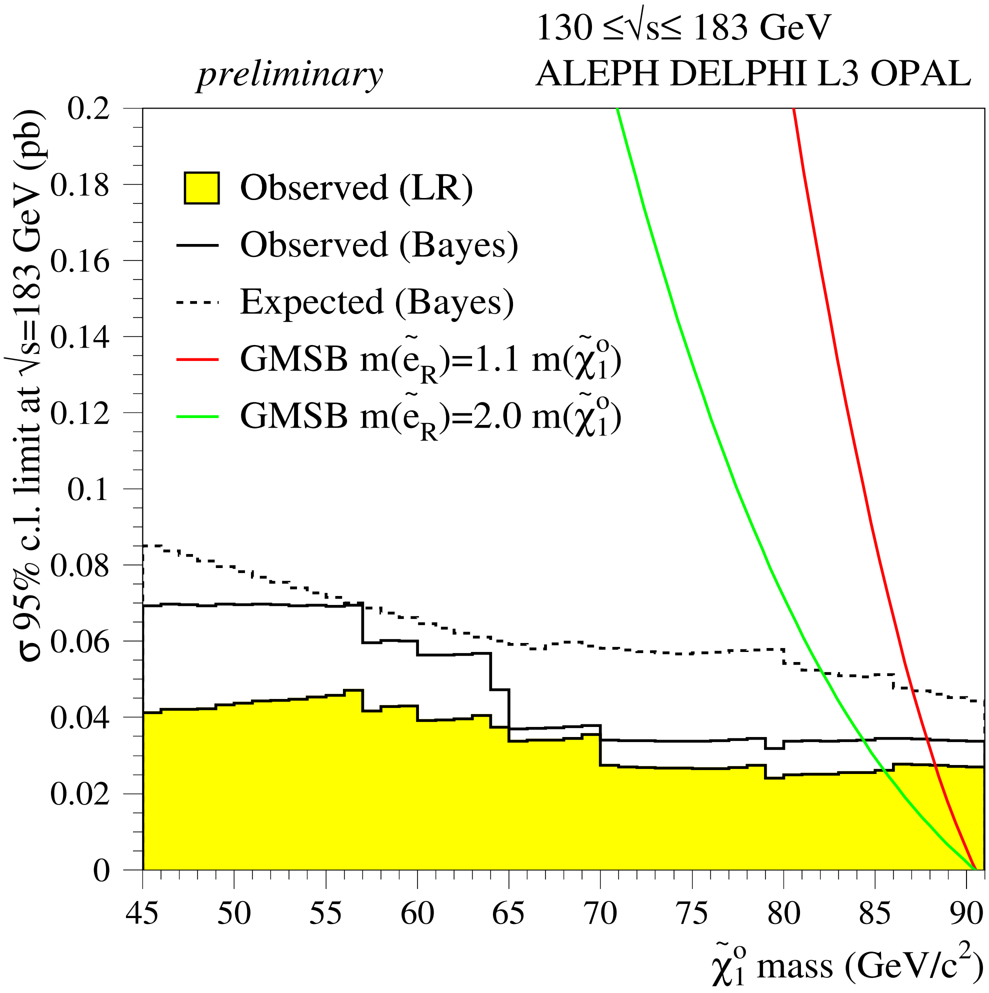
- Check recoil mass spectrum of pre-selected acopl. γ's: good agreement with SM (mainly $\nu\bar{\nu}\gamma\gamma$)
- Combined ADLO



62 Events observed vs 61.8 Expected

$\gamma\gamma + E_{miss}$: $\tilde{G}$ LSP

- In GMSB $\tilde{\chi}\tilde{\chi} \to \gamma\tilde{G}\gamma\tilde{G}$: additional selection
- For $M_{\tilde{\chi}}$=85 GeV: Expect. SM bkg. $\sim$ 3.5 evts.; Data 2 events
- σ upper limit and mass exclusion for GMSB models

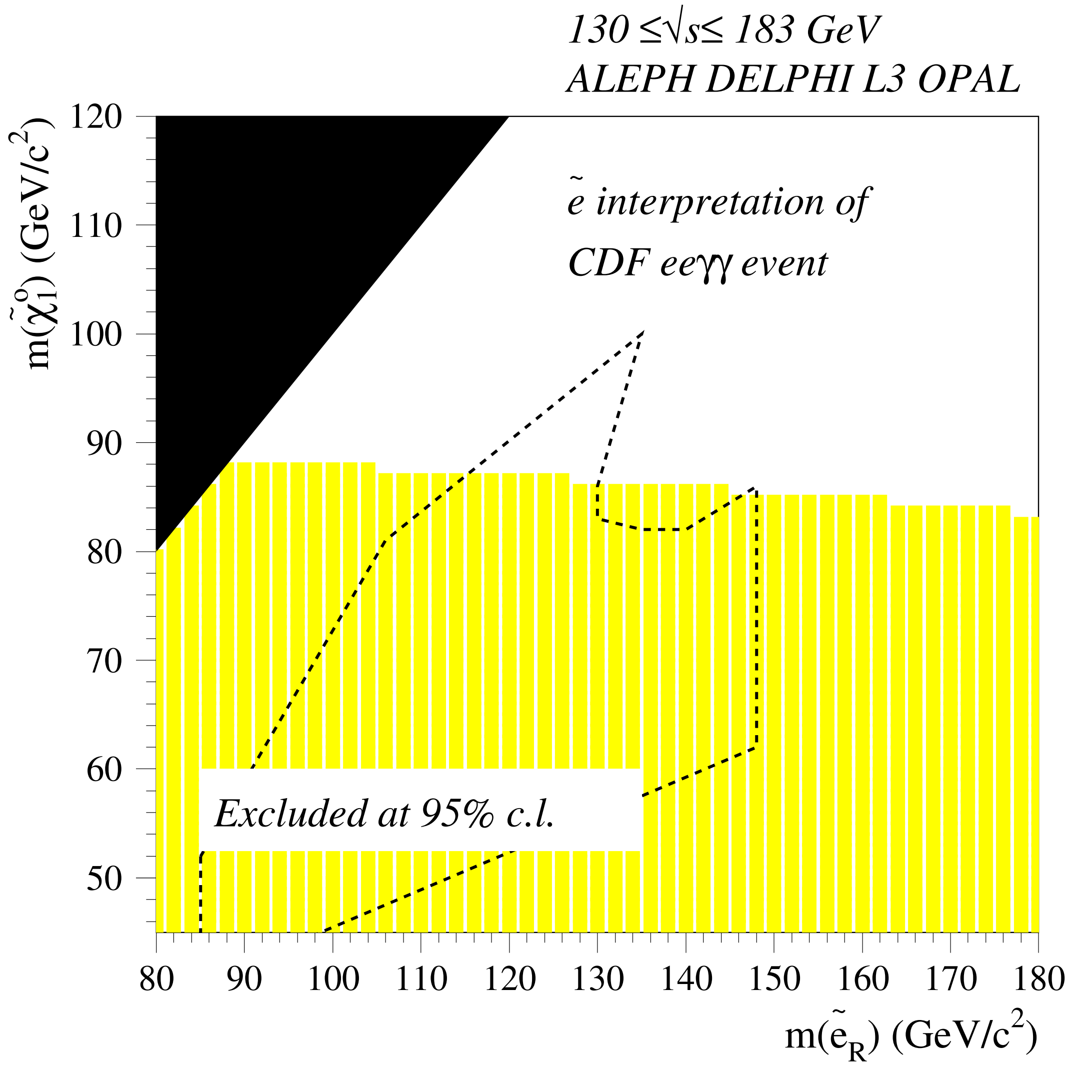


$M_{\tilde{\chi}} \geq$(85-88) GeV $\qquad (\tilde{\chi} \sim \tilde{B})$

- Improv. w.r.t. single-exp. $\sim$(4-8) GeV

$\gamma\gamma + E_{miss}$: $\tilde{G}$ **LSP**

- Comparison with GMSB interpretation of the CDF event



GMSB interpretation of CDF event (almost) excluded by LEP2 data

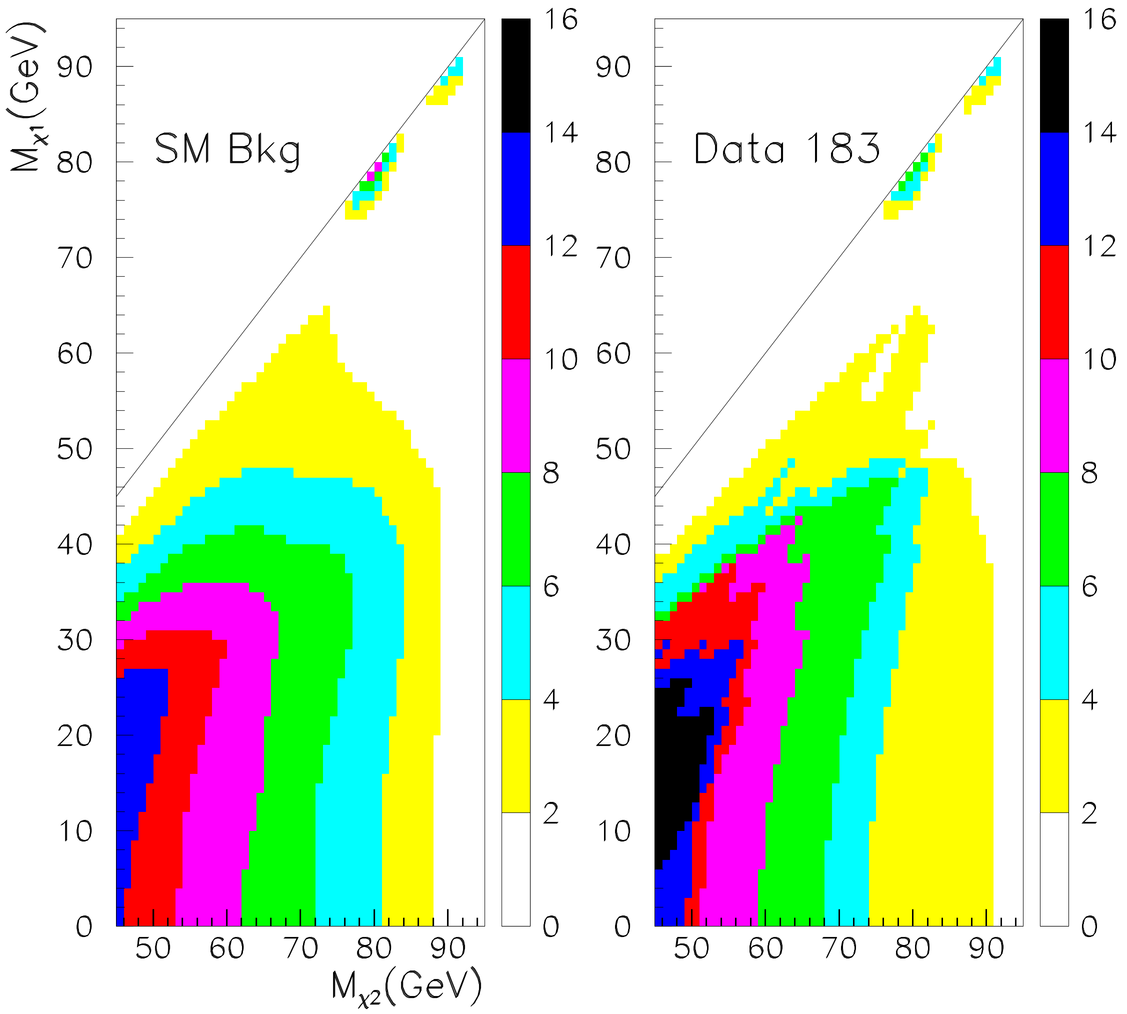
$\gamma\gamma + E_{miss}$: $\tilde{\chi}_2\tilde{\chi}_2 \rightarrow \tilde{\chi}\gamma\tilde{\chi}\gamma$ Kane scenario

- For acopl-γ's with $M_{rec} > 100$ GeV the 4-LEP exp. at 161+172 GeV observed (5+4)=9 candidates vs (4.4+4.1)=8.5 expected (KORALZ)
- Claim SUSY signal: hep-ph/9705382 - G. Kane
  Test and implications of increasing evidence for superpartners
- Assumption: bkg. estimate wrong by a factor 3;
  TRUE bkg ∼2-3 events → Excess ∼5-7 events
- Interpreted as $\tilde{\chi}_2\tilde{\chi}_2 \rightarrow \tilde{\chi}\gamma\tilde{\chi}\gamma$
- From this + CDF event + ... :
  $\tilde{\chi} \sim \tilde{h}$, $\tilde{\chi}_2 \sim \tilde{\gamma}$, $M_1 \sim M_2 \sim M_Z$, $\mu \sim -M_W$
- If this is the case at 183 GeV (60 pb^{-1} per exp.):
  $\sigma_{sig} \geq 0.1$ pb , $N^{ev}_{sig} \sim$ (15-20)
- Different estimate for the process $\gamma\gamma(\gamma)\nu\bar{\nu}$ compared COMPHEP, GRACE, KORALZ:

P. Bain R. Pain - HEP'97 #528 Jerusalem
agreement at the 10% level in the signal region $M_{rec} > 100$ GeV

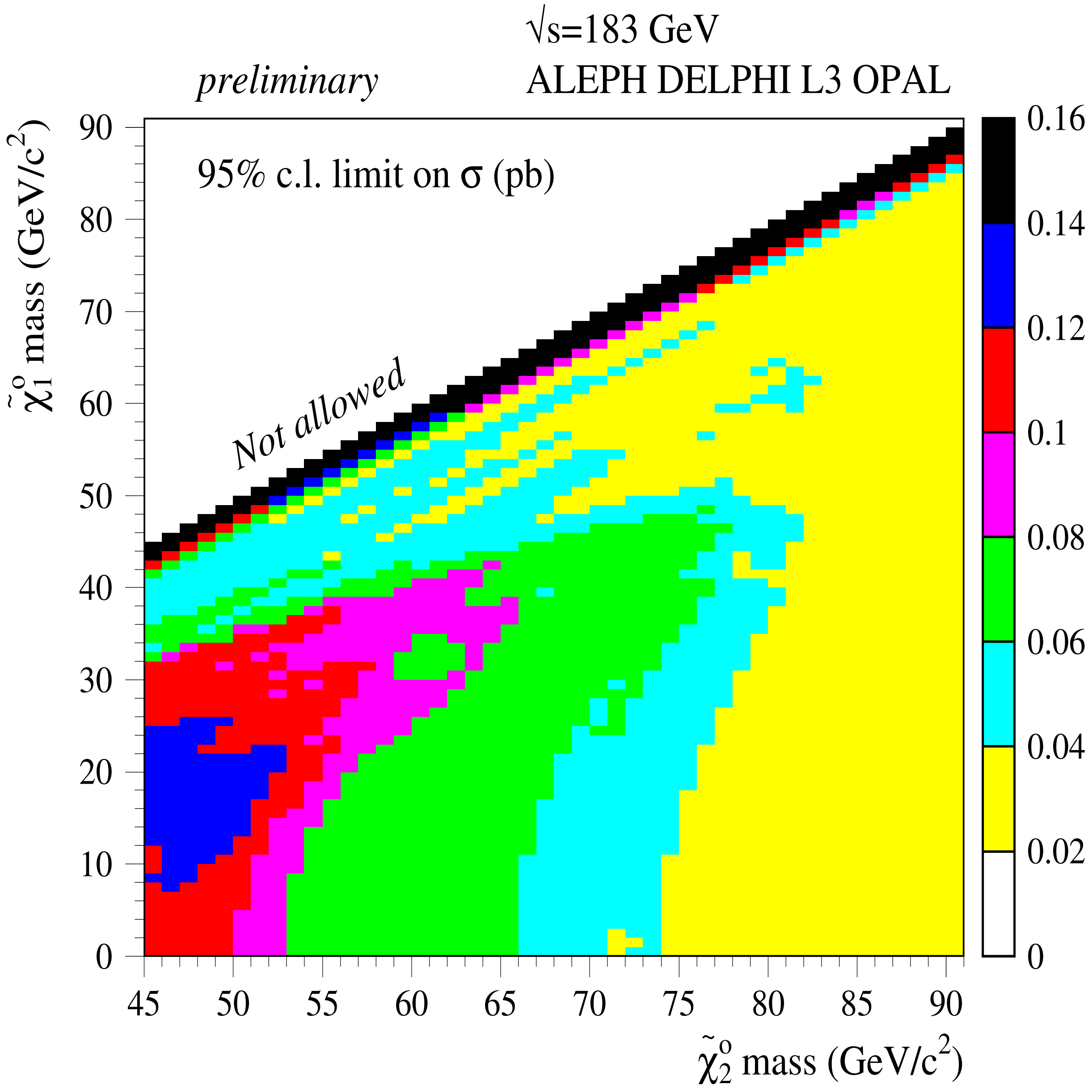
$\gamma\gamma + E_{miss}$: **Kane scenario**

- Good agreement SM expectation with 183 ADLO data



Number of expect. and obs. events in the $M_{\tilde{\chi}1}$-$M_{\tilde{\chi}2}$ plane

$\gamma\gamma + E_{miss}$: Kane scenario

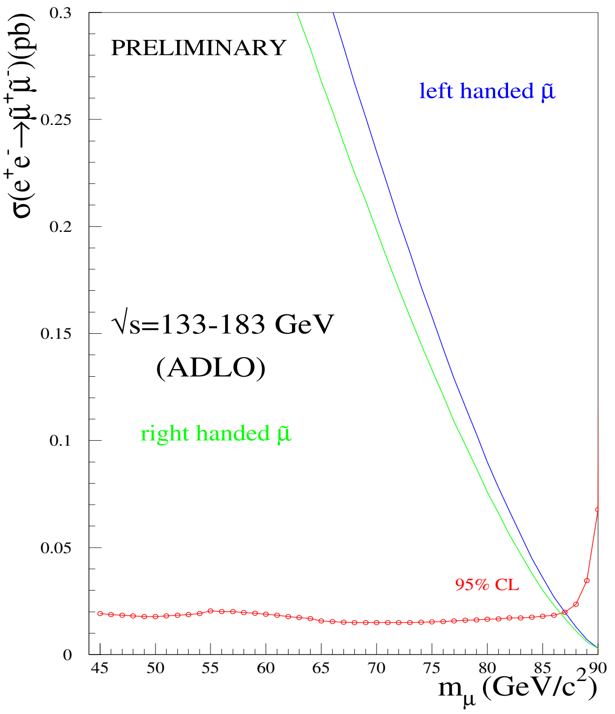


Kane scenario (almost) ruled out by 183 LEP2 data

Stable sleptons: GMSB models

- Very long lived sleptons expected in GMSB models when the $\tilde{G}$ is quite heavy (i.e. $M_{\tilde{G}} > 100$ eV)
- Combined ADLO: Expect. SM bkg. ~ 2; in data 1 cand.

ADLO limits stable sleptons

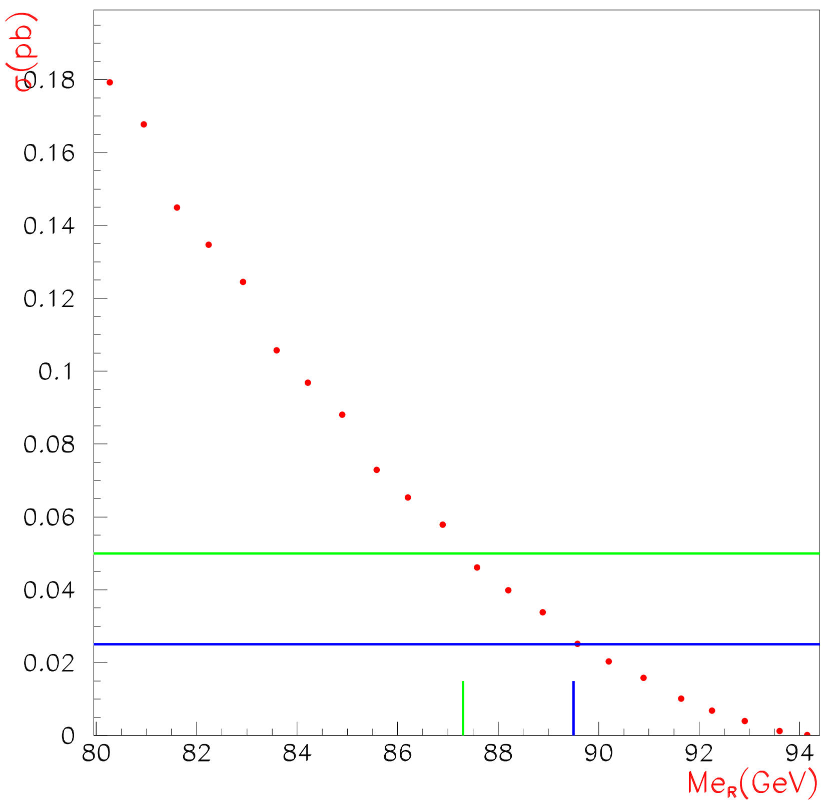


Improvement w.r.t. single experiments

Mass Lower Limit (GeV)		
scenario	SE Act.	Comb. Act.
$\tilde{\mu}_R$ or $\tilde{\tau}_R$	80-82	86.5
$\tilde{\mu}_L$ or $\tilde{\tau}_L$	81-83	87.0

Prospects for 189 GeV combination

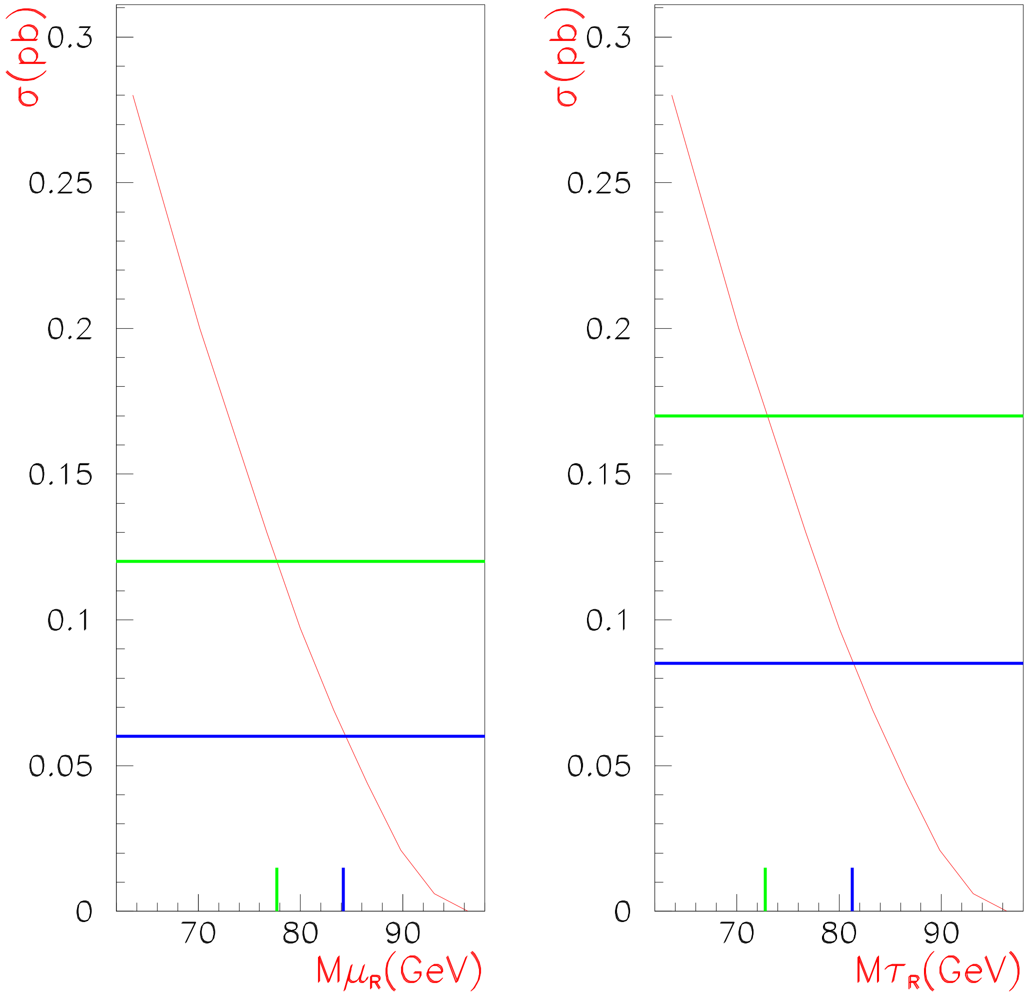
- Do we still expect sizable improvements by combining SUSY results with 150 pb^{-1}/exper. at 189 GeV ?
- Estimated improvements for $\tilde{e}_R$, $\tilde{\mu}_R$, $\tilde{\tau}_R$, $\tilde{b}$, $\tilde{t}$
- It is assumed that most of the background will be subtracted



$\tilde{e}_R$ **for** Δ**M=15 GeV** $\mu = -200$ **GeV,** $\tan\beta = 1.4$

- Expected improvement on $M_{\tilde{e}_R}$ limit $\geq$2 GeV

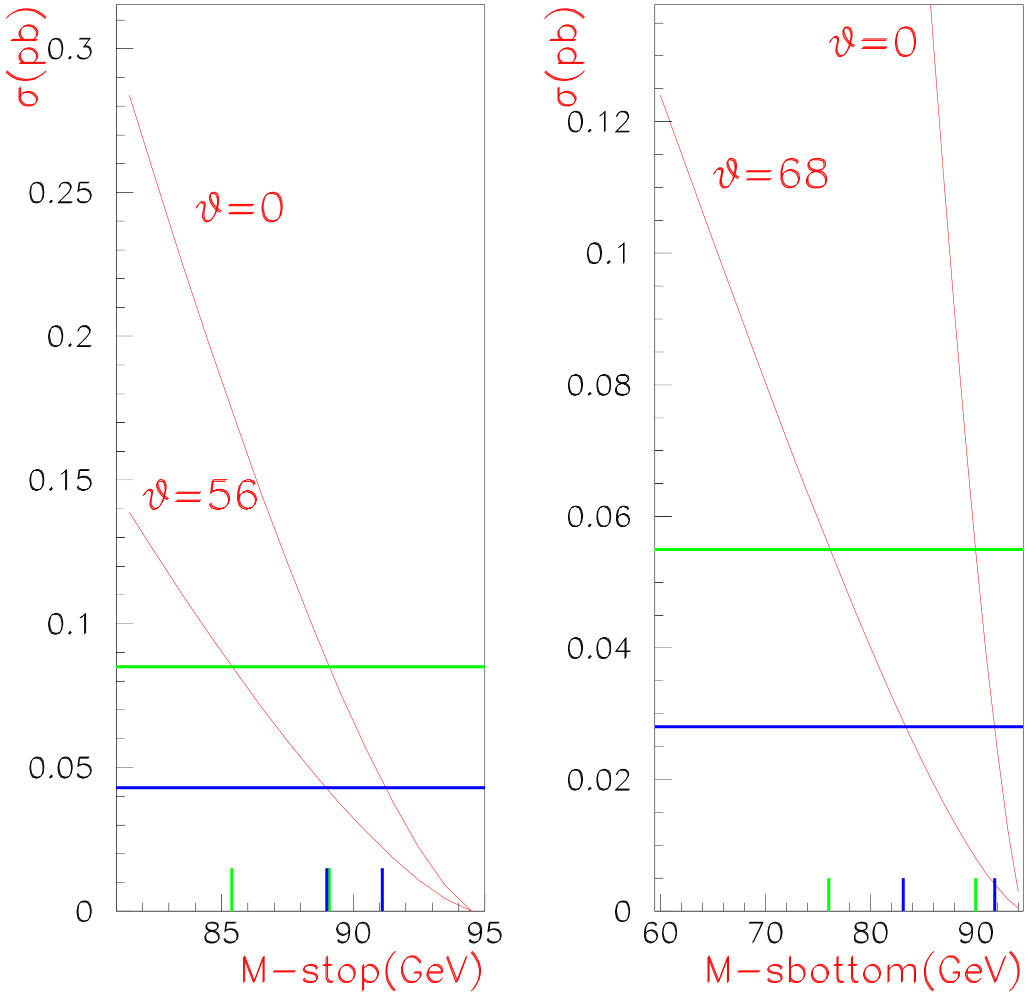
Prospects for 189 GeV combination



$\tilde{\mu}_R$ and $\tilde{\tau}_R$ for ΔM=50 GeV

- Improvements on $\mathrm{M}_{\tilde{\mu}_R}$ limit ∼6 GeV
- Improvements on $\mathrm{M}_{\tilde{\tau}_R}$ limit ∼9 GeV

Prospects for 189 GeV combination



$\tilde{t} \to c\tilde{\chi}$ **and** $\tilde{b} \to b\tilde{\chi}$ **for ΔM=15 GeV**

- Improvements on $M_{\tilde{t}}$ limit: ∼(2-4) GeV for $\theta_{\tilde{t}} = 0°$-$56°$
- Improvements on $M_{\tilde{b}}$ limit: ∼(2-7) GeV for $\theta_{\tilde{b}} = 0°$-$68°$

Prospects for 189 GeV combination

- It is worth to repeat the combination for the old channels:
- Expected gain on Mass limits: (2-9) GeV
- We plan to combine new channels:

$\tilde{\chi}$ LSP

- $\tilde{\chi}^{\pm}$ for any m_0
- Neutralinos
- Prepare tools for the combined LSP limit

$\tilde{G}$ LSP

- Sleptons with any lifetime (4 different experimental topologies) limit in the plane $M_{\tilde{\ell}}$-$M_{\tilde{G}}$
- Cascade decays: $\tilde{\chi}\tilde{\chi} \rightarrow \tilde{\ell}\ell\tilde{\ell}\ell \rightarrow \tilde{G}\ell\ell\tilde{G}\ell\ell$

$\tilde{\chi}$ LSP with R$_P$ violation ?

- It's a huge amount of work: more man-power needed (wait until the end of LEP2 ?)

Conclusions: toward LEP200 combination

- The LEPSUSY-wg experienced 2 years of productive and stimulating work but NO SUSY found
- The sensitivity for many SUSY particles has been improved by 2-10 GeV
- Beyond that a lot of useful discussions and exchange between the LEP experiments improved our knowledge on SUSY searches
- We are preparing methods and tools for more ambitious combinations in both Gravity-MSB and GMSB scenarios
- The combination of R-parity violating topologies is still to be discussed: we will need more people to be involved
- At the end of LEP200 the LEPSUSY-wg will provide the best knowledge on SUSY searches for a large region of the SUSY parameter space up to the light-up of LHC
- We still have the hope (and about 11-17 GeV to go) that our group won't provide very good SUSY limits but approximate measurements of the properties of SUSY particles
- A special Thank to: M. Antonelli, V. Buescher, A. De Min, L. Duflot, A. Favara, P. Giacomelli, F. Gianotti, F. Holldorfer, L. Pape, W. Orejudos, S. Rosier-Lees