LEP Jamboree
27/2/2001

LEP SUSY working group status report

P. Giacomelli
INFN, Bologna
Univ. of California, Riverside

- **Working group details**
- **Combined results of the working group**
- **Conclusions**

All results shown here are Preliminary!

LEP SUSY working group

The LEP SUSY WG members:

Aleph: B. Clerbaux, G. Ganis

Delphi: A. De Min, L. Pape (convener)

L3: A. Favara, S. Rosier

Opal: P. Giacomelli, G. W. Wilson

Additional people actively involved in discussions and data combinations:

F. Cerutti, M. Maggi, R. McPherson

People providing the data: Too many to be listed.

Many thanks to all of them!

RPV-SUSY starting to combine data as well

Input data

- For each SUSY particle the 4 LEP experiments provide:
  - number of observed data events
  - number of expected background events
  - efficiency for the signal as a function of
    a) the SUSY particle mass
    b) the LSP mass

Additional information on:
http://lepsusy.web.cern.ch/lepsusy/Welcome.html

Data samples per experiment

$\sqrt{s}$ (GeV)	183	189	192	196	200	202	204-208	Total
$\int L$ (pb^{-1})	55	170	28	80	80	40	163-215	610-665

Previous LEP SUSY wg reports:
A. De Min 20/7/2000
S. Rosier 5/9/2000

Statistical methods

- Confidence levels computed with the Likelihood Ratio (LR) test-statistic in a "modified" frequentist approach[a]
  - The Likelihood Ratio test-statistic:

$$X = \frac{\mathcal{L}(s+b)}{\mathcal{L}(b)}$$

  - The modified frequentist approach: signal "s" excluded at confidence level "CL" if:

$$1 - CL \leq \frac{CL_{s+b}}{CL_b} = \frac{P_{s+b}(X \leq X_{obs})}{P_b(X \leq X_{obs})} = \frac{\int_0^{X_{obs}} \frac{dP_{s+b}}{dX} dX}{\int_0^{X_{obs}} \frac{dP_b}{dX} dX}$$

- Combining different events/channels/experiments becomes trivial since:

$$X^{tot} = \prod_{i=1}^{N_{chan}} \prod_{j=1}^{n_i} X_{ij}$$

[a] A.L. Read, DELPHI 97-158 PHYS 737

Statistical methods

- For counting experiments (as for the SUSY WG case):

$$X = \frac{\prod_{i=1}^{N_{chan}} \frac{e^{-(s_i+b_i)}(s_i+b_i)^{n_i}}{n_i!}}{\prod_{i=1}^{N_{chan}} \frac{e^{-b_i} b_i^{n_i}}{n_i!}} = e^{-s_{tot}} \prod_{i=1}^{N_{chan}} \prod_{j=1}^{n_i} \left(1 + \frac{s_i}{b_i}\right)$$

- and, since $P(X \leq X_{obs}) = P(\ln(X) \leq \ln(X_{obs}))$,

$$\ln(X) = -s_{tot} + \sum_{k=1}^{n} n_k \ln\left(1 + \frac{s_k}{b_k}\right) = -s_{tot} + \sum_{k=1}^{n} n_k w_k$$

→ it reduces to a simple sum of weighted events!

- In practice CL's are computed with a program based on FFT[a]

[a] H.Hu and J.Nielsen, Wisc-Ex-99-352

Statistical estimators

Estimators based on *Probability* ($\mathcal{P}(k,\mu) = e^{-\mu}\,\mu^k/k!$)

SM: agreement with the SM

$$\varepsilon_{\mathrm{SM}} = \prod_{ch=1}^{N} \mathcal{P}(n_{ch}^{obs}, b_{ch})$$

NoDeficit: sensitive to *deficits*

$$\varepsilon_{\mathrm{NoDeficit}} = \prod_{ch=1}^{N} \sum_{k=0}^{n_{ch}^{obs}} \mathcal{P}(k, b_{ch})$$

Confidence Level = Probability ($\varepsilon \le \varepsilon_{obs}$)

NoExcess: sensitive to *excesses*

$$\varepsilon_{\mathrm{NoExcess}} = \prod_{ch=1}^{N} \sum_{k=n_{ch}^{obs}}^{\infty} \mathcal{P}(k, b_{ch})$$

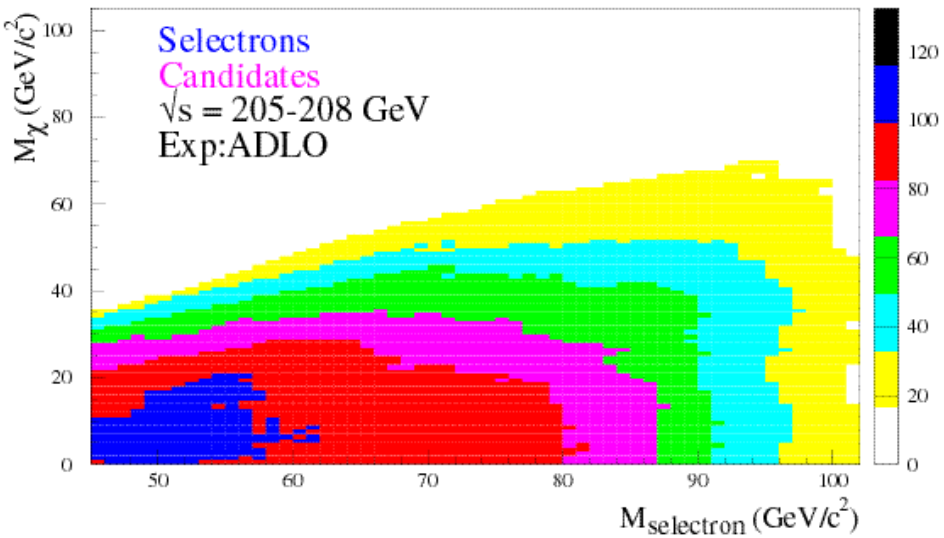
Confidence Level = Probability ($\varepsilon \ge \varepsilon_{obs}$)

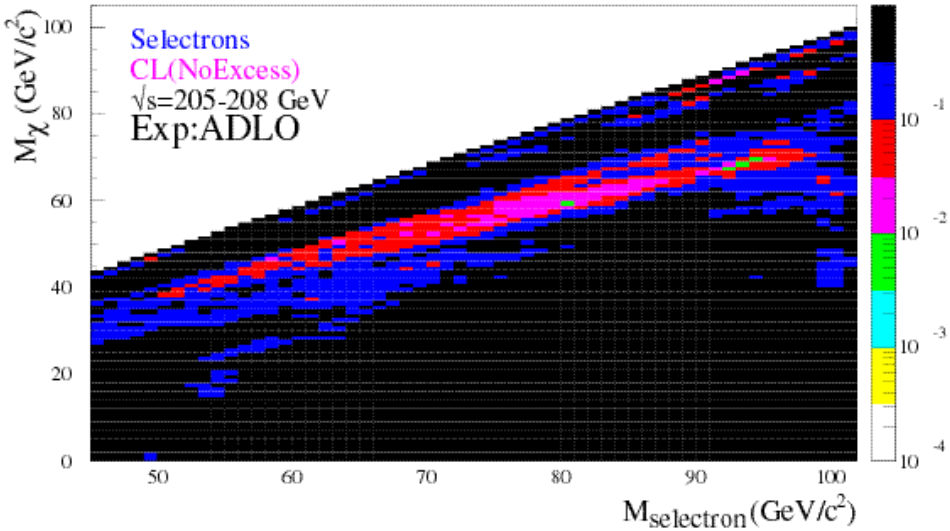
Selector search

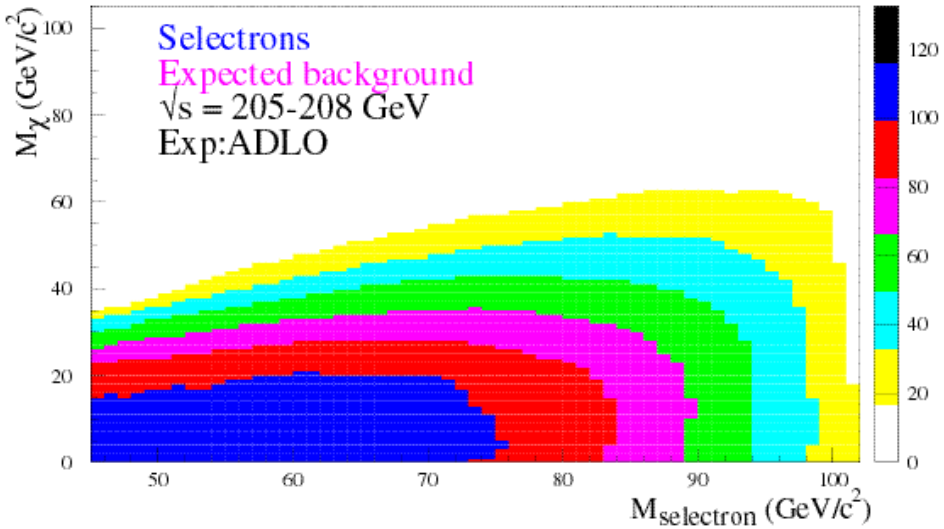
$\tilde{e} \rightarrow e \tilde{\chi}^1_0$

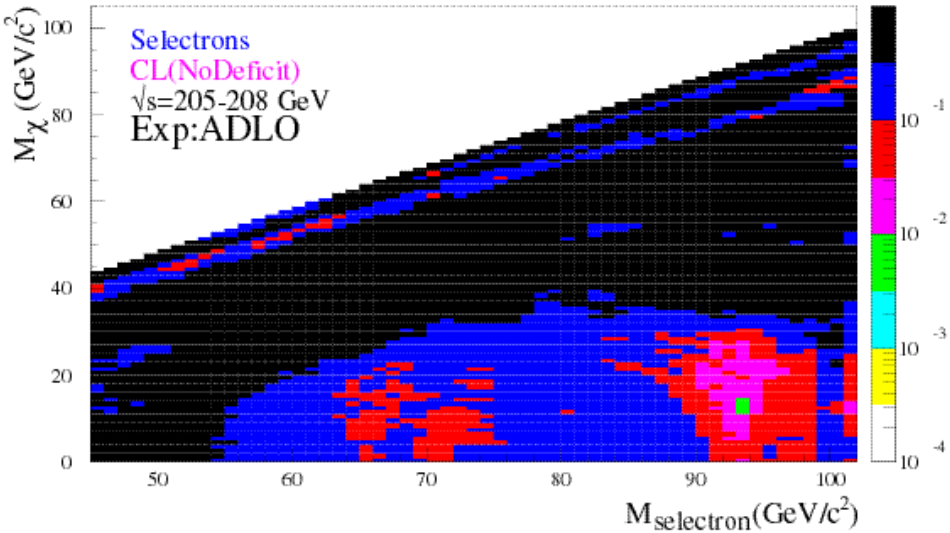
Year 2000 data

Acoplanar electron pairs







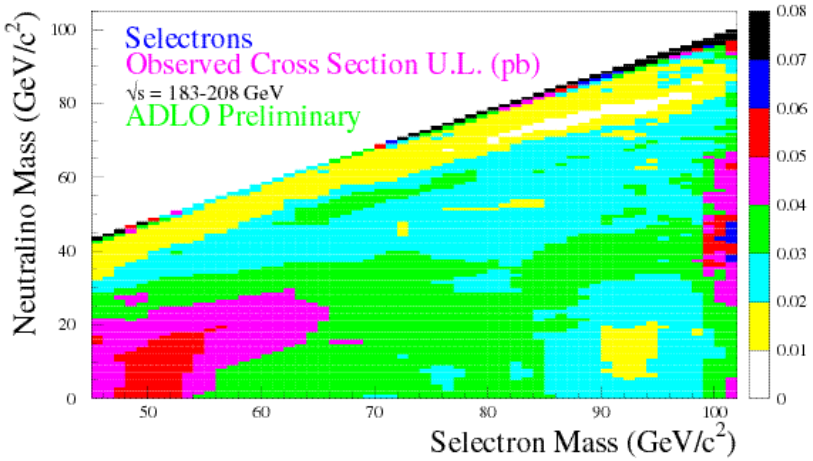


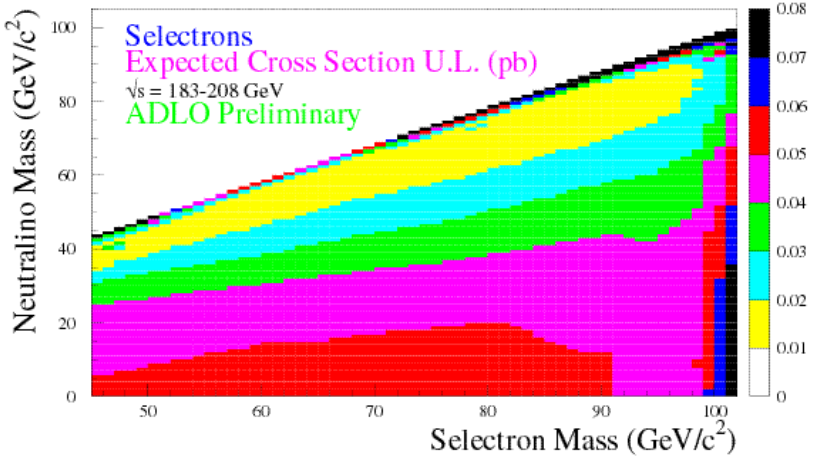
Selector search

No excess ➪ derive limits

183-208 GeV data

$\tilde{e} \rightarrow e \tilde{\chi}^1_0$

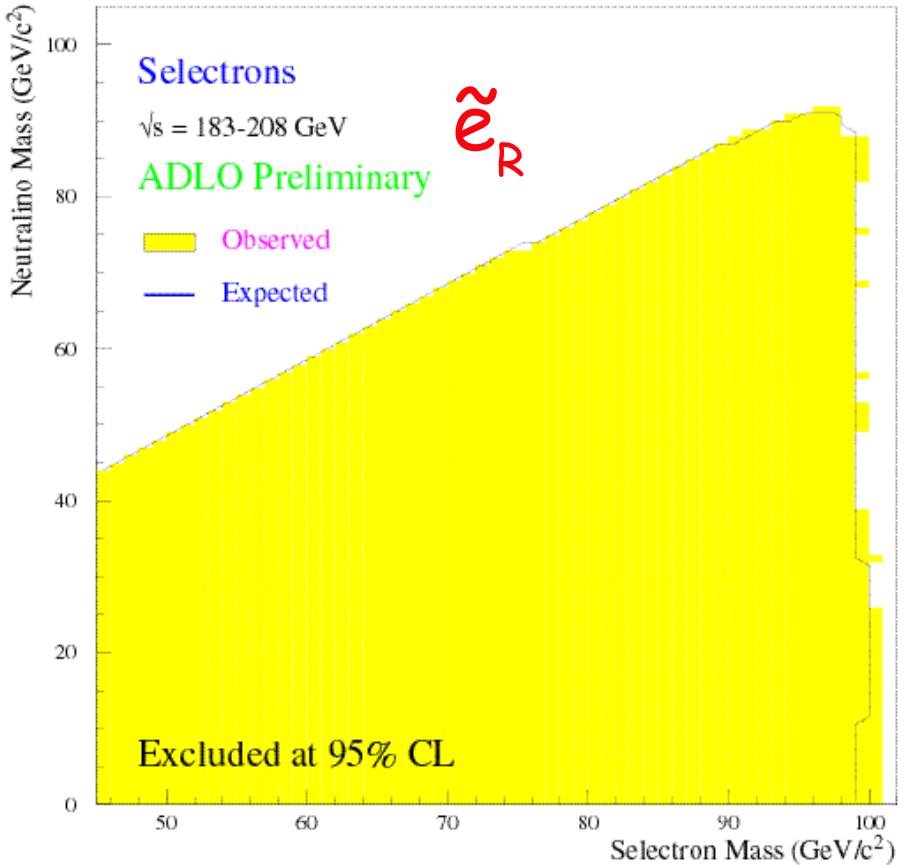




Acoplanar electron pairs

tan β = 1.5

μ = -200 GeV



$m_{\tilde{e}} \geq 99.4$ GeV (99.3 GeV) at 95% CL for $m_{\tilde{\chi}^0_1} = 40$ GeV

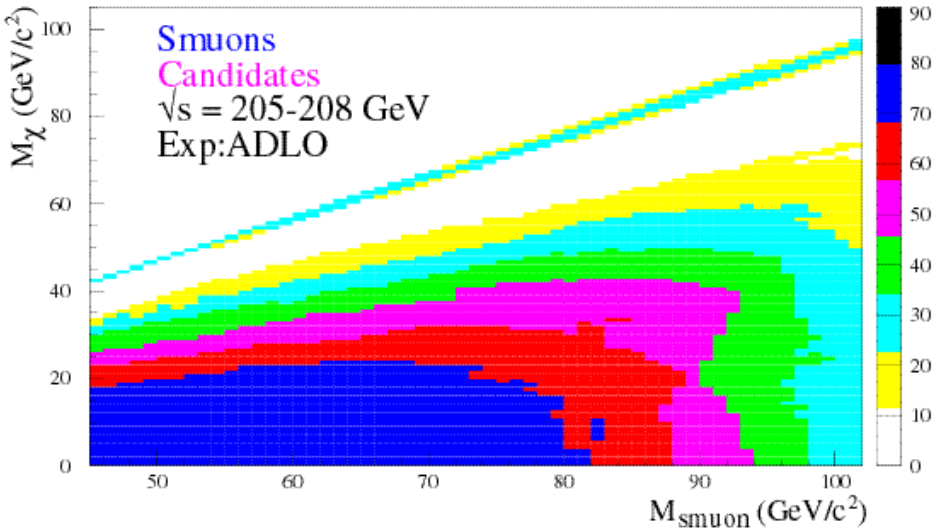
obs. exp.

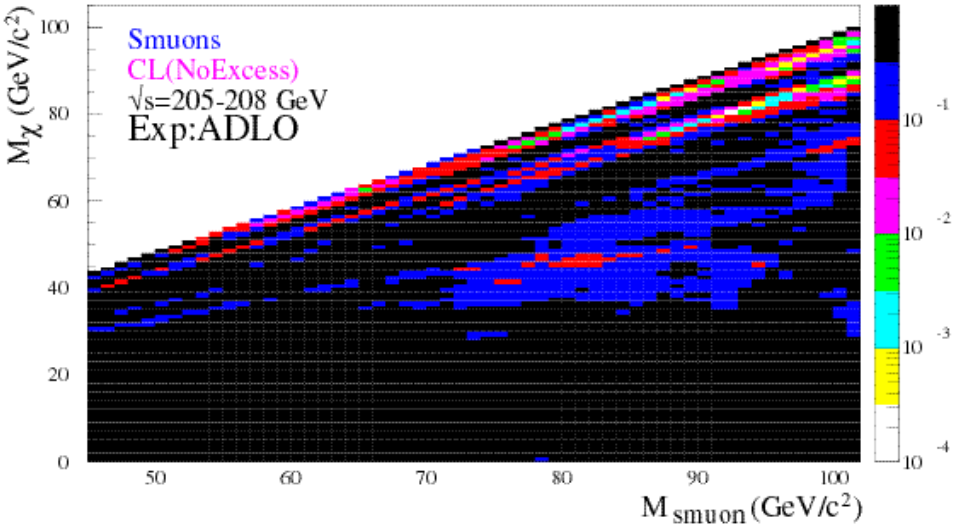
Smuon search

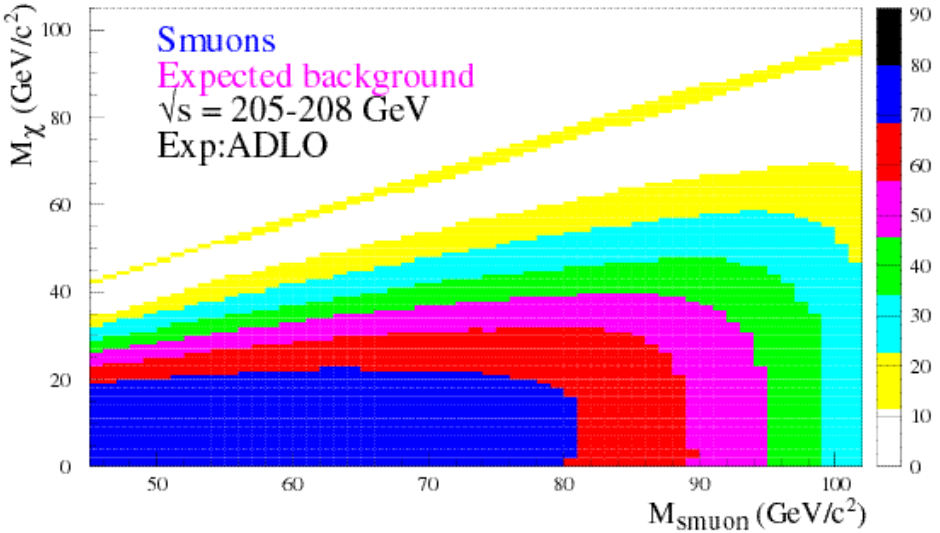
Year 2000 data

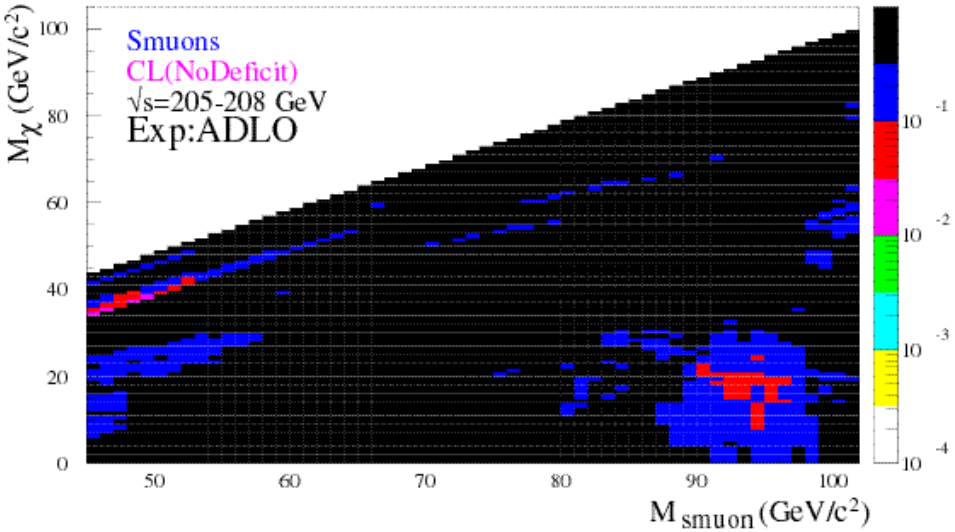
$\tilde{\mu} \rightarrow \mu \tilde{\chi}^1_0$

Acoplanar muon pairs





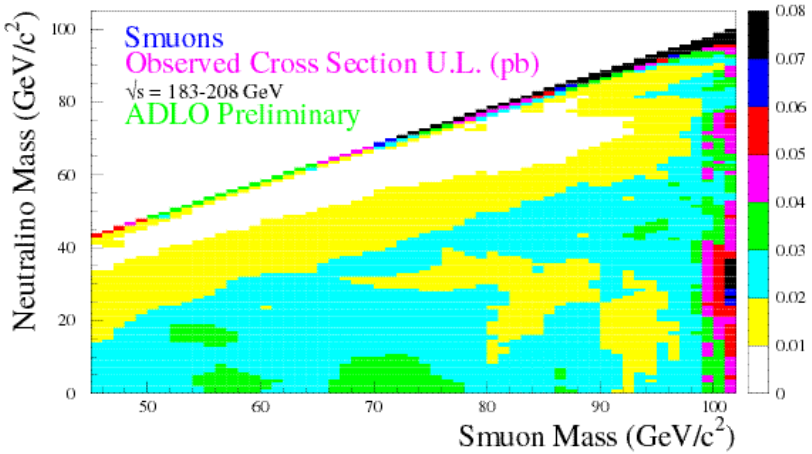


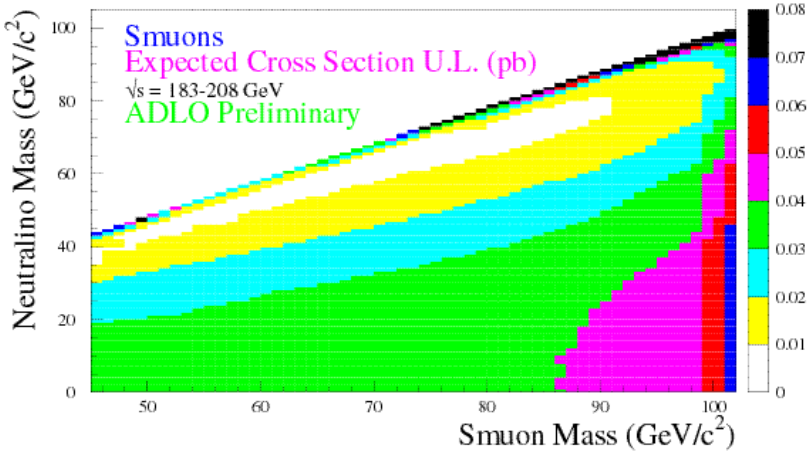


Smuon search

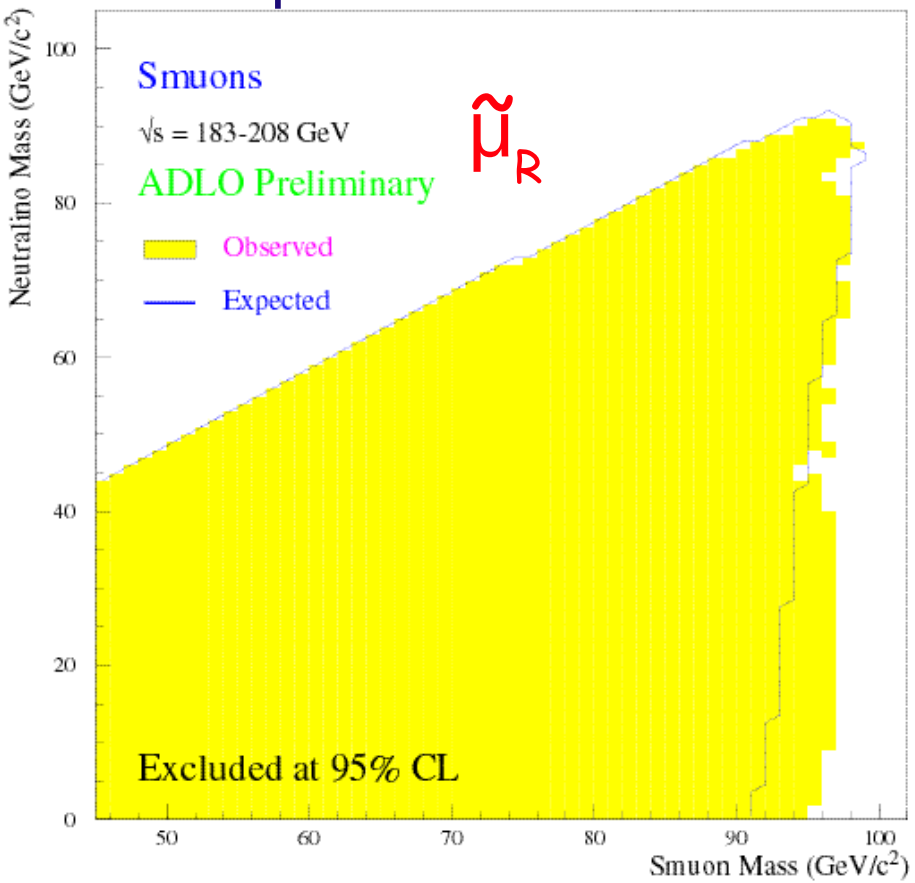
No excess ⇨ derive limits $\tilde{\mu} \rightarrow \mu \tilde{\chi}^1_0$ Acoplanar muon pairs

183-208 GeV data





tan β = 1.5
μ = -200 GeV



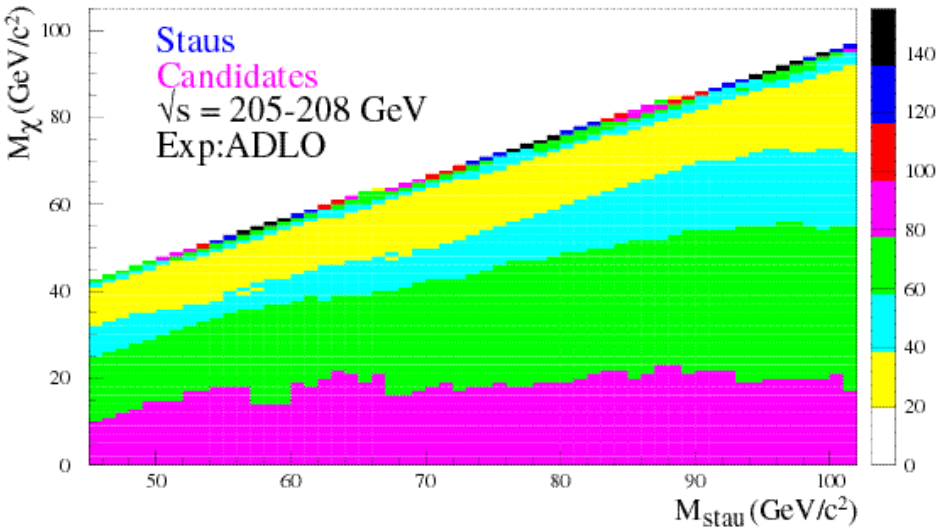
$m_{\tilde{\mu}} \geq 96.4$ GeV (91.7 GeV) at 95% CL for $m_{\tilde{\chi}^0_1} = 40$ GeV
obs. exp.

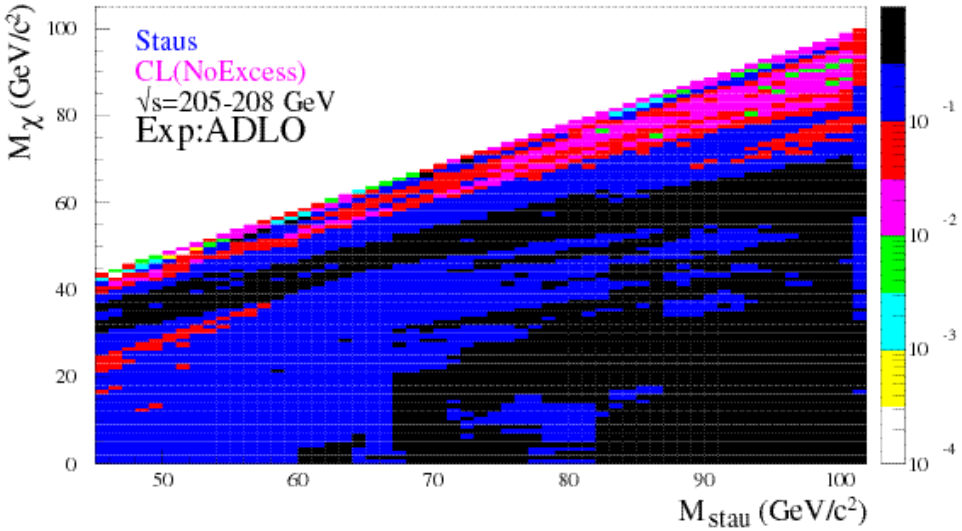
Stau search

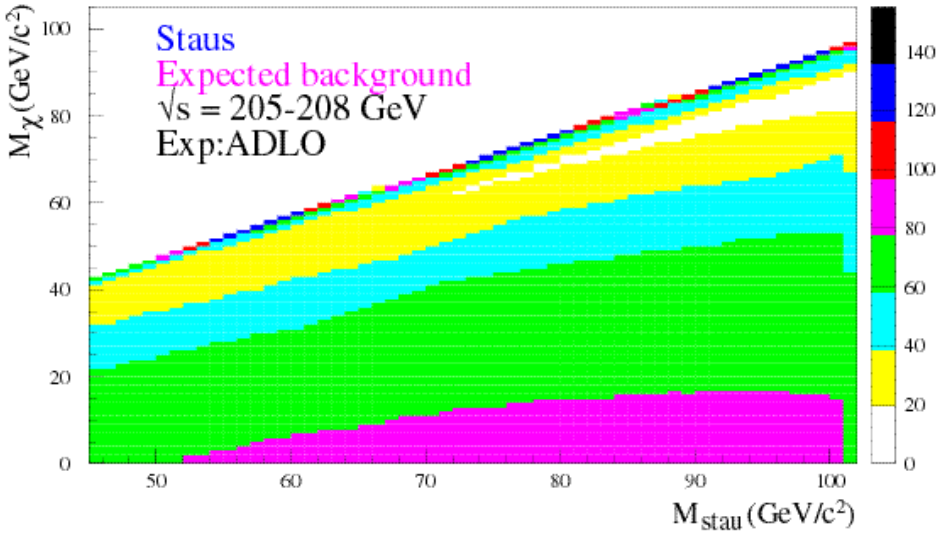
$\tilde{\tau} \rightarrow \tau \tilde{\chi}^1_0$

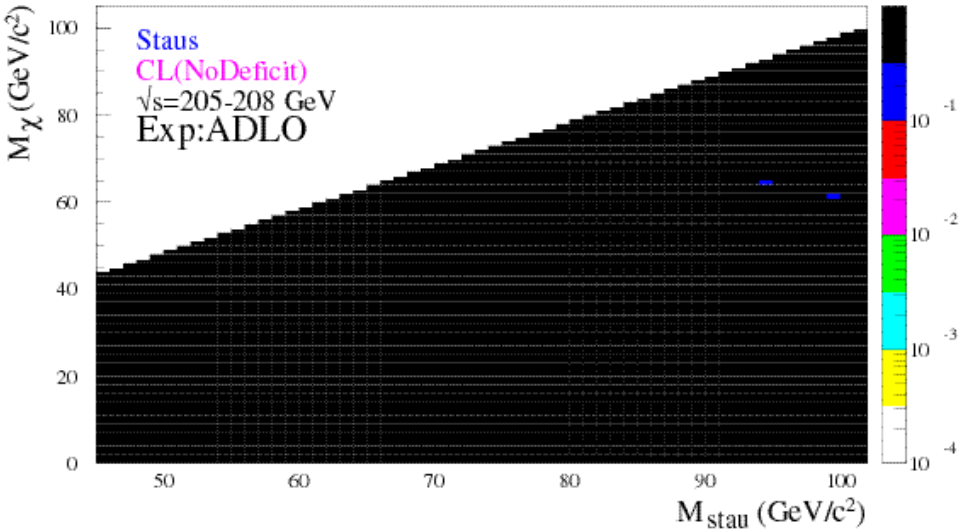
Year 2000 data

Acoplanar tau pairs





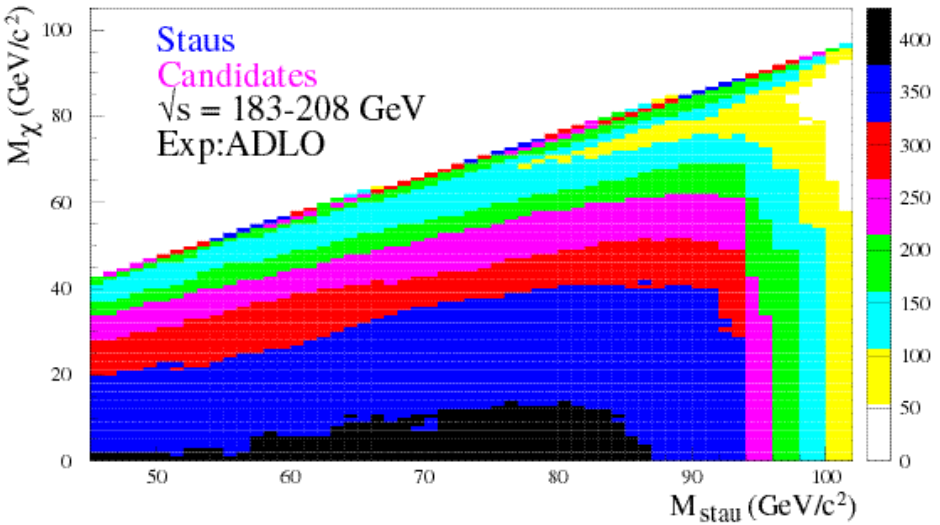


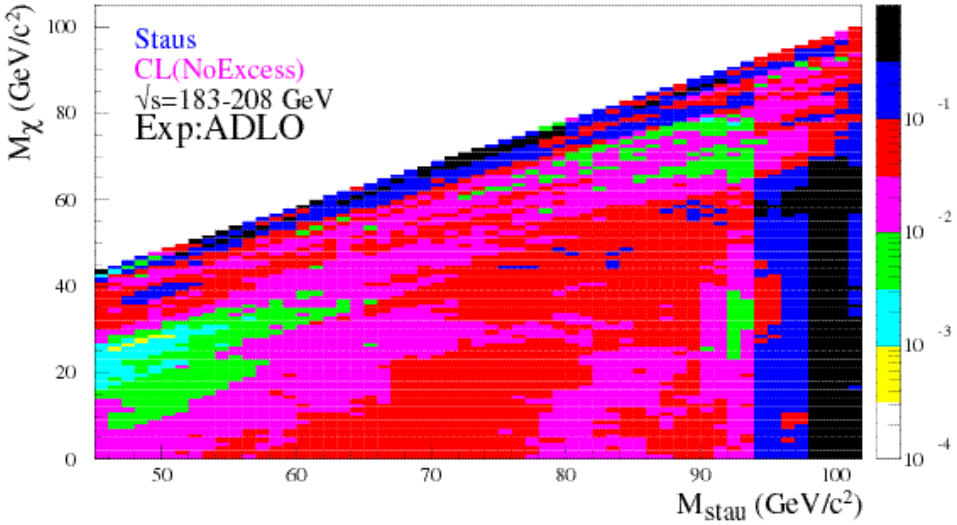


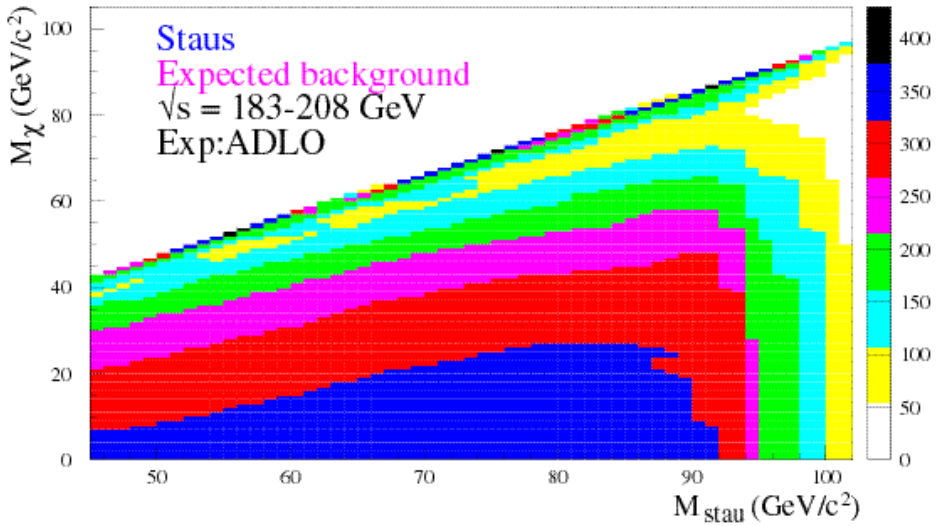
Stau search

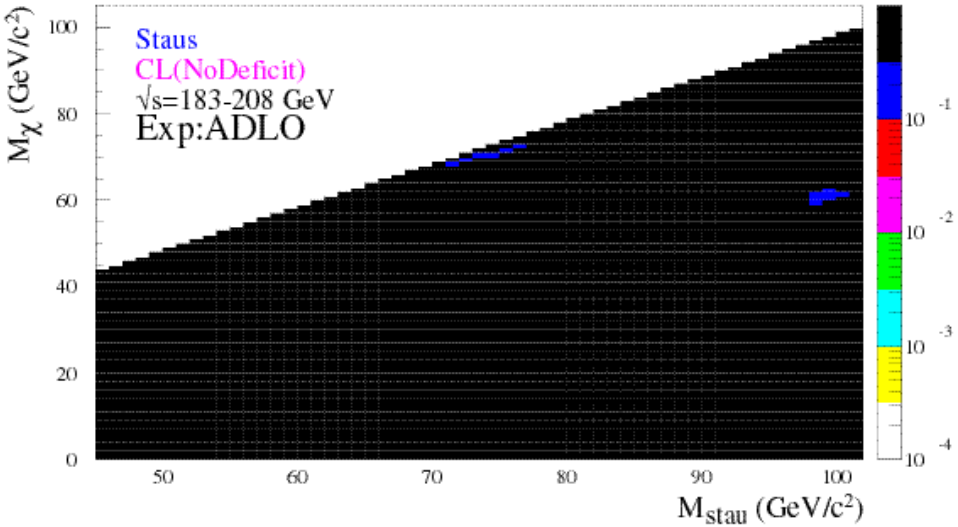
$\tilde{\tau} \rightarrow \tau \tilde{\chi}^1_0$ Acoplanar tau pairs

183-208 GeV data









Stau search

No excess ⇨ derive limits

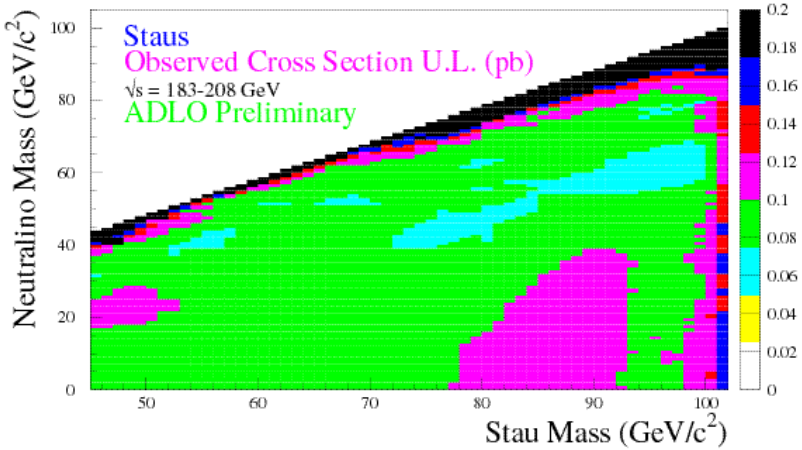
$\tilde{\tau} \rightarrow \tau \tilde{\chi}^1_0$

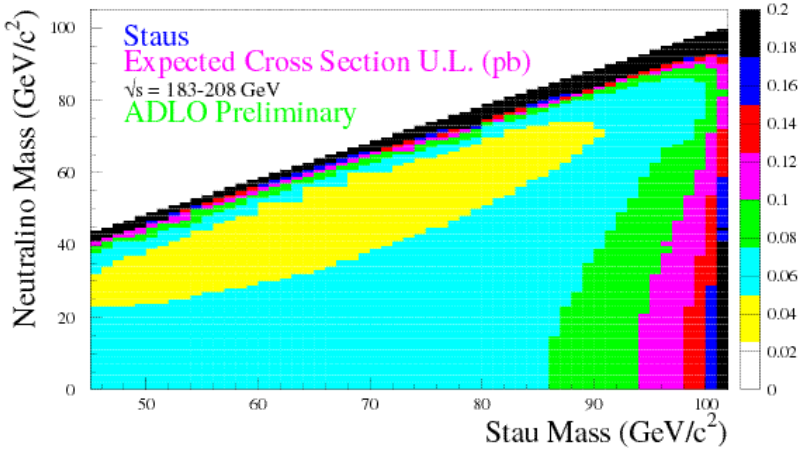
Acoplanar tau pairs

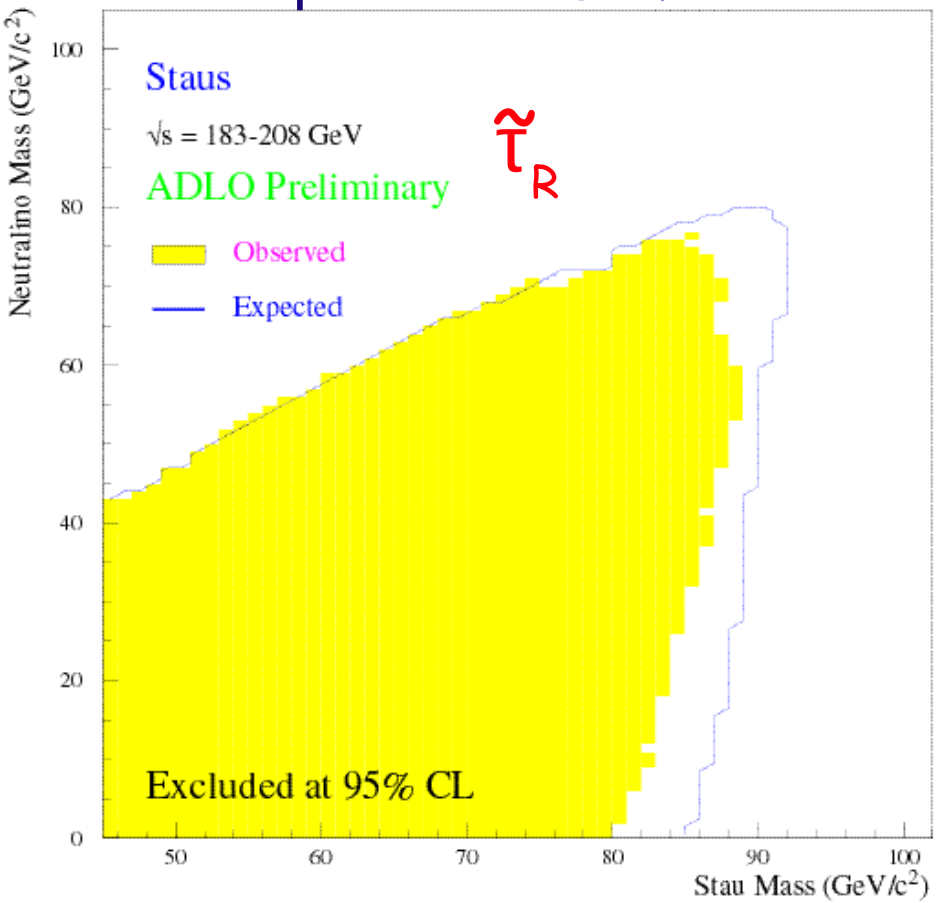
183-208 GeV data

tan β = 1.5

μ = -200 GeV







$m_{\tilde{\tau}} \geq 87.1$ GeV (89.3 GeV) at 95% CL for $m_{\tilde{\chi}^0_1} = 40$ GeV

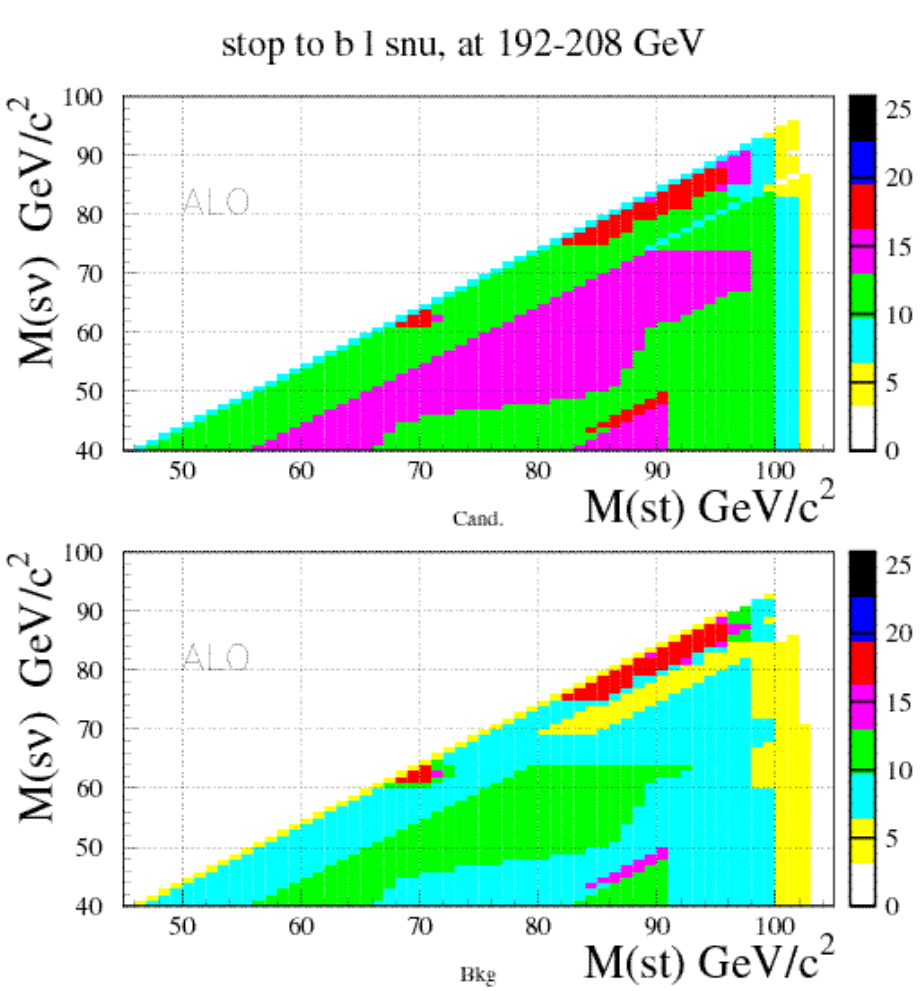
obs. exp.

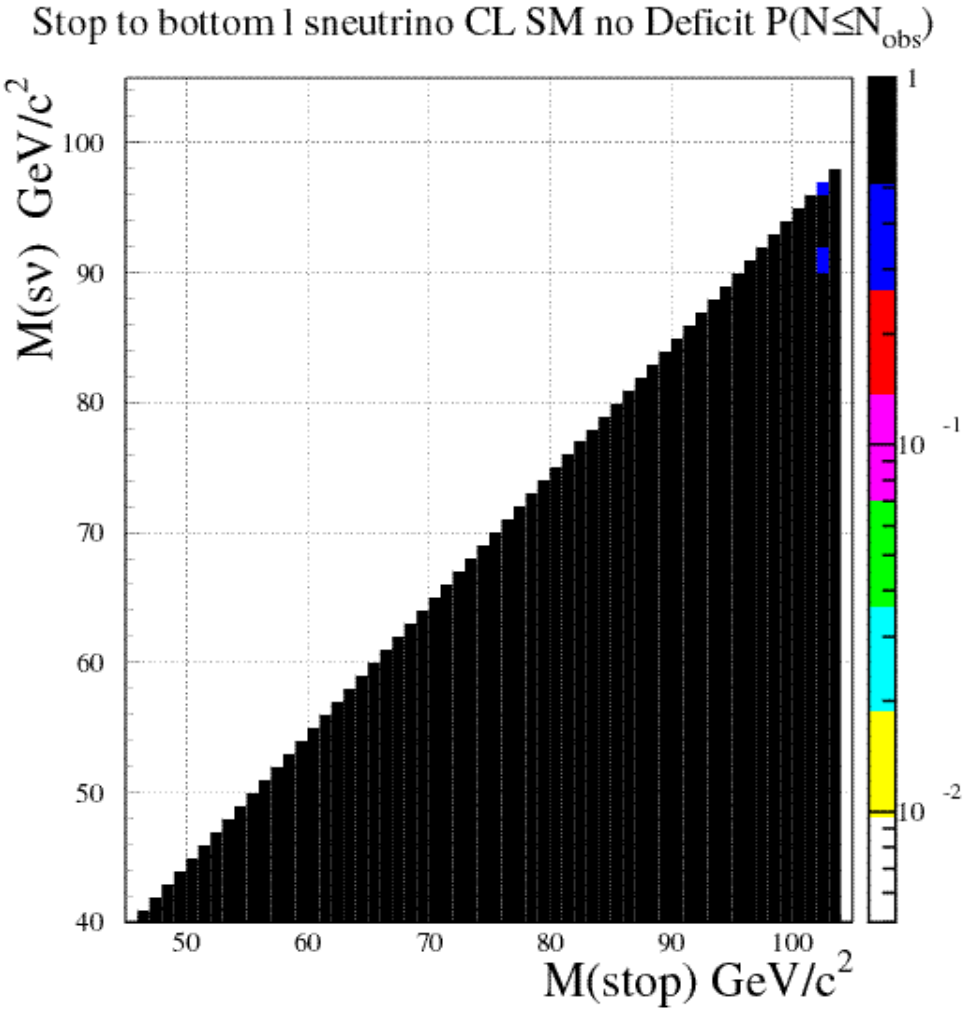
Stop search

$\tilde{t} \rightarrow b l \tilde{\nu}$

Acoplanar b jets + leptons

192-208 GeV data

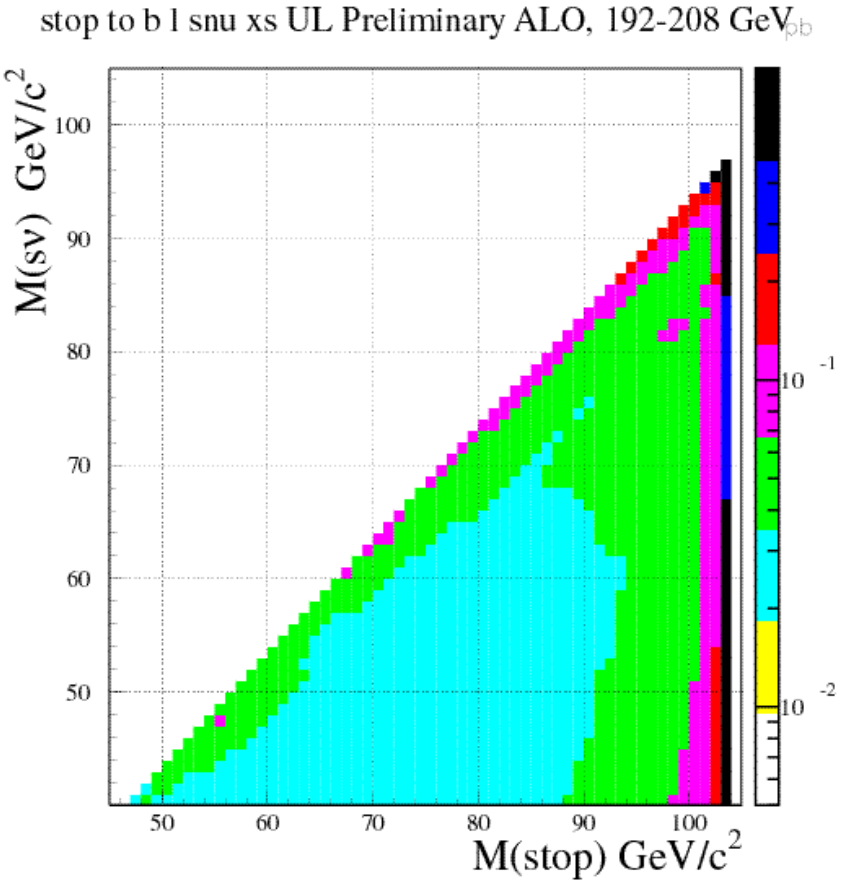


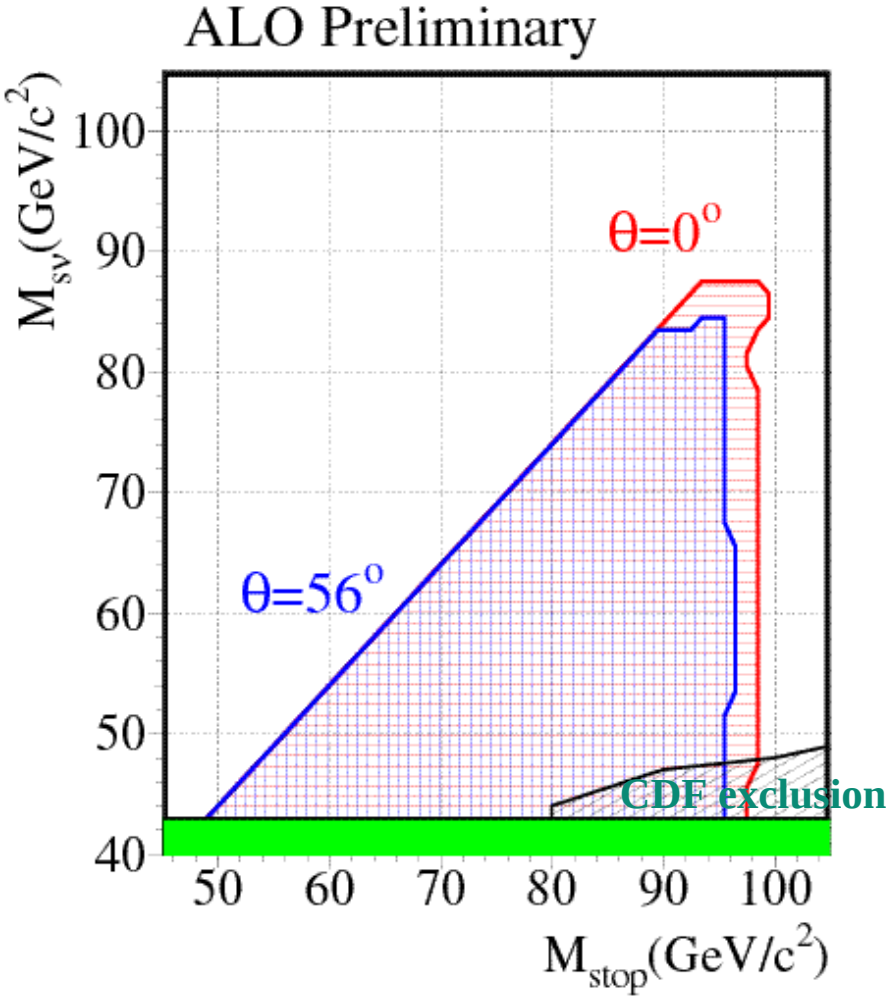


Stop search

No excess ➪ derive limits $\tilde{t} \rightarrow bl\,\tilde{\nu}$ Acoplanar b jets + leptons

192-208 GeV data





$m_{\tilde{t}} \geq 99$ (97) GeV at 95% CL for $(m_{\tilde{t}} - m_{\tilde{\nu}}) = 40$ GeV

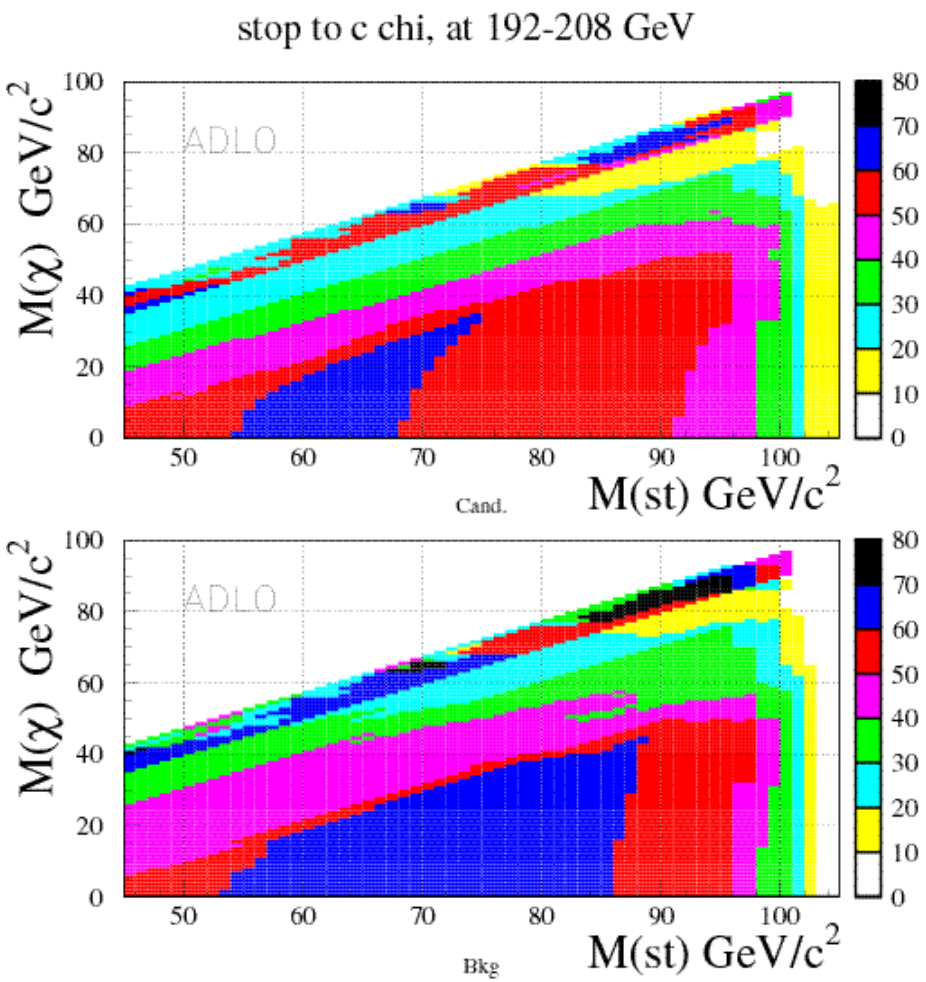
$\theta=0^0$ $\theta=56^0$

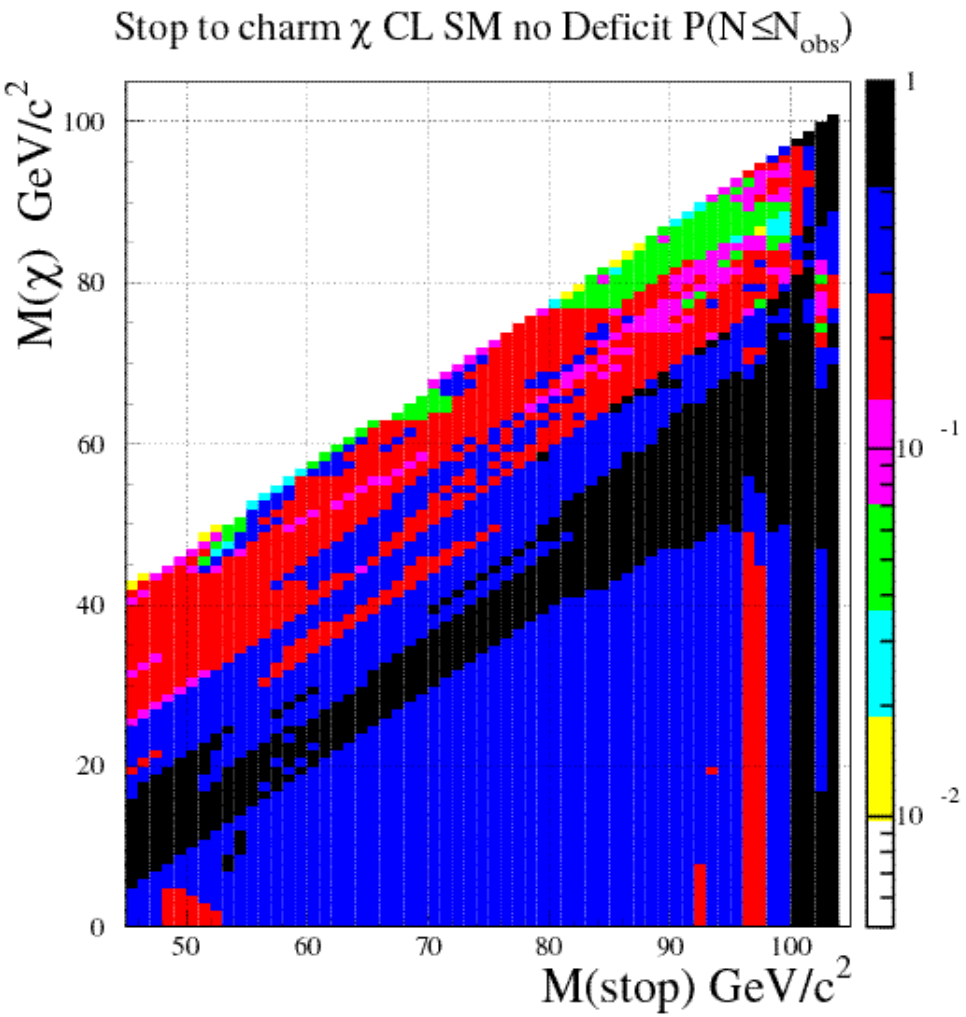
Stop search

$\tilde{t} \rightarrow c\,\tilde{\chi}^1_0$

Acoplanar c jets

192-208 GeV data

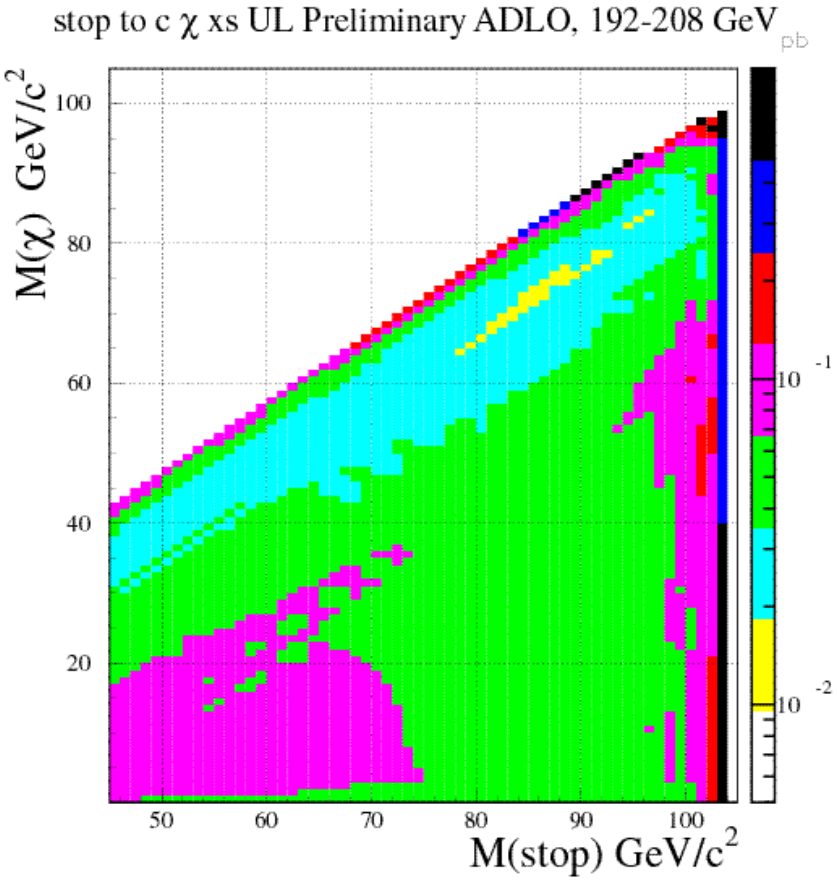


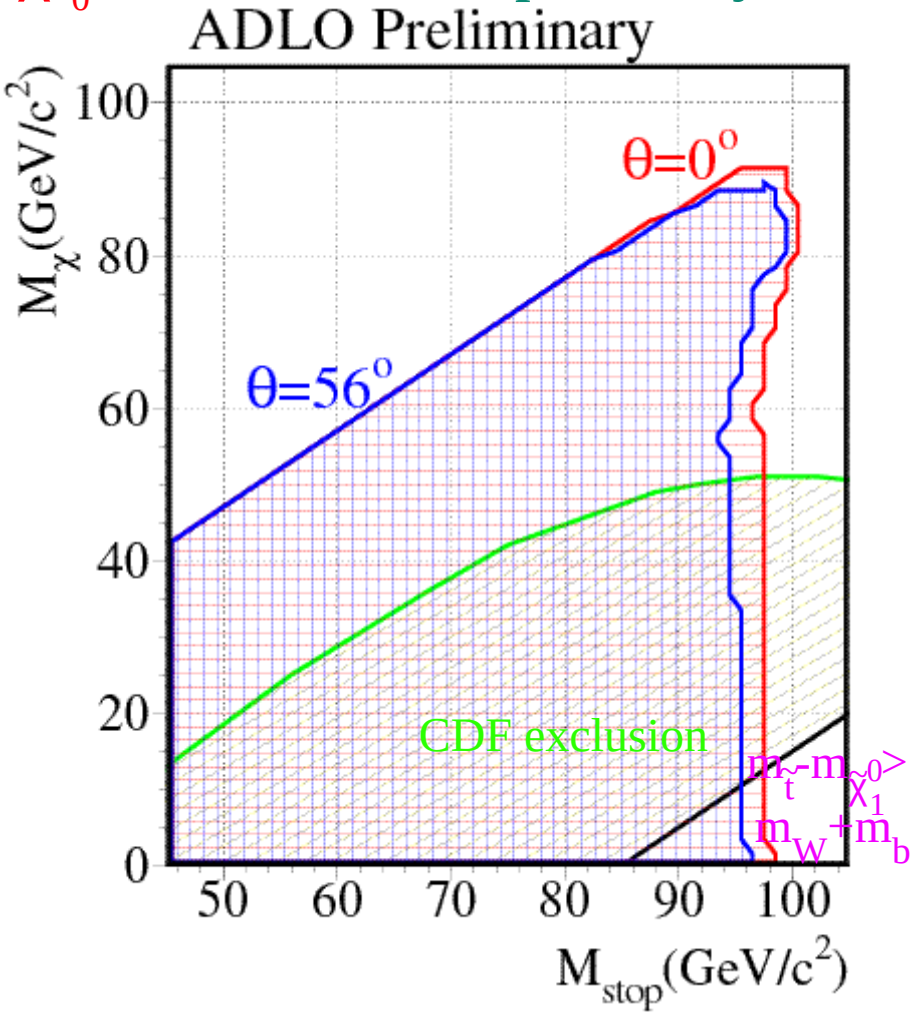


Stop search

No excess ➪ derive limits $\tilde{t} \rightarrow c\,\tilde{\chi}^1_0$ Acoplanar c jets

192-208 GeV data





$m_{\tilde{t}} \geq 98$ (95) GeV at 95% CL for $(m_{\tilde{t}} - m_{\tilde{\chi}^0_1}) = 40$ GeV

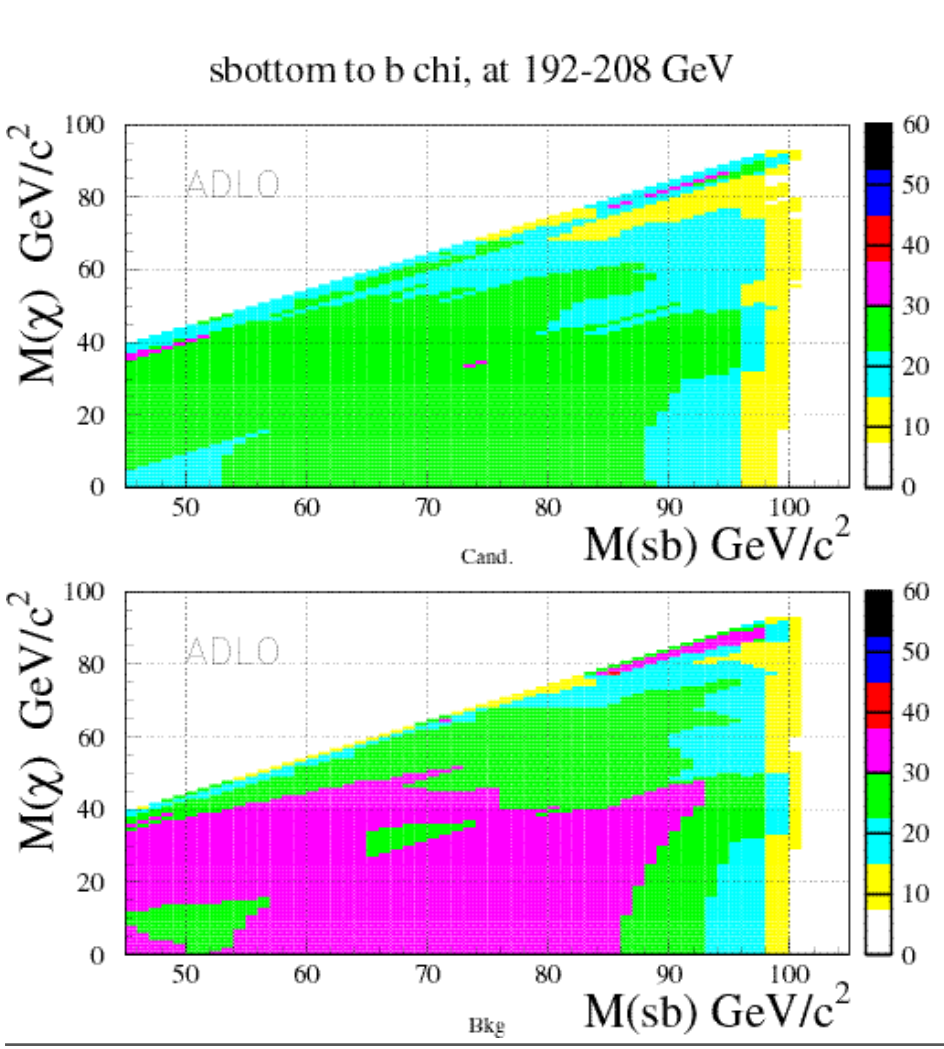
$\theta=0^0$ $\theta=56^0$

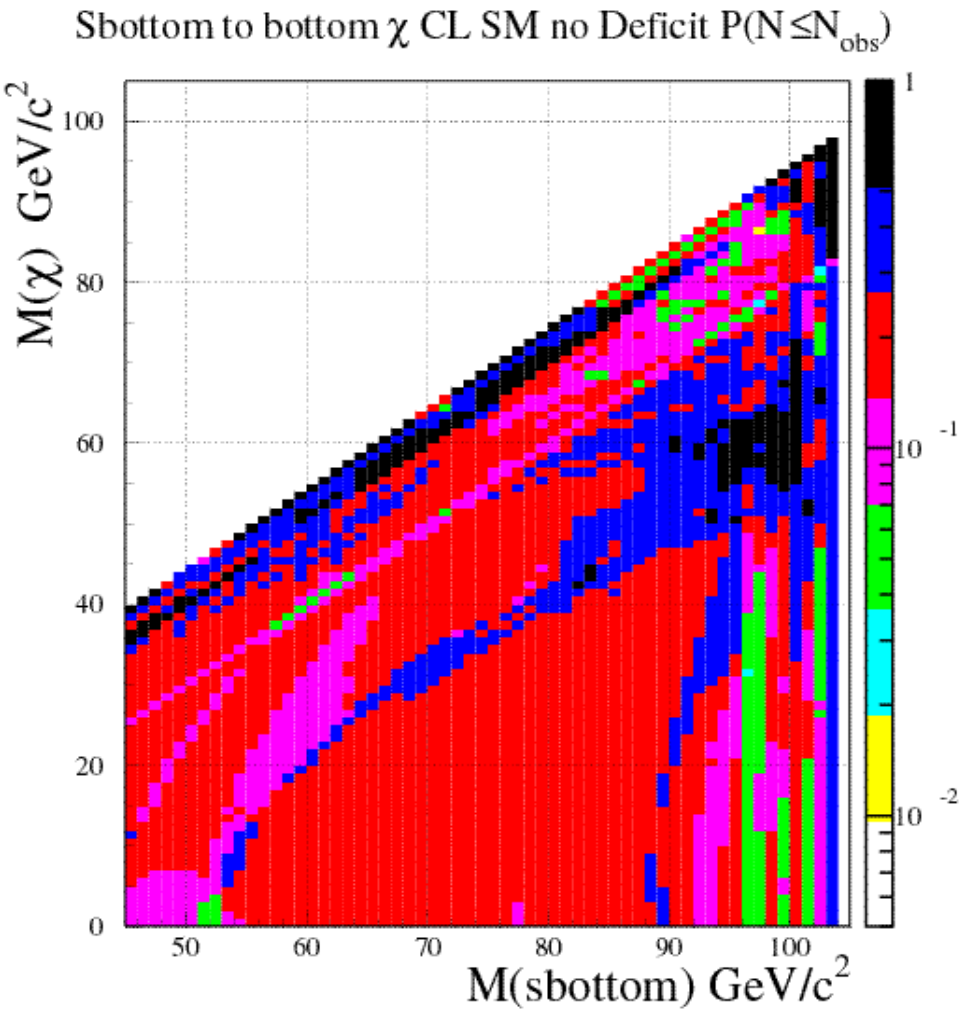
Sbottom search

$\tilde{b} \rightarrow b \tilde{\chi}^1_0$

Acoplanar b jets

192-208 GeV data

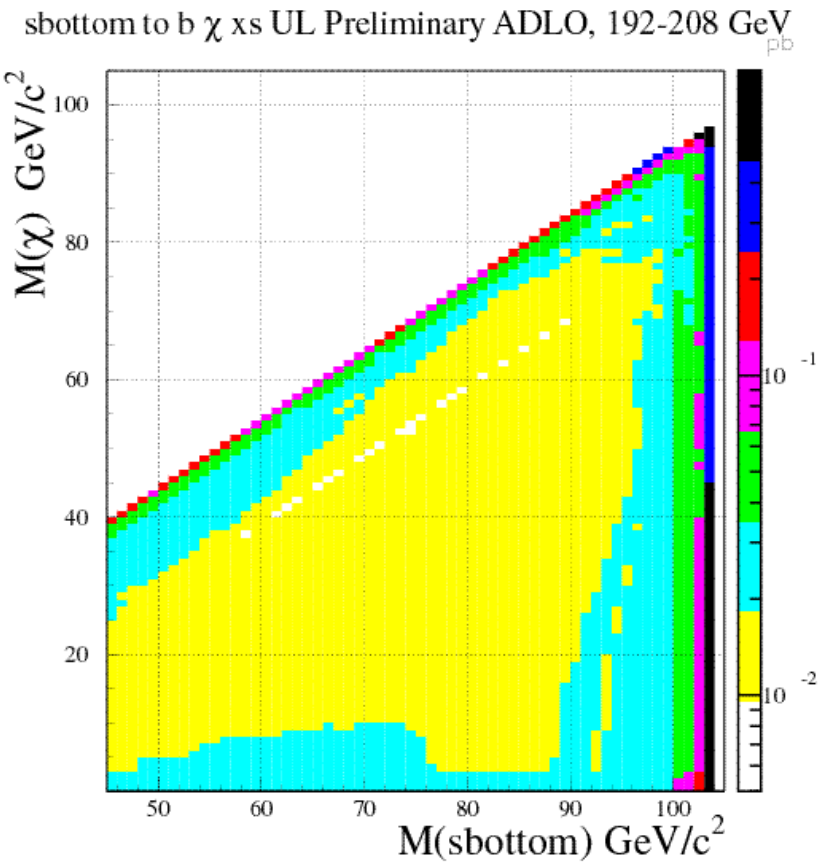


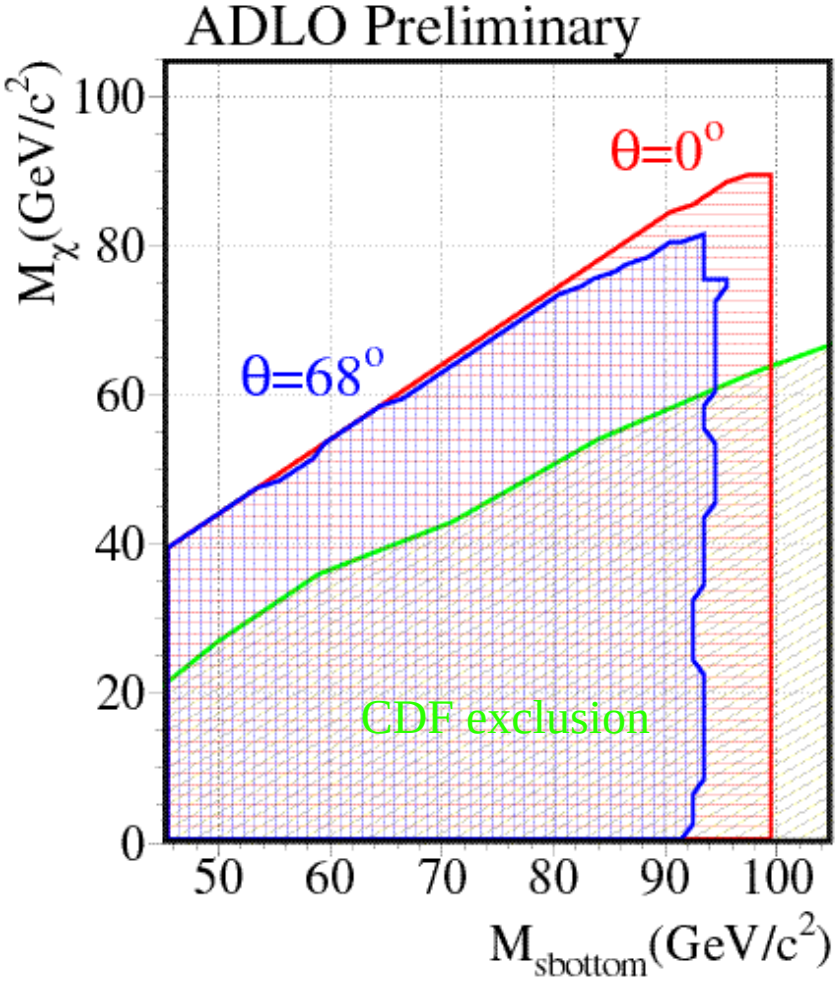


Sbottom search

No excess ⇨ derive limits $\tilde{b} \rightarrow b \tilde{\chi}^1_0$ Acoplanar b jets

192-208 GeV data

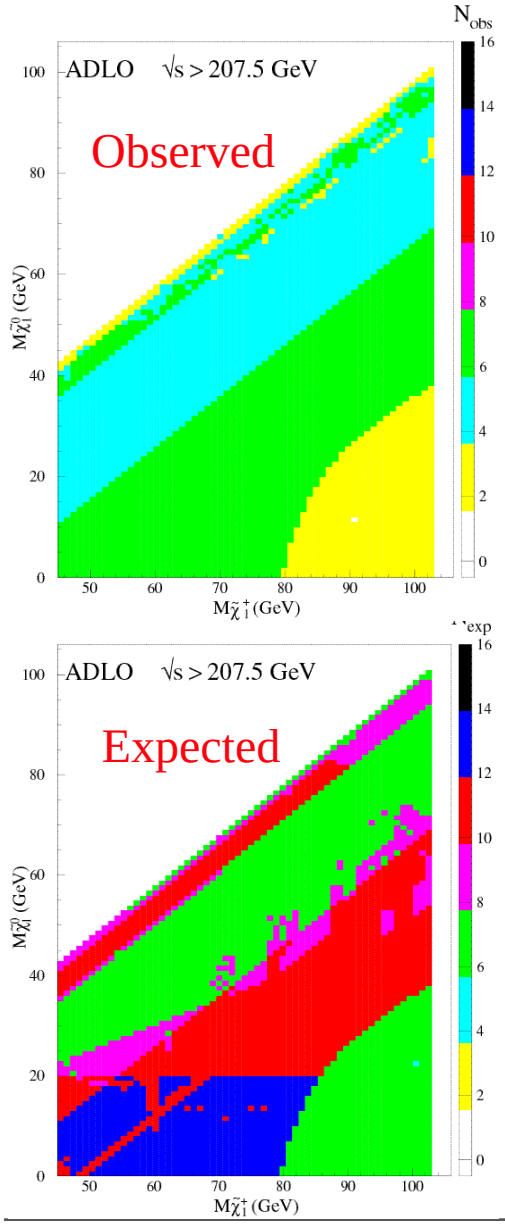




$m_{\tilde{b}} \geq$ 99 (95) GeV at 95% CL for $(m_{\tilde{b}} - m_{\tilde{\chi}^0_1}) = 20$ GeV

θ=0⁰ θ=68⁰

Chargino search



Gaugino-like chargino
(large sneutrino mass)

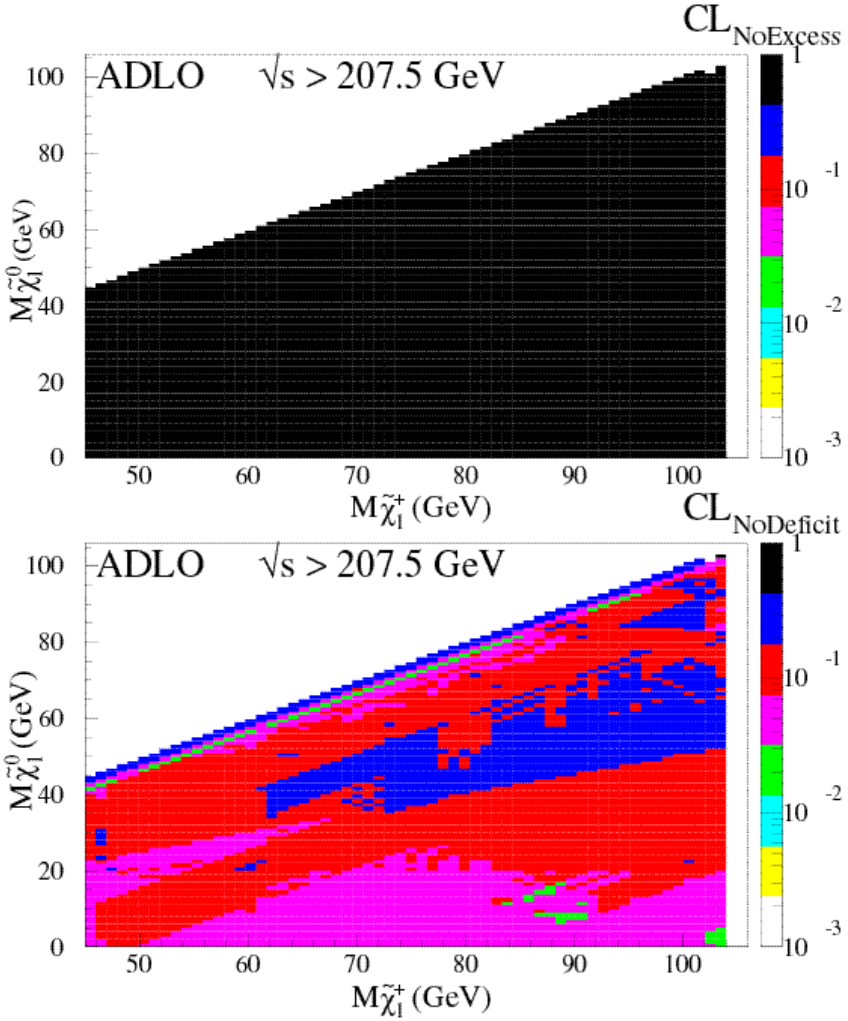
BR ($\tilde{\chi}^+_1 \rightarrow W^+\tilde{\chi}^0_1$) = 100%

$\sqrt{s} \geq 207.5$ GeV

L = 35.2 pb^{-1}

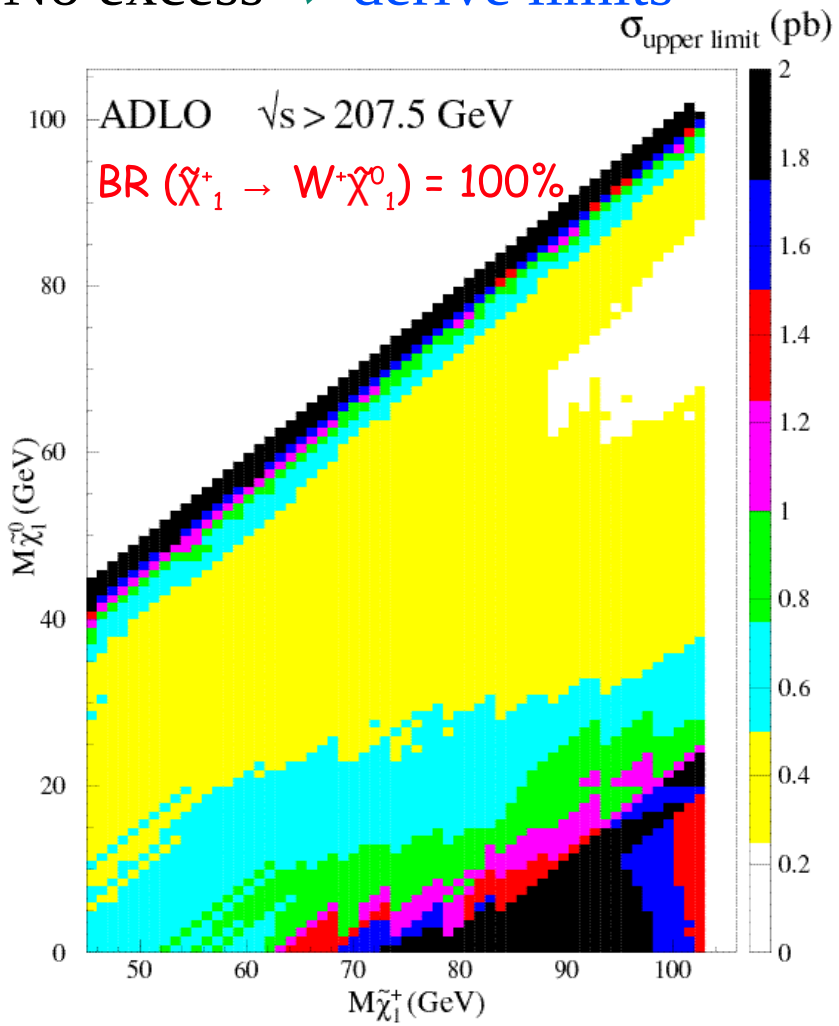
Small deficit

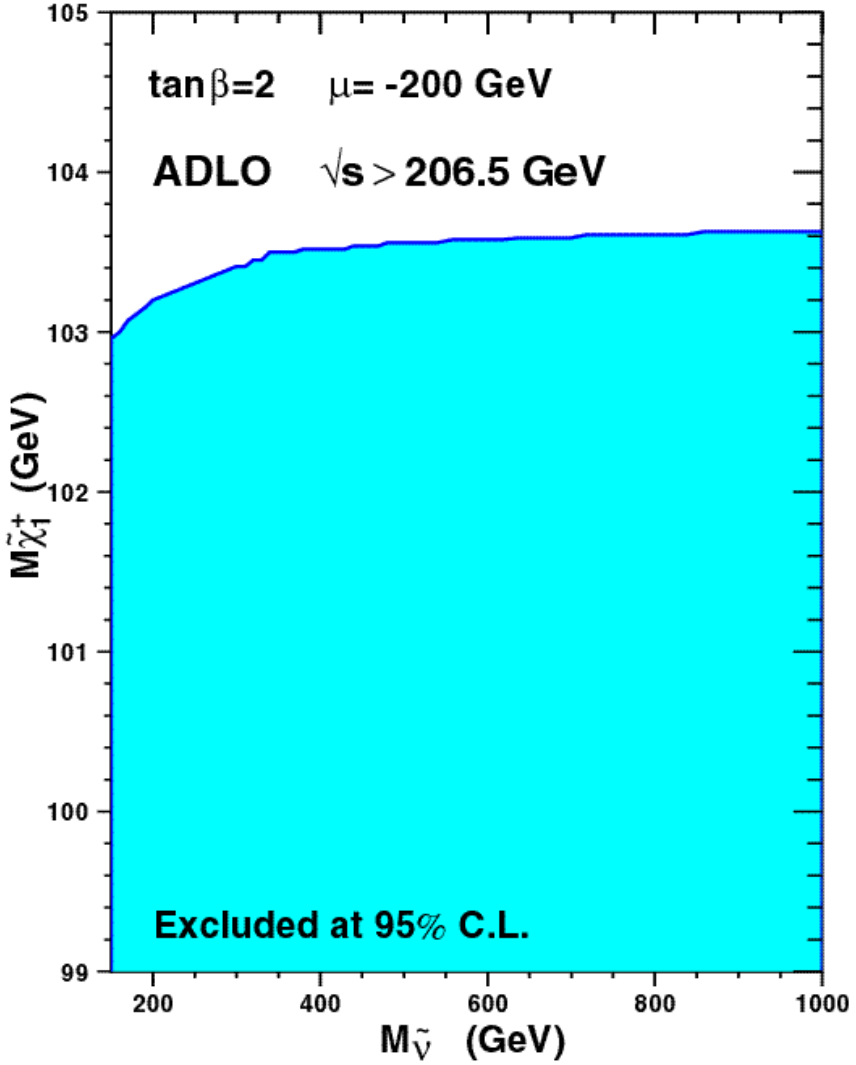
Leptons,
leptons+jets, jets



Chargino search

No excess ⇨ derive limits





$m_{\tilde{\chi}^+_1} \geq 103.5\ (103.3)$ GeV at 95% CL for $m_{\tilde{\nu}} > 300$ GeV

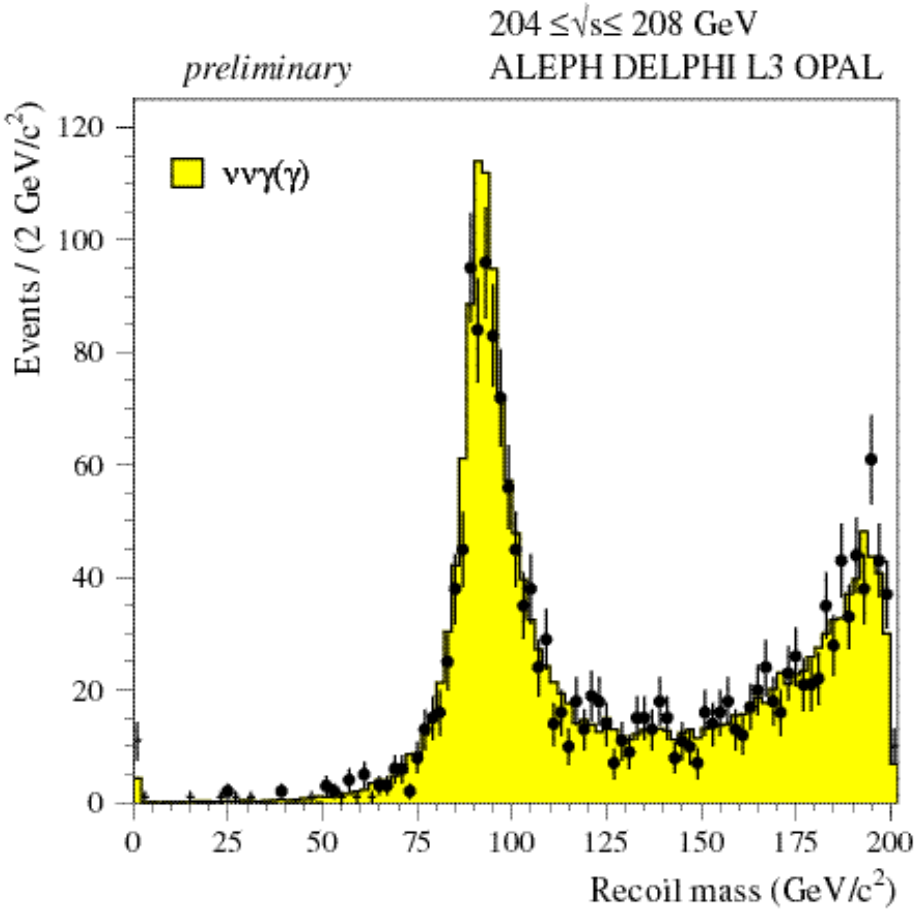
obs. exp.

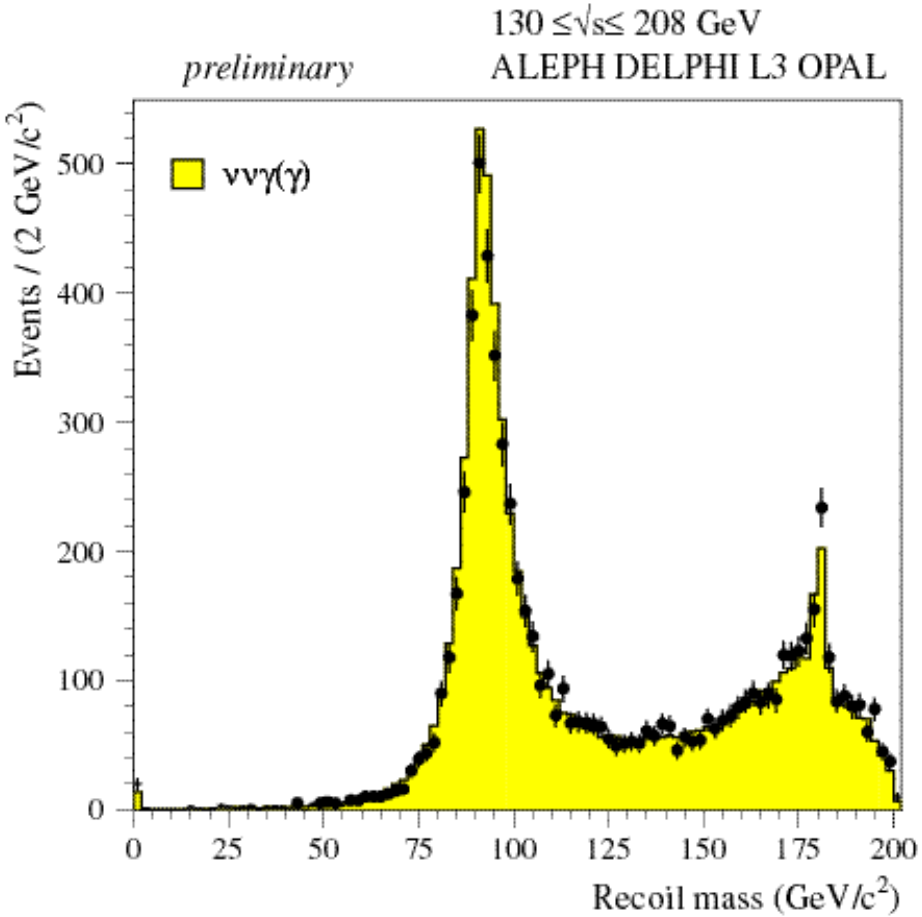
Single photons

$e^+e^- \rightarrow \tilde{\chi}^0_2\tilde{\chi}^0_1 \rightarrow (\tilde{\chi}^0_1\gamma)\tilde{\chi}^0_1$ or $e^+e^- \rightarrow \tilde{G}\tilde{\chi}^0_1 \rightarrow (\tilde{G}\gamma)\tilde{G}$ ... $\gamma + \not{E}$

Year 2000 data

130-208 GeV: 7364/7501.7



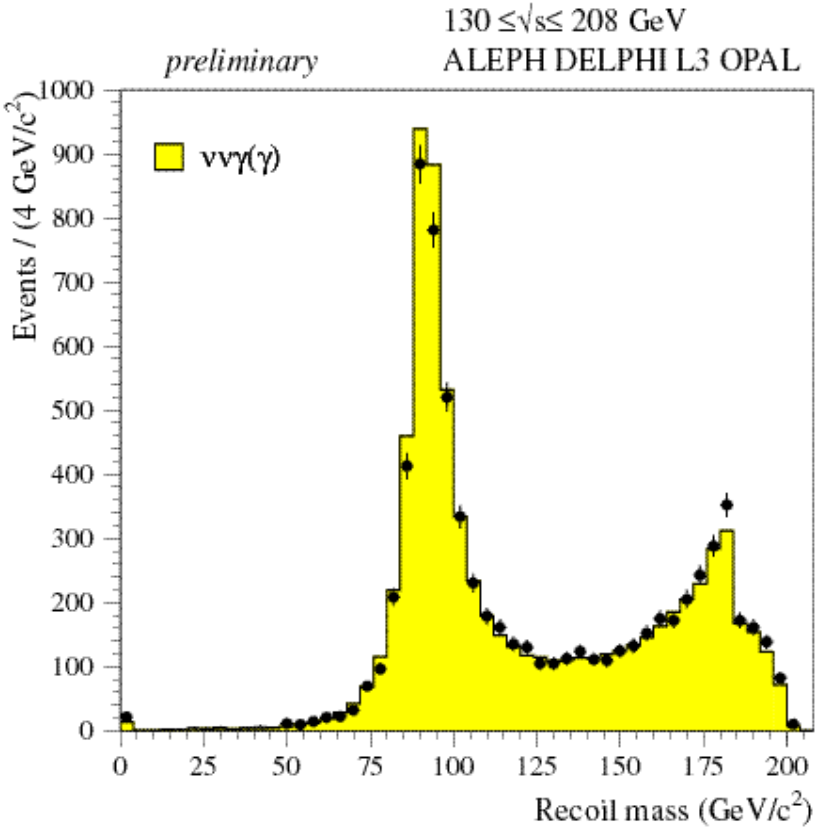


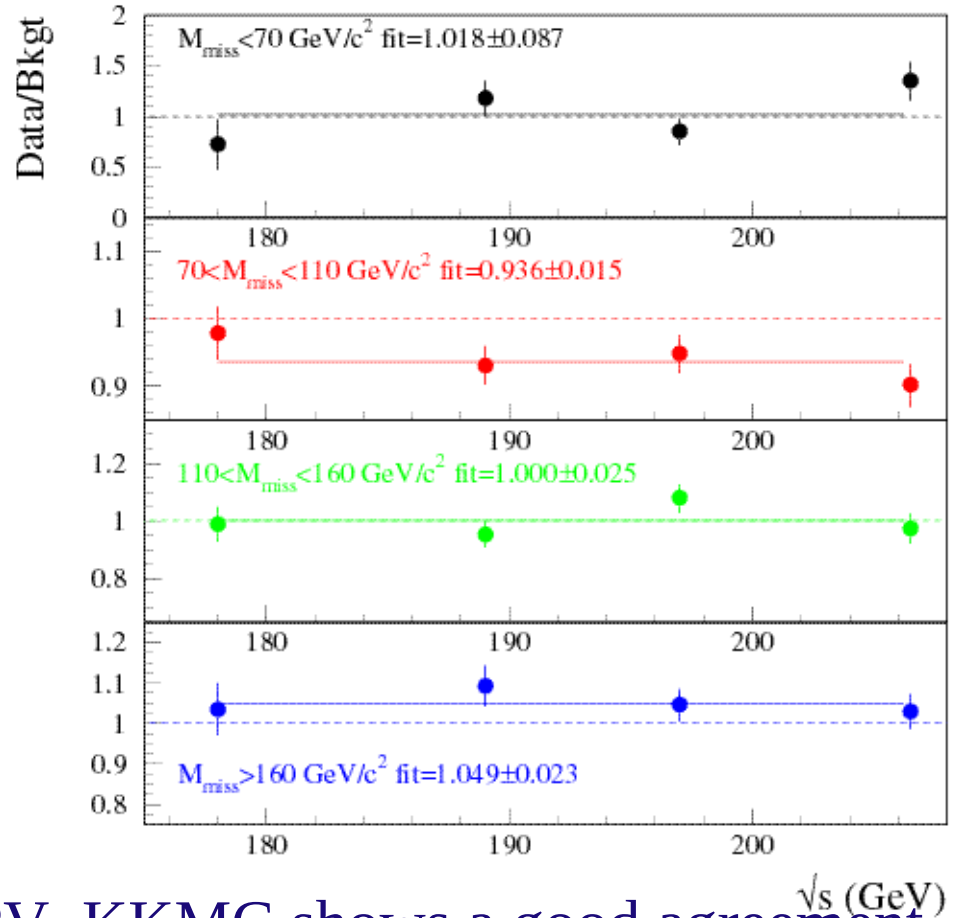
Deficit under Z peak and excess in the tail (using mostly KoralZ)

Single photons

$e^+e^- \to \tilde{\chi}^0_2\tilde{\chi}^0_1 \to (\tilde{\chi}^0_1\gamma)\tilde{\chi}^0_1$ or $e^+e^- \to \tilde{G}\tilde{\chi}^0_1 \to (\tilde{G}\gamma)\tilde{G}$ ... $\gamma + \not{E}$

130-208 GeV data





Data better reproduced by NunuGPV. KKMC shows a good agreement with NunuGPV. Will use KKMC or NunuGPV from now on.

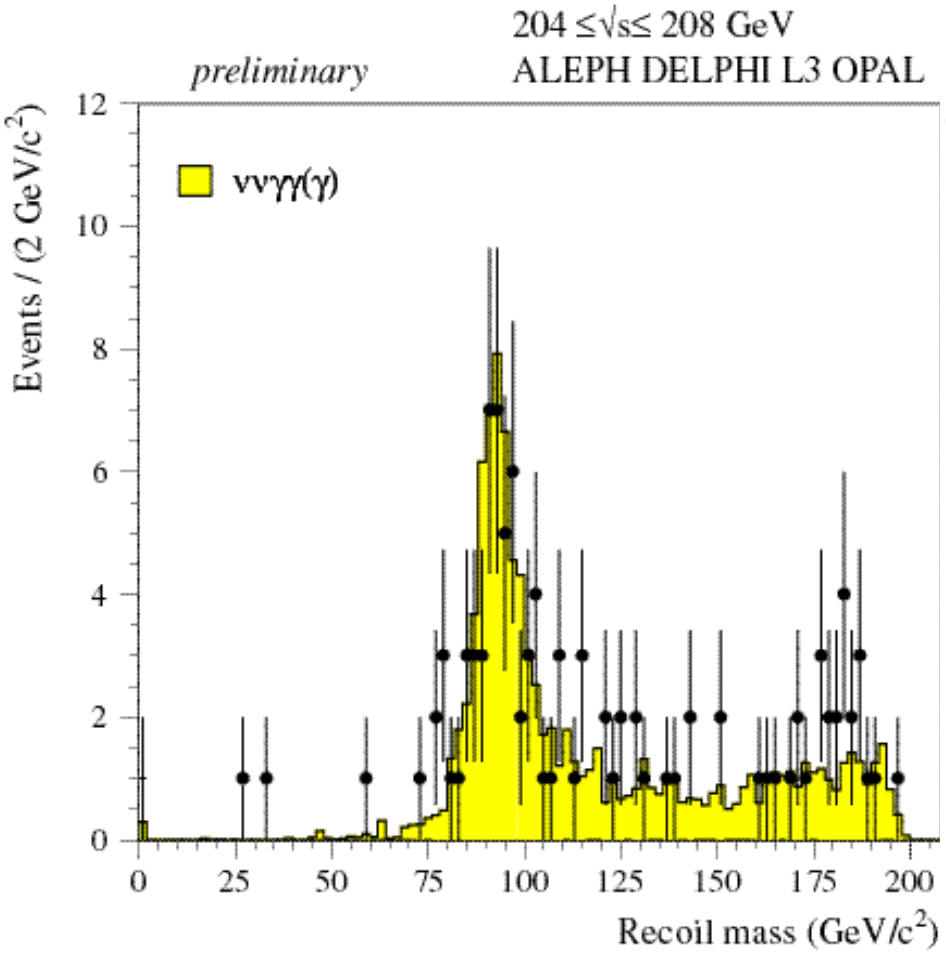
Acoplanar photon pairs

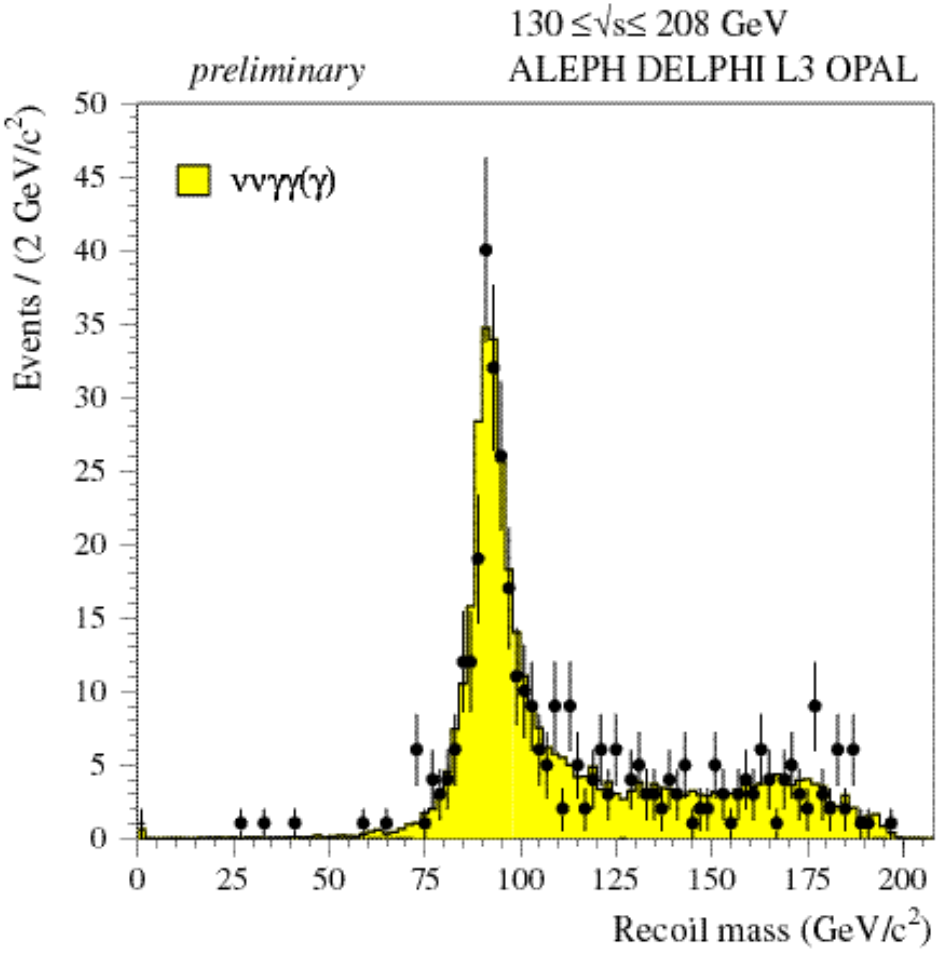
$e^+e^- \rightarrow \tilde{\chi}^0_1\tilde{\chi}^0_1 \rightarrow (\tilde{G}\gamma)(\tilde{G}\gamma)$

$\gamma\gamma + \not{E}$

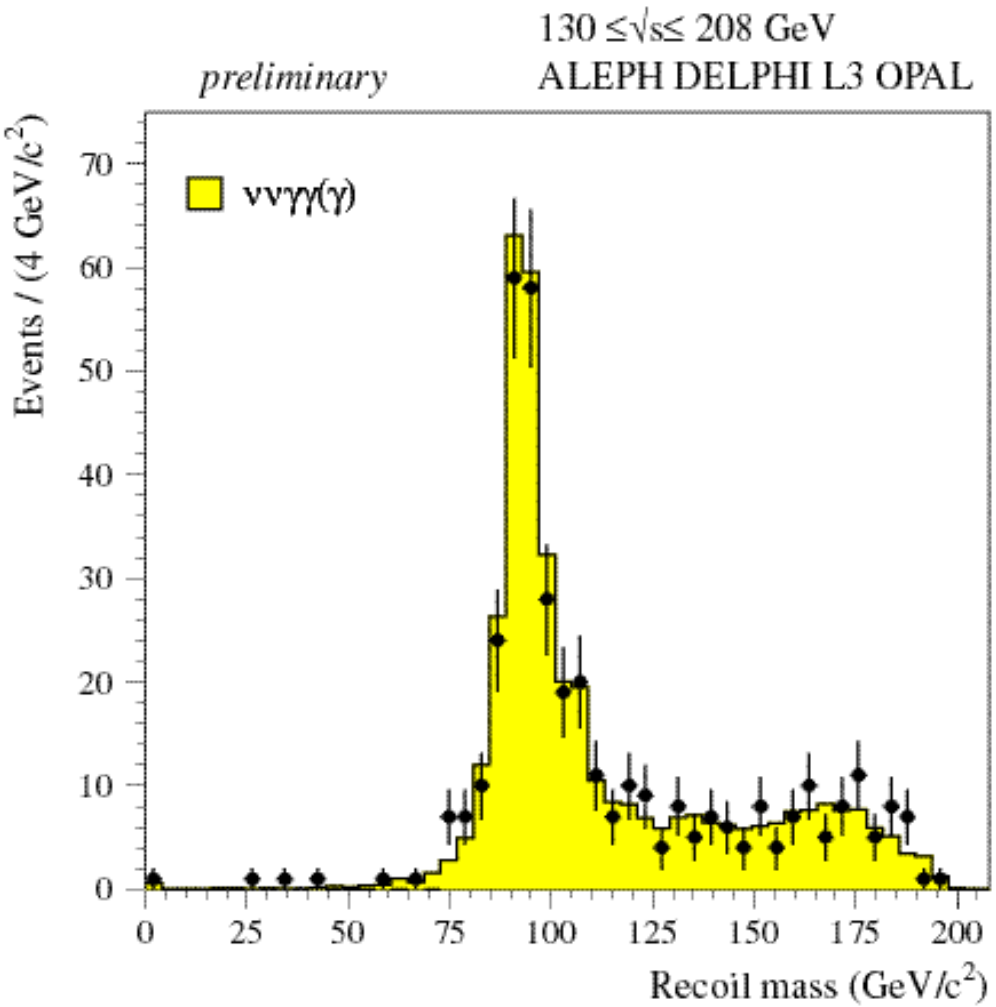
Year 2000 data

130-208 GeV: 384/388.7





Acoplanar photon pairs



Conclusions

- No significant excess has been observed in the LEP data combined, which amount to roughly 2.5 fb^{-1}
- The "stau excess" is not confirmed by the data taken in 2000
- Several ≥ 2.5 standard deviation "excesses" observed by individual experiments were checked during the 2000 data taking and not confirmed
- The limits obtained are still preliminary and we expect "final" results to be available for the summer

Future plans

- Many things remain to be done:
  - limits on LSP
  - more complete interpretations with large parameter scans
  - GMSB with particle lifetimes
  - RPV channels (many!)
  - and more...
- LEP SUSY combined results will by written in the form of papers.