XXXIII INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS

SUSY Searches at HERA

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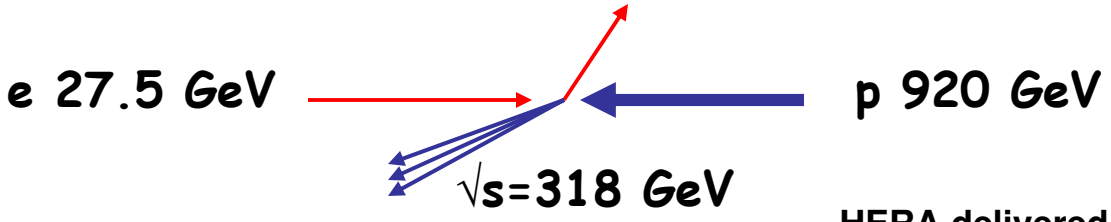
On behalf of the H1 and ZEUS collaborations

- HERA performances
- R-parity violation SUSY phenomenology at HERA
- squark production
  - first and second generations
  - stop production
- gaugino production
  - gaugino production in MSSM
  - neutralino production in GMSB
- Summary and Conclusions

HERA performances



Lumi integrated by experiments so far:

HERA I

e+p ~ 110 pb-1

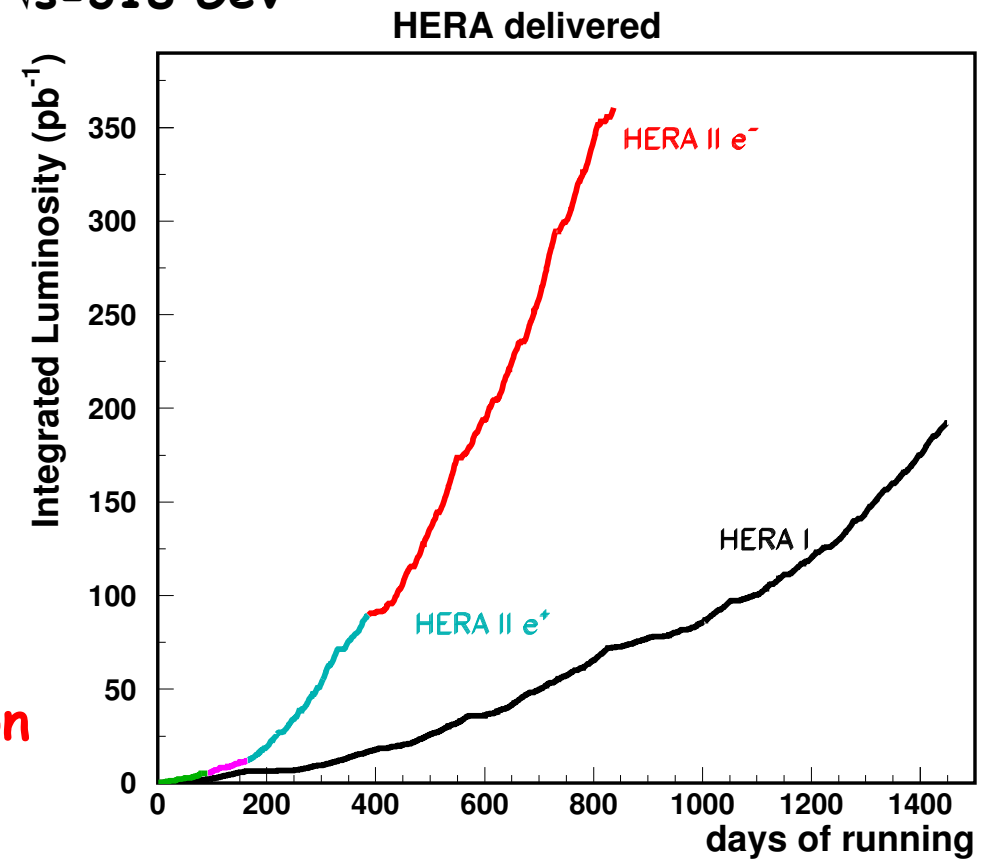
e-p ~ 15 pb-1

HERA II (polarisation ~ 30-40%)

e+p ~ 40 pb-1

e-p ~ 215 pb-1

Results presented based on HERA I data



HERA running up to summer 2007

R-parity violation phenomenology at HERA

R-parity violating terms in SUSY superpotential:

$$W_{\not R_p} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i D_j \bar{D}_k$$

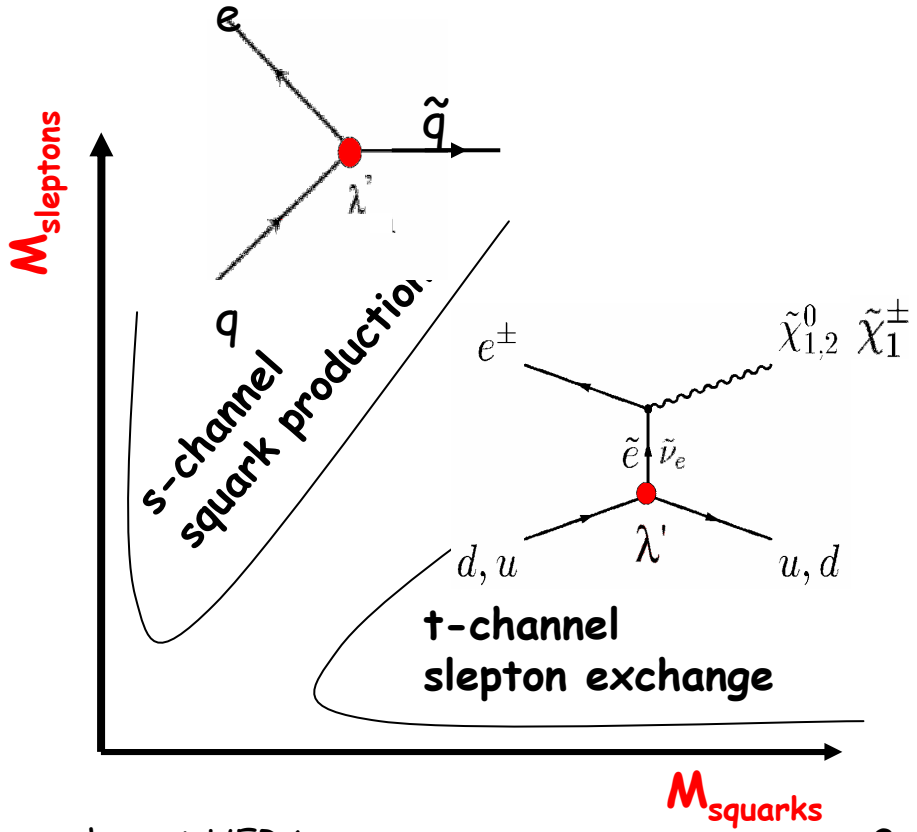
Consequences of R-parity violation:

- Sparticles can be single produced at colliders
- LSP not stable

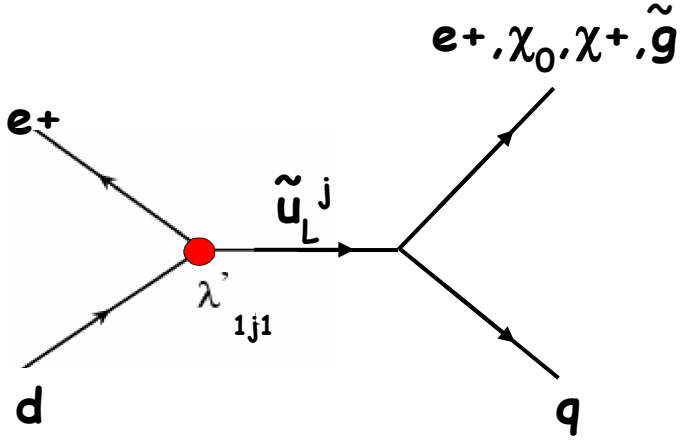
In particular if λ' different from 0 sparticles can be single produced in ep interactions at HERA

⟹ **Squarks or gauginos production**

Which process dominates depends on sleptons and squarks masses

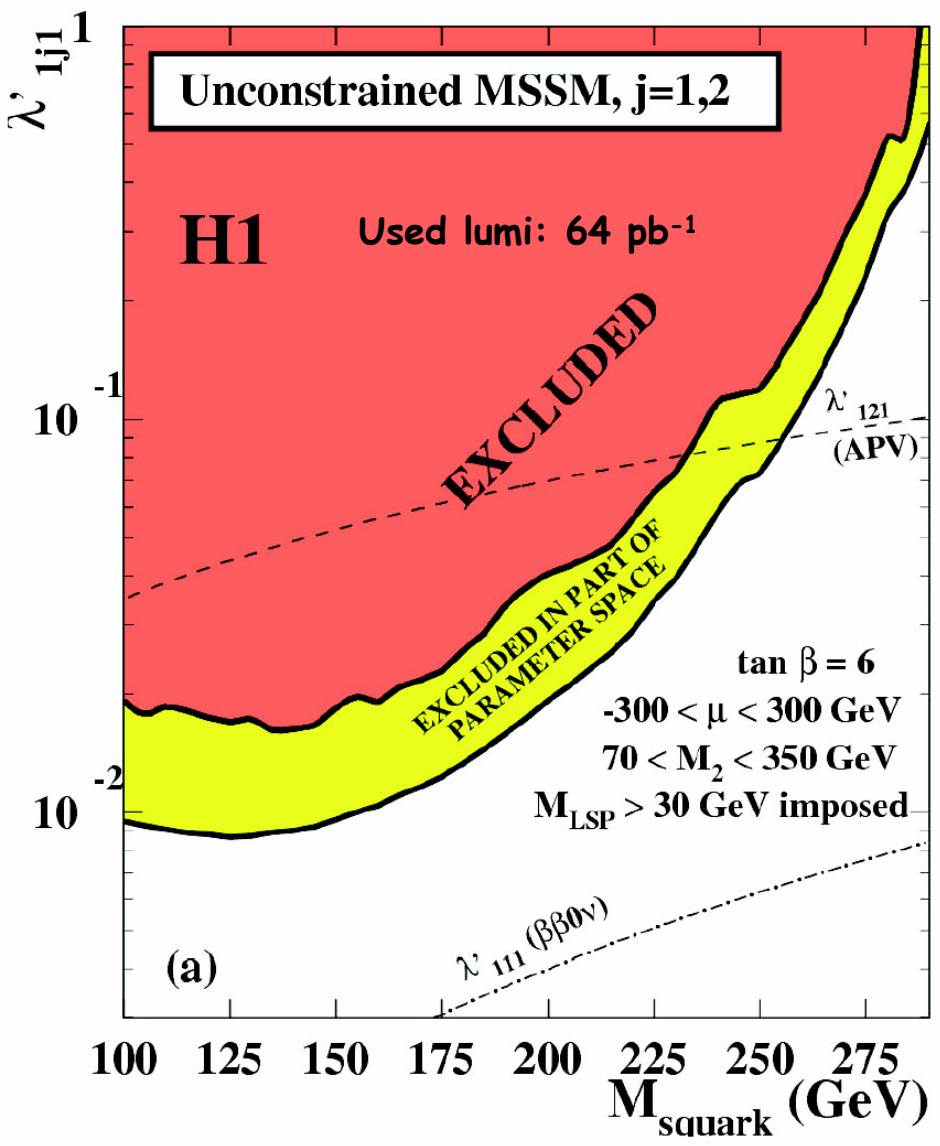


Unconstrained MSSM: 1st and 2nd squark gen.



- H1 performed a complete search for resonant squark production of all flavors
- squarks with masses up to 275 GeV are excluded at 95% CL for a coupling of em strength

[Eur. Phys. J. C36 (2004) 425]



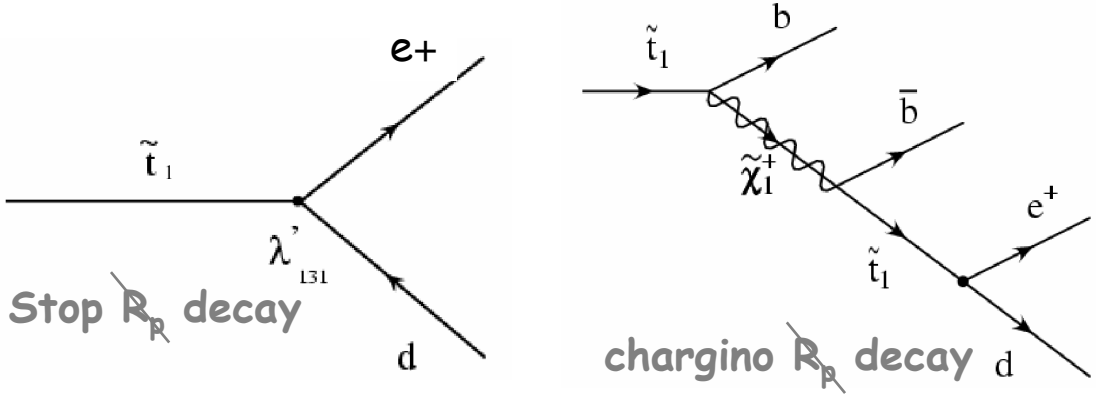
Unconstrained MSSM: stop production

- Stop assumed to be the lightest sfermion
- ZEUS searched for stop production looking at R-parity violating and gauge decays.H1 published similar results

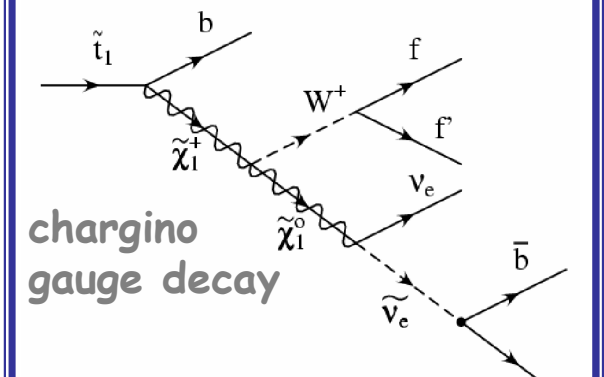
[Eur. Phys. J. C36 (2004) 425]

$$W_{\not R_p} \sim \lambda'_{131} e_L \tilde{t}_L \bar{d}_R$$

NC-like channels → e+ jet(s)



CC-like channels → ν jets



Almost full branching ratio coverage

Unconstrained MSSM: stop production (contd)

data 99-00: L=65 pb^{-1}

NC-like

- Q^2_{DA} > 3000 GeV^2
- y_{DA} > 0.4 – 0.7

(tuned along the reconstructed mass)

e+ jet (e-J):

$P_{t,antipar}/P_{t,par}$ < 0.05

(enrich the sample of single-jet events)

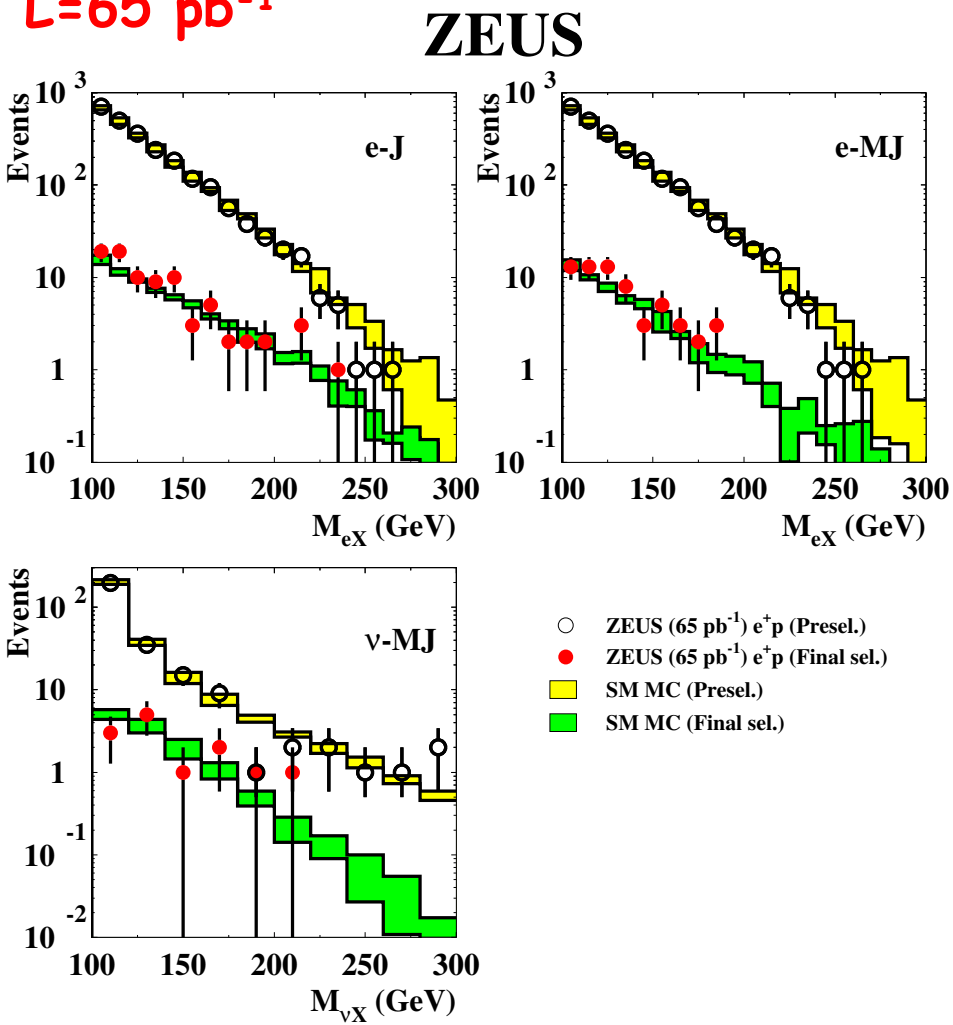
e+ multi-jet (e-MJ):

$P_{t,antipar}/P_{t,par}$ > 0.05

(enrich the sample of multi-jets events)

CC-like (ν-MJ)

- $\not{P}_t$ > 20 GeV
- y_{JB} > 0.6
- $P_{t,antipar}/P_{t,par}$ > 0.1



Unconstrained MSSM: stop production (contd)

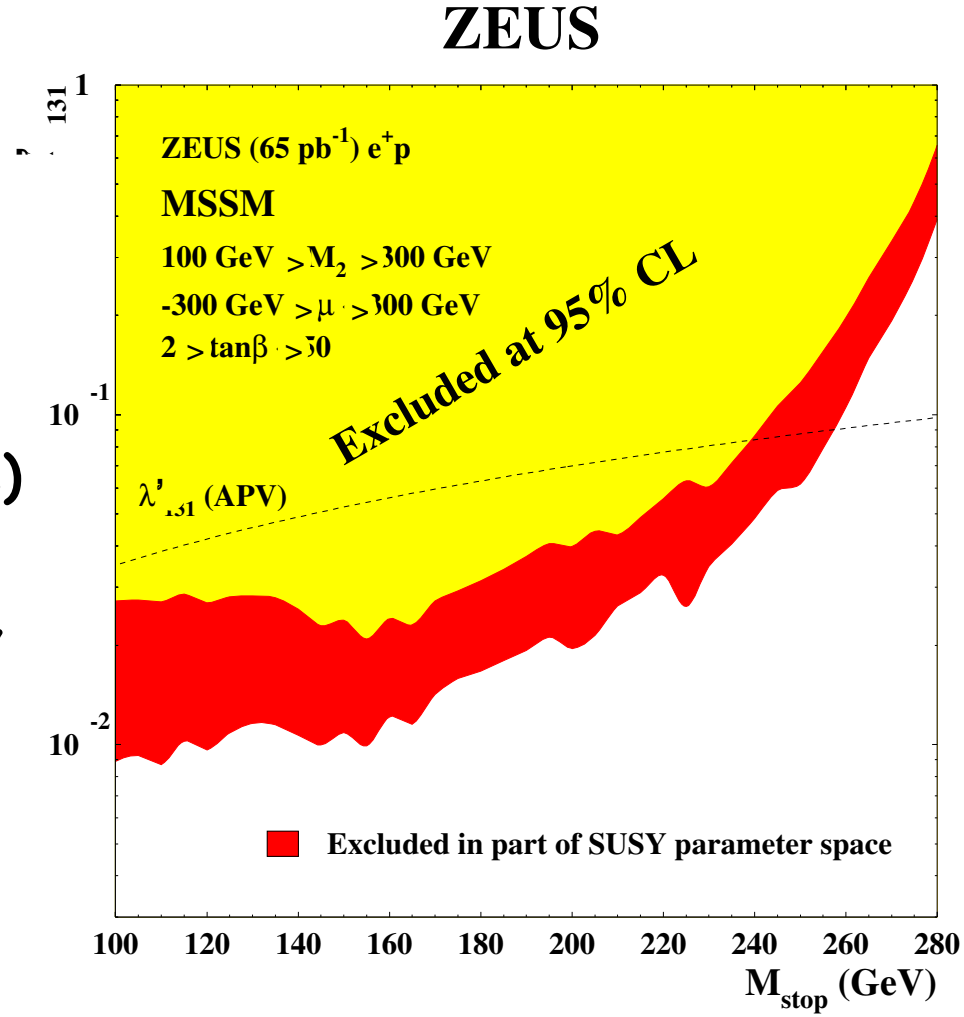
Limits at 95% CL evaluated combining the three channels

Weak dependence on the MSSM parameters μ, M_2, $\tan\beta$

Scenarios where χ_0 is not the LSP or $m_{\chi 0}$ >30 GeV (LEP limits) have been discarded

Stop mass up to 270-280 GeV excluded for coupling of em strength

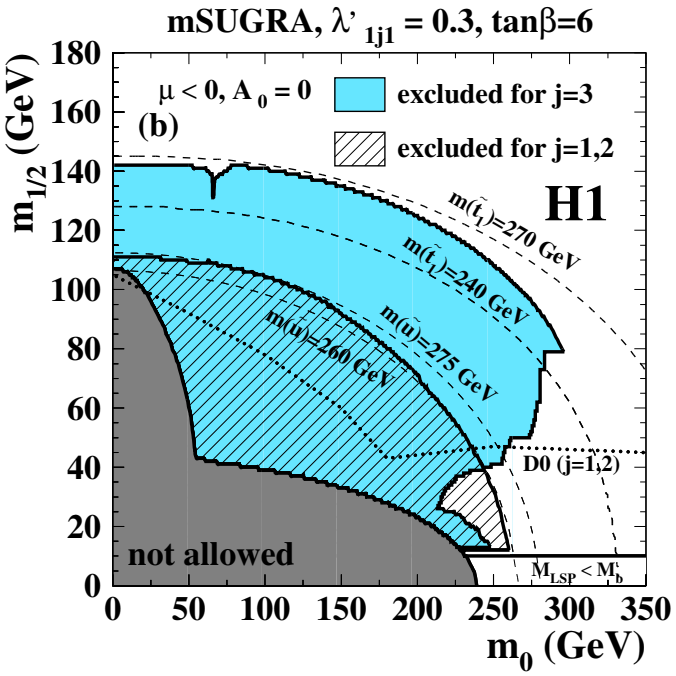
Improve on APV limit for stop masses < 250 GeV



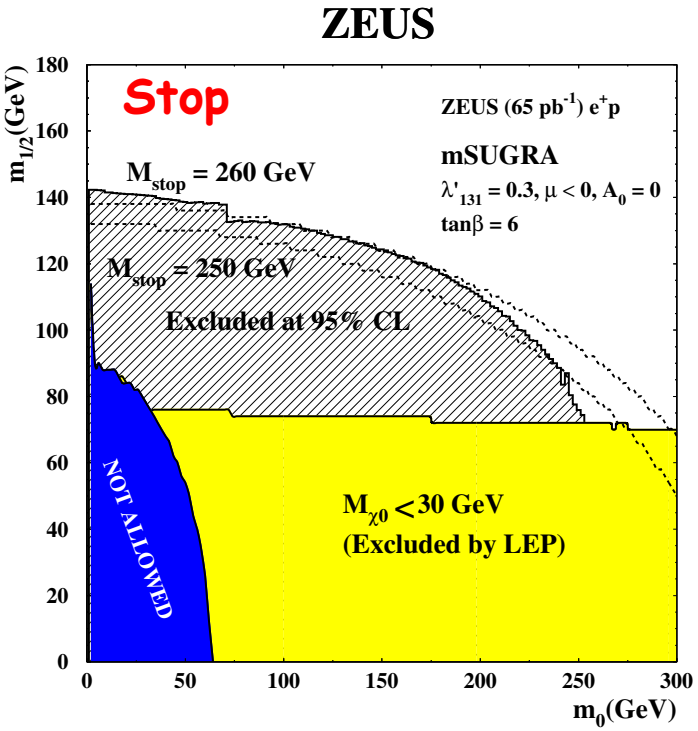
mSUGRA: squark production

Model parameters: m_0 (common scalar mass at GUT scale), $m_{1/2}$ (common gaugino mass), tanβ, sign(μ) and A_0 (common trilinear coupling).

Assuming λ' of em strength limits on the plane $(m_0, m_{1/2})$ can be evaluated for fixed values of tanβ, sign(μ) and A_0.



[Eur. Phys. J. C36 (2004) 425]



For 1st and 2nd generations, H1 limits improve on D0 (di-electron channel)
For stop, masses below 260 GeV are excluded in a large part of the par. space

Stop production: comparison with Tevatron

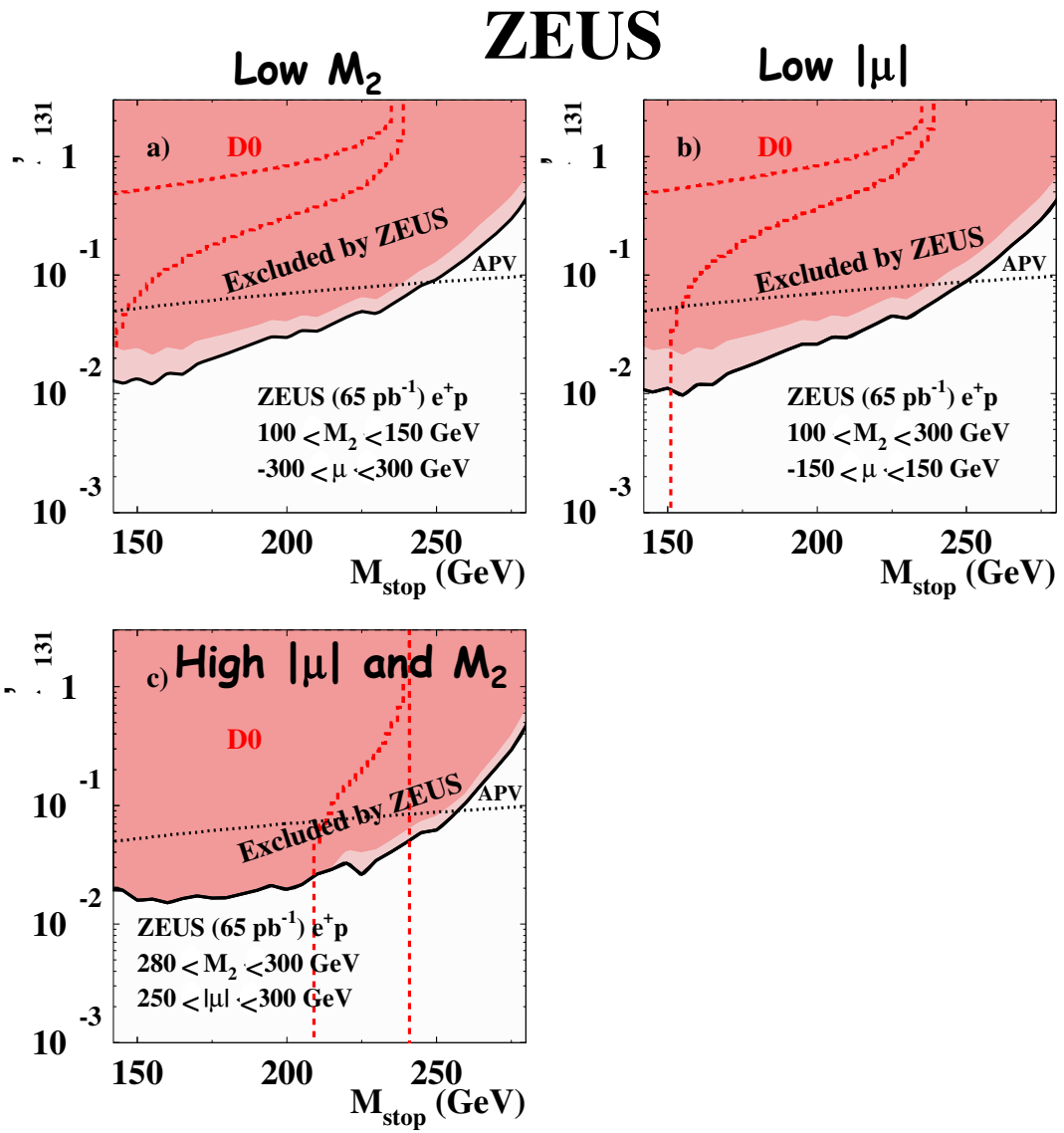
Tevatron limits on leptoquarks as a function of the Br (LQ $\rightarrow$ eq) [D0 collab. Phys. ReV. D Rapid Comm. 71, 051803 (2004)] can be converted in limit on stop production

Unconstrained MSSM

Hera limits are better for not too high $|\mu|$ or M_2
For large $|\mu|$ and M_2 Tevatron limits become competitive since in this region $\tilde{\chi}^+$ mass is large and the stop predominantly decay in eq

mSUGRA

For the mSUGRA scenario the stop gauge decay is always relevant and the HERA limits are better

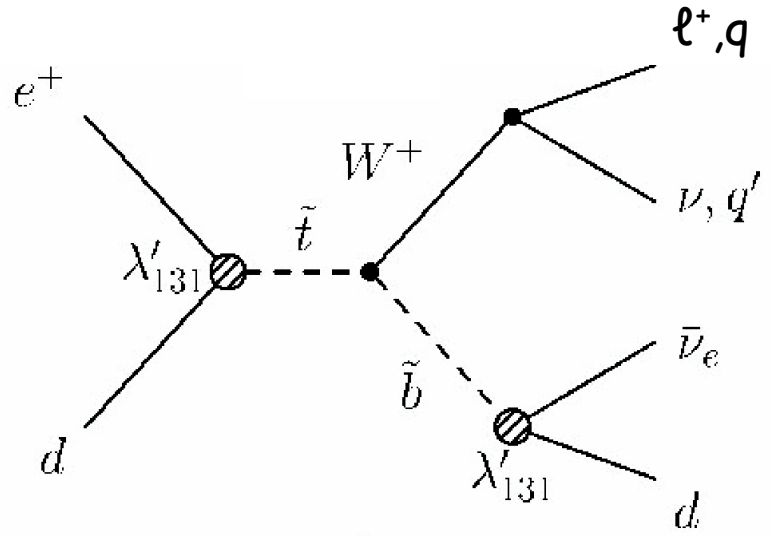


bosonic stop decay

Scenario considered: $M_{stop} > M_{sbottom}$, squark decay to gauginos forbidden

Complementary to previous stop-search

$$W_{\not R_p} \sim \lambda'_{131} e_L \tilde{t}_L \bar{d}_R + \lambda'_{131} \nu_{e,L} \tilde{b}_L \bar{d}_R$$

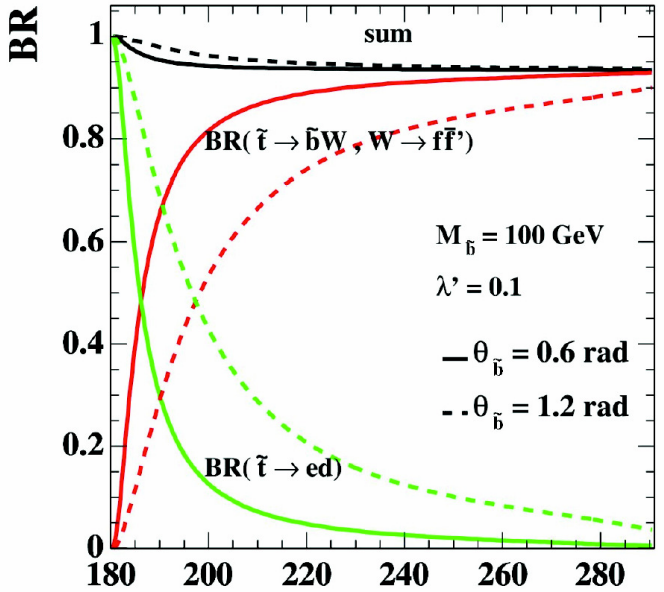


Stop bosonic decay dominant for $M_{stop} > M_{sbottom} + M_W$

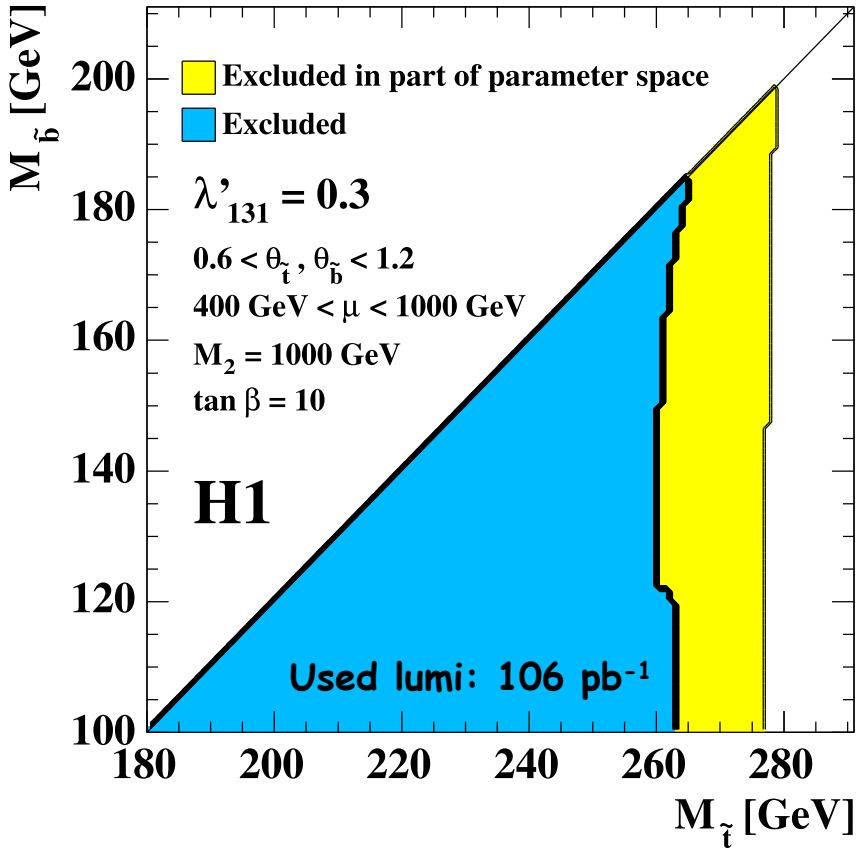
Also analysed the R-parity violating stop decays which dominates for $M_{stop} \sim M_{sbottom} + M_W$

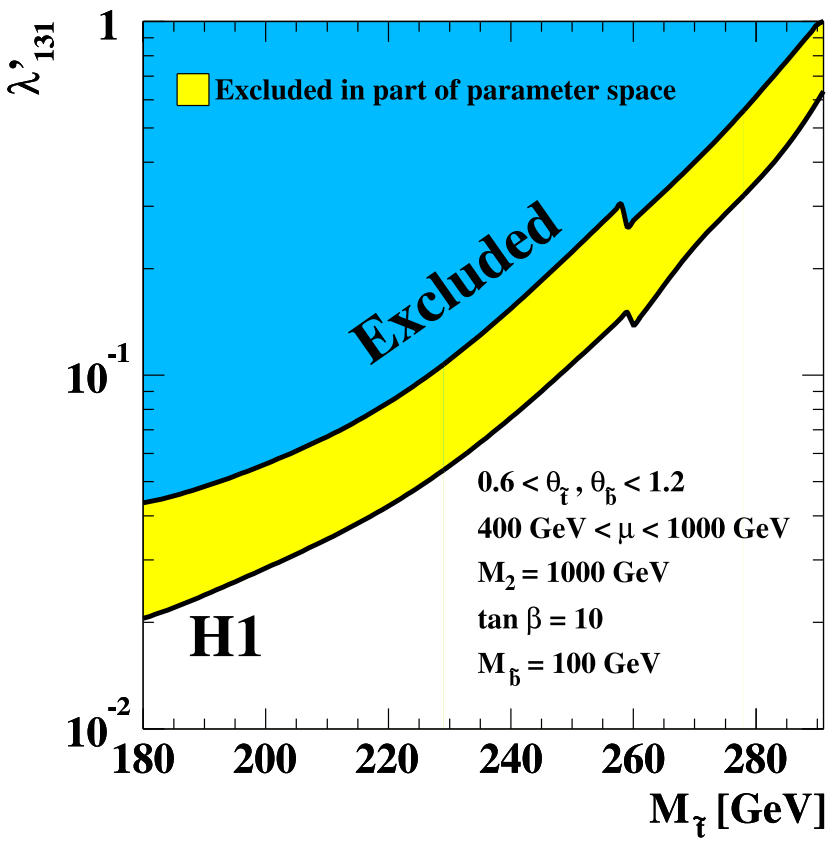
Almost full coverage of branching ratios

[Phys. Lett. B599 (2004) 159]



bosonic stop decay (contd)





For λ' of em strength stop masses up to 275 GeV excluded

For $M_{sbottom}$=100 GeV, at M_{stop} =200 (250) GeV
allowed coupling domain λ'< 0.03 (0.1)

Gaugino production

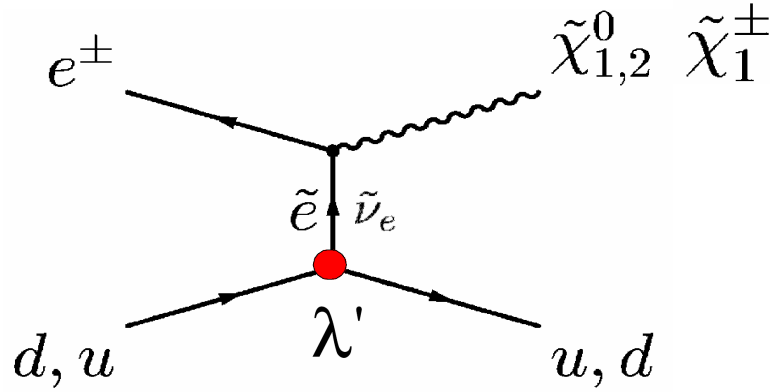
Different scenario considered: $M_{squarks} >> M_{sleptons}$

s-channel suppressed, t-channel slepton exchange dominant

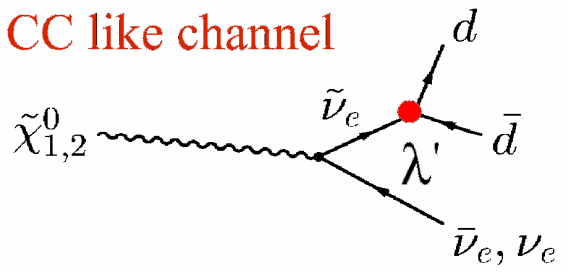
$$W_{\not R_p} \sim -\lambda'_{1jk}\tilde{e}_L u^j_L \bar{d}^k_R$$

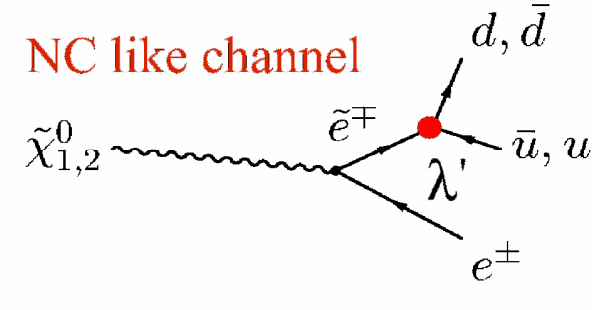
gaugino production

$\sigma \sim \lambda'^2$



gaugino decay
(same channels for χ^0 e $\chi^{\pm}$)





$\tilde{\chi}^{\pm}$ decay to the same final state
BRs add up to almost 100%

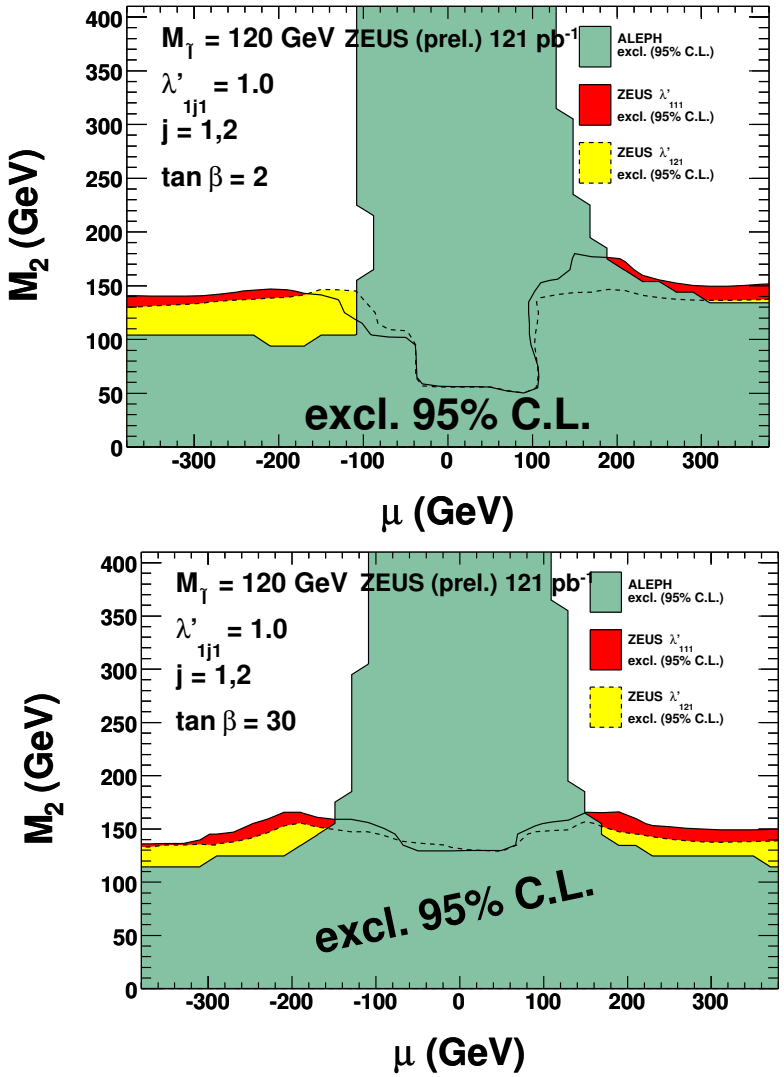
Gaugino production (contd)

Limits in MSSM:
results from both channels combined

ZEUS extends LEP2 constraints
(Eur. Phys. J. C37 (2004) 129, hep-ex/0406009)
for high $|\mu|$ > 100 GeV to
M_2 ~ 160 GeV

Results independent of the squark sector

➡ λ'_{121} ~ 1 are not excluded by indirect measurements when the squarks has large masses



GMSB scenario (light gravitino phenomenology)

In this scenario gravitino is very light (tipical mass < 10^{-3} eV) and is the LSP

GMSB parameters in addition to SM:

Λ: Mass scale of sparticles M:Mass of messengers particles

N: number of messengers tanβ

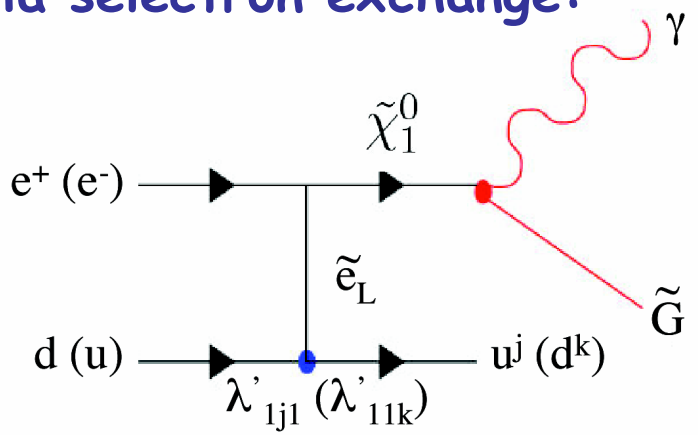
sign(μ) $\sqrt{F}$: SUSY breaking scale (related to gravitino mass)

Mass of $\tilde{e}_L$ treated also as free parameter

Studied the single neutralino production via selectron exchange:

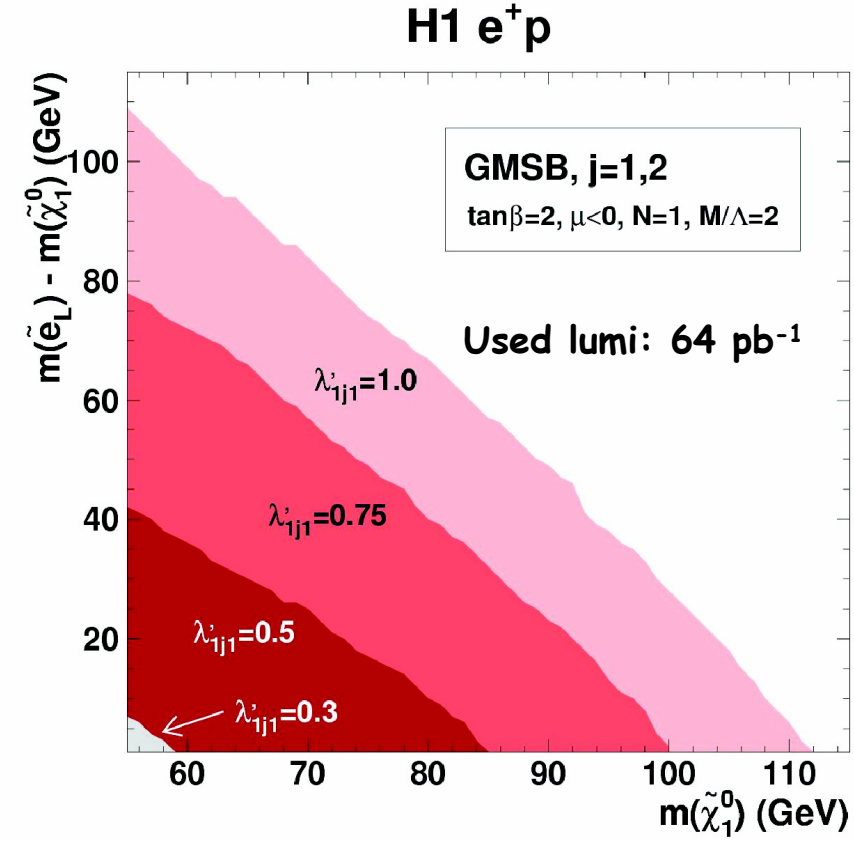
$$W_{\not R_p} \sim -\lambda'_{1jk}\tilde{e}_L u^j_L \bar{d}^k_R$$

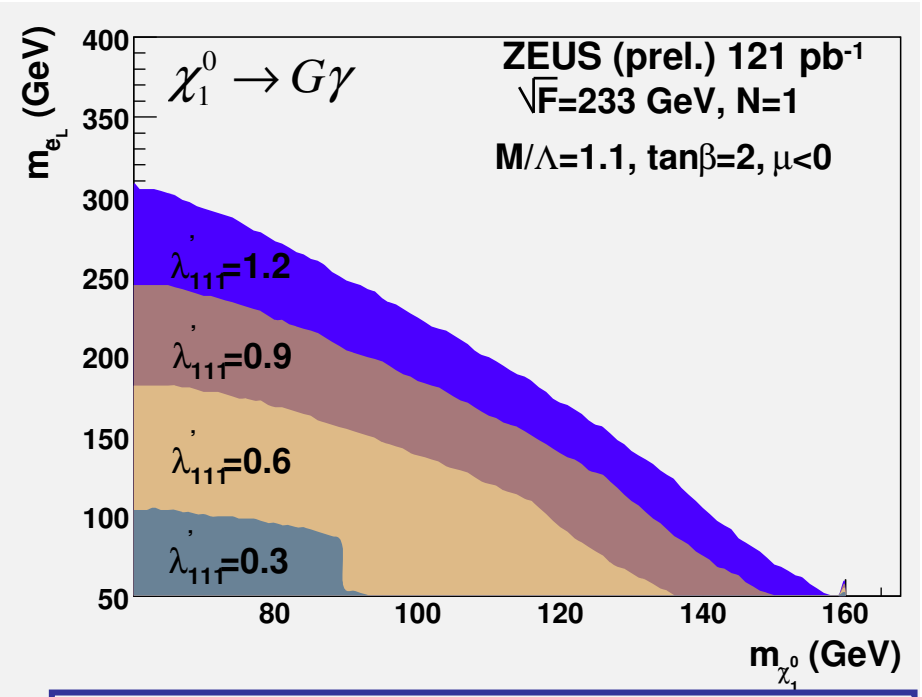
electron/positron beam probe different couplings



GMSB scenario (contd)

No deviations observed ⟹ exclusion limits





For $\lambda'_{111}=1$ masses up to $M_{\tilde{e}}$ = 260 GeV and $M_{\tilde{\chi}}$ = 150 GeV can be excluded at 95% CL

High squark masses ⟹ indirect constraints less effective ⟹ λ' can be large

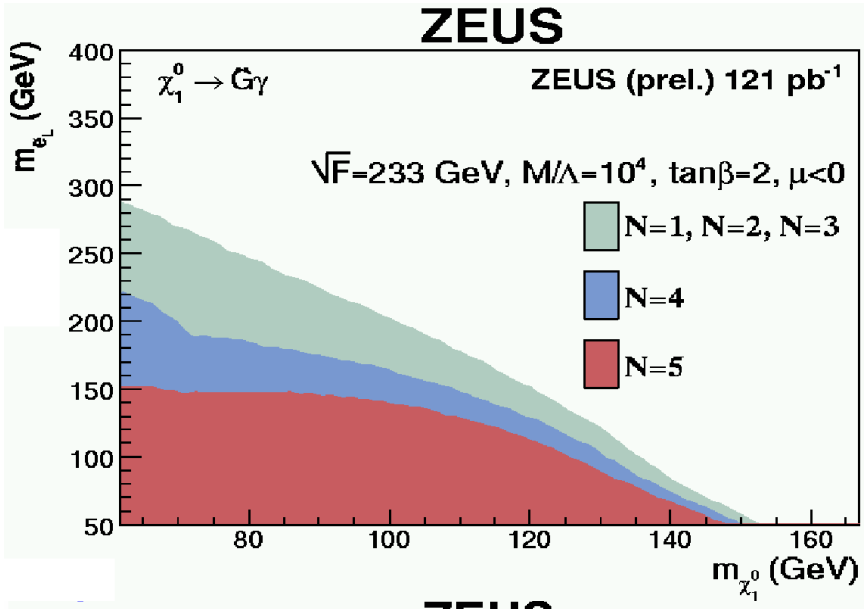
Comparison: ZEUS used more luminosity, e^-p data also included, slightly different parameters, use of a discriminant algorithm gives higher sensitivity

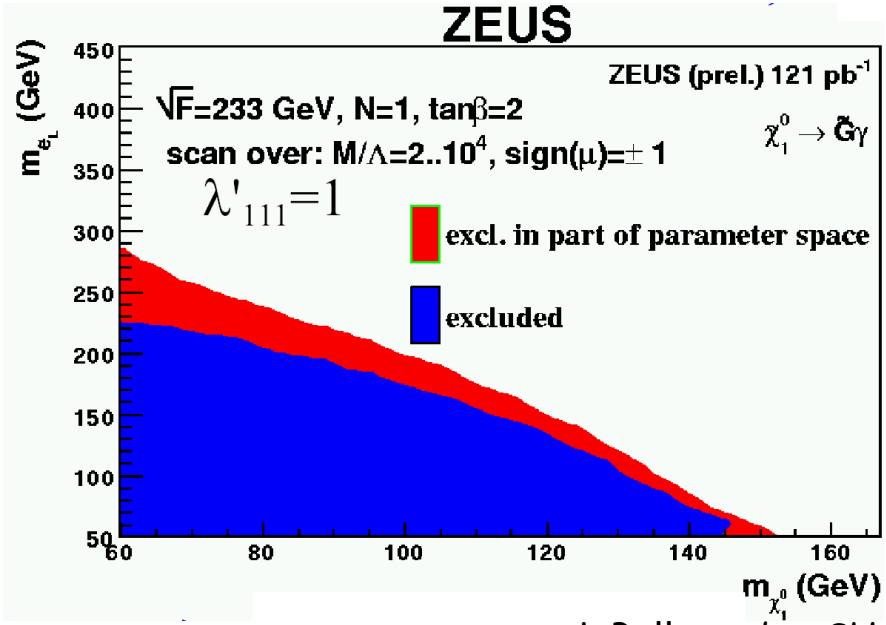
GMSB scenario (contd)

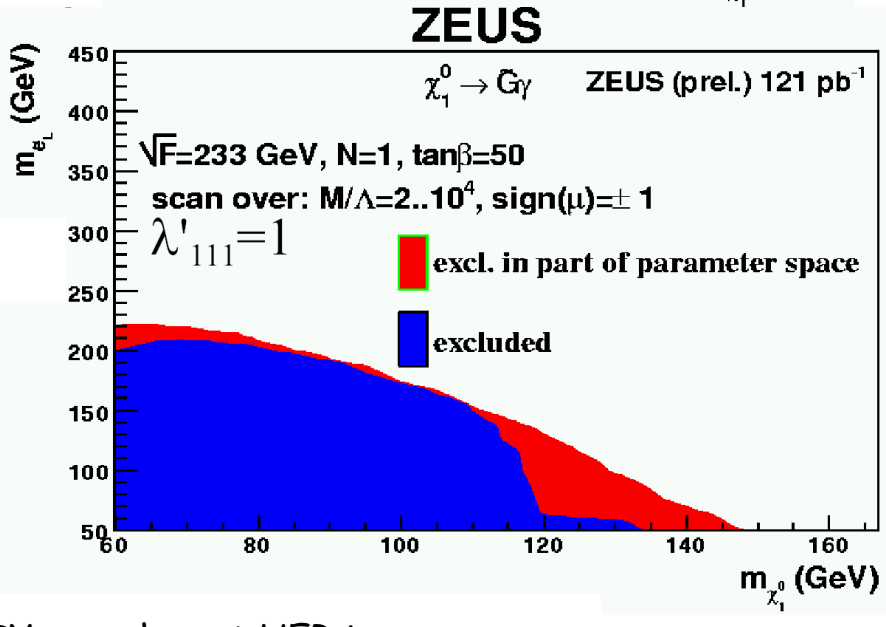
Large scanning of the parameters:

- different N
- different M/Λ, sign(μ), tanβ

➡ **Limits valid in large part of the GMSB parameter space**







Summary and Conclusions

- **Studied large variety of SUSY scenario assuming Rp violation**

  HERA particularly well suited to study squark production
  Squark of all flavors can be excluded up to mass close to the kinematic limit for λ' coupling of em strength.

  But also for scenarios where squarks are much heavier than sleptons
  HERA constraints are complementary and competitive with LEP and Tevatron ones.

- **HERA II data analysis going on:**

  The sensible increasing in luminosity will allow to improve the sensitivity especially for those channels which have a larger cross section for electrons (down squark production, slepton exchange mediated by λ'_{11k})

  Lepton polarization will also increase sensitivity for specific process

New interesting results from HERA expected soon !