



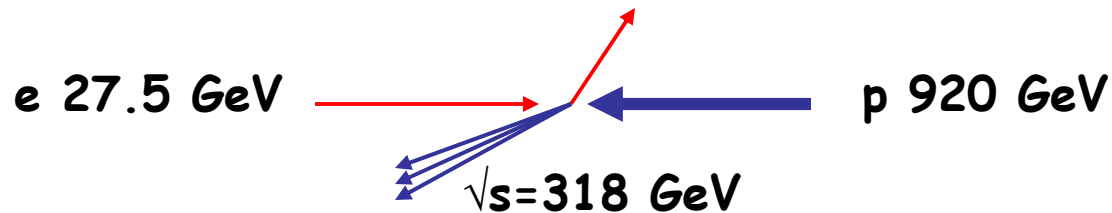
SUSY Searches at HERA

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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

$e+p \sim 110\ \text{pb}^{-1}$

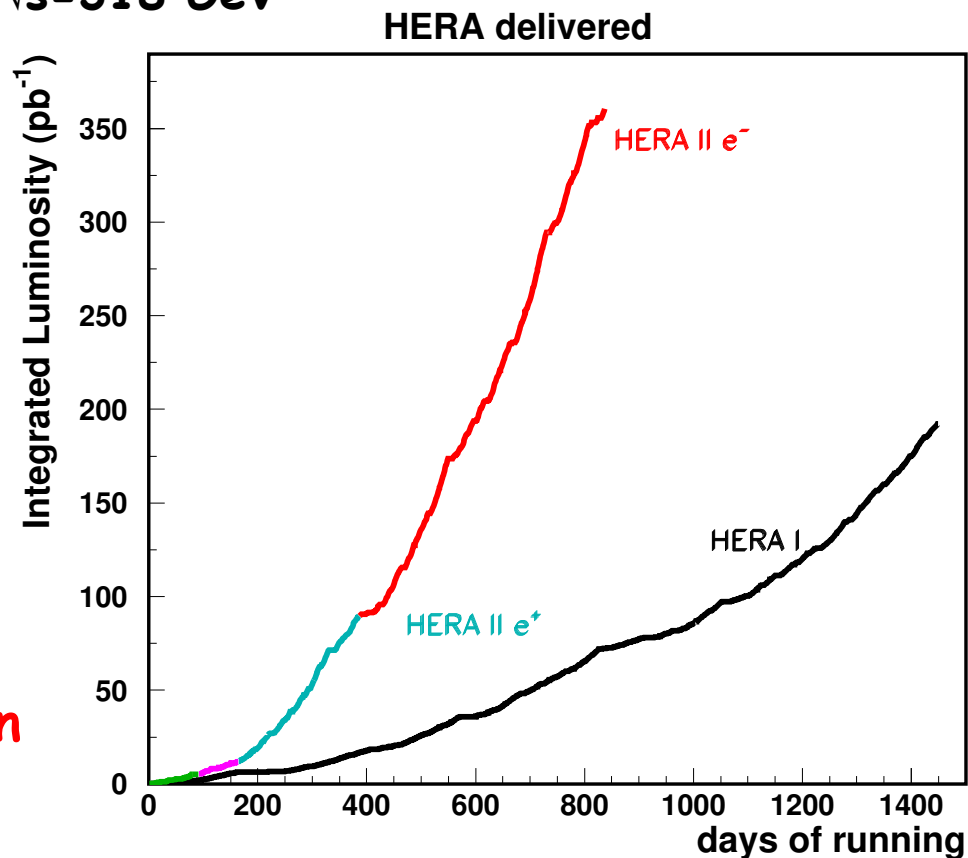
$e-p \sim 15\ \text{pb}^{-1}$

HERA II (polarisation $\sim 30-40\%$)

$e+p \sim 40\ \text{pb}^{-1}$

$e-p \sim 215\ \text{pb}^{-1}$

Results presented based on
HERA I data



HERA running up to summer 2007

L.Bellagamba, SUSY searches at HERA

R-parity violation phenomenology at HERA

R-parity violating terms in SUSY superpotential:

$$W_{R/p} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i D_j \bar{D}_k$$

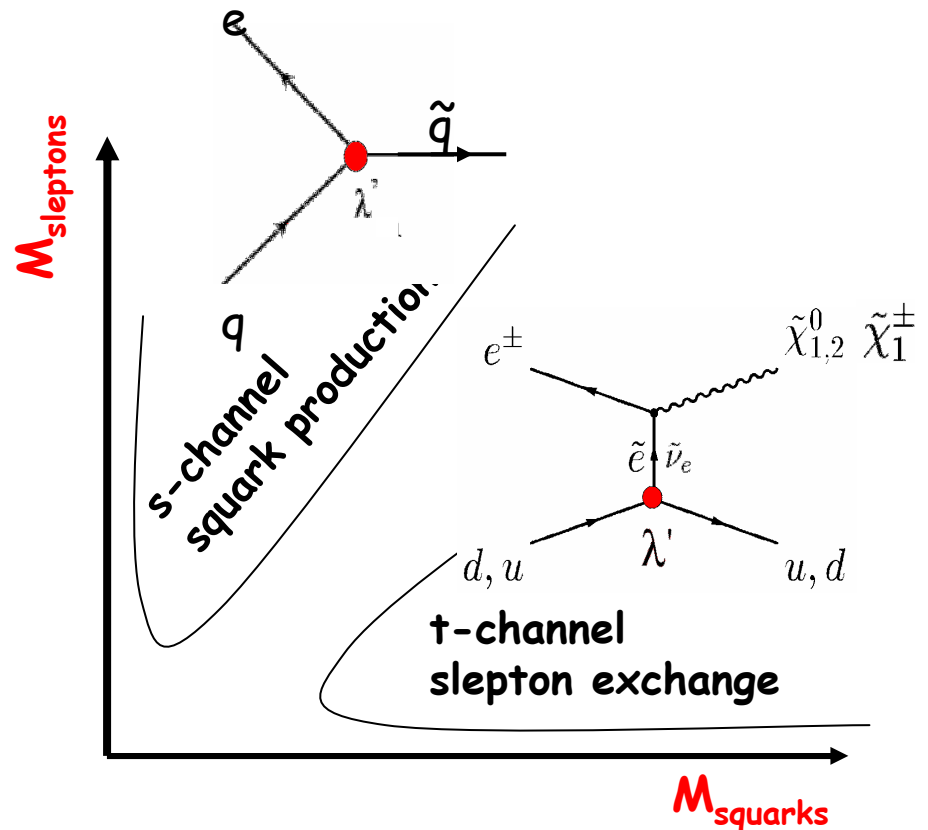
Consequences of R-parity violation:

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

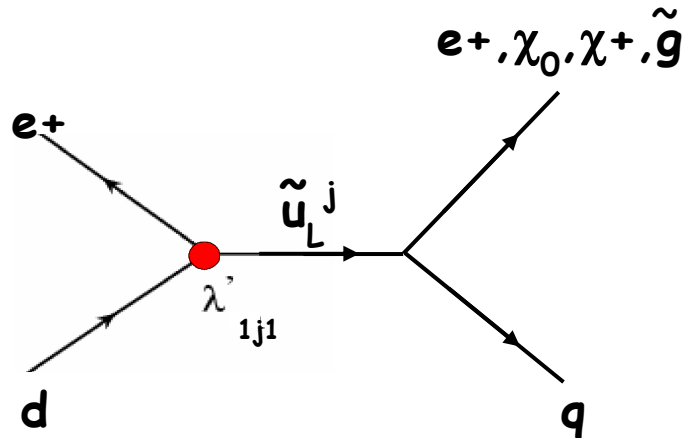
In particular if λ' different from 0 sparticles can be single produced in ep interactions at HERA

→ Squarks or gauginos production

Which process dominates depends on sleptons and squarks masses

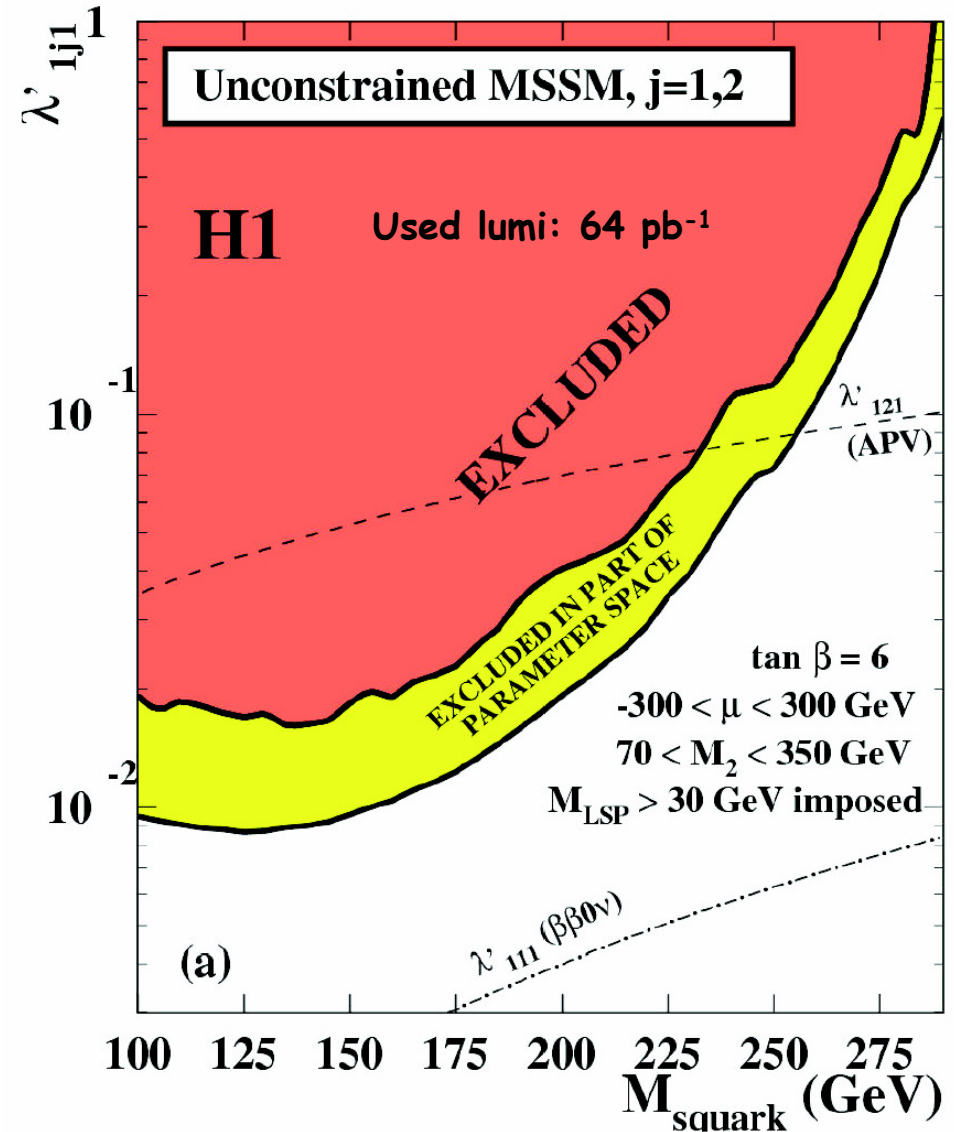


Unconstrained MSSM: 1st and 2nd squark gen.



- 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]



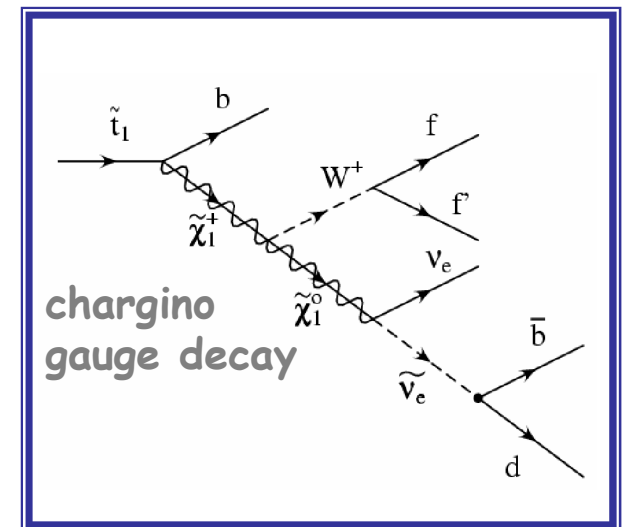
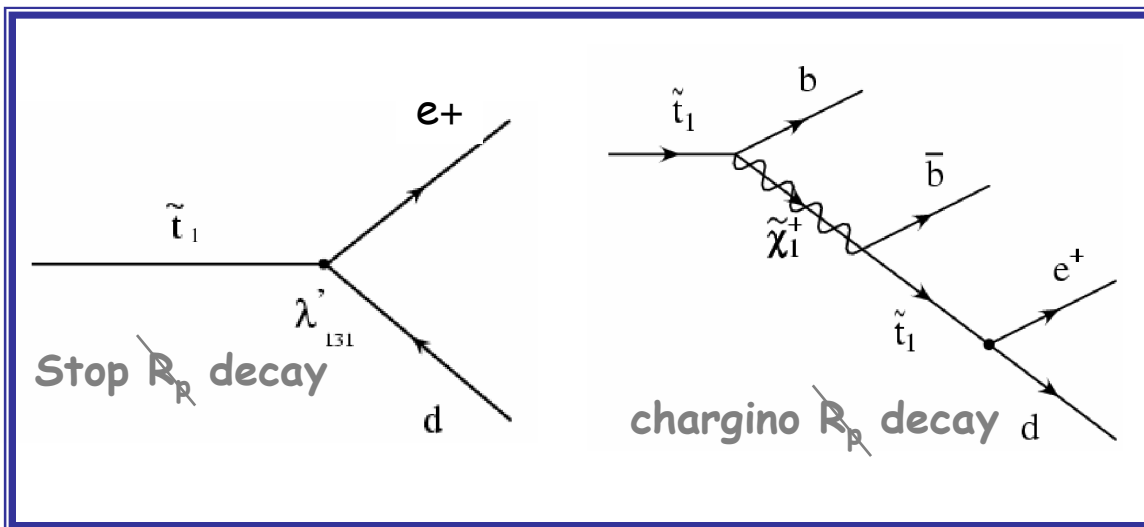
Unconstrained MSSM: stop production

- 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]

$$W_{R/p} \sim \lambda'_{131} e_L \tilde{t}_L \bar{d}_R$$

NC-like channels $\rightarrow e^+ \text{ jet}(s)$

CC-like channels $\rightarrow \nu \text{ jets}$



Almost full branching ratio coverage

Unconstrained MSSM: stop production (contd)

NC-like

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

- $Q_{DA}^2 > 3000 \text{ GeV}^2$
 - $Y_{DA} > 0.4 - 0.7$
- (tuned along the reconstructed mass)

e+ jet (e-J):

$P_{t, \text{antipar}}/P_{t, \text{par}} < 0.05$
(enrich the sample of single-jet events)

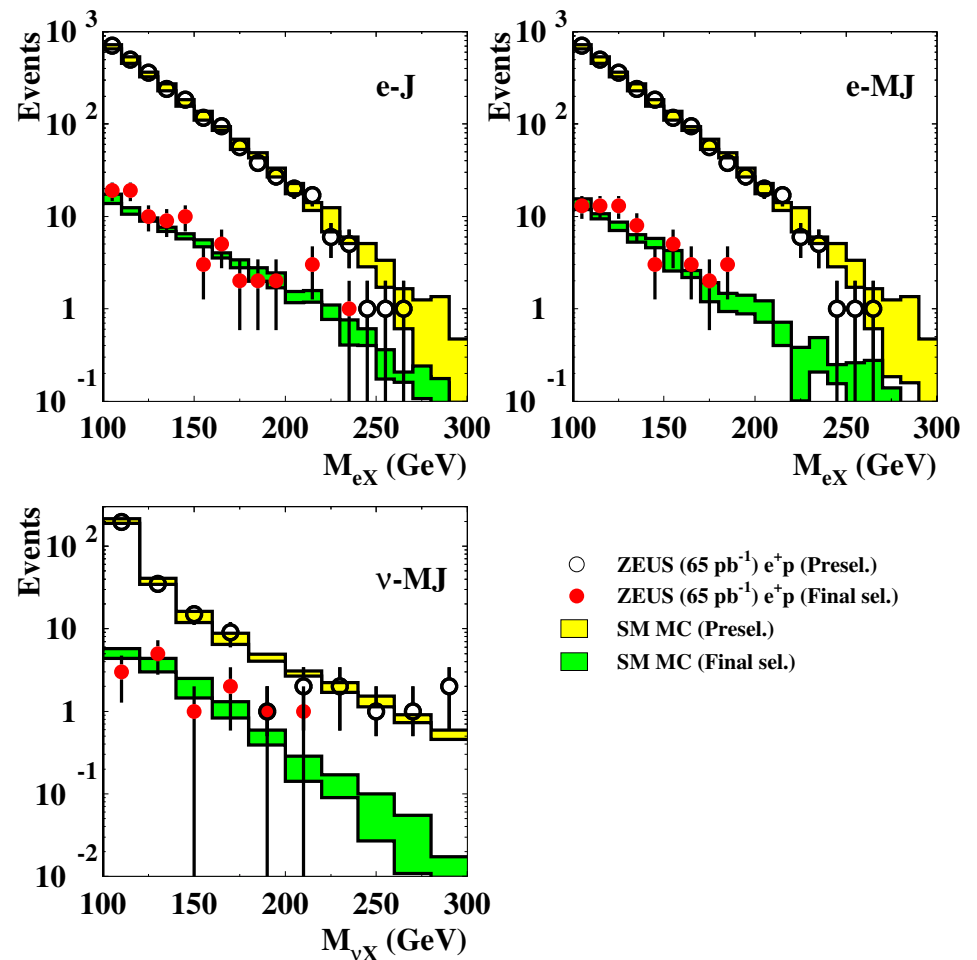
e+ multi-jet (e-MJ):

$P_{t, \text{antipar}}/P_{t, \text{par}} > 0.05$
(enrich the sample of multi-jets events)

CC-like (ν -MJ)

- $P_t > 20 \text{ GeV}$
- $Y_{JB} > 0.6$
- $P_{t, \text{antipar}}/P_{t, \text{par}} > 0.1$

ZEUS



Unconstrained MSSM: stop production (contd)

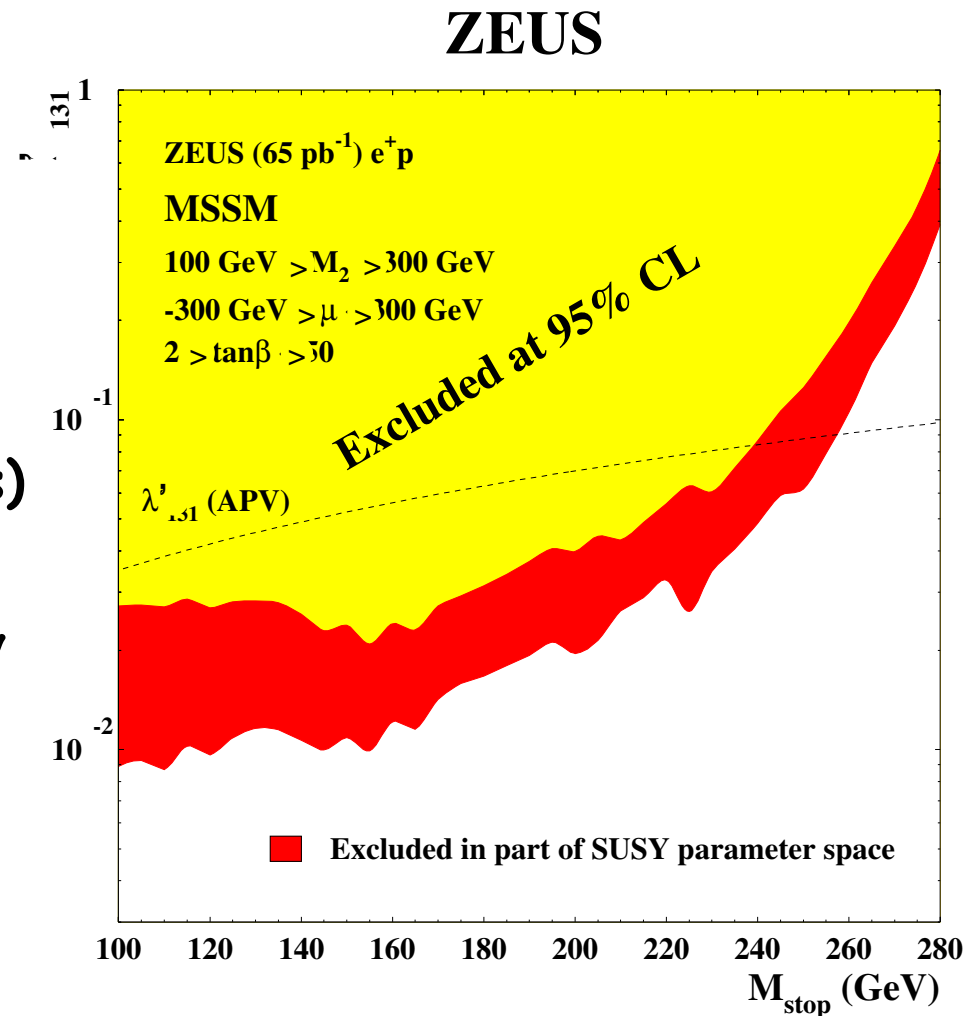
Limits at 95% CL evaluated
combining the three channels

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

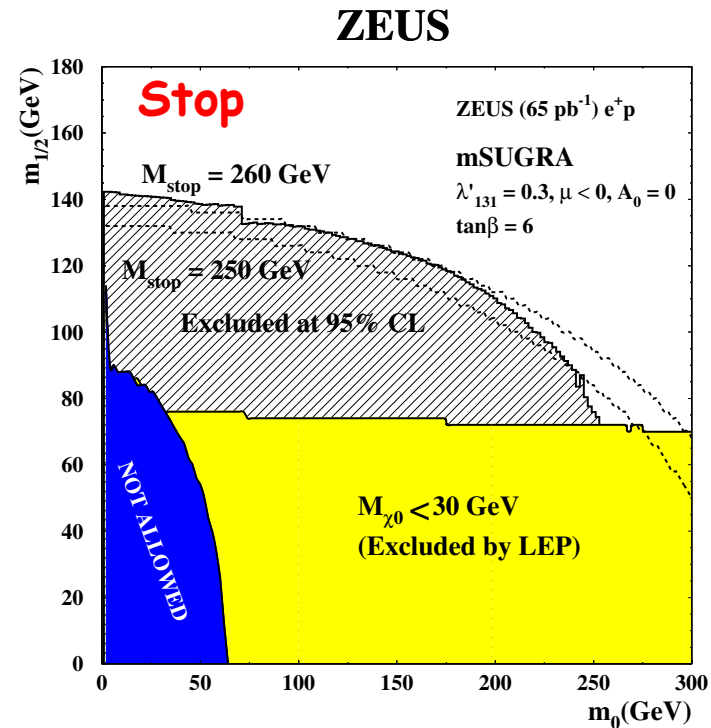
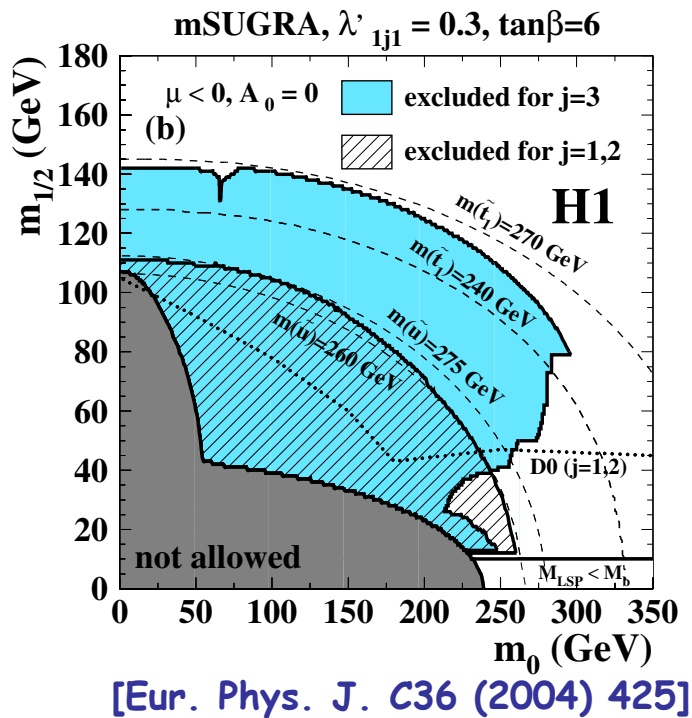
Improve on APV limit for stop
masses < 250 GeV



mSUGRA: squark production

Model parameters: m_0 (common scalar mass at GUT scale), $m_{1/2}$ (common gaugino mass), $\tan\beta$, $\text{sign}(\mu)$ 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 $\tan\beta$, $\text{sign}(\mu)$ and A_0 .



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

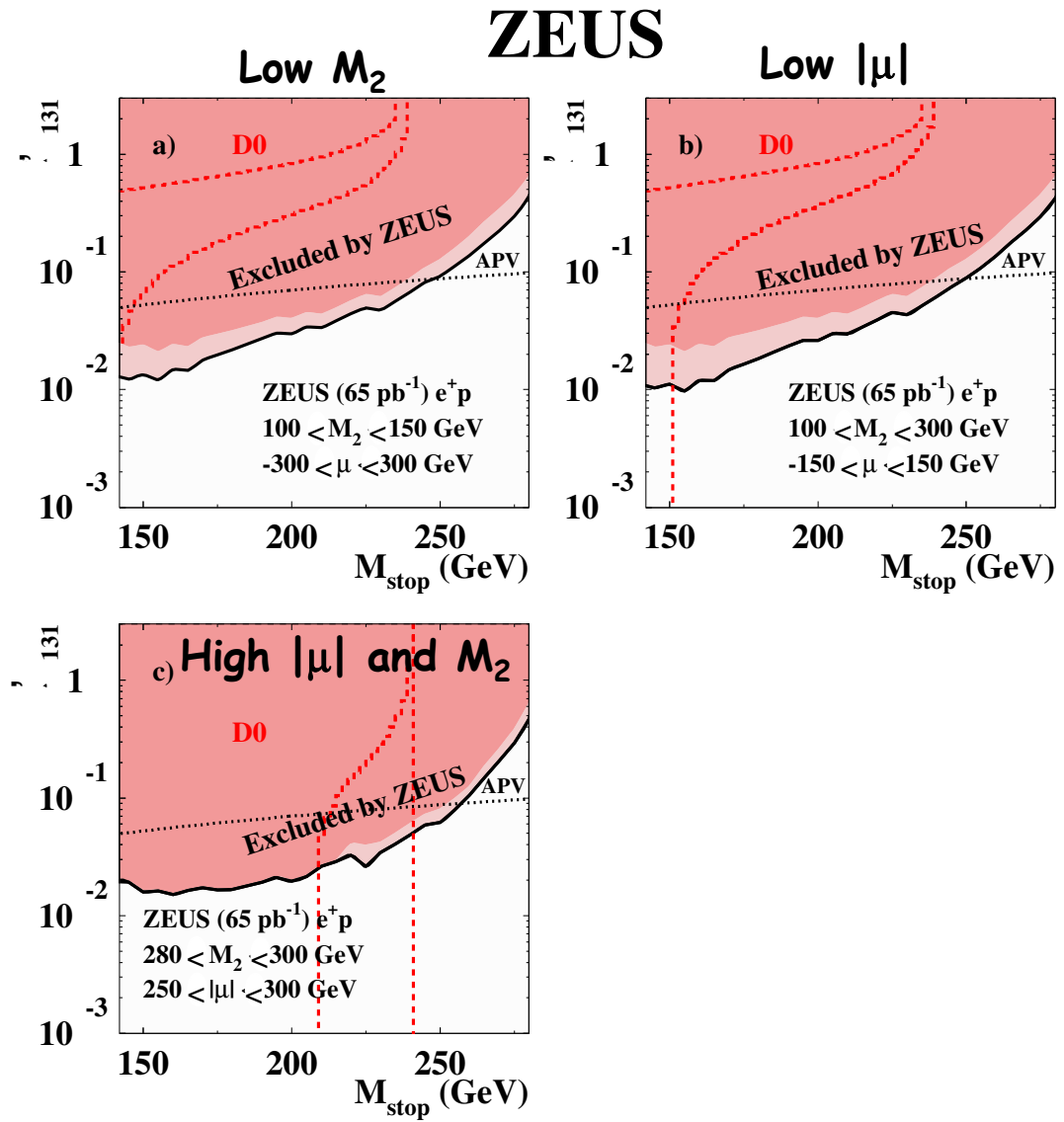
Unconstrained MSSM

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: $M_{\text{stop}} > M_{\text{sbottom}}$,
squark decay to gauginos forbidden

Complementary to previous stop-search

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

Stop bosonic decay dominant for

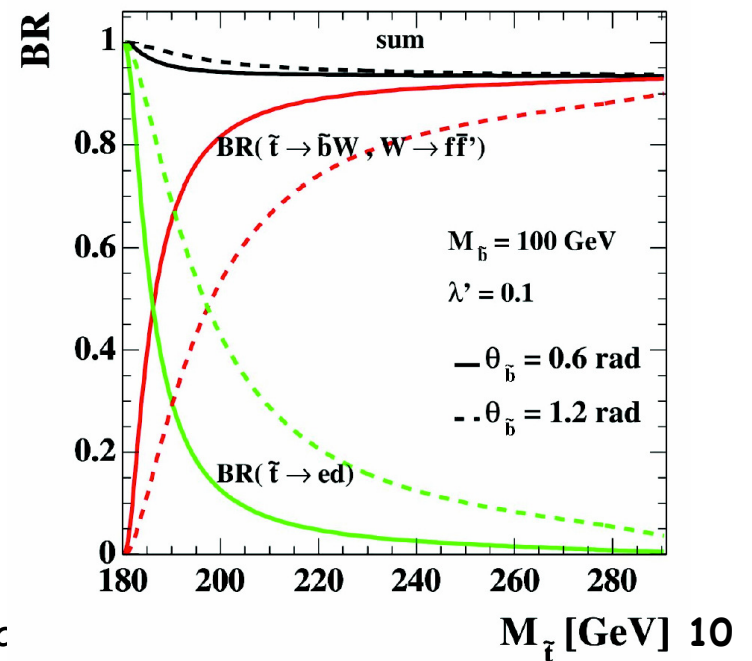
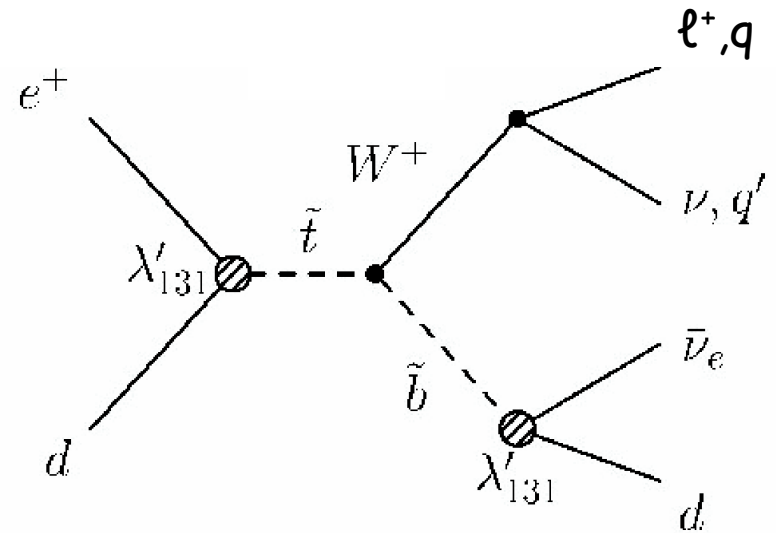
$$M_{\text{stop}} > M_{\text{sbottom}} + M_W$$

Also analysed the R-parity violating
stop decays which dominates for

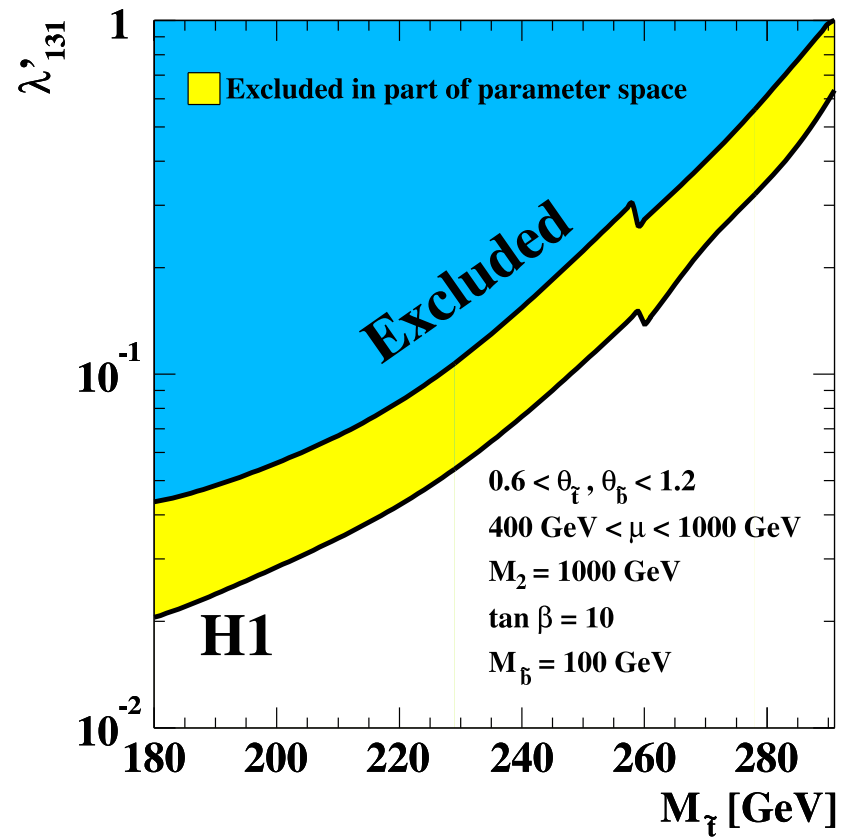
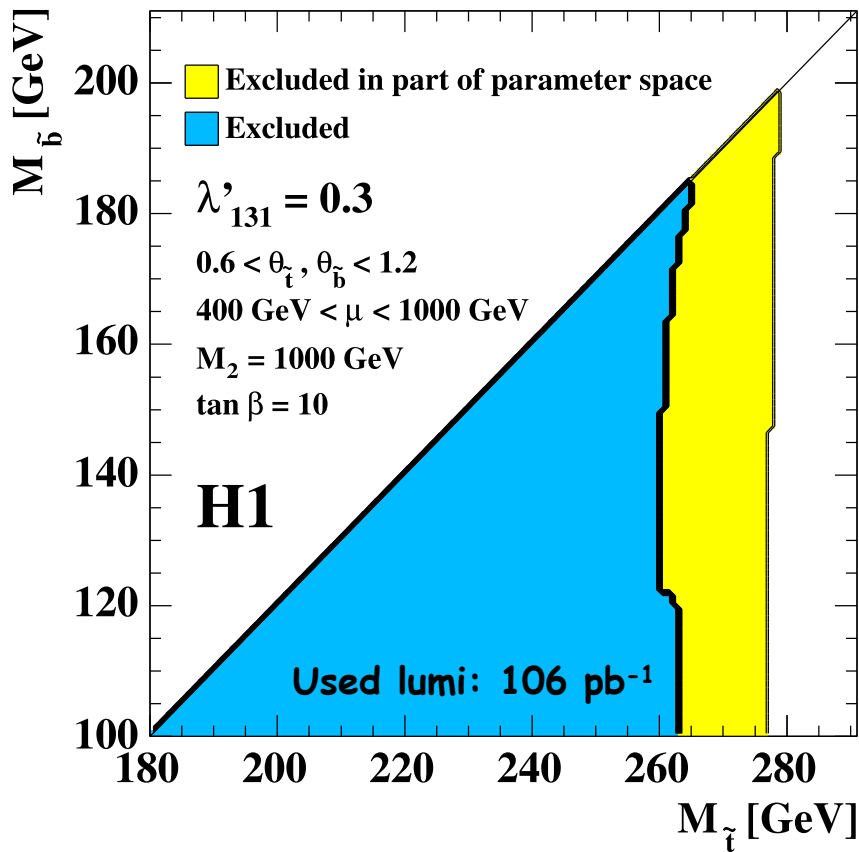
$$M_{\text{stop}} \sim M_{\text{sbottom}} + M_W$$

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

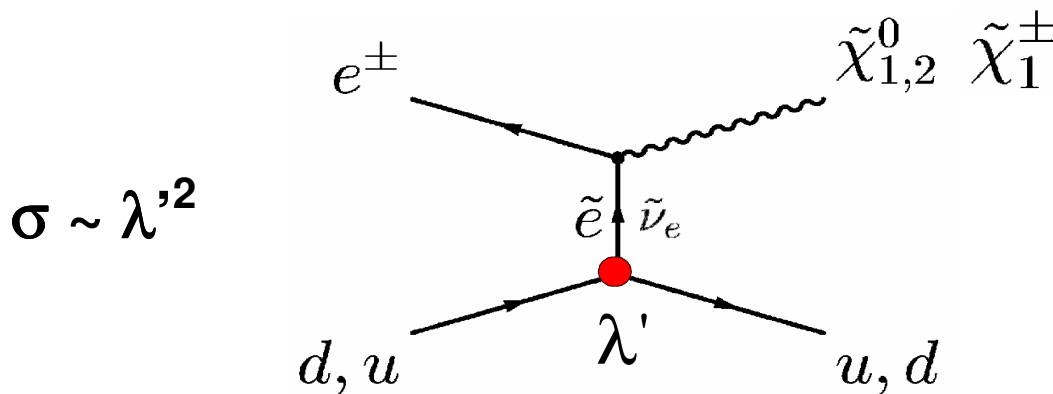
Gaugino production

Different scenario considered: $M_{\text{squarks}} \gg M_{\text{sleptons}}$

s-channel suppressed, t-channel slepton exchange dominant

$$W_{R/p} \sim -\lambda'_{1jk} \tilde{e}_L u_L^j \bar{d}_R^k$$

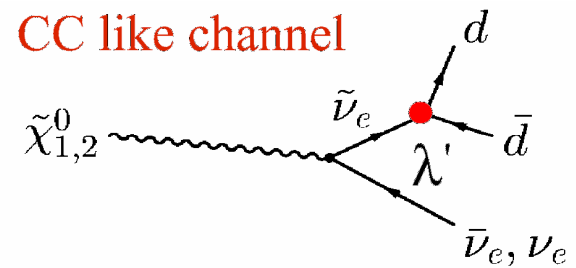
gaugino production



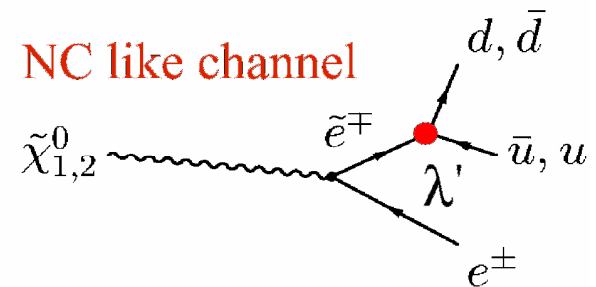
gaugino decay

(same channels for χ^0 e χ^\pm)

CC like channel



NC like channel



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

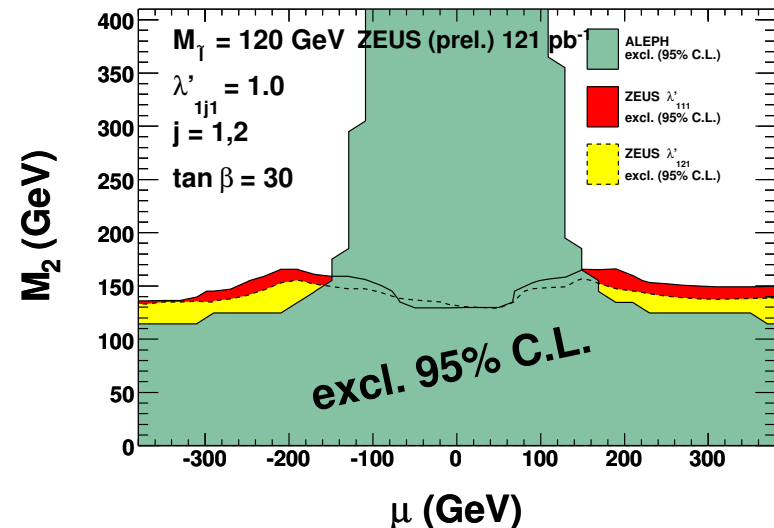
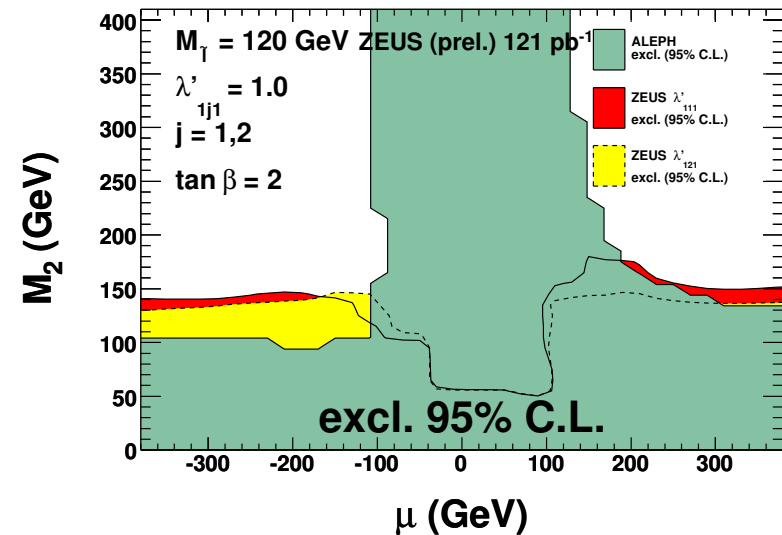
Gaugino production (contd)

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
 $M_2 \sim 160$ GeV

Results independent of the squark sector

→ $\lambda'_{121} \sim 1$ are not excluded by indirect measurements when the squarks has large masses



GMSB scenario (light gravitino phenomenology)

In this scenario gravitino is very light (typical 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 $\tan\beta$

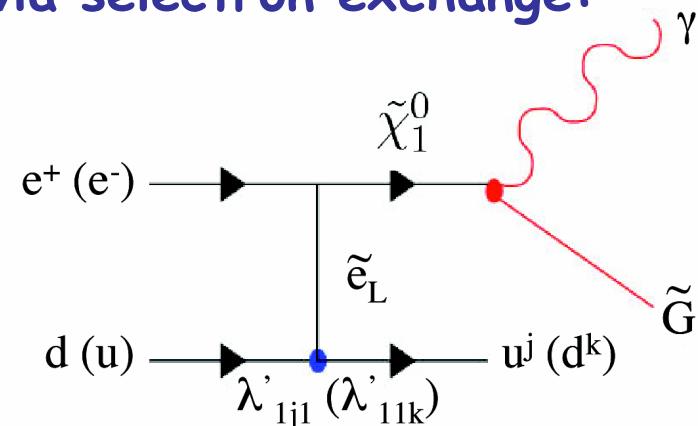
$\text{sign}(\mu)$ \sqrt{F} : SUSY breaking scale (related to gravitino mass)

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

Studied the single neutralino production via selectron exchange:

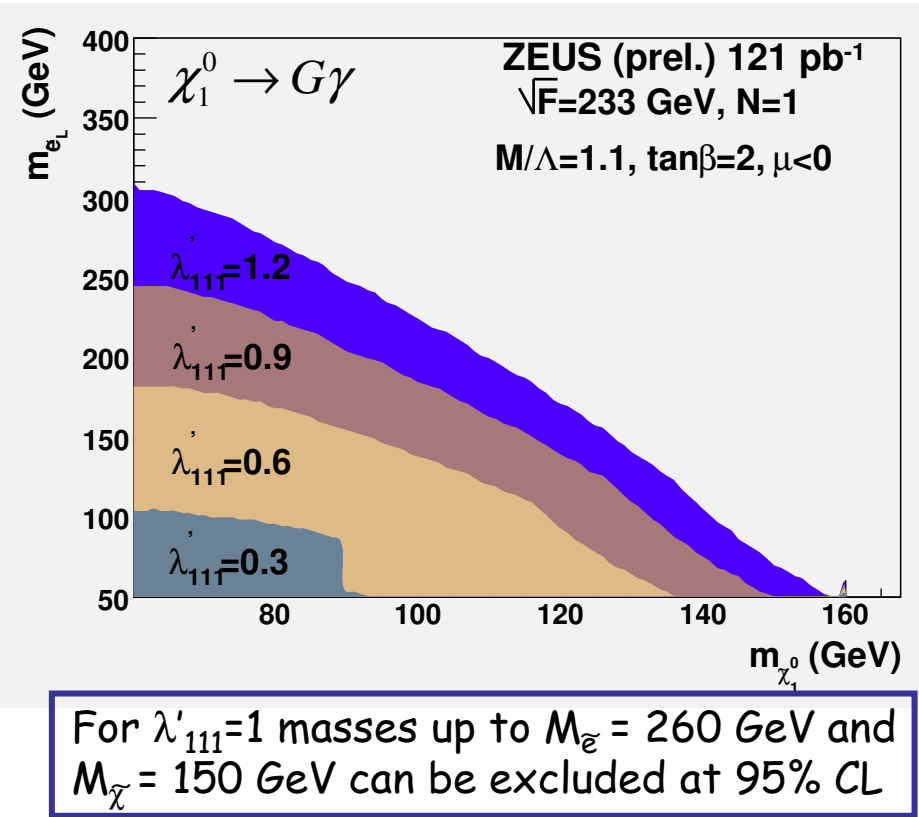
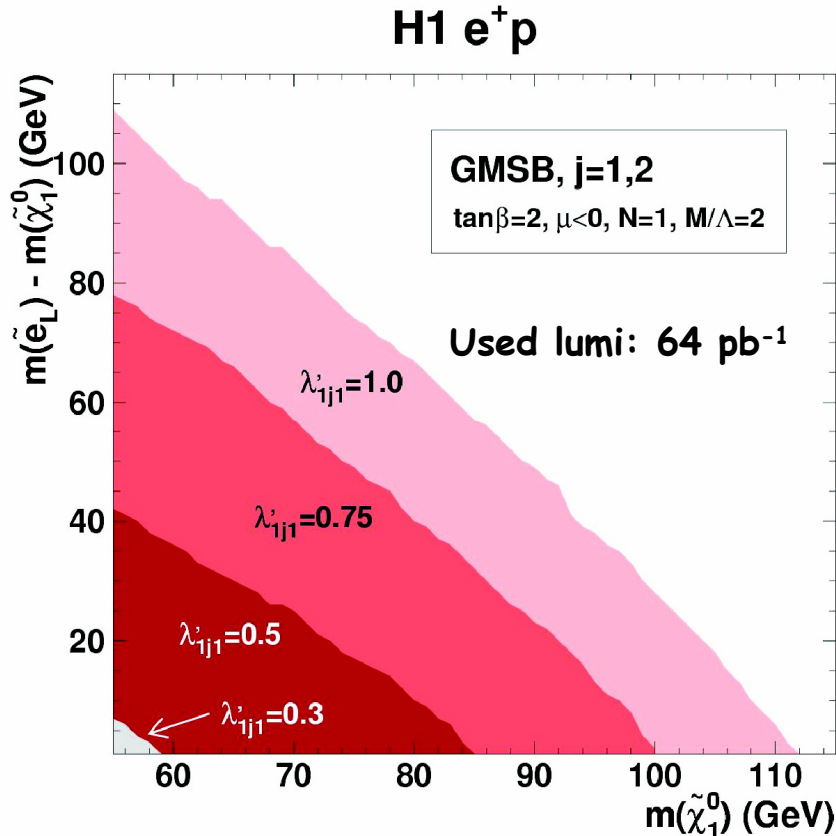
$$W_{R/p} \sim -\lambda'_{1jk} \tilde{e}_L u_L^j \bar{d}_R^k$$

electron/positron beam probe
different couplings



GMSB scenario (contd)

No deviations observed \Rightarrow exclusion limits



High squark masses \Rightarrow indirect constraints less effective $\Rightarrow \lambda'$ can be large

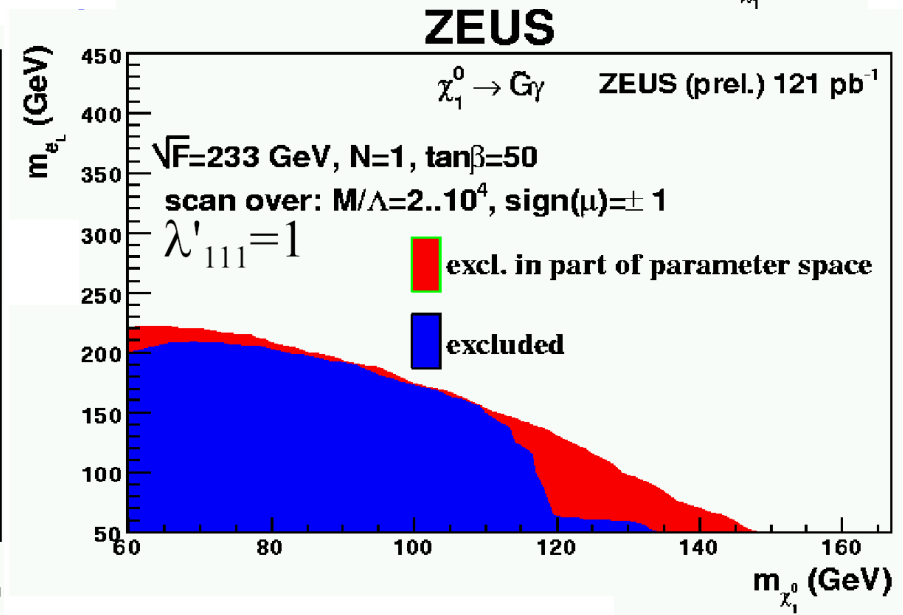
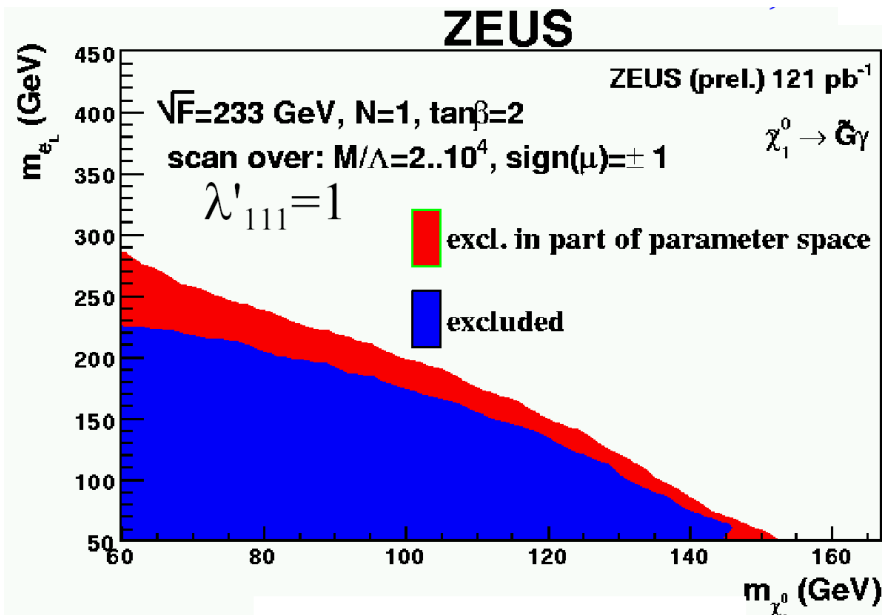
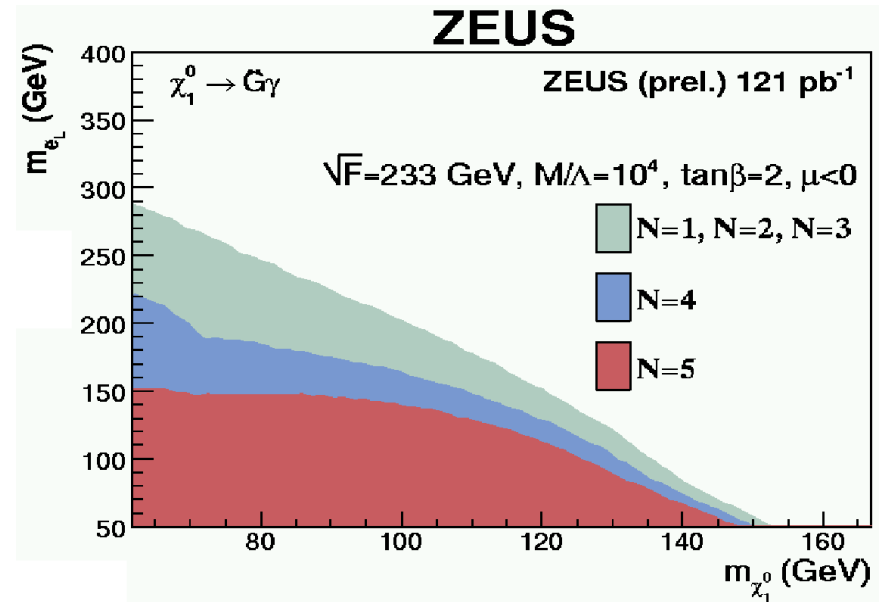
Comparison: ZEUS used more luminosity, e-p data also included, slightly different parameters, use of a discriminant algorithm gives higher sensitivity

GMSB scenario (contd)

Large scanning of the parameters:

- different N
- different M/Λ , $\text{sign}(\mu)$, $\tan\beta$

➔ 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 !