Search for Superlight Gravitinos at HERA

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Content of the talk

- $\not{R}_p$ SUSY
- GMSB scenario
- Neutralino production and decay
- Event selection and Results
- Mass and coupling limits within GMSB Model
- Summary

$\not{R}_p$ SUSY

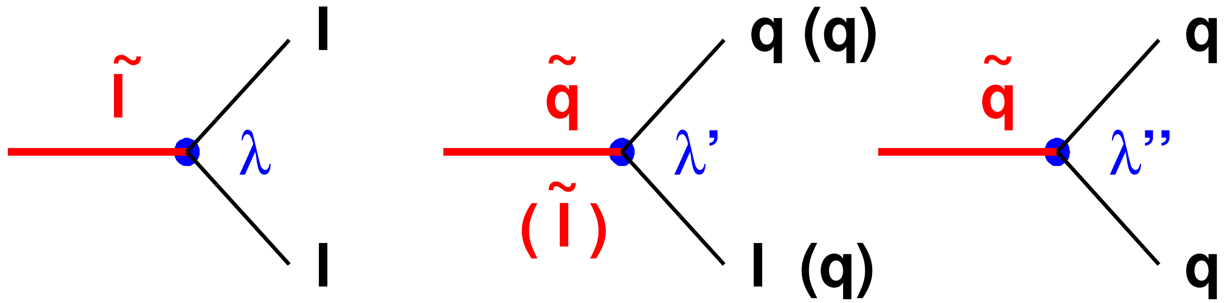
$$R_P = (-1)^{3B+L+2S}$$

$B =$ baryon number ; $L =$ lepton number ; $S =$ spin

$R_P = 1$ for SM particles and $R_P = -1$ for SUSY particles

R_P can explicitly be broken by trilinear couplings in the superpotential:

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



Gauge Mediated SUSY Breaking (GMSB)

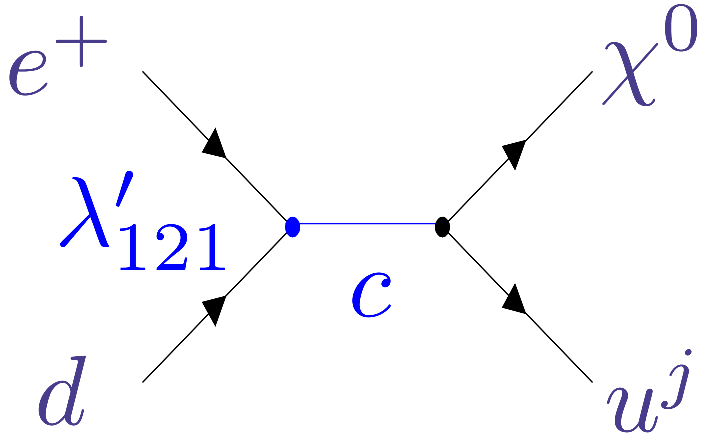
- If SUSY exists, since we don't see SUSY particles, the symmetry must be broken.
- in GMSB models SUSY is broken at a high energy scale in a "hidden" sector via the SM gauge interactions.
- Main difference to other models (e.g. mSUGRA) is the mass of the gravitino ($\tilde{G}$), where the ($\tilde{G}$) is too heavy to play a significant role in the phenomenology.
- In GMSB the ($\tilde{G}$) is typically light ($<$ 1 GeV) and the lightest SUSY particle (LSP).
- Next-lightest (NLSP) is typically the lightest neutralino – $\tilde{\chi}_1^0$ (or the lightest scalar lepton) .

Parameters of GMSB model

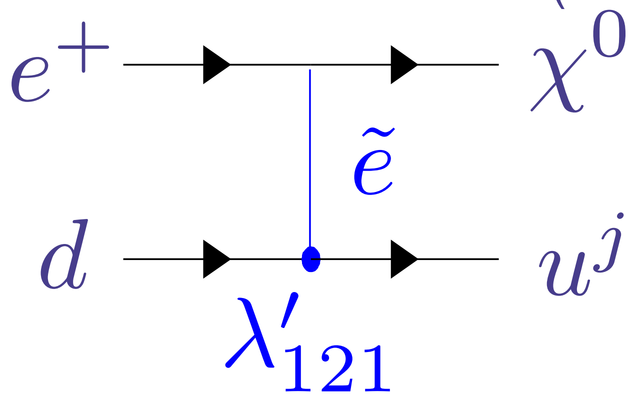
- GMSB models typically have six new parameters w.r.t those of the SM :
  - SUSY breaking scale $\sqrt{F_0}$ which also determines the $\tilde{G}$ mass.
  - Λ sets the overall mass scale of the SUSY particles.
  - M – the mass of the messenger particles (M & $\Lambda \longrightarrow m_{\tilde{e}}, m_{\chi_0}$).
  - N (1,2) – the number of messenger particles.
  - $\tan\beta$ (2,6) – the ratio of the Higgs vacuum expectation values.
  - sign(μ) – the sign of the Higgs sector mixing parameter

$R\!\!\!/_p$ Neutralino Production

Previous HERA analyses: s channel squark (low squark mass)

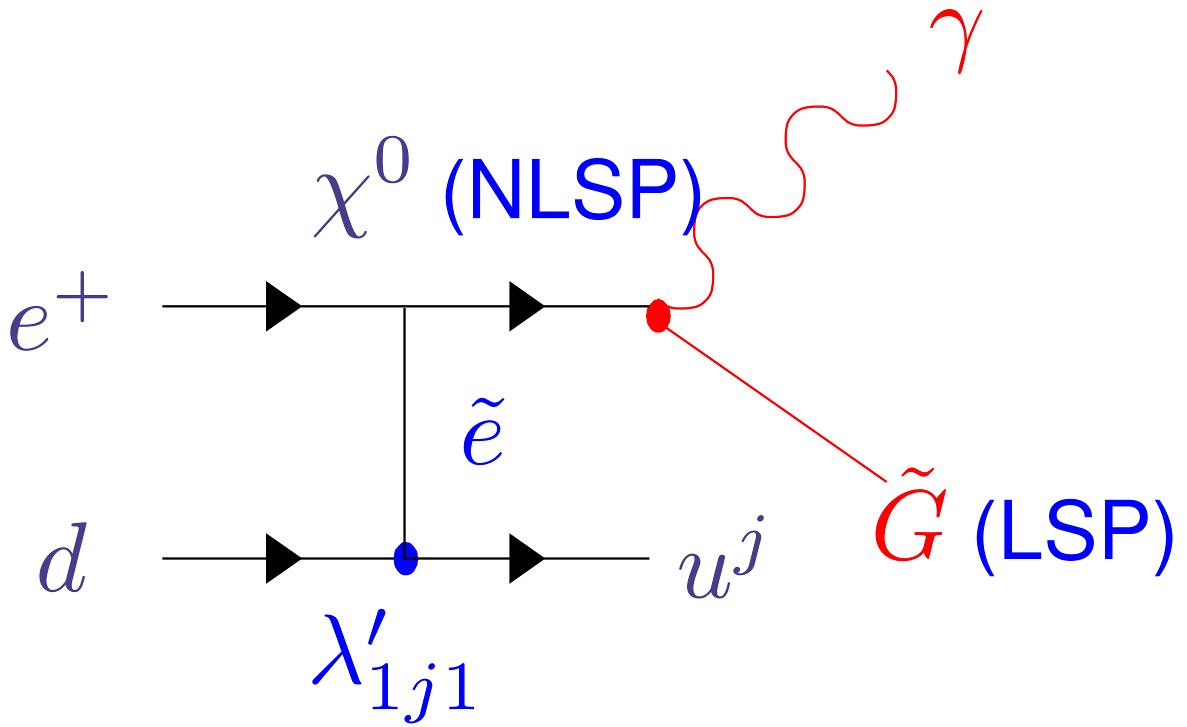


New in this analysis: t channel selectron (low selectron mass)



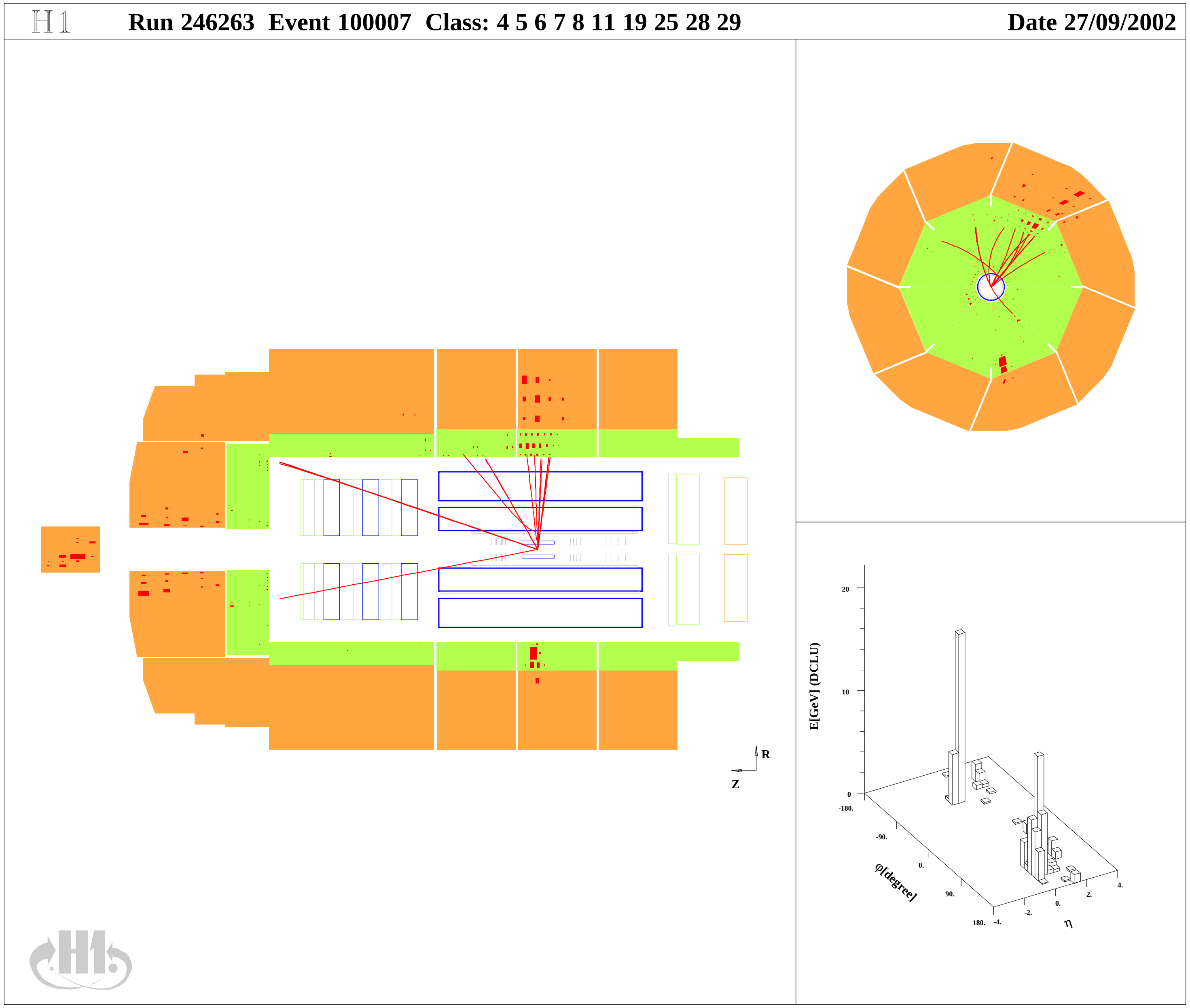
- Analyse SUSY independent of Tevatron squark mass limits.
- Set first λ'_{121} limits for low selectron / large squark masses

Neutralino Production via t channel selectron exchange at HERA



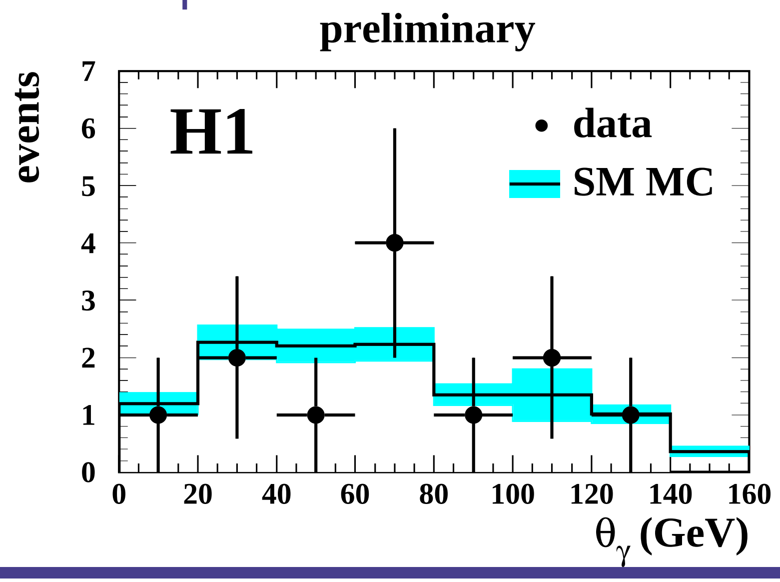
- Assume one Yukawa coupling $(\lambda'_{1j1}/\lambda'_{11k})$ dominates and $\tilde{\chi}^0_1 \to \gamma\tilde{G}$ has unobservably short lifetime ("superlight gravitino" $\approx$ eV).
- Study $\not{R}_p$ SUSY independent of squark mass, dependent on $m_{\tilde{e}}, m_{\chi_0}$.
- Experimental signal: $P_T^{\mathrm{miss}}(\tilde{G})$, photon and jet.

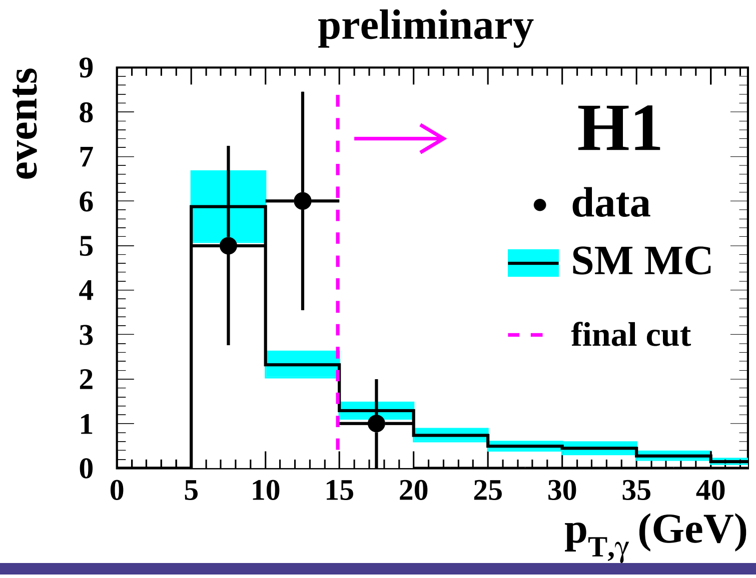
Signal Event Display – Monte Carlo!



Event Selection

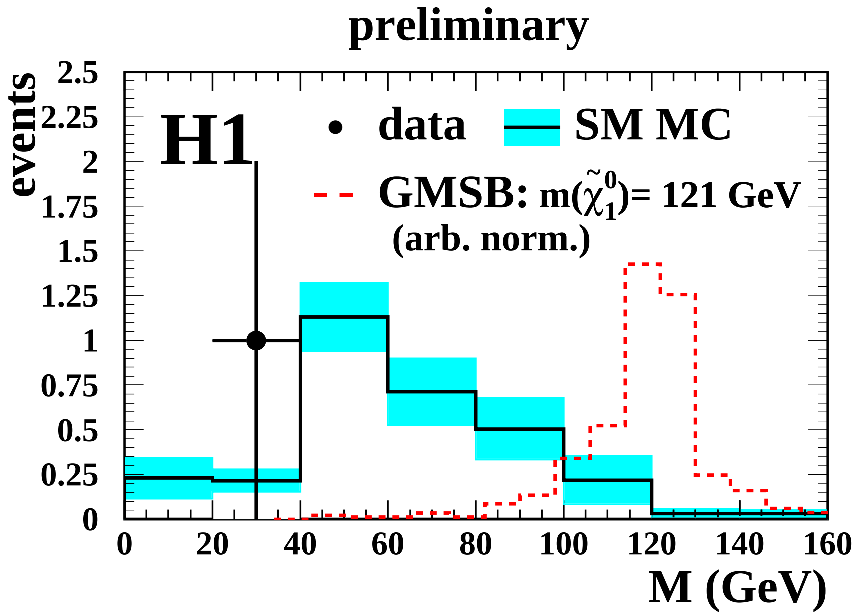
- 64pb^{-1} of e^+p data and 14pb^{-1} of e^-p data – COM energy of 320 GeV.
- Basic selection:
  - Non-ep rejection, timing and vertex requirements.
  - ($\tilde{G}$) $P_T^{\mathrm{miss}} > 25$ GeV
  - (Jet) $P_T^{\mathrm{Jet}} > 5$ GeV and within good tracking acceptance.
  - (Photon) $P_T^{\mathrm{Photon}} > 5$ GeV, isolated and within good tracking acceptance.





Final Selection and Results

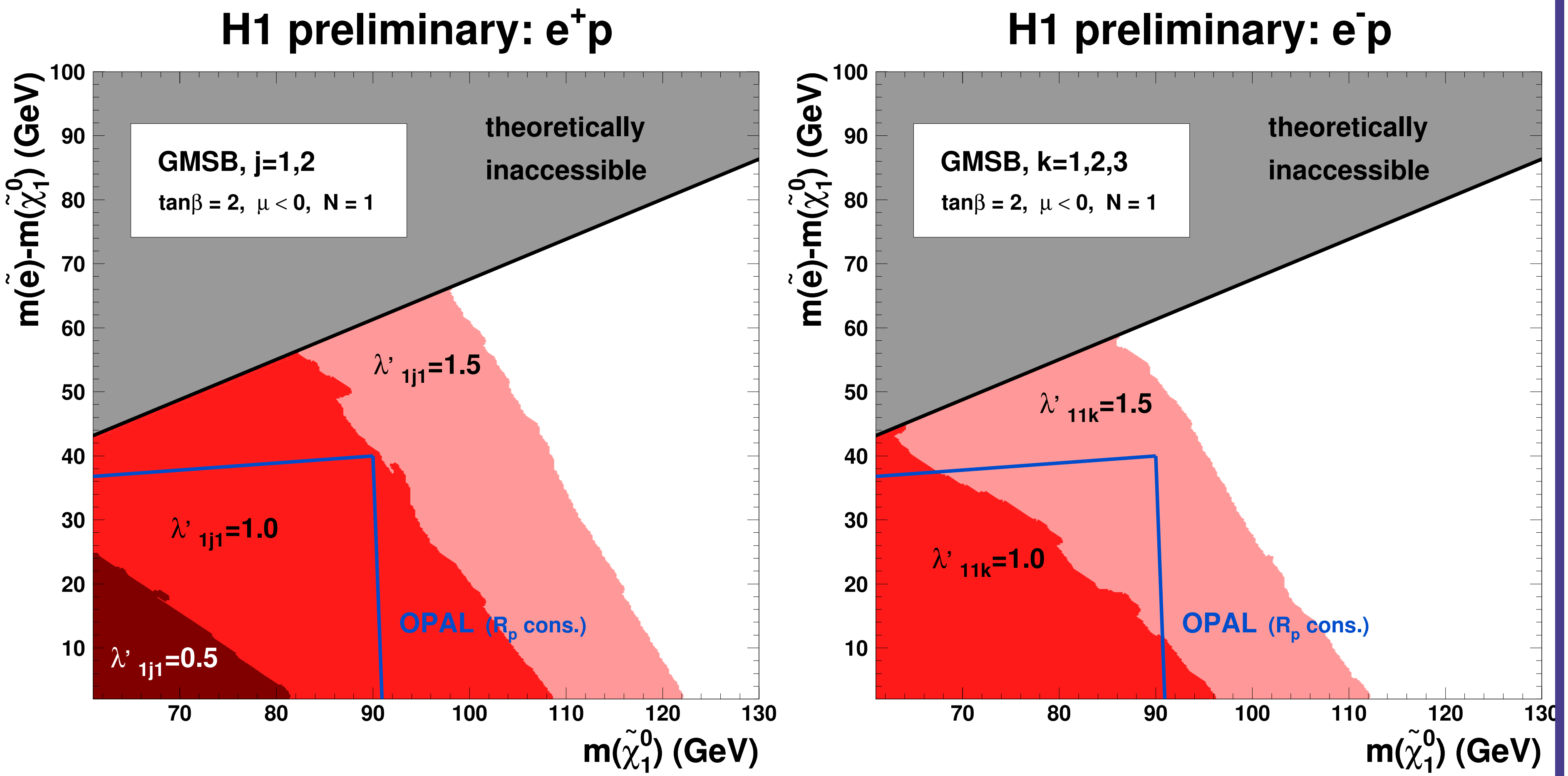
- From the 12 events selected as described (*cf.* 11.9$\pm$1.5 expected), require:
  - Photon $P_T > 15$ GeV
  - (Against CC-DIS) Longitudinal momentum loss: $\Sigma(E - p_z) > 15$ GeV.
- No candidates in e^+p (*cf.* 1.9$\pm$0.2 exp'd)
- One candidate in e^-p (*cf.* 1.2$\pm$0.2 exp'd)
- SM expectation is mainly CC-DIS.
- Signal selection efficiency (SUSYGEN) ranges between 10% and 30%



- Assume one non-interacting particle $\longrightarrow$ missing energy. Add 4-vector to photon 4-vector to give χ_0 mass. Mass resolution $\approx$ 7 GeV. (Candidate has $M_{\chi_0} = 37$ GeV).

GMSB Model Interpretations

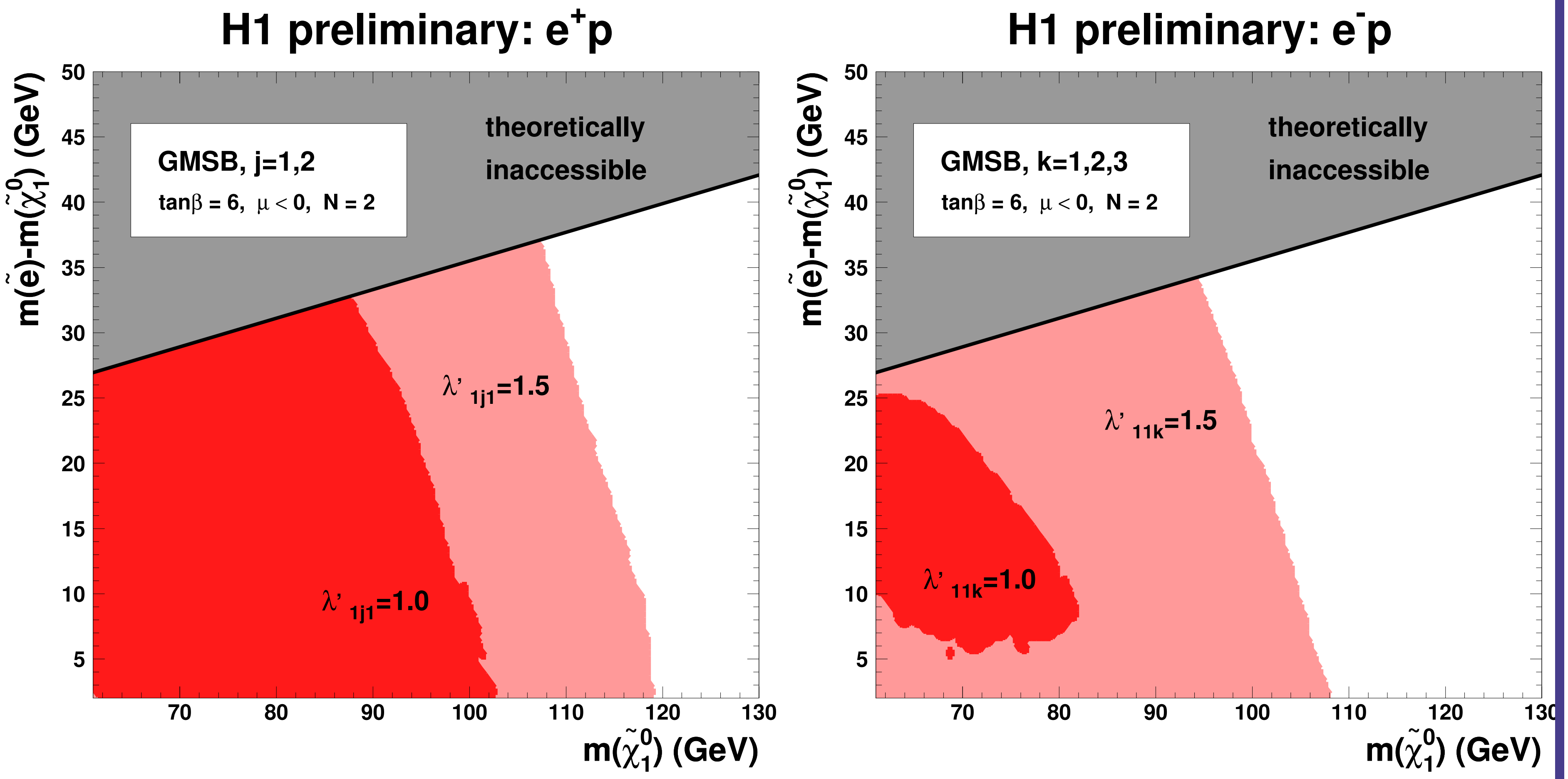
- No significant deviation from SM $\longrightarrow$ derive GMSB limits.
- Fix $\tan\beta$, N and sign(μ) and transform Λ and M into $m(\tilde{\chi}_1^0)$ and $m(\tilde{e})$.



- For $\lambda' = 1$ can exclude $m(\tilde{\chi}_1^0) < 108$ GeV, and $m(\tilde{e}) < 138$ GeV.

GMSB Model Interpretations

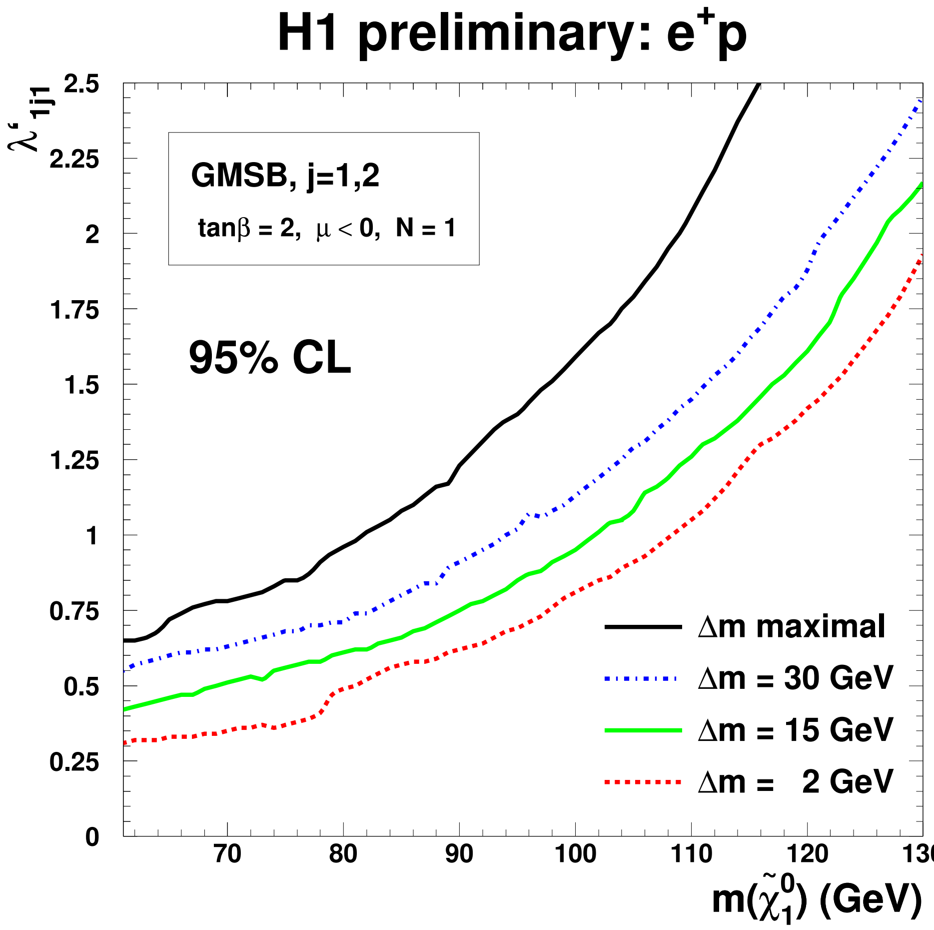
- Increase $\tan\beta$ from $2 \longrightarrow 6$ and N from $1 \longrightarrow 2$

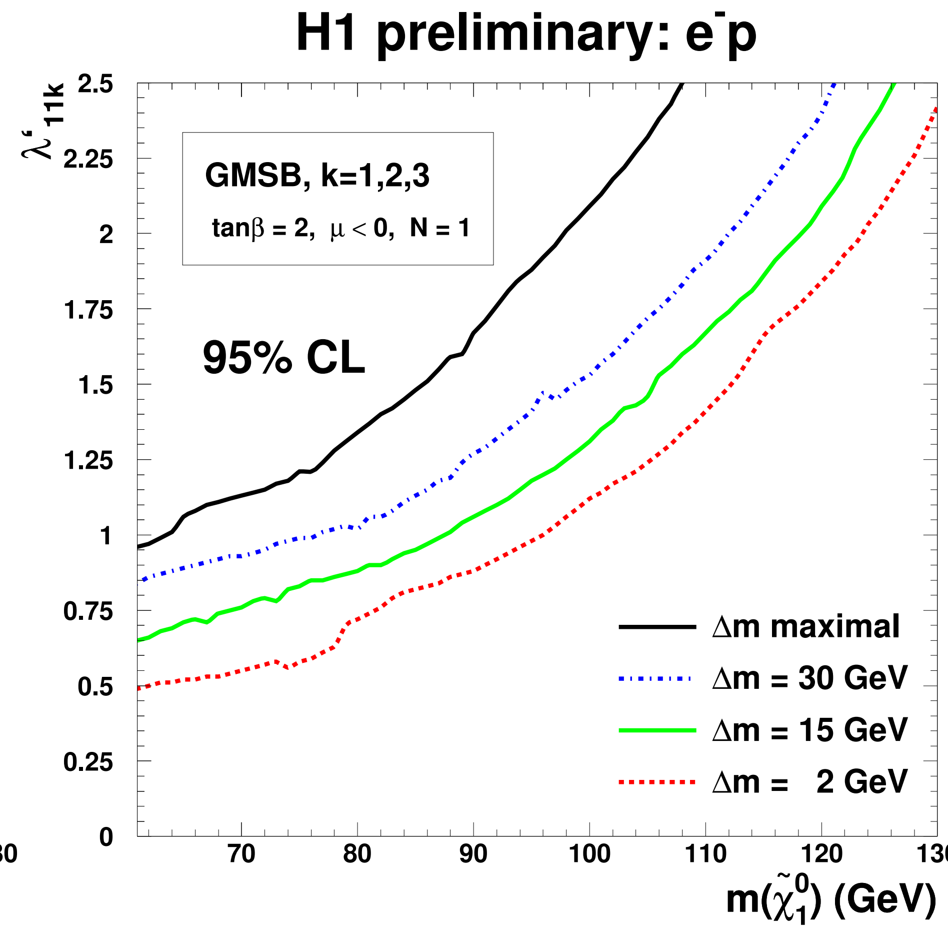


- At given masses, variation of N only gives a small effect on cross-section, whereas increasing $\tan\beta$ significantly decreases cross-section.

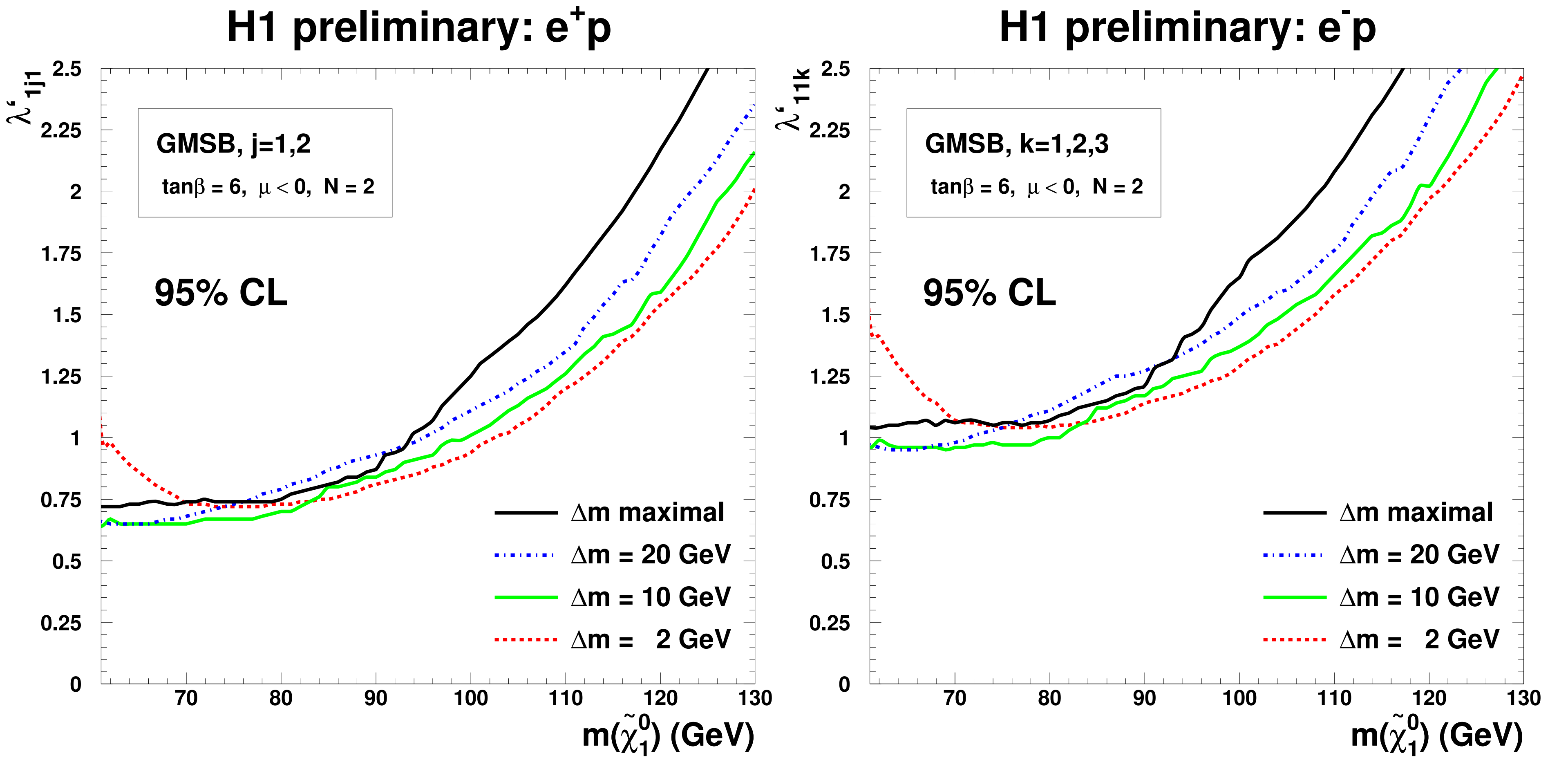
GMSB Model Interpretations

- Derive limits on the $R\!\!\!/_p$ couplings λ'_{1j1} (j =1,2) and λ'_{11k}(k =1,2,3).
- Function of neutralino mass for various selectron-neutralino mass differences.





GMSB Model Interpretations



- Overall, for $m(\tilde{\chi}_1^0) \approx m(\tilde{e}) \approx$ 60 GeV, exclude λ'_{121} >0.3 (e.m. strength) and $\lambda'_{112/3} > 0.5$.

Summary

- Search for superlight gravitinos at HERA
  – events with a photon, jet and missing P_T.
- No deviation from the Standard Model.
- Derive constraints on GMSB models.
- $m(\tilde{\chi}_1^0) < 108$ GeV and $m(\tilde{e}) < 138$ GeV for Yukawa coupling $\mathcal{O}(1)$.
- $\lambda'_{1j1} < 0.3$ and $\lambda'_{11k} < 0.5$ for $m(\tilde{\chi}_1^0)$ and $m(\tilde{e}) \approx 55$ GeV.
- First limits independent of squark masses for λ'_{121} & λ'_{113}.

Prospects for exclusion limits at HERA-II