

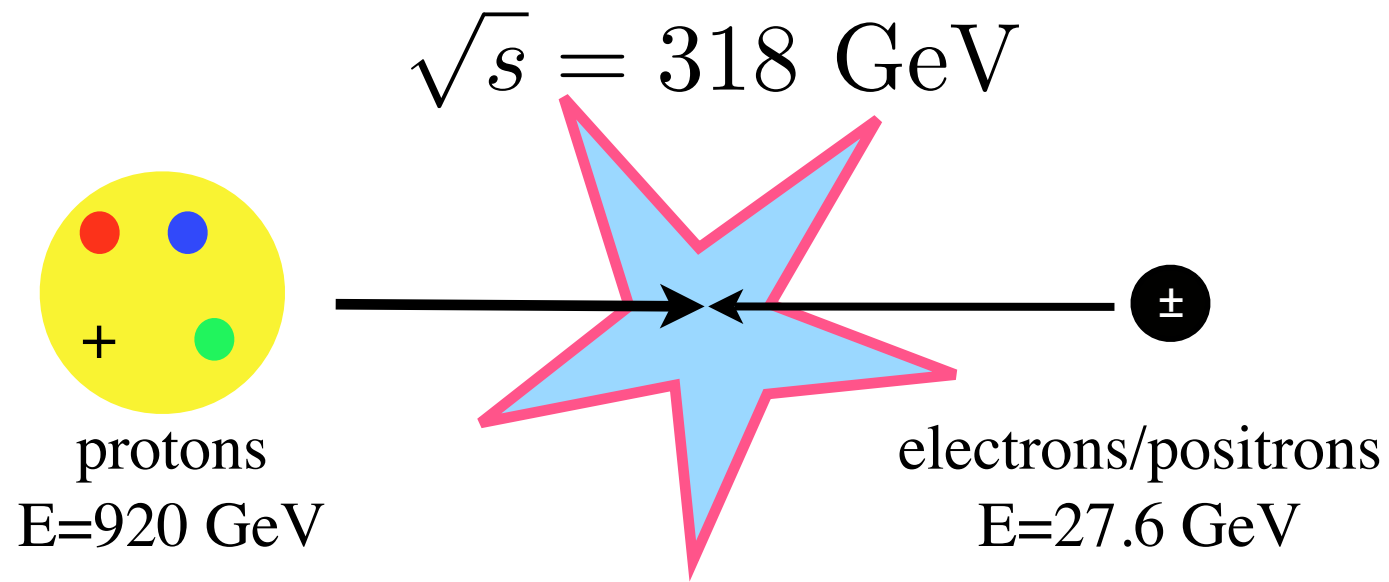
XVIII International Workshop on
Deep-Inelastic Scattering
DIS 2010, Firenze, 19.-23. April 2010

Search for Squark Production in R-Parity Violating Supersymmetry with the HI Experiment at HERA

Michael Herbst - Universität Heidelberg
on behalf of HI collaboration



HERA Lepton Hadron Collider



full HERA luminosity:

$$e^+ p : 255 \text{ pb}^{-1}$$

$$e^- p : 183 \text{ pb}^{-1}$$

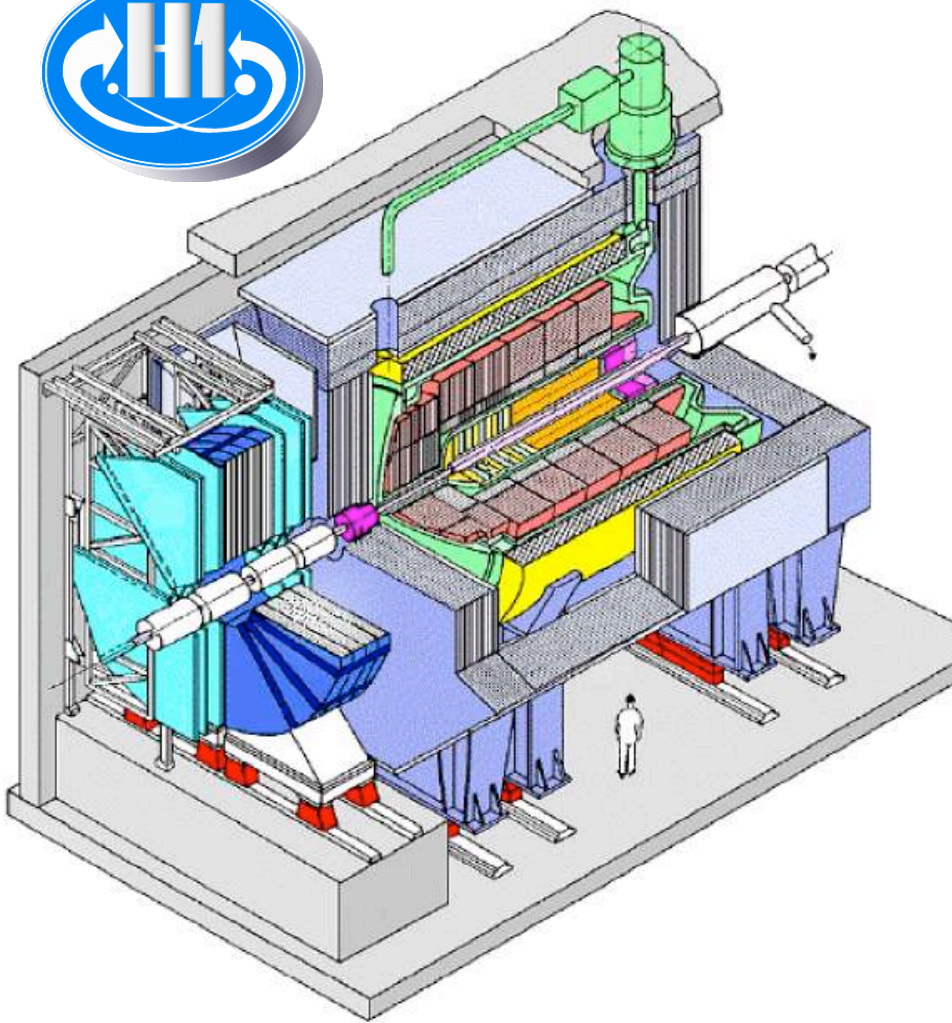
increase as compared to
previous H1 publication¹:

$$e^+ p : \times 4$$

$$e^- p : \times 13$$

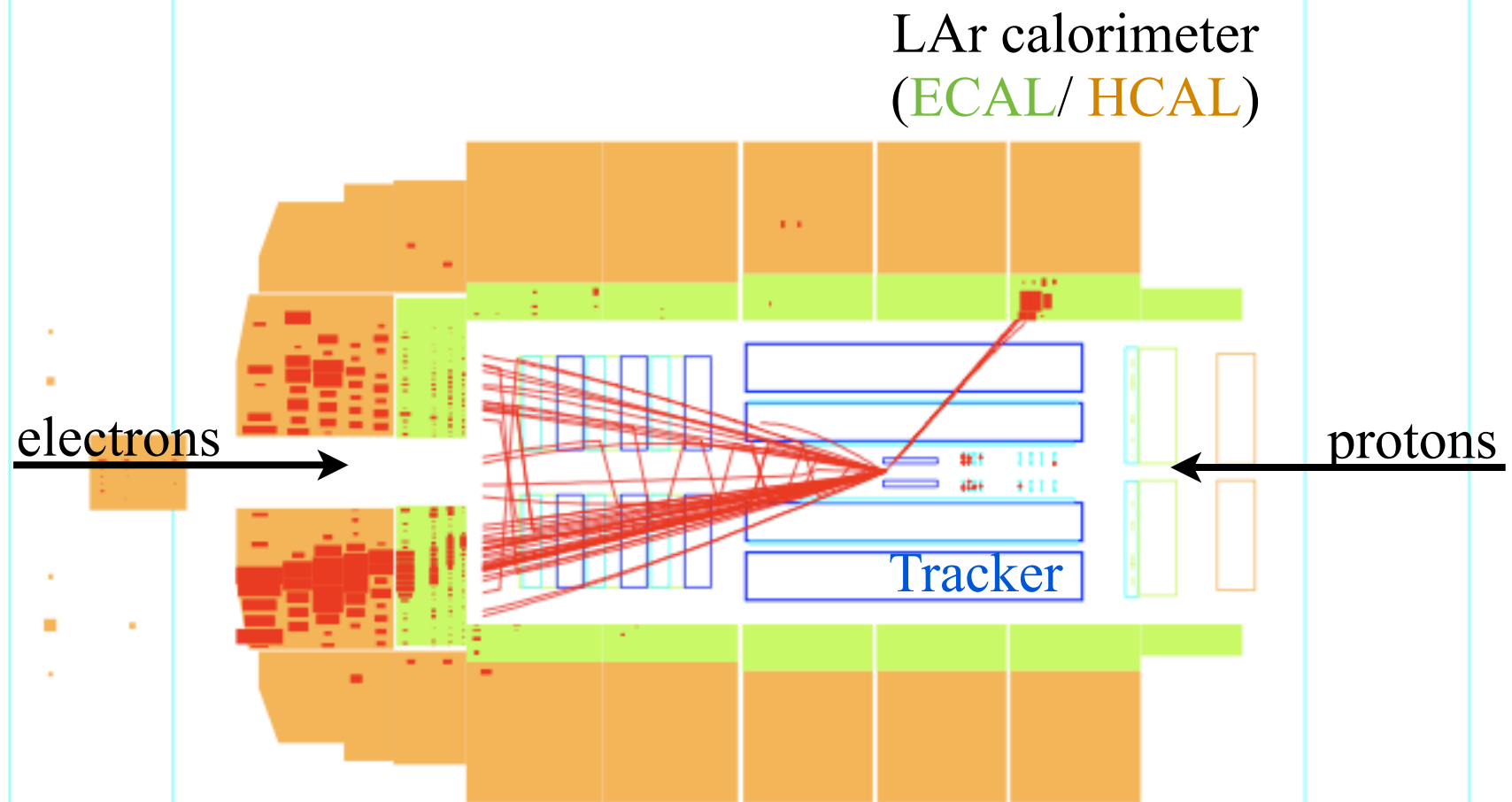
¹Search for Squark Production in R-Parity Violating Supersymmetry at HERA,
Eur. Phys. J. C36:425-440,2004 (hep-ex/0403027)

The H1 Experiment at HERA



“forward” direction

muon system



identification of electrons (e), muons (μ), jets *and neutrinos* (ν)
in $\sim 4\pi$ solid angle

good reconstruction of hadronic final state via energy flow algorithm

Squark Production at HERA

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

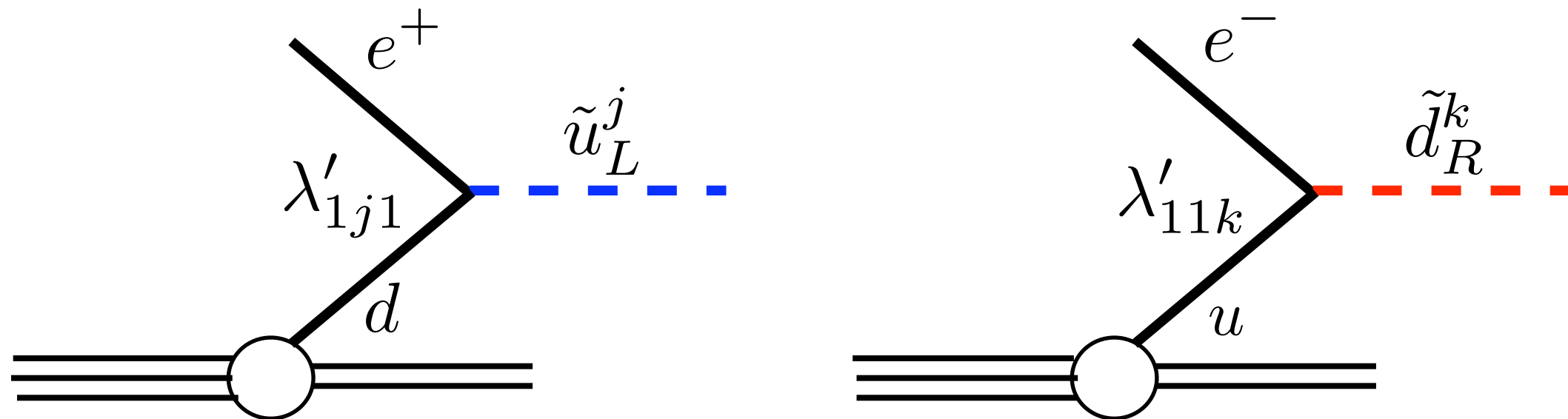
R-Parity Violating Superpotential

SM: $R_P = 1$ SUSY: $R_P = -1$

$$W_R = \frac{1}{2} \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{1}{2} \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

L: left hand. (s)leptons, **Q**: left hand. (s)quarks, **D**: right hand. down-type (s)quarks
i,j,k generation indices (27 couplings)

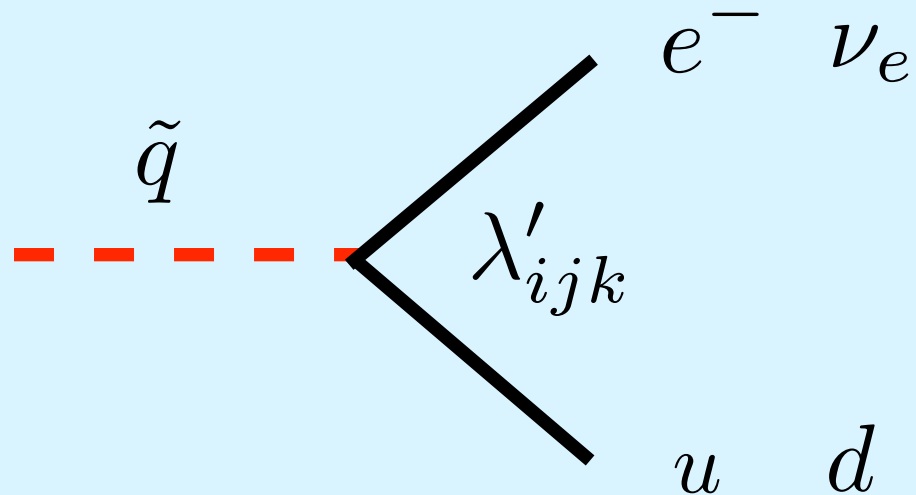
resonant production of single squarks in ep-collisions



◆ squark masses up to \sqrt{s} accessible

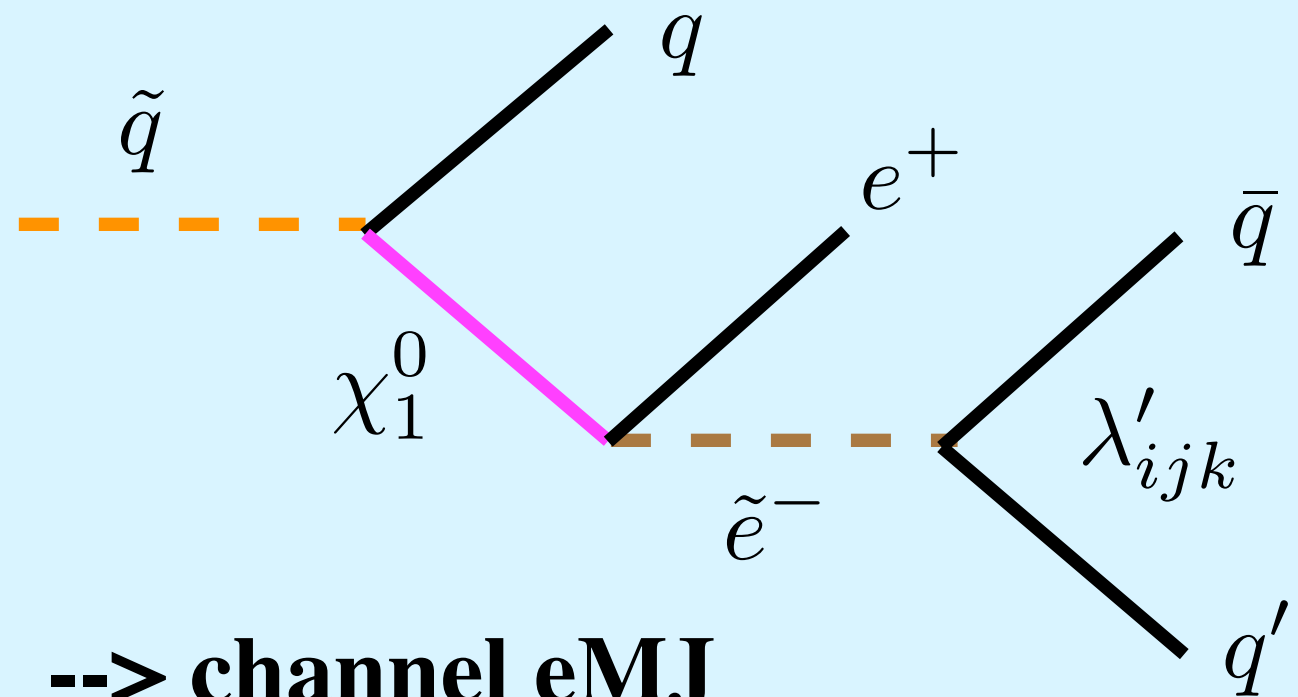
Squark Decay - Final State Topologies

squark directly R-parity violating:



--> **channel eq, vq**

example for
cascade with LSP decaying R-parity violating:



--> **channel eMJ**

- single λ' coupling dominance hypothesis
- various final states with electrons, muons, neutrinos and jets
- decay products have significant transverse momenta and are mainly emitted in forward direction

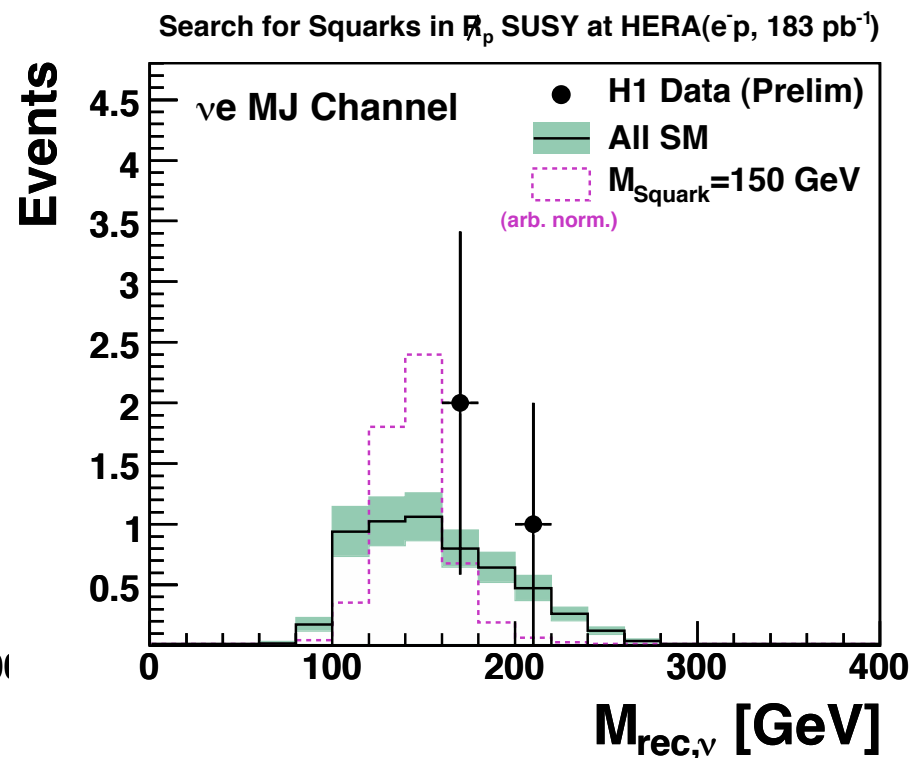
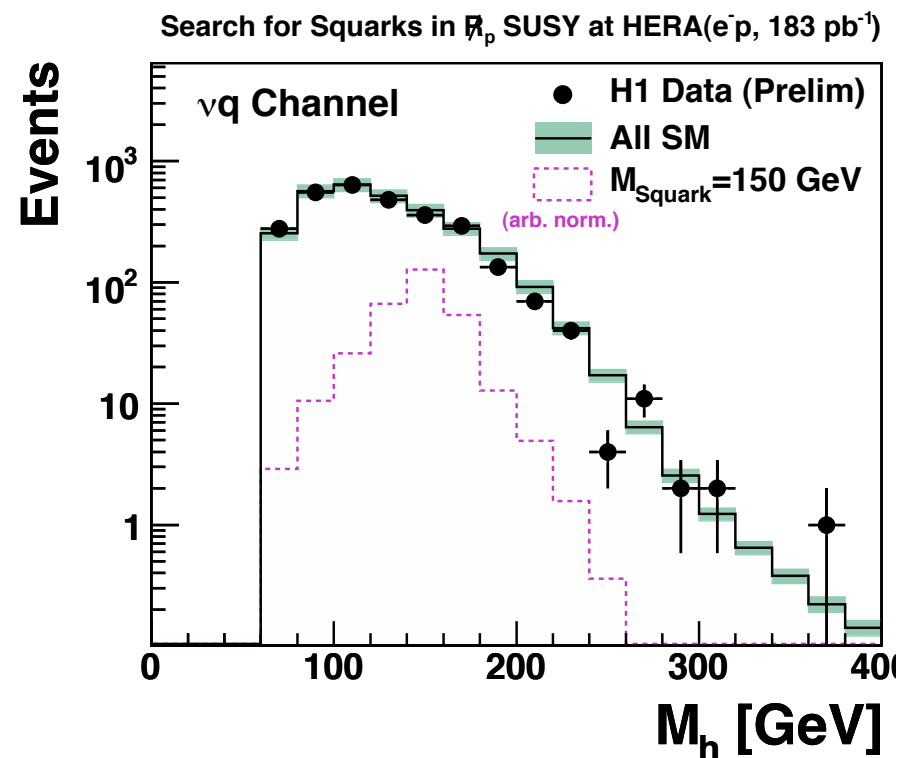
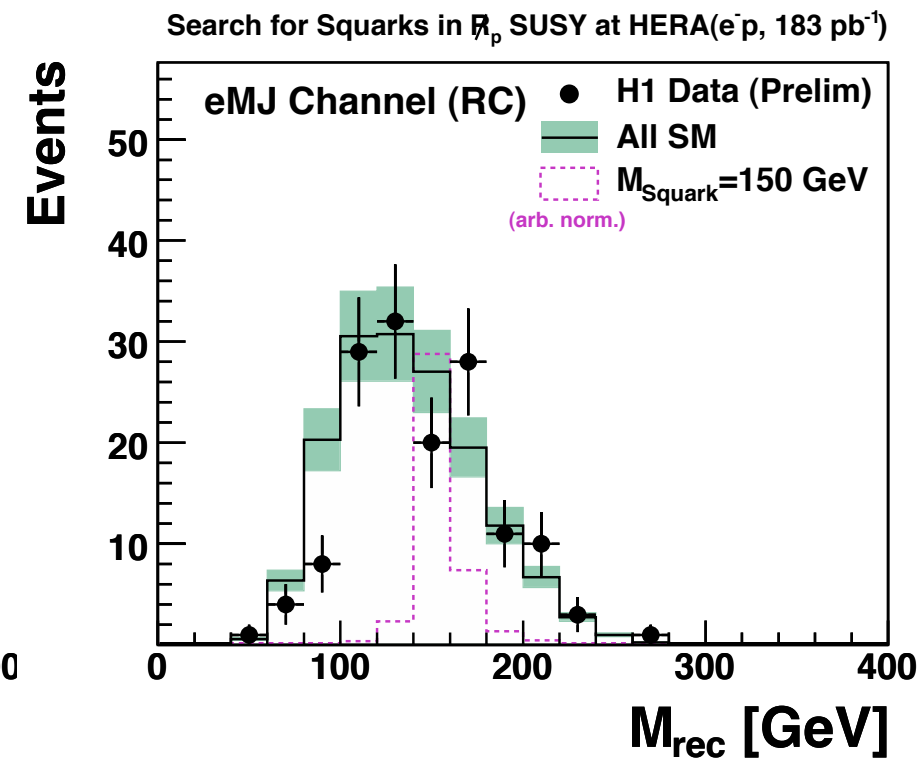
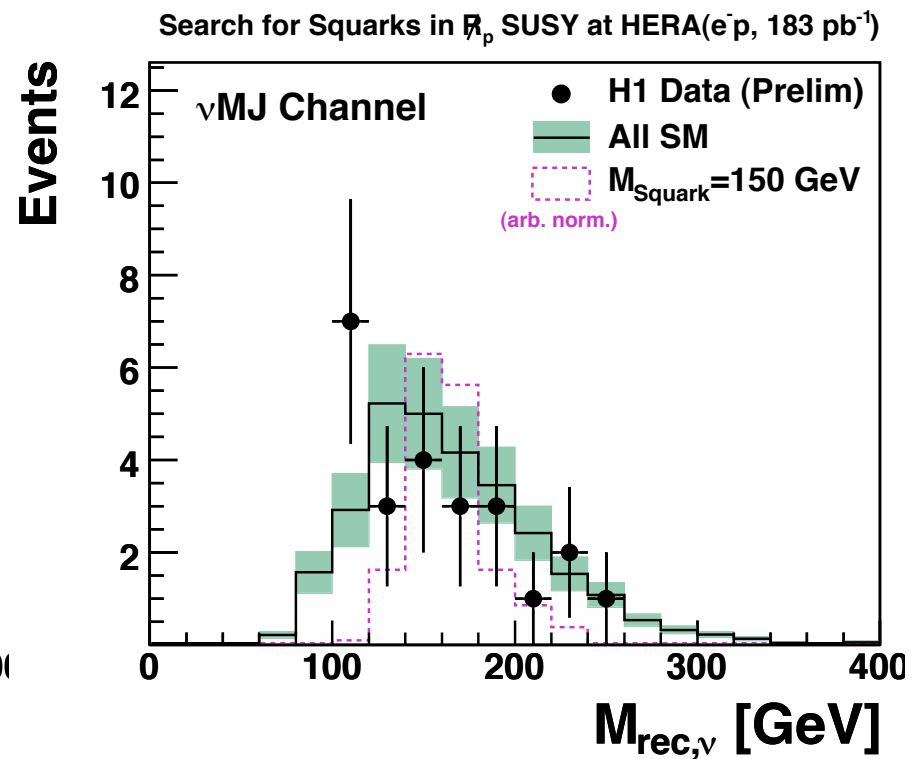
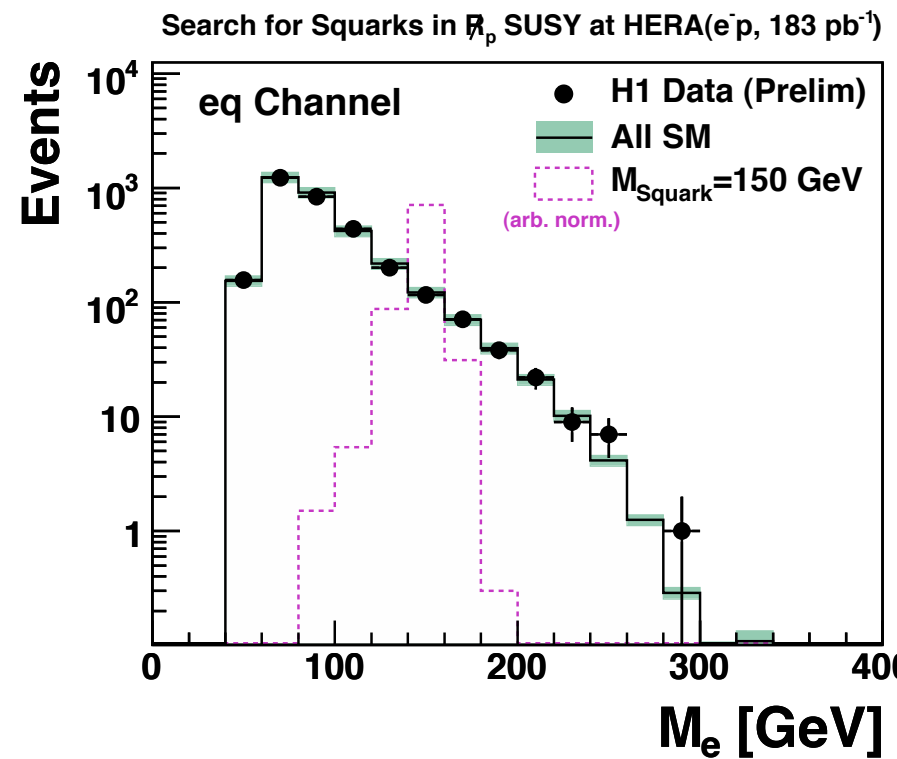
Search Results

Search for Squarks in RPV SUSY with H1 (Preliminary)					
Channel	e^+p (255 pb ⁻¹)		e^-p (183 pb ⁻¹)		Signal Efficiency
	Data	SM Expectation	Data	SM Expectation	
eq	2946	2899 ± 302	3121	3215 ± 336	30 – 40%
νq	-	-	2858	2983 ± 358	50 – 60%
eMJ (RC)	140	145.6 ± 21.3	147	157.7 ± 23.8	10 – 40%
eMJ (WC)	1	0.58 ± 0.36	0	1.3 ± 0.3	5 – 20%
νMJ	19	23.4 ± 5.8	24	28.9 ± 7.2	5 – 15%
$eeMJ$	2	1.7 ± 0.5	0	1.5 ± 0.5	5 – 35%
$e\mu MJ$	0	0.03 ± 0.03	0	0.03 ± 0.02	5 – 15%
νeMJ	5	8.2 ± 2.0	3	5.6 ± 1.2	5 – 40%
$\nu\mu MJ$	0	0.06 ± 0.03	0	0.04 ± 0.02	5 – 20%

Selection has been optimised to minimize the expected limit.

All investigated topologies in good agreement with SM expectation!

Mass Distributions (e-p 184pb⁻¹)



In e-p and e+p data
 no significant
 deviation from
 SM background
 observed

Interpretation of Search Results

- **No sign for SUSY in complete HERA data!**
- Use selection results to derive limits
on R-parity violating couplings and squark masses.

Method of Limit Calculation

Input for each channel:

- N_{Data} , $N_{\text{SM Expectation}}$, $\Delta(N_{\text{SM Expectation}})$
(inside sliding masswindow)
- Signal selection efficiency ε
- Branching ratio (SUSYGEN3)

Combination of search channels for **95% CL upper limit**
using modified frequentist approach based on Likelihood Ratio.

Minimal Supersymmetric Standard Model

MSSM-124

- In principle 124 parameter (masses, mixings, phases)
- Use as phenomenological model:
 - squark masses parameters (slepton masses set 90 GeV)
 - gaugino masses determined via Radiative Electroweak Symmetry Breaking (3 parameter)

$\tan \beta$ - **ratio** of the two **Higgs VEV's**

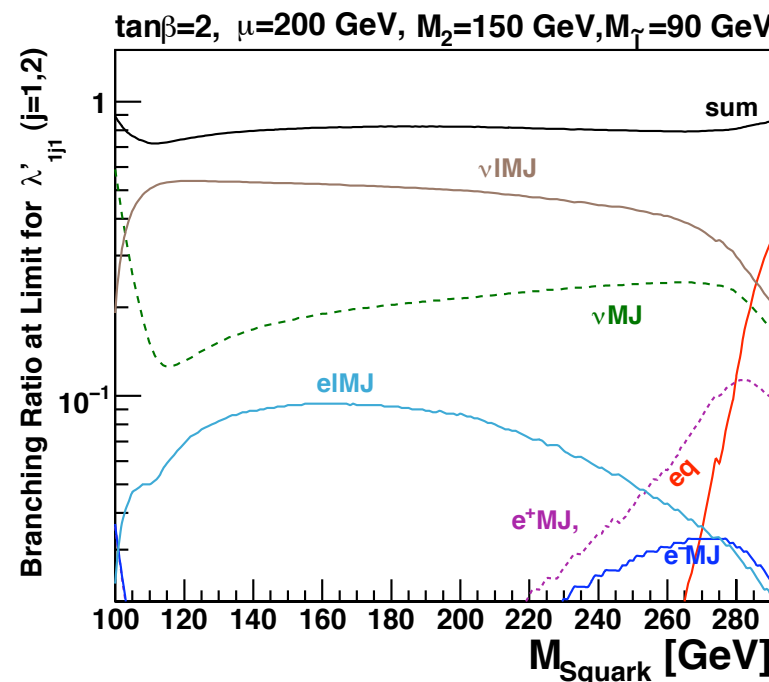
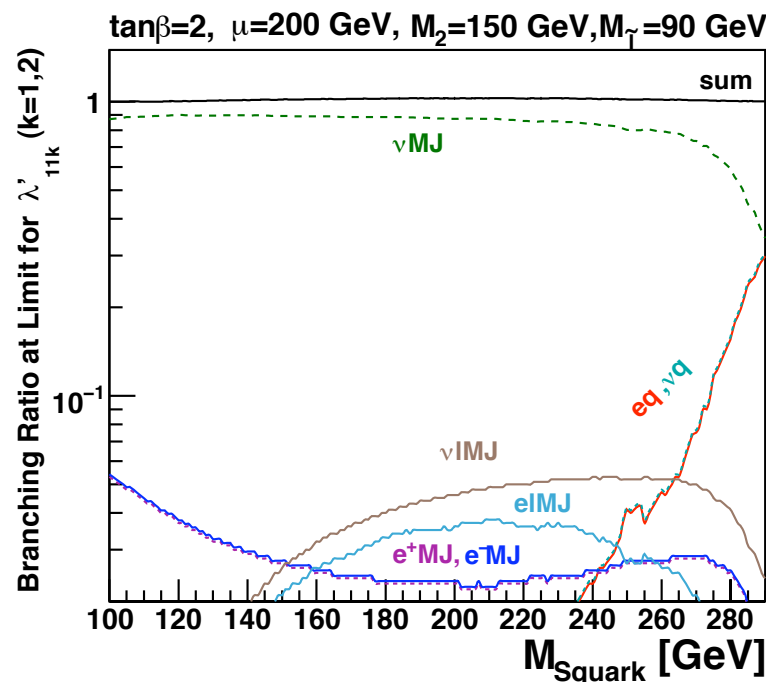
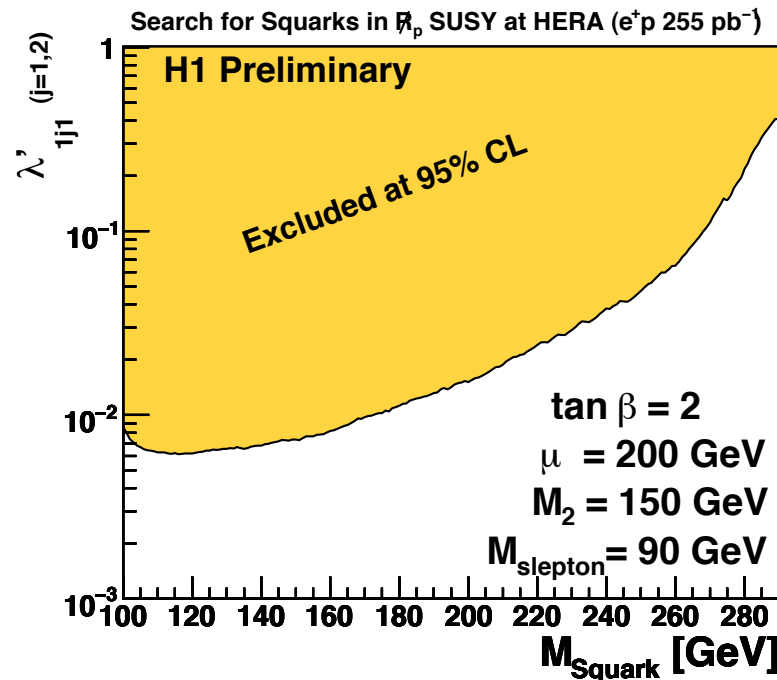
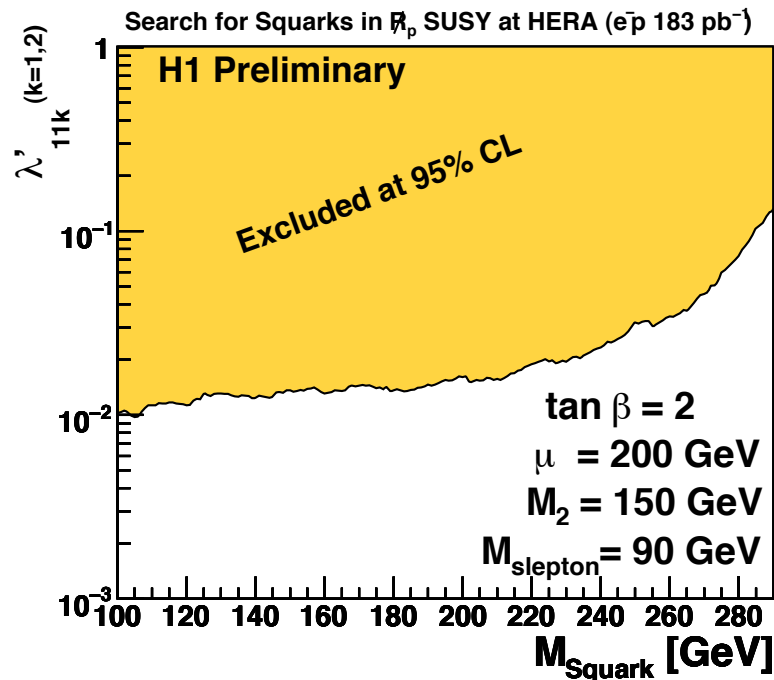
μ - **mixing** term between **Higgs doublets**

M_2 - **common mass** scale of **SU(2)** sparticles

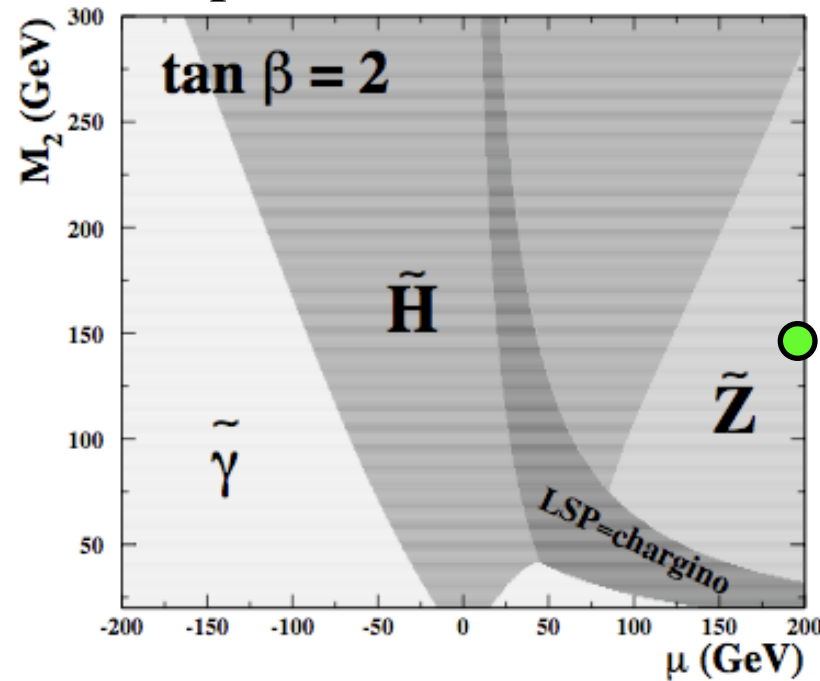
A lot of scenarios to study; masses of gauginos in cascade decays determine selection efficiencies for signal events.

MSSM example: Zinolike Neutralino Scenario

- zino dominated neutralino



Composition of Neutralino₁

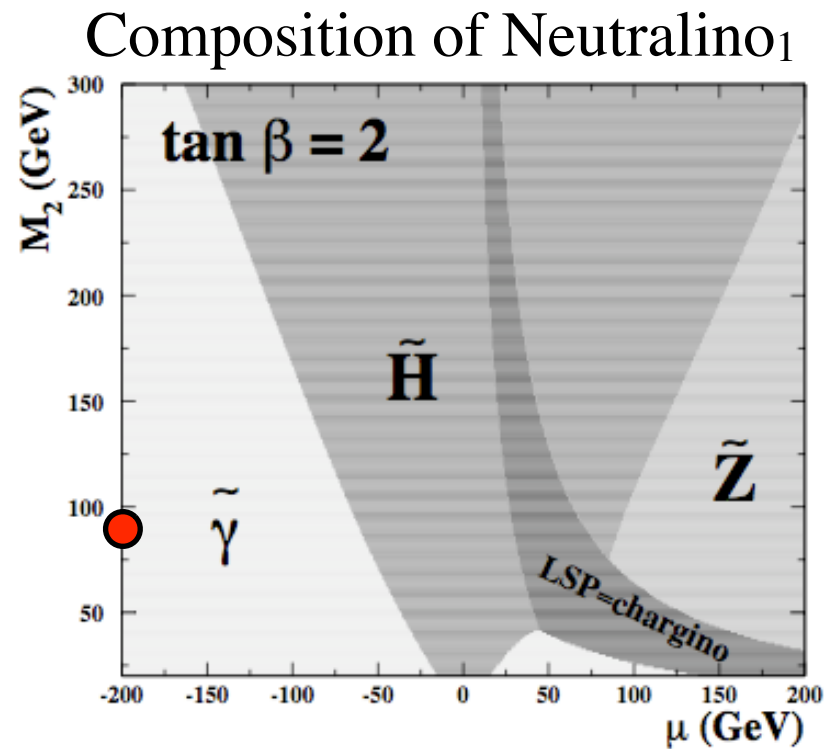
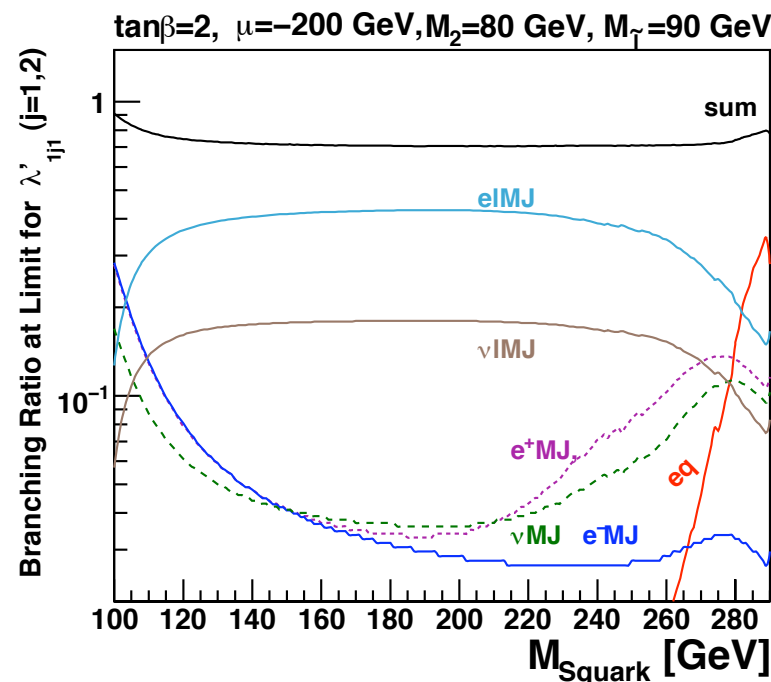
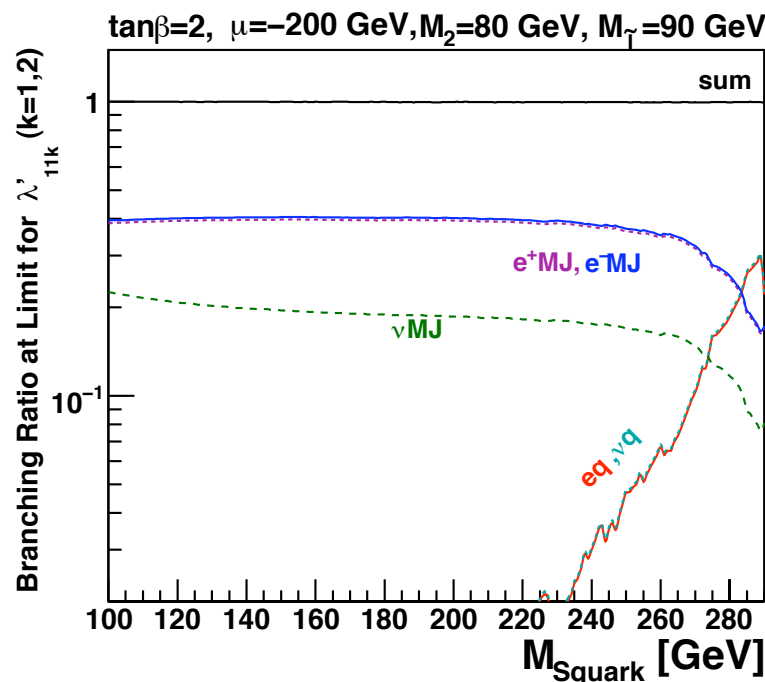
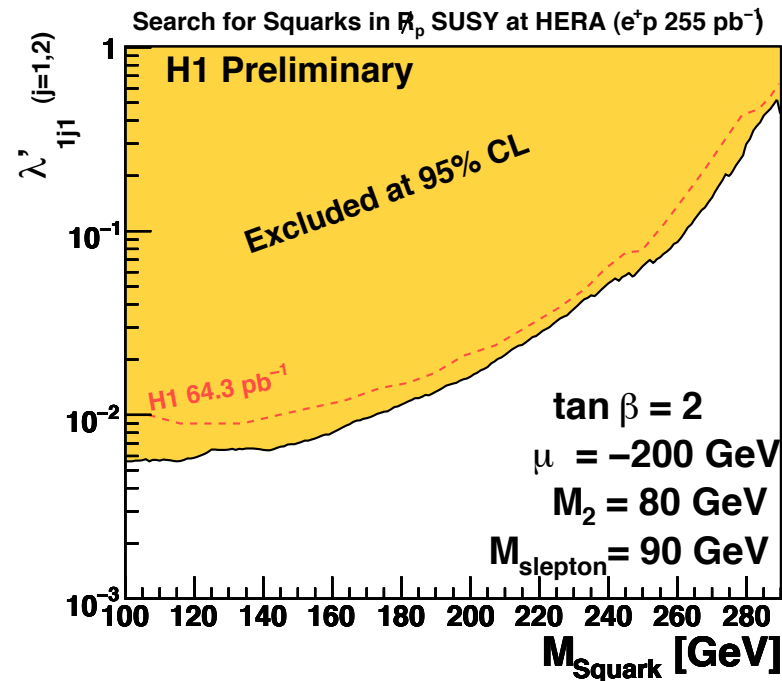
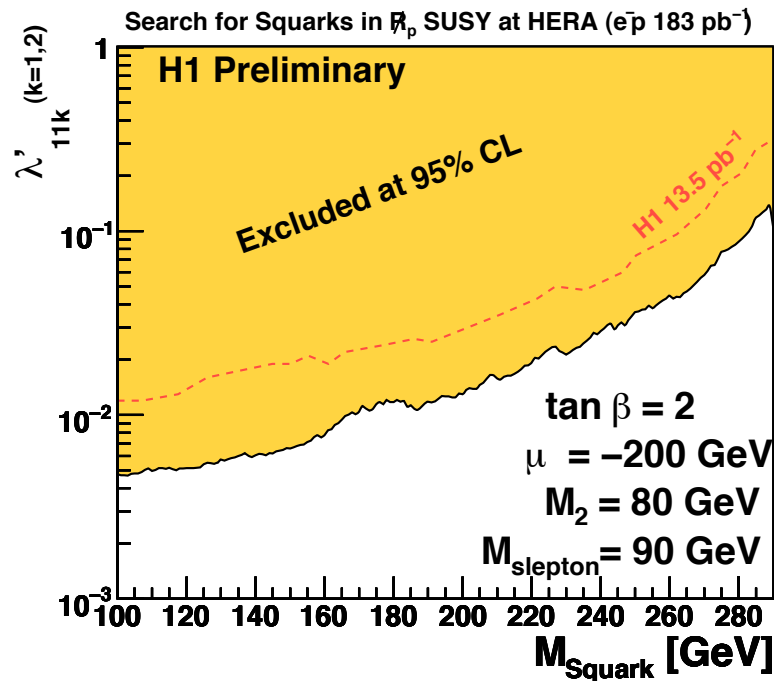


final states with neutrinos dominate limit calculation

$\mu, \tan \beta, M_2$
 determine REWSB

MSSM example: Photinolike Neutralino Scenario

- photino dominated neutralino



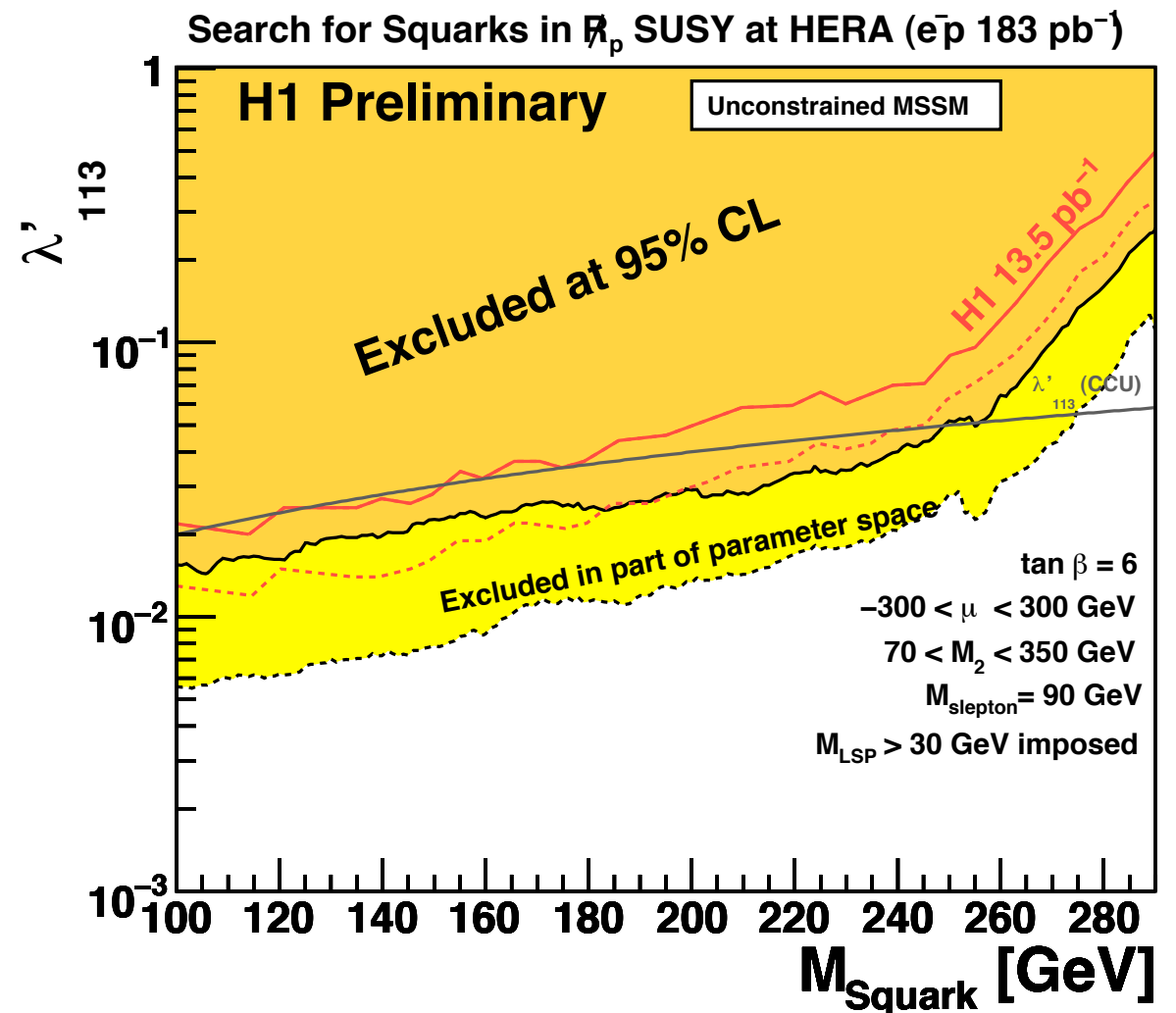
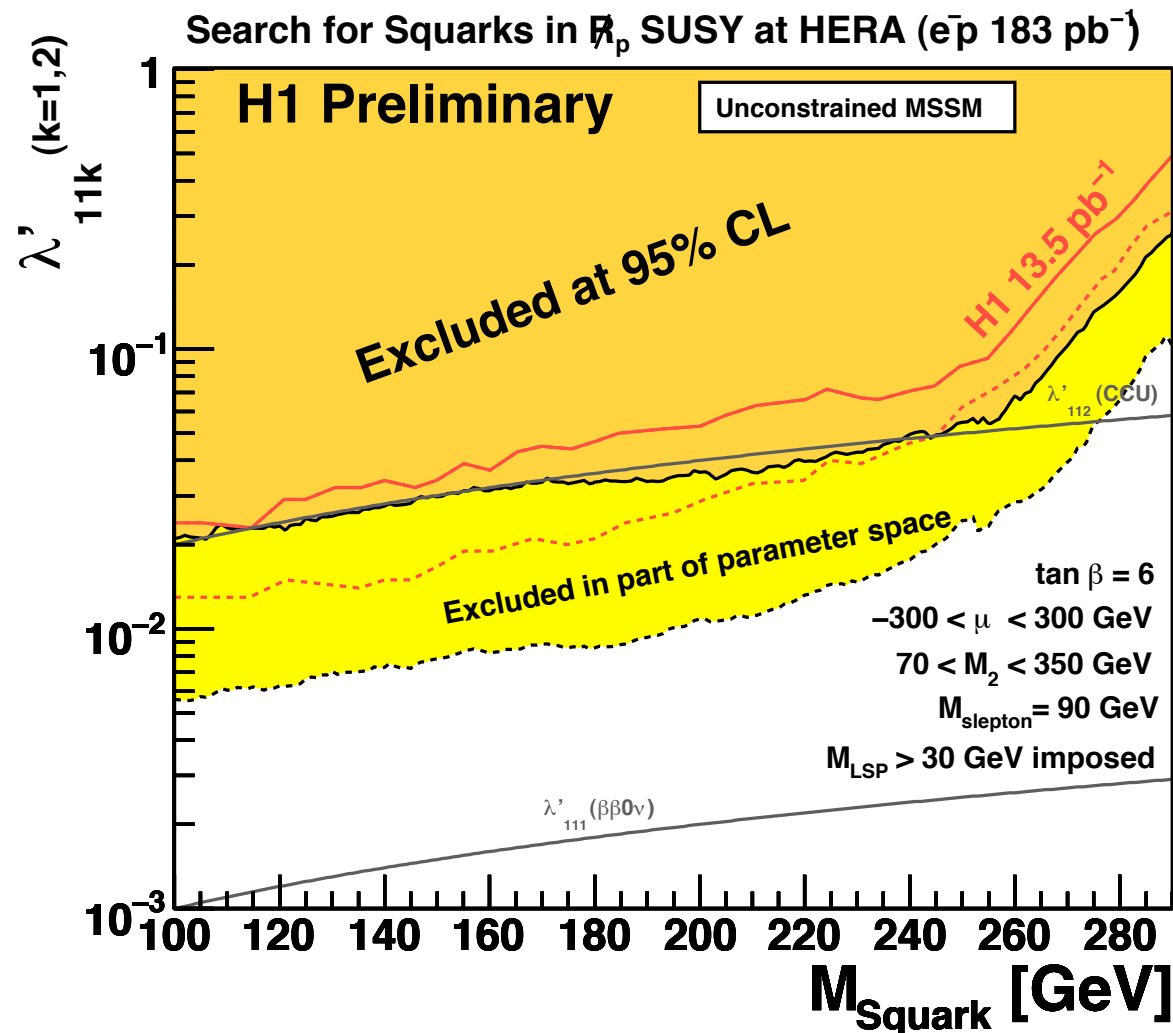
final states with electrons dominate limit calculation

$\mu, \tan \beta, M_2$ determine REWSB

MSSM full Parameter Scan: Down-type Squarks

$$\tilde{d}_R, \tilde{s}_R$$

$$\tilde{b}_R$$



for a Yukawa coupling of electromagnetic coupling strength:

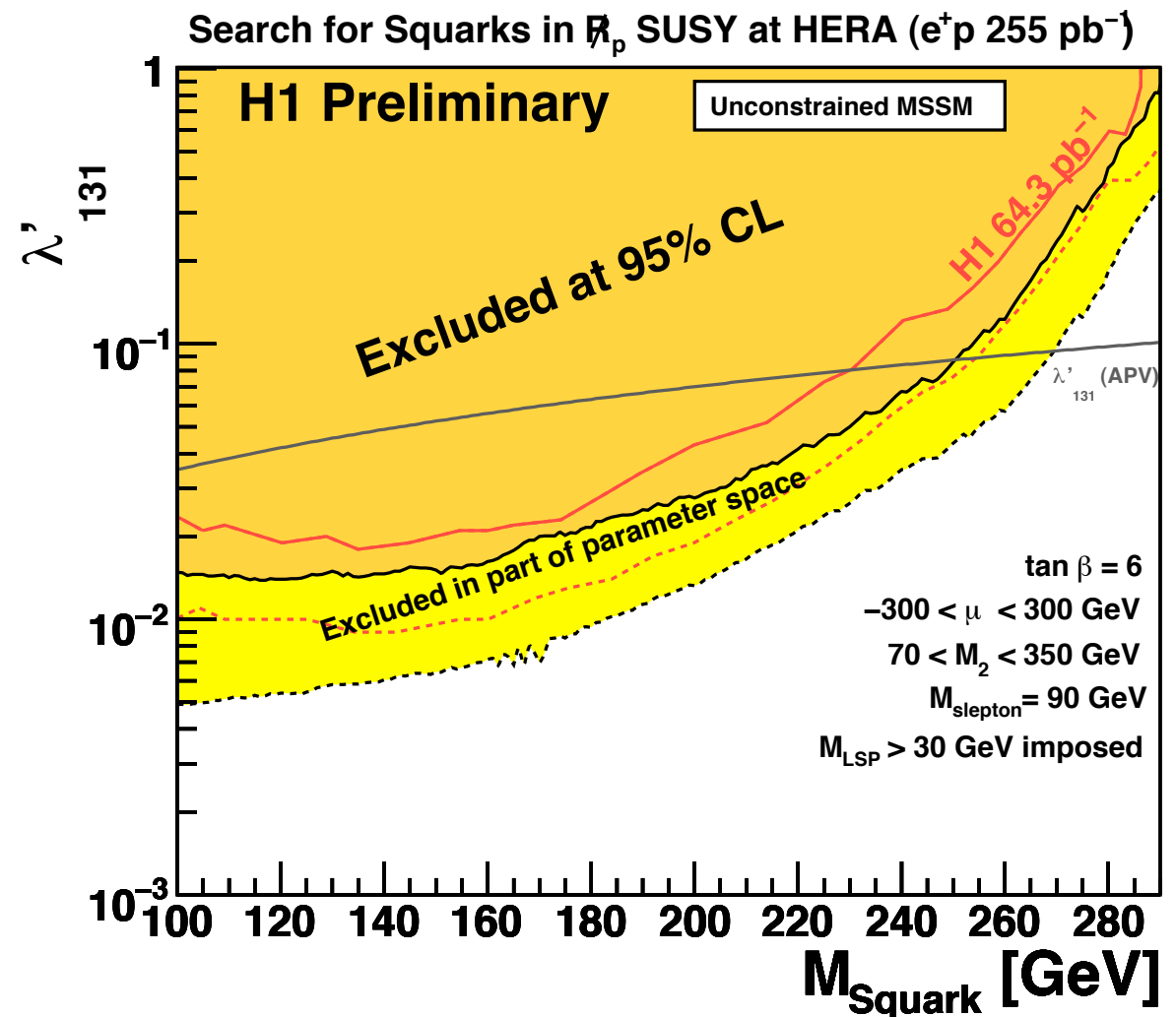
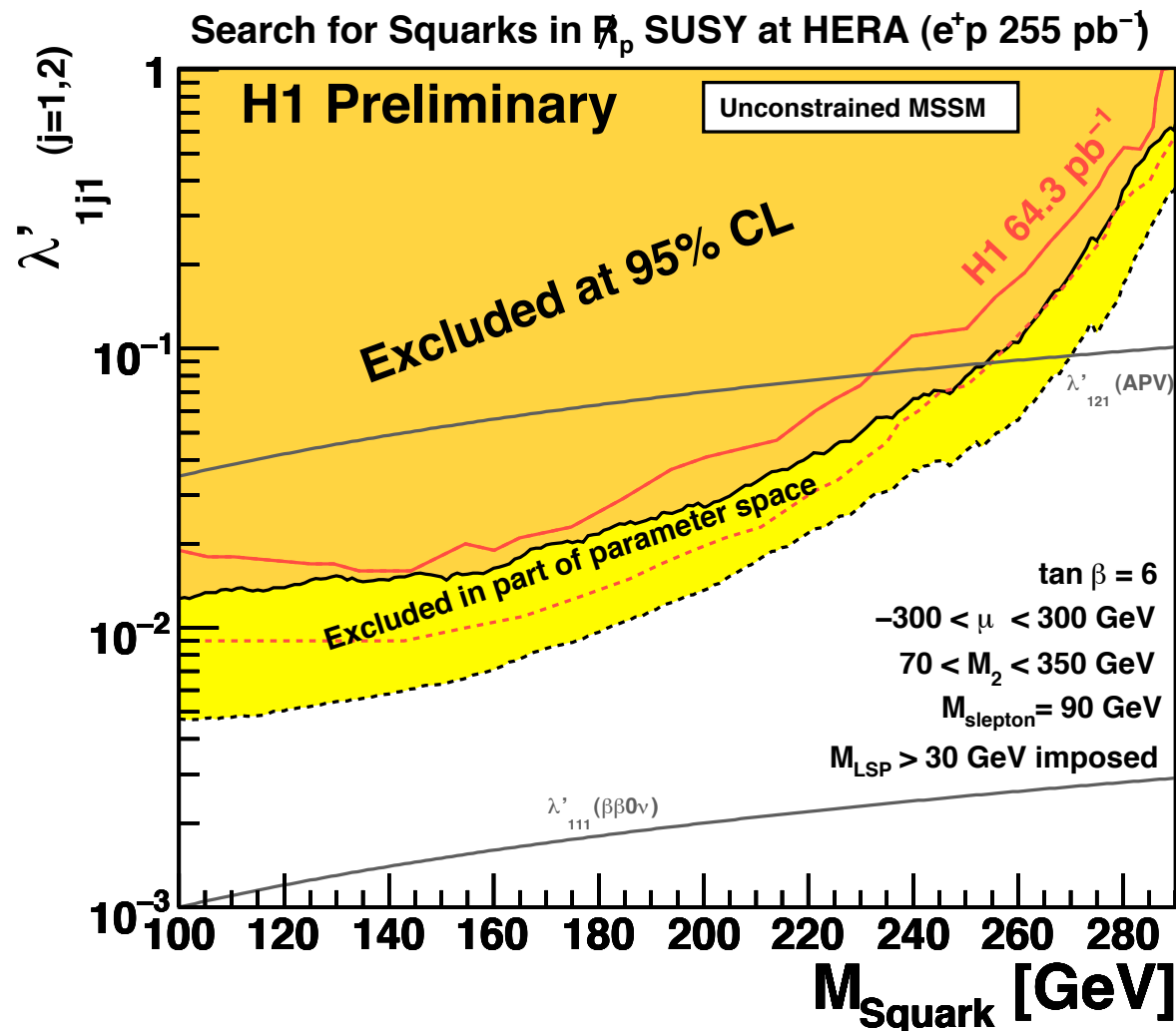
$$\lambda'_{11k} = \sqrt{4\pi\alpha_{em}} = 0.3$$

Down-type squarks up to **290 GeV** are excluded at 95% CL

MSSM full Parameter Scan: Up-type Squarks

$$\tilde{u}_L, \tilde{c}_L$$

$$\tilde{t}_L$$



for a Yukawa coupling of electromagnetic coupling strength:

$$\lambda'_{1j1} = \sqrt{4\pi\alpha_{em}} = 0.3$$

Up-type squarks up to **275 GeV** are excluded at 95% CL

minimal Supergravity Model (mSUGRA)

breaking mechanism yields complete SUSY model:

- assumption of unification at GUT scale and REWSB
- complete model via evolution of RGE's
- only 5 parameter determine masses and mixings

m_0 - common mass of scalar (**spin 0**) sparticles

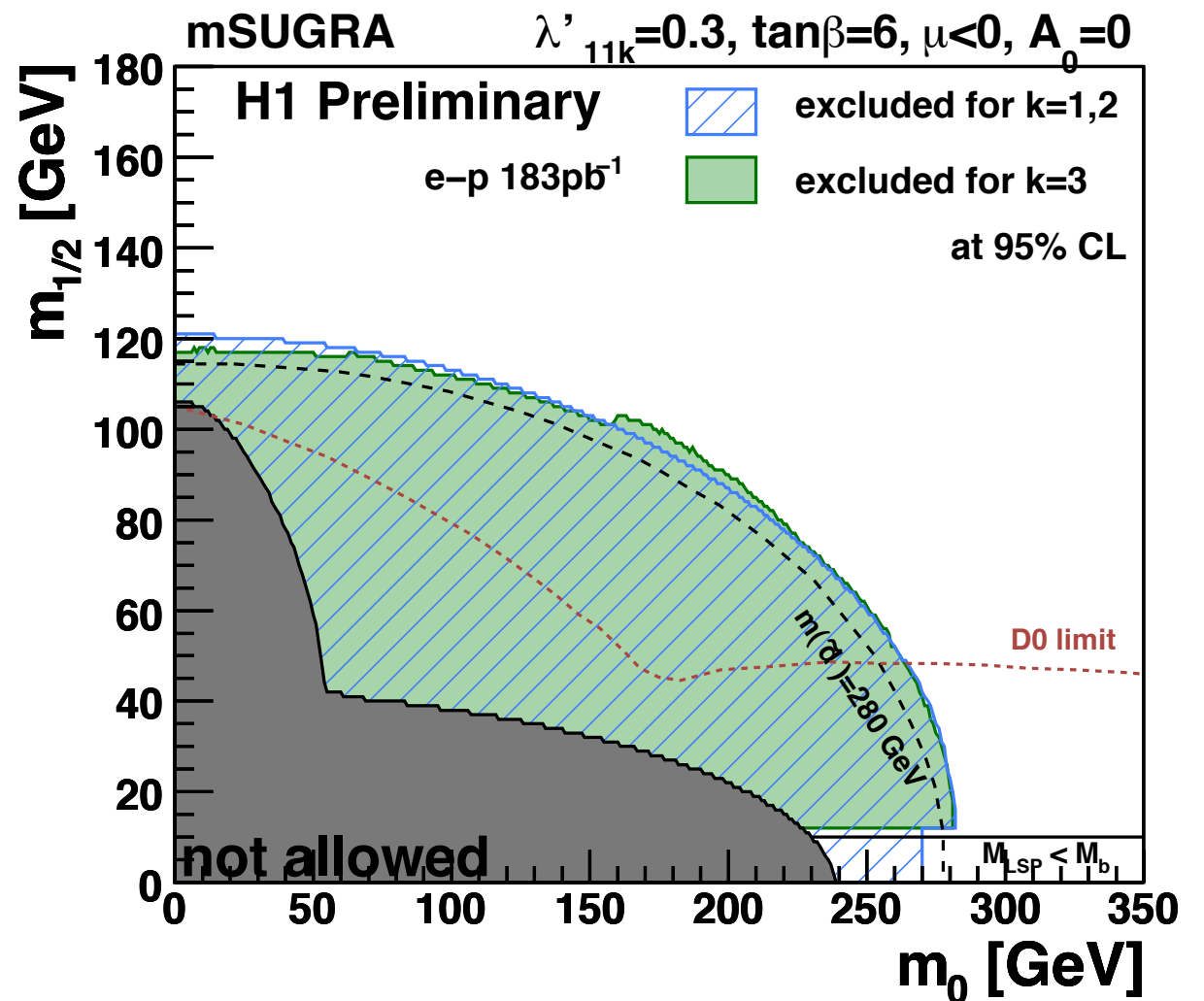
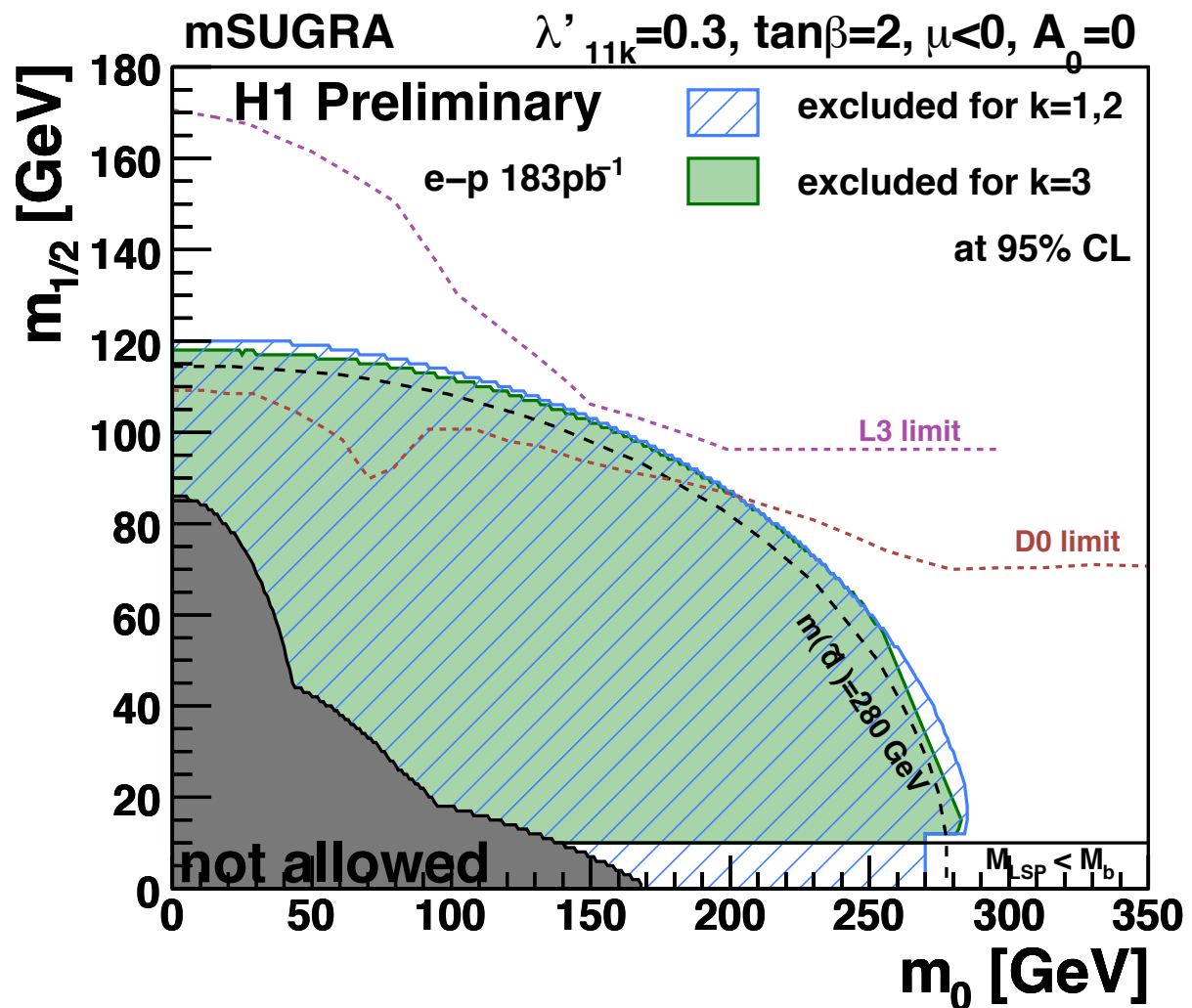
$m_{1/2}$ - common mass of fermionic (**spin 1/2**) sparticles

$\tan \beta$ - **ratio** of the two Higgs **VEV's**

$sign(\mu)$ - **sign of** mixing term between **Higgs doublets**

A_0 - common **trilinear coupling**

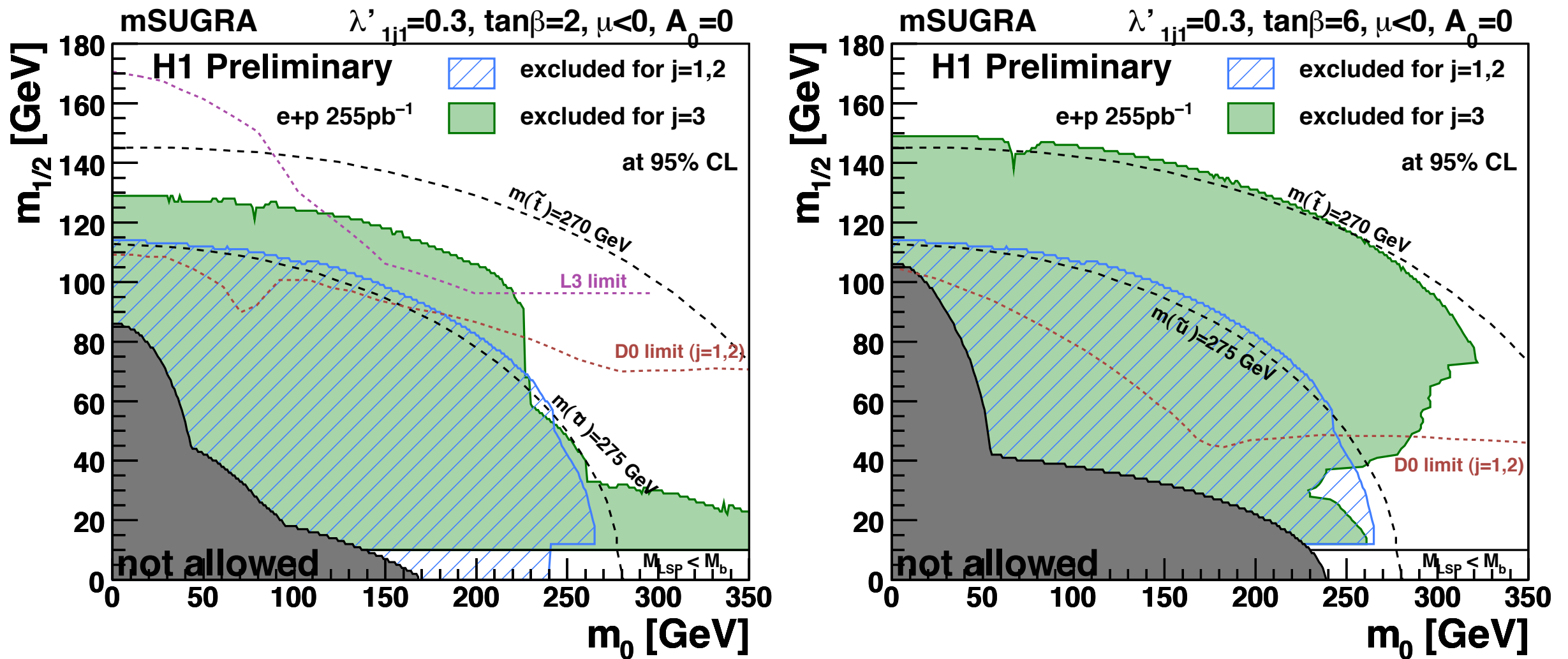
mSUGRA - Down-type Squarks



assuming a coupling strength: $\lambda'_{11k}=0.3$

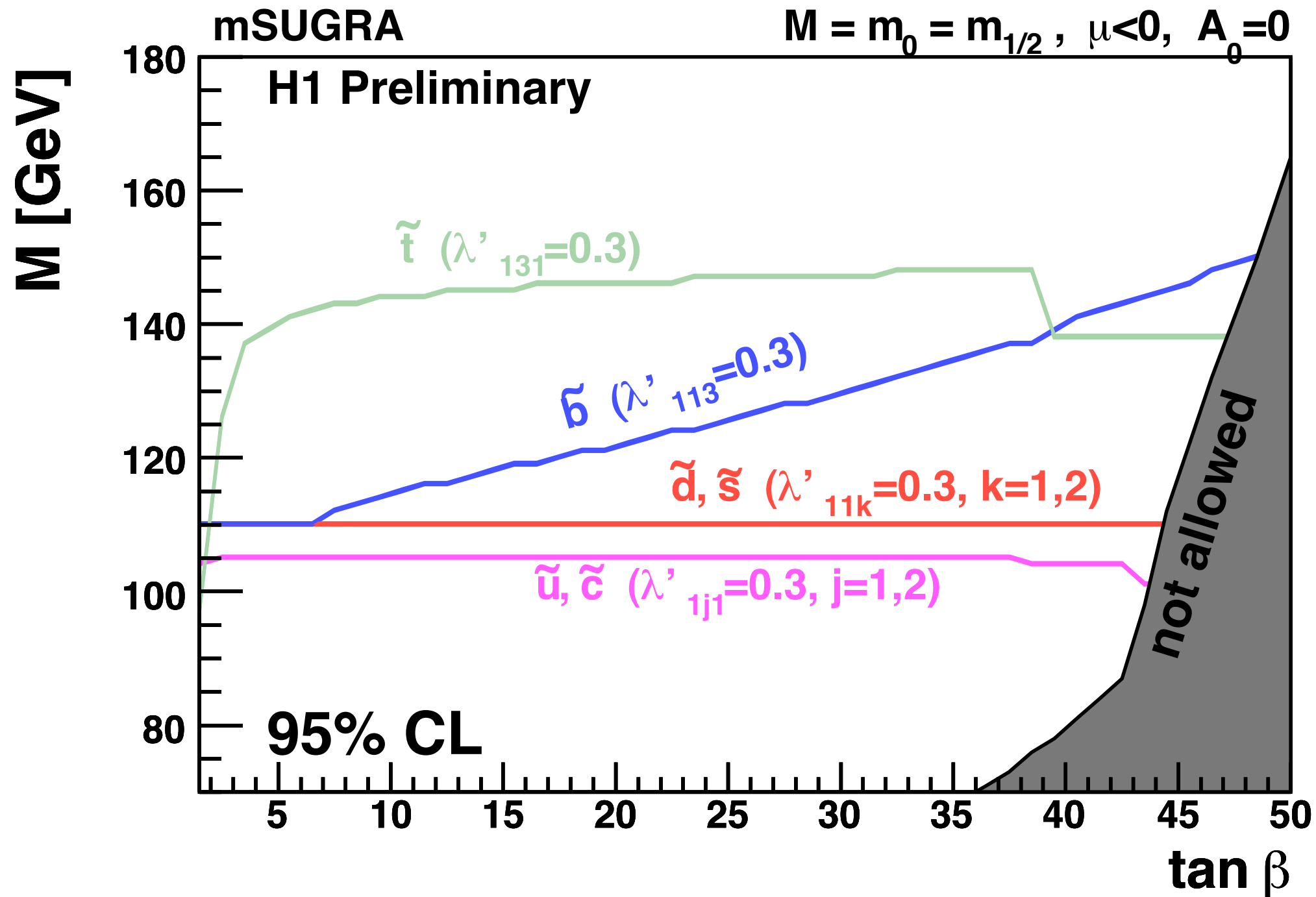
the indicated region can be excluded at 95% CL

mSUGRA - Up-type Squarks



assuming a coupling strength: $\lambda'_{ij}=0.3$
 the indicated region can be excluded at 95% CL

Dependence of mSUGRA limits on $\tan \beta$



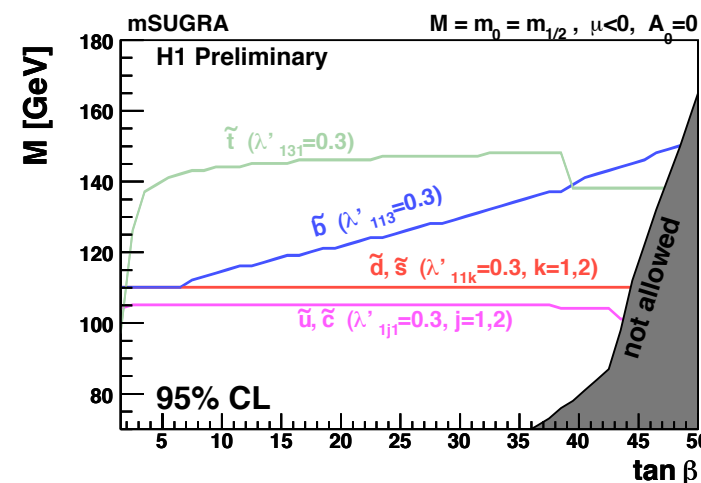
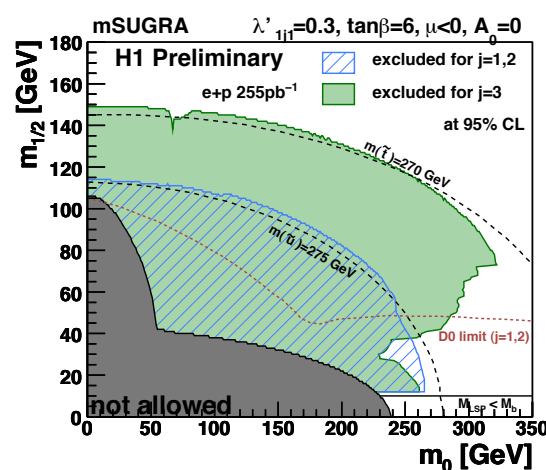
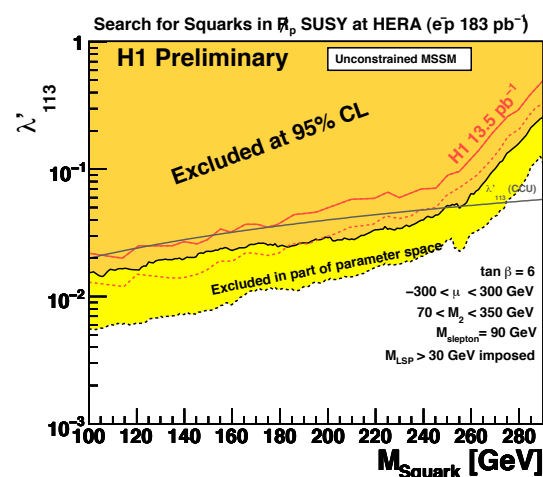
Strong mixing between stop (sbottom) states at higher $\tan \beta$ leads to dependence for third generation squarks.

Summary

- RPV SUSY searched for in complete data set of the H1 experiment at HERA
 - No significant deviation from SM expectation observed!
 - Interpretation of search results in phenomenological MSSM and mSUGRA model.
- For a Yukawa coupling of electromagnetic strength

$$\lambda'_{1j1}, \lambda'_{11k} = 0.3$$

- Up-type Squarks can be excluded up to **275 GeV**
- Down-type Squarks can be excluded up to **290 GeV**

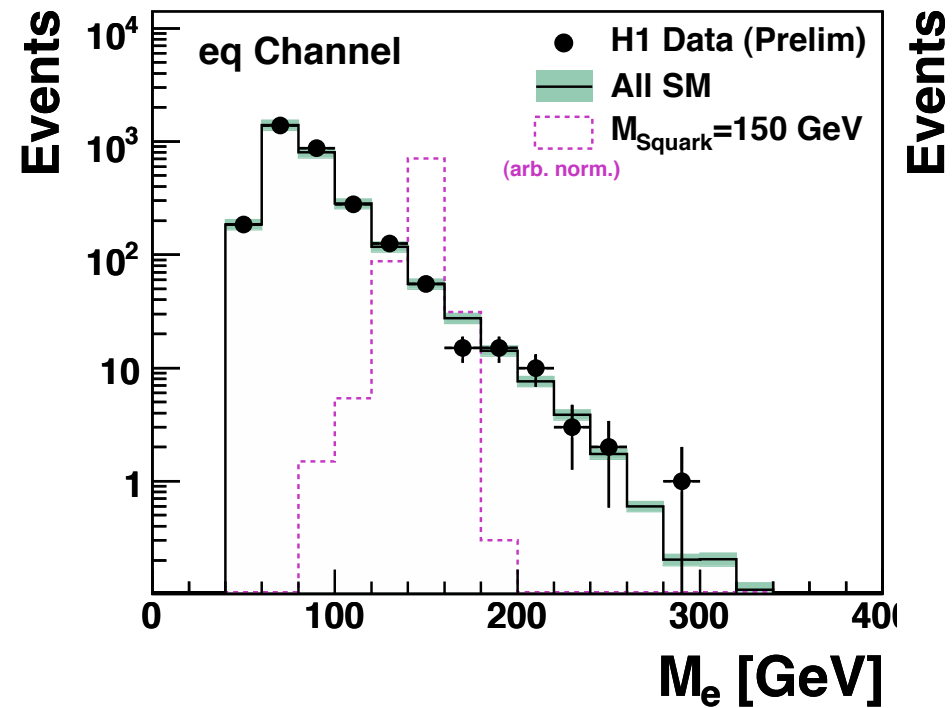


at 95% CL.

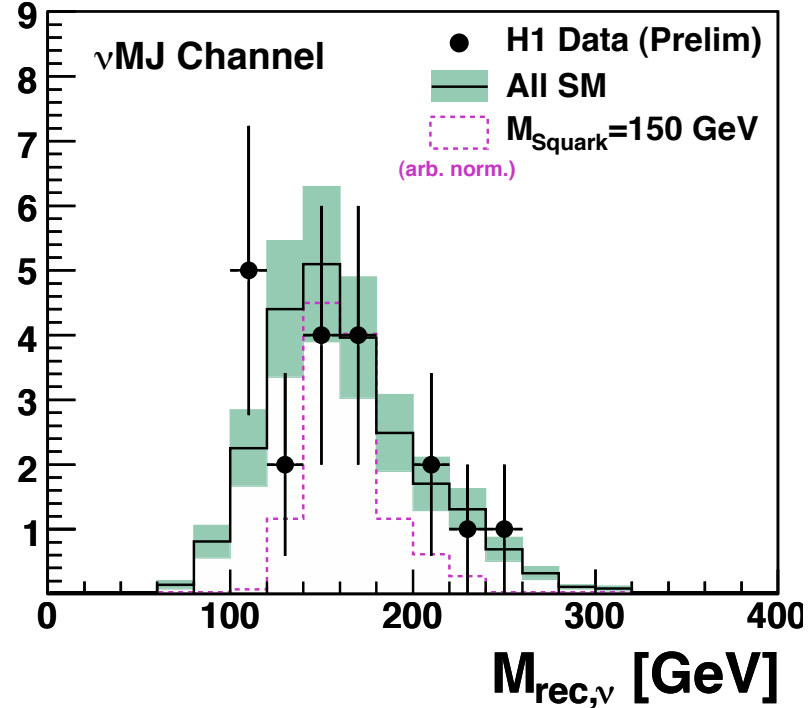
BACKUP

Mass Distributions (e+p 255pb⁻¹)

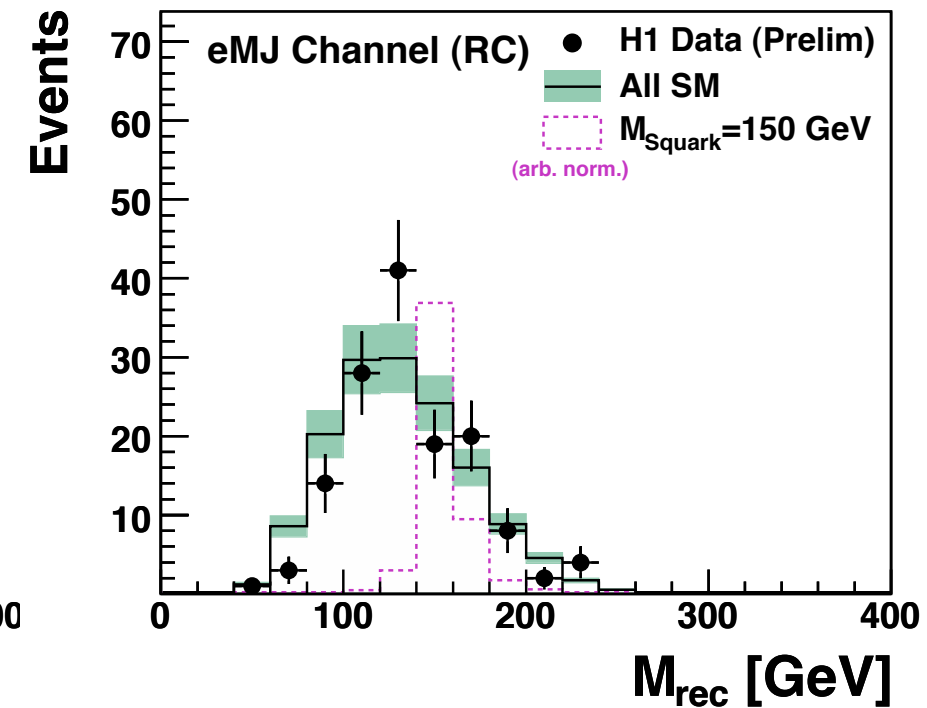
Search for Squarks in \tilde{R}_p SUSY at HERA(e+p, 255 pb⁻¹)



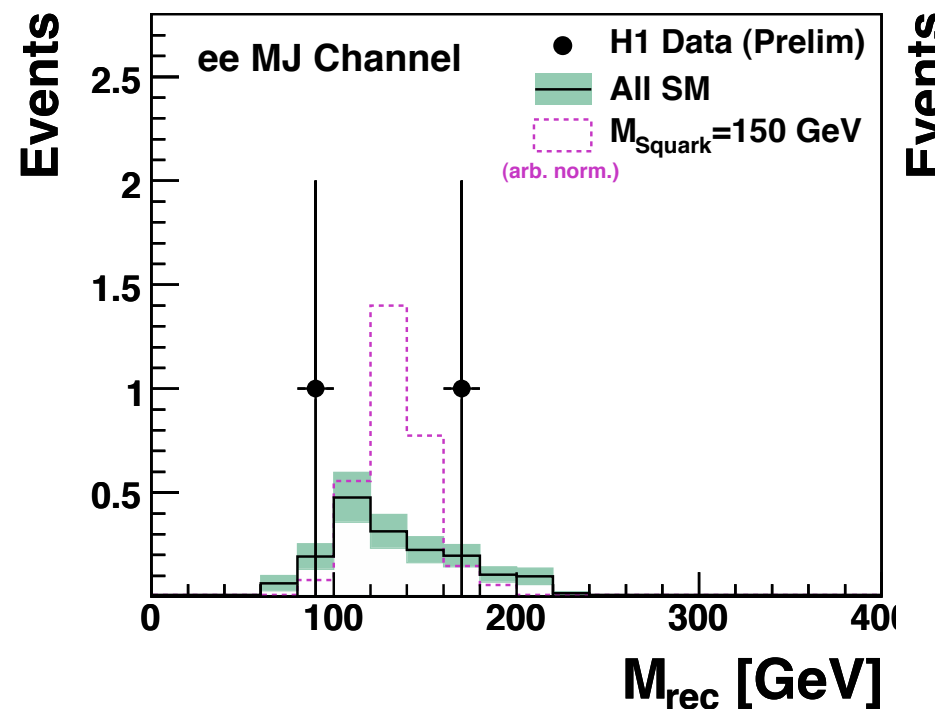
Search for Squarks in \tilde{R}_p SUSY at HERA(e+p, 255 pb⁻¹)



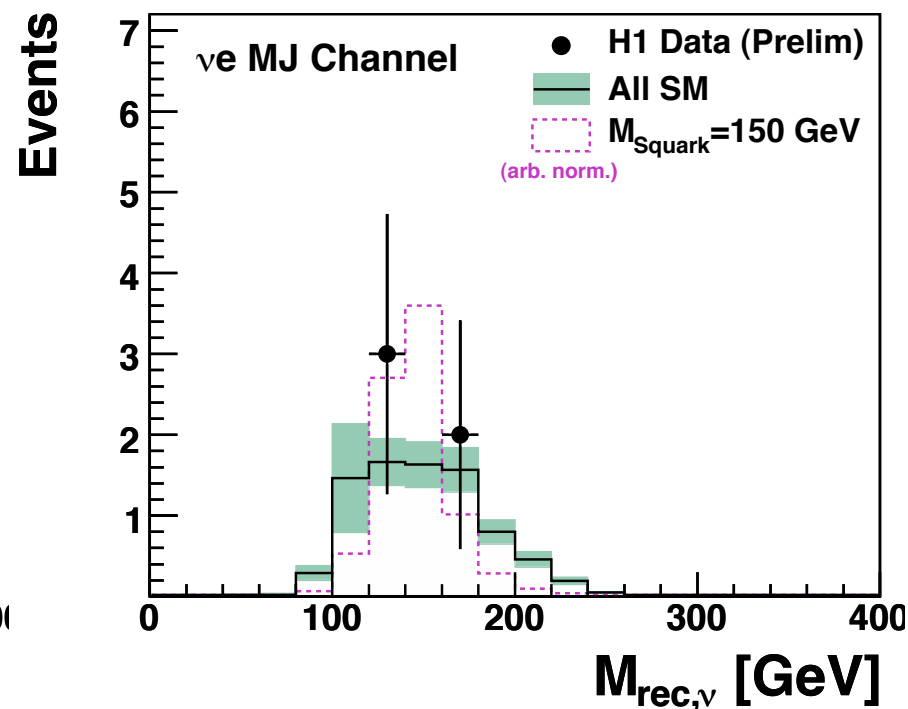
Search for Squarks in \tilde{R}_p SUSY at HERA(e+p, 255 pb⁻¹)



Search for Squarks in \tilde{R}_p SUSY at HERA(e+p, 255 pb⁻¹)



Search for Squarks in \tilde{R}_p SUSY at HERA(e+p, 255 pb⁻¹)



Search for Squarks in \tilde{R}_p SUSY at HERA(e+p, 255 pb⁻¹)

