

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

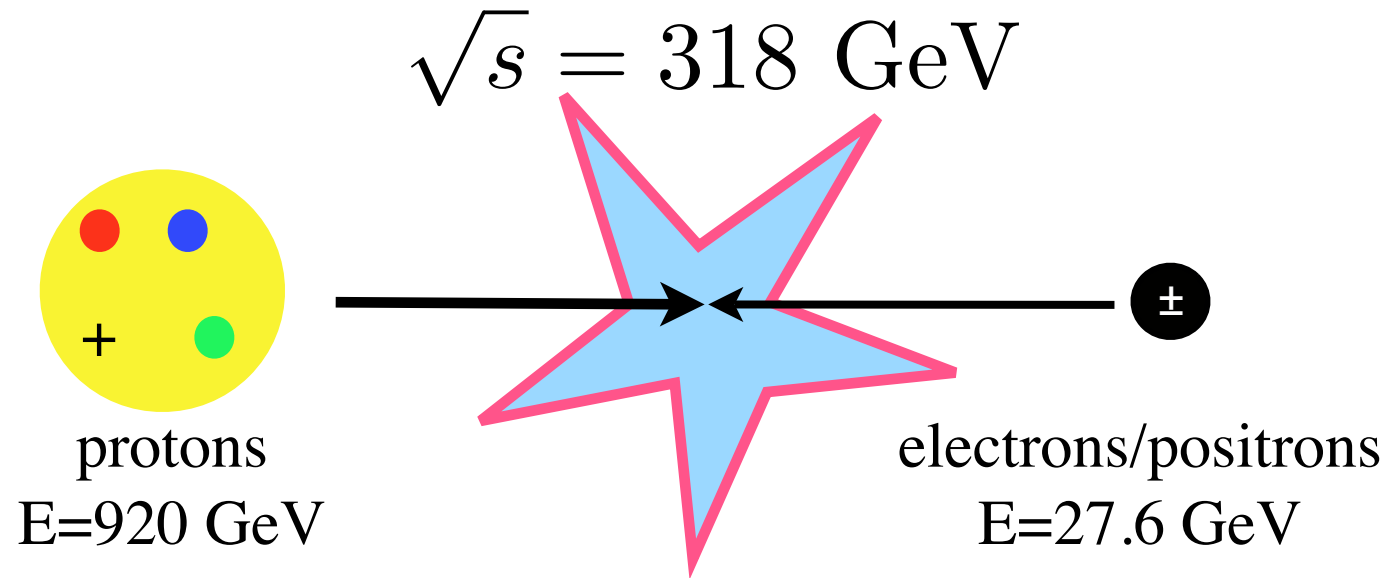


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on behalf of HI collaboration





# HERA Lepton Hadron Collider



full HERA luminosity:

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

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

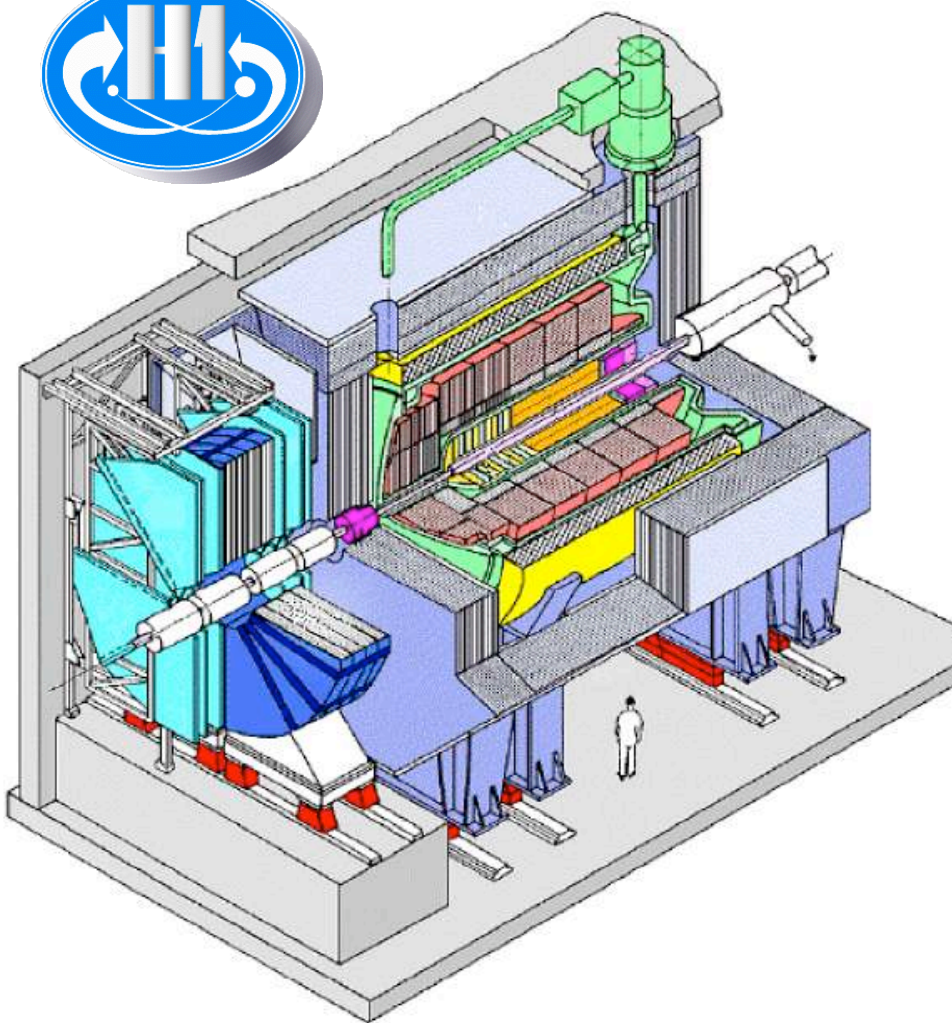
increase as compared to  
previous H1 publication<sup>1</sup>:

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

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

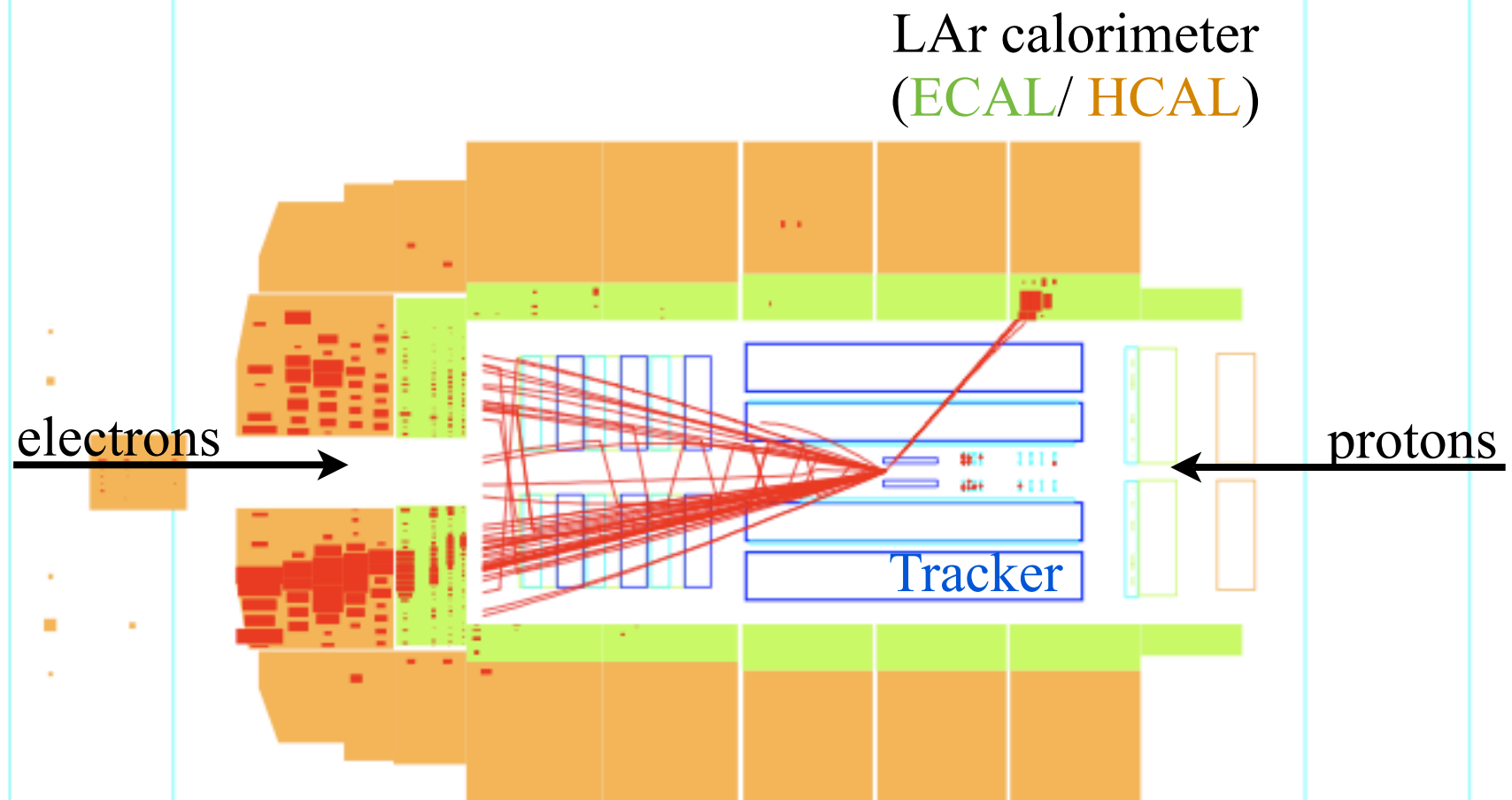
<sup>1</sup>Search for Squark Production in R-Parity Violating Supersymmetry at HERA,  
Eur. Phys. J. C36:425-440,2004 (hep-ex/0403027)

# The H1 Experiment at HERA



“forward” direction

muon system



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

good reconstruction of hadronic final state via energy flow algorithm



# Squark Production at HERA

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

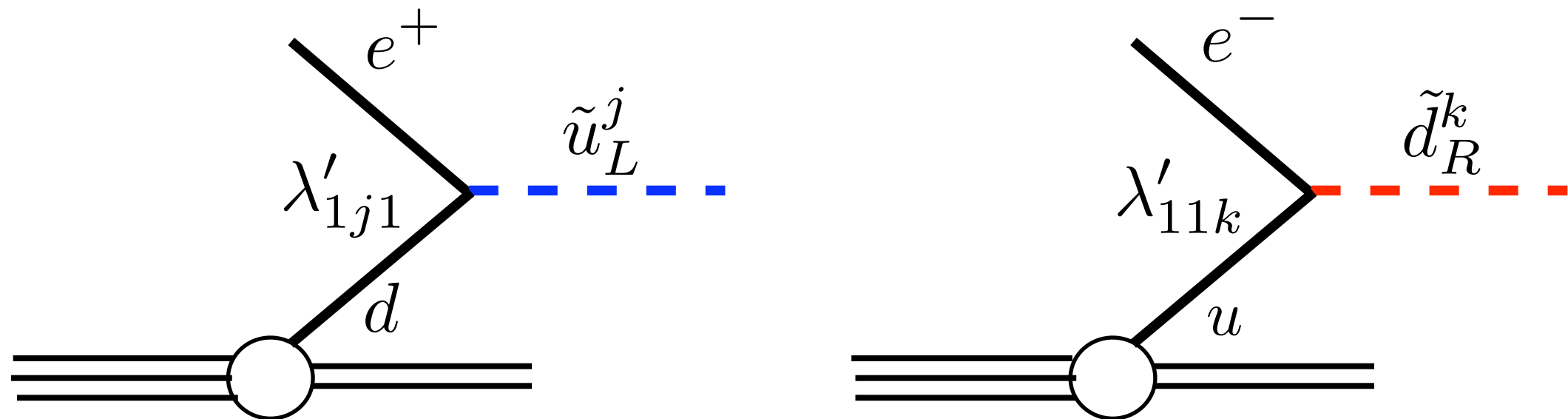
R-Parity **Violating** Superpotential

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

$$W_R = \frac{1}{2} \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} \textcolor{blue}{L}_i \textcolor{red}{Q}_j \textcolor{green}{\bar{D}}_k + \frac{1}{2} \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

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

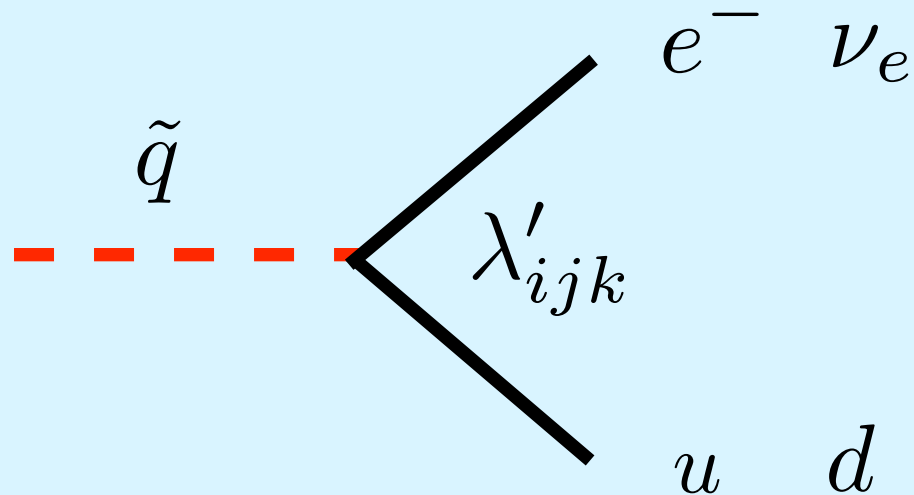
**resonant production of single squarks in ep-collisions**



◆ squark masses up to  $\sqrt{s}$  accessible

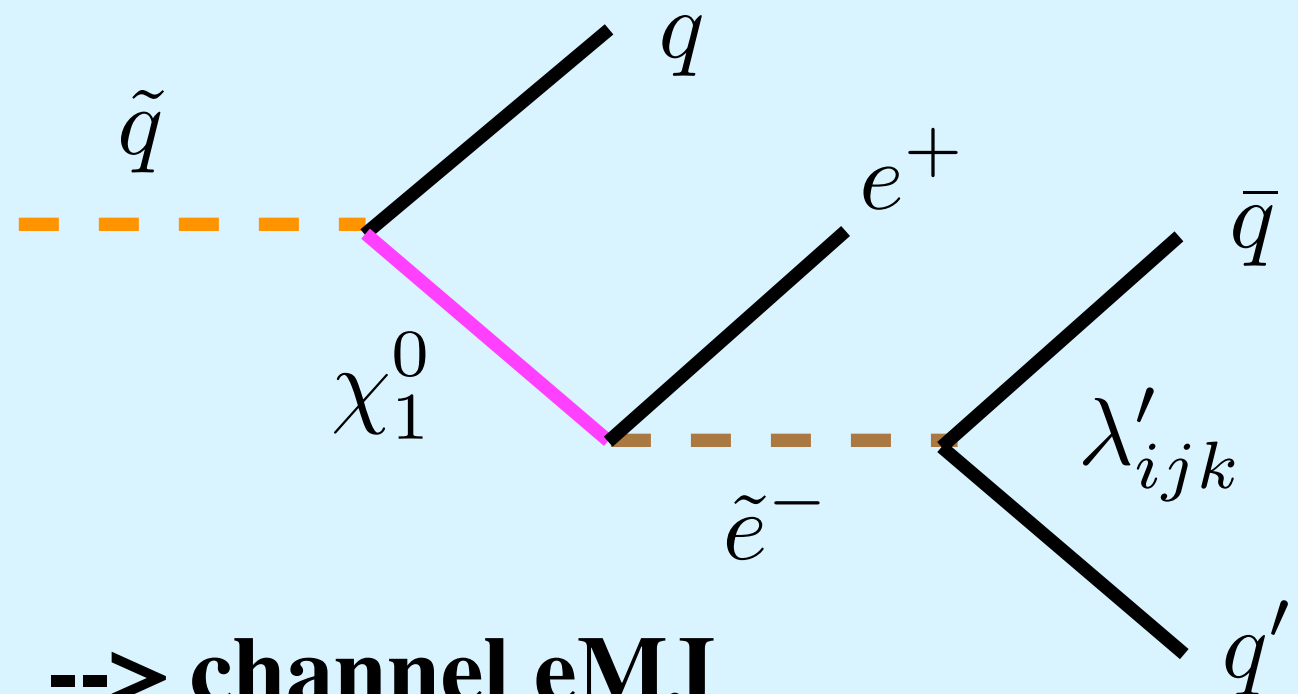
# Squark Decay - Final State Topologies

squark directly R-parity violating:



--> channel eq, vq

example for  
cascade with LSP decaying R-parity violating:



--> channel eMJ

- single  $\lambda'$  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

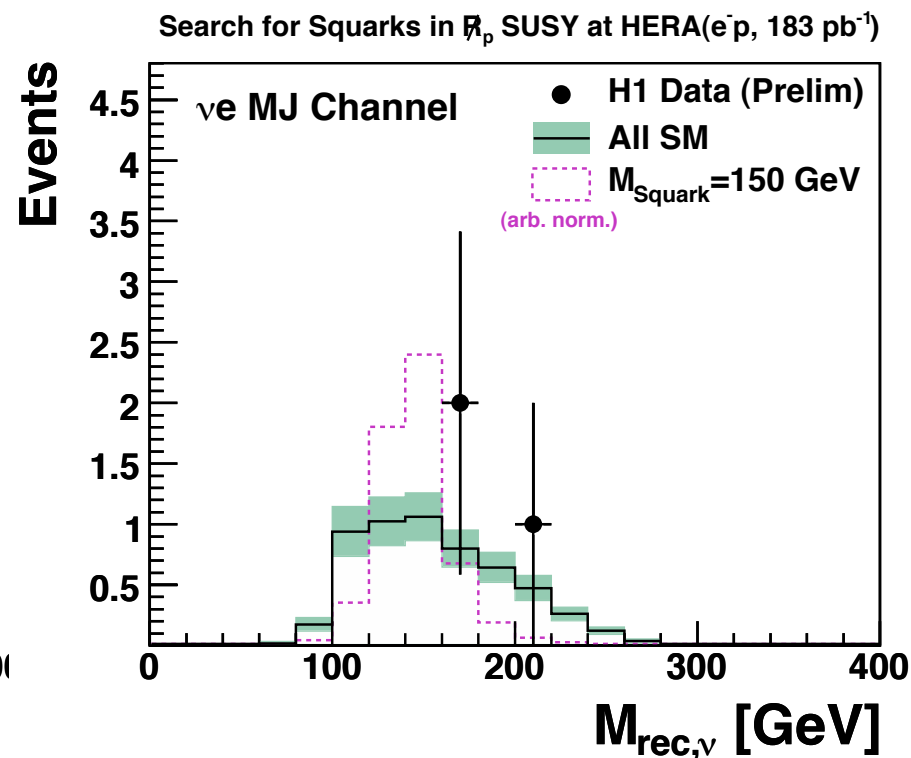
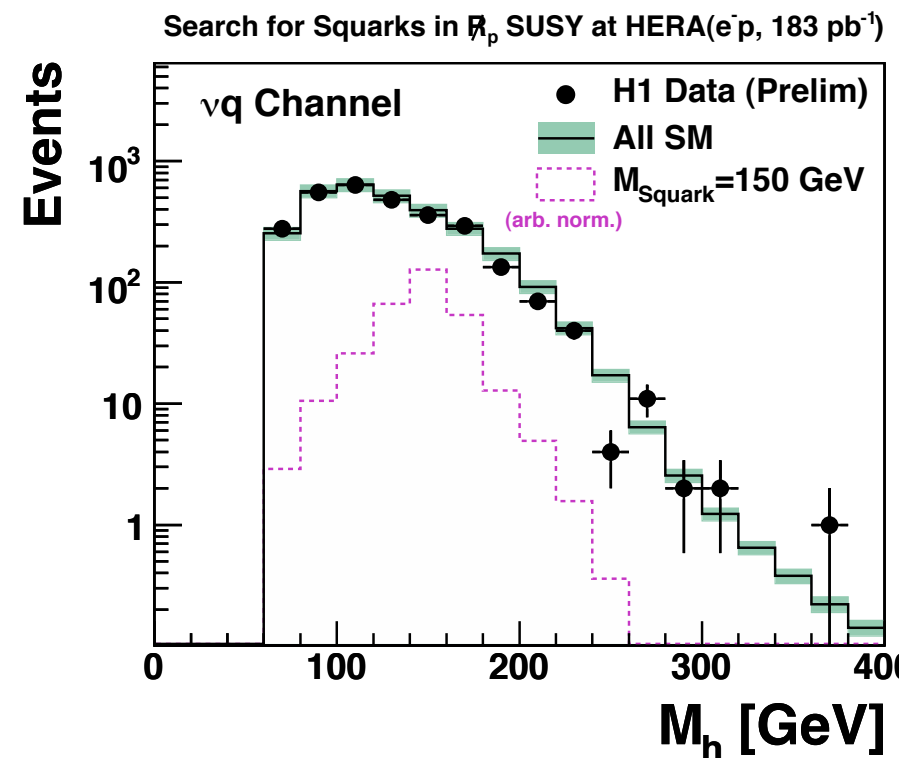
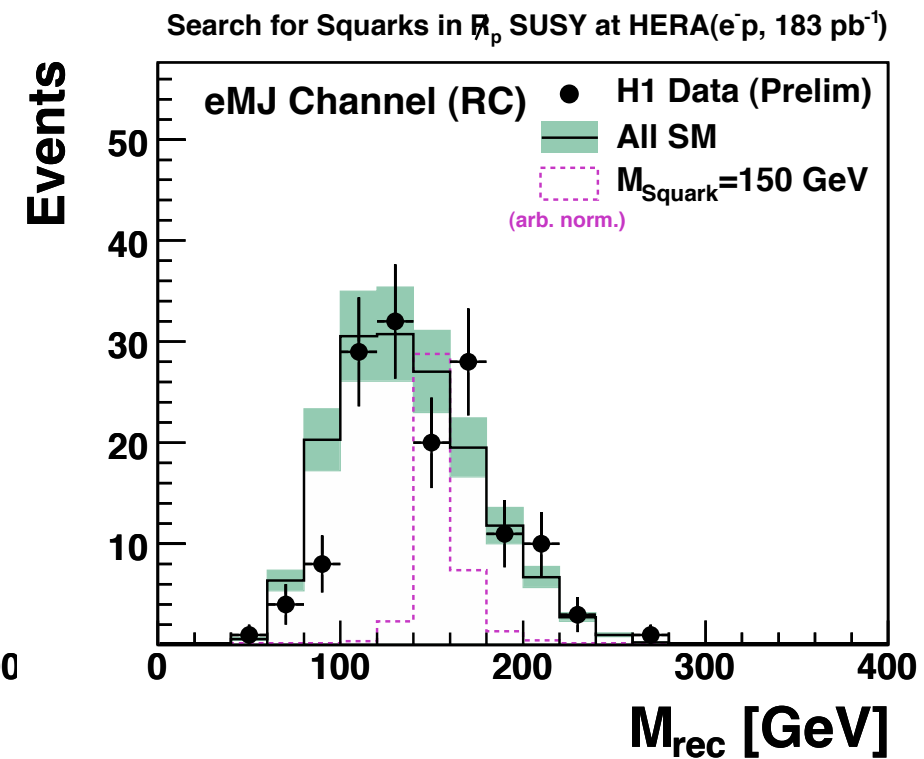
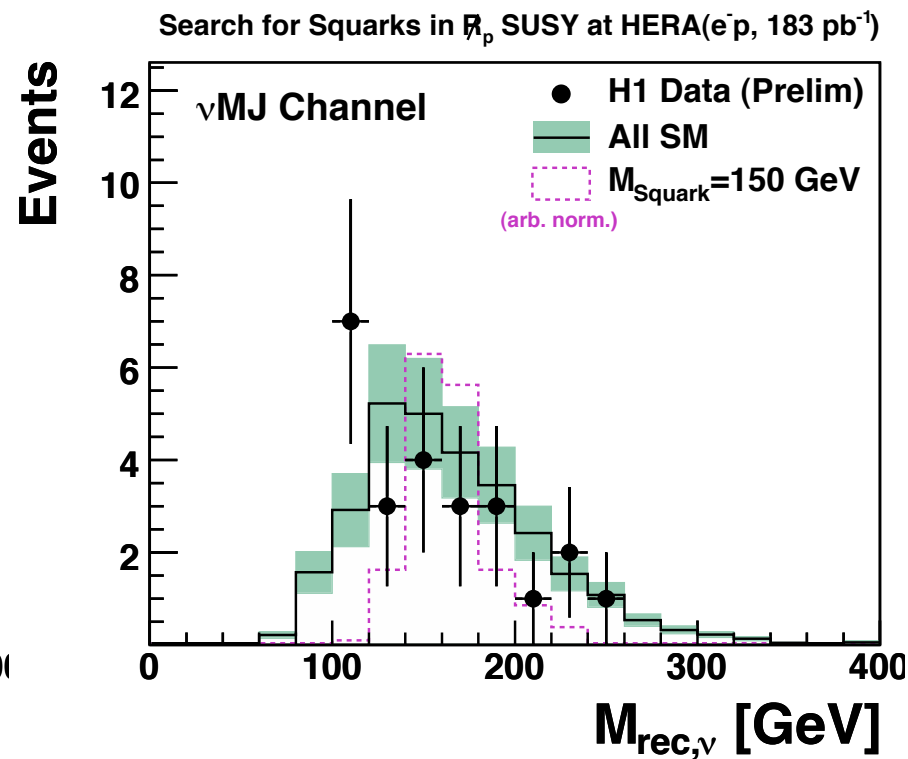
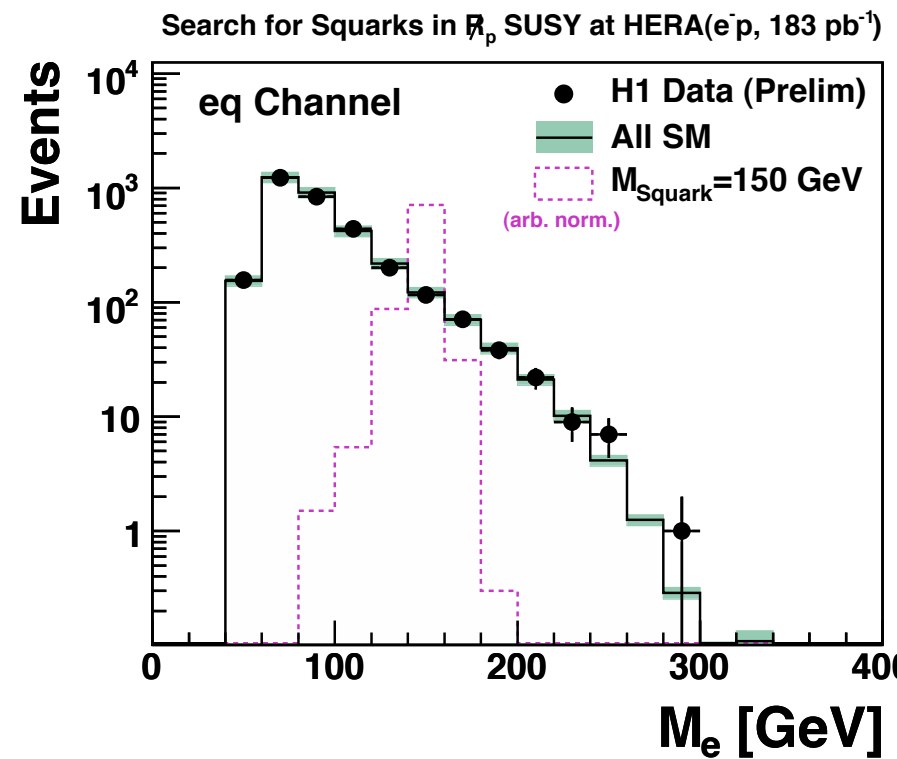
# Search Results

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	$2899 \pm 302$	3121	$3215 \pm 336$	30 – 40%
$\nu q$	-	-	2858	$2983 \pm 358$	50 – 60%
$eMJ$ (RC)	140	$145.6 \pm 21.3$	147	$157.7 \pm 23.8$	10 – 40%
$eMJ$ (WC)	1	$0.58 \pm 0.36$	0	$1.3 \pm 0.3$	5 – 20%
$\nu MJ$	19	$23.4 \pm 5.8$	24	$28.9 \pm 7.2$	5 – 15%
$eeMJ$	2	$1.7 \pm 0.5$	0	$1.5 \pm 0.5$	5 – 35%
$e\mu MJ$	0	$0.03 \pm 0.03$	0	$0.03 \pm 0.02$	5 – 15%
$\nu eMJ$	5	$8.2 \pm 2.0$	3	$5.6 \pm 1.2$	5 – 40%
$\nu\mu MJ$	0	$0.06 \pm 0.03$	0	$0.04 \pm 0.02$	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<sup>-1</sup>)



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:

- $N_{\text{Data}}$ ,  $N_{\text{SM Expectation}}$ ,  $\Delta(N_{\text{SM Expectation}})$   
(inside sliding masswindow)
- Signal selection efficiency  $\varepsilon$
- 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**

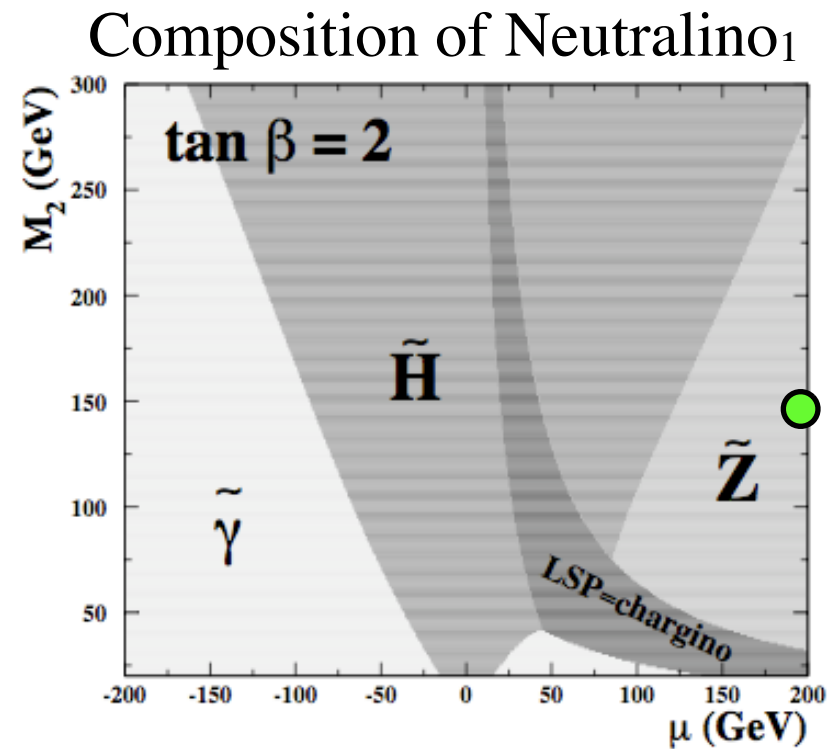
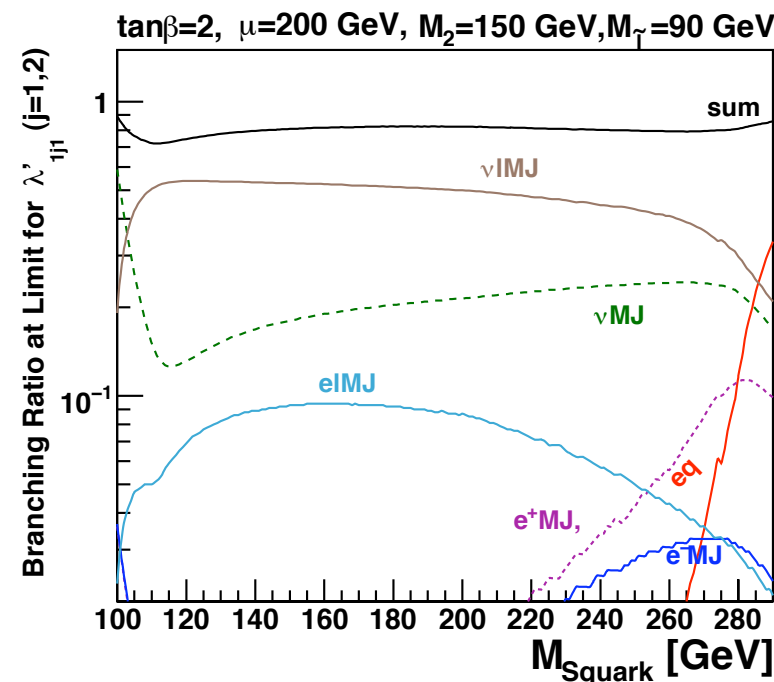
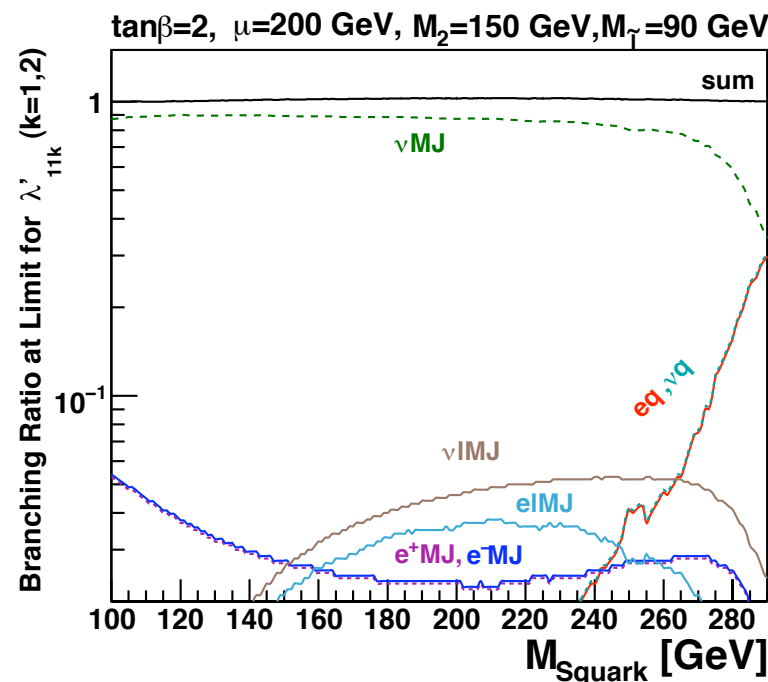
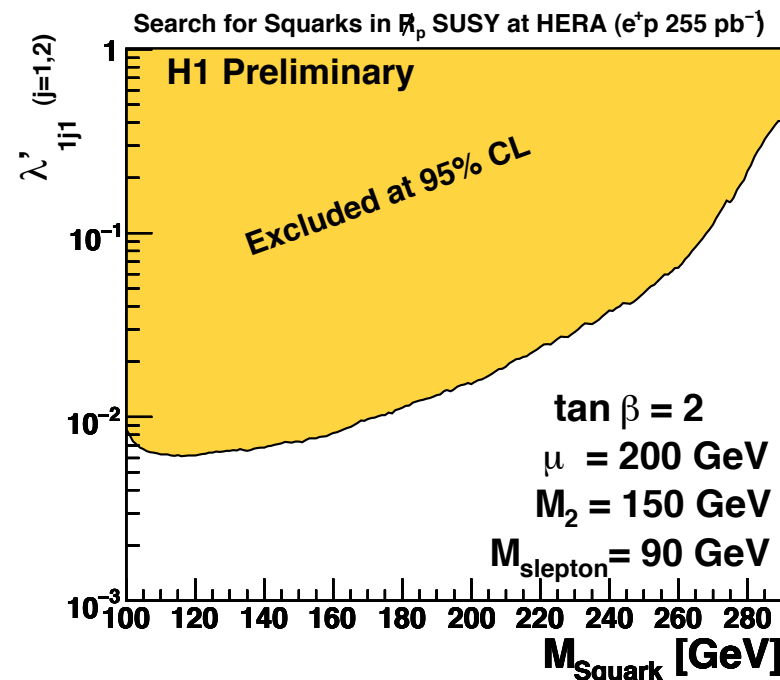
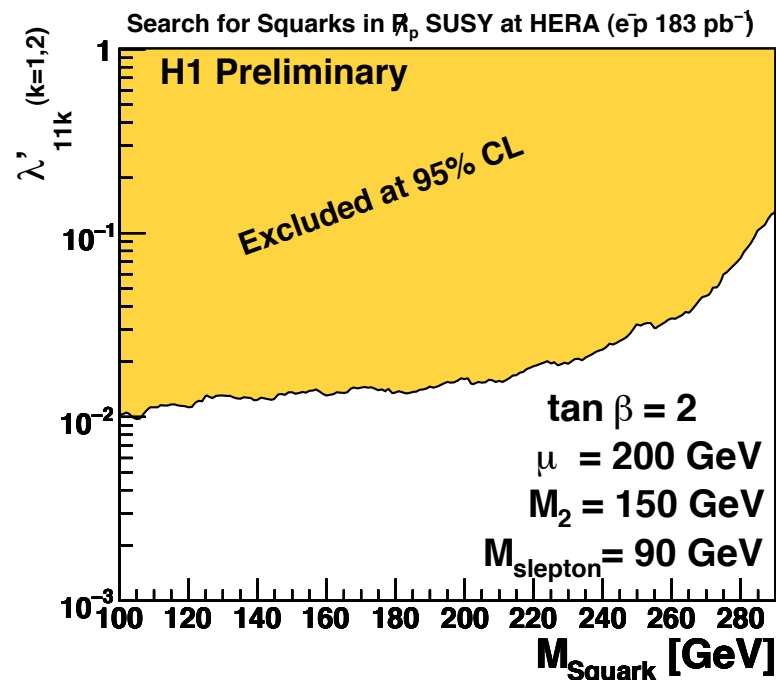
$\mu$  - **mixing** term between **Higgs doublets**

$M_2$  - **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

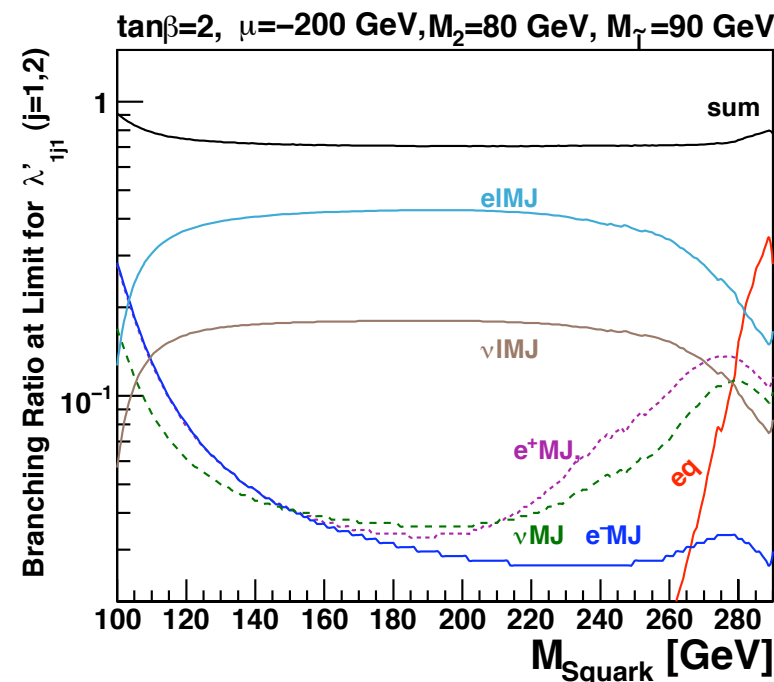
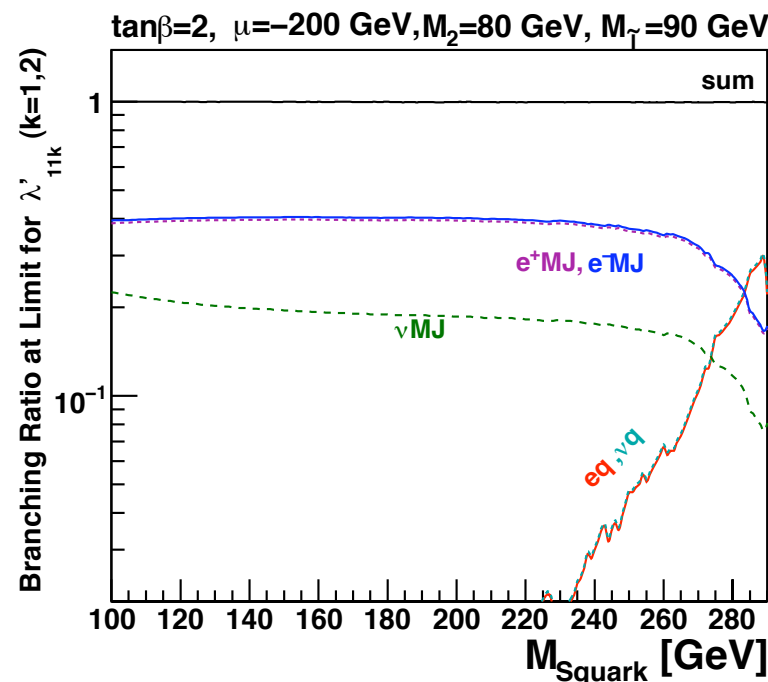
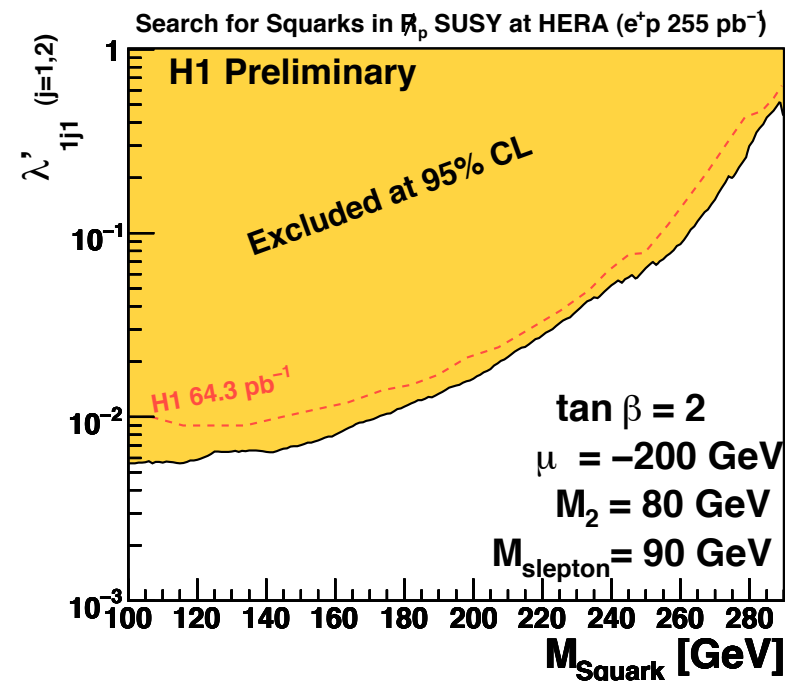
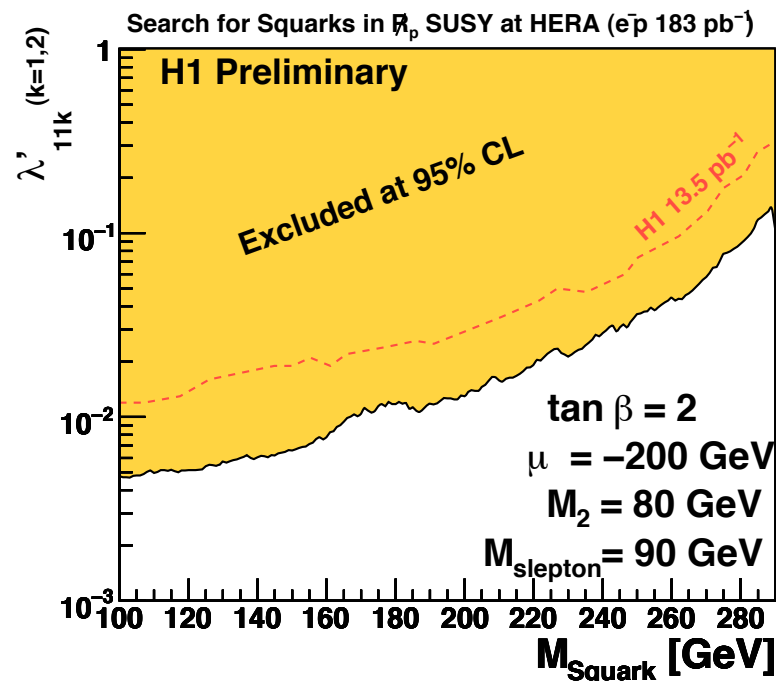


final states with neutrinos  
dominate limit calculation

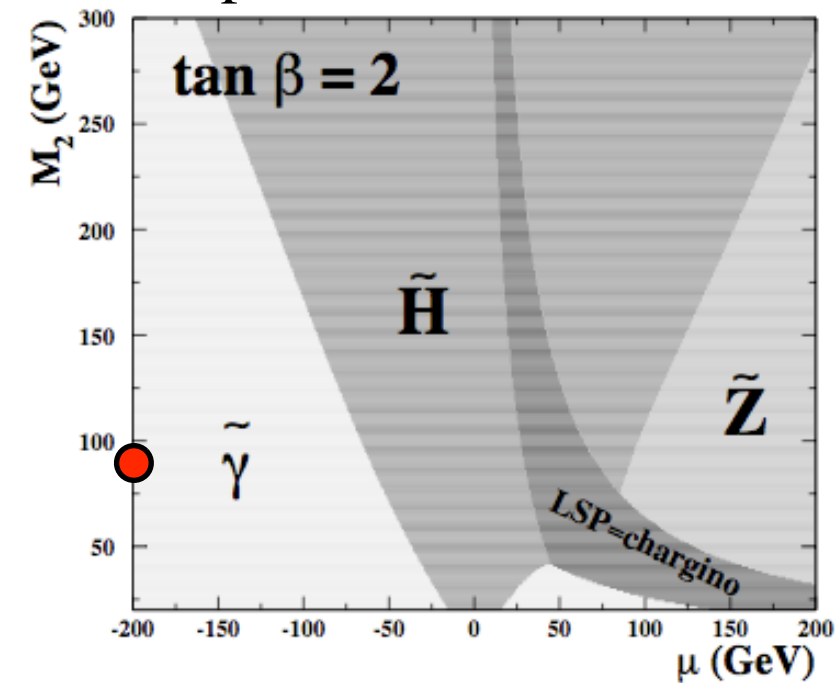
$\mu, \tan \beta, M_2$   
determine REWSB

# MSSM example: Photinolike Neutralino Scenario

- photino dominated neutralino



Composition of Neutralino<sub>1</sub>



final states with electrons  
dominate limit calculation

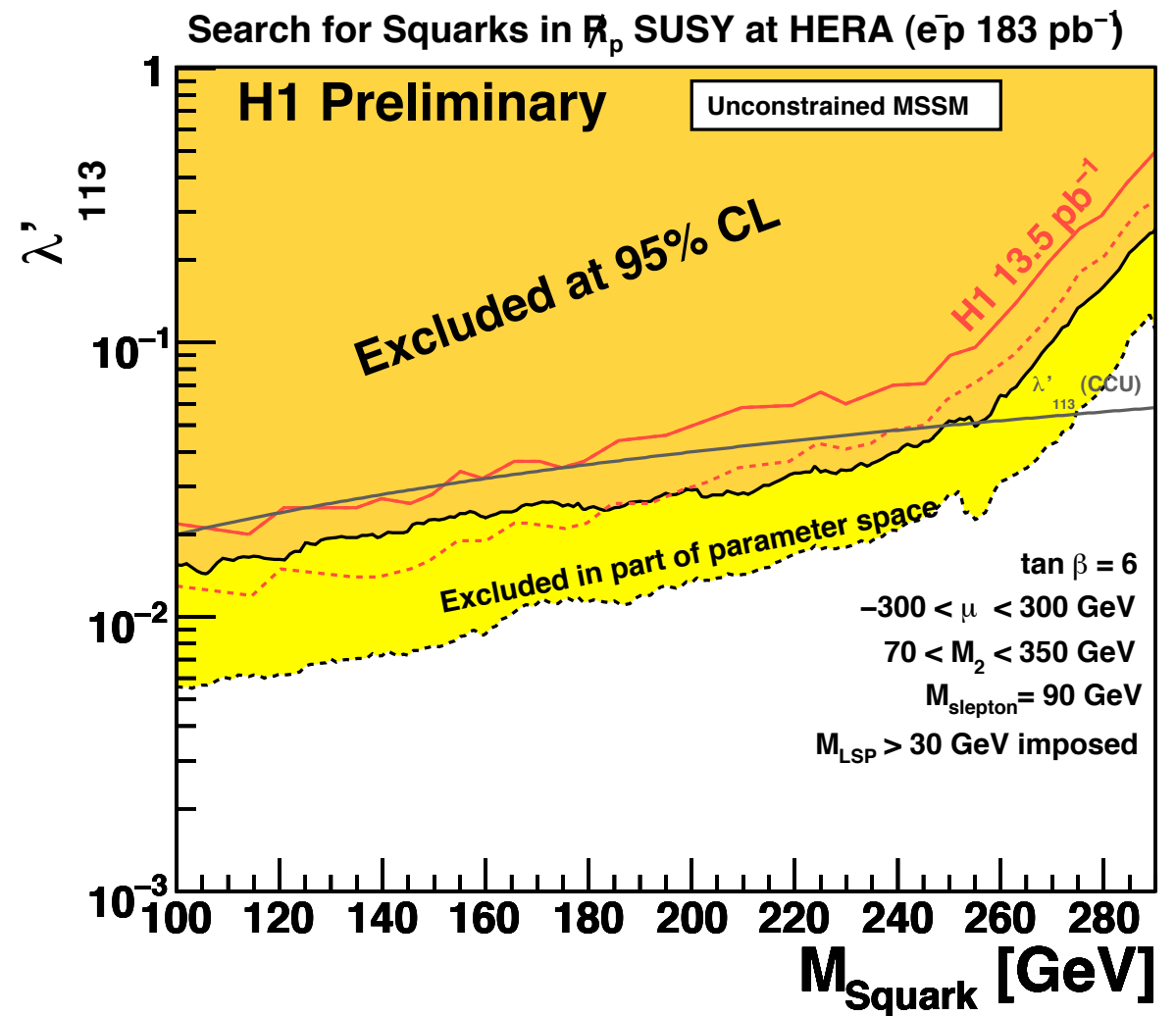
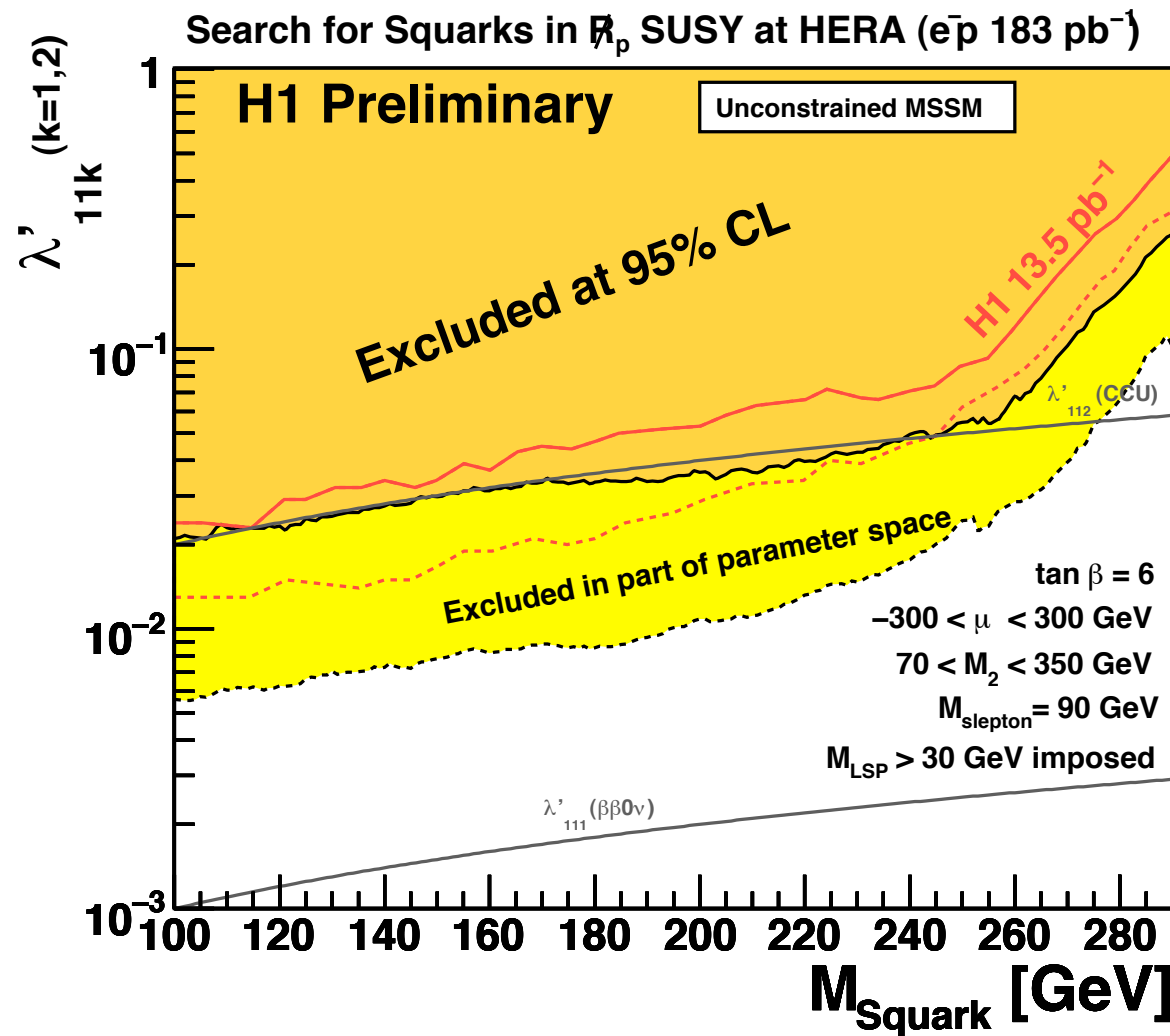
$\mu, \tan \beta, M_2$   
determine REWSB



# MSSM full Parameter Scan: Down-type Squarks

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

$$\tilde{b}_R$$



for a Yukawa coupling of electromagnetic coupling strength:

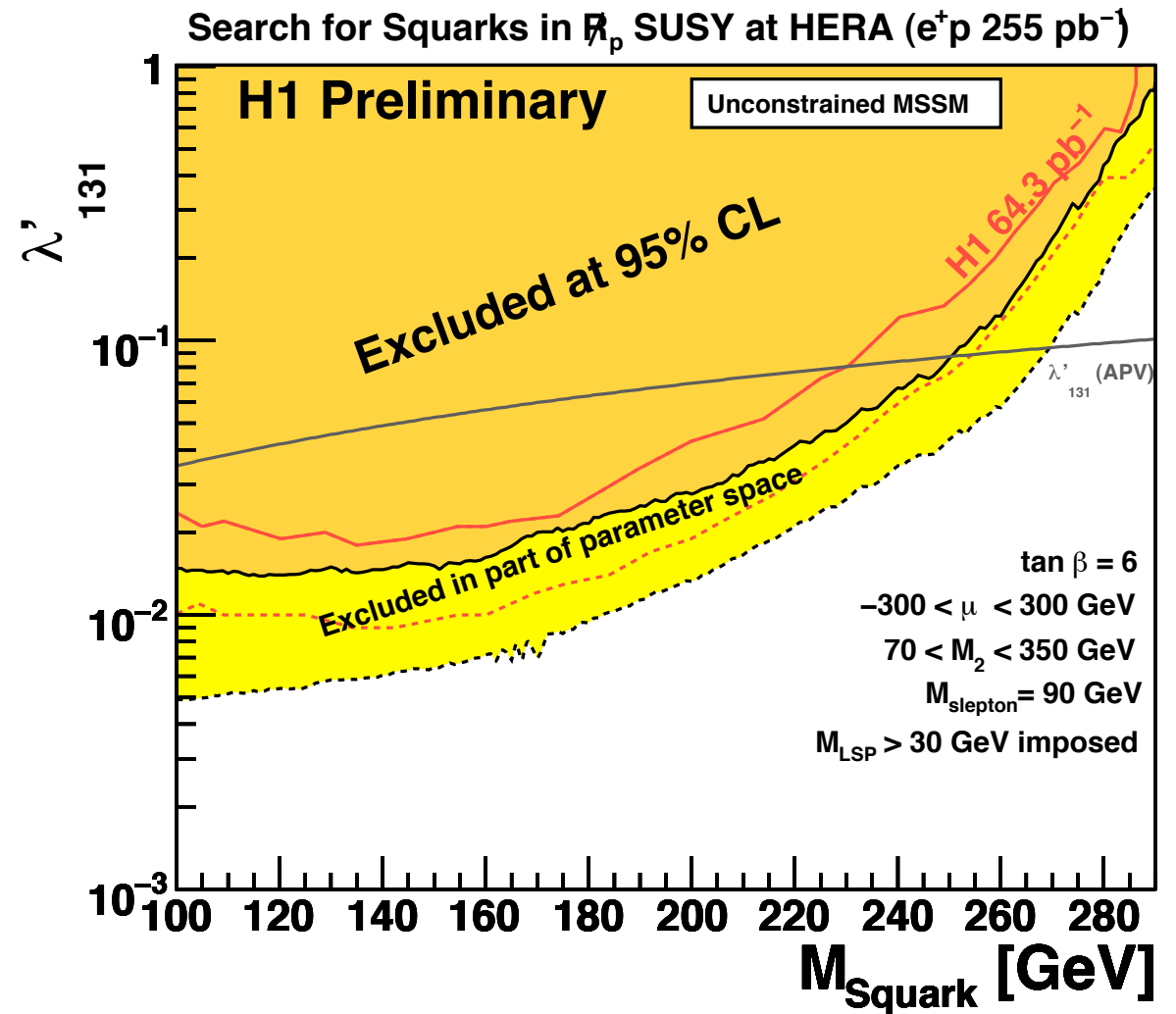
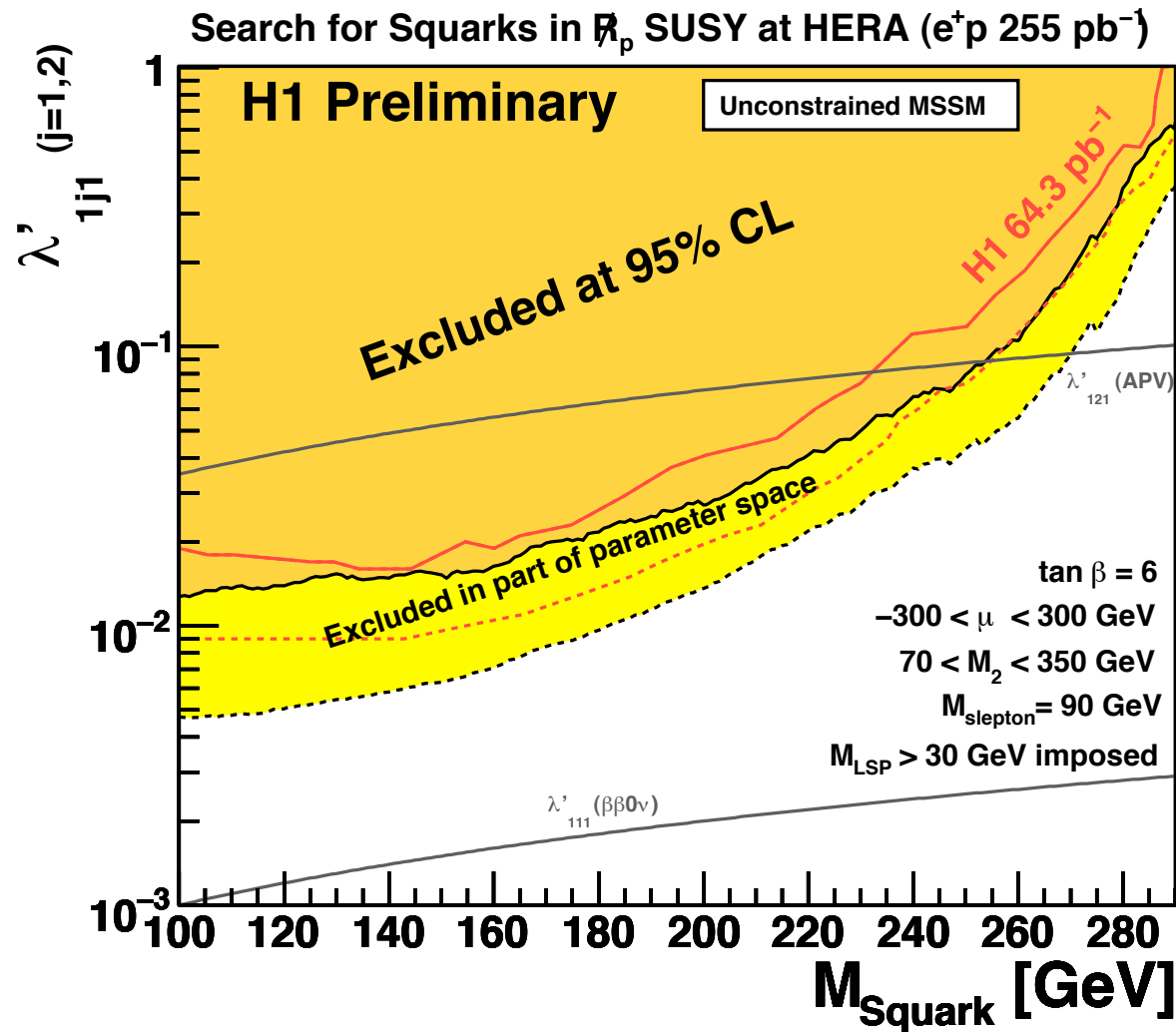
$$\lambda'_{11k} = \sqrt{4\pi\alpha_{em}} = 0.3$$

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

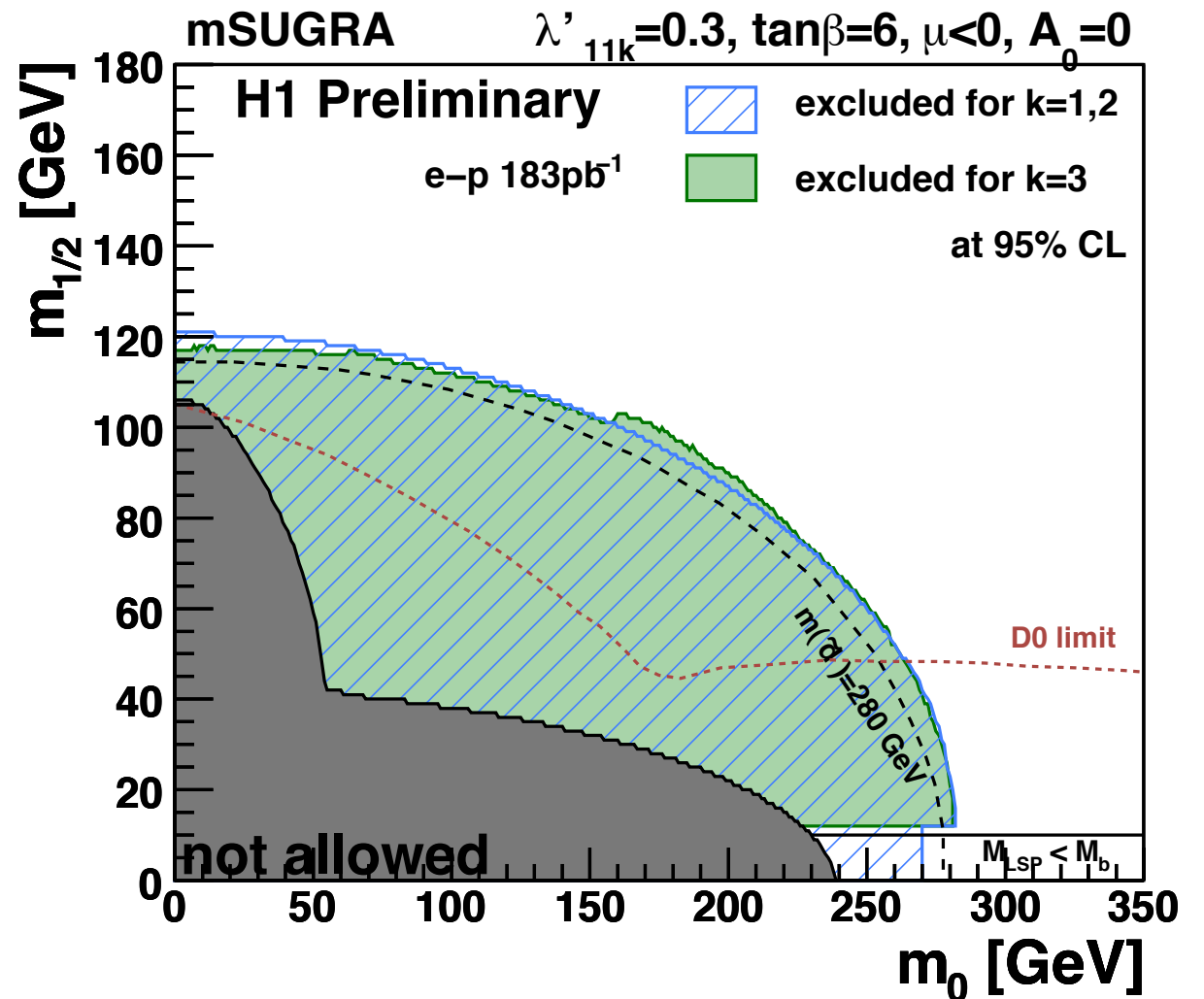
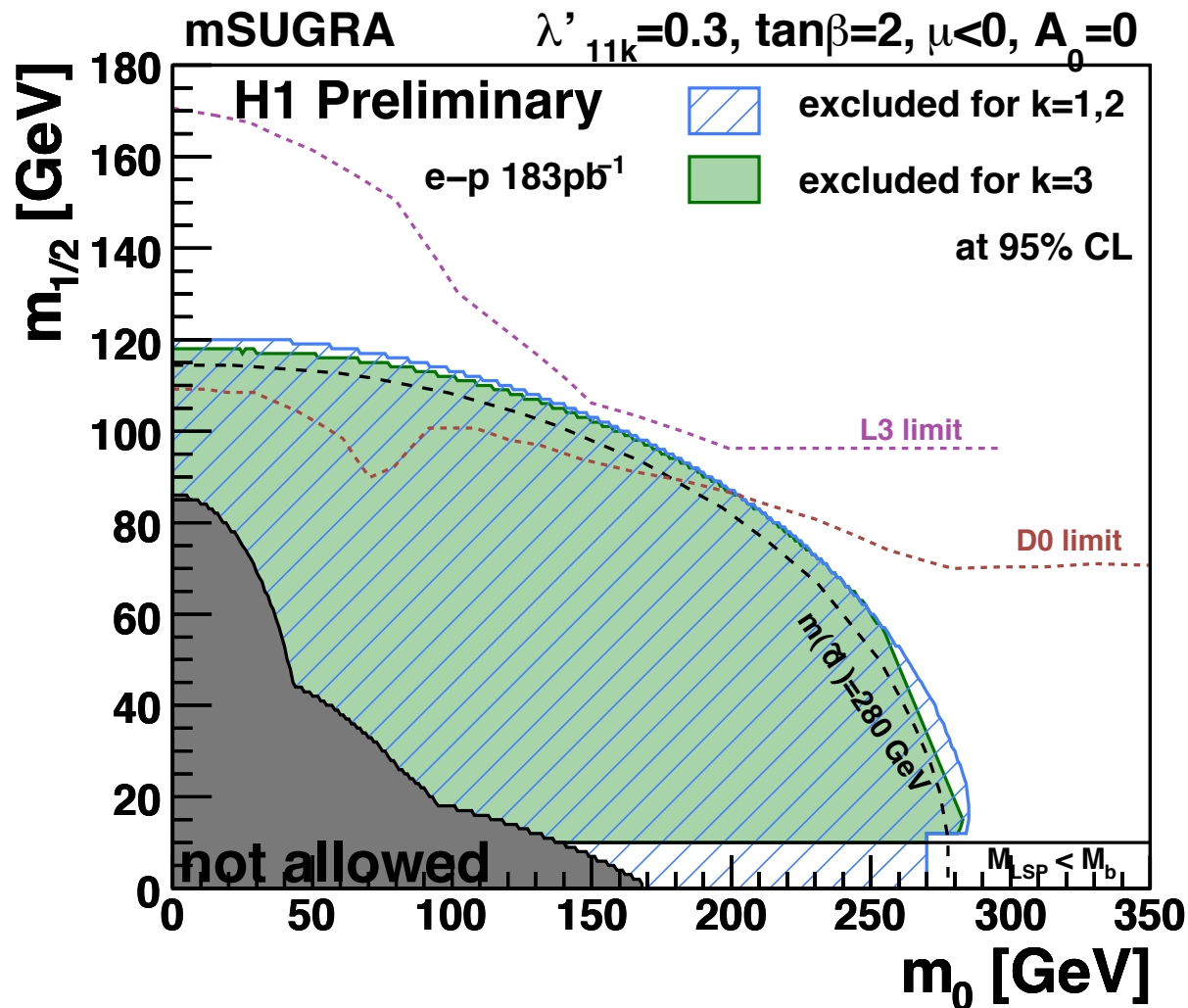
$\tan \beta$  - **ratio** of the two Higgs **VEV's**

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

$A_0$  - common **trilinear coupling**

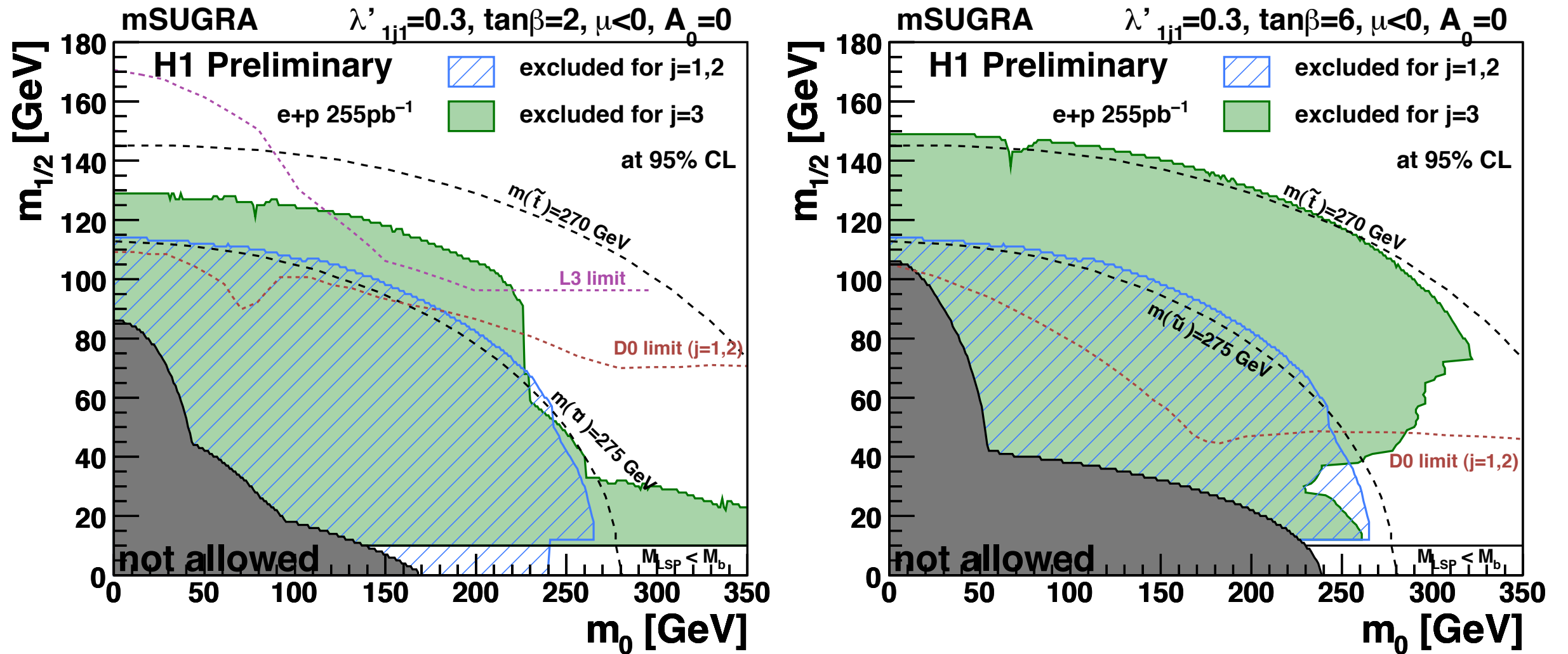


# mSUGRA - Down-type Squarks



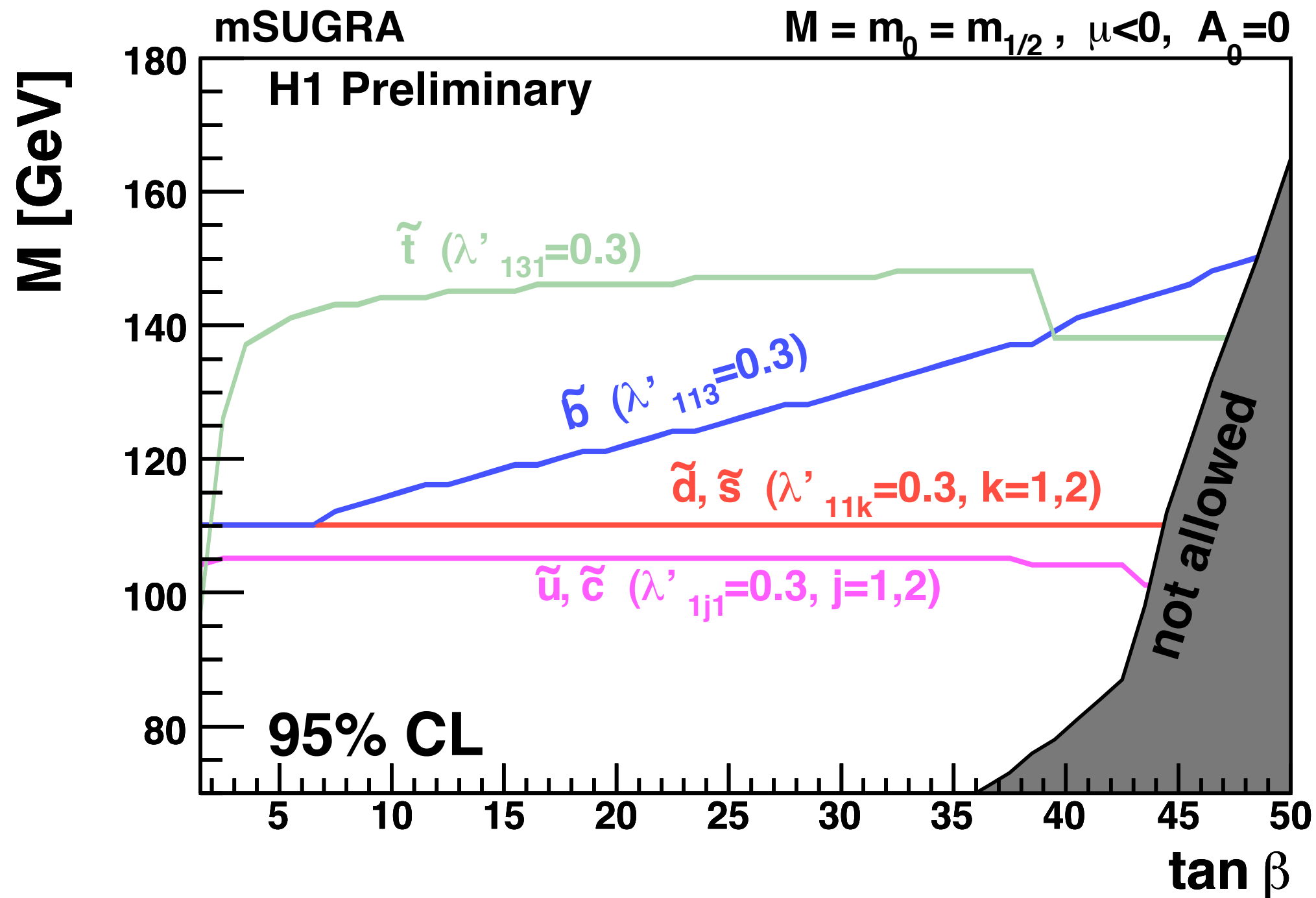
assuming a coupling strength:  $\lambda'_{11k}=0.3$   
the indicated region can be excluded at 95% CL

# mSUGRA - Up-type Squarks



assuming a coupling strength:  $\lambda'_{1j1}=0.3$   
 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

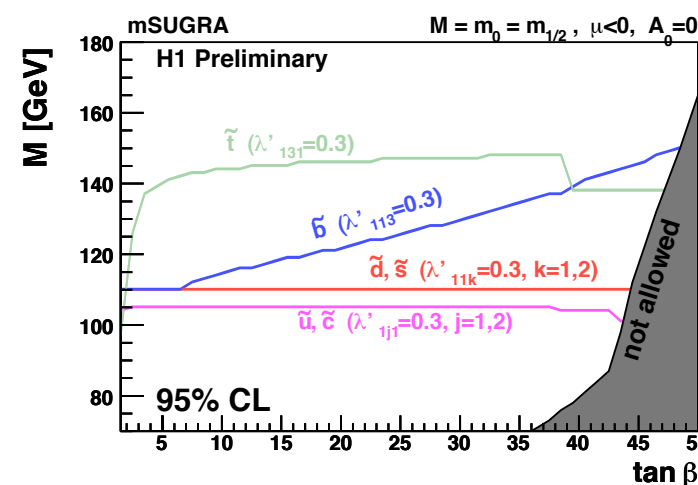
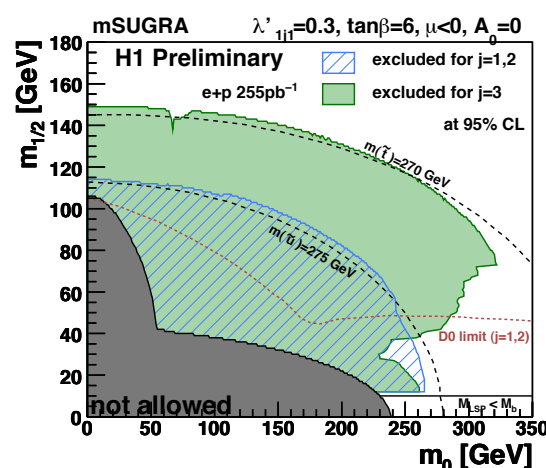
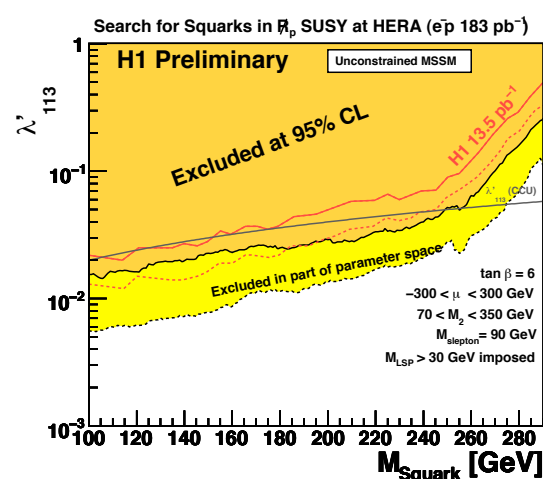
- RPV SUSY searched for in complete data set of the H1 experiment at HERA
- No significant deviation from SM expectation observed!
- Interpretation of search results in phenomenological MSSM and mSUGRA model.

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<sup>-1</sup>)

