Search for Squark Production in R-Parity Violating SUSY at HERA

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On behalf of H1-Collaboration

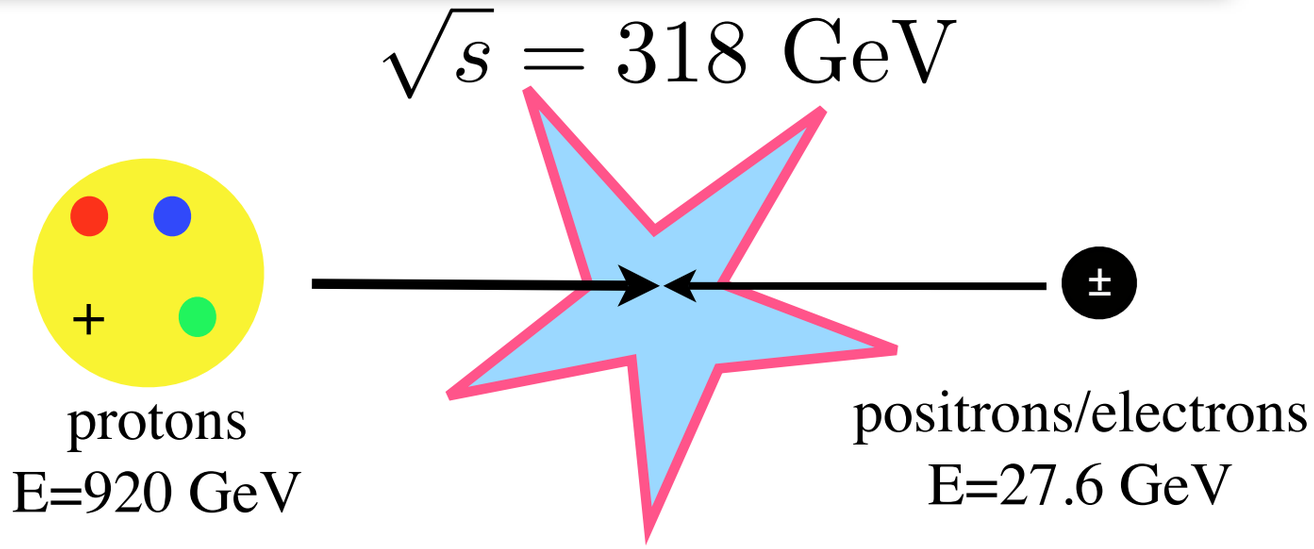
H1-Experiment at HERA (DESY)

full HERA luminosity:

$$e^+p : 255\ pb^{-1}$$
$$e^-p : 183\ pb^{-1}$$

increase wrt HERA-1 publication[1]:

$$e^+p : \times\ 4$$
$$e^-p : \times\ 13$$



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

SUSY R-Parity Violation

"new" quantum number: $R_P = (-1)^{3B+L+2S}$

from conservation: stable LSP (missing energy), prevent proton decay
only pair production of susy particles possible

Interesting consequences for ep-collisions at HERA
if R-Parity is violated!

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

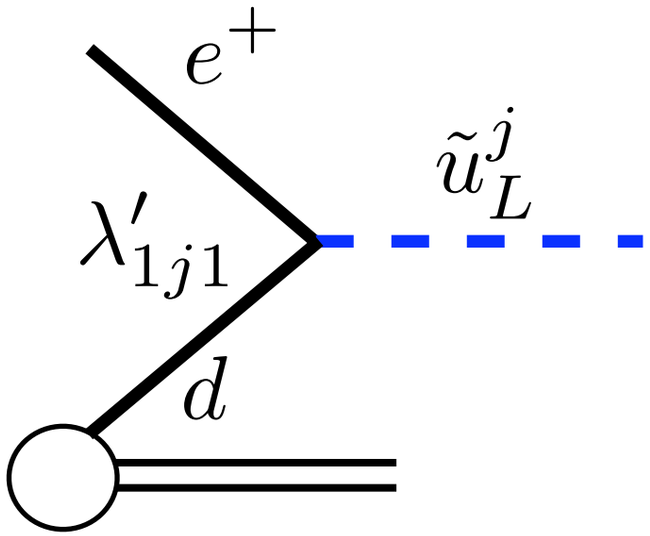
L: left-handed (s)leptons, **Q**: left-handed (s)quarks, **D**: right-handed down-type (s)quarks

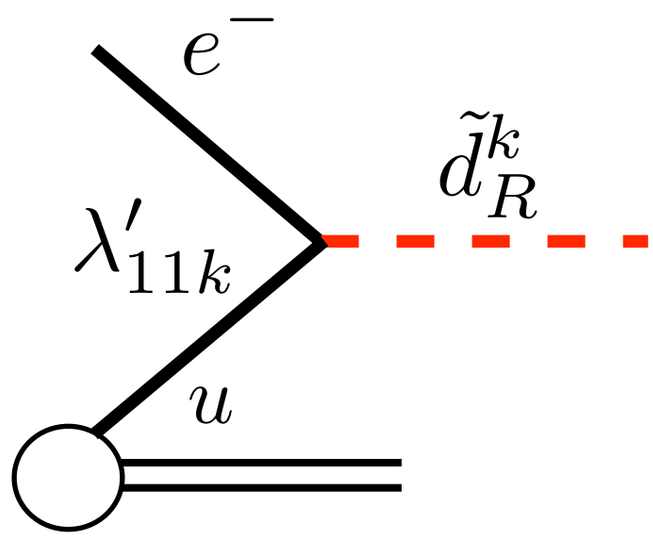
i,*j*,*k* generation indices (27 couplings)

R_p Violating terms allow for
single resonant squark production in ep-collisions!

Single Resonant Production

squark production in ep-collision





◆ Squark masses up to $\sqrt{s}$ accessible!

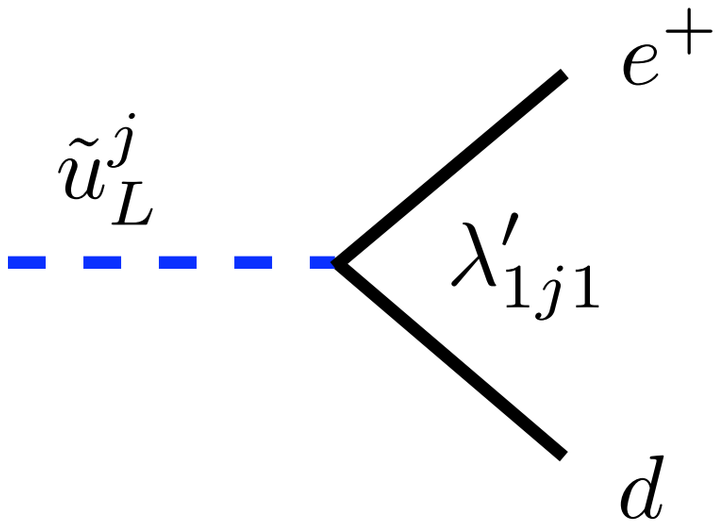
different sensitivity for electrons and positrons
(proton valence quark structure)

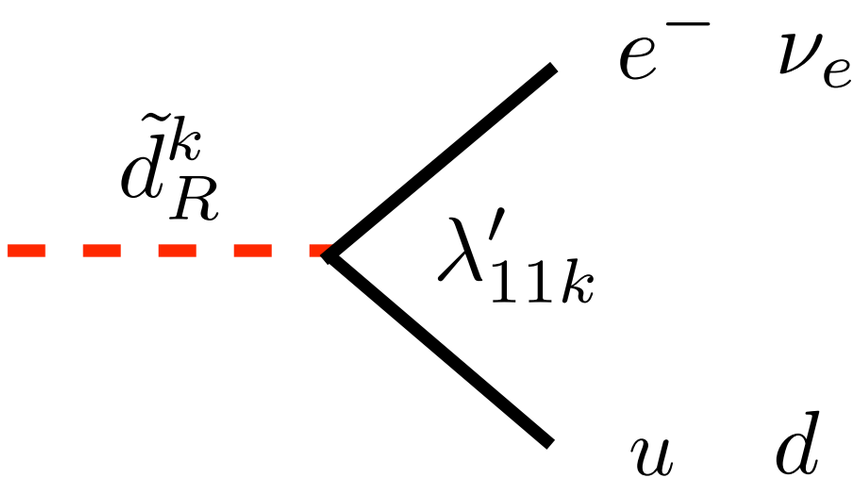
$$e^+p : \lambda'_{1j1}$$
$$e^-p : \lambda'_{11k}$$

currently analysis considers only k,j=1,2 (due to mixing in stop/sbottom sector)

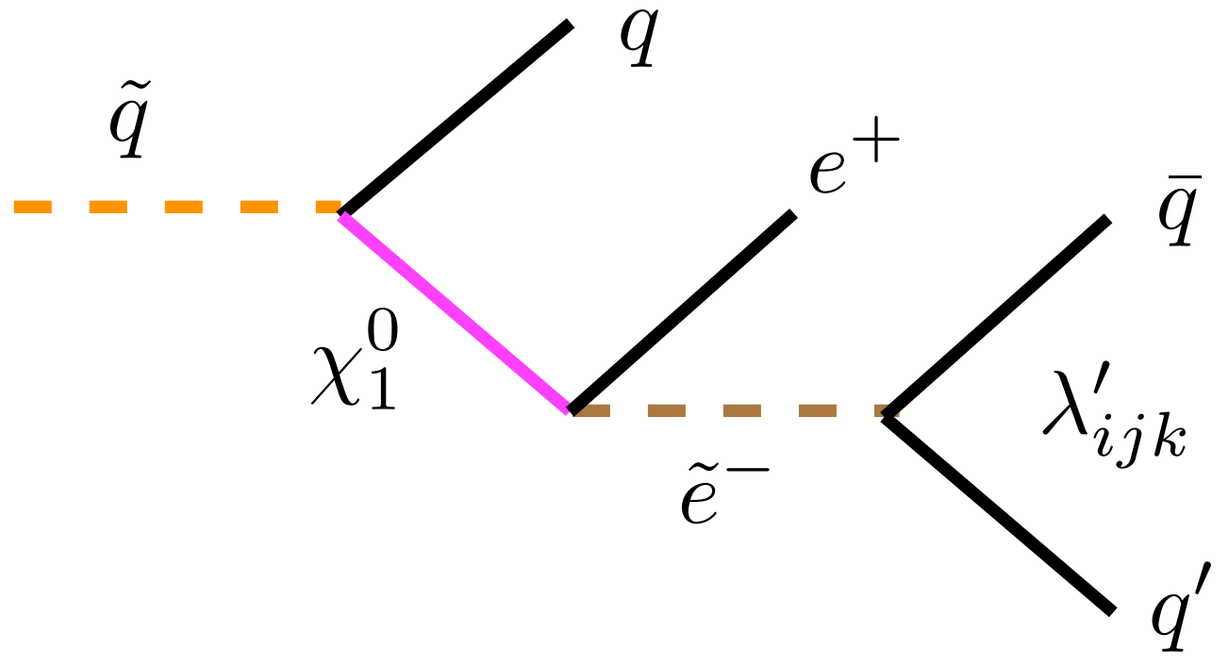
Squark Decays

DIS like decay signatures





example decay
into Neutralinos (Charginos)



many different final states possible

masses of particles in cascades determine selection efficiencies

only one coupling different from zero: production and decay over same coupling

Multitude of final states

channels with isolated electron

electron + jet eq

lepton + multijet channels

electron + multi jet eMJ
(right/ wrong charged)

multilepton + multijet channels

electron + multi jet + 2nd electron $eeMJ$

electron + multi jet + muon $e\mu MJ$

channels with missing energy (neutrinos)

neutrino + jet νq
only possible for $e^- u \rightarrow \tilde{d}^k_R \rightarrow \nu q$

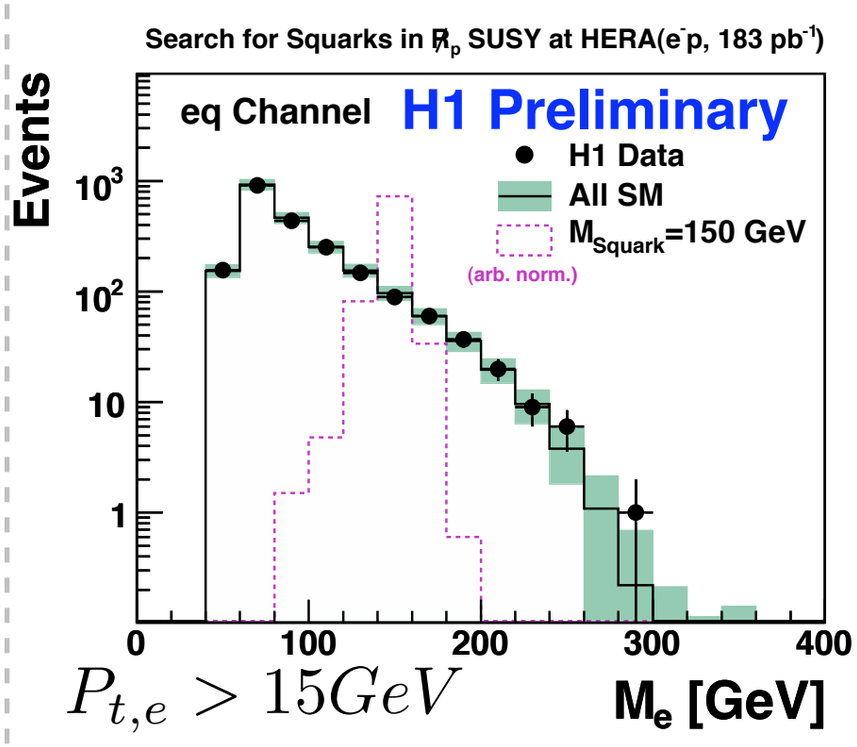
neutrino + multi jet νMJ
not considered currently

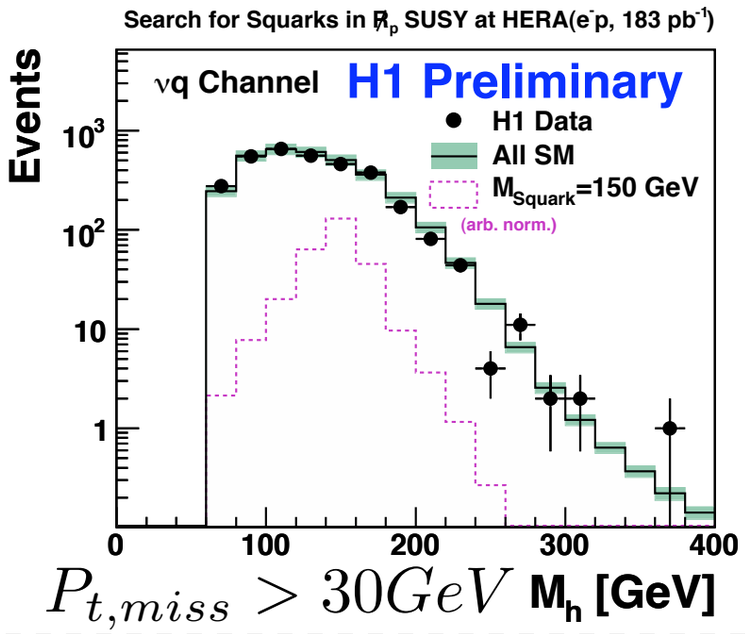
neutrino + multi jet + electron νeMJ

neutrino + multi jet + muon $\nu \mu MJ$

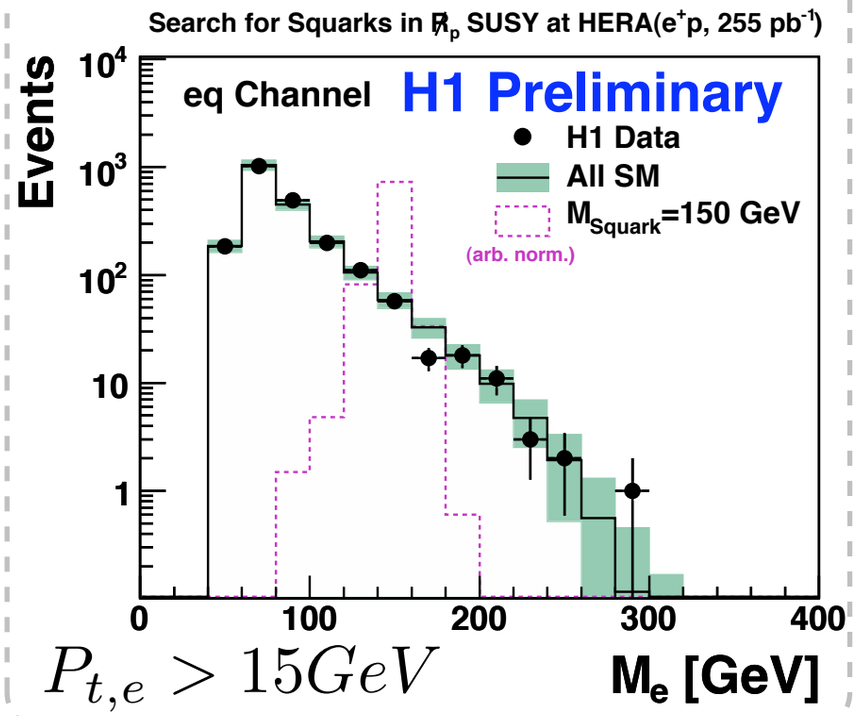
DIS-like Channels

electron data

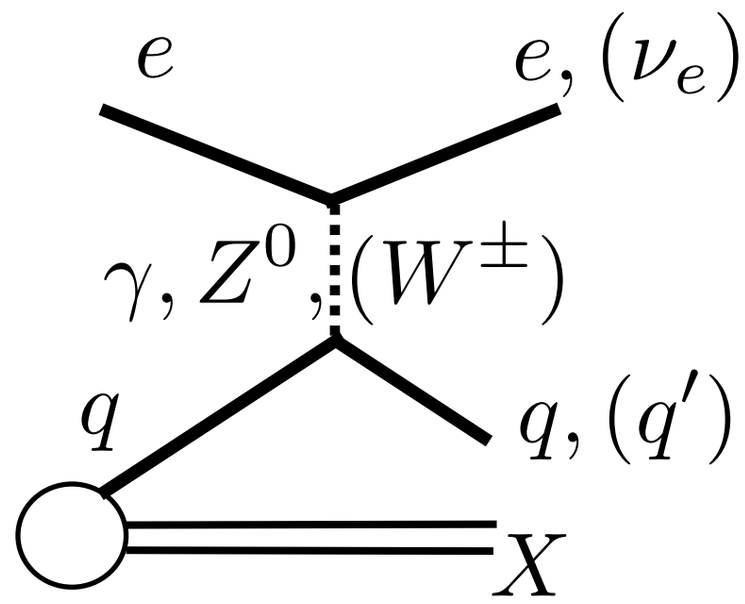




positron data



irreducible DIS background



reconstructed invariant masses of intermediate particles:

$$M_{e,h} = \sqrt{x_{e,h} s}$$

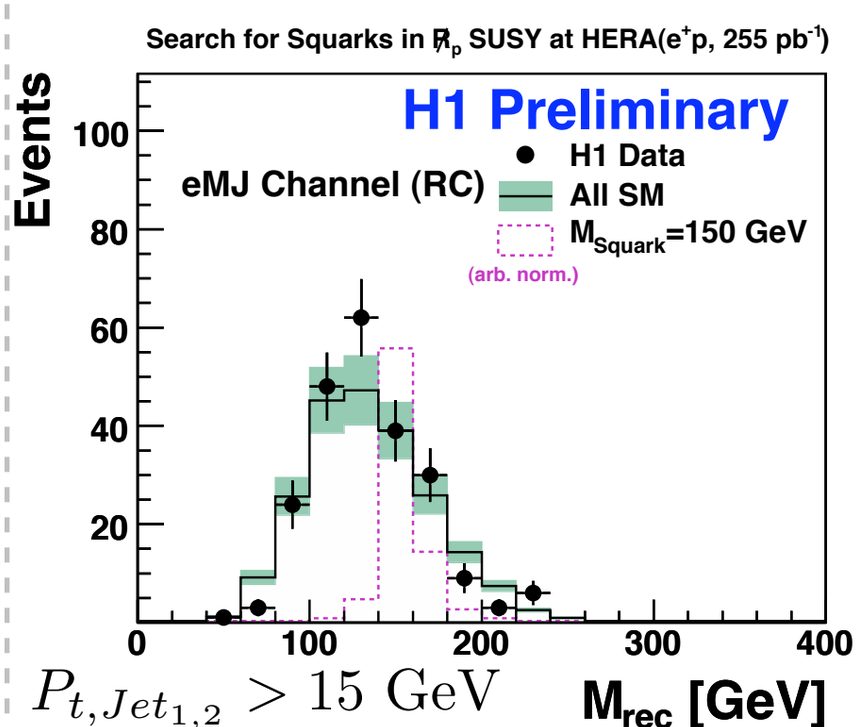
e: from electron
h: from hadronic final state

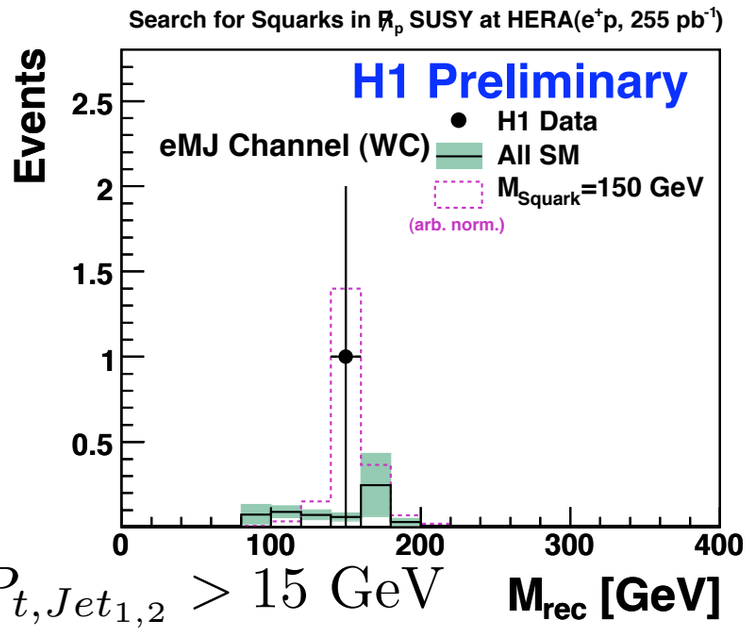
channels dominated by neutral and charged current events

no deviation from SM background observed

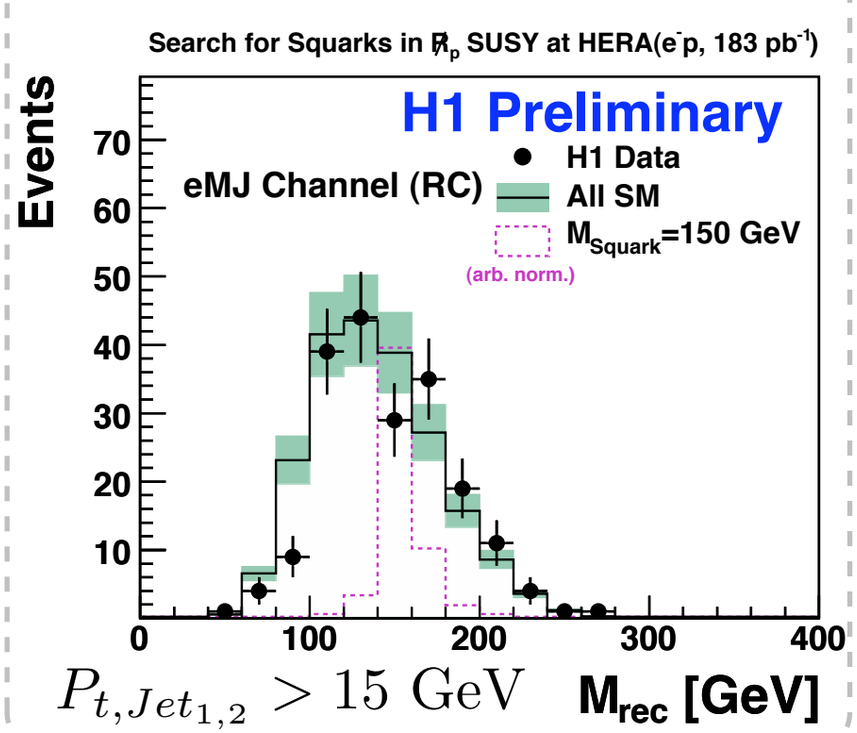
NC-like Multijet Channels

positron data

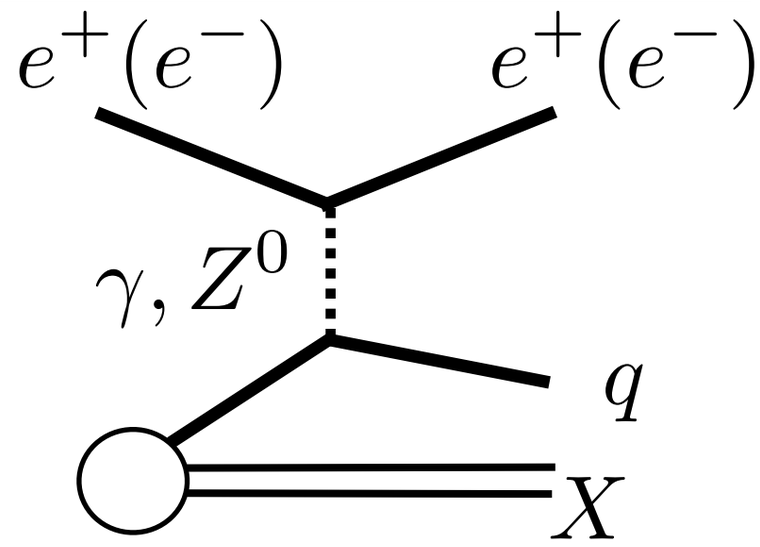




electron data



always expect outcoming/incoming lepton of same charge



reconstructed invariant masses of intermediate particles:

$$M_{rec} = \sqrt{4E_e^0(\sum_i E_i - E_e^0)}$$

i: all jets and electrons, excluding proton remnant

no deviation from SM background observed

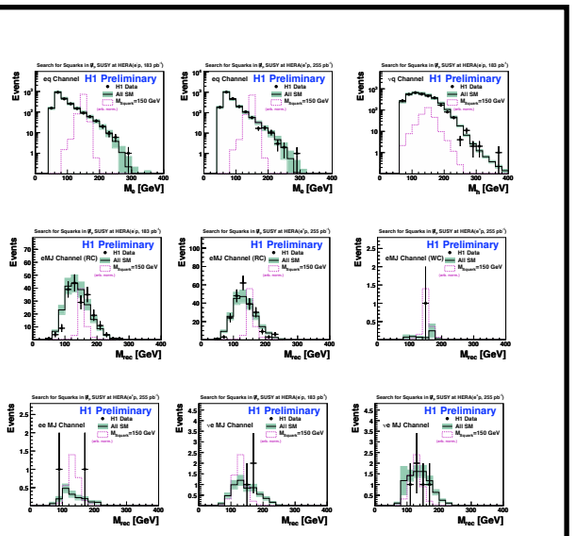
Total event yields

H1 (Preliminary) — Search for Squarks in RPV SUSY					
	e^+p (255 pb^{-1})		e^-p (183 pb^{-1})		
Channel	Data	**SM Expectation**	Data	SM Expectation	Efficiency
eq	**2116**	2120 ± 260	**2127**	2190 ± 270	$25 - 40\%$
νq	-	-	**3191**	3320 ± 400	$45 - 65\%$
eMJ (RC)	**225**	219 ± 33	**197**	210 ± 32	$10 - 50\%$
eMJ (WC)	**1**	0.6 ± 0.4	**0**	1.3 ± 0.3	$10 - 20\%$
$eeMJ$	**2**	1.7 ± 0.5	**0**	1.5 ± 0.5	$10 - 40\%$
$e\mu MJ$	**0**	0.03 ± 0.02	**0**	0.03 ± 0.02	$10 - 20\%$
νeMJ	**5**	8.2 ± 2.0	**3**	5.6 ± 1.2	$10 - 40\%$
$\nu\mu MJ$	**0**	0.06 ± 0.03	**0**	0.05 ± 0.03	$10 - 20\%$

- all topologies in good agreement with SM expectation
- derive limits on R-Parity Violating couplings

Limit in (unconstrained) MSSM scenario

for each channel invariant mass distributions for data and mc (apply mass window)



X

for each channel efficiency and branching ratio (depends on susy model) (SUSYGEN3)

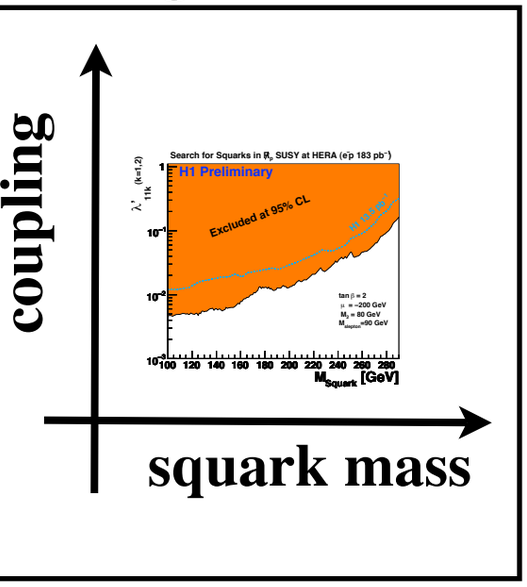
$\tan\beta, \mu, \mathrm{M}_2$

Channel	Efficiency
eq	$25-40\%$
νq	$45-65\%$
eMJ (RC)	$10-50\%$
eMJ (WC)	$10-20\%$
$eeMJ$	$10-40\%$
$e\mu MJ$	$10-20\%$
νeMJ	$10-40\%$
$\nu\mu MJ$	$10-20\%$

X **Branching Ratio for channel (model)**

calculate frequentist 95% CL limit on coupling for considered model combining all channels

=



$e^+p : \lambda'_{1j1}$

$e^-p : \lambda'_{11k}$

the experimental observation excludes with 95% confidence level a value of the coupling higher than the limit

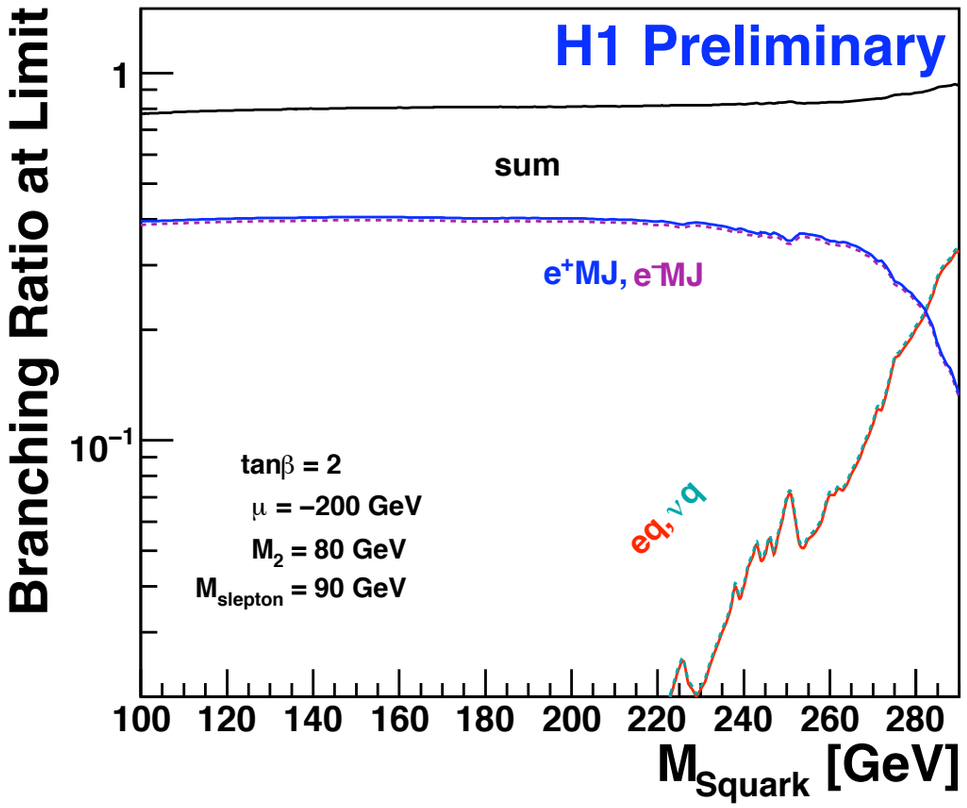
Model: photino-like neutralino

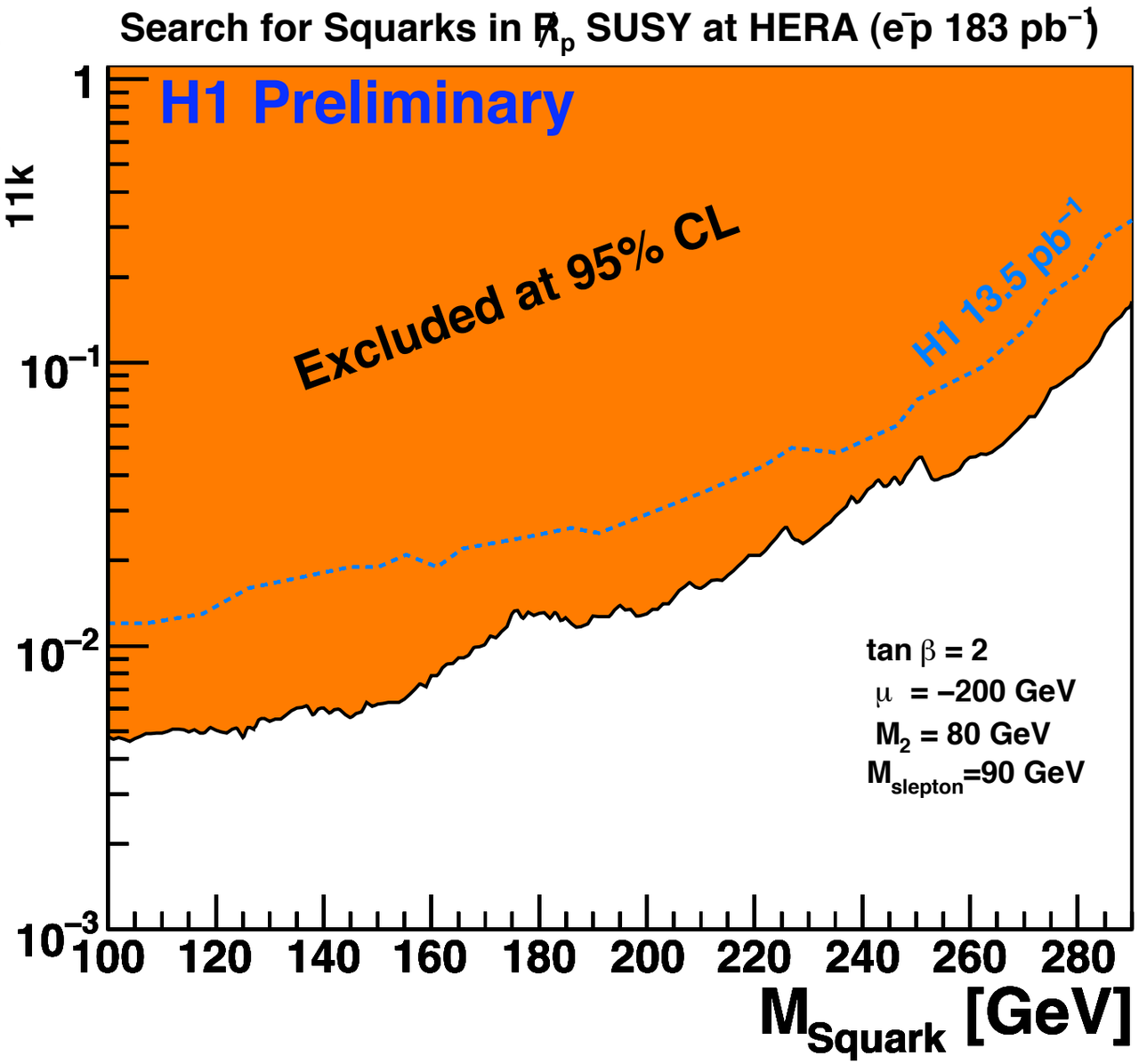
$$e^- p : \lambda'_{11k}$$

$$\tan\beta = 2$$

$$\mu = -200 \text{ GeV}$$

$$M_2 = 80 \text{ GeV}$$



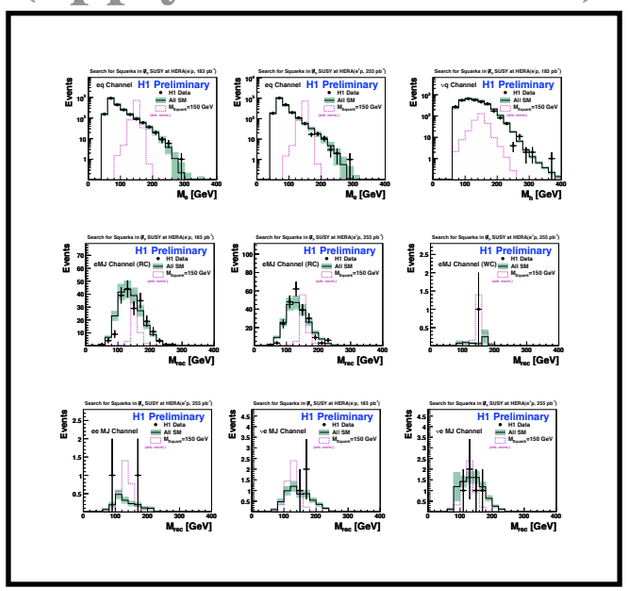


dominant "photino"-like neutralino

(electromagnetic coupling)

Scan (unconstrained) MSSM models

for each channel
invariant mass
distributions
for data and mc
(apply mass window)



X

for each channel
efficiency and branching ratio
depends on susy model
(SUSYGEN3)

for each considered model

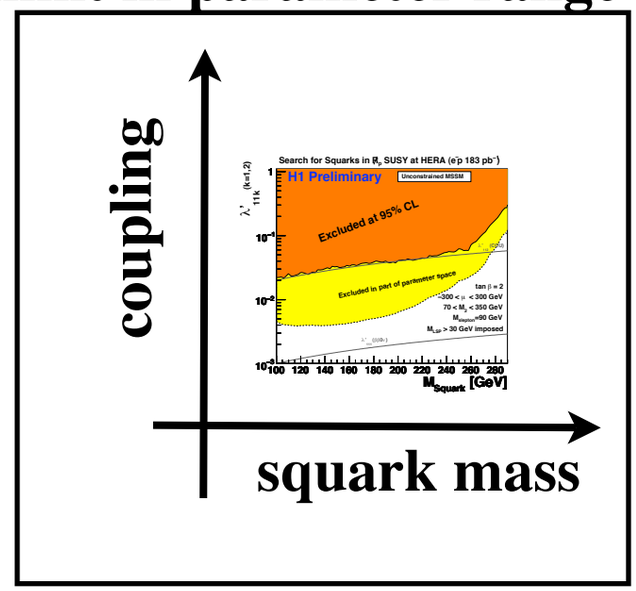
Channel	Efficiency
eq	$25-40\%$
νq	$45-65\%$
eMJ (RC)	$10-50\%$
eMJ (WC)	$10-20\%$
$eeMJ$	$10-40\%$
$e\mu MJ$	$10-20\%$
νeMJ	$10-40\%$
$\nu\mu MJ$	$10-20\%$

X **Branching Ratio for channel (model)**

=

calculate frequentist
95% CL limit on
coupling
for considered scenario
combining all channels

derive weakest and strongest limit in parameter range



$$e^+p : \lambda'_{1j1}$$

$$e^-p : \lambda'_{11k}$$

$$\tan\beta = 2$$

$$-300 < \mu < 300 \text{ GeV}$$

$$70 < M_2 < 350 \text{ GeV}$$

$$M_{LSP} > 30 \text{ GeV}$$

$$M_{slepton} = 90 \text{ GeV}$$

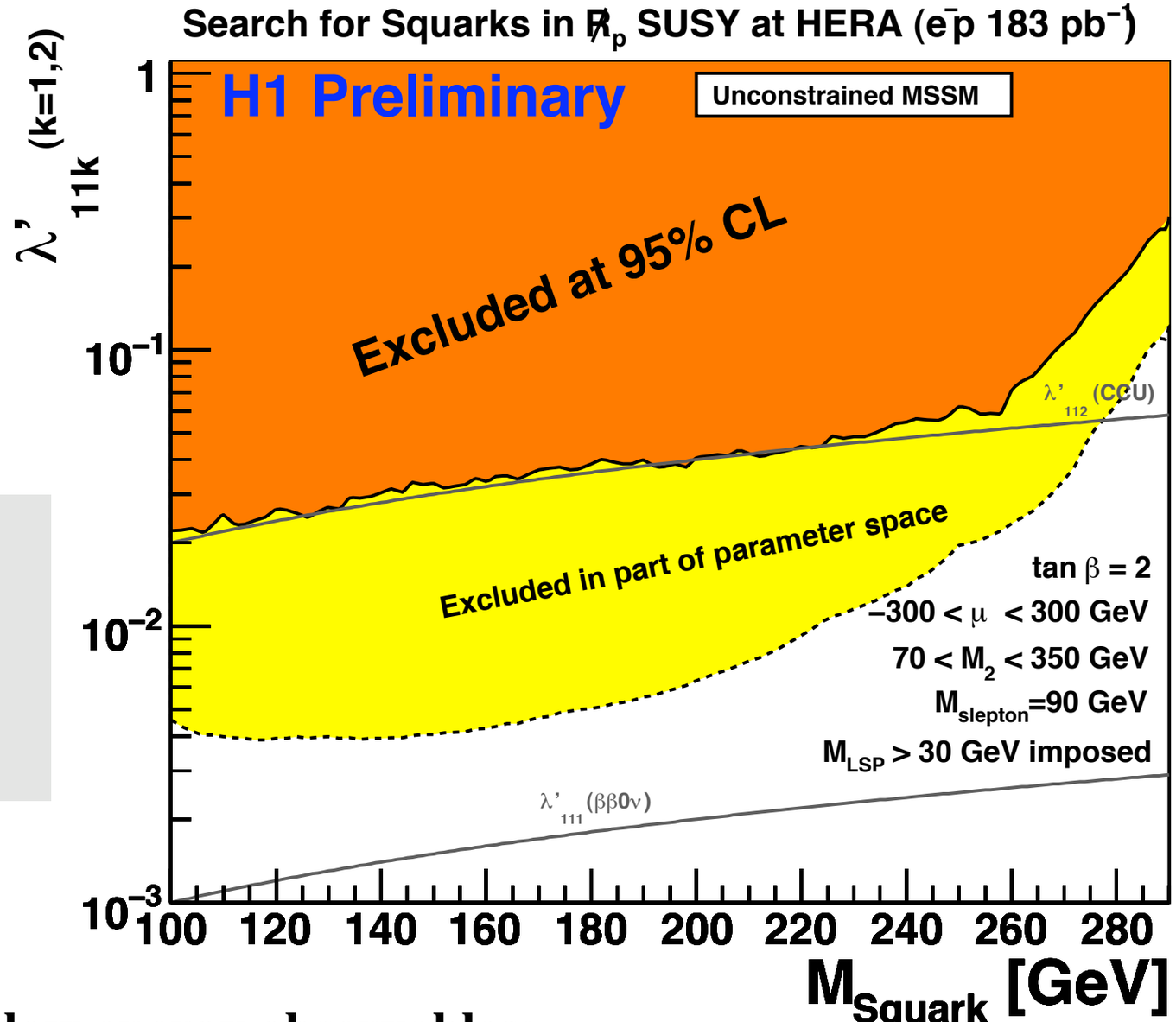
Limit on Down-type Squarks

$$e^- p : \lambda'_{11k}$$

Valid for first and second generation squarks

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

For $\lambda' = \sqrt{4\pi\alpha_{em}} \approx 0.3$
squarks of the first two generations
can be excluded up to masses **290 GeV**



comparision to limits from low energy observables:

charged current universality λ'_{112}

neutrinoless-doublebeta decay λ'_{111}

Limit on Down-type Squarks

$$e^- p : \lambda'_{11k}$$

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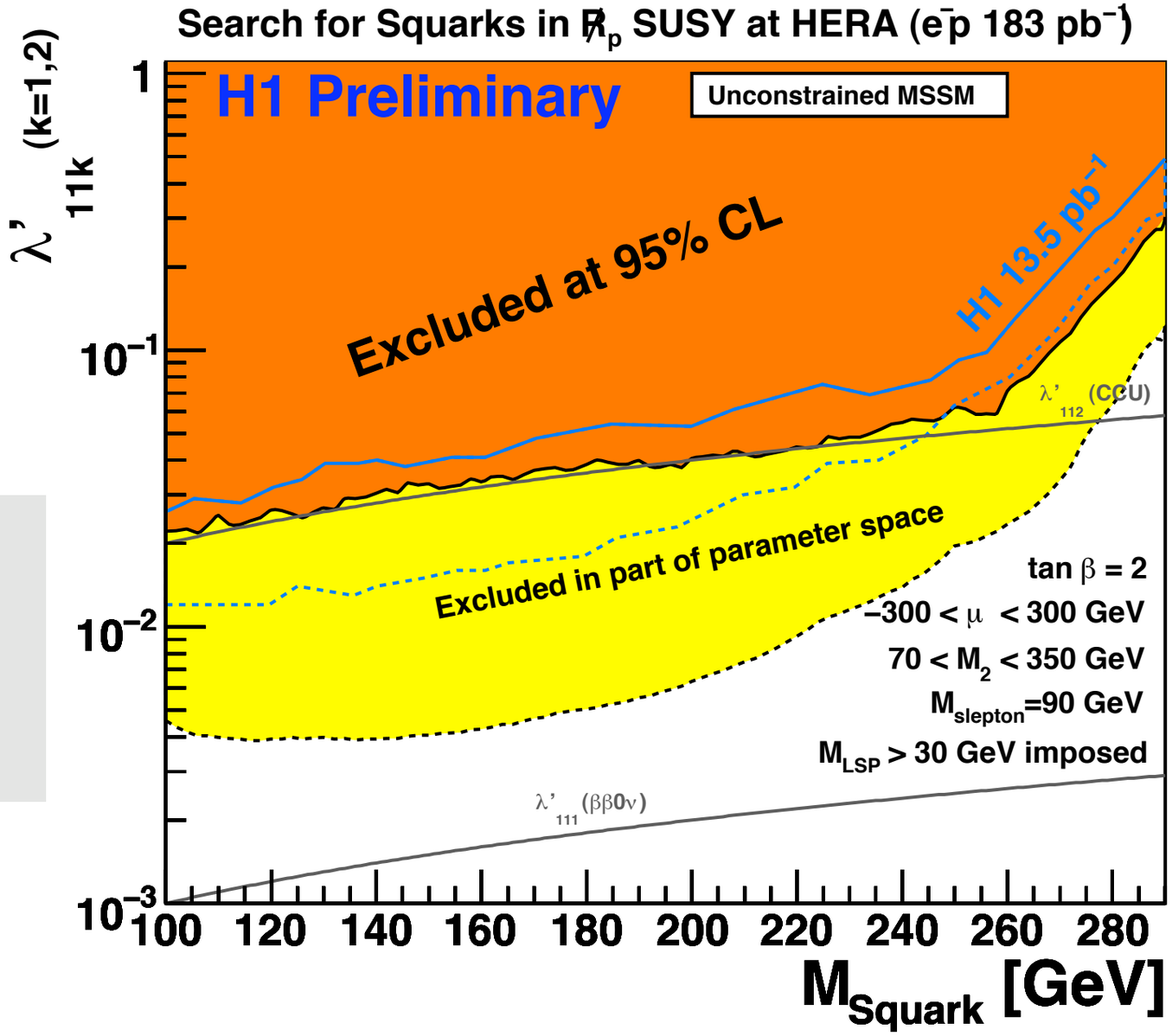


compared to HERA-1 H1 limits

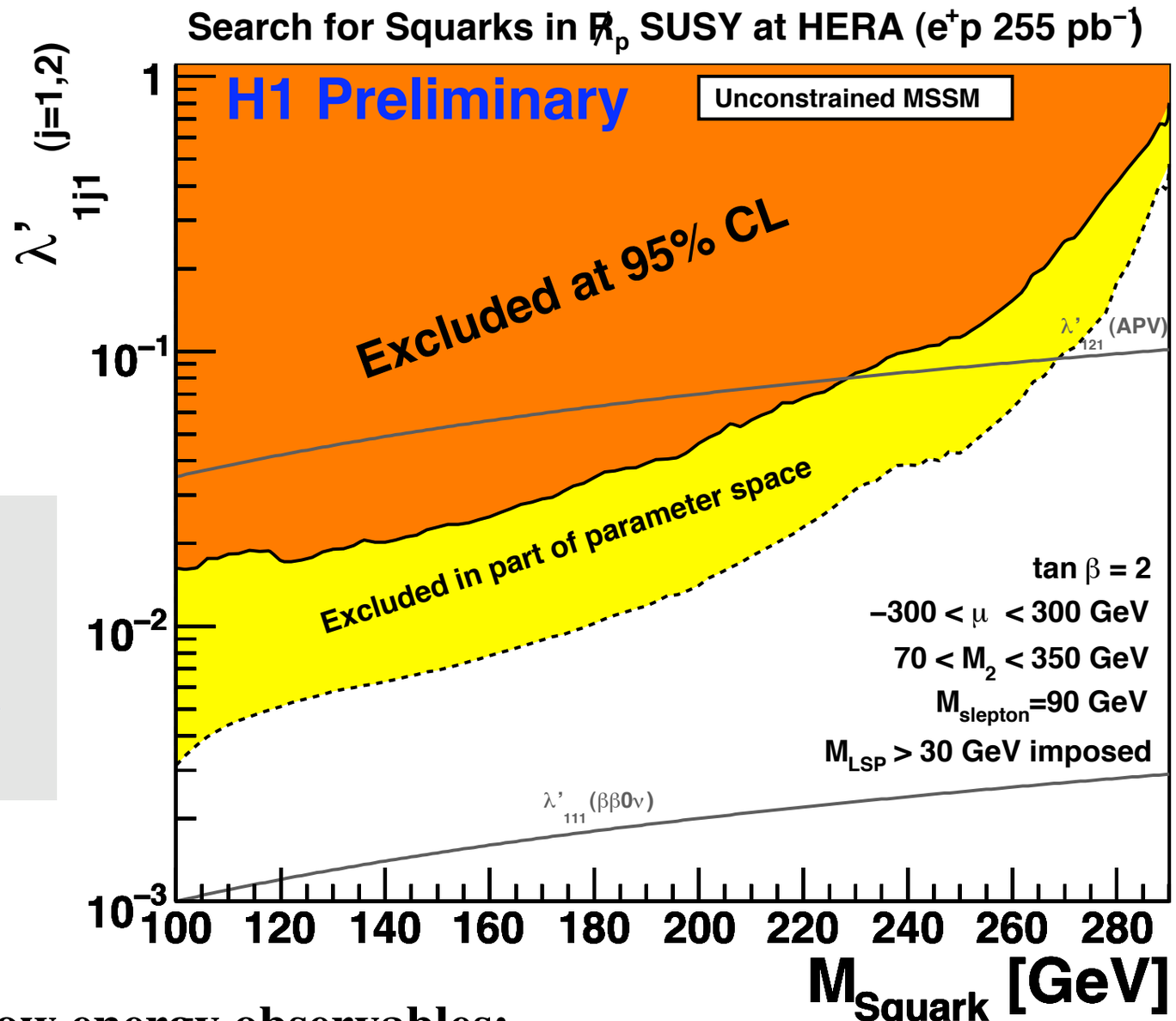
Limit on Up-type Squarks

$$e^+p : \lambda'_{1j1}$$

Valid for first and second generation squarks

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

For $\lambda' = \sqrt{4\pi\alpha_{em}} \approx 0.3$
squarks of the first two generations
can be excluded up to masses **275 GeV**



comparision to limits from low energy observables:

atomic parity violation λ'_{121}

neutrinoless-doublebeta decay λ'_{111}

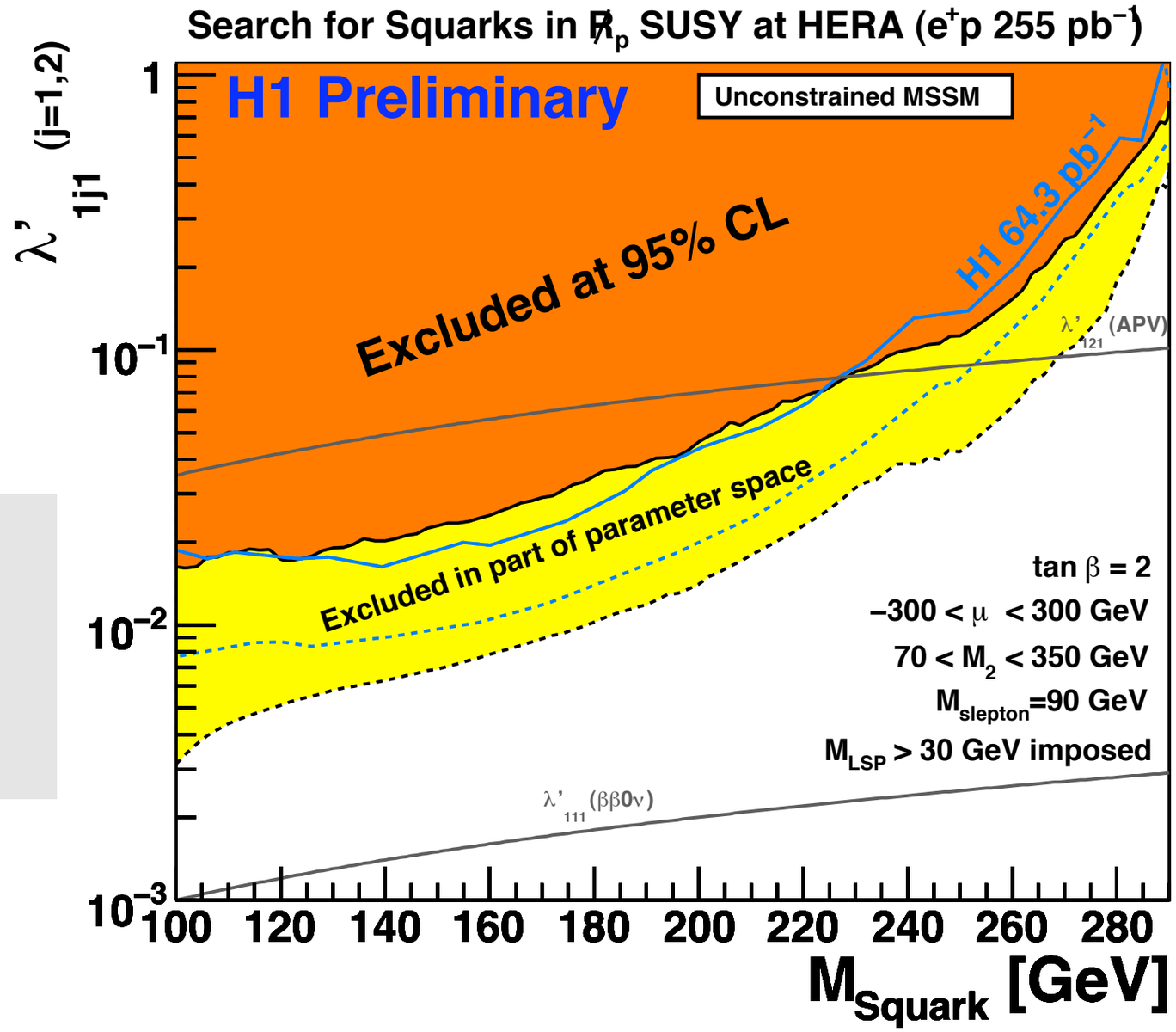
Limit on Up-type Squarks

$$e^+p : \lambda'_{1j1}$$

Valid for first and second generation squarks

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

For $\lambda' = \sqrt{4\pi\alpha_{em}} \approx 0.3$
squarks of the first two generations can be excluded up to masses **275 GeV**



compared to HERA-1 H1 limits

Conclusions

- no evidence for squark production in HERA data found
- 95% CL limits on coupling λ'_{1j1} and λ'_{11k} derived $_{(j,k=1,2)}$
- Squarks of first two generations can be excluded up to

  masses **275 GeV** $(\tilde{u}_L, \tilde{c}_L)$**, 290 GeV** $(\tilde{d}_R, \tilde{s}_R)$ for $\lambda' = 0.3$
- extended domain explored

Thank you HERA (and all involved) for exciting physics