SUSY Searches at H1

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Outline

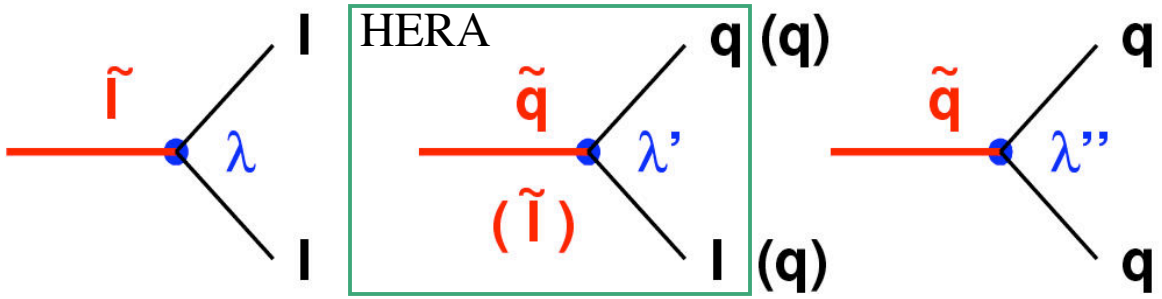
- SUSY and R-parity violation
- Search for Bosonic Stop Decays in R-parity Violating Supersymmetry
- Search for Light Gravitinos in Events with Photons and Missing Transverse Momentum
- A General Search for New Phenomena in $e^{\pm}p$ Scattering
- Summary of Results

SUSY and R-parity

$R_p = (-1)^{3B + L + 2S}$
= 1 for SM particles
= -1 for SUSY particles

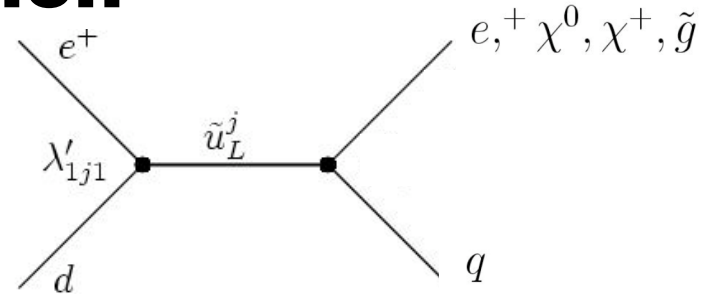
- The most general SUSY (MSSM) model allows Yukawa couplings between two SM fermions and a sfermion, squark or slepton, introducing R-parity violation

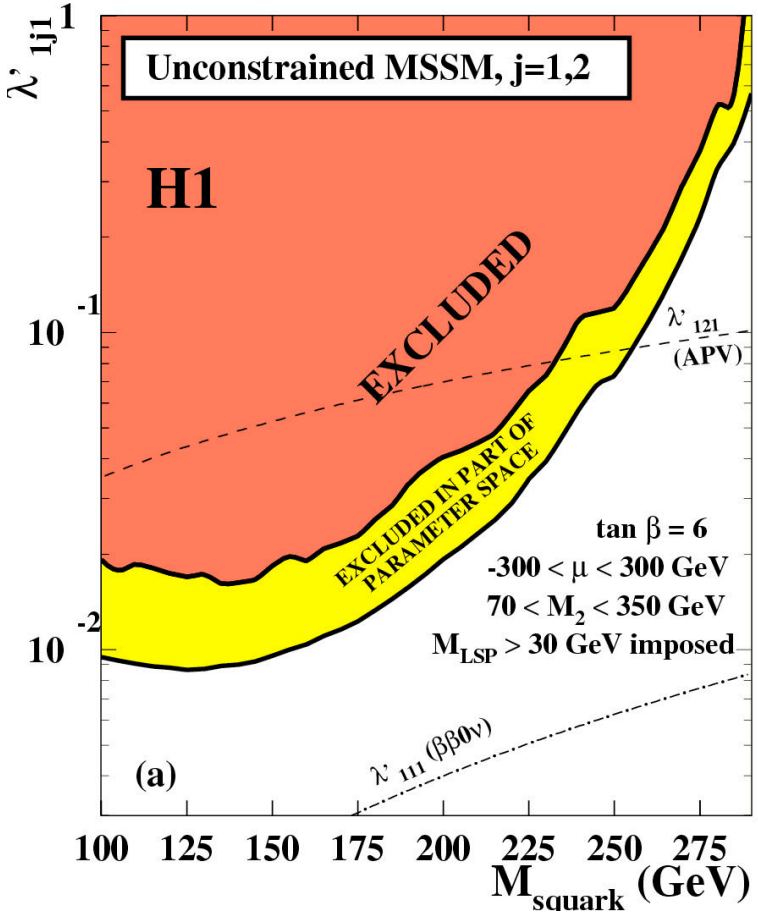
$$W_{\not R_p} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i D_j \bar{D}_k$$



- At HERA the resonant production of single SUSY particles is possible through e-q fusion

Search for Squark Production in R-parity Violating SUSY





- A complete search for resonant production of squarks of all flavours via the Yukawa coupling λ' has been performed by H1
- No evidence for squark production found
- At 95% C.L. squarks of all flavours with masses up to 275 GeV excluded for a coupling of electromagnetic strength

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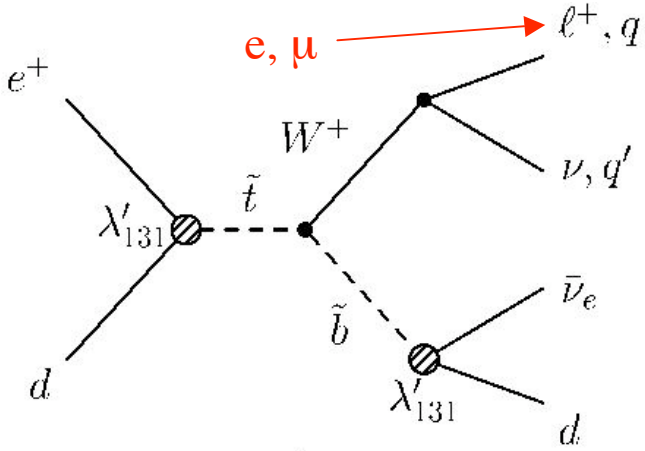
Bosonic Stop Decays: Phenomenology

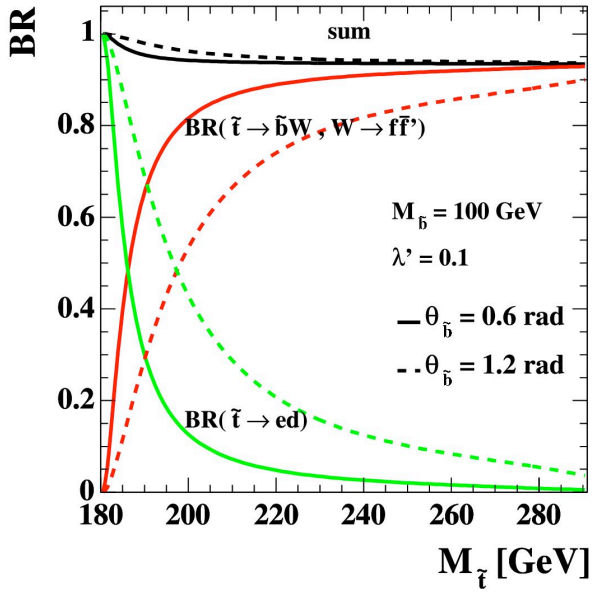
$$W_{R\not p} \sim \lambda'_{131} e_L \tilde{t}_L \bar{d}_R + \lambda'_{131} \nu_{e,L} \tilde{b}_L \bar{d}_R$$



- Resonant production of a stop quark and the R-parity violating bosonic decay of stop and sbottom quarks via the λ'_{131} coupling - complimentary to previous search for squark production analysis
- Stop and sbottom quarks assumed the lightest in this model, where $M_{\tilde{t}} > M_{\tilde{b}}$
- Kinematic range of real bosonic decays:

$$M_{\tilde{t}} > M_{\tilde{b}} + M_W$$

- The decay mode $\tilde{t} \rightarrow ed$ is also analysed, which dominates for $M_{\tilde{t}} \leq M_{\tilde{b}} + M_W$
- Almost full coverage of branching ratios achieved by analysing these 4 channels



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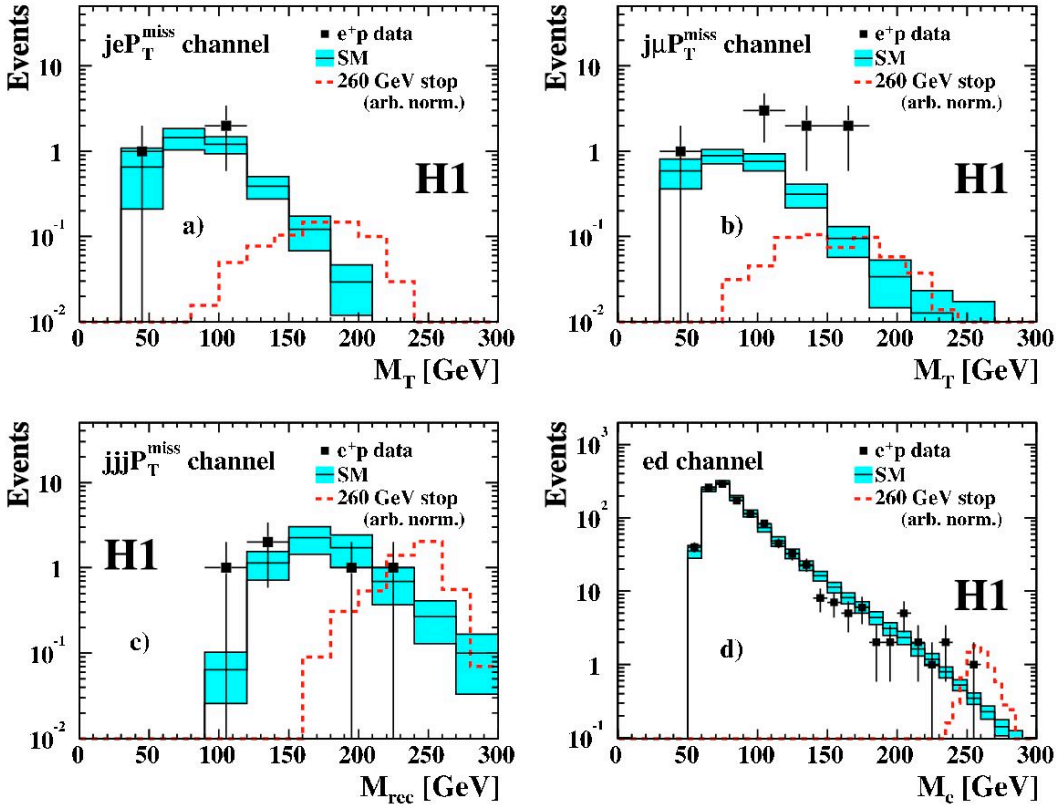
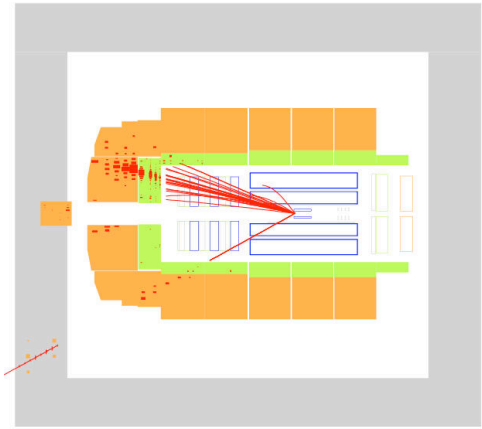
Bosonic Stop Decays: Kinematic Selection

Total e^+p Luminosity Analysed: 106 pb^{-1} e^+p





Event Signature:

Jet + lepton + P_T^{miss} or 3 jets + P_T^{miss}

High P_T Leptons seen at HERA!

See talk by C. Veelken

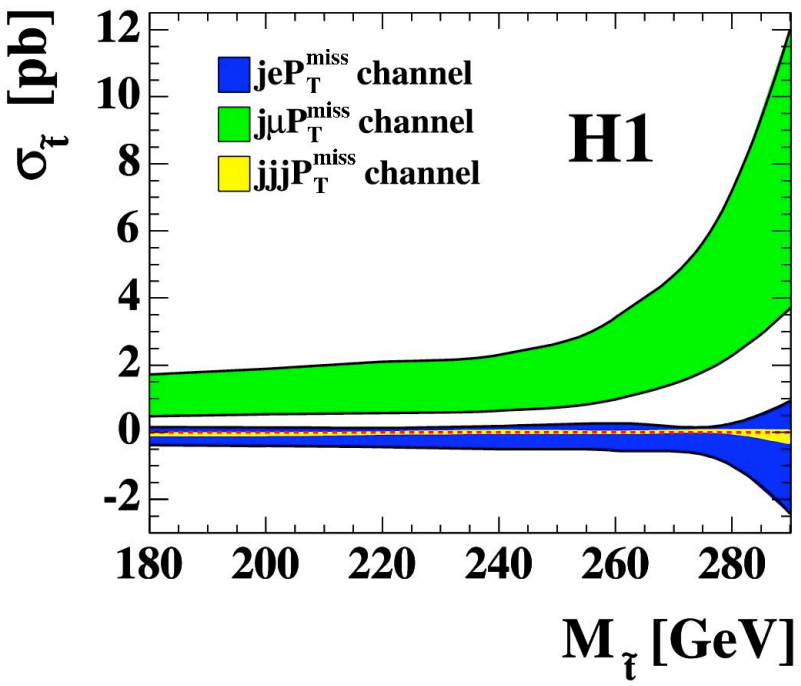
- Bosonic Stop Decay Channels:
  - $P_T^{lepton} > 10$ GeV
  - $P_T^{miss} > 12$ (25) GeV
  - $P_T^{jet(s)} > 10$ (20,15,10) GeV
- R-parity Violating $\tilde{t} \rightarrow ed$ Channel:
  - $P_T^{lepton} > 20$ GeV
  - $P_T^{jet} > 20$ GeV
- Selection efficiencies of 30 - 50%

Slight excess observed in muon channel, but no significant deviation from SM

Stop Production Cross Section

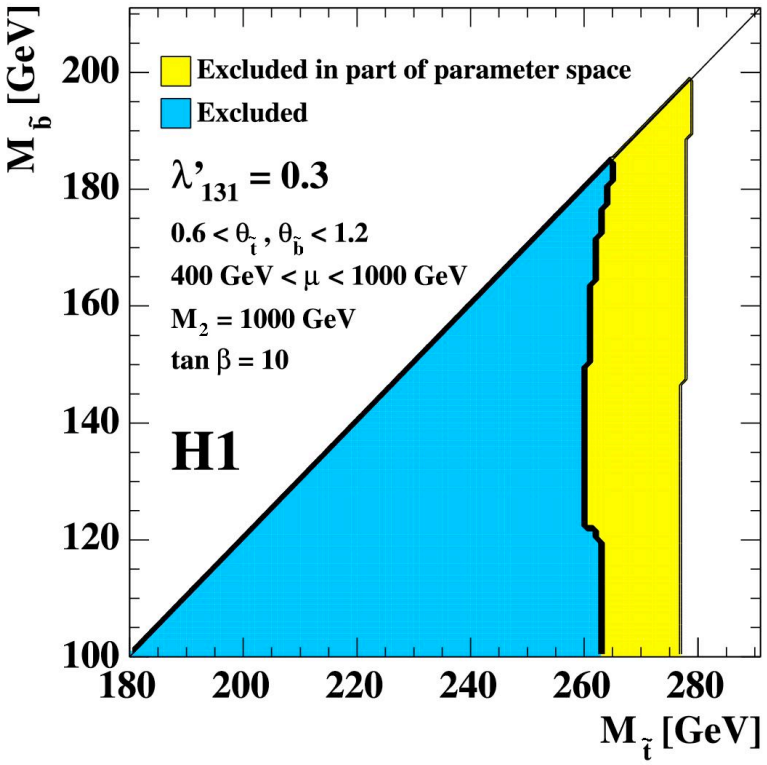
- Assuming the presence of a stop mass, determine an allowed 1 sigma range $\Delta\sigma_{\tilde{t}}$ for the stop production cross section

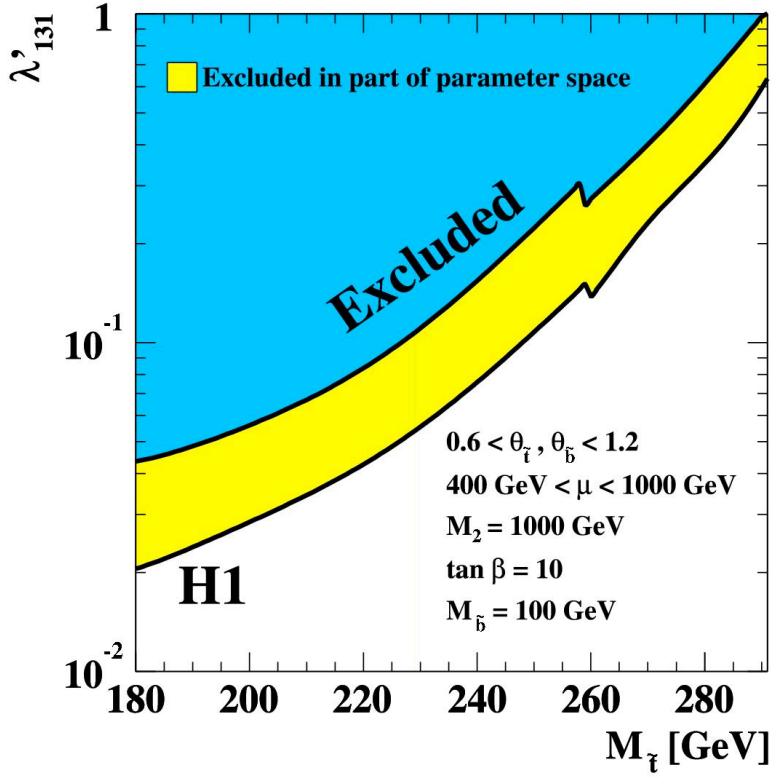
$$\sigma_{\tilde{t}}(M_{\tilde{t}}) = \frac{N_{Data} - N_{SM}}{\varepsilon \cdot BR \cdot \mathcal{L}}$$



- Discrepancy in μjP_T^{miss} channel is not confirmed by other channels
- Probability that observed rate of $jjjP_T^{miss}$ channel fluctuates up to a level compatible with μjP_T^{miss} channel is ~ 1%
- Bosonic stop production does not explain the observed H1 high P_T isolated lepton events

Stop Production Limits



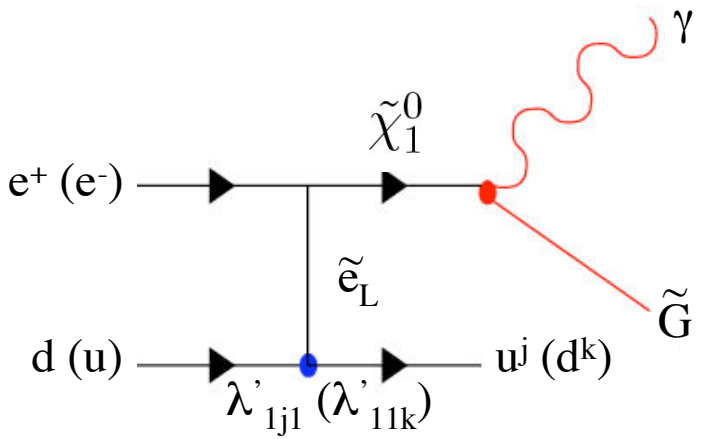


- Perform 5 SUSY parameter scan: $M_{\tilde{t}}$, $M_{\tilde{b}}$, $0.6 < \theta_{\tilde{t},\tilde{b}} < 1.2$, $400 < \mu < 1000$
- For λ'_{131} of electromagnetic strength, stop masses up to 275 GeV are excluded
- For $M_{\tilde{b}} = 100$ GeV, at a $M_{\tilde{t}}$ of 275 GeV, the allowed domain is $\lambda'_{131} \leq 0.3$
- Complementary results to previous H1 search for squark production

Light Gravitinos: Phenomenology

hep-ex/0501030

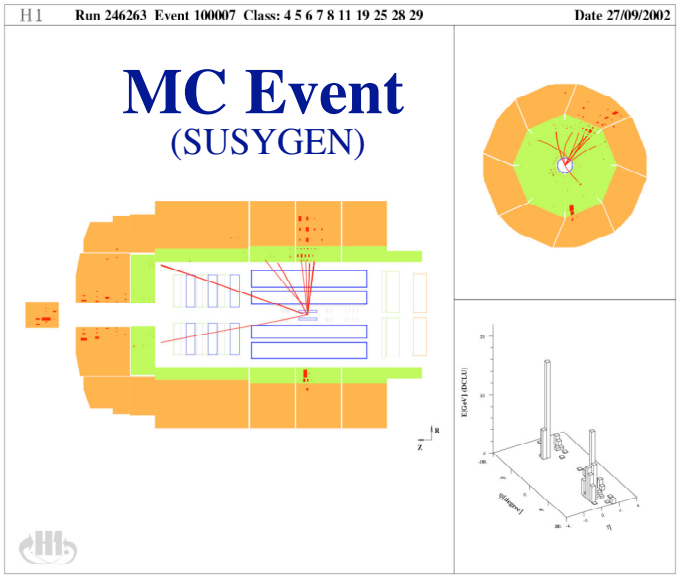
$$W_{\not R_p} \sim -\lambda'_{1jk}\tilde{e}_L u^j_L \bar{d}^k_R$$



- Main difference to other SUSY models is the mass of the Gravitino ($\tilde{G}$), which is small ($< 10^3$ eV) and is the lightest SUSY particle (LSP)
- The single production of a neutralino has been investigated in this model, mediated by selectron exchange (while previous analyses assumed squarks within the kinematic limit)
- The analysis is completely independent of the squark sector
- Different couplings tested with e^+ and e^- data
- GMSB models typically have 6 new parameters compared to the SM:

Λ : Mass scale of SUSY particles	$\tan\beta$: ratio of Higgs vacuum expectation values
M : Mass of "messenger" particles ($m_{\tilde{e}}$, $m_{\tilde{\chi}}$)	sign(μ) : sign of Higgs mixing parameter
N : Number of messenger particles	$\sqrt{F}$: SUSY breaking scale (related to $m_{\tilde{G}}$)

Light Gravitinos: Kinematic Selection

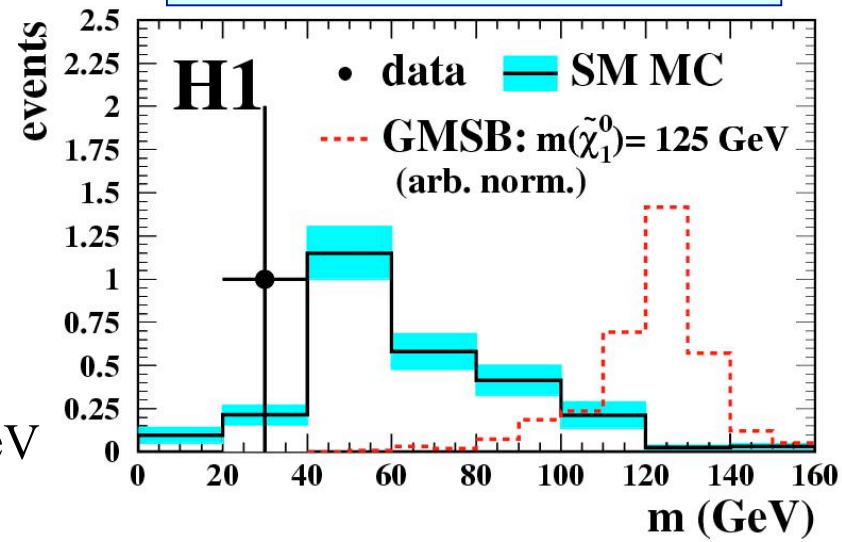


Event Signature:

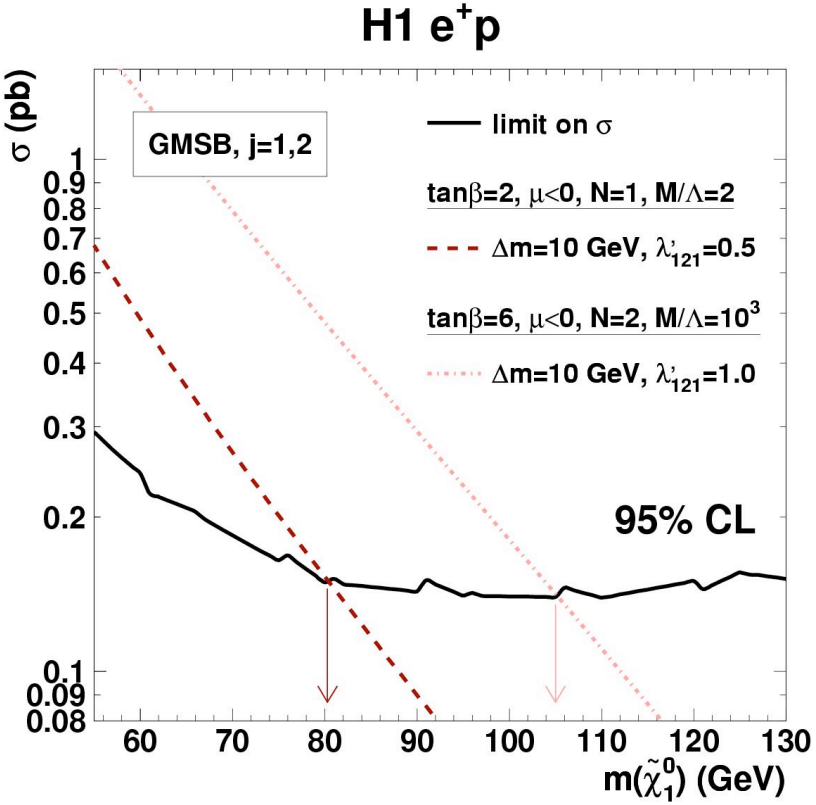
$\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ occurs with unobservably small lifetime: expect photon + jet + P_T^{miss}

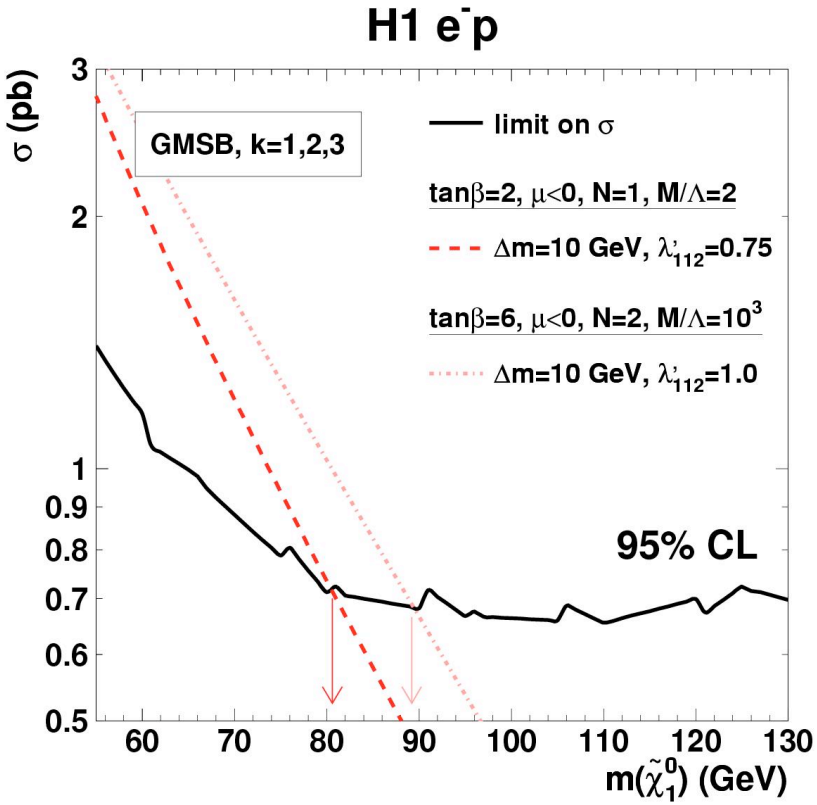
- Main SM background: radiative CC
- Event Selection:
  $P_T^{photon} > 15$ GeV (isolated, no associated track)
  $P_T^{jet} > 5$ GeV
  $P_T^{miss} > 25$ GeV (from Gravitino)
  $\Sigma (E - P_z) > 15$ GeV (against CC DIS)
- Selection efficiencies of 10 - 35%
- e^+p : No candidate observed (1.8 ± 0.2 SM)
- e^-p : One candidate observed (1.2 ± 0.2 SM)
- Assume one non-interacting particle: reconstructed neutralino mass, m = 36 ± 4 GeV

Total Luminosity Analysed:
64 pb^{-1} (e^+p), 14 pb^{-1} (e^-p)



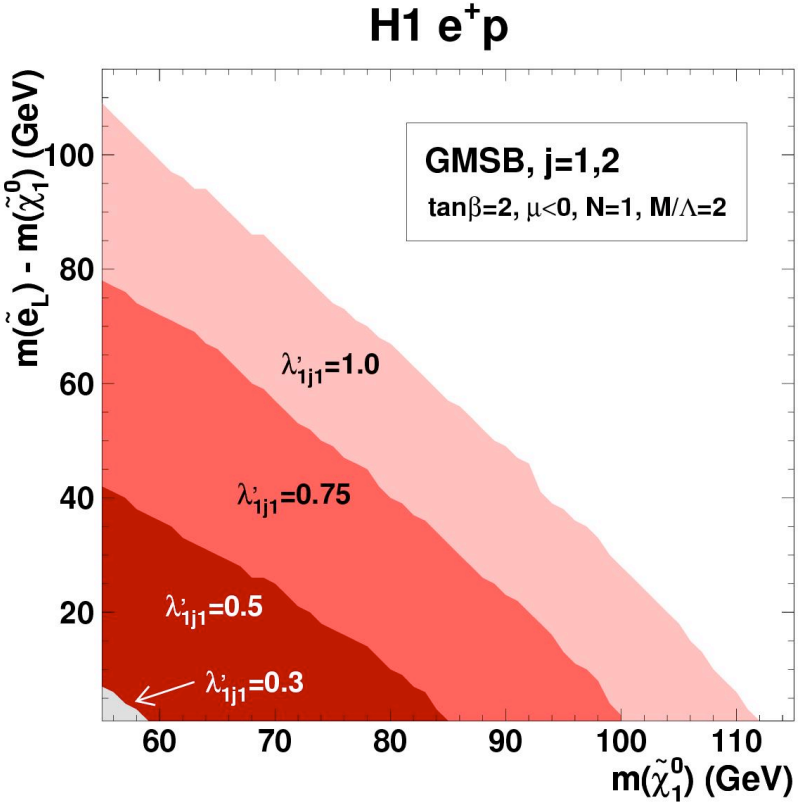
Gravitino Cross Section Limits

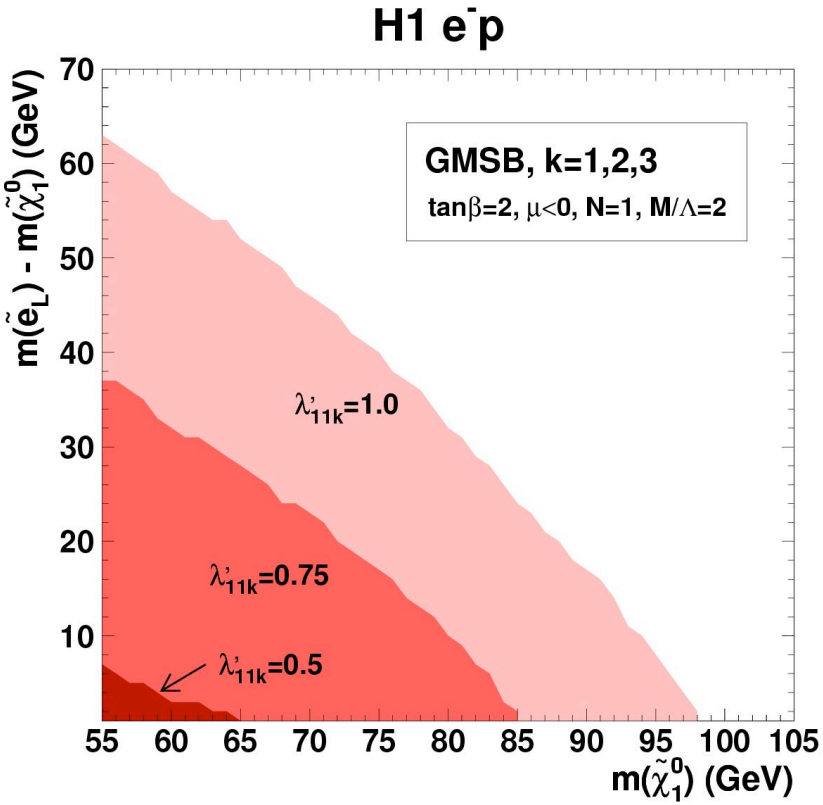




- No significant deviation from SM : derive limits on GMSB model at 95% CL
- Limits less stringent at low neutralino masses due to lower detection efficiency
- For comparison, GMSB cross sections for different couplings λ'_{121} and λ'_{112} with fixed values of tanβ, N and μ

Gravitino Exclusion Limits





- For small Δm: neutralino masses up to 112 GeV are excluded for $\lambda' = 1.0$
- Similarly, for large Δm: selectron masses up to 164 GeV are excluded for $\lambda' = 1.0$
- For masses close to 55 GeV, couplings $\lambda'_{1j1} > 0.3$ and $\lambda'_{11k} > 0.5$ are excluded
- First HERA limits on R-parity violating SUSY independent of squark sector

H1 General Search

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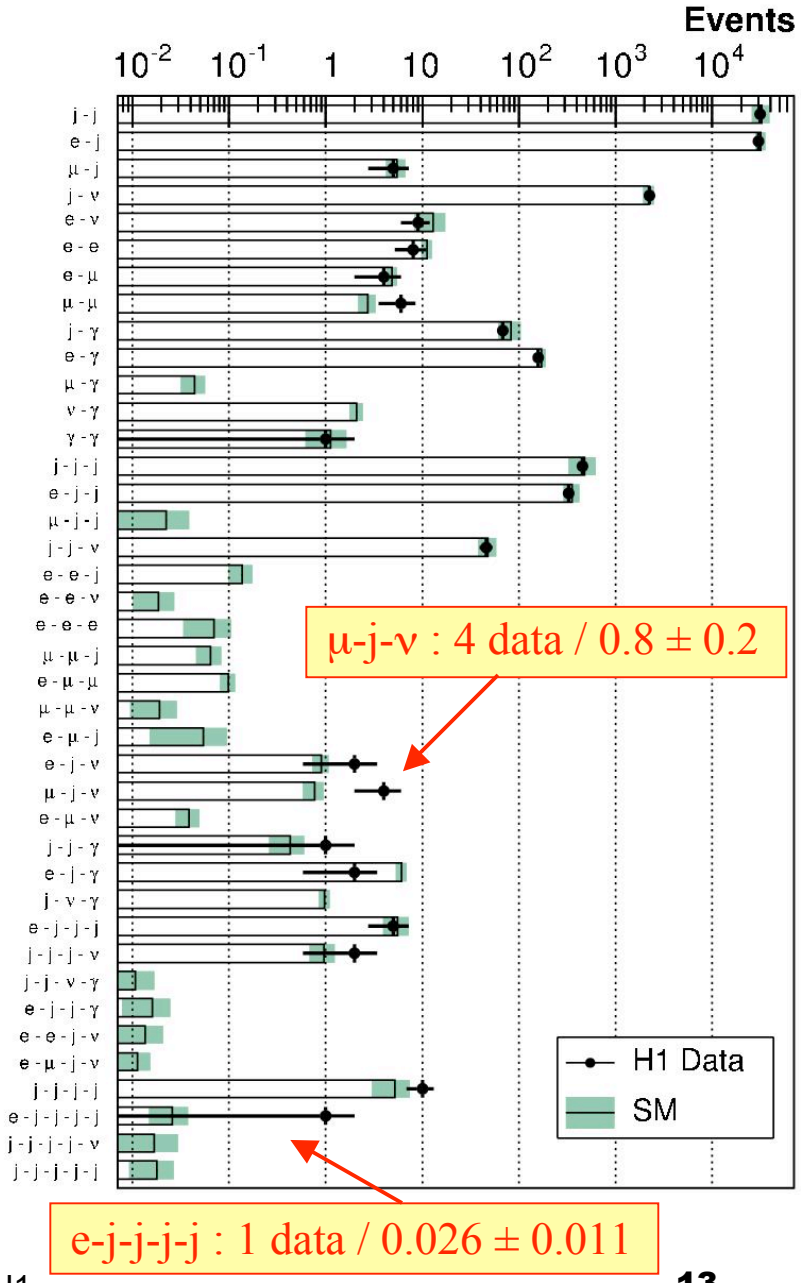
- Presents a general picture of the H1 HERA I data at high P_T - and the consistency with the SM
- Look for isolated, high P_T particles: e, μ, γ, jet, ν

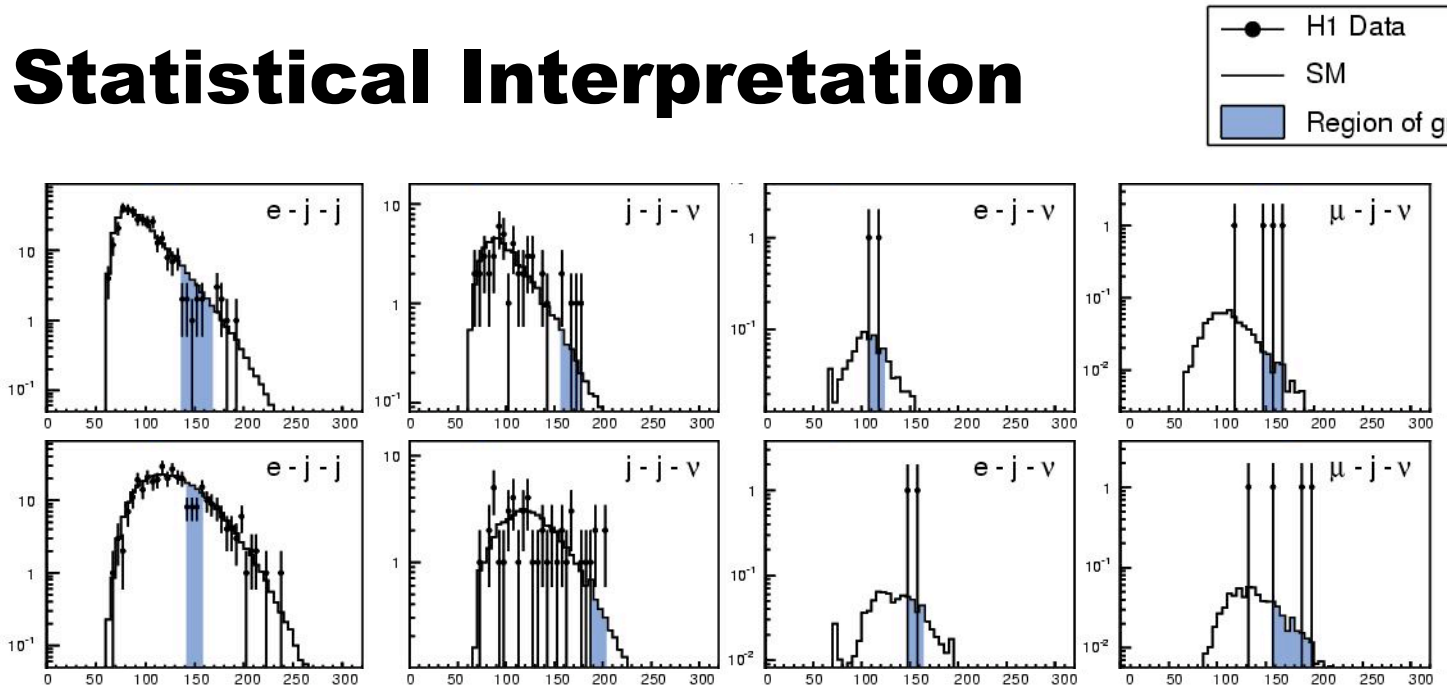
Selection Criteria:

$P_T^{part} > 20$ GeV, $10 < \theta^{part} < 140$, $D(\eta\text{-}\phi)^{part} > 1.0$

- Events classed into exclusive channels (≥ 2 particles): e-j, j-j, j- ν, e-j-j and so on…
- Overall agreement with the SM observed



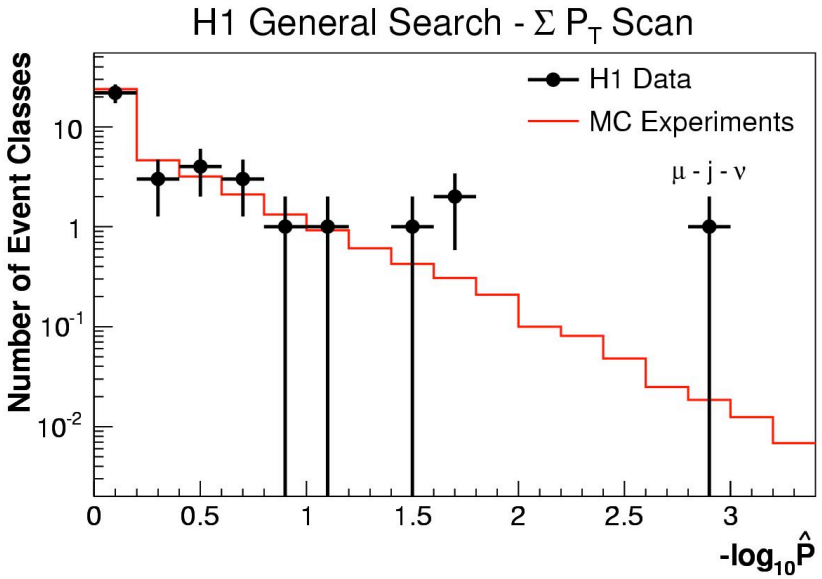
H1 General Search
Statistical Interpretation

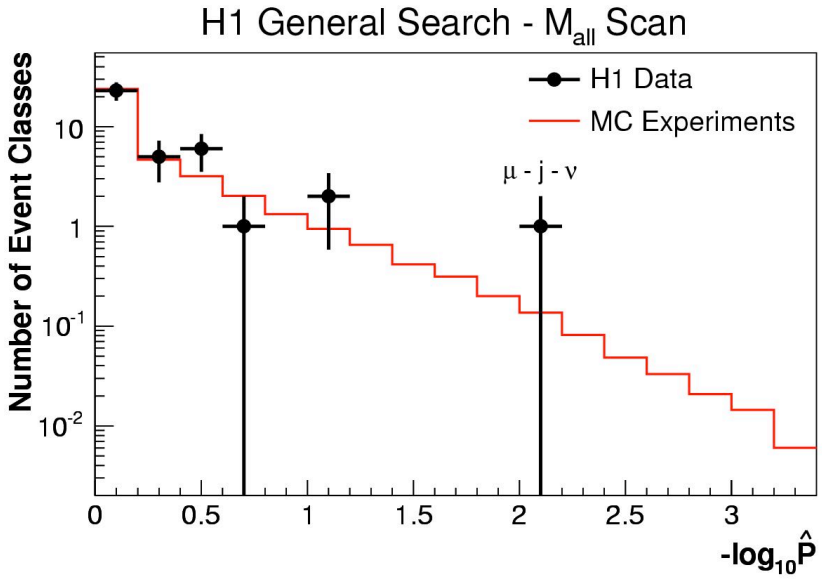


Example Distributions

- Look for deviations in ΣP_T and M_T^{all} distributions
- Determine the region of greatest deviation p_{min} by estimating the probability of upward or downward fluctuations in the distributions
- The method can find narrow resonances and atypical events as well signals spread of large areas of phase space

H1 General Search
Statistical Interpretation

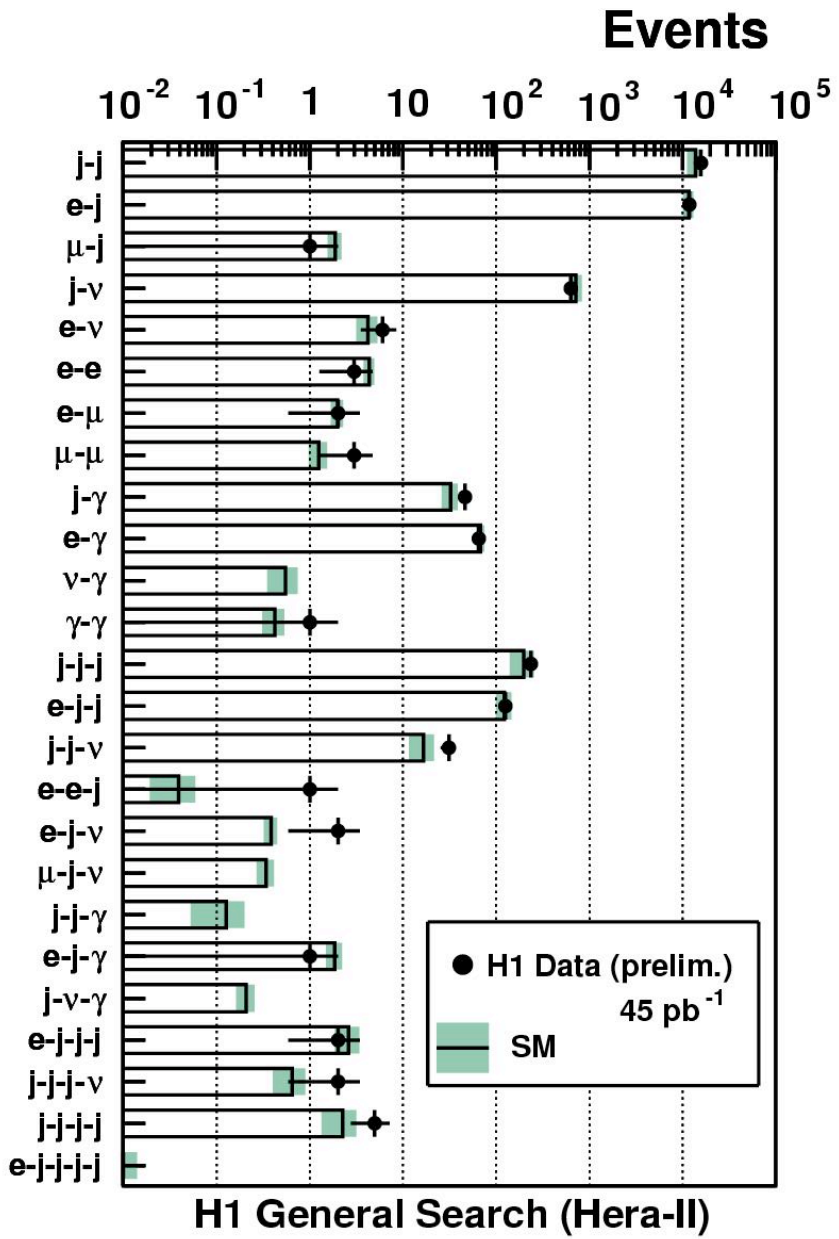




- Compare data event classes with prediction with that from many MC experiments, calculated according to the SM expectation
- $\hat{P}$ is then a measure of the significance of the the deviation observed in the data
- In each channel, low values of $-\log_{10}\hat{P}$ indicate good agreement between data/MC
- The global probabilities to find an event class with $\hat{P}$ smaller than that observed in the μ-j-ν channel are 3% (28%) for the ΣP_T (M_T^{all}) distributions

H1 General Search HERA II

- H1 General Analysis also performed on HERA II e^+p data (45 pb^{-1})
- Again overall agreement is observed between the data and SM
- Deviations from the SM expectation in the e-j-ν channel also observed in dedicated analysis



Summary of Results

- Many SUSY analyses have been performed by H1 on the HERA I data

- No evidence for Bosonic Stop Production found
- The process cannot explain the H1 high P_T leptons
- Stop masses up to ~ 275 GeV are excluded for $\lambda'_{131} = 0.3$

- No deviation from SM seen in Light Gravitino search
- Constraints derived on GMSB models
- Neutralino (Selectron) masses up to ~ 112 (164) GeV excluded for for $\lambda'_{1jk} = 1.0$

- H1 data (1994-2004) has been searched for deviations from the SM at high P_T
- Good agreement between data and the SM is found in most event classes
- The most significant deviation in the HERA I data is found in the μ-j-ν class, a topology where deviations have been previously reported