General Search for New Phenomena and a Search for Magnetic Monopoles at HERA

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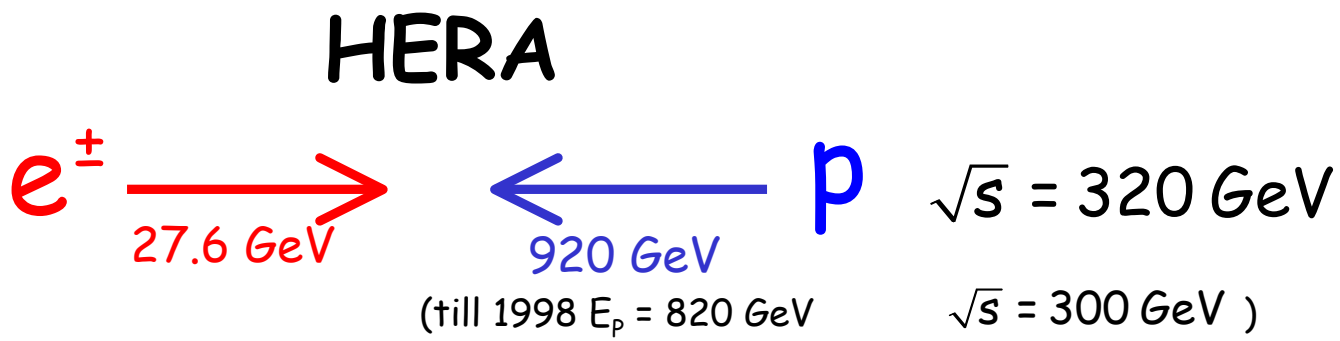
on behalf of the
H1 Collaboration

- **General search for new phenomena at HERA**
- **Direct Search for Magnetic Monopoles**

General Search for New Phenomena



- Dedicated searches for new phenomena performed
  - Isolated leptons and multielectrons,
  - Leptoquarks,
  - Flavour changing NC,
  - Lepton flavour violation,
  - Excited fermions,
  - Supersymmetry

- But, have we missed something? → General search

General Search Analysis Strategy

- **Search for deviations from the SM in a model independent way (don't rely on assumptions concerning the characteristics of a SM extension)**
- **Select event sample at high Pt**
  - Investigate **all** final state configurations of ep interactions with **≥2 particles** (**electron, muon, jet, photon, neutrino**)
  - Common phase space for all particles

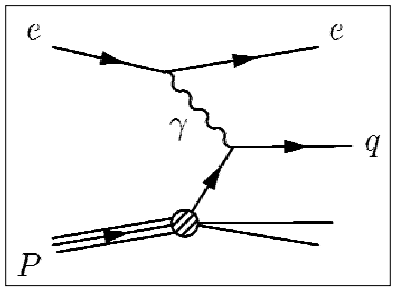
    $P_T > 20$ GeV $10° < \theta < 140°$
  - Classification of events according to the final state

    e-j, j-j, μ-j, j-ν, …, e-e-j, j-j-j, …

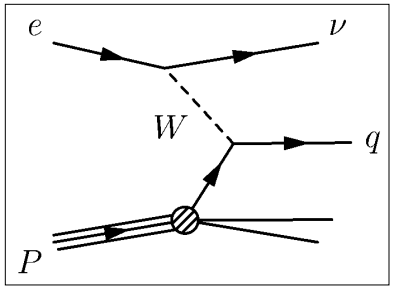
- **Search for deviations – dedicated statistical analysis**

SM Processes and MC Generation

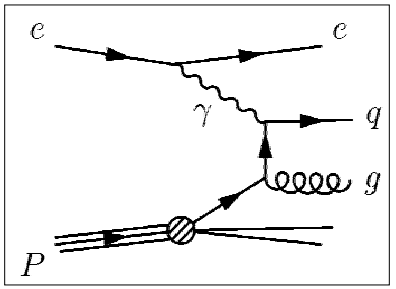
General Search needs SM predictions for all processes at HERA



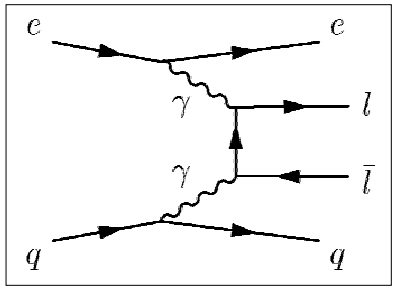
neutral current DIS
Rapgap



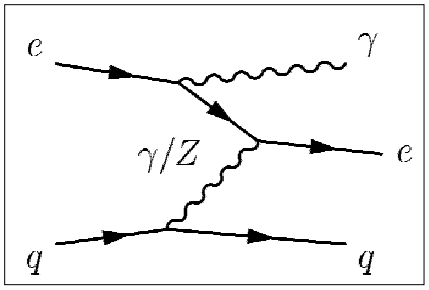
charged current DIS
Django



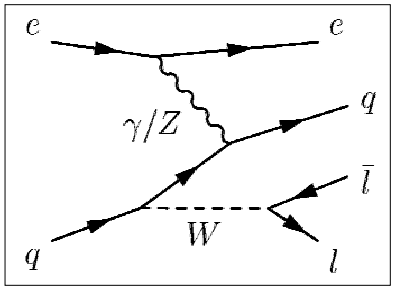
photoproduction
Pythia



lepton pair production
Grape

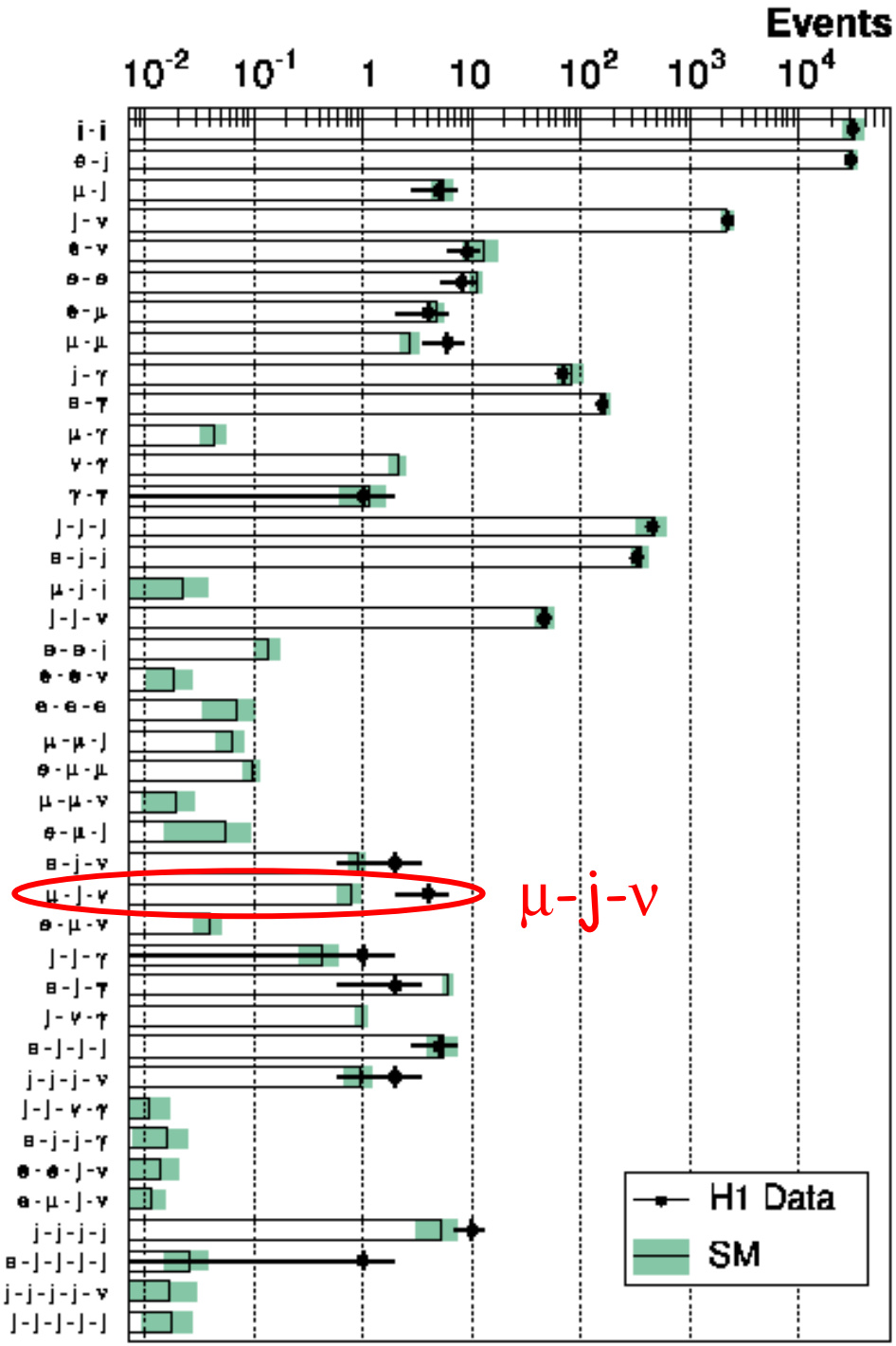


W production
Epvec



QED Compton
Wabgen

Event Yields



HERA I

e^+p $\mathcal{L}$ = 100 pb^{-1}

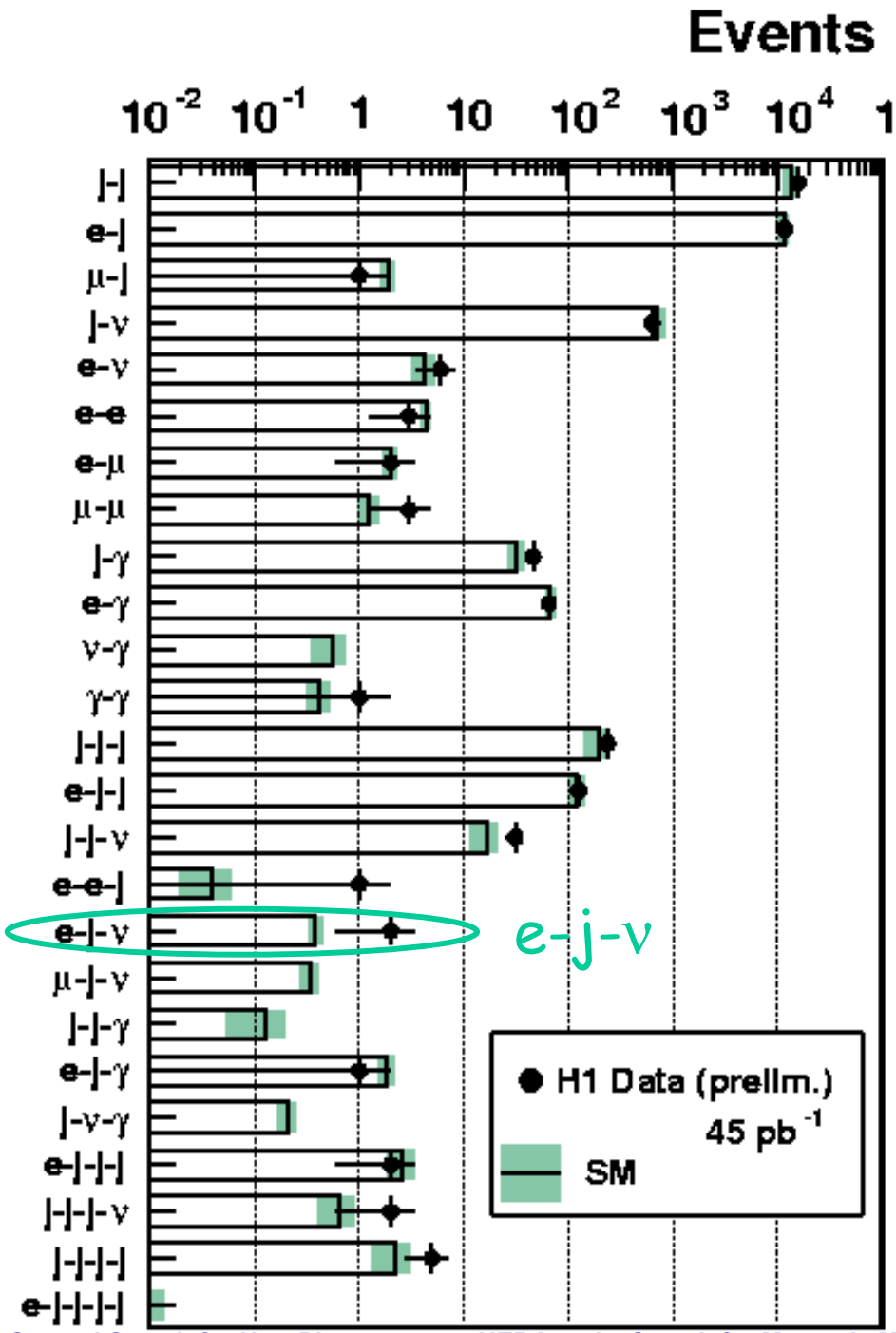
e^-p $\mathcal{L}$ = 15 pb^{-1}

- all possible event classes with ≥ 2 particles investigated
- in total 23 event classes found to be populated by data

- Overall good agreement with SM
- some deviations

(already found in dedicated analysis)

Event Yields



HERA II

$\mathcal{L}$ = 45 pb^{-1}

- all possible event classes with ≥ 2 particles investigated
- in total 20 event classes found to be populated by data

- Overall good agreement with SM
- Some deviation:
  see isolated lepton talk

Search for Deviations

- Systematic search for deviations in differential (1-dim) distributions

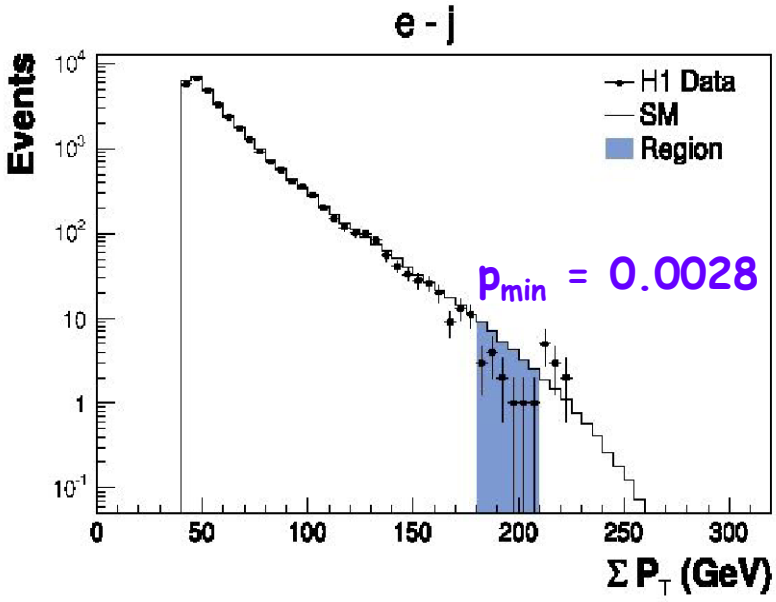
$$M_{all} = \sqrt{\left(\sum_i P_i\right)^2} \qquad \sum P_T = \sum_i \sqrt{P_{x,i}^2 + P_{y,i}^2}$$

- Statistical algorithm $\rightarrow$ 3 steps
  - regions of most interest in the distribution
  - event class of most interest
  - global significance

Regions of Most Interest

Find the regions in the distribution with largest deviation (deficit or excess)

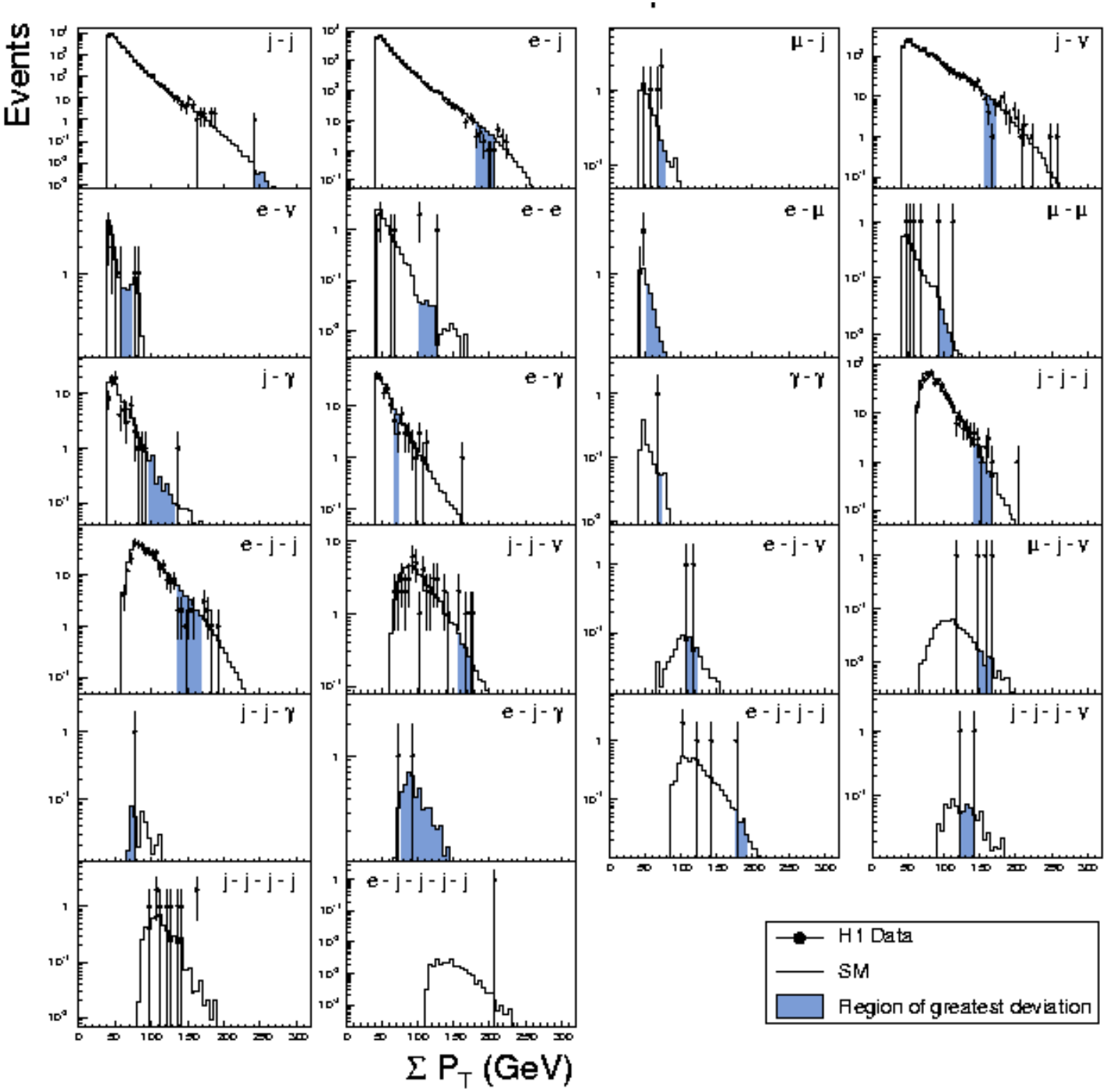
- Check all possible connected regions and find the probability p of fluctuation of the SM
- The region of most interest is the region with smallest probability $p=p_{min}$ $\Leftrightarrow$ region of largest deviation



Estimate the significance of deviation in an event class

- Find the probability $\hat{P}$ to observe a deviation with $p<p_{min}$ anywhere in an event class
- The event class of most interest is the one with the smallest $\hat{P}$

Systematic Search

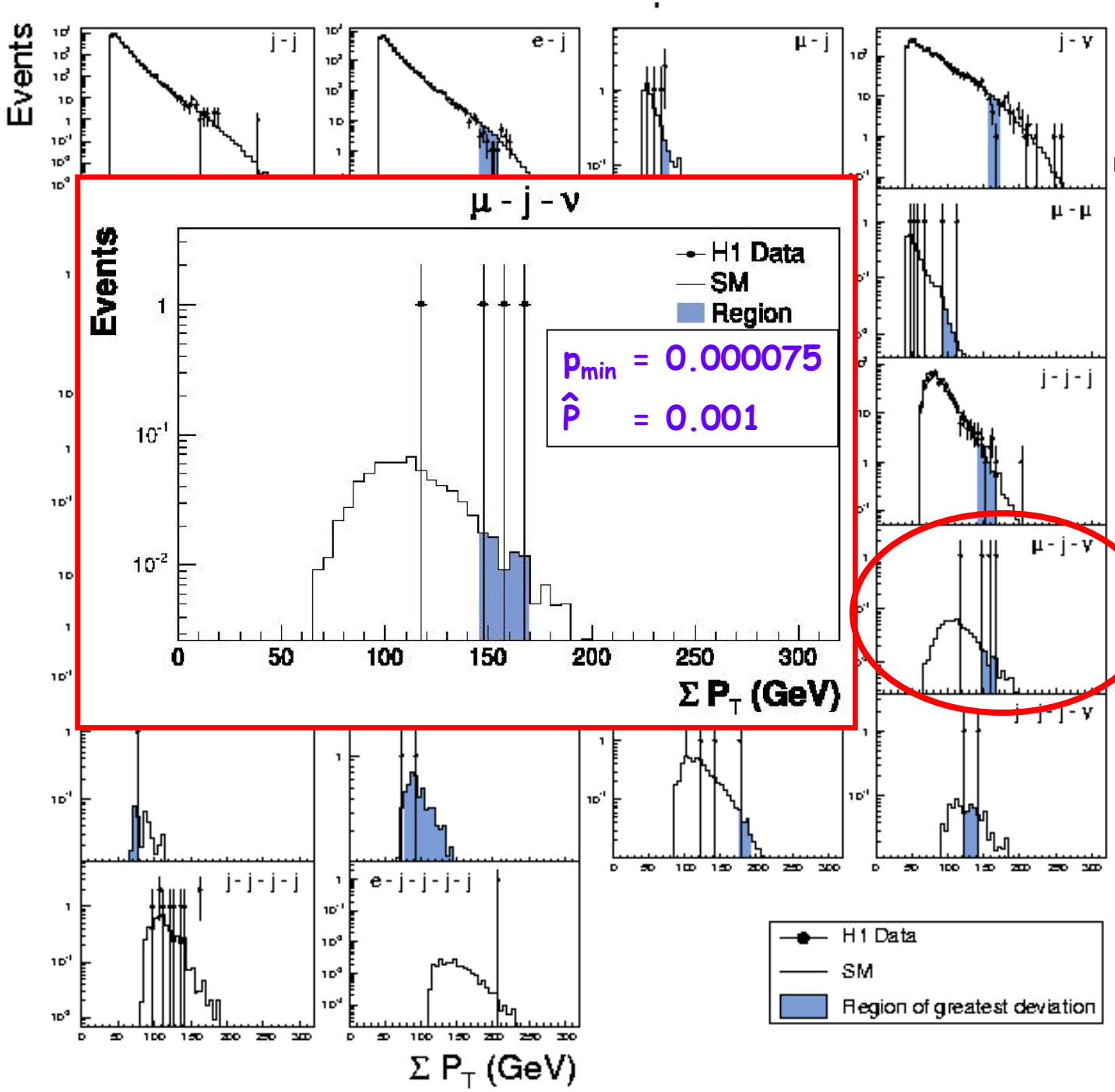


HERA I

$\mathcal{L}$ = **115 pb^{-1}**

P_T and M_{all} distributions examined in **all** event classes

Systematic Search



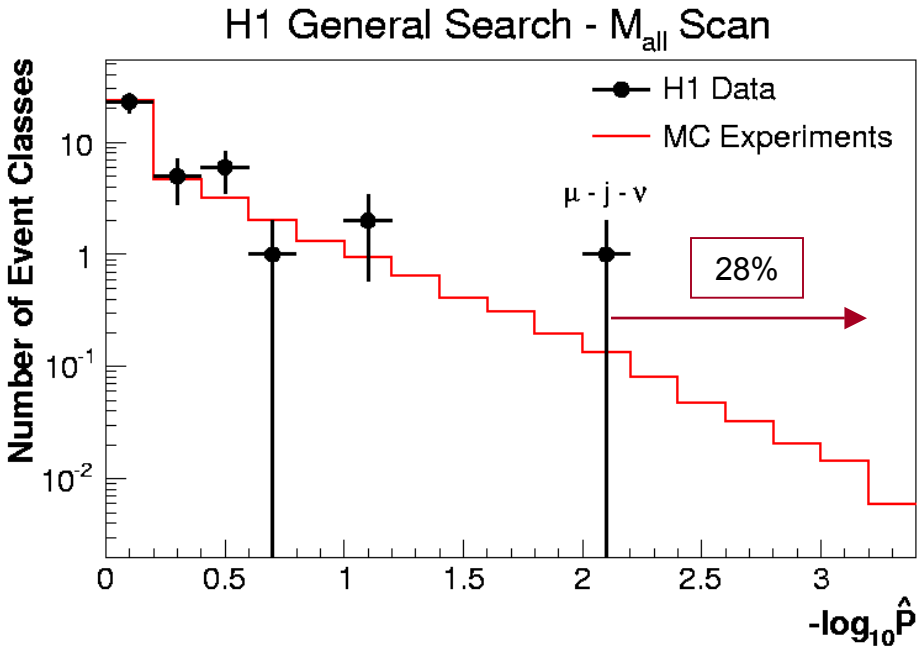
HERA I

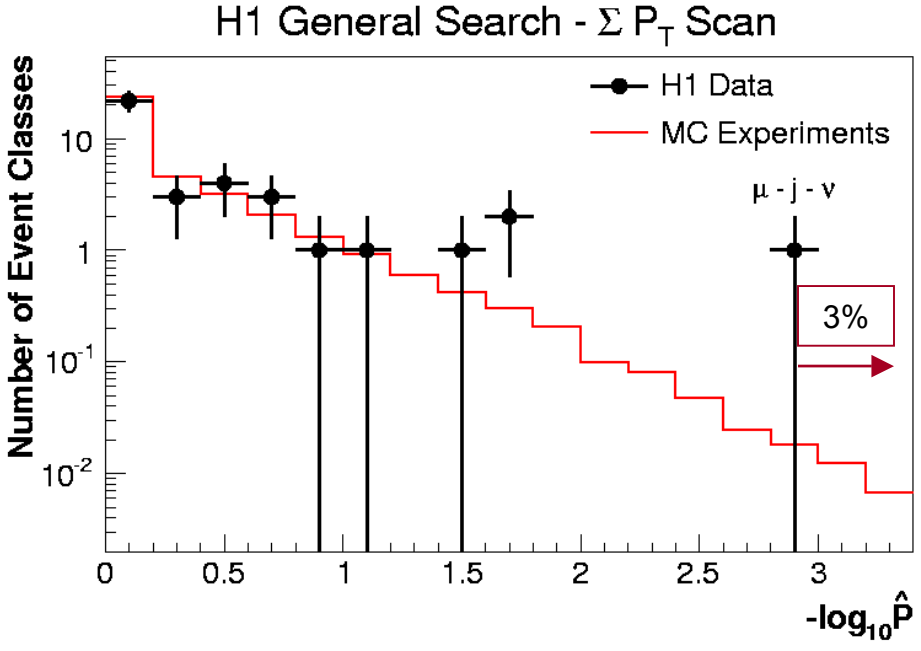
P_T and M_{all} distributions examined in **all** event classes

Largest deviation found in μ-j-ν event class

Global Significance

Overall agreement with SM quantified by taking into account the large number of event classes





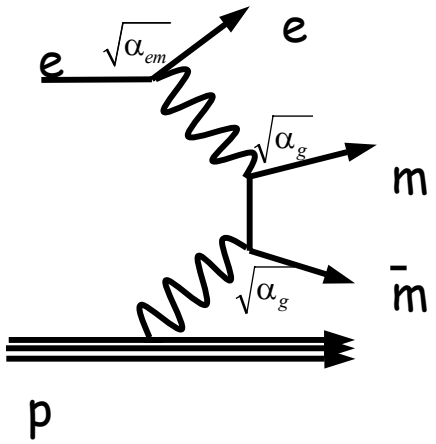
- Most significant deviation found in μ-j-ν

(consistent with observation of dedicated analysis)

No additional deviations found

Search for Magnetic Monopoles at HERA

First search for magnetic monopoles in e^+p interactions at $\sqrt{s} = 300\ GeV$



QED coupling for Dirac monopole g_D

$\alpha_g = g_D^2/4\pi = 34$

$\alpha_{em} = 1/137$

} Ionisation energy loss ~10^3 larger than for min. ionising charged particles

⇓

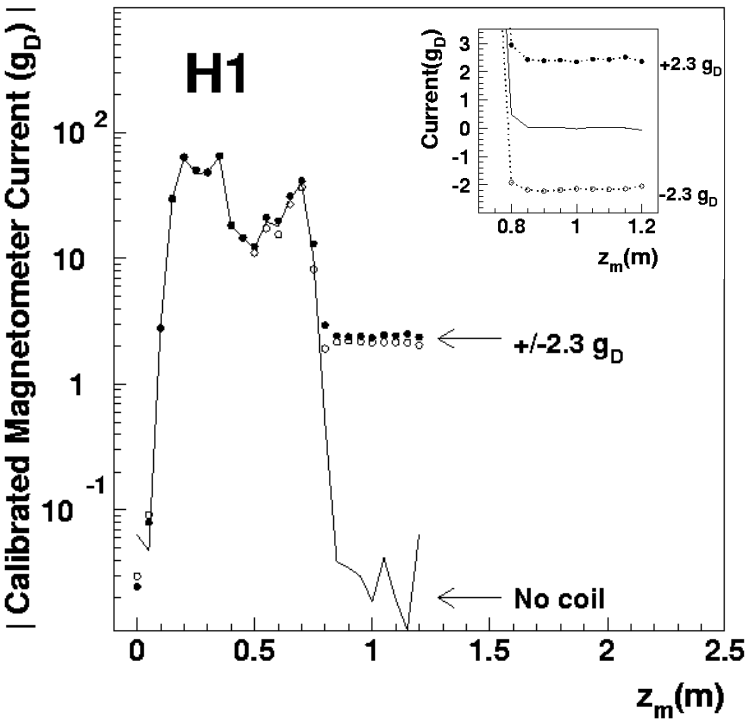
Monopoles produced in the e^+ p collisions **may be stopped in the beam pipe** surrounding the interaction point

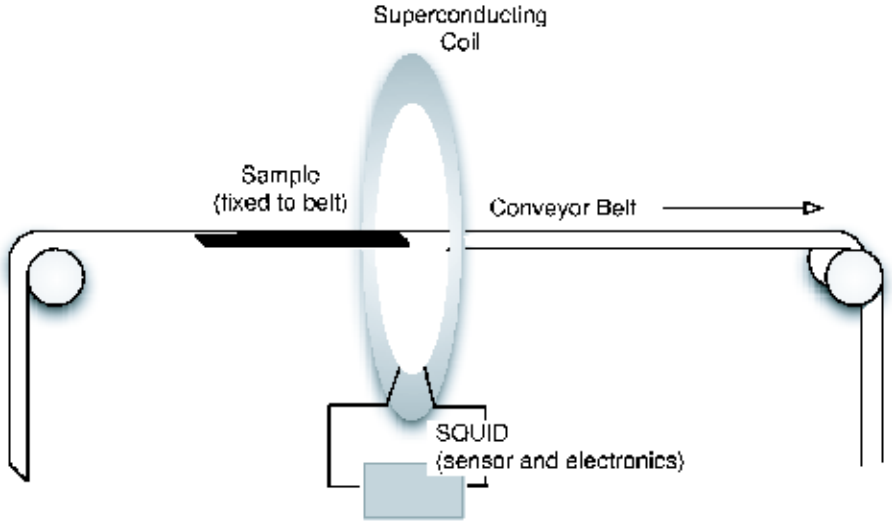
Binding energy of monopoles stopped in the Al beam pipe expected to be large (Milton et al) ⇒ **monopoles should remain trapped in the material**

Examine the Al beam pipe used in the 1994-1997 running period exposed to integrated luminosity of 62 pb^{-1}

Method of Measurement

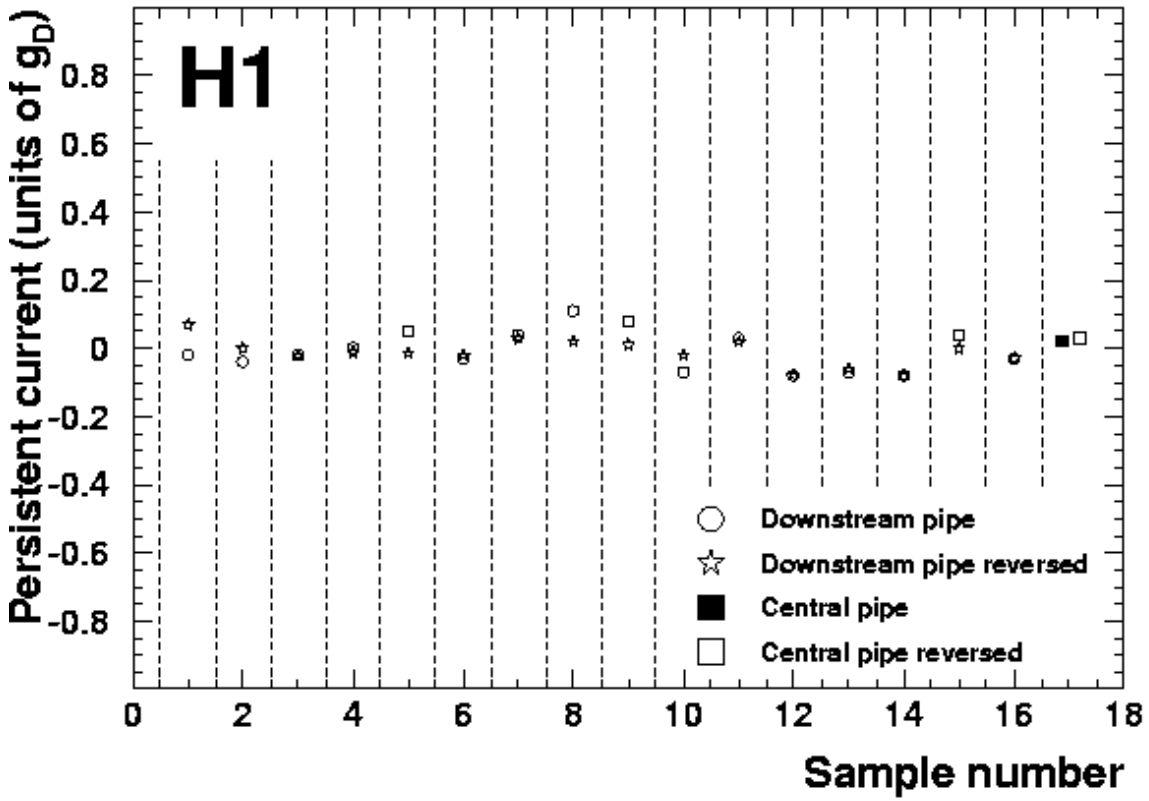
- Cut the beam pipe into strips
- Pass each strip through a superconductcting coil coupled to a SQUID sensitive to monopoles of charge $\geq 0.1\ g_D$





- Trapped monopoles will cause persistent current in the superconducting coil – after complete passage of strip through coil

Results of Measurements



- No magnetic monopole of strength > 0.1 g_D had stopped in the measured strips
- The result is interpreted in terms of limits on the monopole pair production cross section

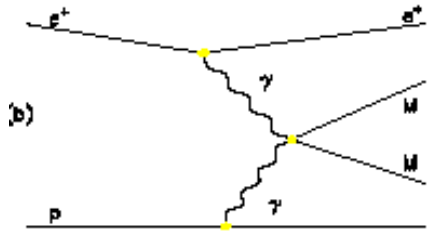
Limits on the Cross Section

- Model needed to compute the efficiencies **but**,

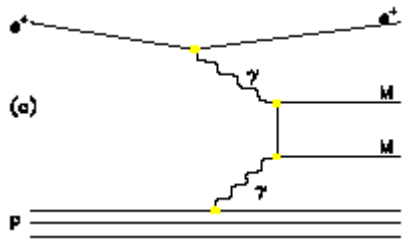
$\alpha_g = 34 \Rightarrow$ Perturbation theory not applicable

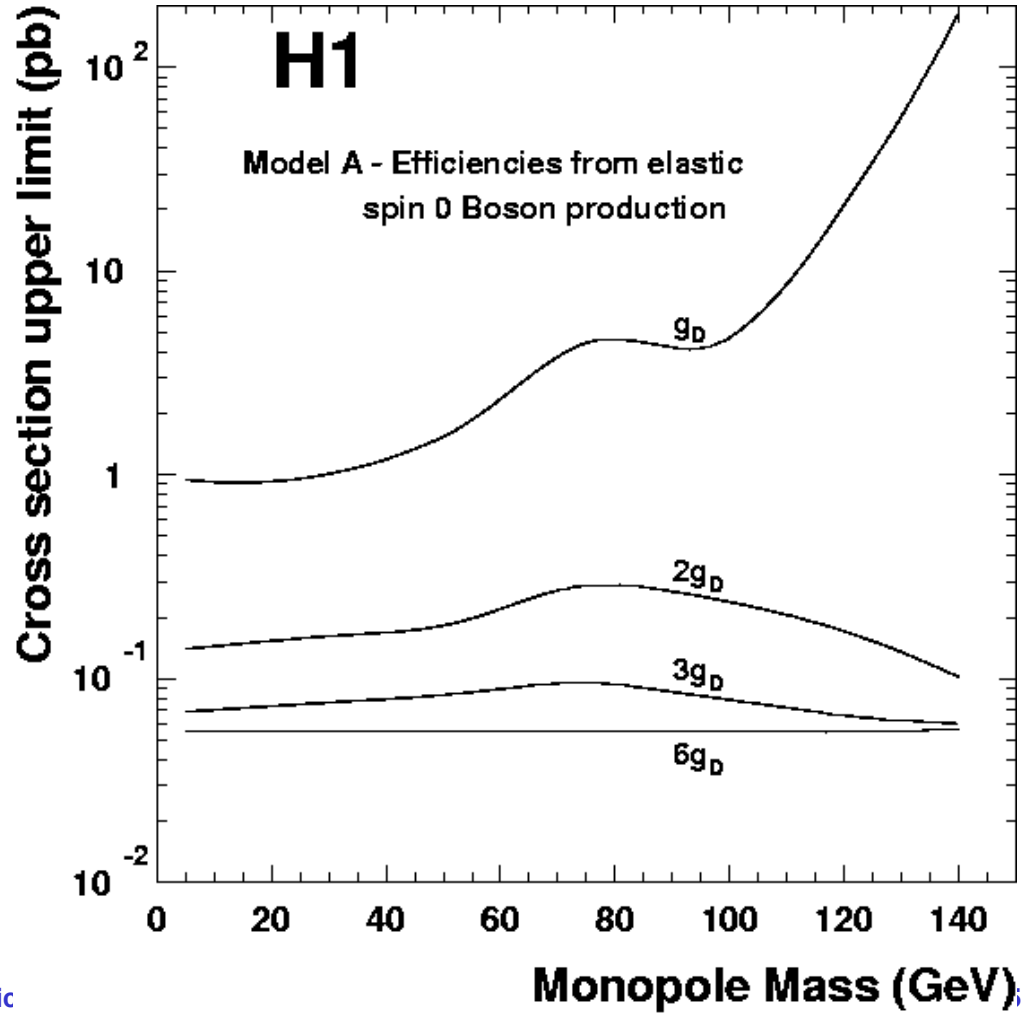
However 2 models used

-Model A – spin 0 monopole



-Model B – spin $\frac{1}{2}$ monopole





Summary

- For the first time all event topologies involving isolated electrons, photons, muons, jets and neutrinos studied in a single analysis
- Most significant deviation found in μ - j - ν
  (consistent with observation of dedicated analysis)
- **No additional deviations found**

- The first direct search for magnetic monopoles in e^+p collisions at HERA at $\sqrt{s}$ of 300 GeV
- **No monopole signal observed**
- Upper limits on the cross section for pair production of monopoles with charge 1-6g_d and up to a mass of 140 GeV within the context of two models

Region of most interest

$$p_{\text{region}} = G_{\text{syst}}(\text{BG}) \otimes P_{\text{Poisson}}(N_{obs} \geq N_{SM}, N_{obs} < N_{SM})$$

N_{SM} = number of **expected** events in region

N_{obs} = number of **observed** events in region

$$p = \begin{cases} A \int_0^\infty db\, G(b; N_{SM}, \delta N_{SM}) \sum_{i=N_{obs}}^{\infty} \frac{e^{-b} b^i}{i!} & \text{if } N_{obs} \geq N_{SM} \\ A \int_0^\infty db\, G(b; N_{SM}, \delta N_{SM}) \sum_{i=0}^{N_{obs}} \frac{e^{-b} b^i}{i!} & \text{if } N_{obs} < N_{SM} \end{cases}$$

$$\text{with} \quad A = 1 \Big/ \left[\int_0^\infty db\, G(b; N_{SM}, \delta N_{SM}) \sum_{i=0}^{\infty} \frac{e^{-b} b^i}{i!} \right].$$

Event Class of Most Interest

Qunatify the significance of the deviation found

What is the probability P to observe a deviation with $p<p_{min}$ anywhere in the distribution of an event class?

- dice hypothetical histograms H_{hyp} according to the pdf of the SMexpectation
- for each of those H_{hyp} the algorithm is run to find the region of largest deviation determined by p_{min}^{hyp}
- $$\hat{P} = \frac{\text{number of } H_{hyp} \text{ with } p_{\min}^{hyp} < p_{\min}^{data}}{\text{total number of } H_{hyp}}$$ measure of statistical significance
- The event class of most interest is the one with the smallest $\hat{P}$

Limits on the Cross Section