

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

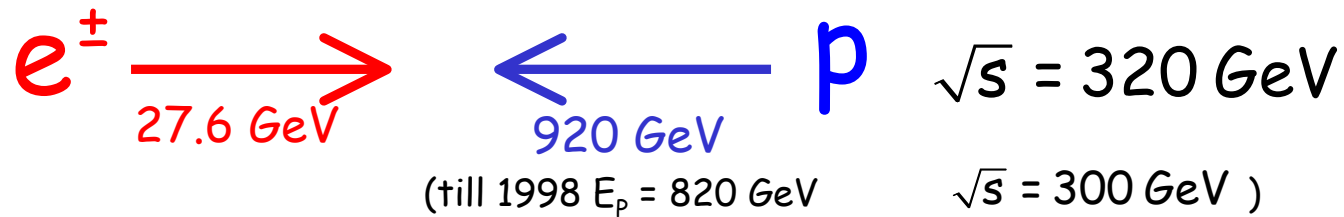
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on behalf of the
H1 Collaboration

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

General Search for New Phenomena

HERA



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

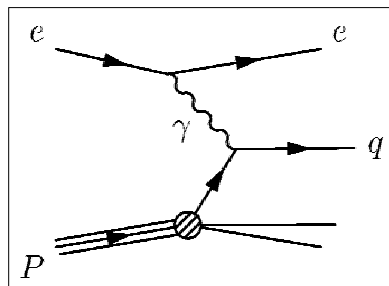
- But, have we missed something? → **General search**

General Search Analysis Strategy

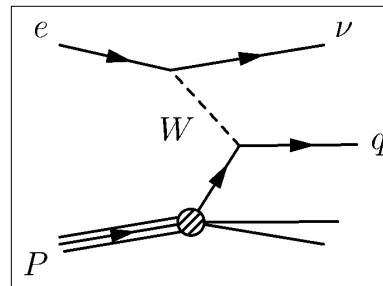
- Search for deviations from the SM in a model independent way (don't rely on assumptions concerning the characteristics of a SM extension)
- Select event sample at **high Pt**
 - Investigate all final state configurations of ep interactions with ≥ 2 particles (electron, muon, jet, photon, neutrino)
 - Common phase space for all particles
 $P_T > 20 \text{ GeV}$ $10^\circ < \theta < 140^\circ$
 - Classification of events according to the final state
 $e-j, j-j, \mu-j, j-\nu, \dots, e-e-j, j-j-j, \dots$
- Search for deviations - dedicated statistical analysis

SM Processes and MC Generation

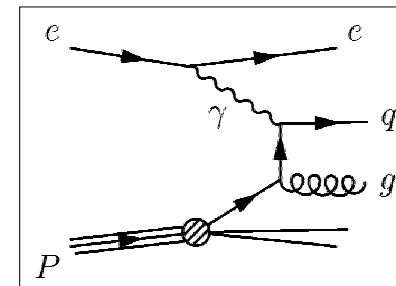
General Search needs SM predictions for all processes at HERA



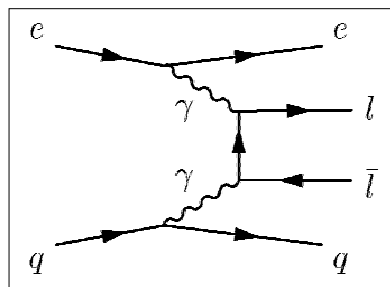
neutral current DIS
Rapgap



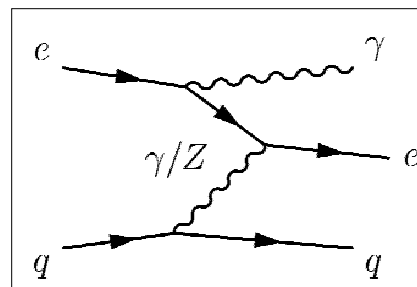
charged current DIS
Django



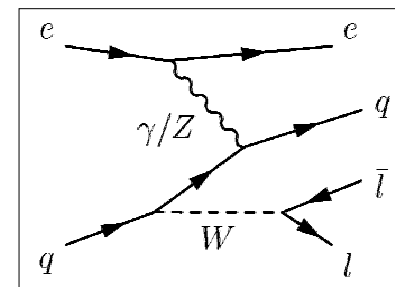
photoproduction
Pythia



lepton pair production
Grape

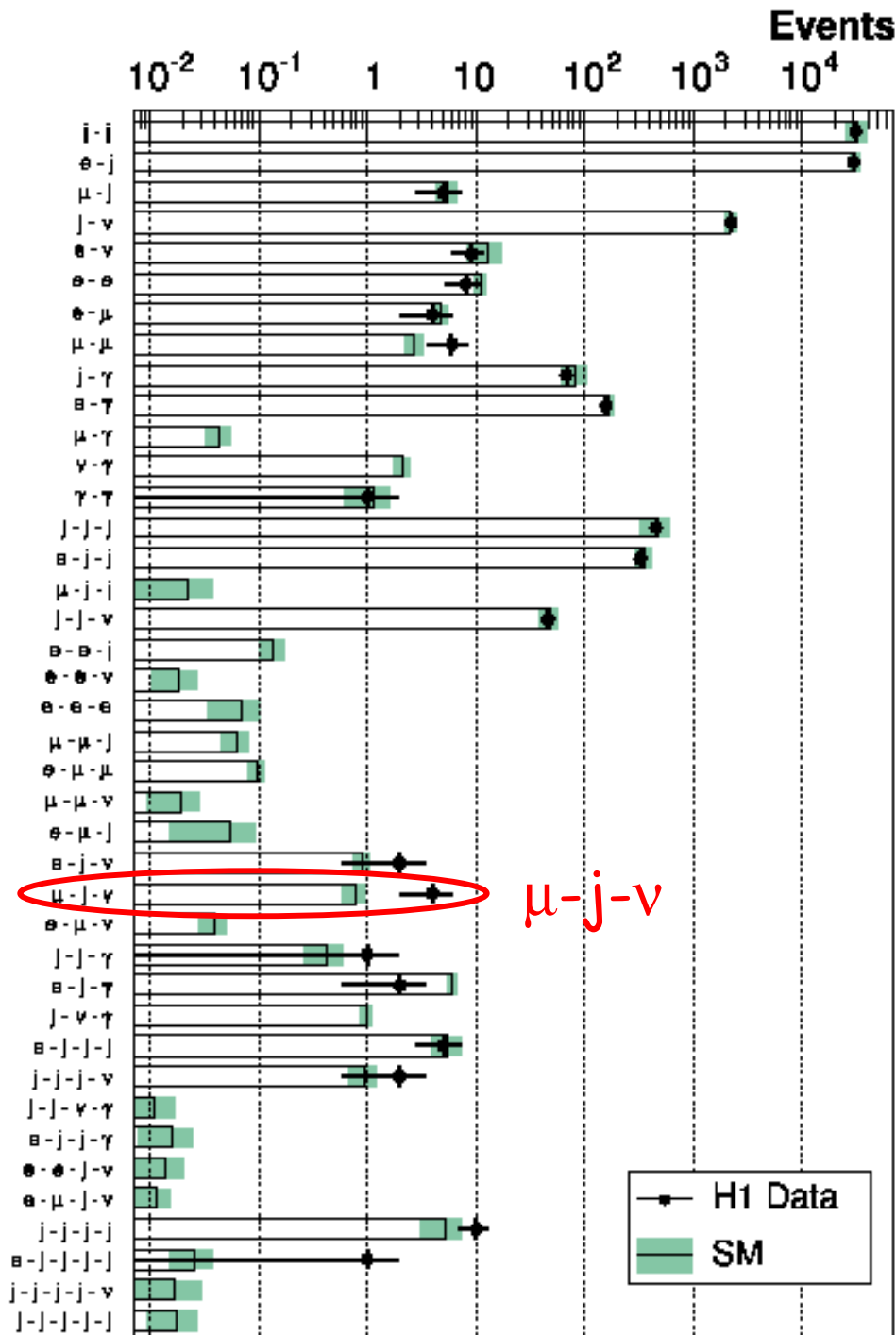


W production
Epvac



QED Compton
Wabgen

Event Yields



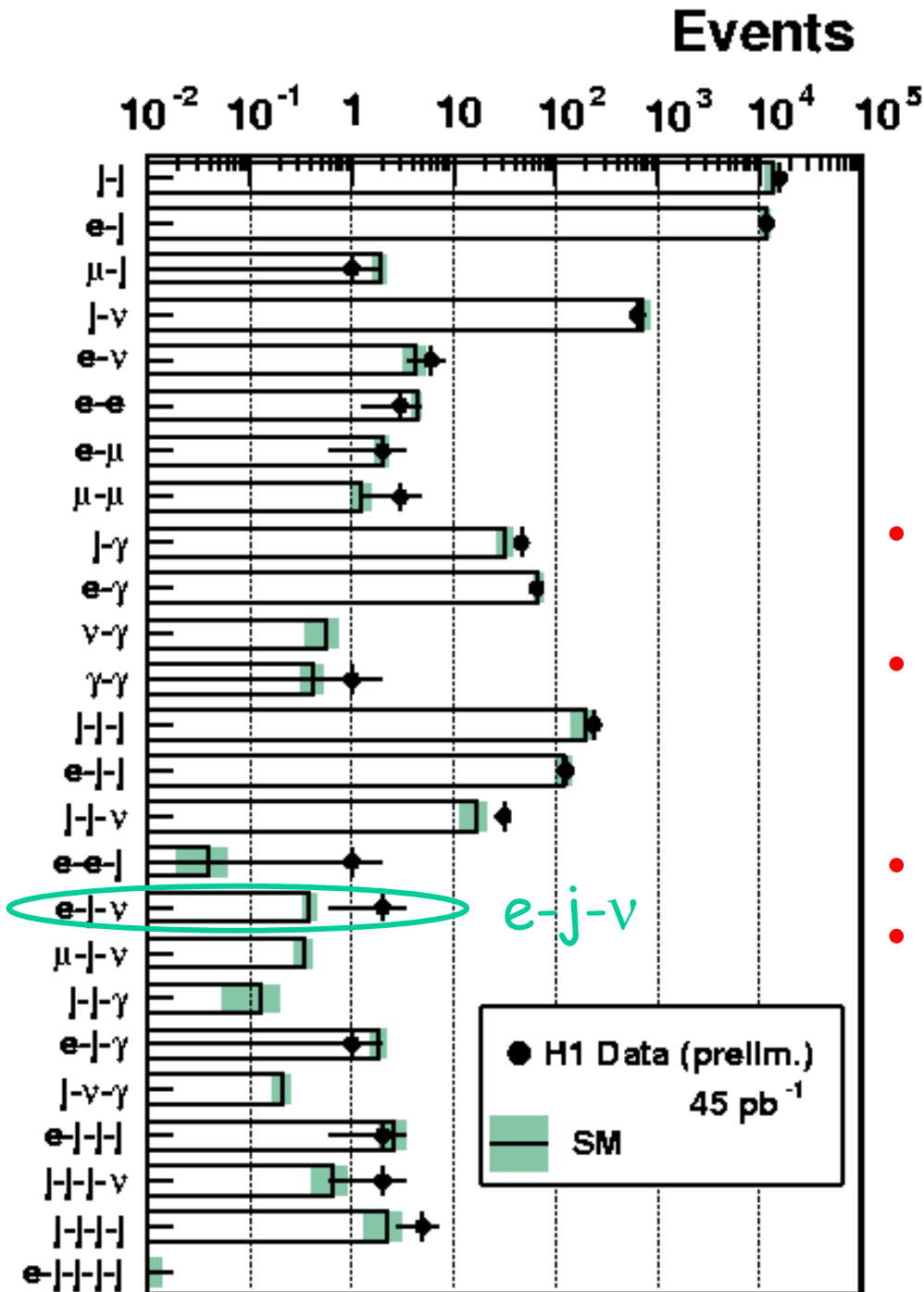
HERA I

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

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

- 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

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

- 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**

$$M_{all} = \sqrt{\left(\sum_i P_i\right)^2}$$

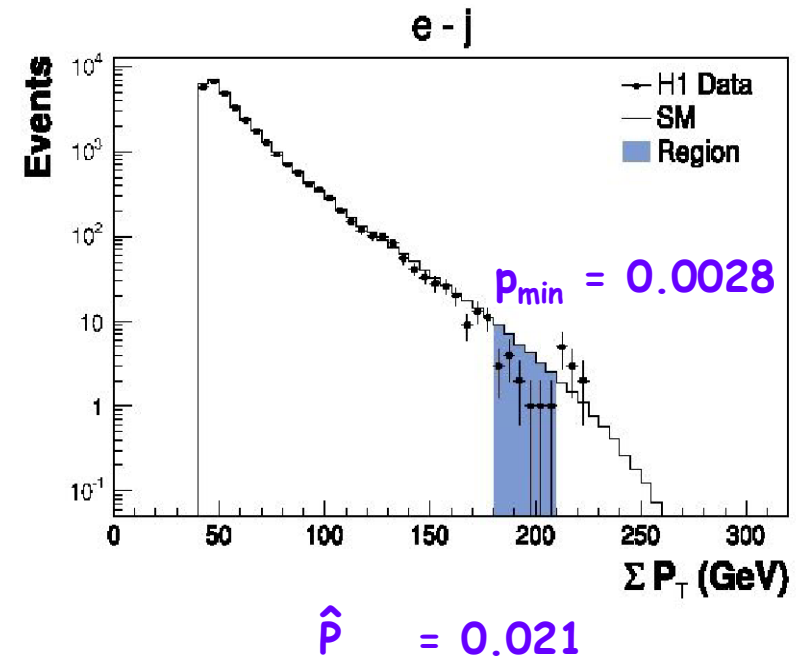
$$\sum P_T = \sum_i \sqrt{P_{x,i}^2 + P_{y,i}^2}$$

- **Statistical algorithm → 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

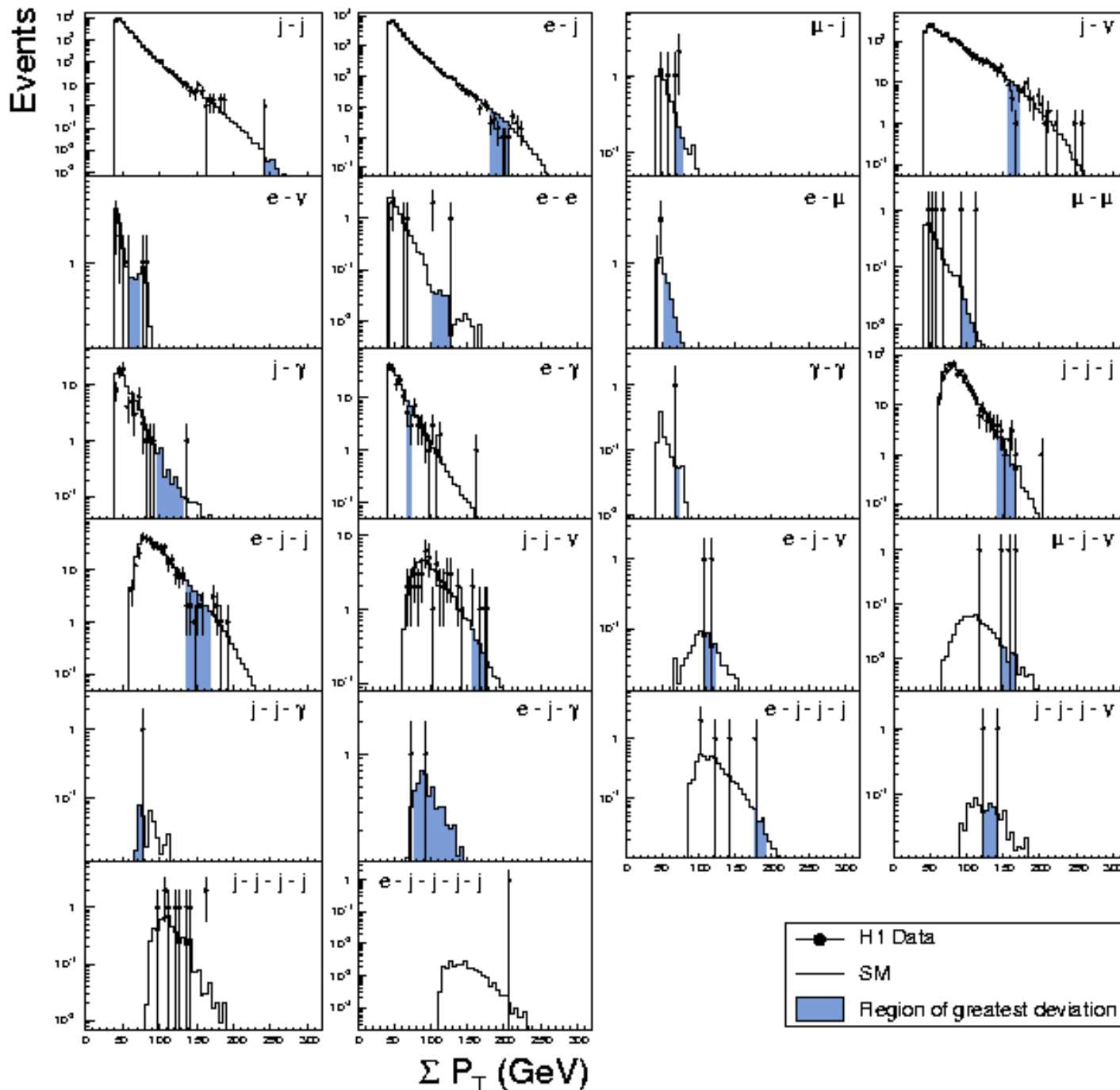
- Find the probability \hat{P} to observe a deviation with $p < p_{\min}$ *anywhere* in an event class
- The event class of most interest is the one with the smallest \hat{P}

Systematic Search

HERA I

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

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

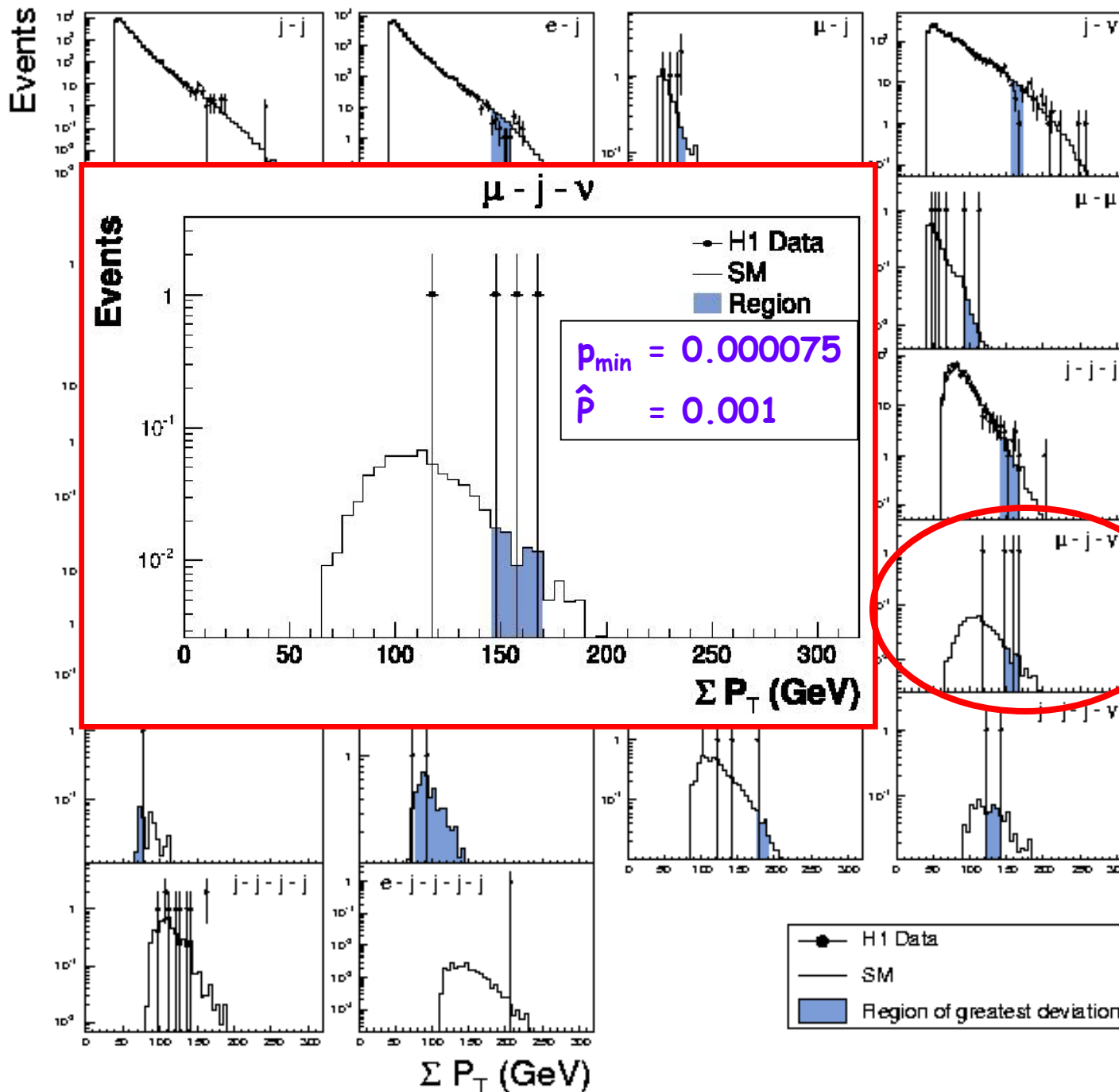


Systematic Search

HERA I

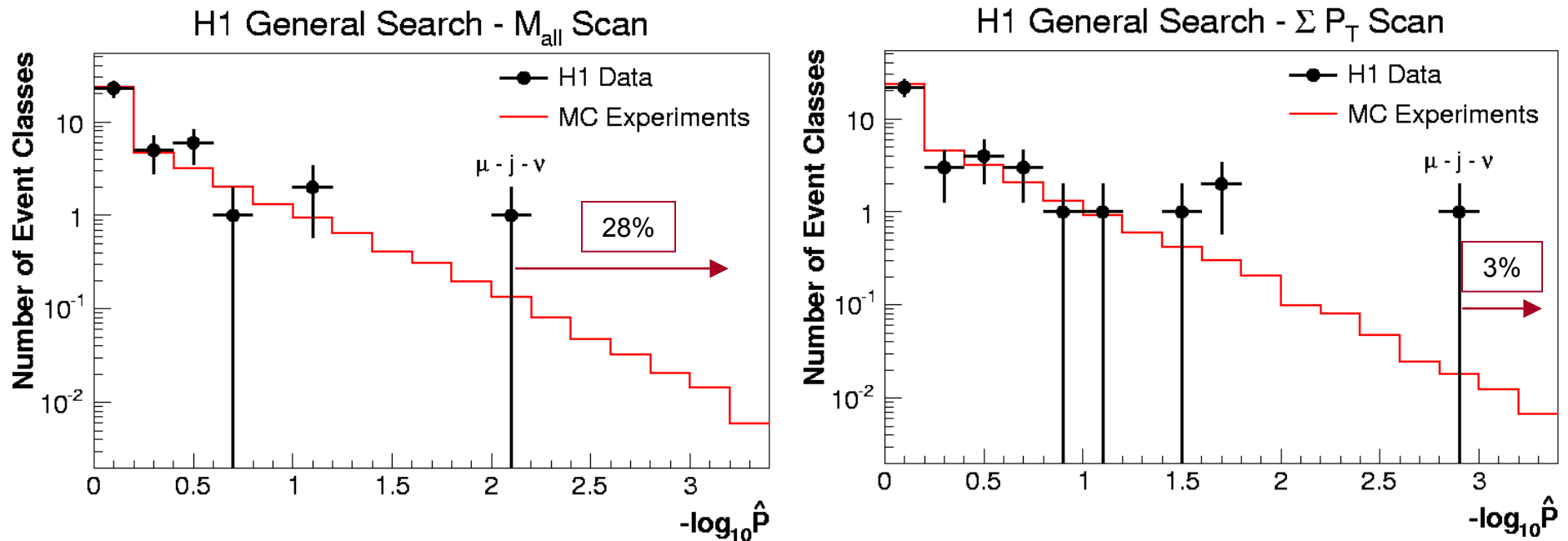
P_T and M_{all} distributions examined in all event classes

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

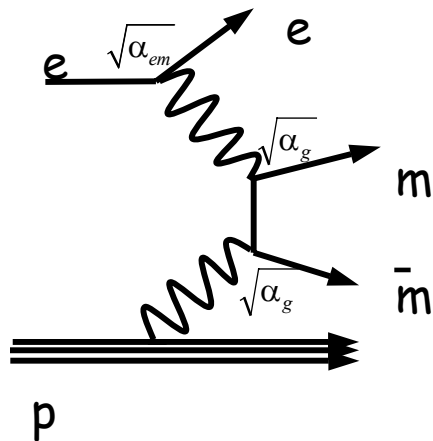


- Most significant deviation found in $\mu - j - \nu$
(consistent with observation of dedicated analysis)

No additional deviations found

Search for Magnetic Monopoles at HERA

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



QED coupling for Dirac monopole g_D

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

$$\alpha_{em} = 1/137$$

} Ionisation energy loss $\sim 10^3$ larger than for min. ionising charged particles
 \Downarrow

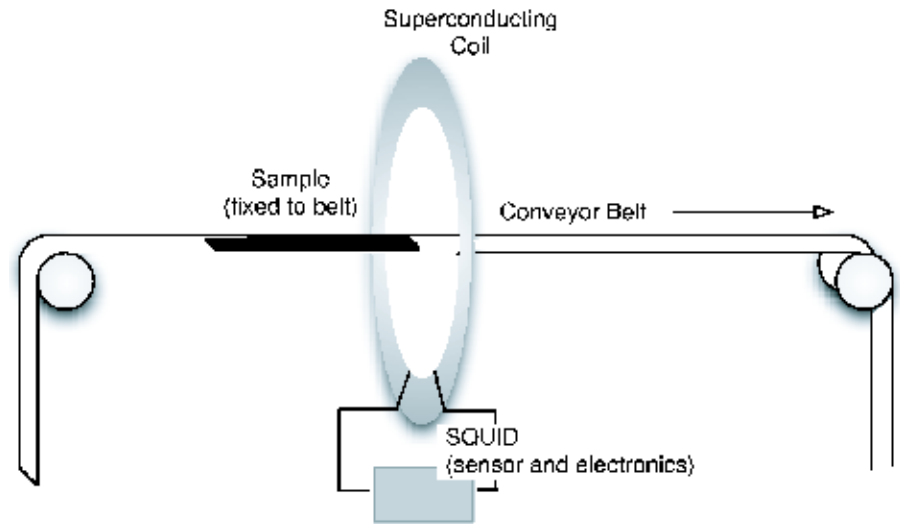
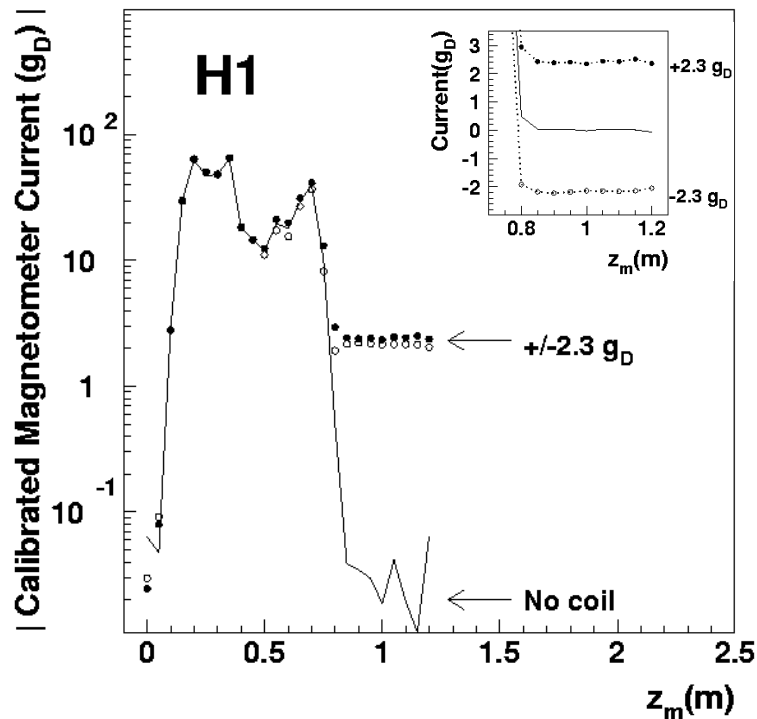
Monopoles produced in the e^+p collisions may be stopped in the beam pipe surrounding the interaction point

Binding energy of monopoles stopped in the Al beam pipe expected to be large (Milton et al) \Rightarrow 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}

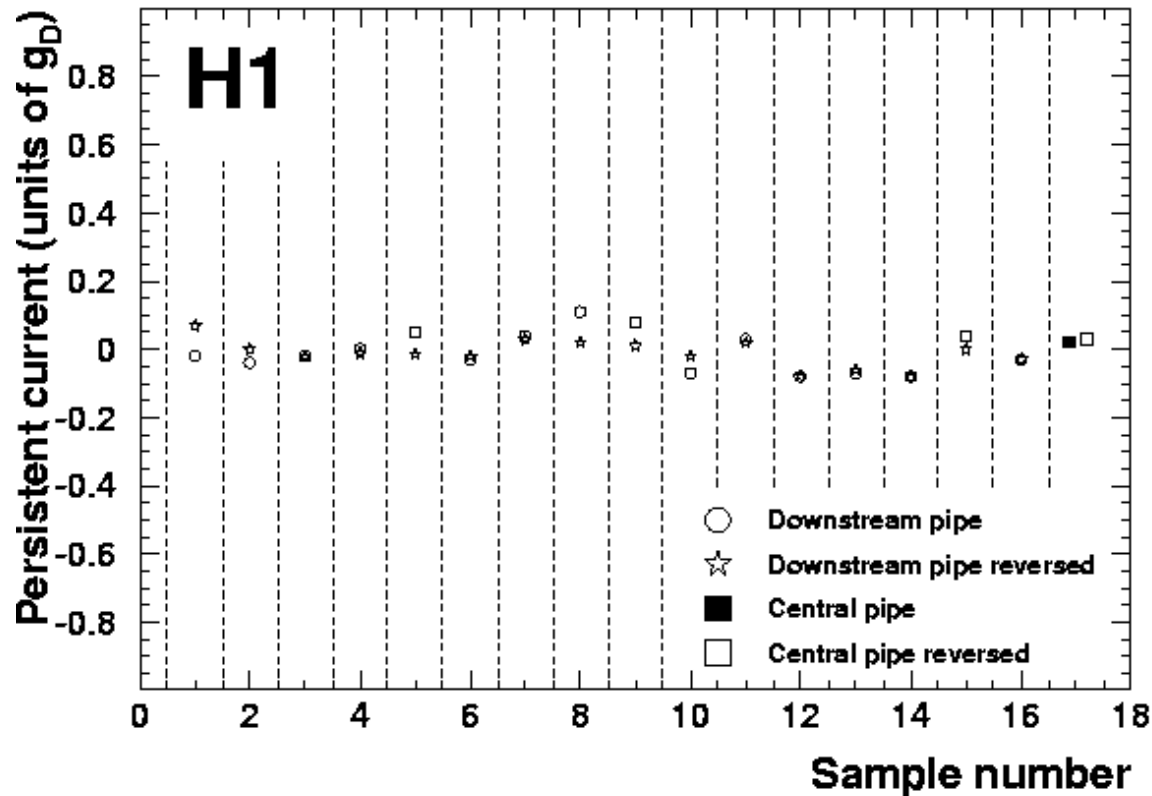
Method of Measurement

- Cut the beam pipe into strips
- Pass each strip through a superconducting 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



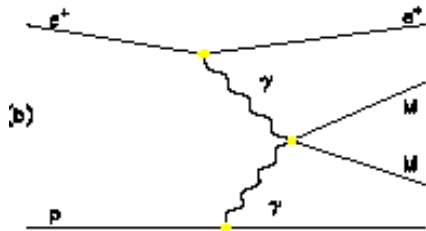
- No magnetic monopole of strength $> 0.1 g_D$ had stopped in the measured strips
- The result is interpreted in terms of limits on the monopole pair production cross section

Limits on the Cross Section

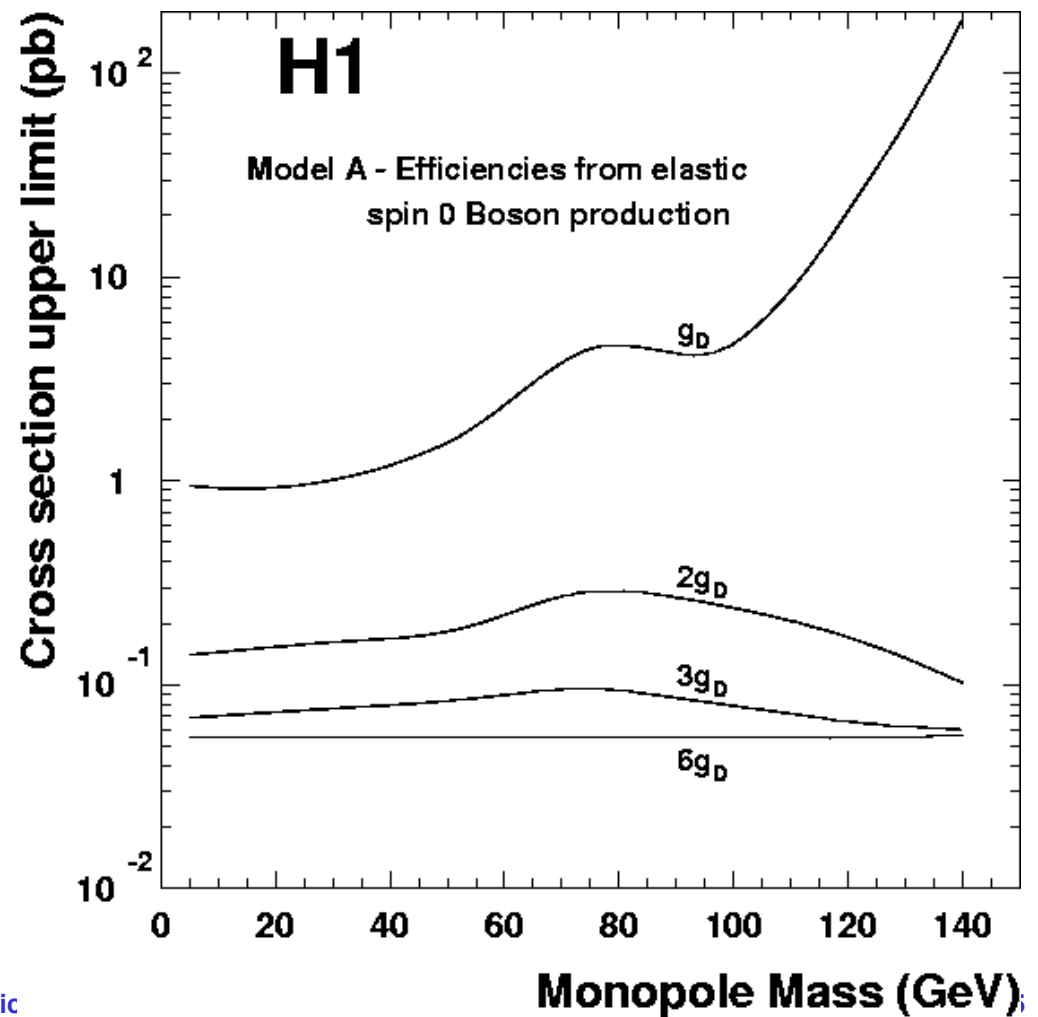
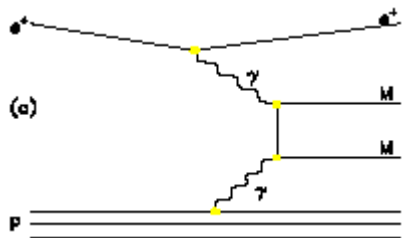
- Model needed to compute the efficiencies but,
 $\alpha_g = 34 \Rightarrow$ Perturbation theory not applicable

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 $\mu - j - \nu$ (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

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

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

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

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

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

Event Class of Most Interest

Quantify 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 SM expectation
- 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

