

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

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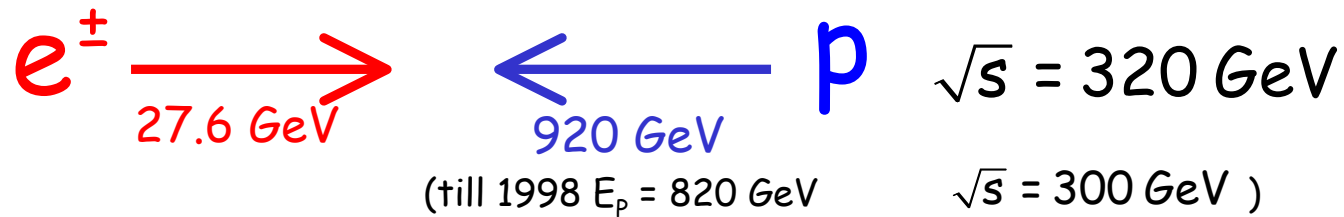
University of Montenegro / MPI Munich  
on behalf of the  
H1 Collaboration

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

# General Search for New Phenomena

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## 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**

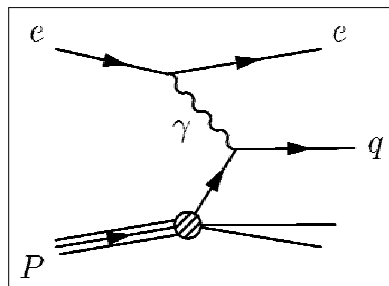
# General Search Analysis Strategy

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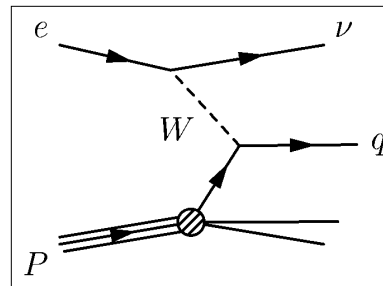
- Search for deviations from the SM in a model independent way (don't rely on assumptions concerning the characteristics of a SM extension)
- Select event sample at **high Pt**
  - Investigate all final state configurations of ep interactions with  $\geq 2$  particles (electron, muon, jet, photon, neutrino)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

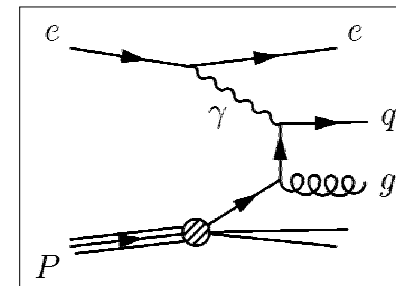
General Search needs SM predictions for all processes at HERA



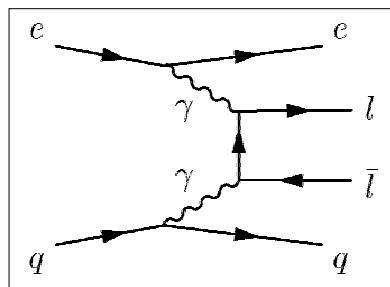
neutral current DIS  
Rapgap



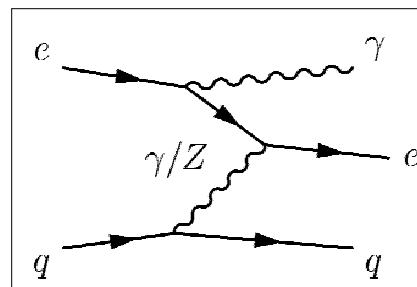
charged current DIS  
Django



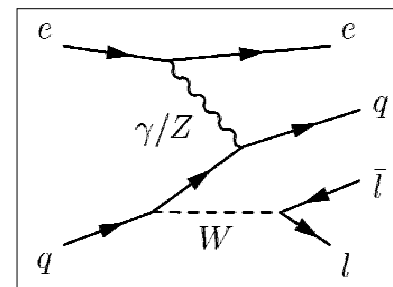
photoproduction  
Pythia



lepton pair production  
Grape

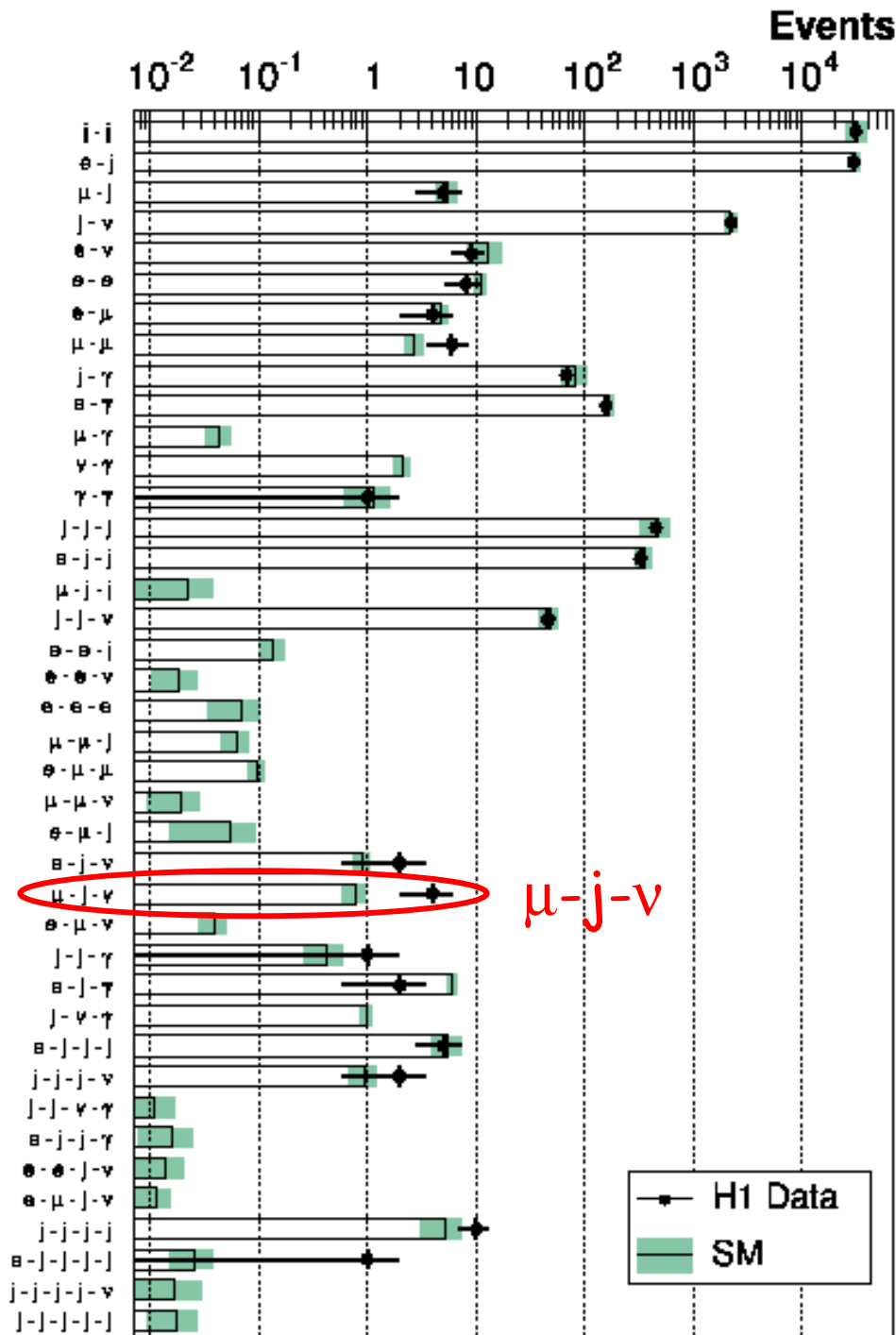


W production  
Epvec



QED Compton  
Wabgen

# Event Yields



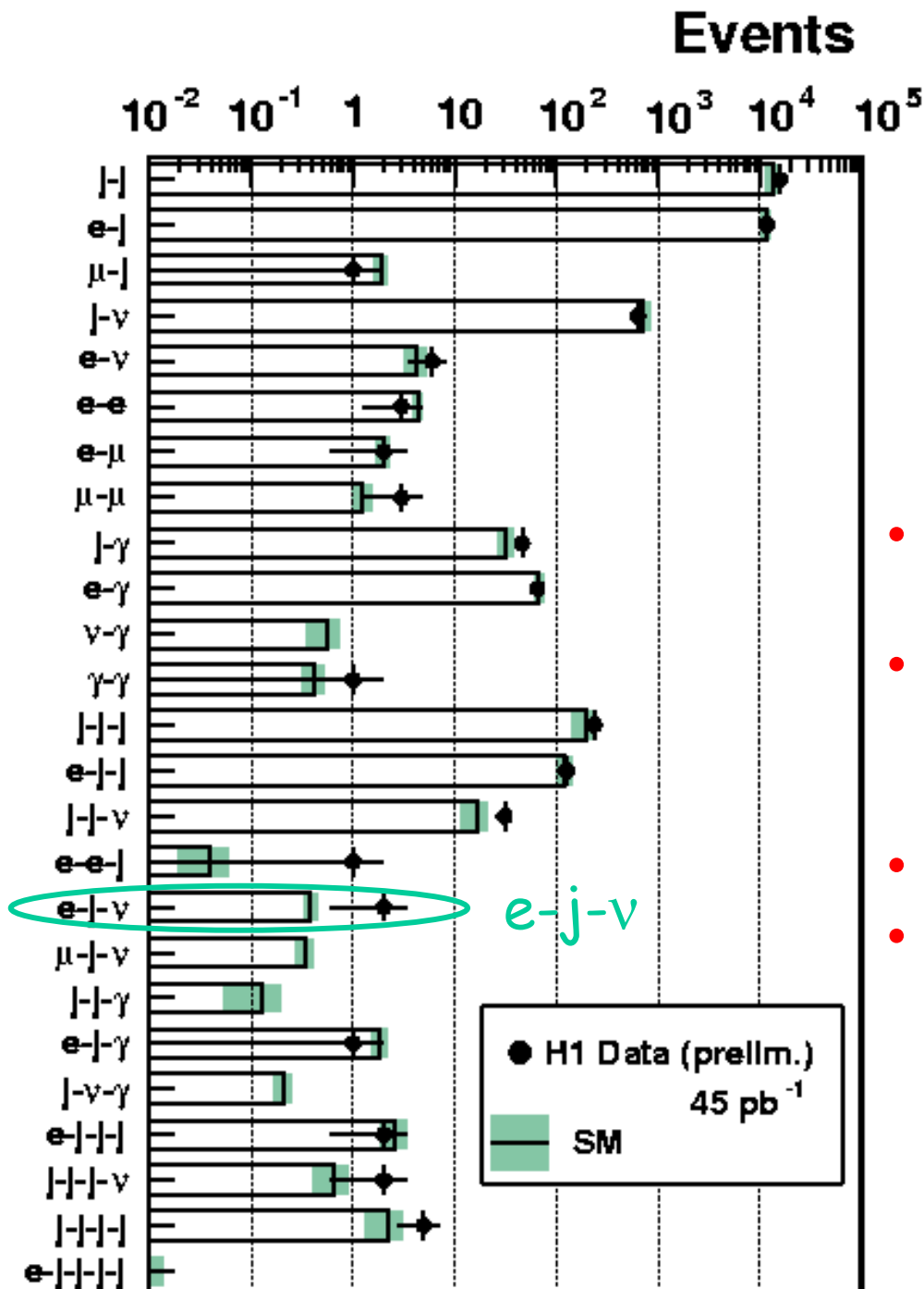
## HERA I

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

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

- all possible event classes with  $\geq 2$  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  $\geq 2$  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

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

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

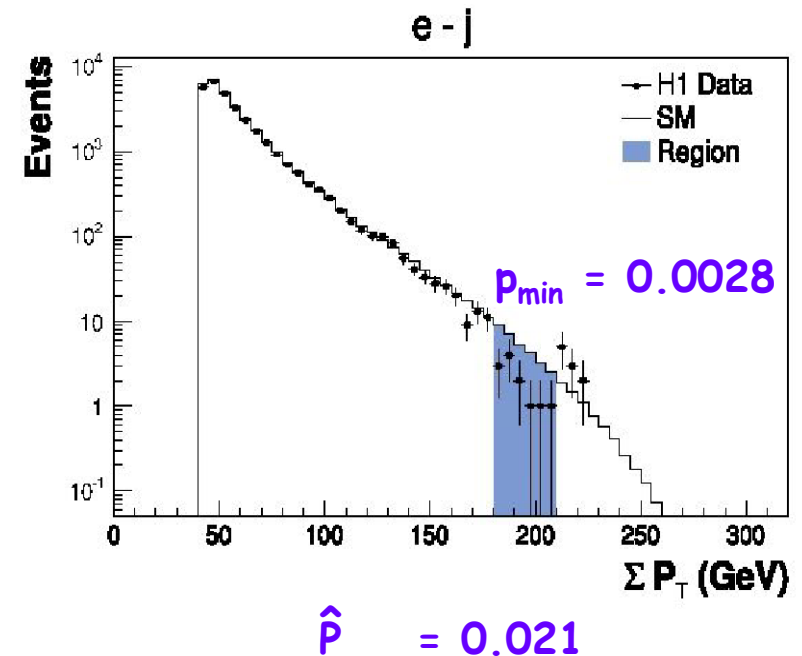
$$\sum P_T = \sum_i \sqrt{P_{x,i}^2 + P_{y,i}^2}$$

- **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

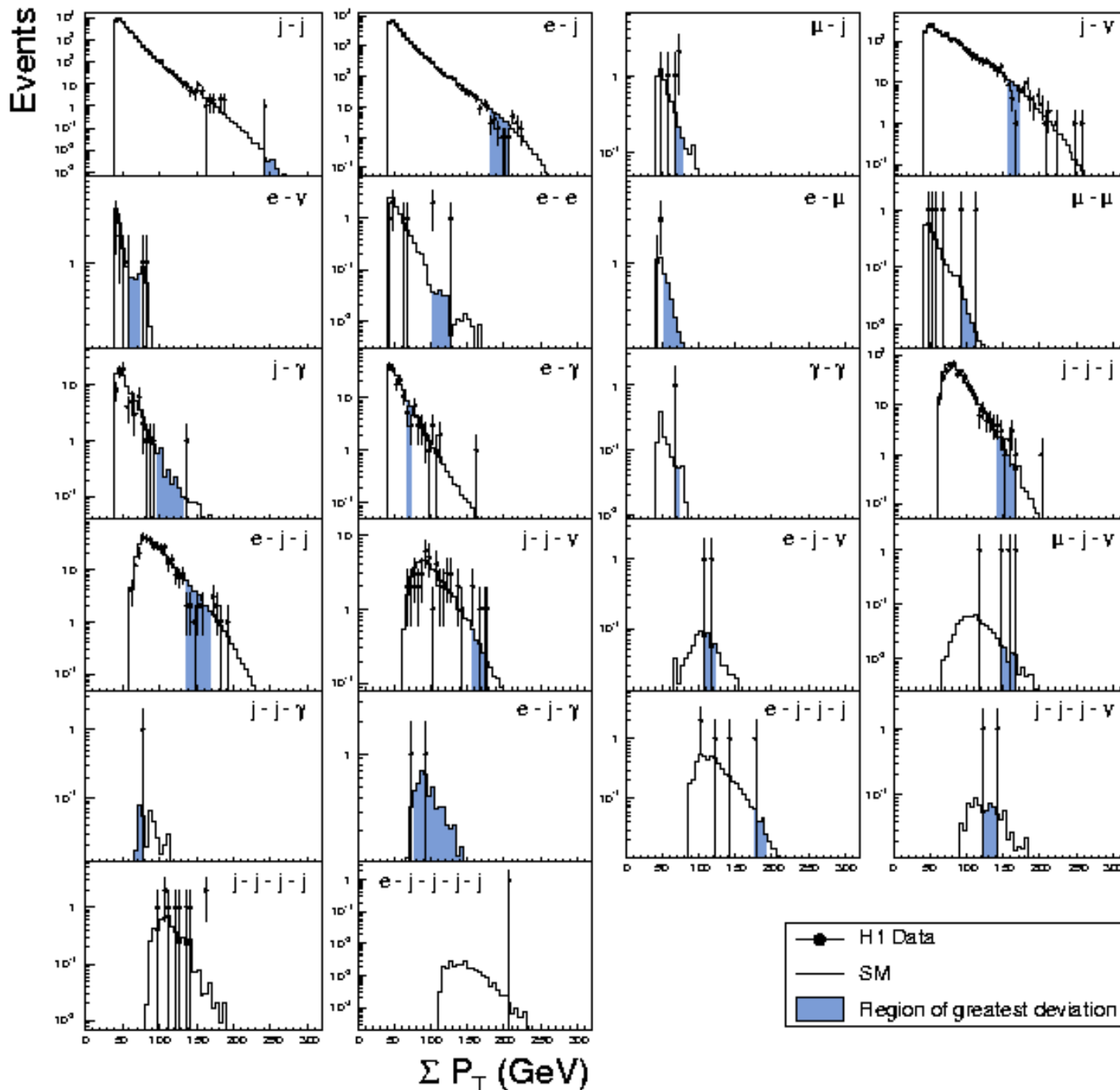
- Find the probability  $\hat{P}$  to observe a deviation with  $p < p_{\min}$  **anywhere** in an event class
- The event class of most interest is the one with the smallest  $\hat{P}$

# Systematic Search

**HERA I**

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

$P_T$  and  $M_{\text{all}}$  distributions examined in all event classes

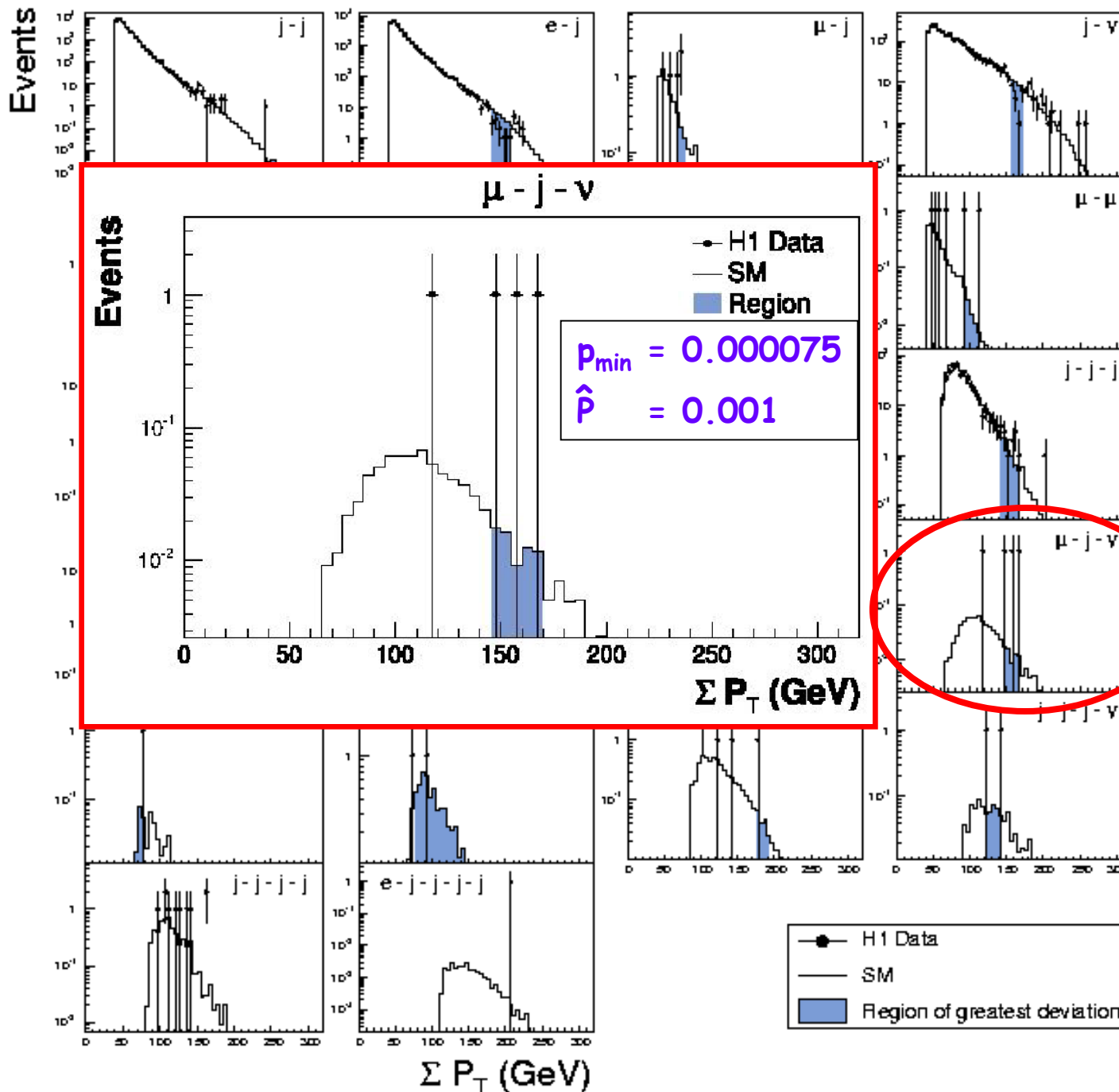


# Systematic Search

## HERA I

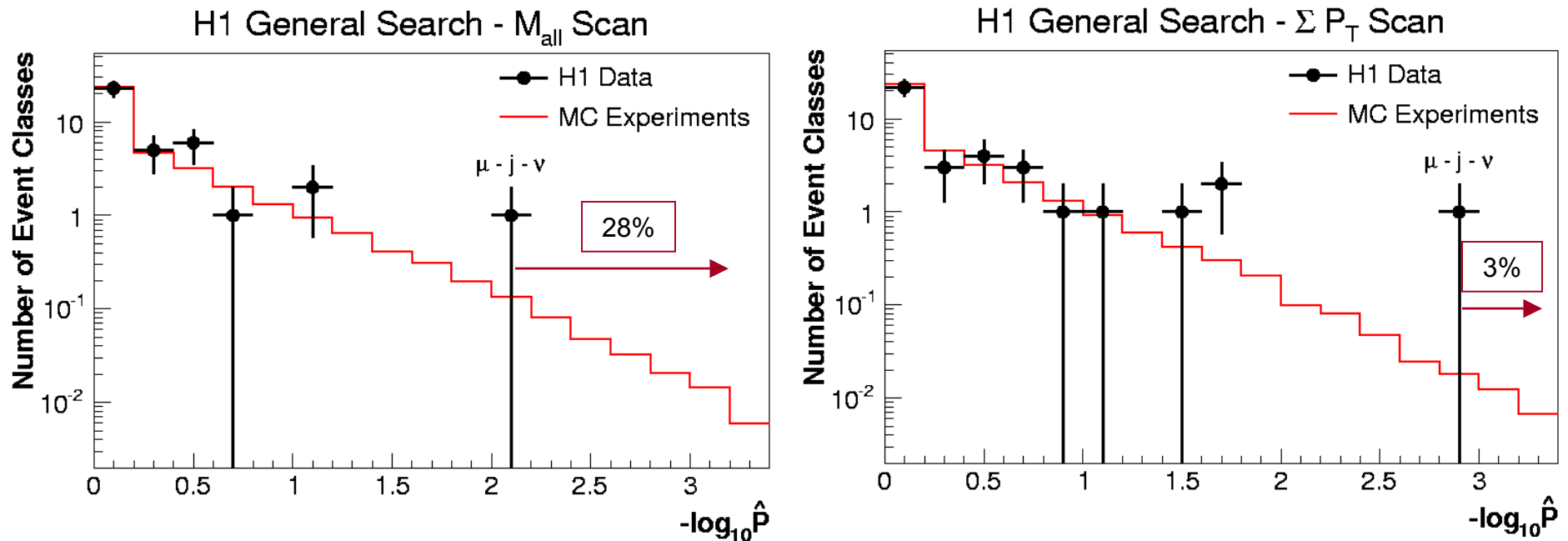
$P_T$  and  $M_{all}$  distributions examined in all event classes

Largest deviation found in  $\mu$ - $j$ - $\nu$  event class



# Global Significance

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

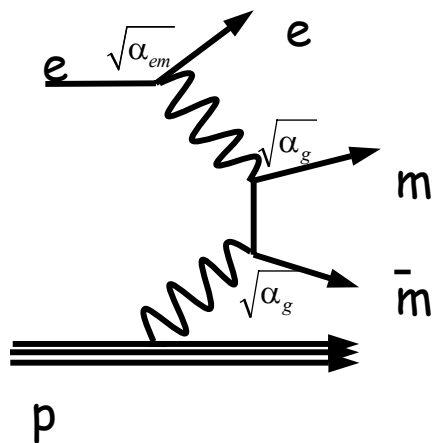


- Most significant deviation found in  $\mu - j - \nu$   
(consistent with observation of dedicated analysis)

**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  
 $\Downarrow$

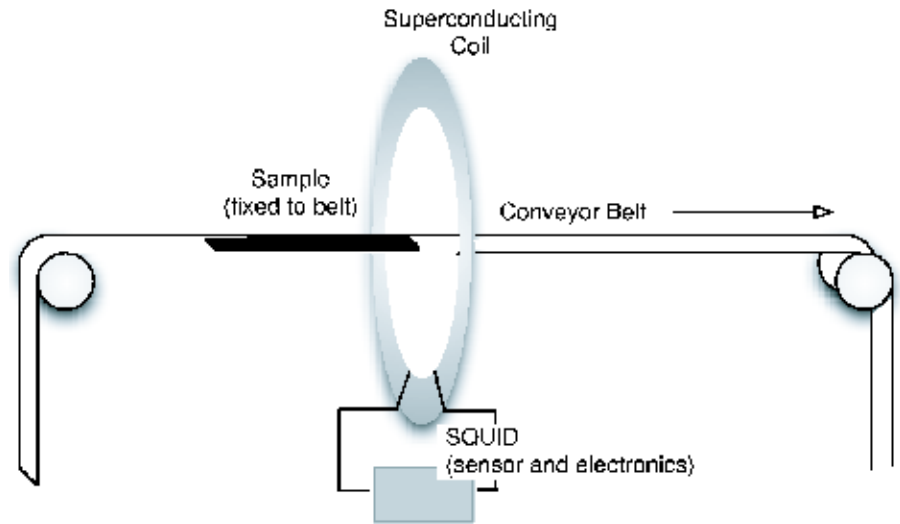
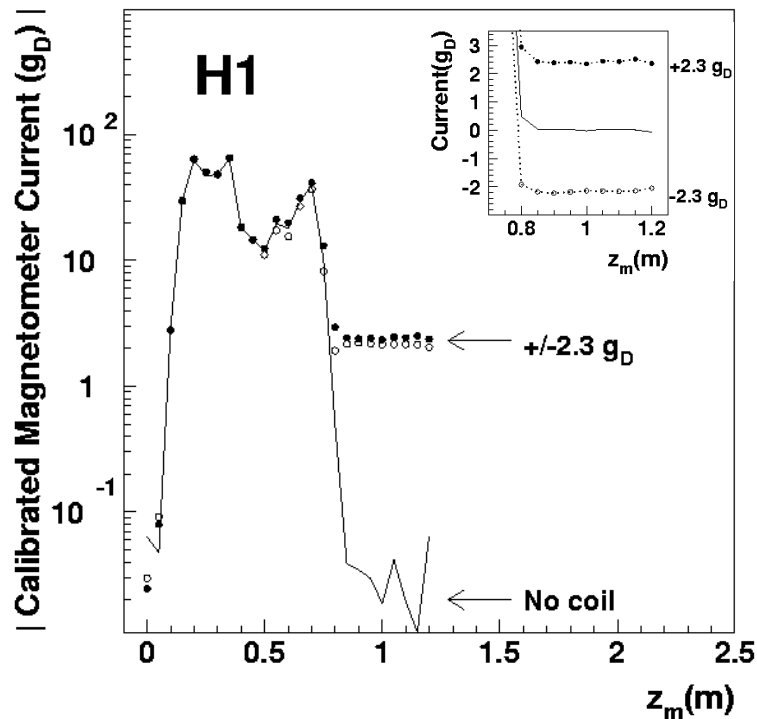
Monopoles produced in the  $e^+p$  collisions **may be stopped in the beam pipe** surrounding the interaction point

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  $62 \text{ pb}^{-1}$

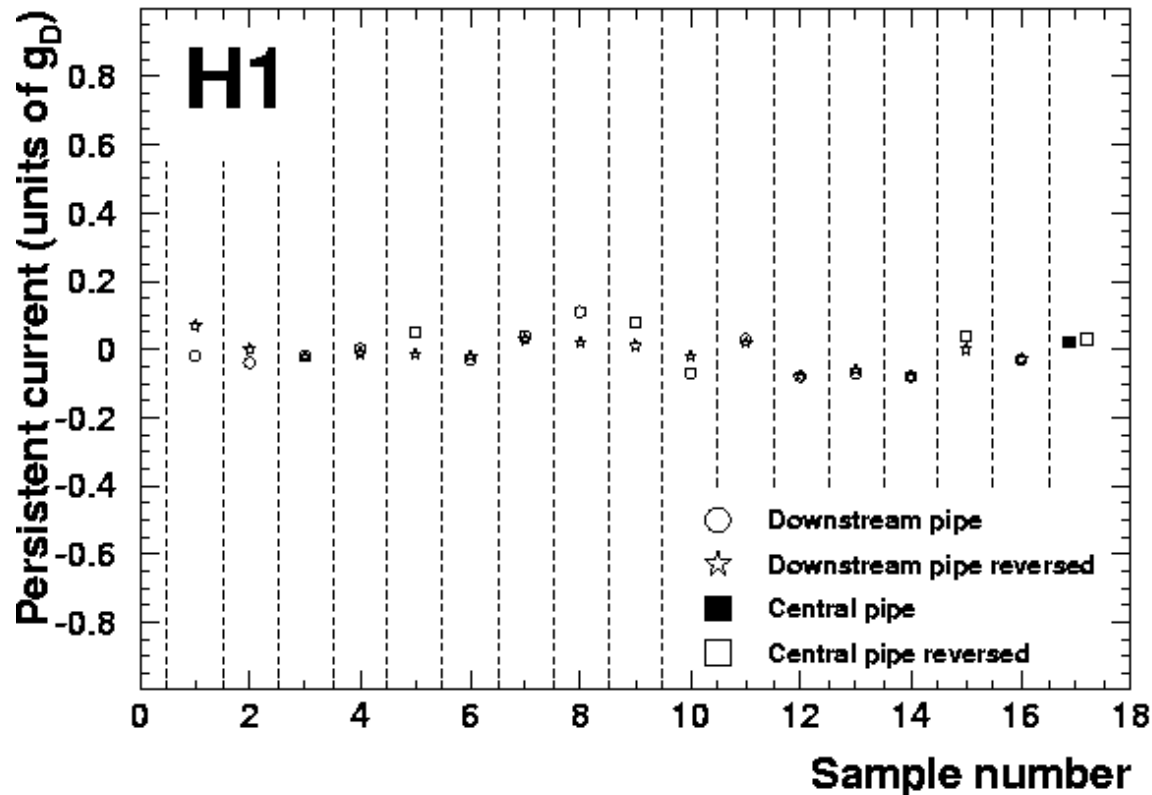
# Method of Measurement

- 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



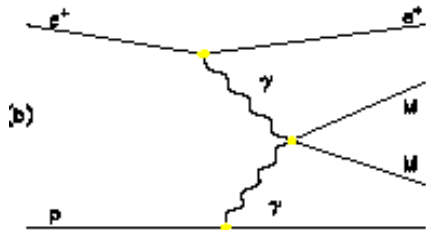
- No magnetic monopole of strength  $> 0.1 g_D$  had stopped in the measured strips
- The result is interpreted in terms of limits on the monopole pair production cross section

# Limits on the Cross Section

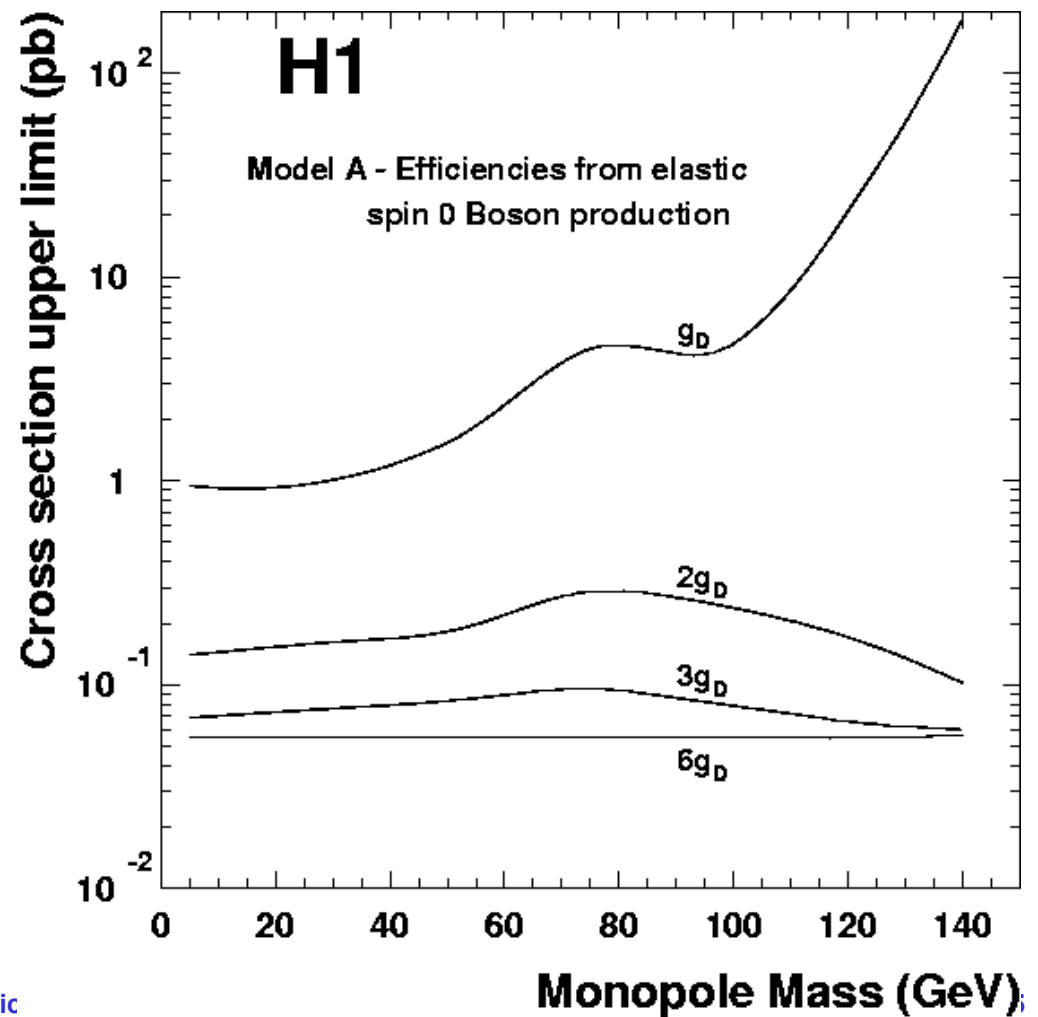
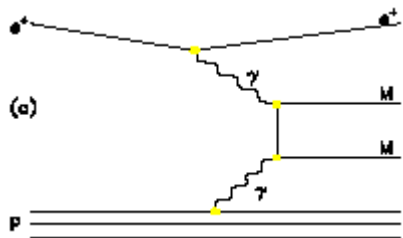
- Model needed to compute the efficiencies but,  
 $\alpha_g = 34 \Rightarrow$  Perturbation theory not applicable

However 2 models used

-Model A - spin 0 monopole



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



# Summary

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- 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

$N_{\text{obs}}$  = 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

