A general search for new phenomena at HERA

H1 Collaboration

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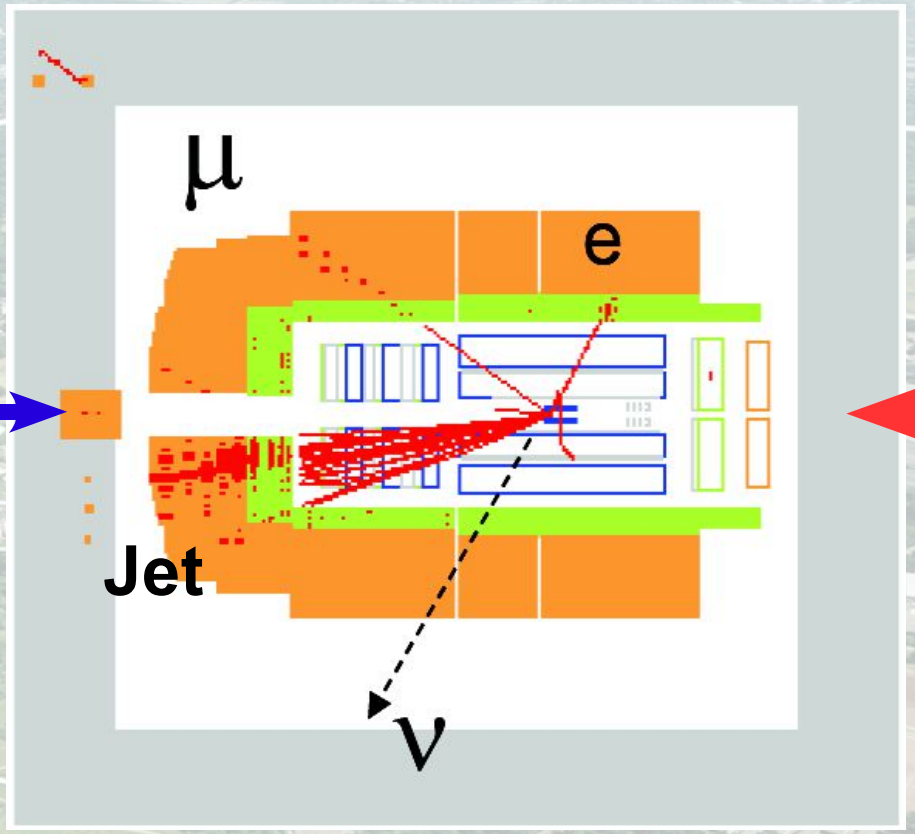


$e^{\pm}$ (27.5 GeV)

p (820, 920 GeV)

The 2 ways of searches

- Look for predicted signatures of BSM models
  - ➔ Adapt an analysis for each exotic prediction
    - ↘ Larger sensitivity
- Look for deviations to the SM in its tails:
  investigate all possible high P_T topologies
    - ↘ Greater generality
  - ➔ Signature based
  - ➔ Also look for the unexpected
  - ➔ Minimise the probability of missing something

↘ Developed by H1 for HERA I data [PLB 602, 14 (2004)]

↘ Requires a very good understanding of detector and SM processes

The analysis strategy

- Isolated high P_T particles: e, γ, μ, jet and ν
  - ➔ Tight identification criteria based on detector performances
- A common phase space:
  - ➔ $P_T^{part} > 20$ GeV
  - ➔ $10 < \theta^{part} < 140$ degrees
  - ➔ $D_{part}\ \eta - \varphi > 1$
- Classification of events into exclusive channels (>=2 particles) (e-j, j-j, j-ν, e-j-j, ...)
- Look for possible deviations in ΣP_T and M_{all} distributions
- Determine statistical significance of largest deviations observed

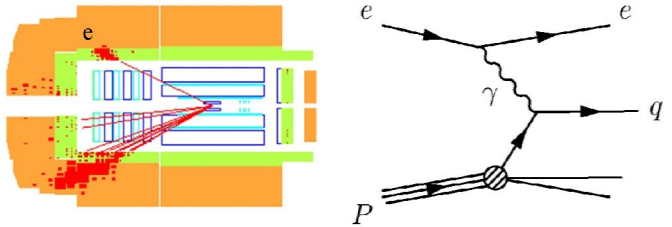
➘ New analysis based on the full H1 HERA II data set: 337 pb^{-1}

SM processes

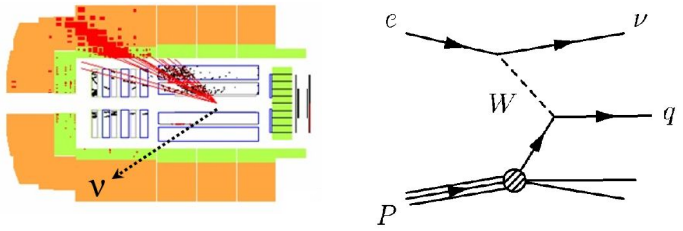
➔ Need simulation of all ep processes

➔ Large MC statistic required (multi-particle classes)

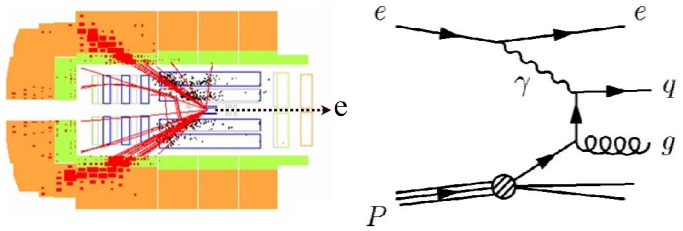
- Neutral Current DIS $ep \to eX$



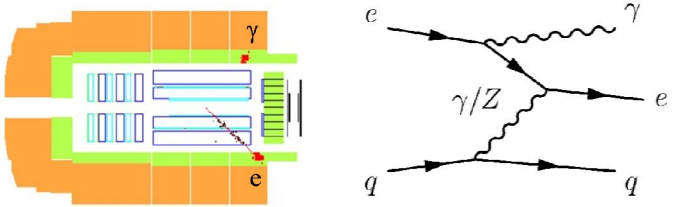
- Charged Current DIS $ep \to \nu X$



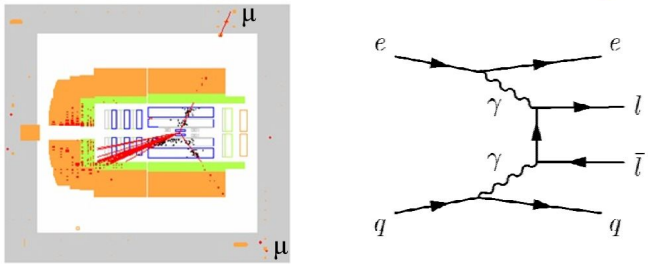
- Photoproduction $\gamma p \to X$



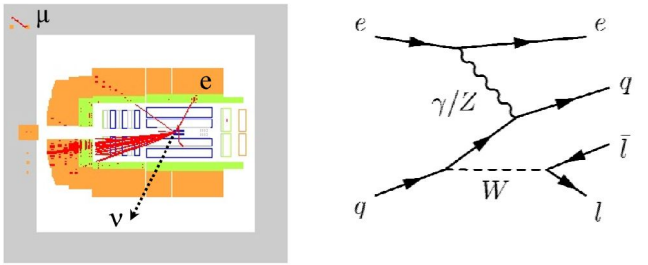
- QED Compton $ep \to e\gamma X$



- Lepton pair production $ep \to ellX$



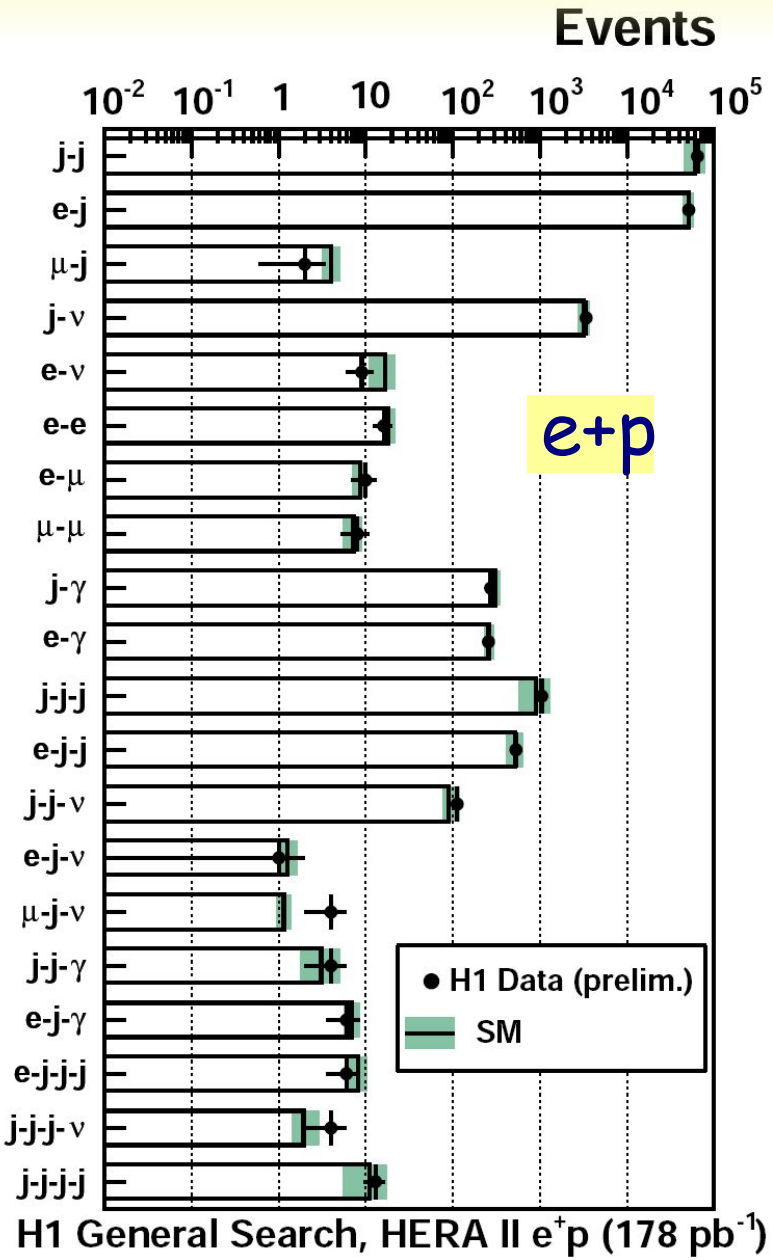
- W production $ep \to eWX$

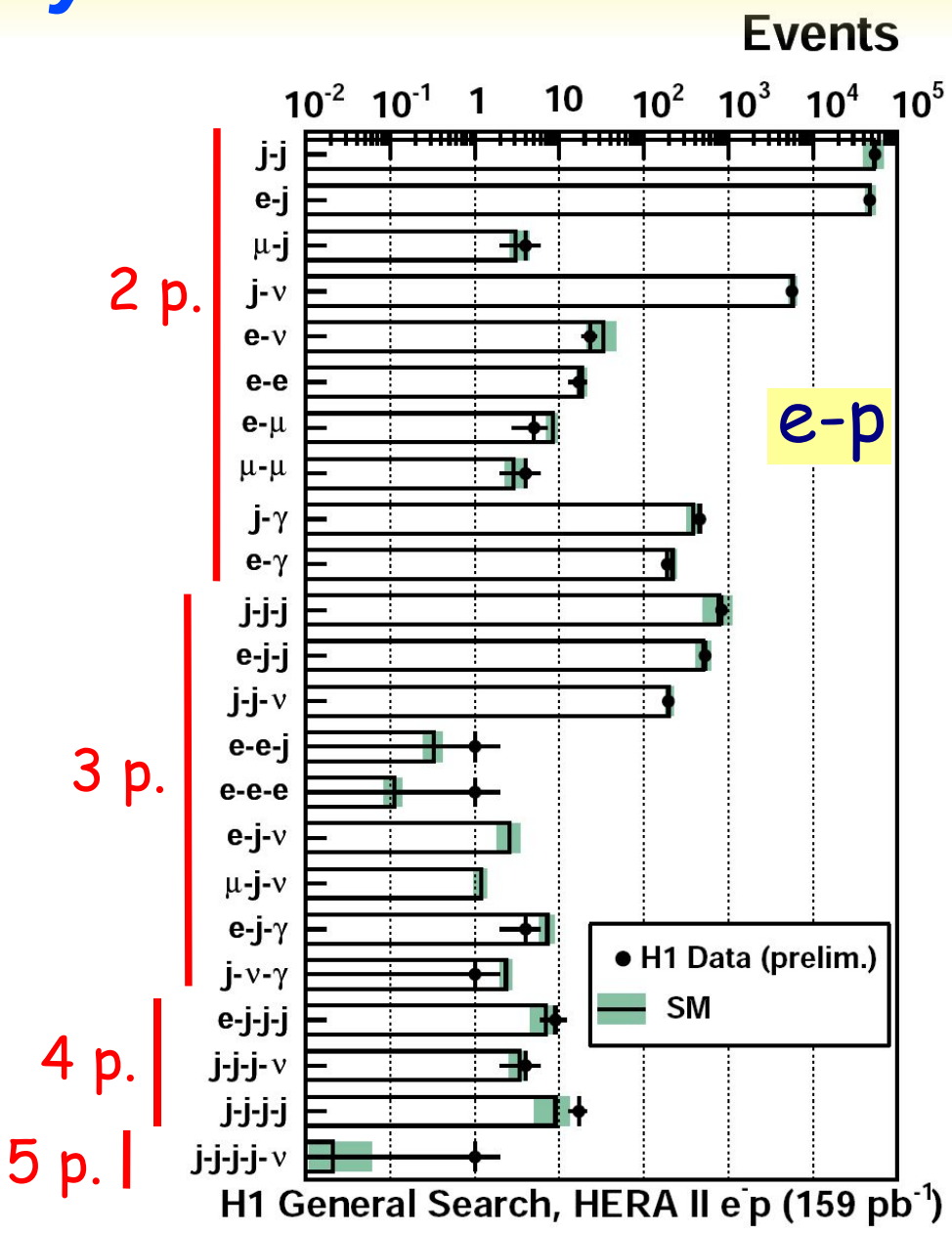


➔ QCD processes: O(α_s) + PS

QED processes: O(α^2) + PS

Event yields





↘ Good agreement with SM in most classes

Search for deviations

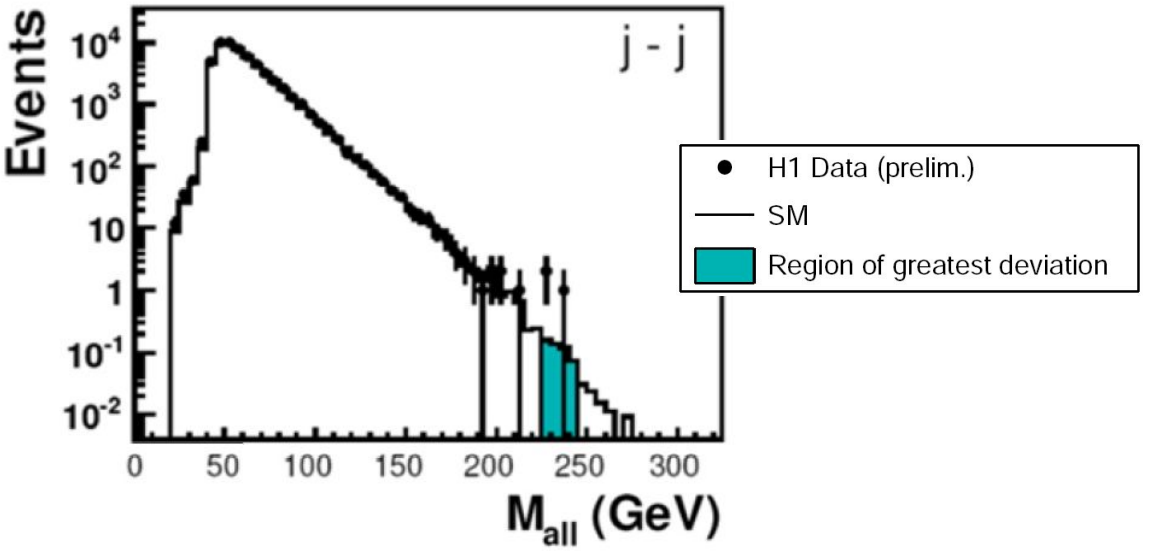
↘ Identify regions of largest deviations between data / SM

- Investigate 1D Σ P_T and M_{all} distributions
- Probability *p* of up or down fluctuations in each regions:

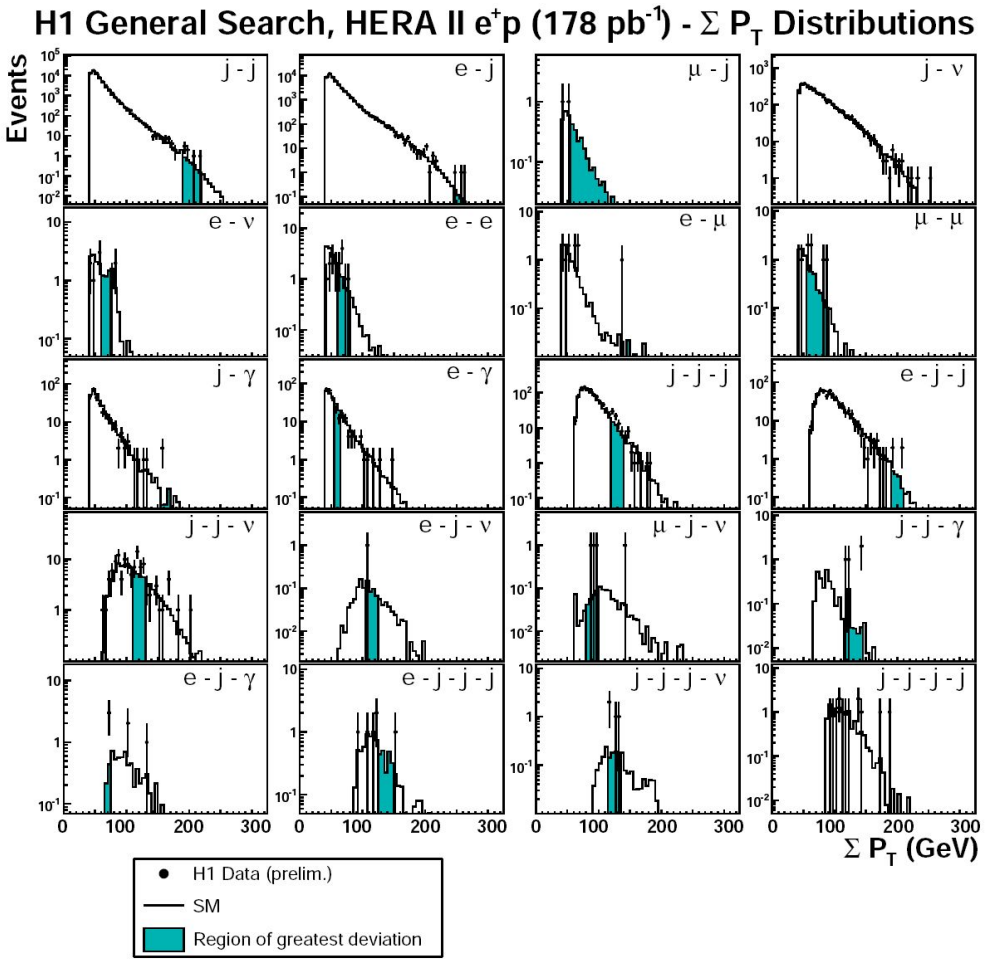
$$p = \begin{cases} A \int_0^\infty db\, G(b; N_b, \delta N_b) \sum_{i=N_{obs}}^{\infty} \frac{e^{-b} b^i}{i!} & \text{if } N_{obs} \geq N_b \\ A \int_0^\infty db\, G(b; N_b, \delta N_b) \sum_{i=0}^{N_{obs}} \frac{e^{-b} b^i}{i!} & \text{if } N_{obs} < N_b \end{cases}$$

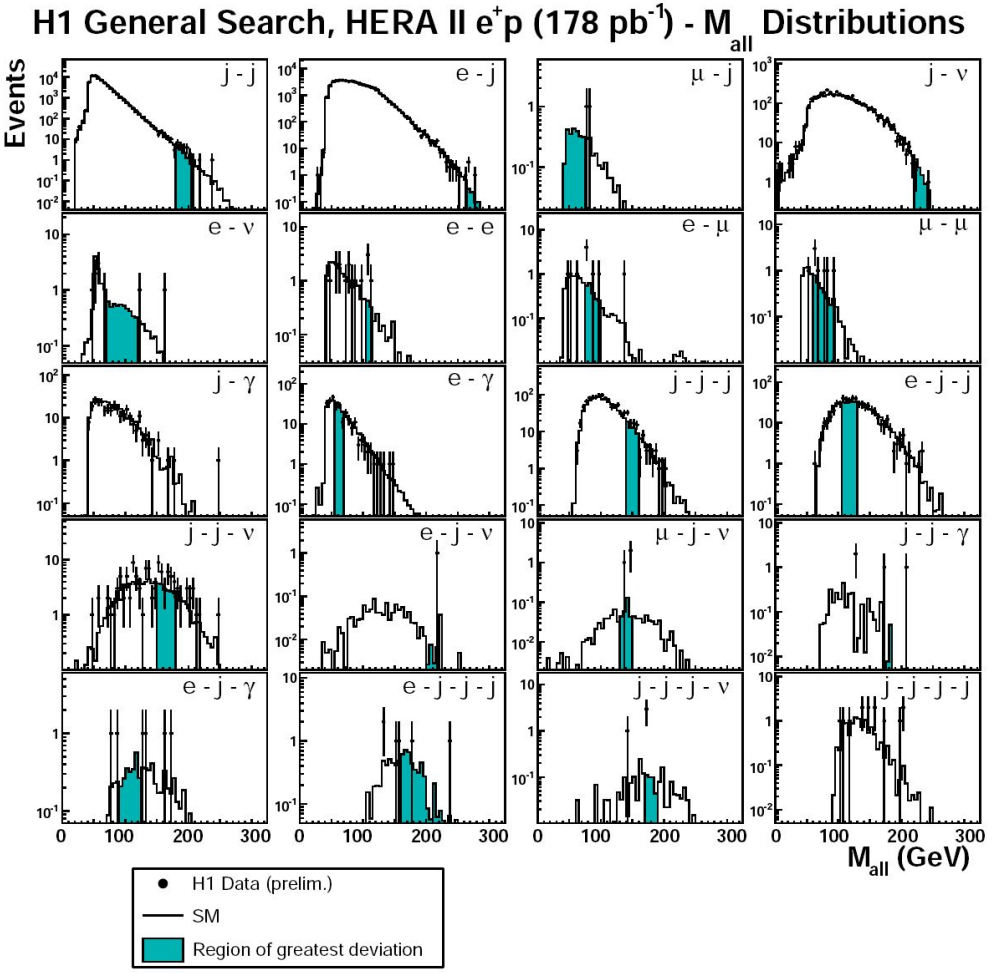
(A = normalisation constant)

- Most interresting region: *p* minimum -> p_{min}^{data}



ΣP_T and M_{all} distributions: e+p

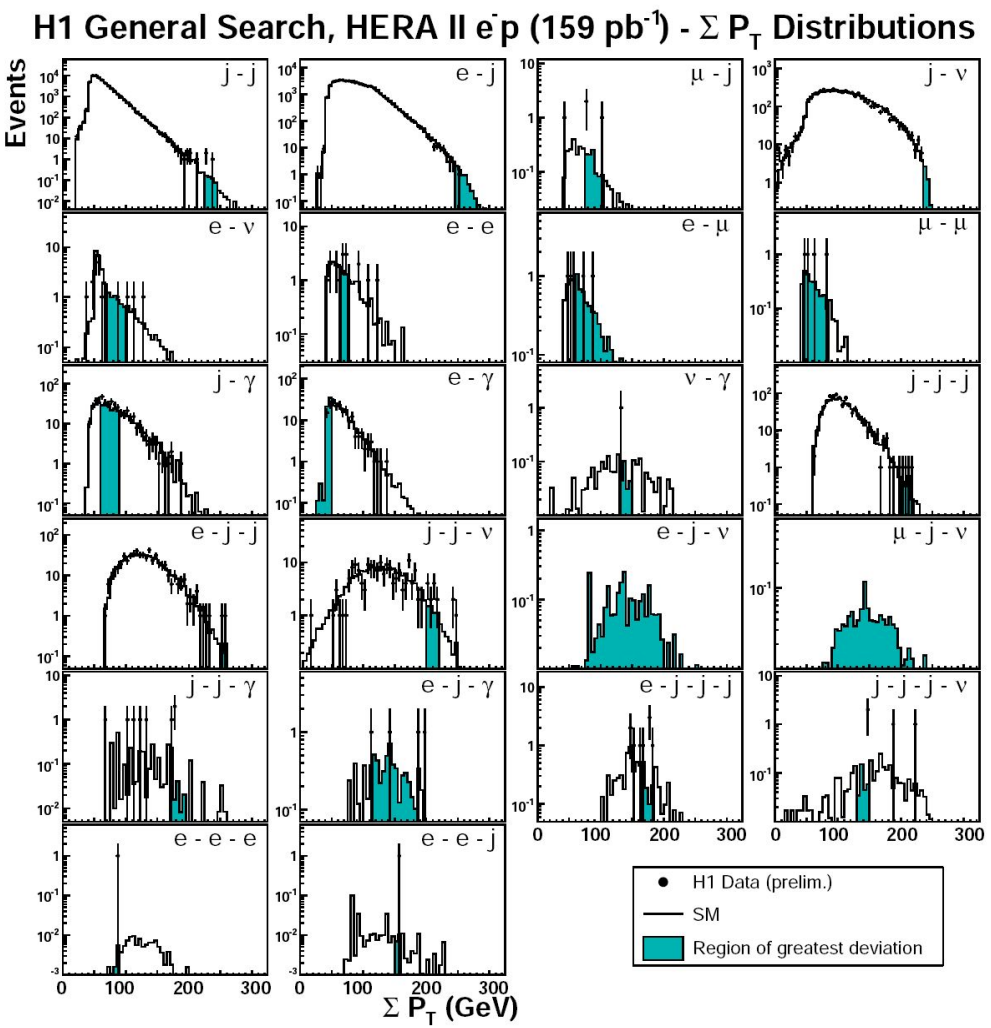


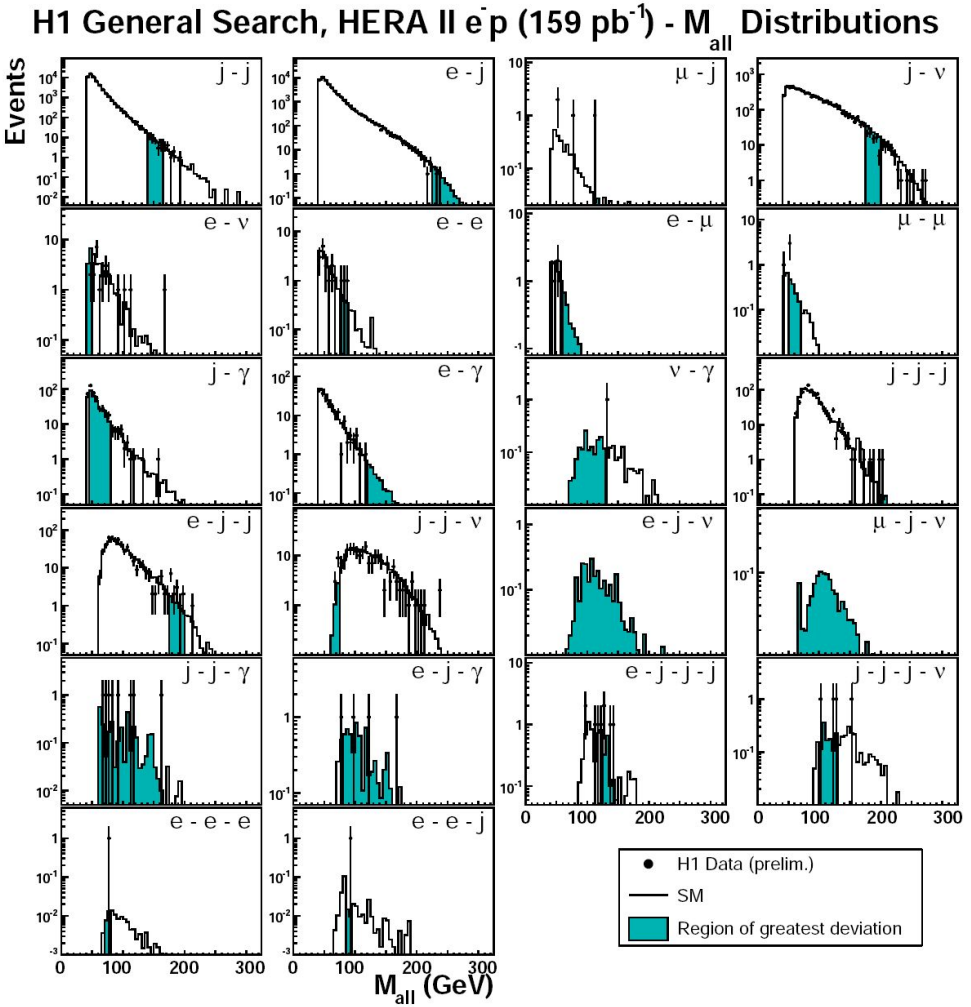


➔ A systematical scan of all classes

➔ Classes with Nb jets >= 4 are not considered

ΣP_T and M_{all} distributions: e-p





➔ Some regions with deviations found

➔ Are they significant ?

Quantify the deviation

↘ Quantify the significance of each deviation found

- What is the probability ($\hat{P}$) to observe somewhere else in the histogram a region with $p < p_{min}^{data}$?

  ➔ Pull random histograms H_{ran} according to the SM expectation

$$\hat{P} = \frac{\text{number of } H_{ran} \text{ with } p_{min}^{ran} < p_{min}^{data}}{\text{number of } H_{ran}}$$

  ➔ $\hat{P}_{data}$ = significance of p_{min}^{data}

  ➔ $\hat{P}_{data}$ can be used to compare results of different event class

  ➔ p_{min} = "5 σ" corresponds to ~ $-\log_{10} \hat{P}_{data}$ = 5-6

↘ Smallest $\hat{P}_{data}$ → most interresting channel

Determine the global significance

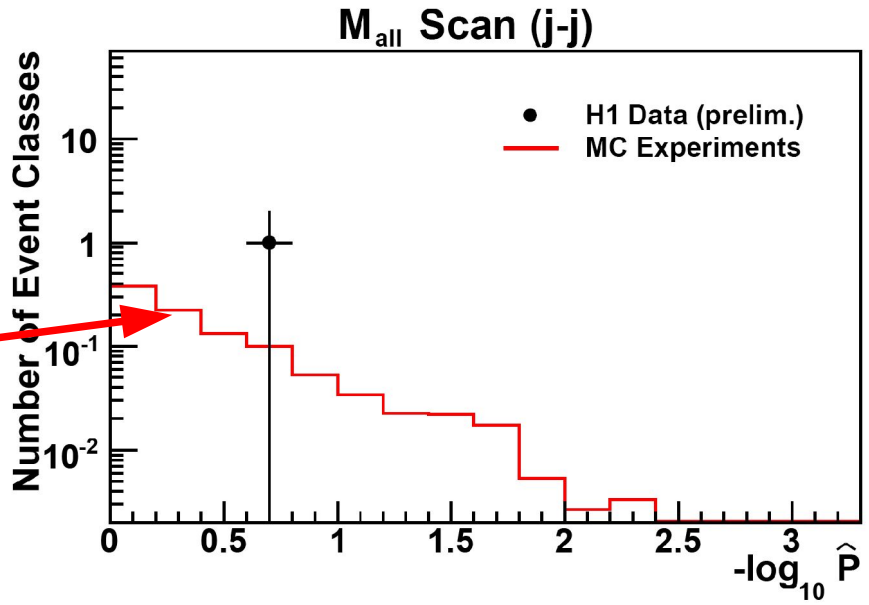
↘ Multiple classes studied, limited statistic:
small $\hat{P}$ values can occur

- What is the expectation for $\hat{P}$ using this method and if we redo an experiment ?

➔ Replace data by many "HERA MC experiments" with the luminosity of the data

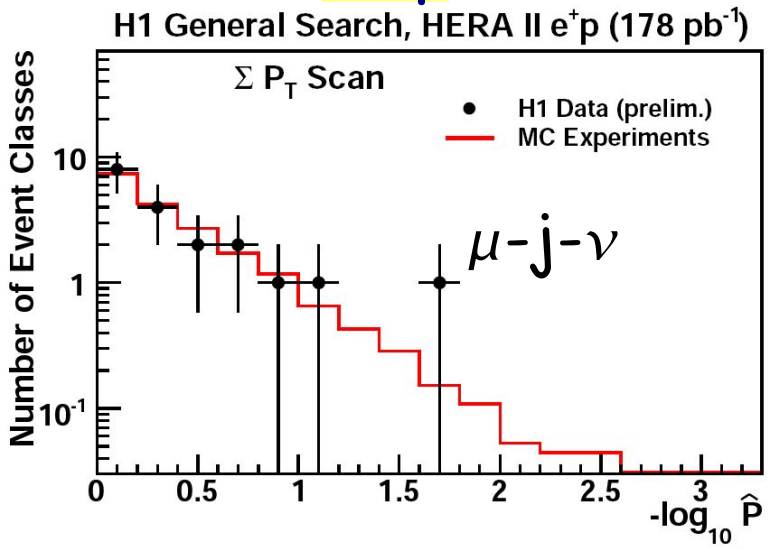
➔ Apply the same algorithm

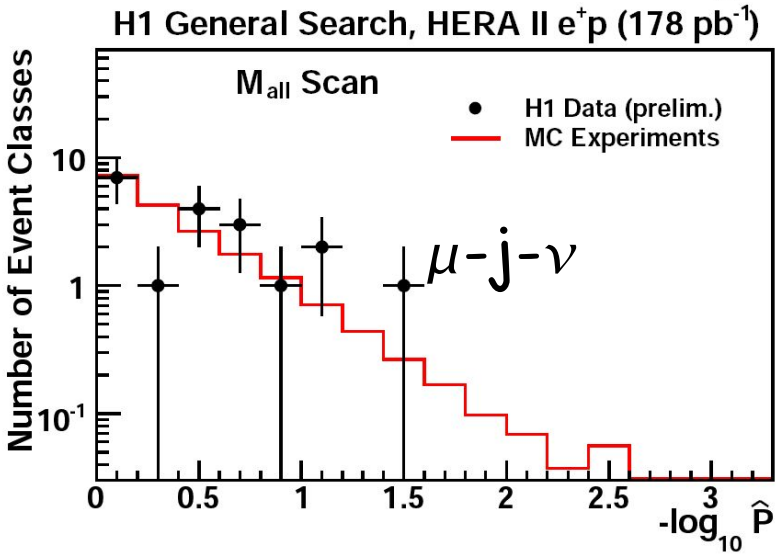
➔ $\hat{P}_{MC}$



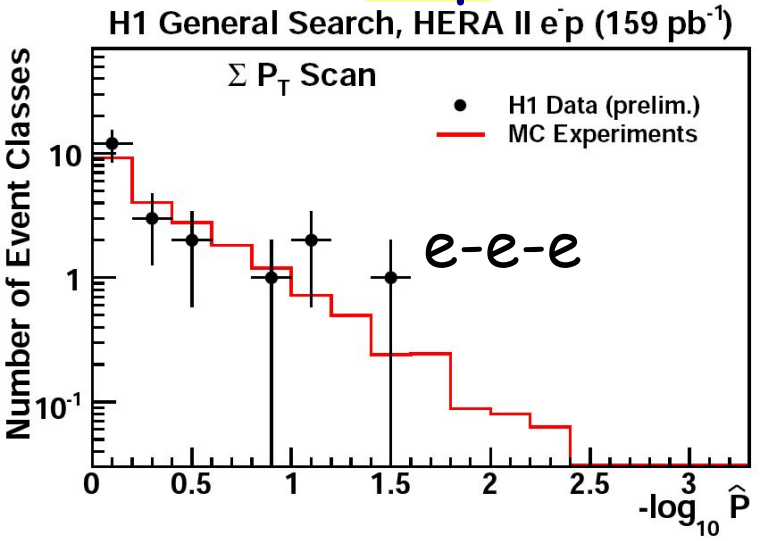
Global significance

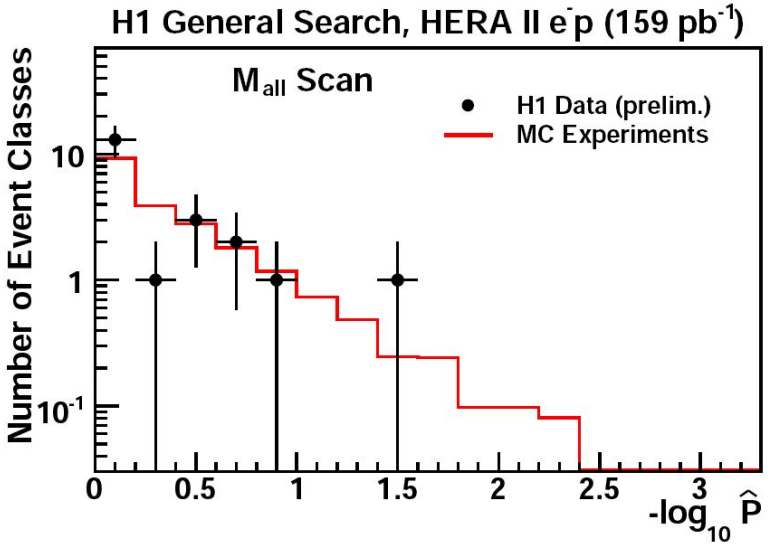
e+p





e-p



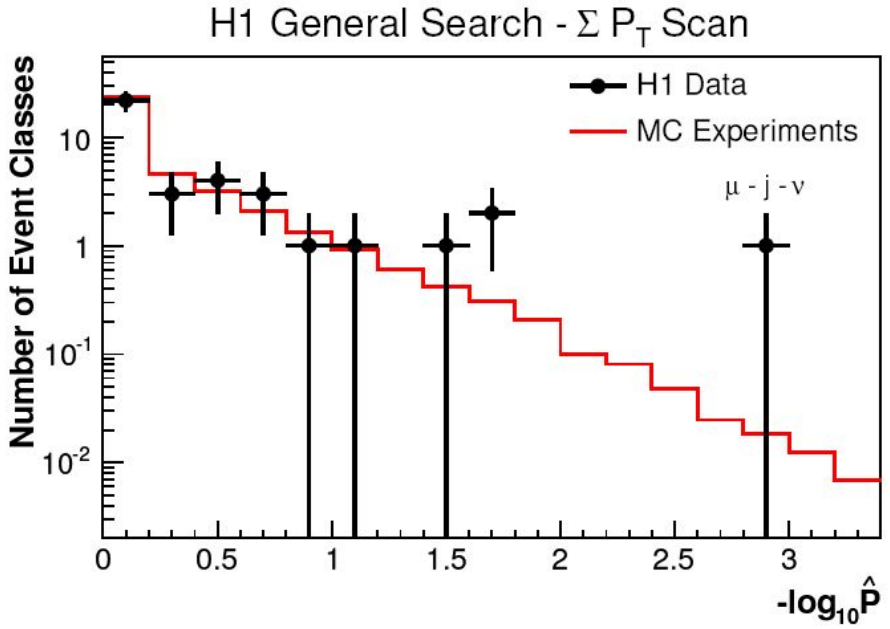


➔ The distribution of $\hat{P}$ observed in data classes is described by MC experiments

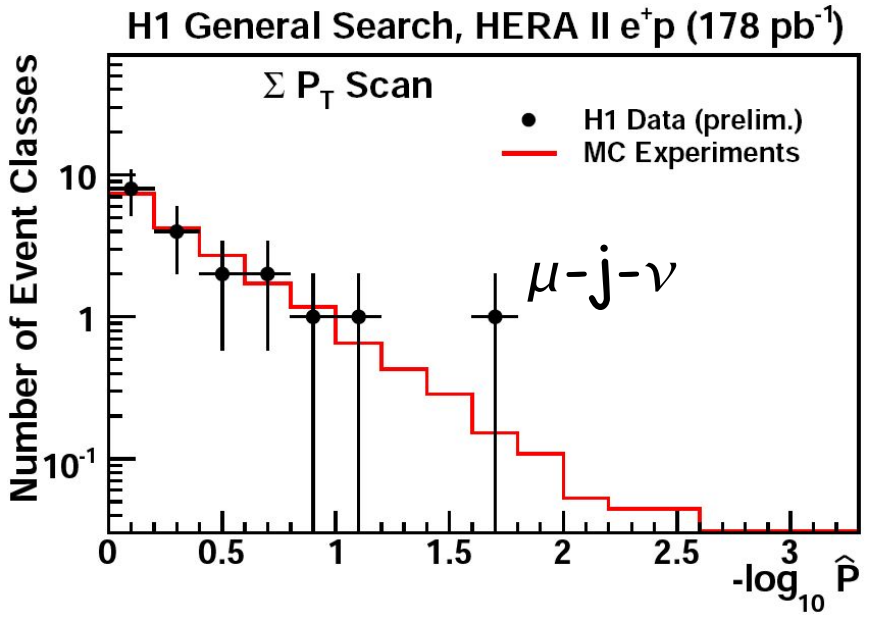
General search and isolated lepton events

- Corresponds to the topology of isolated leptons events (W production in SM)

HERA I, 117 pb^{-1}, mainly e+p



HERA II, 178 pb^{-1}, e+p



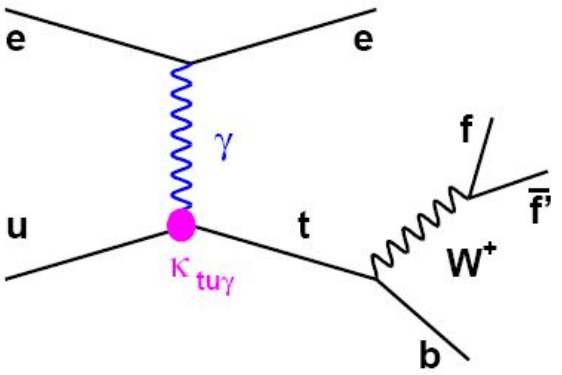
- HERA I: ~3% of MC experiments would produce a similar deviation
- Deviation less important than in HERA I data

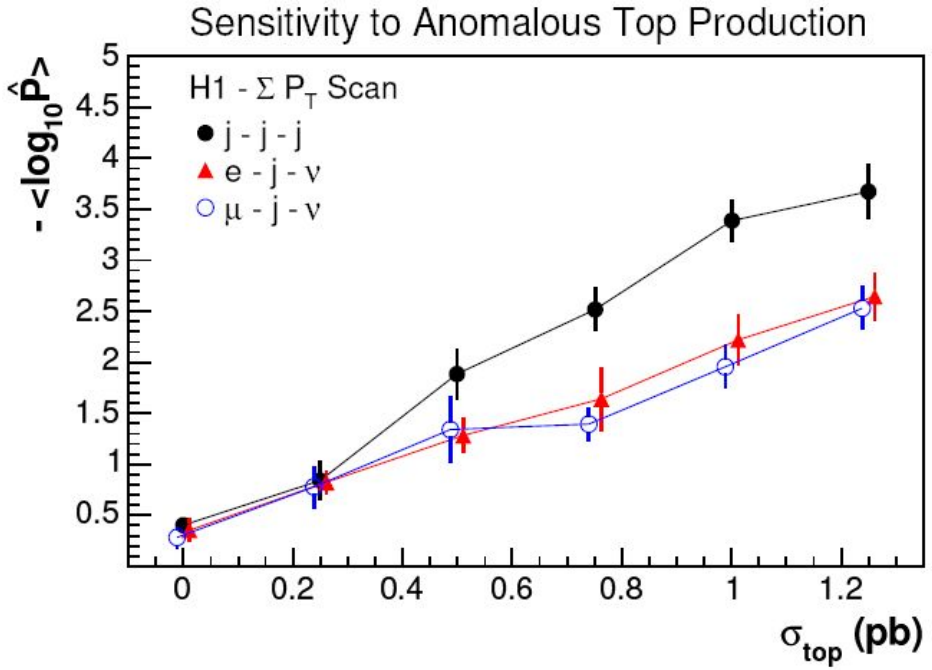
- μ-j-ν is the most deviating class in e+p for both HERA I and II data

Sensitivity to new physics

↘ Test the sensitivity of the method to new physics

- Anomalous top production via FCNC
  - ➔ A decay t → bW would appear mostly in j-j-j, e-j-ν and μ-j-ν
  - ➔ Evolution of $-\log_{10} \hat{P}$ as a function of σ_{top}





- In j-j-j: $-\log_{10} \hat{P}$ ~2 for σ_{top} = 0.5 pb
  - ➔ From H1 dedicated analysis in hadronic channel: σ_{top} < 0.48 pb at 95% C.L.
- $-\log_{10} \hat{P} \geq 3$ for σ_{top} ~ 1.5 pb

↘ Sensitivity equivalent or slightly lower than dedicated searches

Summary

- A model independent search for new physics has been performed using all H1 HERA I+II data
  - ➔ In total: 455 pb^{-1}
  - ➔ All high P_T event topologies systematically investigated
  - ➔ Good understanding of the detector and SM processes
- No very significant deviation observed in e+p or e-p HERA II data
- But ...
  - ➔ The most deviating class is μ-j-ν in all e+p data (HERA I and HERA II)
  - ➔ Corresponds to isolated leptons topology

↘ It is the broadest range signature based search done at a collider