



The VIIIth Rencontres de Moriond on
QCD AND HIGH ENERGY HADRONIC INTERACTIONS

General Search for New Phenomena in ep Scattering at HERA

Martin Wessels, DESY

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Motivation & Strategy

- ✓ many dedicated searches for new physics models (LQ, LFV, FCNC, SUSY, ...)
- ✓ some model-independent searches in exclusive final states (lepton production)

? But: Are we missing something?

- ➡ investigate all final states produced at high P_T in ep collisions
- ➡ do not rely on assumptions about characteristics of a SM extension

- considered particles

electron, photon, muon, jet, neutrino

- common phase space

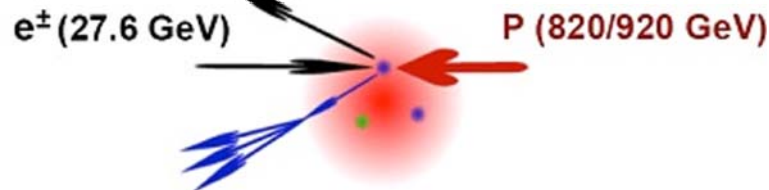
$P_T > 20 \text{ GeV}$ $10^\circ < \theta < 140^\circ$

- classification of events into exclusive classes

e-j or μ - ν -j or j-j-j-j

- systematic search for deviations using dedicated statistic algorithm

General Search @ H1



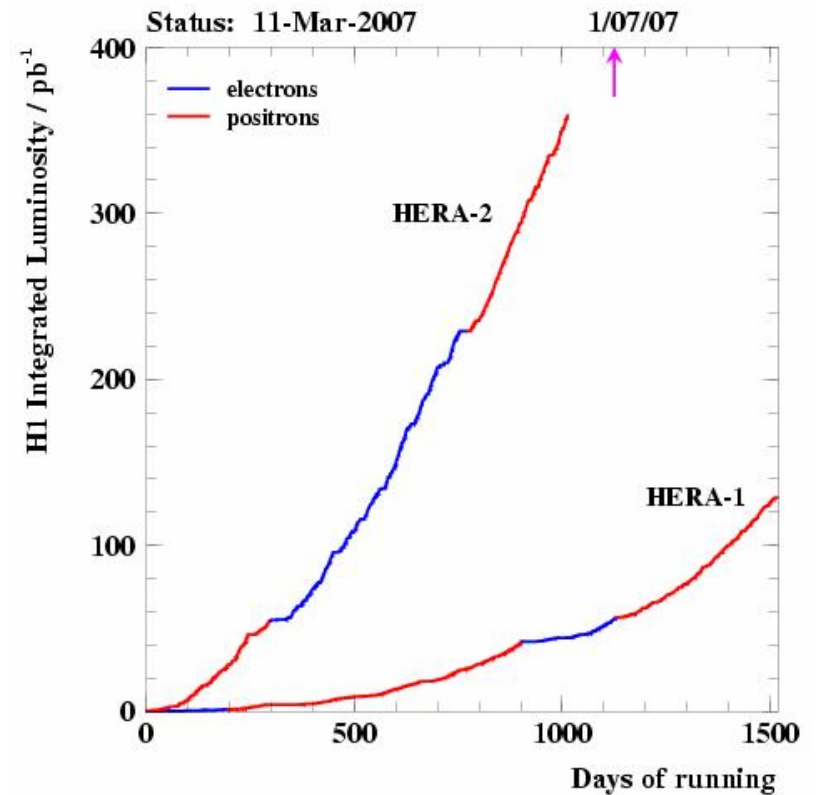
Data samples

HERA I (1992-2000)

- $e^-p \approx 15 \text{ pb}^{-1}$
- $e^+p \approx 105 \text{ pb}^{-1}$

HERA II (2002-2007)

- $e^-p \approx 160 \text{ pb}^{-1}$
- $e^+p \approx 200 \text{ pb}^{-1}$

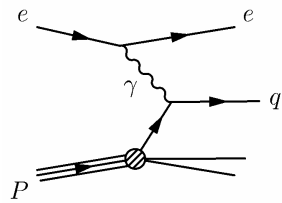
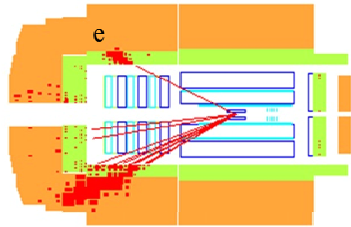


- ➡ HERA I: e^+p dominated (GS published, Phys Lett B602 (2004) 14-30)
- ➡ HERA II: large e^-p data sample (GS 2005/06 e^-p , Preliminary)

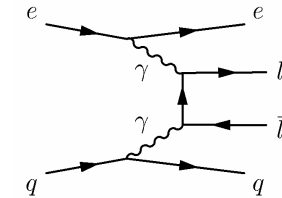
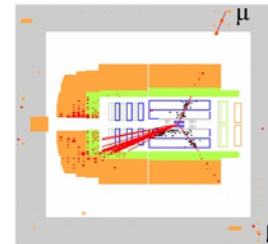
SM Processes & MC Generation

General Search needs SM prediction for all ep processes

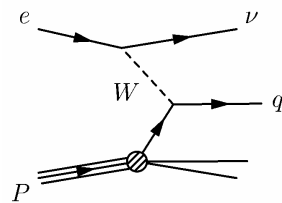
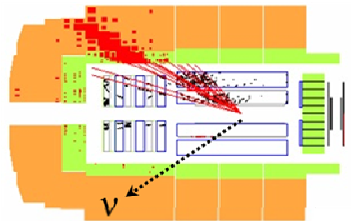
neutral current DIS $ep \rightarrow eX$



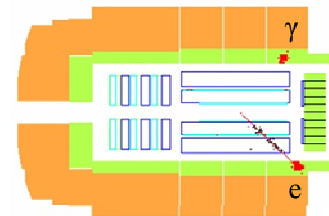
lepton pair production $ep \rightarrow ellX$



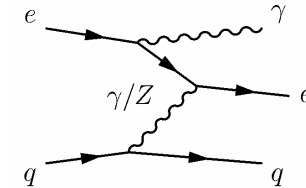
charged current DIS $ep \rightarrow \nu X$



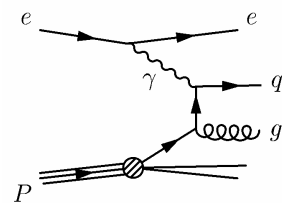
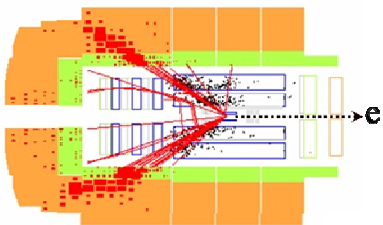
QED Compton



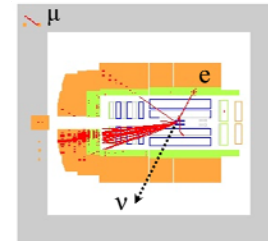
$ep \rightarrow e\gamma X$



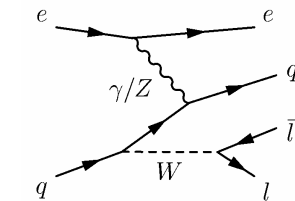
photoproduction $\gamma p \rightarrow X$



W production



$ep \rightarrow eWX$

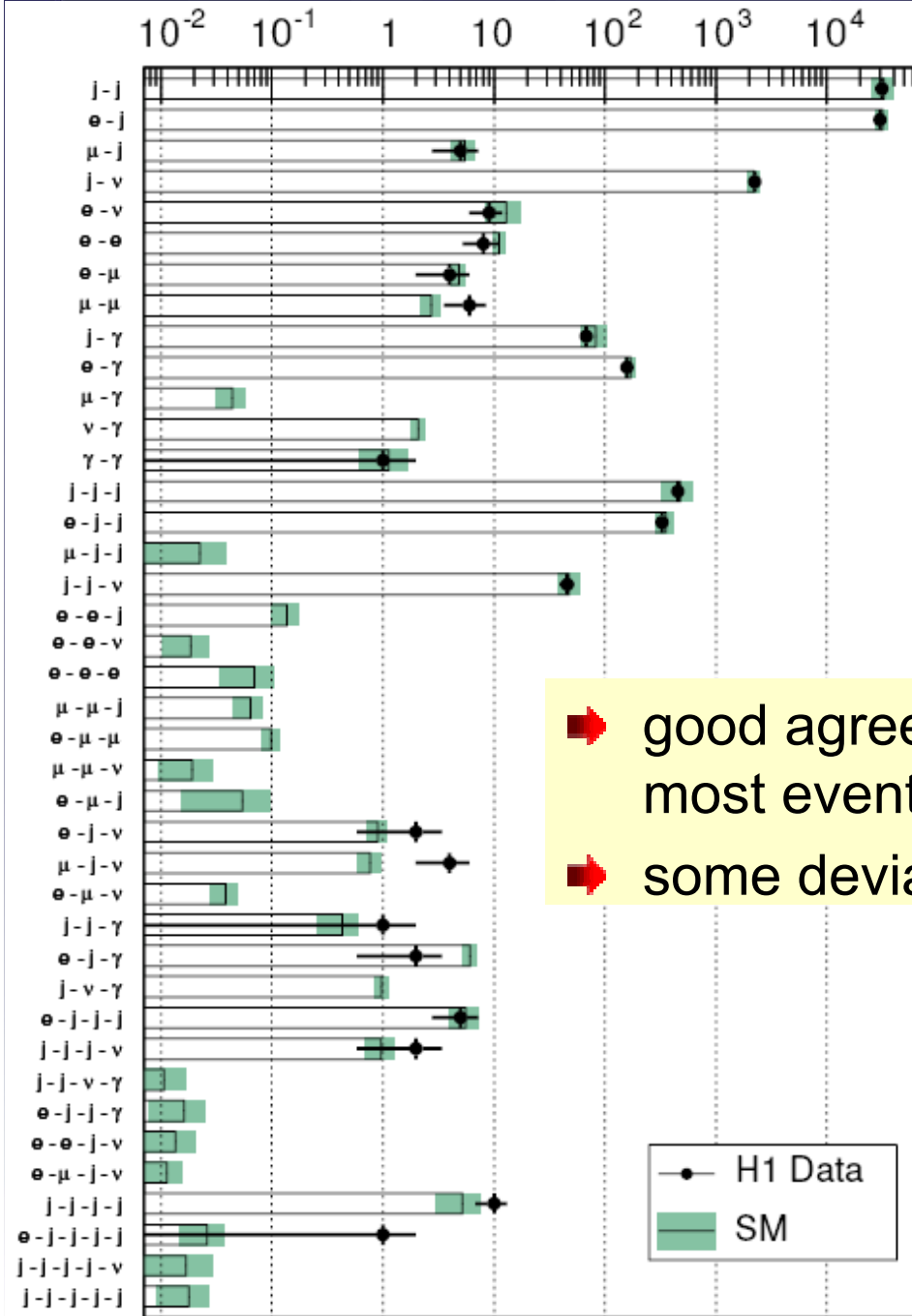


QCD processes: $O(\alpha_s) + PS$ or QED processes: $O(\alpha^2) + PS$

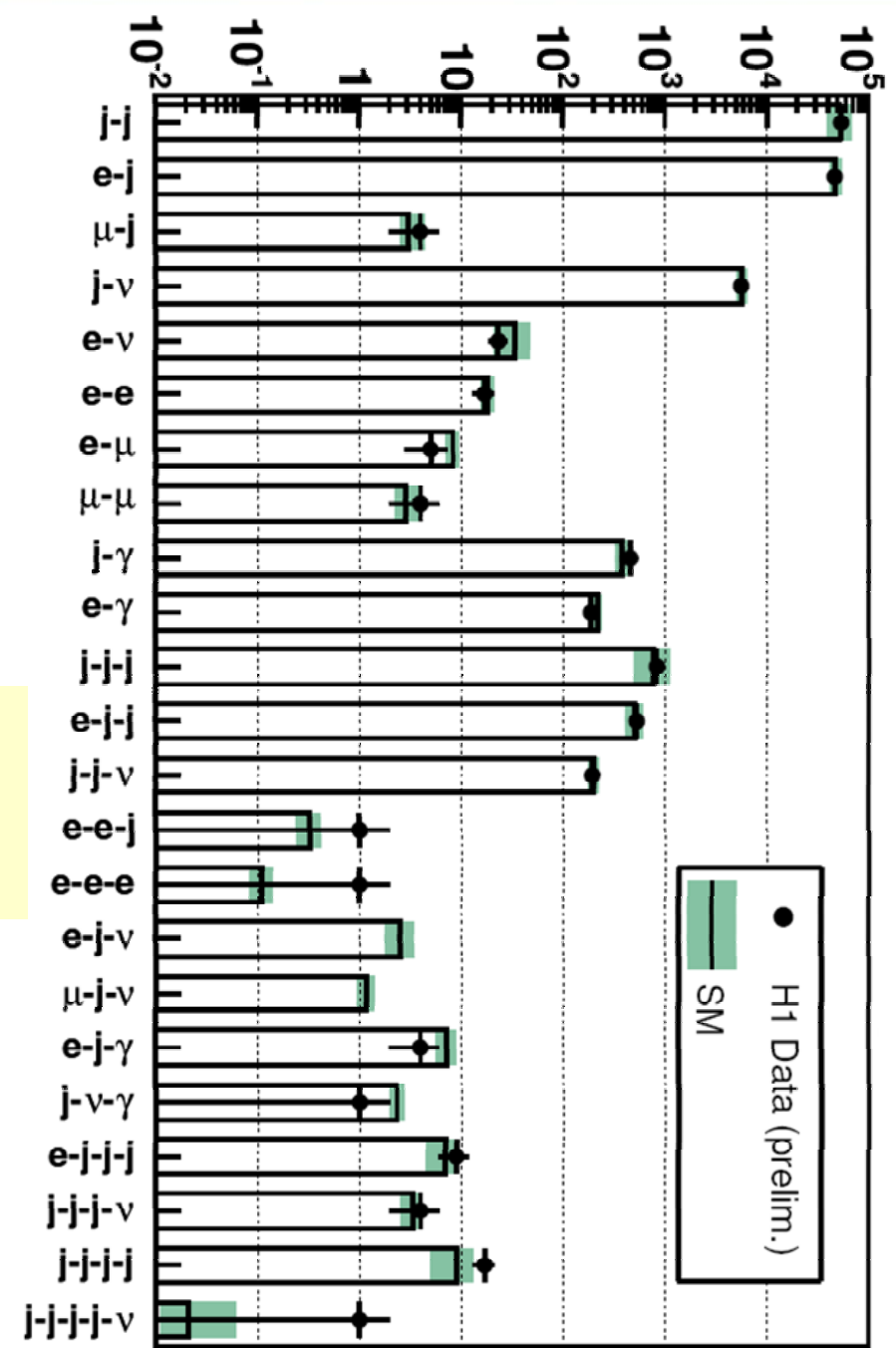
HERA I (117 pb⁻¹)

Event Yields

HERA II e-p (159 pb⁻¹)



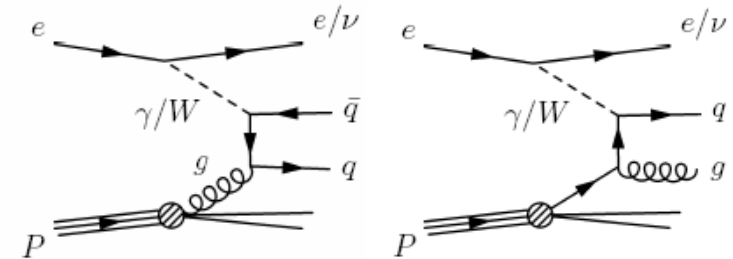
➡ good agreement for most event classes
➡ some deviations



Multi-Jet Final States

First analysis investigating ≥ 4 jet final states at high P_T

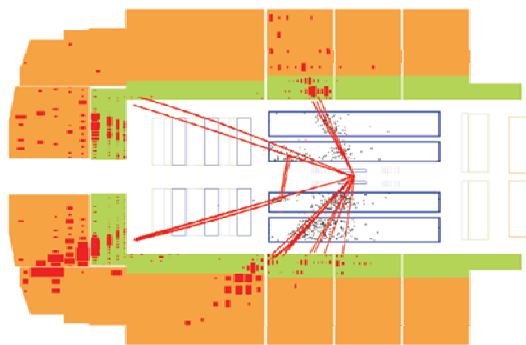
- slight overshoot of data in j-j-j-j class
- one event found in j-j-j-j-e and j-j-j-j- ν classes
- ! dominant SM contributions (γ P, NC/CC DIS) contain two jets produced by PS



MC $O(\alpha_s)$ (BGF/QCDC)

1. Is the j-j-j-j-X MC prediction reliable?

- ➔ tests using low P_T γ P and DIS samples show an adequate description of distributions



j-j-j-j- ν event

2. Does used MC prediction contain all relevant SM processes?

- MC prediction yields only $\sim 10^{-4}$ events in tails of distributions $\rightarrow \sigma$ of $O(10^{-3} \text{ fb})$
- ➔ rare SM processes might contribute ($ep \rightarrow eWWX$)
- ➔ j-j-j-j-X classes excluded from search for deviations

Search for Deviations

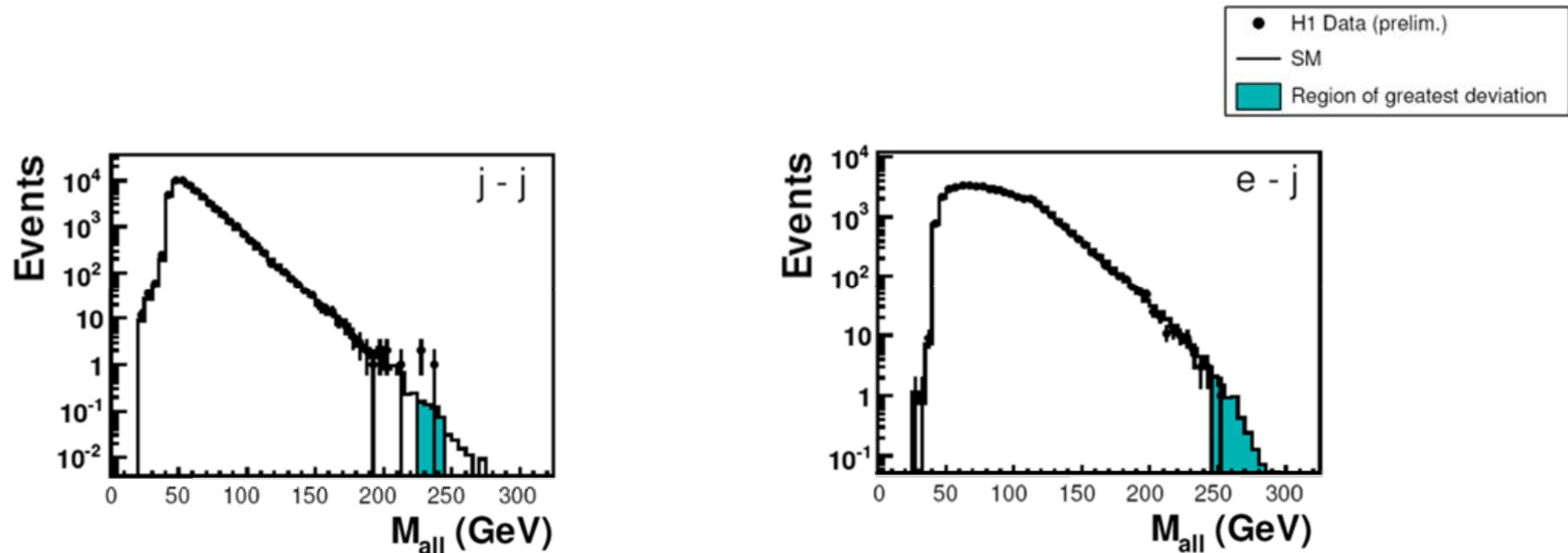
systematic search for deviations between data and SM prediction
in differential (1-dim) distributions with high sensitivity to BSM signals

M_{all} : invariant mass of objects $\sum P_T$: sum of transverse momenta

dedicated statistical algorithm:

1. **regions of most interest**
search region of largest deviation in given histogram
2. **event class of most interest**
weigh up significance of deviations found
3. **global significance**
decide if “event class of most interest” is interesting at all

1. Region of Largest Deviation



$$N_{obs} = 3$$
$$N_{SM} = 0.5 \pm 0.2$$
$$p_{min} = 0.02$$

excess region

$$N_{obs} = 1$$
$$N_{SM} = 6.4 \pm 3.9$$
$$p_{min} = 0.10$$

deficit region

- scan all possible connected regions with size \geq resolution and calculate probability p that data agrees with SM
- region of most interest is that with smallest probability $p=p_{min}$

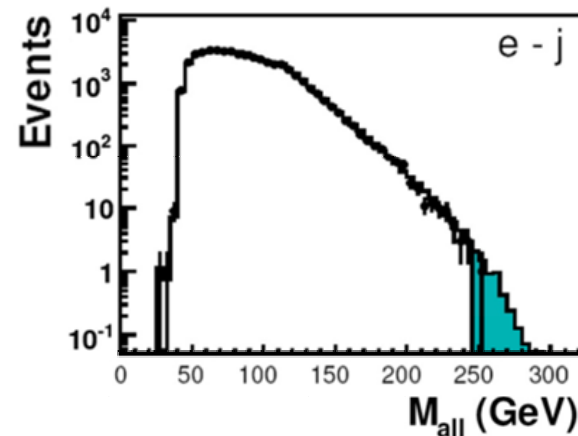
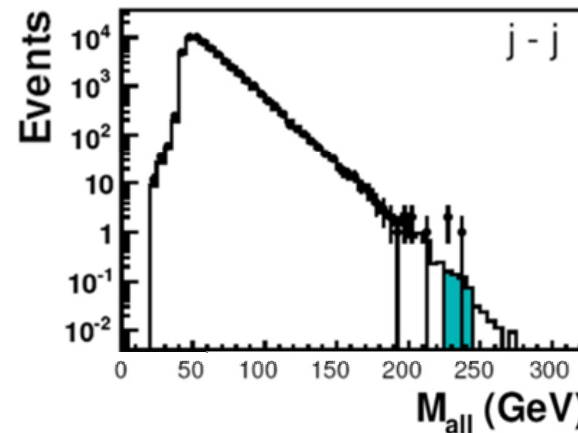
2. Event Class of Most Interest

✎ determine a measure of the deviations' statistical significance which allows to compare event classes

? What is the probability \hat{P} to observe a deviation with $p < p_{min}$?

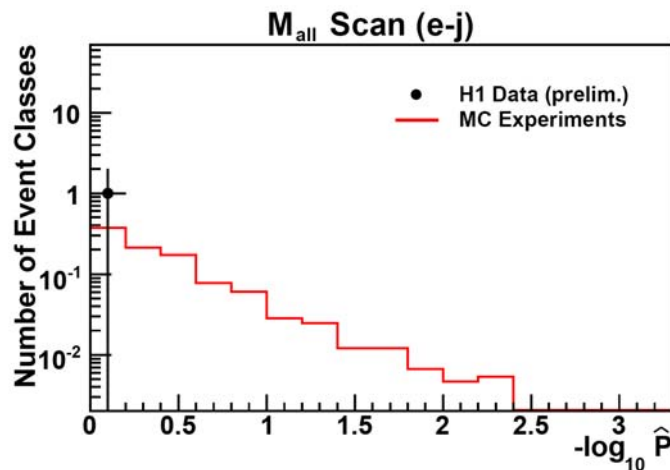
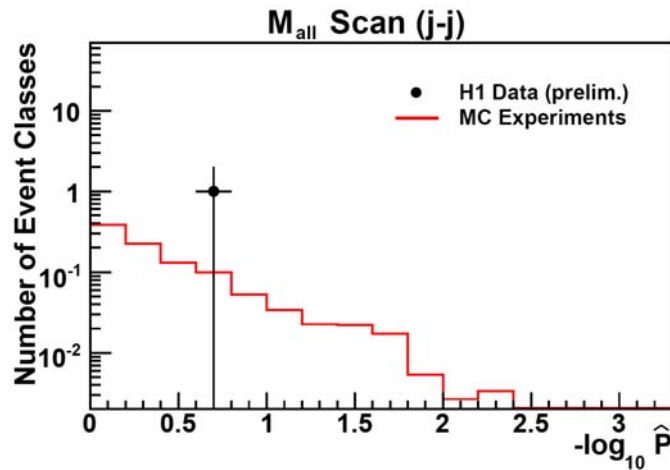
- dice hypothetical histograms H_{hyp} according to pdf of SM expectation
- for each H_{hyp} run the algorithm to find region of largest deviation: p_{min}^{hyp}

$$\hat{P} = \frac{\text{num } H_{hyp} \text{ with } p_{min}^{hyp} < p_{min}^{data}}{\text{tot num } H_{hyp}}$$



- ➡ \hat{P} is measure for significance of p_{min}^{data}
- ➡ event class of most interest is that with smallest \hat{P} value

3. Global Significance



✂ take into account that small \hat{P} values (have to) occur among the multiplicity of studied event classes

? What would be the outcome if we could redo the experiment?

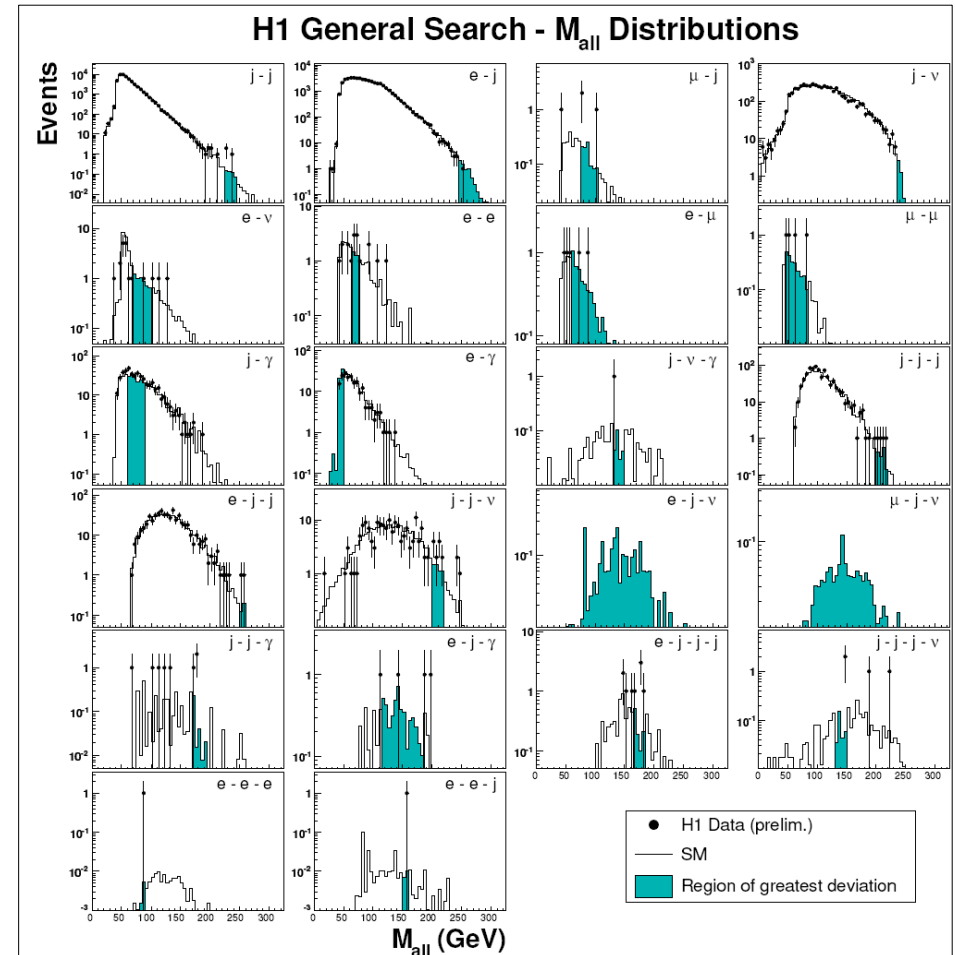
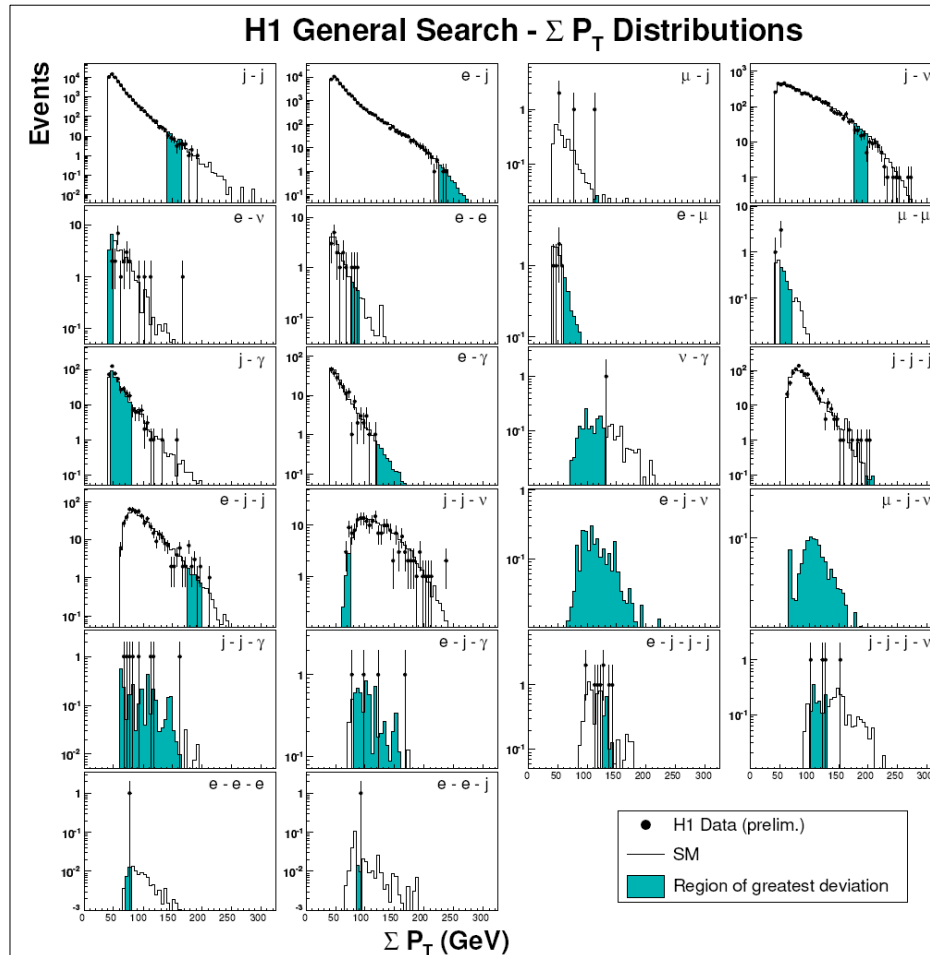
- replace data histograms with MC pseudo-data and determine according \hat{P}_{MCE} values

$$\hat{P}_{MCE} = \frac{\text{num } H_{hyp} \text{ with } p_{min}^{hyp} < p_{min}^{pseudo}}{\text{tot num } H_{hyp}}$$

➡ expectation for data \hat{P} values is given by distribution of \hat{P}_{MCE} from multiple MC experiments

ΣP_T and M_{all} Distributions

HERA II e-p (159 pb⁻¹)



all event classes have systematically been scanned for deviations

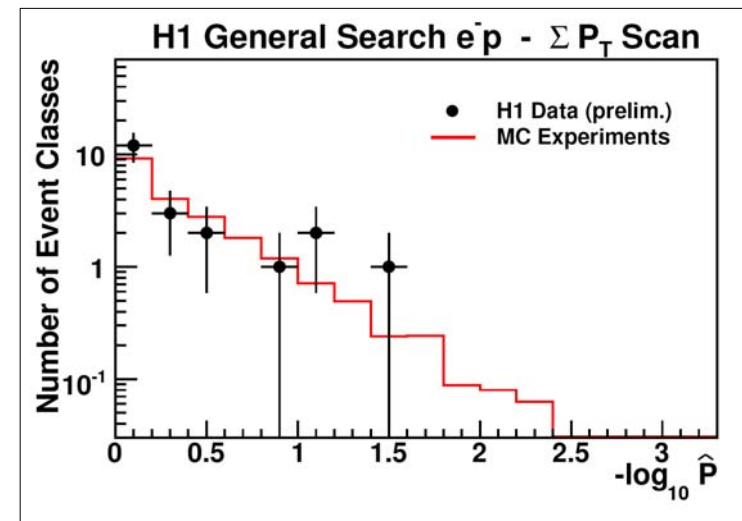
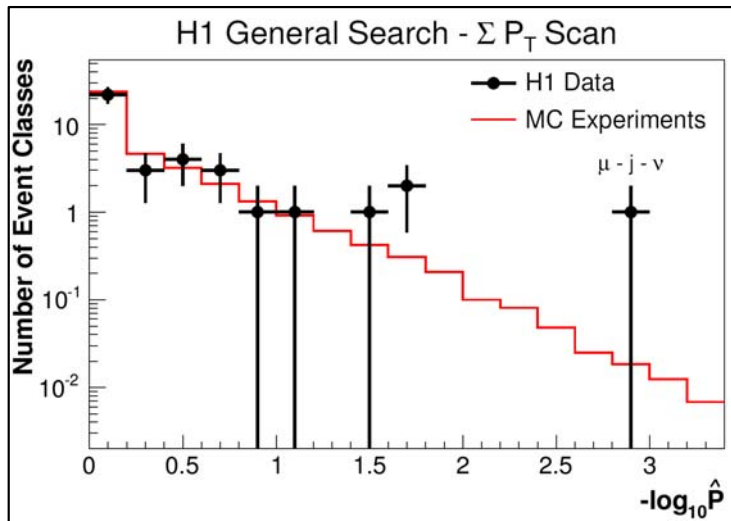
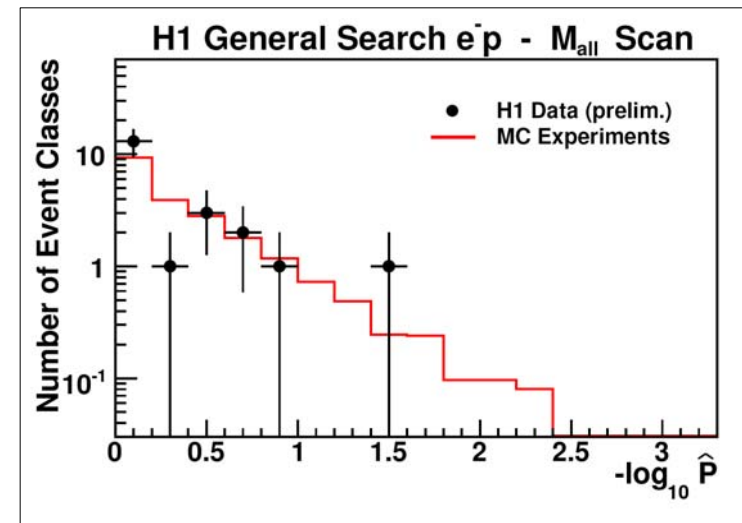
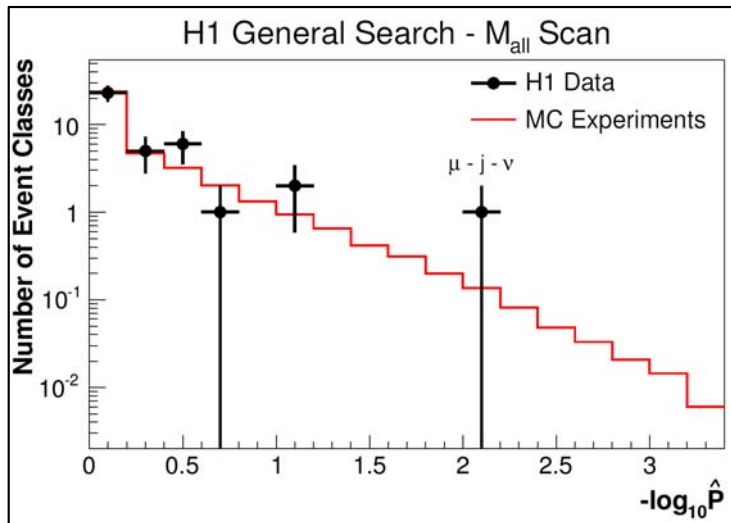
➡ allows quantification of *overall* agreement between HERA data and SM

Search Results

HERA I (117 pb⁻¹)

HERA II e

-1)



➡ $\mu - j - \nu$: $\sim 3\%$ of MC experiments would produce a deviation more significant

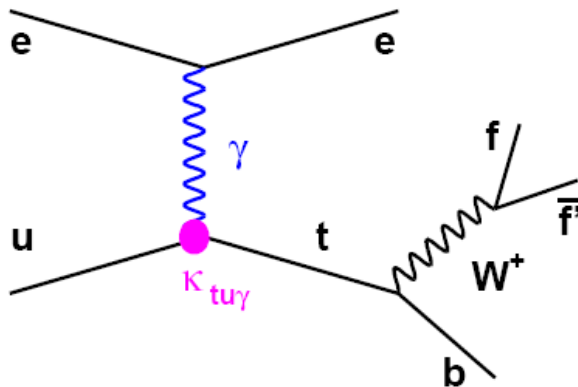
➡ no event classes with remarkably small \hat{P} values observed

Sensitivity to New Physics

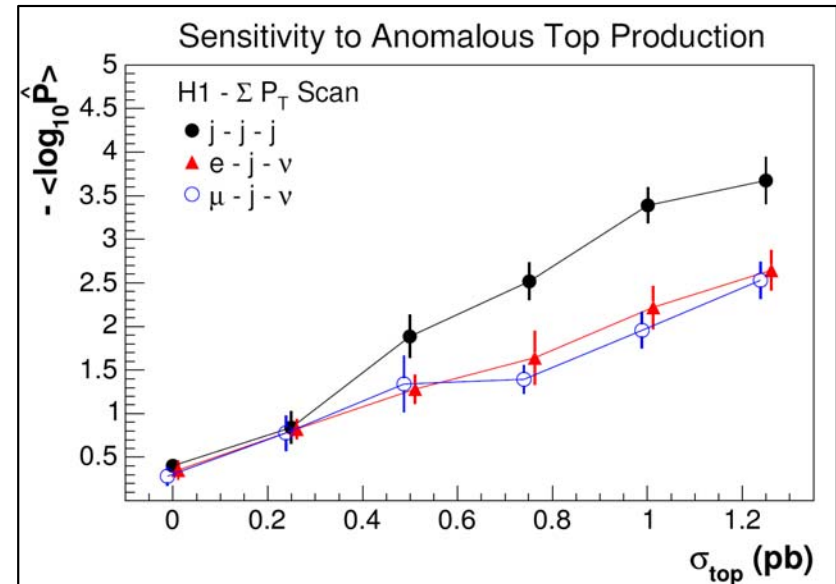
- pseudo data samples have been used to test sensitivity to new physics

Example

- ➔ anomalous top production via FCNC



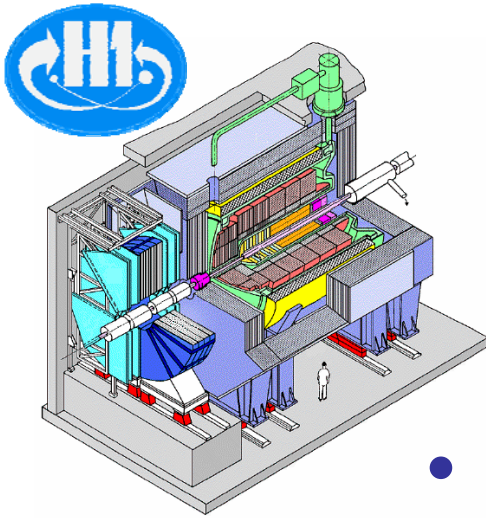
- event classes sensitive on $t \rightarrow bW$ decay considered (j-j-j, e-j-v, μ -j-v)
- $-\langle \log \hat{P} \rangle$ as function of top production cross-section investigated



- ➔ largest sensitivity for ΣP_T scan in j-j-j event class:
 $-\langle \log \hat{P} \rangle$ of 2 for $\sigma_{top} \sim 0.5$ pb
- ➔ all 3 event classes with $-\langle \log \hat{P} \rangle$ be above 3 for $\sigma_{top} \sim 1.5$ pb

$$H1: \sigma_{t \rightarrow bqq} < 0.48 \text{ @ } 95\% \text{ CL}$$

Summary



- a model-independent search for new physics signals is performed at HERA using all possible final state configurations at high P_T
- no significant deviation has been observed
- factor 2 increase in e^+p data sample expected: watch the unexpected!