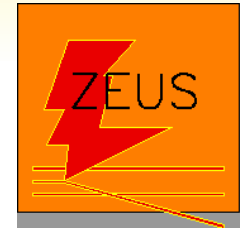


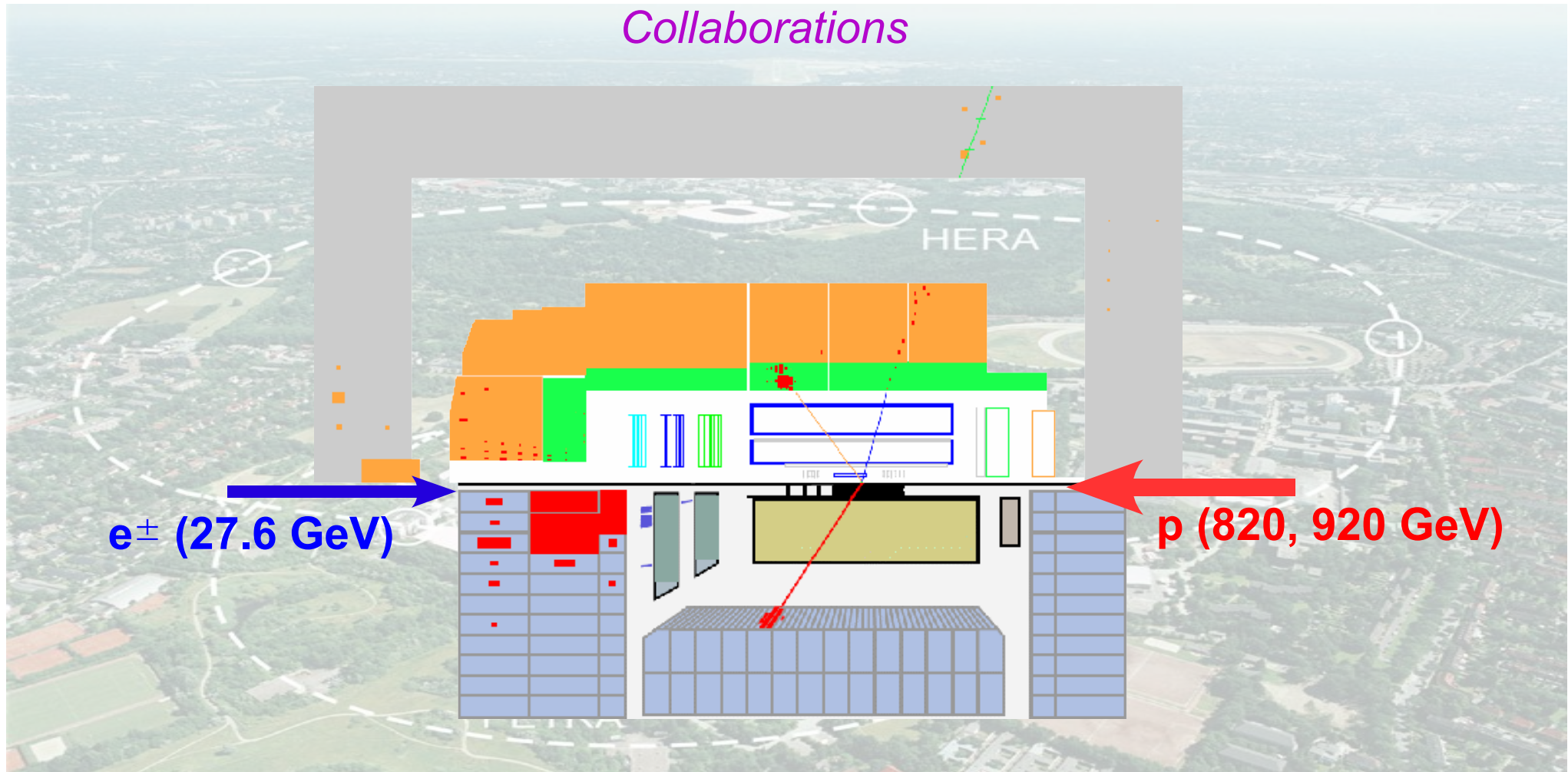
Model Independent Searches in ep Collisions



Emmanuel Sauvan
CPPM Marseille

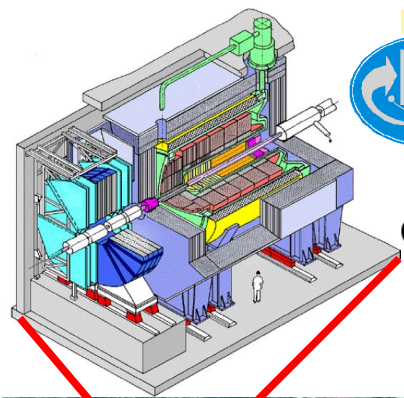


*On behalf of H1 and ZEUS
Collaborations*

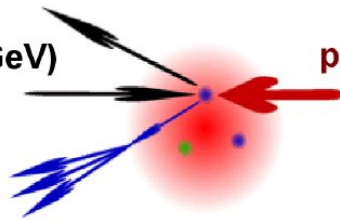




The HERA ep collider

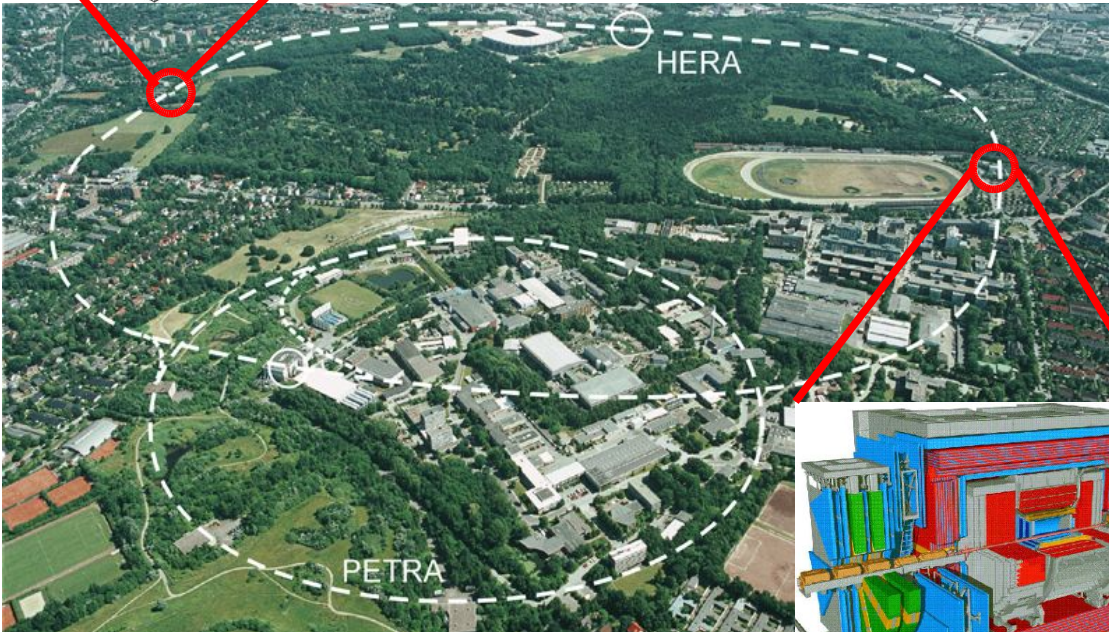


e^\pm (27.6 GeV)



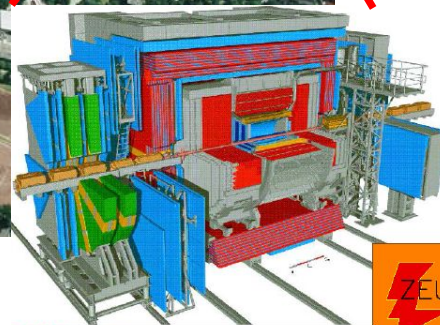
p (820/920 GeV)

• $\sqrt{s} = 320$ GeV



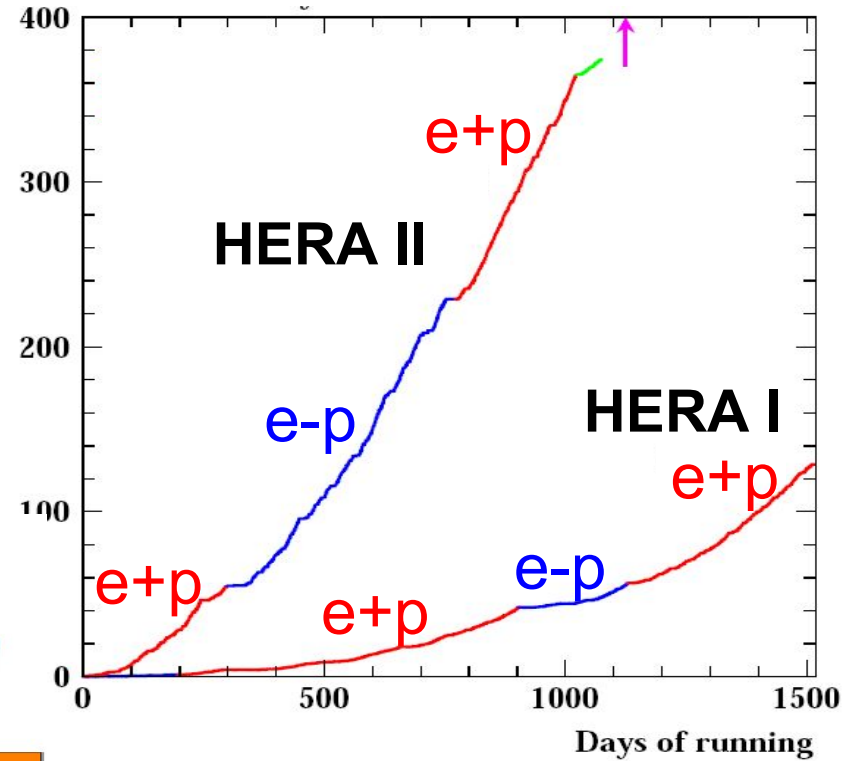
HERA

PETRA



ZEUS (HERA)

H1 Integrated Luminosity / pb^{-1}



- HERA I: 1992-2000, $\sim 120 \text{ pb}^{-1}$ per experiment
 - HERA II: 2003-2007, $\sim 360 \text{ pb}^{-1}$ per experiment
- ↘ In total H1+ZEUS together accumulated $\sim 1\text{fb}^{-1}$

Hunting for New Physics at HERA

↘ The instrument: HERA is a frontier collider

→ $\mathcal{L} \sim 0.5 \text{ fb}^{-1}$: search for processes with $\sigma < 1 \text{ pb}$

- Parton luminosity: HERA collides beyond LEP
- Backgrounds: HERA has less than Tevatron

↘ Model independent searches

- Do not rely on specific exotic signatures
- Precise data / SM comparisons in

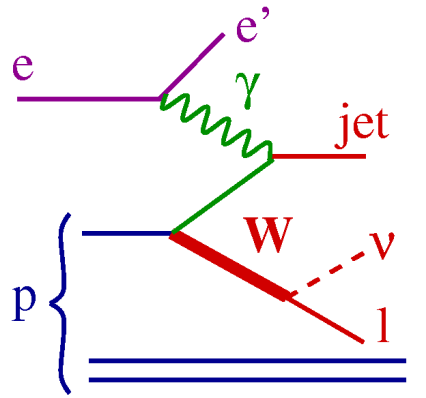
→ Final states with a low SM expectation

→ High P_T tails of the SM: investigate all possible final states

↘ Prerequisite:

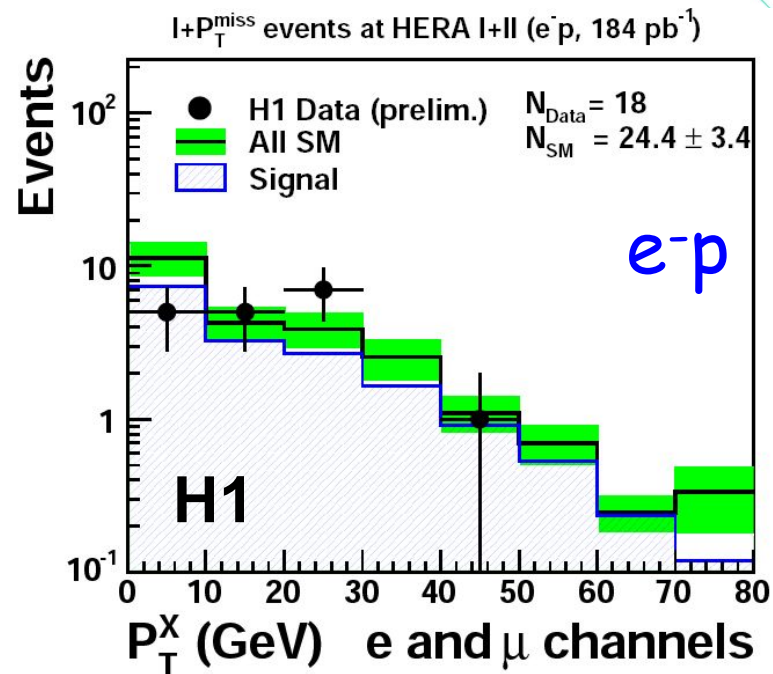
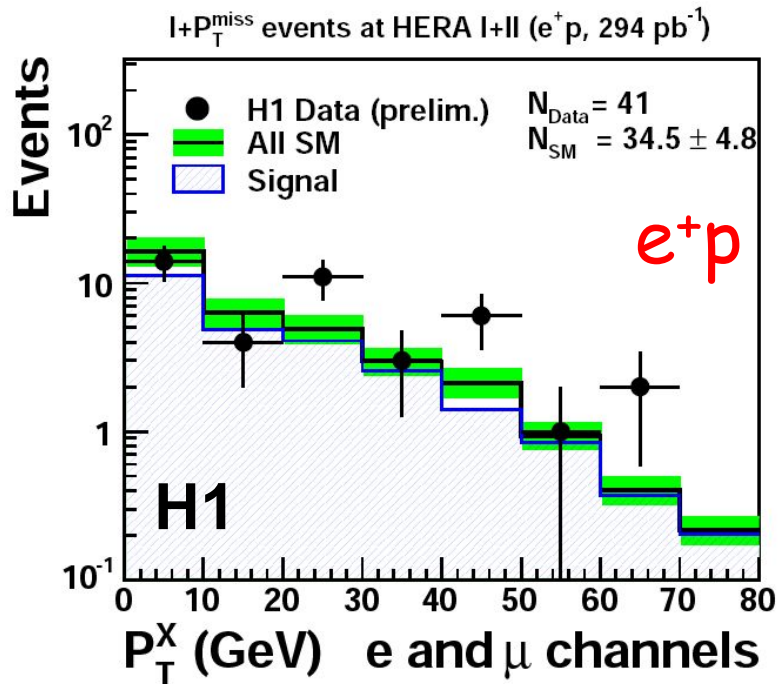
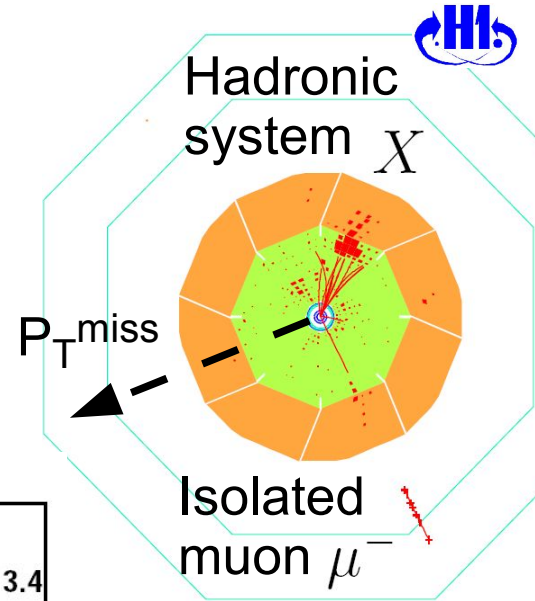
- Control of the detector response
- Understanding and simulation of all SM processes

W production at HERA ($W \rightarrow e, \mu$)



SM W: $\sigma \sim 1.3$ pb

- Events with high $P_T^{e, \mu}$, P_T^{miss} and hadronic system (P_T^X)
 - H1 in HERA I, for $P_T^X > 25$ GeV: an excess of data events (3σ)
- All H1 HERA I+II data: 478 pb⁻¹
 - Events at high P_T^X also observed in latest data



↘ Different observations in e^+p and e^-p

Isolated leptons: H1 and ZEUS

- Analysis also performed by ZEUS, HERA I+II data: 492 pb⁻¹

→ A good agreement with the SM is observed

| | | electrons | muons |
|--------------------------------------|---------------------------|----------------|----------------|
| P _T ^X > 25 GeV | | data / SM | data / SM |
| e ⁺ | H1 294 pb ⁻¹ | 11 / 4.7 ± 0.9 | 10 / 4.2 ± 0.7 |
| | ZEUS 286 pb ⁻¹ | 3 / 3.9 ± 0.6 | 3 / 3.6 ± 0.5 |
| e ⁻ | H1 184 pb ⁻¹ | 3 / 3.8 ± 0.6 | 0 / 3.1 ± 0.5 |
| | ZEUS 206 pb ⁻¹ | 3 / 3.2 ± 0.6 | 2 / 2.4 ± 0.4 |

- In e+p H1: 21 / 8.9 ± 1.5 (3 σ)

ZEUS: agreement with the SM

- In e-p agreement with SM for both H1 and ZEUS

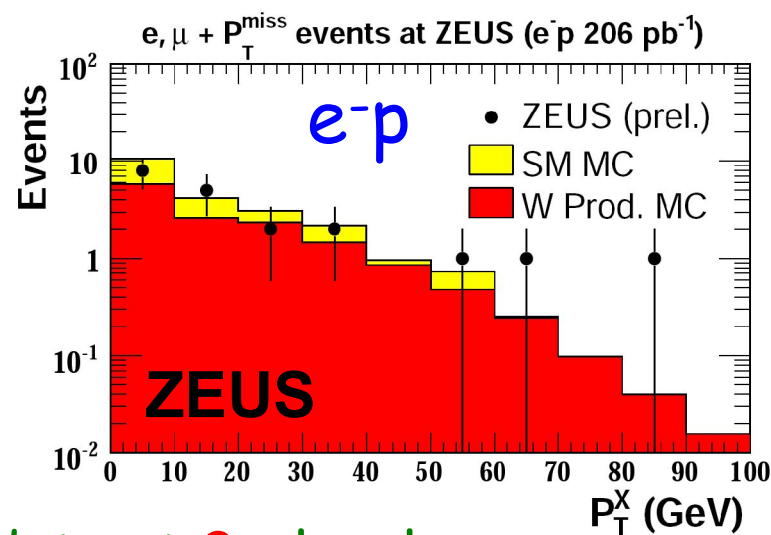
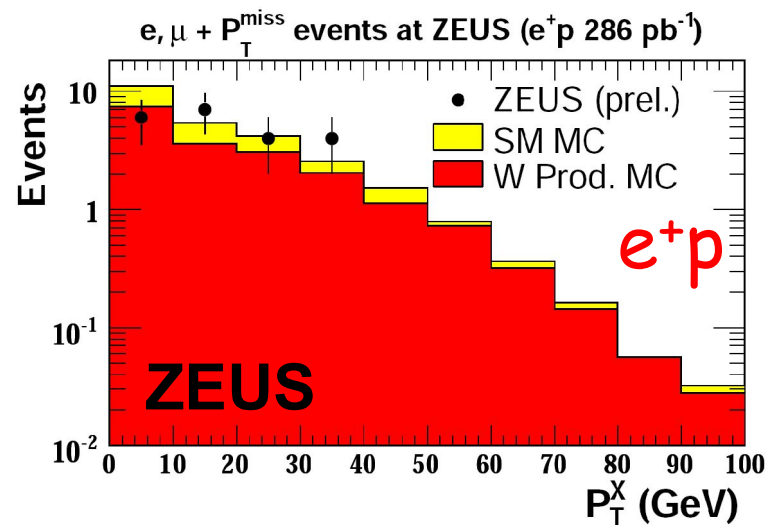
- Smaller acceptance for ZEUS

H1: θ^{e,μ} > 5° / ZEUS: θ^{e,μ} > 15°

→ But most H1 events are in ZEUS acceptance

↘ H1 excess remains in e+p data at 3σ level

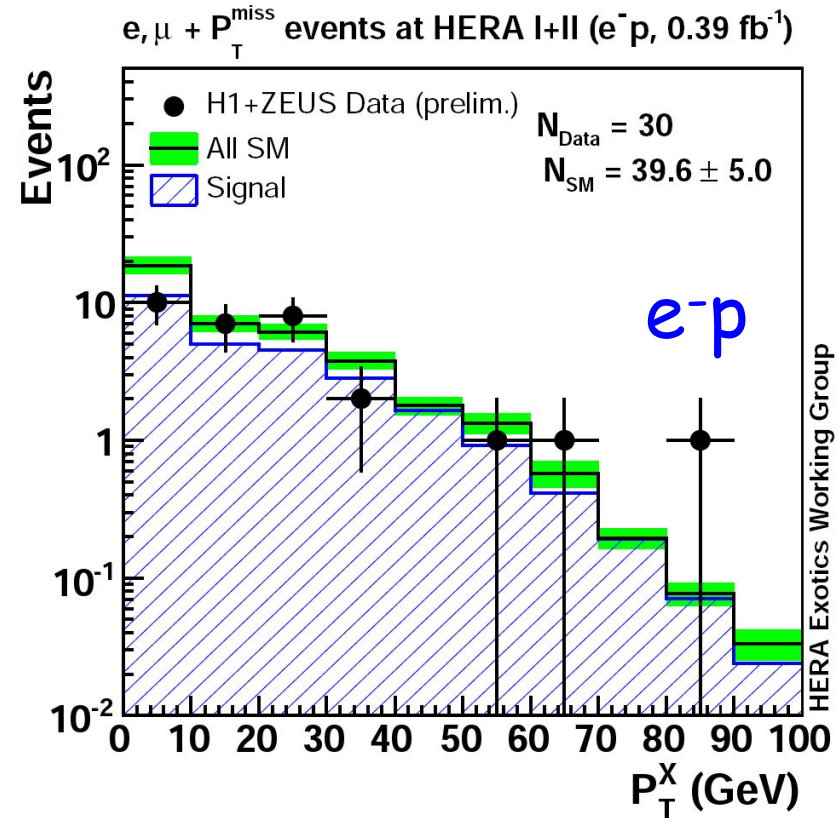
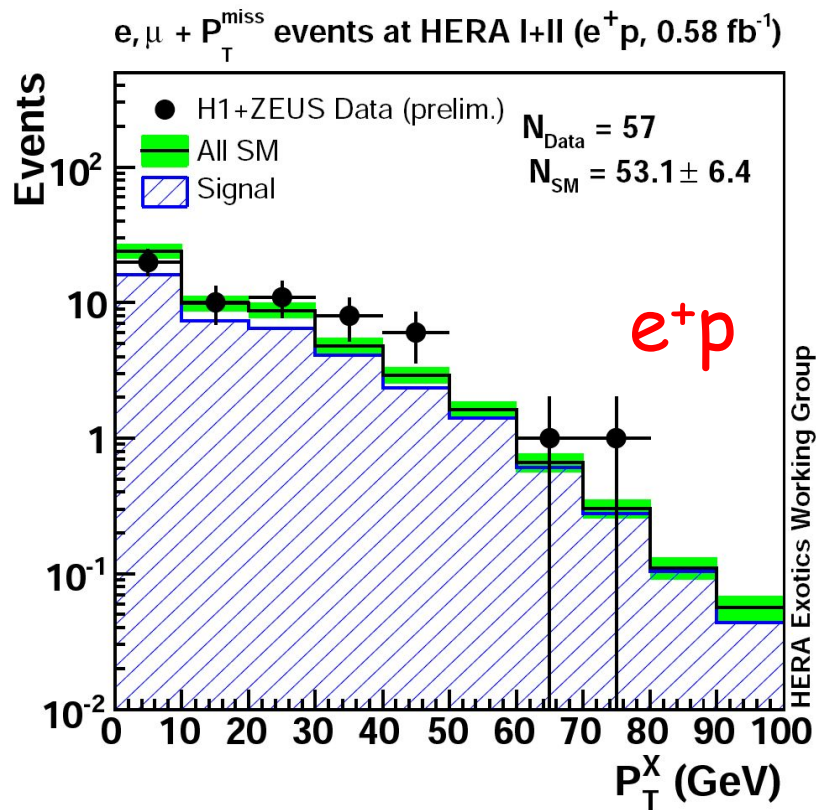
↘ Not clarified with HERA II data



H1 and ZEUS Combination

↘ H1 and ZEUS analyses combined in a common phase-space

→ Total luminosity: 0.97 fb^{-1}



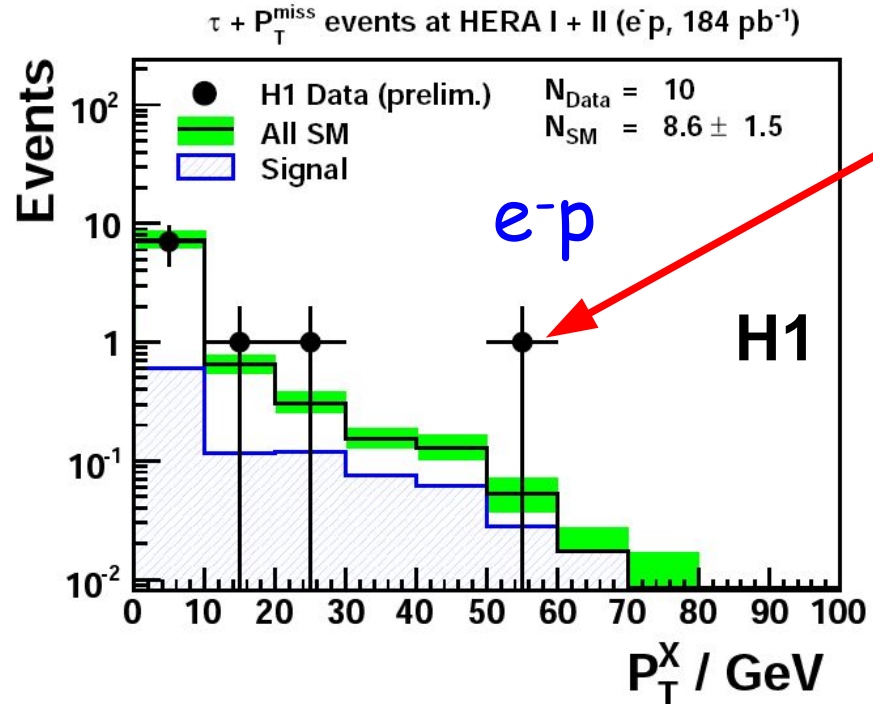
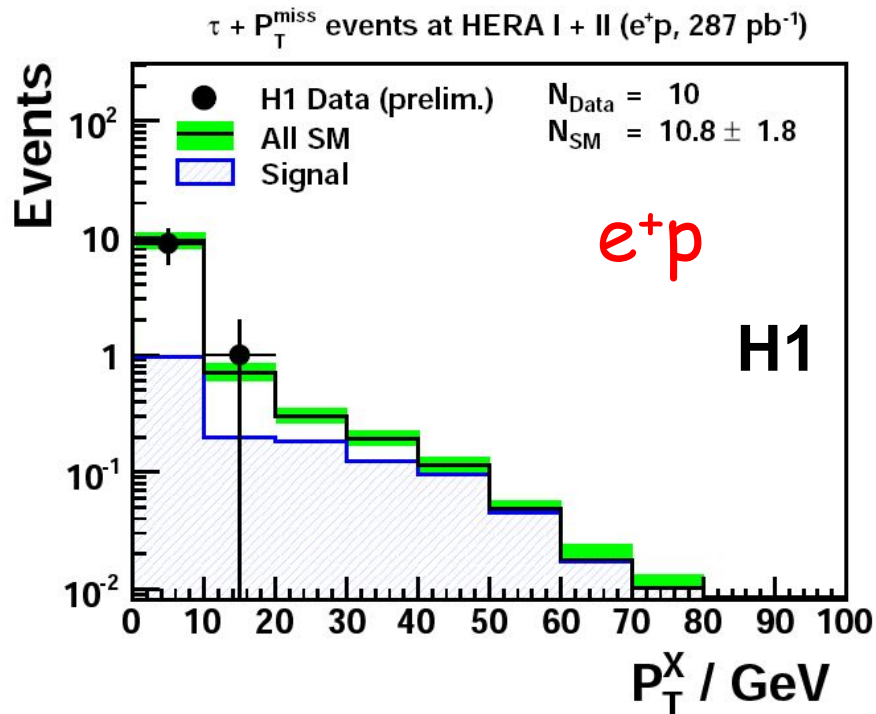
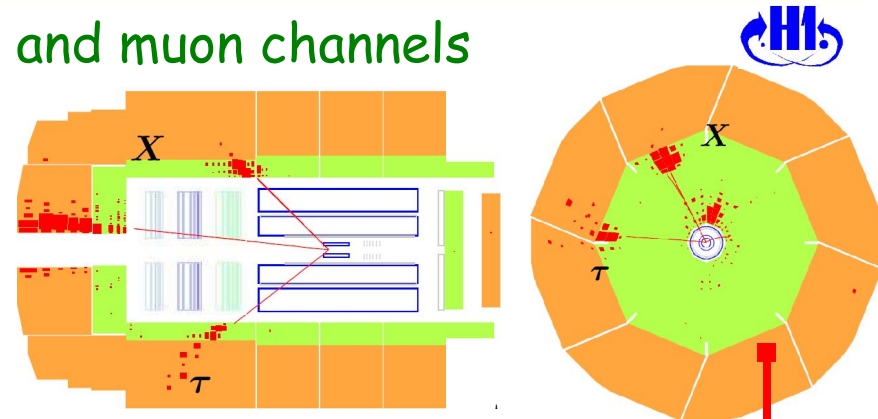
- Good agreement with the SM in the global sample
- Fluctuation in $e+p$ for $P_T^X > 25 \text{ GeV}$ is reduced (1.8σ)

Isolated $\tau + P_T^{\text{miss}}$ events

→ To complement isolated electron and muon channels

- H1 analysis, full HERA I+II (471 pb⁻¹)
- τ identified in the hadronic 1-prong decay

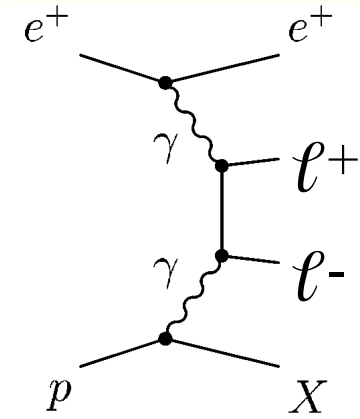
→ Jets with a single track in charged current event



→ Good agreement in e^+p and e^-p

→ ZEUS: 2 high P_T^X events for 0.2 ± 0.05 SM in HERA I data

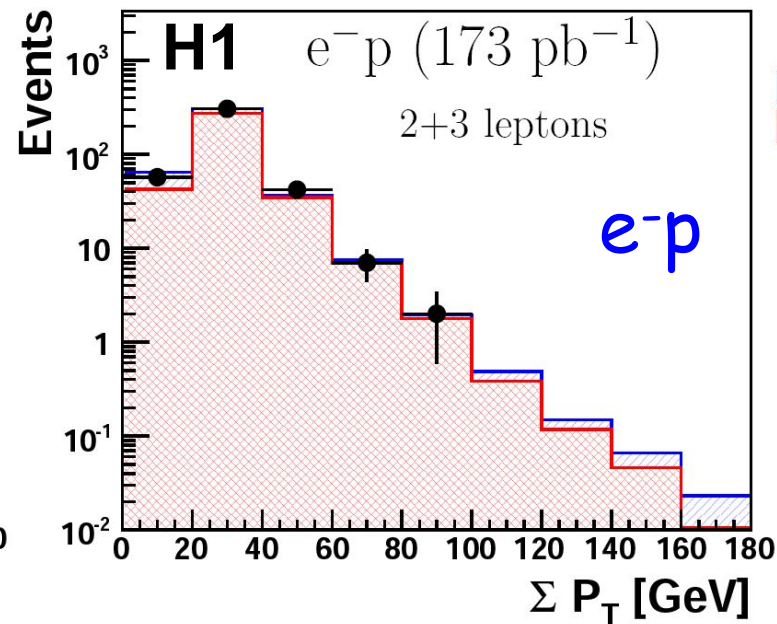
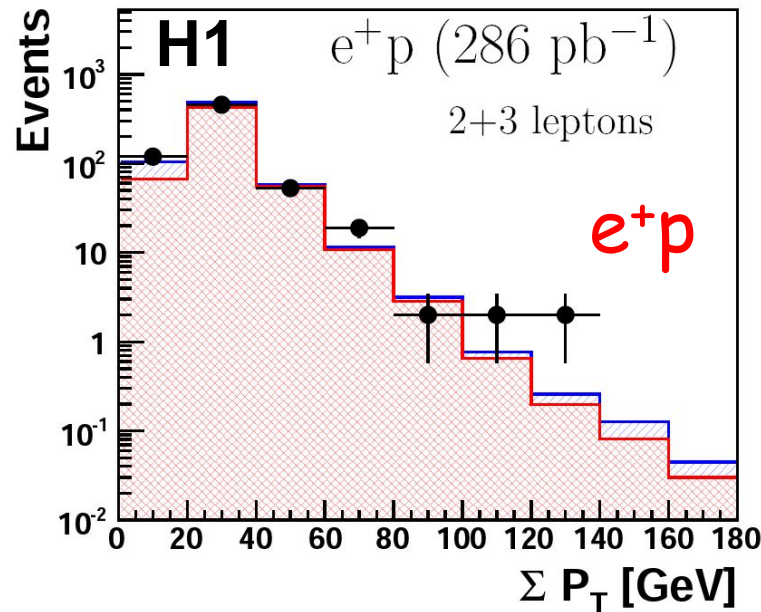
Multi-lepton events (e, μ)



$\sigma \sim 1 \text{ pb}$ (high P_T)

↘ Low and well controlled SM contribution

- Mainly produced via $\gamma\text{-}\gamma$ in SM
- Look for events with at least 2 isolated high- P_T leptons (e, μ)
 - $ee, eee, e\mu, \mu\mu, e\mu\mu$
- H1 analysis performed on all HERA I+II data (459 pb^{-1})
 - ΣP_T : hardness of the events



● H1 Data (prelim.)
 DIS+Compton
 Pair Production

→ Striking events observed for $\Sigma P_T > 100 \text{ GeV}$

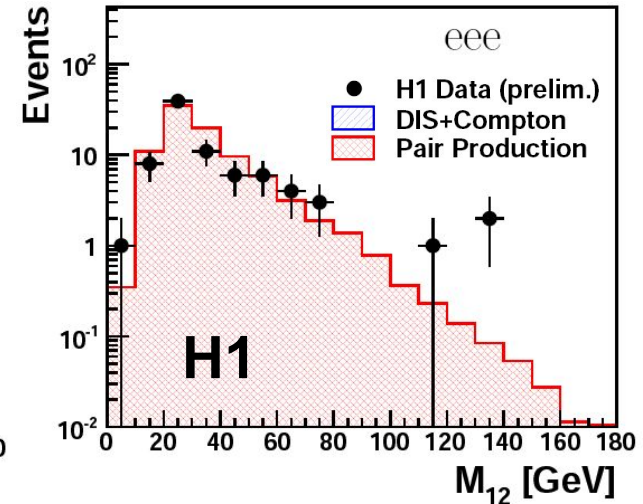
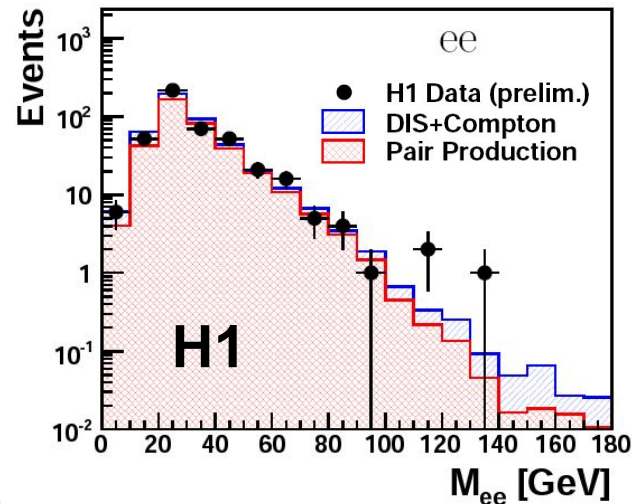
→ In $e+p$ only : $4 / 1.2 \pm 0.2$

Multi-electron events: H1/ZEUS

- ZEUS: analysis performed for multi-electron topologies (478 pb⁻¹)

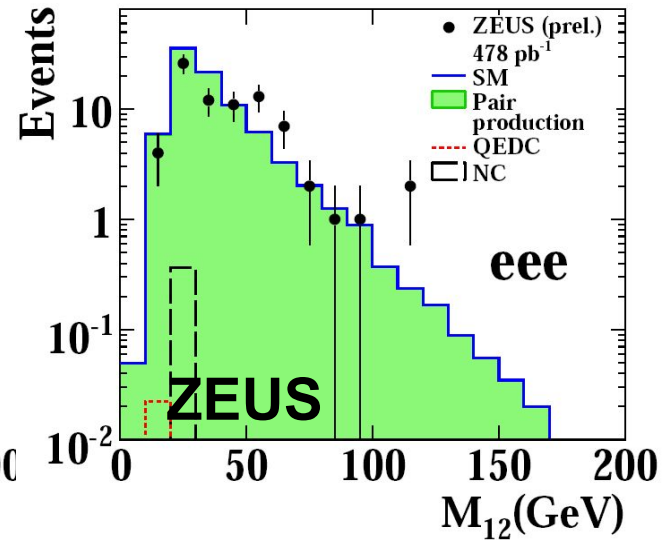
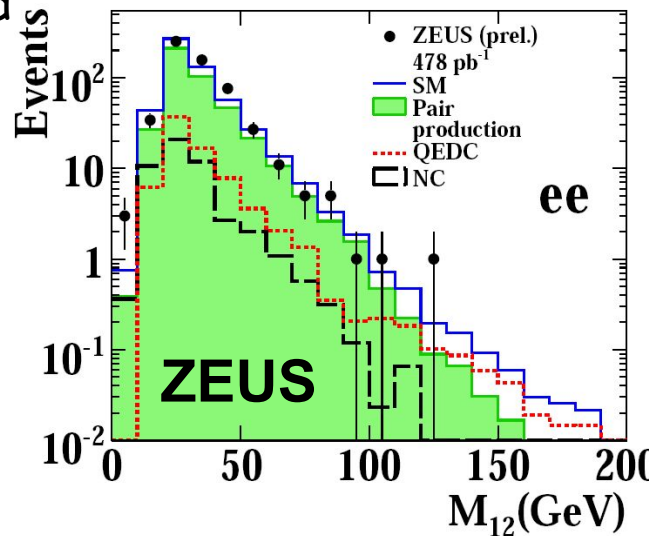
- Phase space similar to H1

- For $M_{12} > 100$ GeV



Signal Background

| | data | SM | Pair prod. | DIS+QEDC |
|------|------|-----------|------------|-----------|
| H1 | | | | |
| ee | 3 | 1.5 ± 0.3 | 0.9 ± 0.2 | 0.6 ± 0.2 |
| eee | 3 | 0.9 ± 0.2 | 0.9 ± 0.2 | < 0.005 |
| ZEUS | | | | |
| ee | 2 | 1.9 ± 0.2 | 0.9 ± 0.1 | 1.0 ± 0.2 |
| eee | 2 | 1.0 ± 0.1 | 1.0 ± 0.1 | < 0.005 |



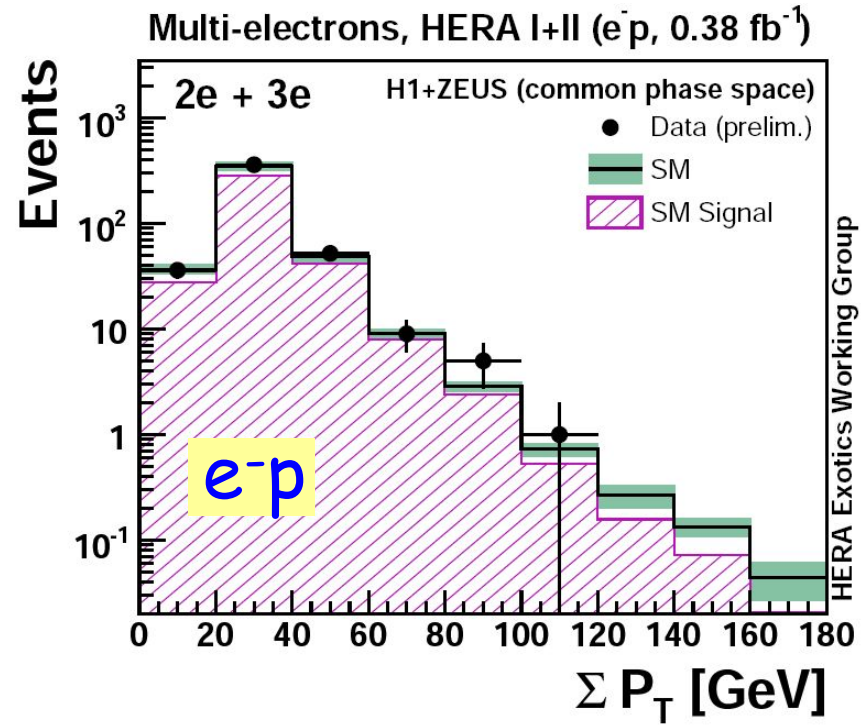
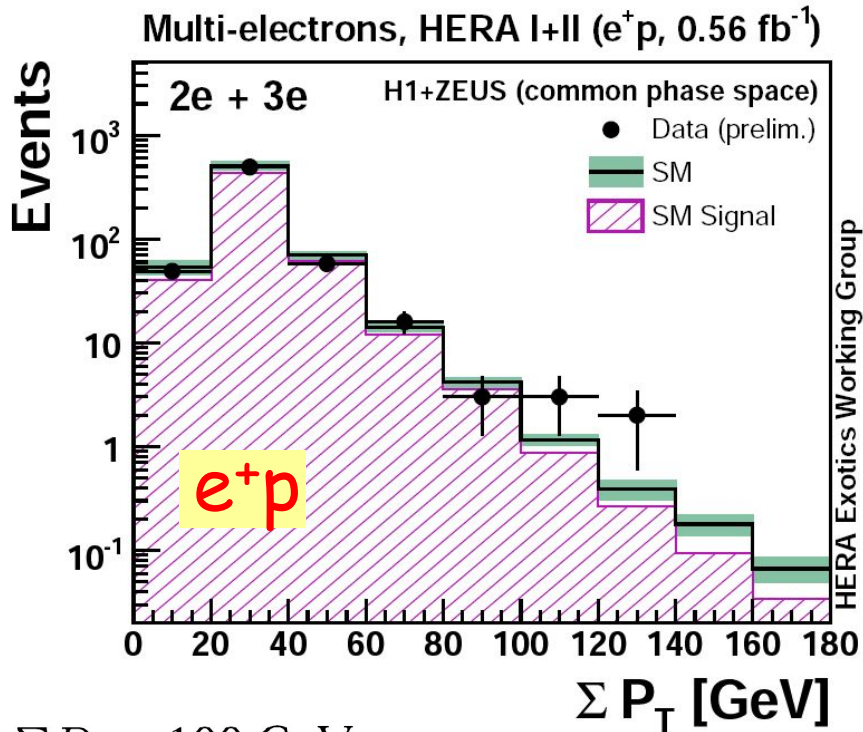
→ H1: no new ee(e) event, HERA I excess not confirmed

→ ZEUS: good data/MC agreement, result comparable to H1

Multi-electron: H1 and ZEUS Combination

↘ H1 and ZEUS analyses combined in a common phase-space

→ Total luminosity: 0.94 fb^{-1}



$\Sigma P_T > 100 \text{ GeV}$

| Data sample | Data | SM |
|----------------------------------|------|-----------------|
| $e^+p (0.56 \text{ fb}^{-1})$ | 5 | 1.82 ± 0.21 |
| $e^-p (0.38 \text{ fb}^{-1})$ | 1 | 1.19 ± 0.14 |
| $e^\pm p (0.94 \text{ fb}^{-1})$ | 6 | 3.00 ± 0.34 |

→ Few high P_T events observed mainly in $e+p$

General Search

→ A signature based search: investigate all high P_T topologies

- H1, full HERA II data (337 pb⁻¹)

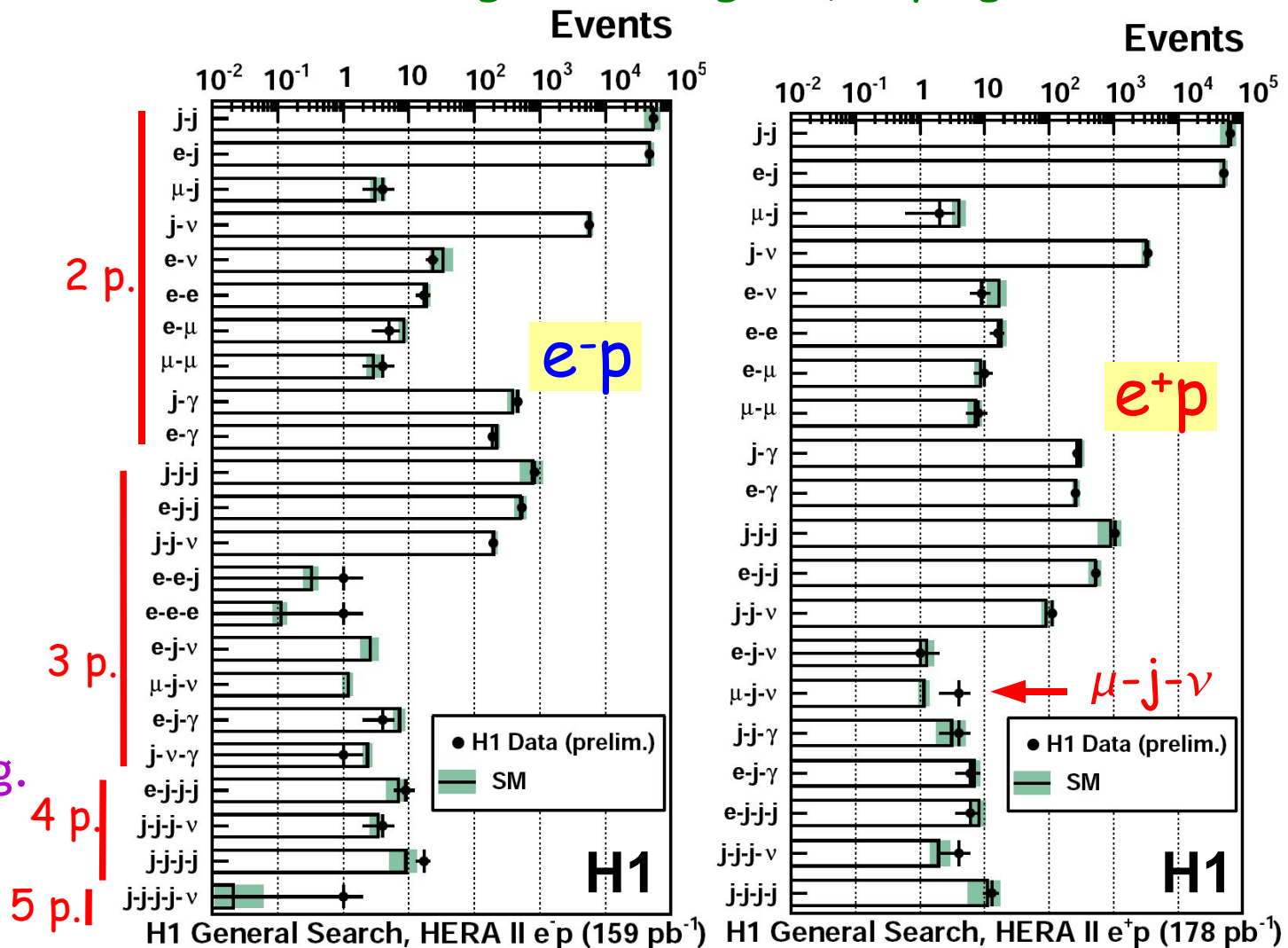
HERA I data published (117 pb⁻¹) [PLB 602(2004)14]

- Isolated particles
→ e, γ , μ , jet, ν

- A common phase space

→ $P_{T\text{part}} > 20$ GeV

→ $10 < \theta_{\text{part}} < 140$ deg.

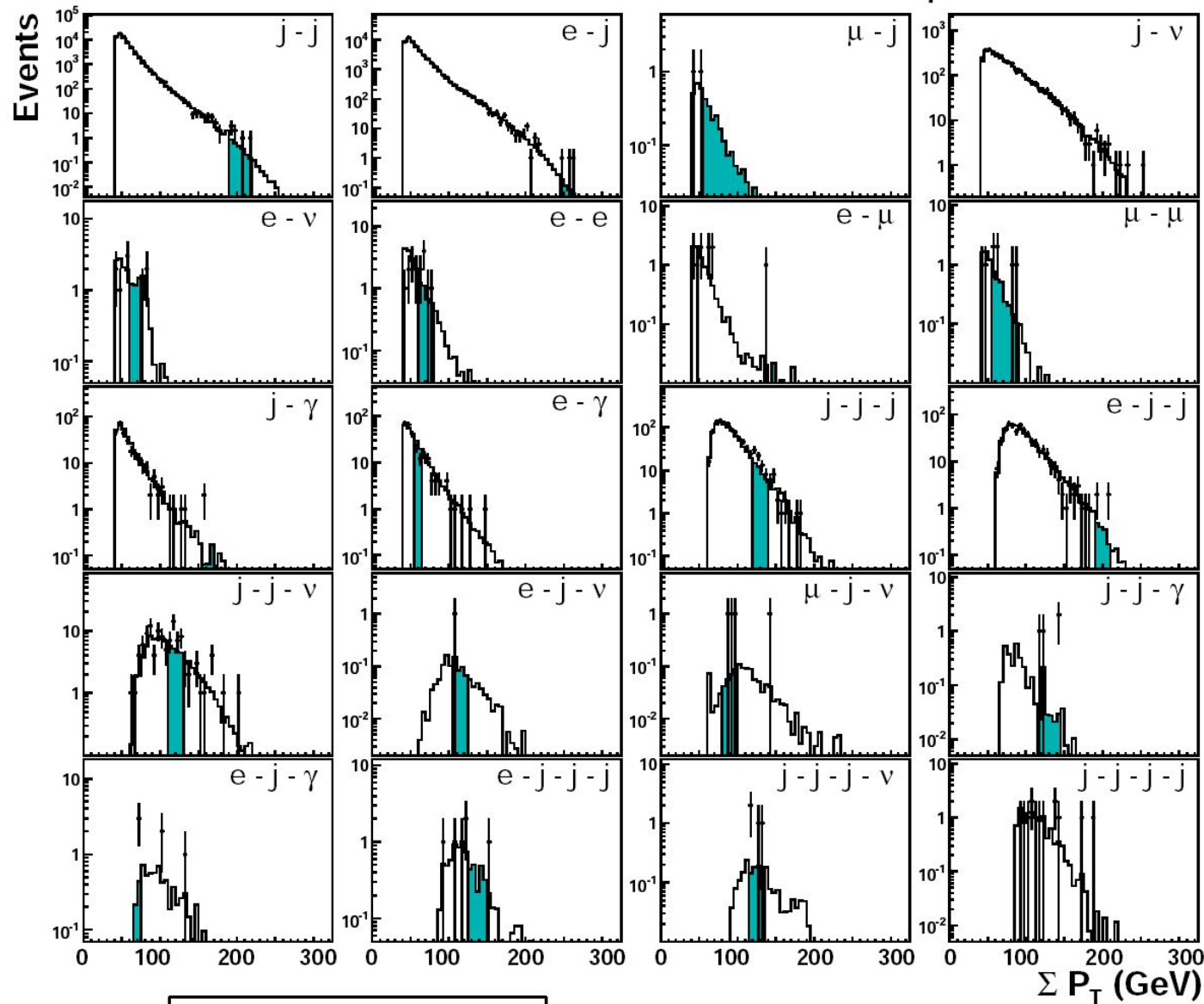


→ Good agreement with SM in most classes

→ Good understanding of the detector and of SM processes

General Search: ΣP_T distributions

H1 General Search, HERA II e^+p (178 pb^{-1}) - ΣP_T Distributions



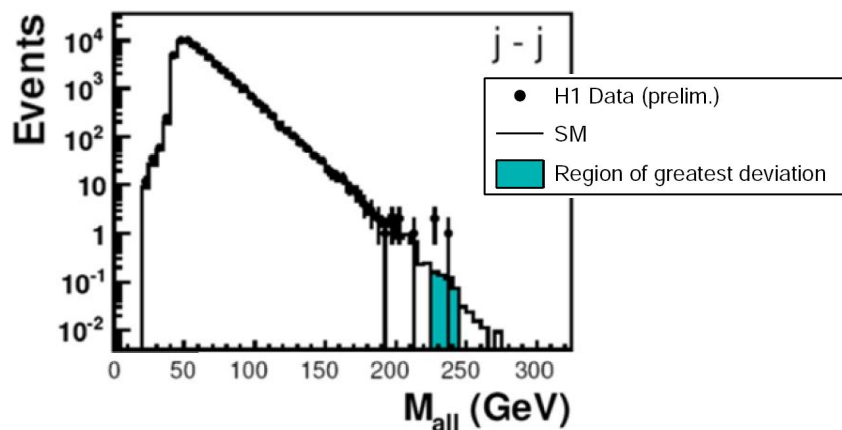
→ A systematical scan of all classes

→ Some regions with deviations found

→ Are they significant ?

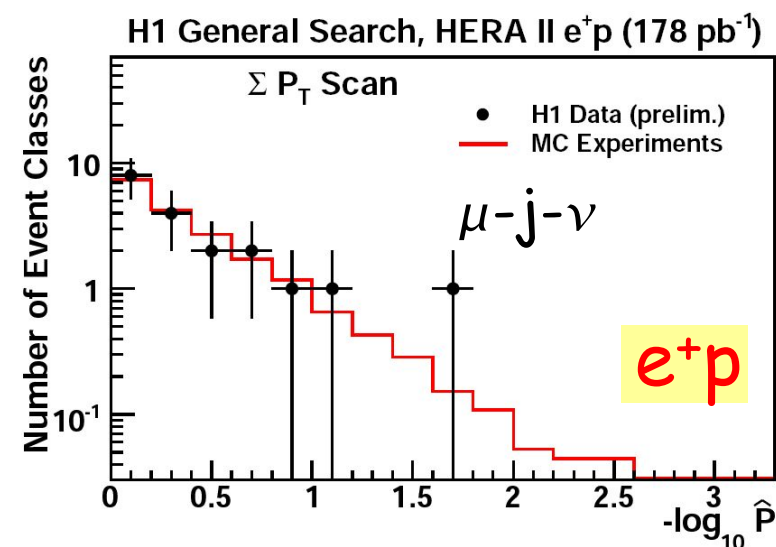
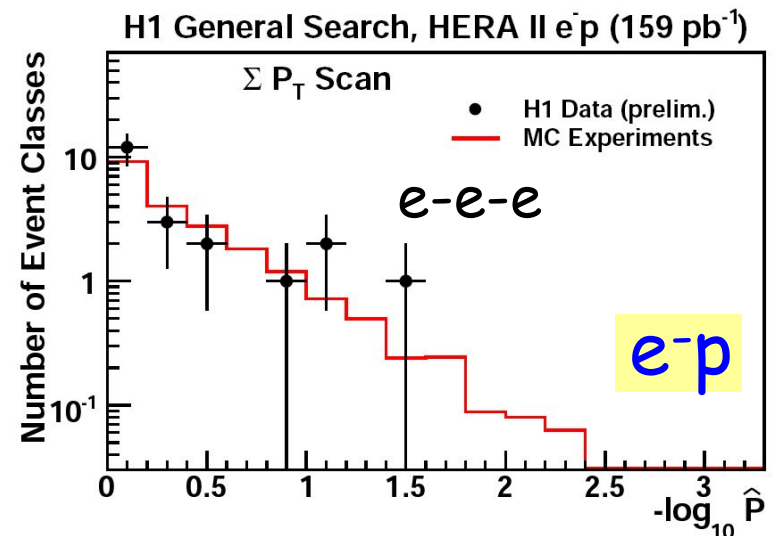
General Search: statistical analysis

- Classes with Nb jets ≥ 4 are not considered
(MC prediction not reliable enough)
- Identify regions of largest deviations data/SM
→ Investigate 1D ΣP_T and M_{all} distributions



- Statistical analysis to quantify the significance of deviations (\hat{P})
 - Most significant deviation at HERA II: μ -j- ν in e+p
 - Was also the case in HERA I data ($-\log_{10} \hat{P} \sim 3$)

↘ Corresponds to the topology of isolated leptons events



Summary

- High energy running of HERA ended on March, 20 2007
 - In total: $\sim 1 \text{ fb}^{-1}$ collected by H1 and ZEUS together
 - ↘ Combined analyses
- Model independent searches are performed
 - Isolated lepton topologies
 - Multi-lepton topologies
 - General high- P_T search
- Agreement with the SM in most of all possible final states
 - No significant excess
- A 3σ excess remains in H1 e+p data for isolated leptons
- No excess in ZEUS data for the same channel

↘ H1 and ZEUS combinations are underway, towards final HERA results