Multi leptons and isolated leptons and missing p_T at HERA

Monica Turcato
Hamburg University

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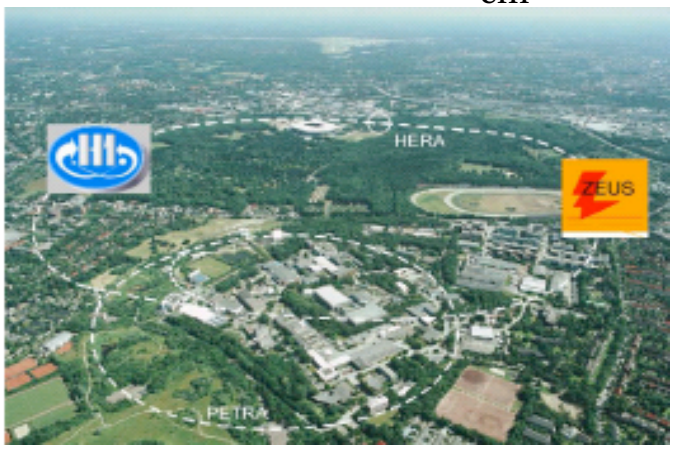
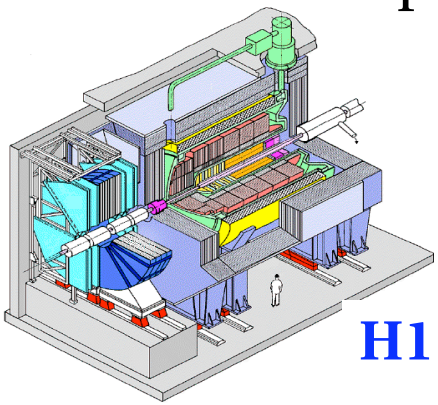
HERA physics

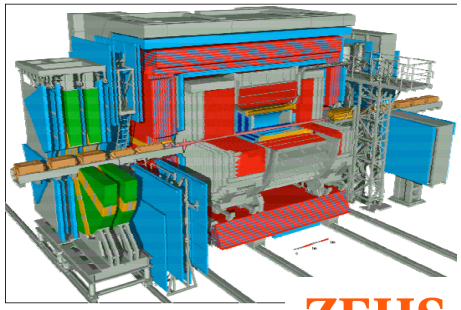
HERA: $e^{\pm}p$ collider, $E_{cm} \sim 318$ GeV



ZEUS and H1: multipurpose experiments located in two of the interaction points.



H1

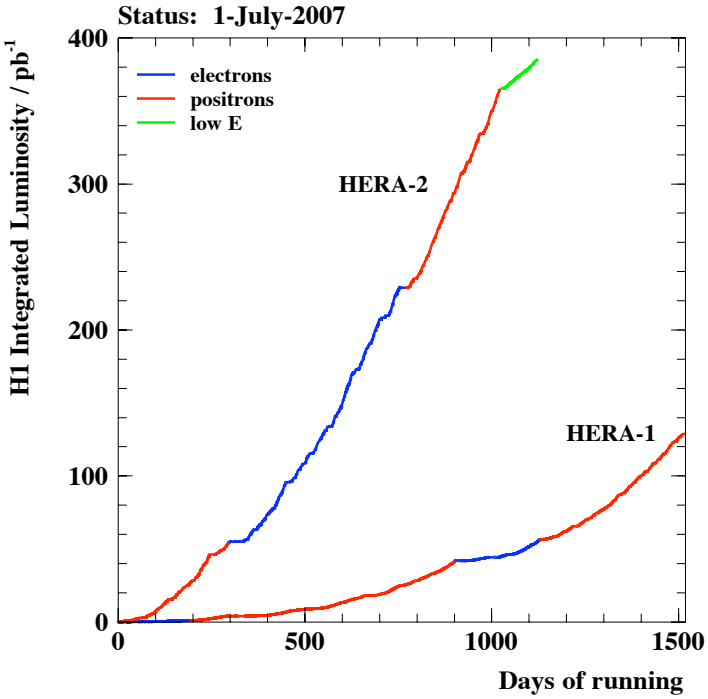


ZEUS

Data taking ended in June 07.

Collected luminosity :

~0.5 fb^{-1} per experiment



Rare ($\sigma \sim 1$ fb) phenomena may become visible.

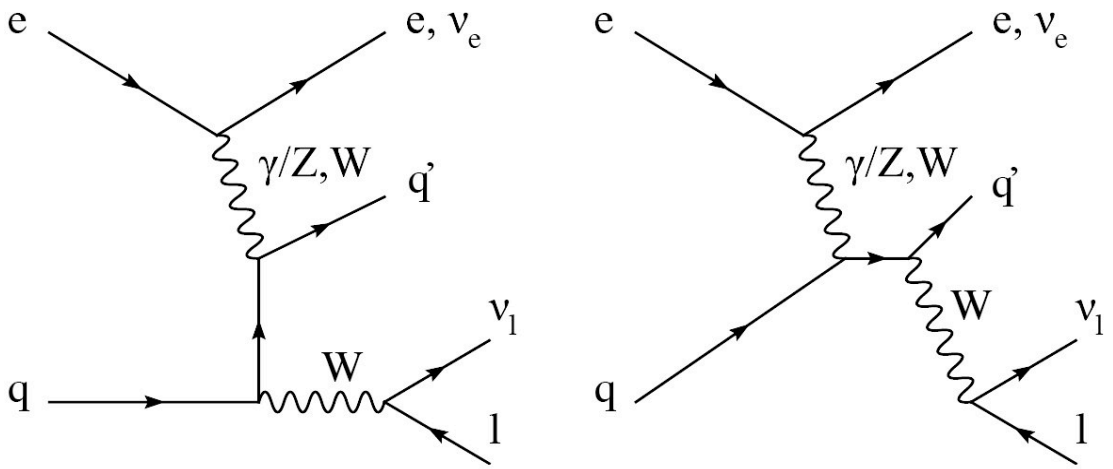
Introduction

Look for beyond the standard model physics:

- Look for events in which one or more isolated leptons are found in the final state. Isolated leptons provide a clean signal.
- SM expectation for high-p_T isolated leptons with missing p_T and for high-p_T dileptons is low. An observation of even a small number of events can be a signal of new physics.
- The ZEUS and H1 experiments can combine their data and have a better sensitivity to new phenomena (data sample available is ~1 fb^{-1}).

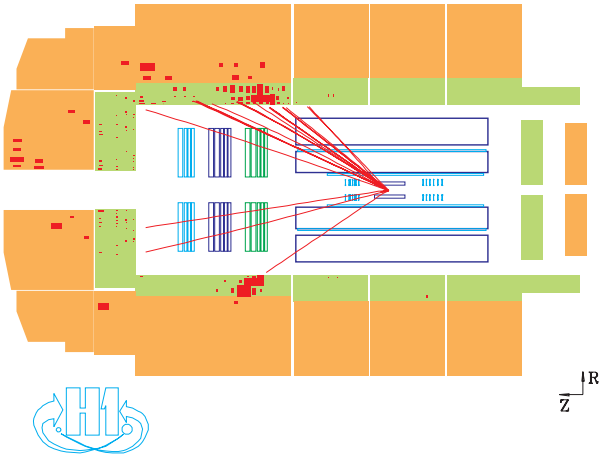
Isolated leptons with missing p_T

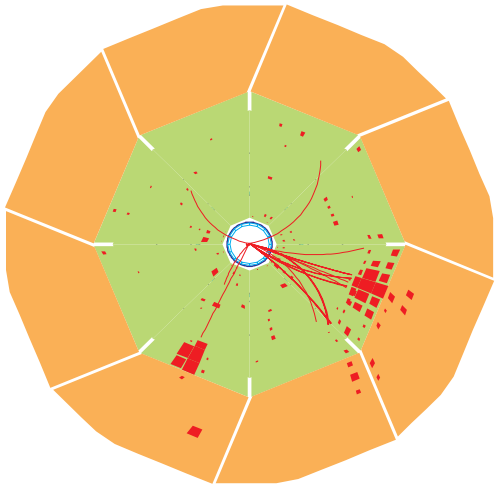
- Main SM source of isolated leptons in events with large missing p_T: W production ($\sigma \sim 1.3$ pb). In SM processes the p_T of the hadronic system, p_T^X, is usually small.



- Cross sections predictions at NLO with an uncertainty of ~15%.
- Background come from neutral current events, with fake missing p_T, charged current, with a fake lepton, and dilepton events.

Event selection





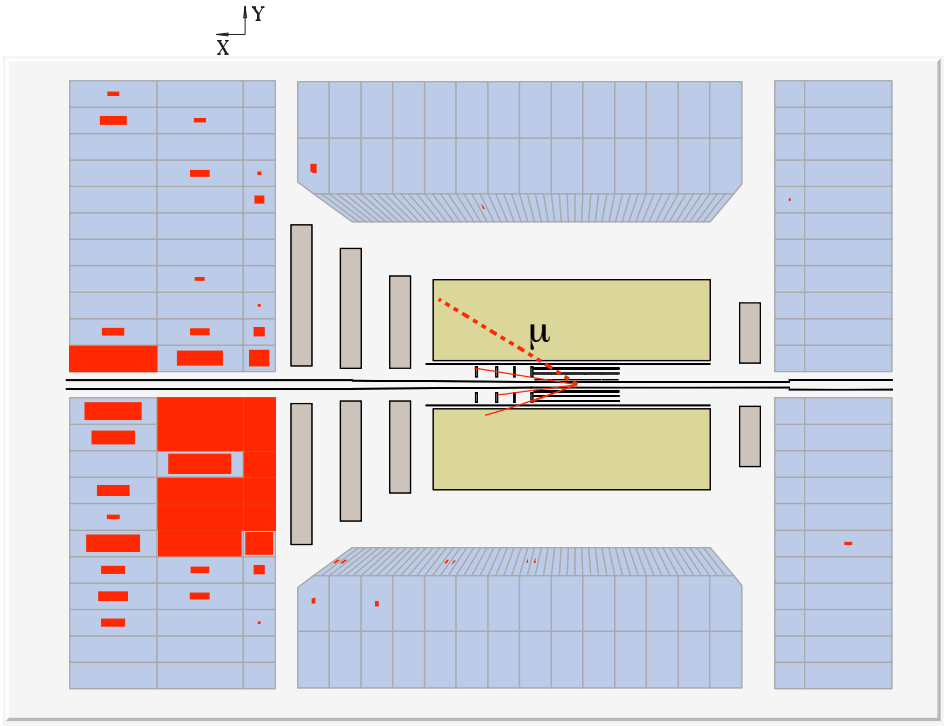
Data selection require a high p_T lepton and missing p_T in the event.

Originally, the analyses done by the two experiments covered slightly different angular regions. Then, a common phase space was agreed.

H1: $5^o < \vartheta_l < 140^o$, ZEUS: $15^o < \vartheta_l < 120^o$.

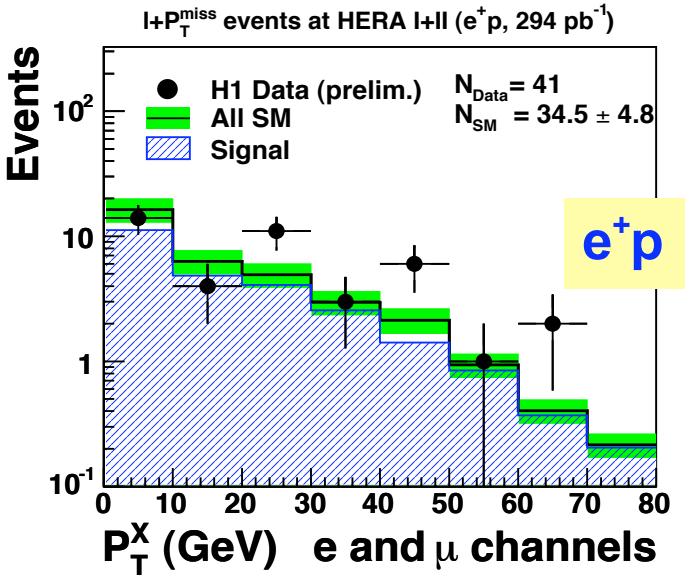
Common: $15^o < \vartheta_l < 120^o$.

$p_T^l > 10$ GeV, $p_T^{miss} > 12$ GeV

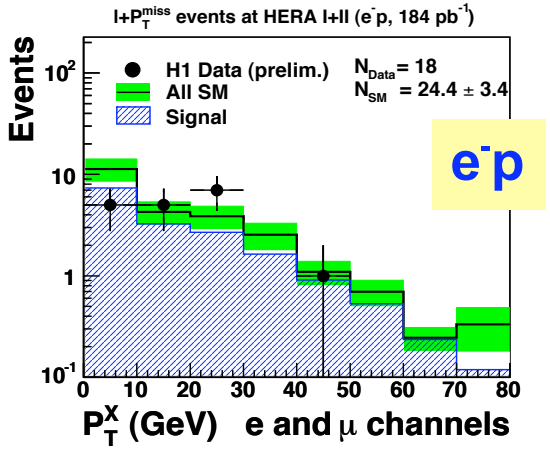


Isolated leptons with missing p_T at H1

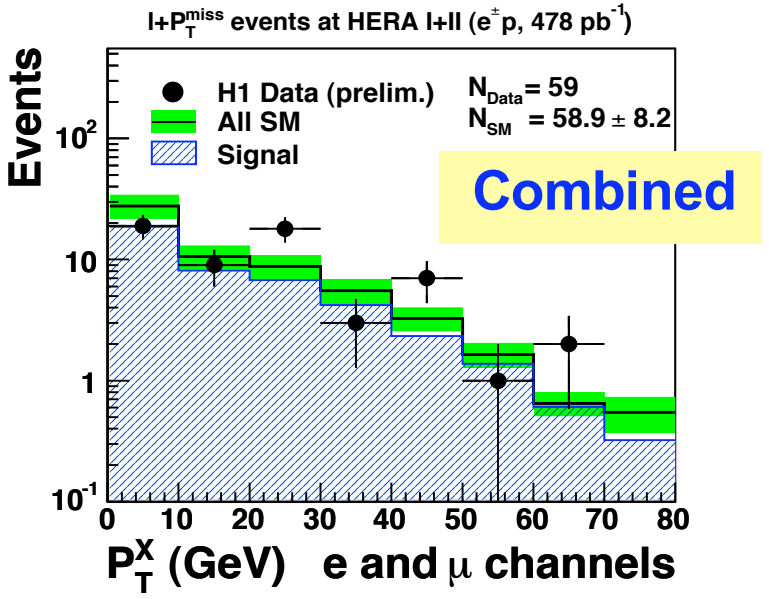
Original H1 analysis: $5^o < \vartheta_l < 140^o$. Excess found in the e^+p data sample.



H1 Preliminary l+P_T^{miss} events at HERA I+II		Electron obs./exp. (Signal contribution)	Muon obs./exp. (Signal contribution)	Combined obs./exp. (Signal contribution)
e^+p	Full Sample	26 / 27.3 ± 3.8 (71%)	15 / 7.2 ± 1.1 (85%)	41 / 34.5 ± 4.8 (74%)
294 pb^{-1}	$P_T^X > 25$ GeV	11 / 4.7 ± 0.9 (75%)	10 / 4.2 ± 0.7 (85%)	21 / 8.9 ± 1.5 (80%)
e^-p	Full Sample	16 / 19.4 ± 2.7 (65%)	2 / 5.1 ± 0.7 (78%)	18 / 24.4 ± 3.4 (68%)
184 pb^{-1}	$P_T^X > 25$ GeV	3 / 3.8 ± 0.6 (61%)	0 / 3.1 ± 0.5 (74%)	3 / 6.9 ± 1.0 (67%)
$e^\pm p$	Full Sample	42 / 46.7 ± 6.5 (69%)	17 / 12.2 ± 1.8 (82%)	59 / 58.9 ± 8.2 (72%)
478 pb^{-1}	$P_T^X > 25$ GeV	14 / 8.5 ± 1.5 (68%)	10 / 7.3 ± 1.2 (79%)	24 / 15.8 ± 2.5 (73%)

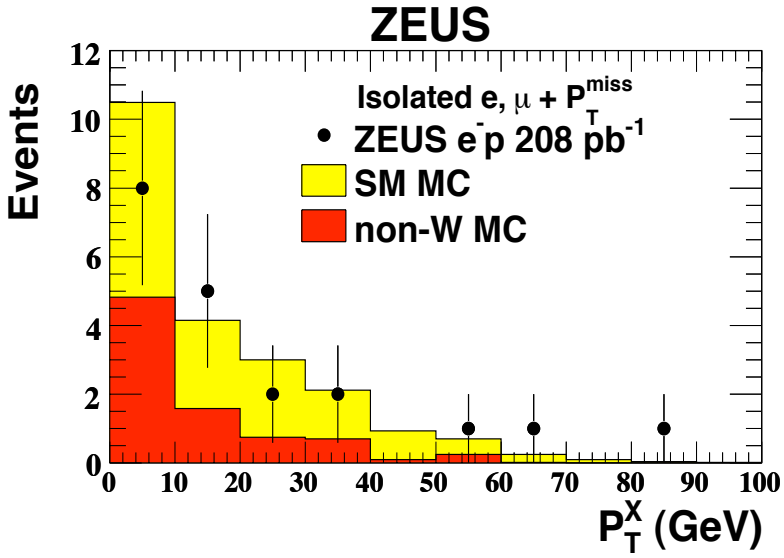


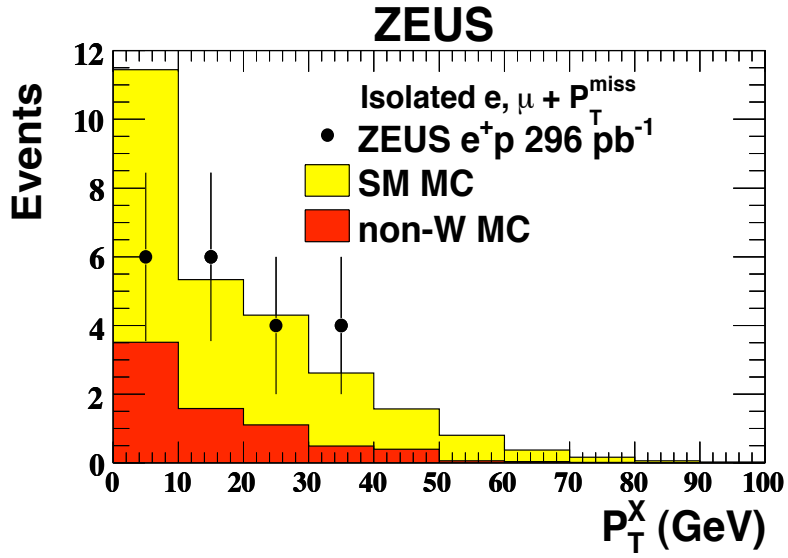
3σ significance in the e^+p data sample. Agreement with SM in e^-p



Isolated leptons with missing p_T at ZEUS

A similar excess was not observed by ZEUS, in $15^o < \vartheta_l < 120^o$.



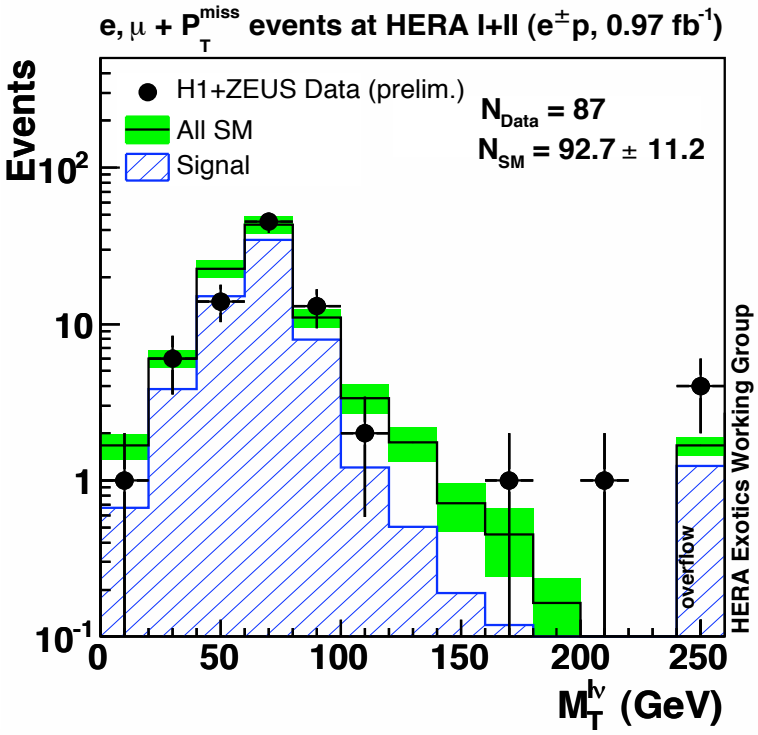


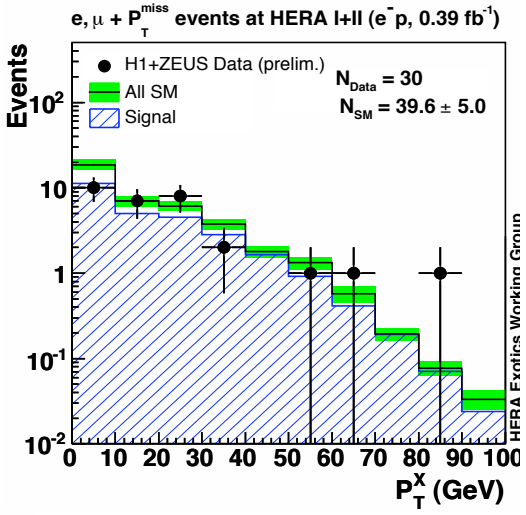
Isolated e Candidates	$P_T^X < 12$ GeV	$12 < P_T^X < 25$ GeV	$P_T^X > 25$ GeV
e^-p 208 pb^{-1}	$9/11.3 \pm 1.5$ (54%)	$5/3.4 \pm 0.5$ (62%)	$3/3.2 \pm 0.5$ (69%)
e^+p 296 pb^{-1}	$7/12.6 \pm 1.7$ (68%)	$5/3.9 \pm 0.6$ (72%)	$3/4.0 \pm 0.6$ (77%)
$e^\pm p$ 504 pb^{-1}	$16/23.9 \pm 3.1$ (61%)	$10/7.4 \pm 1.0$ (67%)	$6/7.3 \pm 1.0$ (73%)

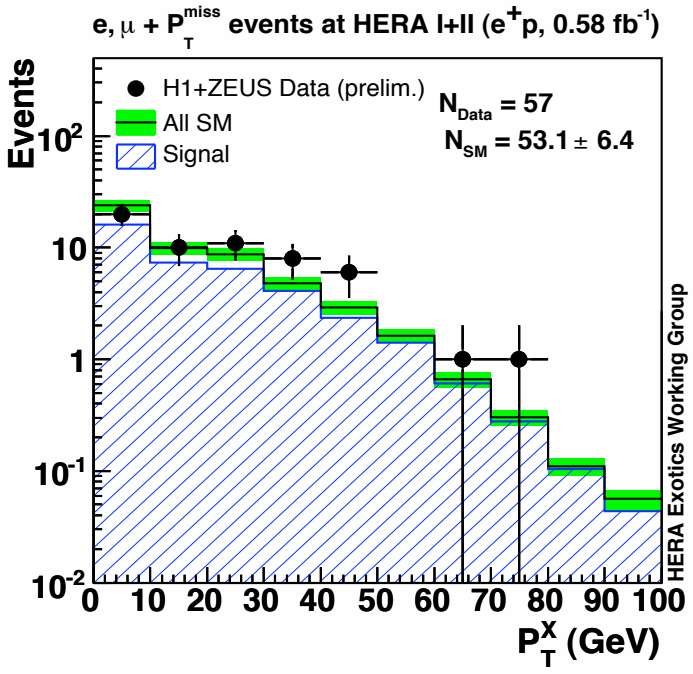
Isolated μ Candidates	$12 < P_T^X < 25$ GeV	$P_T^X > 25$ GeV
e^-p 208 pb^{-1}	$1/1.6 \pm 0.3$ (77%)	$2/2.3 \pm 0.4$ (85%)
e^+p 296 pb^{-1}	$2/2.2 \pm 0.3$ (82%)	$3/3.4 \pm 0.5$ (81%)
$e^\pm p$ 504 pb^{-1}	$3/3.8 \pm 0.6$ (80%)	$5/5.7 \pm 0.8$ (83%)

Agreement with SM for all the lepton types in all the periods.

ZEUS+H1 data combination





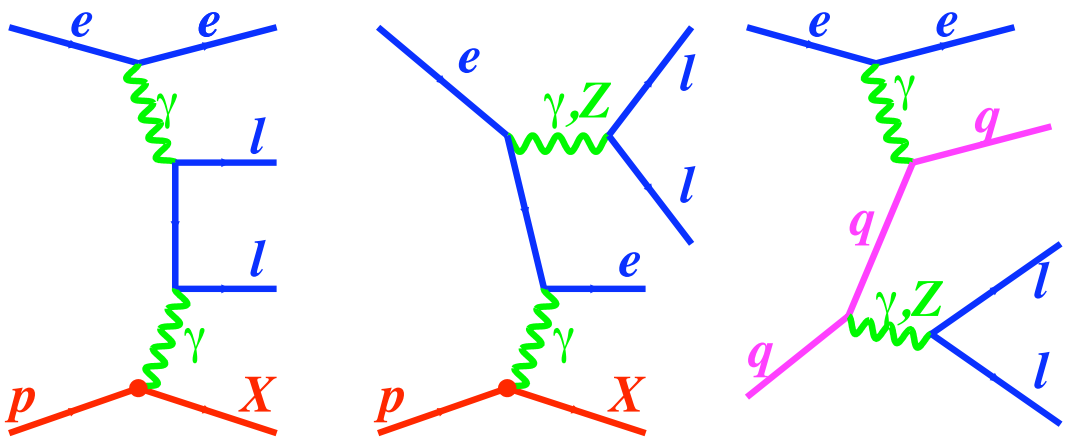


$p_T^X > 25$GeV			
	Electrons	Muons	Combined
e^+p	$12/7.4 \pm 1.0$	$11/7.2 \pm 1.0$	$23/14.6 \pm 1.9$
e^-p	$4/6.0 \pm 0.8$	$2/4.8 \pm 0.7$	$6/10.6 \pm 1.4$
$e^\pm p$	$16/13.3 \pm 1.7$	$13/12.0 \pm 1.6$	$29/25.3 \pm 3.2$

Data in reasonable agreement with SM.
Excess reduced to 1.8 σ in the e^+p data sample.

Multi-leptons

In ep interactions, dominated by the $\gamma\gamma$ process.



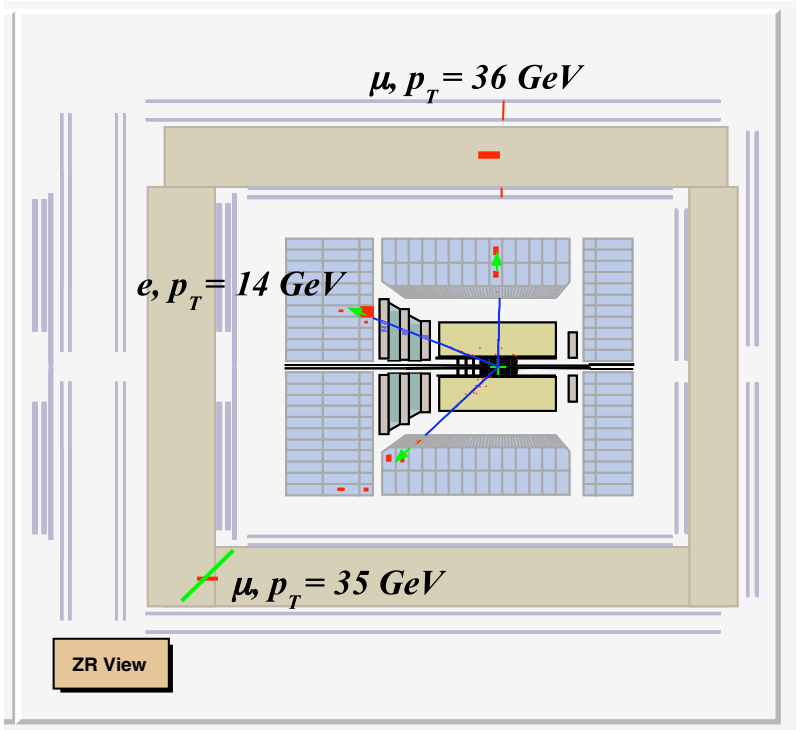
This is a QED process: the predictions from SM are very precise.

The SM cross section at high masses, high p_T is low: we can look for new phenomena.

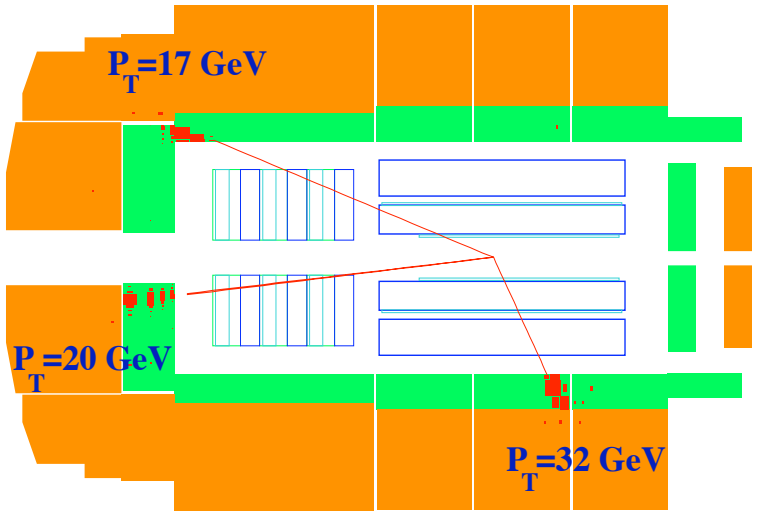
Background: NC DIS, QED Compton for multi-electrons, cosmics for muons.

Data selection

- ZEUS: ee, eee, μμ(e)
  - p_T>10,5 GeV (electrons), 5,5 GeV (muons), 20°< ϑ <150° (160°)
- H1: all topologies with electrons and muons: ee, eee, μμ, eμμ, eμ.
  - Look for events with two high-p_T leptons:
  - p_T^{l1}>10 and p_T^{l2}> 5 GeV and 20°< ϑ_l < 150°
  - Additional lepton: E_e>5 GeV or p_T^{μ}>2GeV (5°< ϑ_l < 175°)
- ZEUS+H1: common phase space has been defined.

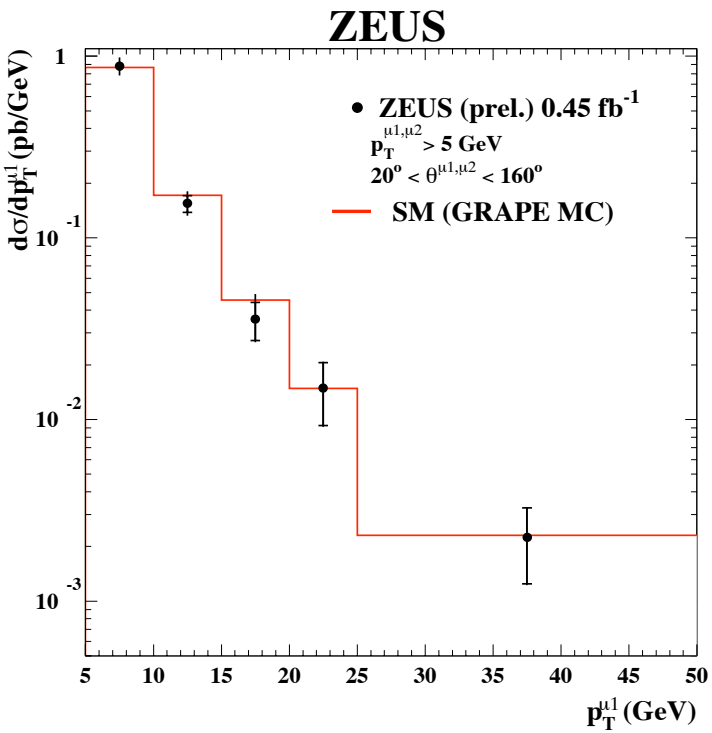


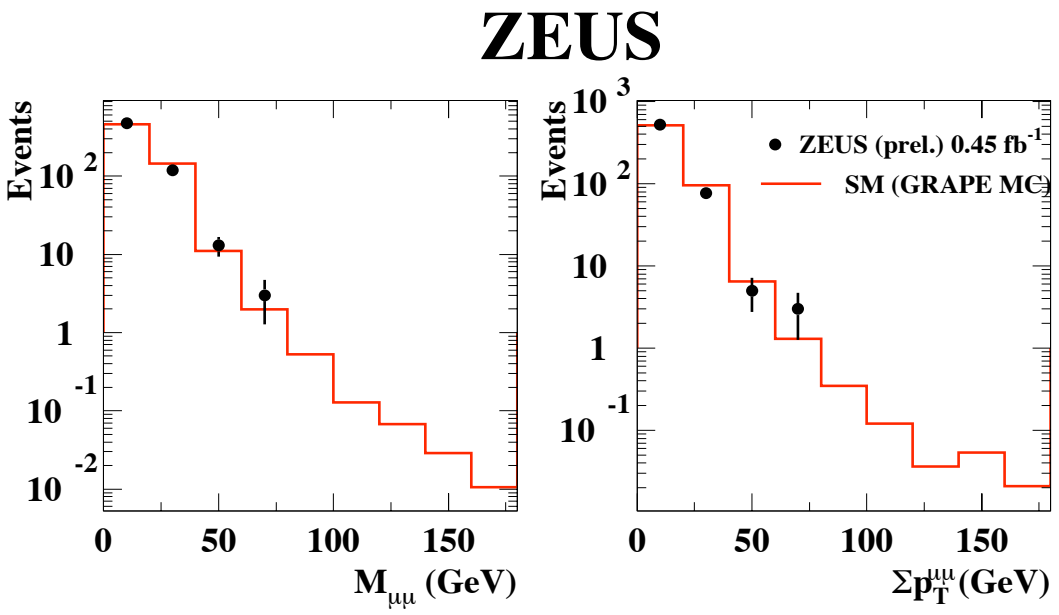
3e



ZEUS dimuon events

Good agreement with the SM predictions.

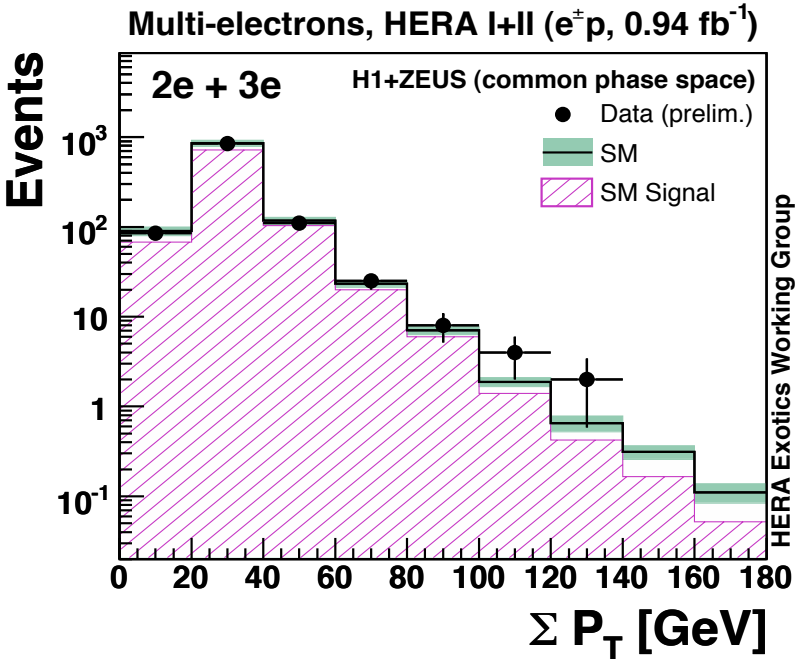


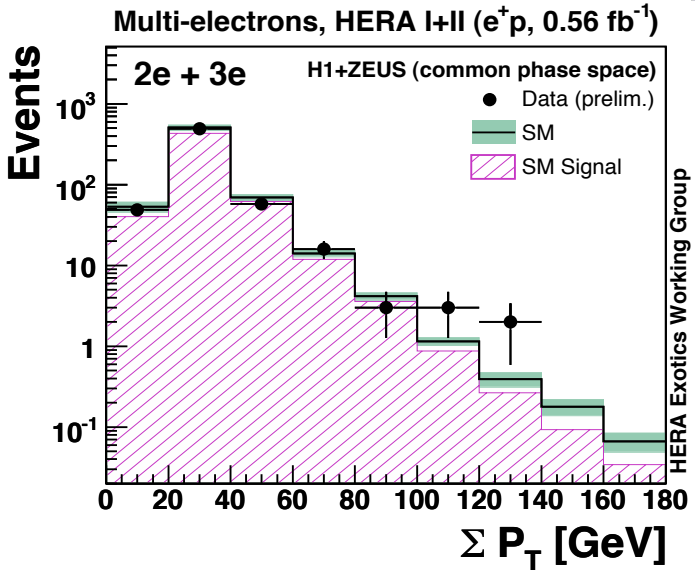


Cross sections were also measured in this inclusive region. Good agreement with the standard model predictions has been observed.

ZEUS+H1 multi-electron events

$\Sigma(p_T)$ measured in the common phase space.





5 out of 6 high-sum(p_T) events were observed in e^+p collisions.

H1+ZEUS Multi-electron analysis HERA I+II (0.94 fb^{-1}, preliminary)

ΣP_T >100 GeV				
Data sample	Data	SM	Pair Production	NC-DIS + Compton
e^+p (0.56 fb^{-1})	5	1.82 ± 0.21	1.28 ± 0.16	0.54 ± 0.10
e^-p (0.38 fb^{-1})	1	1.19 ± 0.14	0.79 ± 0.09	0.40 ± 0.08
$e^{\pm}p$ (0.94 fb^{-1})	6	3.00 ± 0.34	2.07 ± 0.24	0.94 ± 0.16

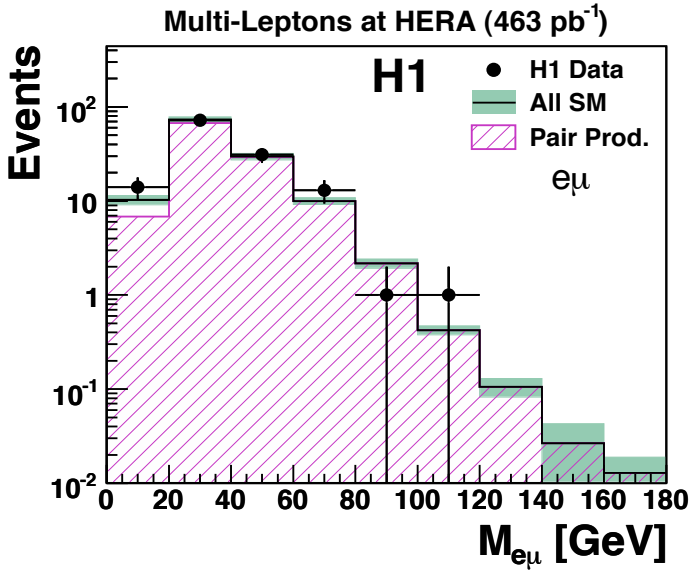
4 events come from H1, 2 from ZEUS.

Other topologies from H1

Additional topologies: eμ, eμμ, eeμ, eeee.

Multi-Leptons at HERA (463 pb^{-1})

Selection	Data	SM	Pair Production (GRAPE)	NC DIS + Compton
ee	368	390 ± 46	332 ± 26	58 ± 30
$\mu\mu$	201	211 ± 32	211 ± 32	< 0.005
$e\mu$	132	128 ± 9	118 ± 8	10.0 ± 2.5
eee	73	70 ± 7	69.8 ± 7.0	0.2 ± 0.1
$e\mu\mu$	97	102 ± 14	102 ± 14	< 0.005
$ee\mu$	4	1.43 ± 0.26	1.18 ± 0.20	0.25 ± 0.14
$eeee$	1	0.33 ± 0.07	0.33 ± 0.07	< 0.005
$(\gamma\gamma)_e$	146	138 ± 12	135 ± 11	3.0 ± 1.0
$(\gamma\gamma)_\mu$	163	162 ± 24	162 ± 24	< 0.005



5 events at high $\Sigma(p_T)$ observed, combining all the topologies.

Multi-Leptons at HERA (463 pb^{-1})

$\sum P_T > 100$ GeV

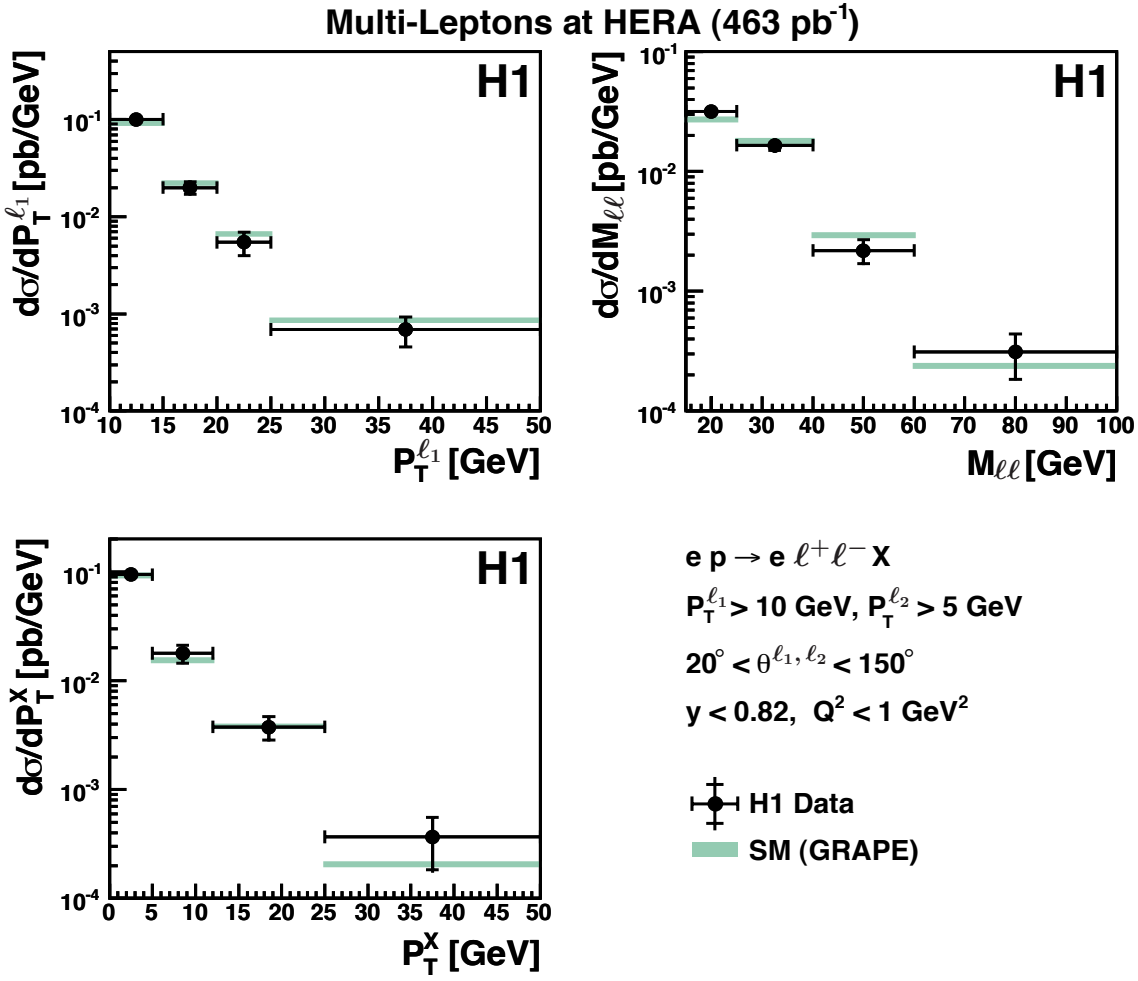
Data sample	Data	SM	Pair Production (GRAPE)	NC DIS + Compton
e^+p (285 pb^{-1})	5	0.96 ± 0.12	0.78 ± 0.09	0.18 ± 0.05
e^-p (178 pb^{-1})	0	0.64 ± 0.09	0.51 ± 0.07	0.13 ± 0.04
All (463 pb^{-1})	5	1.60 ± 0.20	1.29 ± 0.15	0.31 ± 0.09

Photon-photon cross sections

$\gamma\gamma$ cross sections measured for photoproduction events.

Good agreement with SM predictions.

Precision will be improved by combining ZEUS and H1 data.



Conclusions

- Topologies with one isolated electron and missing p_T or with multi-leptons in the final state have been studied with the ZEUS and H1 detectors at HERA.
- In general, good agreement with the SM has been found.
- A few events at high-p_T of the hadronic system, and at high $\Sigma(p_T)$ of the lepton pair, have been observed in e^+p collisions in a region where the SM expectation is low.
- The combination of the data from the two experiments is improving the precision of the measurements (~1 fb^{-1} of data available).

References

- ZEUS Coll., *Search for events with an isolated lepton and missing transverse momentum and a measurement of W production at HERA,* ZEUS-pub-08-005, DESY-08-089.
- H1 Coll., *Events with an isolated lepton (electron or muon) and missing transverse momentum at HERA,* H1prelim-07-063.
- ZEUS and H1 Coll., *Isolated leptons and missing p_T: H1+ZEUS combination,* ZEUS-prel-07-029, H1prelim-07-162.
- H1 Coll., *Multi-lepton production at high transverse momenta in ep collisions at HERA,* DESY-08-065.
- ZEUS Coll., *Multi-muon production at HERA,* ZEUS-prel-08-006.
- ZEUS Coll., *Multi-electron production at HERA,* ZEUS-prel-07-022.
- ZEUS and H1 Coll., *Multi-electron events at HERA (H1+ZEUS),* ZEUS-prel-07-024, H1prelim-07-166.