Multi-lepton production in ep collisions at ZEUS

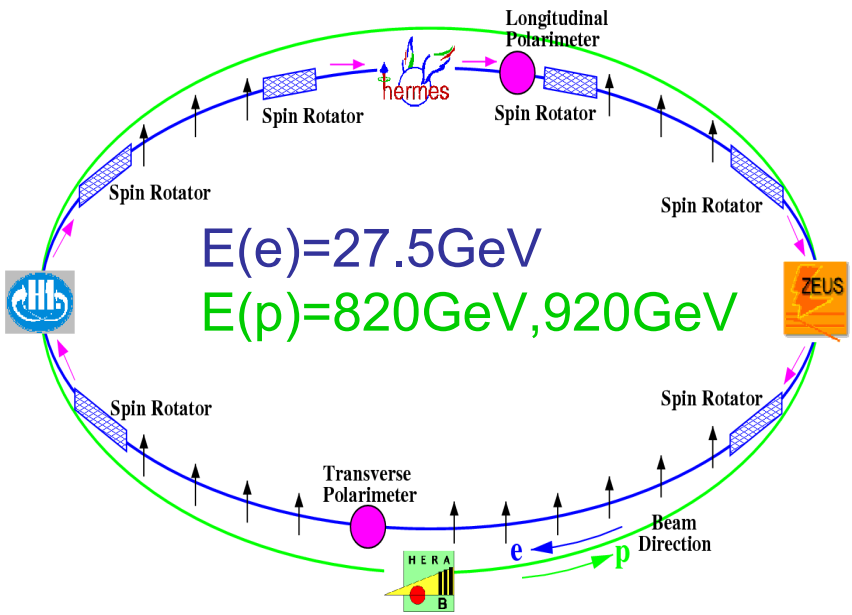
Osamu Ota
on behalf of ZEUS collaboration
Tokyo Metropolitan University
DIS2007, Munich, 19.Apr.2007

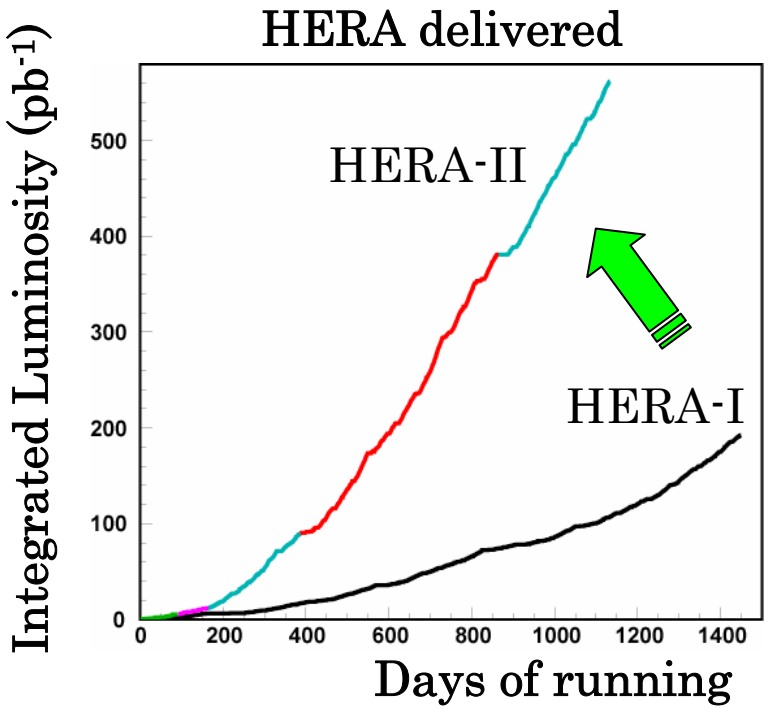
Contents

- Introduction / HERA, Multi-leptons
- Motivation
- Multi-electrons analysis
- Di-taus analysis
- Conclusions

Introduction / HERA

- DESY, Hamburg in Germany.
- only ep collider in the world.

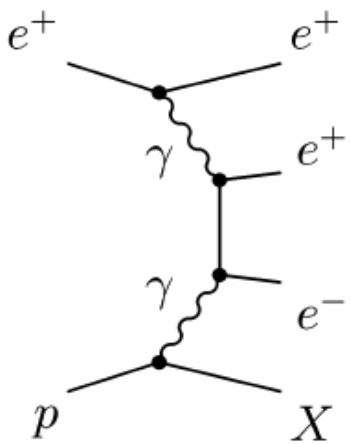




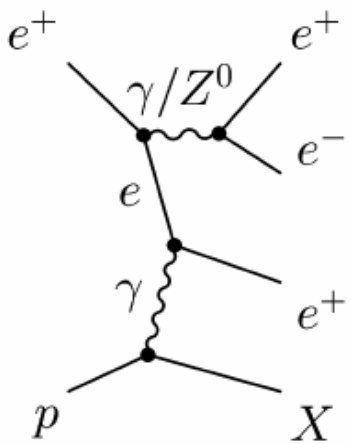
- HERA-II (2003~)
  - Luminosity upgrade
  - Colliding experiment@ZEUS,H1

Introduction / Multi-leptons@HERA

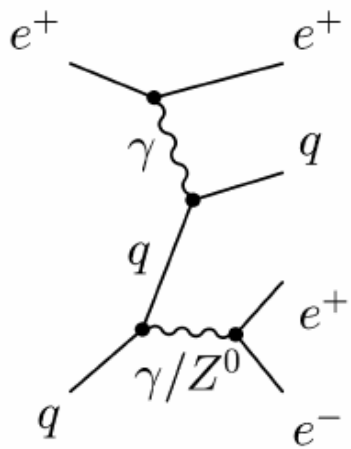
- Multi-lepton production in e-P collisions can be explored up to M_{ee} ~ O(100GeV)
- The dominant is QED process as predicted by the Standard Model (SM).



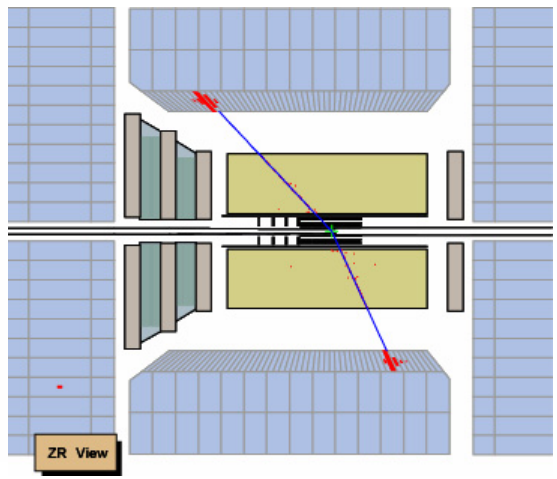
Bethe-Heitler
→Dominant process



Cabibbo-Parisi



Drell-Yan



- Any excess over the SM prediction, especially at high mass region, can be sensitive to new phenomena.

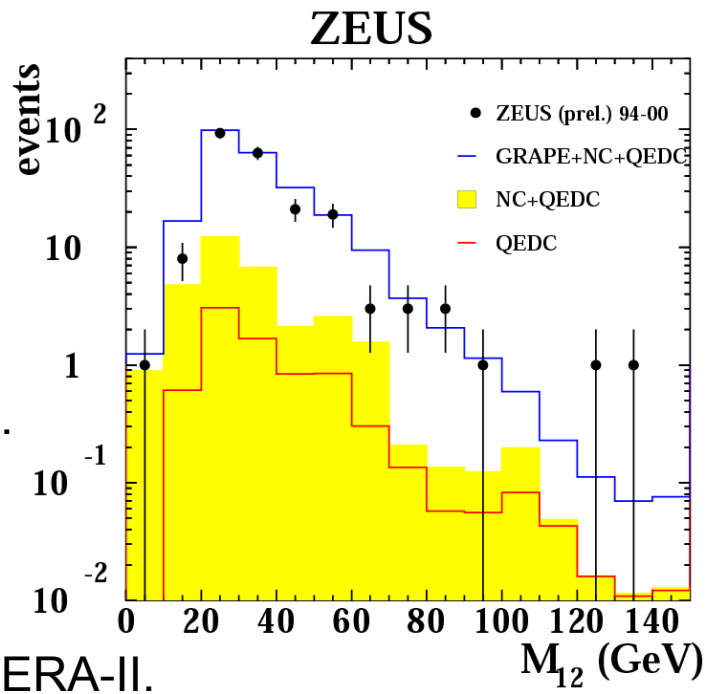
Motivation

- Analysis with HERA-I data.
  - Reported at DIS03 workshop.

Type	Data	SM	GRAPE	NC DIS	QEDC
all ee	191	213.9 ± 3.9	182.2 ± 1.2	23.9 ± 3.7	7.8 ± 0.5
$E_{T,1} > 30\,\text{GeV}$	6	5.7 ± 0.3	4.4 ± 0.2	0.9 ± 0.2	0.4 ± 0.1
$M_{12} > 100\,\text{GeV}$	2	0.77 ± 0.08	0.47 ± 0.05	0.12 ± 0.06	0.18 ± 0.03

Table 2: *Number of selected events with two electrons in the data and simulations of Standard Model processes.*

  - Consistent with the SM and no excess was found.
  - H1 observed excess in Data at high M_{12} .



- Since then, we took a large amount of luminosity in HERA-II.
  - Of those data, preliminary for ICHEP06 with ~ 300 pb-1.
  - Analysis with similar phase space of H1 with a much increased luminosity ~150 pb-1, total 446 pb-1.

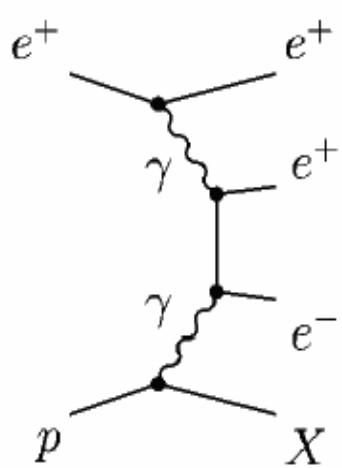
Multi-electrons

- Data taking : 1996-2006
- Luminosity : 446pb-1

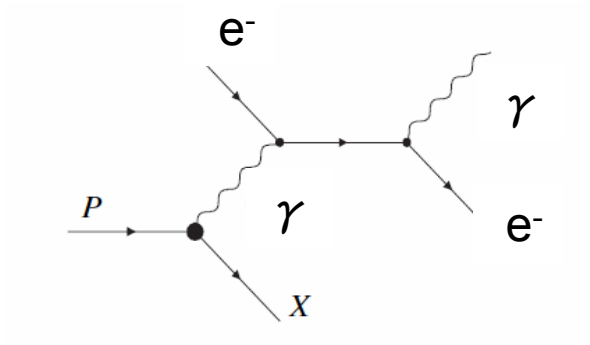
Event topology

Signal

Bethe-Heitler

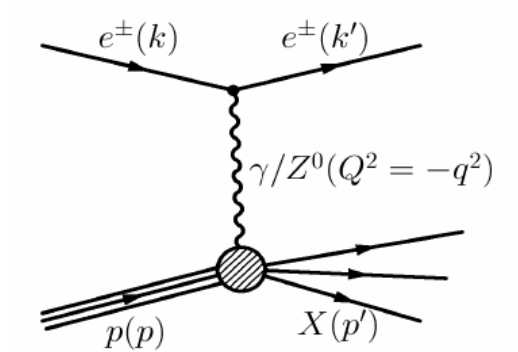


Back ground



Misidentified photon as an electron

QEDC



Misidentified charged particle in jets as an electron

NC

Electron selection

◆Require 2 EM-clusters in CAL.
◆Also require track match to clusters.
◆E_e >10GeV (H1:E_e >5GeV)

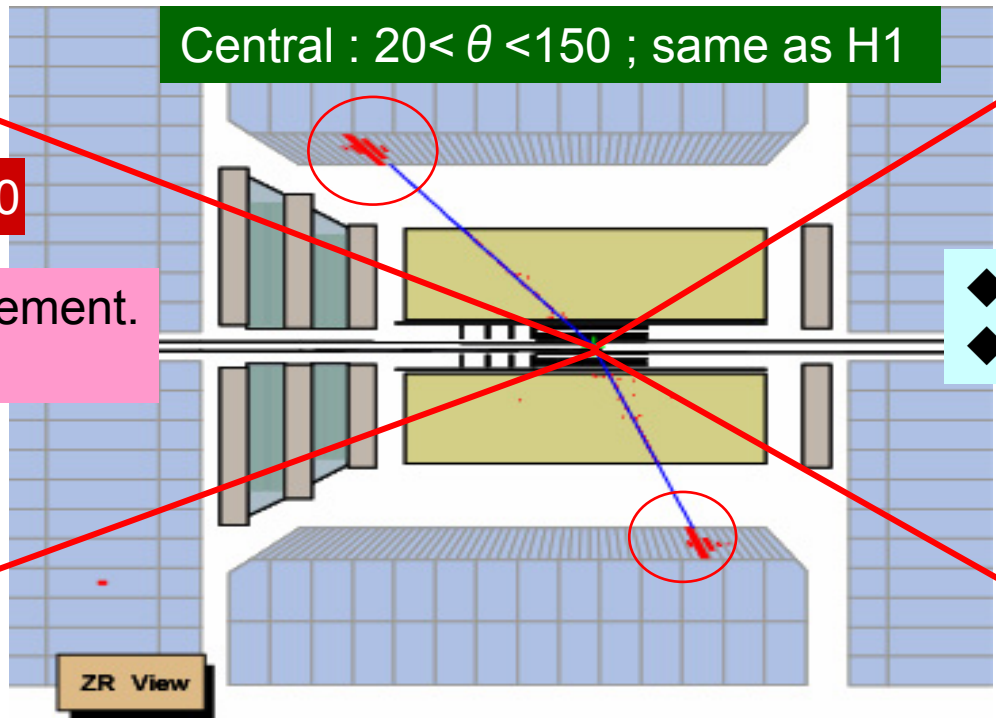
Central : 20< θ <150 ; same as H1

Forward : 5< θ <20

◆No track requirement.
◆E_e >10GeV

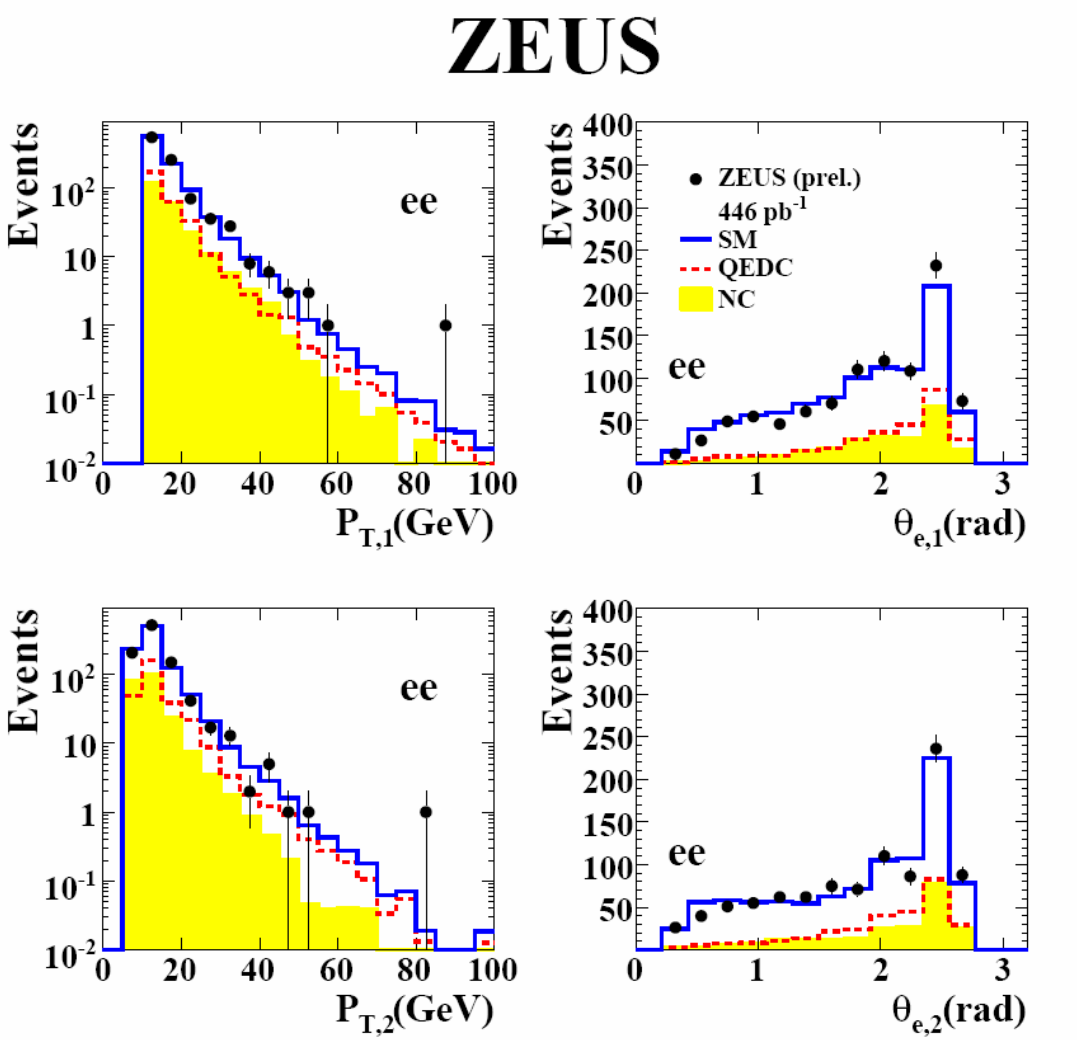
Rear : 150< θ <175

◆No track requirement.
◆E_e >5GeV



◆At least 2 electrons should be found in central region.
−Highest Pt electron > 10GeV : 1st electron.
−Second highest Pt electron > 5GeV : 2nd electron.

Distributions in ee topology

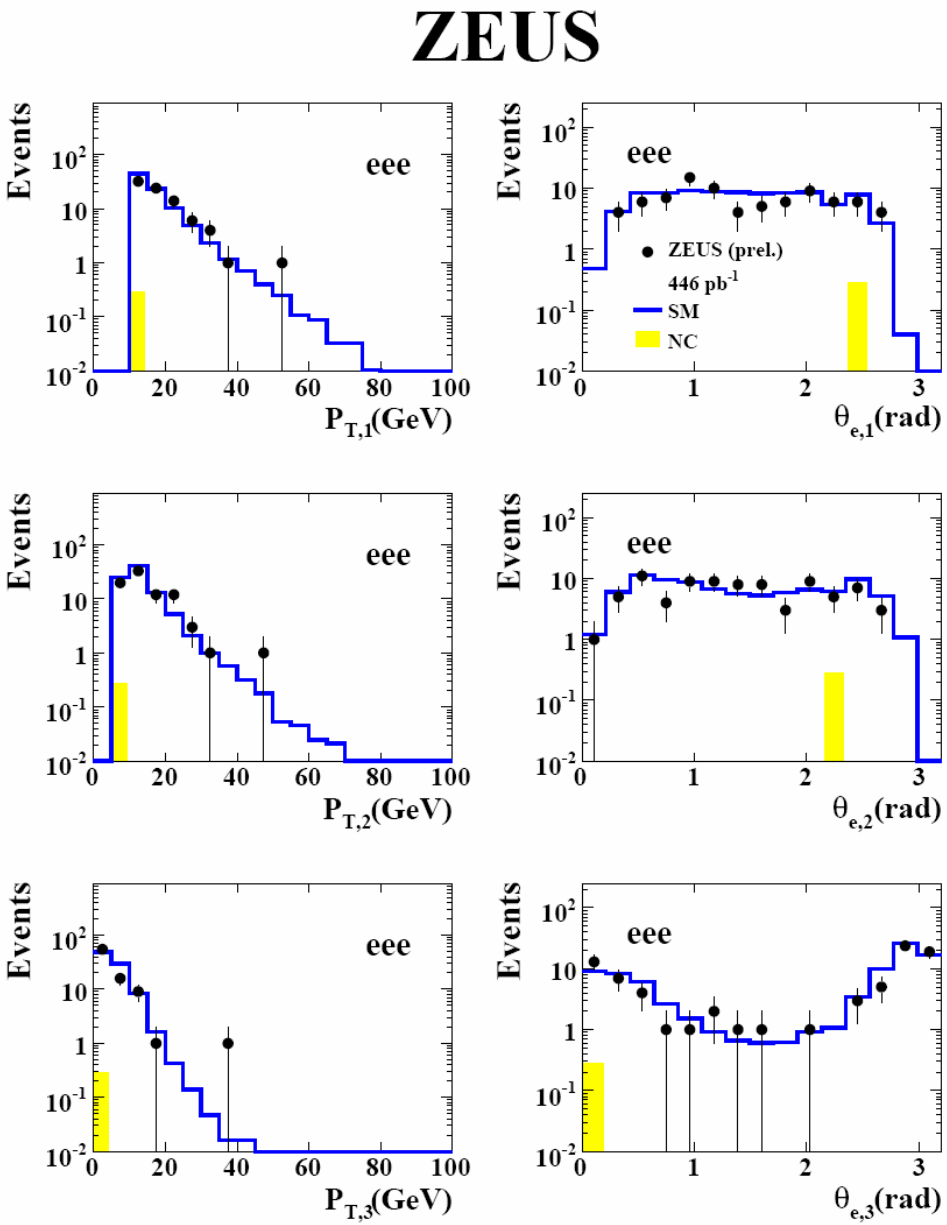


- Data
- SM = SIGNAL + QEDC +NC
- QEDC
- NC

$P_{T,1}$: Pt of 1st electron.
$P_{T,2}$: Pt of 2nd electron.

$\theta_{e,1}$: θ of 1st electron.
$\theta_{e,,2}$: θ of 2nd electron.

- Data is in good agreement with the SM



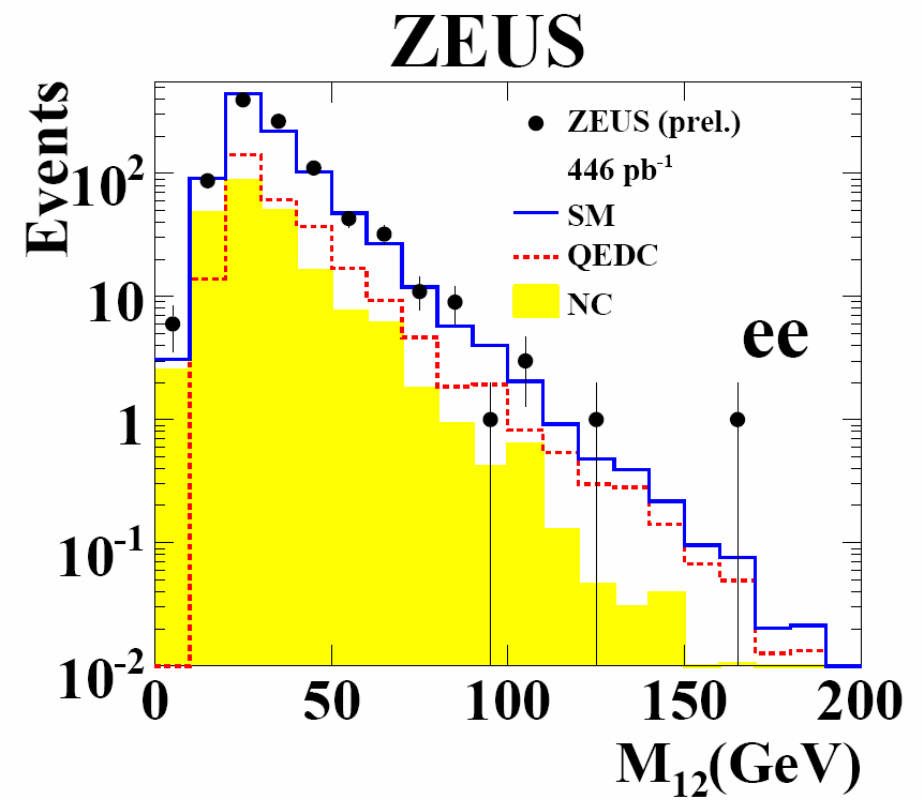
Distributions in eee topology

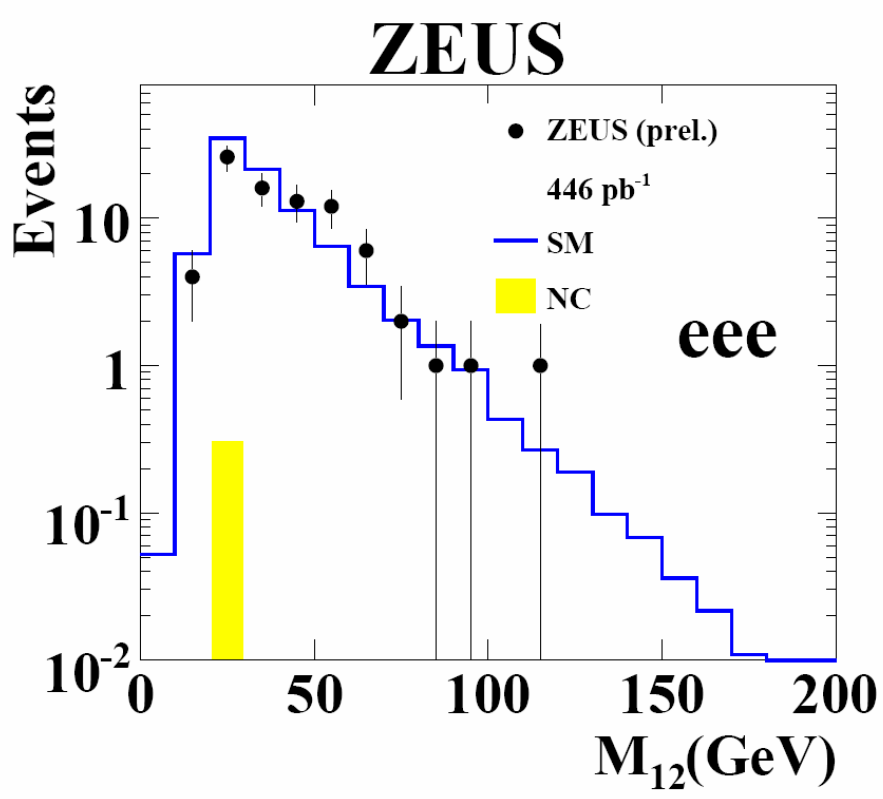
$P_{T,1}$: Pt of 1st electron.
$P_{T,2}$: Pt of 2nd electron.
$P_{T,3}$: Pt of 3rd electron.

$\theta_{e,1}$: θ of 1st electron.
$\theta_{e,2}$: θ of 2nd electron.
$\theta_{e,3}$: θ of 3rd electron.

- In eee topology, also good agreement with the SM

Mass spectrum





- M_{12} = Mass of two highest Pt electrons.
- The SM gives a good description of the measurements.

Results

M_{12}>80GeV

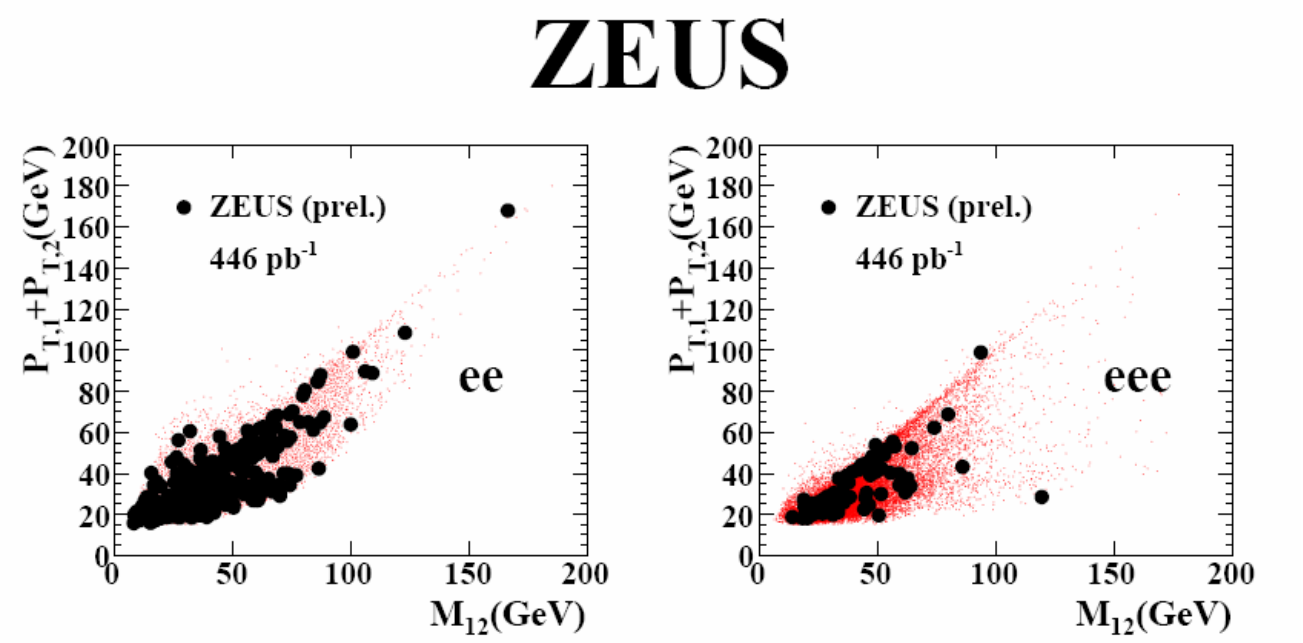
Topology	DATA	SM	GRAPE	QEDC	NC
ee	15	14.0 ± 1.1	5.7 ± 0.6	6.0 ± 0.6	2.2 ± 0.4
eee	3	$3.4^{+0.6}_{-0.3}$	3.4 ± 0.3	< 0.2	< 0.5

M_{12}>100GeV

Topology	DATA	SM	GRAPE	QEDC	NC
ee	5	4.3 ± 1.1	1.1 ± 0.2	2.3 ± 1.1	0.9 ± 0.2
eee	1	$1.1^{+0.5}_{-0.1}$	1.1 ± 0.1	< 0.02	< 0.5

- Good agreement between Data and Mc
- Upper limits at 68% given.
- Includes electron energy uncertainty and Luminosity uncertainty.

Mass vs. Pt

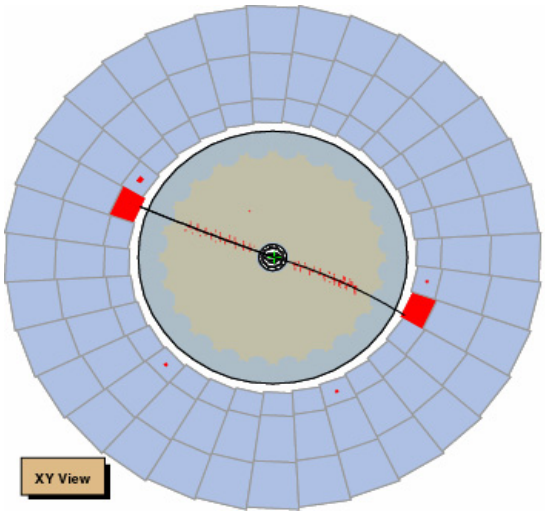


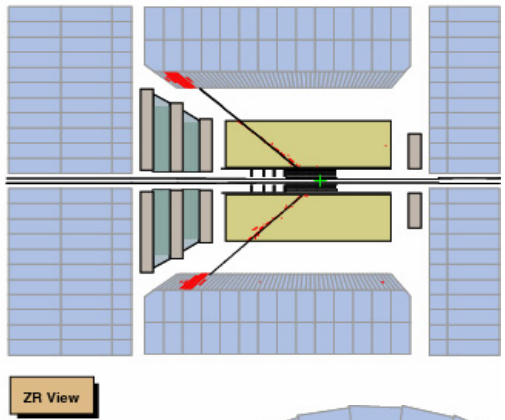
- Data
- Signal MC (GRAPE)

$P_{T,1} + P_{T,2}$
→Scalar sum of Pt of 1st and 2nd electron.

- In ee topology, high mass events are formed from two central high-Pt electrons.
- In eee topology, such events formed from one forward and one central electron.

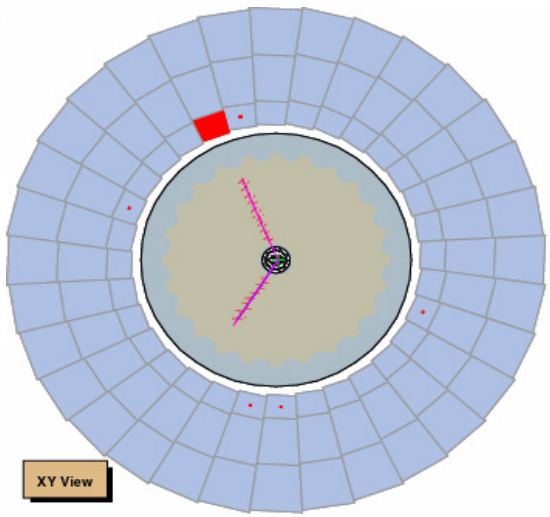
Highest mass event

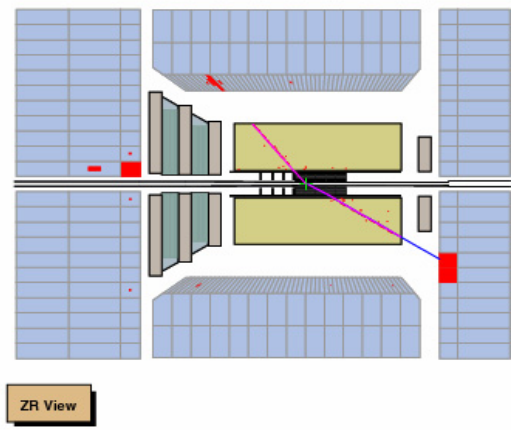




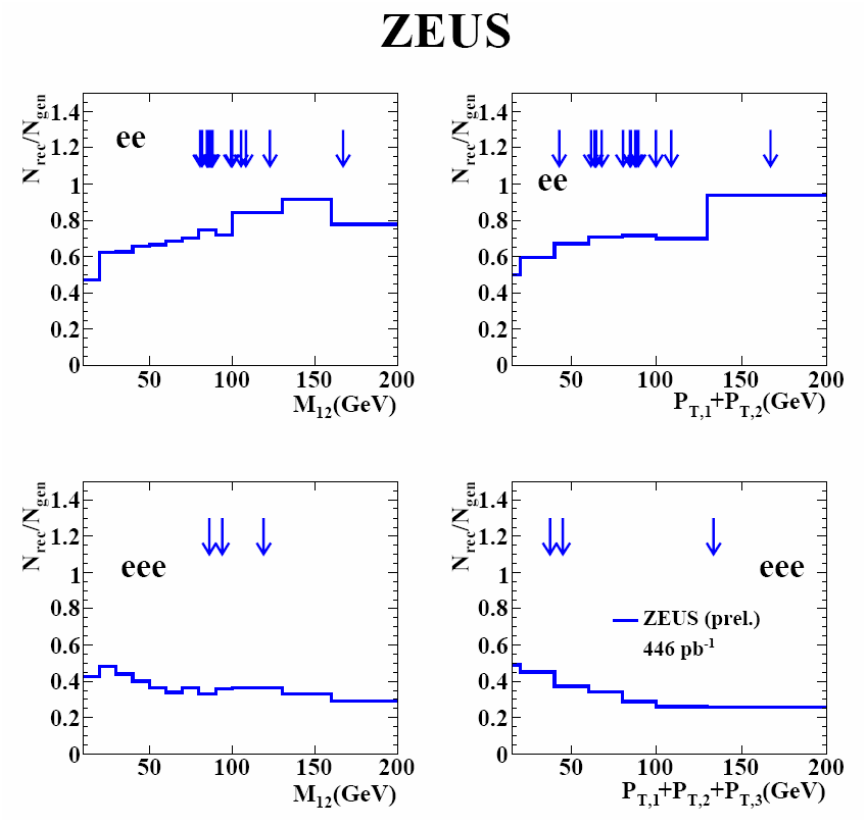
ee : M_{12} =166GeV

eee : M_{12} =119GeV





Acceptance



- Acc = N_{rec}/N_{gen}
  - N_{rec} → all selection cut
  - N_{gen} → kinematic cut
    - Ee_true
    - Pt_true
    - θ _true

- Arrow are shown events M_{12}>80GeV

ee : we maintain a high acceptance in high-mass region.
eee : acceptance remains reasonable over full mass region.

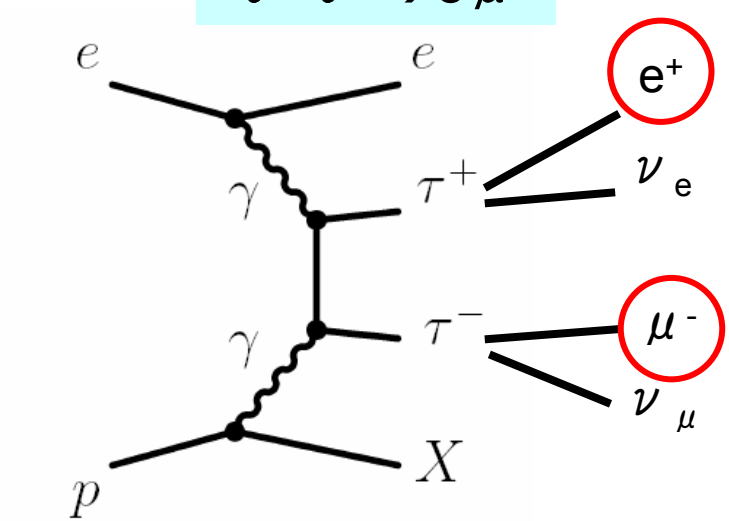
Di-taus

- Data taking : 2005
- Luminosity : 135 pb-1

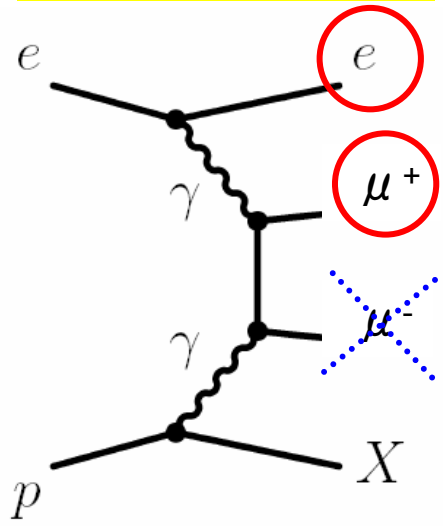
Event topology

Signal process

$\tau^+\tau^- \rightarrow e\,\mu$



SM Background



- Di-taus decaying to electron and muon.
  - Br = 6.19%

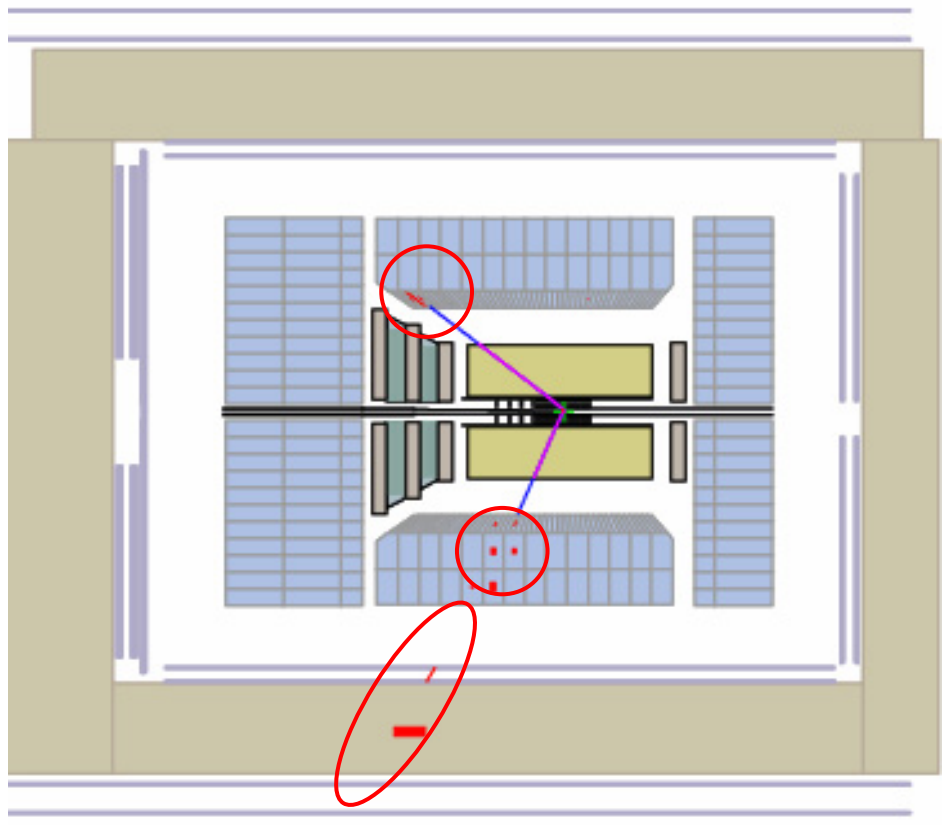
- Di-muons events.
  - One muon pass through the beam pipe

- Clever selection is necessary to remove Di-muons events.
- Very challenging analysis!! → First ZEUS results.

Event selection

- Electron identification :
  - Match track to EM cluster in the CAL.
  - E_e >4GeV, θ_e <150°

- Muon identification :
  - Track from tracking chamber match to the MIP cluster in CAL.
  - Track from MUON chamber match to the one from tracking chamber.
  - Pt>2GeV

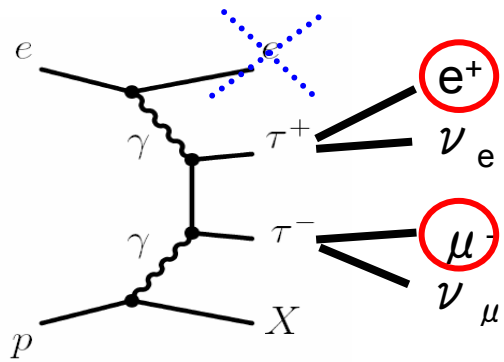


→*Needed further BG rejection*

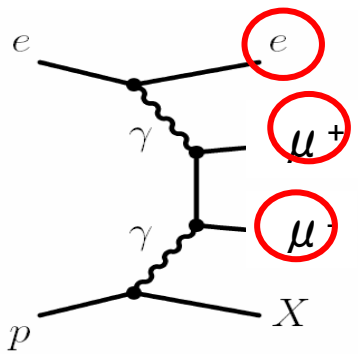
Di-muons (BG) rejection

- At HERA, E-P_z is conserved to be 55GeV ($2E_{beam}$) unless particles escape in –z direction.
  - Initial state : e(E_e 0,0,-P_e), P(E_p,0,0,P_p)

Signal
- sometimes electron escapes down beam pipe



Di-muons (BG)
- electron must be a scattered electron.

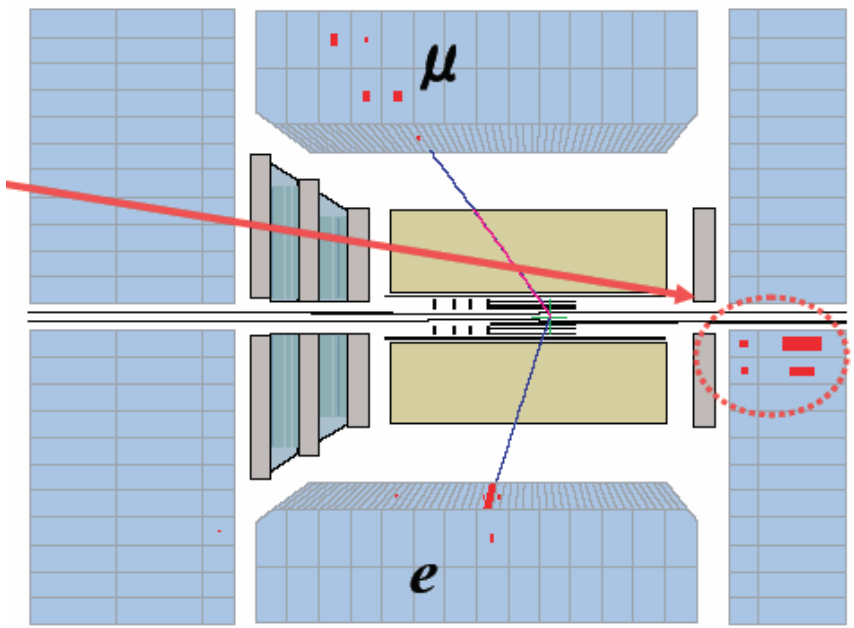


Required E-Pz < 45GeV

Di-muons (BG) rejection (cont'd)

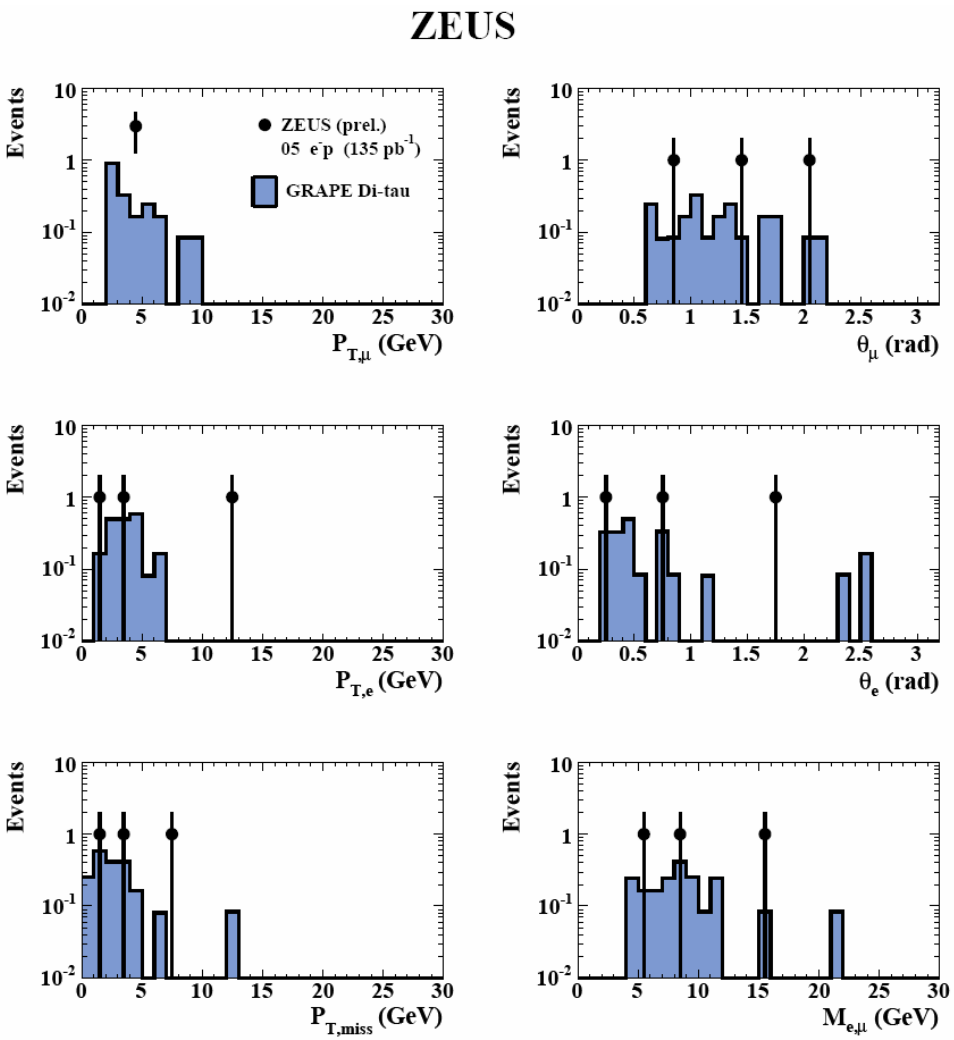
- Require no extra muon candidates found with looser selection criteria.

- e.g.
MIP cluster in the CAL without track matching regards as a muon candidate.
→reject as a BG.



MC expectation	
Signal	2.0 evt
Di-muons (BG)	0 evt

Results

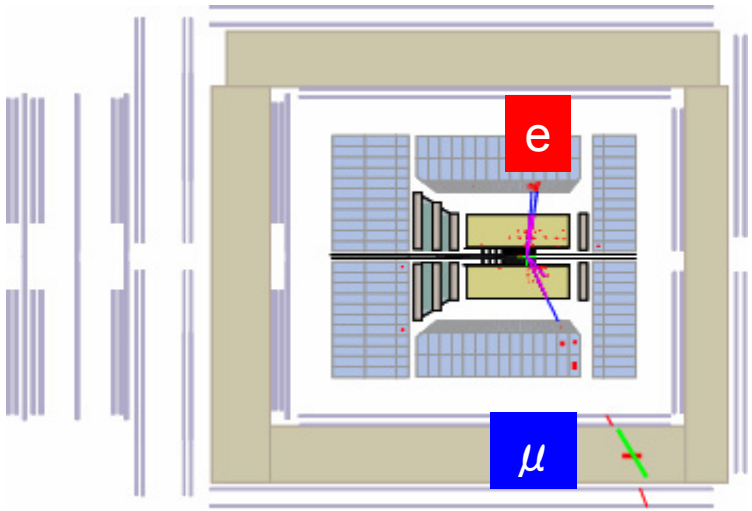


2005 : 135 pb-1

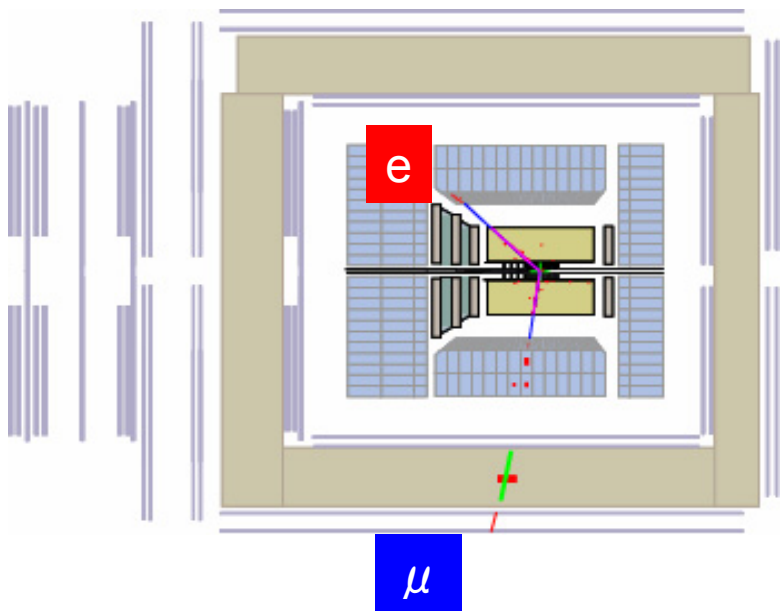
DATA	2 τ (signal)	2 μ (Background)
3	2.0±0.8	< 0.2

- Finally, 3 events are found.
- No BG expectation.
- Event yield is consistent with the SM.
- Upper limits at 68% CL given

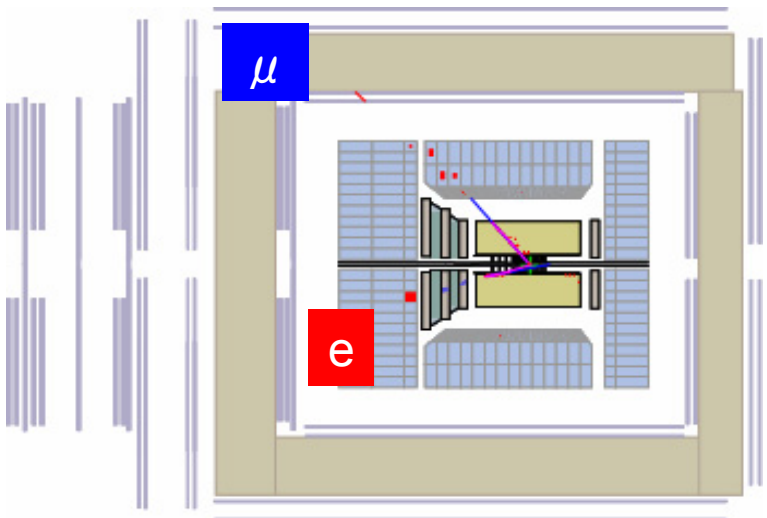
Event display



$M_{e\mu}$ =15.7GeV



$M_{e\mu}$ =9.8GeV



$M_{e\mu}$ =5.8GeV

Conclusions

- Multi-electrons
  - Analysis of HERA-I and HERA-II data 446 pb^{-1} with similar H1 phase space.
  - Data and MC are in good agreement in ee and eee topologies.
  - No excess is found in high-mass region.
- Di-taus
  - Analyzed HERA-II data 135 pb^{-1}
  - Clever BG rejection was developed
  - Finally, 3 events are found and no BG expectation.
  - Event yield is consistent with the SM.

Back up slide

The ZEUS detector

Uranium Calorimeter

lAngular coverage :

$2.5^\circ < \theta < 178.4^\circ$

lEnergy resolution :

$$\sigma(E)/E = 18\%\sqrt{E(GeV)} \oplus 2\% \quad EMC$$

$$\sigma(E)/E = 35\%\sqrt{E(GeV)} \oplus 1\% \quad HAC$$

Central Tracking Detector (CTD)

lAngular coverage :

$15^\circ < \theta < 164^\circ$

l Resolution

$$\sigma(Pt)/Pt = 0.58\% Pt(GeV) \oplus$$

$$0.65\% \oplus 0.14\%/Pt$$

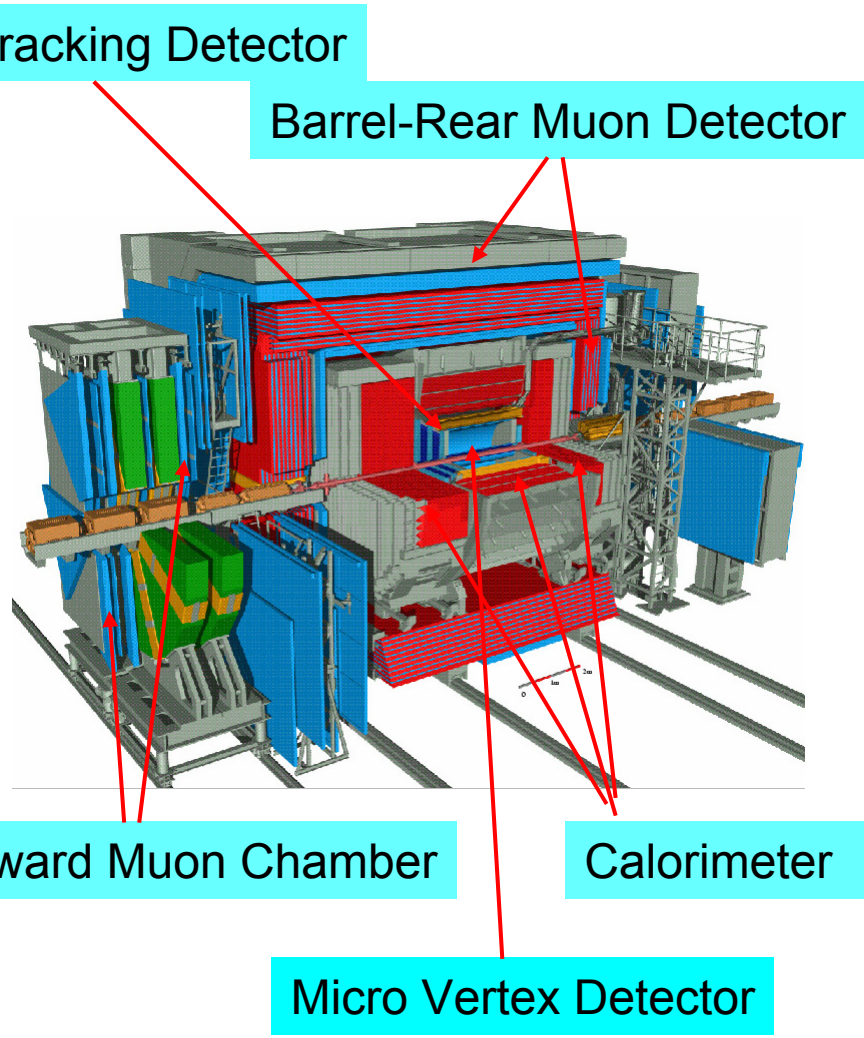
Micro Vertex Detector (MVD)

lAngular coverage :

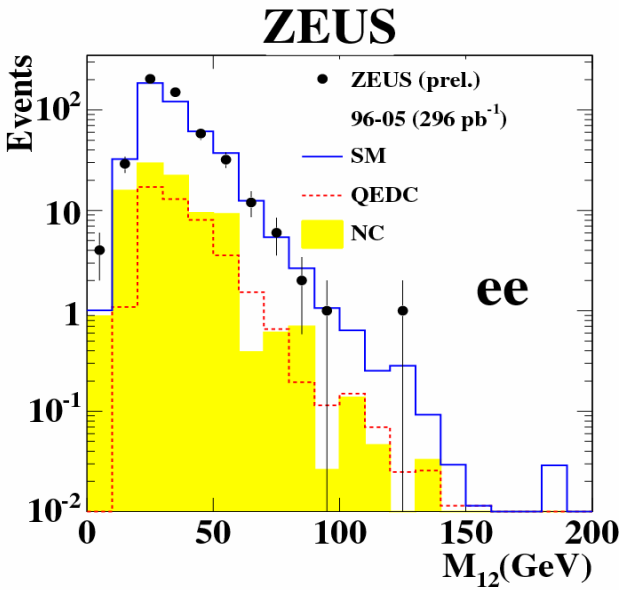
$10^\circ < \theta < 150^\circ$

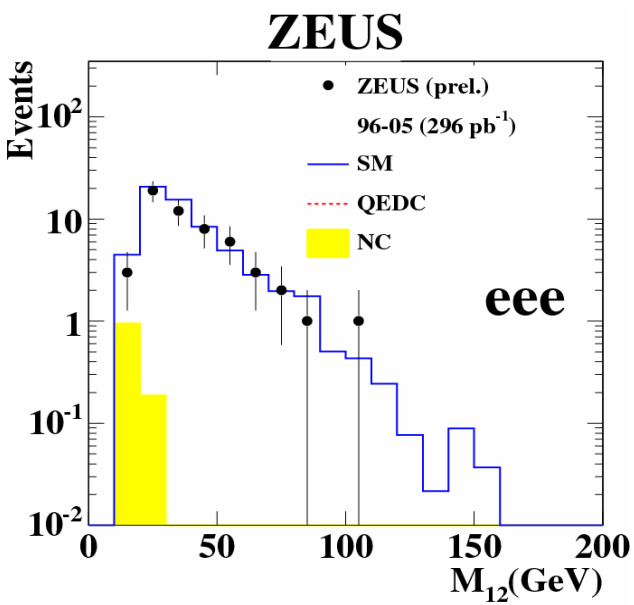
lHit resolution

100 μm at $\theta = 90^\circ$,1mm at $\theta = 20^\circ$



ZEUS multi-electron analysis





Selection	Data	SM	GRAPE	QEDC	NC
e^+p (L=144 pb^{-1})					
"ee" $M_{12} > 50$ GeV	26	31 ± 5	25 ± 3	2 ± 0.4	4 ± 1.4
"ee" $M_{12} > 100$ GeV	1	0.8 ± 0.4	0.5 ± 0.1	0.2 ± 0.2	$0.10^{+0.13}_{-0.09}$
"eee" $M_{12} > 50$ GeV	6	8 ± 1	8 ± 1	< 0.06	< 0.2
"eee" $M_{12} > 100$ GeV	1	$0.40^{+0.2}_{-0.03}$	0.40 ± 0.03	< 0.01	< 0.2
e^-p (L=152 pb^{-1})					
"ee" $M_{12} > 50$ GeV	27	36 ± 5	23 ± 3	4 ± 0.9	9 ± 1.9
"ee" $M_{12} > 100$ GeV	0	0.7 ± 0.3	0.4 ± 0.1	0.2 ± 0.2	$0.10^{+0.13}_{-0.10}$
"eee" $M_{12} > 50$ GeV	6	7 ± 0.8	7 ± 0.8	< 0.07	< 0.2
"eee" $M_{12} > 100$ GeV	0	$0.40^{+0.2}_{-0.03}$	0.40 ± 0.03	< 0.01	< 0.2

lHERA-I + HERA-II

−Analyzed 296 (pb-1)

−Preliminary for ICHEP2006

→Good agreement with the Standard Model.