Lepton pair production in ep collisions at HERA

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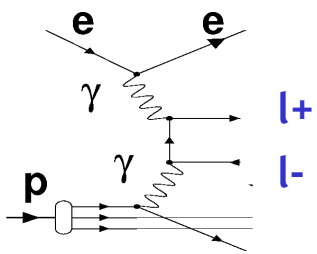
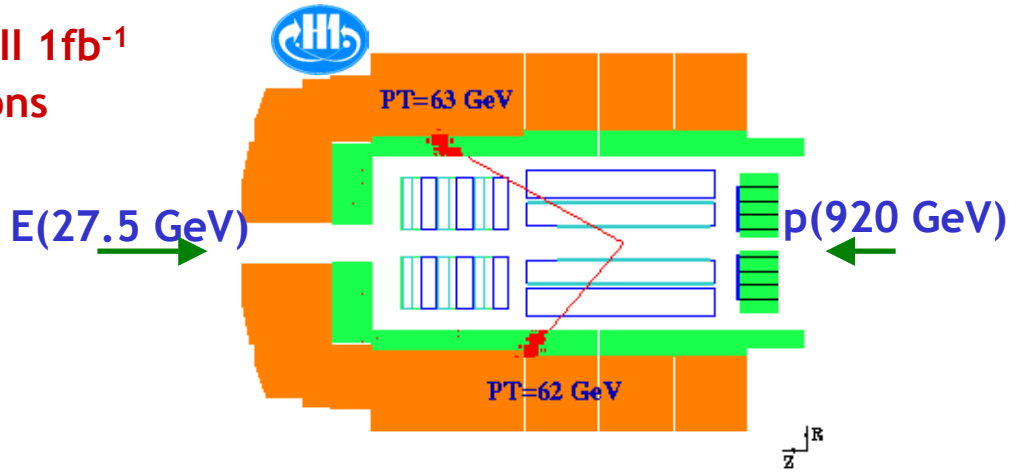
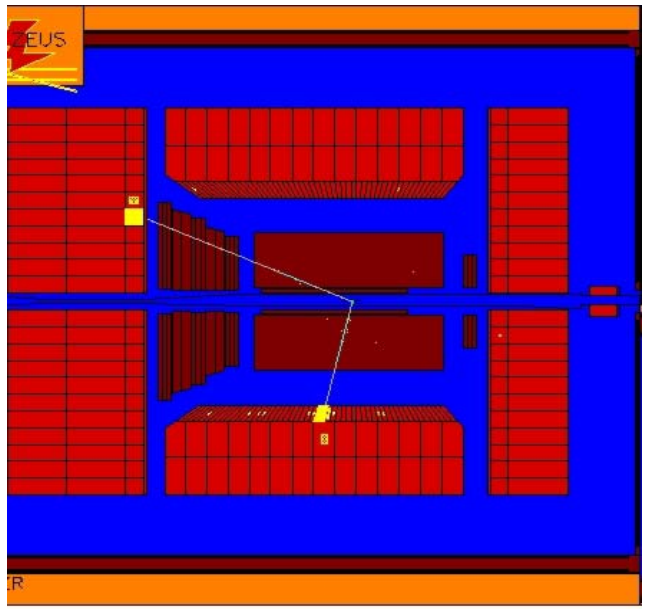
On behalf of H1 and ZEUS collaboration

Introduction

- HERA e±p collider $\sqrt{s}$=300-318 GeV
- HERA I : H1/ZEUS ~120 pb-1 HERA II 1fb^{-1}
- Di-lepton production in e-p collisions possible mainly trough $\gamma\gamma$ collisions







Spectacular topology

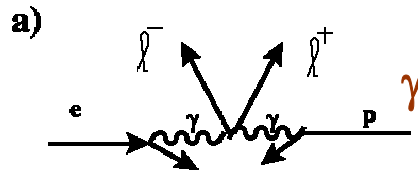
Precise SM prediction

Interesting phase space for BSM signals

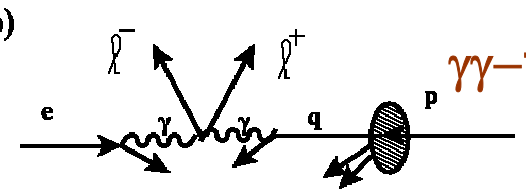
(e+p $\rightarrow$ e^{-}H$^{++}\rightarrow$ e-l+l+ see J.Dingfelder talk in BSM)

Standard Model Processes

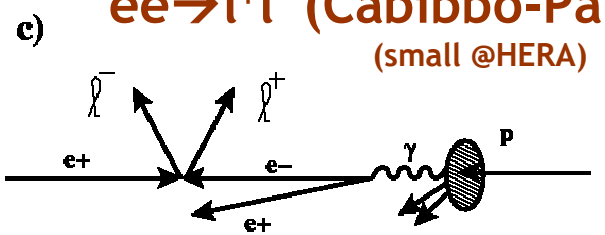
Signal



γγ–elastic

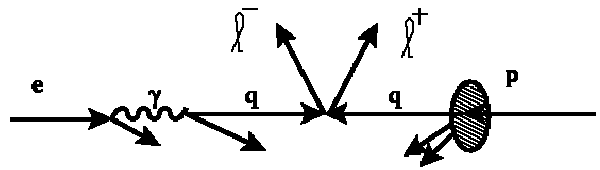


γγ–inelastic
quasi-elastic



ee→l^+l^- (Cabibbo-Parisi)
(small @HERA)

$\gamma^*/Z \rightarrow l^+l^-$



qq→l^+l^- (Drell-Yan)
(small @HERA)

+Resonant/HQ production (low PT< 5 GeV)

GRAPE (T.Abe et al.) **: full diagram a+b+c (EW)+proton structure**

Background

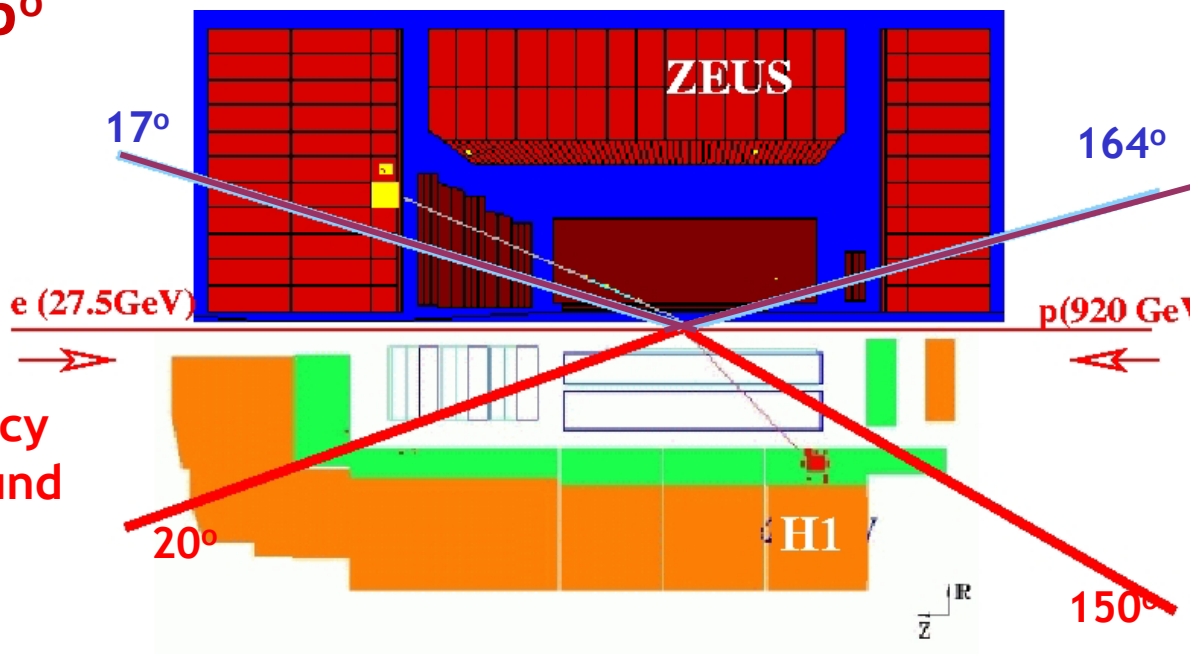
NC-DIS ep→eX fake 2nd electron from radiation or mis-id
Compton: eγ(p)→e+photon(->fake 2nd e)

Fake muons from hadrons (negligible)

H1 and ZEUS : electron identification

- Electron identified in calorimeters $5^o<\theta<175^o$ (isolated)
- Central region:
  - H1 : $20^o<\theta<150^o$
  - ZEUS: $17^o<\theta<164^o$
  - calo-tracker redundancy exploited for background rejection: Good quality isolated track required

Uranium ,6500 cells, precise timing, em:$\sigma(E)=18\%/\sqrt{E}$



LAr,44000 cells em:$\sigma(E)=12\%/\sqrt{E}$

Electrons ordered in PT:
e1,e2,e3⇔PT1>PT2>PT3

Multi-electron selection

- Two central high PT electrons
  - H1 : $P_T(1)>10$ GeV $P_T(2)>5$ GeV $20^o<\theta<150^o$
  - ZEUS: $P_T(1)>10$ GeV $E(2)>10$ GeV $17^o<\theta<164^o$
- + any other electron(3^{rd}) identified in the calo $5^o<\theta<175^o$

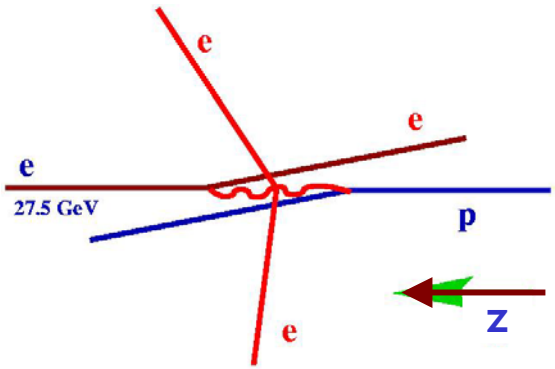
H1 115 pb^{-1}	Data	SM	Grape	NC+Compton
2e	105	118.2±12.8	93.3±11.5	25.0±5.5
3e	16	21.6±3.0	21.5±3.0	0.1±0.0

Statistical and systematical errors

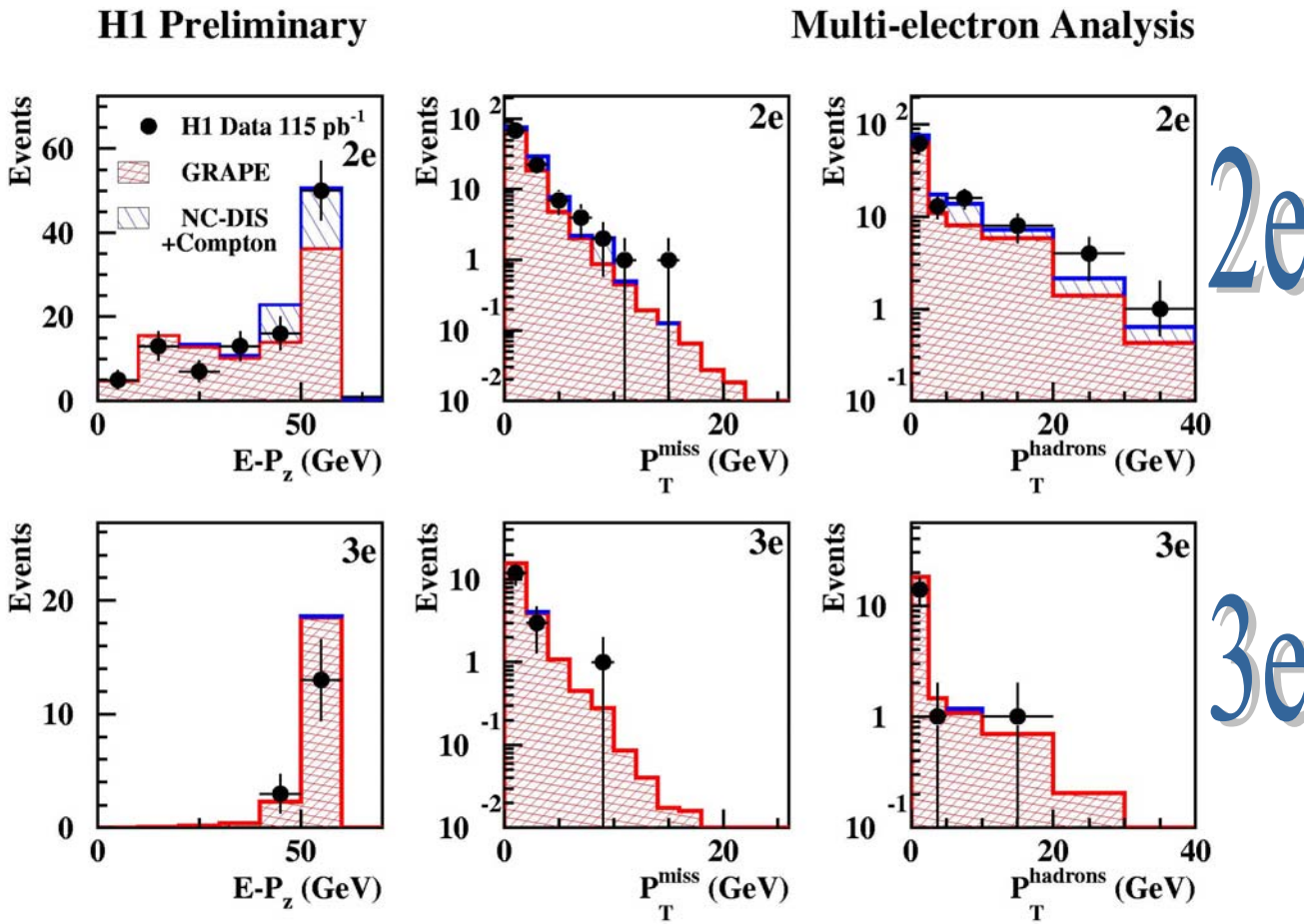
ZEUS 130 pb^{-1}	Data	SM	Grape	NC+Compton
2e	191	213.9±3.9	182.2±1.2	31.7±3.7
3e	26	34.7±0.5	34.7±0.5	-

Statistical errors

Inclusive Distribution (H1)



- Longitudinal momentum as expected for 2e and 3e
  - (E-Pz=2*Ee=55 GeV when all particles detected)
- No high P_t^{miss}
- Inelasticity spectrum well described



Electron transverse momenta (H1)

H1 Preliminary

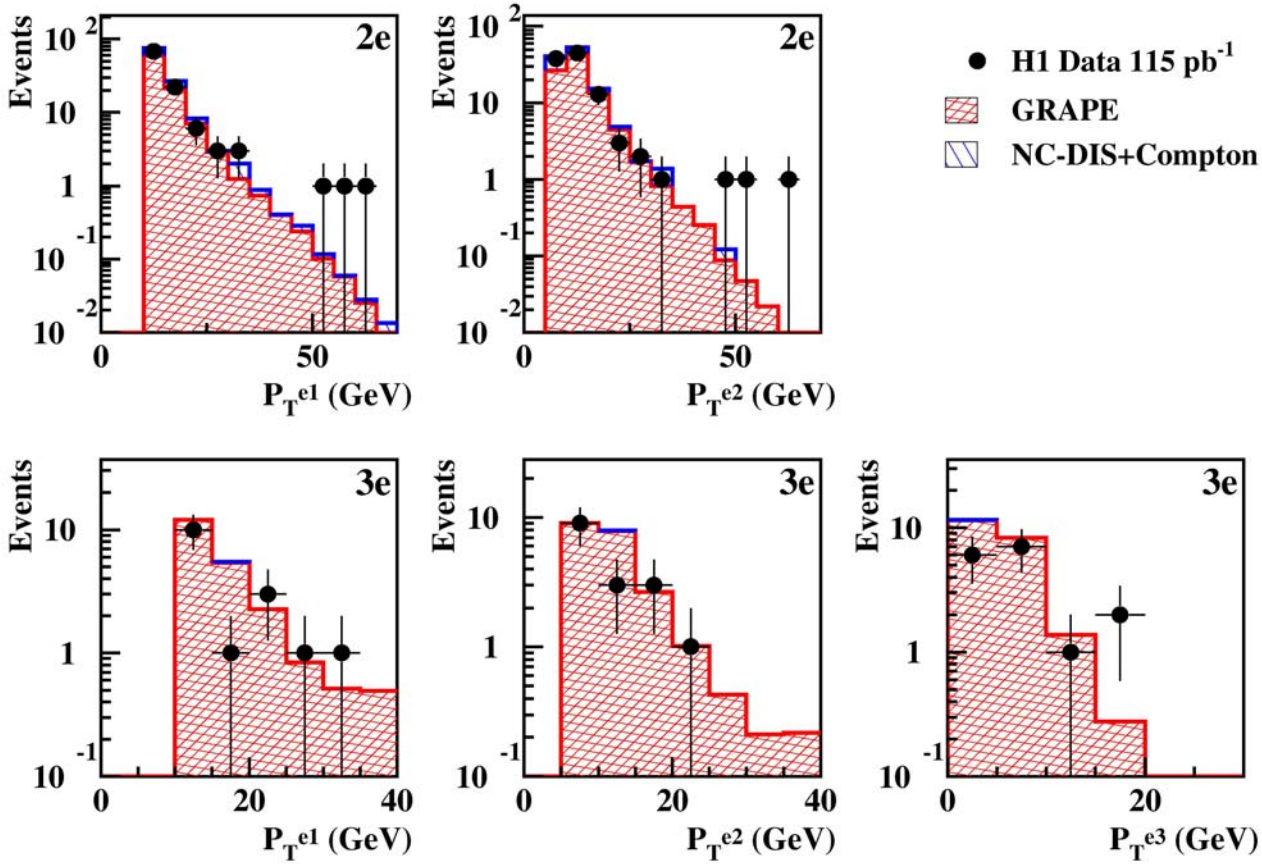
Multi-electron Analysis

2e

Steep spectra

Good overall description

Three 2e events @PT>50 GeV



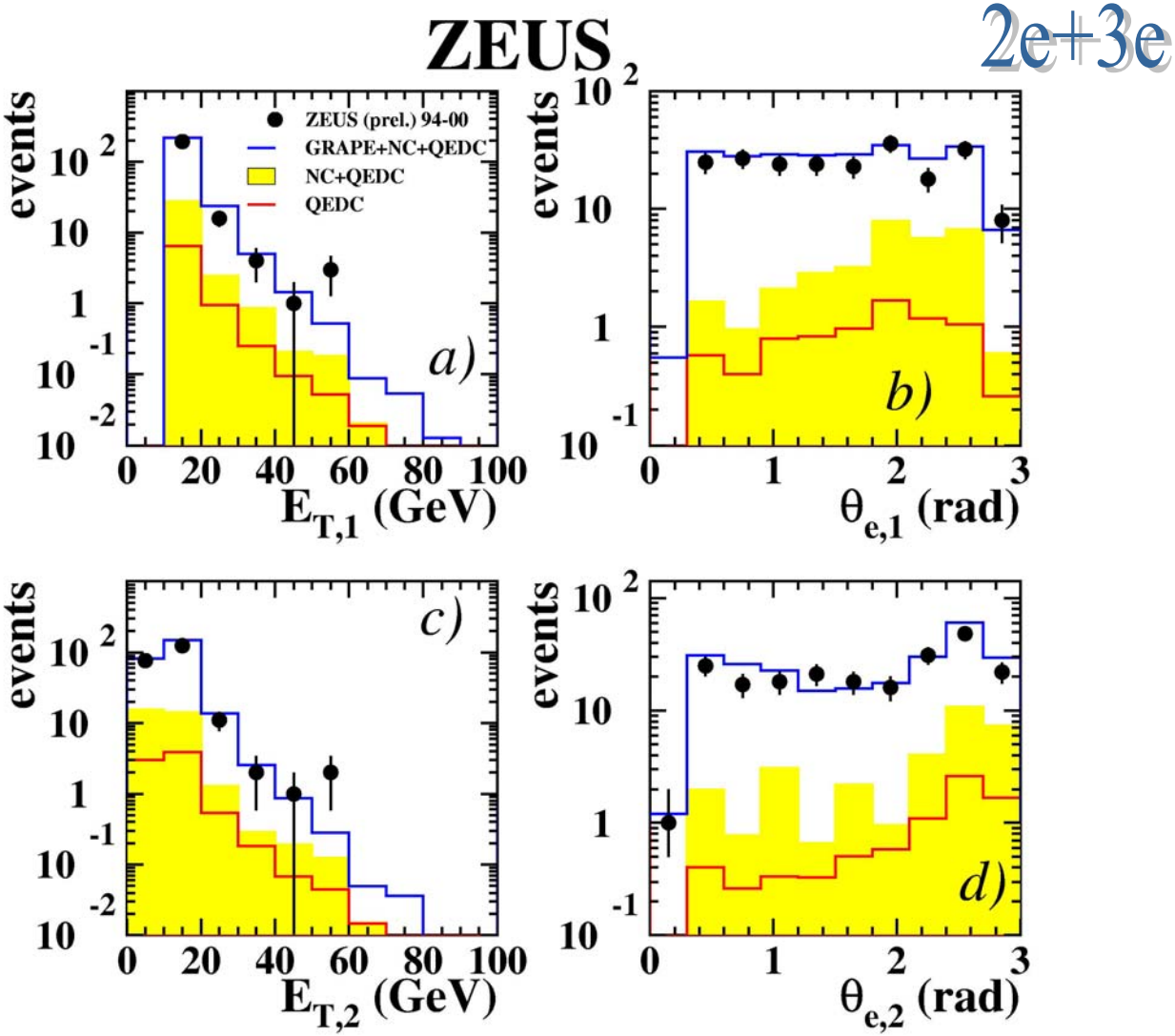
3e

Electron PT and polar angles (ZEUS)

Good overall description

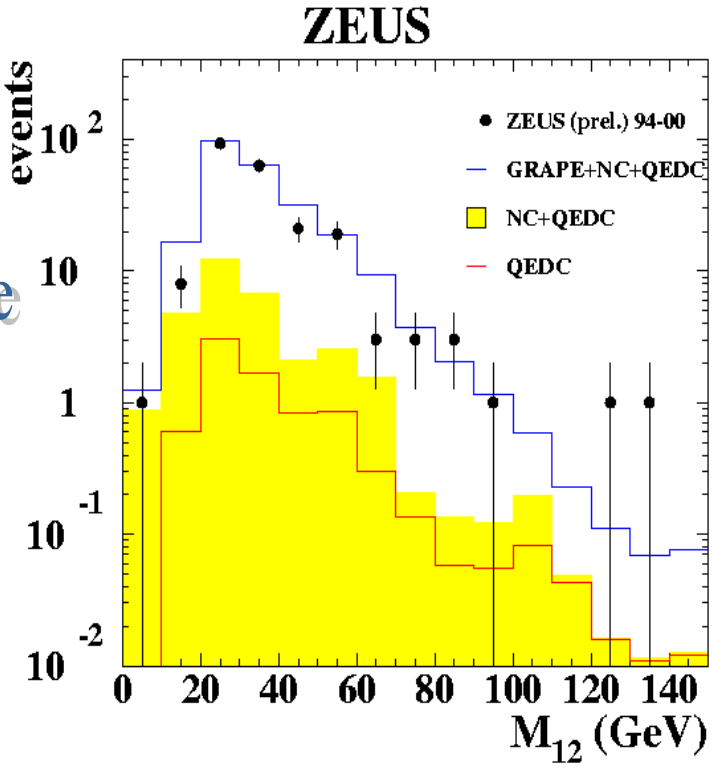
PT1>30 GeV
8(Data)/7.1(SM)

Two events with
PTe1,2>50 GeV



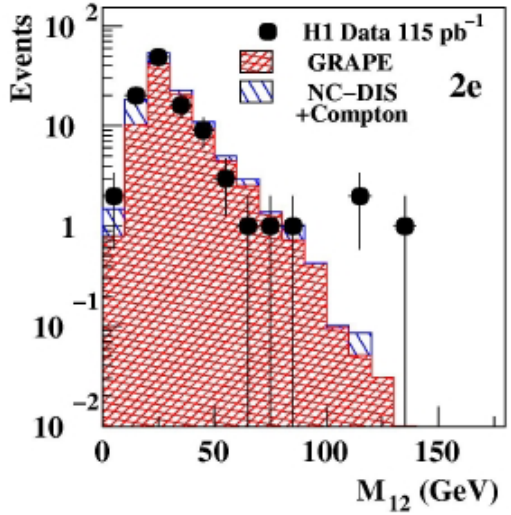
Mass distribution M_{12}

Mass of two highest PT electrons in the event

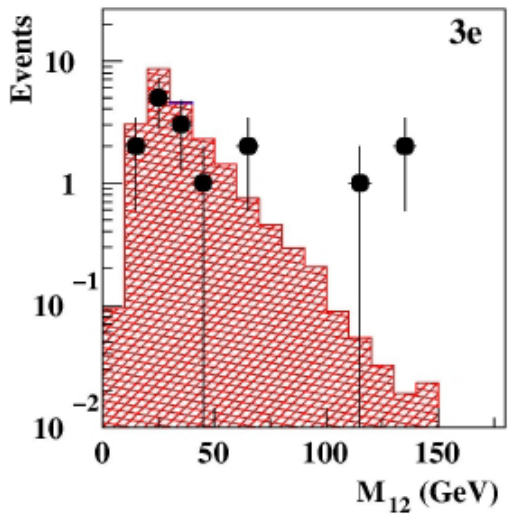


2e+3e

H1



2e



3e

Good overall agreement

Several events at high mass M_{12}>100 GeV

Multi-electron events at high mass M_{12}>100 GeV

H1 115 pb^{-1}	Data	SM	Grape	NC+Compton
2e	3	0.25±0.05	0.21±0.04	0.04±0.03
3e	3	0.23±0.04	0.23±0.04	0.0±0.0

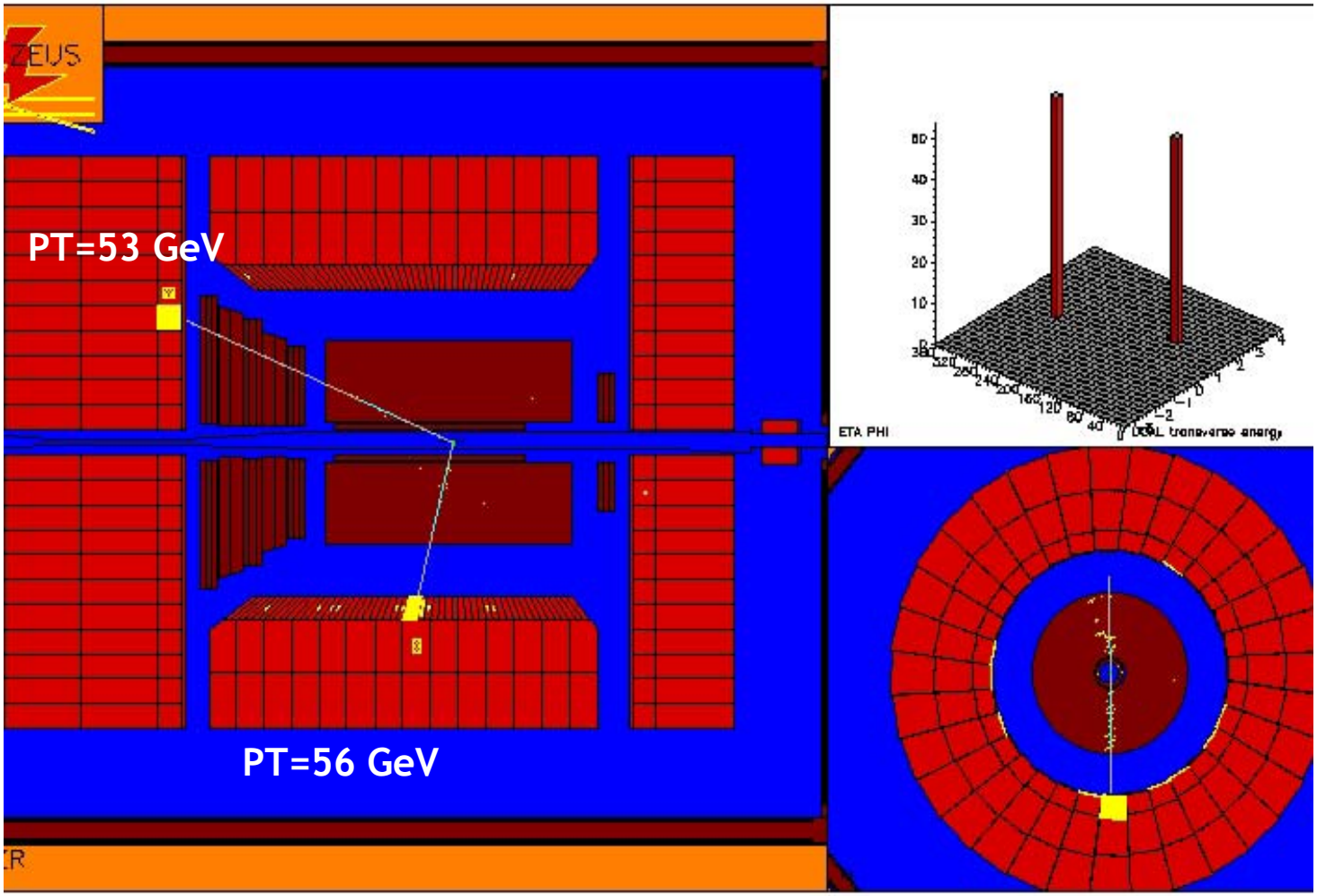
Statistical and systematical errors

ZEUS 130 pb^{-1}	Data	SM	Grape	NC+Compton
2e	2	0.77±0.08	0.47±0.05	0.30±0.07
3e	0	0.37±0.04	0.37±0.04	-

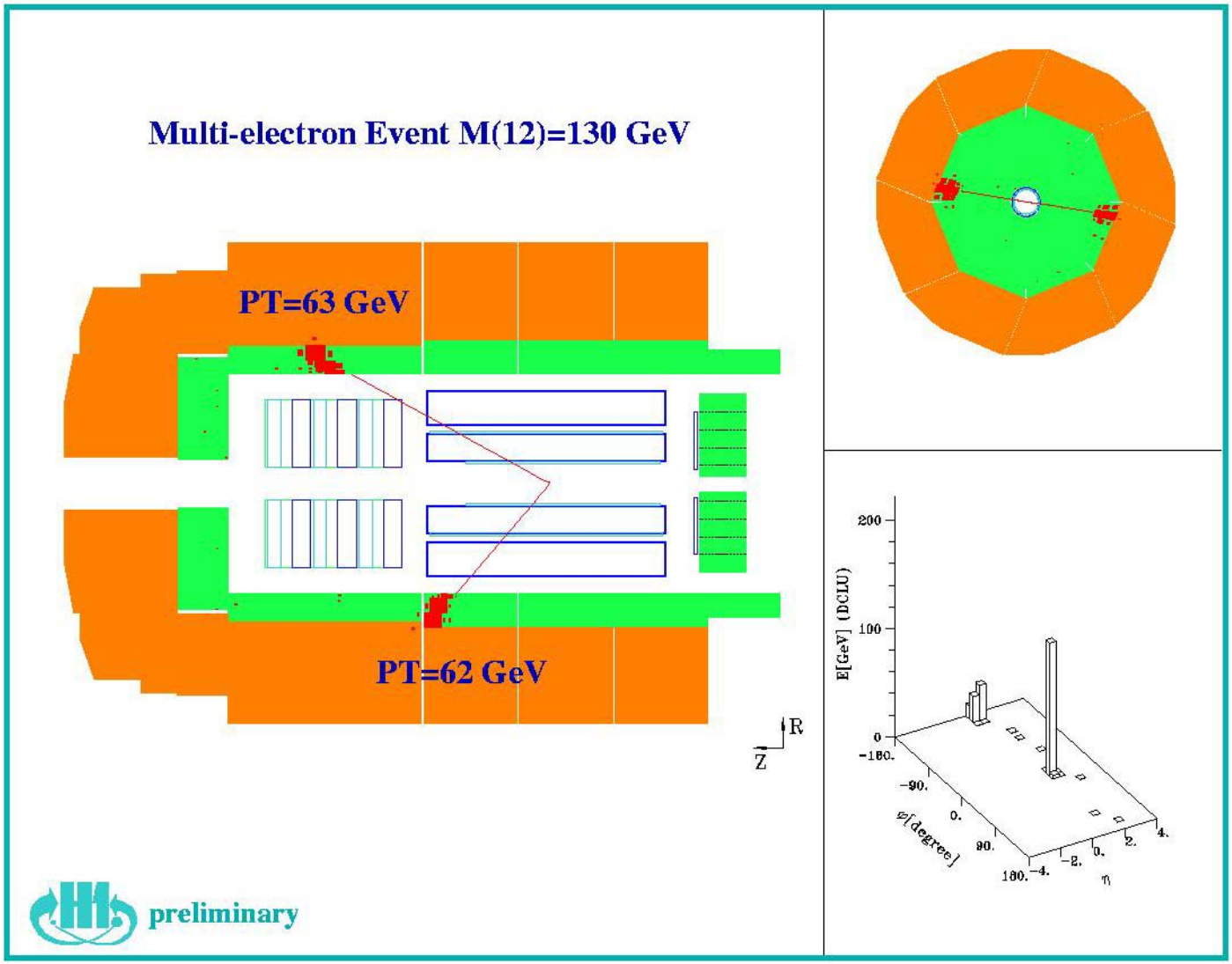
Statistical errors

Reminder: H1/ZEUS different polar angle domains

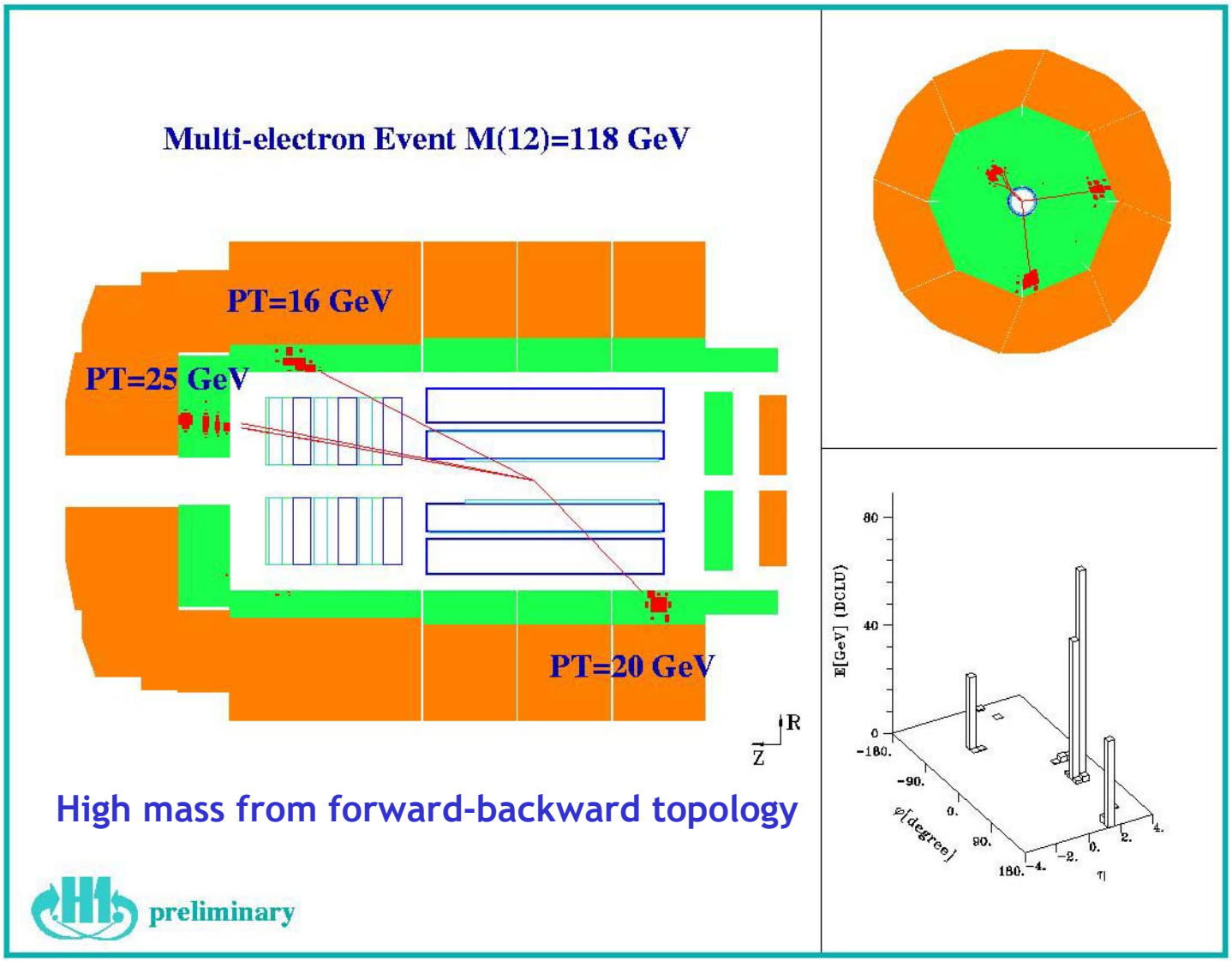
Example 2e event (ZEUS) M_{12}=134 GeV



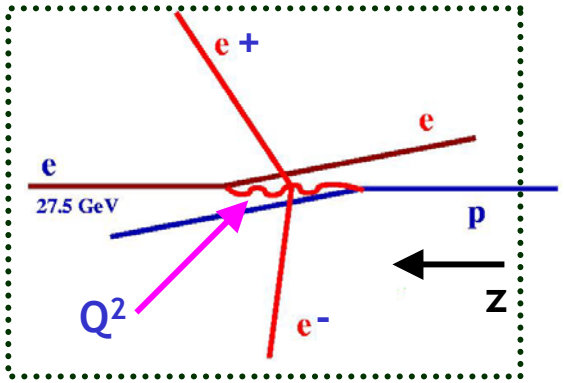
Example 2e event (H1) M_{12}=130GeV



Example 3e event (H1) M_{12}=118 GeV



H1: Cross section measurement $ep \rightarrow ee^+e^-X$

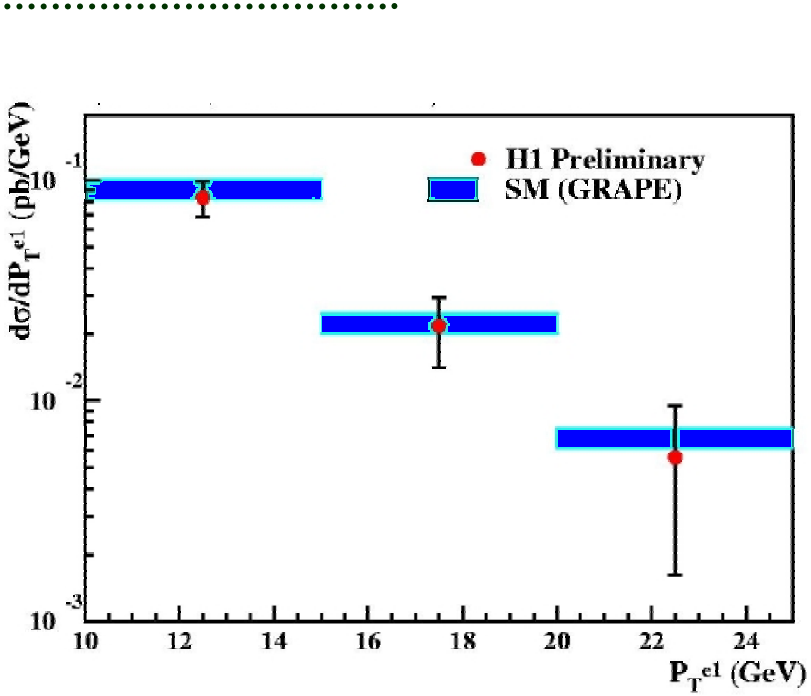


2e Sample E-Pz<45 GeV , opposite charges

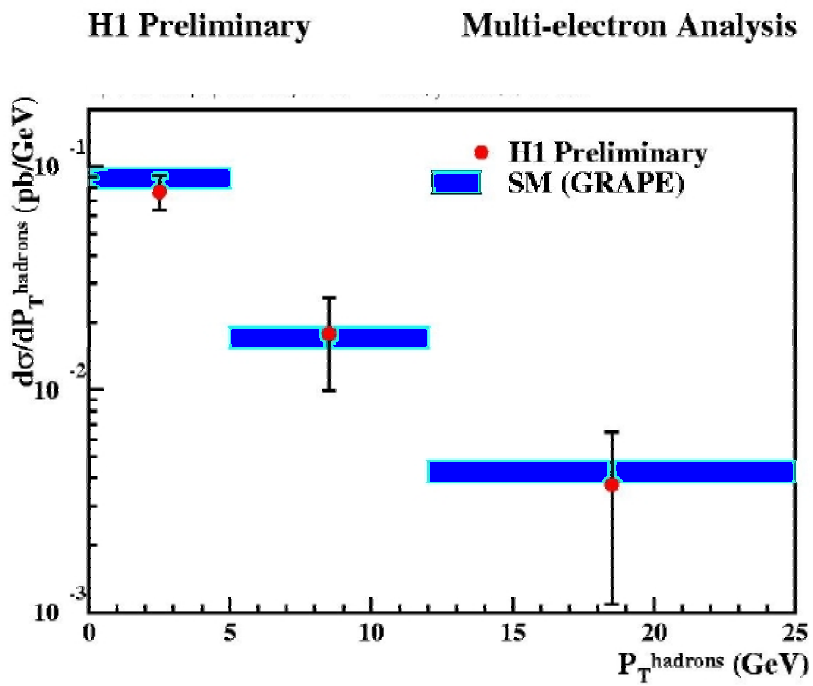
$P^e_T(1,2)>10,5$ $\quad 20^o<\theta<150^o$

$y<0.82$ $\quad Q^2<1\ GeV^2$

Data/MC: 41/48.3±6.1(1.9BG)



Good agreement

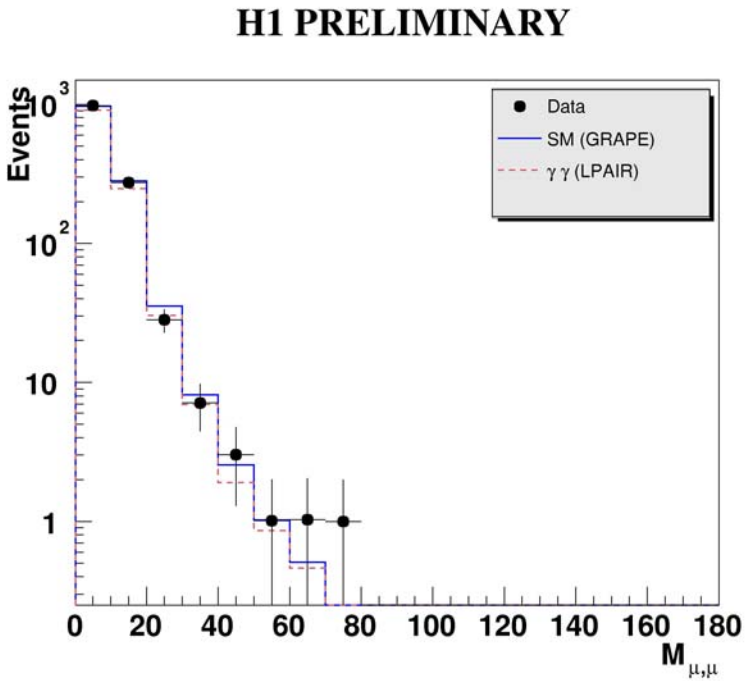


Inelastic process well described

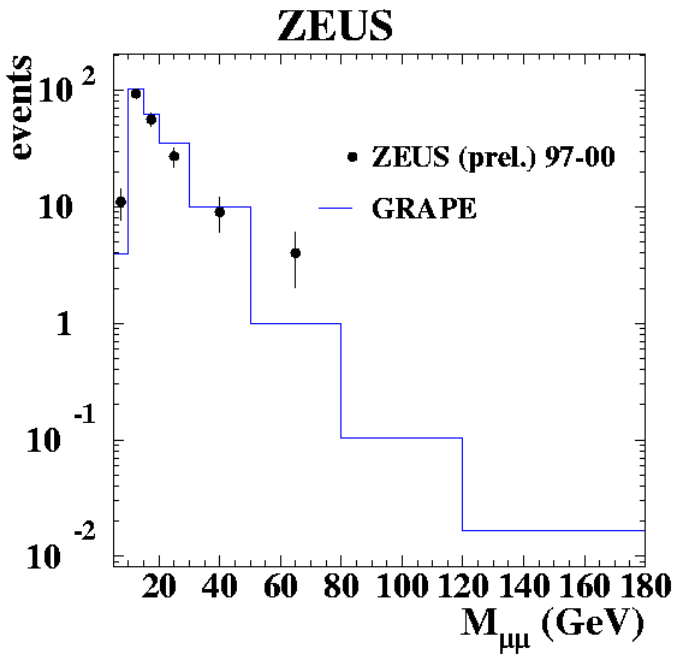
Multi-muon Events

Muons identified in central tracker, mips in Calo and external muon chambers signals

$PT(\mu_{1,2})>2GeV$ $20^o<\theta_\mu<160^o$
$L=70pb^{-1}$



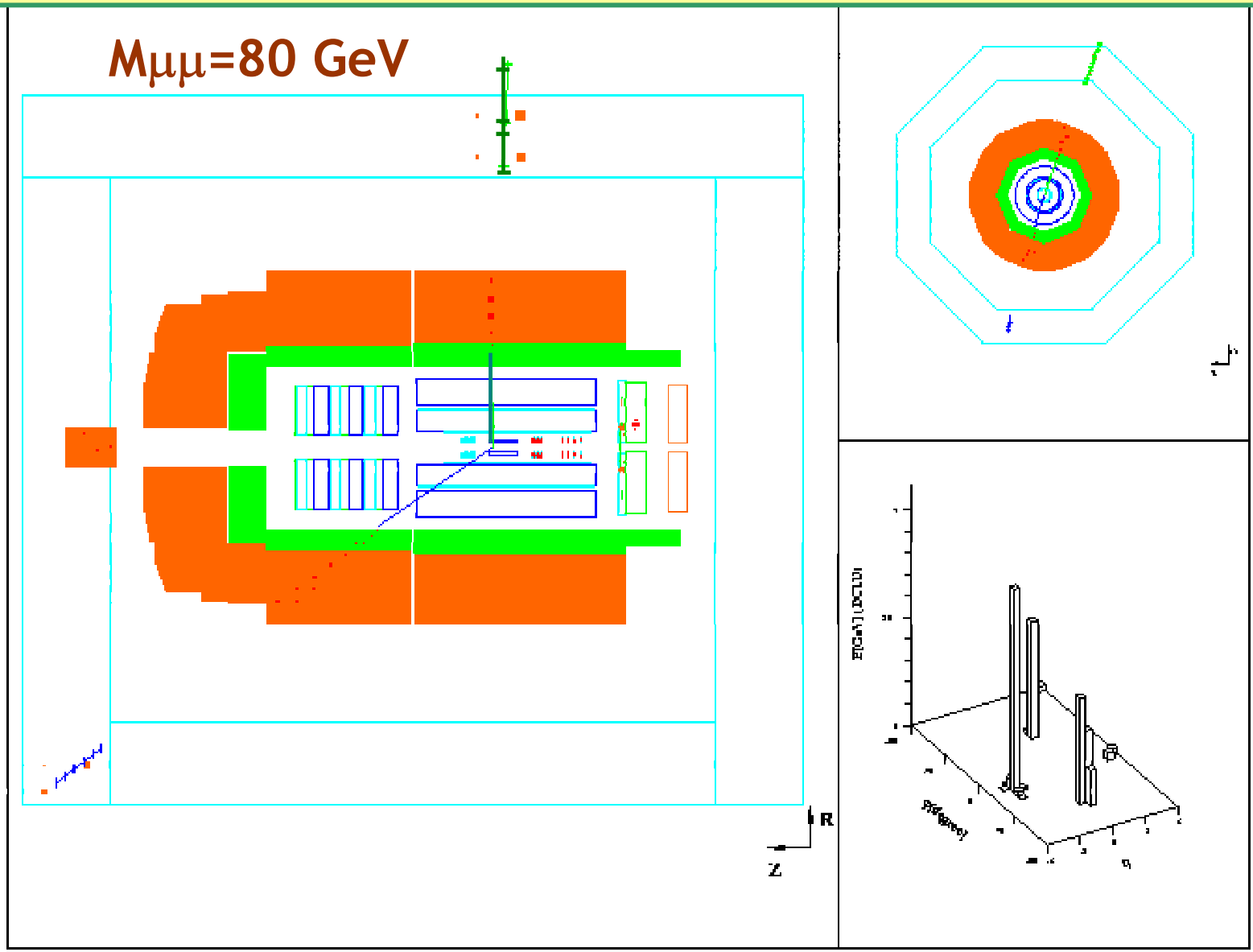
$PT(\mu_{1,2})>5GeV$ $20^o<\theta_\mu<160^o$
$L=105pb^{-1}$



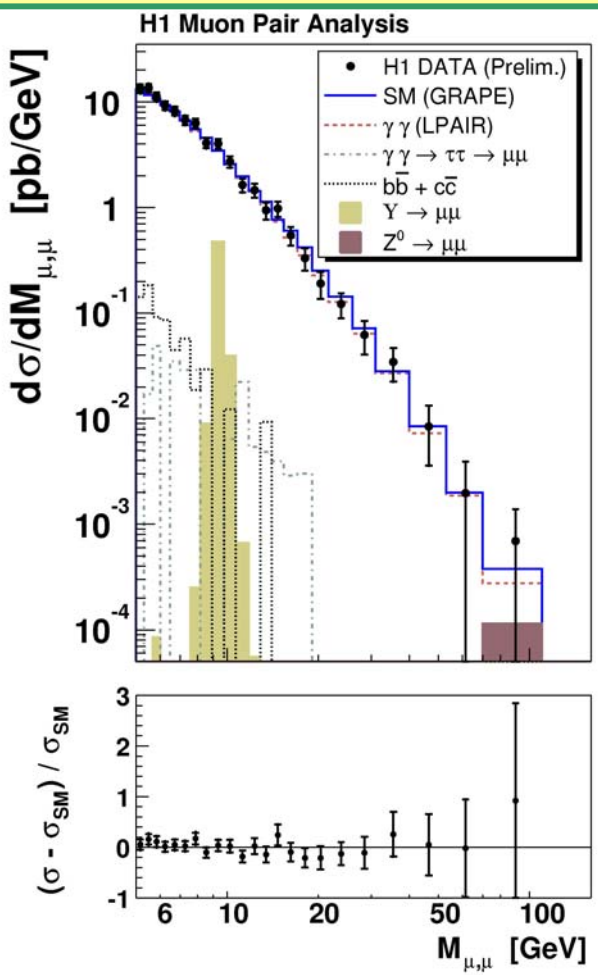
No events at high M12>100

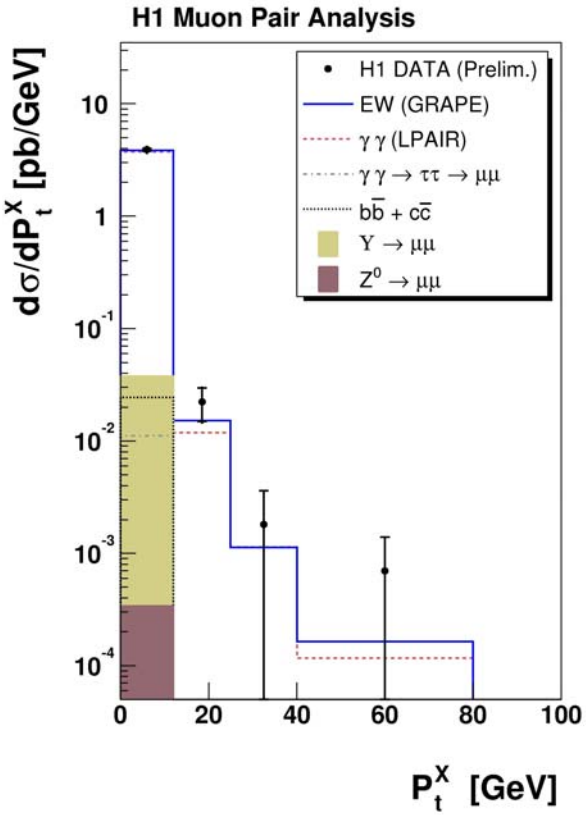
H1: ~1ev expected from e-channel

Example of di-muon event (H1)



H1 Di-muon Cross Section Measurement





$PT(\mu_{1,2})>2GeV\ 20^o<\theta_\mu<160^o$

Total Cross-section	46.5±1.3±4.7 pb	SM:46.2
Inelastic Cross-Section	20.8±0.9±3.3 pb	SM:21.5

Good agreement with SM

Good description of inelasticity spectrum

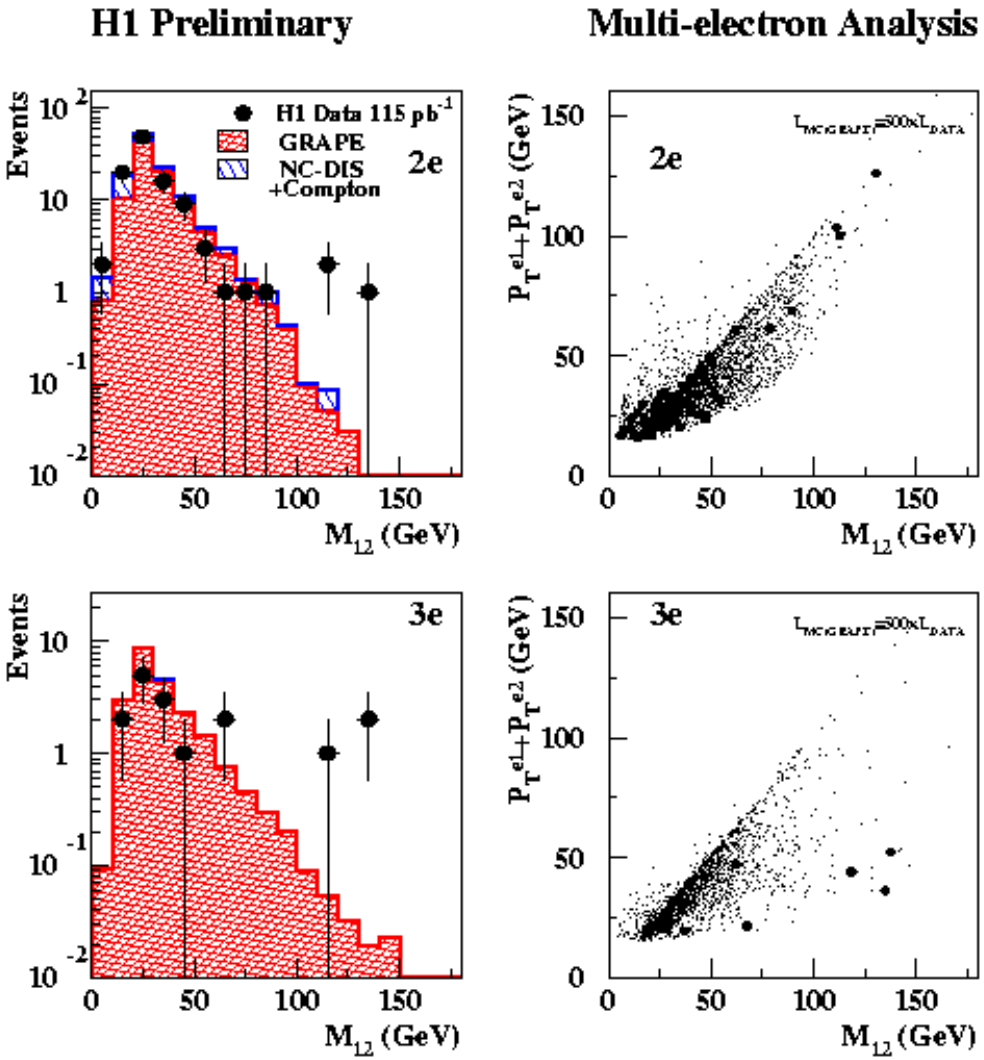
Summary

- Multi-electron and multi-muon production has been measured in ep collision for
  - PT's up to 50 GeV
  - M(ll) up to 100 GeV
- Good overall agreement is found with the SM calculation.
- Multi-electron events with M12> 100 GeV observed :
  - 2e : 3/0.25 (H1) 2/0.77 (ZEUS)
  - 3e : 3/0.23 (H1) 0/0.37 (ZEUS)
- Promising for future investigation with 1fb-1 at HERA II

Events at High Mass (H1)

2e

3e

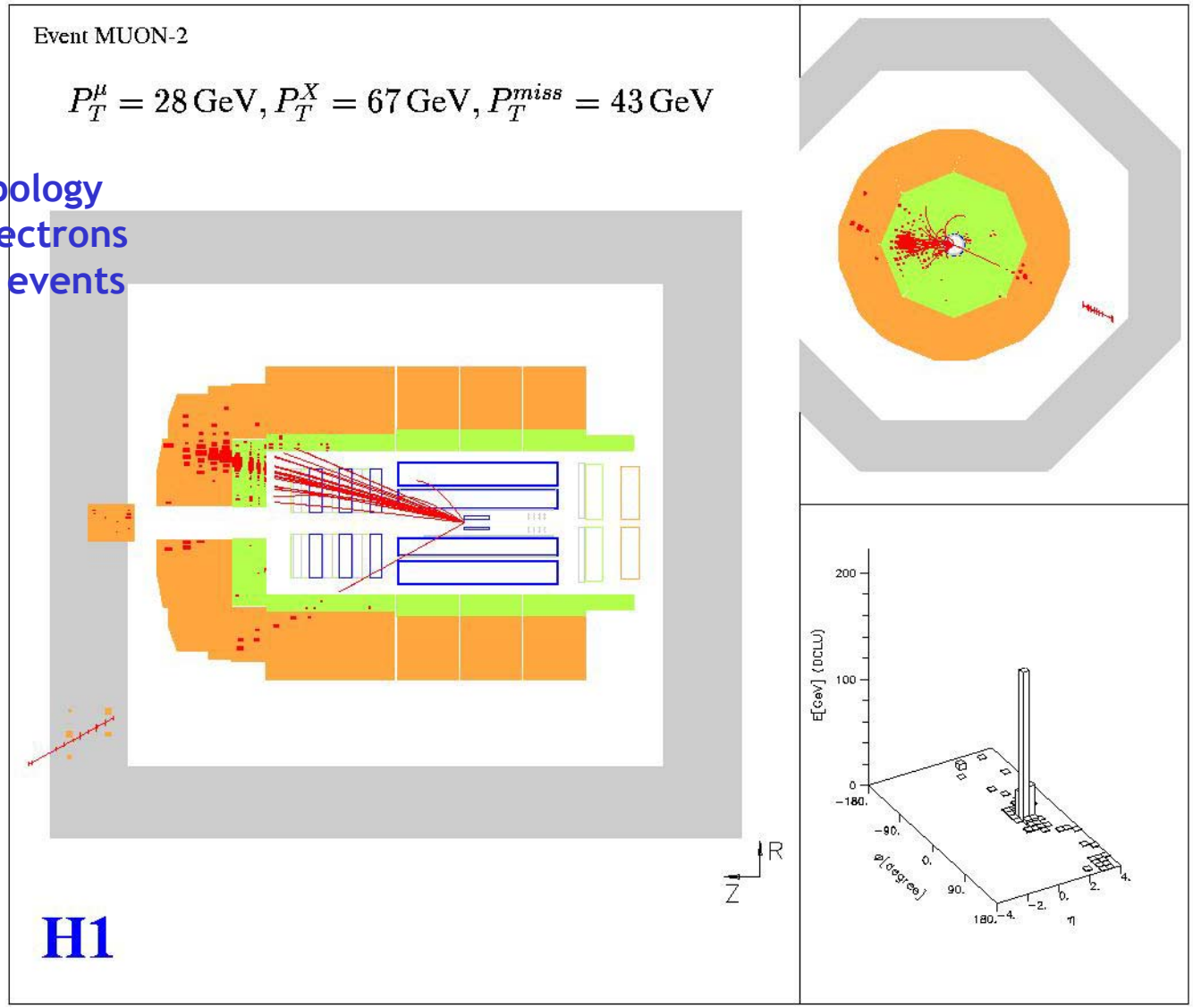


The 3 high mass pairs have also high PT

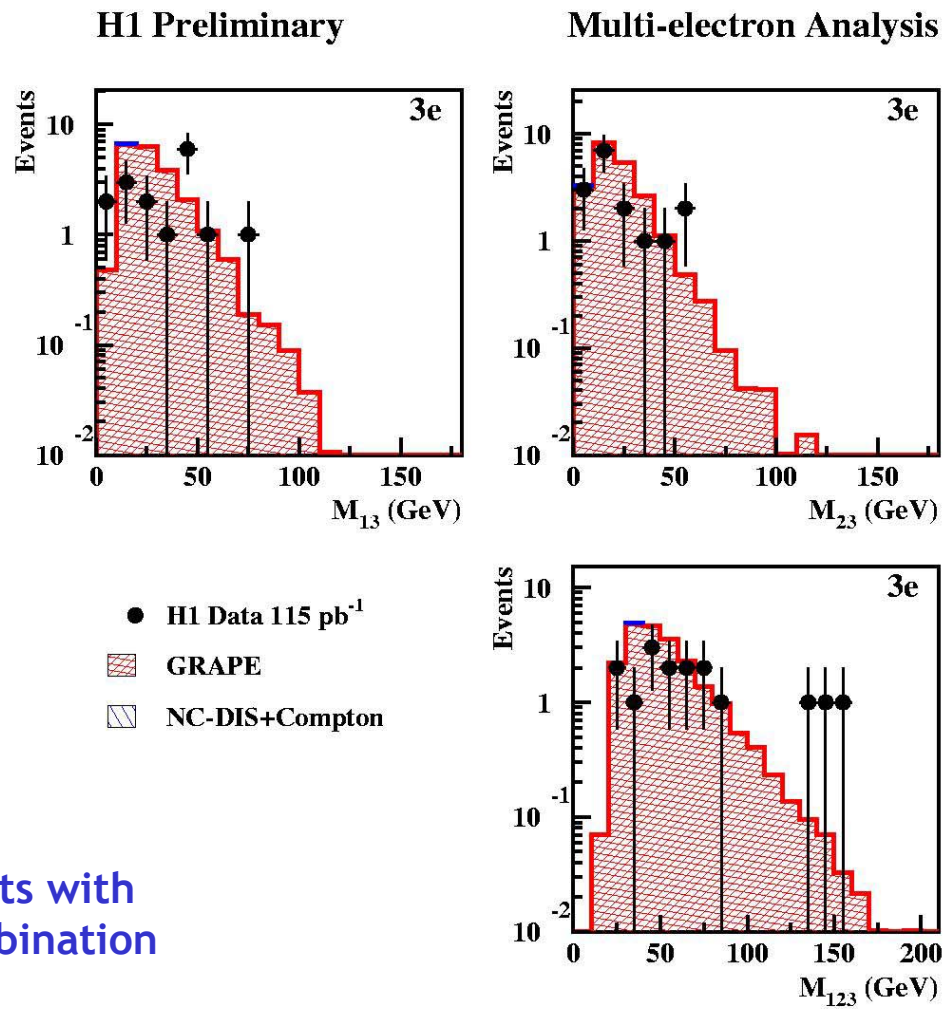
The 3 high mass pairs have a bwd-fwd topology

Isolated leptons event

Not the same topology
As high mass di-electrons
High PT jet in the events

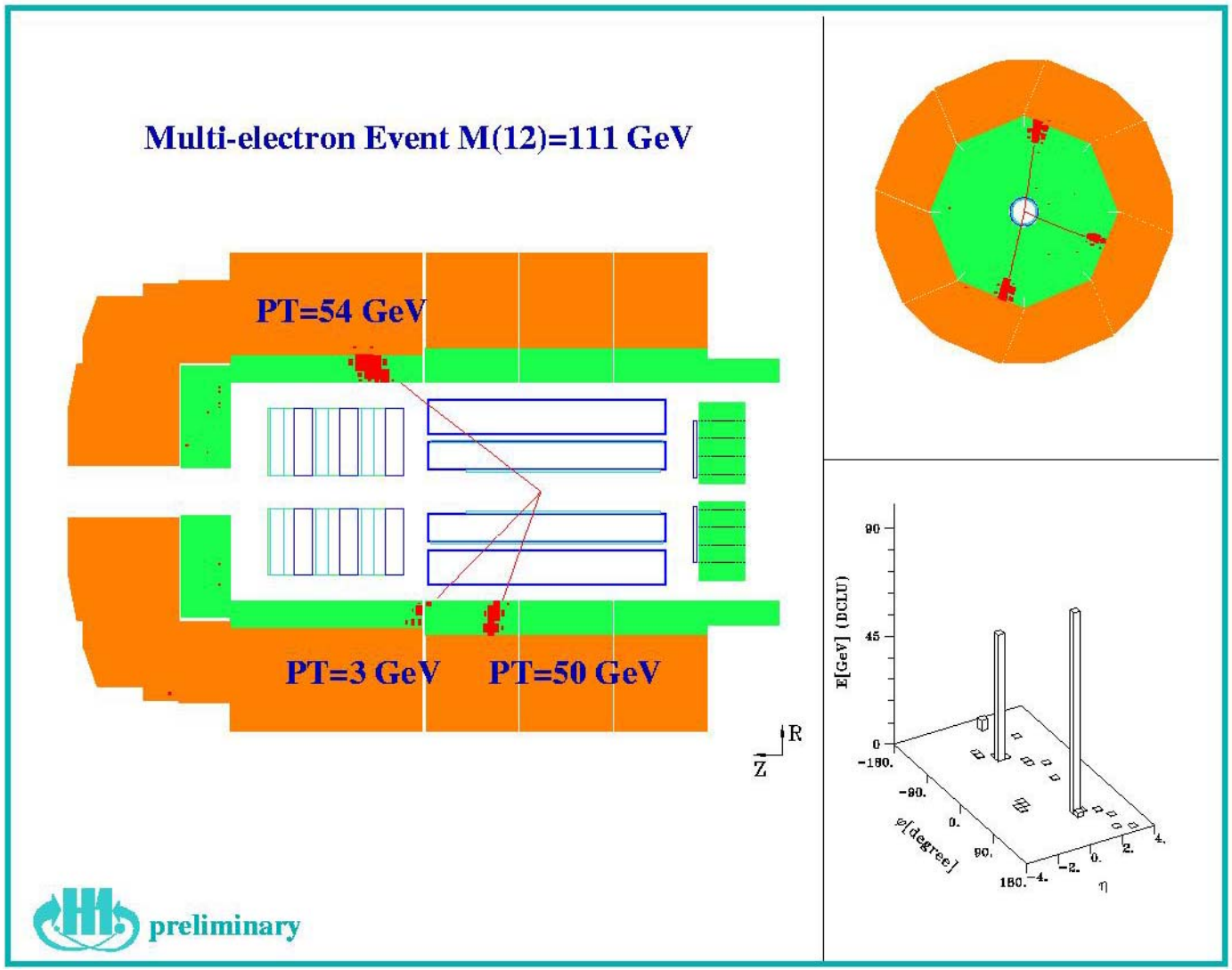


Mass combinations for 3e events

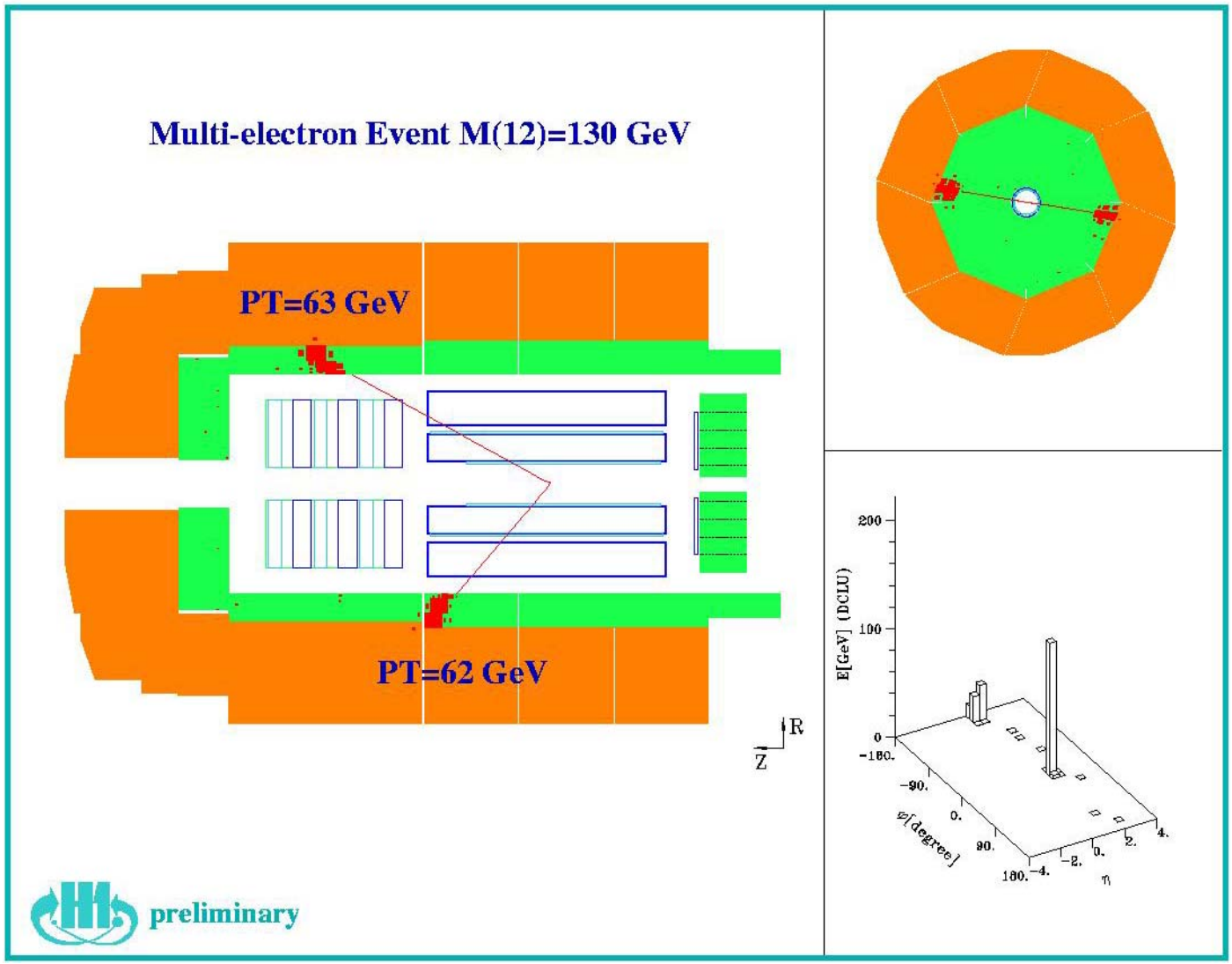


No other events with high mass combination

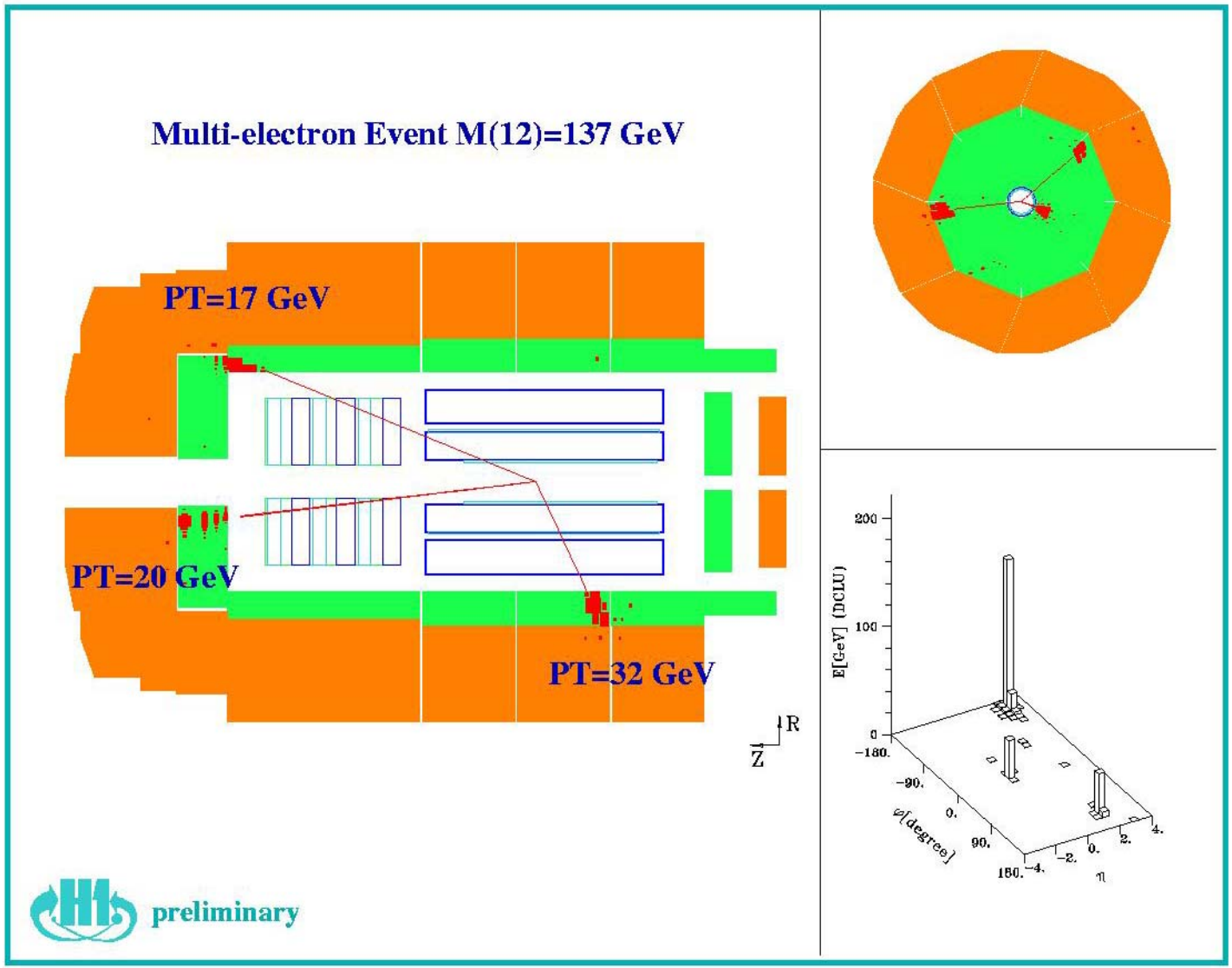
High Mass Event (H1) M



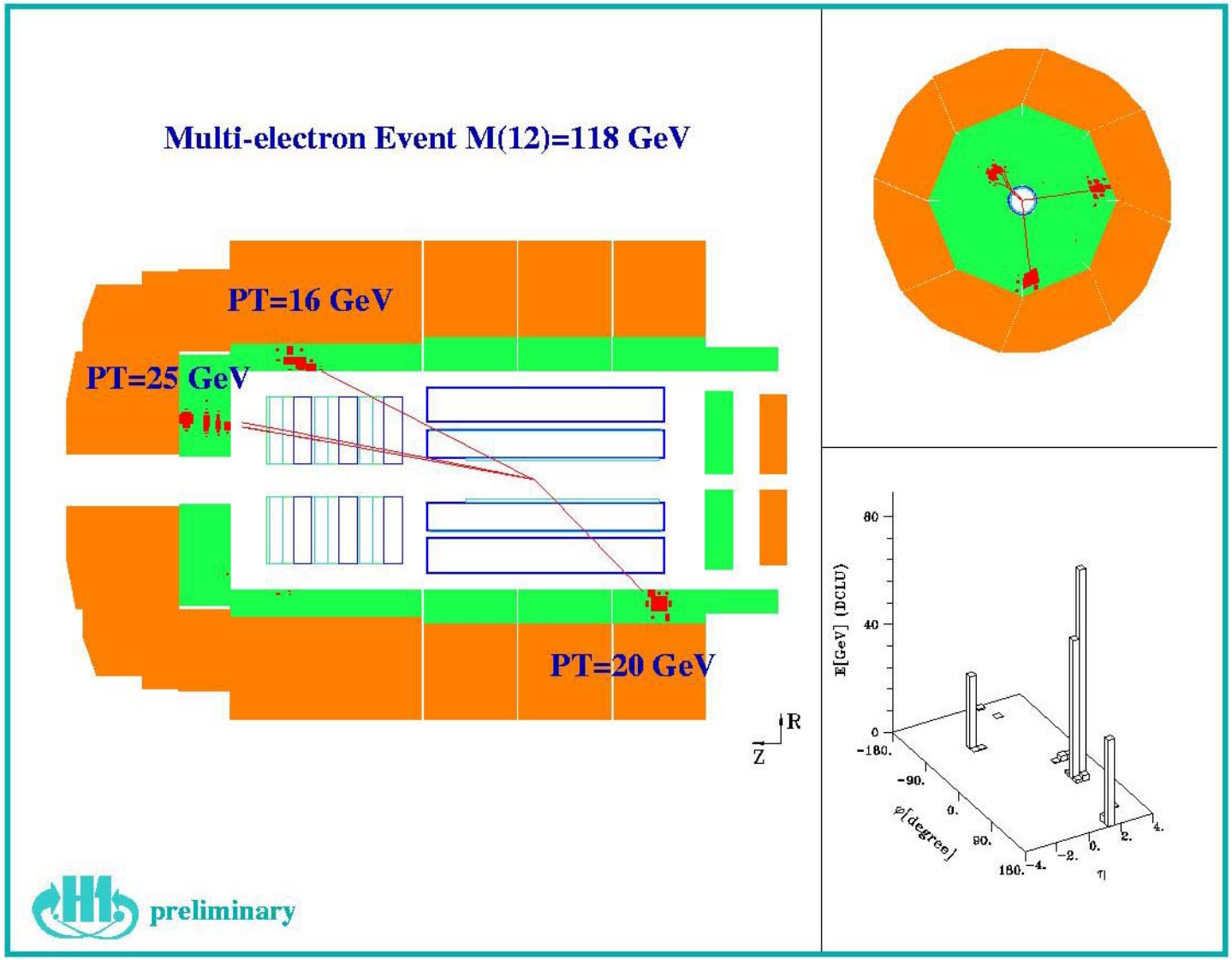
High Mass Event (H1)



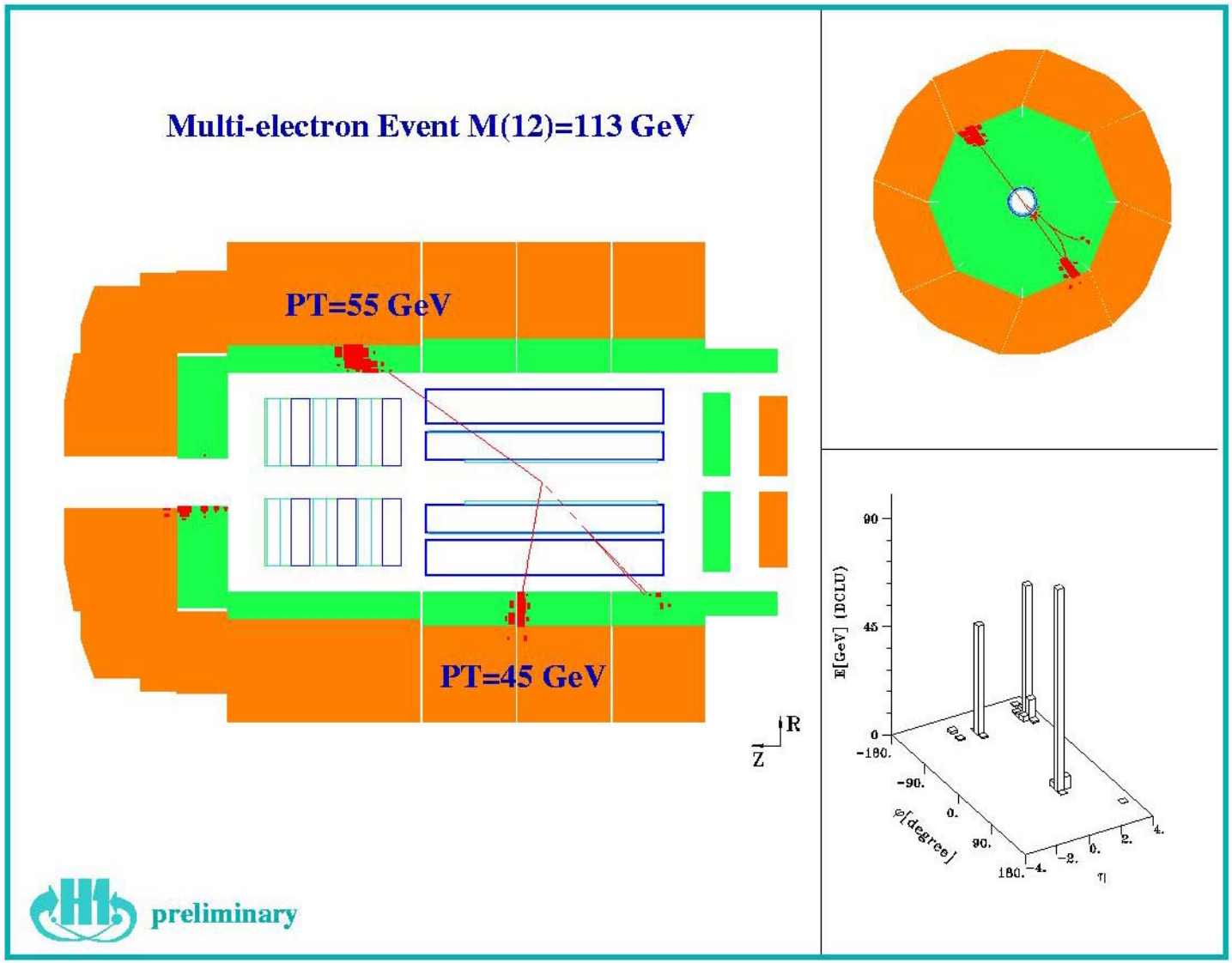
High Mass Event (H1)



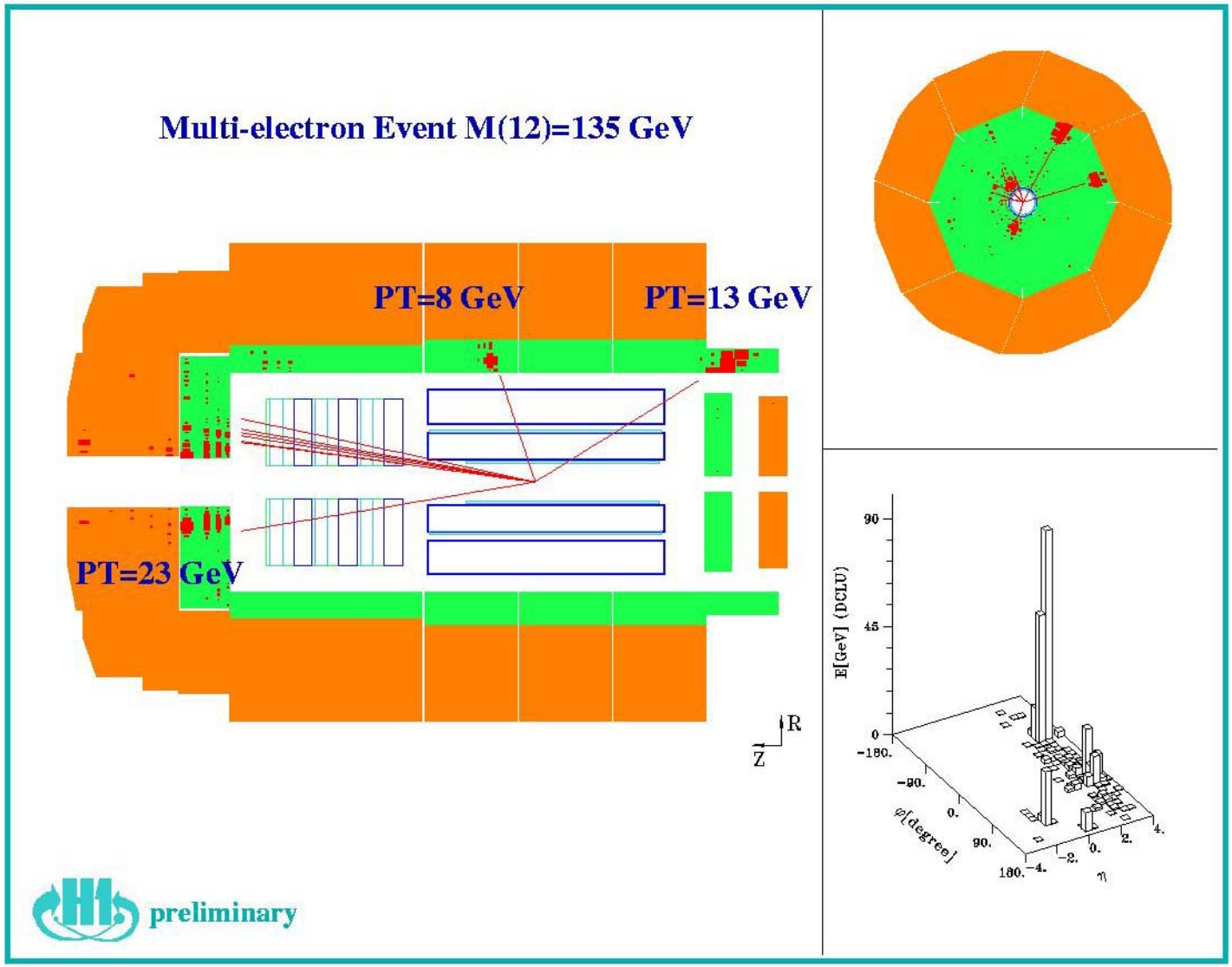
High Mass Event (H1)



High Mass Event (H1)

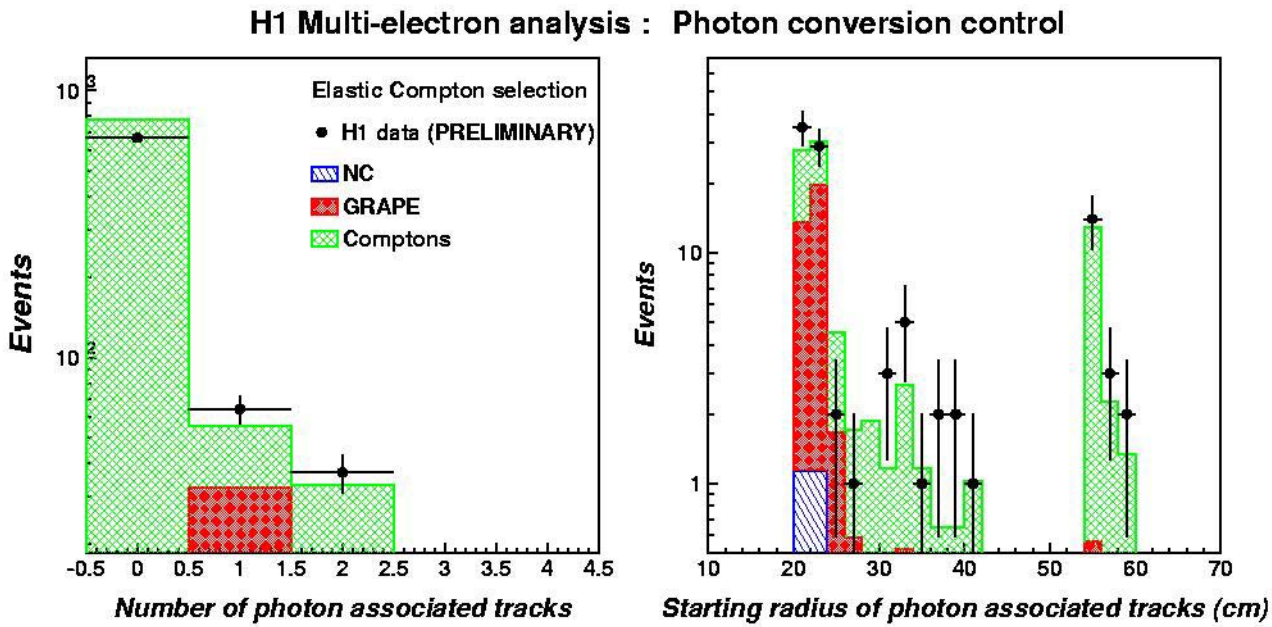


High Mass Event (H1)



Control Analysis: photon conversions

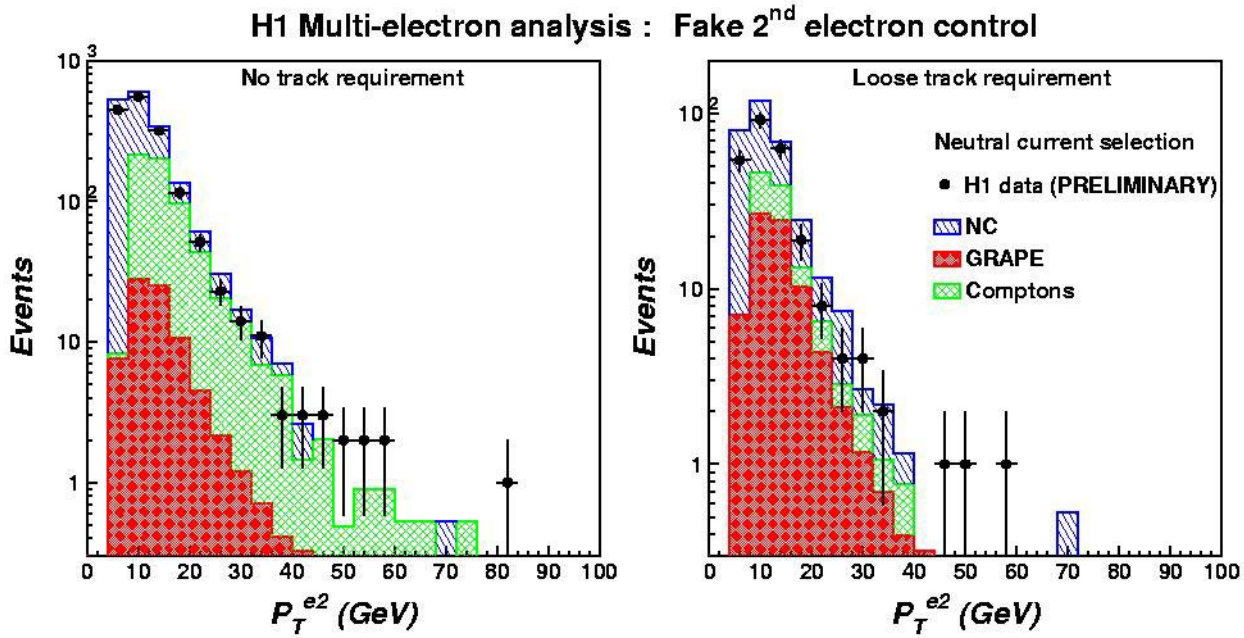
- Photon conversions studied with a clean Compton sample: two e.m. clusters and nothing else



H1 innner detector tomography with high PT photons
Good Description by the simulation, conversion @high PT under control

Fake electrons : control analysis

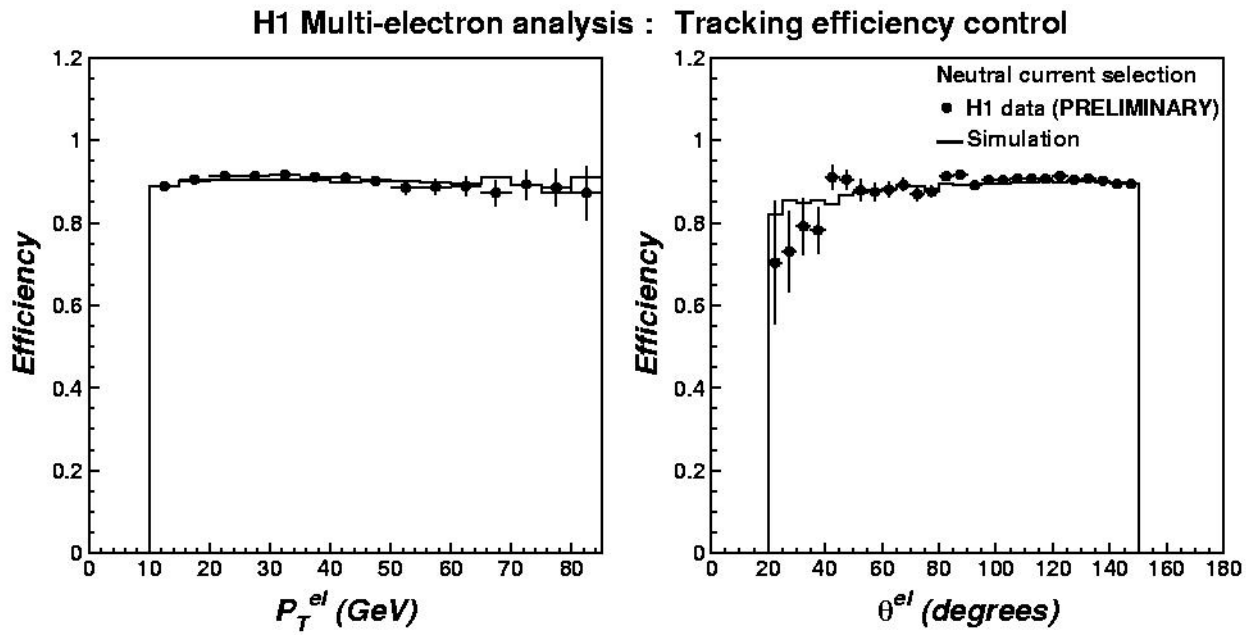
- Second e.m. cluster studied in a sample where a good isolated electron already identified



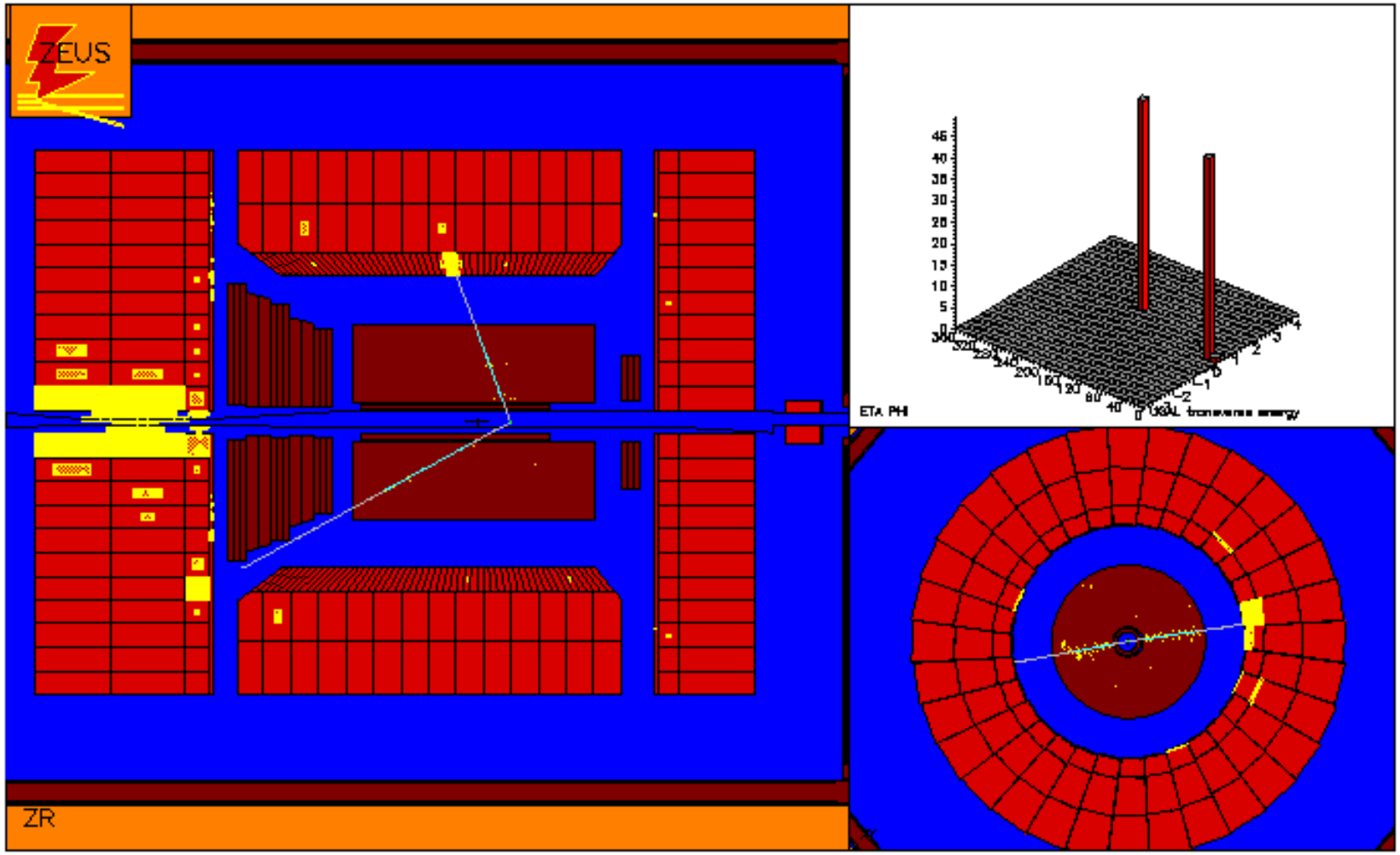
Good description of fake electrons: under control
Asking for a track greatly reduce the Compton component

Tracking efficiency control

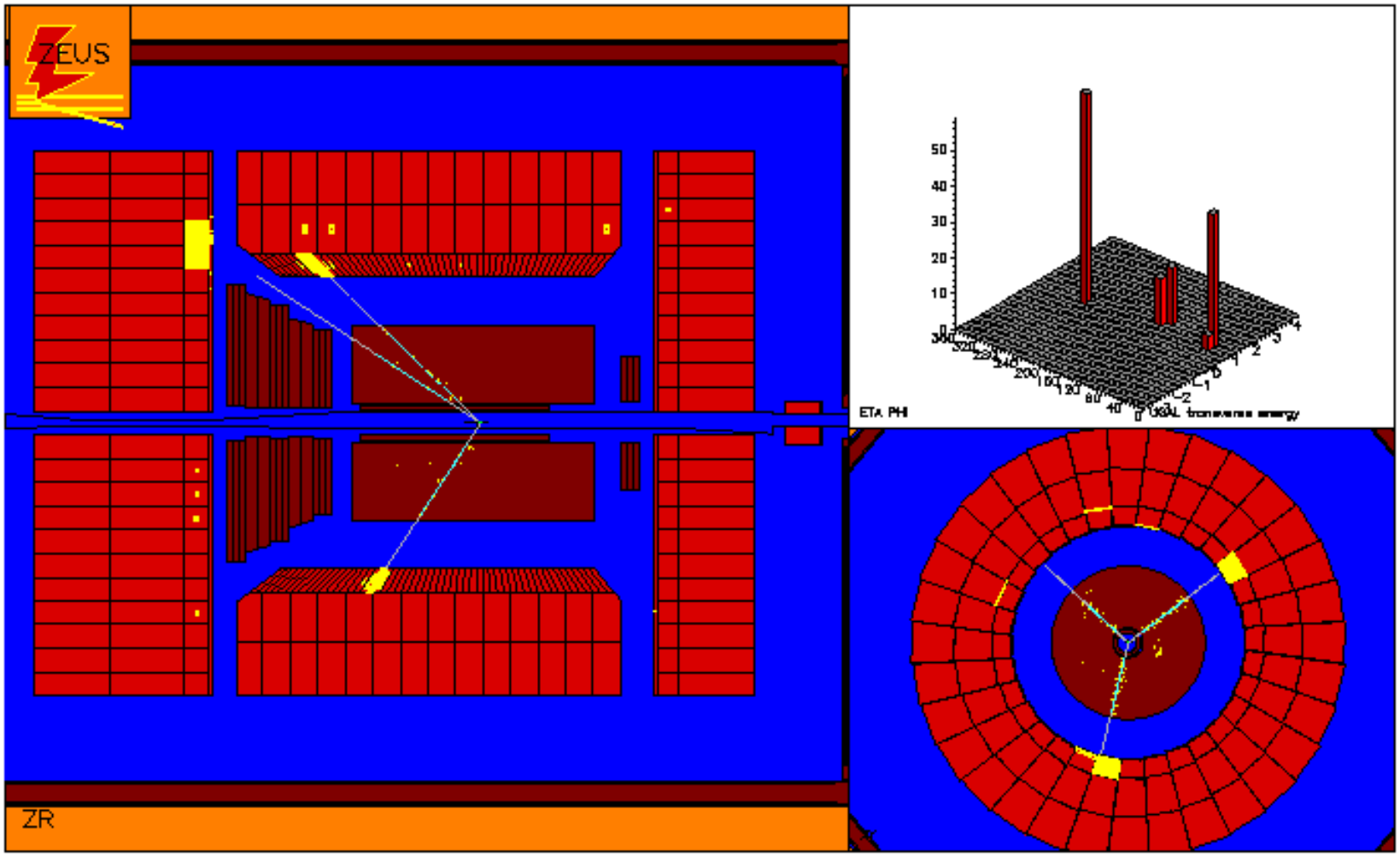
- Track requirement efficiency has been calculated from an inclusive NC-DIS sample



High Mass Events (ZEUS) M12=122 GeV

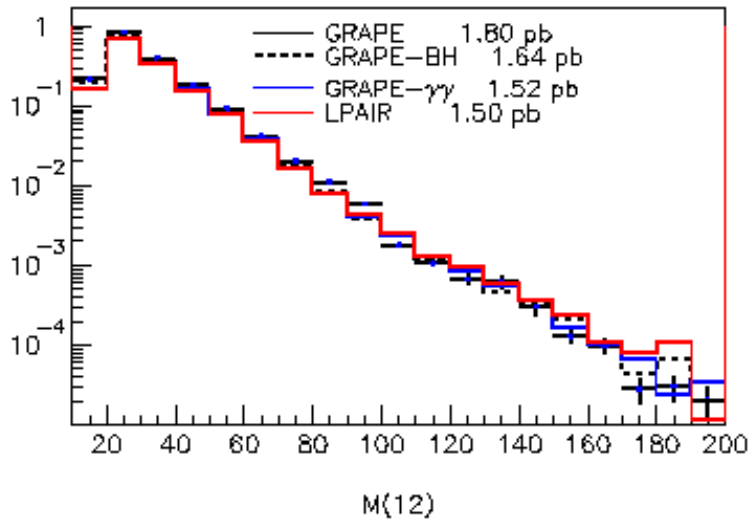


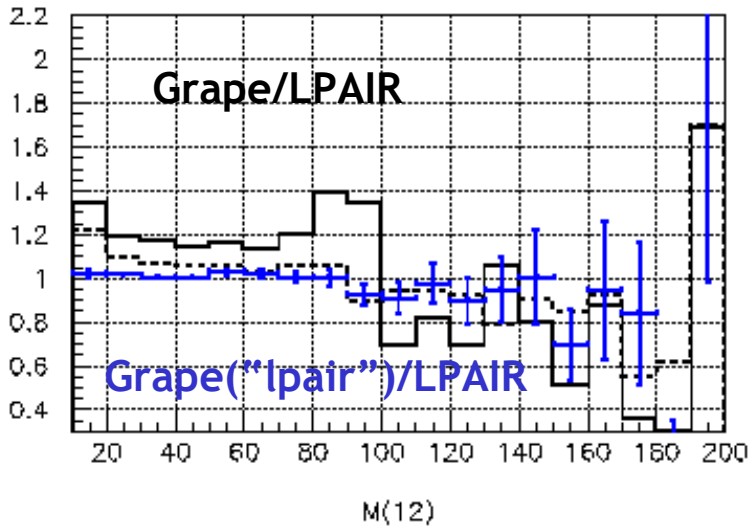
High Mass Event (ZEUS) M12=94 GeV



GRAPE/LPAIR comparison

- Grape: full EW diagrams
- Lpair: only $\gamma\gamma$
- Increase of ~20%
- $Z \rightarrow ee$ and $\gamma \rightarrow ee$ contributions





LPAIR: Vermaseren calculation based on peripheral diagrams only

H1 multi-e events

2/3 "2e" events have a third electron