European Physical Society
HEP 2007

Multileptons and H++ at HERA

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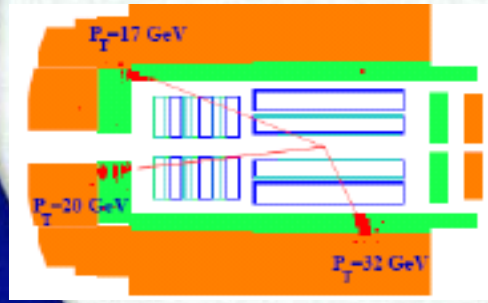
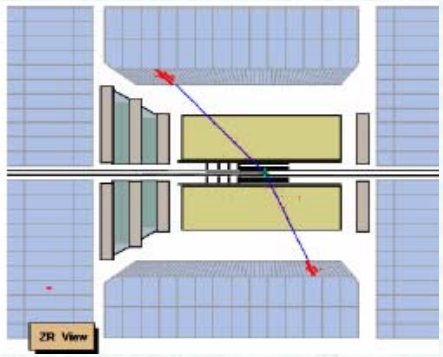
on behalf

and





Outlook:

- Introduction
- Multi-leptons at high-pt
- Search for doubly charged Higgs
- Summary

Presented results:

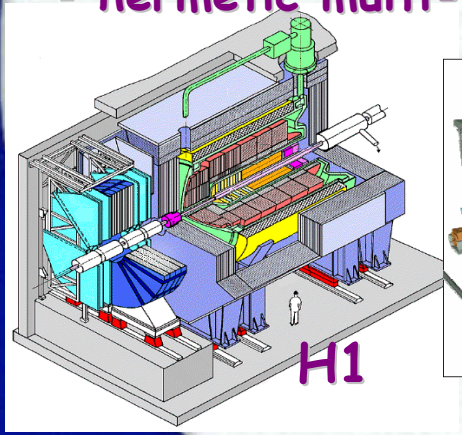
H1: H1prelim 07-062

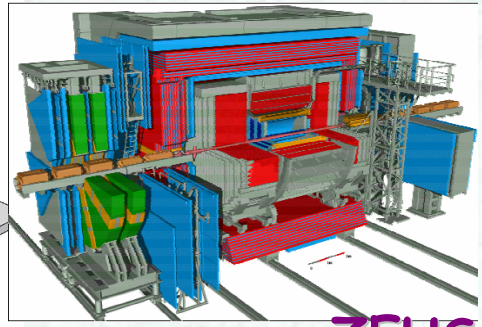
H1 Coll, Phys. Lett. B 638 (2006) 432

ZEUS: ZEUSprelim 2007

HERA experiments

- ep collision at H1 and ZEUS
- hermetic multi- purpose detectors





- HERA-I: 1992-2000 L~120 pb^{-1}/exp.
- HERA-II 2002-2007 L~350 pb-1/exp.
  - -Luminosity upgrade:
  - ~10x more e-p data than in HERA-I
  - -Longitudinally polarized lepton beam

Presented results:

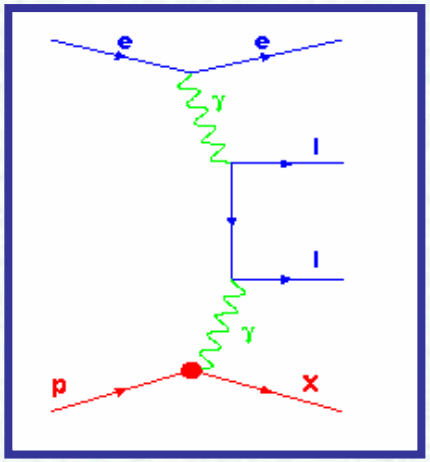
	H1	ZEUS
e+p	286 pb-1	272 pb-1
e-p	173 pb-1	206 pb-1
Total	459 pb-1	479 pb-1

Total luminosity ~ $1fb^{-1}$

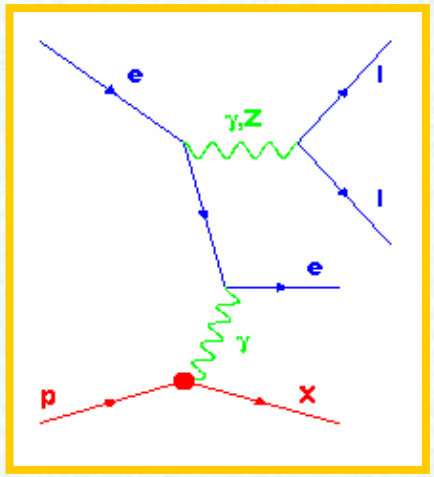
=> rear/new phenomena σ~1pb shoud be visible in HERA

Multi-lepton events at HERA

How are lepton pairs produced ?



γγ process dominant



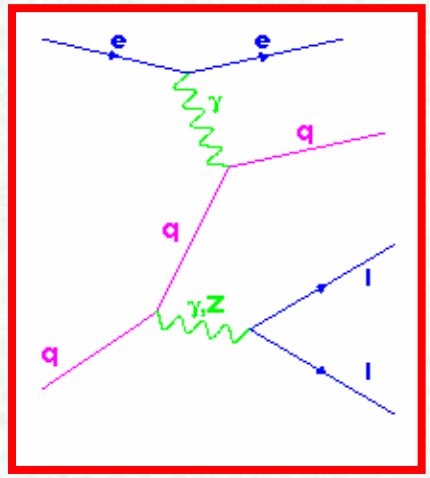
Cabbibo-Parisi

- ee -> ee

annihilation & Scattering

- ee -> μμ

annihilation



Drell-Yan negligible

Multi-lepton production is a QED process

-very well understood in the Standard Model

Any excess over SM prediction <u>at high mass region</u>
is sensitive to new phenomena (e.g. $H^{\pm\pm}$)

Multi-lepton events at high mass

Selection:

- Look for events with at least 2 high Pt leptons:
- $P_t^{l1} > 10$ and $P_t^{l2} > 5$ GeV and $20^\circ < \theta_l < 160^\circ$
- Additional lepton: Ee>5 GeV or $P_t^{\mu} > 2$GeV $(5^\circ < \theta_l < 175^\circ)$
- Covered topologies:

  * H1: ee, eμ, μμ and eee, eμμ
  * ZEUS: ee, eee

Dominant background:

- NC DIS: DIS e + fake electron
- QED Compton: γ misidentified as e

Invariant mass M_{ll}:

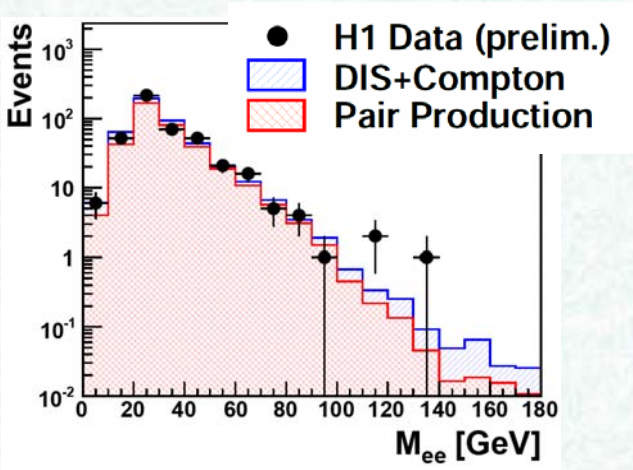
- Reconstructed using 2 highest Pt leptons

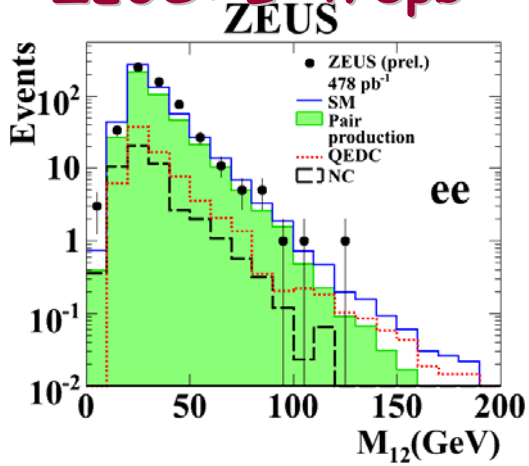
Multi-electron mass

H1: L= 459 pb^{-1}

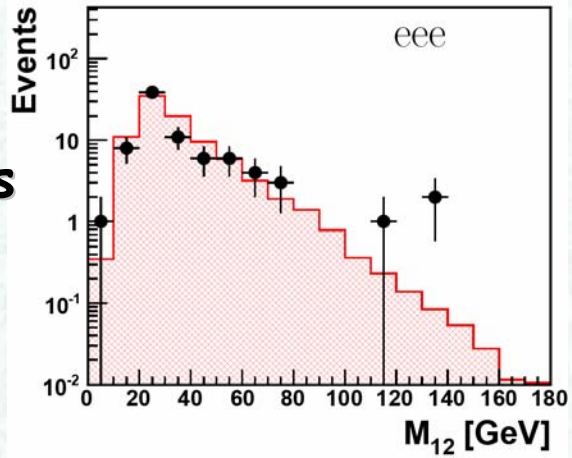
ZEUS: L=478pb^{-1}

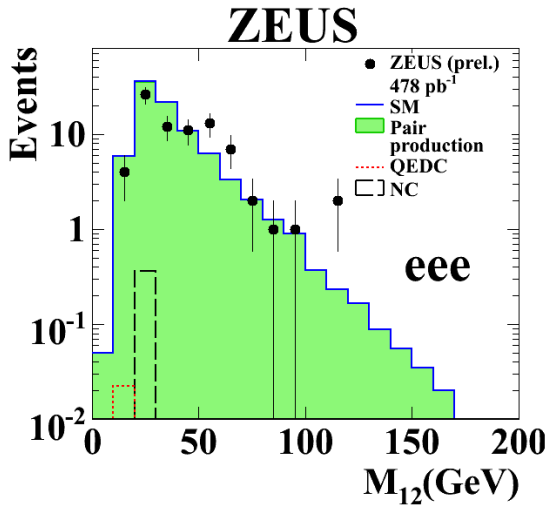
ee events





eee events

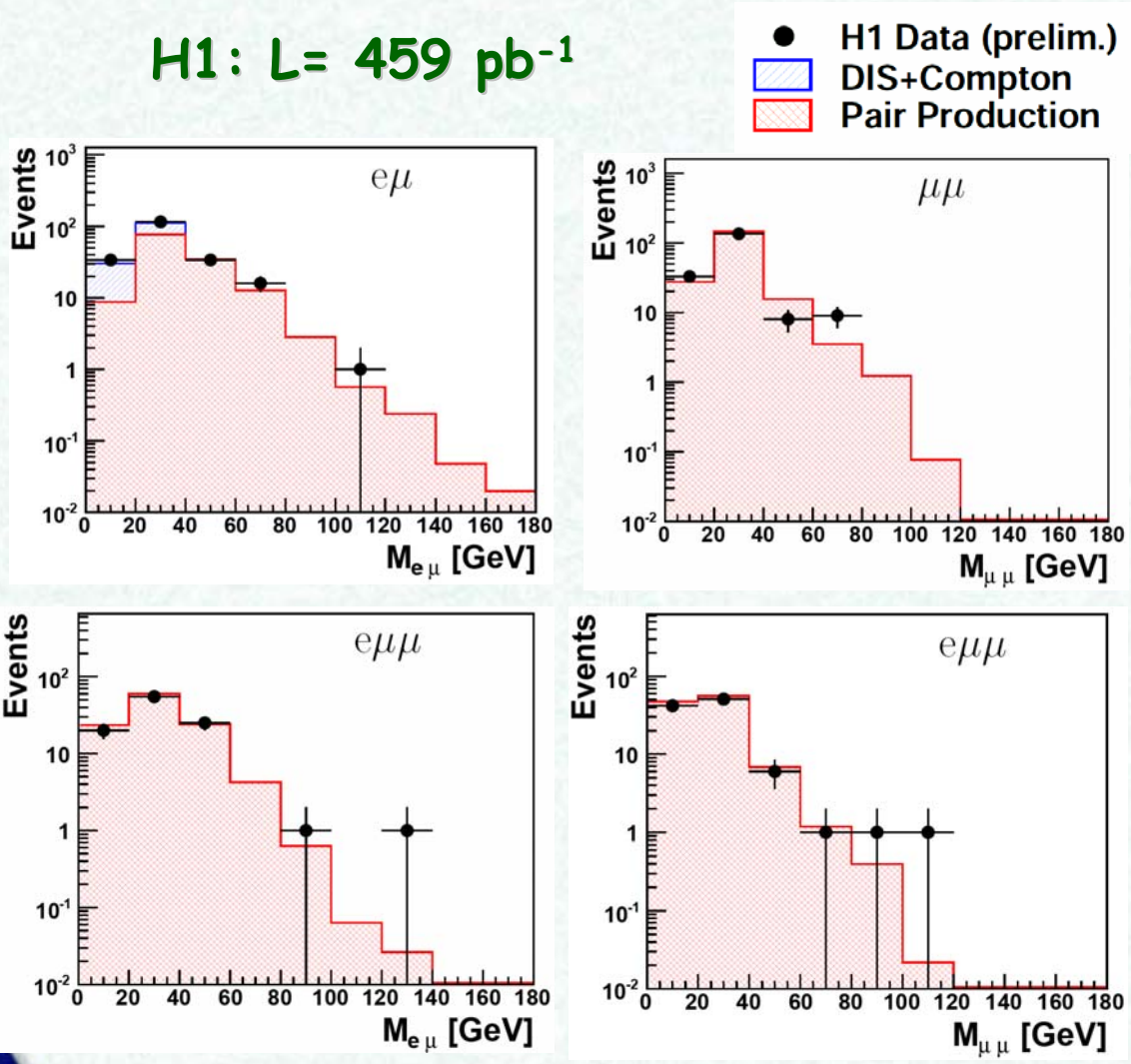




Overall good agreement with the Standard Model

Topologies with μ(s)

H1: L= 459 pb^{-1}



Di-lepton topology

Tri-lepton topology

Overall good agreement with the Standard Model

Event yields at high M_{ll} > 100 GeV

H1 Preliminary: L= 459 pb^{-1}

	Selection	Data	SM	Pair Production	NC-DIS + Compton
	e^+p collisions (286 pb^{-1})				
e$^+$p	ee M_{12} >100 GeV	3	1.0 ± 0.2	0.6 ± 0.2	0.4 ± 0.1
	$\mu\mu$ $M_{\mu\mu}$ >100 GeV	0	0.06 ± 0.03	0.06 ± 0.03	—
	eμ $M_{e\mu}$ >100 GeV	1	0.53 ± 0.05	0.53 ± 0.05	—
	eee M_{12} >100 GeV	3	0.6 ± 0.1	0.6 ± 0.1	—
	e$\mu\mu$ $M_{e\mu}$ >100 GeV	1	0.04 ± 0.02	0.04 ± 0.02	—
	e$\mu\mu$ $M_{\mu\mu}$ >100 GeV	1	0.007 ± 0.005	0.007 ± 0.005	—
	e^-p collisions (173 pb^{-1})				
e$^-$p	ee M_{12} >100 GeV	0	0.55 ± 0.1	0.3 ± 0.1	0.25 ± 0.07
	$\mu\mu$ $M_{\mu\mu}$ >100 GeV	0	0.03 ± 0.02	0.03 ± 0.02	—
	eμ $M_{e\mu}$ >100 GeV	0	0.3 ± 0.05	0.3 ± 0.05	—
	eee M_{12} >100 GeV	0	0.32 ± 0.06	0.32 ± 0.06	—
	e$\mu\mu$ $M_{e\mu}$ >100 GeV	0	0.04 ± 0.01	0.04 ± 0.01	—
	e$\mu\mu$ $M_{\mu\mu}$ >100 GeV	0	0.006 ± 0.004	0.006 ± 0.004	—

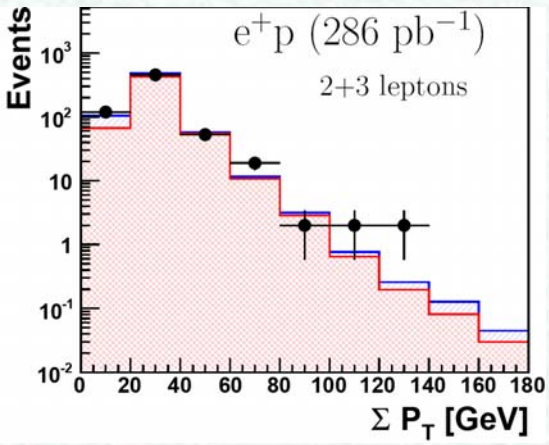
All high mass events M_{ll} > 100 GeV from e+p data

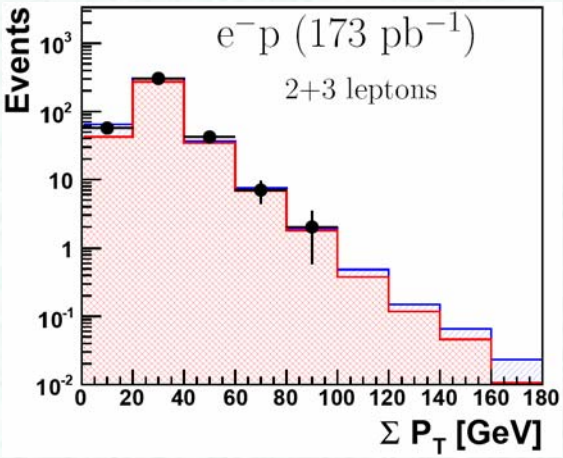
ZEUS Preliminary: e+p (L=272pb^{-1}) e+p (L=206pb^{-1})

	Data sample	Data	SM	Pair Production	Compton	NC DIS
e+p	ee	1	0.9 ± 0.1	0.5 ± 0.07	0.4 ± 0.12	0.07 ± 0.03
	eee	2	$0.6\ ^{+0.5}_{-0.07}$	0.6 ± 0.07	<0.01	< 0.5
e-p	ee	1	0.8 ± 0.08	0.4 ± 0.04	0.39 ± 0.10	0.04 ± 0.01
	eee	0	$0.4\ ^{+0.5}_{-0.05}$	0.4 ± 0.05	<0.01	< 0.5

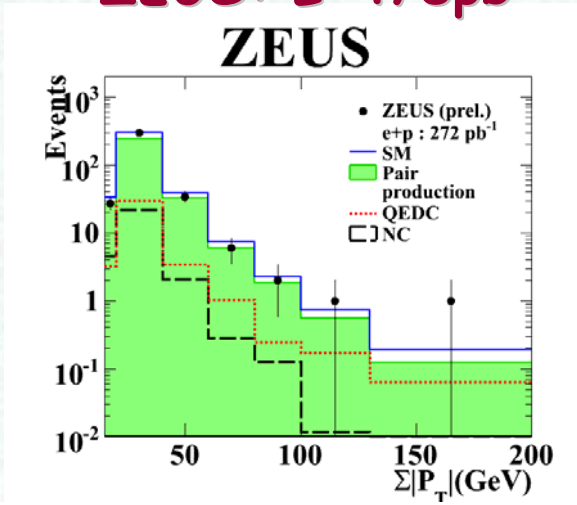
Multi-leptons: scalar ΣPt distribution

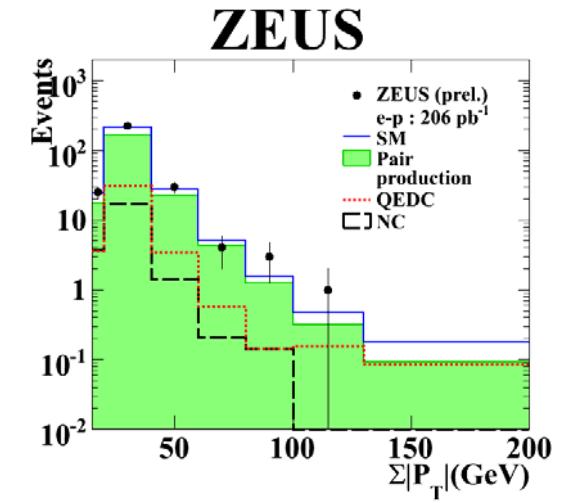
H1: L= 459 pb^{-1}





ZEUS: L=478pb^{-1}





Good agreement with SM

Event yields at scalar $\Sigma P_t > 100$ GeV

H1 Preliminary: L= 459 pb^{-1}

Data sample	Data	SM	Pair Production	NCDIS + Compton
e+p L=286pb	4	1.2 ± 0.2	1.0 ± 0.2	0.2 ± 0.1
e-p L=173pb	0	0.8 ± 0.2	0.6 ± 0.2	0.2 ± 0.1
All L=459pb	4	1.9 ± 0.4	1.5 ± 0.3	0.4 ± 0.1

H1:All events at high ΣPt come from e+p data

ZEUS Preliminary: L=478pb^{-1}

Data sample	Data	SM	Pair Production	Compton	NC DIS
e+p L=272pb	2	$0.93\ ^{+0.10}_{-0.09}$	0.67 ± 0.07	$0.23\ ^{+0.07}_{-0.06}$	0.02 ± 0.01
e-p L=206pb	1	$0.65\ ^{+0.08}_{-0.07}$	0.41 ± 0.04	$0.24\ ^{+0.07}_{-0.06}$	0.01 ± 0.01
All L=478pb	3	$1.58\ ^{+0.16}_{-0.12}$	1.08 ± 0.11	$0.47\ ^{+0.15}_{-0.11}$	0.03 ± 0.01

Search for doubly charged Higgs

In extension to SM:

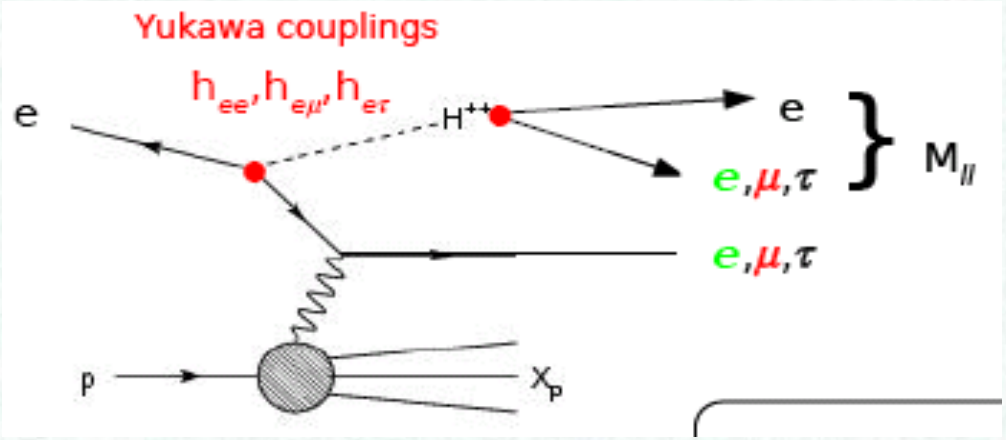
- $H^{\pm\pm}$ appears in Higgs triplet(s) of non-zero hypercharge
- Left-right symmetries: $SU(2)_R \times SU(2)_L \times U(1)_{B-L}$
- provides mass to Majorana neutrinos
- Couplings to leptons $h_{ll}^{R,L}$ unknown

  Democratic scenario: $h_{ee}=h_{e\mu}=h_{e\tau}$

  One dominant coupling $h_{el}>>0$, others ~0

HERA: $e^{\pm}p \rightarrow l^{\pm} H^{\pm\pm} X$

where $H^{\pm\pm} \rightarrow e^{\pm} l^{\pm}$



Double charged Higgs

Selection:

- ✓Data: HERA-I L=118 pb-1
- ✓ee, eμ: based on multi-lepton analysis
- ✓eτ with τ->e,μ and hadrons
- ✓ 2 high-Pt leptons with the same charge as a beam lepton
- ✓Reconstruct inv. mass Higgs candidates - M_{ll}

Results:

M_{ll}>65 GeV

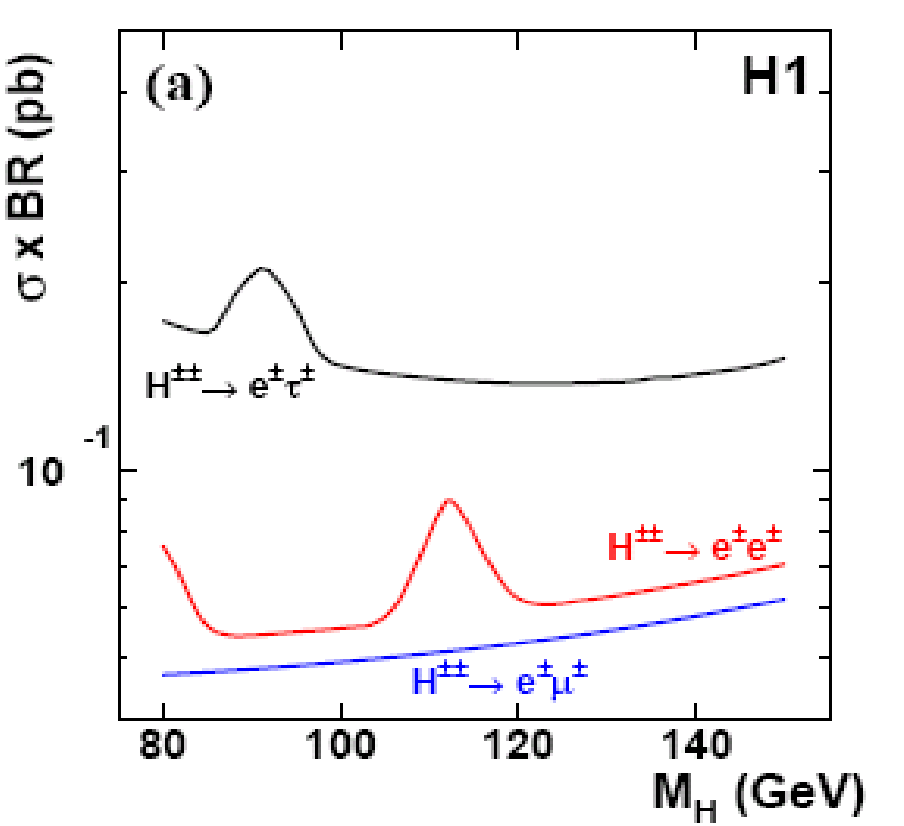
	Obs	SM exp.
ee	3	2.45 ±0.11
eμ	1	4.17± 0.44
eτ	1	2.1 ± 0.5

M_{ll}>100 GeV

Only one ee event satisfies the final selection createria

No evidence for $H^{\pm\pm}$ => set limits

Double charged Higgs: results



Upper limits for $H^{\pm\pm}$ production at 95%C.L. derived by modified frequentist method

$H^{\pm\pm} \rightarrow e^{\pm}\tau^{\pm}$

$H^{\pm\pm} \rightarrow e^{\pm}e^{\pm}$

$H^{\pm\pm} \rightarrow e^{\pm}\mu^{\pm}$

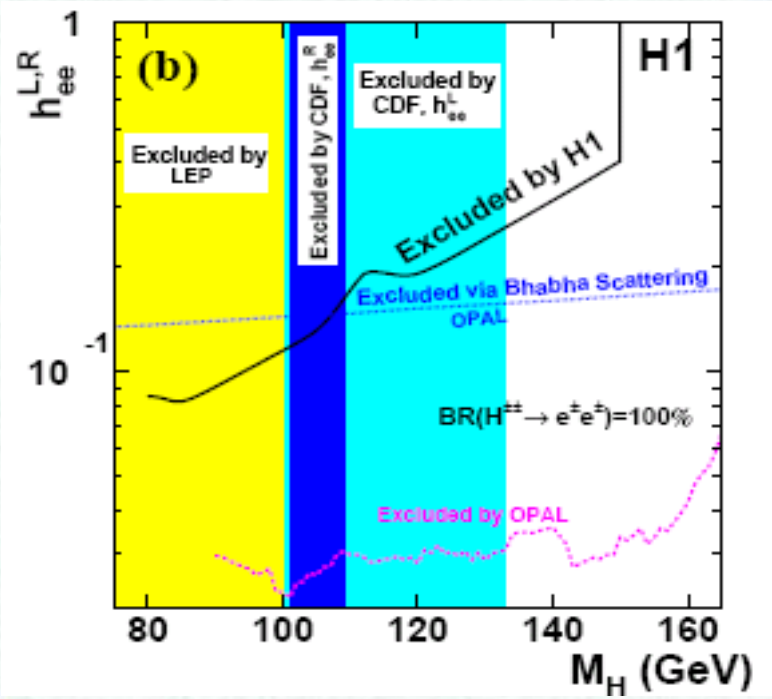
Best sensitivity:

$\sigma \times Br(h_{e\mu}) < 0.05$ pb

Double charged Higgs: upper limits on h_{ee}

$H^{\pm\pm}$ boson couples to electron-electron pair only

Topologies: ee and eee (excess was observed in HERA I data)



LEP, TeVatron:

-$H^{\pm\pm}$ Pair Production: h_{el} independent

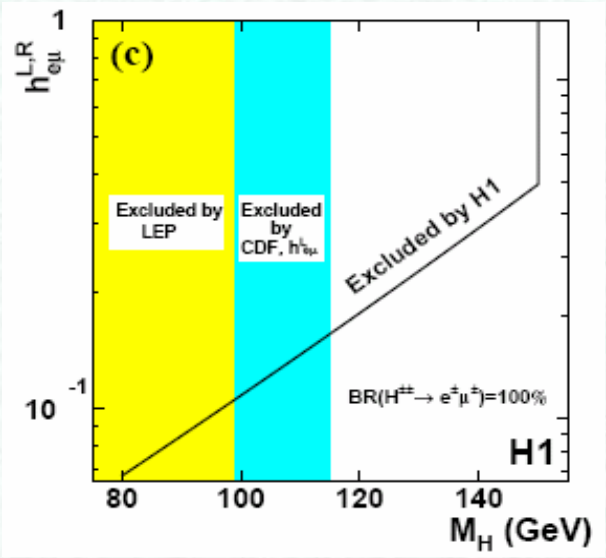
OPAL:

-$H^{\pm\pm}$ single production

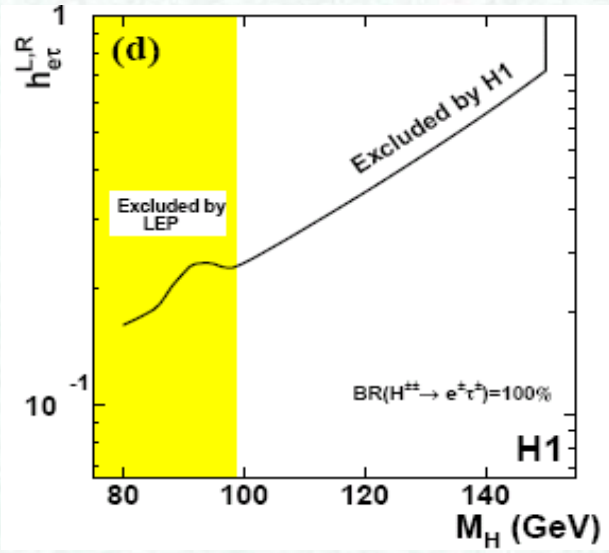
Limits are set for left- and right-handed $h_{e\mu}$ couplings

Doubly charged Higgs: upper limits on $h_{e\mu}$ and $h_{e\tau}$

- $H^{\pm\pm}$ boson couples to electron-muon pair only
- Topologies: $e\mu$ and $e\mu\mu$



- $H^{\pm\pm}$ boson couples to electron-tau pair only
- Topologies: $e\tau$ and $e\tau\tau$



For couplings of em. strength $h_{e\mu}$~0.3: mass exclusion $M_{H^{\pm\pm}} > 141$ GeV

$h_{e\tau}$~0.3: mass exclusion $M_{H^{\pm\pm}} > 112$ GeV

HERA limits extend beyond LEP, TeVatron reach

Summary

- **Multi-lepton production has been investigated in ep collision**
  - all HERA data were analysed by both ZEUS and H1 coll. (~1fb)
  - general good agreement with the SM prediction
  - Events at ΣE_t > 100 GeV:

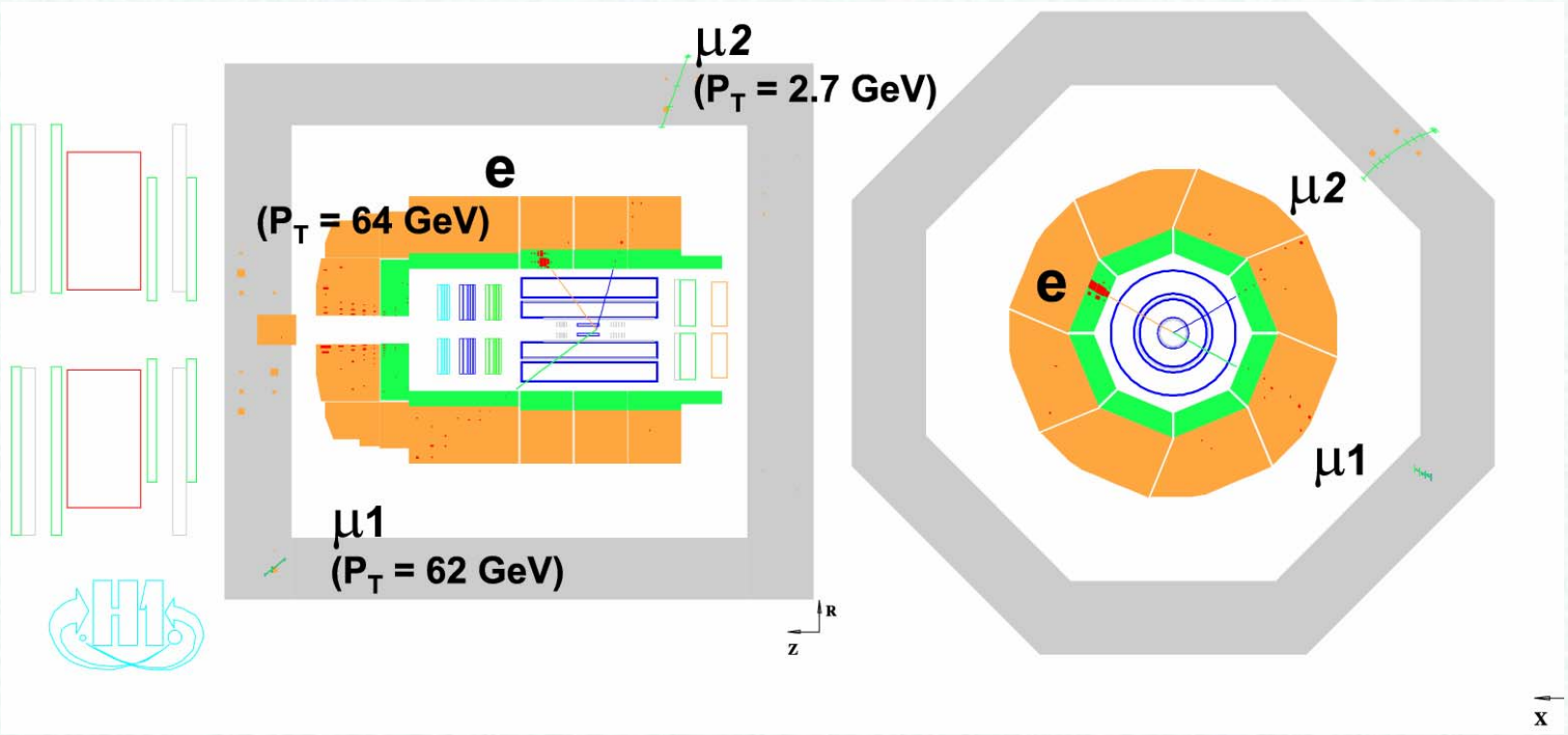
    H1: 4 observed where 1.9 is expected (all events in e+p collision)

    ZEUS: 3 observed where 1.6 is expected (2 in e+p and 1 in e-p collision)

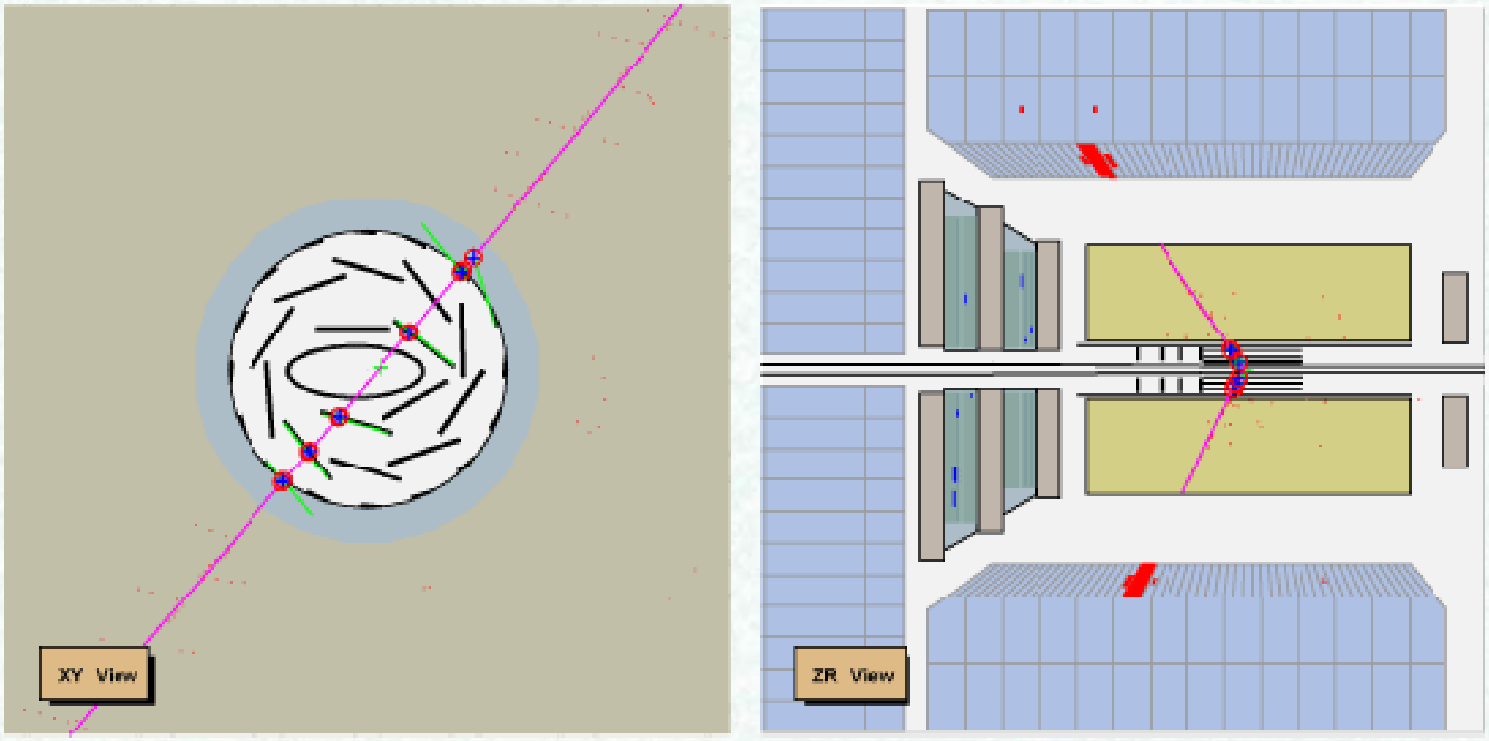
- **Exotic production of $H^{\pm\pm}$ has been studied by H1:**
  - All e, μ, τ topologies analysed
  - Constrains on the $H^{\pm\pm}$ production cross-section x Br were obtained
  - Limits were set on diagonal h_{ee} and non-diagonal couplings $h_{e\mu}$, $h_{e\tau}$
  - HERA limits extend beyond LEP and TeVatron reach

Backup slides

High mass events H1



High mass events ZEUS



Mass = 100.8 GeV, Pt^{e1} = 50.4 GeV, Pt^{e2} = 50.0 GeV,
θ_{e1} = 1.12(rad), θ_{e2} = 0.97(rad).

Multi-electrons: summary tables

H1 HERA-I+II (L=459pb^{-1}, preliminary)

H1 Multi-lepton analysis HERA I+II (459 pb^{-1}, preliminary)

Selection	Data	SM	Pair Production	NC-DIS + Compton
ee	446	450 ± 68	375 ± 42	75 ± 39
$\mu\mu$	185	194 ± 38	194 ± 38	—
eμ	201	194 ± 26	136 ± 13	58 ± 17
eee	81	90 ± 10	90 ± 10	—
e$\mu\mu$	102	112 ± 19	112 ± 19	—

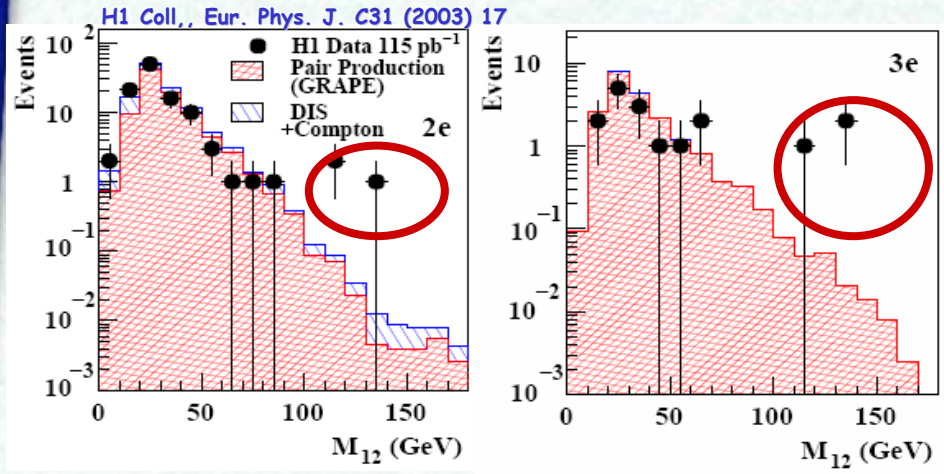
ZEUS HERA-I+II (L=478pb^{-1}, preliminary)

Type	DATA	SM	Pair production	QEDC	NC
2e	573	561±36.2	431.2±25	79.1±26.1	50.6±4.6
3e	79	88.8±5.7	88.4±5.7	0.02±0.01	0.4±0.01
2e+3e	652	649.7±36.4	519.6±25.6	79.1±26.1	51.0±4.6

Motivation

➢H1 results for ee and eee channels (HERA-I data)

Distribution of inv. Mass of 2 highest Pt electrons

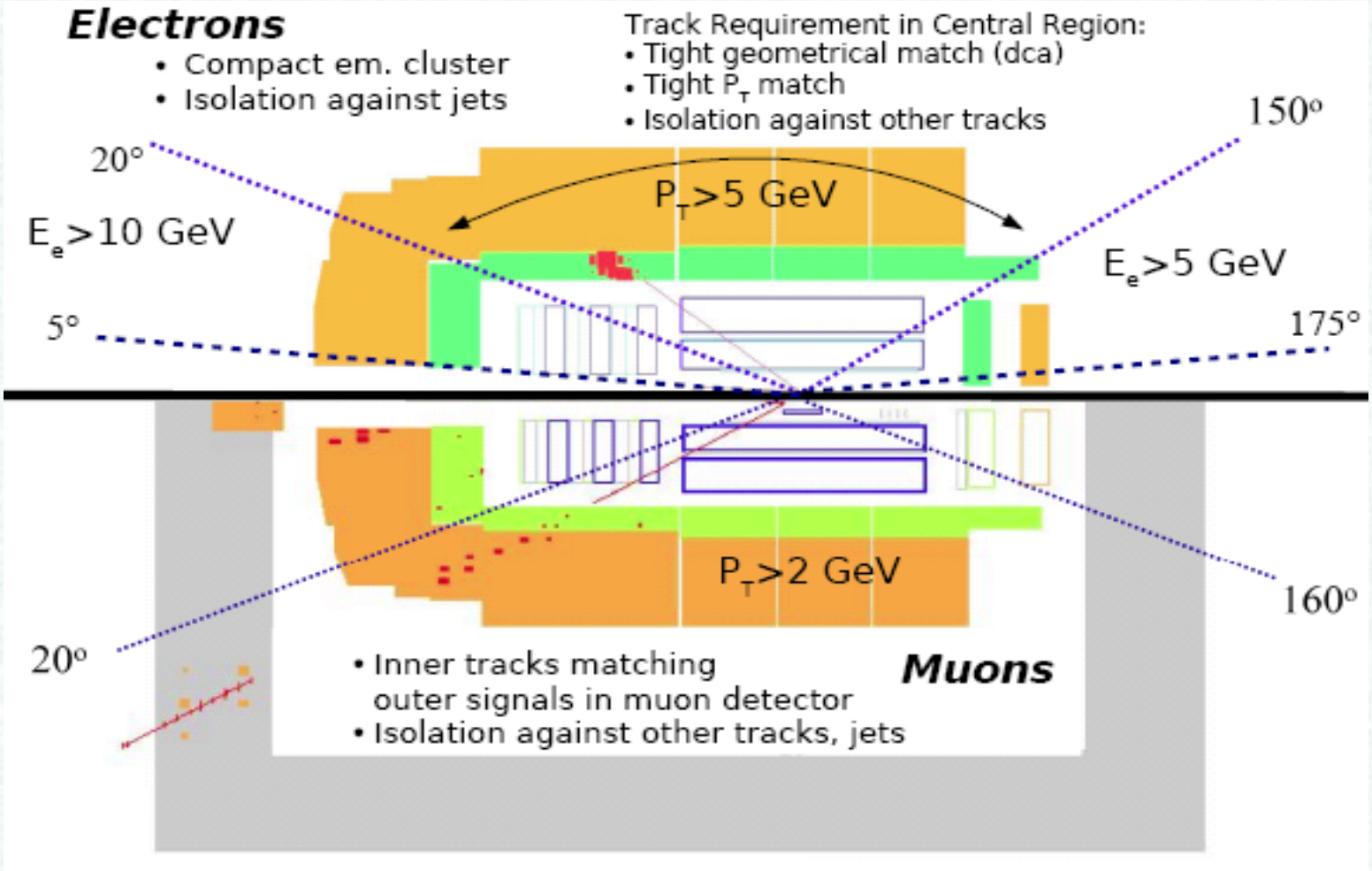


- General good agreement with SM
- Interesting events at Mee >100 GeV

Selection	Data	SM	Pair Production (GRAPE)	DIS + Compton
"2e" $M_{12} > 100$ GeV	3	0.30 ± 0.04	0.21 ± 0.03	0.09 ± 0.02
"3e" $M_{12} > 100$ GeV	3	0.23 ± 0.04	0.23 ± 0.03	< 0.02 (95% C.L.)

$H^{\pm\pm}$ production?

Event Selection H1



Event Selection ZEUS

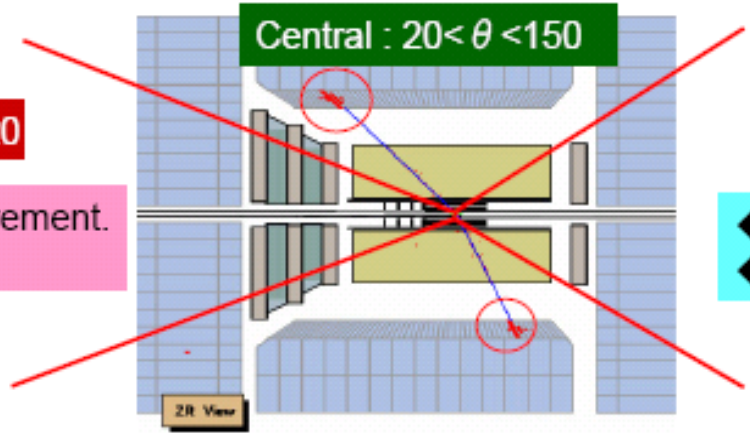
◆Require 2 or more EM-clusters in CAL.
◆Track match : Ptrk>3GeV, DCA<8cm
◆E_e >10GeV

◆Prim fitted track ←new
◆MVD hit : r+z >=2 ←new
◆Track Isolation : Imppar<2cm ←new

Central : 20< θ <150

Forward : 5< θ <20

◆No track requirement.
◆E_e >10GeV



Rear : 150< θ <175

◆No track requirement.
◆E_e >5GeV

◆For central electron:
–Pt>10GeV : 1st electron.
–Pt>5GeV : 2nd electron.

◆Geometry cuts:
–Super crack cut
–RCAL radius cut
–Chimney cut