

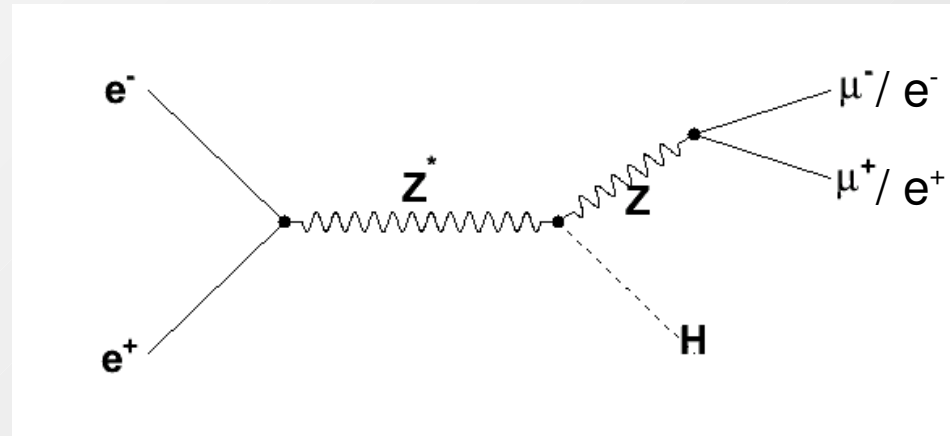
# *Study of ZH recoil mass*

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## Introduction

### ▪ Motivation of recoil mass study

- $e^+e^- \rightarrow ZH \rightarrow l^+l^- X$  is the golden channel for measurement of Higgs mass and coupling of ZH.
- This mode is useful for the detector optimization.



### ▪ Today's topic

- Reconstruction of recoil mass distribution.
- Estimation of the measurement accuracy for the ZH cross section and Higgs mass.

## Simulation setup

### Setup

- Full-simulator : Jupiter
  - detector : GLD, GLD' and J4LDC
    - ✓ J4LDC : LDC like geometry in Jupiter.
- Reconstruction : MarlinReco (event reconstruction)
  - LCIO-file is converted to ROOT-file by the interface program.
- Analysis : ROOT

### Detector geometry

		GLD	GLD'	J4LDC
VTX	Rin (mm)	17.50	1.60	1.50
	Rout (mm)	60.00	60.00	60.00
TPC	Rin(m)	0.40	0.40	0.30
	Rout(m)	2.06	1.80	1.58
	Zmax(m)	2.60	2.35	2.16
B-Field(T)		3.00	3.50	4.00

## Data sample

- CM energy : 250 GeV
- Initial beam energy spread :
  - gauss distribution ( $\sigma(e^-)=0.28\%$ ,  $\sigma(e^+)=0.18\%$ )
  - Previous study (TILC08) : uniform distribution ( $\sigma(\Delta E/E)=0.05\%$ )
- signal :  $ee \rightarrow ZH \rightarrow ee/\mu\mu X$ 
  - Luminosity :  $670 \text{ fb}^{-1}$  (5000 events)
- B.G. :  $ee \rightarrow ZZ \rightarrow ee/\mu\mu qq$ 
  - Luminosity :  $252 \text{ fb}^{-1}$  (20000 events)

**The number of events are scaled to  $250\text{fb}^{-1}$ .**

## Analysis outline

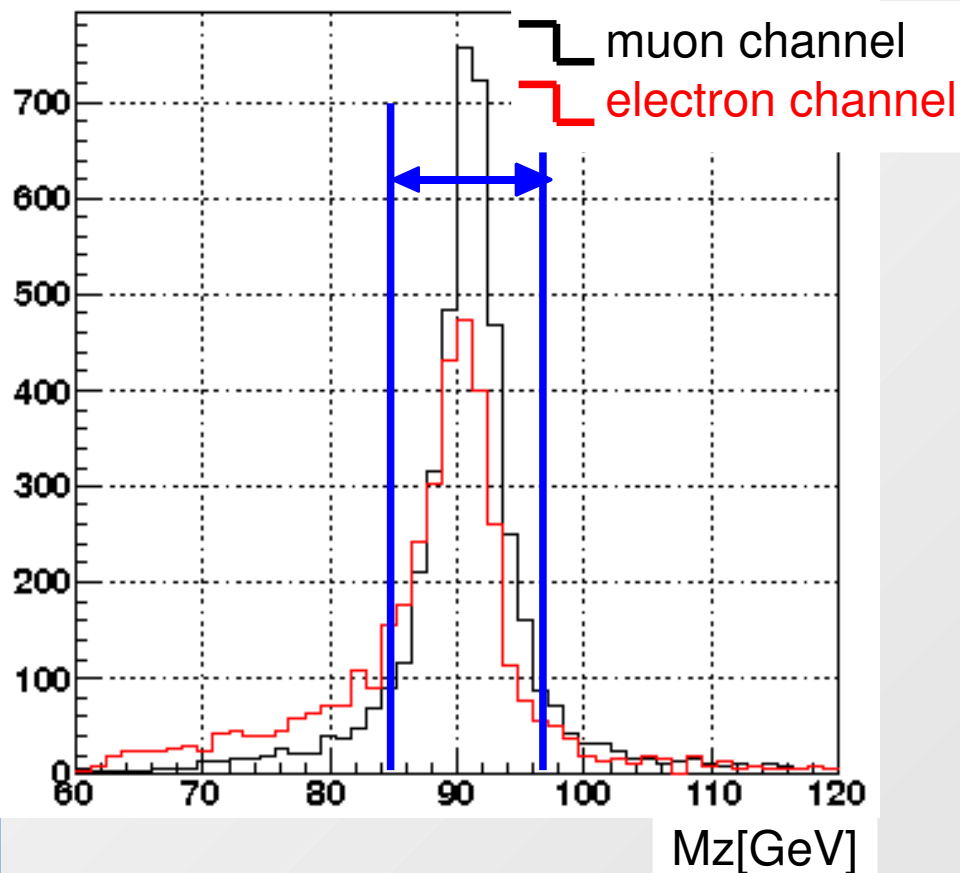
1. Selection of 2 lepton tracks from Z.
  - Two tracks with the highest energy were selected.
2. Selection of well-reconstructed events.
3. Reconstruction of Higgs recoil mass.
4. Estimation of measurement accuracy for  $\sigma(\text{ZH})$  and  $M_{\text{H}}$ .

**The selection of well-reconstructed events are shown.**

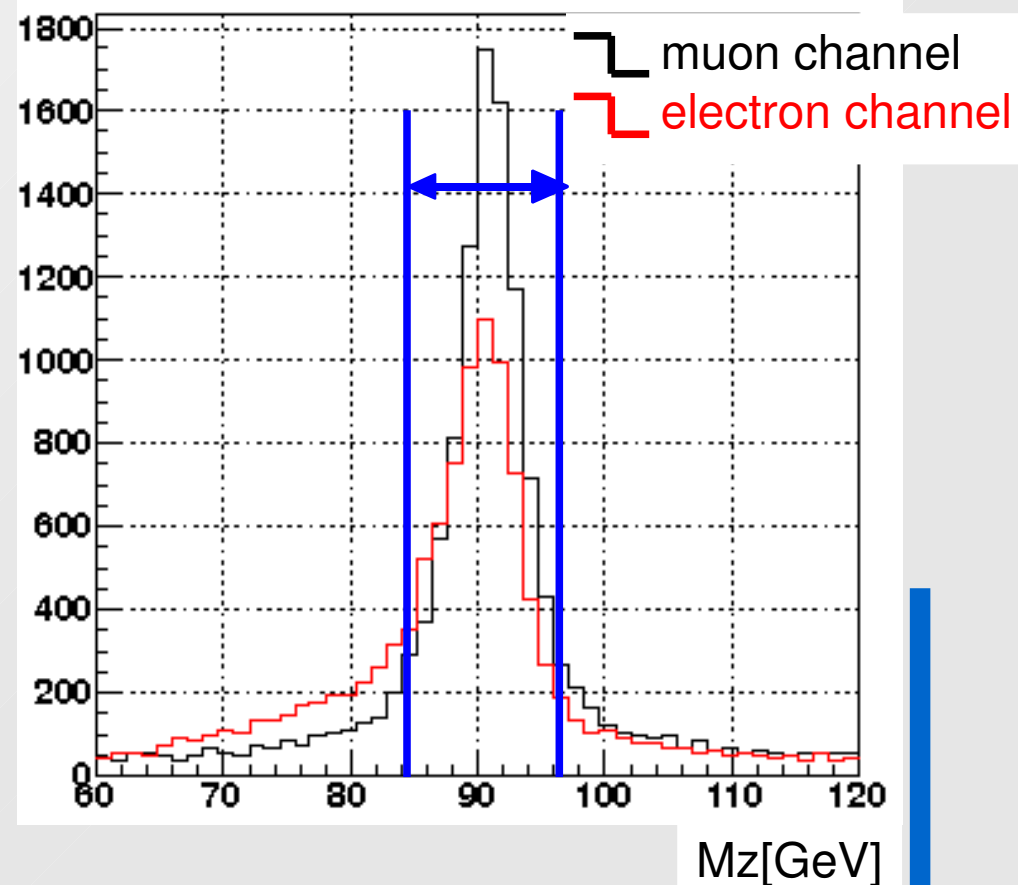
## Reconstructed $M_z$ cut

- $M_z$  is reconstructed with the selected two lepton tracks.
- Events with  $M_z$  of 85-97 GeV are selected.
  - The cut corresponds to 3 sigma range of the distributions.

GLD' : ZH  $\rightarrow$  ee/ $\mu\mu$  X

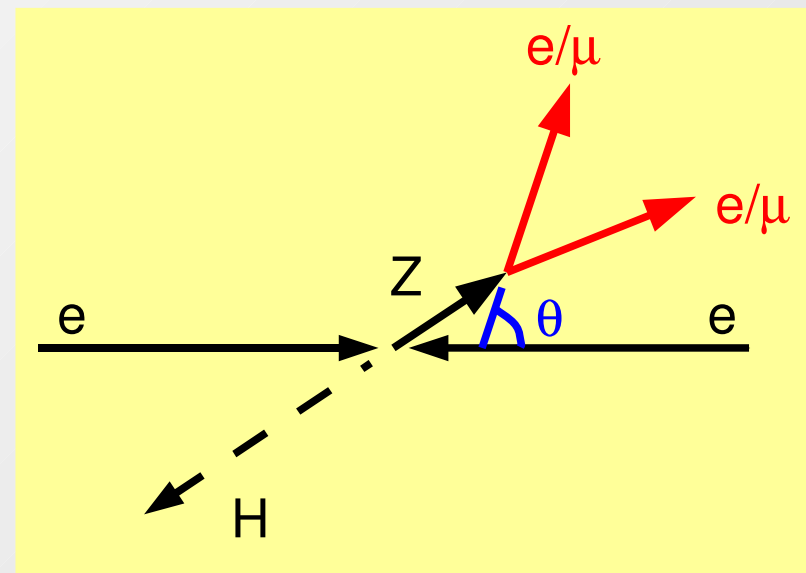


GLD' : ZZ  $\rightarrow$  ee/ $\mu\mu$  qq

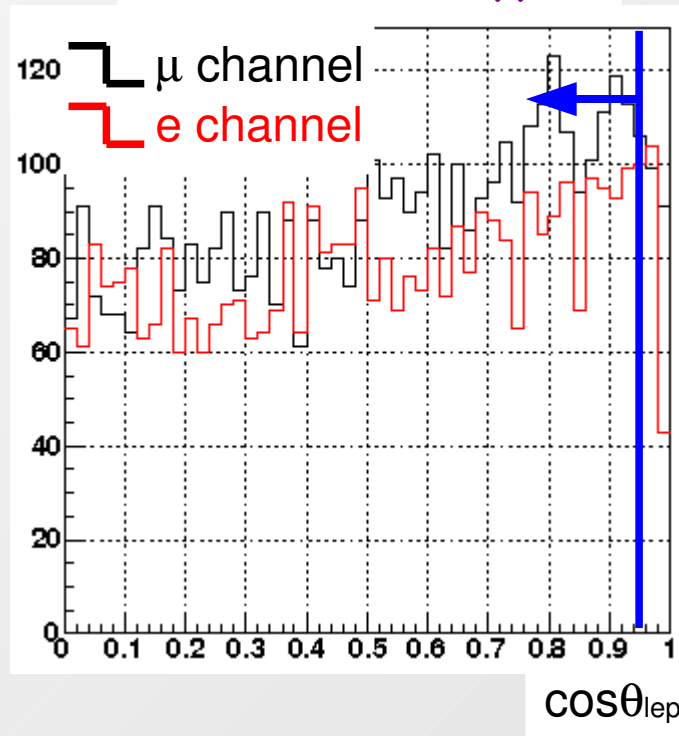


## Track angle cut

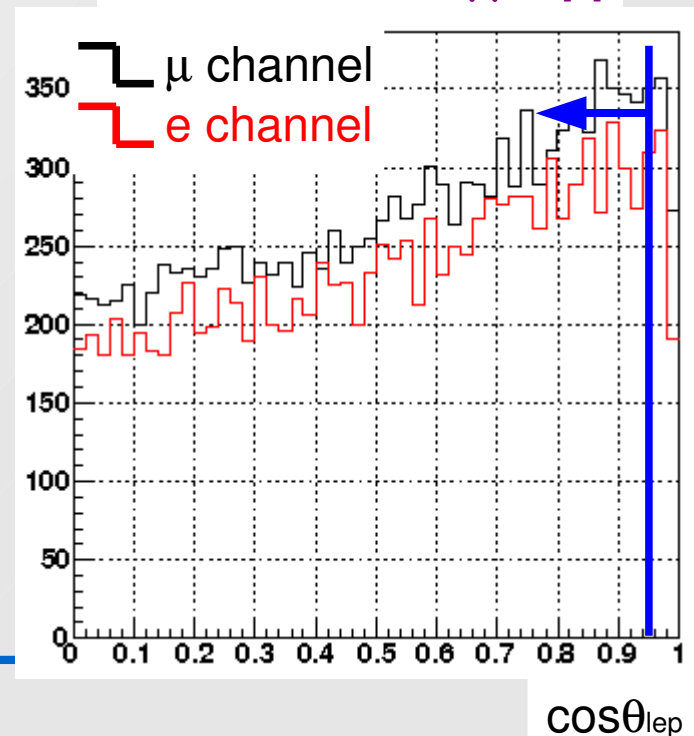
- The angular cut is applied to two lepton tracks for selection of well reconstructed tracks.
  - TPC coverage :  $|\cos\theta| < 0.98$
  - The track angle is required to be  $|\cos\theta_{lep}| < 0.95$



GLD' : ZH  $\rightarrow$  ee/ $\mu\mu$  X



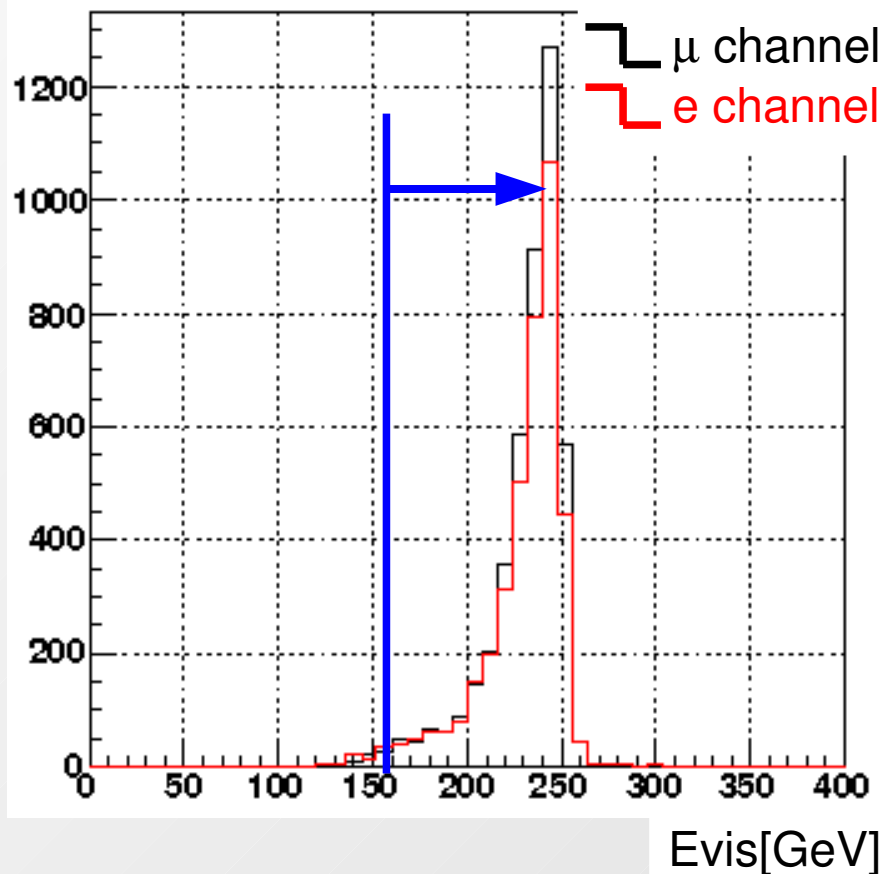
GLD' : ZZ  $\rightarrow$  ee/ $\mu\mu$  qq



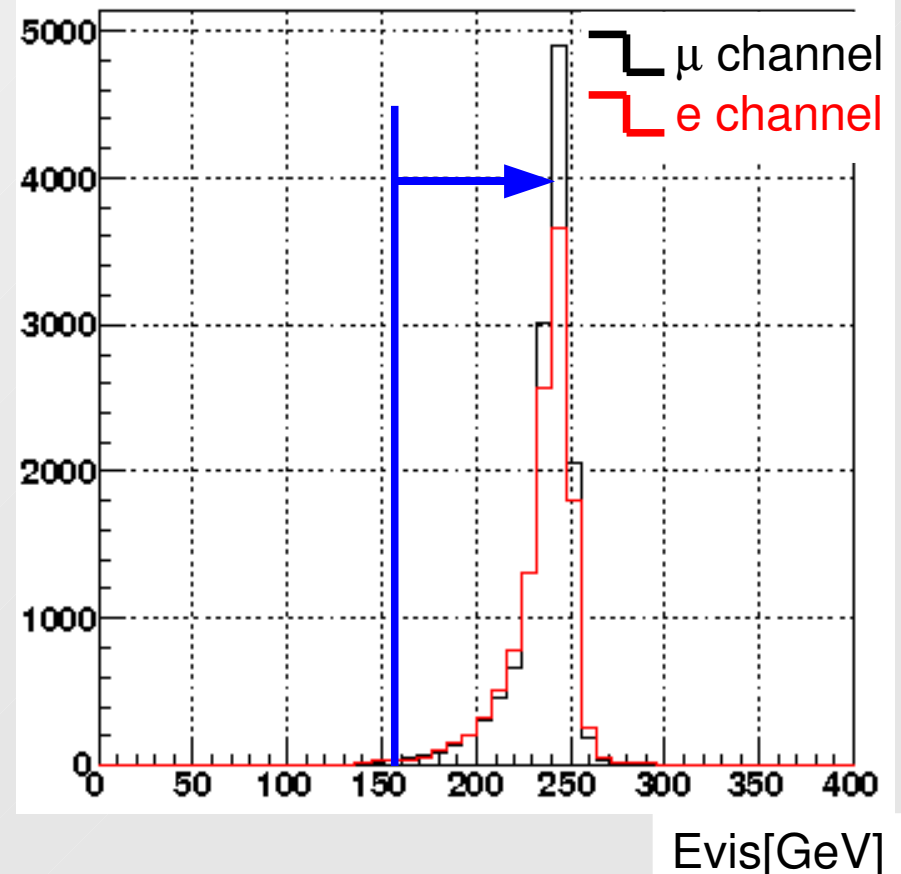
## Cut for total energy deposit

- The total energy deposit in the calorimeter was checked.
- The event of total energy above 160 GeV is selected.
  - ♦  $E_{\text{CM}} - M_z \sim 160 \text{ GeV}$

GLD' : ZH  $\rightarrow$  ee/ $\mu\mu$  X



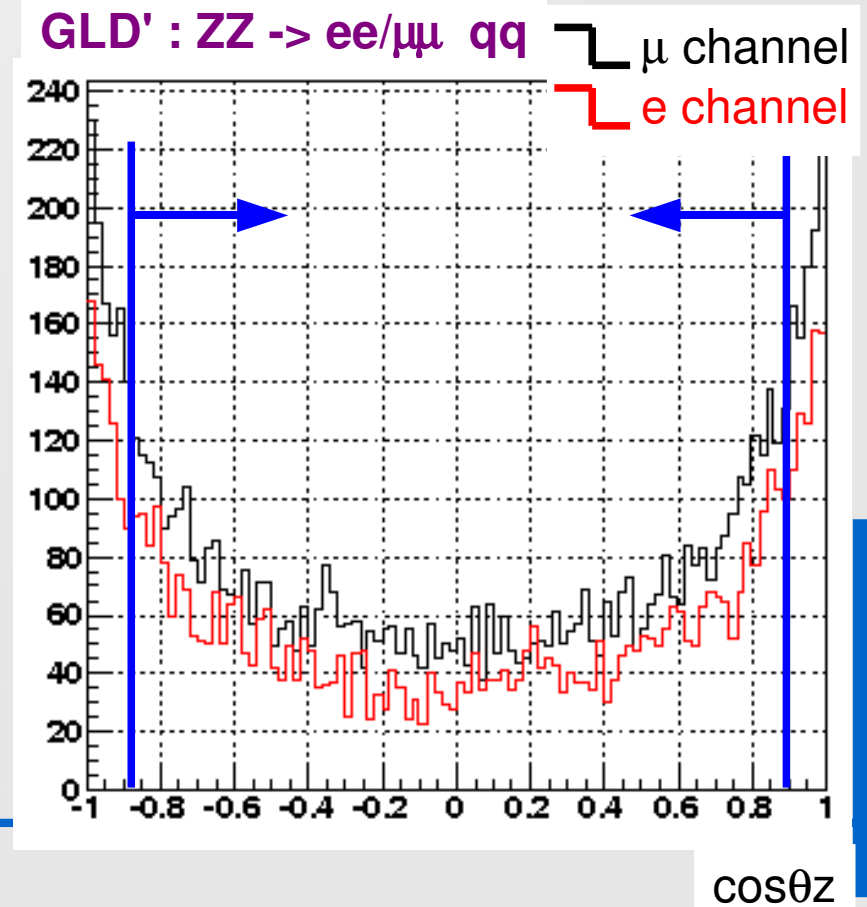
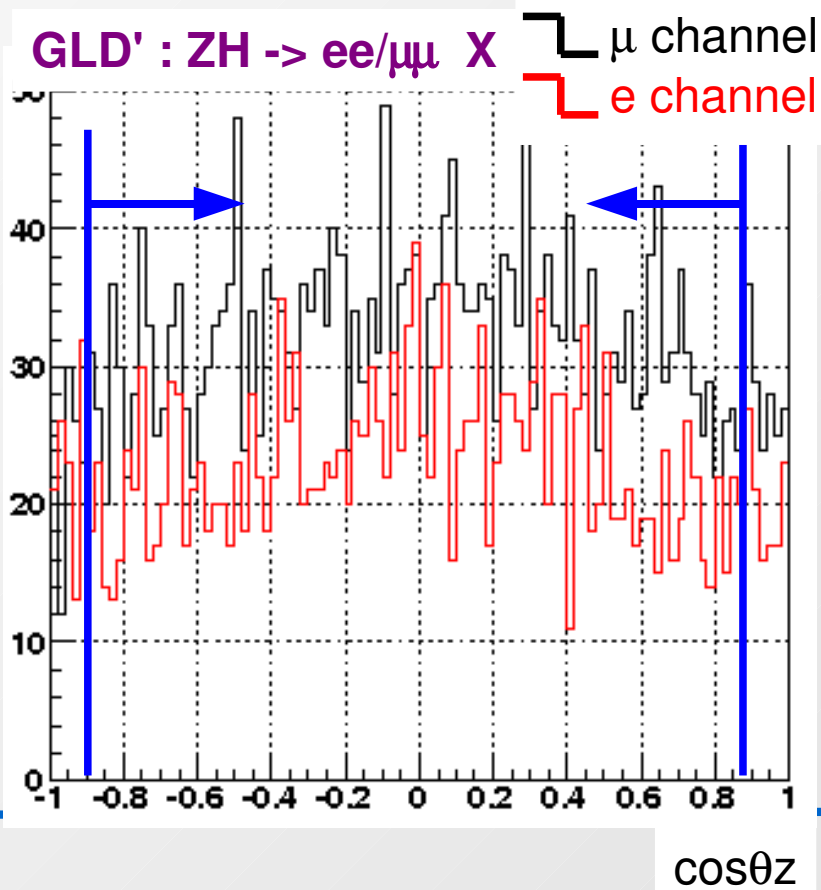
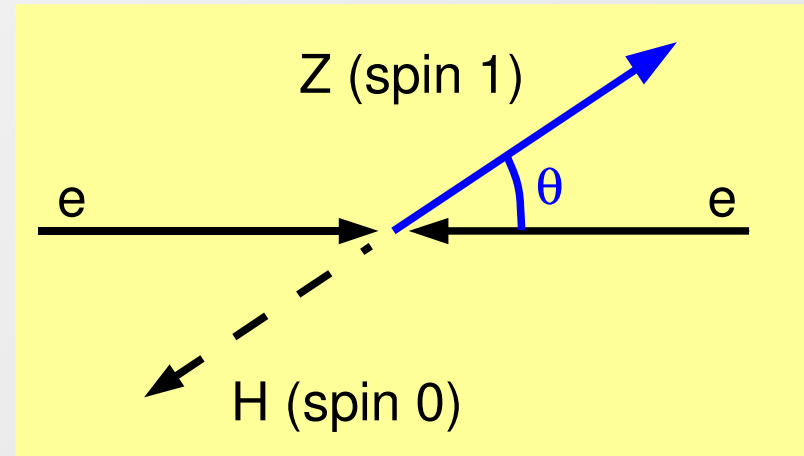
GLD' : ZZ  $\rightarrow$  ee/ $\mu\mu$  qq





## Z production angle cut

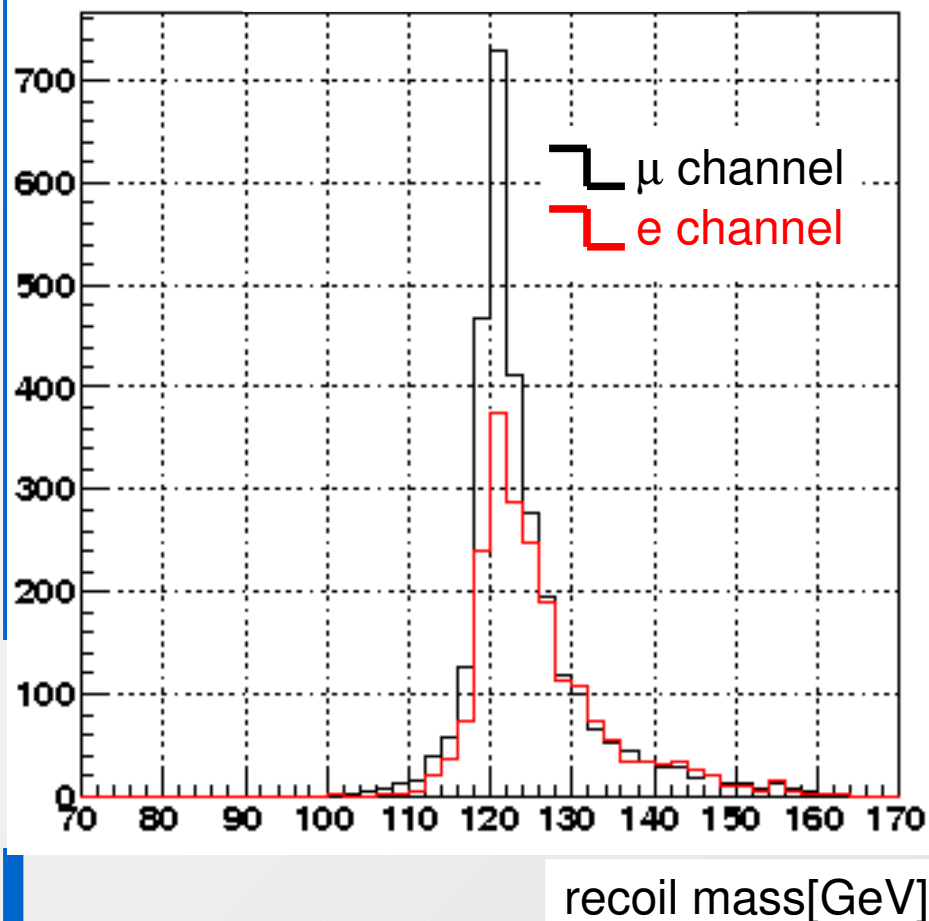
- **The Z production angle cut is applied.**
  - The events is the range of  $|\cos\theta_z| < 0.9$  are selected.
  - This cut position is tentative.



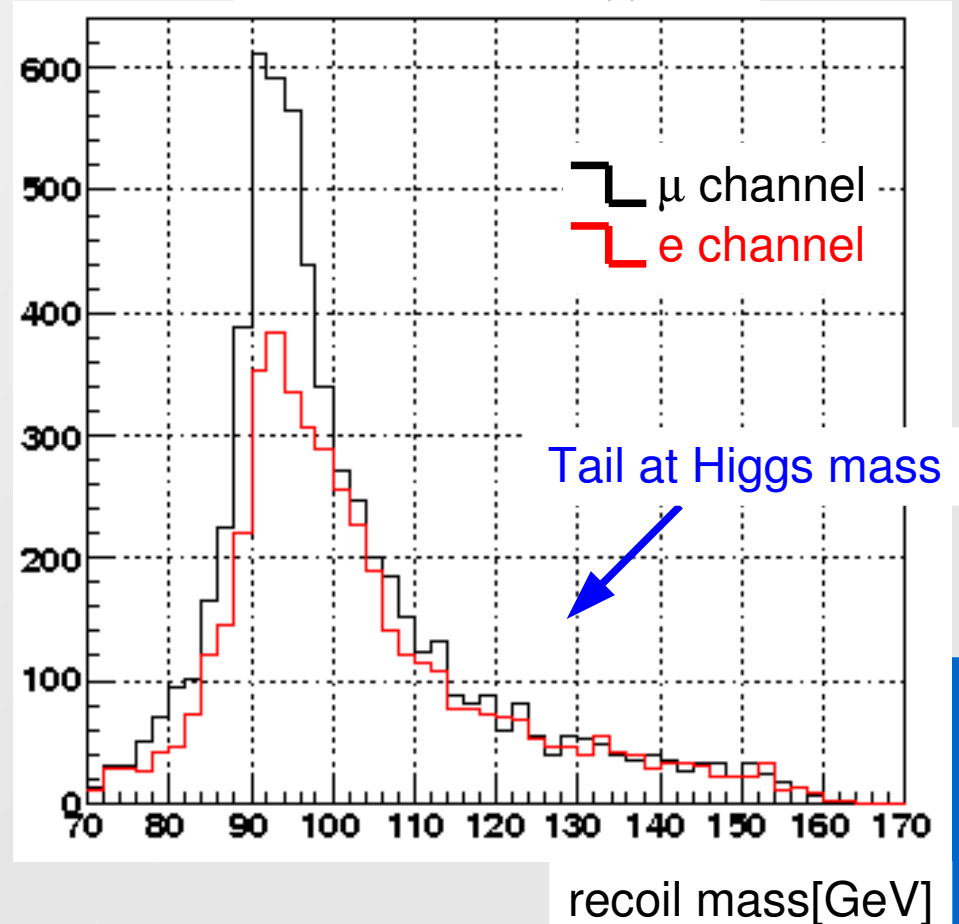
## Reconstructed recoil mass

- **The recoil mass is reconstructed after all the cuts.**
  - ♦ A peak is observed at 120GeV for signal events.
  - ♦ There is a tail from B.G. at Higgs mass.

GLD' : ZH  $\rightarrow$  ee/ $\mu\mu$  X



GLD' : ZZ  $\rightarrow$  ee/ $\mu\mu$  qq



## Reduction summary of electron channel

- The reduction rate of electron channel is summarized for each cut.

ZH -> eeX	GLD	GLD pirme	J4LDC
No cut	5000	5000	5000
2 tracks from Z	3949(79.0%)	3904(78.1%)	3939(78.8%)
85<Mz<97	2594(51.9%)	2559(51.2%)	2626(52.5%)
cos $\theta_{lep} < 0.95$	2350(47.0%)	2325(46.5%)	2379(47.6%)
Evis > 160GeV	2295(45.9%)	2280(45.6%)	2340(46.8%)
cos $\theta_z < 0.9$	2082(41.6%)	2071(41.4%)	2128(42.6%)

ZZ -> ee qq	GLD	GLD pirme	J4LDC
No cut	53000	53000	52340
2 tracks from Z	31530(59.5%)	31583(59.6%)	30903(59.8%)
85<Mz<97	17548(33.1%)	17805(33.6%)	17460(33.8%)
cos $\theta_{lep} < 0.95$	16014(30.2%)	16324(30.8%)	15976(30.9%)
Evis > 160GeV	15974(30.1%)	16300(30.8%)	15947(30.9%)
cos $\theta_z < 0.9$	12368(23.3%)	12598(23.8%)	12289(23.8%)

**Signal acceptance : ~42%**  
**B.G. acceptance : ~24%**

## Reduction summary of muon channel

- The reduction rate of muon channel is summarized for each cut.

ZH -> mmH	GLD	GLD pirme	J4LDC
No cut	5000	5000	5000
2 tracks from Z	4470(89.4%)	4472(89.4%)	4436(88.7%)
85<Mz<97	3581(71.6%)	3584(71.7%)	3575(71.5%)
cos $\theta_{lep} < 0.95$	3203(64.1%)	3214(64.3%)	3204(64.1%)
Evis > 160GeV	3154(63.1%)	3170(63.4%)	3158(63.2%)
cos $\theta_z < 0.9$	2891(57.8%)	2921(58.4%)	2898(58.0%)

ZZ -> mmqq	GLD	GLD pirme	J4LDC
No cut	53000	53000	52340
2 tracks from Z	35876(67.7%)	35640(67.2%)	34626(67.0%)
85<Mz<97	23866(45.0%)	23892(45.1%)	23280(45.0%)
cos $\theta_{lep} < 0.95$	21563(40.7%)	21627(40.8%)	20998(40.6%)
Evis > 160GeV	21529(40.6%)	21587(40.7%)	20969(40.6)
cos $\theta_z < 0.9$	16658(31.4%)	16610(31.3%)	16212(31.4)

**Signal acceptance : ~58%**  
**B.G. acceptance : ~31%**

## Fitting result

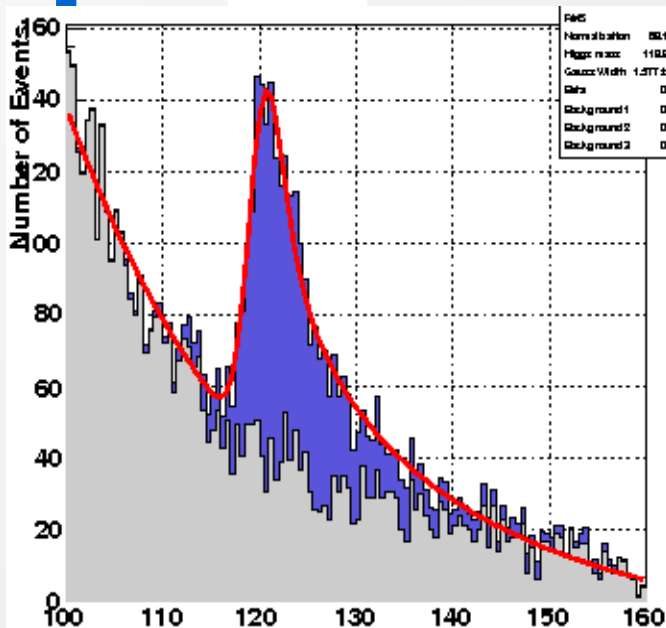
- The distribution of the recoil mass is fitted by the empirical function:

$$F(m) = N_H \int F_H(m, t) e^{\frac{-t^2}{2\sigma^2}} dt + F_Z(m)$$

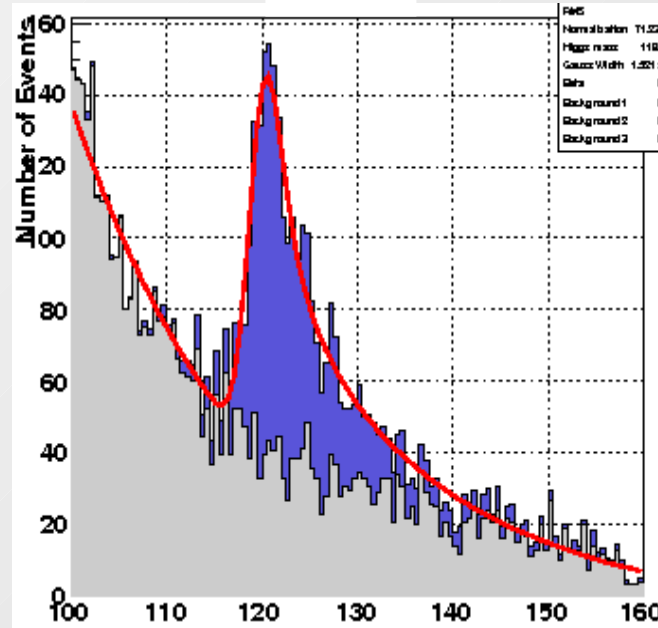
$$F_H(m, t) = \left( \frac{m+t-M_h}{\sqrt{s}-M_h} \right)^{2\alpha}$$

$$\beta = \frac{2\alpha}{2\pi \log \sqrt{s}/m_e - 1}$$

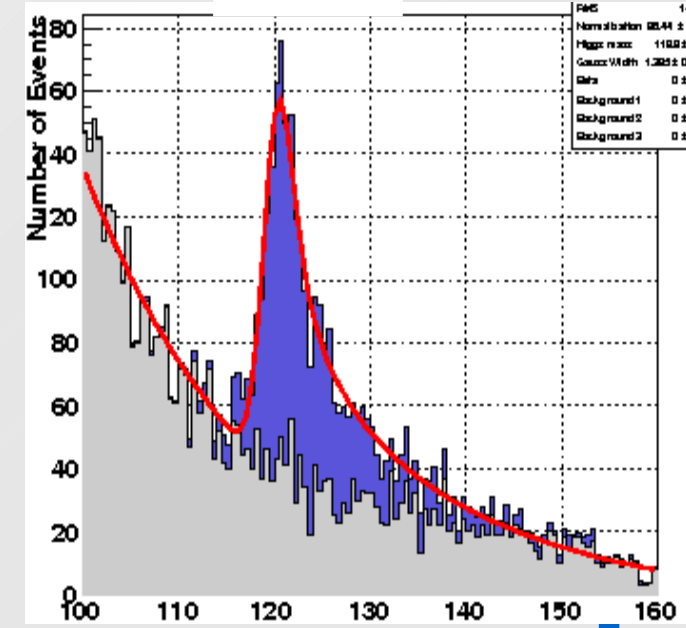
GLD



GLD'



J4LDC



Measurement accuracy of  $\sigma(\text{ZH})$  and Higgs mass are estimated from the fitting result.

## Estimation of measurement accuracy

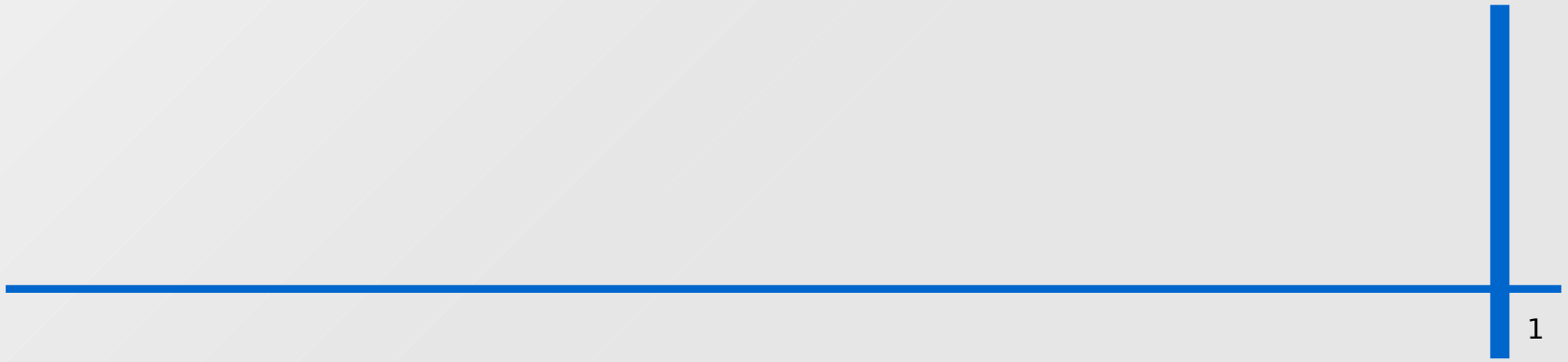
- Measurement accuracy of  $\sigma(\text{ZH})$  and  $M_{\text{H}}$  is evaluated from the fitting result.
- Measurement accuracy for  $250\text{fb}^{-1}$ 
  - ZH cross-section : 1.9% (for GLD)  
1.8% (for GLD')  
2.0% (for J4LDC)
  - Higgs mass: 119MeV (for GLD)  
110MeV (for GLD')  
95.7MeV (for J4LDC)
- **Measurement accuracy of  $\sigma(\text{ZH})$  is the same level for GLD, GLD' and J4LDC.**
- **For J4LDC, the resolution of  $M_{\text{H}}$  is better than GLD and GLD'.**
  - This results would come from the difference in the magnetic field.
  - It might change with the different diffusion term of TPC.
- The resolution of  $M_{\text{H}}$  is worse than previous study (@TILC08) because the initial beam spread becomes wider.
  - $\sigma(\Delta E/E)=0.05\%$  -->  $\sigma(e^-)=0.28\%$ ,  $\sigma(e^+)=0.18\%$ .

## Summary

- Study of ZH recoil mass is ongoing for GLD, GLD' and J4LDC.
- The recoil mass distribution is reconstructed after the selection cuts.
  - $M_z$ , track angle, total energy and production angle.
- The measurement accuracy of ZH cross-section and Higgs mass is estimated for  $250\text{fb}^{-1}$ .
  - Cross-section :  $\sim 1.9\%$
  - Higgs mass :  
119MeV (GLD), 110MeV (GLD'), 95.7MeV (J4LDC)

## Plans

- Progress of the optimization study for ILD.
- Estimation of other B.G. (e.g.  $ee \rightarrow WW \rightarrow e\nu e\nu$ )



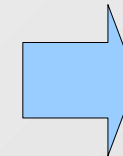


# Detector geometry

## Previous study @TILC08

		GLD	GLD'	J4LDC
VTX	Rin (mm)	20.00	1.80	1.60
	Rout (mm)	50.00	48.00	46.00
	Layer thickness (mm)	0.50	0.50	0.50
TPC	Rin(m)	0.40	0.40	0.30
	Rout(m)	2.06	1.80	1.58
	Zmax(m)	2.60	2.35	2.16
	Z <sub>Drift region</sub> (m)	2.55	2.30	2.11
B-Field(T)		3.00	3.50	4.00

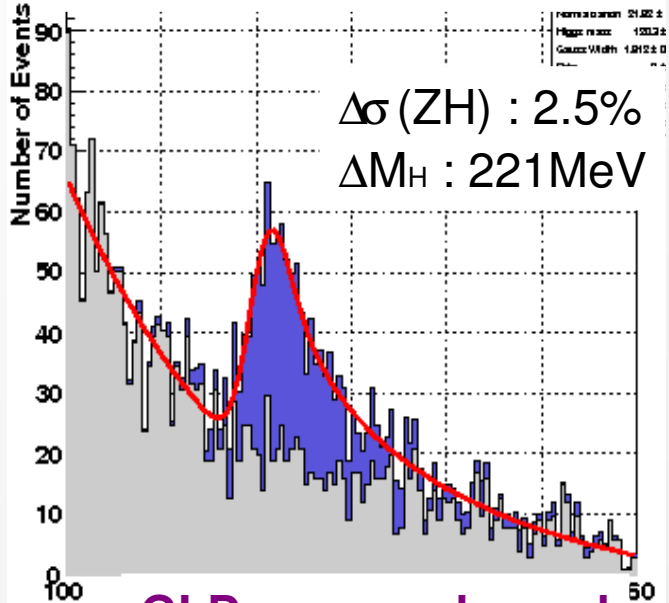
## New detector parameter



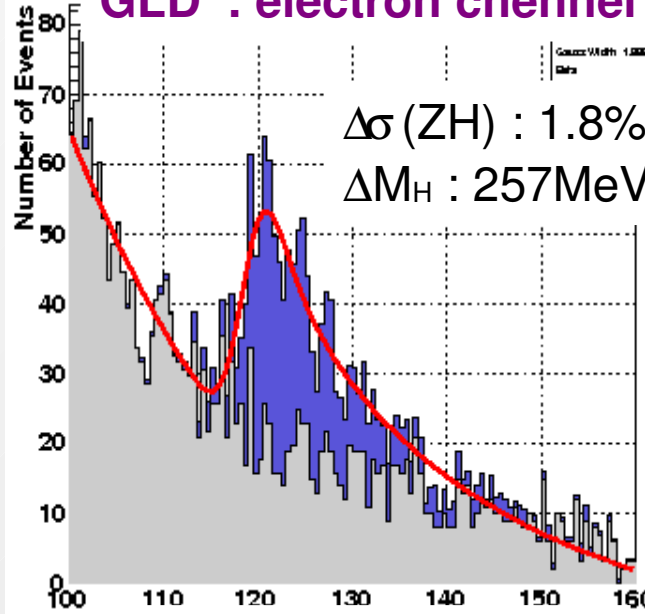
	GLD	GLD'	J4LDC
	17.50	1.60	1.50
	60.00	60.00	60.00
	0.94	0.94	0.94
	0.40	0.40	0.30
	2.06	1.80	1.58
	2.60	2.35	2.16
	2.50	2.30	2.06
	3.00	3.50	4.00

# Fitting results

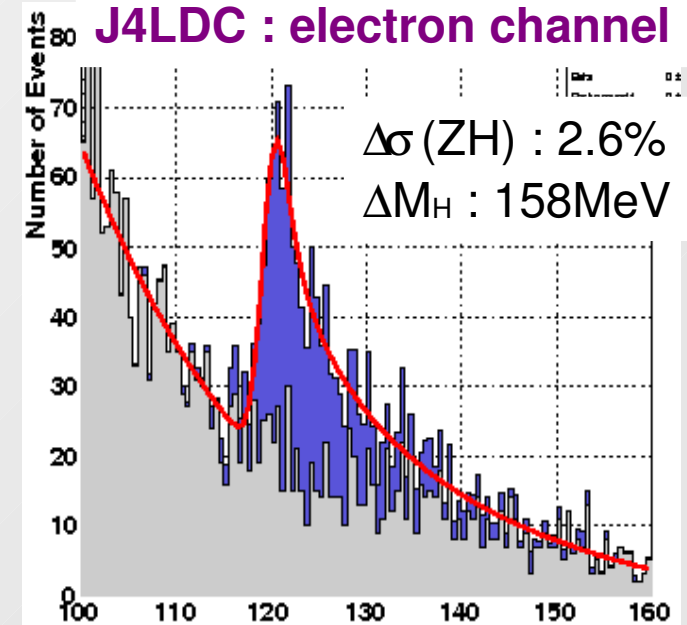
GLD : electron channel



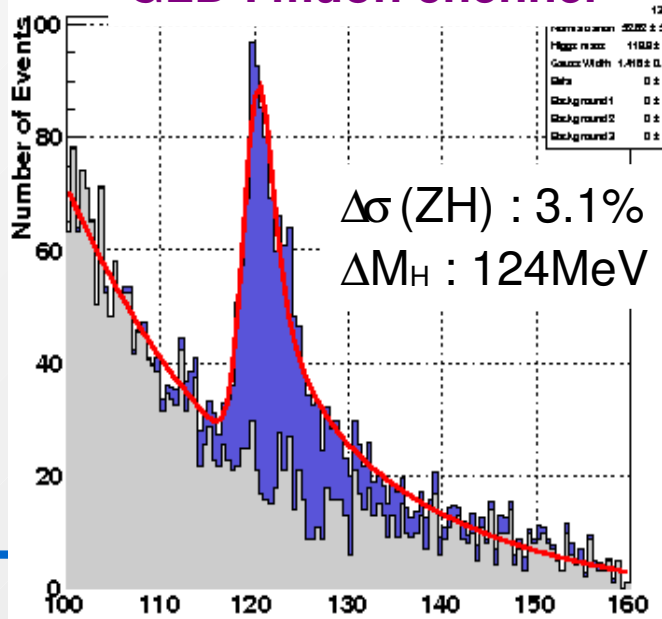
GLD' : electron channel



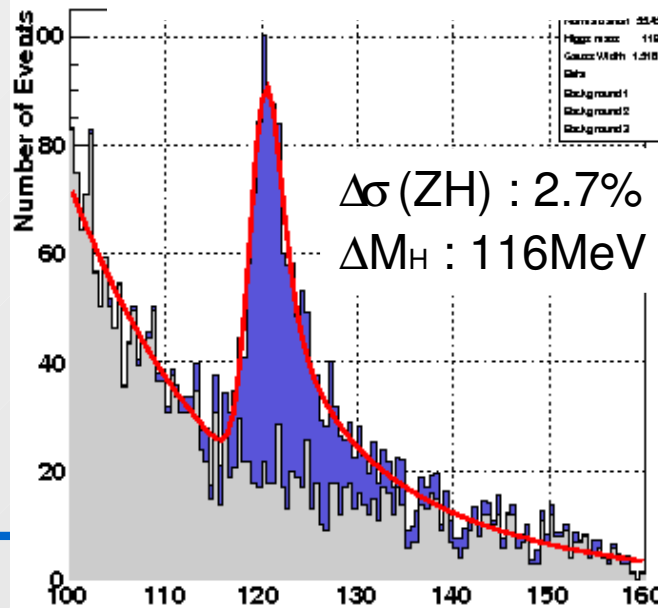
J4LDC : electron channel



GLD : muon channel



GLD' : muon channel



J4LDC : muon channel

