SM Higgs Recoil Mass and Cross Section Analysis at ILC

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OUTLINE

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- Introductory Remarks
- Background Rejection
- Analysis Methods:
  - Fitting Formulas
  - Correction of the Recoil Mass
- Results

} 230GeV electron channel: ***LDC01_01Sc*** (A Complete SM Analysis)

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- Results for 250GeV (For ILD LOI Proposal):
  - electron and muon channels:
    - *LDC01_06Sc, LDCPrime_02Sc, LDC_GLD_01Sc*
    - *DESY Central Production*

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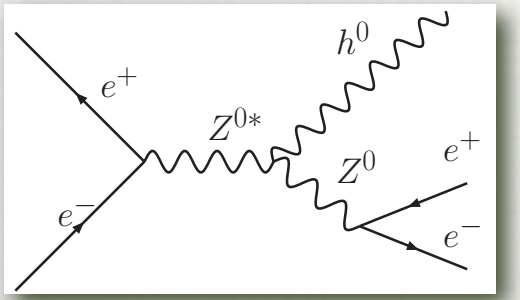
- Summary

INTRODUCTORY REMARKS

- Higgs-Strahlung Process:



- Higgs Recoil Mass:

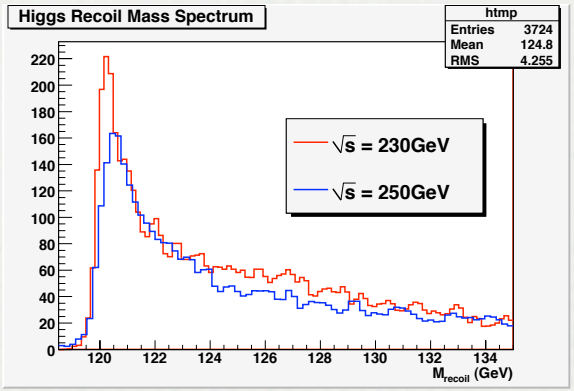
$$m^2_{h^0} = s + m^2_{Z^0} - 2E_{Z^0}\sqrt{s}$$

- Cross Section and Coupling Strength Measurement:

$$g^2 \propto \sigma = N/\mathcal{L}\epsilon$$

$$\sqrt{s} = 230GeV$$
$$M_{h^0} = 120GeV$$

230GeV: Recoil Mass has better resolution*.



Beam Simulation:
GUINEA-PIG

Event Generator:
PYTHIA 6.3

Simulation:
Mokka v06-05,
LDC01_01Sc

Reconstruction:
MarlinReco v00-04
(FullLDCTracking)
PandoraPFA v01-01

Electron ID:
CutBasedEID
Efficiency > 99.5%
Rejection Rate of Pions > 98%

Selection of e^+e^- in final state:
Invariant mass nearest to the Z^0 mass.

- Beamstrahlung, ISR and FSR are included

- With only detector acceptance cut applied, $|\cos\theta|<0.983$;

- Assume Luminosity to be 500 fb^{-1}

Reactions	Cross Section
$Z^0h \rightarrow eeX$	6.304 fb
$ee \rightarrow ee$	596 $x10^3$ fb
$ee \rightarrow \tau^+\tau^- \rightarrow ee+4\nu$	146 fb
$ee \rightarrow W^+W^- \rightarrow ee+2\nu$	181 fb
$ee \rightarrow Z^0/\gamma^* Z^0/\gamma^* \rightarrow eeff$	113 fb

* François Richard, Philip Bambade: ELAN Document-2007-001

230GeV electron channel:

BACKGROUND REJECTION (I):

SM Higgs Decay

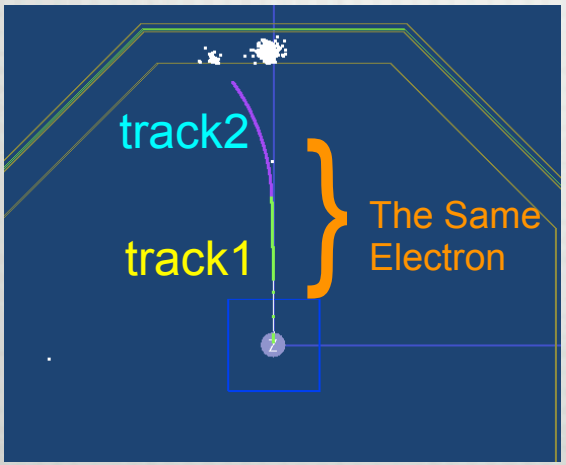
Number of Tracks for Bhabha, ττ, and WW

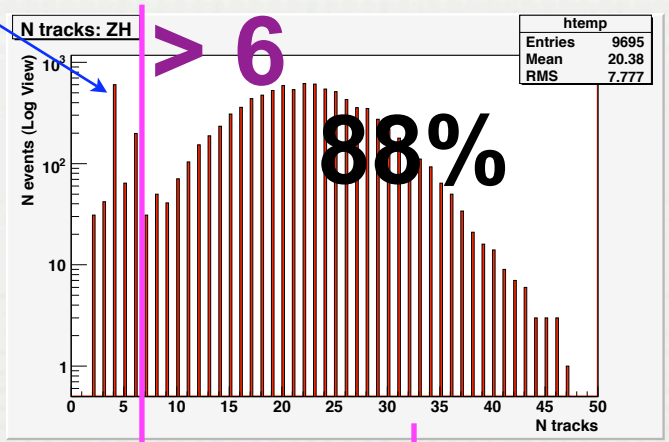
$Z^0h \rightarrow eeX$	ee (bhabha)	$\tau^+\tau^- \rightarrow$ ee+4ν	$W^+W^- \rightarrow$ ee+2ν
e+e- and 2 jets	e+ e- Multiplicity is 2		

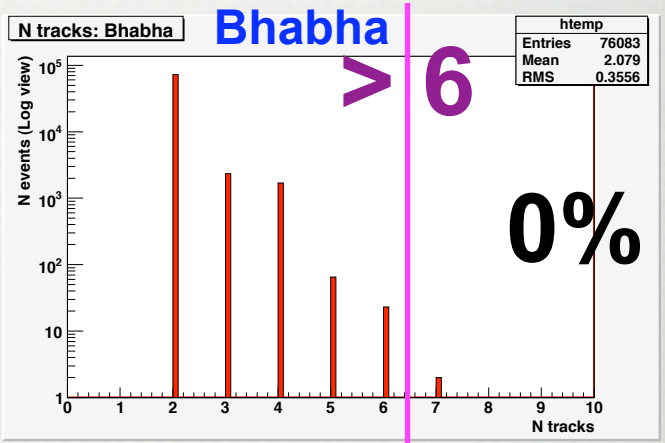
H->tautau

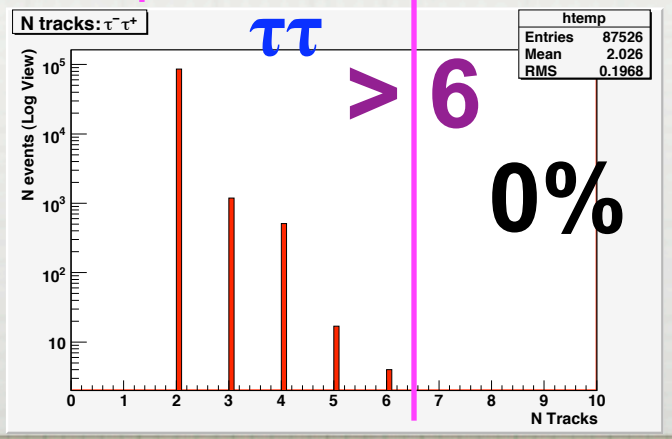
Number of tracks is NOT multiplicity for electrons.

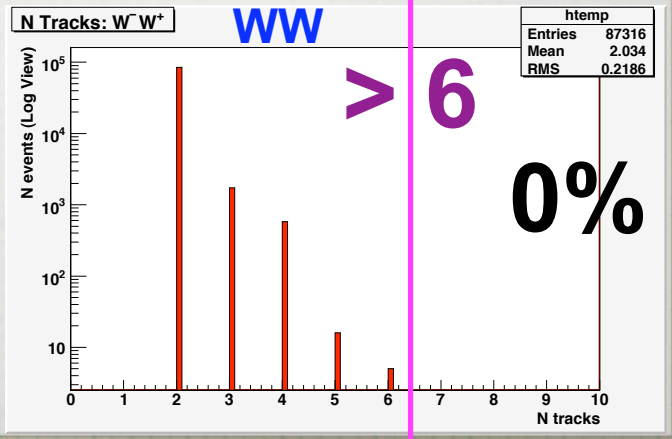
Several tracks can belong to one electron











230GeV electron channel:

BACKGROUND REJECTION (II): ZZ

Likelihood:

$$L = \prod_i P_i$$

Probability

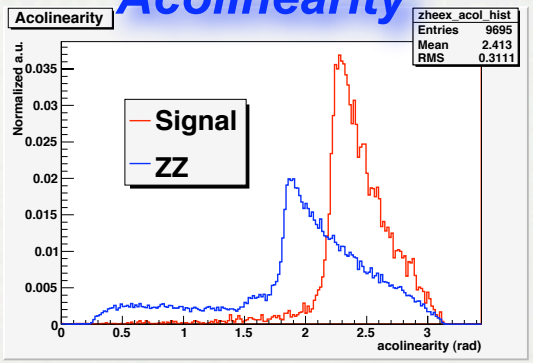
i th Variable

Likelihood Fraction:

$$f_L = L_S/(L_S + L_B)$$

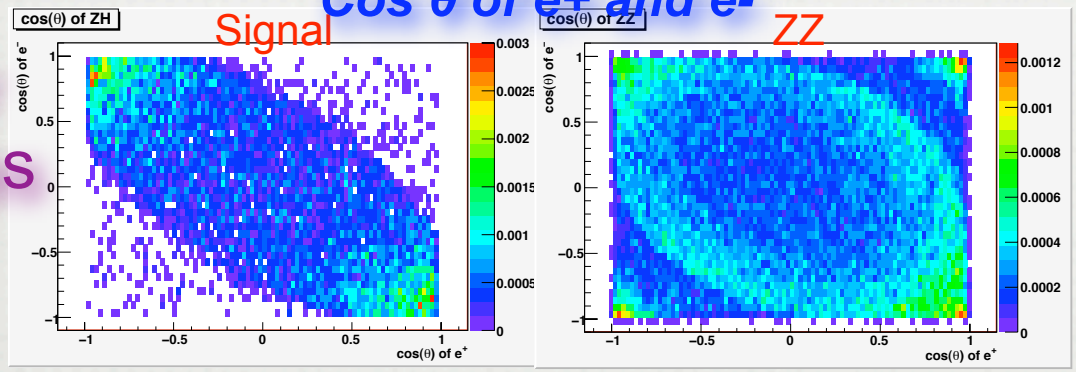
within (0, 1)

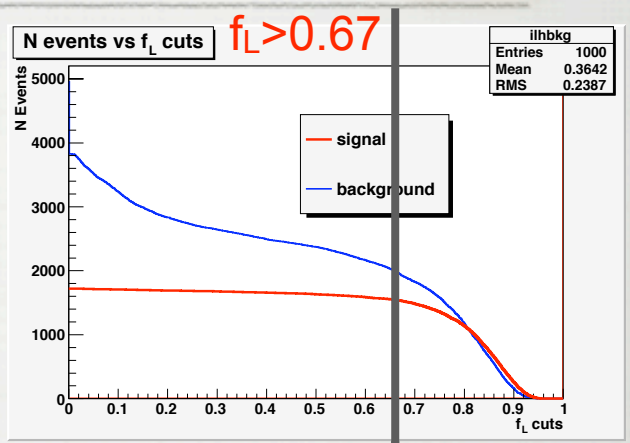
Acolinearity

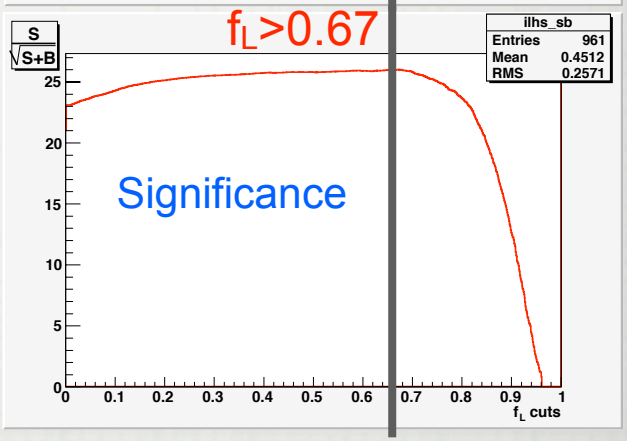


Cos θ of e+ and e-

Angular Variables ONLY







Efficiency[1,2]:
ZH: 55.5%
ZZ: 3.5%

1. ***The efficiency with in fitting range, say M_{recoil} within 118.5GeV to 135GeV, which excludes large number of events on the recoil mass tail.***
2. ***Already included the cut on the "Number of Tracks".***

230GeV electron channel:

FITTING FORMULA:

Both itself and its First Derivative are continuous at ALL Points

Signal:

$$f(x) = N \begin{cases} e^{-\frac{(x-x_0)^2}{2\sigma^2}} & : \quad \frac{x-x_0}{\sigma} \leq k \\ \beta e^{-\frac{(x-x_0)^2}{2\sigma^2}} + (1-\beta) e^{-(x-x_0)\frac{k}{\sigma}} e^{\frac{k^2}{2}} & : \quad \frac{x-x_0}{\sigma} > k \end{cases}$$

Pure Gaussian

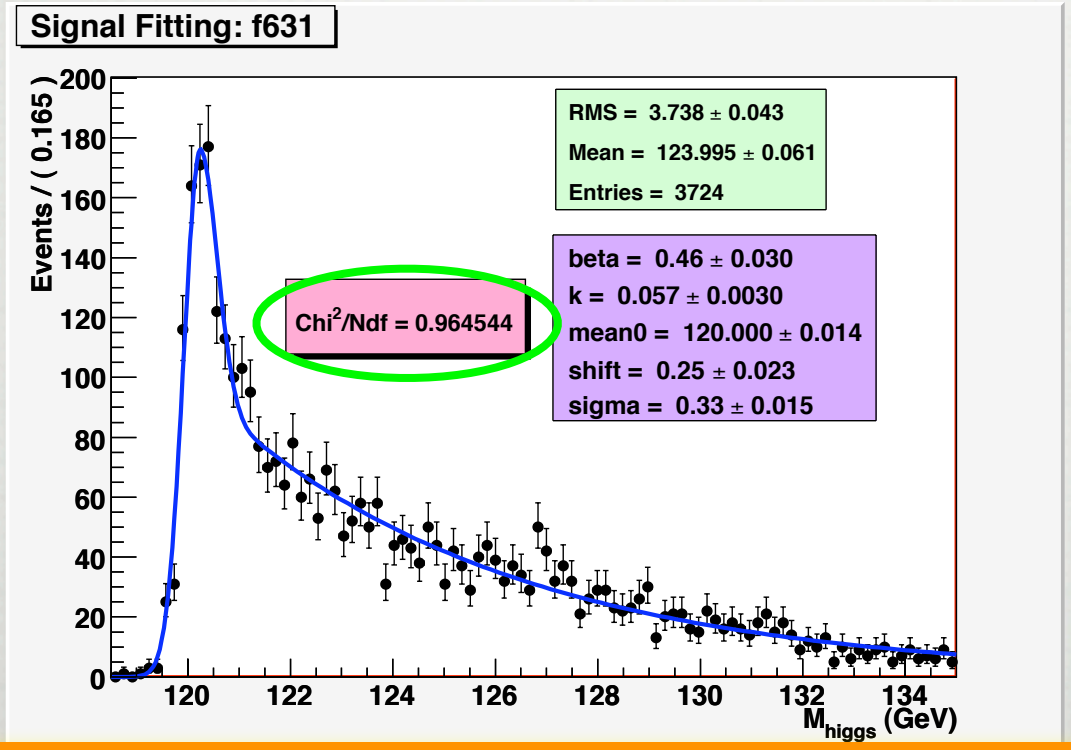
Gaussian fraction

Gaussian Part

Modified exponential

a factor for continuity

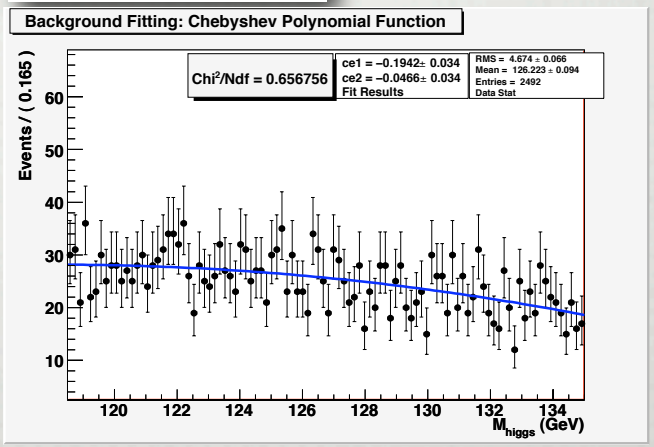
Move the linking point to the right side of Higgs Peak.



BG: Chebyshev Polynomial

$$1 + \sum_{i=1,n} a_i T_i(x)$$

only employed 2 coefficients



The *Fitting Range, 118GeV to 135GeV* is perfectly described by this formula.

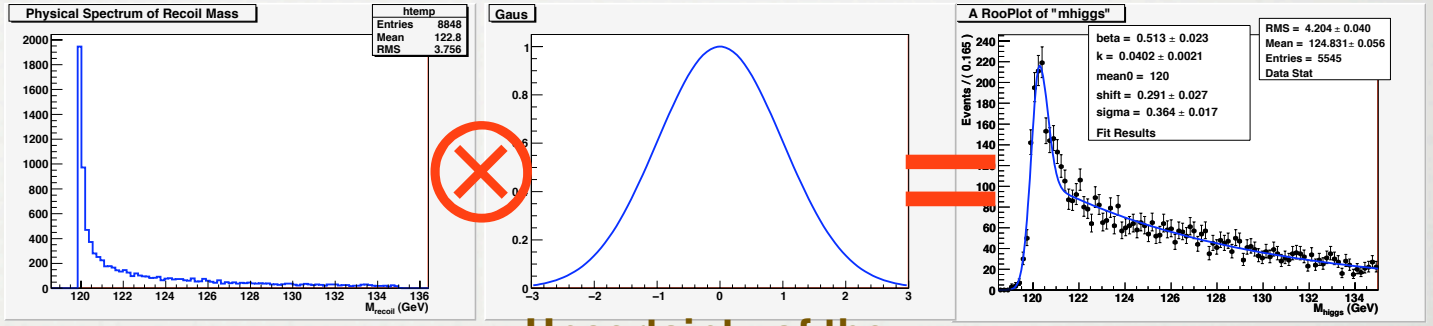
230GeV electron channel:

CORRECTION OF THE RECOIL MASS

Actually, The Recoil Mass Peak (the max. bin) is NOT at 120GeV: It has a shift because of the Detector Responses Uncertainty

Shift: independent of the fitting formula

The Convolution: shifted the peak to the positive side.



Physics Spectrum | Uncertainty of the Detector Response | Final Spectrum

In Order to Determine the Shift:

1. Set The Higgs Mass at: 117, 118, 119, 121, 122, and 123 GeV
2. Do the same Simulation and Reconstruction as that of 120 GeV
3. Measure the Shifts

The Correction

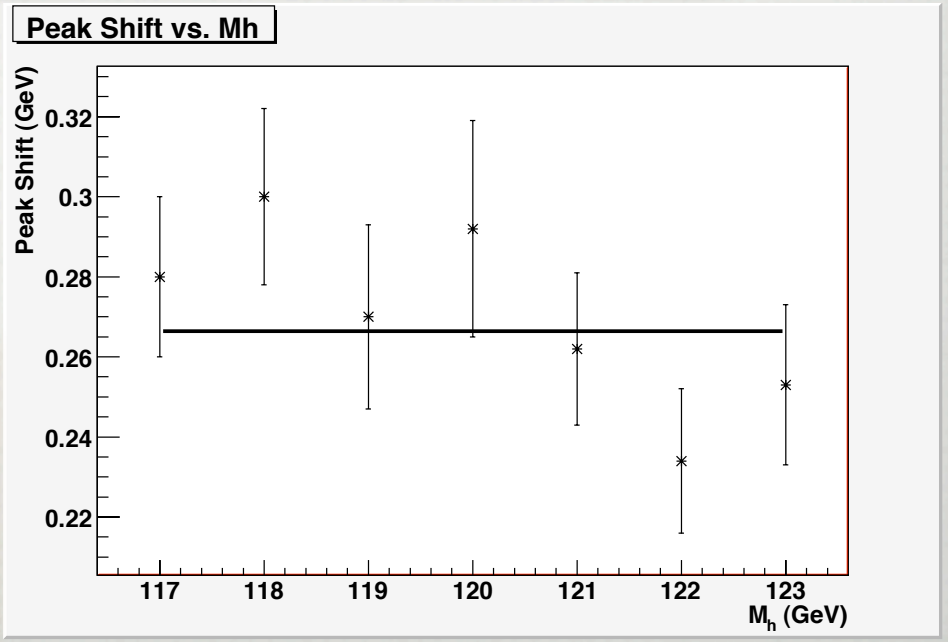
Uncertainty of the Correction (Systematic Error)

Mean of the Shift:

$$\bar{S} = 0.270\ GeV$$

Standard Deviation:

$$\sigma(S) = 0.021\ GeV$$



230GeV electron channel:

LIKELIHOOD FITTING AND THE RESULTS

Build the composite model as:

$$M_E(x) = N_S \cdot S(x) + N_B \cdot B(x)$$

- N_S: N evts of Signal
- $S(x)$: PDF of Signal
- N_B: N evts of Background
- $B(x)$: PDF of Background

Set N_S, N_B and mean0 (the recoil mass) to be fitting parameters. These are the variables we want to measure.

The Results: *L=500 fb^{-1}*

Recoil Mass:

120.022 ± 0.039 (± 0.021) GeV

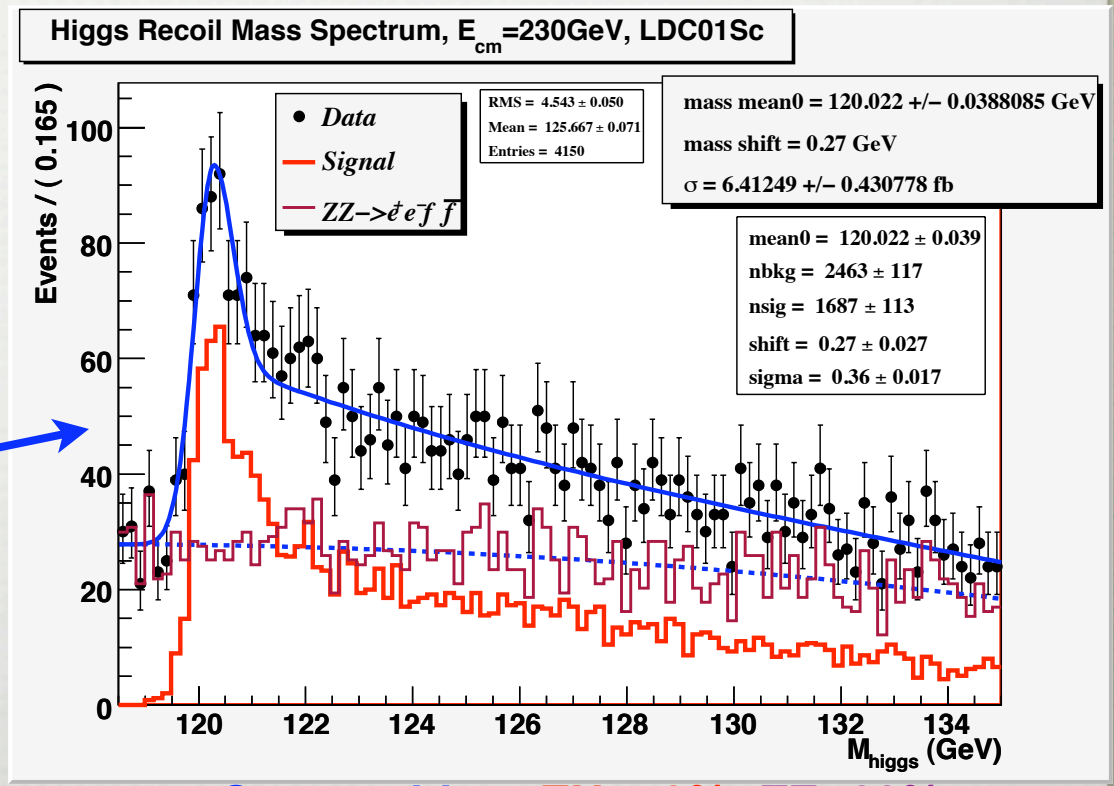
stat. err sys. err

Cross Section:

6.41 ± 0.43 fb

Mass Resolution:

360 ± 17 MeV



Composition: ZH: 40%; ZZ: 60%

RESULTS FOR 250GEV ELECTRON AND MUON CHANNELS

For The ILD Optimization, For the LOI:
Ecm = 250GeV, both electron and muon channels were analyzed, in 3 detector models.

Detector Model:
- LDCPrime_02Sc
- LDC01_06Sc
- LDC_GLD_01Sc

Event Generation:
250GeV samples, by Akiya Miyamoto (KEK)
http://ilcphys.kek.jp/soft/generator-ild/index.html

Simulation and Reconstruction:
Standard Reconstruction Chain, By DESY Production Group
http://www-flc.desy.de/simulation/databasereco/

Reaction	Cross Section	N events	Weight*
Zh->eeX	7.5 fb	10k	0.3751
Zh->μμX	7.5 fb	10k	0.3751
ee-> Z^0 Z^0 ->eeff	78,7 fb	10k	4.37
ee-> Z^0 Z^0 ->μμff	79.0 fb	10k	4.37

**Assume luminosity is 500 fb^{-1}*

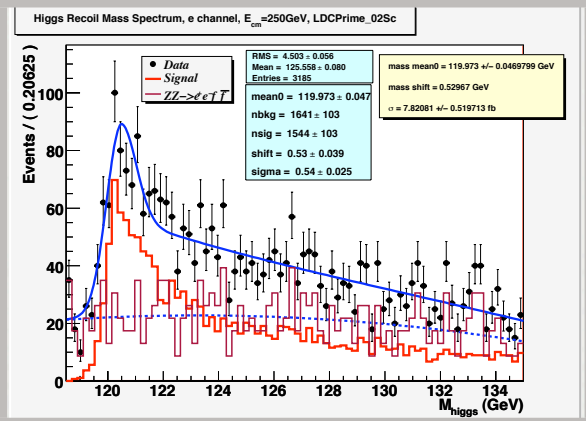
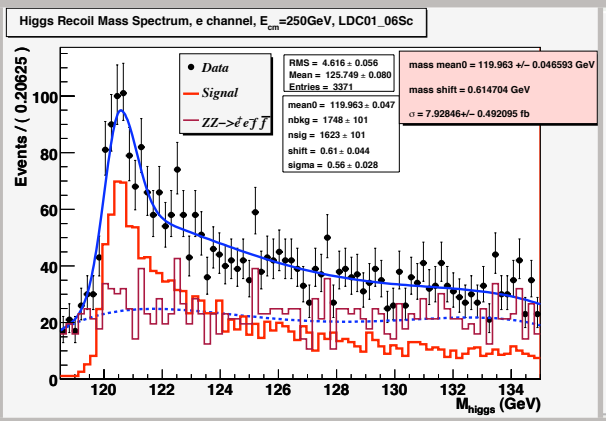
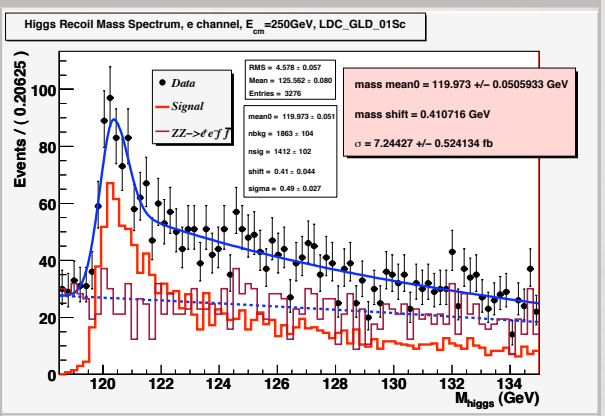
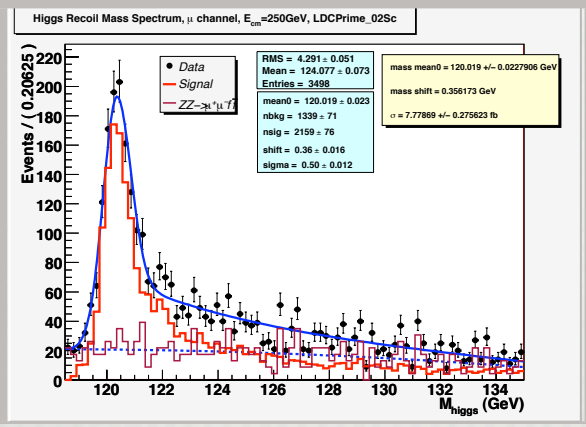
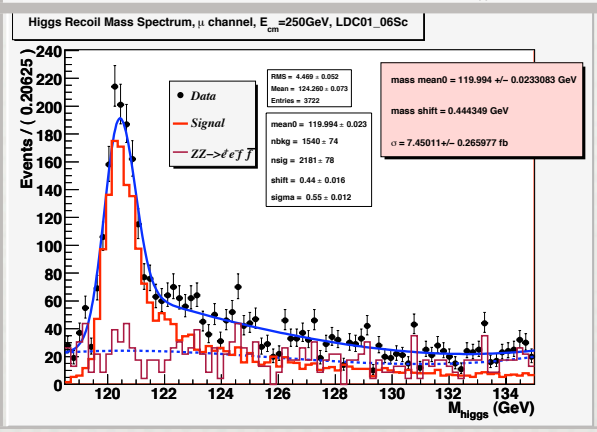
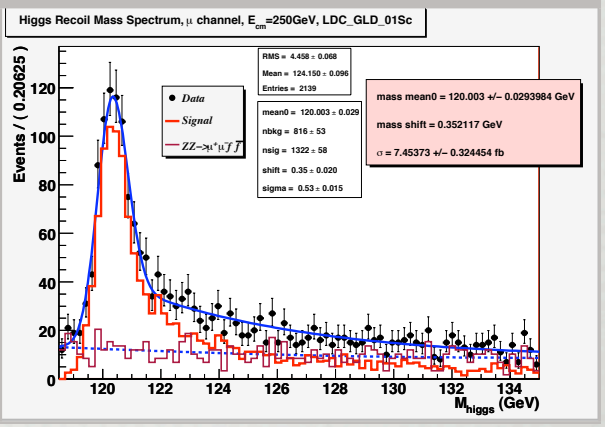
ZZ Background Rejections:
Same Likelihood Methods Were Applied
acolinearity and cos θ of e^+ and e^-

The Efficiencies*:

Efficiency	LDCPrime_02Sc	LDC01_06Sc	LDC_GLD_01Sc
Zh->eeX	39.5%	37.2%	39.0%
Zh->μμX	55.5%	52.7%	35.5%

**Efficiency here is the efficiency of signal selection, within fitting range, say M_{recoil} within 118.5GeV to 135GeV, which excludes large number of events on the recoil mass tail*

RESULTS FOR 250GEV ELECTRON AND MUON CHANNELS

Model	LDCPrime_02Sc	LDC01_06Sc	LDC_GLD_01Sc
electron channel			
muon channel			

Muon channel has much more visible peak than that of electron channel

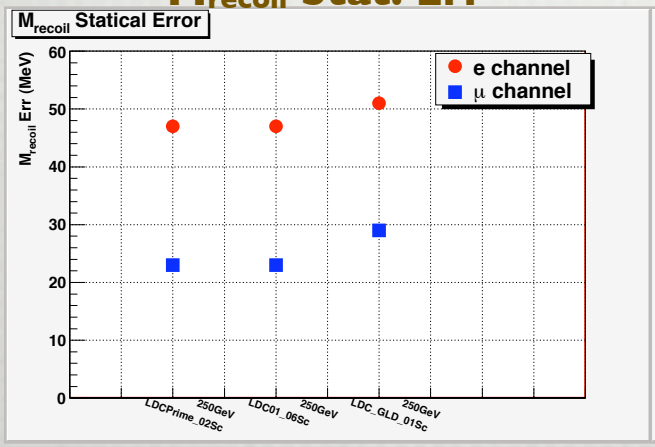
If you cannot see the numbers, go on to the next slide the "results summary table"

RESULTS FOR 250GEV ELECTRON AND MUON CHANNELS

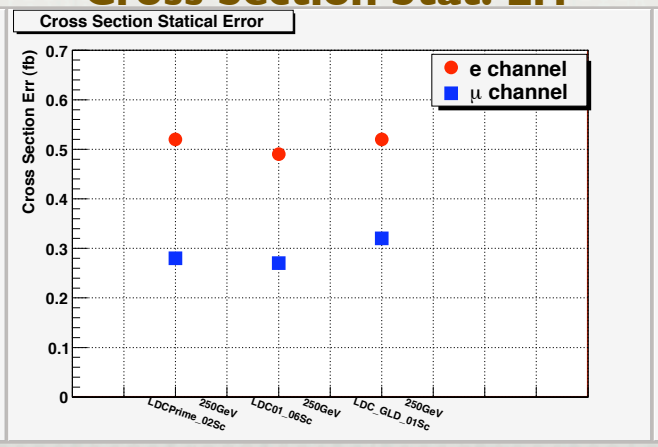
Assume luminosity is 500 fb^{-1}, stat. errs times √2 for 250 fb^{-1} ones

Ecm (GeV)	Detector Model	Channel	M_{recoil} Stat. Err (MeV)	Cross Section Stat. Err (fb)	Mass Resolution (MeV)
250	LDCPrime_02Sc	e	47	0.52	540 ± 25
		μ	23	0.28	500 ± 12
	LDC01_06Sc	e	47	0.49	560 ± 28
		μ	23	0.27	550 ± 12
	LDC_GLD_01Sc	e	51	0.52	490 ± 27
		μ	29	0.32	530 ± 15

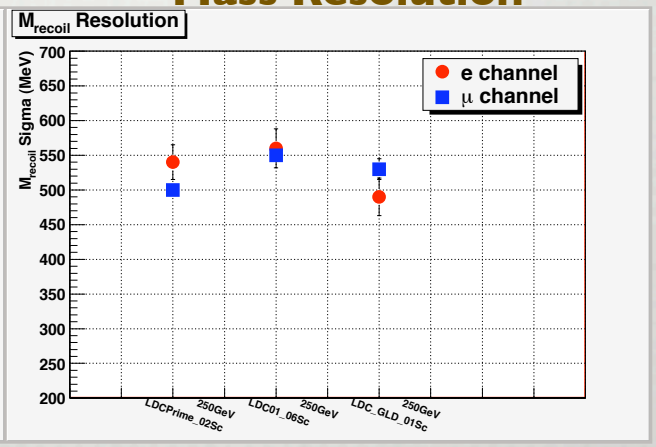
M_{recoil} Stat. Err



Cross Section Stat. Err



Mass Resolution



SUMMARY

- A Full Analysis Chain was developed (based on 230GeV electron channel)
- 250 GeV LOI benchmark studies: Only Model Independent Variables for ZZ rejection, but it is too early to say it is “model independent” analysis, because the backgrounds are not complete temporarily.
  - It is an incomplete model independent analysis
- The study for LOI shows that:
  - Muon channel is nevertheless the best channel, but electron channel can provide the complementary statistics
  - No big difference between the three detector models found from this recoil mass analysis

THE END:
THANKS!

BACKUP SLIDES:

RESULTS FOR 250GEV ELECTRON AND MUON CHANNELS

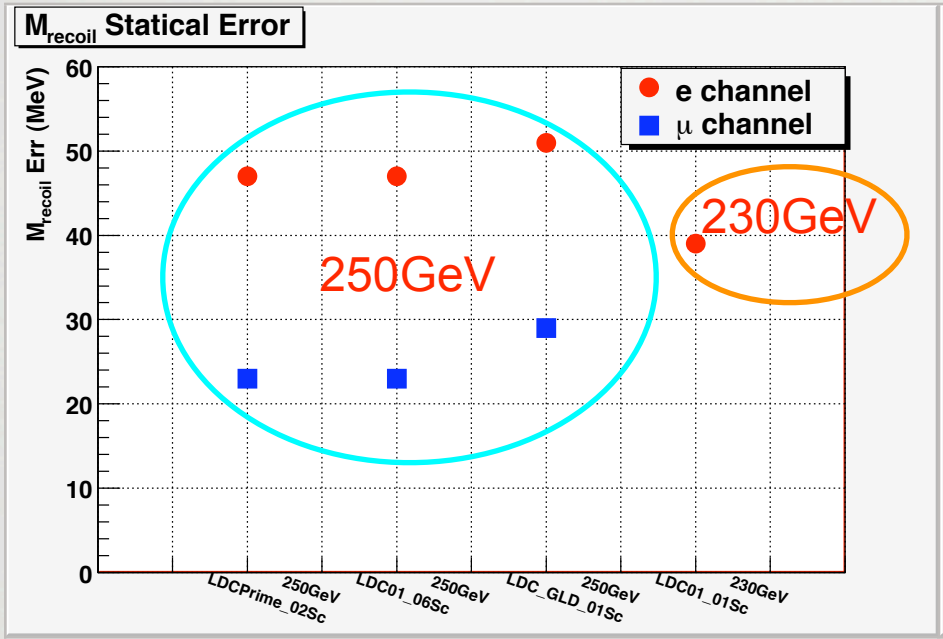
**Assume luminosity is 250 fb^{-1}*

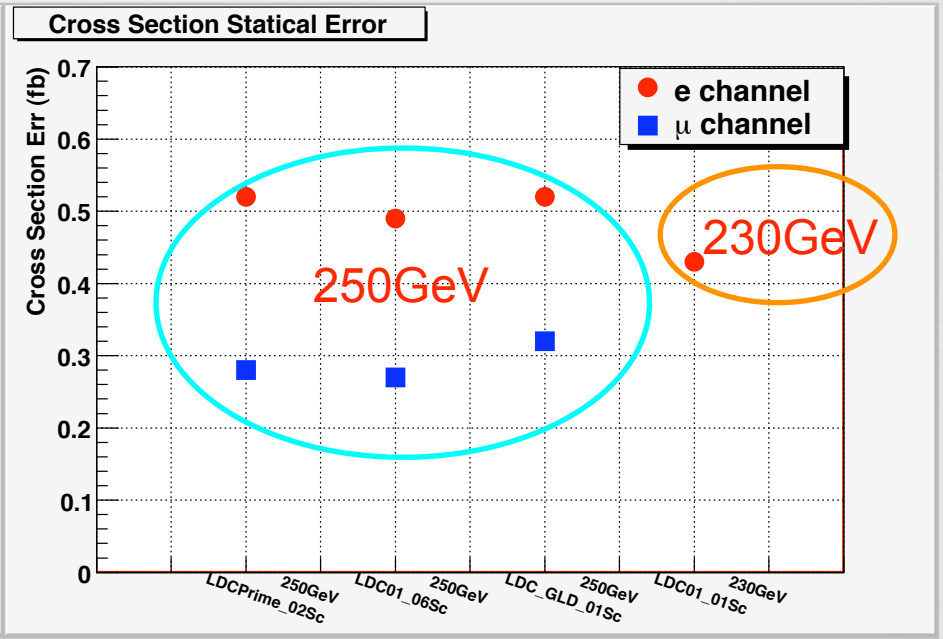
Ecm (GeV)	Detector Model	Channel	M_{recoil} Stat. Err (MeV)	Cross Section Stat. Err (fb)	Mass Resolution (MeV)
250	LDCPrime_02Sc	e	66	0.74	540 ± 25
		μ	33	0.38	500 ± 12
	LDC01_06Sc	e	66	0.69	560 ± 28
		μ	33	0.38	550 ± 12
	LDC_GLD_01Sc	e	72	0.74	490 ± 27
		μ	41	0.45	530 ± 15

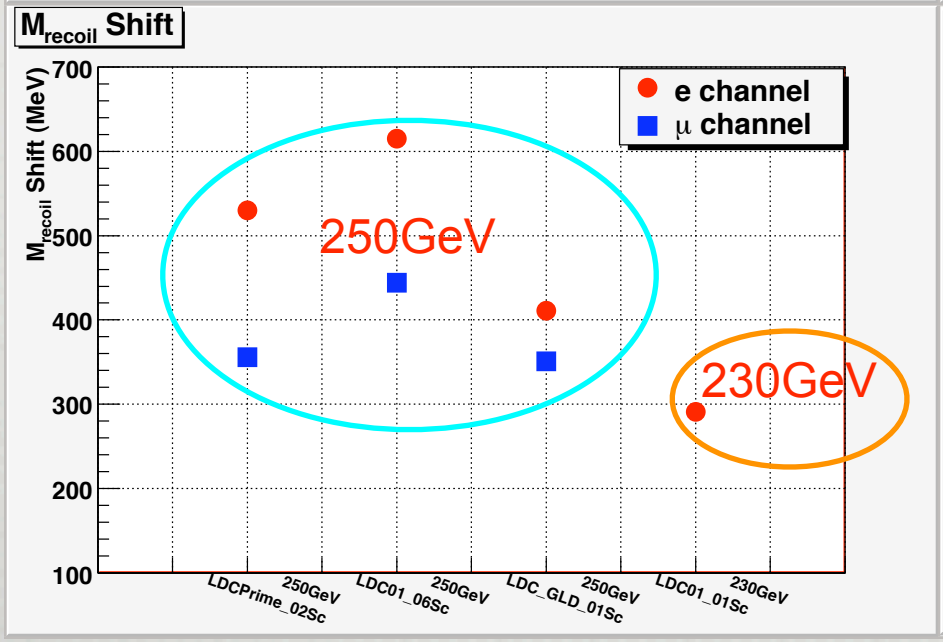
RESULTS SUMMARY TABLE

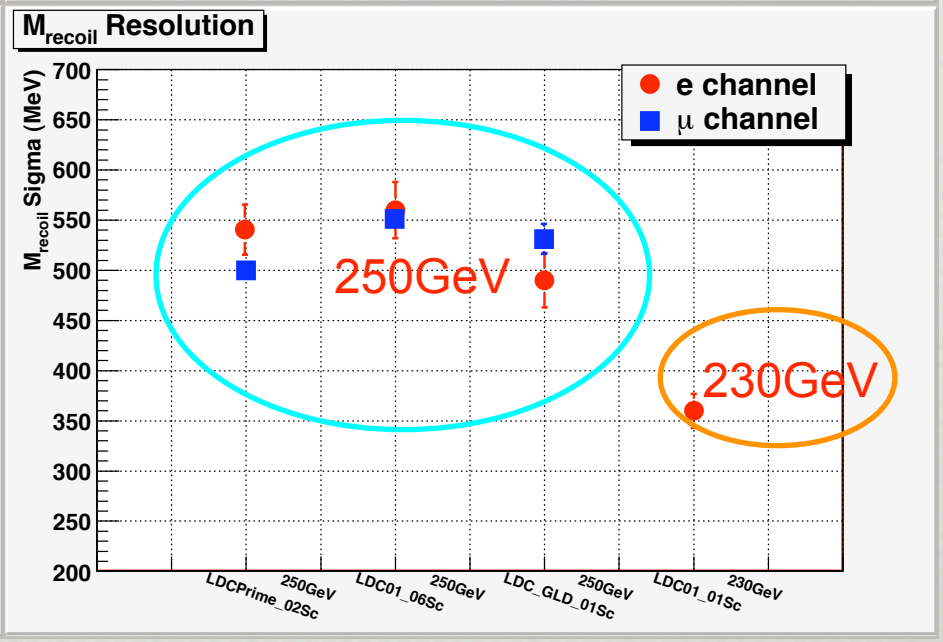
Ecm (GeV)	Detector Model	Channel	M_{recoil} Statistical Err (MeV)	Cross Section Statistical Err (fb)	Peak Shift (MeV)	Mass Resolution (MeV)
250	LDCPrime_02Sc	e	47	0.52	530	540 ± 25
		μ	23	0.28	356	500 ± 12
	LDC01_06Sc	e	47	0.49	615	560 ± 28
		μ	23	0.27	444	550 ± 12
	LDC_GLD_01Sc	e	51	0.52	411	490 ± 27
		μ	29	0.32	352	530 ± 15
230	LDC01_01Sc	e	39	0.43	291	360 ± 17

RESULTS SUMMARY PLOTS



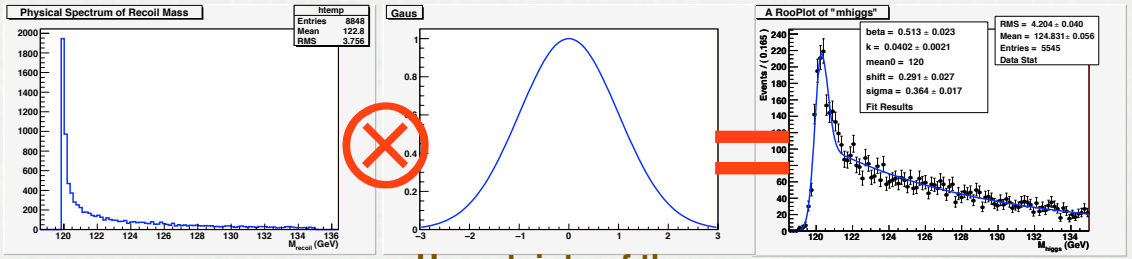






CONVOLUTION VS. LIKELIHOOD FITTING

The Convolution: shifted the peak to the positive side.



Physics Spectrum | Uncertainty of the Detector Response | Final Spectrum

Both are well proved good methods!

Likelihood Fitting:

Fitting to the *Final Spectrum*,

Fitting result is the *peak in the final spectrum*,

Need to determine the peak shift from detector response,

Don't need a good formula for the physical spectrum

Convolution Fitting:

Fitting to the *Physical Spectrum cov. Detector Response*,

Fitting result is the *peak in the physical spectrum*,

Need a good formula of the physical spectrum

Don't need to determine the peak shift

BEAM SIMULATION: GUINEA-PIG

GUINEA-PIG Beam Parameters:

$E_{CM}(GeV)$	230	250	350
$energy(GeV)$	115	125	175
$sigma_x(mm)$	639	639	639
$sigma_y(mm)$	5.7	5.7	5.7
$sigma_z(\mu m)$	138	150	210
$beta_x(mm)$	9.2	10	14
$emitt_y(10^{-6}m \cdot rad)$	0.04	0.04	0.04

Interface of GUINEA-PIG and PYTHIA:

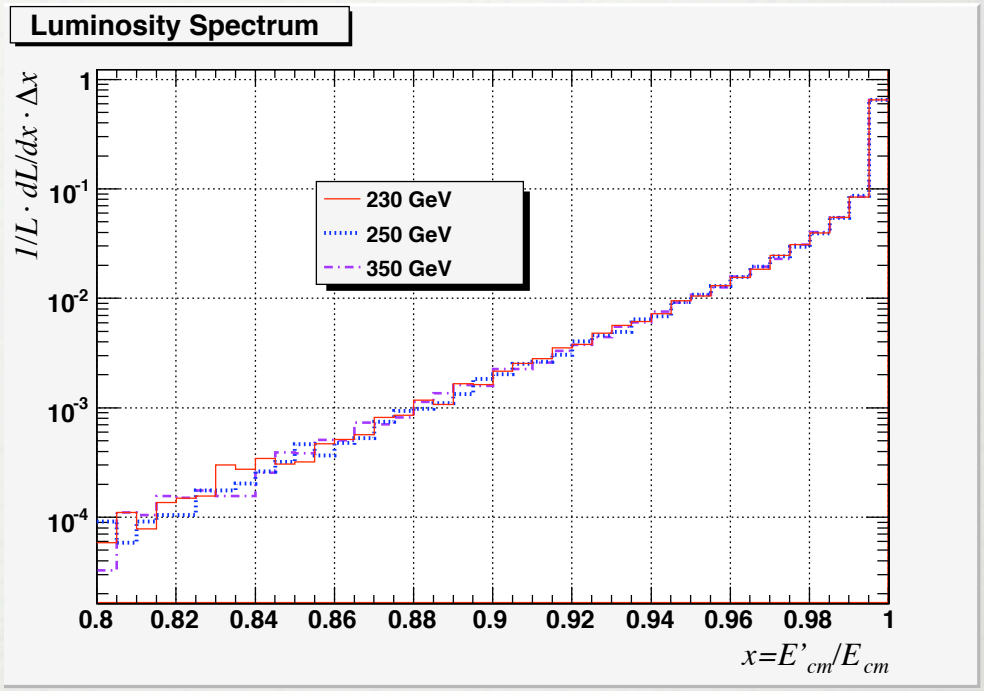
CALYPSO

Author of GUINEA-PIG and CALYPSO is Daniel Schulte (CERN)

Refer to:

"Machine-Detector Interface at CLIC": CERN-PS-2001-002-AE; CLIC-Note-469; Daniel.Schulte@cern.ch

Luminosity Spectrum:



The luminosity spectrum resulting from the beamstrahlung only, for $E_{CMS} = 230GeV$, $250GeV$, $350GeV$, where the E'_{cm} is the E_{cm} after beamstrahlung, and the bins have a width of $\Delta x = 0.5\%$

TRACKING RESOLUTIONS

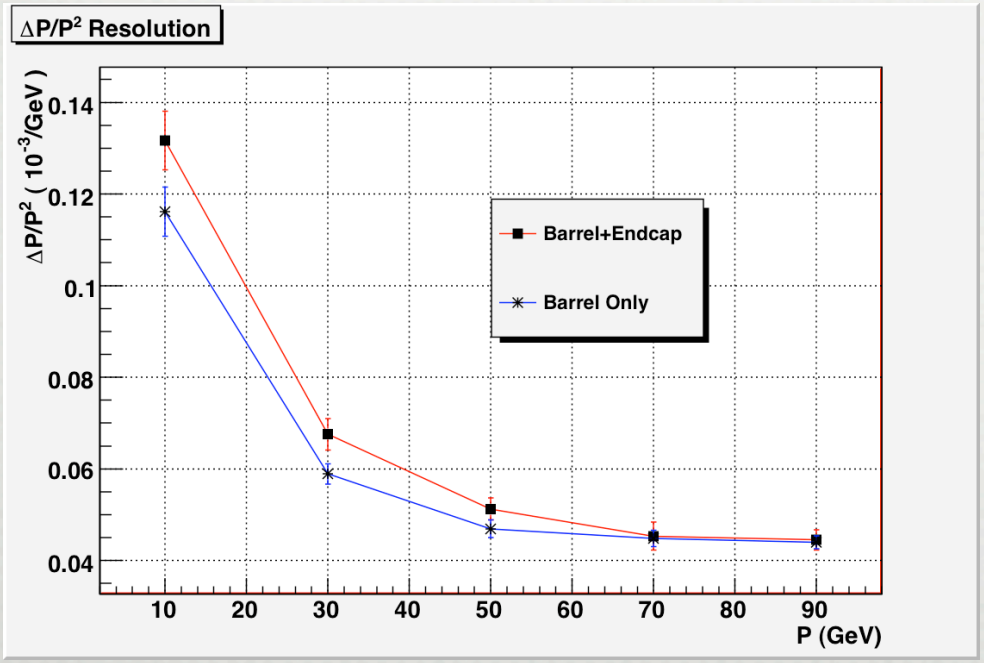
Electron Tracking Resolutions for LDC01_01Sc

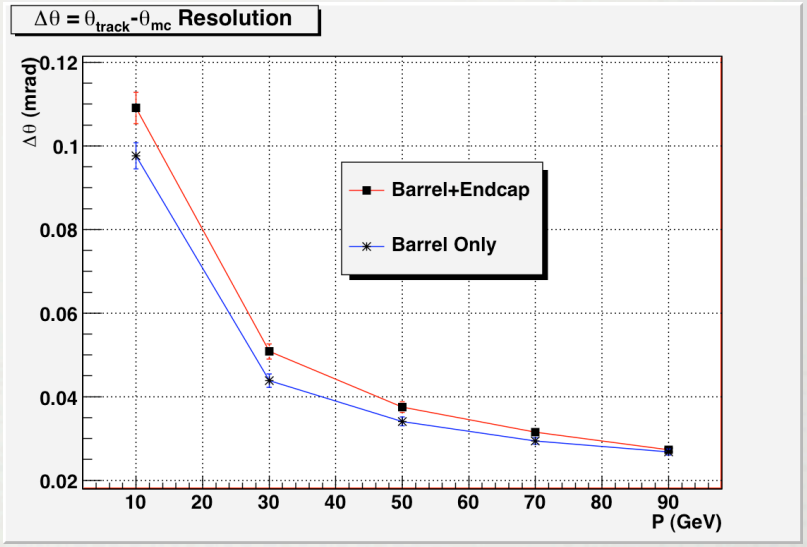
e.g. E > 30 GeV, Barrel

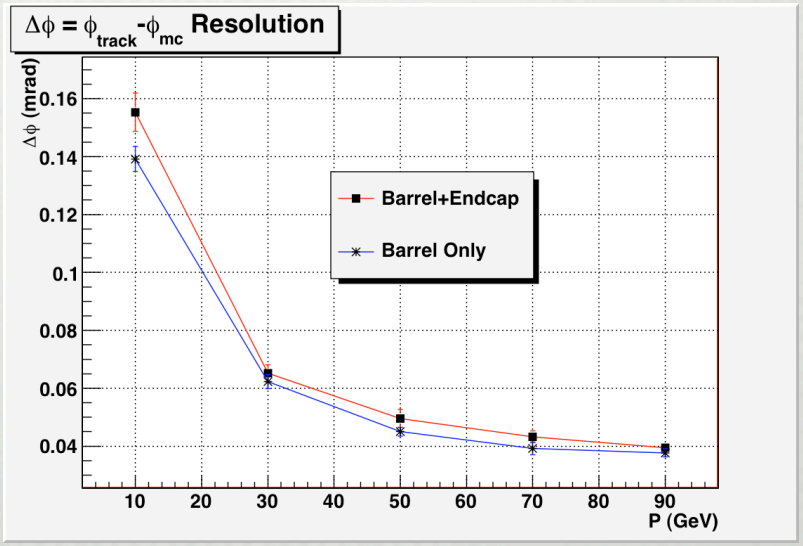
σ(1/P) < 6x10-5 (1/GeV)

σ(θ) < 0.05 mrad

σ(φ) < 0.07 mred







ELECTRON IDENTIFICATION

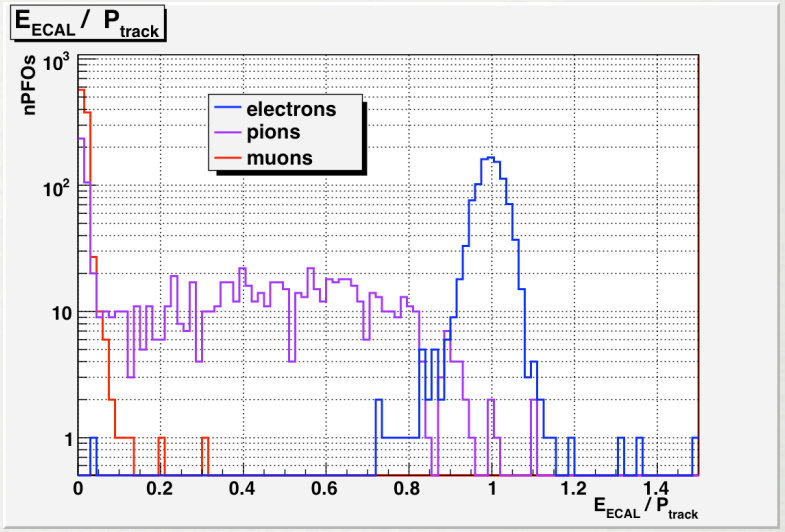
Identification Variables:

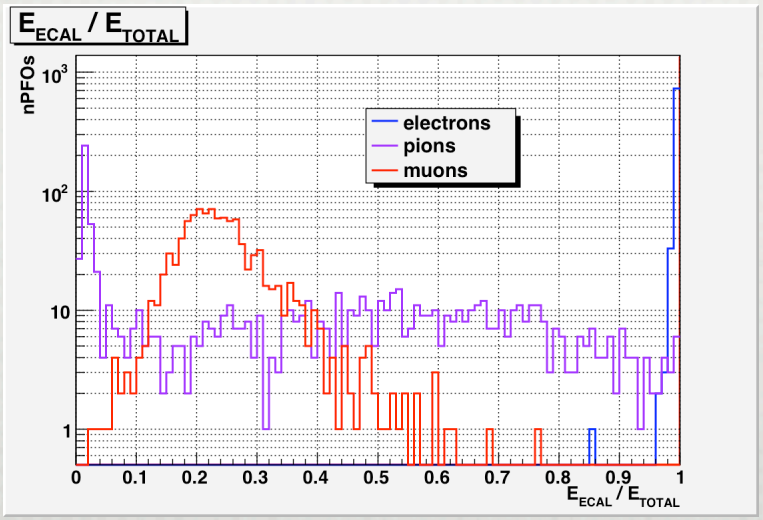
$$EPratio = E_{ECAL} / P_{Track}$$

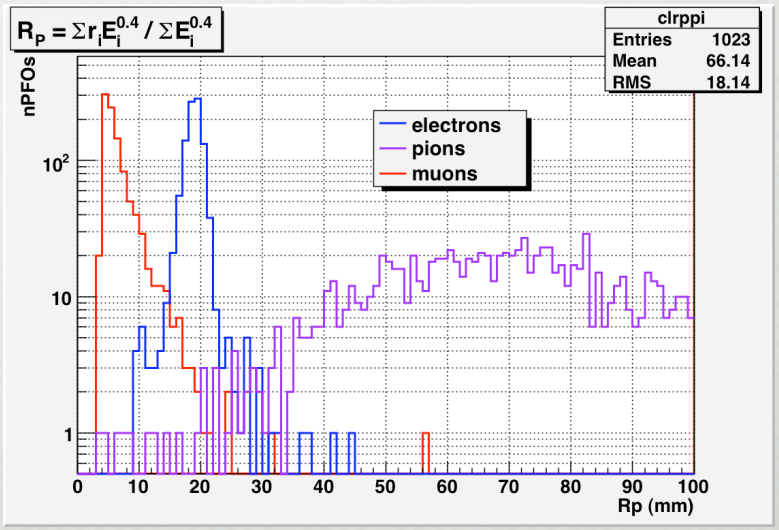
$$Efrac = E_{ECAL} / E_{total} \quad of\ a\ \ Cluster$$

$$R_P = \sum_{i=nHits} r_i E_i^{0.4} / \sum_{i=nHits} E_i^{0.4} \ of\ a\ \ Cluster$$

Plots showed the 30GeV e-, mu- and pi- samples in LDC01_01Sc Model







ELECTRON IDENTIFICATION

Efficiencies and Rejection Rates of Different Cut Scenarios

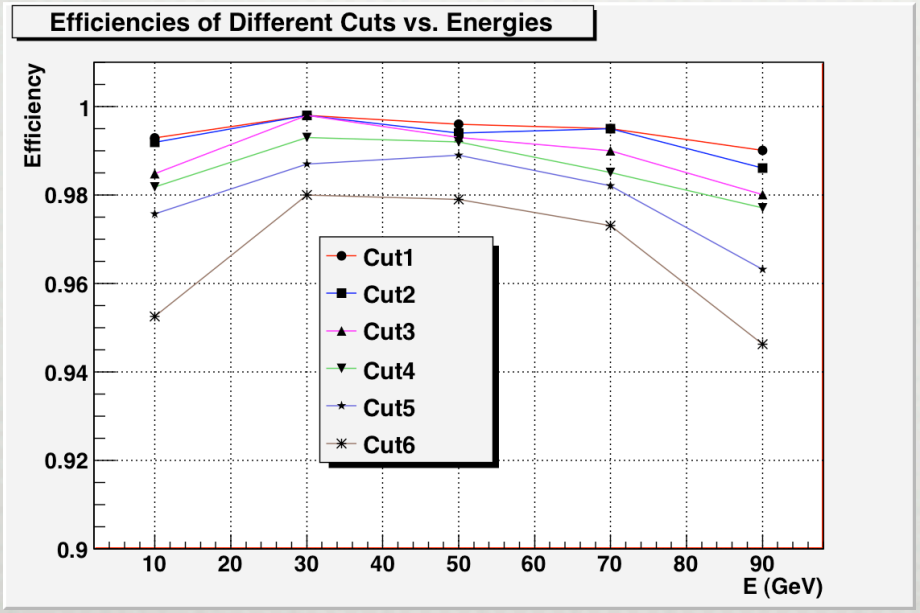
1 to 6, looser to tighter (or softer to harder)

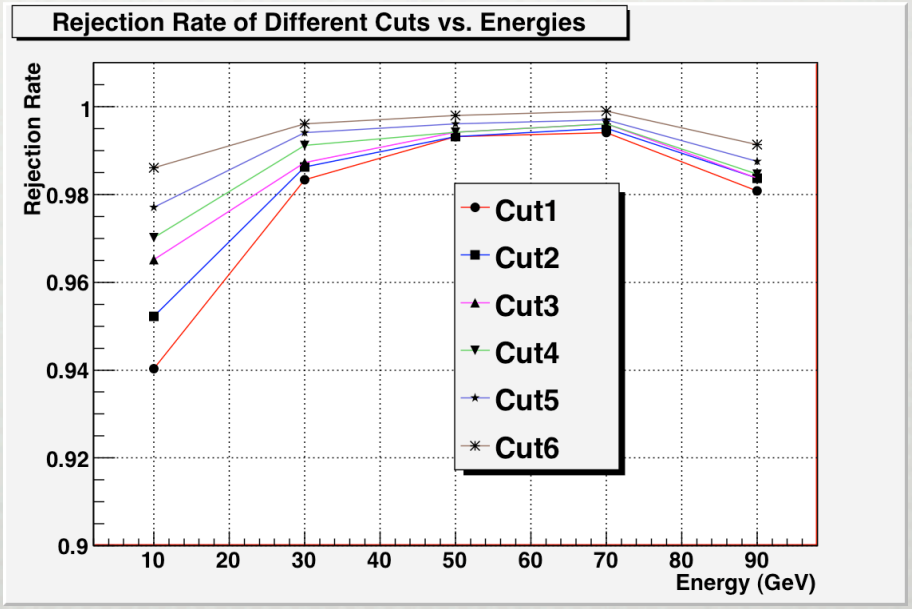
Cut Scenario	1	2	3	4	5	6
Epratio	0.6	0.65	0.7	0.75	0.8	0.85
Efrac	0.96	0.96	0.97	0.97	0.98	0.98
Rp	51	49	47	45	43	41

Cut Scenario 2 was chosen::

Efficiency > 99.5%

Rejection Rate of Pions > 98%

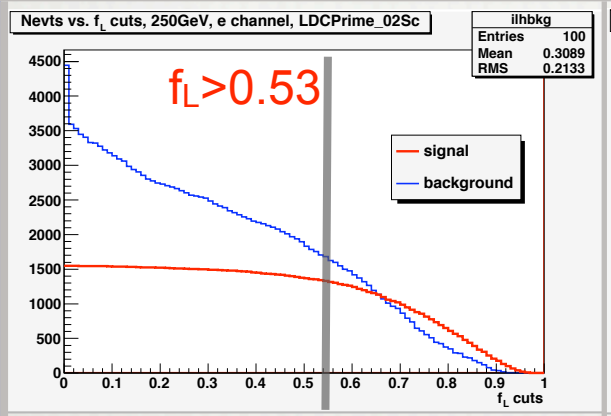
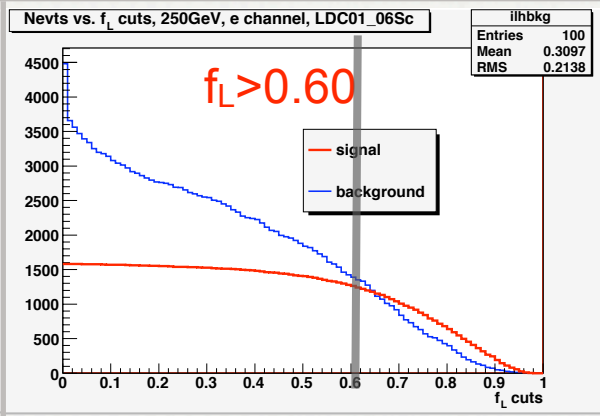
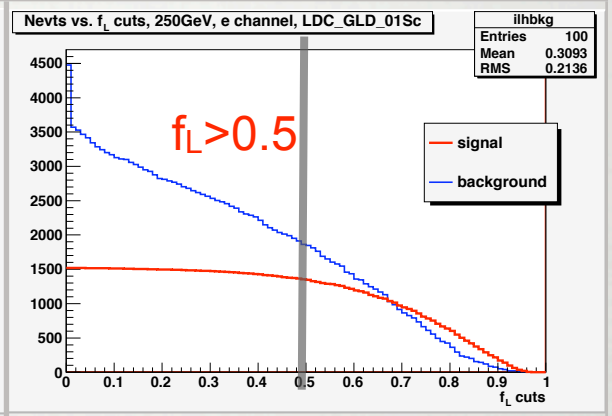
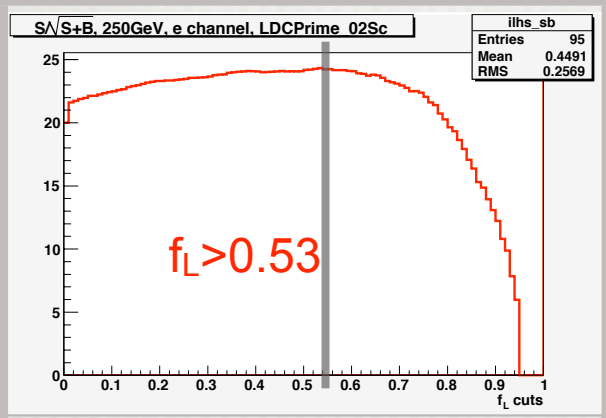
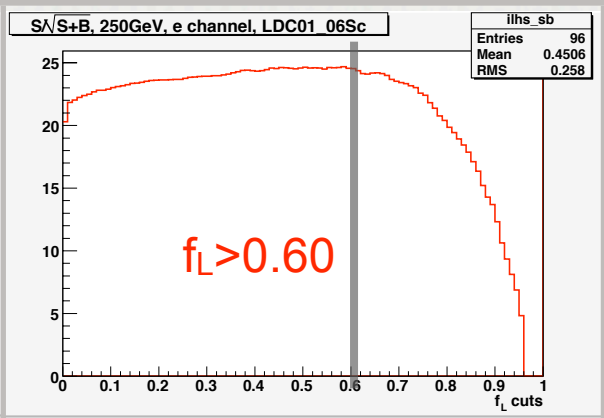
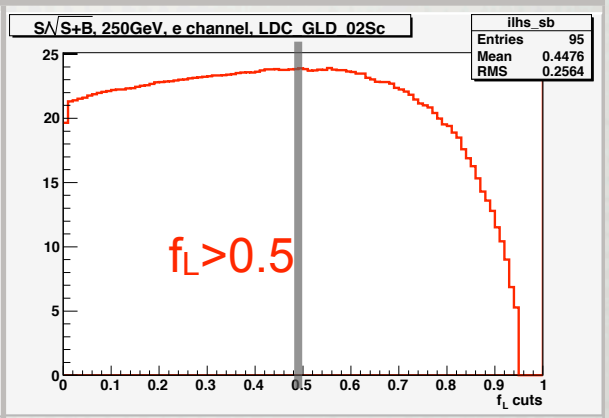




250GeV electron and muon channels:

ZZ BACKGROUND REJECTION (2): SEARCH FOR F_L CUTS

e channel

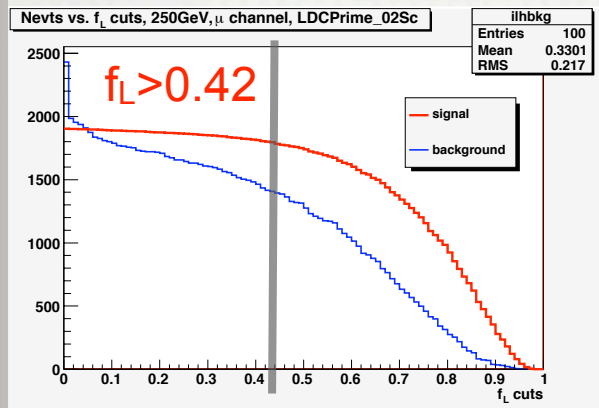
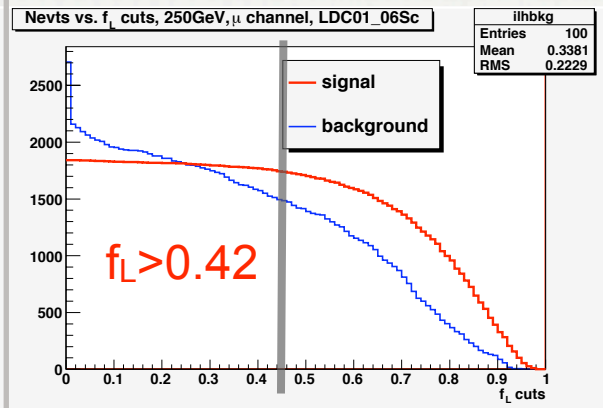
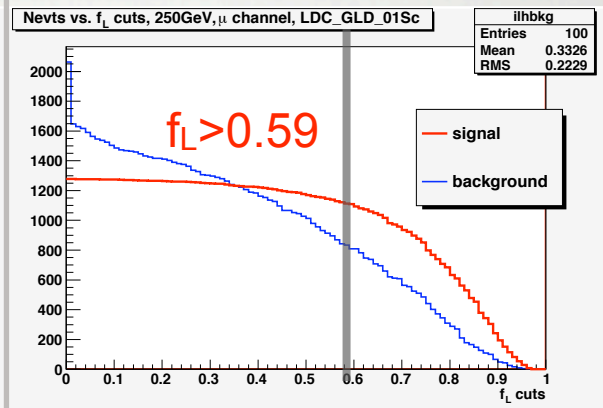
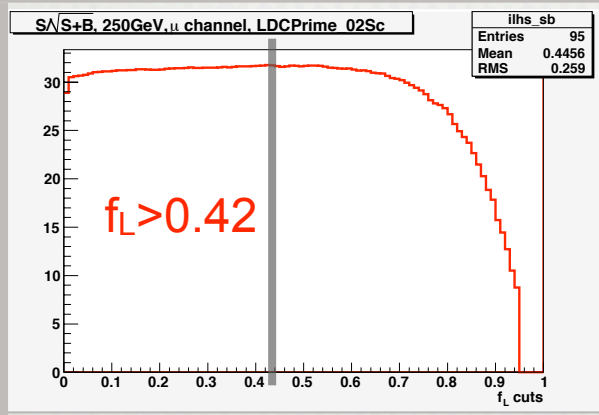
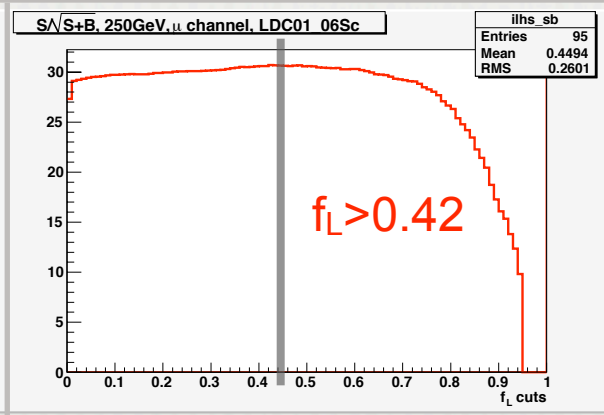
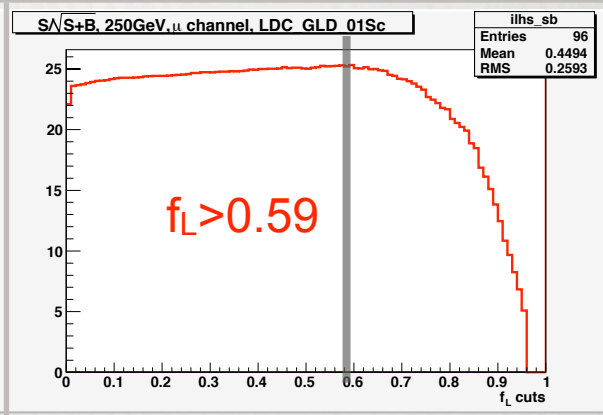
Model	LDCPrime_02Sc	LDC01_06Sc	LDC_GLD_01Sc
Nevts remained after f_L cuts			
$S/\sqrt{(S+B)}$ vs. f_L			
Efficiency[+]	39.5%	37.2%	39.0%

[+]***Efficiency here is the efficiency of signal selection, within fitting range, say M_{recoil} within 118.5GeV to 135GeV, which excludes large number of events on the recoil mass tail***

250GeV electron and muon channels:

ZZ BACKGROUND REJECTION (2): SEARCH FOR F_L CUTS

μ channel

Model	LDCPrime_02Sc	LDC01_06Sc	LDC_GLD_01Sc
Nevts remained after f_L cuts			
S/√(S+B) vs. f_L			
Efficiency+	55.5%	52.7%	35.5%

+Efficiency here is the efficiency of signal selection, within fitting range, say M_{recoil} within 118.5GeV to 135GeV, which excludes large number of events on the recoil mass tail

230GeV electron channel:

FITTING FORMULA: BACKGROUND

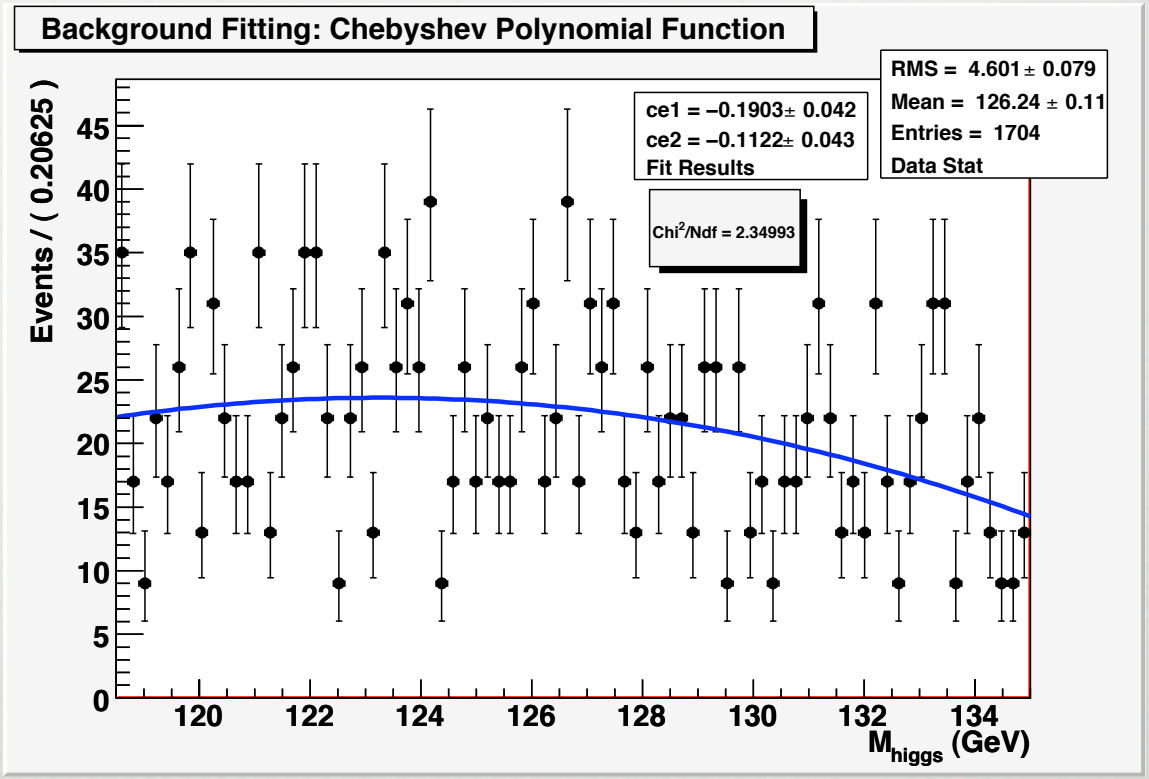
Chebyshev Polynomial Function

Coefficients

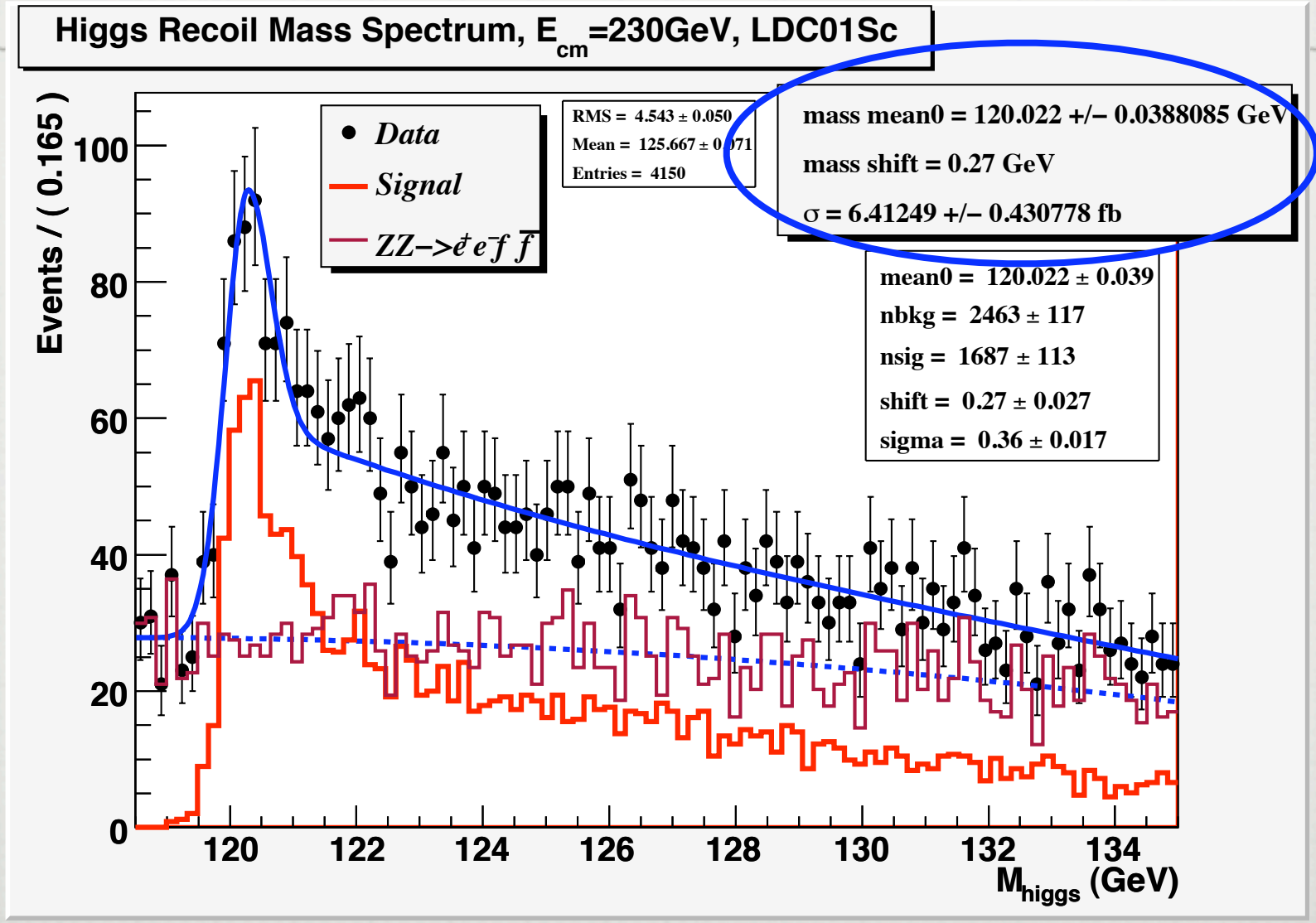
$$1+\sum_{i=1,n} a_i T_i(x)$$

$$T_0(x) = 1$$
$$T_1(x) = x$$
$$T_2(x) = 2x^2 - 1$$
$$T_3(x) = 4x^3 - 3x$$
$$T_4(x) = 8x^4 - 8x^2 + 1$$
$$T_5(x) = 16x^5 - 20x^3 + 5x$$
$$T_6(x) = 32x^6 - 48x^4 + 18x^2 - 1.$$

Note: in this study, only 2 or 3 coefficients are employed, in order to get a flat fit of the background



230GeV electron channel:
RESULTS

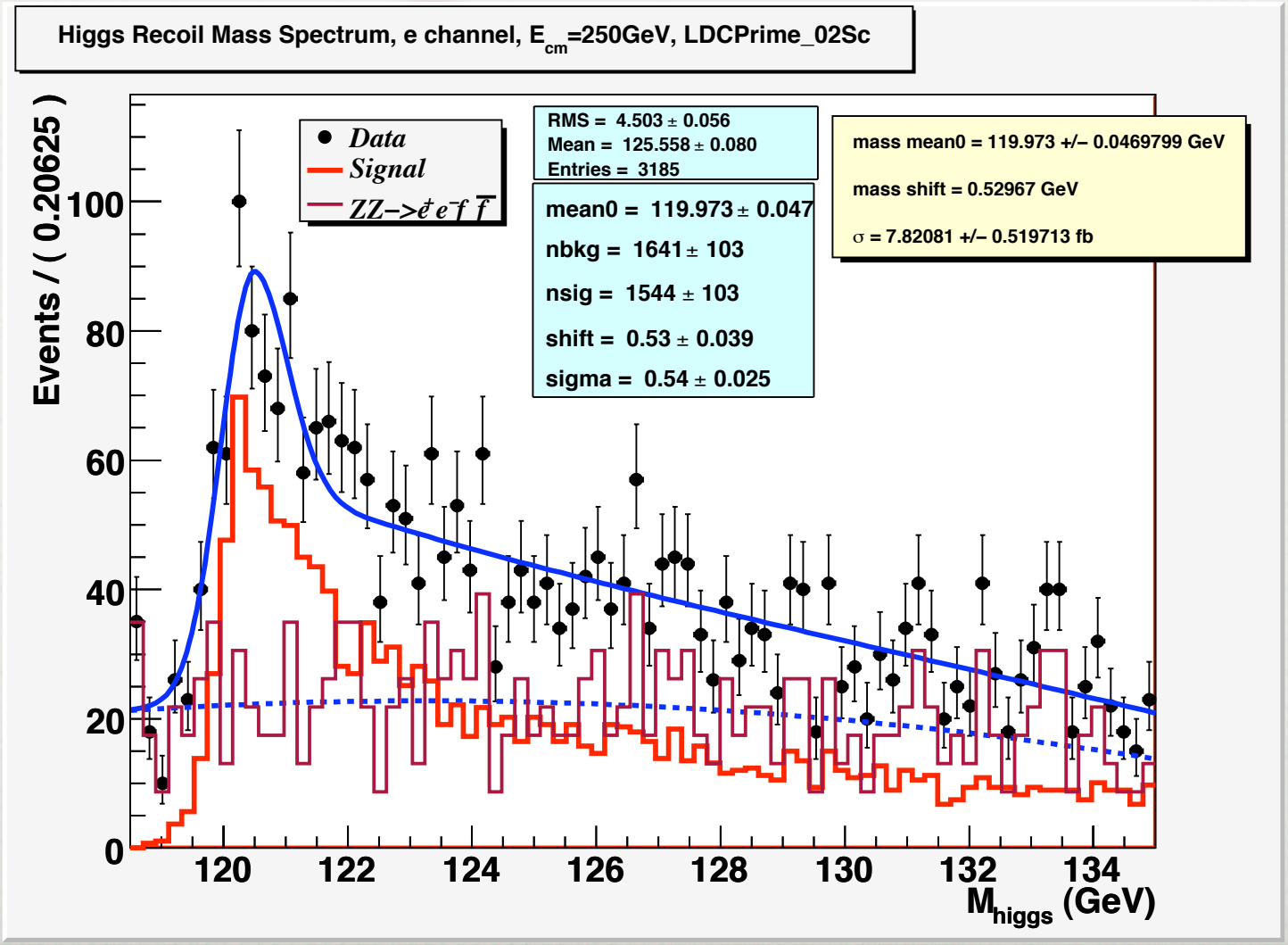


Composition: ZH: 40%; ZZ: 60%

250GeV electron and muon channels:

RESULTS:

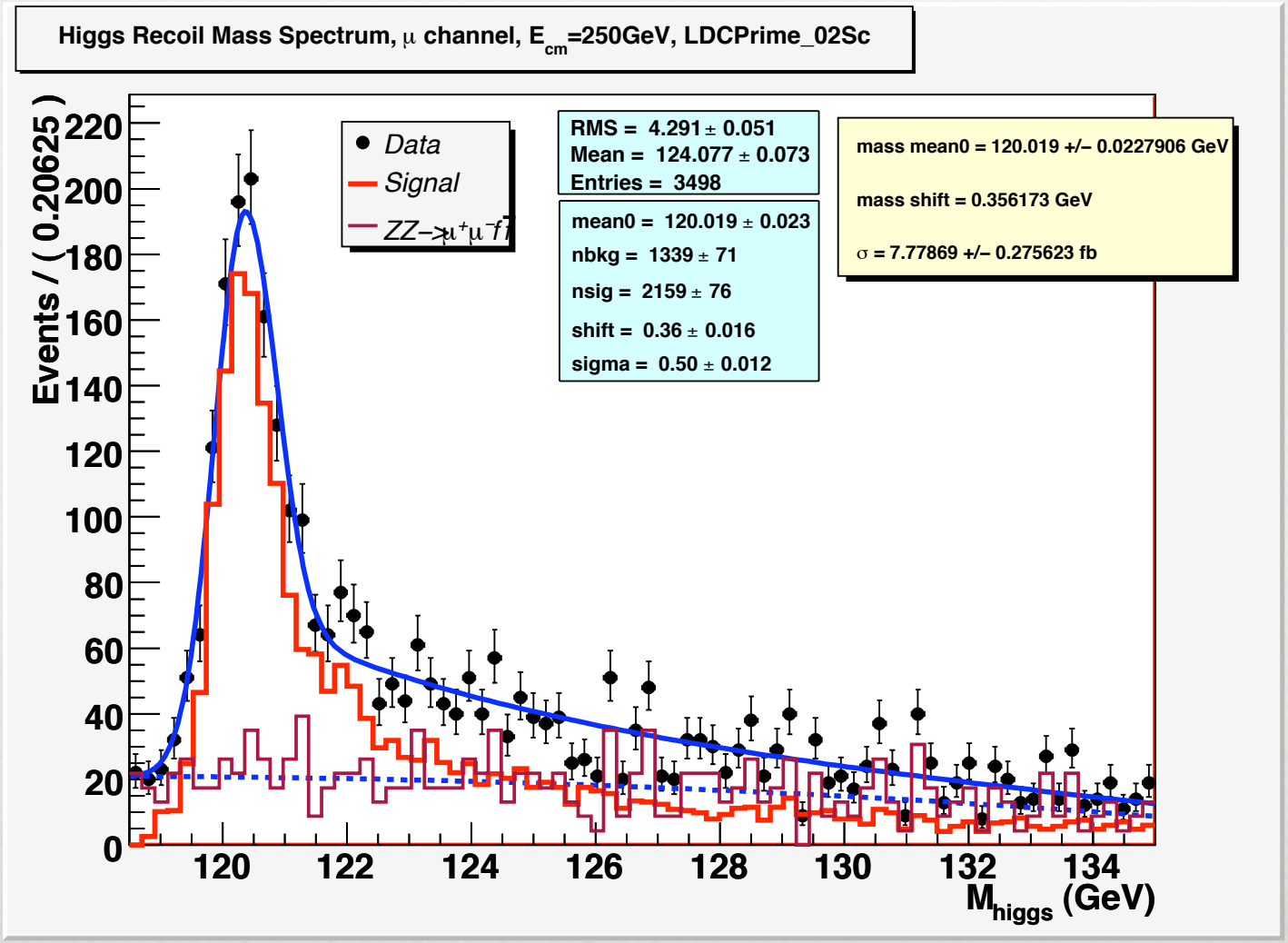
LDCPrime_02Sc e channel



250GeV electron and muon channels:

RESULTS:

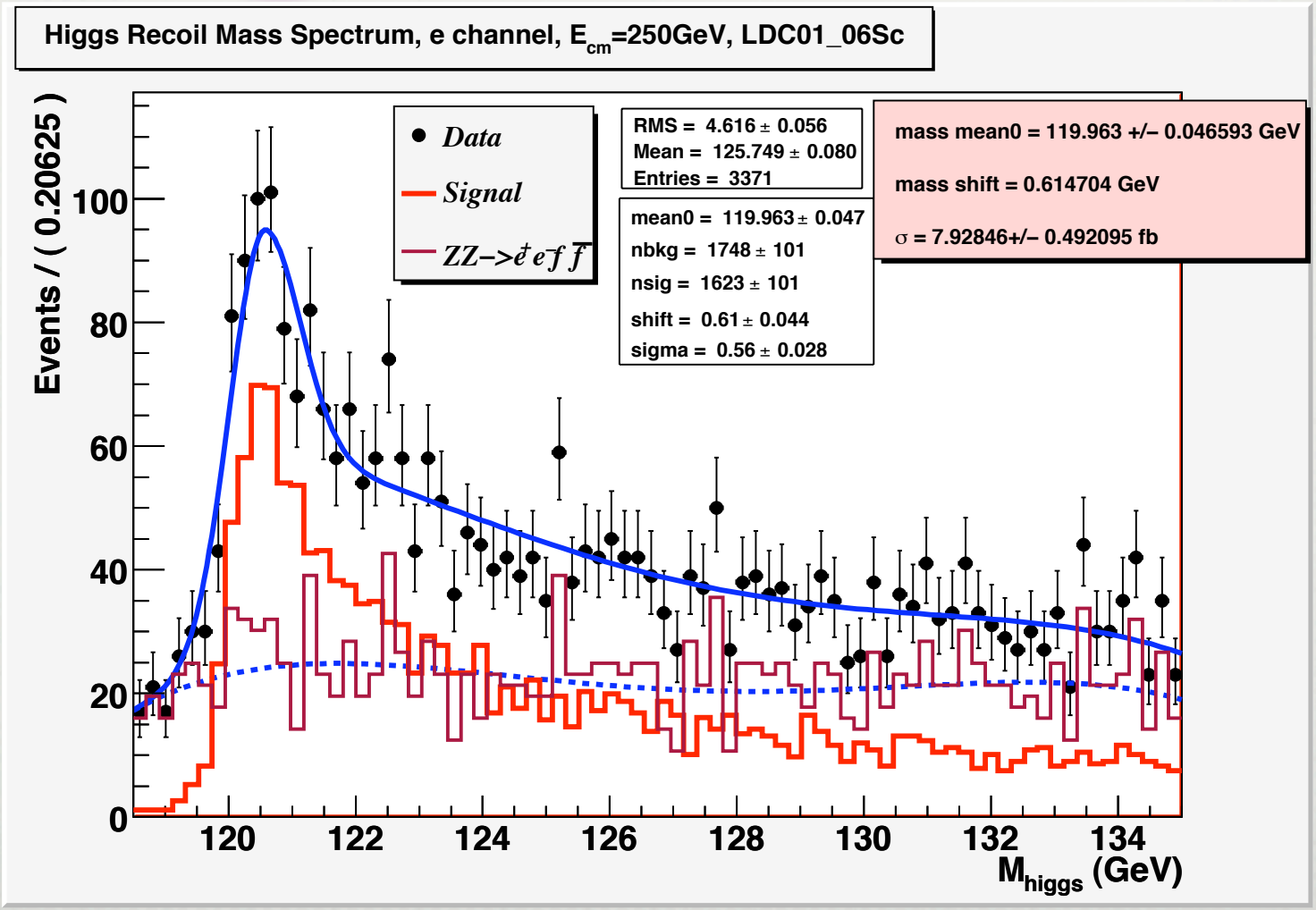
LDCPrime_02Sc μ channel



250GeV electron and muon channels:

RESULTS:

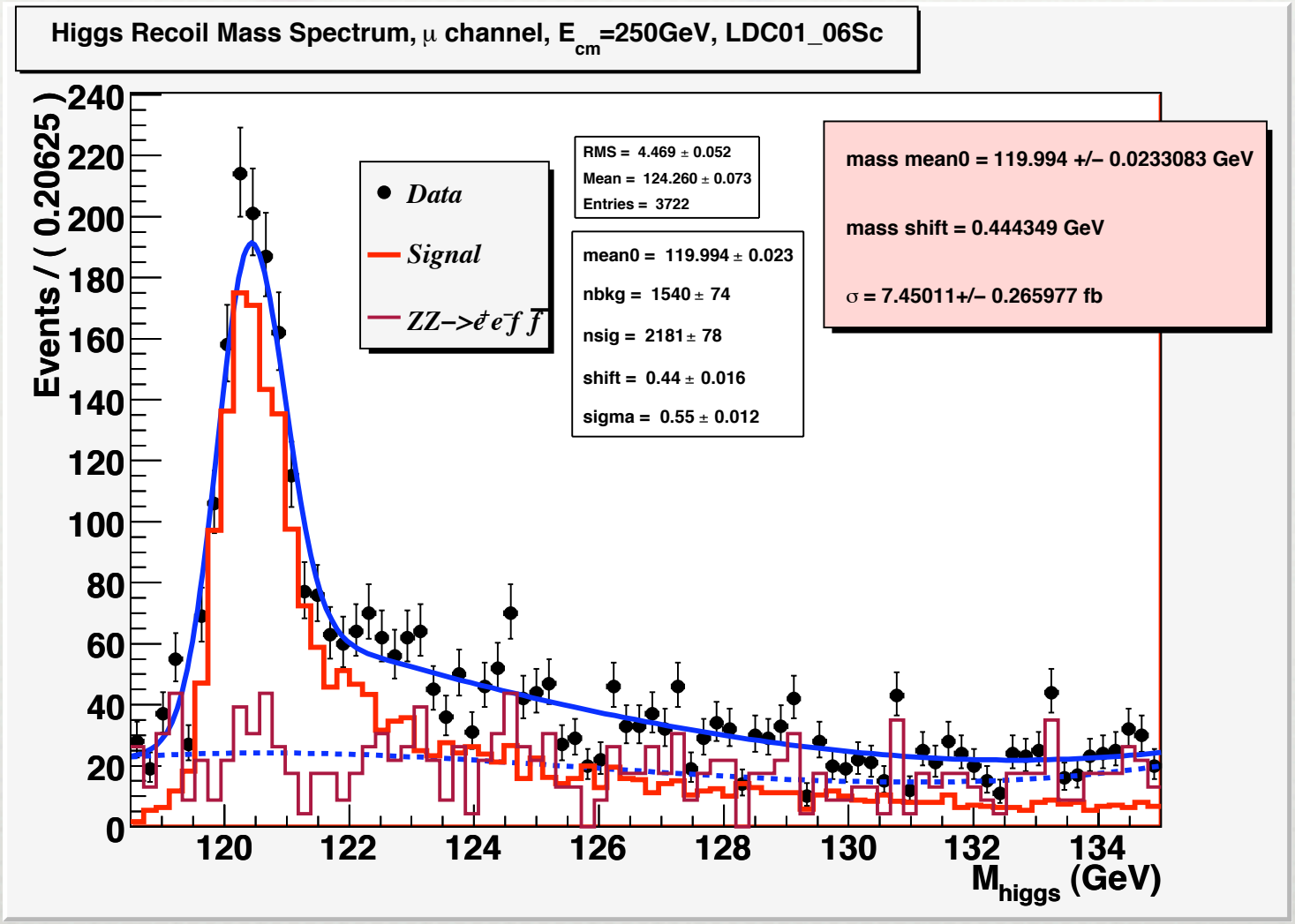
LDC01_06Sc e channel



250GeV electron and muon channels:

RESULTS:

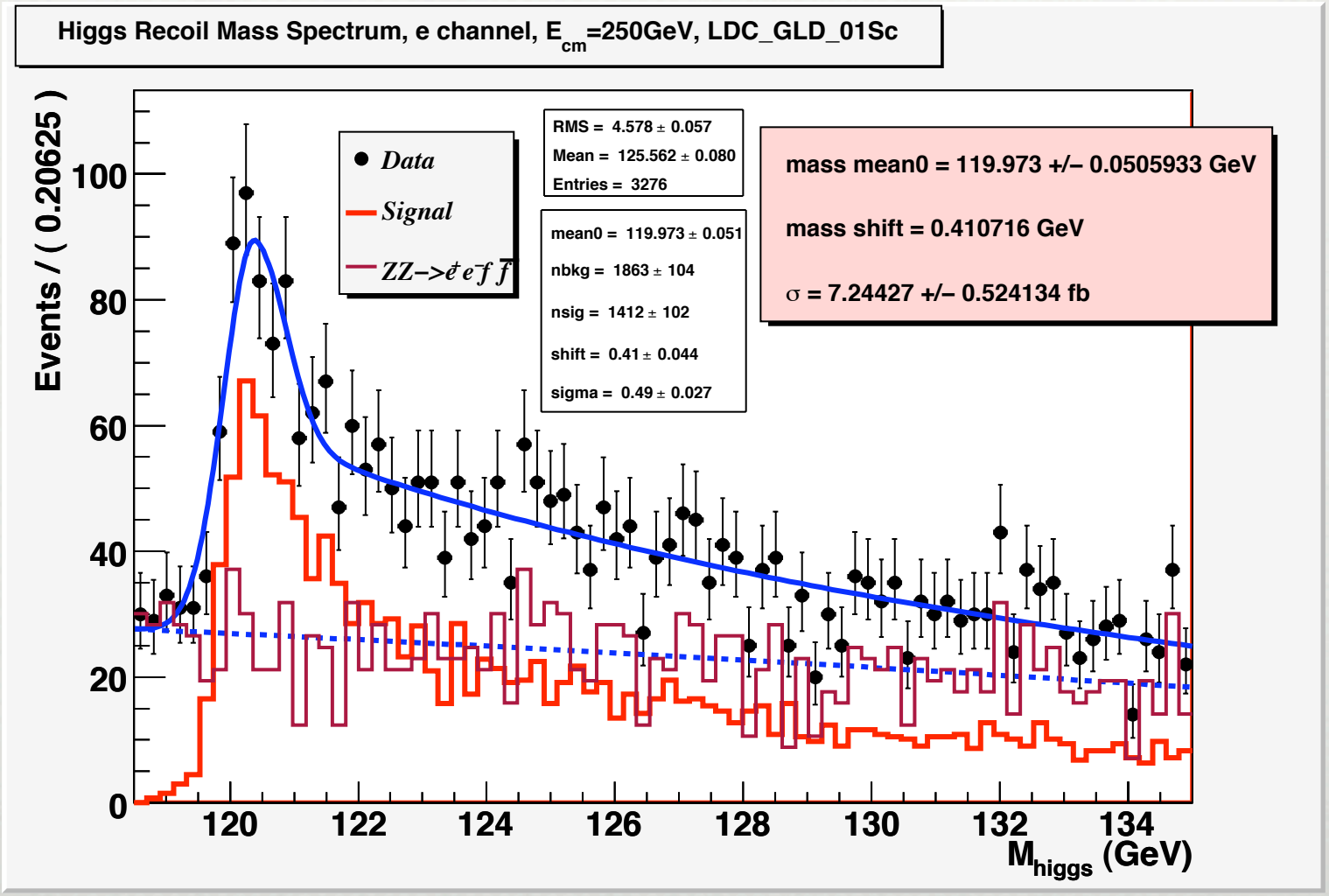
LDC01_06Sc μ channel



250GeV electron and muon channels:

RESULTS:

LDC_GLD_01Sc *e channel*



250GeV electron and muon channels:

RESULTS:

LDC_GLD_01Sc μ channel