Updates: e^+e^-→ZH Recoil mass

Case study working meeting - Higgs recoil

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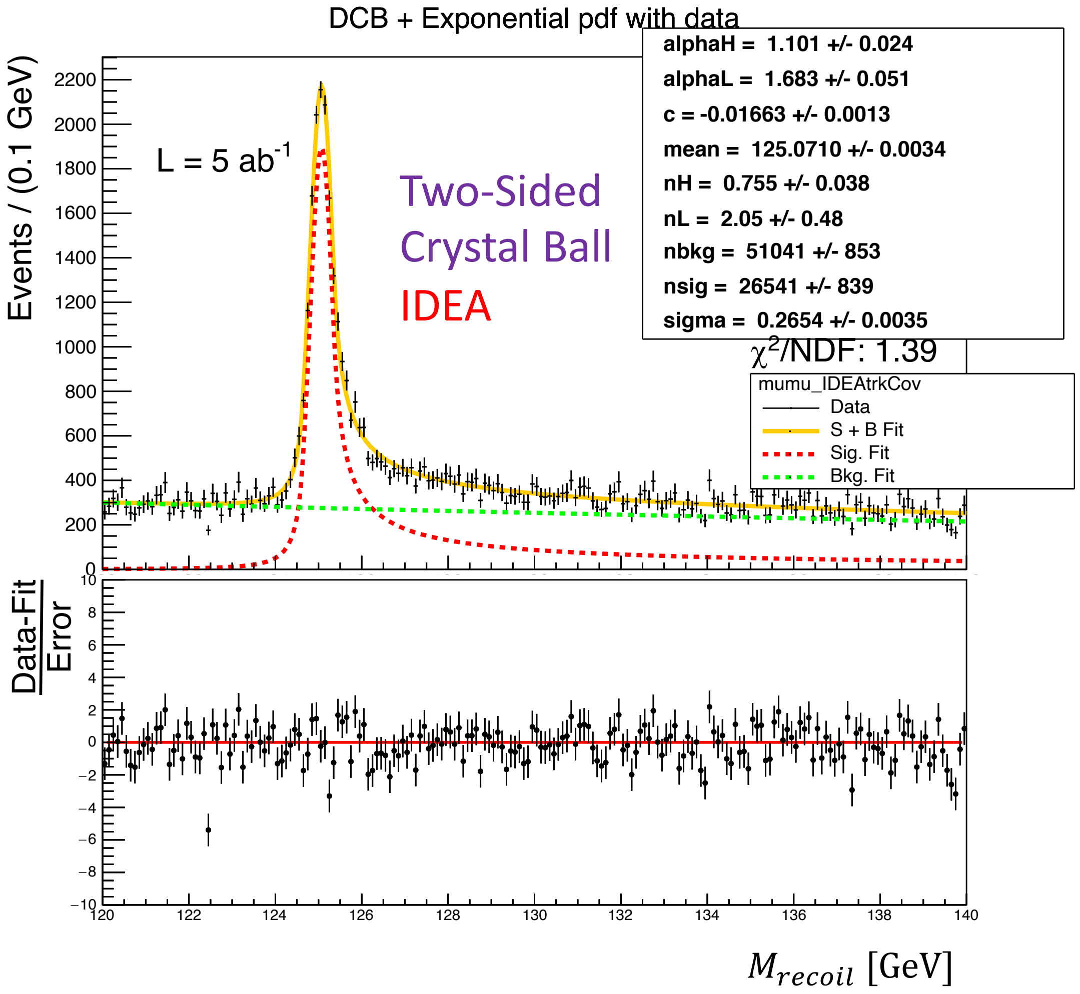
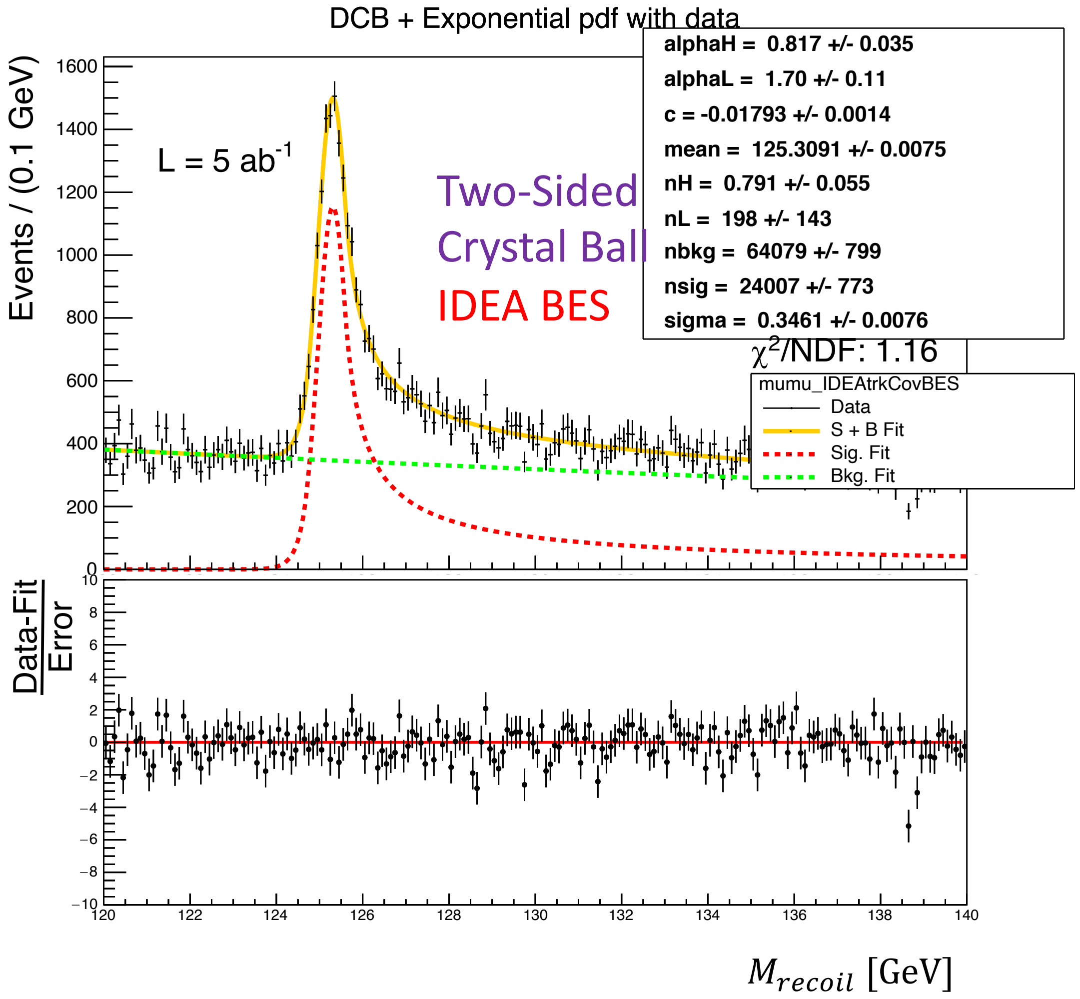
25/03/2021

Plans

- Selections
  - Cutflow table
  - Comparison of selections
- New Modelled Signal
- Fixing the parameters of Signal + Background fit of ZH+ZZ+WW
- Background fit
- Fixing the parameters of Signal + Background fit of ZH+ZZ

Two-Sided Crystal Ball + Exponential fit of M_{recoil} in the Higgs region (120-140 GeV)





- Large uncertainty of number of signal
- Need to investigate on the large uncertainty
- BES was not studied in this update

Previous talk on 2nd FCC-France Workshop

CutFlow Table

CutFlow Table

2		Lumi = 5 / ab	ZH	ZH	ZH	ZH	ZZ	ZZ	ZZ	ZZ	WW	WW	WW	WW	recoil between 120-140 GeV	
3				Total efficiency %	Cut efficiency %	# in Mrecoil		Total efficiency	Cut efficiency %	# in Mrecoil		Total efficiency	ut efficiency %	# in Mrecoi	S/B	(S/Sqrt(S+B))
4		Xsec (pb)	0.201037			120-140 GeV	1.35899			120-140 GeV	16.4385			120-140 GeV		
5		(XSec*Lumi)	1005185				6794950				82192500					
6		cumulative														
7		Total number of events	1005185			27104	6794950			33135	82192500			114124	0.18	64.9
8		# of mu+mu-	34511	100.00	3.43	27079	529294	100.00	7.79	32695	1200594	100.00	1.46	113631	0.19	65.0
9		# of events with at least one Z inside 73-120 GeV	27765	80.45	80.45	26231	352312	66.56	66.56	21532	323238	26.92	26.92	66617	0.30	77.6
10		# of events with at least one Z inside 80-110 GeV	26829	77.74	96.63	25572	334807	63.26	95.03	20124	204371	17.02	63.23	51058	0.36	82.2
11		# of events with at least one Z inside 80-100 GeV	26080	75.57	97.21	24831	321483	60.74	96.02	19559	133185	11.09	65.17	37455	0.44	86.8
12																
13		# of events with pt-of-lepton-sum inside 10-70 GeV	25454	73.76	94.87	24347	243278	45.96	72.66	18741	108806	9.06	53.24	35441	0.45	86.9
14																
15	follows row #11	# of events with Mrecoil between 110-155 GeV	26044	75.47	99.86	24831	42304	7.99	13.16	19559	69370	5.78	52.09	37455	0.44	86.8
16		# of events with Mrecoil between 120-140 GeV	24831	71.95	95.34	24831	19559	3.70	46.23	19559	37455	3.12	53.99	37455	0.44	86.8
17																
18	follows row #16	# of events with pt-of-lepton-sum > 10 GeV	24347	70.55	98.05	24347	18741	3.54	95.82	18741	35441	2.95	94.62	35441	0.45	86.9
19		# of events with pt-of-lepton-sum > 15 GeV	23724	68.74	97.44	23724	17747	3.35	94.70	17747	33543	2.79	94.64	33543	0.46	86.6
20		# of events with pt-of-lepton-sum > 20 GeV	22811	66.10	96.15	22811	16460	3.11	92.75	16460	30798	2.57	91.82	30798	0.48	86.2
21																
22	follows row #16	# of events with one pt-mu > 20 GeV	17428	50.50	70.19	17428	15607	2.95	79.79	15607	26803	2.23	71.56	26803	0.41	71.2
23		# of events with one pt-mu > 25 GeV	13917	40.33	79.85	13917	13333	2.52	85.43	13333	21140	1.76	78.87	21140	0.40	63.3
24		# of events with one pt-mu > 30 GeV	9916	28.73	71.25	9916	10146	1.92	76.10	10146	15230	1.27	72.04	15230	0.39	52.8
25																
26	follows row #20	# of events with pt-of-lepton-sum < 70 GeV	22811	66.10	100.00	22811	16460	3.11	100.00	16460	30798	2.57	100.00	30798	0.48	86.2

- The total efficiency and cut efficiency were shown
- Only about 3% of ZH events have at least pair of muons
- The M_{recoil} selection keeps about 95% of ZH, but remove about 40%-50% of ZZ and WW
- The p_T^Z selection keeps about 95% of ZH, keeps about 92% of ZZ and WW

Lin. Scale

M_{recoil} control plots

	Sel. 1	Sel. 2	Sel. 3
Sel. 4	Sel. 5	Sel. 6	Sel. 7

Cumulative:

Sel.1: At least one μ^+ one μ^-

Sel.2: $73\ \mathrm{GeV} < m_Z < 120\ \mathrm{GeV}$

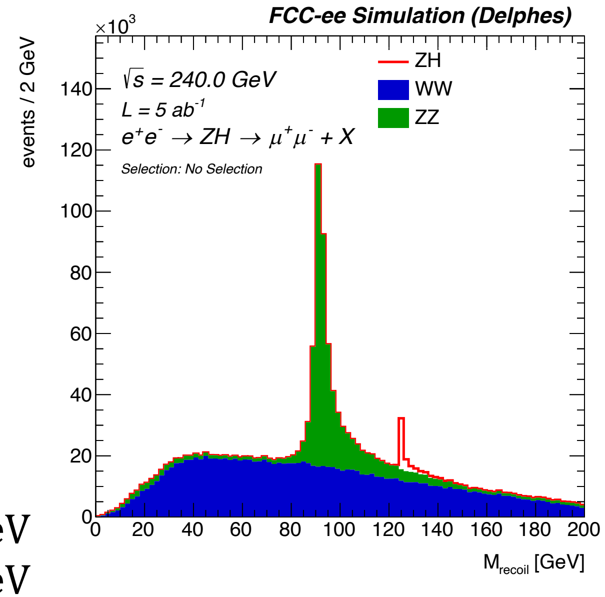
Sel.3: $80\ \mathrm{GeV} < m_Z < 110\ \mathrm{GeV}$

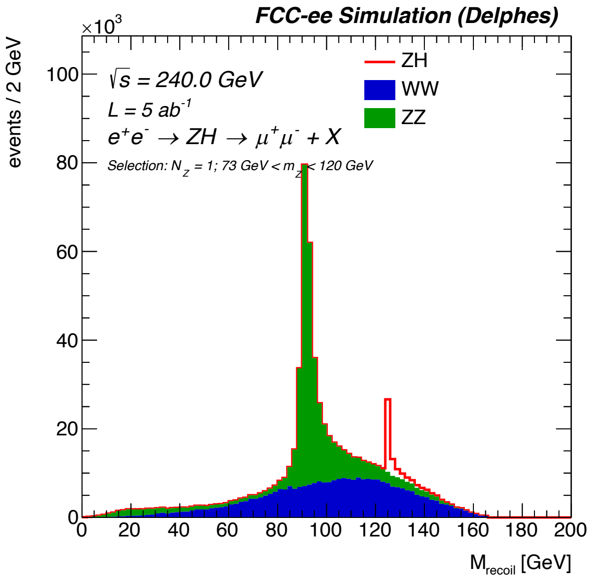
Sel.4: $80\ \mathrm{GeV} < m_Z < 100\ \mathrm{GeV}$

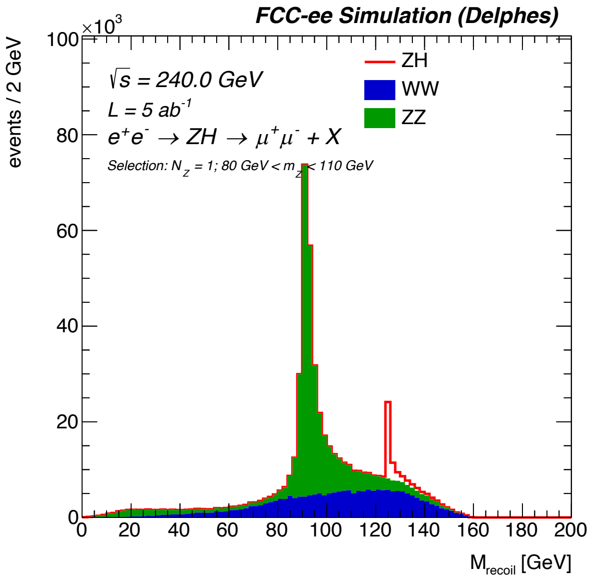
Sel.5: $10\ \mathrm{GeV} < p_T^Z < 70\ \mathrm{GeV}$

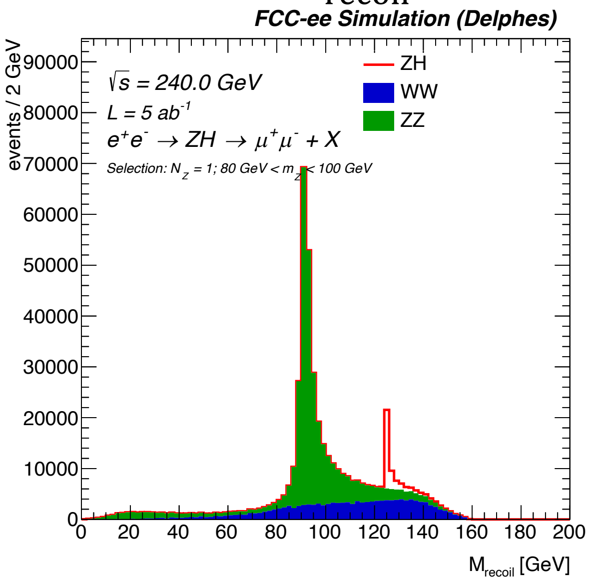
Sel.6: $110\ \mathrm{GeV} < M_{\mathrm{recoil}} < 155\ \mathrm{GeV}$

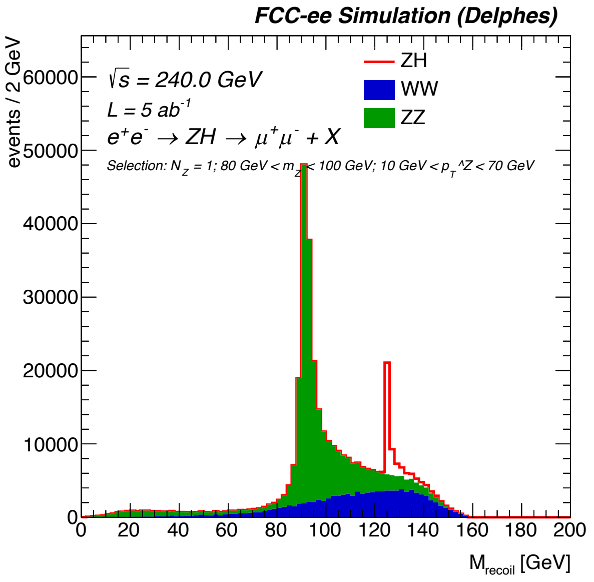
Sel.7: $120\ \mathrm{GeV} < M_{\mathrm{recoil}} < 140\ \mathrm{GeV}$

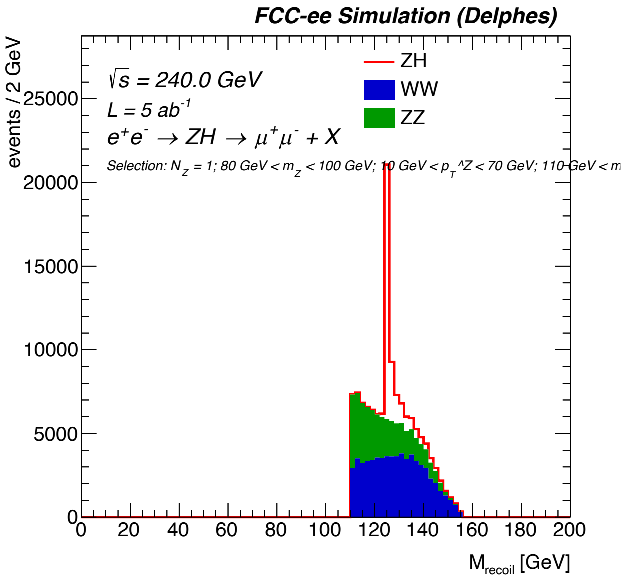


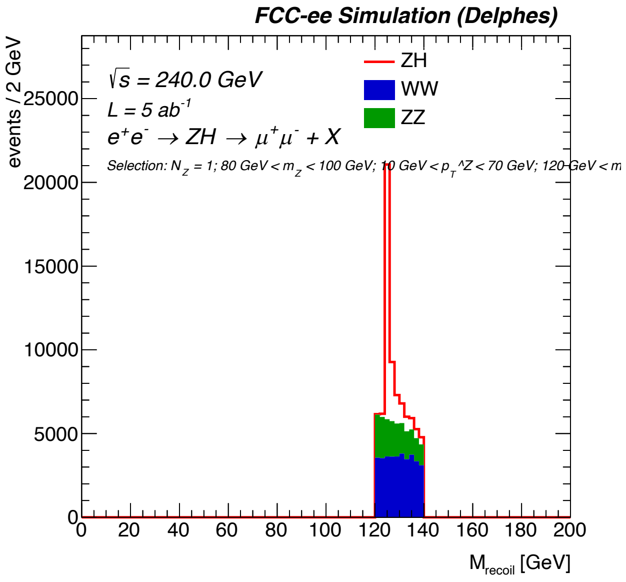








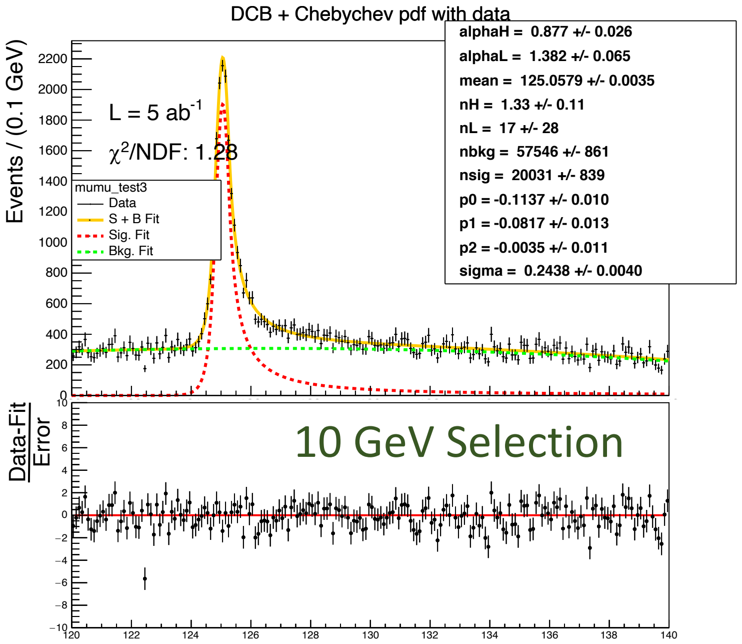




Comparison of 10 GeV Selection and 10-to-70 GeV Selection

10GeV Selection

1. At least one Z boson
2. $m_Z \in [80, 100]$ GeV
3. $p_T^{\mu} > 10$ GeV



M$_{recoil}$ [GeV]

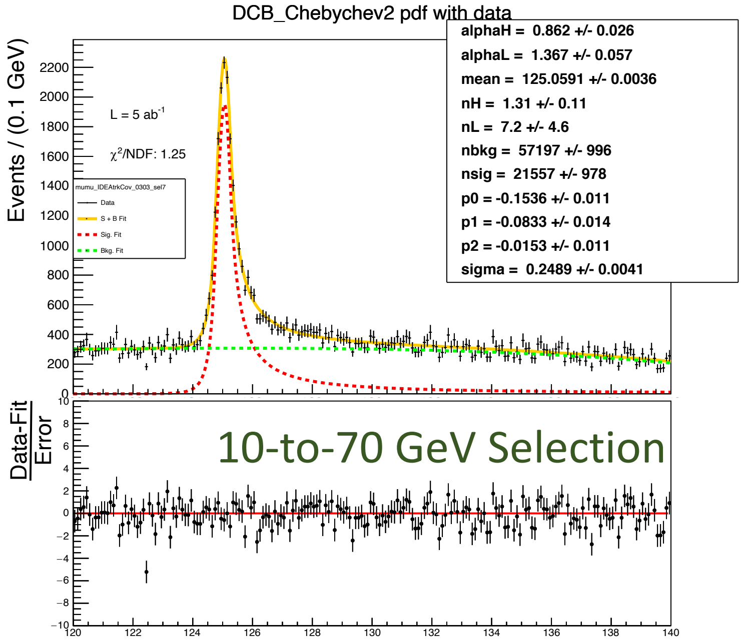
$\frac{\Delta N_{sig}}{N_{sig}} = 4.2\%$

Integral ZH =23389

$N_{sig}^{fit} / N_{sig}^{integral} = 85.6\%$

10-to-70 GeV Selection

1. At least one μ^+ one μ^-
2. At least One Z boson
3. $m_Z \in [80, 100]$ GeV
4. $p_T^Z \in [10, 70]$ GeV



M$_{recoil}$ [GeV]

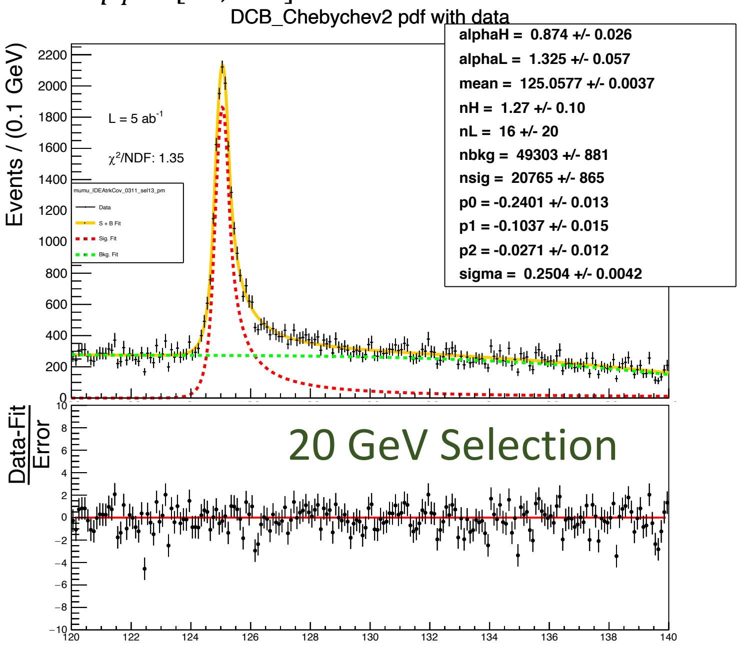
$\frac{\Delta N_{sig}}{N_{sig}} = 4.5\%$

Integral ZH = 24337

$N_{sig}^{fit} / N_{sig}^{integral} = 88.6\%$

20 GeV Selection

1. At least one μ^+ one μ^-
2. Z from pair of $\mu^+\mu^-$
3. At least One Z boson,
4. $m_Z \in [80, 100]$ GeV
5. $p_T^Z \in [20, +\infty]$ GeV



M$_{recoil}$ [GeV]

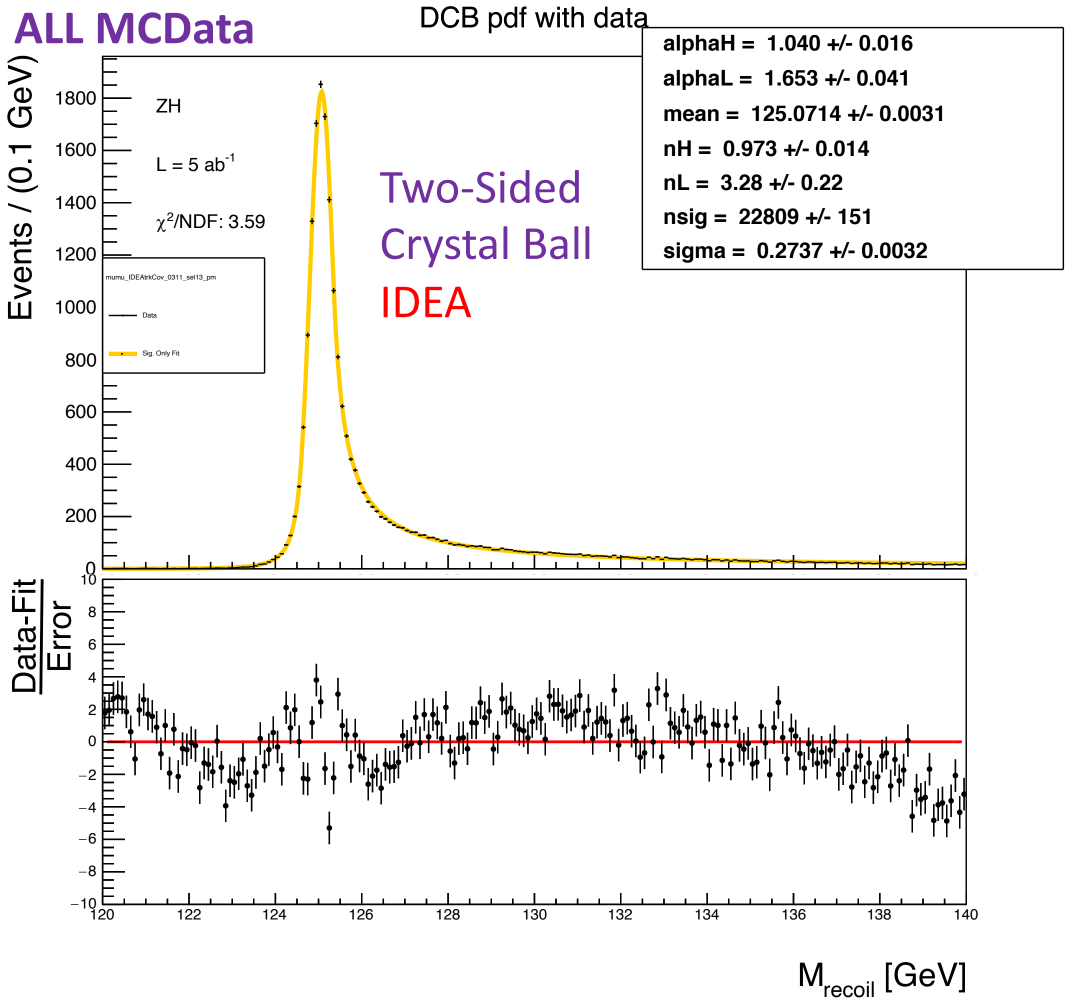
$\frac{\Delta N_{sig}}{N_{sig}} = 4.2\%$

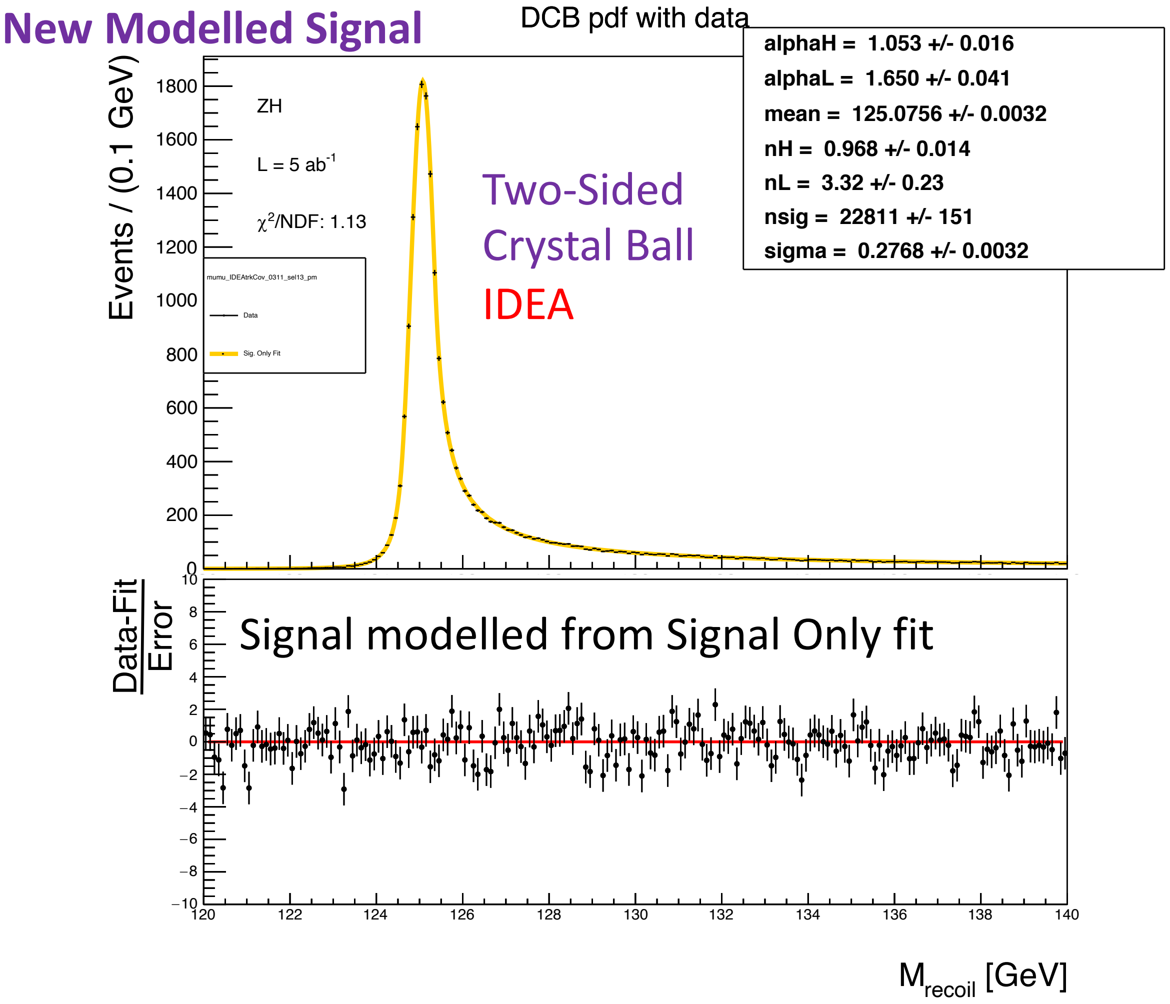
Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 91.0\%$

- 20 GeV selection increases the $\chi^2/_{NDF}$ and increase the $N_{sig}^{fit} / N_{sig}^{integral}$ ratio
- Will use 20 GeV selection in the following

Two-Sided Crystal Ball + Chebychev2 fit of M_{recoil} in the Higgs region (120-140 GeV)

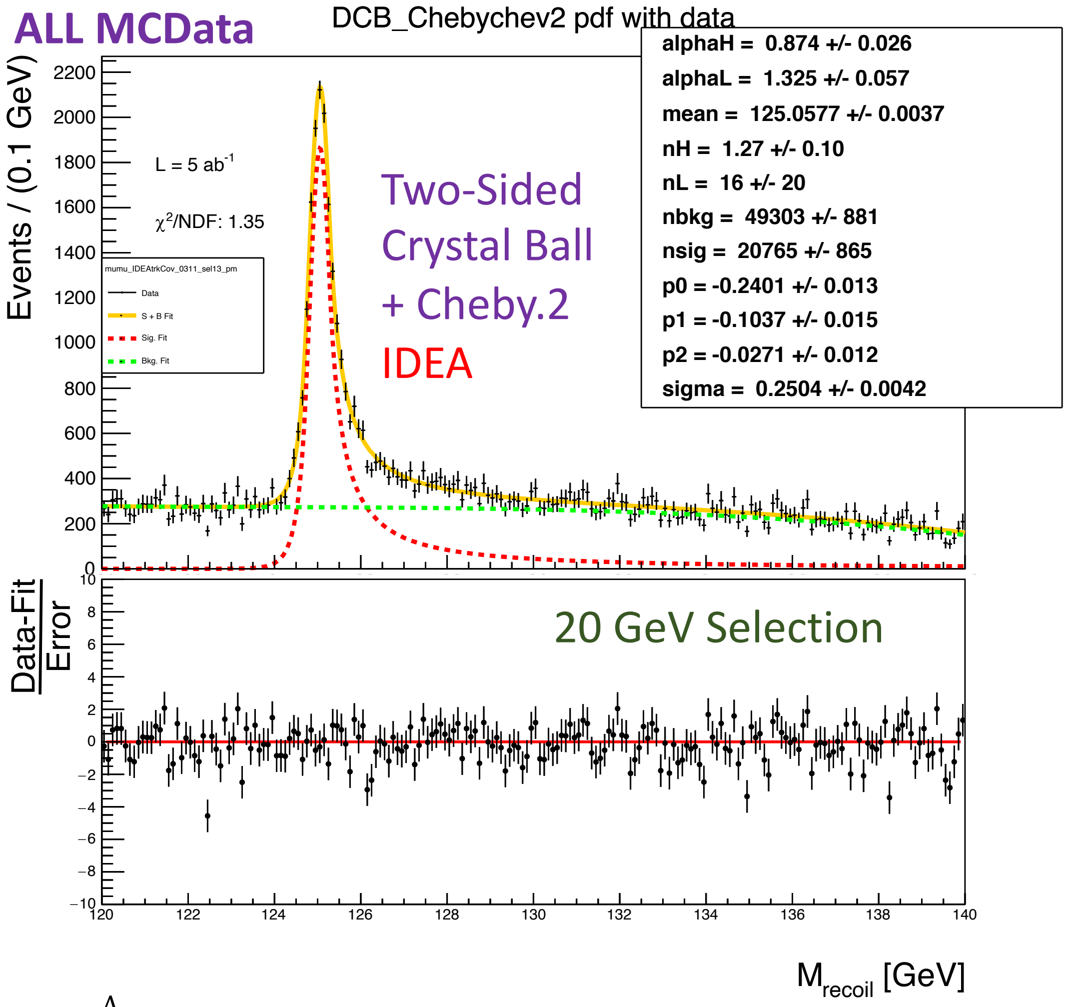




- $\chi^2/_{NDF}$ is far from 1, double crystal ball does not describe the signal well
- Need to find other function for the signal modeling
- Moddlled the signal with the signal only fit result to have a perfect signal shape

ALL MCData:
All data come from the MC simulation
New Modelled Signal:
ZH signal is modelled to perfect shape

Comparison of 2nd order Chebychev and Simple Polynomial



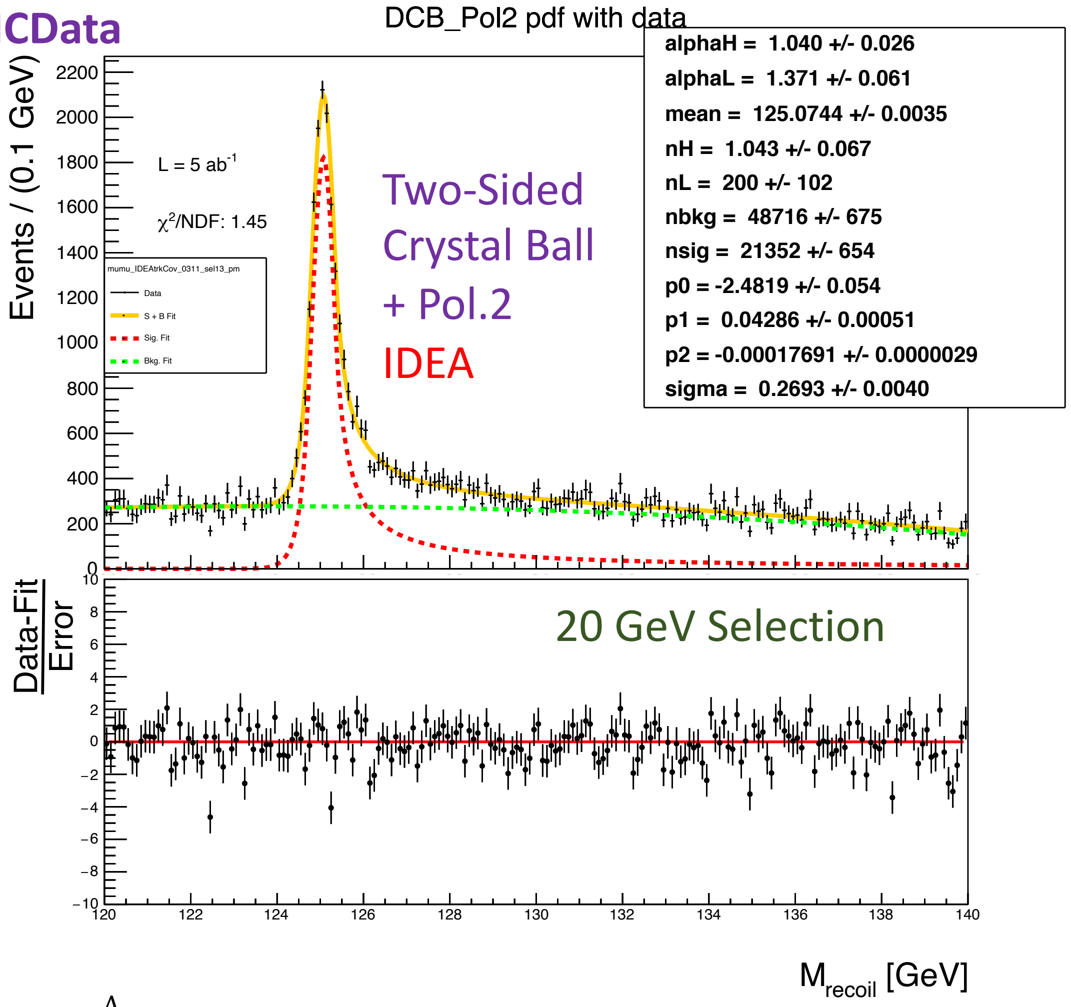
$\frac{\Delta_{N_{sig}}}{N_{sig}} = 4.2\%$

$80\ \text{GeV} < M_Z < 100\ \text{GeV}$

$p_T^Z > 20\ \text{GeV}$

IntIntegral ZH =22811

$N_{sig}^{fit} / N_{sig}^{integral} = 91.0\%$



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 3.1\%$

$80\ \text{GeV} < M_Z < 100\ \text{GeV}$

$p_T^Z > 20\ \text{GeV}$

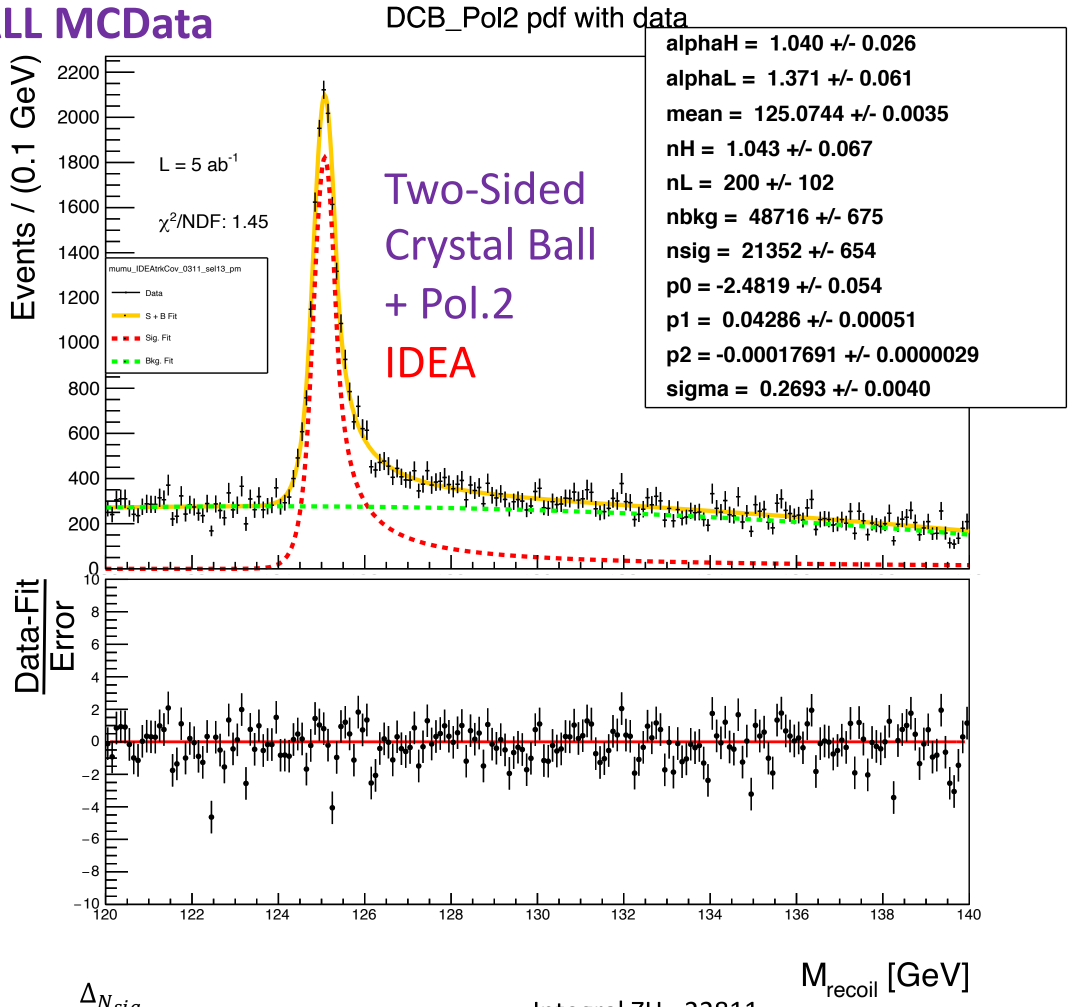
Integral ZH =22811

$N_{sig}^{fit} / N_{sig}^{integral} = 93.6\%$

- Pol.2 has little worse $\chi^2/_{NDF}$ but better precision on the number of signal
- Will use Pol.2 in the following study

Comparison of ALL MCData fit and New Modelled Signal fit

ALL MCData



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 3.1\%$

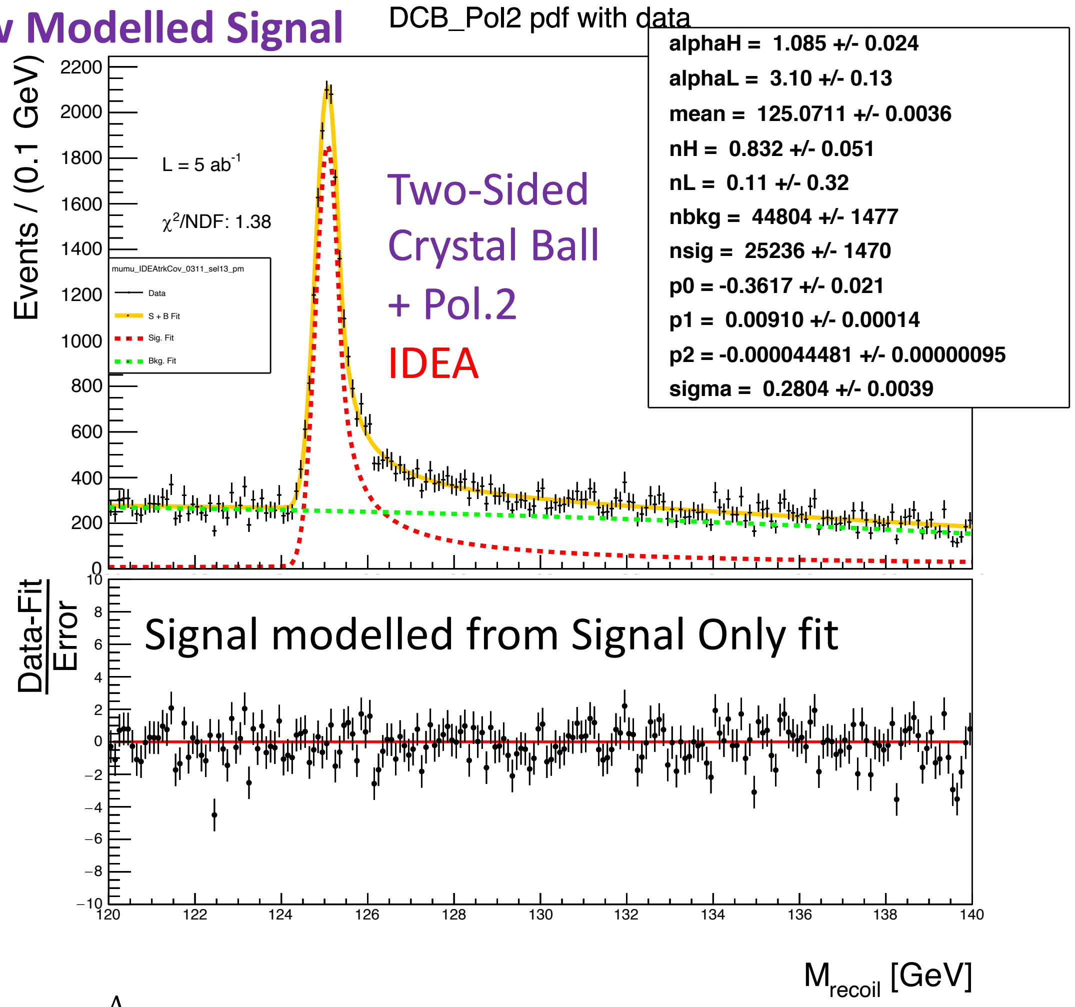
$80\text{ GeV} < M_Z < 100\text{ GeV}$

$p_T^Z > 20\text{ GeV}$

Integral ZH =22811

$N_{sig}^{fit} \Big/ N_{sig}^{integral} = 93.6\%$

New Modelled Signal



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 5.8\%$

$80\text{ GeV} < M_Z < 100\text{ GeV}$

$p_T^Z > 20\text{ GeV}$

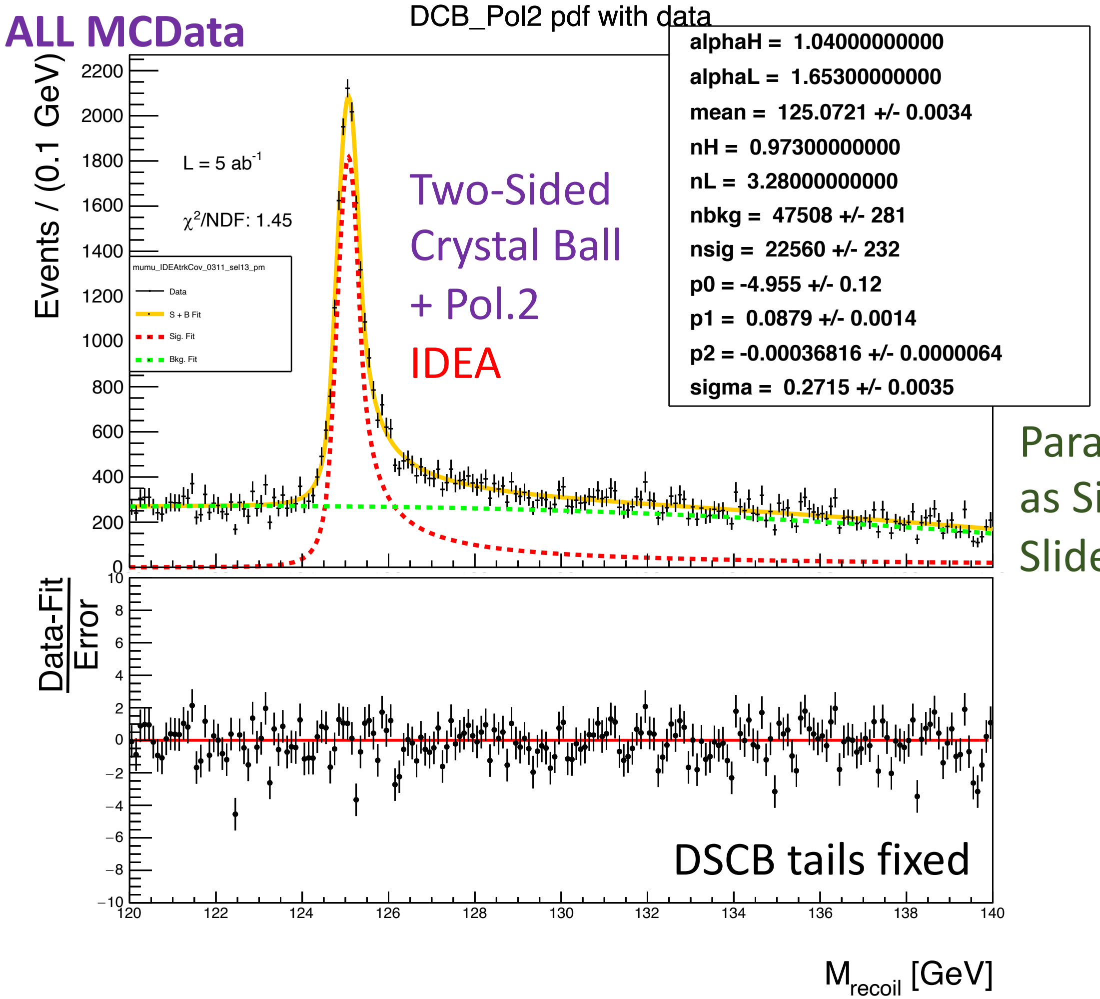
Integral ZH =22811

$N_{sig}^{fit} \Big/ N_{sig}^{integral} = 110.6\%$

- New modelled signal fit has larger uncertainty of number of signal even if we have perfect signal shape
- Background has more contribution to the uncertainty than the signal

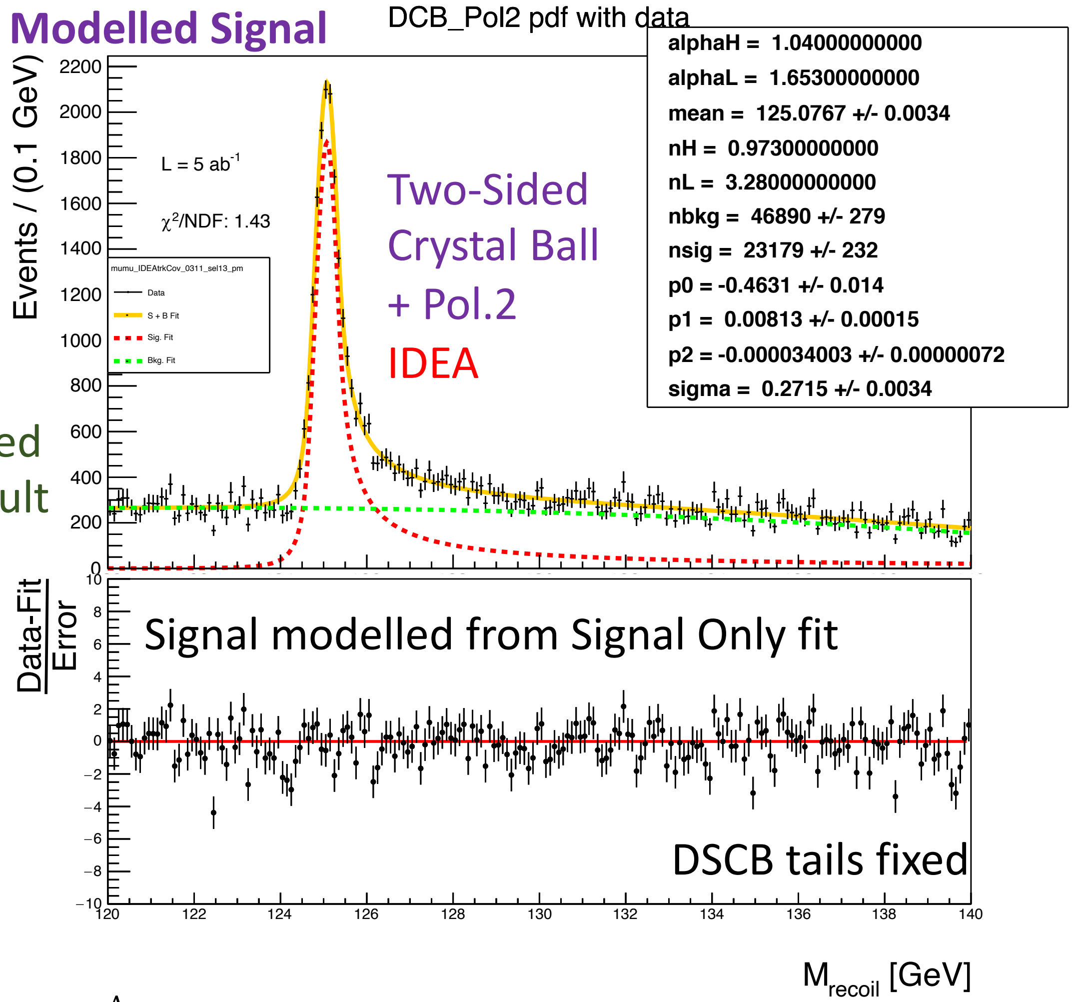
Two-Sided Crystal Ball + Pol2 fit of M_{recoil} in the Higgs region (120-140 GeV)

ALL MCData



Parameters were fixed as Signal Only fit result Slide 7 left plot

New Modelled Signal



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 1.03\%$

$80\ \text{GeV} < M_Z < 100\ \text{GeV}$

$p_T^Z > 20\ \text{GeV}$

Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 98.9\%$

$\frac{\Delta_{N_{sig}}}{N_{sig}} = 1.00\%$

$80\ \text{GeV} < M_Z < 100\ \text{GeV}$

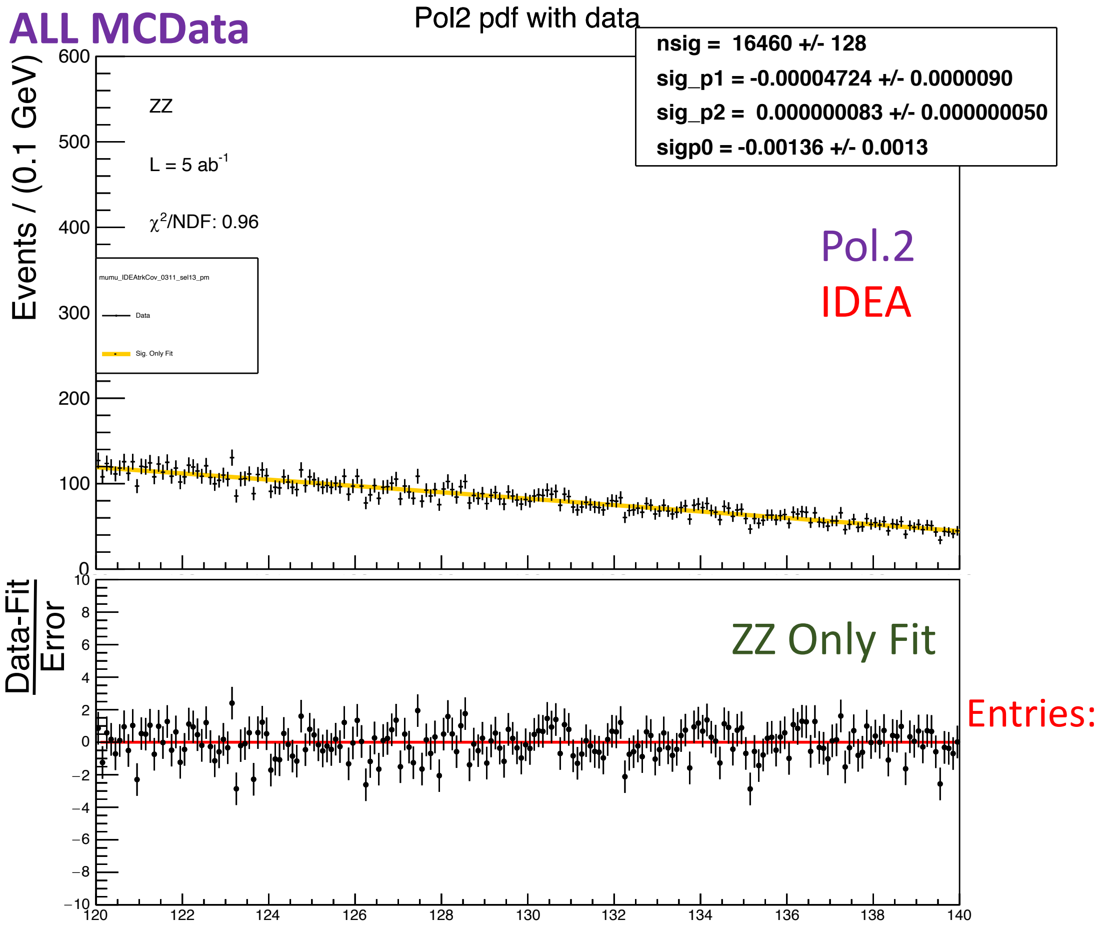
$p_T^Z > 20\ \text{GeV}$

Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 101.6\%$

- After fixing the tails, the uncertainty of number of signal ~ 1.0%
- Need to investigate the backgroud

Bkg. Pol2 fit of M_{recoil} in the Higgs region (120-140 GeV)



$\frac{\Delta N_{sig}}{N_{sig}} = 0.78\%$

$80\text{ GeV} < M_Z < 100\text{ GeV}$

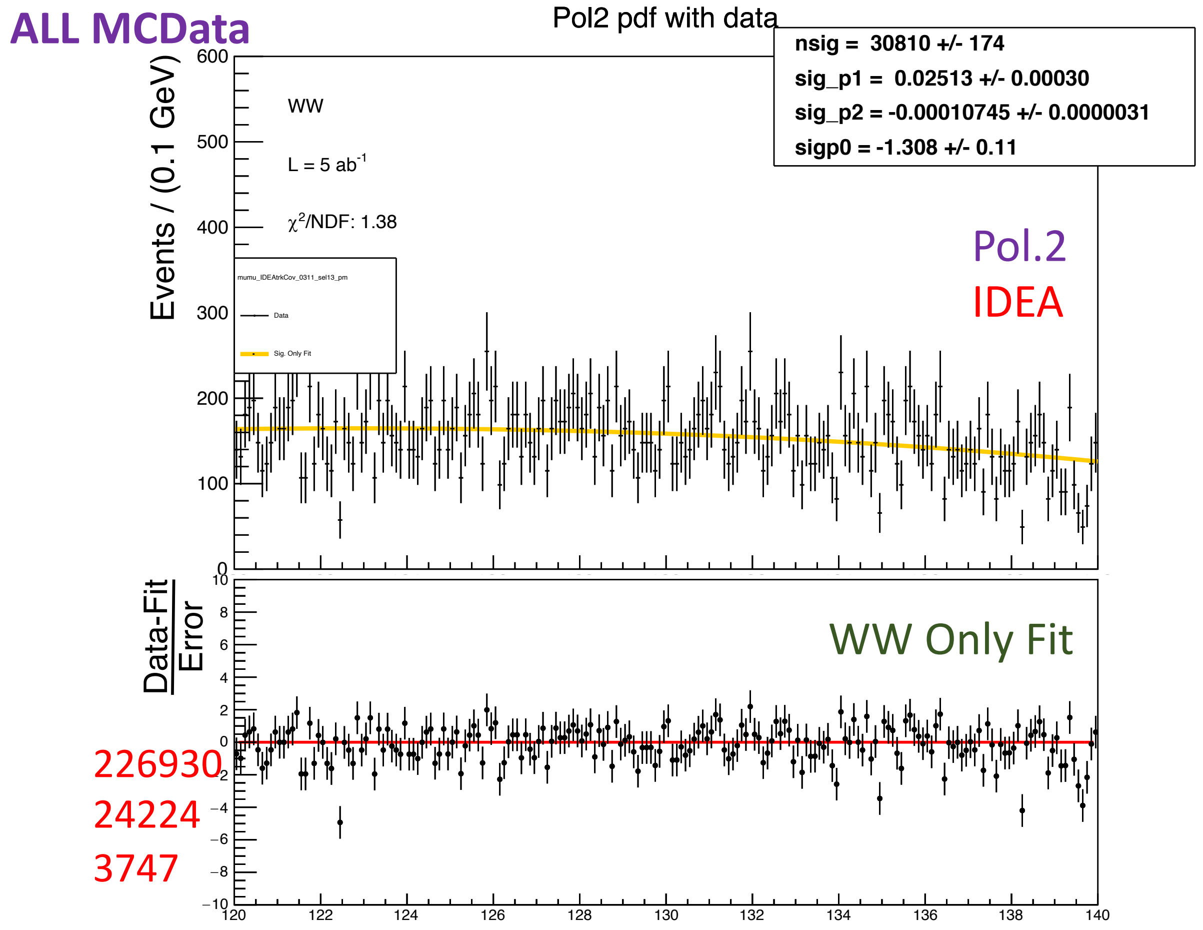
$p_T^Z > 20\text{ GeV}$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 100.0\%$

Entries:

ZH:	226930
ZZ:	24224
WW:	3747



$\frac{\Delta N_{sig}}{N_{sig}} = 1.04\%$

$80\text{ GeV} < M_Z < 100\text{ GeV}$

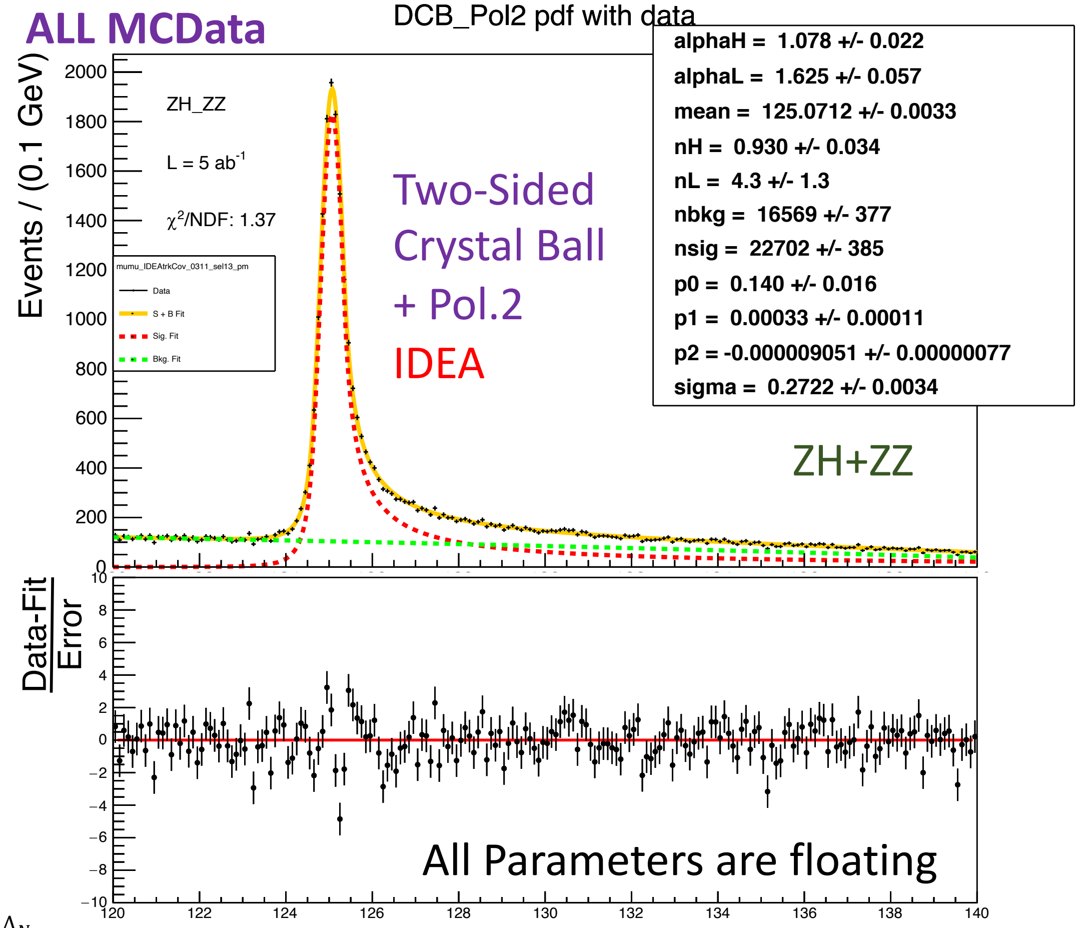
$p_T^Z > 20\text{ GeV}$

Integral WW = 30797

$N_{sig}^{fit} / N_{sig}^{integral} = 100.0\%$

- WW has low statistic and large uncertaity (~100 times less than ZH)
- May need to generate more events
- Will focus only ZZ background

Two-Sided Crystal Ball + Pol2 fit of M_{recoil} in the Higgs region (120-140 GeV)



$\frac{\Delta N_{sig}}{N_{sig}} = 1.70\%$

$\frac{\Delta N_{bkg}}{N_{bkg}} = 2.28\%$

$80 \text{ GeV} < M_Z < 100 \text{ GeV}$

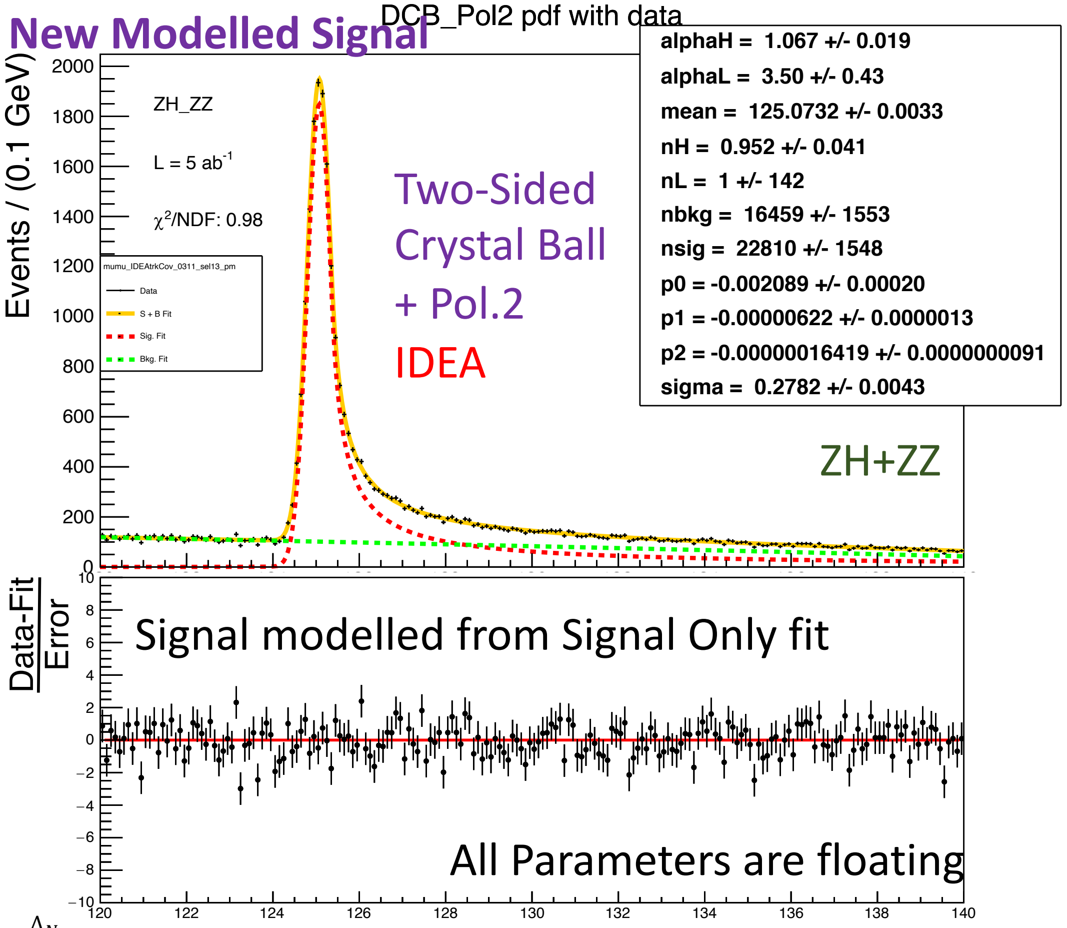
$p_T^Z > 20 \text{ GeV}$

Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 99.5\%$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 100.7\%$



$\frac{\Delta N_{sig}}{N_{sig}} = 6.79\%$

$\frac{\Delta N_{bkg}}{N_{bkg}} = 9.44\%$

$80 \text{ GeV} < M_Z < 100 \text{ GeV}$

$p_T^Z > 20 \text{ GeV}$

Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 100.0\%$

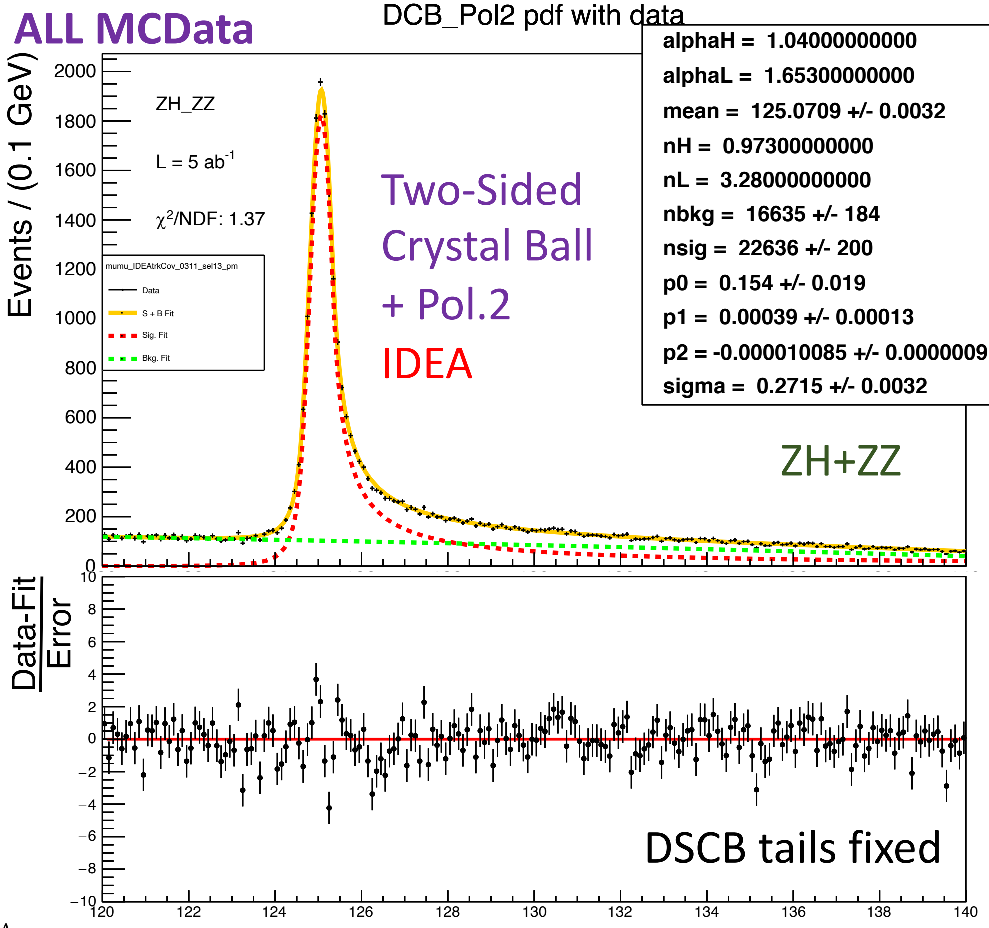
Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 100.0\%$

- All MCData has good precision on Nsig
- The uncertainty of New Modelled Signal fit may come from the nL

Two-Sided Crystal Ball + Pol2 fit of M_{recoil} in the Higgs region (120-140 GeV)

ALL MCData



$\frac{\Delta N_{sig}}{N_{sig}} = 0.88\%$

$\frac{\Delta N_{bkg}}{N_{bkg}} = 1.26\%$

$80\text{ GeV} < M_Z < 100\text{ GeV}$

$p_T^Z > 20\text{ GeV}$

Integral ZH = 22811

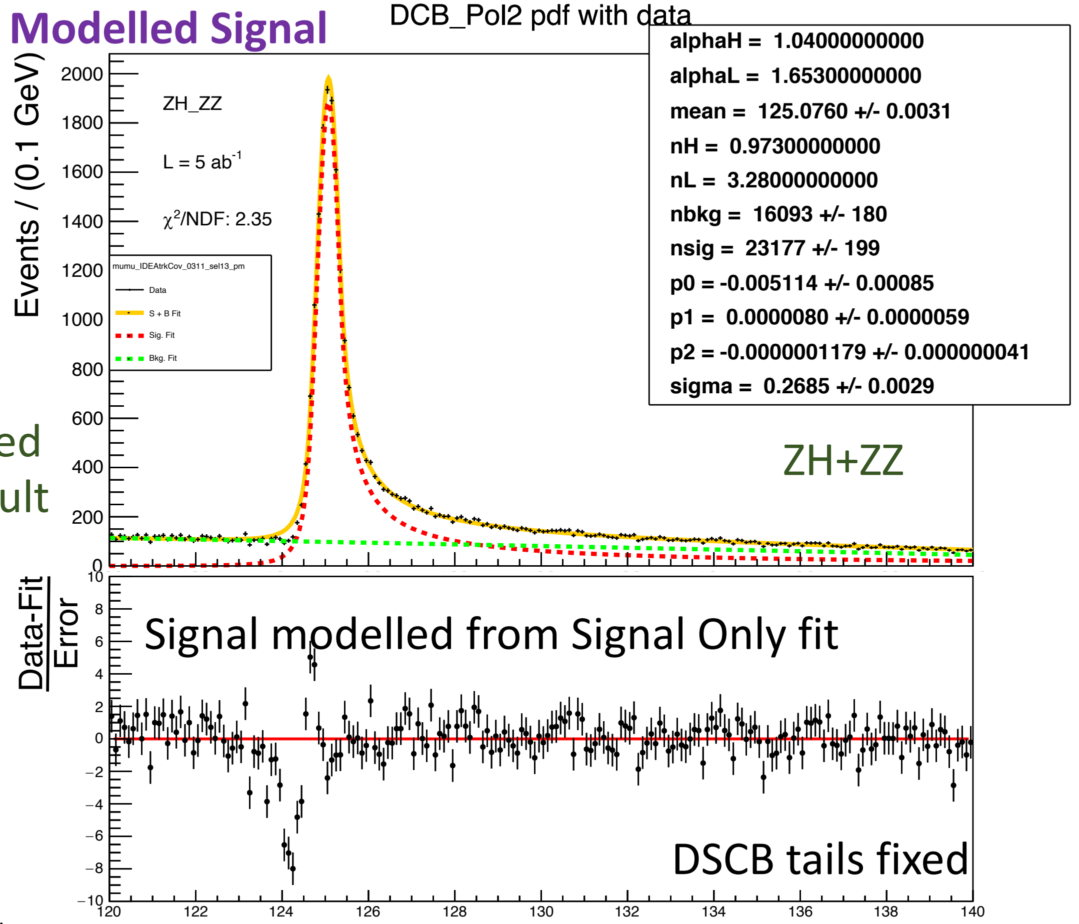
$N_{sig}^{fit} / N_{sig}^{integral} = 99.2\%$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 101.1\%$

Parameters were fixed as Signal Only fit result Slide 7 left plot

New Modelled Signal



$\frac{\Delta N_{sig}}{N_{sig}} = 0.86\%$

$\frac{\Delta N_{bkg}}{N_{bkg}} = 1.12\%$

$80\text{ GeV} < M_Z < 100\text{ GeV}$

$p_T^Z > 20\text{ GeV}$

Integral ZH = 22811

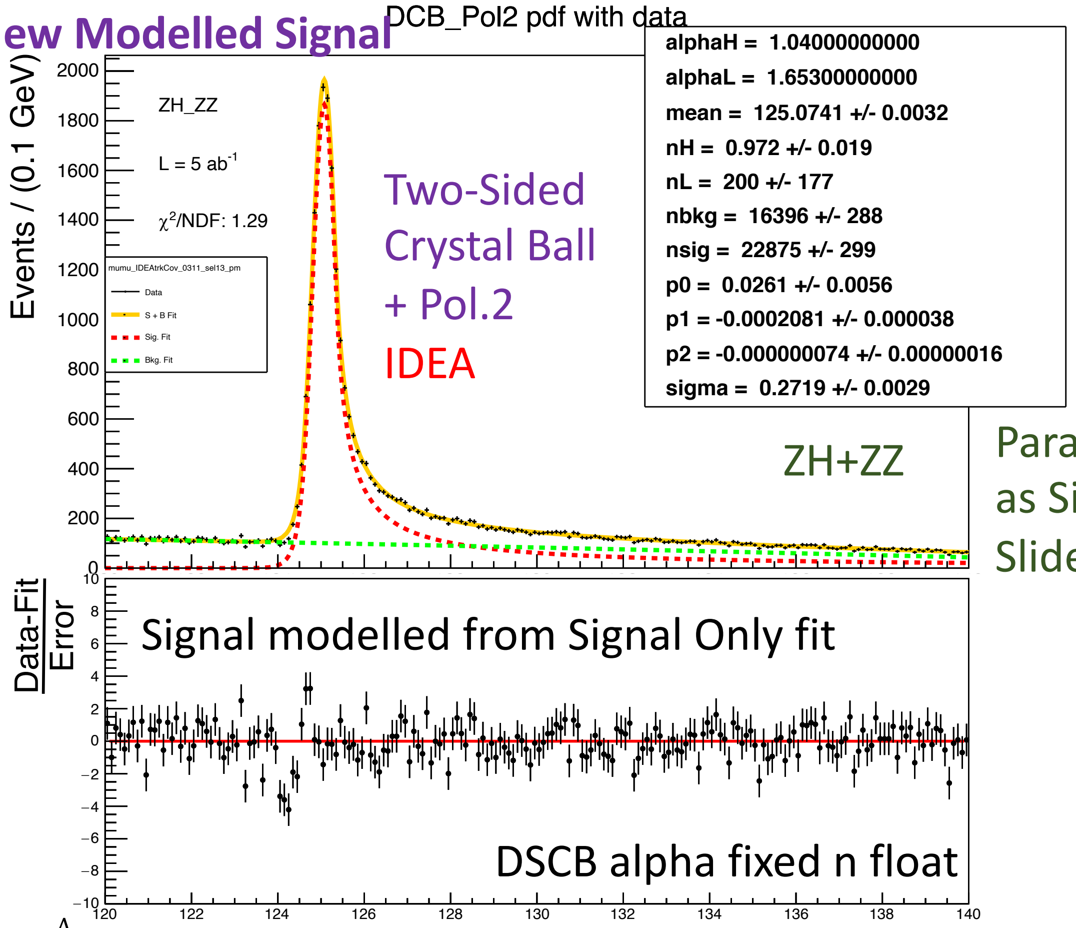
$N_{sig}^{fit} / N_{sig}^{integral} = 101.6\%$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 97.8\%$

- After fixing the DSCB tails, the uncertainty of signal ~ 0.9% for both ALL MCData and New Modelled Signal
- But the $\chi^2/_{NDF}$ of New Modelled Signal is not good (2.35)

Two-Sided Crystal Ball + Pol2 fit of M_{recoil} in the Higgs region (120-140 GeV)



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 1.31\%$

$\frac{\Delta_{N_{bkg}}}{N_{bkg}} = 1.76\%$

$80 \text{ GeV} < M_Z < 100 \text{ GeV}$

$p_T^Z > 20 \text{ GeV}$

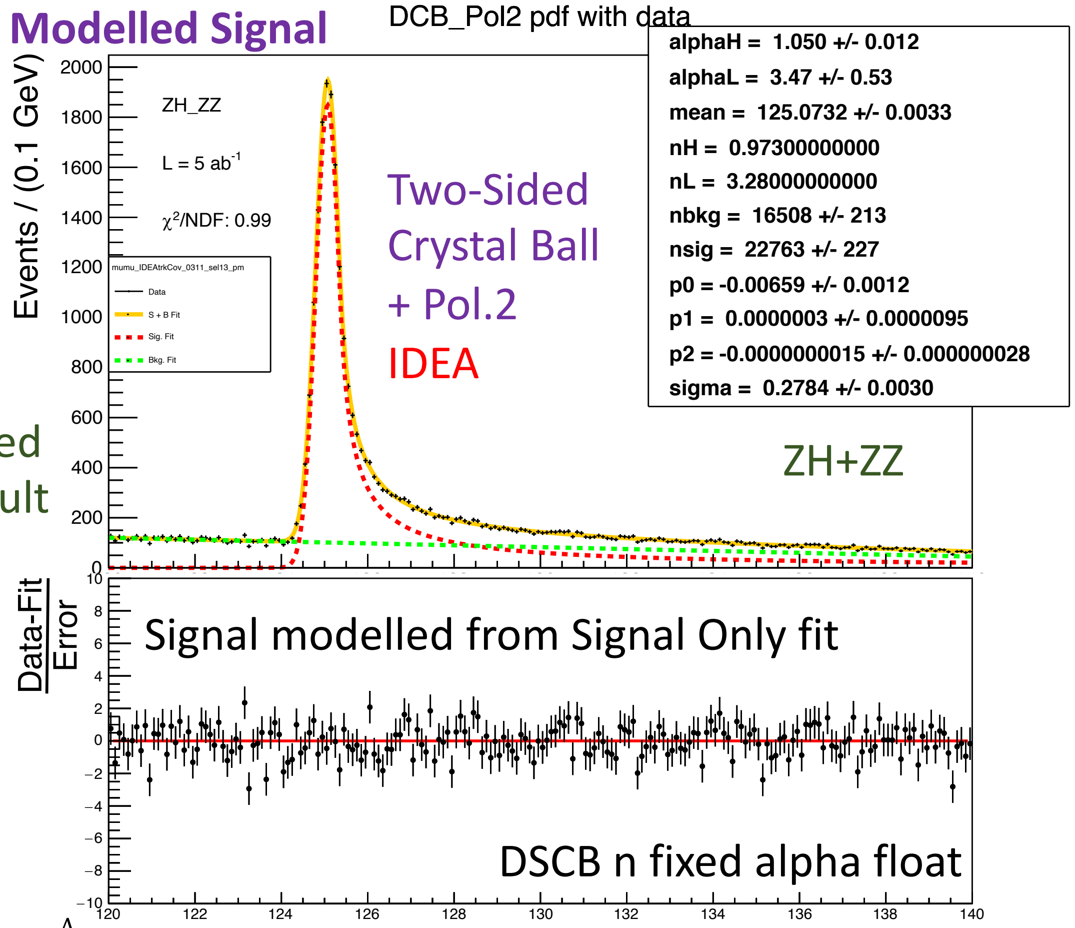
Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 100.3\%$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 99.6\%$

Parameters were fixed as Signal Only fit result Slide 7 left plot



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 1.00\%$

$\frac{\Delta_{N_{bkg}}}{N_{bkg}} = 1.29\%$

$80 \text{ GeV} < M_Z < 100 \text{ GeV}$

$p_T^Z > 20 \text{ GeV}$

Integral ZH = 22811

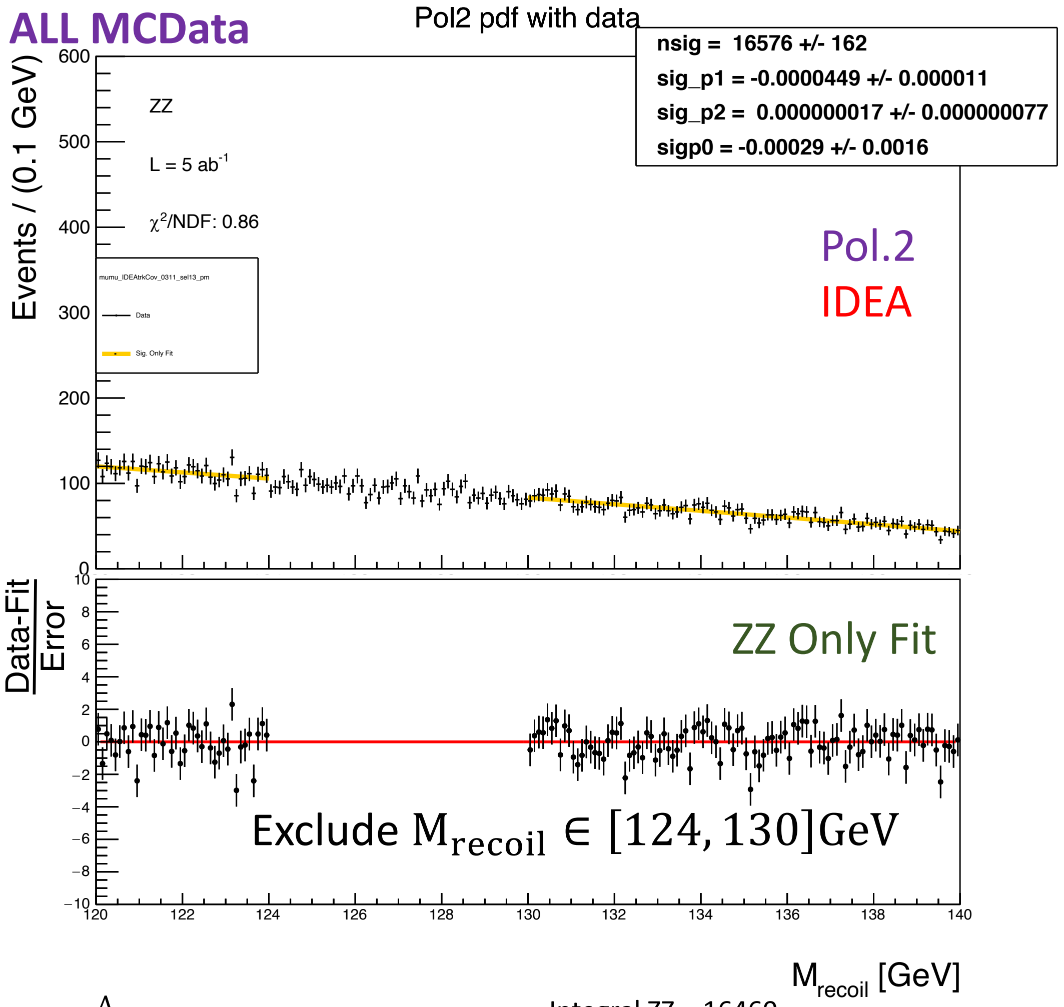
$N_{sig}^{fit} / N_{sig}^{integral} = 99.8\%$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 100.3\%$

- After floating alphas, $\chi^2/_{NDF} \sim 1.0$

Sideband fit of Bkg. with Pol.2 fit of M_{recoil} in the Higgs region (120-140 GeV)



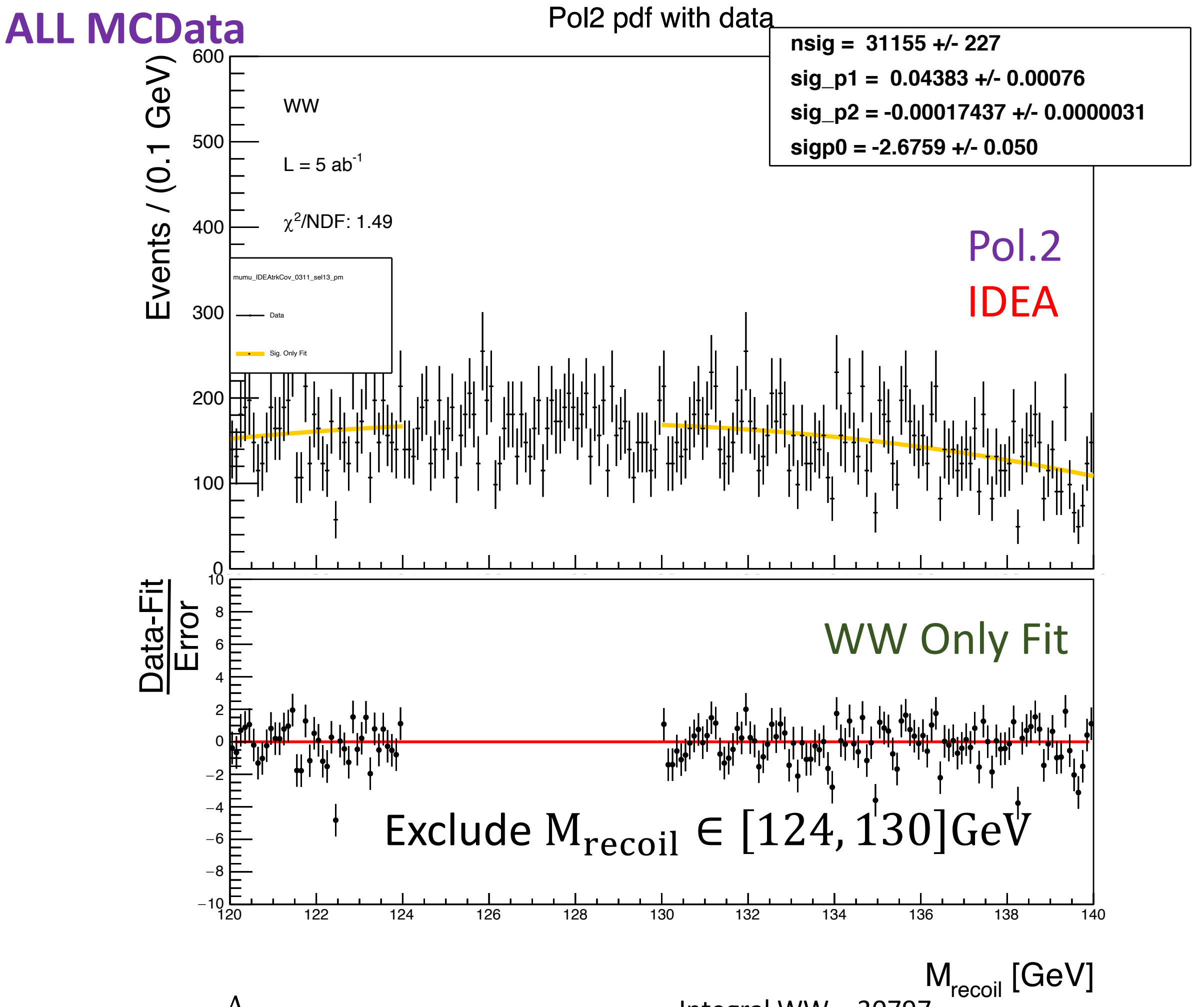
$\frac{\Delta_{N_{sig}}}{N_{sig}} = 0.98\%$

$80\text{ GeV} < M_Z < 100\text{ GeV}$

$p_T^Z > 20\text{ GeV}$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 100.7\%$



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 0.73\%$

$80\text{ GeV} < M_Z < 100\text{ GeV}$

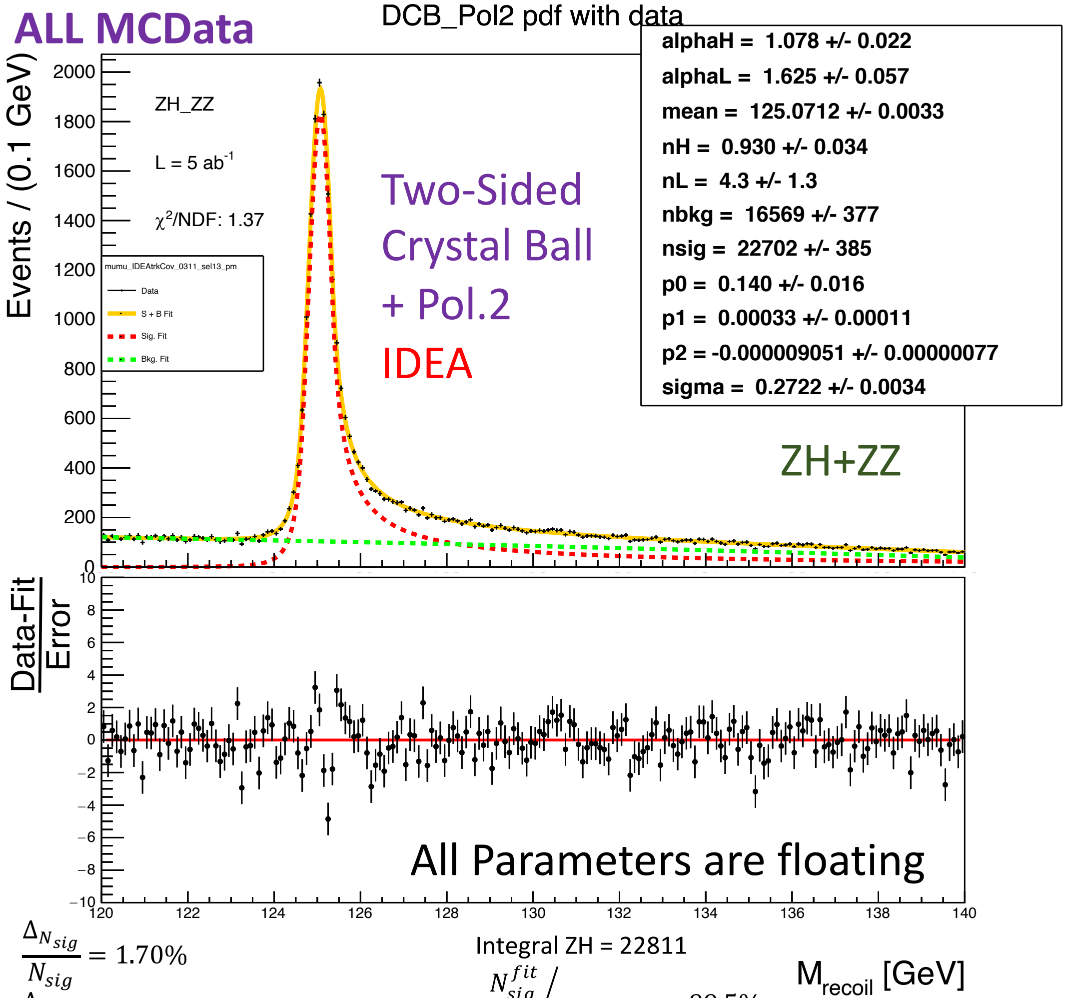
$p_T^Z > 20\text{ GeV}$

Integral WW = 30797

$N_{sig}^{fit} / N_{sig}^{integral} = 101.2\%$

Two-Sided Crystal Ball + Pol2 fit of M_{recoil} in the Higgs region (120-140 GeV)

ALL MCData



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 1.70\%$

$\frac{\Delta_{N_{bkg}}}{N_{bkg}} = 2.28\%$

$80\ \text{GeV} < M_Z < 100\ \text{GeV}$

$p_T^Z > 20\ \text{GeV}$

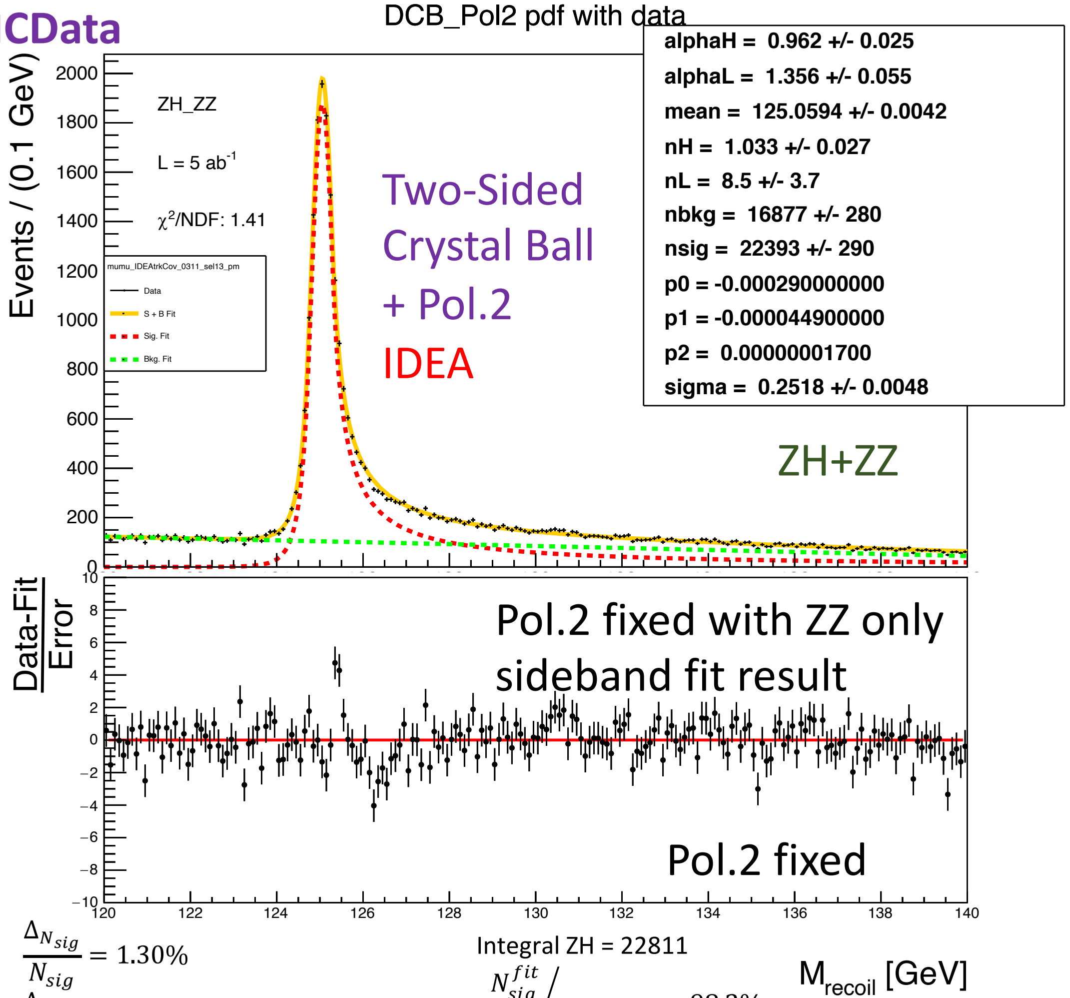
Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 99.5\%$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 100.7\%$

ALL MCData



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 1.30\%$

$\frac{\Delta_{N_{bkg}}}{N_{bkg}} = 1.66\%$

$80\ \text{GeV} < M_Z < 100\ \text{GeV}$

$p_T^Z > 20\ \text{GeV}$

Integral ZH = 22811

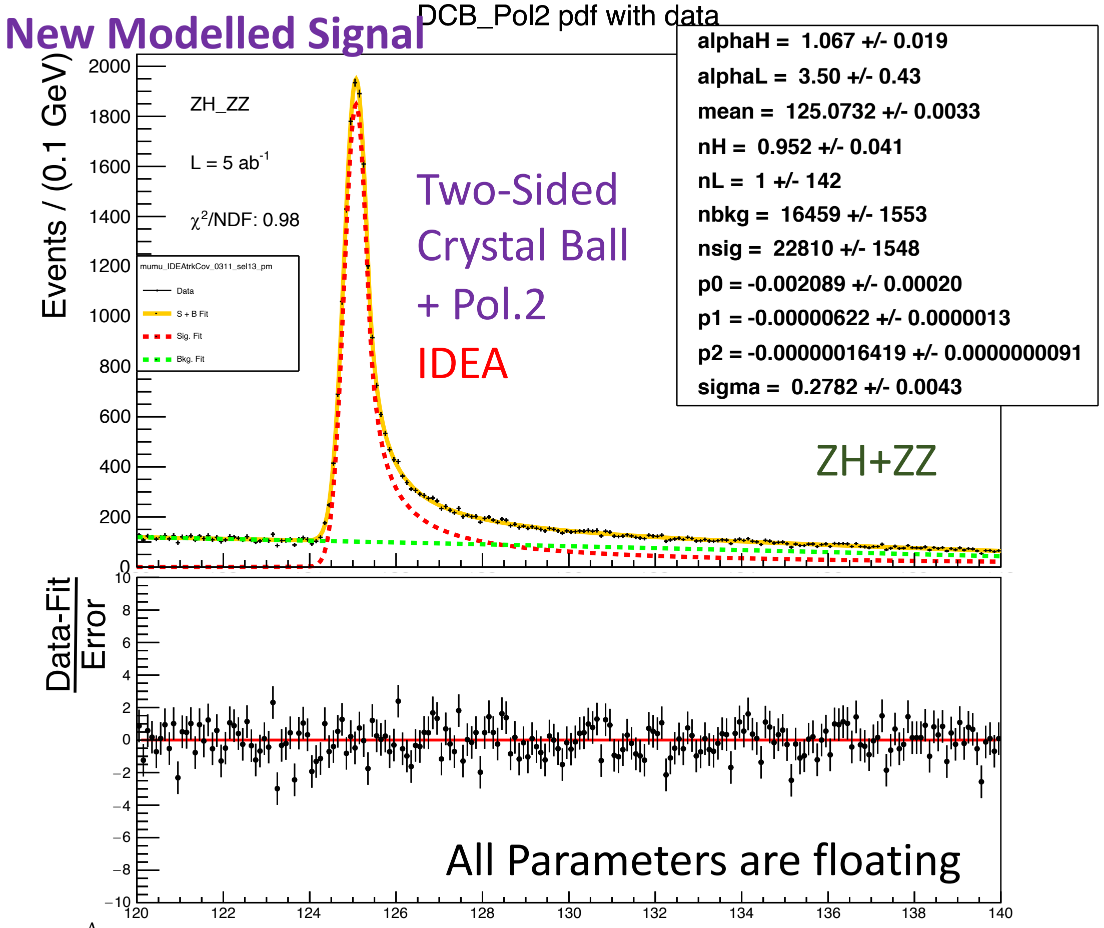
$N_{sig}^{fit} / N_{sig}^{integral} = 98.2\%$

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 102.5\%$

- Fixing Pol.2 can improve the nsig uncertainty

Two-Sided Crystal Ball + Pol2 fit of M_{recoil} in the Higgs region (120-140 GeV)



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 6.79\%$

$\frac{\Delta_{N_{bkg}}}{N_{bkg}} = 9.44\%$

80 GeV $< M_Z <$ 100 GeV

$p_T^Z > 20$ GeV

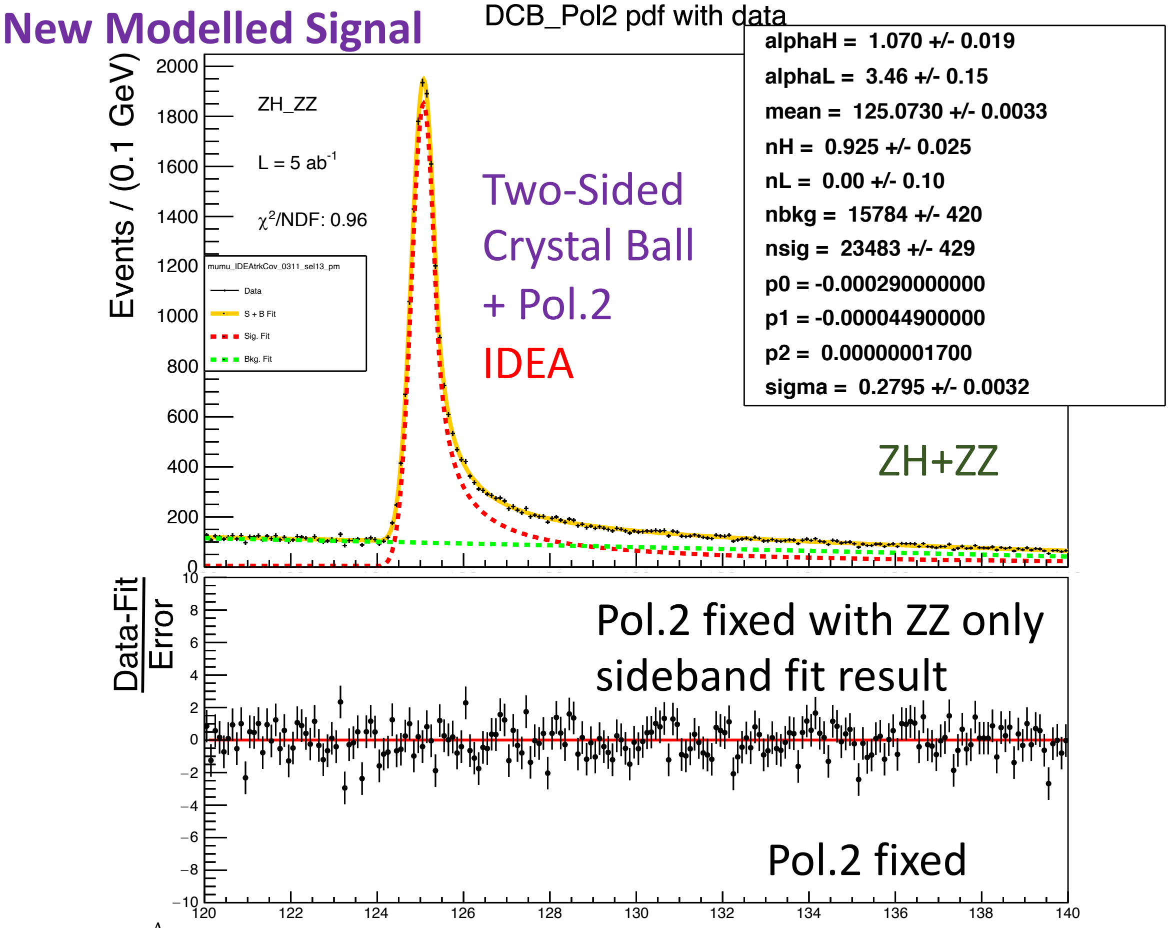
Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 100.0\%$

M_{recoil} [GeV]

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 100.0\%$



$\frac{\Delta_{N_{sig}}}{N_{sig}} = 1.83\%$

$\frac{\Delta_{N_{bkg}}}{N_{bkg}} = 2.66\%$

80 GeV $< M_Z <$ 100 GeV

$p_T^Z > 20$ GeV

Integral ZH = 22811

$N_{sig}^{fit} / N_{sig}^{integral} = 102.9\%$

M_{recoil} [GeV]

Integral ZZ = 16460

$N_{sig}^{fit} / N_{sig}^{integral} = 95.9\%$

- Fixing Pol.2 decreases the nsig uncertainty from ~ 7% → 2%
- Need to fix the choice of nL

Fitted Width, mass, Nsig in the Higgs mass region (120-140 GeV)

Two-Sided Crystal Ball + Pol.2 fit ZH+ZZ+WW	σ_H (GeV)	Δ_{σ_H} (GeV)	M_H (GeV)	Δ_{M_H} (GeV)	$\Delta_{N_{sig}}/N_{sig}$
All MCData	0.2693	0.0040	125.0744	0.0035	3.1%
All MCData tails fixed	0.2715	0.0035	125.0721	0.0034	1.0%
New Modelled Signal	0.2804	0.0039	125.0711	0.0036	5.8%
New Modelled Signal, tails fixed	0.2715	0.0034	125.0767	0.0034	1.0%

Two-Sided Crystal Ball + Pol.2 fit ZH+ZZ	σ_H (GeV)	Δ_{σ_H} (GeV)	M_H (GeV)	Δ_{M_H} (GeV)	$\Delta_{N_{sig}}/N_{sig}$
All MCData	0.2722	0.0034	125.0712	0.0033	1.7%
All MCData tails fixed	0.2715	0.0032	125.0709	0.0032	0.9%
New Modelled Signal	0.2782	0.0043	125.0732	0.0033	6.8%
New Modelled Signal, tails fixed	0.2685	0.0029	125.0760	0.0031	0.9%

For all the cases, the $\boldsymbol{\sigma_H}$ ~0.27, $\boldsymbol{\Delta_{\sigma_H}}$ ~ 0.003, M_H ~ 125.07, $\boldsymbol{\Delta_{M_H}}$ ~ 0.003.

After fixing the tails, $\Delta_{N_{sig}}/N_{sig}$ ~ 1.0%

Conclusions

- Will focus on 20 GeV selection

- Fixing tails parameters can decrease the uncertainty of number of signal

- WW has low statistic and large uncertainty

- For ZH+ZZ fit, ALL MCData, the $^{\Delta_{N_{sig}}}/_{N_{sig}} \sim 2.0\%$
  - Fixing DSCB tails, $^{\Delta_{N_{sig}}}/_{N_{sig}} \sim 1.0\%$
  - Fixing Polynomial, $^{\Delta_{N_{sig}}}/_{N_{sig}} \sim 1.0\%$

- For all the fit, the $\boldsymbol{\sigma_H}$ ~0.27, $\boldsymbol{\Delta_{\sigma_H}}$ ~ 0.003, M_H ~ 125.07, $\boldsymbol{\Delta_{M_H}}$ ~ 0.003.
- After fixing the tails, $^{\boldsymbol{\Delta_{N_{sig}}}}/_{\boldsymbol{N_{sig}}}$ ~ 1.0%

Next-Step

- Study the Beam Energy effect
- Reconstruct using generator-level muon instead of recorded muon
- Magnetic filed :2T->3T

BackUp

Simulations

- **Simulation configurations:**
  - **Generator:** Pythia 8 (DelphesPythia8_EDM4HEP)

  - **Detector card:**
    - **IDEA:** $DELPHES_DIR/cards/IDEAtrkCov.tcl

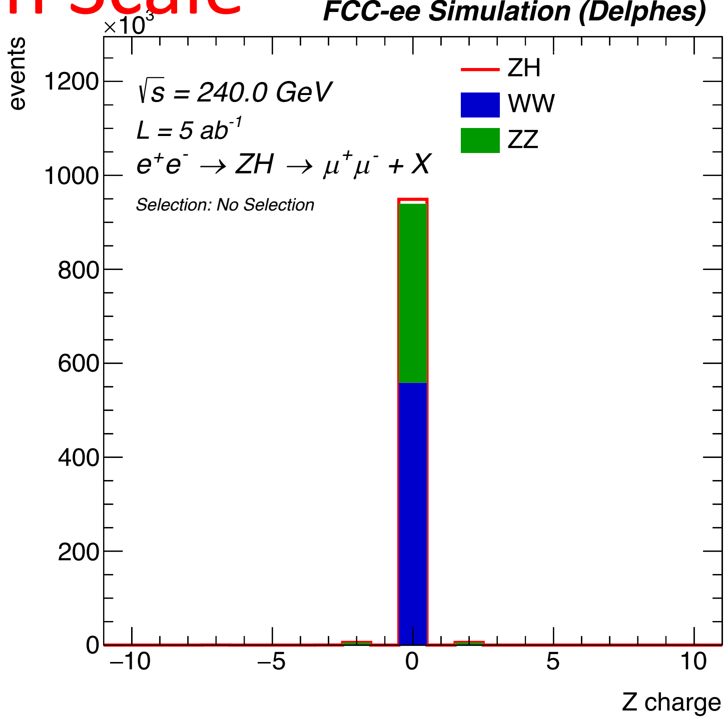
  - **Channels: ZH, ZZ and WW**
    - **10^7 events for each channel produced inclusively**
    - **Focus on $\mu^+\mu^-$ pair final state (e^+e^- final state reconstruction has some issues)**

  - **$\sqrt{s} = 240$ GeV**

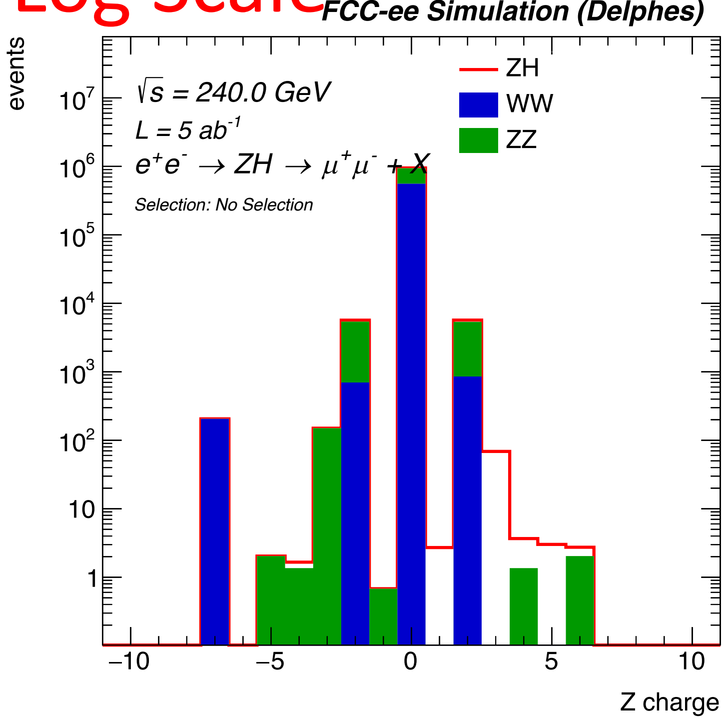
  - **ISR and FSR on**

Z charge check

Lin Scale



Log Scale




```
Number of Muons: 2
before reso.charge = 1.14482e+22
legs[0].charge = 1
after reso.charge = 1.14482e+22
before reso.charge = 1.14482e+22
```

Initial Z charge is incorrect

Events with inccorect charge but will not affect the analysis
Comes from the fact that the initial value of edm4hep.charge is incorrect

Stacked Histograms

CutFlow Table

	Lumi = 5 / ab	ZH	ZH	ZH	ZH	ZZ	ZZ	ZZ	ZZ	WW	WW	WW	WW	recoil between 120-140 GeV	
			Total efficiency %	Cut efficiency %	# in Mrecoil		Total efficiency %	Cut efficiency %	# in Mrecoil		Total efficiency	Cut efficiency	# in Mrecoi	S/B	(S/Sqrt(S+B))
	Xsec (pb)	0.201037			120-140 GeV	1.35899			120-140 GeV	16.4385			120-140 GeV		
	(XSec*Lumi)	1005185				6794950				82192500					
	cumulative														
	Total number of events	1005185			27104	6794950			33135	82192500			114124	0.18	64.9
	# of mu+mu-	34511	100.00	3.43	27079	529294	100.00	7.79	32695	1200594	100.00	1.46	113631	0.19	65.0
	# of events with at least one Z inside 73-120 GeV	27765	80.45	80.45	26231	352312	66.56	66.56	21532	323238	26.92	26.92	66617	0.30	77.6
	# of events with at least one Z inside 80-110 GeV	26829	77.74	96.63	25572	334807	63.26	95.03	20124	204371	17.02	63.23	51058	0.36	82.2
	# of events with at least one Z inside 80-100 GeV	26080	75.57	97.21	24831	321483	60.74	96.02	19559	133185	11.09	65.17	37455	0.44	86.8
	# of events with pt-of-lepton-sum inside 10-70 GeV	25454	73.76	94.87	24347	243278	45.96	72.66	18741	108806	9.06	53.24	35441	0.45	86.9
follows row #11	# of events with Mrecoil between 110-155 GeV	26044	75.47	99.86	24831	42304	7.99	13.16	19559	69370	5.78	52.09	37455	0.44	86.8
	# of events with Mrecoil between 120-140 GeV	24831	71.95	95.34	24831	19559	3.70	46.23	19559	37455	3.12	53.99	37455	0.44	86.8
follows row #16	# of events with pt-of-lepton-sum > 10 GeV	24347	70.55	98.05	24347	18741	3.54	95.82	18741	35441	2.95	94.62	35441	0.45	86.9
	# of events with pt-of-lepton-sum > 15 GeV	23724	68.74	97.44	23724	17747	3.35	94.70	17747	33543	2.79	94.64	33543	0.46	86.6
	# of events with pt-of-lepton-sum > 20 GeV	22811	66.10	96.15	22811	16460	3.11	92.75	16460	30798	2.57	91.82	30798	0.48	86.2
follows row #16	# of events with one pt-mu > 20 GeV	17428	50.50	70.19	17428	15607	2.95	79.79	15607	26803	2.23	71.56	26803	0.41	71.2
	# of events with one pt-mu > 25 GeV	13917	40.33	79.85	13917	13333	2.52	85.43	13333	21140	1.76	78.87	21140	0.40	63.3
	# of events with one pt-mu > 30 GeV	9916	28.73	71.25	9916	10146	1.92	76.10	10146	15230	1.27	72.04	15230	0.39	52.8
follows row #20	# of events with pt-of-lepton-sum < 70 GeV	22811	66.10	100.00	22811	16460	3.11	100.00	16460	30798	2.57	100.00	30798	0.48	86.2