Higgs Recoil Mass and Cross Section Analysis at ILD_00

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Introductory Remarks

ZH Recoil Ana. Group:

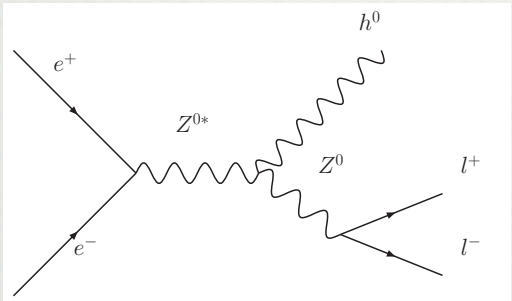
(EU) Hengne Li, Roman Poeschl, Francois Richard, Manqi Ruan, Zhiqing Zhang

(JP) Kazutoshi Ito, Yosuke Takubo, Hitoshi Yamamoto

Reviewers:

(EU) Klaus Desch, (JP) Akiya Miyamoto

- 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:

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

- Mh = 120 GeV

- Ecm = 250 GeV

- Beam Energy Spread:
0.3% for each beam

- Luminosity:
500 fb-1 in Analysis
250 fb-1 results will also be reported as requested by the ILD LOI

- Detector Model:
ILD_00

- Event Generation:
SLAC

- Simulation & Reconstruction:
DESY & KEK

Introductory Remarks

$e^+_R e^-_L$

e+: +1.0, e-: -1.0

μμX

Reactions	Cross-Section
μμX	**17.1 fb**
$\mu\mu$	17.1 pb (330.4 fb)
$\tau\tau$	17.1 pb
$\mu\mu\nu\nu$	849.0 fb
$\mu\mu\mu\mu$	11.4 fb
$\mu\mu ee$	1106.7 fb
$\mu\mu\tau\tau$	23.1fb
$\mu\mu qq$	277.7 fb

eeX

Reactions	Cross-Section
eeX	**17.9 fb**
ee	17.3 nb (733.9 fb)
$\tau\tau$	17.1 pb
$ee\nu\nu$	1015.6 fb
$ee\mu\mu$	1106.7 fb
eeee	995.6 fb
$ee\tau\tau$	965.1 fb
eeqq	1366.5 fb

$e^+_L e^-_R$

e+: -1.0, e-: +1.0

Reactions	Cross-Section
μμX	**10.97 fb**
$\mu\mu$	12.9 pb (215.6 fb)
$\tau\tau$	12.9 pb
$\mu\mu\nu\nu$	45.0 fb
$\mu\mu\mu\mu$	7.2 fb
$\mu\mu ee$	1088.6 fb
$\mu\mu\tau\tau$	14.7 fb
$\mu\mu qq$	148.6 fb

Reactions	Cross-Section
eeX	**11.29 fb**
ee	17.3 nb (658.9 fb)
$\tau\tau$	12.9 pb
$ee\nu\nu$	27.5 fb
$ee\mu\mu$	1088.6 fb
eeee	982.4 fb
$ee\tau\tau$	948.8 fb
eeqq	1168.9 fb

(1) ***μμνν*** and ***eeνν*** have major contribution from WW, but also from ZZ.

(2) In the analysis, ***μμff*** refers to ***μμee + μμμμ + μμττ + μμqq***, and ***eeff*** refers to ***eeμμ + eeee + eeττ + eeqq***

Pre-cuts for ee and μμ:
(cross-sections after pre-cuts are in blankets)

Pre-cuts for $\mu\mu$:

- $M_{\mu^+\mu^-} \in (71.18, 111.18)\ GeV$
- $P_{T\mu^+\mu^-} > 10\ GeV$
- $M_{recoil} \in (105, 165)\ GeV$

Pre-cuts for ee:

- $|cos\theta_{e^+/e^-}| < 0.95$
- $M_{e^+e^-} \in (71.18, 111.18)\ GeV$
- $P_{Te^+e^-} > 10\ GeV$
- $M_{recoil} \in (105, 165)\ GeV$

Preparation 1: Lepton ID

- Refer to the study of Hajrah Tabassam, from discussions with Roberval Walsh, we define our cuts for lepton ID as:

muon ID

$$E_{ecal}/E_{total} < 0.5$$
$$E_{cal}/P_{track} < 0.3$$

electron ID

$$E_{ecal}/E_{total} > 0.6$$
$$E_{cal}/P_{track} > 0.9$$

Pol. ($e^+_R e^-_L$) for illustration

Cuts (for P>15GeV): single particle	μμX (muon ID)	eeX (electron ID)
N_{true} (N truth)	31833	34301
$N_{true \cap iden}$	31063	33017
N_{iden}	33986	34346
Efficiency ($N_{true \cap iden}/N_{true}$)	97.6%	96.3%
Purity ($N_{true \cap iden}/N_{iden}$)	91.4%	96.1%
Efficiency Both lepton ID: (no P request, select according to Mz)	**95.4%**	**98.8%**

We dropped the improvements on the two muon ID applied in previous study, which is to search for the other muon from tracks if only one muon identified, (refer to my previous reports).

Preparation 2: $\Delta P/P^2$ criterion in the selection of lepton candidates

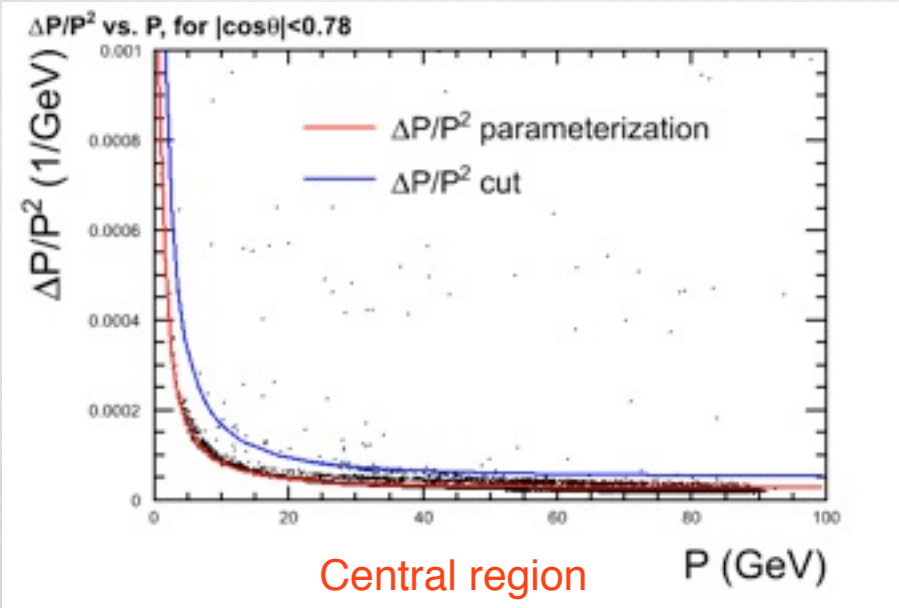
- Parameterize $\Delta P/P^2$ for central region

$$\Delta P/P^2 = a \oplus b/P;$$
$$where\ a = 2.5 \times 10^{-5};\ b = 8 \times 10^{-4}$$

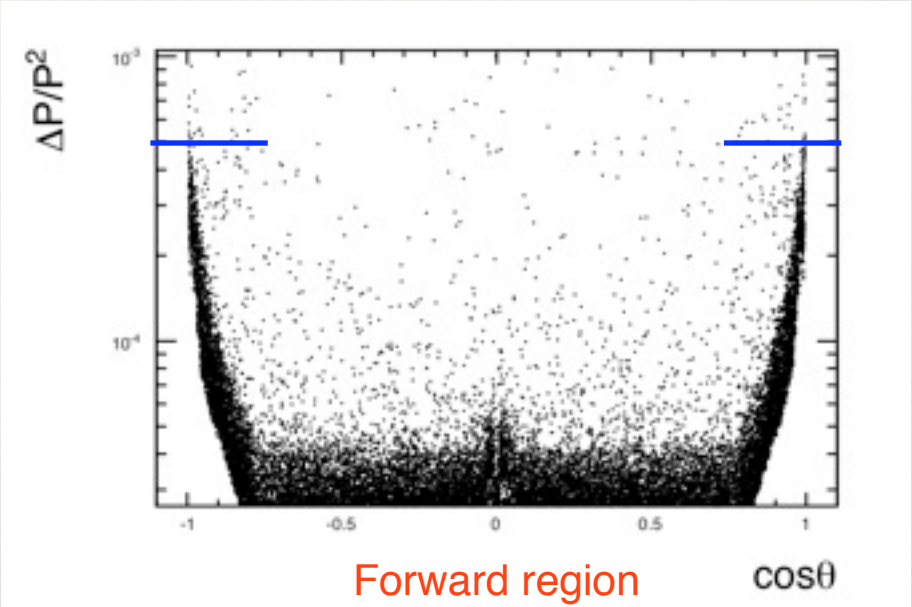
- The criterion $\Delta P/P^2$ applied

$$|cos\theta| < 0.78: \quad \Delta P/P^2 < 2 \times (2.5 \times 10^{-5} \oplus 8 \times 10^{-4}/P)$$
$$|cos\theta| > 0.78: \quad \Delta P/P^2 < 5 \times 10^{-4}$$

$\Delta P/P^2$ Criterion	N evts on recoil mass peak, Mh within (119, 121) GeV
Before Apply	2812
After Apply	2791



Central region



Forward region

Preparation 3: Fitting Methods

- Two methods applied for the signal:
  - Gaussian Peak Exponential Tail (GPET)

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

  - Convolution of Empirical with Gaussian (CEG)

$$F(x) = N e^{-Ax} \int_{x_0-x}^{\sqrt{s}-x} F_H(x+t) e^{-\frac{t^2}{2\sigma^2}} dt;$$

$$F_H(x) = \left(\frac{x-x_0}{\sqrt{s}-x_0} \right)^{\beta-1}$$

- Background:
  - Polynomial with 3 coefficients

Analysis Procedures

Higgs Decay Model	SM Higgs Decay	Model Independent
Background Rejection	SM Cut-chain	MI Cut-chain
	Likelihood Further Rej.	Likelihood Further Rej.
Fitting		

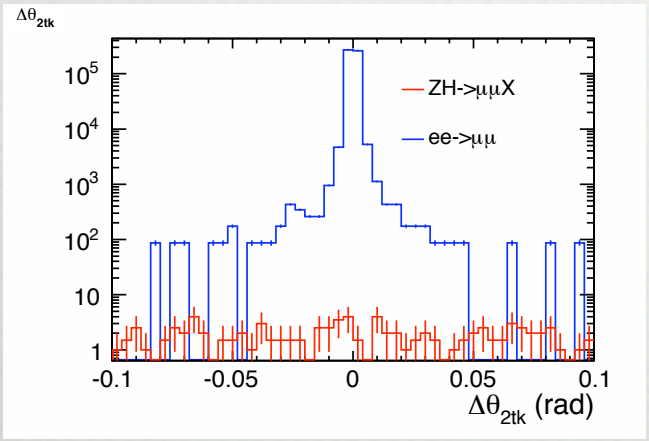
- Background Rejection
  - Rejection by Cuts
    - SM Cut-Chain: Assume SM Higgs Decay
    - MI Cut-Chain: Independent of Higgs Decay Model
  - Further Rejection by Likelihood
- Fitting and Results

BKG Rejection by Cuts: SM Cut-Chain

- For SM Higgs decay, multiplicity in the final states is the most efficient criterion to reject the 2f and WW

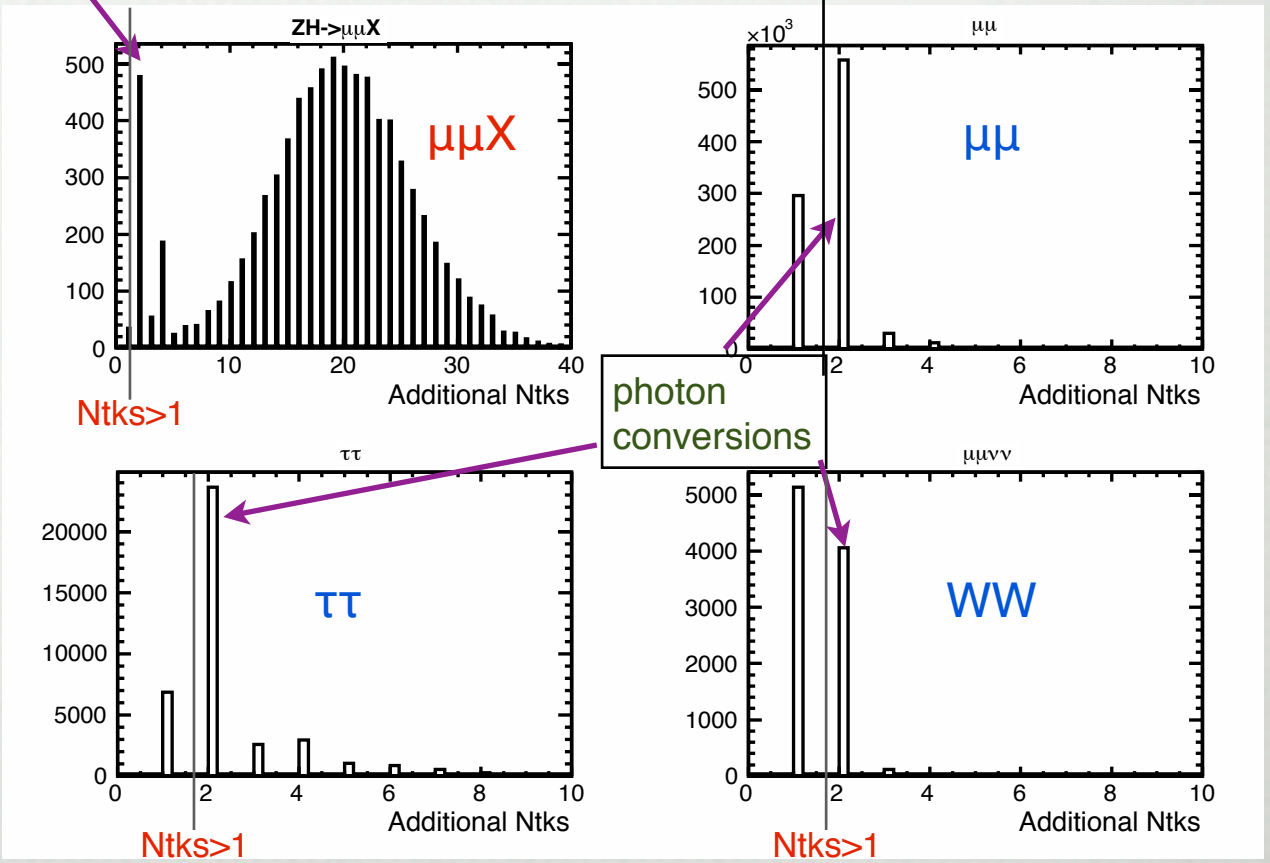
Pol. ($e^+_R e^-_L$) for illustration

- In order to keep the H->ττ in the signals :
  - At most: Ntks>1
  - How to reject evts with Ntks=2 in μμ, ττ and WW ?
- Define $\Delta\theta_{2tk}$: Δθ between these two additional tracks for Ntks=2.



H->ττ

Additional Number of Tracks besides the two lepton candidates



BKG Rejection by Cuts: SM Cut-Chain

Pol. ($e^+_R e^-_L$) for illustration

μμX

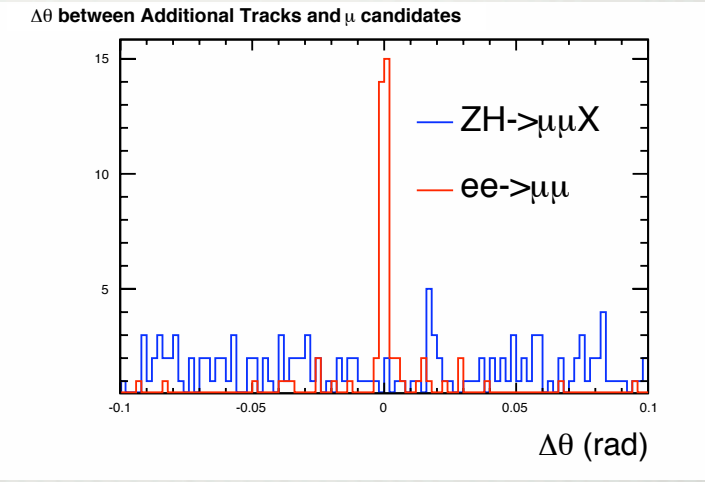
Nevts remained:	ZH->μμX	ee->μμ	ee->ττ	ee->μμνν
before any restriction:	8563	8.5M	8.6M	425k
Both μ identified	8169 (95.4%)	143k (1.7%)	257k (3%)	374k(88.1%)
+ pre-cuts	7166 (83.7%)		17k (0.2%)	54k (12.6%)
+ Ntks>1	7112 (83.0%)	8.8k (0.10%)	2k (0.025%)	959 (0.23%)
+ $\|\Delta\theta_{2tk}\|>0.01$	7100 (82.9%)	819 (0.01%)	1558 (0.02%)	122 (0.03%)
+ $\|\Delta\theta_{min}\|>0.01$	7000 (81.7%)	506 (0.006%)	346 (0.004%)	18 (0.004%)
+ acop (0.2, 3.0)	6495(75.8%)	354 (0.004%)	0 (0%)	18 (0.004%)
+ Mh (115, 150) GeV	6130(71.6%)	229 (0.003%)	0 (0%)	16 (0.004%)

eeX

Nevts remained:	ZH->eeX	ee->ee	ee->ττ	ee->eeνν
before any restriction:	8588	8.7G	8.6M	508k
Both e identified:	8439 (98.3%)	267k (0.003%)	965k(11.3%)	415k (81.6%)
+ pre-cuts	5593 (62.5%)		29k (0.3%)	61k (12.1%)
+ Ntks>1 :	5548 (62.0%)	16k (2×10^{-6})	8309 (0.1%)	1708 (0.34%)
+ $\|\Delta\theta_{2tk}\|>0.01$	5540 (61.9%)	2607 (3×10^{-7})	5885 (7×10^{-4})	279 (0.05%)
+ $\|\Delta\theta_{min}\|>0.01$	5448 (60.9%)	844 (1×10^{-7})	1212(1×10^{-4})	31 (0.006%)
+ acop (0.2, 3.0)	5054 (56.5%)	712 (8×10^{-8})	0 (0%)	30 (0.006%)
+ Mh (115, 150) GeV	4631 (51.8%)	456 (5×10^{-8})	0 (0%)	11 (0.002%)

Nevts are weighted according to the cross-sections and luminosity 500 fb^{-1}

- Seems $\Delta\theta_{2tk}$ is not enough
- Define $\Delta\theta_{min}$:
  - the smallest $\Delta\theta$ between the additional tracks and the muon candidates



- Because mis-identification of other particles to be muons/ electrons

BKG Rejection by Cuts: MI Cut-Chain

- muon channel with pol. $e^+_R e^-_L$ for illustration
- μμ are pre-cutted

- Cuts, based on lepton pair properties:
  - $P_{Tdl} > 20\ GeV$
  - $M_{dl} \in (80,\ 100)\ GeV$
  - $acop \in (0.2,\ 3.0)$

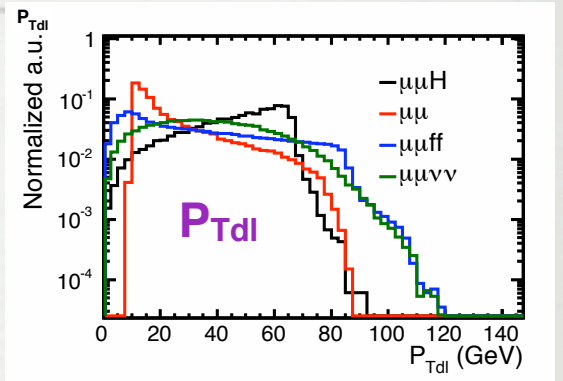
Pol. $e^+_R e^-_L$ for illustration

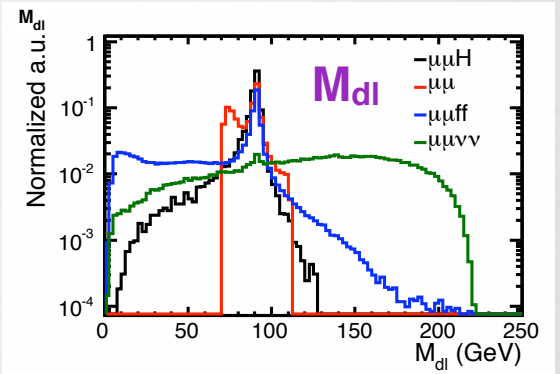
μμX

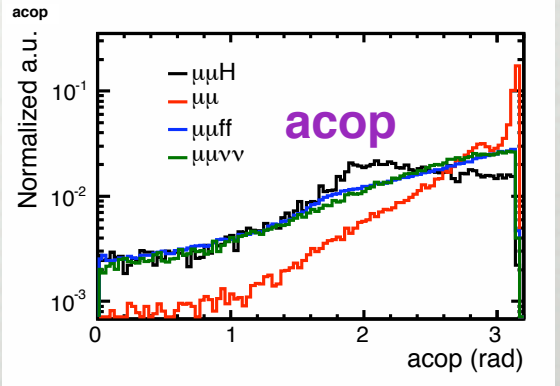
Nevts remained:	ZH->μμX	ee->μμ	ee->ττ	ee->μμνν	ee->μμff
before any restriction:	8563	8.5M	8.6M	425k	710k
Both μ id + pre-cuts	7166 (83.7%)	143k (1.7%)	17k (0.2%)	54k (12.6%)	48k (6.7%)
+ P_{Tdl} > 20 GeV	6777(79.1%)	71k(0.81%)	12k(0.14%)	46k(10.8%)	38k(5.4%)
+ $M_{dl} \in$ (80, 100) GeV	6230(72.7%)	54k(0.64%)	6578(0.08%)	27k(6.4%)	30k(4.2%)
+ acop (0.2, 3.0)	5827(68.0%)	45k(0.53%)	0(0%)	25k(6.0%)	27k(3.8%)

eeX

Nevts remained:	ZH->eeX	ee->ee	ee->ττ	ee->eevv	ee->eeff
before any restriction:	8588	8.7G	8.6M	508k	2.2M
Both e id + pre-cuts	5593 (62.5%)	267k (0.003%)	29k (0.3%)	61k (12.1%)	41k (1.8%)
+ P_{Tdl} > 20 GeV	5283 (59.1%)	195 (0.002%)	20k (0.24%)	53k (10.4%)	35k (1.6%)
+ $M_{dl} \in$ (80, 100) GeV	4508 (50.4%)	108 (0.001%)	12 (0.14%)	29k (5.8%)	25k (1.1%)
+ acop (0.2, 3.0)	4211 (47.1%)	98k (0.001%)	866 (0.01%)	28k (5.4%)	23k (1.0%)







BKG Rejection by Cuts: Independent of Higgs Decay Model

NEW!

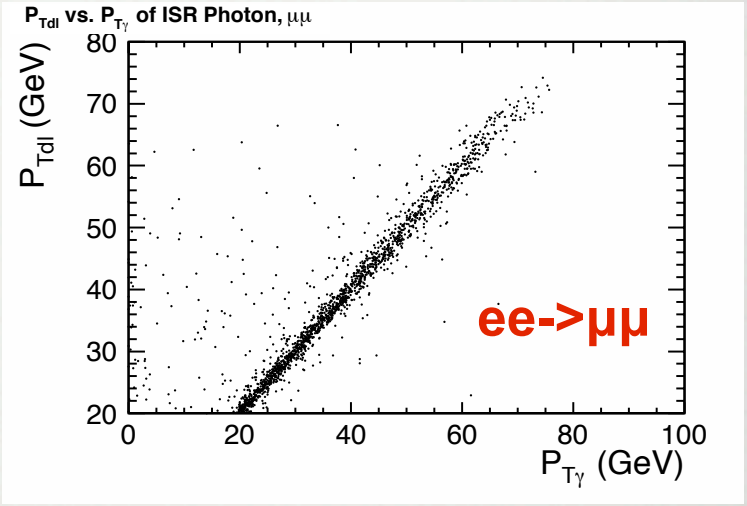
ISR P_T balance for μμ and ee rejection

Idea: (Thanks to Francois' idea)

- **For μμ and ee: P_T of ISR photon should balance the P_T of di-lepton system;**
- **For signal: Impossible to have ISR to balance Z P_T, independent of Higgs decay model.**

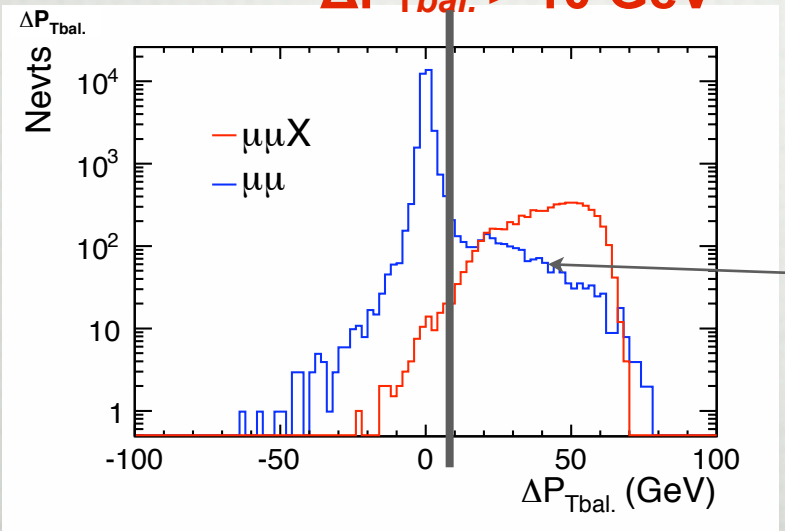
Requirements:

- **$M_{dl} \in$ (80, 100) GeV: large FSR events are removed**
- **P_{Tdl} > 20 GeV: Large P_T ISR photon can be detected**



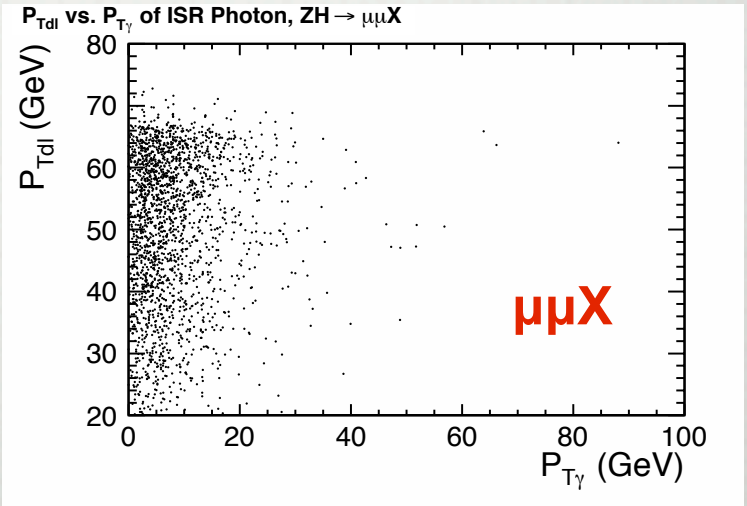
Define $\Delta P_{Tbal.} = P_{Tdl} - P_{T\gamma}$

$\Delta P_{Tbal.}$ > 10 GeV



Reduces μμ and ee further by 1 to 2 orders of magnitude
Signal lost: ~1%

ISR photon conversions



BKG Rejection by Cuts: Independent of Higgs Decay Model

To reject the ISR Photon conversions:

- **Cut $|\Delta\theta_{2tk}|>0.01$: Only apply on events with 2 additional tracks**
- **Reject μμ and ee Further by a factor of 2.**

Pol. $e^+_R e^-_L$ for illustration

μμX

Nevts remained:	ZH->μμX	ee->μμ	ee->ττ	ee->μμνν	ee->μμff
before any restriction:	8563	8.5M	8.6M	425k	710k
cuts applied before	5827(68.0%)	45k(0.53%)	0(0%)	25k(6.0%)	27k(3.8%)
+ $\Delta P_{Tbal.} > 10$ GeV	5712(66.7%)	2618(0.03%)	0(0%)	23k(5.5%)	25k(3.6%)
+ $\|\Delta\theta_{2tk}\|>0.01$	5704(66.6%)	1044(0.01%)	0(0%)	23k(5.4%)	25k(3.6%)
+ Mh (115, 150) GeV	5553(64.8%)	761(0.009%)	0(0%)	16k(3.8%)	15.5k(2.2%)

eeX

Nevts remained:	ZH->eeX	ee->ee	ee->ττ	ee->eeνν	ee->eeff
before any restriction:	8588	8.7G	8.6M	508k	2.2M
cuts applied before	4211 (47.1%)	98k (0.001%)	866 (0.01%)	28 (5.4%)	23k (1.0%)
+ $\Delta P_{Tbal.} > 10$ GeV	4095 (45.8%)	6618 (8×10^{-7})	606 (0.007%)	24k (4.7%)	22k (0.98%)
+ $\|\Delta\theta_{2tk}\|>0.01$	4089 (45.7%)	3660 (4×10^{-7})	519 (0.006%)	23.5k (4.6%)	21.5k (0.98%)
+ Mh (115, 150) GeV	3960 (44.3%)	2706 (3×10^{-7})	260 (0.003%)	16.5k (3.3%)	13k (0.59%)

BK Further Rejection by Likelihood

After Cuts Rejection, Apply Further Rejection using Likelihood Method

Likelihood:

$$L = \prod_i P_i$$

Probability

i th Variable

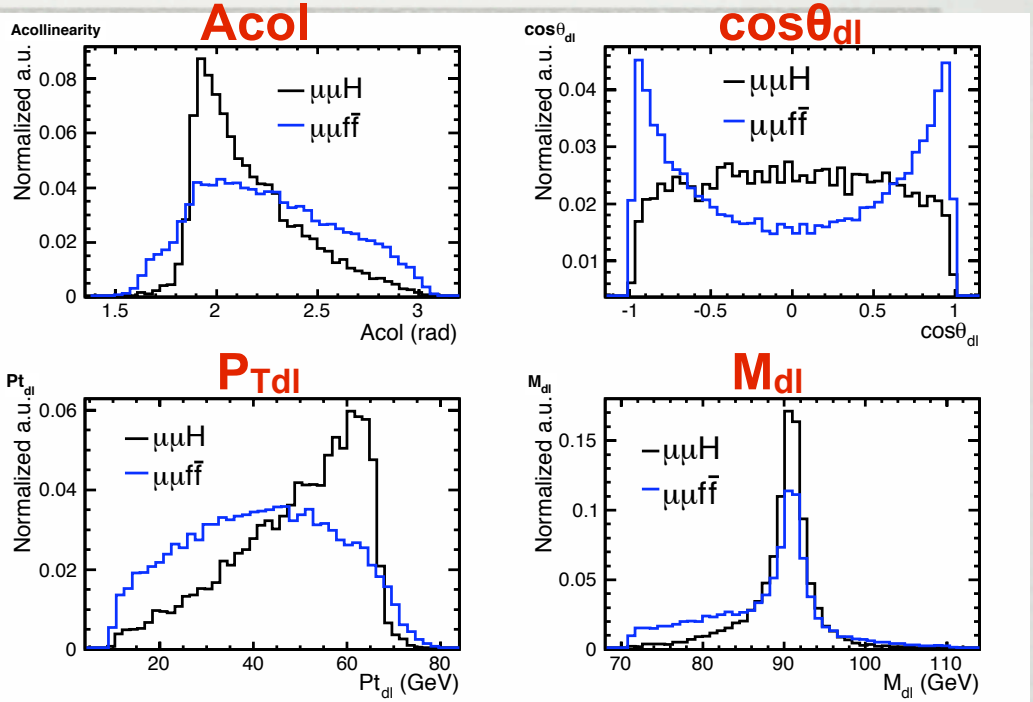
Likelihood Fraction:

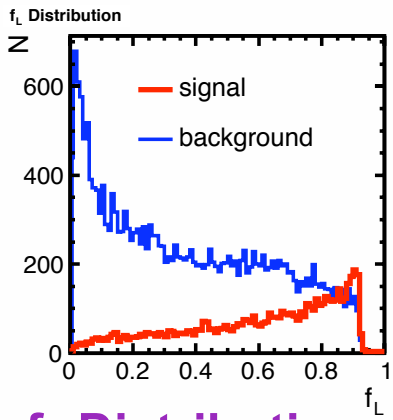
$$f_L = L_S/(L_S + L_B)$$

within (0, 1)

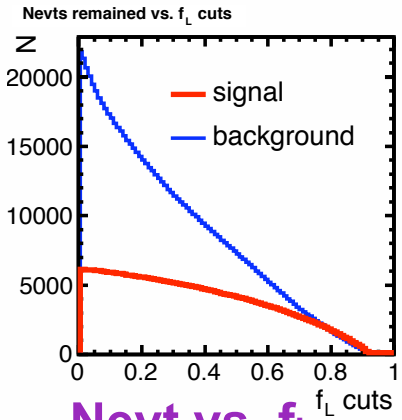
Decide the f_L cut by the maximum significance

PDFs

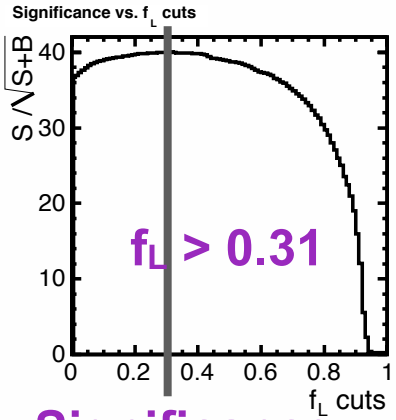




f_L Distribution



Nevt vs. f_L



Significance

Taken:

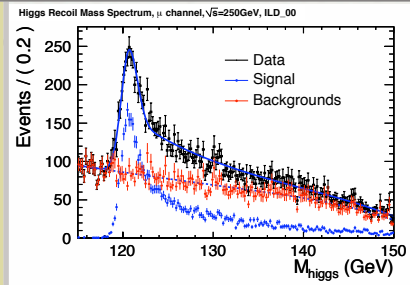
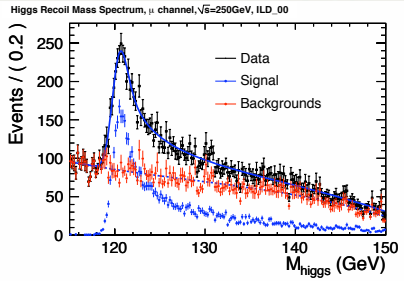
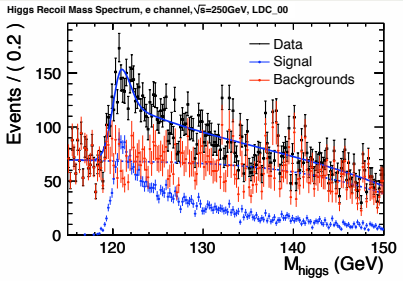
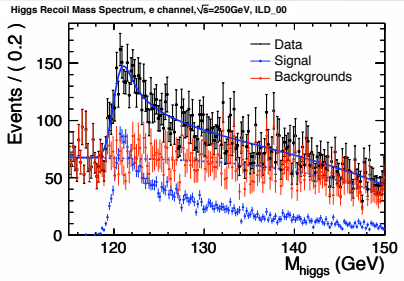
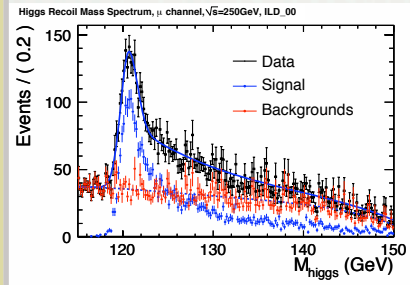
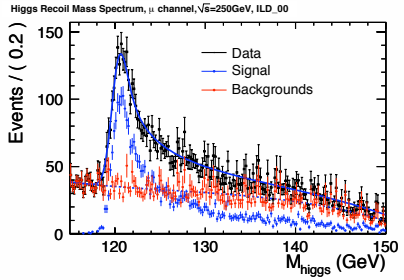
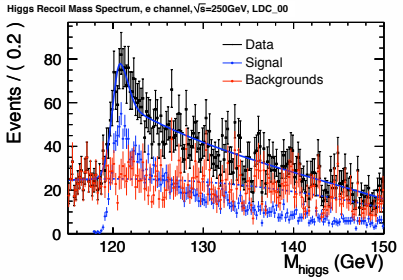
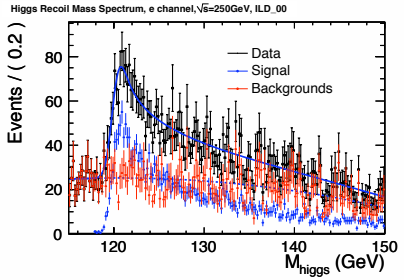
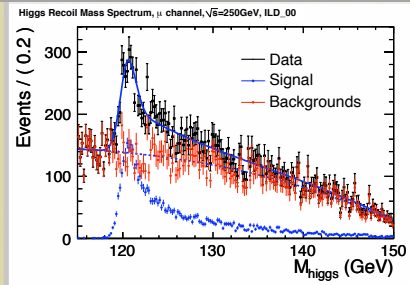
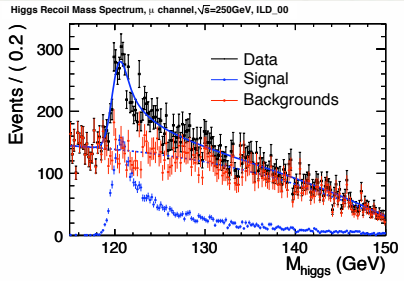
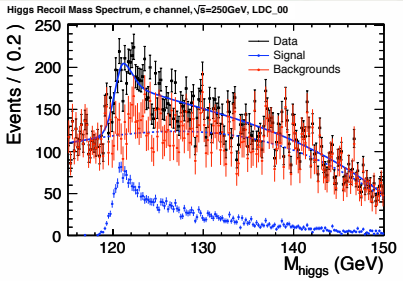
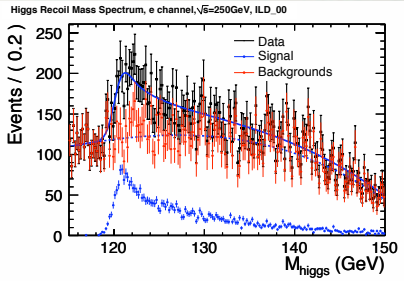
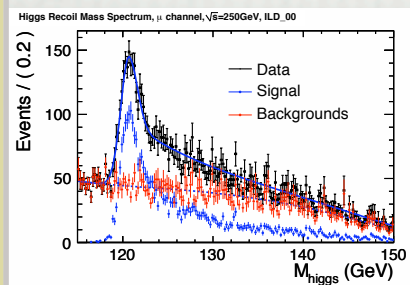
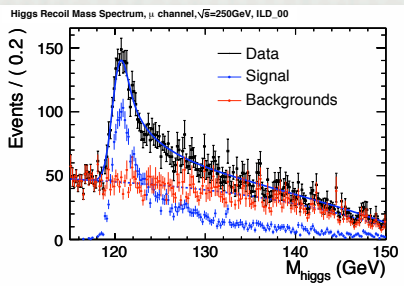
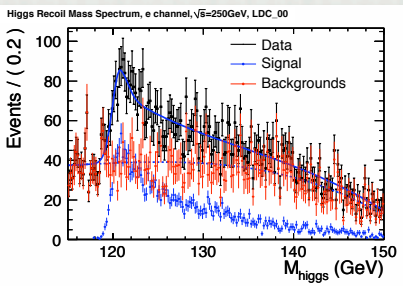
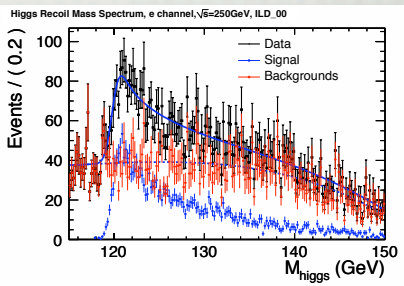
Pol. $e^+_R e^-_L$
muon channel
SM Analysis

For illustration

Background Rejection Summary Table

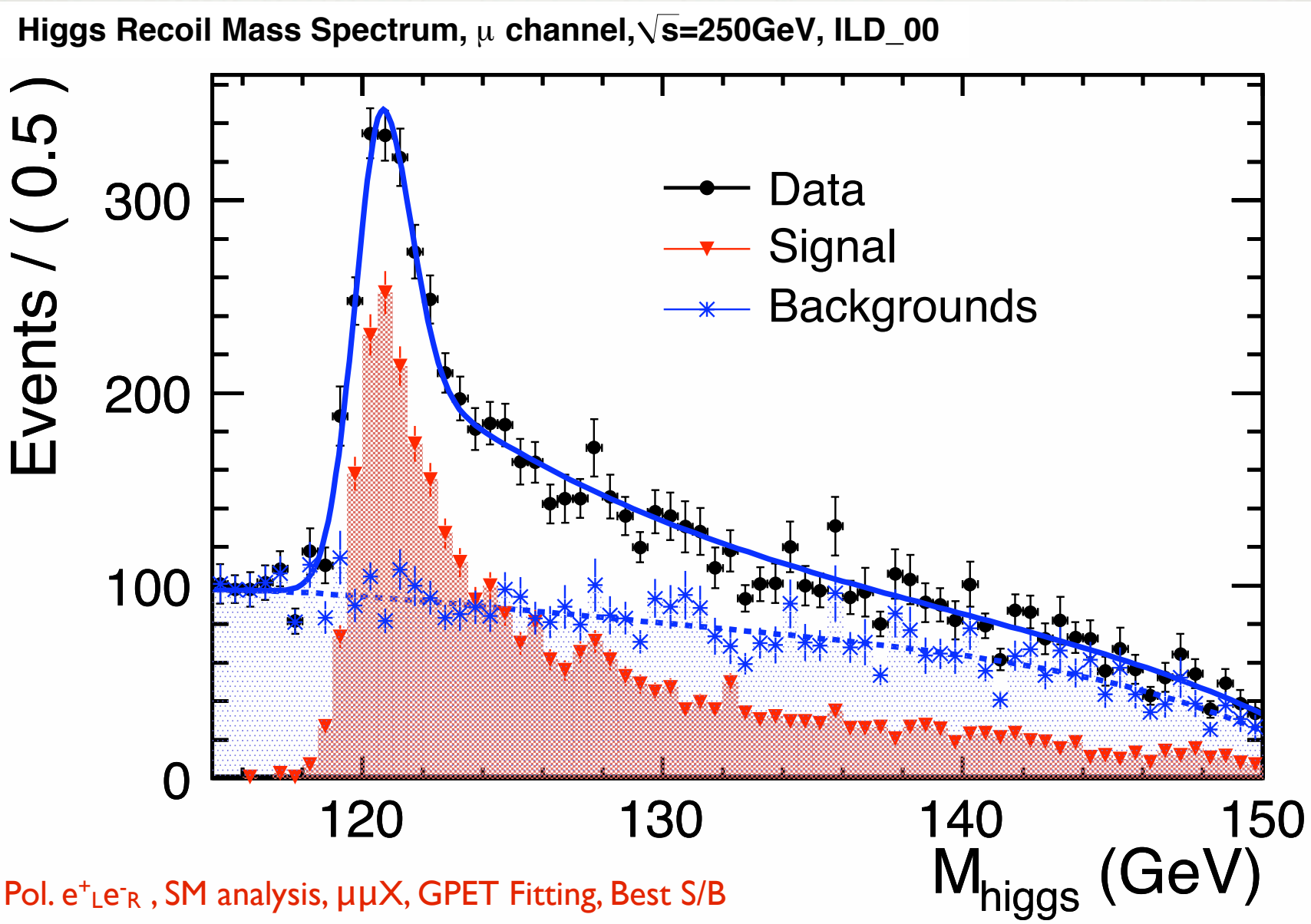
Ana.	Pol.	Ch.	Cuts	μμX/eeX	μμ/ee	ττ	μμνν/eeνν	μμff/eeff	S/B	S/√(S+B)
SM	e^+_R e^-_L	μ	SM cut-chain:	6130(71.6%)	229	0	16	21.9k		
			+ f_L>0.31	5116(59.7%)	63	0	7	11.3k	0.45	39.8
		e	SM cut-chain:	4631(51.8%)	456	0	11	20.2k		
			+ f_L>0.33	3939(44.0%)	180	0	6	10.5k	0.37	32.6
	e^+_L e^-_R	μ	SM cut-chain:	3947(72.0%)	146	0	0	11.0k		
			+ f_L>0.27	3435(62.6%)	31	0	0	5.3k	0.64	36.7
		e	SM cut-chain:	3947(72.0%)	338	0	2	9.9k		
			+ f_L>0.30	2480(43.9%)	112	0	0	4.7k	0.52	29.0
MI	e^+_R e^-_L	μ	MI cut-chain:	5553(64.8%)	761	0	16k	15.5k		
			+ f_L>0.19	4600(53.7%)	471	0	8244	9297	0.26	30.6
		e	MI cut-chain:	3960(44.3%)	2706	260	16.5k	13k		
			+ f_L>0.17	3374(37.7%)	1524	260	9403	8175	0.17	22.4
	e^+_L e^-_R	μ	MI cut-chain:	3605(65.7%)	518	0	1452	7309		
			+ f_L>0.24	3208(58.5%)	362	0	1075	4563	0.53	33.4
		e	MI cut-chain:	2511(44.5%)	2457	195	1339	6119		
			+ f_L>0.29	2154(38.2%)	1463	195	837	3439	0.36	24.0

Fittings

Ana.	Pol.	μμX		eeX	
		GPEG	CEG	GPET	CEG
SM	$e^+_R e^-_L$				
	$e^+_L e^-_R$				
MI	$e^+_R e^-_L$				
	$e^+_L e^-_R$				

My Favorite Fitting I: (GPET)

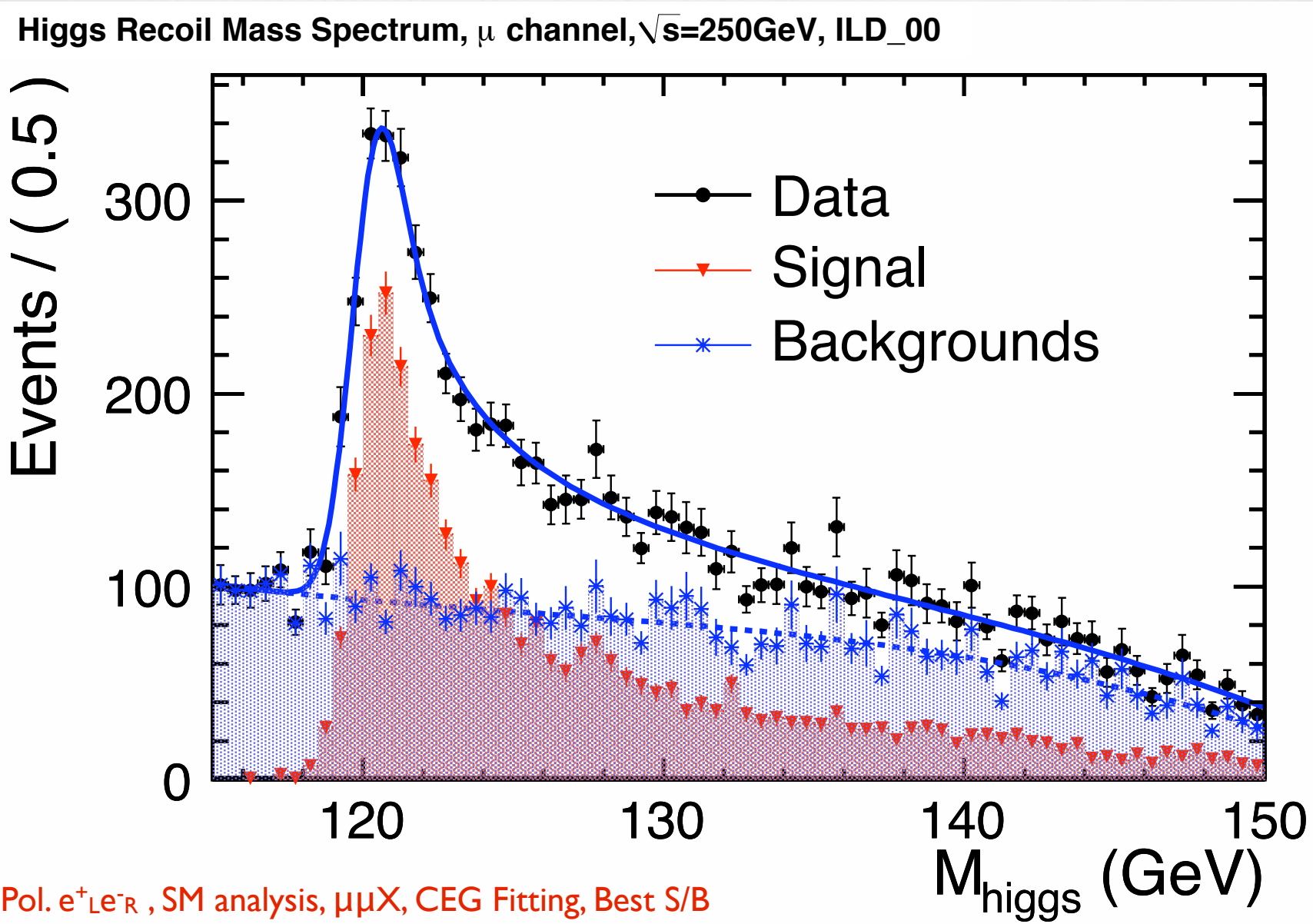
M Higgs :
119.981 ± 0.50 GeV
Cross-Section:
11.31 ± 0.39 fb (0.34%)



Pol. $e^+_L e^-_R$, SM analysis, μμX, GPET Fitting, Best S/B

My Favorite Fitting II: (CEG)

M Higgs :
120.069 ± 0.51 GeV
Cross-Section:
11.33 ± 0.39 fb (3.4%)



Pol. $e^+_L e^-_R$, SM analysis, μμX, CEG Fitting, Best S/B

Mass Resolution vs. Beam Energy Spread

An Important Issue, before give you all the results:

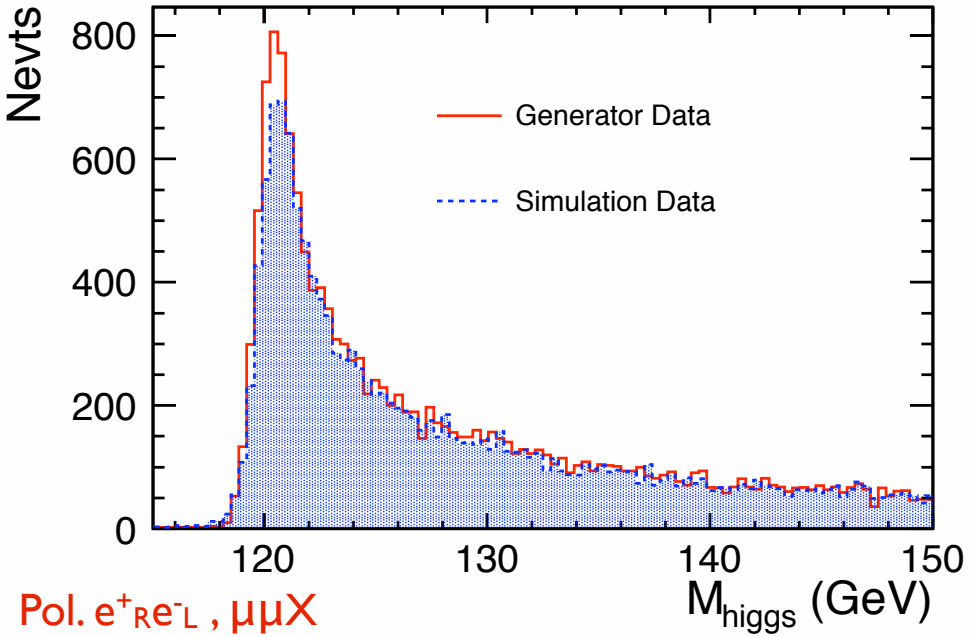
- **The Mass Resolution introduced by Beam Energy Spread (0.3% for each beam), is larger than we expected.**

By (Gaussian) fitting the left side of the Mass Peak of:

- **the Generator Data: ΔM_{beam} = 730 MeV**
- **the Simulation Data: ΔM_{total} = 870 MeV**

$$\Delta M_{total} = \Delta M_{beam} \oplus \Delta M_{detector}$$

$$\Rightarrow \Delta M_{detector} = 470 \text{ MeV}$$



Which means:

The Machine Introduced more inaccuracy into the Recoil Mass measurement than our ILD Detector!

In reporting the results: I Will Separate the Stat. Err. of Mh into δM_{beam} and $\delta M_{detector}$ accordingly .

Results Summary Table

Results in Blue: according to 500 fb^{-1},
Results in Red: according to 250 fb^{-1}, as requested by the ILD LOI.

Ana.	Pol.	Ch.	M_h stat. err. (MeV)						Cross-Section stat. err. (%)		S/B	S/√(S+B)
			δM_{total}		δM_{beam}		$\delta M_{detector}$					
SM	$e^+_R e^-_L$	μ	44	62	37	52	24	34	3.1	4.4	0.45	39.8
		e	72	102	54	76	47	66	4.4	6.2	0.37	32.6
	$e^+_L e^-_R$	μ	50	71	42	59	27	38	3.4	4.8	0.64	36.7
		e	82	116	62	88	54	76	4.8	6.8	0.52	29.0
MI	$e^+_R e^-_L$	μ	49	69	41	58	27	38	3.8	5.4	0.26	30.6
		e	100	141	75	106	66	93	5.2	7.4	0.17	22.4
	$e^+_L e^-_R$	μ	52	74	44	62	28	40	3.7	5.2	0.53	33.4
		e	112	158	84	119	73	103	5.8	8.2	0.36	24.0

- The Stat. Err. of M_h is separated into δM_{beam} and $\delta M_{detector}$ according to the ΔM_{beam} and $\Delta M_{detector}$, (different for μμX and eeX; for eeX, ΔM_{total} = 970 MeV, ΔM_{beam} = 730 MeV and $\Delta M_{detector}$ = 640 MeV)
- Stat. Err.s of Cross-Section are reported relatively (in %), since the cross-sections are different between two polarization setups

Conclusions and To Do List

Conclusions

- Analyses are done and methods are validated for μμX and eeX channels, with full polarizations.
- Both fitting methods give the similar good results
- Machine introduced larger error into the Higgs mass measurement than the ILD Detector
- Mh stat. err.s are separated into machine contributions and detector contributions : Helpful for the detector performance study

To Do List

- Results with LOI requested polarizations (e:+80%, p:-30%) and (e:-80%, p:+30%) will be given as soon as possible.
- Up to now, no gamma-gamma backgrounds taken into the fittings: results are coming soon.

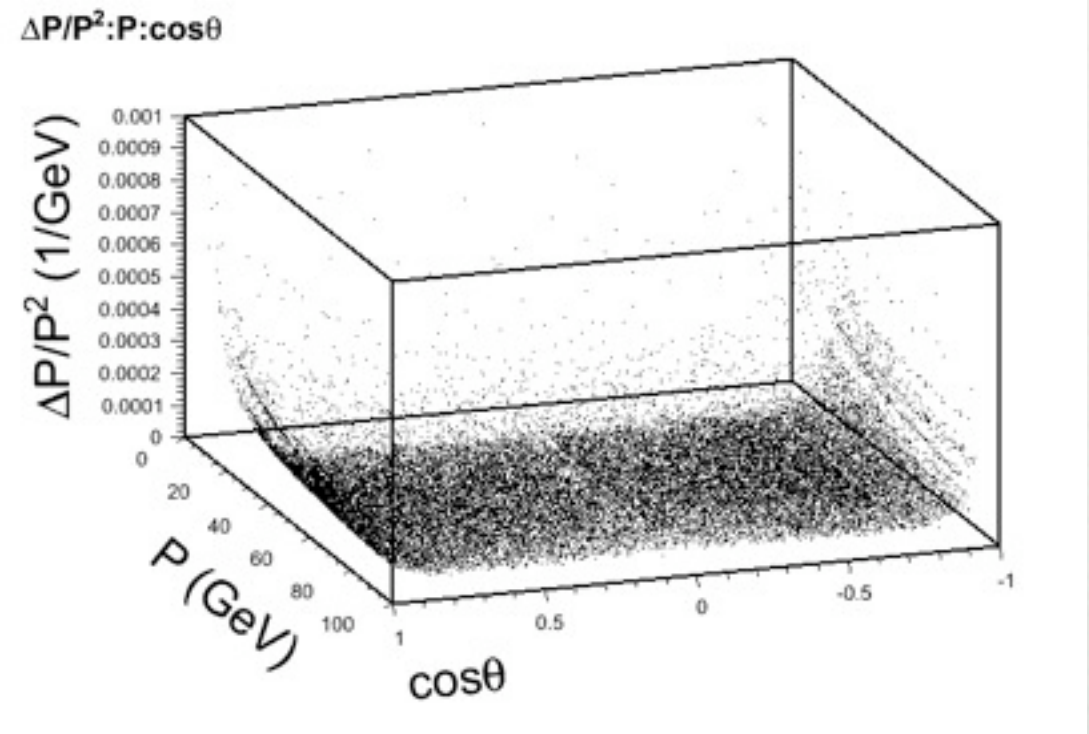
Kazutoshi is going to give the talk about the gamma-gamma rejection next.

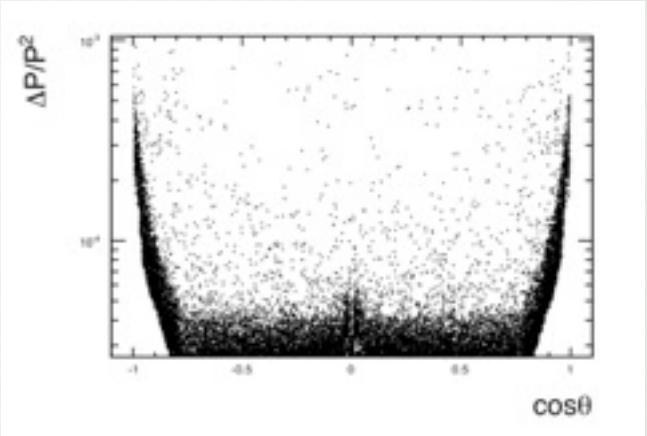
Thanks!

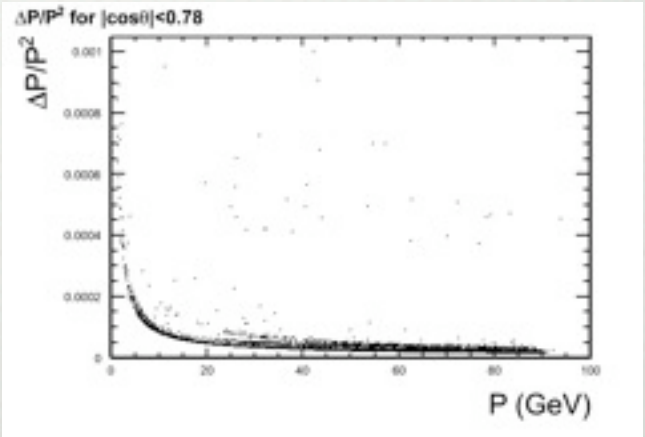
Backup Slides

$\Delta P/P^2$ criterion in the selection of lepton candidates

- Protect our study from bad measured tracks
- $\Delta P/P^2$ criterion for our lepton candidates is applied
  - With Francois' directions and validations step by step







Background Rejection Summary Table

Pol.	Ana.	Cha.	Cuts	μμX/eeX	μμ/ee	ττ	μμνν/eeνν	μμff/eeff	S/B	S/√(S+B)
e+R e-L	SM	μ	SM cut-chain:	6130(71.6%)	229	0	16	21.9k		
			+ fL>0.31	5116(59.7%)	63	0	7	11.3k	0.45	39.8
		e	SM cut-chain:	4631(51.8%)	456	0	11	20.2k		
			+ fL>0.33	3939(44.0%)	180	0	6	10.5k	0.37	32.6
	MI	μ	MI cut-chain:	5553(64.8%)	761	0	16k	15.5k		
			+ fL>0.19	4600(53.7%)	471	0	8244	9297	0.53	33.4
		e	MI cut-chain:	3960(44.3%)	2706	260	16.5k	13k		
			+ fL>0.17	3374(37.7%)	1524	260	9403	8175	0.36	24.0
e+L e-R	SM	μ	SM cut-chain:	3947(72.0%)	146	0	0	11.0k		
			+ fL>0.27	3435(62.6%)	31	0	0	5.3k	0.26	30.6
		e	SM cut-chain:	3947(72.0%)	338	0	2	9.9k		
			+ fL>0.30	2480(43.9%)	112	0	0	4.7k	0.17	22.4
	MI	μ	MI cut-chain:	3605(65.7%)	518	0	1452	7309		
			+ fL>0.24	3208(58.5%)	362	0	1075	4563	0.64	36.7
		e	MI cut-chain:	2511(44.5%)	2457	195	1339	6119		
			+ fL>0.29	2154(38.2%)	1463	195	837	3439	0.52	29.0

Results

SM

Pol.	Ch.	Fit.	M_h (GeV)	Cross-Section (fb)
$e_R^+e_L^-$	$\mu\mu X$	GPET	119.977 ± 0.044	17.15 ± 0.54 (3.1%)
		CEG	120.158 ± 0.046	17.21 ± 0.54 (3.1%)
	eeX	GPET	119.954 ± 0.072	18.38 ± 0.81 (4.4%)
		CEG	120.226 ± 0.078	18.35 ± 0.80 (4.4%)
$e_L^+e_R^-$	$\mu\mu X$	GPET	119.981 ± 0.050	11.31 ± 0.39 (3.4%)
		CEG	120.069 ± 0.051	11.33 ± 0.39 (3.4%)
	eeX	GPET	119.997 ± 0.084	11.46 ± 0.55 (4.8%)
		CEG	120.021 ± 0.082	11.41 ± 0.55 (4.8%)

MI

Pol.	Ch.	Fit.	M_h (GeV)	Cross-Section (fb)
$e_R^+e_L^-$	$\mu\mu X$	GPET	119.938 ± 0.049	16.75 ± 0.65 (3.9%)
		CEG	120.073 ± 0.054	16.73 ± 0.64 (3.8%)
	eeX	GPET	120.094 ± 0.110	20.29 ± 1.06 (5.3%)
		CEG	120.286 ± 0.100	20.35 ± 1.06 (5.3%)
$e_L^+e_R^-$	$\mu\mu X$	GPET	120.004 ± 0.052	11.24 ± 0.42 (3.7%)
		CEG	120.102 ± 0.054	11.05 ± 0.41 (3.7%)
	eeX	GPET	119.981 ± 0.112	10.79 ± 0.63 (5.8%)
		CEG	119.922 ± 0.112	10.77 ± 0.63 (5.8%)

SM Rejection

N_{evts} Remained:	$\mu\mu X$	$\mu\mu$	$\tau\tau$	$\mu\mu\nu\nu$
Before any restriction:	8563	8.5M	8.6M	425k
Both μ identified	8169 (95.4%)		257k (3%)	374k (88.1%)
+ pre-cuts	7166 (83.7%)	143k (1.7%)	17k (0.2%)	54k (12.6%)
+ $N_{add.TK} > 1$	7112 (83.0%)	8.8k (0.10%)	2k (0.025%)	959 (0.23%)
+ $\Delta\theta_{2tk} > 0.01$	7100 (82.9%)	819 (0.01%)	1558 (0.02%)	122 (0.03%)
+ $\Delta\theta_{min} > 0.01$	7000 (81.7%)	506 (0.006%)	346 (0.004%)	18 (0.004%)
+ acop (0.2, 3.0)	6495(75.8%)	354 (0.004%)	0 (0%)	18 (0.004%)
+ M_h (115, 150) GeV	6130(71.6%)	229 (0.003%)	0 (0%)	16 (0.004%)

Table 4: Number of events remained after each cuts for $\mu\mu$X, Polarization $e^+_R e^-_L$

N_{evts} Remained:	eeX	ee	$\tau\tau$	$ee\nu\nu$
Before any restriction:	8588	8.7G	8.6M	508k
Both e identified	8439 (98.3%)		965k(11.3%)	415k (81.6%)
+ pre-cuts	5593 (62.5%)	267k (0.003%)	29k (0.3%)	61k (12.1%)
+ $N_{add.TK} > 1$	5548 (62.0%)	16k (2×10^{-6})	8309 (0.1%)	1708 (0.34%)
+ $\Delta\theta_{2tk} > 0.01$	5540 (61.9%)	2607 (3×10^{-7})	5885 (7×10^{-4})	279 (0.05%)
+ $\Delta\theta_{min} > 0.01$	5448 (60.9%)	844 (1×10^{-7})	1212 (1×10^{-4})	31 (0.006%)
+ acop (0.2, 3.0)	5054 (56.5%)	712 (8×10^{-8})	0 (0%)	30 (0.006%)
+ M_h (115, 150) GeV	4631 (51.8%)	456 (5×10^{-8})	0 (0%)	11 (0.002%)

Table 5: Number of events remained after each cuts for eeX, Polarization $e^+_R e^-_L$

SM Rejection

N_{evts} Remained:	$\mu\mu X$	$\mu\mu$	$\tau\tau$	$\mu\mu\nu\nu$
Before any restriction:	5484	6.4M	6.4M	22.5k
Both μ identified	5248 (95.7%)		193k (3%)	17.8k(79.2%)
+ pre-cuts	4620 (84.2%)	93.5k (1.5%)	13.4k (0.2%)	3883 (17.3%)
+ $N_{add.TK} > 1$	4592 (83.7%)	5680 (0.09%)	1626 (0.025%)	58 (0.26%)
+ $\Delta\theta_{2tk} > 0.01$	4584 (83.6%)	526 (0.008%)	1171 (0.02%)	6 (0.03%)
+ $\Delta\theta_{min} > 0.01$	4513 (82.3%)	335 (0.005%)	260 (0.004%)	0 (0%)
+ acop (0.2, 3.0)	4172 (76.1%)	249 (0.004%)	0 (0%)	0 (0%)
+ M_h (115, 150) GeV	3947 (72.0%)	146 (0.002%)	0 (0%)	0 (0%)

Table 6: Number of events remained after each cuts for $\mu\mu$X, Polarization $e^+_L e^-_R$

N_{evts} Remained:	eeX	ee	$\tau\tau$	$ee\nu\nu$
Before any restriction:	5645	8.7G	6.4M	35.2k
Both e identified	5544 (98.2%)		725k(11.3%)	21.6k (61.3%)
+ pre-cuts	3534 (62.6%)	241k (0.003%)	22k (0.3%)	3999 (11%)
+ $N_{add.TK} > 1$	3503 (62.1%)	14.6k (1.7×10^{-6})	6244 (0.1%)	71 (0.2%)
+ $\Delta\theta_{2tk} > 0.01$	3497 (61.9%)	2216 (3×10^{-7})	4423 (0.07%)	8 (0.02%)
+ $\Delta\theta_{min} > 0.01$	3445 (61.0%)	645 (7×10^{-8})	911 (0.01%)	2 (0.0006%)
+ acop (0.2, 3.0)	3209 (56.9%)	552 (6×10^{-8})	0 (0%)	2 (0.006%)
+ M_h (115, 150) GeV	2935 (52.0%)	338 (4×10^{-8})	0 (0%)	2 (0.006%)

Table 7: Number of events remained after each cuts for eeX, Polarization $e^+_L e^-_R$

MI Rejection

N_{evts} Remained:	$\mu\mu X$	$\mu\mu$	$\tau\tau$	$\mu\mu\nu\nu$	$\mu\mu ff$
Before any restriction	8563	8.5M	8.6M	425k	710k
+ Both μ identified	8169.5 (95.4%)		257k (3.0%)	374k (88.1%)	432k (60.9%)
+ pre-cuts	7166 (83.7%)	143k (1.7%)	18k (0.2%)	53k (12.6%)	48k (6.7%)
+ $P_{Tdl} > 20\ GeV$	6777 (79.1%)	71k (0.81%)	12k (0.14%)	46k (10.8%)	38k (5.4%)
+ $M_{dl} \in (80,\ 100)\ GeV$	6230 (72.7%)	54k (0.64%)	6578 (0.08%)	27k (6.4%)	30k (4.2%)
+ $acop \in (0.2,\ 3.0)$	5827 (68.0%)	45k (0.53%)	0 (0%)	25k (6.0%)	27k (3.8%)
+ $\Delta P_{Tbal.} > 10\ GeV$	5712 (66.7%)	2618 (0.03%)	0 (0%)	23k (5.5%)	25k (3.6%)
+ $\lvert\Delta\theta_{2tk}\rvert > 0.01$	5704 (66.6%)	1044 (0.01%)	0 (0%)	23k (5.4%)	25k (3.6%)
+ $M_{recoil} \in (115,\ 150)\ GeV$	5553 (64.8%)	761 (0.009%)	0 (0%)	16k (3.8%)	15.5k (2.2%)

Table 13: Number of events remained after each cuts for $\mu\mu$X, Polarization $e^+_R e^-_L$.

N_{evts} Remained:	eeX	ee	$\tau\tau$	$ee\nu\nu$	$eeff$
Before any restriction	8588	8.7G	8.6M	508k	2.2M
+ Both μ identified	8791 (98.3%)		965k (11.3%)	415k (81.7%)	880k (40.0%)
+ pre-cuts	5593 (62.5%)	267k (0.003%)	29k (0.34%)	61k (12.1%)	41k (1.8%)
+ $P_{Tdl} > 20\ GeV$	5283 (59.1%)	195 (0.002%)	20k (0.24%)	53k (10.4%)	35k (1.6%)
+ $M_{dl} \in (80,\ 100)\ GeV$	4508 (50.4%)	108 (0.001%)	12 (0.14%)	29k (5.8%)	25k (1.1%)
+ $acop \in (0.2,\ 3.0)$	4211 (47.1%)	98k (0.001%)	866 (0.01%)	28 (5.4%)	23k (1.0%)
+ $\Delta P_{Tbal.} > 10\ GeV$	4095 (45.8%)	6618 (8×10^{-7})	606 (0.007%)	24k (4.7%)	22k (0.98%)
+ $\lvert\Delta\theta_{2tk}\rvert > 0.01$	4089 (45.7%)	3660 (4×10^{-7})	519 (0.006%)	23.5k (4.6%)	21.5k (0.98%)
+ $M_{recoil} \in (115,\ 150)\ GeV$	3960 (44.3%)	2706 (3×10^{-7})	260 (0.003%)	16.5k (3.3%)	13k (0.59%)

Table 14: Number of events remained after each cuts for eeX, Polarization $e^+_R e^-_L$.

MI Rejection

N_{evts} Remained:	$\mu\mu X$	$\mu\mu$	$\tau\tau$	$\mu\mu\nu\nu$	$\mu\mu ff$
Before any restriction	5484	6.4M	6.4M	22.5k	629.6k
+ Both μ identified	5248 (95.7%)		193k (3.0%)	17.8k (79.2%)	363 (57.6%)
+ pre-cuts	4620 (84.2%)	93k (1.5%)	13k (0.21%)	3883 (17.3%)	26k (4.2%)
+ $P_{Tdl} > 20\ GeV$	4380 (79.9%)	47k (0.74%)	9041 (0.14%)	3478 (15.5%)	19k (3.1%)
+ $M_{dl} \in (80,\ 100)\ GeV$	4046 (73.8%)	36k (0.56%)	4943 (0.08%)	2692 (12.0%)	14k (2.2%)
+ $acop \in (0.2,\ 3.0)$	3771 (68.8%)	29k (0.46%)	0 (0%)	2492 (11.1%)	13k (2.0%)
+ $\Delta P_{Tbal.} > 10\ GeV$	3697 (67.4%)	1701 (0.027%)	0 (0%)	2421 (10.8%)	11.8k (1.9%)
+ $\lvert\Delta\theta_{2tk}\rvert > 0.01$	3692 (67.3%)	710 (0.011%)	0 (0%)	2392 (10.6%)	11.7k (1.9%)
+ $M_{recoil} \in (115,\ 150)\ GeV$	3605 (65.7%)	518 (0.008%)	0 (0%)	1452 (6.5%)	7309 (1.2%)

Table 15: Number of events remained after each cuts for $\mu\mu$X, Polarization $e^+_L e^-_R$.

N_{evts} Remained:	eeX	ee	$\tau\tau$	$ee\nu\nu$	$eeff$
Before any restriction	5645	8.7G	6.4M	35200	2.1M
+ Both μ identified	5544 (98.2%)		725k (11.3%)	22k (61.4%)	773k (36.8%)
+ pre-cuts	3534 (62.6%)	241k (0.0028%)	22k (0.34%)	3998 (11.4%)	21k (1.0%)
+ $P_{Tdl} > 20\ GeV$	3334 (59.1%)	182k (0.002%)	15k (0.24%)	3562 (10.1%)	18 (0.8%)
+ $M_{dl} \in (80,\ 100)\ GeV$	2845 (50.4%)	98k (0.001%)	8781 (0.14%)	2495 (7.1%)	12k (0.57%)
+ $acop \in (0.2,\ 3.0)$	2673 (47.4%)	89k (0.001%)	650 (0.01%)	2317 (6.6%)	11k (0.52%)
+ $\Delta P_{Tbal.} > 10\ GeV$	2606 (46.2%)	5984 (7×10^{-7})	455 (0.007%)	2221 (6.3%)	10k (0.48%)
+ $\lvert\Delta\theta_{2tk}\rvert > 0.01$	2602 (46.1%)	3307 (4×10^{-7})	390 (0.006%)	2191 (6.2%)	10k (0.48%)
+ $M_{recoil} \in (115,\ 150)\ GeV$	2511 (44.5%)	2457 (3×10^{-7})	195 (0.003%)	1339 (3.8%)	6119 (0.29%)

Table 16: Number of events remained after each cuts for eeX, Polarization $e^+_L e^-_R$.