Recent progress on e+e- -> gammaZ analysis

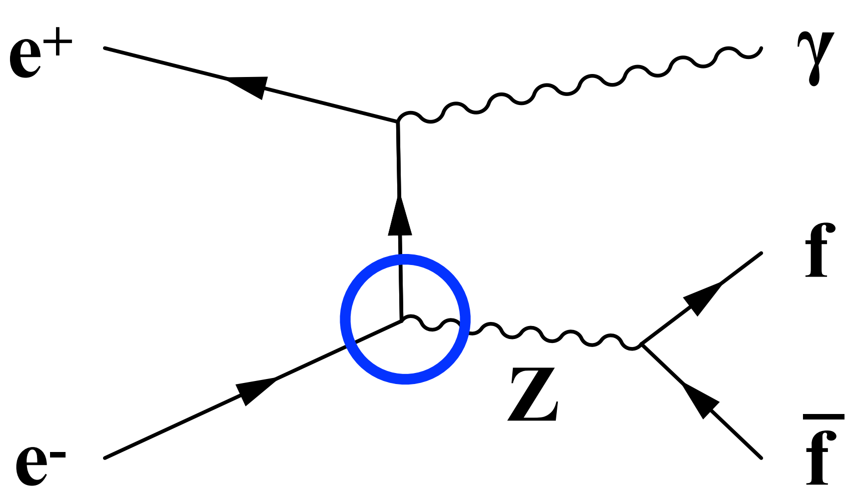
Takahiro Mizuno

Introduction (1)

Primary Target of ILC 250: to precisely measure *the coupling constants between Higgs boson and various other particles*

SMEFT

- Model-independent analysis of BSM effects
- SU(2) × U(1) gauge invariant
- Need to combine various processes **including the process without Higgs**



e^+e^- -> gamma Z process

Asymmetry in left- and right-handed **eeZ coupling** is very powerful to improve the constraints on SMEFT operators

Introduction (2)

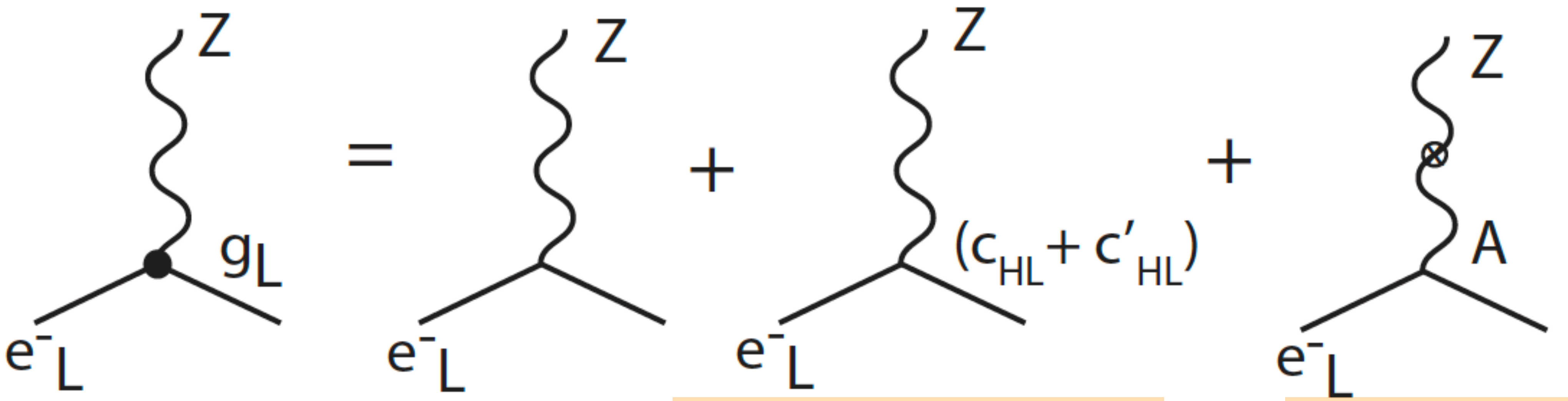
ΔL

$$-i\frac{c_{HL}}{v^2}(\Phi^\dagger \overleftrightarrow{D}^\mu\Phi)(\overline{L}\gamma_\mu L)$$

$$4i\frac{c'_{HL}}{v^2}(\Phi^\dagger t^a \overleftrightarrow{D}^\mu\Phi)(\overline{L}\gamma_\mu t^a L)$$

$$-i\frac{c_{HE}}{v^2}(\Phi^\dagger \overleftrightarrow{D}^\mu\Phi)(\overline{e}\gamma_\mu e)$$

eeZ coupling contains BSM effect



Contact interaction

AZ mixing

Contribution to the deviation in the eeZ couplings is **different for each polarization**

$$g_L = \frac{g}{c_w}\left[(-\frac{1}{2}+s_w^2)(1+\frac{1}{2}\delta Z_Z) - \frac{1}{2}(\underline{c_{HL}} + \underline{c'_{HL}}) - s_w c_w \delta Z_{AZ}\right]$$

$$g_R = \frac{g}{c_w}\left[(+s_w^2)(1+\frac{1}{2}\delta Z_Z) - \frac{1}{2}\underline{c_{HE}} - s_w c_w \delta Z_{AZ}\right]$$

$$\delta Z_{AZ} = s_w c_w\Big((8c_{WW}) - (1-\frac{s_w^2}{c_w^2})(8c_{WB}) - \frac{s_w^2}{c_w^2}(8c_{BB})\Big)$$

Introduction (3)

Left-right asymmetry in the cross section

$$A_{\mathrm{LR}} = \frac{\sigma_{\mathrm{L}} - \sigma_{\mathrm{R}}}{\sigma_{\mathrm{L}} + \sigma_{\mathrm{R}}} \frac{1}{\langle|\mathcal{P}_{\mathrm{e}}|\rangle}$$

$$P_e = \frac{P_e^- - P_e^+}{1 - P_e^- P_e^+}$$

$P_e^{\pm}$: $e^{\pm}$ polarisation (respectively)

A_{LR} Measurement -> determination of eeZ coupling for e_L and e_R

-> constraint SMEFT operators

Current best measurement

A_{LR}= 0.1514 ± 0.0019 (statistic error) ± 0.0011(systematic error)

LEP: **17 million** Z decays (ALEPH + DELPHI + L3+ OPAL, LEP-I, 1989-1995)
SLC: **600 thousand** Z decays (SLD, 1992-1998, polarization of e^-)
ILC250: **90 million** radiative return events

Introduction (3)

How much we can improve the systematic errors?

Need full detector simulation of radiative return events
-> detailed study of background events

A_{LR} Measurement -> determination of eeZ coupling for e_L and e_R
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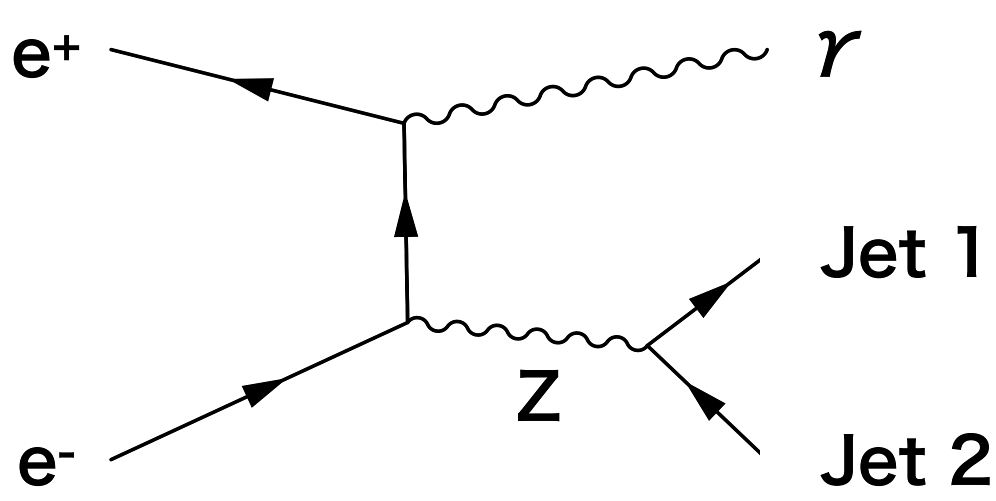
Simulation Setup

Full simulation

- event generator: Whizard2
- Geant4 based full simulation of realistic detector model
- realistic event reconstruction from detector signals
- E_{CM}= 250 GeV & 2 beam polarizations: (P_{e^-}, P_{e^+}) = (-0.8, +0.3), (+0.8, -0.3)

Signal: e^+e^- -> Zγ -> 2 jets +γ

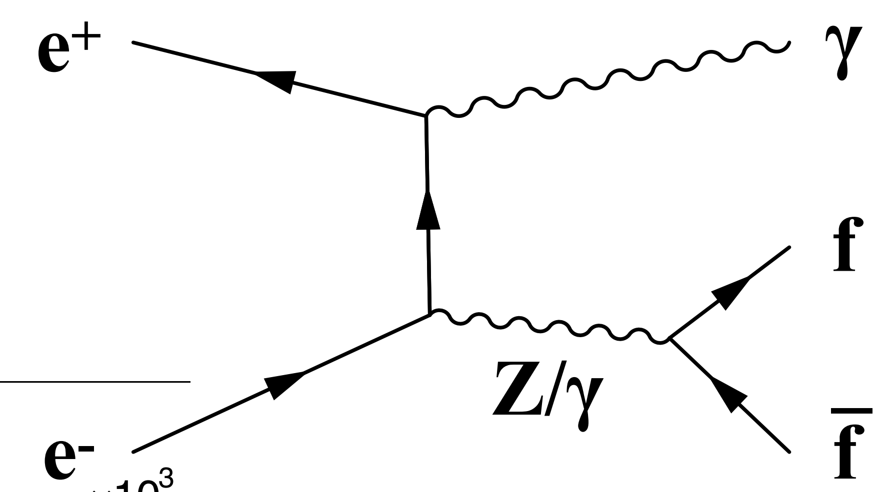


Background (e.g. e^+e^- -> Z e^+e^- -> 2 jets + e^+e^-

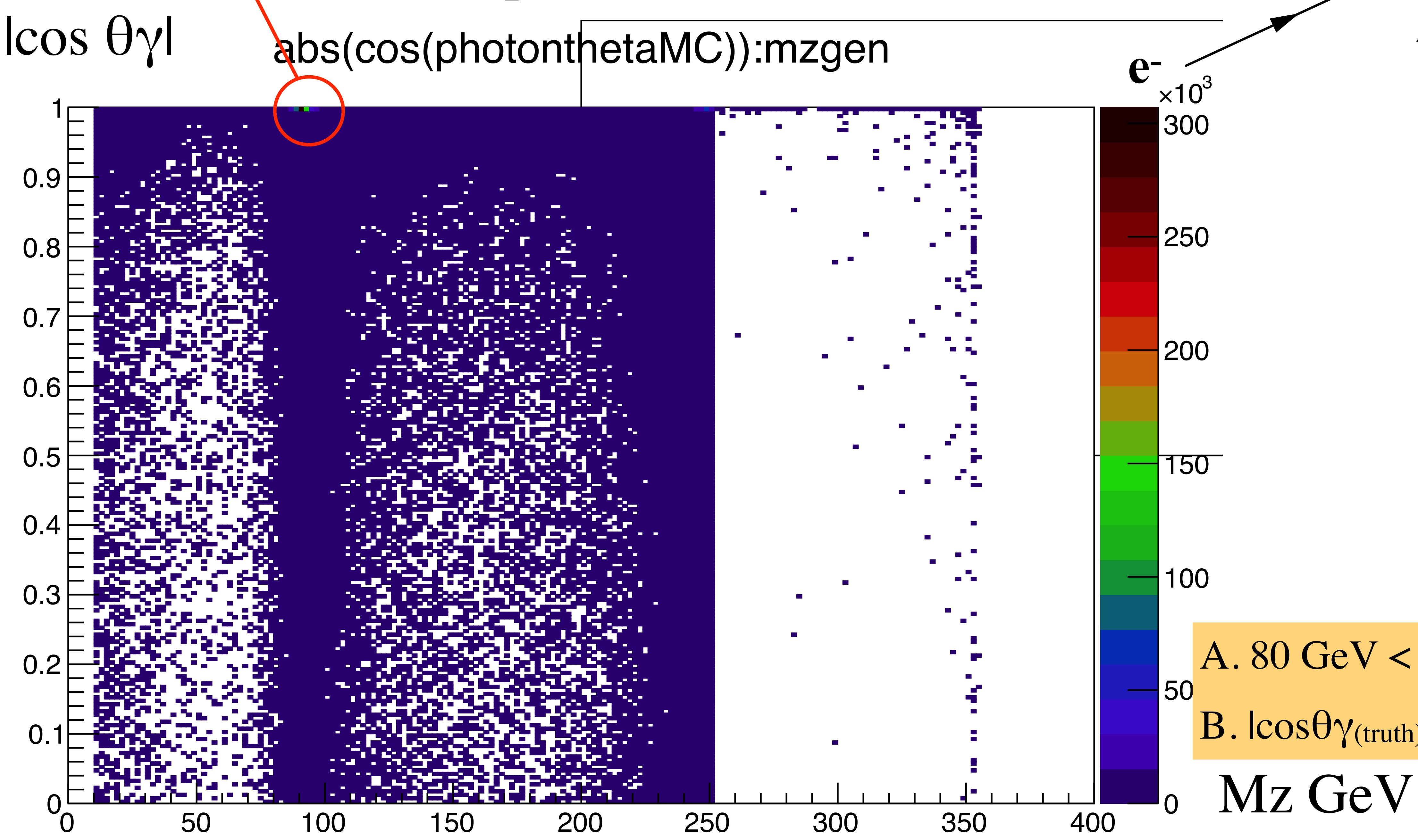
e^+e^- -> Z $\nu^+\nu^-$ -> 2 jets + $\nu^+\nu^-$)

Signal event definition

Signal event: radiative return



eLpR events



A. 80 GeV < $Mz_{(truth)}$ < 100 GeV

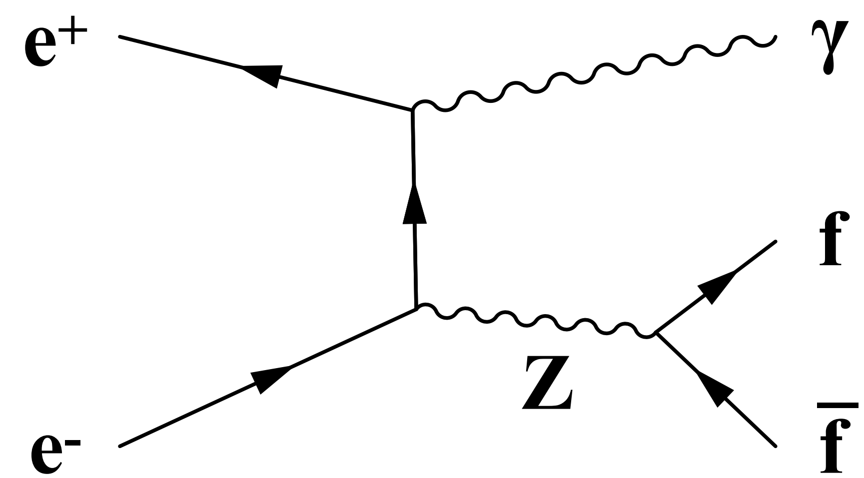
B. $|\cos\theta\gamma_{(truth)}| > 0.999$

Signal event definition

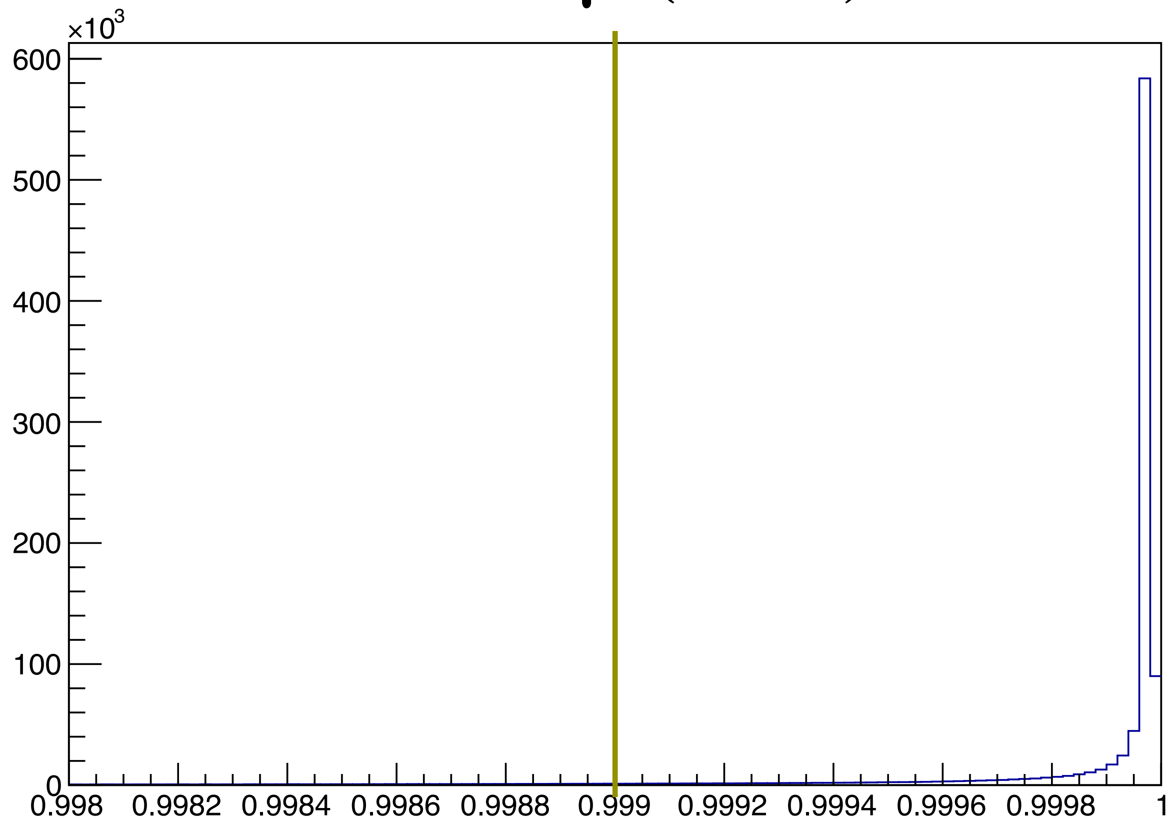
Signal event (e^+e^- -> gamma Z):

A. 80 GeV < $M_{Z(truth)}$ < 100 GeV

B. $|\cos\theta_{\gamma(truth)}| > 0.999$

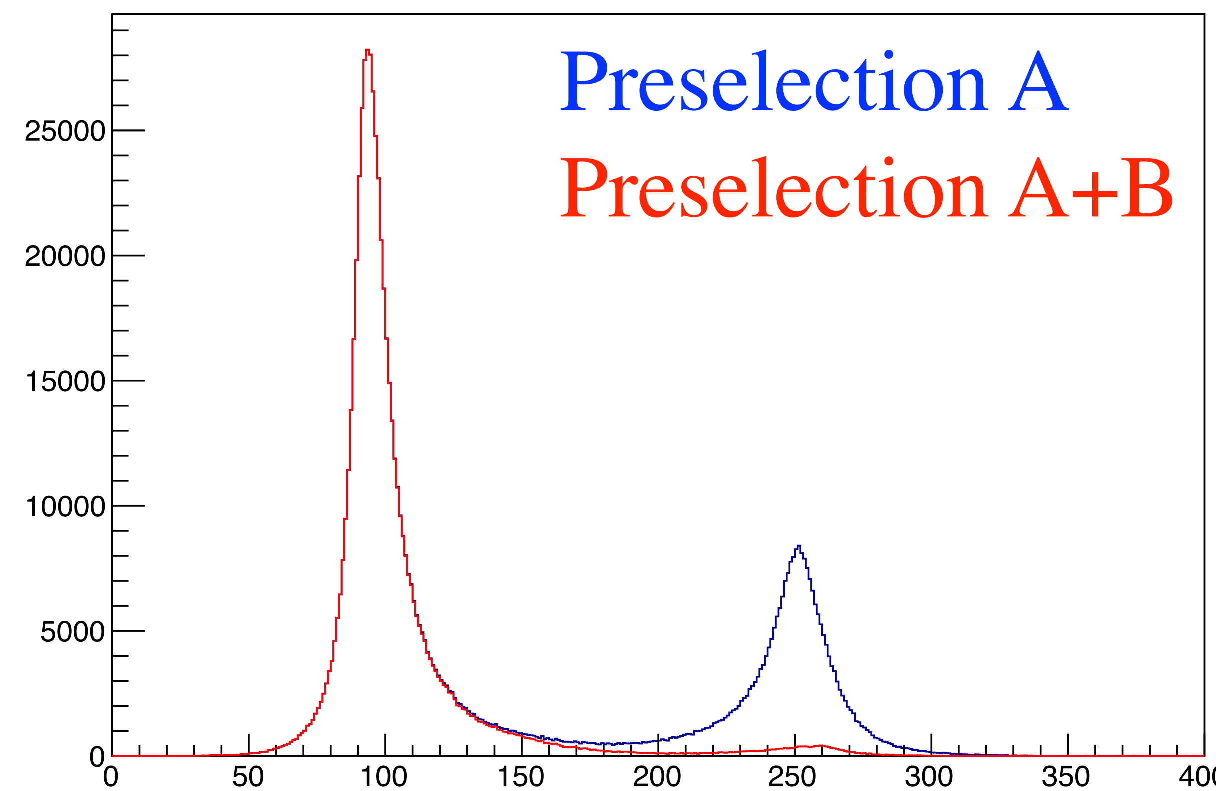


$|\cos\theta_\gamma|$ (truth)



$|\cos\theta_\gamma|$

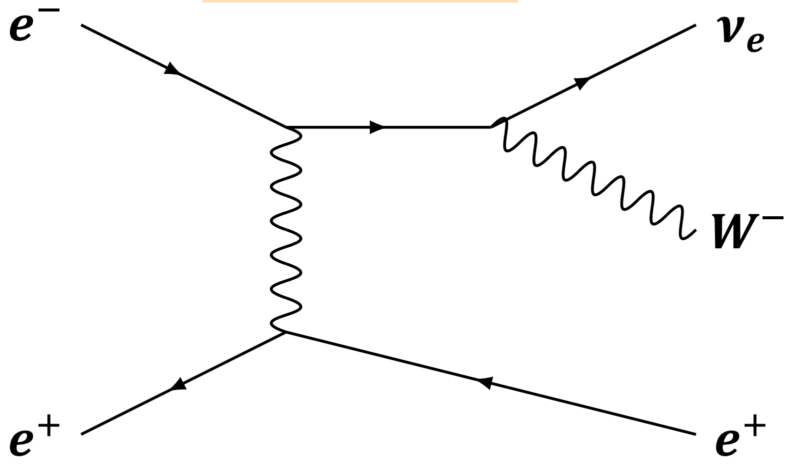
Mz (PFO)



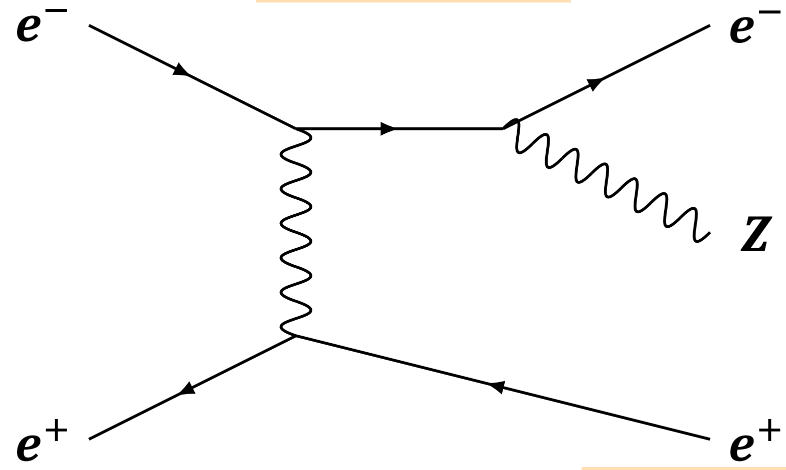
Mz GeV

Background exclusion

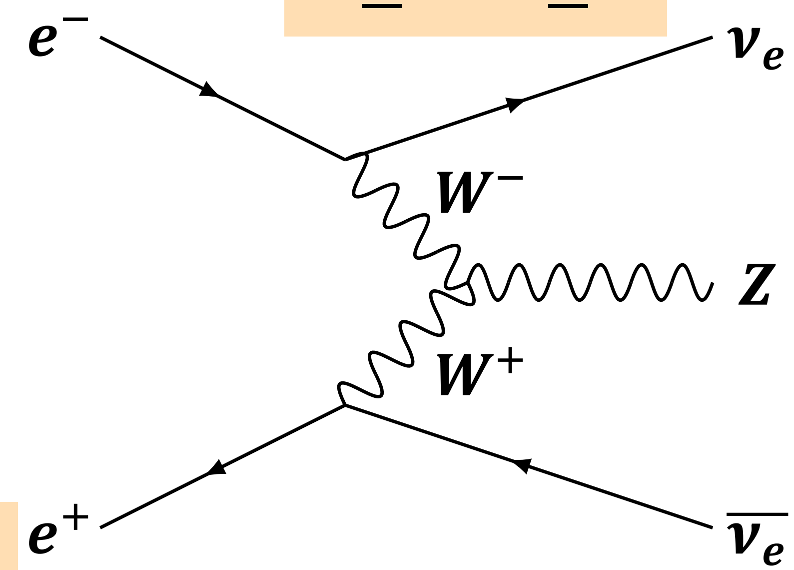
4f_sw_sl



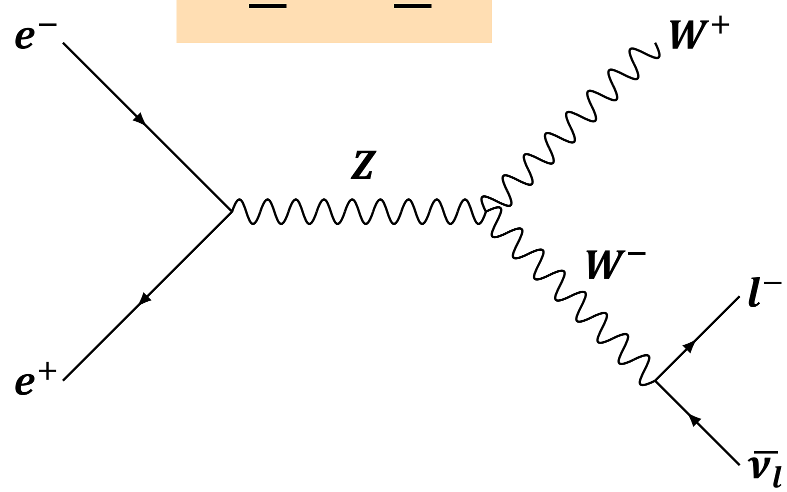
4f_sze_sl



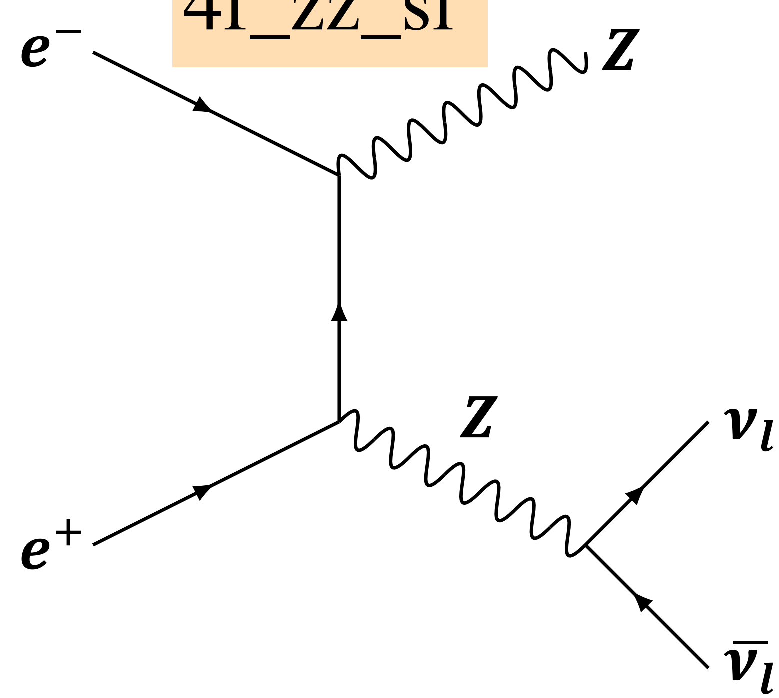
4f_sznu_sl



4f_ww_sl



4f_zz_sl

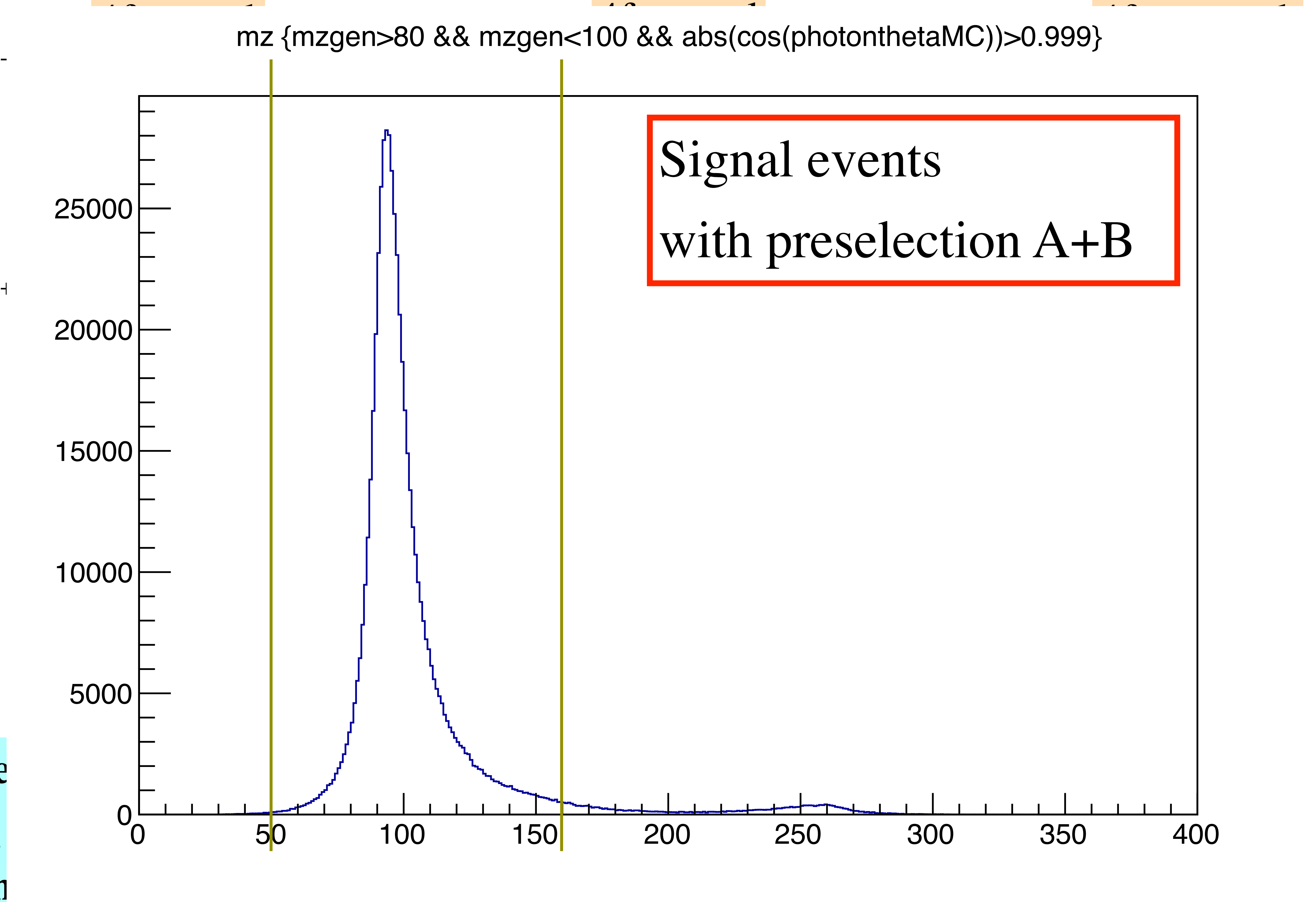


Selection cuts:

1. veto events which have energetic photos (>50 GeV) detected, since we focus on first the signal events in which photon is collinear in the beam direction

2. 50 GeV < reconstructed Z mass (Mz) < 160 GeV

Background exclusion



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Efficiency Table

Signal event (e^+e^- -> gamma Z):

A. 80 GeV < $M_{Z(truth)}$ < 100 GeV

B. $|\cos\theta_{\gamma(truth)}|$ > 0.999

Signal & Background efficiencies

	2f_z_h $e_L p_R$	2f_z_h $e_R p_L$
Before selection	3.74299E+07	1.23229E+06
#Photon = 0	2.92246E+07	928022
50 GeV < Mz < 160 GeV	1.74413E+07	662753

	4f_ww_sl $e_L p_R$	4f_ww_sl $e_R p_L$	4f_zz_sL $e_L p_R$	4f_zz_sl $e_R p_L$
Before selection	5.4929E+06	3035.7	245138	8169.29
#Photon = 0	5.35789E+06	2982.24	232818	7715.97
50 GeV < Mz < 160	2.03951E+06	1548.43	60315.1	2249.75

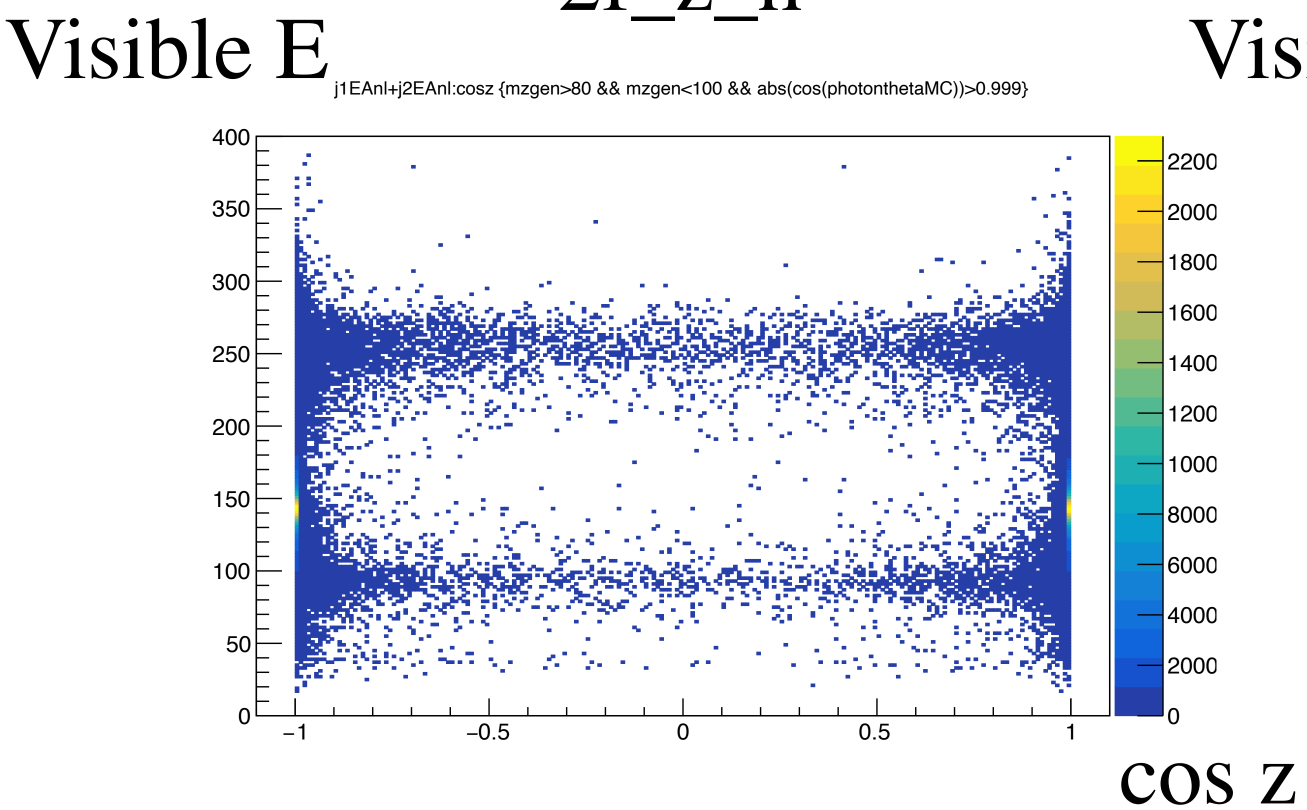
	4f_sw_sl $e_L p_L$	4f_sw_sl $e_L p_R$	4f_sw_sl $e_R p_L$	4f_sw_sl $e_R p_R$	4f_sze_sl $e_L p_L$	4f_sze_sl $e_L p_R$	4f_sze_sl $e_R p_L$	4f_sze_sl $e_R p_R$	4f_sznu_sl $e_L p_R$	4f_sznu_sl $e_R p_L$
Before selection	30008.7	3.00222E+06	1517.18	6195.72	182044	416318	21339.4	37609	132757	2296.34
#Photon = 0	24949.9	2.80253E+06	1460.55	5140.18	72698.8	199971	9153.62	15031.6	131744	2271.7
50 < Mz < 160 GeV	19565.9	599082	480.956	4022.26	7986.61	16586.8	942.256	1656.89	124115	2154.86

Future Plan

Use new cut criteria

- ●. nPhoton
- 1. Visible energy e.g. 120 to 160 GeV
- 2. Visible particles direction e.g. |cos z| > 0.95
- 3. ycut
- ●. Mz

2f_z_h



4f_sw_sl