# ZH recoil mass
# rejection of 2 photon background

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# *2 photon background*

- **For analysis of ZH recoil mass, we don't use the particles from decay of Higgs boson.**
    - If there are at least two electrons or muons in the final states, it becomes to be background.
- **The 2-photon backgrounds have large cross section.**
    - $\gamma\gamma \rightarrow$ ee : 2.6 nb
    - $\gamma\gamma \rightarrow$ mm : 2.6 nb
- **Rejection of these 2-photon backgrounds are needed for analysis of ZH recoil mass.**

- **Today's topic is the status of the rejection using pre-selected samples.**
    - Luminosity: 250 fb-1
    - Polarization: (electron = +80%, positron = -30%)

# *pre-selection*

- **2-photon samples were reconstructed after applying the pre-selection.**

  - Pre-selection for muon channel: $\gamma\gamma \to \mu\mu$

    - $\Sigma \, p_t > 10$ GeV/c.

  - Pre-selection for electron channel: $\gamma\gamma \to ee$

    - $N_e$good is more than 2.
      or
    - $N_e$good is 2.

    - $\Sigma \, p_t > 10$ GeV/c.
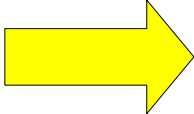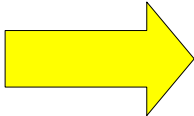
    - $M_z > 60$ GeV/c$^2$.

    $N_e$good = Number of e+ or e- where $|\cos\theta| < 0.95$.

Reduction summary of pre-selection. (scaled to 250 fb$^{-1}$)

| process | generated | selected | rate |
|---------|-----------|----------|------|
| $\gamma\gamma \to mm$ | $6.5 \times 10^8$ | $1.1 \times 10^5$ | 0.02% |
| $\gamma\gamma \to ee$ | $6.5 \times 10^8$ | $4.8 \times 10^6$ | 0.74% |

For more information: http://ilcphys.kek.jp/soft/preselection/index.html

# *Selection*

- **The number of events with 250 fb$^{-1}$ after applying the cuts (M$_Z$, M$_{recoil}$, p$_t^{di-lepton}$, acop.)**

  - Muon channel:
    – Signal: 929.9
    – $\gamma\gamma \to \mu\mu$: 16.9   ⟹   Additional cuts is not needed.

  - Electron channel:
    – Signal:921
    – $\gamma\gamma \to ee$: 5688   ⟹   Some cuts is needed.

- **To reject $\gamma\gamma \to ee$ events, the number of hits on BeamCal was checked.**

# *Hits on BeamCal*

- **We can not use the BeamCal information.**
  - The simulated samples are not taken into account the crossing angle.

- **We can estimate the energy on BeamCal using the BcalTagEfficiency processor.**
  - BcalTagEfficiency processor:
    - This processor calculate the energy on BeamCal using the energy and momentum at IP.

- **The number of events which have hits on BeamCal;**
  - Signal: 0.56 / 921 = 0.06%

    Threshold of energy is 40 GeV.
  - $\gamma\gamma \rightarrow$ ee: 848.9 / 5688 = 14.9%

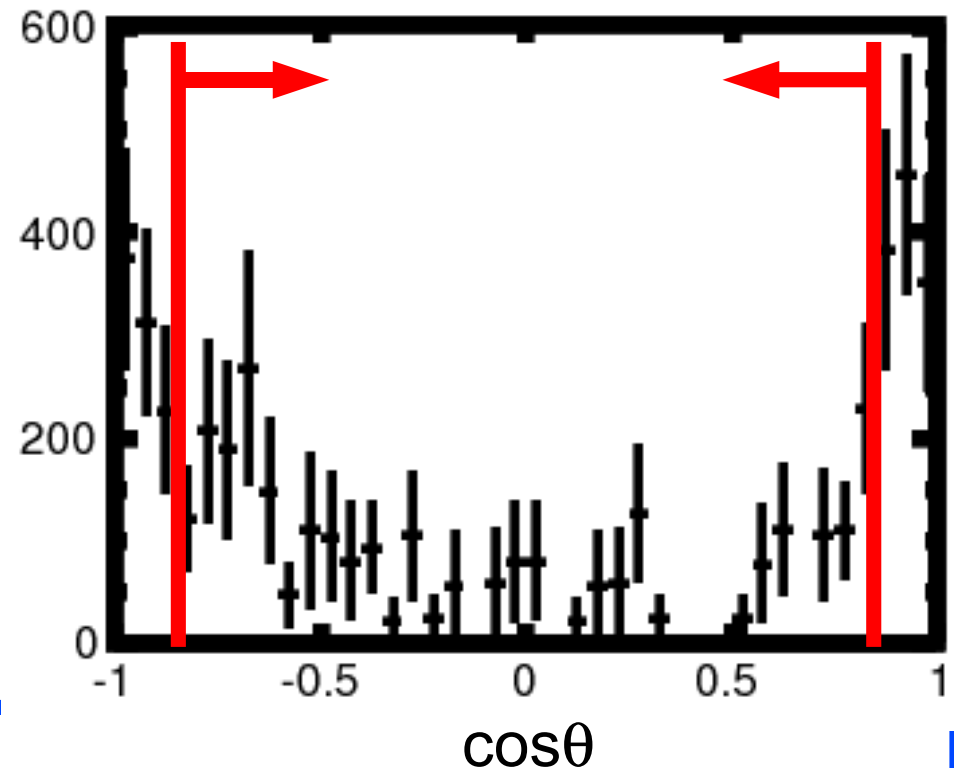  <span style="color:red">The events which have hits on BeamCal were rejected.</span>

# _cosθ in the rest frame of Z boson_

- **The distribution of cosθ in the rest frame was checked.**
  - The z-axis is the flight direction of Z boson.
  - Z boson decays into electron pairs, uniformly.
  - The events in the range of |cosθ| < 0.8 are selected.
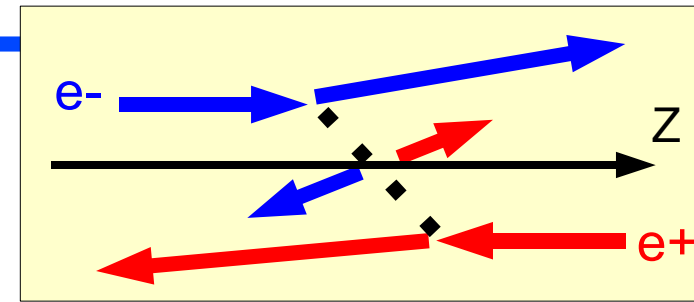
cosθ of electron
in the rest frame (signal)
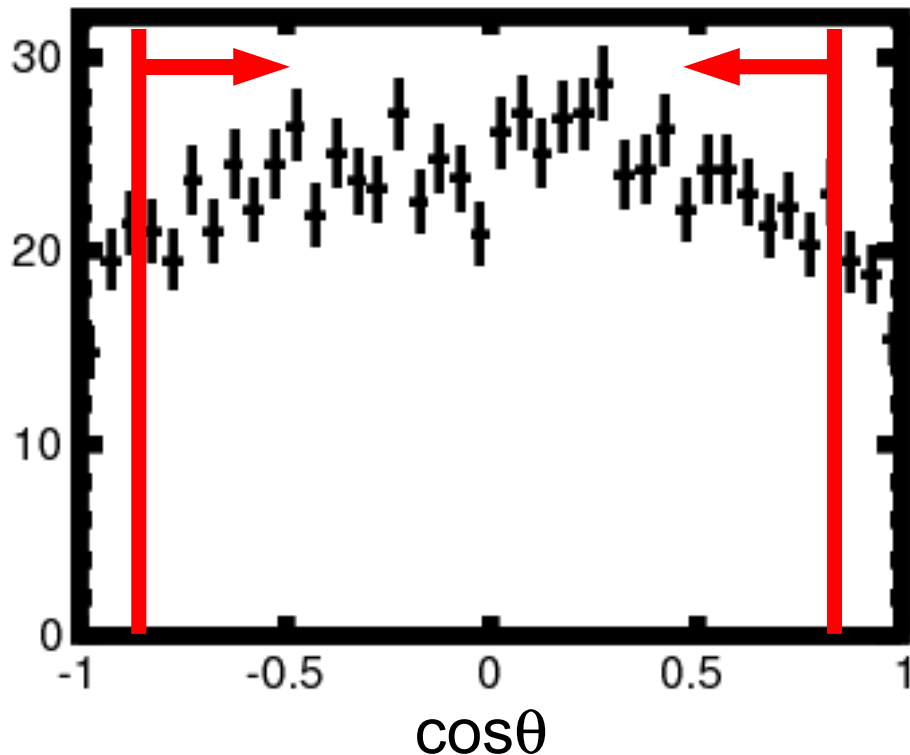
(2-photon background)
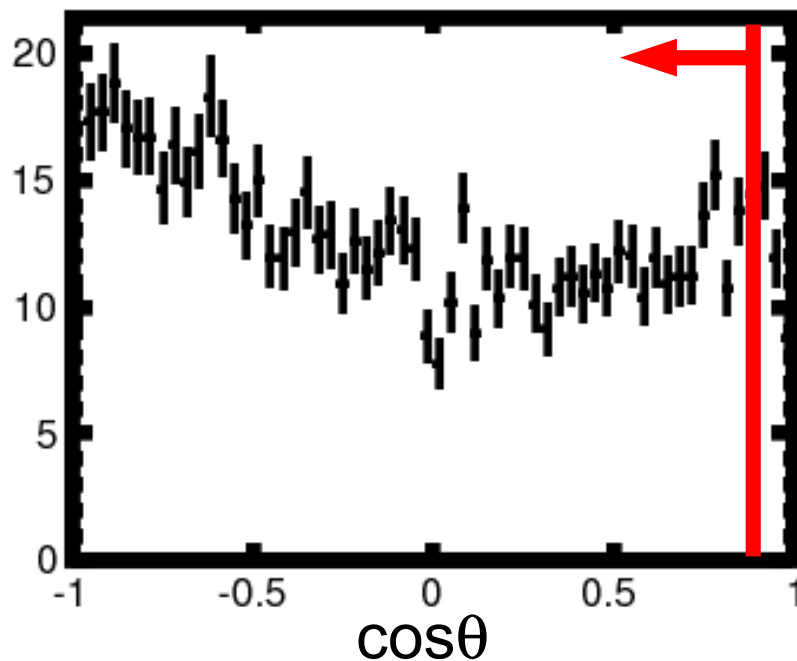


cosθ

cosθ

# *cosθ in the lab frame*
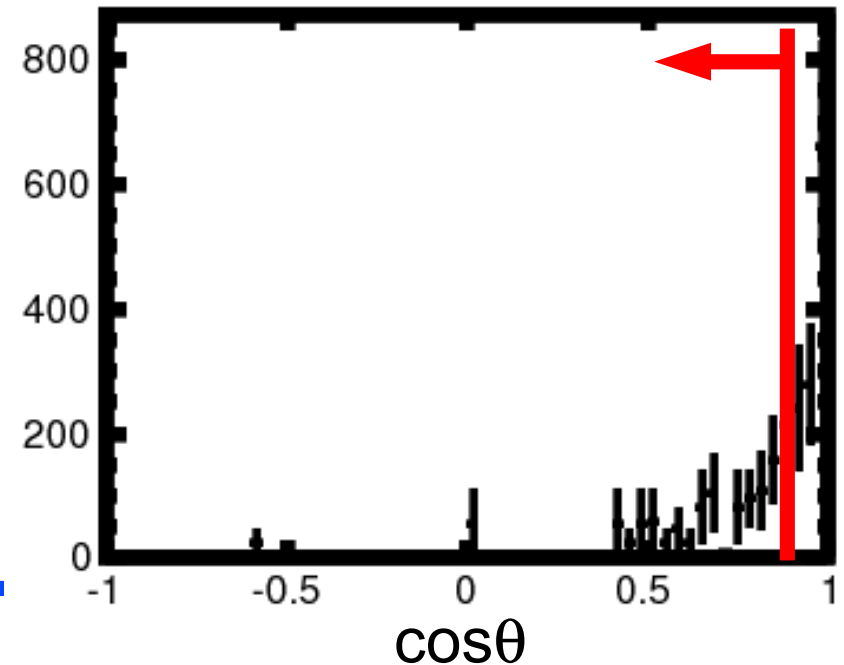


- **cosθ in the lab frame was checked.**
  - The z-axis is the direction of electron beam.
  - For 2-photon backgrounds, the out-going beams could be assigned as the electron tracks from decay of Z boson.
  - The track angle is required to be cosθ<0.8 and cosθ>-0.8 for electron and positron, respectively.

cosθ of electron in the lab frame (signal)

(2-photon background)

# Reduction rate

- **After applying all the cuts,**
  **$\gamma\gamma \to$ ee events are rejected to 321.**
- **701 events are remained for signal(ZH $\to$ eeX).**

| | ZH $\to$ $\mu\mu$X | $\gamma\gamma \to \mu\mu$ | ZH $\to$ eeX | $\gamma\gamma \to$ ee |
|---|---|---|---|---|
| generated | 1754 | $6.50 \times 10^8$ | 1869 | $6.50 \times 10^8$ |
| pre-selection | | $1.1 \times 10^5$ | | $4.82 \times 10^6$ |
| selection($M_Z$, etc.) | 929.9 | 16.9 | 921 | 5688 |
| $N_{BeamCal}$ | | | 920 | 4839 |
| cos$\theta$ (rest frame) | | | 767 | 2391 |
| cos$\theta$ (lab frame) | | | 701 | 321 |

# *Summary*

- **The status of 2-photon background rejection using pre-selected data samples was shown.**

- **To reject them, the hits on BeamCal and two angle cuts, $\cos\theta_{\text{rest frame}}$ and $\cos\theta_{\text{lab frame}}$, were applied.**

- **The number of remained events for electron channel;**

  - Signal (ZH $\rightarrow$ eeX): 1869 $\rightarrow$ 701 events.

  - $\gamma\gamma \rightarrow$ ee: 6.5 x $10^8$ $\rightarrow$ 321 events.

- **Since the pre-selected samples had been downloaded on Saturday, these results might be improved.**

# Backup slides

# *Rejection study at generator level*

- **We checked the rejection of 2-photon bkg. at generator level.**

Remained events

| mode | $N_{before}$ | $N_{after}$ | Weight | $N_W$ remained |
|------|---------|--------|--------|-------------|
| aa_e2e2_1 | 1289369 | 4 | 29 | 116 |
| aa_e2e2_2 | 1294729 | 0 | 213 | 0 |
| aa_e2e2_3 | 1295007 | 0 | 213 | 0 |
| aa_e2e2_4 | 1296134 | 0 | 213 | 0 |
| aa_e1e1_1 | 1177169 | 181 | 29 | 5249 |
| aa_e1e1_2 | 1178103 | 171 | 213 | 36423 |
| aa_e1e1_3 | 1178130 | 195 | 213 | 41535 |
| aa_e1e1_4 | 1296285 | 16 | 213 | 1768 |

For electron channel, there are more than 4 electrons, generated pairs and out-going beams.
More rejection will be needed for electron channel.