

XCC (XFEL Compton Collider) Detector Backgrounds

Tim Barklow
XFEL $\gamma\gamma$ Collider Meeting
Jan 27, 2021

ILC beam beam background dominated by incoherent e^+e^- pairs

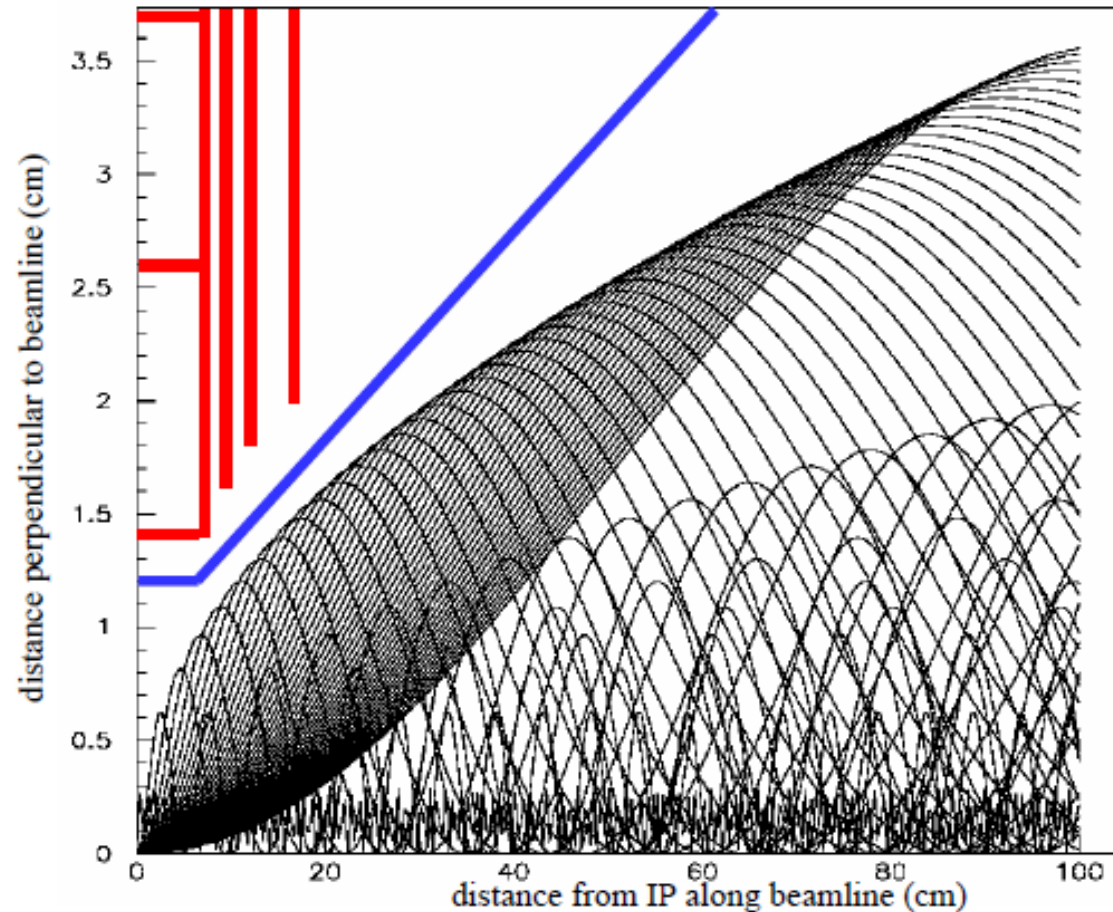
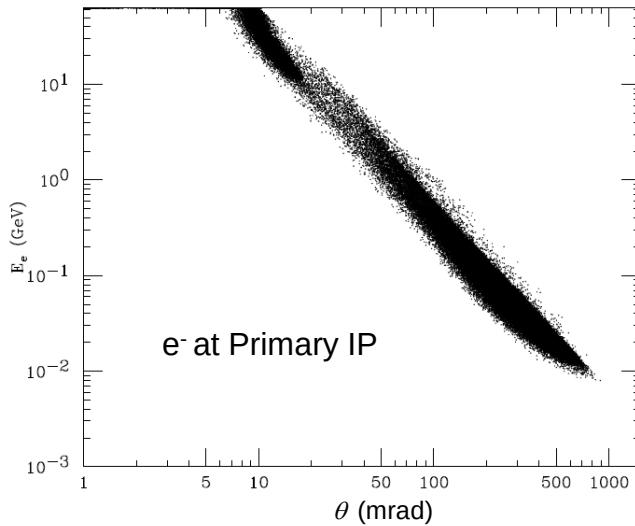
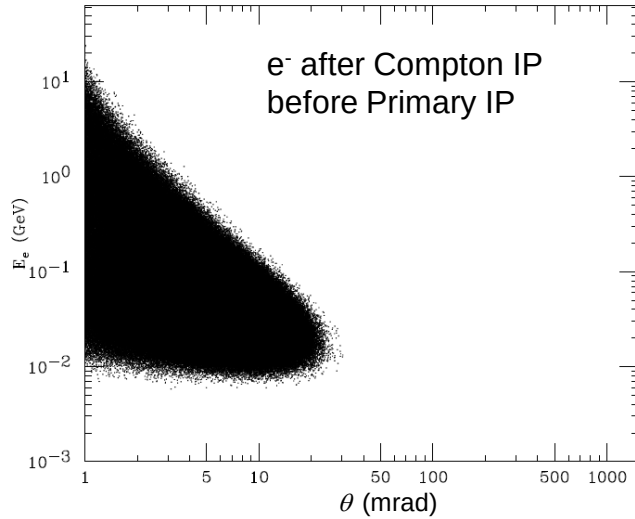


Figure 23 12mm beam pipe at the interaction point with VXD and maximum envelope of the e^+e^- pair backgrounds in a 5 Tesla field.

XCC background: 10 – 100 MeV e^- deflected by EM field of opposing beam

e^- Energy vs angle



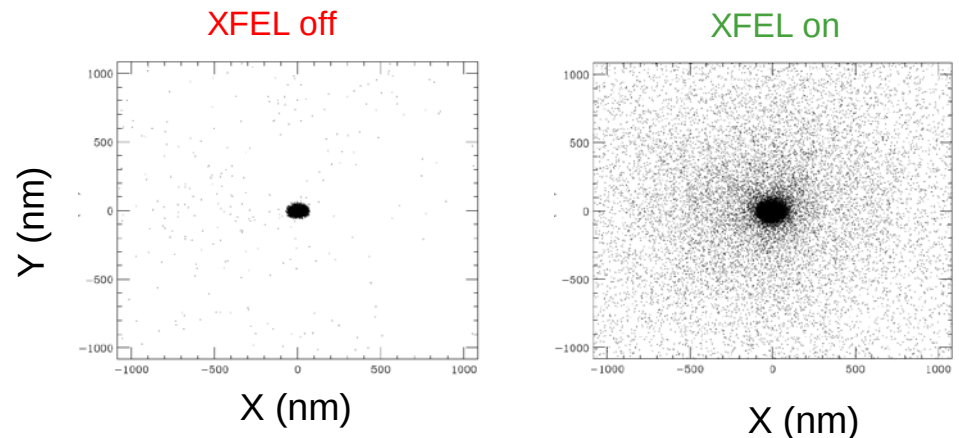
Counterintuitive: electrons are more (less) of a detector problem as we convert less (more) of the e^- at the Compton IP

Kick given to a particle in beam 1 from the EM field of beam 2:

$$\Delta\theta_1 \propto \frac{N_2}{\sigma_2^2} r_1$$

N_2 and σ_2 are beam 2 bunch population and transverse size, r_1 is the transverse distance between particle1 & bunch 2 center

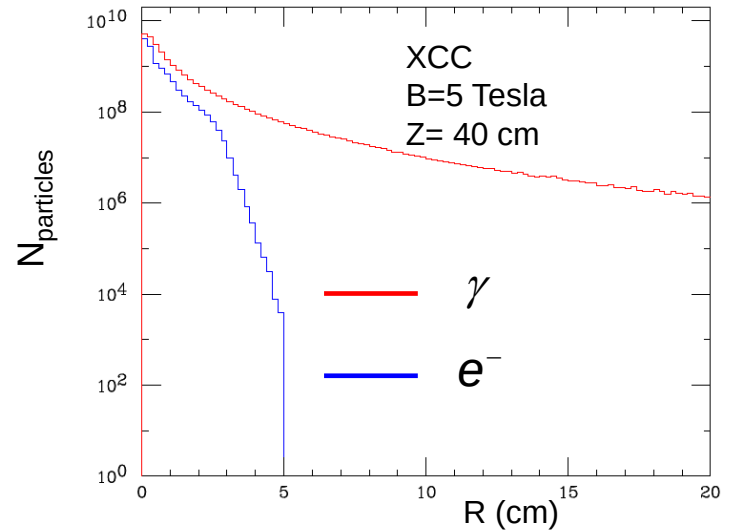
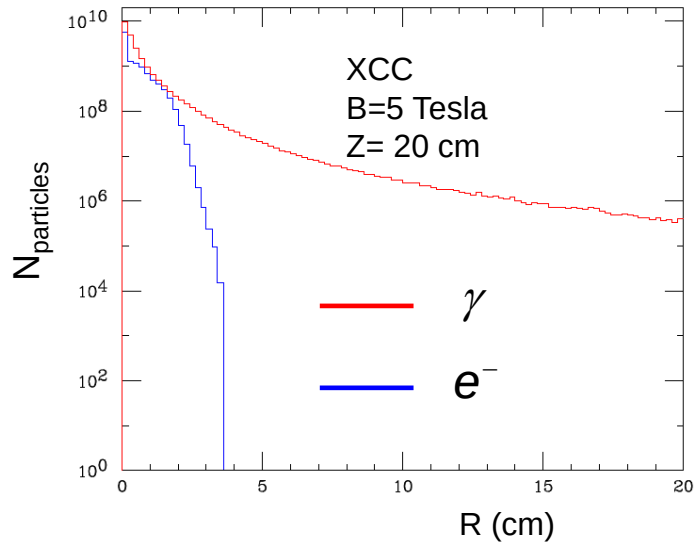
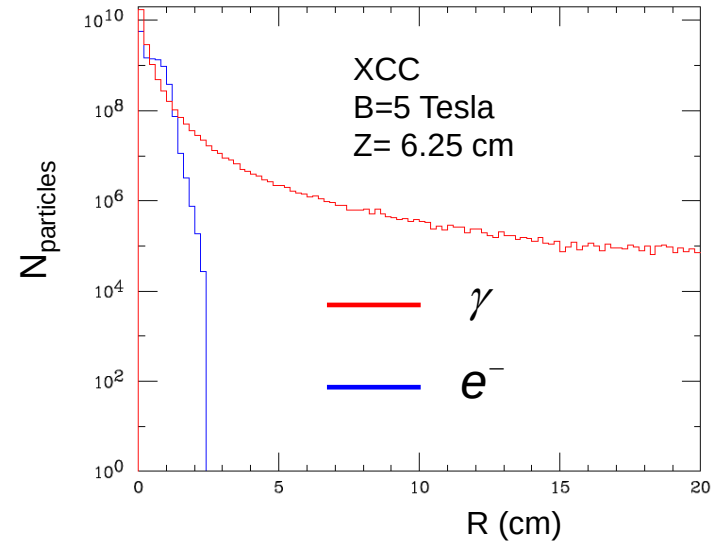
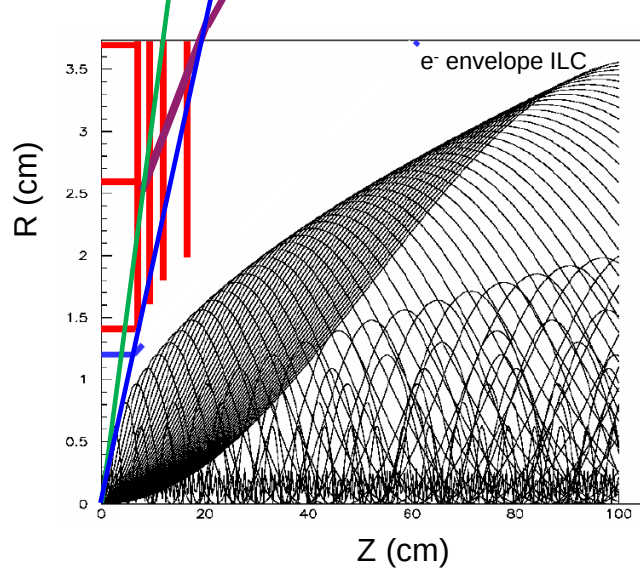
e^- Y vs X at primary IP



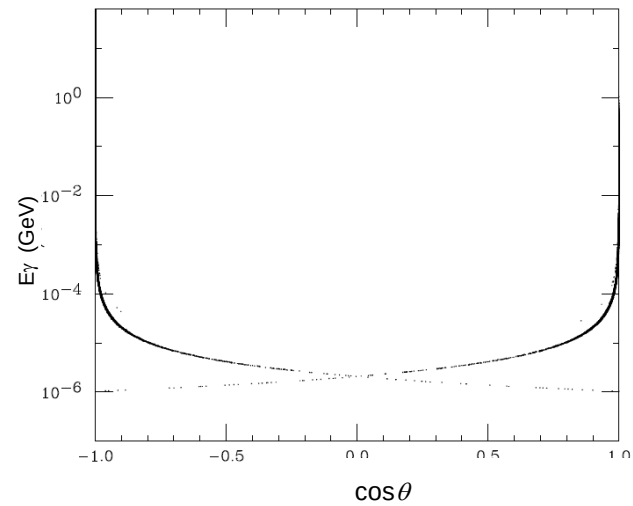
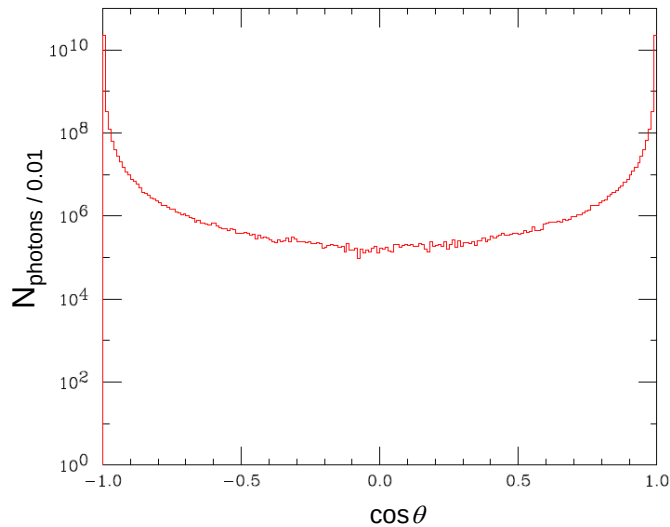
XCC background: 10 – 100 MeV e^- deflected by EM field of opposing beam

Barrel tracker XCC
Barrel tracker ILC
 e^- envelope XCC

SiD@ILC vs SiD@XCC



XCC detector background: 1 – 30 keV γ from Compton IP

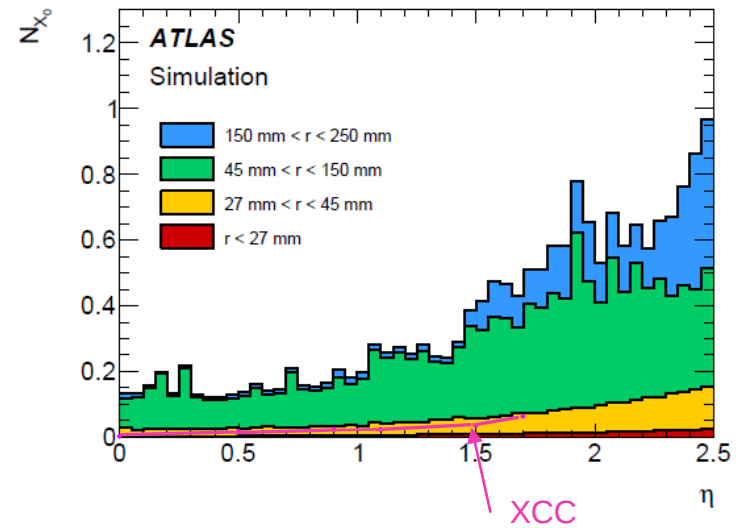
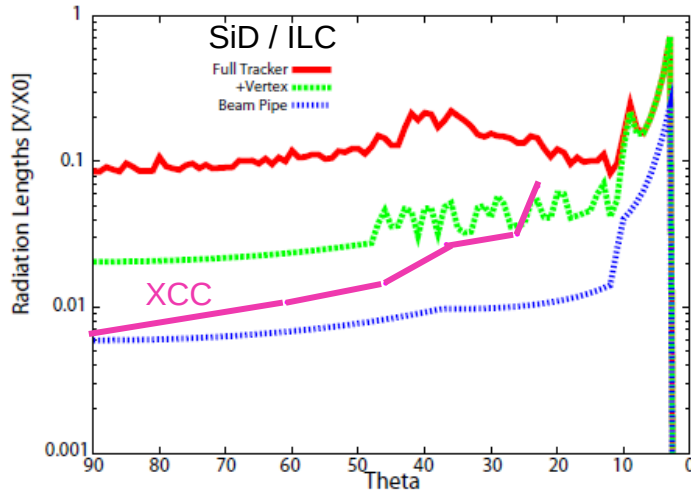


Calculate N_γ & N_{hits} at $R = 4$ cm,
assuming 400 μm thick Be beampipe at $R = 2.5$ cm
and 100 μm Si thick layer at $R = 4$ cm

$\cos\theta$	E_γ (keV)	N_γ (cm^{-2})	N_{hits} (cm^{-2})
0	2	1×10^3	1×10^3
0.5	4	2×10^5	2×10^5
0.7	7	8×10^5	7×10^5
0.8	11	2×10^6	1×10^6
0.9	21	9×10^6	8×10^5
0.93	30	2×10^7	6×10^5

ATLAS upgrade for HL-LHC assumes 60 hits/ cm^2
per event in 100 μm Si thick layer at $R = 4$ cm
so we make this our goal.

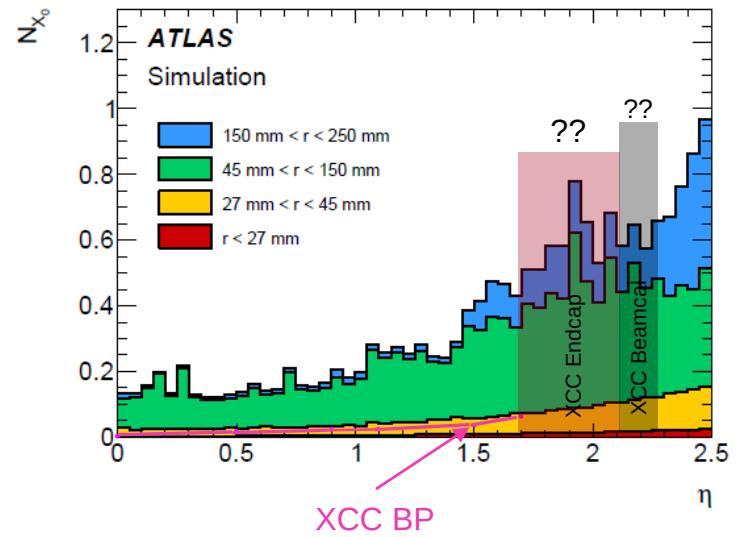
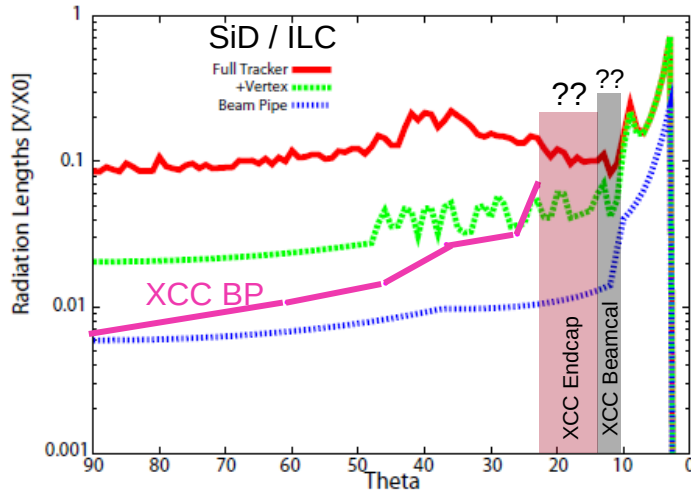
XCC detector beampipe X_0 vs ILC and LHC



$\cos \theta$	$\theta(^{\circ})$	η	XCC		SiD / ILC		ATLAS / LHC	
			$X_0(\text{Be+Pb})$ (%)	$X_0(\text{BP total})$ (%) *	$X_0(\text{Be } 400 \mu\text{m})$ (%)	$X_0(\text{BP total})$ (%)	$X_0(\text{BP total})$ (%)	$X_0(\text{BP+IBL})$ (%)
0	90	0	0.15	0.64	0.11	0.60	0.41	2.4
0.5	60	0.5	0.24	0.91	0.13	0.80	0.48	2.8
0.7	46	0.9	0.60	1.3	0.16	0.84	0.60	3.5
0.8	37	1.1	1.5	2.3	0.19	1.0	0.71	4.1
0.9	26	1.5	2.1	2.8	0.26	1.0	0.97	5.7
0.93	22	1.7	5.1	5.8	0.31	1.0	1.2	6.8

* $X_0(\text{BP total})_{\text{XCC}} = X_0(\text{Be+Pb}) + [X_0(\text{BP total})_{\text{SiD/ILC}} - X_0(\text{Be } 400 \mu\text{m})]$

XCC detector beampipe X_0 vs ILC and LHC



$\cos \theta$	$\theta(^{\circ})$	η	XCC		SiD / ILC		ATLAS / LHC	
			$X_0(\text{Be+Pb})$ (%)	$X_0(\text{BP total})$ (%) *	$X_0(\text{Be } 400 \mu\text{m})$ (%)	$X_0(\text{BP total})$ (%)	$X_0(\text{BP total})$ (%)	$X_0(\text{BP+IBL})$ (%)
0	90	0	0.15	0.64	0.11	0.60	0.41	2.4
0.5	60	0.5	0.24	0.91	0.13	0.80	0.48	2.8
0.7	46	0.9	0.60	1.3	0.16	0.84	0.60	3.5
0.8	37	1.1	1.5	2.3	0.19	1.0	0.71	4.1
0.9	26	1.5	2.1	2.8	0.26	1.0	0.97	5.7
0.93	22	1.7	5.1	5.8	0.31	1.0	1.2	6.8

* $X_0(\text{BP total})_{\text{XCC}} = X_0(\text{Be+Pb}) + [X_0(\text{BP total})_{\text{SiD/ILC}} - X_0(\text{Be } 400 \mu\text{m})]$

Detector for $\gamma\gamma \rightarrow H$ at $E_{\text{cm}}=125$ GeV - Summary

Have taken SiD detector and made minimal modifications necessary to adapt it to the XCC experimental environment

- Increase beampipe radius from $R=1.2$ cm to $R=2.5$ and reduce barrel tracker $|\cos\theta|_{\text{max}}$ from 0.98 to 0.93 to accommodate larger electron envelope.
- Coat beryllium beam pipe with z-dependent layer of lead to reduce tracker hit occupancy to level of ATLAS upgrade inner tracker at HL-LHC.
- Move BeamCal from $0.999 < |\cos\theta| < 0.999999$ to $0.97 < |\cos\theta| < 0.98$, where background energy flux is the same as that expected at the ILC.
- Endcap tracker and calorimeter are undefined at the moment.

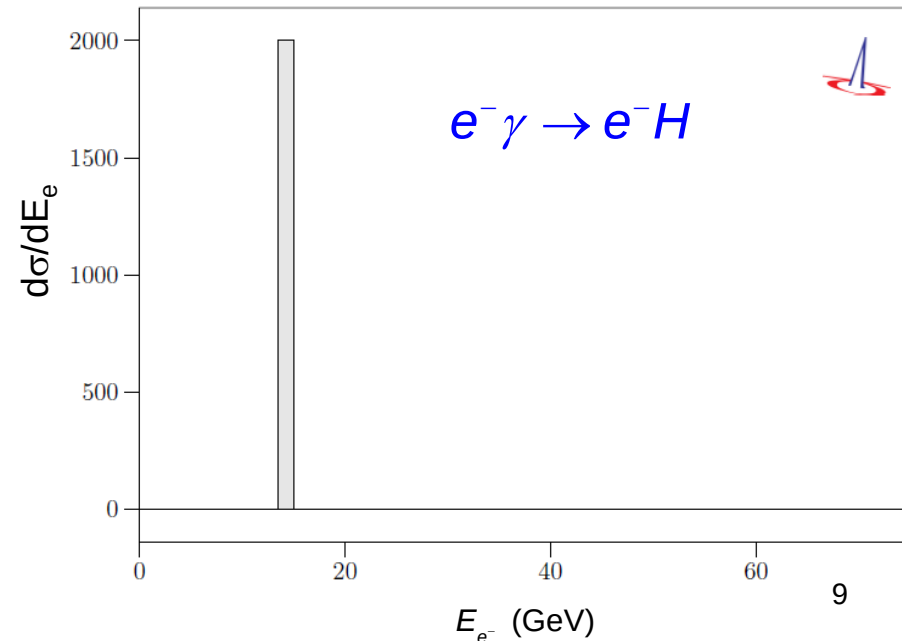
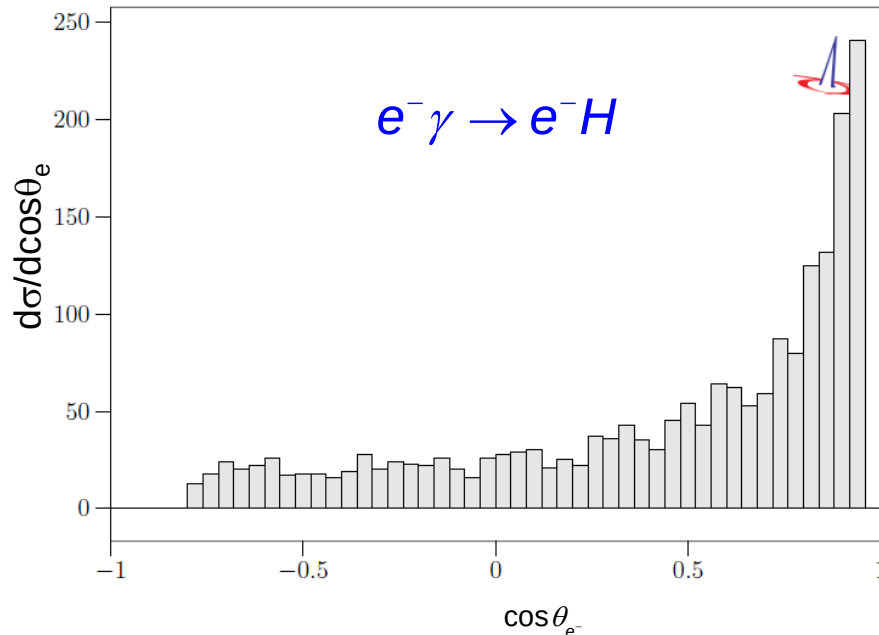
Detector background running $e^- \gamma \rightarrow e^- H$ at $E_{\text{cm}}=140$ GeV

So far, we have been talking about the backgrounds while running $\gamma\gamma \rightarrow H$ at

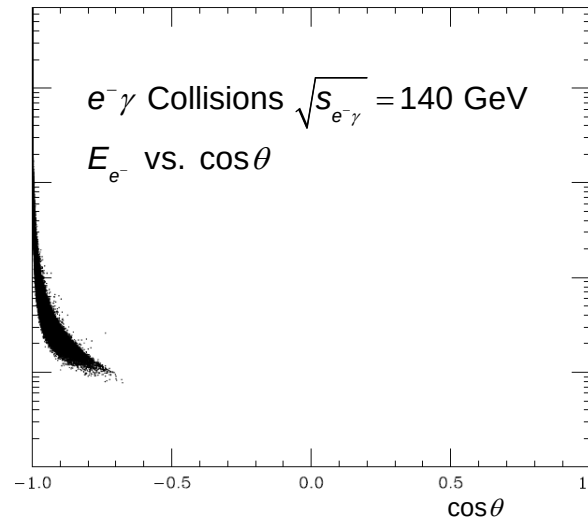
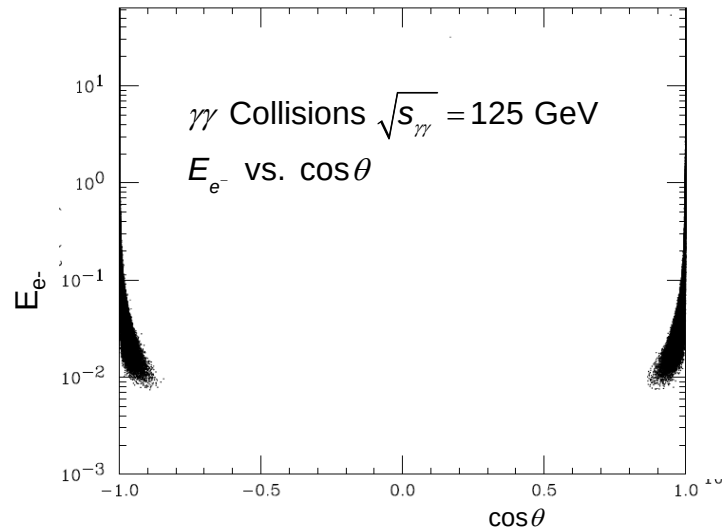
$\sqrt{s_{\gamma\gamma}}=125$ GeV. To convert the measured values of $\sigma \times BR(H \rightarrow xx) \propto \frac{\Gamma_{\gamma\gamma} \Gamma_{xx}}{\Gamma_{\text{tot}}}$

into Higgs couplings we need to measure $\sigma(e^- \gamma \rightarrow e^- H) \propto \Gamma_{\gamma\gamma}$ at $\sqrt{s_{e^- \gamma}}=140$ GeV.

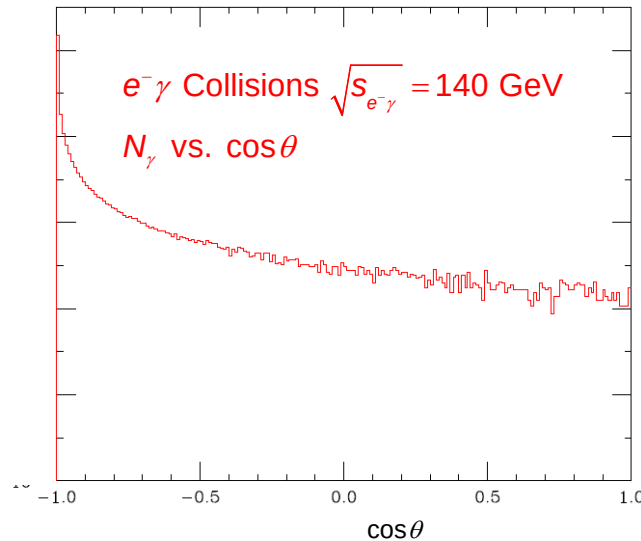
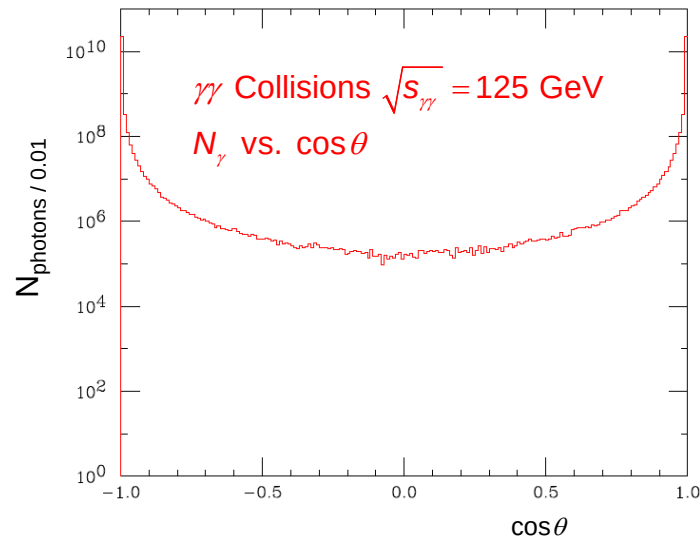
The signal is a monochromatic 14.1 GeV photon produced mostly in the forward direction. The main background is $e^- \gamma \rightarrow e^- e^+ e^-$ where, typically, two of the three final state $e^{\pm}$ are produced back-to-back with $|\cos\theta| > 0.99$.



Detector Background: $\gamma\gamma \rightarrow H$ at $E_{\text{cm}}=125$ GeV vs. $e^-\gamma \rightarrow e^-H$ at $E_{\text{cm}}=140$ GeV



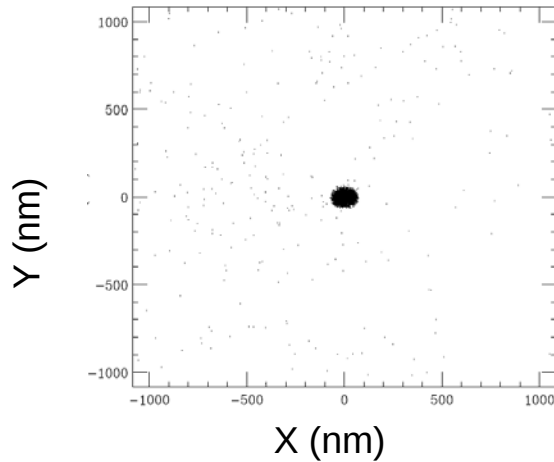
The 1 keV photons with $\cos\theta > 0$ will be absorbed by the 400 μm thick Be beampipe w/o any lead coating. Without any Compton electrons for $\cos\theta > 0$ the beampipe radius can be restored to 1.2 cm for $\cos\theta > 0$. In general the detector and backgrounds for $\cos\theta > 0$ will be ILC-like.



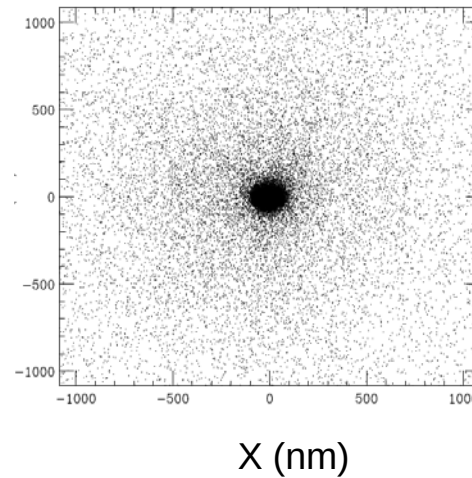
Detector Background: $e^- \gamma \rightarrow e^- H$ at $E_{cm}=140$ GeV

e^- Y vs X at primary IP

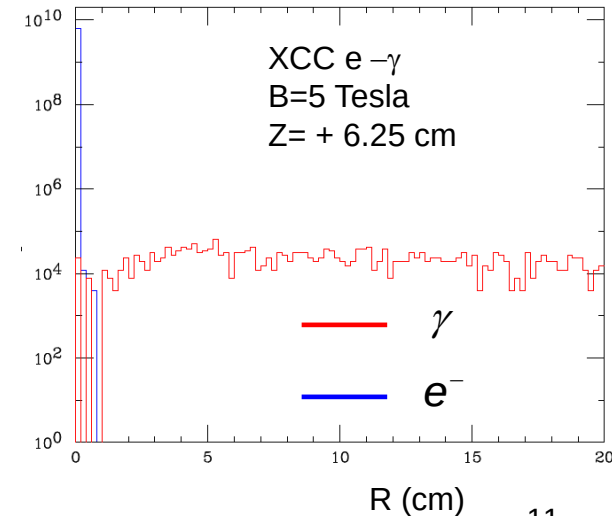
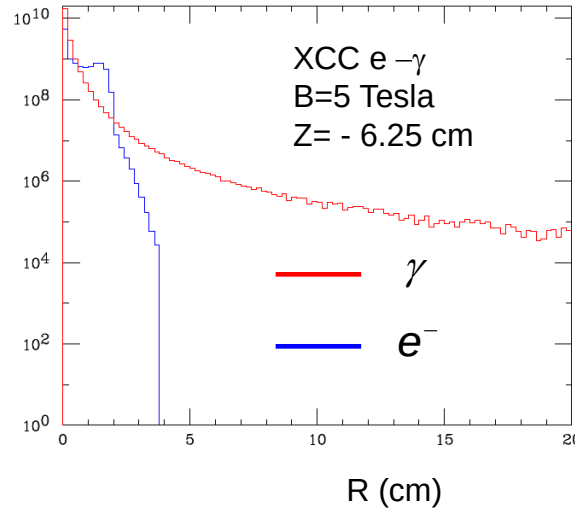
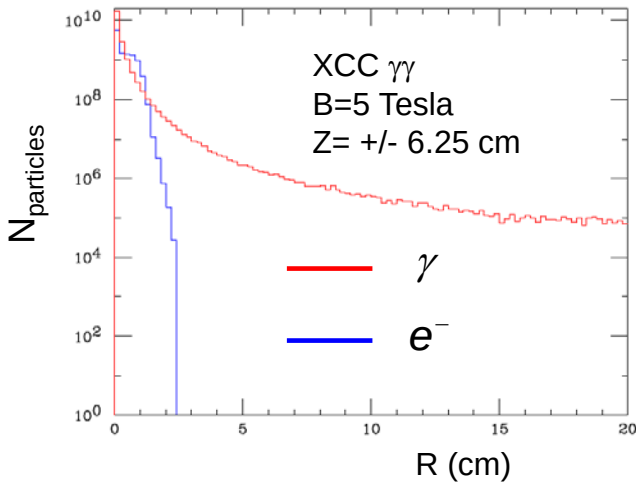
XFEL off



XFEL on



In the backward direction $\cos\theta < 0$ the electron background is worse for $e^- \gamma$ collisions due to the higher EM field of the opposing unscattered electron beam. The beampipe radius will have to be increased from 2.5 cm to 4 cm for $\cos\theta < 0$ and the solid angle coverage of the barrel tracker will be reduced from $|\cos\theta| < 0.93$ to $|\cos\theta| < 0.84$.



Detector for $e^- \gamma \rightarrow e^- H$ at $E_{\text{cm}}=140$ GeV - Summary

Happily, most of the detector differences going from $\gamma\gamma$ to $e^- \gamma$ collisions are favorable. The signal is in the forward direction, where the detector and the experimental environment are now completely ILC-like. The detector in the backward region is degraded a little bit w.r.t. what can be built for $\gamma\gamma$ collisions, but luckily this should have a small impact given the nature of the signal.

