Initial Studies on Input signals for FCCee Interaction Point Fast Feedback Systems

John Salvesen

CERN- Geneva, Switzerland, University of Oxford- Oxford, UK

Abstract

The Future Circular Lepton Collider (FCCee) is the leading proposal at CERN for future collider development. To ensure design luminosity is achieved, a collision feedback system should keep the beams in collision to within $\sim 0.05\sigma$. The proposed primary input signal to the collision feedback is from beam-beam deflection experienced by colliding bunches. Complementary signals, such as beamstrahlung radiation, may provide additional information. Expected beam-beam deflections, radiation emission and impact on luminosity are modelled using GUINEA-PIG++ over a range of input offsets to model the impact of vibration.

Introduction and Model

At FCCee, beams are brought into collision at 4 Interaction Points (IPs) with a large crossing angle of 15 mrad. Ground motion, magnet jitter and beam-beam effects cause bunch drift, and loss of luminosity. A feedback system is required to account for this, applying correction kicks based on signals from prior bunch(es) or non-colliding pilot bunches. Beam deflection signals are obtained by use of downstream Beam Position Monitors (BPMs) and photons collected with a photon monitor.

Beam-beam simulations were performed using GUINEA-PIG++ (*1*), the C++ version of GUINEA-PIG (*2*). It uses a strong-strong model of colliding beams and includes the emission of Beamstrahlung (BS), production of incoherent and coherent pairs, as well as hadronic backgrounds.

Offset limits are 5σ in the respective axis, except $t\bar{t}$ x offsets, which are 2.5σ due to rapid loss of luminosity. Gaussian bunches were used across all working points. Parameters as of 22/05/2023 are shown below, assuming layout PA31-3.0, with 4IPs.

Accelerator Parameters

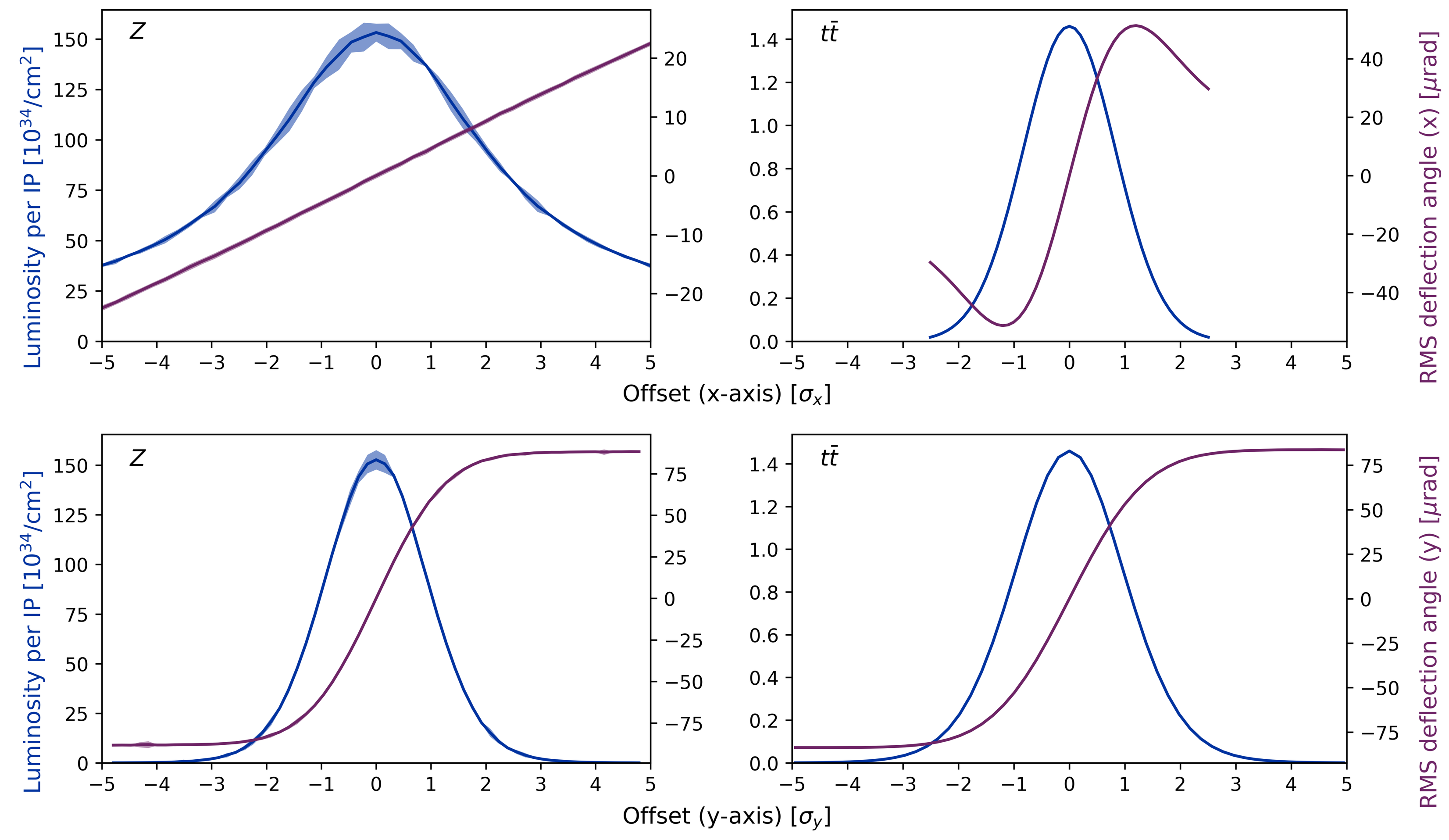
Working Point	E [GeV]	Particles [10^{11}]	β_x [m]	β_y [pm]	σ_x [nm]	σ_y [nm]	σ_z [mm]
Z	45.6	1.51	0.71	1.4	8840	31.3	12.7
WW	80	1.45	2.17	2.2	21850	46.9	5.41
ZH	120	1.15	0.71	1.4	13050	37.4	4.70
$t\bar{t}$	182.5	1.55	1.59	1.6	39870	50.6	2.17

Model Parameters

Working Point	cut_x	cut_y	cut_z	n_x	n_y	n_z	n_t	n_m
Z, WW, ZH	$150\sigma_x$	$60\sigma_y$	$3\sigma_z$	256	256	512	1	100,000
$t\bar{t}$	$12\sigma_x$	$10\sigma_y$	$3\sigma_z$	128	128	256	1	100,000

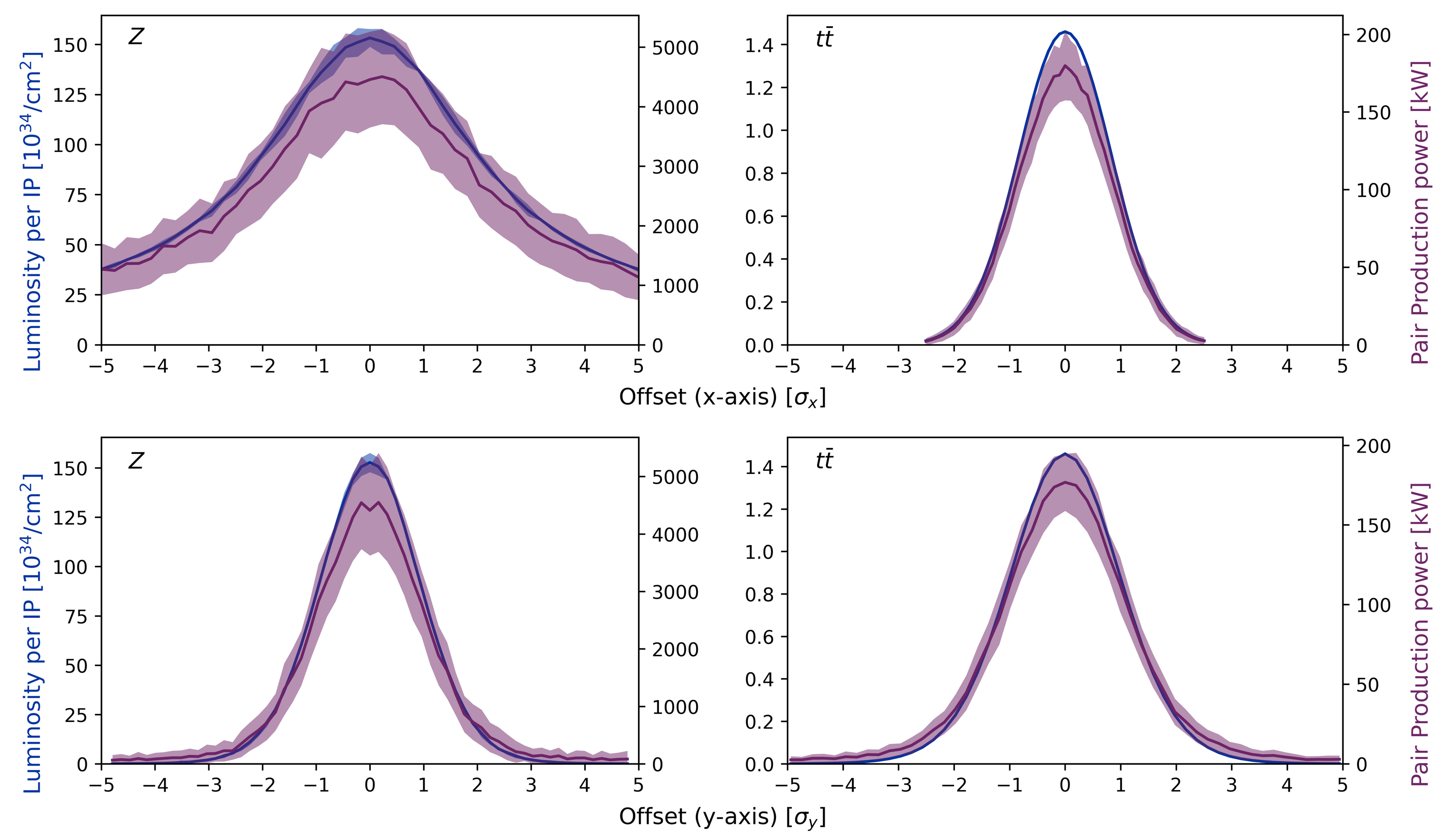
Primary Signal: Beam Deflection

The proposed primary IP feedback signal is position information from downstream BPMs. The beam position at this BPM is directly related to the deflection angle at the IP. The below results show the angular deflection at the IP for offsets in both x and y. In future, evolution of the beam will be tracked in the magnetic fields of the experiment, and surrounds machine optics.



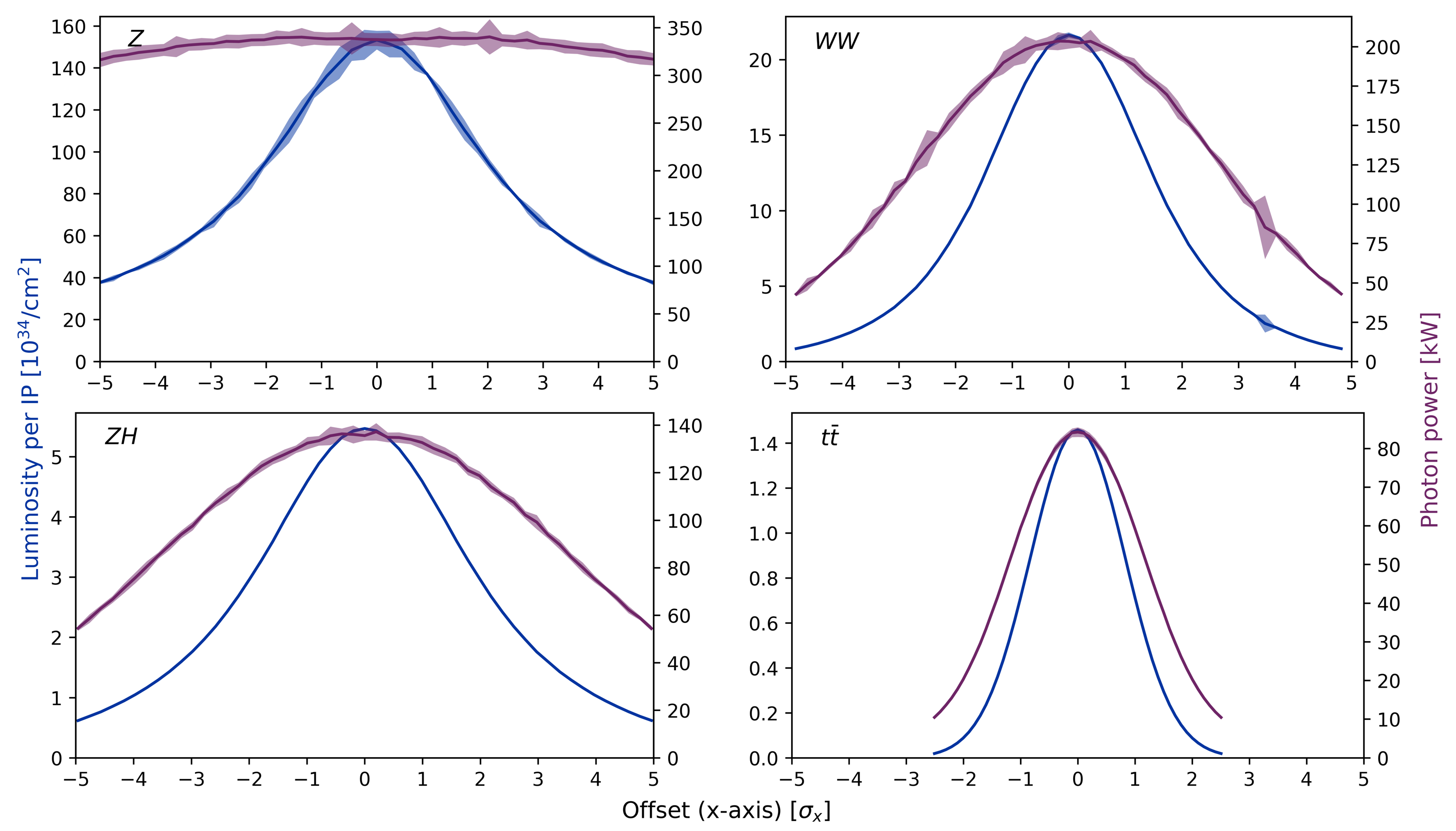
Secondary Signal: Pairs

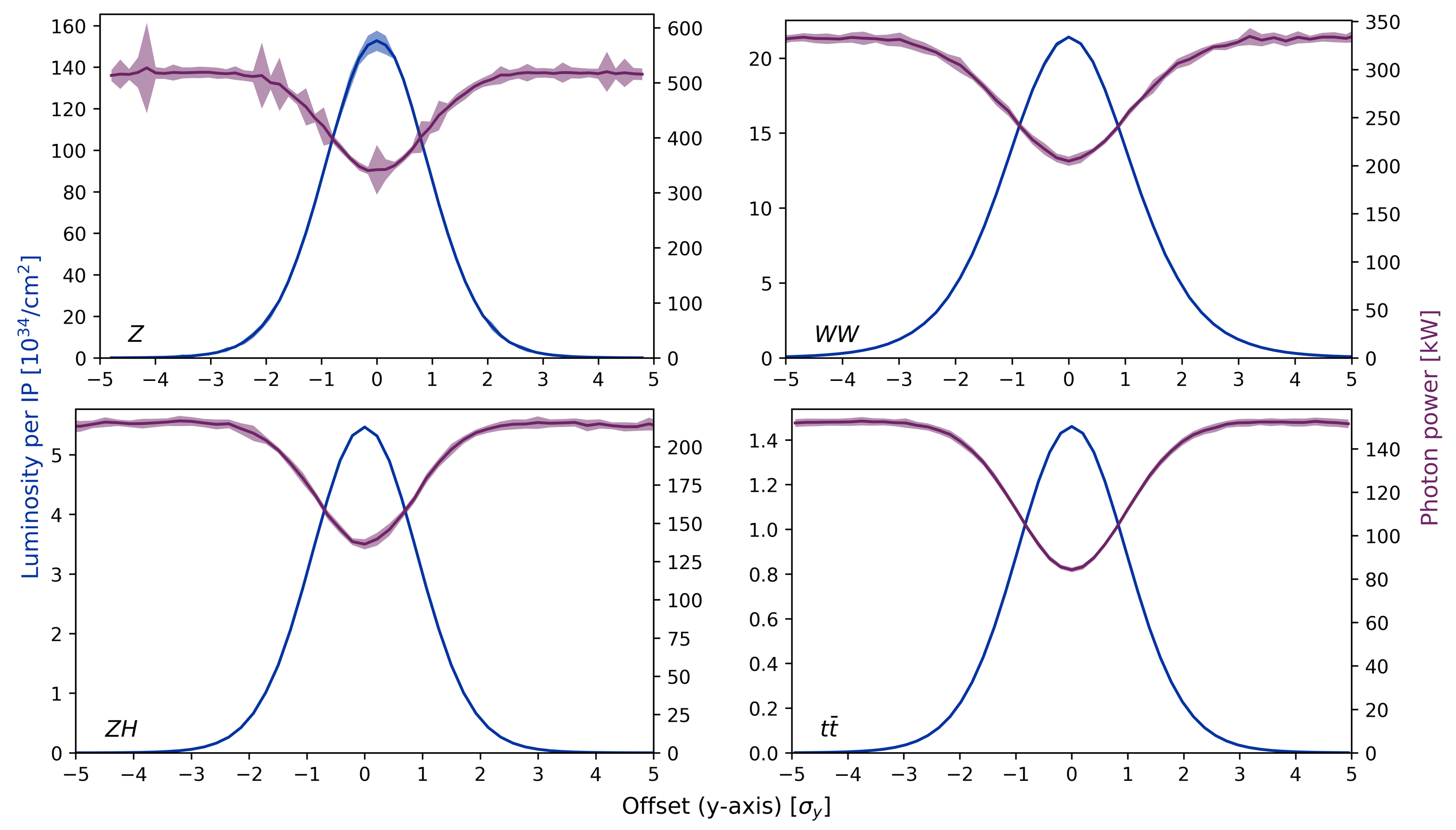
The background resulting from produced pairs also provides a potentially usable IP feedback signal. This represents a technical challenge to monitor. The power of pair particle radiation is shown for offsets in x and y respectively, following the change in luminosity directly.



Secondary Signal: BS Photons

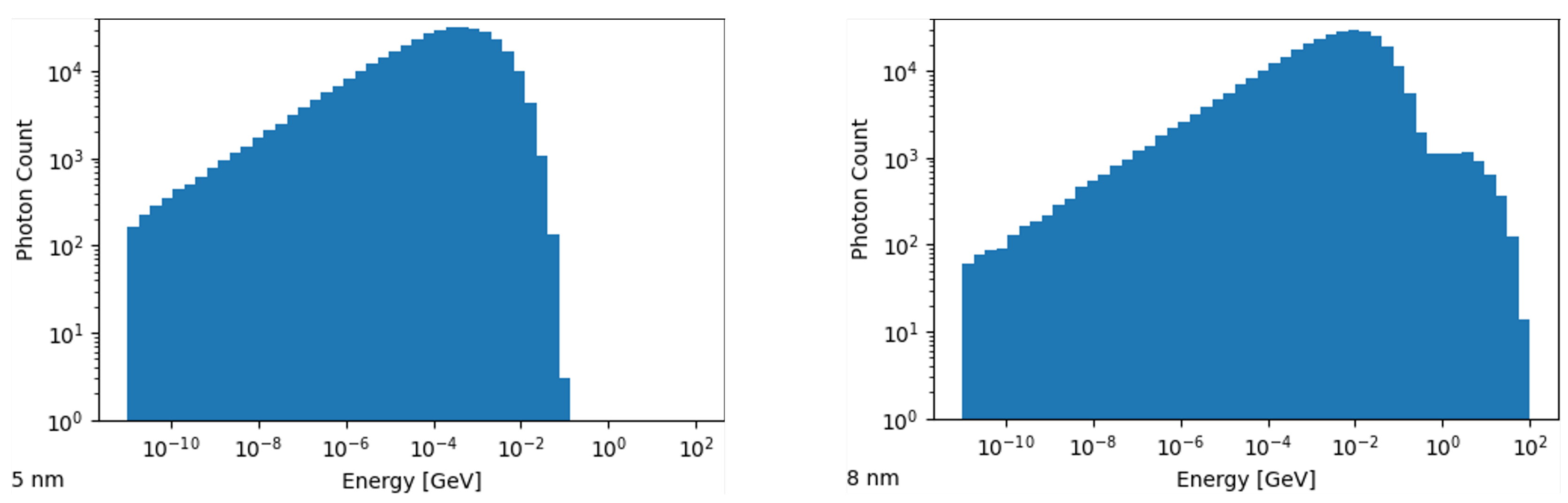
Beamstrahlung photons provide a complementary signal to the BPM signals. Monitoring BS photons represents a major technical challenge due to the high power output. While BS power is scalar, the beam deflection causes a change in photon emission angle that may also be detectable downstream. Beam offsets in y cause enhancement of the power output, greater than previously cited BS radiation power of order 400kW per IP at the Z working point (*3*).



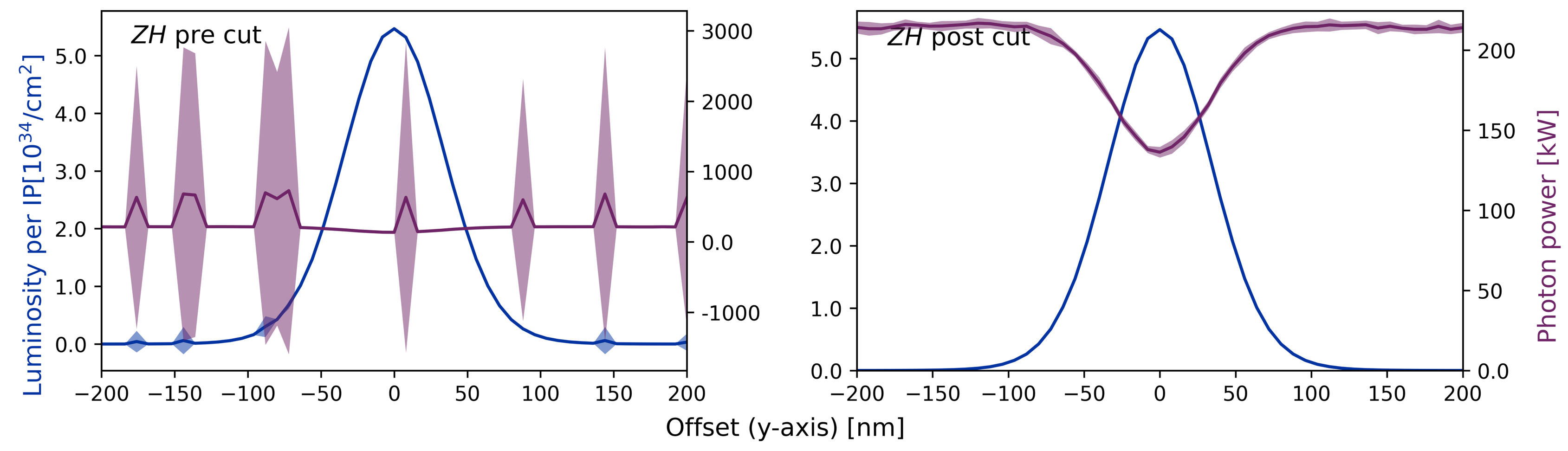


Unexplained Spectra and Selection Cuts

Photon energy distributions showed unexpected high energy tails in Z, WW and ZH. Example distributions for Z and $t\bar{t}$ are shown. Despite the tail having low population, the high energy obscured the expected trend. Analysis is ongoing, though it appears related to grid cut lengths.



To address trends due to BS radiation, results affected by the high energy tail are excluded. BS photon energy per repeat greater than 1.5 times median were cut. No cuts are made within a simulation run. Selection cuts removed a low proportion of runs (<2%).



Running mode	Z_x	ZH_y	WW_x	WW_y	ZH_x	ZH_y	$t\bar{t}_x$	$t\bar{t}_y$
Proportion of runs cut [%]	1.61	1.68	1.59	0.69	1.39	0.99	0.04	0
No. Repeats	100	100	20	20	20	20	100	100

References

1. G. Le Meur *et al.*, *EUROTeV Reports* (2009).
2. D. Schulte, PhD thesis, Hamburg U., 1997.
3. M. Boscolo *et al.*, "Challenges for the interaction region design of the Future Circular Collider FCC-ee", tech. rep.

FCCIS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the European Union's Horizon 2020 research and innovation programme under grant agreement No 951754.

Acknowledgements

I would like to acknowledge the support of the following: Frank Zimmermann, Phil Burrows, Andrea Ciarma, Andrea Latina, and Katsunobu Oide.