Simulation of Beam-induced Backgrounds for the Cool Copper Collider

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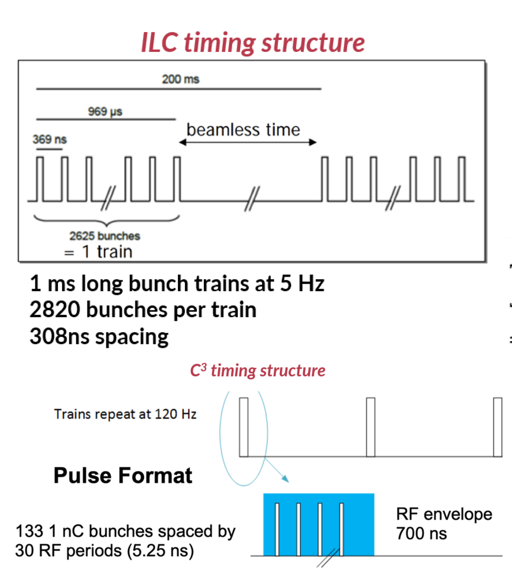
The Cool Copper Collider (C^3)

- C^3 is a newly proposed e^+e^- Linear Higgs Factory
  - 250 GeV collision energy, upgradable to 550 GeV, with possible extensions to the TeV-scale.
- Key differences in the C^3 design w/ respect to ILC:
  - Accelerating Technology: Higher gradients - more compact design.
  - Bunch Structure: bunches spaced two orders of magnitude closer together with ~ 3 times smaller particle density.
  - Train Structure: higher train repetition frequency with an order of magnitude fewer bunches per train.

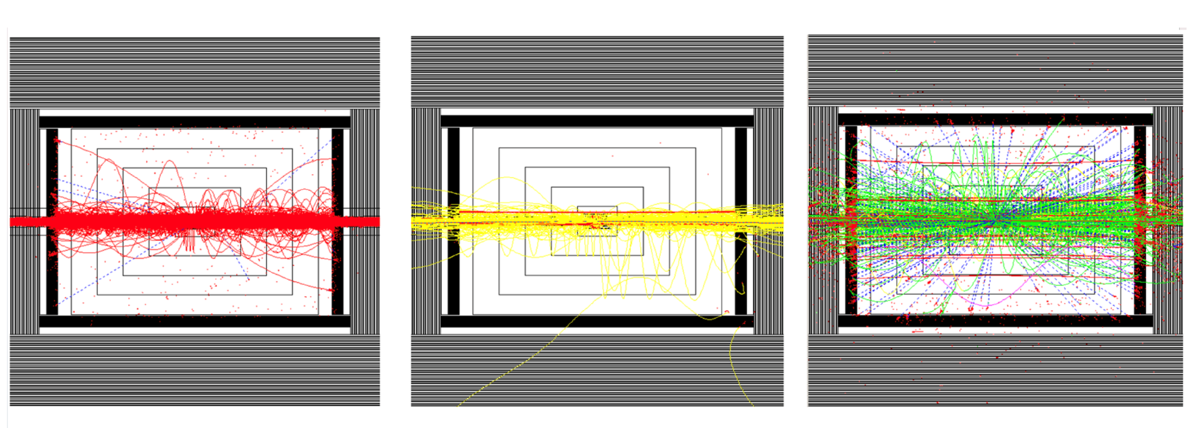
	C^3		ILC	
Parameter [Unit]	Value	Value	Value	Value
CM Energy [GeV]	250	550	250	500
Luminosity [$\cdot 10^{34}/\mathrm{cm}^2 s$]	1.3	2.4	1.35	1.8/3.6
Gradient [MeV/m]	70	120	31.5	31.5
Geometric Gradient [MeV/m]	63	108	20.5	31
Length [km]	8	8	20.5	31
Num. Bunches per Train	133	75	1312	2625
Train Rep. Rate [Hz]	120	120	5	5
Bunch Spacing [ns]	5.26	3.5	554	554/366
Bunch Charge [nC]	1	1	3.2	3.2
Crossing Angle[rad]	0.014	0.014	0.014	0.014
Site Power[MW]	~ 150	~ 175	111	173/215

Table 1: Beam parameters for C^3 and ILC . The final focus parameters for C^3 are preliminary[1].



Beam & Machine Backgrounds

- Various backgrounds that originate in the BDS or the IR of C^3 can deteriorate detector performance:
  - Beam-induced Backgrounds: secondary e^+e^- pair background and $\gamma\gamma \to$ hadrons from beam-beam interactions in the IR.
  - Machine-induced Backgrounds: halo muon production from beam-collimator interactions in the BDS, neutron production in the beam dumps.



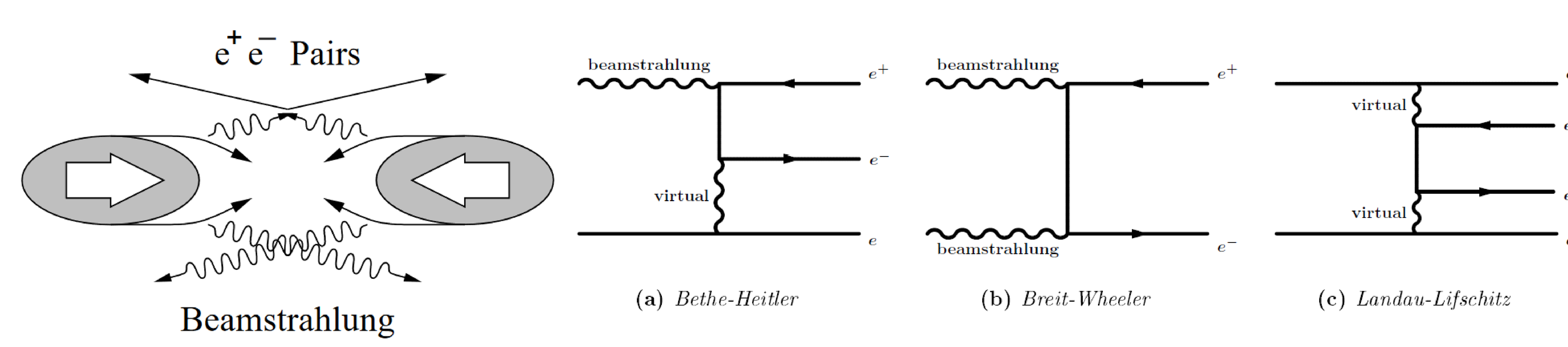
Want to Learn More?

Join in Building the Future of C^3

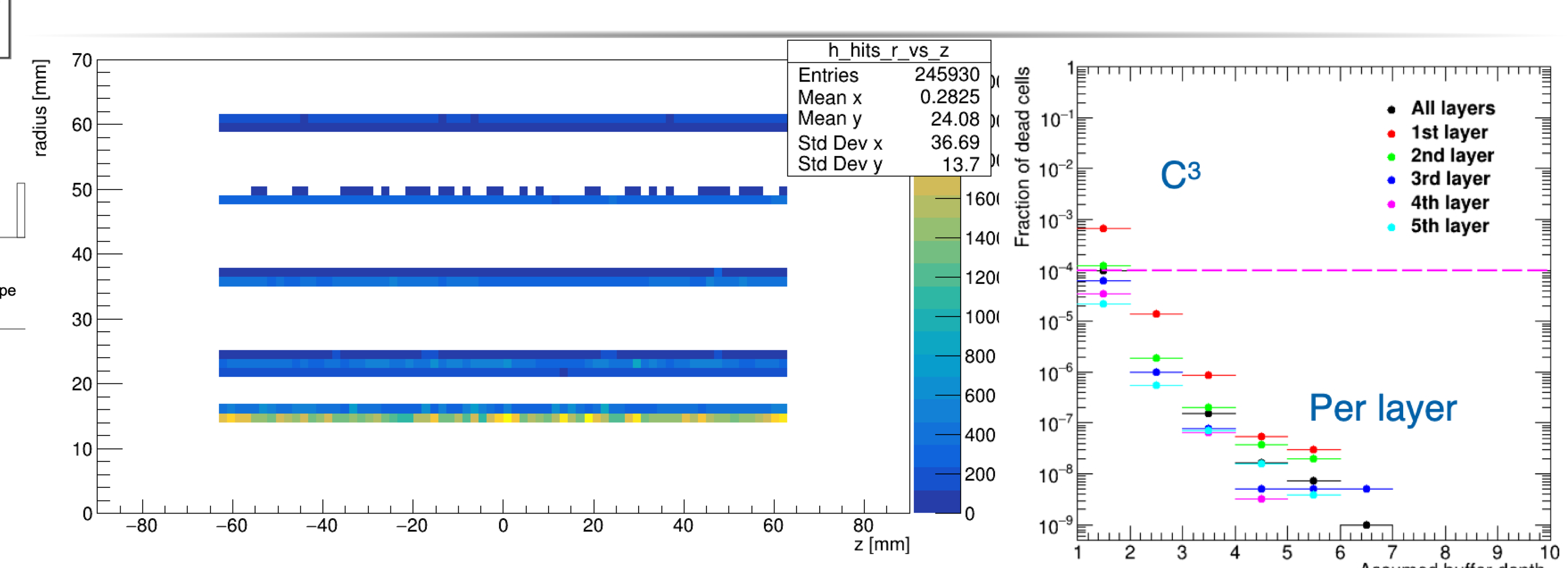
- C^3 Proposal Paper: arXiv:2203.07646v2
- C^3 R&D Plan: arXiv:2203.09076v2
- Ask to join the Mailing List! c3-developments@slac.stanford.edu

e^+e^- Pair Background

- Beamstrahlung photons produce incoherent e^+e^- pairs, boosted in the forward direction
  - Around 10^5 pairs / bunch crossing expected with C^3
  - Most are deflected, but a small fraction reach detector
- Simulation of background using GUINEA-PIG [4]
  - Interaction of produced particles w/ the detector is carried out in Geant4 through DD4hep, assuming an SiD-like detector.



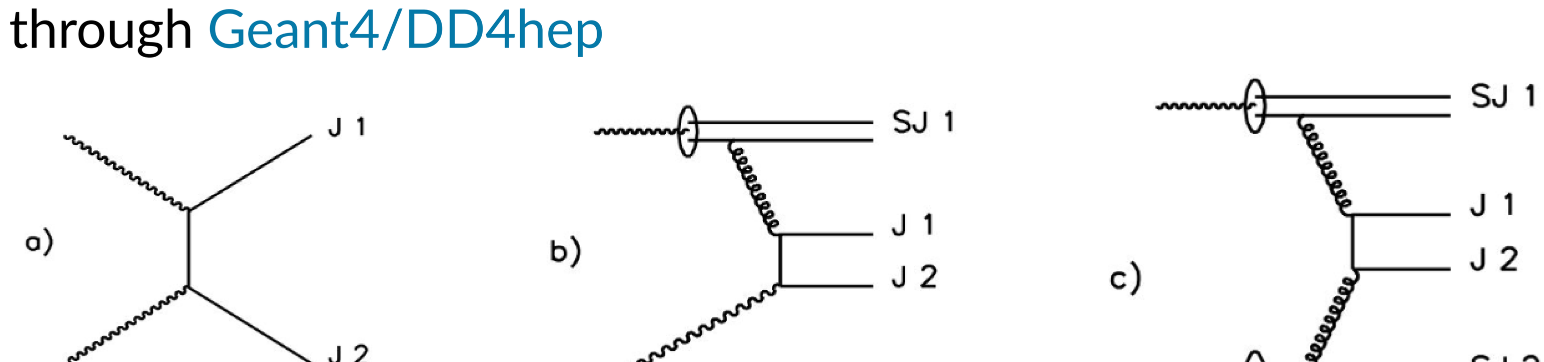
Pair Background Simulation



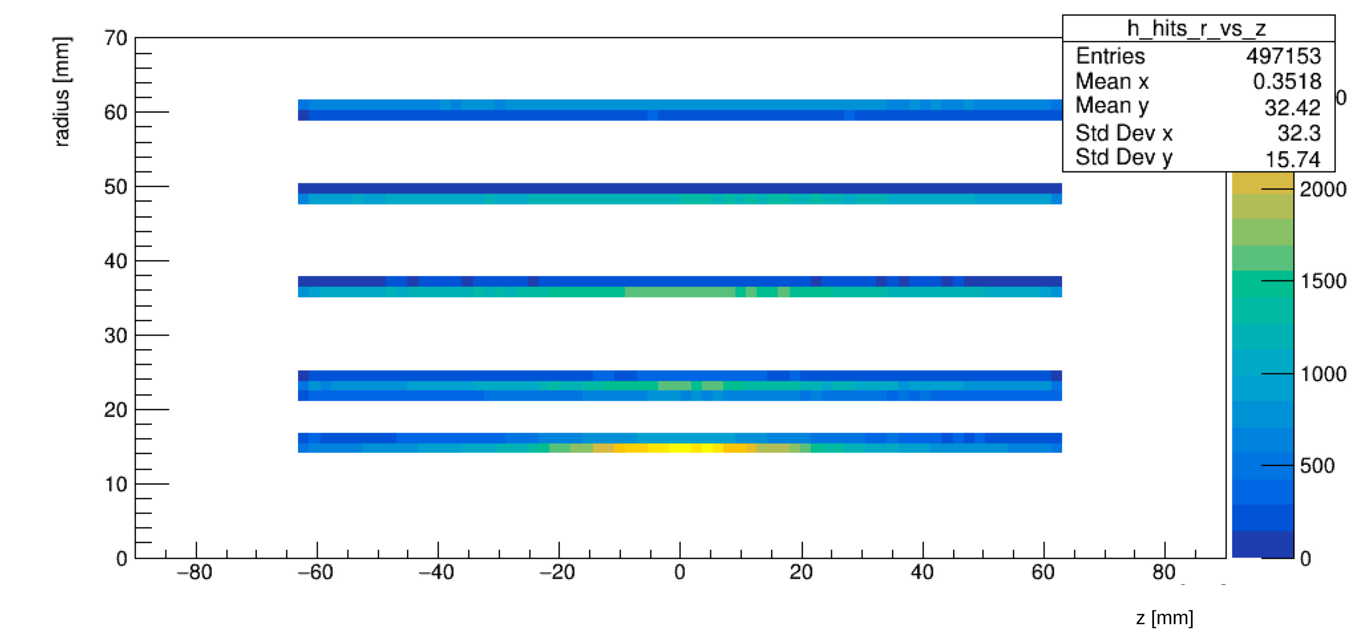
Left: 2D spatial distribution of pair background hits within the first five C^3 vertex detector layers. Right: The occupancy in the C^3 vertex detector, defined as the fraction of cells with hits equal to or larger than the assumed buffer depth, as a function of buffer depth.

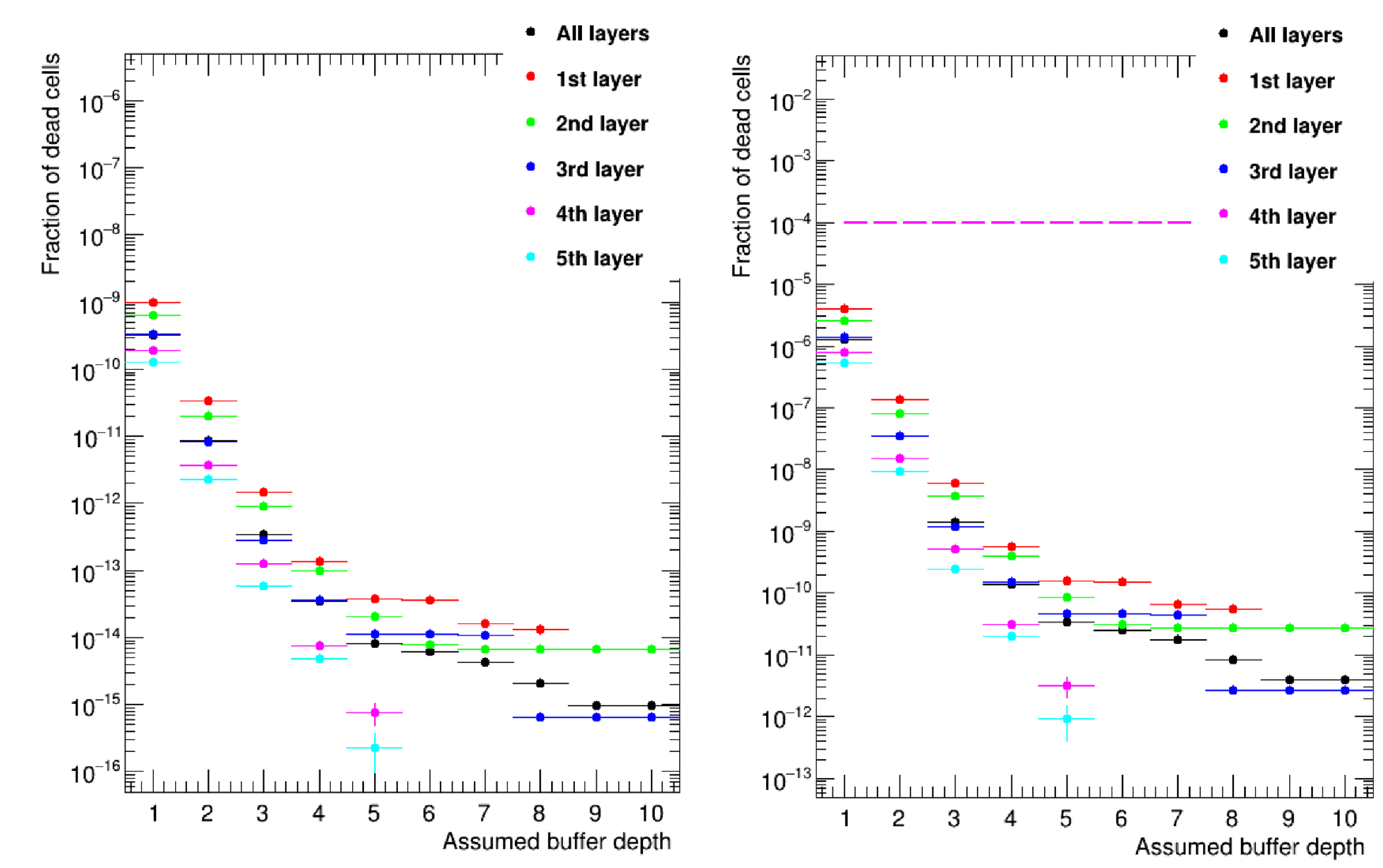
Hadron Photoproduction Background

- Beamstrahlung photons can also produce a hadronic background
  - rate $\sim 10^5$ smaller than the e^+e^- pair background
  - More central than incoherent pairs, may still impact reconstruction
- PYTHIA was used for the simulation of the $\gamma\gamma \to$ hadrons processes above $\sqrt{s_{\gamma\gamma}} > 10$ GeV.
  - a dedicated generator [2] will be used for lower energies, to account for cross-section mismodelling effects
  - The produced hadrons were then interfaced with the detector through Geant4/DD4hep



Hadron Background Simulation





Top: 2D spatial distribution of hadron background hits within the first five C^3 vertex detector layers. Bottom Left: Occupancy in the vertex detector as a function of buffer depth for the hadron photoproduction background. Only the generated events with $\sqrt{s_{\gamma\gamma}} > 10$ GeV were used. Bottom Right: Rescaled occupancy to include the total $\sqrt{s_{\gamma\gamma}}$. This, combined with the pair production occupancy, closely matches up with ILC estimations [3].

Key Takeaways

- C^3 is a compact, upgradable, and sustainable Higgs Factory.
- Although we must account for the e^+e^- pairs and hadron photoproduction backgrounds, they are very manageable.
- The ILC is a valid reference for C^3 studies, with C$^3 \sim$ ILC$/10$.
- There is plenty more to do:
  - generate the full suite of hadron photoproduction background by including processes < 10 GeV
  - expand data production and investigate more backgrounds.

References

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