Simulation of Beam-induced Backgrounds for the Cool Copper Collider

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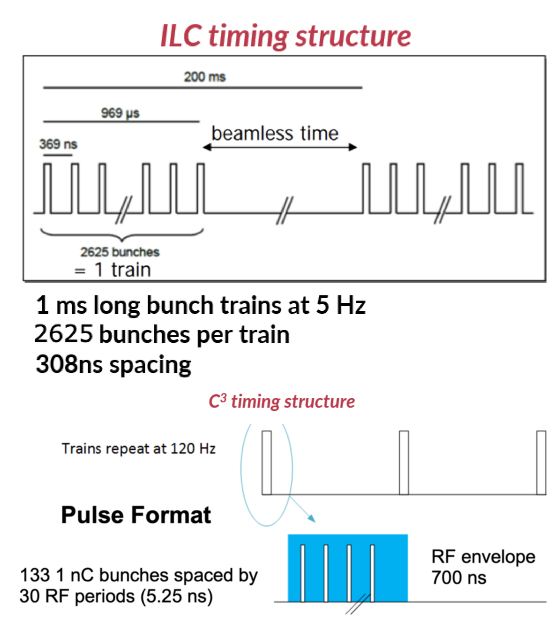
The Cool Copper Collider (C³)

- C³ is a newly proposed e^+e^- Linear Higgs Factory
  - E_{CM} 250 GeV $\rightarrow$ 550 GeV $\rightarrow$ TeV-Scale
- Key differences in the C³ design w/ respect to ILC:
  - Accelerating Technology: Higher gradients - more compact design.
  - Bunch Structure: 2 orders closer + ~ 3 times smaller particle density.
  - Train Structure: higher train rep. freq., one order fewer bunches/train.

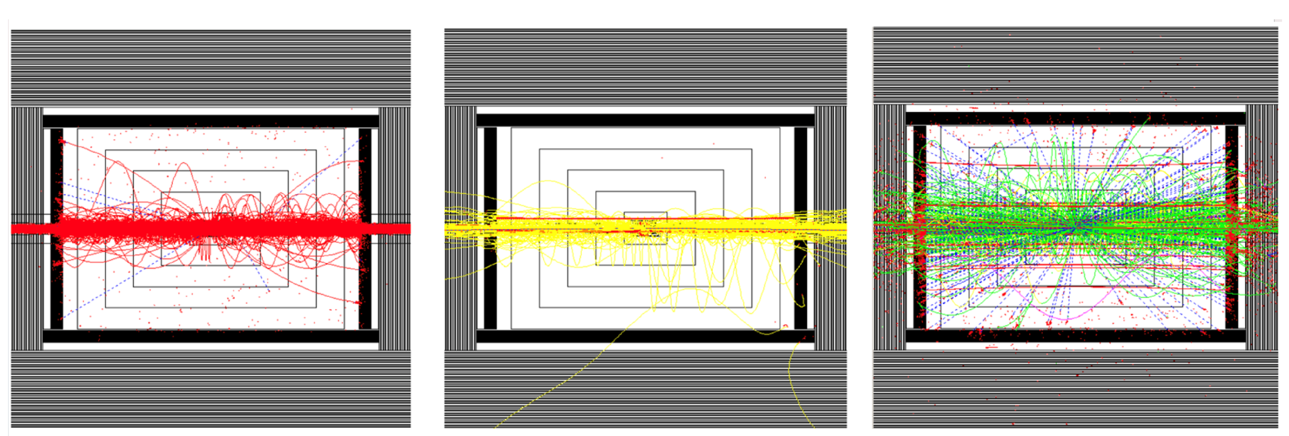
	C^3		ILC	
Parameter [Unit]	Value	Value	Value	Value
CM Energy [GeV]	250	550	250	500
Luminosity [$\cdot 10^{34}/\mathrm{cm}^2 s$]	1.3	2.4	1.35	1.8/3.6
Gradient [MeV/m]	70	120	31.5	31.5
Geometric Gradient [MeV/m]	63	108	20.5	31
Length [km]	8	8	20.5	31
Num. Bunches per Train	133	75	1312	2625
Train Rep. Rate [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]	$\sim$ 150	$\sim$ 175	111	173/215

Table 1: Beam parameters for C³ and ILC . The final focus parameters for C³ are preliminary[1].



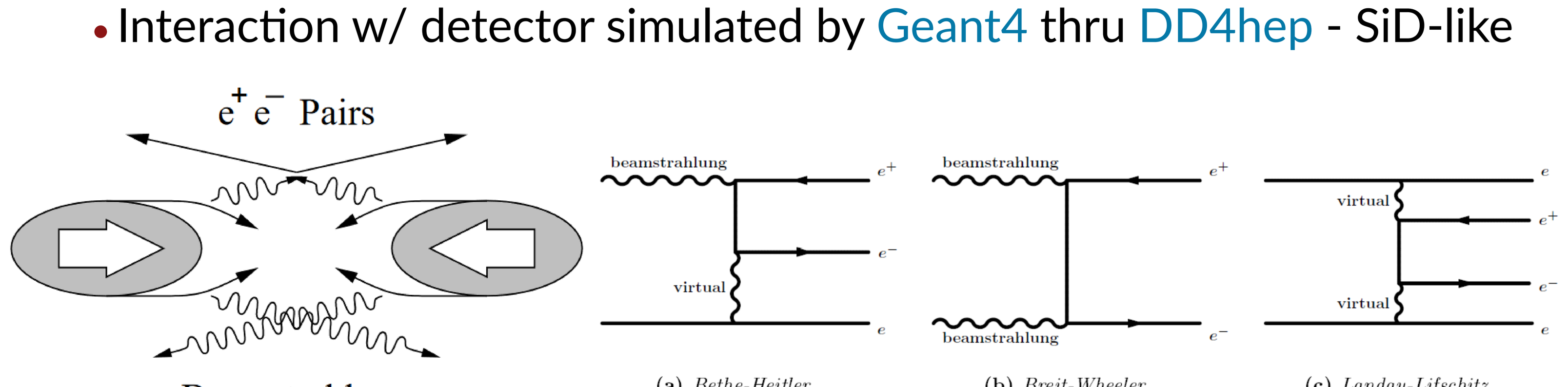
Beam & Machine Backgrounds

- Various backgrounds originate in the BDS or the IR of C³
- Can deteriorate detector performance:
  - Beam-induced Backgrounds: secondary e^+e^- pairs, $\gamma\gamma \rightarrow$ hadrons
  - Machine-induced Backgrounds: halo muon, neutron production

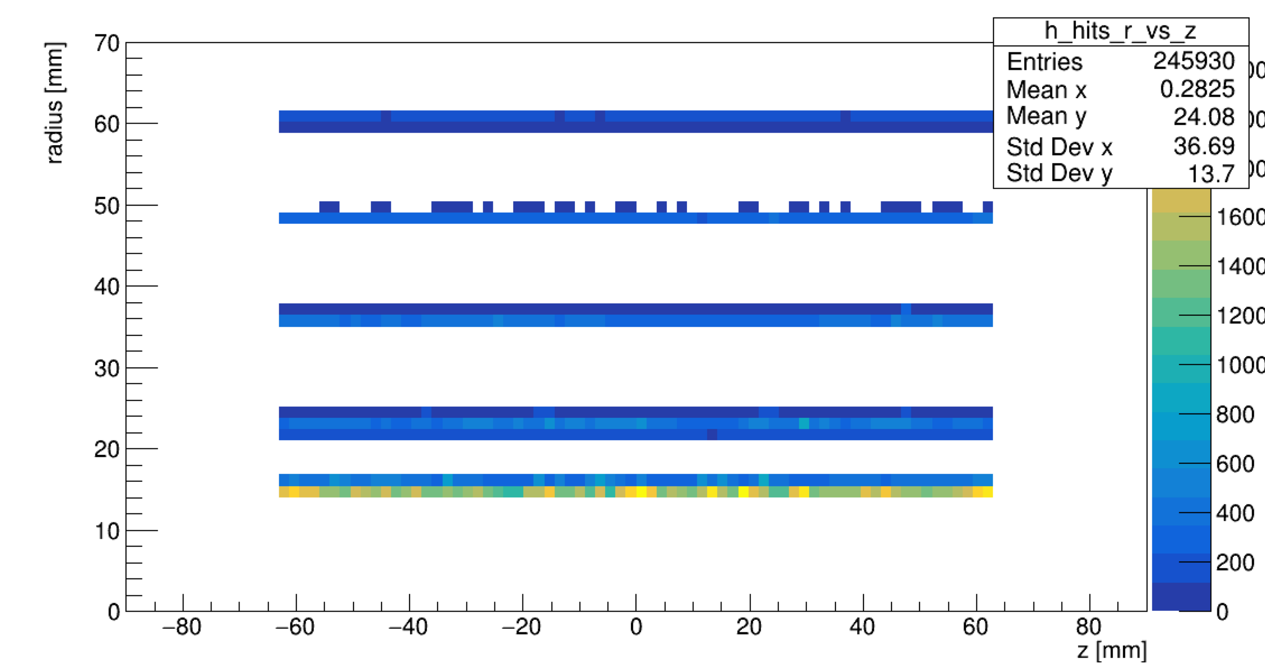


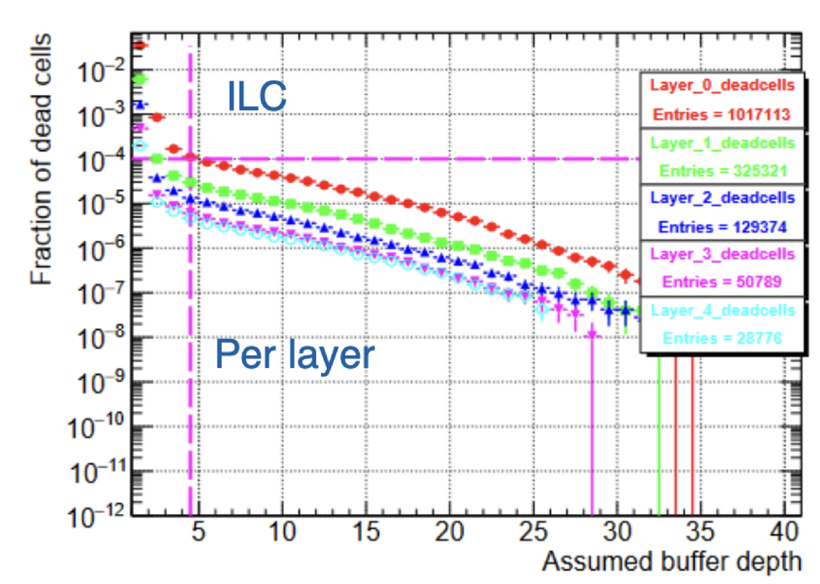
e^+e^- Pair Background

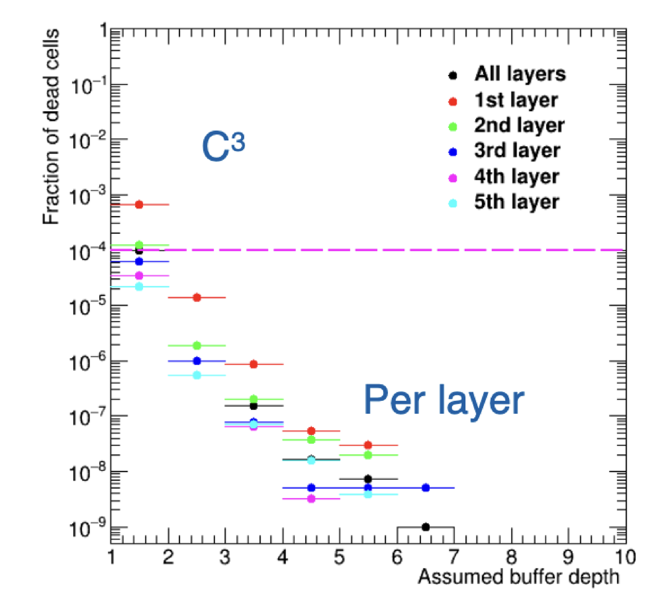
- Beamstrahlung photons produce incoherent e^+e^- pairs, forward-boosted
  - Around 10^5 pairs / bunch crossing expected with C³
  - Most are deflected, but a small fraction reach detector
- Simulation of background using GUINEA-PIG [4]
  - Interaction w/ detector simulated by Geant4 thru DD4hep - SiD-like



Pair Background Simulation



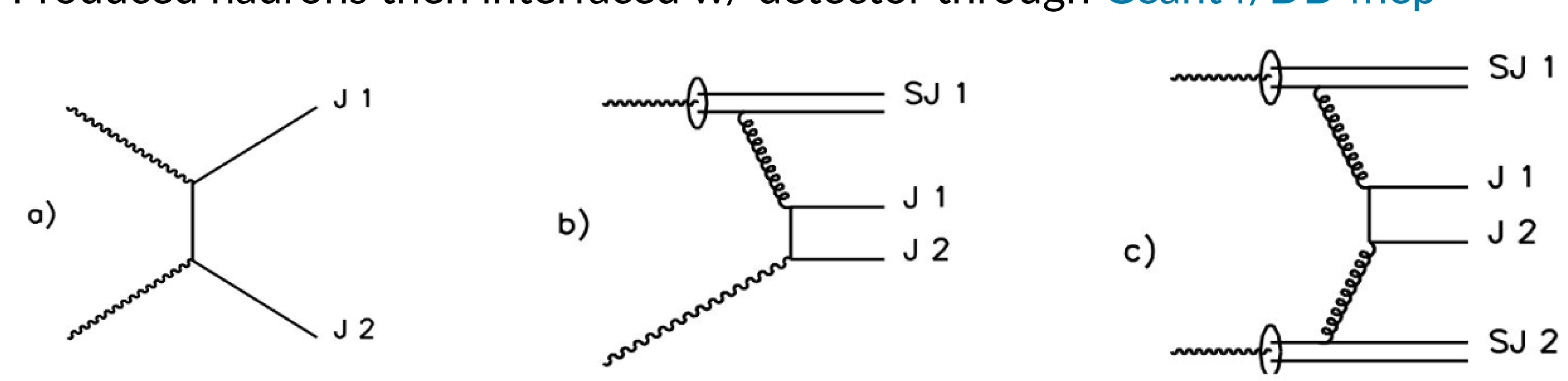




Top: 2D spatial distribution of pair background hits within first five C³ vertex detector layers. Bottom Left: The occupancy of all backgrounds in the ILC vertex detector [3] defined as the fraction of cells with hits equal to or larger than the assumed buffer depth, as a function of buffer depth. Bottom Right: Similar occupancy for C³ pair background.

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 used for simulation of processes above $\sqrt{s_{\gamma\gamma}} > 10$ GeV
  - a dedicated generator [2] will be used for lower energies
  - Produced hadrons then interfaced w/ detector through Geant4/DD4hep

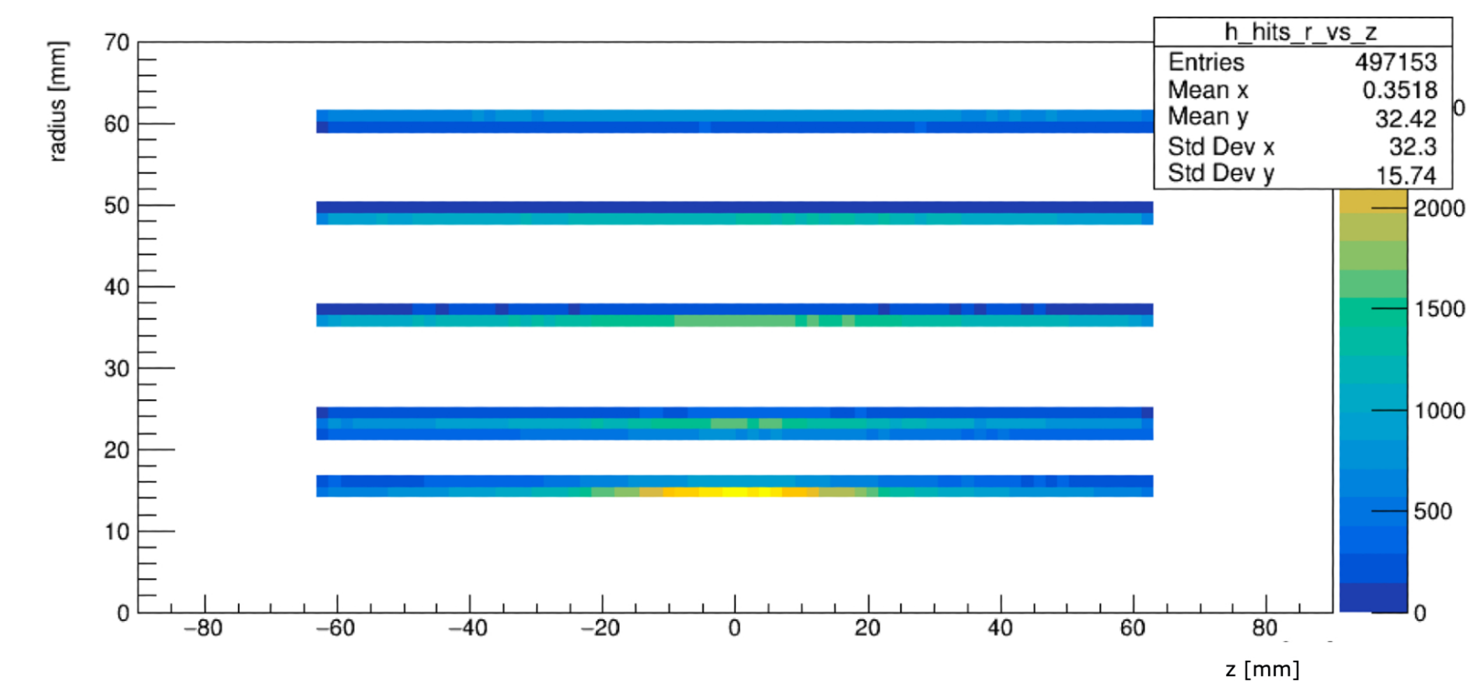


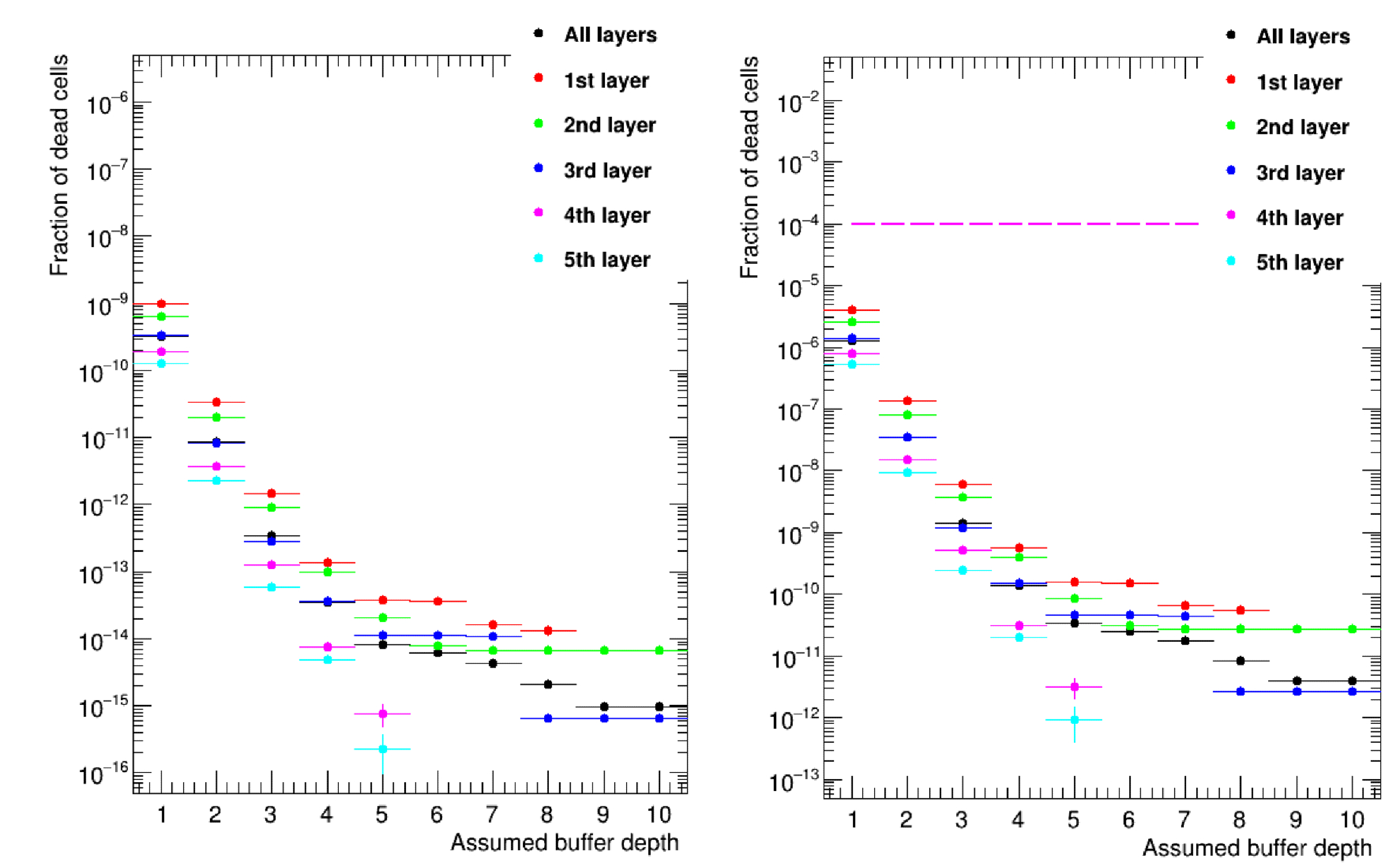
Want to Learn More?

Join in Building the Future of C³

- C³ Proposal Paper: arXiv:2203.07646v2
- C³ R&D Plan: arXiv:2203.09076v2
- Join the C³ Mailing List! c3-developments@slac.stanford.edu

Hadron Background Simulation





Top: 2D spatial distribution of hadron background hits within the first five C³ vertex detector layers. Bottom Left: Occupancy in the vertex detector as a function of buffer depth for the hadron background. Only the generated events with $\sqrt{s_{\gamma\gamma}} > 10$ GeV were used. Bottom Right: Rescaled occupancy as an estimation of the total $\sqrt{s_{\gamma\gamma}}$. This, combined with the pair production occupancy, closely matches up with ILC estimations [3].

Key Takeaways

- C³ is a compact, upgradable, and sustainable Higgs Factory proposal.
- We must account for the e^+e^- pairs and $\gamma\gamma \rightarrow$ hadron backgrounds.
- They are, however, very manageable.
- The ILC is a valid reference for C³ studies, with C³ $\sim$ ILC/10.
- There is plenty more to do:
  - generate full suite of hadron background by including processes < 10 GeV
  - expand data production and investigate more backgrounds.

References

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[2] T. Barklow, L. d'Hautuille, C. Milke, B. Schumm, A. Schütz, M. Stanitzki, and J. Strube. A study of the impact of high cross section ilc processes on the sid detector design, 2016.

[3] T. Behnke, J. E. Brau, P. N. Burrows, J. Fuster, M. Peskin, M. Stanitzki, Y. Sugimoto, S. Yamada, and H. Yamamoto. The international linear collider technical design report - volume 4: Detectors, 2013.

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