Pair Production Backgrounds at C3

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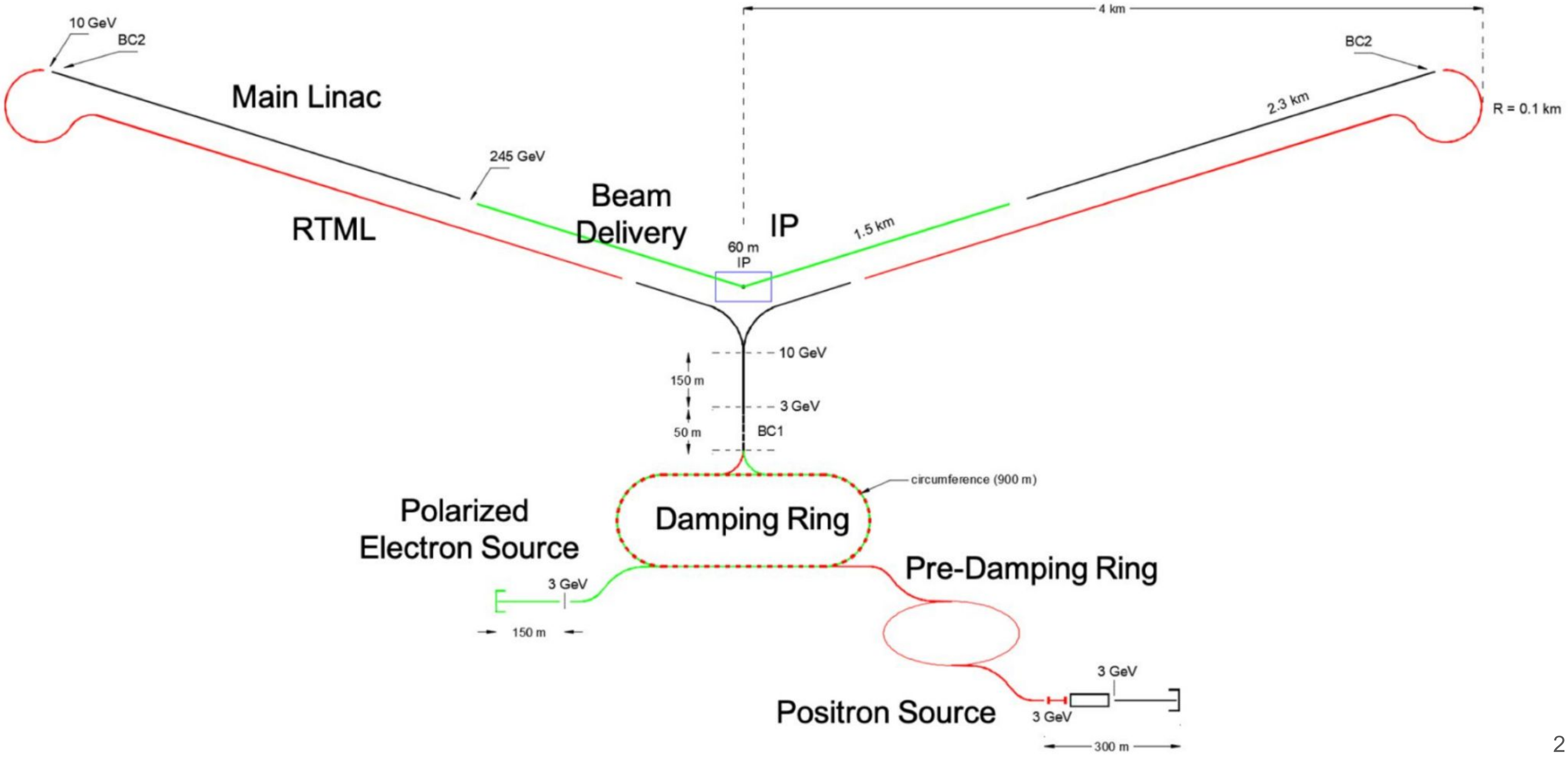
C^3 - 8 km Footprint for 250/550 GeV



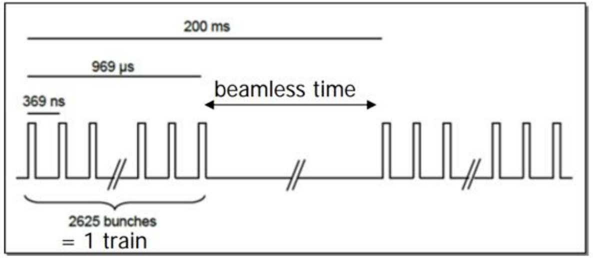
The C3 Accelerator Parameters

Collider	NLC	CLIC	ILC	C^3	C^3
CM Energy [GeV]	500	380	250 (500)	250	550
Luminosity [x10^{34}]	0.6	1.5	1.35	1.3	2.4
Gradient [MeV/m]	37	72	31.5	70	120
Effective Gradient [MeV/m]	29	57	21	63	108
Length [km]	23.8	11.4	20.5 (31)	8	8
Num. Bunches per Train	90	352	1312	133	75
Train Rep. Rate [Hz]	180	50	5	120	120
Bunch Spacing [ns]	1.4	0.5	369	5.26	3.5
Bunch Charge [nC]	1.36	0.83	3.2	1	1
Crossing Angle [rad]	0.020	0.0165	0.014	0.014	0.014

- C3 Accelerator design utilizes cryogenic copper to achieve improved acceleration gradients
- Similar luminosity to ILC, bunch spacing is significantly smaller
- Must consider what that means for the C3 backgrounds, considering ILC

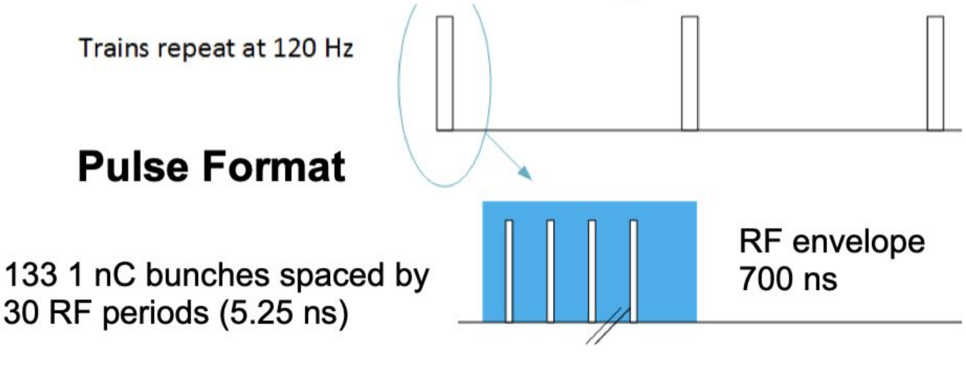
Going from ILC to C^3 beam parameters

ILC timing structure



1 ms long bunch trains at 5 Hz
2820 bunches per train
308 ns spacing

C^3 timing structure



- C3 has a radically different bunch structure from ILC
- Time structure and electronics needs are different at low level
  - But modern clocking and timing performance means that C3 ~ ILC/10 where beam-based background's impact on performance considerations is concerned

Going from ILC to C^3 beam parameters

Parameter	Units	Value
β_x^*	mm	12
β_y^*	mm	0.12
$\epsilon_{N,x}^*$	nm	900
$\epsilon_{N,y}^*$	nm	20
σ_x^*	µm	210.12
σ_y^*	µm	3.13
σ_z^*	µm	100
n_b		133
f_{rep}	Hz	120
N		$6.25 \cdot 10^9$
θ_c	rad	0.014

- The emittances on the table are normalized. The transverse beam size is calculated as:

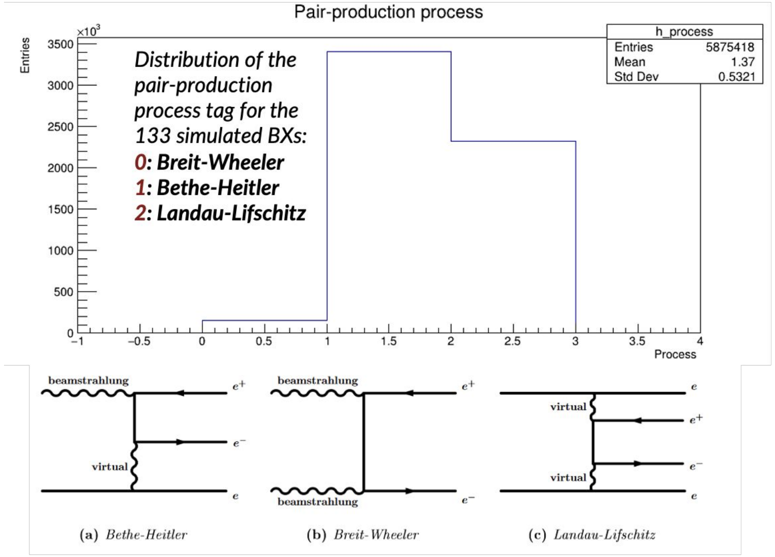
$$\sigma_{x,y}^* = \sqrt{\epsilon_{x,y}^* \beta_{x,y}^*} = \sqrt{\frac{\epsilon_{L,x,y}^* \beta_{x,y}^*}{\gamma}}, \ \gamma = \frac{E}{m_e c^2} = \frac{\sqrt{s}}{2 m_e c^2}$$

Needed a few relevant params:

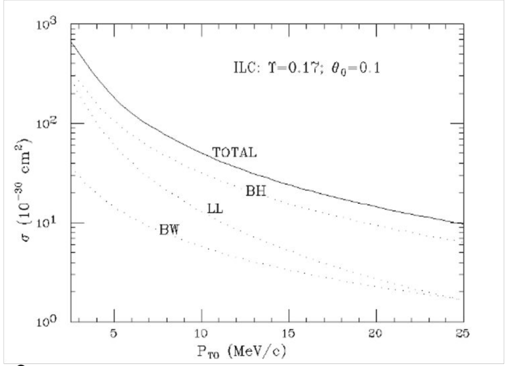
- Number of bunches
- Repetition frequency
- Emittances

	Initial Tests	Emilio's Values
Energy spread	0.1%	0.3%
Energy spread distribution	Gaussian	Flat
Offset in x direction (nm)	0	5
Offset in y direction (nm)	0	0.2
Waist shift in x direction (µm)	0	0
Waist shift in y direction (µm)	0	0
Crossing angles (not compensated by crab scheme)	0	0

Beam Parameters and the GuineaPig Simulation



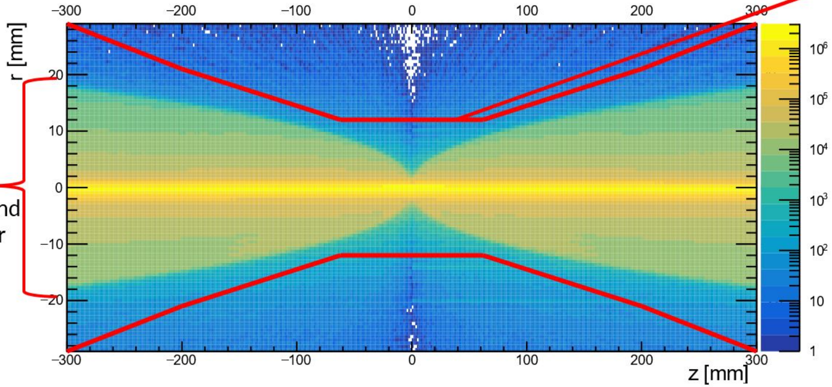
Source: https://bib-pubdb1.desy.de/record/405633/files/PhDThesis_ASchuetz_Publication.pdf



Source:
https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.44.2209&rep=rep1&type=pdf

- This background comes from generation of virtual photons as bunches pass through each other or from hard bremsstrahlung, "incoherent pairs"
- To simulate the pair background, we used the GUINEA-PIG (GP) program:
  - For this study, simulate primary production modes production of e+/e- pairs from beam and beamstrahlung initiated backgrounds
  - Also handles for hadron photoproduction, but known inaccuracies have led us to utilize alternate methods

Pair Production Occupancies

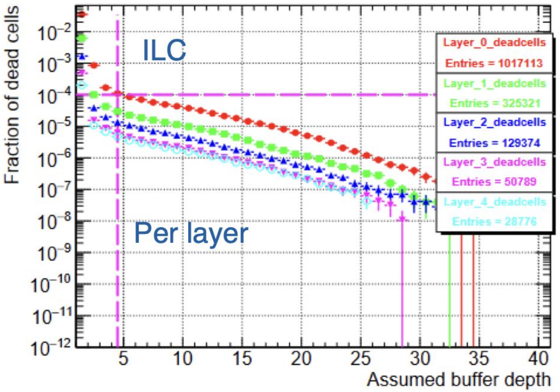


Beam pipe outline

Region of closest approach: r=12 mm for |z|<62 mm

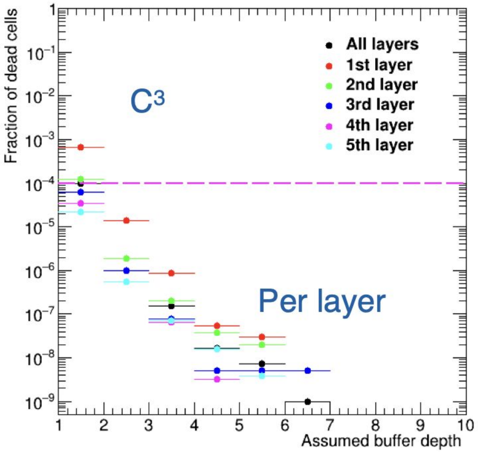
The 1st SiD vtx detector layer is proposed to be placed 2 mm outside of that (at r=14 mm)

Convention: r>0 for y>0 and vice verse (for visualization purposes)



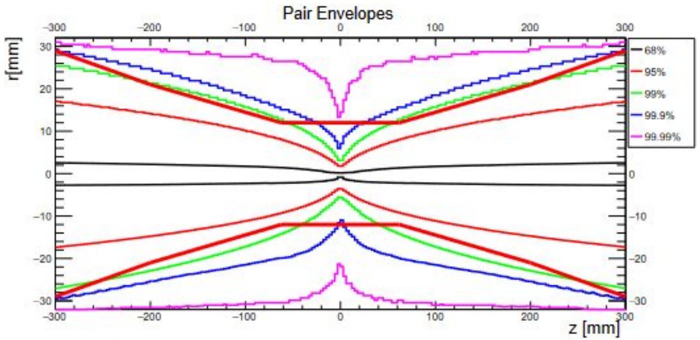
ILC TDR includes all backgrounds, C3 only incoherent pairs

To mind for comparison: ILC bunch train is 10x longer than C3

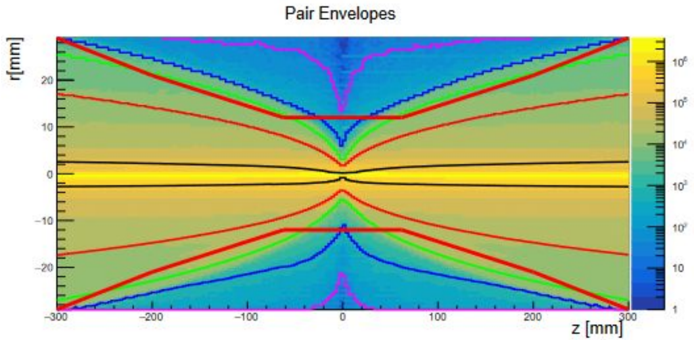


Pair Production - Dependence on solenoid B-field

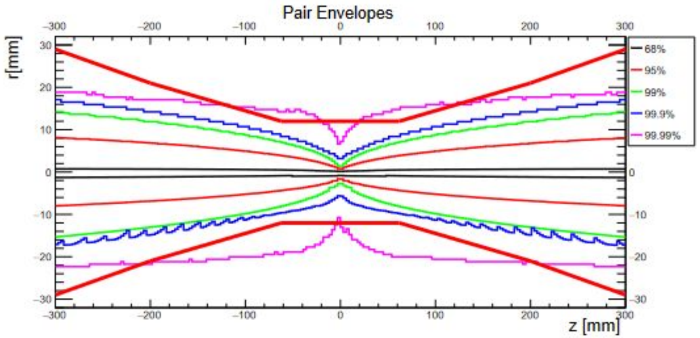
(a) B = 2 T



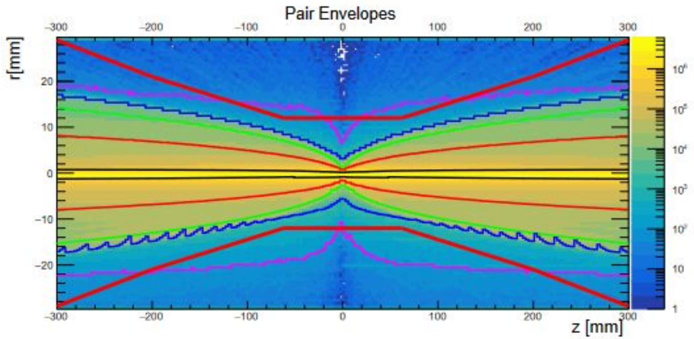
(a) B = 2 T



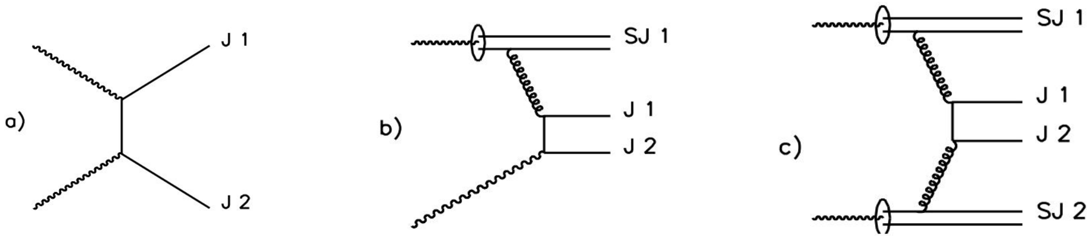
(b) B = 5 T



(b) B = 5 T



Hadron Photoproduction Backgrounds



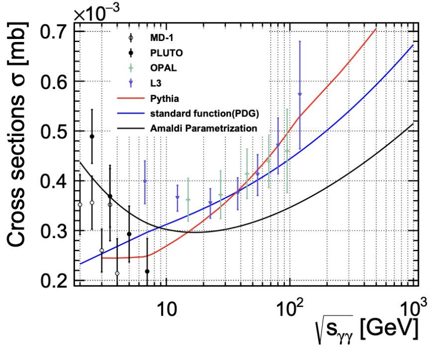


FIG. 2: Comparison of cross sections for $\gamma\gamma \to$ hadron processes as a function of centre of mass energy obtained from Amaldi parameterization [3], Standard paramerization [8] in PDG, Pythia and data from LEP [1], PETRA [6] and VEPP [5]

- Hadron photoproduction (HP) is smaller than the pair production background
  - HP cross section ~0.44 microbarns, incoherent pair production larger by 10^5
  - However, HP is more central
- Background will go to the central part of detector
  - Larger diphoton center-of-mass compared to incoherent pairs
  - Comparatively larger probability of physics impact, especially for jet clustering

Hadron Photoproduction: Spectra and Generators

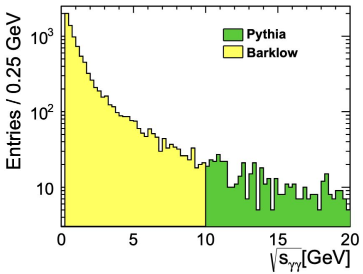


FIG. 1: Energy spectrum of $\gamma\gamma \to$ low p_T hadron events as a function of centre-of-mass energy. The figure shows the energy cutoff of 10 GeV below which the events are generated by the Barklow generator. Above 10 GeV the events are generated by Pythia.

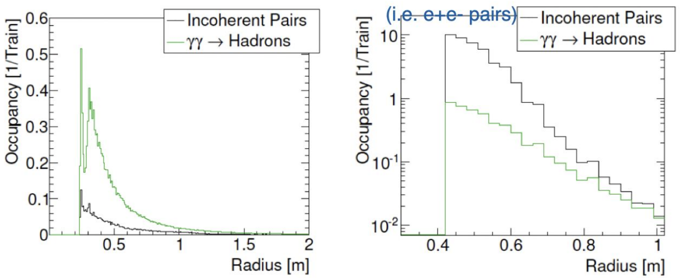
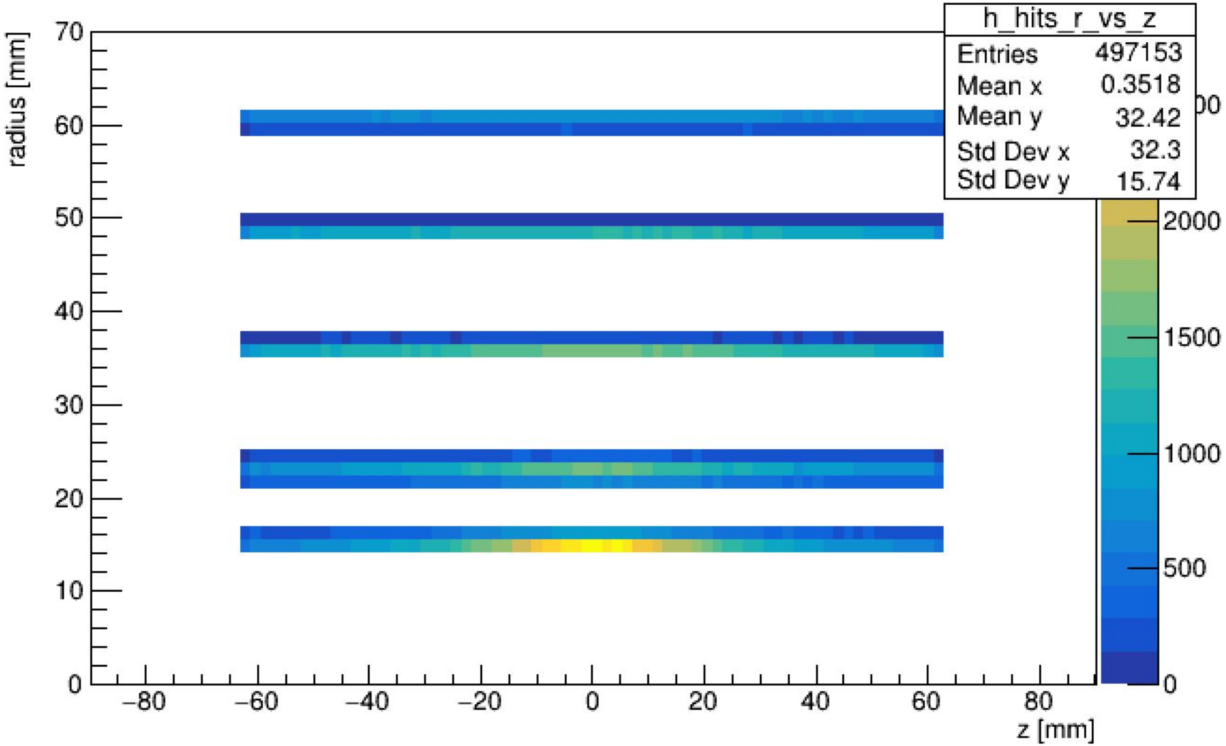


Figure 14. The radial distribution of the train occupancy per pad in ECal (left) and per cell in HCal (right) endcap [10].

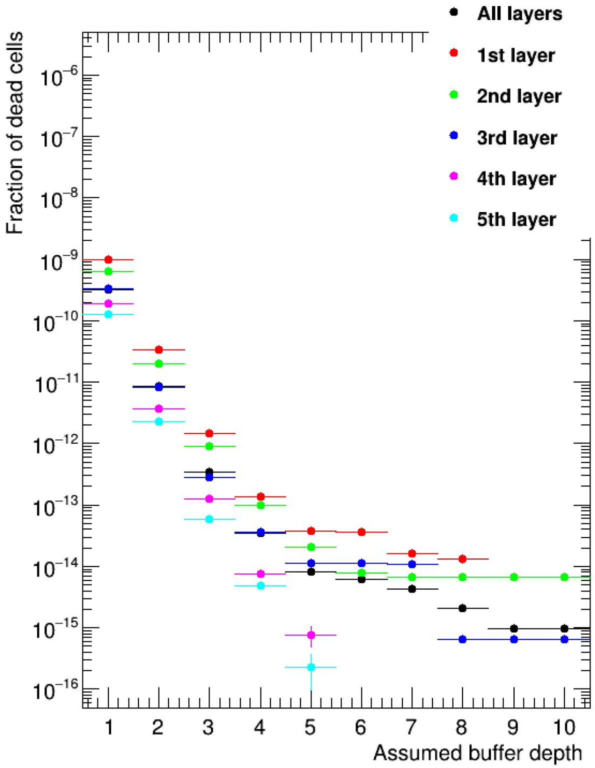
- Using Pythia to simulate the hadron photoproduction
  - Note: Pythia only simulates part of the spectrum past 10 GeV
  - Direct-direct process only appears from our first results due to this
- Next steps: use WHIZARD plugin from Tim Barklow to simulate hadron photo production 0.211-10 GeV range
  - Should also investigate incoherent muon pair production

Occupancy Results with Pythia 8



Occupancy Results with Pythia 8

Occupancy is scaled by production cross section for pythia 8 events

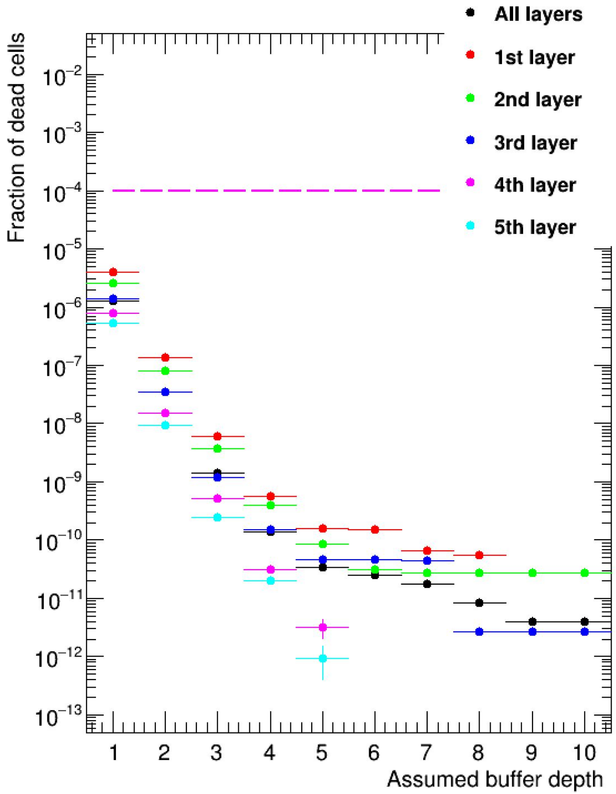


NB: This is **only** the occupancy from hadron photoproduction. Not overlaid with incoherent pairs!!!

Occupancy Results with Pythia 8

Occupancy rescaled to total hadron photoproduction cross section (10^3 larger)

When summed with incoherent pairs plot, starts to produce long occupancy tail seen in ILC plot.



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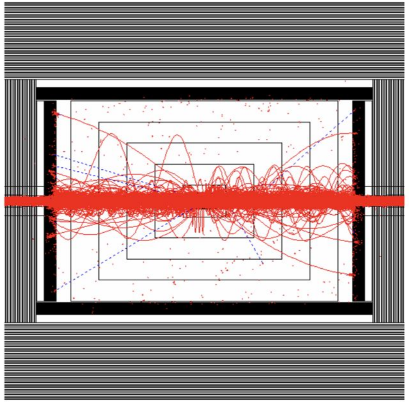
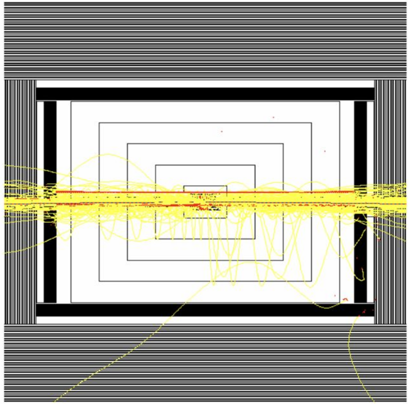
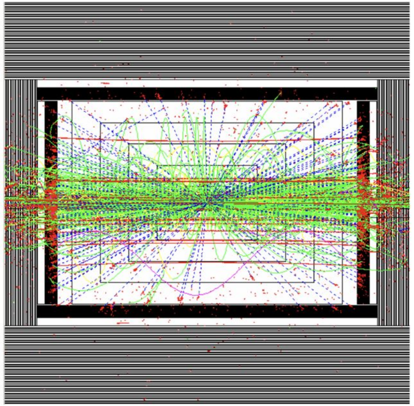
Eventual Breadth of Our Simulations



8600 e^+e^- pairs / train strike detector



154 $\mu^+\mu^-$ pairs / train
56 GeV / train detected energy
24 detected charged tracks / train



56 hadronic events / train
no pt cut; Ecm down to $\pi^+\pi^-$ threshold
454 GeV / train detected energy
100 detected charged tracks / train

- C3 background rates are expected to be similar constituency to ILC
  - Total amount per bunch train divided by 10, assuming electronics to handle 5ns bunch spacing
  - Proper simulation of 5ns bunch spacing requires simulation tech. from LHC (shared with MuC community)
- Nearly all ILC background studies can be used and reexamined in the context of C3
  - Gives us a good rule-of-thumb to proceed forward with, and a wealth of knowledge to draw from

Conclusions

- C3 beam-induced-background studies making steady progress
  - Occasionally difficult to collect all necessary information together
  - New generators and active development helping to clarify further directions (thanks Tim!)
- Two background processes remaining
  - Low energy hadron photoproduction from Barklow-gen
  - Muon incoherent pairs (also Barklow-gen?)
  - Will need updated CIRCE cards for C3 to get completely accurate results
  - Happy to help update any part of generator pipeline to Whizard 2.x
- Will move over summer to key4hep / edm4hep, rather than raw GEANT
  - C3 background overlay will require significant technical work compared to ILC (bunch spacing)