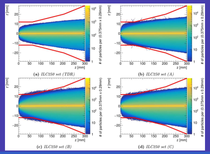
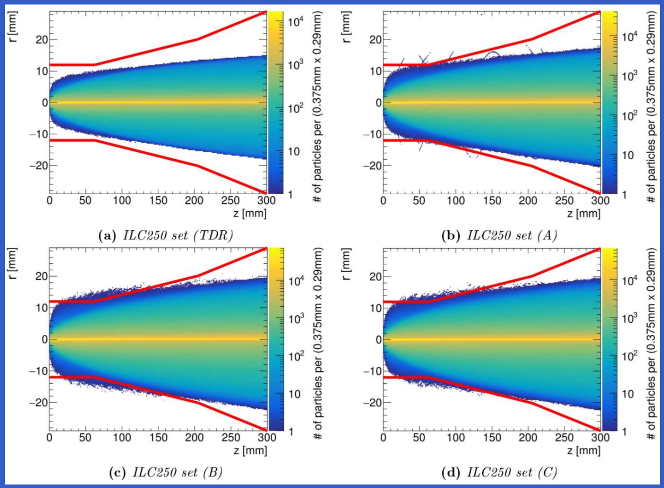


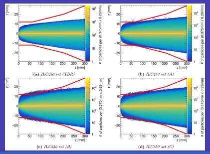
Background Simulation Overview: Full Simulation Tools for C^3



Chris Potter

University of Oregon

Charge From C^3 Workshop Organizers



The backgrounds - *To do list*

1. e+e– pair background from beam-beam interactions (*GuineaPig*)
   - It depends on center-of-mass energy, the number of bunches per train, and the beam parameters
2. Machine background from the interaction of the beam with the beam line components
   - i.e. Muons from the BDS (*MUCARLO*)
3. Neutron background from the main beam dumps (*FLUKA*)
4. $\gamma\gamma$ to Hadrons background (*GuineaPig+WHizard)*

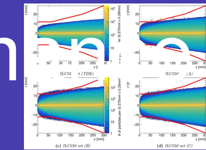
The goal is to simulate all three of them and evaluate their impact on the SiD-like detector

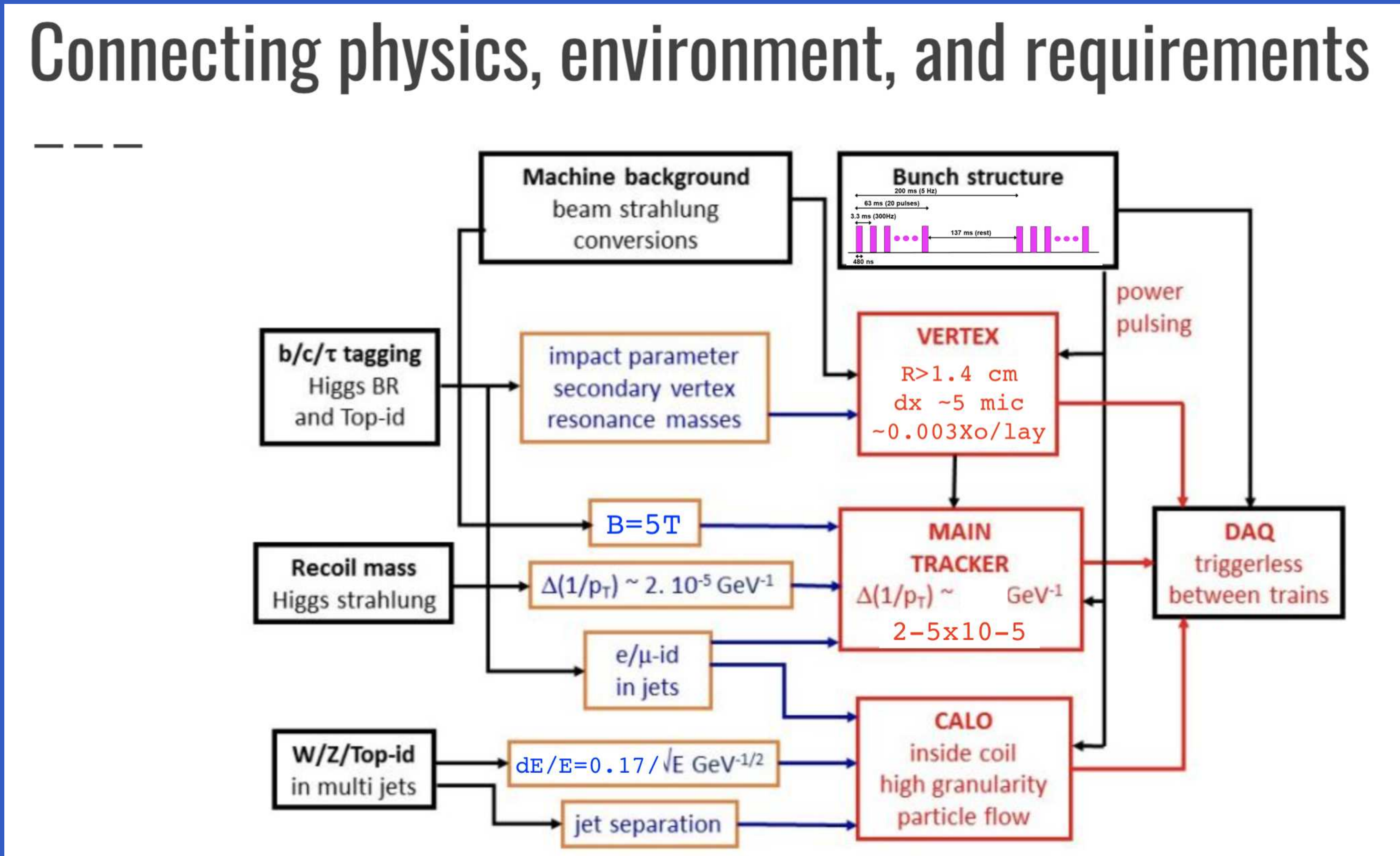
>> simulate with the Geant4 the background particles and interface with detector

Beam 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

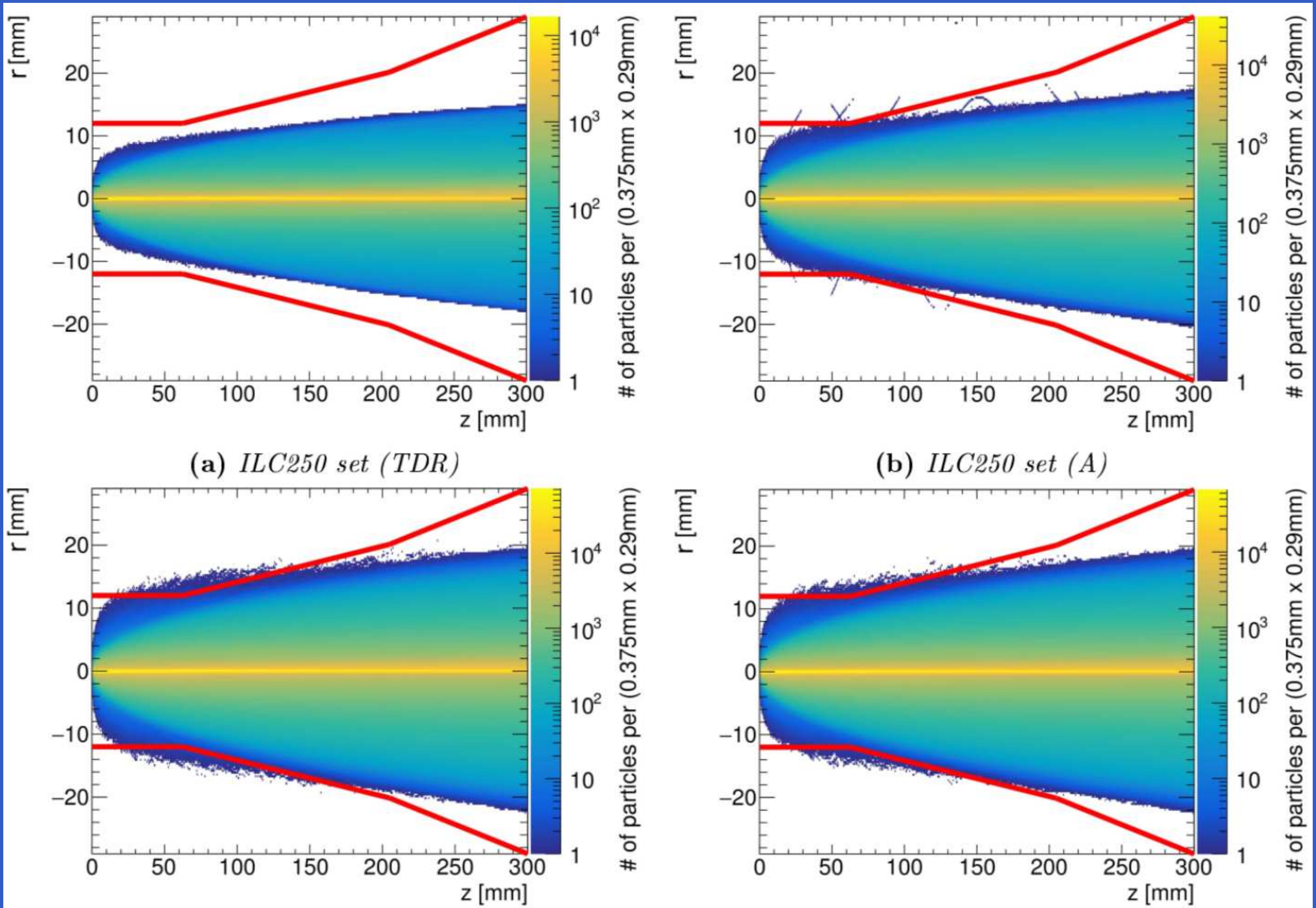
Physics Goals, Beam Constraints, Detector Perform





SiD parameters based on the Detailed Baseline Design (DBD, arXiv:1306.6329) from 2013, to be updated (figure based on Markus Klute, AWLC2020 slide).

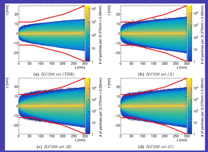
GuineaPig: Generator of Unwanted Interactions for Numerical...Interfaced to Geant



(a) *ILC250 set (TDR)* **(b)** *ILC250 set (A)* **(c)** *ILC250 set (B)* **(d)** *ILC250 set (C)*

Beamstrahlung pairs for ILC250 beam parameters impact vertex detector and forward calorimeter.

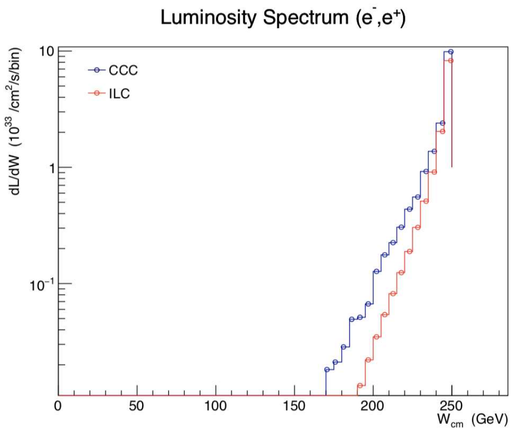
CAIN: Beam-Beam Interactions $e^+e^-\gamma$ (C. Vernieri)

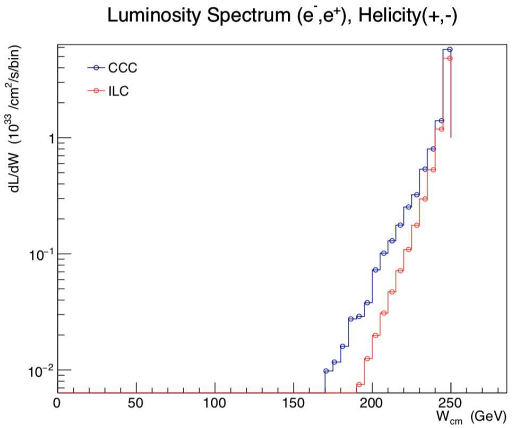


CAIN studies

Luminosity of e+e- interactions as a function of the centre of mass of energy for ILC and CCC, inclusively and assuming polarized beams

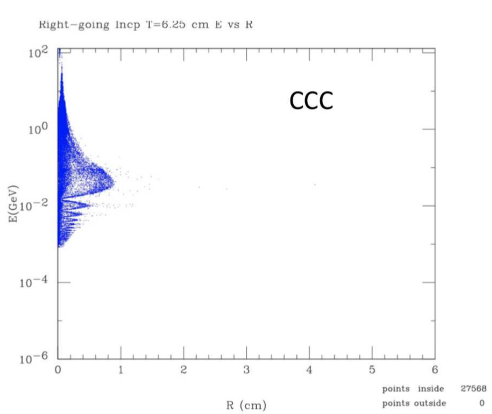
CCC shows a larger spread, but the peak luminosity is not affected.

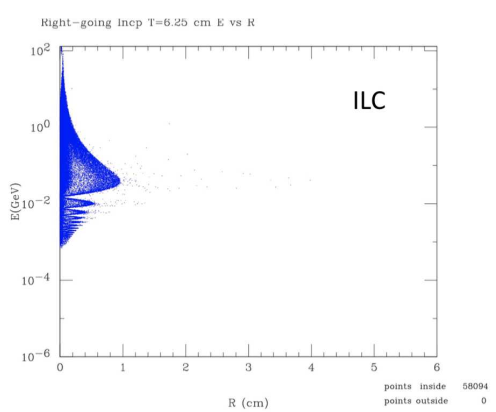




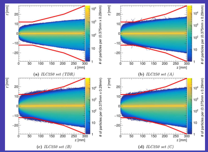
Distribution of the charged momentum of incoherent pairs produced from γ evaluated at z=6.25 cm as a function of the distance from the interaction point (R) for ILC and CCC

The expected background for CCC is compatible with the ILC detectors assumptions for the beam pipe position.





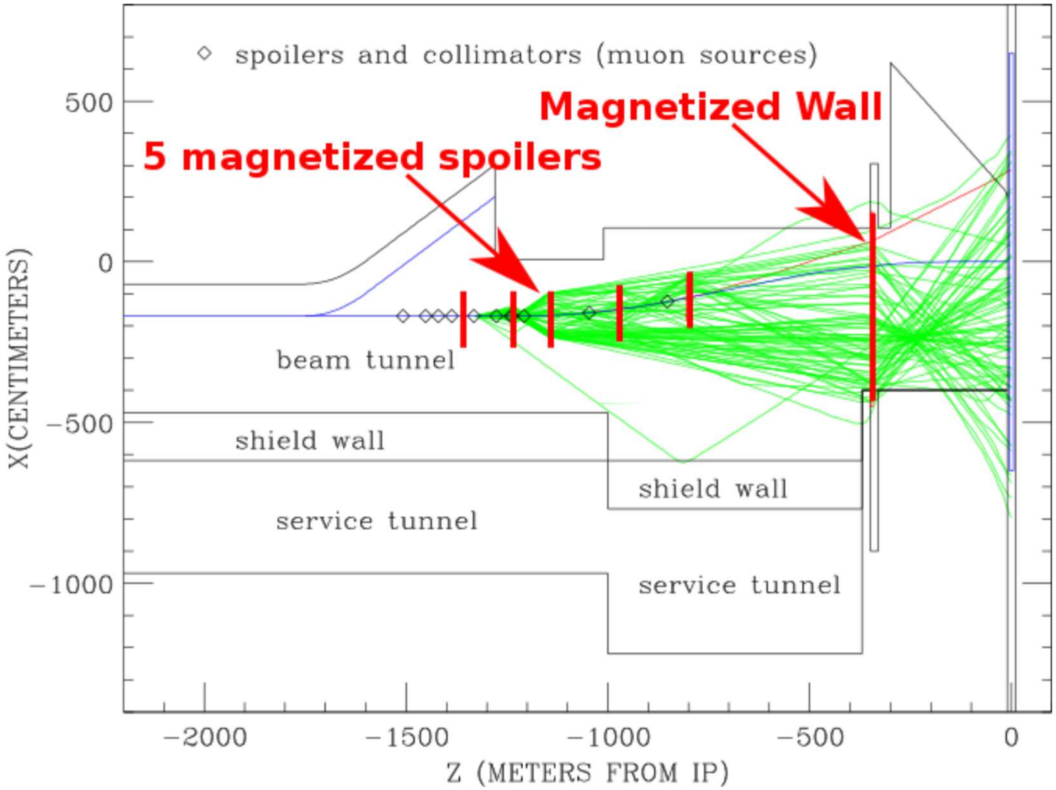
MuCarlo: Muons From Beam Interaction with BDS



Muon spoiler scenarios

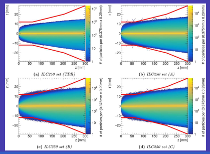
There are TWO SPOILER SCENARIOS under discussion:

- **5 Spoilers**
- **5 Spoilers + Wall**



e⁻ beam line

Whizard: W, HIggs, Z And Respective Decays (1)



- **WHIZARD**
- **HOME**
  - Main Page
- **MANUAL, WIKI, NEWS**
  - Manual
  - Wiki Page
  - CLIC page on WHIZARD
  - News
  - Tutorials
  - Delphes Fast Simulation
  - WHIZARD talks
  - ChangeLog
- **REPOSITORY, LAUNCHPAD, BUG TRACKER**
  - Launchpad Support Page
  - Subversion Repository
  - Public Git Repository
  - Support Questions
  - Bug Tracker

The WHIZARD Event Generator

The Generator of Monte Carlo Event Generators for Tevatron, LHC, ILC, CLIC, CEPC, FCC-ee, FCC-hh, SppC and other High Energy Physics Experiments

---

What is WHIZARD?

WHIZARD is a program system designed for the efficient calculation of multi-particle scattering cross sections and simulated event samples.

Tree-level matrix elements are generated automatically for arbitrary partonic processes by using the Optimized Matrix Element Generator O'Mega. Matrix elements obtained by alternative methods (e.g., including loop corrections) may be interfaced as well. The program is able to calculate numerically stable signal and background cross sections and generate unweighted event samples with reasonable efficiency for processes with up to eight final-state particles; more particles are possible. For more particles, there is the option to generate processes as decay cascades including complete spin correlations. Different options for QCD parton showers are available.

Polarization is treated exactly for both the initial and final states. Final-state quark or lepton flavors can be summed over automatically where needed. For hadron collider physics, an interface to the standard LHAPDF is provided. For Linear Collider physics, beamstrahlung (CIRCE) and ISR spectra are included for electrons and photons. The events can be written to file in standard formats, including ASCII, StdHEP, the Les Houches event format (LHEF), HepMC, or LCIO. These event files can then be hadronized.

WHIZARD supports the Standard Model and a huge number of BSM models. Model extensions or completely different models can be added. There are also interfaces to FeynRules and SARAH.

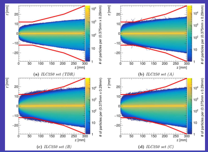
CURRENT RELEASE

- **The official versions are 2.8.4 (released: July 8th, 2020) and 3.0.0α (released March 3rd, 2020).**

  The distribution tarballs of the sources can be found here (2.8.4, link) and (3.0.0α, link).
- Nightly build tarballs can be downloaded: (link).

Whizard is meant (here) to do background $\gamma\gamma \to q\bar{q}$ but it is full suite physics process generator.

Whizard: W, HIggs, Z And Respective Decays (2)



```
model=SM_CKM
mH=125.0 GeV
wH=0.004 GeV

process ilc250_eLpR_2f1h="e-", "e+" => "Z", "H"
compile

sqrts=250 GeV
beams= "e-", "e+"  => isr, isr
beams_pol_density=@(-1), @(+1)
beams_pol_fraction=80%, 30%
integrate(ilc250_eLpR_2f1h)

$shower_method="PYTHIA6"
?hadronization_active=true
$hadronization_method="PYTHIA6"
$ps_PYTHIA_PYGIVE="PMAS(25,1)=125.0; PMAS(25,2)=0.004"

n_events=10000
sample_format=stdhep
simulate(ilc250_eLpR_2f1h)
```

Model and Model Parameters

Higgstrahlung!!

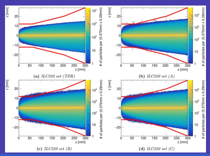
Center of mass energy, beam polarization and ISR. No beamstrahlung here…

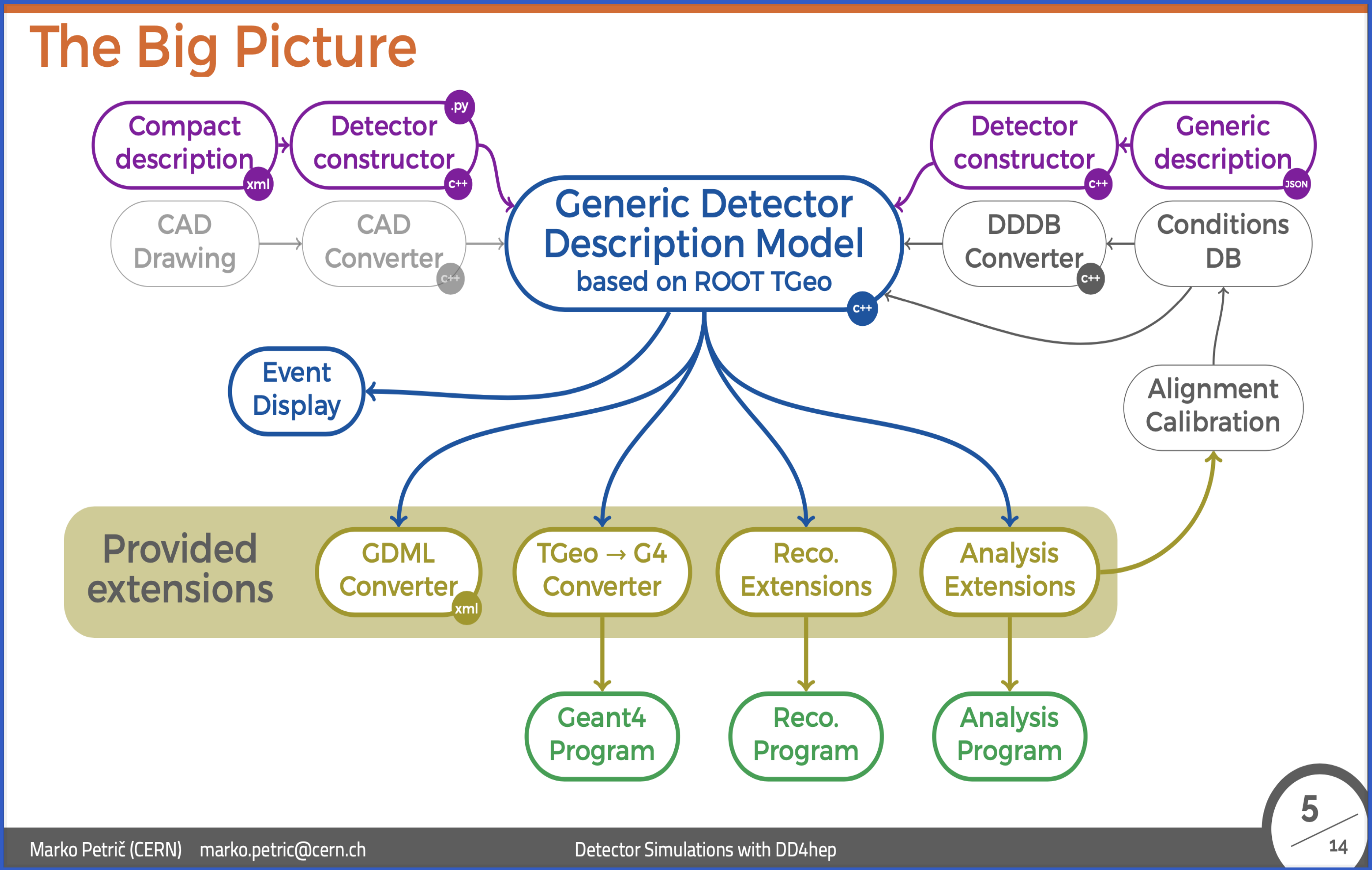
Use Pythia6 to decay Z and H, and to do parton shower and hadronization

Several formats available, use stdhep here

Example script for physics event generation with Pythia6 for Z and H decay and hadronization.

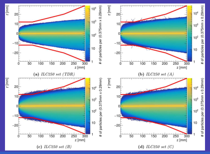
DD4Hep: Detector Description Interface to Geant4



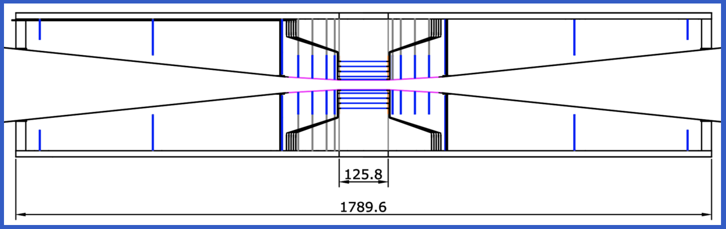


Compact detector description functionality allows detector specification with simple XML scripting.

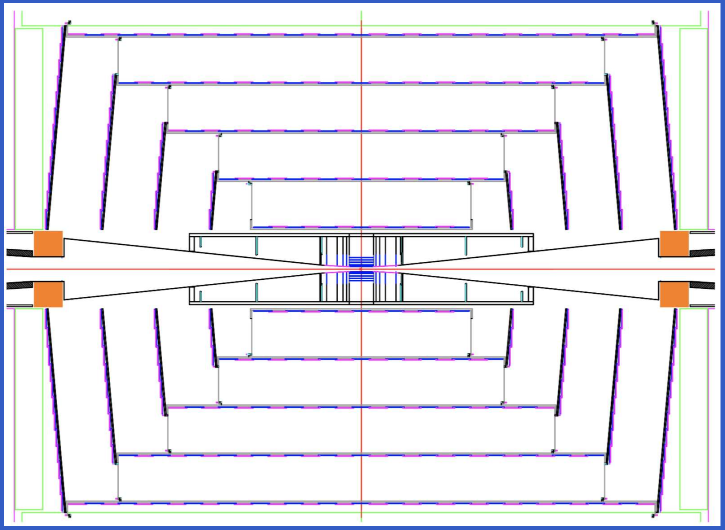
SiD Detailed Baseline Design (arXiv:2110.09965)



Vertex Detector



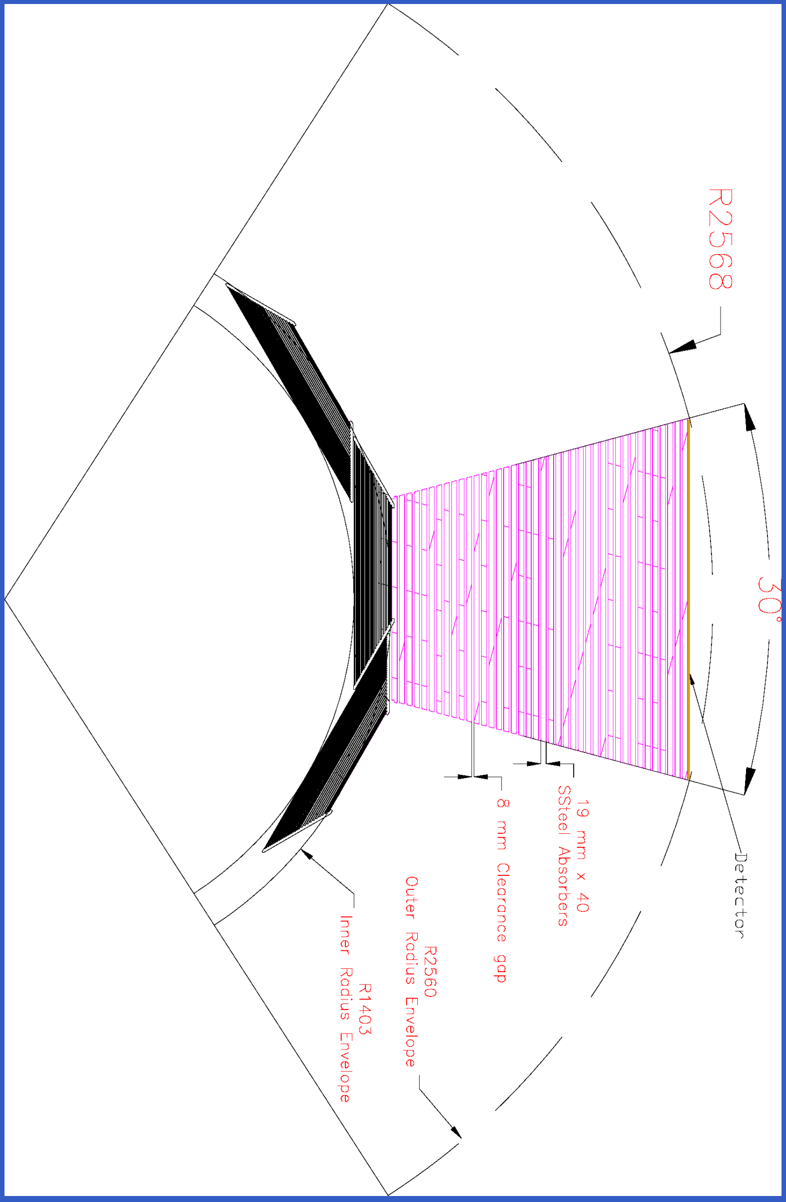
Tracker



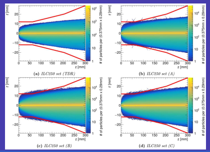
Barrel Parameters

SiD Barrel	Technology	In rad	Out rad	z extent
Vtx detector	Silicon pixels	1.4	6.0	± 6.25
Tracker	Silicon strips	21.7	122.1	± 152.2
ECAL	Silicon pixels-W	126.5	140.9	± 176.5
HCAL	RPC steel	141.7	249.3	± 301.8
Solenoid	5 Tesla SC	259.1	339.2	± 298.3
Flux return	Scint-steel	340.2	604.2	± 303.3

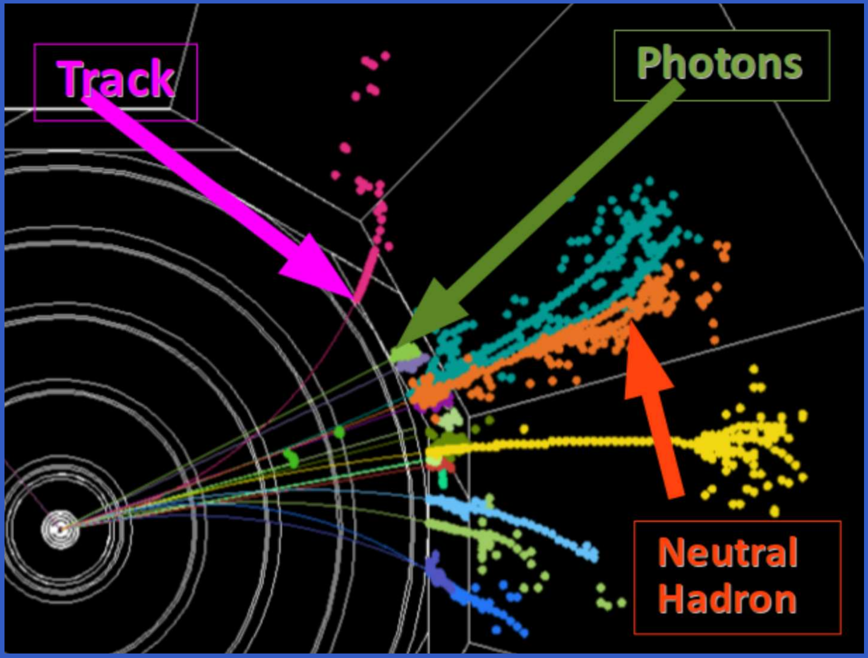
Calorimetry: ECal and HCal

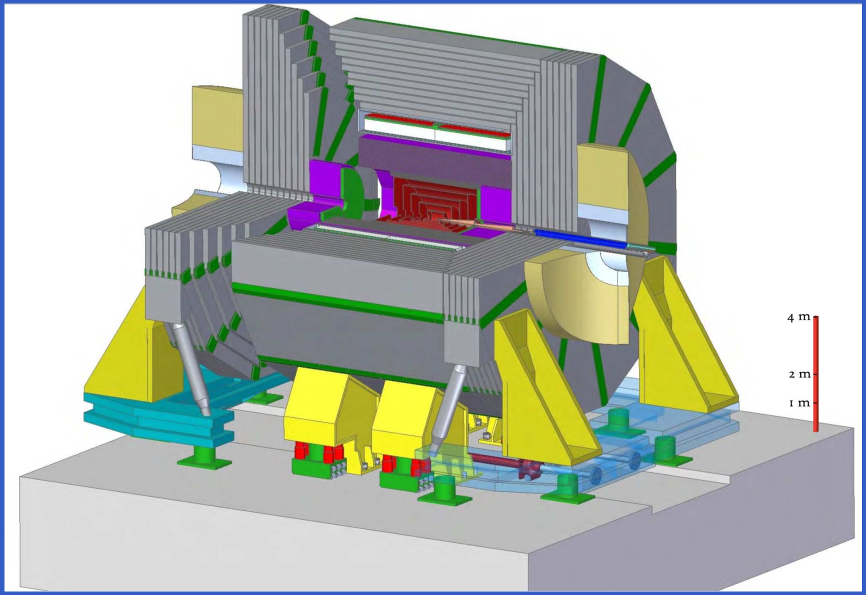


Updated SiD Design (arXiv:2110.09965)



- SiD was designed to take advantage of the particle flow technique. This requires the calorimetery to be placed inside the solenoid.
- The vertex detector, tracker and electromagnetic calorimeter (ECal) use silicon strips and pixels.
- The use of Monolithic Active Pixels (MAPS) for improved performance and reduced cost is now under investigation.
- The updated hadronic calorimeter (HCal) now uses scintillator rather than RPCs, and the readout is now analog rather than digital.
- The iron yoke is now dodecahedral rather than octahedral, and the barrel/endcap interface is now at 30 degrees rather than vertical.





SiD Vertex Detector and Beampipe in the DBD

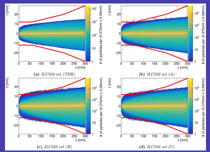
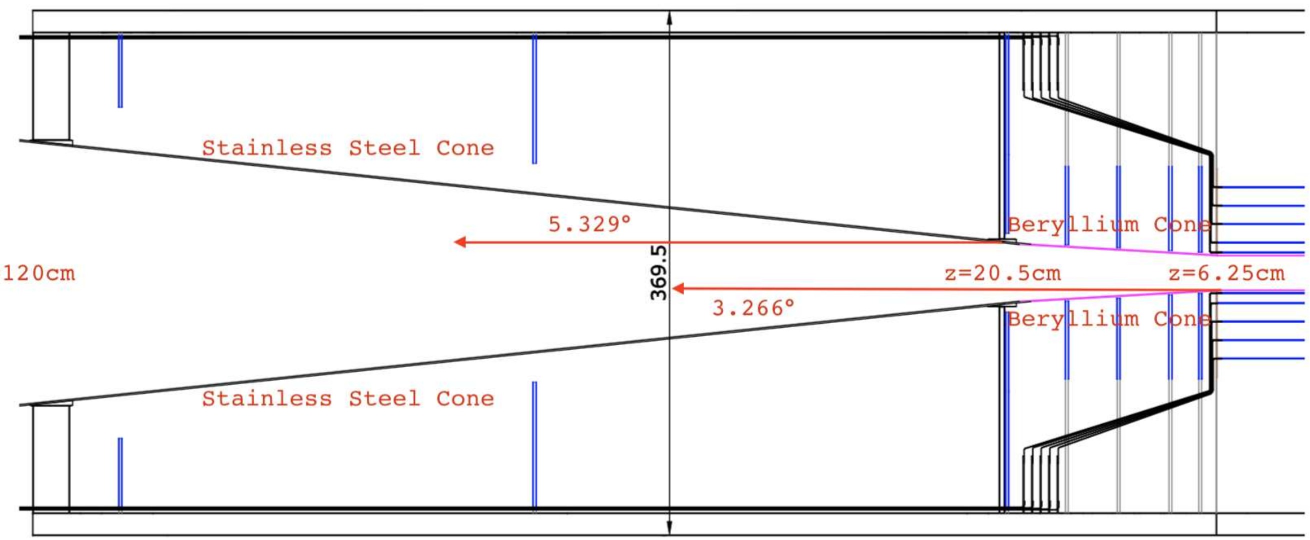


Figure II-2.2
R-z view of the vertex detector and its support structure. Cable routes are also shown with DC-DC converters located on the support structure near the end of the first set of pixel disks. Dimensions are in mm.

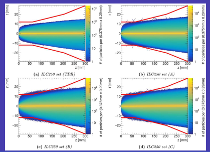


7.4.2 Beampipe

The beampipe through the central portion of the vertex detector has been taken to be all-beryllium. Within the barrel region of the vertex detector, the beryllium beampipe forms a straight cylinder with inner radius of 1.2 cm and a wall thickness of 0.04 cm. At $z = \pm 6.25$ cm a transition is made to a conical beampipe with a wall thickness of 0.07 cm. The half angle of the cone is 3.266°. Transitions from beryllium to stainless steel are made beyond the four inner vertex disks, at approximately $z = \pm 20.5$ cm. The initial stainless steel wall thickness is 0.107 cm; it increases to 0.15 cm at approximately $z = \pm 120$ cm. The half angle of the stainless steel cone is 5.329°. The inner profile of the beampipe is dictated by the need to avoid the envelope of e^+e^- pairs from beamstrahlung.

ILC TDR Volume 4. The beampipe paragraph is almost identical to that in the SiD LoI.

SiD Beampipe: Compact XML Description

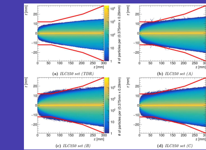


BeamPipe.xml - emacs@hepilc01.uoregon.edu

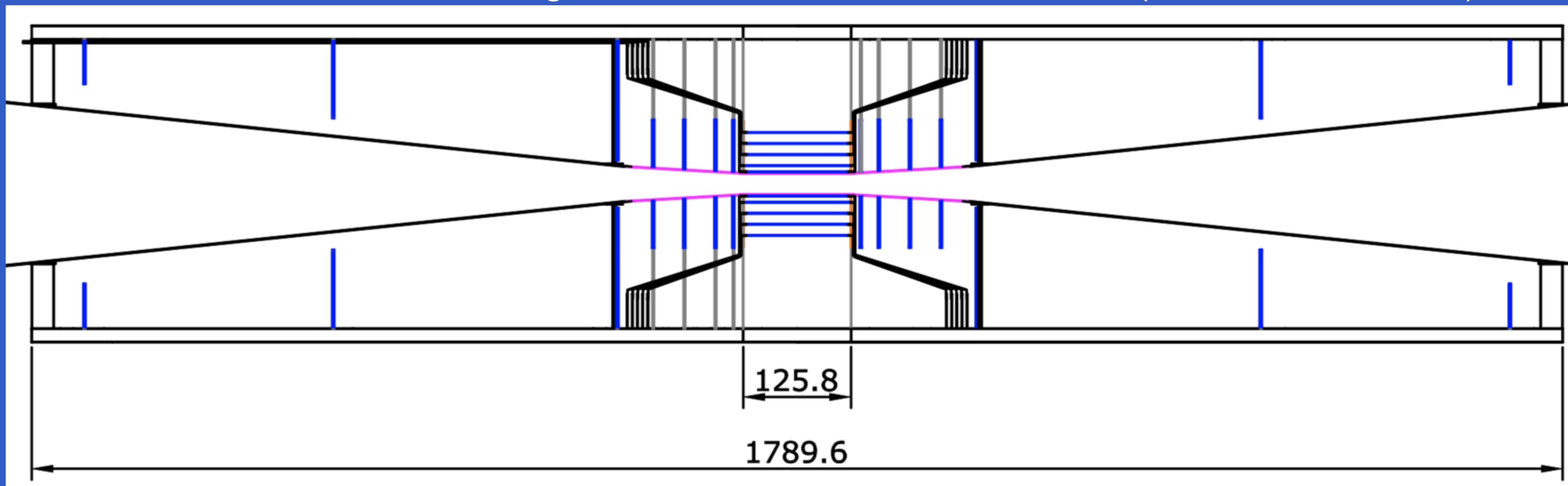
File Edit Options Buffers Tools XML Help

```xml
<comment>Beampipe</comment>

<comment>Parameters from ILC TDR V4 7.4.2. (CP)</comment>
<!-- (defined in main xml) constant name="bp_cone_slope" value="0.0570643"/ -->
<constant name="bp_cone_dr" value="(20.50-6.25)*bp_cone_slope*cm"/>
<constant name="steel_cone_slope" value="0.0932777"/>
<constant name="steel_cone_dr" value="(120.0-20.5)*steel_cone_slope*cm"/>

<detectors>
 <comment>Be Beampipe and Be Cones</comment>
 <detector name="Beampipe" type="DD4hep_PolyconeSupport" insideTrackingVolume="true" vis="BeampipeVis">
  <material name="Beryllium"/>
  <zplane rmin="bp_cone_dr+1.20*cm" rmax="bp_cone_dr+(1.20+0.07*1.0016)*cm" z="-20.50*cm"/>
  <zplane rmin="1.20*cm" rmax="(1.20+0.04)*cm" z="-6.25*cm"/>
  <zplane rmin="1.20*cm" rmax="(1.20+0.04)*cm" z="6.25*cm"/>
  <zplane rmin="bp_cone_dr+1.20*cm" rmax="bp_cone_dr+(1.20+0.07*1.0016)*cm" z="20.50*cm"/>
 </detector>
<comment>Steel Beampipe Cones</comment>
<detector name="ForwardSupportTube" type="DD4hep_PolyconeSupport" insideTrackingVolume="true" vis="BeampipeVis">
  <material name="Steel235"/>
  <zplane rmin="steel_cone_dr+bp_cone_dr+1.20*cm" rmax="steel_cone_dr+bp_cone_dr+(1.20+0.15*1.0043)*cm" z="-120.0*cm"/>
  <zplane rmin="bp_cone_dr+1.20*cm" rmax="bp_cone_dr+(1.20+0.107*1.0043)*cm" z="-20.50*cm"/>
  <zplane rmin="bp_cone_dr+1.20*cm" rmax="bp_cone_dr+(1.20+0.107*1.0043)*cm" z="20.50*cm"/>
  <zplane rmin="steel_cone_dr+bp_cone_dr+1.20*cm" rmax="steel_cone_dr+bp_cone_dr+(1.20+0.15*1.0043)*cm" z="120.0*cm"/>
</detector>
</detectors>
```

SiD Vertex Detector Design



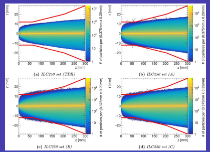
DBD vertex detector design. From the ILCD TDR Volume 4 (arXiv:2110.09965.)

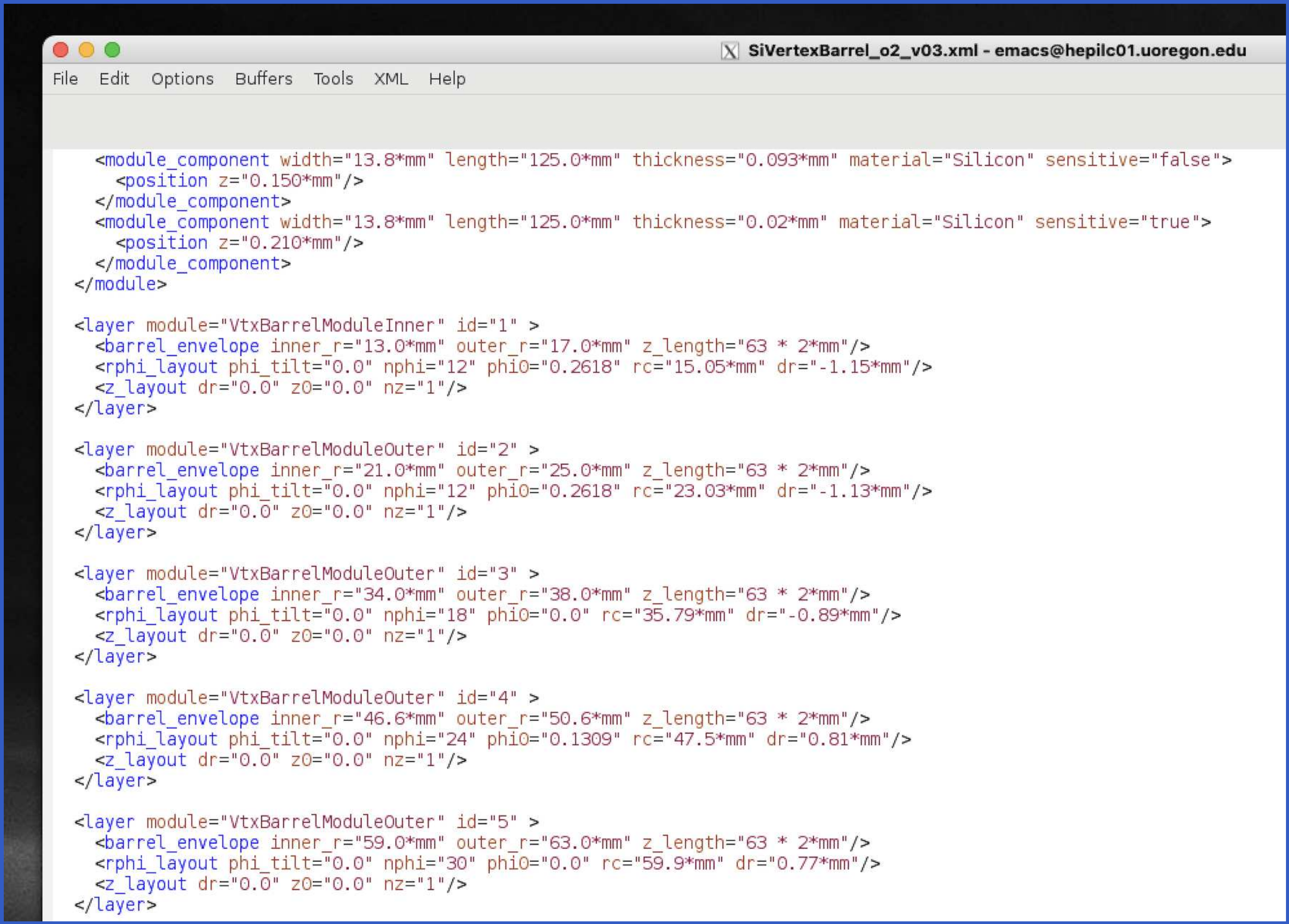


- The goals include hit resolution better the 5 μm in the barrel, less the 0.3% radiation lengths per layer, less then 130 μW/mm^2 in the barrel, and single bunch time resolution.
- These goals motivate five layers instrumented with silicon pixels in the barrel, eight silicon disks, and an additional six silicon disks at large z to provide hermeticity to $\cos\theta \approx 0.984$.
- Plans: optimize pixel size for MAPS vertex detector [a]. Investigate mechanical support structures, cooling and stability, and alignment studies.

[a] Vertex detector MAPS is a longterm wish (or dream). See Nick Sinev's parallel talk on " Chronopixel Silicon CMOS Sensor Development for the ILC ".

SiD Vertex Detector: Compact XML Description



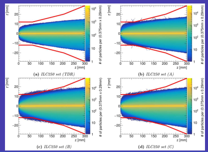


SiVertexBarrel_o2_v03.xml - emacs@hepilc01.uoregon.edu

File Edit Options Buffers Tools XML Help

```xml
    <module_component width="13.8*mm" length="125.0*mm" thickness="0.093*mm" material="Silicon" sensitive="false">
      <position z="0.150*mm"/>
    </module_component>
    <module_component width="13.8*mm" length="125.0*mm" thickness="0.02*mm" material="Silicon" sensitive="true">
      <position z="0.210*mm"/>
    </module_component>
  </module>

  <layer module="VtxBarrelModuleInner" id="1" >
    <barrel_envelope inner_r="13.0*mm" outer_r="17.0*mm" z_length="63 * 2*mm"/>
    <rphi_layout phi_tilt="0.0" nphi="12" phi0="0.2618" rc="15.05*mm" dr="-1.15*mm"/>
    <z_layout dr="0.0" z0="0.0" nz="1"/>
  </layer>

  <layer module="VtxBarrelModuleOuter" id="2" >
    <barrel_envelope inner_r="21.0*mm" outer_r="25.0*mm" z_length="63 * 2*mm"/>
    <rphi_layout phi_tilt="0.0" nphi="12" phi0="0.2618" rc="23.03*mm" dr="-1.13*mm"/>
    <z_layout dr="0.0" z0="0.0" nz="1"/>
  </layer>

  <layer module="VtxBarrelModuleOuter" id="3" >
    <barrel_envelope inner_r="34.0*mm" outer_r="38.0*mm" z_length="63 * 2*mm"/>
    <rphi_layout phi_tilt="0.0" nphi="18" phi0="0.0" rc="35.79*mm" dr="-0.89*mm"/>
    <z_layout dr="0.0" z0="0.0" nz="1"/>
  </layer>

  <layer module="VtxBarrelModuleOuter" id="4" >
    <barrel_envelope inner_r="46.6*mm" outer_r="50.6*mm" z_length="63 * 2*mm"/>
    <rphi_layout phi_tilt="0.0" nphi="24" phi0="0.1309" rc="47.5*mm" dr="0.81*mm"/>
    <z_layout dr="0.0" z0="0.0" nz="1"/>
  </layer>

  <layer module="VtxBarrelModuleOuter" id="5" >
    <barrel_envelope inner_r="59.0*mm" outer_r="63.0*mm" z_length="63 * 2*mm"/>
    <rphi_layout phi_tilt="0.0" nphi="30" phi0="0.0" rc="59.9*mm" dr="0.77*mm"/>
    <z_layout dr="0.0" z0="0.0" nz="1"/>
  </layer>
```

Summary and Conclusion



- The hardware for a C^3 detector along the beamline must take into account beam-induced backgrounds in its design.
- The beampipe, vertex detector, and forward calorimetry must be designed to avoid radiation damage and high occupancy.
- Tools to generate these backgrounds are available and have been in use for SiD studies:
  - GuineaPig for pairs from beamstrahlung, and CAIN for beam-beam interactions.
  - MuCarlo for muons from beam interactions with the beam delivery system.
  - Fluka for neutrons from the beam dumps.
  - Whizard for low p_T hadrons from $\gamma\gamma \rightarrow q\bar{q}$.
  - Compact DD4Hep detector descriptions provide an simple XML interface to Geant4.
- A re-optimization for C^3 beam parameters should be straightforward, and SiD provides a convenient baseline.
- An SiD-like detector for C^3 may incorporate completely new features like subdetectors for particle identification.
- An SiD-like detector may also include new MAPS technology for ECal, Tracker, and Vertex Detectors.