Mini-Workshop on ILC Infrastructure and CFS for Physics and Detectors

The International Linear Collider

IP Background Simulations

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KIT, DESY

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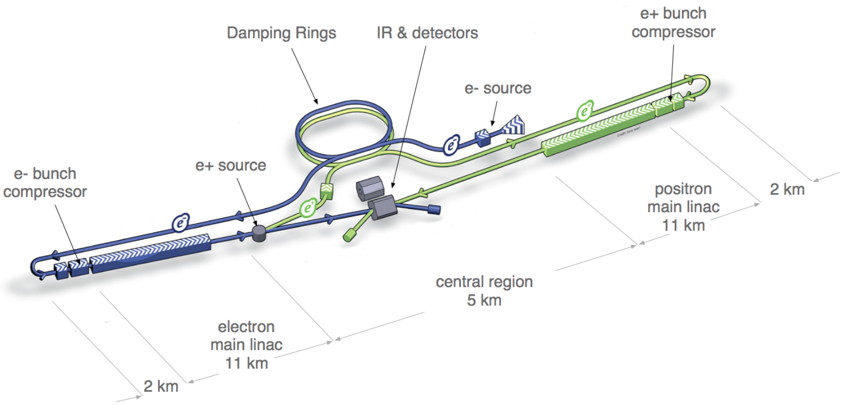
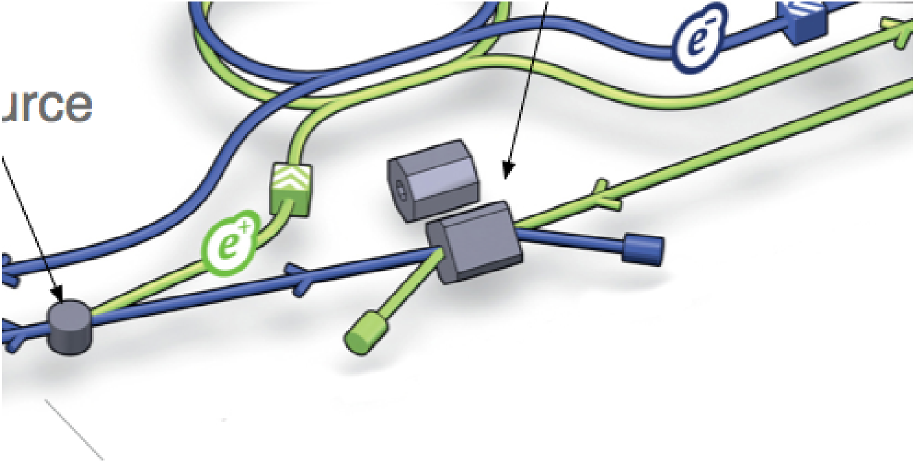
The layout of the ILC



The layout of the ILC



Background sources

The main sources of background:

- Pair background
- Bhabha scattering
- $\gamma\gamma \to$ hadrons
- Neutrons from the beam dumps
- Background from Final-Focus system
    - Beam halo collimators
    - Muon spoilers

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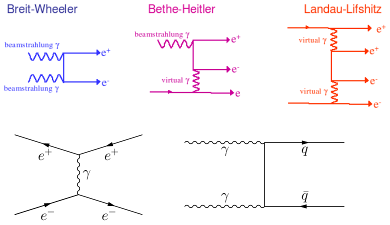

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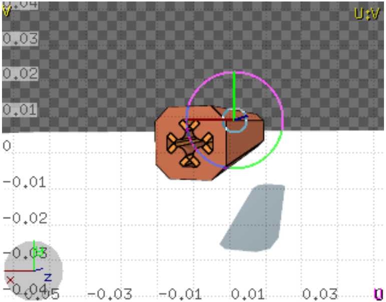

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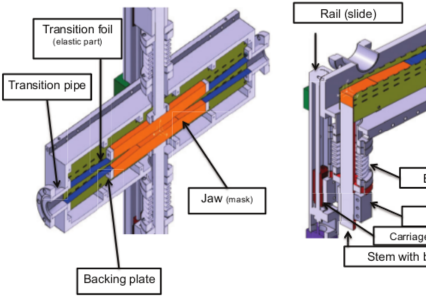

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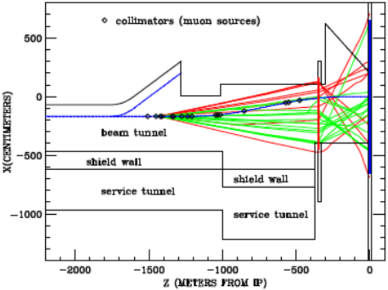

Simulation tools

Simulation tools used for the studied background sources:

- Pair background - GuineaPig
- Bhabha scattering - Pythia
- $\gamma\gamma \rightarrow$ hadrons - Pythia
- Neutrons from the beam dumps - FLUKA
- Beam halo collimators - BDSIM
- Muon spoilers - MUCARLO

PAIR BACKGROUND

GuineaPig data

Accelerator parameters needed as input to GuineaPig are available for different ILC modes.

Already simulated pair background files for >3900 bunches are on the Grid as service to the community.[1]

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One bunch has about 200,000 background particles:

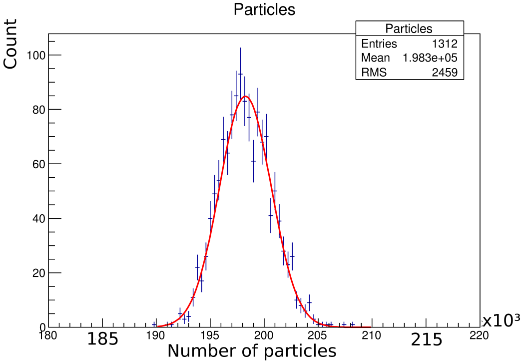
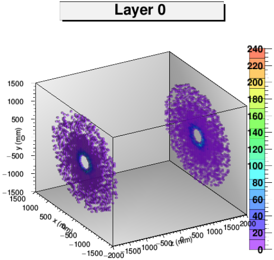


Figure 1 : Distribution of number of pair background particles per bunch in a train of 1312.

Pair background in the SiD detector

Specific studies:

- Hit distribution in the subdetectors
- Occupancy and buffer depth studies
- Origins of the background particles induced by beam-beam interactions
- Time of arrival of the background particles at the subdetectors wrt time of the bunch-crossing



SiD detector

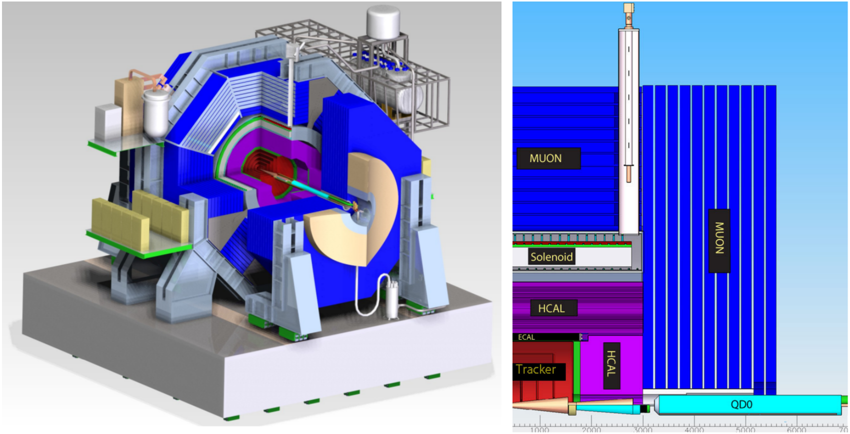


Figure 2 : SiD detector model: Vertex detector (red), ECAL (green), HCAL (pink), Muon system (blue)

Hits in the SiD - EcalEndcaps

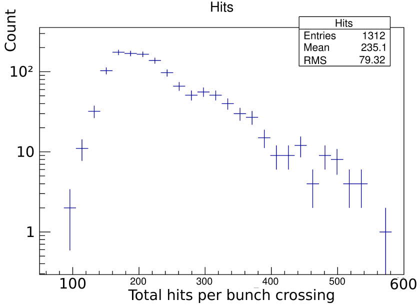


Figure 3 : Hits of pair background particles from a full train in the EcalEndcaps

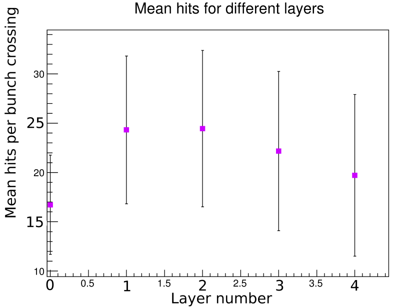
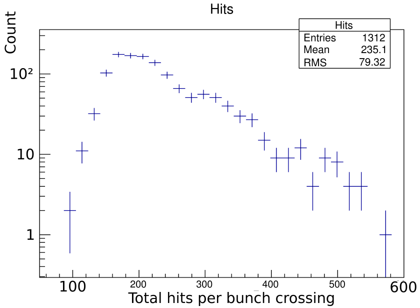


Figure 4 : Comparison of the MEAN number of hits in the first 5 layers of the EcalEndcaps.

In the EcalEndcaps only, there are about 200 hits per bunch crossing.

The mean number of hits per layer is between 15 and 25 hits, per full bunch crossing!

Hits in the SiD - EcalEndcaps



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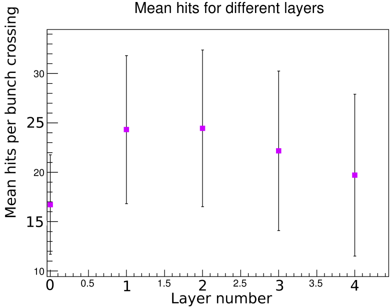


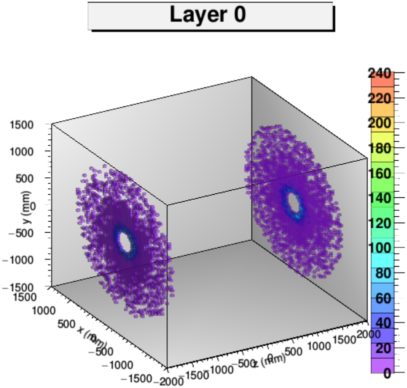
Figure 4 : Comparison of the MEAN number of hits in the first 5 layers of the EcalEndcaps.

In the EcalEndcaps only, there are about 200 hits per bunch crossing.

In comparison:

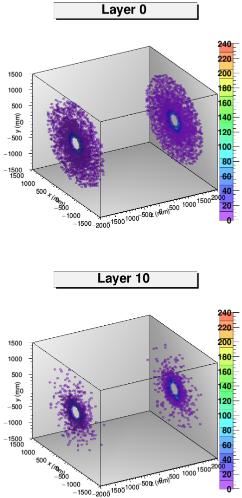
$e^+e^- \to ZH \to 4$ jets: $\sim$ 2100 hits in the EcalEndcaps ▸ Go to event display

3D hit map animation of the EcalEndcaps



Most of the hits are around the beam pipe → Ring of fire

3D hit map animation of the EcalEndcaps



Pair background origins

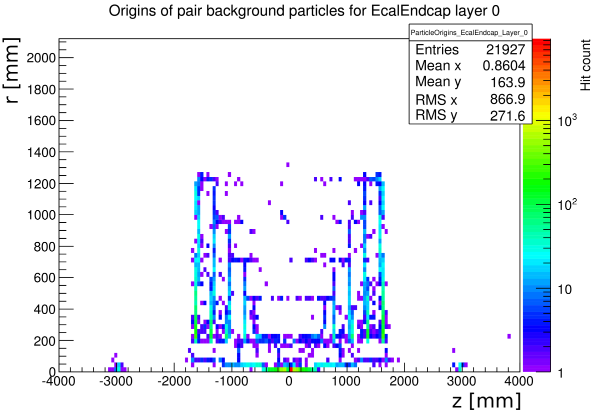
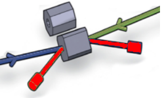


Figure 5 : 2D map of the origins of the pair background particles that hit the EcalEndcap layer 0.

Most of the background particles are coming from the IP as expected. But there are a lot of particles backscattering from the tracker layers and the BeamCal.

NEUTRONS FROM THE BEAM DUMP

FLUKA simulation of the ILC Beam Dump



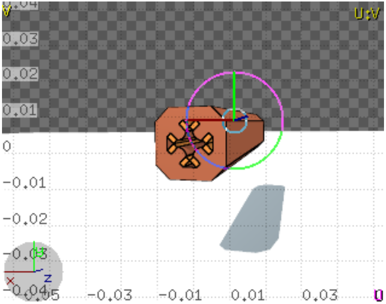
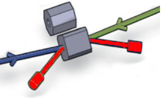
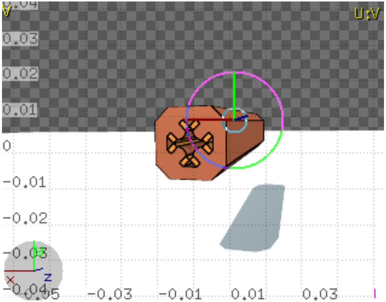


Figure 6 : FLUKA simulation model of one of the ILC lattice quadrupoles.

- The beam is dumped into a water tank after collision.
- Neutrons are emitted that radiate the surroundings.
- Neutrons fly back towards the detectors.

FLUKA simulation of the ILC Beam Dump





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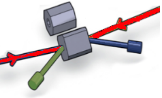
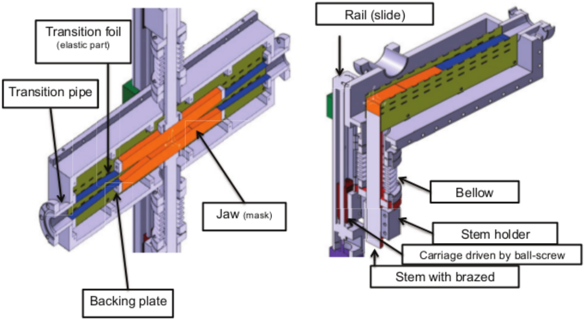
Simulation

With Benno List (DESY): Pluging the real extraction line lattice into FLUKA.
Realistic simulation of the interaction between the neutrons,the lattice and the detectors.

BACKGROUND FROM BEAM HALO COLLIMATORS

Beam Halo collimators





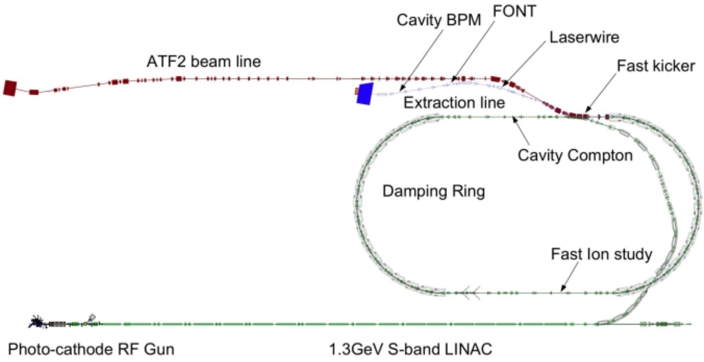
By driving collimator blocks into the beam:

- The beam halo is cut off.
- Wakefields are induced.
- New background is produced.

Accelerator Test Facility 2

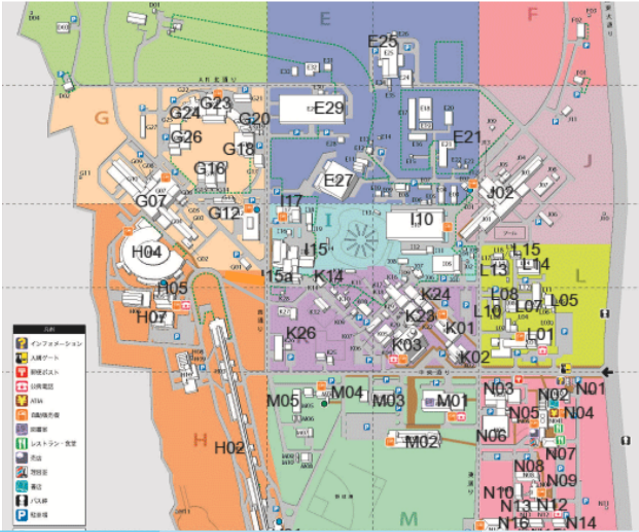
ATF2

- Test bench for the Final-Focus system of the ILC → very close to the ILC 500
- Achieving 40 nm beam size (goal: 37 nm)



Accelerator Test Facility 2

ATF2: Extension of the Accelerator Test Facility (ATF) at KEK



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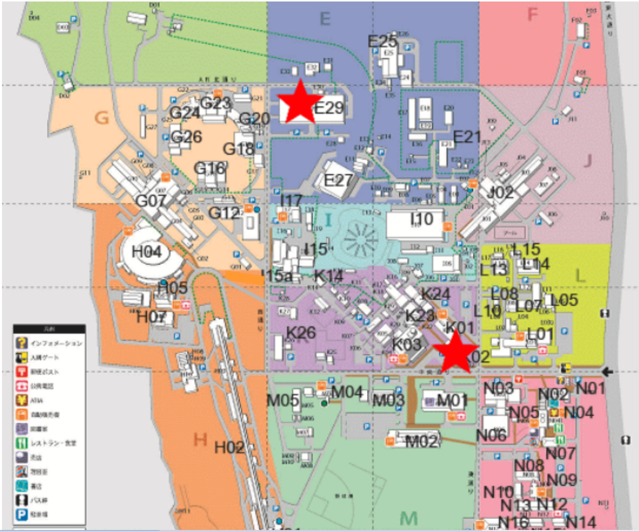
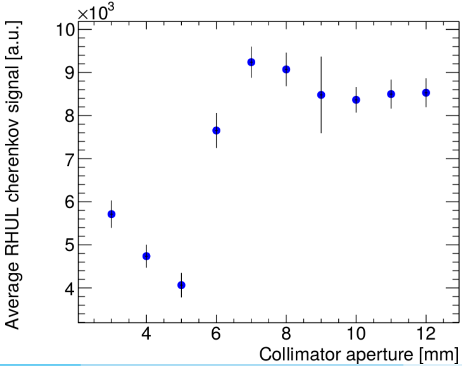


Beam time at ATF2 in March

At the moment, I am joining the ATF2 beam time, thanks to the E-JADE program (www.e-jade.eu).

- Measuring the background generated by the installed beam halo collimator with Cherenkov detector
- Simulating the background with BDSIM

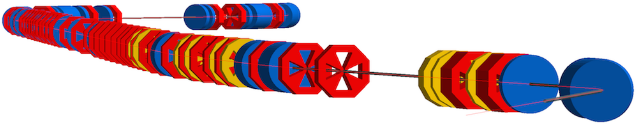


FIRST RESULTS

BDSIM

BDSIM is:

- a Geant4 extension toolkit for simulation of particle transport in accelerator beamlines
- developed at RHUL



Accelerator descriptions from other tools such as MADX can be converted to BDSIM input.

Cultural experiences

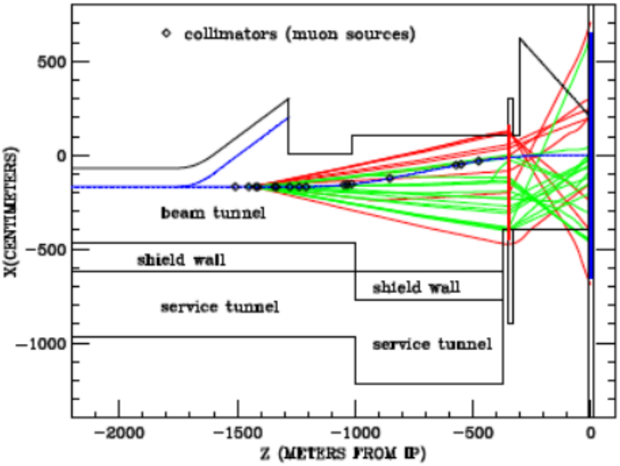
Overnight stay in a traditional ryokan -

near the Snow Monkey park in Nagano.

MUONS FROM SPOILERS

Muon from spoilers

Lewis Keller: MUCARLO simulation of the muon tracks in the BDS tunnel.
4-vectors of muons at IP are available to simulate muons in detectors



Muons at IP

Number of the muons at the IP

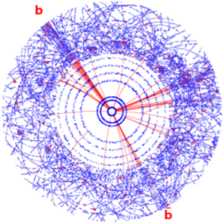
Tunnel Condition	#/Bunch in 6.5m Detector Radius	#/200 Bunches in 2.5m TPC
No spoilers	138	9648
5m magnetized rectangular wall spoiler (z = 344-349m from IP) fill tunnel	25	1008
3 doughnut spoilers (z = 1408, 1227, 1143m from IP), L=5m R=0.7m	3.3	273
Wall + doughnut spoilers	0.5	17

Summary

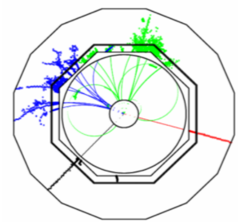
Current effort in simulating the background at the IP:

- Background from beam-beam interactions
- Neutron background from the beam dump
- Background from Beam Halo collimators in the Final-Focus system
- Muon background from spoilers

The LHC $pp \to H + X$



The ILC $e^+e^- \to HZ$



Thanks!

どうもありがとうございます。

References

- /ilc/user/a/aschuetz/GuineaPig
- T. Behnke, et al. *The International Linear Collider - Technical Design Report*, 2013.
- N. Fuster-Martínez, IFIC (CSIC-UV), et al. *Design study and construction of a transverse Beam Halo Collimation system for ATF2*, 2015. http://accelconf.web.cern.ch/AccelConf/IPAC2015/papers/wepmn059.pdf
- MUCARLO simulations: Lewis Keller (SLAC)
- Mark Thomson. *Physics and Detectors at the ILC*, 2013. https://www.royalholloway.ac.uk/physics/documents/pdf/events/particlephysicsseminars/13-14markthomson23oct2013.pdf

Additional Material

3. *ILC*
    - Some facts about the SiD detector

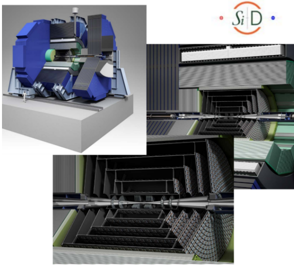
4. *Additional SiD simulation plots*
    - Higgs event display
    - Hit maps of the EcalEndcap
    - Absolute time of hits
    - Hit energy deposition

5. *The Final-Focus system*

SiD detector

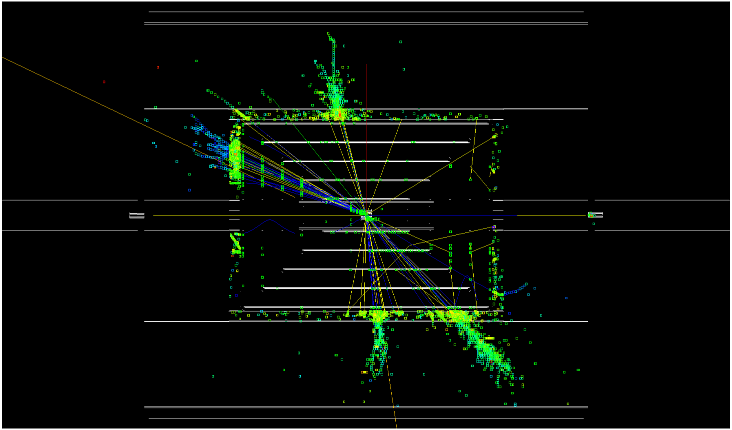
SiD has a very convincing design:

- compact and robust
- full silicon vertex detector and tracker
  Vertex detector:
  - $<5\,\mu\text{m}$ resolution
  - Momentum resolution $\sim$ 2-5 $\times 10^{-5}$ GeV^{-1}
  - $\sim 0.1\,\%$ X_0 per layer
  - Single bunch timing resolution
  - $\cos(\theta) \approx 0.984$
- highly granular calorimetry optimized for Particle Flow (ECAL: radiation length = 26 X_0, EM energy resolution $= 0.17/\sqrt{E} \bigoplus 1\%$)



$e^+e^- \to ZH \to 4$ jets in the SiD detector

$e^+e^- \to ZH \to 4$ jets in the SiD detector
Displayed with WIRED4



Go back

Hit maps of the inner most EcalEndcap layer

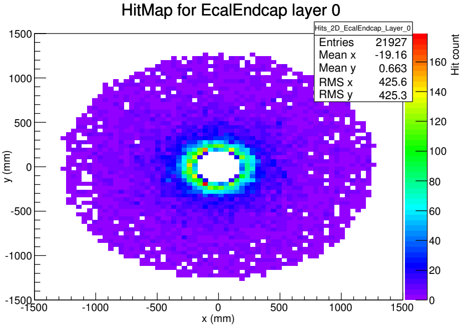


Figure 7 : 2D hit map of the hits from a full pair background train in the EcalEndcap layer 0.

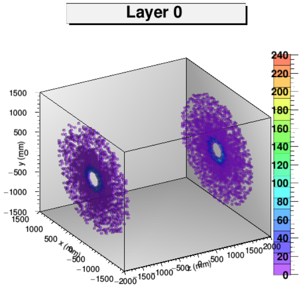


Figure 8 : 3D hit map of the hits from a full pair background train in the EcalEndcap layer 0.

Most of the hits are around the beam pipe → Ring of fire

Absolute time of hits in the EcalEndcaps

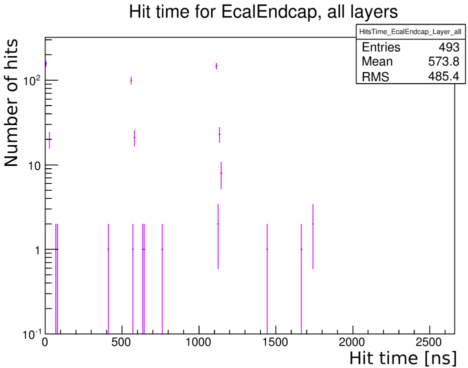


Figure 9 : Number of particles arriving at the EcalEndcaps as a function of the absolute time.

The pair background particles don't arrive all at the same time.
The second smaller peak of particles are backscatter particles.

Absolute time of hits in the EcalEndcaps

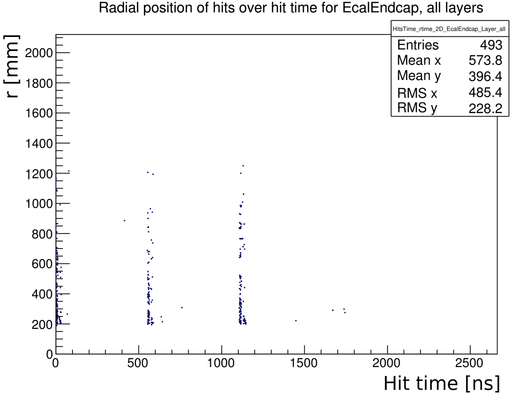


Figure 9 : The radial position of the particles arriving at the EcalEndcaps.

The pair background particles don't arrive all at the same time.
The second smaller peak of particles are backscatter particles.

Energy deposition of hits in SiD-EcalEndcaps

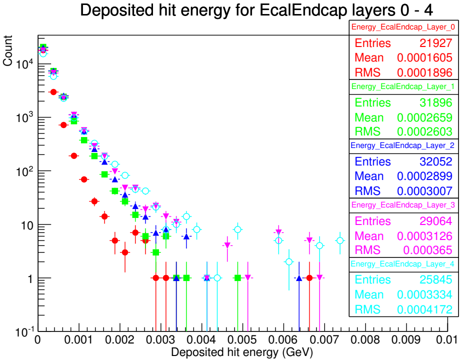


Figure 10 : Energy distribution of the hits in the first five layers of the SiD EcalEndcaps

The distributions reach up to about 8 MeV.

The Final-Focus system

The Final-Focus (FF) uses:

- Strong compact superconducting quadrupoles to focus the beam at the IP (single collision point with a 14 mrad beam-crossing angle)
- Sextupoles providing local chromaticity correction
- Two superconducting octupole doublets, which use nonlinear focusing to reduce the amplitude of beam-halo particles while leaving the beam core untouched $\rightarrow$ permitting larger collimation amplitude
- Collimators and spoilers to prevent the beam halo and background particles from entering the detectors