Study of high energy electron reconstruction for the Beam Calorimeter at ILC

Madalina Stanescu-Bellu

DESY - Zeuthen

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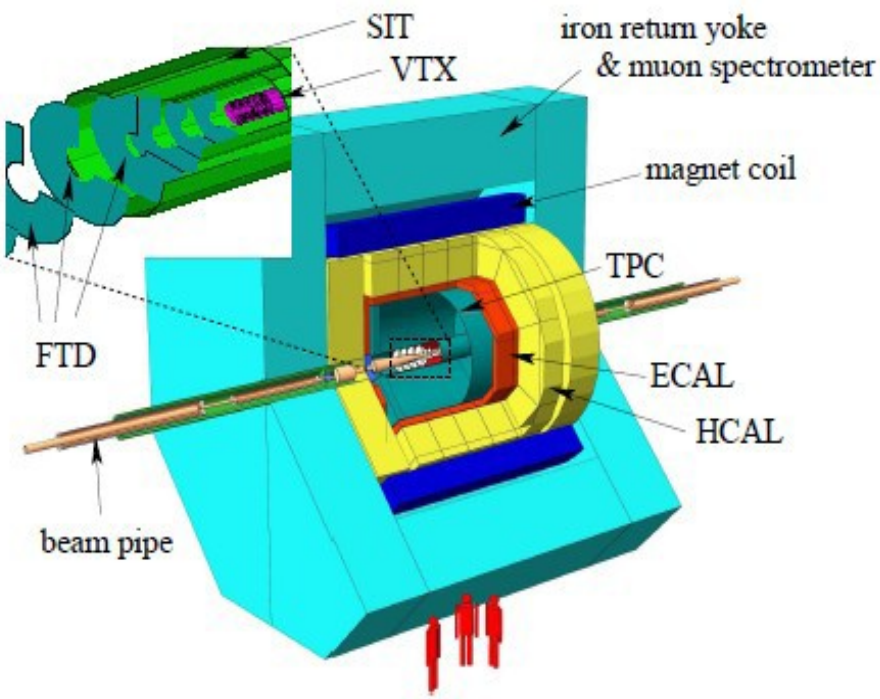
Detector Concepts at the ILC. The ILD Concept



Detector Concepts:

1) Large Detector Concept

2) GLD

1 and 2 merged into the International Large Detector (ILD)

3) Silicon Detector SiD

4) the 4th concept

Forward region of the ILC

Improves the hermeticity (covers more an precise area for detection) down to few mrad polar angles.

Luminosity detector (LumiCal) –

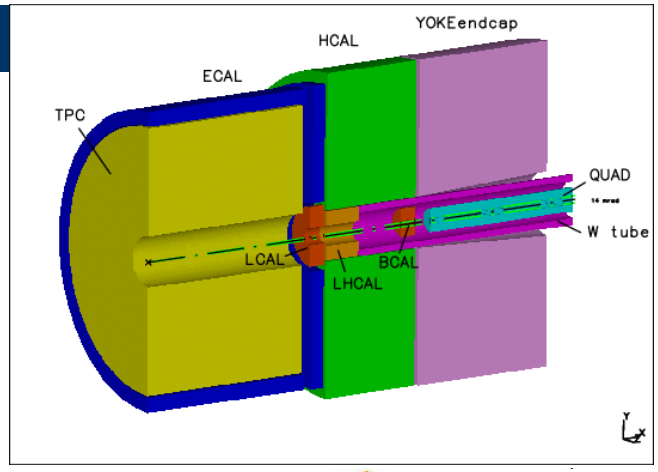
-> precise luminometer measuring the rate of Bhabba events

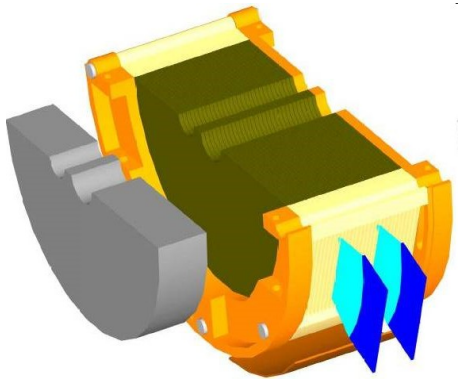
-> acts as mask (reduces background)

Beam calorimeter (BeamCal) –

-> Polar angles 5->40 mrad (fills the whole of LumiCal)

-> reduces the backscattering of pairs into the inner ILC detector

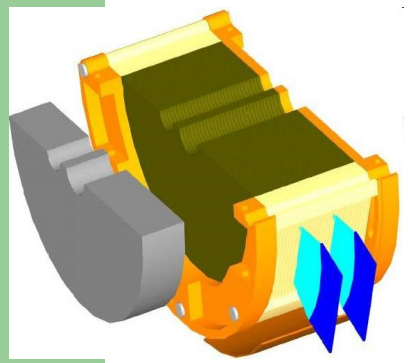




Grey = Graphite (10cm, to reduce low energetic backscattered particles from Bcal)

Green = BeamCal (30layers)

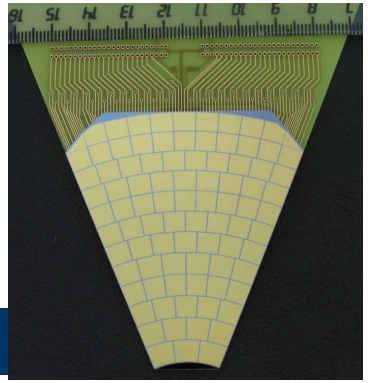
BeamCal



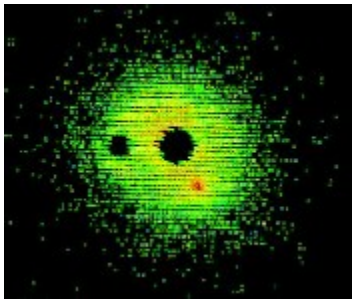
EM longitudinal sandwich calorimeter
30layers of Sensors(Diamond)
alternating with Absorbers(Tungsten)

Length=12cm; OuterRadius=15cm
14mrad beam crossing angle

Sensors must resist to high radiation



*One sensor segment (17 rings divided into 8mm*8mm pads*

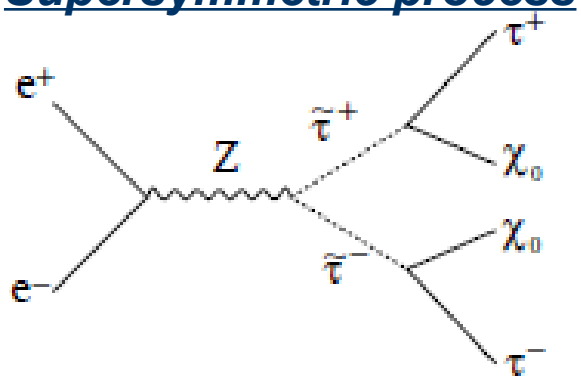


green=Beamstrahlung pairs
black=beam pipes
red=reconstructed high energy electron

Analysis of vast amount of deposited energy from e+e- beamstrahlung pairs → fast estimation of the luminosity *and* ***post collision measurement of colliding beams parameters***

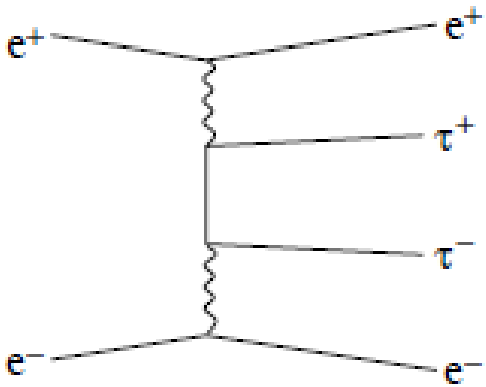
BeamCal – task

(1) ***Supersymmetric process***



The Neutralinos escape without being detected => only the taus are visible.

(2) ***2Photons – SM process***



QED process with high cross-section, background from process (1).

Can be suppressed by electron or positron tagging.

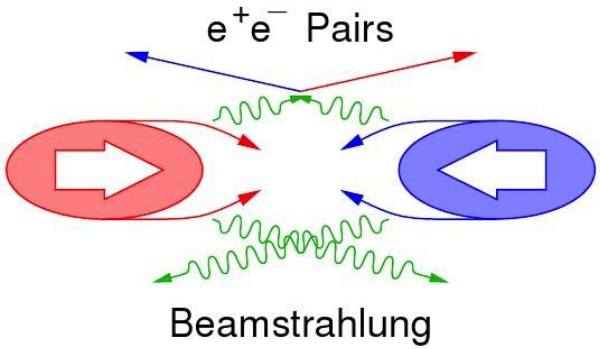
Conclusion: BeamCal should reconstruct the Single High Energetic Electrons from (2).

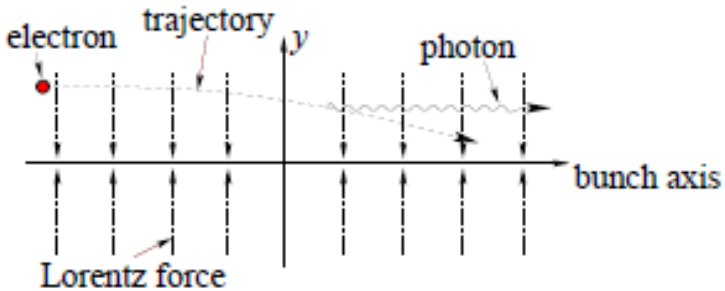
Guinea Pig - BeamBeam interaction simulation

When linear e+ e- beams go through each other

- **The electric field is mainly compensated, while the magnetic fields of the bunches add up.**
- **Bunches are squeezed by the magnetic field → LUMINOSITY ENHANCEMENT →**
- **Transverse acceleration →**
- **Energy loss in the form of synchrotron radiation: BEAMSTRAHLUNG → BACKGROUNDS**

e+e- from the beams→ gamma-gamma → Beamstrahlung e+e-





Guinea Pig - BeamBeam interaction simulation

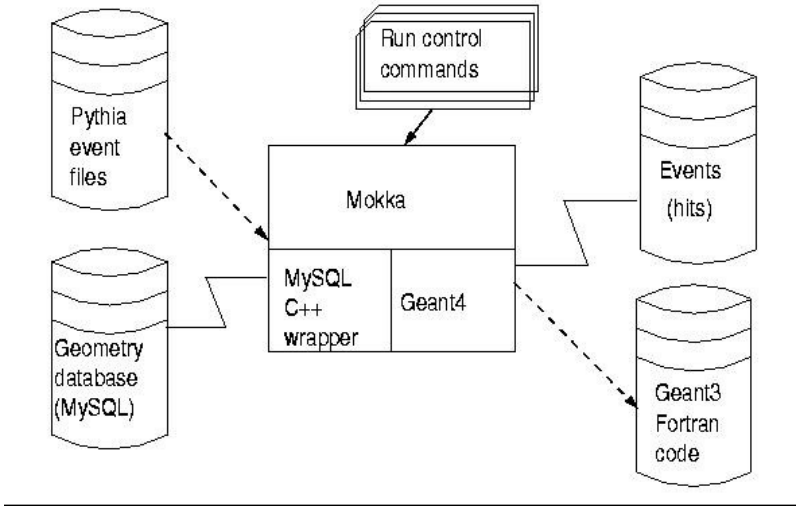
MONTE CARLO BACKGROUND Simulation from collision of two beams (e+e- or e-e-).
Energy of each beam = 250GeV => a total 500GeV Central Mass Energy

BEAM AND ACCELERATOR PARAMETERS:	***NOMINAL***	***SB-2009***
Number of bunches per train	*2625*	*1312*
Particles per beam	*2.0 x 10^10*	*2.0 x 10^10*
Horizontal Beamsize	*640 nm*	*470nm*
Vertical Beamsize	*5.7 nm*	*5.8 nm*
Horizontal Emittance	*10.0 mm x mrad*	*10.0 mm x mrad*
Vertical Emittance	*0.040 mm x mrad*	*0.035 mm x mrad*
Luminosity	*2 x 10^34*	*1.5 x 10^34*

OUTPUT:
ASCII format files, 1 file for 1 Bunchcrossing (BX), with Beamstrahlung e+ and e- parameters:
Energy in GeV/c (positive for e-, negative for e+); Velocity (v/c): vx,vy,vz

Mokka - general software schema

- → C++ simulation using GEANT4 (which simulates passage of particles through matter)
- → GEOMETRY DATA DRIVEN, several detector models in MySQL geometry database.
- → ALL DETECTORS INCLUDED IN SIMULATIONS (comparing to BECAS, another BeamCal simulation software, which has only BeamCal)
- → Runtime for 1BX:
  - → MOKKA: 3 days
  - → BECAS: 0.5 day
- → Magnetic Field in MOKKA can be:
  - → Constant on Z axis
  - → 1D field map on Z axis
  - → 2D field map



Mokka- Parameters and files

INPUT: Guinea Pig files (1 file = 1 BX)

OUTPUT: LCIO format files (1 file = 1 BX)

PARAMETERS:

DetectorModel ILD_00fw – **old BeamCal geometry** with 1D field map
ILC_Main_Crossing_angle 14mrad (angle between beam pipes)
LorentzTransformationAngle 7mrad.
Mokka version: 06-07-patch02

BEAMSTRAHLUNG BACKGROUND FILES:

2000 BXs of nominal accelerator and beam parameters passed through Mokka (from DESY Hamburg)

SIGNAL FILES:

- high energetic electrons passed through Mokka (~4000 for each of 50-100-150-200-250GeV), with enough distribution on the impact points for each radius of BeamCal
- another set for Calibrating (~2000 for each of the 5 energies), at the central radii

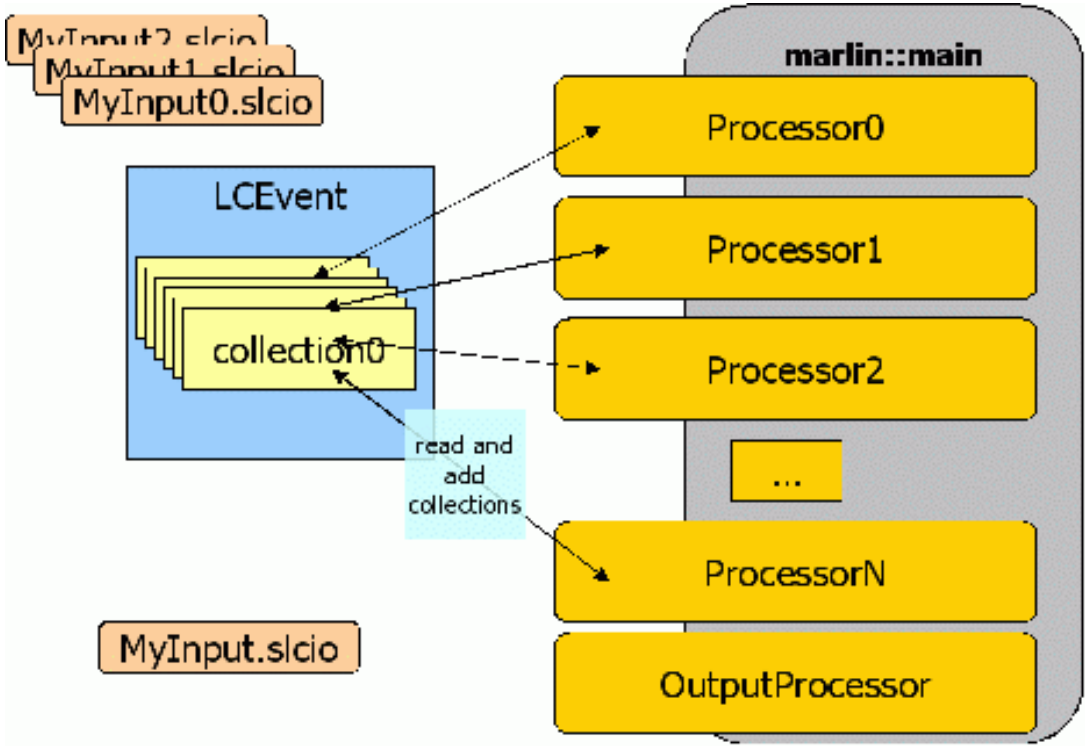
Marlin

Modular Analysis and Reconstruction for the LINear collider

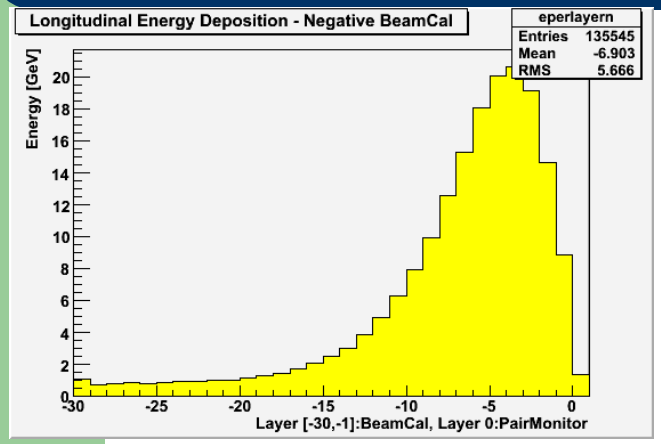
We wrote a ***processor*** ***which converts:***
SLCIO format file generated by Mokka, into ROOT format files necessary for the reconstruction algorithm.

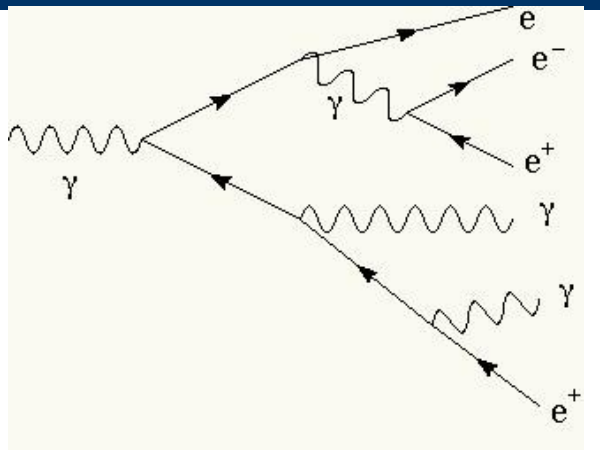
ROOT file:

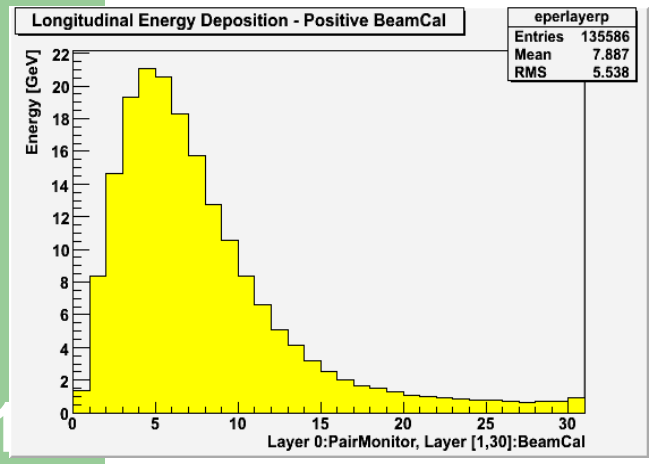
tree with a branch for each pad :
coordinates of pad and total energy deposited in the pad from the hits.



Beamstrahlung pairs - longitudinal shower development - 2000BXs in Mokka





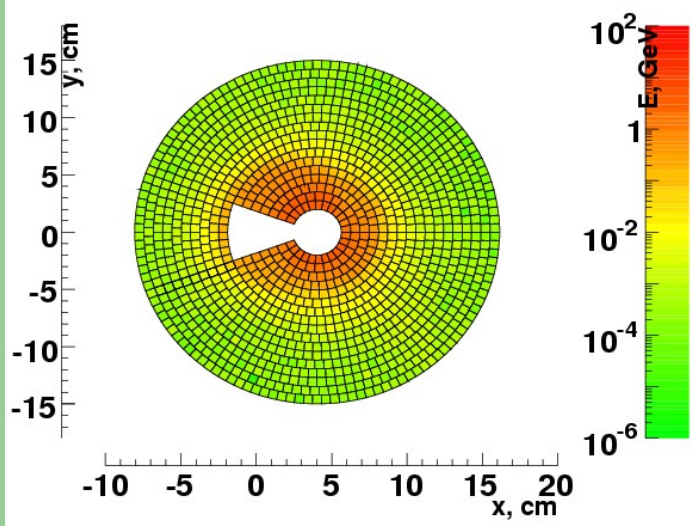


Visualization of an EM shower evolution: sequence of bremsstrahlung and pair production of incoming electrons/ photons.

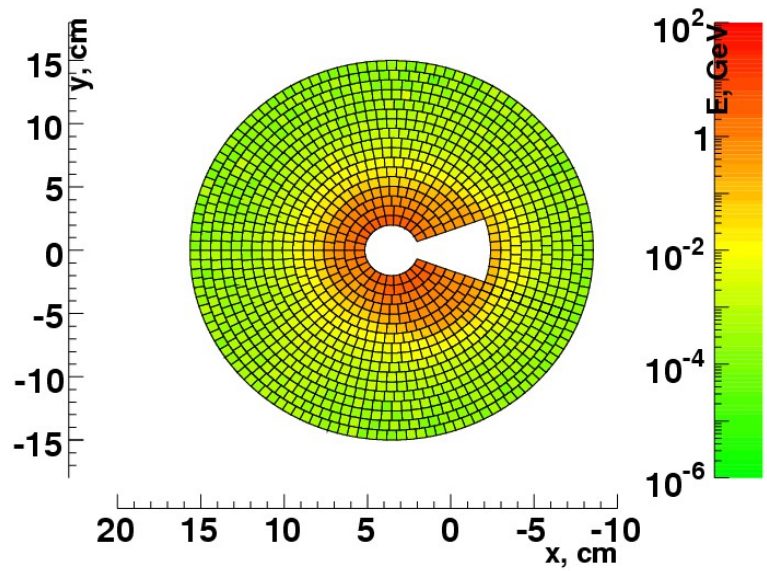
Maximum for Longitudinal Shower: 4th BCal layer. 1Absorber layer=1Tungsten radiation length=0.35cm

In 1 radiation length, electrons loose all but 1/e of energy by bremstrahlung, and photons 7/9 of energy by pair production.

Beamstrahlung pairs - transversal shower development – 2000BXs in Mokka



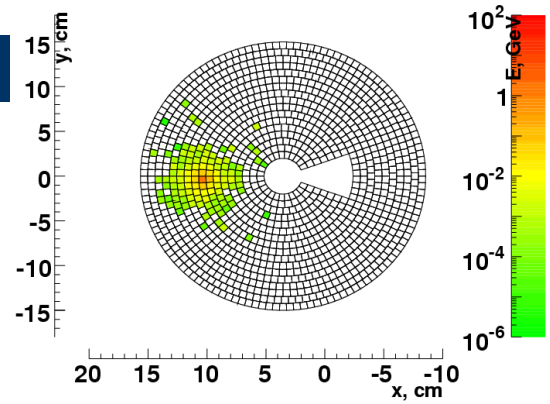
BCAL ON NEGATIVE Z



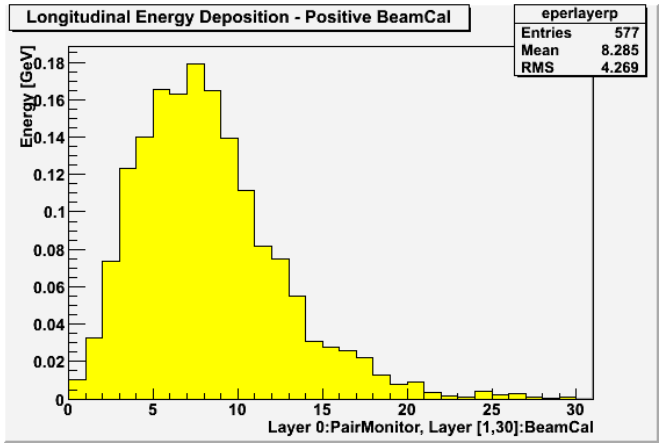
BCAL ON POSITIVE Z

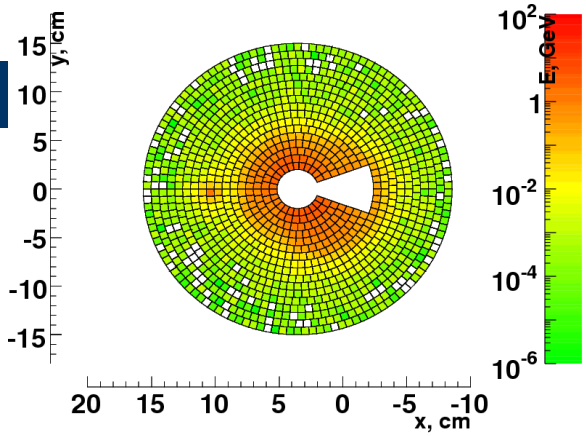
Maximum development around the first radii. 1Cell Size= 0.8 RM (1 Moliere Radius RM has 90% of all transversal E). White DeadArea is for Beam Pipes passage with 14mrad Crossing Angle, outgoing pipe being in the middle.

Single High Energetic Electron shower development – 100GeV in Mokka



Transversal shower of 100GeV electron.





Transversal shower of 100GeV electron on top of Beamstrahlung Background.

Longitudinal shower of 100GeV sHEE. Peak at 7th BCal Layer, deeper than background.

Reconstruction Algorithm

Background influence:

- From 10 BXs of beamstrahlung background, calculate Mean and RMS for each pad
- Superimpose an 11th background BX with 1 single High Energetic electron (1 sHEe)
- Subtract from each cell the background Mean and 1 RMS (against fluctuations).
- Search for clusters:

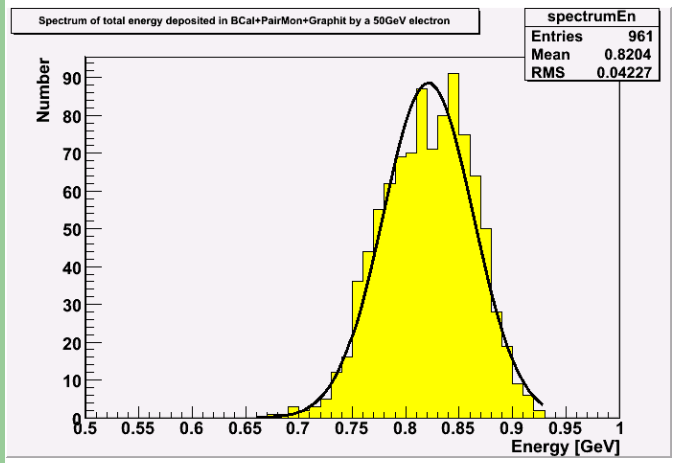
Cluster definition:

- 1 cluster is made of towers with more then 10 consecutive cells

- Around the tower with maximal energy (Enmax), search neighboring towers
- If one of the neighbor towers has En>0.9 Enmax, then search neighbors for this tower too

- **A cluster is considered a reconstructed electron if the Energy, Radius and Phi are within 1 RMS of the original values of the generated sHEe.**

Calibration of BeamCal



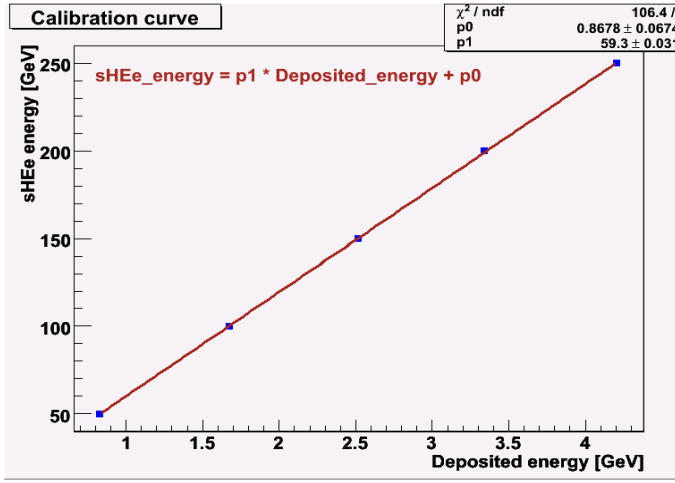
The detector acts with a linear response to the shower (because not all is measured by the sensors, most is deposited in the absorbers).

Generate sHEEs with energy 50-100-150-300-250GeV, ***that have the shower ~fully inside BeamCal*** (i.e. at the medium radia) and plot energy spectrum

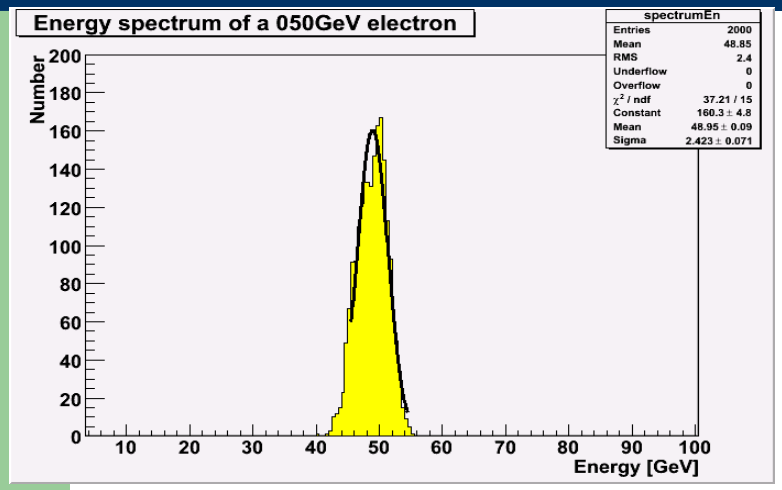
Make Gauss fit, use the Means in the ***calibration curve and fit linearly.***

Calibration result will be used in the algorithm to identify the initial energy from the reconstructed cluster :

sHEe energy = 59.3 * deposited energy + 0.86



Energy resolution



The energy resolution of a calorimeter can be parameterized as
σ = p2*E + Resolution*sqrt(E) + p0 ***Where:***

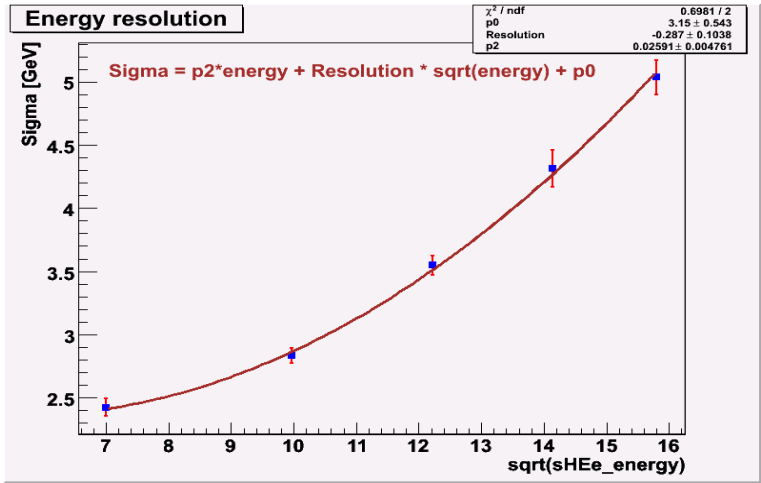
1st term = detector non-uniformity and calibration uncertainty

2nd term = Resolution = statistics-related fluctuations (intrinsic shower fluctuations, sampling fluctuations)

3rd term = electronic noise

Use the same entries from the calibration histograms, but scaled with the calibration result. ***fit polynomially.***

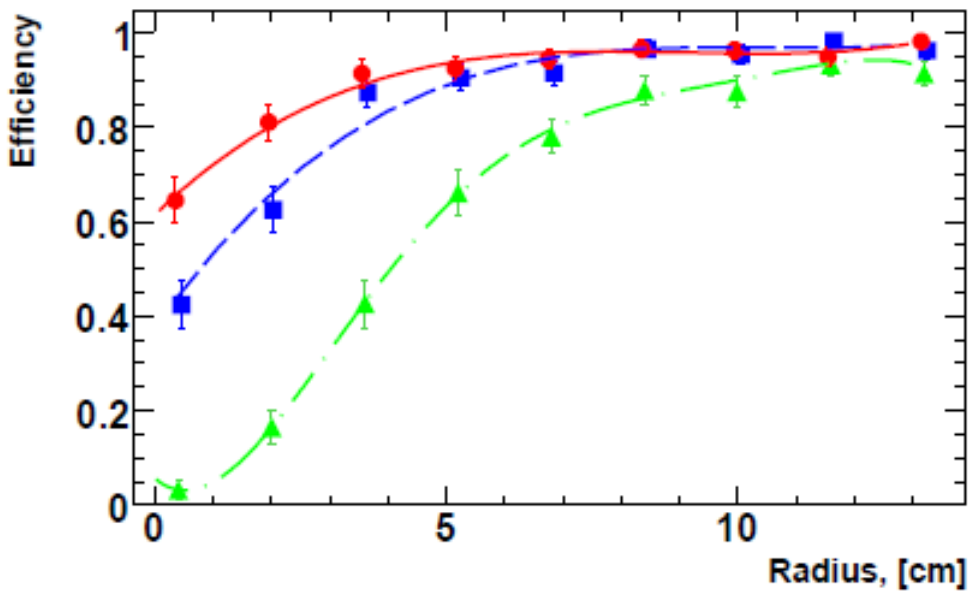
Energy resolution = 28%



Efficiency analysis - BeCas background files - BeCas signal files

Eff = Nb of reconstructed clusters / Nb of generated signal electrons

Electrons of higher energies or at higher radii are better reconstructed.



Reconstruction efficiency for sHEe as a function of radius: 50 (triangle), 150 (square), 250 (circle) GeV nominal beam parameters.

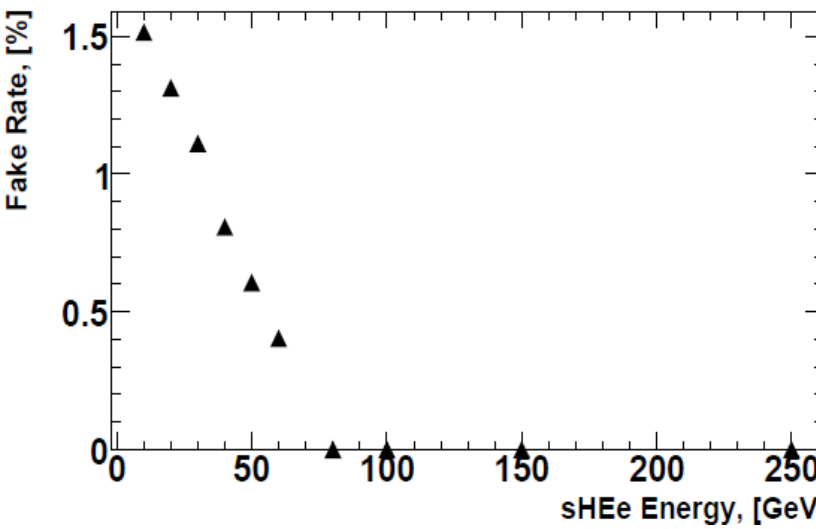
Fake rate analysis - Mokka background files - BeCas signal files

→ BXs of Beamstrahlung background can be mistakenly interpreted as sHEe.

→ Causes: ***<u>the Beamstrahlung spectrum has a tail at high energies; large local fluctuations in the background.</u>***

→ We apply the algorithm in the same way, but use the 11th background BX without superimposing with a sHEe.

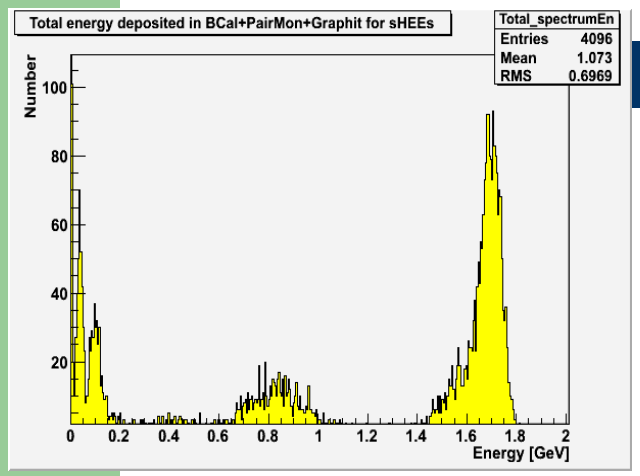
→ For every energy E, plot number of reconstructed signal electrons of energy >= E

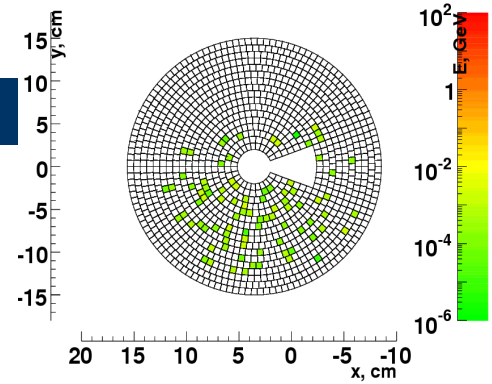


<u>Fake Rate = 1.5 %</u>

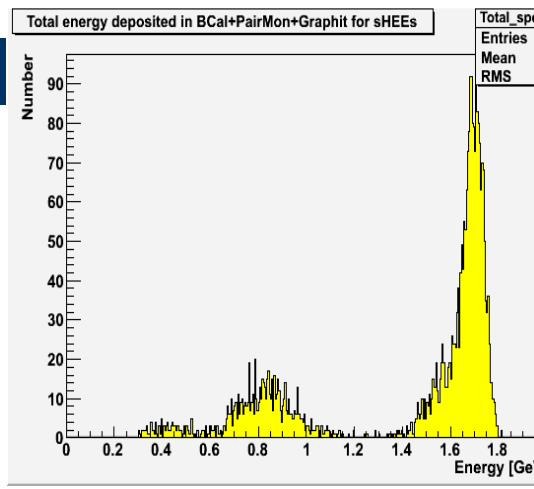
Higher than 60GeV the fake rate is too small and we need higher statistics to investigate more precisely.

Generation of signal files – new set





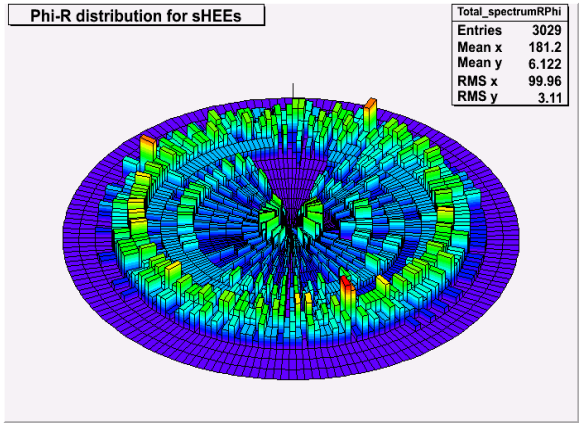
CUT the low energy (which are mainly showers with no defined impact point) ---------->



I prepared in MOKKA a new set of signal files, 4000 for each energy.

PROBLEM:

It seems there are no impact points from the 12th radii forth (if the momenta are changed to direct the electron to higher radii, I just get showers with no defined impact point (probably because of backscattering).



Conclusions and future steps

What we did:

- We simulated in Mokka 2000 BXs of beamstrahlung pairs, with nominal beam parameters.
- We simulated in BeCas Single High Energy Electrons (sHEs)of 50-100-150-200-250 GeV and superimposed them on the background.
- An algorithm was developed to detect a sHEE on top of the pair background, and first efficiency and fake rate results were done.

Next steps:

- Tuning of the algorithm (change the number of RMS's threshold)
- Optimization of calorimeter segmentation. (both for smallest fake rate and highest efficiency in reconstruction)
- A new set of signal files was generated in Mokka. Algorithm will be run on these too.

Outlook:

- Results of this analysis will be used for stau production studies in the ILD detector.

THANK YOU VERY MUCH FOR LISTENING !!

Thanks to Olga Novgorodova-Desy Z. and to Mikael Berggren-Desy H. for support !!