CLIC beam related background studies and in-situ calibration of LumiCal

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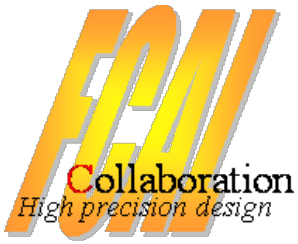
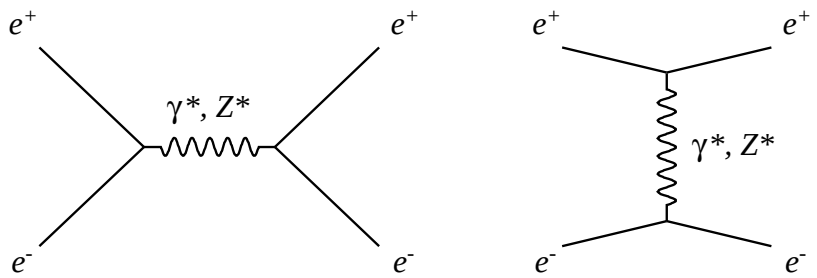


Outline

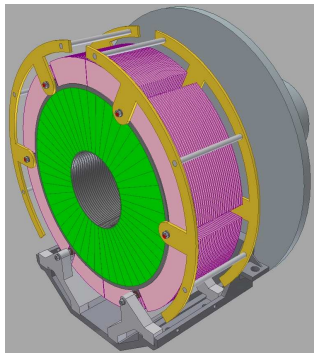
Luminosity Measurement at the CLIC

- Bhabha scattering as gauge process.
- At $3\,\mathrm{TeV}$ CMS energy, one Bhabha event is expected every 10 bunch trains.
- LumiCal - reconstruct EM showers and provide measurement of the integrated luminosity.



(a) s channel (b) t channel

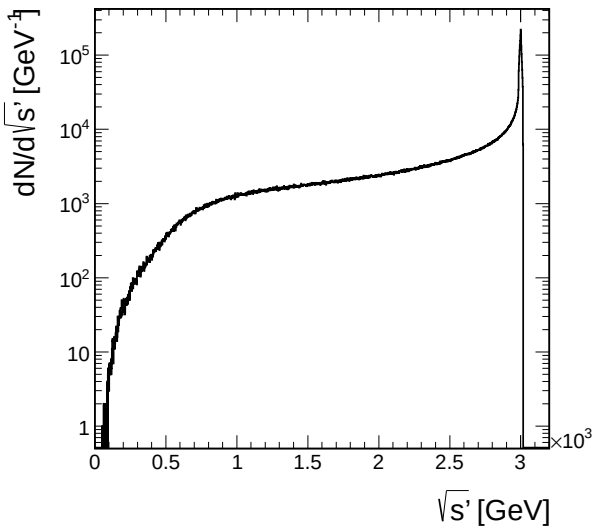
Feynman diagrams of Bhabha scattering process



Mechanical structure of the LumiCal

In Situ Energy Calibration

- Need to determine the LumiCal energy scale. This will allow to scale from the charge collected in the calorimeter to the energy deposited by EM showers.
- Need to calibrate in situ because small changes in energy scale might occur during operation time.
- Need a reference point for scaling - most probable energy of luminosity spectrum ($3\,\mathrm{TeV}$).



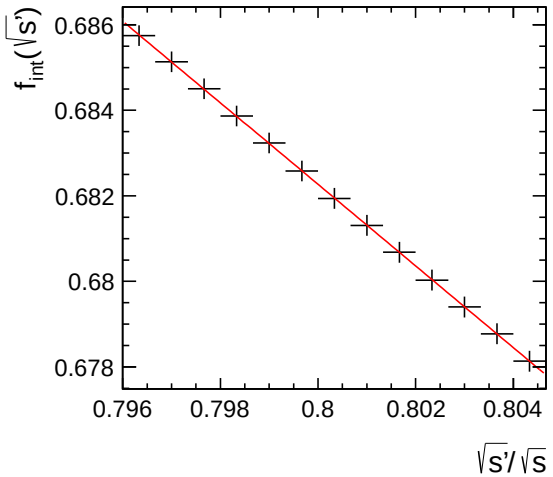
(Luminosity spectrum as obtained from GuineaPig.)

Requirement on accuracy in energy scale

- Required accuracy in luminosity measurement - 10^{-2}.

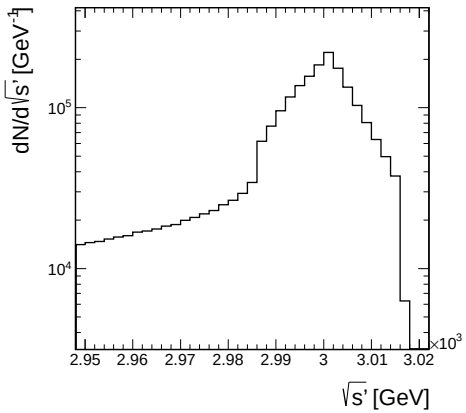
$$\mathcal{L}_{int} = \frac{N_B}{\sigma_B}$$

- Want to control the accuracy of N_B.
  - full containment of shower (fiducial volume $44 < \theta < 80\,\mathrm{mrad}$).
  - energy above 80% of CMS energy.
- Required accuracy in energy scale determined from integrated luminosity spectrum.
  At the CLIC, the energy scale uncertainty has to be below 0.9%.

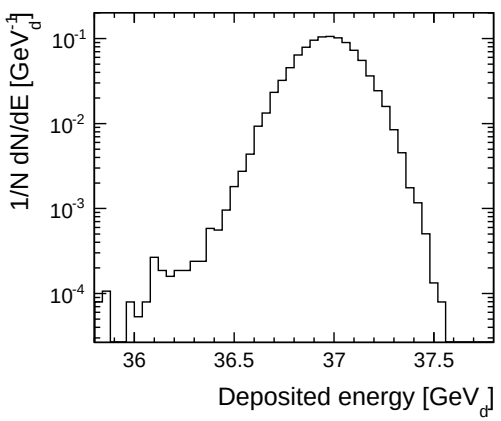


In Situ Energy Calibration

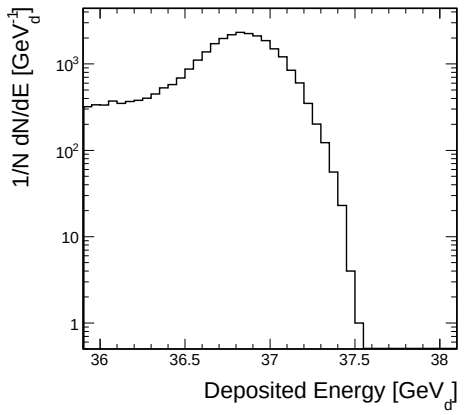
- Luminosity spectrum was fully simulated using GuineaPig (beam-beam effects), BHWide (Bhabha scattering) and MOKKA (full detector simulation).
- Spectrum was reconstructed from LumiCal.
  Only events within fiducial volume were taken into account.
- Spectrum is smeared, $10\,\mathrm{GeV}$, due to beam energy spread.
- Additional smearing, $8\,\mathrm{GeV}$, due to energy resolution of the LumiCal.
  ($a_{res} = 0.21\sqrt{\mathrm{GeV}}$)



Generated

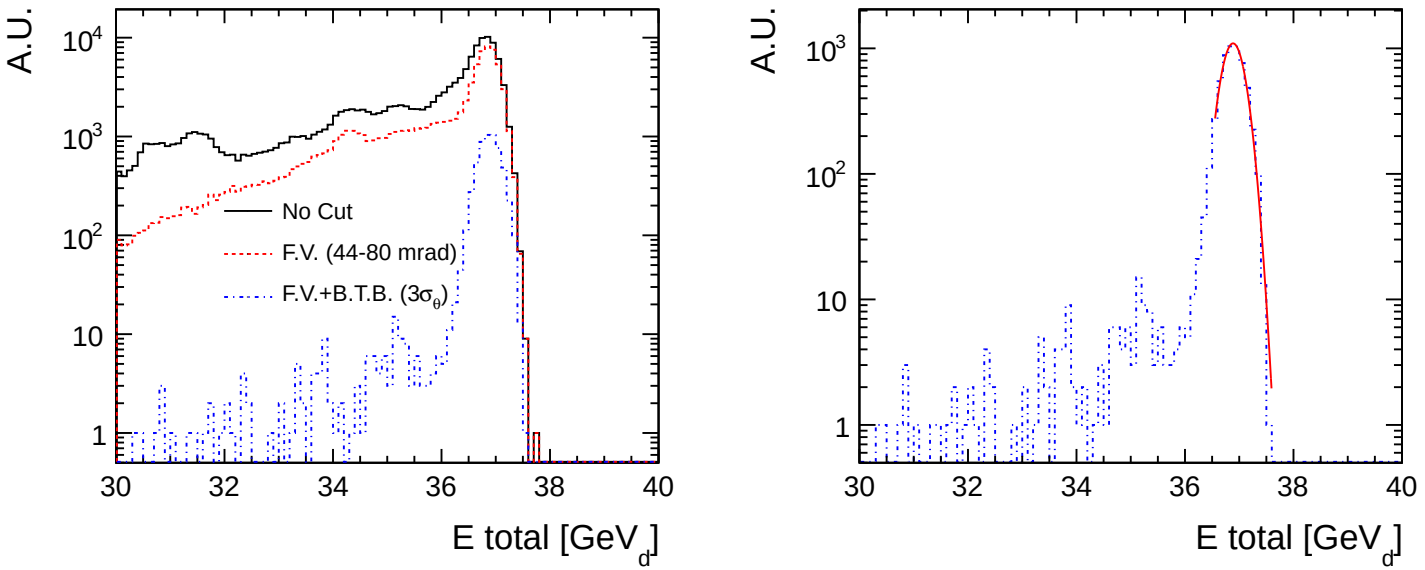


Detector ($3\,\mathrm{TeV}$)



Reconstructed

In Situ Energy Calibration - Results



- Energy scale factor (uncertainty) from CLIC luminosity spectrum is found to be $36.883(0.003)3\,\mathrm{TeV}$
  for statistics accumulated during ~ 0.13 years assuming $\mathcal{L}_{int} = 500\,\mathrm{fb}^{-1}$ during 1 year.
- Expectation value (STDEV) of total deposited energy from mono-energetic $3\,\mathrm{TeV}$ beam is $36.96\,(0.15)\,\mathrm{GeV_d}$

CLIC beam related background studies

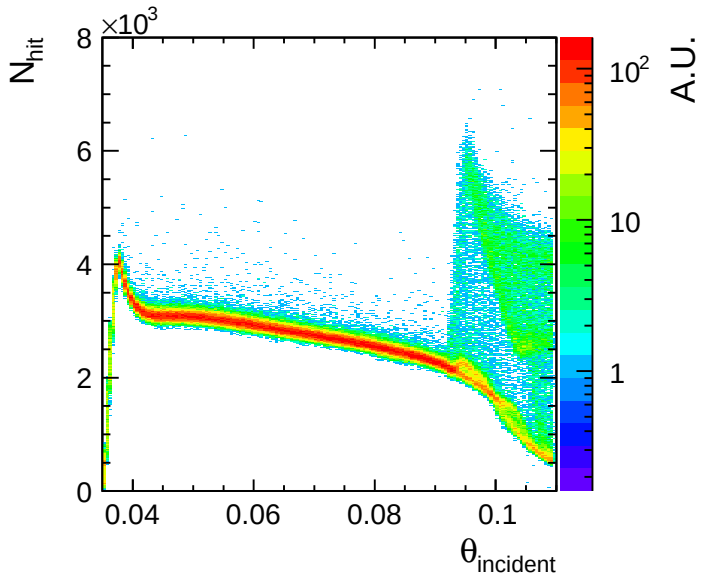
- The need for high luminosity at the CLIC achieved with small transverse-size beams (bunches).
- Beamstrahlung radiation occurs due to very strong beam-beam space charge effects.
- Beam-induced background:
  - $\gamma\gamma \rightarrow$hadrons
  - Incoherent e^+e^- pairs

Background sample for Analysis:

Background classification	# of events per BX	# of BX for analysis
$\gamma\gamma \rightarrow$hadrons	3.2	19,898
incoherent pairs	$3 \cdot 10^5$	936

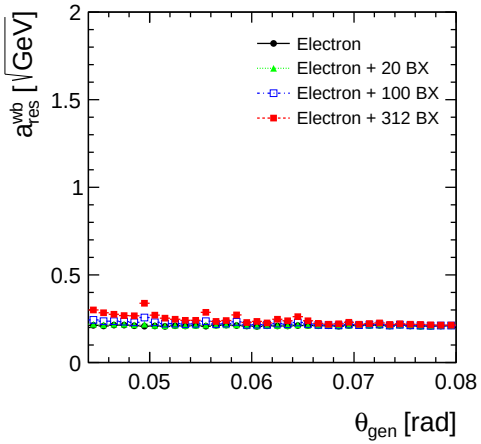
Energy Res. in Presence of Beam-Induced Backgrounds

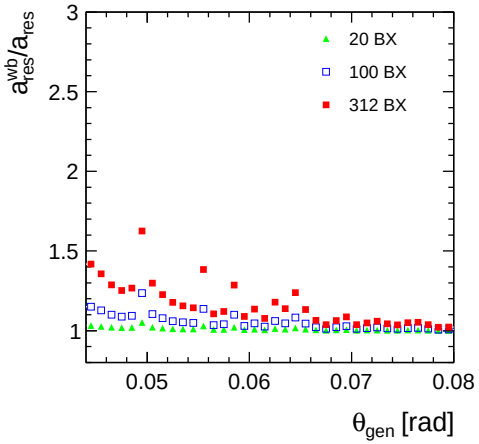
A new method to calculate the energy resolution in presence of beam-induced background was implemented.
This method takes into account the fluctuations in the electromagnetic shower created by the Bhabha scattered particles in the LumiCal.
The results are presented following.



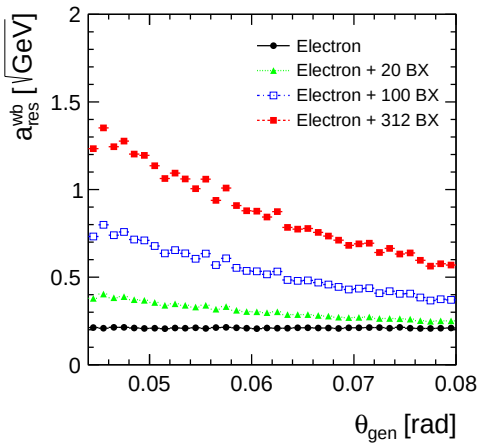
Energy Res. in Presence of Beam-Induced Backgrounds

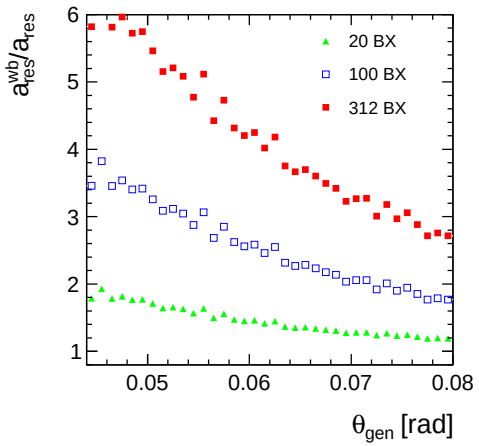
incoherent pairs



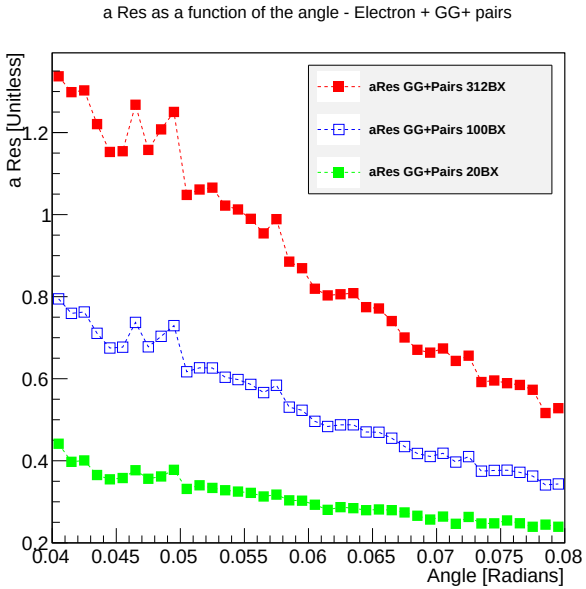


$\gamma\gamma \rightarrow$hadrons





Energy res. in presence of both backgrounds combined



The energy resolution in presence of incoherent pairs- and $\gamma\gamma \rightarrow$hadrons backgrounds combined is deteriorated roughly by factor 6 if summed over a full train, or by factor 2 if summed over 20 BXs.

(Compared to 1.9 and 1.1 when averaging on fluctuations in num. of pads hit by e^- shower).

Summary and Next Steps

Summary:

- LumiCal energy calibration - the energy scale uncertainty has to be below 0.9%.
- Simulated in-situ calibration yields energy scale uncertainty which is well below requirement.
- In-situ calibration of the LumiCal is possible by applying fiducial volume and back-to-back cuts on the total deposited energy spectrum.
- The average signal from beam-induced background may be subtructed, but fluctuations deteriorate energy resolution. Therefore need to minimize the time interval between readout sampling of the LumiCal.

Next steps:

- Full simulation of the luminosity spectrum taking cross section into account.
- In-situ energy calibration of the LumiCal in presence of beam-induced backgrounds.

Thank you!