Electron Tagging with the BeamCal

André Sailer

CERN-PH-LCD, Humboldt-Universität zu Berlin

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Outline

1 Why Electron Tagging

2 Electron Distribution vs. Energy and Angles

3 BeamCal Detector

4 Backgrounds in the BeamCal

5 Tagging Algorithm

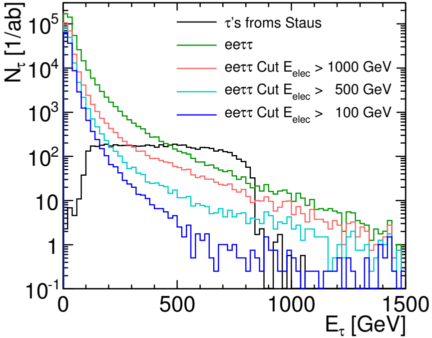
6 Reconstruction Efficiency/Purity

7 Energy Resolution

8 Summary

Why Electron Tagging

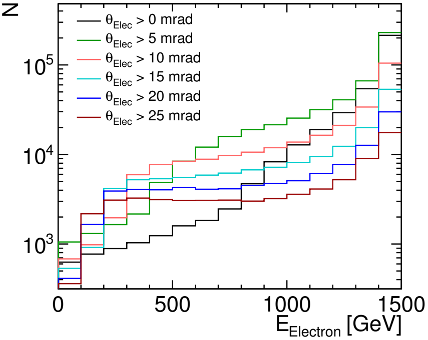
- Searches for slepton pairs
- Event topology: lepton pair and missing energy
- Energy of lepton depends on mass difference between slepton and neutralino (here SuSy Point K' as at CLIC09)
  - $m_{\tilde{\tau}} = 896$ GeV
  - $m_{\tilde{\chi}^0} = 554$ GeV
  - Cross-section: 1.4 fb
- Largest cross-section of background: ee $\rightarrow$ ee$\tau\tau$
  - 2386 fb (from WHIZARD)
- Tag electrons to reject this background

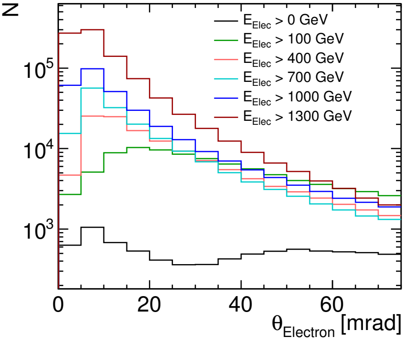


Events with $E_\tau > 10$ GeV and $\theta_\tau > 20^\circ$ for both τ's, Cut for one electron above 10 mrad with different minimum energies.

Electron Distribution vs. Energy and Angles

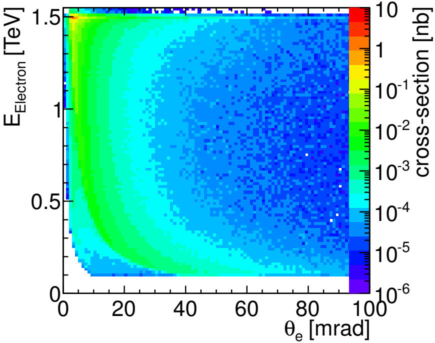
- Plots below: Exclusive categories
- High energy electrons, and forward peaked





Bhabha Event Rate

- Radiative Bhabhas with huge cross-section
- Longitudinal boost can give lower energy electron large angle
- Compared GUINEAPIG/BHWIDE/WHIZARD
- GP underestimates rate at interesting angles > 10 mrad
- WHIZARD and BHWIDE are similar, but WHIZARD $Q^2 > 4$ GeV also cuts 400 GeV at 10 mrad ($p_t = 4$ GeV particles
- Cross-section for single electron with $E > 100$ GeV and $\theta > 10$mrad about 0.1 nb ($\mathscr{L}_{BX} \approx 4 \cdot 10^{-3}$nb^{-1})



WHIZARD

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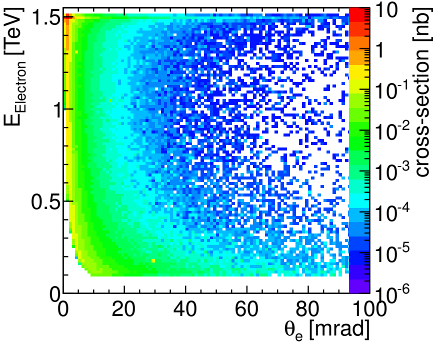
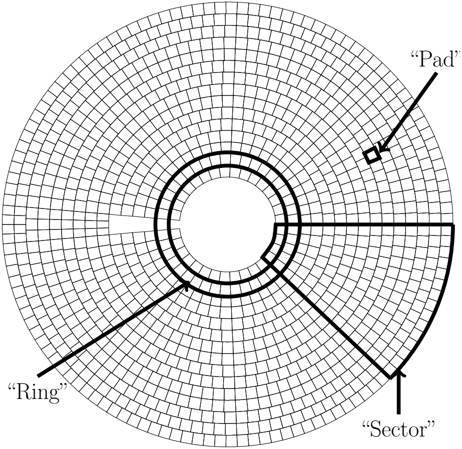


BHWIDE

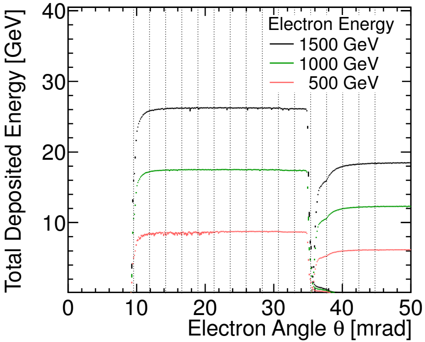
BeamCal Detector

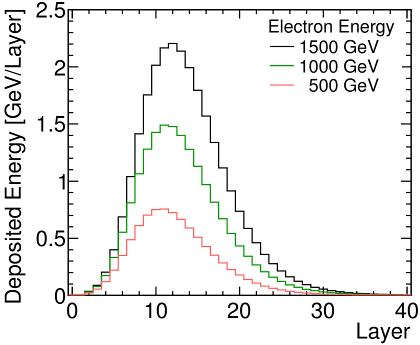
- 10 mrad to 45 mrad
- Absorber for incoherent pairs
- Mask for downstream elements (QD0, BPM)
- Radiation hard sensors required
- Electron tagging for background suppression
- Tungsten sandwich calorimeter, Molière radius of about 1 cm
- Pad size 8×8 mm^2



Signal from high Energy Electrons

- Dense showers from electrons
- 26 GeV Total from 1.5 TeV electron
- Down to 8 GeV for 0.5 TeV electrons
- Maximum near layer 10
- Maximum deposit per pad 2 GeV to 0.7 GeV



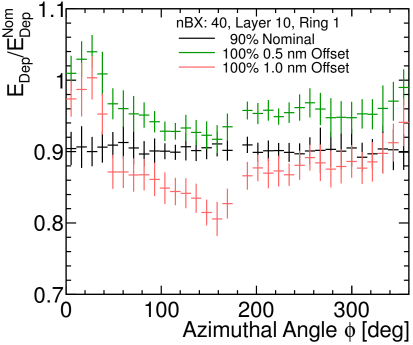


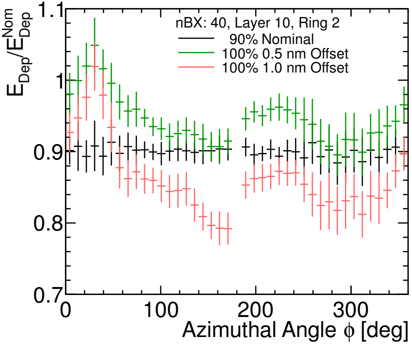
Background in the BeamCal

- Occupancy: Almost every pad sees a hit in every BX
- Energy deposits
  - From incoherent pairs: 33 TeV/BX
  - From $\gamma\gamma \rightarrow$ Hadrons: 150 GeV/BX, will be ignored, other backgrounds also negligible
- Will have to integrate several BX for during one read-out window
- Using 40 BX, or 20 ns integration windows

Background and Vertical Beam Offsets

- Energy distribution in the BeamCal from pairs affected by vertical offset in bunch crossing (due to deflection of incoherent pairs)
- For small offsets (ca. 1 nm) constant in some, decreased in other parts
- Mixing of background events leads to larger fluctuation of backgrounds

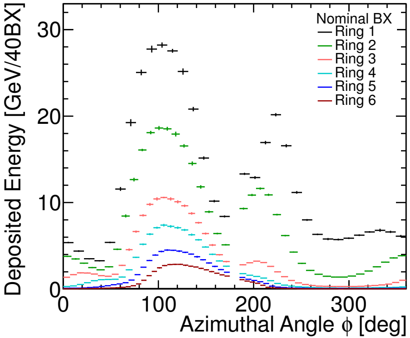




Background and Fluctuations

- Integrated 40 BX, maximum deposit 30 GeV in single pad in layer 10
- Lower average with mixed background samples (50% 0 nm offset, 50% 1 nm offset)
  - Each read-out window selects randomly from the samples
- Fluctuations of deposited energy from backgrounds important for tagging algorithm
  - Standard deviation $\sigma_{\text{pad}}^{max} \approx 0.4$ GeV to 0.5 GeV
  - Larger fluctuations for mixed background samples

Nominal only



Energy deposit for 40 BX of incoherent pair background in layer 10

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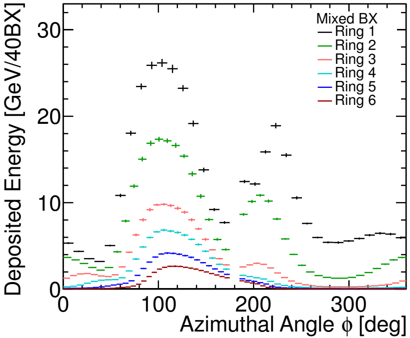

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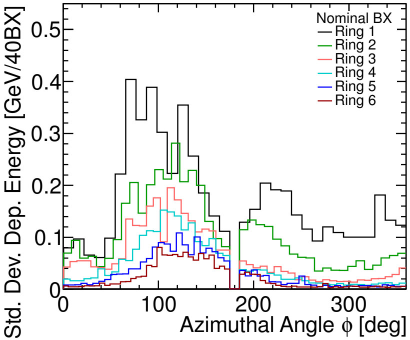

Standard deviation of energy deposit for 40 BX of incoherent pair background in layer 10

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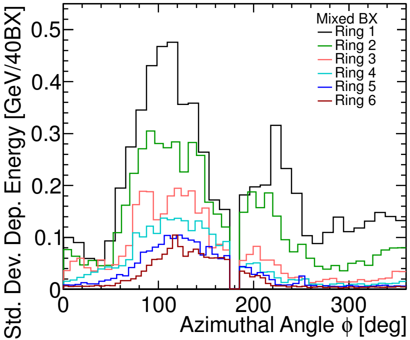
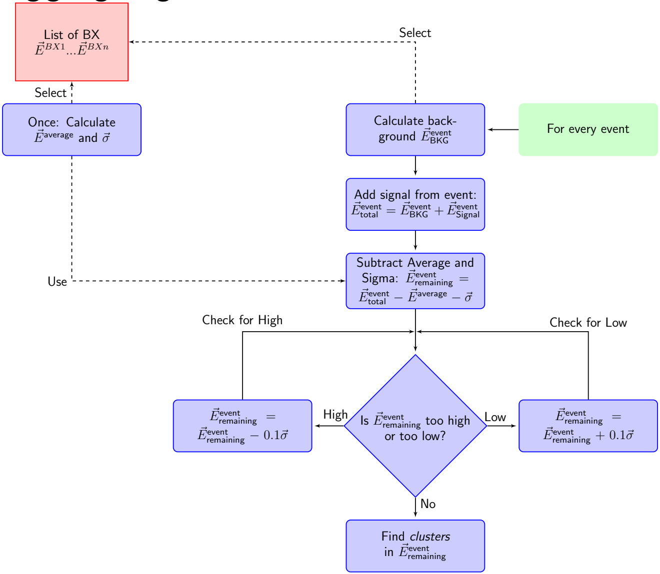


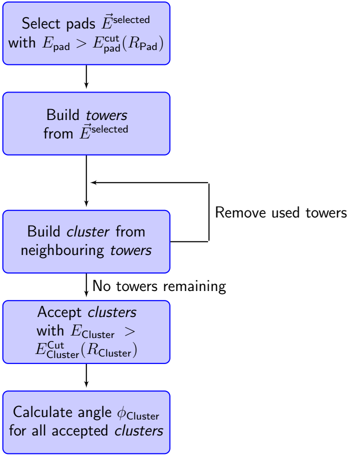
Standard deviation of energy deposit for 40 BX of incoherent pair background in layer 10

Tagging Algorithm



- Event: One read-out window
- $\vec{E}$: Pad energies

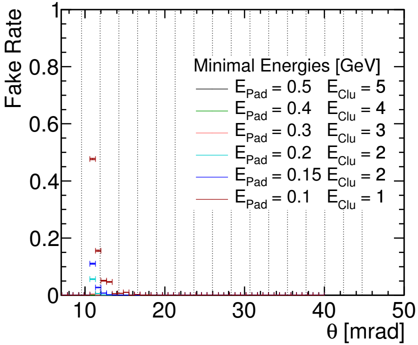
Tagging Algorithm II



- Only select pads in layer 10 and behind
- $E_{\text{pad}}^{\text{cut}}$ depends on ring R of pad
- *Towers* are pads in the same ring and at the same ϕ in different layers
- *Tower* needs at least 4 pads
- Largest *Tower* is used as first seed for search

Reconstruction Purity

- Tuned algorithm to reject all clusters not caused by these high energy electrons
- Started with single cut for all pads and clusters
- Chose cuts, so that no fake electron remains
- One fake electron cluster is found in 50k events
- Could also use a cut based on variance $\vec{\sigma}$ (e.g. $1 \times \vec{\sigma} \ldots 5 \times \vec{\sigma}$)



Fake rate

Reconstruction Purity

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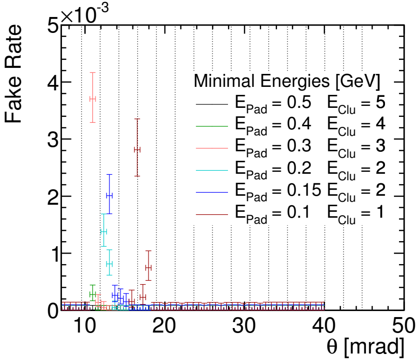

Lower limits of fake rate

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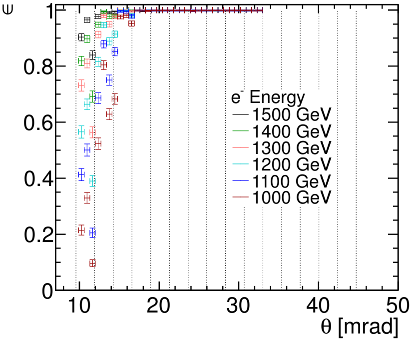
Ring	$E_{\text{pad}}^{\text{cut}}$ [GeV]	$E_{\text{Cluster}}^{\text{Cut}}$ [GeV]
0	0.5	5.0
1	0.4	4.0
1.5	0.3	3.0
2.5	0.2	2.0
3.5	0.15	2.0
4.5	0.1	1.0

Tagging Efficiency vs. Electron Energy

- Simulated single electrons from 0.5 to 1.5 TeV
- Excluding events near the incoming beam pipe hole, and $\theta > 10$ mrad
- Efficiency depends on energy and angle
- From some angle on all electrons found
- Highest efficiency ($\varepsilon = 1_{-0.003}$)
- Near boundaries between rings, efficiency drops



Electron Energy: 1.0 to 1.5 TeV

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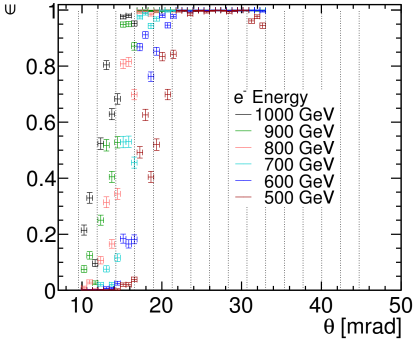

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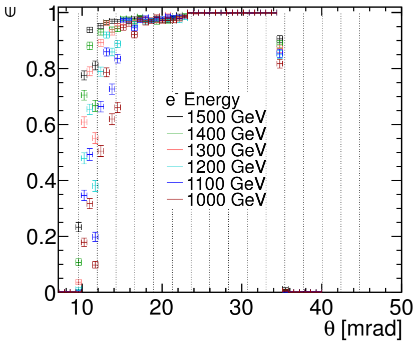

Electron Energy: 1.0 to 1.5 TeV. Including area around incoming beam pipe: 5% reduction in efficiency

Tagging Efficiency vs. Electron Energy

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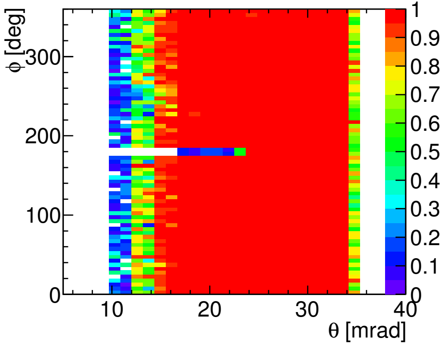
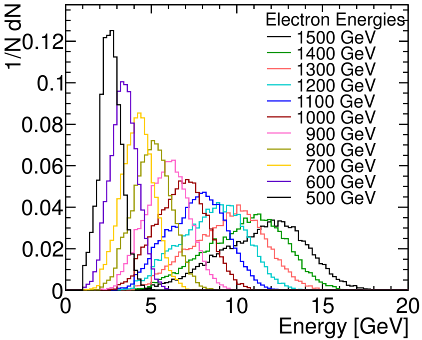


Electron Energy: 1.0 TeV, Efficiency versus Polar and Azimuthal angle

Energy Resolution

- Electron cluster energy distribution
  - Somewhat Gaussian shaped (better at lower energies)
- Calculate calibration between electron and cluster energy
  - Linear in this region (0.5 to 1.5 TeV)
- And energy resolution: $100\%/\sqrt{E[\text{GeV}]} + 20\%$



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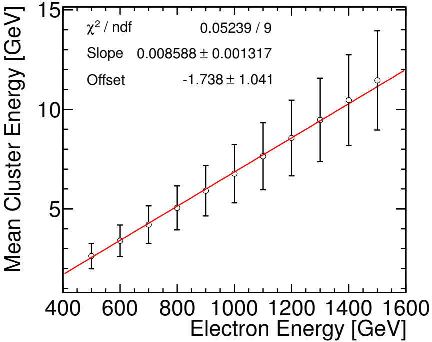

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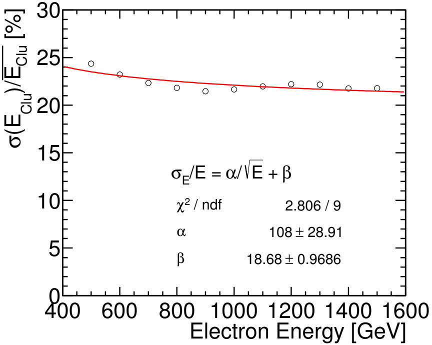
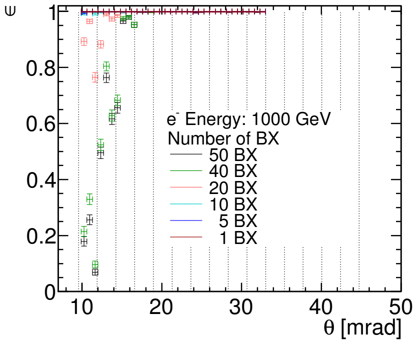


Tagging Efficiency vs. #BX

- For differently sized read-out windows
- Tuned cuts to reduces fakes
- Only shown for 1 TeV electrons
- Up to 10 BX basically every electron found
- Small difference between 40 and 50 BX (but background sample is limited)



Summary

- Electron tagging for two-photon events might be useful for some analyses
- Electron tagging is possible at CLIC, even with moderately large read-out windows of 25 ns, and moderate background fluctuations
- For larger angles ($\theta \approx 20$ mrad) all electrons with $E > 0.5$ TeV found
- Shorter read-out windows is better
- At low angles boundaries between rings reduce efficiencies
- Cuts tuned for minmal fake rate, but few percent probably acceptable
- Looked only down to 500 GeV electrons
- Cuts can be tuned better, so that later layers are not cut as harshly, some combination with $\vec{\sigma}$ based cuts