ScEcal response, combined calorimeters study

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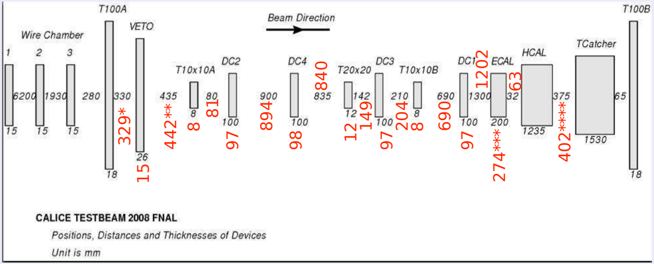
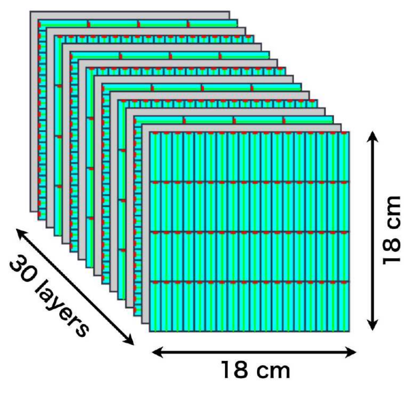
Beam setup



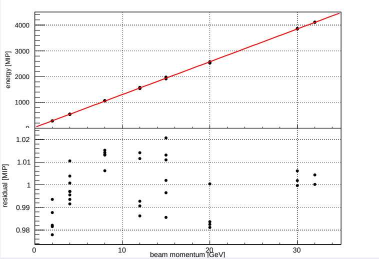
- Distances for setup with ScECAL written in red.
- ScECAL: 3.5 mm mainly tungsteen, 3.0 mm scintillator
- AHCAL: 2 cm steel absorber-0.5cm scintillator
- TCMT: 8x 2cm steel (TCMT1) and 8x 10cm steel (TCMT2) absorber, 0.5cm thick scint. stripes
- 10x10 cm trigger for e,π^- runs (1-32) GeV, 20x20 cm trigger for muon 32 GeV runs
- differential Cerenkov counter for e-π selection
- veto wall for halo events exclusion and 100x100 trigger for μ selection

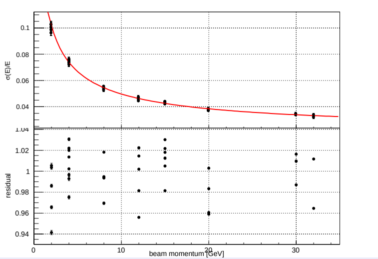
ScECAL

- build and operated by the Japanese CALICE groups
- strip detector, strips (10x45) mm
- absorber 88% tungsteen, 12% cobalt 0.5% carbon, equipped with 40x40 pixels MPPC
- 72 strips in one layer, 30 layers, $21.3 \cdot X_0$ depth
- built together with AHCAL and TCMT in MT6 area, FNAL
  - runs taken in September 2008 and May 2009 (used for further study)
- analysis of response on electrons from September 2008 in CAN-016: **First Stage of the Energy Response adn Resolution of the Scintillator ECAL in the Beam Test at FNAL, 2008**



Linearity and resolution of electrons





- $E = a + b \cdot x$
- $a = (33.0 \pm 0.2)$ MIP
- $b = (127.50 \pm 0.02)$ MIP/GeV
- deviation from linearity ≈ 1-2 (CAN-016: 6 % using a=0 MIP)%

- $\sigma(E)/E = (a/\sqrt{E} \oplus b \oplus c/E)$
- $a = (14 \pm 0.1)\% \cdot \sqrt{GeV}$ $b = (2.20 \pm 0.04)\%$ $c = (0 \pm 0.3) \cdot GeV$

- CAN-016: $\sigma(E)/E = (a/\sqrt{E} \oplus b)$
  - Central: $Const: \ (1.59 \pm 0.03)\%$ $Stoch: (14.80 \pm 0.04)\% \cdot \sqrt{GeV}$

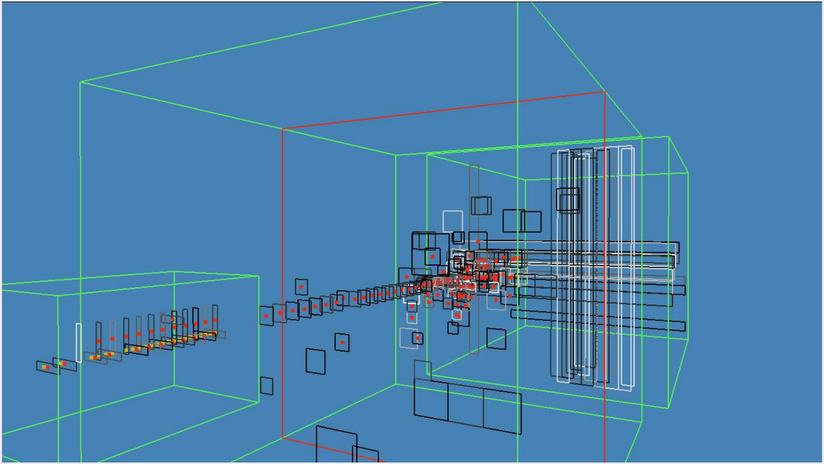
Purification of π^- sample, cuts inherited from Nils Feege thesis

- events scattered before reaching AHCAL first 5 layers with energy $>$ 4 MIP
  - 96 % AHCAL pedestal exclusion→ 96% of spurious trigger events excl.
  - reproduced 96 % efficiency for ScECAL: first 7 layers of ScECAL with energy $>$ 7 MIP
- no signal in a veto wall (efficiency 40 %)
- multiplicity counter cut signal in (2200,3800) ADC
- outer cherenkov excluded (e selection), inner cherenkov signal $>$6 GeV, no inner cherenkov($<$6 GeV)
- scintillator behind TCMT for muon selection (20 % eff. from veto+1x1m)
  - $>$ 4 GeV: first hadron interaction in the AHCAL or ScECAL
- cuts for runs below 8 GeV needs additional study using simulations

Used runs

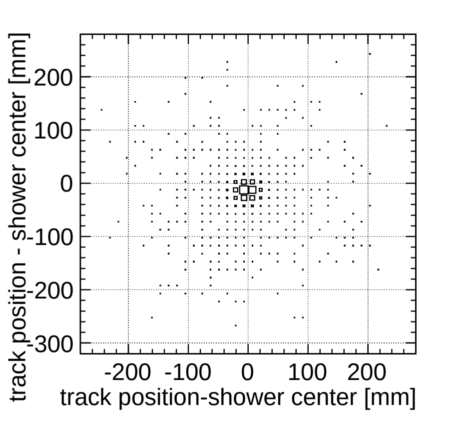
- π^- from FNAL-2009 test-beam period
- energies: 2,4,12,15,20,32 GeV
  - due to problems of μ separation used only energyies $>= 12$ GeV
- DAQ of some runs above 6 GeV with signal from an inner cherenkov tube

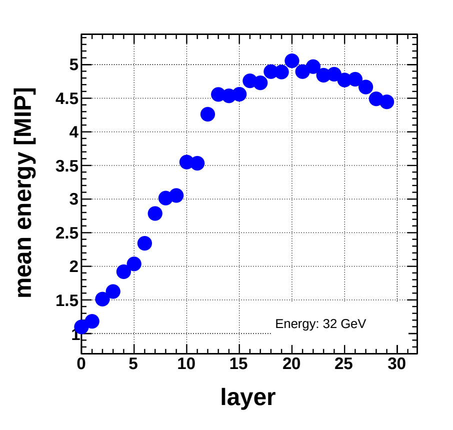
Track finder and shower start finder



- CED event display developed in common frame with AHCAL and TCMT in cooperation with Katsushige Kotera
- due to selection of electrons developed a shower start finder also for a ScECAL
- the track position in ScECAL: x position of vertical and y position of horizontal strips (yellow)

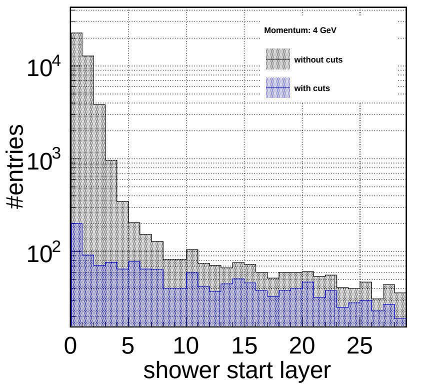
Check of relative position of ScECAL and AHCAL

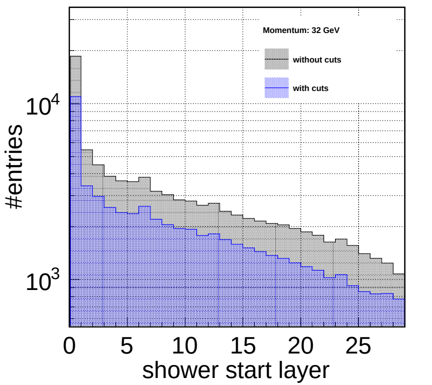




- for all of runs the ScECAL is centered relative to AHCAL (left)
- energy profiles shows no problem with layers ordering

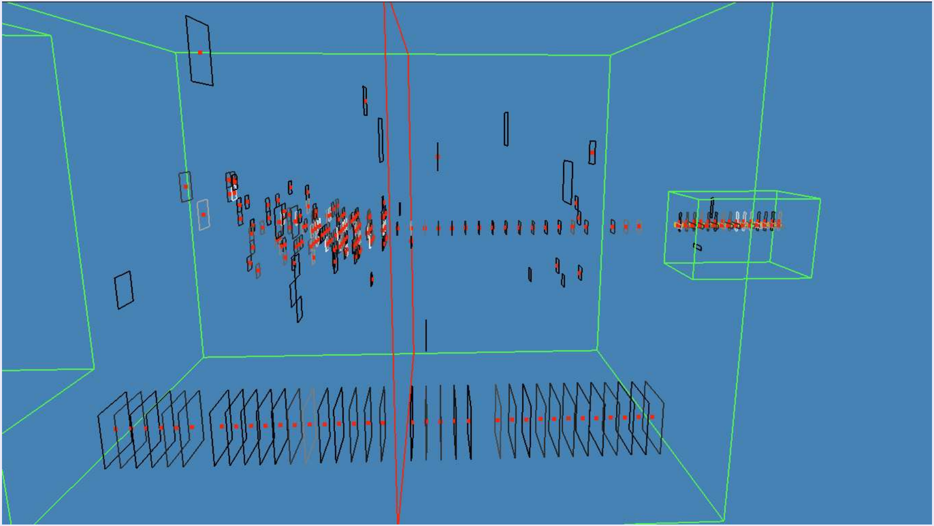
Shower start layer in ScECAL





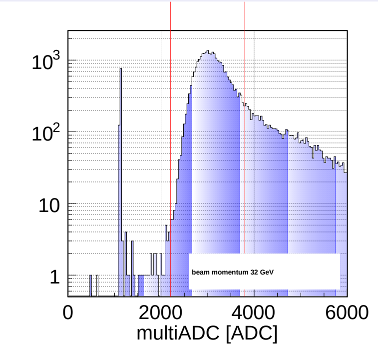
- shower start layer in ScECAL before(after) cut on a cherenkov signal in inner and outer tube
- exclusion of events with shower start layer $<= 3$ in ScECAL

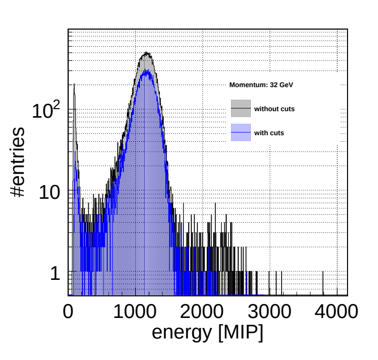
Exclusion of halo events



- without Ecal cuts on # hits in 6x6 and 12x12 cm cells in first 5 layers, Nils thesis
- possible cut on halo events with shower starts in the AHCAL

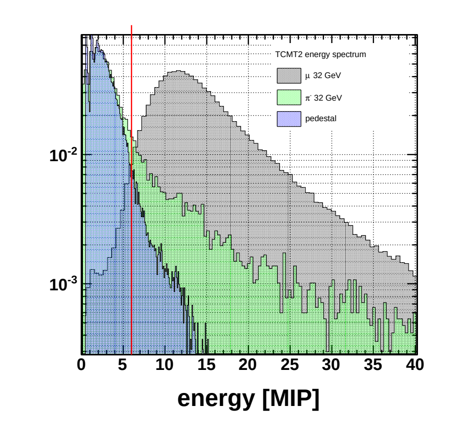
exclusion of no(multi)-particle events

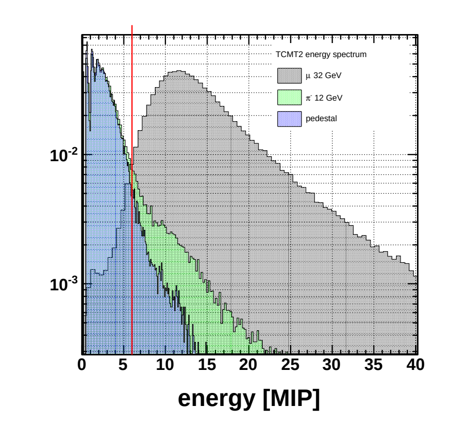




- multiplicity counter behaviour quite the same for all energies (left).
- set `multiADC` > 2200 to exclude no particle events
- set `multiADC` < 3800 to exclude multi particle events
- Right: Energy spectrum in AHCAL+TCMT1 with shower st.l. in AHCAL
- still emergence of additional μ peak

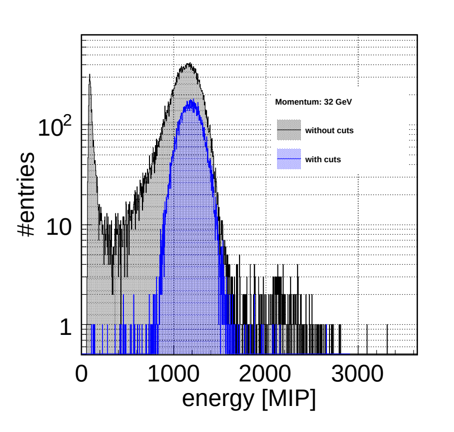
Using TCMT2 as a veto; energy cut on TCMT2

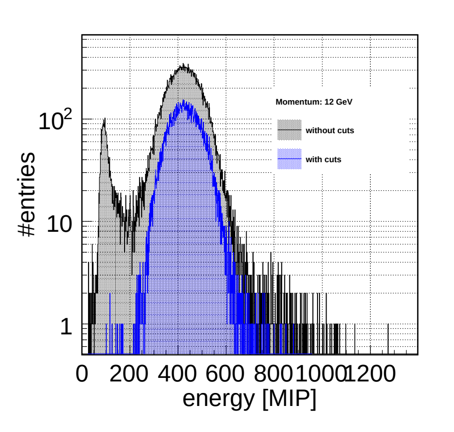




- exclusion of 97 % of 32 GeV μ events
- exclusion of 35 % of beam events for 32 GeV (left)
- exclusion of 21 % of beam events for 12 GeV (right)
- exlusion 11 % noise events → exlusion of 11 % of good events

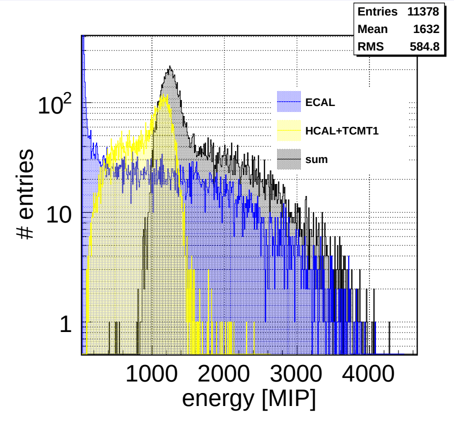
Energy spectra in AHCAL+TCMT1 after π^- selection

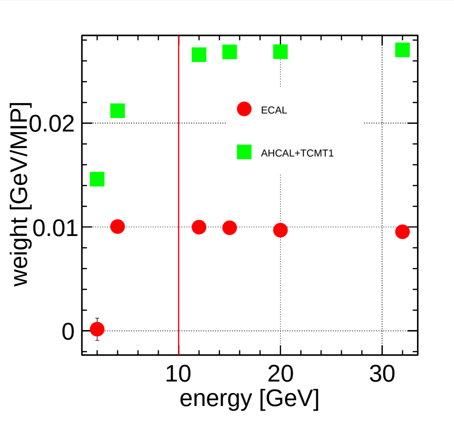




- No additional μ peak for energy spectra of AHCAL+TCMT1 with shower start in the AHCAL
- 32 Gev π^- left, 12 GeV π^- right

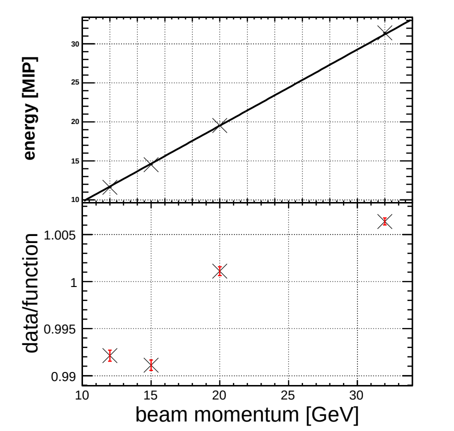
Weighting factors energy dependence

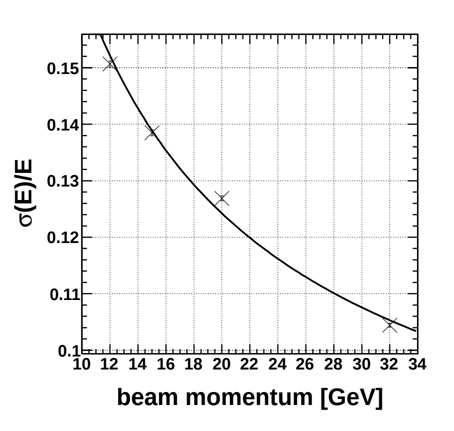




- **Formula for rec. energy:**
  $E = w_{ScECAL} \cdot E_{ScECAL} + w_{AHCAL+TCMT1} \cdot E_{AHCAL+TCMT1}$
- Formula for χ^2(Right fig.) : $((\sum_i w_i \cdot E_i) - p_{beam})^2$ $i =${ScECAL,HCAL+TCMT1}
- energy dependence of AHCAL and TCMT1 weights for energies < 12 GeV
- Formula for χ^2 : $((\sum_{beam}(\sum_i w_i \cdot E_i) - p_{beam})(+const = 0))^2$

Linearity and Resolution of combined calorimeters

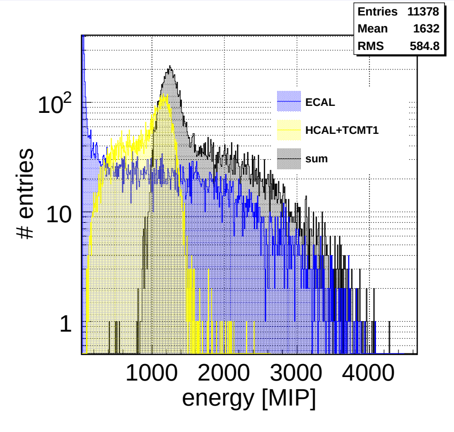


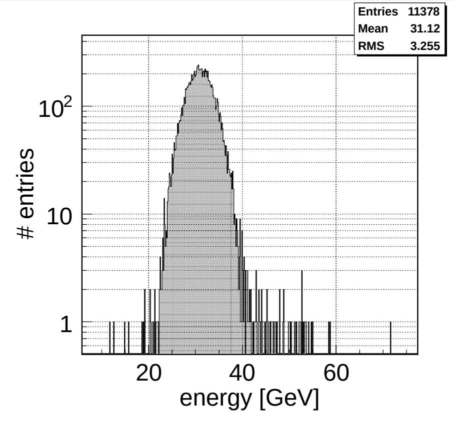


- $w_{ECAL} = 9.611 \pm 0.002$ MeV/MIP
- $w_{HCAL} = 26.931 \pm 0.002$ MeV/MIP
  - (CAN-029 : $w_{HCAL} = 27.6$ MeV/MIP)
- $w_{AHCAL}/w_{ScECAL} = 2.802 \pm 0.003$
- Estimation of w_{AHCAL}/w_{ScECAL} from sh.st. layer: $A \cdot \exp[-\lambda \cdot$ layer$]$ $\lambda_{AHCAL}/\lambda_{ScECAL} \approx 3$

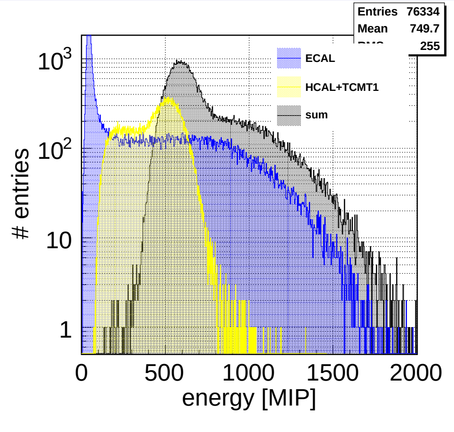
- $\sigma(E)/E = (a/\sqrt{E} \oplus b \oplus c/E)$
- $a = (48.1 \pm 0.3)\% \cdot \sqrt{GeV}$ $b = (6.2 \pm 0.1)\%$ $c = (0 \pm 2) \cdot GeV$

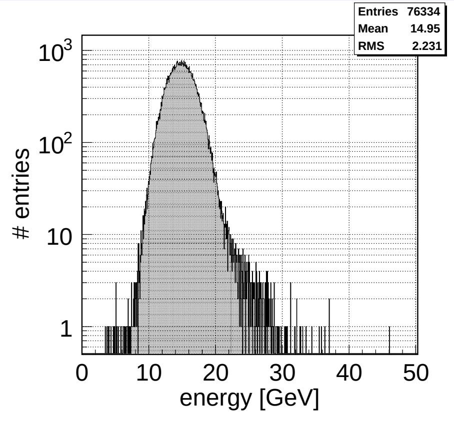
Example of an energy spectrum with application of weights 32 GeV





Example of an energy spectrum with application of weights 20 GeV





Conclusion

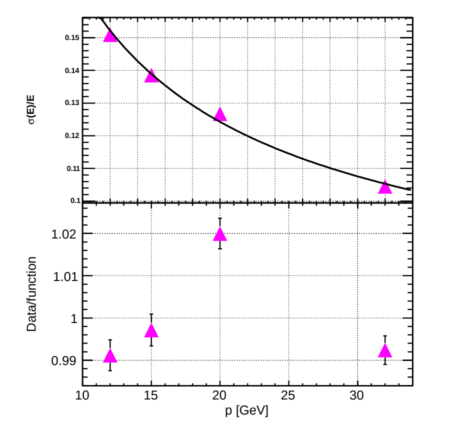
- developed tools for finding the track and the shower start layer in ScECAL
- found consistency of the ScECAL response on electron for our dataset with the study using FNAL-2008 data
- estimated the weights for ScECAL and AHCAL+TCMT1 for energy response correction
- needed further investigation of cuts using now developed simulation of test-beam setup with ScECAL

Acknowledgement

- Katsushige Kotera for intensive cooperation, help with the ScECAL reconstruction software and organizing the phone meeting
- Katsushige Kotera and Shaojun Lu for their implementation of ScECAL in the CALICE analysis frame

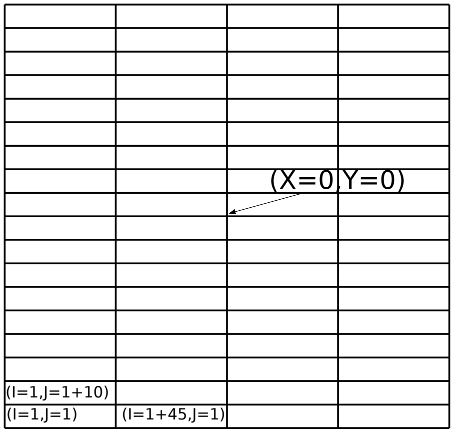
Backup

Linearity and Resolution using low energies



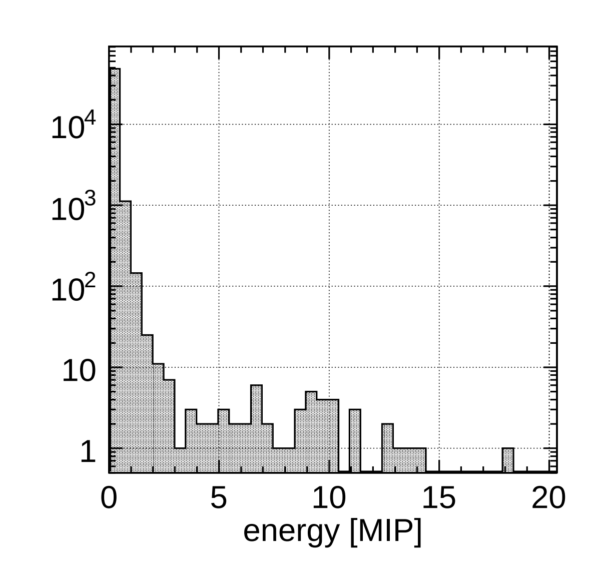
- $\sigma(E)/E = (a/\sqrt{E} \oplus b \oplus c/E)$
- $a = (45 \pm 0.8)\% \cdot \sqrt{GeV} \qquad b = (0 \pm 0)\% \quad c = (0 \pm 0) \cdot GeV$

ScECAL reconstruction



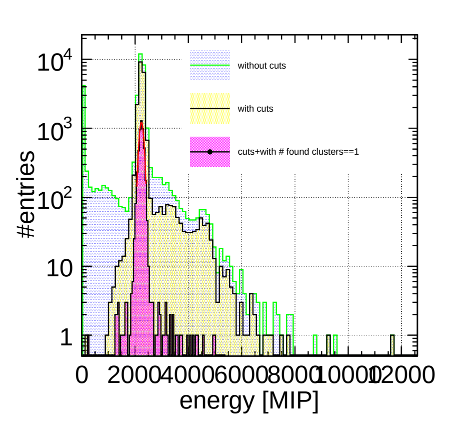
- changed the

ScECAL noise in first 7 layers

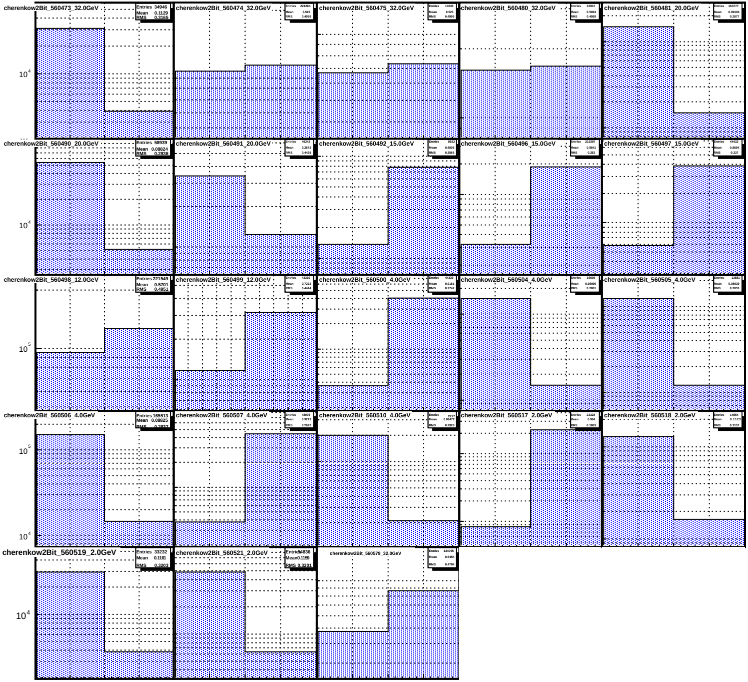


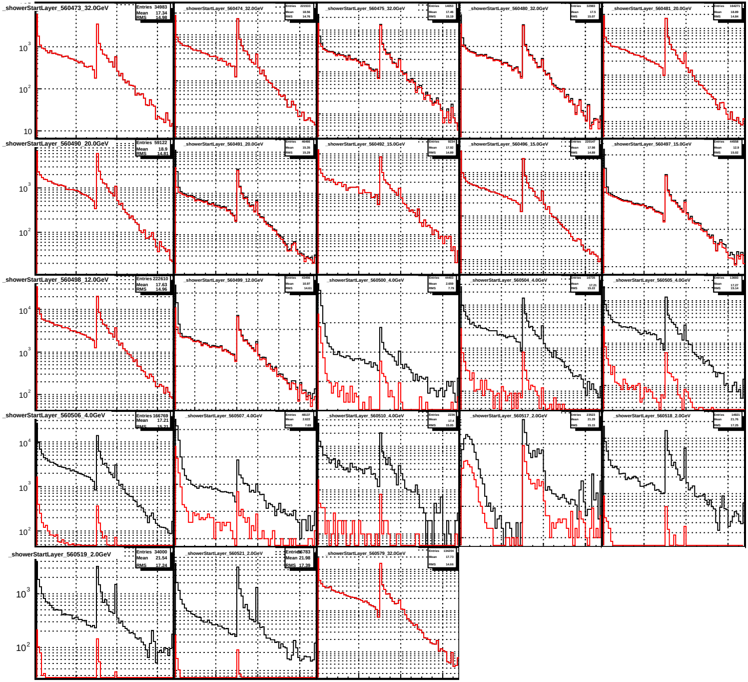
ScECAL response on electrons, topological purification of sample

- Eletron selection problems:
  - double particle events
  - π^- events contamination
  - lateral profile
- Cuts:
  - $\frac{E_{ECAL}}{E_{ECAL+HCAL+TCMT}} >$ CUT; CUT $= 0.9$
  - multiplicity counter amplitude$(2000, 5000)$
  - shower center in 20x20 mm square around the ScECAL center
  - # events after selection > 1000



- For creating pure one-event electron samples using Trackwiseclustering algorithm to separate only one cluster
  - parameters of clustering algorithm changed on the fly $(R_{ij}, A_{ij}) : (92, 25) \rightarrow (10, 10)$


cherenkow2Bit_560473_32.0GeV
cherenkow2Bit_560474_32.0GeV
cherenkow2Bit_560475_32.0GeV
cherenkow2Bit_560480_32.0GeV
cherenkow2Bit_560481_20.0GeV
cherenkow2Bit_560490_20.0GeV
cherenkow2Bit_560491_20.0GeV
cherenkow2Bit_560492_15.0GeV
cherenkow2Bit_560496_15.0GeV
cherenkow2Bit_560497_15.0GeV
cherenkow2Bit_560498_12.0GeV
cherenkow2Bit_560499_12.0GeV
cherenkow2Bit_560500_4.0GeV
cherenkow2Bit_560504_4.0GeV
cherenkow2Bit_560505_4.0GeV
cherenkow2Bit_560506_4.0GeV
cherenkow2Bit_560507_4.0GeV
cherenkow2Bit_560510_4.0GeV
cherenkow2Bit_560517_2.0GeV
cherenkow2Bit_560518_2.0GeV
cherenkow2Bit_560519_2.0GeV
cherenkow2Bit_560521_2.0GeV
cherenkow2Bit_560579_32.0GeV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Entries 34983
Mean 17.34
RMS 14.98
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_showerStartLayer_560475_32.0GeV
_showerStartLayer_560480_32.0GeV
_showerStartLayer_560481_20.0GeV
_showerStartLayer_560490_20.0GeV
Entries 59122
Mean 18.9
RMS 14.81
_showerStartLayer_560491_20.0GeV
_showerStartLayer_560492_15.0GeV
_showerStartLayer_560496_15.0GeV
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Entries 222610
Mean 17.63
RMS 14.96
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_showerStartLayer_560518_2.0GeV
_showerStartLayer_560519_2.0GeV
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Mean 21.98
RMS 17.39
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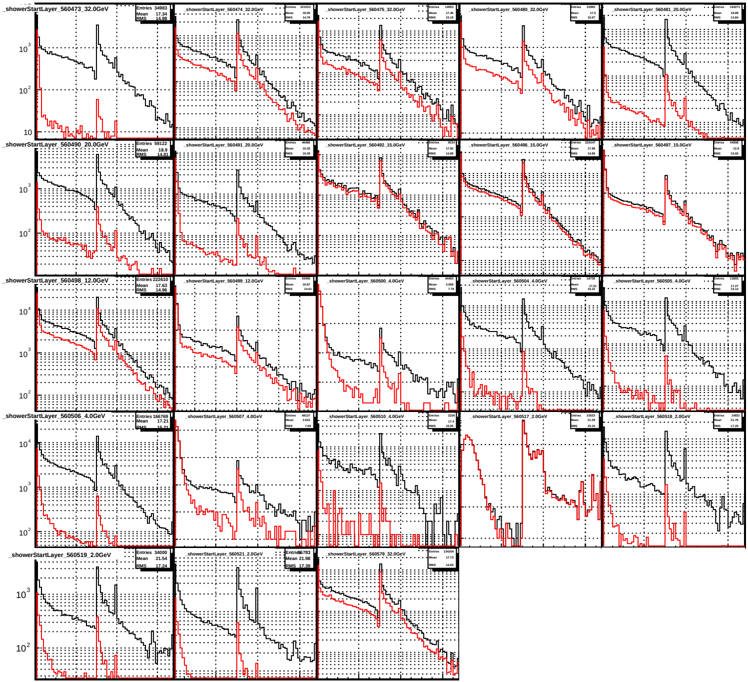
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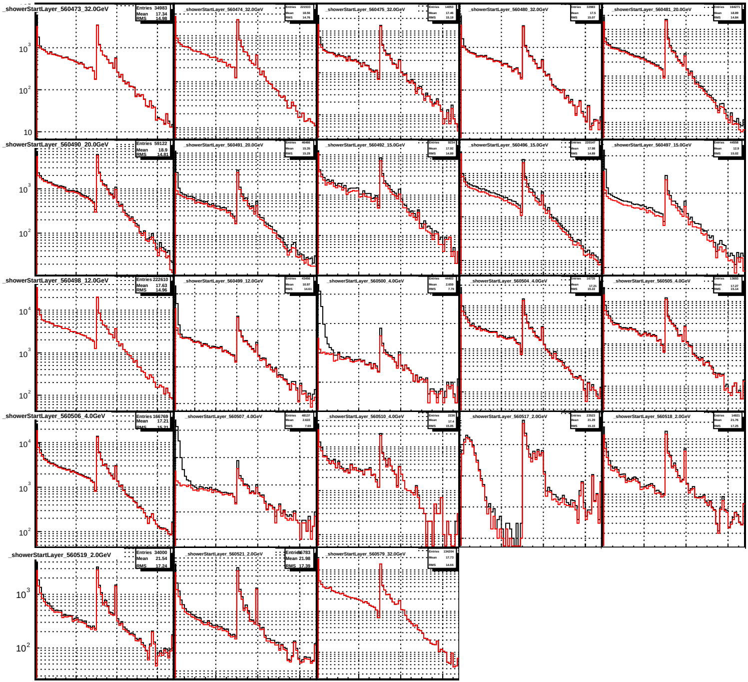
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10
10^2
10^3
10^4