Comments from Roman on 20251009

Dear Joao,

sorry for this late mail. I/we have some further (minor) comments to the HCAL section (after quick reading). Sorry, I forgot to send them earlier this week. The comments refer to draft version 0.7.3

- Axis labels of Fig. 7.30 are not defined (We know what it is but not the ordinary reader)

Answer: Fig. 7.30 is the ECAL chapter. Do you rather mean the Fig. 8.30 in the HCAL Chapter. Bu in any case, both Figures 8.30 and 7.30 in the latest version do not have the axis-label-missing issue, as attached below.

Chapter 7 Electromagnetic Calorimeter

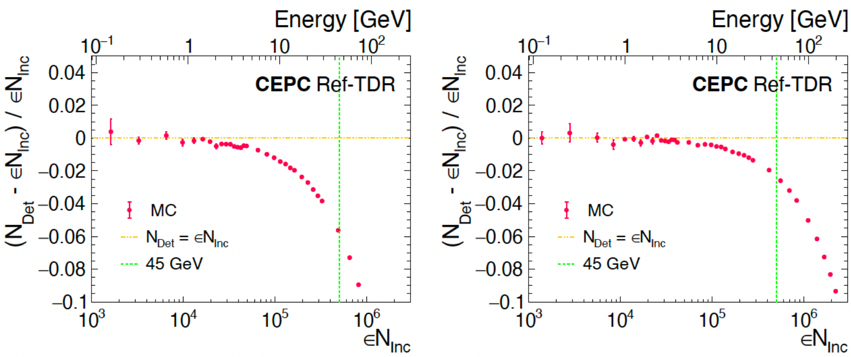

Figure 7.30: Simulated SiPM responses to BGO ($1 \times 1 \times 40\,\text{cm}^3$) scintillation light: (a) NDL EQR10 11-3030D-S with a 10 µm pixel pitch, and (b) NDL EQR06 11-3030D-S with a 6 µm pixel pitch. In the figures, the red points represent the simulation results, the blue dashed line corresponds to the expected non-linearity SiPM response using a function described in [24].

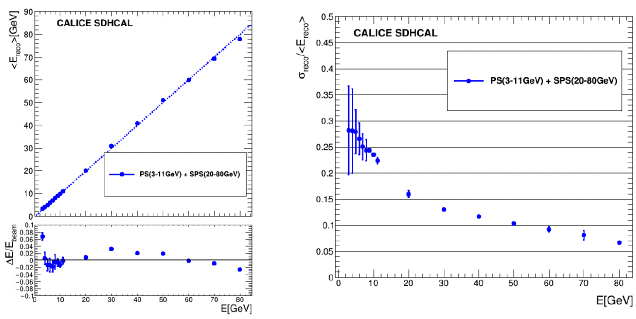

Figure 8.30: (a) Energy linearity and (b) energy resolution using all the test beam data collected at CERN with PS and SPS [41].

- Sec. 8.4.2.4: I find the addendum on QC a bit thin but that's maybe all we can expect at the moment

Answer: Indeed, this part should be improved along with the R&D. In the arxiv submitted version we added some text to tell an automatic batch testing platform will be developed to quickly measure the properties of the GS tiles and to control their quality.

- Please use consistent units in Fig. 8.18 (ADC Counts p.e., just spotted this now)

Answer: The 3 plots are Cs137, cosmic ray, beam electrons, where the Cs137 figure is in unit of ADC counts, it is now changed to in unit of p.e. .

- Sec. 8.4.5: I find the discussion on the difference between the cosmic spectrum and the KEK spectrum a bit odd. Of course some electrons start a shower but many pass as MIPs and these should be visible in the peal (i.e. the MPV). Sure electrons are in the relativistic rise of the dE/dx spectrum but I am not sure whether this explains a factor of three. The argumentation with showering electrons is wrong or at least doubtful in any case. Would also be useful to remind on the X0 of GS.

Answer: Thanks for pointing out this question. We did some more studies and calculations. For GS, X = 1.59 cm. The 10 mm thickness corresponds to t = 0.63 X . Taking rho=6g/cm^3, Zeff=56.6, the critical energy E_c for GS is about 10 MeV. For a 5 GeV electron (E   E_c), the energy loss is dominated by bremsstrahlung, not ionization, e.g. See the figure below from PDG:

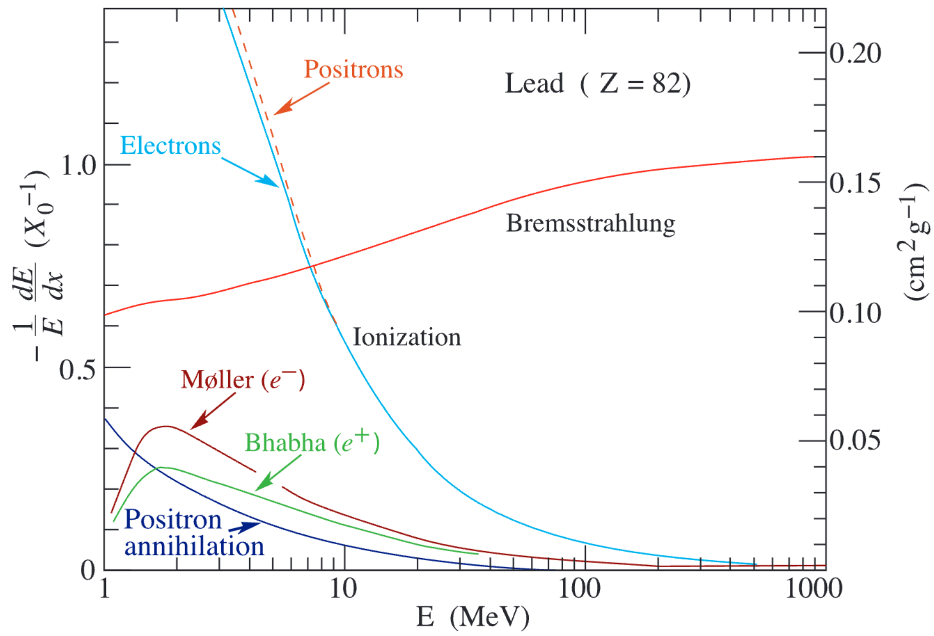

Figure 34.11: Fractional energy loss per radiation length in lead as a function of electron or positron energy. Electron (positron) scattering is considered as ionization when the energy loss per collision is below 0.255 MeV, and as Møller (Bhabha) scattering when it is above. Adapted from Fig. 3.2 from Messel and Crawford, *Electron-Photon Shower Distribution Function Tables for Lead, Copper, and Air Absorbers*, Pergamon Press, 1970. Messel and Crawford use $X_0(\mathrm{Pb}) = 5.82\ \mathrm{g/cm}^2$, but we have modified the figures to reflect the value given in the Table of Atomic and Nuclear Properties of Materials ($X_0(\mathrm{Pb}) = 6.37\ \mathrm{g/cm}^2$).

First, we can calculate (and also from the figure above) the ionization energy loss of 5 GeV electron passing through 0.63 X0 of material is very small, caculated to be something like 2 MeV.

Now, the question is actaully all about bremstrahlung: What is the probability for a 5 GeV electron traversing 0.63 X _without_ any breamstrahlung photon having an energy more than 10 MeV? Now let's calculate, taking some formula from PDG:

https://pdg.lbl.gov/2025/reviews/rpp2024-rev-passage-particles-matter.pdf

first, take the following formula:

the review by Koch & Motz [15].

Except at these extremes, and still in the complete-screening approximation, the number of photons with energies between k_{min} and k_{max} emitted by an electron travelling a distance $d \ll X_0$ is

$$N_\gamma = \frac{d}{X_0}\left[\frac{4}{3}\ln\left(\frac{k_{\mathrm{max}}}{k_{\mathrm{min}}}\right) - \frac{4(k_{\mathrm{max}} - k_{\mathrm{min}})}{3E} + \frac{k_{\mathrm{max}}^2 - k_{\mathrm{min}}^2}{2E^2}\right] . \qquad (34.30)$$

in our case, kmin=10MeV, kmax=5GeV, which is the initial Electron energy 5GeV, we have:

$$N_{photons/X_0}(k > 10\ \text{MeV}) = \int_{k_{min}}^{E_0} \frac{dN}{dk} dk = \int_{10\ \text{MeV}}^{5000\ \text{MeV}} \frac{1}{k} dk$$

put all numbers inside, we have N photons (k>10MeV) = 3.91 (may be i didn't calculate very correct but it should be around this number).

Now, to get the probablility of zero (0) photon has energy above 10 MeV, we can use the poisson function:

P(n=0; mu=3.91) = P(0) = exp(-3.91) = 0.02

this means only 2% of the 5 GeV electrons have zero bremstrahlung photon radated greater than 10 MeV, which is the beginning rising edge of a Landau distribution.

Therefore, the energy deposition spectrum for 5 GeV electrons is not a MIP peak plus a shower tail. It is a broad, continuous Landau-like distribution dominated from the start by events that have initiated showers. The Most Probable Value (MPV) of this distribution is naturally much higher than that of a single MIP.

The text is also updated correspondingly for clearity.

You may still want to take these comments into account. They don't change overall conclusions that you will see in our final report.

Cheers,

Roman

dopn