EMC Preshower and its energy correction with SciTil

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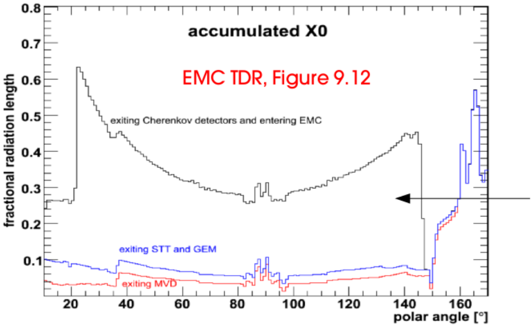
Overview

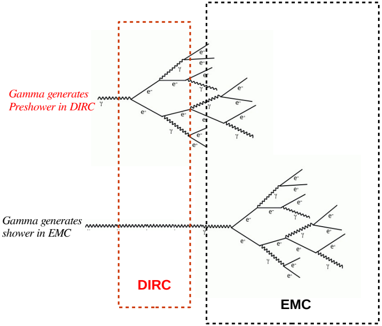
1. Introduction
2. Analysis and Results
3. Conclusion

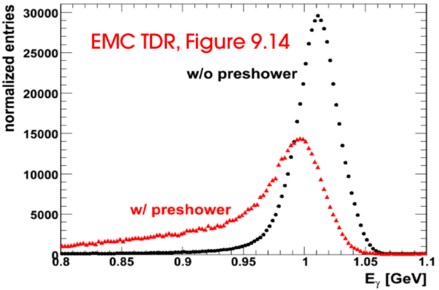
Preshower

- The presence of other detectors in front of the electromagnetic calorimeter with a high material budget leads to the possibility for a high energetic photon to start the electromagnetic shower in front of the EMC. An electromagnetic shower started in front of the EMC is called a **Preshower**.



DIRC detector contributes most to the material budget in front of the EMC.





- In Panda, we have a SciTil in between DIRC and EMC, which has low material budget, insensitive to gamma, but has a high efficiency to charged particles. In a study for BaBar experiment, it was shown that, by detecting preshower by DIRC itself, 50% of the converted gamma can be recovered. But in our case, separate detector would discover conversion with full efficiency and enhance the energy resolution.

Monte Carlo event generation

- We generated single photon MC events in PandaRoot (version 27316).

Parameters for MC generation

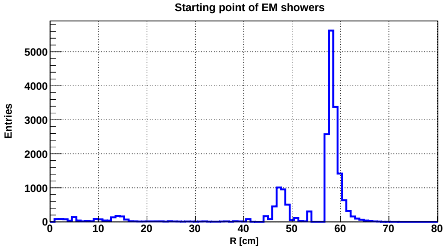
- Event generator : Box generator.
- Detector simulation : Geant3.
- Energy(γ) = 1 GeV.
- Polar angle(θ) = Barrel region : 22^o - 140^o.
- Azimuthal angle (ϕ) = 0^o - 360^o.
- Number of events = 10000.

Identification of Preshowers using MC track info.

- For a gamma particle, the radial distance of the starting point of an EM shower (R) is estimated as,

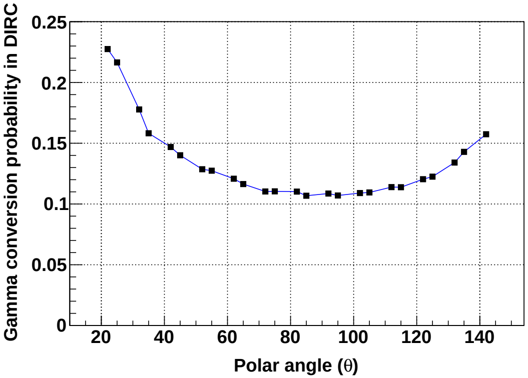
$$\mathbf{R} = \text{Minimum of the radial distances of the starting vertices of the secondary particles.}$$

If, $\mathbf{R} < \mathbf{R}_{EMC}$; shower is identified as Preshower.
Where, $\mathbf{R}_{EMC}$ is the inner radius of EMC.
The distribution between $\mathbf{R} = \mathbf{46.1\ cm}$ and $\mathbf{R} = \mathbf{49.1\ cm}$, gives the number preshowers in DIRC.

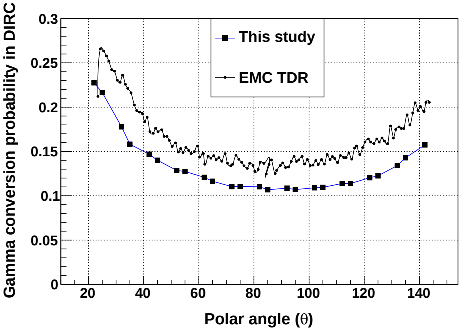


Gamma conversion probability

- Gamma conversion probability in DIRC $= \frac{\text{No. of preshowers in DIRC}}{\text{No. of events generated}}$



Comparision with EMC TDR

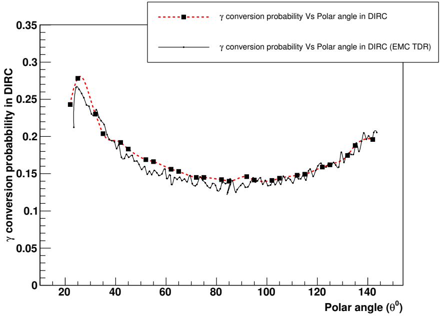


- The variation of gamma conversion probability with the polar angle is compared with that in EMC TDR. Though the shape of the both graphs are more or less same, there is a constant mismatch throughout the range of the polar angle.

Comparision of DIRC Geometries

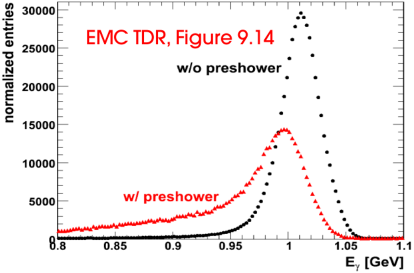
DIRC geometry	Gamma conversion probability
1. **EMC TDR**: DIRC quartz slab, thickness = 1.7 cm, DIRC bar support (Aluminium), thickness = 0.5 cm Total thickness in terms of radiation length $= \frac{1.7}{12.3} + \frac{0.5}{8.9} = 19.43\ \%$	15% @ 90^o
2. **This work (latest DIRC geometry in pandaroot)**: DIRC quartz slab, thickness = 1.7 cm, DIRC bar cover (Carbon fibre), thickness = 0.6 cm Total thickness in terms of radiation length $= \frac{1.7}{12.3} + \frac{0.6}{18.8} = 17.01\ \%$	11% @ 90^o

- Although the total fractional radiation length assumed in this work is less by 2% than the EMC TDR. This could be explained by the additional support structure which is not homogeneously distributed over the phi or something else.

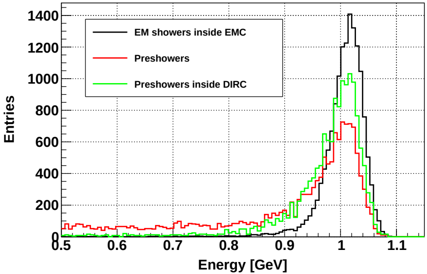


- In the Panda Physics book, the DIRC volume is given to be between R = 45 cm and R= 54 cm.
- If we consider, the DIRC radii between 45 cm and 54 cm, the variation gamma conversion probability vs polar angle is almost match with that of the previous simulation (EMC TDR).
- Therefore, we suspect that in the previous study, the range of the DIRC volume was also taken to be different from what we considered in our simulation.

Effect of Preshower on the reconstructed photon energy in EMC

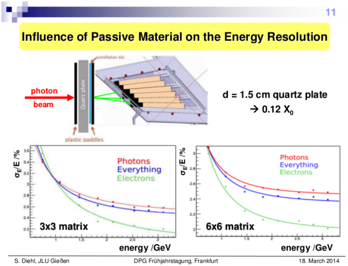


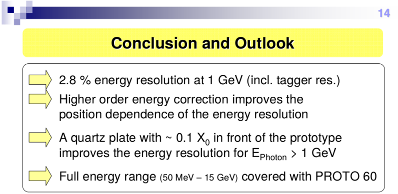
In the previous report (EMC TDR), it is shown that the reconstructed energy of photons with preshower (w/ preshower) is worse than that for non-preshower events (w/o preshower). This is due to the preshowers in DIRC, which adds a low end tail part to the distribution.



In our study, it is observed that the energy spectrum of non preshower events is more or less of the Gaussian type. The Preshower events contributes a low end tail part to the distribution. But the effect of the preshower is not as prominent as found in the previous study, considering the shift of the mean of the distribution.

Bonn Beam test results on preshower





S. Diehl, German physical society meeting,2014, Frankfurt.

1. **Photons** : Non-preshower events, do not show signal on scintillator paddle behind quartz bar.
2. **Electrons** : Preshower events, show signal to the scintillator paddle.
3. **Everything** : Preshower + non-preshower events.

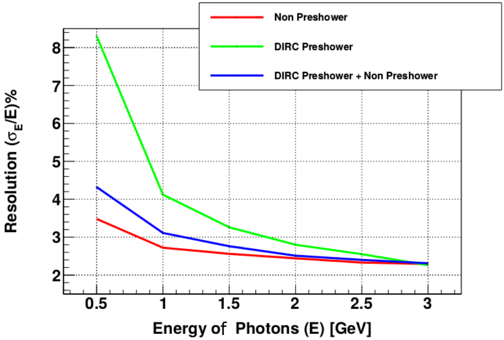
Comparision with Bonn beam test results

- We set $\phi = 100^o$ (fixed) to generate the MC events and the events are classified as follows :
  1. Non-pre : Non-preshower events, $\mathbf{R} > \mathbf{57\ cm}$.
  2. DIRC-pre : DIRC-preshower events, $\mathbf{R} > \mathbf{46.1\ cm\ and\ R} < \mathbf{49.1\ cm}$
  3. DIRC-pre + Non-pre : DIRC-preshower + non-preshower events.

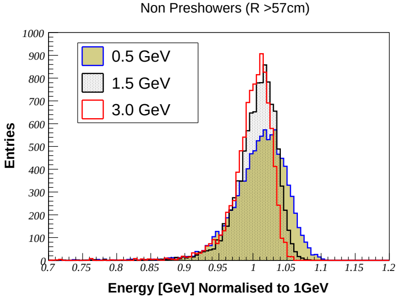
- To fit the energy distribution, we use Novosibirsk function. The same function was also used by EMC group to analyze the beam test results,

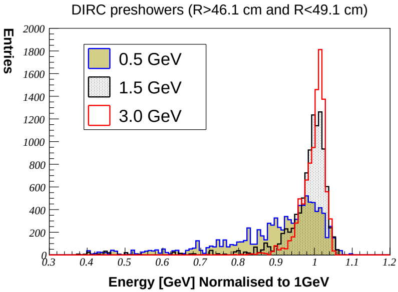
$$F(x) = Nexp\Big[-\frac{1}{2\sigma_o^2}ln^2\Big(1-\frac{x-\bar{x}}{\sigma_E}\eta\Big)-\frac{\sigma_o^2}{2}\Big] \quad (1)$$

Energy vs Resolution

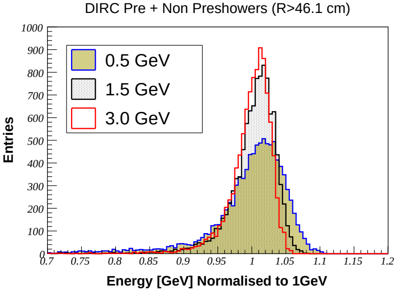


- As the energy of the photons increases, the resolution becomes better for all three categories of events. However we do not see this improvement is due to the presence of preshowers in DIRC quartz bar, as concluded by the Bonn beam time results.





It has seen that the effect of preshowers is more prominent in lower energy(0.5 GeV) than that in higher energy.



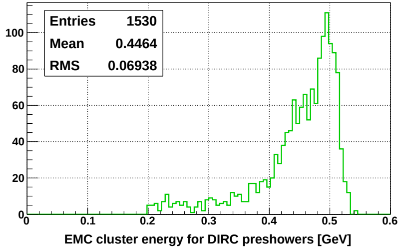
Energy correction for preshower events

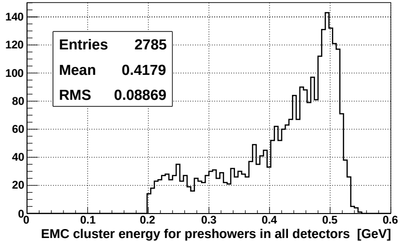
Parameters for MC generation: Box generator

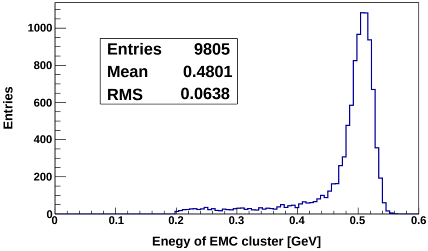
- Energy(γ) $=$ 0.5 GeV.
- Polar angle(θ) $=$ Barrel region : 22^o - 140^o.
- Azimuthal angle (ϕ) $=$ 100^o, fixed.
- Number of events $=$ 10000.

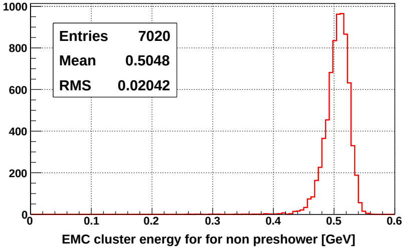
Selection cut:

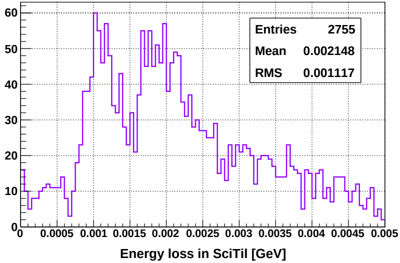
Reconstructed energy of MC cluster $>$ 0.2 GeV.

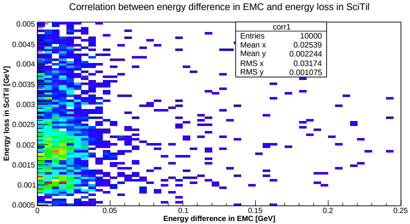




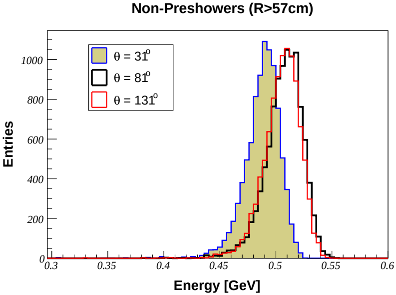

Entries
Entries 9805
Mean 0.4801
RMS 0.0638
0 200 400 600 800 1000
0 0.1 0.2 0.3 0.4 0.5 0.6
Enegy of EMC cluster [GeV]

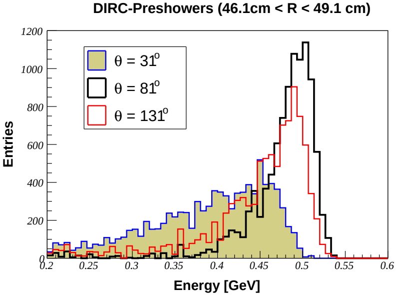

Entries 7020
Mean 0.5048
RMS 0.02042
0 200 400 600 800 1000
0 0.1 0.2 0.3 0.4 0.5 0.6
EMC cluster energy for for non preshower [GeV]


Entries 2755
Mean 0.002148
RMS 0.001117
0 10 20 30 40 50 60
0 0.0005 0.001 0.0015 0.002 0.0025 0.003 0.0035 0.004 0.0045 0.005
Energy loss in SciTil [GeV]


Correlation between energy difference in EMC and energy loss in SciTil
corr1
Entries 10000
Mean x 0.02539
Mean y 0.002244
RMS x 0.03174
RMS y 0.001075
Energy loss in SciTil [GeV]
0.0005 0.001 0.0015 0.002 0.0025 0.003 0.0035 0.004 0.0045 0.005
0 0.05 0.1 0.15 0.2 0.25
Energy difference in EMC [GeV]

- The correlation plot in the previous slide clearly shows the structure of electron passage, but we do not see any correlation between energy loss in SciTil and the missing energy in EMC which we could use for the correction.
- We see the dependency of energy distribution on the incident angle (θ) of the photons, for both preshower and non-preshower events.



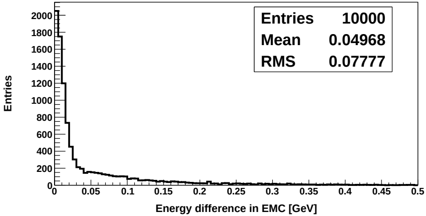


Energy Correction for Preshower events

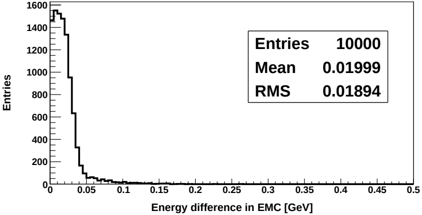
We define,

Energy difference in EMC = | Energy (EMC cluster) − Energy of the generated events(0.5 GeV)|

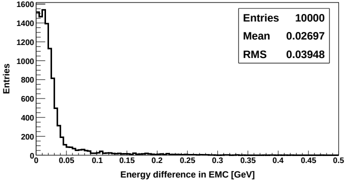
- We see a θ - dependency of the energy difference in EMC



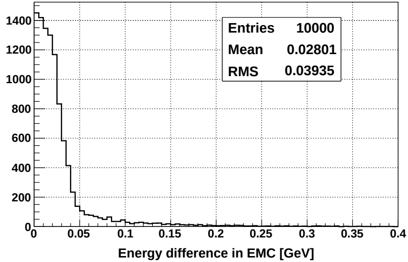
$\underline{\theta = 31^o}$



$\underline{\theta = 81^o}$

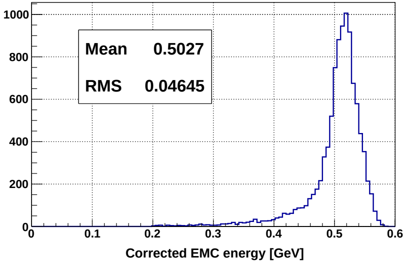


$\underline{\theta = 131^o}$



$\underline{\theta = 22^o \text{ - } 140^o}$

- For Preshower events i,e events for which there is a nonzero energy loss in SciTil,
  Energy(corrected) = Energy(EMC cluster) + Mean value of energy difference in EMC(0.02801 GeV).

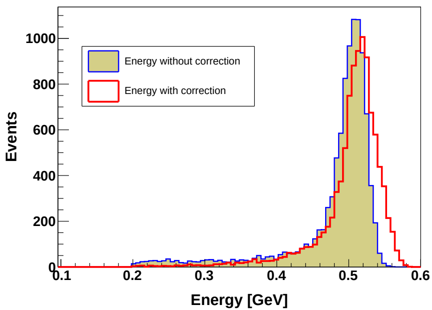


Resolution of Energy spectrum

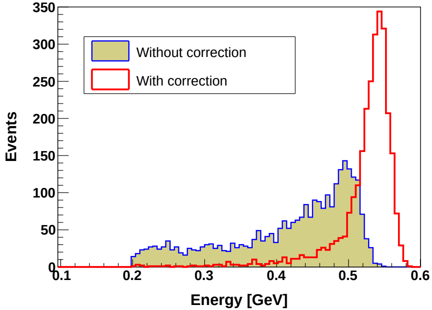
$$\frac{\Delta E}{E} = \frac{S.D.}{\text{Mean Value}} = \frac{\text{RMS of root histogram}}{\text{Mean Value}}$$

- Energy of EMC cluster without correction, $(\frac{\Delta E}{E})= 13.28\%$.
- Energy of Non-preshower events, $(\frac{\Delta E}{E}) = 4.04\%$.
- Energy of EMC cluster with correction $\frac{\Delta E}{E}) = 9.24\%$

Comparison of Energy spectrum with and without correction



EMC cluster energy for all events



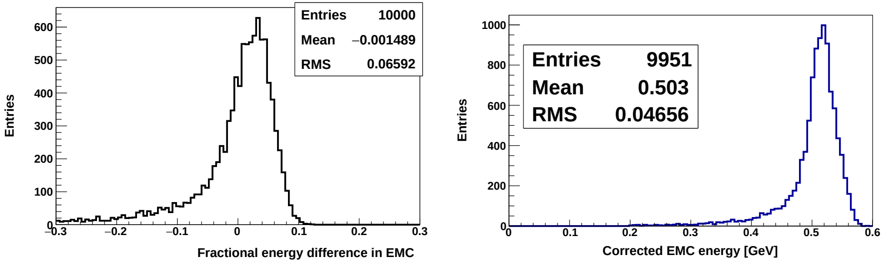
EMC cluster energy for all preshower events

An another approach

We define,

Fractional energy difference in EMC

$$= \frac{\text{Energy (EMC cluster)} - \text{Energy of the generated events(0.5 GeV)}}{\text{Energy of the generated events(0.5 GeV)}}$$



- For Preshower events i,e events for which there is a nonzero energy loss in SciTil, Energy(corrected) = Energy(EMC cluster) + [Mean of fractional energy difference(0.001489) × Energy (EMC cluster)].
- Energy of EMC cluster with correction $(\frac{\Delta E}{E}) = 9.25\%$

Summary

- We studied the preshowers in PANDA target spectrometer using PandaRoot.
- For a photon candidate of energy 1 GeV, the conversion probability inside DIRC material is found to be 11% at the polar angle of 90^o and it increases to 23% at 22^o.
- The reconstructed energy in EMC for non-preshower events is more or less a Gaussian distribution. The preshowers contribute a low-end tail part to it without a prominent shift of the mean value.
- The more energetic photons show better resolution in reconstructed energy distribution, for both preshower and non-preshower events. However, the effect of preshowers is more prominent in lower energy events (< 1 GeV).
- We implemented a rough correction to the energy of the preshowers by adding the average missing energy in EMC. This gives a noticeable difference in the energy distribution of the preshower events and we observed an enhancement of nearly 30 %, in the resolution of reconstructed photon energy in EMC.

Summary

- We have also adopted an another approach for energy correction of the preshowers by using the average fractional energy difference in EMC. In the enhancement of the energy resolution, it almost resembles with the first approach.
- We hope we could convince that SciTil detector can be useful in detecting a preshower event and hence to compensate the lost energy. This was rather a quick-and-dirty job which nonetheless fulfilled our above goal, with which we were satisfied. Therefore we plan to conclude this study as a SciTil group. We hope the EMC group finds this result also useful and continue to elaborate the algorithm and to implement into the PANDA software.

The End