Study of EMC Preshower detection and correction with SciTil

Kamal Dutta and Kushal Kalita

Department of Physics, Gauhati University

Assam, India

Panda LVI. Collaboration Meeting, February 29 - March 4, 2016,

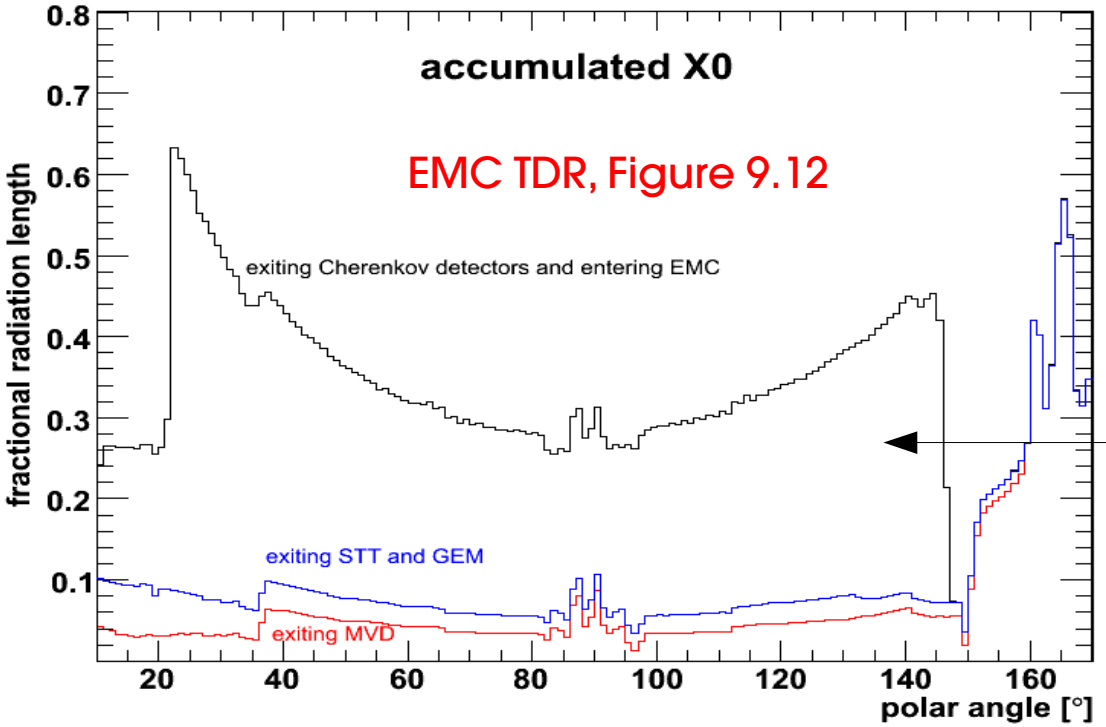
Ruhr-Universität Bochum Universitätsstraße 15044780 Bochum, Germany

Contents

- Introduction
- Preshower in DIRC
- Simulation in PandaRoot
- Results and Conclusion

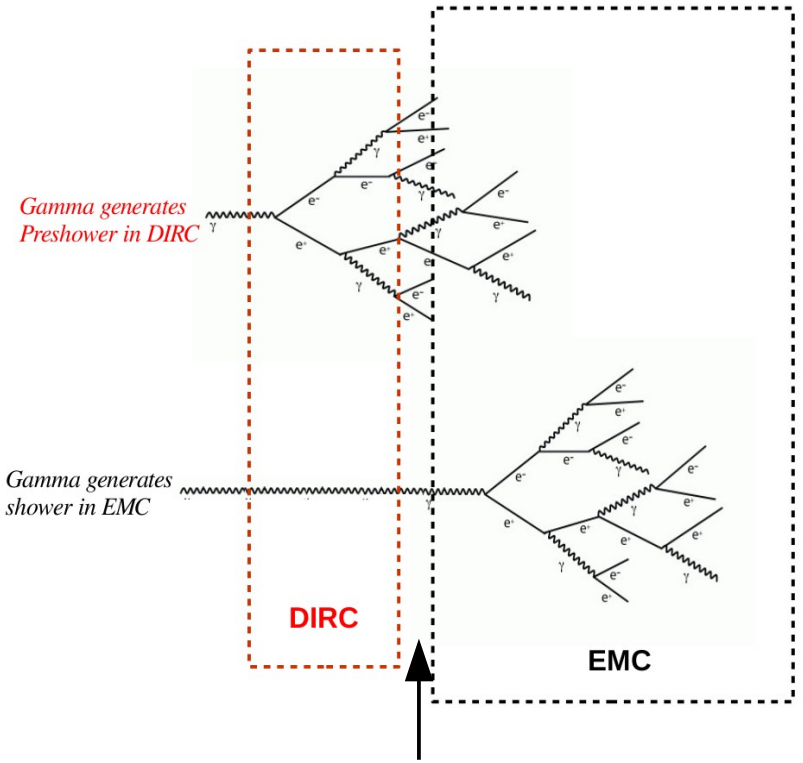
Introduction

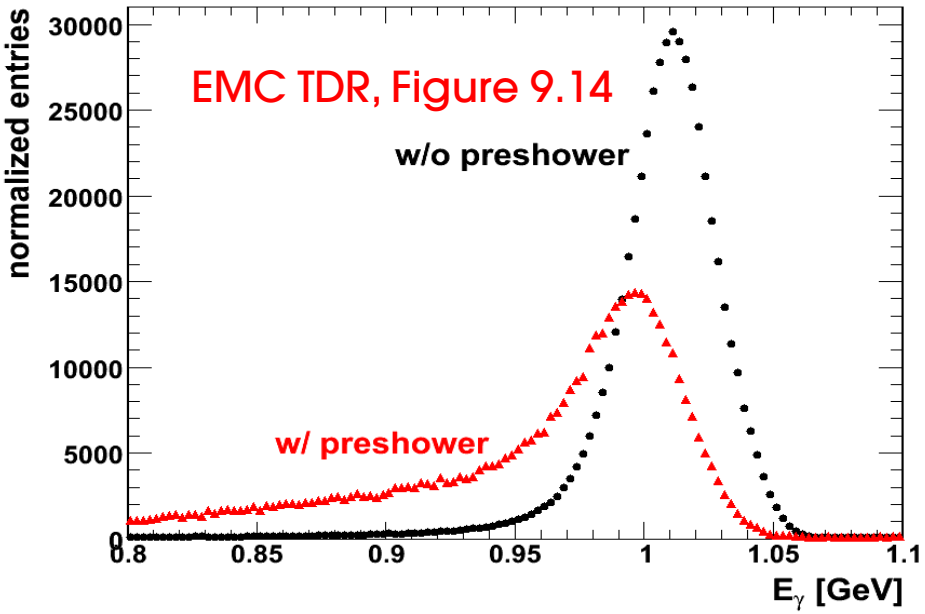
- The presence of other detectors in front of the electromagnetic calorimeter with a high material budget leads to the possibility for a high energetic photon to start the electromagnetic shower in front of the EMC. An electromagnetic shower started in front of the EMC is called **Preshower**.



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

Preshower in DIRC





DIRC preshowers lead to a degradation of the energy resolution.

- 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.

Simulation in PandaRoot (version 27316)

Our strategy

- Study the Preshowers inside DIRC : as a first step, reproduce the results from EMC group (EMC TDR section 9.2.1).
- Develop a smart algorithm to compensate the energy resolution deterioration using SciTil.

Our work

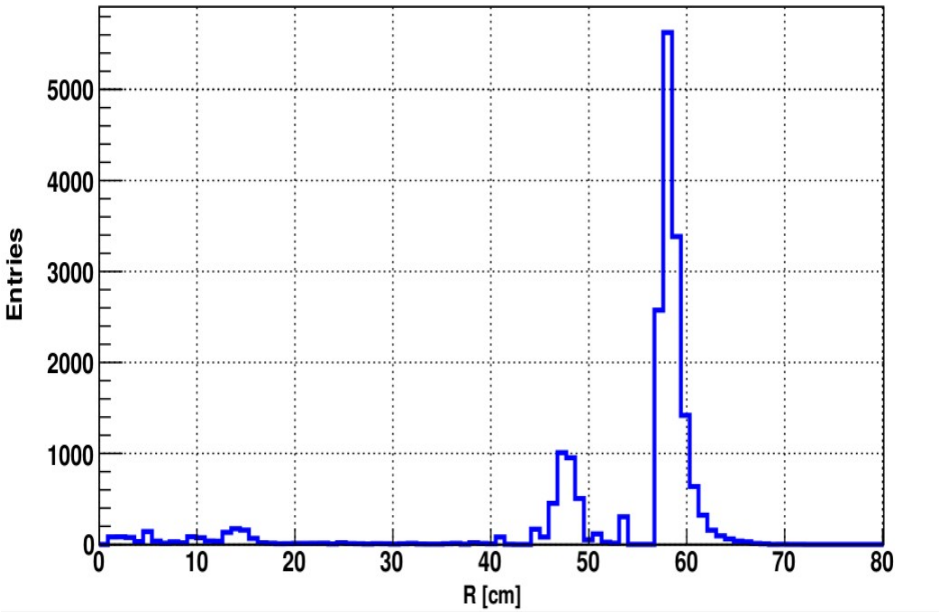
- Single photon MC events of energy 1 GeV are generated in pandaroot using box generator.

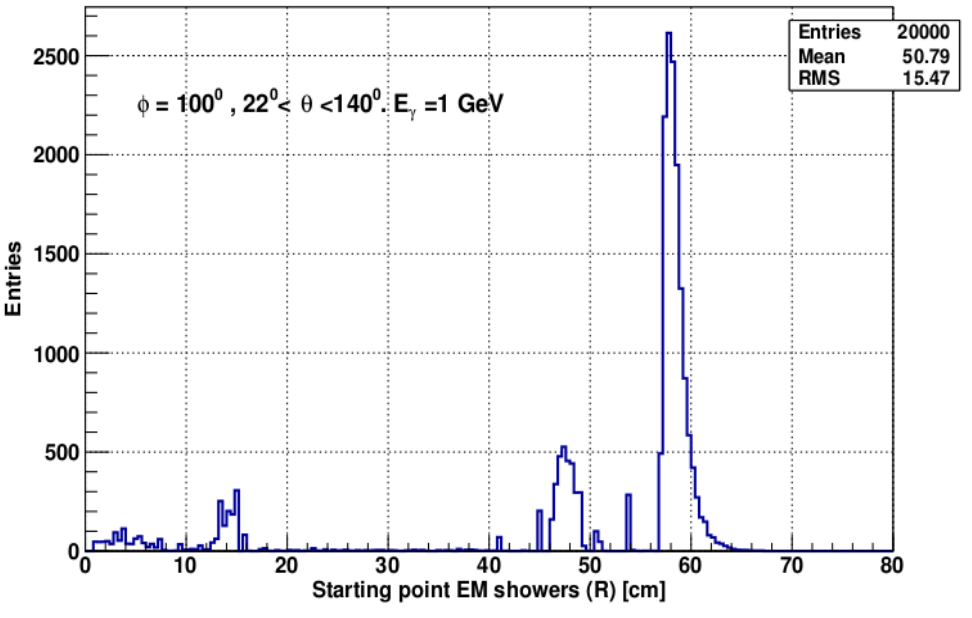
```
boxGen->SetPRange(1.0,1.0);
boxGen->SetPhiRange(0., 360.);
boxGen->SetThetaRange(22., 140.);
boxGen->SetXYZ(0., 0., 0.);
```

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

  R = Minimum of the radial distances of the starting vertices of the secondary particles.

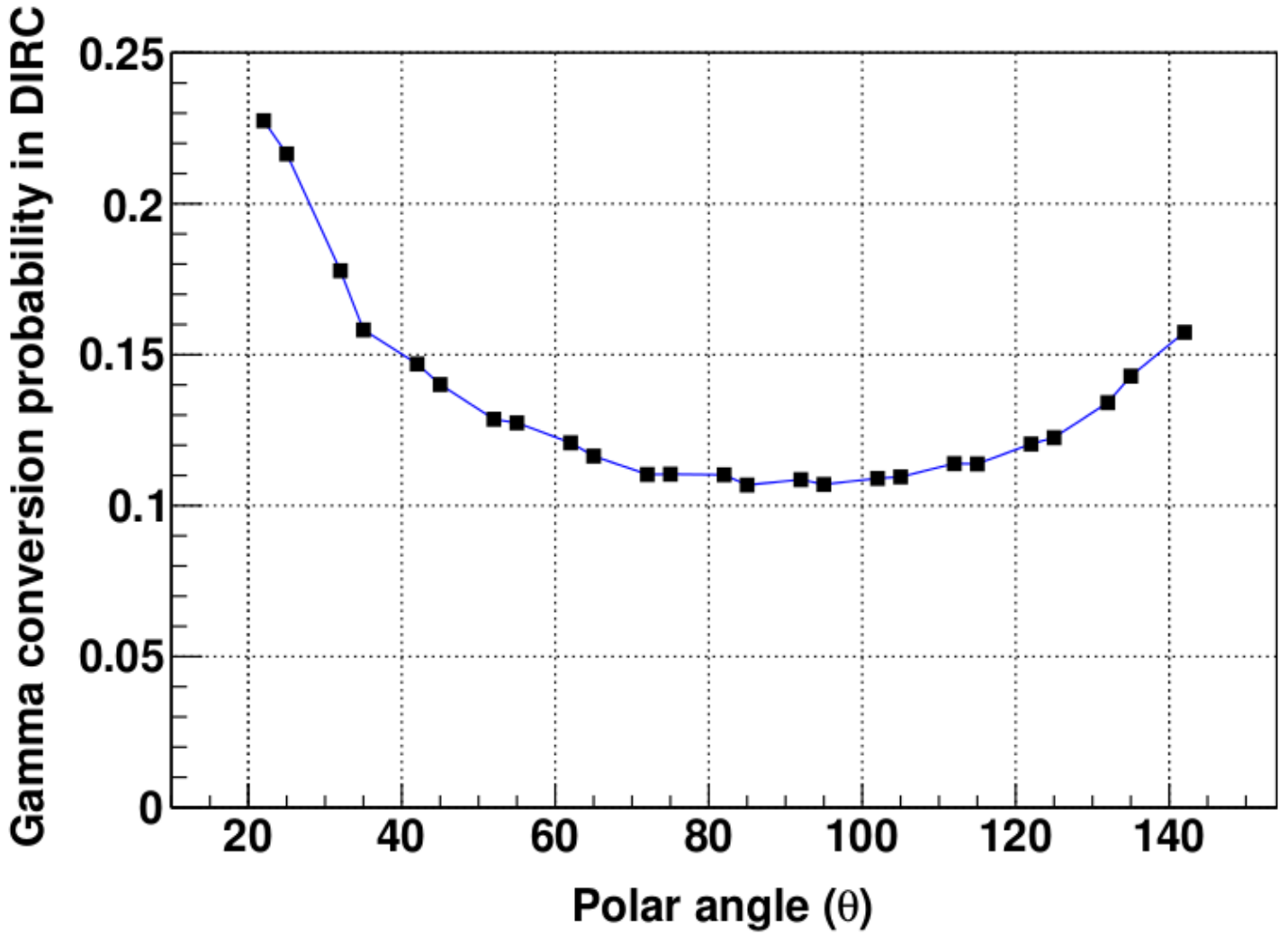
Starting point of EM showers

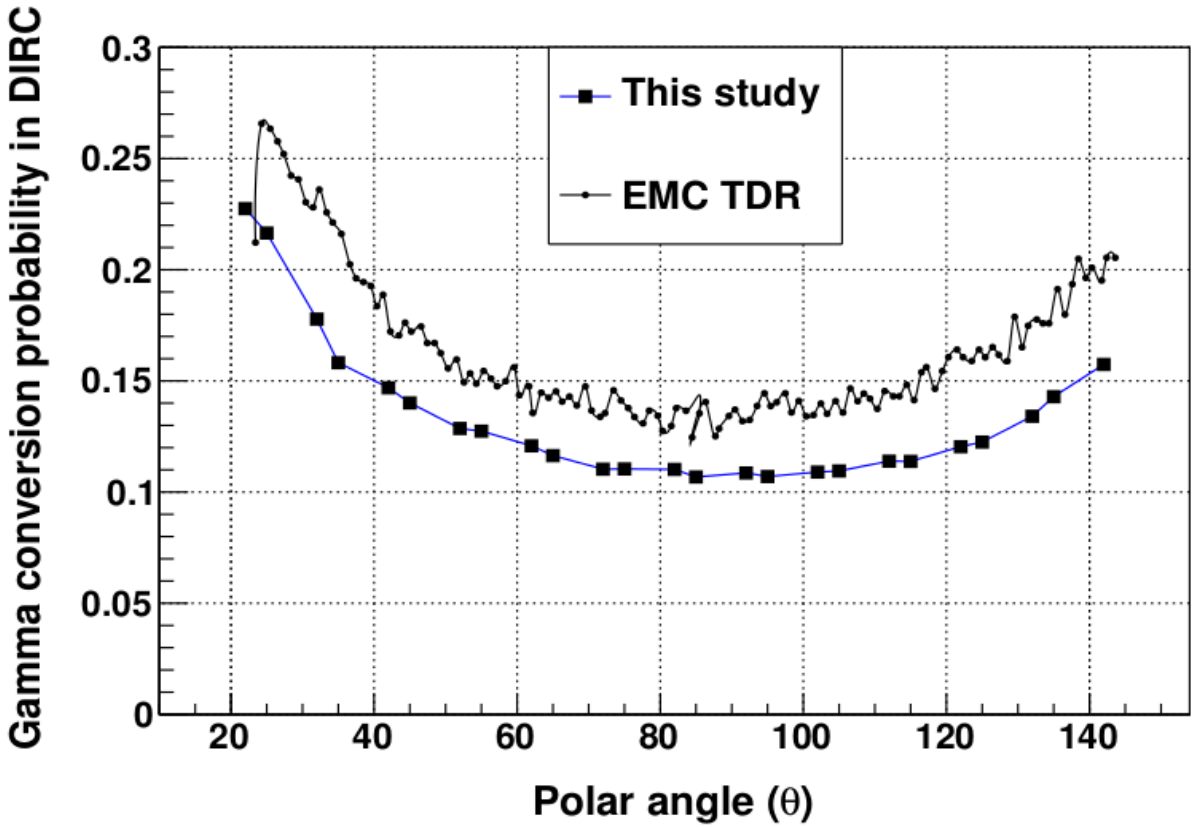




- Showers having 46.1 < R < 49.1 cm are identified as Preshowers in DIRC .

- $Gamma\ conversion\ probability\ in\ DIRC = \dfrac{No.\ of\ preshowers\ in DIRC}{No.\ of\ total\ generated\ gamma}$

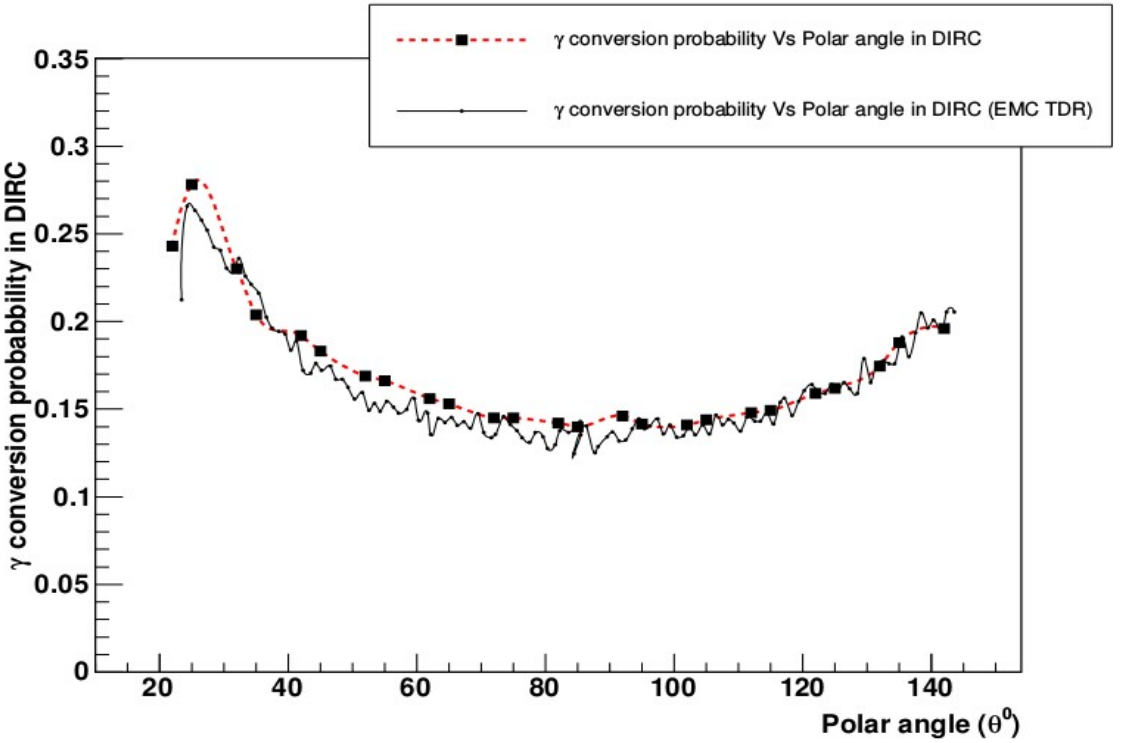

Gamma conversion probability in DIRC
0.25
0.2
0.15
0.1
0.05
0
20
40
60
80
100
120
140
Polar angle (θ)



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.

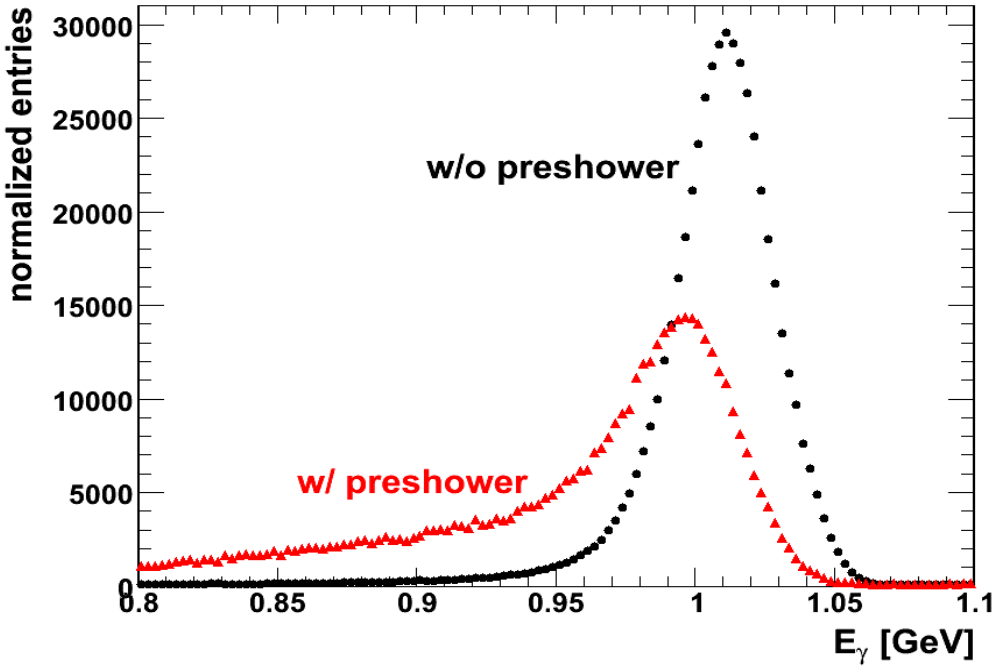
DIRC geometry	Gamma conversion probability
1. **EMC TDR**: DIRC quartz slab, thickness = 1.7 cm, DIRC bar support (Aluminium), thickness = 0.5 cm Total thickness in terms of radiation length = $\frac{1.7}{12.3} + \frac{0.5}{8.9} = 19.43\ \%$	0.11 @ $\theta = 90^0$
3. **This work (latest DIRC geometry 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 = $\frac{1.7}{12.3} + \frac{0.6}{18.8} = 17.01\ \%$	0.15 @ $\theta = 90^0$

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.

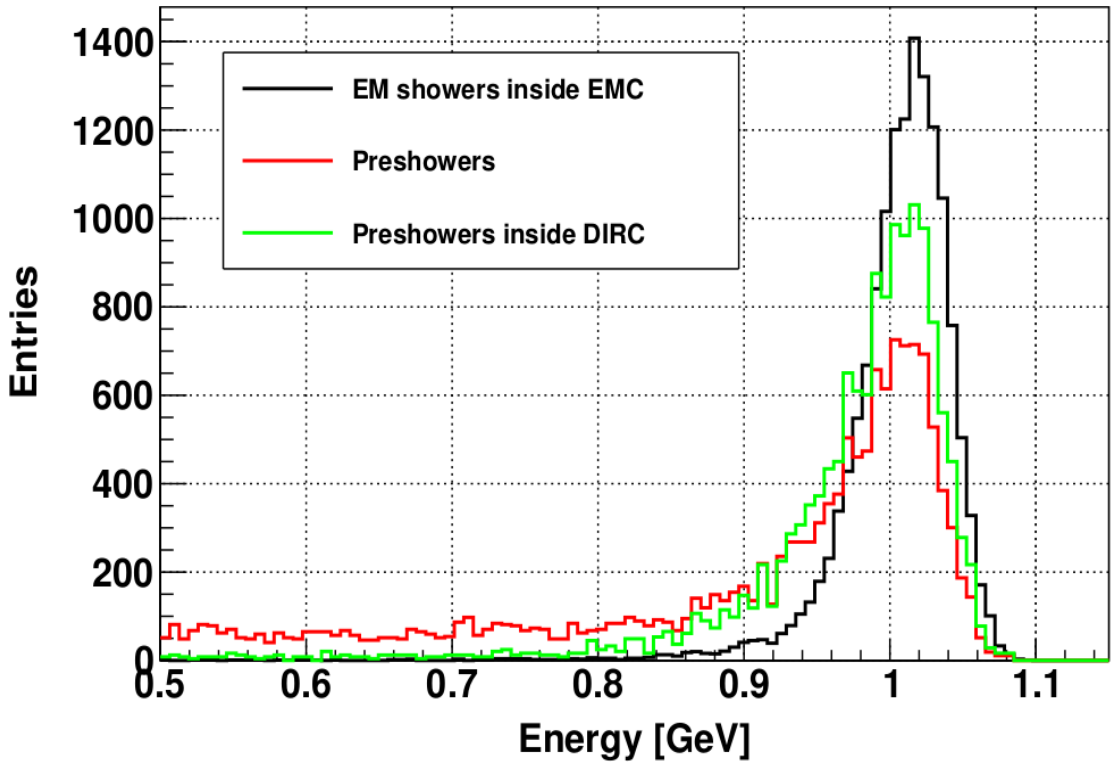


- In the Panda Physics book, the DIRC volume is given to be between R = 45 cm and R= 54 cm.
- If we consider, the DIRC radii between 45 cm and 54 cm, the variation gamma conversion probability vs polar angle is almost match with that of the previous simulation (EMC TDR) .
- Therefore, we suspect that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

Effect of Preshower on the energy resolution of photons



- In the previous study (EMC TDR), it has been obtained that the energy resolution for preshower events (**w/ preshower**) is worse than that for non preshower events (**w/o preshower**). The resolution of the energy spectrum becomes worse due to the preshowers in DIRC and it also adds a low end tail part to the distribution.



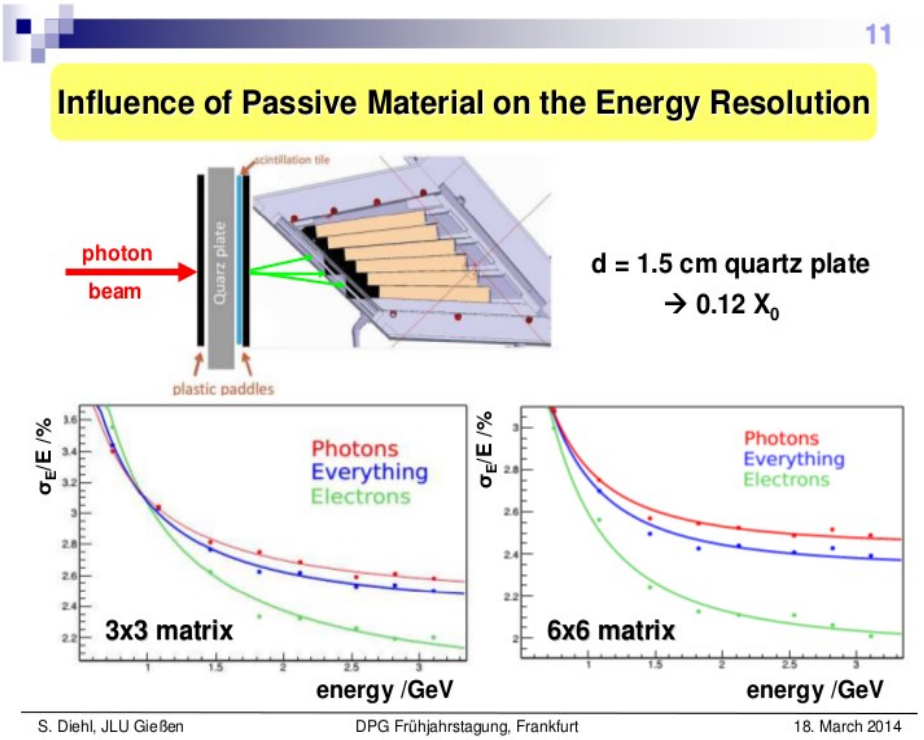
- In our study, it is observed that the energy spectrum of non preshower events is more or less of the Gaussian type. The Preshower events contributes a low end tail part to the distribution. But the effect of the preshower is not as prominent as found in the previous study.

Bonn Beam test results of preshowers

1. **Photons :** Non-preshower events, does not show signal on scintillator paddle behind quartz bar.

2. **Electrons :** Preshower events, shows signal to the scintillator paddle.

3. **Everything :** Preshower + non preshower events.



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

Conclusion and Outlook

- 2.8 % energy resolution at 1 GeV (incl. tagger res.)
- Higher order energy correction improves the position dependence of the energy resolution
- A quartz plate with ~ 0.1 X_0 in front of the prototype improves the energy resolution for E_{Photon} > 1 GeV
- Full energy range (50 MeV – 15 GeV) covered with PROTO 60

Simulation in PandaRoot

- DIRC quartz , thickness(d) = 3 cm (46.1 – 49.1 cm);
- Single photon events in theta = (22^0 – 140^0) and phi = $100^{0.}$
- Showers are classified in terms of the radial distance of the starting point,

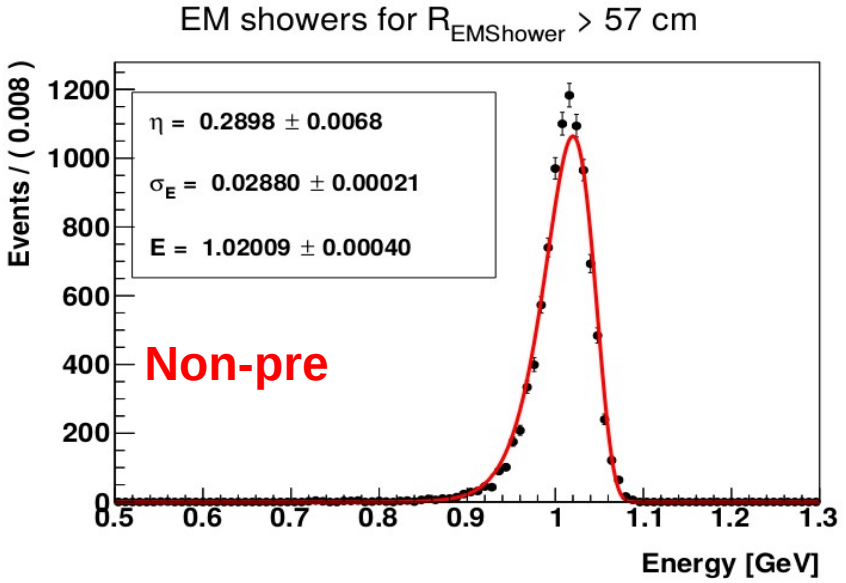
R = minimum of the radial distances of the starting vertices of the secondary particles (page 6).

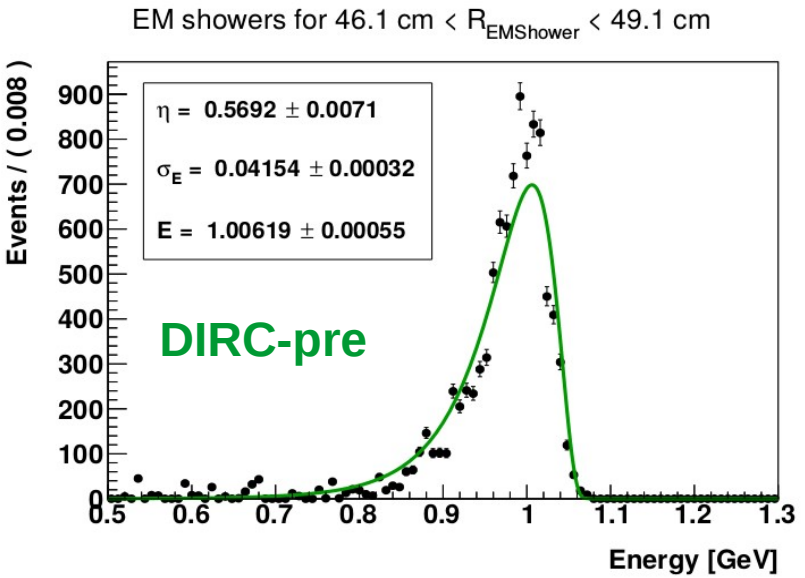
1. **Non pre :** Non-preshower events, R > 57 cm

2. **DIRC pre :** Preshower events, R > 46.1 cm and R < 49.1 cm

3. **DIRC pre + Non pre :** Preshower + non preshower events.

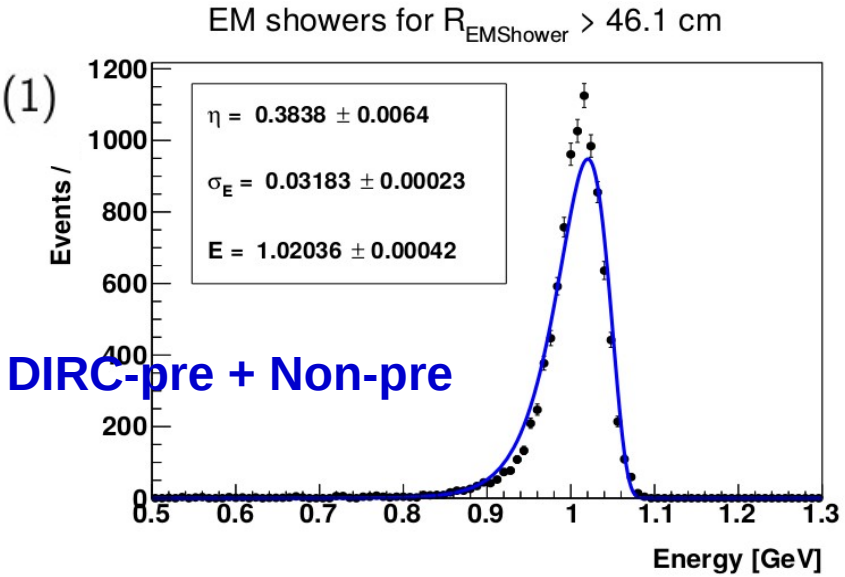
E(gamma) = 1 GeV





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

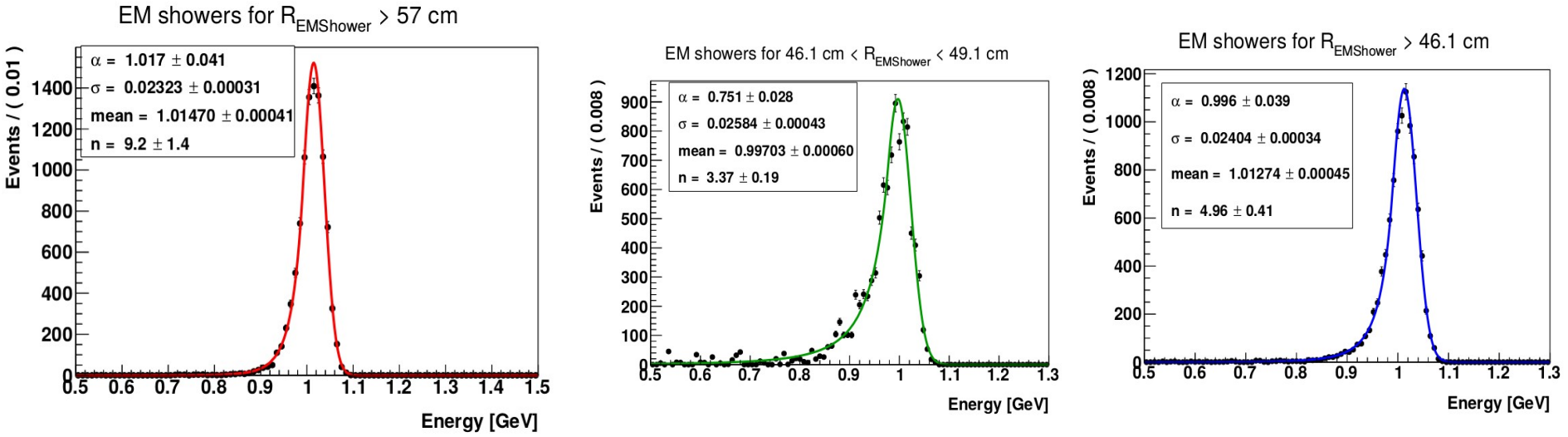
Novosibirsk Function. This is also used by EMC group to analyze the beam test results.



Some other function gives better fit to the energy distribution, e.g Crystal Ball function,

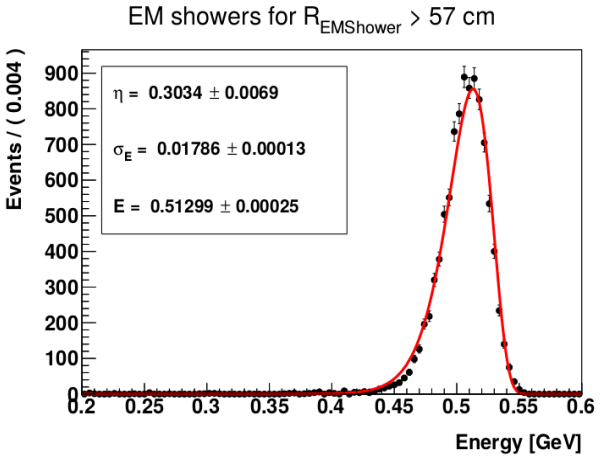
$$F(x) = \frac{1}{N}\begin{cases} exp\Big[-\dfrac{(x-\bar{x})^2}{2\sigma_E^2}\Big], x > \bar{x} - \alpha\sigma_E \\ \dfrac{(n/\alpha)^2 exp(-\dfrac{\alpha^2}{2}}{\Big[(x-\bar{x}/\sigma_E) + n/\alpha - \alpha\Big]^2}, x \leq \bar{x} - \alpha\sigma_E \end{cases} \quad (2)$$

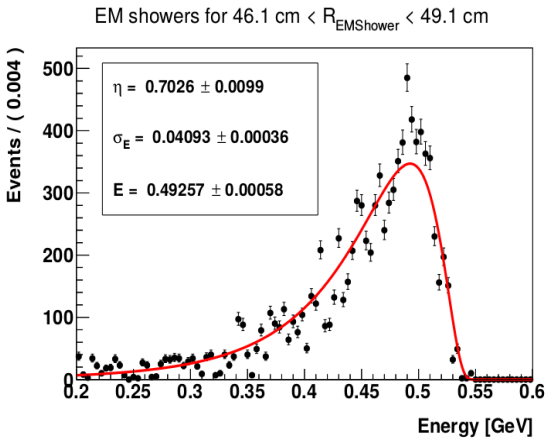
But we would like to use Novosibirsk function in order to be able to compare with Bonn beam time results.

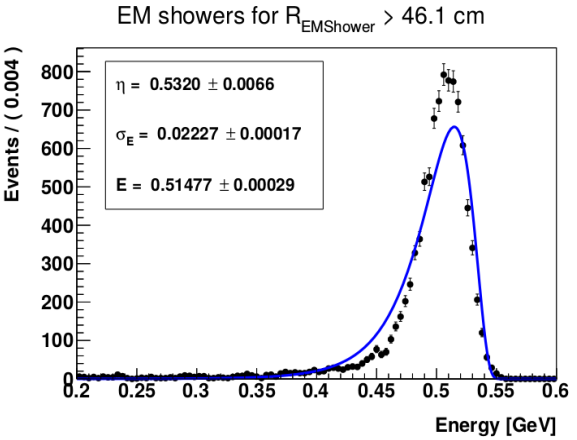


Crystal Ball function fit for 1 GeV photons.

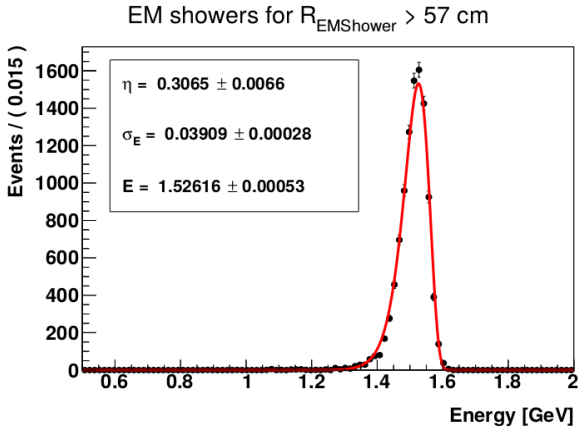
- **E(gamma) = 0.5 GeV**

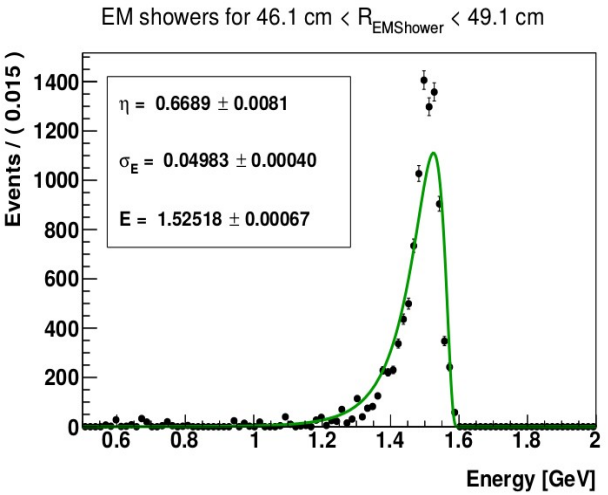


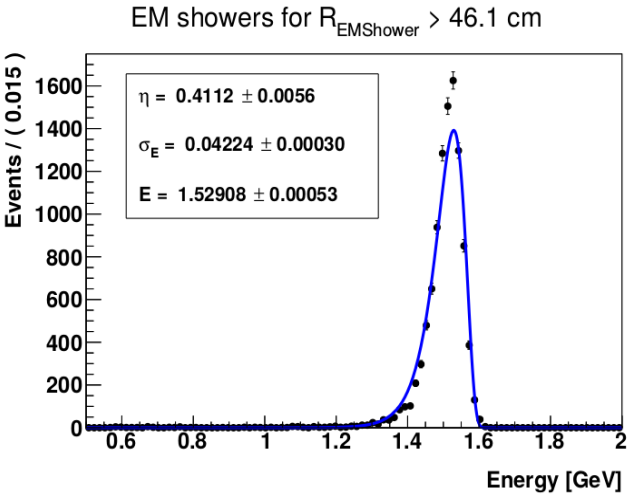




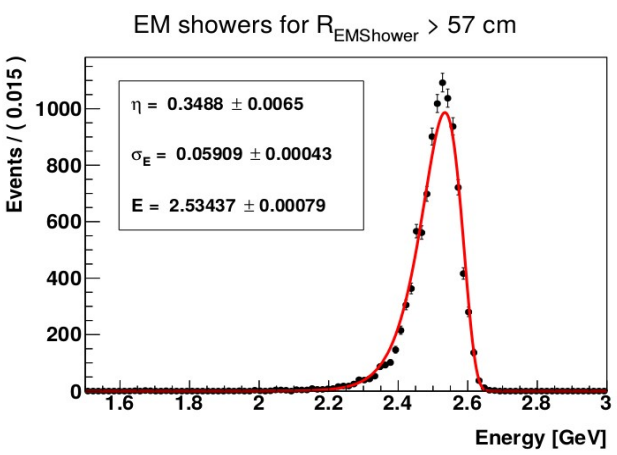
- **E(gamma) = 1.5 GeV**

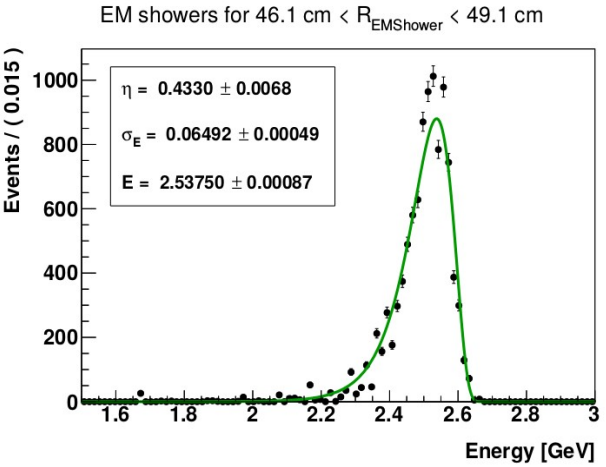


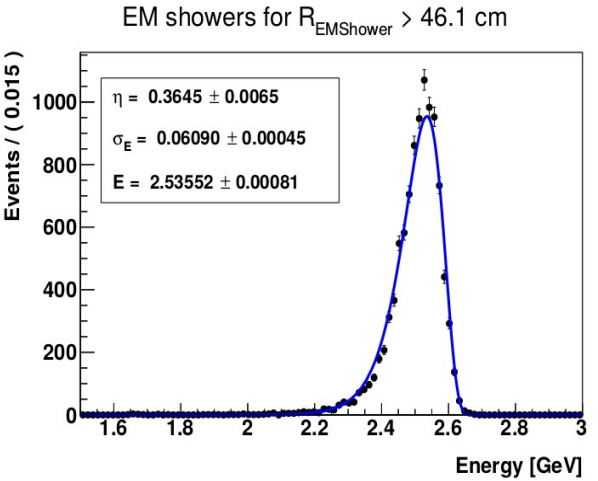




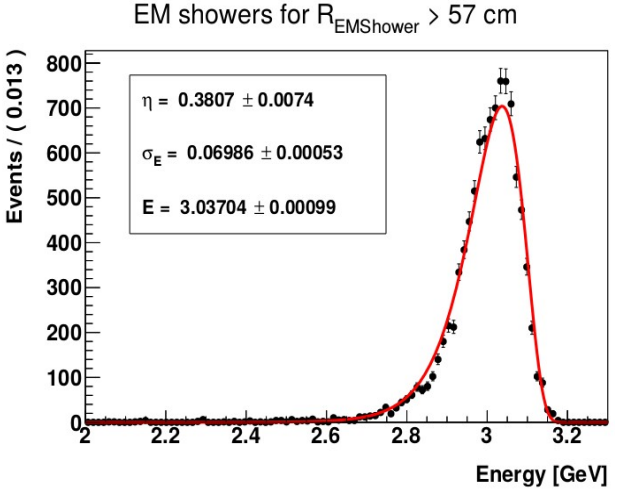
- **E(gamma) = 2.5 GeV**

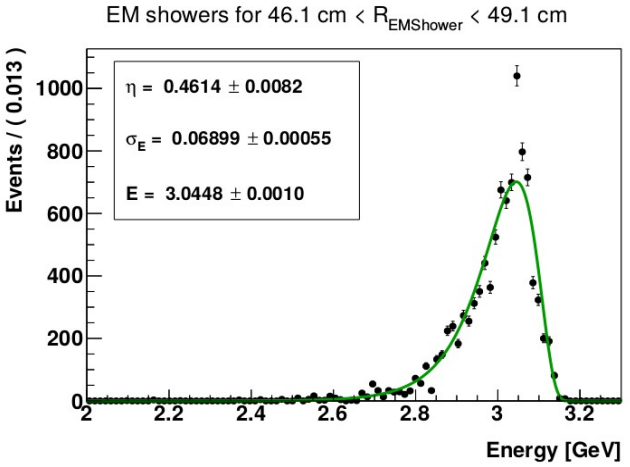


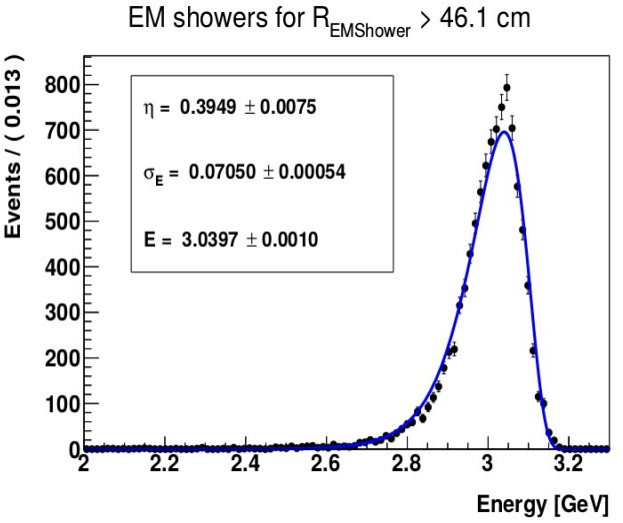




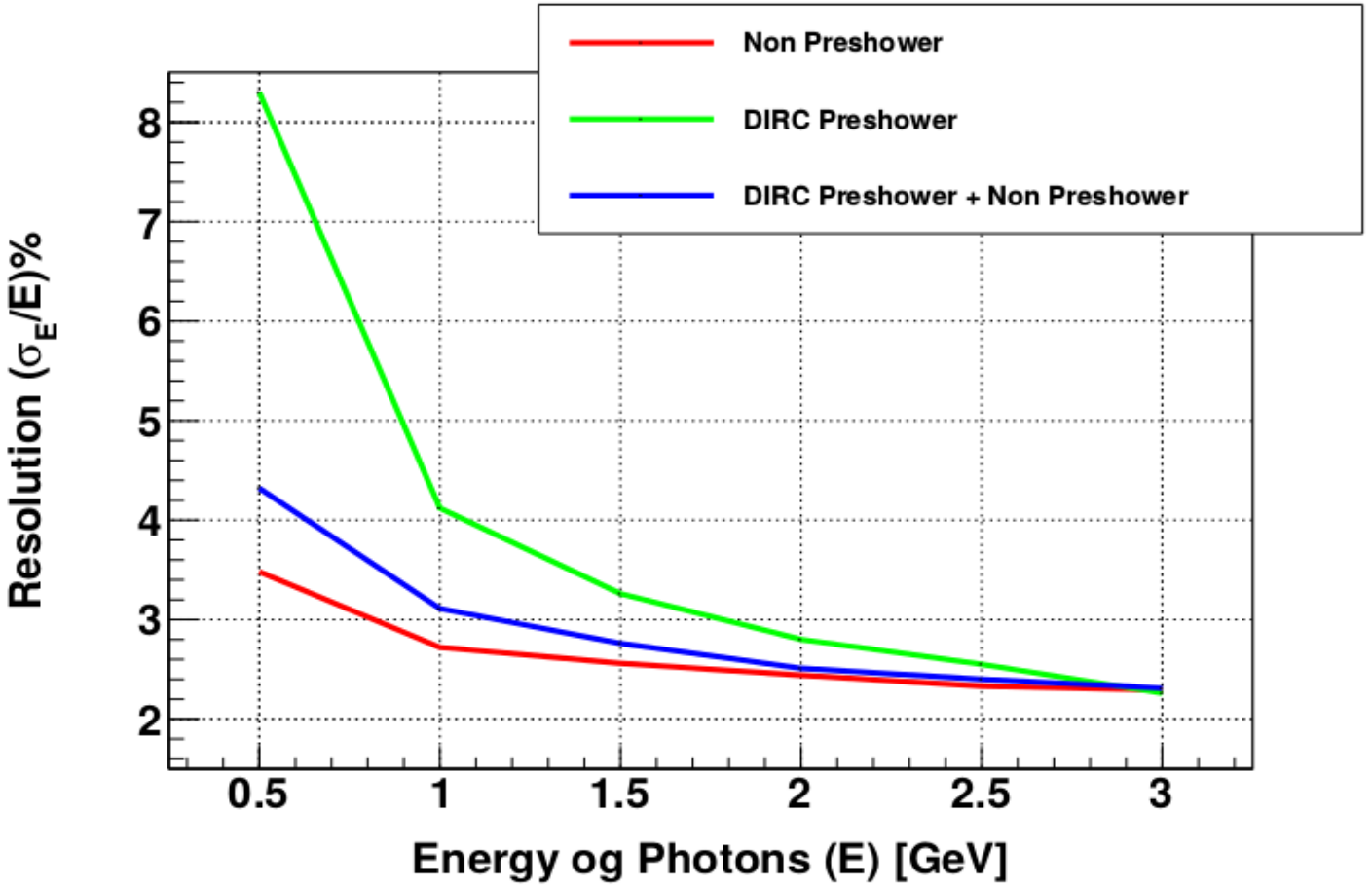
- **E(gamma) = 3.0 GeV**





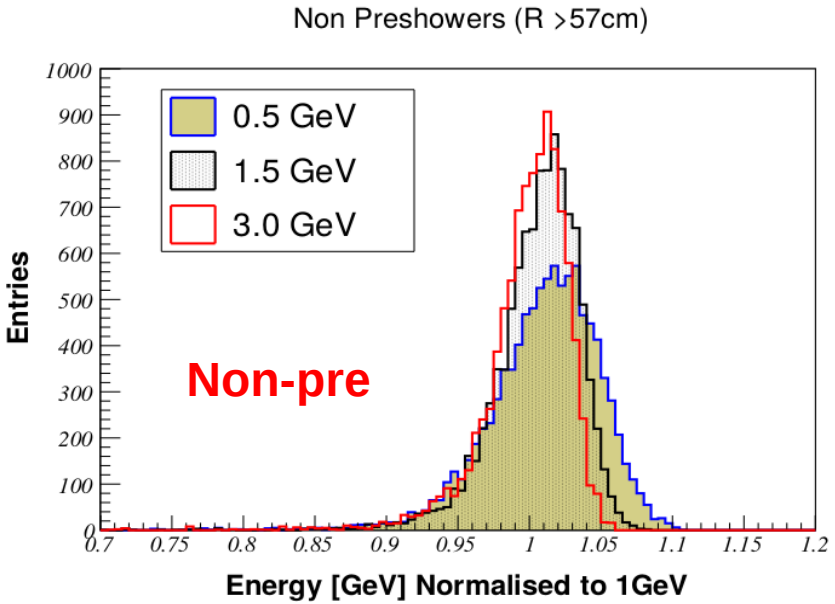


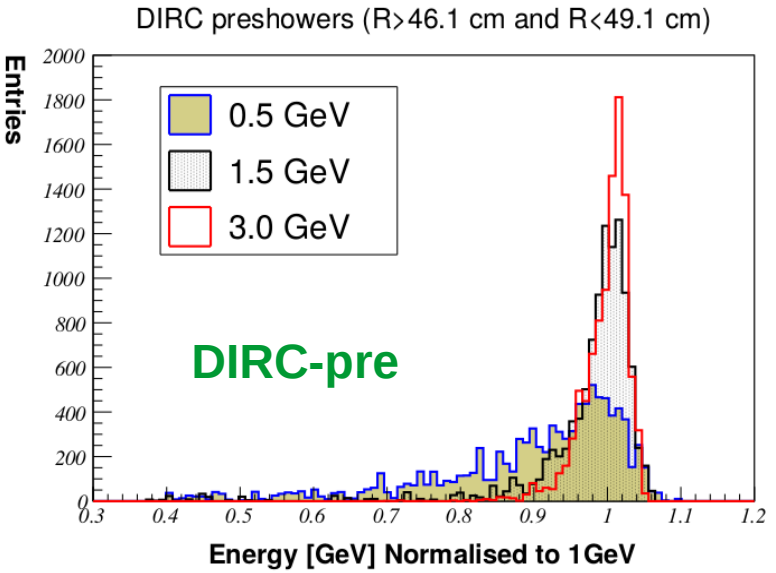
Energy vs Resolution

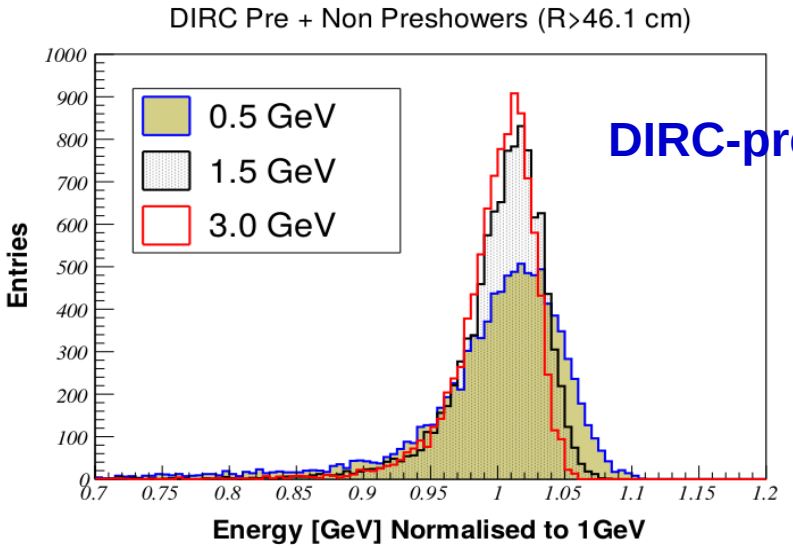


As the energy of the photons increases, the resolution becomes better for all three categories of events. However we do not see this improvement is due to the presence of preshowers in DIRC quartz bar, as concluded by the Bonn beam time results.

Energy vs Resolution







DIRC-pre + Non-pre

Conclusion

- We studied the DIRC preshower 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 90^0 and it increases to 23% at 22^0.
- We observed that there is no prominent deterioration of photon energy resolution due to the Preshowers .
- We would like to conclude that the preshower in Panda barrel DIRC detector does not effect the energy resolution of photon events. However it contributes a low end tail part to the Gaussian shape.
- In case of dependency of energy resolution of photons in EMC on DIRC preshowers, our PandaRoot simulation does not matching with Bonn beam time results (2013).
- We are waiting for new Beam time results.