Study of EMC Preshower correction with SciTil and Study of relative TOF with SciTil

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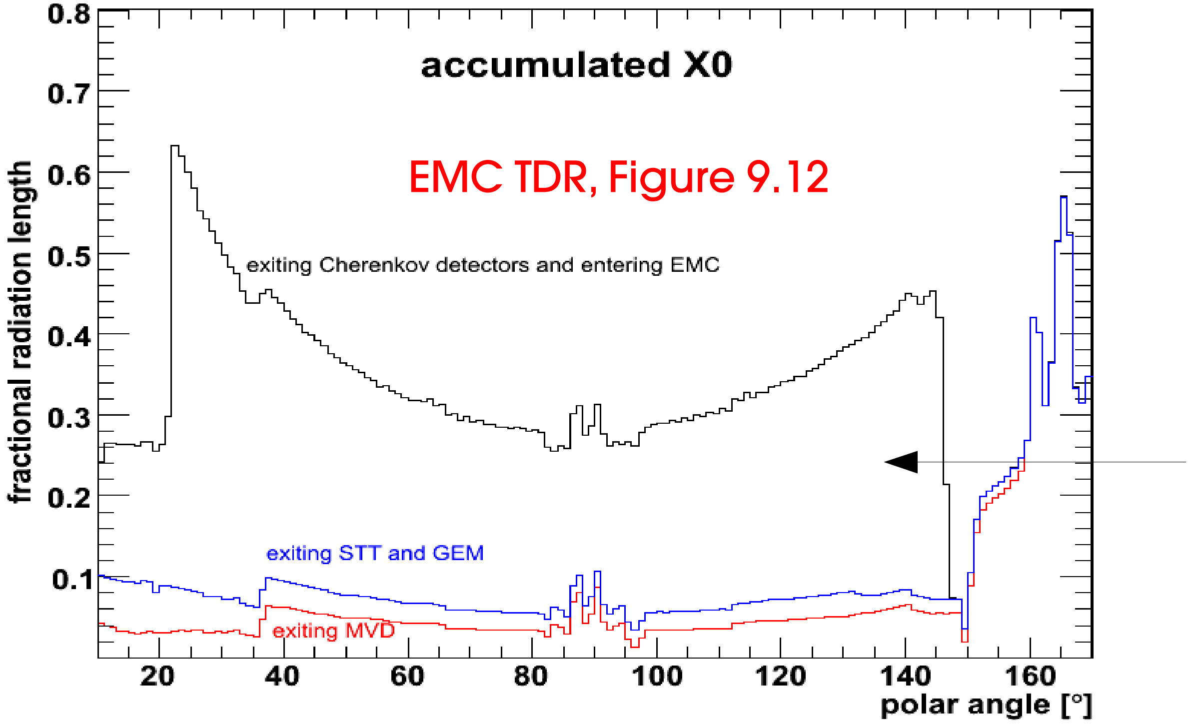
Study of Preshowers in DIRC and the possibility to detect them by TOF (SciTil) detector

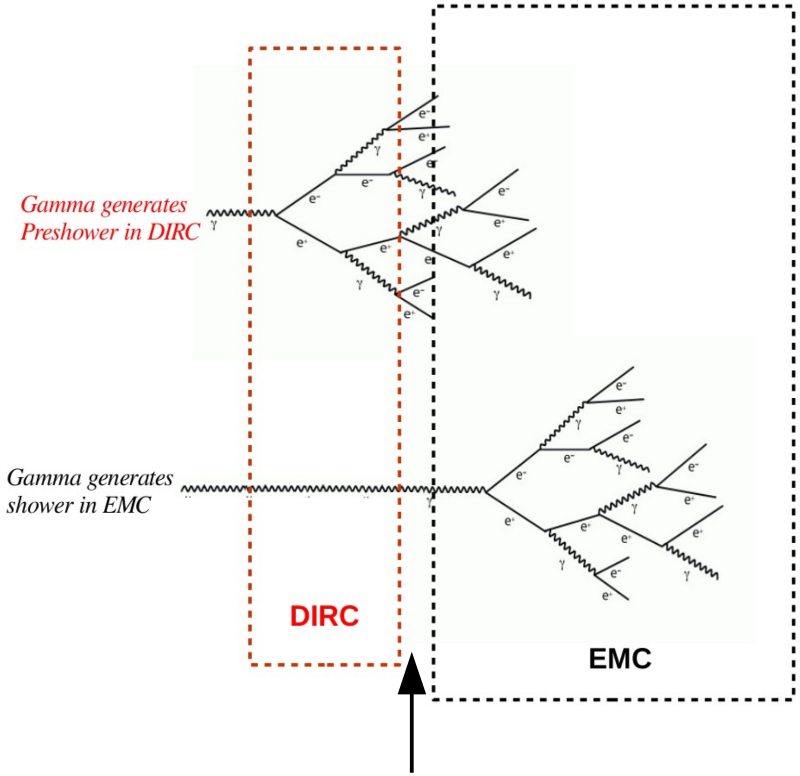
Introduction

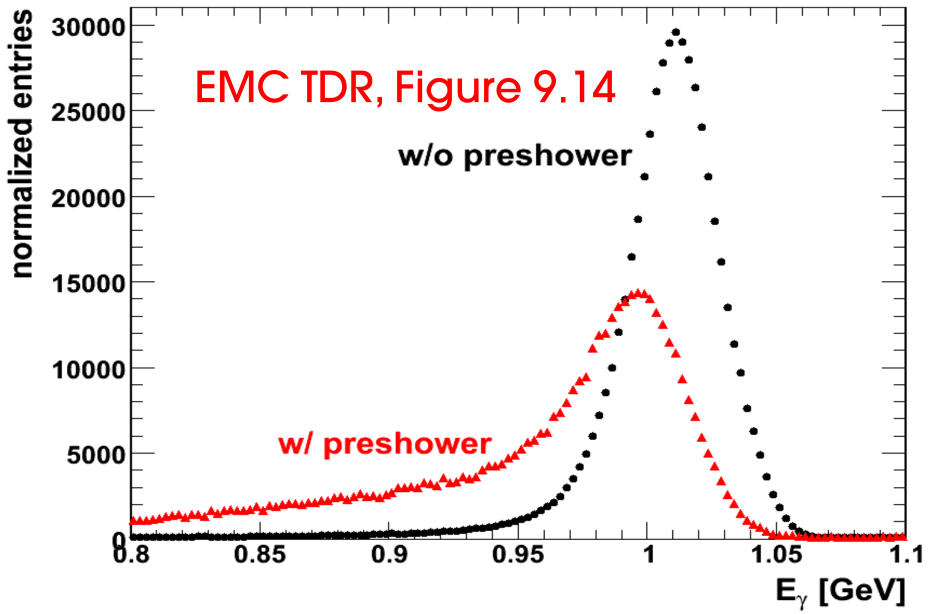
- The presence of high material budget of other detectors in front of Electromagnetic Calorimeter (EMC) lead to the possibility for a high energetic photon to start EM shower before EMC. A EM shower started before EMC is called ***Preshower*.**



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.

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.

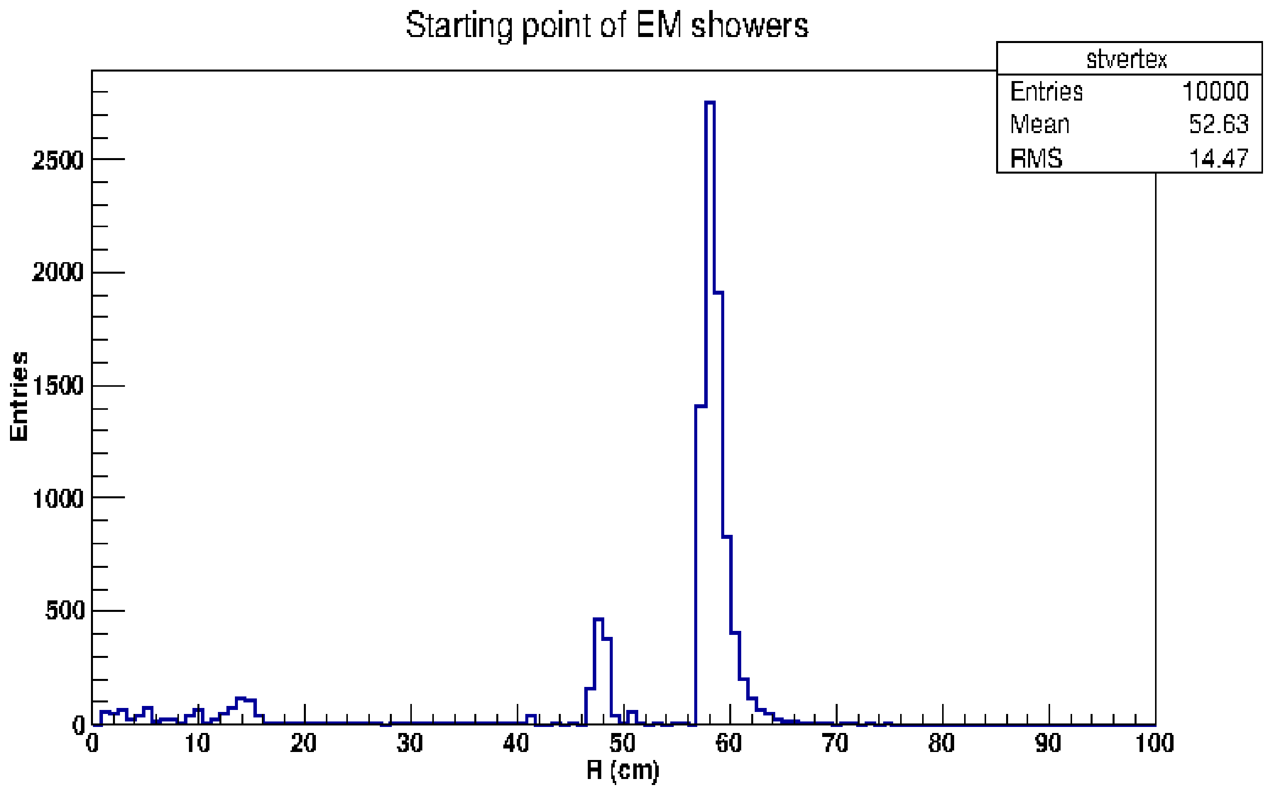
Our work

- 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,

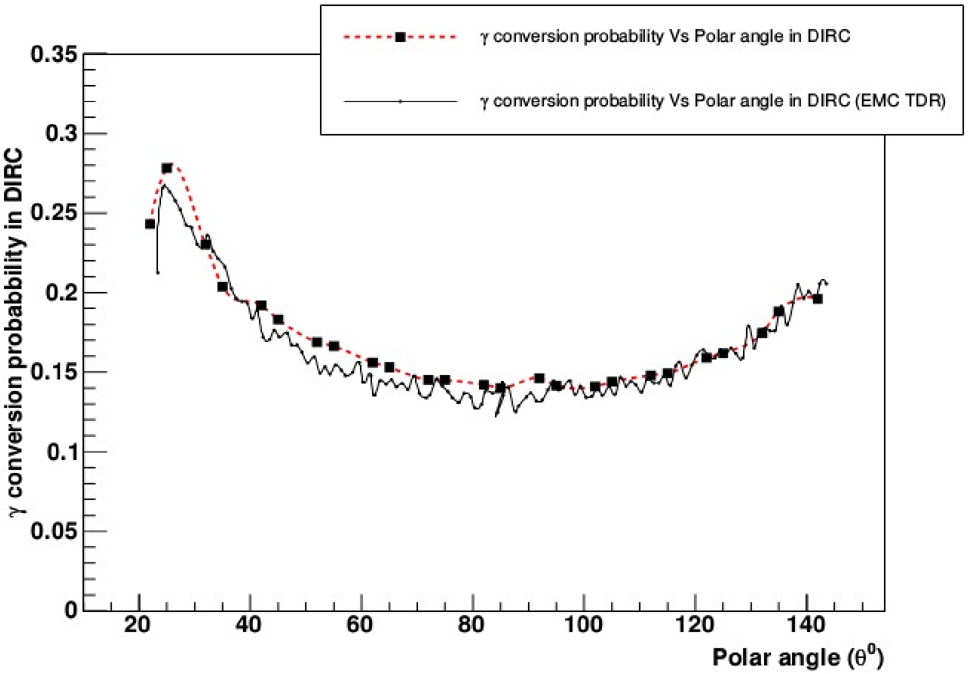
R = Minimum of the radial distances of the starting vertices of the secondary particles.



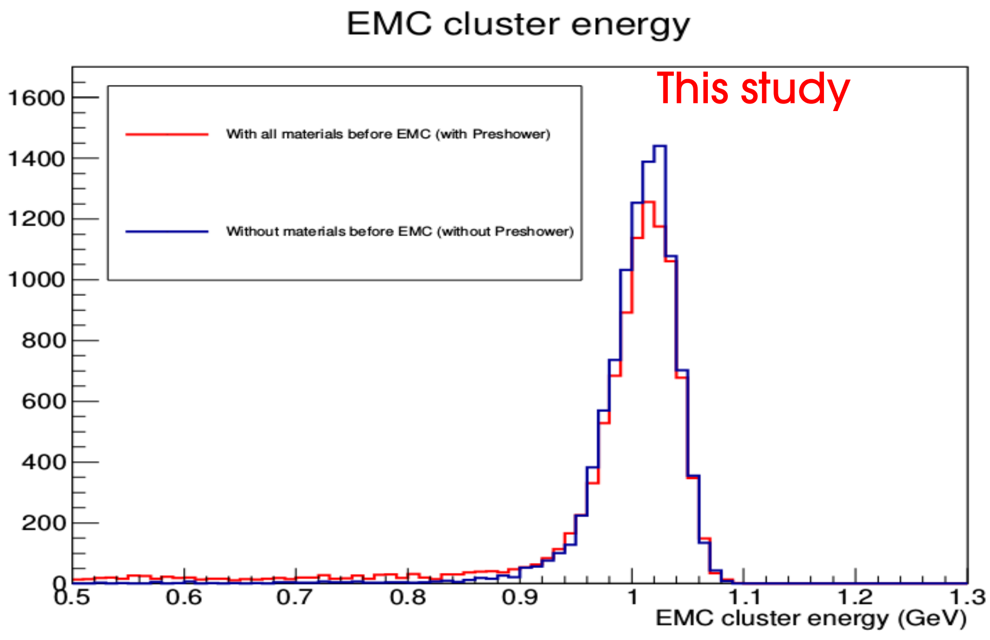
- Showers having 45 < R < 54 cm are identified as Preshowers in DIRC .

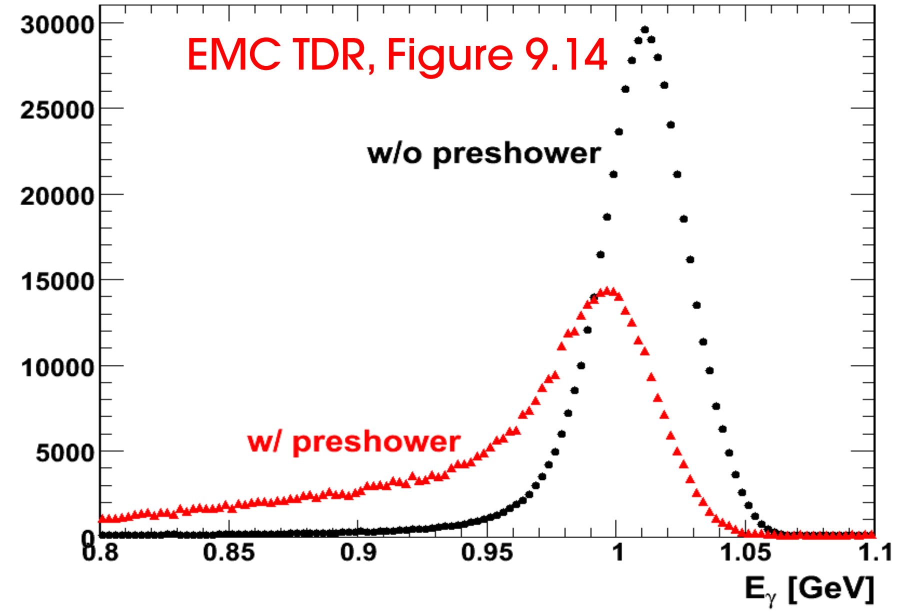
- $$\textit{Gamma conversion probability in DIRC} = \frac{No.\,of\ preshowers\ in DIRC}{No.\,of\ total\ generated\ gamma}$$

The gamma conversion probability in our study is found to be same or slightly higher than that presented in EMC TDR. 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.



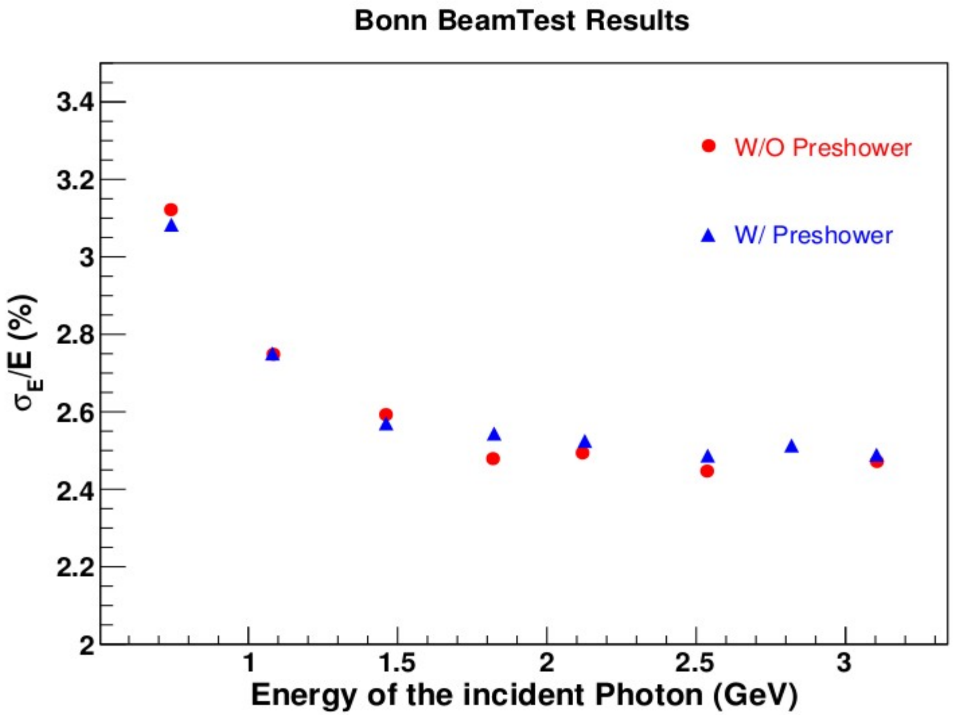
DIRC geometry	Gamma conversion probability
1. **EMC TDR**: DIRC quartz slab, thickness = 1.7 cm, DIRC bar support (Aluminium), thickness = 0.5 cm Total thickness in terms of radiation length = $\frac{1.7}{12.3} + \frac{0.5}{8.9} = 19.43\ \%$	0.14
3. **This work (latest DIRC geometry in pandaroot)**: 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

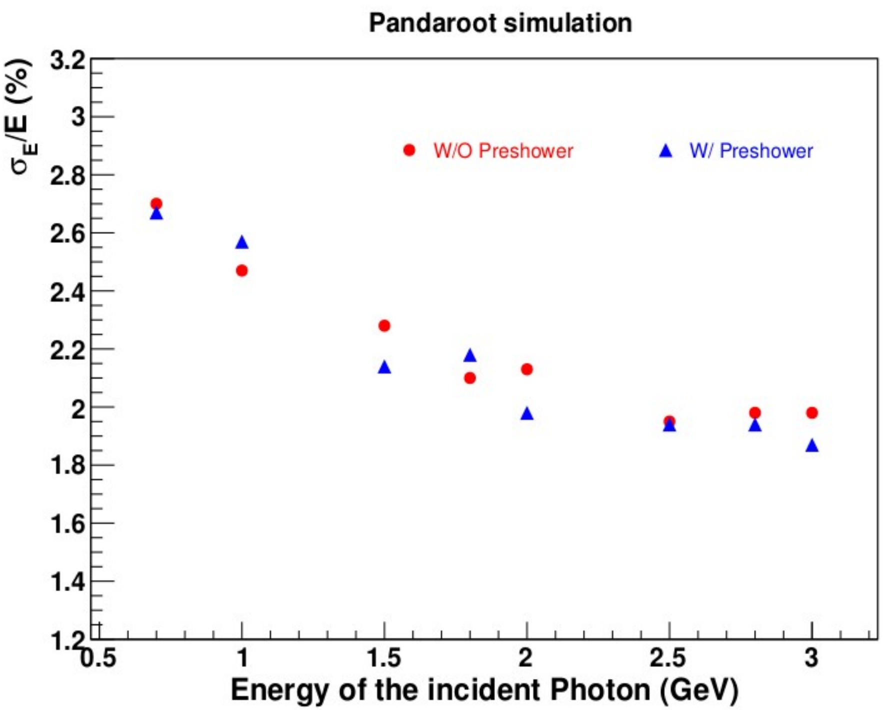




We observed no distinct degradation of energy resolution due to the presence of DIRC preshower, as observed in the previous study (EMC TDR). We have submitted an write up to EMC group to understand this mismatching and a discussion is going on.

The EMC group provided us the Bonn beam test results. We compare the energy resolution at various energies of the incident photon with and without the 1.5 cm thick quartz slab in front of the EMC material.





There is no remarkable change in the energy resolution due to the presence of 1.5 cm thick quartz bar in front of EMC. This is also confirmed in pandaroot by changing the DIRC bar thickness to 1.5 cm.

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 14% at the polar angle of 90^0 and it increases to 25% at 22^0.
- We observed that there is no prominent deterioration of photon energy resolution due to presence of DIRC material in front of EMC. The Bonn beam test also observed the same.
- In a previous simulation study (EMC TDR), a remarkable change in photon energy resolution is observed , which is still not understood.

Study of relative TOF with SciTil

Introduction

- There is no start timing detector in PANDA to record start time (t_0) of an event.
- The convenient algorithm is to use relative time-of-flight for particle identification using SciTil.

Time of flight for a given i-th particle is,

$$T_f = T_i - T_0 \qquad \text{(i)}$$

Where, T_i the arrival time on the SciTil and T_0 is the start time of the event to which the given particle belongs.

How to calculate start time of an event without a start detector ??

Here, we propose an algorithm adopted from **M. Basile et al., Nucl. Instrum. Meth. 179(1981) 477,** which is successfully implemented in Alice collaboration (http://www.bo.infn.it/alice/tof-over/alice_chap1.pdf).

Let us consider that we have ***n*** primary tracks in an event. Then, the zero time for ***i-th*** track can be written as,

$$t_i^0 = t_i - \frac{l_i}{v_i} \qquad \text{(ii)}$$

Each track has 3 possible masses, m_π, m_K and m_p. Thus for ***n*** track there are $\boldsymbol{3^n}$ possible mass configurations.

For a possible mass configuration $\boldsymbol{C\,(m_1, m_2, \ldots\ldots\ldots m_n)}$, the start time of ***i-th*** track can be written as the function of ***C***.

$$t_i^0(C) = t_i - \frac{l_i}{v_i(C)} \qquad \text{(iii)}$$

The weighted average of t^o over n tracks,

$$\langle t^0 \rangle (C) = \frac{\sum_{i=1}^{n} \frac{t_i^0(C)}{(error\, t_i^0(C))^2}}{\sum_{i=1}^{n} \frac{1}{(error\, t_i^0(C))^2}} \qquad \text{(iv)}$$

Where, ***error*** $t^0_i(C)$ is the error on t^0_i determination for the given mass configuration and it is the function of errors in t_i, v_i (in fact momentum p_i) and l_i .

$$\chi^2(C) = \sum_{i=1}^{n} \frac{[t_i^0(C) - \langle t^0 \rangle (C)]^2}{error\ t_i^0(C)} \quad \text{(v)}$$

Therefore,

C_{best} = the best mass configuration for ***n*** tracks

$$= min[\chi^2(C_1), \chi^2(C_2), ... \chi^2(C_{3^n})] \quad \text{(vi)}$$

t^0 determination

The start time of the event is obtained by taking the mean over selected primary tracks corresponding to the best mass configuration, i.e,

$$t^0 = \langle t^0 \rangle (C_{best}) \quad \text{(vii)}$$

Particle identification

The probability of a track to be Pion out of n primary tracks is,

$$W_i(pi) = \frac{\sum_{C^A} P_{C^A}(m_i = m_{pi})}{\sum_{C} P_C} \quad \text{(viii)}$$

Where,

P_C = confidence level of $\chi^2(C)$ with (n-1) degrees of freedom, and

C^A = set of mass configuration in which particle I is assumed to be a Pion.

Using the same, $W_i(K)$ and $W_i(p)$ can also be calculated for Kaon and proton.

It is obvious that,

$$W_i(pi) + W_i(K) + W_i(p) = 1 \quad \text{(ix)}$$

Conclusion

- For Particle identification using SciTil, the convenient algorithm is to use relative time-of-flight.
- An algorithm to calculate start time of an event is proposed here.