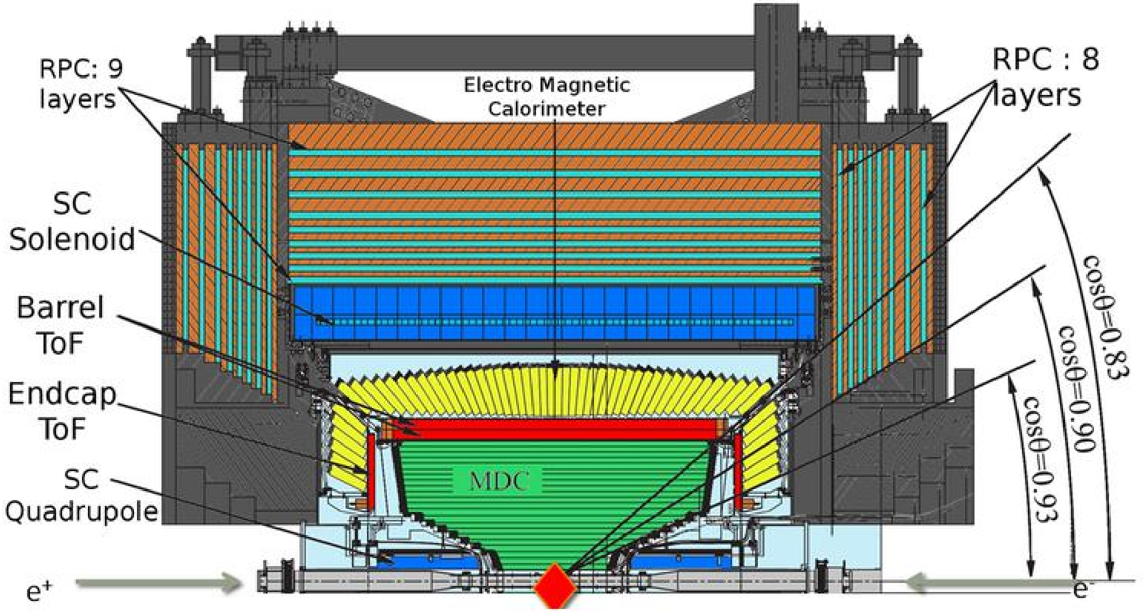
TOF sub-detector

Suyu XIAO from IHEP

20181221

TOF -- Time Of Flight sub-detector

- A Time-Of-Flight system(TOF) for particle identification; time resolution is about 80 ps in the barrel, and about 110 ps in the endcaps, corresponding to a K/π separation of more than 2σ level up to about 1.0 GeV



TOF -- Time Of Flight sub-detector

- TOF is to measure the flight time of **charged particles** for particle identification (PID) by comparing the measured time against the predicted time.

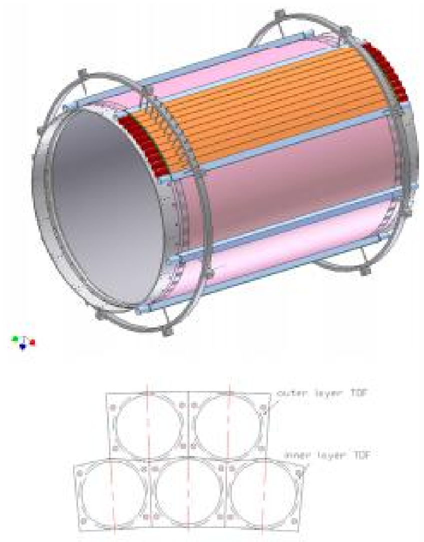
Table 1 Analysis of time resolution for PID

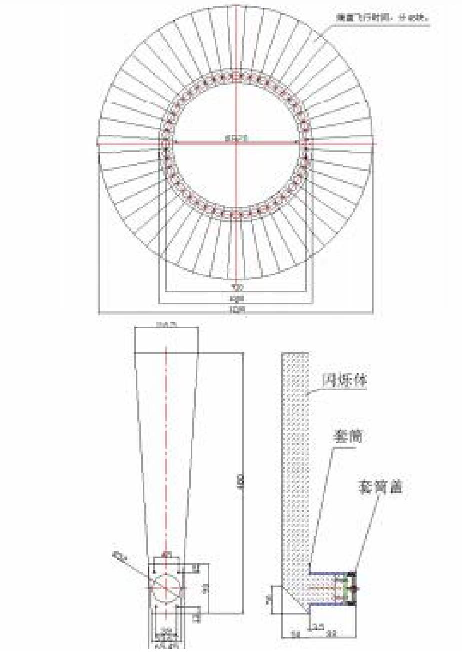
Item	Barrel time reso.	Endcap time reso.
Intrinsic time reso. of one TOF layer for 1 GeV muon	80~90 ps	80 ps
Uncertainty from bunch length	15 mm,35 ps	15 mm,35 ps
Uncertainty from bunch time	~20 ps	~20 ps
Uncertainty from Z position	5 mm,25 ps	10 mm,50 ps
Uncertainty from electronics	25 ps	25 ps
Resolution of expected time of flight	30ps	30ps
Time walk	10ps	10ps
Total time reso, one layer of TOF for 1 GeV muon	100~110ps	110~120ps
Total time reso, double layer of TOF for 1 GeV muon	90ps	

TOF -- Structure

- 2.4m long plastic scintillators arranged as a cylinder with two layers for the barrel, 5cm thick each, and 96 fan-shaped, 5 cm thick, plastic scintillators for two endcaps

plastic scintillator bar
directly coupled with FM-PMT

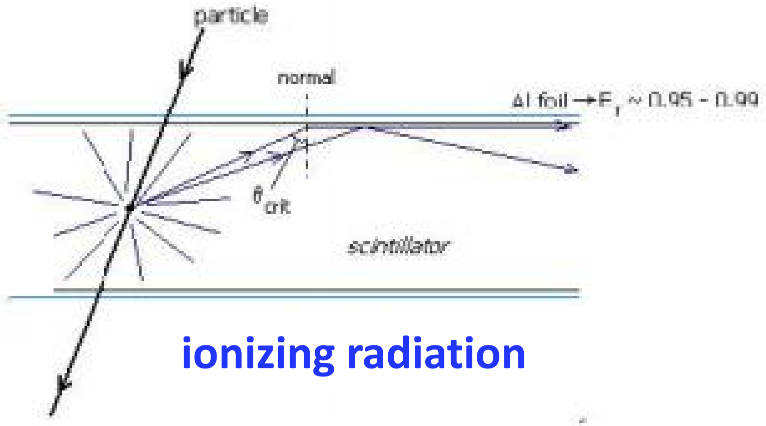




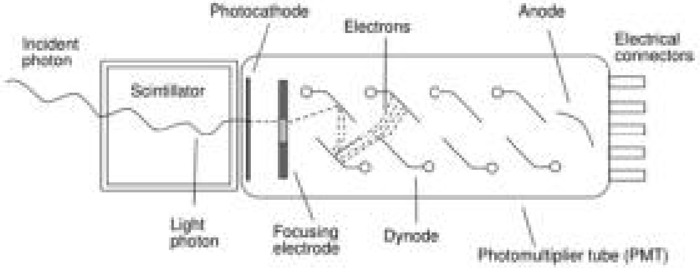
MRPC:
Multi-air gap resistive plate chamber

TOF -- Structure

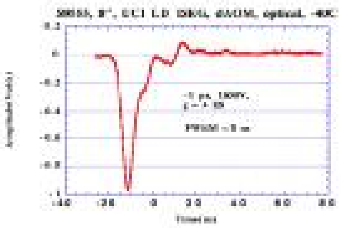
- Scintillator & PMT
- 光电倍增管输出信号，测量量：
  - Time Digital Conversion
  - 脉冲幅度（QTC）正比于产生的光子数目



ionizing radiation



PMT：PhotonMultiplier Tube



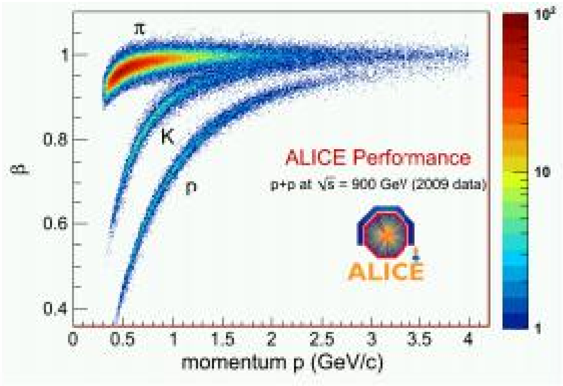
PMT输出信号

TOF -- PID

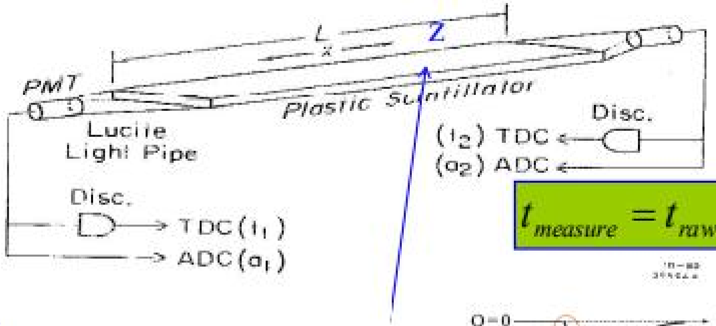
- PID can be done by measuring time

$$\beta = \frac{v}{c} = \frac{L}{c \cdot t} \qquad \beta = \frac{p \cdot c}{E} = \frac{1}{\sqrt{\left(\frac{m \cdot c}{p}\right)^2 + 1}}$$

$$m = \frac{p}{c}\sqrt{\left(\frac{c \cdot t}{L}\right)^2 - 1}$$



TOF -- Calibration

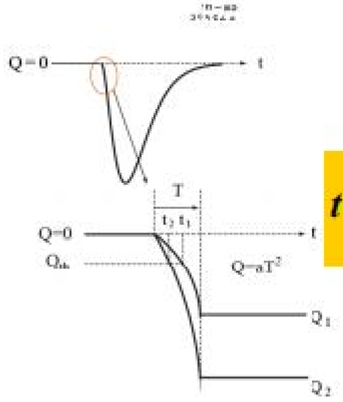


$$t_{measure} = t_{raw} - t_0 - t_{cor}$$

经验公式：

$$t_{cor} = P_0 + \frac{P_1 + P_2 \times z}{\sqrt{Q}} + \frac{P_3}{Q} + P_4 \times z + P_5 \times z^2 + P_6 \times z^3$$

P_0 - P_6：刻度常数



$$t \propto \frac{1}{\sqrt{Q}}$$

- 刻度常数
  - P_0: 时间延迟
  - P_1-P_3: 时幅修正
  - P_4-P_6: 等效速度的修正项
- 从MDC重建的径迹计算预期时间（与测量时间无关）

$$t_{predicted} = L / \beta c, \quad L: \text{flight path}, \quad \beta = p / \sqrt{p^2 + m^2}$$

- 最小化χ^2方法

$$\chi^2(\text{counter, readout unit}) = \sum_{\text{events}} (t_{measure} - t_{predicted})^2$$

- P_0-P_6的获得：

$$\frac{\partial \chi^2}{\partial P_i} = 0, \; i = 0,1\ldots6$$

37

- TOF测量量：每个PMT：一个TDC和一个QTC
  - 原始时间TDC → $t_{measure}$，刻度依赖于脉冲幅度，击中位置 ➔ 一套刻度常数
  - 径迹拟合+径迹外推 → 预期时间$t_{predict}$
  - 最小化∑（$t_{measure} - t_{predict}$）^{2}得到单个PMT时间刻度常数

TOF -- Resolution

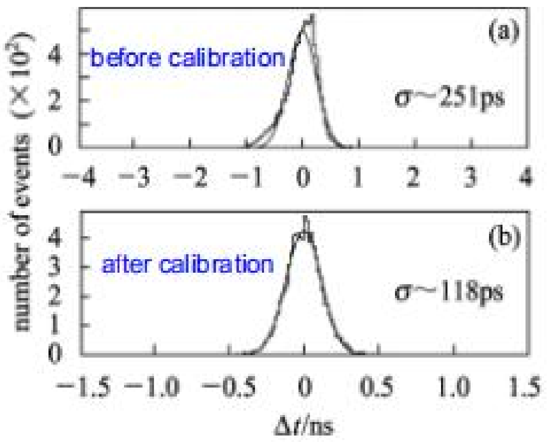
- 分辨的定义：

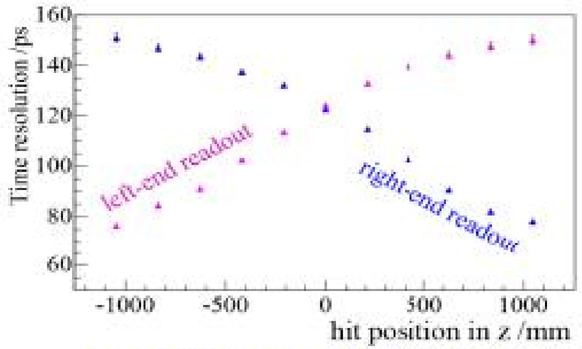
  测量时间—预期时间

$$\sigma^2 \equiv \frac{1}{n}\sum_{\text{events}}(t_{measure} - t_{truth})^2$$

$$\sigma = \sqrt{\sigma^2}$$

- 刻度结果



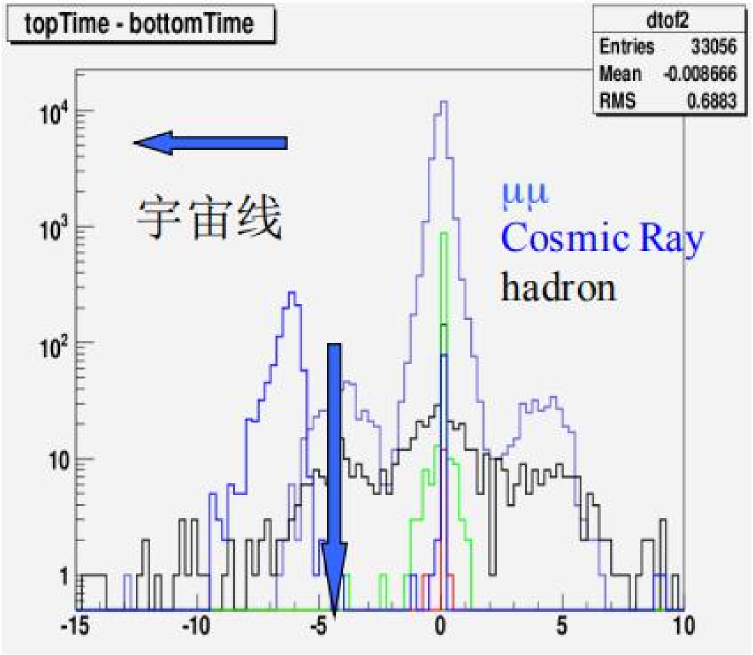


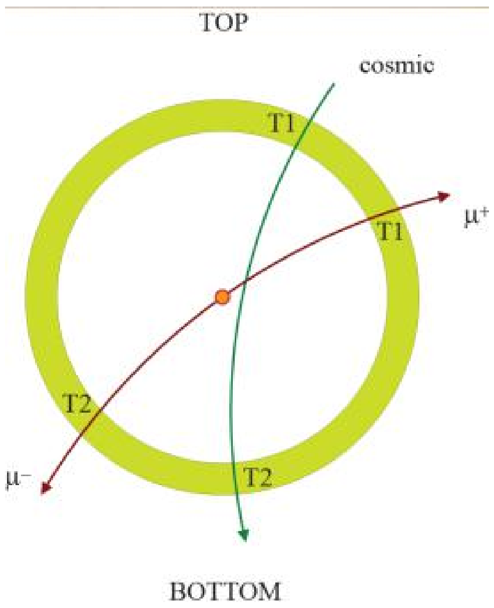
resolution vs hit position for single PMT readout

38

TOF -- Veto bkg

veto cosmic rays:



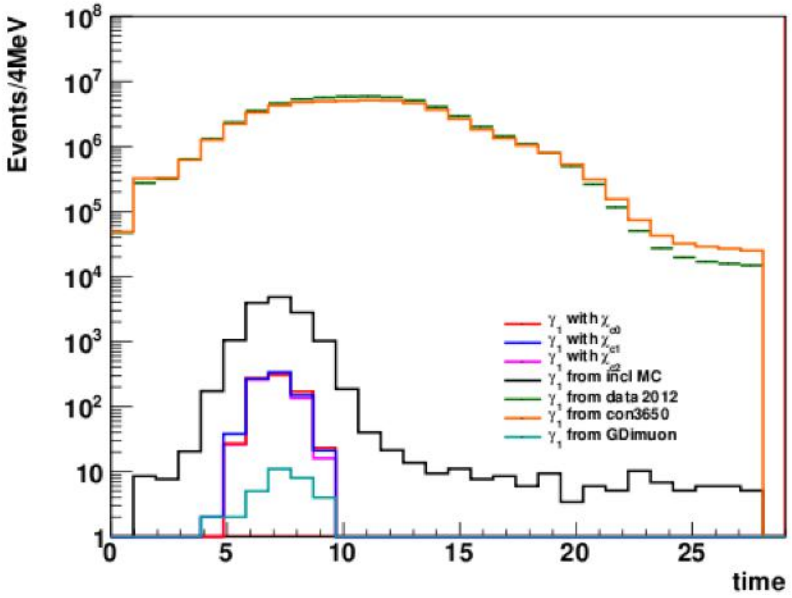


对撞事例：T1 ~ T2
宇宙线： T1 < T2

[0, 14] to veto bkg from other events.

TOF -- Neutral case?

In my previous chi_c -> invisibke case:



I used [4, 10] to veto bkg.

In BESIII Collaboration in Wuhan I was told that (-10, 10) is recommend and generally accepted(in case someone will do neutral invisible analysis).