Necessity of upgrade–TOF at BESIII

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June 8, 2000

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1 TOF status at BESII

♣ It is known that the TOF time resolution is determined by the following relation:

$$\begin{aligned} \sigma_{total} &= \sqrt{\sigma^2_{TOF} + \sigma^2_{beam}} \\ &\cong 180 \quad ps(\text{at} \quad \text{BESII}) \\ &\cong \sqrt{135^2 + 125^2} \quad ps. \end{aligned}$$

There is a great improvement than BESI ($\sim$ 330 ps). The momentum of single particle for 2 σ π/K separation can go up to 0.75 Gev/c.

♣ But loss $\sim$ 30% Eff. of PID Due to MUlti-hits.

♣ Ageing problem.

2 Request for upgrade of TOF in BESIII

1) To make counter pieces smaller to aviod multi-hits.

2) To need to improve σ_t.

♣ Mass resolution of BESII is:

$$m = p\sqrt{\frac{c^2t^2}{L^2} - 1}$$

$$\frac{\sigma_m}{m} = \frac{\sigma_p}{p} + \gamma^2(\frac{\sigma_t}{t} + \frac{\sigma_L}{L})$$

$$\frac{\sigma_p}{p} \approx 2\%, \quad \frac{\sigma_t}{t} \approx 4.7\%, \quad \frac{\sigma_L}{L} \approx 0.5\%.$$

It could be seen that most contribution comes from $\frac{\sigma_t}{t}$.

$$\gamma = \frac{E}{E_0},$$

when E=1 Gev, $\gamma\ \approx 2$ for K and $\gamma\ \approx 7$ for π.

σ_t(ps)	330	180	100	60
$\frac{\sigma_t}{t}$ (%)	8.7	4.7	2.6	1.6

Table 1: $\frac{\sigma_t}{t}$ contribution.

3) PID

♣ Upper limit of momentum for π/K ID is shown in table 2 and Fig.1.

σ_t(ps)	330	250	180	160	100	60
P (Gev)	0.37	0.58	0.75	0.82	1.04	1.32

Table 2: Upper limit of momentum for π/K ID

♣ Efficiency for π selection Eff. (%) is shown in table 3 and Fig.2.

♣ Background study. Results are shown in table 4 and Fig.3.

It is hopeful to suppress bunch length ¡ 1.5cm ($\sigma = 50$ ps) in BEPCII(RF 250M $\rightarrow$ 500M).

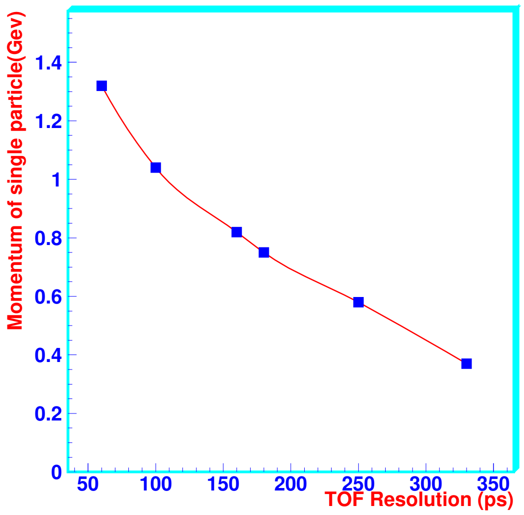


Figure 1: Upper limit of momentum for π/K ID

σ_t(ps)	330	250	160	100	60
1.5 Gev	36.6	72.5	87.6	95.1	99.5
1.1 Gev	69.2	83.8	93.4	99.1	99.9

Table 3: Efficiency for π selection Eff. (%)

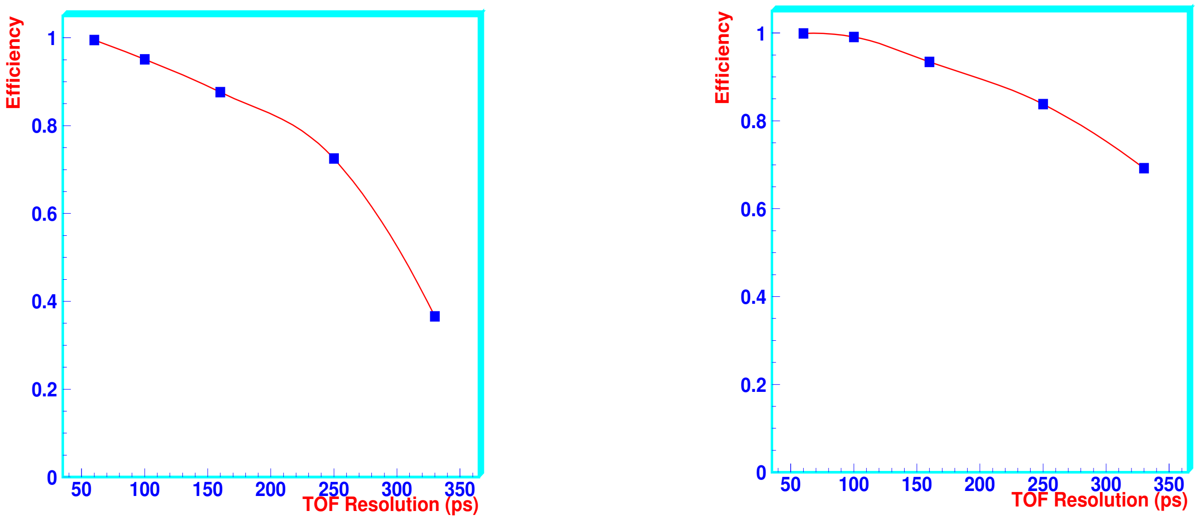
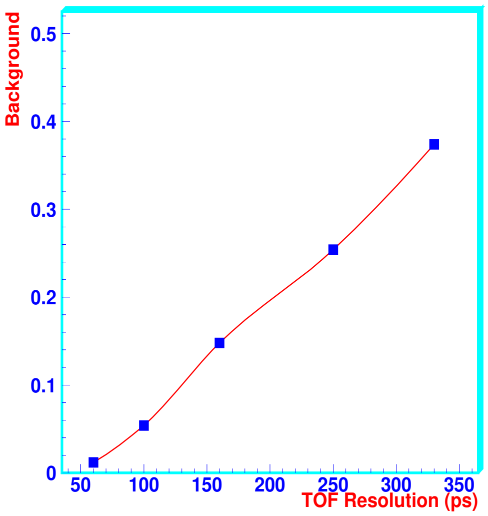


Figure 2: Efficiency for π selection. Left for 1.5 Gev amd right for 1.1 Gev.



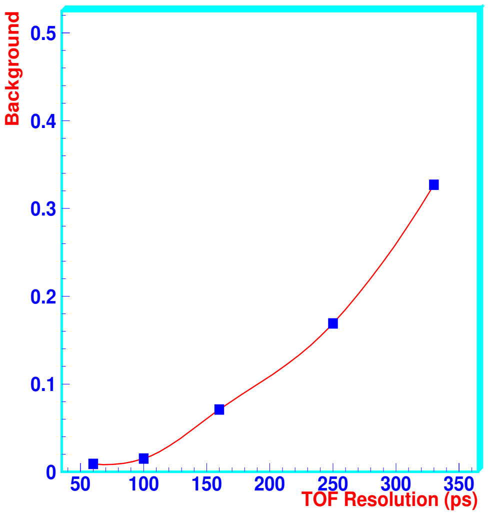


Figure 3: Mis-identification for K. Left for 1.5 Gev amd right for 1.1 Gev.

In the light quark spectroscopy, it is important to sepatate the closed states, such as $\xi(2230)$ and $X(2100)$, two states at $f_J(1710)$ region with 0^{++} and 2^{++}. So, in order to perform good physics analysis, it is important to improve the mass resolution.

Improve PID will increase data selection efficiency and reduce backgrounds events. It is very important for precision measurement, such as J/ψ rare decay and CP violation test.

σ_t(ps)	330	250	160	100	60
1.5 Gev	37.4	25.4	14.8	5.4	1.2
1.1 Gev	32.7	16.9	7.1	1.5	0.7

Table 4: Mis-identification for K (%)

3 Two kinds of options of upgrade TOF

A. Scintillator + Fine Mash PMT

(1) Make scintillators smaller pieces than that in BESII.

- cross section of scintillators to 6cm $\times$ 5cm. (15cm $\times$ 5cm in BESII).
- Length: Longer than BESII(2.84m) $\sim$ 3.1m.

- Same PMT, but number will be $\times$ 2.5 = 240 PMT. (cost will be higher $\sim$ 10 million RMB)
- Expected $\sigma_t \sim 80$ ps.

(2) Double layer scintillator.

- Same size of scintillator as (1)
- Same PMT, but number will be $\times$ 5 (more exoensive)
- Expected $\sigma_t \sim 60$ ps.

B. New development — multi gap resistive plate chamber(RPC)

History:

- PPC – PSC – RPC
- PPC (parallel plate chamber)
  - HV: 3 – 4 kv
  - σ_t: 190 ps
- PSC (pestov spark counter)
  - Gap: 100 μm
  - Gas pressure: 12 bar
  - HV: 4 – 6 kv
  - σ_t: 50 ps

ALICE (LHC detetor) TOF prototype —— multi gap RPC

- Area of cell: 3 $\times$ 3 cm^2
- Anode, cathode: Aluminium
- Resistive electrode: Glass ($\rho \approx 2 \times 10^{12}$ Ω cm)
- 4 gaps (or more)
- Gap: 300 μm
- Operation: Avalanche mode
- Preamplifier: $\times$ 10
- Gas: $C_2H_2F_4$ + 10% SF_6 + 5% isobutane Non-falmmable gas
- Gas pressure: Atomospheric

- Detection efficiency: ¿ 95%
- σ_t: 50 – 80 ps
- HV: 5 – 7 kv
- Cost: cheap

So, this is an attractive condidate of TOF with high time resolution.

4 R&D for multi-gap RPC

R&D for multi-gap RPC needs to understand:

- σ_t = ? (σ_t=80ps is expected)
- How large of cell? 3×20 cm^2 ?
- How hard of manufacture?
- What is the cost?
- How about the stability and reliability of the counter? lifetime?
- Preamplifier (fast + 10ω noise)
- Get experience of detail technology

5 Summary

- Should consider new TOF in BESIII for improvement of PID, mass resolution and decrease of multi-hits.
- There are two kinds of option for upgrade TOF in BESIII.
- Multi-gap RPC is a attractive candidate of upgrade TOF, but need the efforts for R&D.