Time of Flight Detectors at RHIC

- **Time of Flight Measurements at RHIC**
  - TOF detector as a PID devices
  - PHENIX-TOF and BRAHMS-TOF
- **PHENIX Time-of-Flight Detector**
  - Mechanical design and PID capability
  - Detector performance in year-1 operation
- **Hadron PID by PHENIX-TOF**
- **Summary**

Tatsuya Chujo
for the PHENIX Collaboration

BROOKHAVEN NATIONAL LABORATORY
managed by Brookhaven Science Associates for the U.S. Department of Energy

Time of Flight Measurements at RHIC

- Hadronic observables for QGP search

1. Identified single particle spectra and yields
2. Special and temporal evolution of the source, extrapolated by Hanbury-Brown Twiss effect (HBT)
3. Strangeness abundance
4. In-medium modification of ϕ meson's property

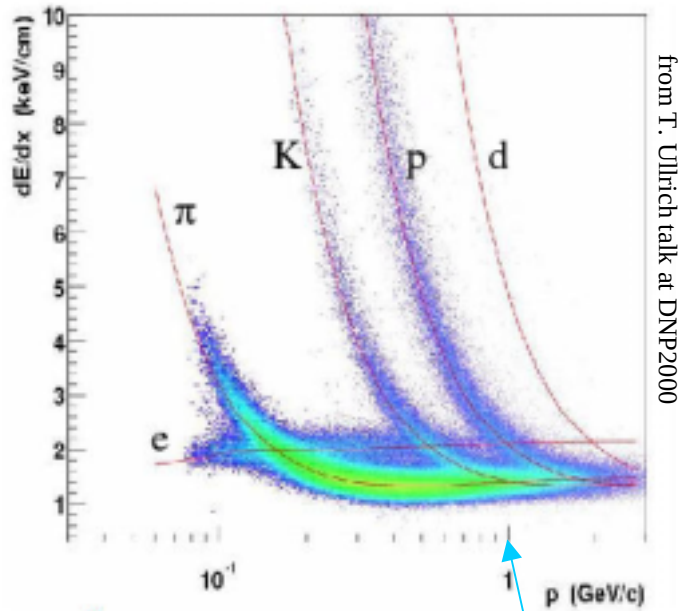
……

Precise measurement of identified hadrons in wide p_T range is required to understand the collision dynamics at RHIC

Needed high timing resolution TOF detector at RHIC experiments

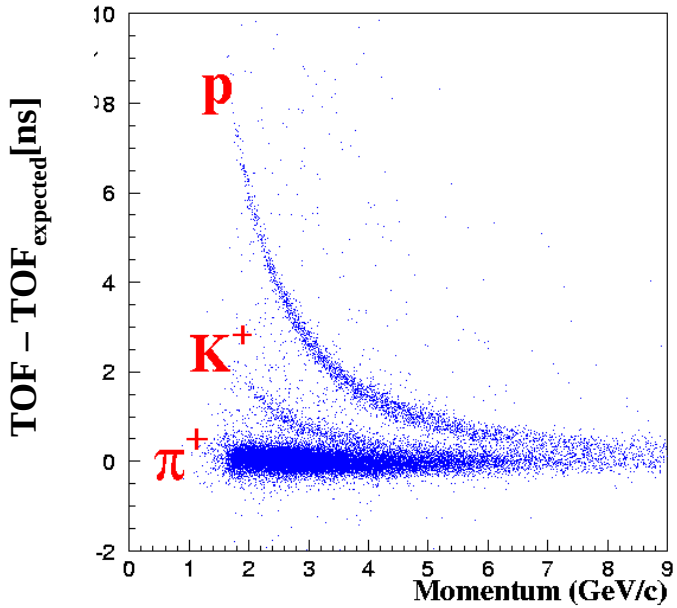
Why PID by TOF Is Important ?

PID by dE/dx in TPC (STAR)



from T. Ullrich talk at DNP2000

PID by TOF (WA98)



1.0 GeV/c

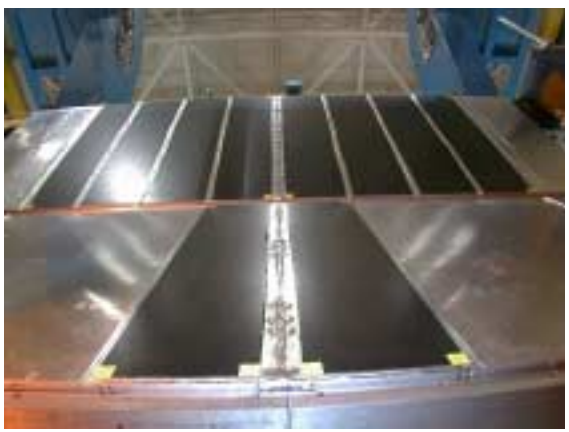
- **Limitation of PID capability by dE/dx : p < 1 GeV/c π/K separation**
- **PID by TOF : Clear π/K/p separation at higher momentum.**

TOF Detectors in HI Experiments

AGS-E802 (1987-1996)

AGS-E866 (1993-1996)

SPS-WA98 ARM II (1995-1996)

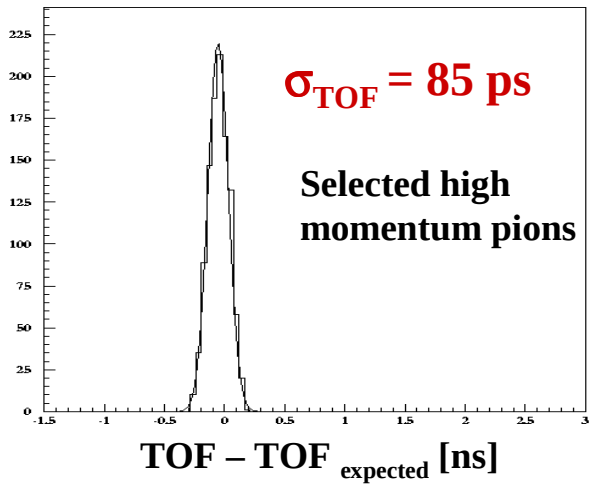


PHENIX
(2000-)

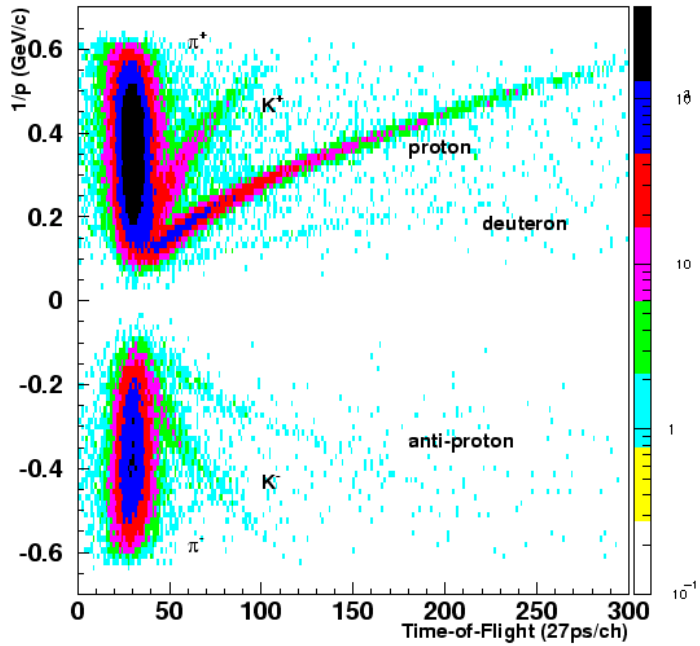
- **TOF is considered as the most reliable and stable devices for charged particle identification.**

Performance @ CERN WA98 Experiment

TOF resolution



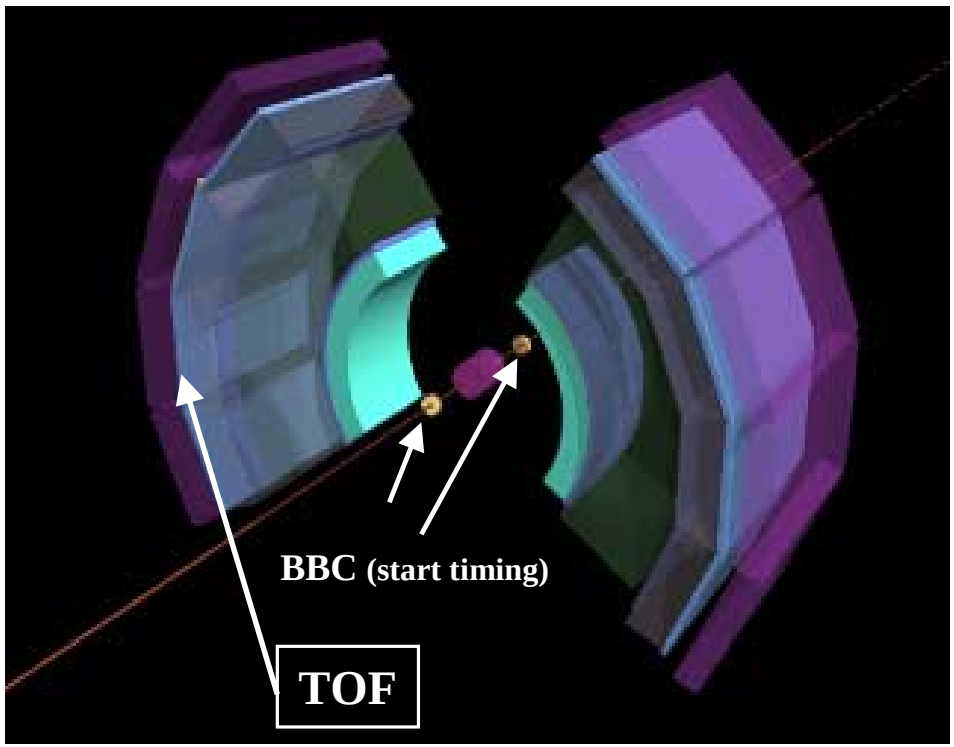
PID performance



- **Achieved timing resolution : σ_{TOF} = 85 ps**
- **Demonstrated clear π/K/p separation.**
- **Installed tested WA98-TOF counter in PHENIX.**

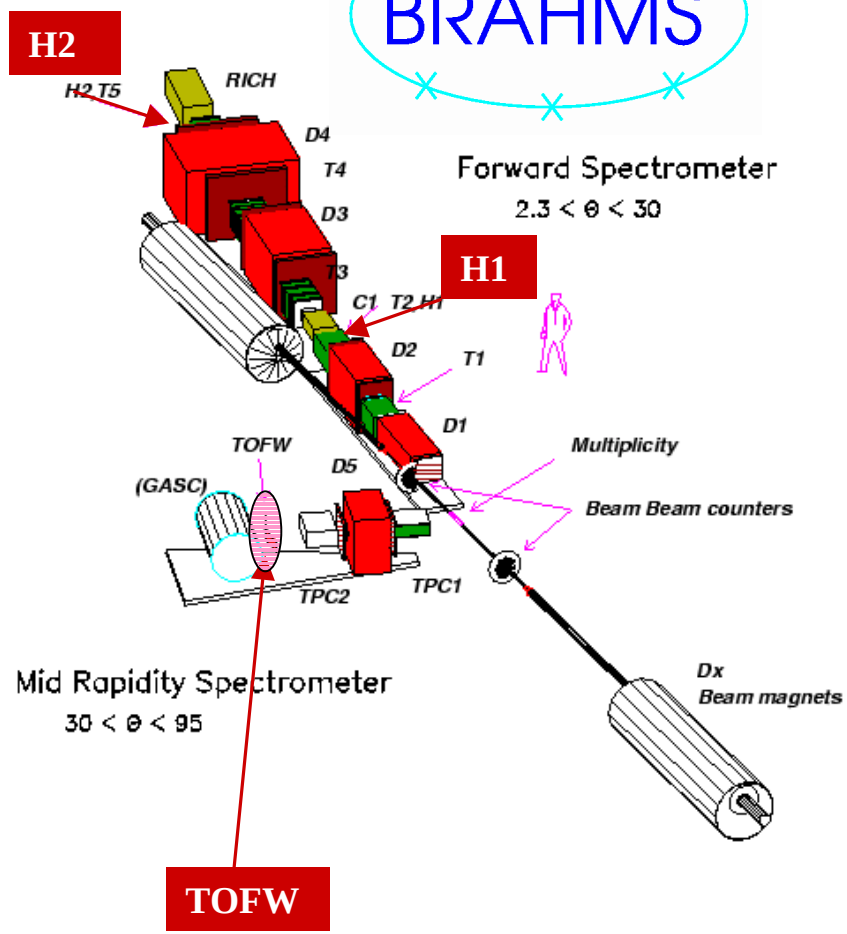
TOF Detectors at RHIC

PHENIX



PHENIX Central Arm Detectors

BRAHMS



PHENIX-TOF vs. BRAHMS-TOF

	PHENIX	BRAHMS		
		H1	H2	TOFW
Acceptance	**mid-rapidity** $-0.35 < \eta < 0.35$	forward rap. $1.2 < \eta < 3.5$	forward rap. $2.0 < \eta < 3.5$	mid rap. $0 < \eta < 1.2$
Distance from vertex	**5m**	**9 m**	**20m**	**4m**
4 σ π/K separation	**< 2.4 GeV/*c***	**< 3.3 GeV/*c***	**< 5.0 GeV/*c***	**< 2.2 GeV/*c***
4 σ K/p separation	**< 4.0 GeV/*c***	**< 5.7 GeV/*c***	**< 8.5 GeV/*c***	**< 3.7 GeV/*c***

•BRAHMS : Cherenkov counters are also used for hadron PID at high momentum

- **PHENIX : Finely segmented high resolution TOF at mid-rapidty.**
- **BRAHMS: Wide kinetic coverage, PID @ high momentum with Cherenkov counter.**

*** In this talk, only PHENIX-TOF detector are reviewed.**

PHENIX-TOF Basic Design

Acceptance

: driven by HBT and ϕ meson

$\Delta\theta$ = 40 deg. ($\Delta\eta$ = 0.7) , $\Delta\phi$ = 45 deg.

Timing Resolution

: p_T distribution more than 2 GeV/c and ϕ meson measurement

Required σ_{TOF} < 80 ~ 100 ps for

4σ π/K separation at p = 2.4 GeV/c
4σ K/p separation at p = 4.0 GeV/c

(@ flight path = 5m)

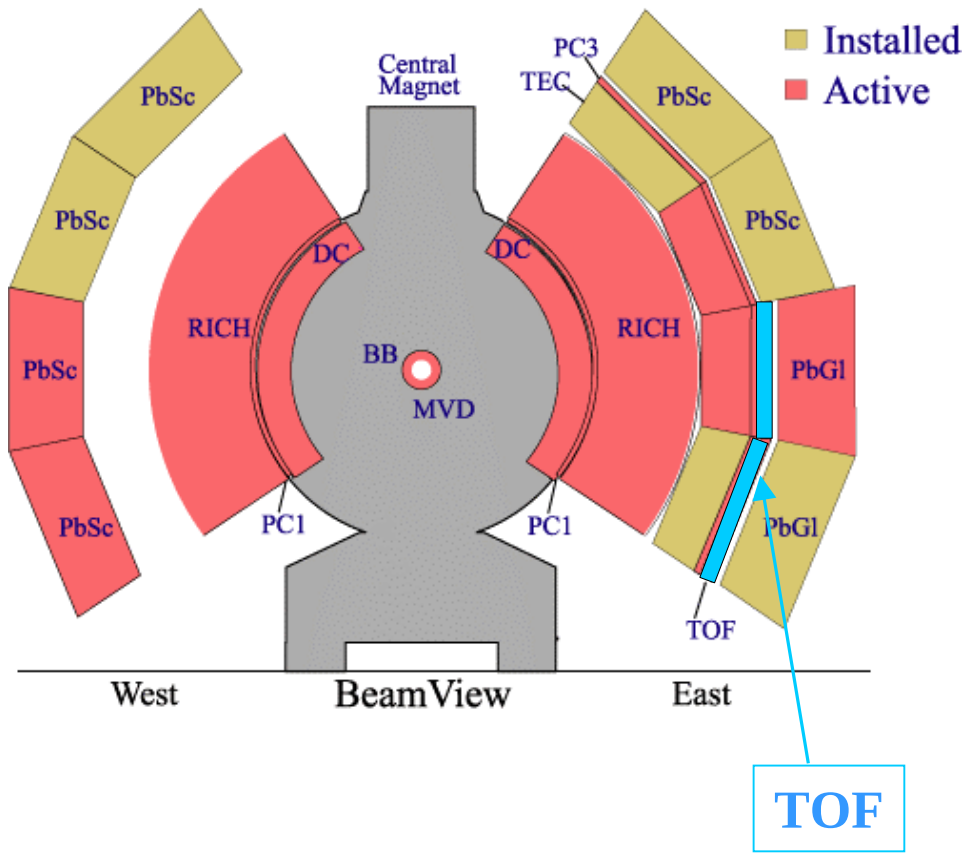
Segmentation

: Keep the occupancy level < 10 %

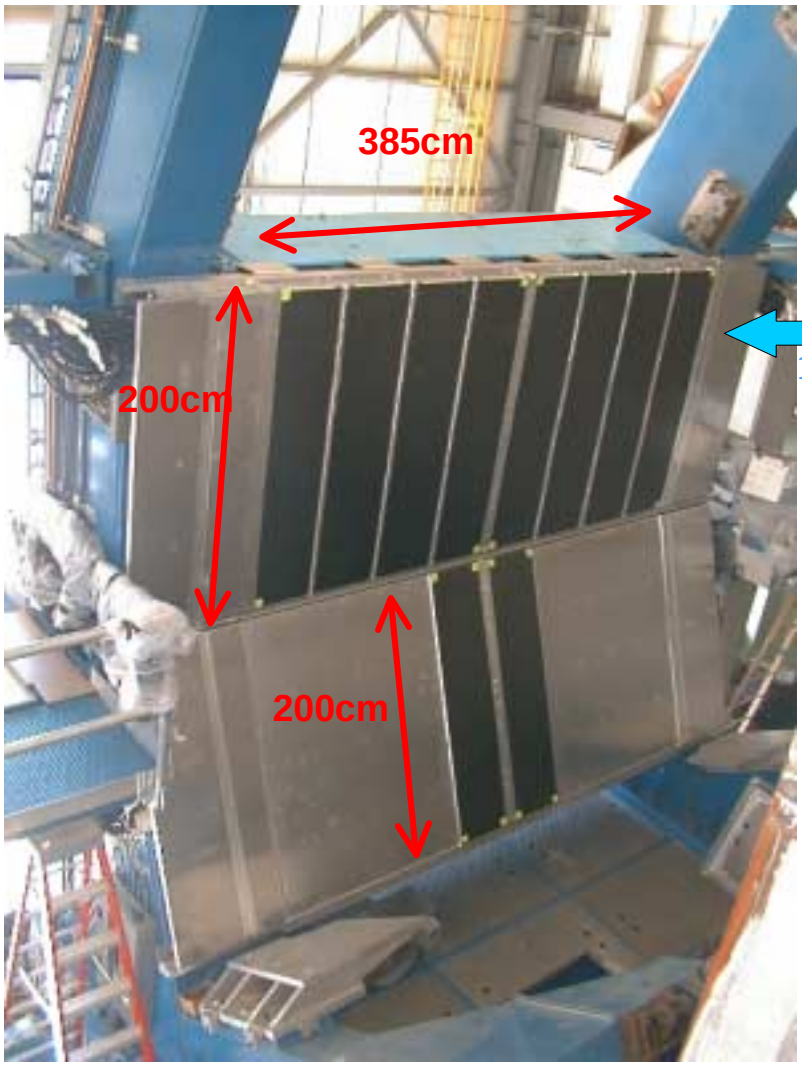
$$\frac{dN_{ch}}{dy} \cong 1500 \rightarrow \cong 1000 segments$$

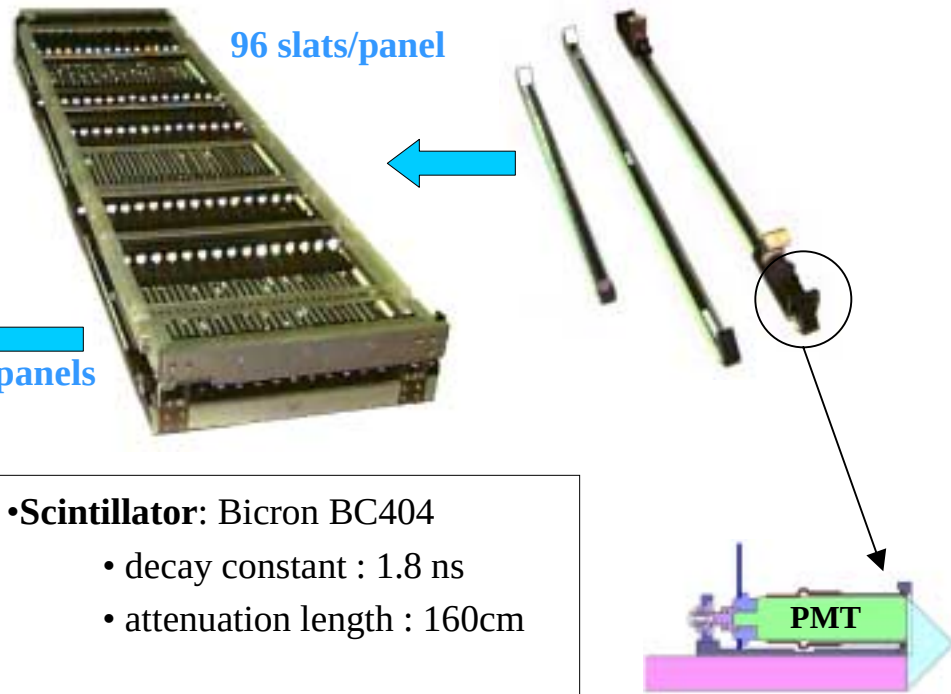
Δϕ = 45 deg. , Δη = 0.7

~ 100 cm²/segment at 5 m from vertex



PHENIX-TOF Components



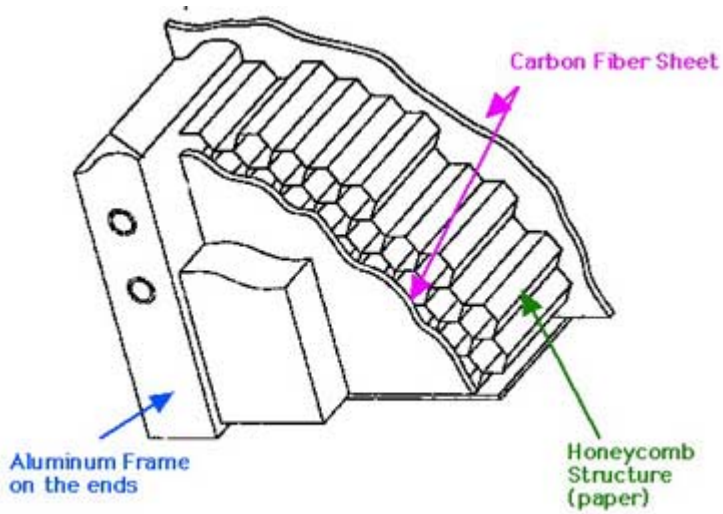


- **Scintillator**: Bicron BC404
  - decay constant : 1.8 ns
  - attenuation length : 160cm
- **PMT** : Hamamatsu R3478S
  - Rise time : 1.3 ns
  - Transit time : 14 + - 0.36 ns

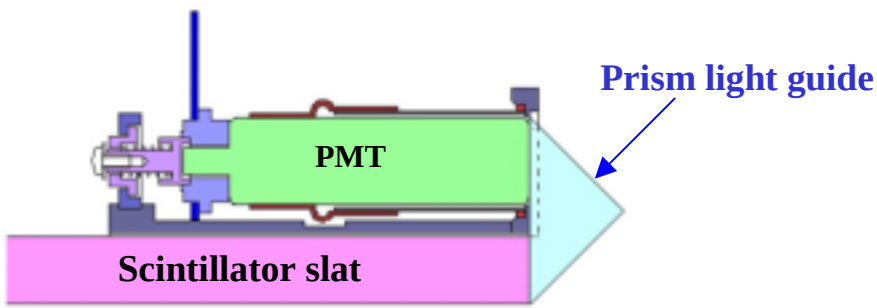
- **Consists of 960 plastic scintillators**
- **PMT readout at both ends of scint. (1920 ch.)**

Features of TOF Mechanical Design

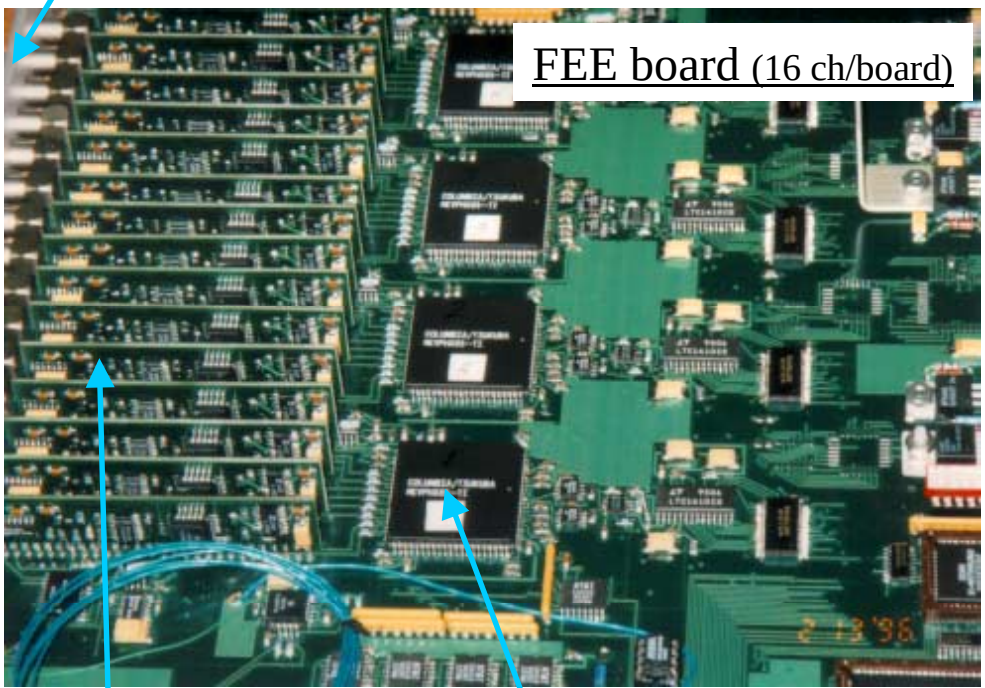
1. **Used Honeycomb Board for scint. stacking**
   - Rigid structure with mass-less in 2m x 0.5 m
   - Carbon fiber sheet + “honeycomb” structure
   - Uniform structure



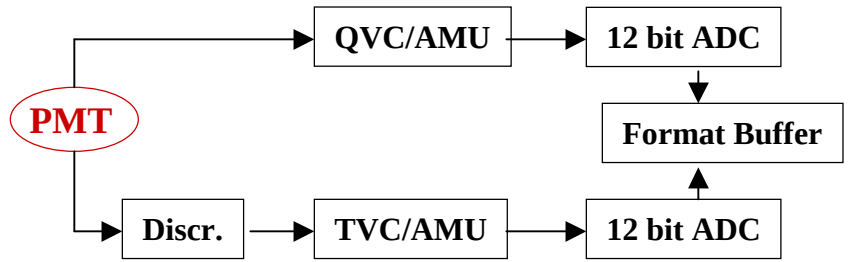
2. **Used prism light guide to reduce dead space**



Front End Electronics (FEE)



Block Diagram of FEE



- **Custom-made chips of TVC+AMU and QVC+AMU**
  Overall timing resolution of < 25 ps
- **Use of Analogue Memory Unit (AMU)**
  Programmable up to 4 μ sec delay w/o coaxial delay cables.

• 16 inputs for PMT signals per board, which are split for timing and charge measurements

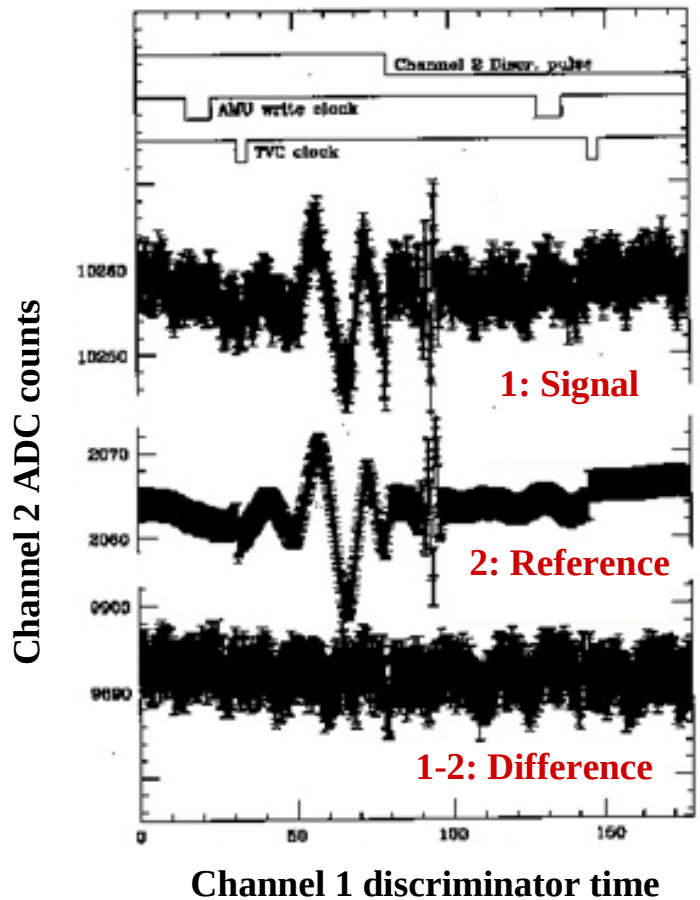
Front End Electronics (cont.)

Elimination of Cross Talk between adjacent channels

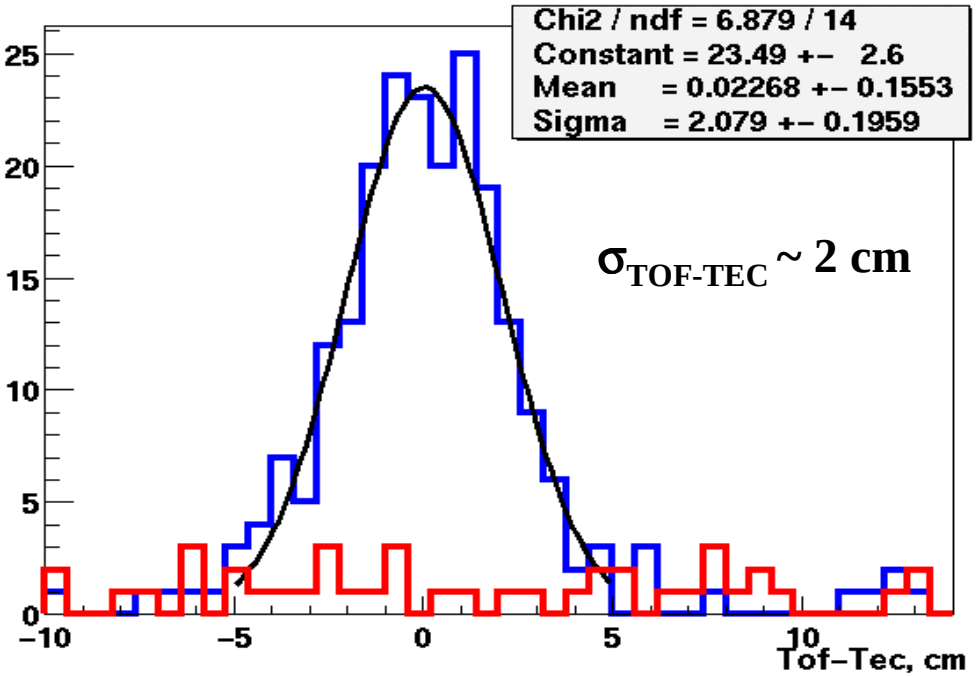
Each channel consists of two independent ch.

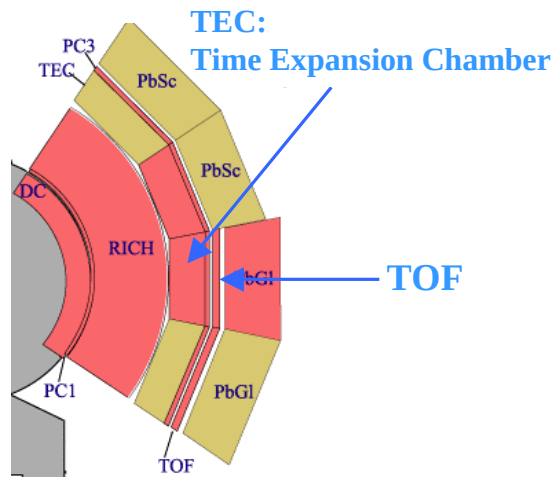
1. Signal : connected to PMT
2. Reference: antenna for cross talk elimination

No cross talk in differential output



TEC/TOF Matching



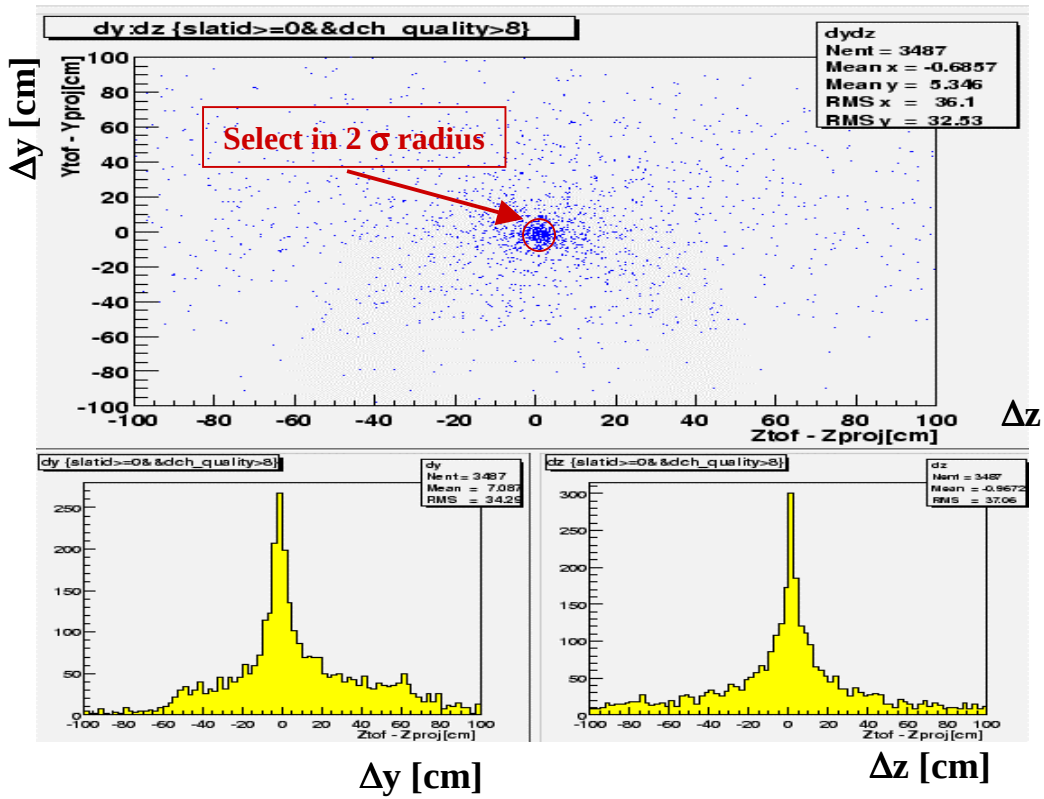


- $\sigma_{TOF-TEC}$ = 2cm ➡ Corresponding to the TOF resolution of 120 ps
- Consistent with TOF intrinsic timing resolution without slewing correction.

Timing resolution will be improved by fine tuning of calibration parameters.

➡ σ_{TOF} ~ 80 ps

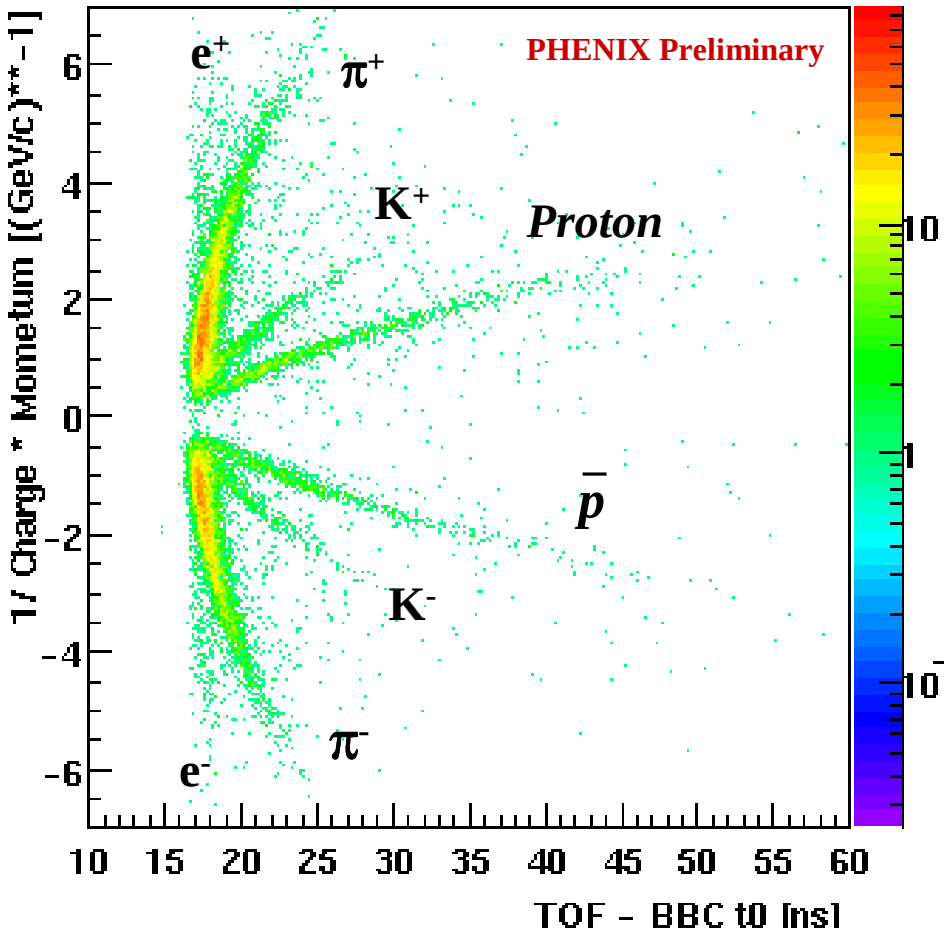
Global Track/TOF Association



Association window size : *dr* = 5 cm (~ 2σ of in y-z projection plane)

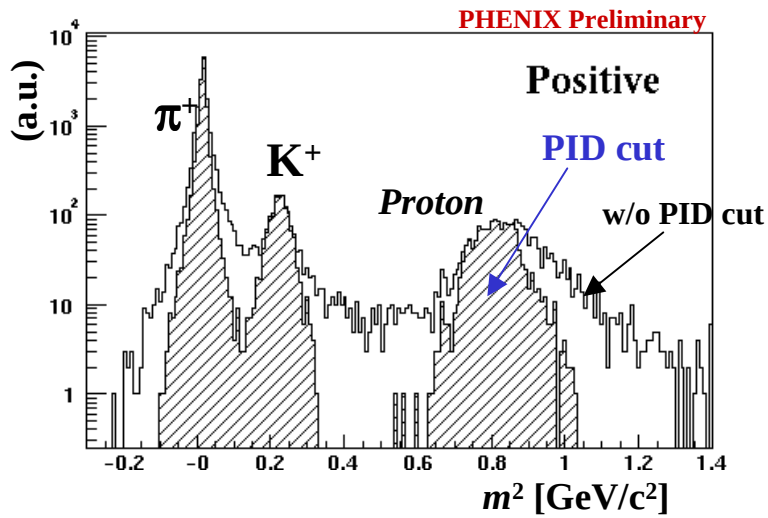
***Clear correlation between global tracks and TOF hit positions are seen**

Hadron PID by PHENIX-TOF



Note:

* No slewing correction
* Applied track association cut
  : dr = 5 cm
* No acceptance/efficiency/decay corrections



Clear hadron PID achieved

$$m^2 = p^2\left\{\left(\frac{TOF}{L}\right)^2 - 1\right\}$$

Summary

- **Reviewed PHENIX-TOF detector functionality and performance from the first RHIC run.**
- **Tracking detectors (DC/PC/TEC) and TOF detector had been operated successfully during the run.**
- **TOF intrinsic timing resolution ~120 ps have been achieved by TEC/TOF hit position matching without slewing correction.**
- **Fine tuning of TOF timing calibration parameters will be done.**
- **Clear hadron PID have been achieved.**
- **Lots of interesting physics will come next.**
  1) Single particle spectra for π^+, π^-, K^+, K^-, p and $\bar{p}$($<p_T>$, centrality dependence)
  2) Particle ratio K/π, $\bar{p}/p$ etc. and their centrality/p_T dependence
  3) HBT analysis
  4) $\phi \longrightarrow K^+K^-$ physics