PHENIX TOF Upgrade Project

Tatsuya Chujo
for the PHENIX Collaboration

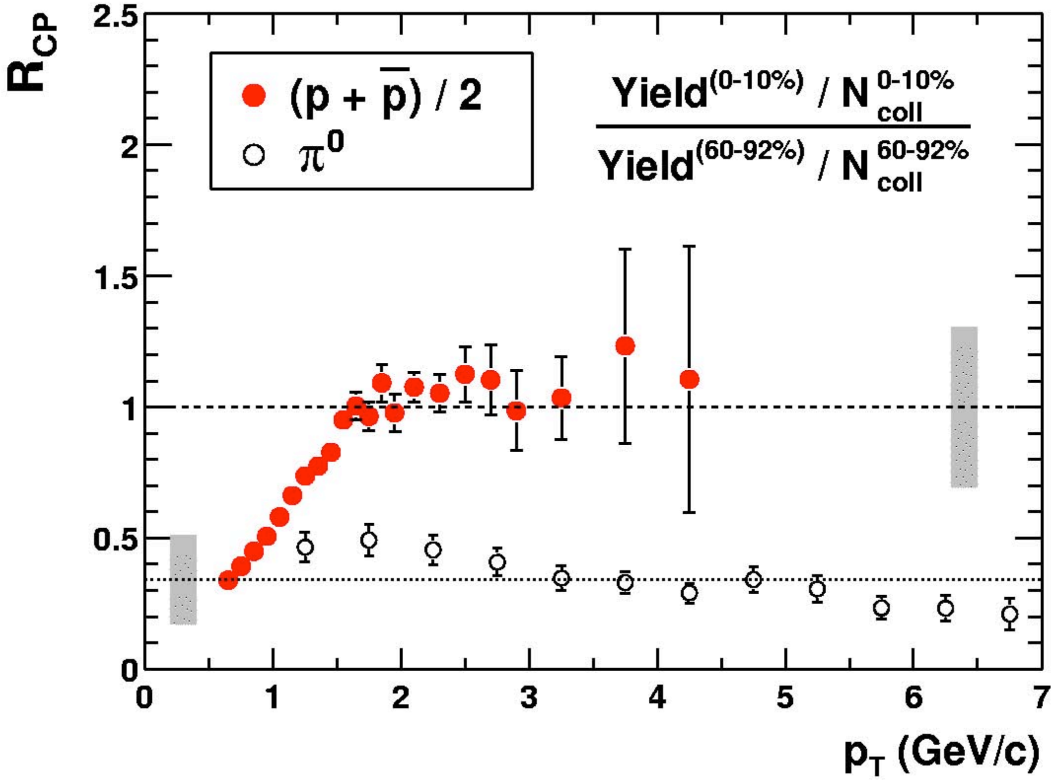
VANDERBILT UNIVERSITY

PHENIX

Outline

1. Introduction
   - Physics motivation.
   - PHENIX high p_T PID upgrade project.
2. MRPC-TOF Design
   - System requirements.
   - Design consideration for PHENIX.
3. Building MRPC Prototypes
4. Detector Performance
   - KEK beam test setup and results.
5. Summary and Schedule

Physics Motivations



PHENIX: PRL 91, 172301 (2003), PRC 69, 034909 (2004)
Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

- One of the most striking results so far at the heavy ion experiments at RHIC:
  - Strong suppression of π^0 yields above p_T ~ 2 GeV/c.
  - No suppression for baryons at intermediate p_T (2-5 GeV/c), **"Baryon anomaly at RHIC"**.
- Need to understand the hadronization mechanism, *i.e.* recombination and jet fragmentations, at intermediate p_T and beyond (< 10 GeV/c).
- **Importance of continuous PID capability from low p_T to high p_T.**

PHENIX High p_T PID Upgrade

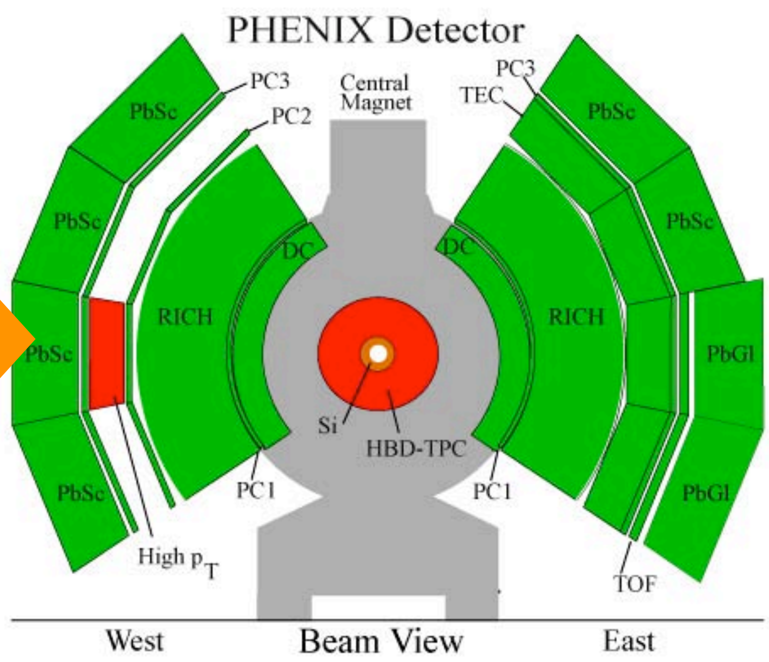
Aerogel & Time-of-Flight (TOF)

- Together with the Aerogel, TOF and RICH, we can extend the PID **beyond 5 GeV/c.**
- **Coverage: ~ 4 m^2 in PHENIX west arm.**

AEROGEL Cherenkov detector:

- n = 1.0113.
- Completed full installation for Run5.

Additional TOF counter is required for K/p separation below 5 GeV/c.

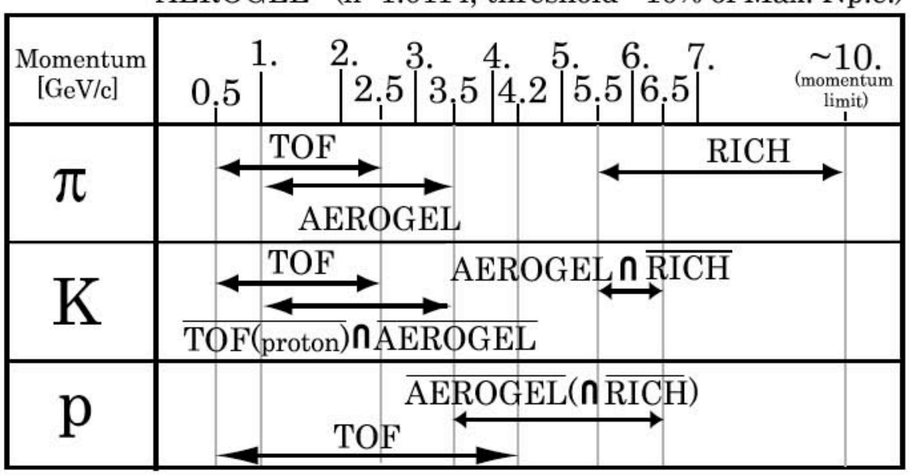


Extension of Charged Hadron PID Capability

		Pion-Kaon separation	Kaon-Proton separation
TOF	σ~100 ps	0 - 2.5	- 5
RICH	n=1.00044 γth~34	5 - 17	17 -
Aerogel	n=1.01 γth~8.5	1 - 5	5 - 9

With TOF

AEROGEL : (n=1.0114, threshold= 10% of Max. Np.e.)

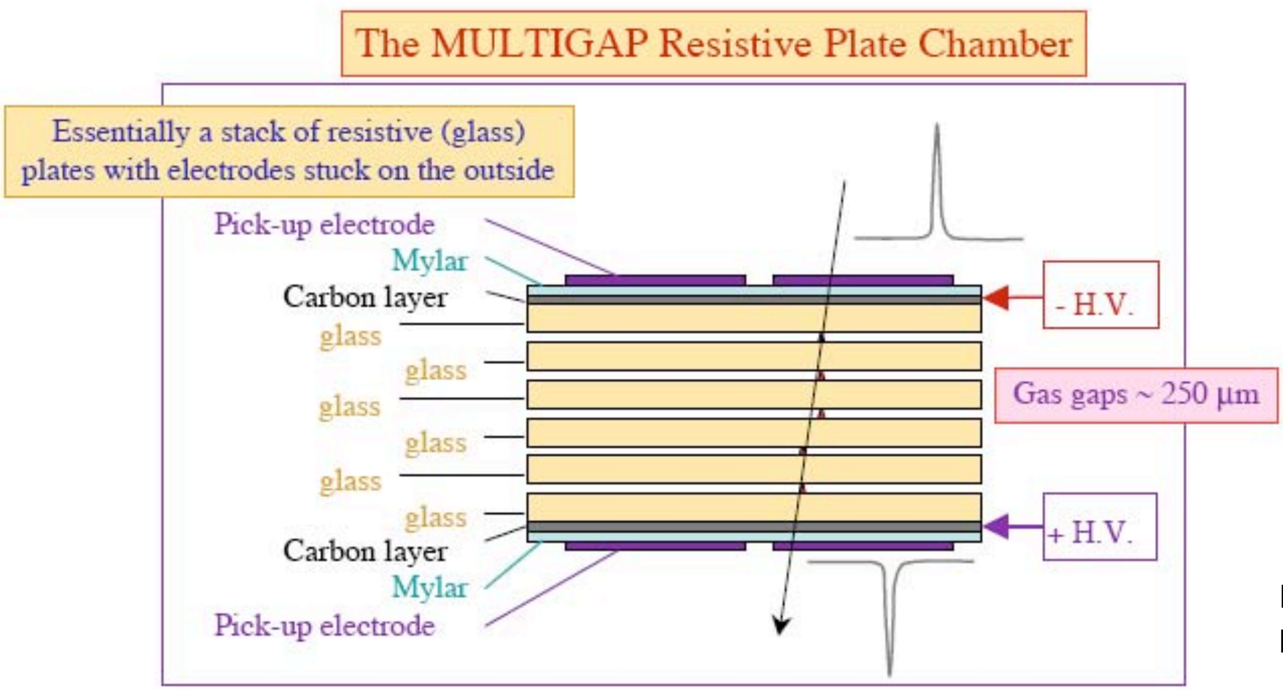


Aerogel together with TOF can extend the PID capability < 10 GeV/c

- **Without TOF, no K-proton separation at p_T < 5 GeV/c.**

MRPC: Multi-gap Resistive Plate Chamber

- A stack of resistive plates (glass) with electrodes stuck on the outside.
- Internal glass plates electrically floating, take and keep correct voltage by electrostatics and flow of electrons and ions produced in gas avalanches.
- Resistive plates transparent to fast signals, induced signals on external electrodes is sum of signals from all gaps (also, equal gain in all gaps)
- Operated in avalanche mode for TOF detector.



From QM2001 (ALICE-TOF) poster by Crispin Williams.

PHENIX-MRPC: System Requirements

Why MPRC-TOF?

- Cost effective compared to scinti.+PMT based TOF.
- Easy to build a large area detector which can be extended from 1 sector (Run-6) to full West arm coverage in the future.
- New generation of TOF detector.
  - Good timing resolution (<100 ps)
  - Reasonable efficiency (> 95%).
- Extensive R&D by LHC-ALICE and RHIC-STAR.

Our GOAL:

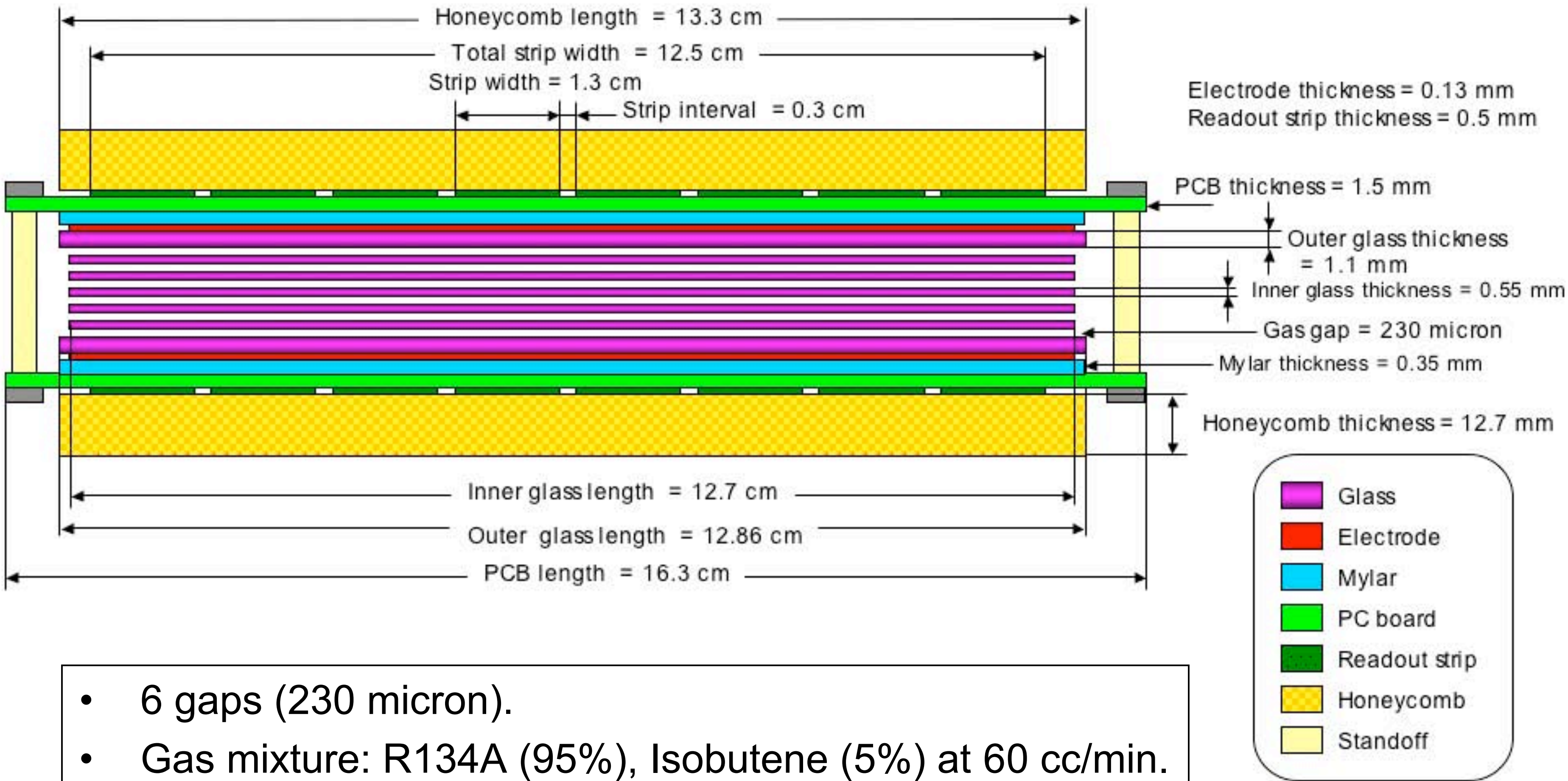
- **Timing resolution: < 100 ps**
- **Detection efficiency: > 95 %**
- **Occupancy: < 10 %**
- **Total cost: < 500k**

PHENIX-MRPC: Design Considerations

1. **Single stack type MRPC.**
   - ALICE (10 gaps, double stack), STAR (6 gaps, single stack).
   - Better performance for double stack, but single stack is easier to build and satisfies our performance requirements.
   - Space limitation (< 2”) in PHENIX.

2. **Strip Readout pad design.**
   - Location will be 4.85 m from vertex.
   - Hit position determined by timing info.
   - Strip design with double ended readout reduces the number of electronics channels significantly.

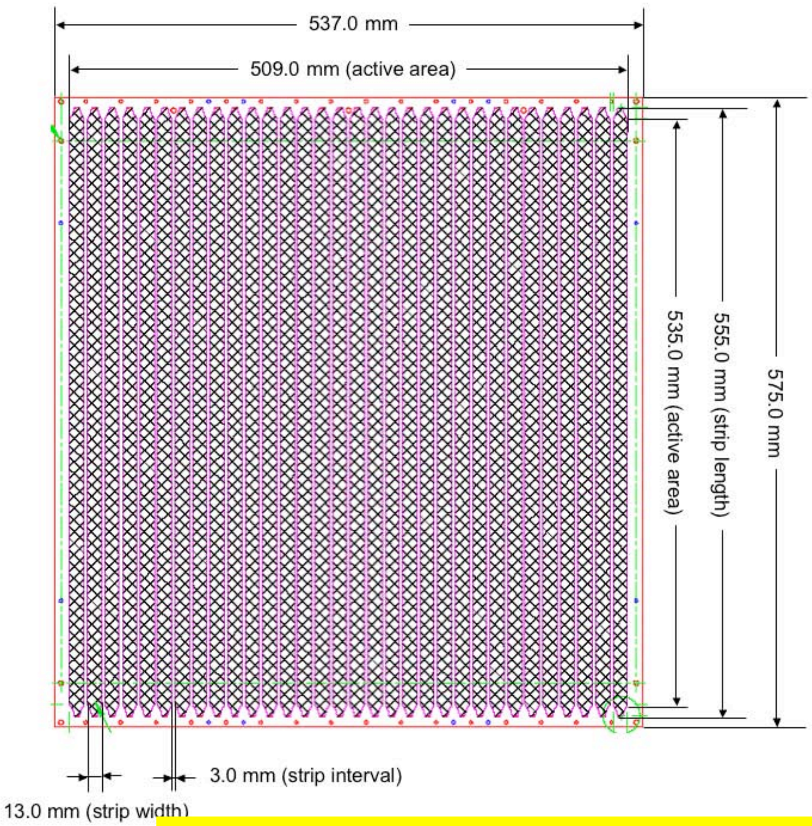
PHENIX-MRPC: Detail



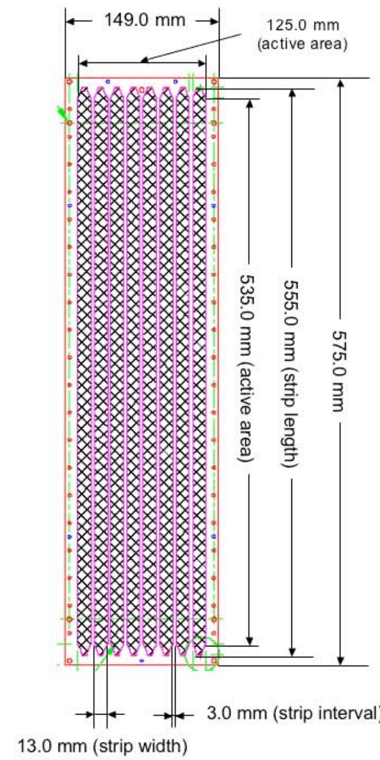
- 6 gaps (230 micron).
- Gas mixture: R134A (95%), Isobutene (5%) at 60 cc/min.
- HV: ±7.5 kV

3 Prototypes

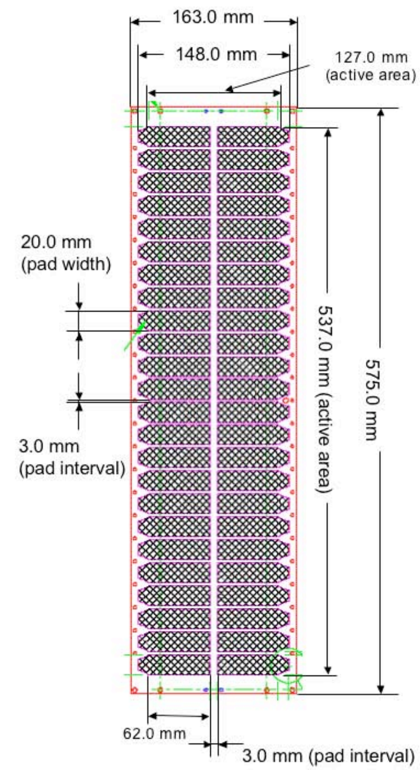
PH1



PH2



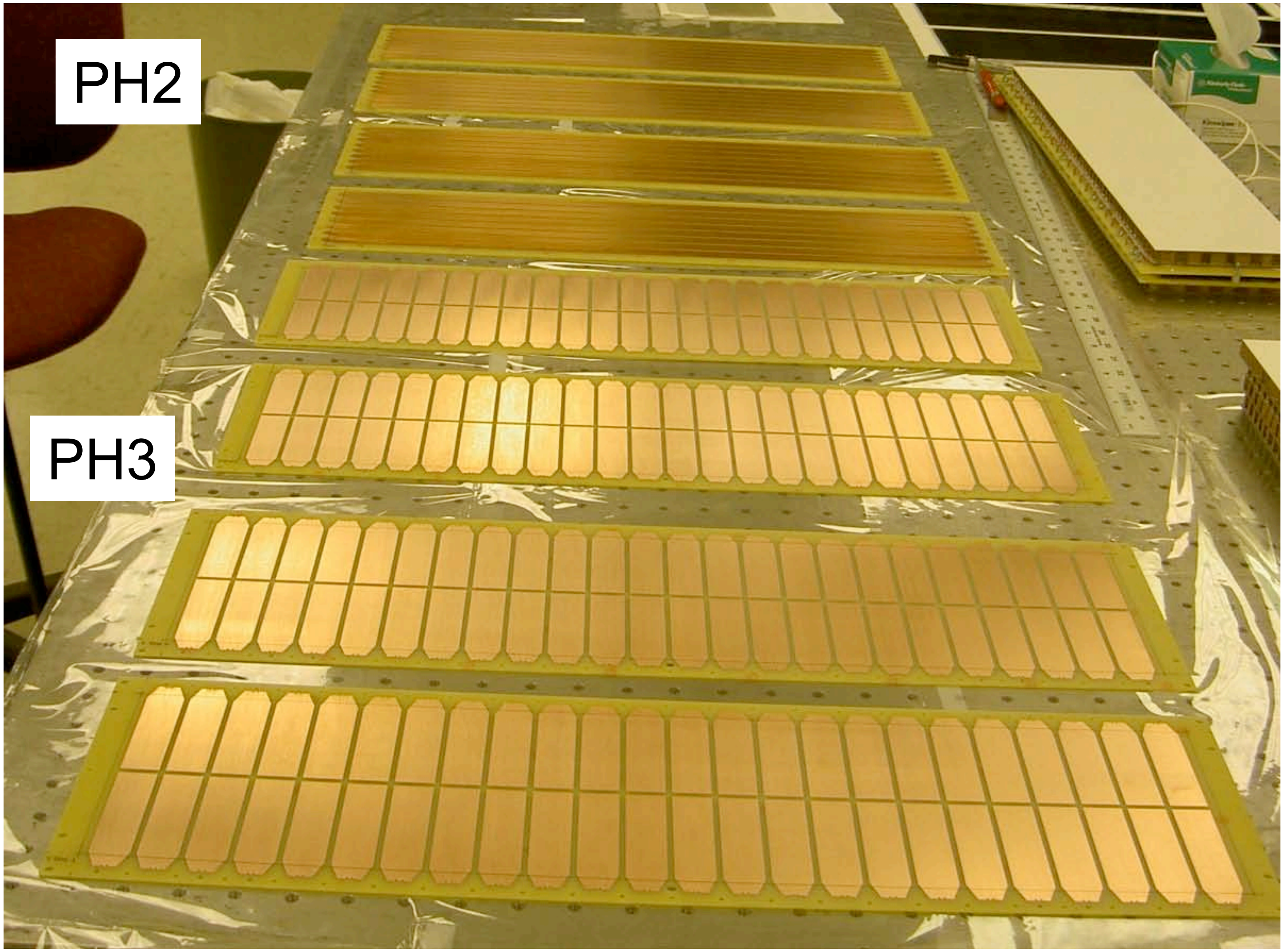
PH3



<u>Different pad/strip design, same structure inside</u>

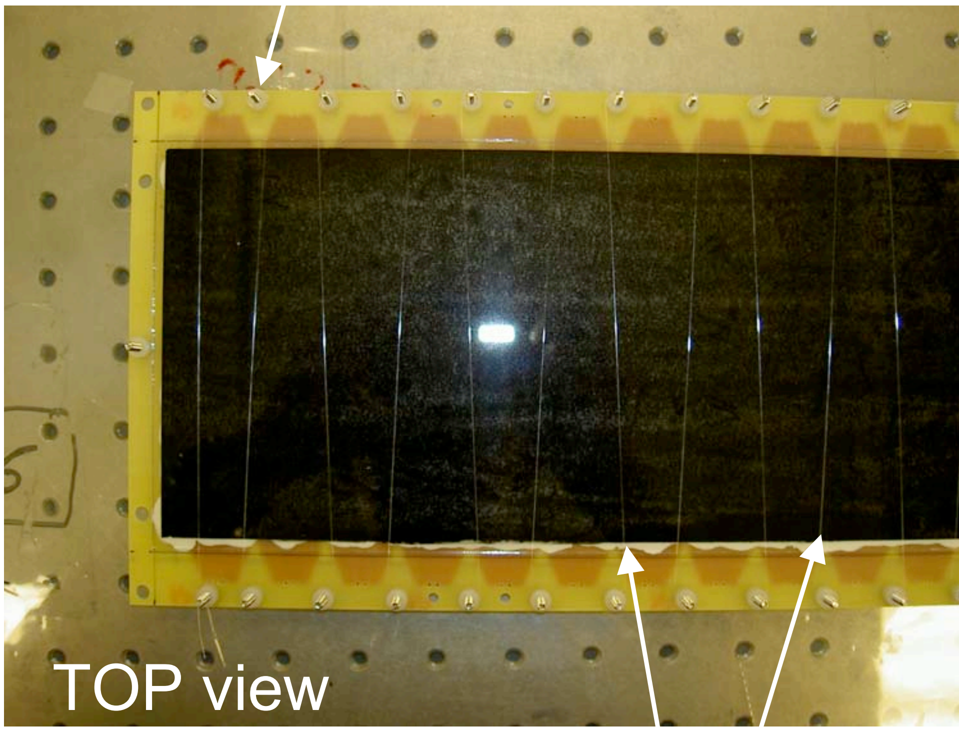
- PH1: 50.9 x 53.5 cm^2, 32 strips, readout at both ends.
- PH2: 12.5 x 53.5 cm^2, 8 strips, readout at both ends.
- PH3: 12.7 x 53.7 cm^2, 48 pads (6x2 cm^2), similar to STAR MRPC.

Readout strip-pad (PH2/3)

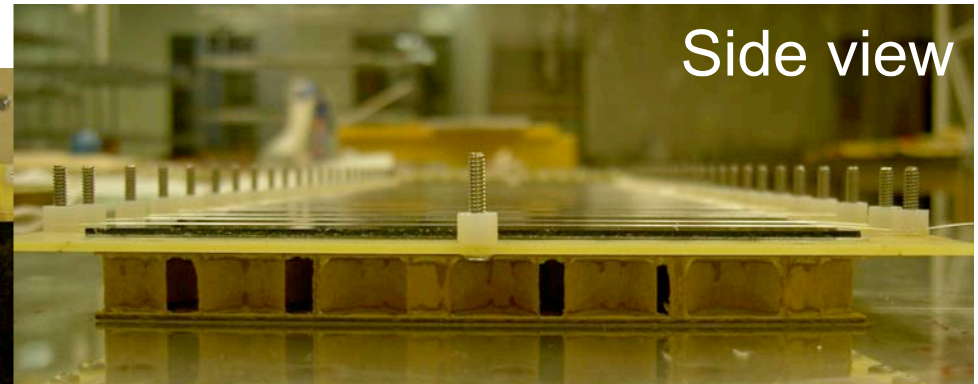


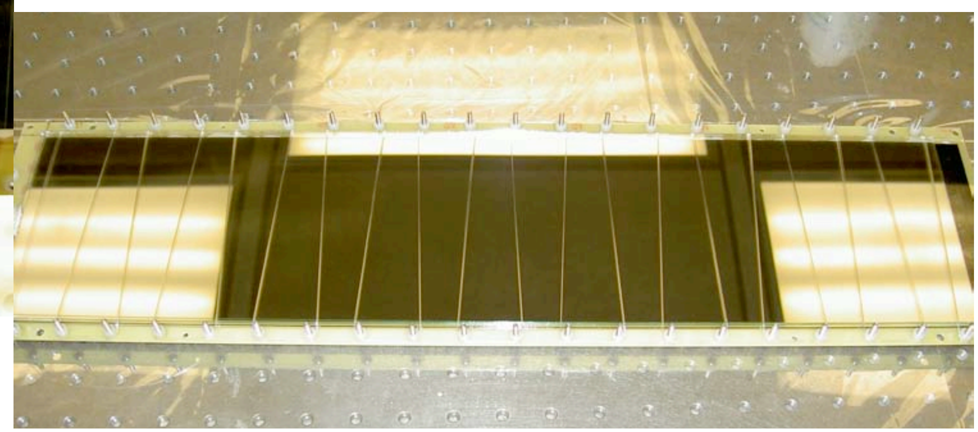
Assembly Pictures

Nylon standoff

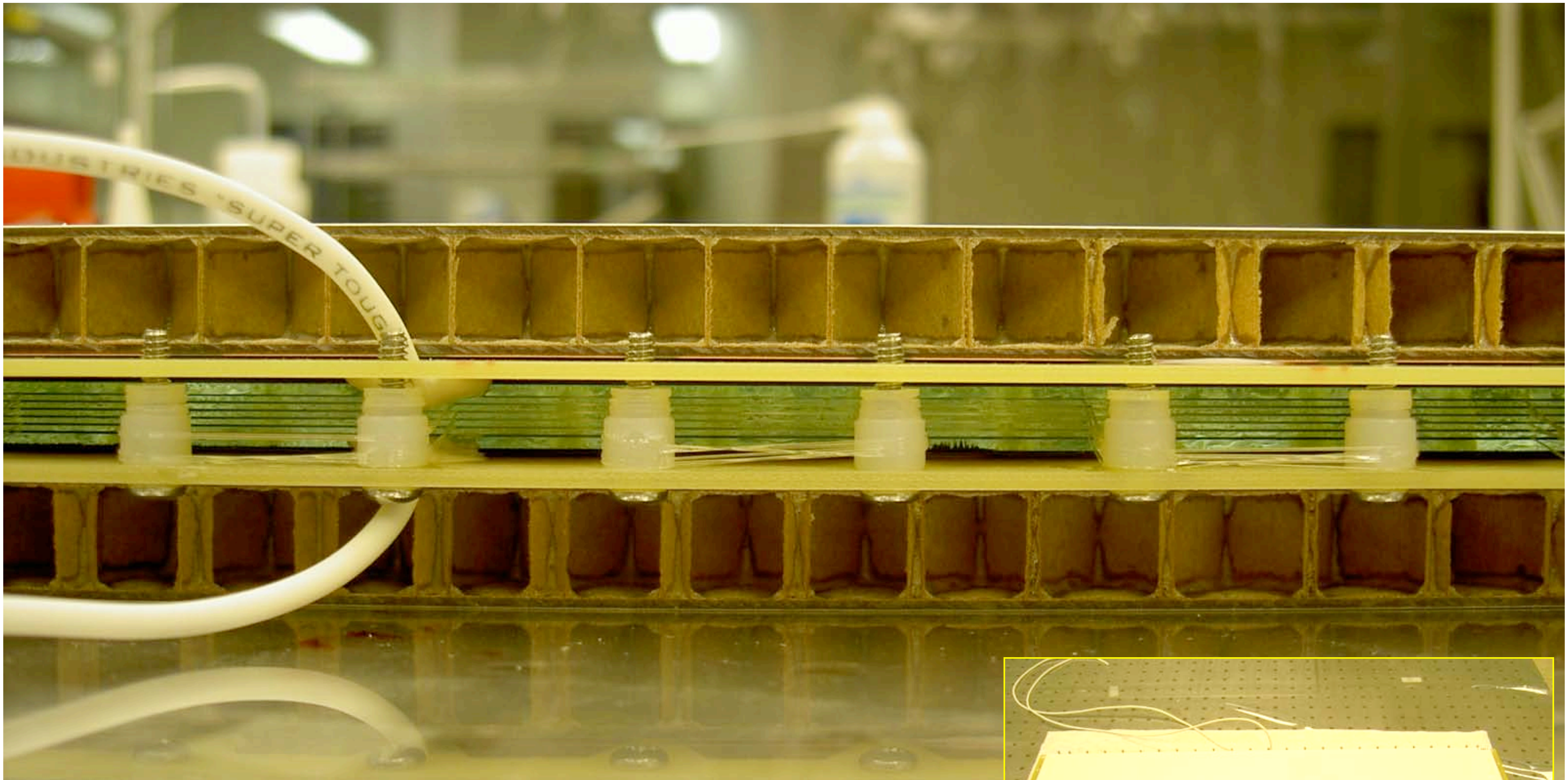


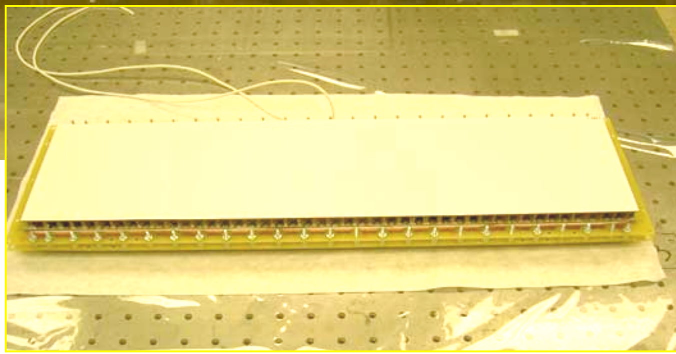
Fishing line



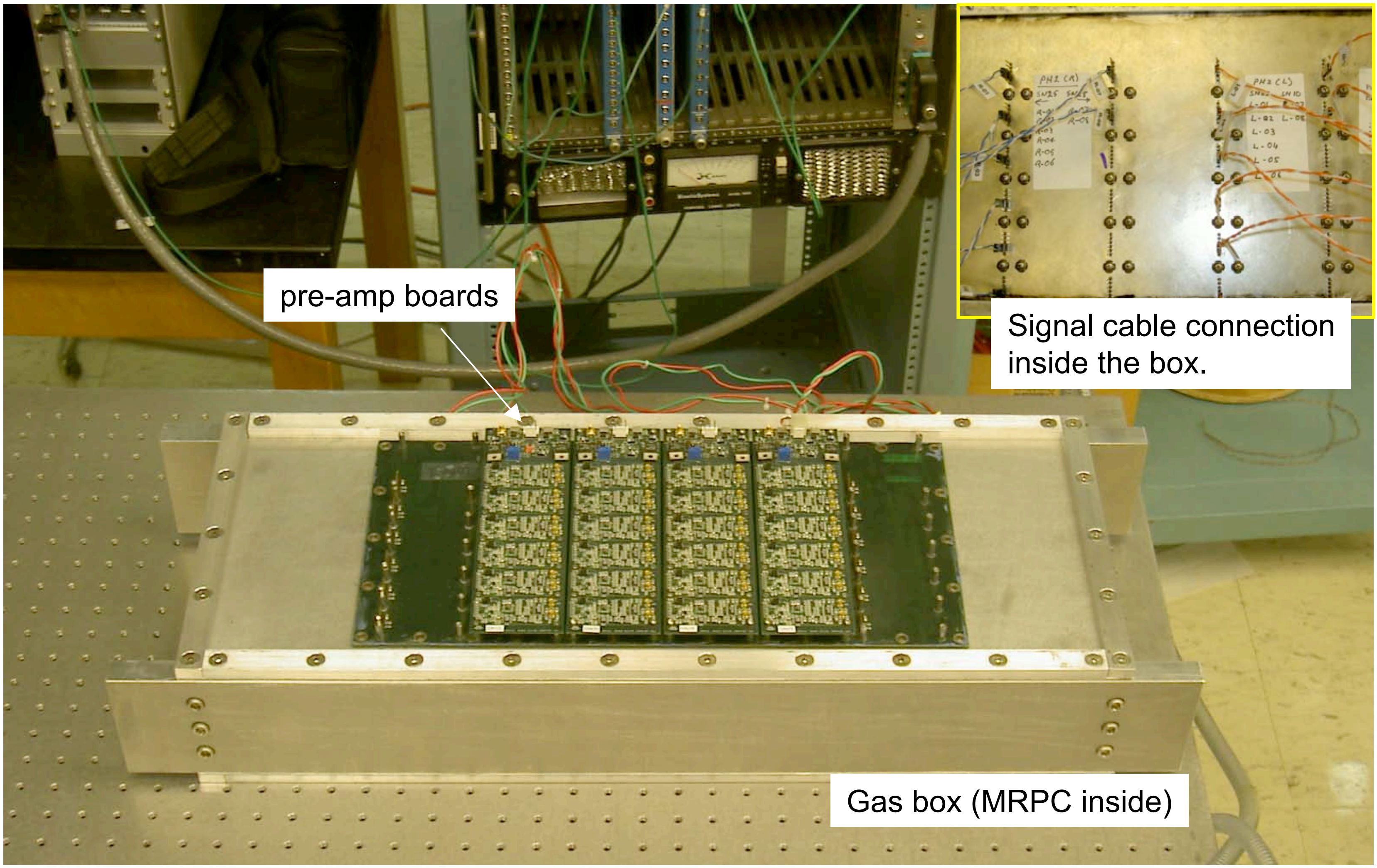


Assembly Pictures (cont.)





Preamp and Gas Box

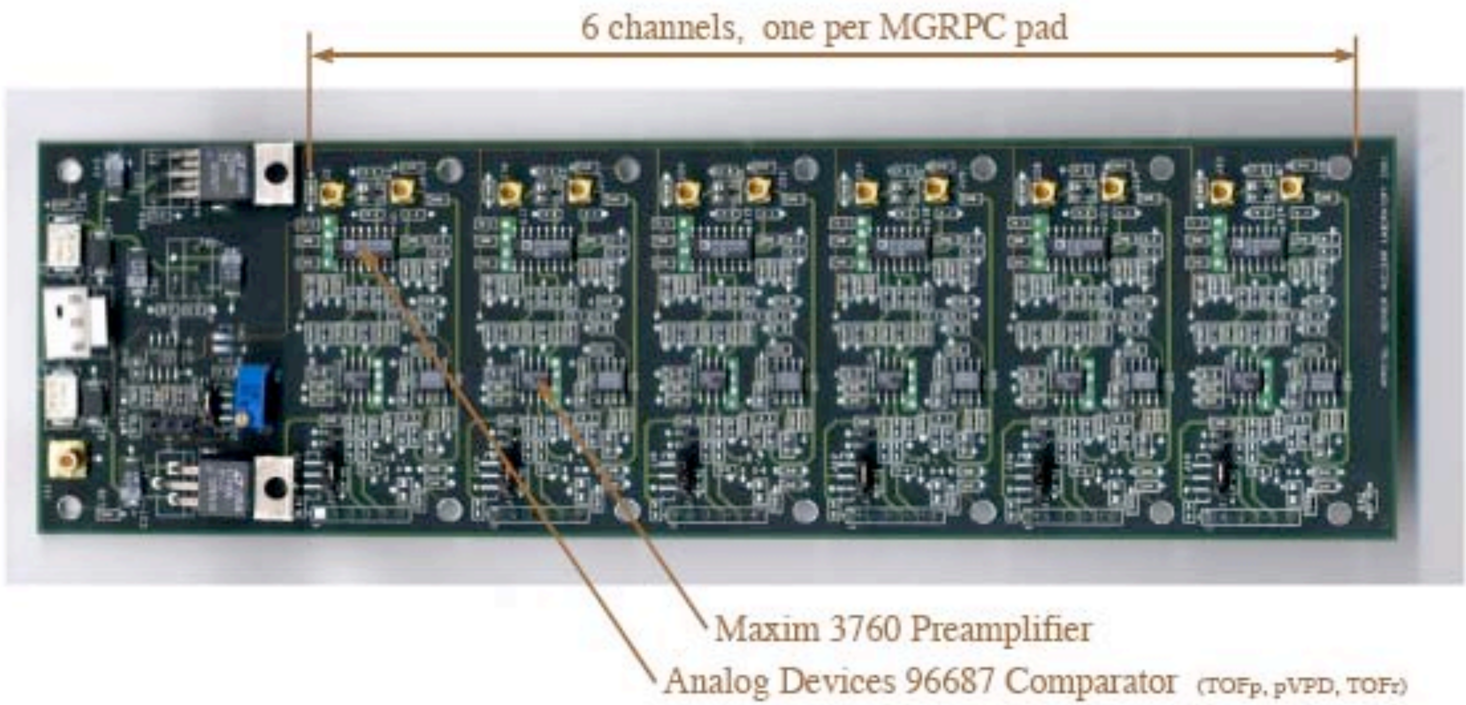


HV test and cosmic ray data taking has been done on the test bench.

Preamp (from STAR)

Used STAR TOFr preamp

- Fast current amplification (MIP hit for STAR MRPC: ~25 fC) using MAXIM 3760 chip.
- Discriminate using standard components.



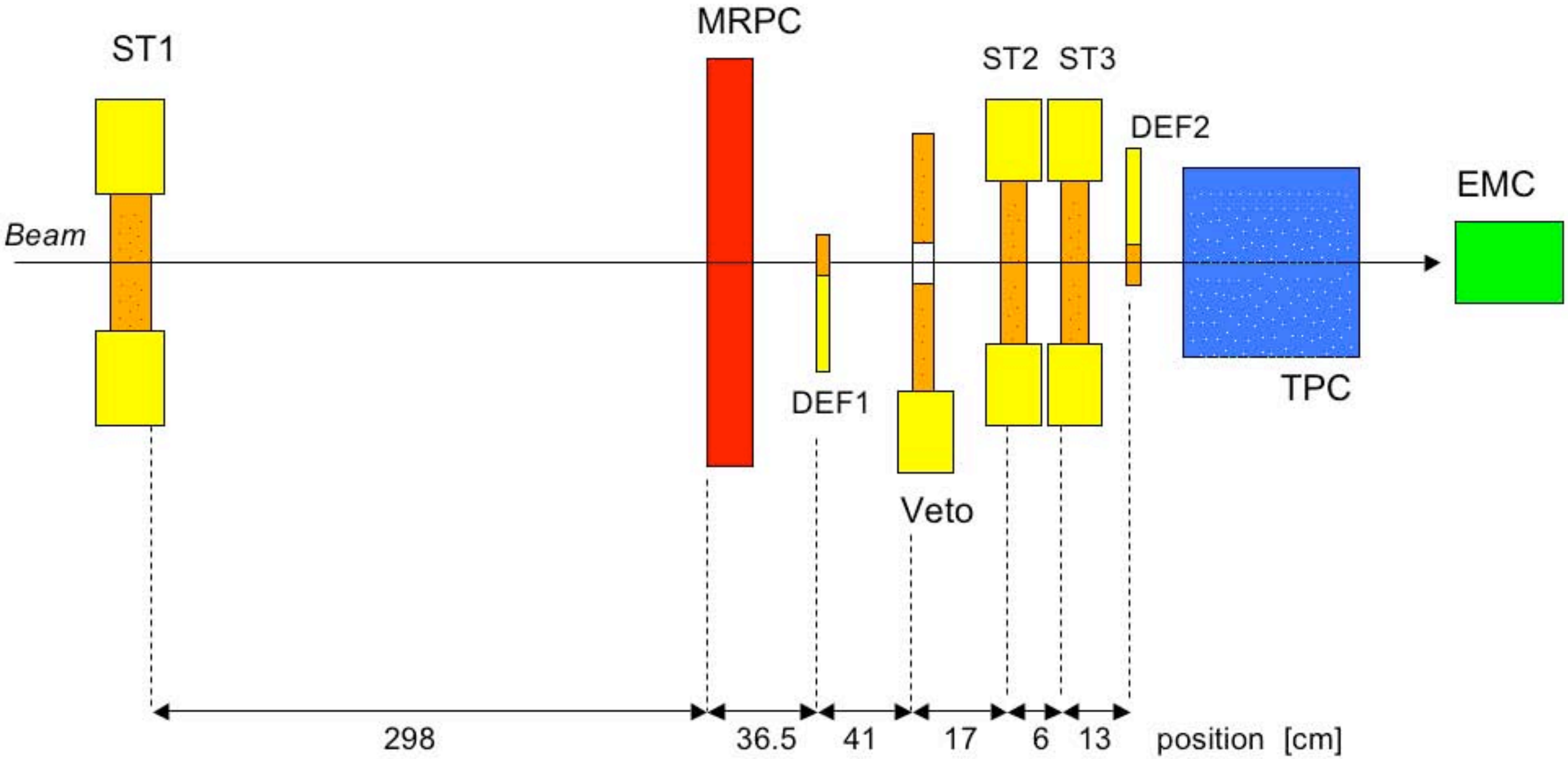
KEK Beam Test

- Experiment: KEK-T561 (2004.6.1 - 6.8).
- Participating Institutions: Univ. of Tsukuba, Vanderbilt Univ.
- Beam: KEK-PS secondary 2 GeV/c pion and proton beams (some kaons and deuterons).
  - 20 counts/ spill, (1 spill ~ 2 sec duration).

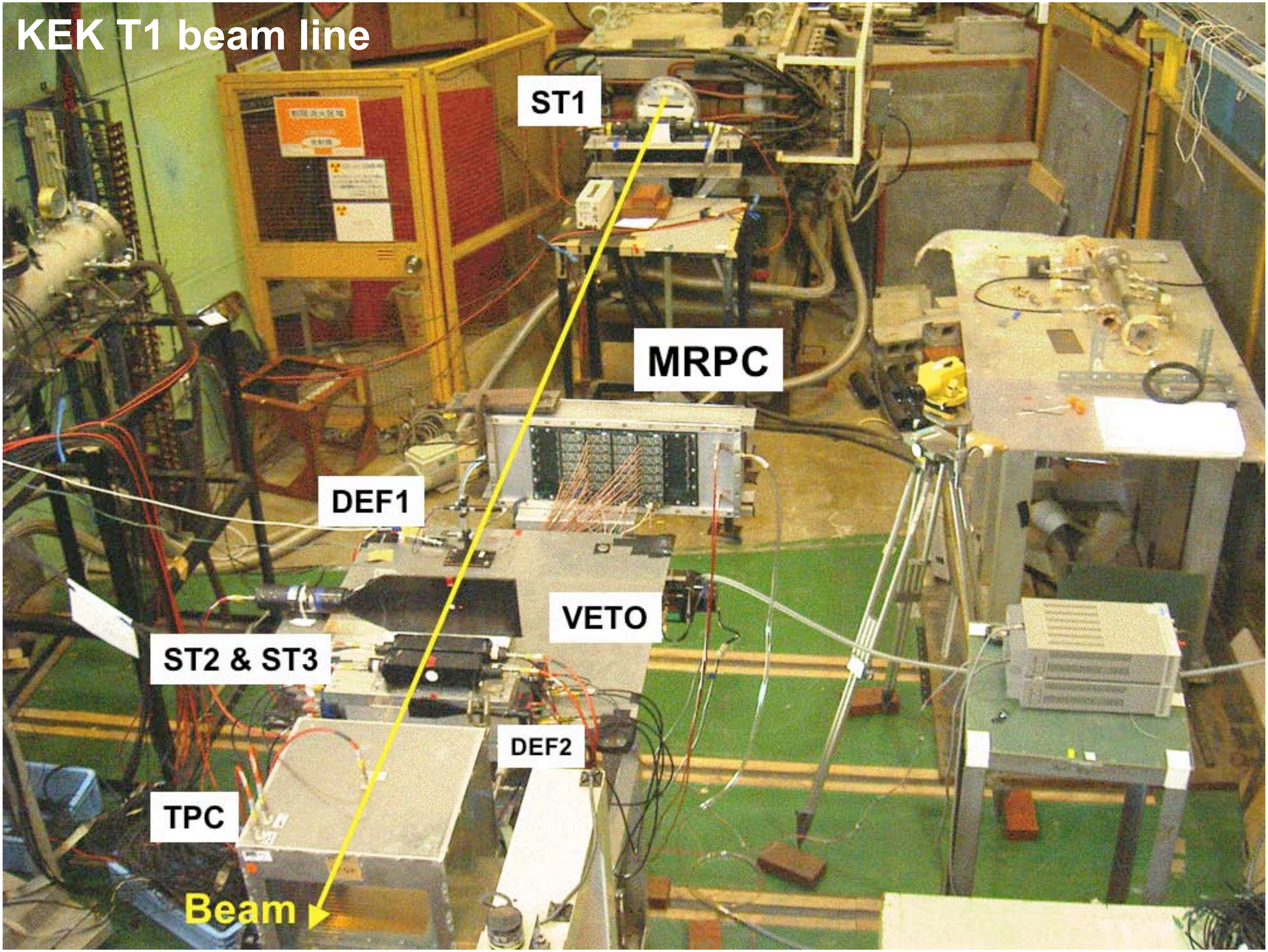
- Control parameters:
  1. Detector type (PH1,2,3).
  2. Applied high voltage.
  3. Beam position (horizontal and vertical scans)
     - Across the chamber.
     - Within a pad/strip.
  4. Discriminator threshold.
  5. Gas mixture
     - Default: R134A: Isobutene = 95:5 @ 1cc/sec flow rate.
     - No performance change seen in:
       - 97%/3% mixture, 92%/7% mixture, and x2 gas flow rate.

Checked detection efficiency and timing resolution.

KEK-T561 Experimental Setup

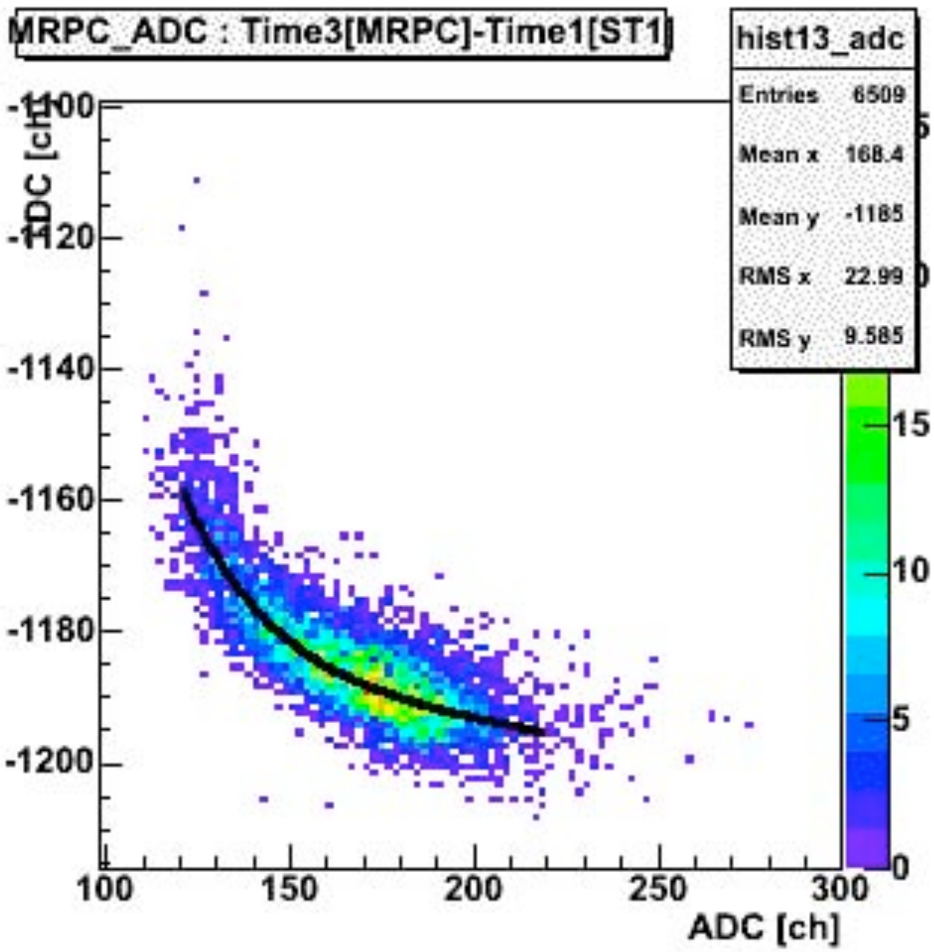


Beam trigger: ST1 & ST2 & ST3 & DEF1 & DEF2 & VETO-bar

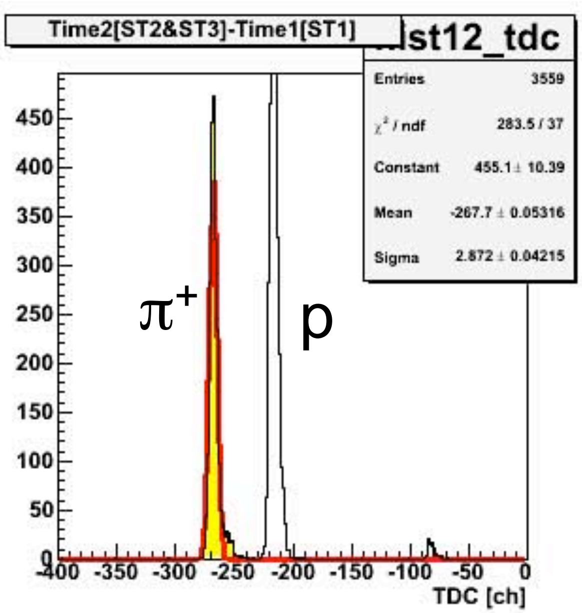


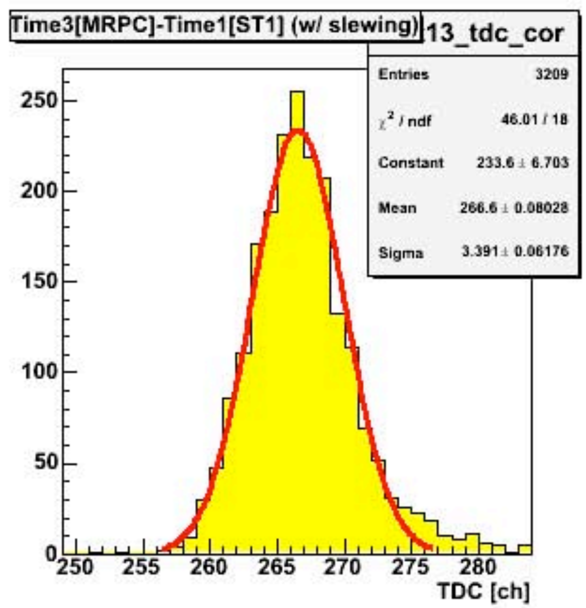
KEK T1 beam line
ST1
MRPC
DEF1
VETO
ST2 & ST3
DEF2
TPC
Beam

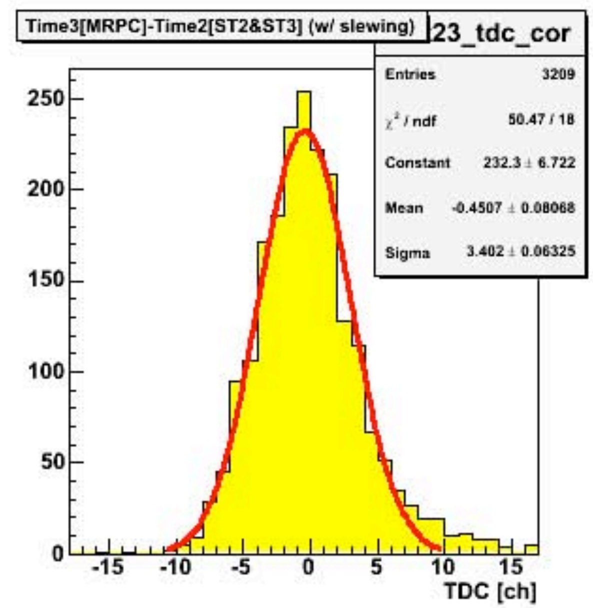
Slewing effect



- Typical T-A correlation plot.
- Strong slewing effect seen.
- **Usual slewing correction used for PMT- scinti. based TOF is applicable.**







Run #: 206

PH2

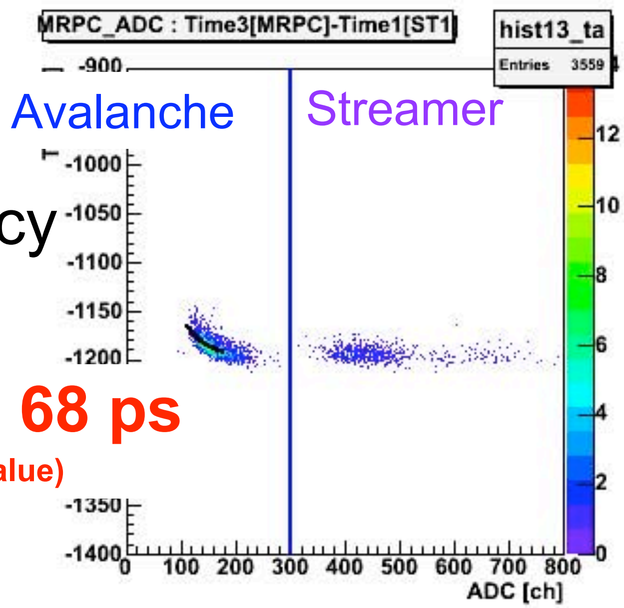
PH2, HV = 15.00 kV
threshold: 120 mV, hit ch. #: 0-1
PID: π^+ (p = +2.0 GeV/c)

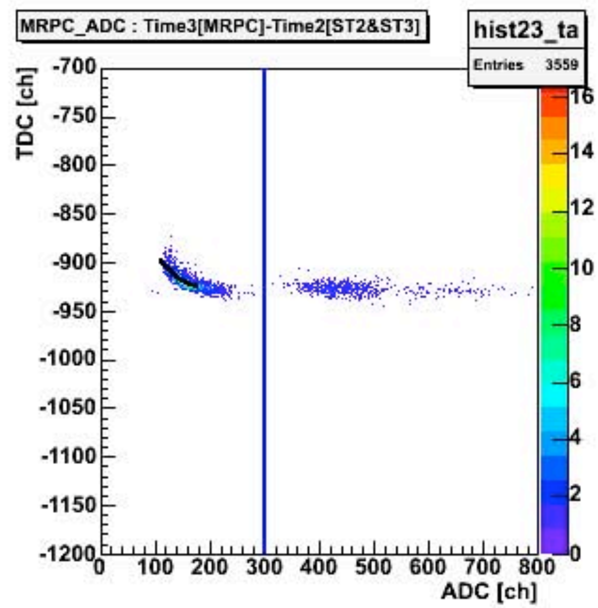
ϵ (hit) : 90.17 [%]
ϵ (w/ next hit): 90.17 [%]
ϵ (all channel): 90.17 [%]

efficiency

σ_T (MRPC) = 68.07 ± 0.51 ps
σ_T (ST1) = 50.52 ± 0.35 ps
σ_T (ST2&ST3)= 51.00 ± 0.38 ps
ADC fit range: 110 - 180 ch
Streamer: 20.07 [%] (644/3209)
σ_{13}(w/slewing) = 85.46 ps
σ_{13}(streamer) = 112.72 ps

σ_T = 68 ps
(best value)





PH1 and PH3 Performance

Run #: 335 — PH1

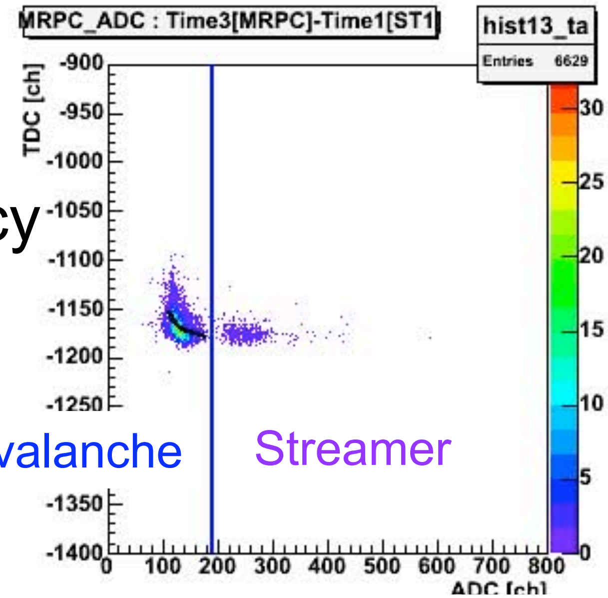
PH1, HV = 15.50 kV
threshold: 100 mV, hit ch. #: 2-3
PID: π^+ (p = +2.0 GeV/c)

ϵ (hit) : 92.07 [%]
ϵ (w/ next hit): 92.03 [%]
ϵ (all channel): 92.03 [%]

efficiency

σ_T (MRPC) = 152.74 $\pm$ 0.38 ps
σ_T (ST1) = 51.45 $\pm$ 0.26 ps
σ_T (ST2&ST3)= 51.12 $\pm$ 0.27 ps
ADC fit range: 110 - 180 ch
Streamer: 7.42 [%] (453/6103)
σ_{13}(w/slewing) = 164.96 ps
σ_{13}(streamer) = 109.91 ps

σ_T



Avalanche   Streamer

Run #: 307 — PH3

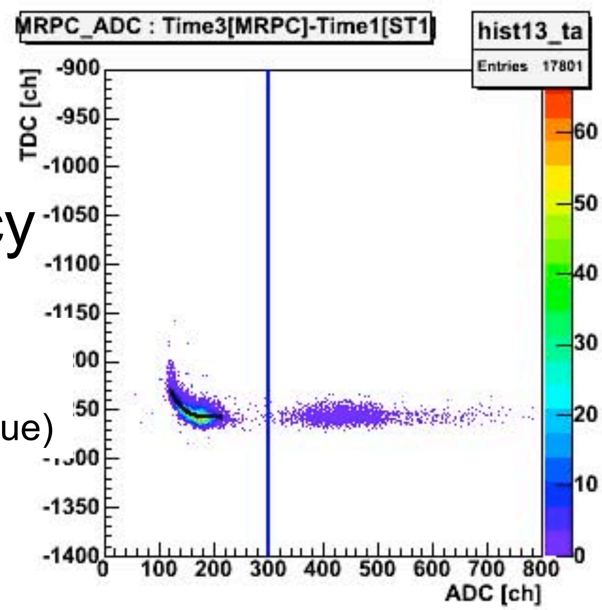
PH3, HV = 15.00 kV
threshold: 100 mV, hit ch. #: 2
PID: π^+ (p = +2.0 GeV/c)

ϵ (hit) : 97.80 [%]
ϵ (w/ next hit): 97.80 [%]
ϵ (all channel): 97.80 [%]

efficiency

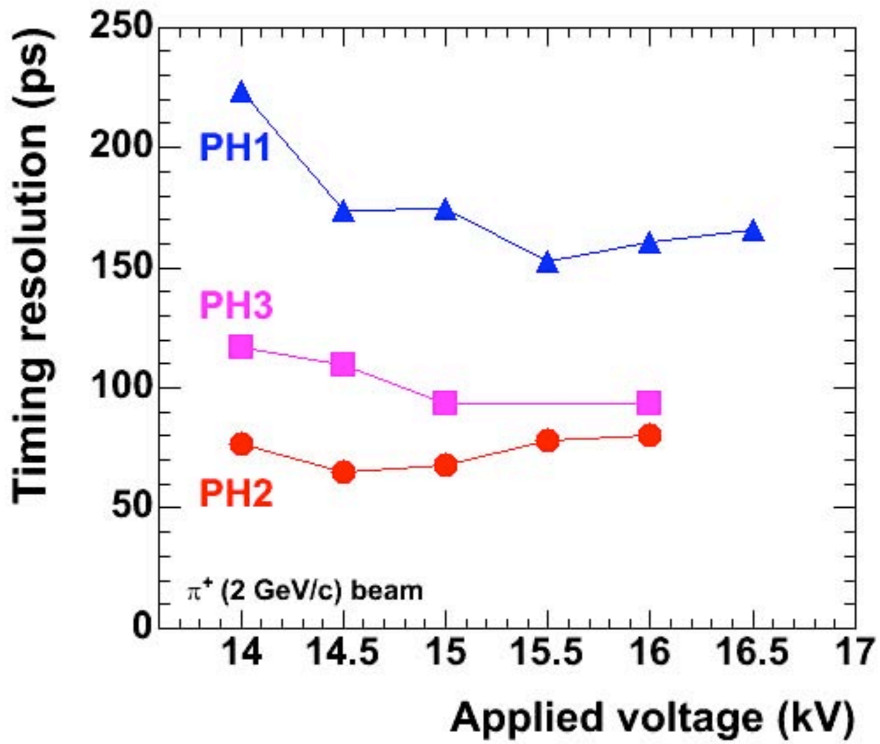
σ_T (MRPC) = 66.59 $\pm$ 0.17 ps
σ_T (ST1) = 51.49 $\pm$ 0.17 ps
σ_T (ST2&ST3)= 50.83 $\pm$ 0.16 p
ADC fit range: 120 - 220 ch
Streamer: 10.58 [%] (1842/17410)
σ_{13}(w/slewing) = 84.80 ps
σ_{13}(streamer) = 93.75 ps

σ_T (best value)

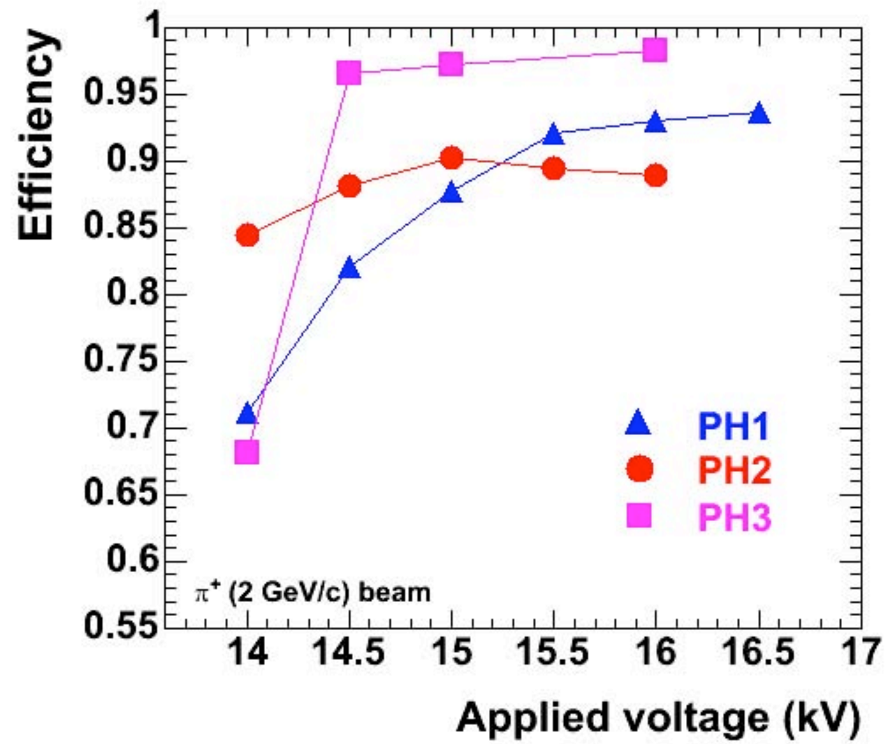


HV scan (detector type dep.)

Time Resolution

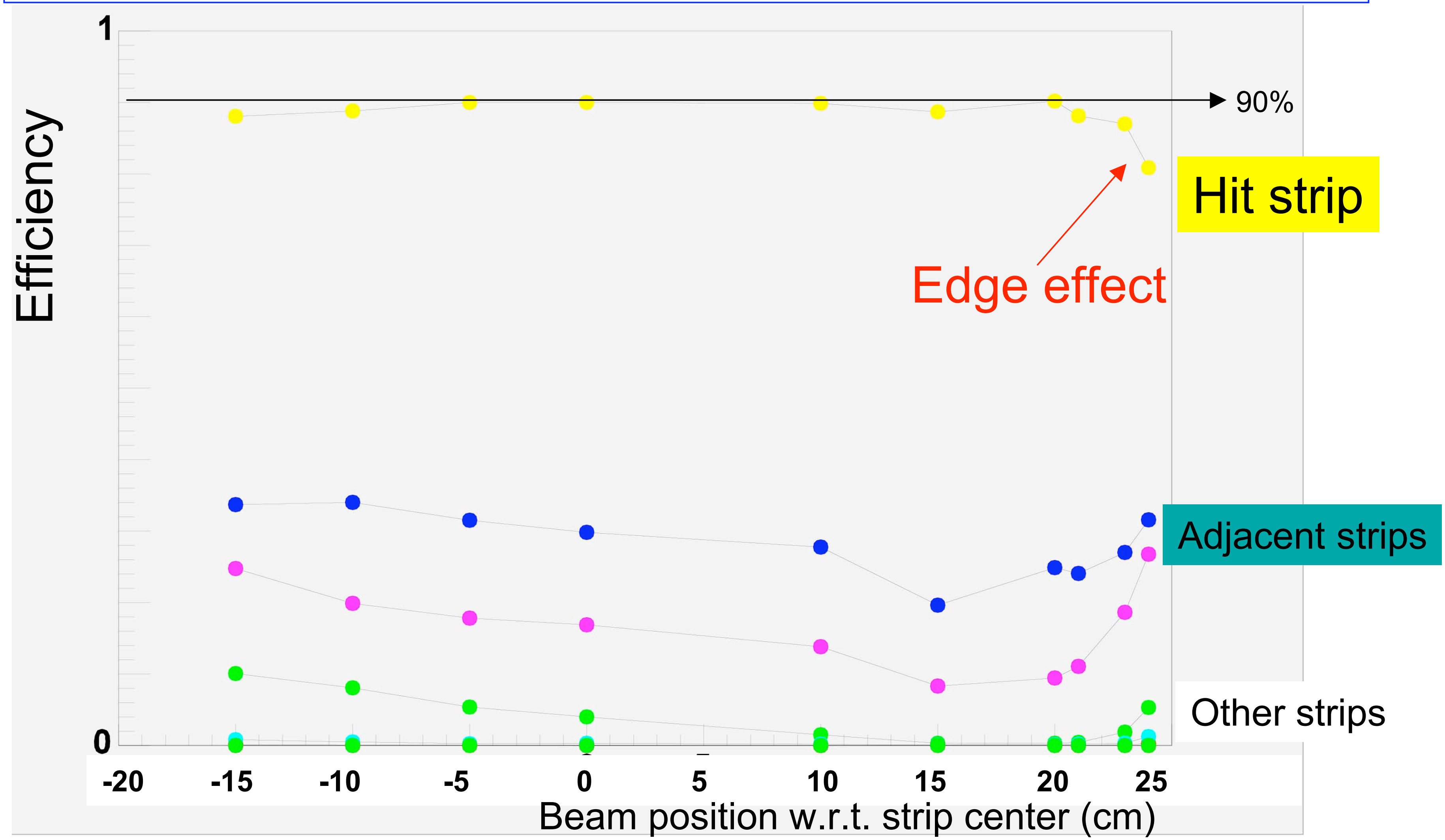


Efficiency



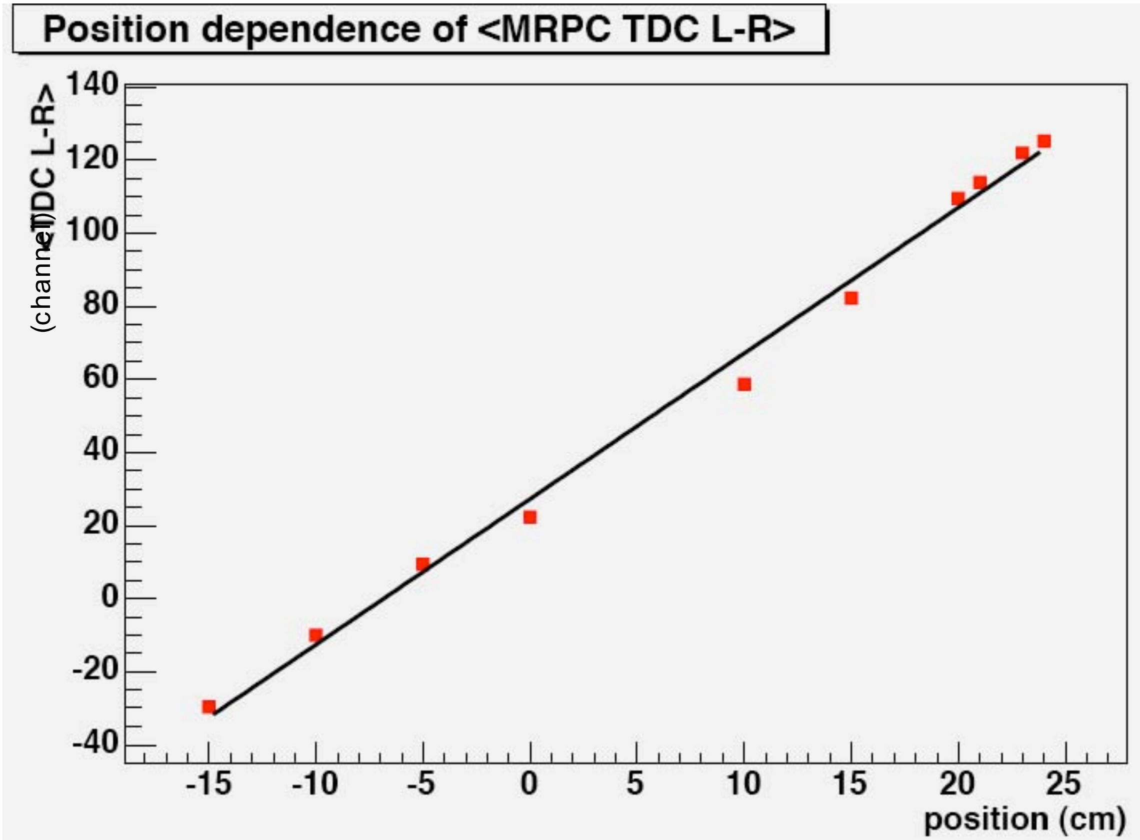
- PH1: worse timing resolution (>150 ps), same efficency as PH2. Problem on uniformity of performance across the chamber. Difficulties in mechanical assembly.
- PH2: **68ps timing resolution** at optimal condition, but 90% efficiency. Solution → increase strip width.
- PH3: comparable timing resolution with PH2 (best value: 67ps), 98% efficiency.

Horizontal scan along strips (PH2)



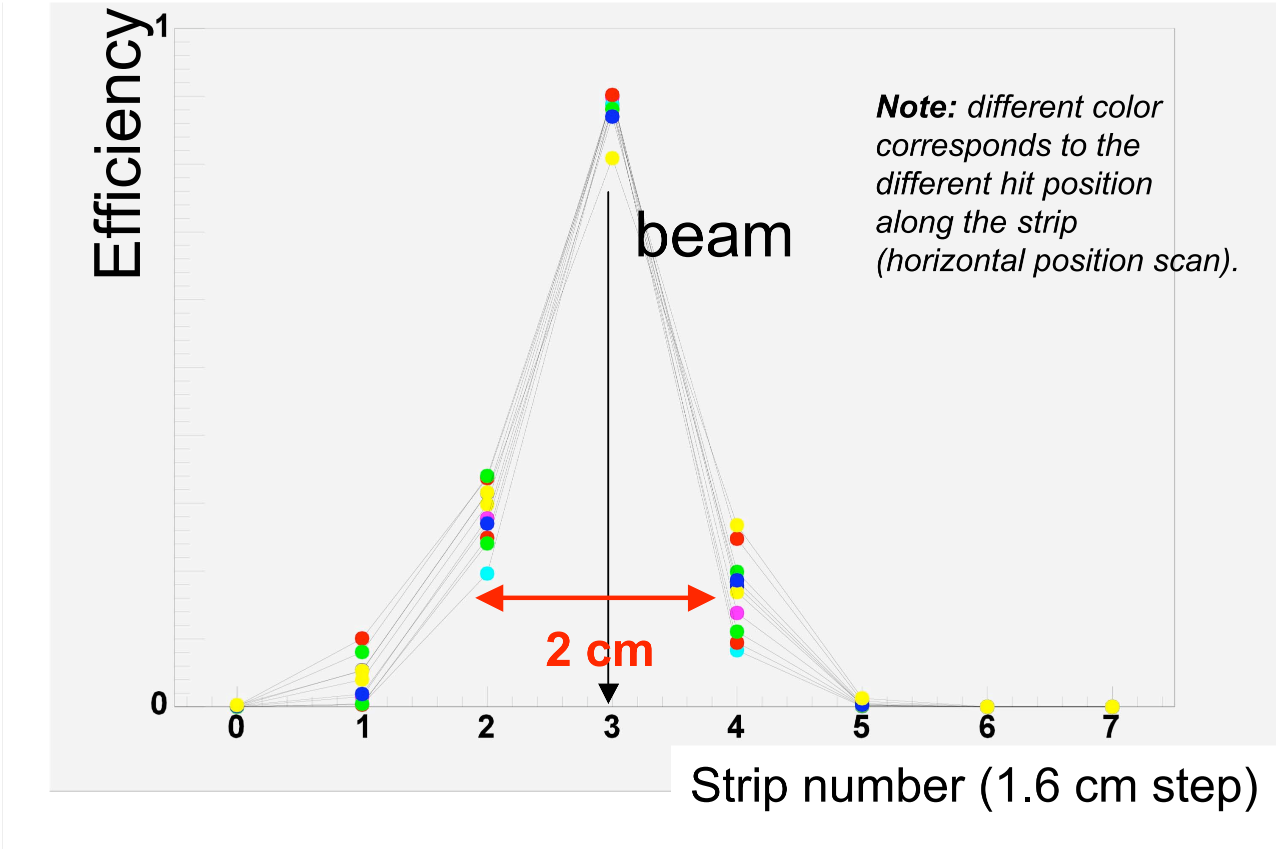
Uniform efficiency along the strip.

Position Determination



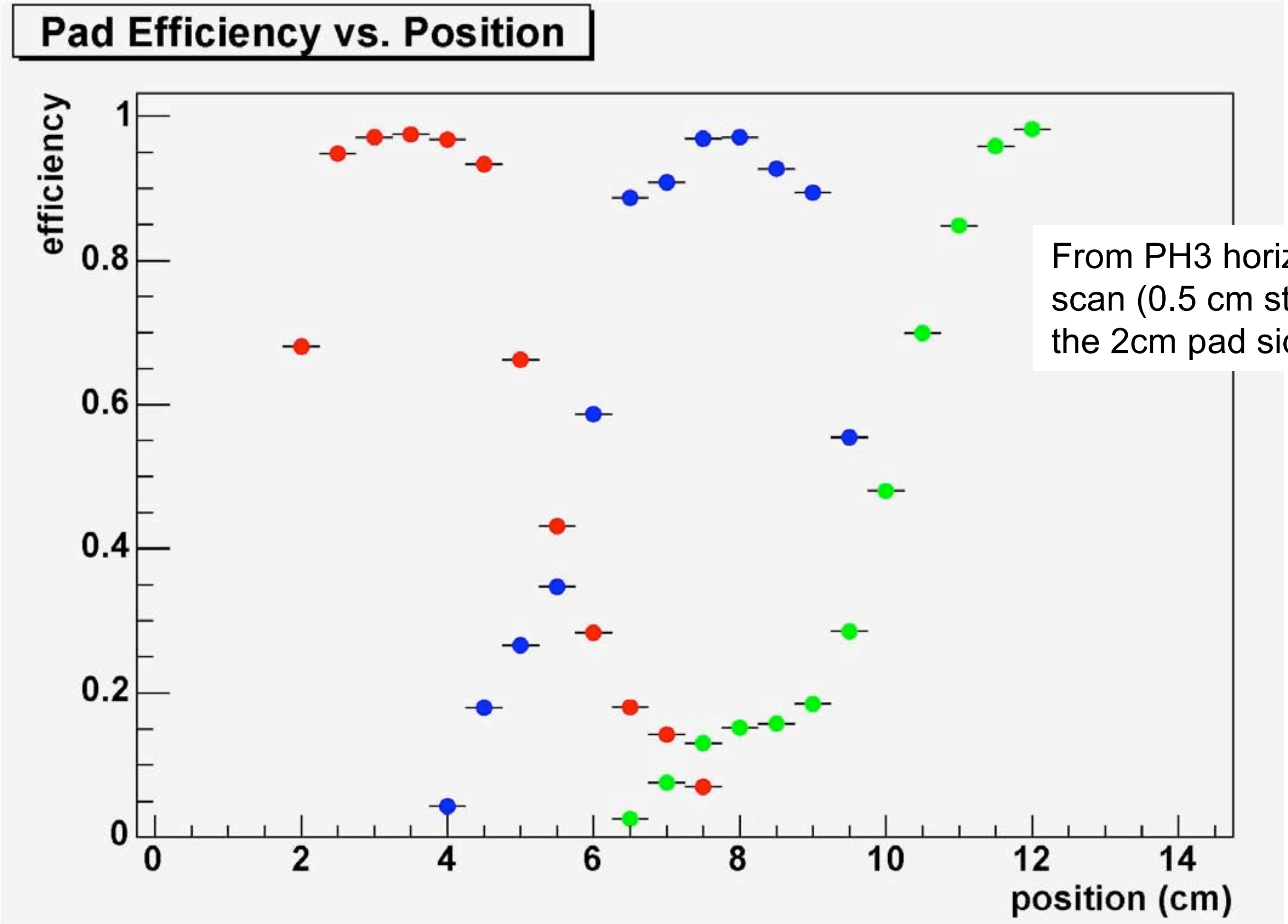
Similar to scintillation counter, hit position can be determined by (left - right) time difference.

Charge sharing in strips (PH2)



- Diameter of imaged charge would be ~2cm.
- Lower efficiency in PH2 than PH3 can be understood due to the strip width being smaller than the size of the charge dist.

Charge sharing in pads (PH3)



From PH3 horizontal position scan (0.5 cm step) along the 2cm pad side.

- PH3 pad size is 2x6 cm^2. If beam hits the center of the pad, efficiency is ~98% (justify 2 cm readout width).
- If beam hits between the pads or off-center, detection efficiency number is distributed to the adjacent pads.

Summary and Schedule

- We build three different MRPC TOF prototypes and tested with beams at KEK.
- **Beam test results**
  - **PH1** (big chamber, strip): ~150 ps timing resolution. 90% efficiency, same as PH2 (same strip width as PH2). Problem on uniformity.
  - **PH2 (strip): ~70 ps timing resolution and 90% efficiency under the nominal operation mode.**
  - **PH3** (pad): comparable timing resolution for PH2, ~98% efficiency.
  - Solution for PH2 efficiency: **increase strip width.**
- **Schedule**
  - New prototype "PH4" (strip width 1.3cm → 2.0cm) will be build and tested in RHIC-Run5 (also PH2/ PH3 will be installed for comparison).
  - Make a decision of the production type for RHIC-Run6 (2005-2006).
  - Full installation for PHENIX 1-sector (4 m^2) and Physics data taking in Run6.

PHENIX

Special Thanks to W.J. Llope (Rice Univ.)

*12 Countries; 57 Institutions; 460 Participants**

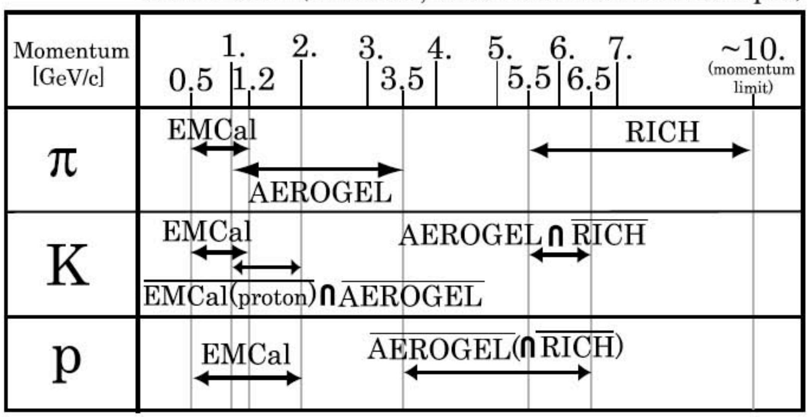
Brazil	University of São Paulo, São Paulo
China	Academia Sinica, Taipei, Taiwan
	China Institute of Atomic Energy, Beijing
	Peking University, Beijing
France	LPC, University de Clermont-Ferrand, Clermont-Ferrand
	Dapnia, CEA Saclay, Gif-sur-Yvette
	IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, Orsay
	LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau
	SUBATECH, Ecòle des Mines at Nantes, Nantes
Germany	University of Münster, Münster
Hungary	Central Research Institute for Physics (KFKI), Budapest
	Debrecen University, Debrecen
	Eötvös Loránd University (ELTE), Budapest
India	Banaras Hindu University, Banaras
	Bhabha Atomic Research Centre, Bombay
Israel	Weizmann Institute, Rehovot
Japan	Center for Nuclear Study, University of Tokyo, Tokyo
	Hiroshima University, Higashi-Hiroshima
	KEK, Institute for High Energy Physics, Tsukuba
	Kyoto University, Kyoto
	Nagasaki Institute of Applied Science, Nagasaki
	RIKEN, Institute for Physical and Chemical Research, Wako
	RIKEN-BNL Research Center, Upton, NY
	University of Tokyo, Bunkyo-ku, Tokyo
	Tokyo Institute of Technology, Tokyo
	University of Tsukuba, Tsukuba
	Waseda University, Tokyo
S. Korea	Cyclotron Application Laboratory, KAERI, Seoul
	Kangnung National University, Kangnung
	Korea University, Seoul
	Myong Ji University, Yongin City
	System Electronics Laboratory, Seoul Nat. University, Seoul
	Yonsei University, Seoul
Russia	Institute of High Energy Physics, Protovino
	Joint Institute for Nuclear Research, Dubna
	Kurchatov Institute, Moscow
	PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg
	St. Petersburg State Technical University, St. Petersburg
Sweden	Lund University, Lund
USA	Abilene Christian University, Abilene, TX
	Brookhaven National Laboratory, Upton, NY
	University of California - Riverside, Riverside, CA
	University of Colorado, Boulder, CO
	Columbia University, Nevis Laboratories, Irvington, NY
	Florida State University, Tallahassee, FL
	Georgia State University, Atlanta, GA
	University of Illinois Urbana Champaign, Urbana-Champaign, IL
	Iowa State University and Ames Laboratory, Ames, IA
	Los Alamos National Laboratory, Los Alamos, NM
	Lawrence Livermore National Laboratory, Livermore, CA
	University of New Mexico, Albuquerque, NM
	New Mexico State University, Las Cruces, NM
	Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
	Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY
	Oak Ridge National Laboratory, Oak Ridge, TN
	University of Tennessee, Knoxville, TN
	Vanderbilt University, Nashville, TN

*as of July 2002

Backup Slides

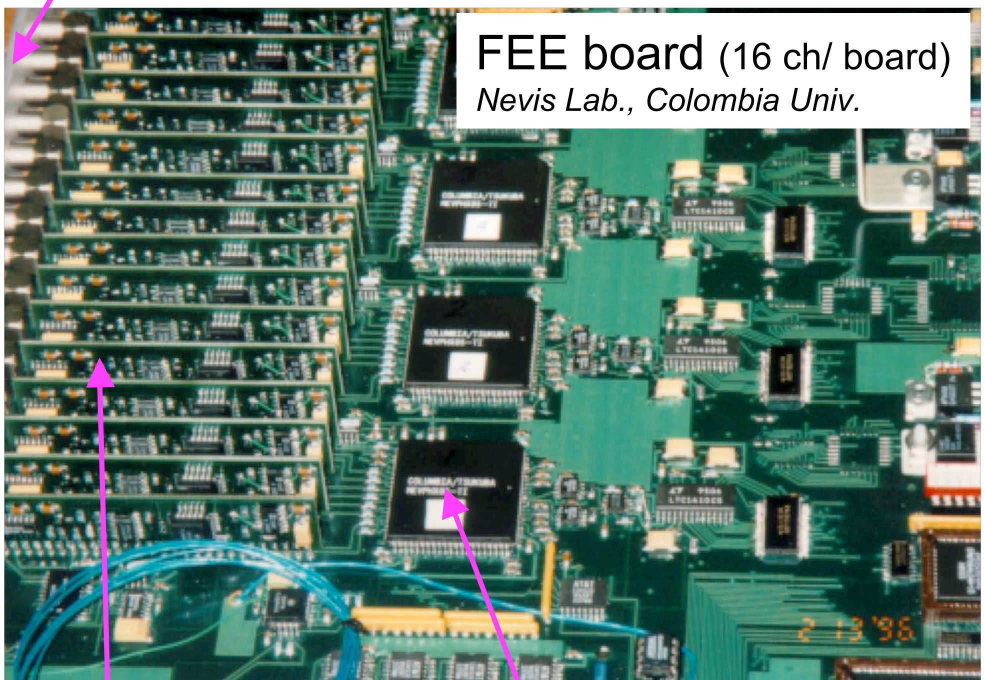
Without TOF

AEROGEL : (n=1.0114, threshold= 10% of Max. Np.e.)



PHENIX-TOF-E Front End Electronics

PMT input lemo

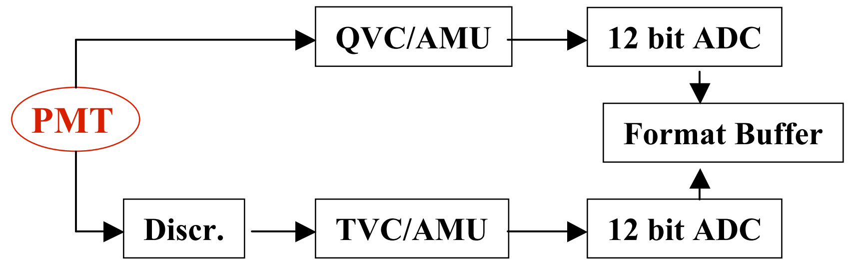


FEE board (16 ch/ board)
Nevis Lab., Colombia Univ.

Discriminator Sub-board

TVC+AMU chip (4ch /chip)

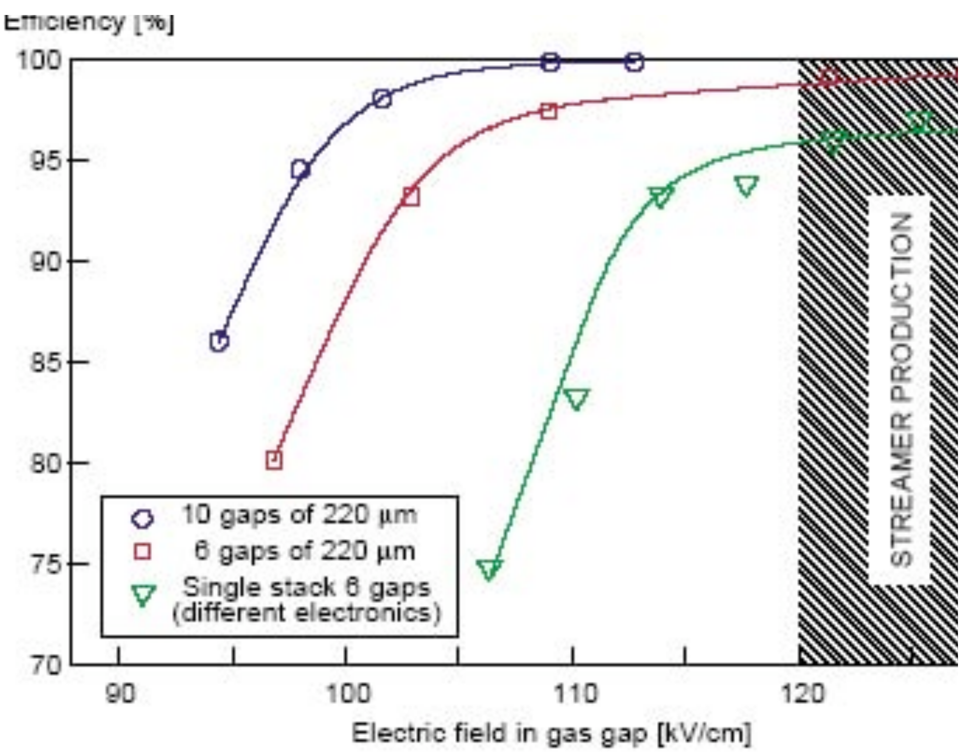
Block Diagram of FEE

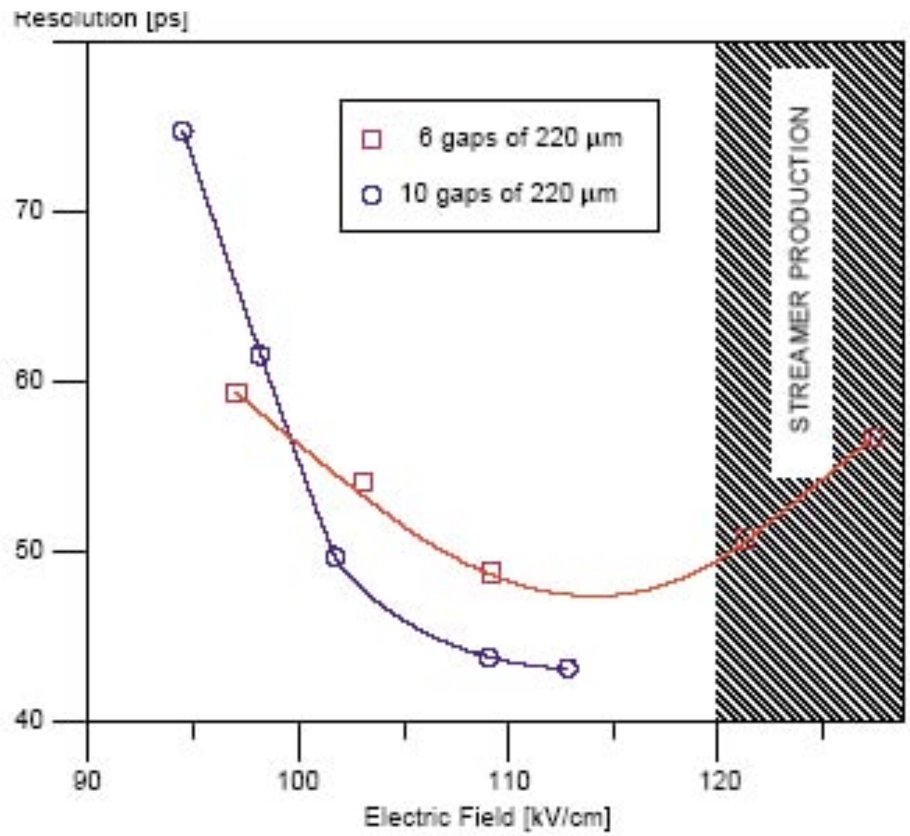


- Custom-made chips of TVC+AMU and QVC+AMU
  Overall timing resolution of < 25 ps
- Use of Analogue Memory Unit (AMU)
  Programmable up to 4 m sec delay w/o coaxial delay cables.

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

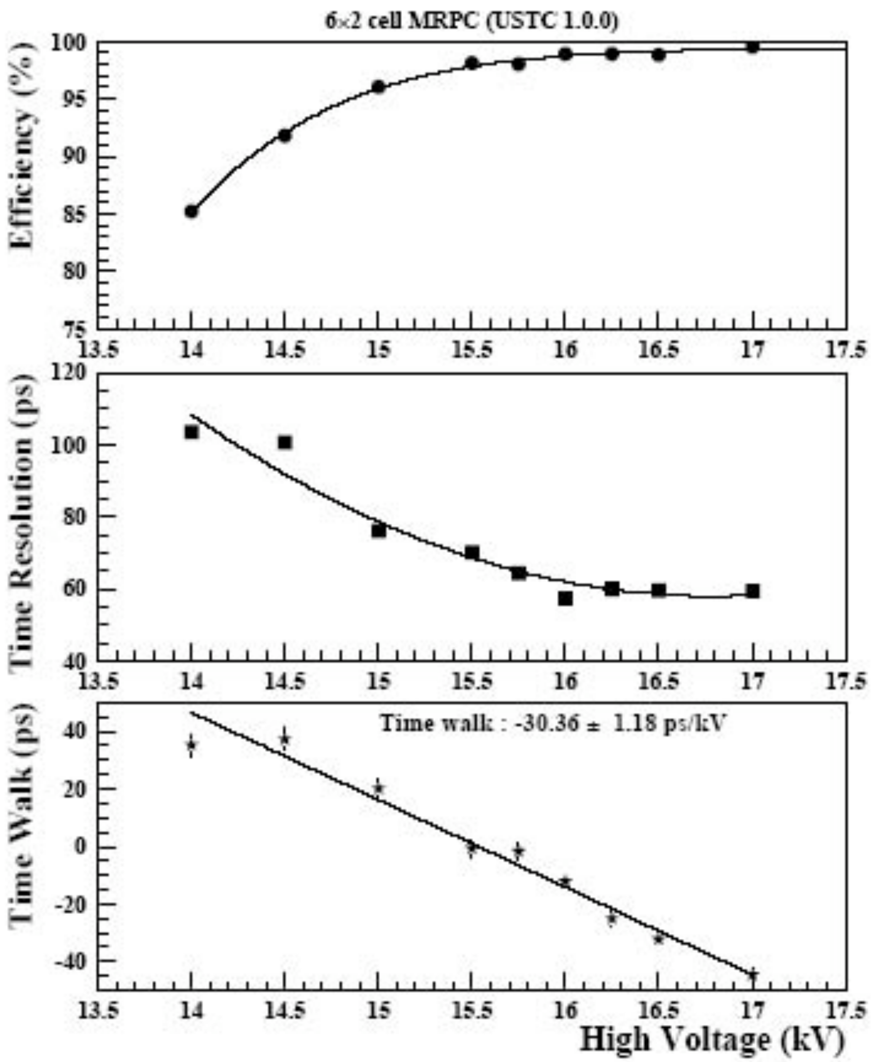
Double vs single stack performance





ALICE R&D: double stack is better, but comparable overall performance.

STAR MRPC performance



- Single stack
- 6 gaps
- chamber size 20x6 cm^2
- readout pad: 3x6 cm^2