



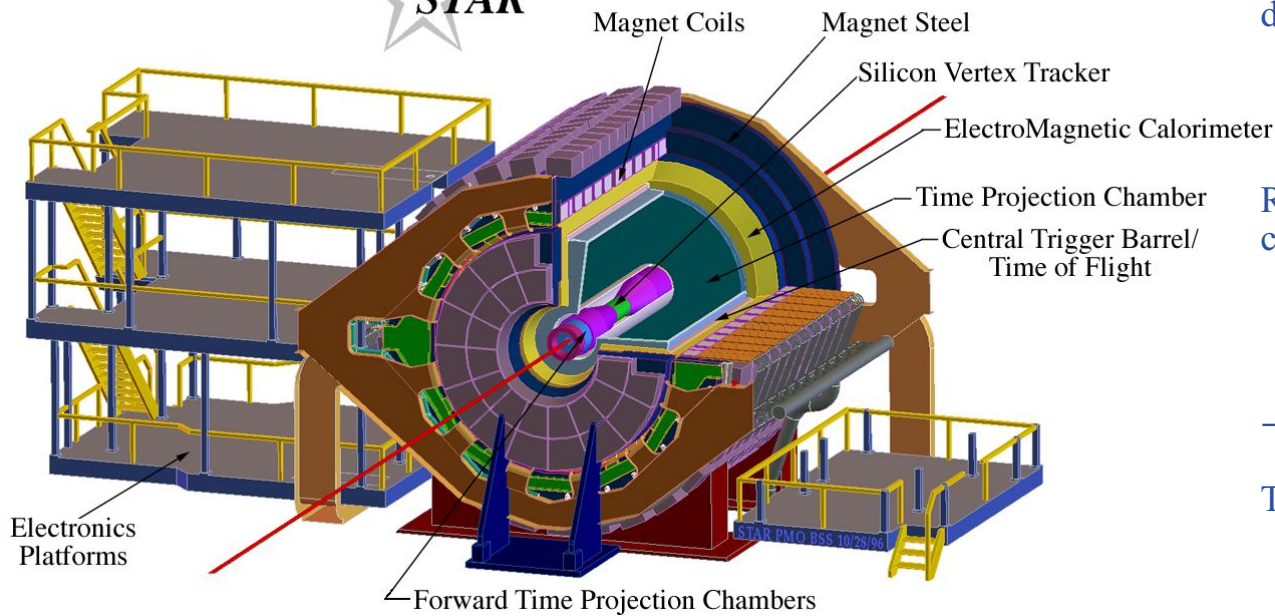
Large-Area Fast-Timing Systems in STAR

W.J. Llope
Rice University
for the ☆ Collaboration

CAARI 2010
Ft. Worth, Texas
August 12, 2010

OUTLINE:

- Our MRPCs
- Test beam results
- Full-sized prototypes
- The full-barrel TOF
- Muon Telescope MRPCs
- The full-barrel MTD



STAR's strength = wide acceptance
 defined by its Time Projection Chamber (TPC)
 PID: π/K $p < 0.6$ GeV
 $(\pi+K)/p$ $p < 1.0$ GeV

Roughly **half** the charged hadrons $\pi/K/p$
 cannot be directly identified!
 short reach in P_T (minijets)
 large backgrounds to secondary vertices
 & resonances

→ STAR needed Time of Flight (TOF).....

TOF space immediately surrounds the TPC
 path length from ~ 2.1 m to ~ 3.2 m
 excellent tracking & “extrapolation”

Throughout the early 1990's, we designed a
 Scintillator+Mesh Dynode PMT TOF....

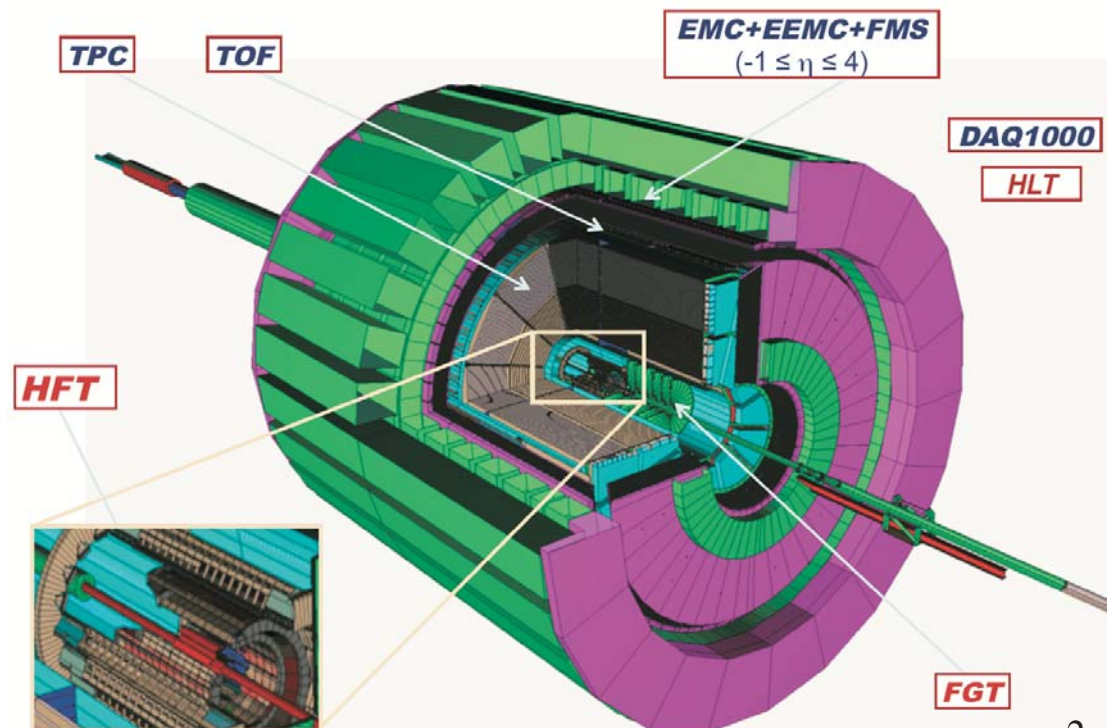
It met the requirements, but the major problem was the
 huge size and epic cost of mesh dynode PMTs

Very expensive!
 for $\sim 10\%$ occupancy → 50 M\$

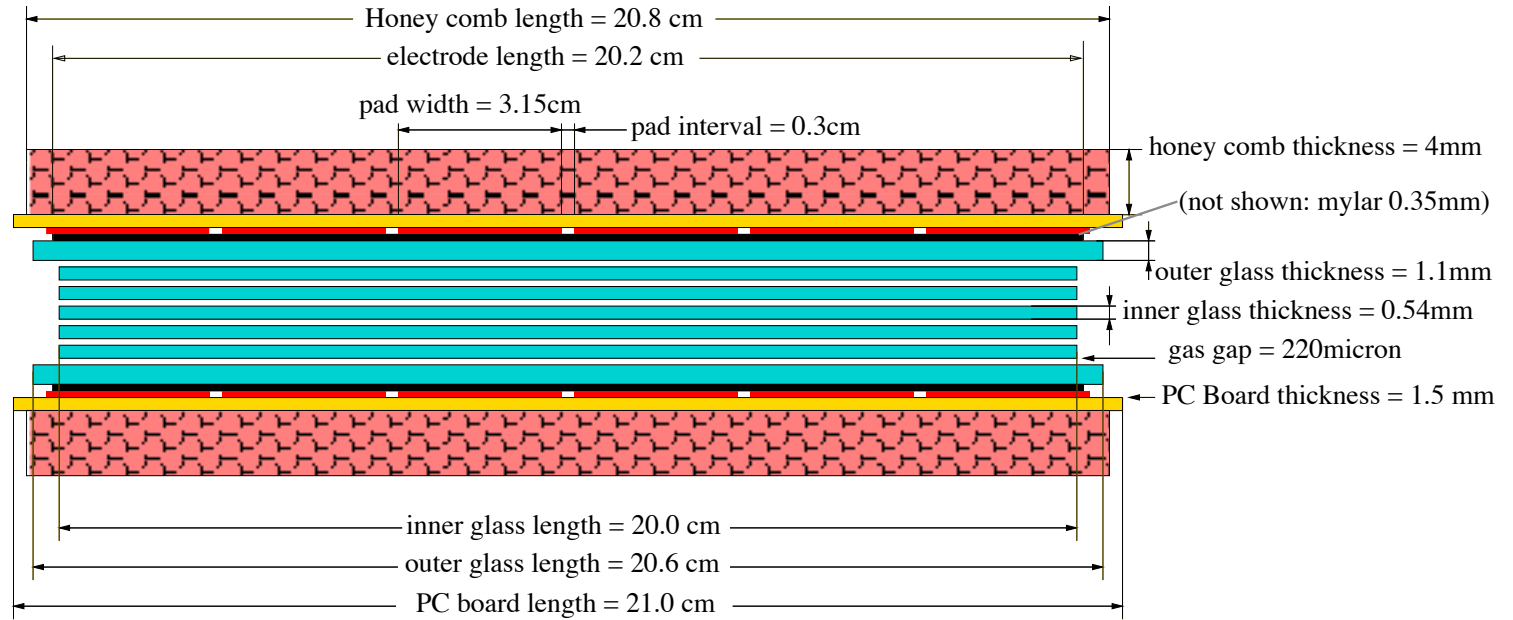
Sea change for us the late 1990's....

E. Cerron Zeballos, *et al.*, NIM A 374, 132 (1996).
 M.C.S. Williams, Nucl. Phys. A 698, 464 (2002).

We immediately began developing our own
 MRPCs, and testing them parasitically in
 LAA/ALICE test beam at CERN



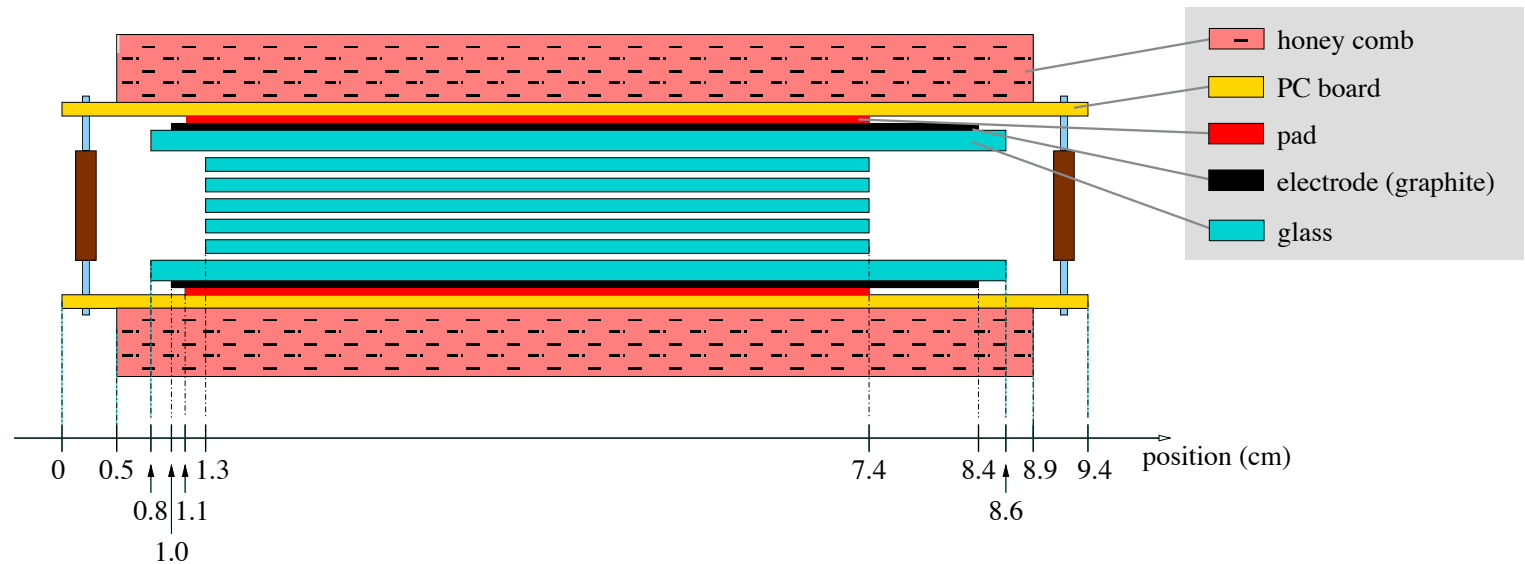
STAR's Variant...



Overall size
21.4 x 9.4 cm

Six 220 μm gas gaps
Fishing line spacers

inner glass 0.54mm
outer glass 1.1 mm

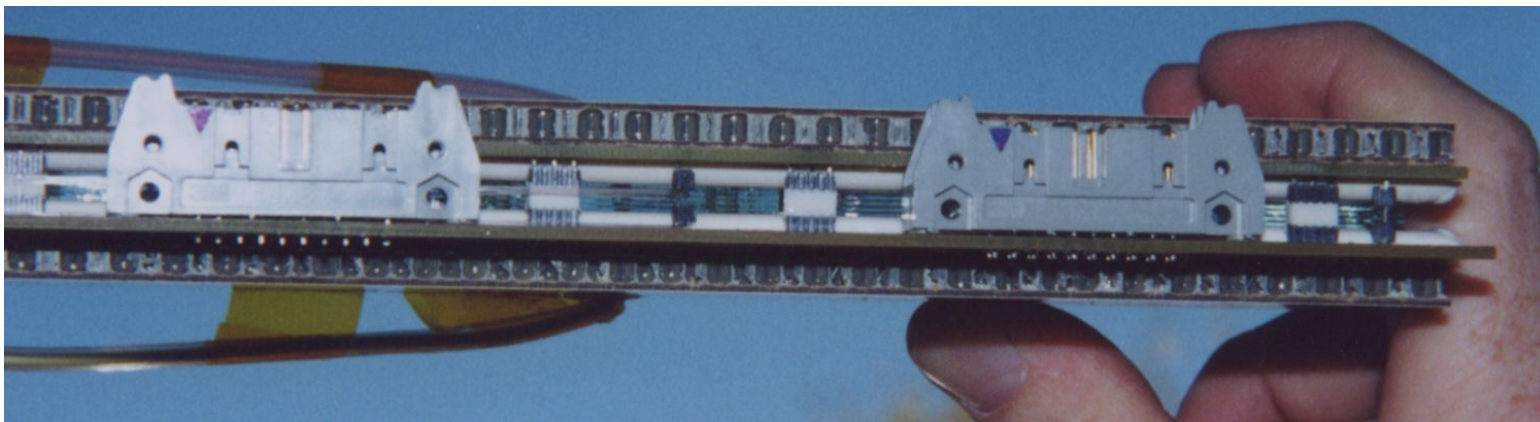


Float glass & Graphite tape electrodes

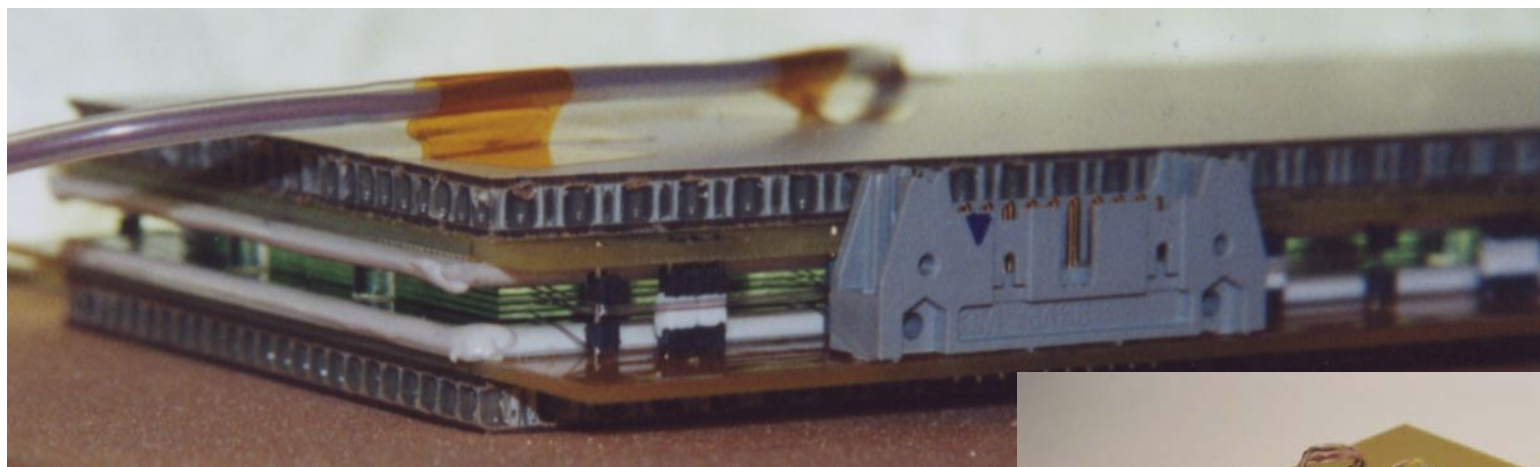
$10^{12-13} \Omega/\text{cm}$ volume & $10^5 \Omega/\text{sq}$ surface, respectively
operating voltage: $\pm 7 \text{ kV}$

Gas: 95% Freon R-134a, 5% isobutane

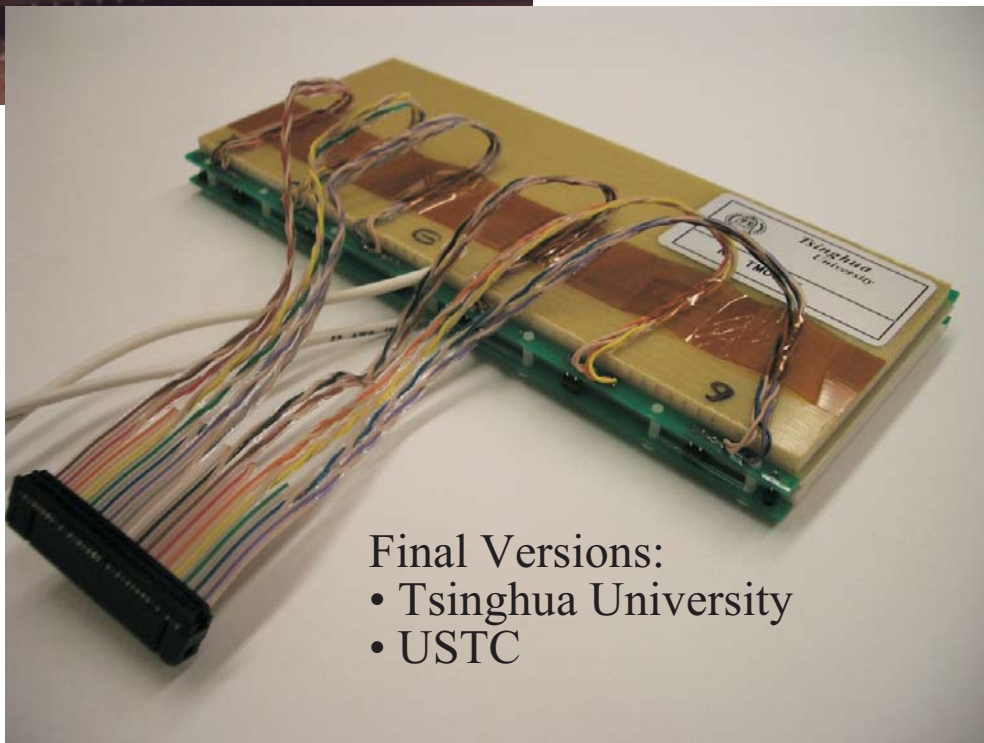
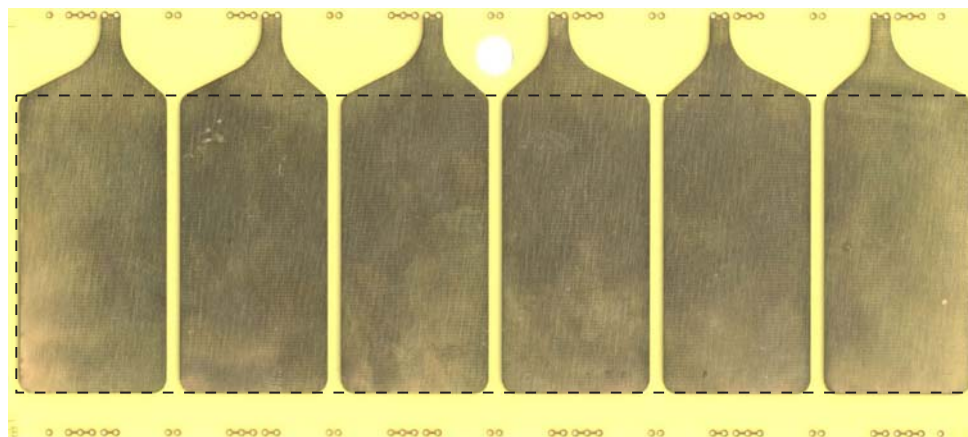
in STAR, recirculating as of this year



Prototype (~2001)



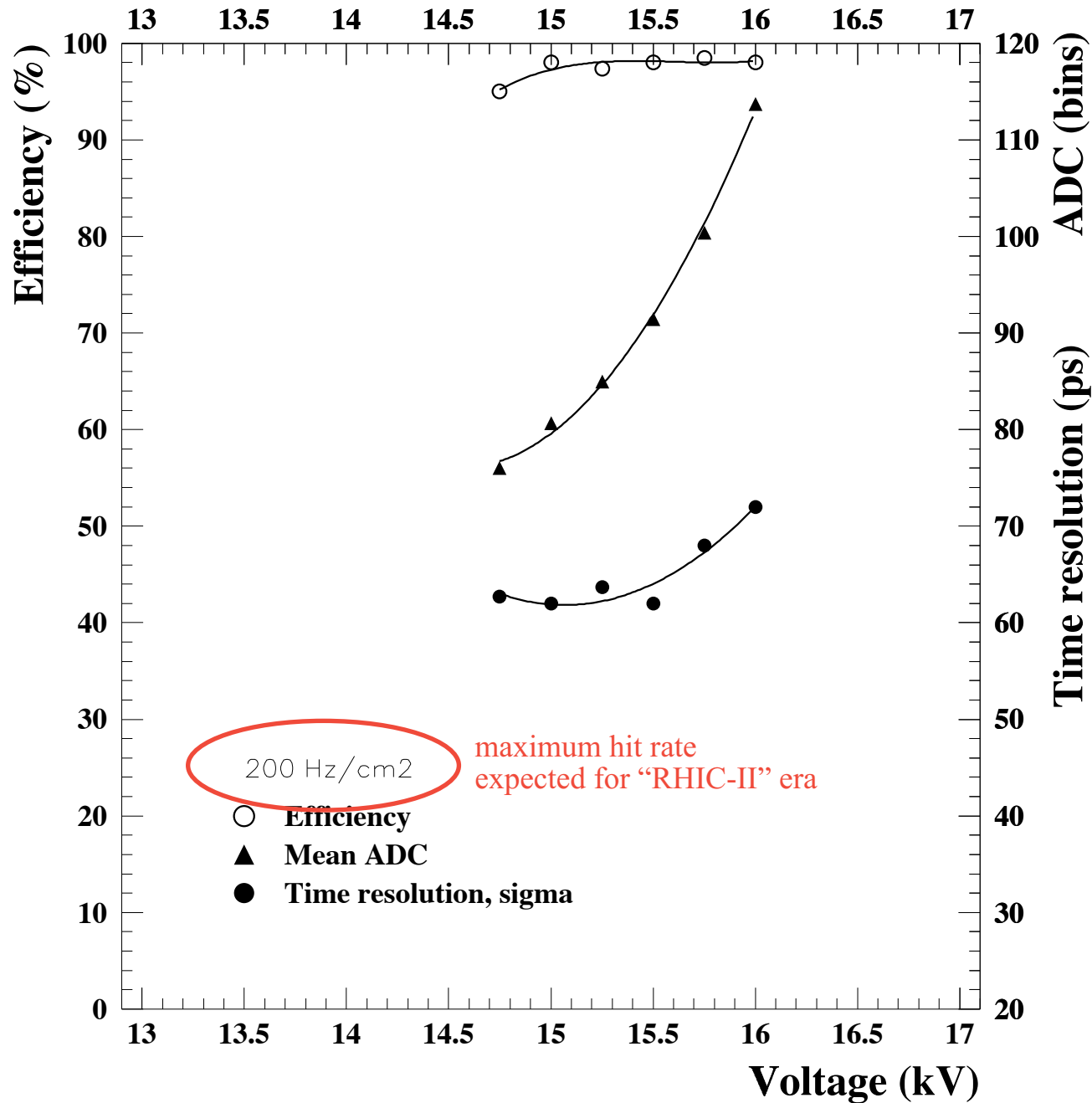
6 single-ended read-out pads per MRPC:



Final Versions:

- Tsinghua University
- USTC

Rice 10 pad 3 center (pad 31.5mmx63mm) K.card 7GeV/c JUNE/2001



June 2001:
final CERN test results...

focus then shifted to a full-sized prototype system for STAR:

“TOFr”

a “tray”

$-1 < \eta < 0$

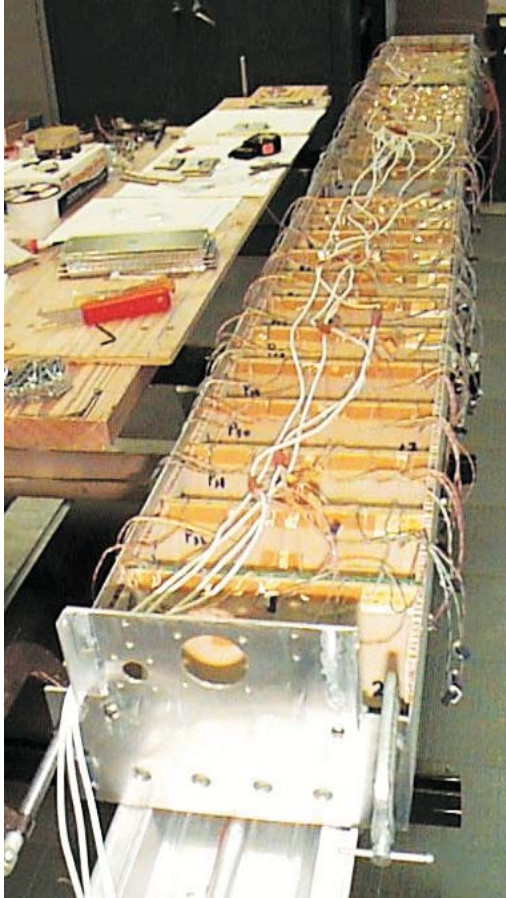
$\Delta\phi \sim 1/60^{\text{th}}$ of 2π

with ~ 30 MRPCs

STAR full-sized prototypes (2002-2005)

optimize the mechanical design, simplify fabrication, improve tolerances
develop and optimize the electronics

TOFr (Run-3)



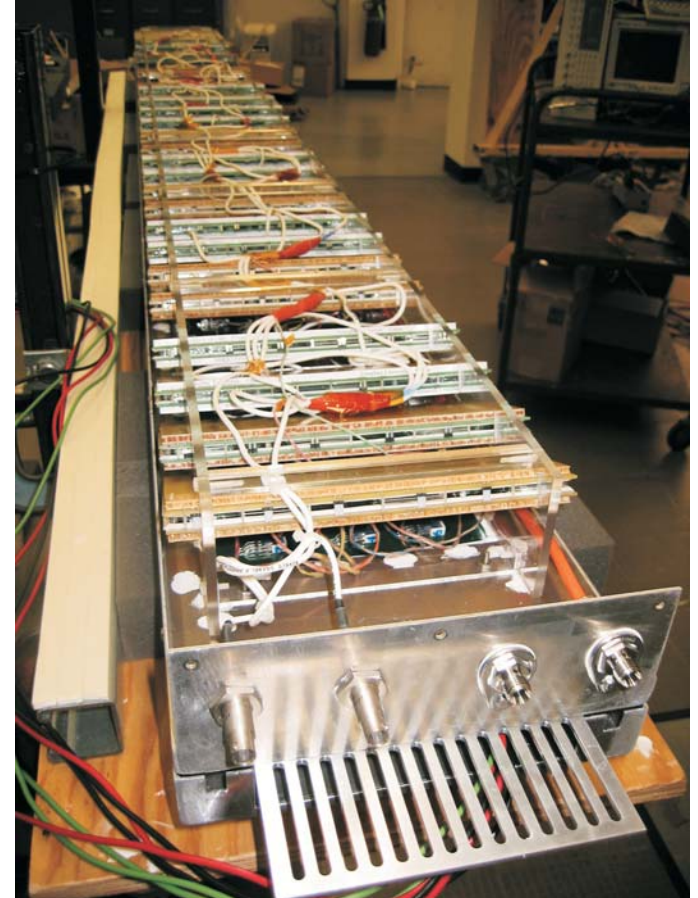
Box built by hand
Gaskets + wrong sealant
Two layers of electronics
long cables
CAMAC DAQ
Imprecise MRPC positioning

TOFr' (Run-4)



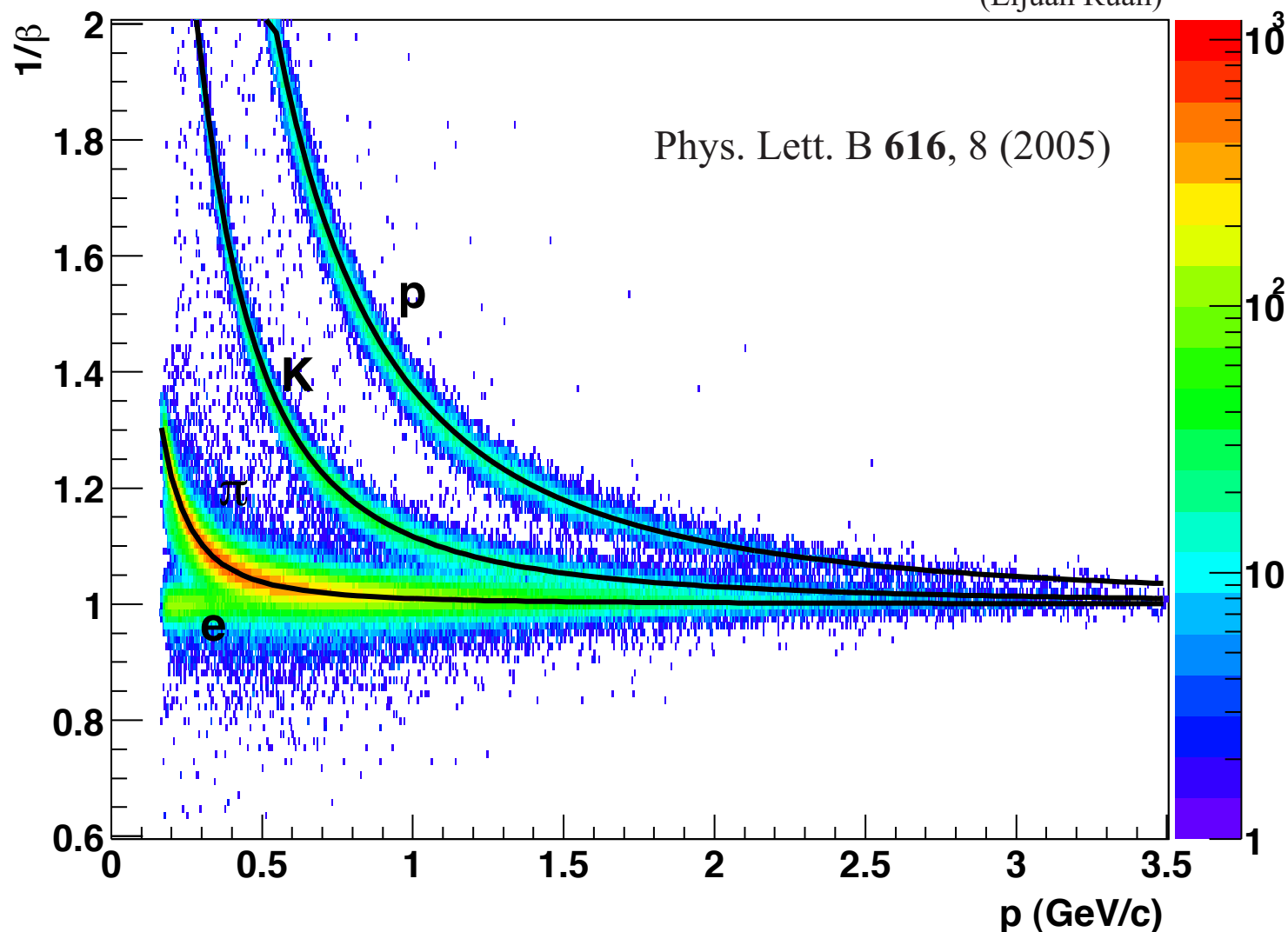
“Shoebox” built out-of-house
Correct sealant
One layer of electronics
long cables
CAMAC DAQ
Imprecise MRPC positioning

TOFr5 (Run-5)



“Shoebox” built out-of-house
Correct sealant
Two layer of electronics
local digitization (CERN HPTDC)
Precise MRPC positioning
“Integrated” water cooling

Each prototype completely new “from the ground up”
a few MRPCs used in all three prototypes to look for aging effects...

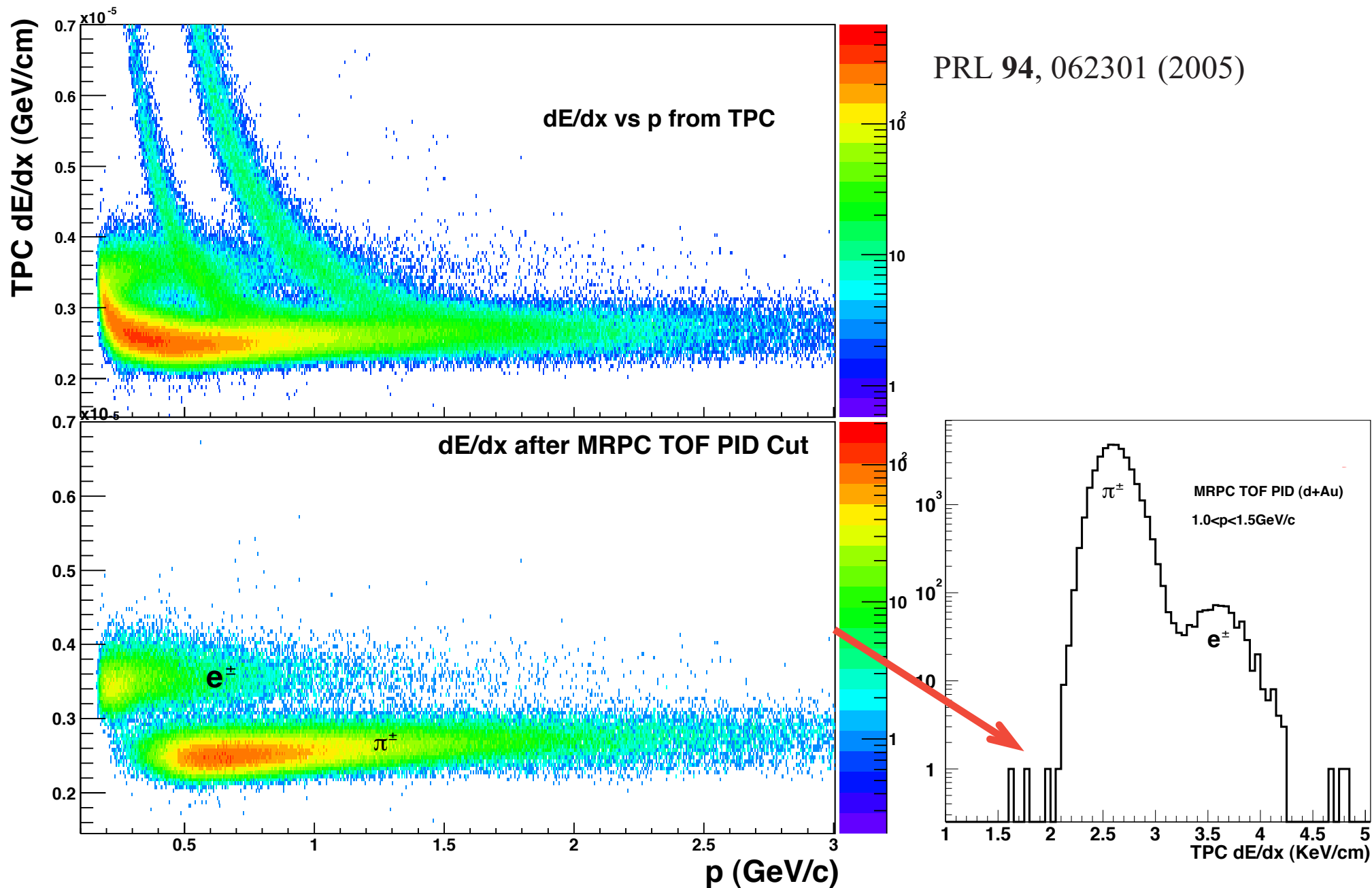


start resolution ~85ps
 stop (MRPC) resn ~85ps
 total ~120ps

→ $\pi/K/p$ to ~1.6 GeV/c, and $(\pi+K)/p$ to ~2.8 GeV/c

First physics result from an MRPC-based TOF System
 on hadron Pt-distributions & the Cronin Effect in RHIC p+p & d+Au collisions

TOF in combination with TPC dE/dx also allows effective *electron PID*...
complementary to calorimetric measurements from the Calorimeters BEMC/BSMD...



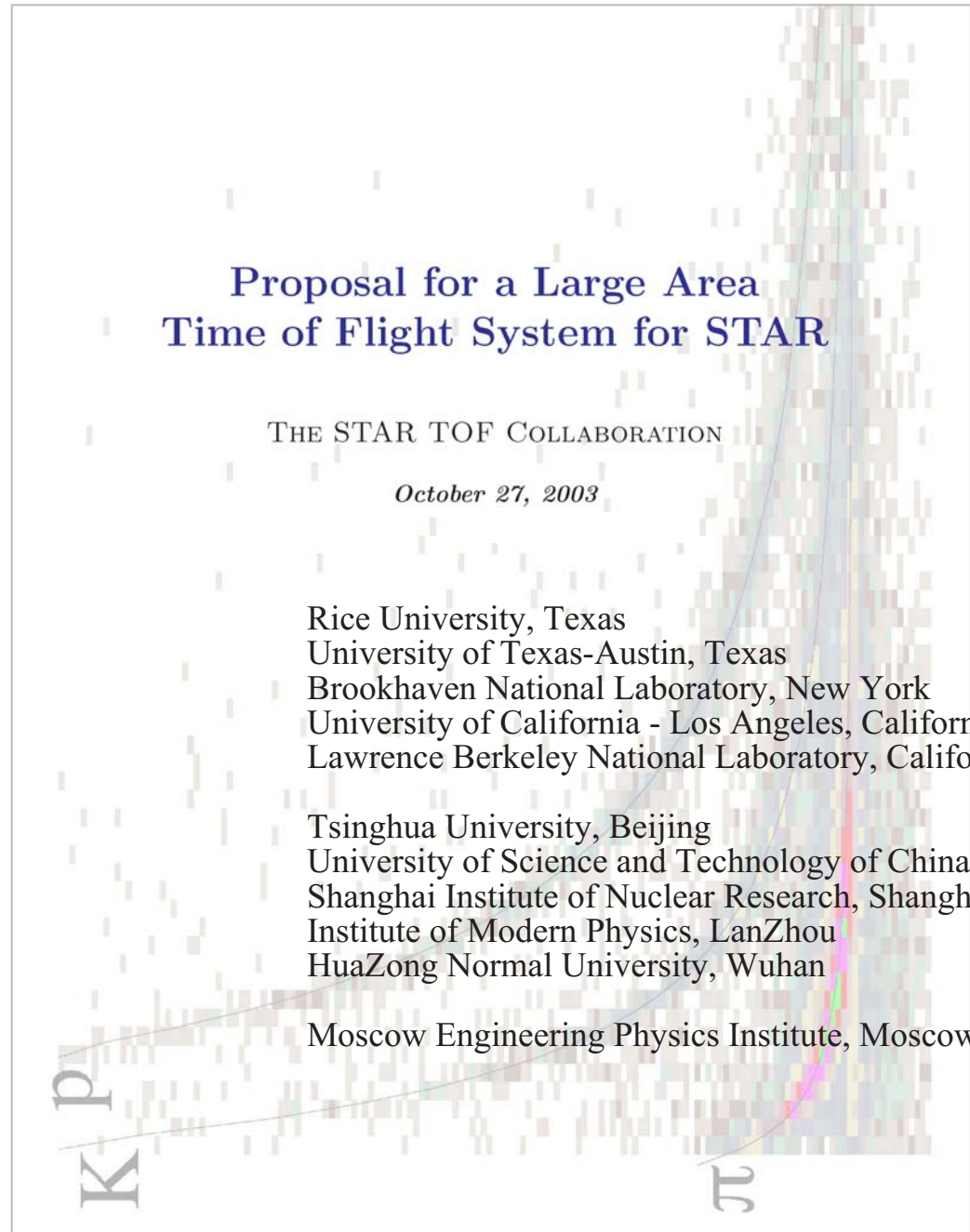
Following 3 full TOFrX prototypes,
MRPCs then “proven” for STAR...

Then proposed a full system:

- cover entire cylindrical surface of TPC
 $\Delta\phi=2\pi$, $-1<\eta<1$
- ~ 50 m² total area
120 trays
32 MRPCs/tray
6 channels/MRPC \rightarrow 23,040 chs
- 3840+ MRPCs contributed by China
- Tray fabrication & testing in Texas
- Digitization on-board
- US Cost: 4.7 M\$
Chinese contribution: 2.3 M\$

Construction project completed
“on-time” in late 2009

All 120 trays installed for RHIC Run-10



Electronics

TINO (Rice)

TDIG (Blue Sky Electronics)

TCPU (Blue Sky Electronics)

TDIG (UT-Austin)

Seals gas box, includes 3 NINO chips

Digitization, includes 3 HPTDC chips

Collects data from each tray

Collects tray data & ships it to STAR DAQ

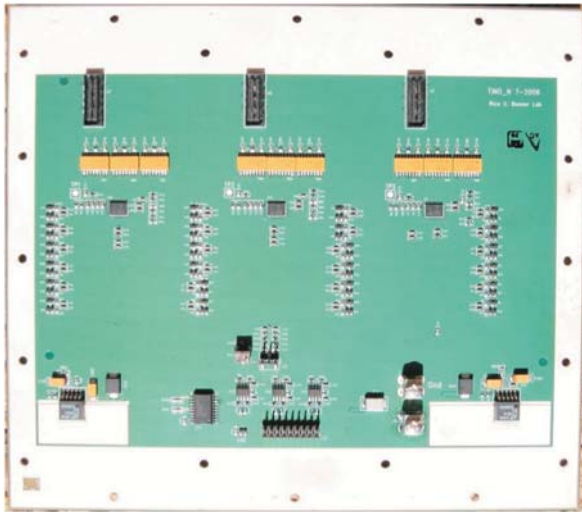
960 boards

960 boards

120 boards

4 boards

TINO



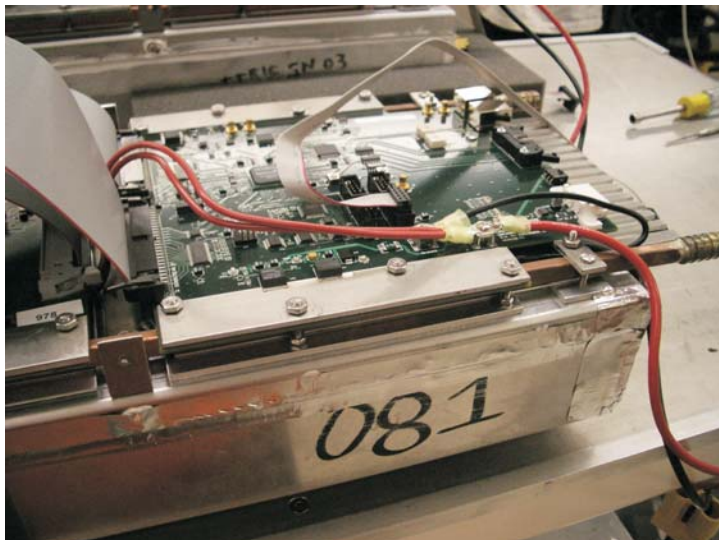
TDIG



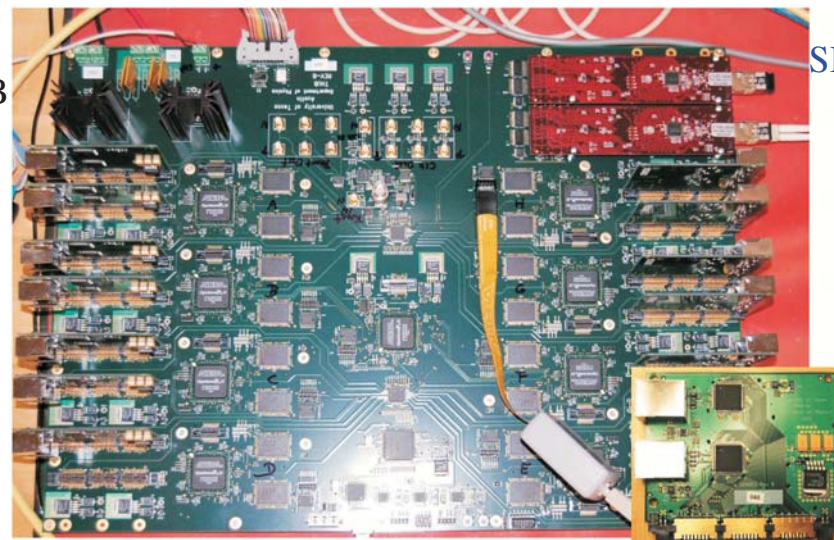
Start-side:
same electronics
except TINO→TPMT

*thanks to
CERN et al
R&D for
NINO, HPTDC,
SIU/DRORC!!*

TCPU



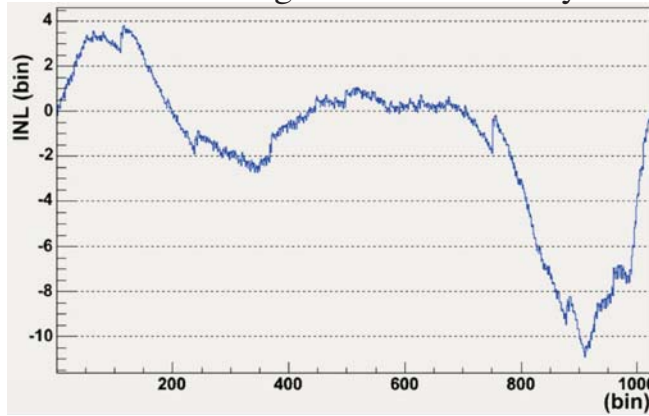
THUB



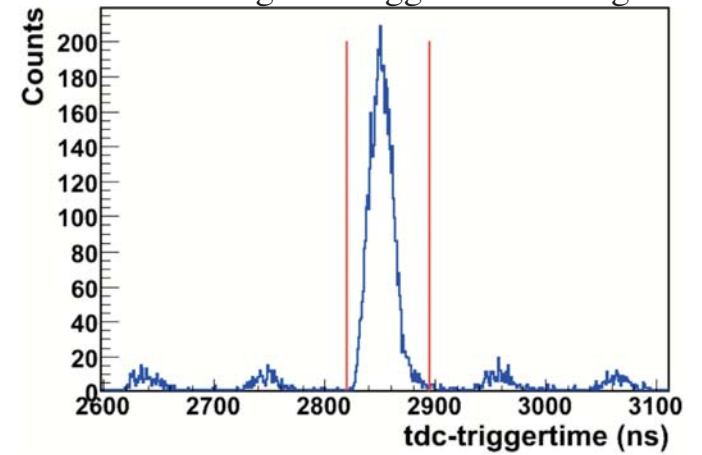
SIU/RORC

Calibrations....

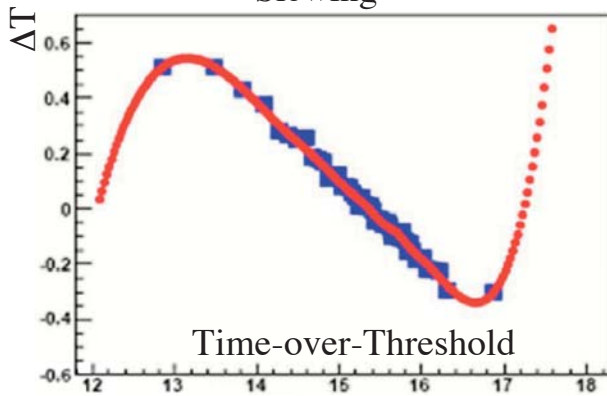
HPTDC Integrated Non-linearity



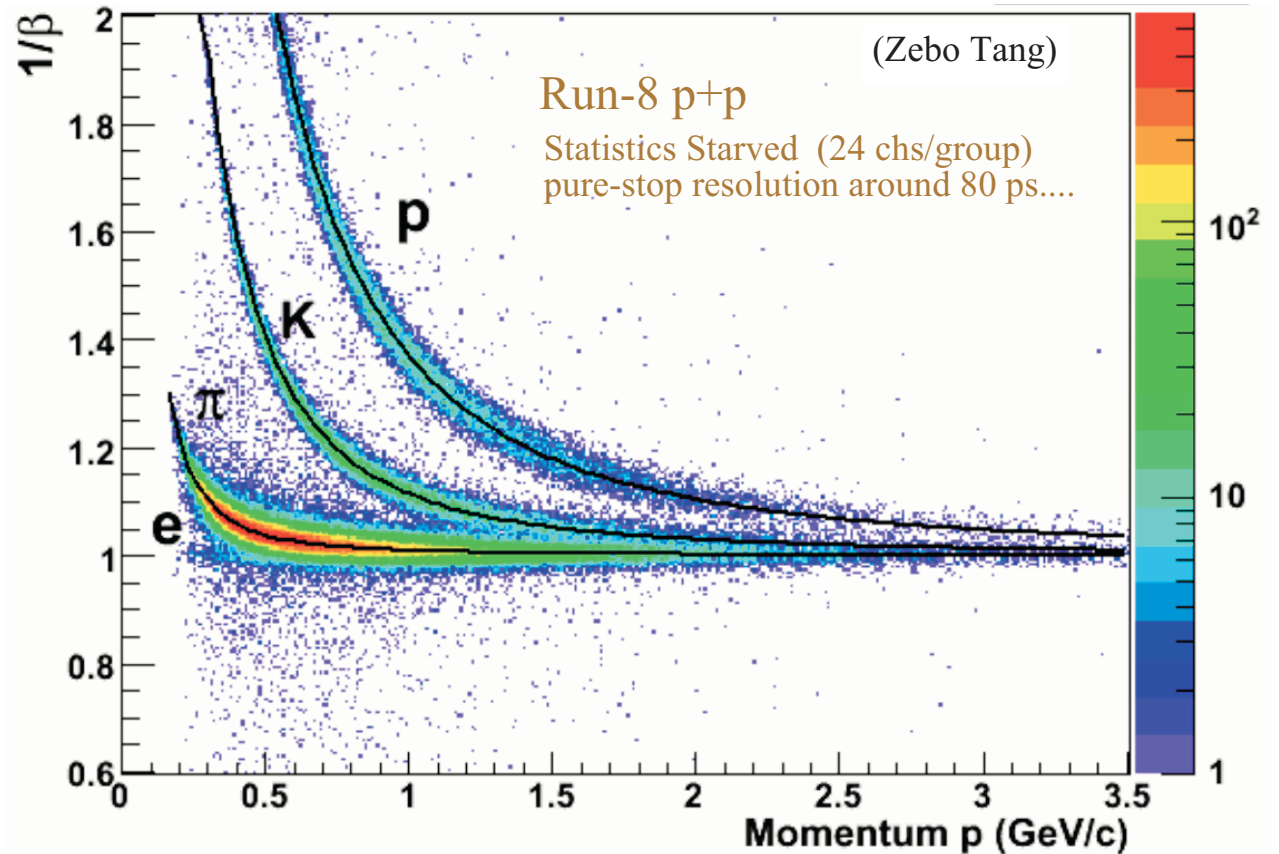
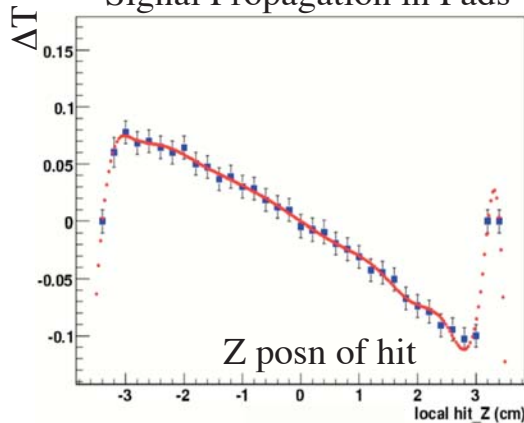
Selecting the Triggered Crossing



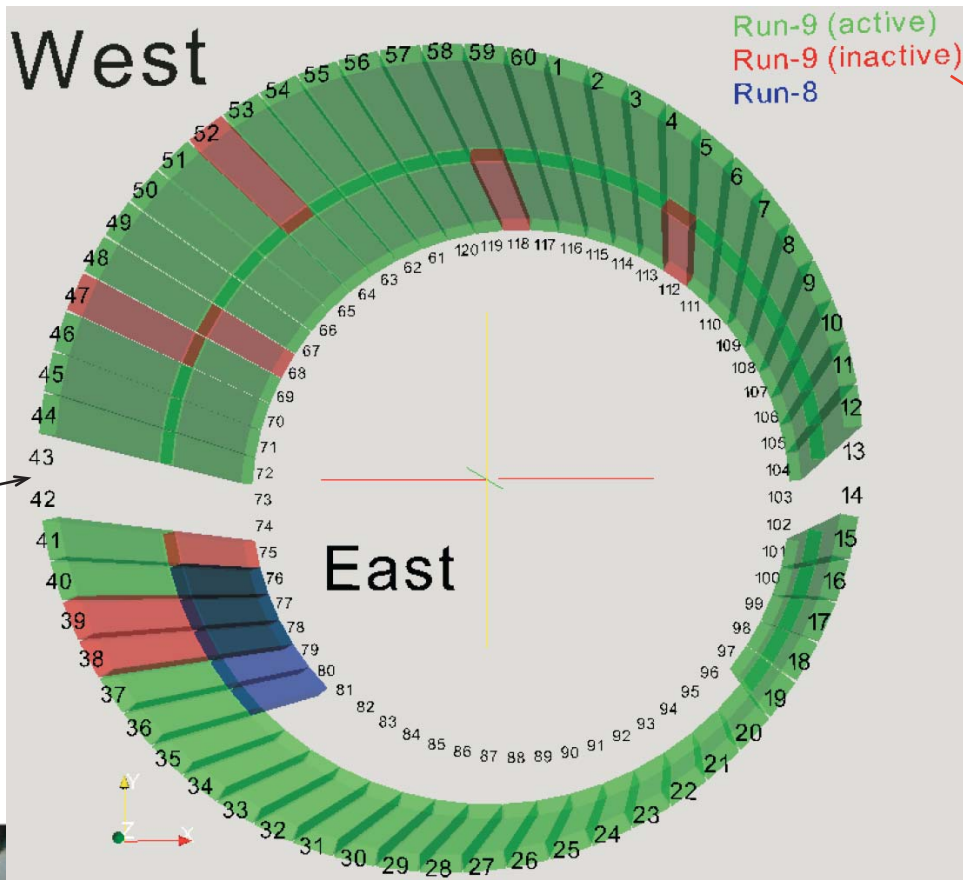
Slewing



Signal Propagation in Pads



Run-8 2008
 5 trays
 Run-9 2009
 94 trays (86)
 Run-10 2010
 120 trays (119)



Run-9: 94 trays installed

Problems with 8 trays...

LV cabling: 2 trays
 sense wires disconnected

HV cabling: 5 trays
 2 cables pinched by poletip
 3 cables improperly connected

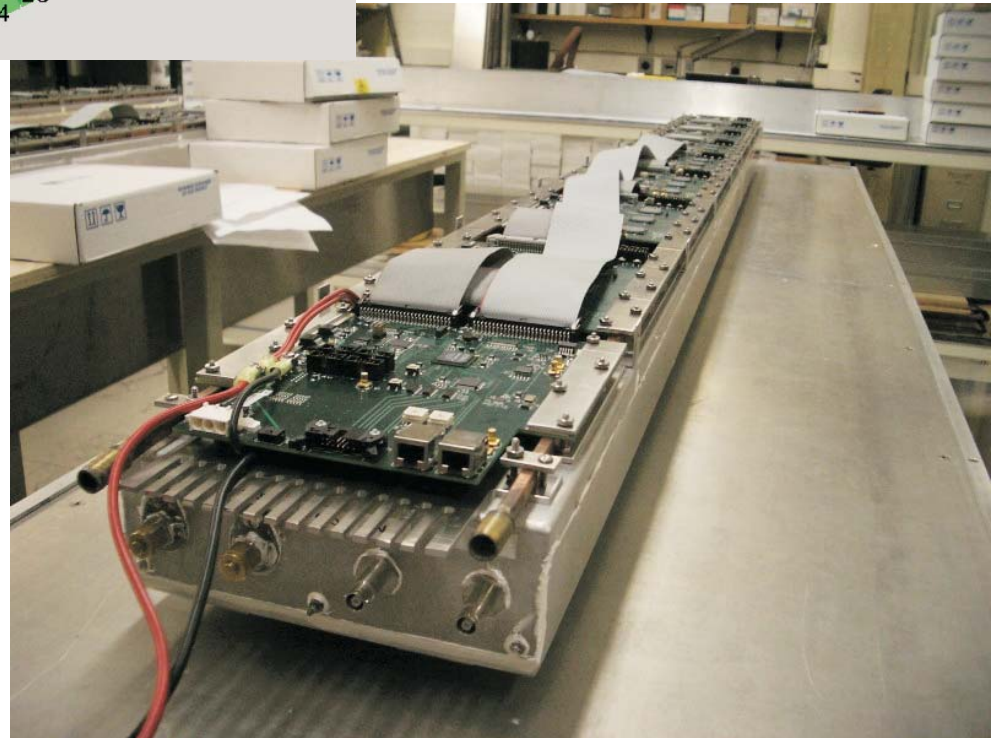
One bad TCPU board

86 trays collected good data...
 All were fixed before Run-10...

but now 1 bad HV cable
 (behind TPC support arms)

TPC support arms

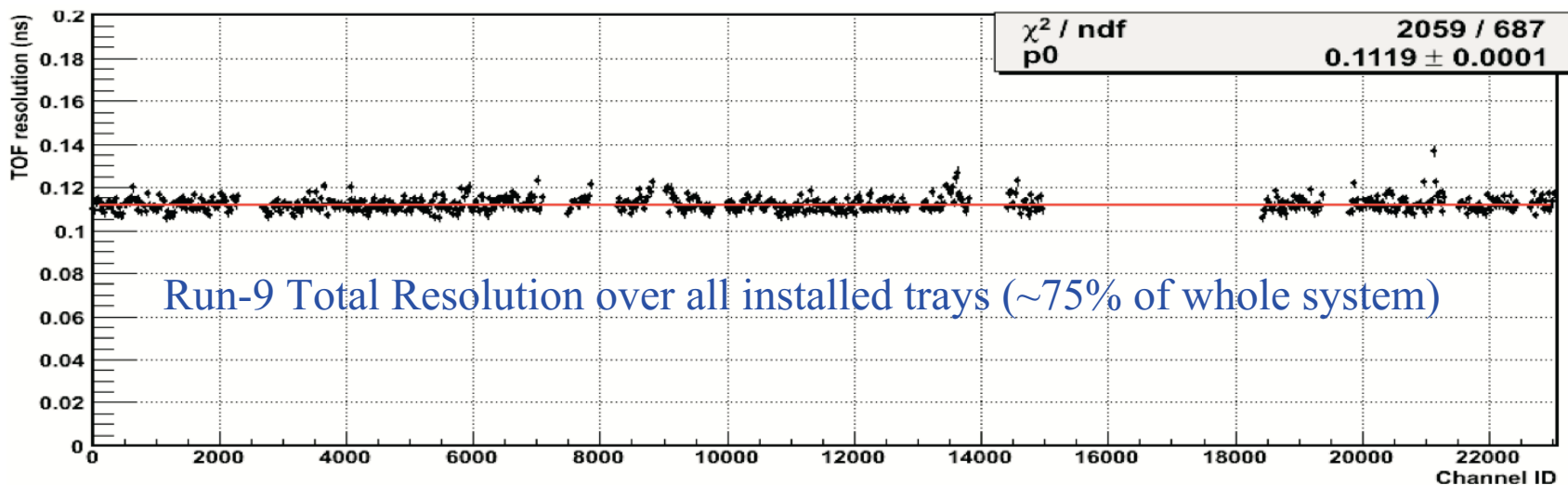
...special jack used to support TPC for installation of these trays before present Run-10....



Resolution History

Operating condition		Timing Resolution (ps)			
		Start time	Overall	Stop time	
Run 3	200GeV d+Au	85	120	85	
	200GeV p+p	140	160	80	
Run 4	62GeV Au+Au	55	105	89	
	200GeV Au+Au	Full-field	27	86	82
		Half-field	20	82	80
Run 5	200GeV Cu+Cu (ToT)	50	92	75	
	62GeV Cu+Cu (ToT)	82	125	94	
Run 8	200GeV d+Au (ToT)	NA	NA	NA	
	200GeV p+p (ToT)	83	112	75	
Run 9	500GeV p+p (ToT)	85	115	78	
	200GeV p+p (RFF) (ToT)	81	110	74	
Run 10	200GeV Au+Au (preliminary)	30	87	82	

Calibration done in groups of 24 channels - low Nmatches available

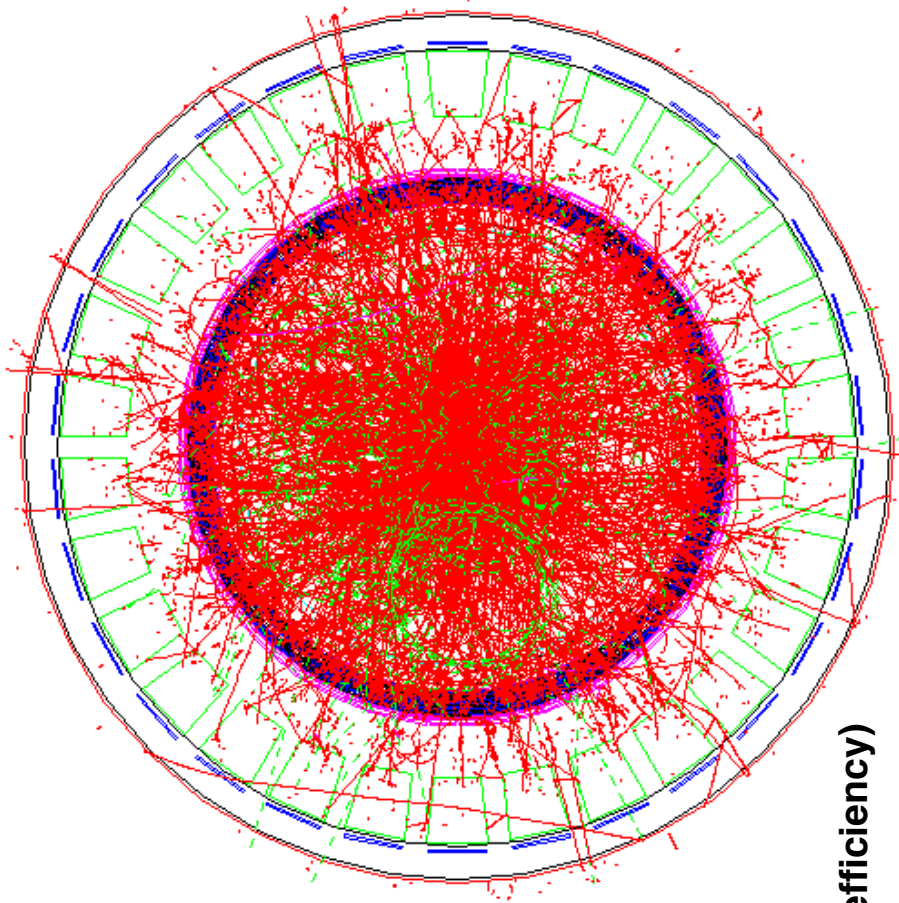


STAR “Muon Telescope Detector” (MTD)

To address another “hole” in
STAR’s acceptance (muon ID)

Basic Idea

- Put double-ended fast-timing MRPCs outside STAR
- Use electromagnetic calorimeter & magnet’s steel backlegs as π absorbers
- Require good correlation of hit position and time to charged track reconstructed in the TPC to select muons with low backgrounds

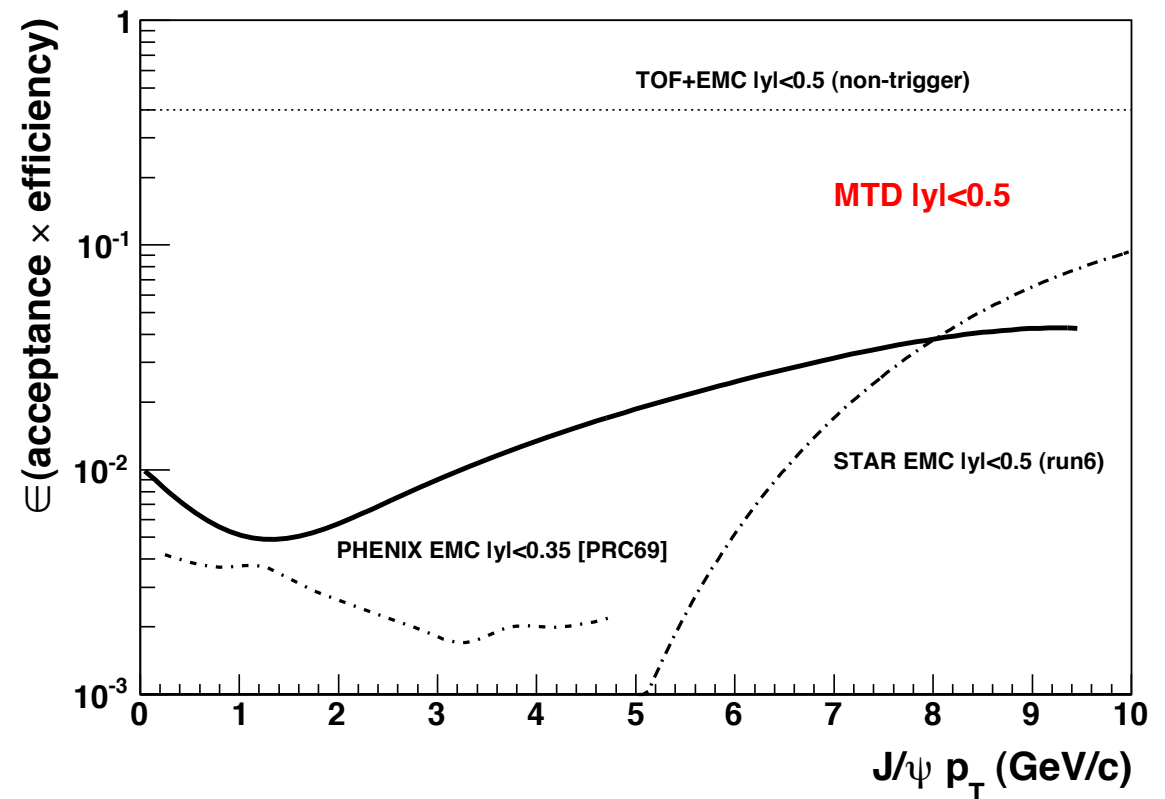


Physics goals:

large samples of J/Ψ & Y mesons
via two μ decay

superior to electron channels
less Bremsstrahlung
avoid backgrounds from γ conversions

$e+\mu$ correlations from heavy flavor decays

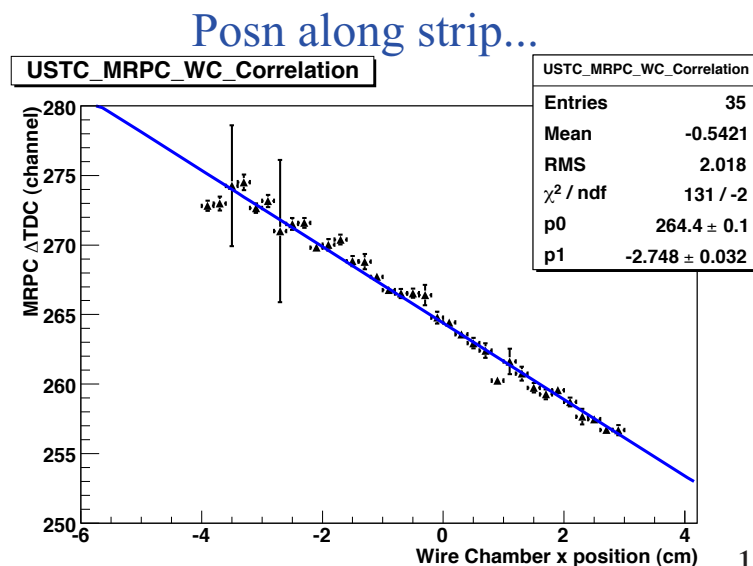
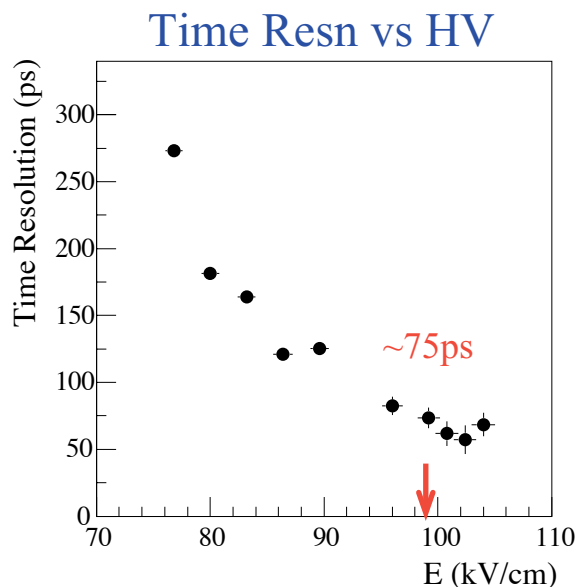
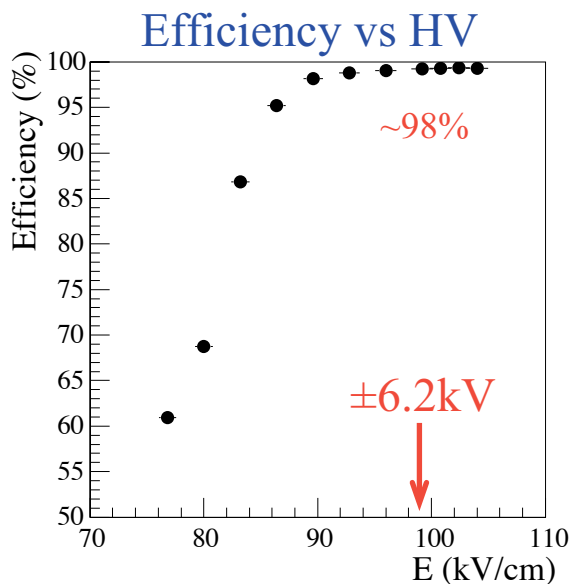
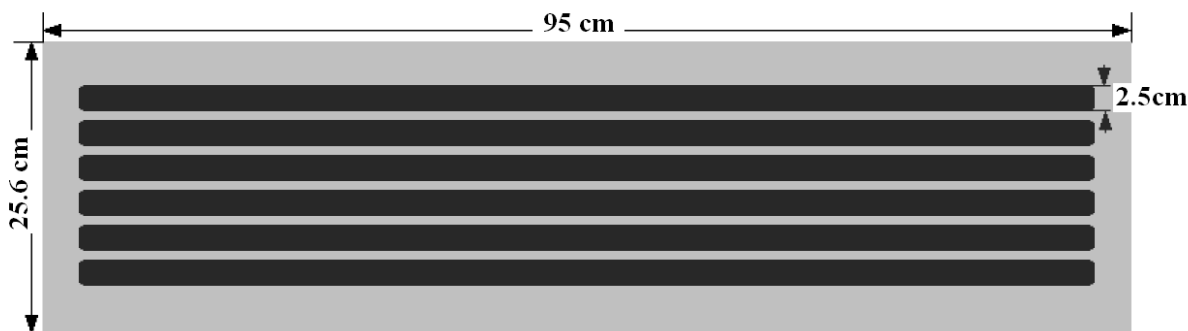
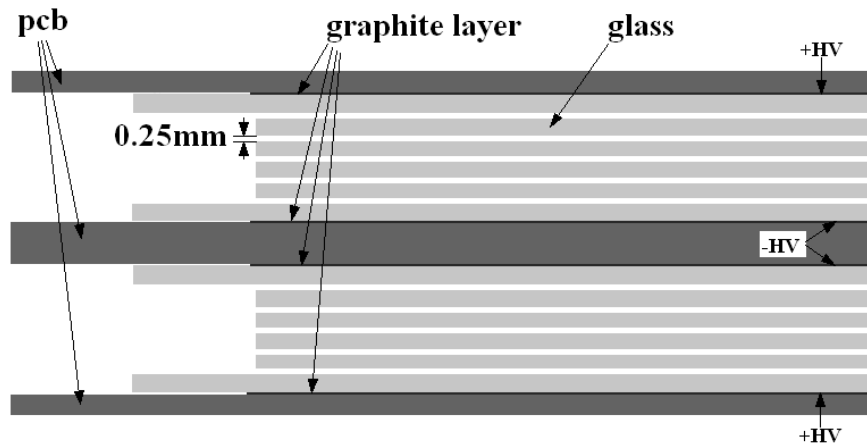


STAR MTD Prototype “LMRPCs”

Much larger than TOF MRPCs...
 Double-stack *a la* ALICE TOF...
 MRPCs fabricated at USTC (China)

...Tested in a FNAL Test beam (T963)

Y. Sun *et al.*, NIM A 593, 307 (2008)



First MTD Prototype “MTD7”

2 LMRPCs arranged end-to-end

“Simple FEE” (based on MAX 3760)

WJL *et al.*, NIM A **596**, 430 (2008)

long cables before digitization
digitized with STAR TRG “CDB” boards

Operated throughout RHIC Run-7 & 8

→ timing resolution was “poor”

~ 300 ps

due to long cables and the specific
digitization electronics used

See also L. Ruan *et al.*,
J. Phys. G **36**, 095001 (2009)

Second MTD Prototype “MTD9”

3 LMRPCs arranged side-by-side

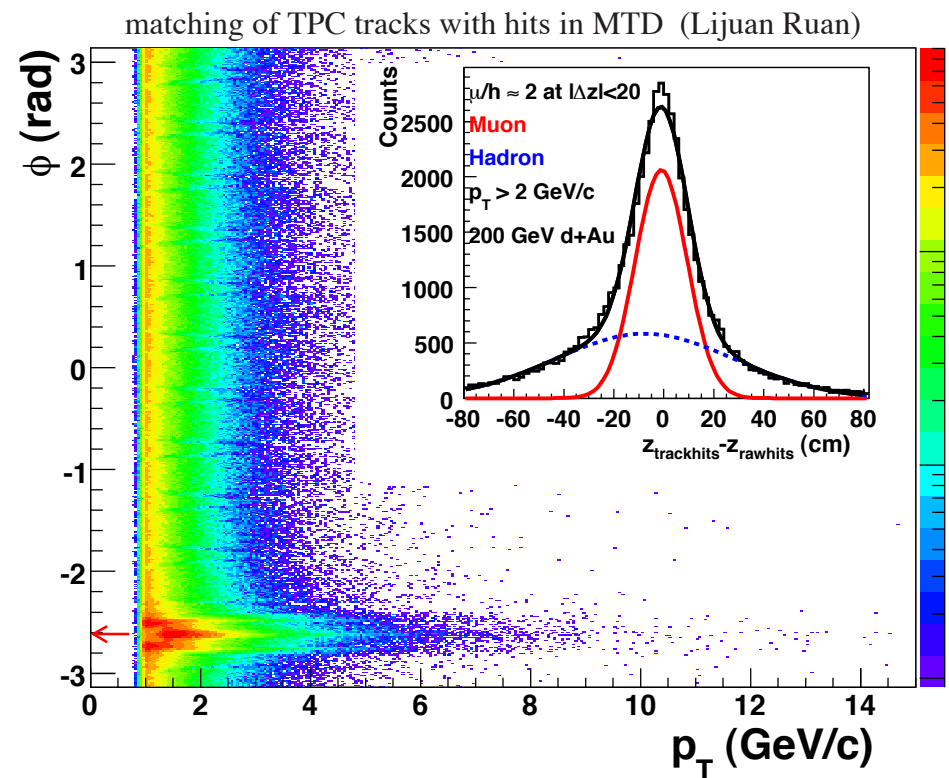
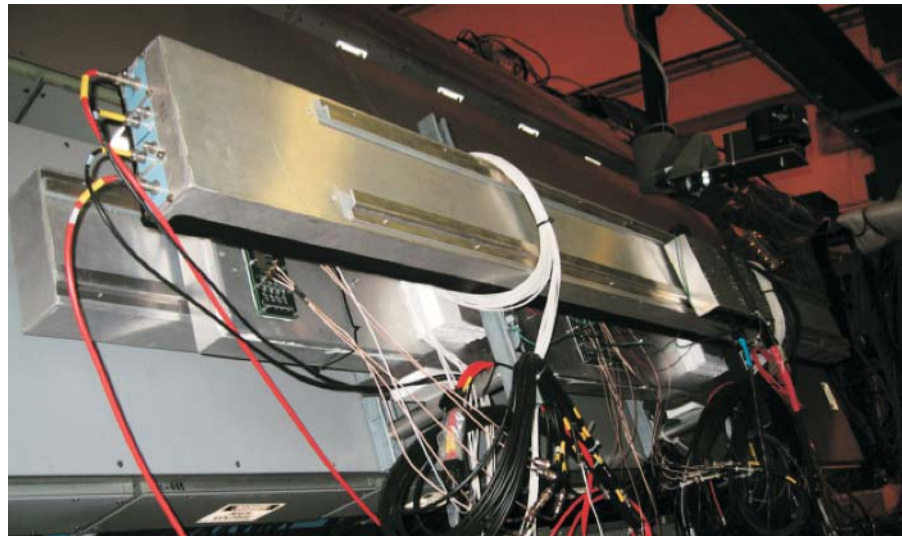
Uses TOF Electronics

TINO (based on NINO chip)

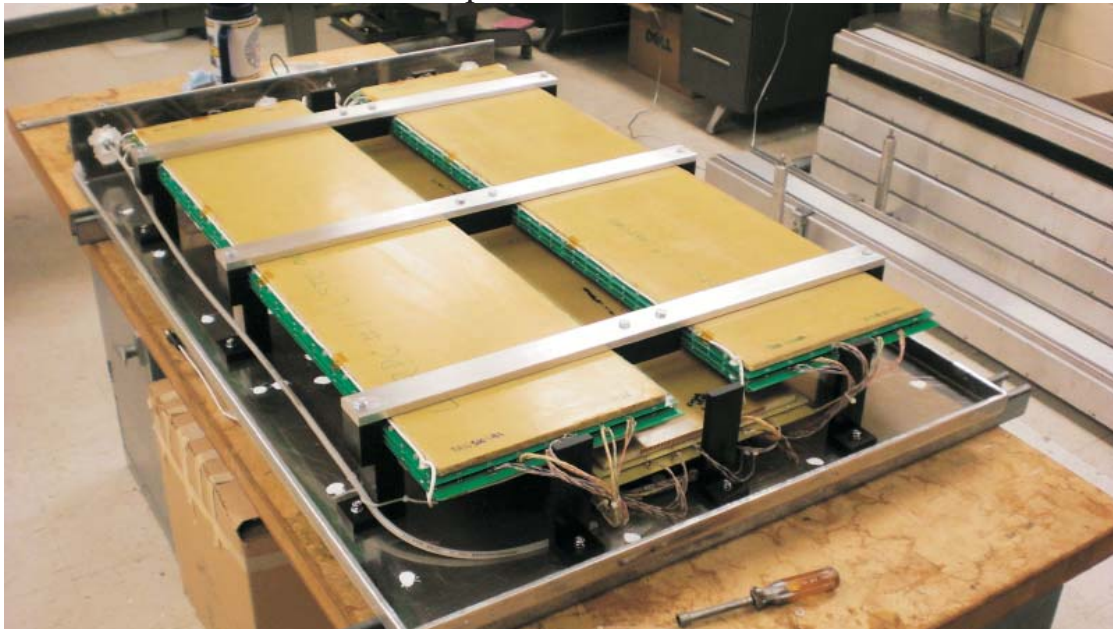
TDIG (based on HPTDC chip)

TCPU+THUB+TTRG (readout & triggering)

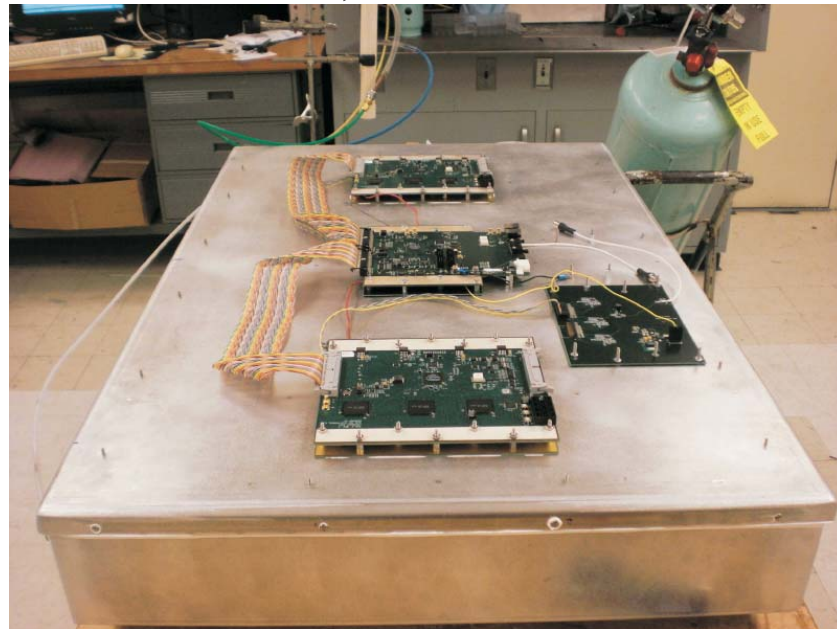
Not much data collected in Run-9, but it ran throughout the recent Run-10.



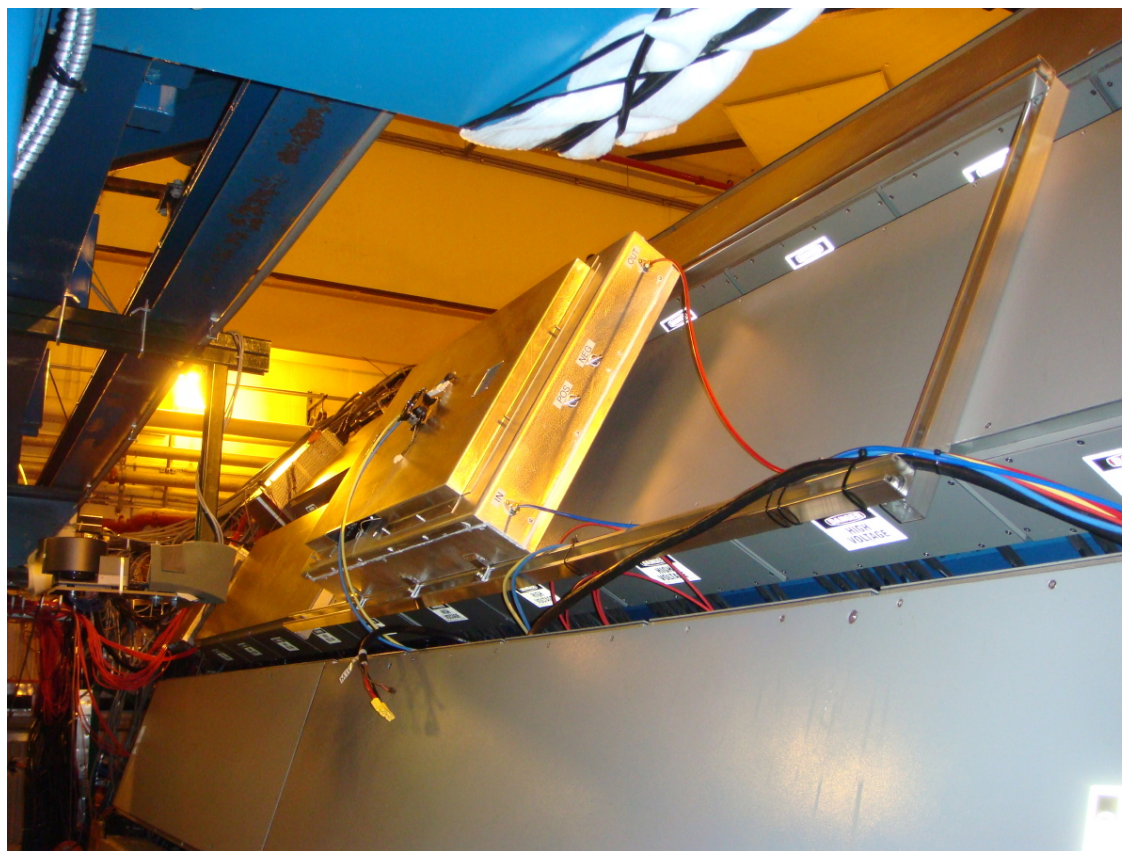
MTD9 open



MTD9 closed, with electronics



MTD9 mounted onto exterior of STAR in Run-9



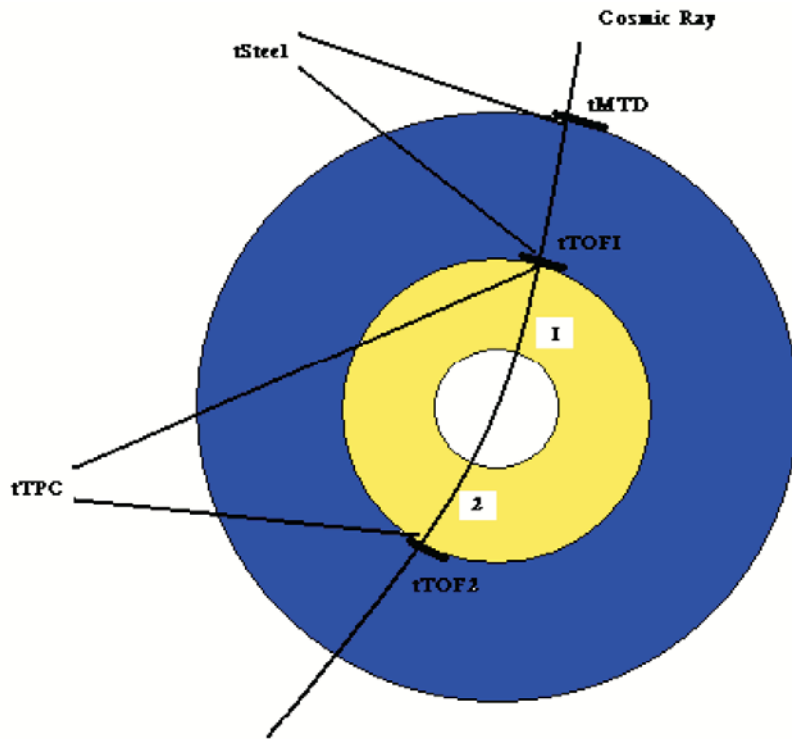
MTD9 prototype in RHIC Run-10

Timing resolution in Au+Au collisions in progress (statistics limited right now)

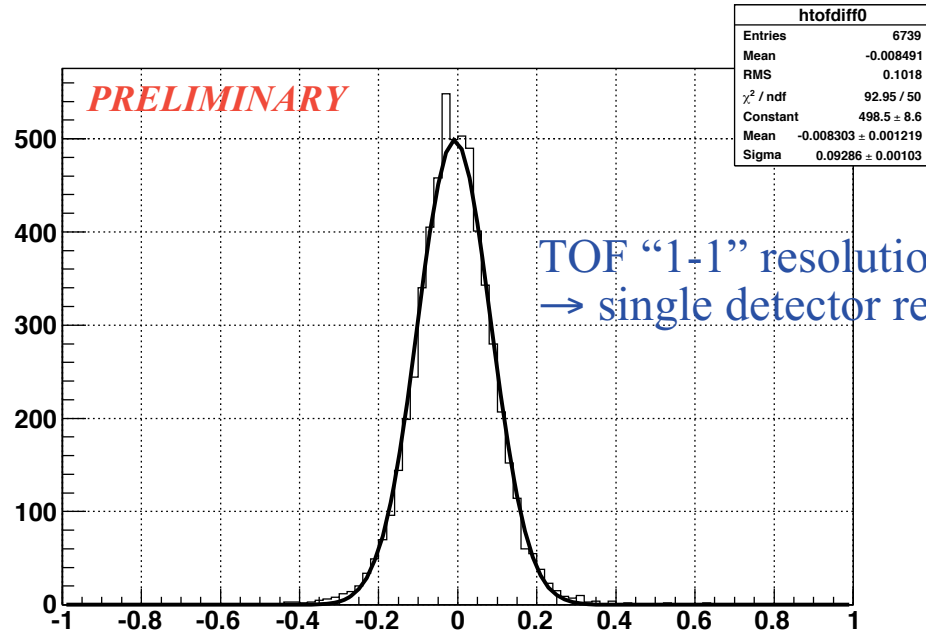
In the meantime, study the timing performance using a few days of cosmics from a special data stream, 0.1Hz

“start time” from two TOF MRPCs
 “stop time” from MTD9 tray (LMRPCs)

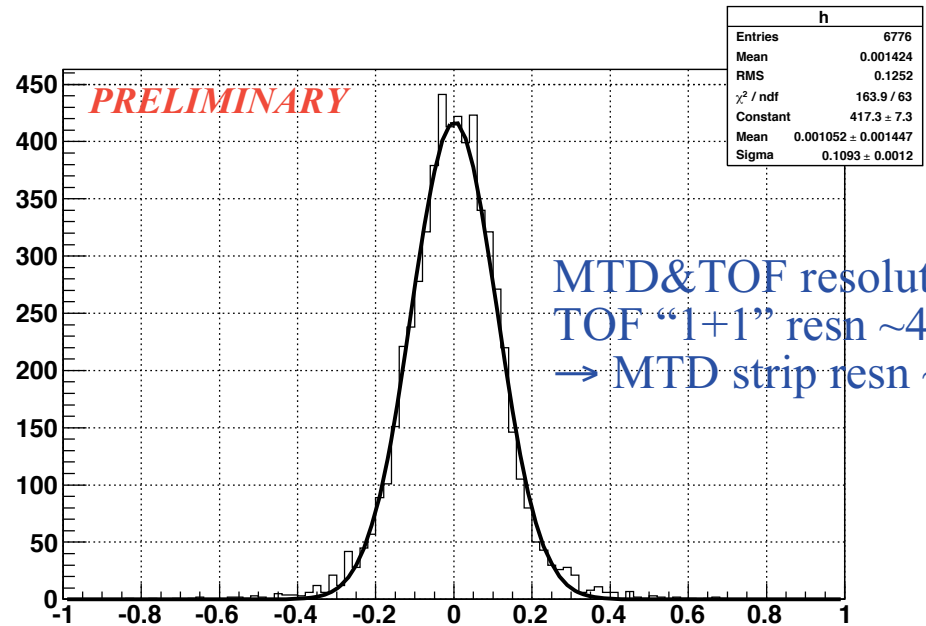
& perform standard slewing/offset calibrations



Analysis by Liang Li (UT-Austin)
 and Lijuan Ruan (BNL)



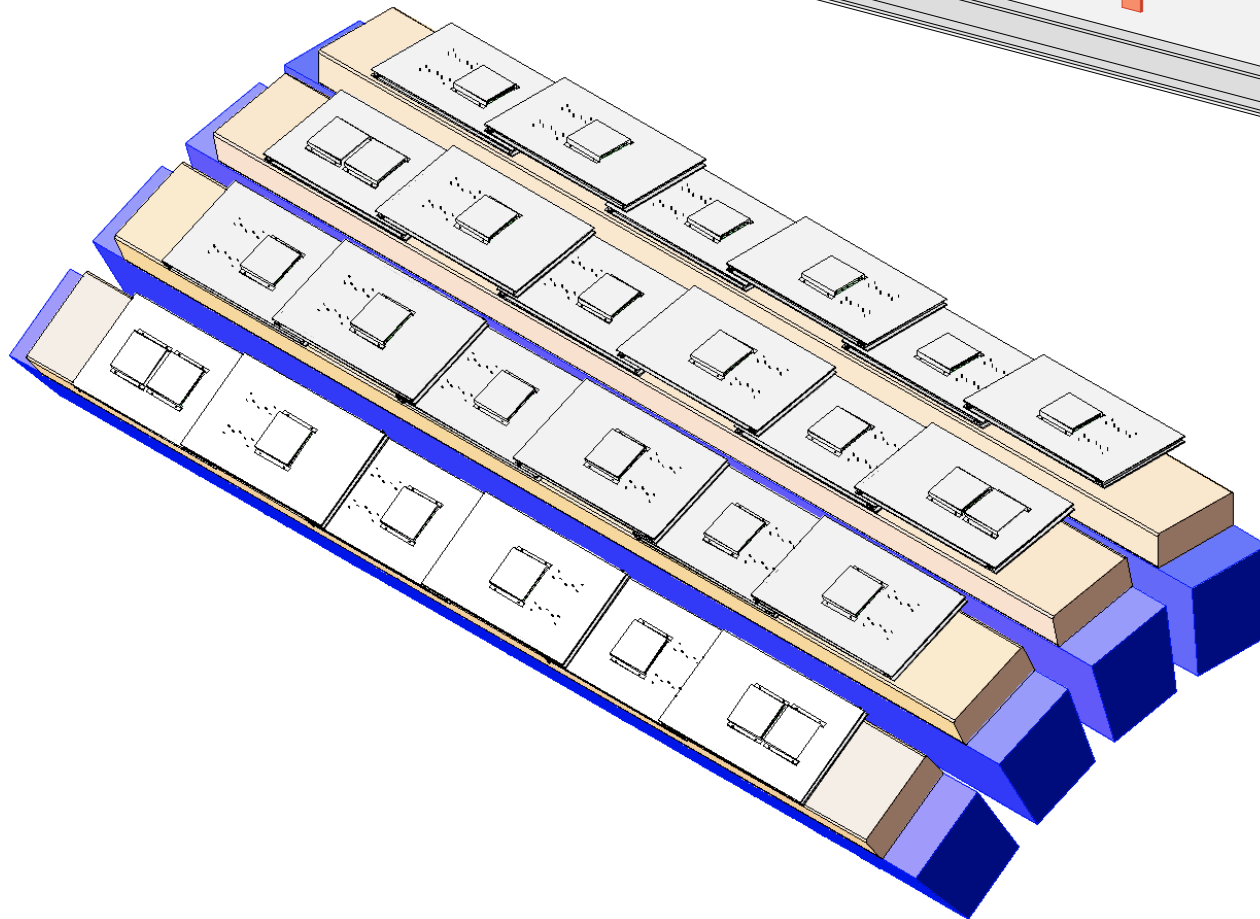
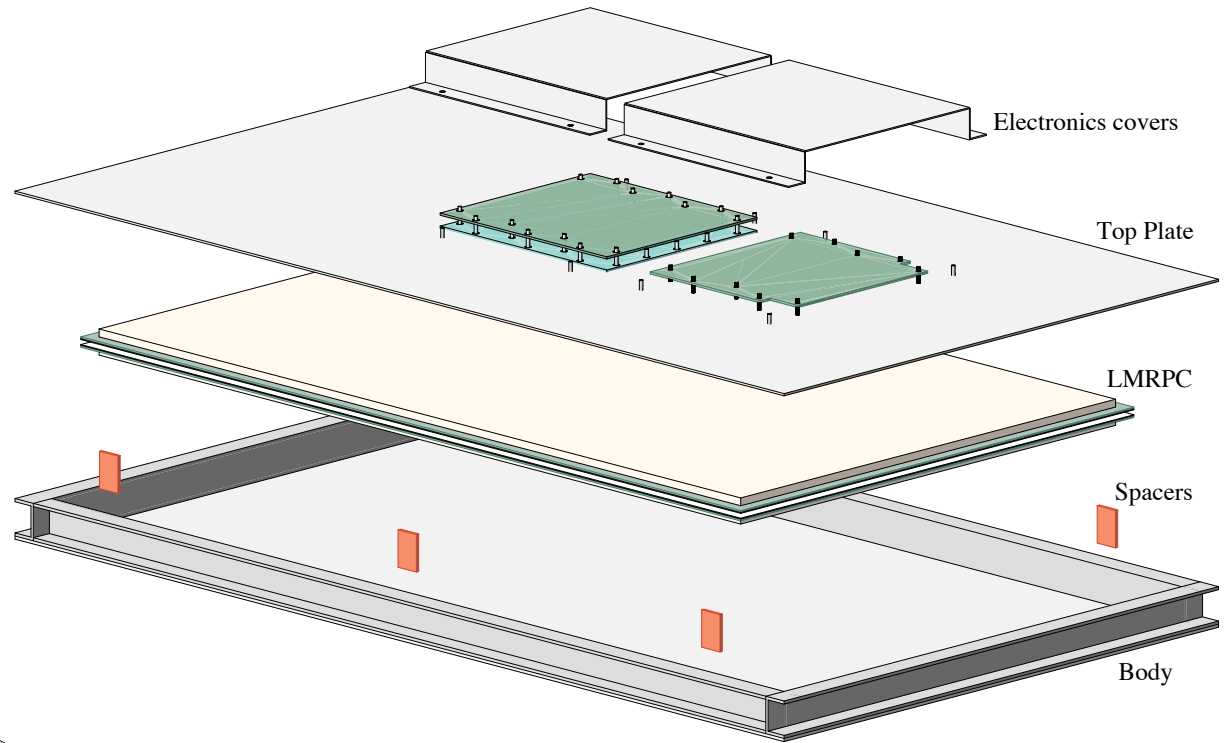
TOF “1-1” resolution \sim 93ps
 \rightarrow single detector resn \sim 66ps



MTD&TOF resolution \sim 109ps
 TOF “1+1” resn \sim 46ps
 \rightarrow MTD strip resn \sim 99ps

Full System has been proposed....

- 117 trays
- Large single-stack MRPCs (55cm x 89cm)
- STAR TOF electronics



Project cost ~1.5 M\$

Proposal recently under review

Again,

- MRPCs from China
- Mechanics & testing in Texas

“Final” prototypes to be operated during next-year’s Run-11

Hoping for full system in 2013.

Summary

The **full-barrel Time of Flight system** is fully installed last summer & ran very well in RHIC Run-10...

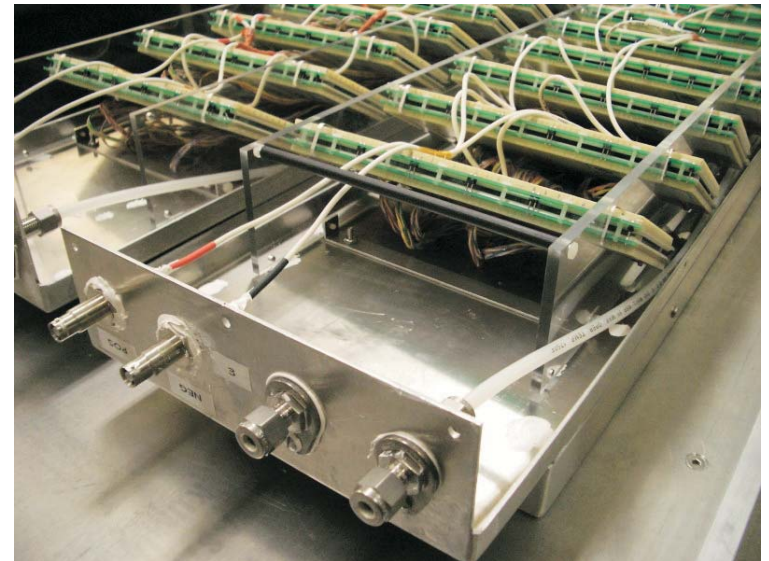
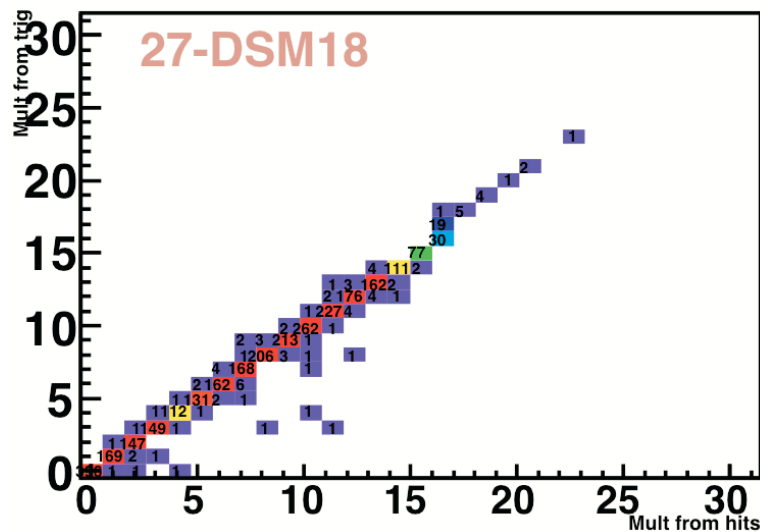
... 2 bad channels out of 23,040

... 1 disabled tray out of 120 (one bad HV cable, will be fixed a.s.a.p.)

... 1 tray disabled late in the run because of a board failure.

... MRPC time resolution ~ 80 ps

...NINO multiplicity bit also being collected & sent to the STAR "Level-0" trigger



A **full-barrel MTD** to add muon PID to STAR

...much larger double-ended MRPCs

...prototypes operated in several recent RHIC runs

Very encouraging timing performance achieved with cosmics in Run-10

Three tray patch with WMRPCs will be installed in Run-11.

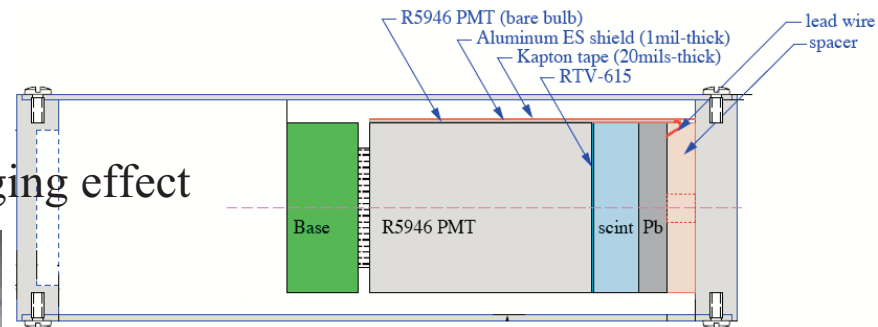
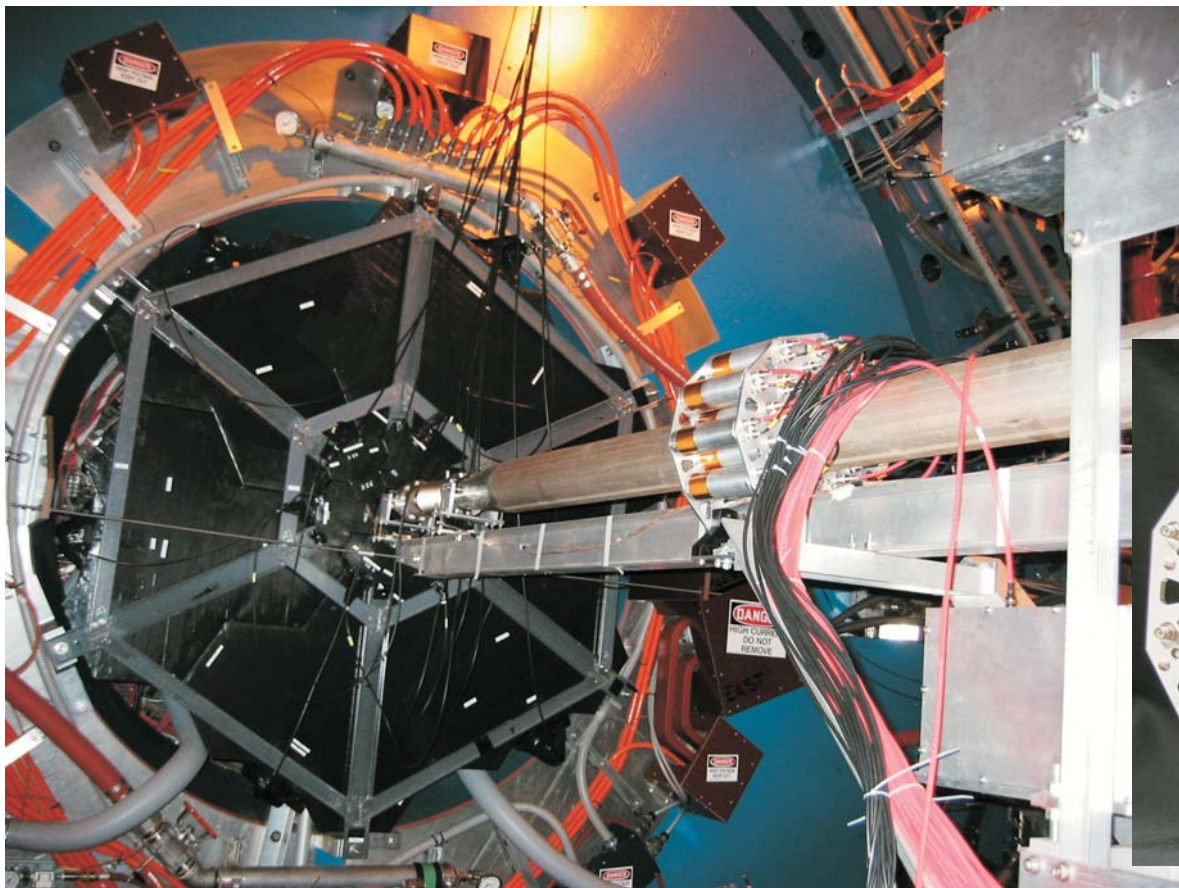
Proposal for the full system under review - full system expected 2013.



BACKUP
SLIDES

Upgraded Start Detector

3 chs/side “pVPD” → 19 chs/side “upVPD”
improves efficiency per event, and resolution due to averaging effect



Pb + Scint + Mesh dynode PMTs
standard linear resistive bases



improves efficiency per event for a start-time in p+p from ~10% to ~35%...
improves start-time resolution in Au+Au by a factor of $\sqrt{6}$...

provides inputs to STAR triggers to select primary vertex positions near the center of STAR
main input to STAR min. bias triggers in Run-7, 76M events collected with mb-vpd trigger

showed a ~60% efficiency per event in the Run-8 9.2 GeV engineering run!!

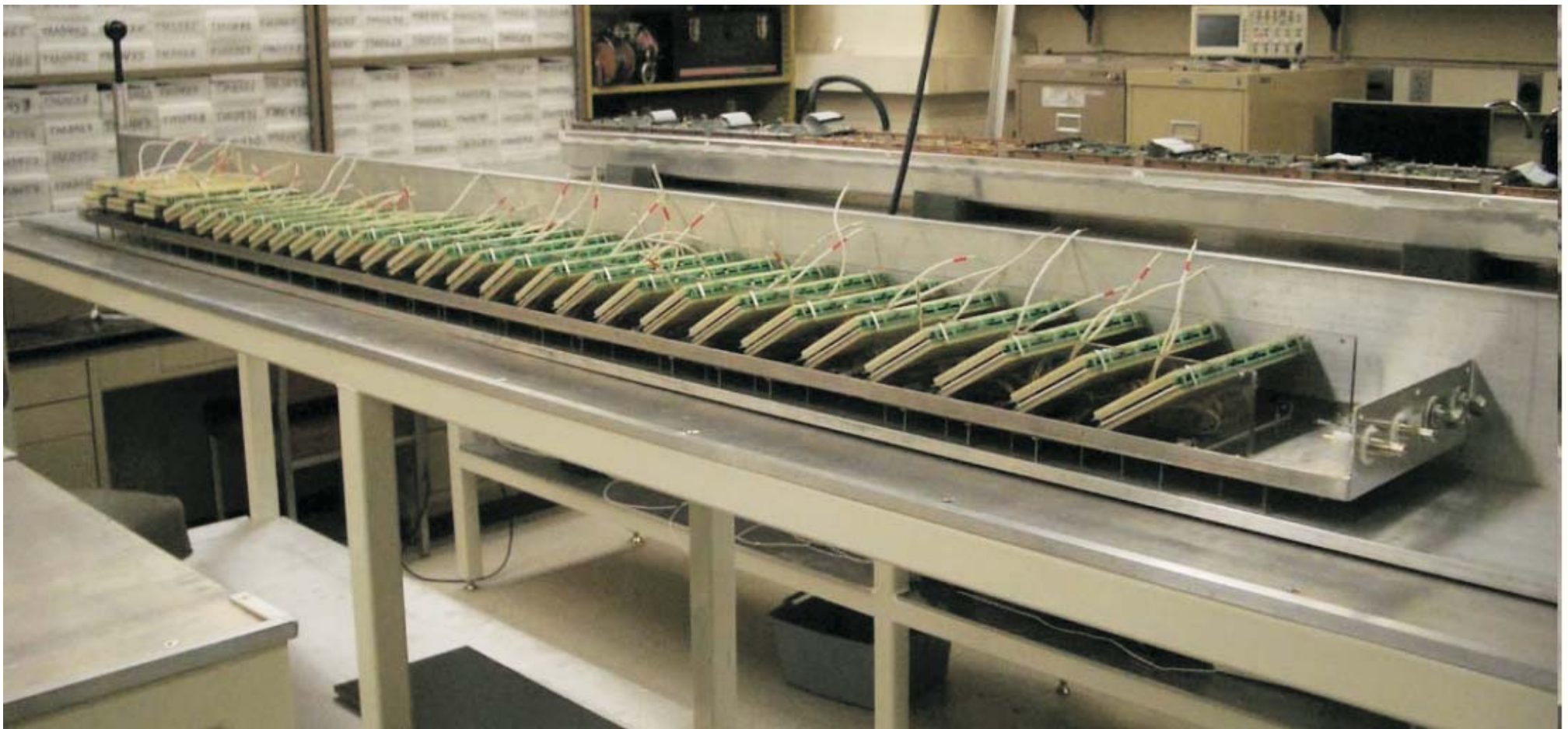
32 MRPCs per tray

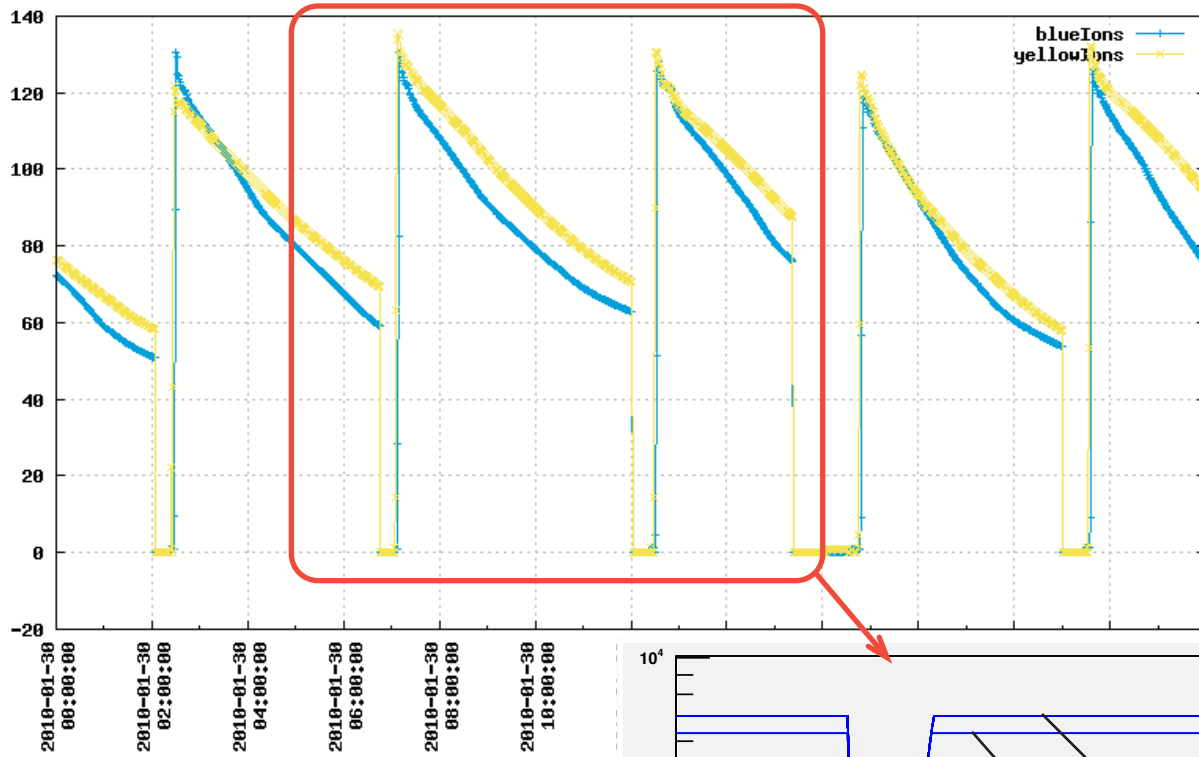
Very limited space for detector placement (~3 inches)

Perfectly “normal” MRPC orientation is thus impossible
generally normal to within ~8 degrees

“Inner Sides” (1/4 inch-thick Lexan) cut on a CAD-CAM machine.
MRPC positioning then precise to ~10 mils in each direction

2 HV busses, One 1/4” polyflow tube, Dow-Corning DC730 Freon Resistant Sealant





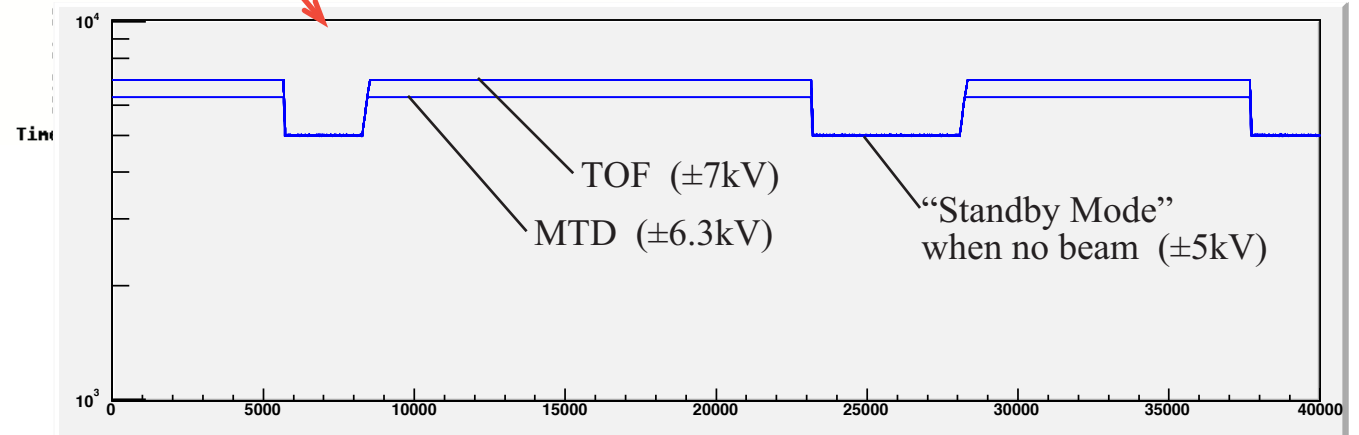
TOF & MTD9 HV Currents during running...

120 TOF trays

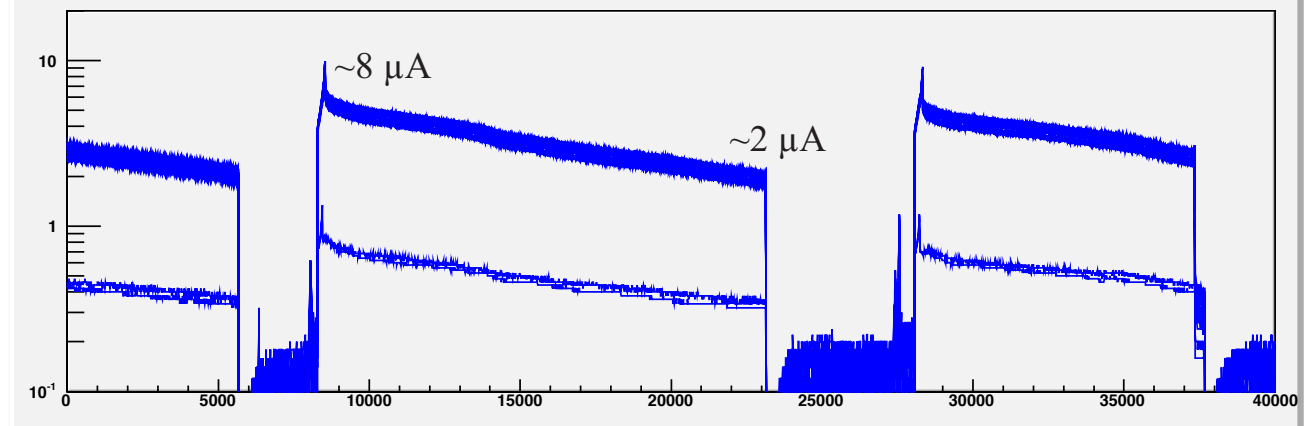
24 TOF supplies
(12 Pos & 12 Neg)

→ 10 trays/supply

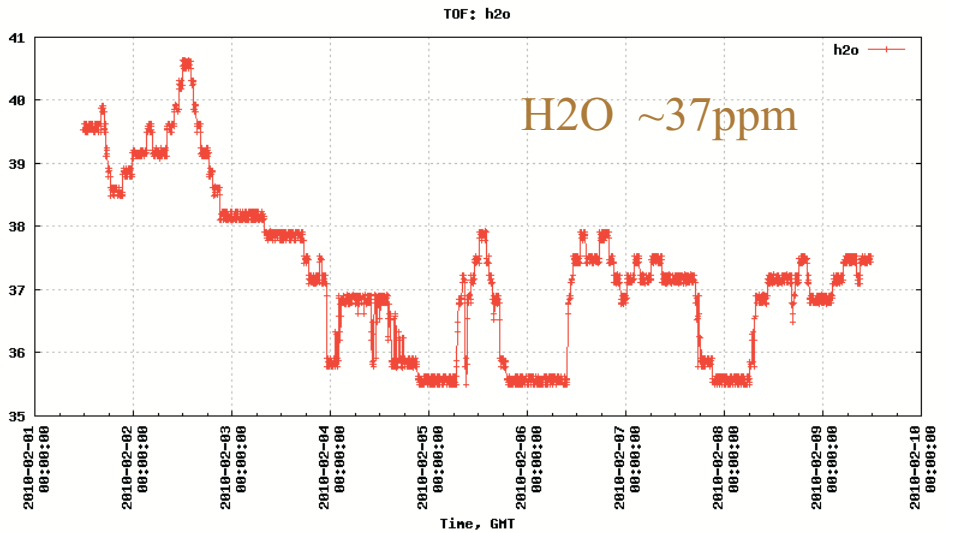
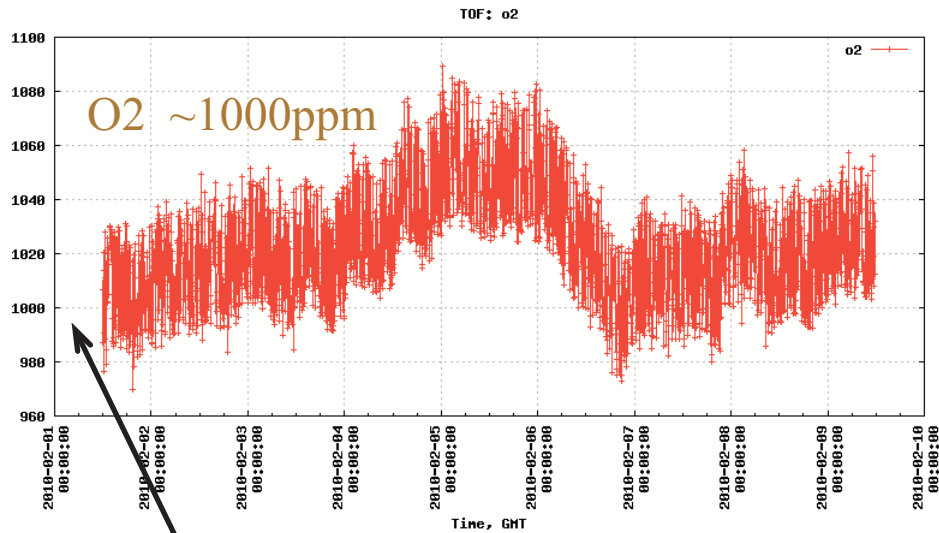
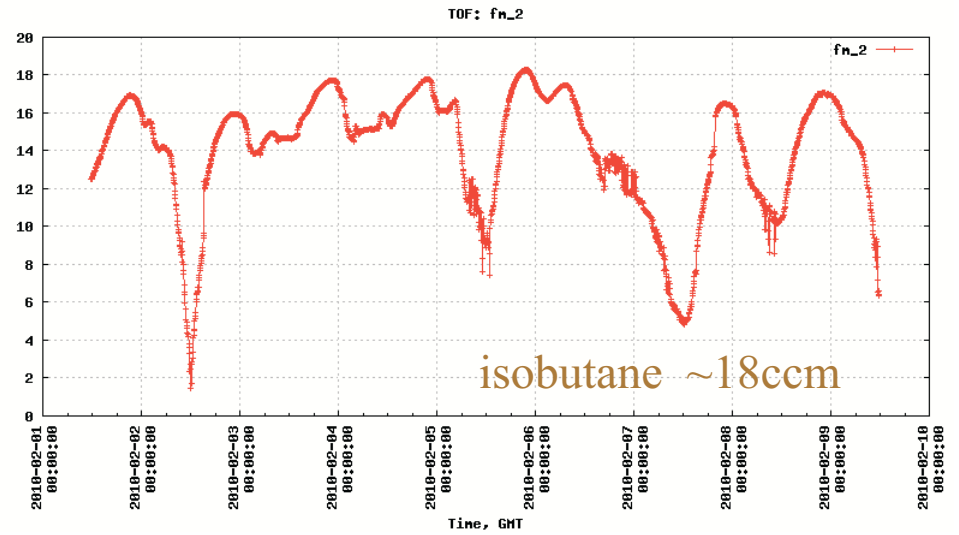
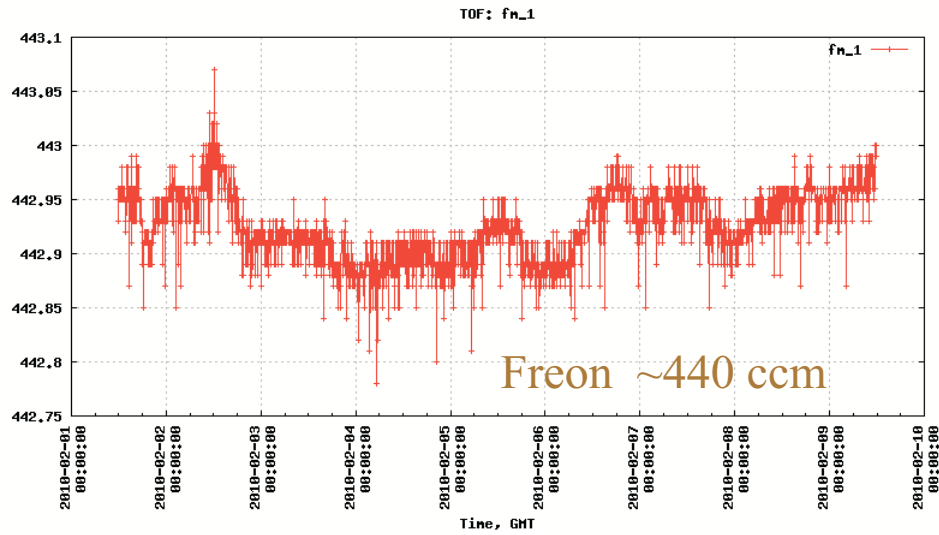
→ 320 MRPCs/supply



$$2 \mu\text{A}/320 \text{ MRPCs} = \sim 6 \text{ nA/MRPC}$$



Some Gas System Parameters....



1000 ppm (0.1%) O2 implies 0.5% air....

Flow rate is 440 sccm Freon + 20 sccm Isobutane, so Leak Rate is ~2.3 sccm, which is low/acceptable.

...further reduced by another factor of ~5 by insuring trays at overpressure w.r.t. atmosphere....