



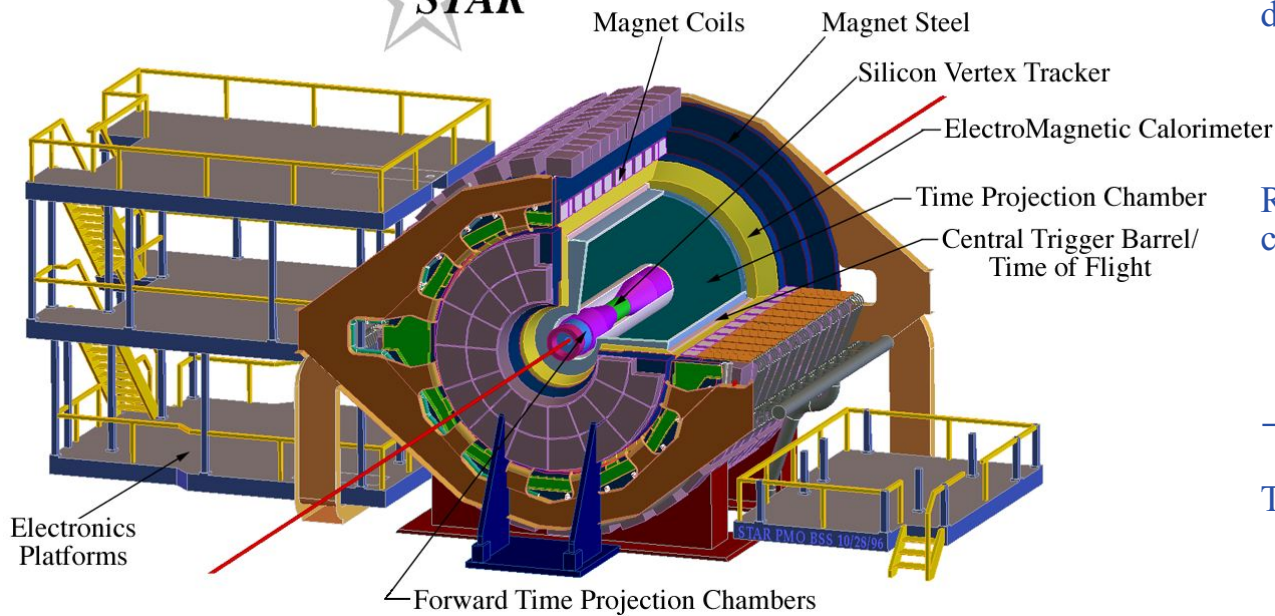
Multigap RPCs in STAR

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Rice University
for the ☆ Collaboration

RPC 2010
GSI, Darmstadt, Germany
February 10, 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	$p < 0.6 \text{ GeV}$
$(\pi+K)/p$	$p < 1.0 \text{ GeV}$

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 $\sim 2.1\text{m}$ to $\sim 3.2\text{m}$
 excellent tracking & “extrapolation”

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

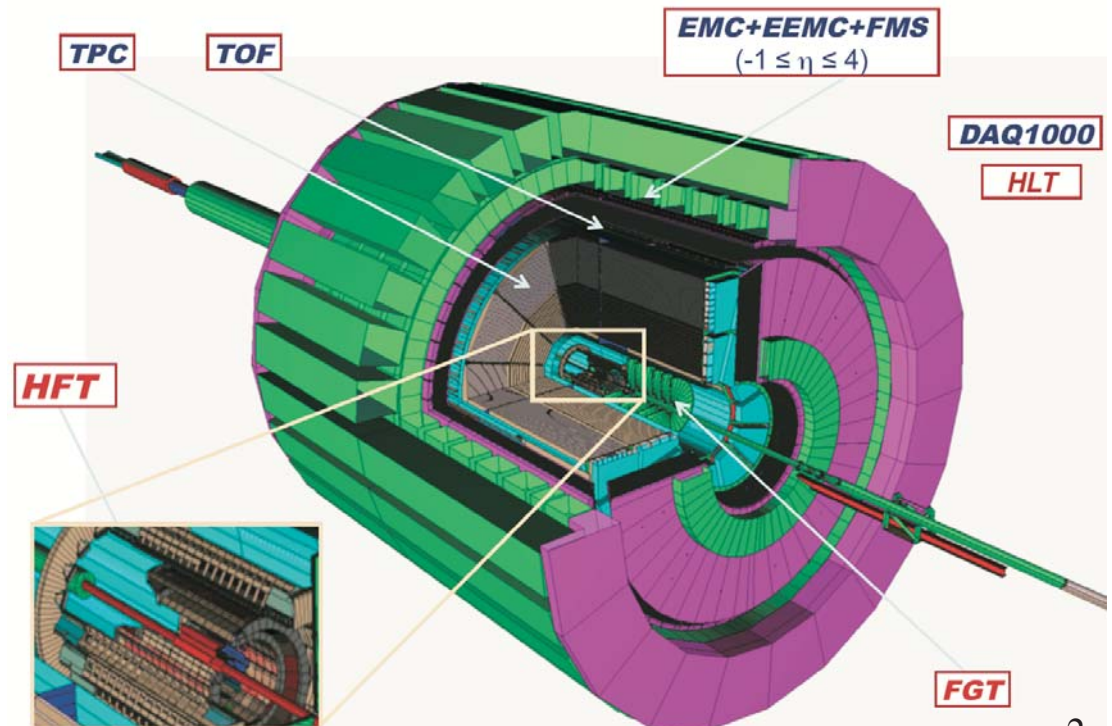
It met the requirements, but the major problem was the huge size and epic cost of mesh dynode PMTs

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

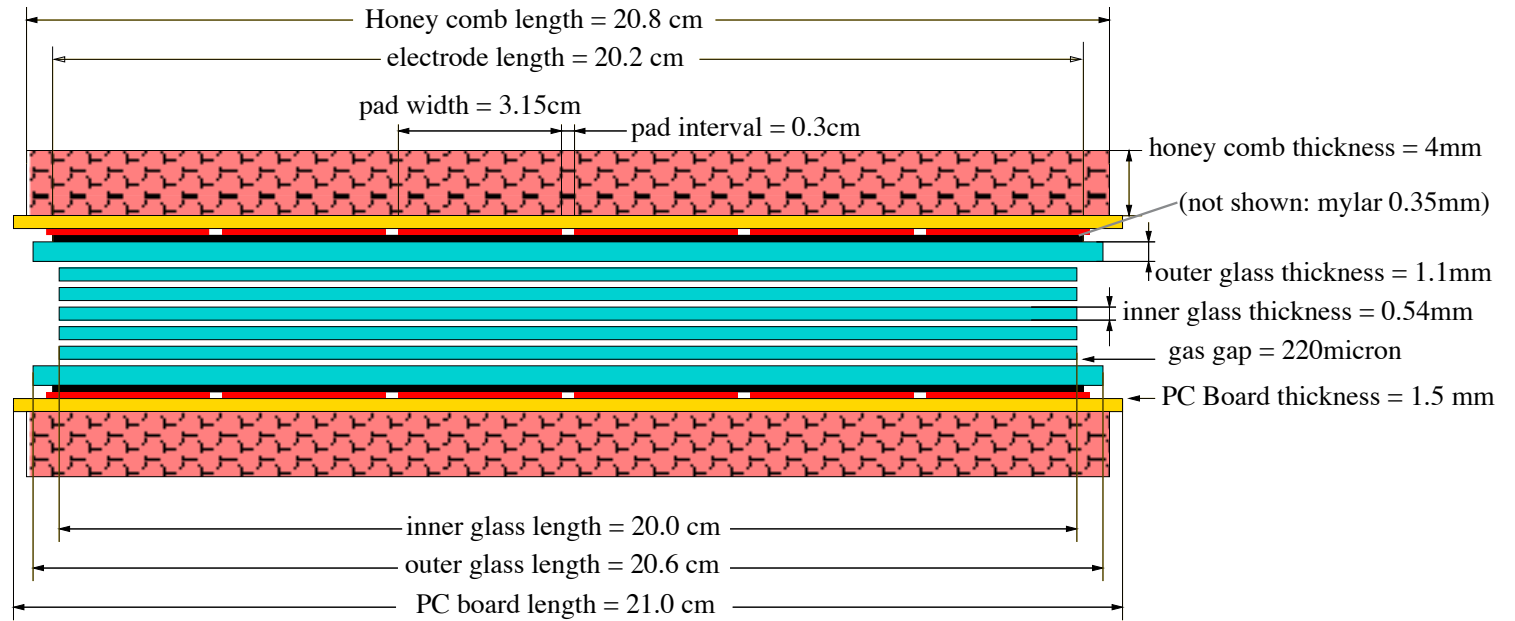
Sea change for us the late 1990's....

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



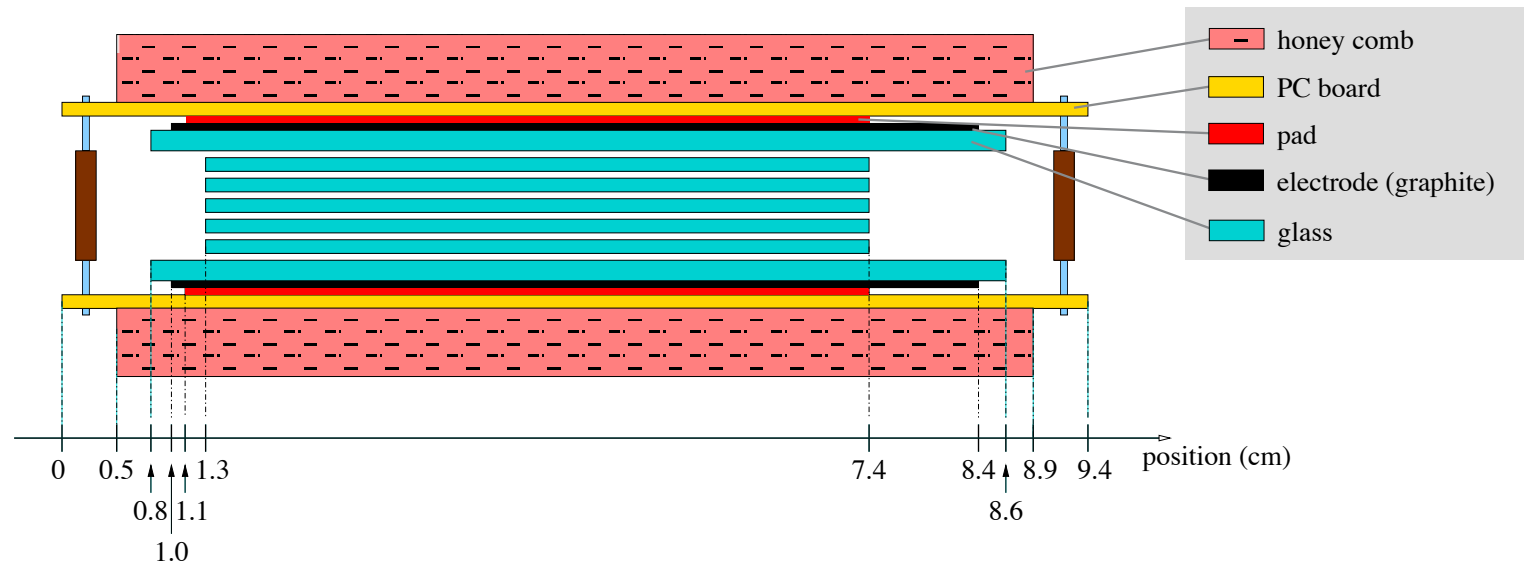
STAR's Variant...



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

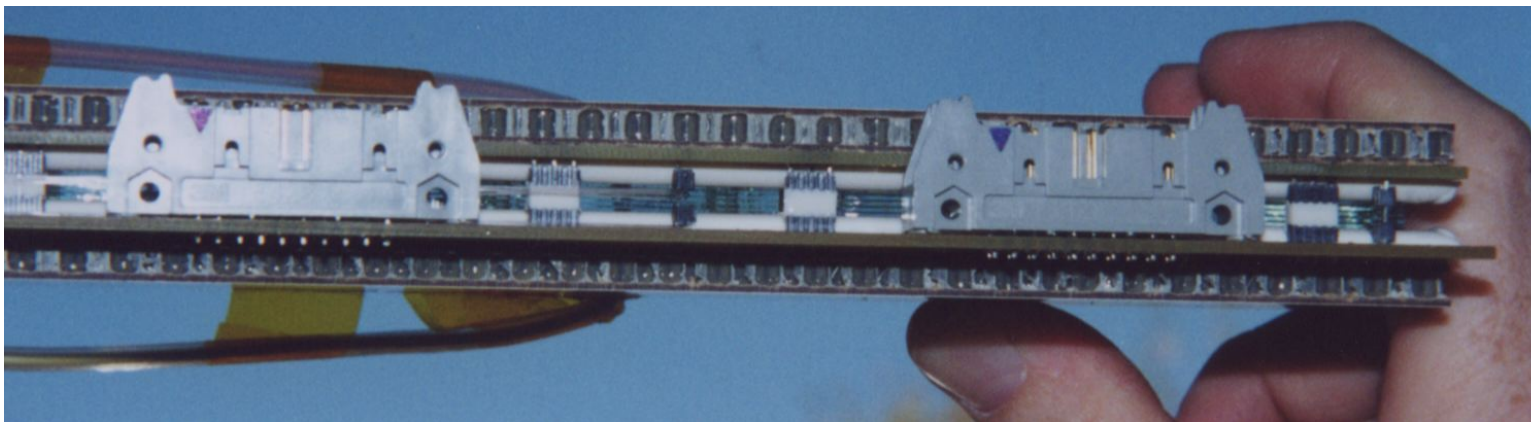


Float glass & Graphite tape electrodes

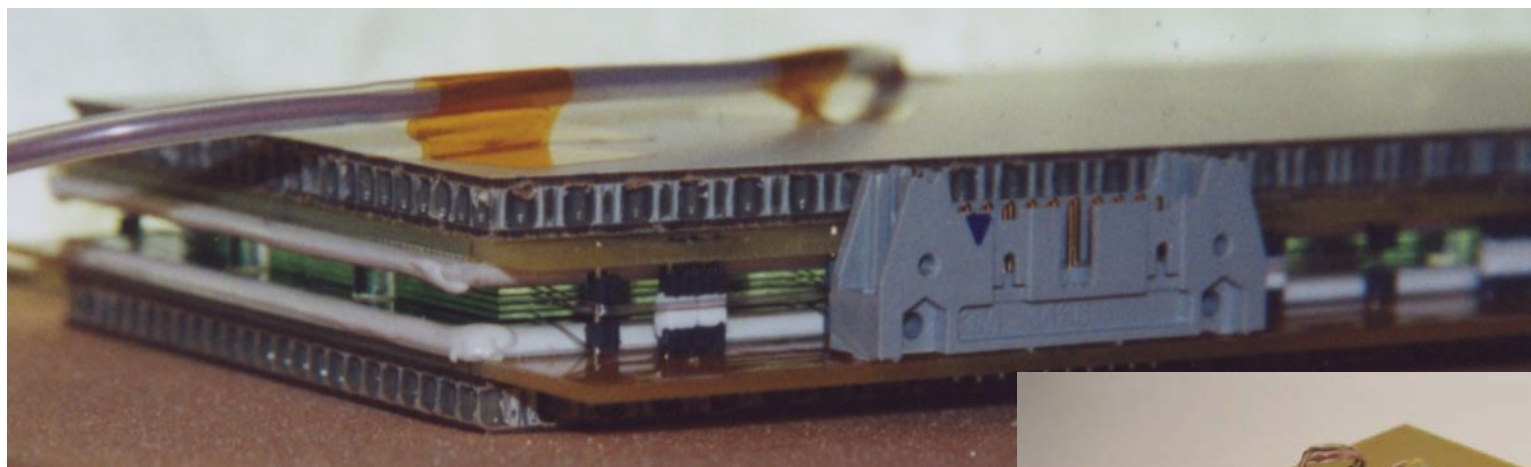
$10^{12-13} \Omega/\text{cm}$ volume & $10^5 \Omega/\text{sq}$ surface, respectively
 operating voltage: $\pm 7 \text{ kV}$

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

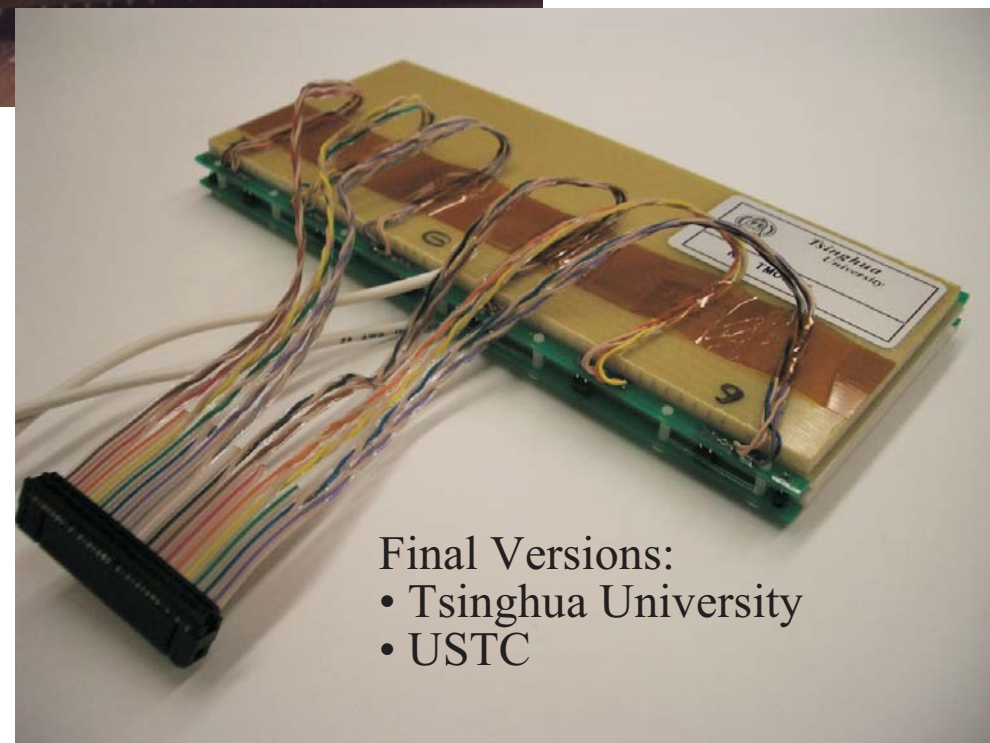
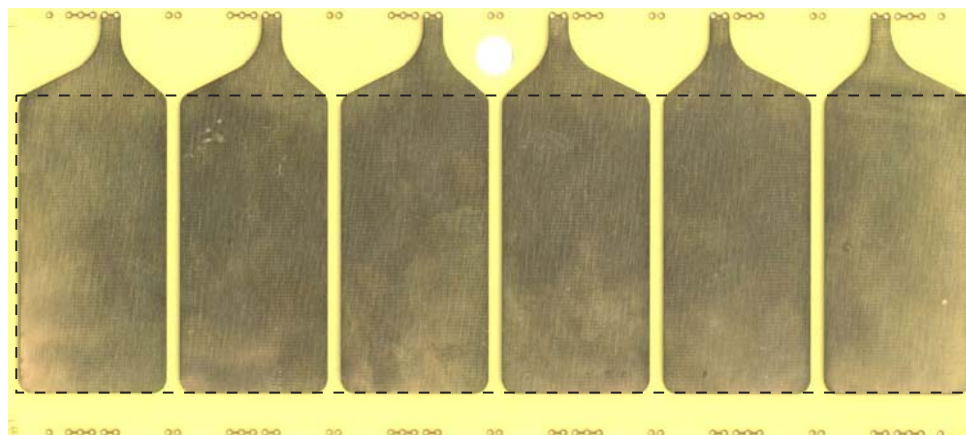
in STAR, recirculating as of this year



Prototype
(~2001)



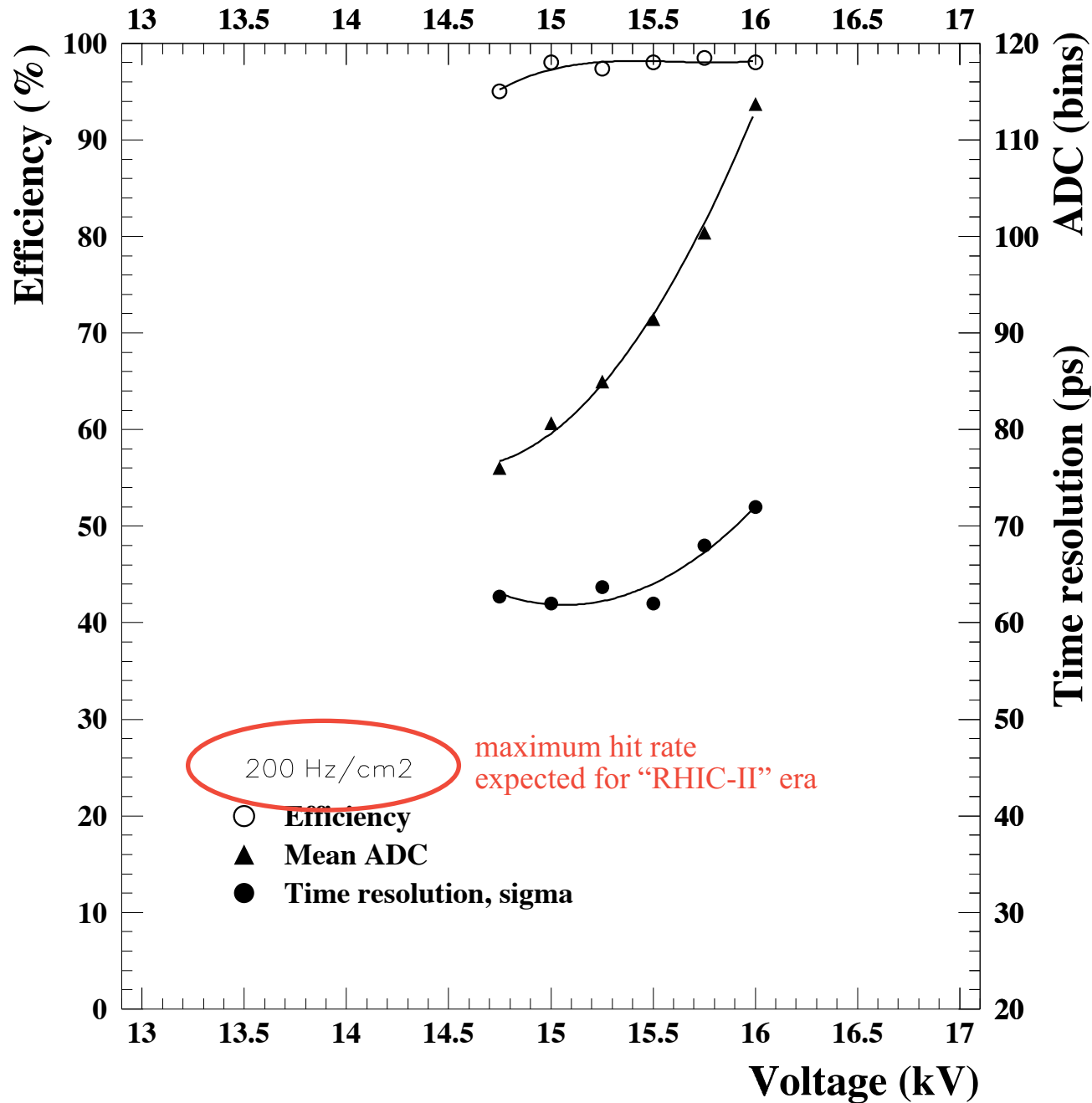
6 single-ended read-out pads per MRPC:



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”

$$-1 < \eta < 0$$

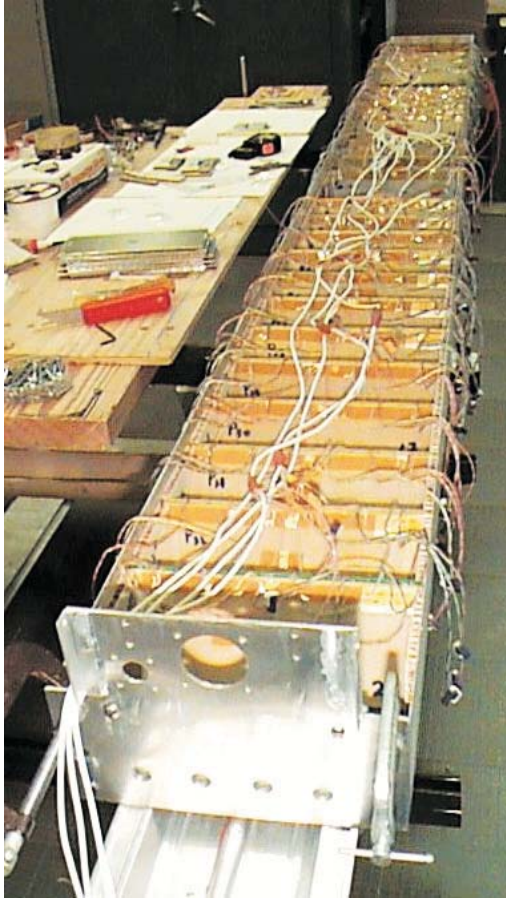
$$\Delta\phi \sim 1/60^{\text{th}} \text{ of } 2\pi$$

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)



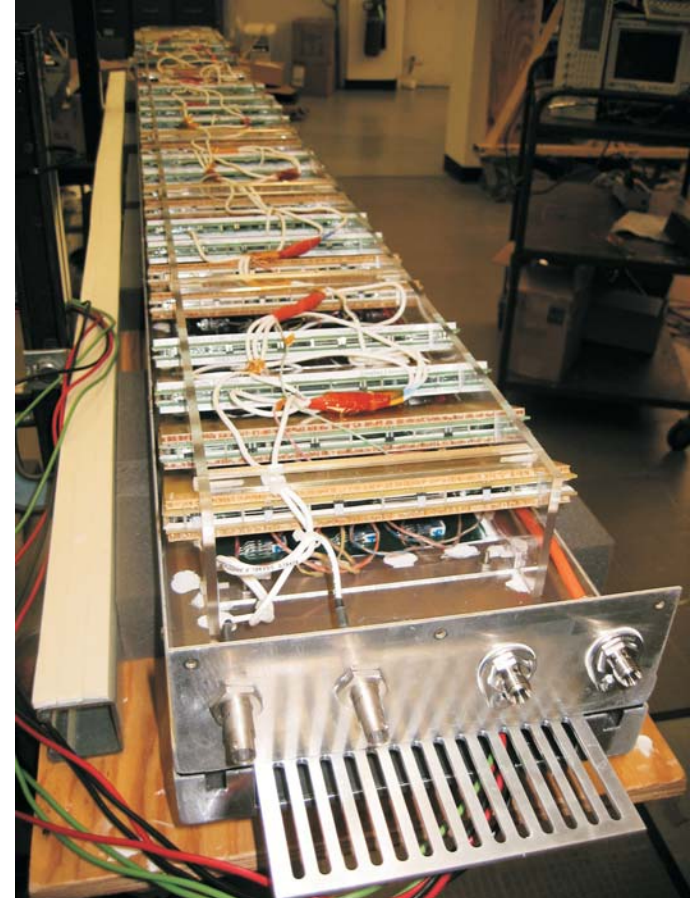
Box built by hand
Gaskets + wrong sealant
Two layers of electronics
long cables
CAMAC DAQ
Imprecise MRPC positioning

TOFr' (Run-4)



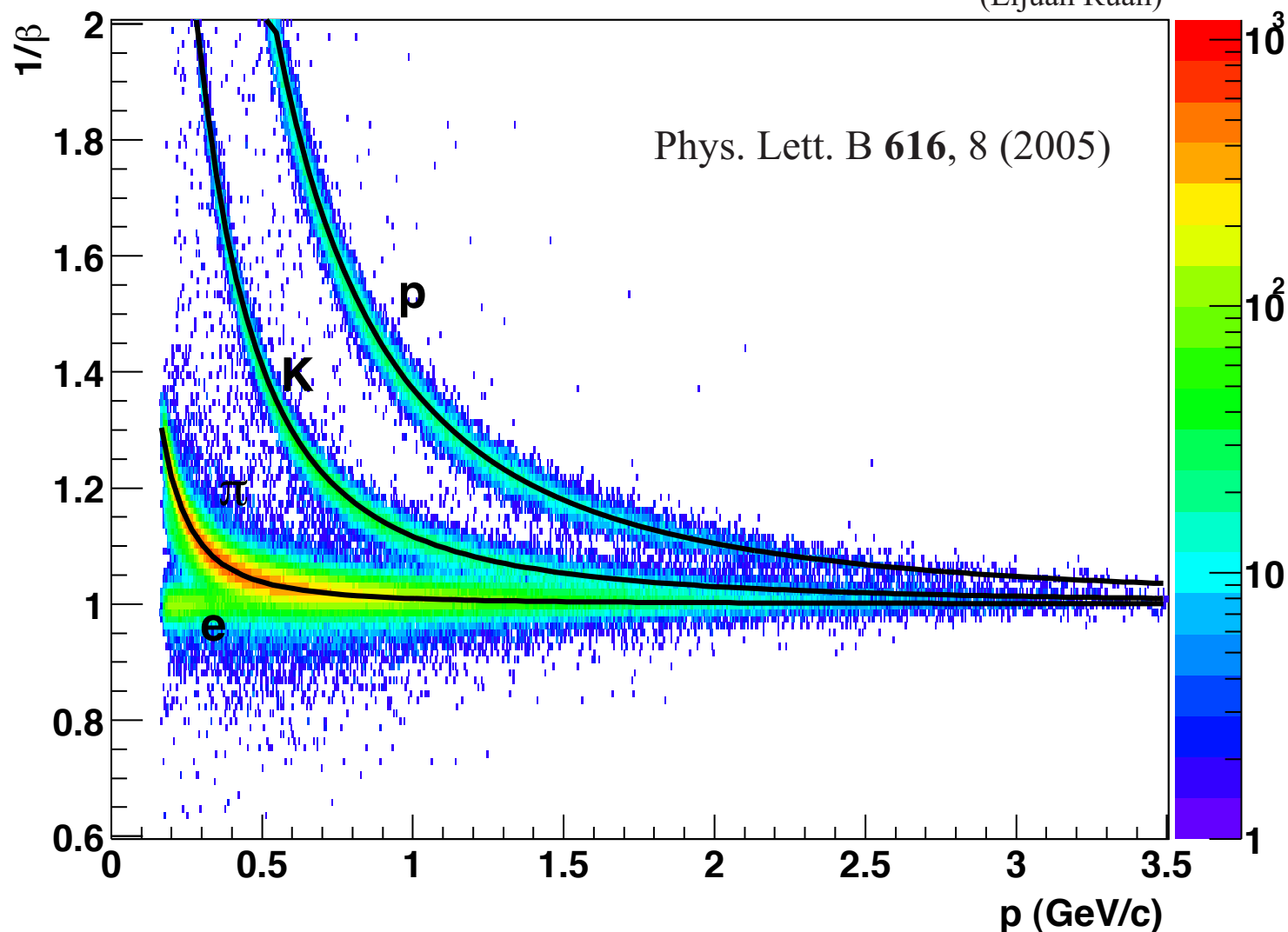
“Shoebbox” built out-of-house
Correct sealant
One layer of electronics
long cables
CAMAC DAQ
Imprecise MRPC positioning

TOFr5 (Run-5)



“Shoebbox” 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...

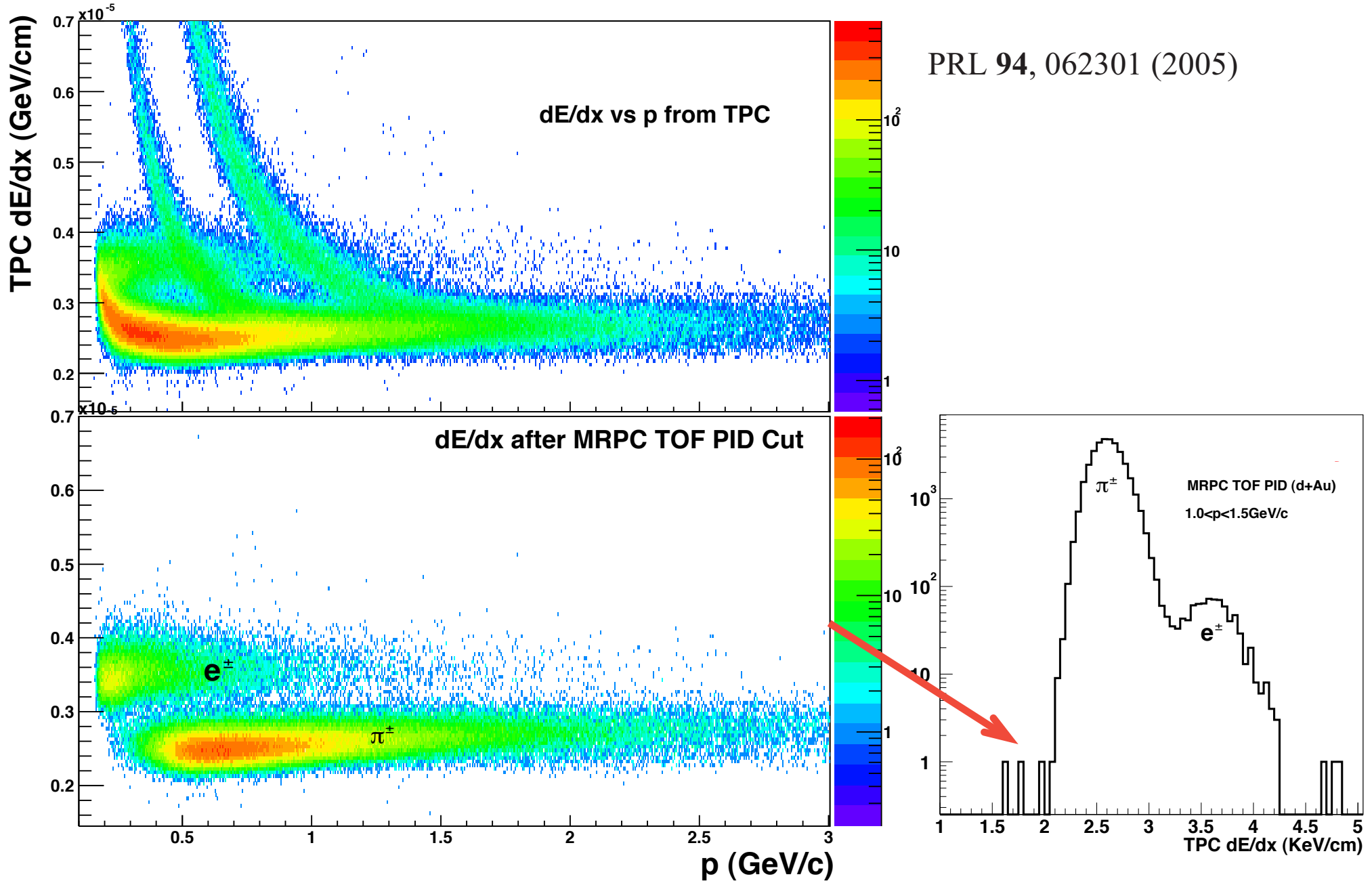


start resolution $\sim 85\text{ps}$
 stop (MRPC) resn $\sim 85\text{ps}$
 total $\sim 120\text{ps}$

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

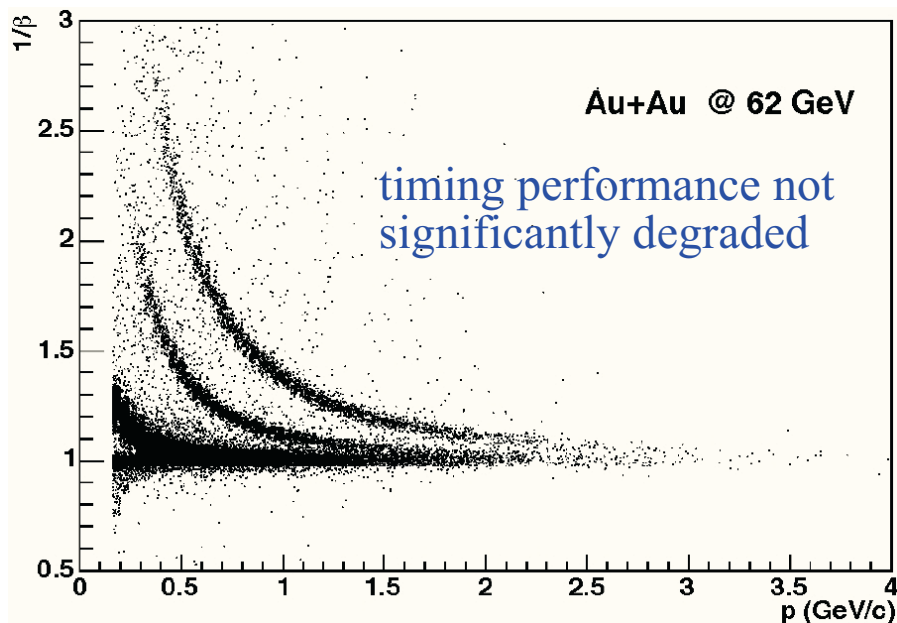
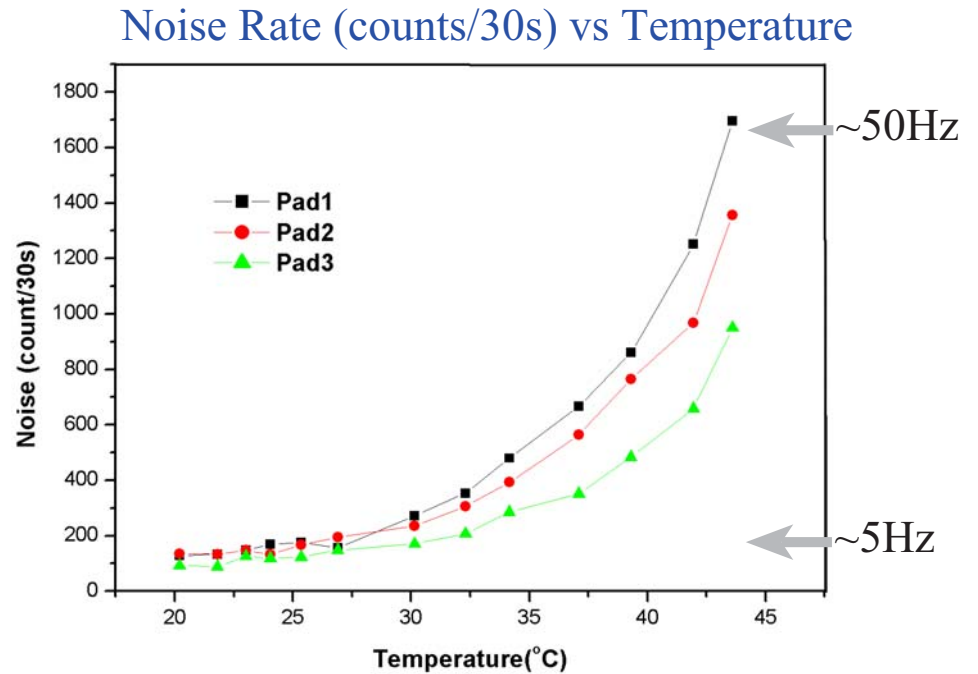
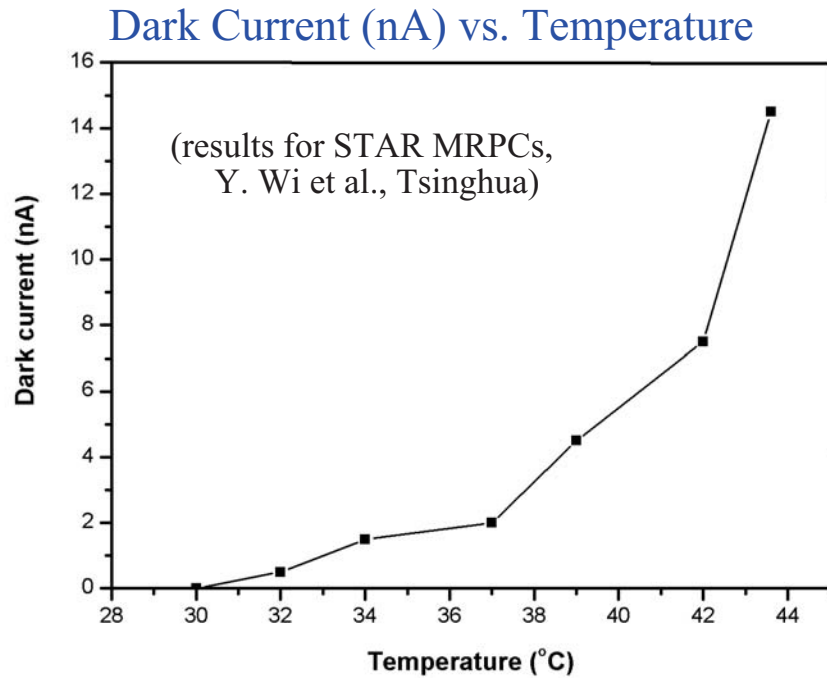
First physics result from an MRPC-based TOF System
 on hadron Pt-distributions & the Cronin Effect in RHIC p+p & d+Au collisions

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

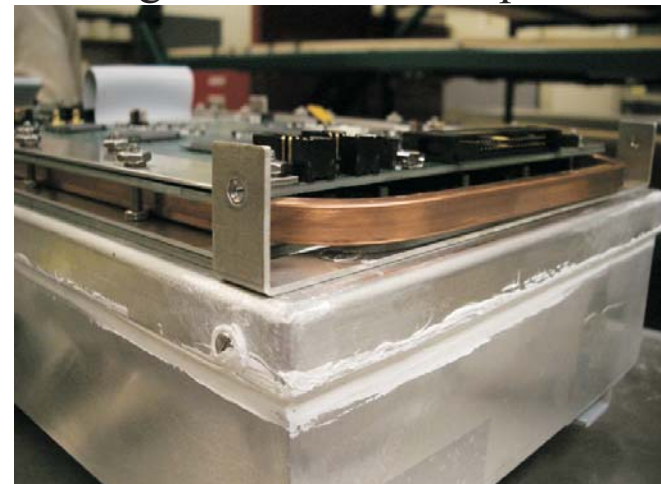


TOF' (Run-4) ran hotter than TOFr (Run-3)...

large number of components on single FEE layer that seals the gas box *heats the box interior*



New design (TOFr5 & final system):
two layers of electronics (TINO & TDIG)
w/ rectangular Cu water loop in between



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

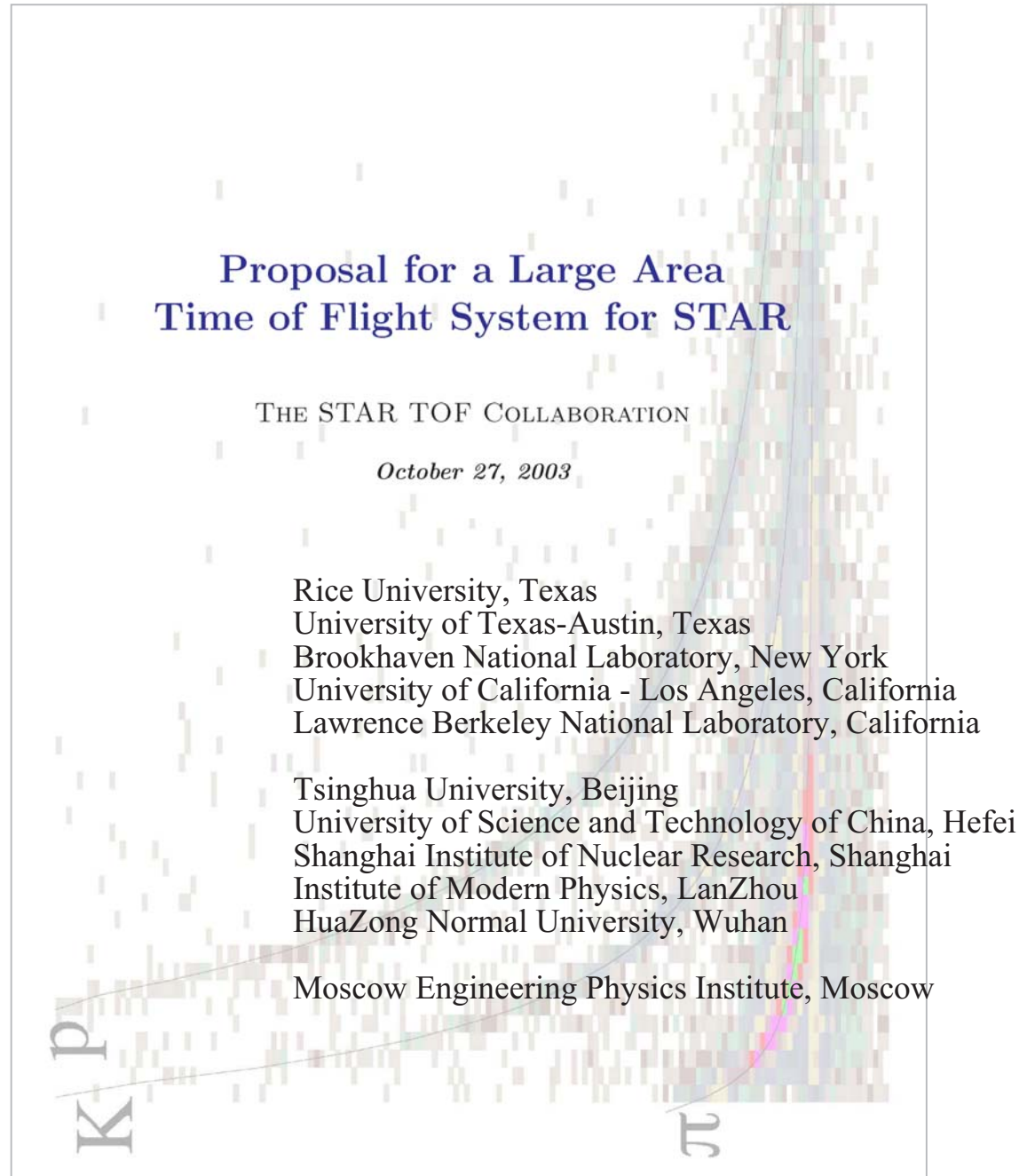
Then proposed a full system:

- 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\$

Project successfully completed this year

All 120 trays installed and running in
present RHIC Run-10

2 dead channels out of 23040
1 tray with a bad HV cable
...will be fixed this summer



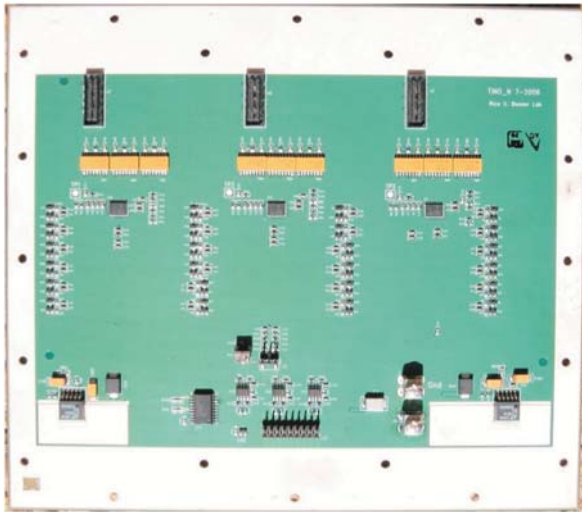
Electronics

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



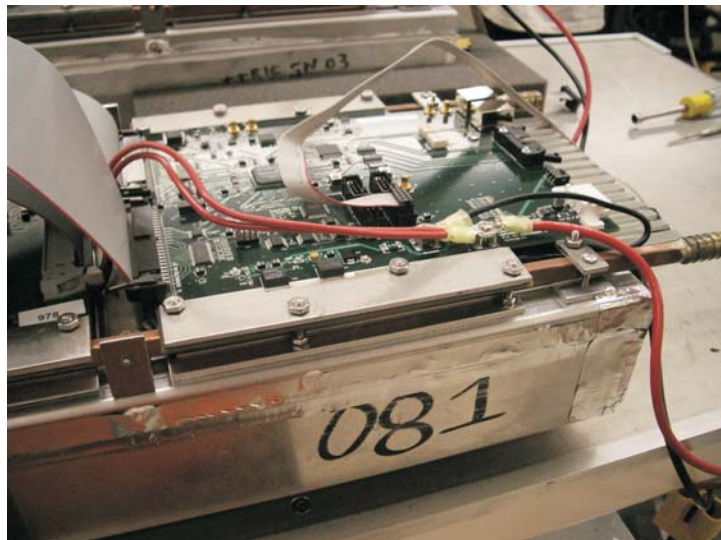
TDIG



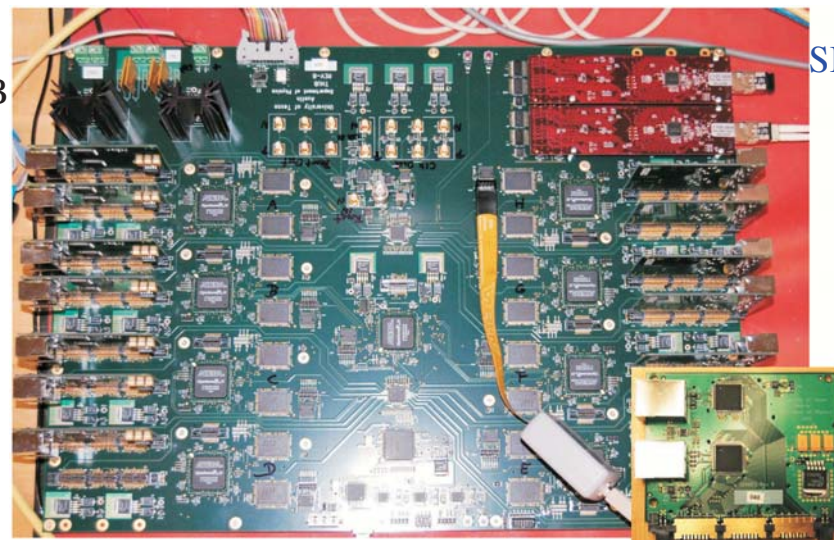
Start-side:
 same electronics
 except TINO → TPMT

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

TCPU

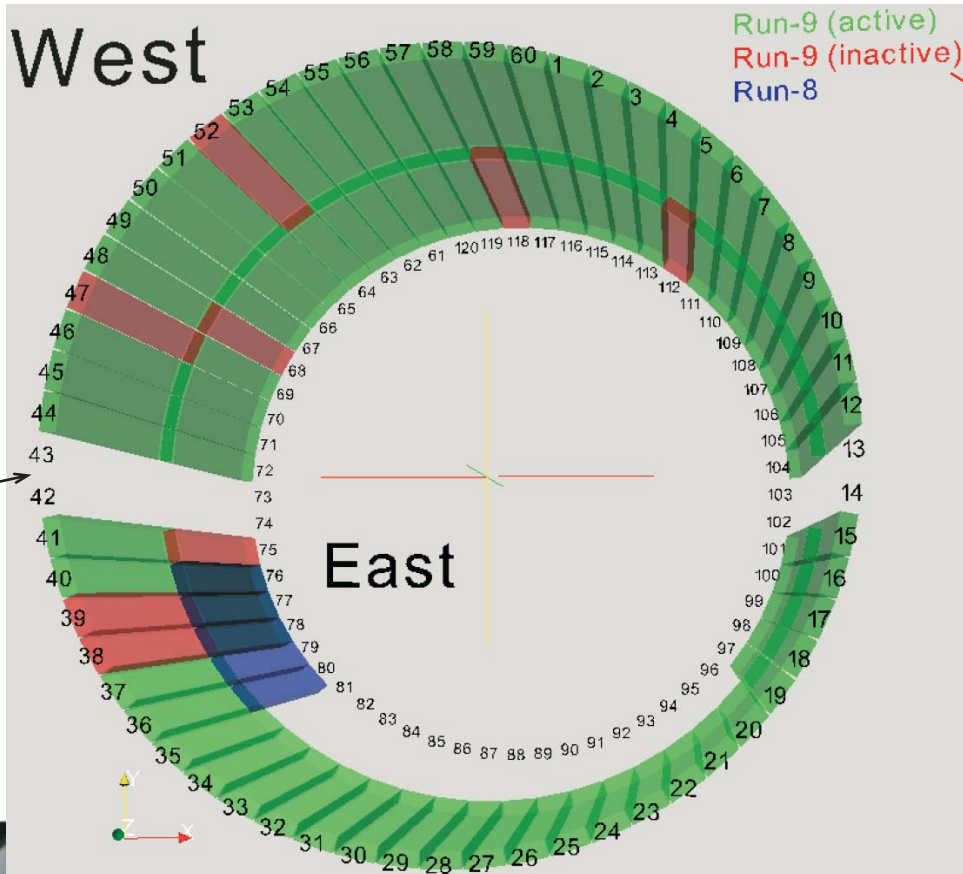


THUB



SIU/RORC

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

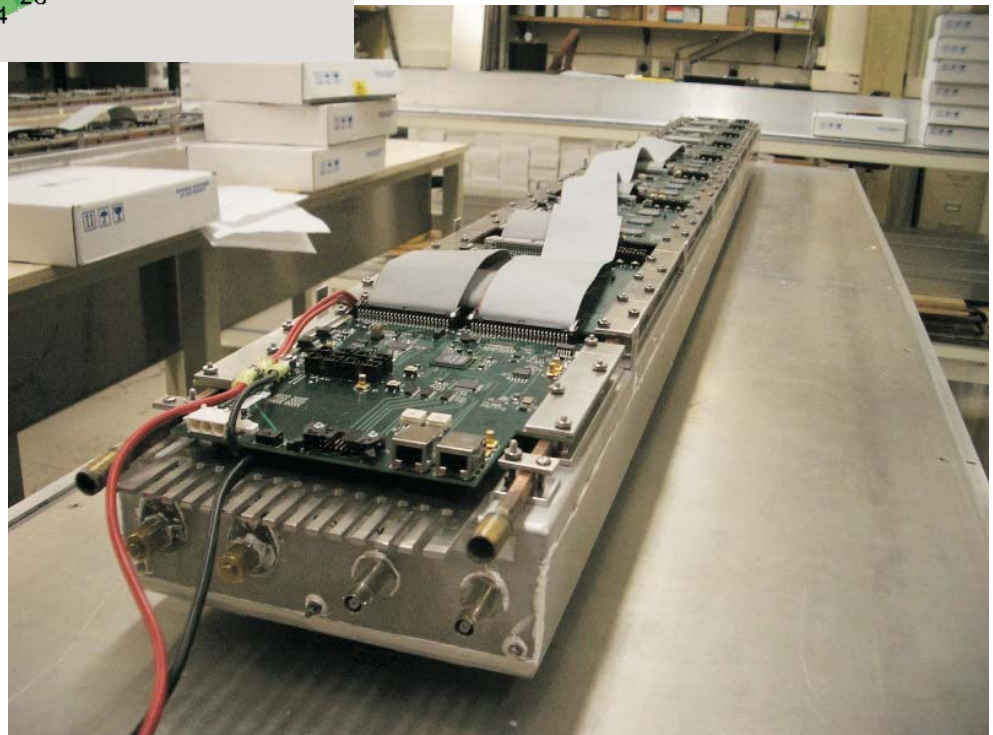
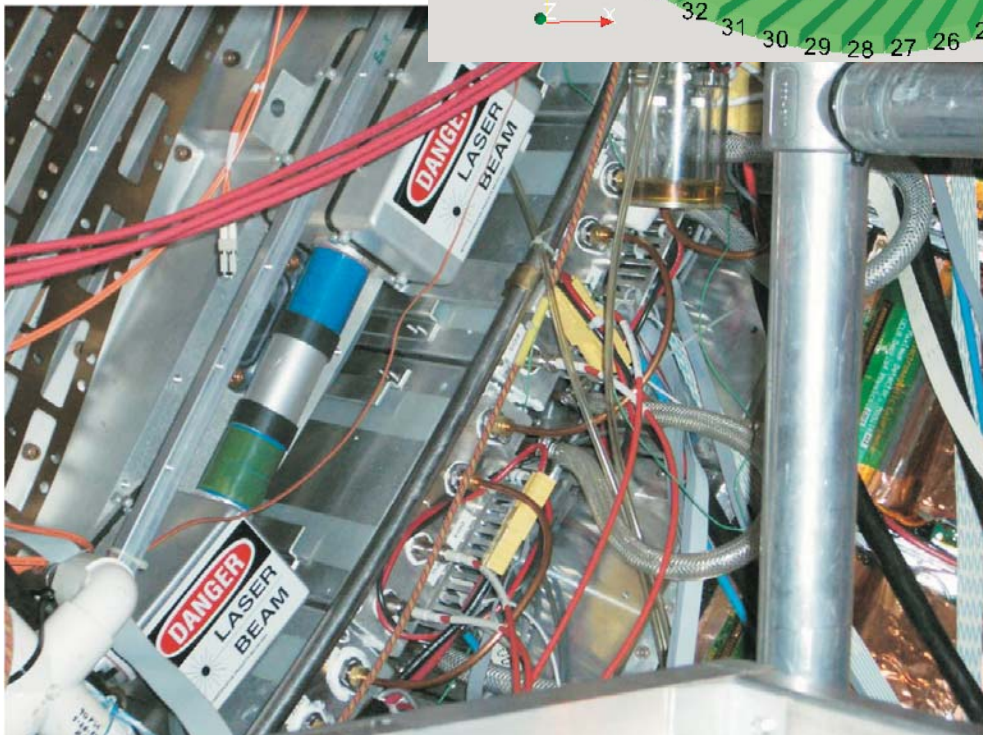
One bad TCPU board

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

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

TPC support arms

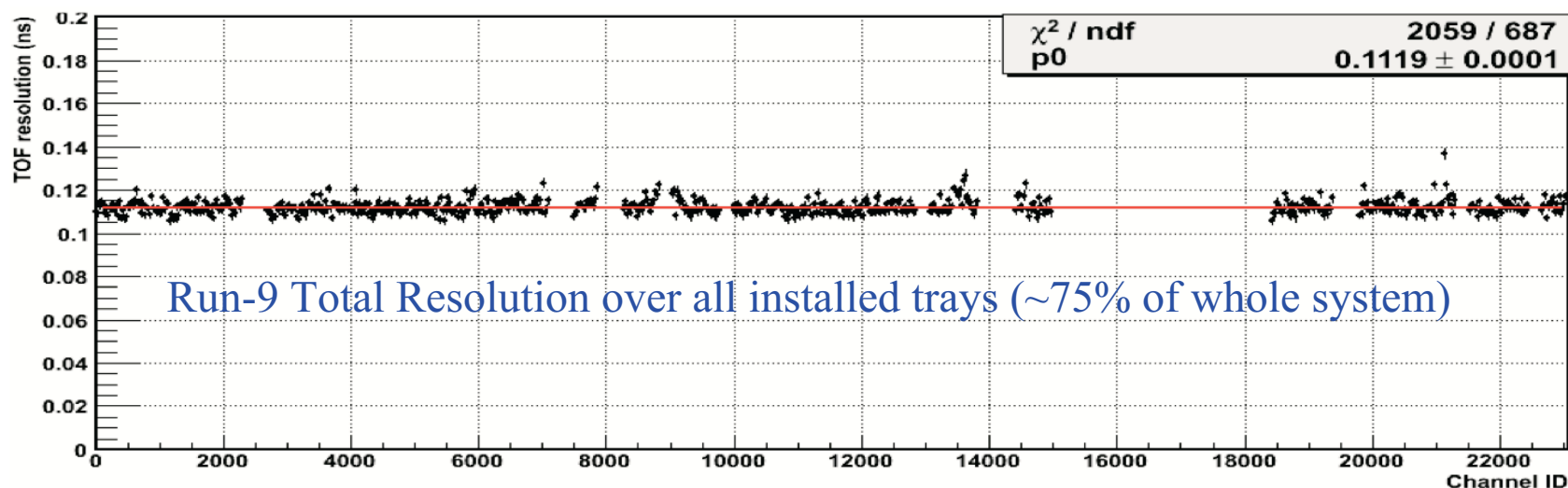
...special jack used to support TPC for installation of these trays before present Run-10....



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

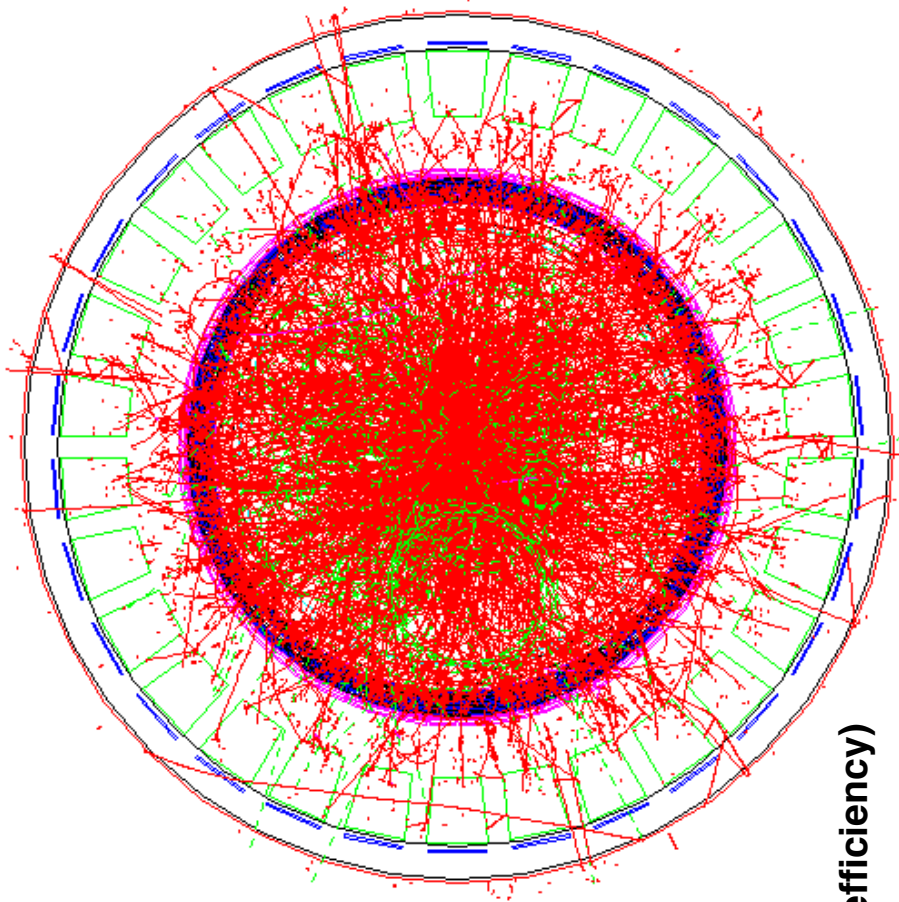


STAR “Muon Telescope Detector” (MTD)

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

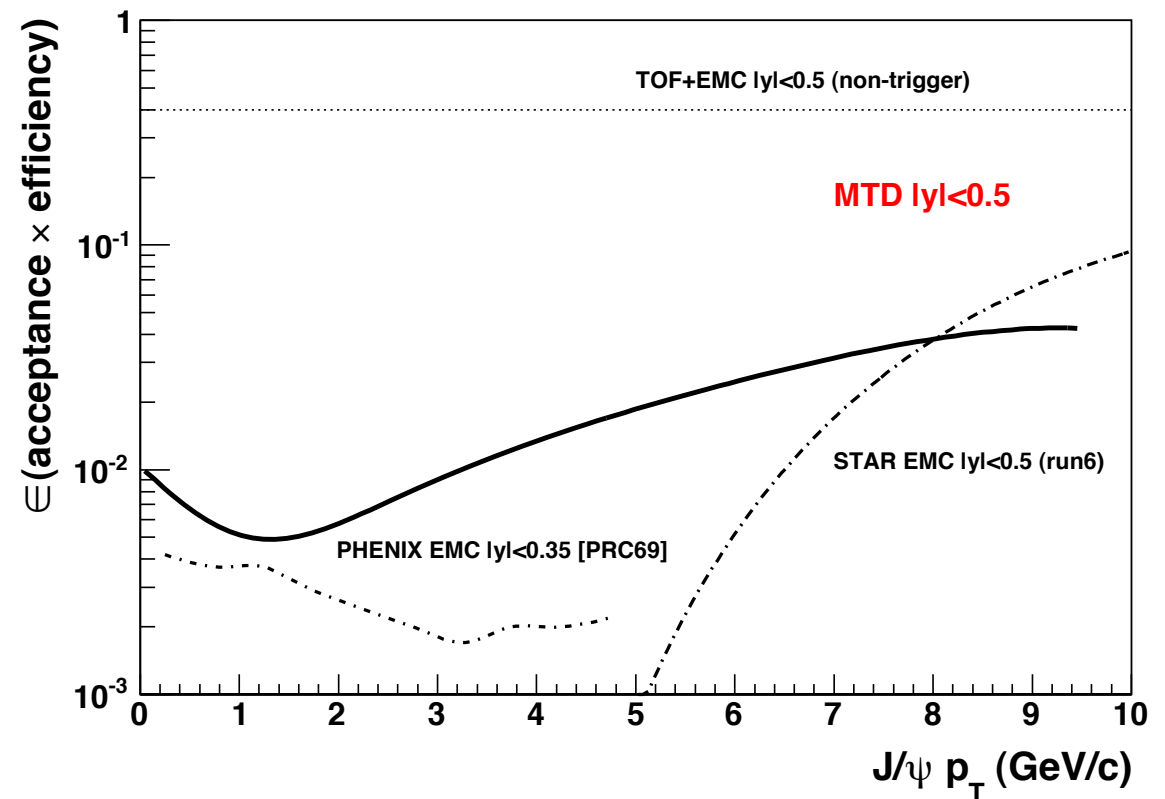


Physics goals:

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

superior to electron channels
less Bremsstrahlung
avoid backgrounds from γ conversions

$e+\mu$ correlations from heavy flavor decays

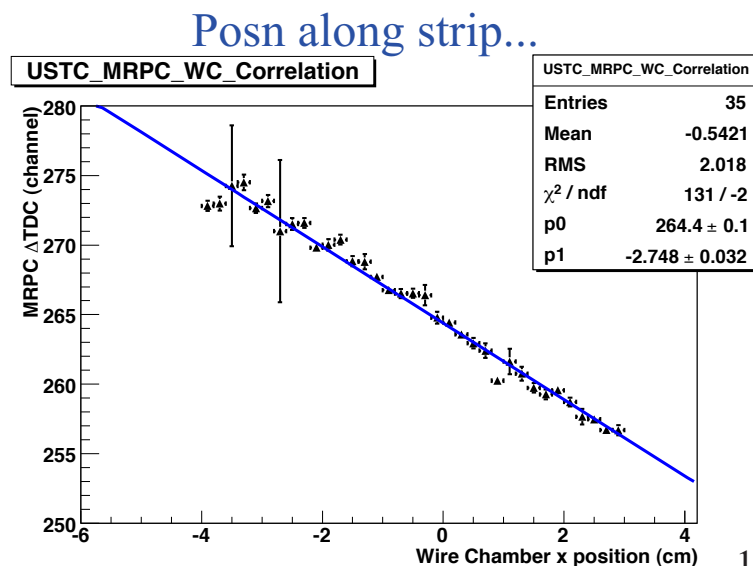
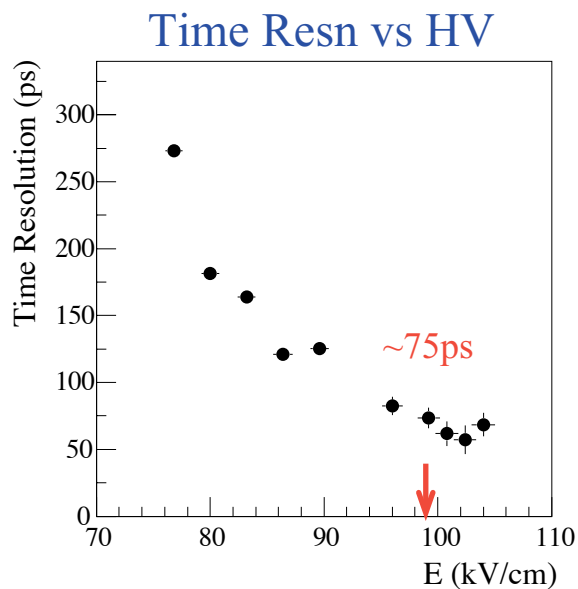
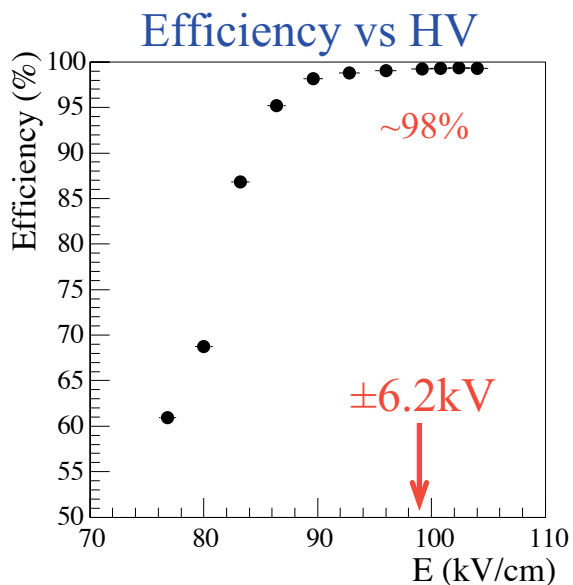
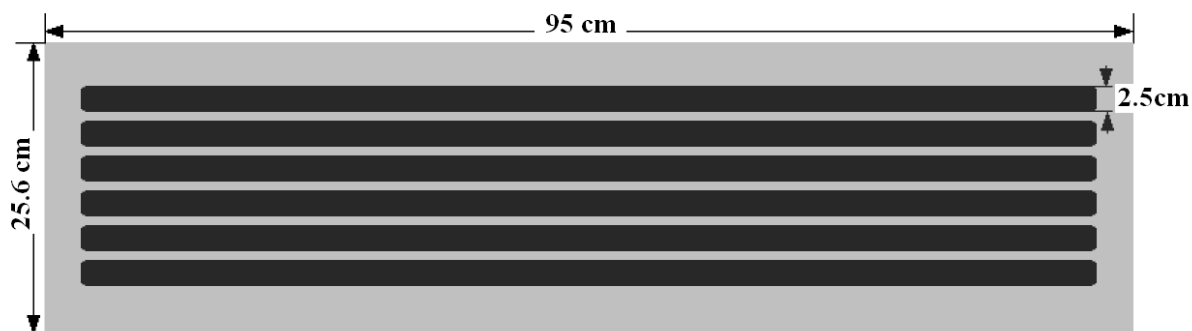
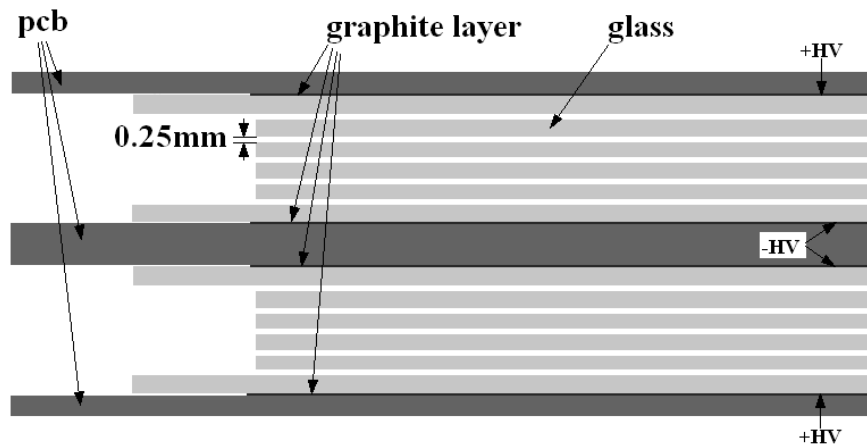


STAR MTD Prototype “LMRPCs”

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 specific
electronics used

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

Second MTD Prototype “MTD9”

3 LMRPCs arranged side-by-side

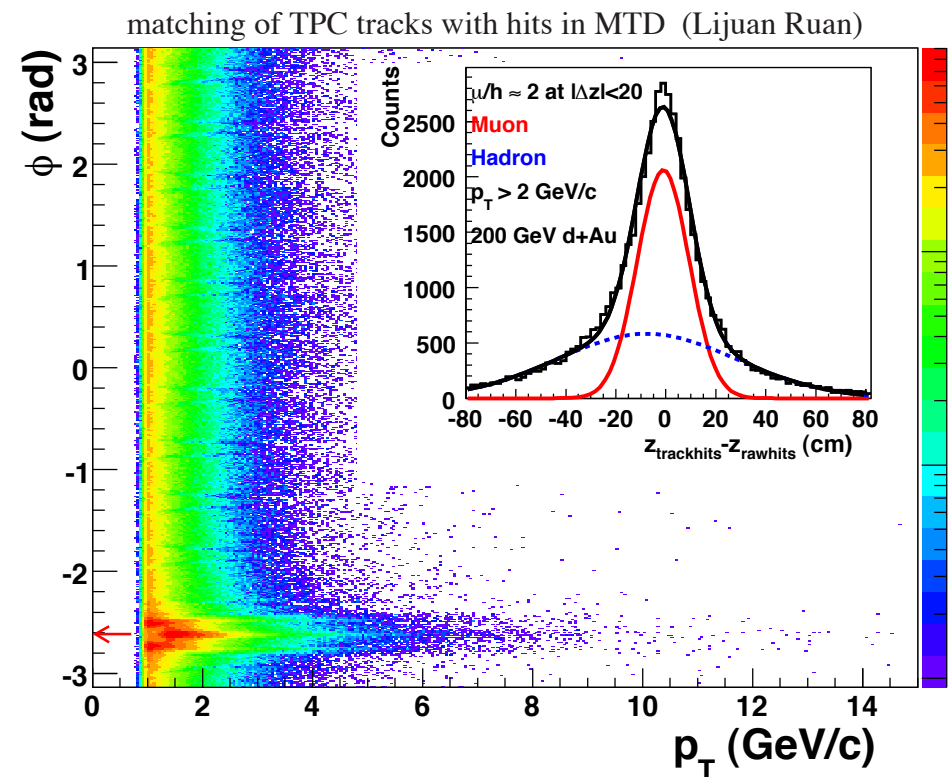
Uses TOF Electronics

TINO (based on NINO chip)

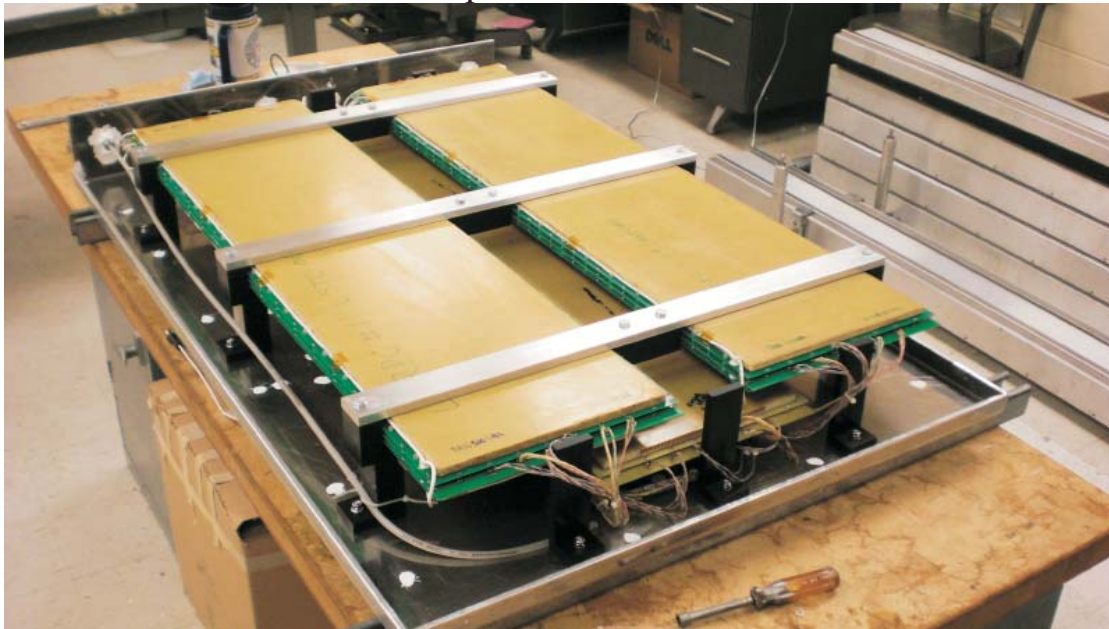
TDIG (based on HPTDC chip)

TCPU+THUB+TTRG (readout & triggering)

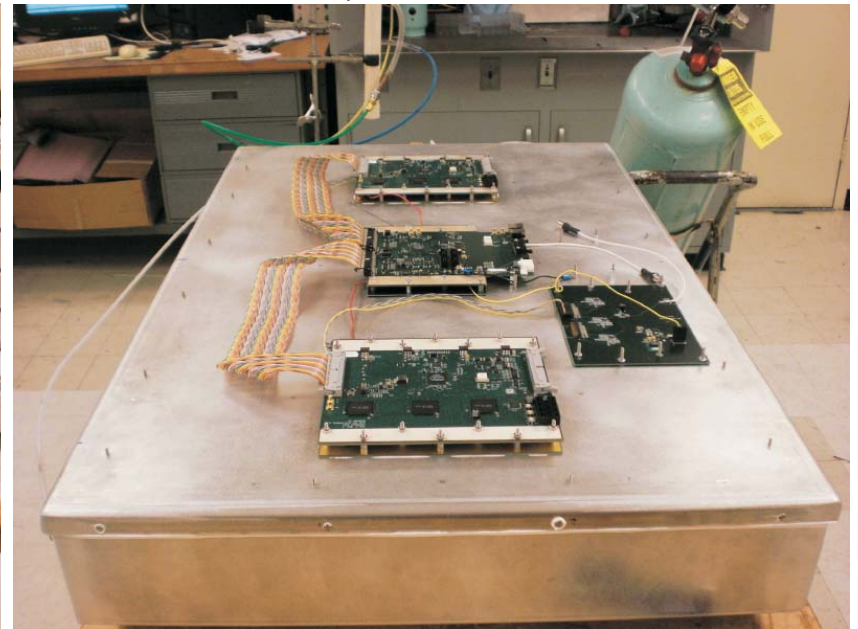
Not much data collected in Run-9, but is running in present Run-10.



MTD9 open



MTD9 closed, with electronics

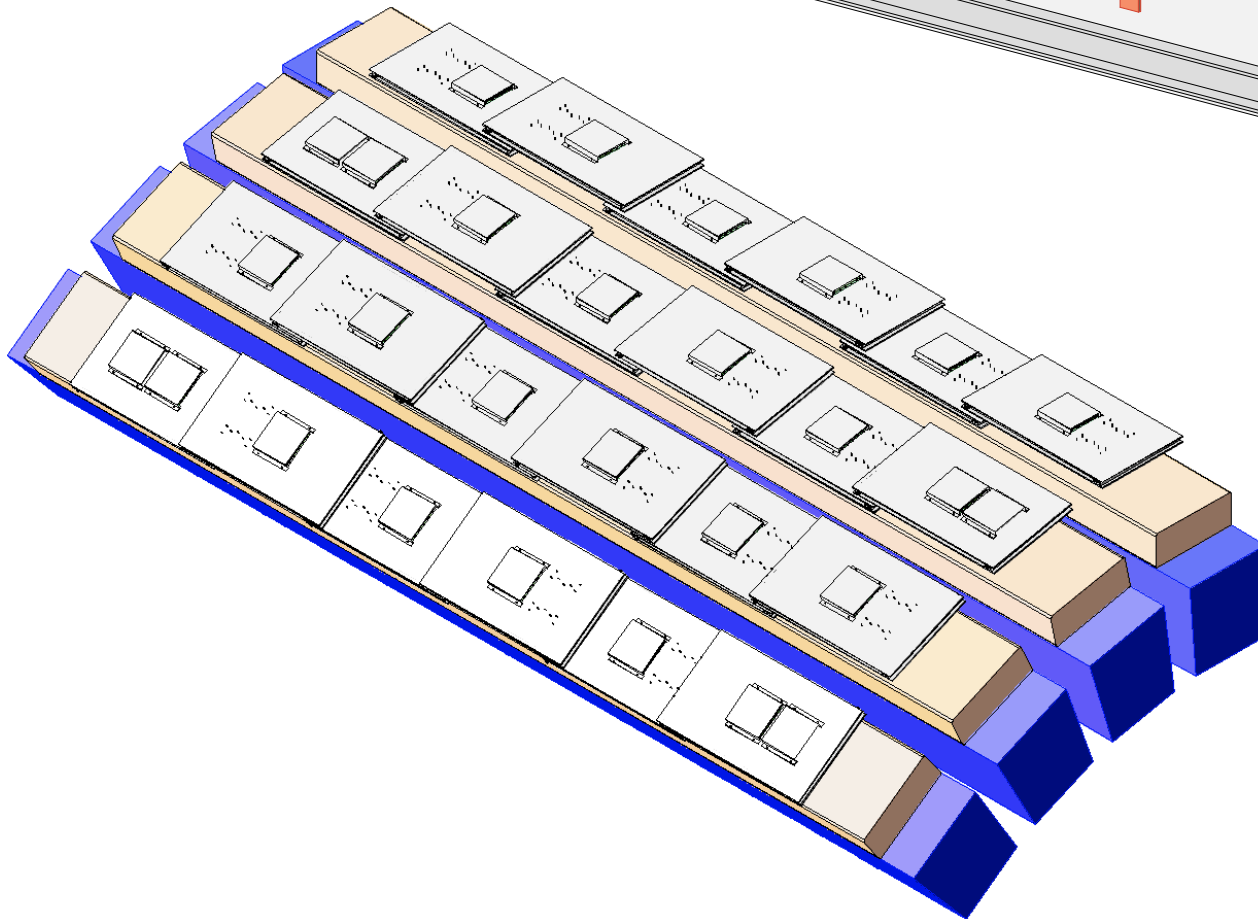
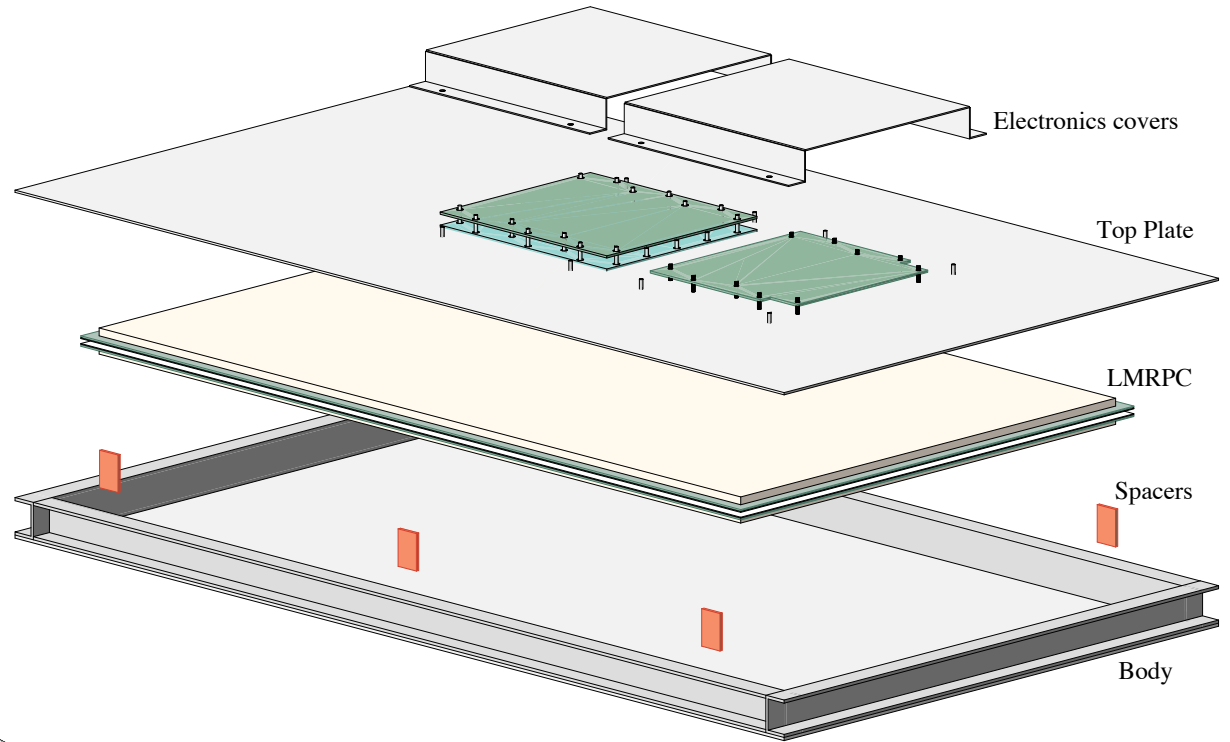


MTD9 mounted onto exterior of STAR in Run-9



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 2012.

Summary

The **full-barrel Time of Flight system** is fully installed as of this summer & is running well in the present RHIC run...

... 2 bad channels out of 23,040

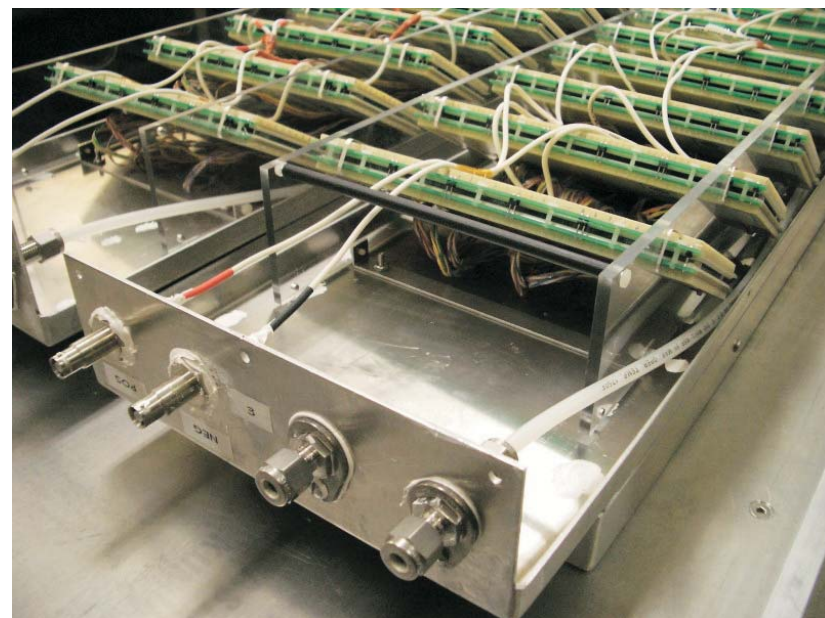
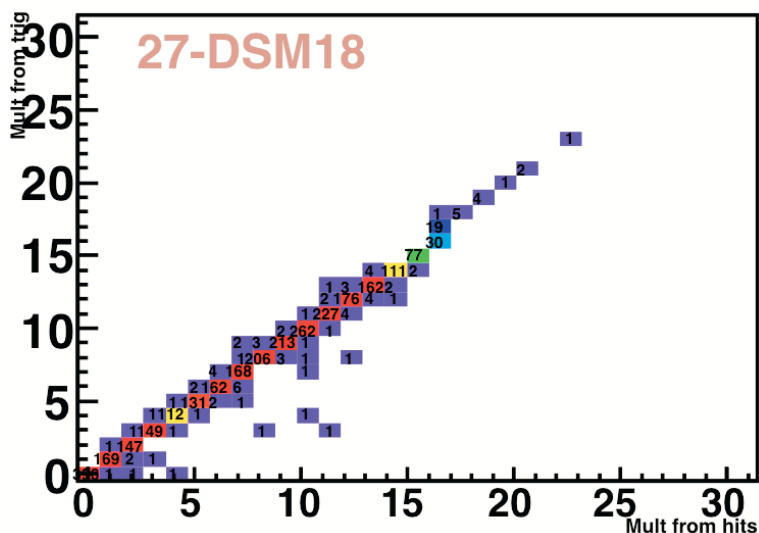
... 1 disabled tray out of 120 (one bad HV cable, will be fixed next shutdown)

... MRPC time resolution ~ 80 ps

... development of our TOF MRPCs possible thanks to CERN test-beam time donated to us by LAA/ALICE!

... design & performance of our electronics hugely benefitted by LAA Project & other CERN/LHC R&D!

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



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

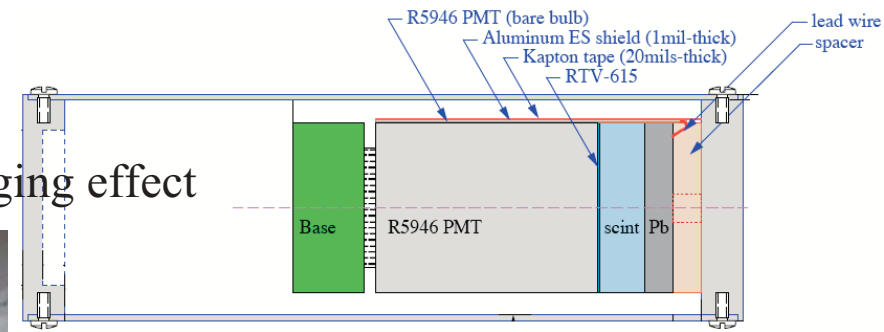
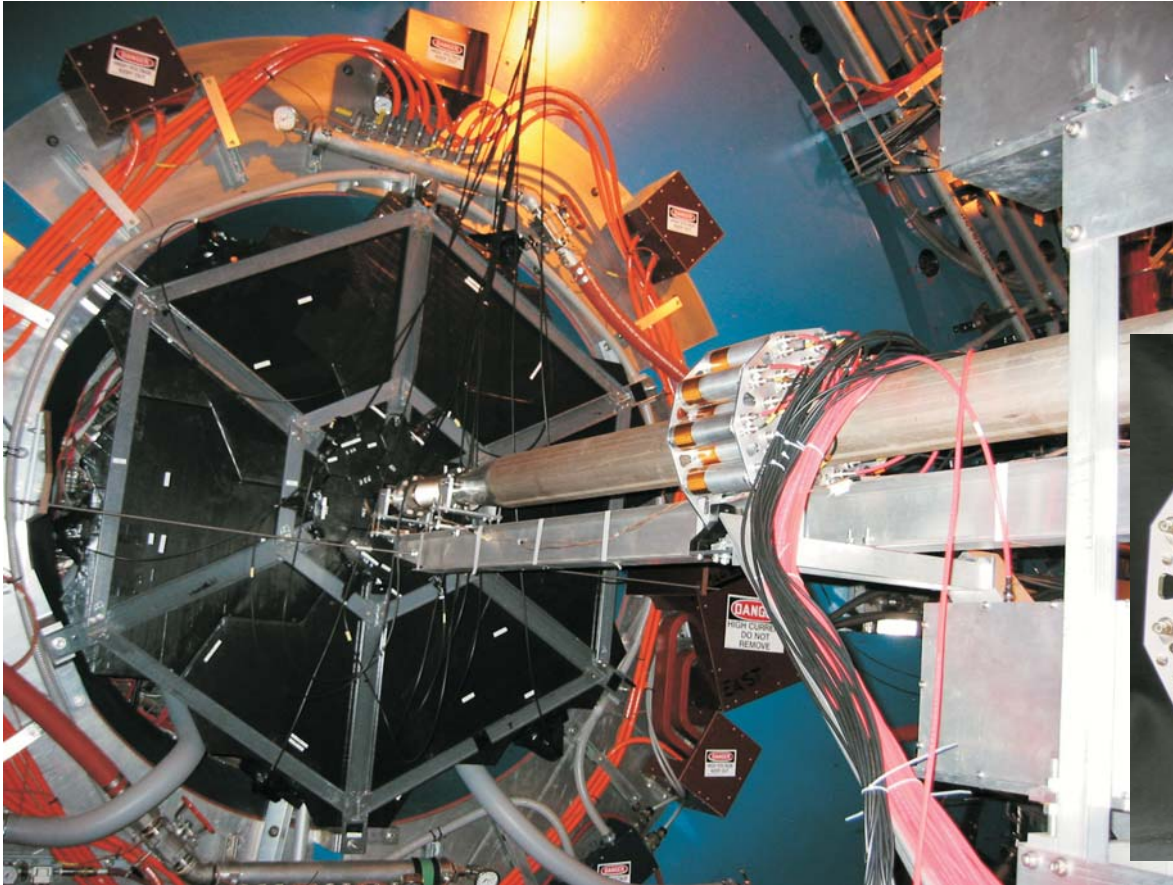
...much larger double-ended MRPCs

...prototypes operated in several recent RHIC runs

Proposal for the full system presently under review.

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

