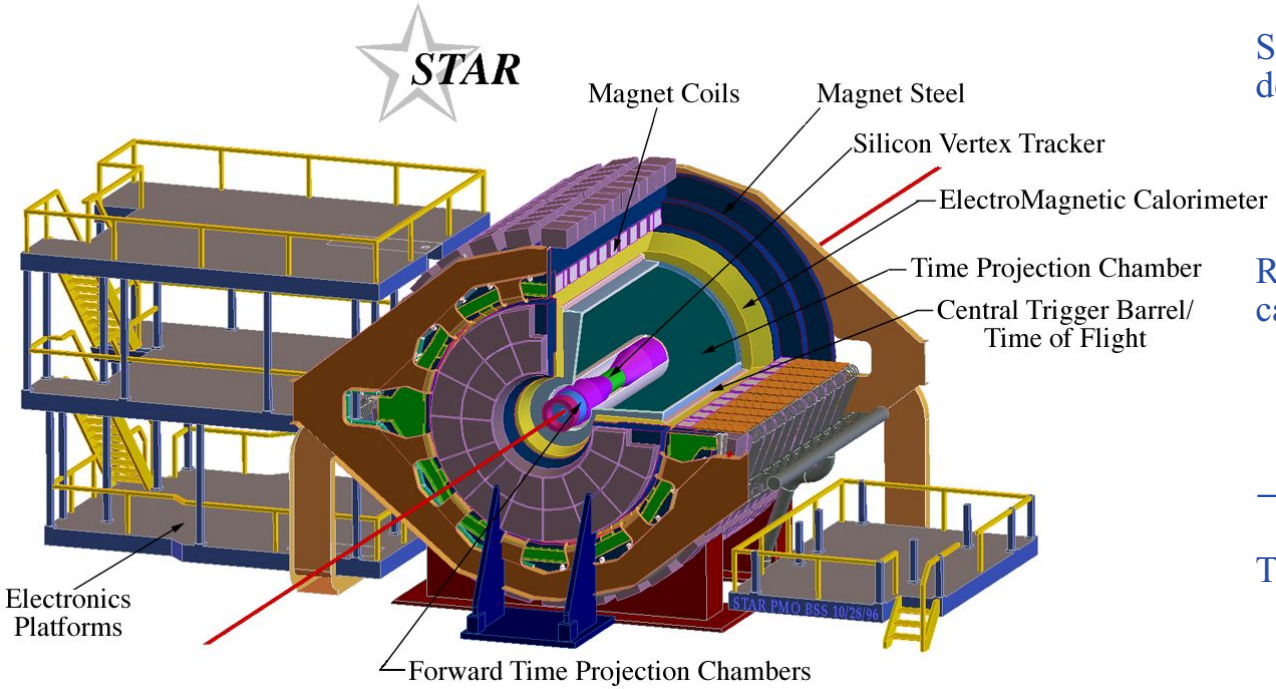
Large-Area Fast-Timing Systems in STAR

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 π/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 ~2.1m to ~3.2m
excellent tracking & "extrapolation"

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

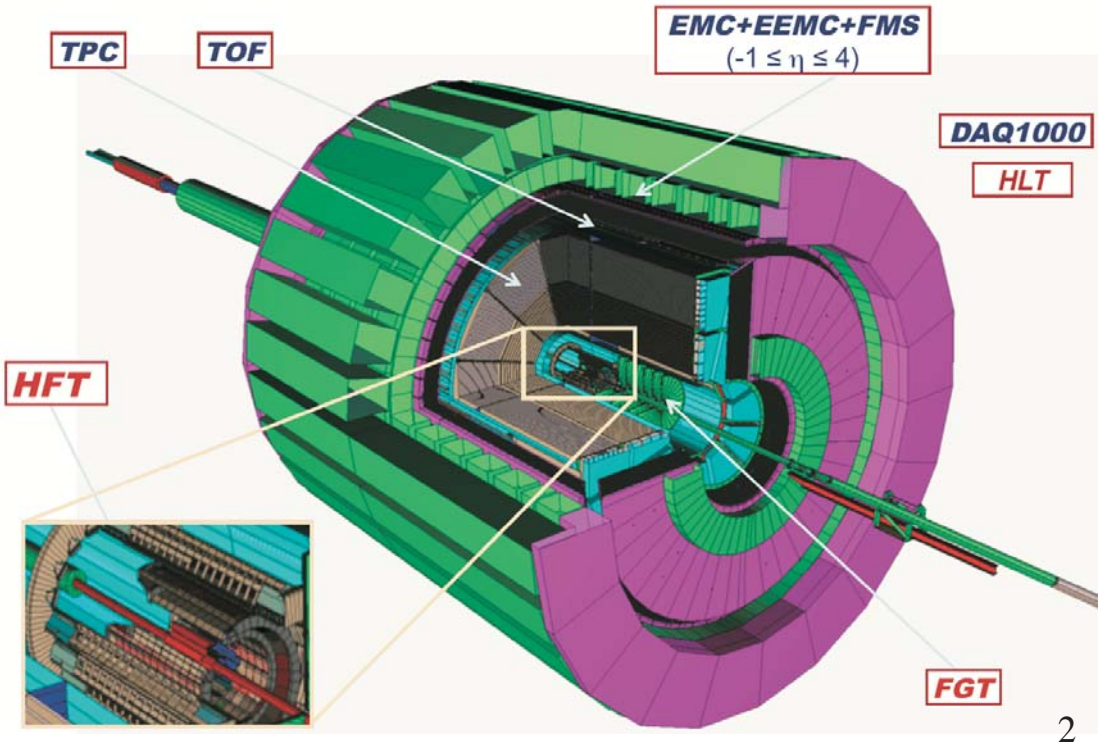
It met the requirements, but the major problem was the
huge size and epic cost of mesh dynode PMTs

Very expensive!
for ~10% occupancy → 50 M$

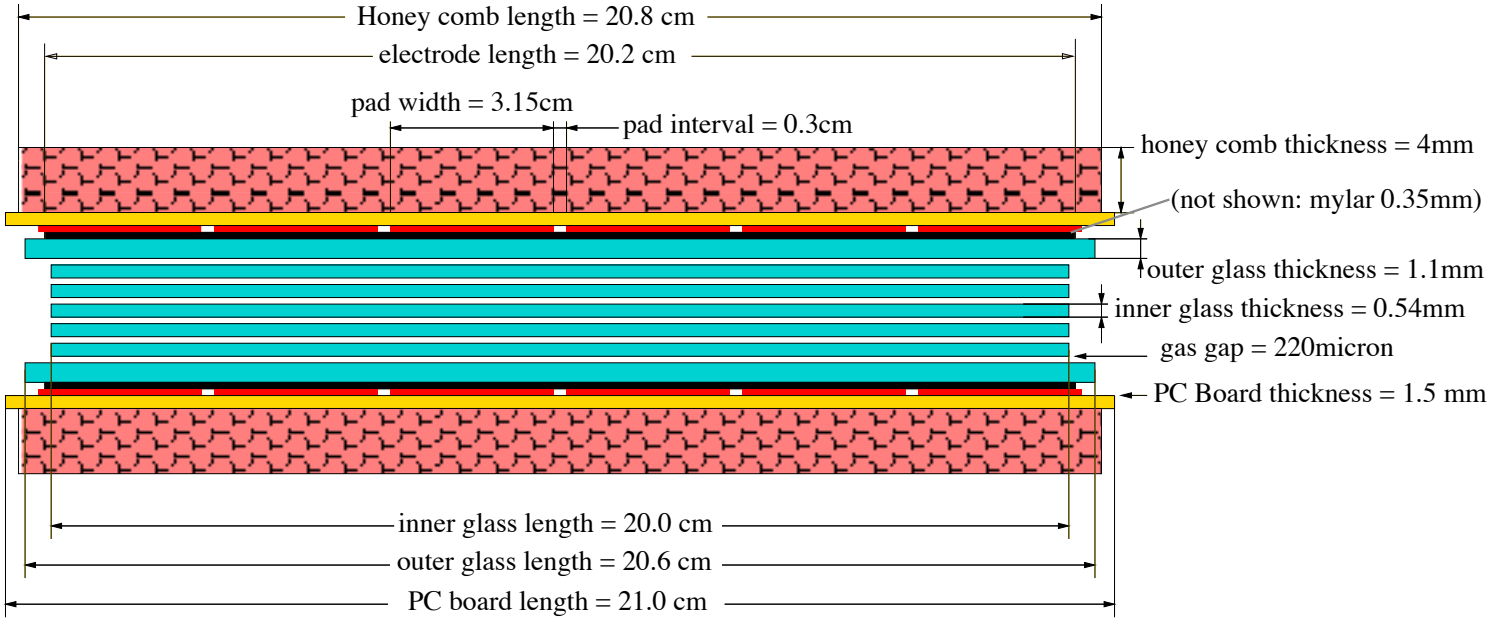
Sea change for us the late 1990's....

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



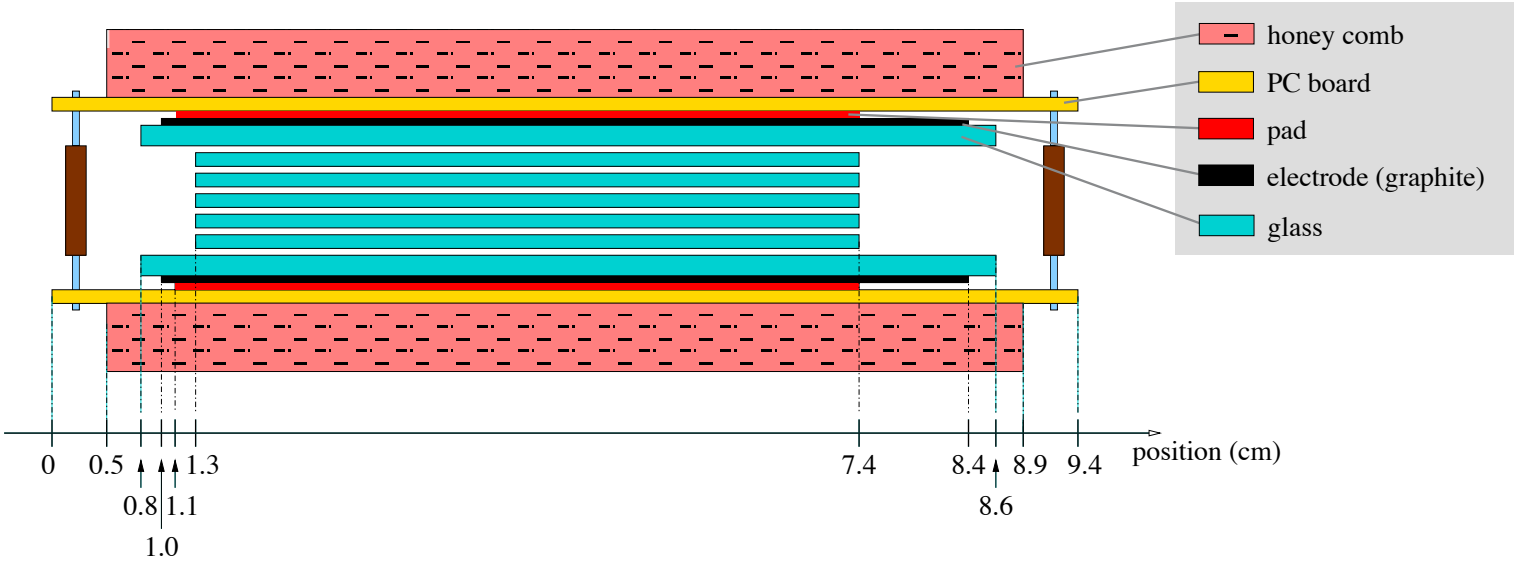
STAR's Variant...



Overall size
21.4 x 9.4 cm

Six 220 μm gas gaps
Fishing line spacers

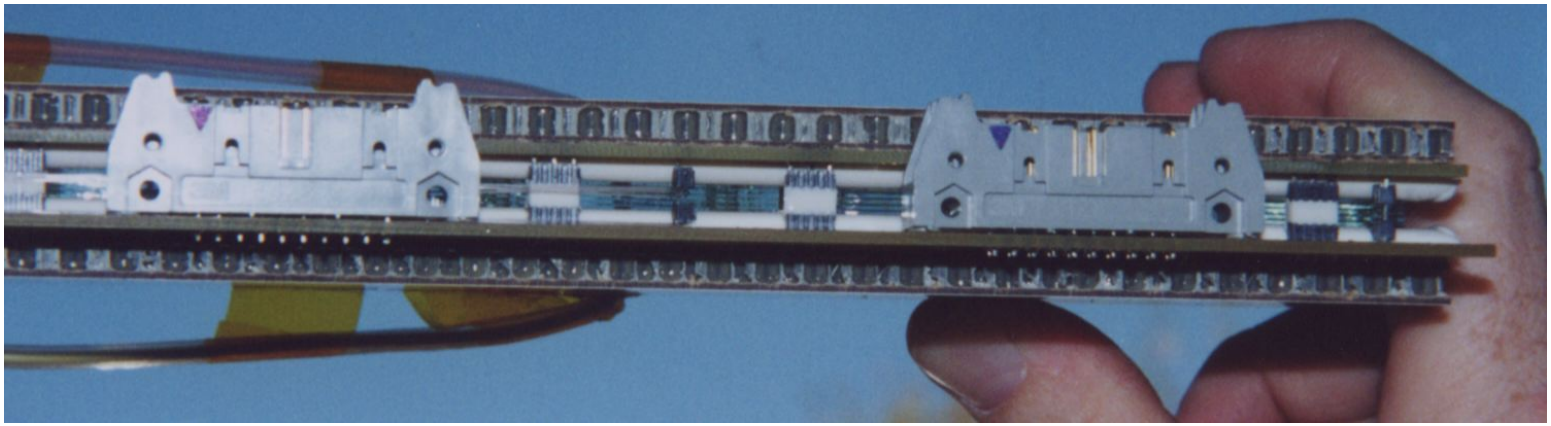
inner glass 0.54mm
outer glass 1.1 mm

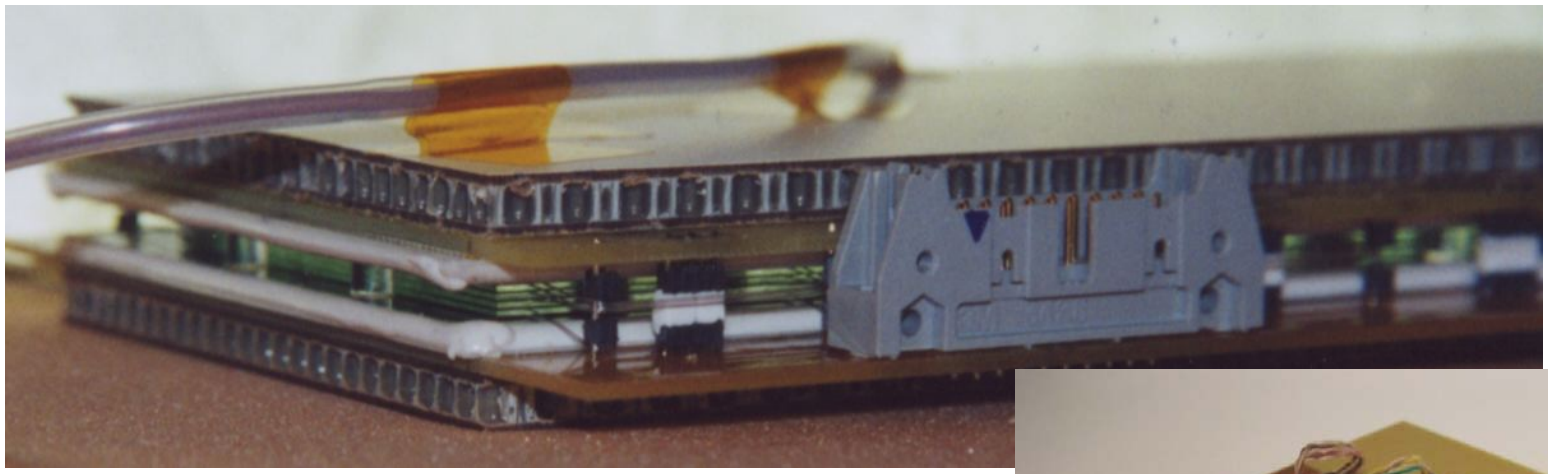


Float glass & Graphite tape electrodes

$10^{12\text{-}13}$ Ω.cm volume & 10^{5} Ω/square surface
Operating voltage: ±7 kV

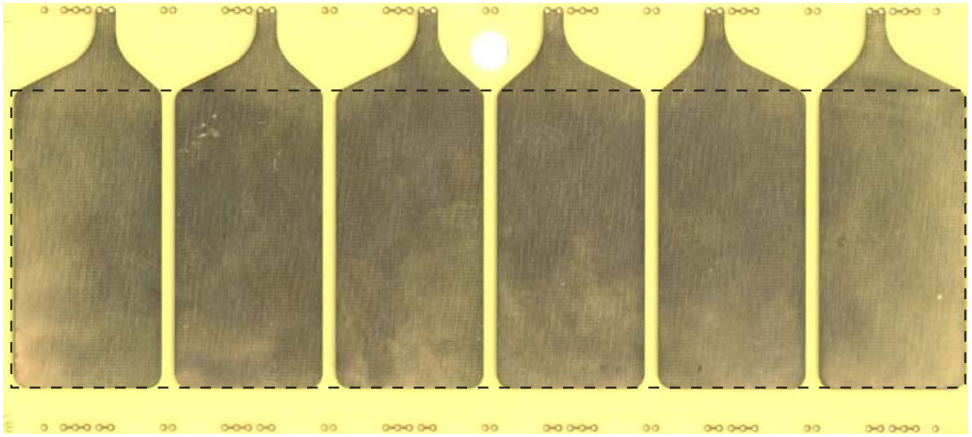
Gas: 95% Freon R-134a, 5% isobutane

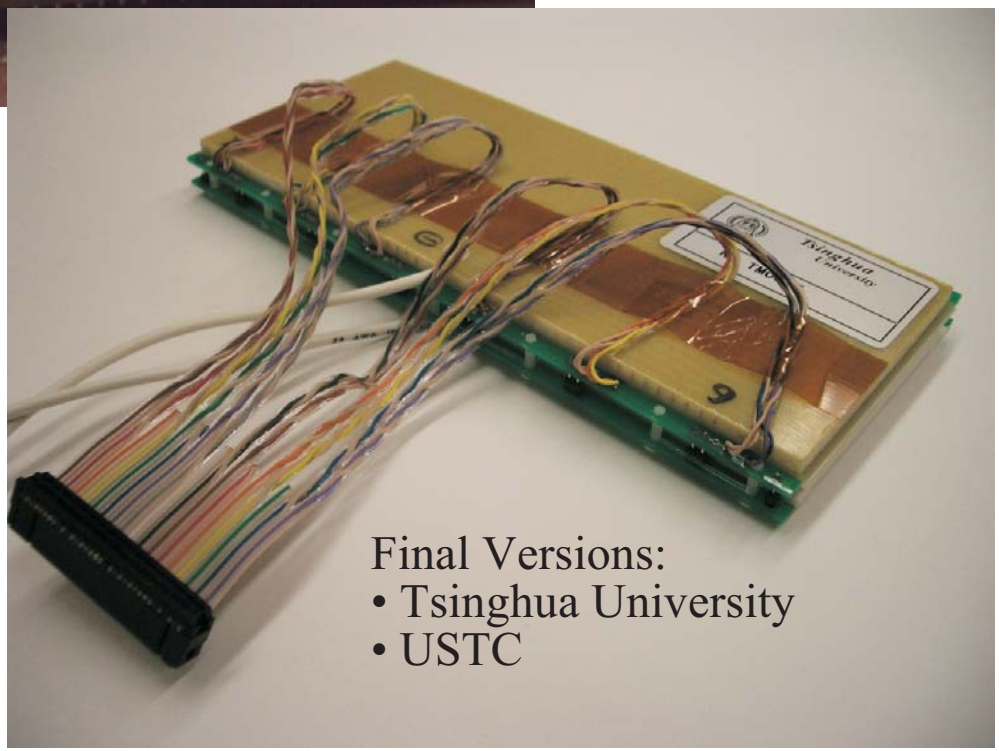




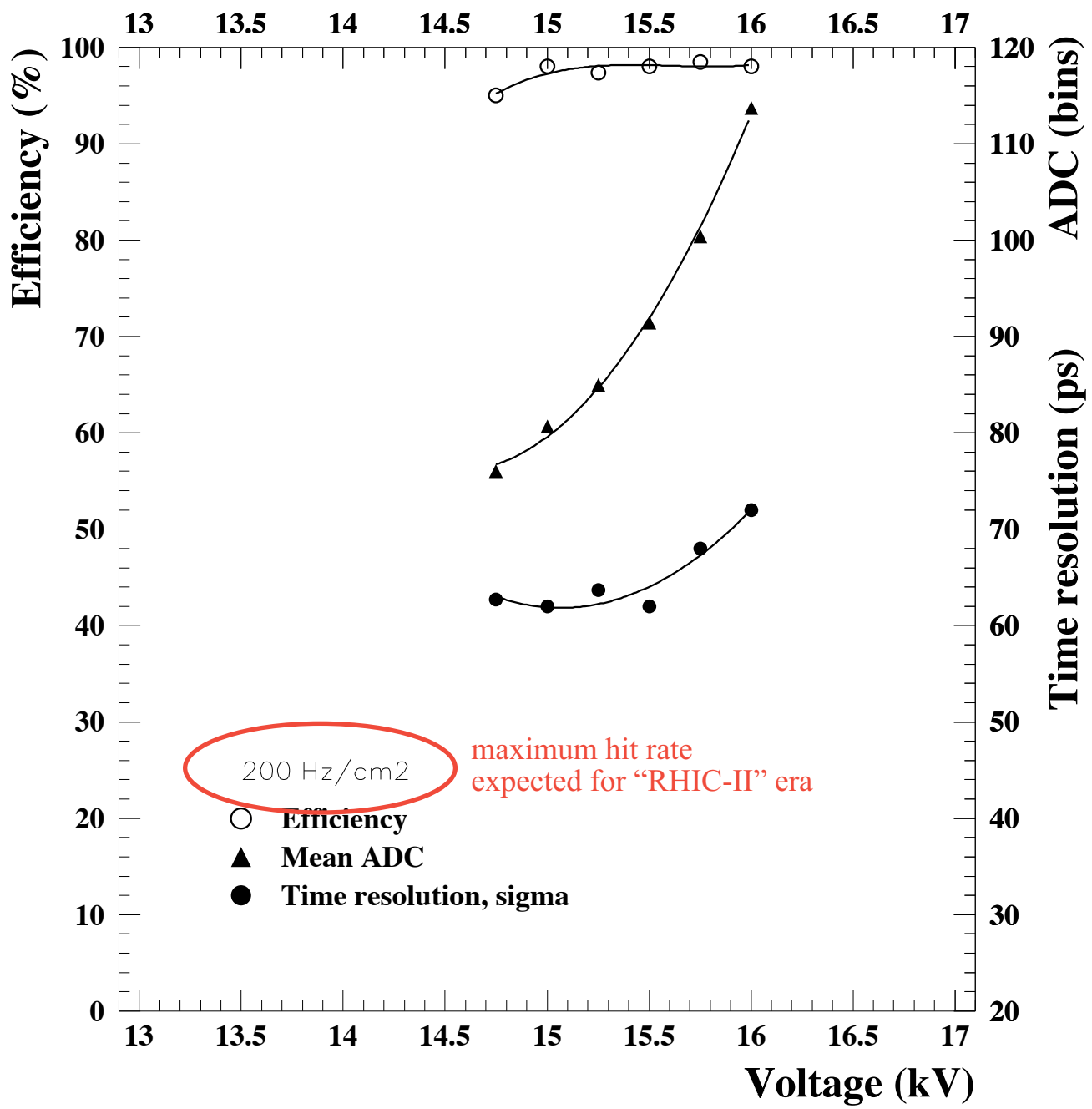
Prototype
(~2001)

6 single-ended read-out pads per MRPC:





Final Versions:
• Tsinghua University
• USTC



June 2001:
final CERN test results...

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

"TOFr"

a "tray"

$-1<\eta<0$

$\Delta\phi \sim 1/60^{th}$ of 2π

with ~30 MRPCs

STAR full-sized prototypes (2002-2005)

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

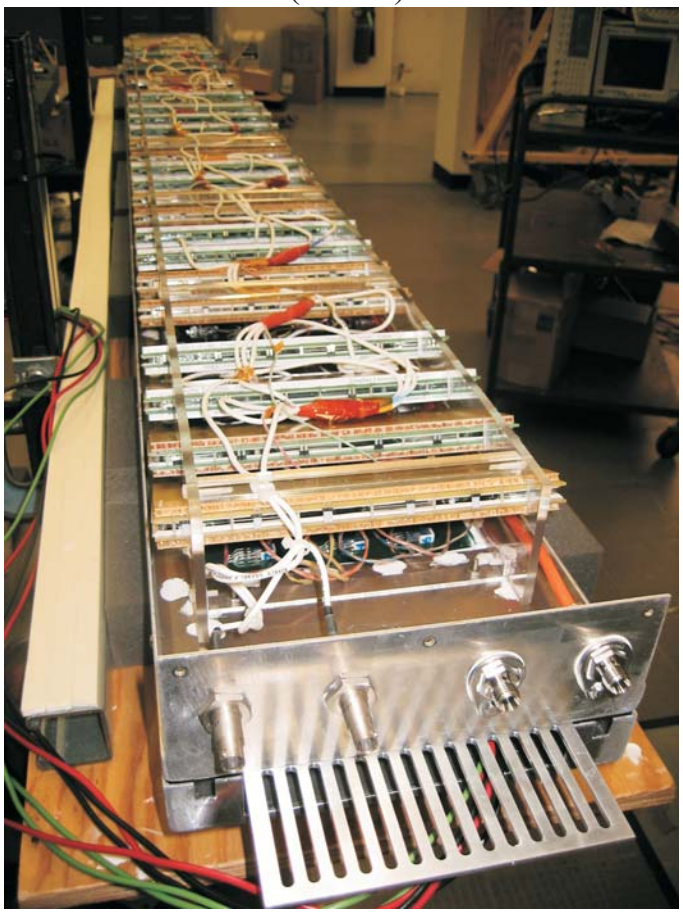
TOFr (Run-3)

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)

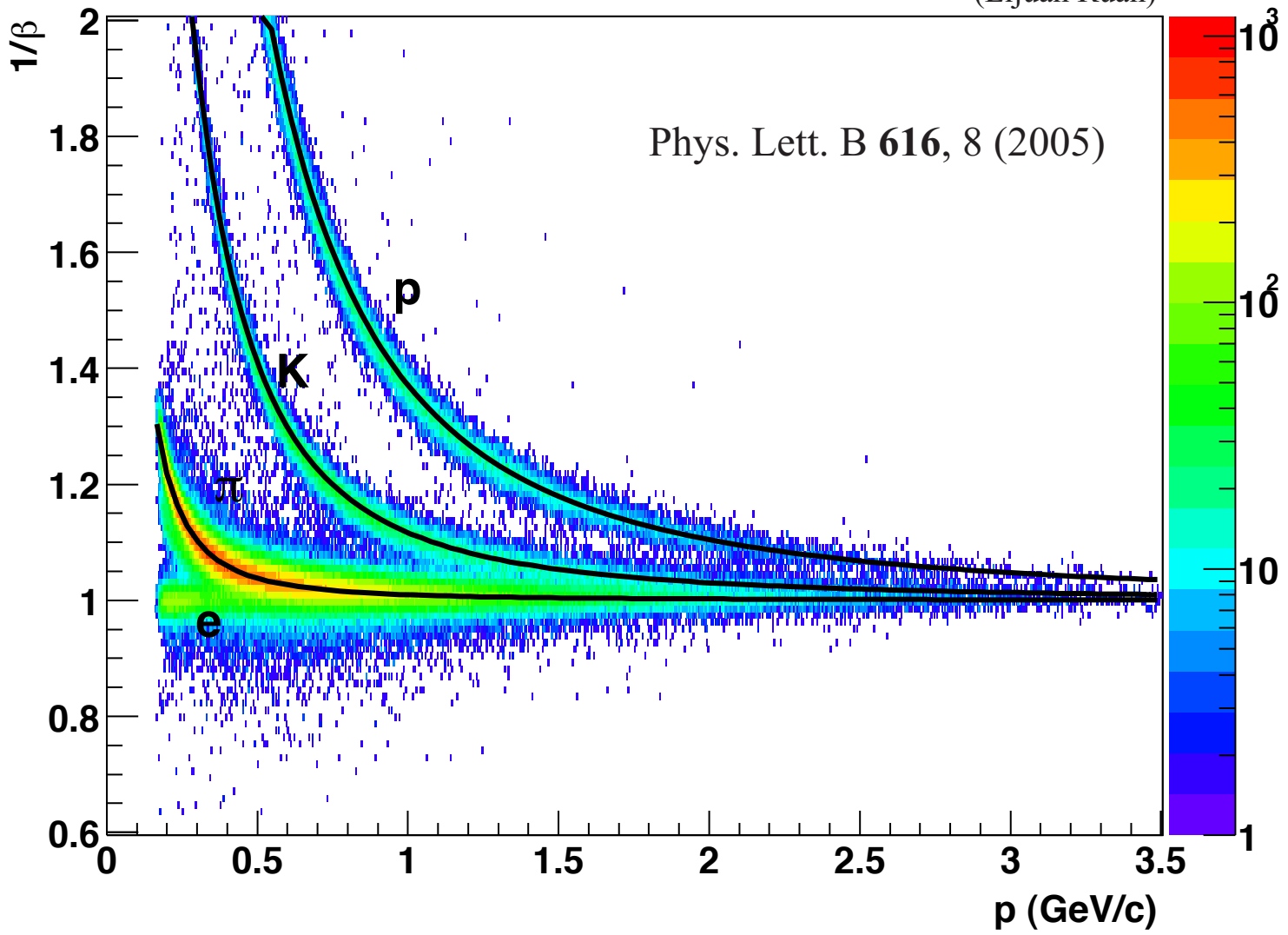


"Shoebox" built out-of-house
Correct sealant
Two layer of electronics
local digitization (CERN HPTDC)
Precise MRPC positioning
"Integrated" water cooling

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

TOFr+pVPD in RHIC Run-3 (d+Au)

(Lijuan Ruan)



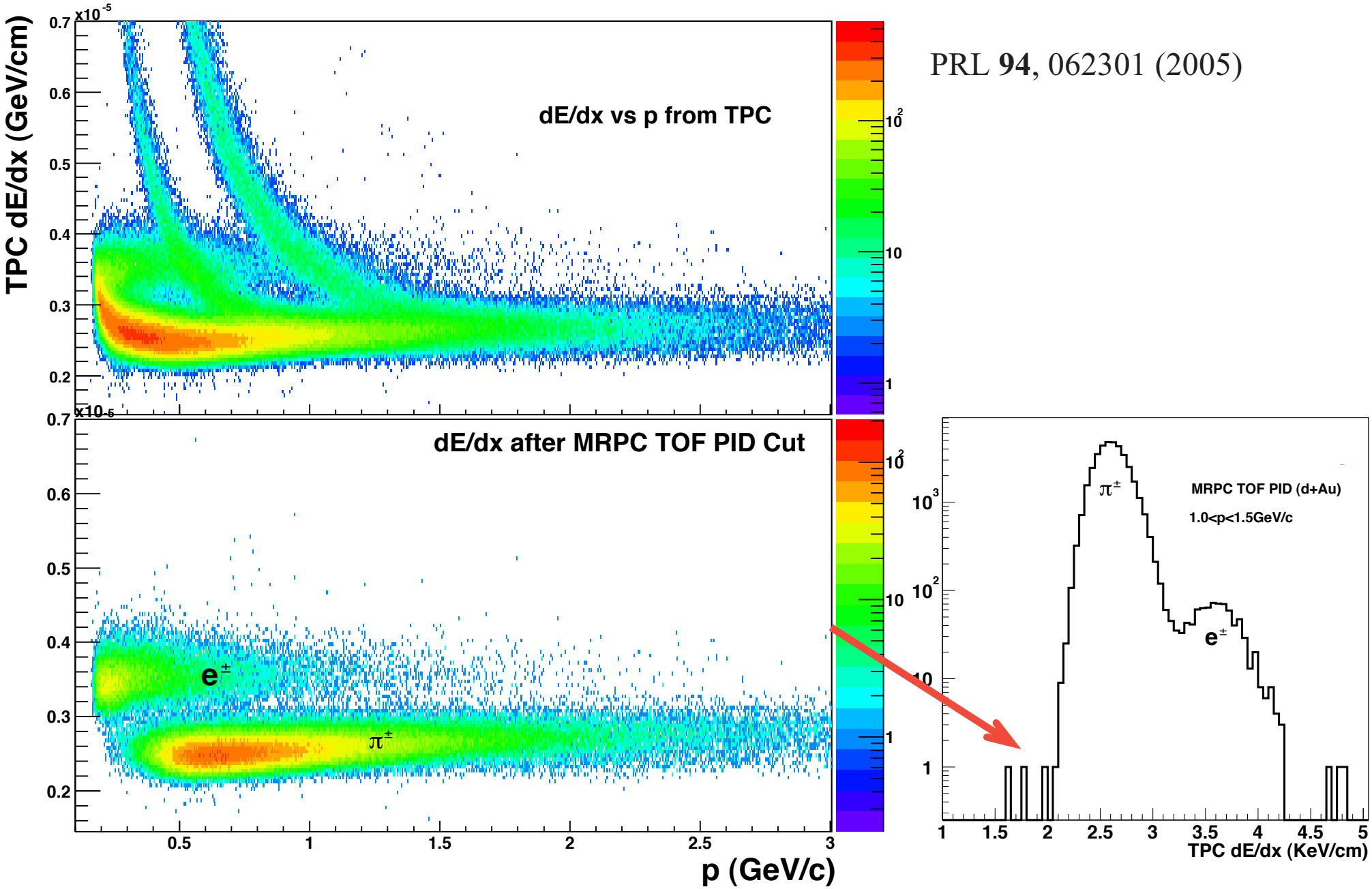
start resolution	~85ps
stop (MRPC) resn	~85ps
total	~120ps

→ π/K/p to ~1.6 GeV/c, and (π+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....

PRL **94**, 062301 (2005)



http://wjllope.rice.edu/~TOF/TOF/Documents/TOF_20040521.pdf

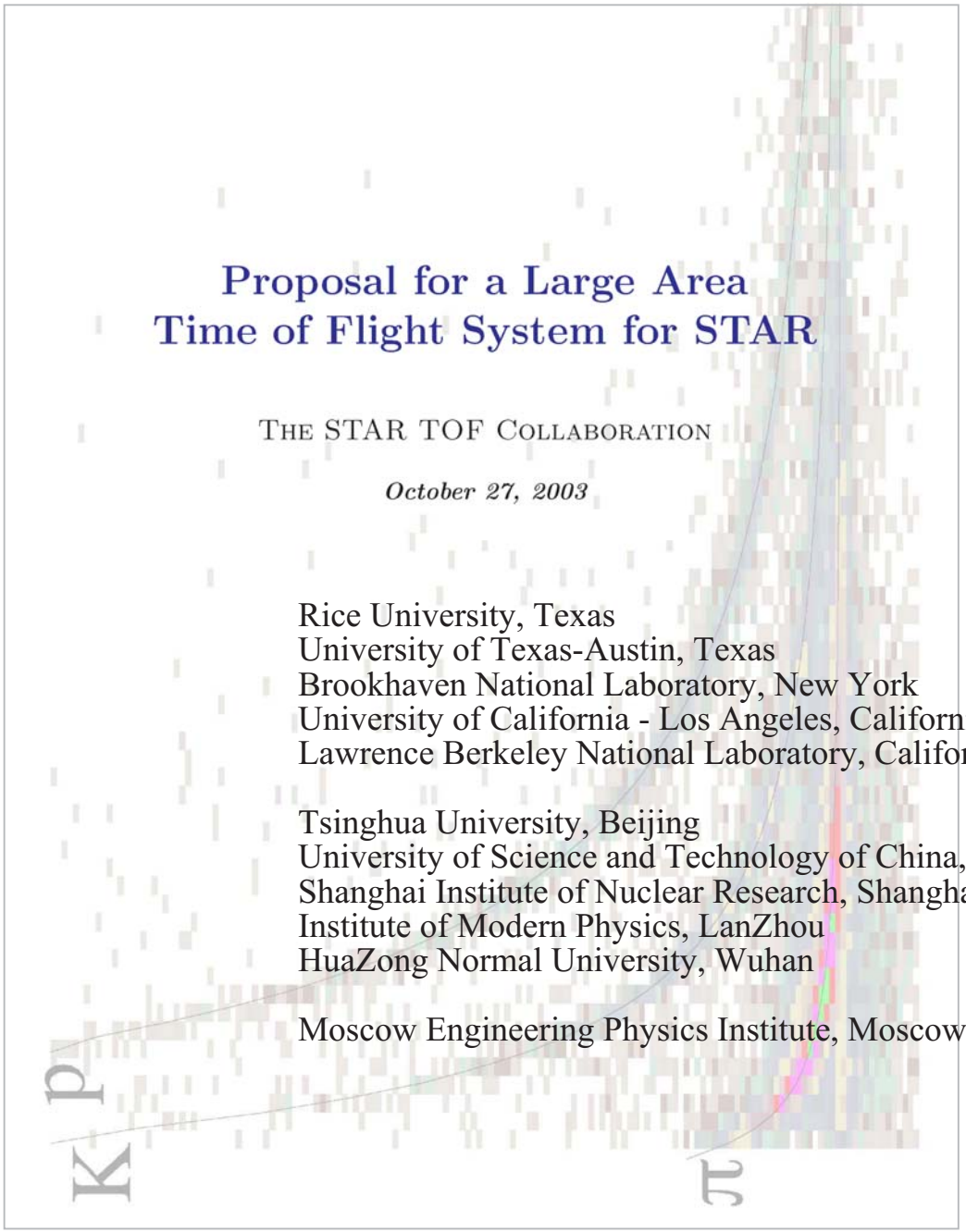
Following 3 full TOFrX prototypes, MRPCs then "proven" for STAR...

Then proposed a full system:

- cover entire cylindrical surface of TPC
  $\Delta\phi=2\pi$, $-1<\eta<1$
- ~50 m^2 total area
  120 trays
  32 MRPCs/tray
  6 channels/MRPC → 23,040 chs
- 3840+ MRPCs contributed by China
- Tray fabrication & testing in Texas
- Digitization on-board
- US Cost: 4.8 M$
  Chinese contribution: 2.3 M$

Construction project completed "on-time" in late 2009

All 120 trays installed for RHIC Run-10



Proposal for a Large Area Time of Flight System for STAR

THE STAR TOF COLLABORATION

October 27, 2003

Rice University, Texas
University of Texas-Austin, Texas
Brookhaven National Laboratory, New York
University of California - Los Angeles, California
Lawrence Berkeley National Laboratory, California

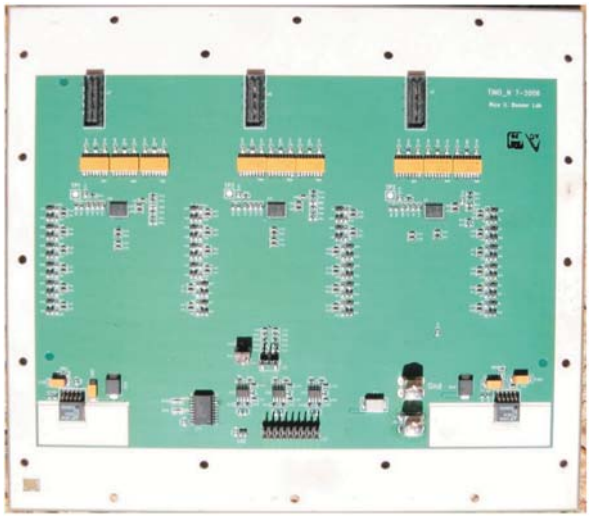
Tsinghua University, Beijing
University of Science and Technology of China, Hefei
Shanghai Institute of Nuclear Research, Shanghai
Institute of Modern Physics, LanZhou
HuaZong Normal University, Wuhan

Moscow Engineering Physics Institute, Moscow

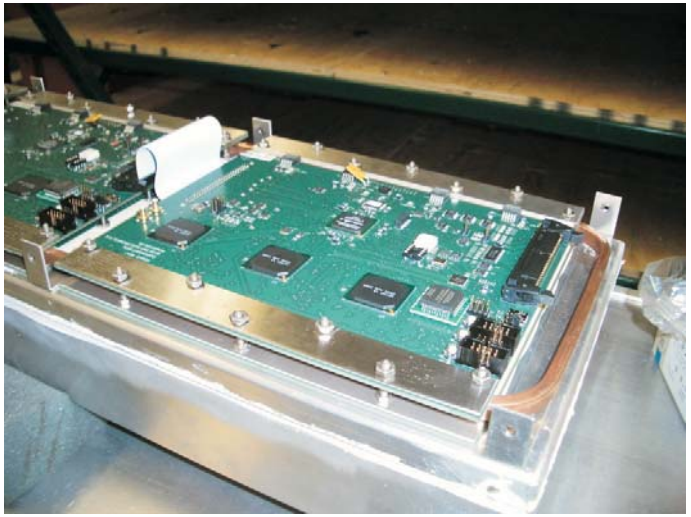
Electronics

TINO (Rice)	Seals gas box, includes 3 NINO chips	970 boards
TDIG (Blue Sky Electronics)	Digitization, includes 3 HPTDC chips	970 boards
TCPU (Blue Sky Electronics)	Collects data from each tray	122 boards
THUB (UT-Austin)	Collects tray data & ships it to STAR DAQ	4 boards

TINO



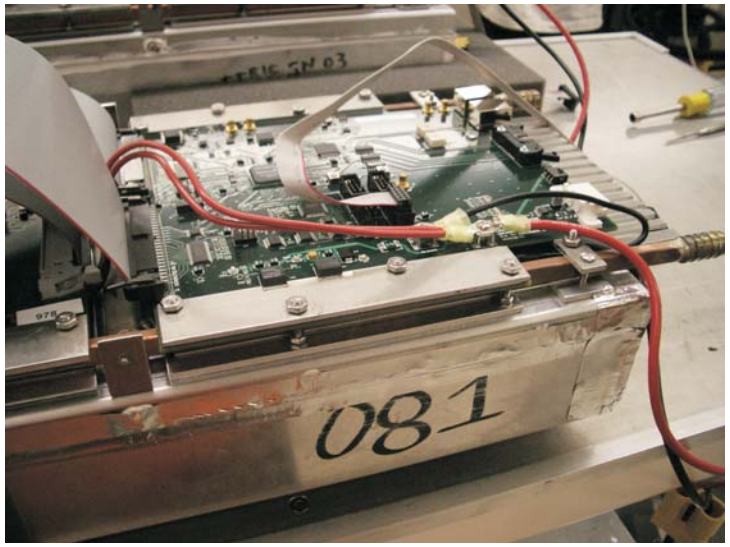
TDIG



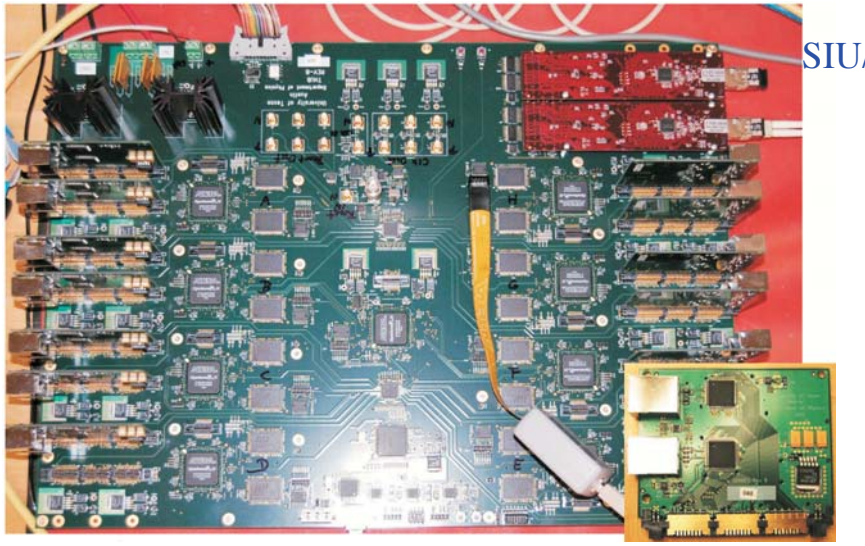
Start-side:
same electronics
except TINO→TPMT

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

TCPU



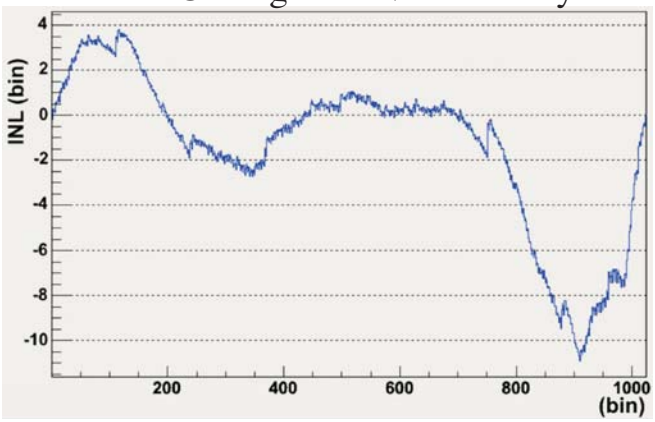
THUB



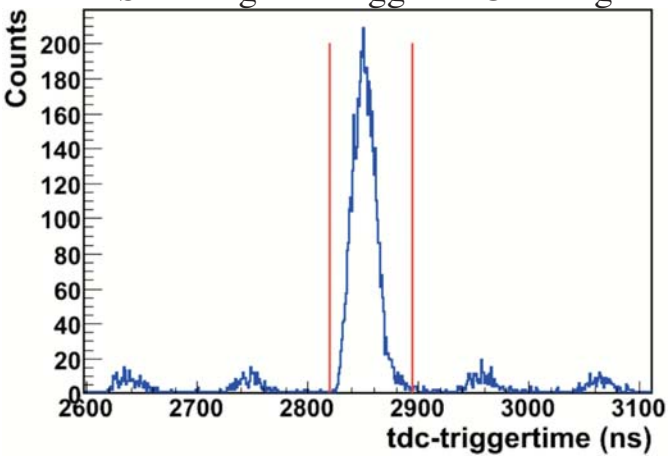
SIU/RORC

Calibrations....

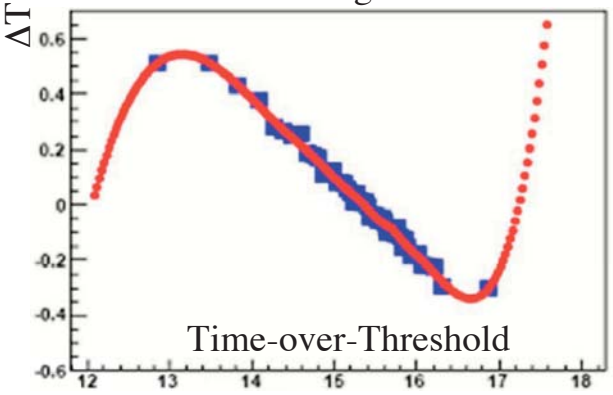
HPTDC Integrated Non-linearity



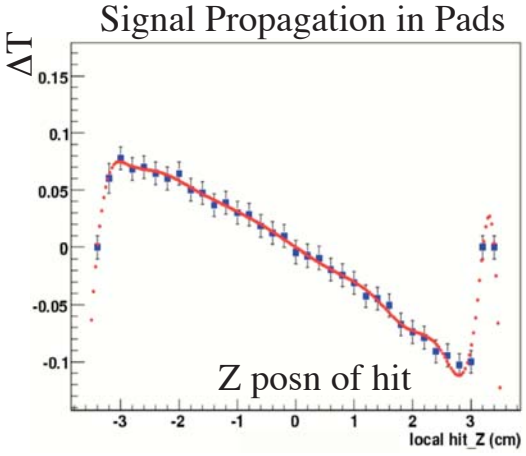
Selecting the Triggered Crossing

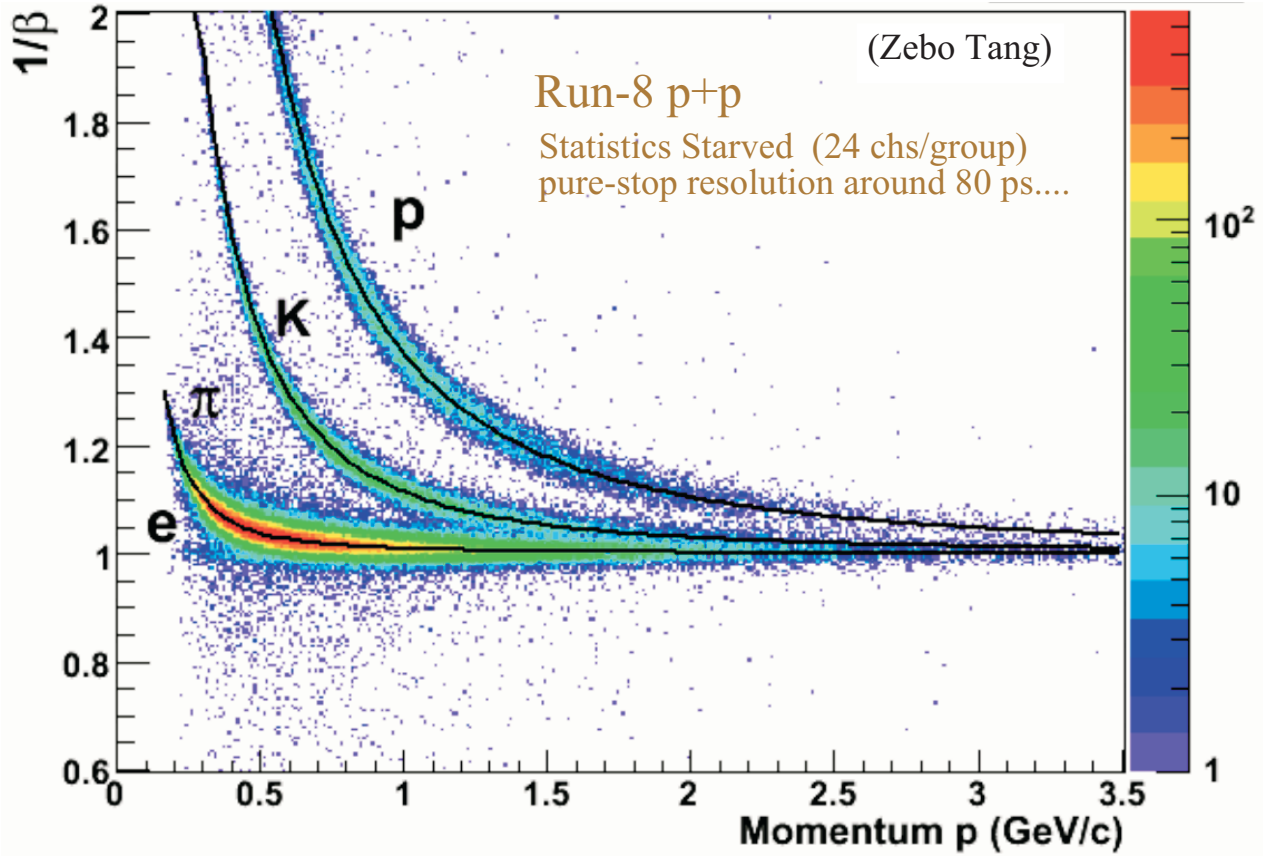


Slewing

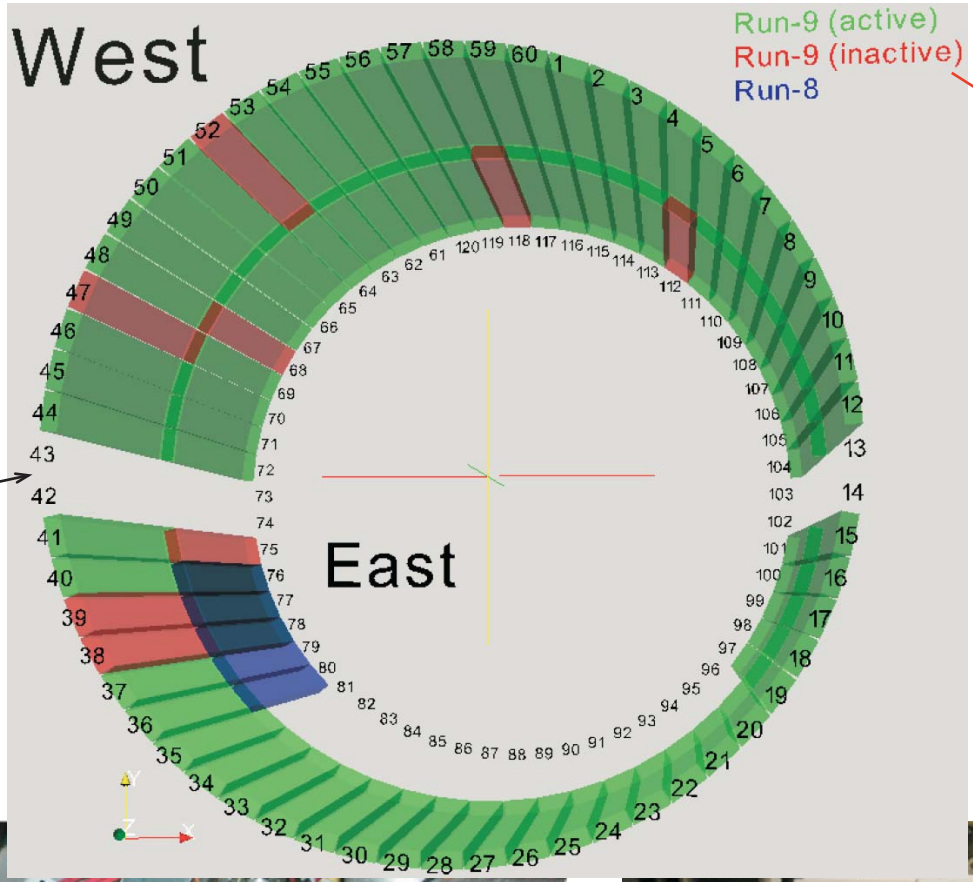


Signal Propagation in Pads





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



TPC support arms

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

Run-9: 94 trays installed

Problems with 8 trays...

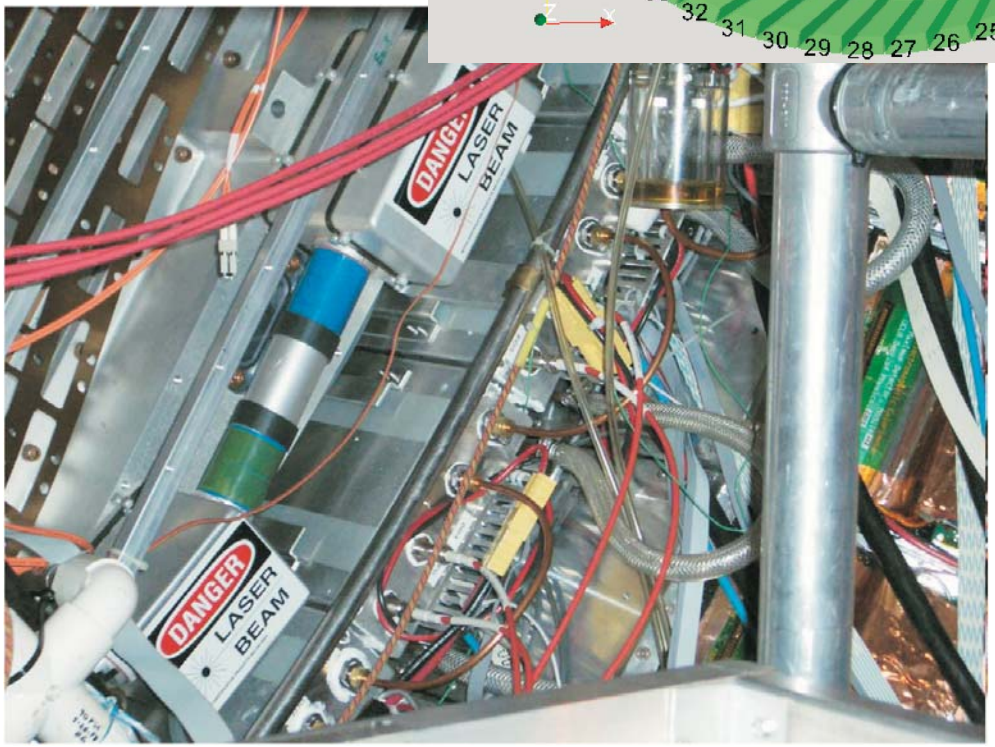
LV cabling: 2 trays
sense wires disconnected

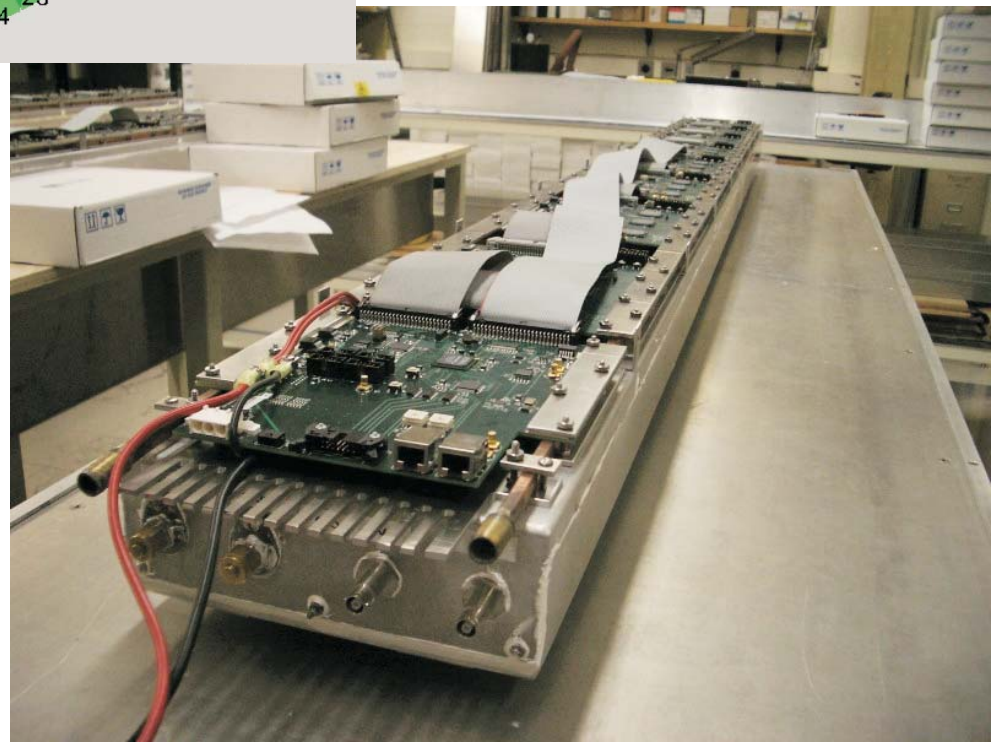
HV cabling: 5 trays
2 cables pinched by poletip
3 cables improperly connected

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)

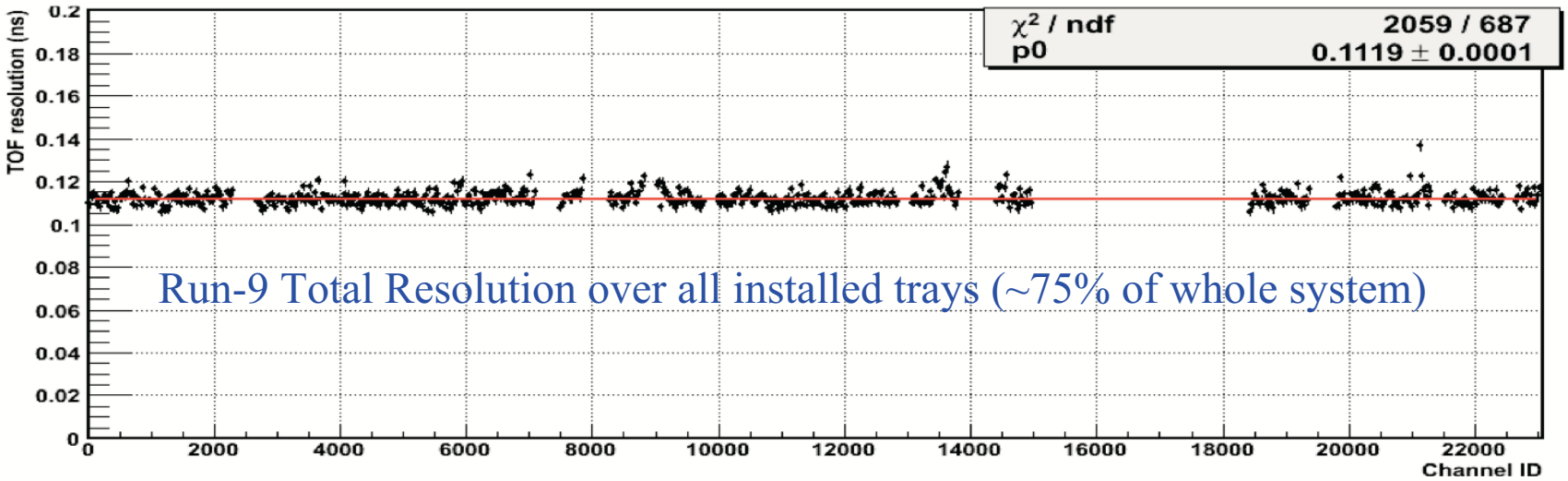




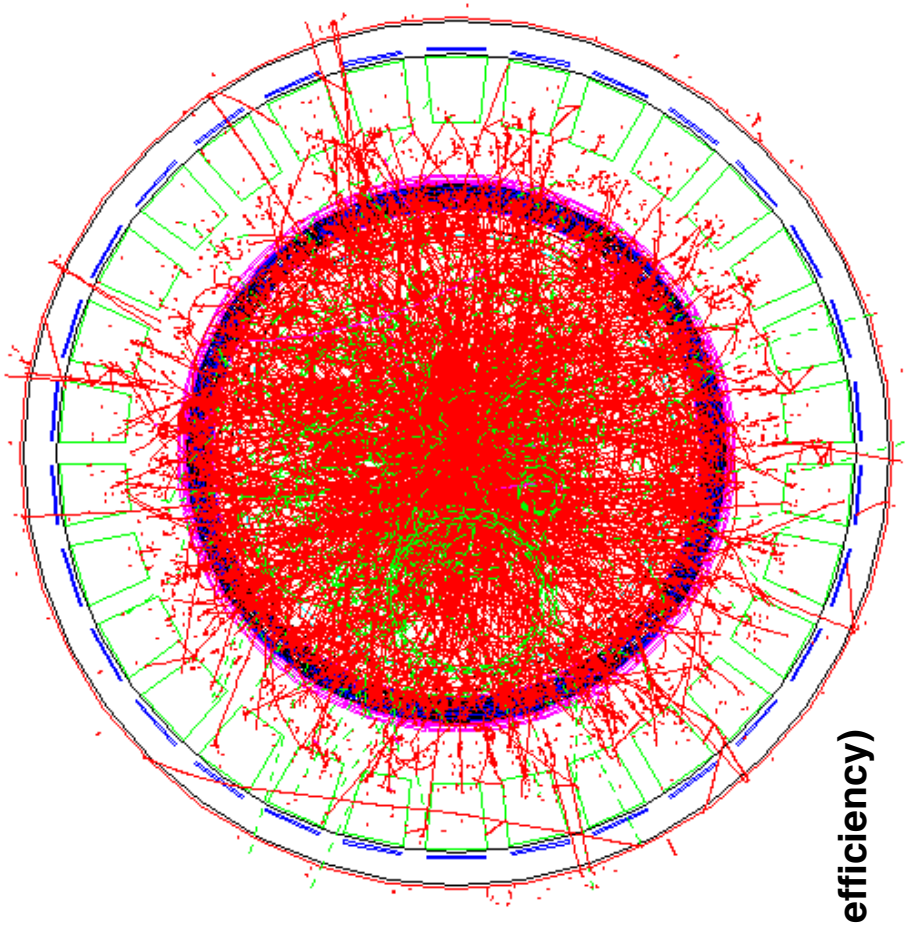
Resolution History

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



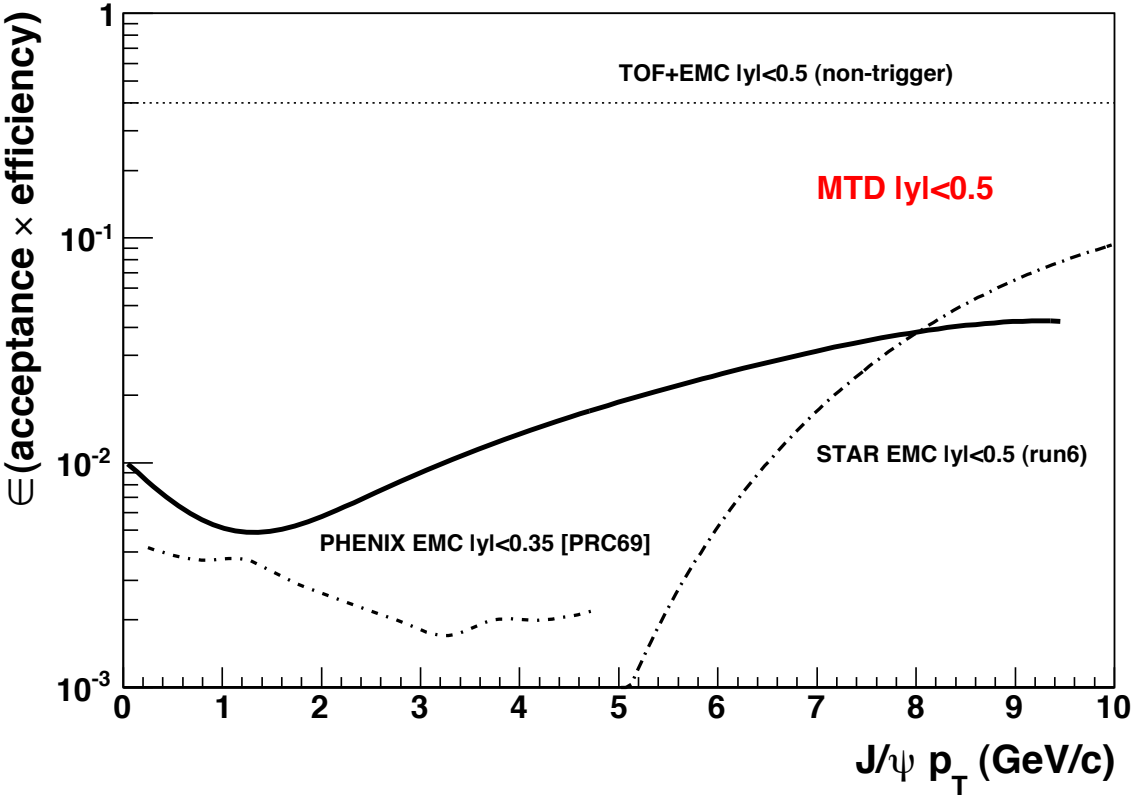
Run-9 Total Resolution over all installed trays (~75% of whole system)



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

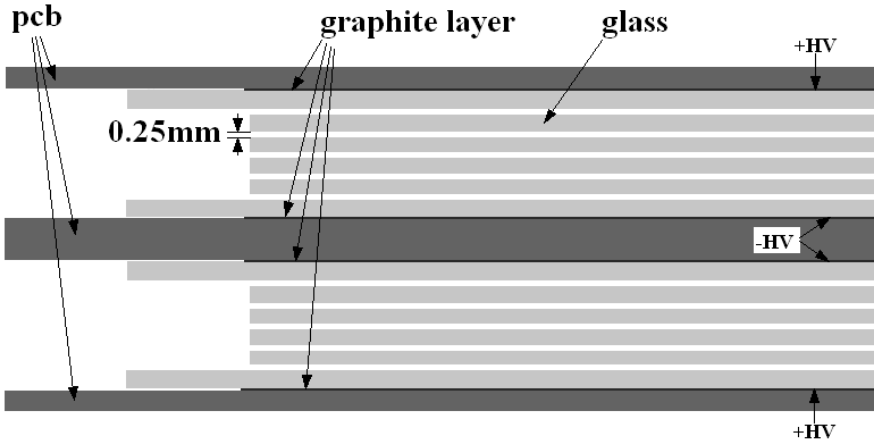
e+μ correlations from heavy flavor decays

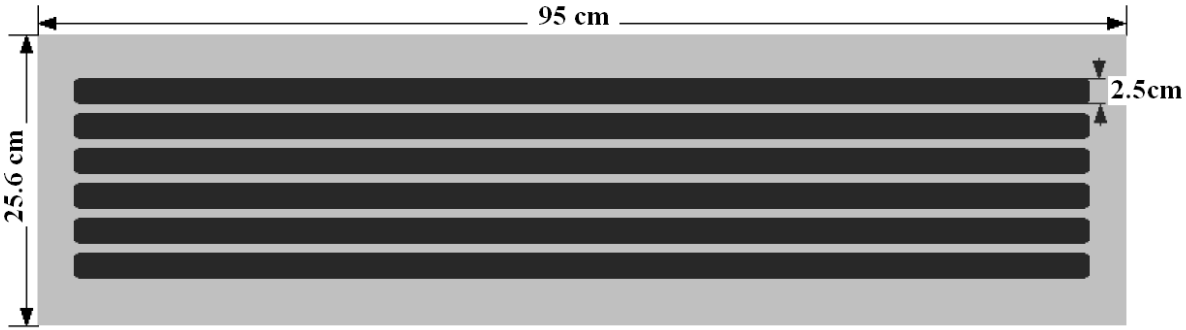
STAR MTD Prototype "LMRPCs"

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

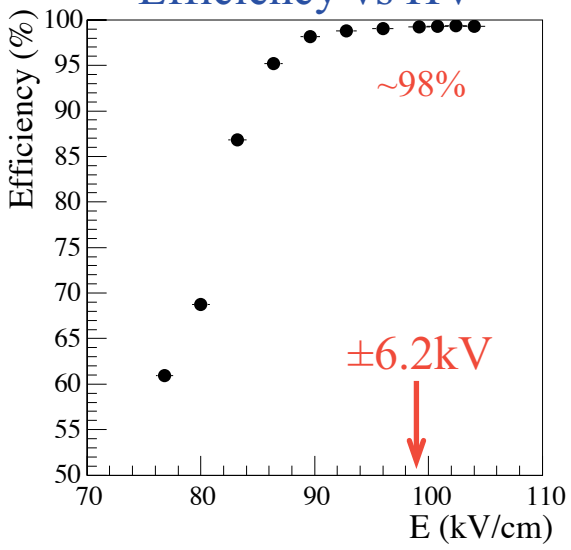
...Tested in a FNAL Test beam (T963)

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

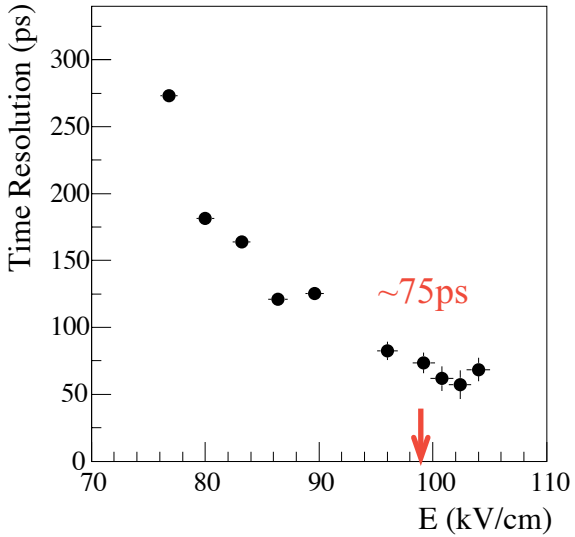




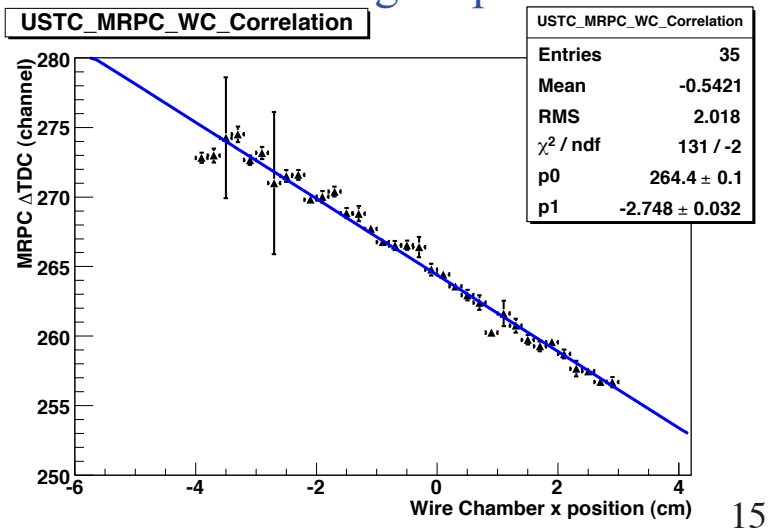
Efficiency vs HV



Time Resn vs HV



Posn along strip...



First MTD Prototype "MTD7"

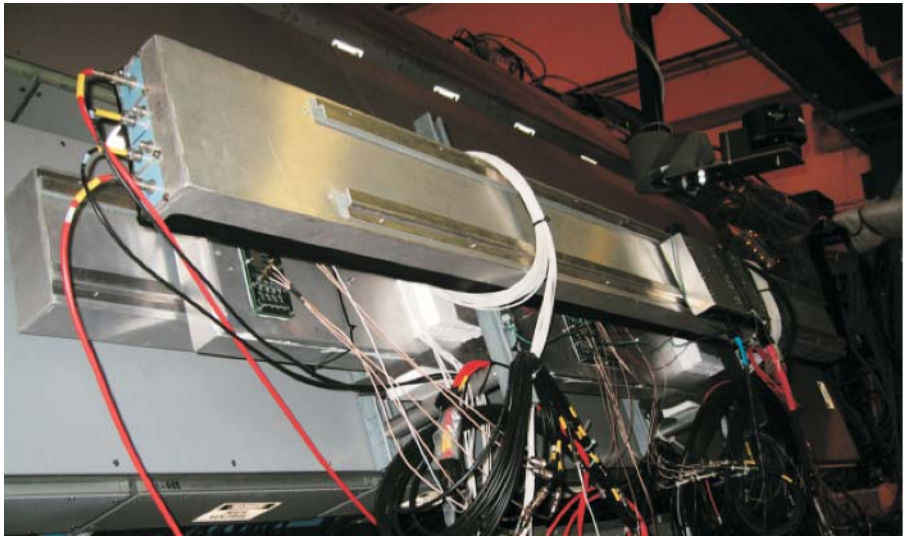
2 LMRPCs arranged end-to-end

"Simple FEE" (based on MAX 3760)
WJL *et al.*, NIM A **596**, 430 (2008)

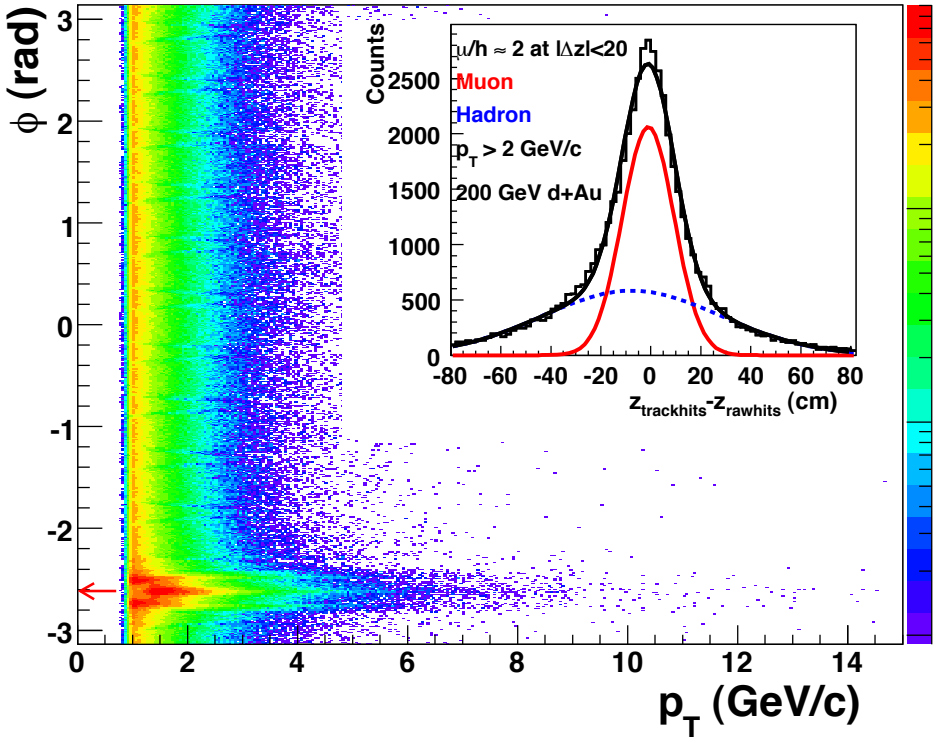
long cables before digitization
digitized with STAR TRG "CDB" boards

Operated throughout RHIC Run-7 & 8

→ timing resolution was "poor"
~ 300 ps
due to long cables and the specific digitization electronics used



matching of TPC tracks with hits in MTD (Lijuan Ruan)



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

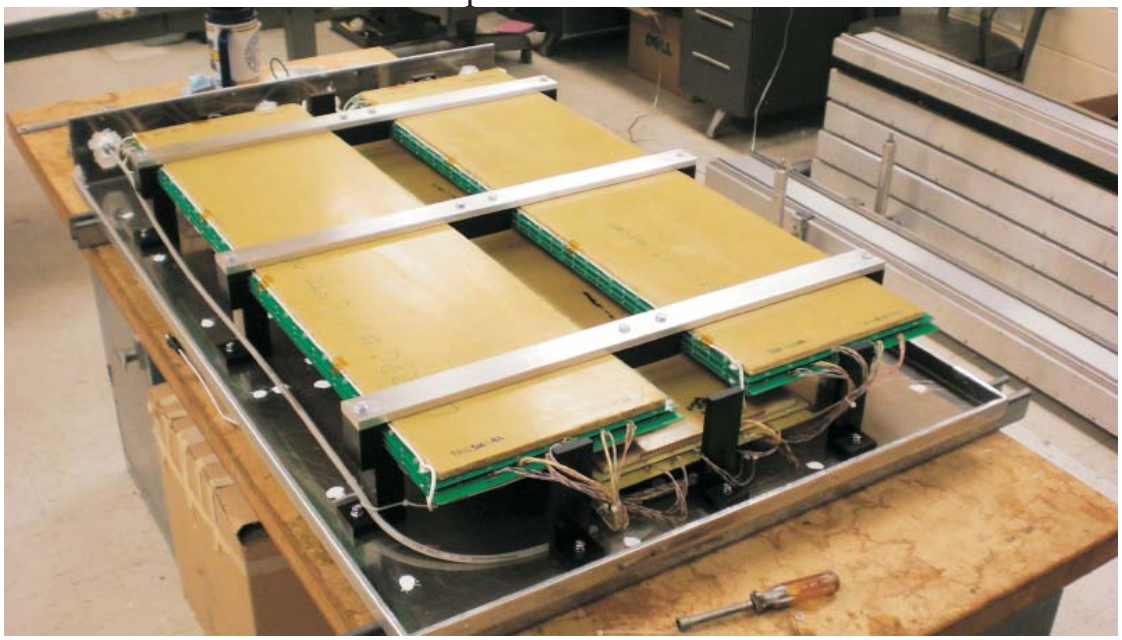
Second MTD Prototype "MTD9"

3 LMRPCs arranged side-by-side

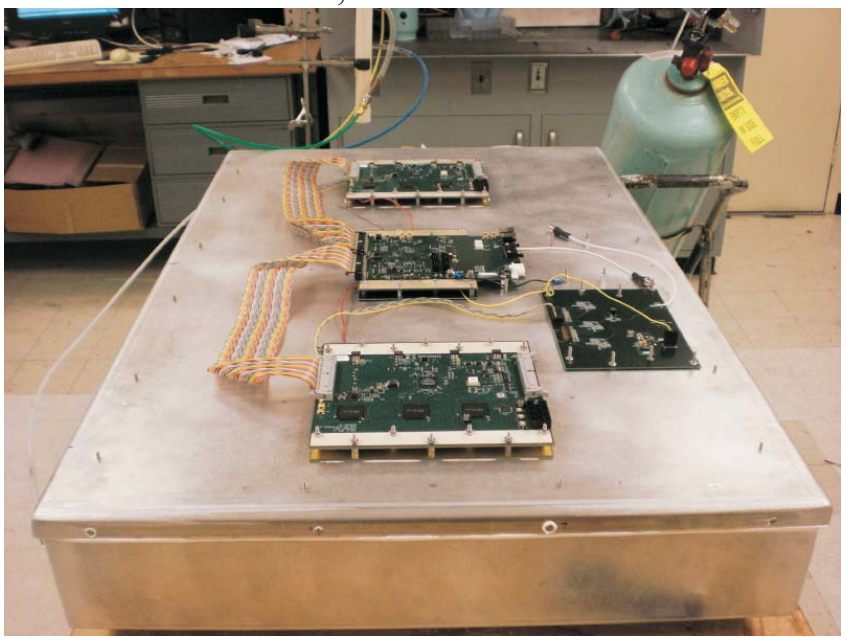
Uses TOF Electronics
TINO (based on NINO chip)
TDIG (based on HPTDC chip)
TCPU+THUB+TTRG (readout & triggering)

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

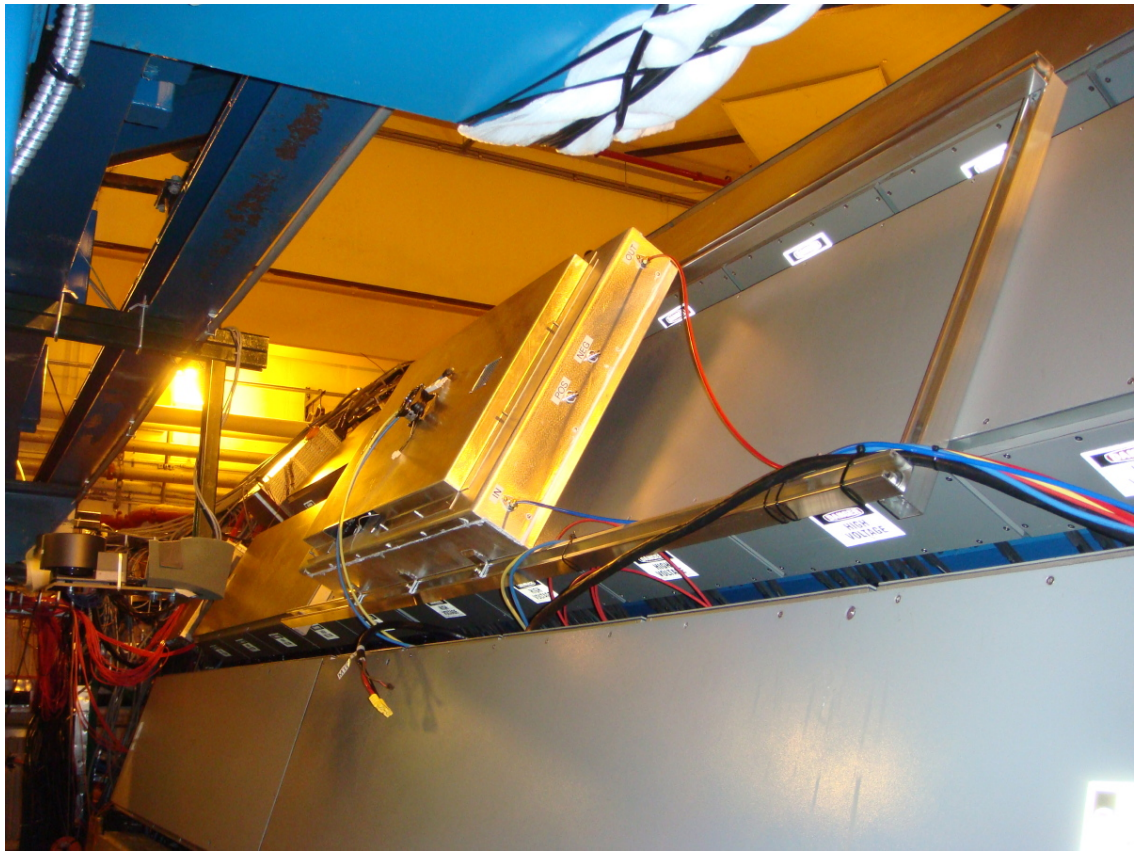
MTD9 open



MTD9 closed, with electronics



MTD9 mounted onto exterior of STAR in Run-9

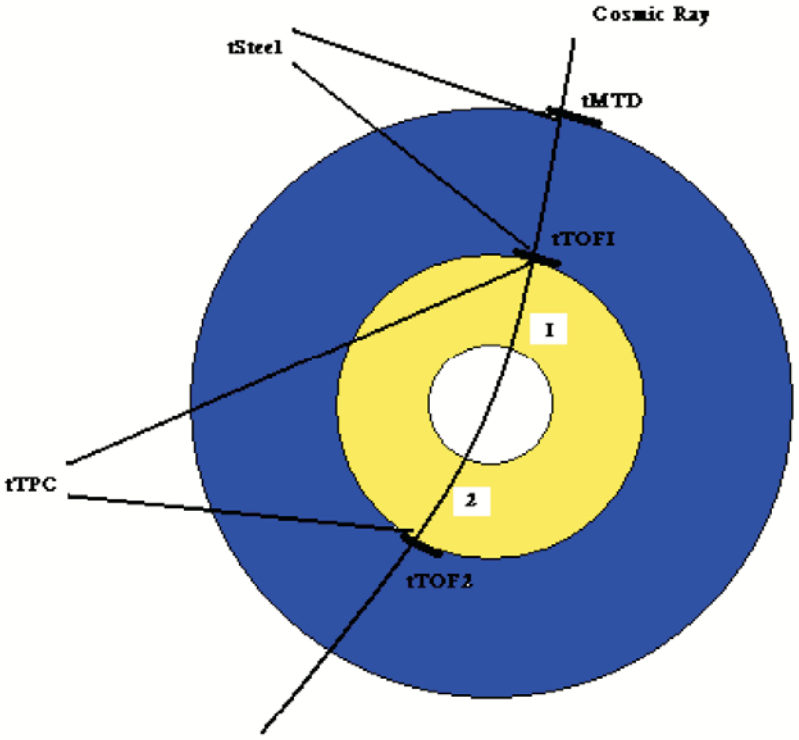


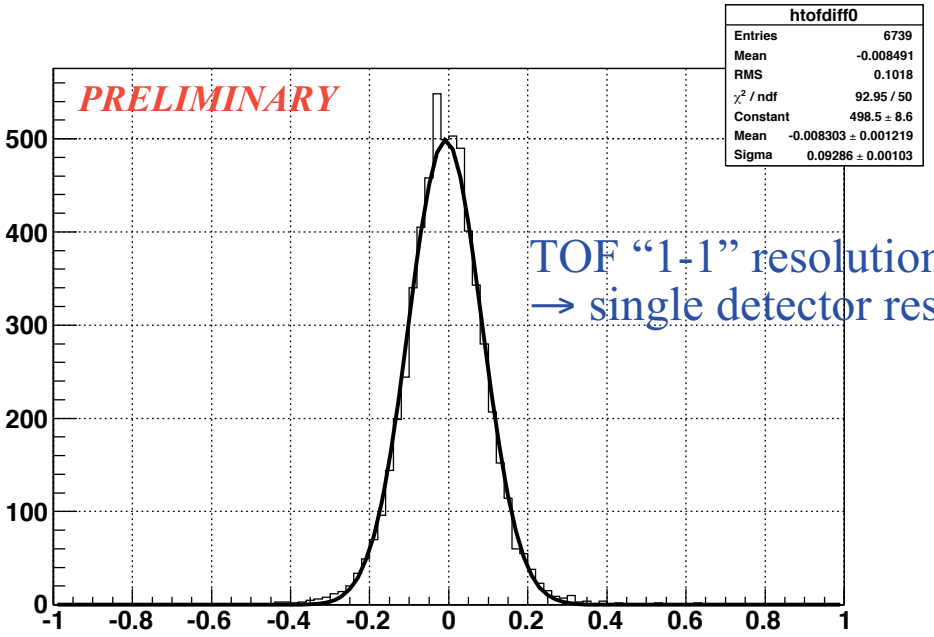
MTD9 prototype in RHIC Run-10

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

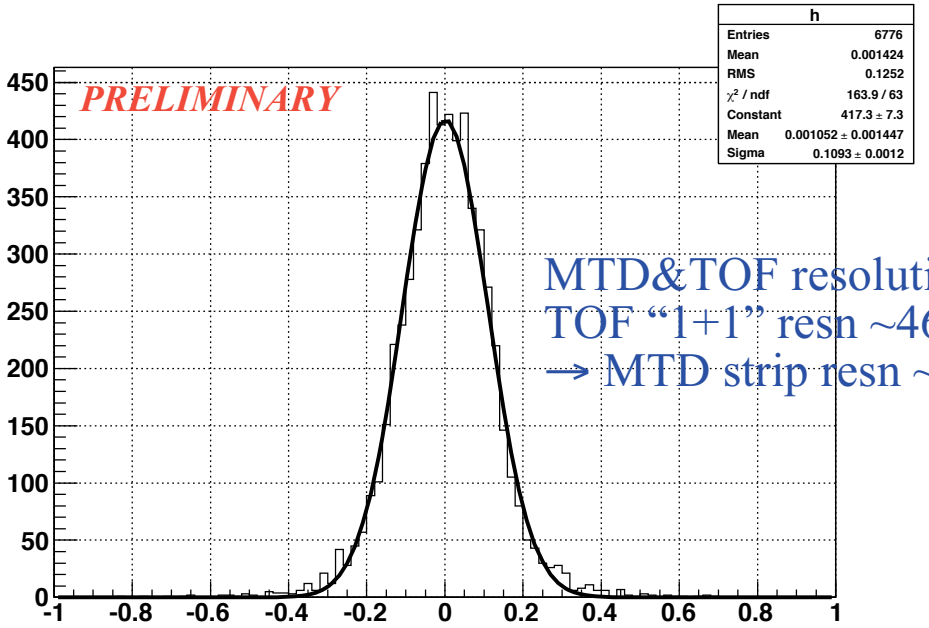
"start time" from two TOF MRPCs
"stop time" from MTD9 tray (LMRPCs)

& perform standard slewing/offset calibrations





TOF "1-1" resolution ~ 93ps
→ single detector resn ~66ps



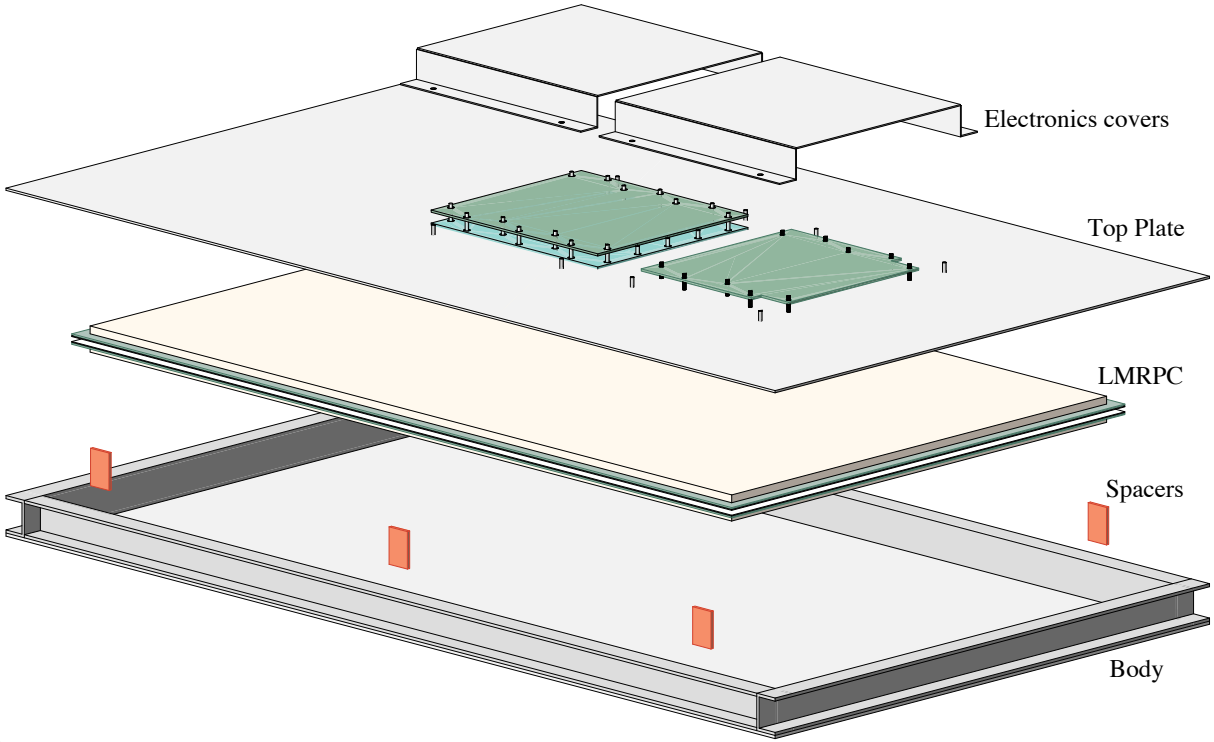
MTD&TOF resolution ~109ps
TOF "1+1" resn ~46ps
→ MTD strip resn ~99ps

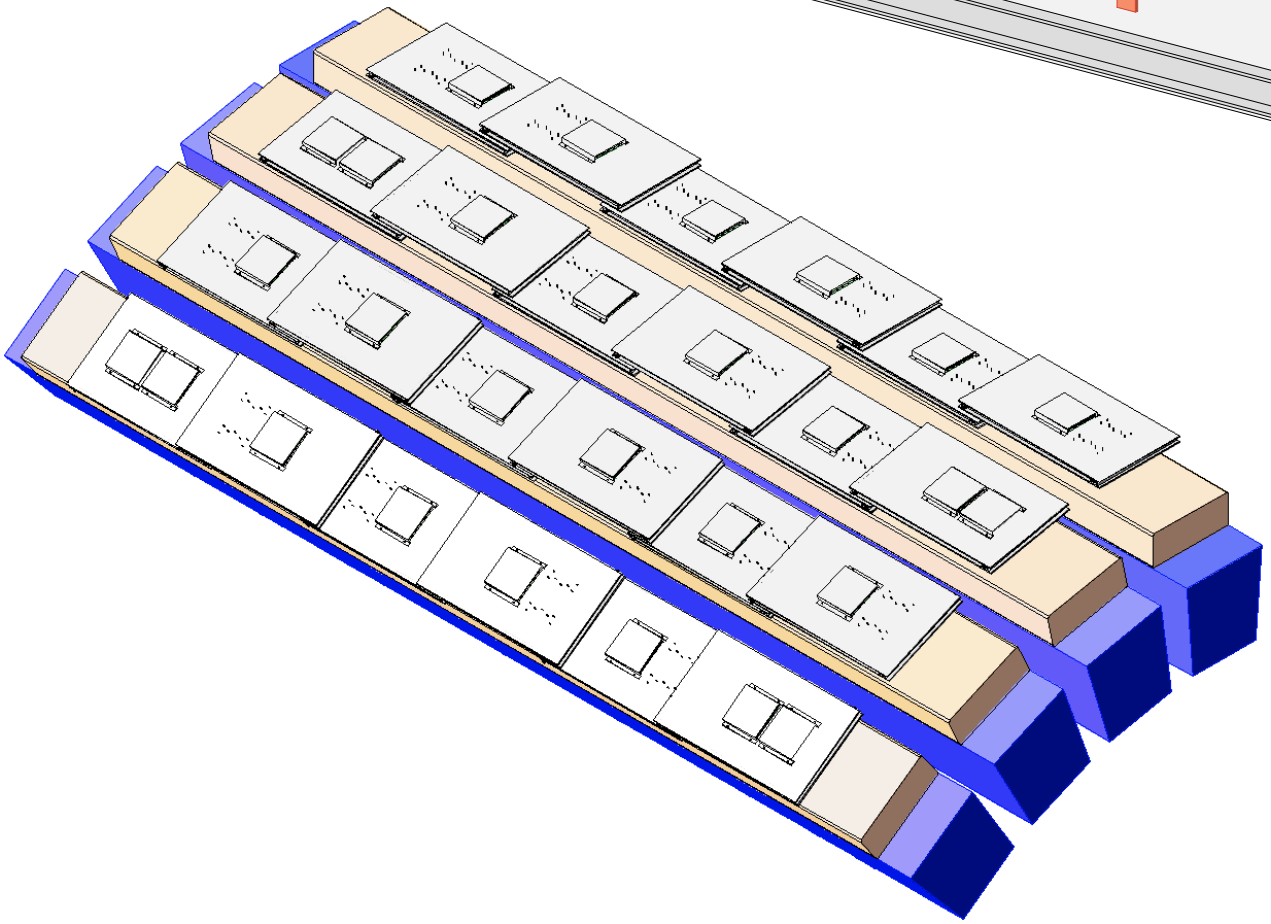
Analysis by Liang Li (UT-Austin)
and Lijuan Ruan (BNL)

Sat Jul 31 17:44:51 2010

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 in the summer of 2009
& ran very well in RHIC Run-10...

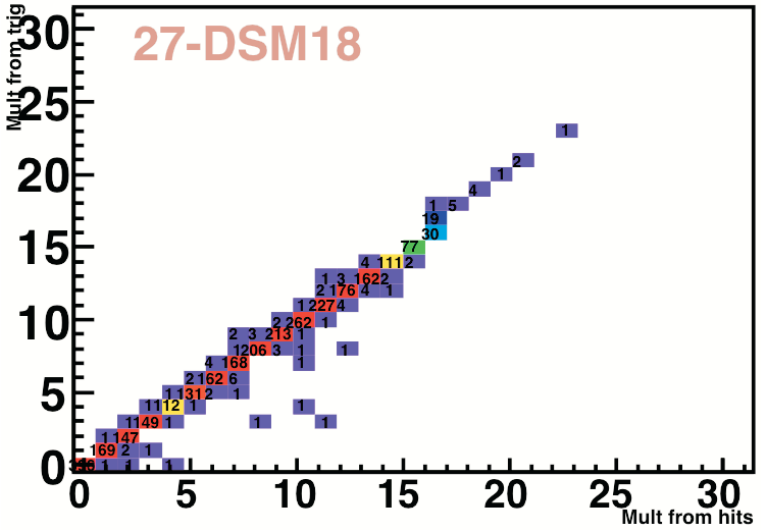
... 2 bad channels out of 23,040

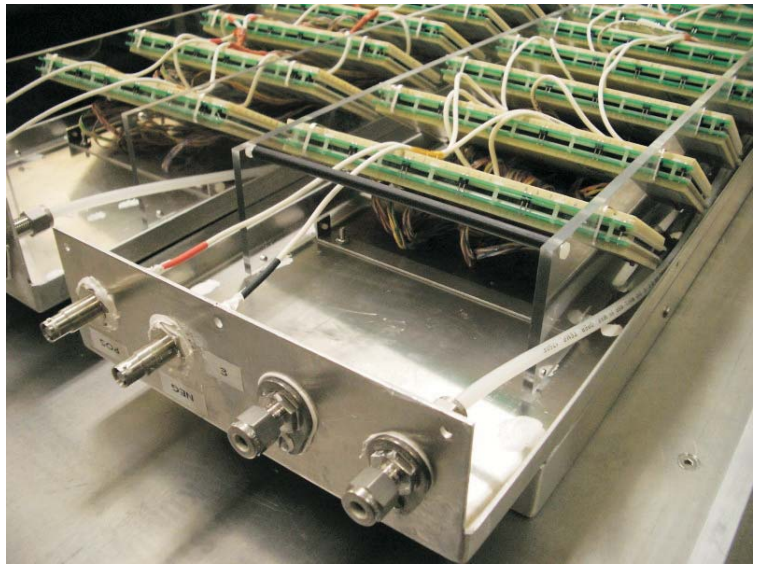
... 1 disabled tray out of 120 (one bad HV cable, will be fixed a.s.a.p.)

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

... MRPC time resolution ~80ps

...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

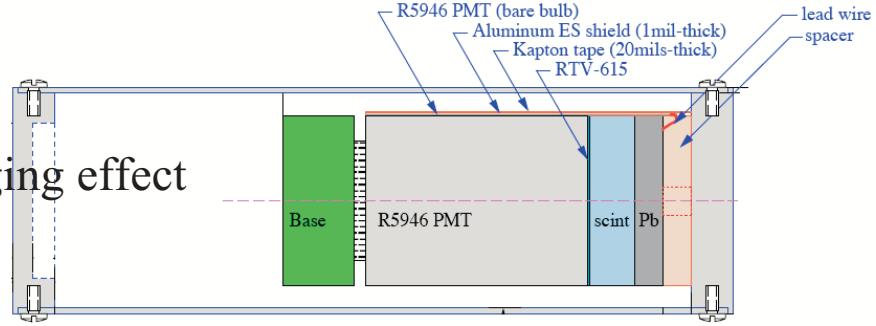
Three tray patch with WMRPCs with be installed in Run-11.

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

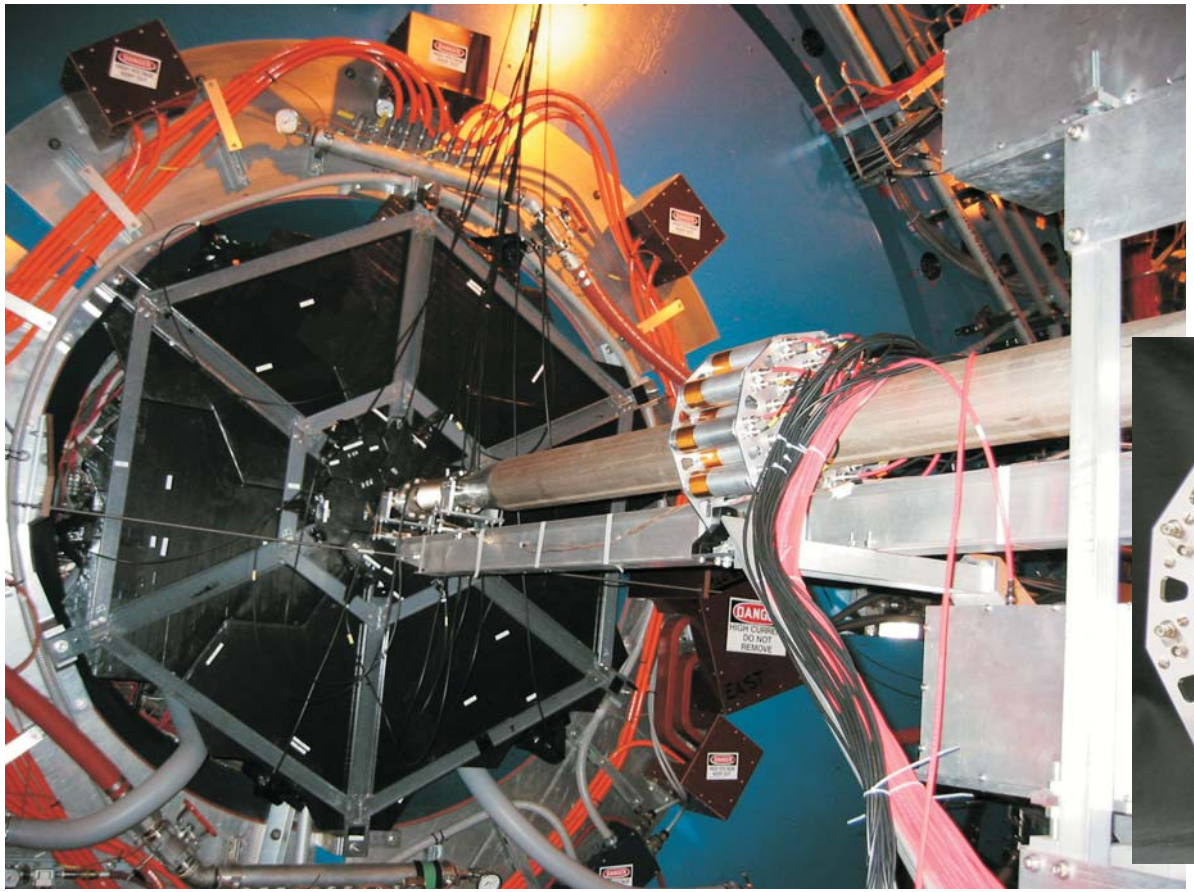
BACKUP SLIDES

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!!

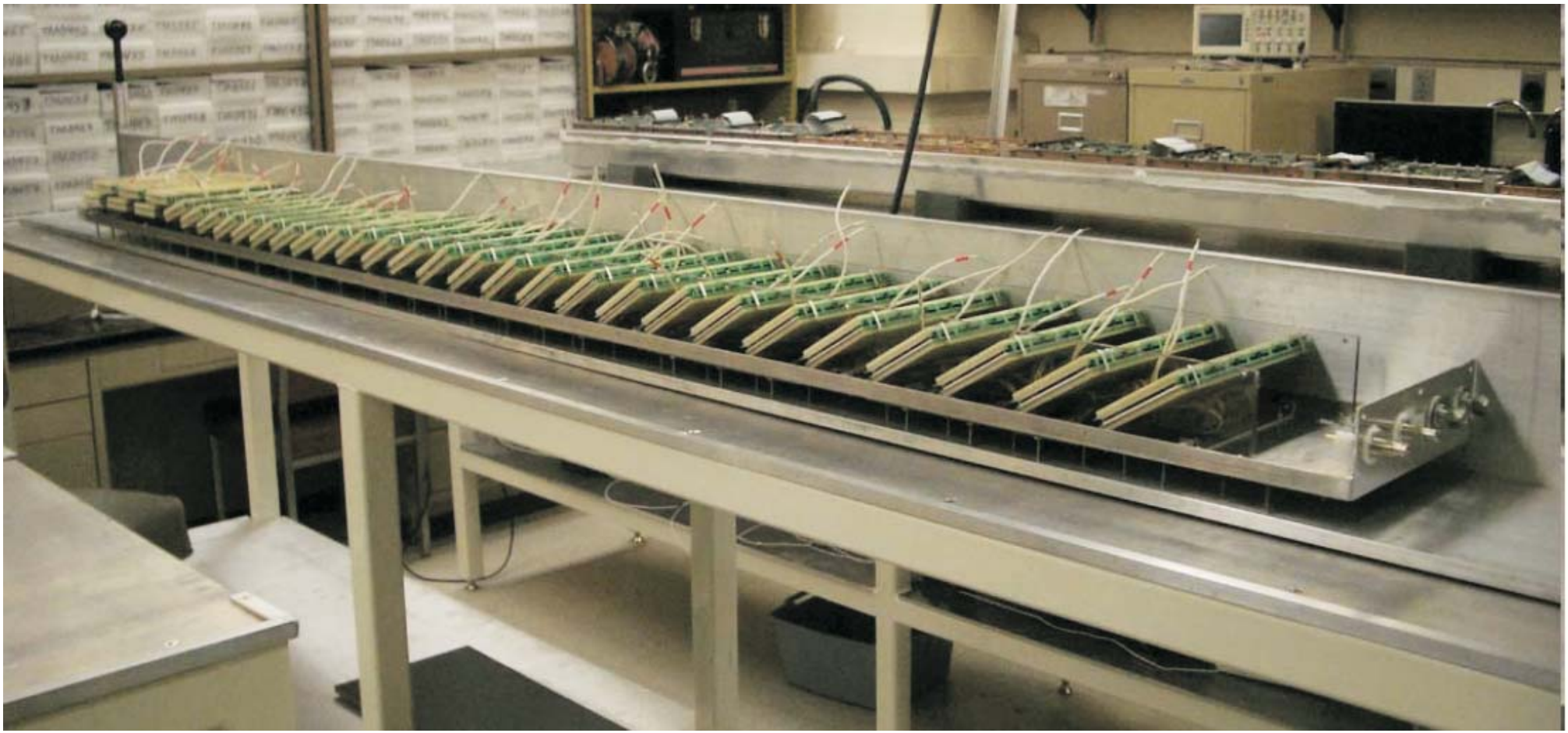
32 MRPCs per tray

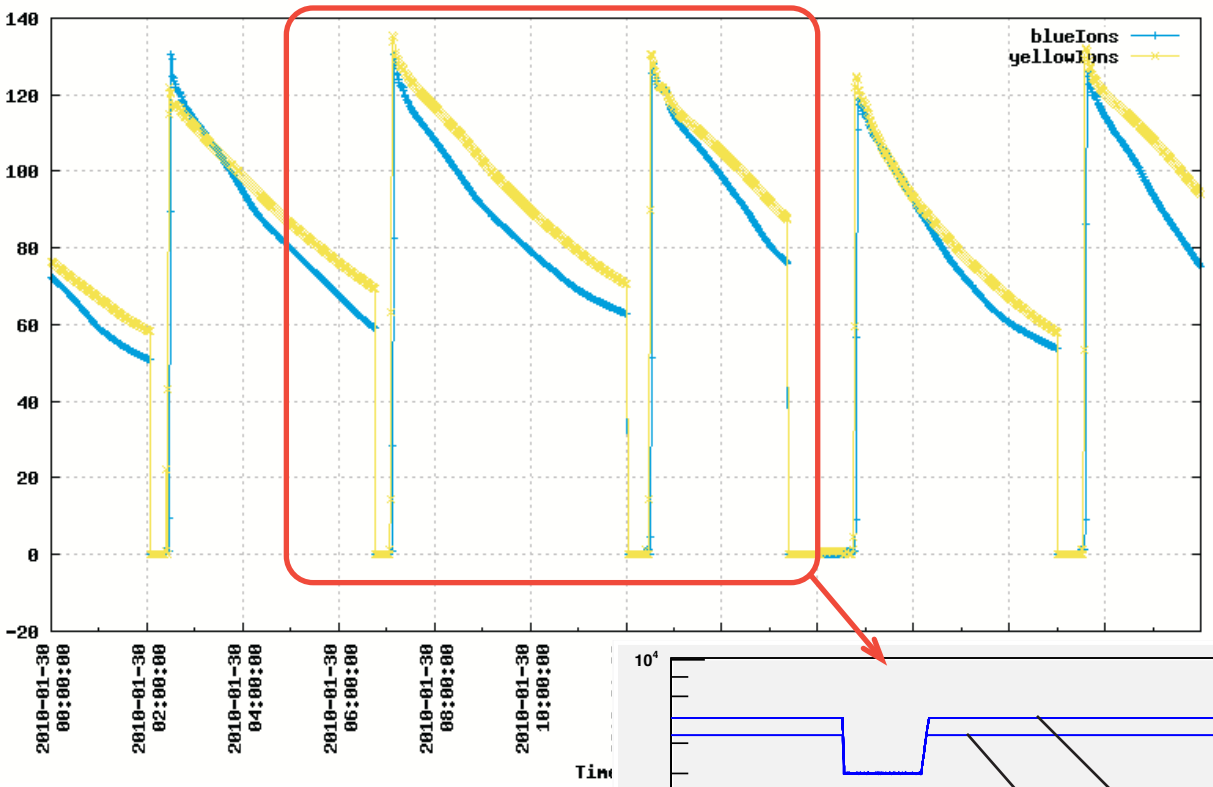
Very limited space for detector placement (~3 inches)

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



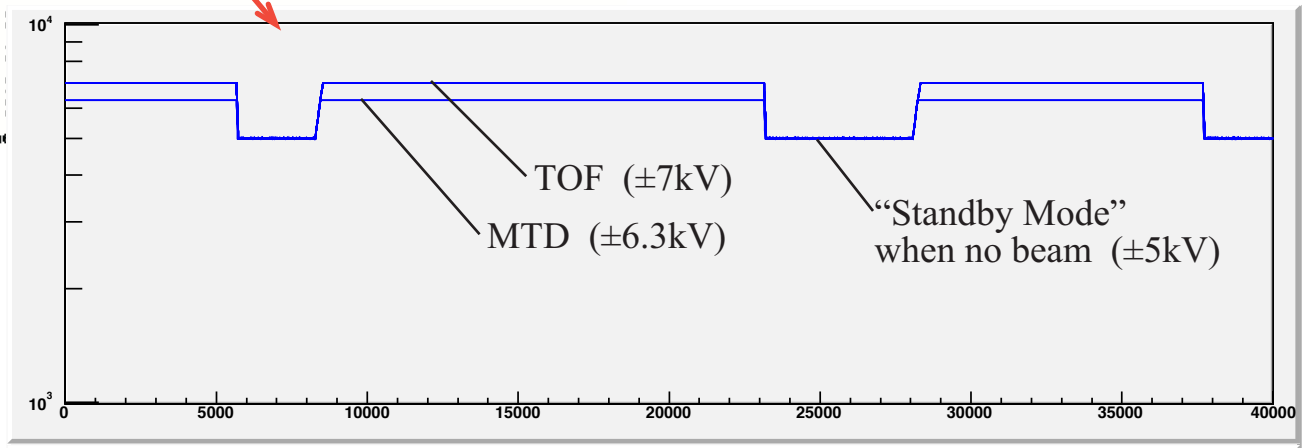


TOF & MTD9 HV Currents during running....

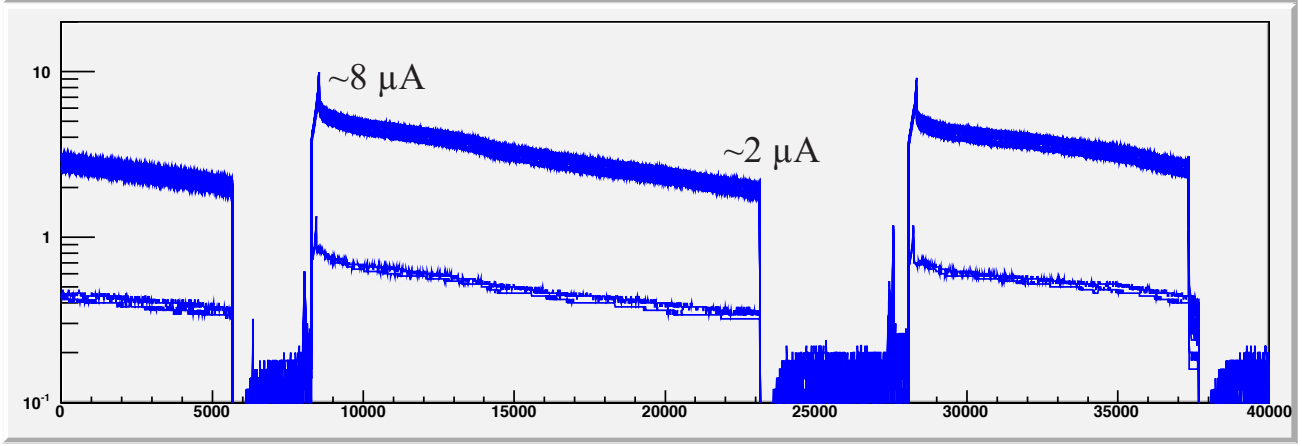
120 TOF trays

24 TOF supplies
(12 Pos & 12 Neg)

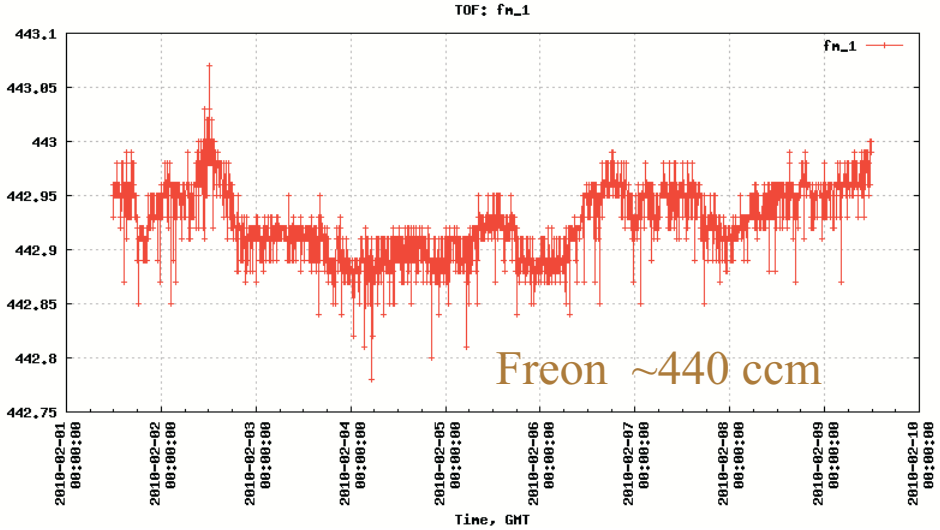
→ 10 trays/supply
→ 320 MRPCs/supply

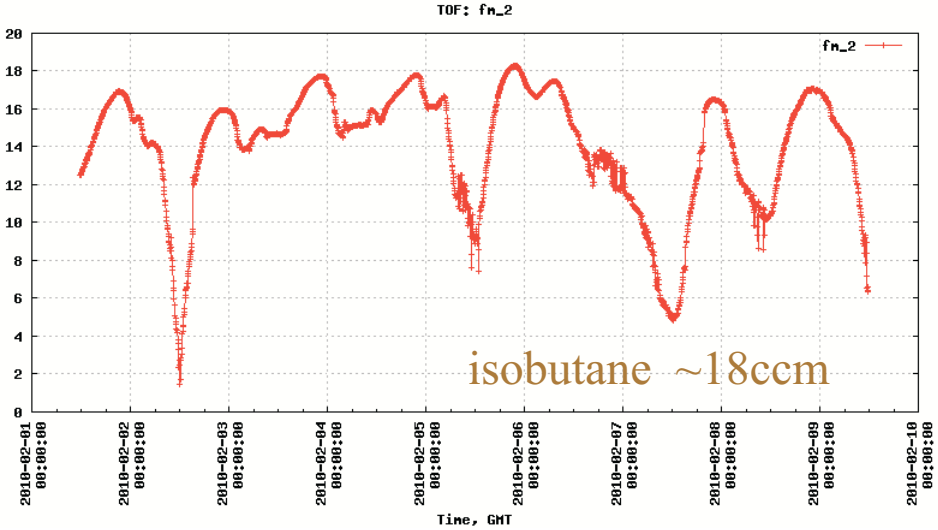


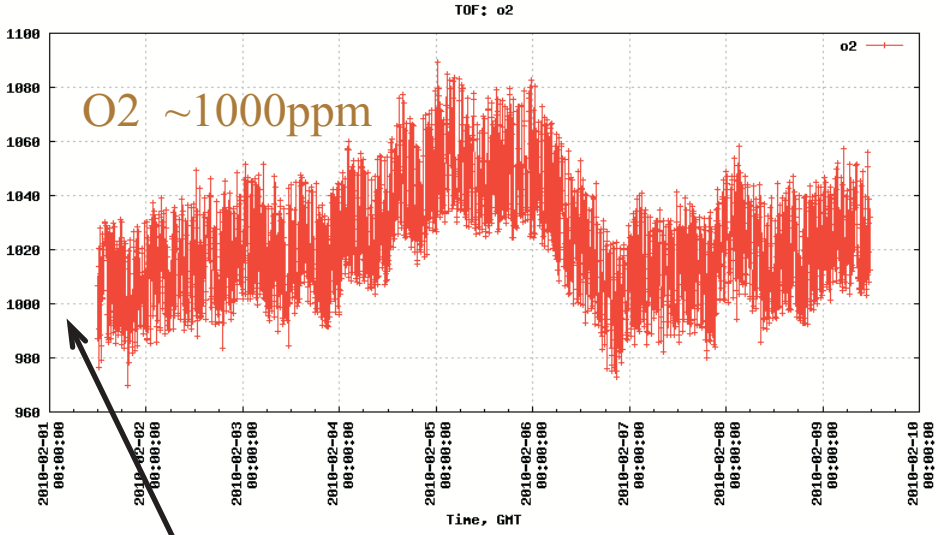
2 μA/320 MRPCs = ~6 nA/MRPC

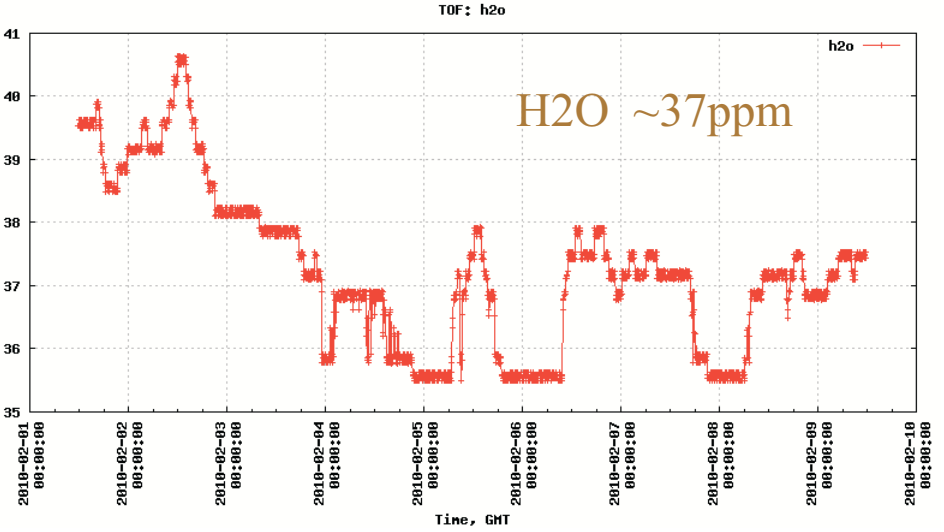


Some Gas System Parameters....









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.

...O2 reduced by another factor of ~5 by insuring trays at overpressure w.r.t. atmosphere....