Detector Design & Construction

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☆ TOF Review, BNL

January 26-27, 2006

Outline:

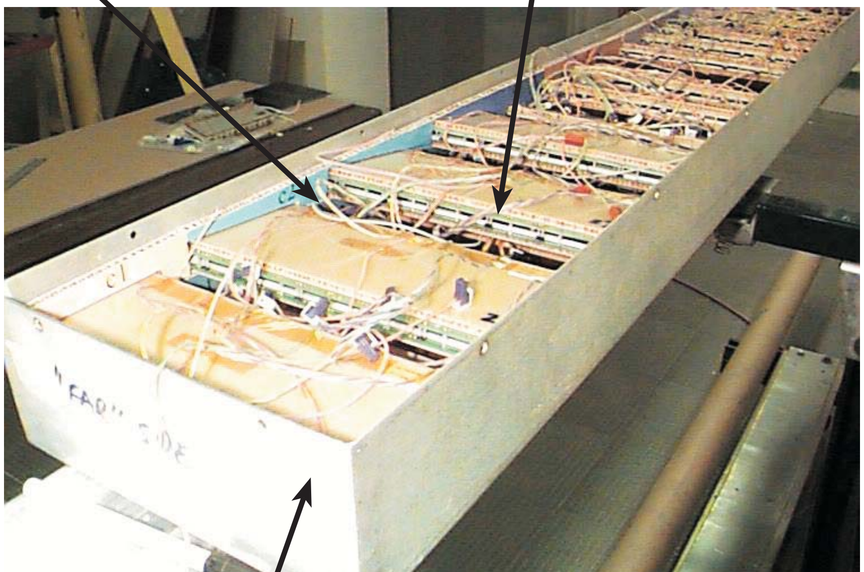
- Tray mechanical design
  TOFr, TOFr’, TOFr5, &TOFrX
- Impact of full system on STAR
- Integration Volumes
- MRPC design, materials, tolerances
- High Voltage
- Start detector

D&M: TOFr (Run-3)

first implementation of the MRPC technology in a collider experiment
readout uses (TOFp's extremely well-understood) CAMAC DAQ
→ do these detectors work at all for us?

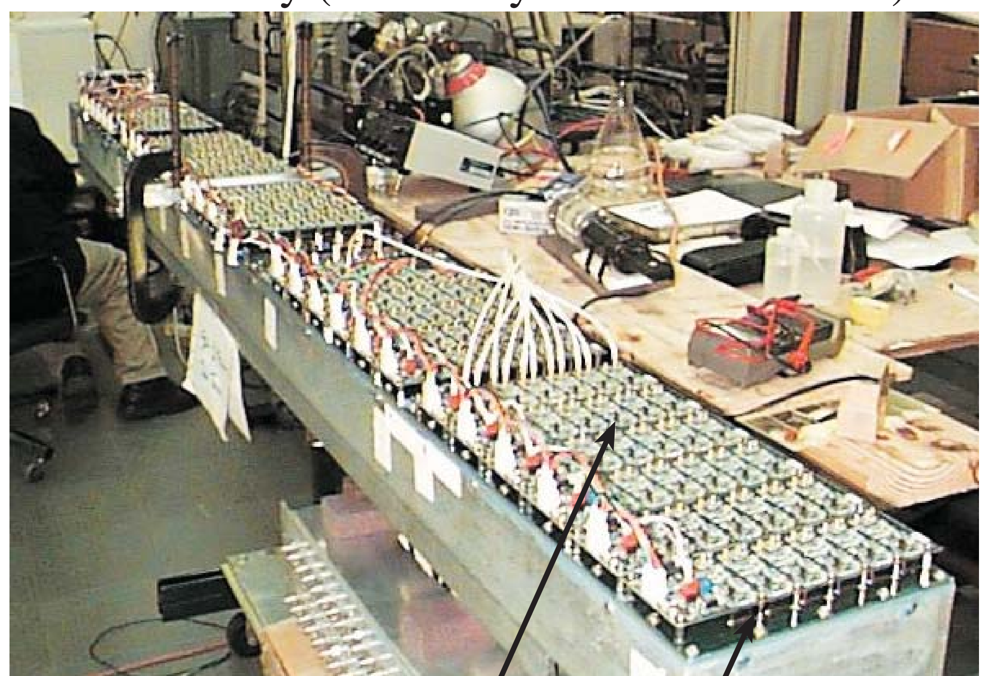
welded/tapped rail assembly
(glued gaskets also)

"sawtooths" USTC & CERN MRPCs



standard CTB tray

final TOFr tray (note many cables not shown!)

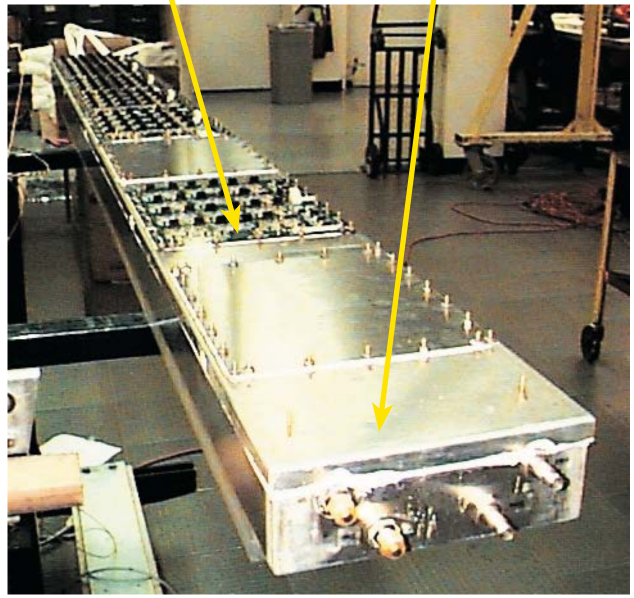


FEE layer F/T layer

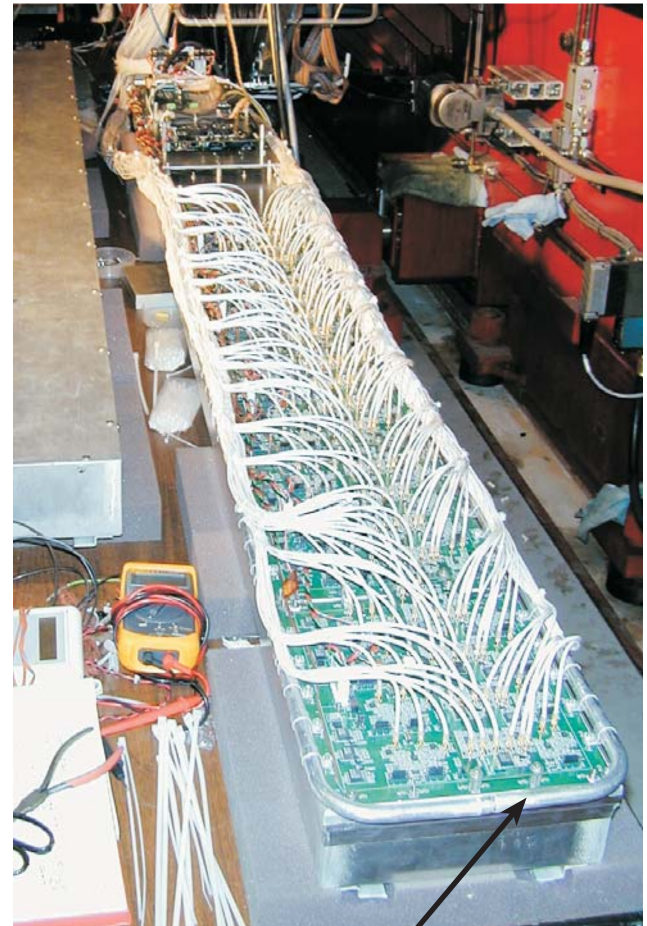
- fabrication extremely labor intensive...
  sawtooths, rail assy
- complicated gas sealing...
  gaskets, sealant (was also *wrong* sealant)
- MRPC placement w/in box too imprecise...
  each sawtooth placed individually
- overall, too tall

D&M: TOFr' (Run-4)

completely new tray and electronics
    first system to use a TOF-specific box, not a recycled CTB box
one FEE layer, which also closes the gas volume
new batches of MRPCs (USTC, Tsinghua)

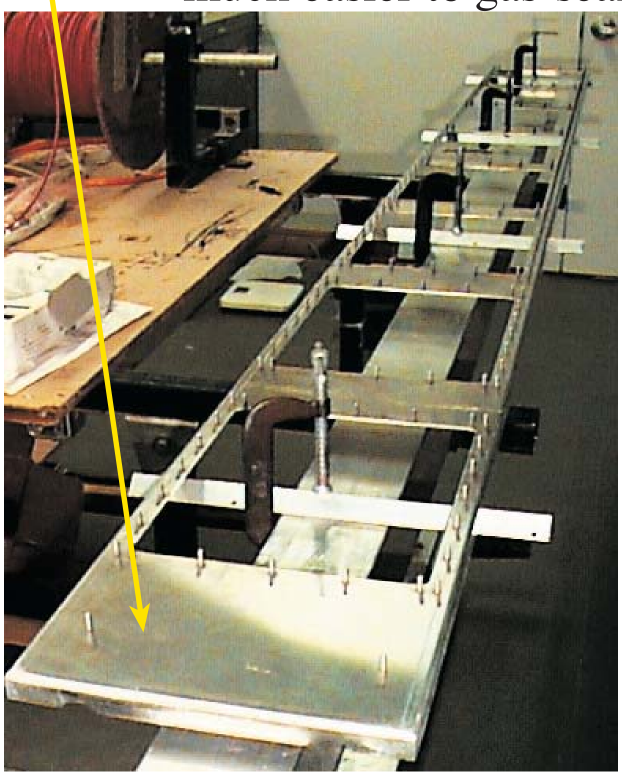


TFEE   "Shoebox" top



"last minute" cooling loop

top assy now fabbed out of house
- stamped, braked, welded
- PEM studs
  - positioned to few mils
  - no tapping
  - much easier to gas-seal



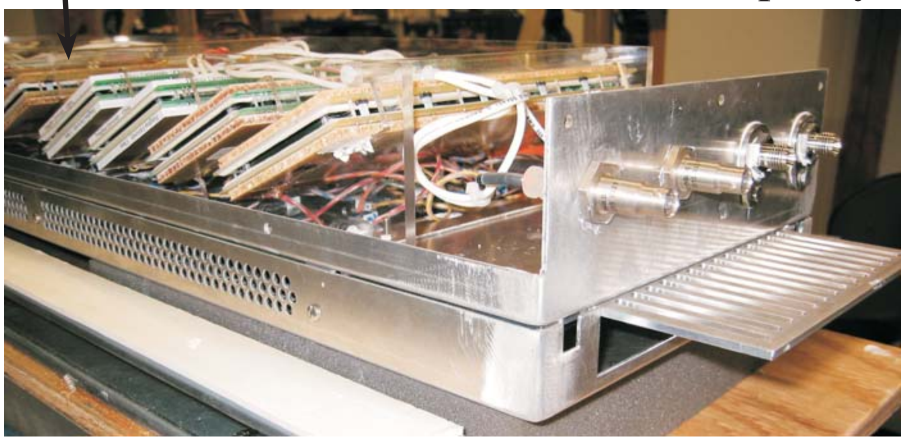
- fabrication ~~extremely~~ labor intensive...
  sawtooths, ~~rail assy~~
- ~~complicated gas sealing~~...
  ~~gaskets~~, *less* sealant (but the correct sealant this time)
- MRPC placement w/in box too imprecise...
  each sawtooth placed individually
- overall, too tall

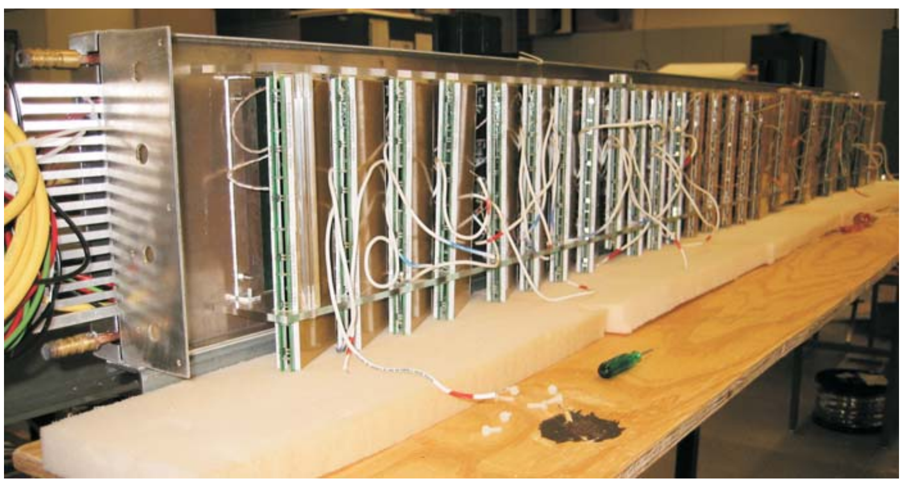
FEE dumped a lot of heat into the box
    increased MRPC current draw, & noise rates...
    timing seemed o.k. but...

D&M: TOFr5 (Run-5)

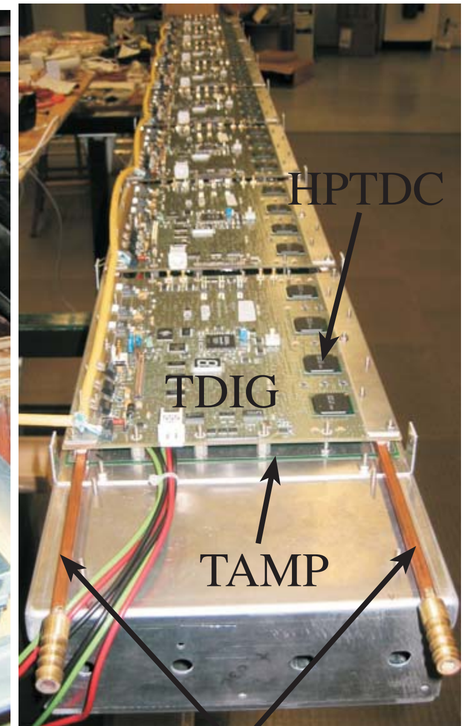
First attempt at on-board digitization
Back to two layers of on-board electronics
Integrated cooling loop
new batches of MRPCs (USTC & Tsinghua)

"Inner Sides" instead of sawtooths...
- lexan machined on hurco machine to few mils
- MRPCs held in reveals cut into the inner sides
- Inner sides bolt to underside of top assy





perf. cover assy



cooling loop

- ~~fabrication extremely labor intensive~~...
  - ~~sawtooths, rail assy~~
- ~~complicated gas sealing~~...
  - ~~gaskets~~, *less* sealant
- ~~MRPC placement w/in box too imprecise~~...
  - ~~each sawtooth placed individually~~
- ~~overall, too tall~~

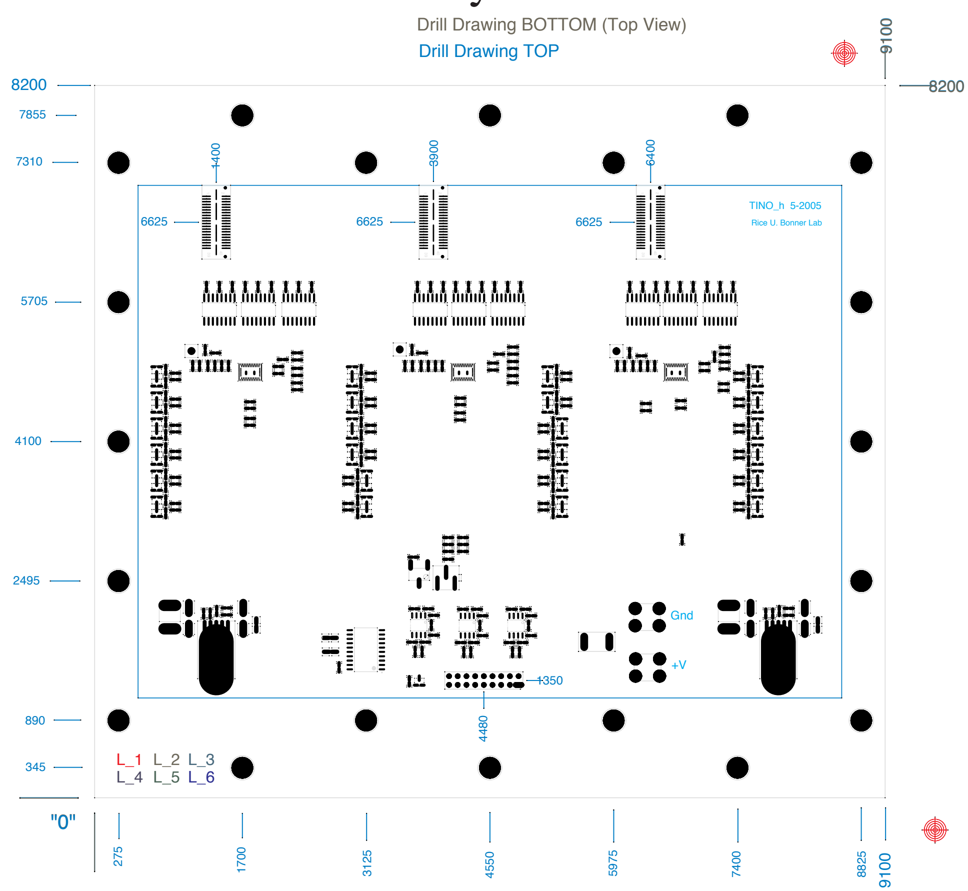
small tweaks to box & inner sides design
integration of TINO, TDIG version 2, & cooling

TOFr5 cooling loop tests & efficiency/power estimates:
http://wjllope.rice.edu/~TOF/TOFr5/Ttests/TOFr5_T_tests.htm

Mechanical Design Summary

3 generations of TOFr trays
(all rebuilt from the ground up)
all met the physics goals

subsequent trays will be sensibly simplified variants of the TOFr5 design:
- simple, quick, & repeatable to assemble
- gas-tight (by simplified design)
- very precise detector positioning
- open-box MRPC→FEE testing
    - air-core transformer tests
    - time-domain reflectometry tests



Next Generation Tray....

simpler cooling loop design
- 1/4" square → 1/4"x3/8" rectangular
- 2 shims/TDIG disappear...

only small tweaks to mechanical design

TINO
- lower power
- no ringing?
- fully differential
- multiplicity outputs on-chip
- now only need positive LV

next TDIG
- accepts signals from TINO
- address timing cross-talk
- multiplicity
- stretching for start-side ToT?

Effects on other STAR subsystems
- weight
- power, cooling, & temperature
- interaction and radiation lengths
- gas containment

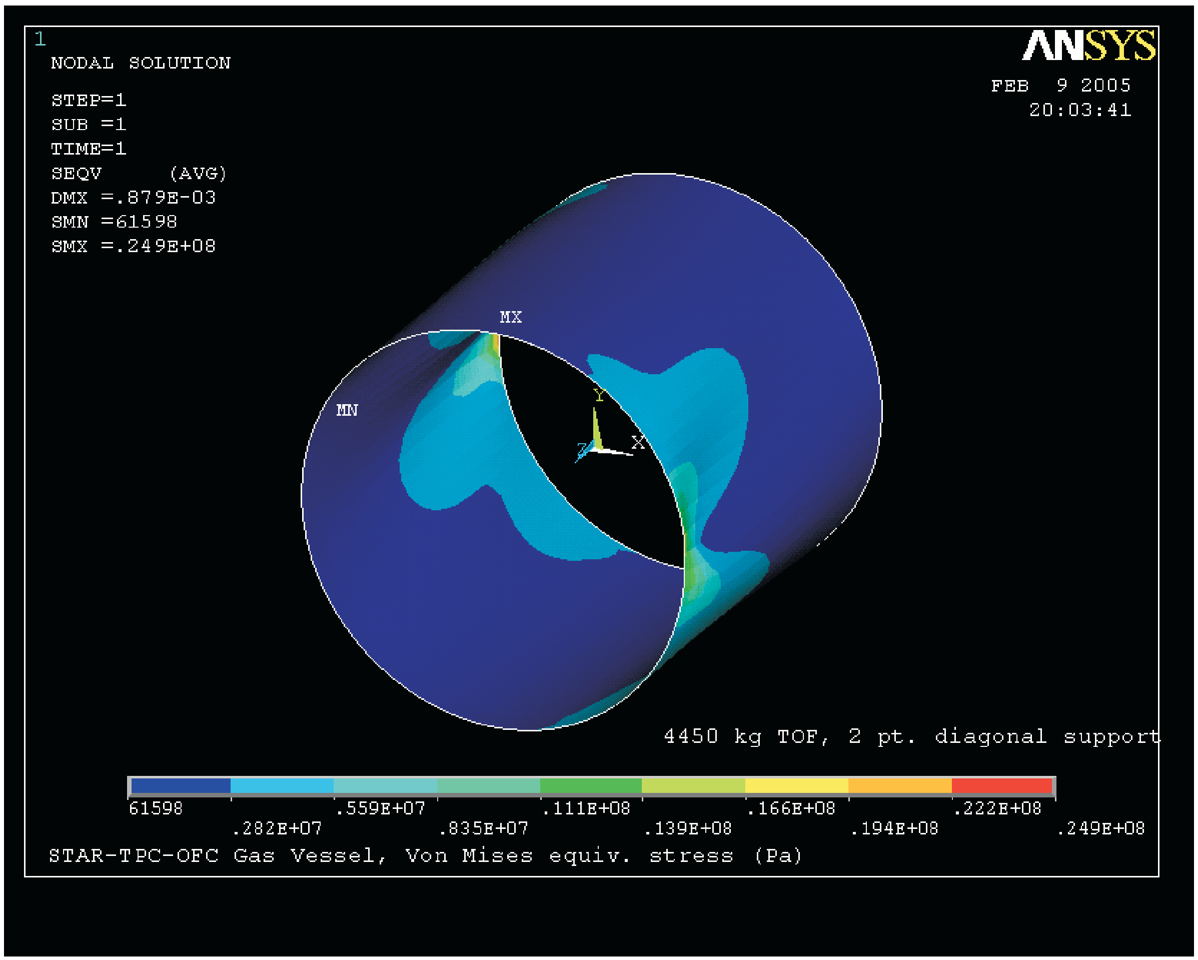
Weight issues

each TOF tray is ~75 lbs,   9,000 lbs total
what are the mechanical safety factors for:

1. “Rails” to TPC OFC epoxy joints
2. TPC support arms and end-structures
3. OFC itself

new ANSys simulations by Derek Shuman for a 10,000 lb TOF

2. assume 4-point support and 2-point support (one arm misaligned).
3. assume specific model for skin composition (glued-on rails stiffen the structure).



results for 1.
tof rails can support
3.2 klb peel
1.6 Mlb shear
2.2 Mlb tension
→ 1 klb trays would not defeat the epoxy

results for 2.
4-support max stress ~ 12.6 MPa
2-support max stress ~ 24.9 MPa

“well under yield point 214 MPa
for the H5052-H34 Al used...”

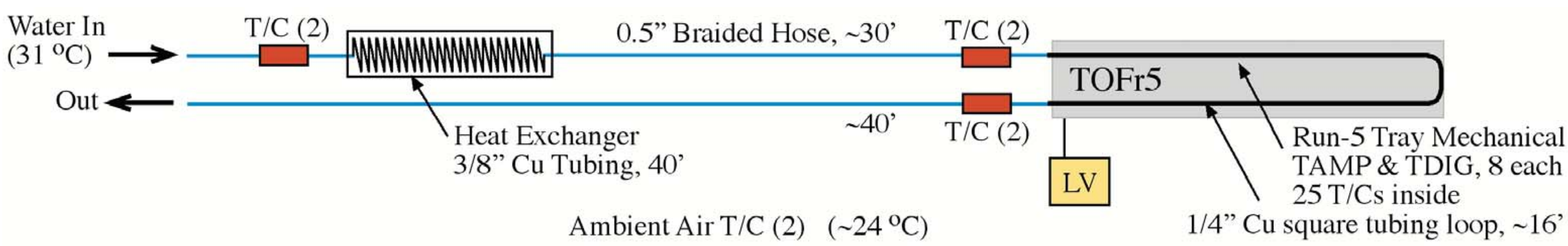
results for 3.
Tangential direction normal stresses
“are only 6.5 MPa localized near
the support in the 2-arm configuration”

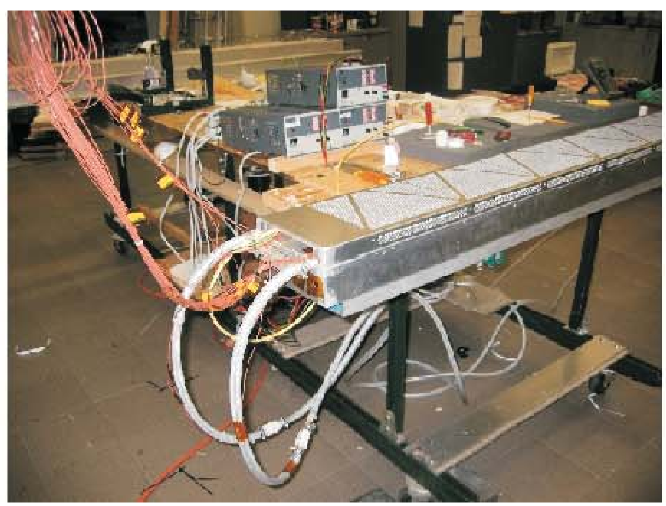
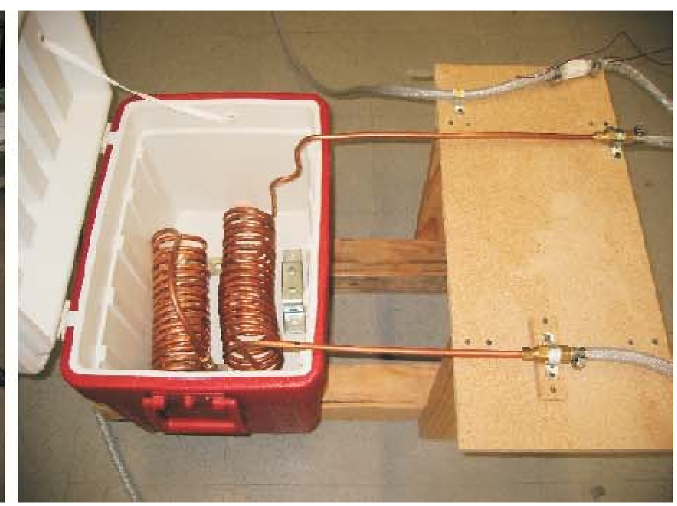
Power, Cooling, & Temperature Issues

TOFr5 electronics drop 140 +/- 10 W (TOFr6 < 100W?)

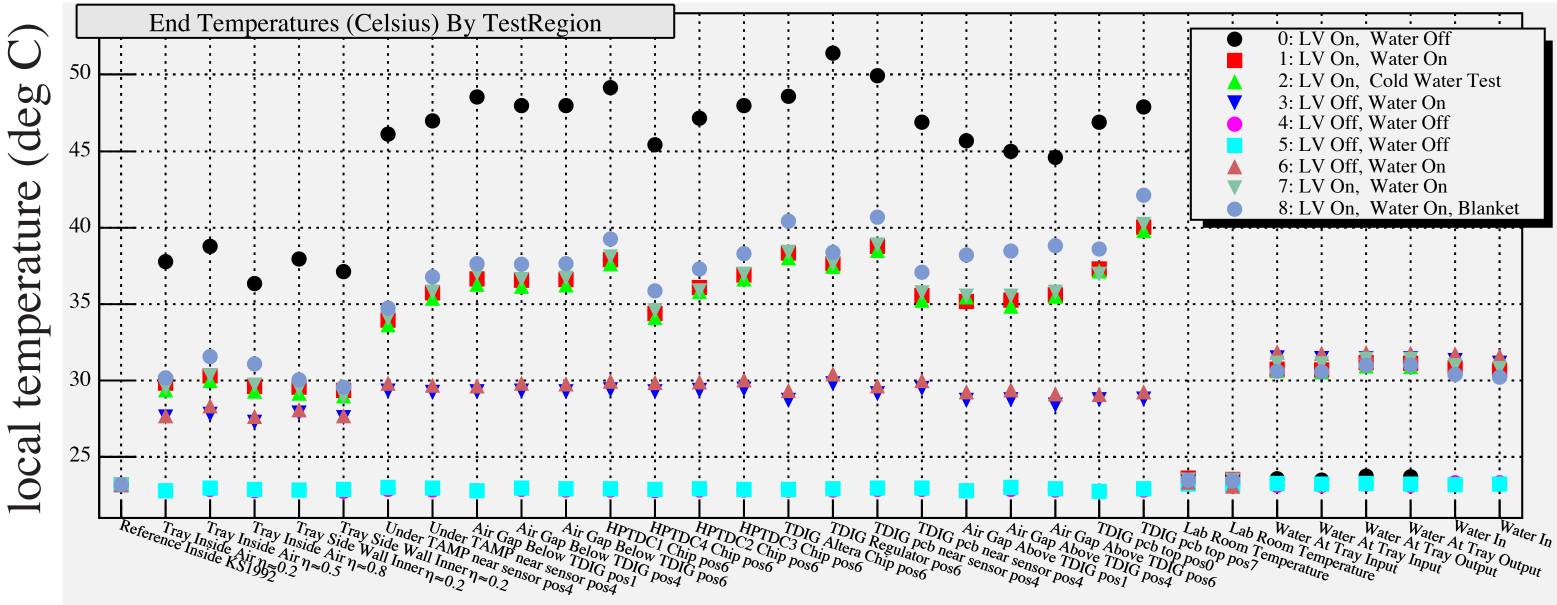
Efficiency of TOFr5's embedded 1/4"-square Cu cooling loop measured at RICE

- 32 Type-T thermocouples inside tray, on electronics, plus ambient, water in&out, etc.
- Kinetics 1992/3516 T/C readout via CAMAC to PC
  - measurement error <0.2 deg C
- full complement of TAMP & TDIG electronics installed and powered up
- water flow unfortunately 31 deg C (is <25 deg C in STAR)
- perforated top assembly!



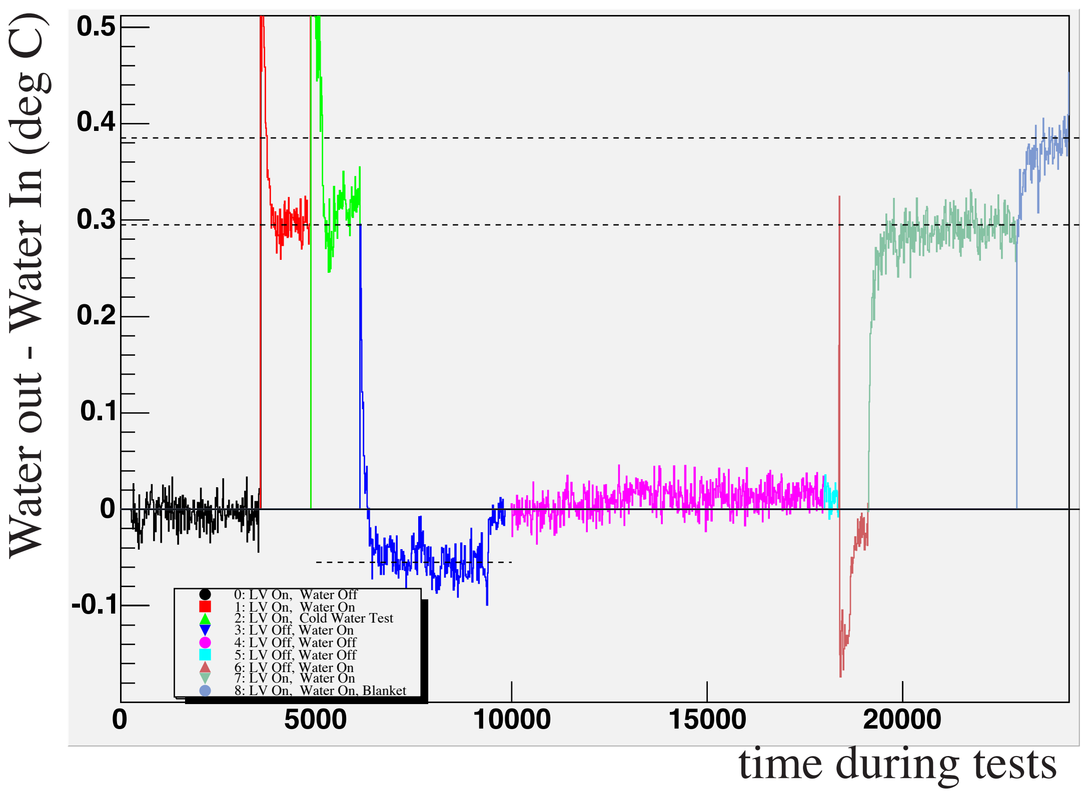
http://wjllope.rice.edu/~TOF/TOFr5/Ttests/TOFr5_T_tests.htm



max T, water flow off
~52 deg C

HPTDC spec
<60 deg C
regulators spec
<80 deg C

max T w/ warm water
~40 deg C



Power estimates

105 W removed by (warm) water!
(~3/4 of 140W total dropped)

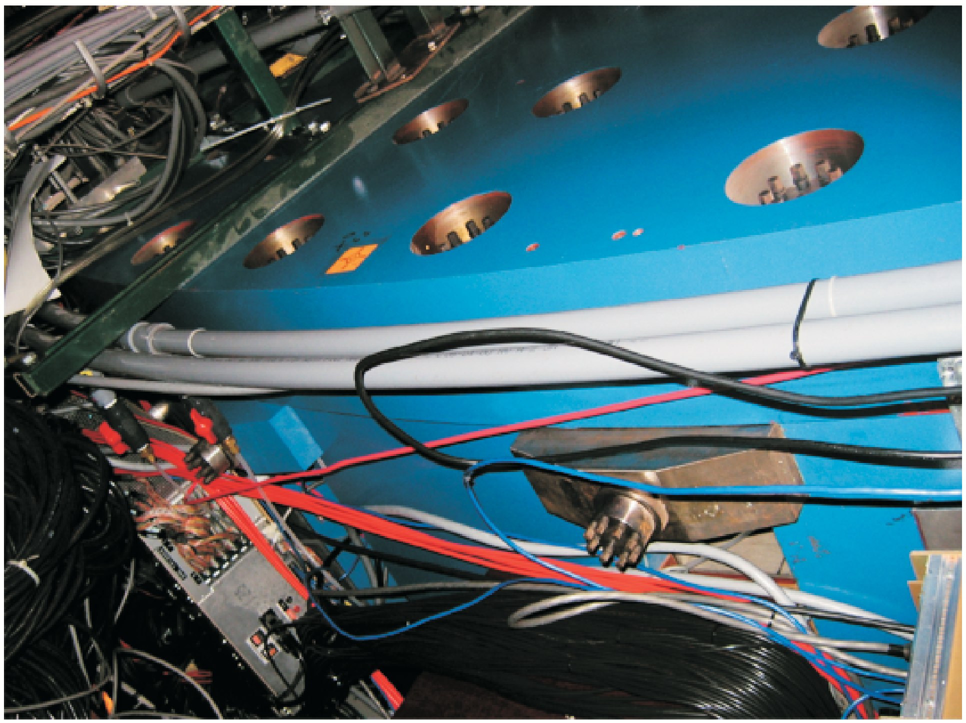
remainder is estimated to be:
- convective ~0W
- radiative (skin) ~3W
- radiative (FEE) ~30W

these calculations suggest radiative power could be ~halved with a solid cover...
TINO also drops total power to <100 W

will repeat these tests using TOFr6 trays
- both solid and perforated cover assys
- both square and rectangular loops (improved thermal efficiency)

TOF Tray cooling using MCW

Recent upgrade of STAR MCW added stand alone 80-ton chiller
This included for TOF 35 kW electronics racks and 30 kW trays
Will use the same water distribution system as for BEMC SMD's



action item:
define cooling water distribution system....

Total power assumption is 120*140W = 17 kW (TAMP) or 120*100W = 12 kW (TINO)
Cooling requirements:

Input temperature	24 deg. C max,	20 deg. C nominal	
Flow rate	2 Gpm max,	1.5 Gpm nominal	
Pressure	150 psi max,	50 psi nominal	(braided hose rating=200 psi)

Secondary production

estimates from AGI+gstar simulations

full description of MRPCs

TOF: ~6.5% of λ_0

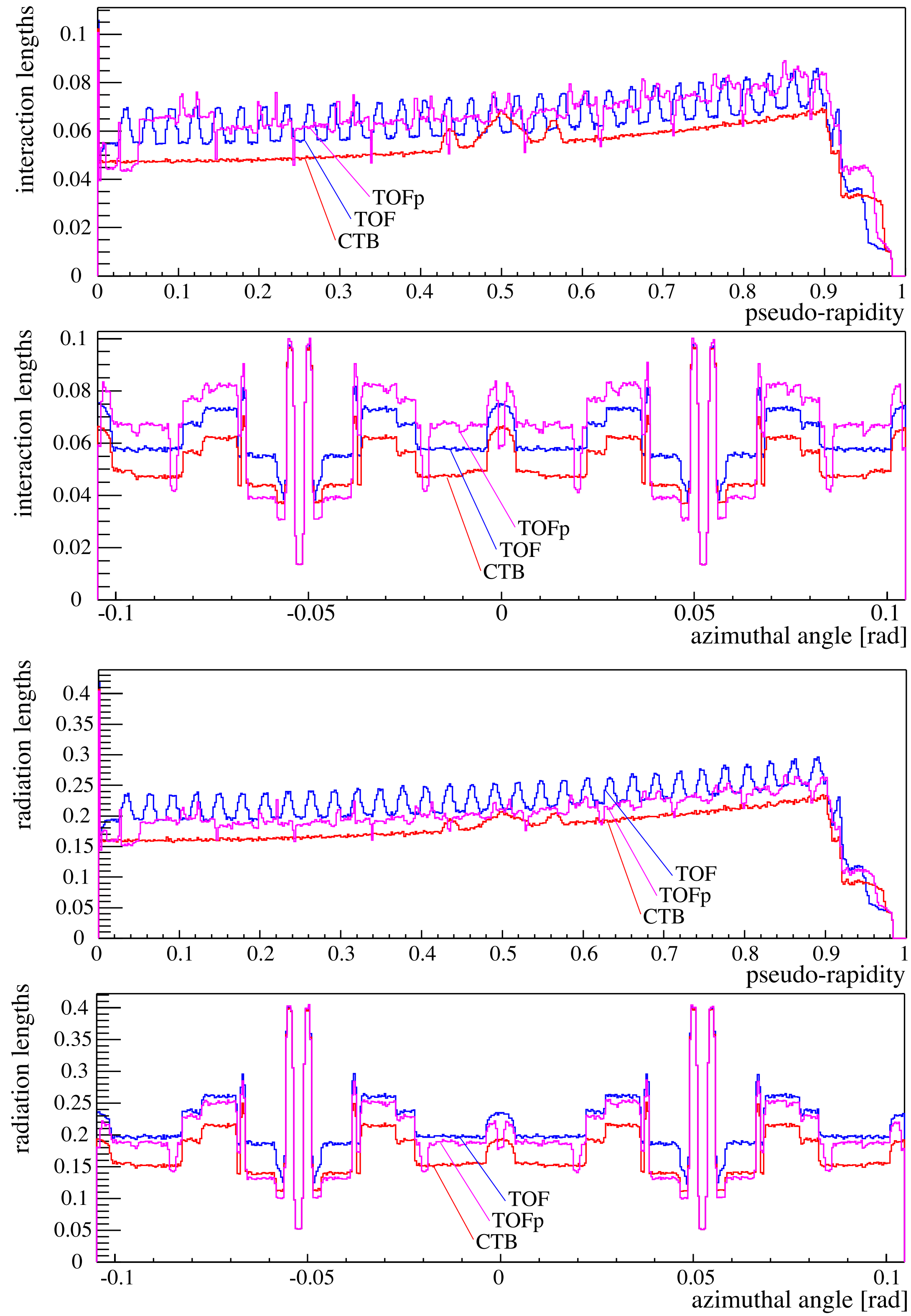
CTB: ~4.9%

→ 32% more than CTB

TOF: ~20% of X_0

CTB: ~15%

→ 33% more than CTB



Gas Containment

best MRPC performance obtained with ~90% Freon, ~5% iso-butane, & 1-5% SF-6
all early papers on MRPCs call this the "standard mixture"

A concern is the detrimental effects that SF6 would have on the TPC/FTPC performance
Alice result: http://rjd.home.cern.ch/rjd/Alice/frac_SF6.html
"...if an electron is to have a 50 % probability to survive 2.5 m drift,
the SF6 level should not exceed 2 ppb."

Thus, we have used only 95% Freon & 5% iso-butane during Runs 3 through 5...

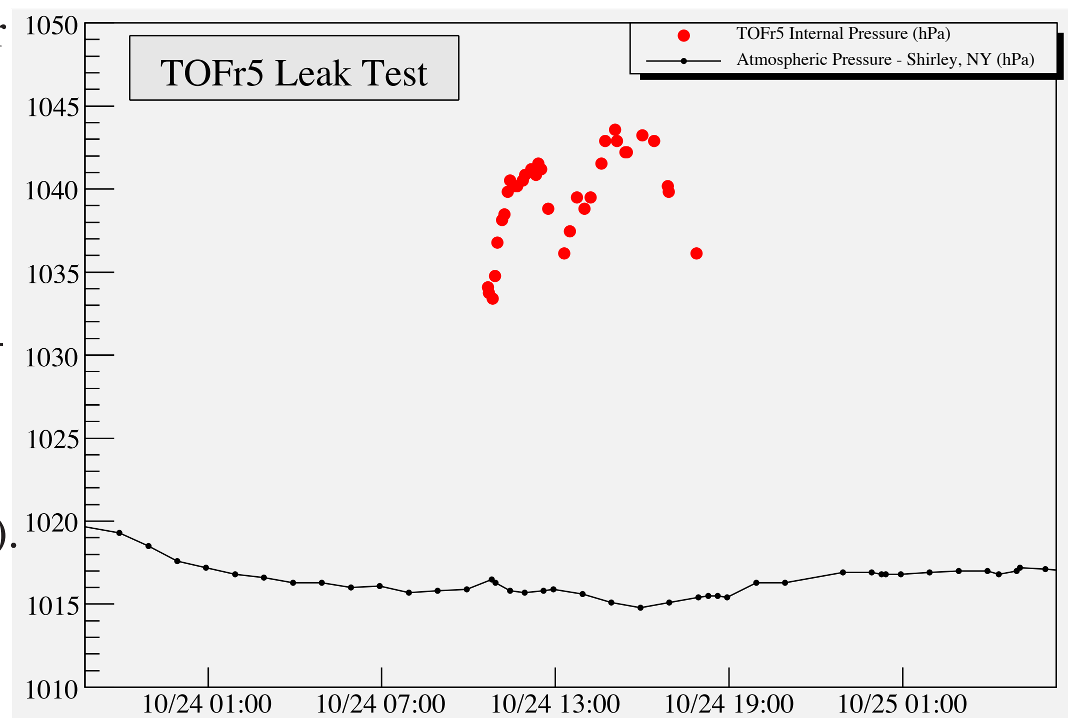
MRPC noise rates and timing performance improve **dramatically** w/ addition of ~1% SF-6.
(documented by Crispin/ALICE).

measured leak rates for 3 TOFr prototypes so far

tray pressurized to ~1" above atmospheric
pressure vs time measured w/ sensitive gauge
HV connectors need to be terminated.
FEE should be off and cool or on and hot.

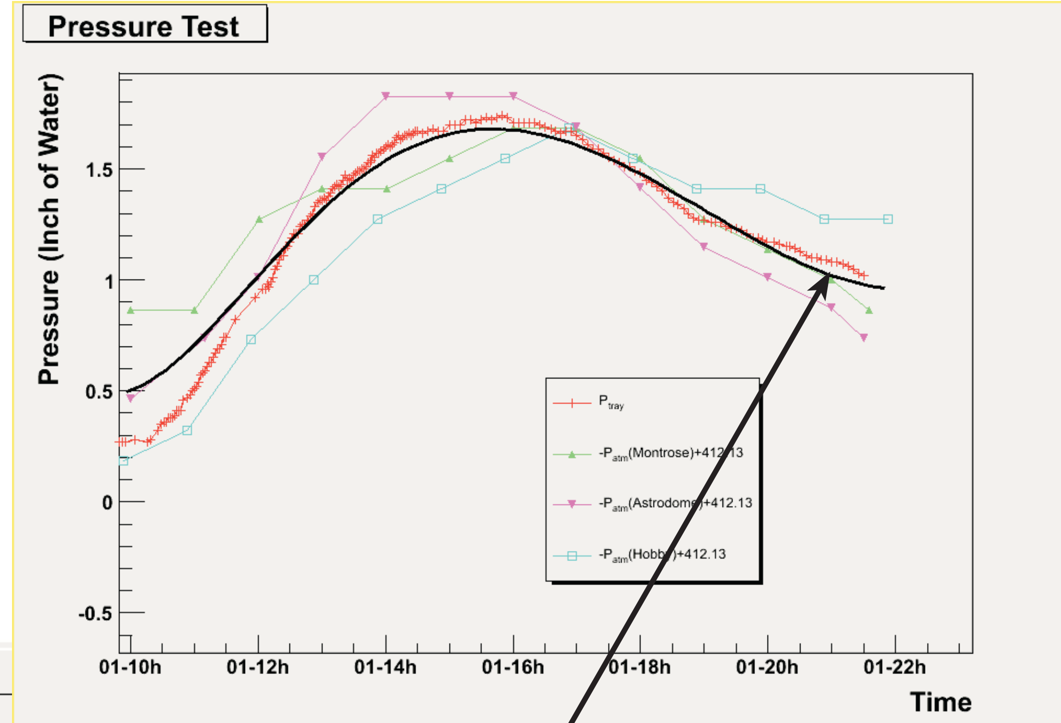
→ finite leak rate measured for TOFr (Run-3) -
modified CTB box
welded rail assy
glued gaskets
solved by adding sealant over gaskets (ugh).

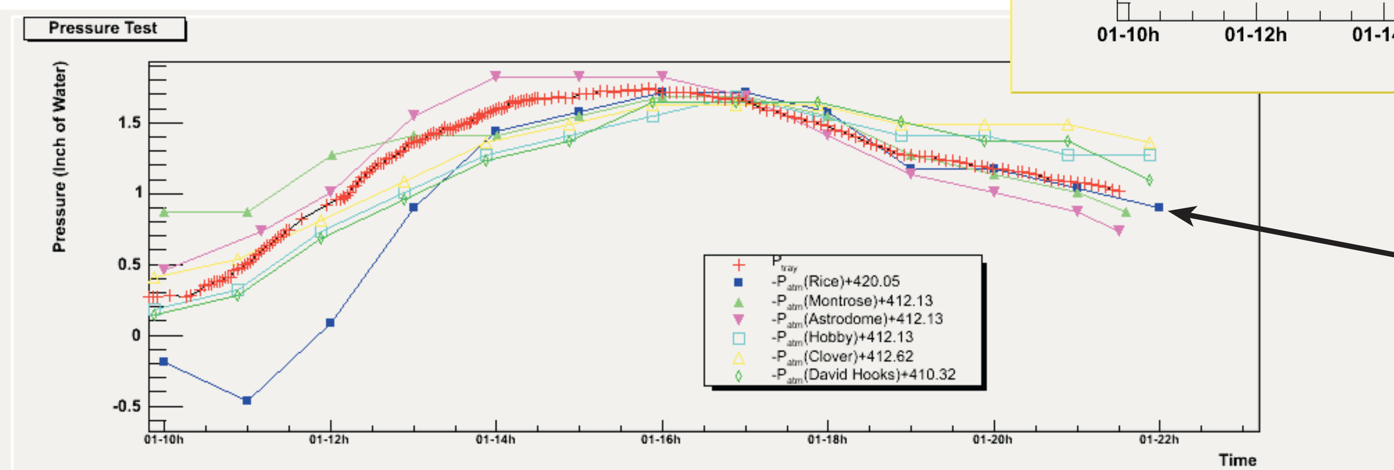
→ no measurable leaks for TOFr' and TOFr5
both "shoe-box" style gas box
FEE sealed directly to tray aluminum



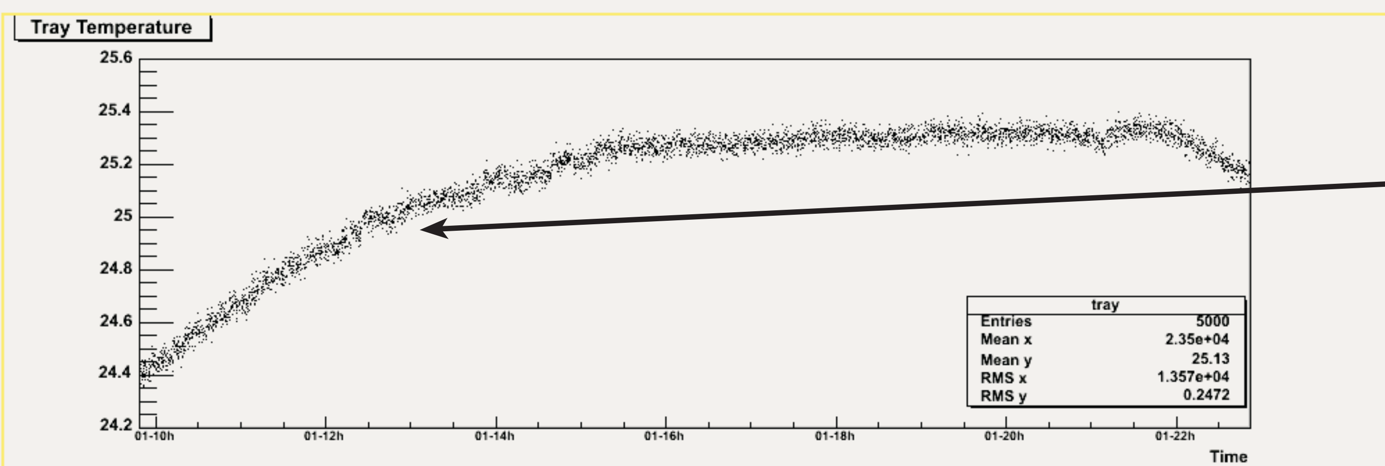
Repeated TOFr5 leak-test @ Rice.....

tray was as removed from STAR after Run-5
longer period
more complete tabulation of atmospheric pressure





tray appears leak-less here.



this temperature variation during the test is a ~0.1% effect...

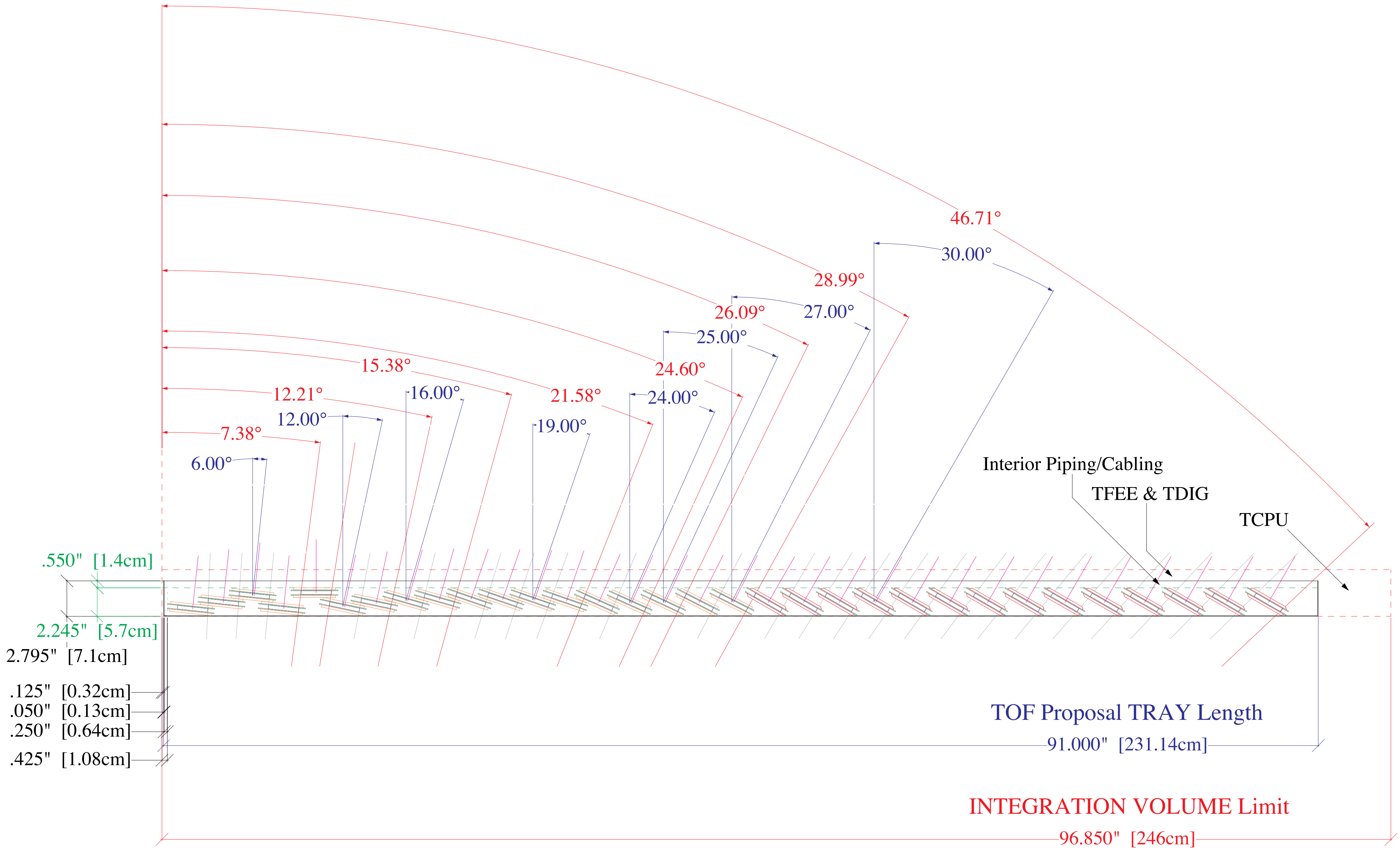
Tray Materials

Item	Material	Qty/tray	Rating or Comment
Tray Mechanical			
Bottom Assy	Welded Aluminum, 50mil	1	same CTB, TOFp, & all 3 TOFr's
Top Assy	Welded Aluminum, 90mil	1	same as TOFr' & TOFr5
Cover Assy	Welded Aluminum, 50mil	1	same as TOFr5, but unperforated
Feet	Braked Aluminum, 90mil, welded on	2	same as CTB, TOFp, & all 3 TOFr's
Standoff strips	UHMW Polyethylene	4	same as CTB, TOFp, & all 3 TOFr's
Inner Sides	Lexan, ~90"x~3"x1/4", milled reveals	2	same design as TOFr5 (TOFr5 used acrylic)
Sealant	DC 730 Freon-Resistent Sealant	~2 oz	same as TOFr' & TOFr5
Hardware	teflon (inner sides) or SS (tray body)	~40	same as TOFr5
Tape	Kapton, 2mil-thick	~20ft	same as all 3 TOFr's
HV			
F/T connectors	Kings 1064 (Reynolds-equiv)	2	10 kV
Interior Bus	Rowe R790-1522	~10' x 2	15 kV, 5A
Fusion tape	Rowe GL30R67WO	~20	~3 layers per splice, 40mil/layer, 12 kV/layer
Gas			
F/T connectors	Swagelok SS for 1/4" tubing	2	same as all 3 TOFr's
interior tubing	generic 1/4" polyflow, ~90"	1	same as all 3 TOFr's
Water			
barb fittings	custom (UT shop), Brass	2	same as TOFr5
hose to fittings	Vinyl braided, two hose clamps per fitting	2	200 psi (1.5x max pump pressure in STAR)
cooling loop	custom, Copper, 1/4"x3/8", 40mil wall	1	must be leakless @ >200 psi (UT test)

tray total weight 75 pounds
tray total volume 40 liters

integrated & efficient water path
electronics completely enclosed in solid metal box

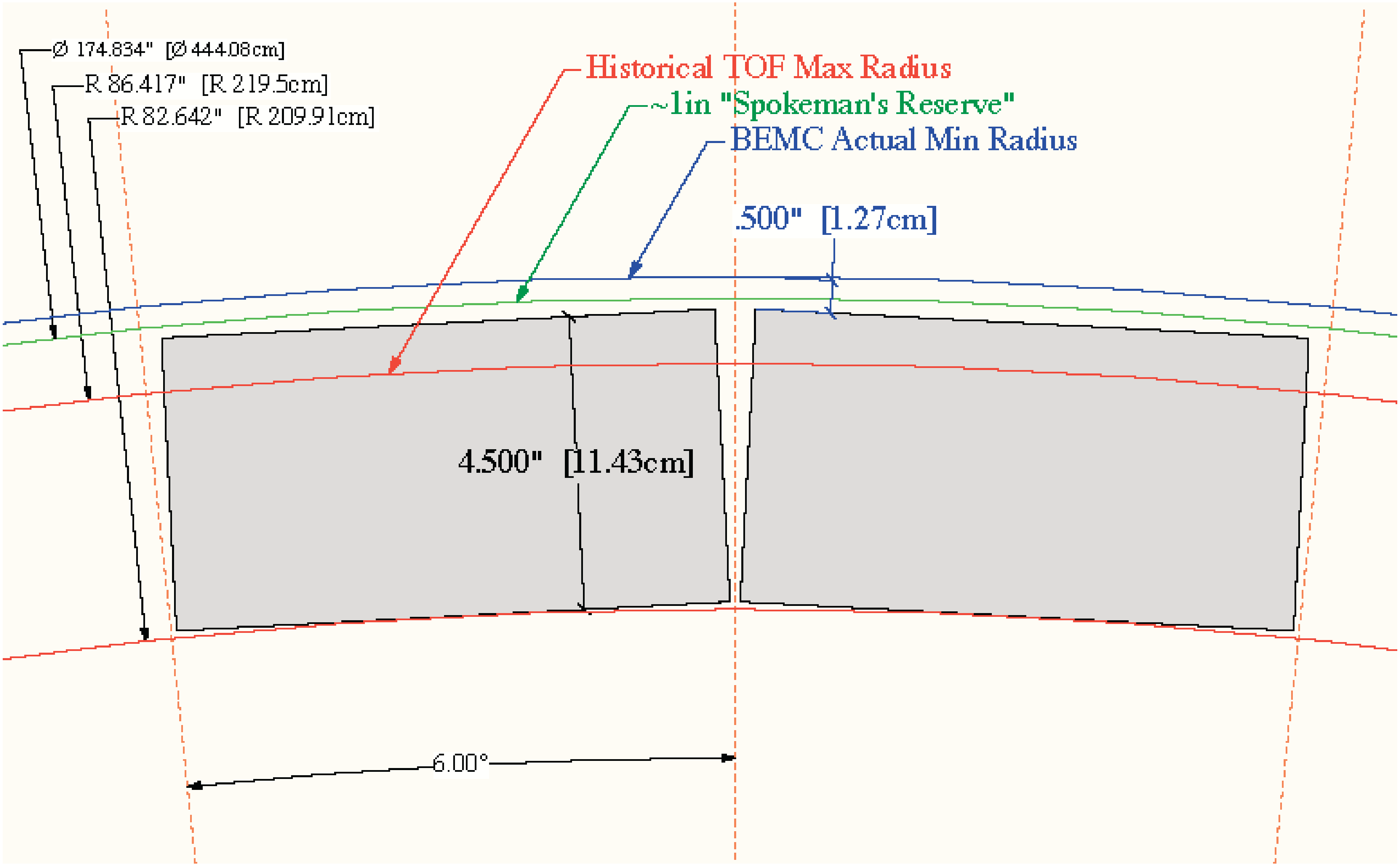
Integration Volumes...



TOFr5 actual length (bottom assy) = 90.000"
TOFr5 actual length (top assy) = 90.180"

CTB length = 95.1"

Final Trays need to add length to allow for TCPU mount.
total length = 95.000"
allows ~2: for cabling bends



Ø 174.834" [Ø 444.08cm]
R 86.417" [R 219.5cm]
R 82.642" [R 209.91cm]
Historical TOF Max Radius
~1in "Spokeman's Reserve"
BEMC Actual Min Radius
.500" [1.27cm]
4.500" [11.43cm]
6.00°

Mechanical mounting

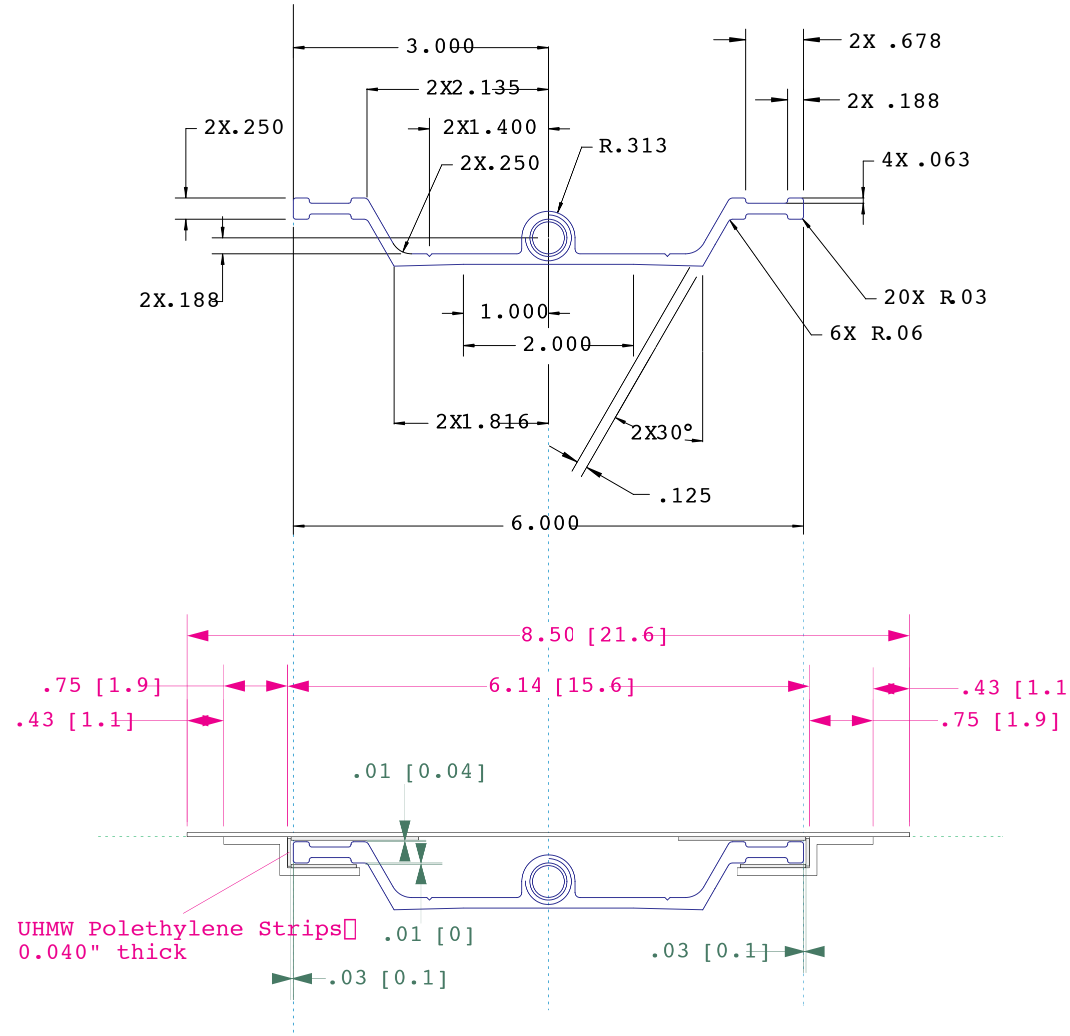
"Feet" under TOF boxes register on "rails" glued to the TPC OFC.

same idea as CTB:
same manufacturer too (Oaks Precision)

- braked 90mil-thick Al feet
- UHMW polyethylene strips 'inside'...
- feet attachment to tray bottom
  - CTB: pop-rivets
  - TOFr: pop-rivets
  - TOFrp: plug-welds
  - TOFr5: plug-welds

assumed tray weight = 75 lb.

from STAR Drawing TPC125-D-1:



as manufactured:
nominal +/-18mil
height variation...

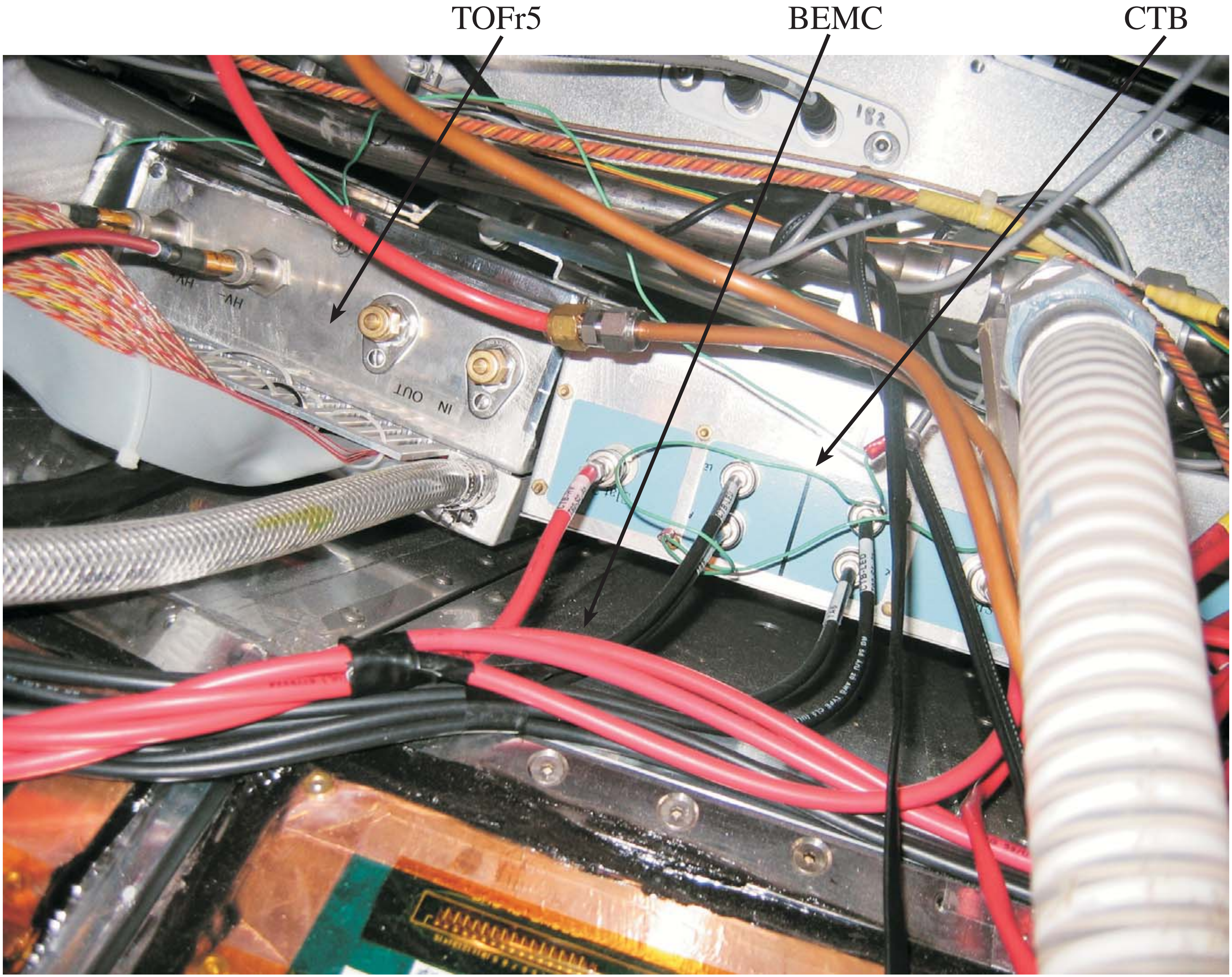
implies STAR phi-dependence
on tray positions to

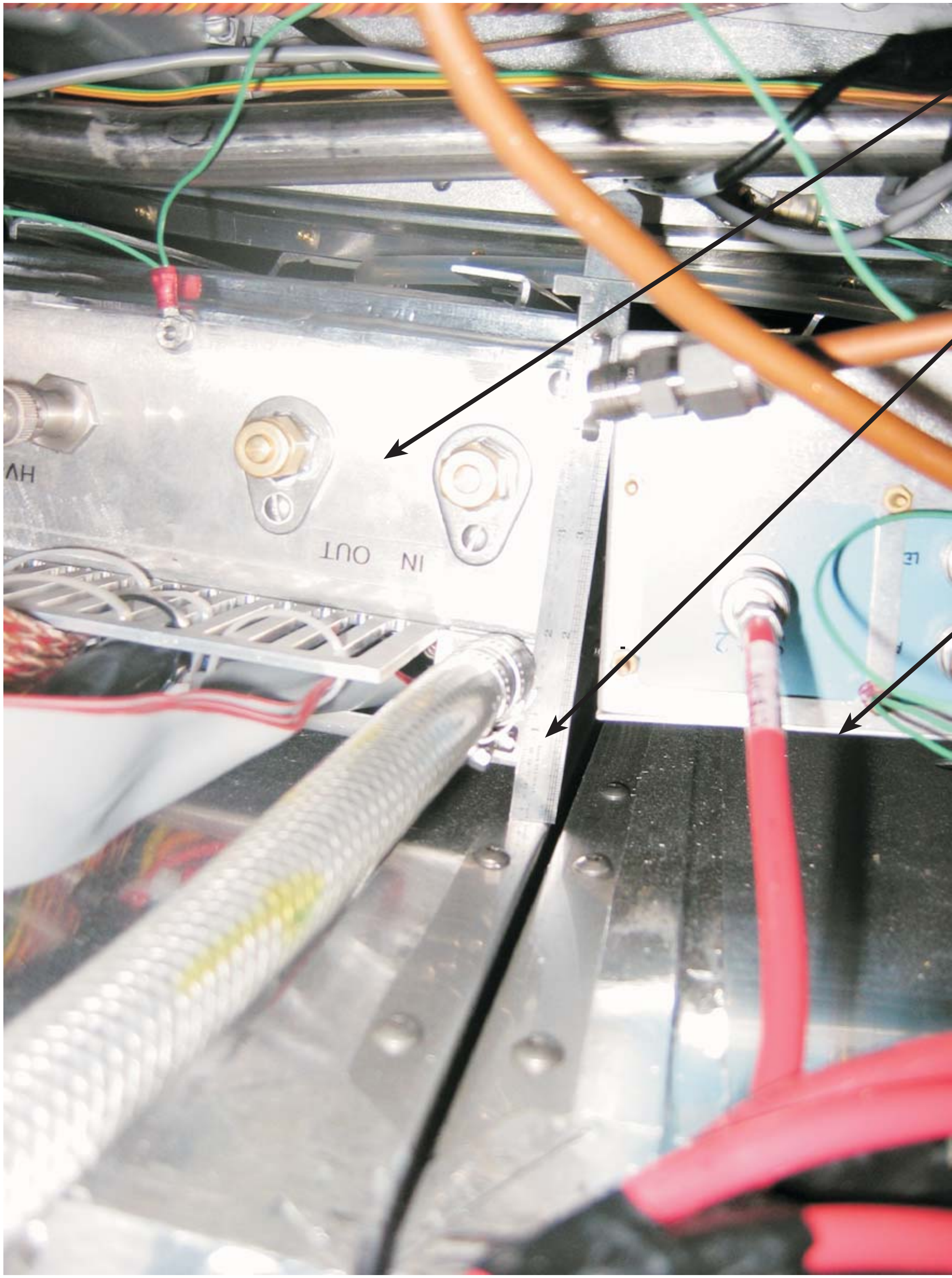
- +/-18mil in R
- +/-30mil in phi

action item: actually measure weight of TOFr5

action item: select one tray from initial production
mount on a rail (these exist @ Rice) as if in 3 or 9 o'clock posn (100% load on 1 rail)
load tray and show one rail can support 3*75 = 225lbs without failure of the welds.

TOFr5 “height” as installed (for Run-6).





TOFr5 (as just installed for Run-6)

measured gap to BEMC is ~0.5”

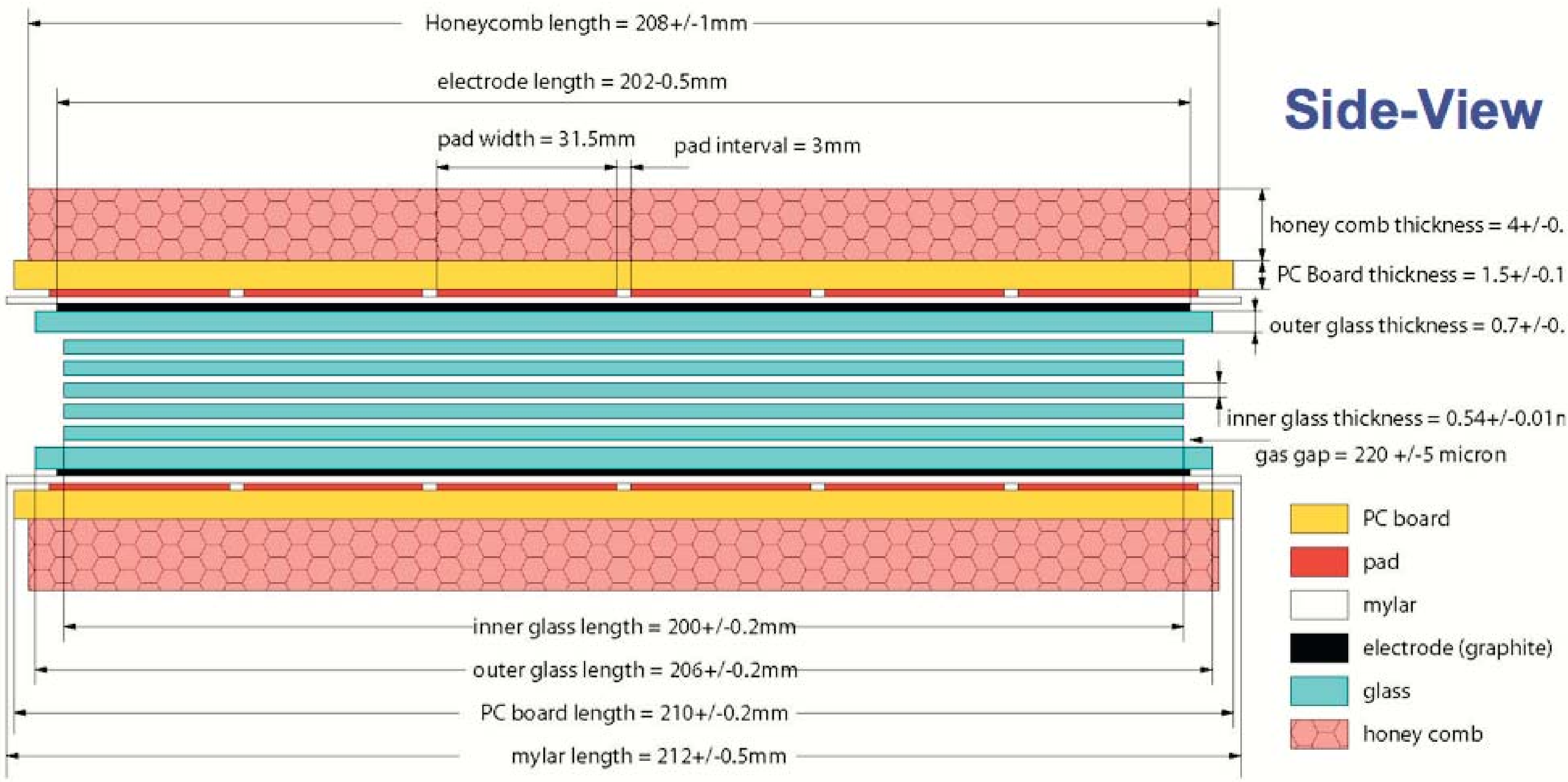
CTB

measurements i made before
run-5 show ~3/16” max variation
in radial distance between CTB & EMC

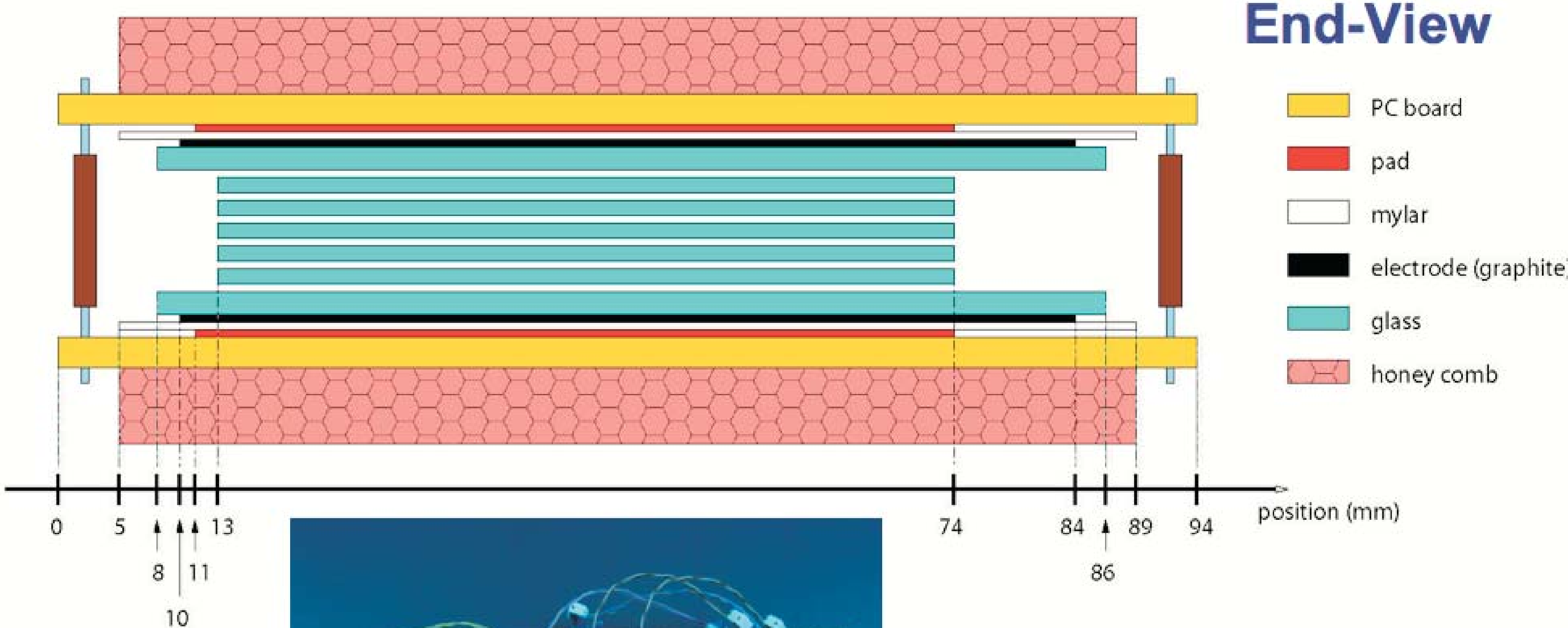
measured each end of ~4 CTB trays
at both ~4 and ~8 o’clock posns
on both east and west...

+/-36mil radial variation due to
rail/strip geometry

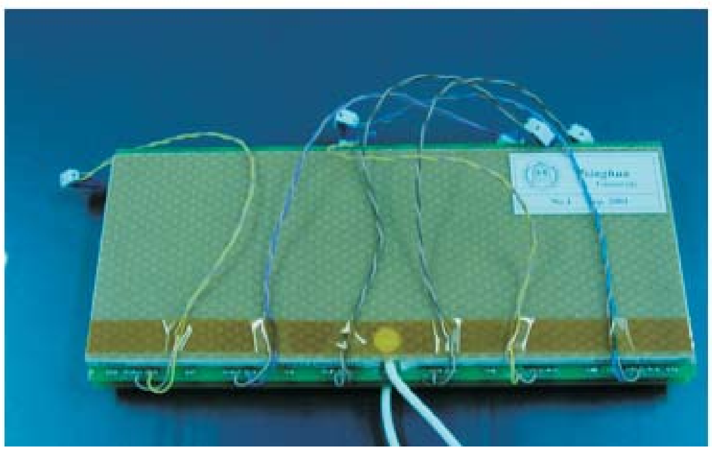
budget is ~400mils (BEMC screws).


Side-View
Honeycomb length = 208+/-1mm
electrode length = 202-0.5mm
pad width = 31.5mm
pad interval = 3mm
honey comb thickness = 4+/-0.
PC Board thickness = 1.5+/-0.1
outer glass thickness = 0.7+/-0.
inner glass thickness = 0.54+/-0.01
gas gap = 220 +/-5 micron
inner glass length = 200+/-0.2mm
outer glass length = 206+/-0.2mm
PC board length = 210+/-0.2mm
mylar length = 212+/-0.5mm
PC board
pad
mylar
electrode (graphite)
glass
honey comb

End-View



PC board
pad
mylar
electrode (graphite)
glass
honey comb
0
5
8
10
11
13
74
84
86
89
94
position (mm)



MRPC List of Materials

material	type	Dimension (mm)	Tolerance (mm) Length,Thickness	quantity
Outer glass	Shenzhen	206×78×0.7	±0.1, ±0.01	2
Inner glass	Shenzhen	200×61×0.54	±0.1, ±0.01	5
Graphite film	ESD EMI Engineering Corp.Japan,SR>500k ohm/□	202×74×0.13	-1.0	2
Mylar film	Dupont Corp.	212×84×0.35	±0.1	2
Honeycomb board	Aoxing Corp.	208×84×4.0	±1.0, ±0.1	2
PCB	Yuandong Corp.	210×94×1.5 6pads, 31.5×63/pad	±0.1, ±0.01	2
L shape supporter	Weishi Corp.	height:3.8	-0.05	4
Nylon wire	Germany	ϕ0.22	±0.005	800cm
Double side tape	3M Corp., type 9690	210×84×0.13	±0.5	4
RTV	CAF4, France			
Nylon screw	Shenzhen	M2.5×12		14

Proposed by Chinese Groups

action item: agree to final tolerances
as +X (max) -Y (max), rejection criteria

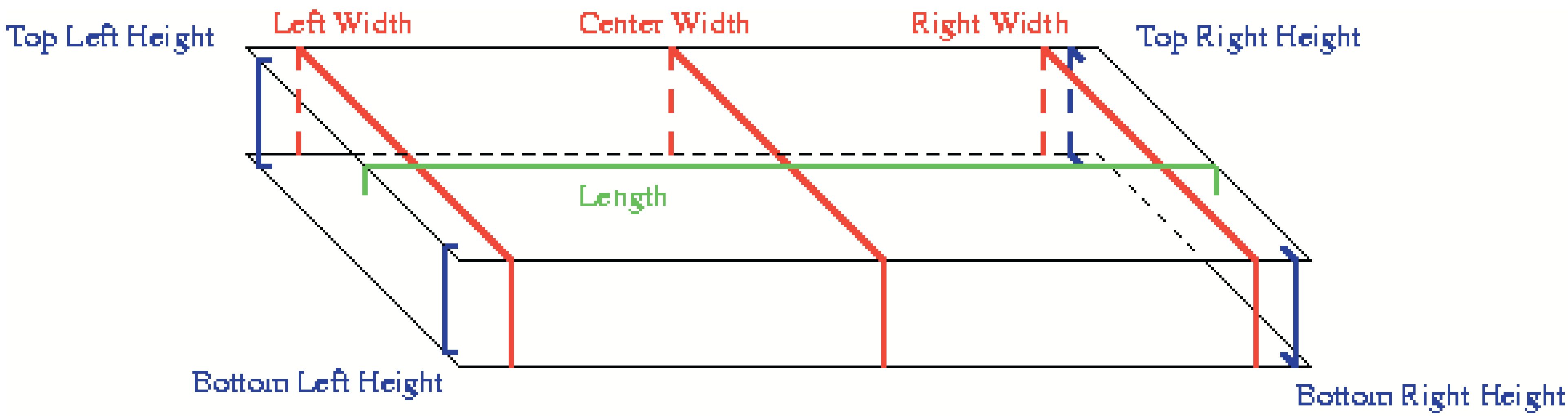
China technical review, April'06 Beijing

Survey of MRPC dimensions and Tolerances

Adam Meier and WJL
http://www.bonner.rice.edu/~adammm/MRPCpage.html

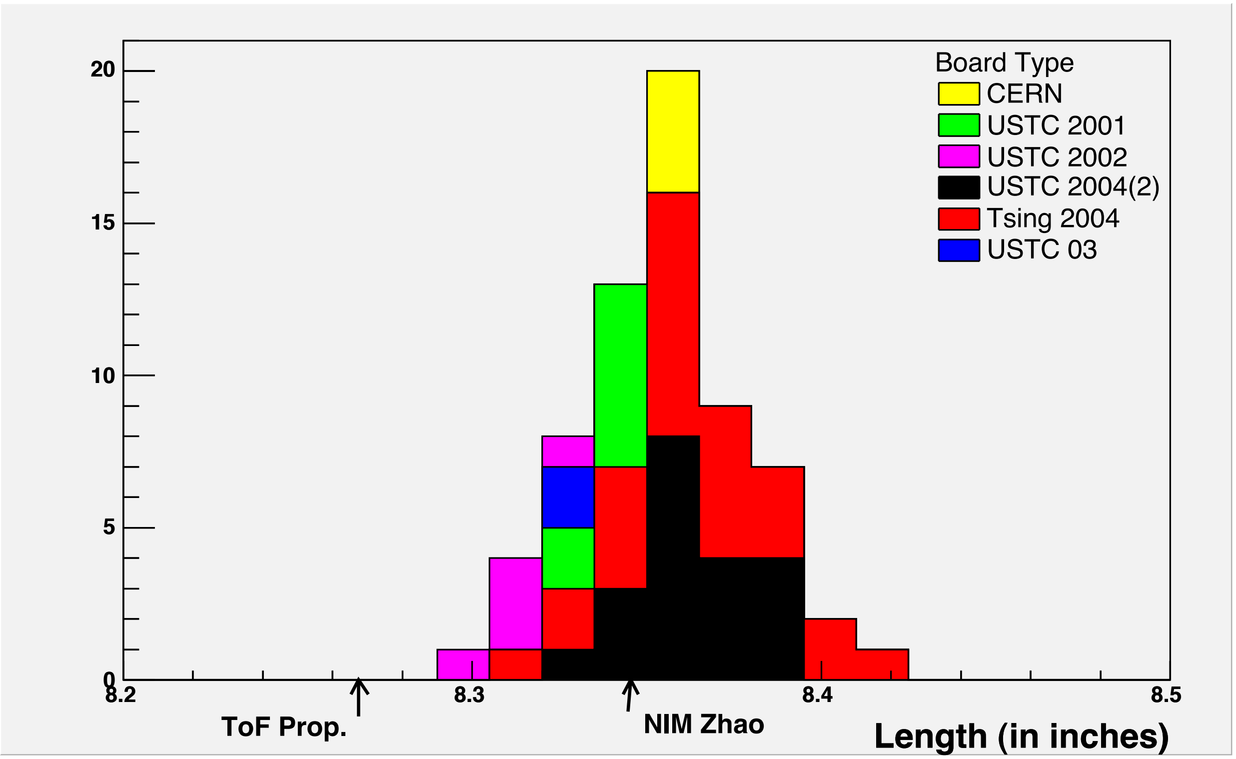
carefully measured all available (prototype) MRPCs
- width and height to ~2mils
- length to ~1/32”

also form distance differences
- → “skewness” (effects on performance?)...

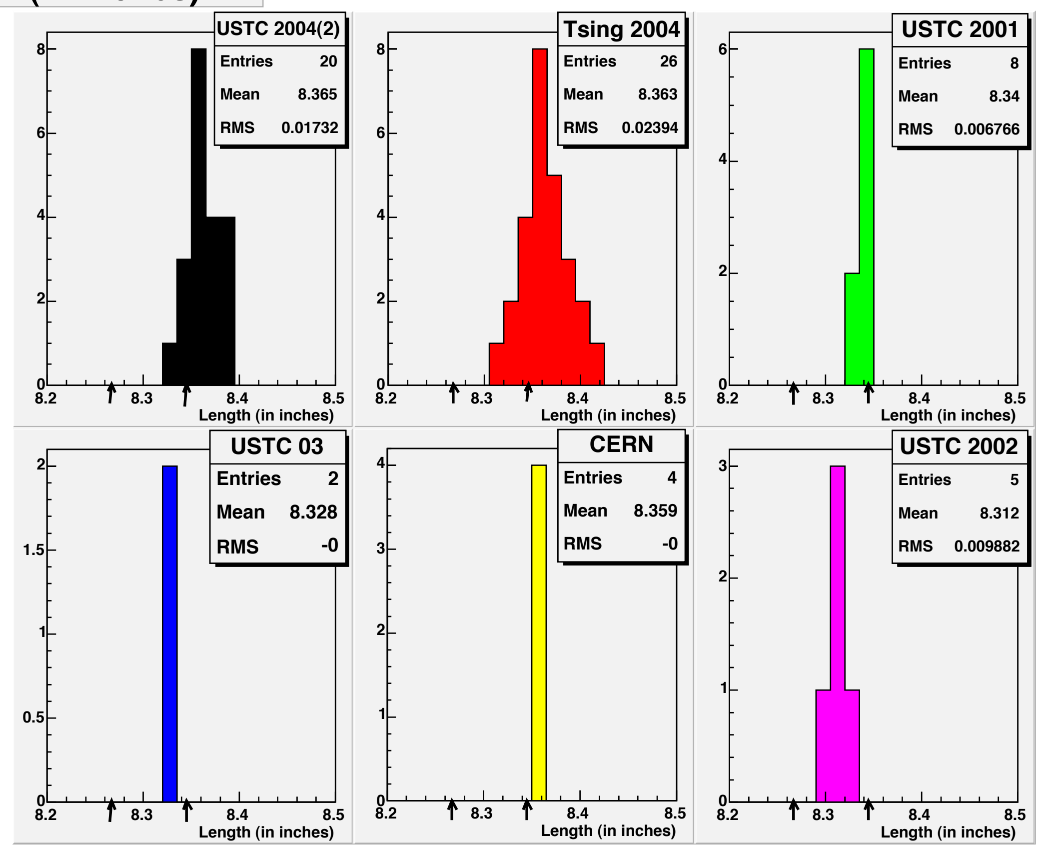


Height and Width bear only on Inner Sides design
- “reveals” in Inner Sides typically over-sized by 20mils.

Length has a hard limit.
- bottom assembly max inner(outer) width is 8.4”(8.5”) and is set in stone.



Tray Bottom Assy
exterior width = 8.5”
interior width = 8.4”

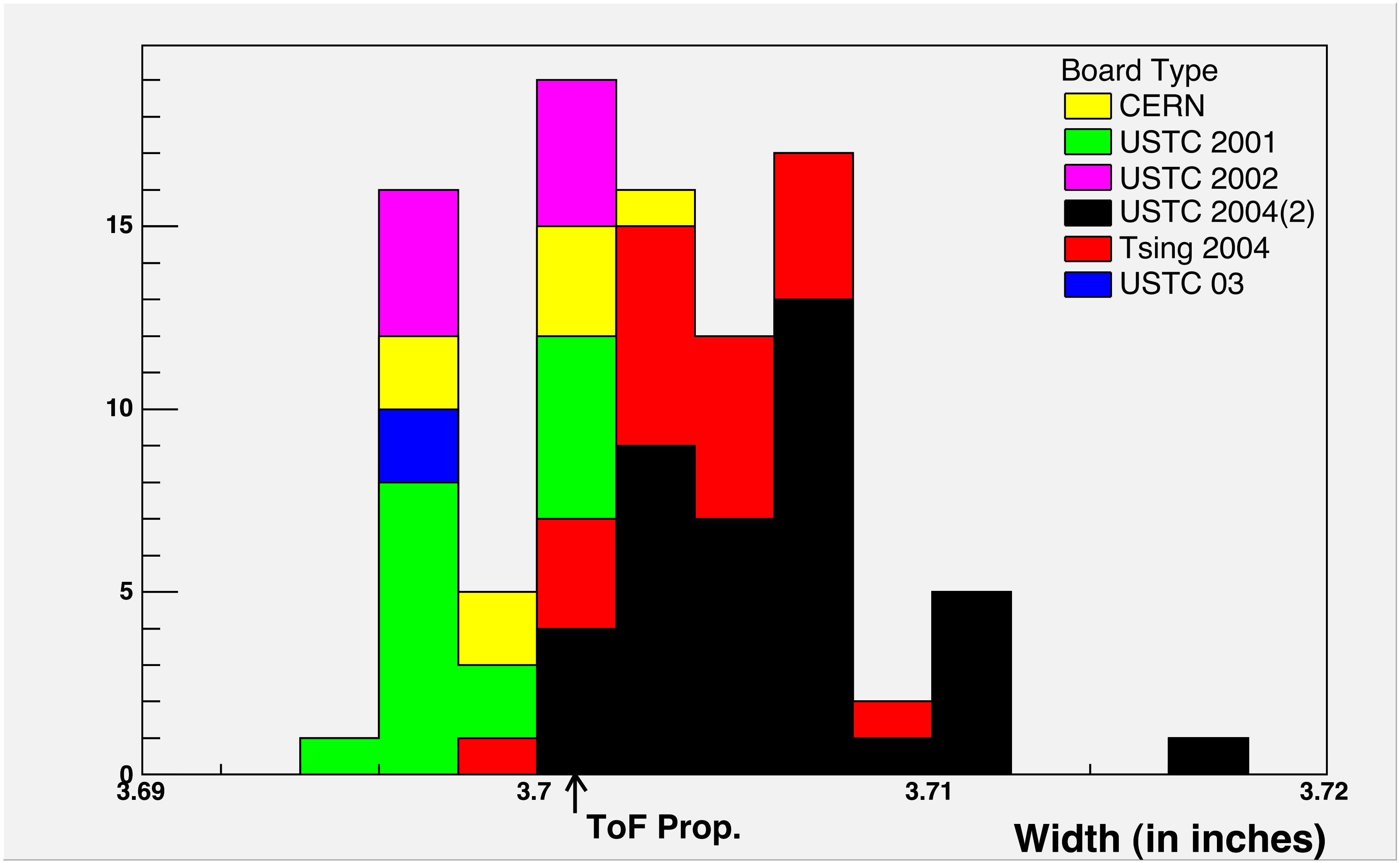


Length of almost all of the latest modules exceed Spec!

problems with mylar layers...
PCB layers...

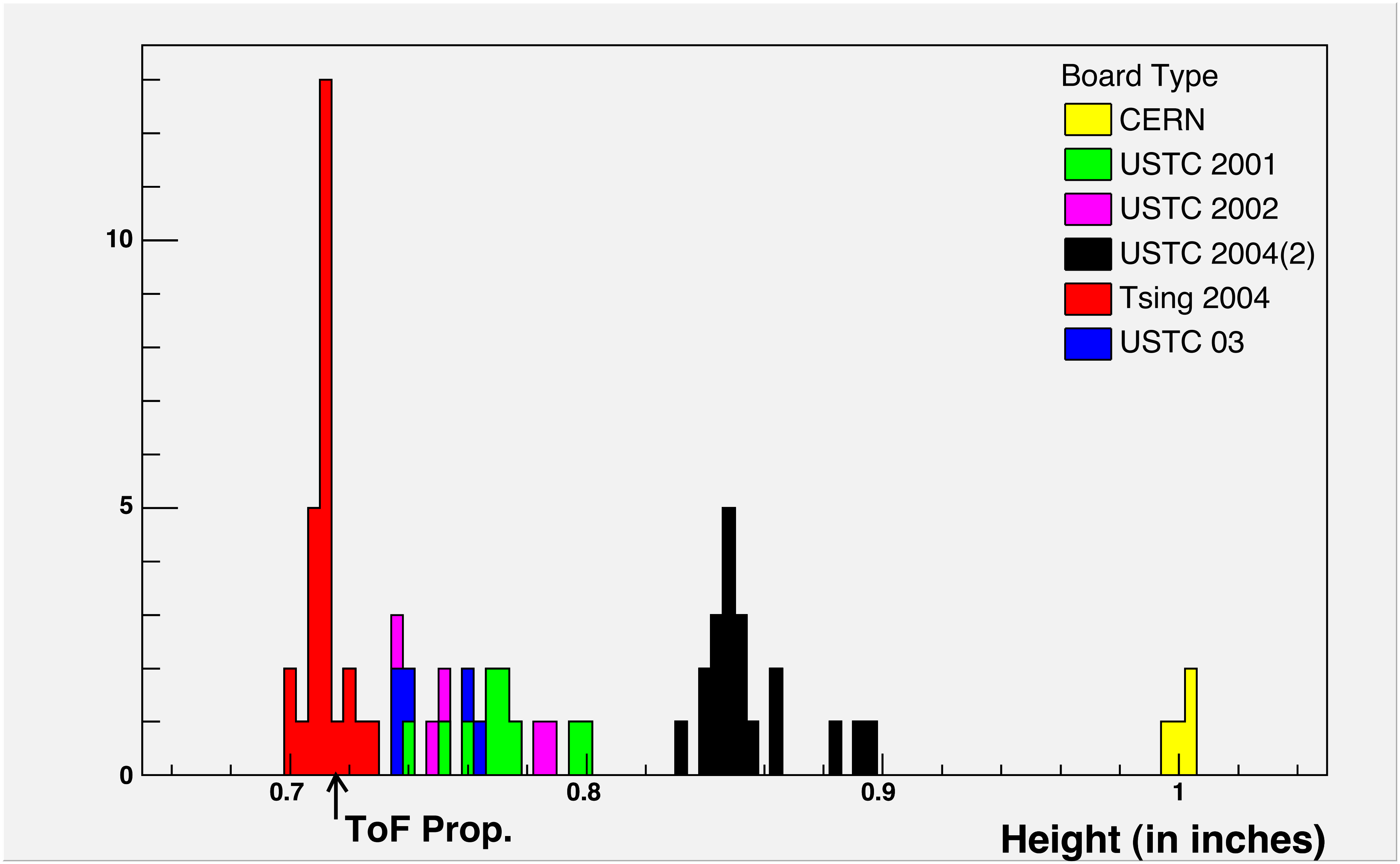
must be brought under better control for final production

Width also excessive...



Bears only on sizing of reveals in the Inner Sides, but needs better QC

Height not too bad....



Bears only on sizing of reveals in the Inner Sides, but needs better QC

Choice of HV Power Supply.

- CAEN SY127 mainframe with A631 pods has been used to supply HV to MRPCs (some problems have been encountered during last two runs - failed A631 modules).

- Each SY127 accommodates 10 A631 pods. Each A631 pod (negative and positive output versions available) supplies 4 independent floating channels. Each output could supply up to 8 KV at 100 uA. (One fully equipped SY127 would serve the entire TOF system). Output current limited internally and also by external limiting resistors located @ distribution boxes.

- Distribution boxes located on the magnet will fan out each pair of + and – HV to up to 10 trays. These boxes will supply required isolation, filtering, current limiting and grounding of the HV (see figure on the next page).

- CPE Italia SPA (rated ~20 KV) cables (HV RG-58) will be used for HV distribution. These cables have been flame tested by Phenix Collaboration.

- Kings (or Reynolds equivalent)) 1065 series 10 KV (DC tested to 25 KV) will be used to interface the HV to power supplies, distribution boxes, and the trays. (The new Reynolds equivalent connectors are rated at 15 KV @ approximately the same cost).

- Remote control and monitoring of the SY127 will be done through CAENET (PC based A1303 PCI-HS CAENET controller already used to control HV system in the past few years).

TOF High Voltage System Requirements.

- High Voltage to provide symmetric HV up to +/- 7.5 KV @ few uA/tray (this current takes into account Beam on condition scaled to RHIC upgrade luminosities).

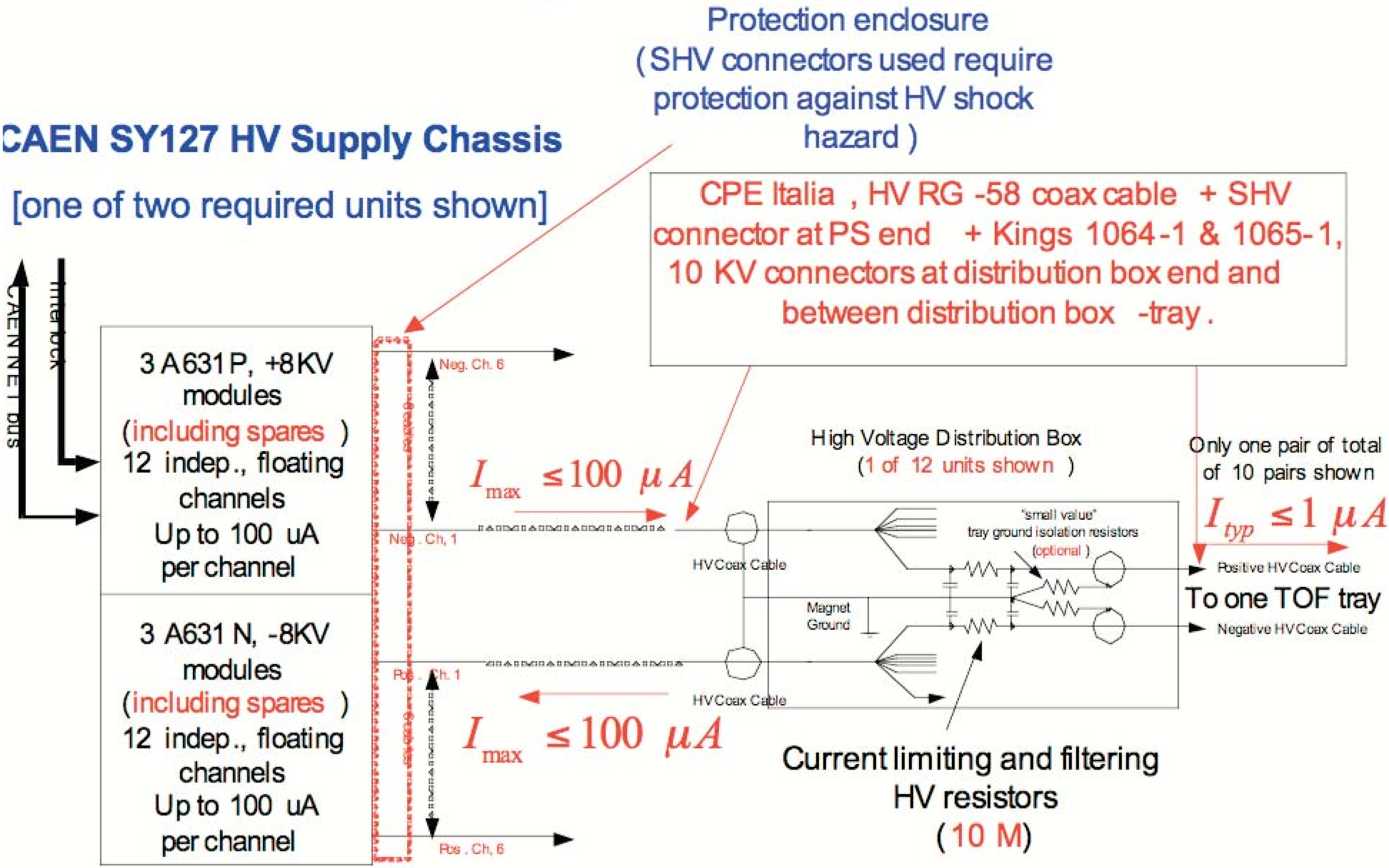
- Remote programability/monitoring: Voltage, current limits, ramping rates, voltage and current monitoring (10 nA resolution).

- Isolation: power supply outputs must be floating. Furthermore, since one set of plus and minus outputs supply current for up to 10 trays tray inputs are isolated from other trauys to avoid interference.

- HV will be interfaced to STAR interlock system.

- Remote control software will be based on EPICS (or LabView) and will be interfaced to STAR controls (logging and alarms).

High Voltage System



LabView GUI for SMD TCP/IP-based HV Control Program for CAEN SY1527 Mainframe Developed by UCLA.

Start-Side Status and Plans

pVPD detectors still in place (4th run now) and seem to be doing as well as always...
But an increased coverage within a similar integration volume is needed

Implement prototype for Run-6
- if prototype performs adequately, prototype will be the deliverable for TOF Project

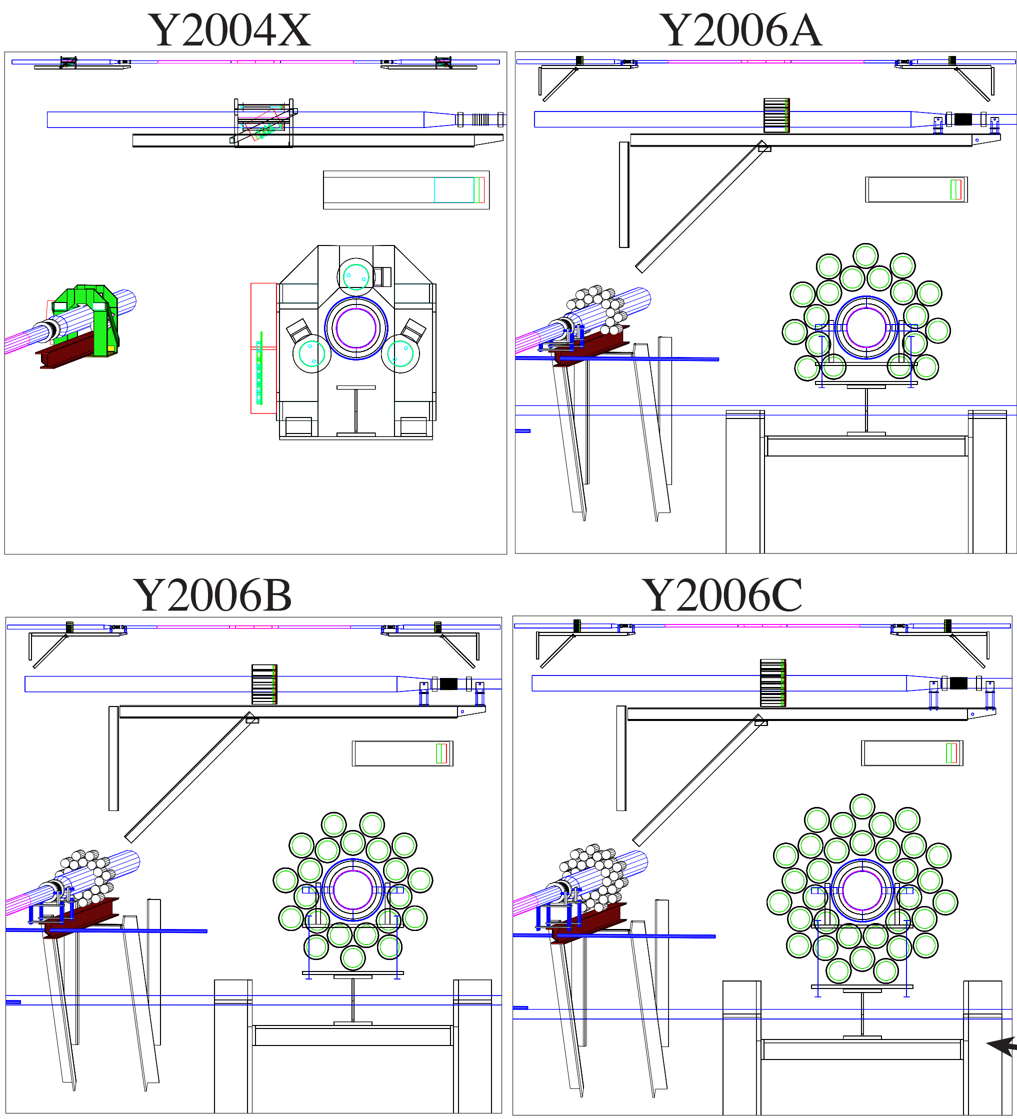
Basic idea
- pVPD 2" linear PMTs + significant shielding → 1.5" mesh PMTs + no shielding...
- increase number of detector channels on each side within same integration volume...
- same Z-location as pVPD (Runs-2 to -5) but smaller radial extent...
- total weight 2/3 of pVPD
- Electronics for Run-6 prototype exactly the same boards as on pVPD in Run-5
- HV for prototype and final system from BBC's LeCroy 1440 supply, cabled & ready now.
- PMTs for prototype detector will be R5946 PMTs from decommissioned TOFp
  - already separated from the TOFp slats, and gain & dark current tested.
  - Pb converter + Scint (a few chs on each side will use quartz or lead glass instead)

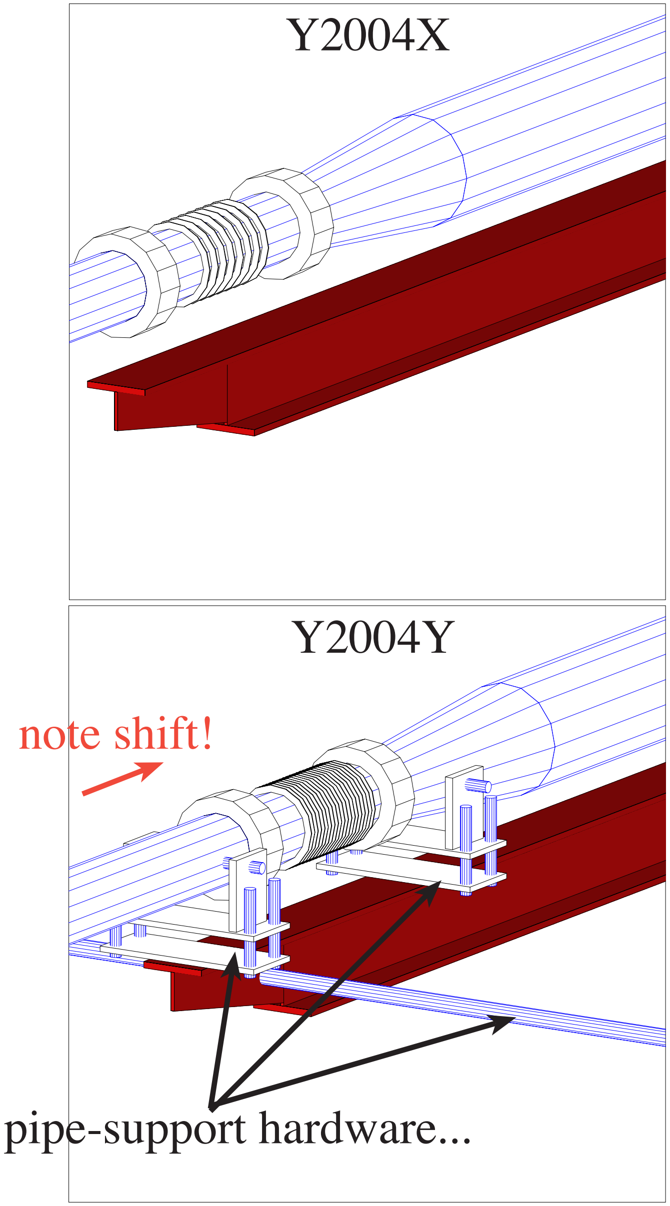
Main R&D developments:
- Detector design, based on full simulations
- PMT base design, need high stability and high rate capability

http://wjllope.rice.edu/~TOF/upVPD/ForwardSimulations/

Simulations of the Upgraded pVPD (Geometry)

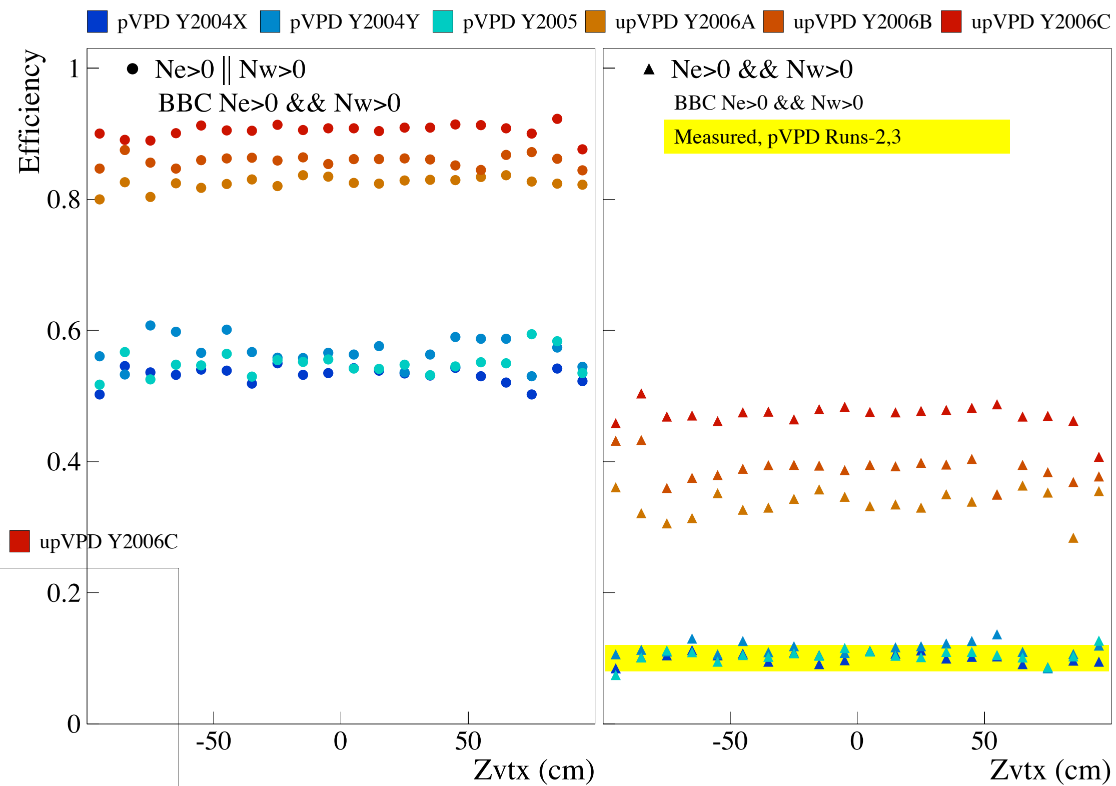
- Strict comparison btw starsim geometry and CADD files from STSG (discrepancies found!)
- First definition of many pipe & I-beam support structure pieces missing from starsim geometry
- Definition of several possible geometries for upVPD
- Performance of the different designs in p+p and Au+Au evts

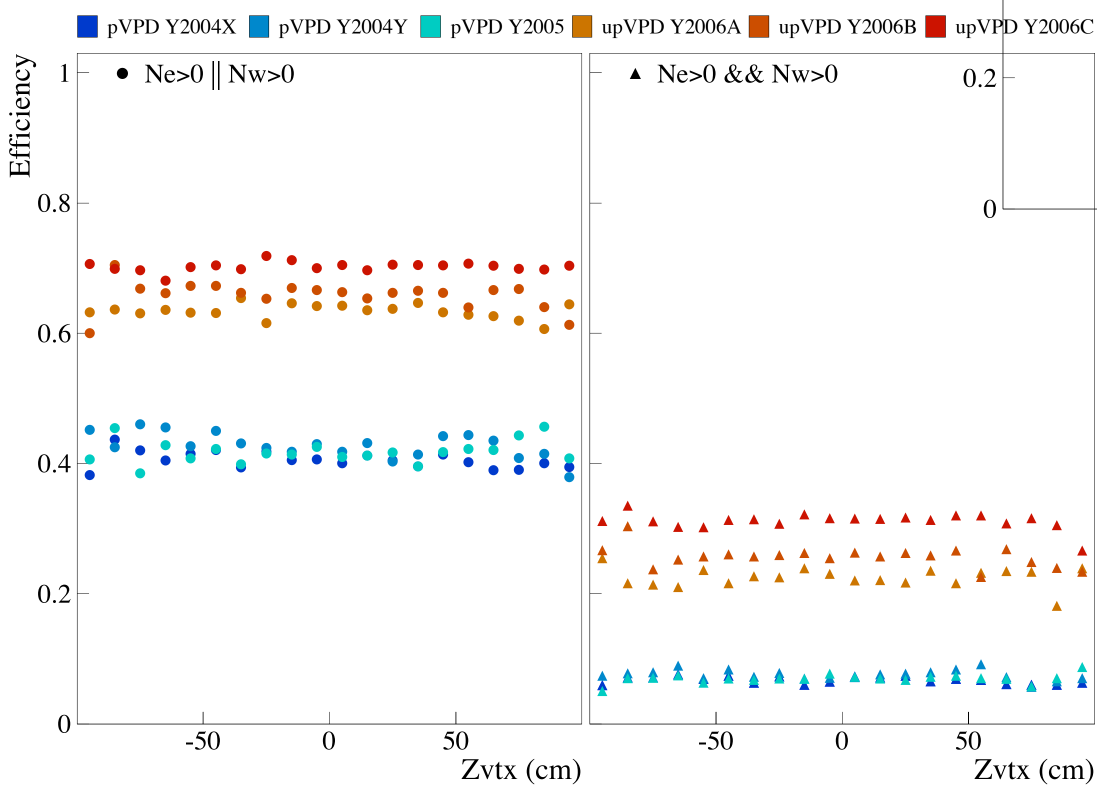




Simulations of the Upgraded pVPD (Performance)

- concentrate on minimum bias p+p collisions (pythia, MSEL=2)
- study efficiency by which detector can produce start times for the different detector geometries





"1.or.1" efficiency
improves from ~55% to ~80-90%

"1.and.1" efficiency
improves from ~10% to ~35-45%

~400% improvement for ~1.5% of the cost

New Bases for the Upgraded pVPD

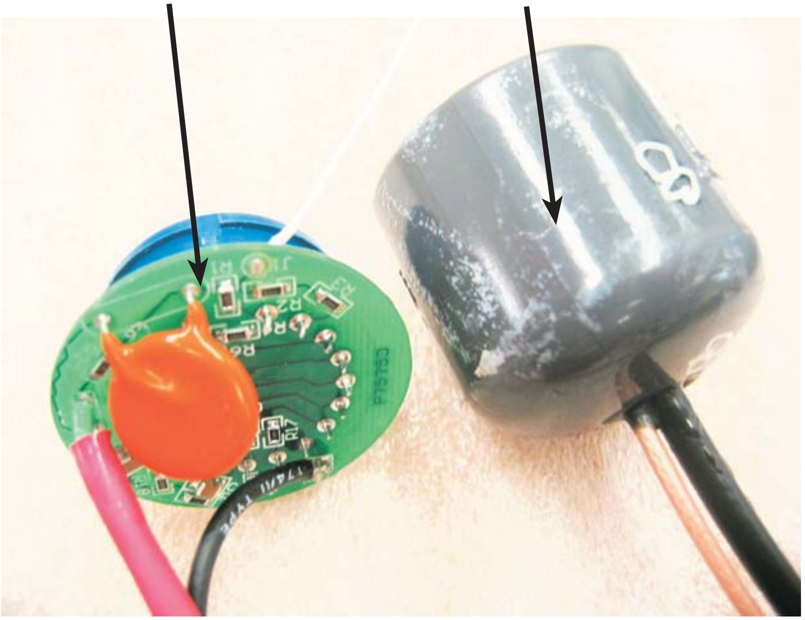
(Vahe Ghazikhanian, J. Mitchell, WJL)

Intended for low-power & high-rate operation with R5946 mesh PMTs

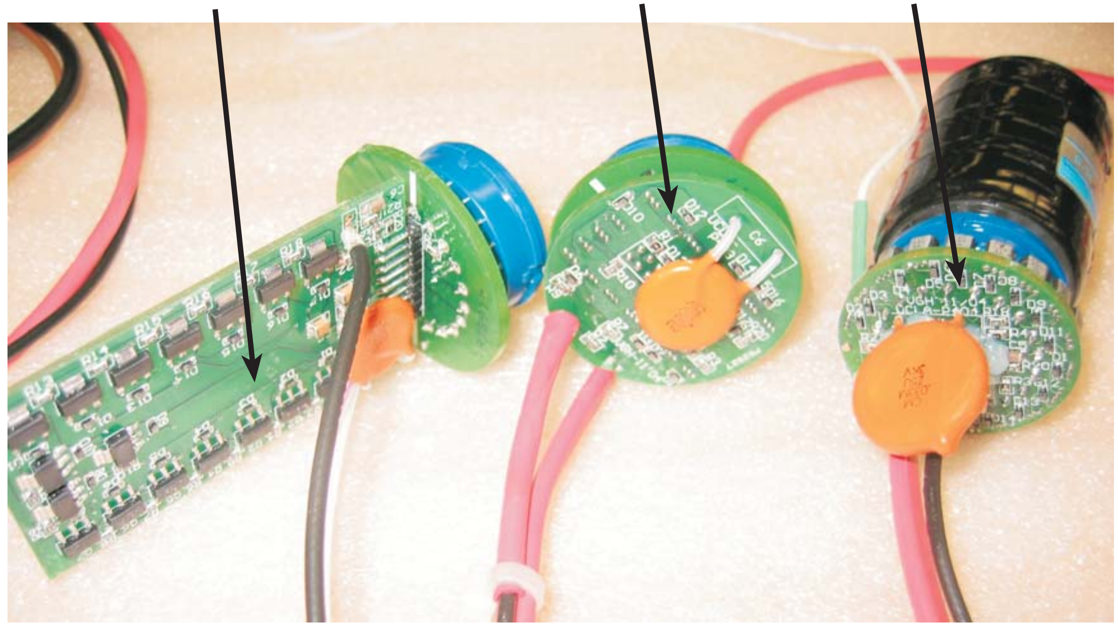
Developed one Linear base, but higher rate than std. Hamamatsu design
- Linear base drops ~2W at 2kV → >50 ^{o}C inside detector assembly...

Developed 3 versions of transistor bases
- MOSFETs are primary voltage divider, current 1/10th of that for the linear base...
- additional factor 10 current drop possible with different bias supply to MOSFETs (resistor chge)...

new linear base CTB base



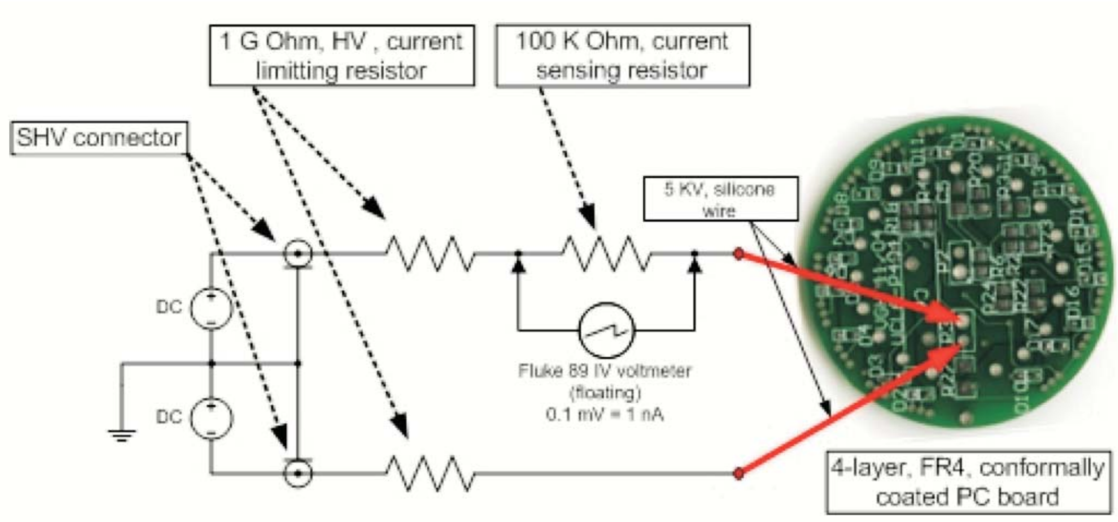
transistor ver. 1 ver. 2 ver.3 w/ PMT

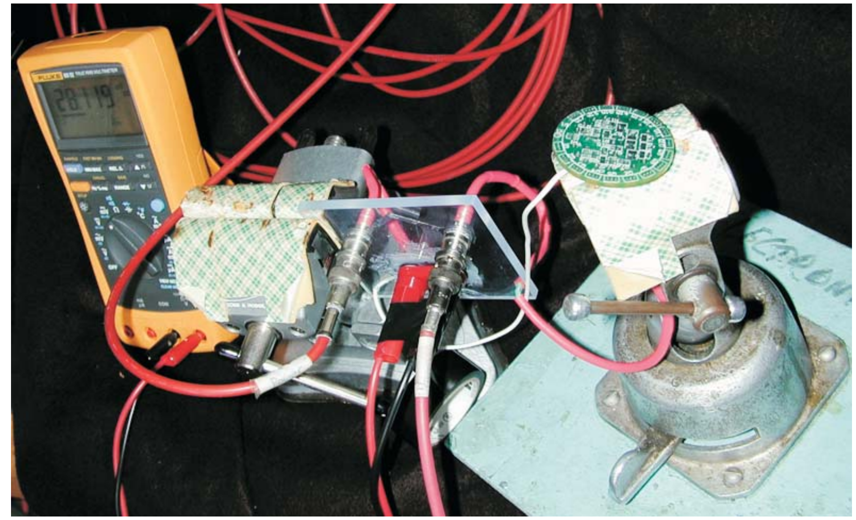


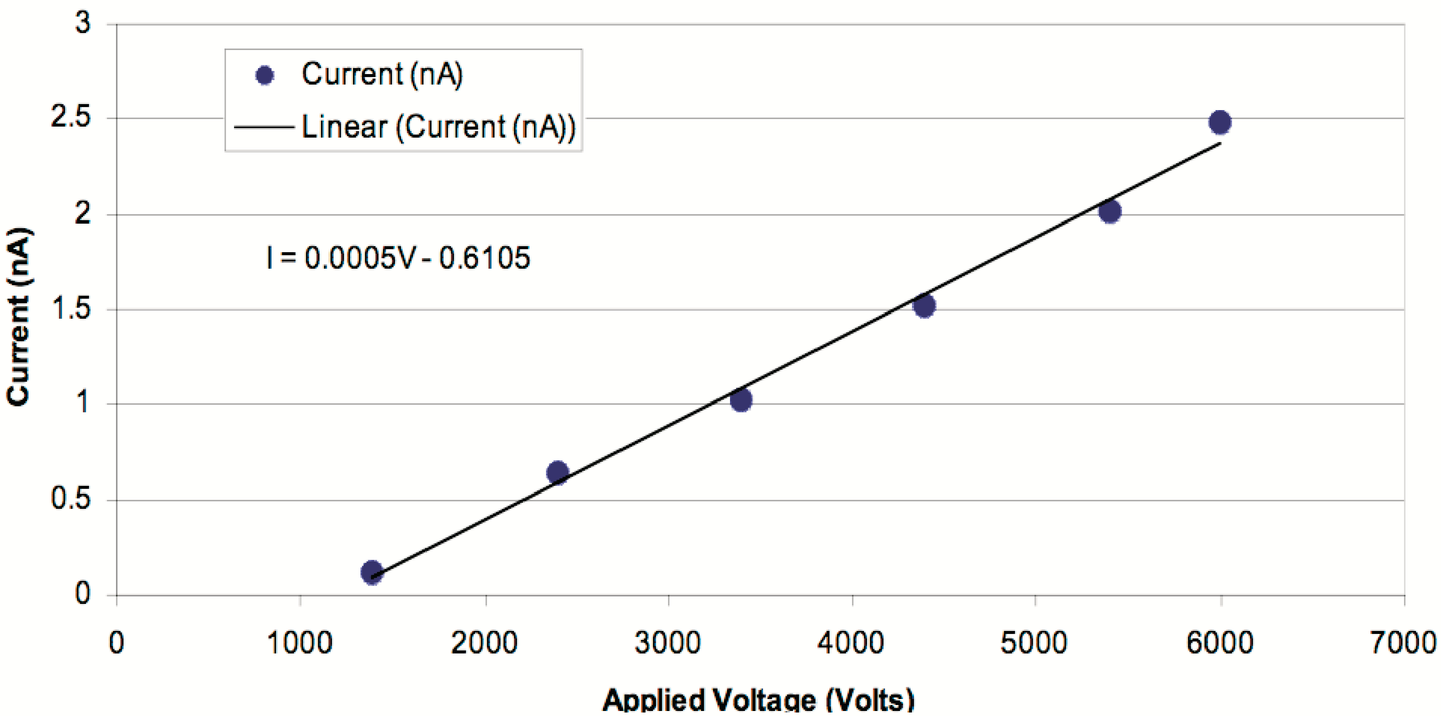
Burned-in for ~1 wk at UCLA, then LED rate-tested at Rice
- Can't see any rate-dependent sag in any of the new bases (several nC pulses, 10's of kHz)

Parts available for ~3 more of latest design transistor base, will build more before Run-6

MOSFET bases for new Start Detector: “2*(max V) + 1kV testing”







no current discontinuities...
no corona...

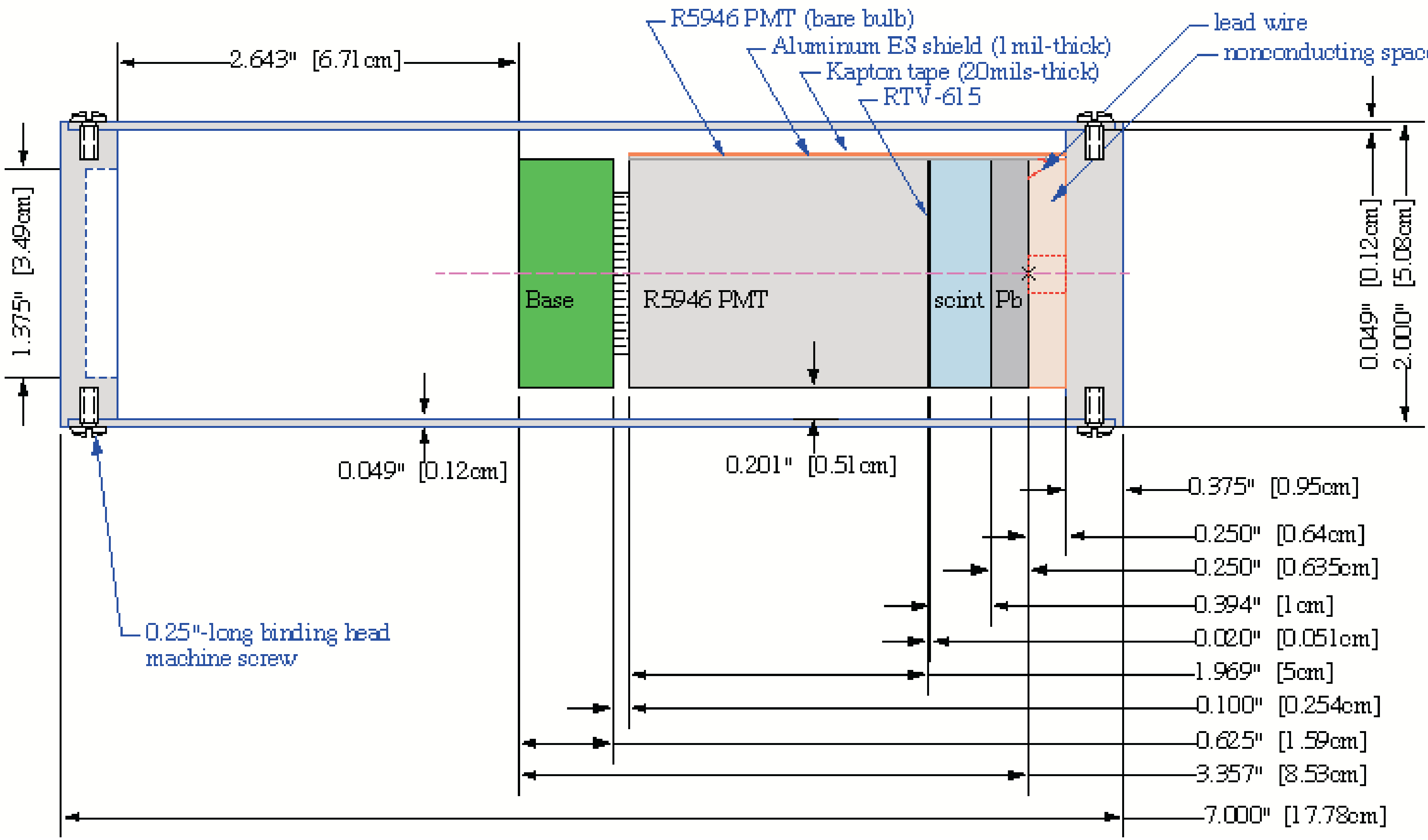
fitted slope consistent with surface resisitivity of FR-4...

removal of conformal coating resulted in visible discharges at that location...

upVPD Detector Assys

parts:
1. thin-walled Al tube, OD 2.00", wall 0.049", length ~ 6.375"
2. Front cap piece
   (Al, 0.375"-thick, OD=1.902", w/ 2 tapped 1/4-20 holes)
3. Rear cap piece
   (Al, 0.375"-thick, OD=1.902", w/ 2 keyed holes for conn
   plus 4 tapped holes around outside for 4-40 screws)

Qty needed = fifty (50).



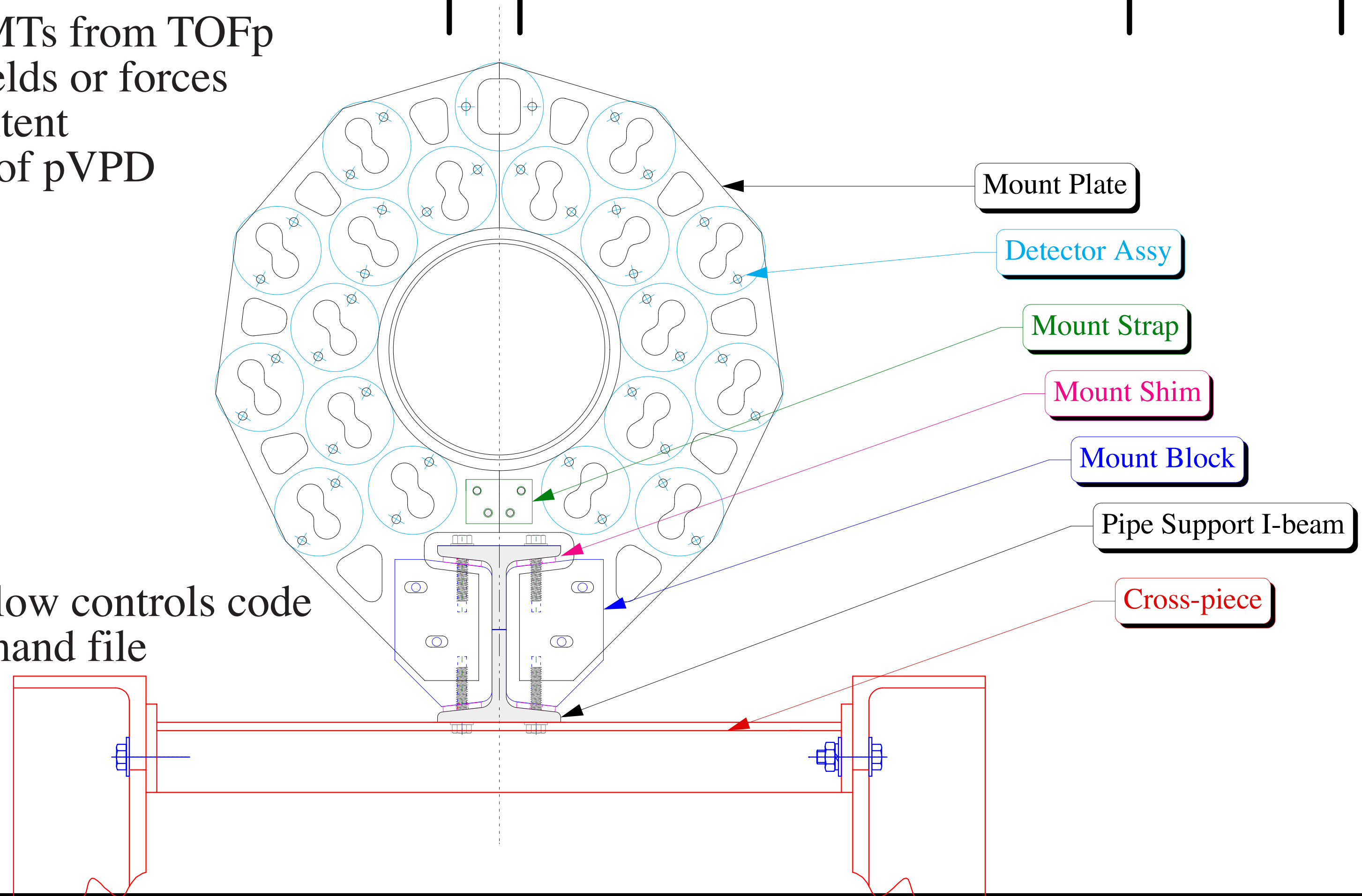
(each labelled "**Pb enclosed. Do Not Disassemble**" - same as for pVPD)...

REVISION HISTORY			
REV	DESCRIPTION	DATE	APPROVED
1	first version	12/29/2005	WJL

Run-6 prototype

19 detectors/side
mesh dynode PMTs from TOFp
no magnetic shields or forces
smaller radial extent
~2/3 the weight of pVPD
same Z-location

need to update slow controls code
Les controls demand file



UNLESS OTHERWISE SPECIFIED
DIM ARE IN INCHES
TOL ON ANGLE ±.01°
2 PL ±.01 3 PL ±.002
INTERPRET DIM AND TOL PER
ASME Y14.5M-1994

THIRD ANGLE PROJECTION

DESIGNED BY: W.J. Llope
DRAWN BY: W.J. Llope
CHECKED BY: J. Hoffmann
APPROVED BY: W.J. Llope
OTHER APPROVALS: TBD
CAD FILE NAME: TOF_107_A_1_MountAssyFront

RICE

TITLE: STAR TOF SYSTEM
Start Detector
Mount Assembly, Front View

SIZE	CAGE CODE	DRAWING NO.	REV
A	N/A	TBD	1

SCALE 1:4 | EST. WGT | SHEET 1 OF 1

Z-location for upVPD is the same as for present pVPD
smaller Z-extent and weight now though