# Detector Construction & Installation

*w.j. llope*

*☆ TOF DOE Review, BNL*

*August 22, 2005*

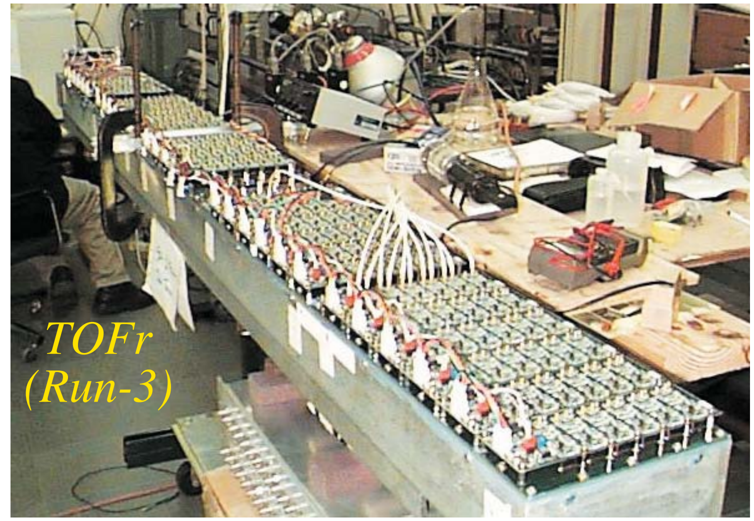
Outline:

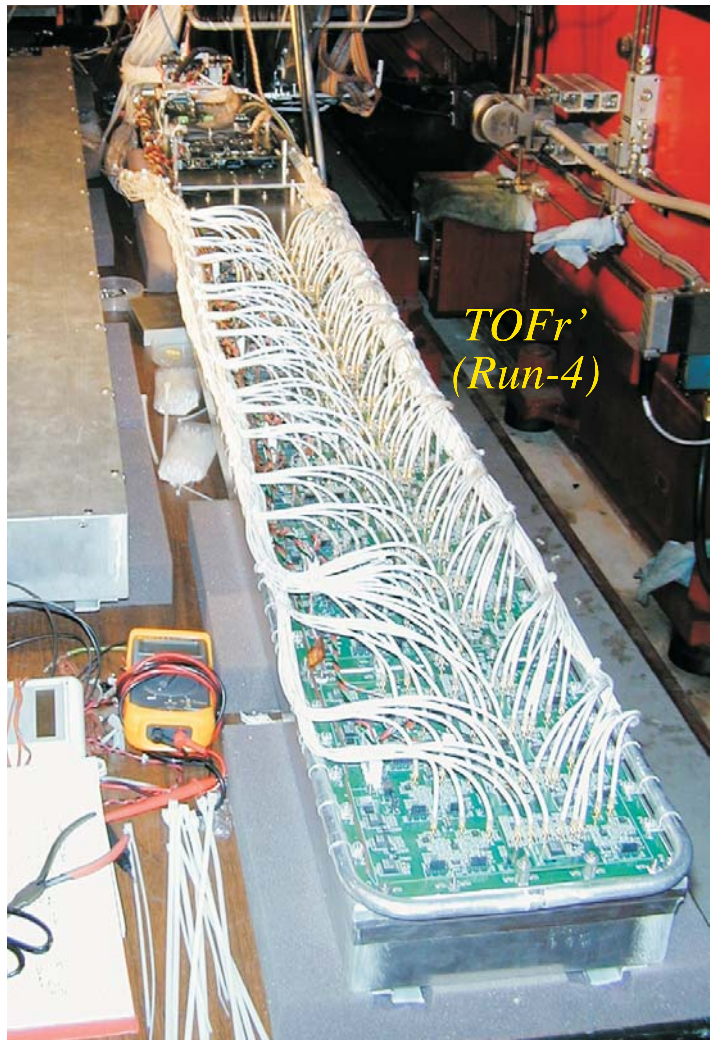
- Tray mechanical design
  - TOFr, TOFr', TOFr5, &TOFr6
- Impact of full system on STAR
  - weight
  - power & temperature
  - secondary production
  - gas containment
- Tray Fabrication
  - space and fixtures
  - detailed procedure
  - 126 tray production plan
- Start detector
  - simulations
  - new based development
  - Run-6 prototype

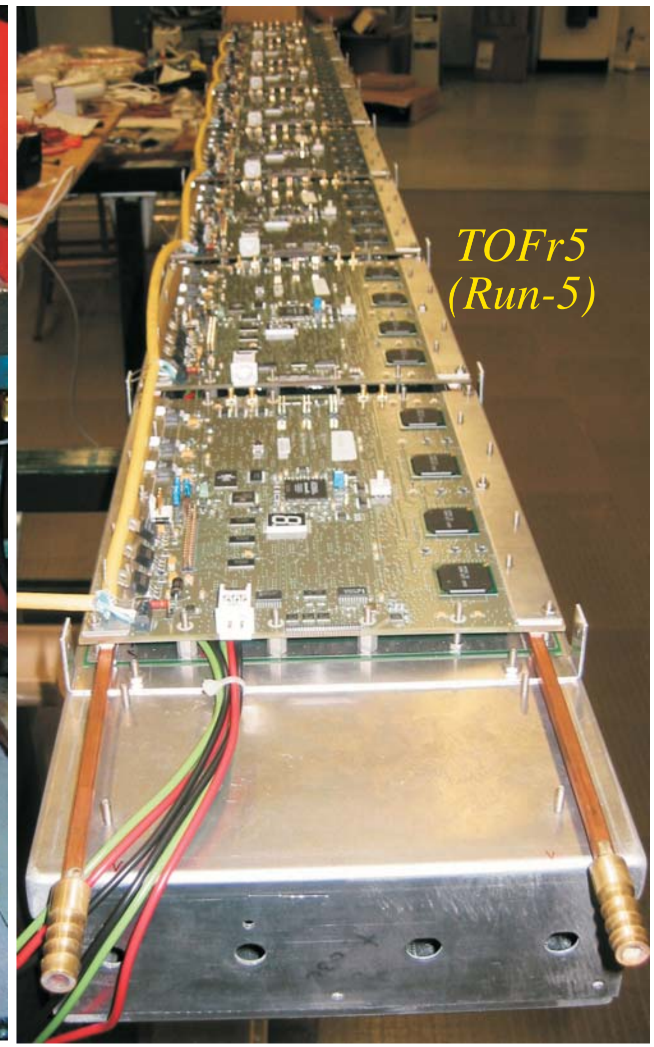
Mechanical Design Summary

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

subsequent trays (TOFr6, ...) will be
simple variants of the TOFr5 design:
- simple, quick, & repeatable to assemble
- very precise detector positioning
- open-box MRPC→FEE testing



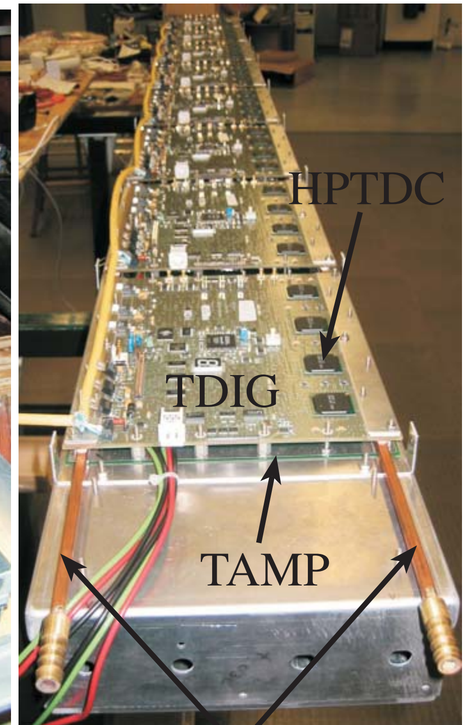




Overview of TOFr5 Design

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

# 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)

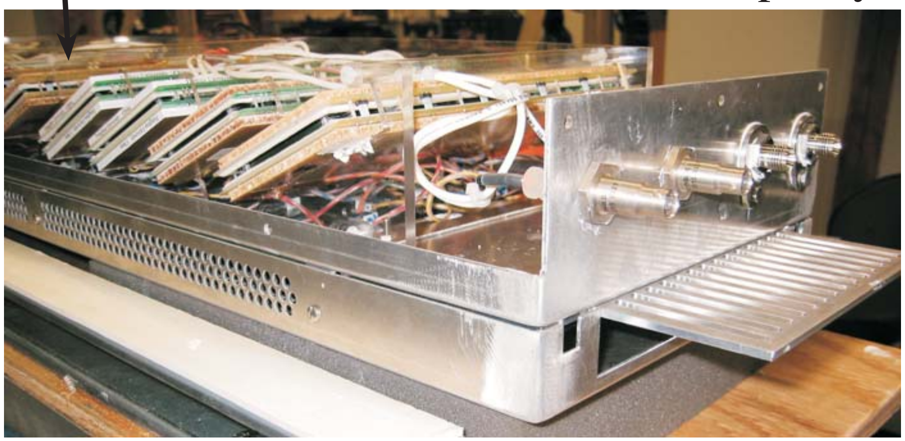


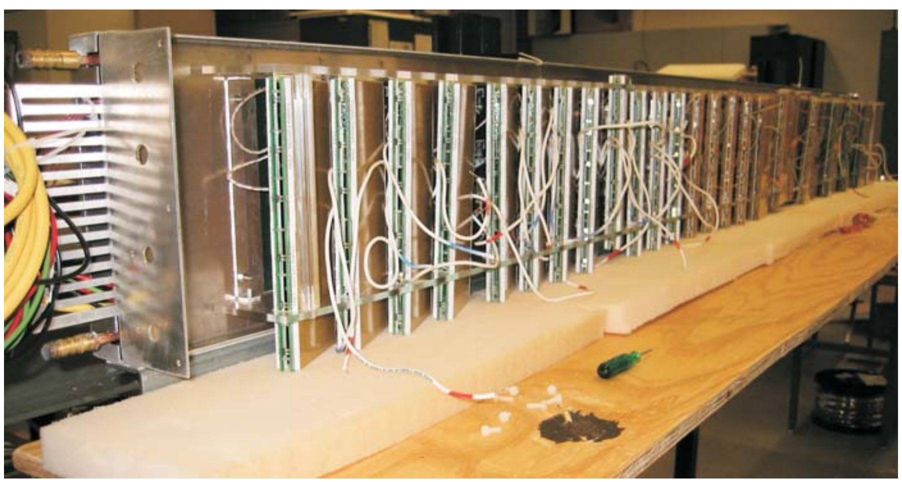

perf. cover assy

cooling loop

"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





- ~~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~~

"bowing" of bottom assy due to welded feet
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

4th Generation Prototype (TOFr6)

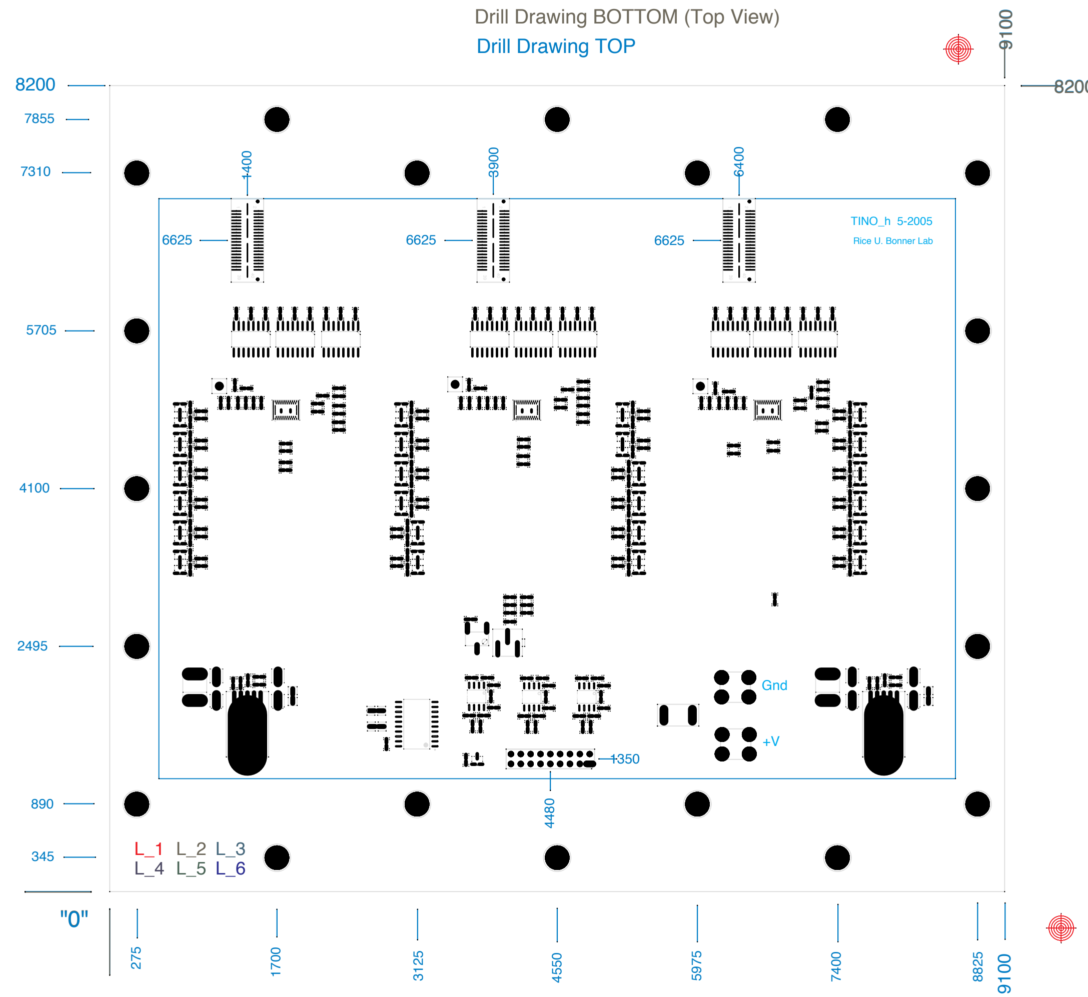
simpler cooling loop design
- 1/4” square → 1/4”x3/8” rectangular

only small tweaks to mechanical design
- TINO
- new cooling loop

tweaks to tray fabrication
- bowing from welded feet
- (moving back to pop-rivets)

TINO
- lower power
- no ringing
- fully differential
- multiplicity outputs
- now only need positive LV!

TDIGb
- accepts signals from TINO
  - (remove discriminators)
- address timing cross-talk
- multiplicity




Tentative Stop-side detectors for Run-6

- 2 trays with single-stack modules
- with “TOFr6” mechanical design

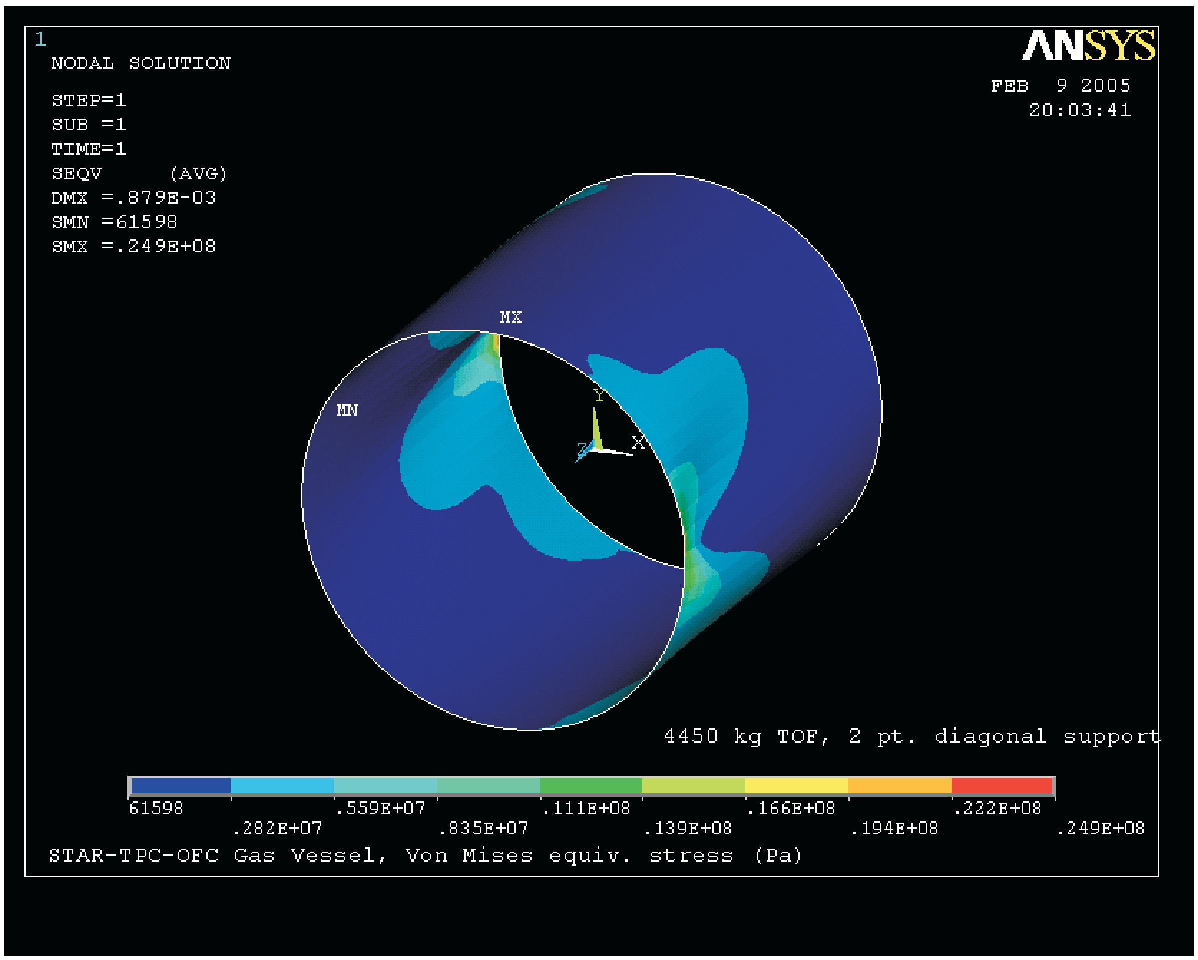
Weight issues

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..."

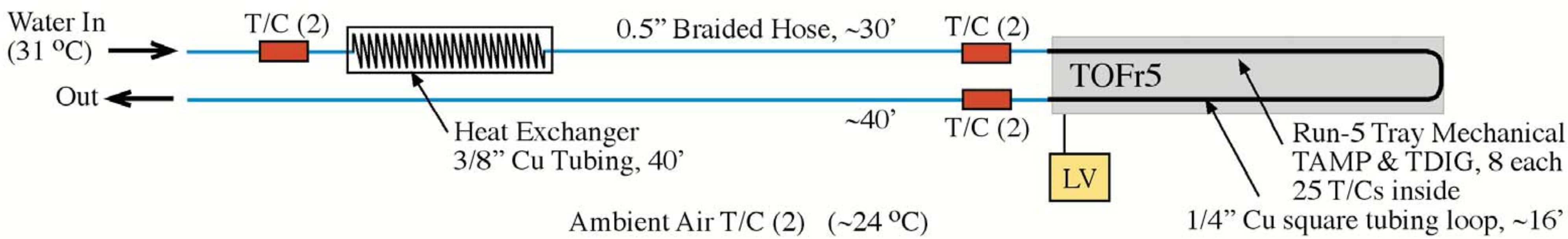
results for 3.
Tangential direction normal stresses
"are only 6.5 MPa localized near
the support in the 2-arm configuration"

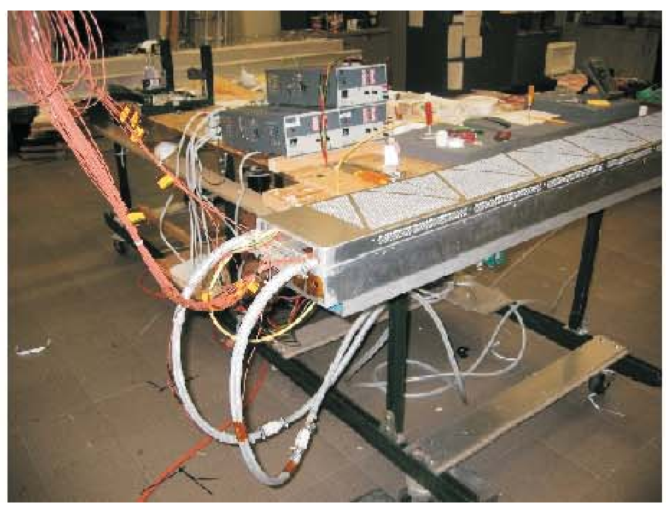
Power, Cooling, & Temperature Issues

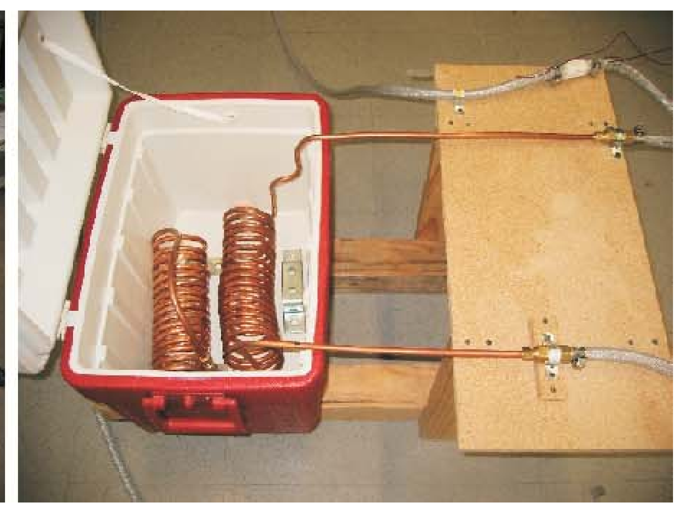
TOFr5 electronics drop 140 +/- 10 W (TOFr6 < 100W?)

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

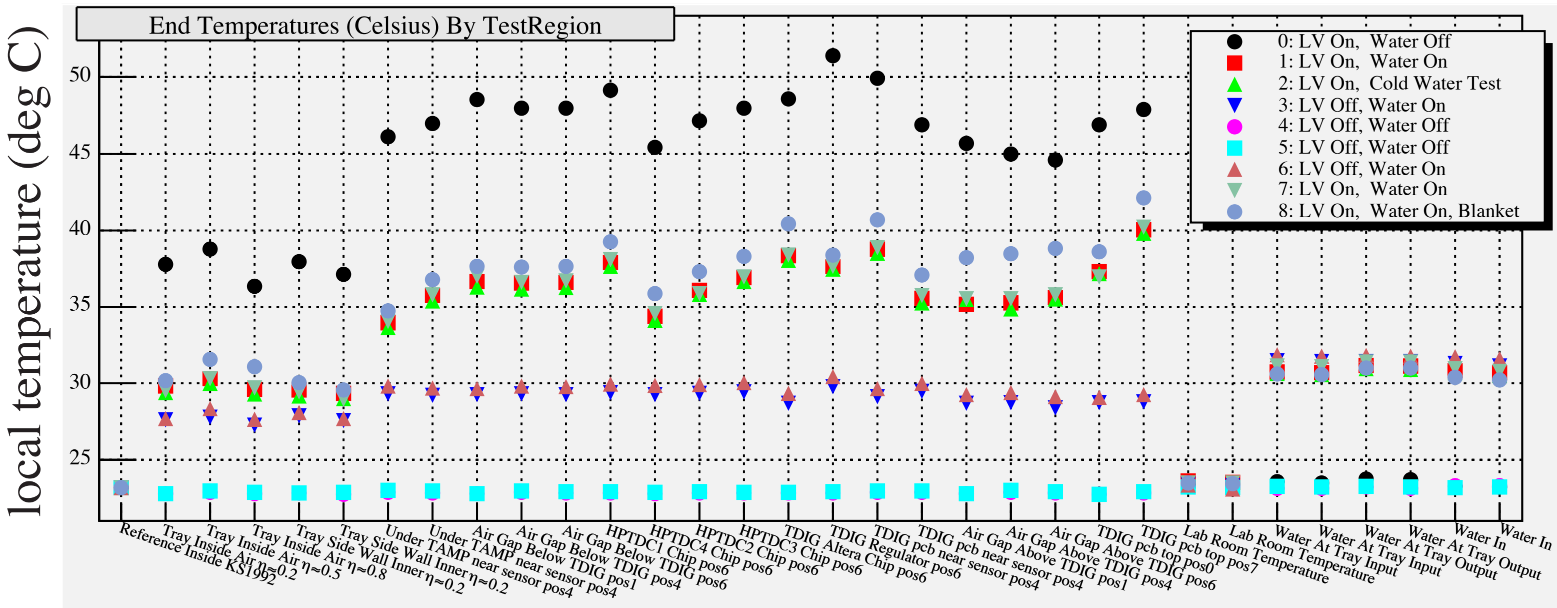
- 32 Type-T thermocouples inside tray, on electronics, plus ambient, water in&out, etc.
- Kinetics 1992/3516 T/C readout via CAMAC to PC
  - measurement error <0.2 deg C
- full complement of TAMP & TDIG electronics installed and powered up
- water flow unfortunately 31 deg C (is <25 deg C in STAR)
-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





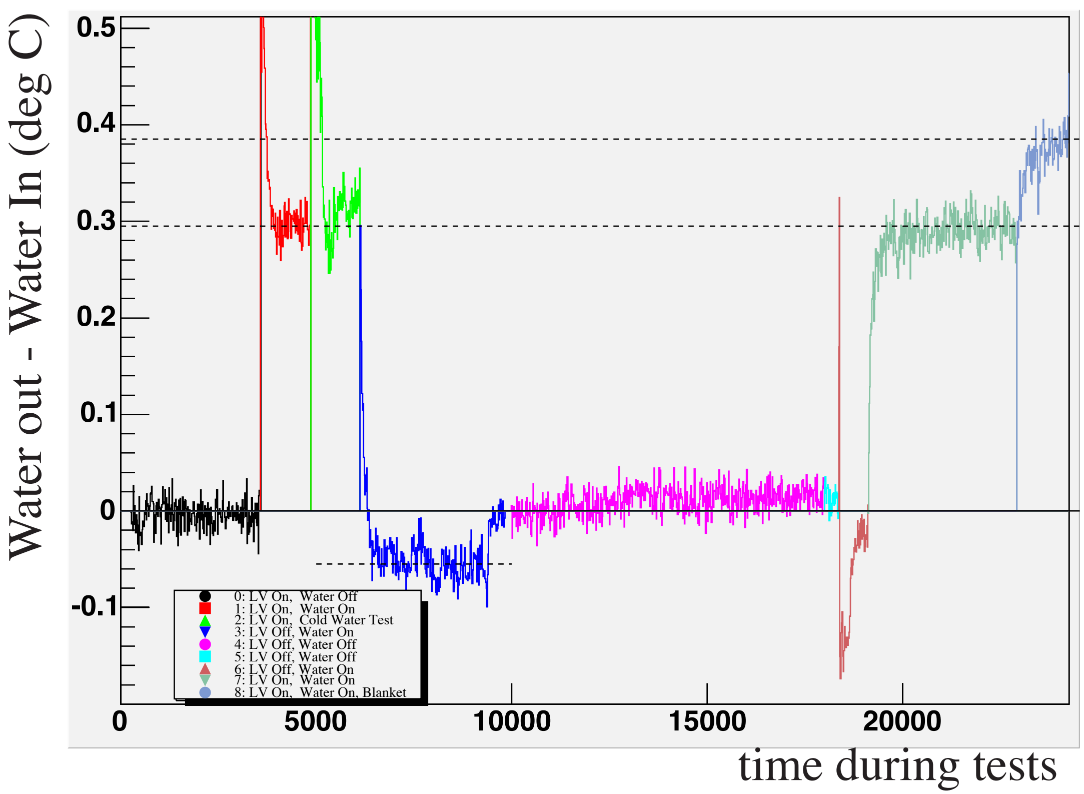
http://wjllope.rice.edu/~TOF/TOFr5/Ttests/TOFr5_T_tests.htm




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)

Secondary production

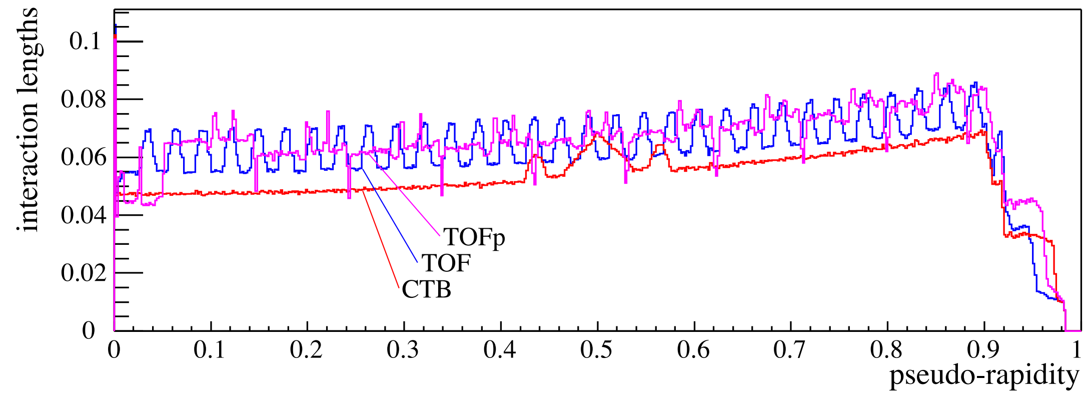
estimates from AGI+gstar simulations

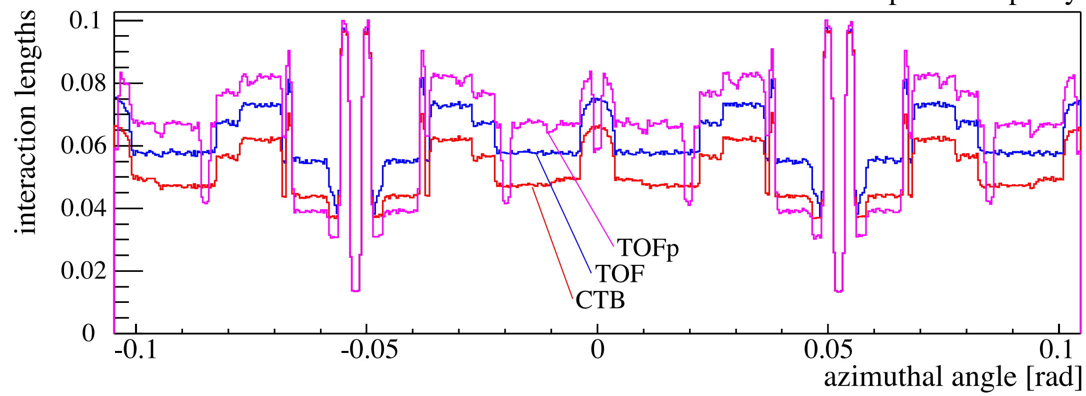
full description of MRPCs

TOF: ~6.5% of $\lambda_0$

CTB: ~4.9%

→ 32% more than CTB

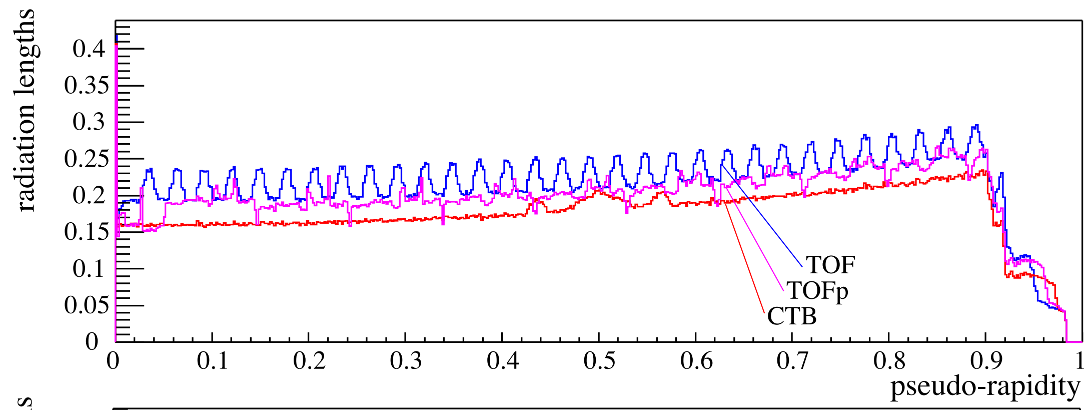


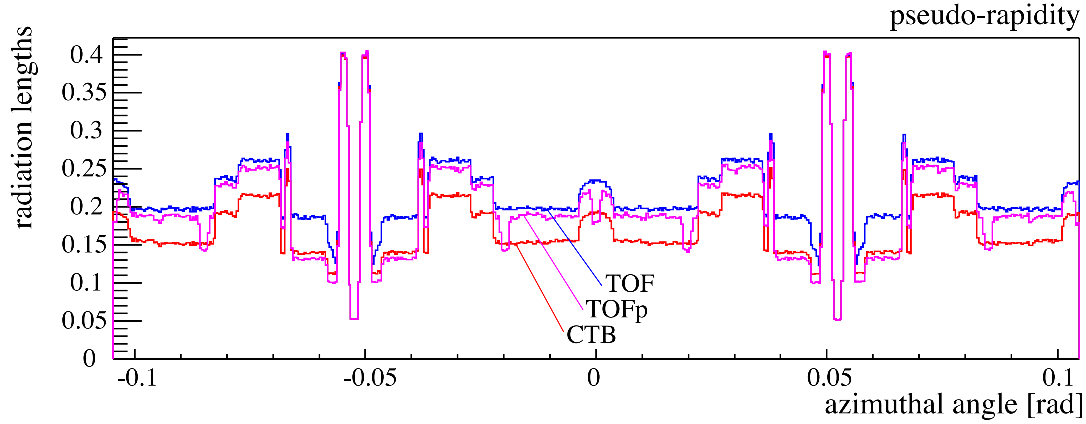




TOF: ~20% of $X_0$

CTB: ~15%

→ 33% more than CTB



Gas Containment

best MRPC performance obtained with 90% Freon, 5% iso-butane, & 5% SF6
most early papers on MRPC just call this "the standard mixture"

concern is the detrimental effects that SF6 would have on the TPC 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."

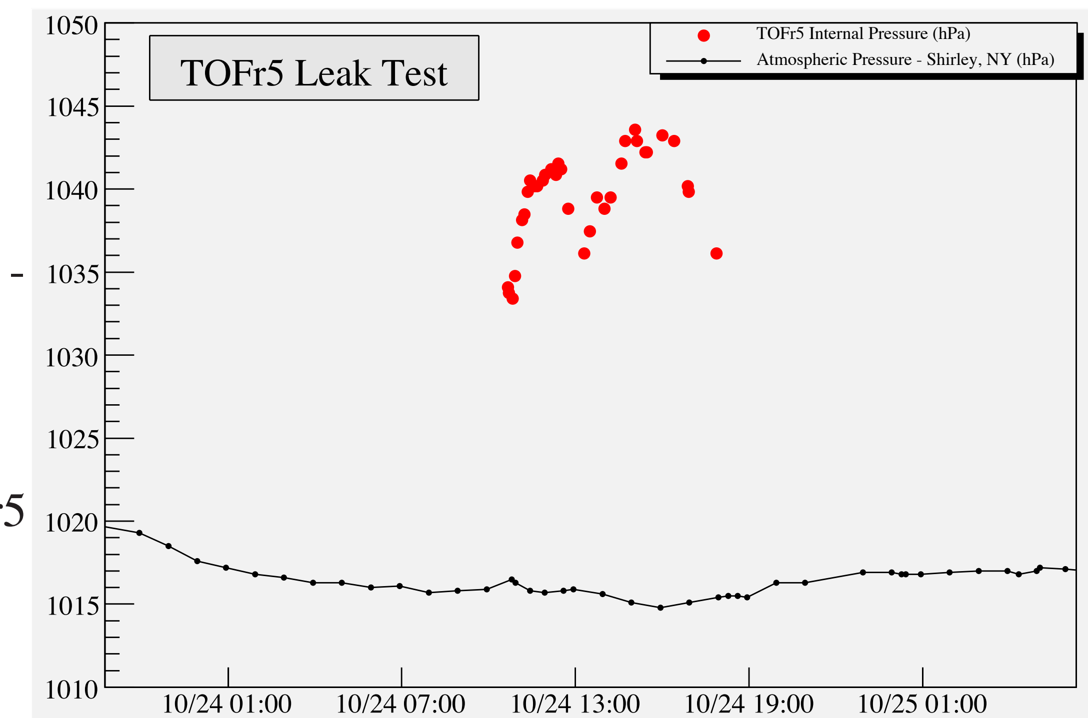
Thus, we have used only 95% Freon & 5% iso-butane during Runs 3 through 5...

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

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



Tray Fabrication Assumptions:

• tray structures produced in Houston at Oaks Precision
  QA/QC of fit & finish and size tolerances at RICE

• electronics produced in Houston (RICE, Blue Sky)
  TINO on tray fabrication critical path, and must undergo stricter pre-install testing

• tray Assembly and testing at UT-Austin
  MRPCs shipped to UT at rate of 160/month
    bench tests of each MRPC in china and documented on WWW
    no gas-box tests of MRPCs at UT before insertion into trays (except first few hundred)
    size tolerance testing only

• tray retesting (HV current draw & noise rates) at BNL

Final tray fabrication follows TOFr5 model...
  requires special table that can hold top+cover assembly flat and at a 90 deg angle

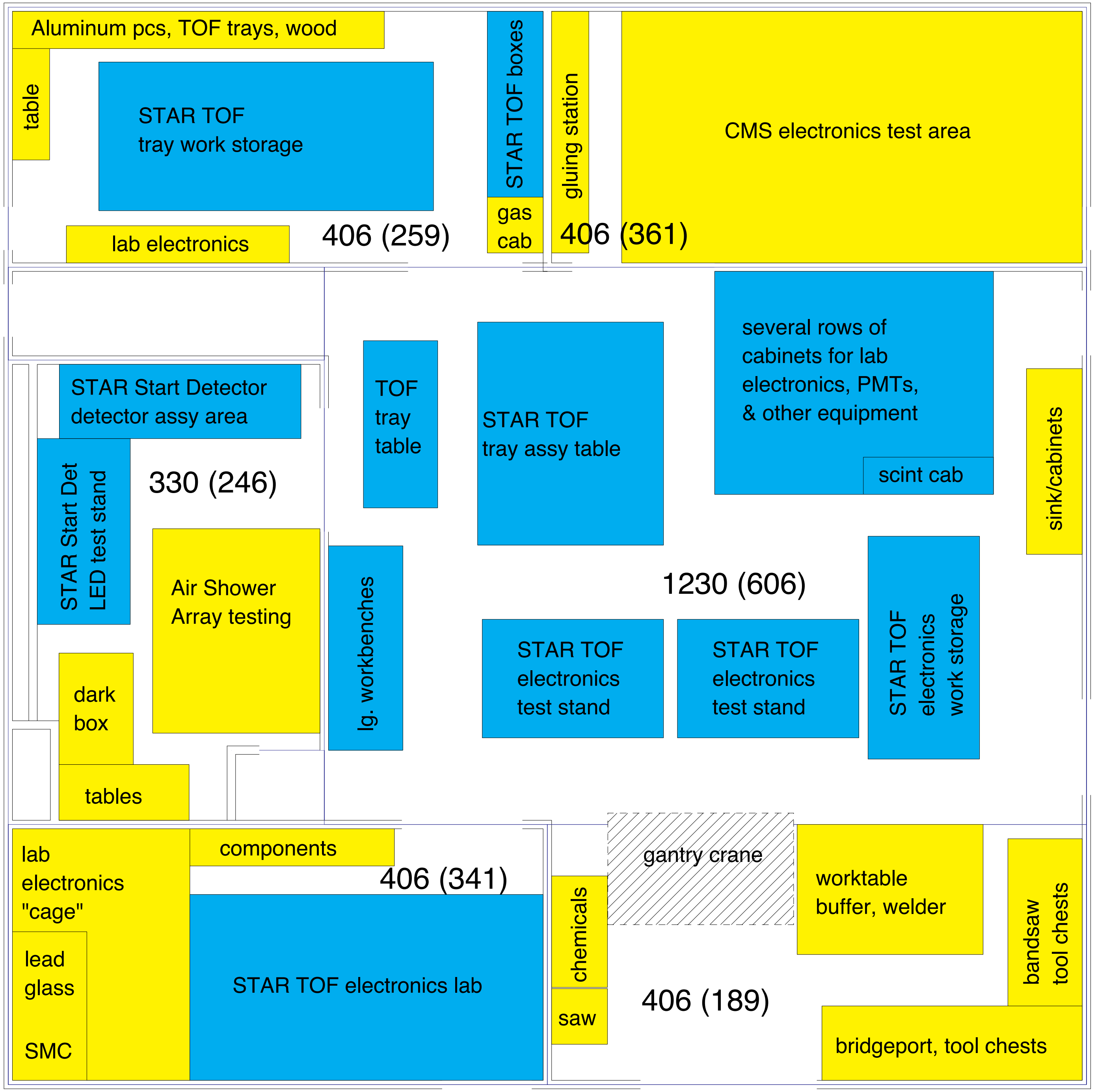
Working now within the group to set up the size and skewness specs & tolerances for MRPCs & Trays

manpower assumed is 2.5yr Mechanical Technician and 1 FTE undergraduate for 2yrs at UT
assumes also UT Postdoc (0.5 FTE) for Fabricated Tray testing
Rice Postdoc (0.5 FTE) for Electronics testing

UT machine shop fabricates inner sides and cooling loops
  labor is contributed...
  raw mtls costs only...

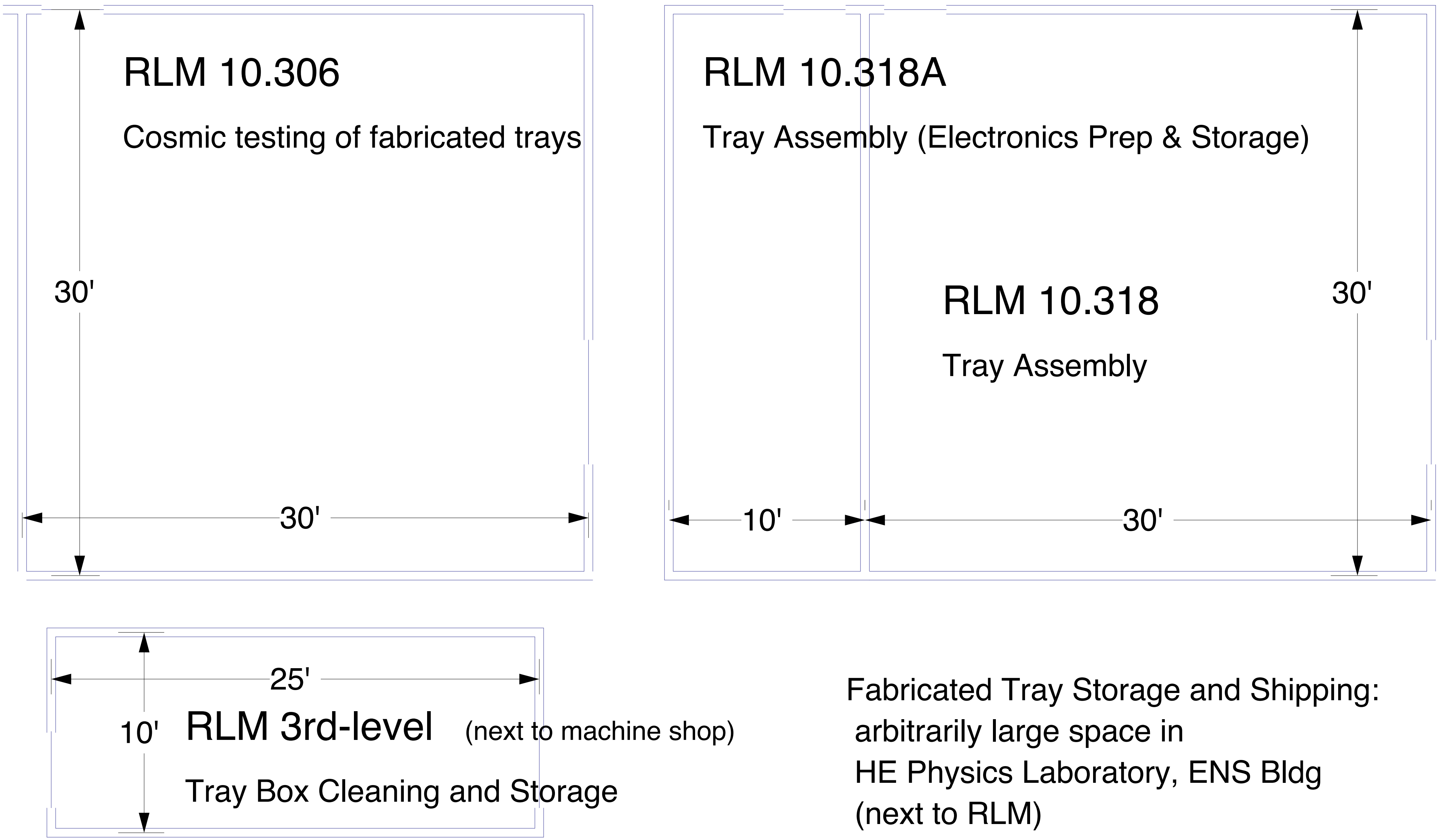
tray fabrication workflow and fabbed tray documentation system is under development.

# Space @ RICE



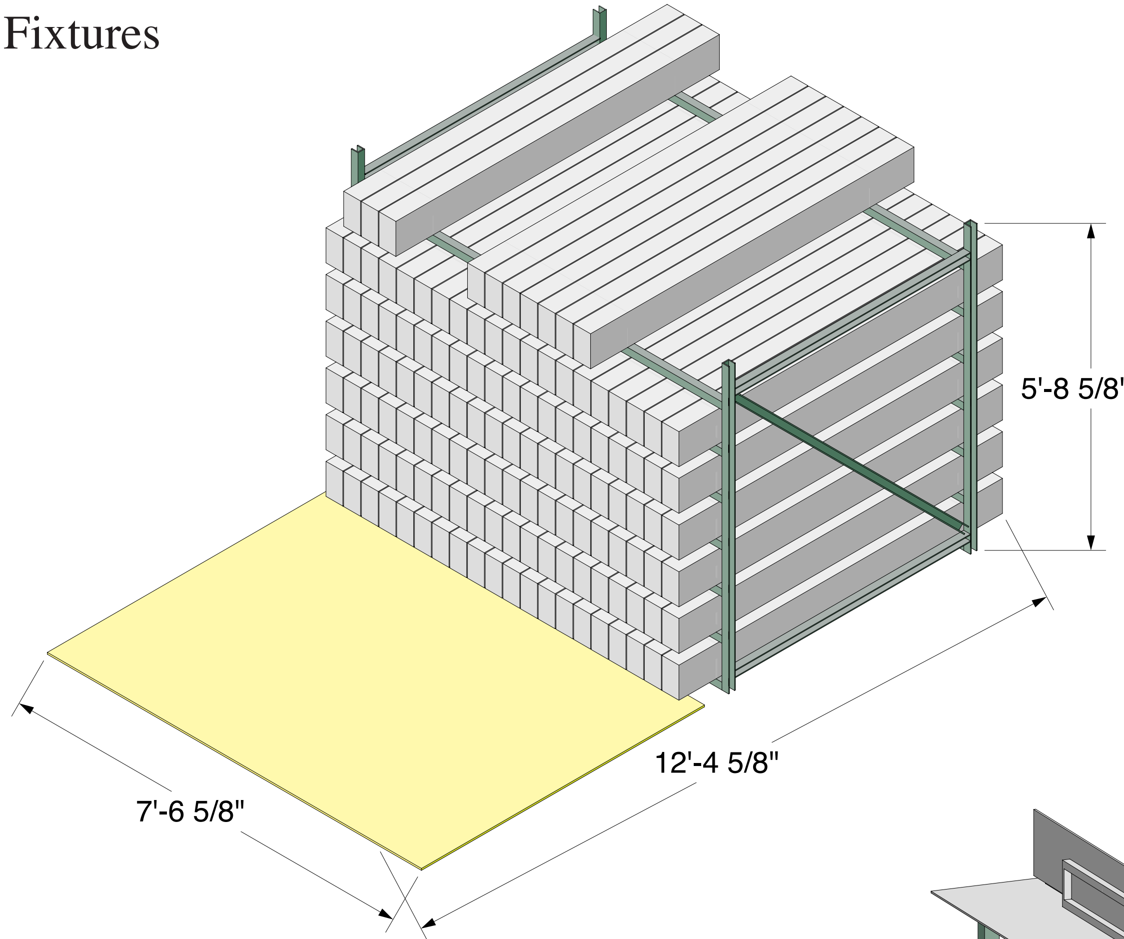
Aluminum pcs, TOF trays, wood
table
STAR TOF
tray work storage
STAR TOF boxes
gas
cab
gluing station
CMS electronics test area
lab electronics
406 (259)
406 (361)
STAR Start Detector
detector assy area
TOF
tray
table
STAR TOF
tray assy table
several rows of
cabinets for lab
electronics, PMTs,
& other equipment
scint cab
sink/cabinets
STAR Start Det
LED test stand
330 (246)
Air Shower
Array testing
lg. workbenches
1230 (606)
STAR TOF
electronics
test stand
STAR TOF
electronics
test stand
STAR TOF
electronics
work storage
dark
box
tables
lab
electronics
"cage"
components
406 (341)
gantry crane
worktable
buffer, welder
bandsaw
tool chests
lead
glass
SMC
STAR TOF electronics lab
chemicals
saw
406 (189)
bridgeport, tool chests

Space @ UT



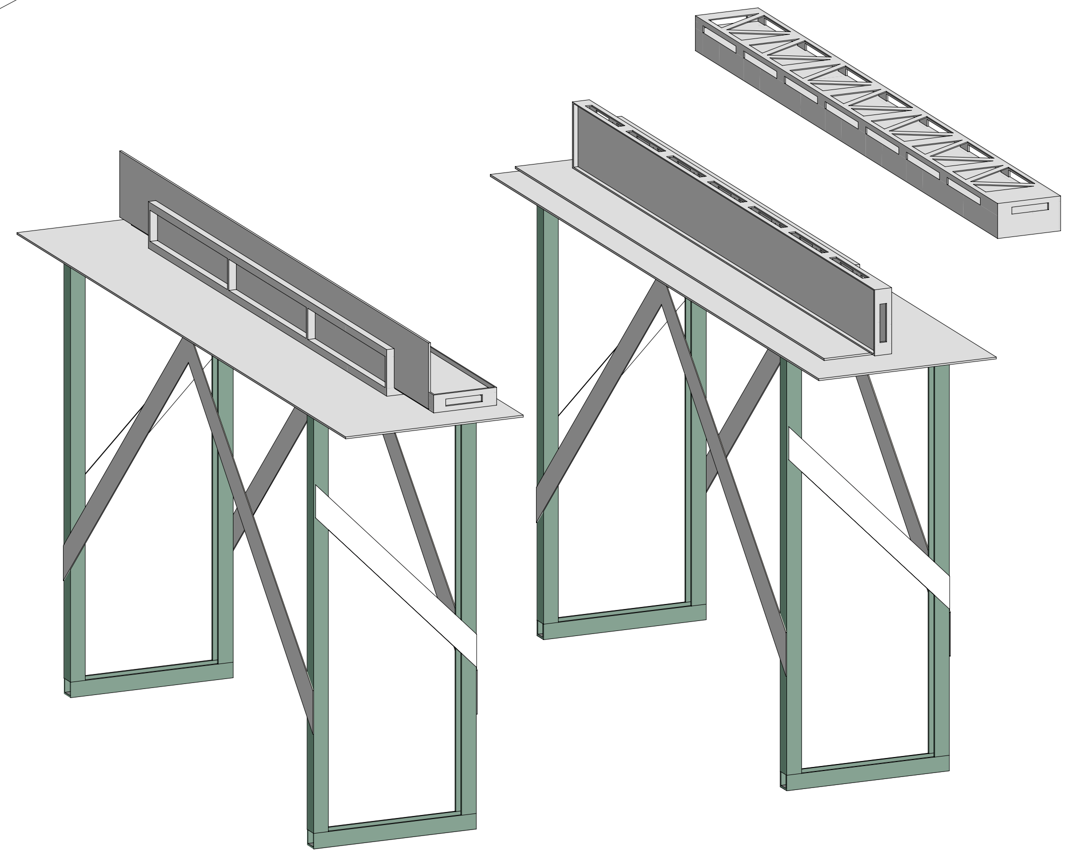

Fabricated Tray Storage and Shipping:
arbitrarily large space in
HE Physics Laboratory, ENS Bldg
(next to RLM)

# Fixtures




Tray Storage Structure

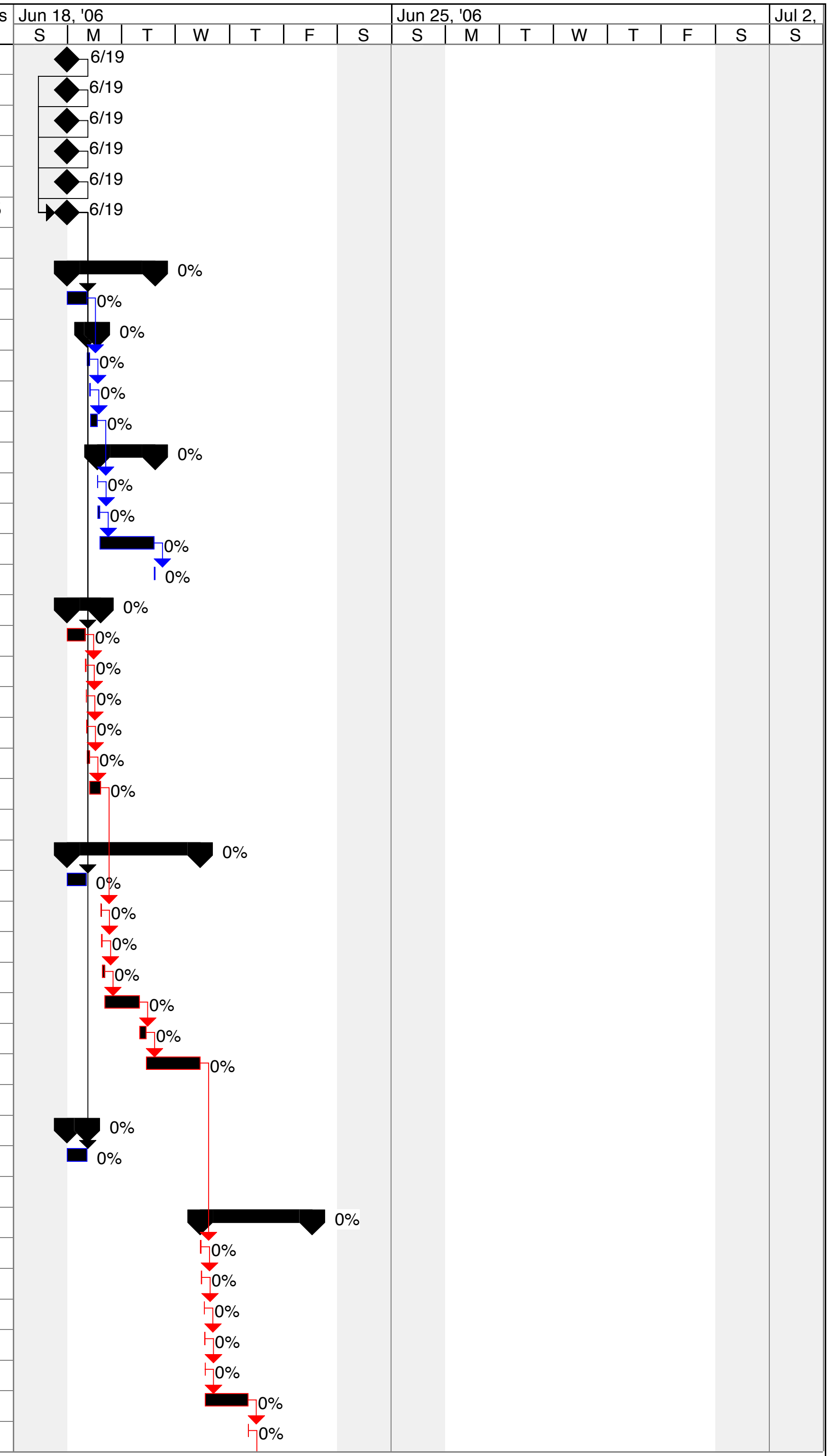
Tray Assembly Fixture



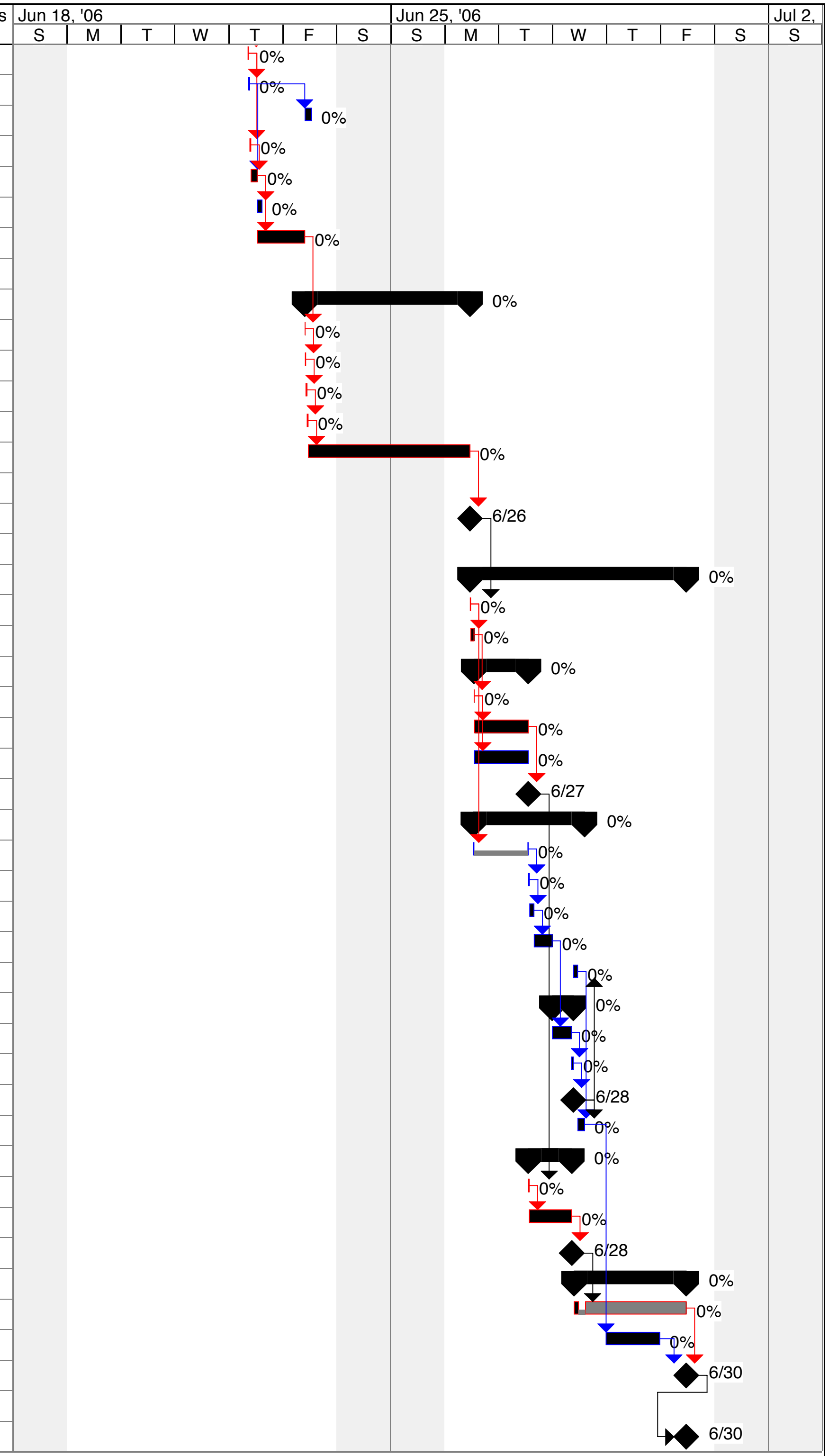
general thinking is that these storage fixtures are constructed at UT during the initial ‘gear-up’ phase of the project

i.e. during tray parts fab at Oaks...

| ID | Task Name | Duration | Start | Finish | Predecess |
|---|---|---|---|---|---|
| 1 | Inner Sides available | 0 days | Mon 6/19/06 | Mon 6/19/06 | |
| 2 | Cooling Loop available | 0 days | Mon 6/19/06 | Mon 6/19/06 | |
| 3 | Tray Structures and Hardware available | 0 days | Mon 6/19/06 | Mon 6/19/06 | |
| 4 | TINO & TDIG in Hand | 0 days | Mon 6/19/06 | Mon 6/19/06 | |
| 5 | Wire and Cabling available | 0 days | Mon 6/19/06 | Mon 6/19/06 | |
| 6 | All Parts in Hand | 0 hrs | Mon 6/19/06 | Mon 6/19/06 | 1,2,3,4,5 |
| 7 | | | | | |
| 8 | Tray Structure Prep | 14.25 hrs | Mon 6/19/06 | Tue 6/20/06 | |
| 9 | inspection & documentation | 1 hr | Mon 6/19/06 | Mon 6/19/06 | 6 |
| 10 | clean bottom, top, cover & brackets | 3.5 hrs | Mon 6/19/06 | Mon 6/19/06 | |
| 11 | dip | 1 hr | Mon 6/19/06 | Mon 6/19/06 | 9 |
| 12 | dry | 0.5 hrs | Mon 6/19/06 | Mon 6/19/06 | 11 |
| 13 | isopropyl scrub | 2 hrs | Mon 6/19/06 | Mon 6/19/06 | 12 |
| 14 | bottom assy prep | 9.75 hrs | Mon 6/19/06 | Tue 6/20/06 | |
| 15 | move bottom assy to bottom prep area | 0.25 hrs | Mon 6/19/06 | Mon 6/19/06 | 13 |
| 16 | seal inner corners and welds | 1 hr | Mon 6/19/06 | Mon 6/19/06 | 15 |
| 17 | curing (bottom assy inner) | 1 day | Mon 6/19/06 | Tue 6/20/06 | 16 |
| 18 | add kapton layer | 0.5 hrs | Tue 6/20/06 | Tue 6/20/06 | 17 |
| 19 | top assy prep | 6 hrs | Mon 6/19/06 | Mon 6/19/06 | |
| 20 | move top assy to fixture (top topside up) | 0.25 hrs | Mon 6/19/06 | Mon 6/19/06 | 6 |
| 21 | install upper brackets | 0.25 hrs | Mon 6/19/06 | Mon 6/19/06 | 20 |
| 22 | install cover assy | 0.25 hrs | Mon 6/19/06 | Mon 6/19/06 | 21 |
| 23 | invert top+cover assy (top topside down) | 0.25 hrs | Mon 6/19/06 | Mon 6/19/06 | 22 |
| 24 | seal PEM studs on underside of top assy | 1 hr | Mon 6/19/06 | Mon 6/19/06 | 23 |
| 25 | curing (top assy inner) | 4 hrs | Mon 6/19/06 | Mon 6/19/06 | 24 |
| 26 | | | | | |
| 27 | TAMP to top assy | 19.25 hrs | Mon 6/19/06 | Wed 6/21/06 | |
| 28 | TAMP inspection & documentation | 0.5 hrs | Mon 6/19/06 | Mon 6/19/06 | 6 |
| 29 | invert top+cover assy (top topside up) | 0.25 hrs | Mon 6/19/06 | Mon 6/19/06 | 25 |
| 30 | remove cover assy and upper brackets | 0.5 hrs | Mon 6/19/06 | Mon 6/19/06 | 29 |
| 31 | reclean near big holes | 1 hr | Mon 6/19/06 | Mon 6/19/06 | 30 |
| 32 | install ground washers | 0.5 hrs | Mon 6/19/06 | Tue 6/20/06 | 31 |
| 33 | seal and bolt down TAMPs to top assy | 3 hrs | Tue 6/20/06 | Tue 6/20/06 | 32 |
| 34 | curing (TAMP to top assy) | 1 day | Tue 6/20/06 | Wed 6/21/06 | 33 |
| 35 | | | | | |
| 36 | MRPCs | 1 hr | Mon 6/19/06 | Mon 6/19/06 | |
| 37 | inspection & documentation | 1 hr | Mon 6/19/06 | Mon 6/19/06 | 6 |
| 38 | | | | | |
| 39 | Loading the Inverted Top Assy | 16.77 hrs | Wed 6/21/06 | Fri 6/23/06 | |
| 40 | install upper brackets and cover assy | 0.5 hrs | Wed 6/21/06 | Wed 6/21/06 | 34 |
| 41 | invert top+cover assy (top topside down) | 0.25 hrs | Wed 6/21/06 | Wed 6/21/06 | 40 |
| 42 | install lower brackets | 0.25 hrs | Wed 6/21/06 | Wed 6/21/06 | 41 |
| 43 | install "closer" inner side | 0.25 hrs | Wed 6/21/06 | Wed 6/21/06 | 42 |
| 44 | rotate fuxture (top on side, closer inner side horizontal) | 0.02 hrs | Wed 6/21/06 | Wed 6/21/06 | 43 |
| 45 | install MRPCs inc connections to TAMP | 4 hrs | Wed 6/21/06 | Thu 6/22/06 | 44 |
| 46 | install cross-pieces and "other" inner side | 0.25 hrs | Thu 6/22/06 | Thu 6/22/06 | 45 |



| ID | Task Name | Duration | Start | Finish | Predecess |
|---|---|---|---|---|---|
| 47 | rotate fixture (top topside down) | 0.25 hrs | Thu 6/22/06 | Thu 6/22/06 | 46 |
| 48 | install reynolds connectors with sealant | 0.5 hrs | Thu 6/22/06 | Thu 6/22/06 | 47 |
| 49 | install HV bus wiring to each MRPC | 2 hrs | Fri 6/23/06 | Fri 6/23/06 | 48 |
| 50 | install gas feedthroughs & interior tubing | 0.5 hrs | Thu 6/22/06 | Thu 6/22/06 | 47 |
| 51 | curing (F/T connectors on top assy) | 2 hrs | Thu 6/22/06 | Thu 6/22/06 | 48,50 |
| 52 | HV tests | 2 hrs | Thu 6/22/06 | Thu 6/22/06 | 51 |
| 53 | MRPC connectivity tests | 6 hrs | Thu 6/22/06 | Fri 6/23/06 | 51 |
| 54 | | | | | |
| 55 | Tray Closing | 9.5 hrs | Fri 6/23/06 | Mon 6/26/06 | |
| 56 | test fit bottom assy onto top assy | 0.25 hrs | Fri 6/23/06 | Fri 6/23/06 | 53 |
| 57 | scribe | 0.25 hrs | Fri 6/23/06 | Fri 6/23/06 | 56 |
| 58 | remove bottom assy and apply sealant | 0.5 hrs | Fri 6/23/06 | Fri 6/23/06 | 57 |
| 59 | install bottom assy, install machine screws | 0.5 hrs | Fri 6/23/06 | Fri 6/23/06 | 58 |
| 60 | curing (bottom assy onto top assy) | 1 day | Fri 6/23/06 | Mon 6/26/06 | 59 |
| 61 | | | | | |
| 62 | Tray Closed | 0 hrs | Mon 6/26/06 | Mon 6/26/06 | 60 |
| 63 | | | | | |
| 64 | Electronics installation and Testing | 32.25 hrs | Mon 6/26/06 | Fri 6/30/06 | |
| 65 | rotate tray (top topside up) | 0.25 hrs | Mon 6/26/06 | Mon 6/26/06 | 62 |
| 66 | move completed tray to tray test area | 0.5 hrs | Mon 6/26/06 | Mon 6/26/06 | 65 |
| 67 | Gas flow for testing | 8.25 hrs | Mon 6/26/06 | Tue 6/27/06 | |
| 68 | connect tray to gas system | 0.25 hrs | Mon 6/26/06 | Mon 6/26/06 | 66 |
| 69 | gas flow started | 1 day | Mon 6/26/06 | Tue 6/27/06 | 68 |
| 70 | Gas Leak testing wtih sniffer | 1 day | Mon 6/26/06 | Tue 6/27/06 | 68 |
| 71 | Gas Quality Acceptable for HV tests | 0 hrs | Tue 6/27/06 | Tue 6/27/06 | 69 |
| 72 | TDIG Installation | 17.5 hrs | Mon 6/26/06 | Wed 6/28/06 | |
| 73 | remove cover assy and upper brackets | 0.5 hrs | Mon 6/26/06 | Tue 6/27/06 | 65 |
| 74 | install cooling loop | 0.5 hrs | Tue 6/27/06 | Tue 6/27/06 | 73 |
| 75 | install TDIG boards | 2 hrs | Tue 6/27/06 | Tue 6/27/06 | 74 |
| 76 | install LV bus (lugs on-tray to boards) | 1 hr | Tue 6/27/06 | Tue 6/27/06 | 75 |
| 77 | Install TDIG cabling (canbus etc) | 2 hrs | Wed 6/28/06 | Wed 6/28/06 | 81 |
| 78 | LV power test | 1.5 hrs | Wed 6/28/06 | Wed 6/28/06 | |
| 79 | install LV test cables (supply to lugs on-tray) | 0.5 hrs | Wed 6/28/06 | Wed 6/28/06 | 76 |
| 80 | LV power-up and documentation | 1 hr | Wed 6/28/06 | Wed 6/28/06 | 79 |
| 81 | LV test passed | 0 hrs | Wed 6/28/06 | Wed 6/28/06 | 80 |
| 82 | Firmware and other electronics setup | 2 hrs | Wed 6/28/06 | Wed 6/28/06 | 77,81 |
| 83 | HV Performance | 4.25 hrs | Tue 6/27/06 | Wed 6/28/06 | |
| 84 | connect HV cables | 0.25 hrs | Tue 6/27/06 | Tue 6/27/06 | 71 |
| 85 | ramp HV and collect V/I data | 4 hrs | Tue 6/27/06 | Wed 6/28/06 | 84 |
| 86 | Tray Stable at Full Voltage | 0 days | Wed 6/28/06 | Wed 6/28/06 | 85 |
| 87 | DAQ Performance | 18 hrs | Wed 6/28/06 | Fri 6/30/06 | |
| 88 | Noise rate tests, dead channel identification | 2 days | Wed 6/28/06 | Fri 6/30/06 | 86 |
| 89 | INL Calibration | 1 day | Thu 6/29/06 | Thu 6/29/06 | 82 |
| 90 | Final test documentation | 0 hrs | Fri 6/30/06 | Fri 6/30/06 | 88,89 |
| 91 | | | | | |
| 92 | Tray complete & Ready for Cosmics Testing | 0 hrs | Fri 6/30/06 | Fri 6/30/06 | 90 |



The procedure is generally

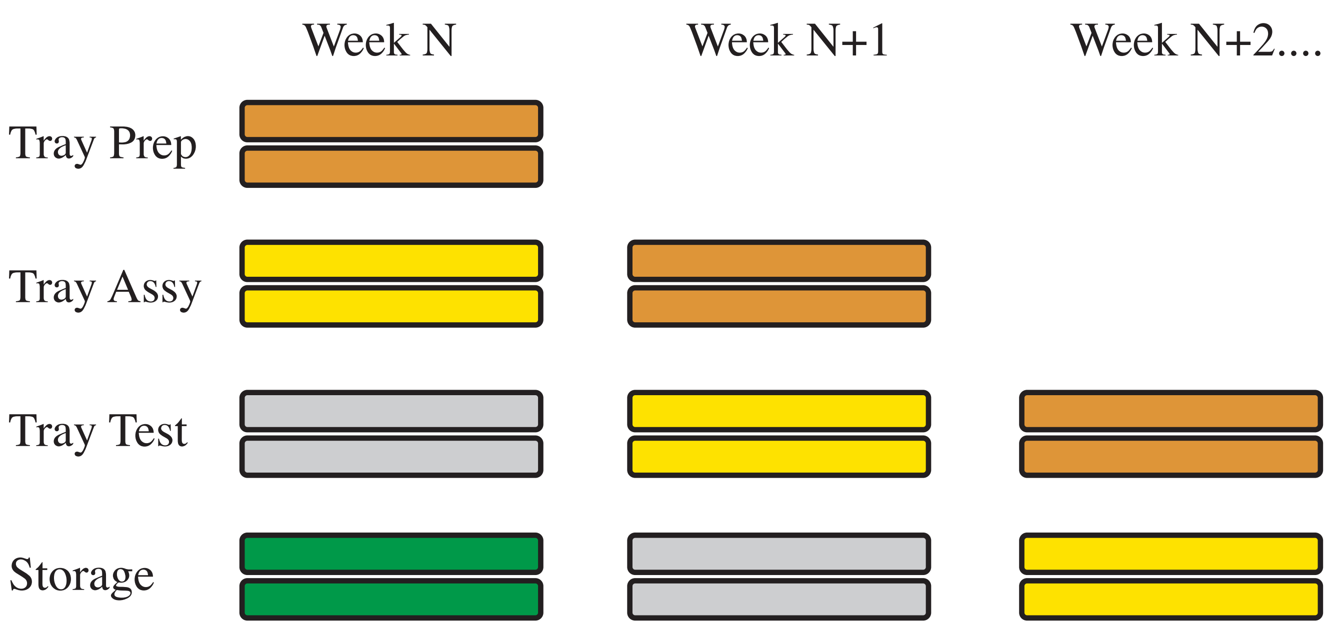
- a series of several "few minute"operations per tray
- punctuated by several ~24 hrs periods of waiting per tray (sealant curing, gas flow, etc...)

Fabrication model:

- at the end of each week
  - two trays emerge from the tray prep area
    - next week these will be in the tray assembly area
  - & two trays emerge from the tray assembly area
    - next week these will be in the tray testing area (gas flow, INL, noise rates, HV draw, etc)

Assumed manpower (1 FTE Tech + 2 FTE UG) and floor space sufficient

Gives some headroom in fabrication/testing schedule w.r.t. MRPC and FEE production



Tray Fabrication Milestones (4/year)

| Date | No. Trays | No./week |
|---|---|---|
| 10/06 | 4 trays | 0.5 trays/week |
| 01/07 | 10 | 0.8 |
| 04/07 | 10 | 0.8 |
| 07/07 | 14 | 1.1 |
| 10/07 | 14 | 1.1 |
| 01/08 | 16 | 1.3 |
| 04/08 | 18 | 1.5 |
| 07/08 | 20 | 1.7 |
| 09/08 | 20 | 1.7 |

installation plan:

- "Skill-of-the-Craft"
- can install either in AB or WAH
- Both US & Chinese institutions participate in installation and commissioning

installation of trays behind the TPC support arms (3 & 9 o'clock, East & West) requires a fixture to hold the TPC while one support arm is removed.

# 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, final start detector installed before FY08 with new PMTs...

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 practically unchanged

- Electronics for Run-6 prototype presumably exactly the same boards as on pVPD in Run-5

- HV for prototype and final system from BBC’s LeCroy 1440 supply

- 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)

- New PMTs for the final detector are costed
  - purchase FY07, to be installed in final structures and ready for FY08 run...

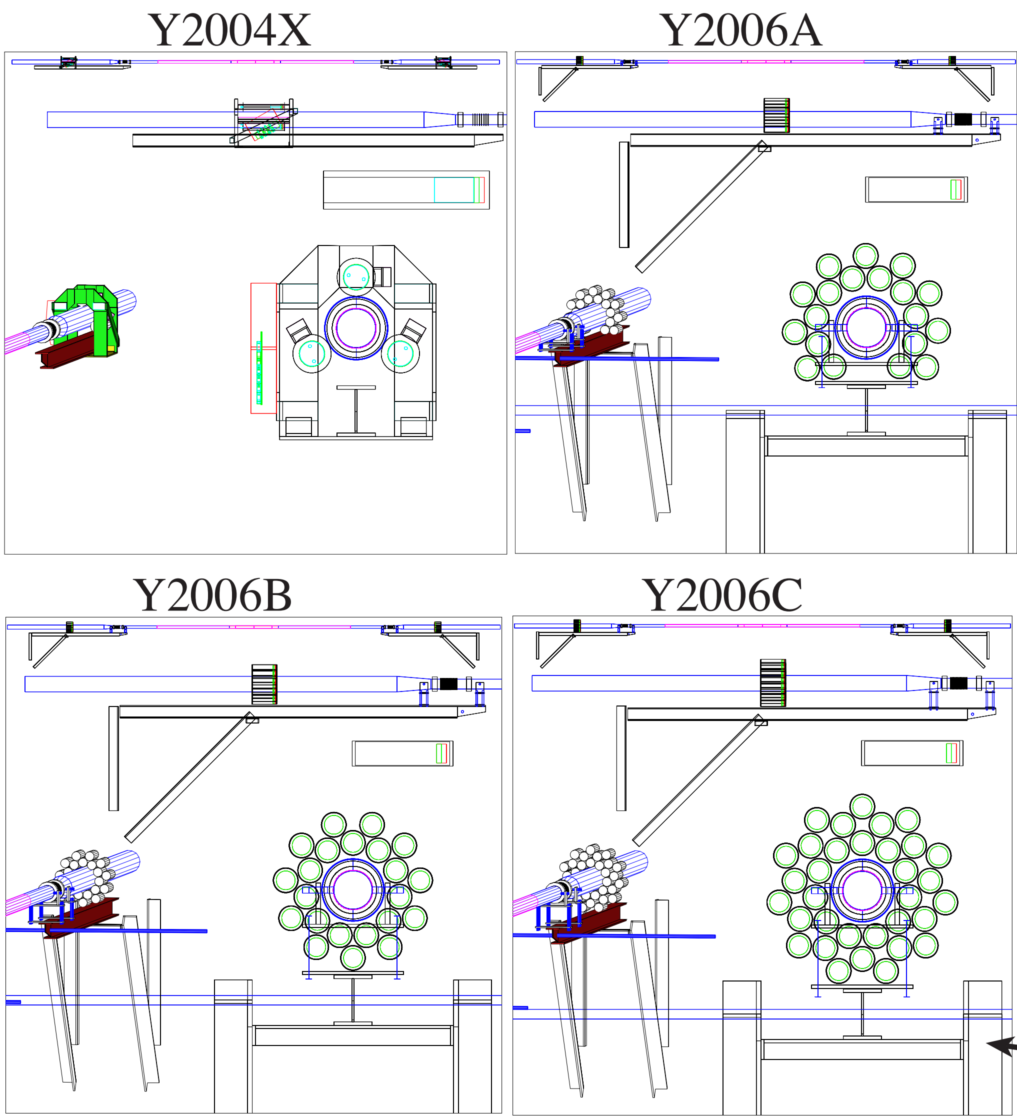
Main R&D developments:

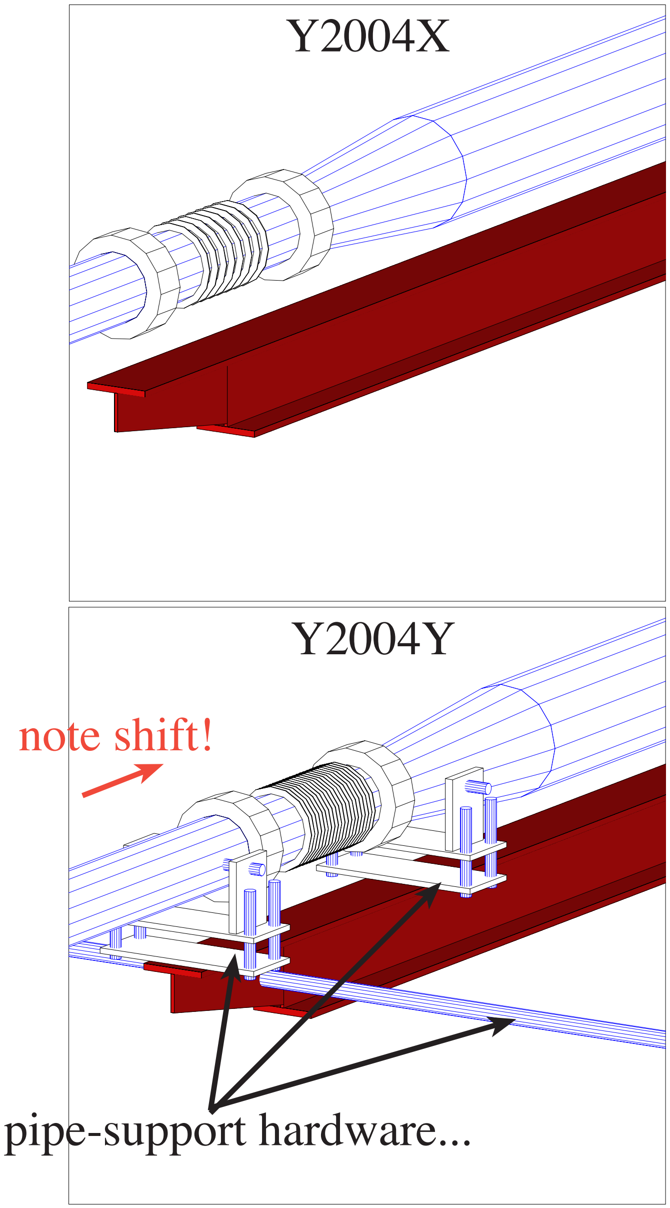
- Detector design, based on full simulations
- PMT base design, need high stability and high rate capability

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

# Simulations of the Upgraded pVPD (Geometry)

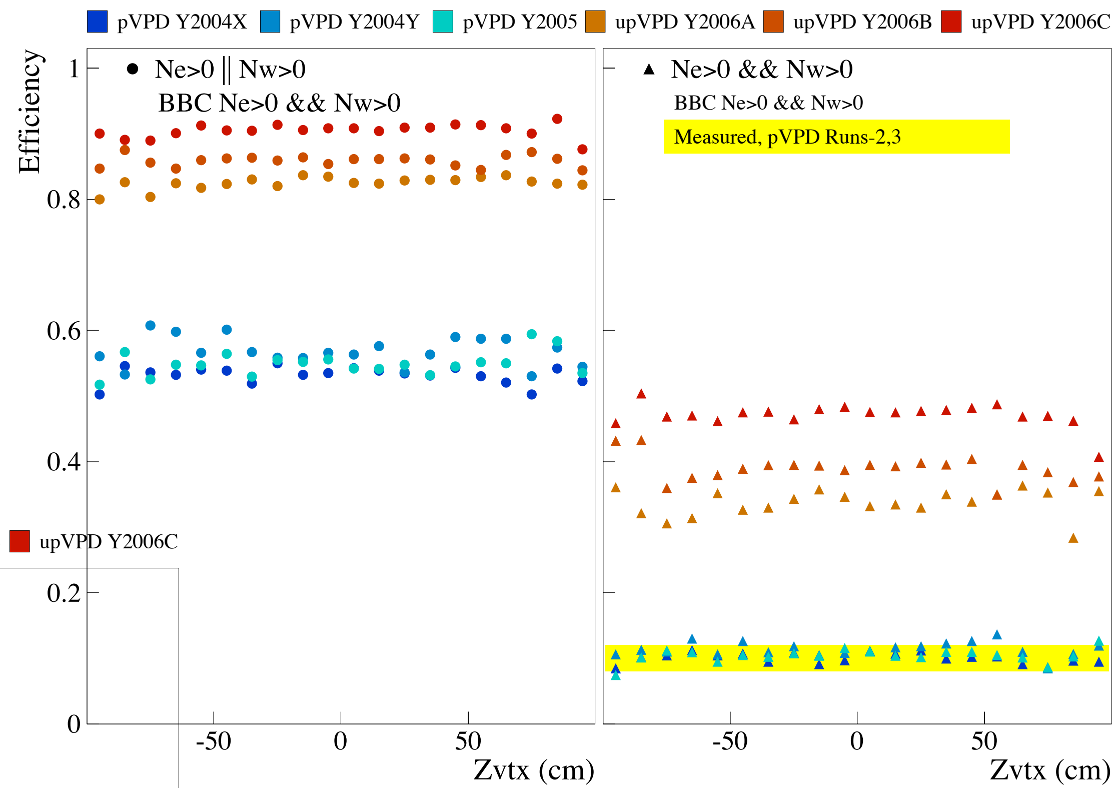
- Strict comparison btw starsim geometry and CADD files from STSG (discrepancies found!)
- First definition of many pipe & I-beam support structure pieces missing from starsim geometry
- Definition of several possible geometries for upVPD
- Performance of the different designs in p+p and Au+Au evts

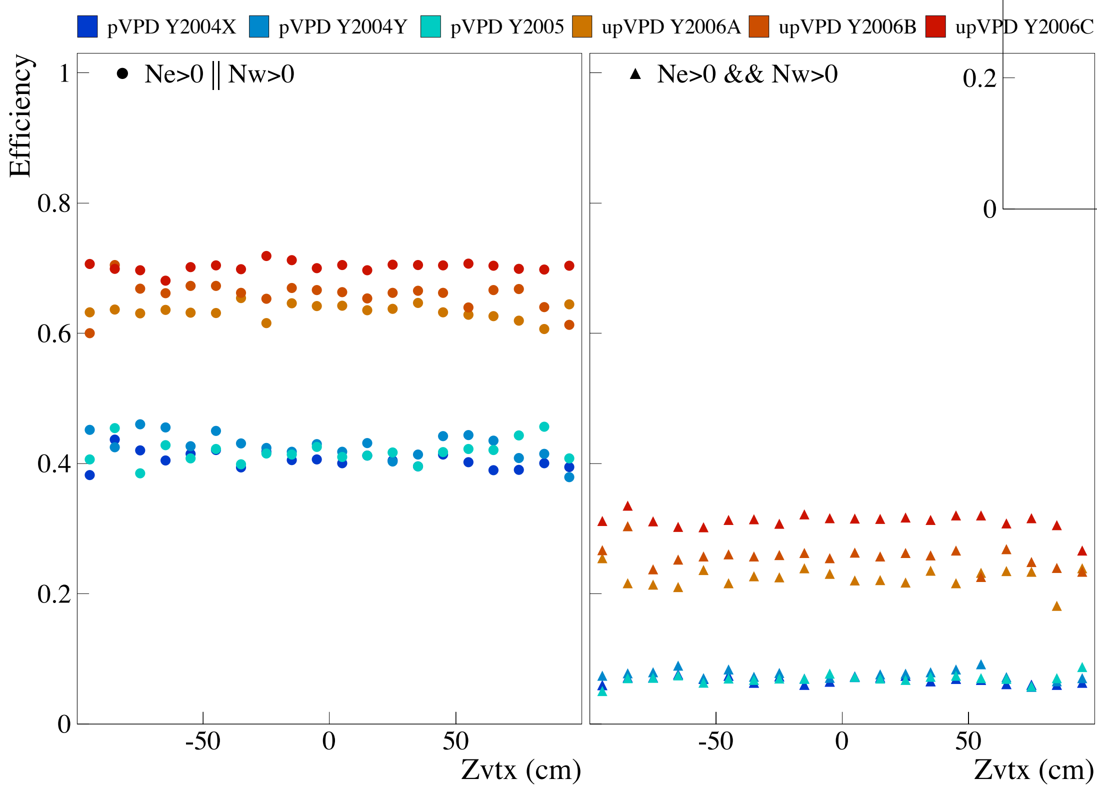


# Simulations of the Upgraded pVPD (Performance)

- 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

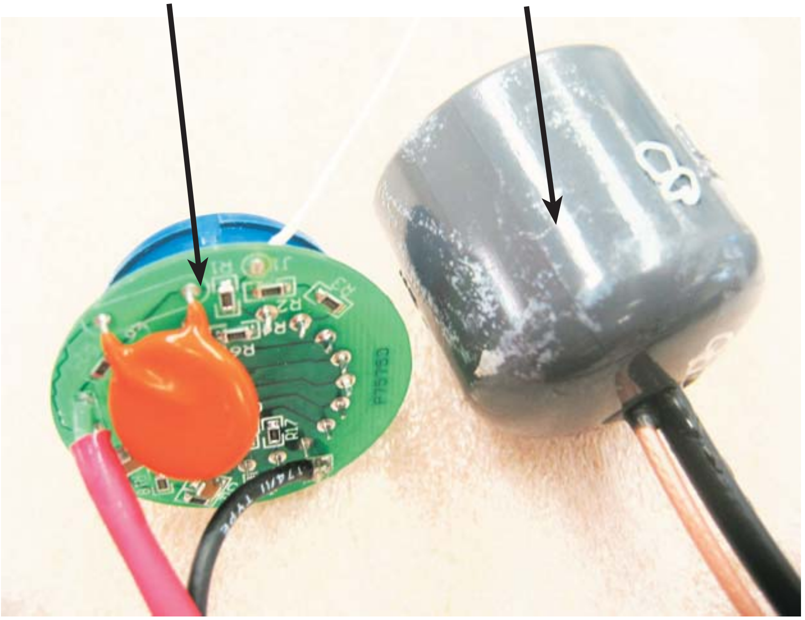
(Vahe Ghazikhanian, J. Mitchell, WJL)

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

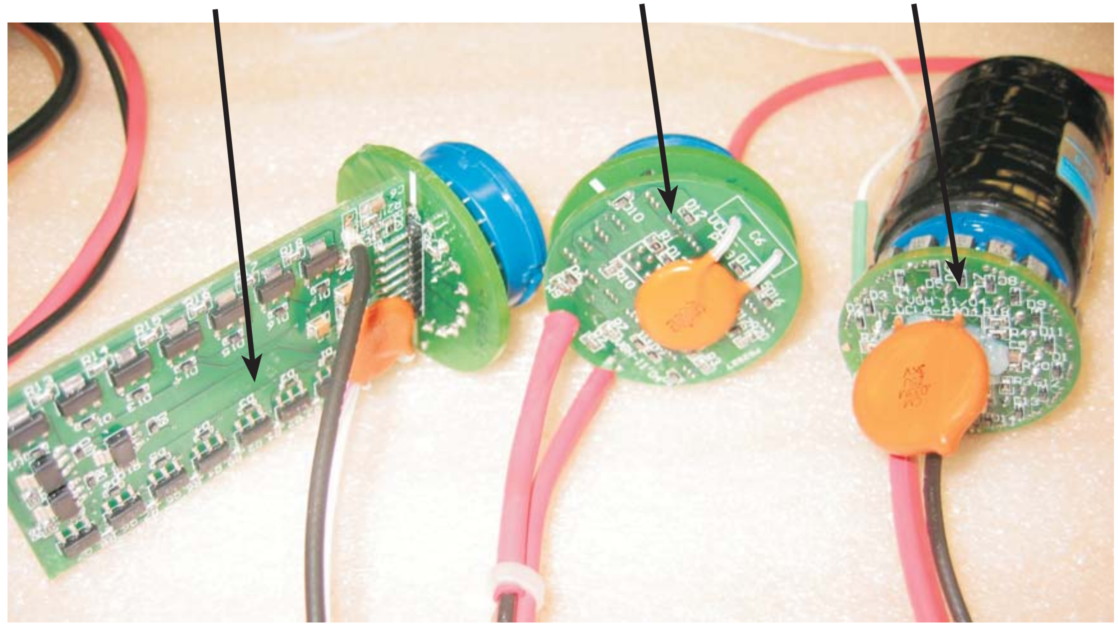
Developed one Linear base, but higher rate than std. Hamamatsu design
    Linear base drops ~2W at 2kV → >50 $^{o}$C inside detector assembly...

Developed 3 versions of transistor bases
    MOSFETs are primary voltage divider, current 1/10$^{th}$ 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

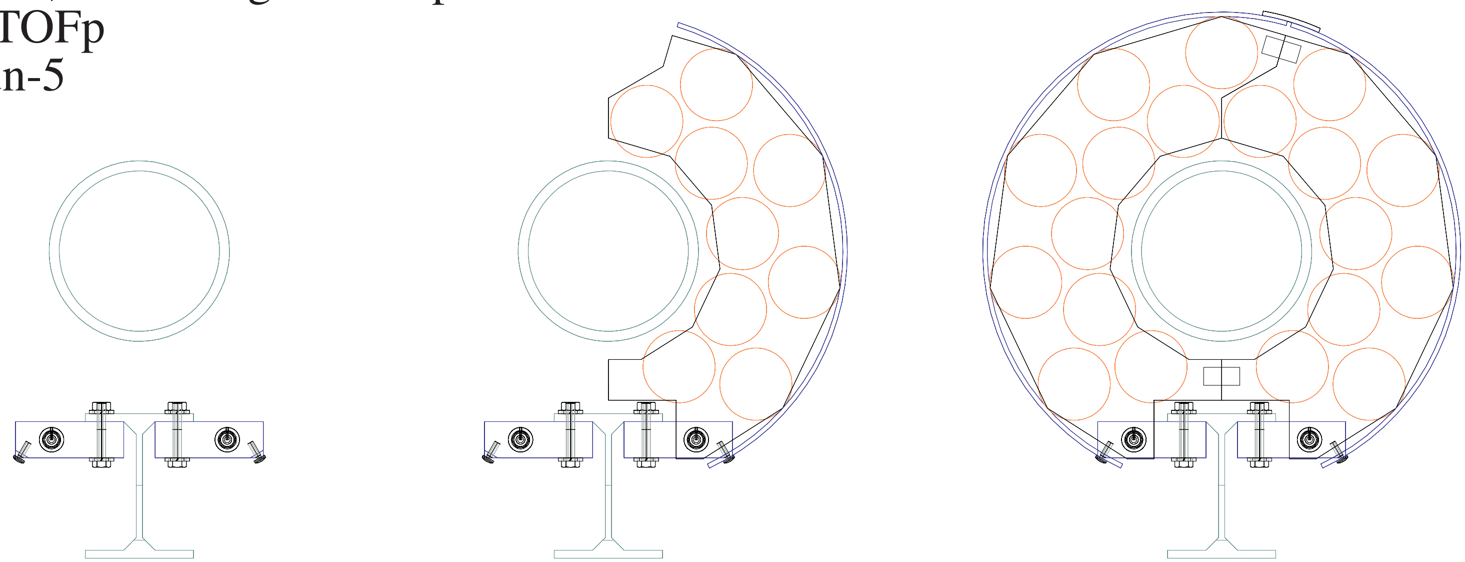
Run-6 prototype

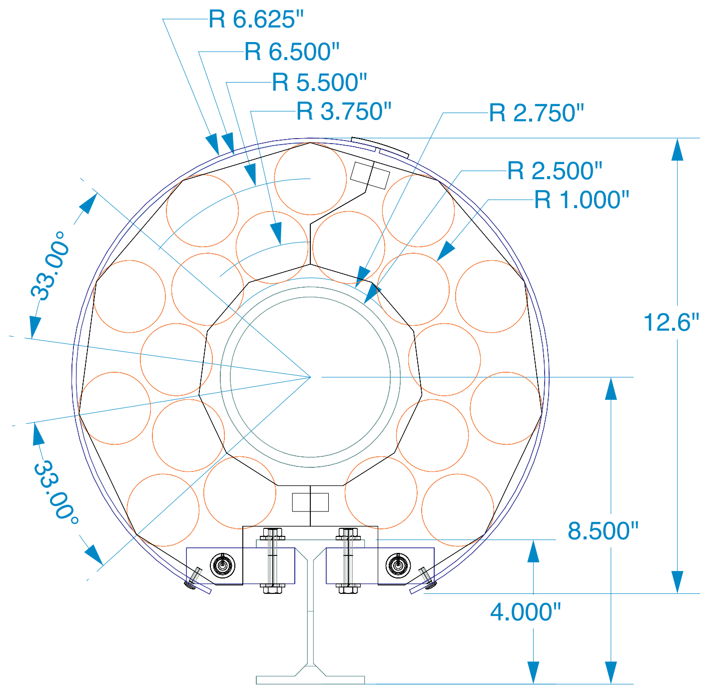
19 detectors/side

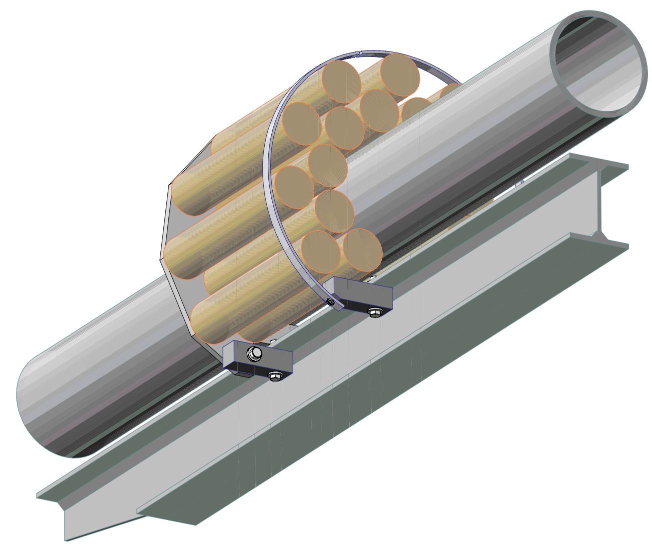
test scintillator, quartz, and lead-glass as optical element

R5946 PMTs from TOFp

electronics from Run-5





Run-8++ “final” detector

24 chs/side

new PMTs purchased FY07