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?

“sawtooths” USTC & CERN MRPCs

welded/tapped rail assembly (glued gaskets also)

final TOFr tray (note many cables not shown!)

standard CTB tray

• 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)

- 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

• 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.

Total power assumption is $120 \times 140 \text{W} = 17 \text{kW}$ (TAMP) or $120 \times 100 \text{W} = 12 \text{kW}$ (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)

Action item: define cooling water distribution system....
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, & 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

<table>
<thead>
<tr>
<th>Item</th>
<th>Material</th>
<th>Qty/tray</th>
<th>Rating or Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom Assy</td>
<td>Welded Aluminum, 50mil</td>
<td>1</td>
<td>same CTB, TOFp, &amp; all 3 TOFr's</td>
</tr>
<tr>
<td>Top Assy</td>
<td>Welded Aluminum, 90mil</td>
<td>1</td>
<td>same as TOFr' &amp; TOFr5</td>
</tr>
<tr>
<td>Cover Assy</td>
<td>Welded Aluminum, 50mil</td>
<td>1</td>
<td>same as TOFr5, but unperforated</td>
</tr>
<tr>
<td>Feet</td>
<td>Braked Aluminum, 90mil, welded on</td>
<td>2</td>
<td>same as CTB, TOFp, &amp; all 3 TOFr's</td>
</tr>
<tr>
<td>Standoff strips</td>
<td>UHMW Polyethylene</td>
<td>4</td>
<td>same as CTB, TOFp, &amp; all 3 TOFr's</td>
</tr>
<tr>
<td>Inner Sides</td>
<td>Lexan, <del>90&quot;x</del>3&quot;x1/4&quot;, milled reveals</td>
<td>2</td>
<td>same design as TOFr5 (TOFr5 used acrylic)</td>
</tr>
<tr>
<td>Sealant</td>
<td>DC 730 Freon-Resistant Sealant</td>
<td>~2 oz</td>
<td>same as TOFr' &amp; TOFr5</td>
</tr>
<tr>
<td>Hardware</td>
<td>teflon (inner sides) or SS (tray body)</td>
<td>~40</td>
<td>same as TOFr5</td>
</tr>
<tr>
<td>Tape</td>
<td>Kapton, 2mil-thick</td>
<td>~20 ft</td>
<td>same as all 3 TOFr's</td>
</tr>
</tbody>
</table>

**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
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
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.

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”

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).
Honeycomb length = 208 +/- 1 mm

electrode length = 202-0.5 mm

pad width = 31.5 mm
pad interval = 3 mm

PC Board thickness = 1.5 +/- 0.1
outer glass thickness = 0.7 +/- 0.0
inner glass thickness = 0.54 +/- 0.01

gas gap = 220 +/- 5 micron

PC board
pad
mylar
glass
electrode (graphite)
honey comb
### MRPC List of Materials

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

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

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.
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
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 programmability/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 trays 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

Protection enclosure
(SHV connectors used require protection against HV shock hazard)

CAEN SY127 HV Supply Chassis
[one of two required units shown]

3 A631P, +8KV modules
(including spares)
12 indep., floating channels
Up to 100 \( \mu \text{A} \) per channel

3 A631 N, -8KV modules
(including spares)
12 indep., floating channels
Up to 100 \( \mu \text{A} \) per channel

CPE Italia, HV RG -58 coax cable + SHV connector at PS end + Kings 1064-1 & 1065-1, 10 KV connectors at distribution box end and between distribution box - tray.

High Voltage Distribution Box
(1 of 12 units shown)

\[ I_{\text{max}} \leq 100 \ \mu \text{A} \]

Current limiting and filtering HV resistors
(10 M)

Only one pair of total of 10 pairs shown
\[ I_{\text{typ}} \leq 1 \ \mu \text{A} \]

To one TOF tray
Positive HV Coax Cable
Negative HV Coax Cable
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 $\rightarrow$ 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
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

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

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