TIMING, or TAGGING

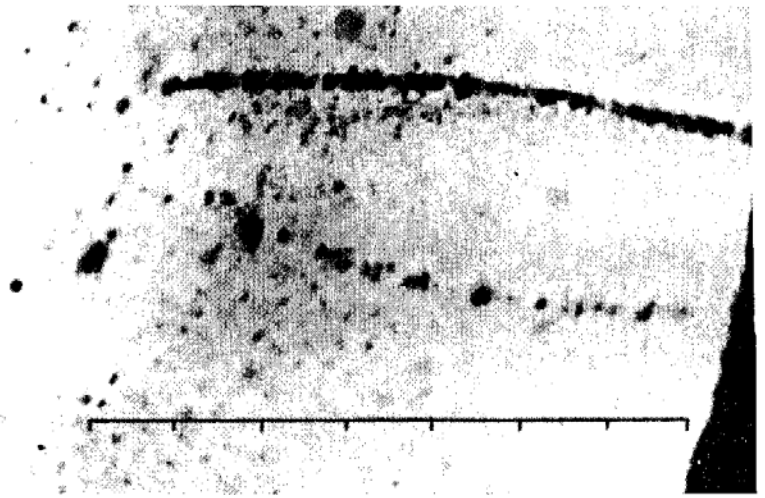
The Muon Telescope Detector

W.J. Llope, Rice University

Wikipedia: “Muons were discovered by Carl D. Anderson & Seth Neddermeyer at Caltech in 1936”

“Who ordered that?!?” – I.I. Rabi in 1937

Actually seems to have been first observed in a cloud chamber in Rostock Germany in 1933!



"The other double trace of the same type (figure 5) shows closely together the thin trace of an electron of 37 MeV, and a much more strongly ionizing positive particle whith a much larger bending radius. The nature of this particle is unknown; for a proton it does not ionize enough and for a positive electron the ionization is too strong. The present double trace is probably a segment from a "shower" of particles as they have been observed by Blackett and Occhialini, i.e. the result of a nuclear explosion".

Kunze, P., Z. Phys. 83, (1933) 1

STAR-MTD "Basic Idea"

With a large area muon detector at mid-rapidity…

Physics:

- di-muon pairs from QGP thermal radiation, quarkonia, light vector mesons, resonances in QGP, and Drell-Yan production
  excellent mass resolution would separate different upsilon states

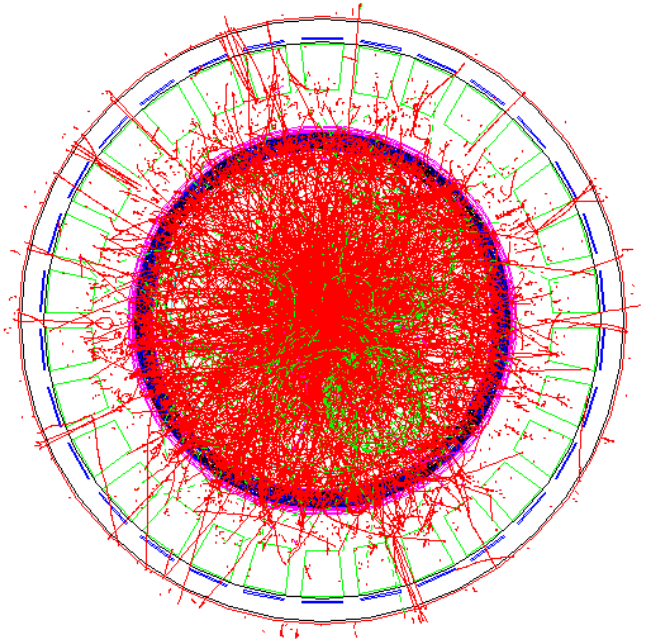
- single muons from the semi-leptonic decays of heavy flavor hadrons… e+muon correlation to distinguish heavy flavor production from initial lepton pair production

- advantages over electrons:
  - no γ conversion
  - much less Dalitz decay contribution
  - less affected by radiative losses in the detector materials

How could this be achieved?

- Hadron shielding is magnet backlegs and BEMC (~$7X_0$)
- Precise timing! start from upVPD, fast TOF hit + fast MTD hit, TPC + HFT matching
- Low-level trigger capability for low to high p_T J/ψ in central Au+Au collisions

Conceptual Design of the STAR-MTD



Multi-gap Resistive Plate Chamber (MRPC):

gas detector, avalanche mode

inexpensive, eay to build, but precise timing

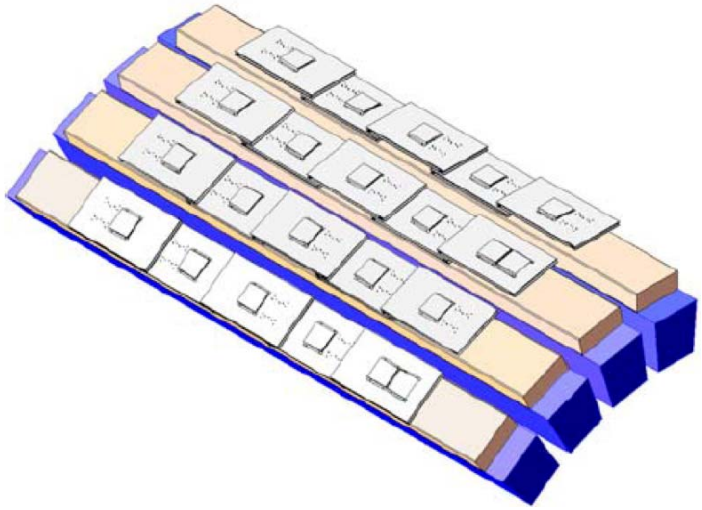
The detectors cover the steel magnet backlegs and leave the φ-gaps uncovered.

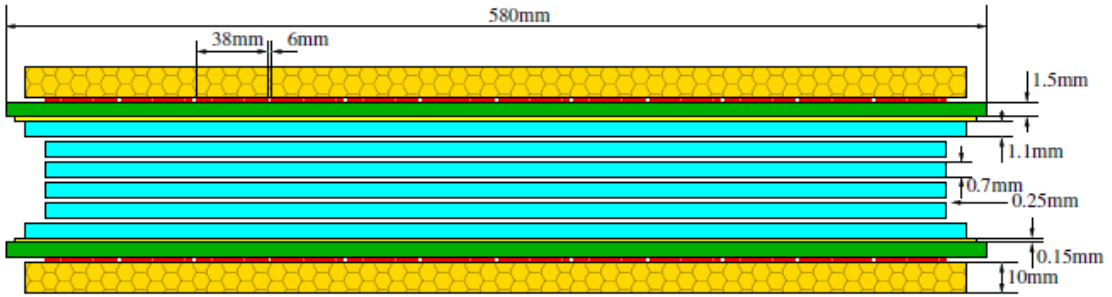
Acceptance: ~45% at $|\eta|<0.5$

118 modules, 1416 readout strips, 2832 channels

Proven detector technologies

MRPC detectors & STAR-TOF electronics





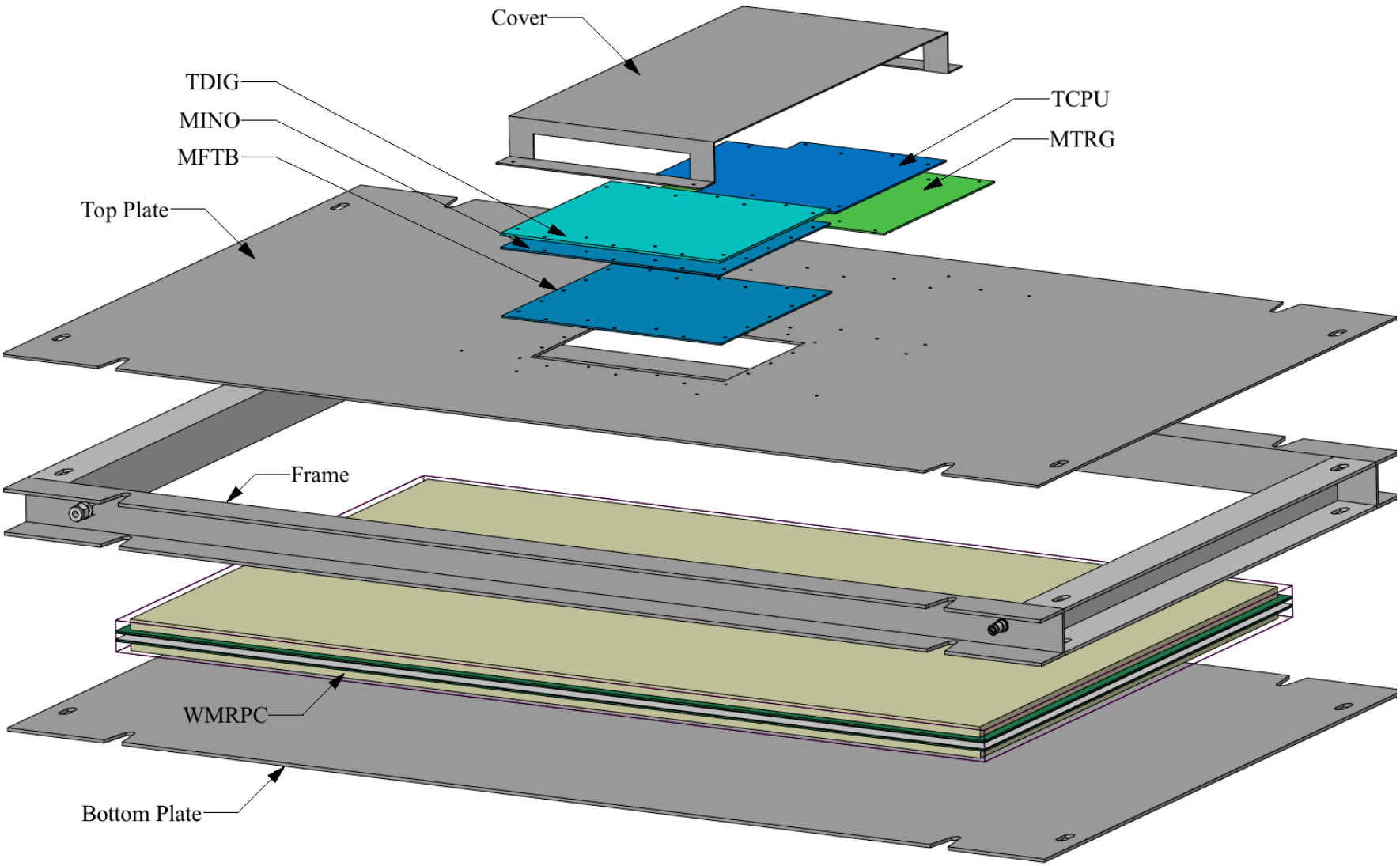
Mechanical Design, Fabrication, and Installation

System	MRPCs	"Tray" Design	Electronics	Installation
STAR TOF	excellent	complicated	new & complicated	simple
STAR MTD	excellent	simple	commodity	complicated

Outline:
- MTD "tray" mechanical design
- MTD11 prototype assembly
- Full system design
- Run-12 installation
- Preparing for Run-13

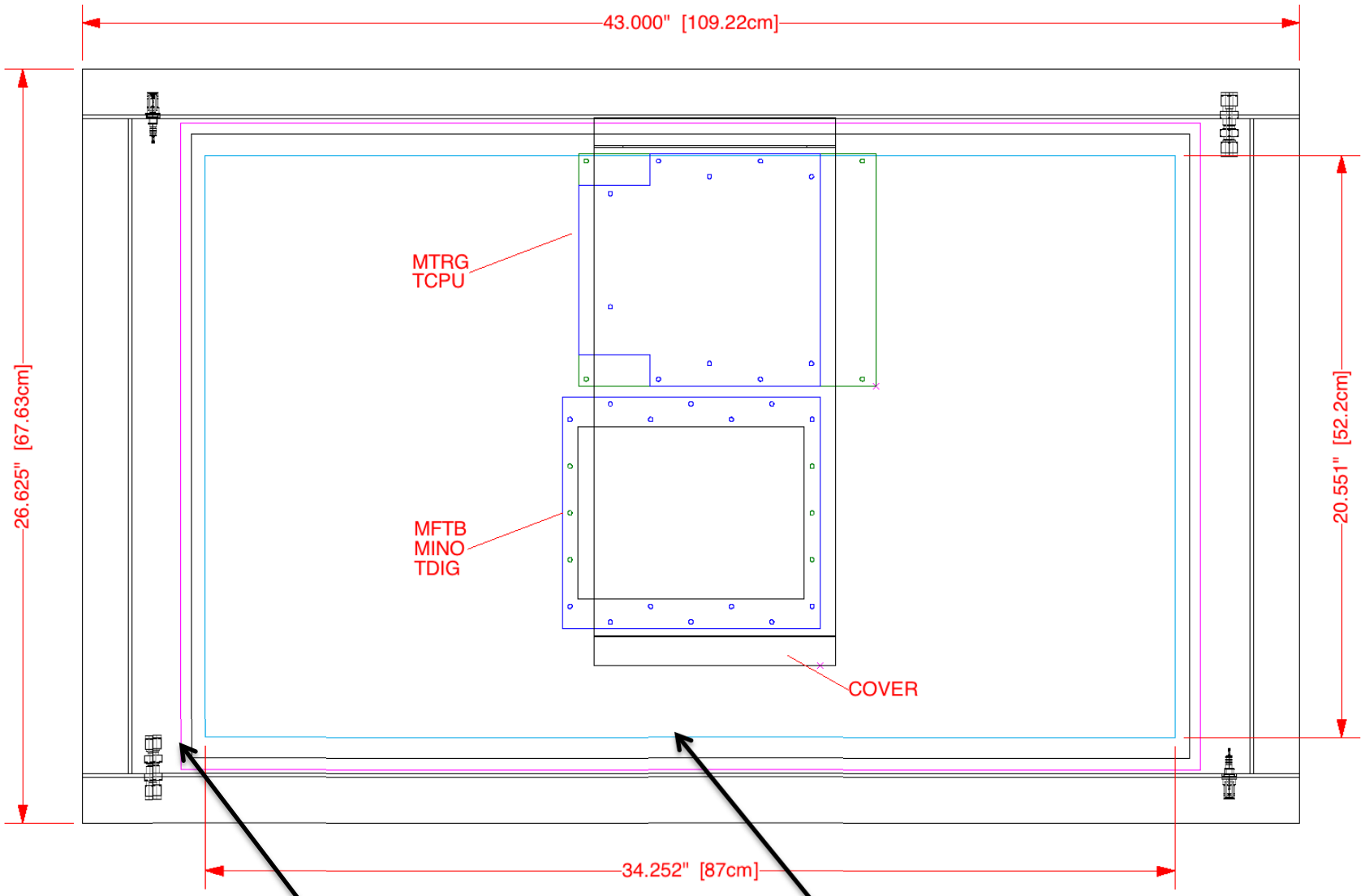
"MTD9" is the older run-9/10 prototype
"MTD11" are new prototypes for run-11

MTD11 Tray Design (Exploded View)



The MTD11 tray design is “final” for the full system

MTD11 Tray Design (Top View)

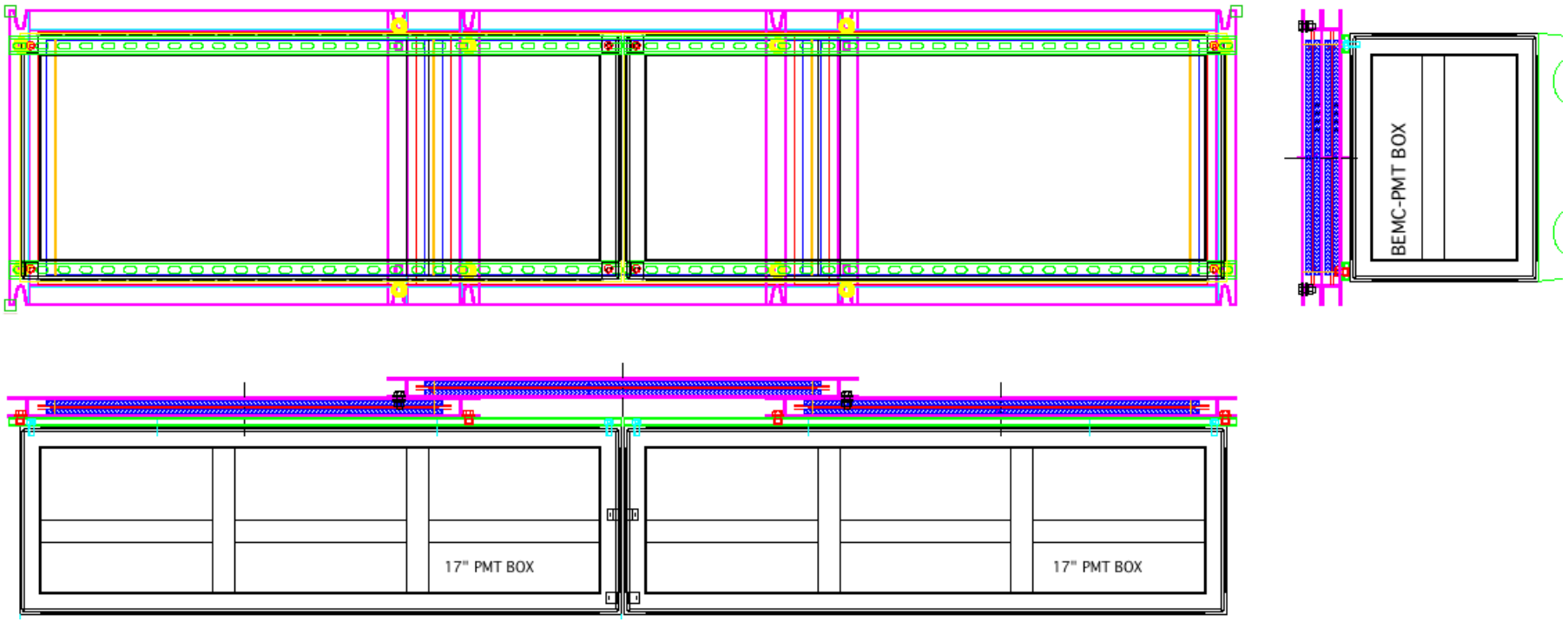


MRPC “footprint”

inner glass stack = “active area”

Initial Design for MTD11 Stacking in STAR

The three MTD11 Trays mount directly onto BEMC PMT boxes
The Trays overlap so that the MRPC active regions meet end-to-end in “Z”

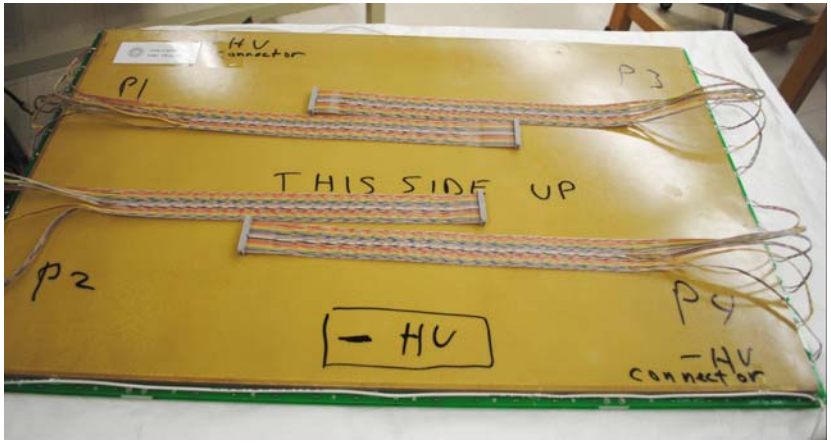


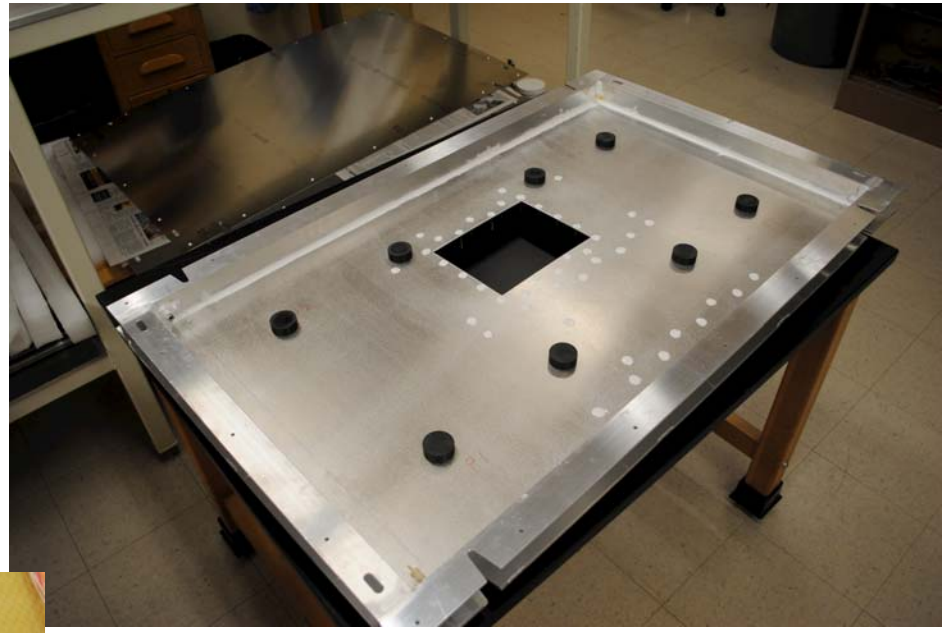
lower row of trays bolt to unistrut on the BEMC PMT boxes
upper row of trays bolt to the lower row of trays

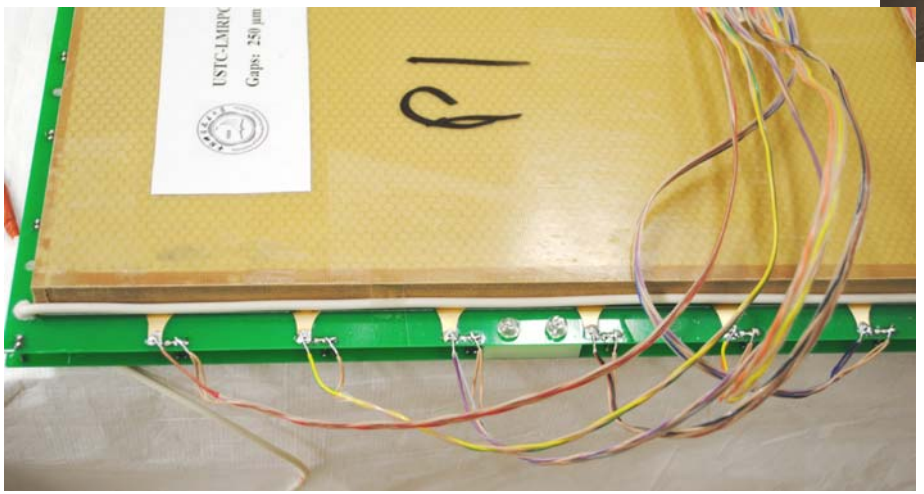
this won’t work for the full system – more on this later in this talk…

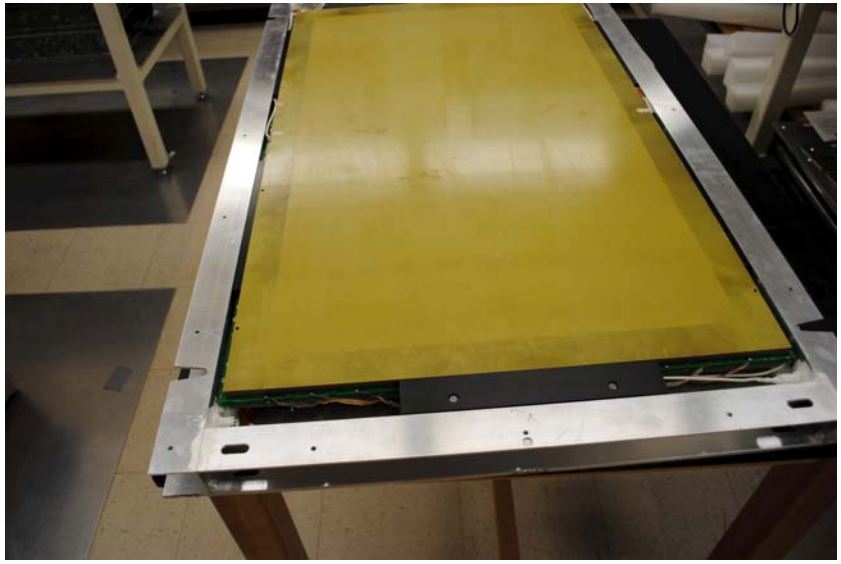
MTD Tray Assembly

Tray “top” (holds electronics) is complicated… Fabricated at Oaks Precision in Houston



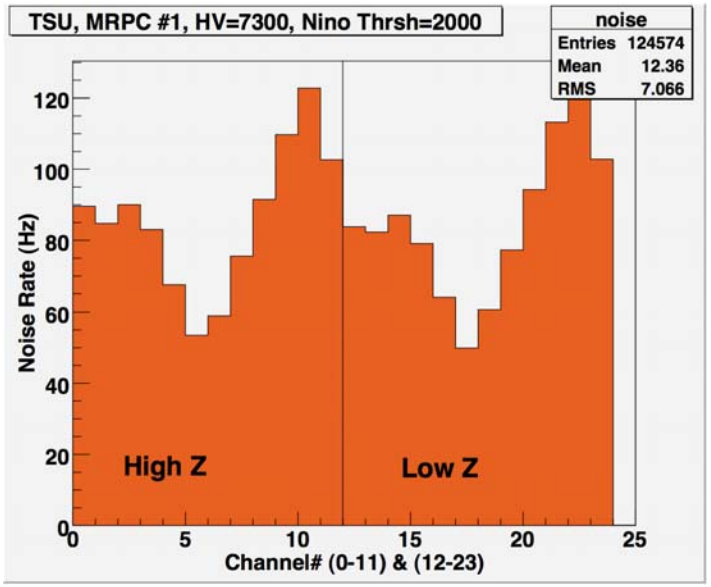


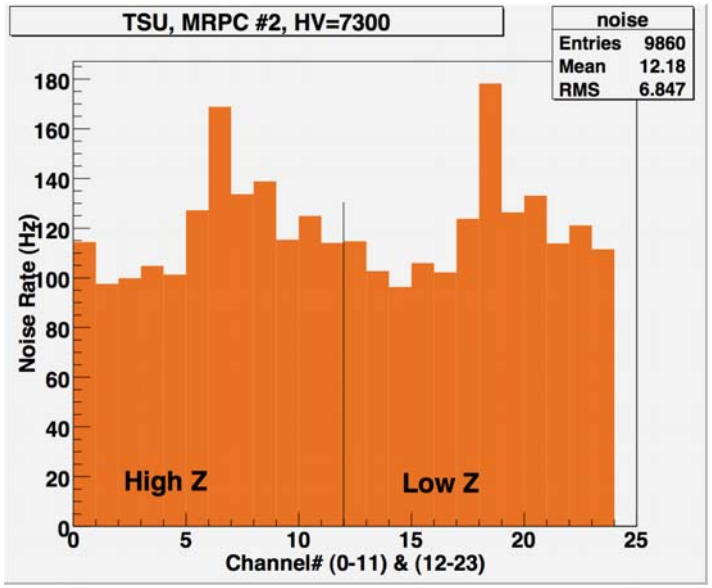


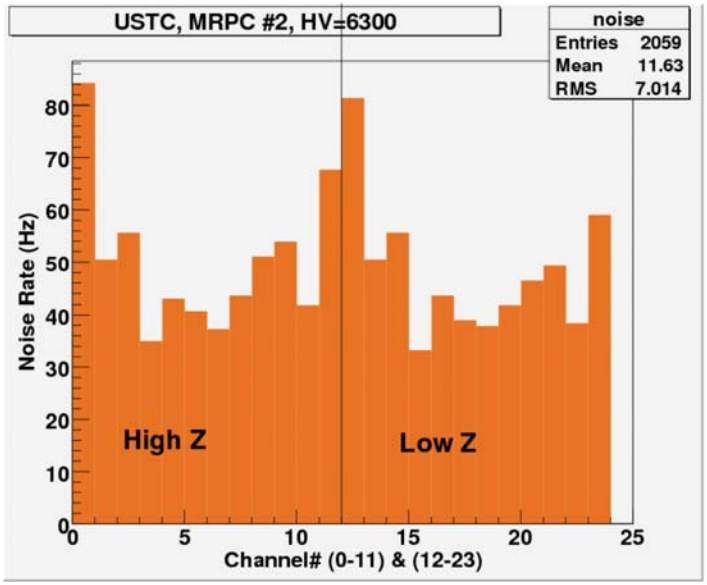


Additional details in Jo’s talk (next)…

MTD11 Test Results at UT-Austin – Hit patterns





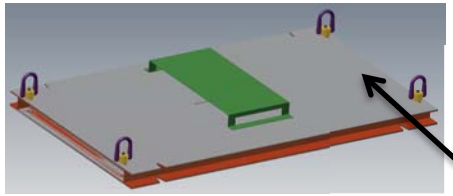


Untriggered cosmics
freon-only
6×250μm gaps: HV = ±7300V
5×250μm gaps: HV = ±6300V
Read-out via full chain of final electronics

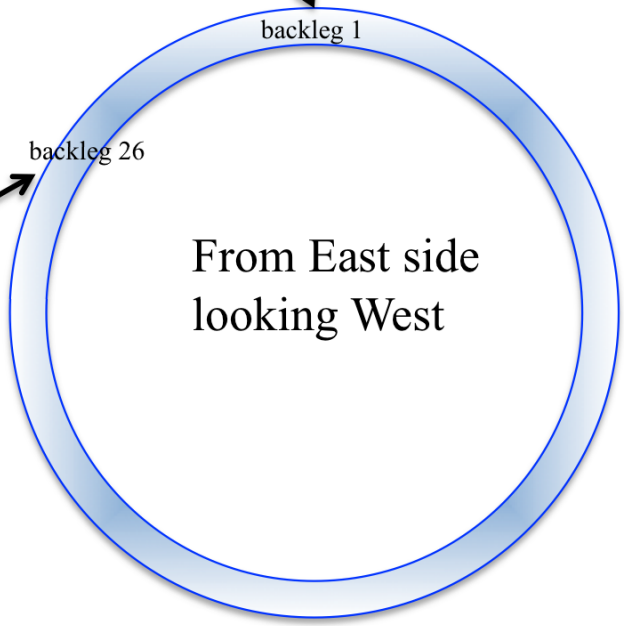
➔ reasonable noise rates…
(strip area = 331 cm^2, so <0.5 Hz/cm^2)
➔ no dead channels…

MTD9 and MTD11 Trays at BNL, December 2010

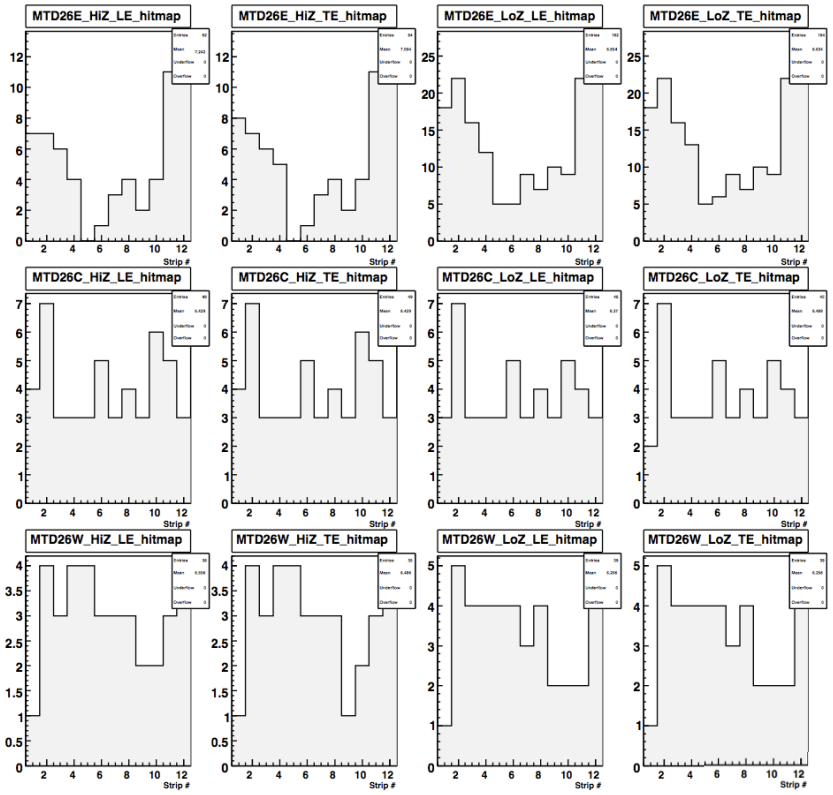
MTD9 & MTD THUB



Three MTD11 trays (craned into place)

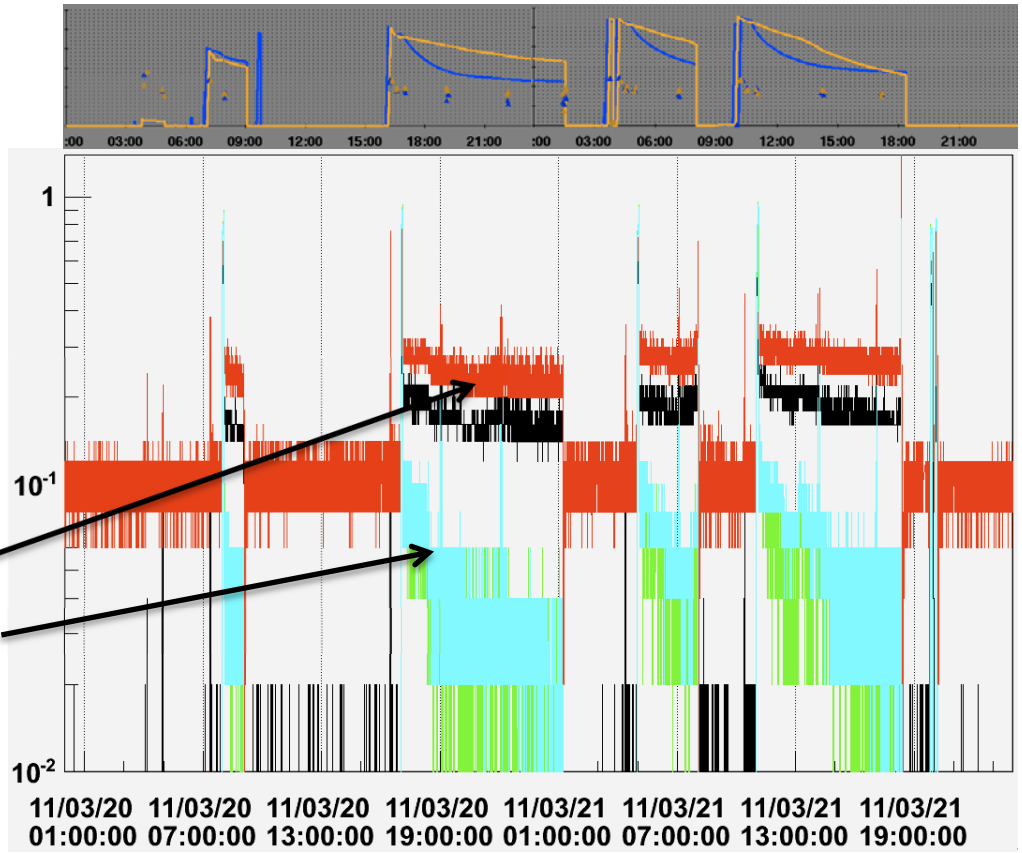


Run 11 Online hit patterns (untriggered) and HV information



online hit patterns look reasonable
(3 MTD11 trays × 2 strip ends × 2 signal edges)

low rate per 1M events because
- this is p+p… ($\sqrt{s_{NN}}$ = 500 GeV)
- MTD11 trigger available late in the run
  data analysis still underway

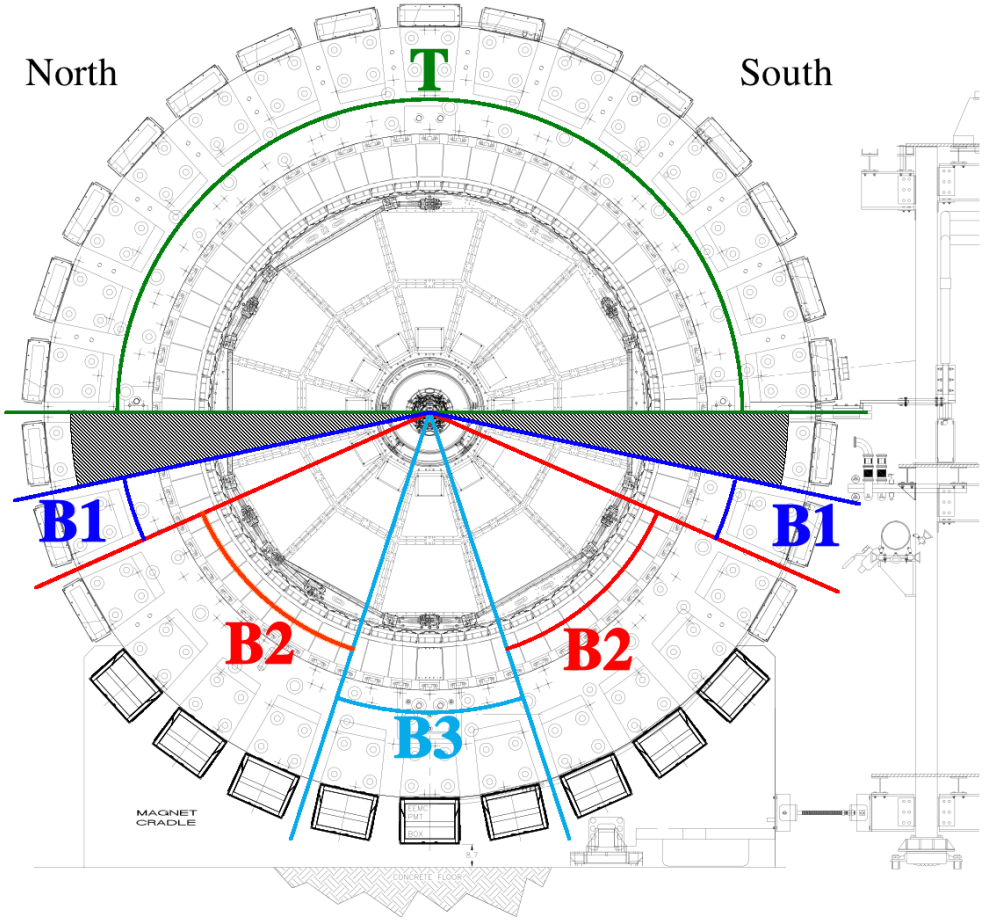


HV monitoring

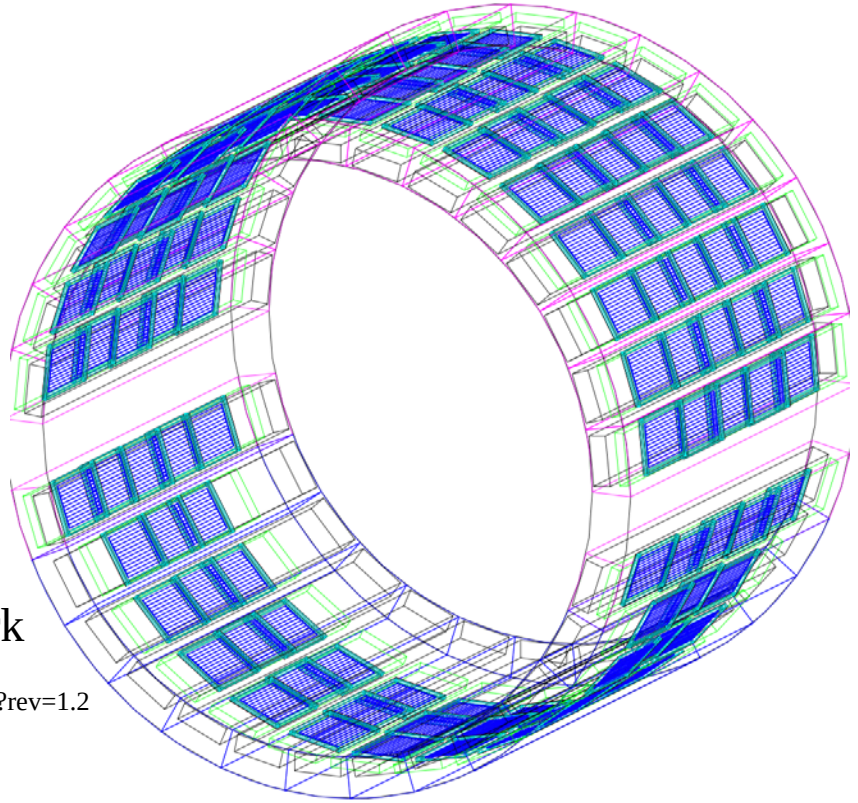
line 1: 6×250 μm gap MTD11 trays, ±7200V
line 2: 5×250 μm gap MTD11 tray+MTD9, ±6200V

Geometry of the Full System

also see http://wjllope.rice.edu/~MTD/MTDintegration.pdf



15 “5-packs” over the top
2 “5-packs” just under equator
11 “3-packs” below
…118 MTD trays total
…N/S & E/W symmetric



implemented in STAR geant simulations framework

http://www.star.bnl.gov/cgi-bin/protected/cvsweb.cgi/pams/geometry/mutdgeo/mutdgeo4.g?rev=1.2

Full System Installation Scheme

The mounting scheme for the MTD full system trays is actually a difficult problem!

MTD trays must mount on top of BEMC PMT boxes…

- access to these some number of these boxes is needed during every shutdown to repair BEMC channels
- typically this work is done by laying down on neighboring PMT boxes
- this implies that 2-3 backlegs of MTD trays would need to be removed to access a single BEMC box!

Scheme used in Run-11 worked, and was the simplest possible for us, but it would be a nightmare for a full system…

- tray positioning is a little too sloppy because of imprecise positioning of unistrut nuts
  - difficult to install the upper layer of trays onto lower layer of trays…
- too much work for STSG (Bob Soja and his expert technicians) to remove/reinstall MTD trays
- too much cabling (dis)connecting & stresses on MTD modules – increased failures & gas leaks?

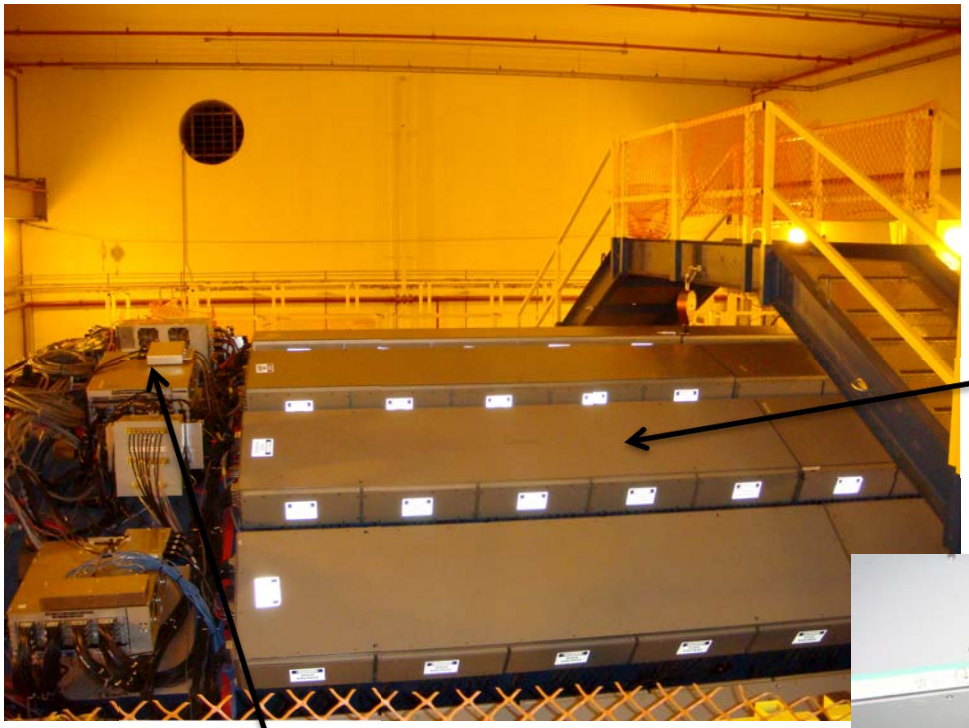
There is another problem too - how do *we* get access to a random tray on top of STAR?

- one cannot simply walk on the MTD layer like one can walk on the PMT boxes
- how do we replace a cable or sniff for gas leaks on a random tray when everything is installed?!?

And yet another problem are obstructions hanging from the boxes below STAR…

This is clearly going to be the hardest part of the total system design….

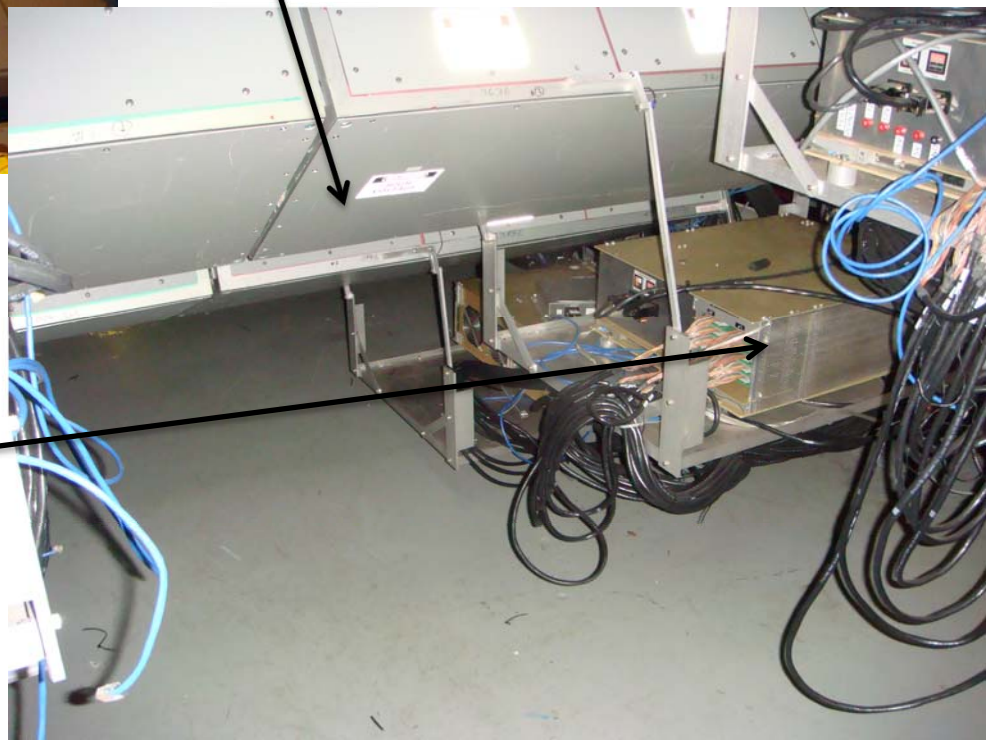
Full System Installation Scheme



above STAR

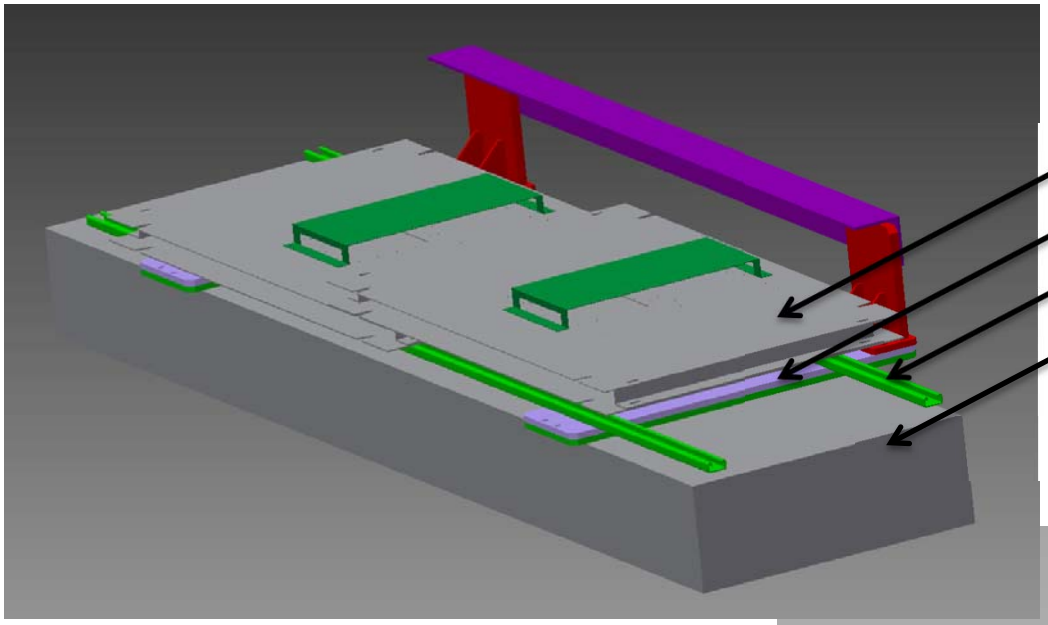
BEMC PMT boxes

below STAR

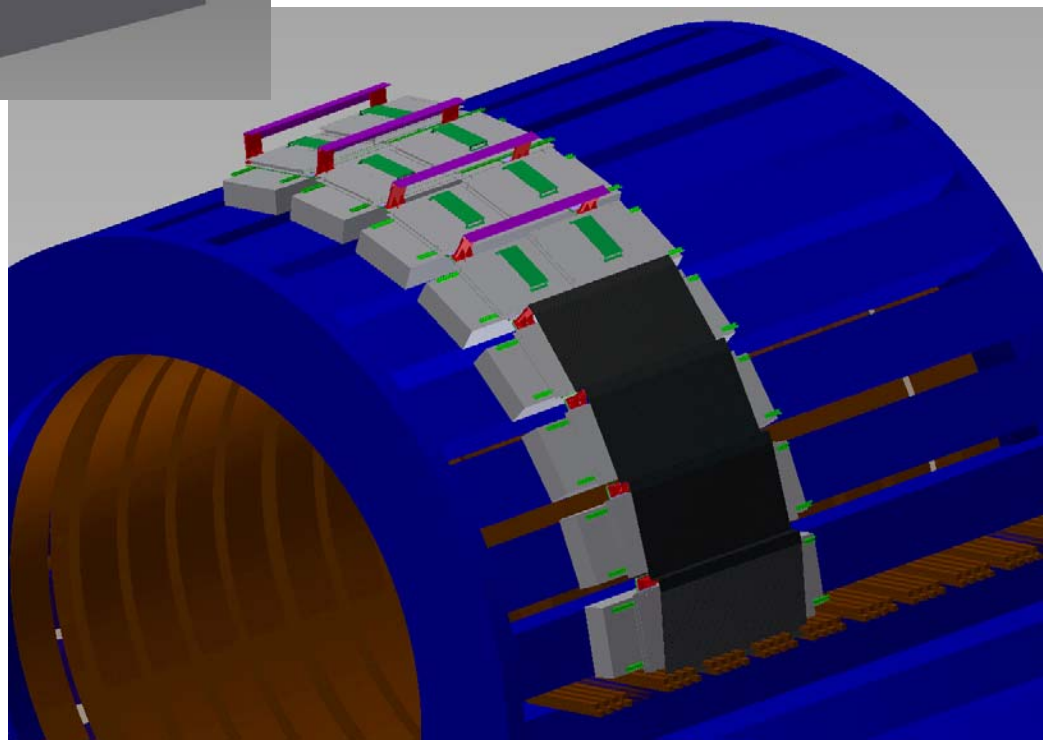


BEMC crates

Full System Installation Scheme

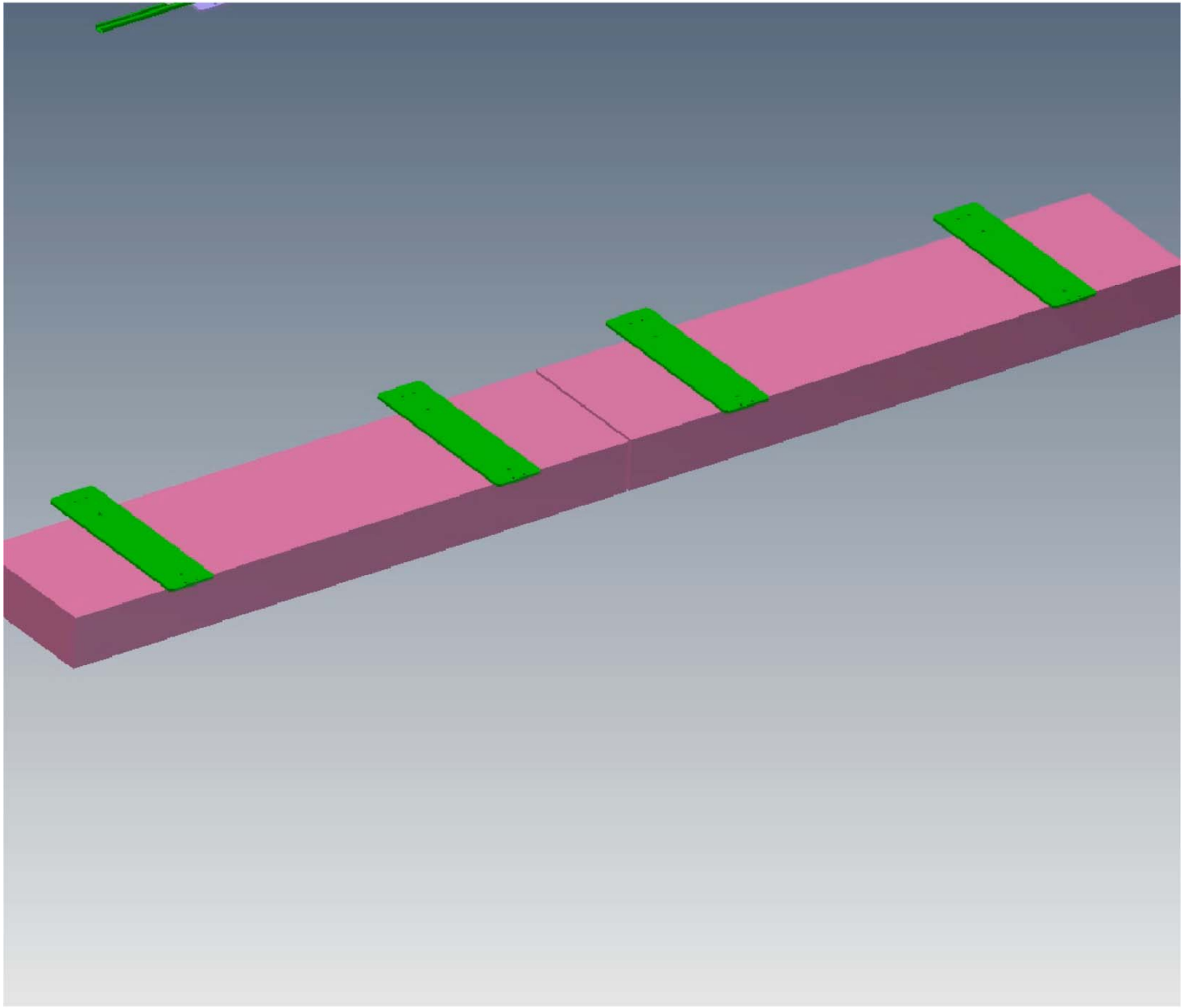


Two PMT boxes per backleg
one "2 pack" on each PMT box
5th MTD tray joins two "2 packs"

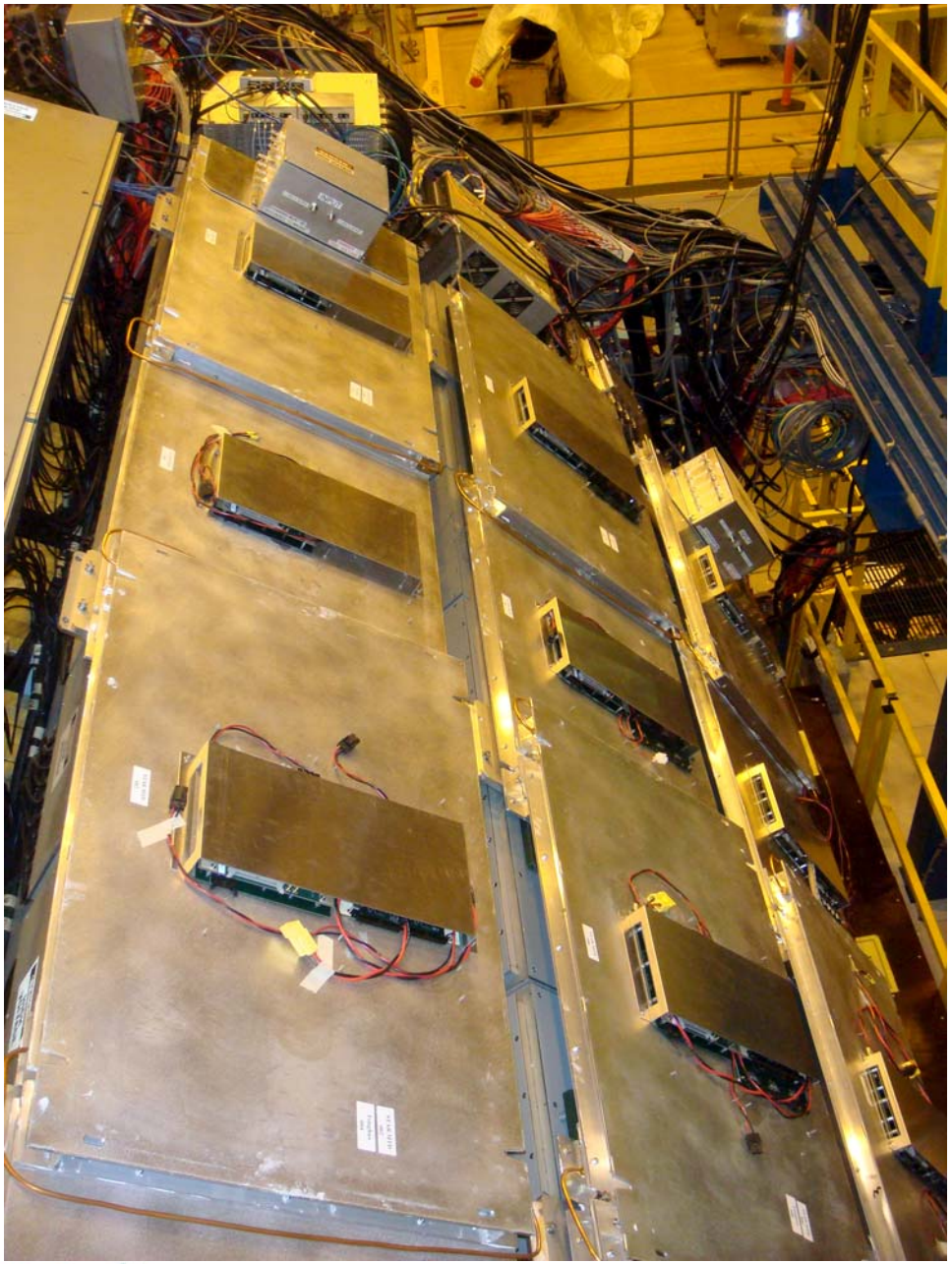


Full System Installation Scheme (Above STAR case)

movie:



Run-12 Installation



Trays on 3 backlegs installed by STSG

Then all cabling added afterwards.
This took ~1.5 man-months (!)

- Anthony Kesich
- Chengming Du
- Chi Yang
- WJL

Thirteen MRPCs operating now…

```
28: tsu,tsu,tsu,tsu,tsu
27: ust,tsu,tsu,tsu,ust
26: xxx,ust,ust,ust,xxx
```

USTC and Tsinghua modules grouped together on single HV supply channels

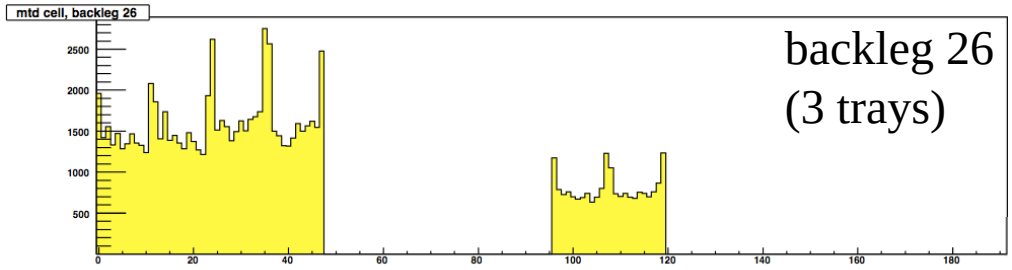
http://www.star.bnl.gov/HyperNews-star/get/startof/2604.html

System has been running fine throughout Run-12.

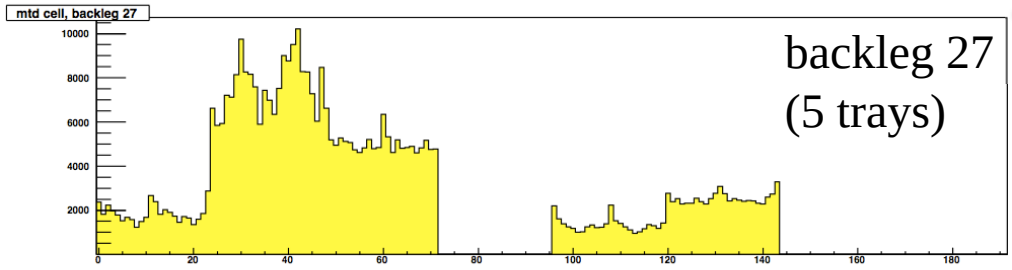
(One problem w/ 28-3 HV polarity fixed mid-run)

Run-12 Installation

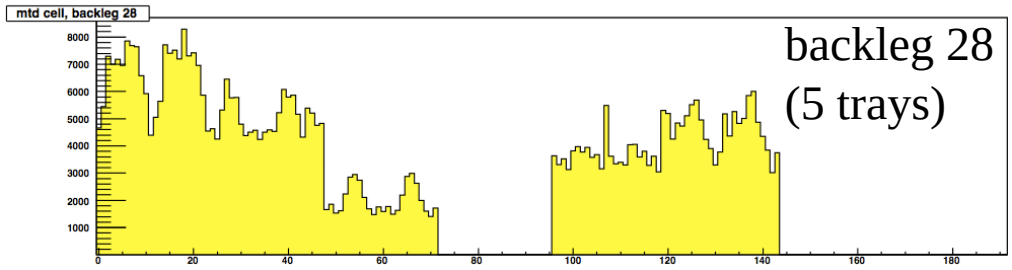
First Noise Rates & ToT distributions from Run-12 trays



backleg 26
(3 trays)



backleg 27
(5 trays)



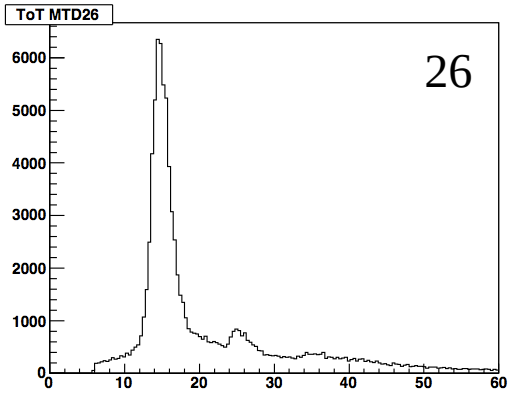
backleg 28
(5 trays)

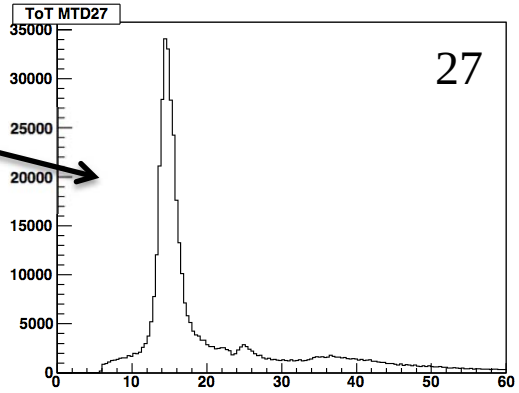
channels are numbered TOF-style…
gas quality is still improving…

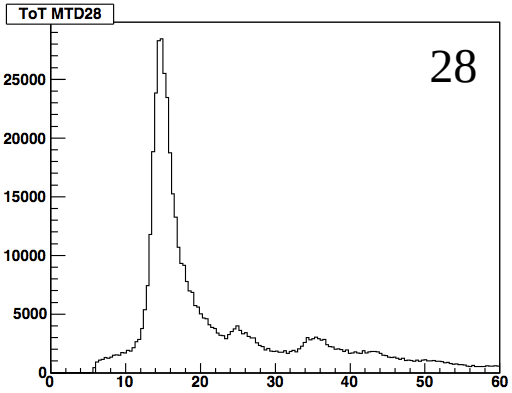
No bad channels

Noise rates averages very reasonable
(<1 Hz/cm^2)

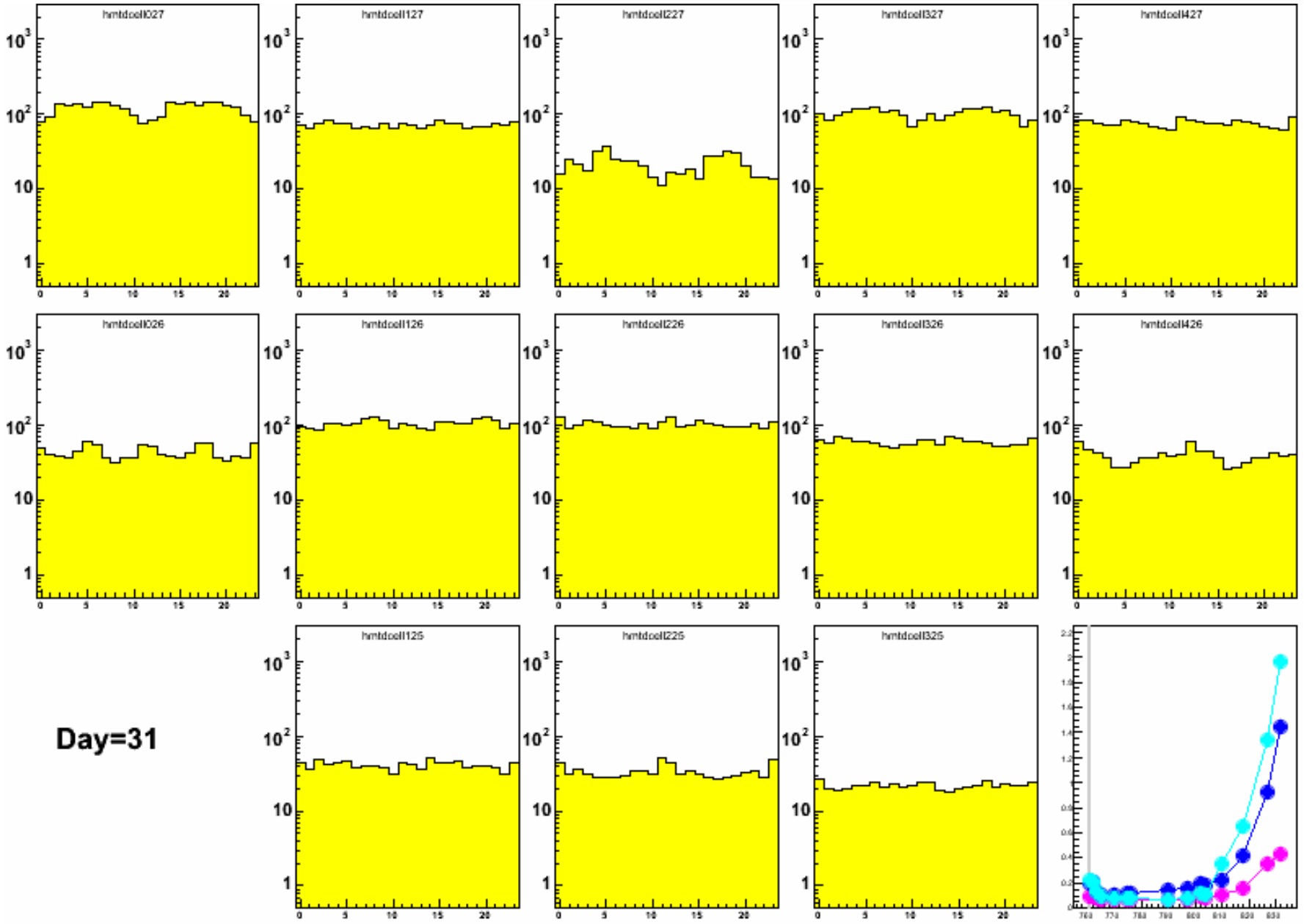
Time-over-Threshold plots
- big avalanche peak
- low streamer percentage



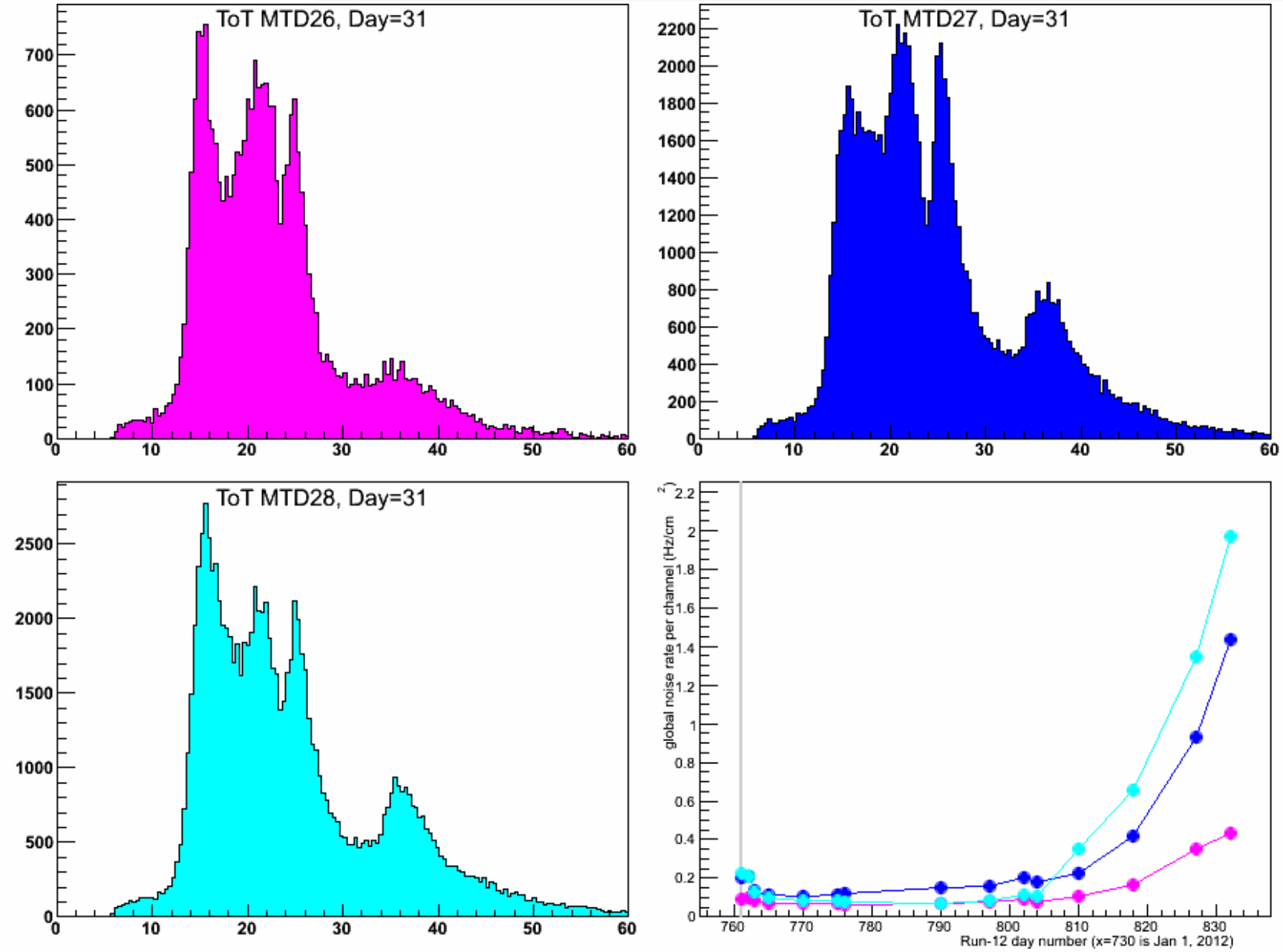




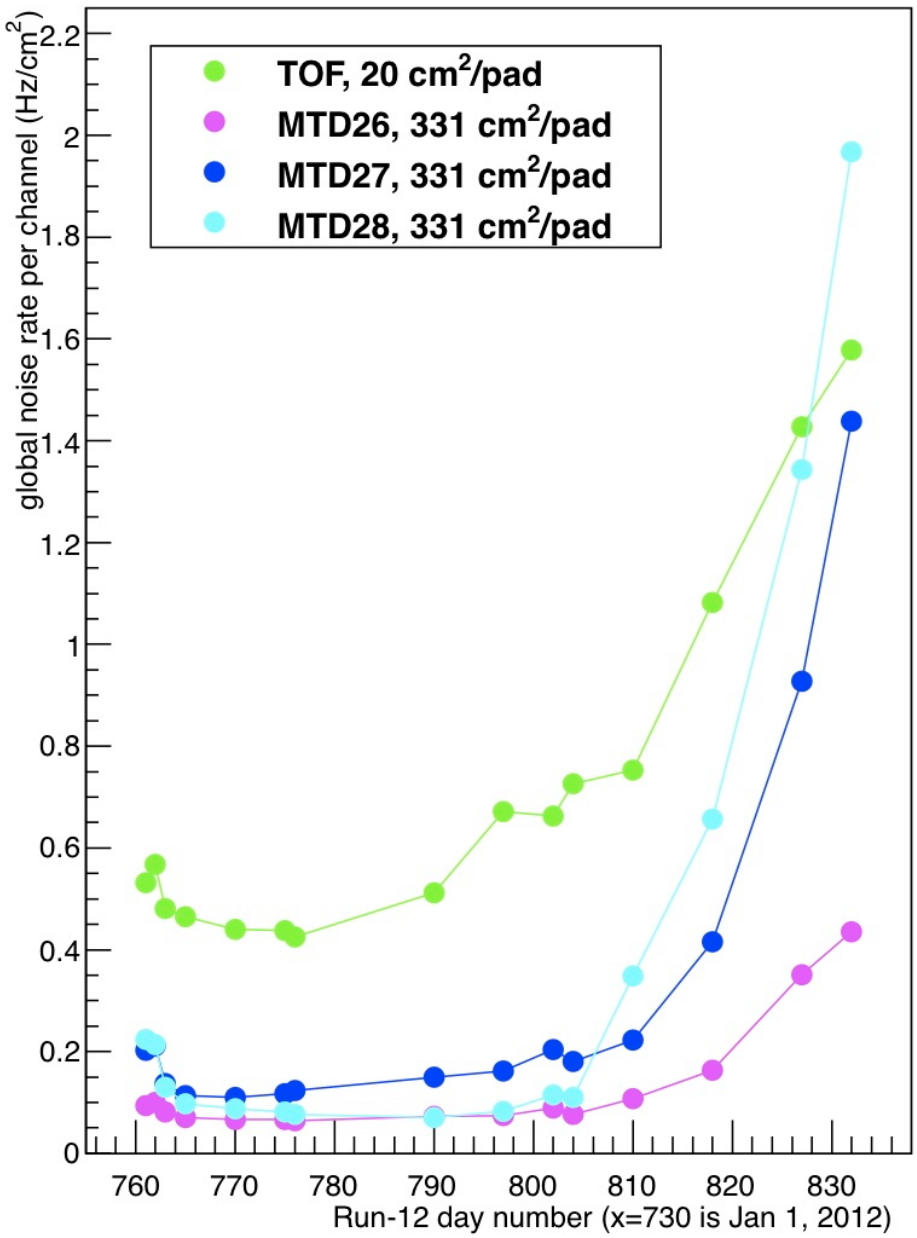
Run-12 noise rates by tray number

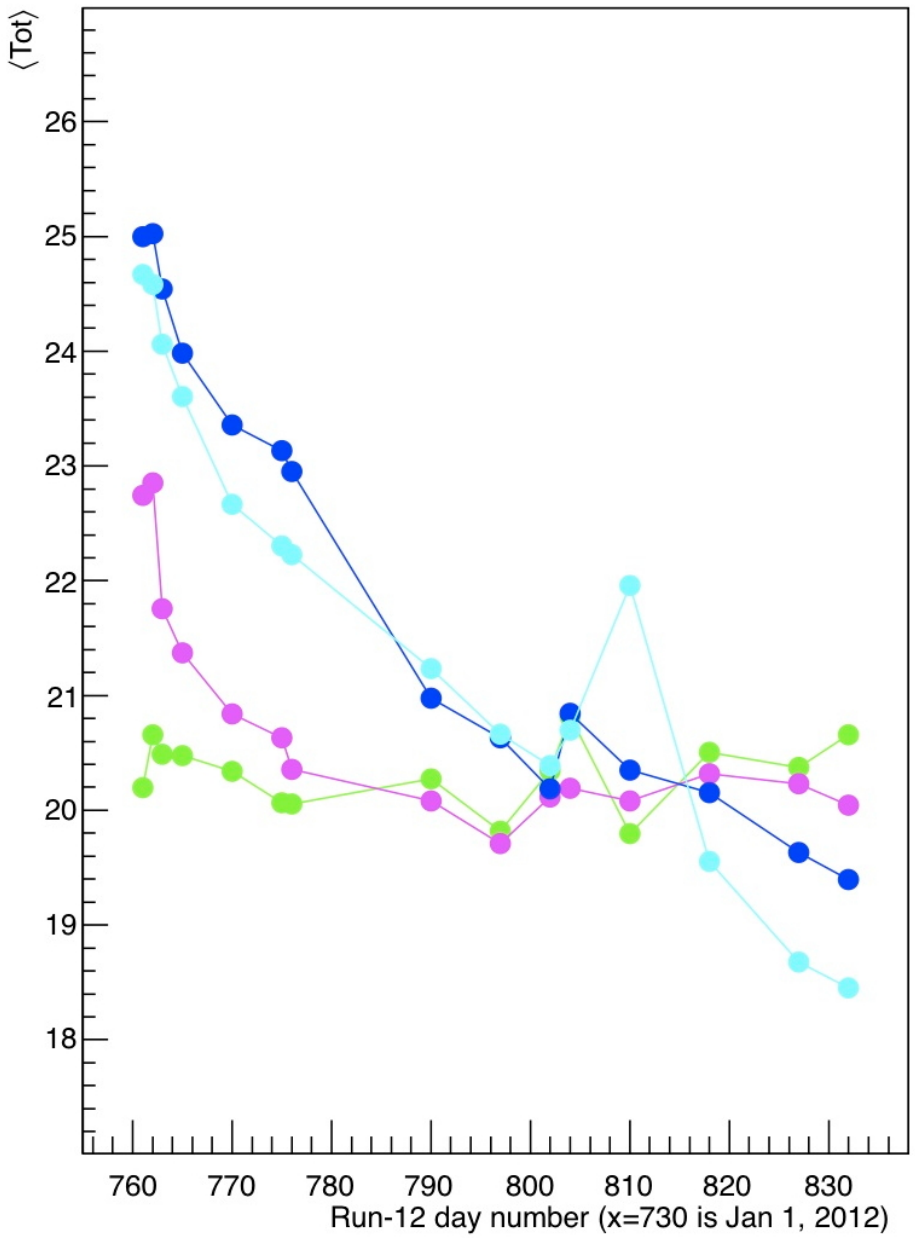


Noise Rates from Run-12 trays

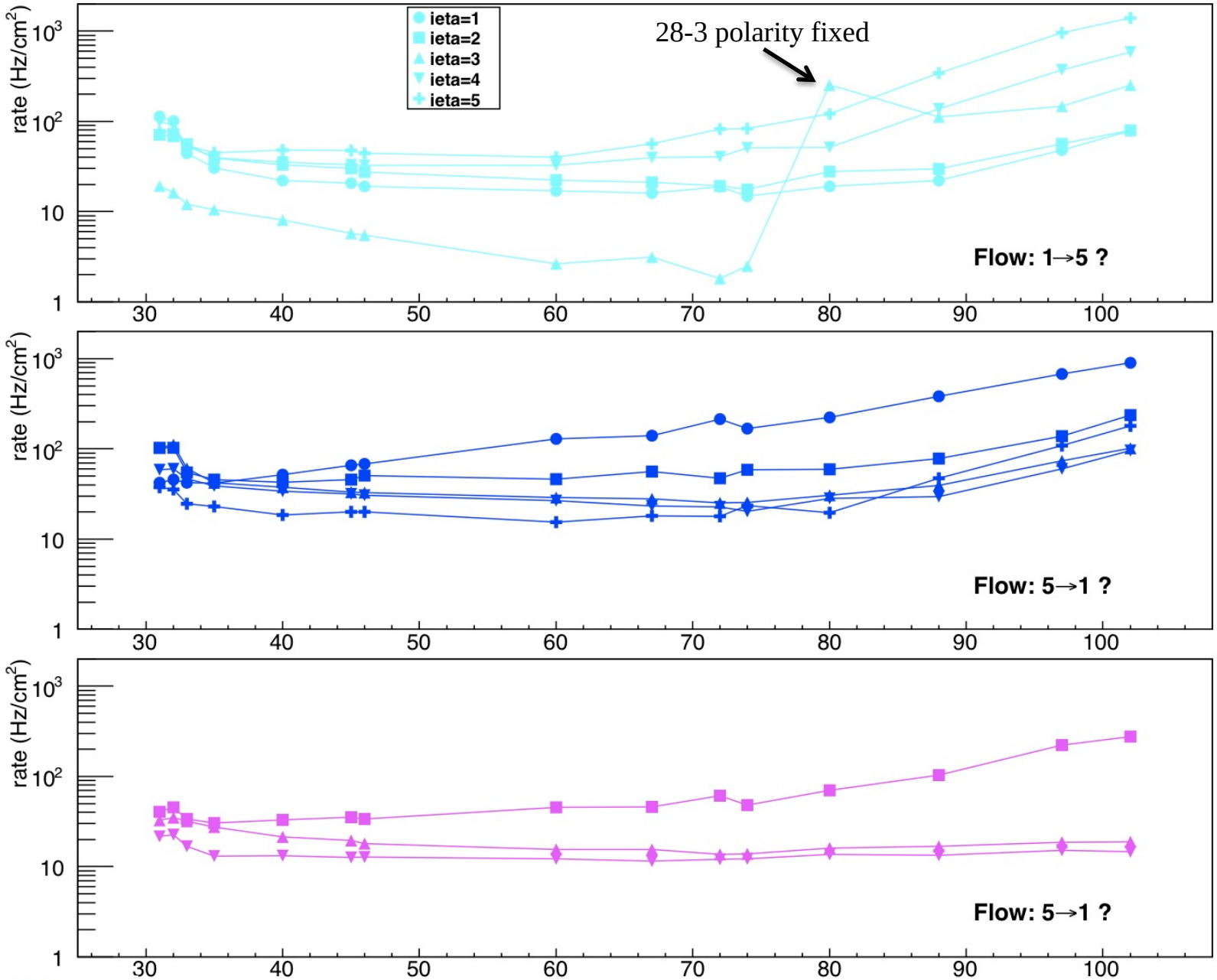


Noise and ToT summary





Gas Poisoning



Preparing for Run-13

In the up-coming shutdown period, we plan on installing 62 trays

This is **a lot**.

Will need at least 3 people to work alongside STSG to cable up trays as they are physically installed.

Otherwise impossible to get access to the trays.

While STAR is in the Assembly Building:

- remove 3 trays from backleg 26, and install 5 trays there
- install 5 trays on backleg 25
- install 5 trays on backleg 29

STAR then rolls back in….

- install trays on backlegs 30, 1, 2, 3, 4, 5, 6, 7….

We have perhaps 1.5 months to get all these backlegs ready!

We have held many meetings with STSG in order to plan for this major effort.

Run-13 Integration

http://www.star.bnl.gov/HyperNews-star/protected/get/mudet/491.html

Action Items

1 (STSG) Determine HFT installation plans

2 (MTD) Define assembly and delivery schedule (DONE)

3 (STSG) Determine LV/HV supply location (DONE)

4 (MTD) Review LV/HV cabling lengths (DONE)

5 (MTD) Coordinate w/ Ciro's group re: LV/HV cabling orders (DONE)

6 (MTD) Review shortHV cable lengths (DONE, lengths optimized to tray)

7 (MTD) Decide on passive vs. networked HV distboxes (DONE, passive)

8 (MTD) Explore using longer MINO-MTRG cables (DONE, stay w/ 80")

9 (MTD) Explore data sanity using 45' cat-6 cables (DONE, bench test done)

10 (STSG) Find nutless/toolless mechanical fasteners

11 (STSG) Update BNL quote for mechanical parts

12 (MTD) Determine where to build mechanical parts (DONE?)

13 (STSG) Determine schedule & plan for BEMC maintenance

14 (STSG) Determine location of gasdist panels

Tray Assembly and Delivery Schedule

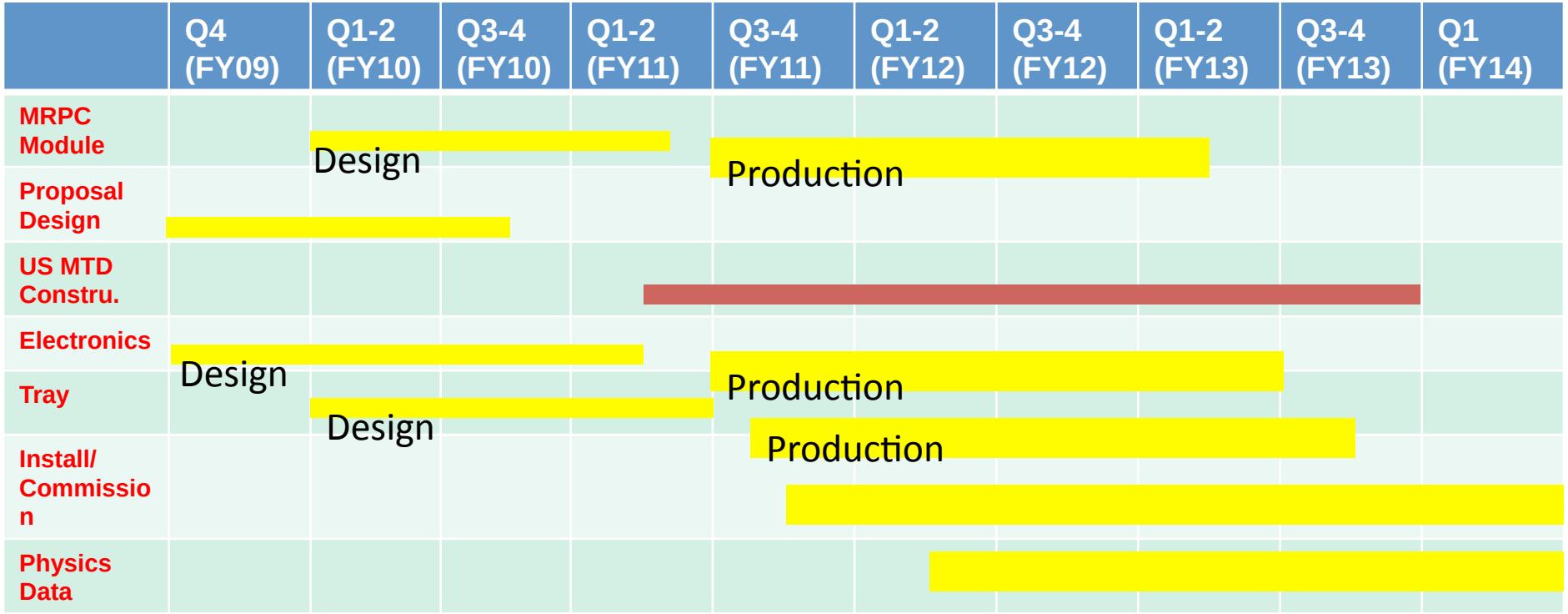
Status: 13 trays installed, 14 trays at UT ready to ship (4/5)

Apr 2	10 Tsinghua MRPCs arrive at UT
Apr 16	8 USTC MRPCs arrive at UT
Apr 30	10 Tsinghua MRPCs arrive at UT
Apr 30	10 trays tested at UT and ready to ship (24 in total ready)
May 29	8 USTC MRPCs arrive at UT
May 29	10 Tsinghua MRPCs arrive at UT (total at UT is now 60 MRPCs)
May 31	10 trays tested at UT and ready to ship (34 in total ready)
Jun 25	10 Tsinghua MRPCs arrive at UT (total at UT is now 70 MRPCs)
Jun 28	10 trays tested at UT and ready to ship (44 in total ready)
Jul 9	8 USTC MRPCs arrive at UT
Jul 23	8 Tsinghua MRPCs arrive at UT
Jul 31	10 trays tested at UT and ready to ship (54 in total ready)
Aug 20	8 USTC MRPCs arrive at UT
Aug 31	10 trays tested at UT and ready to ship (64 in total ready)
Oct 1	8 USTC MRPCs arrive at UT
Nov 12	6 USTC MRPCs arrive at UT

…Electronics production needs to keep pace with tray assembly

…Would be nice to build a tray w/ a VECC MRPC and use that in Run-13!

MTD Schedule



10% installation for Run12, 43% for Run13, 80% for Run 14.
Finish the project by Mar, 2014

MTD institutions: Brookhaven National Laboratory, University of California, Berkeley, University of California-Davis, Rice University, University of Science & Technology of China, Texas A&M University, University of Texas-Austin, Tsinghua University, Variable Energy Cyclotron Centre

US institutions: the electronics, the assembly of the trays and the operation of the detector

Chinese and Indian institutions: the fabrication of the MRPC modules

Summary and Conclusions

MTD will advance our knowledge of the Quark Gluon Plasma…

- low-level trigger capability — for low to high p_T J/ψ in central Au+Au collisions
- excellent mass resolution — separate different upsilon states
- e+muon correlation — distinguish heavy flavor production from initial lepton pair production
- complementary to dielectrons — different background contributions
- rare decay and exotics …

All MTD prototypes and final tray installations have been successful so far…

- Fabricated trays and MRPCs fit together nicely, Bench test results look very good.
- Hit patterns and noise rates in STAR are reasonable.
- "Final" detectors installed on-time for Runs 11 and 12.
- Collected untriggered data throughout Run-11, some triggered data at the end
  - Still working on VPD+MTD timing trigger in Run-12.
- Looking forward to resolution results & add'l development of timing triggers

Successful Run-12 installation (13 trays) using new mounting scheme.

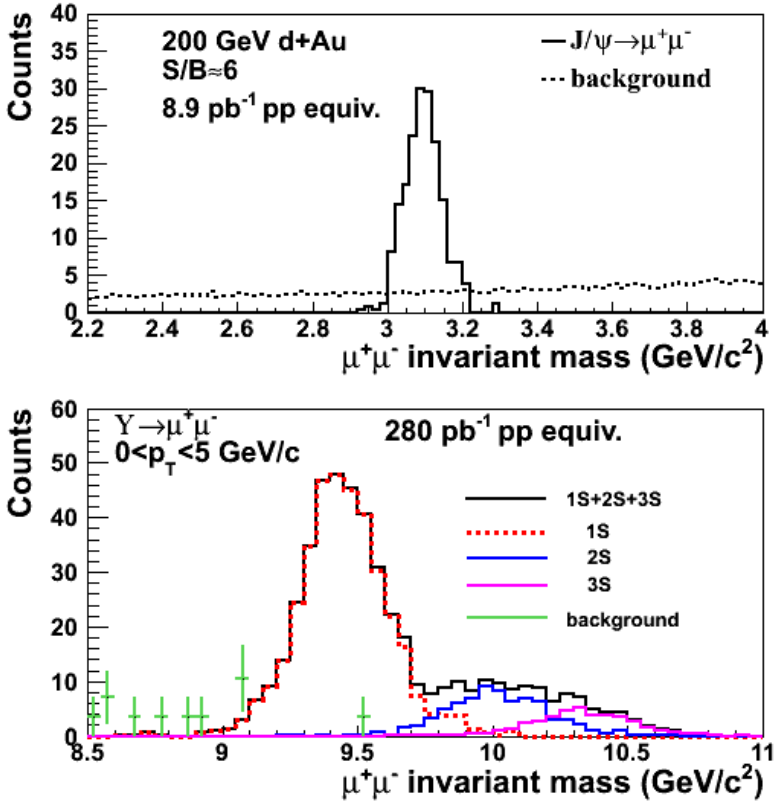
The critical issues in terms of system design involve optimizing some installation details..

>40% coverage for Run-13, remaining MTD detectors installed before Run-15.

谢谢您的款待

backup

High Mass Di-muon Capabilities



1. J/ψ: S/B=6 in d+Au and S/B=2 in central Au+Au
2. With HFT, study B→J/ψ+X; J/ψ→μμ using displaced vertices
3. Excellent mass resolution: separate different upsilon states

Heavy flavor collectivity and color screening, quarkonia production mechanisms:

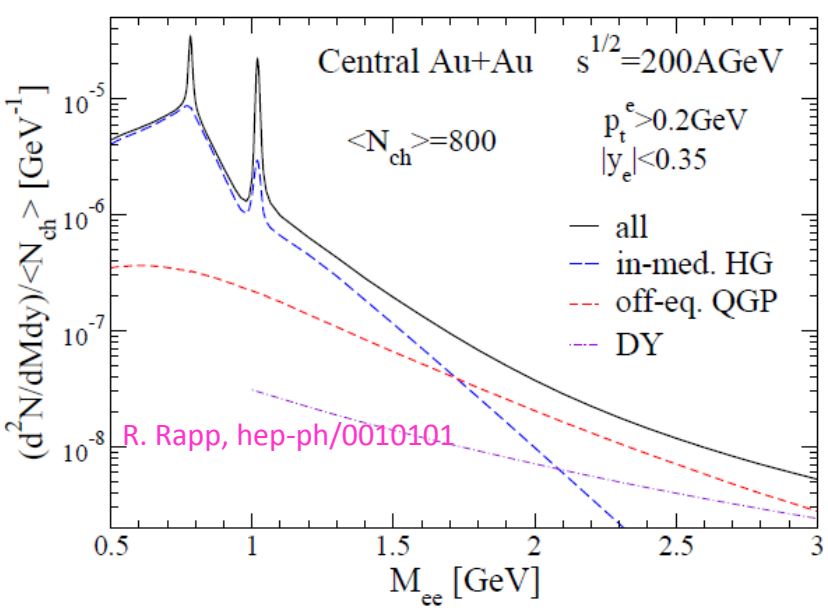
J/ψ R_{AA} and v_2; upsilon R_{AA} …

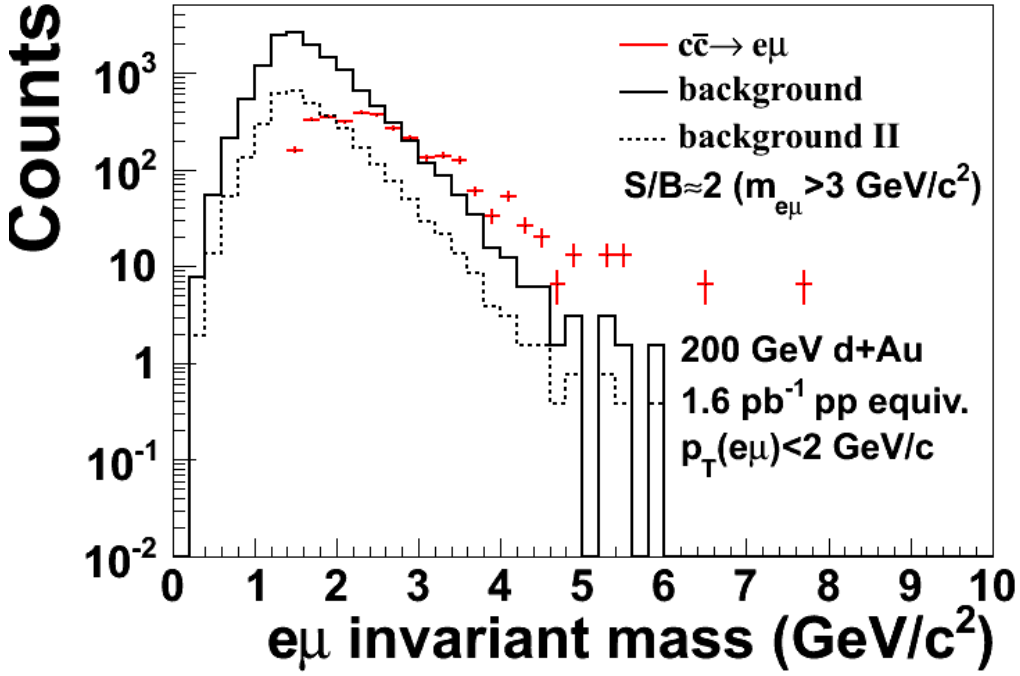
Z. Xu, BNL LDRD 07-007; L. Ruan et al., Journal of Physics G: Nucl. Part. Phys. 36 (2009) 095001

Quarkonium dissociation temperatures - Digal, Karsch, Satz

state	$J/\psi(1S)$	$\chi_c(1P)$	$\psi'(2S)$	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T_d/T_c	2.10	1.16	1.12	> 4.0	1.76	1.60	1.19	1.17

Distinguish Heavy Flavor and Initial Lepton Pair Production: e-muon Correlation



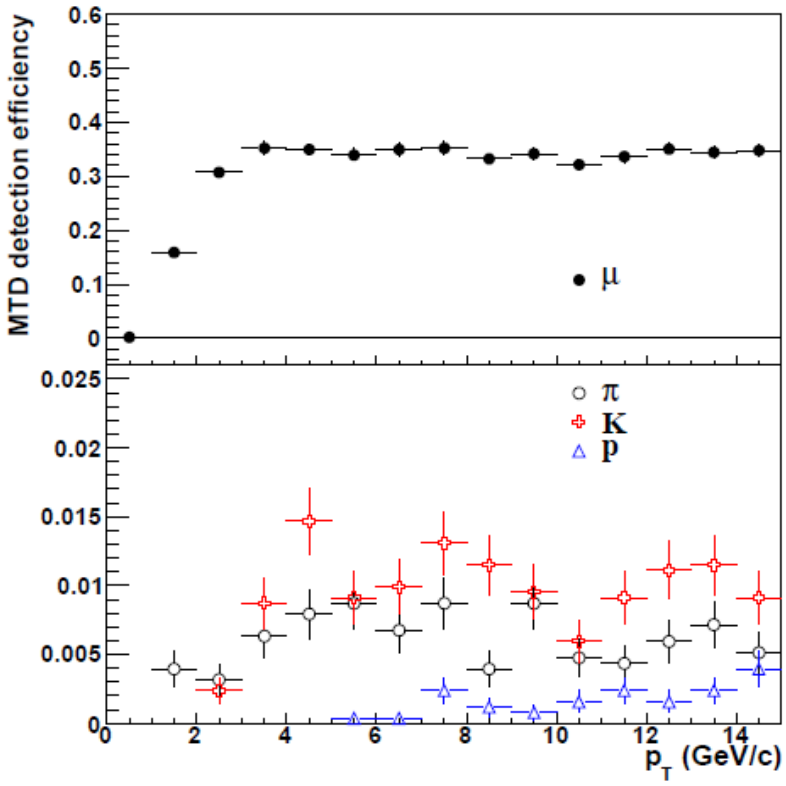


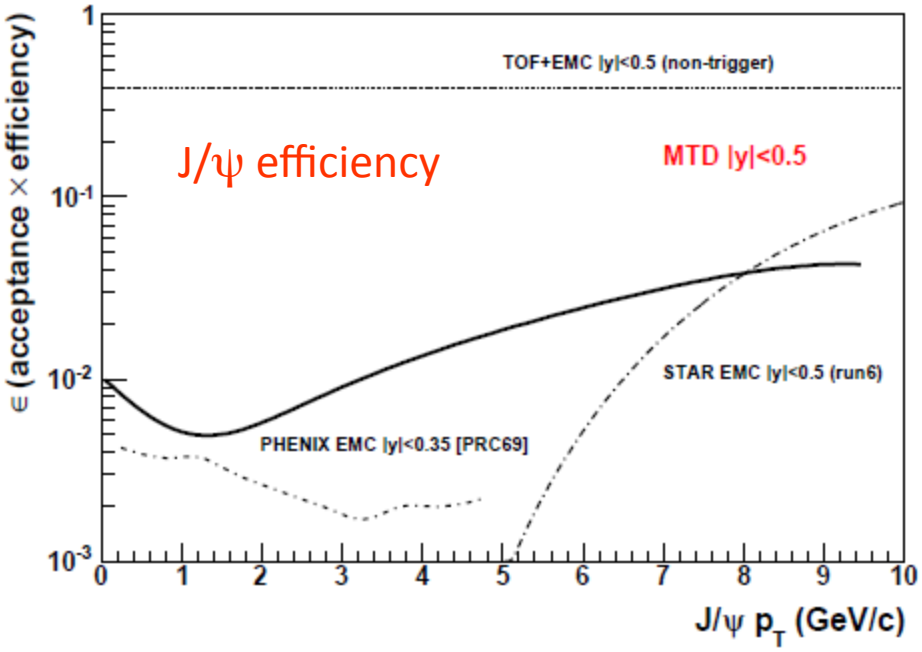
eμ correlation simulation with Muon Telescope Detector at STAR from ccbar:

S/B=2 (M_{eu}>3 GeV/c2 and $p_T(e\mu)$<2 GeV/c)

S/B=8 with electron pairing and tof association

Single Muon and J/ψ Efficiency





1. muon efficiency at |η|<0.5: 36%, pion efficiency: 0.5-1% at p_T>2 GeV/c
2. muon-to-pion enhancement factor: 50-100
3. muon-to-hadron enhancement factor: 100-1000 including track matching, tof and dE/dx
4. dimuon trigger enhancement factor from online trigger: 40-200 in central Au+Au collisions

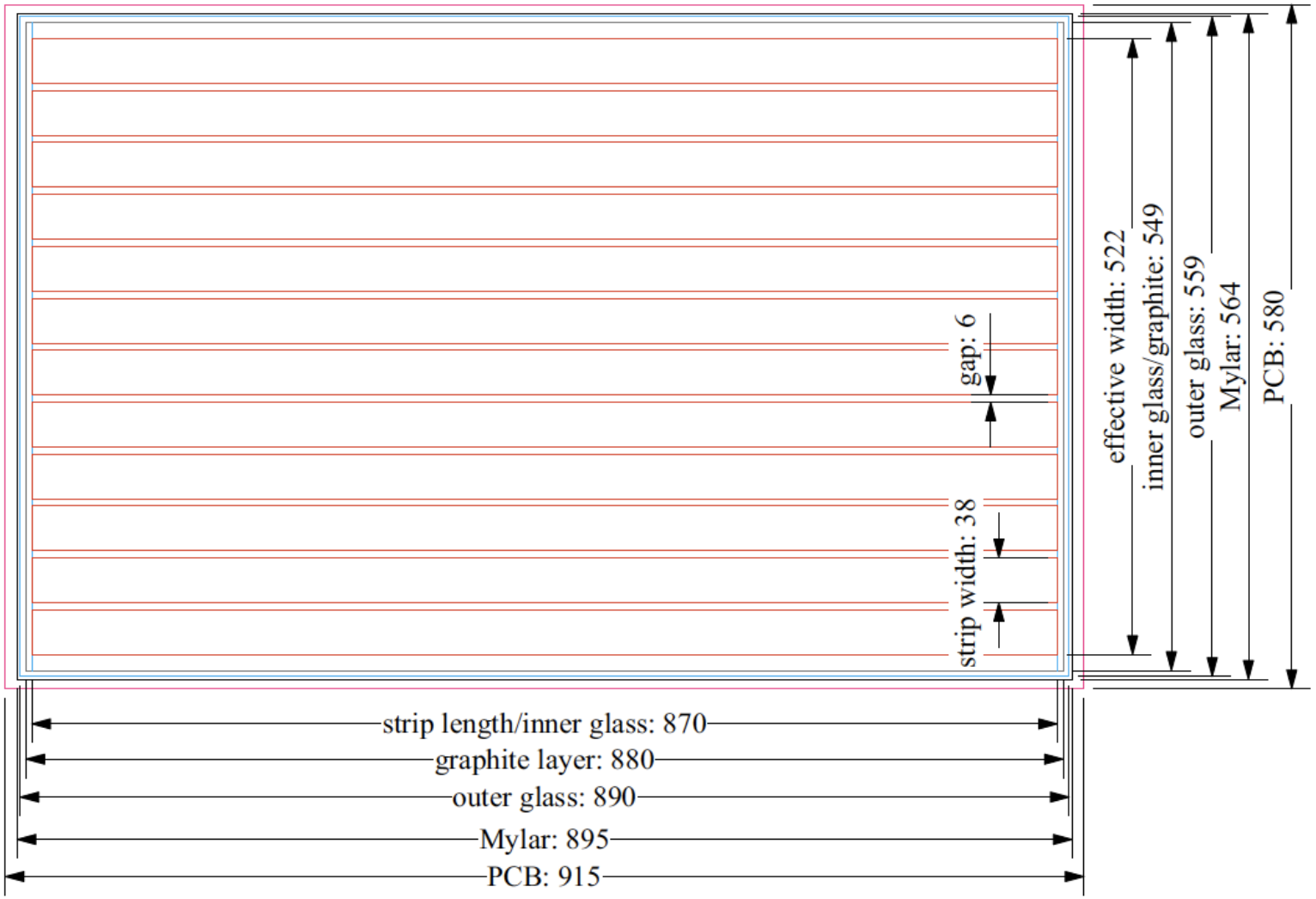
Assumed MRPC Dimensions for MTD11 Prototypes

USTC Prototype

Outer (PCB) 58.0cm x 91.5cm

Active (Pads) 52.2cm x 87.0cm Height = 3cm Weight = 13kg (29lbs)

Tsinghua MRPCs were 93cm long… Prefer 91.5cm

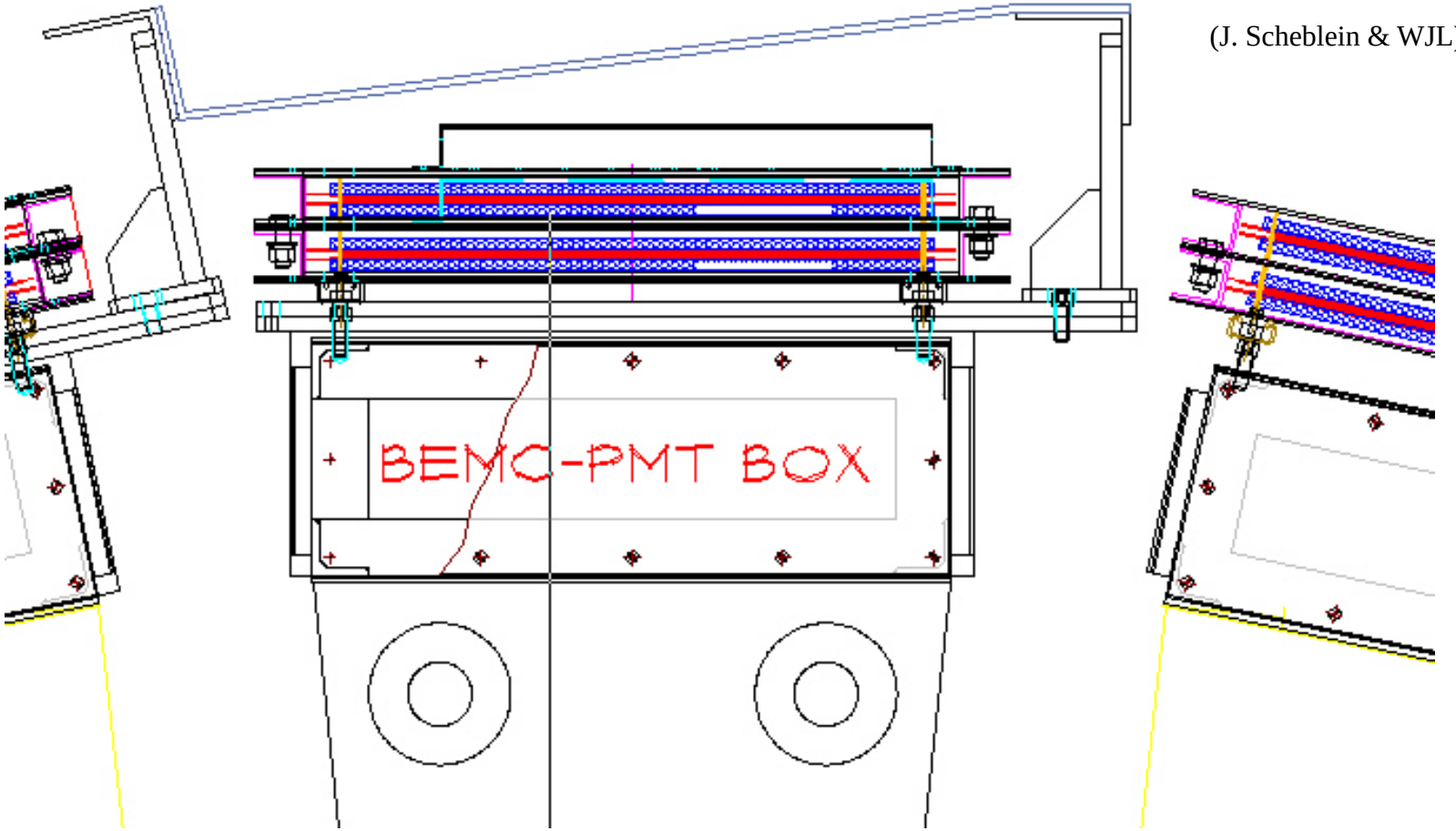


Full System Installation Scheme

new approach: Make mounting more complicated to make integration easier…

- unistrut mounts to two layers of “cross-pieces”
- use available space between backlegs
- install “diamond plate” covers over the top (heat retension?)

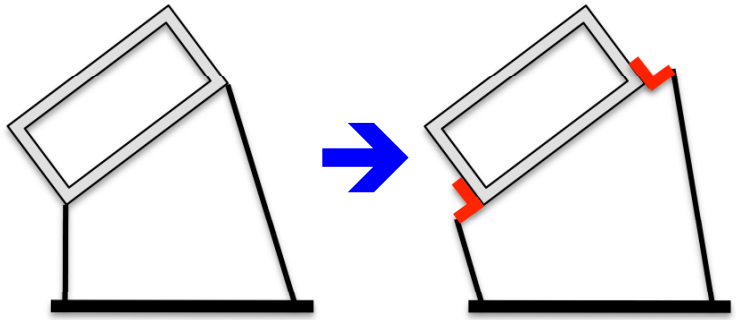
(J. Scheblein & WJL)

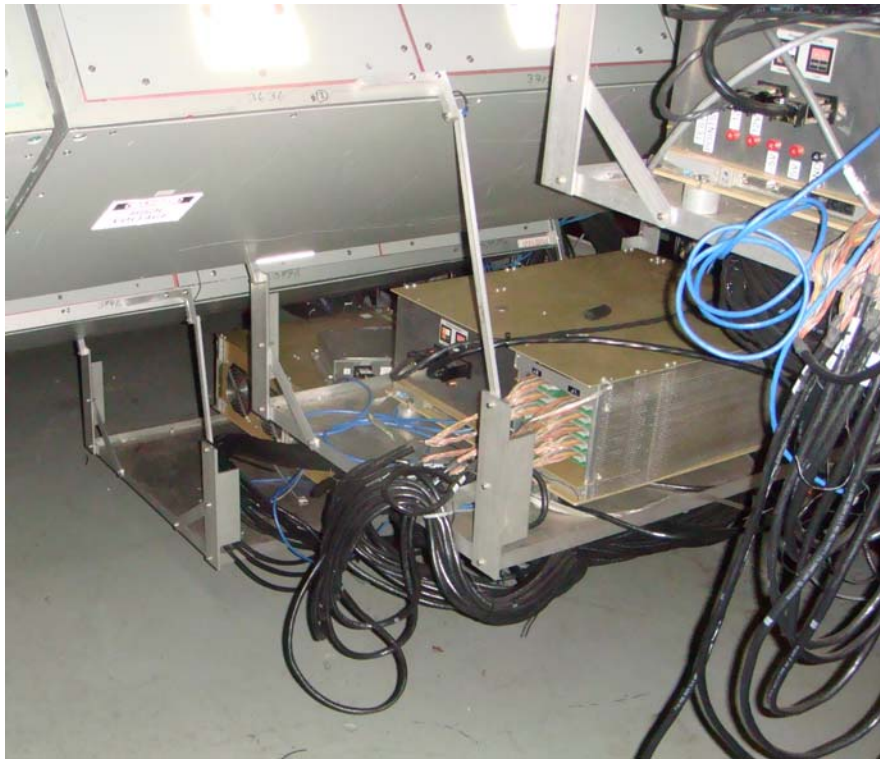


Full System Installation Scheme (Below STAR case)

Under STAR…
not a lot of room down there
not enough slack in BEMC cabling
to move these crates

only viable option known is to
"widen the hangars"





Other items:
fittings and fixtures should be plug and play (limit # of small nuts/bolts)
allow for "foam" filler pieces between PMT boxes

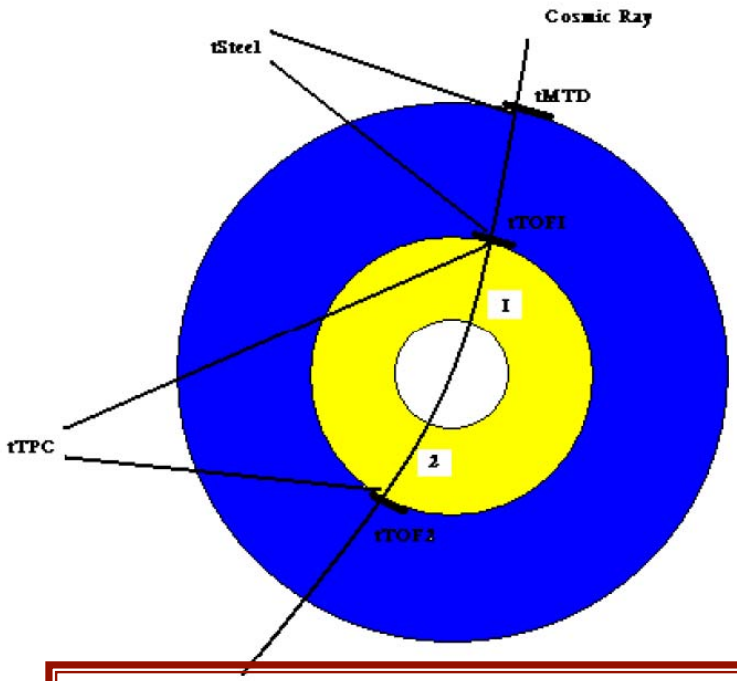
locate local tray testing and storage area
locate space and define fixtures for 2-pack assembly in the AB/WAH

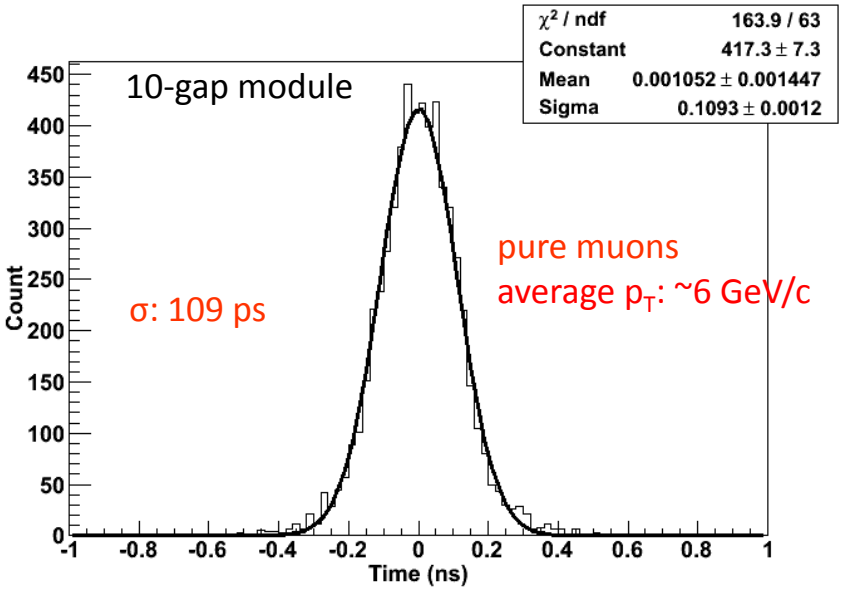
The Details for the R&D Modules

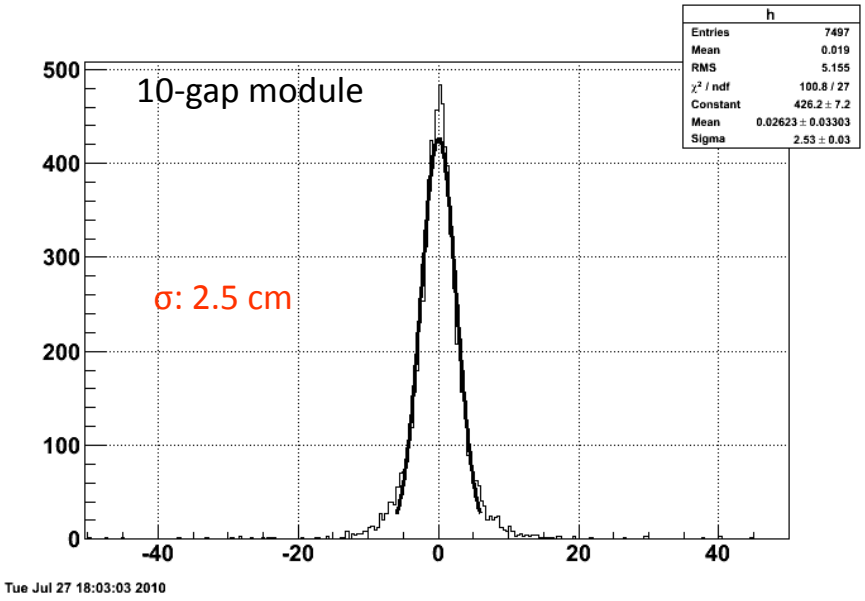
Conditions	Modules and readout
Cosmic ray and Fermi-lab T963 beam tests	**double stacks,** **module size:** 87(z)×17(ϕ) cm^2, Performance: 60 ps, ~0.6 cm at HV ± 6.3 kV
Run 7: Au+Au **Run 8: p+p, d+Au**	**double stacks, 2 modules in a tray,** **module size:** 87(z)×17(ϕ) cm^2, Readout: trigger electronics, Time resolution: 300 ps
Run 9: p+p **Run 10: Au+Au, cosmic ray**	**double stacks, 3 modules in a tray,** **module size:** 87(z)×17(ϕ) cm^2, Readout: TOF electronics; trigger electronics for trigger purpose.
Run 11	**single stack, 1 module in a tray, module size:** 87(z)×52(ϕ) cm^2, Readout: TOF electronics; trigger electronics for trigger purpose, Cosmic ray test performance: <100 ps

R&D from 2007 to 2011 led to a final design.

Run 10 Performance: Time and Spatial Resolution







Cosmic ray trigger

Total resolution: 109 ps

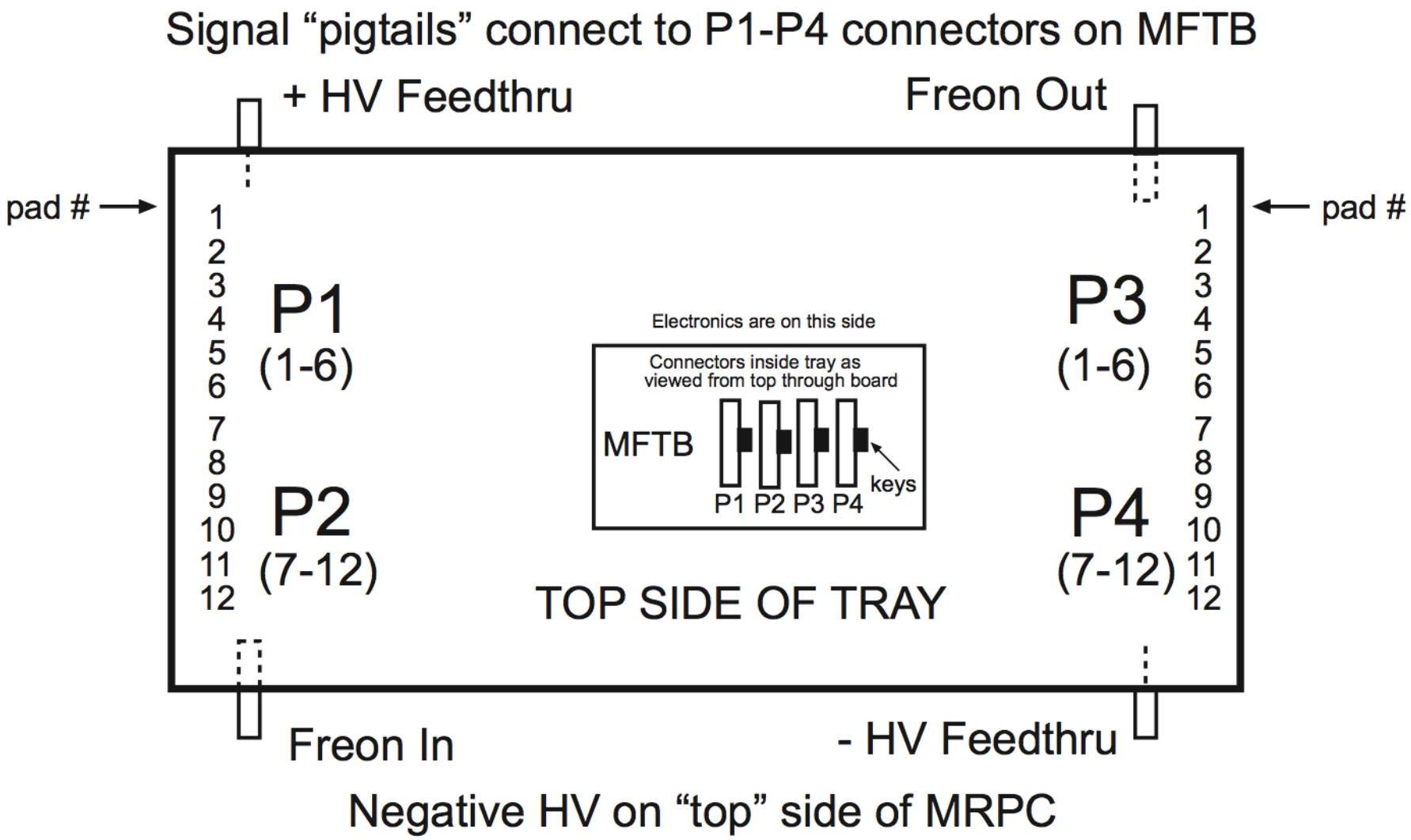
Start resolution (2 TOF hits): 46 ps

Multiple scattering: 25 ps

MTD intrinsic resolution: 96 ps

System spatial resolution: 2.5 cm, dominated by multiple scattering

MTD11 Tray Assembly (Connections Schematic)



UT will make the signal pigtails and ship them to China/India…