TOF Status

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☆ Collaboration Mtg, BNL
February 24, 2005

Outline:

Stop-Side Evolution: TOFr, TOFr’, TOFr5, & beyond...
- **Detectors & Mechanical**
- **Electronics & DAQ**

TOFr5 Commissioning & Preliminary Results

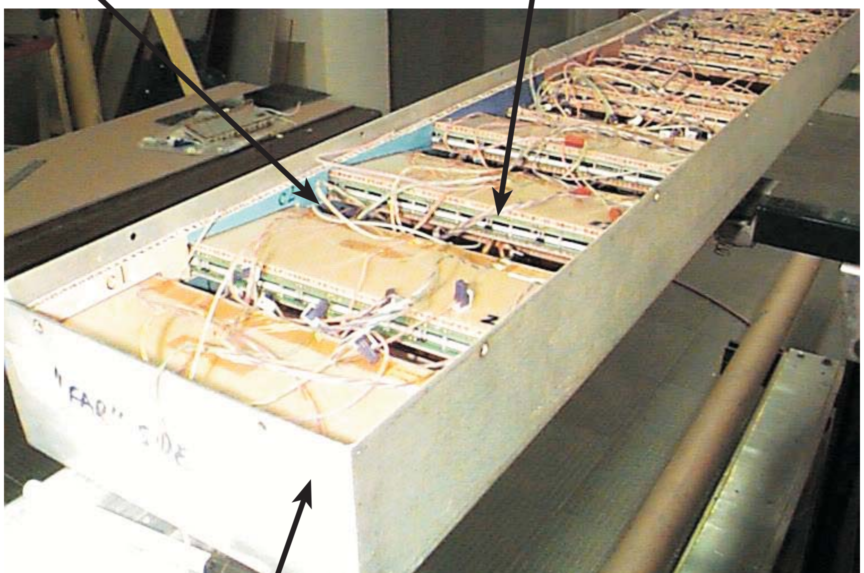
Start-Side Evolution: pVPD & beyond...

Summary & Plans...

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

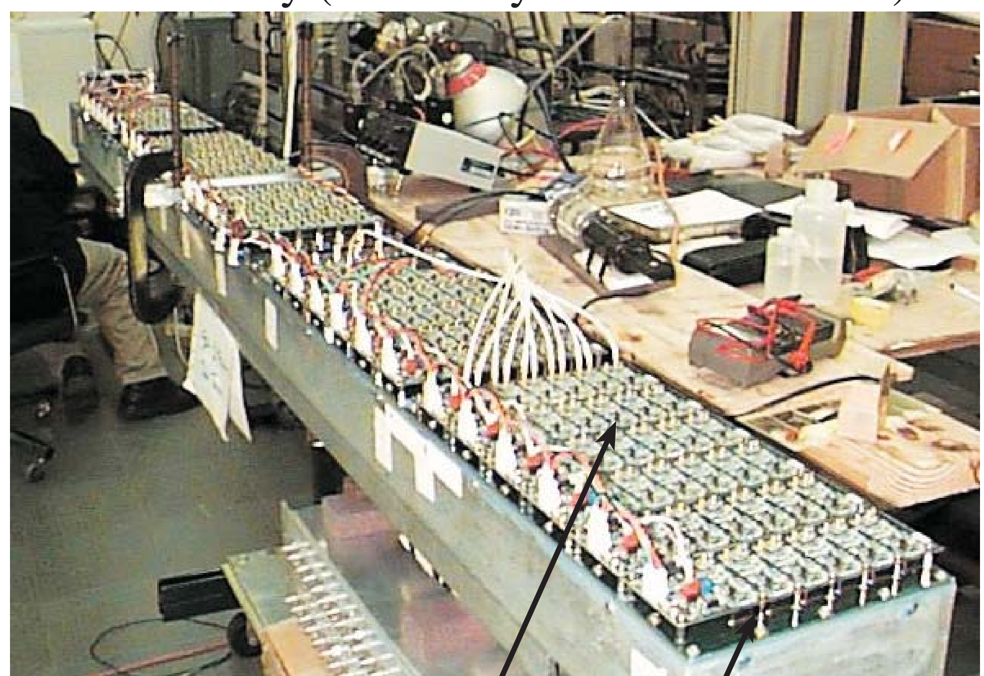


standard CTB tray

welded/tapped rail assembly (glued gaskets also)

- 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

final TOFr tray (note many cables not shown!)

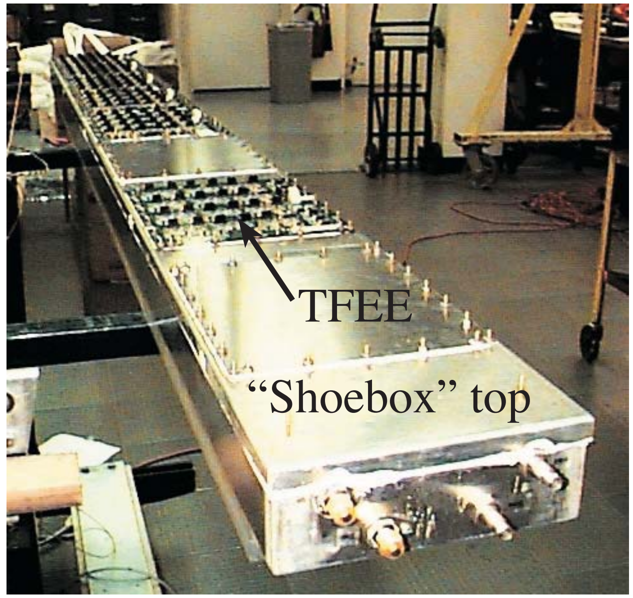


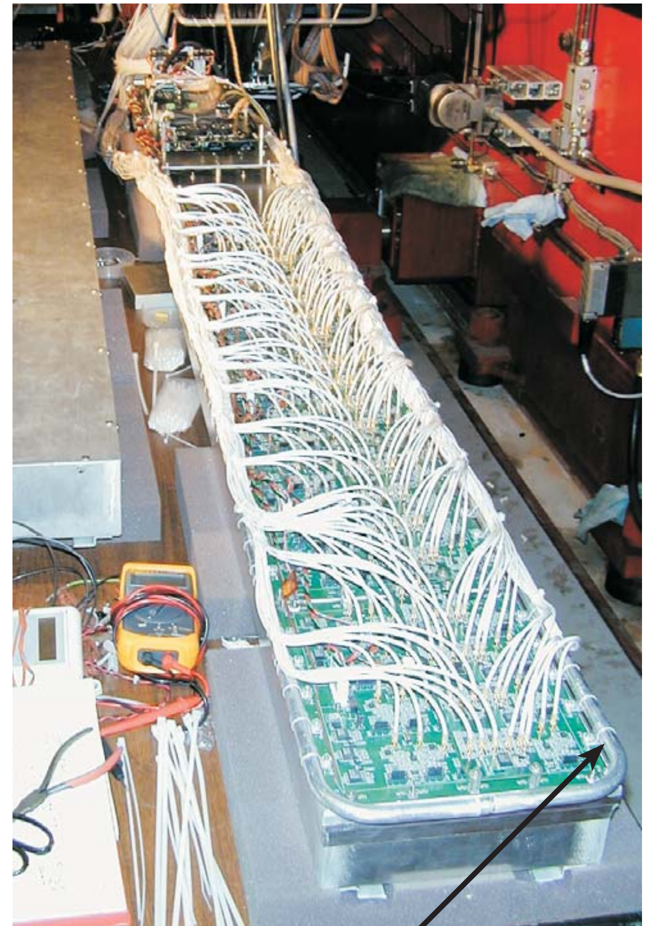
FEE layer F/T layer

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)

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





"last minute" cooling loop

- 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

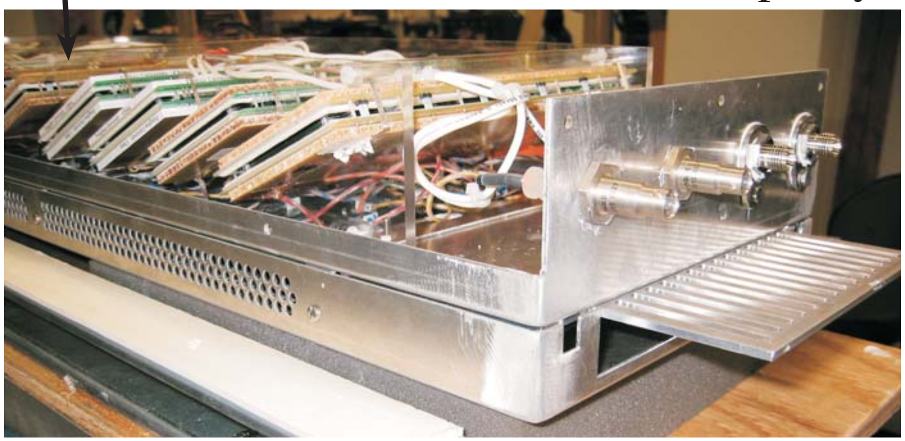
FEE dumped a lot of heat into the box
increased MRPC current draw, & noise rates...
timing seemed o.k. but...

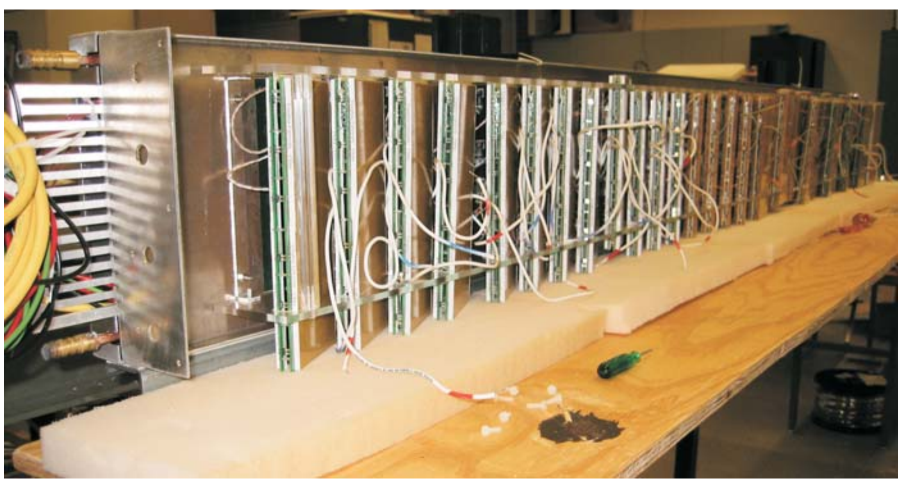
D&M: TOFr5 (Run-5)

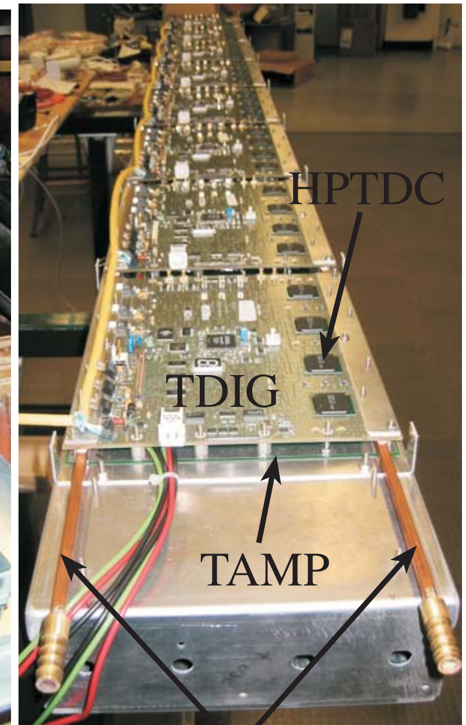
First attempt at on-board digitization
Back to two layers of on-board electronics
Integrated cooling loop
new batches of MRPCs (USTC & Tsinghua)

"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~~

"bowing" of bottom assy due to welded feet
small tweaks to box & inner sides design
integration of TINO, TDIG version 2, & cooling

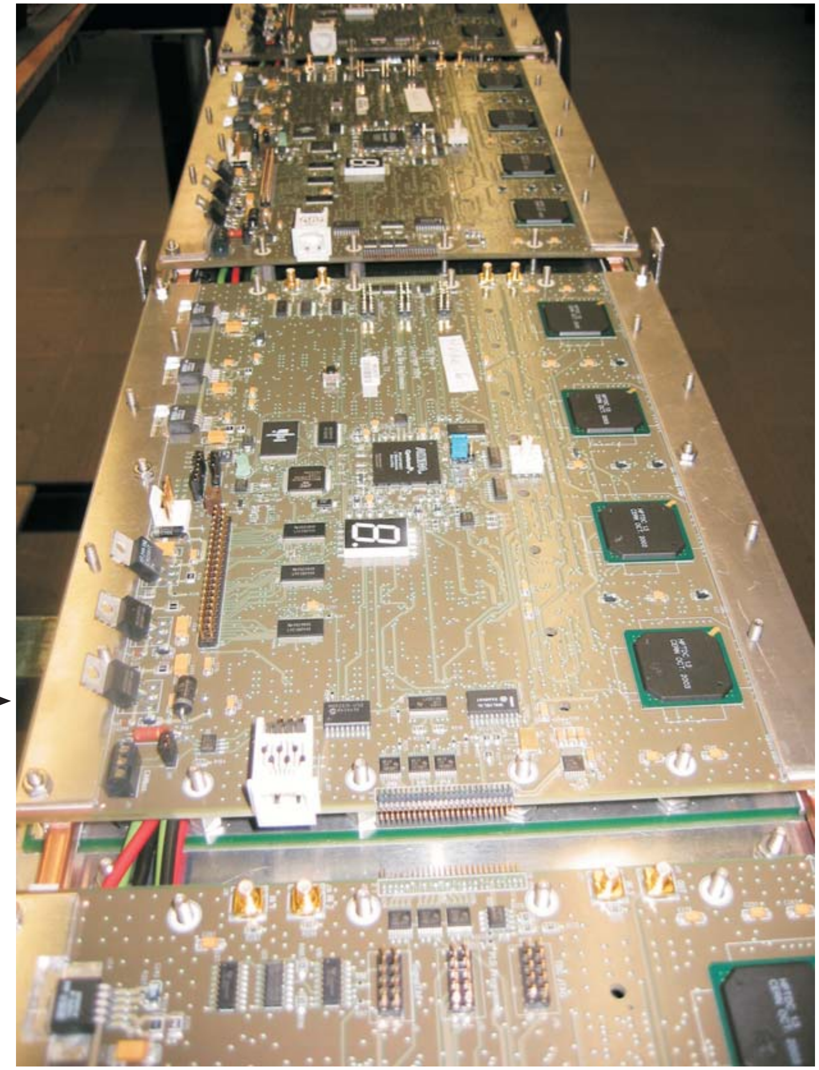
TOFr5 cooling loop tests & efficiency/power estimates:
http://wjllope.rice.edu/~TOF/TOFr5/Ttests/TOFr5_T_tests.htm

DAQ: TOFr5 (Run-5)

"Fixed-target" style DAQ

NIM local trigger based on pVPD signals
CAMAC digitization w.r.t. the local trigger
R/O via PCI board and to STAR over network
Slewing via ADC values

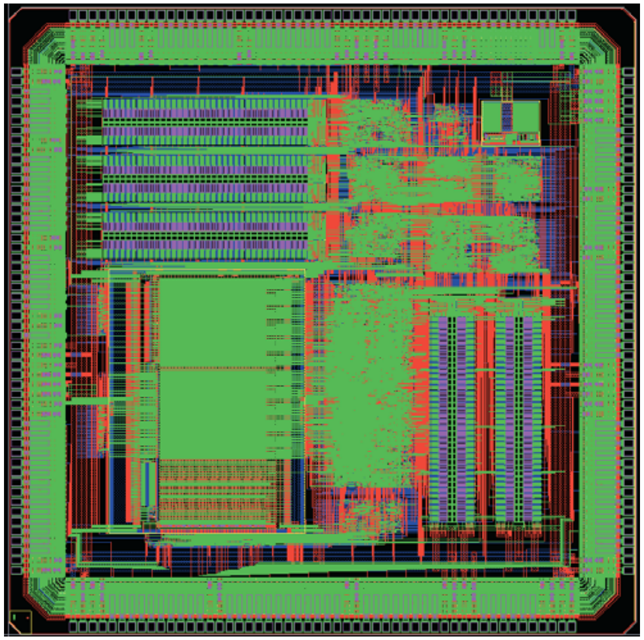
"Collider" style DAQ



No local trigger
HPTDC digitization w.r.t. a Clock
R/O via SIU/RORC fiber directly to STAR
Slewing via Time-Over-Threshold

`ToT=4*TEword - LEword`

DAQ: TOFr5 (Run-5)



More compact
allows it to be on-board
allows high granularity/low occupancy (~10%)
removes need for ~46,000 coaxial signal cables
~3000 miles of cable, platforms of racks

Cheaper
~100 $/channel

Lower power
~140W total for TOFr5, will drop w/ TAMP→TINO (Run-6)

Absolute timing
52 μsec time counters for each (start or stop) channel based on single clock signal
event integrity is easy to see via consistency of measured times (start and stop)

~50ps time bins (CAMAC) → 24.4ps time bins (HPTDC very-high resn mode)

Digitize only first hit in a channel (CAMAC) → Digitize all hits in a channel (HPTDC)

"Trigger-matching" window to select which time stamps to send to DAQ

Readout electronics/protocol well-matched to TPC/DAQ upgrade plans
we're already using the SIU/RORC fiber electronics being considered for the new TPC R/O.

Implemented as
start-side: TPMT→TDIG→TCPU→SIU/RORC
stop-side: TAMP→TDIG→TCPU→SIU/RORC

But will the timing resolution(s) be good enough?!?

Run-5 Operations

DATE	DAY	
• 10/05		TOFr5 fabrication complete TDIG INL Calibrations, Electronics installation, noise rate measurements begin
• 10/26		TOFr5 arrives at WAH, Basic utilities (Gas, HV, LV) installed, repeat testing
• 11/05		TOFr5 installed in STAR, pole-tip closes, TCPU boxes installed Gas flow started (freon only)
• 11/10		HV on
• 11/23		Installation of external (TCPU) electronics boxes Integrated electronics commissioning begins
• 01/12		Clock cable repaired Firmware now able to send data to DAQ in response to TCD triggers
• 01/20	20	Isobutane flow starts Determine that TCPU for West pVPD needs to be replaced
• 01/27	27	TOF now controlled by shift crew, data written locally (for TOFr5 & East pVPD)
• 02/03	34	TCPU for West pVPD replaced, all 3 legs (stop and both starts) now alive
• 02/09	40	TOF now in STAR data stream. Determined that start ToT could be be improved.
• 02/16	47	Feed-through terminators added to fix start-side ToT.

Events Collected (up to Day 54)

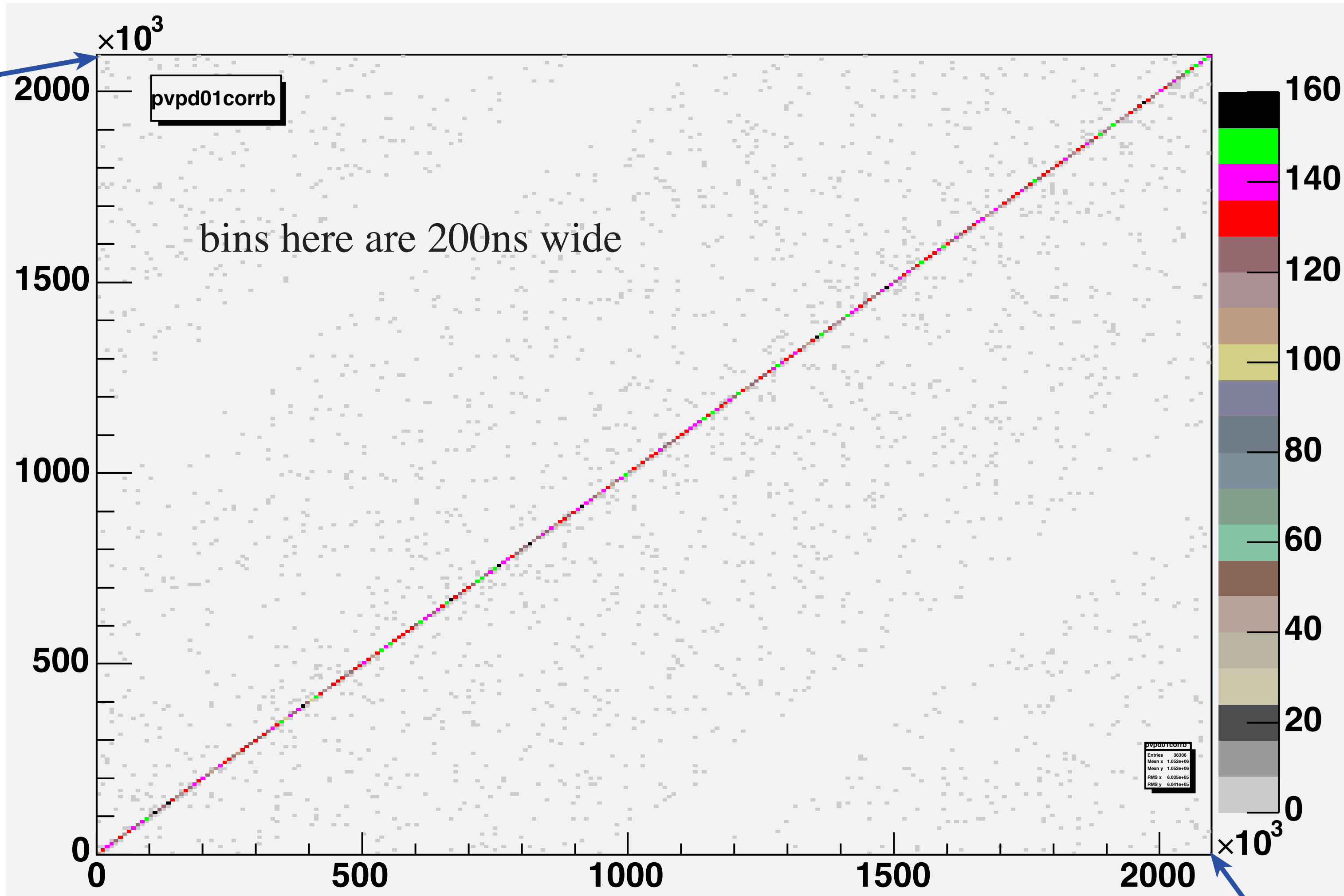
	HT	MB
Total:	11.6M	20.1M
Since day 40:	8.7M	10.4M
Since day 47:	3.8M	5.9M

First Look at the Run-5 Data

http://wjllope.rice.edu/~TOF/TOFr5/Run5data/

Simplest possible plot:
correlation of LE time stamps in two different pVPD detectors (East2 *vs*. East1 shown here)
in events with exactly one time LE stamp in each of these two detectors

51 μsec full scale

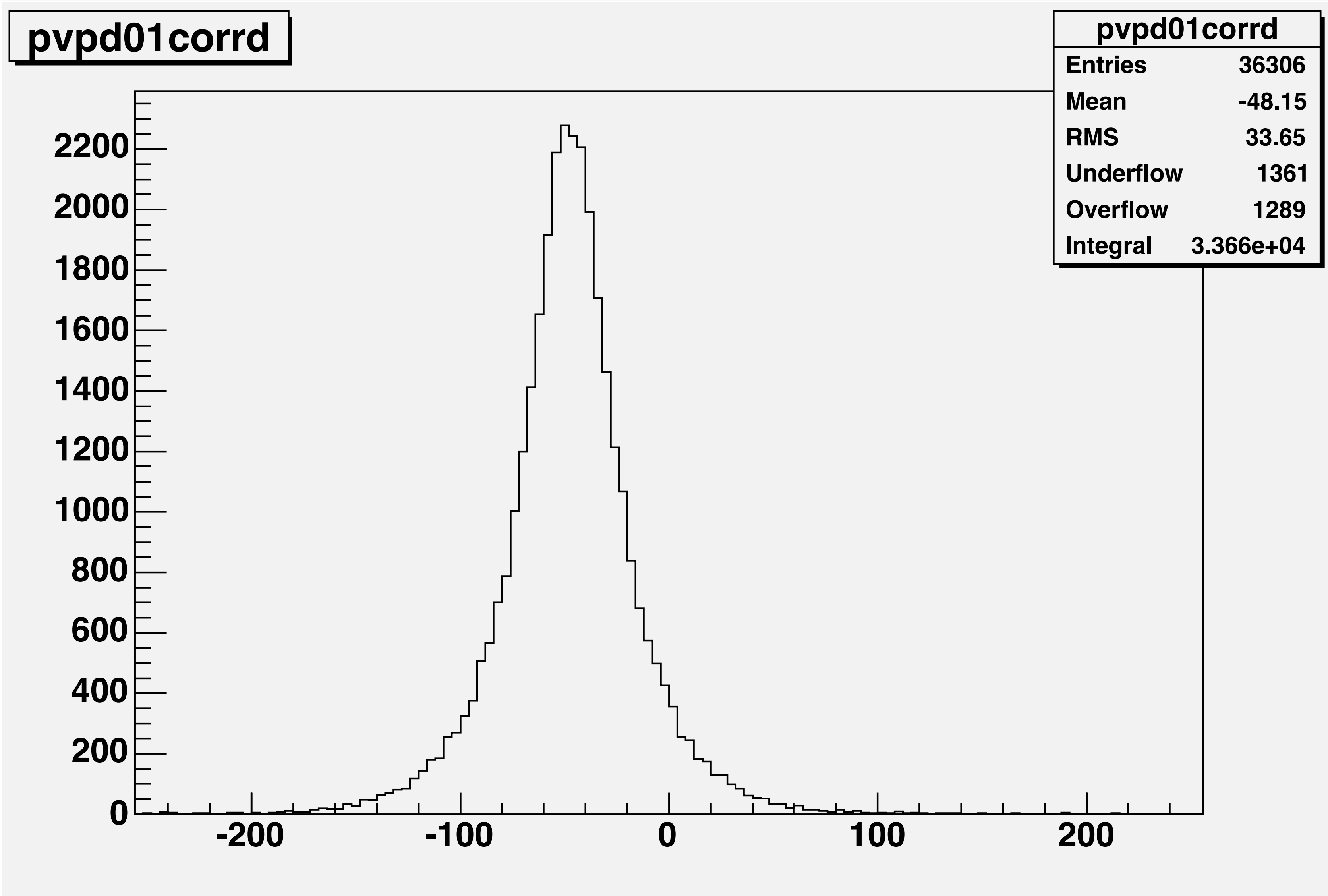


51 μsec full scale

LE time stamps from different start detectors are *highly correlated*!

one can make exactly the same-looking plot for the TE time stamps...
(19 bit resn, 97.6 ps/bin post-INL, same 52 μsec dynamic range as LE stamps)

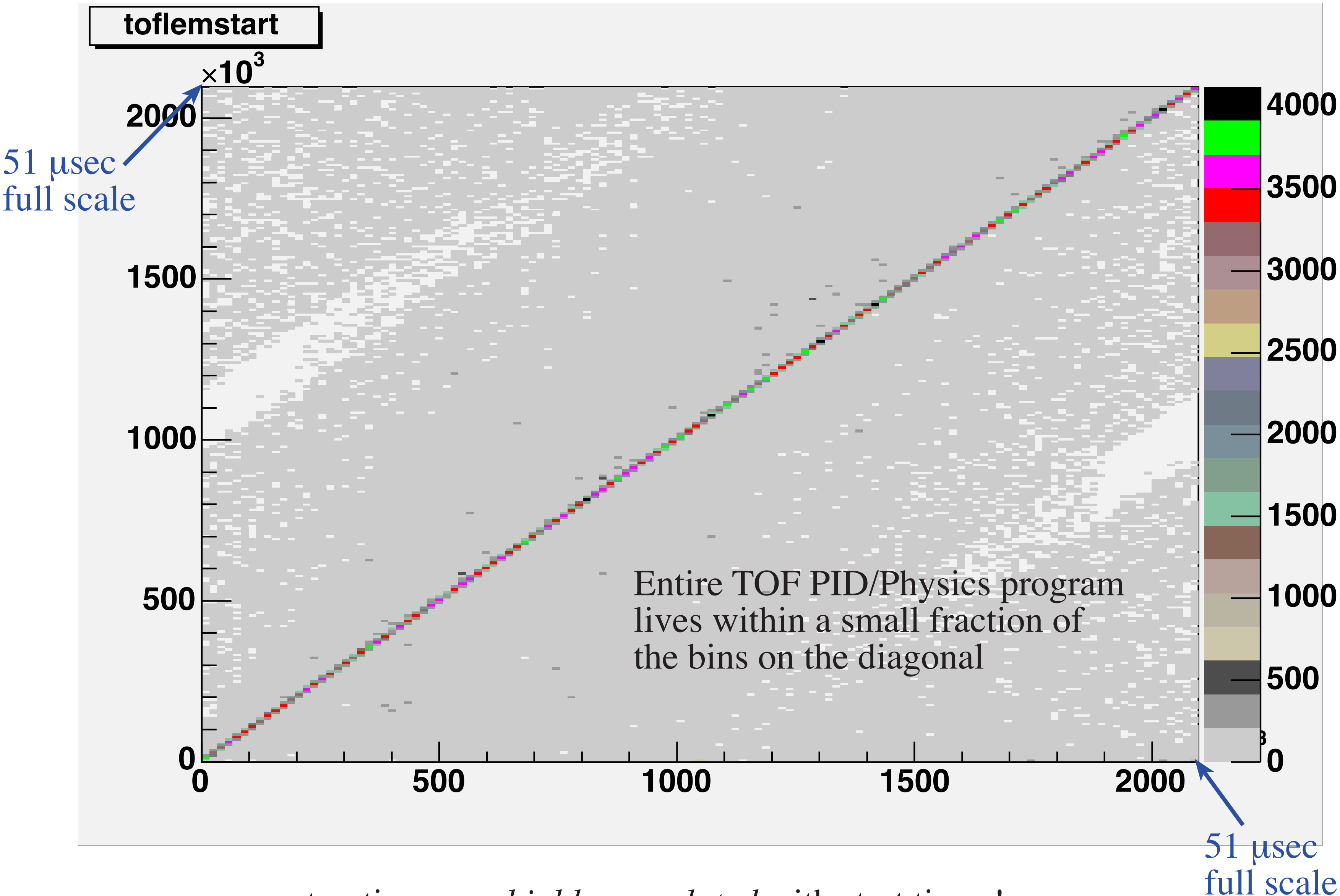
...and the difference distribution



standard deviations near 20-30 very high resn bins, or ~500-700ps
roughly as expected since this is before any corrections are applied...

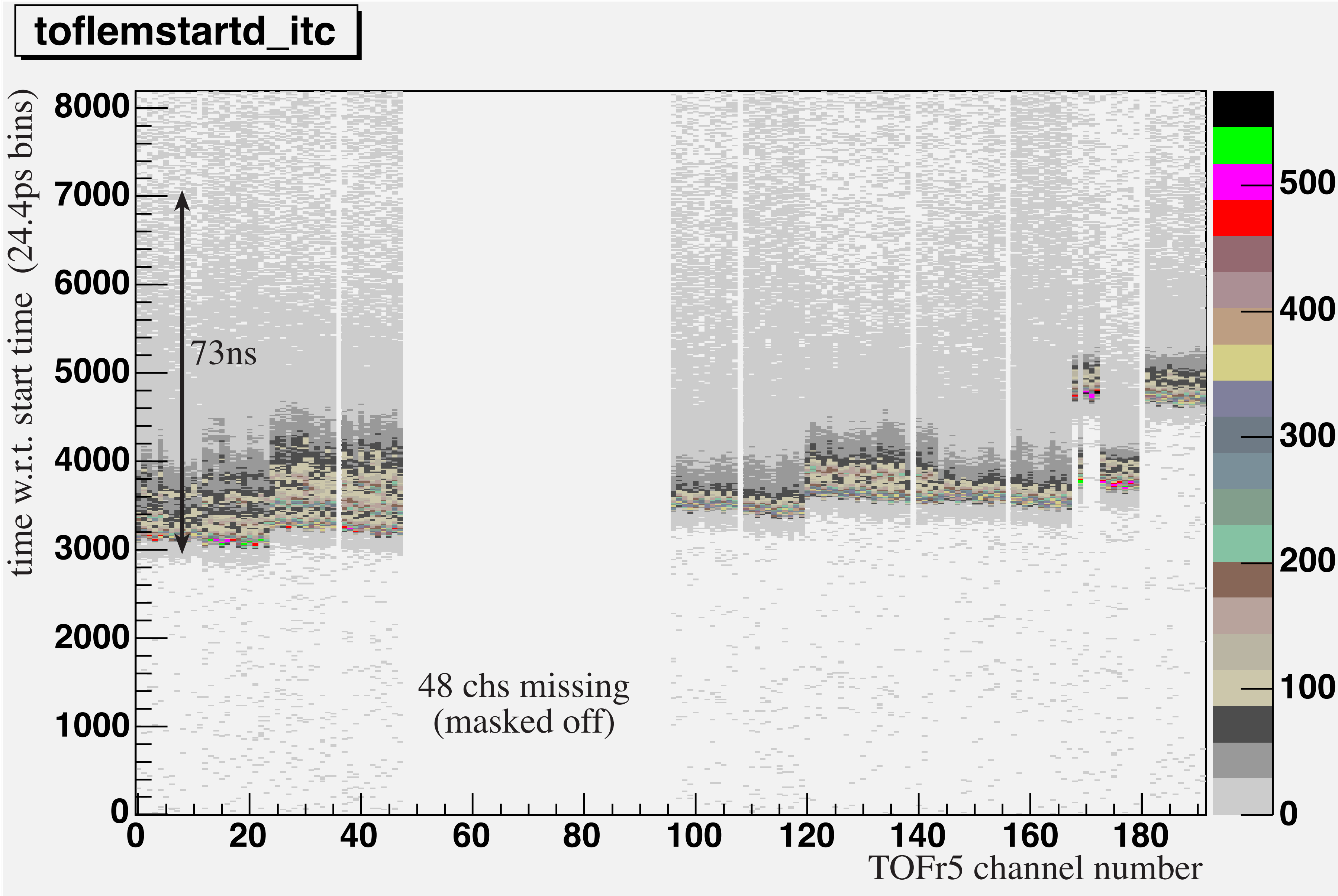
...now calculate a crude start time as (<East> + <West>)/2

...then plot stop-side time stamps versus this quantity (just take earliest TE/LE pair for now)



stop times are *highly correlated* with start times!
this is across TCPUs!

...and the difference distribution



~60-70% of the start side hits are inside a 73ns-wide window

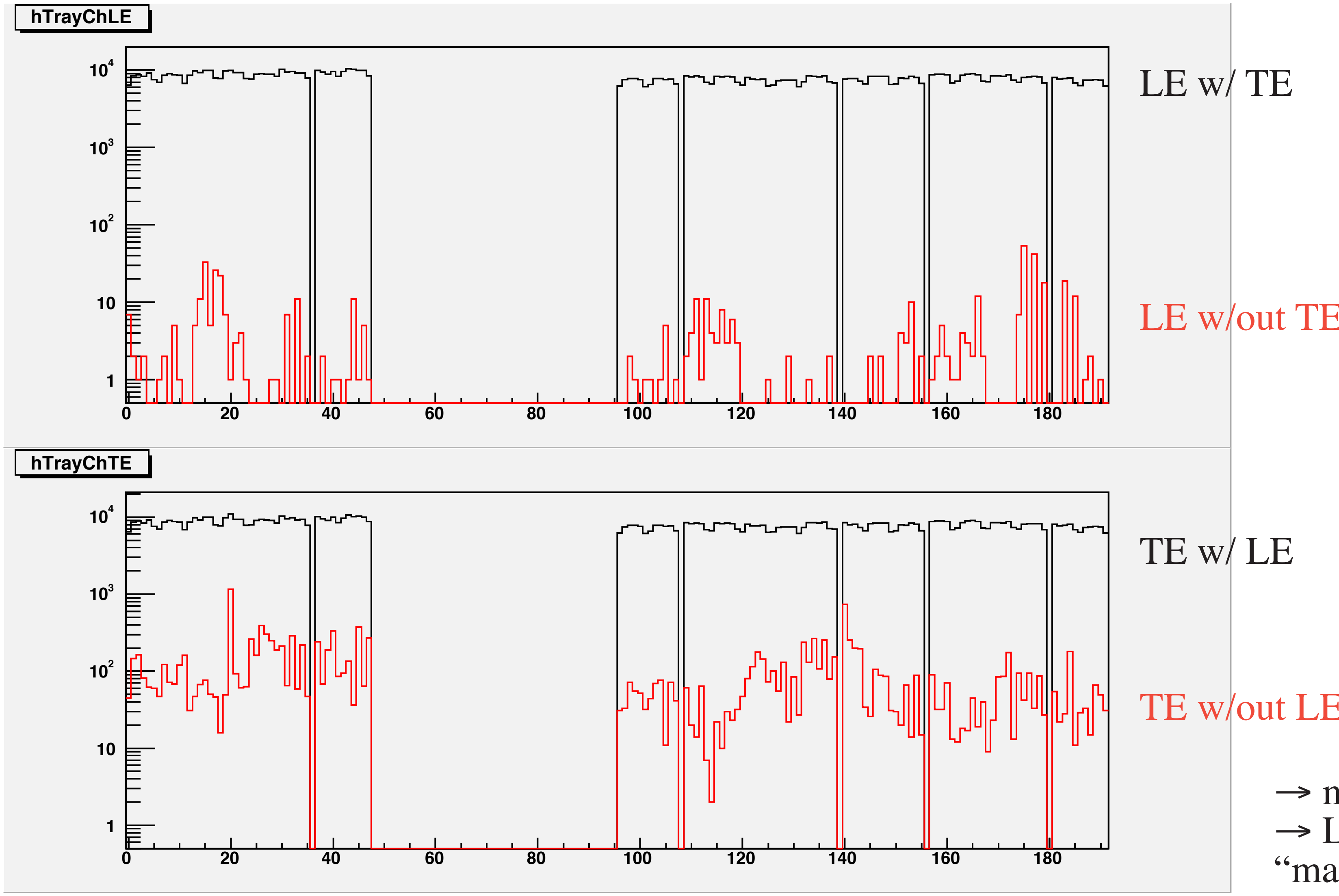
that starts 73ns after the start time calculated from the pVPD time stamps

clear indication of different MRPC termination schemes (in groups of 24 chs)

MAXIM preamp not well (impedance-)matched to MRPCs, need the NINO chip!

so, start-side time stamps are highly correlated with each other, and
stop-side time stamps are highly correlated with a “start” time calculated using the pVPD data...

now apply the maps to match up LE and TE time stamps in single stop detector channels...



→ mapping O.K...
→ LE & TE data “matches up” well...

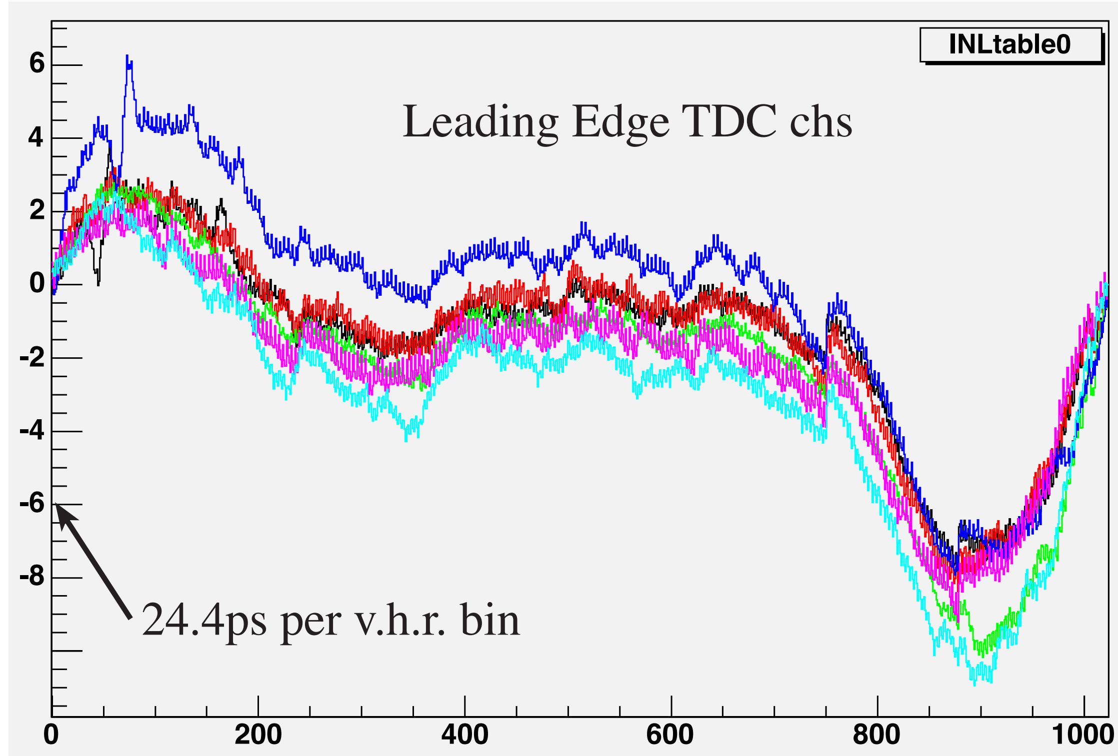
These are all very good signs, but the timing resolution could still be awlful....
→ go after a time resolution estimate next....

INL Corrections (J. Liu *et al.*)

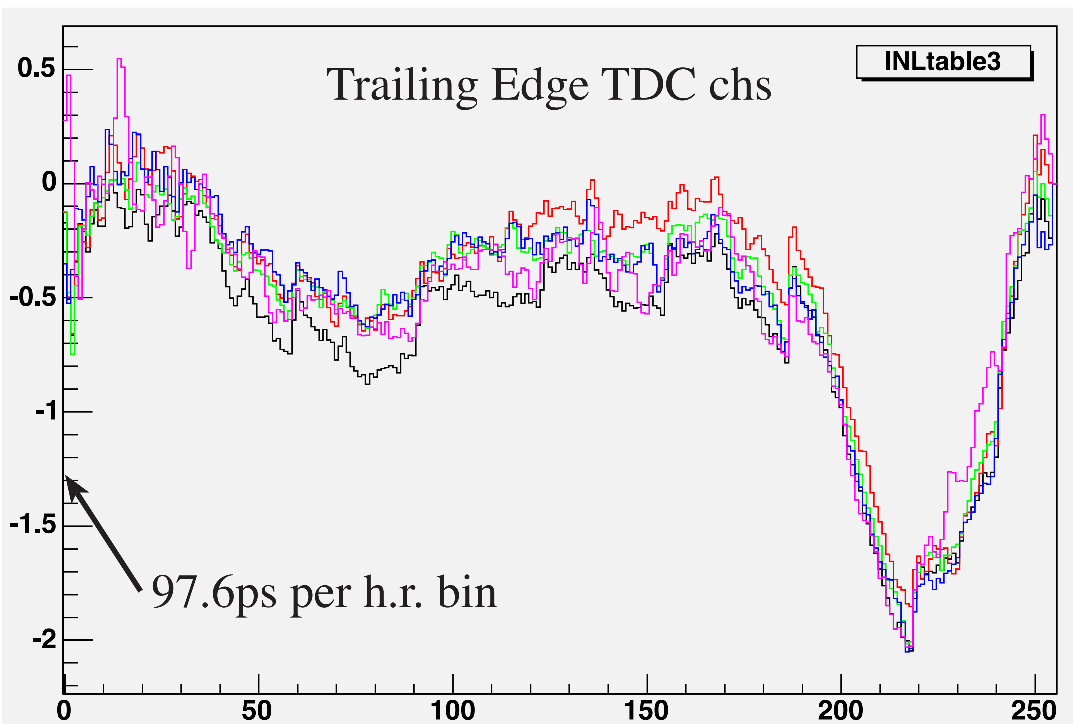
mid-scale in CAMAC TDCs , every bin is the same width, but one needs to map out each channel of a TDC separately to determine what this width is...
generally in range 45-55ps/bin for LeCroy 2228A

A “feature” of the HPTDC is that the **all the time bins in a single chip have different widths...**
modulo 10 & 8 bits for LE (21bits) & TE (19bits)

But all (8 or 32) channels in a single chip use the same INL correction curve...



lowest 10 bits of LE data word is the LE INL bin number

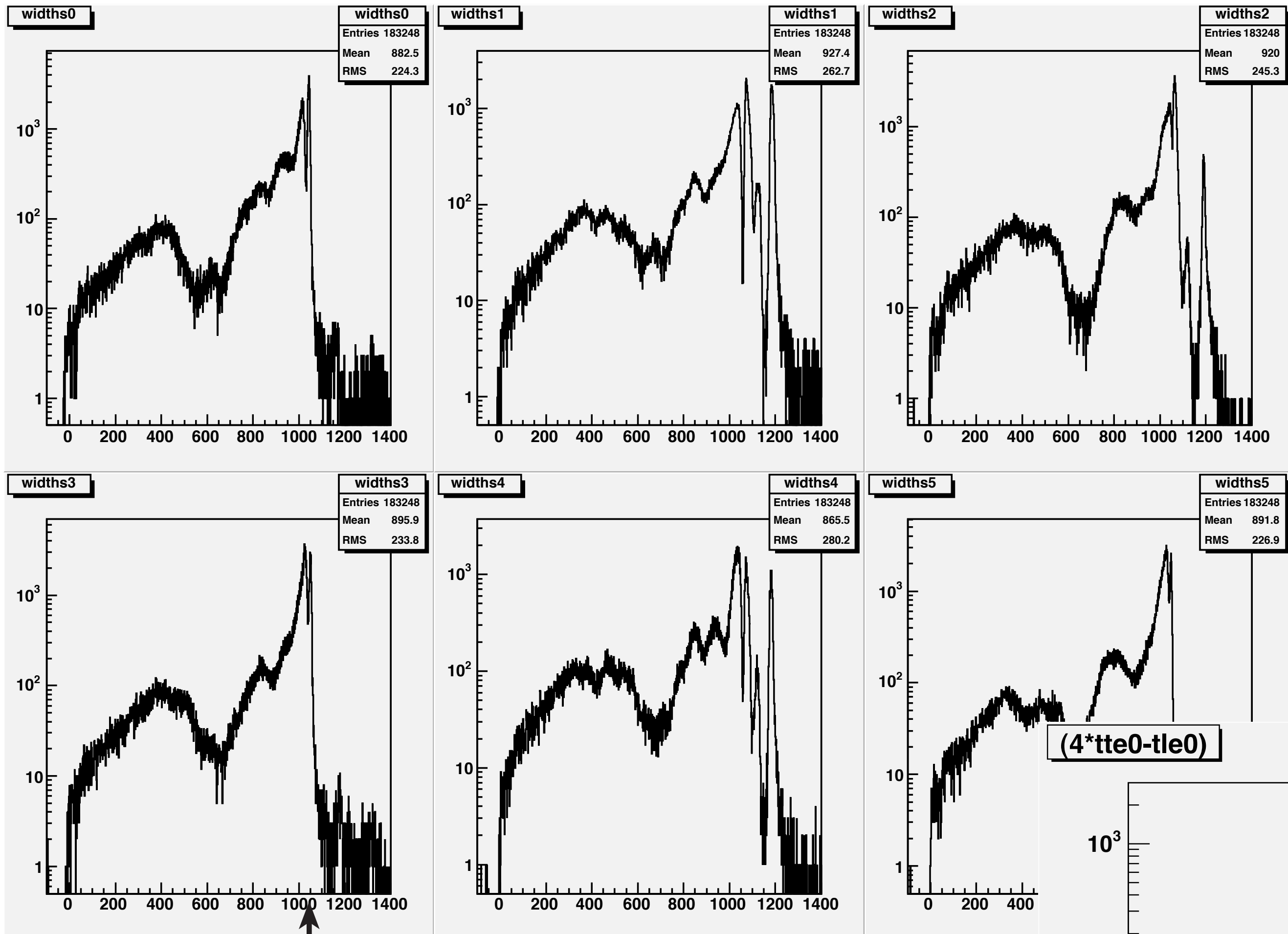


Use a “code density” test to map out the widths of each TDC bin...

Data collected at Rice before run-5

lowest 8 bits of TE data word is the TE INL bin number

Start-side Time-Over-Threshold (ToT)
now, our slewing variable....

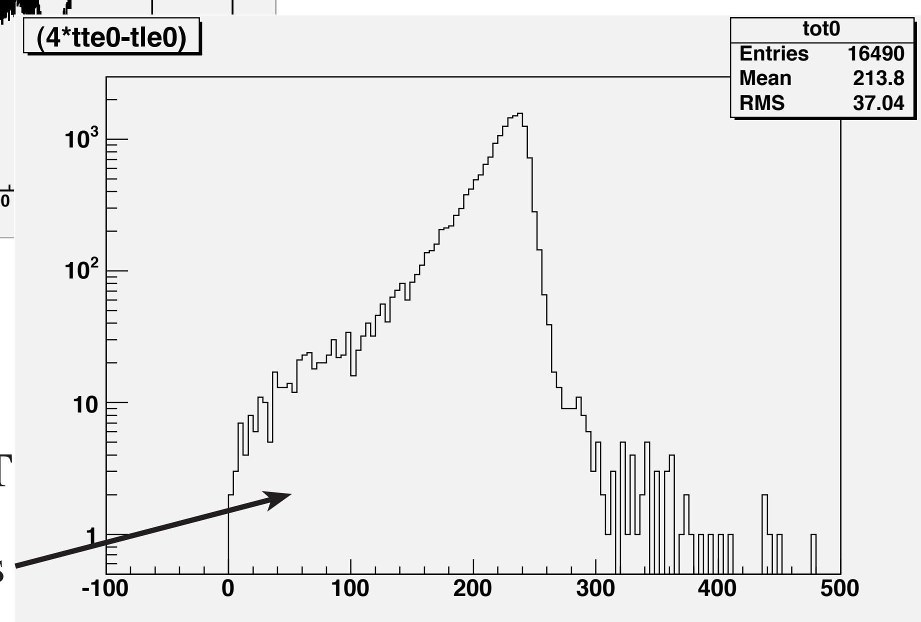


shown later: pre-terminator data can still be calibrated to high resolution, but efficiency is 10-20% lower than with the terminators....

apparent cutoff at widths of ~25-27ns
wierd shape, “additional” peaks....

problem caused by input protection circuit on TPMT

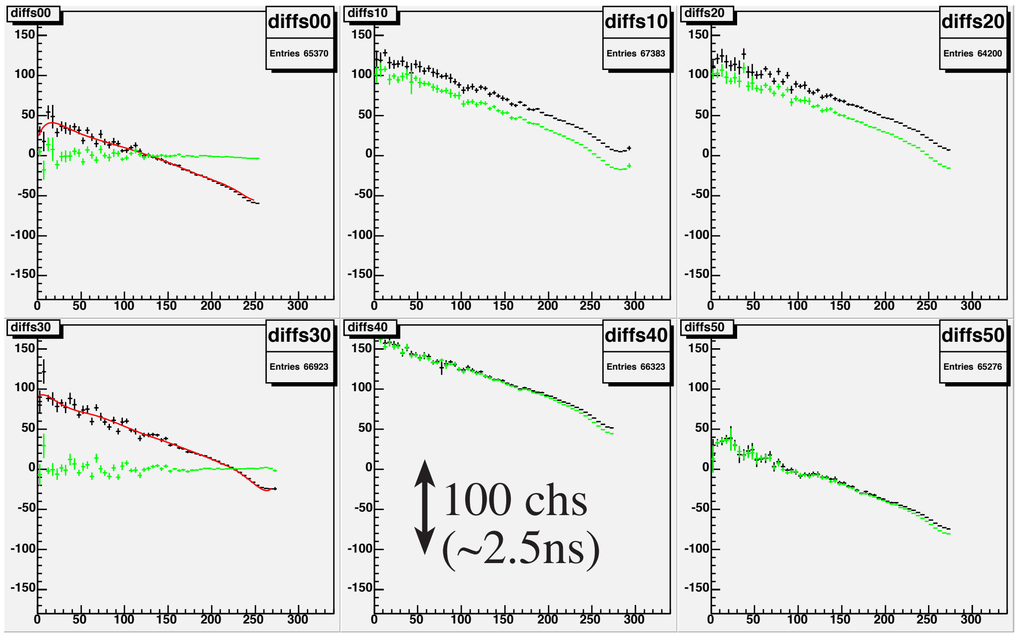
added 50 Ω pass-through terminators to fix this



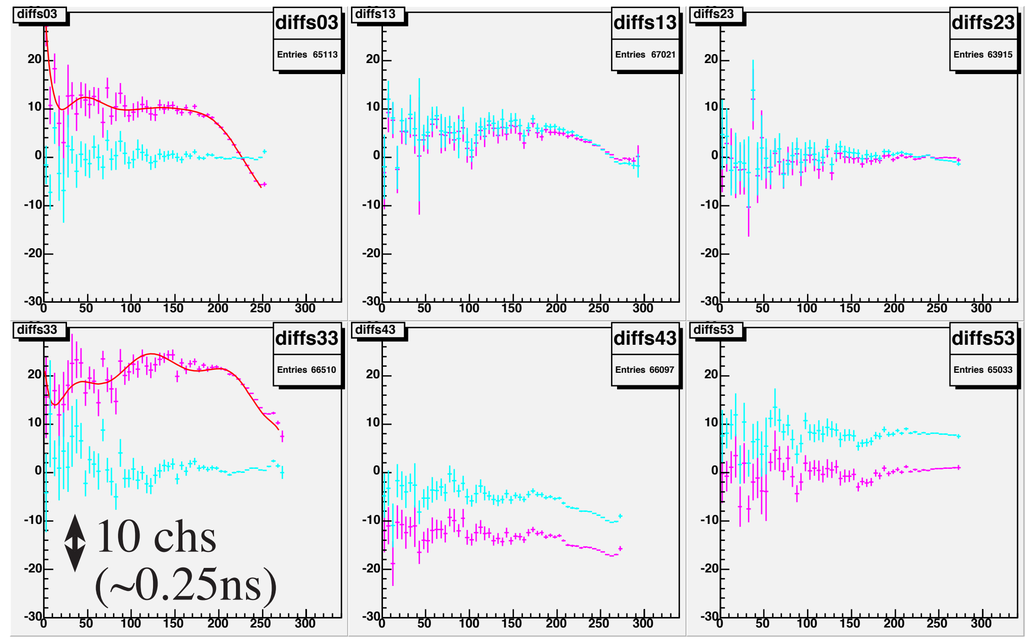
Start-slewing correction using ToT

plot “1-<2>” difference of time stamps vs ToT on each (start-) side separately
iterative procedure (10-12 passes) to flatten these time differences

after first pass:



after fourth pass:



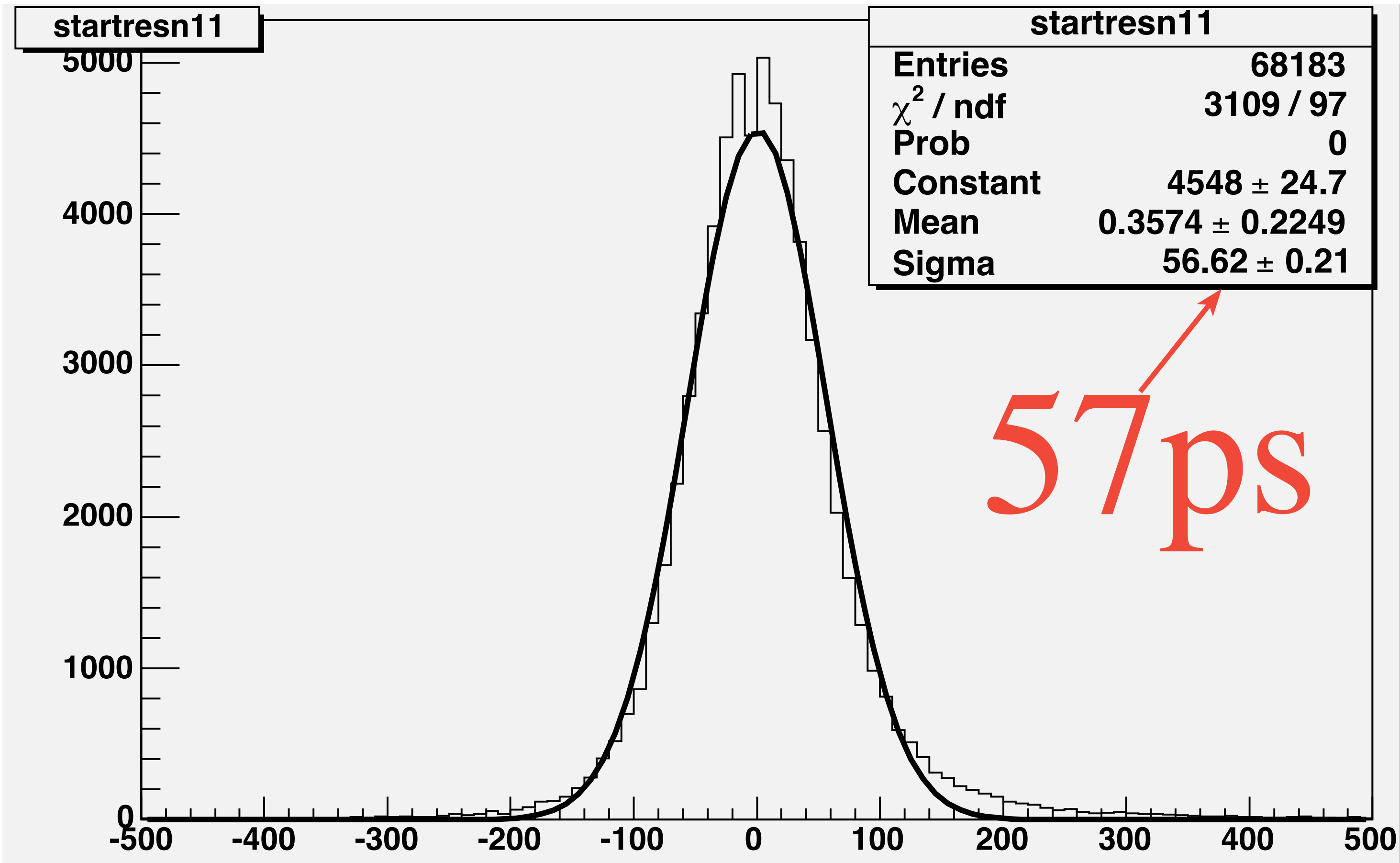
this is just one of several applicable algorithms....

start-slewing curves based on ToT are almost linear...

Start-timing resolution following the INL and Slewing corrections

standard deviation of <2>-<4> difference is related to start resolution by a factor of 0.47

also apply 24.4ps per bin calibration

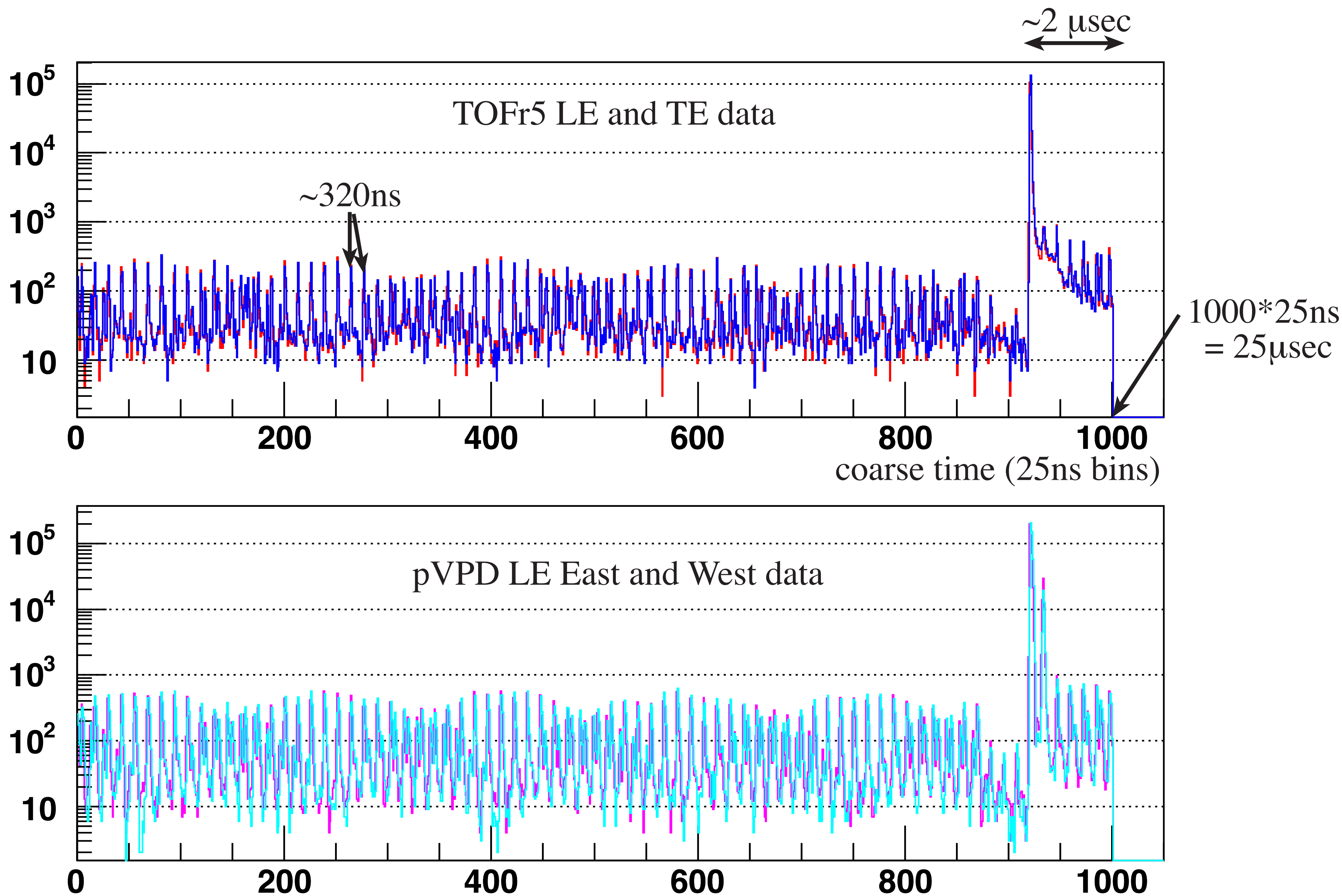


as these data are Cu+Cu, detector's contribution to total timing resolution is "small"
→ essentially isolates resolution of the DAQ system
→ estimate based solely on TOF data, no tracking or other information is needed...

distribution is not Gaussian (another good sign, effective resn for a "full" analysis will be better!)

similar result (54ps) obtained for data taken before the terminators were installed
(but efficiency of the start correction is 10-20% higher with the terminators)

Optimizing Trigger Matching Window using Relative timing... (plots by Jing and Haidong)



main purpose of this is to optimize the trigger matching window... (25 → 5 → ~1 μsec)

easy to see structure of the beam...
clear suppression of hits from previous 3 crossings by "killer bits"

The Run-5 TOF data appear to be absolutely reasonable...

hits are highly correlated across start-side channels

stop-side hits are highly correlated to “start” times calculated in each event using pVPD stamps

The timing resolution extracted from the start side is excellent even at this preliminary stage...

Run-5 Engineering Next Steps:

- Continued optimization of trigger-matching windows etc...
- TOFr5 HV increase by ~500V starting @ access next wednesday

Run-5 Analysis Next Steps:

- Update TOF “reader” to insert the TOF data into the offline chain/StEvent/MuDST etc...
  (Haidong, Jing, Xin)
- Get DAQ maps and INL tables into database
- Get MRPC positions & angles from the CADD files into the database
- Start matching tracks to MRPC cells
  → stop timing resolution and PID.
  → investigation of “double-events” (rate related to width of trigger-matching window)

D&M R&D Next Steps

- Tweaks to mechanical design (box, inner sides, MRPC signal pigtail connections, new cooling loop)
- Development of “TINO”, replaces TAMP & MAXIM preamp with CERN NINO chip
- Development of next-generation TDIG

→ TOFr6

assumption so far is that the existing TOFr5 tray, plus one TOFr6 tray, will be installed for Run-6

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

Basic idea is

2" linear PMTs + significant shielding → 1.5" mesh PMTs + no shielding...
increase number of detector channels on each side within same integration volume...

Electronics come 'for free' from the stop-side
TDIG & TCPU are the same as those on the stop-side, TPMT is very simple
Present (Run-5) electronics supports up to 24 PMTs per side, can easily use two TDIG's/side

HV from BBC's LeCroy 1440 supply (thanks Les)
just need to make the cables...

New PMTs for this detector are already costed in the TOF proposal
Prototypes (*i.e.* Run-6) will be built using R5946 PMTs taken out of TOFp

Main R&D directions right now are then:

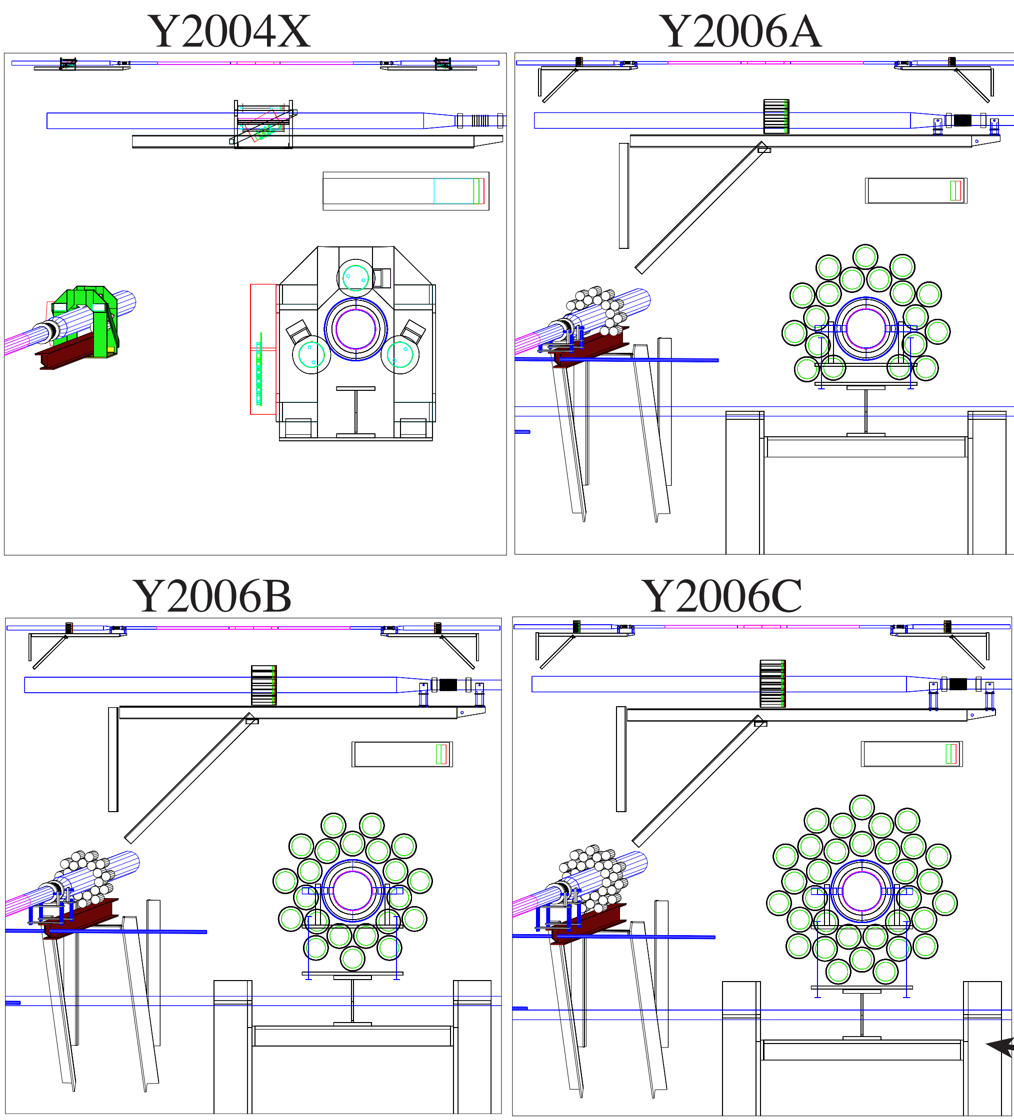
Detector design, based on full simulations
then CADD layout and specific proposal for Run-6 to STSG & STAR Ops...

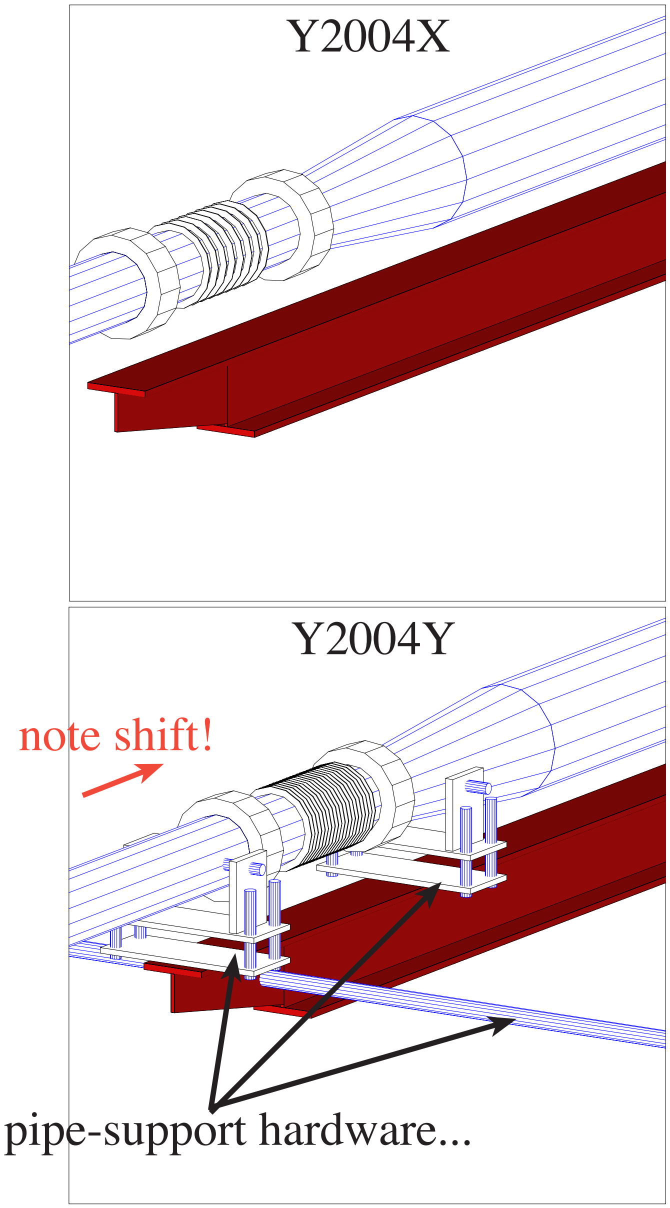
PMT base design
need high stability and high rate capability

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

Simulations of the Upgraded pVPD (Geometry)

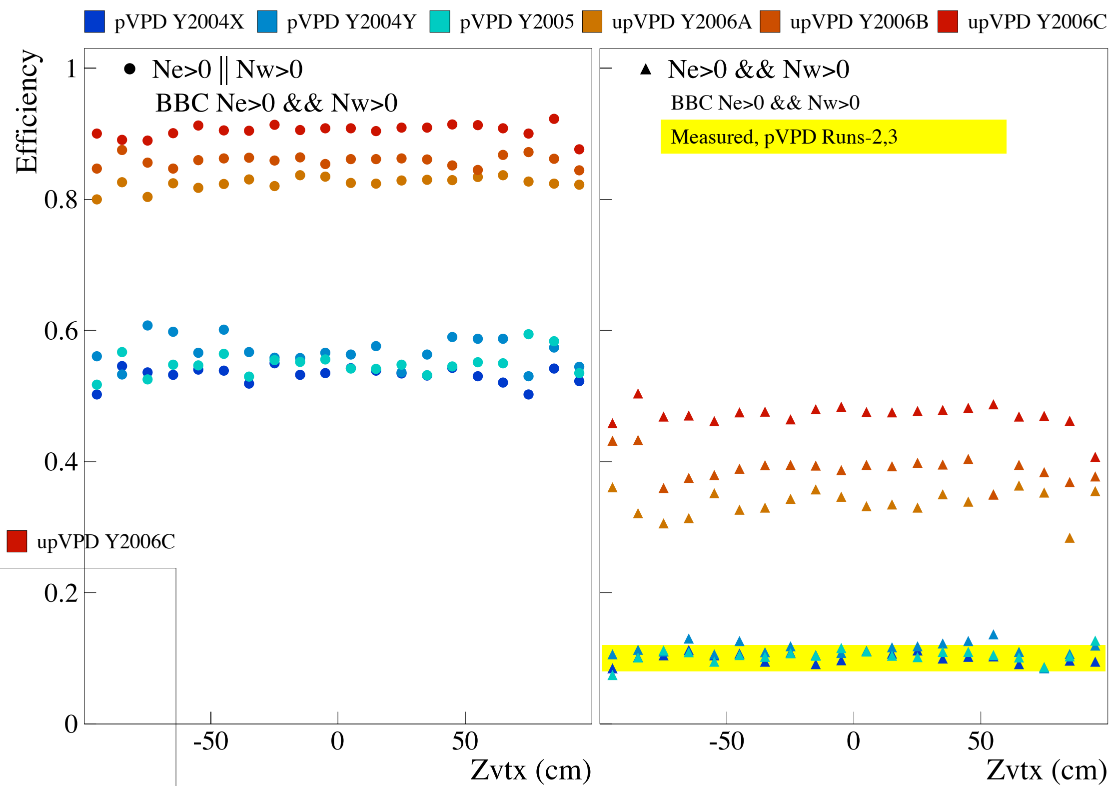
- Strict comparison btw starsim geometry and CADD files from STSG (discrepancies found!)
- First definition of many pipe & I-beam support structure pieces missing from starsim geometry
- Definition of several possible geometries for upVPD
- Performance of the different designs in p+p and Au+Au evts

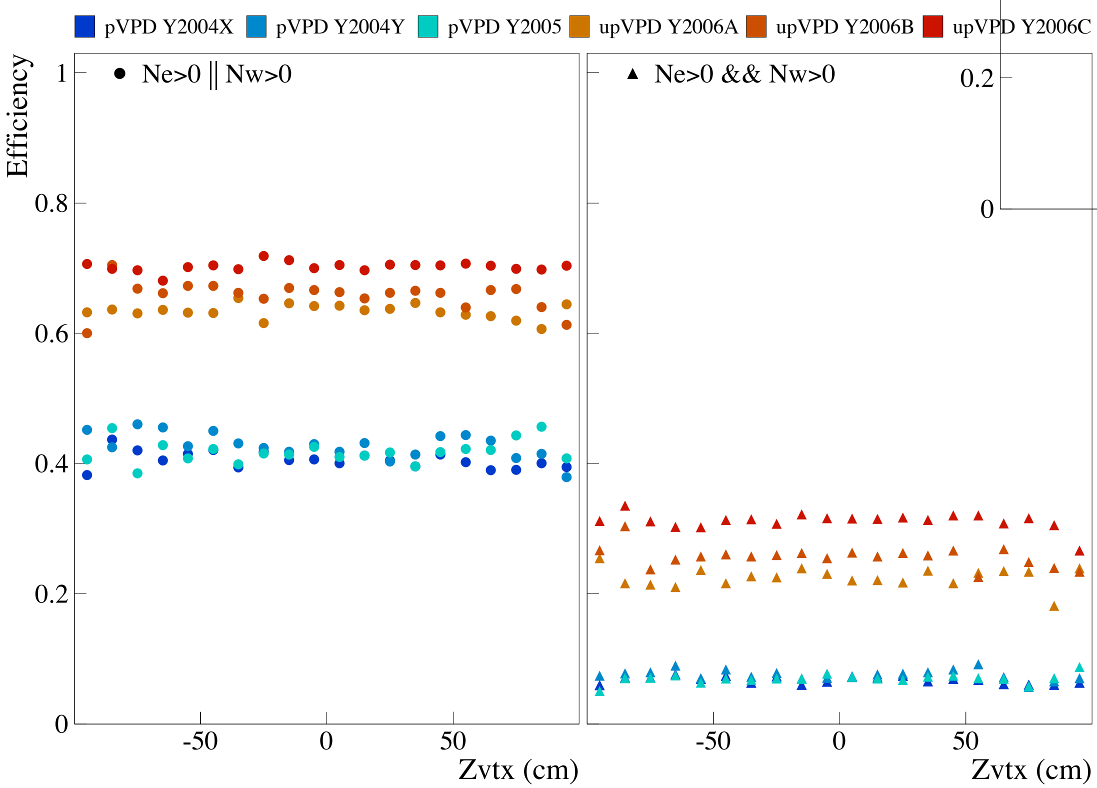




Simulations of the Upgraded pVPD (Performance)

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





upVPD efficiency of at least one hit per evt goes from ~55% to ~80-90%

Efficiency per STAR BBC-triggered evt goes from
~10% (pVPD)
to ~35-45% (upVPD)

~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

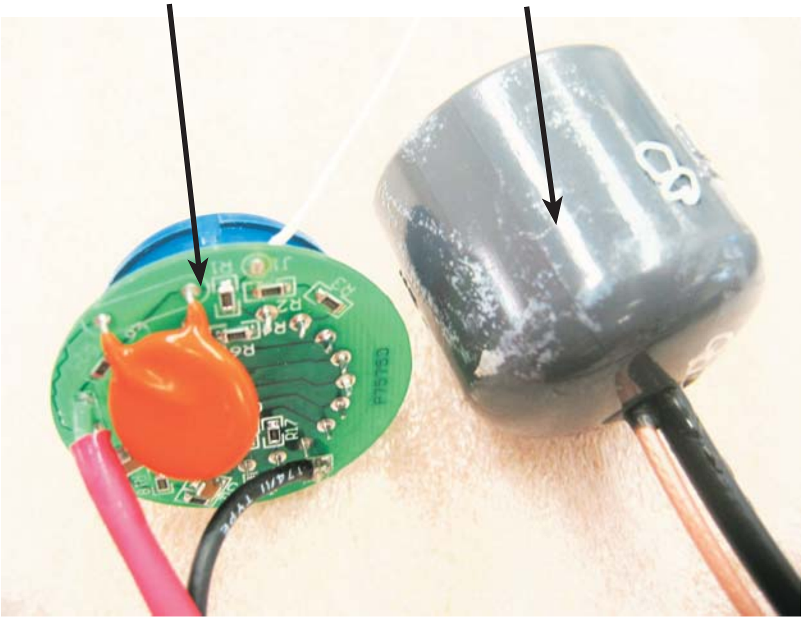
Developed one Linear base, but higher rate than std. Hamamatsu design

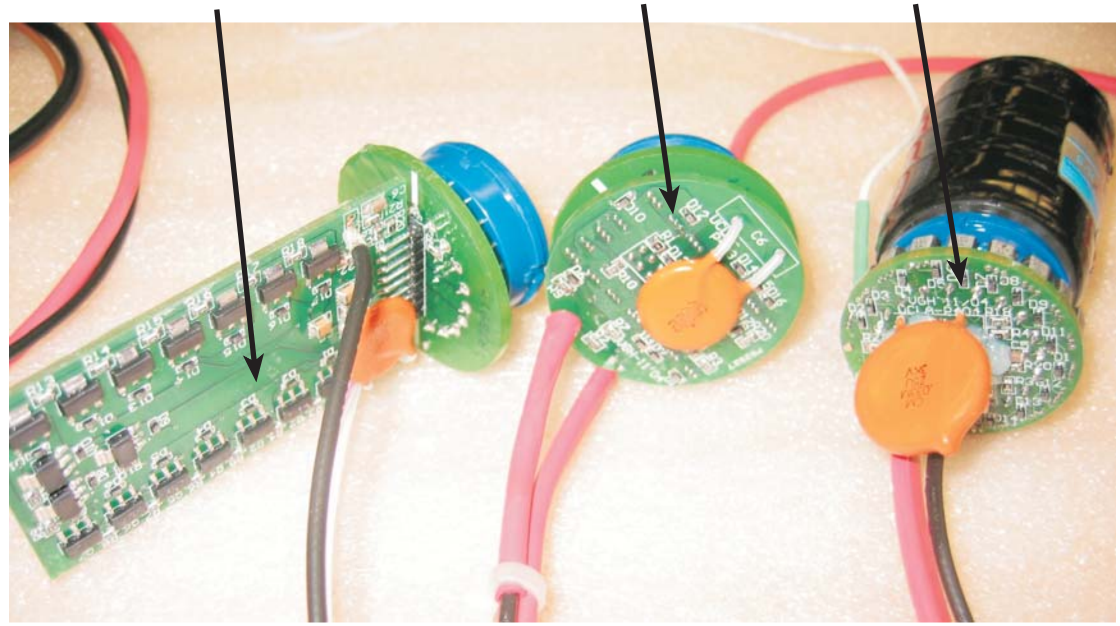
Linear base drops ~2W at 2kV $\rightarrow$ >50 ^{o}C inside detector assembly...

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)...





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

DOE FY06 Budget Request to the President

start at DOE's web site, then

http://www.sc.doe.gov/orm/Budget_Finance/FY_06_Budget/FY_06_Budget.htm

then click on Nuclear Physics, which brings up

http://www.sc.doe.gov/orm/Budget_Finance/FY_06_Budget/NP.pdf

& see pages 30-34

- **National Laboratory Research**
  - BNL RHIC Research: Research support for scientific/technical personnel is decreased by 2.5% ($157,000) from FY 2005. Funding for capital equipment is increased by $2,400,000, with the start of the STAR Time-of-Flight (TOF) Major Item of Equipment (MIE) detector project. .... +2,243

Looks like the DOE (and the CNNSF) are on-board here..

now preparing for a "Technical Design Review Update" document & review in ~2 months...
then Construction Readiness Review before beginning of construction in early FY06...

Summary

Additional improvements to the mechanical design (Inner sides, integrated cooling loop)
    Cheaper, Faster to build, More precise (and hence repeatable) results.

We've left the cozy embrace of TOFp's CAMAC DAQ
Present system looks very much like what we want for the full system
    On-board, clock-based, digitization on both start and stop sides
    R/O using new SIU/RORC fiber electronics

We always expected this run to be solely a commissioning run (no data for physics), but indeed
    we are in the standard data stream now
& *so far, the data seems perfectly capable of supporting high resolution PID*

Working now towards fourth generation TOF system (TOFr6)
    Updated mechanical design including inner sides
    TAMP replaced by TINO
    next generation TDIG

Start detectors
    new simulations underway to optimize the design
    prototype transistor bases built and tested

Working towards replacing pVPD with mesh-tube-based upVPD for Run-6
    Replace PMTs with (already costed) new ones somewhere around Run-7/8

Need 300k$ this FY to get us to construction (TINO, next-generation TDIG, TOFr6, upVPD prototype)