T979 Fast Timing detectors: QUARTIC

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Why: Central Exclusive Production at CMS (& ATLAS) : Approved by CMS+TOTEM (MoUs)

p ← ~ 210 m — X — ~ 210 m → p

X = W^+W^-, Jets, Higgs

Measure protons precisely:
M(X), WWγγ, QCD-Jet physics, etc

Requirements:

1) Excellent time resolution (σ(t) ~ 15 ps → 10 ps)
2) Edgeless on beam side (Δx <~ 200 μm)
3) Radiation hard close to beam (~ 10^{15} p/cm^2)
4) Fast readout (25 ns crossings) --- & trigger signal
5) Segmentation (multi-hit capability)

Challenge, kill pile-up background
[p][X][p] at high luminosity 30/X.
Solution: timing $\Delta t = t_L - t_R$
σ(t) = 15ps → σ(z) = 3.2 mm

Baseline for PPS (CMS&TOTEM) project with CMS:

Cherenkov detectors with quartz radiators:
Angled-bar QUARTIC and L-bar QUARTIC
Light detected by MCP-PMTs or Silicon PMs (SiPMs)

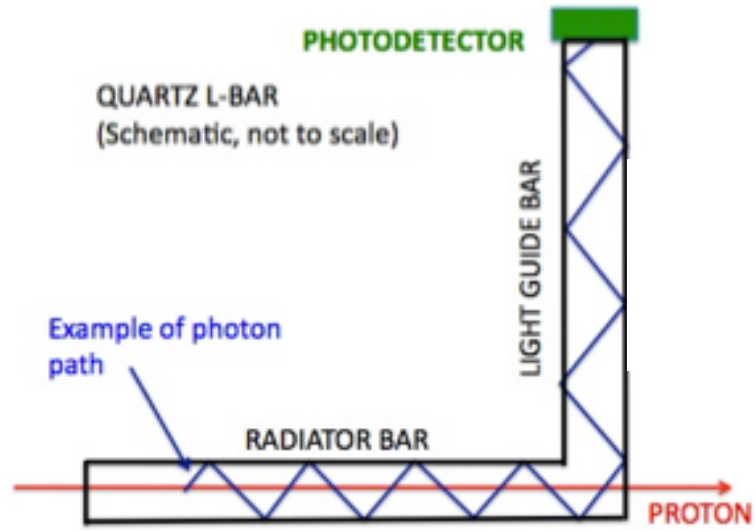
This study

Faster and better Q.E.
but lifetime issues

Small, cheap, but slower
and radiation issues

L-bar QUARTIC principle

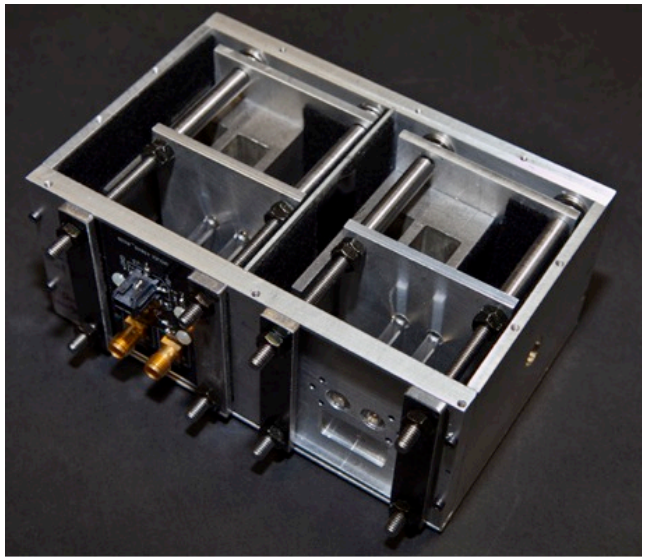
All Cherenkov light is totally internally reflected along radiator bar and about 66% goes promptly along light guide to SiPM or segmented MCP-PMT.
No light "leaks out".
If these conditions satisfied:
1) protons are parallel to radiator
2) n (refractive index) > √2
so TIR maintained in LG-bar



NO MIRRORS!

Radiator close to beam while photo-detector remote (and may be shielded)

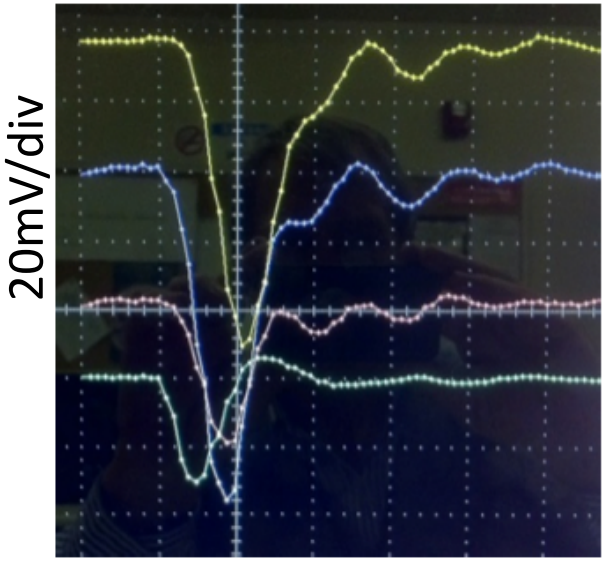
Hodoscope of 3mm x 3mm independent elements
Repeat 4 times in depth for x2 improvement (timetrack): material concern
Finer segmentation eg 2x2 mm^2 ,even 1x1 mm^2, possible in principle



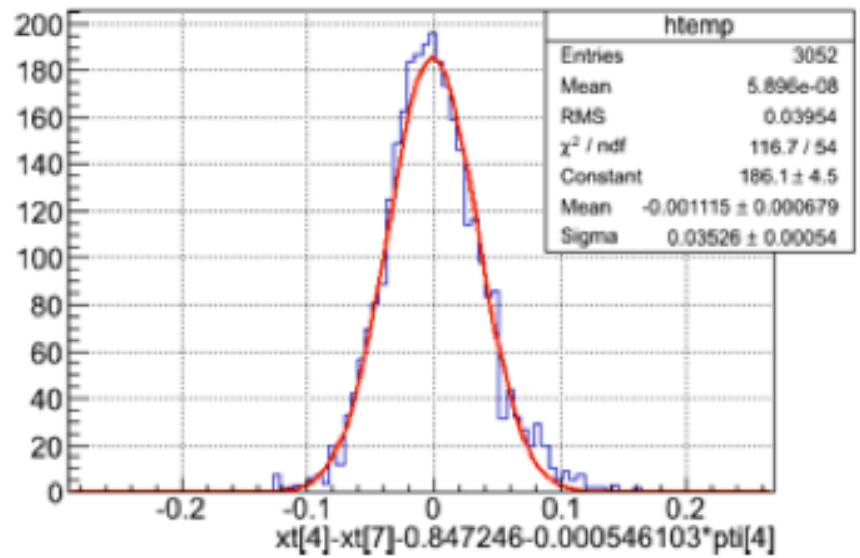
Test of principle: 2 rows of 4 bars in-line, with Hamamtsu MPPC S10362-330050C at 72V.
2012 Beam tests.

Typical event (120 GeV proton) in 3 radiator bars and (bottom) PMT240 in line. 200ps/sample, DRS4 scope
Signal rise times ~ 800 ps

Not edgeless



Δt (30mm bar – PMT240)

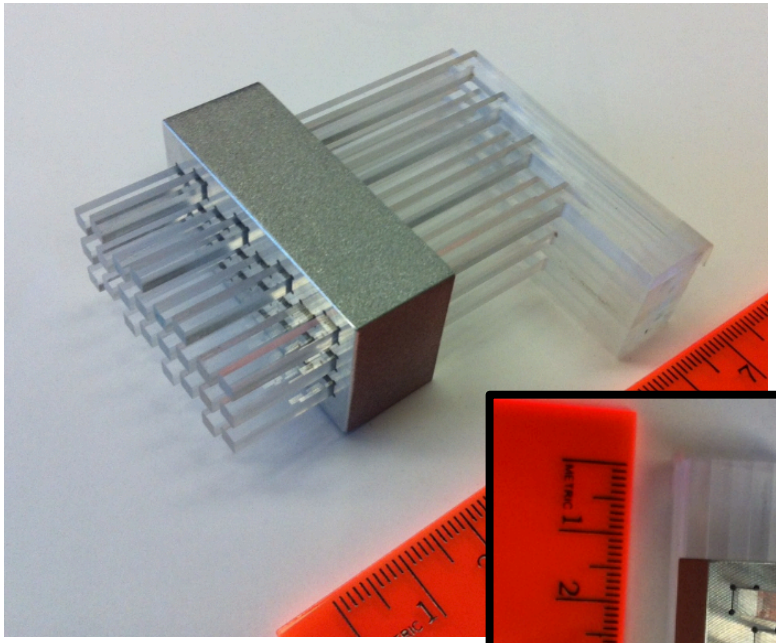


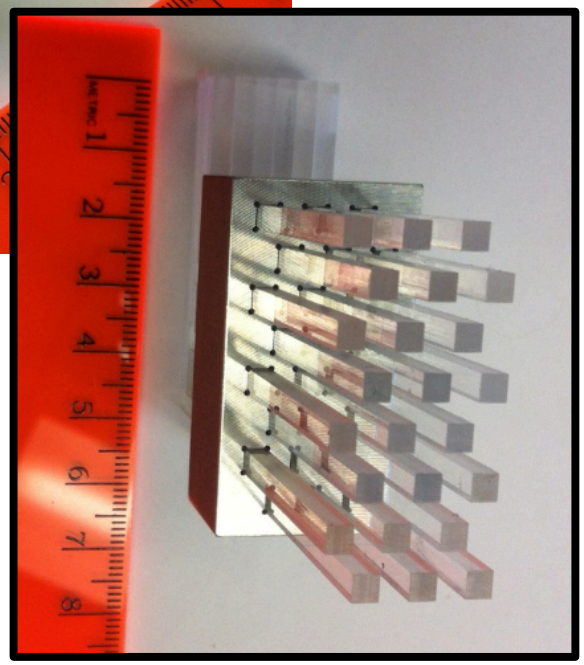
σ(t) = 31 ps for 30 mm bar
Four-in-line → 15 ps

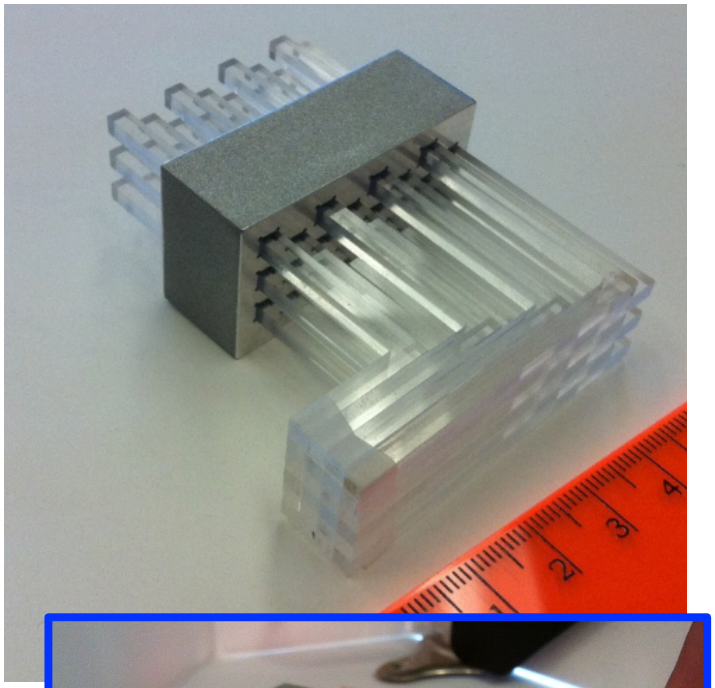
Expected improvements: sapphire bars (+30%) & faster SiPMs (30%?)

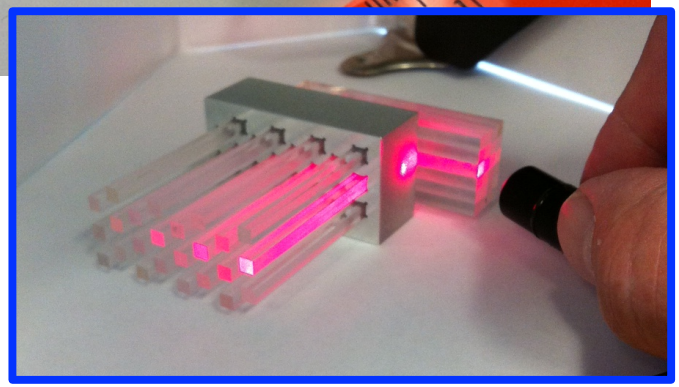
New design for real device for CMS
Edgeless, multichannel (20 → 12 bars installed)
PPS/CMS compatible features

Test assembly (with plexiglas bars).
100 µm spacing between adjacent bars.
Precision block is a “jig”, removed after front of array glued to black plate
Module #1: 4 columns quartz and 2 columns sapphire.

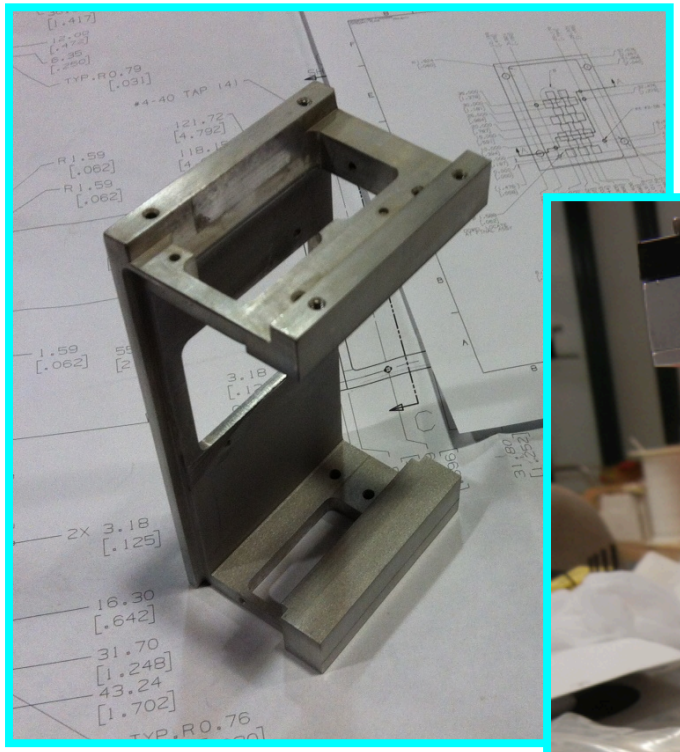


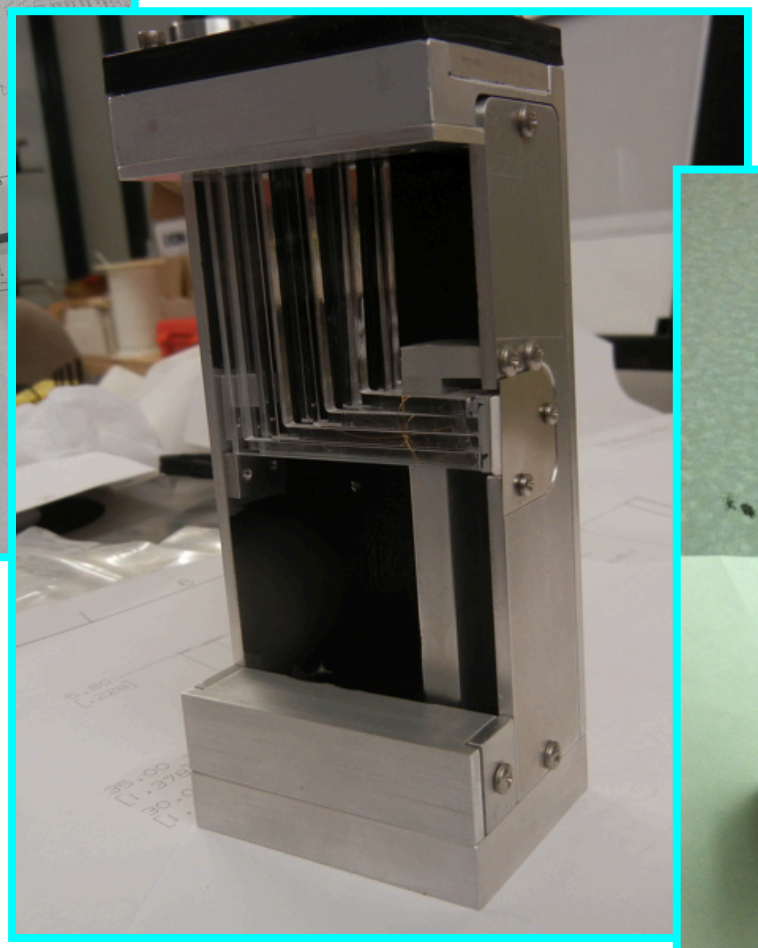






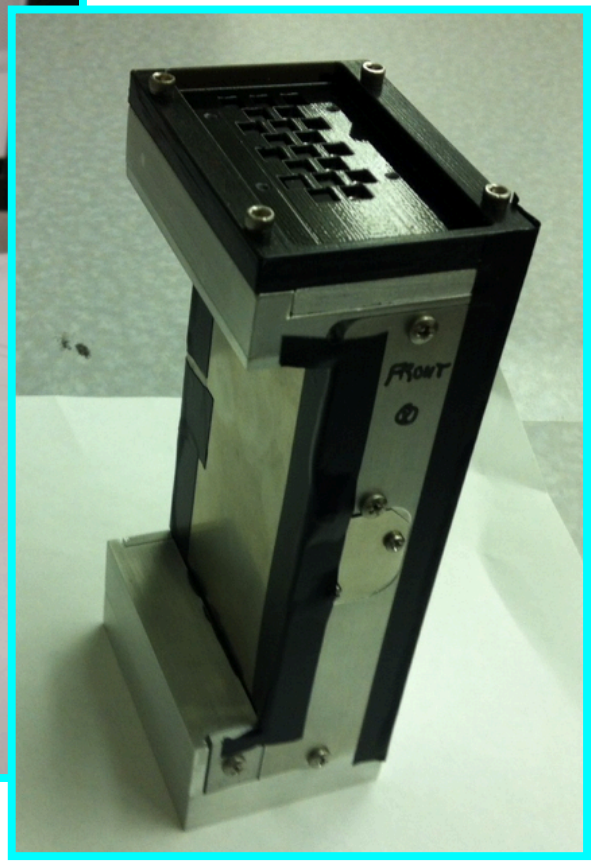
Box machined (electro-erosion) from one
Al. block(Could be 3D-printed)



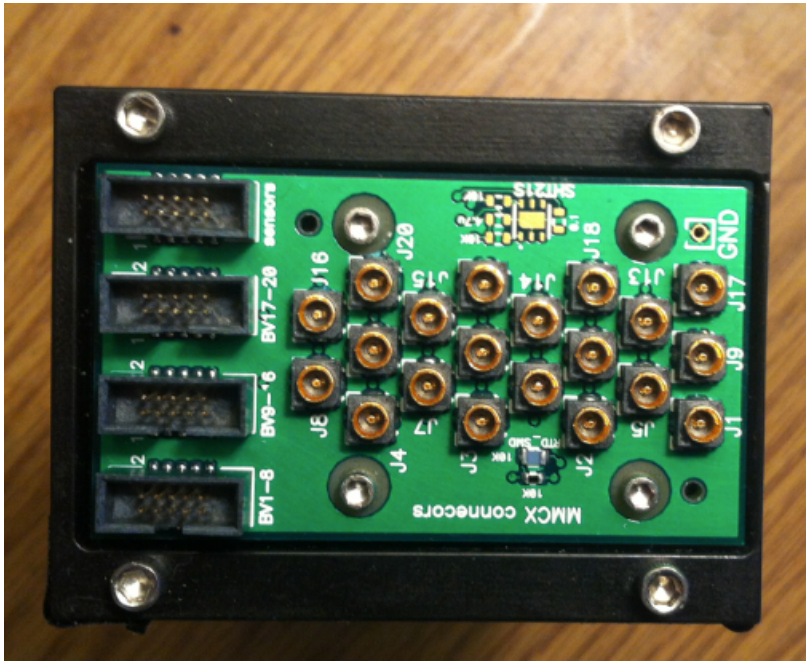


With L-bars assembled
Sideplate removed.

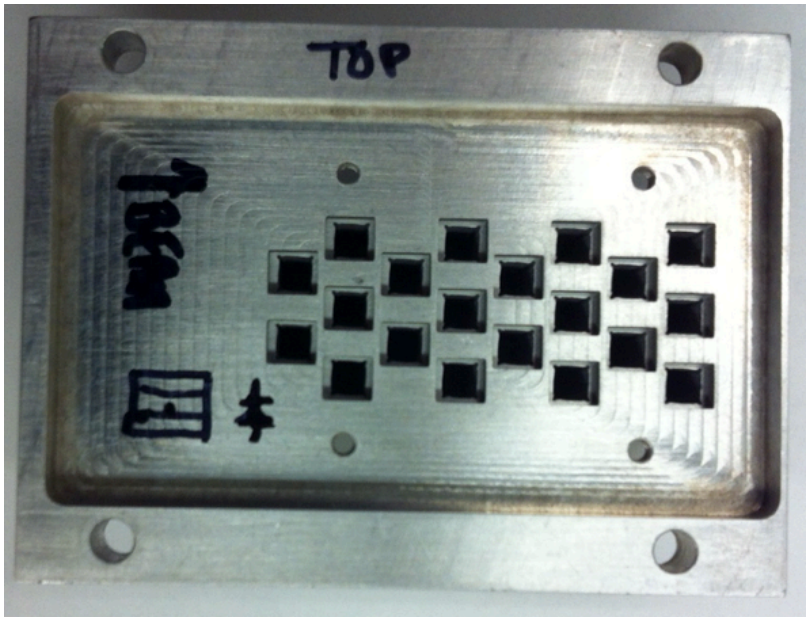
Before SiPM insertion
(Black plate is 3D-printed)



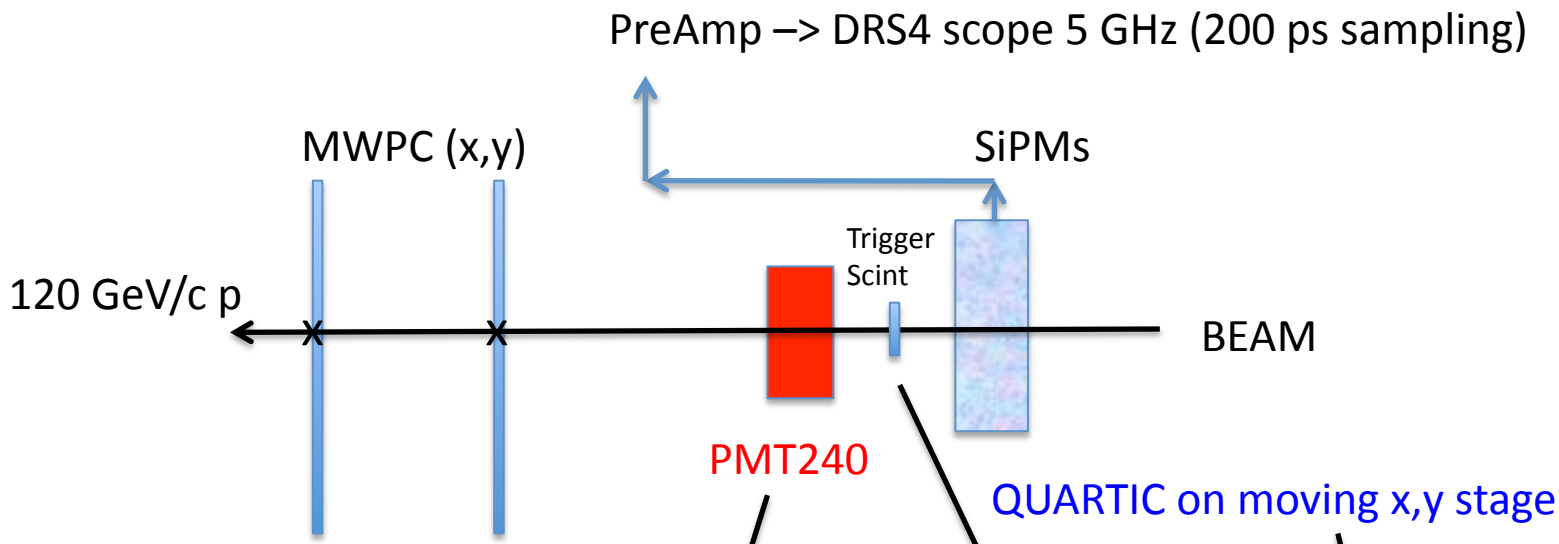
Top view, connectors, pre-amps (Sergey Los)



SiPM holder plate (just drop in)

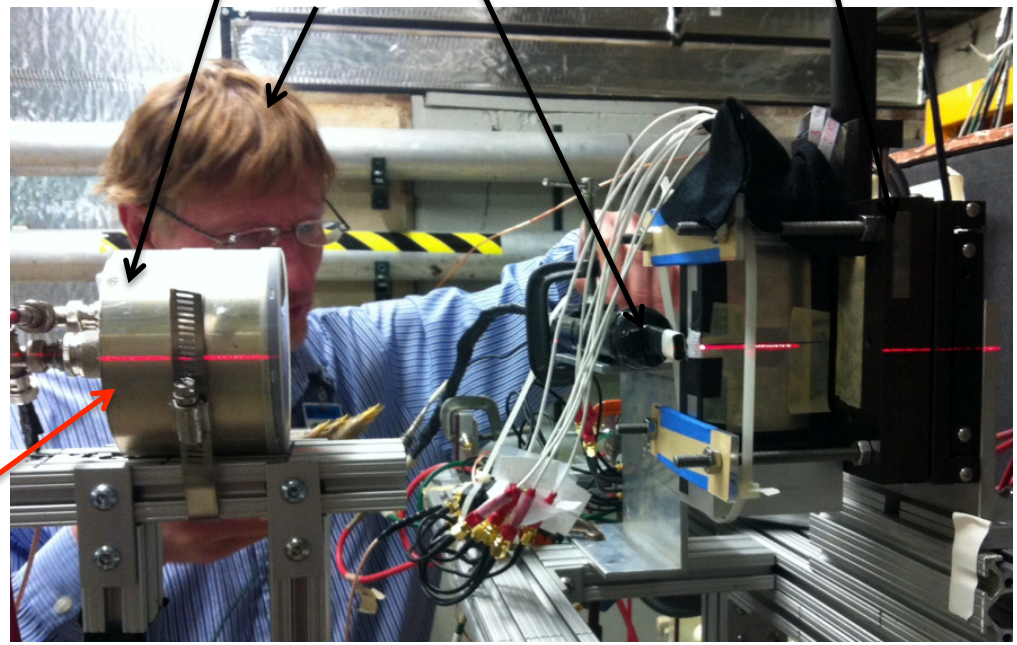


T979 at MTest Jan 2014



Sergey Los

MWPC to select clean single-track events & project to 3x3 mm^2 bars



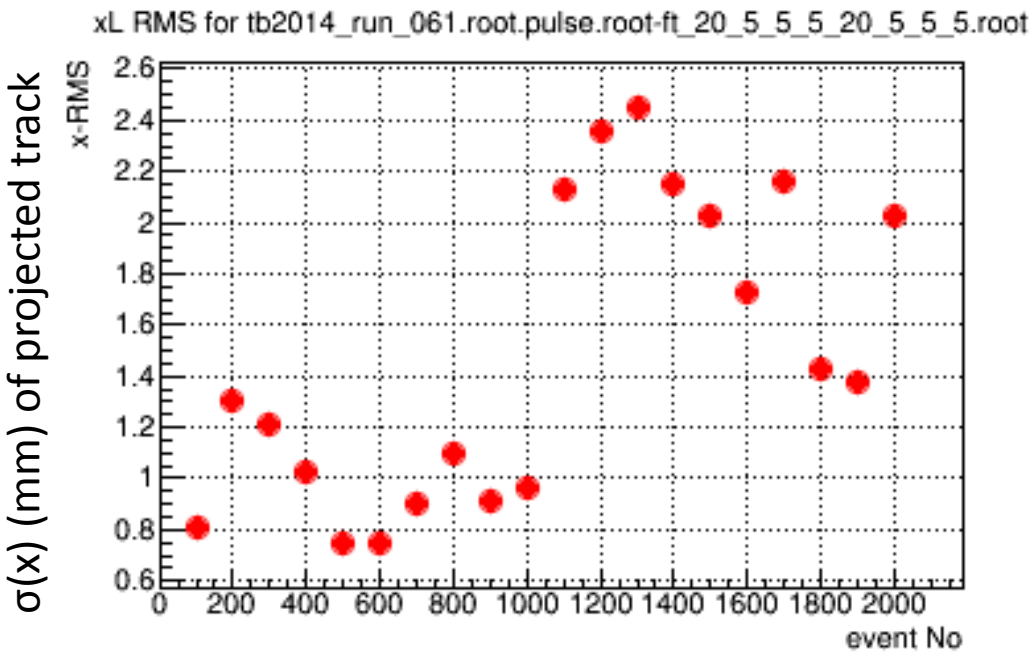
PMT240:
MCP-PMT σ(t) ~ 10 ps
Reference time.

Laser alignment

Needed projected track positions to determine hit bar,
and to select clean non-showering proton events.

MWPCs behind us needed synchronizing with our DRS4 readout events.
Much time spent (Thanks Sten Hansen, Doug Jensen, Ewa Skup, Geoff Savage) getting operational.
Finally success! But off-line found in some runs synchronization lost during run.
Some evidence:

Selecting one particular bar to have signal:



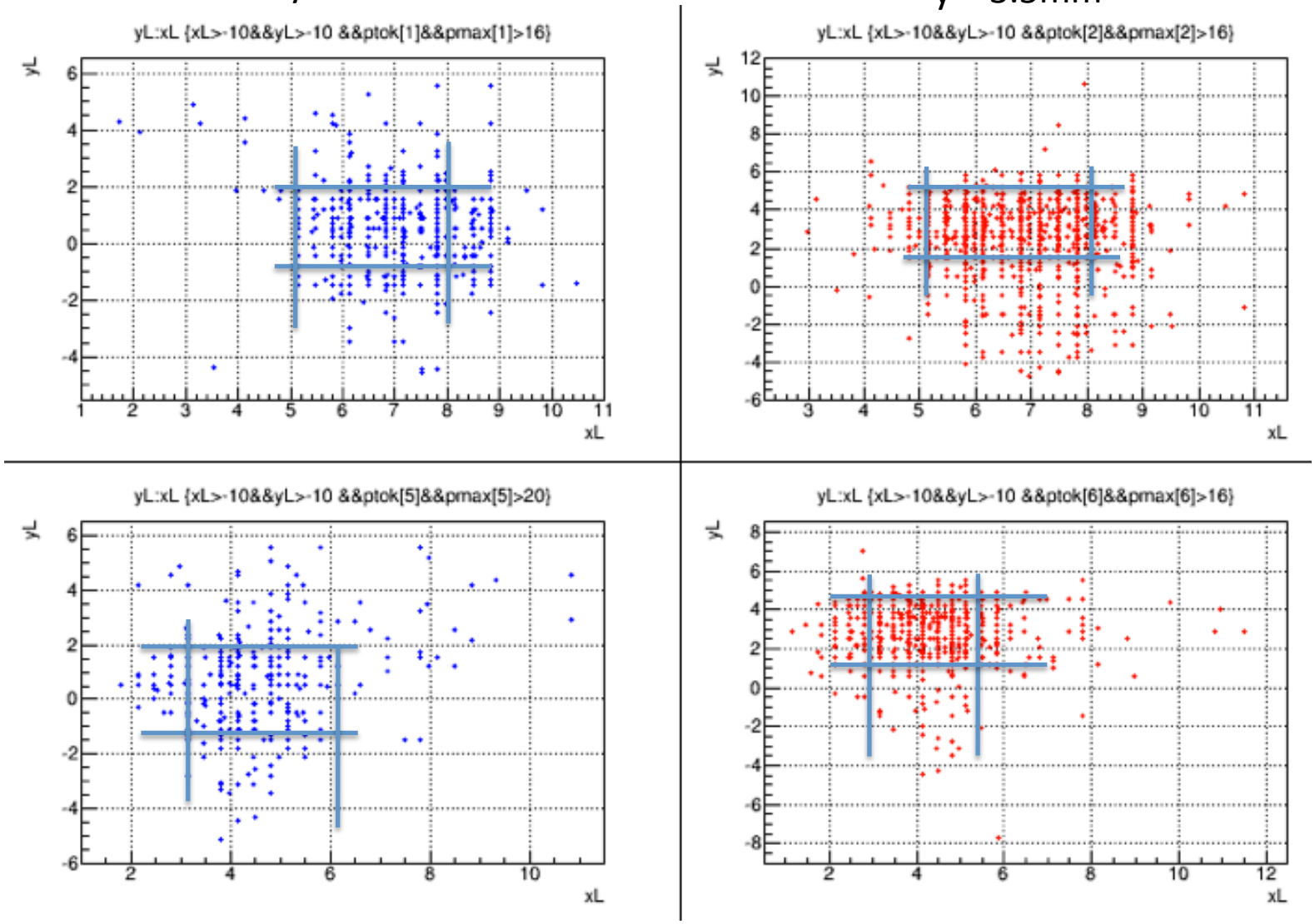
Event # in Run 061

Loses synch. at event #1000.
For some studies only use 1st part of run. (Kept runs short.)

Projected tracks to plane of QUARTIC selecting single 3x3 mm^2 bars with signal

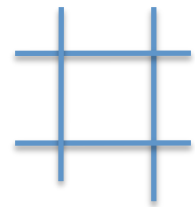
y ~ 0.5mm

y ~ 3.5mm



x ~ 7mm

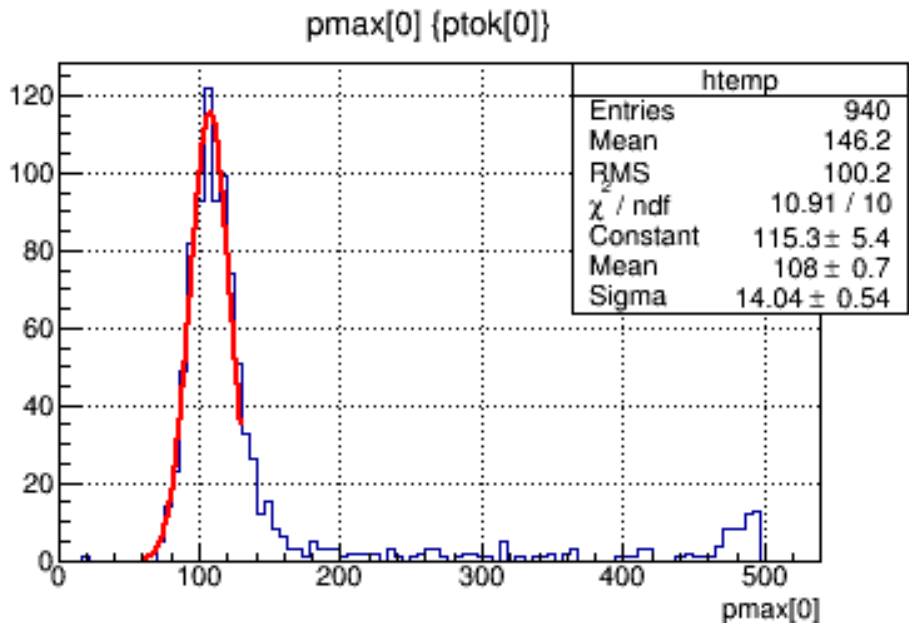
Bar areas

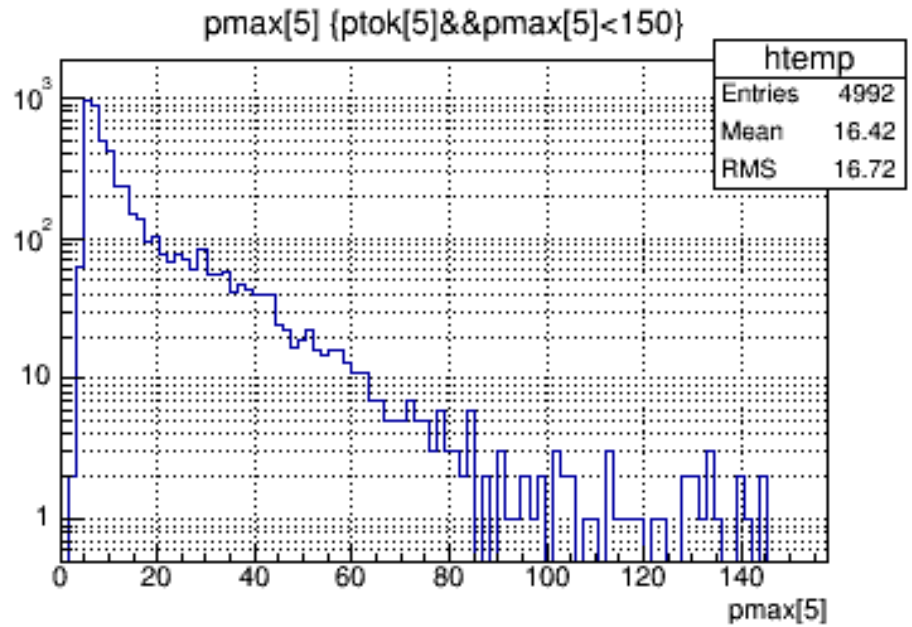


Different scales

x ~ 4mm

Trigger counter is 10x10 mm^2 covering these bars; beam is smaller.
Cause of “out-of-box” tracks? 3 planes would be better.



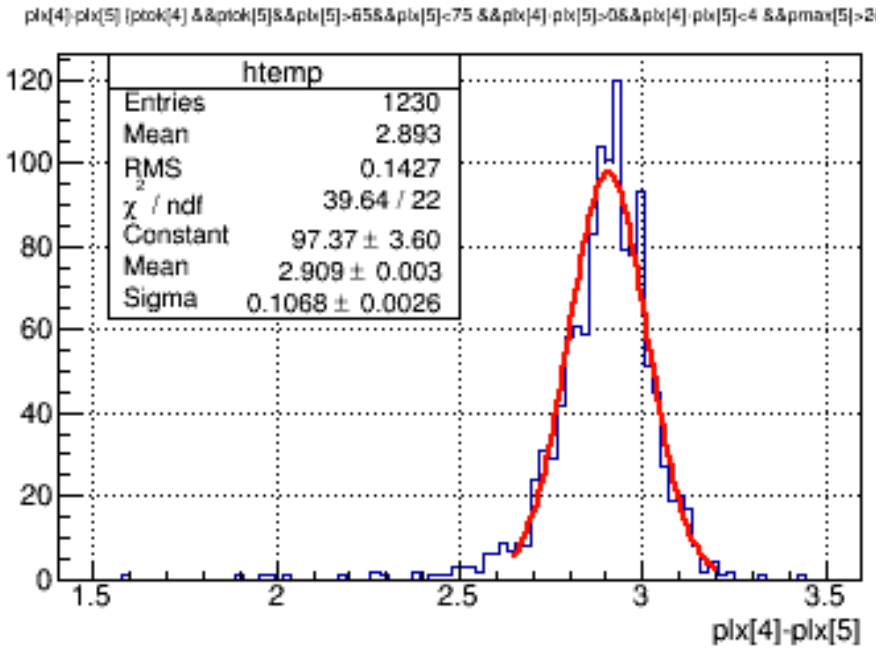


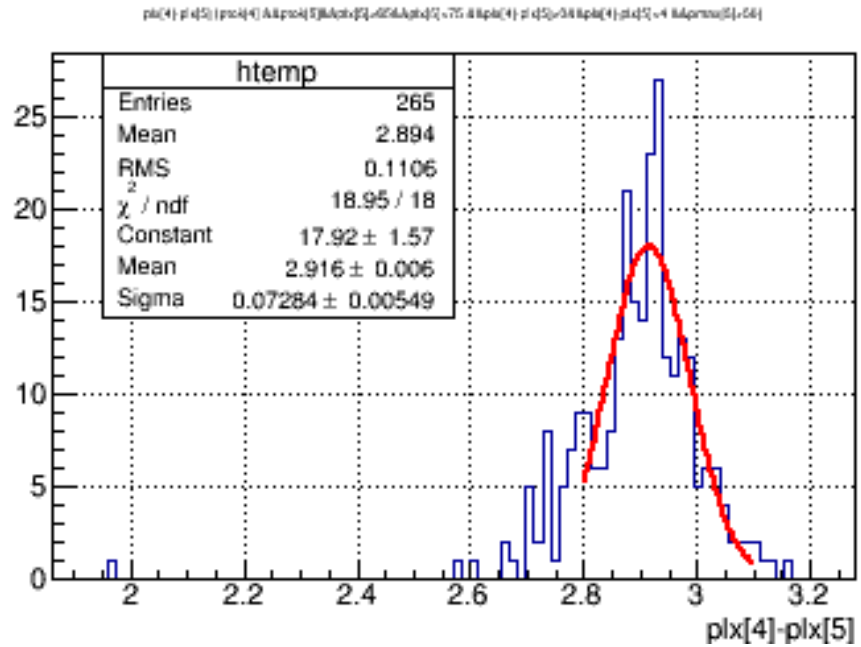
Pulse height spectrum PMT240 (mA)
58 +/- 4 p.e. (Cherenkov in 8mm quartz window)

The PMT240 is a great Cherenkov counter, with time resolution σ(t) ~ 8-10 ps.

Pulse height spectrum 40mm R-bar (mA)
~ 8 p.e. but large spread (Tracks not parallel, clipping edges? ... tbd)

Requiring parallel centered tracks loses statistics, and our time was limited





Raw time difference (in ns) between PMT240 and bar [5] with PH(5) > 20 mA

σ(t) = 107 ps

Time difference (ns) PMT240-Bar 5 with PH cut at 50 mA

σ(t) = 73 ps but effic. ~ 22%

Still have to study with cuts on MWPC tracks, correlations with other bars (Including signals from light-guide bars) etc.

Principle of L-bar demonstrated to ~30 ps in demo-box (2x2 mm^2 trigger counter), but in 12-bar compact module (100 µm) bar separation) preliminary results much worse. Had 10x10 mm^2 trigger and MWPC tracks ... alignment? optical cross-talk? More to do. Long-life MCP-PMT developments and modified LQ-bar geometry encouraging.