NuMI Beam Start-up Draft 9/26/2013

MINOS/MINOS+ collab. Mtg. 27 Sept., 2013 Jim Hylen / FNAL

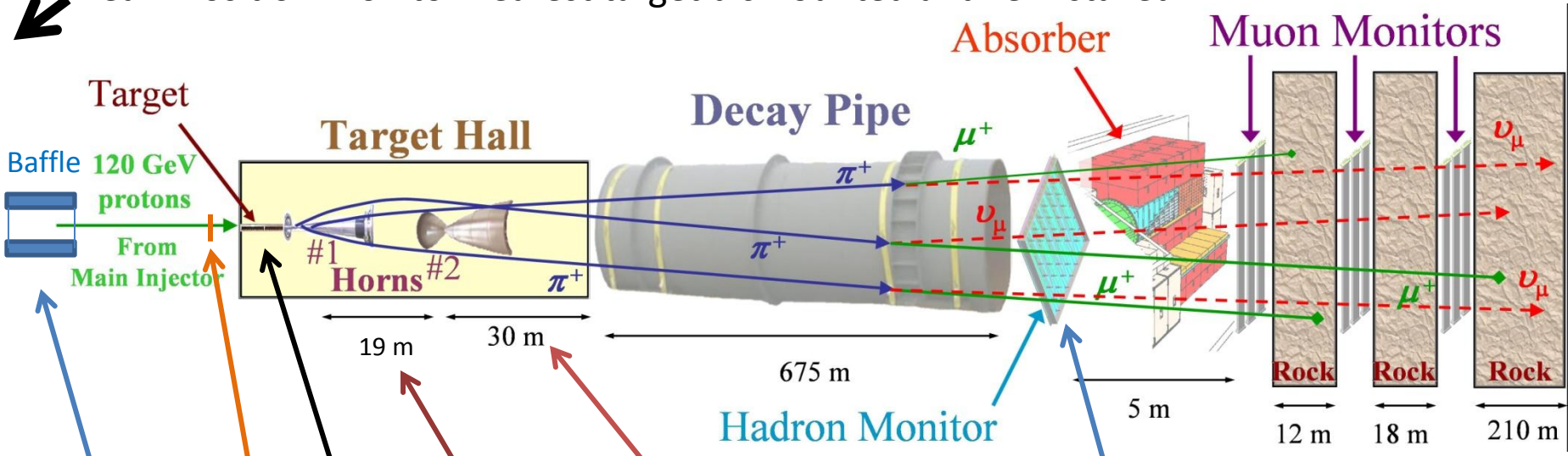
Labor day weekend: target installation !

Timeline of beam adjustments

- Sept 4, 2013 11:27 — 1st beam after scans, turn on horns
- Sept 5, 2013 17:30 — adjust horn current up by 0.6 %
- Sept 9, 2013 11:00 — adjust spot size 1.7 mm -> 1.1 mm RMS (0.9 mm at low int.)
- Sept 10,2013 16:20 — adjust target position up by ~ 0.9 mm

- *Still to do (soon?)* — *adjust spot size on target -> 1.3 mm RMS*
- *In progress* — *timing of Lumberjack –datalogging of some quantities being modified for 1.33 second cycle time*

Primary beam line: new quad magnets, new profile monitors,
Beam Position Monitor nearest target dismounted and re-installed



New hadron monitor

Horn 2 moved 9 m downstream

Horn 1 new for 700 kw operation

New style target for NOVA ME beam, no longer symmetric

New instrument (TVPT) for monitoring beam vertical position

New baffle (larger hole)

Substantial modifications to Target hall dehumidification system & RAW skids

Alignment Step 1: center beam into hadron monitor (without target in way)

last vertical BPM appears 1.00 to 1.25 mm low; go with hadron monitor angle.

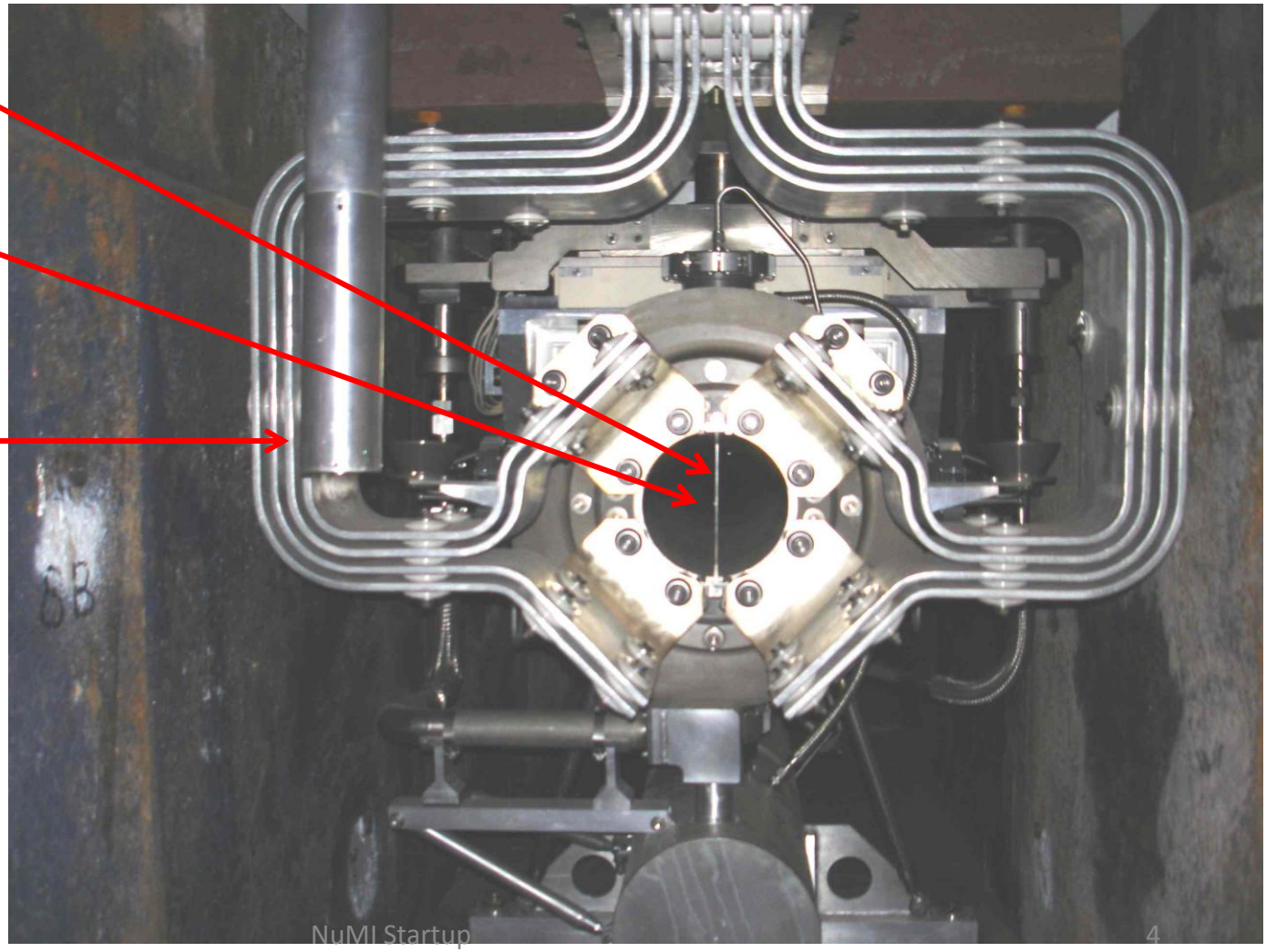
Correct Y from final BPM by 1.00 mm in most of following slides.

Step 2: scan beam across horn “cross hairs” and horn 1 neck

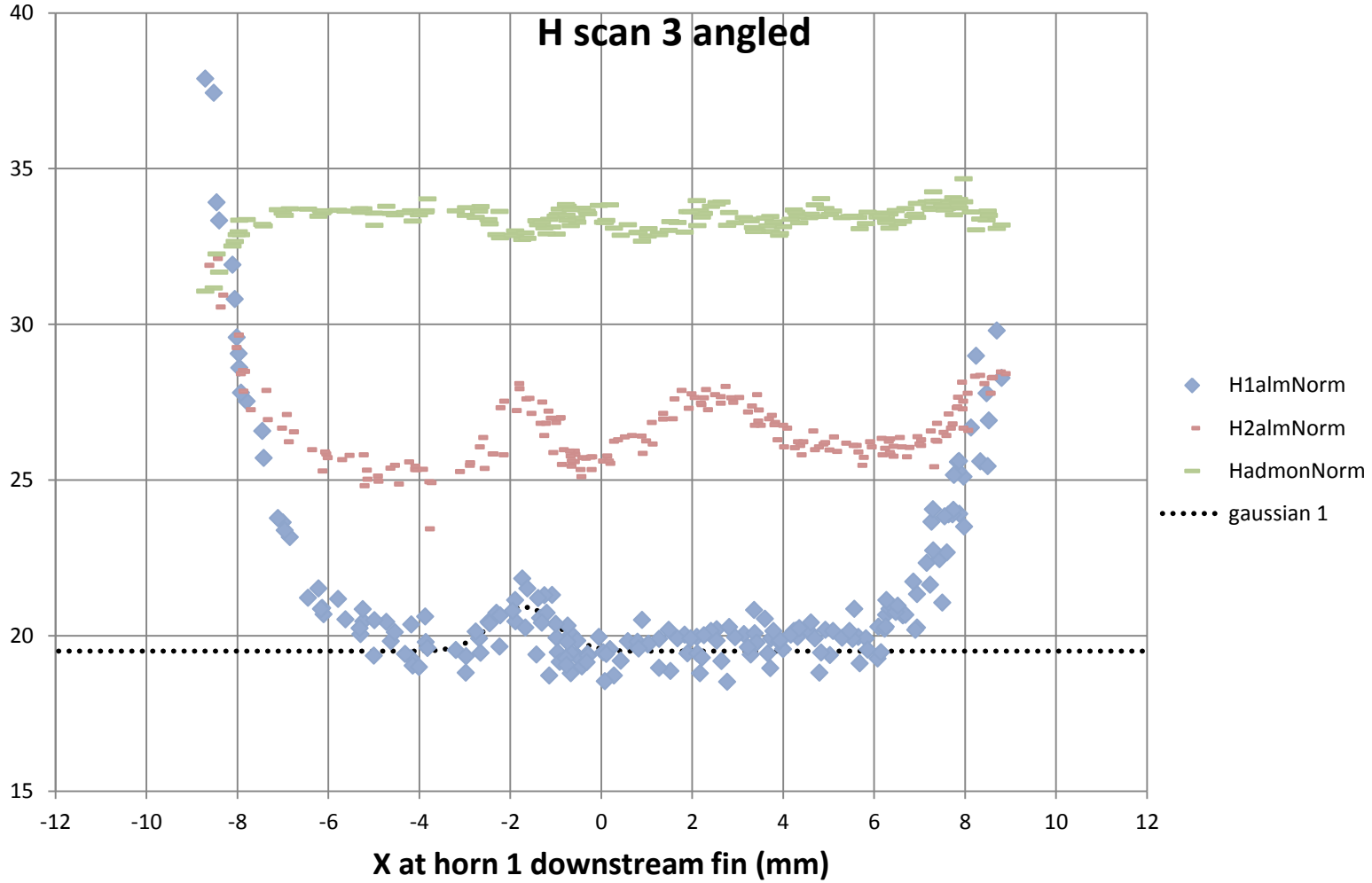
Fin for beam horz. alignment

Nub for beam vert. align

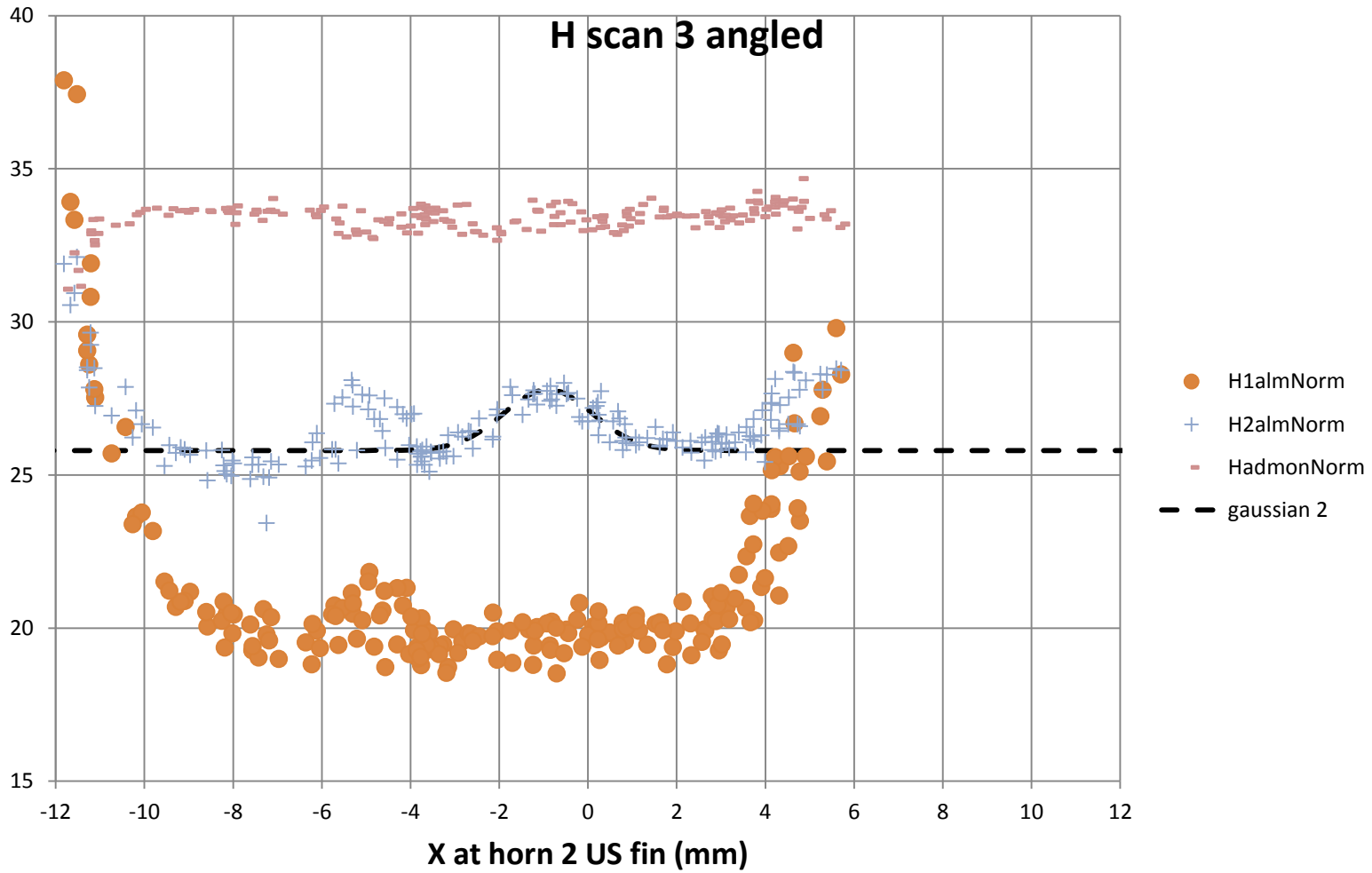
Beam loss mon. to detect beam scatter from fin



See horn 1 fin in BLM 1
Also see sculpting from horn 1 neck



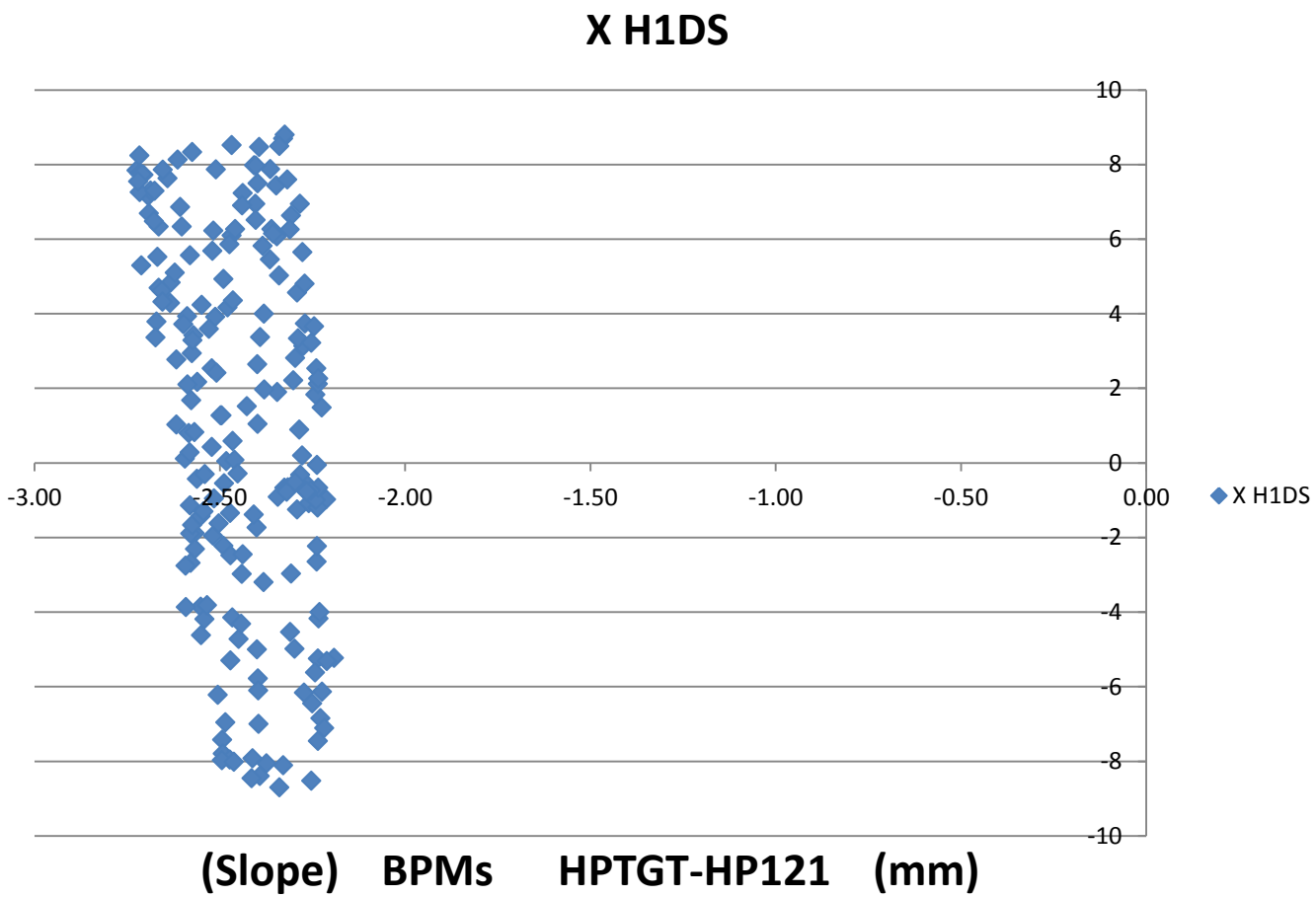
See horn 2 fin in BLM 2
(along with spray from horn 1 fin)



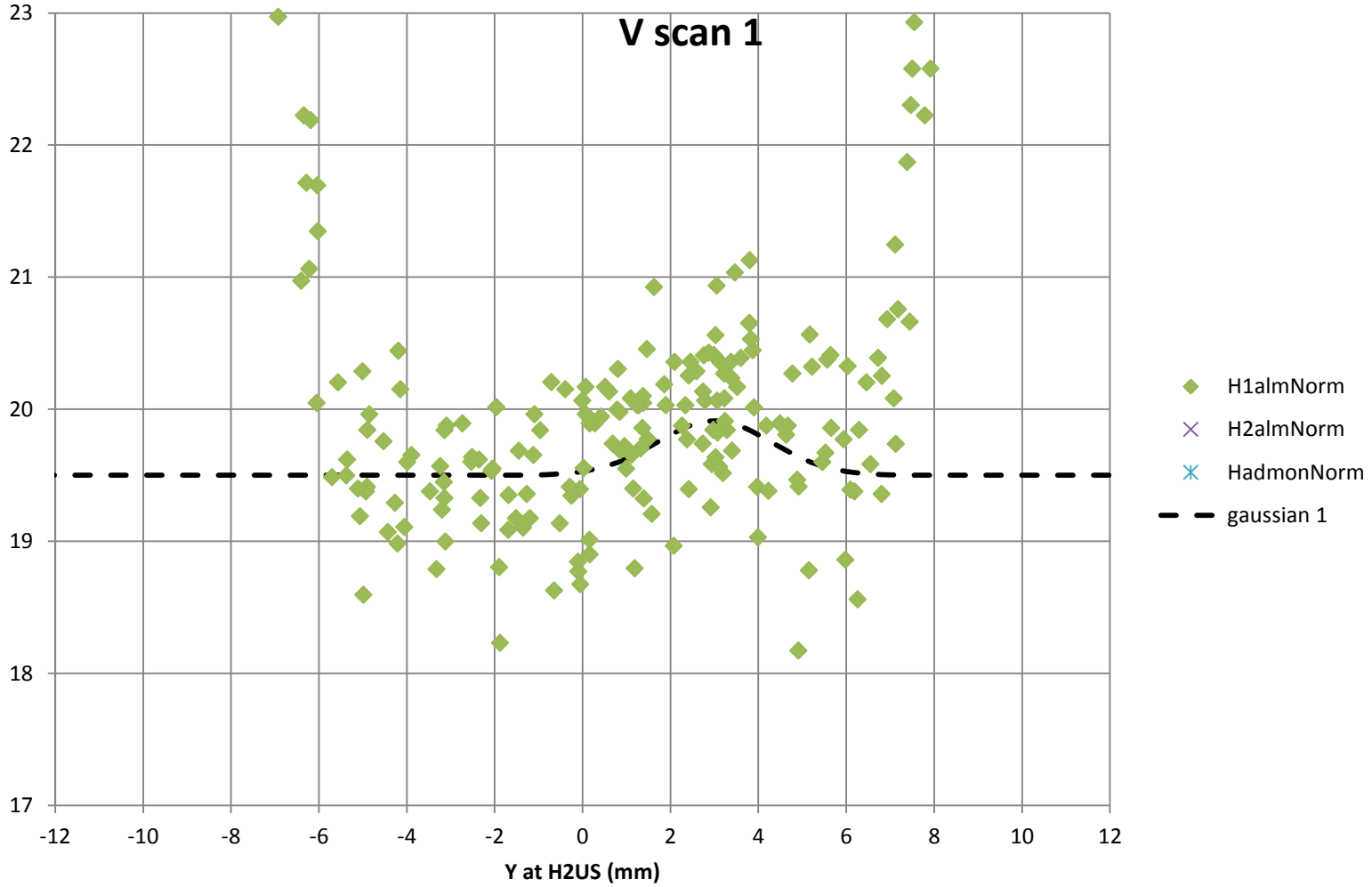
Scans done at low intensity to not destroy horns etc

At low intensity, get ¼ mm jitter in relative BPM readout

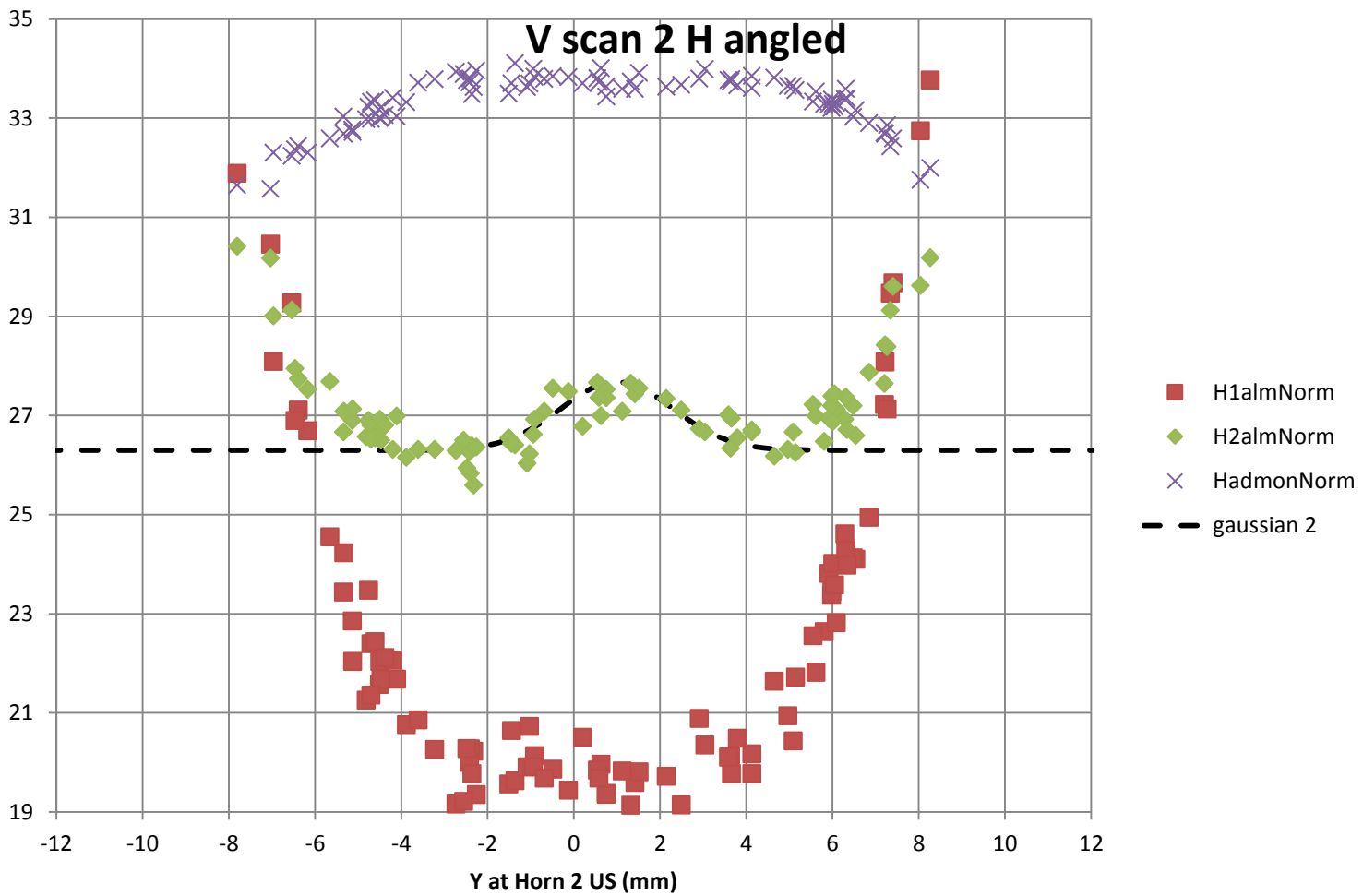
(H scan 3 angled scan)



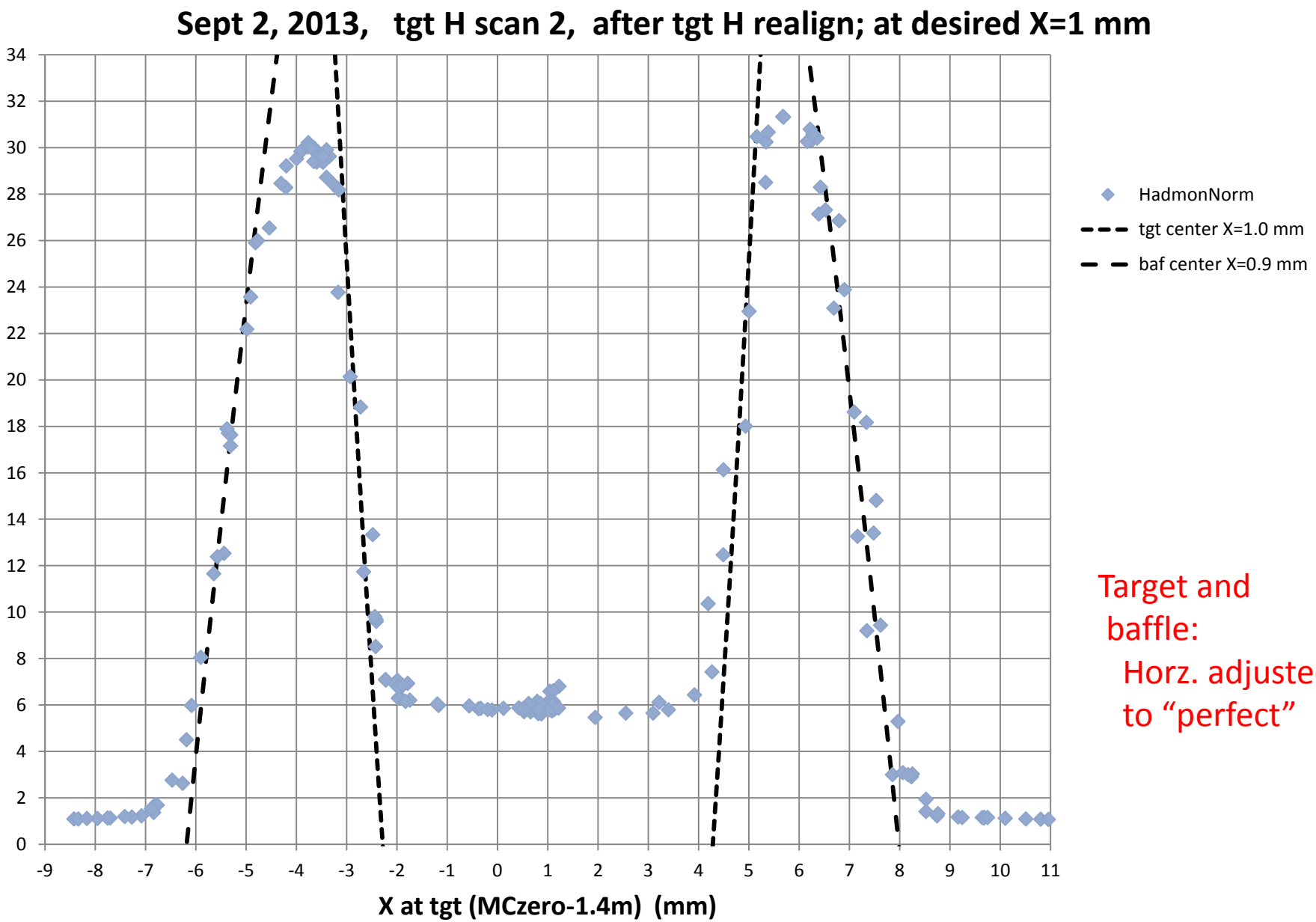
See feature Consistent with H1 fin nub,
but set horn 1 vertical from much more obvious horn 1 neck feature



Horn 2 nub sets horn 2 vertical

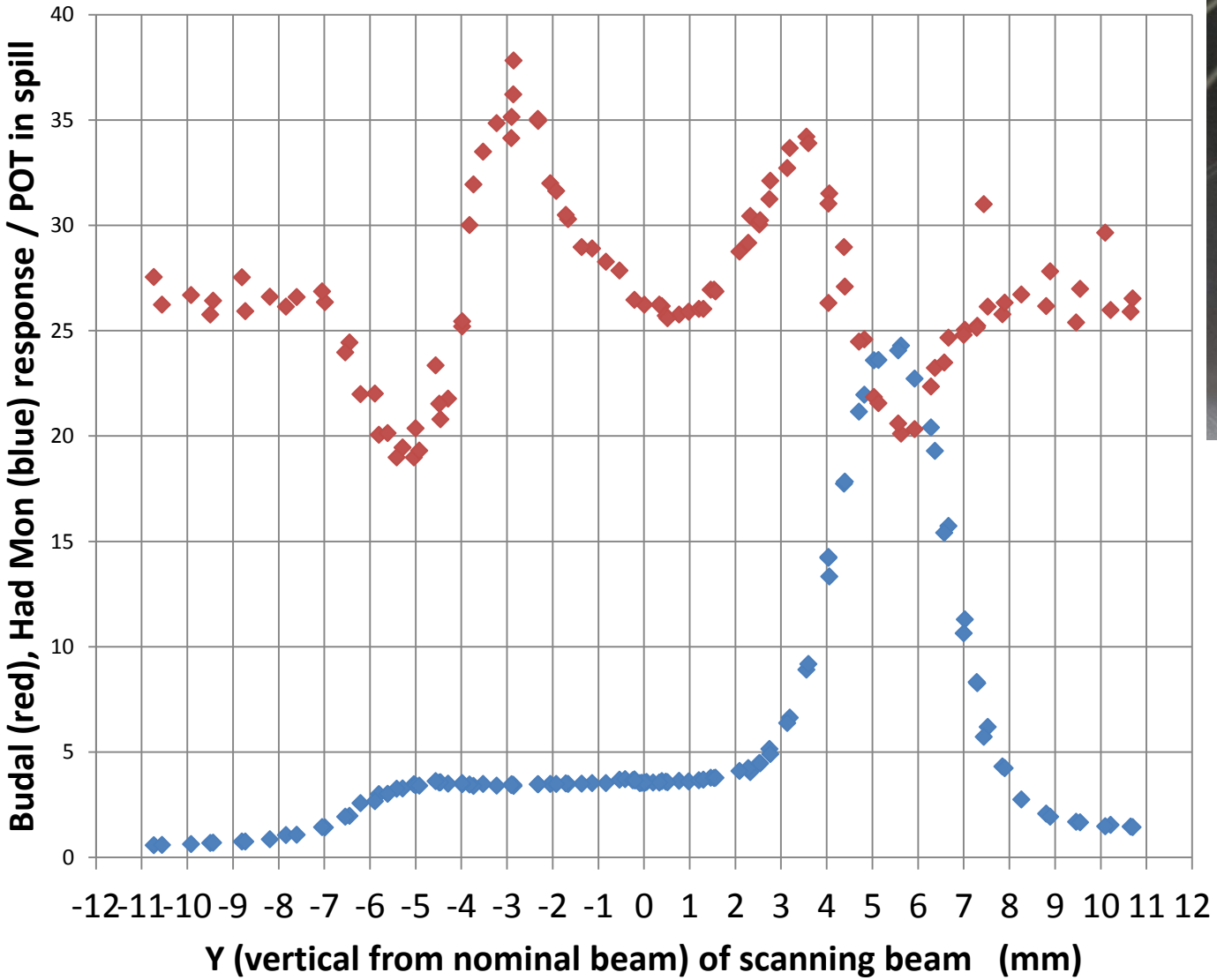


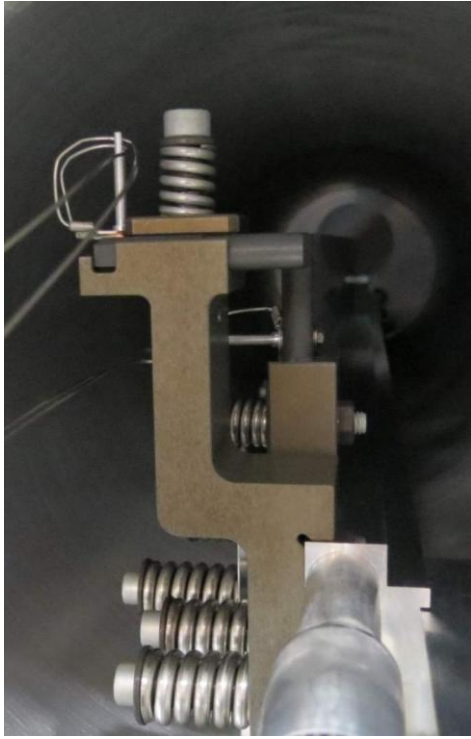
Step 3: install target and scan / realign target & baffle - - horizontal done with Had. Mon.



Target and baffle:
Horz. adjusted to "perfect"

Target Vertical position from Budal cross-fin scan at low intensity



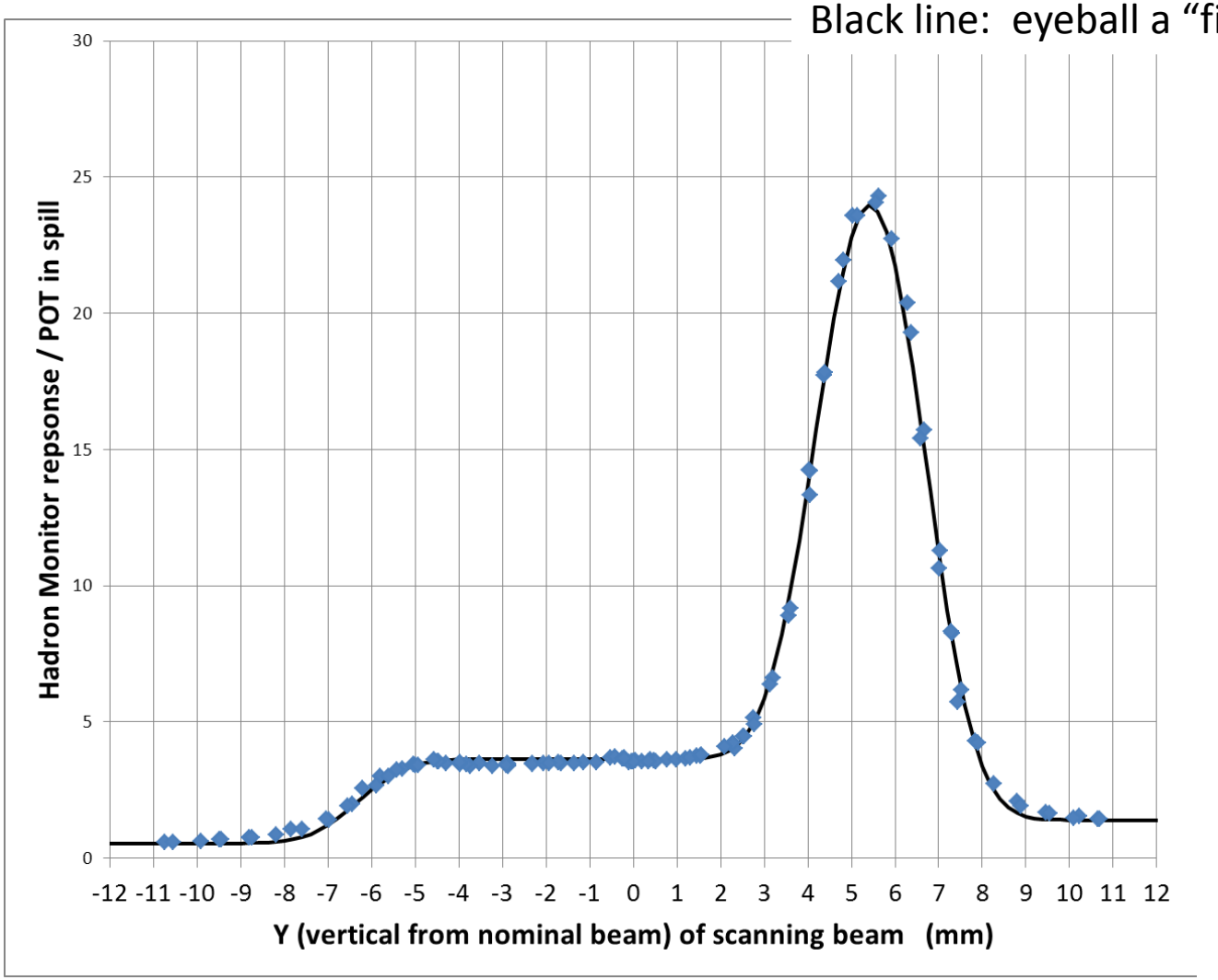


had/tor

HFVS/tor

Budal fin (and thus Target)appears high by ~ 0.3 mm

Target Vertical position
from Hadron Monitor scan at low intensity



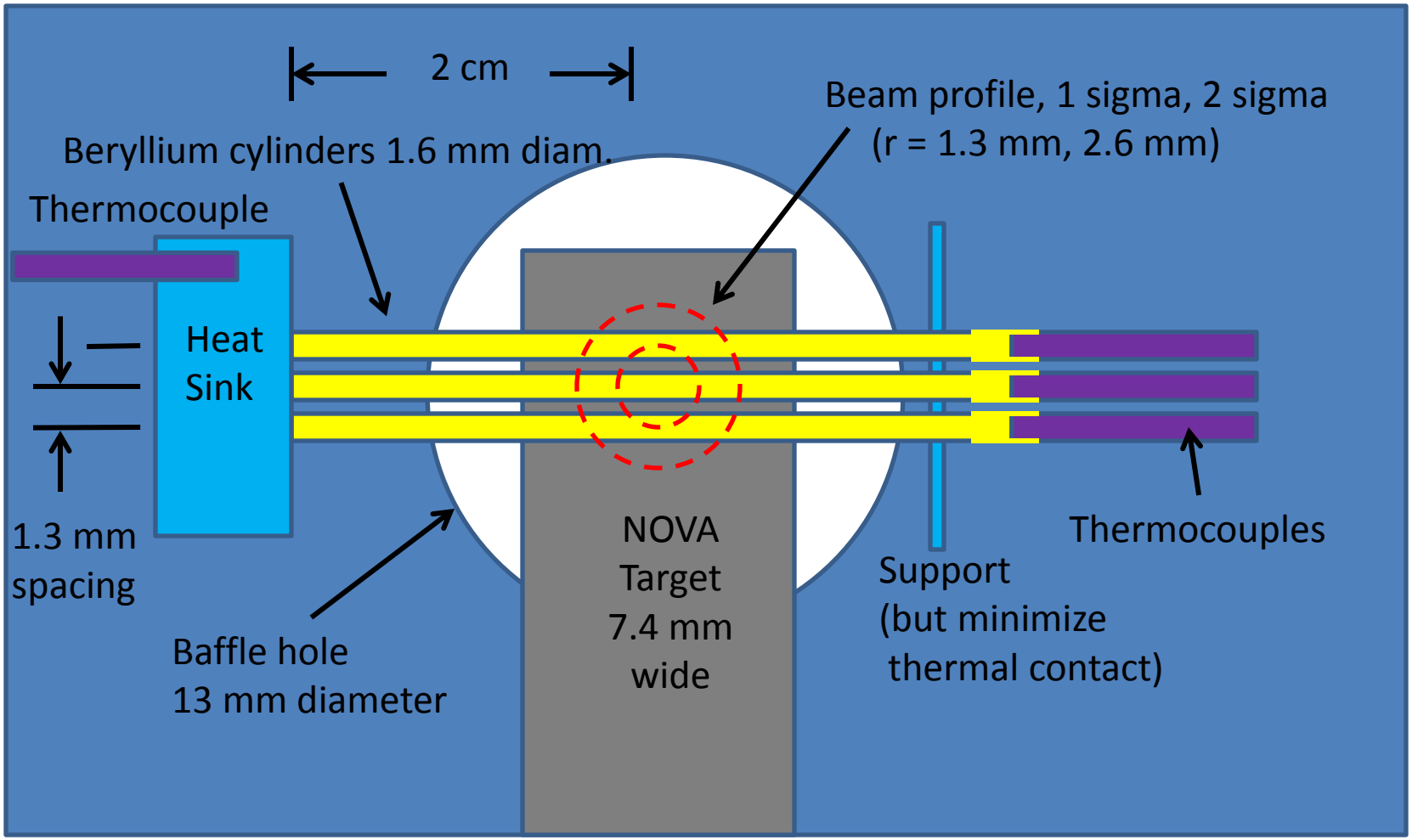
Black line: eyeball a "fit" with parameters:

0.9 mm beam RMS
Y target edge
Y baffle edges
13mm apart
overall amplitude
3attenuation ampl.
upper baffle
target
lower baffle

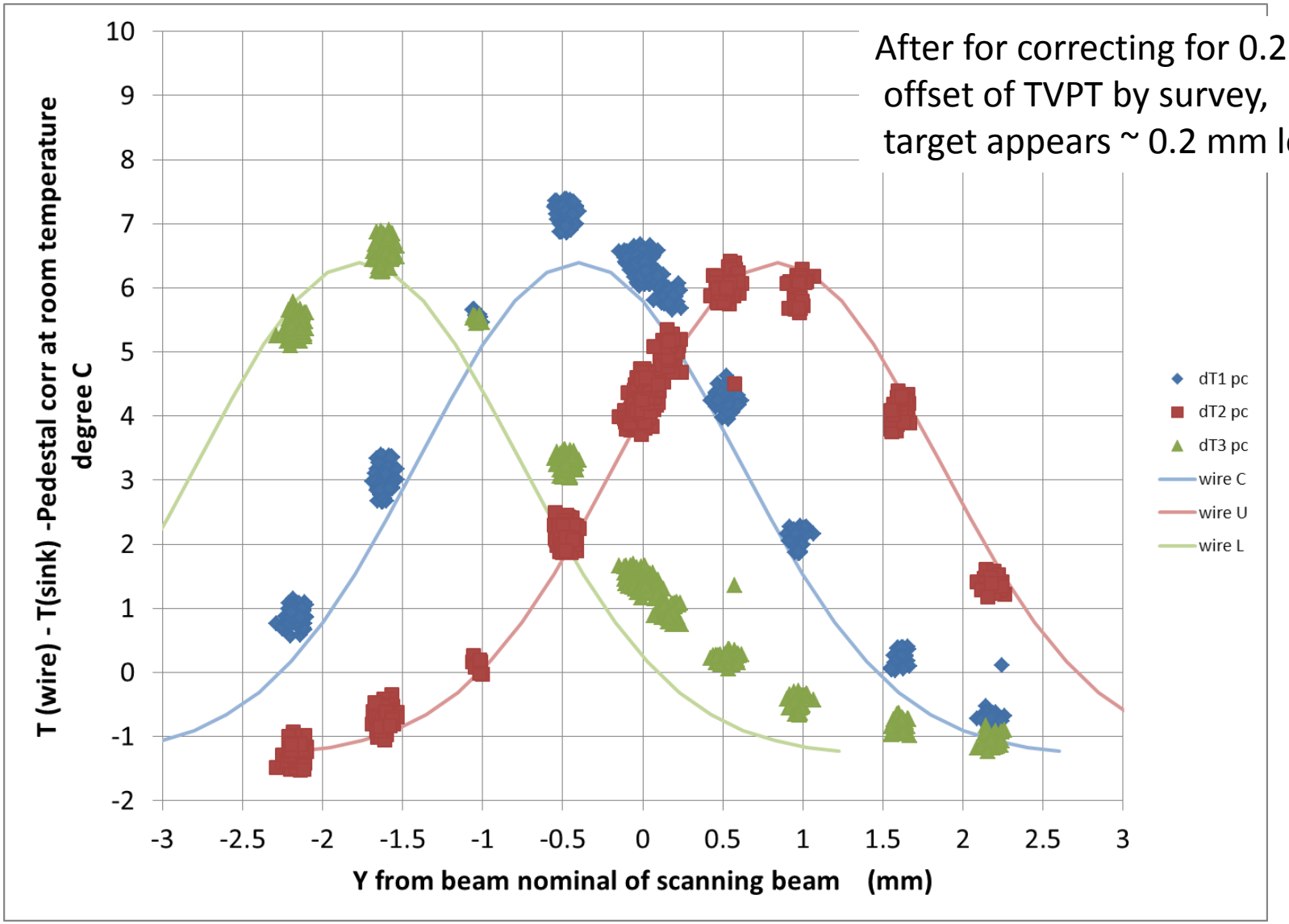
Target appears
high by ~ 0.5 mm

Concept of Target Vertical Position Thermometer

(not to scale; note baffle drawn behind target, although it is actually in front)



Scan of TVPT at high intensity



TVPT monitor during running

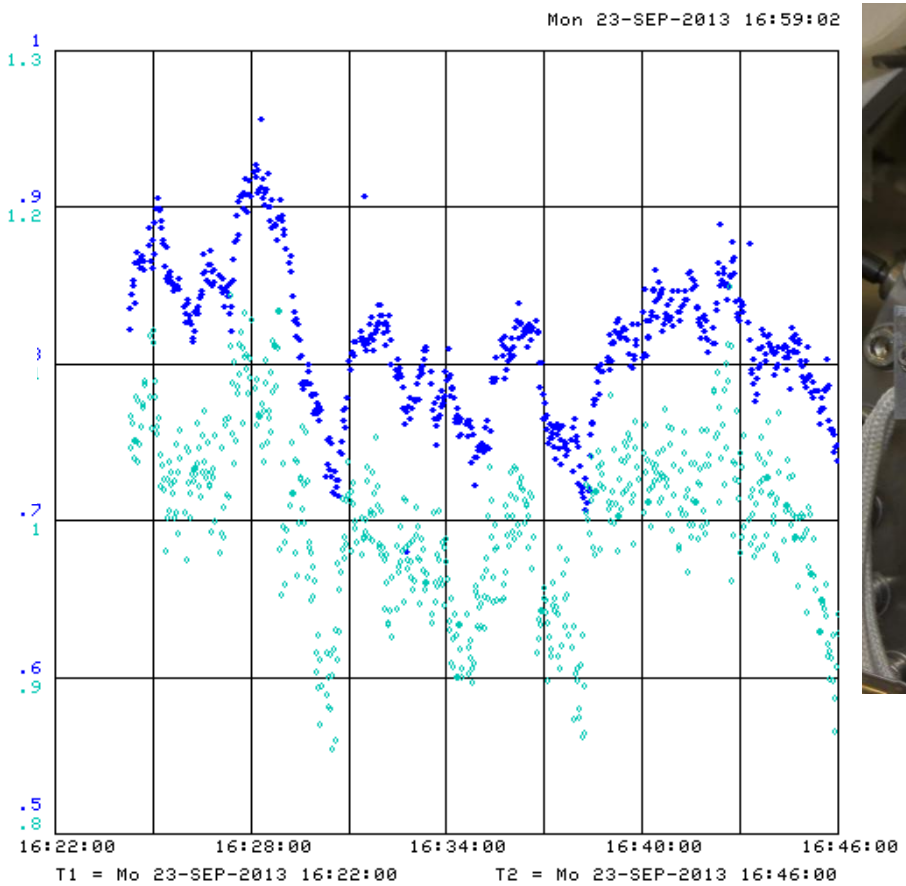
(does not require low intensity scan)

1.0 mm

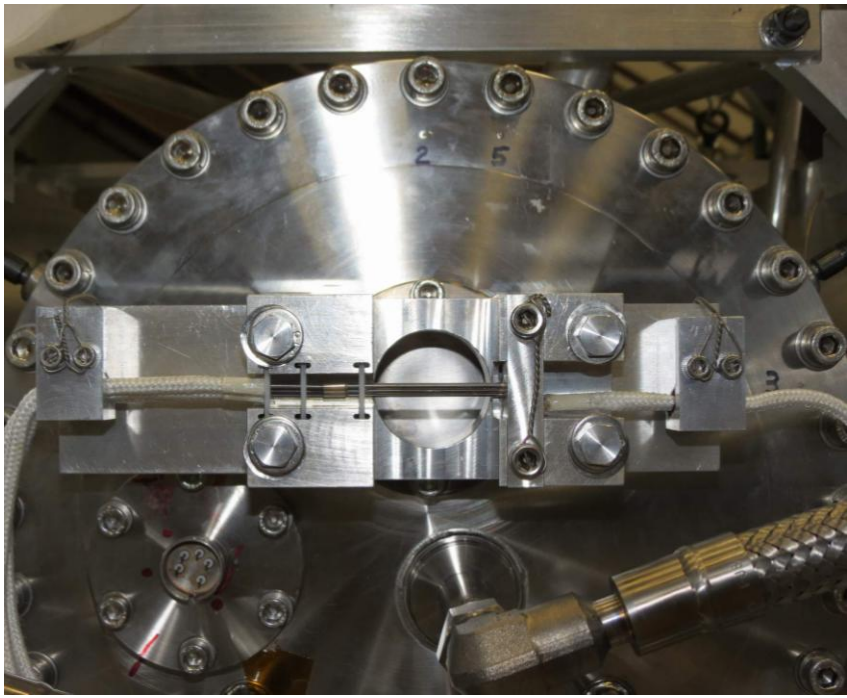
E:TVPT

E:VPTGT (BPM)

0.5 mm



Time (24 minutes total)



Cobbled algorithm for TVPT (dT top wire) / (dT central wire) shows it can track beam motion at 0.1 mm precision

Summary of scan results

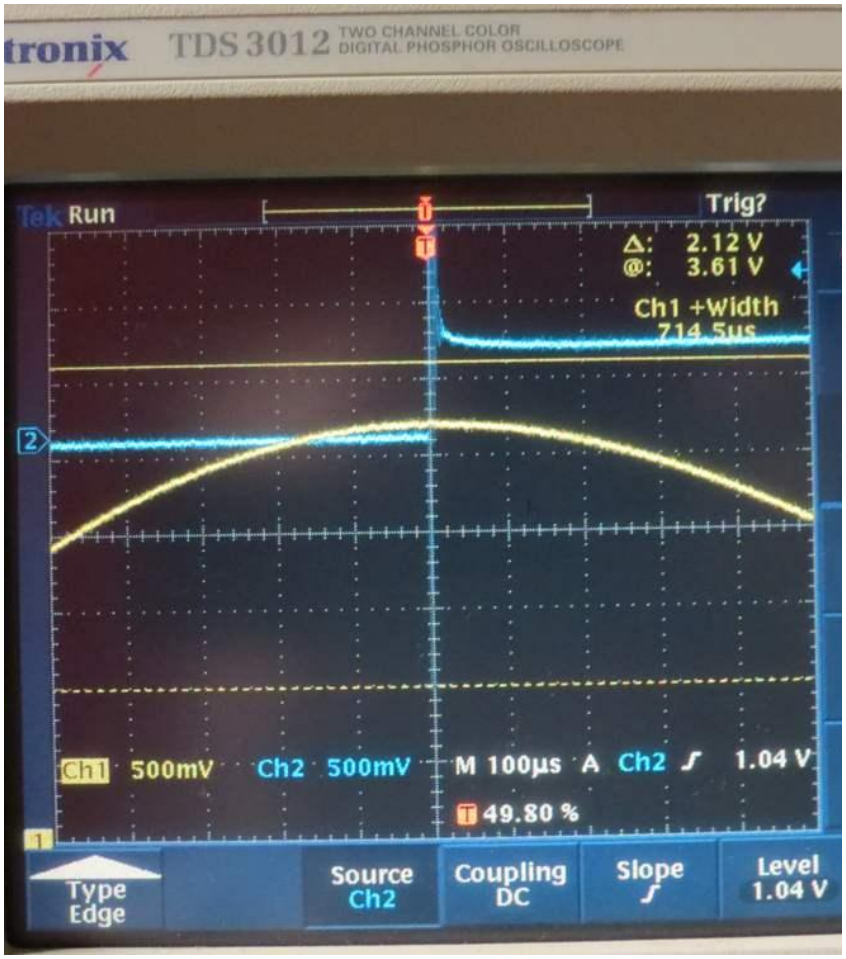
HORZ.	X seen			Beam Set to:	Beam Set to:	X from beam (mm)
	0.82		H1 neck	1.00	1.00	-0.18
	0.63		H1 fin	1.00	1.00	-0.37
	1.80		H2 fin	1.00	1.00	0.80
ave	1.08					
			target	1.00	1.00	0.0
			Had mon			-18
VERT.	Y seen			E:VP121	E:VPTGT	Y from beam (mm)
	0.47		neck	0.00	1.00	0.47
			H1 fin			
	-1.10		H2 fin	0.00	1.00	-1.10
ave n,n,h2	-0.05					
			target	0.00	1.00	**-0.2** to +0.5
			Had mon	0.00	1.00	-15

From NuMI TDR - *tolerances*

	PH2me	Medium	Energy	Beam
	A	B	C	D
	estimated accuracy	Will cause 2% error	error in worst energy bin	error squared
At Fermilab	(mm)	(mm)	(%)	(%)
Position of Beam on Target	0.38	1.20	0.201	0.040
Angle of Beam on Target	0.71	8.16	0.015	0.000
[18.13m]				
Target X	0.50	-	0.000	0.000
Target Angle [1.0m]	0.71	1.67	0.362	0.131
Horn 1 X &	0.50	0.89	0.645	0.416
Horn 1 Angle [3.0m]	0.71	1.69	0.353	0.125
Horn 2 X	1.00	4.28	0.109	0.012
Horn 2 Angle [3.0m]	0.71	23.00	0.002	0.000
Decay Pipe [675m]	25.00	270.00	0.017	0.000
Downstream End				
Near Detector	25.00	209.00	0.029	0.001
Sum			*0.851*	0.724
Times root 2, since two transverse planes			*1.204*	1.449

Horn current

Pulse shape slightly different (horn 2 move), and adjust to new extraction time (1.5 ms)



Beam to horn timing:

Blue: beam from target Budal

Yellow: horn current

100 micro-sec per division

Good to ~ 20 microseconds

Calibration:

Corr. for sample time from peak: 0.04%

All calib. applied:

readout (E:NSLINA+B+C+D) is 99.54% of actual current

(previously 98.17% , MINOS-doc 1303)

Operating Point:

Have set voltage to get 199 kA on readout so 200 kA actual horn current (higher than previously)

Current is temperature (pulse rate) dependent, pulse rate increased since I set voltage, current looks 0.2% low now.

Primary Beam changes

- As part of ANU upgrade
  - 5 quad magnets changed out (better cooling to allow faster repetition rate)
  - Optical Transition Monitor replaced by “low intensity” profile monitor
  - Prototype “button” BPM installed between 121 and TGT, new style for LBNE
  - Total Loss Monitor modified
  - Better readback of magnet currents for regulation, beam permit

- Due to failures
  - 20’ dipole magnet replaced
  - Trim magnet replaced
  - Beryllium window at end of pre-target beam pipe replaced

- To keep radiation losses in pre-target under control
  - At higher power, the target profile monitor will be retracted most of the time
    It will be inserted periodically (daily?) to check on beam spot size
    Devices E:MTGTVM, E:MTGTHM, E:MTGTHS, E:MTGTVS, … will be intermittant

Test of Beryllium target material ?

- Be is order of magnitude more radiation resistant than graphite
- Longer lifetime has advantages:
  - Slower deterioration, more stable neutrino flux to experiments
  - Save lots of money on construction, installation, storage, disposal of targets
  - Less downtime for replacement of targets
- Be targets have run for extended periods (WANF, Mini-BOONE)
- Replacement of NuMI graphite by Be pushes stress to limit
  - Believe Be will survive, but how to test?
  - Propose putting in a couple Be fins, one in highest stress region, one in lower stress region
  - Loss of one fin out of 50 should not make a target non-functional

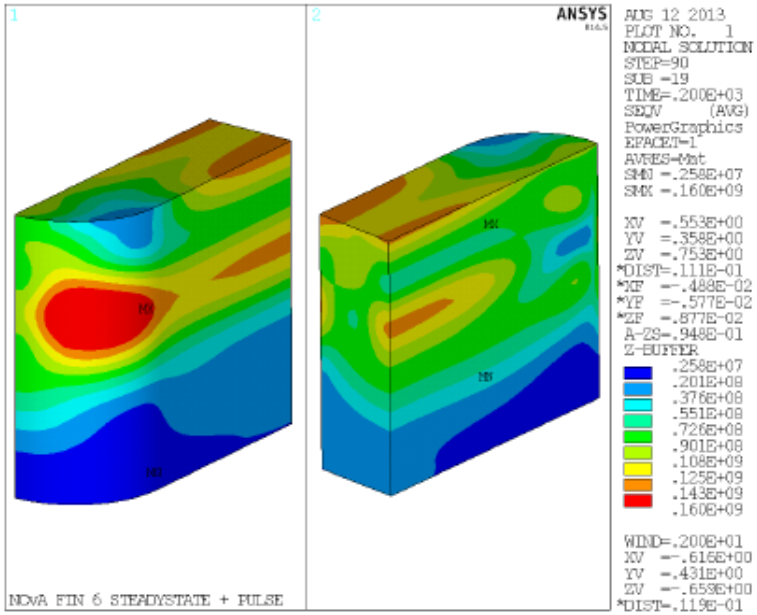
    So minimal impact in case of failure

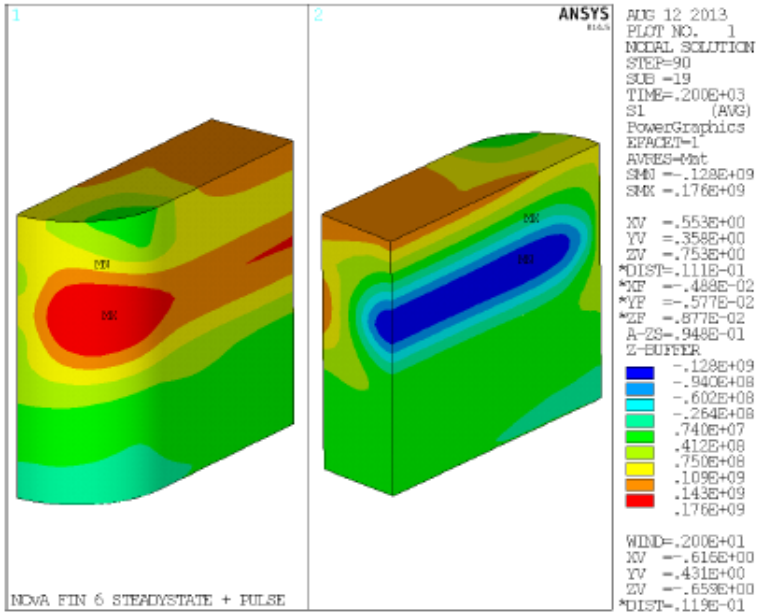
    Success might save 8 targets during NOVA run & help LBNE design

ANSYS of most stressed Be fin, by Brian Hartsell

Fin 6 Stresses - After First Pulse

Left figure is Von-Mises stress, right is maximum principal stress.

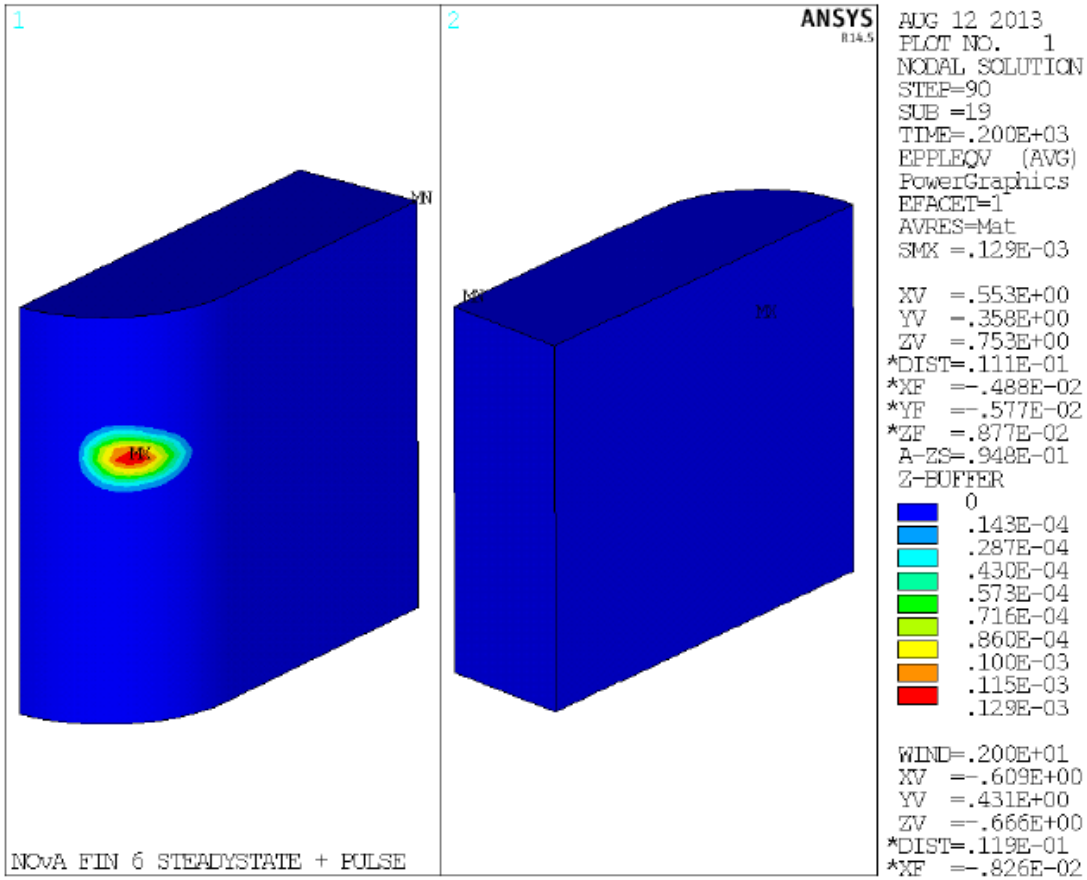




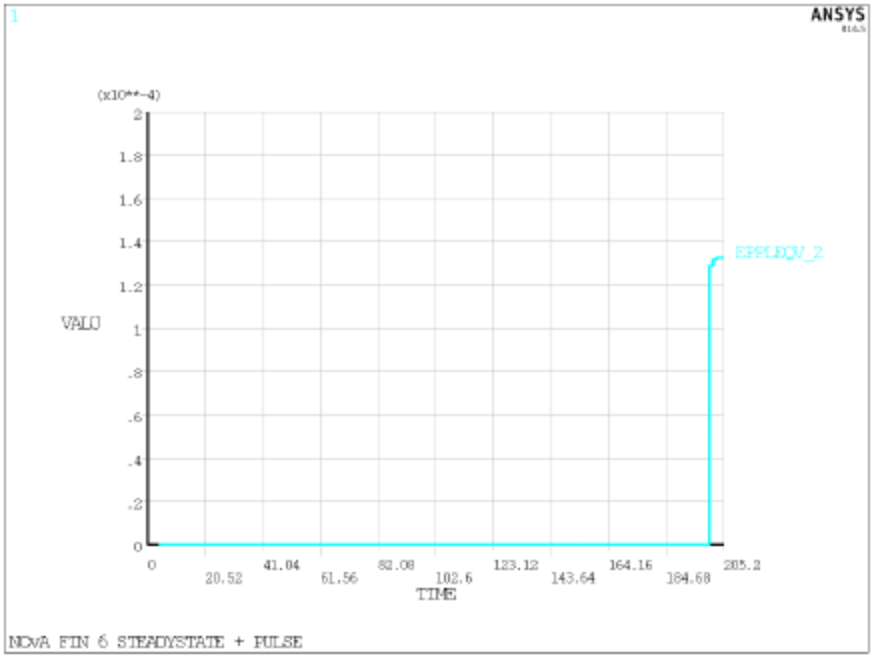
Fin is yielding at the large red spot - Yield is 160 MPa at this temperature.

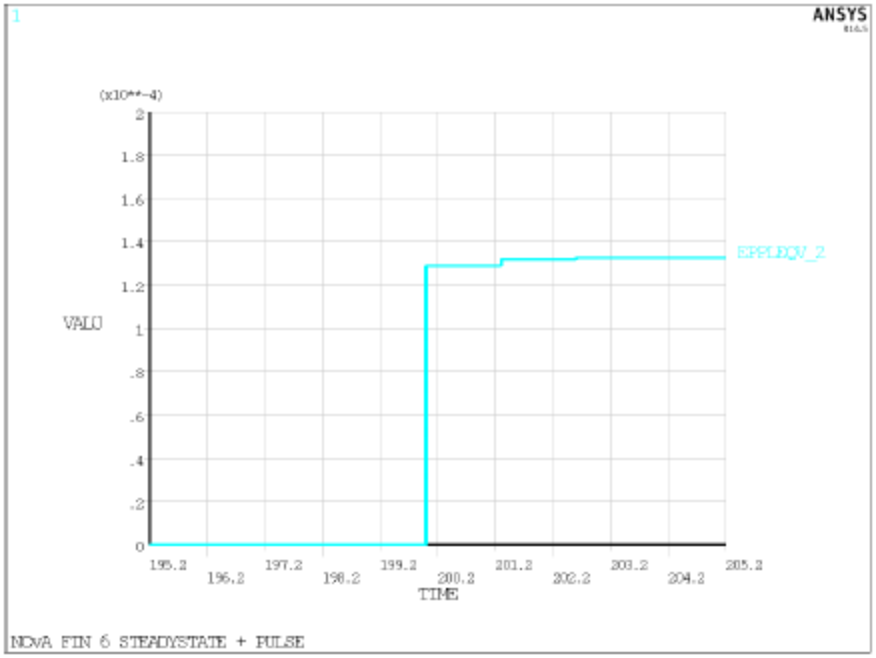
Fin 6 Plastic Strain - After First Pulse

A small amount of yield is shown with 0.013% plastic strain.



Evolution of Plastic Strain

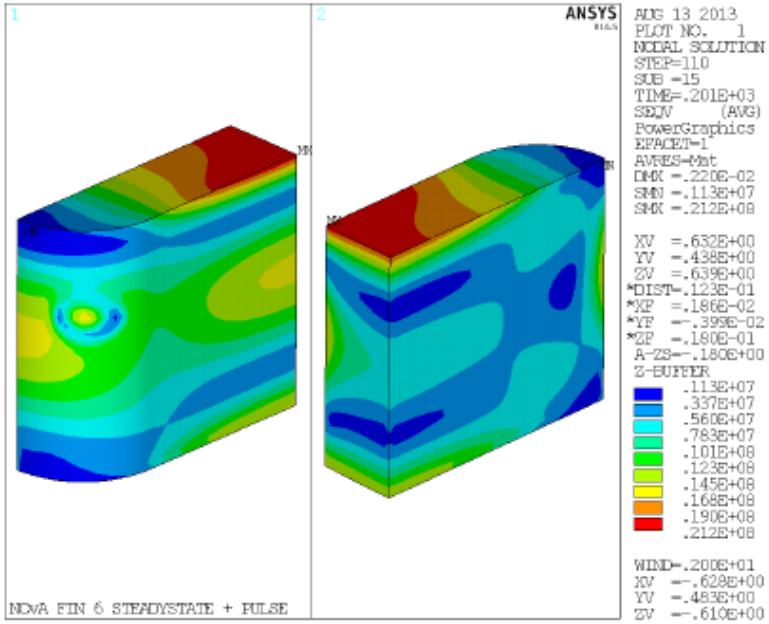


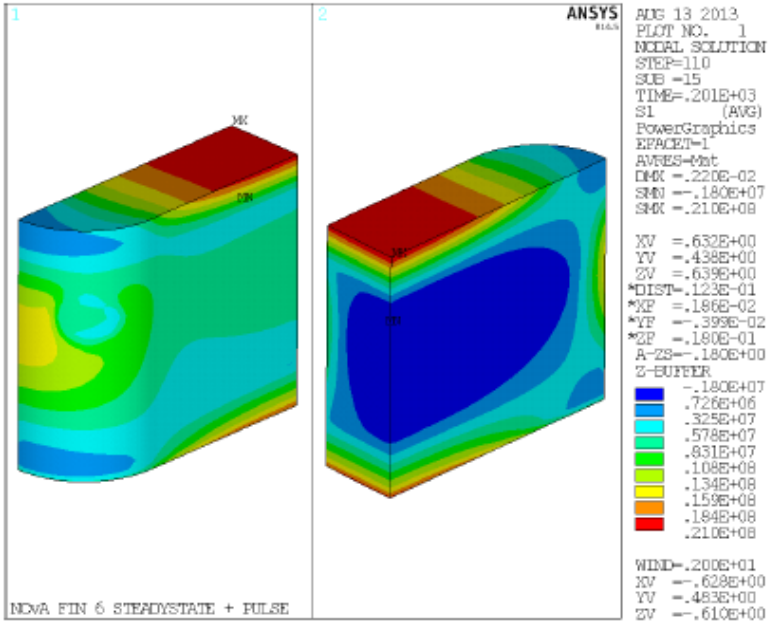


Plastic strain levels off after the four pulses. No ratcheting is evident.

Fin 6 Stresses - After First Cooldown

Left figure is Von-Mises stress, right is maximum principal stress.





There is virtually no compressive pre-load in the beam spot, and a very small amount of pre-load in the area that has been plastically deformed.

Spares

- Targets
  - MET-01 running, new NOVA style target
  - MET-03 (final alignment on carrier) should be finished in a few weeks
  - NT-07, NT-08 available (up to 400 kW)
  - MET-02 ~ December – *put in couple Be fins?*
  - Starting on MET-04, MET-05
- Horn 1
  - PH1-04 running, new 700 kW horn
  - PH1-03 is unused 400 kW spare
  - PH1-05 should be finished ~ Nov/Dec (700 kW horn, on test stand now)
- Horn 2
  - PH2-02 still running (old horn)
  - PH2-03 is completed spare
  - PH2-04 is under construction
- Hadron Monitor
  - NHM-03 running (new)
  - NHM-04 expected in December

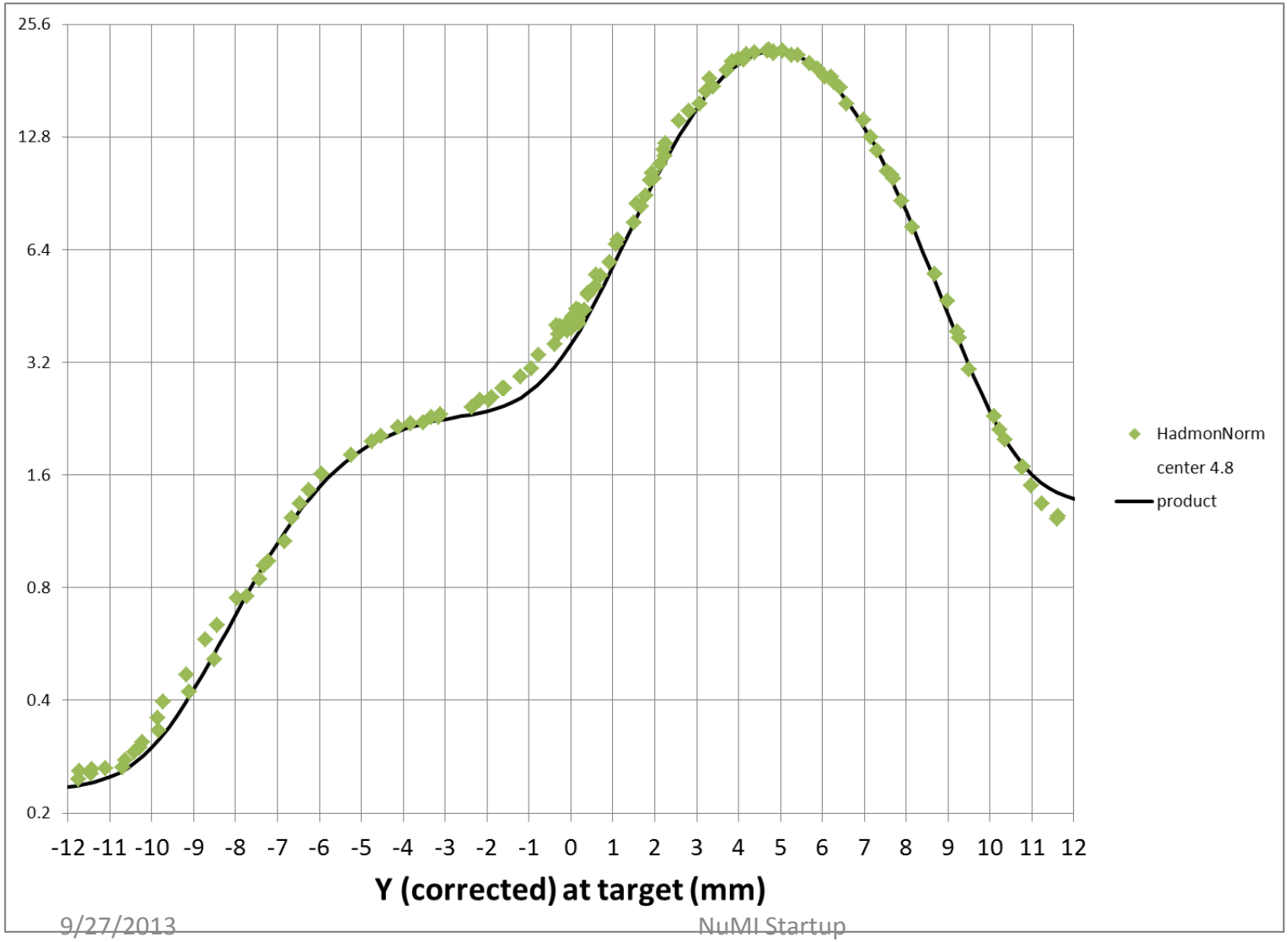
Would someone mine old muon monitor data to see how well ratio of muon monitors showed NT-02 deterioration ?

- Laura Loiacono had plotted this for part of the NT-02 run, but much more data exists

- With higher power, radiation damage may (or may not) accumulate faster this run
- Especially interesting for LBNE design, does this technique really work

Historical Backup

Vertical target scan using hadron monitor
"Fit" by eye with three cumulative gaussians, representing
target fin and two baffle edges, (amplitude = no. of int. lengths, tuned to plot)



Baffle at nominal

Target tip 0.4 mm low

Lack of target symmetry makes this hard to judge

Before smaller spot and target move