Fiber Damage status

John Cooper / Ken Heller

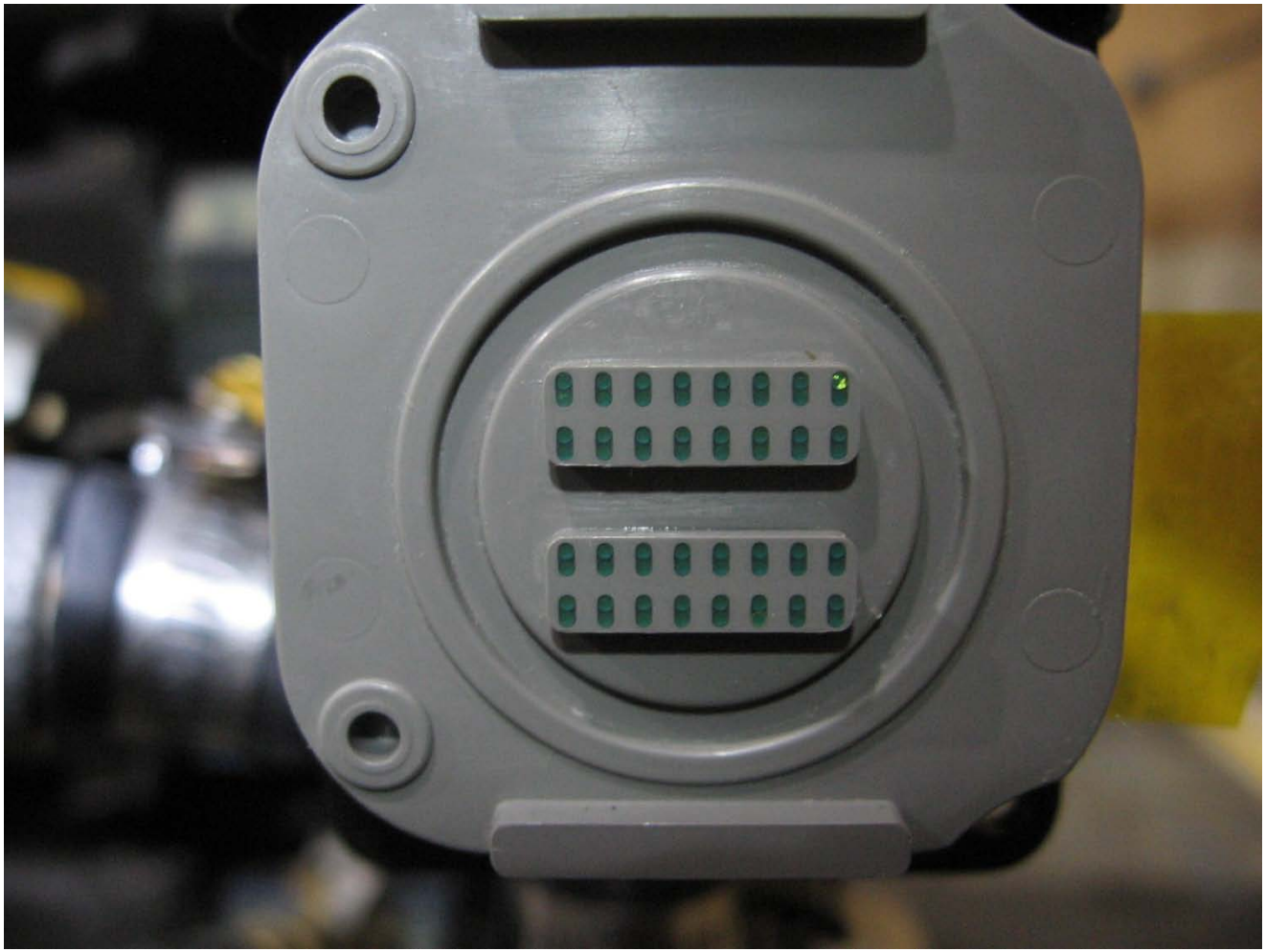
Fiber Damage investigation

- Conclusions to date:
  - There is fiber “damage”, there are no broken fibers.
  - The damage is NOT due to transportation from Minneapolis to Ash River since the 60 of 160 modules built by May 8 but still at Minneapolis had similar damage.
  - Only 0.4% of individual fibers show such damage.
    - If we replace these individual fibers during construction, the problem is small
    - After gluing, must replace 32 fibers (1 km of fiber = $1,000) to fix one bad one.

- Consensus of all parties is that the visual inspection shows a bright fiber end, just one end of the two ends of the ~105 ft long looped fiber.
  - Further consensus that this bright fiber indicates some damage “near” the end of the fiber – right at the end or perhaps further inside the 32-fiber manifold.
  - Fiber is bright because room light is reflecting off something near the end
    - Opinions vary on how far from end: ~ mm → ~1 ft
  - The damage is “visual damage” and different people see different things.
    - A “bright fiber” example that all observers agree on is shown on the next slide.

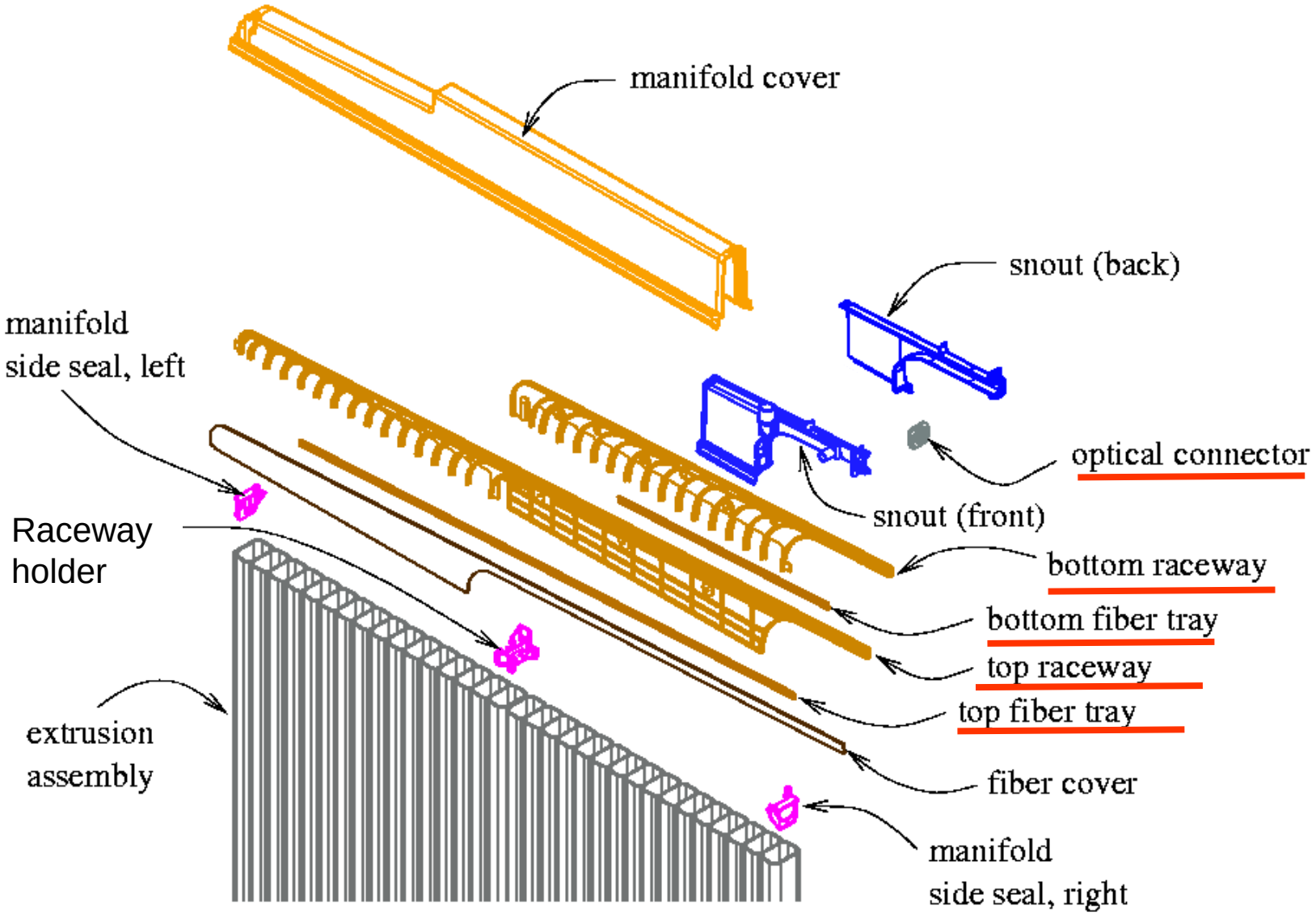
Example of “bright fiber” damage

- This is the optical connector view of fibers from 32 cells arranged in 4 rows
  - Each cell has 2 fiber ends from the same continuous fiber loop down and back in the 50 foot long NOvA cell



For Reference: Manifold Parts

(damage could be in the raceways, fiber trays, or connector)

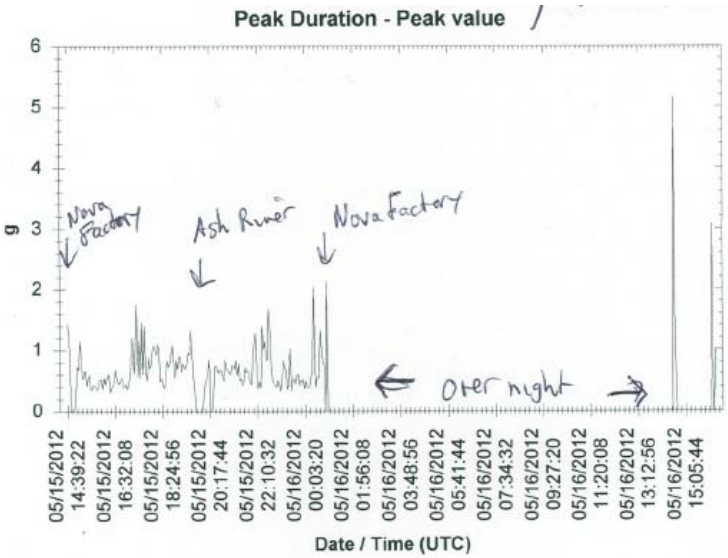


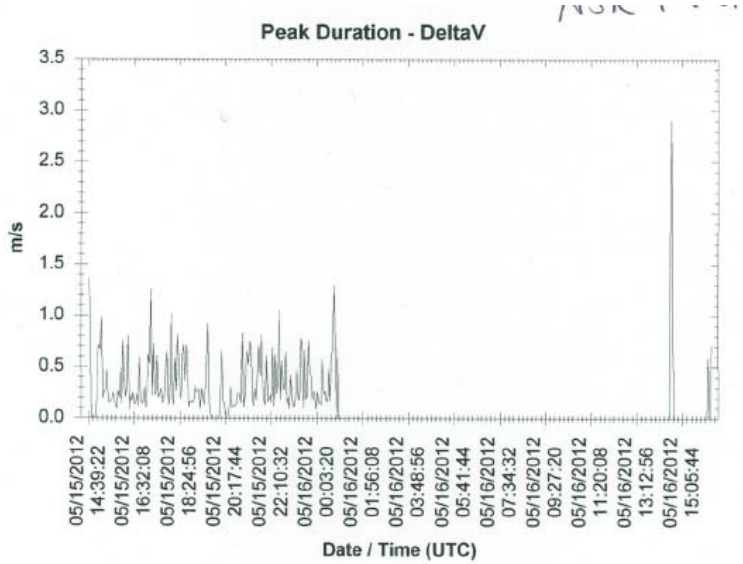
Checks on Fiber Damage in Shipping

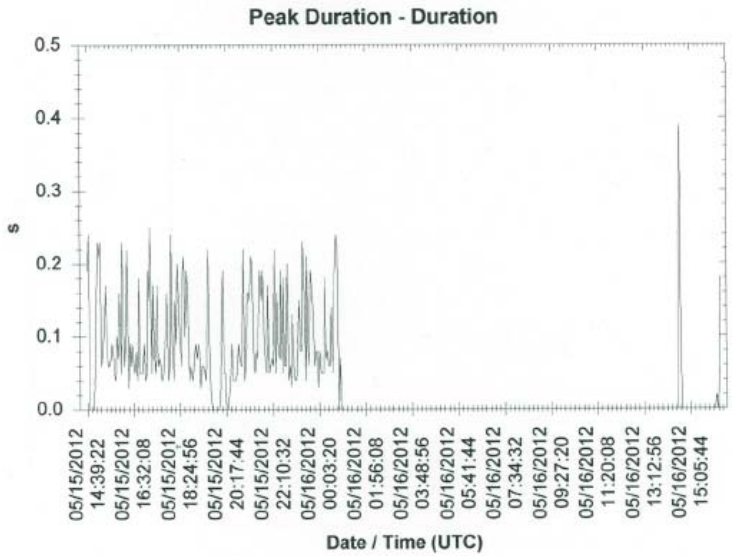
- Ken Heller's plan back on May 8 was to ship another stack of modules on a round trip to Ash River and back to Minneapolis
  - Monitor shock and temperature
  - Check for fiber damage
- The 1st round trip transportation test was done on May 11
  - Initial report of 1 damaged module on return, later report was 5 (others looked).
- A 2nd round trip transportation test was done on May 16
  - But on inspection 3 of the 24 in this stack showed damage <u>before</u> shipping.
  - The same 3 were damaged on return.
- A 3rd round trip was done on May 29
  - But with modules that were studied <u>extensively</u> before shipping
  - No damage before shipping, also no damage after shipping

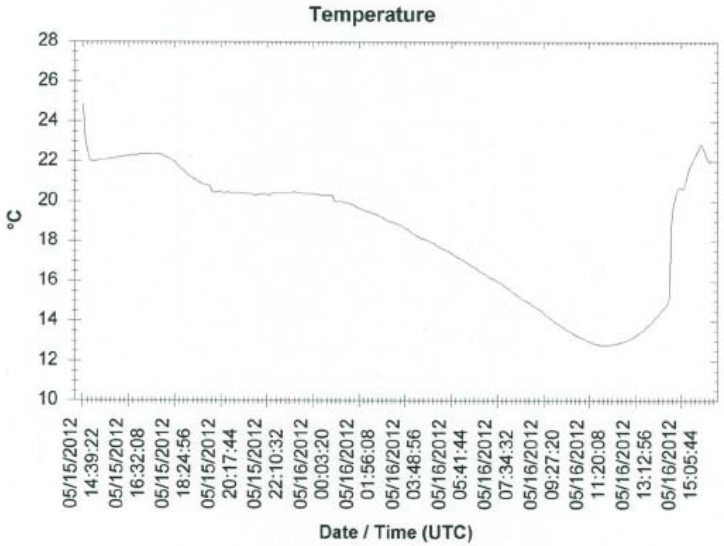
Shock and Temp on 2nd shipment

- Typical peaks of 0.5 – 2.0 g, temperature variation from 24 – 14 °C







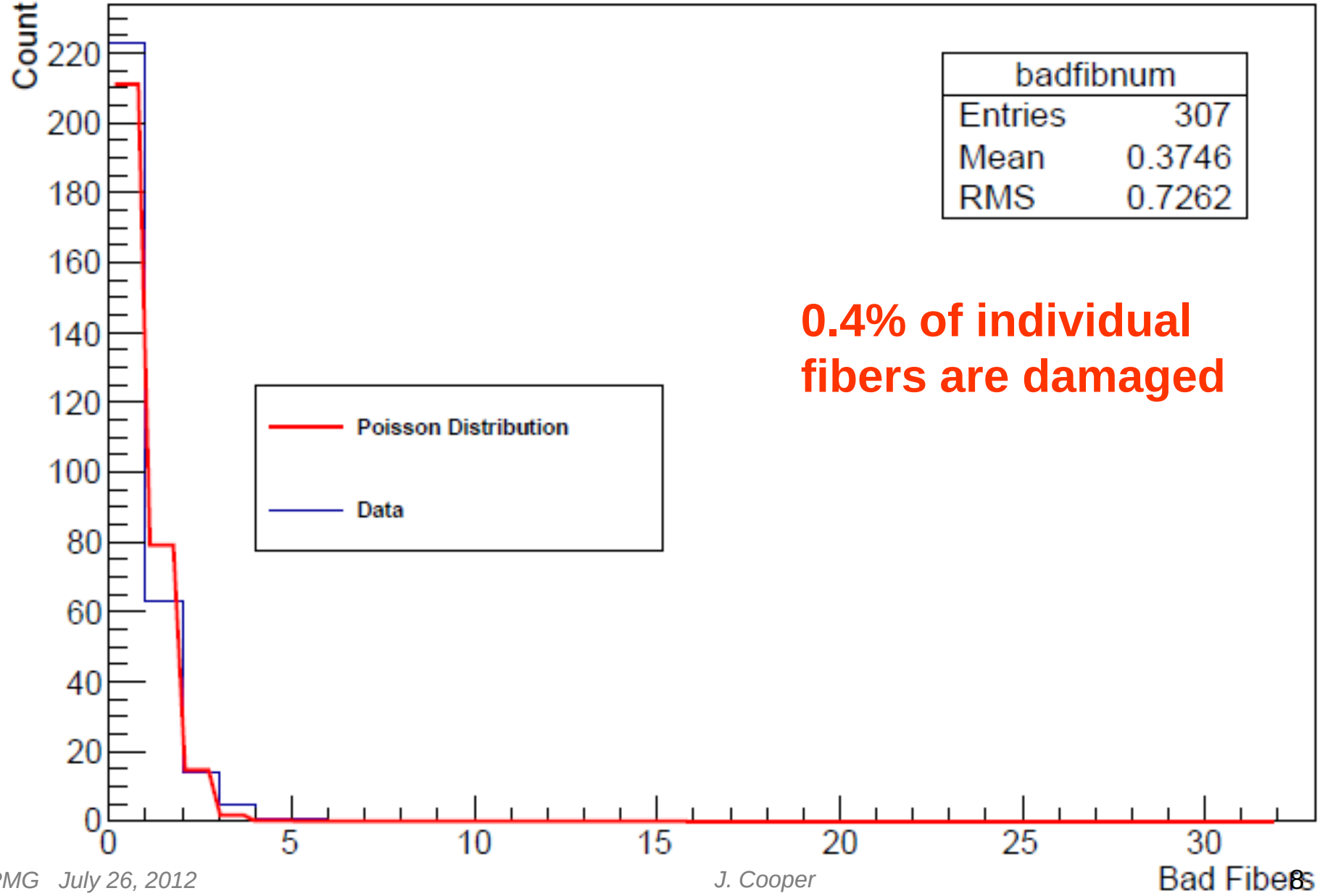


Autopsies and Audits

- A recommendation of the May 8 IPR was that we autopsy damaged modules to better determine the cause.
  - No autopsy done on any of 1st shipment modules.
    - Pivoter work at Ash River had priority on use of those modules.
    - ~20 were sent back to Minneapolis at the end of May.
  - Autopsies at Minnesota on some of the 60 damaged modules at their end were not successful
    - The top of the manifold/snout and the optical connector are potted in glue.
    - All attempts to remove the glue to see the fiber just resulted in destruction of the fibers.

- The Fermilab Directorate ordered a QA team audit on the damage issue after the IPR
  - Halley Brown, TJ Sarlina, JJ Schmidt, and Joe Howell visited on May 17-18
  - They were convinced that transportation was not the issue

Number of Bad Fibers/Module with Visual Fiber Check

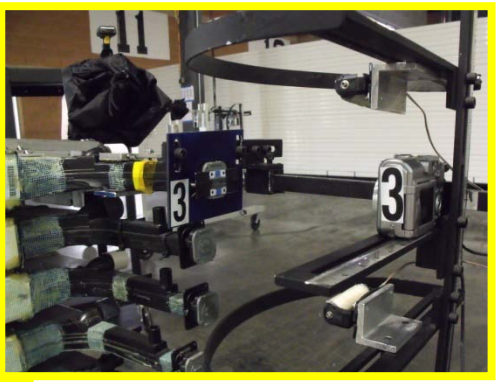


0.4% of individual fibers are damaged

There are TWO other fiber testers

(designed to give quantitative answers)

- Called Fiber Loop Testers (FLT). We had these before the May 8 IPR.
- Minnesota design uses red light into one side of the loop, takes a CCD picture of the other side, then the photo is sampled to check transmission through the loop.



- Michigan State design uses red light into one side, phototransistor on the other side to measure transmission through loop

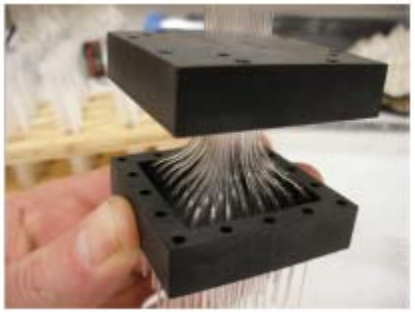
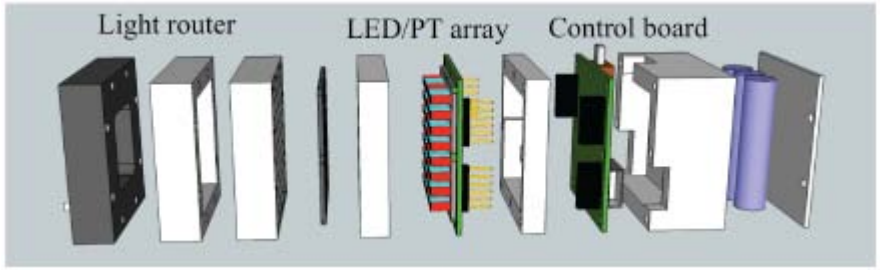


Fig. 2. Photo of light router during construction



More on Fiber Testers

- Both transmission testers were able to find damage in tests on a set of deliberately damaged fibers in a single 50 ft test module.
  - damaged at the manifold (10-30% transmission loss depending on damage done),
    in the middle (10 – 40% loss depending on damage done), and
    at the far end (10-100% loss, 100% was a broken fiber) of the module,
    plus some with no damage at all
  - Both found the same damaged fibers & the same undamaged fibers in this test.
  - For this special single module tested (NOVA-doc-7471)
    - The Minnesota version has a sigma of 7.6% in measuring transmission loss
    - The MSU version has a sigma of 0.2% and should more cleanly separated damaged fibers from undamaged ones as a result
    - In both cases this is the sigma on several measurements of same fiber.

Raw MSU tester data

- On 181 Far Detector modules, for all 32 cells
- Variation due to clear fiber bends in light router
- Large damage obvious, subtle damage may not be

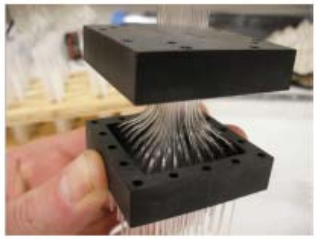
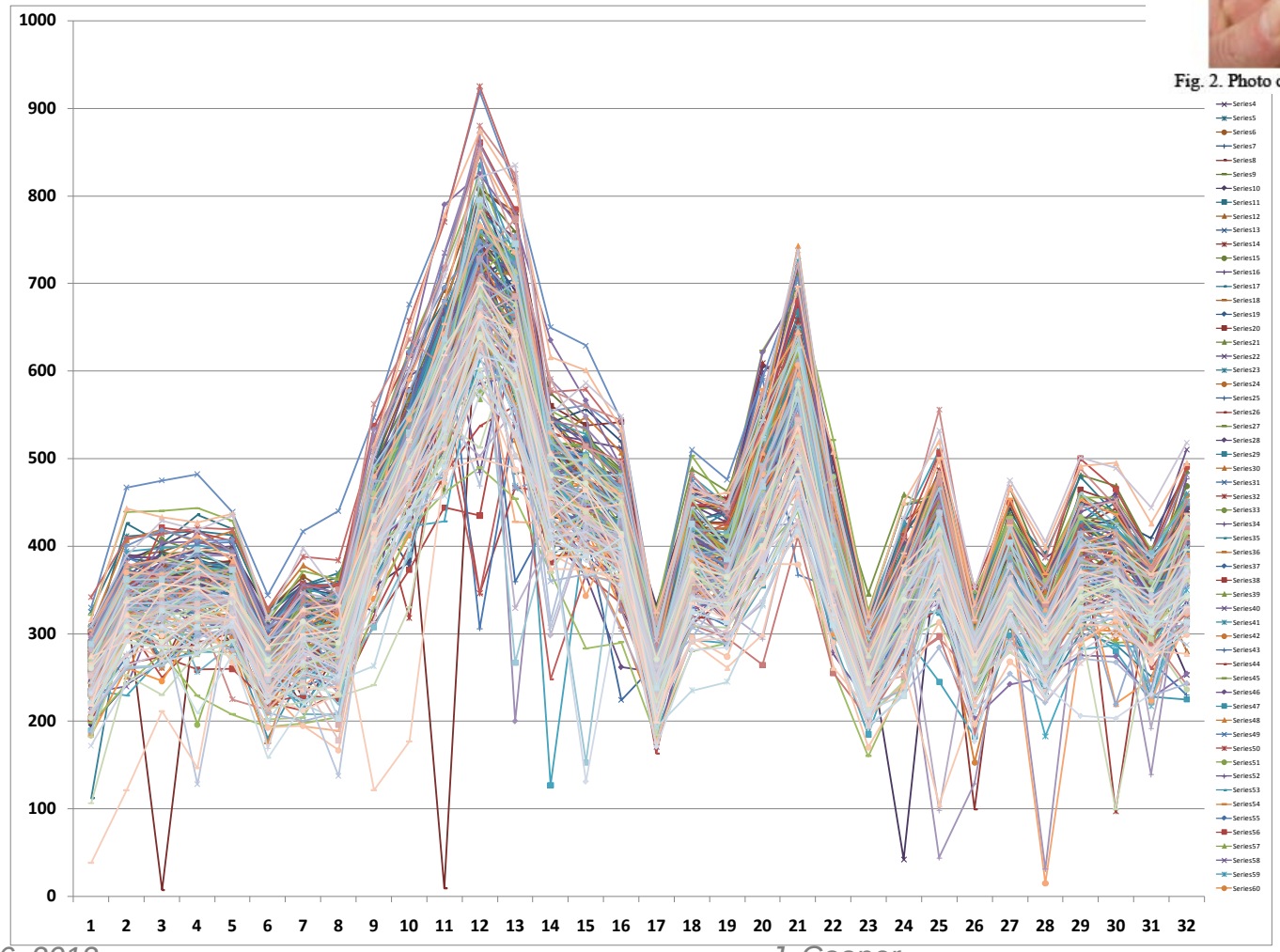
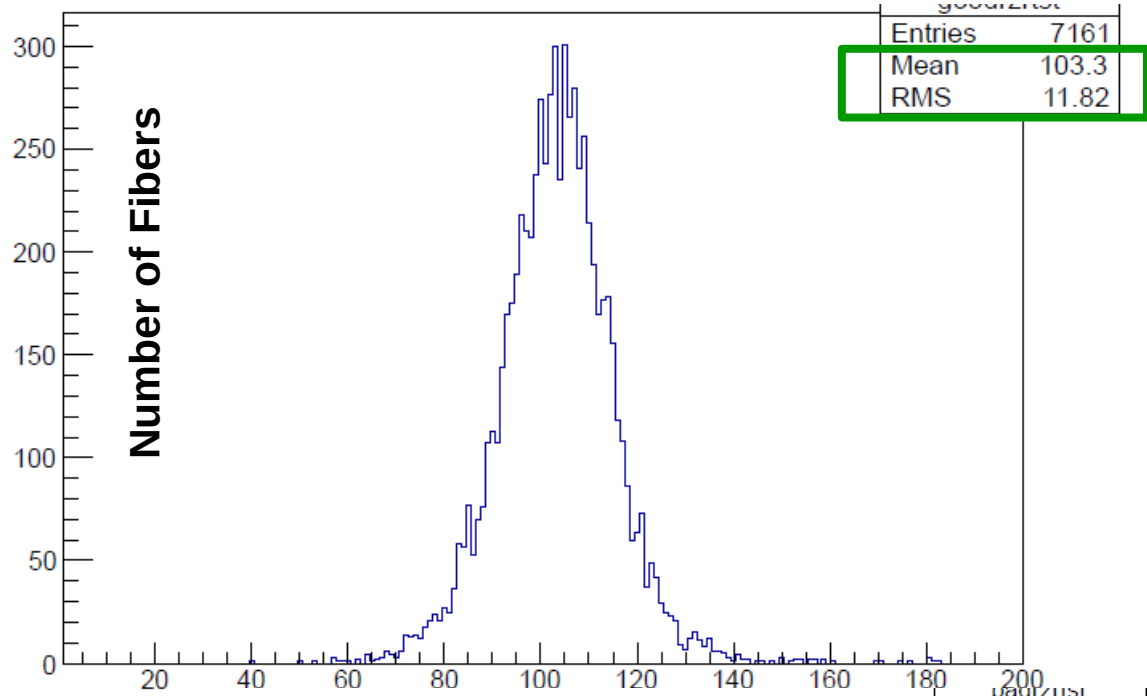


Fig. 2. Photo of light router during construction

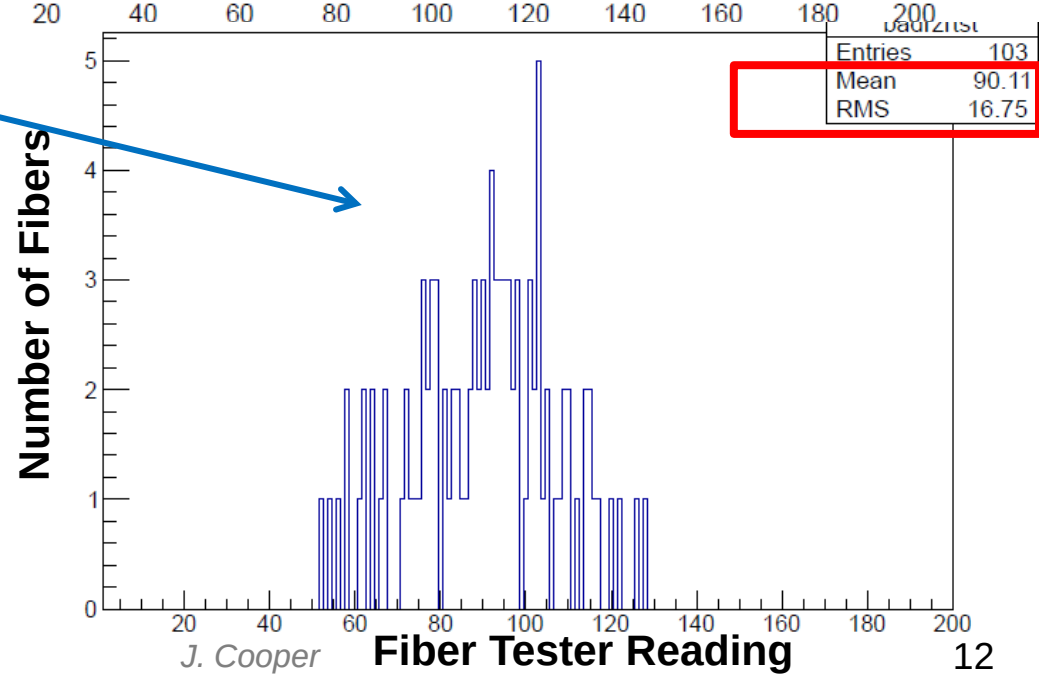


MSU Fiber Tester vs. Visual Fiber Check

- The MSU tester is calibrated by taking the average of each cell on the previous slide, then making a histogram of the values, arbitrarily centered at 100
  - Result to right for cells with no visual fiber damage

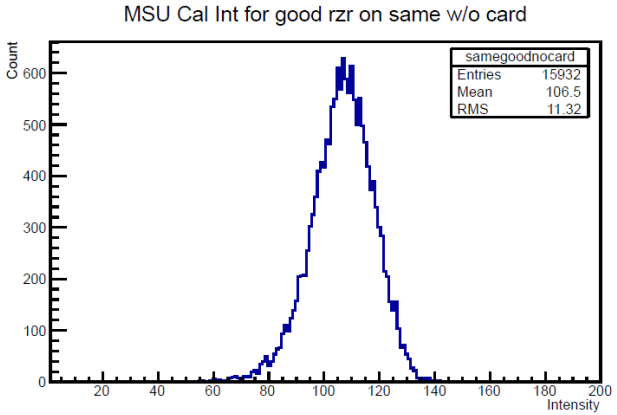


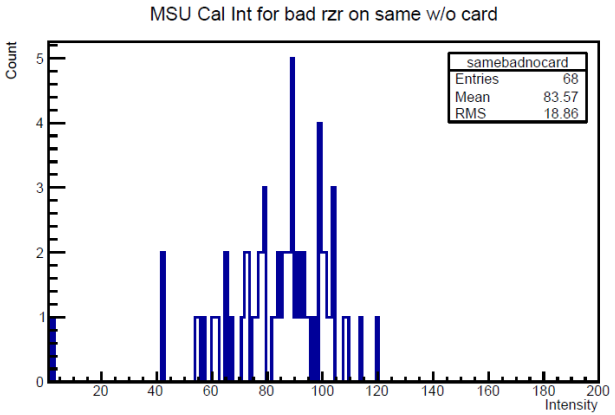
- Then the same distribution is formed for those cells with visual fiber damage
  - A lower mean of 90, but no separable difference between good fibers and visual damaged fibers.
  - Still should separate 103 entries into those where damage is on LED side vs. those on other side of loop, distribution may split?

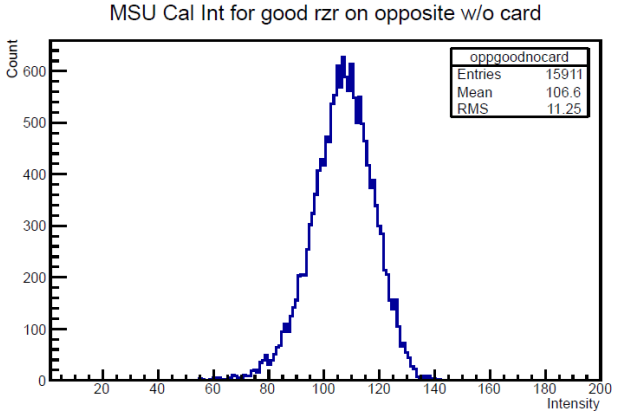


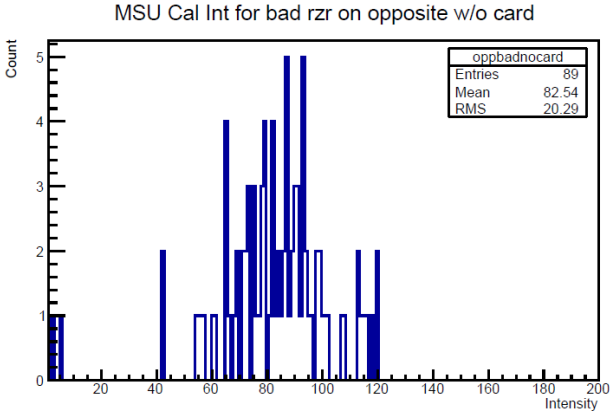
More on MSU tester

- Since the damage is near one end, we checked if the MSU tester could tell the difference
  - MSU tester flashes a red LED in one end and reads out the other
  - Maybe the into the reflective side is transmission is reduced?
  - No









Is it even “damage”?

- Maybe this damage is not significant?
  - Transmission of light through the fiber is exactly what we want
    - MSU testers say the transmission is OK at ~ 90% level
  - BUT there could be a 10% damage effect
    - e.g., scatter some light out of the APD pixel area via damage right at end of a fiber
  - And, it might get worse with time if due to internal crazing

- We decided the way forward was to eliminate this “damage” and get on with production

Module Production Status

- We are in full production at the scheduled rate of 120 – 138 modules per week.

Ken Heller Reports of **TOTALS TO DATE**

Summary Date	4-Jun	11-Jun	18-Jun	25-Jun	2-Jul	9-Jul	16-Jul	23-Jul	30-Jul	6-Aug	13-Aug
Failed visual fiber test	82	202	187	190	191	192	203	205	146 have one damaged fiber		
Failed MSU fiber test	2	13	13	13	13	13	14	14			
Failed flycut test	2	2	2	2	2	2	2	23			
Failed Optical connector Leak test	24	22	22	22	22	22	22	22			
Failed inner seal leak test	1	5	20	19	10	10	8	7			
Failed outer seal leak test	1	4	6	3	5	6	6	4			
Failed final QA	1	7	6	6	7	7	7	7			
Total Failures	113	255	256	255	250	252	262	282			
Total Good Modules	247	355	464	583	711	825	947	1096	2.85 blocks worth		
% Failures	31%	42%	36%	30%	26%	24%	21%	19%			
Good Modules completed by week	36	114	124	119	133	114	122	149	Rate		

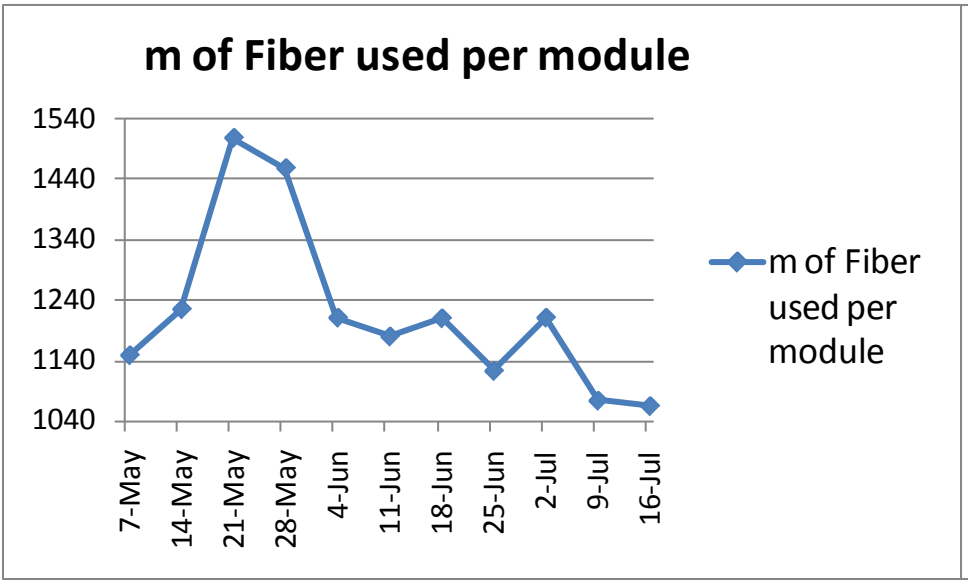
John Cooper calculation of **WEEKLY RATES** & interpretation after talking with Ken Heller

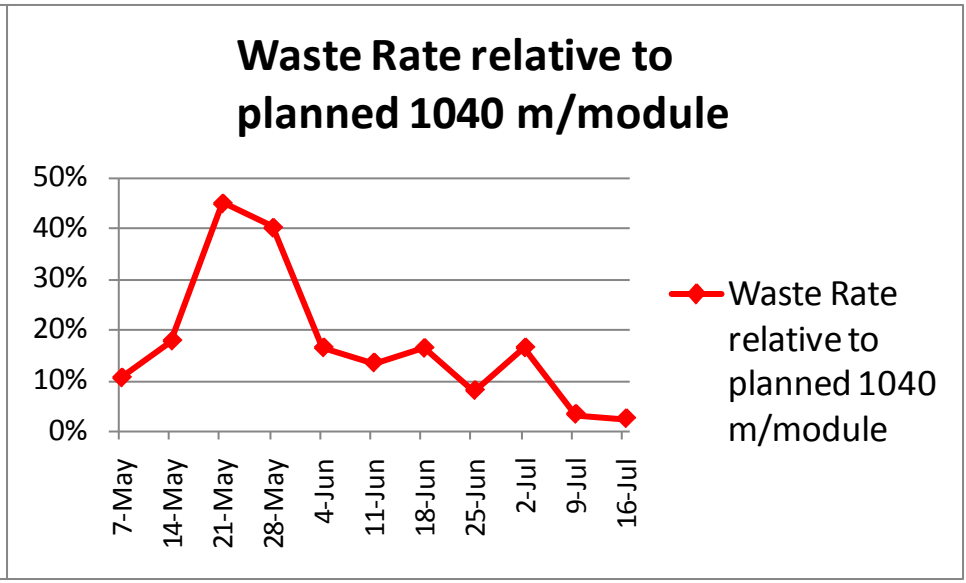
Delta from Previous Week	4-Jun	11-Jun	18-Jun	25-Jun	2-Jul	9-Jul	16-Jul	23-Jul	30-Jul	6-Aug	13-Aug
Failed visual fiber test	22	120	(15)	3	1	1	11	2			
Failed MSU fiber test	2	11	-	-	-	-	1	-			
Failed flycut test	2	-	-	-	-	-	-	21			
Failed Optical connector Leak test	24	(2)	-	-	-	-	-	-			
Failed inner seal leak test	1	4	15	(1)	(9)	-	(2)	(1)			
Failed outer seal leak test	1	3	2	(3)	2	1	-	(2)			
Failed final QA	1	6	(1)	-	1	-	-	-			
Total Failures	53	142	1	-1	-5	2	10	20			
Total Good Modules per Week	31	108	109	119	128	114	122	149			
% Failures each Week	63%	57%	1%	-1%	-4%	2%	8%	12%			

(n) means fixed / revised

How much fiber does it take to eliminate the visual damage?

- Over the last 4 weeks, averaged 5 - 10%
  - 10% more fiber would cost 1.25 M$
  - 5% would cost 0.63M M$





Fiber Damage Summary

- We don't know if visual fiber damage translates into a problem
  - 90% transmission even when "damages"
  - "Fear" that it might get worse, but no evidence
- Strategy has been to eliminate the visual fiber damage by replacing single fibers during construction
  - This DOES WORK if we don't waste too much fiber doing it.
    10% waste = 1.25 M$
  - Also need to quantify QA effort being done to find these fibers
  - And the labor to replace them.
- We are now doing an accounting of fiber wastage and the labor required to find and replace visual damaged fibers
  - Number of fibers with visual damage is small, about 1 fiber out of every 6 modules or 0.5%
  - We have 146 completed modules built so far with only 1 fiber "damaged". WE WILL USE THESE IN THE FAR DETECTOR.