T2K HORN PROJECTS AT COLORADO

E. D. Zimmerman
University of Colorado

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T2K Horn Projects at Colorado

- History of collaboration on T2K beam projects
  - First Horn 2
  - Second Horn 2
- Present and future projects
- Lessons learned so far

Collaboration between CU and KEK

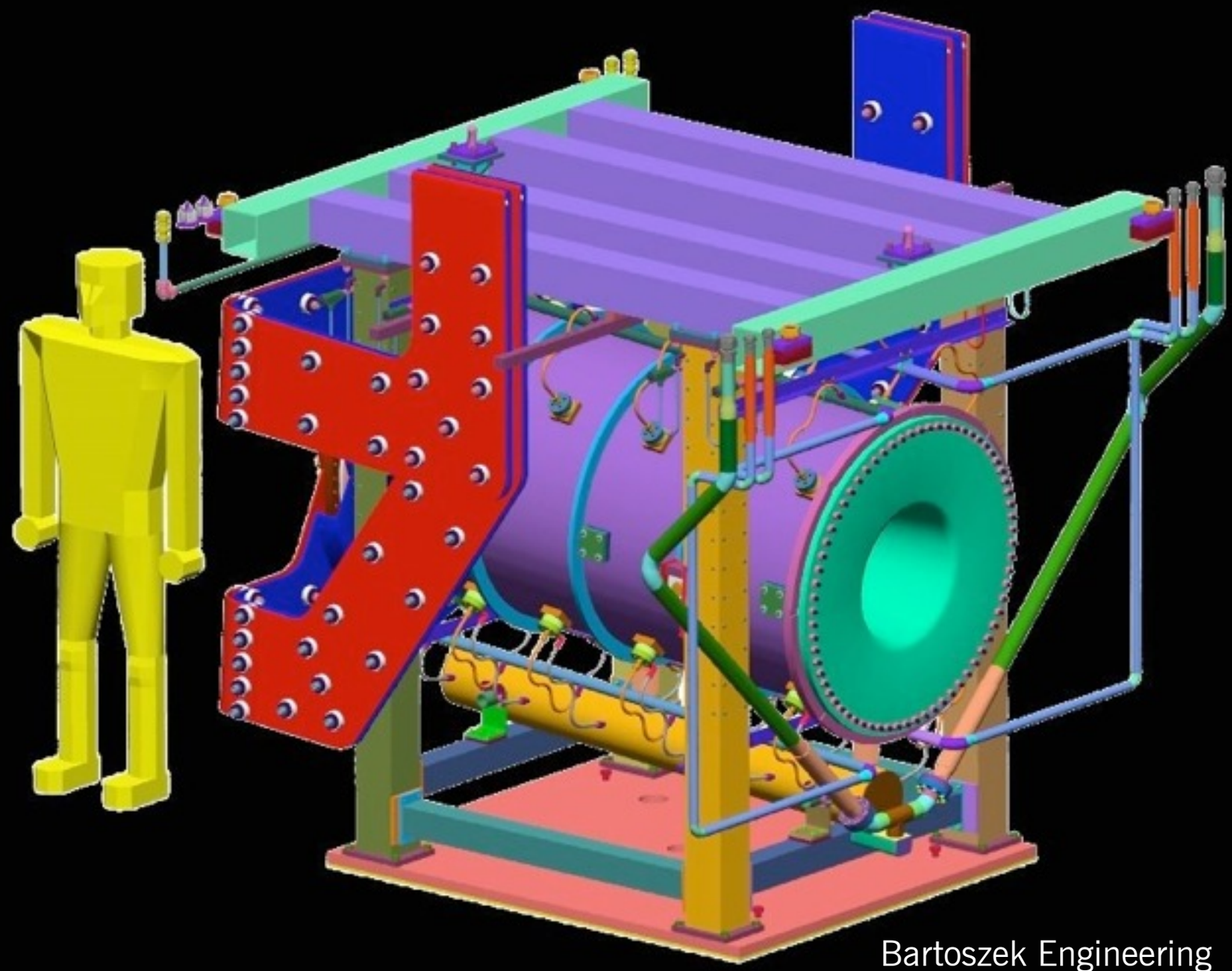
- 2003: began CU work on horn system, with CU and Bartoszek Engineering (at 4th NBI!)
- Began with horn cooling studies, horn conductor geometry Monte Carlo work
  - Undergraduate thesis 2006: Joshua Spitz
- Horn field measurements
  - Undergraduate thesis 2008: Zhon Butcher
  - See NBI2012: talk by Andrew Missert
- Next: engineering design and construction of Horn 2
- Horn 2 and field measurement system were part of original DOE-funded US T2K project

Colorado Horn 2 project

- Why horn 2?
  - Horn 1 area has more interfaces (target, OTR, etc); would be more difficult to specify. Large risk of mistakes leading to impossible installation. Also, work on Horn 1 had already begun when we joined collaboration
    - …but now that these issues are stable we are considering building a spare Horn 1
- Horn 3 is so large that transportation would have been a major challenge.
- Horn 2 “just right.”

Colorado horn project

- Originally, did not intend to have top frame part of project
- …but eventually it became clear it was essential to build the top frame with the horn
- Pre-construction rendering
- Everything on this image was provided by Colorado (except the yellow robot)

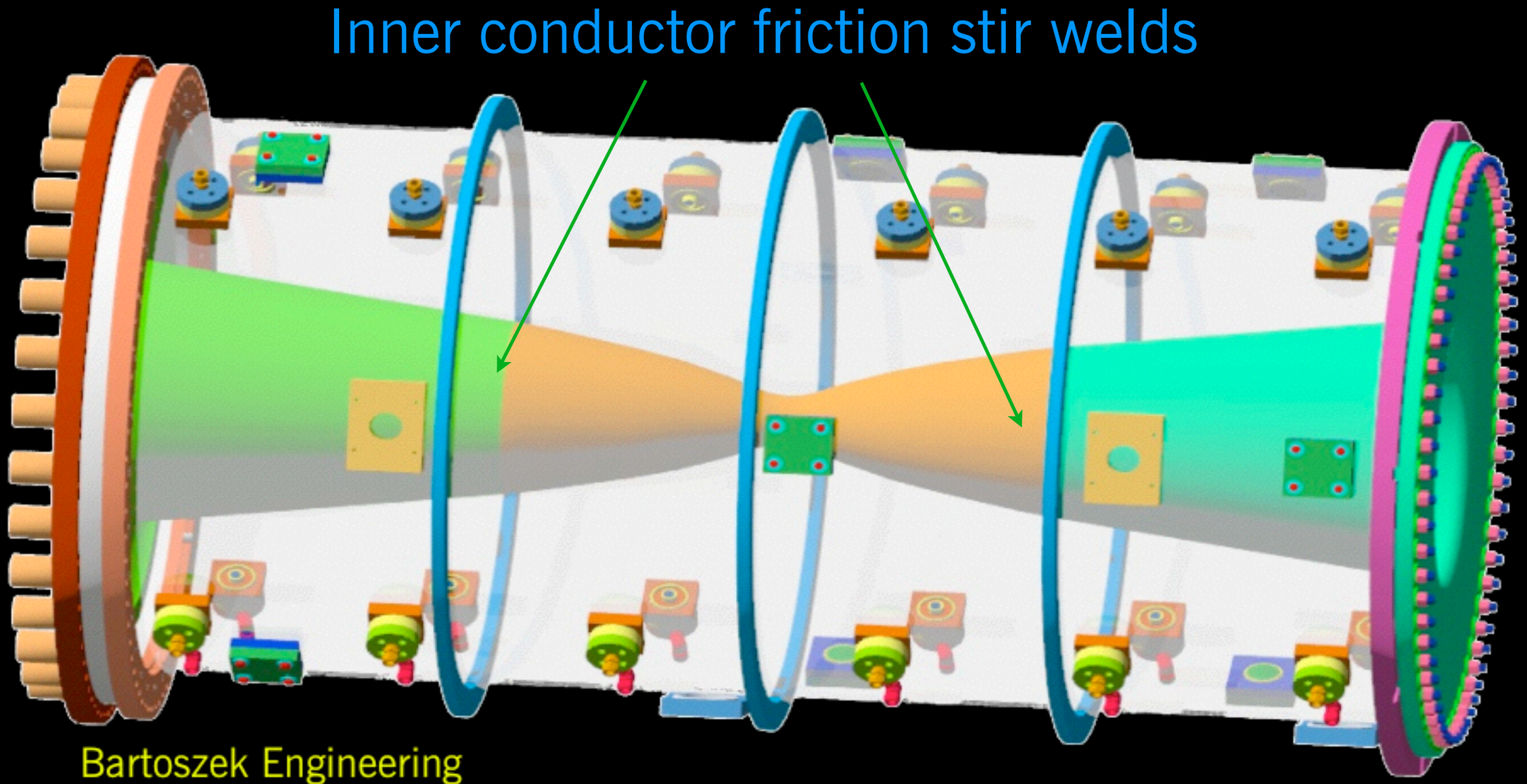


Bartoszek Engineering

Design team

- 1 physics faculty (EDZ)
- 1 contract engineer (Larry Bartoszek), about 1/2 time for three years
- 1 postdoc (Martin Tzanov)
- Collaboration with KEK:
  - Twice-monthly video meetings with KEK neutrino group; extensive discussion about the whole 3-horn system. Design and development tasks in common.
  - Bartoszek also hired by KEK for help on Horn 1, 3 design

Horn conductors



Assembly

- Final assembly of the horn took about two-three months at Colorado, with the following crew:
  - 1 faculty (EDZ)
  - 1 postdoc (Tzanov)
  - 1 undergraduate
  - 1 technician (+ 1 temp on a few days when more hands needed)
  - 1 engineer (Bartoszek, about 1/4 time)

Horn 2 assembly at CU

Connecting stripline ears

Plumbing connections

Project management visit

Horn 2 at CU

Ready for shipping, early July 2008

Second (“spare”) Horn 2 project:
Major differences from original project

- Funded by KEK via REPIC Corporation: very different funding/ management scheme
- New crew:
  - Postdoc: Martin Tzanov → Stephen Coleman
  - Undergrad: Eric Hansen → Daniel Poulson
  - Graduate student: Andrew Missert
  - Technician: Eric Erdos mostly busy with other projects, spent little time on horn
  - New KEK contacts: Ichikawa, Sekiguchi → Sekiguchi, Ishida

Project timeline

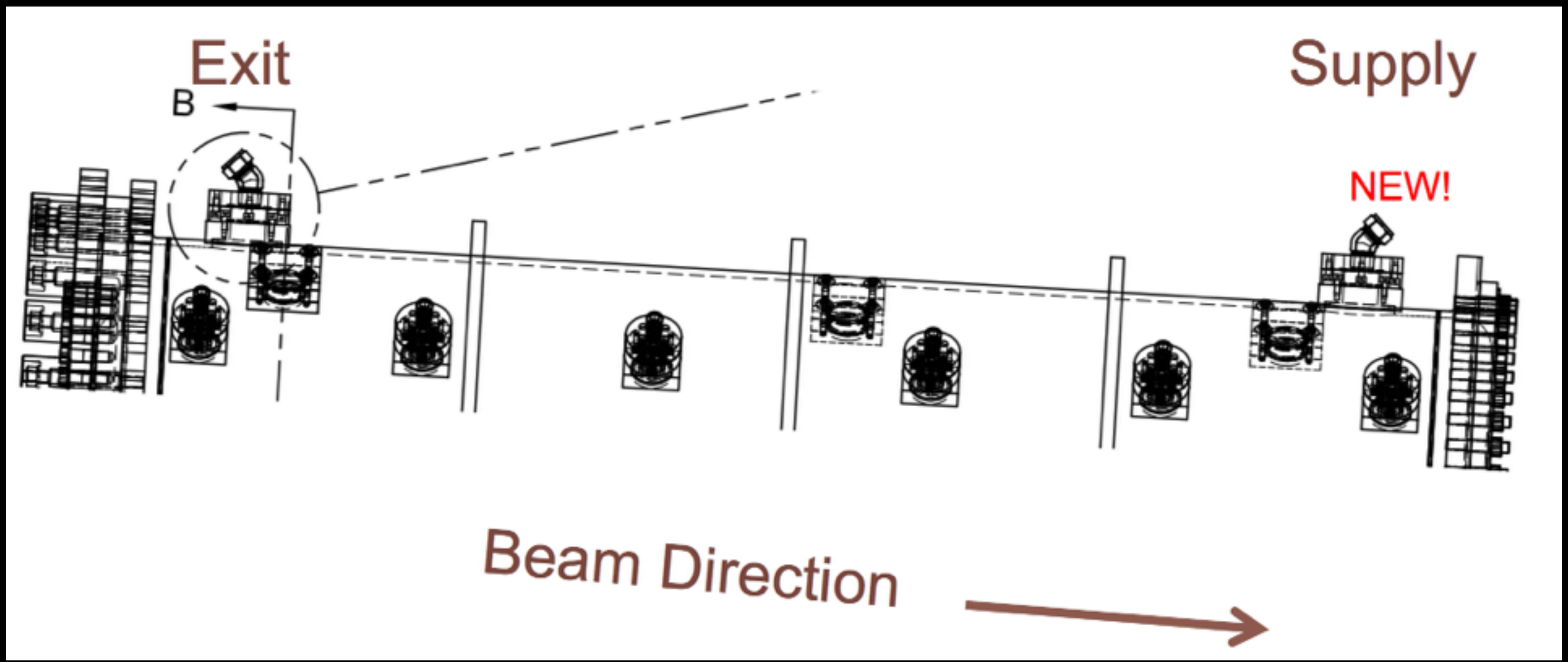
- Fall 2011: first parts ordered, engineering drawings updated
- April 2012: Contract between REPIC and CU for horn assembly finalized
- Summer 2012: most of assembly completed
- November 2012: NBI at CERN (See Stephen Coleman's talk)
- February 2013: horn delivered to KEK
- Summer 2013: horn tested
- February 2014: Horn 2 replaced

More differences from previous horn: scope

- Didn't need to produce inner conductor: first Horn 2 project produced two inner conductors
- Also, had a spare large ceramic ring, but KEK provided one as a backup (so we still have one left!).
- No striplines provided except the "ear" pieces that mount directly to horn
- Of course, we had much assembly infrastructure and tools from the previous project
- We also had 624 photographs from first assembly — we were almost obsessive about documenting every step this way.

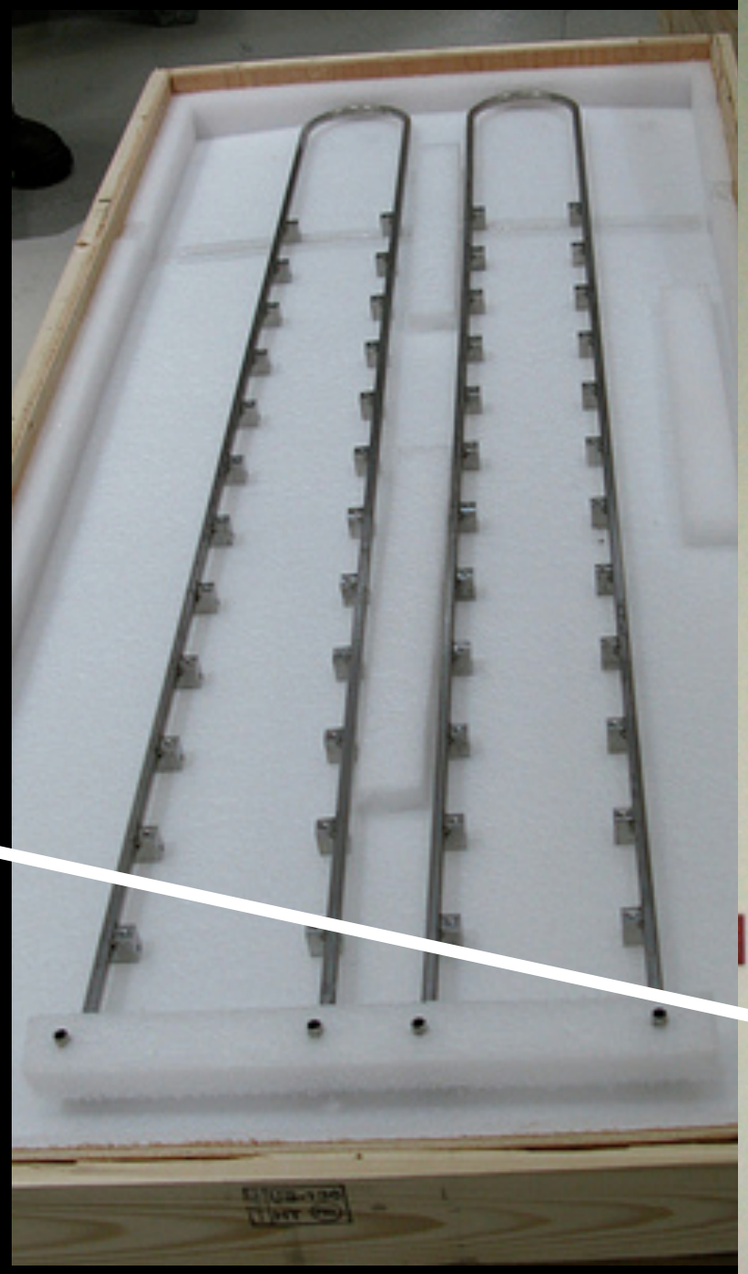
New developments in second Horn 2

- New helium port allows through flow:



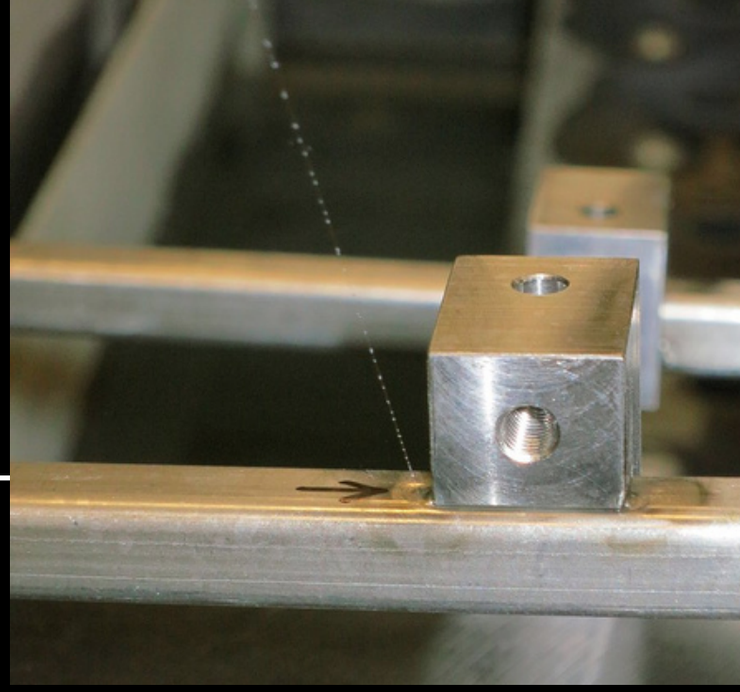
Frame cooling

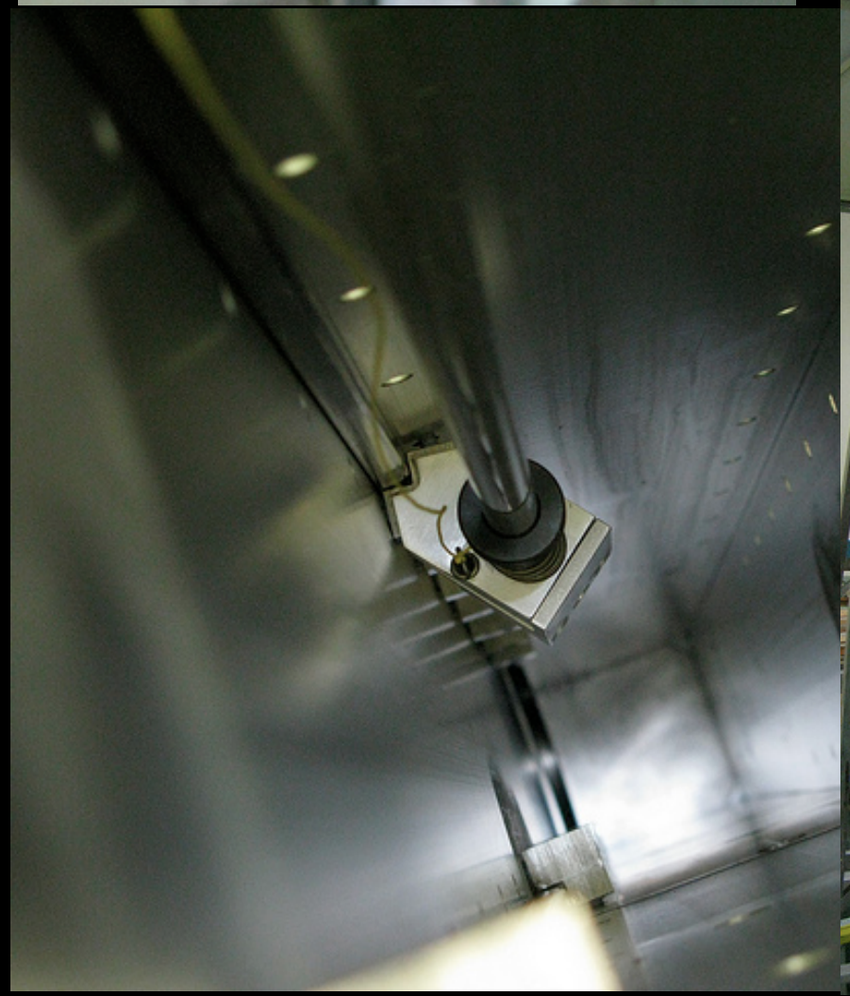
- Loops of square-channel stainless tubing
- Old horn: blocks were welded to tubing and had tapped holes
- Screws from outside frame into blocks pulled tubes into the frame column corners for thermal contact
- This worked fine the first time (maybe we were lucky)



New frame cooling

- Tubes were damaged by block welding process for second Horn 2: water leaks!
- Redesigned to use with new bent tubing with blocks not welded, just pressed against frame using same screw holes
- Developed a “grabber tool” to hold the blocks while someone screwed the blocks into the column
- Assembly took less than a day





New top frame alignment

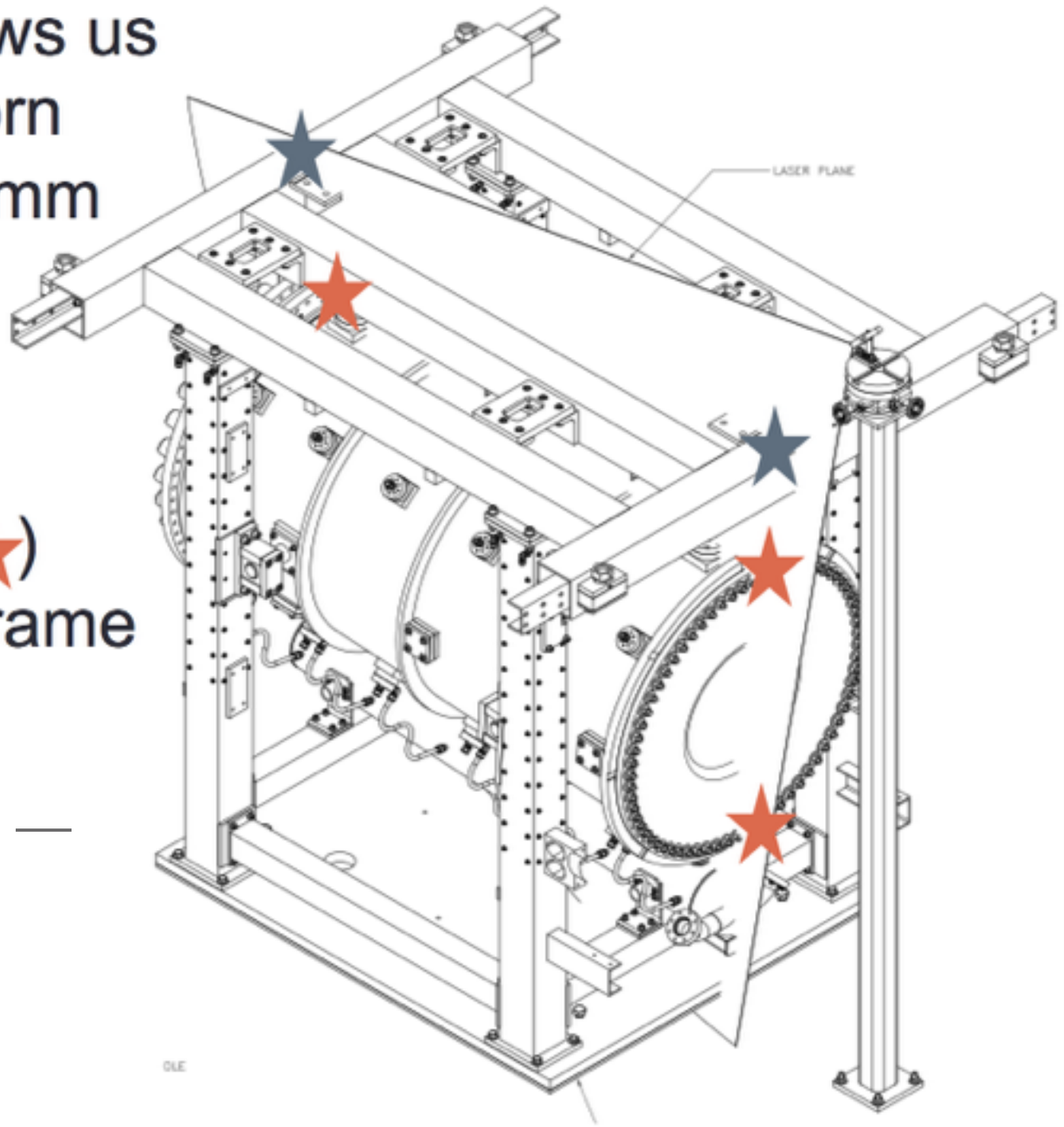
Laser alignment system allows us to locate the center of the horn relative to the top frame to 1mm

(Alignment was eye-balled last time)

Locate 3 points on the horn (★) and 2 scribe lines on the top frame (★)

- First horn was 3mm off at one end — outside tolerance.

- Tried to get 1mm this time.



Plumbing connections

- Old design: indentations for pipes were on parts welded directly to top frame

- Difficult to maintain spacing to required (1mm) precision over long distance

- Had to cut off and replace at a late stage

- Replaced with bolted holders with adjustment frames

Issues

- Most problems (as last time) were in manufacturing of parts
- One vendor (top frame, columns, stripline ears) had trouble maintaining precision of aluminum welds
- Some vendors made a couple of stupid mistakes…
- Vigilant supervision of vendors was critical to the success of the project!

The worst day

- Drain and supply water pipes arrived completely destroyed by shipper (crate was likely dropped from a great height)
- Replacing these parts set our schedule back by over a month

Ready for shipping

Shipping

- Basically the same shipping technique as last time:
  - Custom crate built around the horn
  - Sent on air-suspension truck to Los Angeles
  - Korean Air Cargo B747 to Narita via Seoul-Inchon

Current status and future…

- Horn was delivered in February 2013; installed in target station in February 2014 as part of pre-emptive replacement of all T2K horns
- We're continuing our collaboration with KEK and Bartoszek Engineering on horn system:
  - Work in past year on water nozzle ports: checking integrity of current design with a mockup sitting under a water reservoir
  - Also investigating new nozzle port design
- Our horn factory is idle now, but awaiting new project: discussing with KEK possibility of us assembling spare Horn 1 next year

Thanks to our KEK colleagues for continuing a productive collaboration!