Construction and Test of sMDT Chambers for the ATLAS Muon Spectrometer

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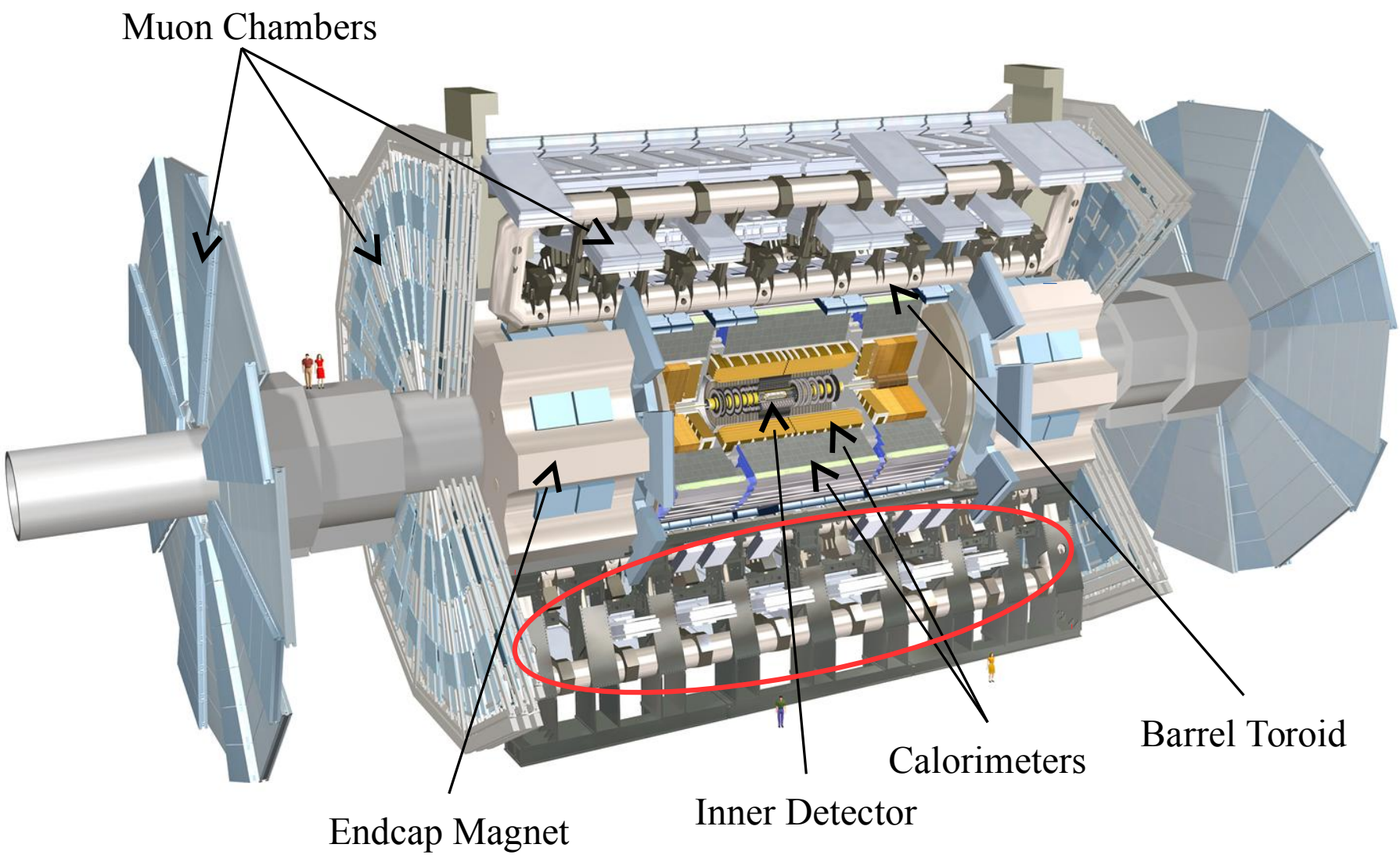
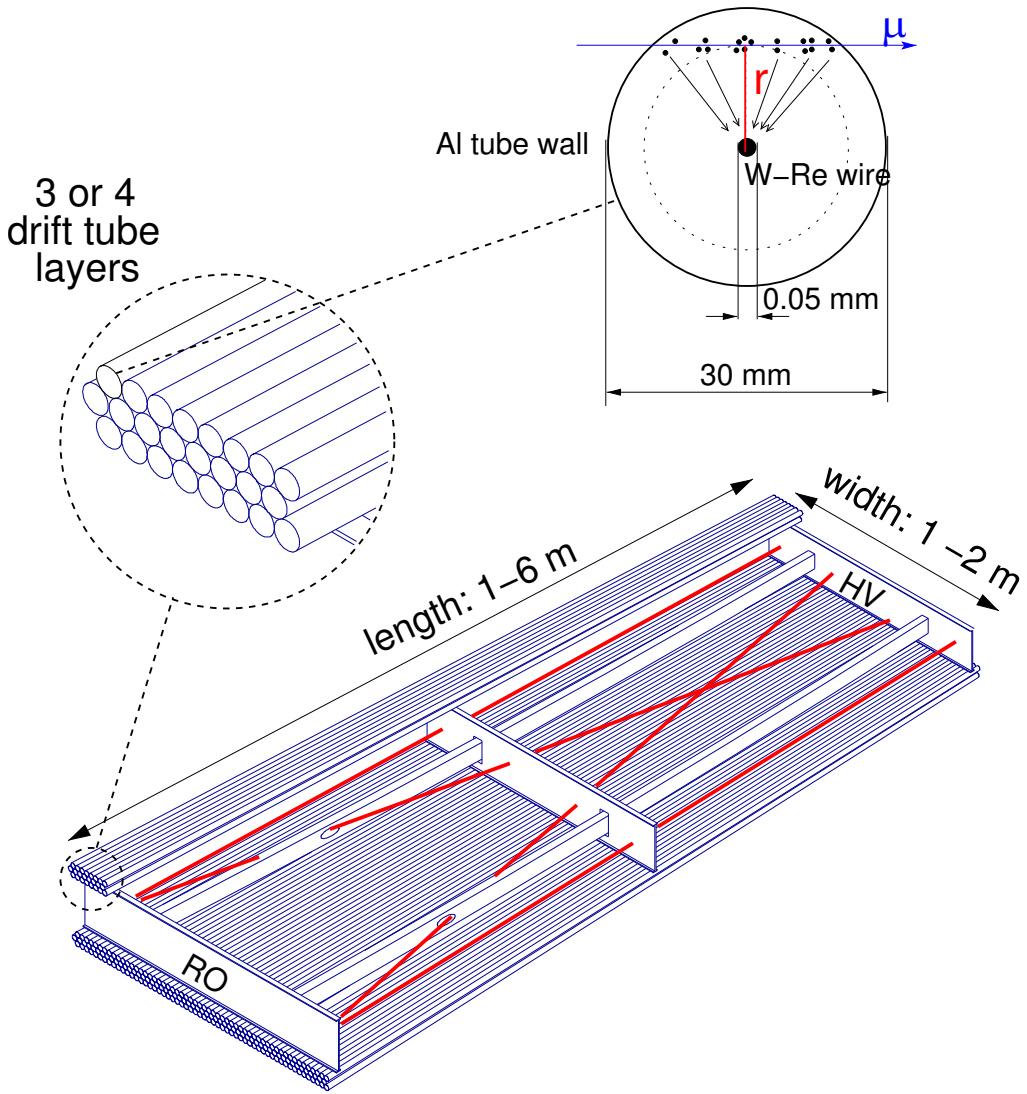
The ATLAS Experiment



Standard Monitored Drift Tube (MDT) Specifications

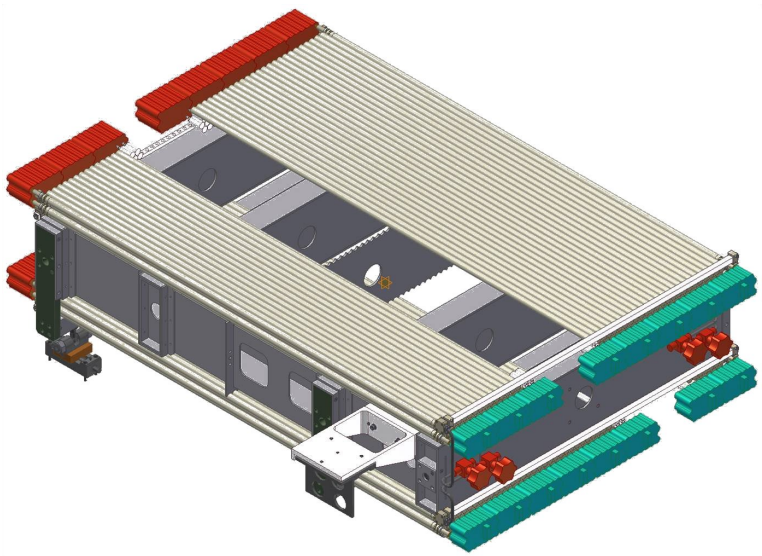


- 93% Ar, 7% CO_2 gas mixture
- 3 bar absolute pressure in the tubes
- HV of 3080 V
- Gas gain: 2×10^4
- Wire position tolerance: $\Delta r < 20\,\mu\mathrm{m}$
- Tube diameter: 30 mm

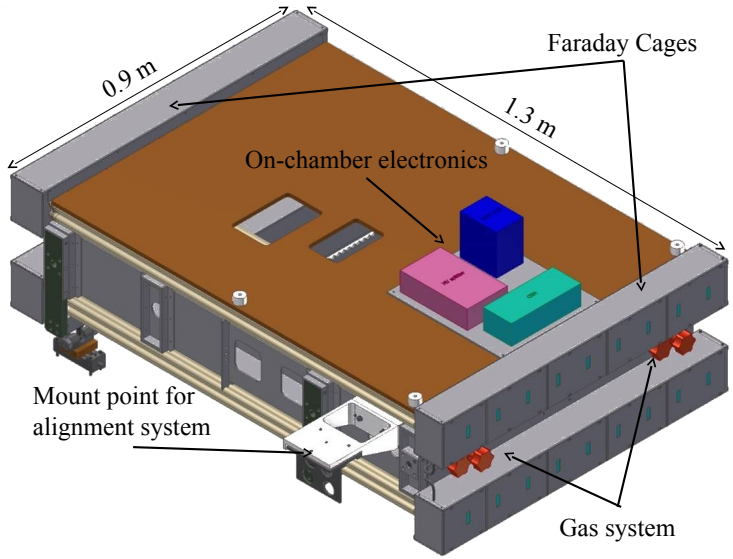
Each chamber has 2 multilayers of tubes. Each multilayer has either 3 or 4 layers of tubes $\rightarrow$ Chamber resolution of 40 $\mu\mathrm{m}$

small diameter MDT (sMDT) Chamber Parameters

- 12 Chambers in total
- sMDTs have tubes with half the diameter (15 v. 30 mm)
- Tube length of 1.1 m



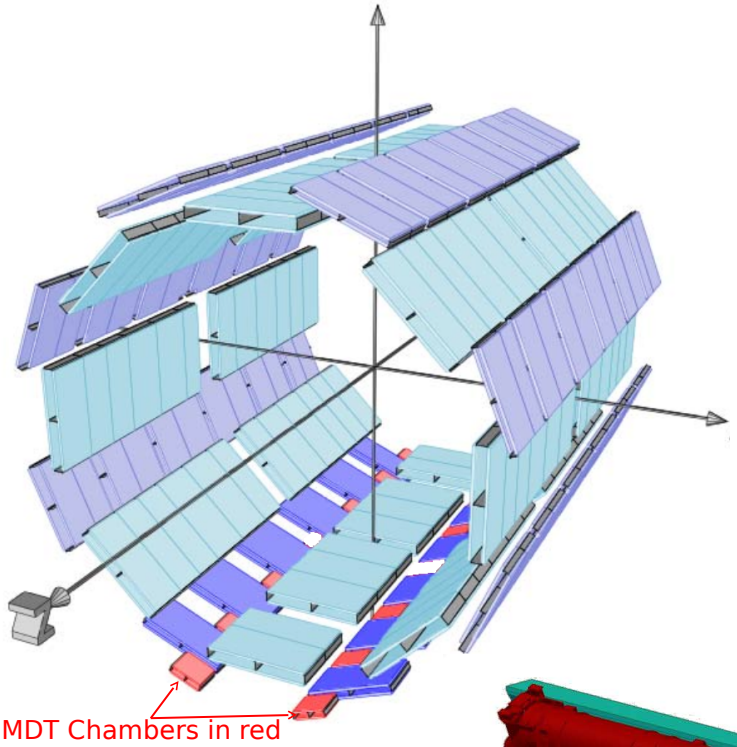
- 54 tubes per layer
- 2 multilayers, each with 4 layers of tubes
- 17 cm between multilayers

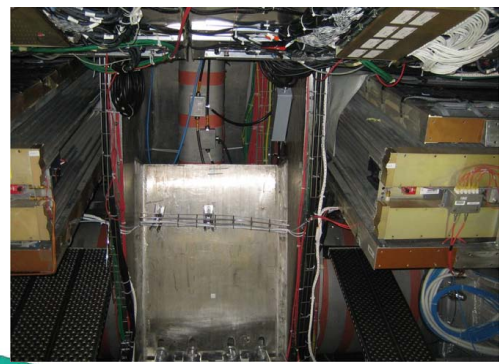


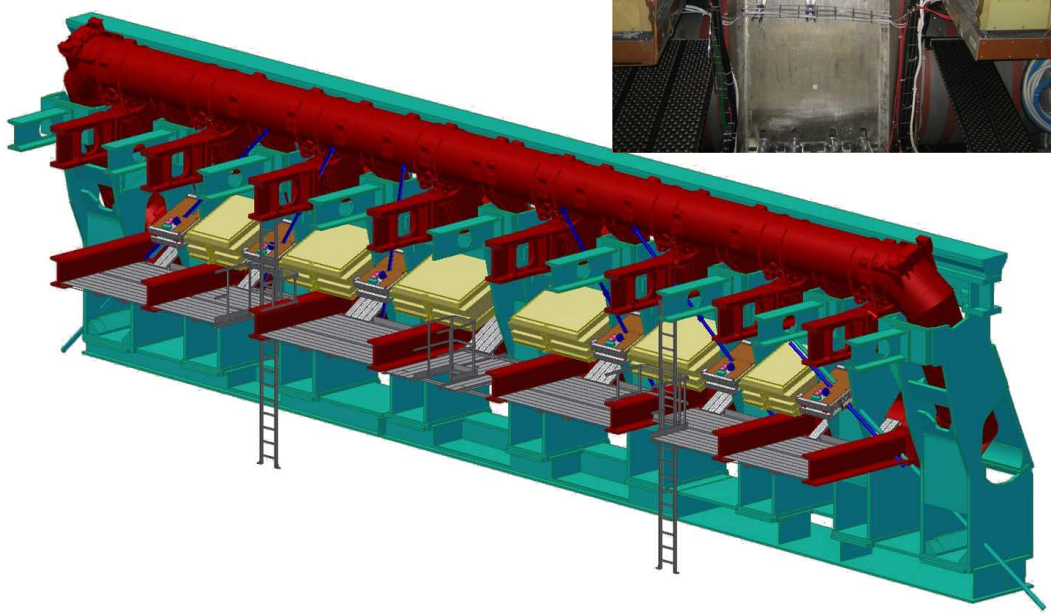
$\Rightarrow$ more than 5000 tubes

Gaps in sMDTs are for the detector alignment system.

Location of New Chambers



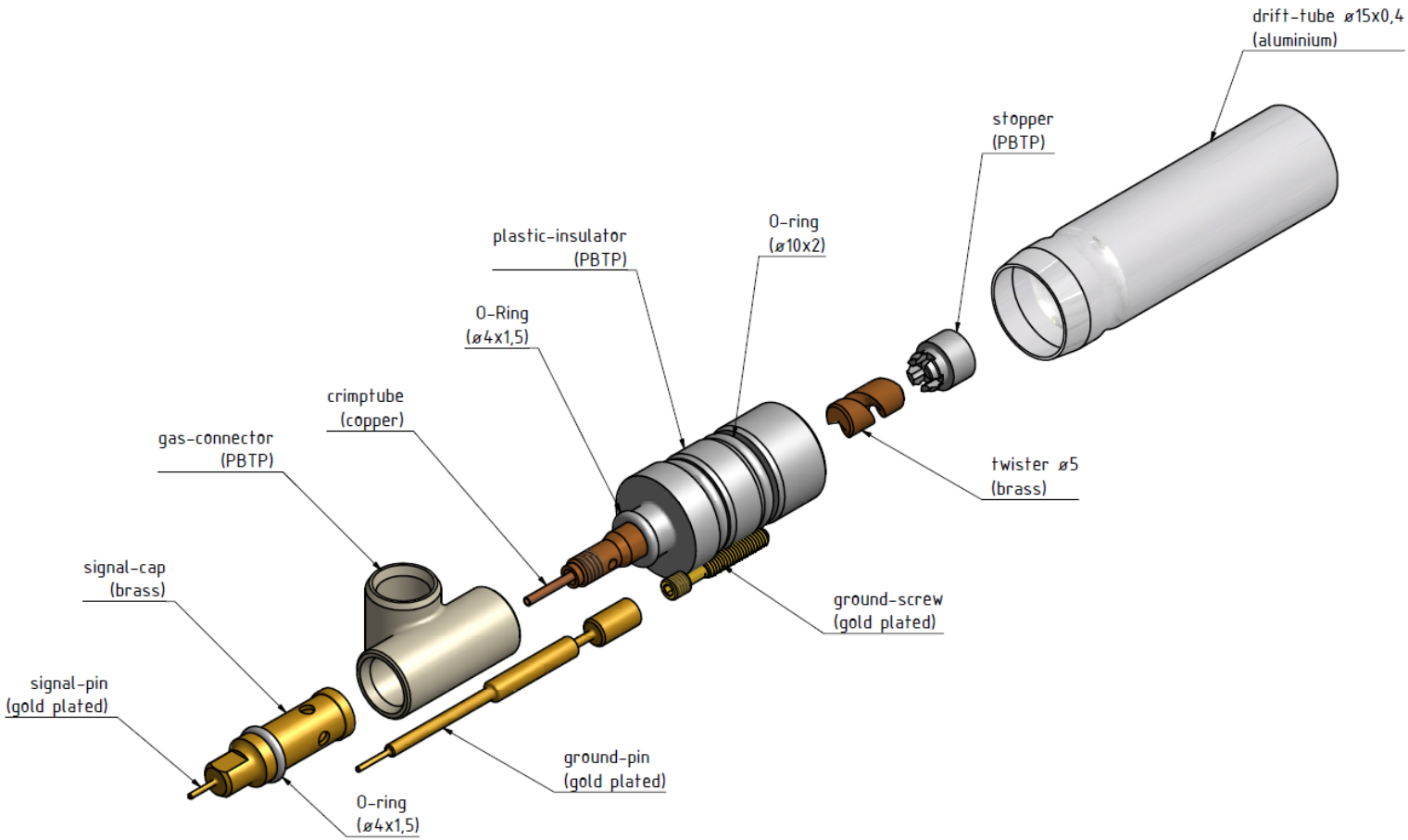




sMDT versus MDT chambers

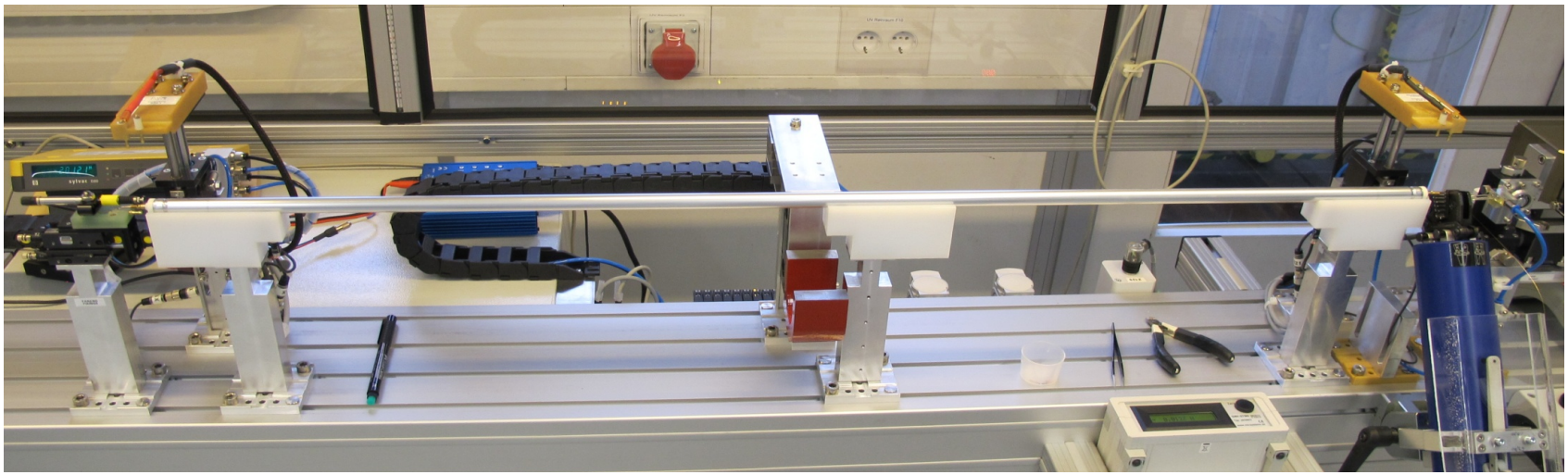
Diameter	30 mm	15 mm
Drift Time	700 ns	185 ns
Chamber resolution	~ 40 μm	

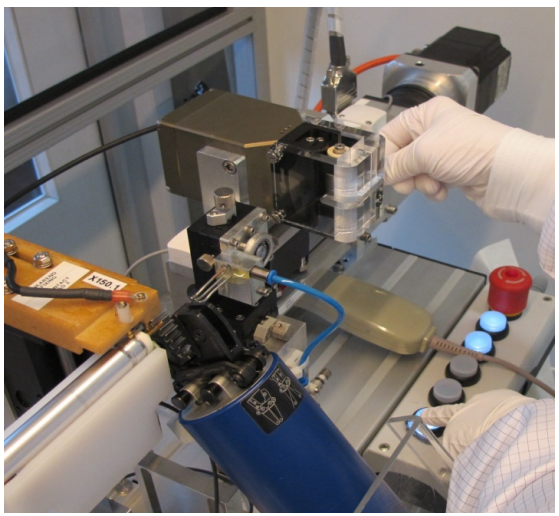
Tube Endplug



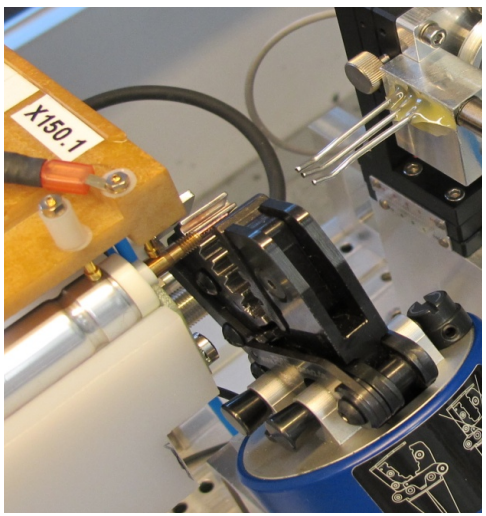
Wire Threading and Tensioning

Wire tension: $T = 355 \pm 15$ g

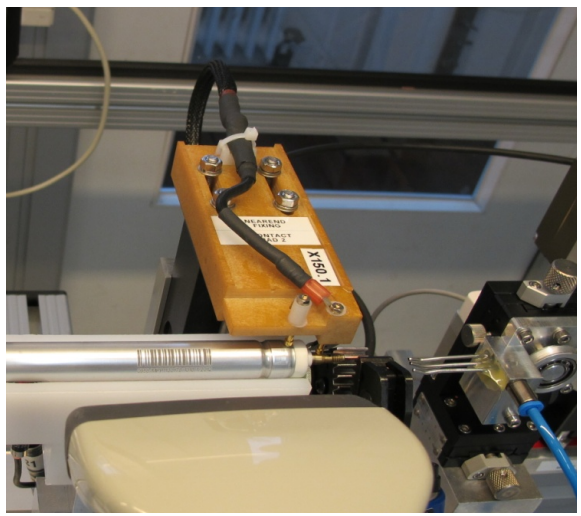




Tensioning Wire



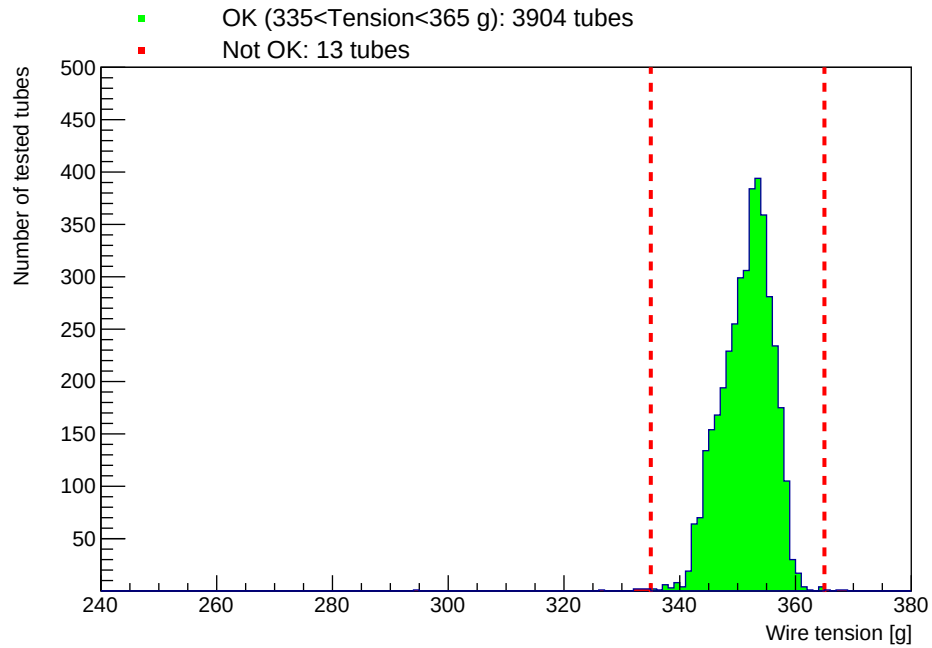
Crimping

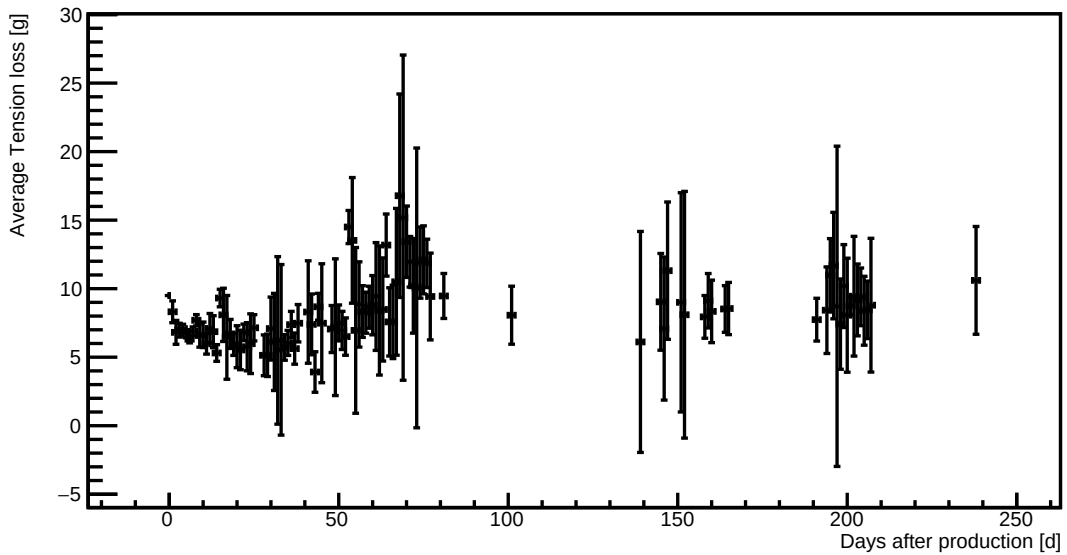


Tension entered into database

Tension Testing Results

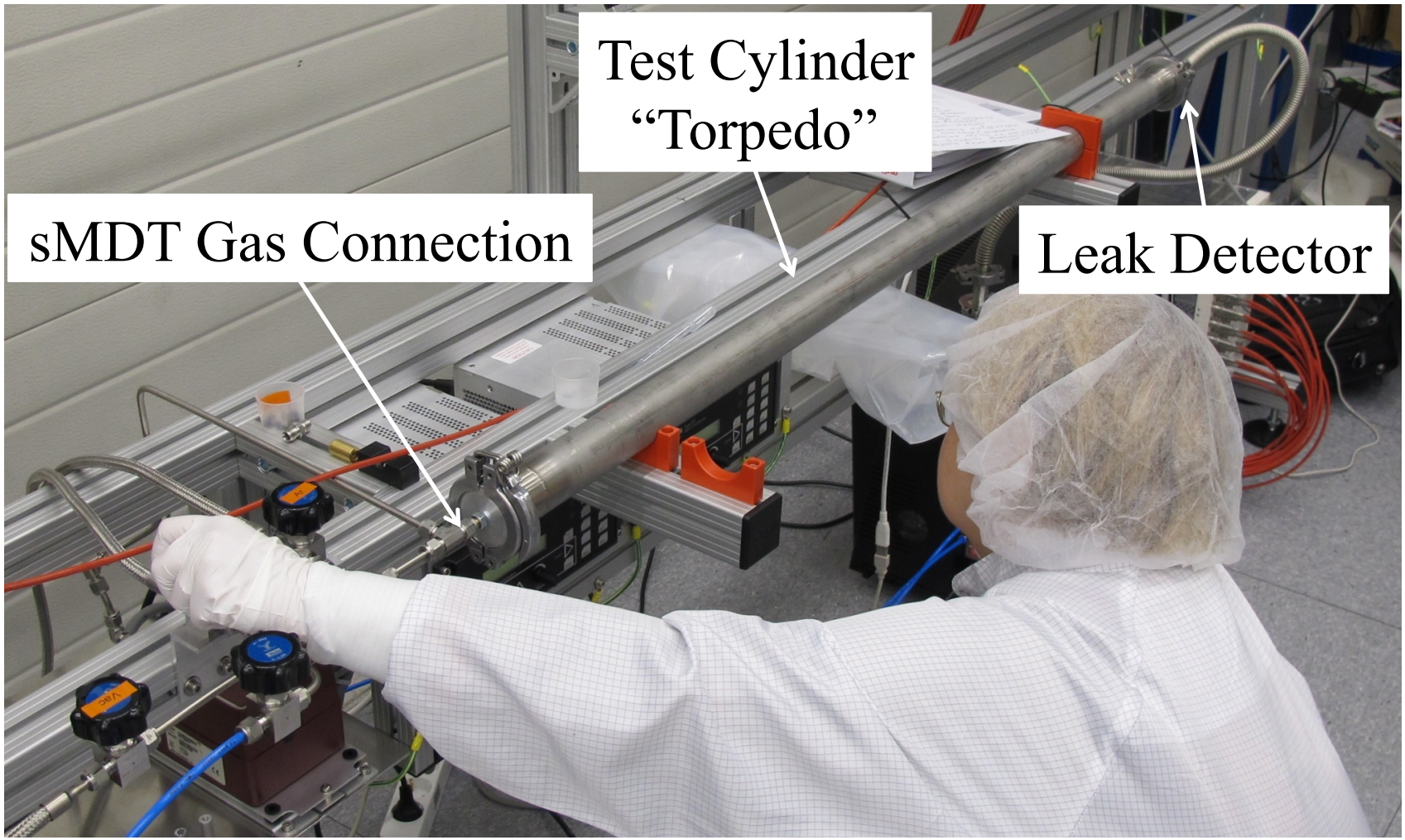
- 99.67% of tubes passed (right)
- Tension spec. ($335 < T < 365$ g) shown in red
- Repeated tension measurements shows small ($5 - 10$ g) loss (bottom)
  - Accounted for in initial tensioning of wire
  - Final tension checked before tube installation





Gas Leak Rate Measurement

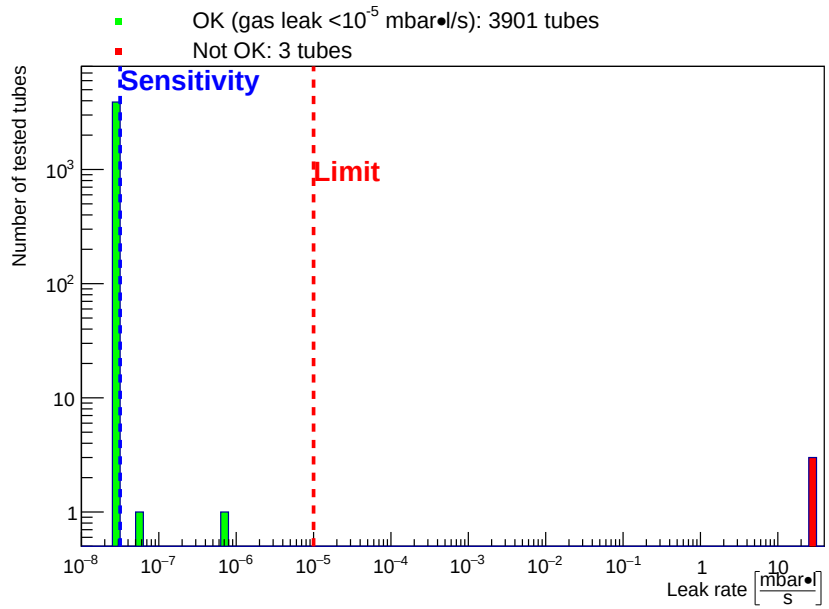
1. Tube is inserted into an evacuated testing cylinder ("Torpedo")
2. Tube is filled with 95% Ar, 5% He to 2 bar
3. Leak detector measures gas leakage into the Torpedo.



Leak rate must be $< 10^{-5}$ mbar $\bullet$ l/s

Gas Leak Test Results

- 99.92% of tubes passed leak test (right)
- Red dotted line shows acceptable leak rate limit ($< 10^{-5}$ mbar•l/s)
- Blue dotted line shows sensitivity limit of the leak detector (3×10^{-8} mbar•l/s)
- Values have been translated from He to Ar leak rates



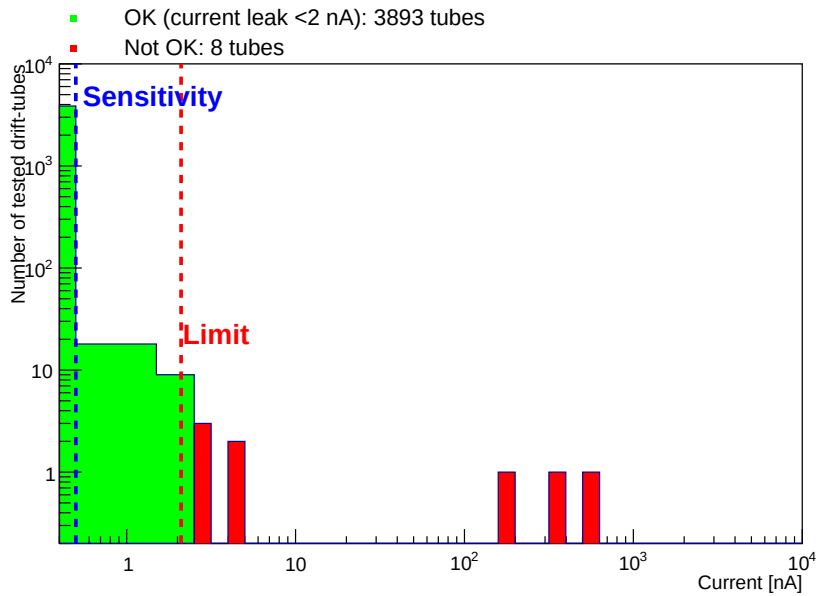
HV Testing

- Tubes are filled with nominal gas (93% Ar, 7% CO_2) at 3 bar
- Voltage raised to 3015 V (working HV is 2730 V)
- Dark current from tube is measured after current stabilizes ($\sim$ 10 min)

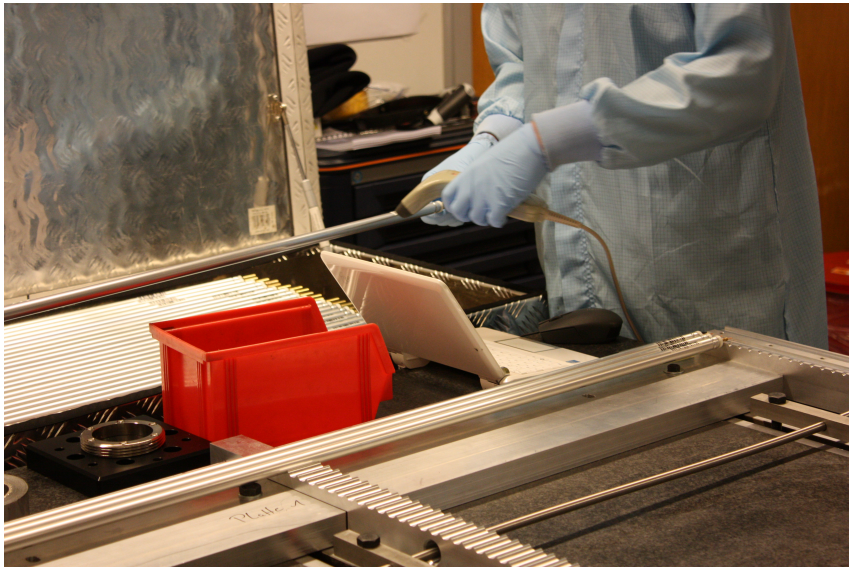
Setup can measure up to 10 tubes at a time
The maximum allowed dark current I_{max} is 2 nA

HV Test Results

- 99.79% of tubes passed test (right)
- Red dotted line shows acceptable current limit (< 2 nA)
- Blue dotted line shows sensitivity limit of the current measurement (0.5 nA)

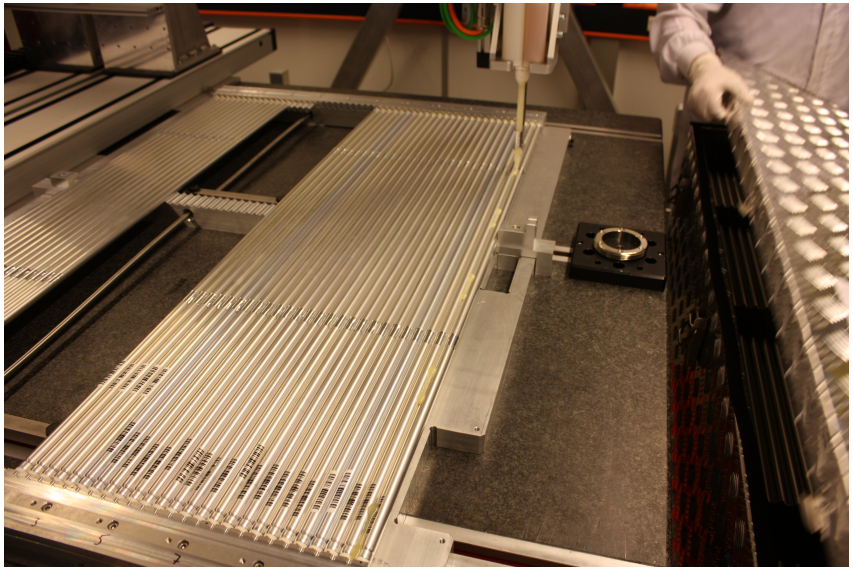


Chamber Assembly (I)

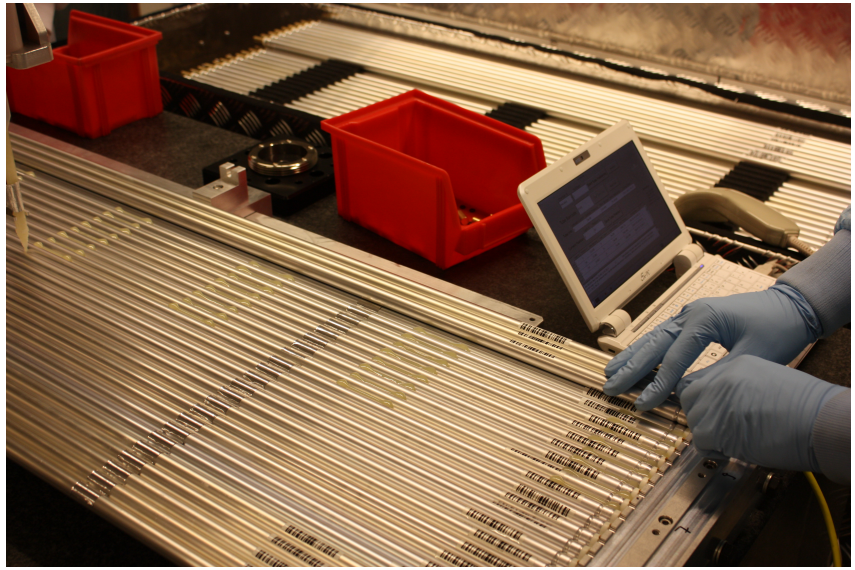


The first layer of tubes.

First layer of tubes completed.

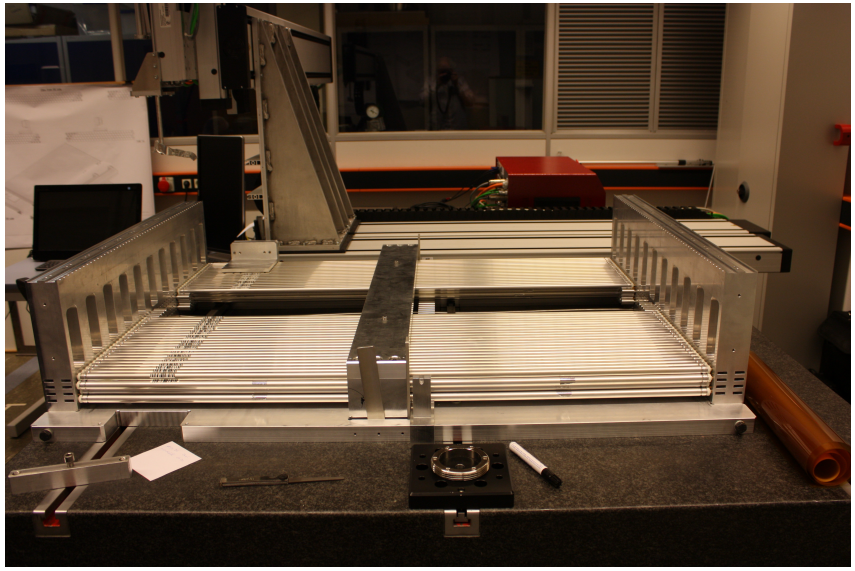


Epoxy for the second layer of tubes.

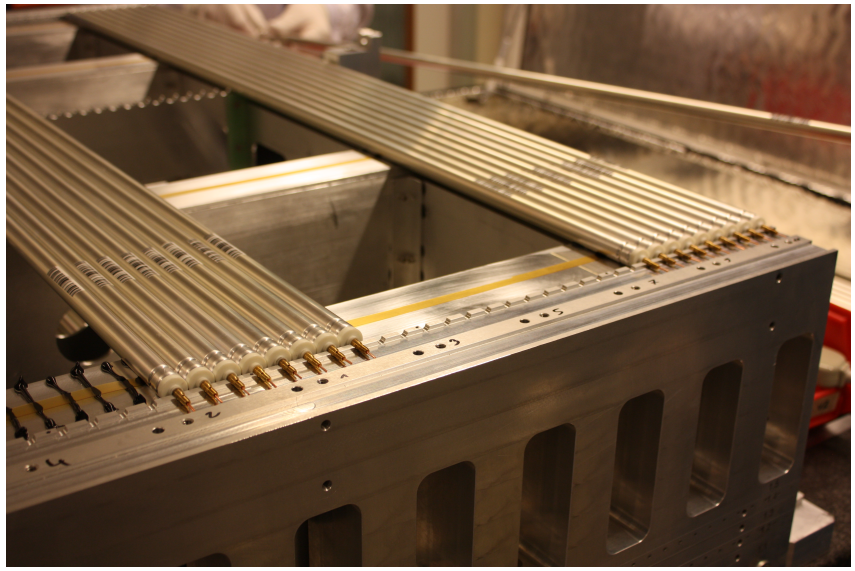


Second layer of tubes.

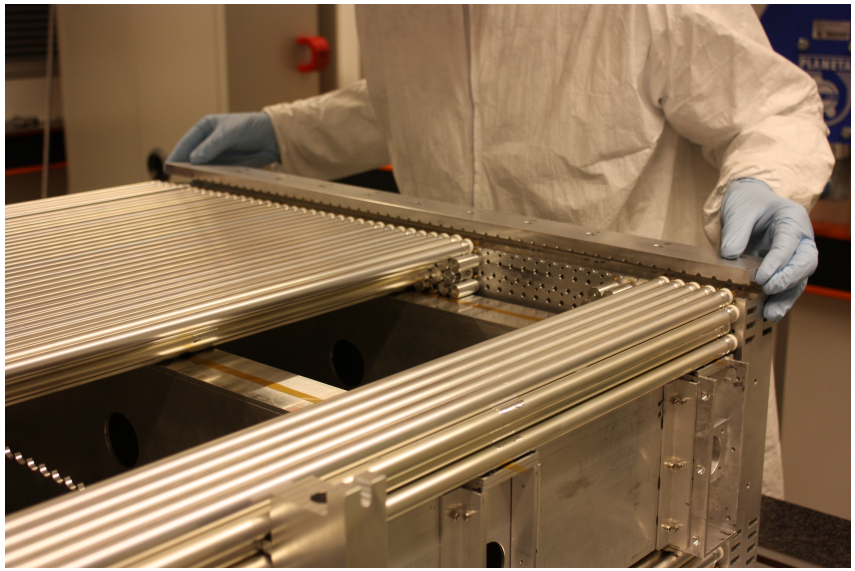
Chamber Assembly (II)



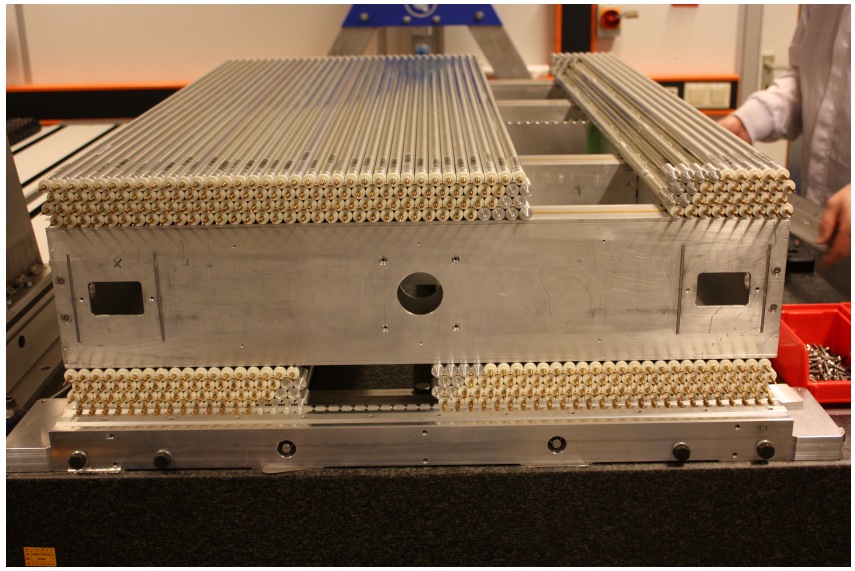
Alignment between the 2 multilayers.



Second multilayer started.



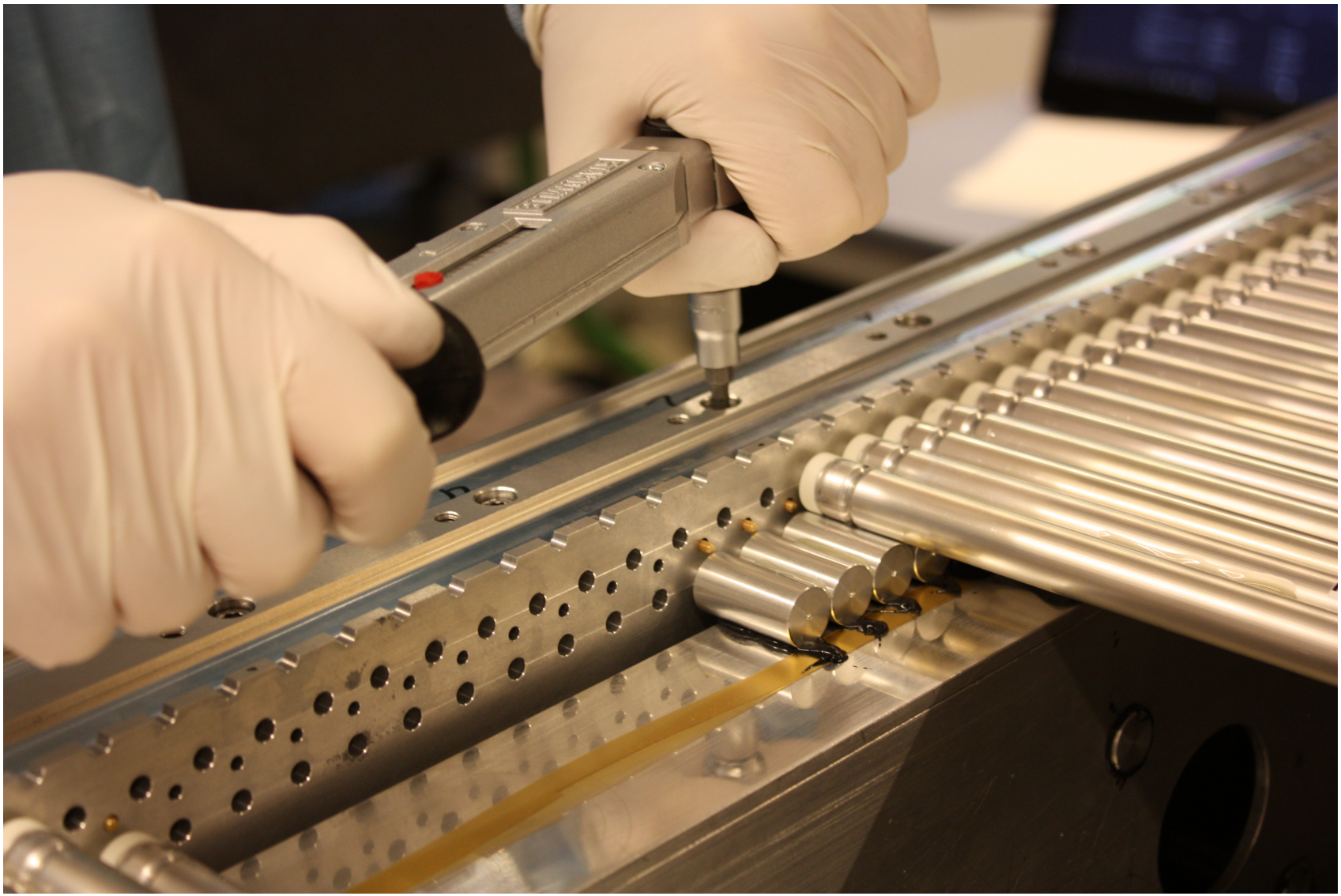
Second multilayer completed.



Completed Chamber

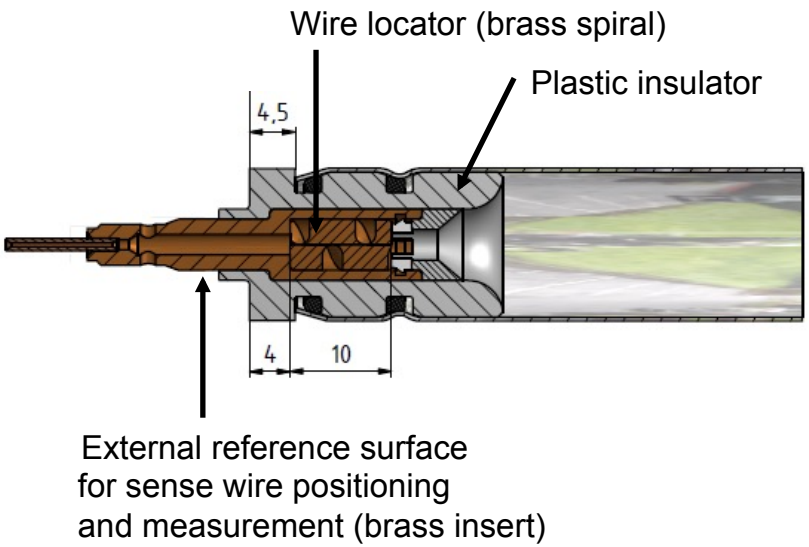
Alignment Combs

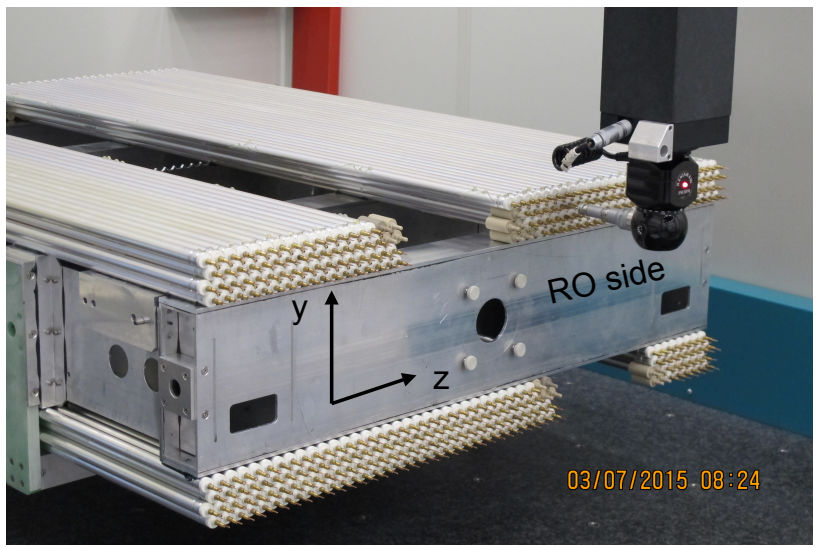
- Holds the tubes in the appropriate locations
- Slots for the tube endplugs as well as grounding pins



Wire Position Measurement

- 5 chambers are measured
- Wire positions recorded at both “Readout” (or “RO”) and “HV” sides
- Measured positions are compared to optimum grid positions.
- A combined fit (both sides of the chamber) is also done
- Measurement done at $\sim 20^{\circ}$ C





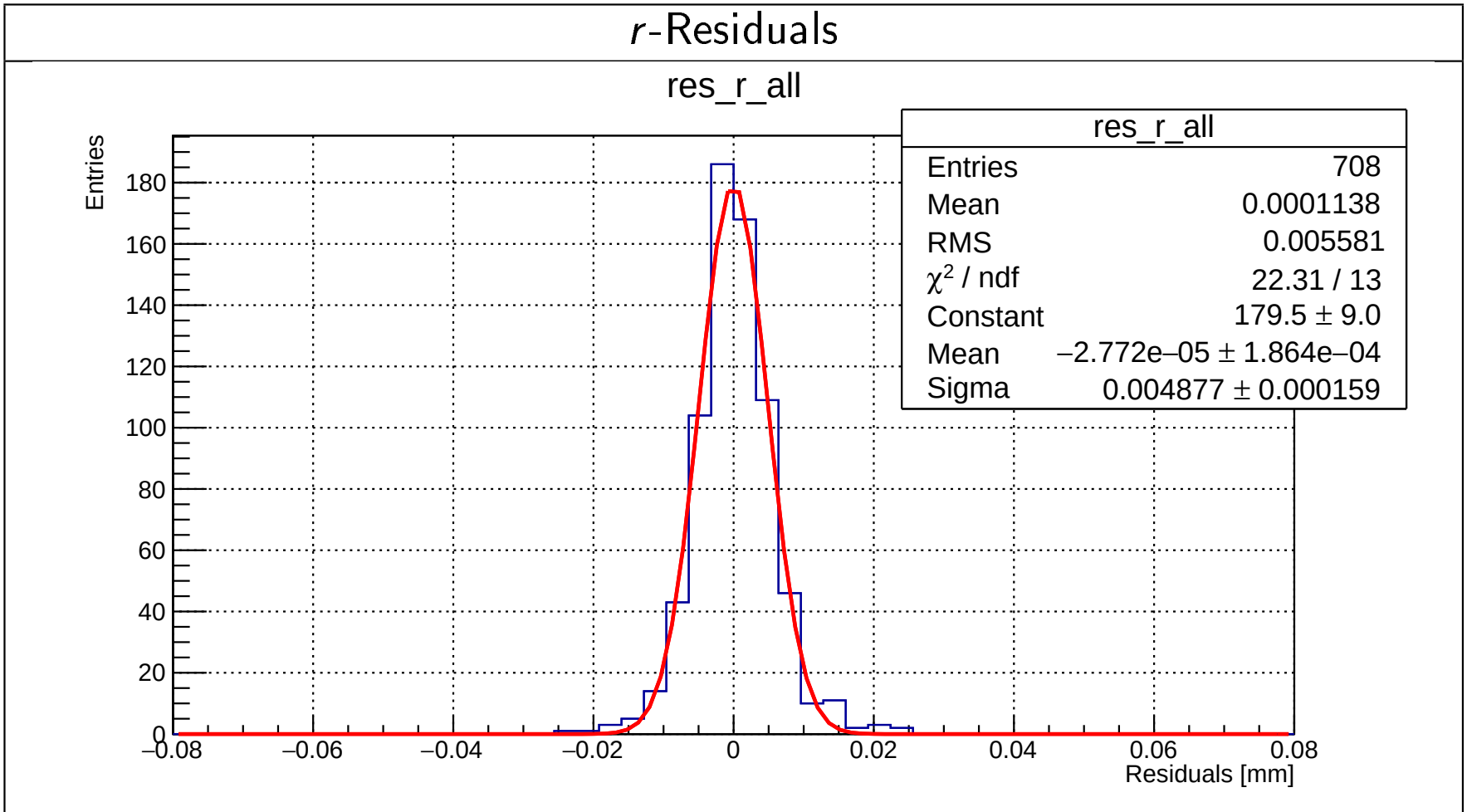
On-Chamber Component Installation

After wire position measurements, gas systems and electronics are installed

- Gas system mounted and tested for leaks
- Electronics mounted
- Systems test:
  - Chamber gas leak rate required to be < 0.2mbar/hr
  - Cosmic rays used to test eletronic readouts in tubes

3C14

- Recent chamber to be constructed and tested
- Most precise chamber constructed
  - Better than 5 μm wire position precision, limited by position measurement



Chamber Geometry Parameters

All fits are within specifications.
"Nominal" values are from comb measurements

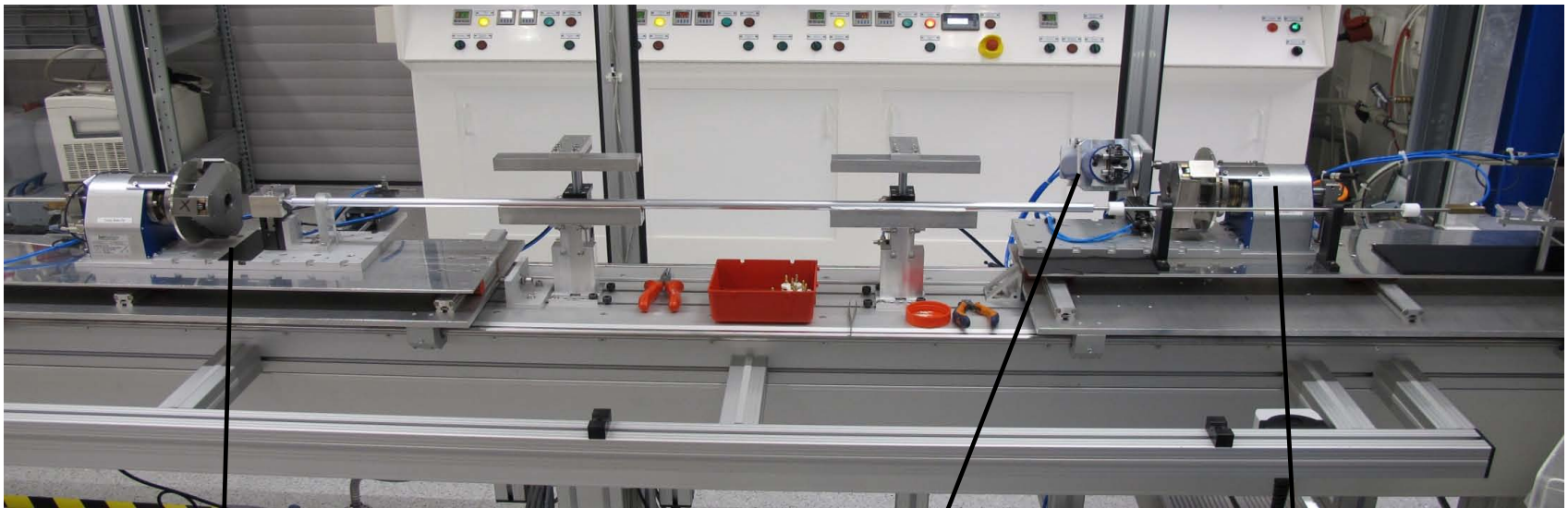
BMG-3C-14	RO-Side	HV-Side	Nominal
z pitch [mm]	15.0993 ± 0.00001	15.0991 ± 0.00001	15.0990
y pitch [mm]	13.079 ± 0.0002	13.079 ± 0.0001	13.090
Multilayer Δz [mm]	-0.012 ± 0.0002	-0.003 ± 0.0004	-0.008
Multilayer Δy [mm]	184.990 ± 0.0004	184.989 ± 0.0007	184.970
RMS (σ) z [mm]	0.0042 (0.0037)	0.0048 (0.0040)	0.020
RMS (σ) y [mm]	0.0061 (0.0054)	0.0066 (0.0056)	0.020

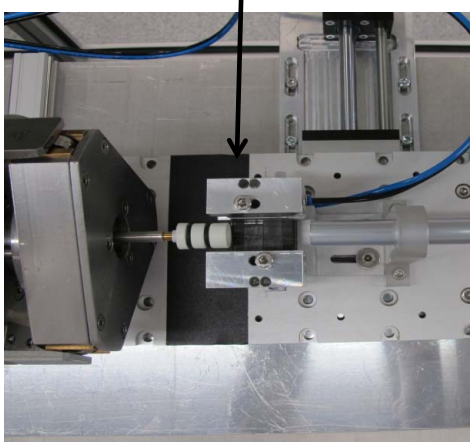
Conclusions

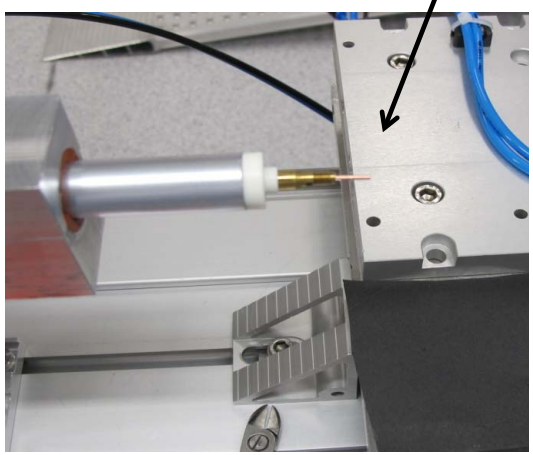
- Half of necessary chambers completed
- Testing shows chambers within specification of wire positions
  - Routinely achieve better than 5 μm precision
- Anticipate chambers to be ready on schedule for installation during 2016/2017 winter shutdown

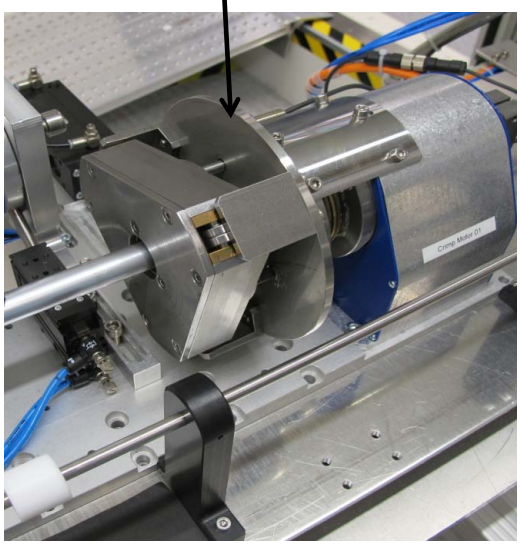
Backup

Wiring Machine









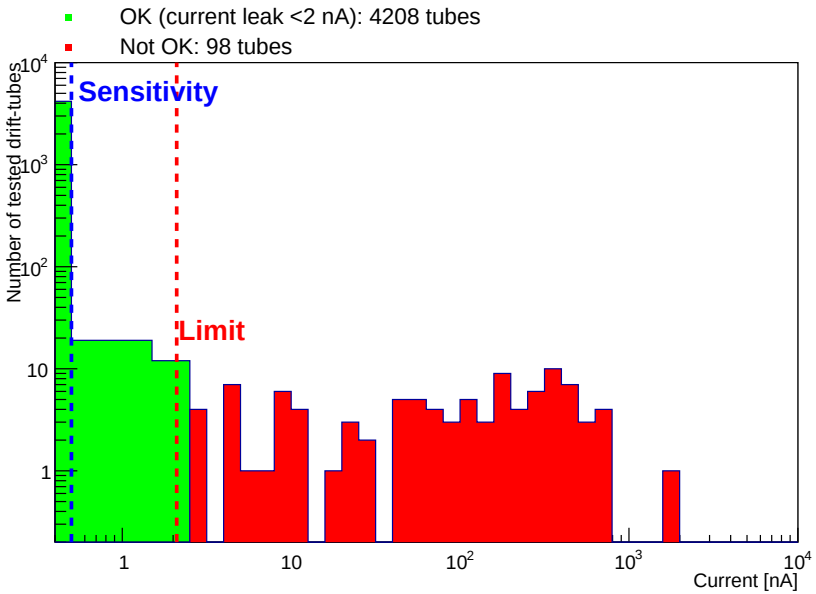
Wire Tension Measurement Detail

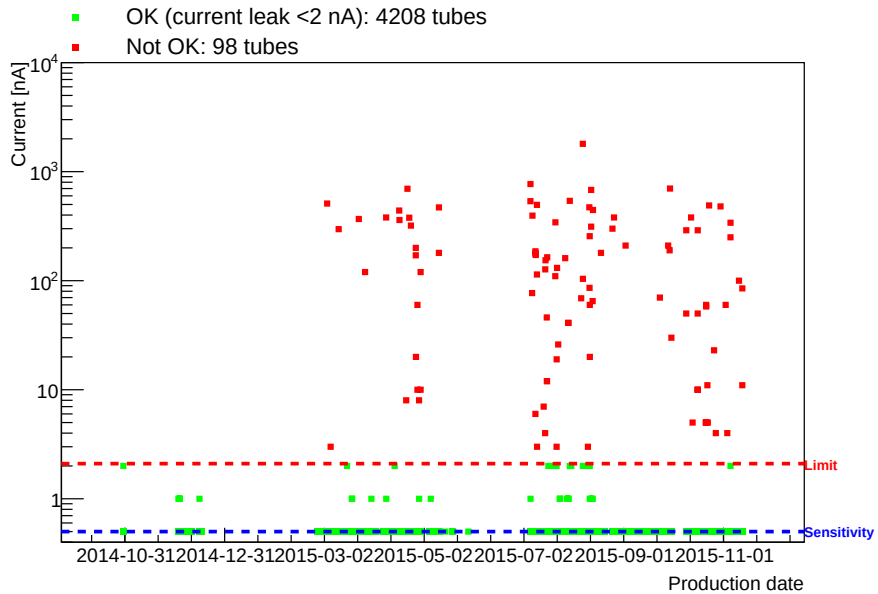
Wave velocity $= \sqrt{\frac{T}{m/L}}$	$\frac{m}{L} = \rho \times \pi r^2$	$f = \frac{v}{\lambda}$
$f = \frac{v}{2L} = \frac{1}{2L}\sqrt{\frac{T}{m/L}}$ $\rightarrow f = \frac{1}{2L}\sqrt{\frac{T}{\rho\pi r^2}}$		

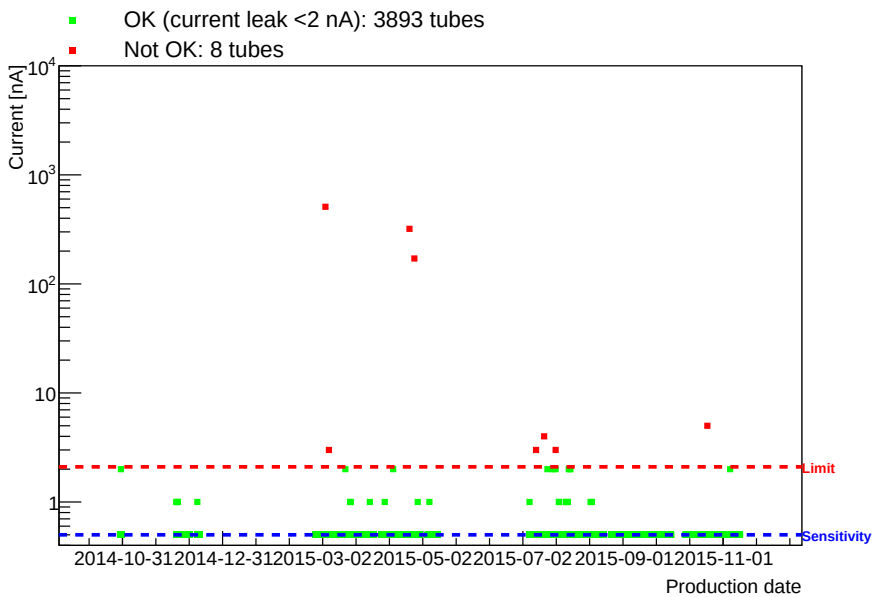
$$T = L^2(2r)^2\nu^2\pi\rho/g$$

$\rho = 19.34\text{g/cm}^3$	$r = 25\mu\text{m}$	$L = 1.1\text{m}$

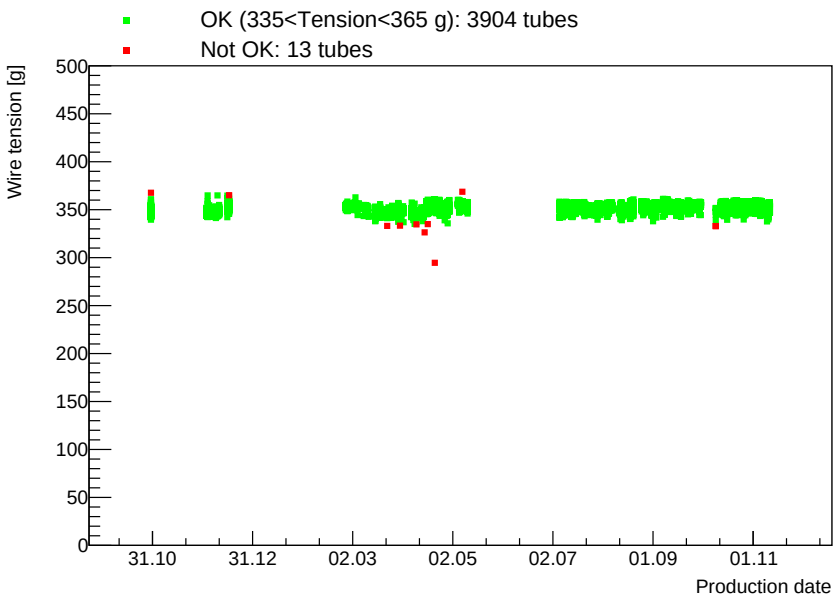
Auxilliary Test Result Plots (I)

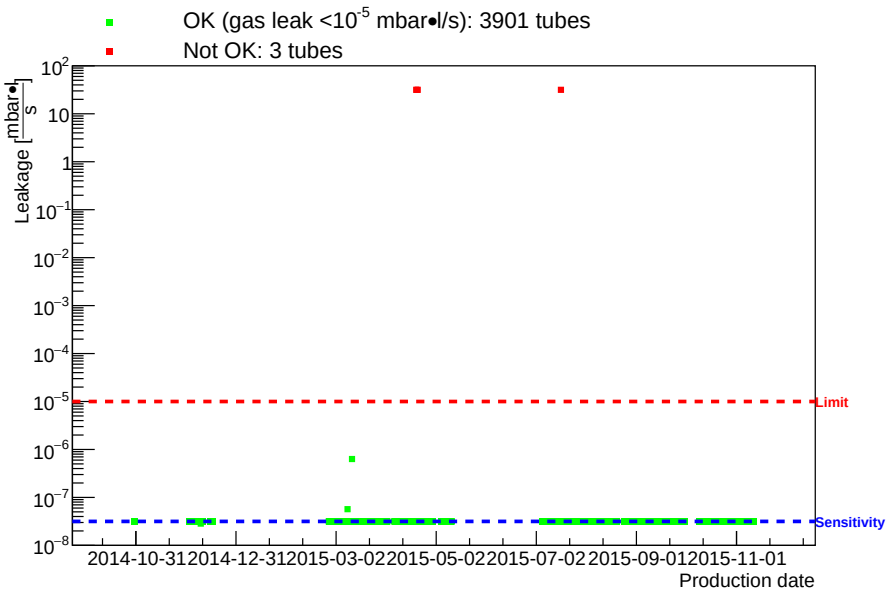




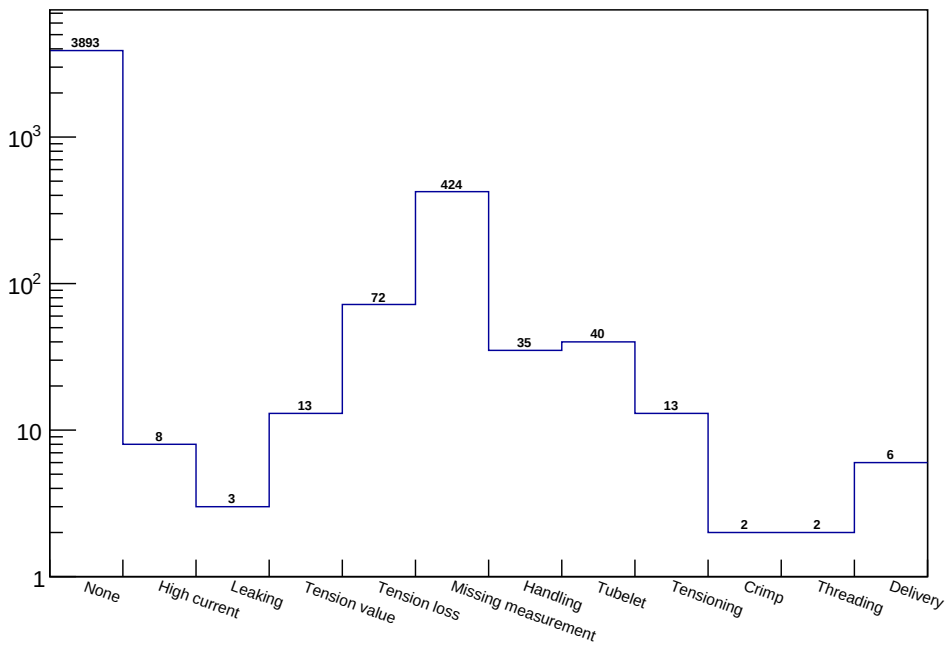


Auxilliary Test Result Plots (II)



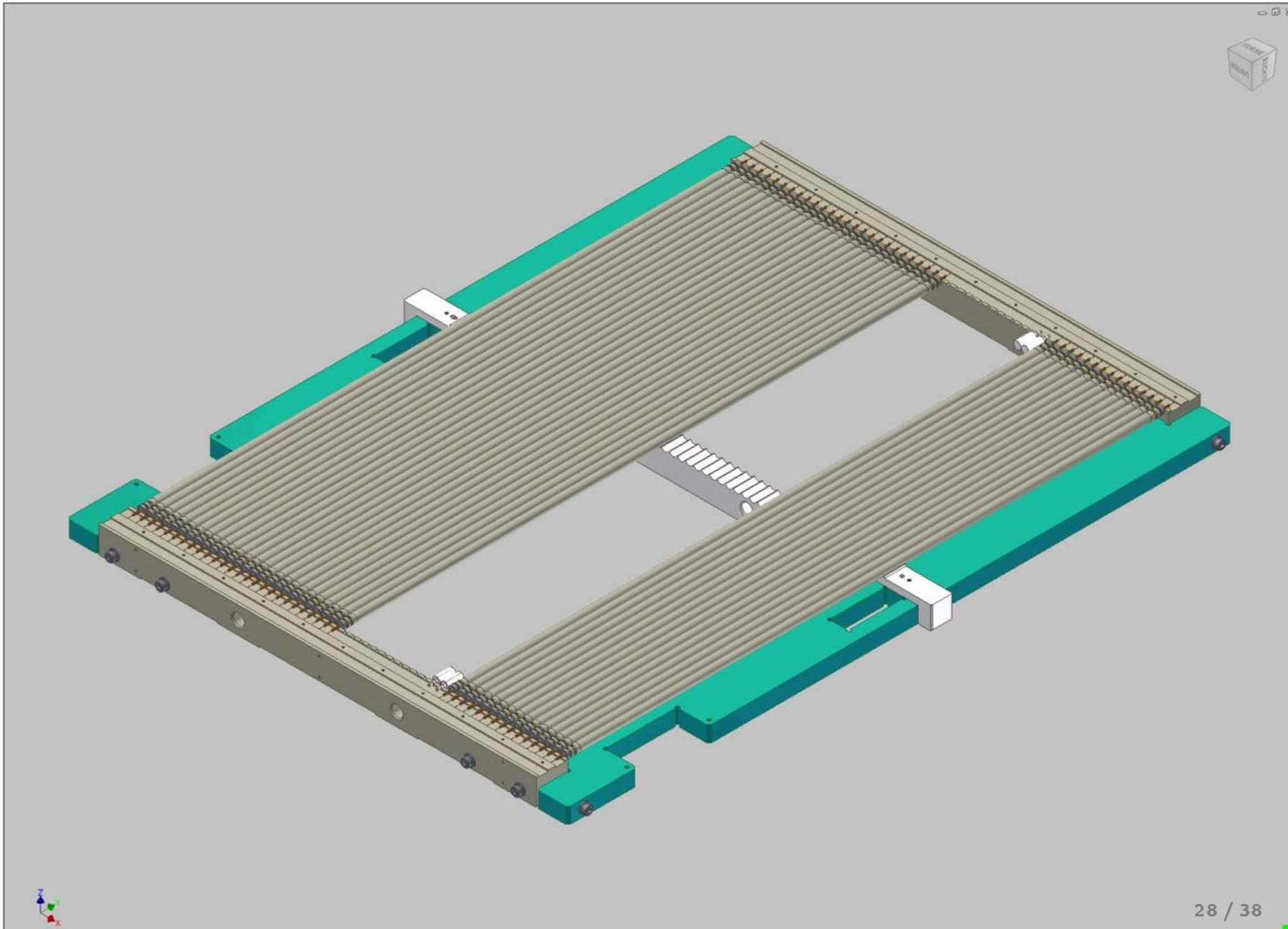


Tube Production Losses

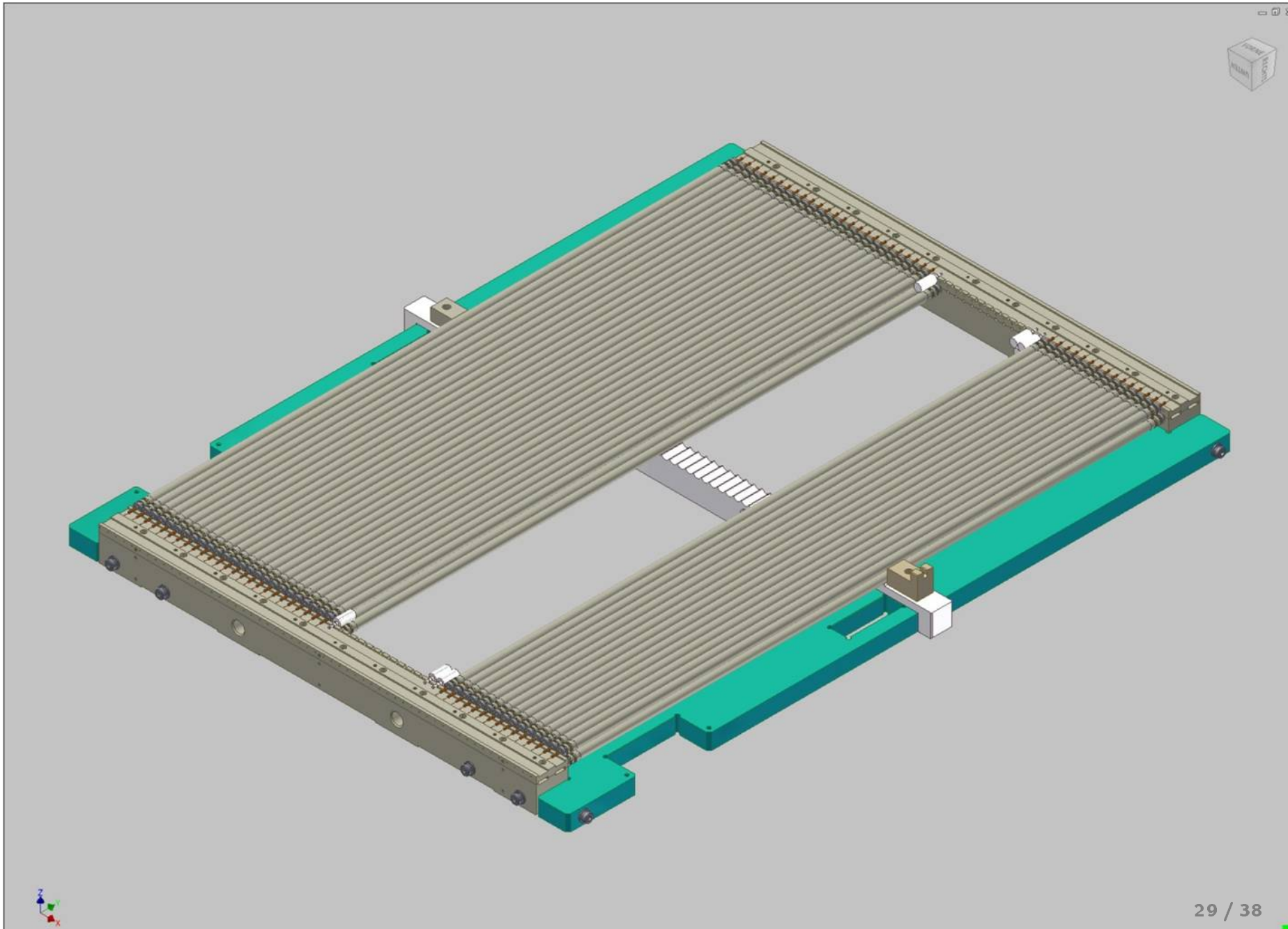


4511 Tubes	Total number
86.30016%	OK
0.1773443%	High current
0.06650410%	Leaking
0.2881844%	Tension value
1.596098%	Tension loss
9.399246%	Missing measurement
0.7758812%	Handling
0.8867213%	Tubelet
0.2881844%	Tensioning
0.04433607%	Crimp
0.04433607%	Threading
0.01330082%	Delivery

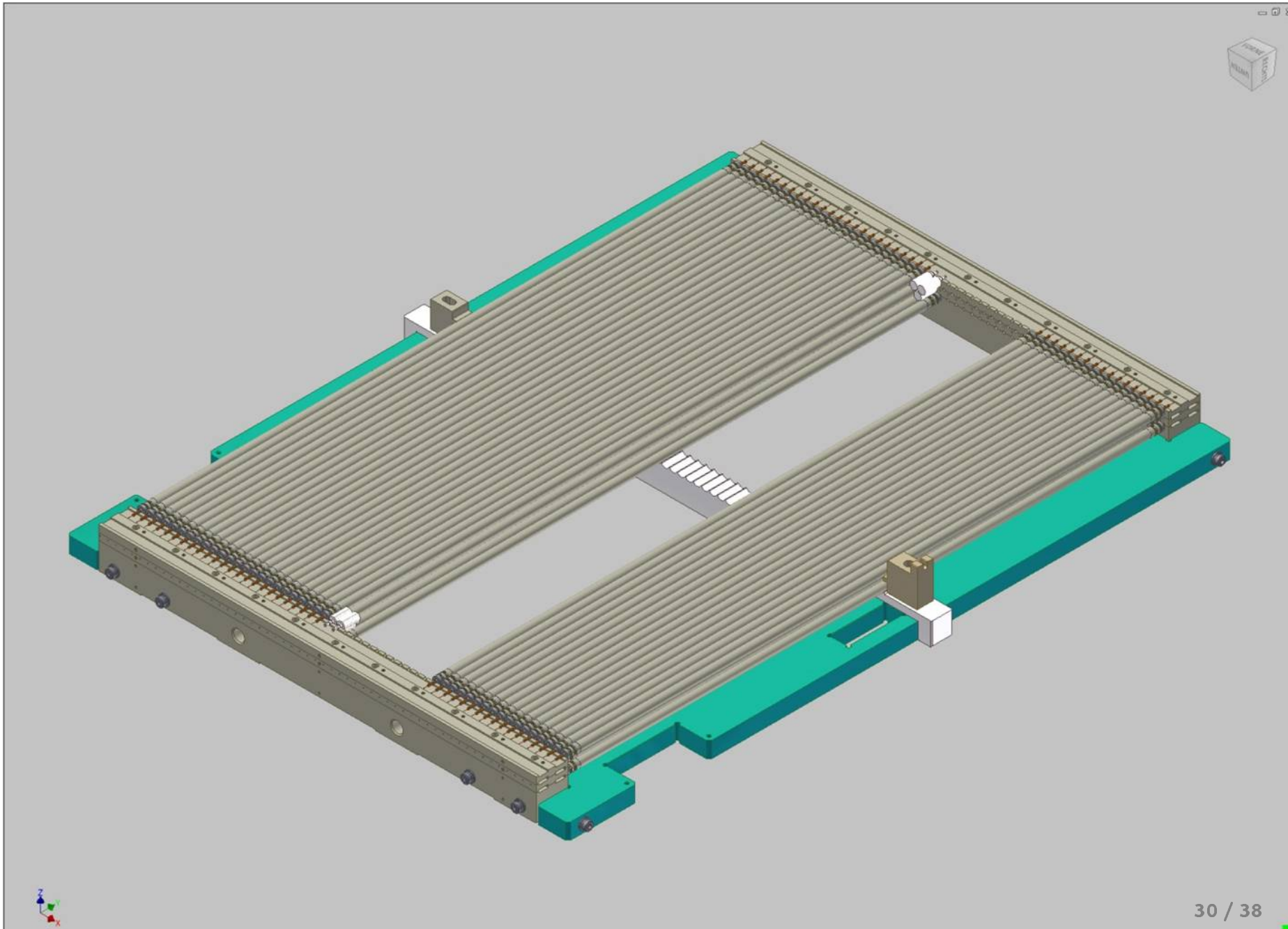
Chamber Construction - Layer by Layer



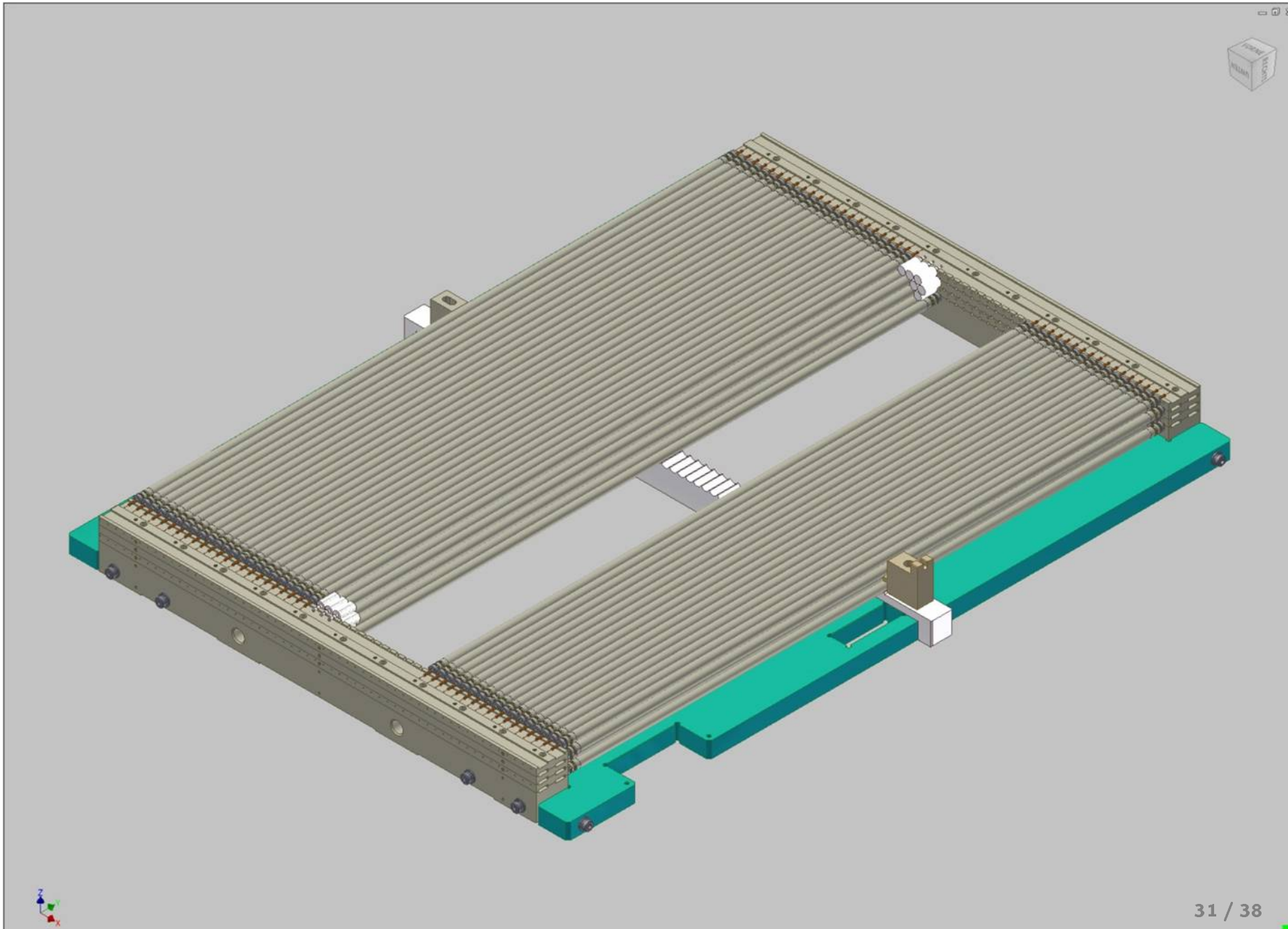
Chamber Construction - Layer by Layer



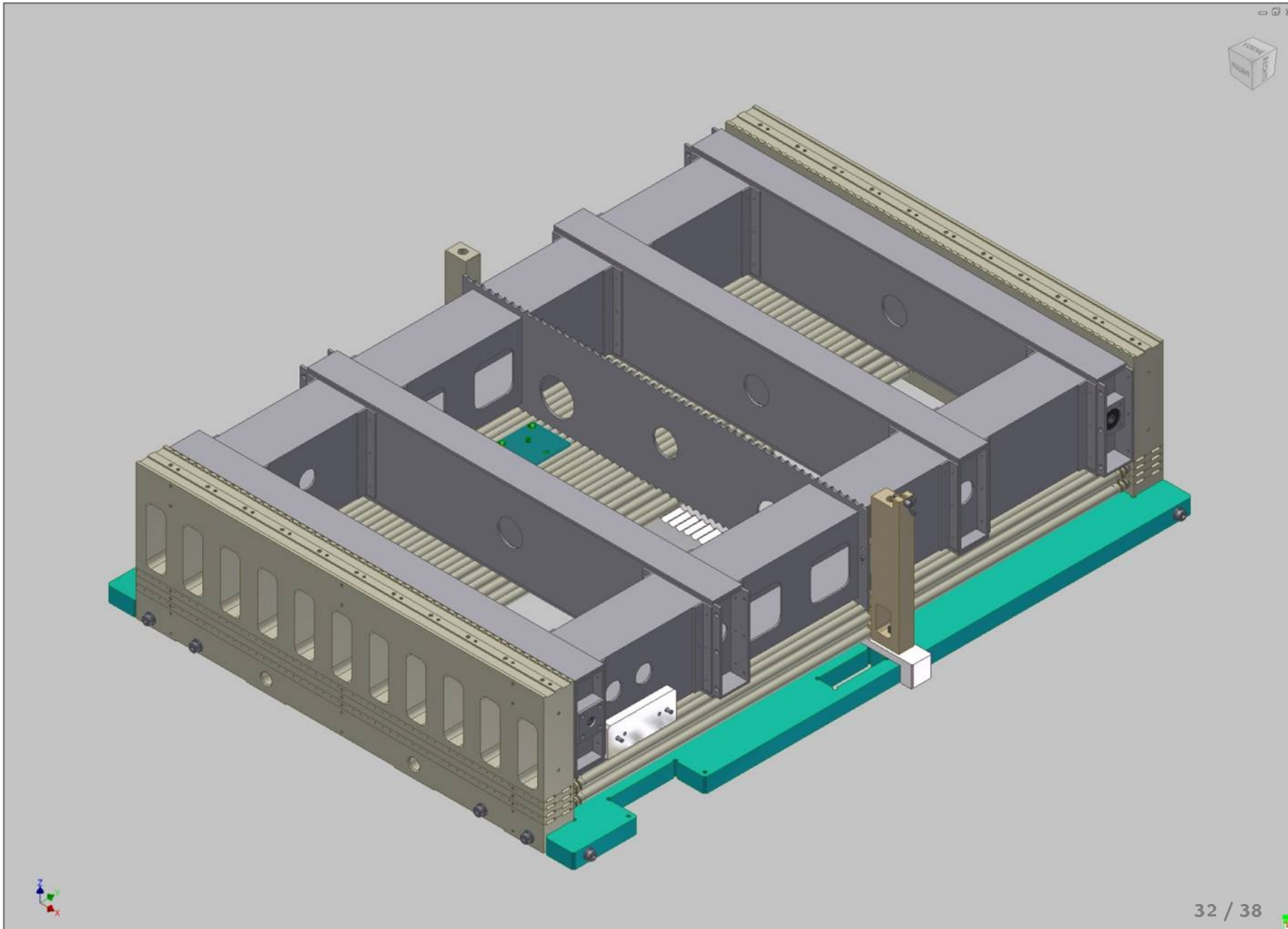
Chamber Construction - Layer by Layer



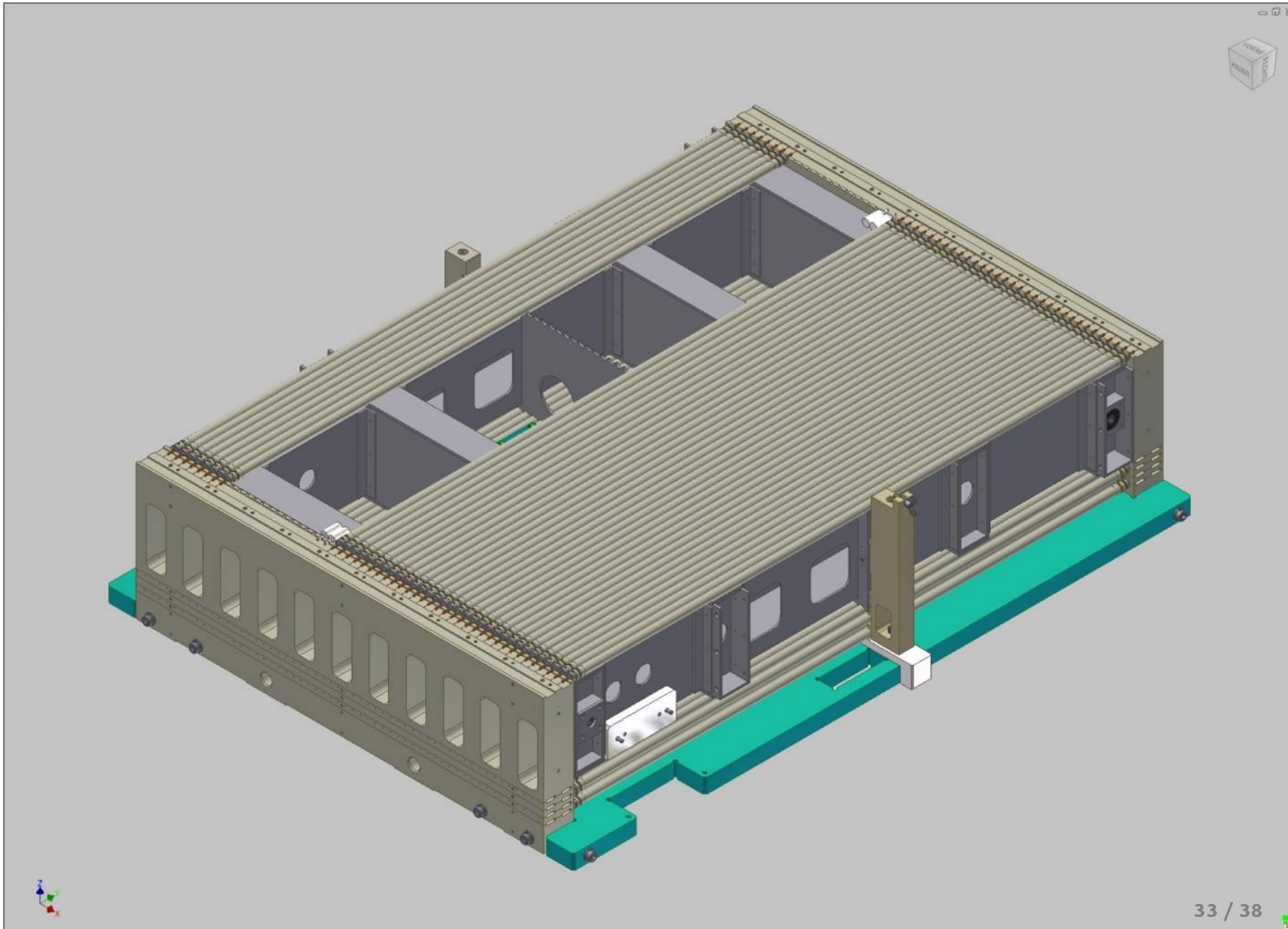
Chamber Construction - Layer by Layer



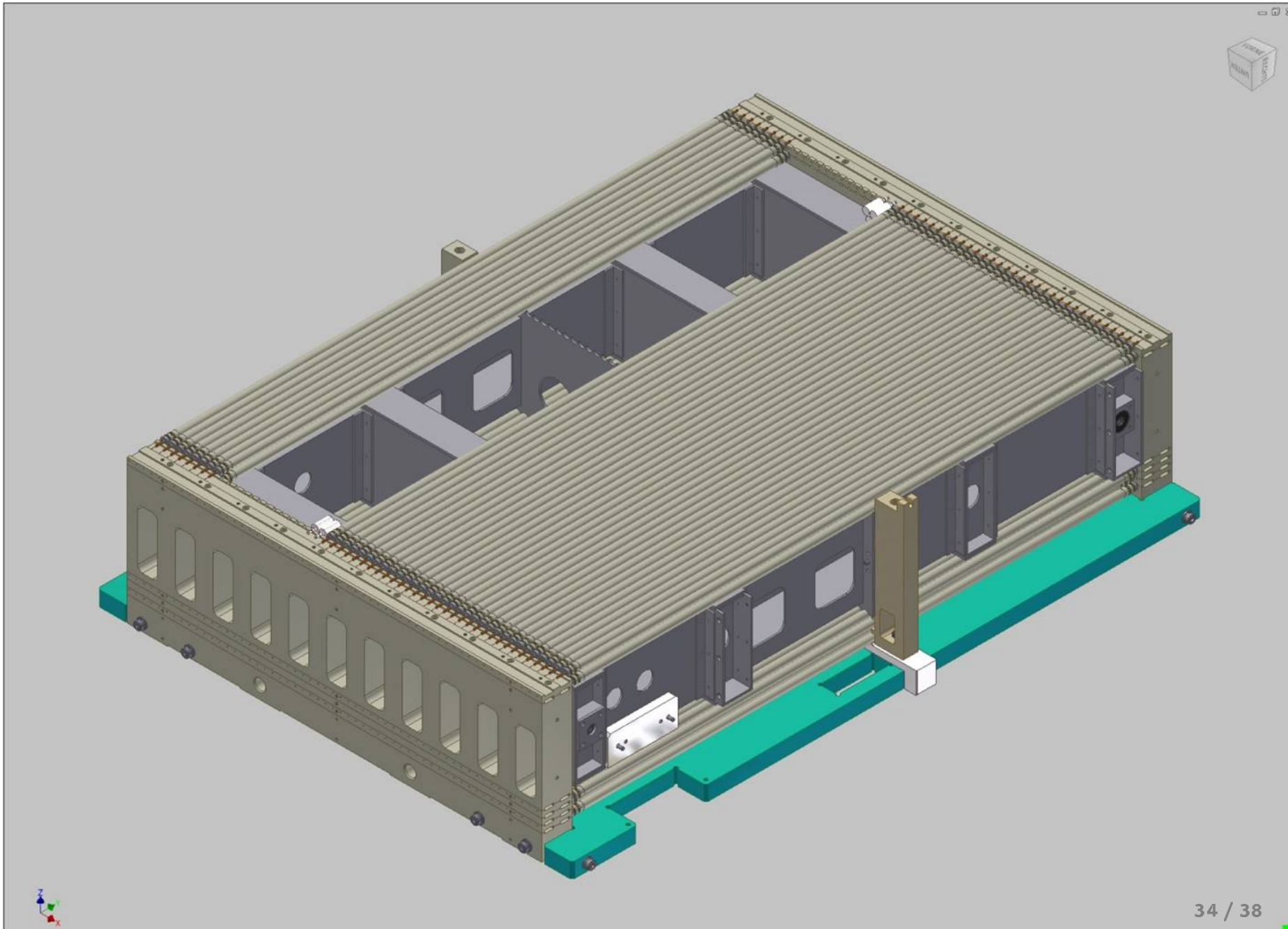
Chamber Construction - Layer by Layer



Chamber Construction - Layer by Layer



Chamber Construction - Layer by Layer



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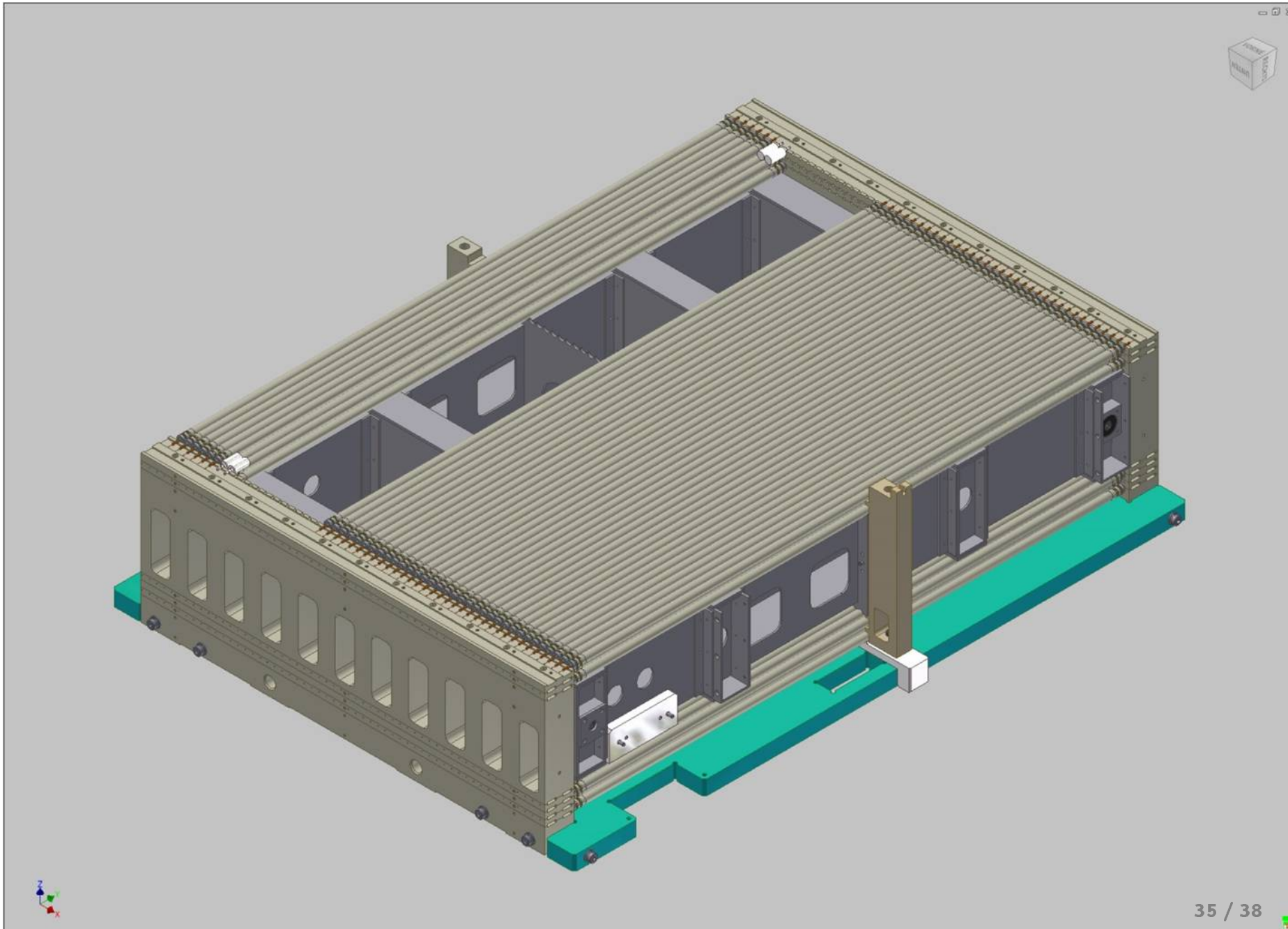

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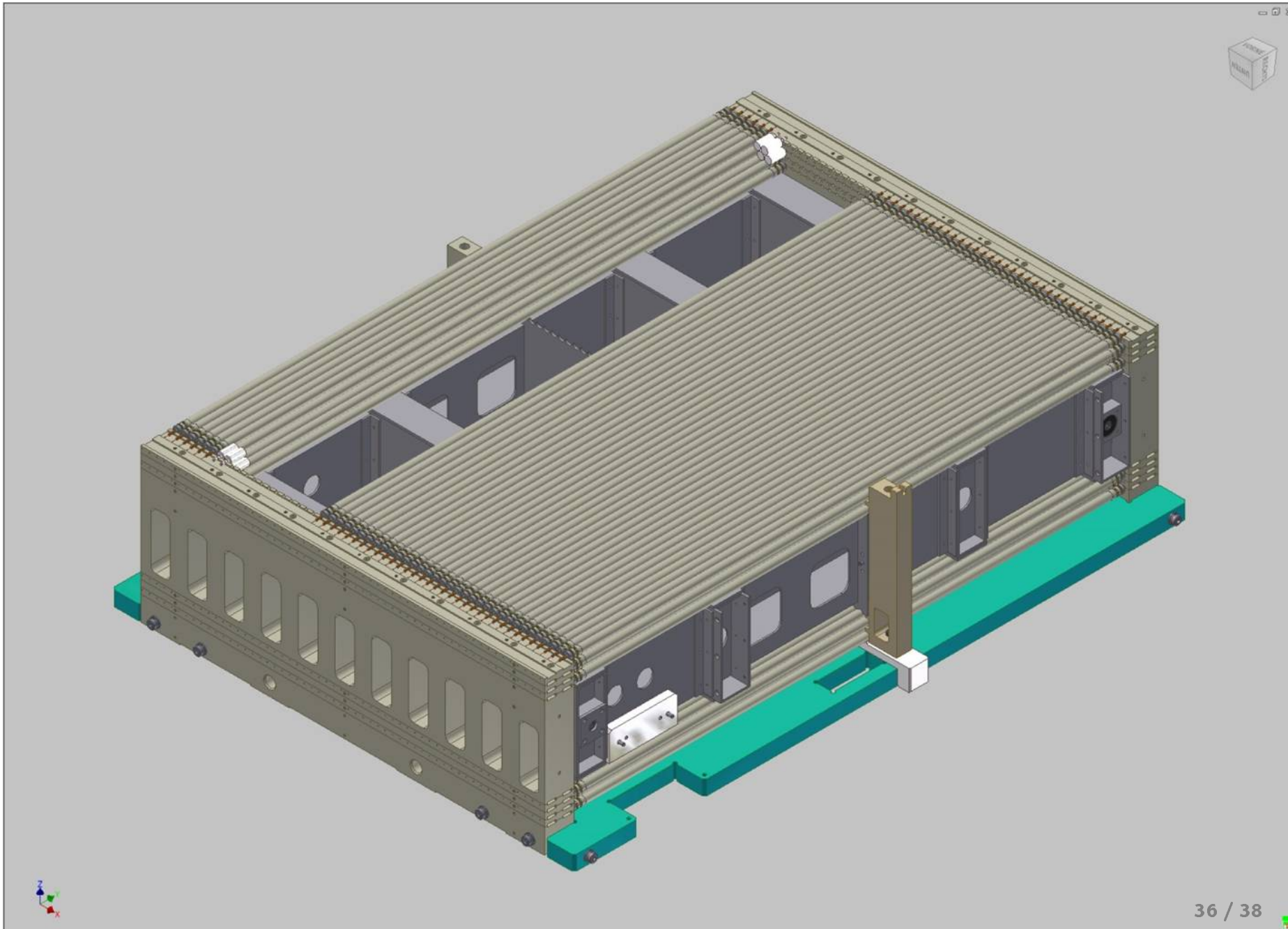
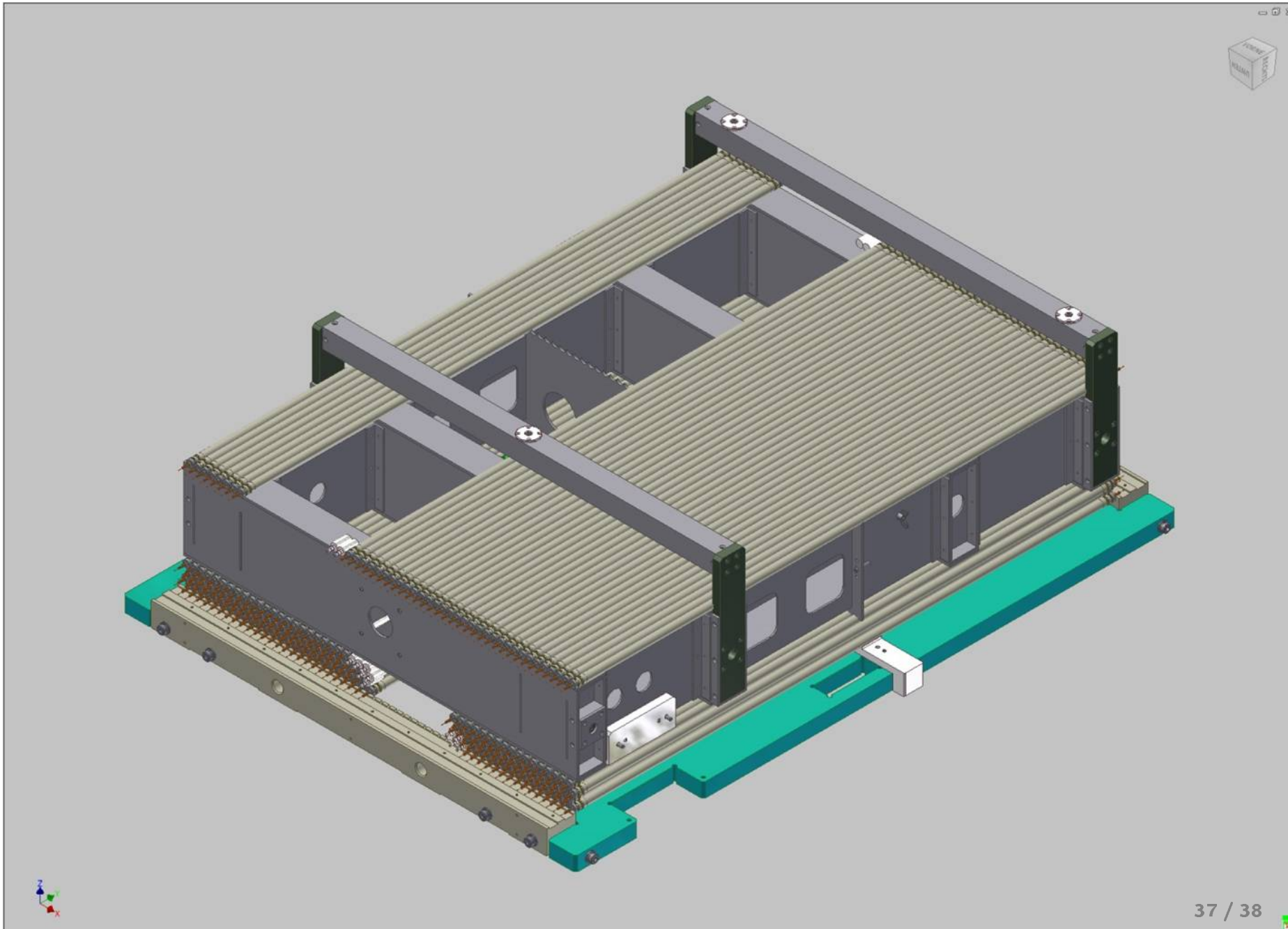
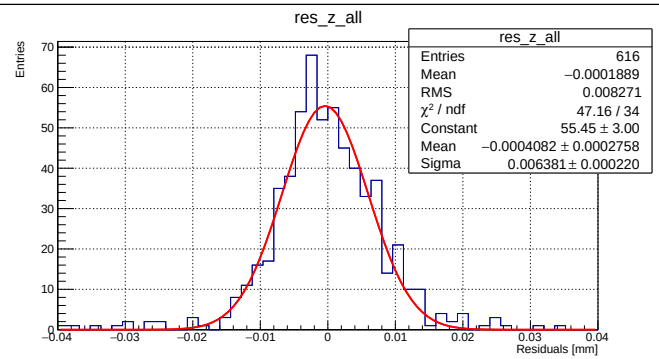
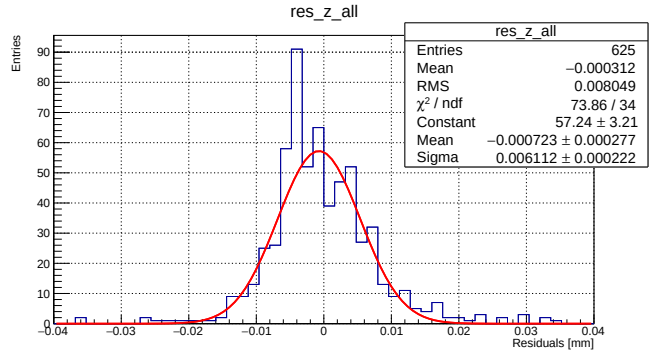


Chamber Construction - Layer by Layer



Remaining Tested sMDTs

Chamber	z-Residuals
3C12	
3A12	
3A14