MUSKINGUM
UNIVERSITY

GEM Rotator Design Progress

Chandika Annasiwatta

MOLLER collaboration meeting

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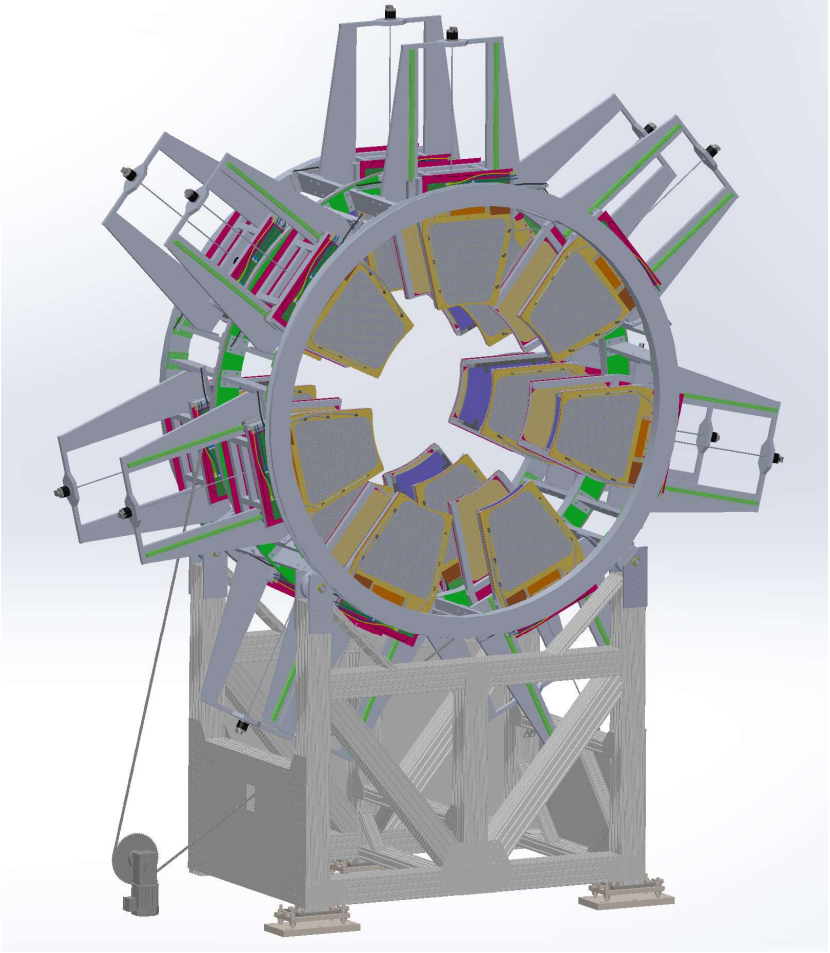
Outline

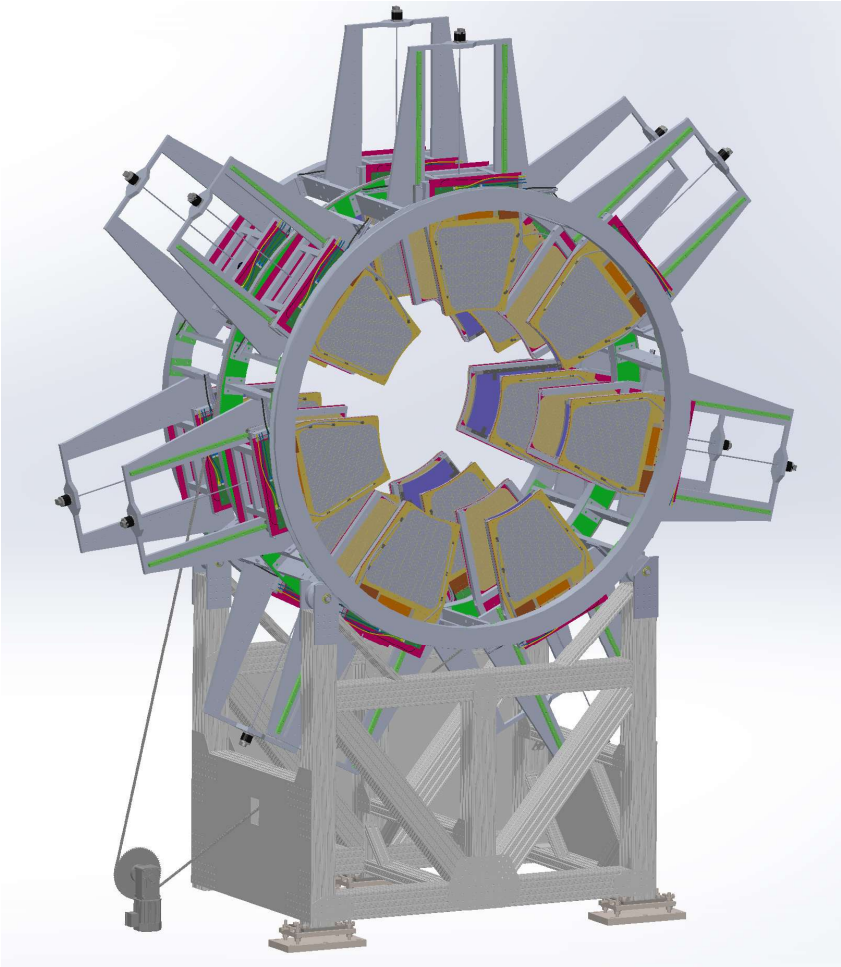
- Subsystem overview
- Radial motion
- Rotational motion
- Simulations
- Stand adjustors
- Cable arrangements
- Assembly procedure
- Summary

Subsystem Overview

- Rotator to support 28 GEM modules (4 layers of 7 modules) and 2 layers of trigger scintillators (2 layers of 7 scintillators) for Counting Mode measurements
- Must rotate system to cover full azimuth in sequential measurements (Rotation of 360 degrees/7 = 51.4 degrees, with at least three stopping positions)
- Must move radially to extract GEMs and Trigger scintillators fully from scattered electron flux for main Integrating Mode measurements
- Minimize mass in the path of scattered electrons
- Minimize use of ferrous materials



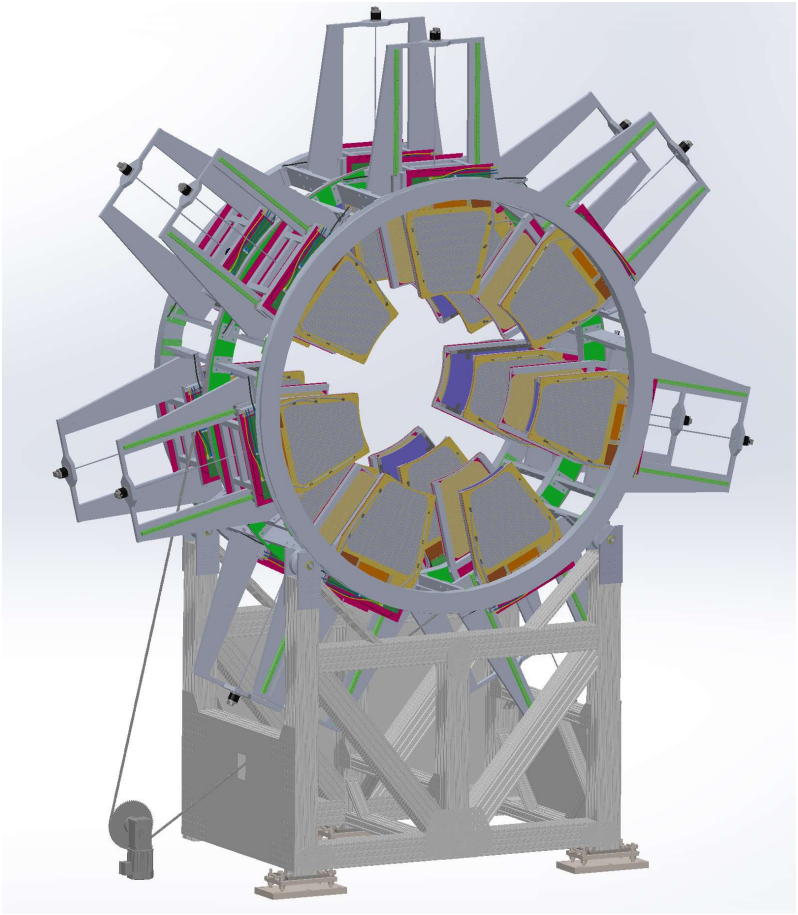
GEM Rotator – Current design



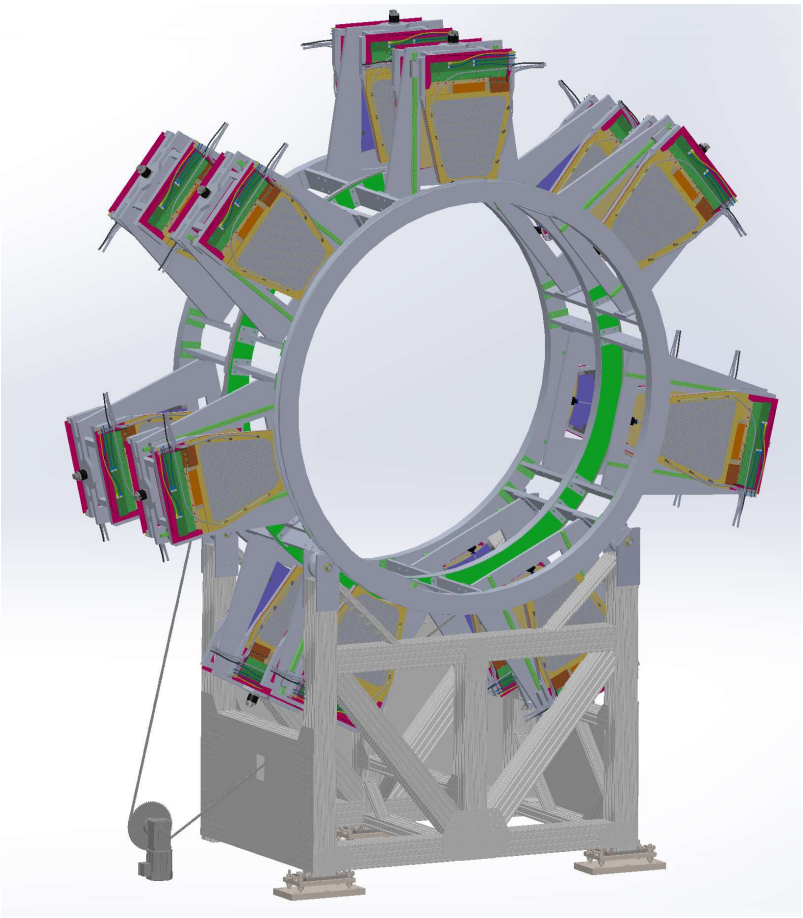
- Three 2.65 m diameter Al wheels
- Rotational motion via chain drive, sprockets on center wheel. Two rollers per wheel.
- V-groove on front wheel, simple roller on back wheel.
- Al (Bosch 80/20 6105-T5) support stand: minimizing Ferrous materials. Bolted not welded.
- Rotational motion: 2-sector $(103°)$ swing, 2 intermediate stops to cover full azimuth.
- Total mass – ~2100 kg
- Stand – ~460 kg

GEM Rotator – Radial motion

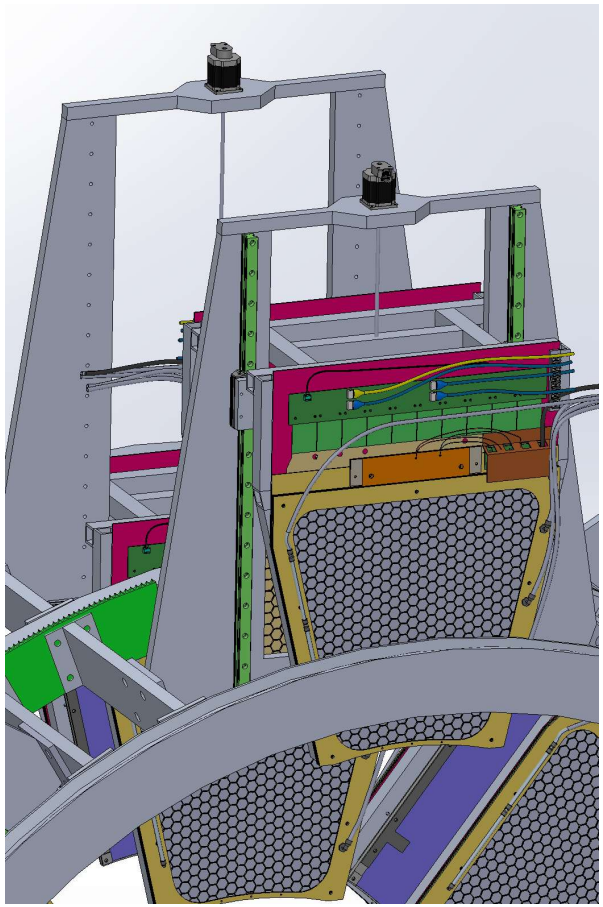
Measurement position



Parked position



GEM Rotator – Radial motion



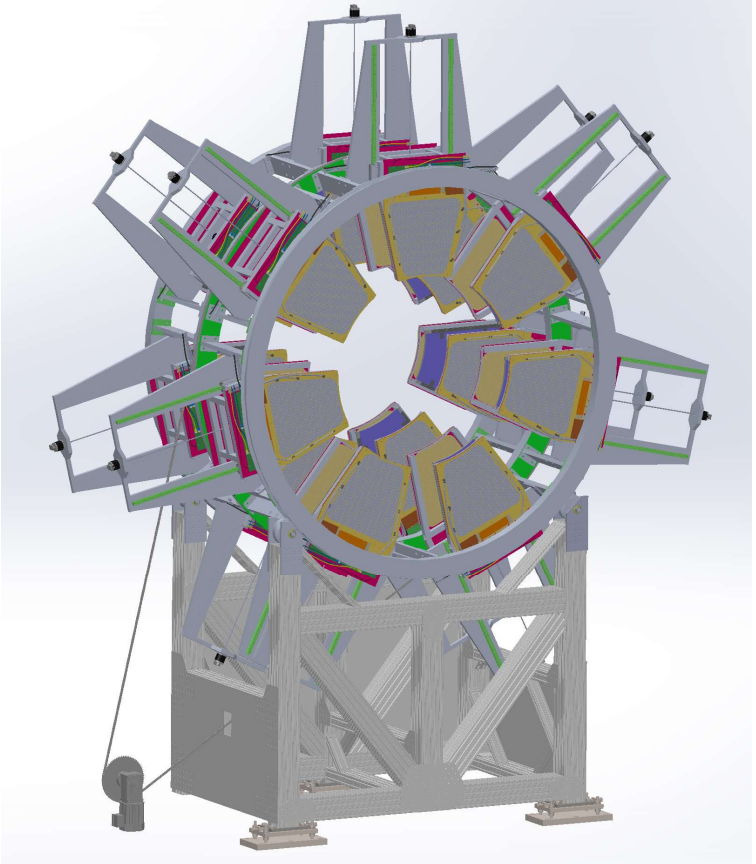
- Radial motion: 14 stepper-motor linear actuators.
- Each moves pair of GEMs and a single trigger scintillator along non-magnetic linear guide rails (Franke FDD guides).
- GEM pair + Scintillator ~= 25 lbs
- Trapezoidal frames supporting the linear motors and guide rails: 6061-T6 aluminum.
- Stepper Motor Linear Actuator : stainless steel screw.
- Radial motion stroke: 760 mm (GEM layers 1&2) and 720 mm (GEM layers 3&4), limited by hard stops at both extremes.
- The 14 linear actuators operate independently: allows insertion of single pair of GEM detectors in a particular semi-septant, for study of any backgrounds in the main detectors caused by the tracking system.
- The holder frame for the GEM and scintillator modules: aluminum & carbon fiber.

GEM Rotator – Rotational motion

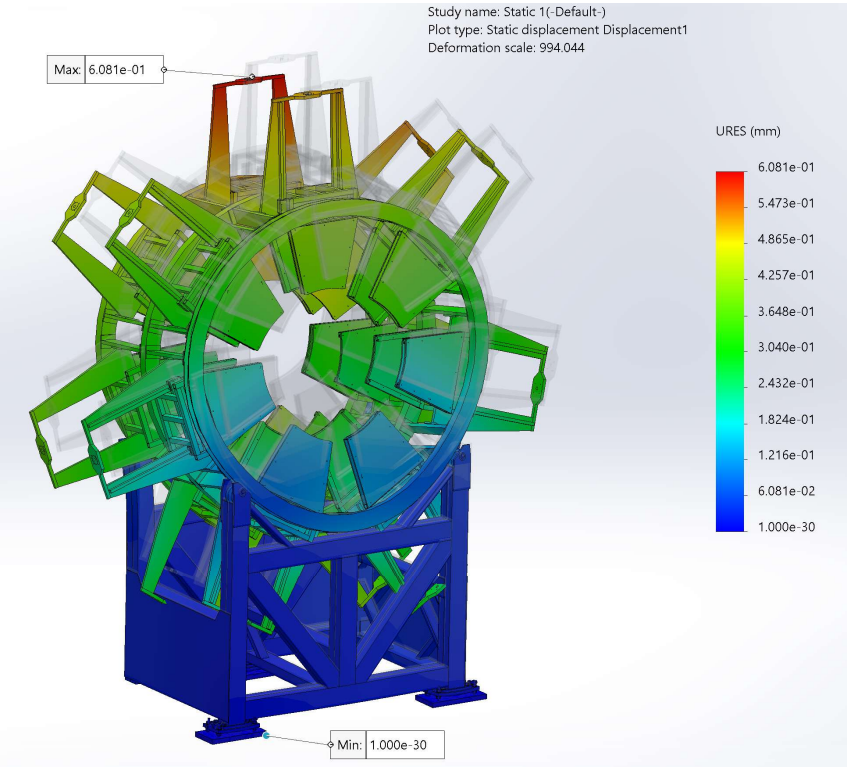
- Chain drive

- Max chain tension to hold max unbalance load (GEM holder + 2 GEMs + scintillator)
  - Measurement position ~= 40 lbs
  - Parked position ~=70 lbs

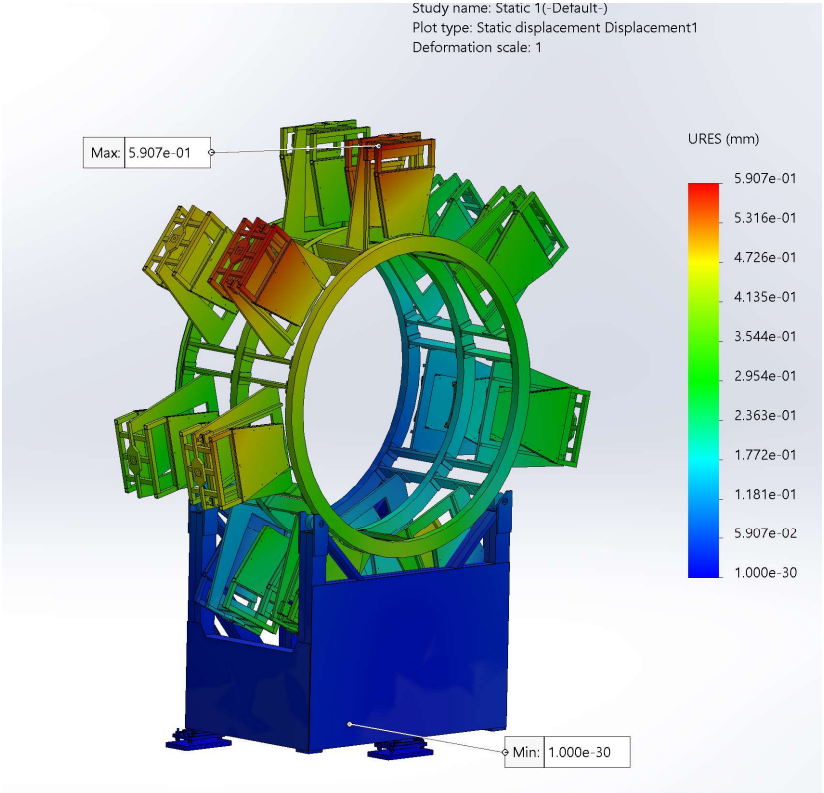
- ANSI Number 50-SS, 316 Stainless Steel, Working load 150 lbs



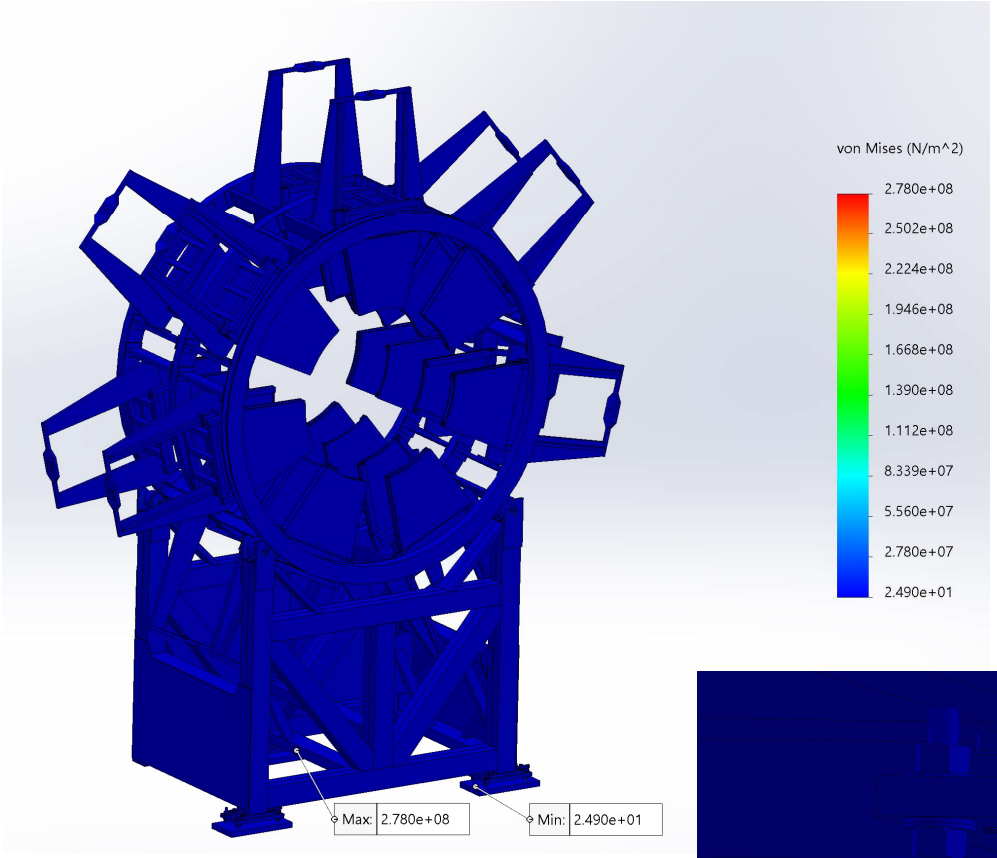
GEM Rotator – FEA displacements

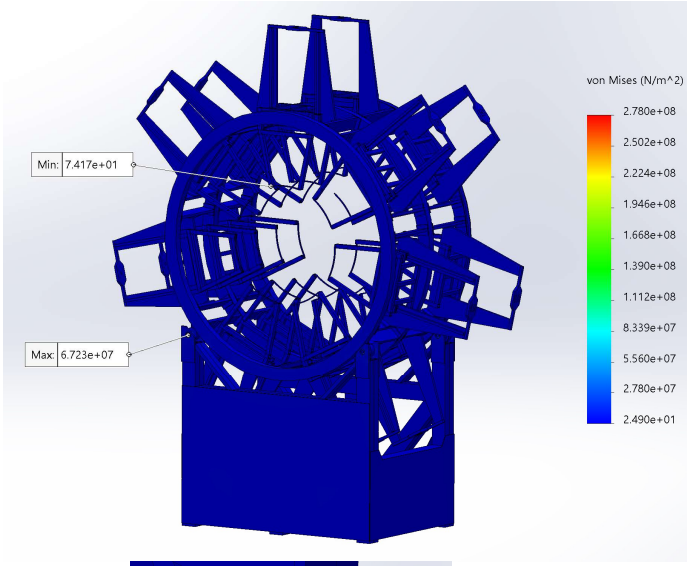


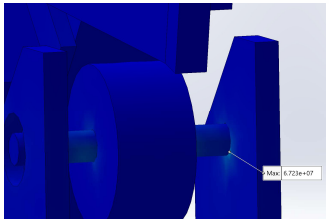
Largest displacement:
< 0.7 mm
- Meets specs (< 3 mm)
(was ~1.7 mm in earlier design)

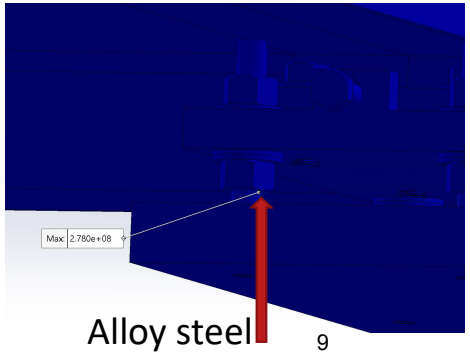


GEM Rotator – FEA Stresses



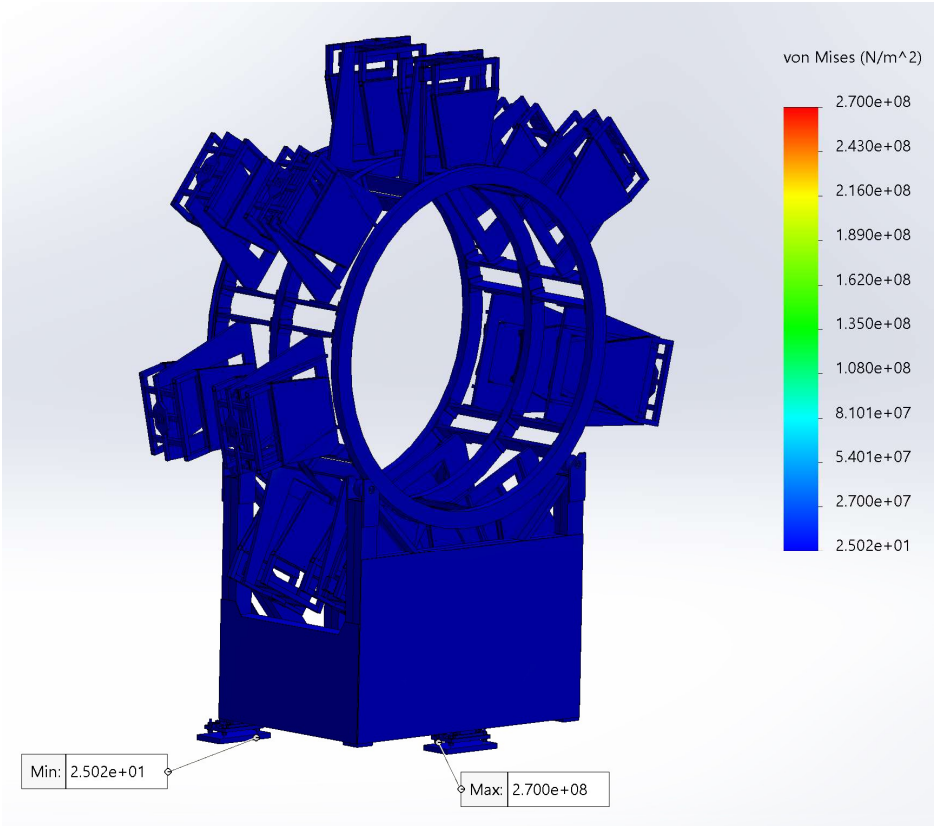


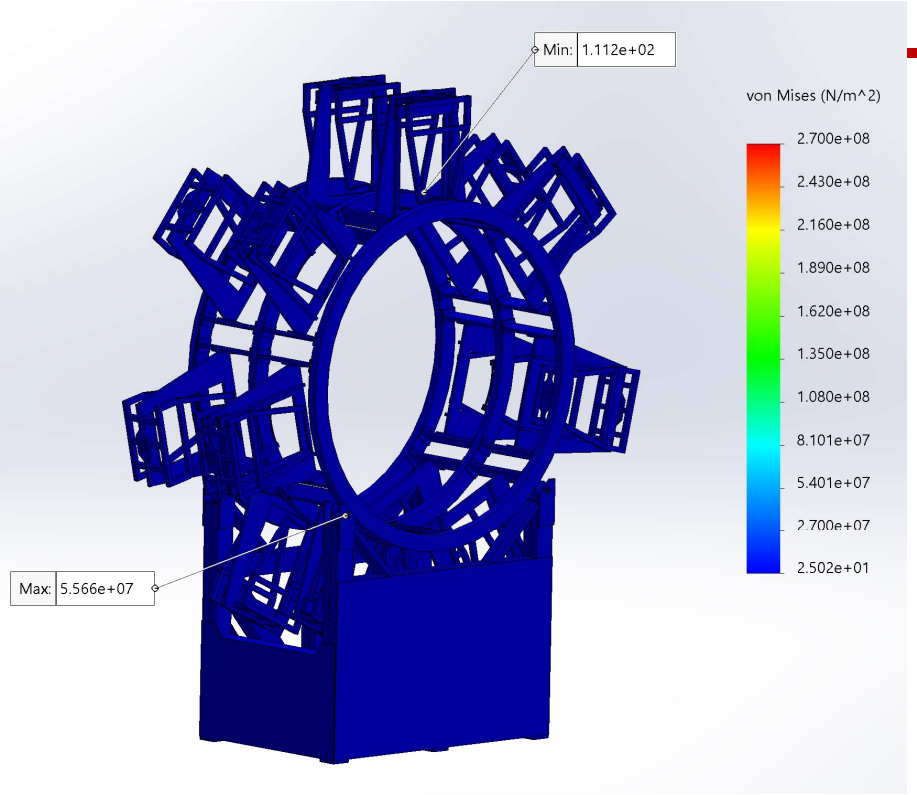




- 6061-T6 Al - Tensile Strength 3.10e+8 N/m^2
- 6105-T5 Al - Tensile Strength 2.21e+8 N/m^2
- Alloy steel -Tensile Strength – 7.23e+8 N/m^2

GEM Rotator – FEA Stresses





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GEM Rotator – Hertzian stress at roller contacts

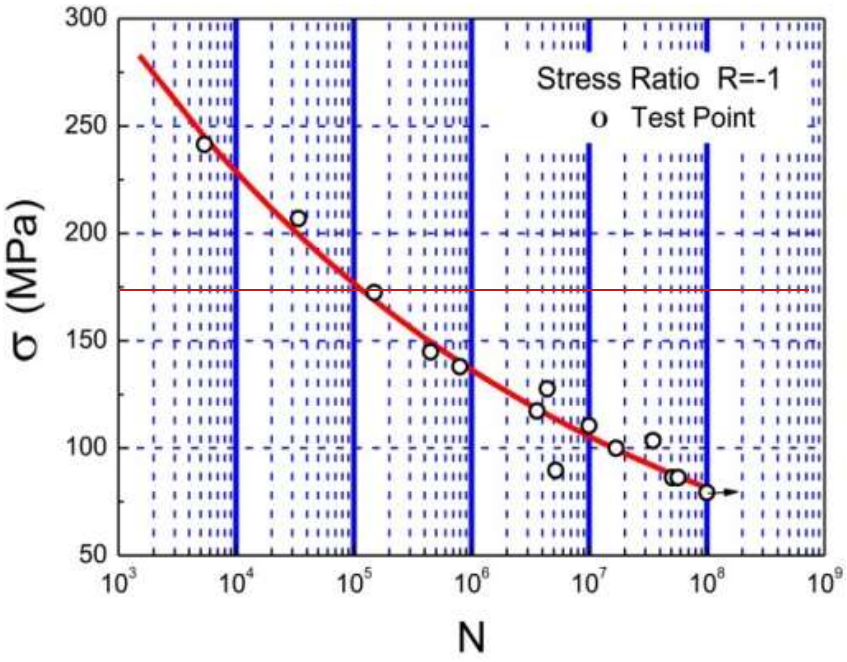
- Hertzian stress analysis at roller contacts:

- Flat roller
  - Max contact pressure 141 Mpa

- V roller
  - Max contact pressure 170 Mpa

- For 6061–T6 Al: fatigue limit: 10^5 repetitions
  expect < 200 repetitions

σ-N curve of 6061-T6 aluminum alloy



0.1 g seismic analysis

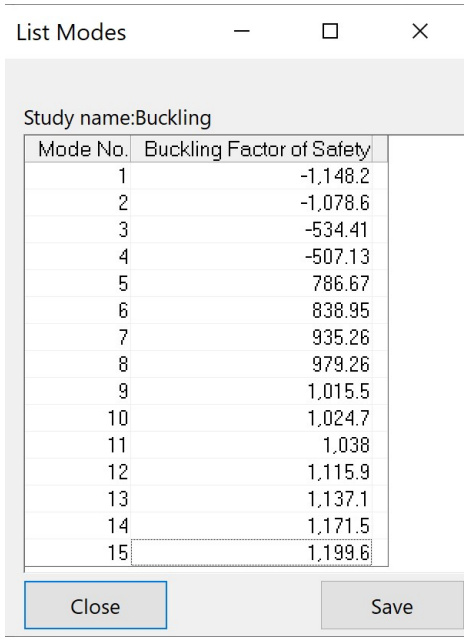
- 0.1 g seismic analysis worst cases
  - Seismic forces in +x (beam direction): deflection 0.9534 mm in +x (0.9023 mm parked)
  - Seismic forces in +x (beam direction): deflection 0.5422 mm in –y
  - Seismic forces in –y (downward): deflection 0.5622 mm in y (0.5496 mm parked)

() - Parked	Max Stress on Base leg – (Alloy Steel) (MN/m^2)	Max Stress on Roller support (Al) (MN/m^2)	X (mm)	Y (mm)	Z (mm)
+x (beam direction)	303.8 (306.7)	77.03 (65.56)	0.9534 (0.9023)	-0.5422 (-0.4645)	0.1869 (-0.1883)
-x	326.9 (325.7)	57.44 (51.25)	-0.4482 (-0.5612)	-0.4044 (-0.3489)	0.1472 (-0.2201)
+z	366.3 (360.7)	72.53 (60.28)	0.5115 (0.5029)	-0.5204 (-0.5344)	0.2836 (0.3509)
-z	205.0 (197.6)	65.51 (51.96)	0.5107 (0.4964)	-0.4743 (-0.4272)	-0.2403 (-0.2707)
+y	250.2 (243.0)	60.50 (50.10)	0.4600 (0.4497)	-0.4260 (-0.3660)	0.1498 (-0.1838)
-y (Downward)	305.8 (297.0)	73.95 (61.23)	0.5622 (0.5496)	-0.5207 (-0.4474)	0.1830 (-0.2246)

- 6061-T6 Al - Tensile Strength 310 MN/m^2
- Alloy steel -Tensile Strength 723 MN/m^2

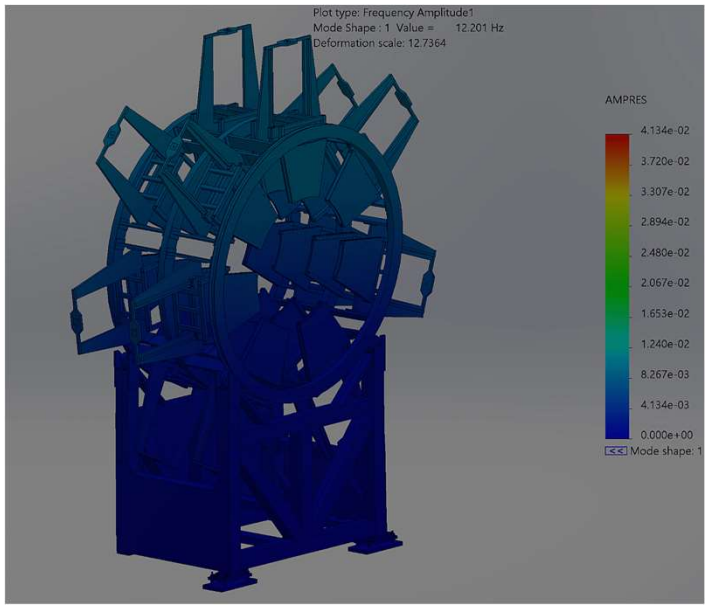
Buckling analysis

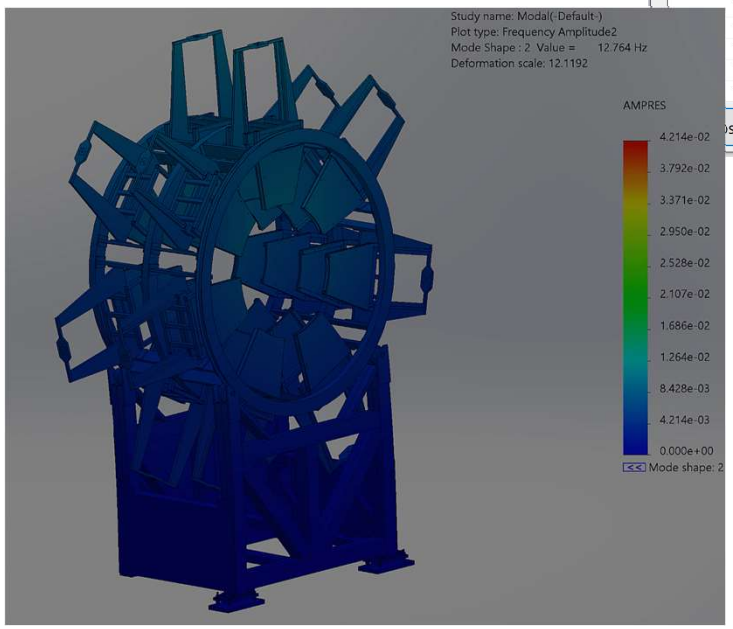
- 1 < BLF, Buckling not predicted. The applied loads are less than the estimated critical loads. Buckling is not expected.
- BLF < -1, Buckling not predicted. Buckling is not expected even if you reverse all loads.



GEM Rotator – Modal analysis

- Lowest resonant frequency is 12.201 Hz > 10 Hz target value





List Modes

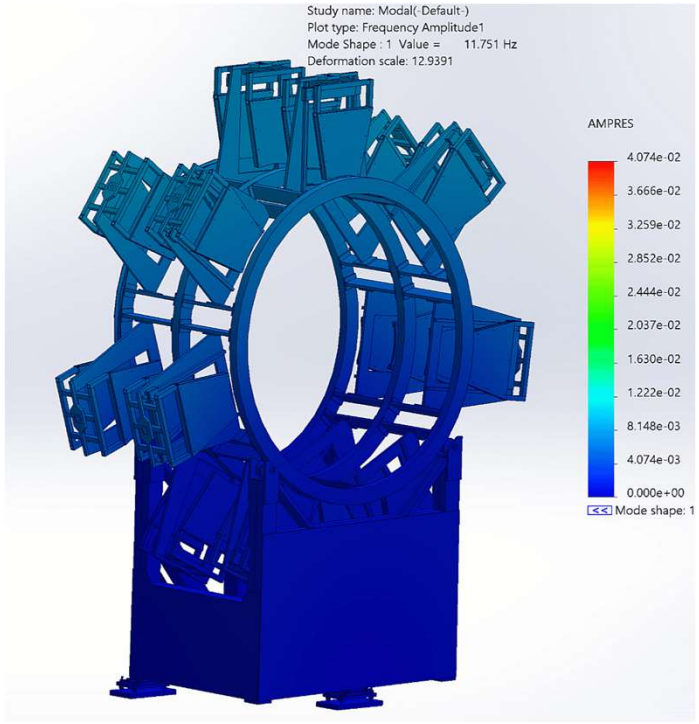
Study name:Modal

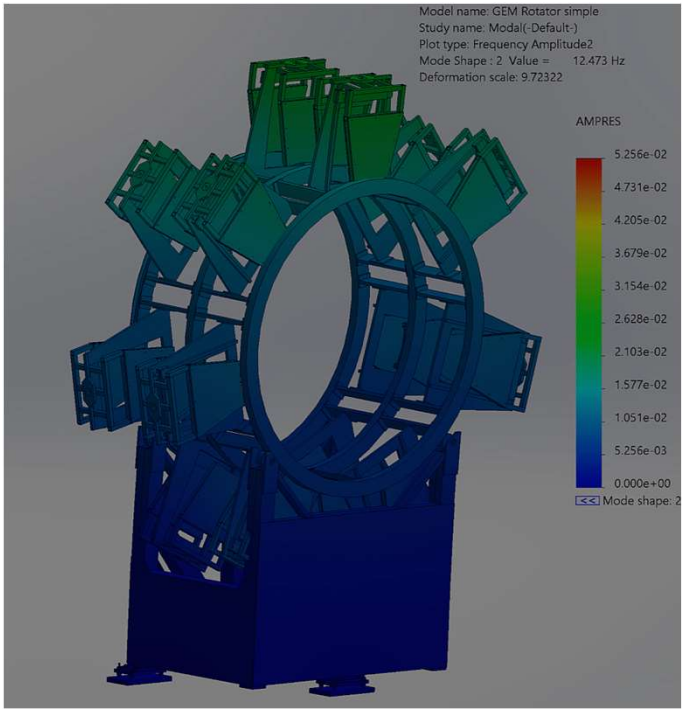
Mode No.	Frequency(Rad/sec)	Frequency(Hertz)	Period(Seconds)
1	76.658	12.201	0.081964
2	80.201	12.764	0.078343
3	135.5	21.565	0.046371
4	158.89	25.288	0.039544
5	163.35	25.998	0.038465
6	163.91	26.086	0.038334
7	164.12	26.12	0.038285
8	164.82	26.231	0.038122
9	164.98	26.257	0.038086
10	165.41	26.326	0.037986
11	165.65	26.364	0.037931
12	165.99	26.418	0.037853
13	166.43	26.488	0.037753
14	167.38	26.639	0.037538
15	167.83	26.711	0.037438

Save Help

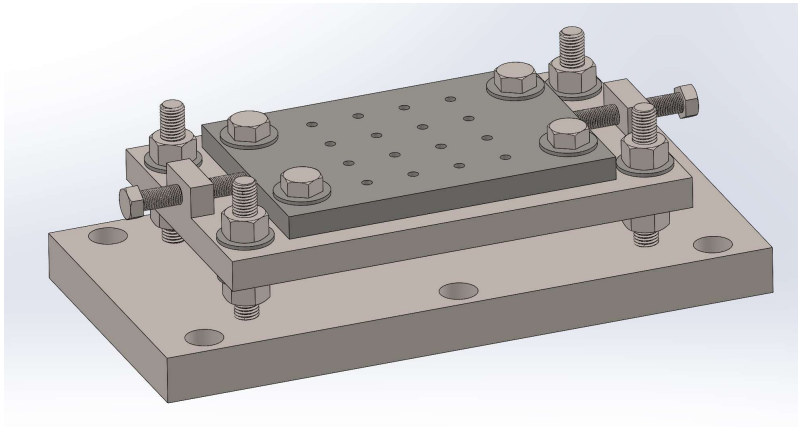
GEM Rotator – Modal analysis

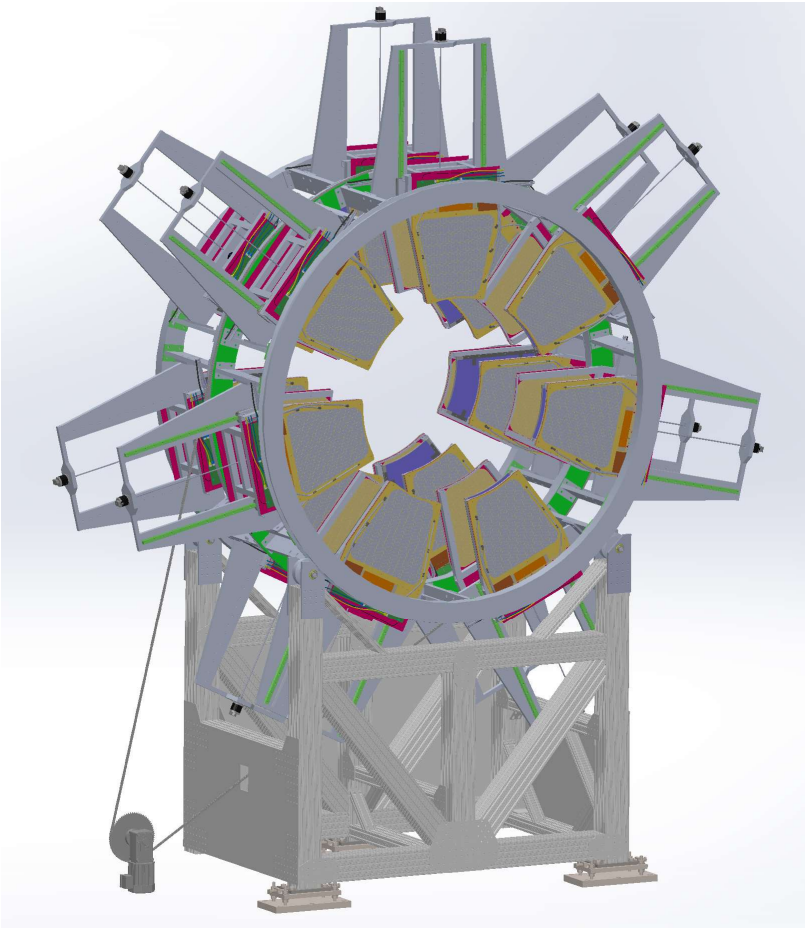
- Lowest resonant frequency is 11.751 Hz > 10 Hz target value





GEM Rotator - Stand adjustors





- Two at the upstream side, and one at the downstream side, grouted to Hall A floor
- ±15 mm adjustment in the y direction (vertical) and ±7.8 mm in the x direction. Give Pitch and Yaw adjustment.
- Location of the Rotator in z (beam direction) not critical.
- Roll angle for the GEMs is adjustable by the rotation mechanism.
- The base-leg adjusters follow designs commonly used in Hall A at JLab for adjustable mounting of heavy equipment.

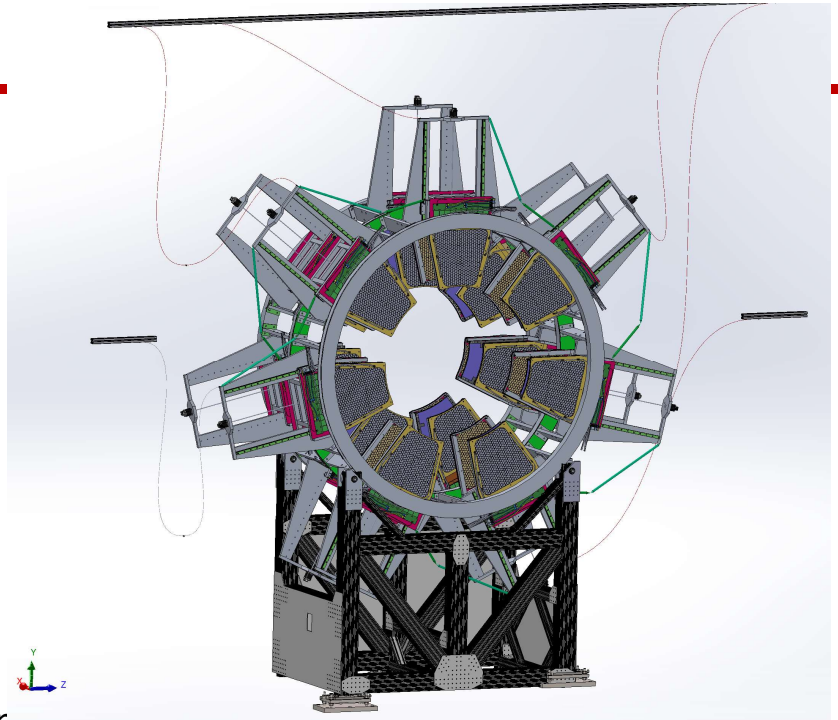
Cable arrangements

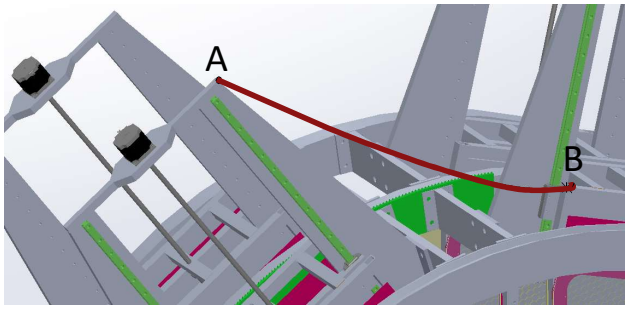
- Cables per GEM module
  4 HDMI cables (OD 7mm).
  1 gas lines (OD 6.35mm).
  1 High Voltage(HV) cable (OD 6mm).

- Cables per Trigger scintillator
  1 HV cable (OD 6mm).
  1 signal cable (OD 6mm).

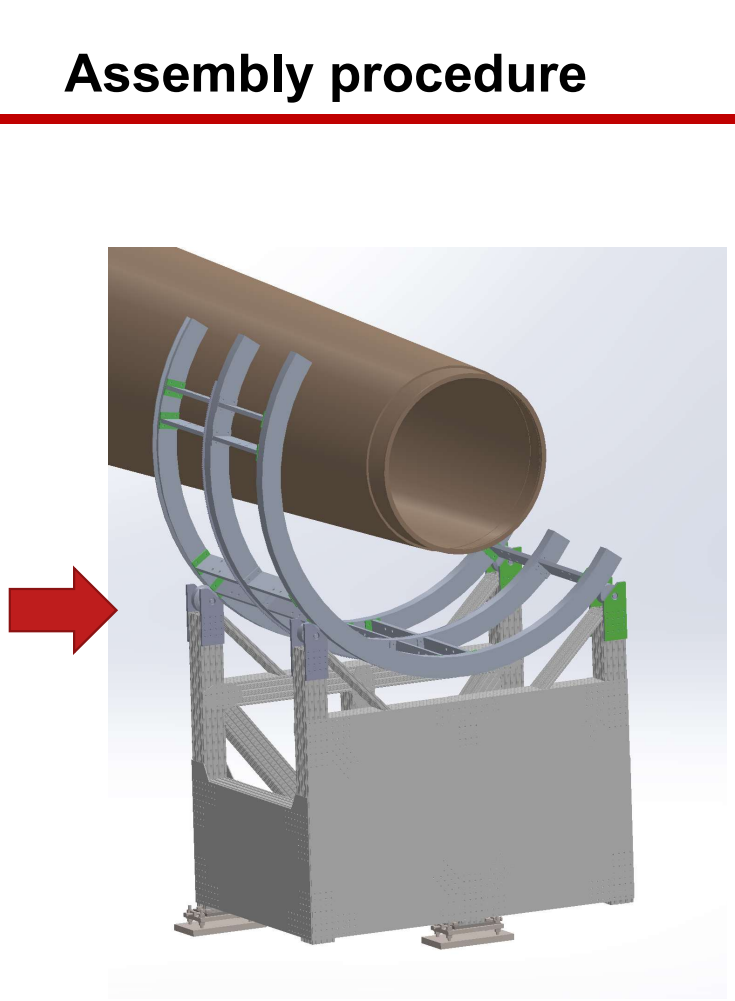
- Radial motion
  - Option 1: Cable and hose carriers (Loop Ht. 14.4” or 22.2”) - Nylon
  - Option 2: Wire bundle attached on two points

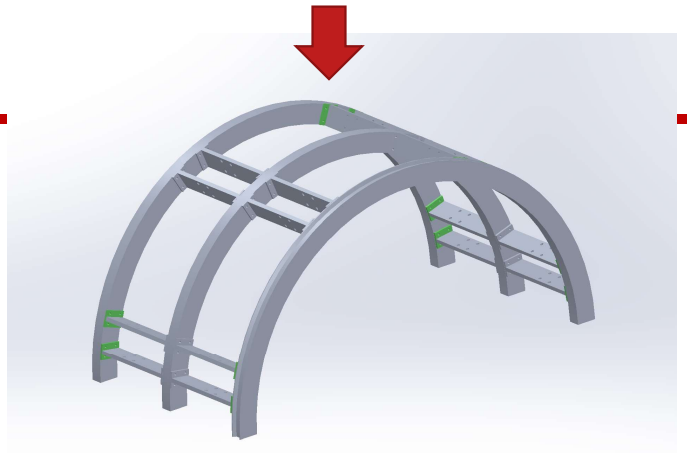
- Rotational motion
  - Cable System suspend from above

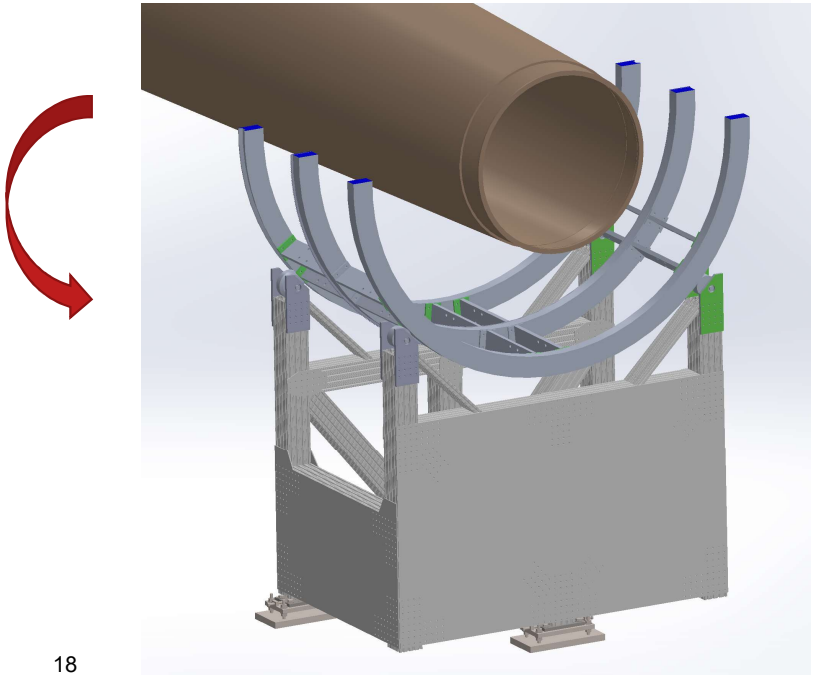




Assembly procedure







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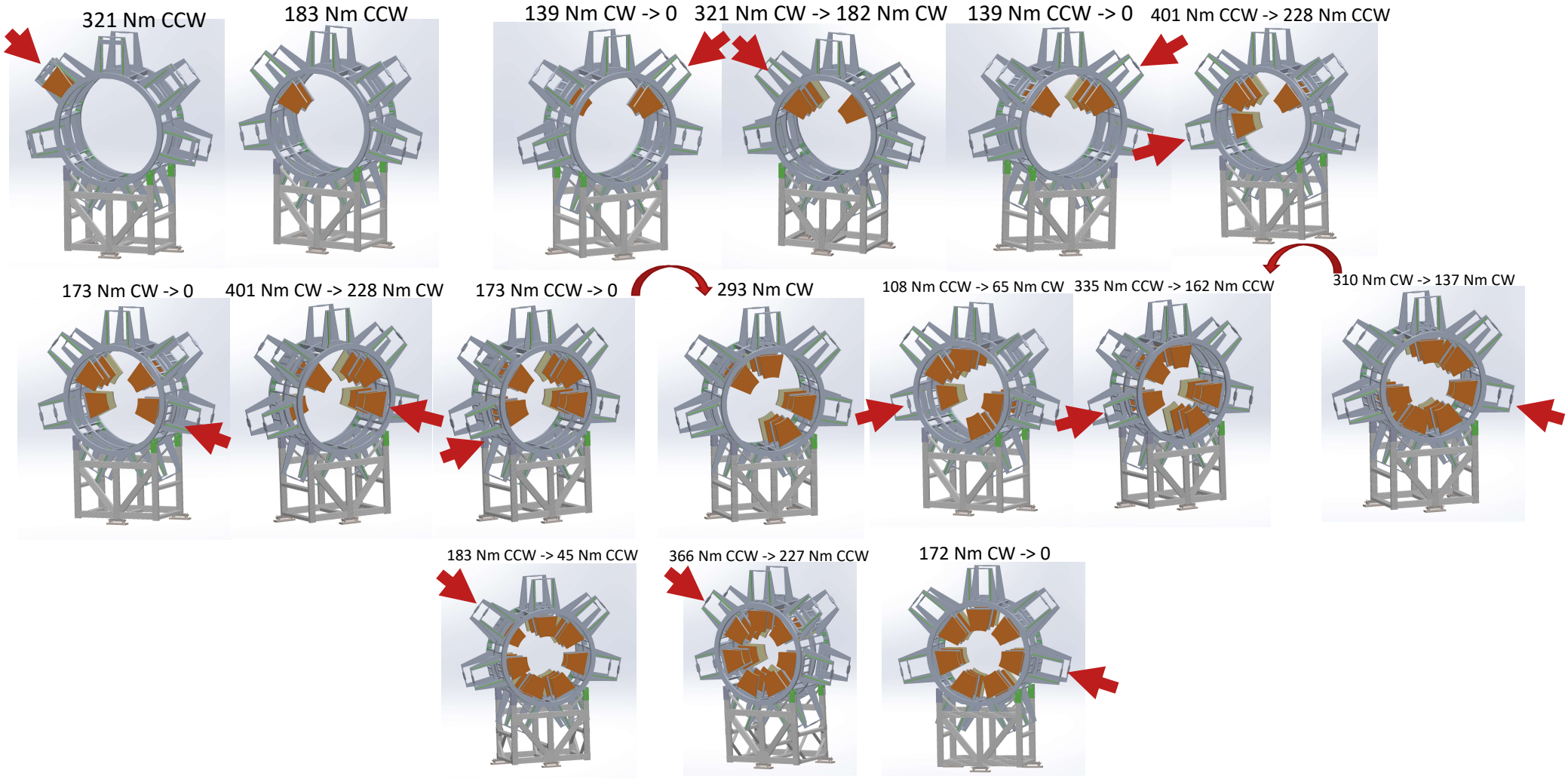

Summary

- GEM rotator
  - Mechanical design is mostly done.
  - Analysis (Static, seismic, Modal, Buckling) are completed.
  - Need to add connection details to the rotator wheel and complete the drawing package.
  - Support stand use commercially available parts other than base leg, side plates and bearing support.

- Radial and rotational motion
  - Stepper motor linear actuator is selected.
  - Radial motion motor and chain selected.
  - Need to select the drive controllers.

- Need to finalize the cable arrangements