Refined Concept of the JUNO Calibration System

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From Last Meeting

Detector response specs

$$E_{true} = \boxed{E_{cent}(Q)} \times \boxed{f(\vec{r})}$$

Nonlinearity Non-uniformity

- Control energy scale to ~1% (nonlinearity and non-uniformity)
- Control energy resolution to ~3% at 1 MeV (including both charge and position resolutions)

Multiple positions, multiple sources!

Outline

- Mechanical system
- Sources

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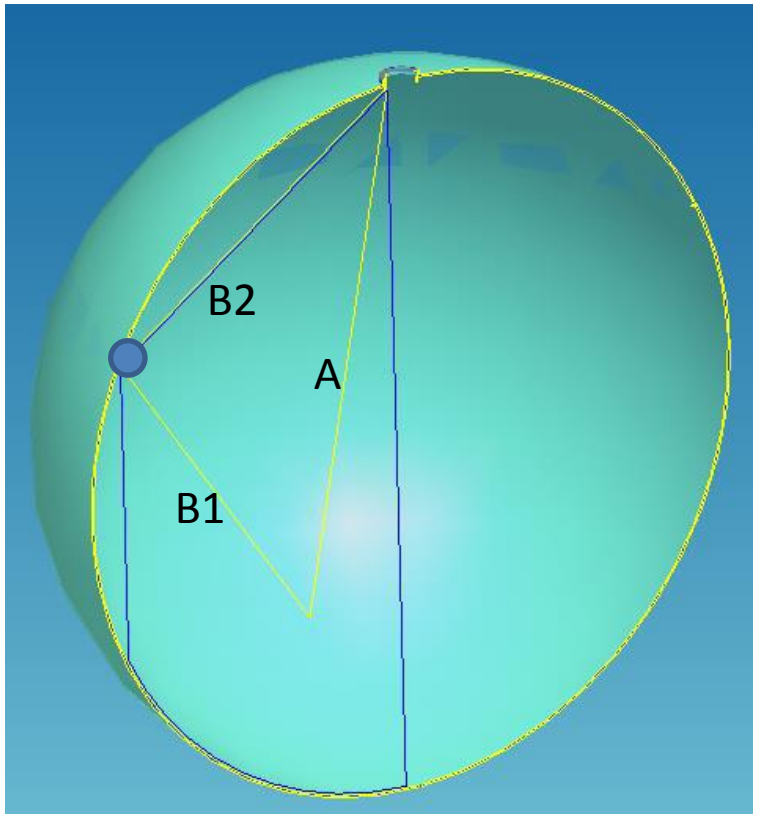
- Sources

Multiple positions=> “4-pi”

But

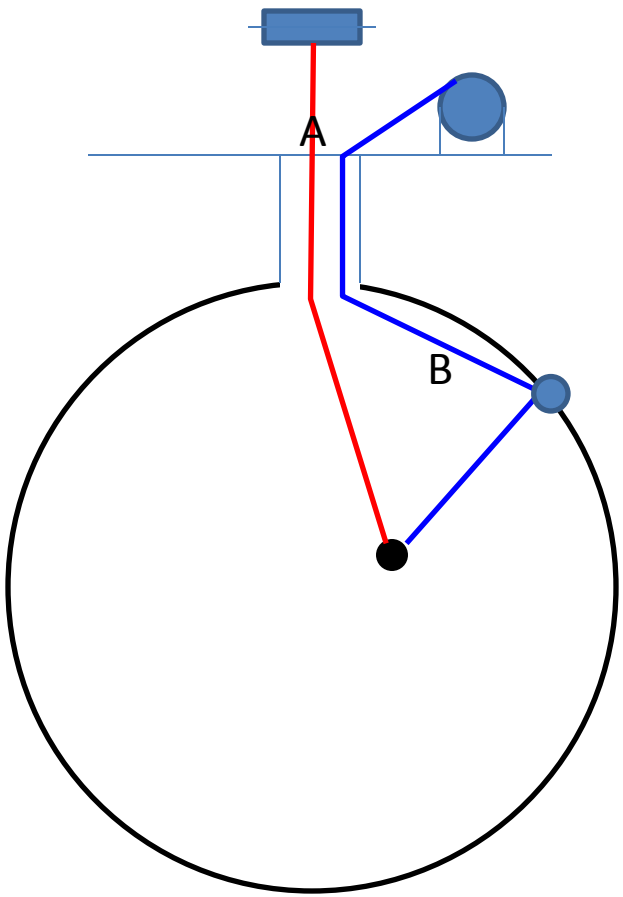
- Light weight (important for the reliability of the system)
- Simple and reliable (not “too much” difficult than Daya Bay ACUs)
- Automatic? Single access penetration
- Allow relatively frequent deployment. Imagine you have to scan the central axes and a few off-center points on a weekly or monthly basis, submarine would be too much a burden …

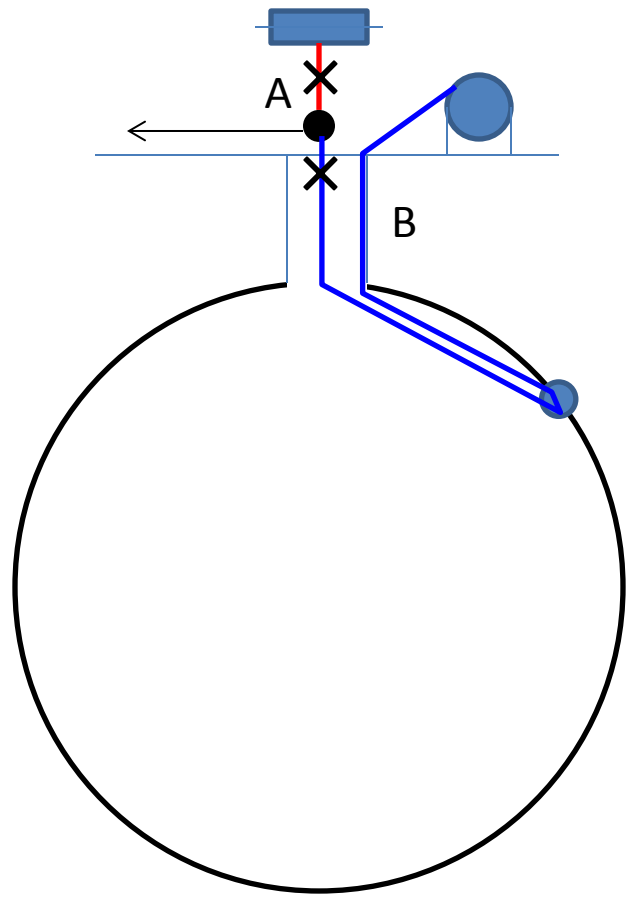
SNO concept



Multiple “B” cable anchor can allow multiple coverage in phi.

Single deployment sequence: a cartoon

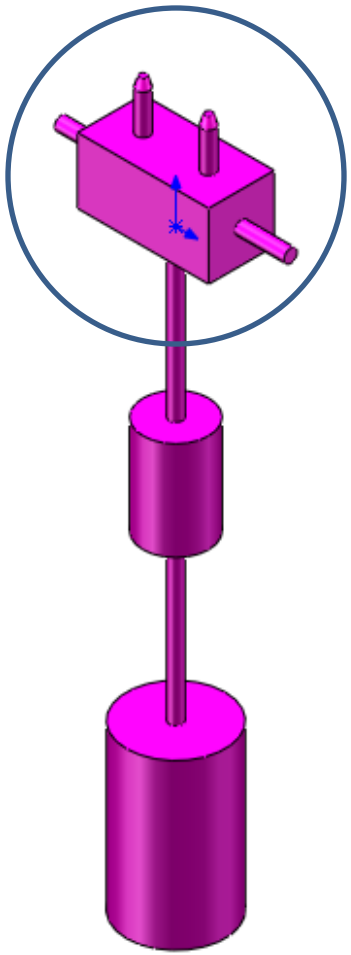




A-B rope synchronous motion

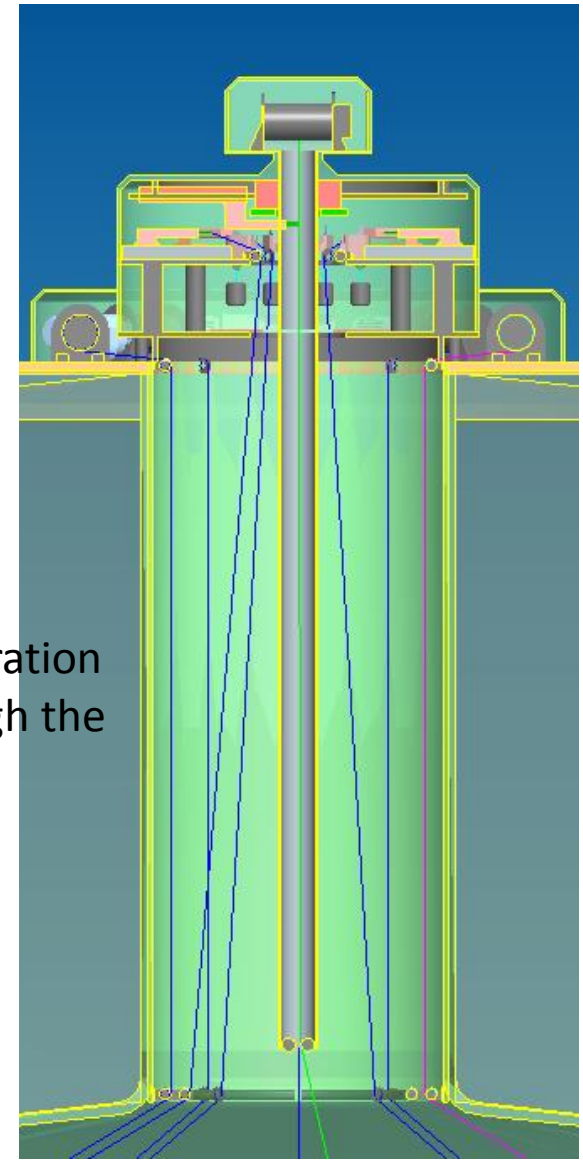
- Detach A, store end of A
- Detach B, store end of B
- Take source, store source
- **Can we automate this???**

Universal source interface

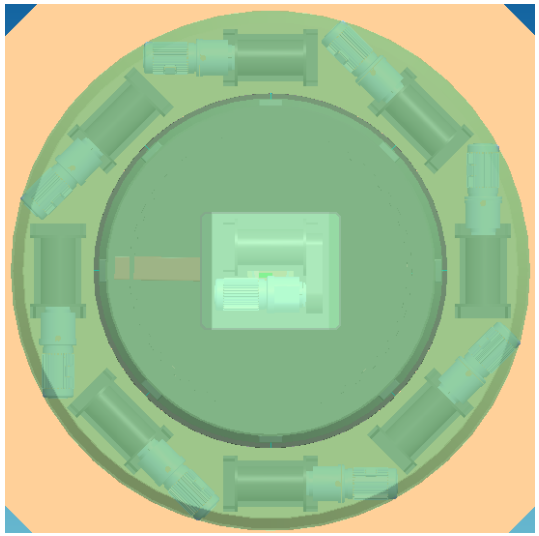


1. Universal attachment structure, e.g. quick connects
2. Need to optimize the design to avoid sharp edges
3. Making all rad source the same size probably impossible, but perhaps can restrict to a common cylindrical shape
4. Optical fiber interface may be different

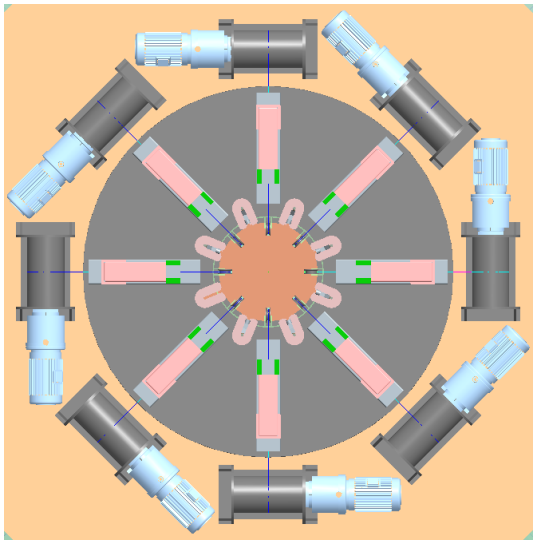
Layout concept: 8 phi scan plane



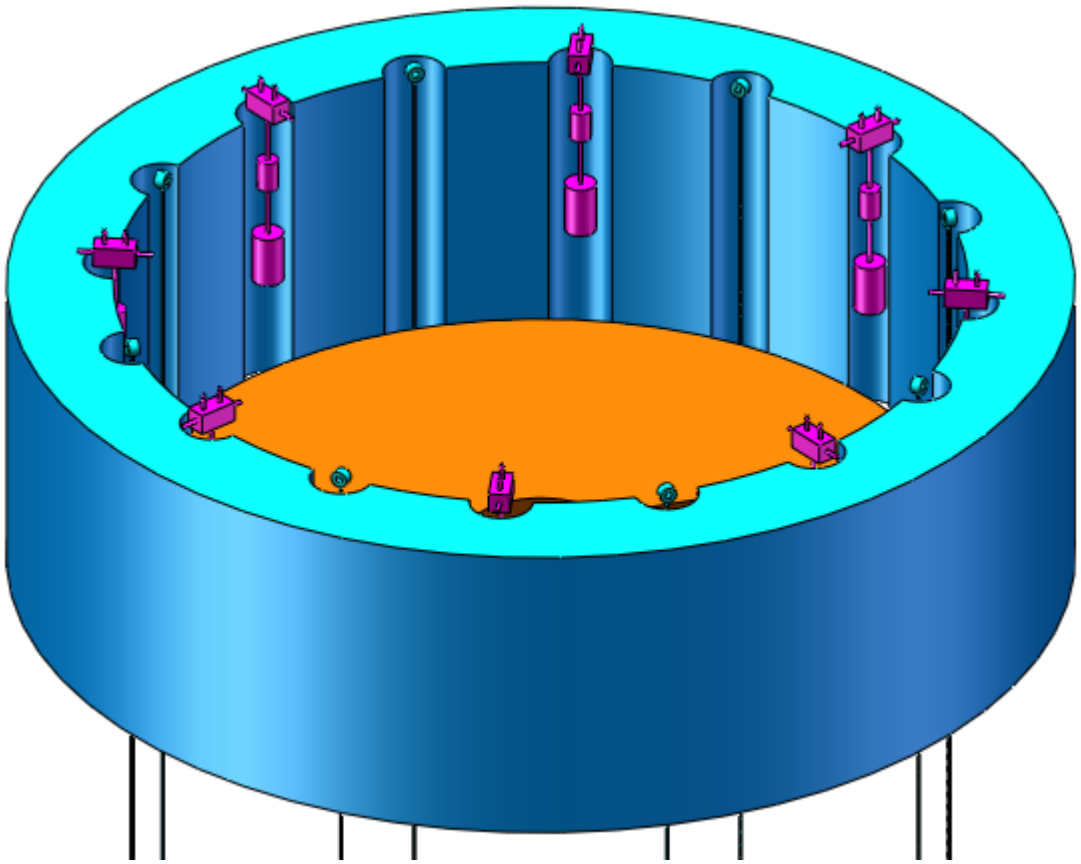
Penetration through the water



8 B rope motor



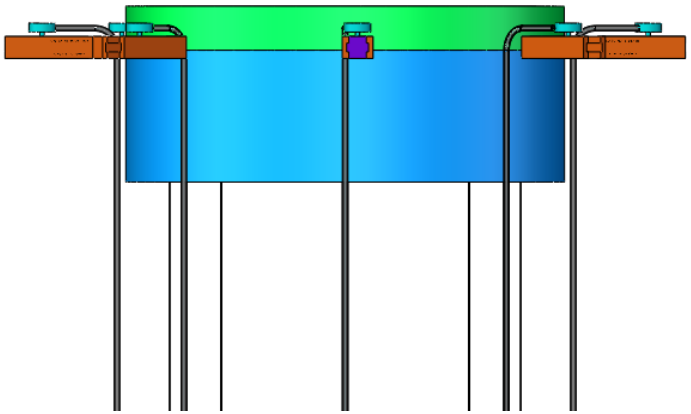
Cable B end storage/source storage

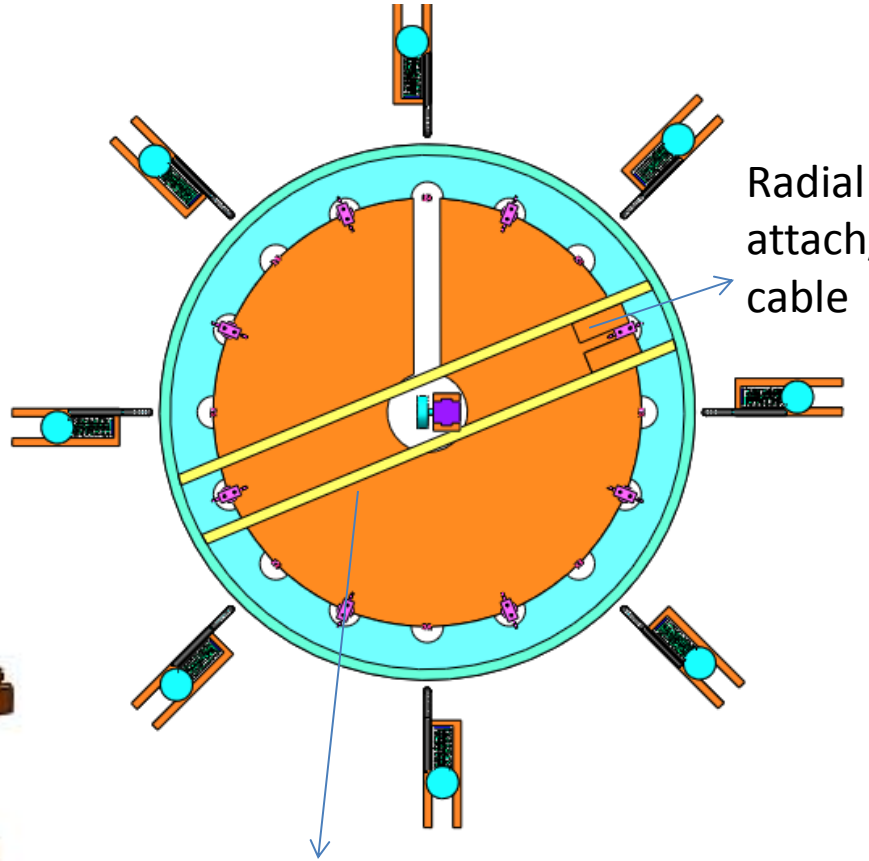


- 8 cable B storage
- Up-to 8 source storage staggered in phi direction

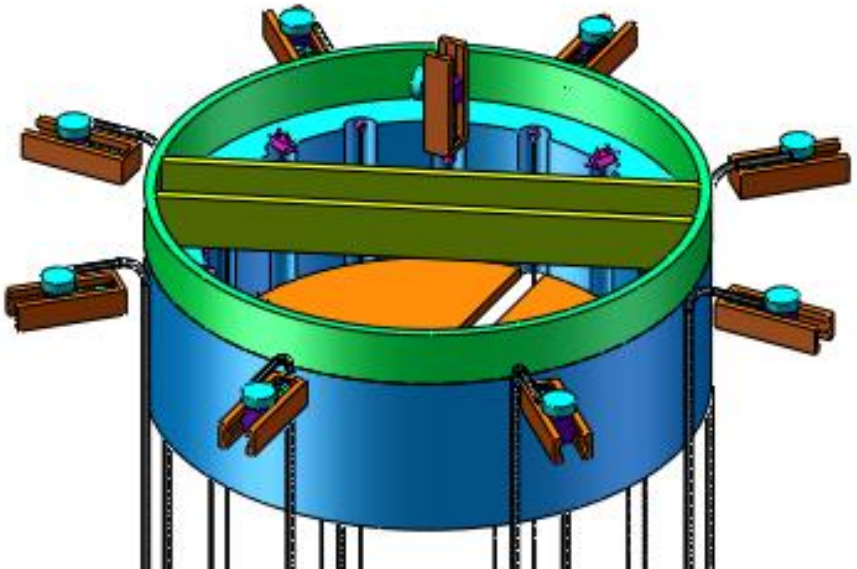
Source change overview

Z motion to attach/detach A cable



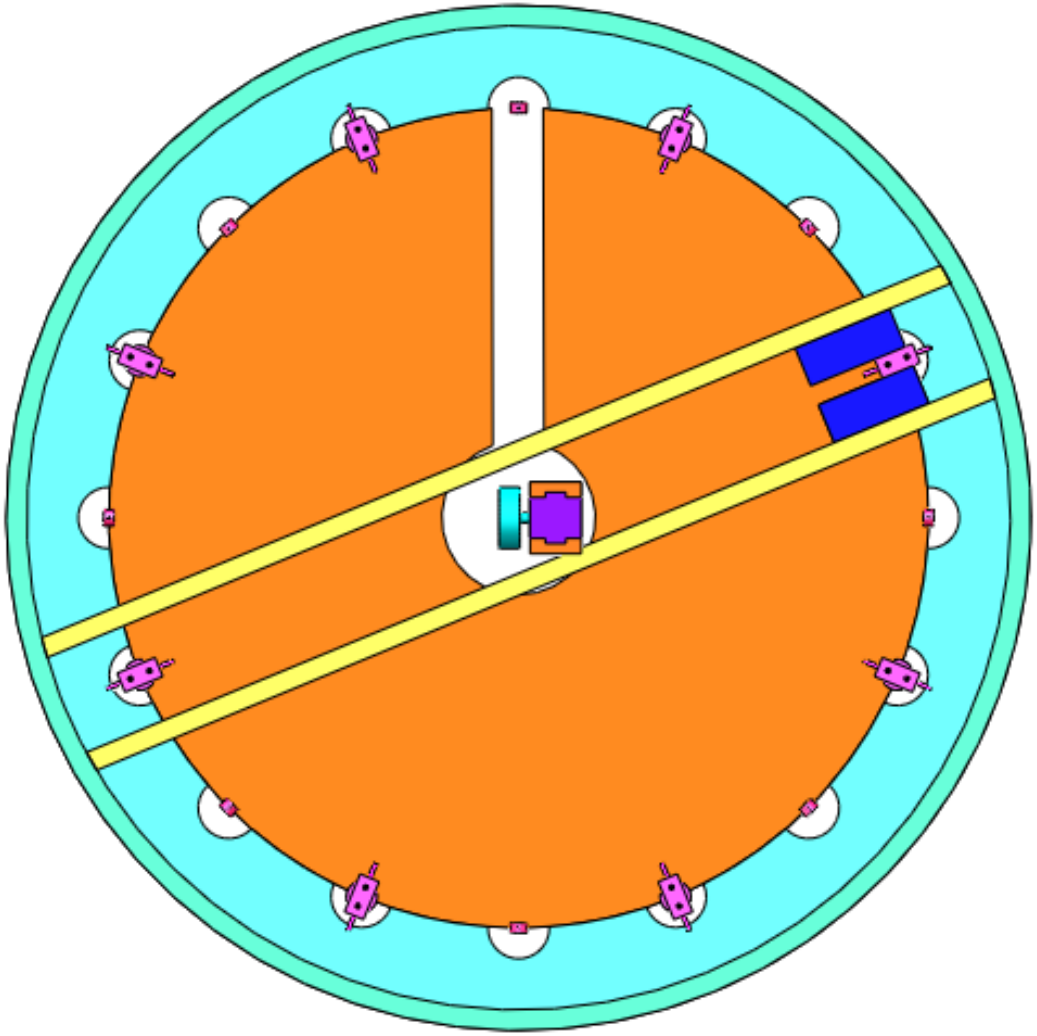


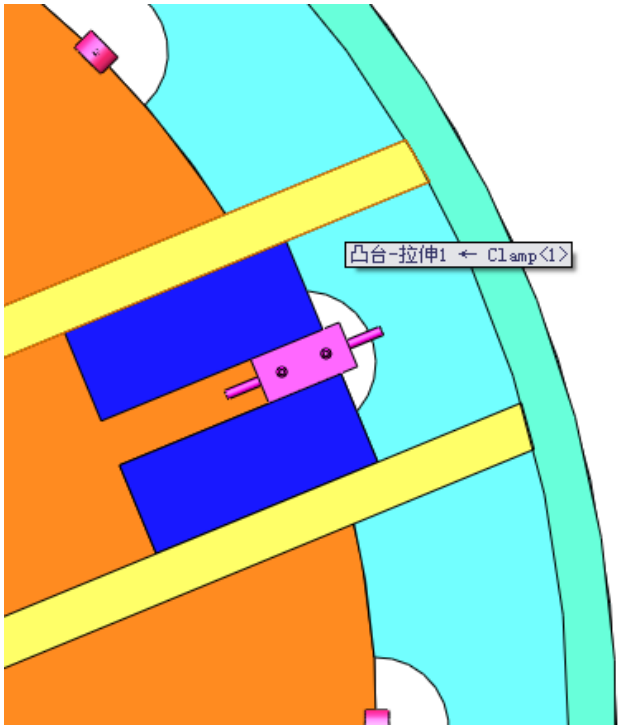
Radial motion to attach/detach B cable



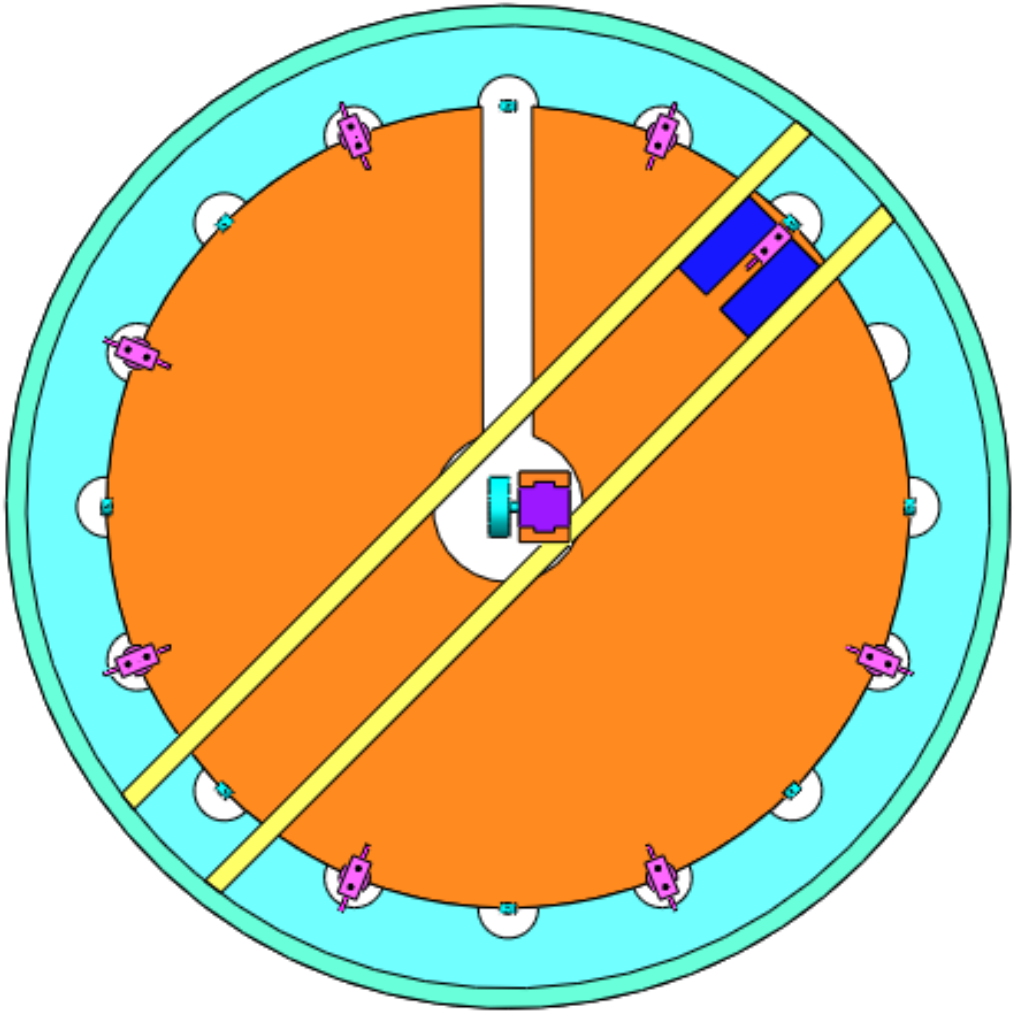
Phi motion to select source & B cable

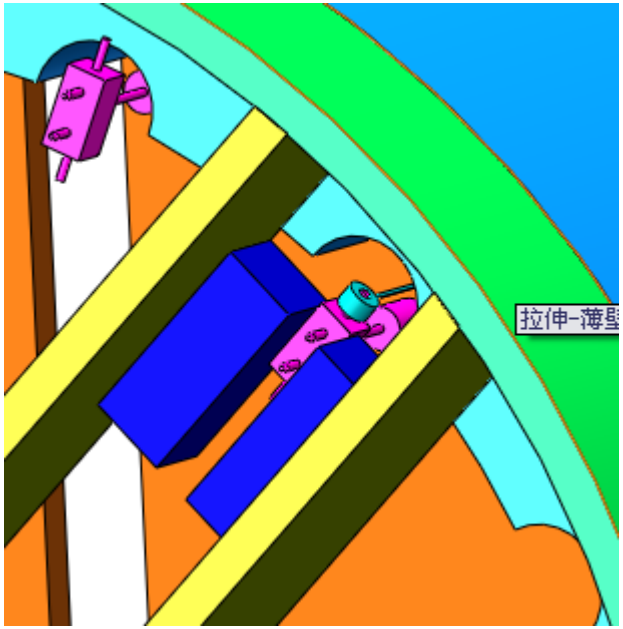
Motion 1: take a source



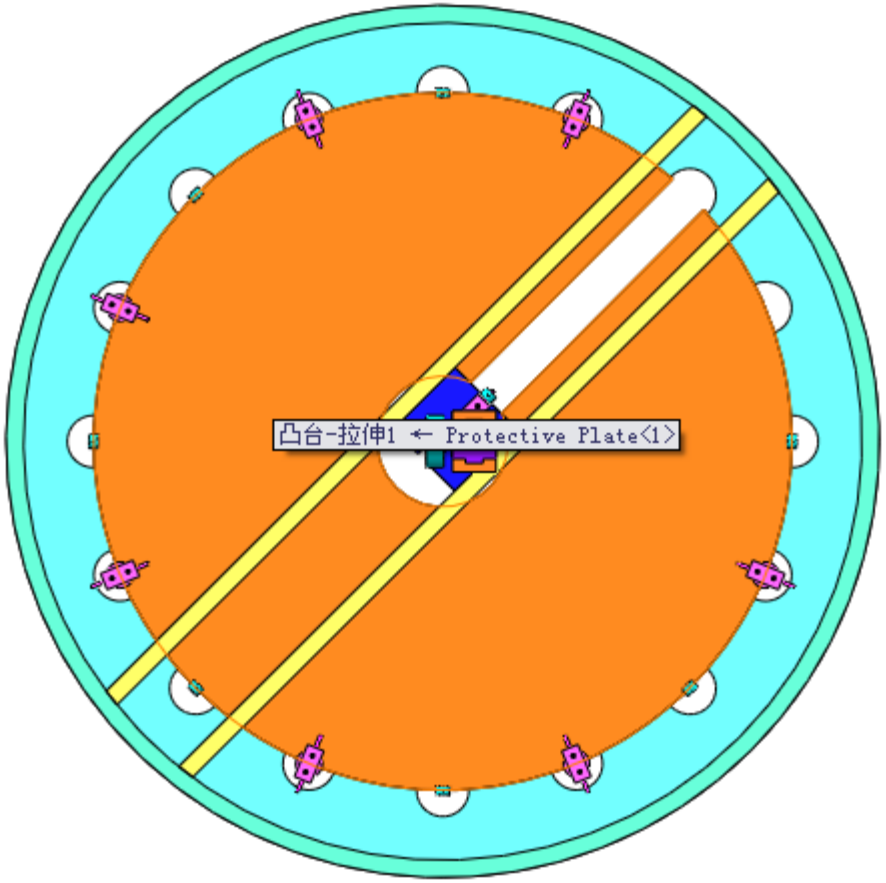


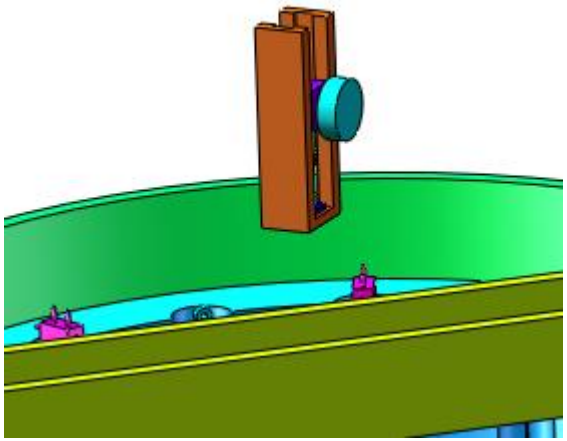
Motion 2: attach B cable





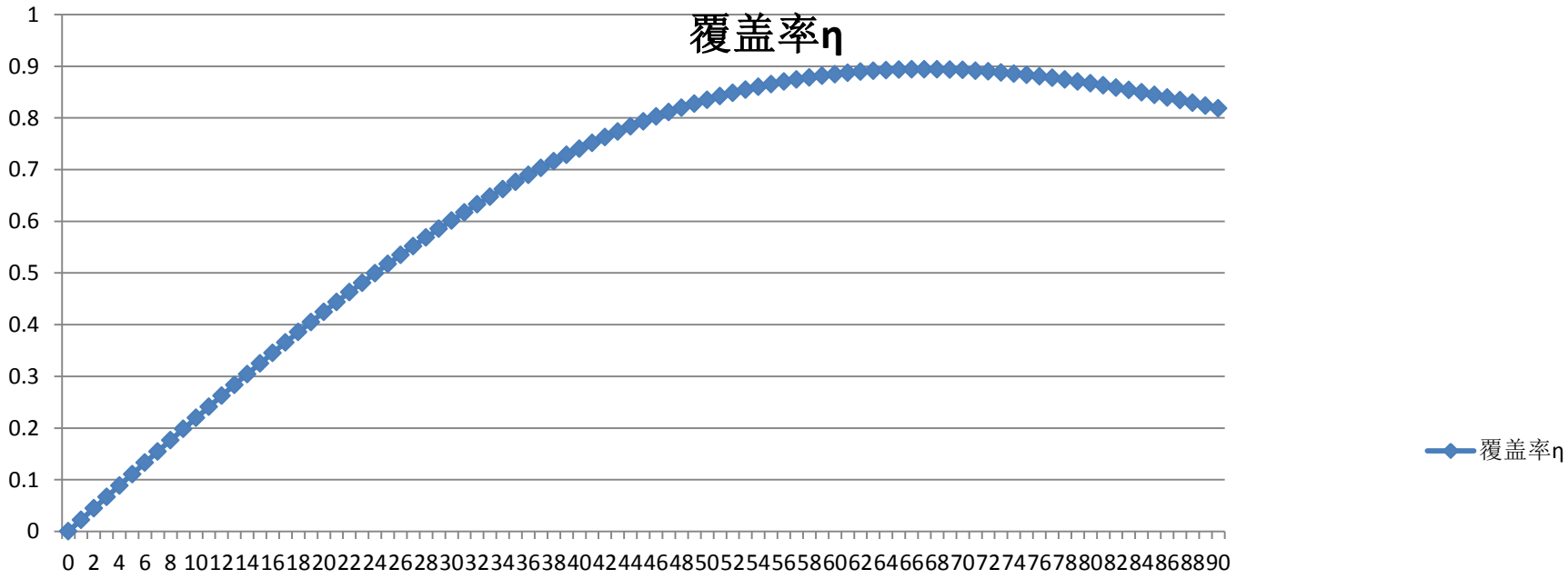
Motion 3: attach A cable





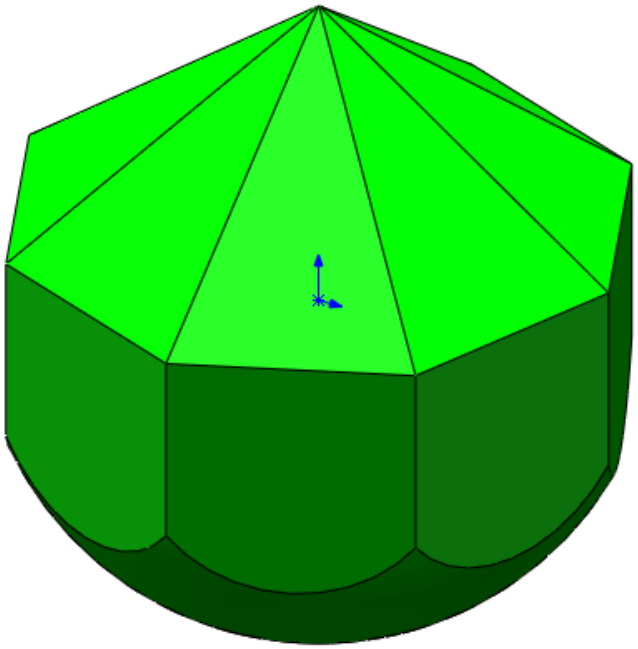
Anchor point location

At latitude 23 degree, theoretical maximum coverage is 89% in a given phi plane



More 3D points?

- If one choose to attach the source with 2 B cable and one A cable, then in principle one can manipulate the source in between phi planes
- Theoretically a 77% volume coverage
- Sounds creative or crazy?



More details

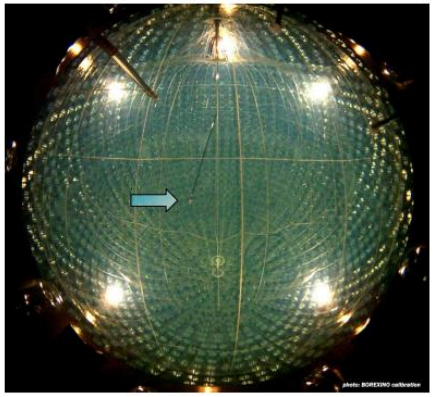
- We have another design firm that is working on an independent design, with more details in source changing sequence
- At present stage, we think that the such level of automation does seem plausible (not totally crazy)
- See appendix

Positioning and position measurement

- Positioning is done by synchronous motion of the A/B cable
- Accuracy is important
- Position feedback
  - Optical: CCD with IR lighting (Borexino)

  proven technology
  - Utrasonic: can incorporate a battery powered ultrasonic emitter in the source weight (industrial, 声学所)

Arxiv: 1207.4816



Outline

- Mechanical system
- Sources

What is being considered

- Linearity:
  - multiple gamma sources (Cs137, Mn54, Ge68, Na22, Co60, K40)
  - Neutron sources: AmC, AmBe, Cf252
  - e+, e-, and alpha vials (continuous B12 spectrum gets us a long way)
- Diffusive source (e.g. Na24 in SNO)
- Other background events in the detector, of course
- Timing/PMT responses/electronics nonlinearity
  - laser diodes with fiber + diffuser ball

Beta/Positron sources

High Q positron emitter:

Positron Emitter	halflife (s)	Q–value (keV)
^{52}Mn	4.831×10^5	3689.29
^{56}Co	6.673×10^6	3543.8
^{72}As	9.4×10^4	3333.9

High Q positron emitter with long-lived EC parent

EC Parent	Halflife (s)	Positron–Emitter	Q–value (keV)
^{44}Ti	1.9×10^9	^{44}Sc	2630.19
^{68}Ge	2.341×10^7	^{68}Ga	1898.9
^{72}Se	7.3×10^5	^{72}As	3333.9
^{82}Sr	2.208×10^6	^{82}Rb	3379.11
^{88}Zr	7.21×10^6	^{88}Y	2600.4
^{100}Pd	3.14×10^5	^{100}Rh	2612.6
^{118}Te	5.2×10^5	^{118}Sb	2634.44
^{128}Ba	2.1×10^5	^{128}Cs	2906.46
^{134}Ce	2.73×10^5	^{134}La	2709.0
^{140}Nd	2.91×10^5	^{140}Pr	2365.8
^{146}Gd	4.171×10^6	^{146}Eu	2857.4
^{160}Er	1.029×10^5	^{160}Ho	2267.8
^{166}Yb	2.04×10^5	^{166}Tm	2015.5
^{172}Hf	5.9×10^7	^{172}Lu	1496.75
^{178}W	1.87×10^6	^{178}Ta	914.8
^{188}Pt	8.81×10^5	^{188}Ir	1786.16
^{194}Hg	1.40×10^{10}	^{194}Au	1478.9
^{202}Pb	1.66×10^{12}	^{202}Tl	340.4

Vial concept (Borexino)

Acrylic vial

LS mixed with source

Borexino source vial

Advantage: LS position/beta spectrum with NO ambiguity from position reconstruction

- Difficulty: energy loss in the acrylic would biases the true energy spectrum
- Can have a few different vial with different thickness or S/V ratio to extrapolate
- Need Monte Carlo
- Looking forward to hear Wei's positron gun idea

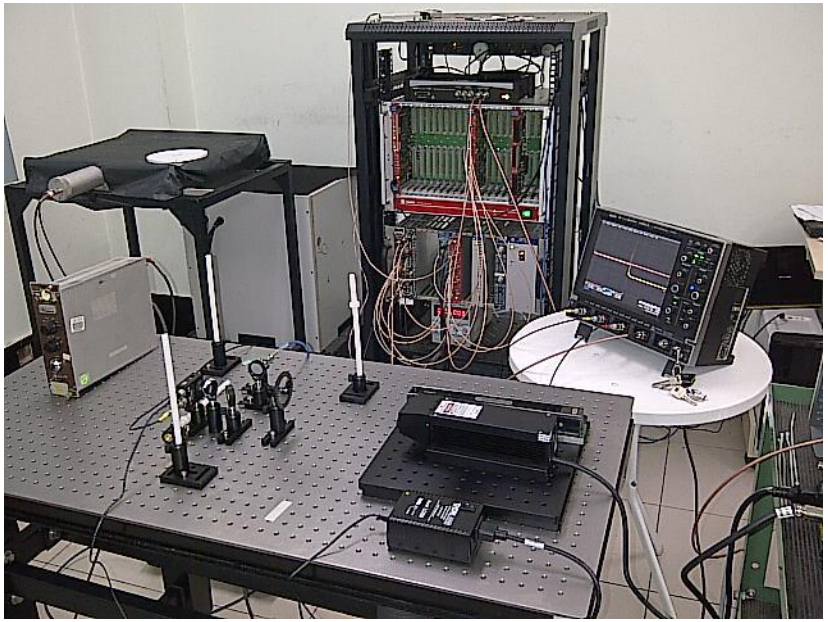
Laser system

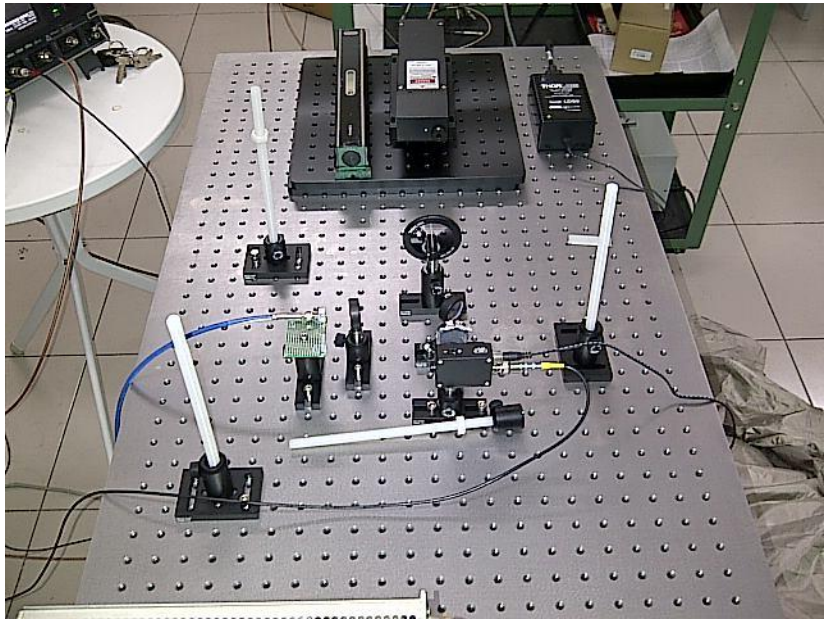
- Current concept, a movable UV-grade fiber (with diffuser) that can move along central axis
  - Advantage: can use laser with different wavelength externally
  - an Daya Bay-ACU like deployment system along the central axis
- Other fiber can be planted at fixed locations, e.g. close to each PMT module

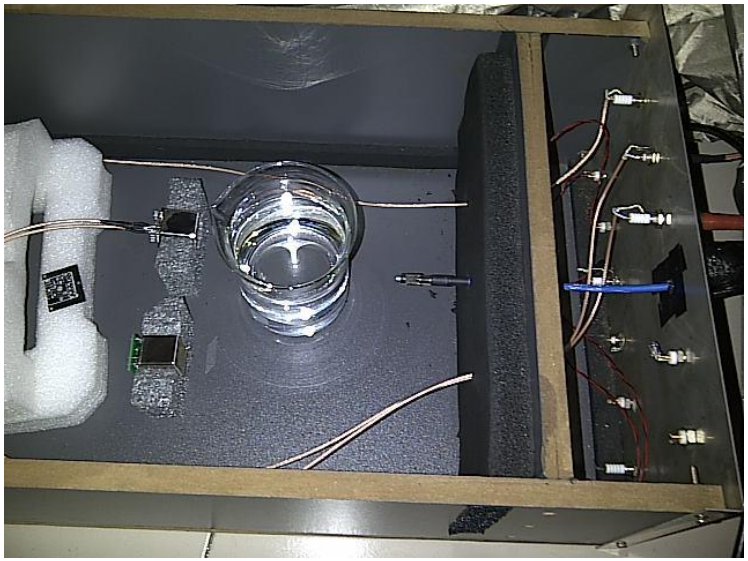
Important application: electronics nonlinearity

- Can use short wavelength UV laser to excite LS, which can generate well-control light strength with the SAME timing profile as charged particles (MACRO, KARMEN, D-Chooz, etc)

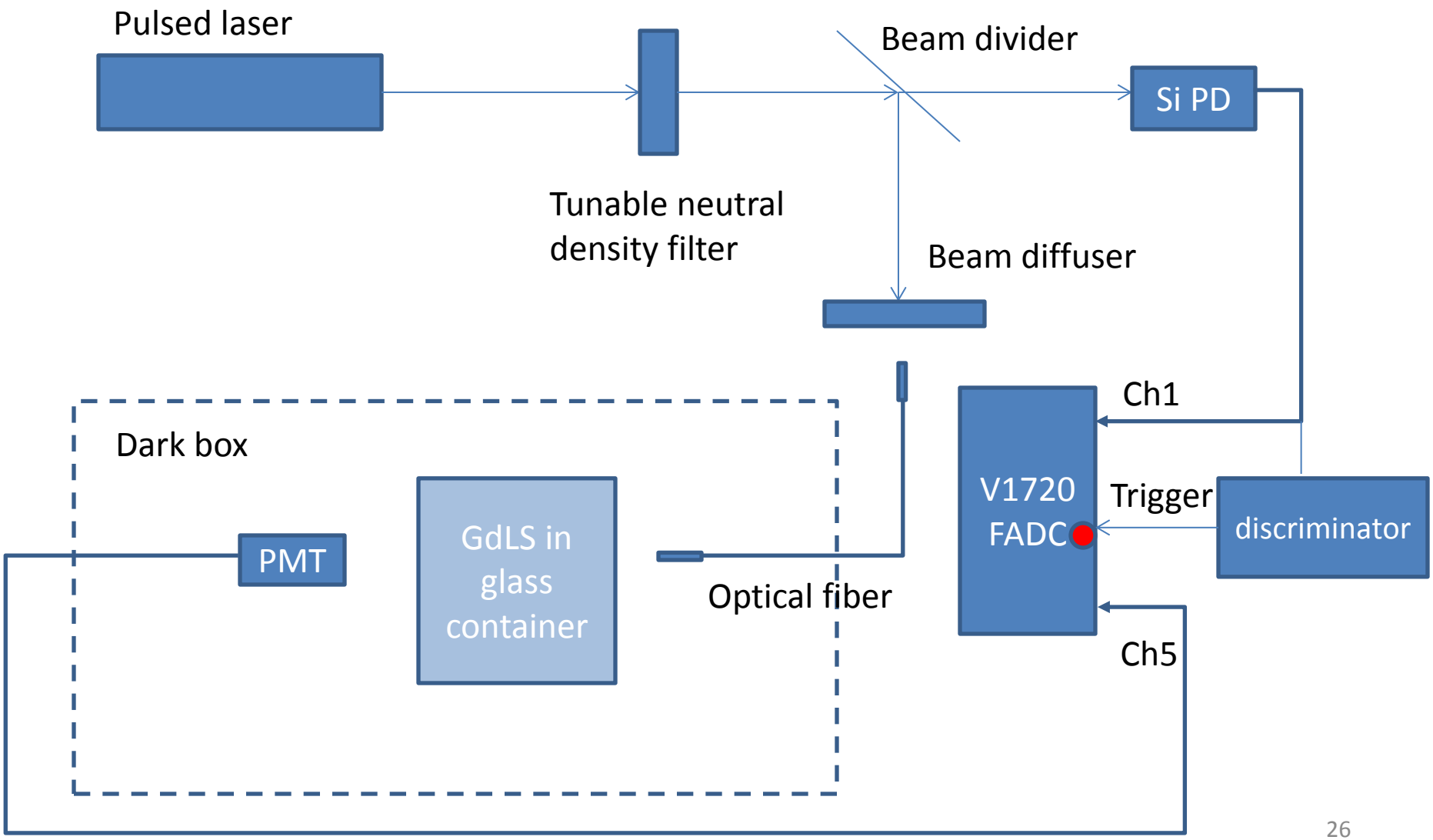
Bench tests at SJTU



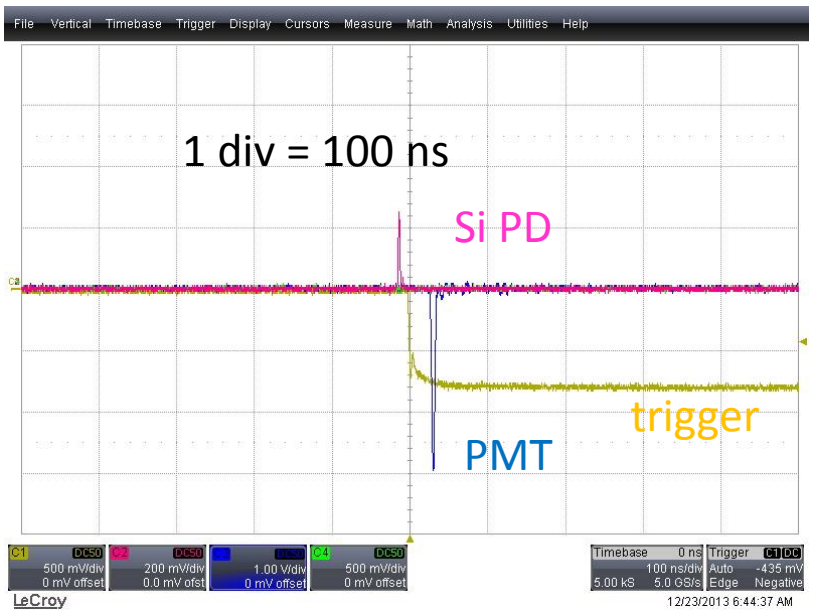


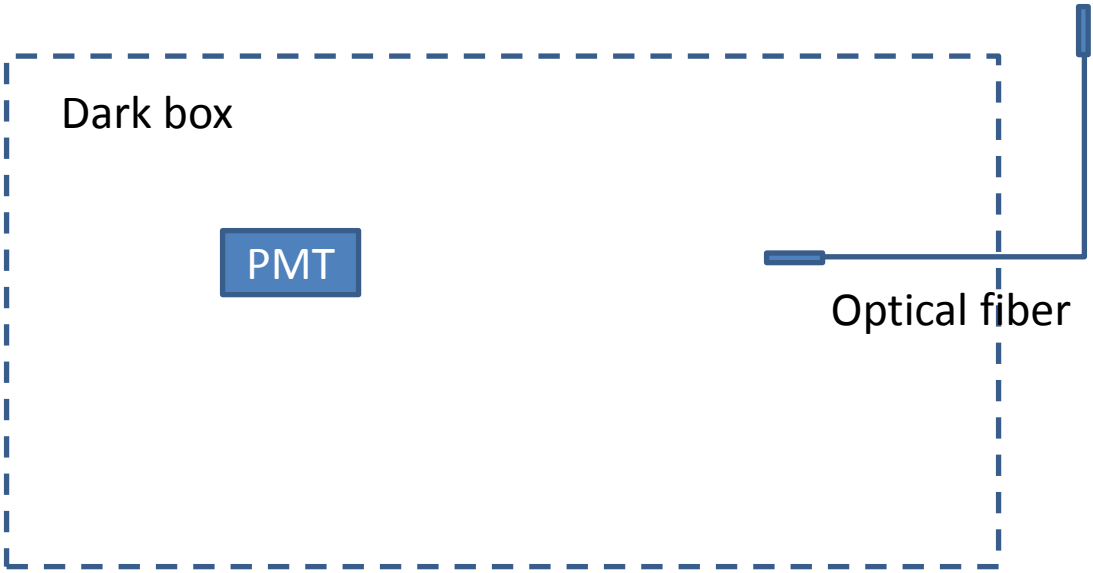


Schematic

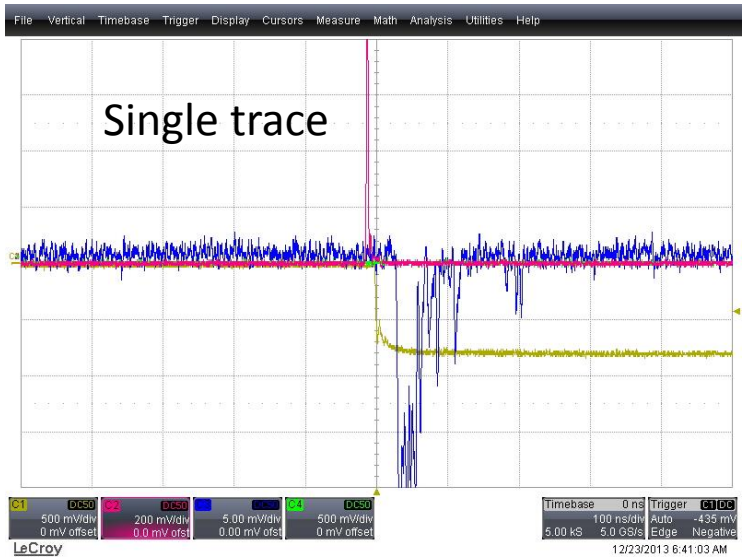

Pulsed laser
Beam divider
Si PD
Tunable neutral density filter
Beam diffuser
Ch1
Dark box
V1720 FADC
Trigger
discriminator
PMT
GdLS in glass container
Optical fiber
Ch5

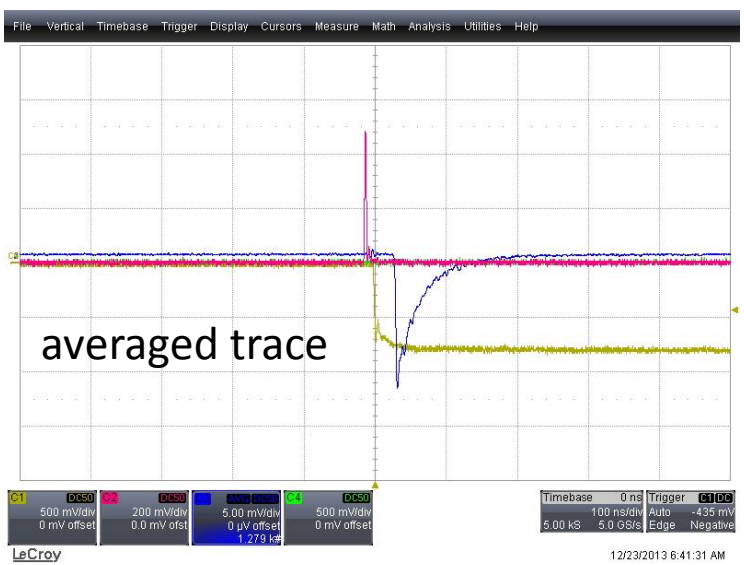
Direct laser light timing

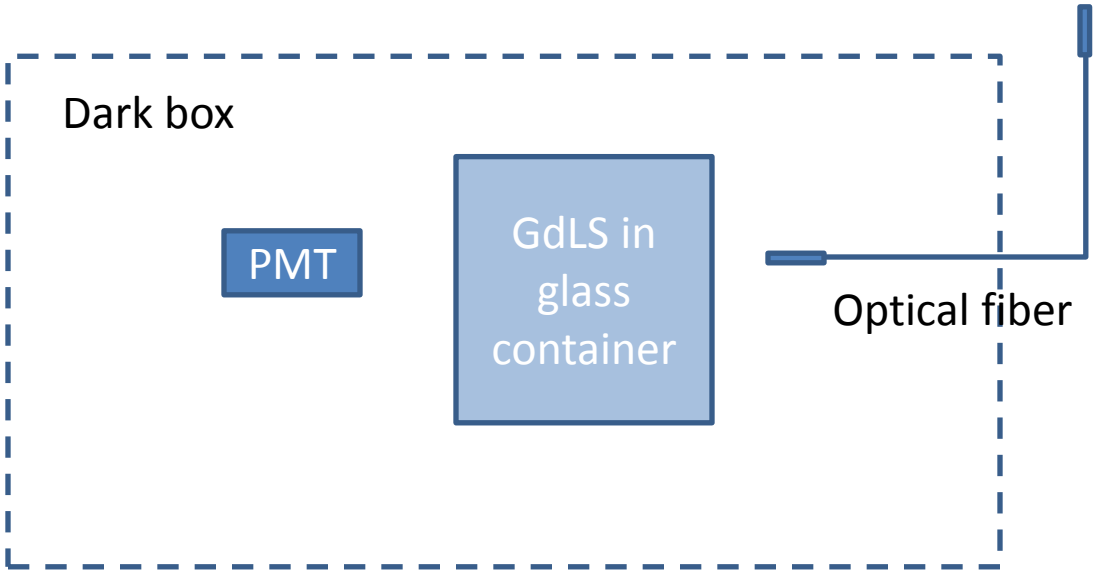




Excited LS light timing





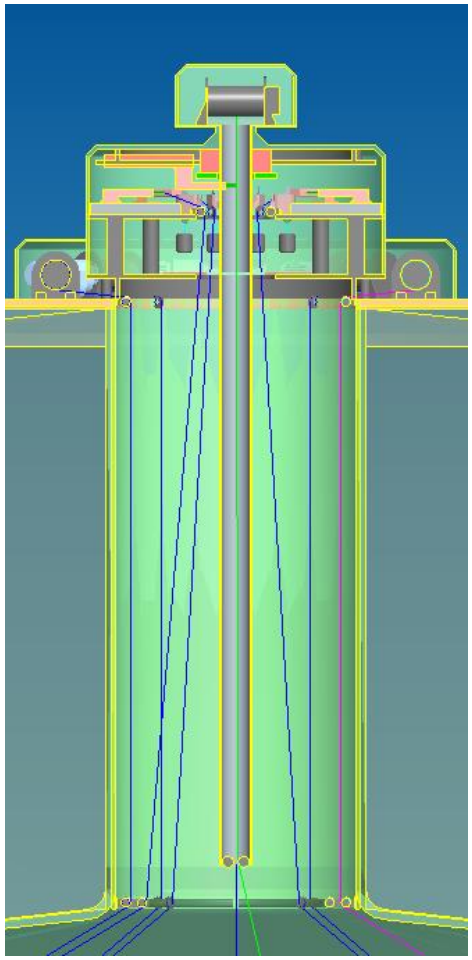


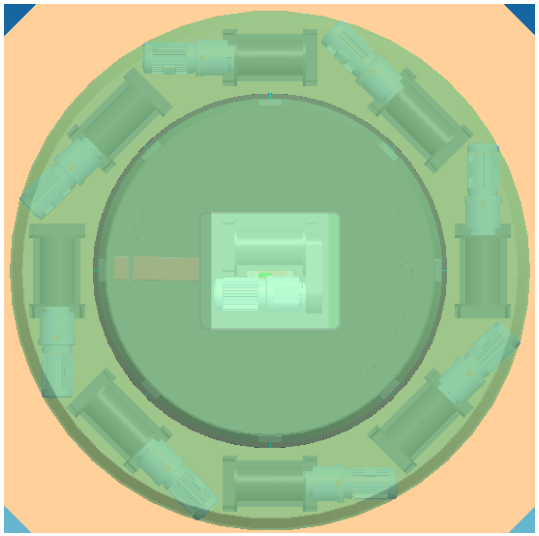
Summary

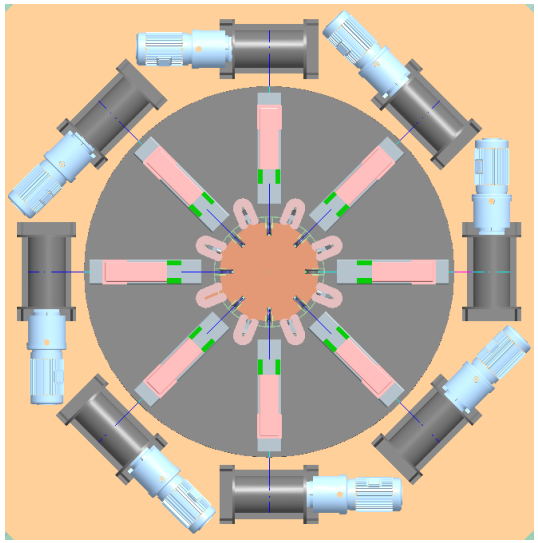
- Conceptual design with an automated cable/pulley based deployment system in program
- Need more simulation work to study the detector and calibration requirement
- A postdoc/junior scientist position has been opened for a while at SJTU (mainly for JUNO), http://inspirehep.net/record/1265332. Please inform potential candidate.

Appendix: design concepts from Ling-Chi design firm

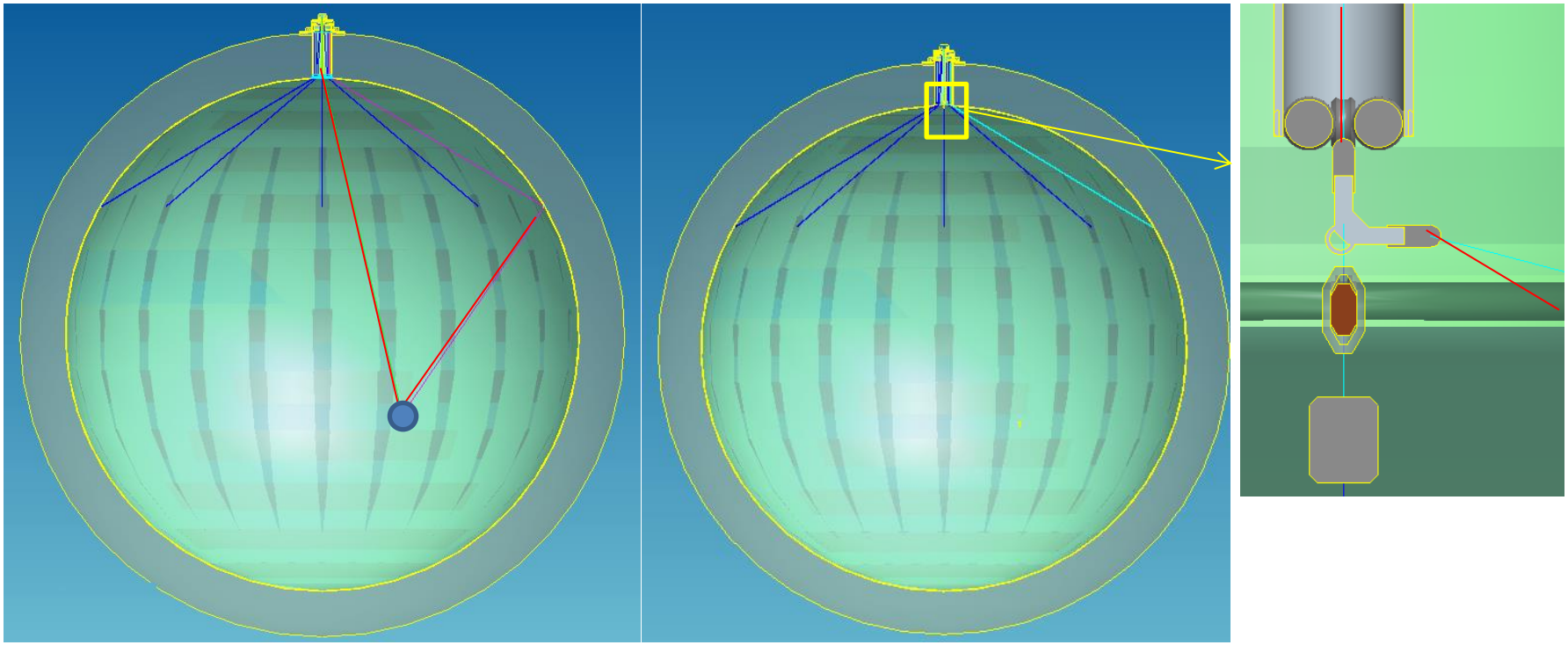
Layout



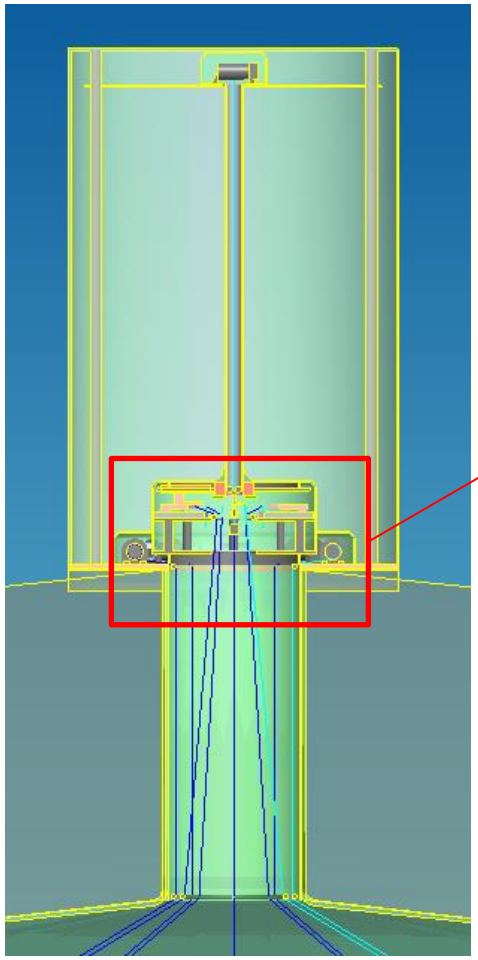


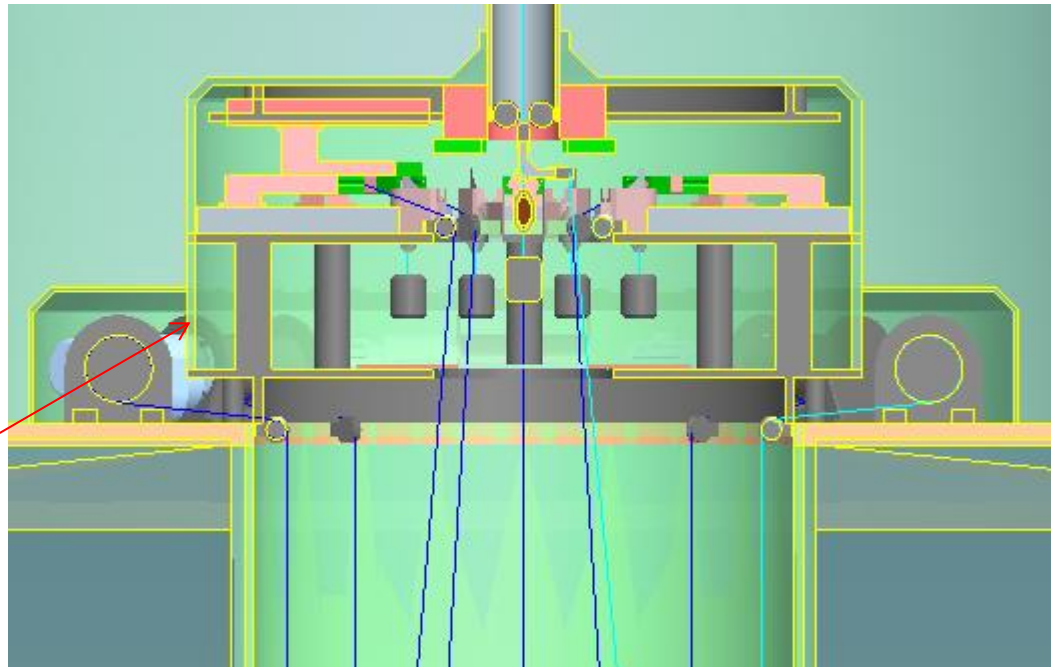


Step 1: retract A cable



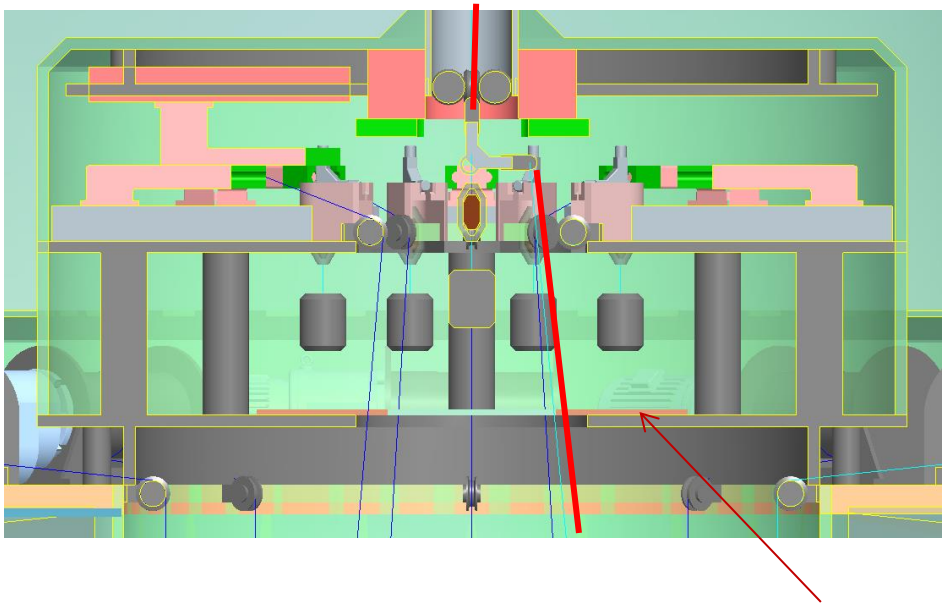
Step 2: lifting the guiding tube together with the source



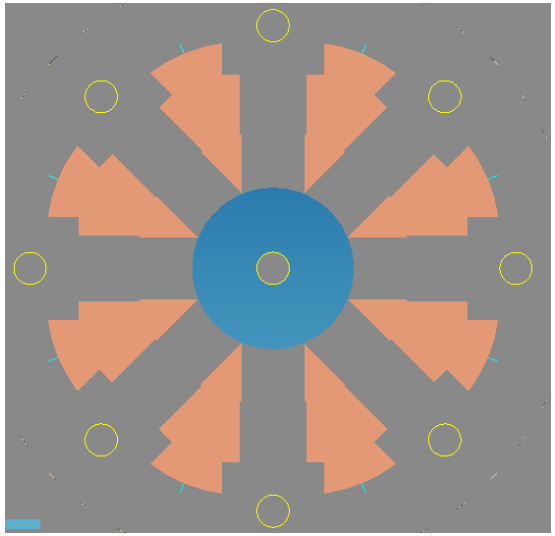


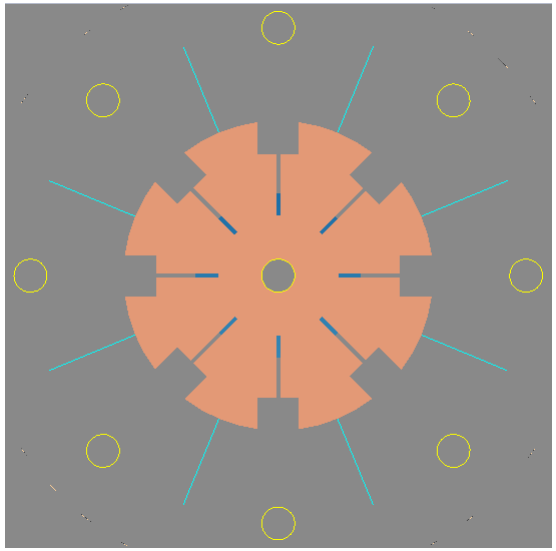
Until source entering into the source-changing chamber

Step 3: fall-protection pieces

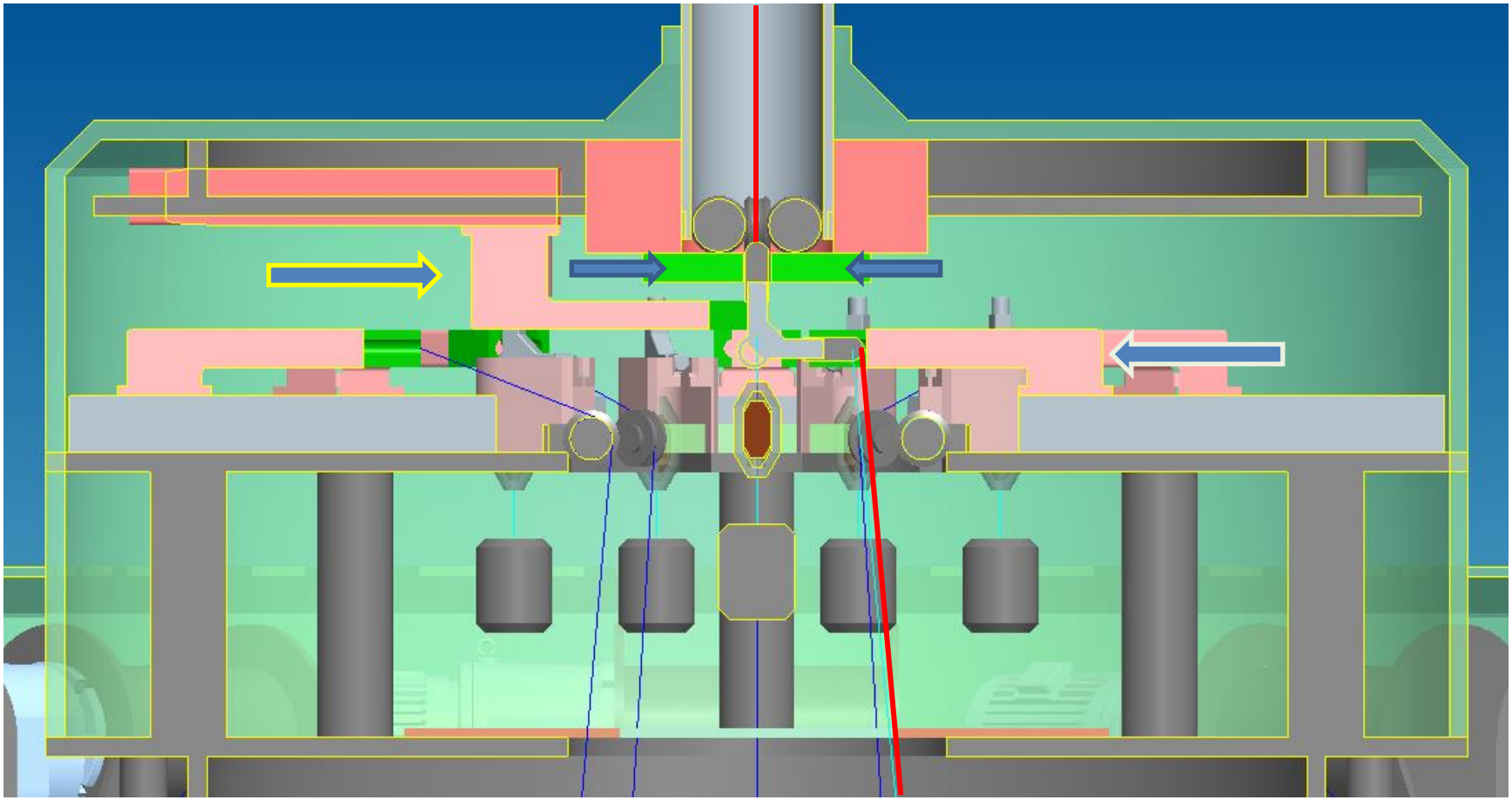


Fall protection

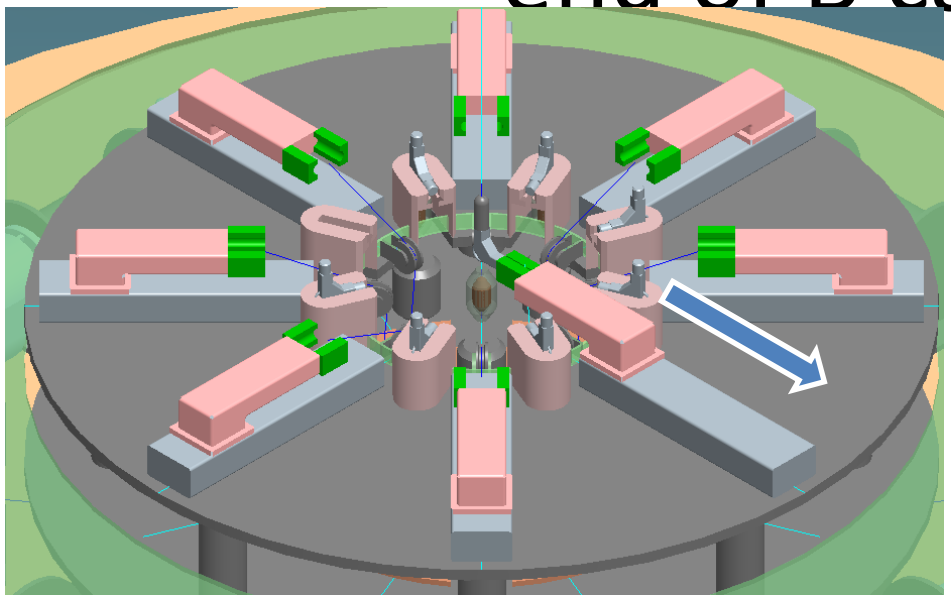


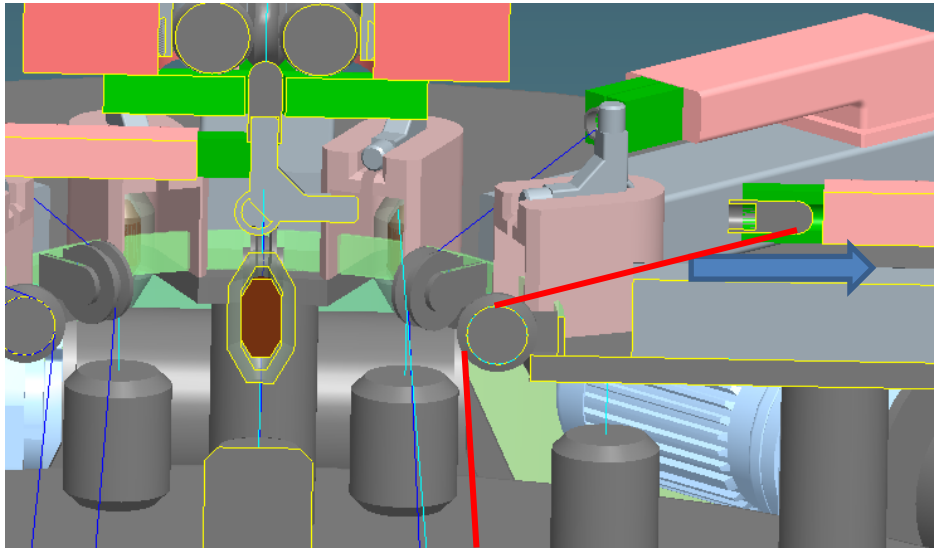


Step 4: fasten the source

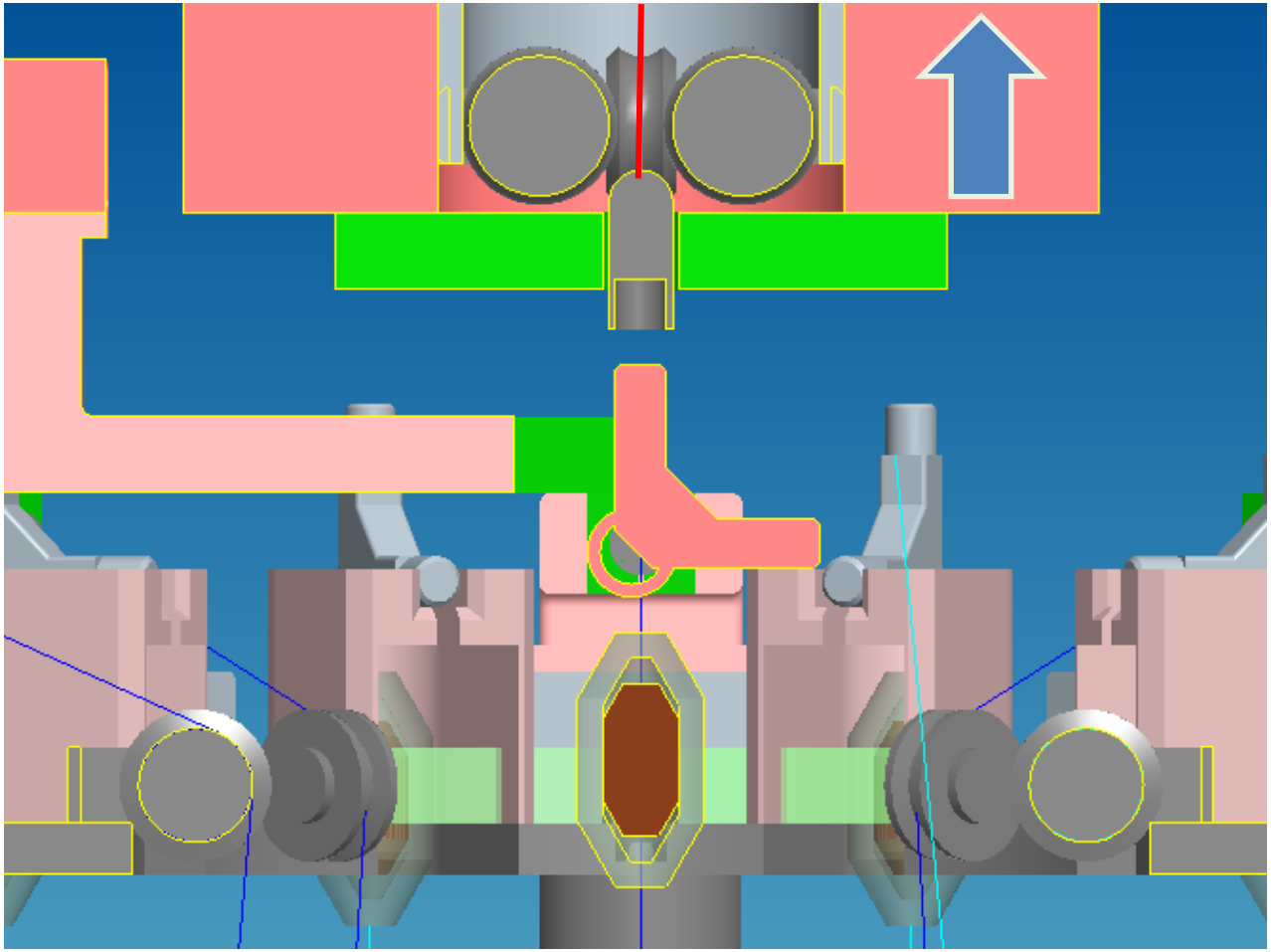


Step 5: detach B cable and store the end of B cable

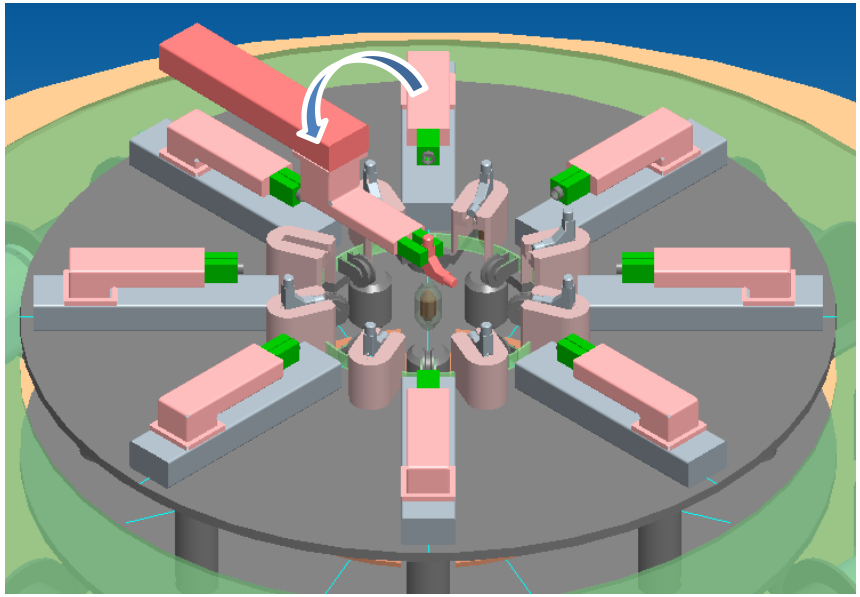


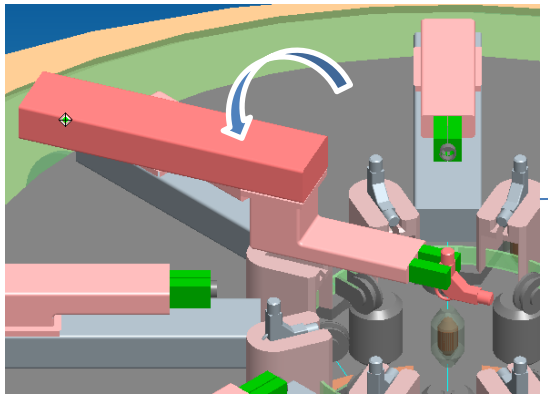


Step 6: detach the A cable

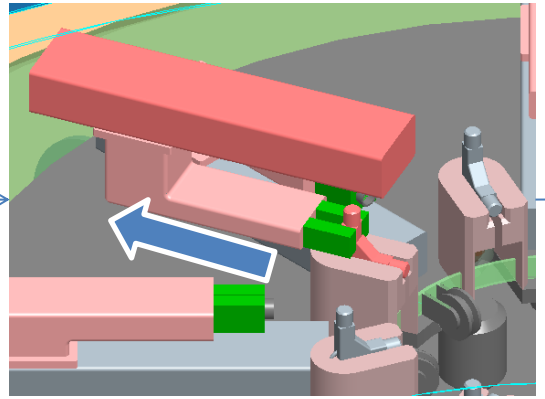


Step 7: put source back into storage

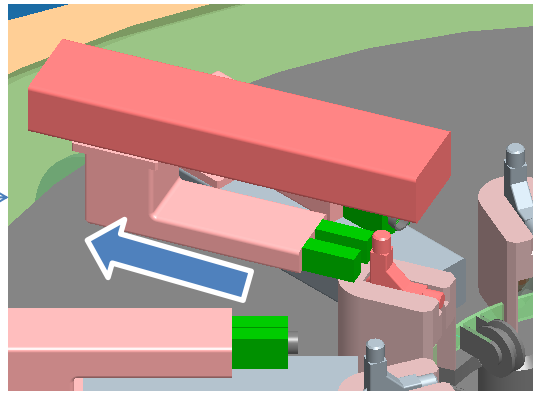




Rotate source hand

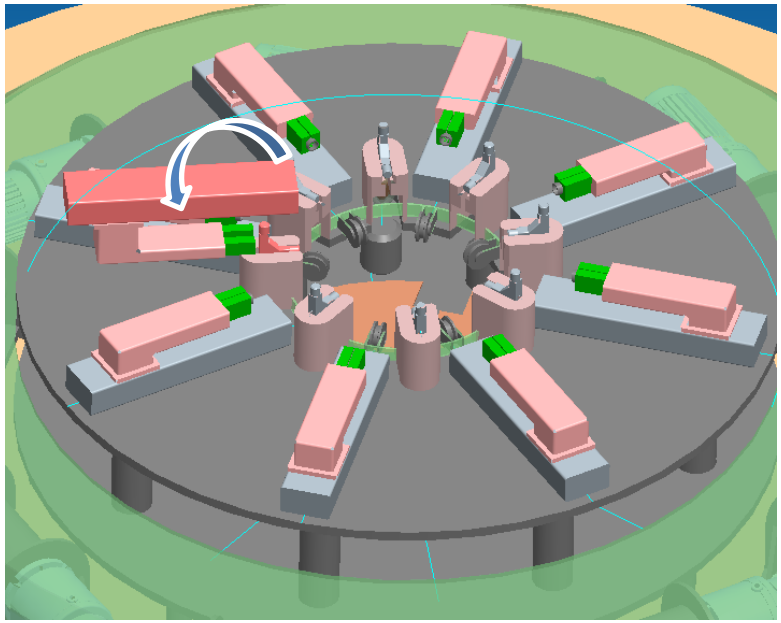


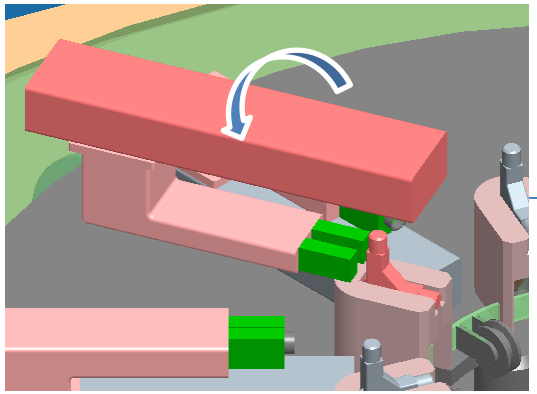
Move radially out



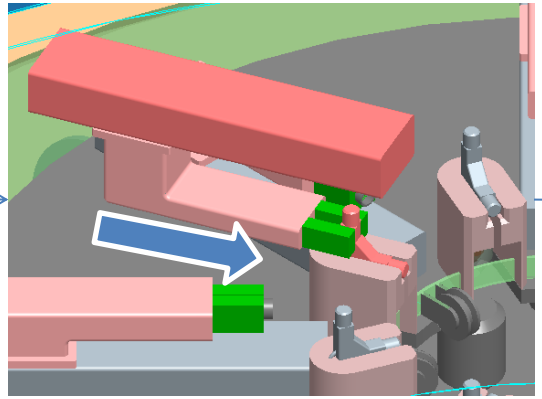
Put down

Step 8: take a new source

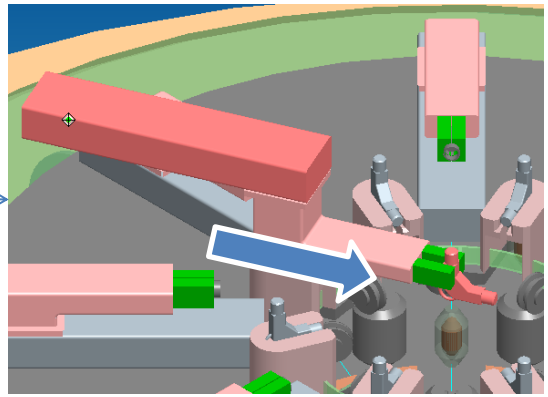




Rotate source arm to desired angle

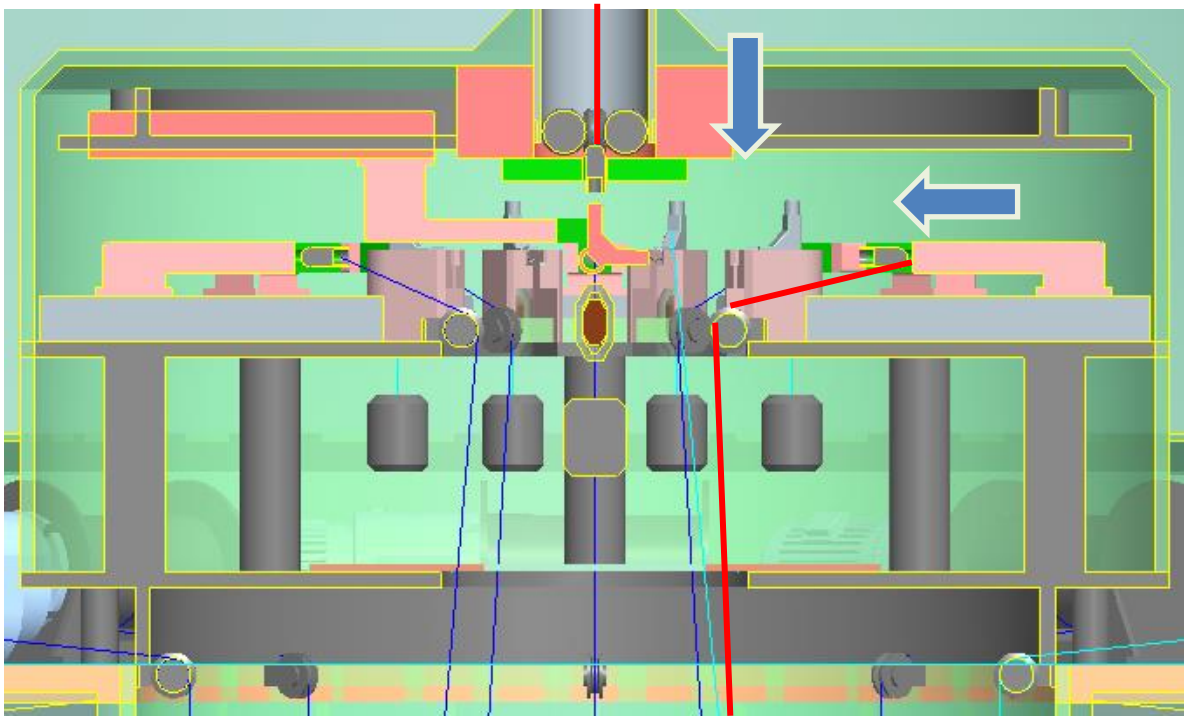


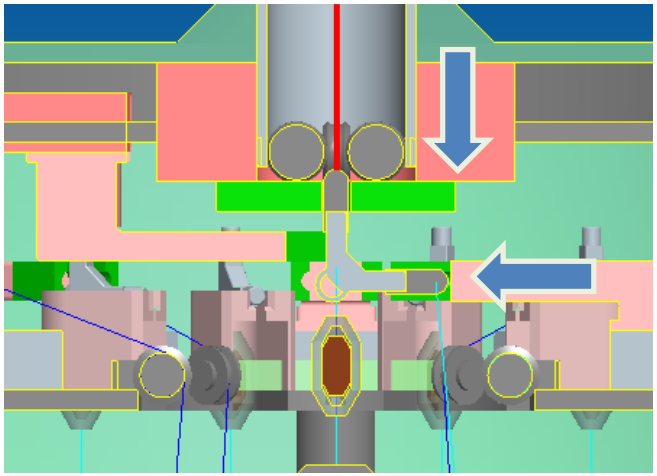
Grab the source



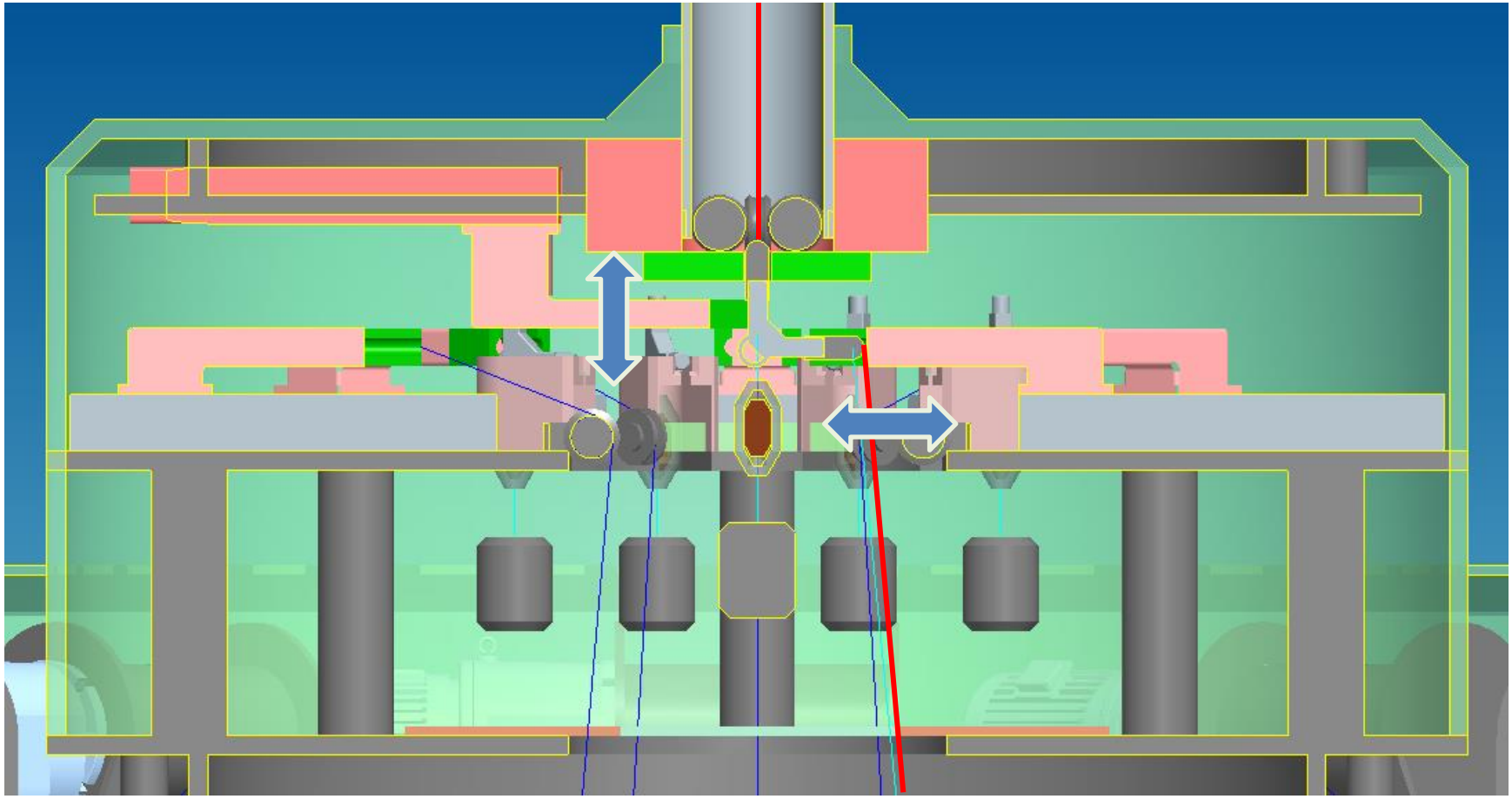
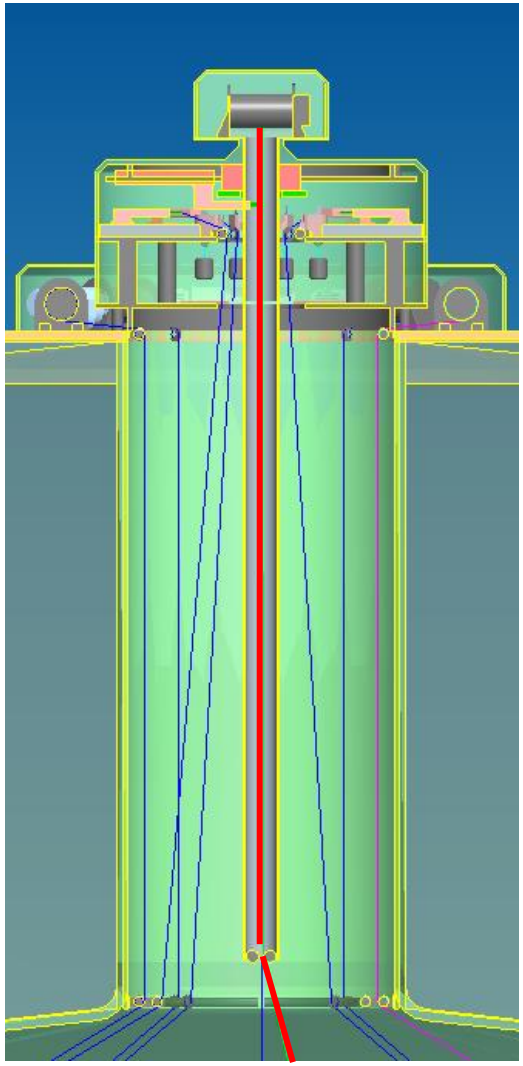
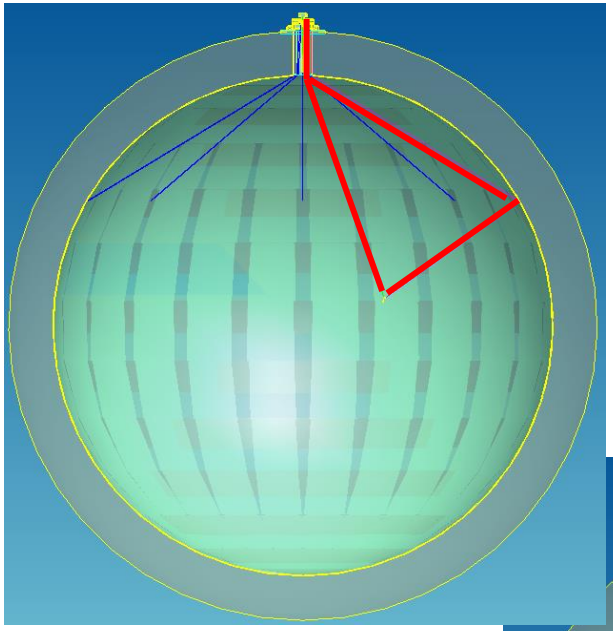
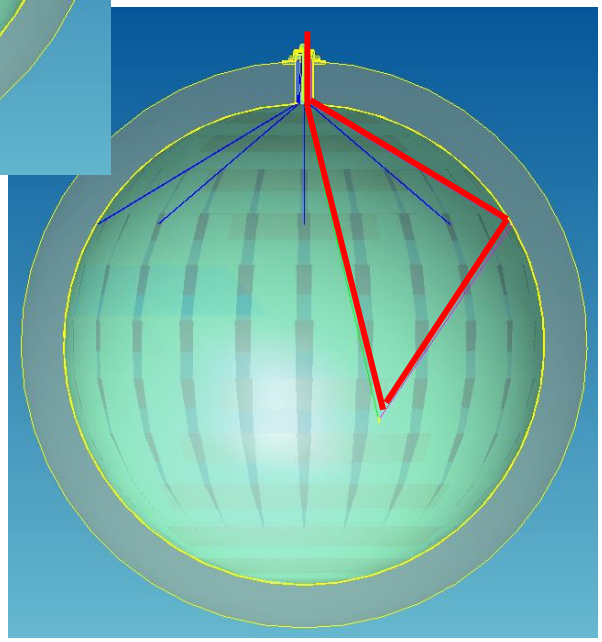
Move source arm radially inward in position

Step 9: attach cables





Step 10: load test



Step 11: deployment