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Engineering Summer School

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Part III Neutron Choppers System Design

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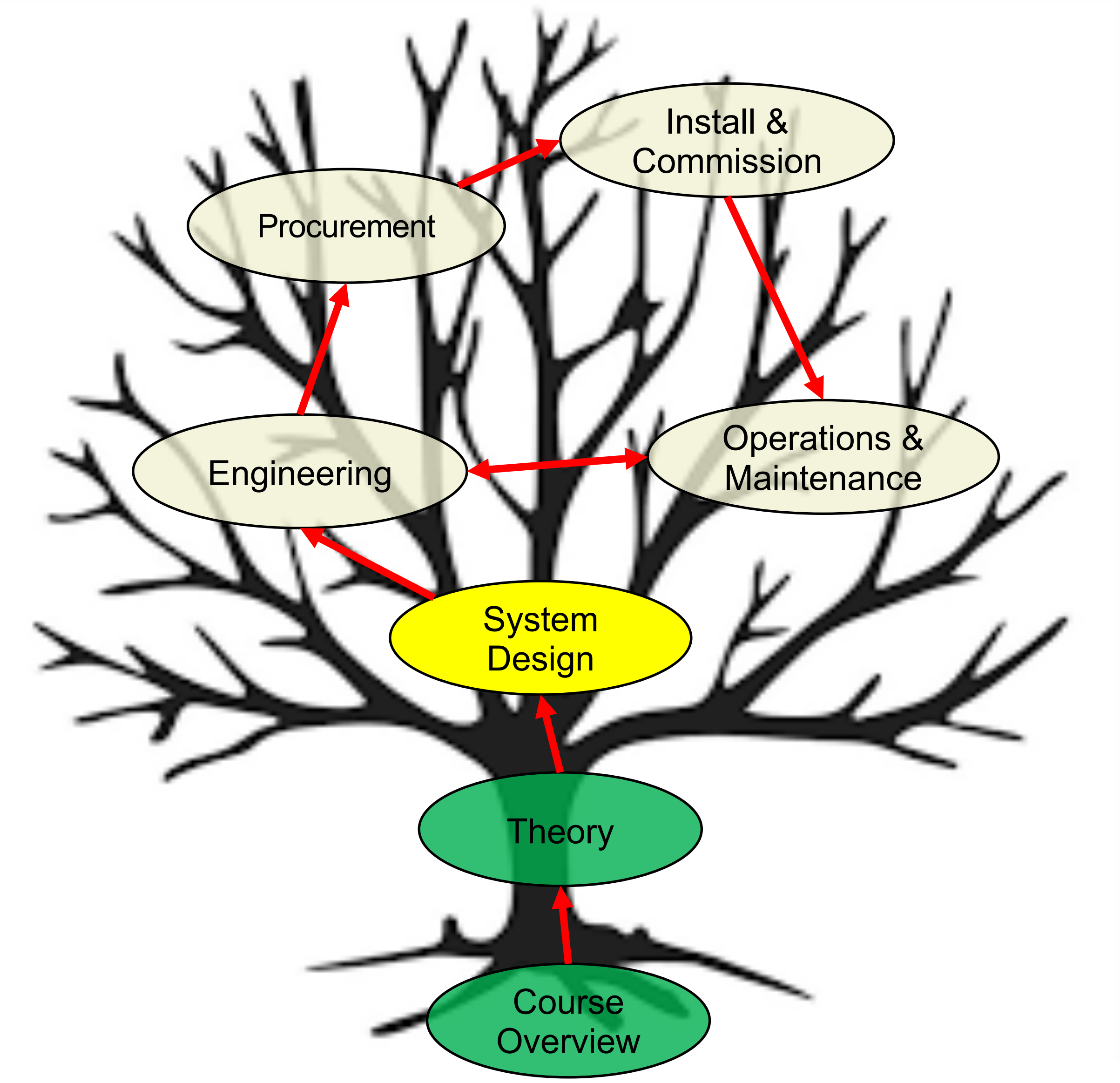
Branches

- The last session with Niko was regarding the Theory of Neutron Choppers-now that you know how a chopper works, what is the best type of chopper to fit your needs?
- I plan to discuss several items which need to be considered when converting chopper requirements into preliminary designs using these neutron choppers.
- The next session will be regarding Neutron Chopper Engineering where Peter will discuss taking preliminary designs to final design status.



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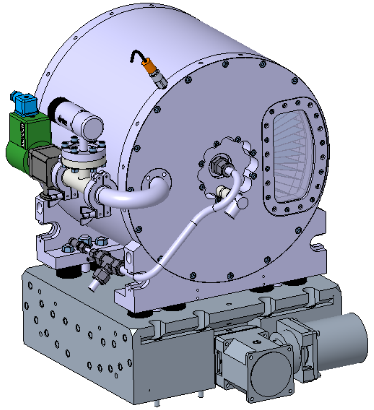
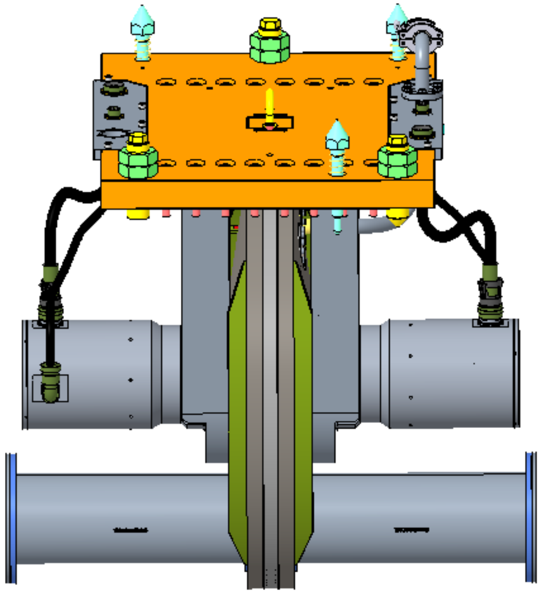
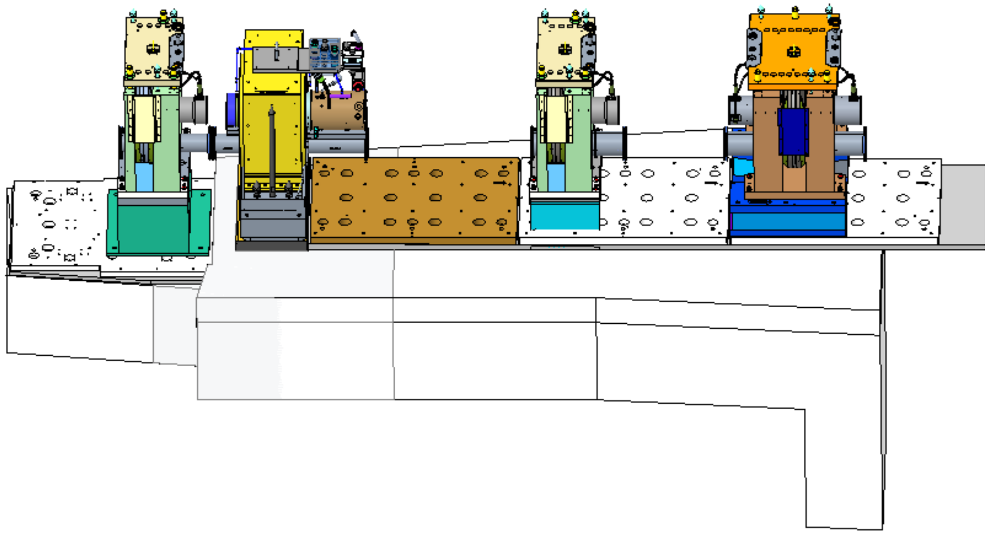
Neutronics Requirements

- Velocity selector or chopper
- One device or an entire instrument
- Determine the neutronics requirements of the rotating wavelength selector

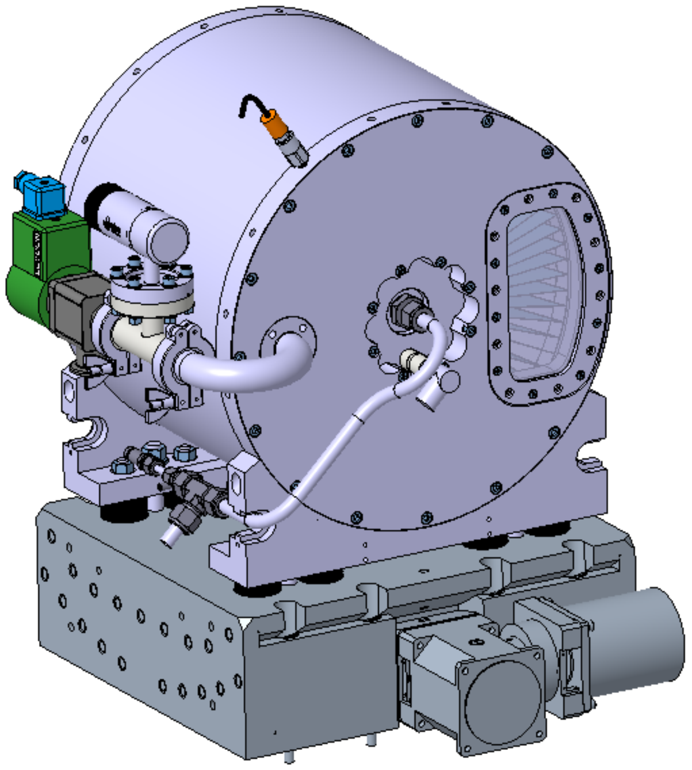






Velocity Selector-System Design

- Velocity selector
  - Precision wavelength selector or high order filter
    - Wavelength range
    - Wavelength deviation
    - Transmission through the velocity selector
  - Talk to chopper/velocity selector engineer or manufacturer about specific rotor designs
- Begin modeling of velocity selector in the instrument
- Look at facility infrastructure for supporting velocity selector needs and how these will be integrated at the instrument, but also where the source of these utilities will be located
  - Vacuum
  - Water cooling
  - Cabling routing
  - Mounting requirements



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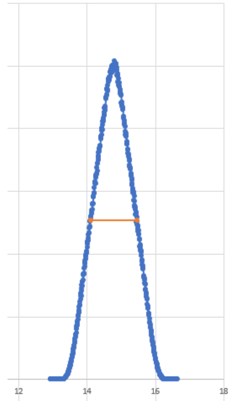
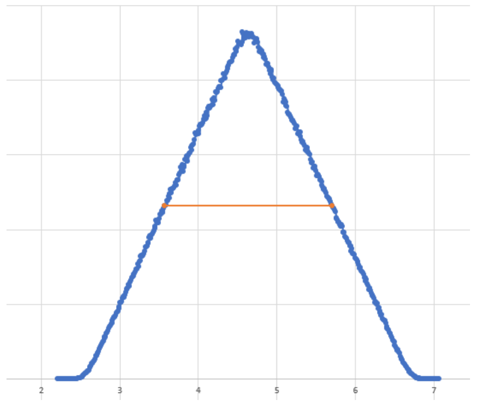
Velocity Selector Considerations

- Wavelength is typically referred to as lambda
- Resolution, delta lambda/lambda, or wavelength deviation from desired wavelength and is expressed in percent
- Precision wavelength selector or high order filter
  - Precision wavelength selector
    - Narrow wavelength selection band
    - Has a low percentage delta lambda/lambda
  - High order filter
    - Wider wavelength selection band
    - Has a high percentage delta lambda/lambda

Delta Lambda/Lambda = 9%
Transmission = 83%



Delta Lambda/Lambda = 47%
Transmission = 91%



- A rotor designed for lower wavelengths decreases the overall wavelength range of the rotor and causes the delta lambda/lambda to get worse
  - 6-16 Å and 6% vs. 2-6 Å and 18% (results from actual rotor calculations)
    - 2 Å neutrons, higher energy, traveling at faster speed, physically harder to differentiate

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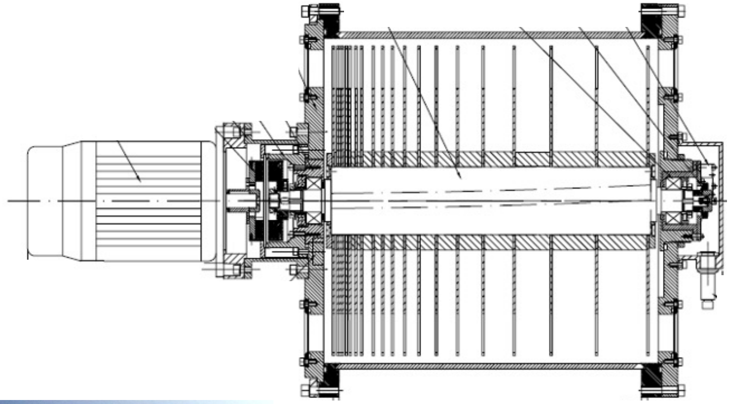
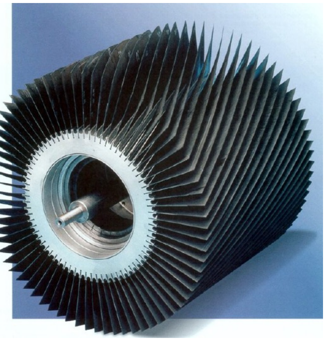
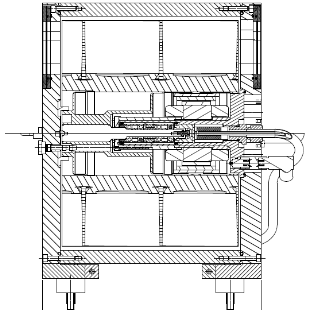
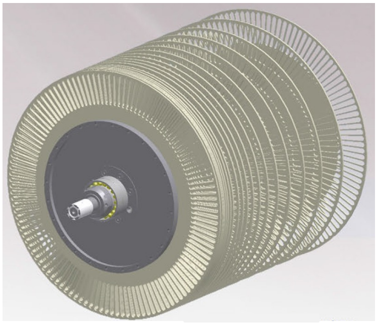
Velocity Selector Considerations

- Transmission
  - Flux losses from neutron beam divergence (a longer rotor and housing require a larger gap length in the neutron guide)
  - Flux losses from rotor-end losses (face losses based on the rotor design)
- Over-all length
  - Not just the in-beam length
- Tilt stage to extend the useable wavelength range
- Maximum speed
  - Water cooling
  - Vacuum level
- Control system runs asynchronously, choppers operate synchronously. No master pulse or reference signal required. Accurate speed control is required to select the proper neutron wavelength.





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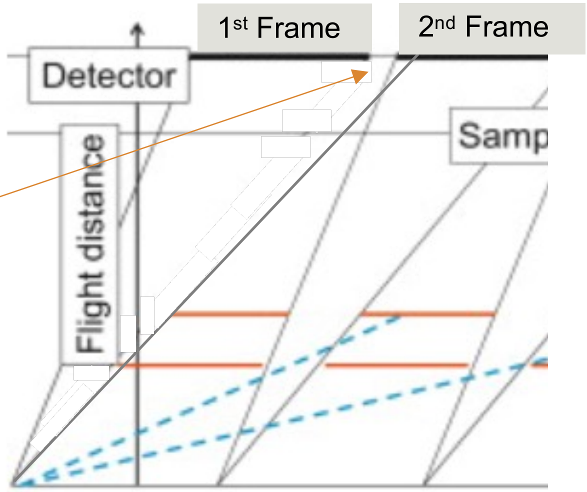
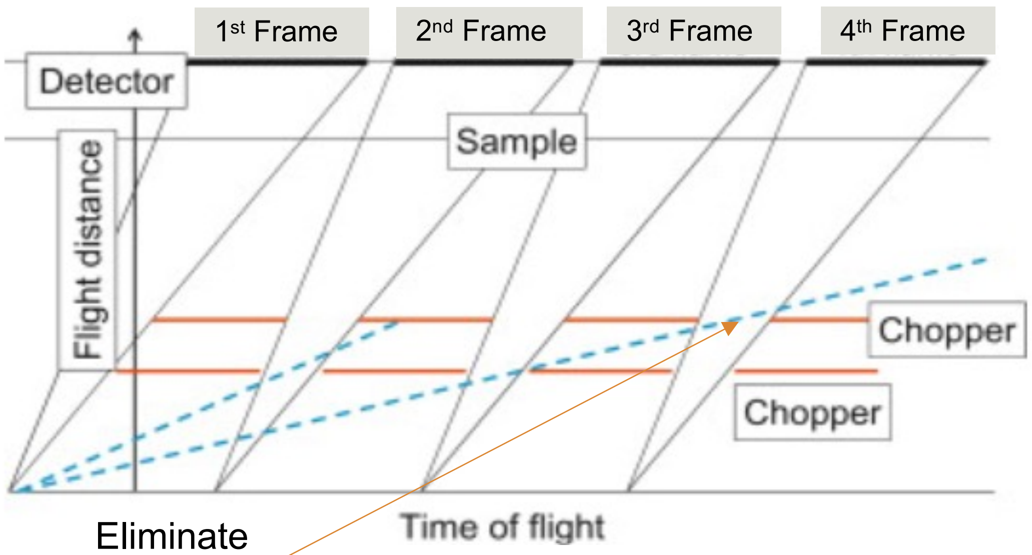
Choppers-System Design

- Determine the types of choppers are needed
  - The instrument scientist would typically determine chopper speed, diameter, aperture sizes and ideal placement of choppers based on simulations via McStas, chopper timing diagrams, and other calculations
  - Talk to instrument engineer and chopper engineer
    - Adjust chopper placement if needed based on physical requirements at the instrument
    - Determine if chopper assumptions are valid/realistic
      - Maximum speed of a high-speed chopper disk is not simply based on diameter, but also includes the cut-out size, both angular and radial depth, and the thickness of the absorber
  - Re-run simulations

Eliminate Frame Overlap





Eliminate Neutron Leakage

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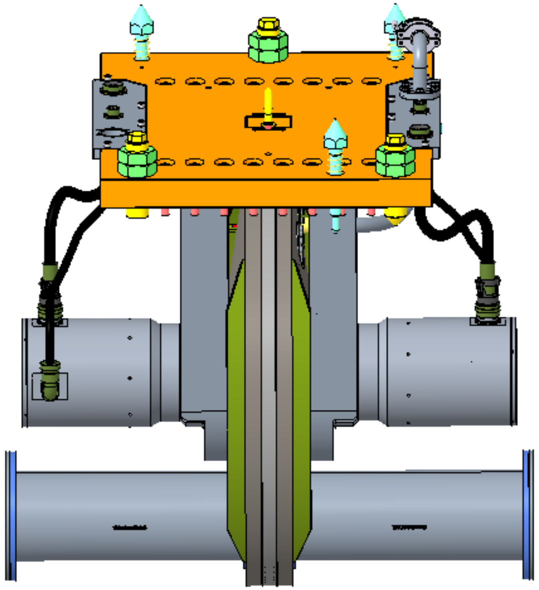
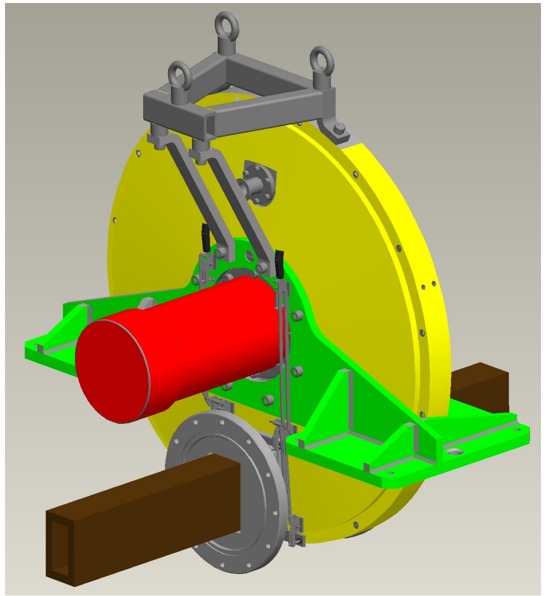
Choppers-Modeling & Support

- Begin modelling of choppers on the instrument.
  - Does the facility have standard or common designs?
    - If so, determine if facility standard designs can be used for each chopper type/location or if unique choppers are needed
  - Look at facility infrastructure for supporting chopper needs and how these will be integrated at the instrument, but also where the source of these utilities will be located (Things to consider-discussed in detail in the engineering talk)
    - Vacuum/gas backfill
    - Water cooling
    - Cabling routing
    - Mounting requirements / any vibration mitigation
    - Control rack location





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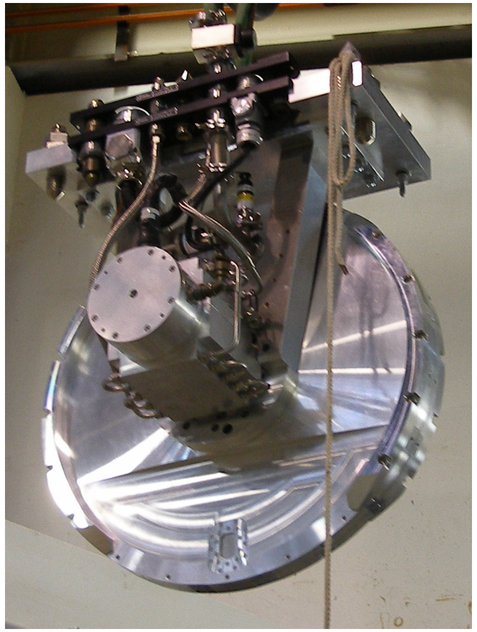
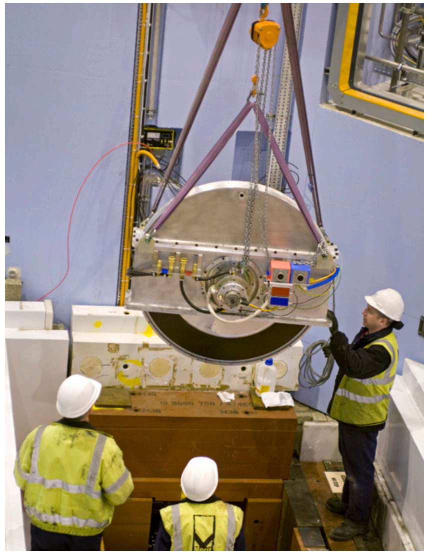
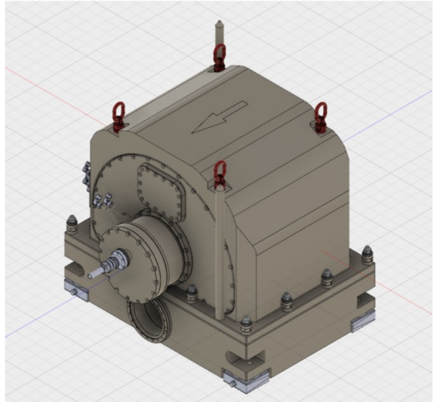
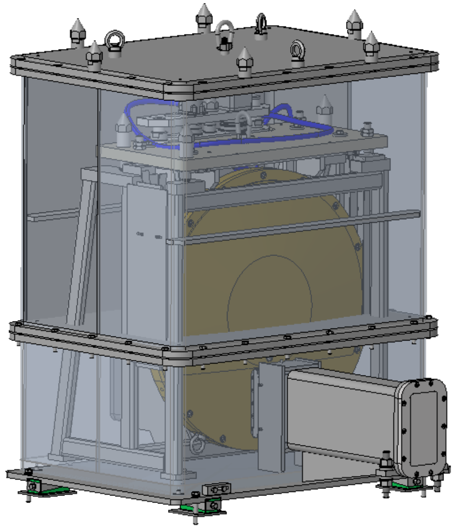
Chopper Housing Considerations

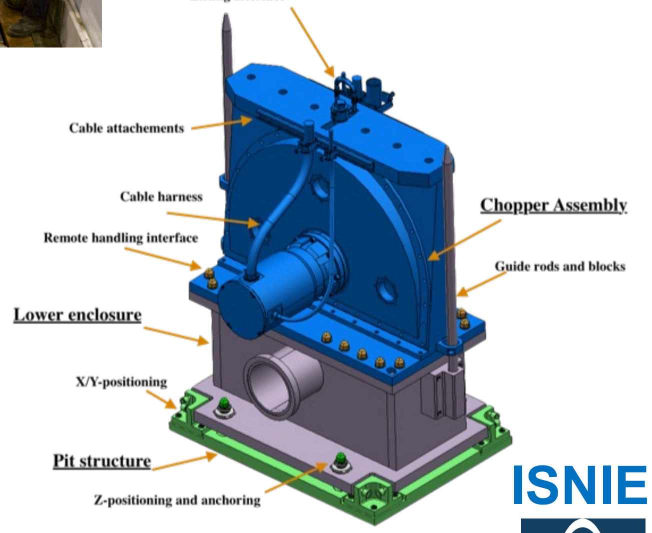
- What type of chopper housing is needed
  - With windows or windowless
- No perfect design exists yet
  - Guide gap
  - Window material / air gaps
  - Maintenance risks











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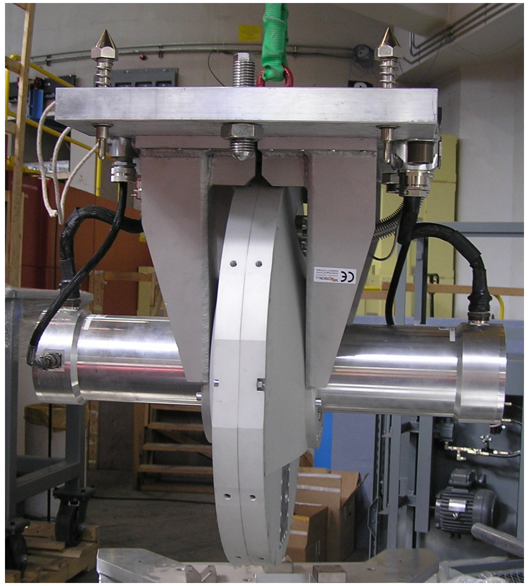
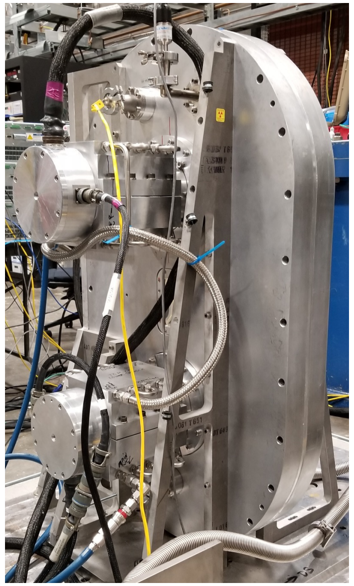
Disk Chopper Considerations

- Disk choppers
  - Physical size (n 0.6, 0.7, 1.0, 1.2, 1.3 m)
  - Speed
    - Majority
      - Accelerator repetition rate (10, 14, 15, 25, 50, & 60 Hz)
    - High speed (up to 350 Hz)
    - Vacuum level
      - High-Speed means high vacuum level
    - Water cooling
      - High-speed will require it
  - Type of drive (magnetic bearing vs. mechanical bearing)
  - Single vs. double (or triple or quadruple)
    - Coaxial vs. parallel axes
  - Number and size of disk apertures
  - Required neutronic transmission at a specified wavelength (10^{-3}, 10^{-5}, 10^{-6})
    - Attenuation material (typical)
      - Boron carbide
      - Boron10 enriched boron carbide
      - Pure boron10
      - Gadolinium

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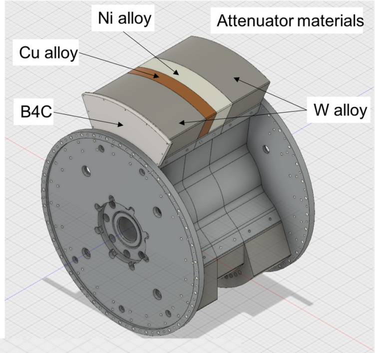
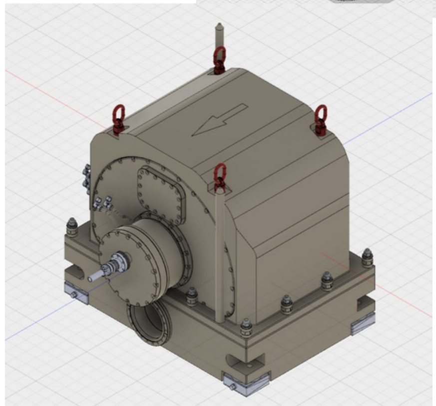
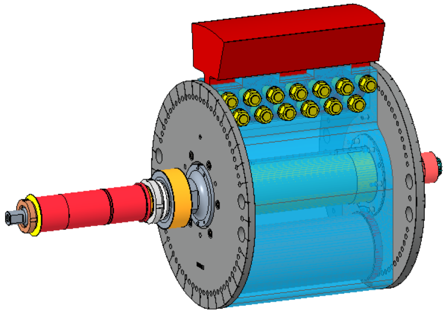
T0/PPS Considerations

- T0/Prompt Pulse Suppression choppers
  - Physical size
  - Speed
    - Typical, accelerator repetition rate (10, 14, 15, 25, 50, & 60 Hz and etc.)
    - J-PARC also operates super-synchronously (multiples of the accelerator operating frequency)
  - Vacuum / gas backfill
  - Cooling required
    - Water typical
    - Forced air is used at J-PARC
  - Physical size and type of material for the blade/hammer that blocks the neutron beam
    - Inconel
    - Nimonic
    - Multi-material blade such as boron carbide, copper alloy, nickel alloy, and Tungsten alloy







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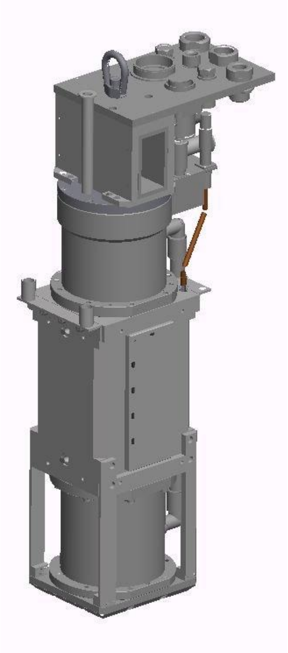
Fermi Chopper Considerations

- Fermi chopper
  - Physical size of the payload and wavelength required
  - Curved or straight payload slats
  - Slats/absorber material (typical)
    - Boron10 enriched boron carbide
    - Pure boron10
    - Gadolinium
  - Speed (typically up to 600 Hz)
    - Vacuum
    - Water cooling



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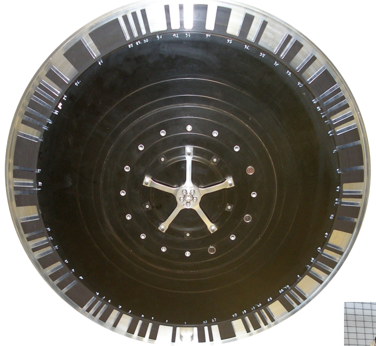
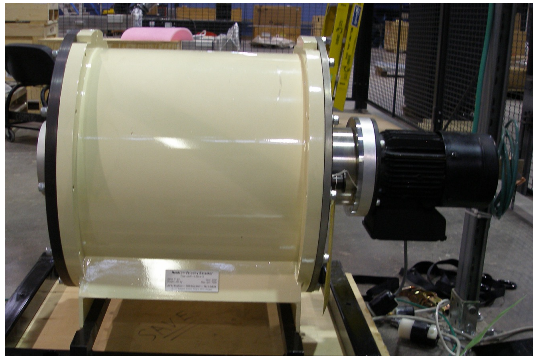
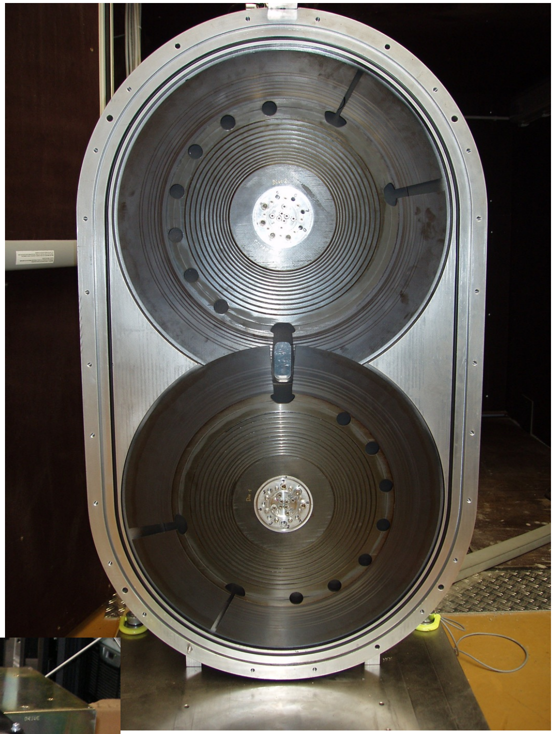
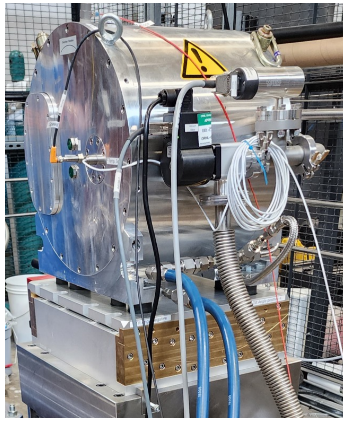
Additional Considerations

- Radiation levels the chopper equipment is exposed to and activation level of the chopper equipment (greater concern with higher power sources)
  - System access for maintenance
    - Time delays
    - Long handled tools
- System cost
  - Purchase cost
  - Initial installation
  - Maintenance requirements
- Control system requirements
  - Size / space
  - Operating voltage and power requirements
  - Uninterruptable Power Supplies (magnetic bearings)
  - Interlocks may include
    - Vacuum gauge controllers
    - Bearing condition monitoring (mechanical bearings)
    - Vibration monitors (mechanical bearings)
    - Water flow
    - Temperature monitoring (bearings, rotor, shaft, motor, water, etc.)
  - Cabling size, quantity, and maximum length
  - Synchronized to a timing pulse (most choppers, not velocity selectors)









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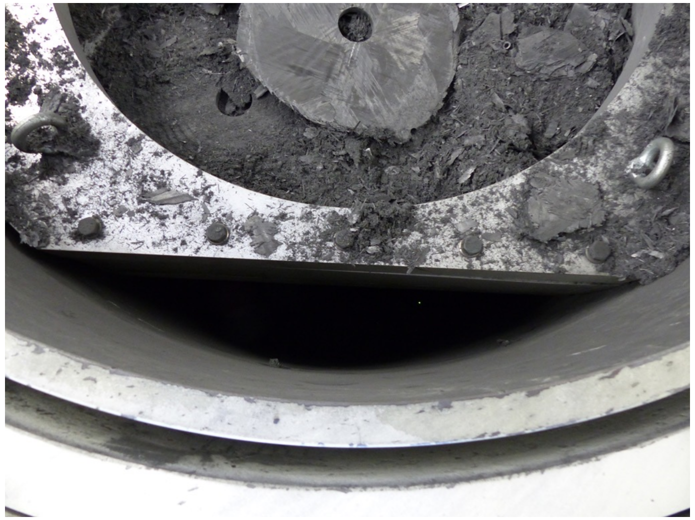
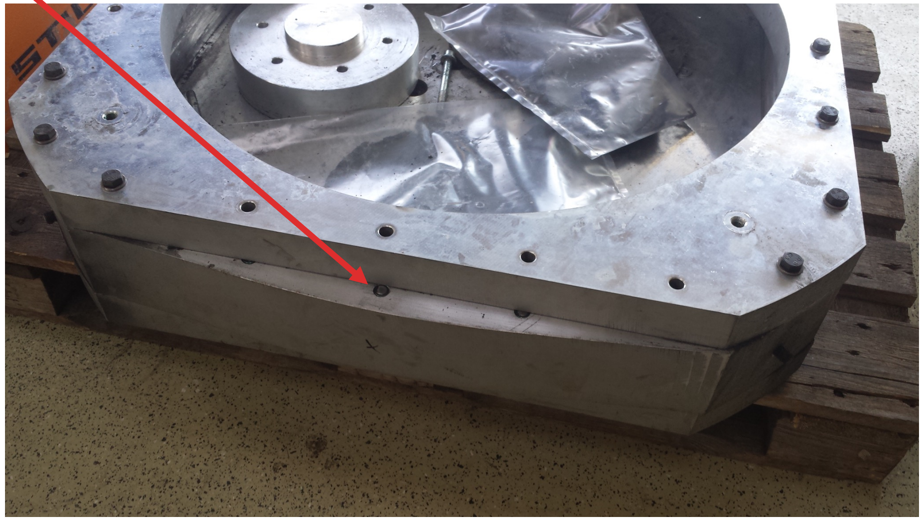
Safety Considerations

- Safety needs to be considered both during installation testing and off-line testing
  - Shielding reinstalled during in-instrument testing or limit personnel access to the area
  - Confinement chamber during off-line testing for personnel protection
    - Carbon fiber disk (same design as disks for the NEAT instrument at HZB, Berlin)
    - Designed operating speed of 20,000 RPM (333.3 Hz)
    - Intentionally ran to failure (June 2015) in a spin-test chamber, which happened at 22,830 RPM (380.5 Hz)
      - Sheared-off bolts still in bent dummy housing





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Additional Considerations

- Consider chopper failure (particles going upstream to source or downstream to sample area with detectors and personnel)
  - Horizontal axis of rotation, less likely
  - Vertical axis of rotation, more likely
    - Controls typically facility dependent administrative controls
      - Installed further away from equipment/personnel under concern
      - Rotor that is prime reliable (jet engine rotor)
- Stray magnetic fields near chopper (magnetic bearings)
  - Require carbon fiber disks instead of aluminum disks
- Dynamic loads of rotating equipment are significantly different than an equal load of static equipment. They should not be considered or mitigated equally
  - 60 Hz chopper
    - 60 revs/sec
    - 3,600 revs/minute
    - >5 million revs/day
    - >5 million load cycles/day

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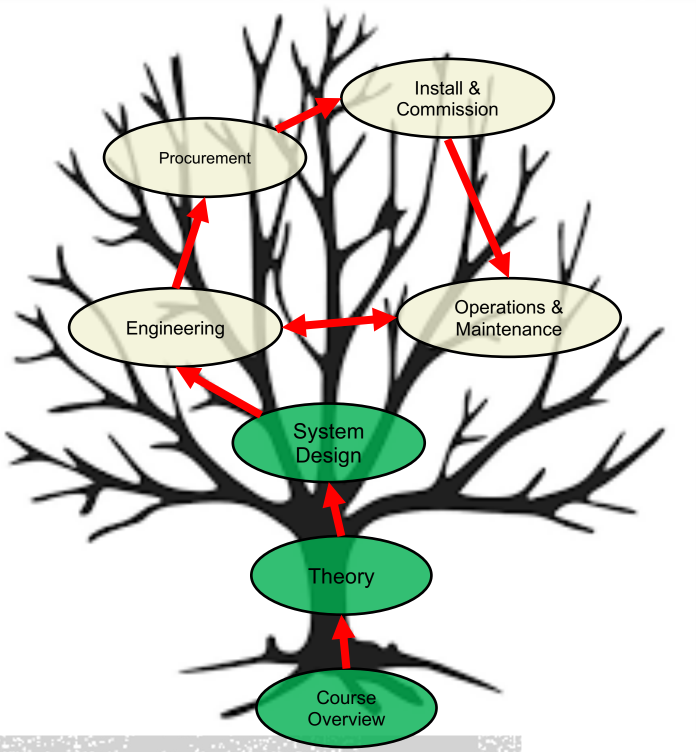
End of the line System Design



Thanks for participating

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Additional Material

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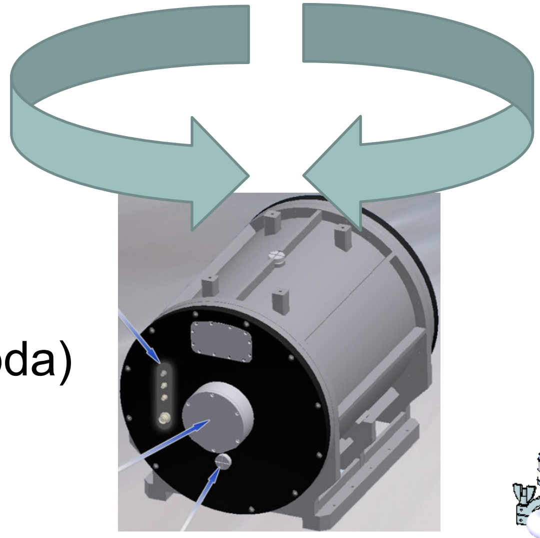
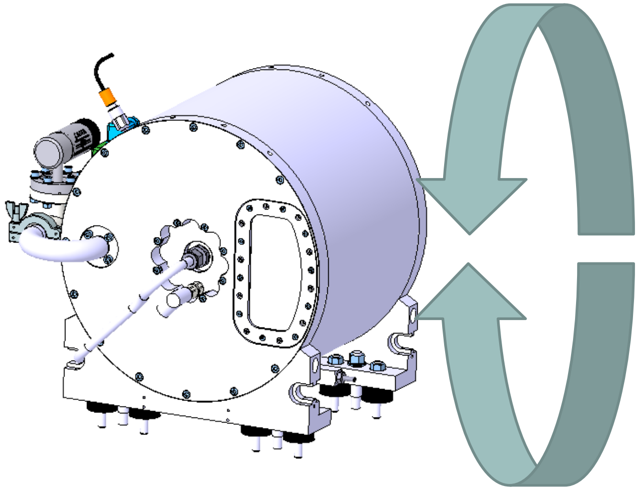
Tilt Stages

- Purpose
  - Extend the wavelength range of the VS
  - Adjust wavelength resolution (delta-lambda/lambda)
- Type used is Manufacturer Independent
  - Window at top or bottom of selector housing
    - Horizontal rotational stage
  - Window at side of selector housing
    - Vertical rotational stage-goniometer stage
- One manufacturer – Only ~15% of VS sold require tilt stage to extend range or resolution
  - Acceptable wavelength range
  - Acceptable wavelength resolution at all wavelengths





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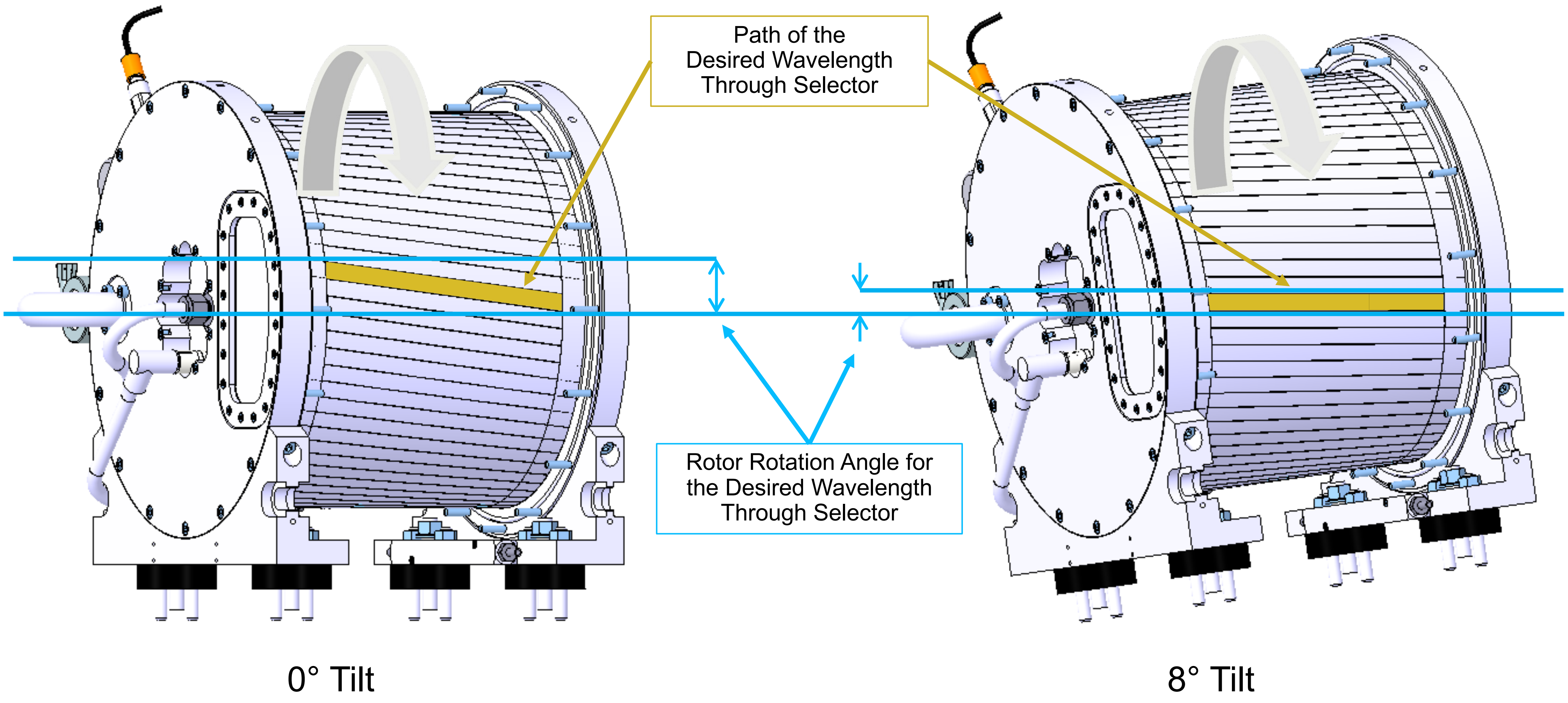
How a Tilt Stage Works

- Change the helix angle or screw angle relative to the neutrons



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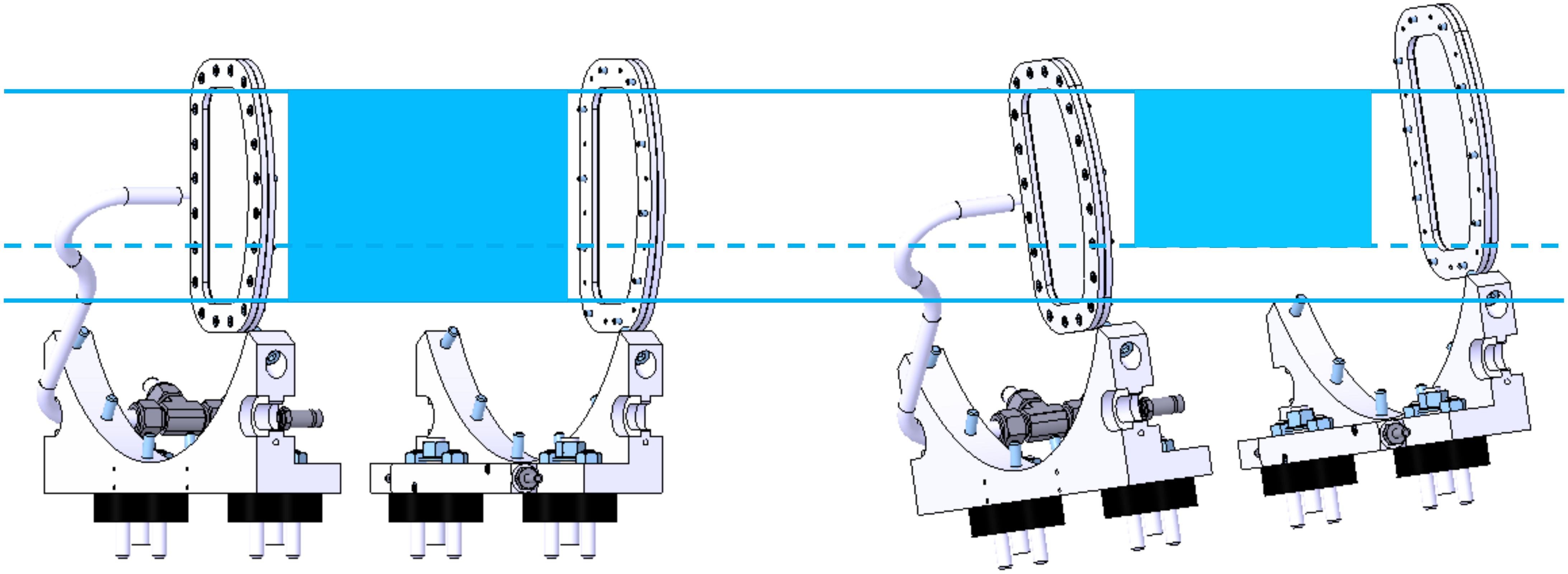
Potential Downside of a Tilt Stage Works

- Results in reduction of maximum beam size through VS



0° Tilt

8° Tilt

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