20mK Space

Jessica Fry

DMRadio Collaboration Meeting

October 8, 2025

Outline

- Goals & Considerations
- Components
- Constraints
- Status
- Open Questions

Design Goals

1. Mechanically support detector components in Woodstock.
2. Thermalize detector components.
3. Thermally & electromagnetically shield sensitive components.
4. Maximize capacitor space.
5. Accommodate future upgrades.

Design Considerations

- Minimize light leaks to hutches.
- Keep sensitive electronics and wires inside shielded hutches.
- Minimize assembly procedures in between plates (i.e. keep necessary wiring along the perimeter).

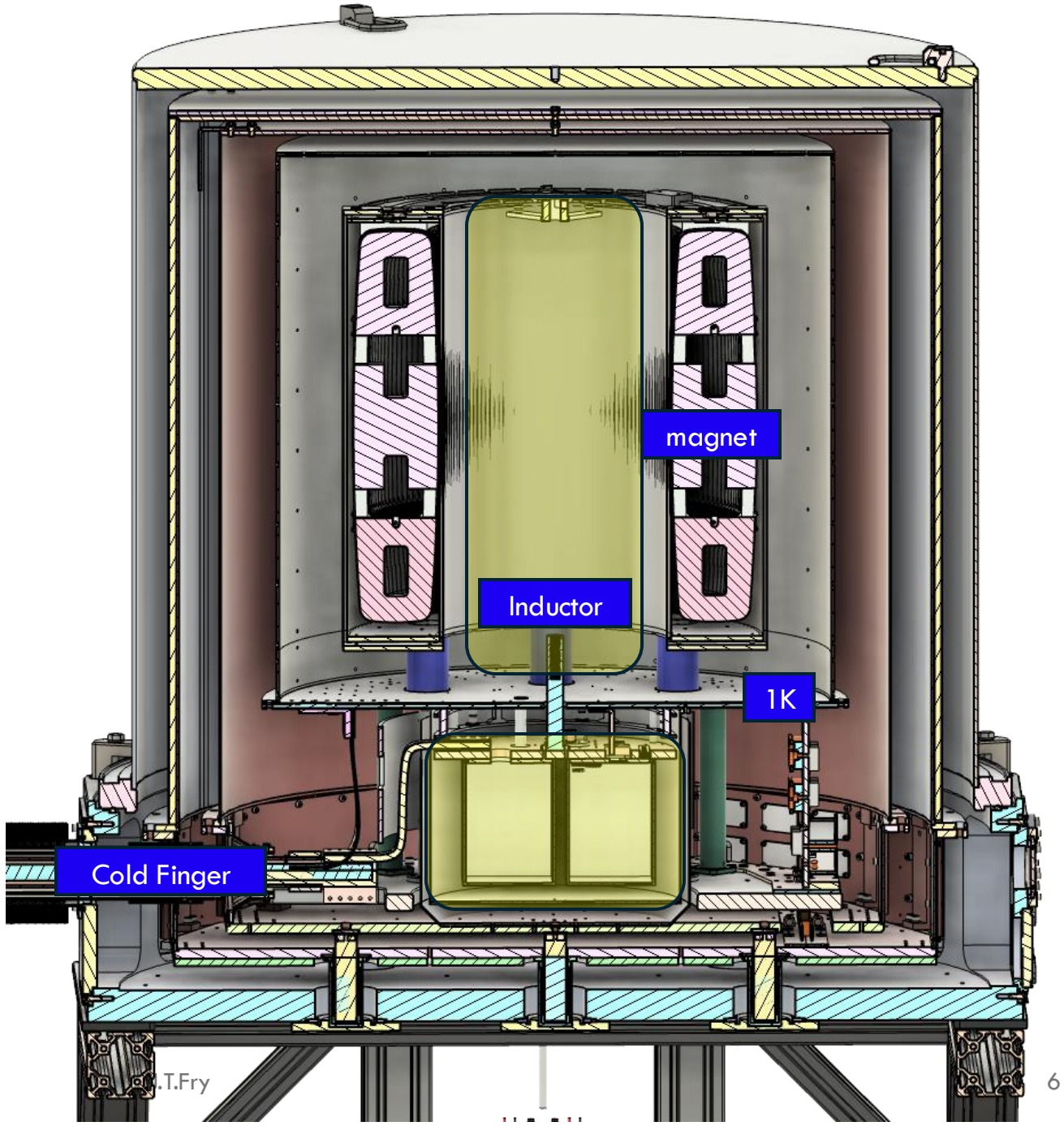
Components

Baseline package: *components for commissioning and initial needle search*

- Detector components
  - Fixed capacitor
  - SQUID
  - Inductor
  - Transformer
- Shields
  - Capacitor hutch
  - SQUID hutch
  - Inductor shield
  - 20mK shield
- Aux devices
  - Actuator feed throughs
  - DC & RF wire feedthroughs
  - Thermometers
  - Heaters
  - Calibration wires
- Thermomechanical
  - 20 mK plate
  - Thermal Strap
  - Mechanical Support
  - XY-centering puck

In Context

- Thermalize to cold finger.
- Mechanically supported from 1K plate.
- Mechanically supported from 4K magnet.
- Mechanically supports and thermalizes resonator and SQUIDs.



In Context

- Thermalize to cold finger
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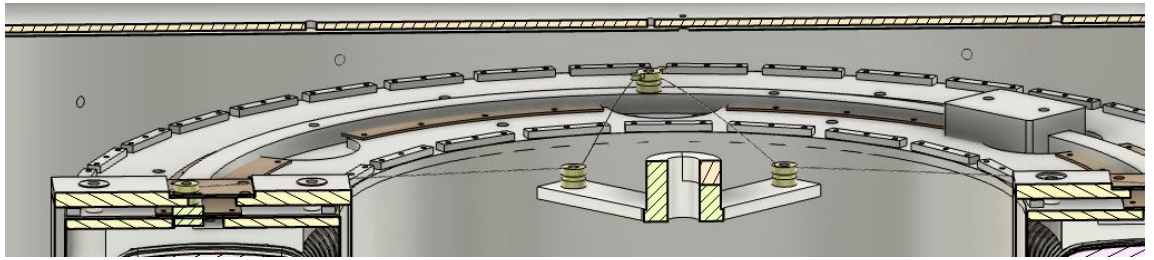

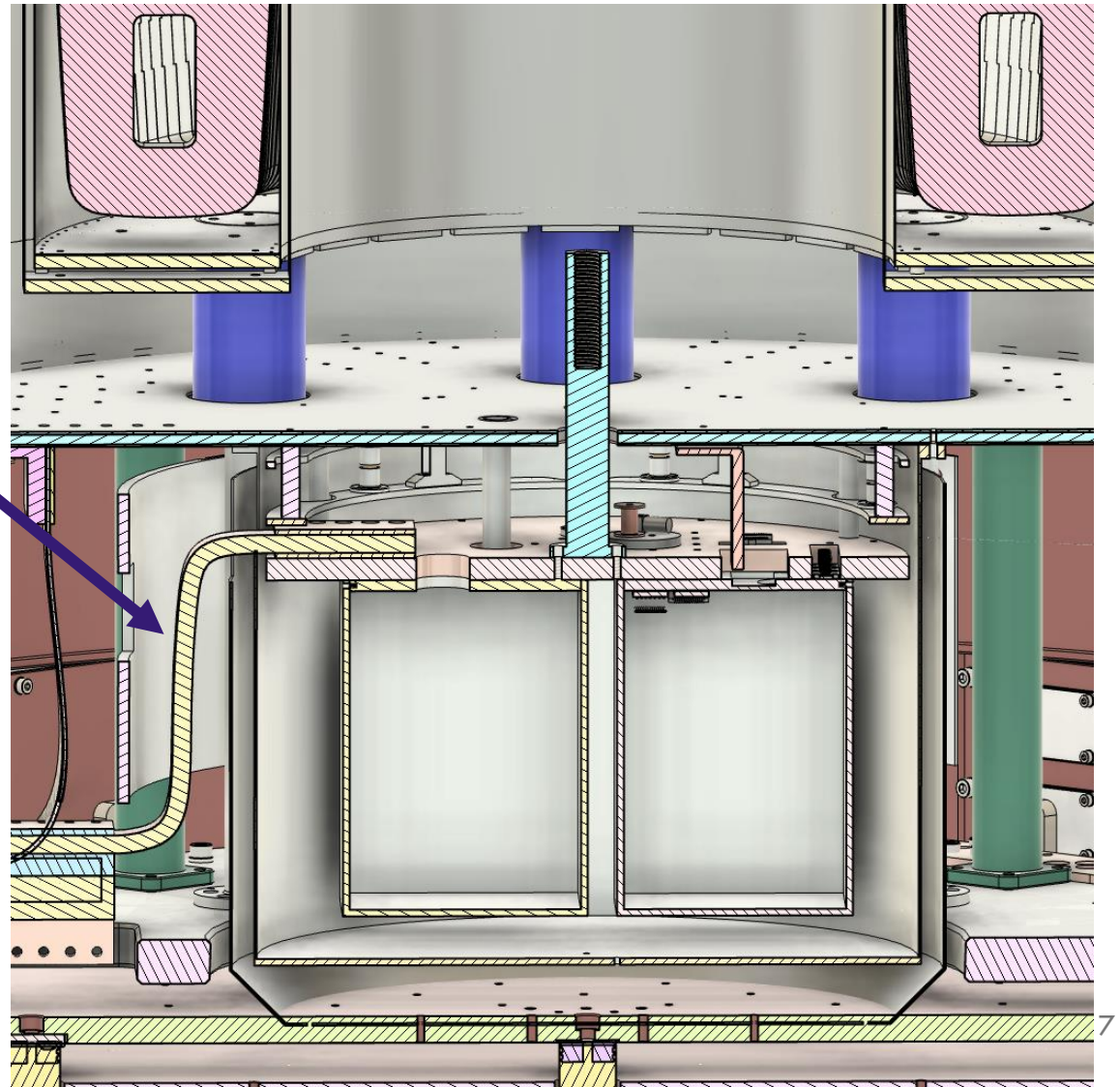

In Context

- Thermalize to cold finger → Thermal Strap
- Mechanically supported from 1K plate → Vespel Compression Support
- Mechanically supported from 4K magnet.
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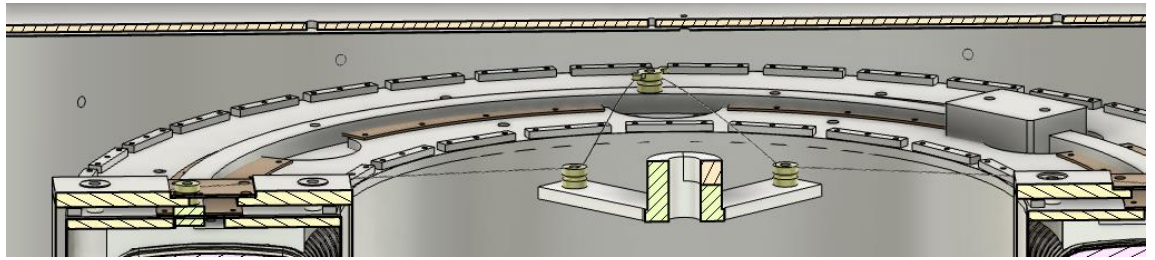
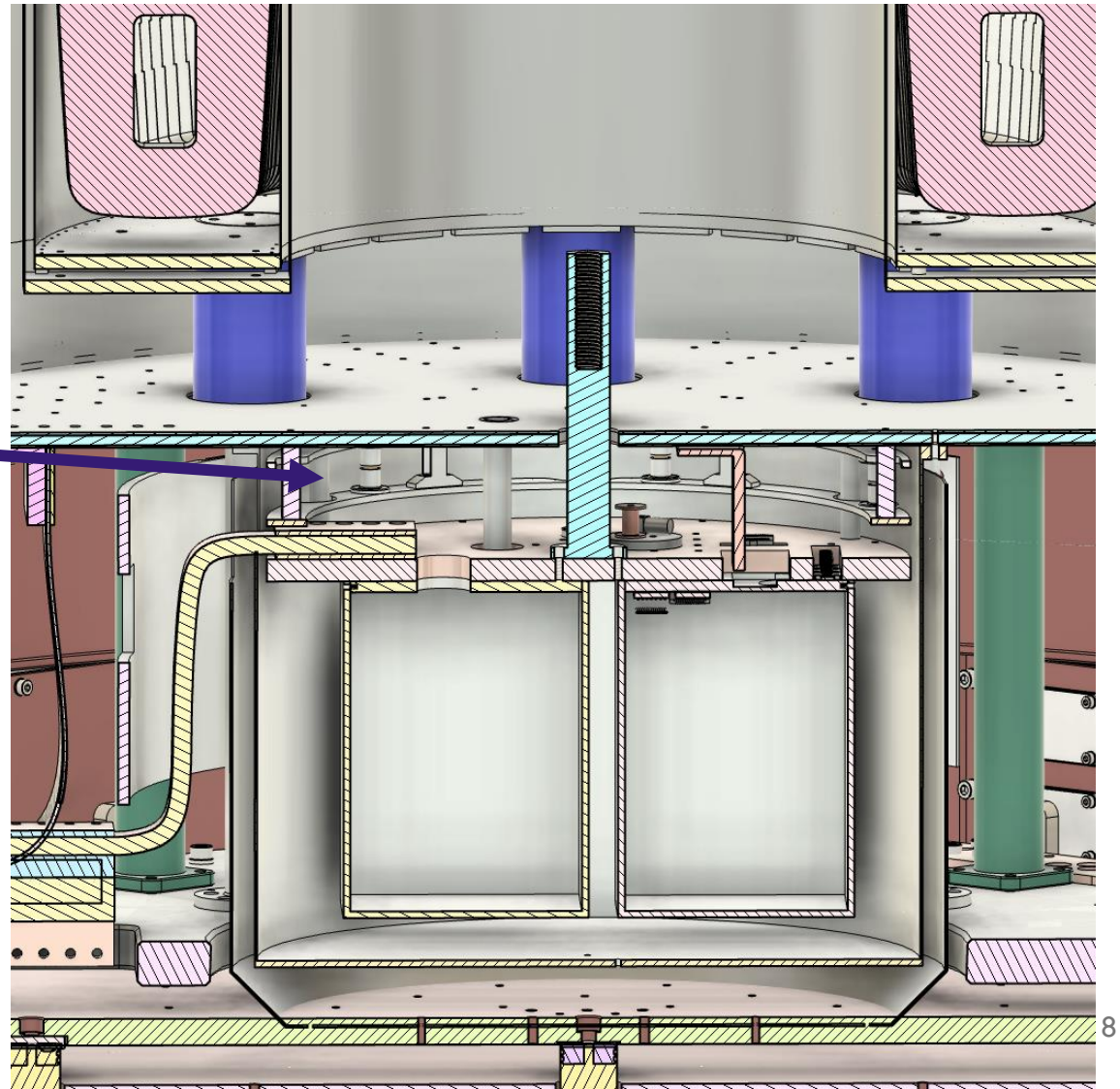
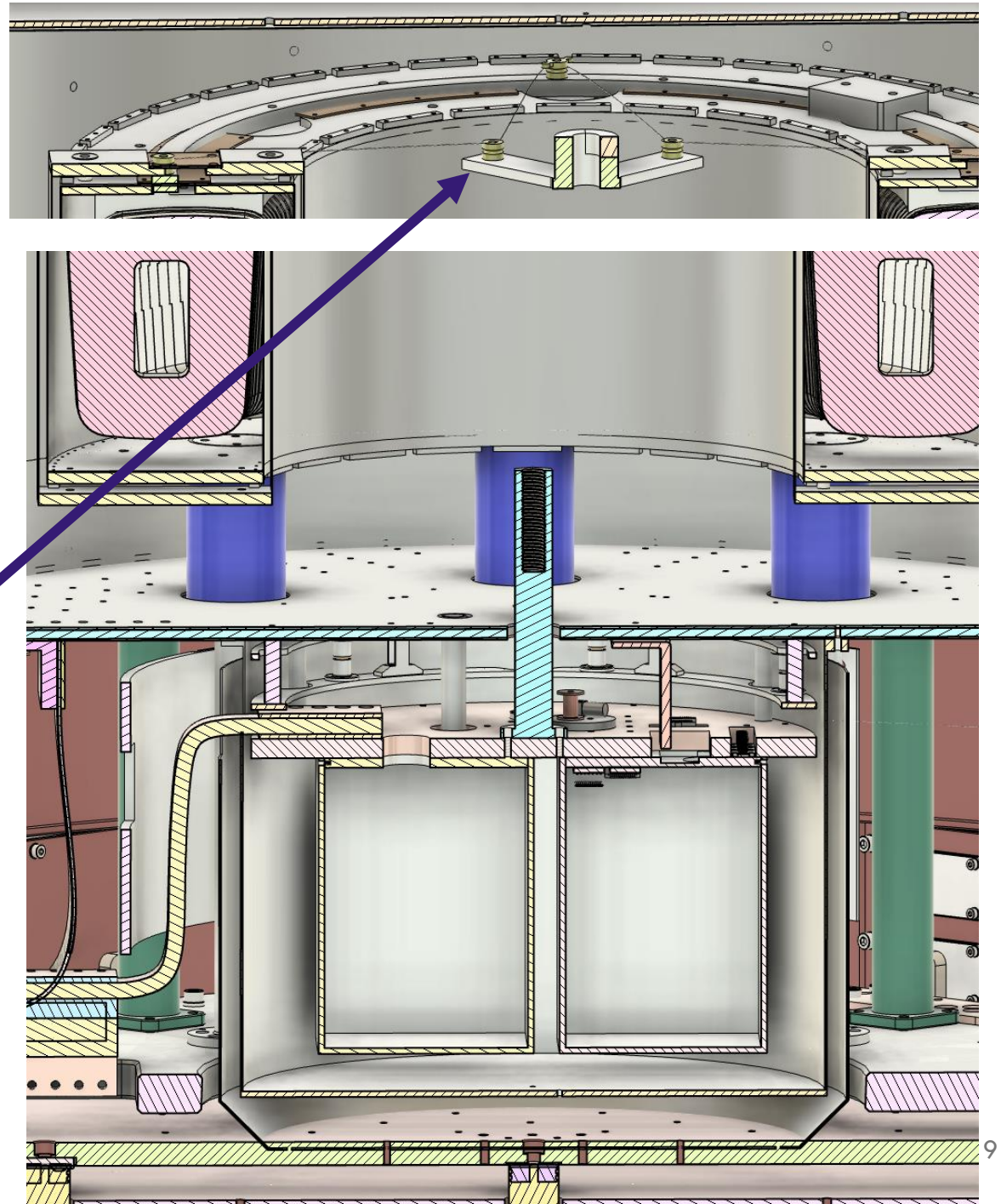




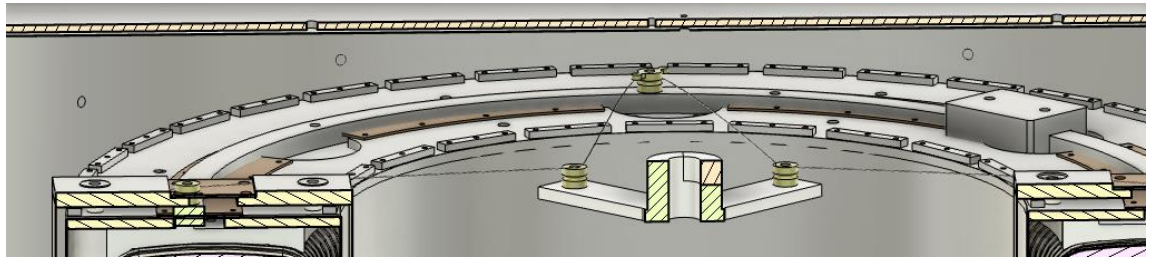
In Context

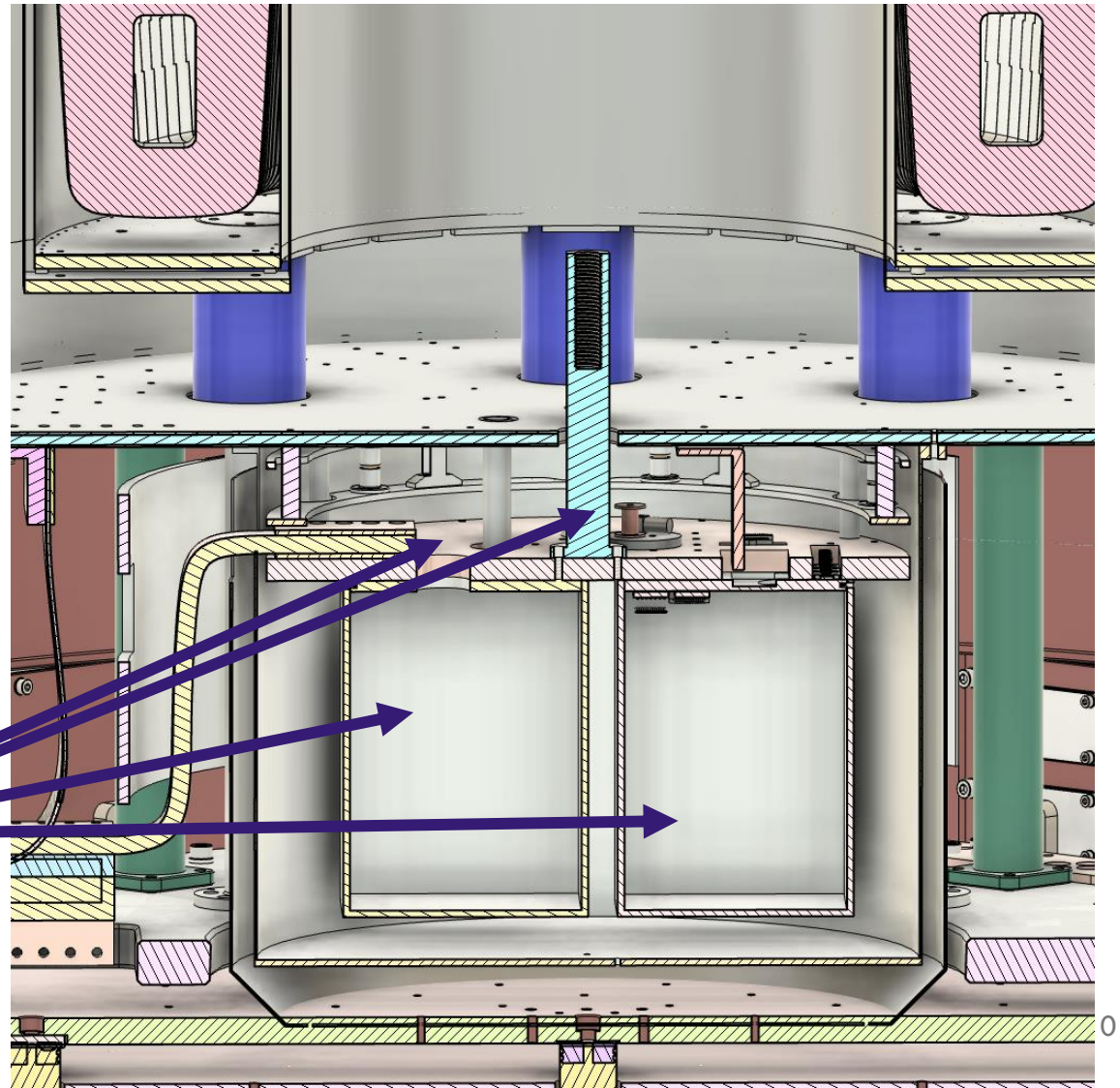
- Thermalize to cold finger → Thermal Strap
- Mechanically supported from 1K plate → Vespel Compression Support
- Mechanically supported from 4K magnet → XY Centering Puck
- Mechanically supports and thermalizes resonator and SQUIDs.



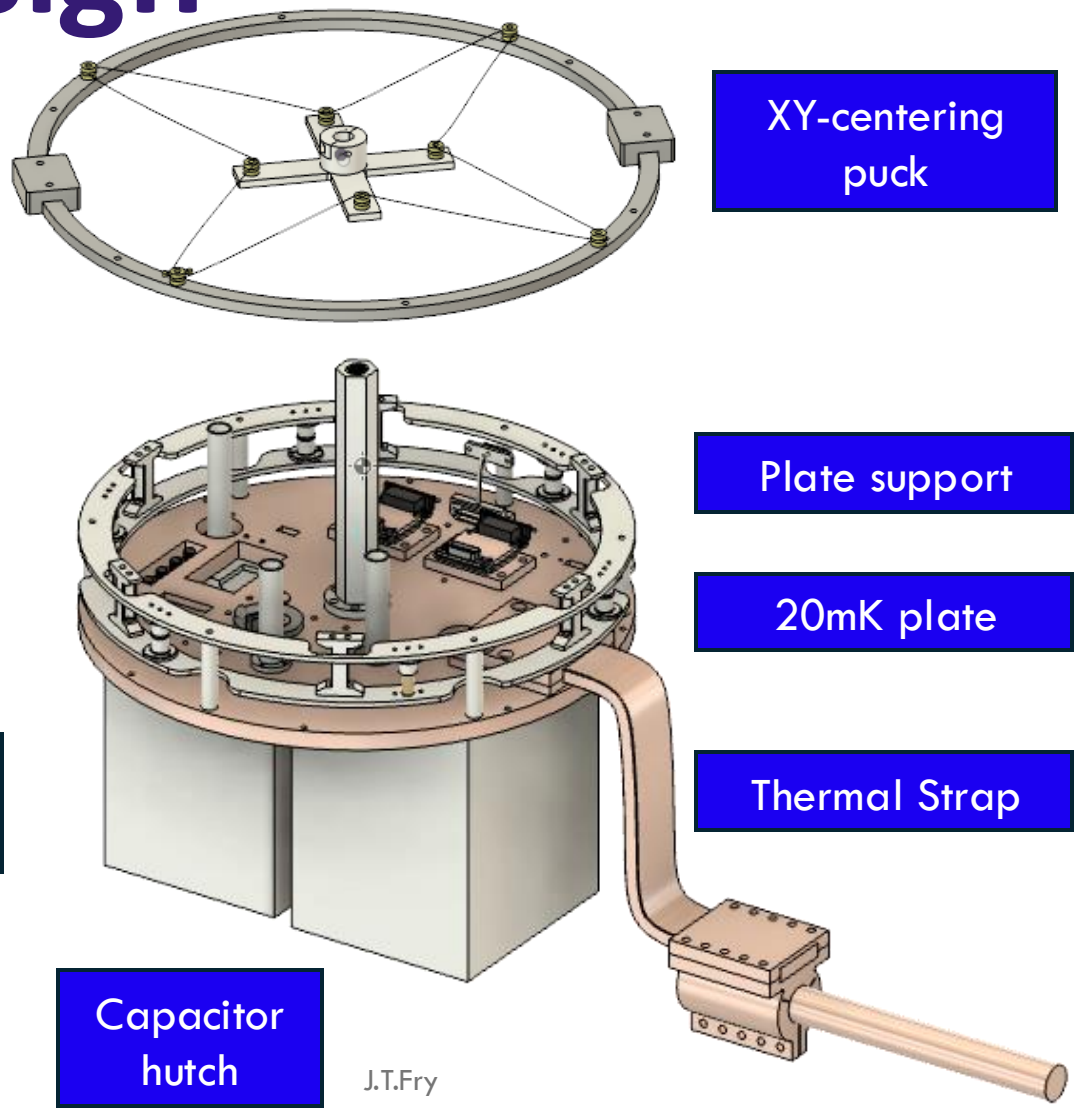
In Context

- Thermalize to cold finger → Thermal Strap
- Mechanically supported from 1K plate → Vespel Compression Support
- Mechanically supported from 4K magnet → XY Centering Puck
- Mechanically supports and thermalizes resonator and SQUIDs → Plate, Inductor support, Hutches

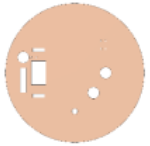




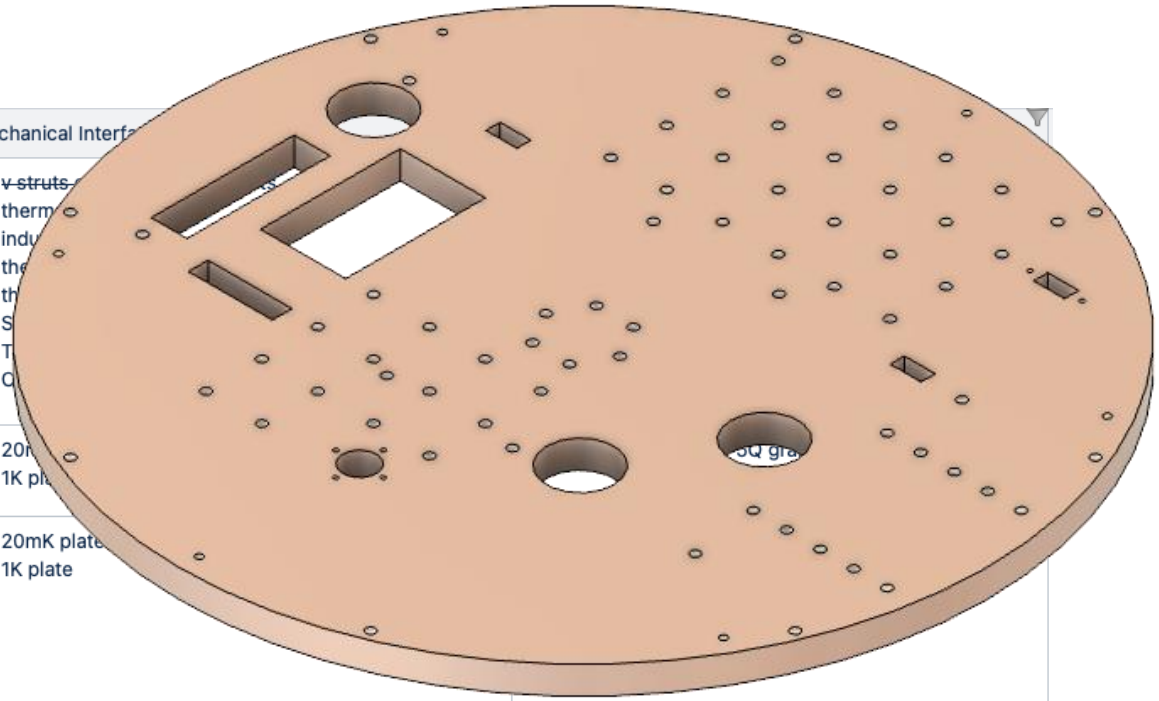
Present Design



Status

Part	CAD	Status	Mechanical Interfaces	Open Questions & Dependencies
20mK Plate	 Receiver>Jessica>20mK plate	▪ Hydrogen Free Copper Acquired ▪ Waiting on other designs to be frozen (Inductor support, compression support)	▪ ~~v struts~~ compression supports ▪ thermal braid ▪ inductor z support ▪ thermometer/heaters (2x) ▪ thru tubes (3x) ▪ SQUID wiring 20mK → 20mK, 20mK → 1K ▪ Thermometry wiring 20mK → 20mK, 20mK → 1K ▪ Calibration wiring 20mK → 20mK	• ~~Analyze the thermal performance of 5mm vs 1/4' vs 10mm plates and optimize cost/conductivity/capacitor space.~~ • ~~Determine if we need blind tapped M5 holes in the plate.~~ • *Need all other interfaces to be finalized before adding mounting holes.*
~~V struts (6x)~~	Receiver>Jessica>strut	▪ Testing Completed	▪ 20mK plate ▪ 1K plate	• vespel SP1 or AXM-5Q graphite?
Compression Support	Receiver>Jessica>compression support	▪ Design Complete ▪ Parts Ordered ▪ Assembly underway ▪ Testing forthcoming	• 20mK plate • 1K plate	▪ Will it perform cold?
Thermal Braid	Receiver>Jessica>50L_20mk_heatstrap_assy	▪ Cold finger clamp contact thermal conductance being evaluated	▪ 1K plate ▪ Cold finger ▪ 20mK plate	
Fixed Capacitor		▪ In design	▪ Capacitor hutch ▪ Screw terminal ▪ Capacitor wiring shielding (thru tube)	• Should I target a capacitance of 85 pF? • Is the assumption of a 10mH inductor and 100kHz needle frequency correct?
SQUID PCB (2x)	https://confluence.slac.stanford.edu/x/lwIUH	▪ Ready	▪ SQUID hutch ▪ Tunable Transformer ▪ SQUID wiring 20mK → 20mK	▪ Is the resulting hole pattern on the SQUID hutch forward compatible?

Status - Plate



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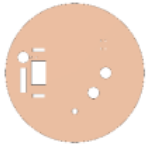
20mK Plate	 Receiver>Jessica>20mK plate	▪ Hydrogen Free Copper Acquired ▪ Waiting on other designs to be frozen (Inductor support, compression support)	▪ ~~v struts~~ ▪ therm ▪ indu ▪ the ▪ th ▪ S ▪ T ▪ C	
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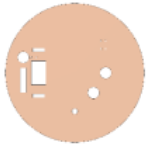
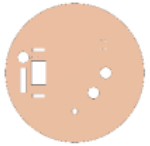
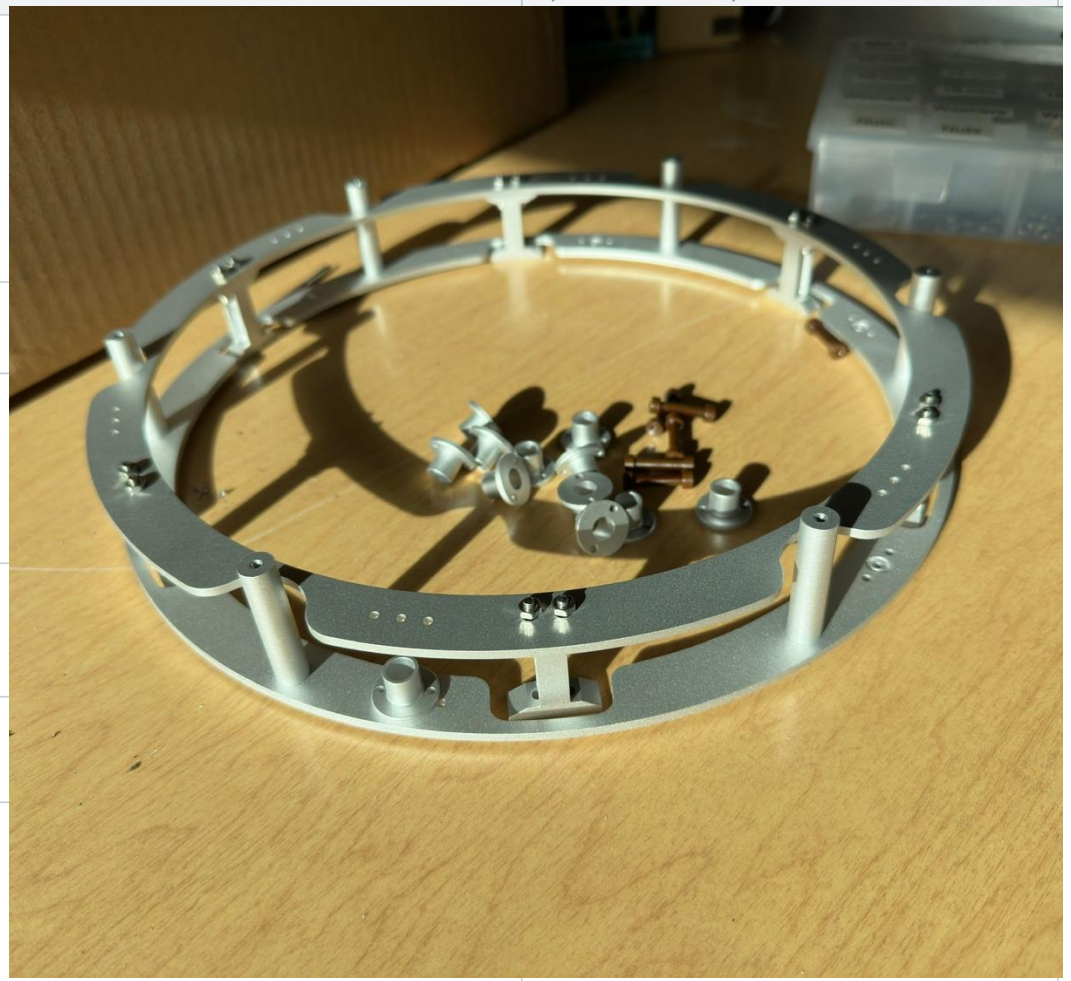
SQUID PCB (2x)	https://confluence.slac.stanford.edu/x/lwIUH	▪ Ready	▪ SQUID hutch ▪ Tunable Transformer ▪ SQUID wiring 20mK → 20mK	▪ Is the resulting hole pattern on the SQUID hutch forward compatible?

Status - Struts

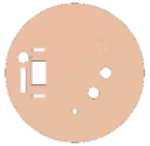
Part	CAD	Status	cies
20mK Plate	 Receiver>Jessica>20mK plate	▪ Hydrogen Free Copper Acquired ▪ Waiting on other designs to be frozen (Inductor support, compression support)	~~rmance of 5mm vs 1/4' vs~~ ~~r space.~~ ~~d tapped M5 holes in the~~ *o be finalized before*
~~V struts (6x)~~	Receiver>Jessica>strut	▪ Testing Completed	aphite?
Compression Support	Receiver>Jessica>compression support	▪ Design Complete ▪ Parts Ordered ▪ Assembly underway ▪ Testing forthcoming	
Thermal Braid	Receiver>Jessica>50L_20mk_heatstrap_assy	▪ Cold finger clamp contact thermal conductance being evaluated	
Fixed Capacitor		▪ In design	nce of 85 pF? nH inductor and 100kHz
SQUID PCB (2x)	https://confluence.slac.stanford.edu/x/lwIUH	▪ Ready	n on the SQUID hutch

Status – Compression Support

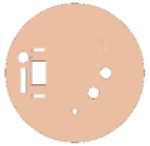
Part	CAD	Status	Mechanical Interfaces	Open Questions & Dependencies
20mK Plate	 Receiver>Jessica>20mK plate	▪ Hydrogen Free Copper Acquired ▪ Waiting on other designs to be frozen (Inductor support, compression support)	▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪	
~~V struts (6x)~~	Receiver>Jessica>strut	▪ Testing Completed	▪ ▪	
Compression Support	Receiver>Jessica>compression support	▪ Design Complete ▪ Parts Ordered ▪ Assembly underway ▪ Testing forthcoming	▪ ▪	
Thermal Braid	Receiver>Jessica>50L_20mk_heatstrap_assy	▪ Cold finger clamp contact thermal conductance being evaluated	▪ ▪ ▪	
Fixed Capacitor		▪ In design	▪ ▪ ▪	
SQUID PCB (2x)	https://confluence.slac.stanford.edu/x/lwIUH	▪ Ready	▪ ▪ ▪	



Status – Thermal Strap

Part	CAD	Status	Mechanical Interfaces	Dependencies
20mK Plate	 Receiver>Jessica>20mK plate	▪ Hydrogen Free Copper Acquired ▪ Waiting on other designs to be frozen (Inductor support, compression support)	▪ ~~v struts~~ compression supports ▪ thermal braid ▪ inductor z support ▪ thermometer/heaters (2x) ▪ thru tubes (3x) ▪ SQUID wiring 20mK → 20mK, 20mK → 1K ▪ Thermometry wiring 20mK → 20mK, 20mK → 1K ▪	~~performance of 5mm vs 1/4' vs~~ ~~timize~~ ~~itor space.~~ ~~tapped M5 holes in the~~ • *Need all oth… …e finalized before adding mount…*
~~V struts (6x)~~	Receiver>Jessica>strut	▪ Testing Completed	▪ ▪	…e?
Compression Support	Receiver>Jessica>compression support	▪ Design Complete ▪ Parts Ordered ▪ Assembly underway ▪ Testing forthcoming	▪ ▪	
Thermal Braid	Receiver>Jessica>50L_20mk_heatstrap_assy	▪ Cold finger clamp contact thermal conductance being evaluated	▪ ▪ ▪	
Fixed Capacitor		▪ In design	▪ ▪ ▪	
SQUID PCB (2x)	https://confluence.slac.stanford.edu/x/lwIUH	▪ Ready	▪ ▪ ▪	

Status – Capacitor & SQUIDs

Part	CAD	Status	Mechanical Interfaces	Open Questions & Dependencies
20mK Plate	 Receiver>Jessica>20mK plate	▪ Hydrogen Free Copper Acquired ▪ Waiting on other designs to be frozen (Inductor support, compression support)	▪ ~~v struts~~ compression supports ▪ thermal braid ▪ inductor z support ▪ thermometer/heaters (2x) ▪ thru tubes (3x) ▪ SQUID wiring 20mK → 20mK, 20mK → 1K ▪ Thermometry wiring 20mK → 20mK, 20mK → 1K ▪ Calibration wiring 20mK → 20mK	• ~~Analyze the thermal performance of 5mm vs 1/4' vs 10mm plates and optimize cost/conductivity/capacitor space.~~ • ~~Determine if we need blind tapped M5 holes in the plate.~~ • *Need all other interfaces to be finalized before adding mounting holes.*
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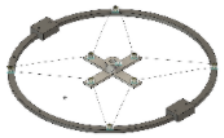
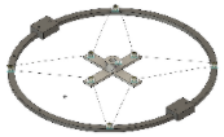
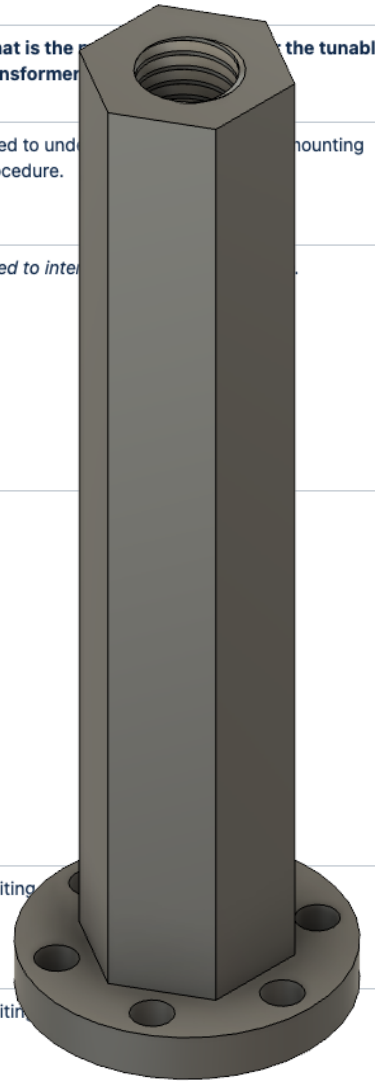
Compression Support	Receiver>Jessica>compression support	▪ Design Complete ▪ Parts Ordered ▪ Assembly underway ▪ Testing forthcoming	• 20mK plate • 1K plate	▪ Will it perform cold?
Thermal Braid	Receiver>Jessica>50L_20mk_heatstrap_assy	▪ Cold finger clamp contact thermal conductance being evaluated	▪ 1K plate ▪ Cold finger ▪ 20mK plate	
Fixed Capacitor		▪ In design	▪ Capacitor hutch ▪ Screw terminal ▪ Capacitor wiring shielding (thru tube)	• Should I target a capacitance of 85 pF? • Is the assumption of a 10mH inductor and 100kHz needle frequency correct?
SQUID PCB (2x)	https://confluence.slac.stanford.edu/x/lwIUH	▪ Ready	▪ SQUID hutch ▪ Tunable Transformer ▪ SQUID wiring 20mK → 20mK	▪ Is the resulting hole pattern on the SQUID hutch forward compatible?

Status – Transformer & Inductor

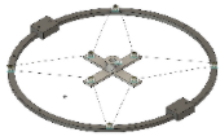
Tunable Transformer		▪ Designed ▪ In testing	▪ SQUID hutch ▪ SQUID PCB ▪ Screw terminals	• **What is the mounting structure for the tunable transformer?**
Inductor	~~Receiver>Ameya>Inductor Frame~~	▪ Designed	▪ XY support ▪ X support ▪ Screw terminal ▪ SQUID wiring shielding (thru tube)	▪ Need to understand thermalization & mounting procedure.
Inductor Z support	Receiver>Jessica>Inductor_rod_support 	▪ Initial design complete	▪ 20mK plate ▪ Inductor ▪ 1K plate	▪ *Need to interface with inductor design.*
Inductor XY support	Receiver>Jessica>Inductor_puck_full 	• Prototype built and tested • Order Niobium outer ring parts.	▪ Inductor ▪ Magnet bracket ▪ Sheath	
SQUID Hutch	Receiver>Jessica>SQUID_box	▪ Initial Design Complete	▪ SQUID ▪ SQUID wiring ▪ Tunable Transformer ▪ Thru tubes	▪ Waiting on interface finalization
Capacitor Hutch	Receiver>Jessica>Capacitor_box	▪ Initial Design Complete	▪ Capacitor ▪ Thru tubes ▪ Capacitor wiring	▪ Waiting on interface finalization

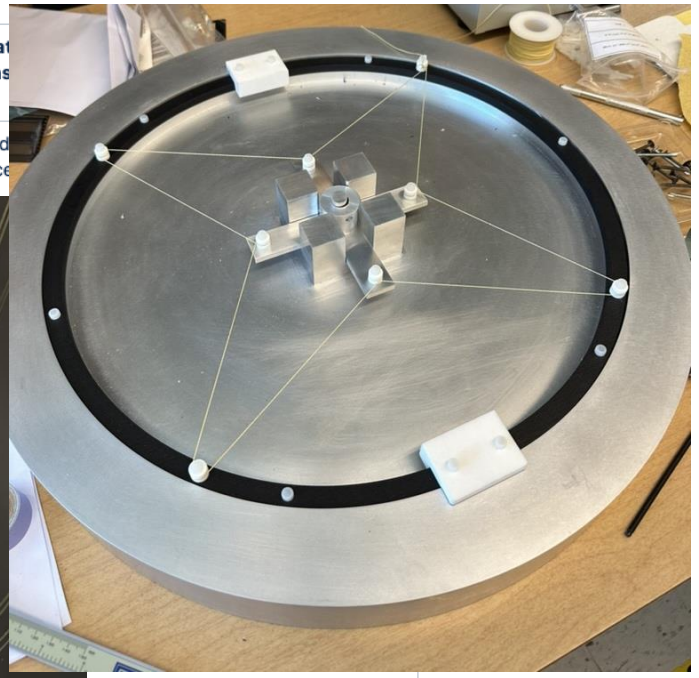
Status – Inductor Z Support

Tunable Transformer		▪ Designed ▪ In testing	▪ SQUID hutch ▪ SQUID PCB ▪ Screw terminals	• **What is the p… t the tunable transformer**
Inductor	~~Receiver>Ameya>Inductor Frame~~	▪ Designed	▪ XY support ▪ X support ▪ Screw terminal ▪ SQUID wiring shielding (thru tube)	▪ Need to und… …hounting procedure.
Inductor Z support	Receiver>Jessica>Inductor_rod_support 	▪ Initial design complete	▪ 20mK plate ▪ Inductor ▪ 1K plate	▪ *Need to inte…*
Inductor XY support	Receiver>Jessica>Inductor_puck_full 	• Prototype built and tested • Order Niobium outer ring parts.	▪ Inductor ▪ Magnet bracket ▪ Sheath	
SQUID Hutch	Receiver>Jessica>SQUID_box	▪ Initial Design Complete	▪ SQUID ▪ SQUID wiring ▪ Tunable Transformer ▪ Thru tubes	▪ Waiting…
Capacitor Hutch	Receiver>Jessica>Capacitor_box	▪ Initial Design Complete	▪ Capacitor ▪ Thru tubes ▪ Capacitor wiring	▪ Waitin…

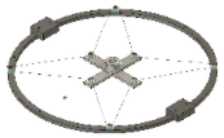


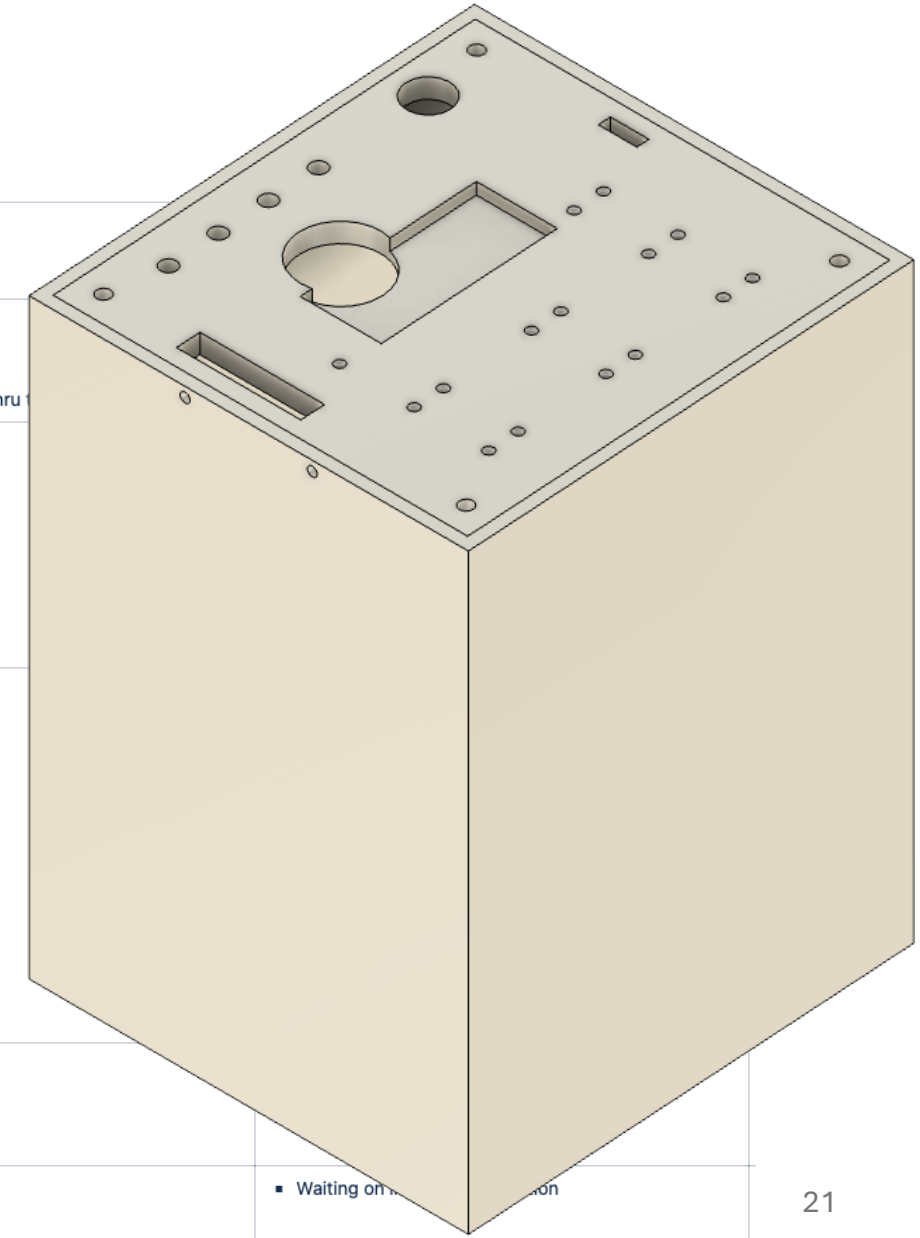
Status – XY Centering Puck

Tunable Transformer		▪ Designed ▪ In testing	▪ SQUID hutch ▪ SQUID PCB ▪ Screw terminals	• **What trans**
Inductor	~~Receiver>Ameya>Inductor Frame~~	▪ Designed	▪ XY support ▪ X support ▪ Screw terminal	▪ Need proce
Inductor Z support	Receiver>Jessica>Inductor_rod_support 	▪ Initial design complete		
Inductor XY support	Receiver>Jessica>Inductor_puck_full 	• Prototype built and tested • Order Niobium outer ring parts.		
SQUID Hutch	Receiver>Jessica>SQUID_box	▪ Initial Design Complete		erface finalization
Capacitor Hutch	Receiver>Jessica>Capacitor_box	▪ Initial Design Complete		erface finalization

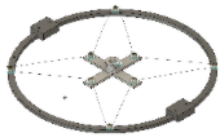


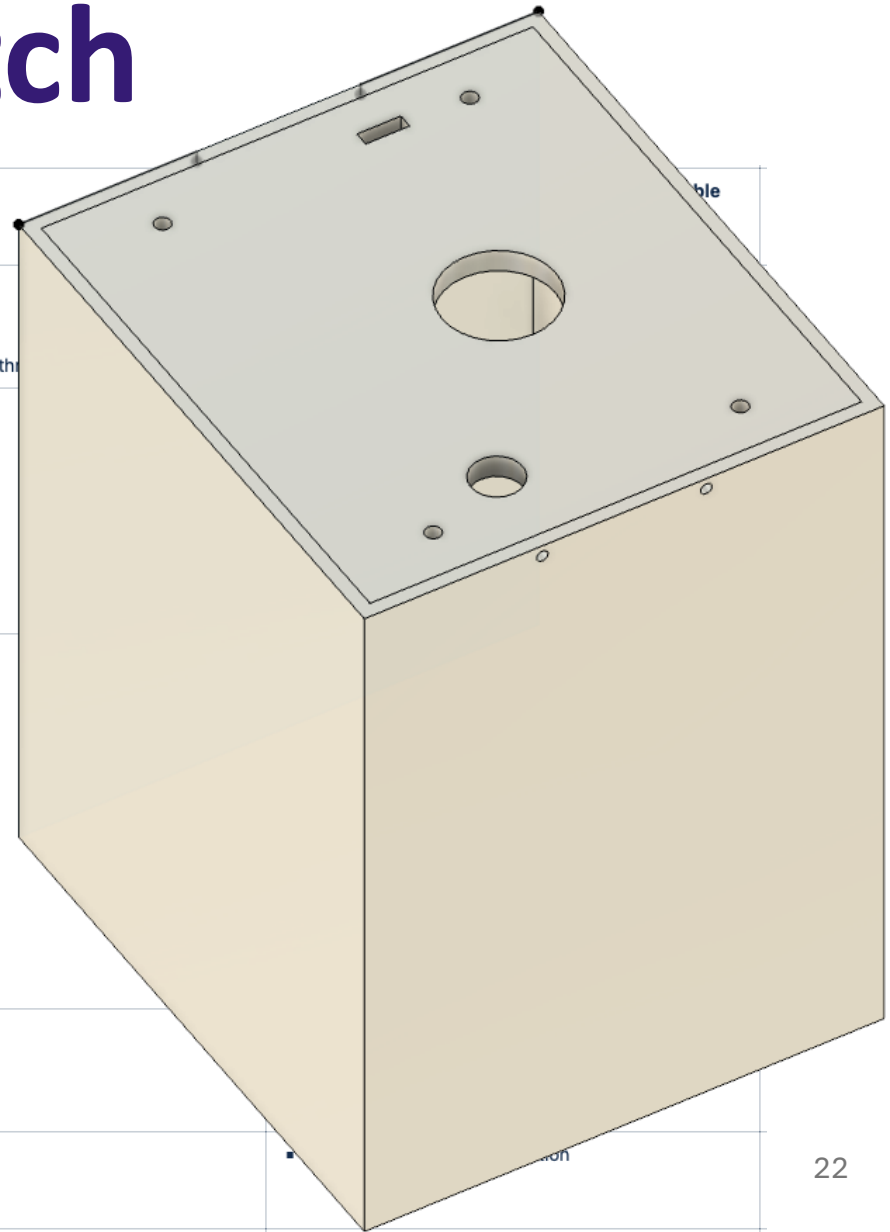
Status – SQUID Hutch

Tunable Transformer		▪ Designed ▪ In testing	▪ SQUID hutch ▪ SQUID PCB ▪ Screw terminals	
Inductor	~~Receiver>Ameya>Inductor Frame~~	▪ Designed	▪ XY support ▪ X support ▪ Screw terminal ▪ SQUID wiring shielding (thru	
Inductor Z support	Receiver>Jessica>Inductor_rod_support 	▪ Initial design complete	▪ 20mK plate ▪ Inductor ▪ 1K plate	
Inductor XY support	Receiver>Jessica>Inductor_puck_full 	• Prototype built and tested • Order Niobium outer ring parts.	▪ Inductor ▪ Magnet bracket ▪ Sheath	
SQUID Hutch	Receiver>Jessica>SQUID_box	▪ Initial Design Complete	▪ SQUID ▪ SQUID wiring ▪ Tunable Transformer ▪ Thru tubes	
Capacitor Hutch	Receiver>Jessica>Capacitor_box	▪ Initial Design Complete	▪ Capacitor ▪ Thru tubes ▪ Capacitor wiring	▪ Waiting on

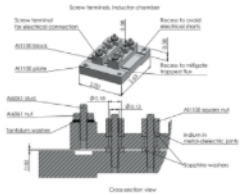


Status – Capacitor Hutch

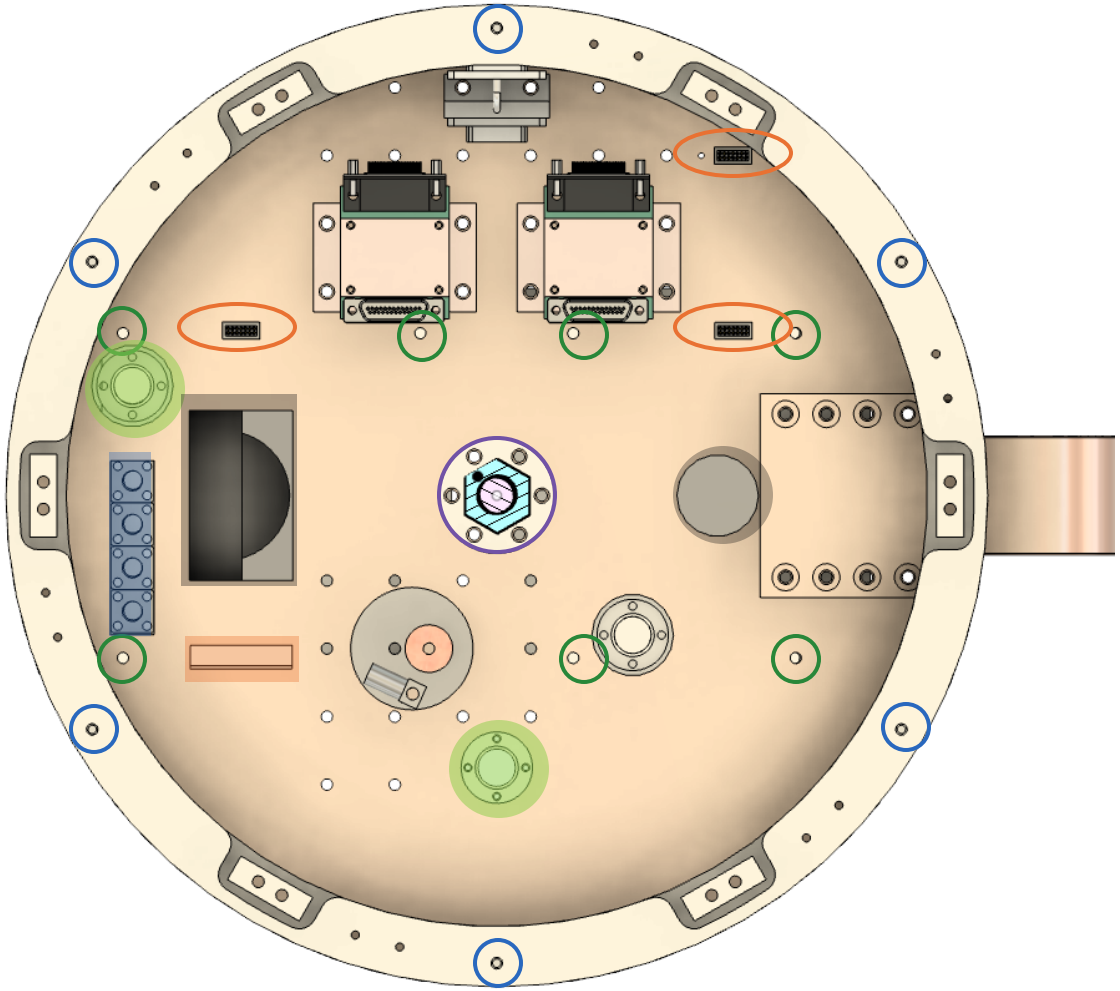
Tunable Transformer		▪ Designed ▪ In testing	▪ SQUID hutch ▪ SQUID PCB ▪ Screw terminals
Inductor	~~Receiver>Ameya>Inductor Frame~~	▪ Designed	▪ XY support ▪ X support ▪ Screw terminal ▪ SQUID wiring shielding (th
Inductor Z support	Receiver>Jessica>Inductor_rod_support 	▪ Initial design complete	▪ 20mK plate ▪ Inductor ▪ 1K plate
Inductor XY support	Receiver>Jessica>Inductor_puck_full 	• Prototype built and tested • Order Niobium outer ring parts.	▪ Inductor ▪ Magnet bracket ▪ Sheath
SQUID Hutch	Receiver>Jessica>SQUID_box	▪ Initial Design Complete	▪ SQUID ▪ SQUID wiring ▪ Tunable Transformer ▪ Thru tubes
Capacitor Hutch	Receiver>Jessica>Capacitor_box	▪ Initial Design Complete	▪ Capacitor ▪ Thru tubes ▪ Capacitor wiring



Status – Thermometers & Heaters

Thermometers/Heaters (6x)		• Wiring plan sketched • Mock-up profile made • Aux holes mapped out	• 20mK Plate • SQUID hutch • Capacitor hutch • Thermometry wiring 20mK → 20mK	• **Is there an updated standardized thermometry design?**
Ring Down/SBI Calibration wires		• Not designed • Need to analyze signal degradation	• Inductor • Calibration wiring 20mK → 20mK	• What loss to the axion current do we expect with a small calibration wire affixed to the inductor support?
Screw Terminals	 Roman's thesis	• Prototype designed • Need to implement for 50L	• SQUID hutch • Tunable transformer • Inductor • Capacitor	• **Should this live in the SQUID hutch or Capacitor hutch?**
SQUID Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring 	• Initial design complete	• 1K plate • 20mK plate • SQUID hutch • various wires ?	• *If we change v strut length, this length must change.*
Capacitor Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring 	• Initial design complete	• 1K plate • 20mK plate • Capacitor hutch • various wires ?	• *If we change v strut length, this length must change.*

Status – Thermometers & Heaters



M3 through support mounting

M4 threaded shield mounting

M4 threaded hutch mounting

M4 threaded inductor support

3.5mm through hole thermometry wiring

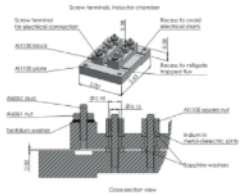
12.7mm thru tube hole

Attocube through holes

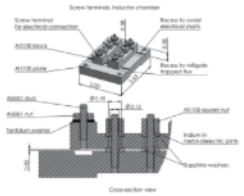
SMA through cut out

MicroD through cut out

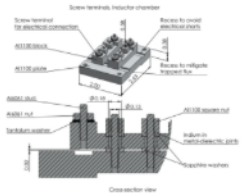
Status – Calibration Wiring

Thermometers/Heaters (6x)	To Do!	• Wiring plan sketched • Mock-up profile made • Aux holes mapped out	• 20mK Plate • SQUID hutch • Capacitor hutch • Thermometry wiring 20mK → 20mK	• **Is there an updated standardized thermometry design?**
Ring Down/SBI Calibration wires		• Not designed • Need to analyze signal degradation	• Inductor • Calibration wiring 20mK → 20mK	• What loss to the axion current do we expect with a small calibration wire affixed to the inductor support?
Screw Terminals	 Roman's thesis	• Prototype designed • Need to implement for 50L	• SQUID hutch • Tunable transformer • Inductor • Capacitor	• **Should this live in the SQUID hutch or Capacitor hutch?**
SQUID Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring 	• Initial design complete	• 1K plate • 20mK plate • SQUID hutch • various wires ?	• *If we change v strut length, this length must change.*
Capacitor Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring 	• Initial design complete	• 1K plate • 20mK plate • Capacitor hutch • various wires ?	• *If we change v strut length, this length must change.*

Status – Resonator Screw Terminals

Thermometers/Heaters (6x)		• Wiring plan sketched • Mock-up profile made • Aux holes mapped out	• 20mK Plate • SQUID hutch • Capacitor hutch • Thermometry wiring 20mK → 20mK	• **Is there an updated standardized thermometry design?**
Ring Down/SBI Calibration wires		• Not designed • Need to analyze signal degradation	• Inductor • Calibration wiring 20mK → 20mK	• What loss to the axion current do we expect with a small calibration wire affixed to the inductor support?
Screw Terminals	 Roman's thesis	• Prototype designed • Need to implement for 50L	• SQUID hutch • Tunable transformer • Inductor • Capacitor	• **Should this live in the SQUID hutch or Capacitor hutch?**
SQUID Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring 	• Initial design complete	• 1K plate • 20mK plate • SQUID hutch • various wires ?	• *If we change v strut length, this length must change.*
Capacitor Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring 	• Initial design complete	• 1K plate • 20mK plate • Capacitor hutch • various wires ?	• *If we change v strut length, this length must change.*

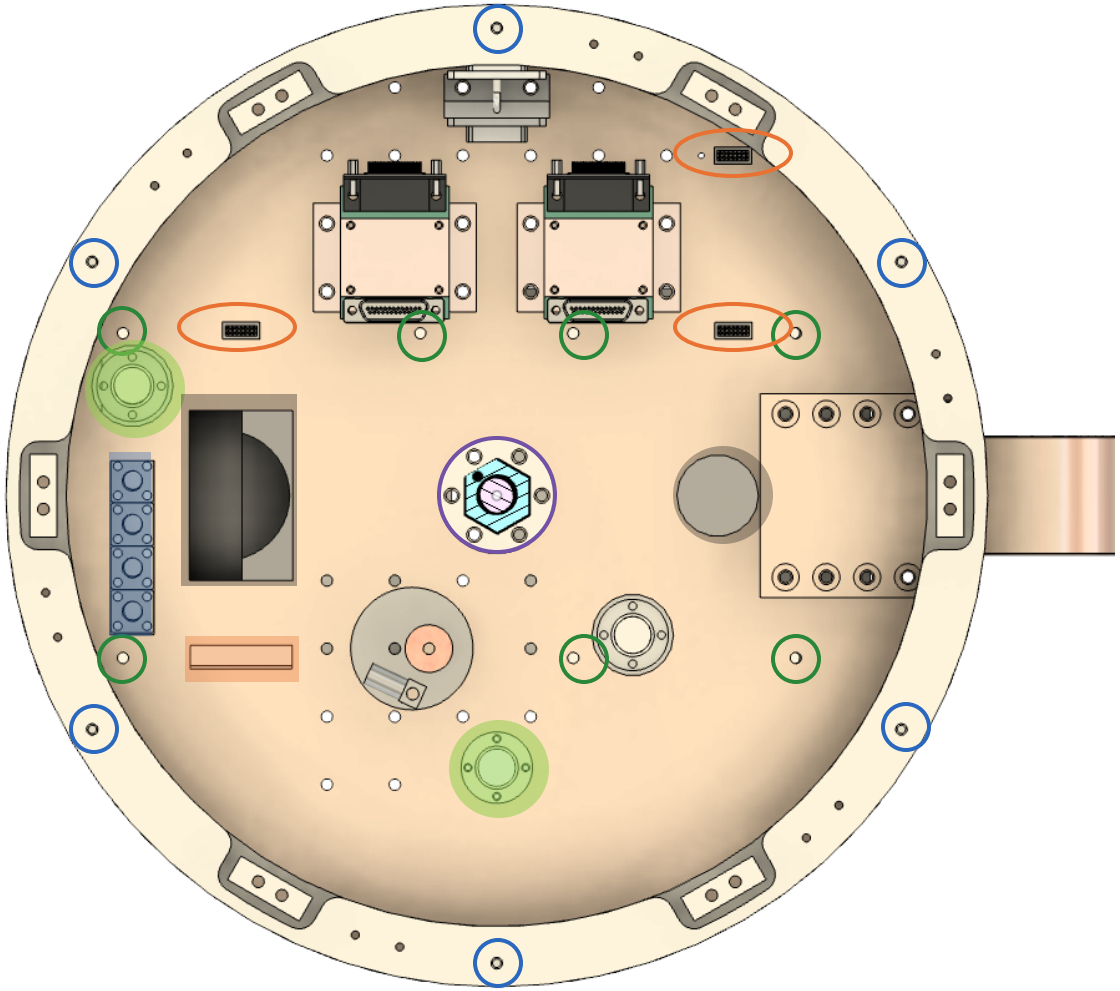
Status – Thru Tubes

Thermometers/Heaters (6x)		• Wiring plan sketched • Mock-up profile made • Aux holes mapped out	• 20mK Plate • SQUID hutch • Capacitor hutch • Thermometry wiring 20mK → 20mK	**dardized thermometry**
Ring Down/SBI Calibration wires		• Not designed • Need to analyze signal degradation	• Inductor • Calibration wiring 20mK → 20mK	rent do we expect with a ed to the inductor
Screw Terminals	 Roman's thesis	• Prototype designed • Need to implement for 50L	• SQUID hutch • Tunable transformer • Inductor • Capacitor	**UID hutch or Capacitor**
SQUID Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring 	• Initial design complete	• 1K plate • 20mK plate • SQUID hutch • various wires	*h, this length must change.*
Capacitor Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring 	• Initial design complete	• 1K plate • 20mK plate • Capacitor hutch • various wires	*length must change.*

Status – Wiring Plan

Calibration Wiring Shielding (thru tube)	Receiver>Jessica>thru_tube_wiring_blank 	• Initial design complete	▪ 1K plate ▪ 20mK plate ▪ Ring Down/SBI Calibration wires	• *If we change v strut length, this length must change.*
SQUID Wiring 20mK → 20mK (2x)	Receiver>Jessica>TCSD-07-D-20.00-01-SIDEA Receiver>Jessica>TCSD-07-D-20.00-01-SIDEB 	• Initial design complete	▪ SQUID PCB ▪ SQUID wiring 20mK → 1K ▪ 20mK plate ▪ SQUID hutch	
Thermometry Wiring 20mK → 20mK (3x)	Receiver>Jessica>mill-max	• Initial design complete	▪ DC Wiring 20mK → 1K ▪ 20mK plate ▪ SQUID hutch ▪ Capacitor hutch	
Calibration Wiring 20mK → 20mK	Receiver>Jessica>mill-max	• Initial design complete	▪ Ring Down/SBI Calibration wires ▪ 20mK plate ▪ DC wiring 20mK → 1K	
DC Wiring 20mK → 1K (3x)	Receiver>Jessica>micro-D_mount	• Initial design complete	▪ Thermometry wiring 20mK → 20mK ▪ Calibration Wiring 20mK → 20mK ▪ 20mK plate ▪ DC Wiring 1K	
SQUID Wiring 20mK → 1K (2x)	Receiver>Jessica>TCSD_to_MicroD	• Initial design complete	▪ SQUID wiring 20mK → 20mK ▪ 20mK plate ▪ SQUID wiring 1K	

Status – Wiring



M3 through support mounting

M4 threaded shield mounting

M4 threaded hutch mounting

M4 threaded inductor support

3.5mm through hole thermometry wiring

12.7mm thru tube hole

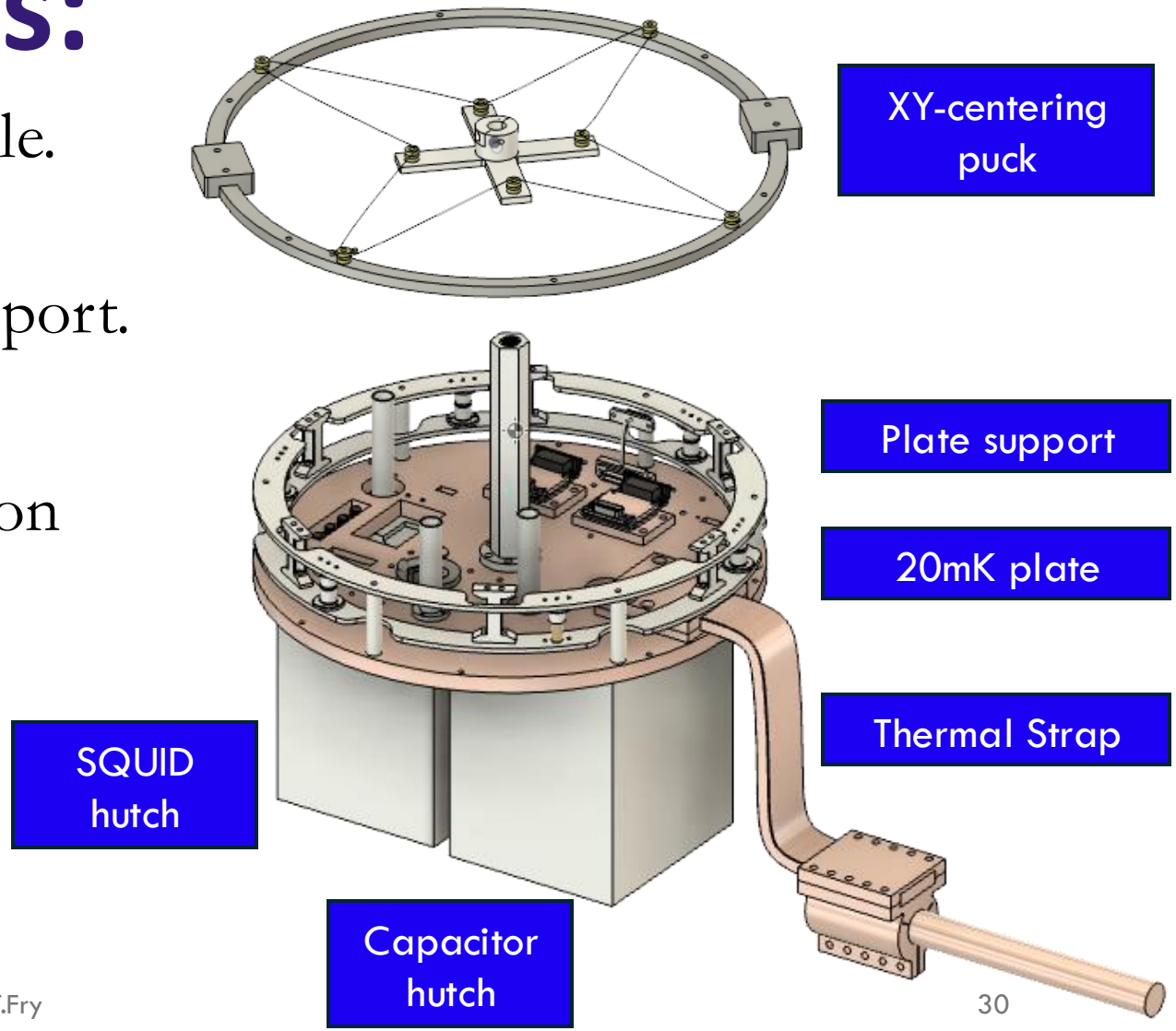
Attocube through holes

SMA through cut out

MicroD through cut out

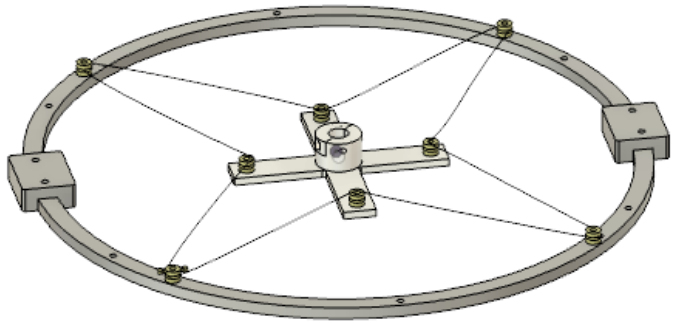
Immediate To Do's:

- Determine cold finger clamp profile.
  - Then machine thermal strap.
- LN2 dip and test compression support.
- Design SQUID mounts.
- Finalize interfaces with collaboration input.



Collaboration Input

- SQUID Hutch > transformer (Tori) ✓
- SQUID Hutch > SQUID (Nicholas) ✓
- Plate > Inductor (Roman)
- Puck > Inductor (Roman)
- Capacitor Hutch > Capacitor (Roman)
- Thru Tube > Calibration Wiring (?)



XY-centering puck

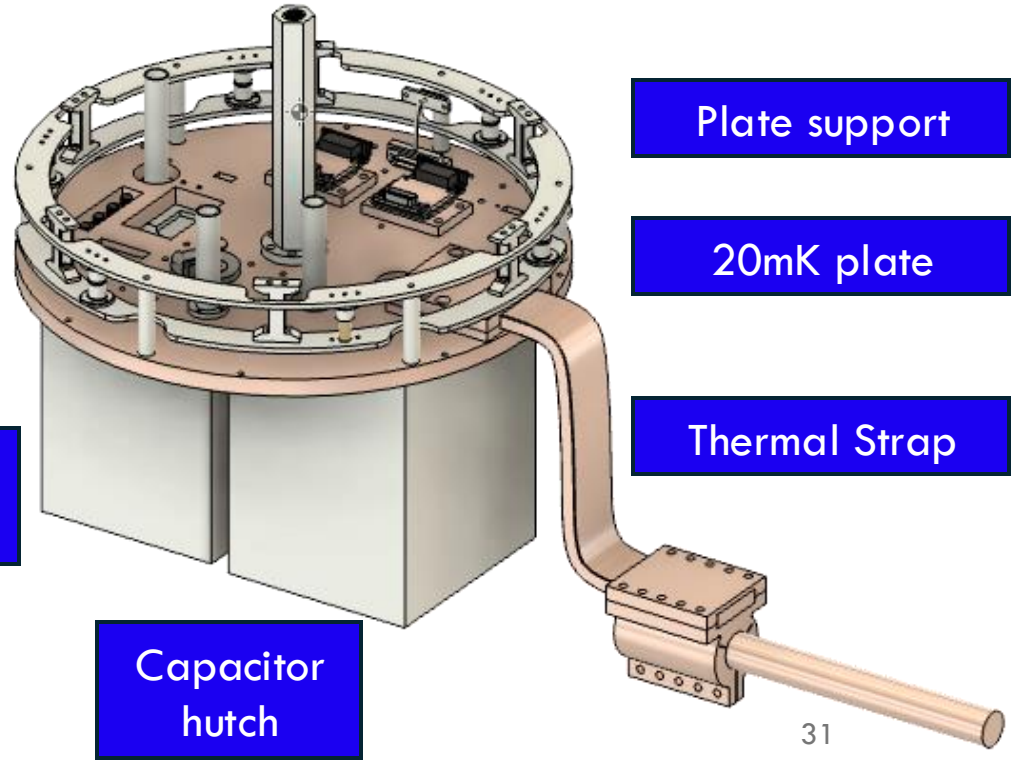


Plate support

20mK plate

Thermal Strap

SQUID hutch

Capacitor hutch