HL-LHC-BGI:
Design Ideas with Timepix4

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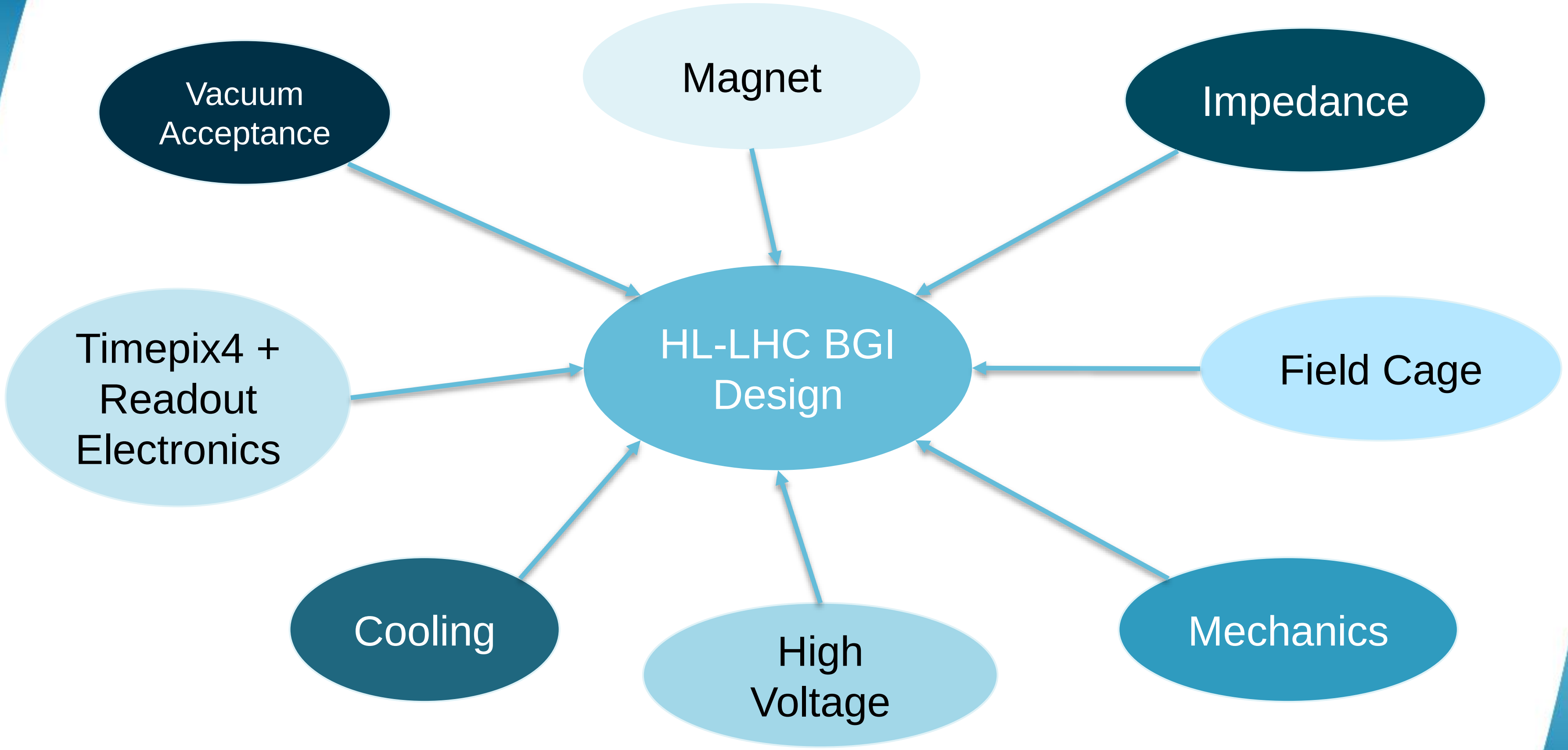
HL-LHC BGI Meeting – 13th February 2024

HL-LHC BGI Design Requirements


Vacuum Acceptance
Magnet
Impedance
Timepix4 + Readout Electronics
HL-LHC BGI Design
Field Cage
Cooling
High Voltage
Mechanics

Conceptual Design Considerations

Goal #1. Provides measurements with < 1% systematic uncertainties (consider beam size contribution to emittance uncertainty, and beam

Design Considerations	Pre-Build Testing	Verification
• Large electrodes should be sufficiently large to ensure uniform E-field • Electrodes should be parallel to prevent profile distortion • Magnetic field must be sufficiently high and uniform • Electrodes and magnet should be well aligned	• CST & IPM simulations with worst-case scenario beams (e.g. worst beam position & space charge) • Check uniformity of electric and magnetic fields with CST • Simulate misalignment within tolerances with CST and IPM?	• Compare BGI measurements with those of other instruments

Conceptual Design Considerations

Goal #2. BGI should fit the given space

Design Considerations	Pre-Build Testing	Verification
• Accommodate 50 mm LHC beam-pipe • Fit inside existing 7 Tesla magnet • ~10 mm of space required for electronics and cooling	• CAD model with attention to tolerances	• Smooth installation process

Goal #3. Meet LHC standards for installation (e.g. vacuum, HV, impedance)

Design Considerations	Pre-Build Testing	Verification
• Follow HV design guidelines (e.g. 3 kV/mm in vacuum) • Minimize sudden changes in beam-pipe • No materials with high outgassing	• Design approval from vacuum group • Impedance simulations	• HV testing • Vacuum acceptance test

Conceptual Design Considerations

Goal #4. Bunch-by-bunch Measurements

Design Considerations	Pre-Build Testing	Verification
• Increase electric field so electron arrivals from one bunch do not overlap with those from the next bunch	• Calculate $t_{drift} = \sqrt{\frac{2xm}{qE}} \ll 25\ ns$	• Compare bunch-by-bunch measurements with other instruments

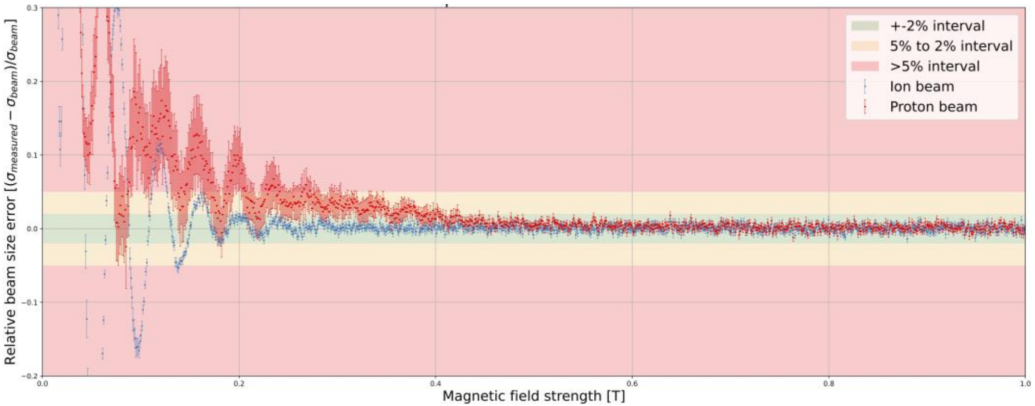
Goal #5. Increase event rate

Design Considerations	Pre-Build Testing	Verification
• High electric field integrated over ionised electron path length • Thin entrance window if necessary	• Compare electric field with PS and SPS instruments to predict event rate	• Measurement with < 5% uncertainties integrating over period where beam is stationary

Mechanical Design Constraints

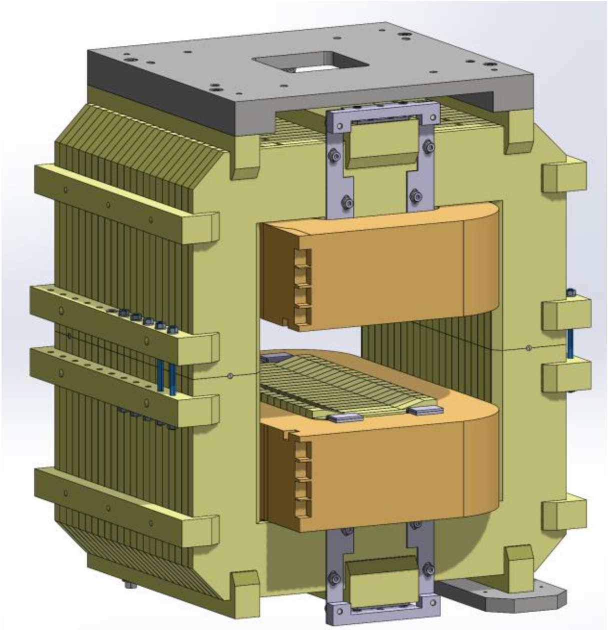
Magnet Requirements

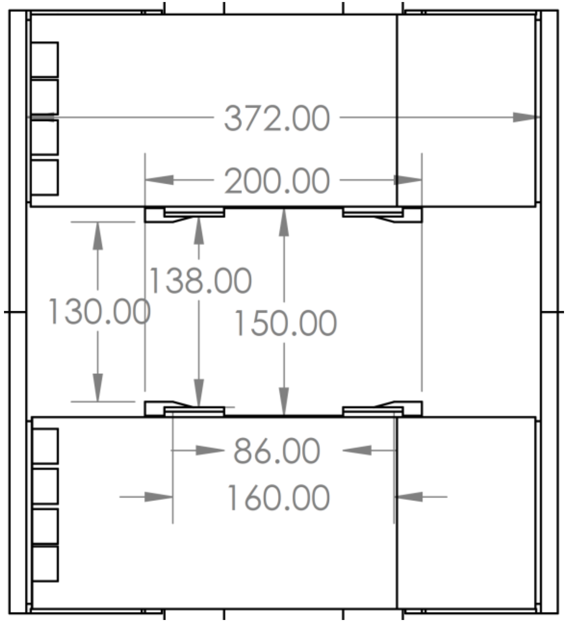
Simulation from Swann:



Conclusion: We need >0.6 T uniform magnetic field

0.7 Tesla Magnet from Magnet Group





- Max flange size that fits is a CF300
- All designs with flange sizes **> CF100** only have **130mm** of vertical space
- We are very limited on vertical space

Other Constraints

Aperture Size

- 50 mm diameter aperture that must be “clear” for the beam to pass through

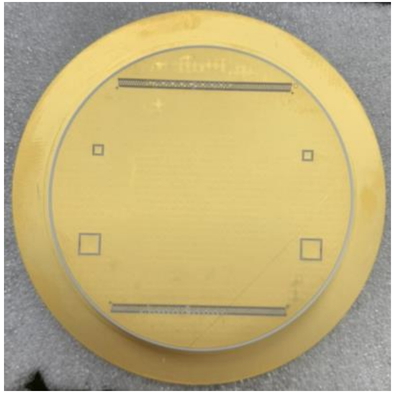
High Voltage Design (-30 kV)

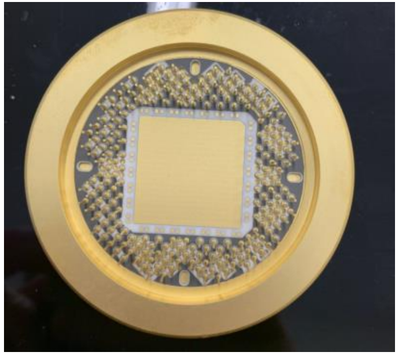
- Minimum 10 mm vacuum gap
- Minimum 30 mm along insulator surfaces
- Minimum 7.5 mm within good bulk insulator material

Current Design Idea

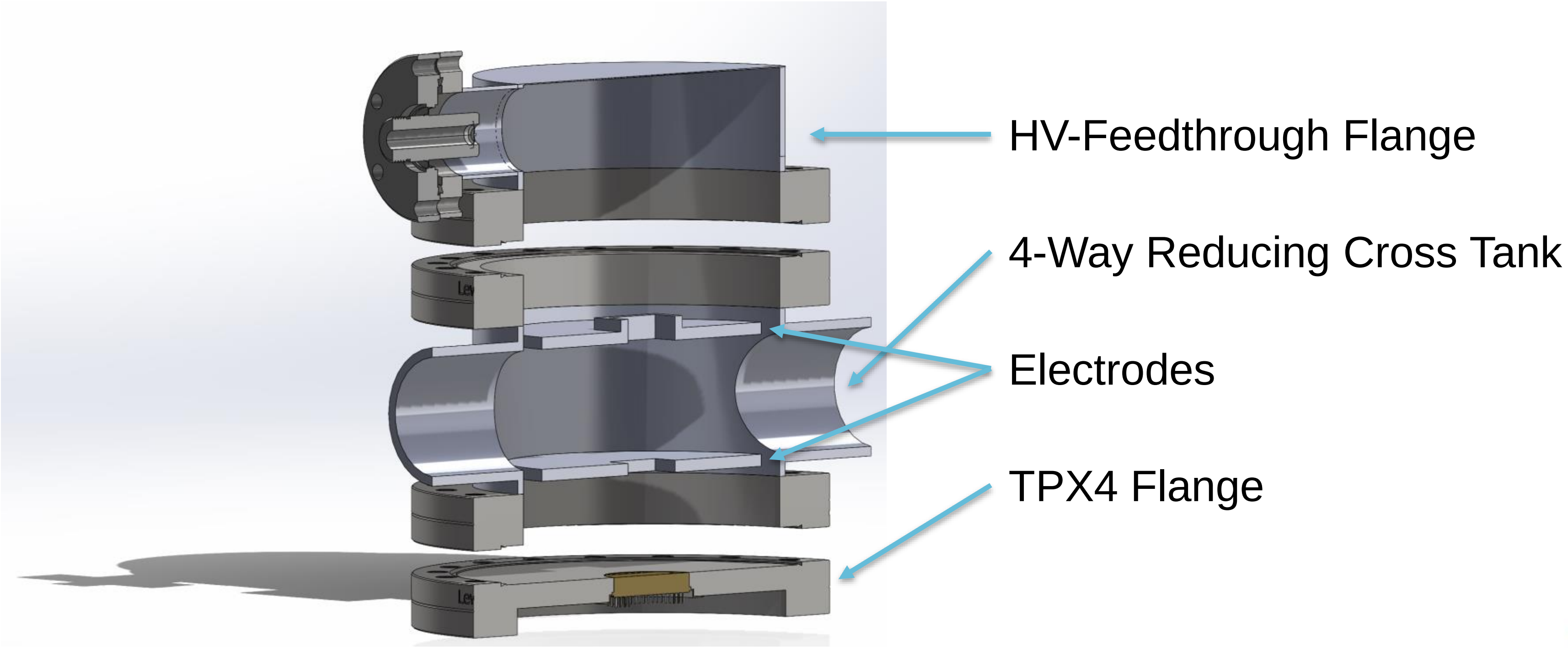
Objectives for 4DPhoton Based Design

- **Reduce cost**
  - Use standard CF flanges instead of custom rectangular CF flange
- **Reduce complexity**
  - Electronics and cooling outside of vacuum
- **Modular design**
  - Could use most of the same components on different accelerators, with accelerator-unique 4-way cross
  - Easier to replace single components (e.g. replace Timepix, but use the same tank)



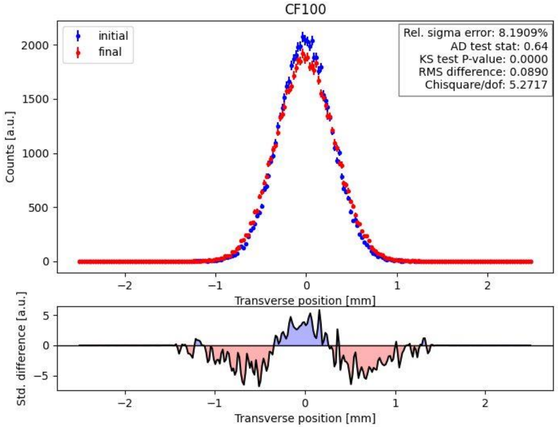


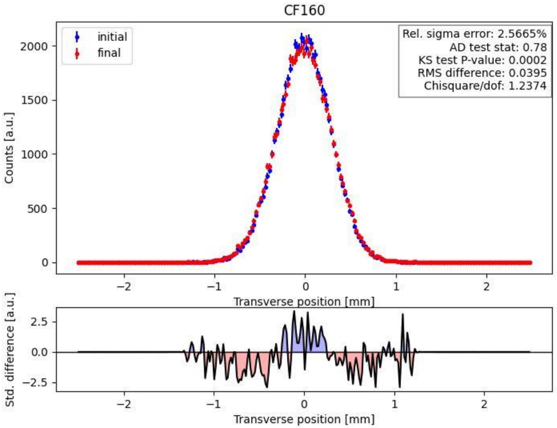
Design Concept

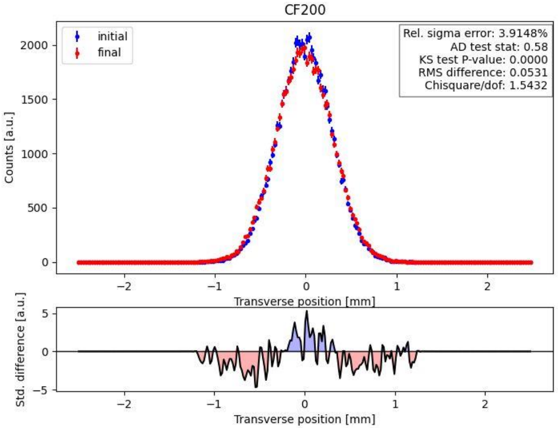


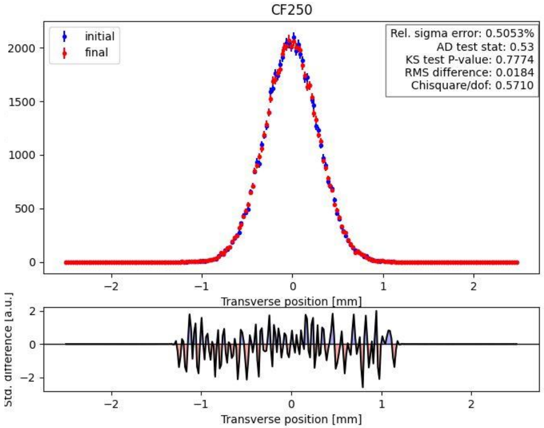
Choosing Flange Sizes and Electrodes

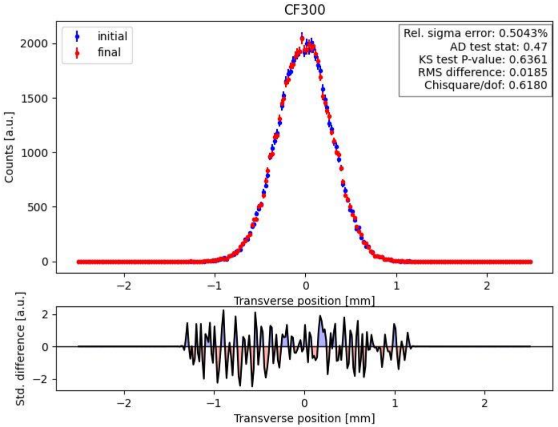
Varying Flange Size



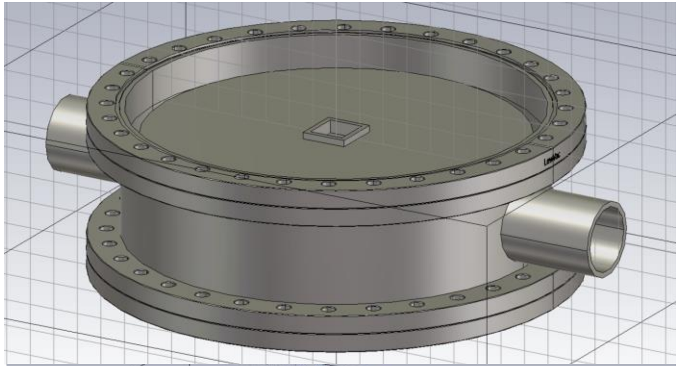


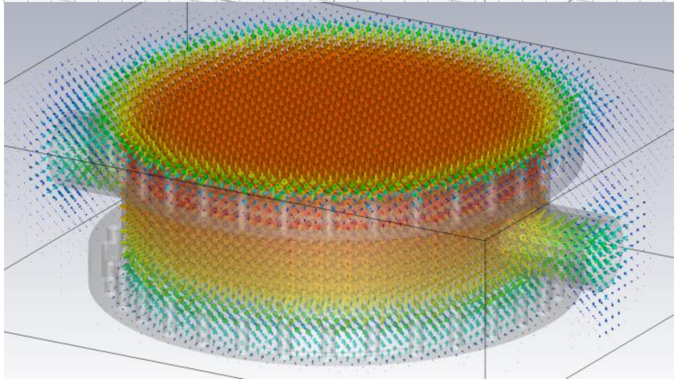






Varying Flange Size Recommendations





Other Considerations

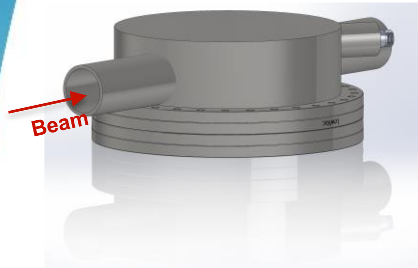
- As flange size increases, so does flange thickness
- > CF250 require M10 instead of M8 screws

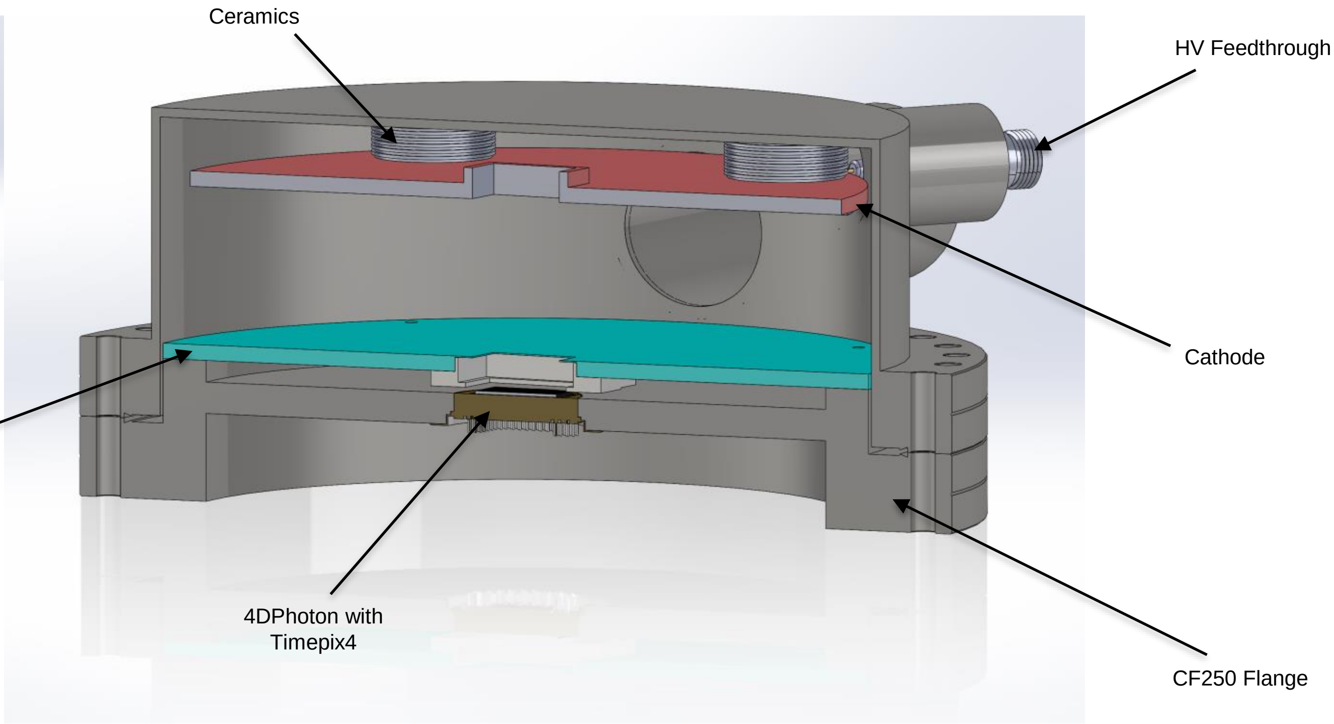
Recommendation

- **Recommend using CF250**, given current information

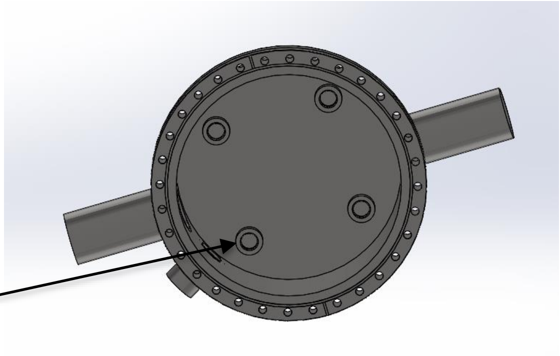
Design Idea for Simulation

Full Assembly

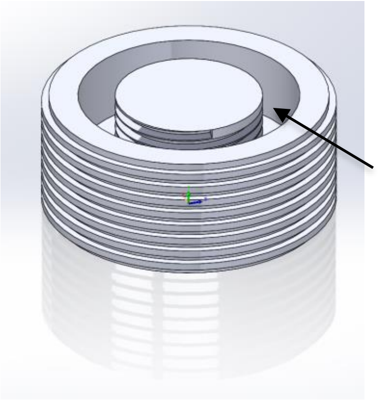




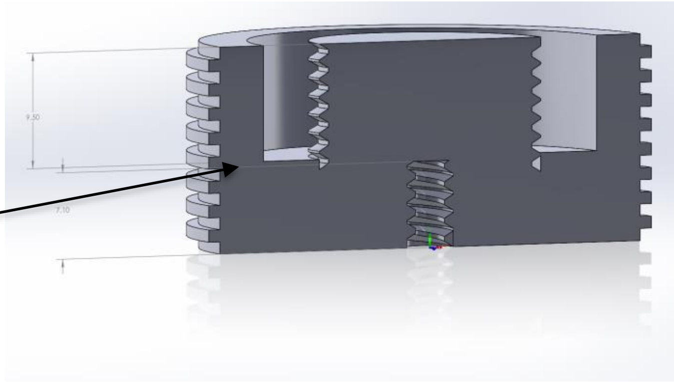
Tank and Ceramics



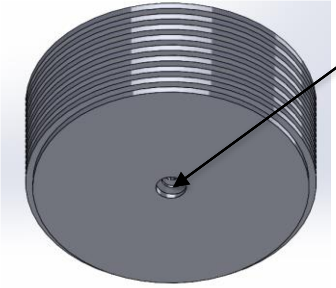
Built-in M20 knut



9.5 mm M20 thread
(tank-side)

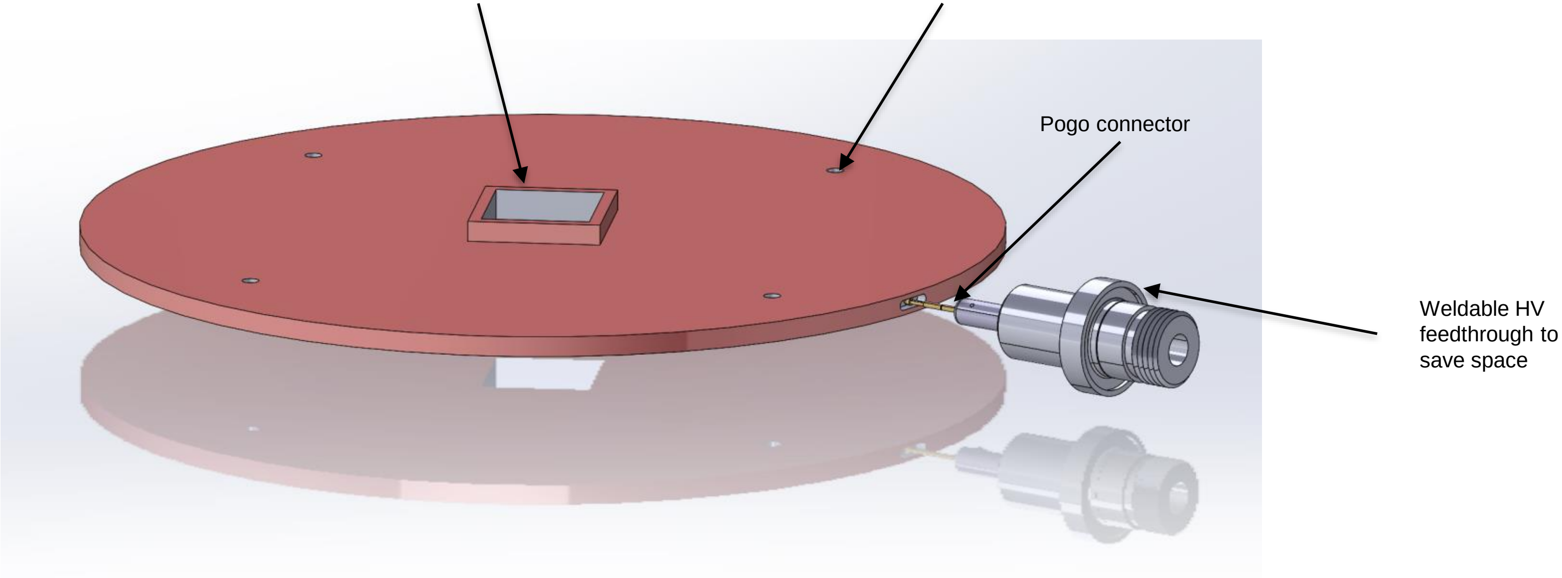


17 mm height

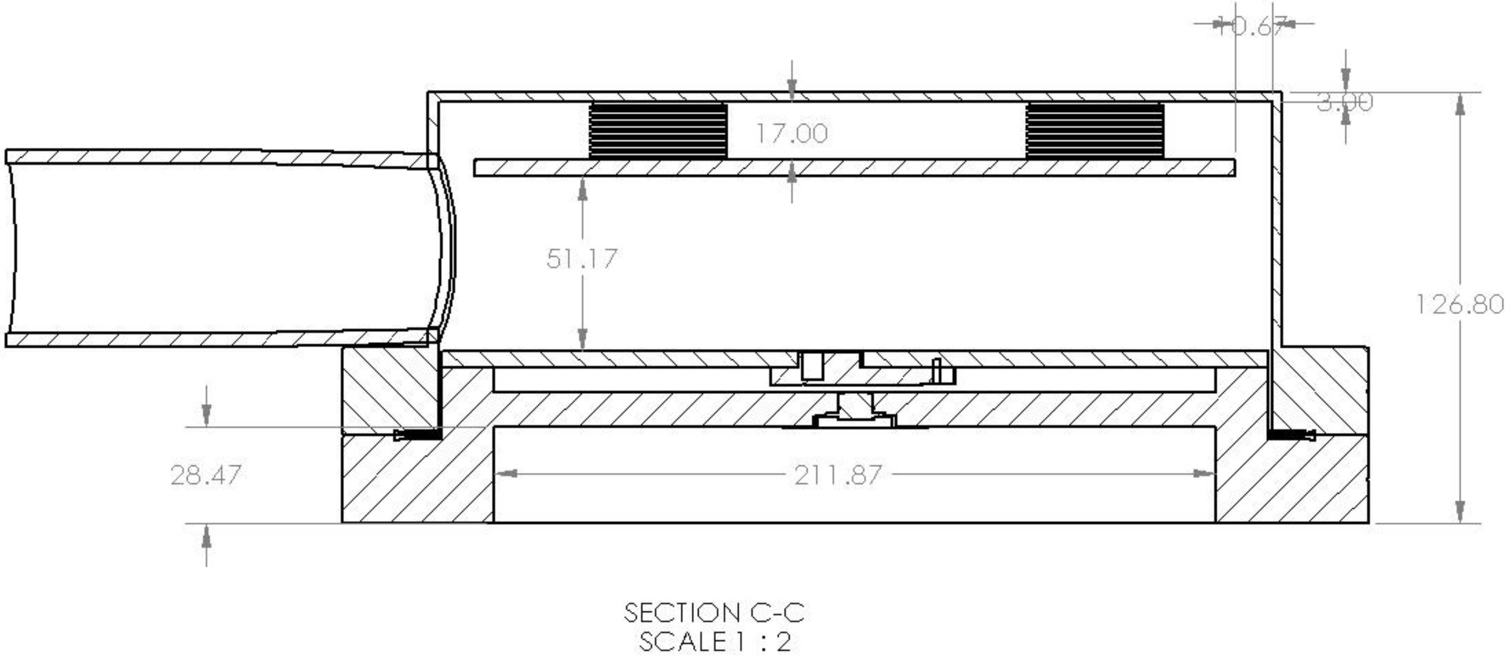


7 mm M4 thread
(cathode-side)

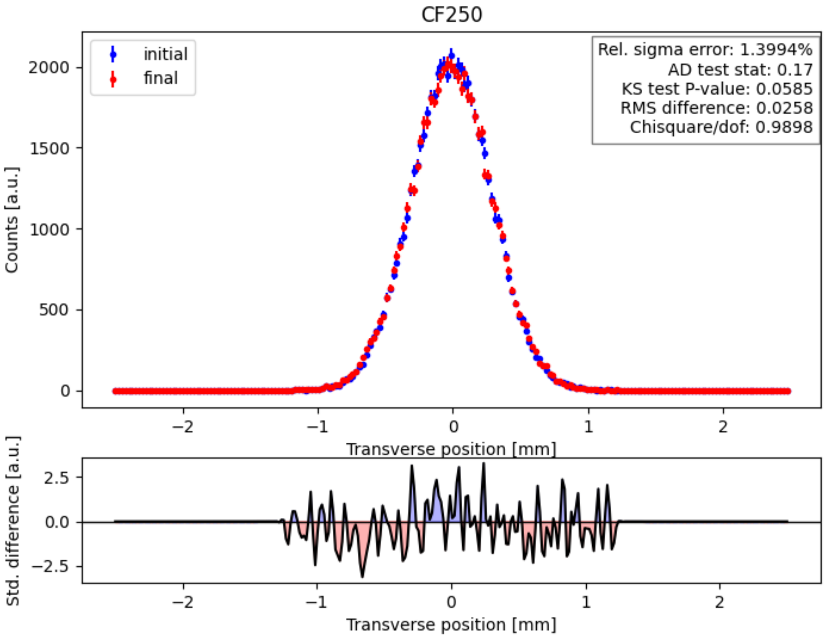
HV Feedthrough and Cathode



Dimensions



Conceptual Design Simulation Results



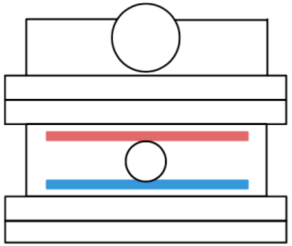
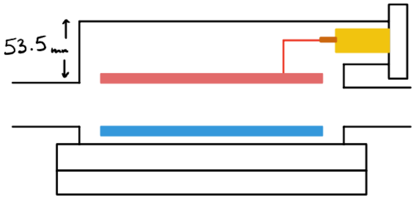
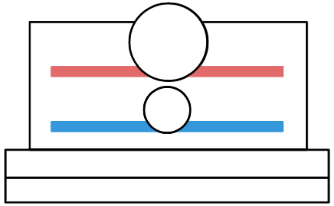
- Simulated with **0.7 T uniform magnetic field**
- Used full CAD model of current conceptual design idea
- Assumed **-30 kV** HV

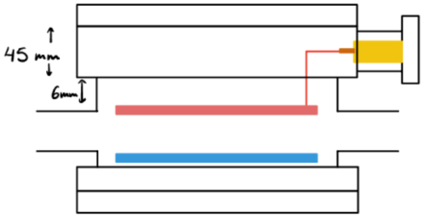
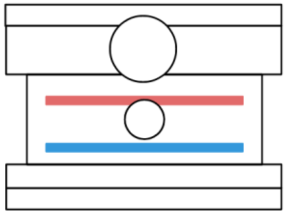
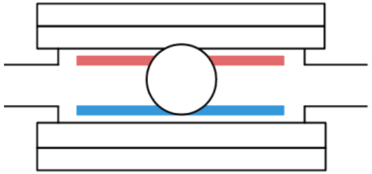
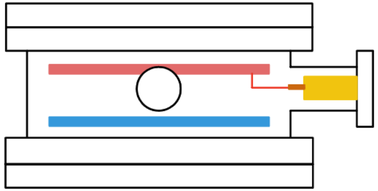
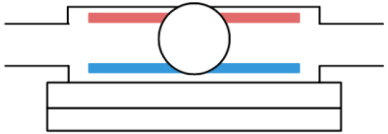
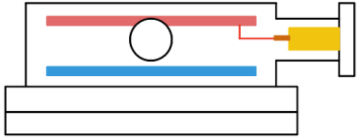
Appendix

Standard Flanges

Name	Thickness (mm)	Flange OD (mm)	Screws
CF63	17.3	131.5	M8
CF75	19,1	117.5	M8
CF100	19.8	151.6	M8
CF125	21.3	171.5	M8
CF150/160	22.4	202.4	M8
CF200	24.6	253.2	M8
CF250	25.9	304.0	M8
CF275	28.4	336.6	M10
CF300	28.5	368.3	M10

HV Feedthrough Design Ideas

Name	Side View	Front View	Height
1a – Elbow HV			$100 + 4\Delta y_{flange} \approx 204\ mm$
1b – Elbow HV			$110 + 2\Delta y_{flange} \approx 162\ mm$

Name	Side View	Front View	Height
2 – In-Flange HV			$107 + 3\Delta y_{flange} \approx 185\ mm$
3a – Side HV			$62 + 4\Delta y_{flange} \approx 166\ mm$
3b – Side HV			$70 + 2\Delta y_{flange} \approx 122\ mm$

Recommendation

- 3b is best case, but will likely have impedance issues
- 1b is second best case, but will likely not fit inside magnet
- Simulate impedance for 1b and 3b
- Investigate impedance mitigation for 3b
- Inquire about 4 cm increase in magnet size for 1b