LHC-BGI:
Design with 4DPhoton Timepix4 Mount

Clara Fleisig

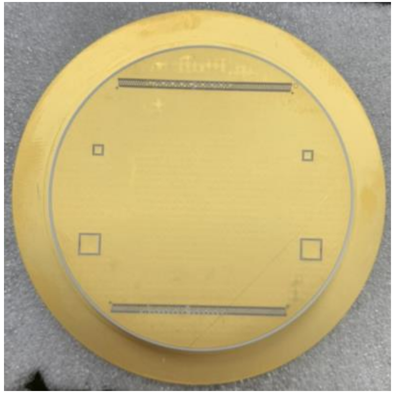
HL-LHC BGI Meeting – 24th January 2024

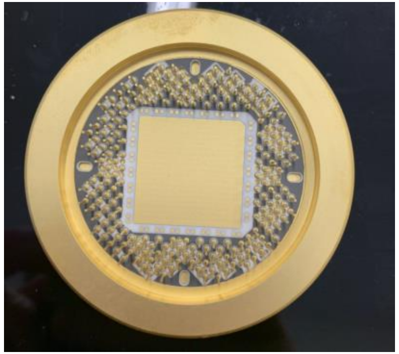
Objectives for 4DPhoton Based Design

- **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)





Conceptual Design Considerations

Goal #1. Provides measurements with < 5% uncertainty (consider beam size contribution to emittance uncertainty, and beam position)

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

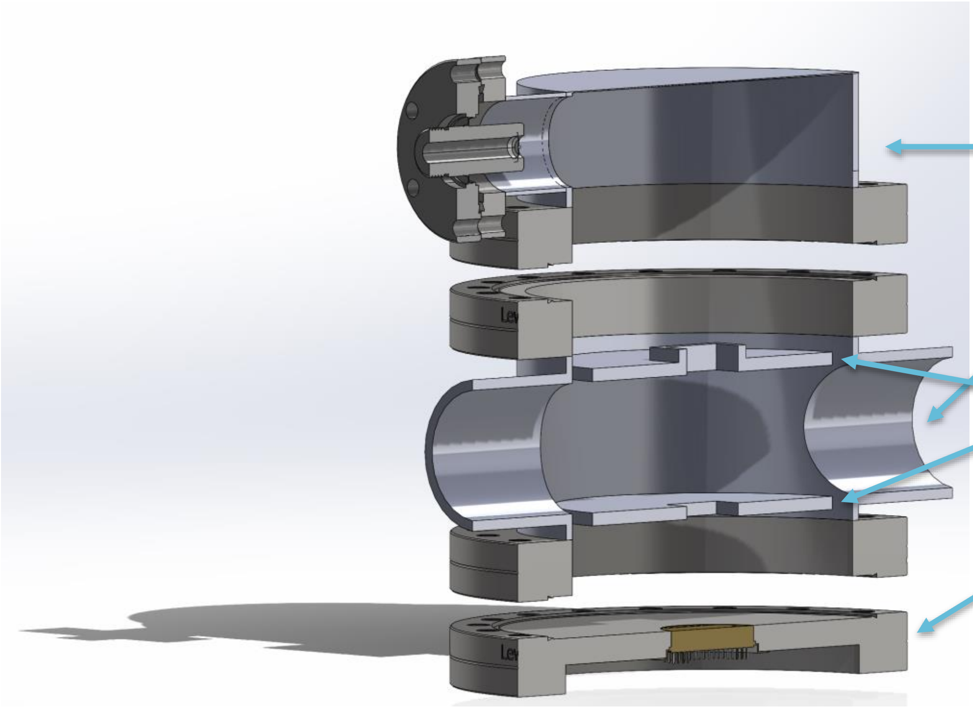
Design Considerations	Pre-Build Testing	Verification
• Increase electric field so electron arrivals from one bunch do not overlap with those from the next bunch	• Calculate $t_{drift} = \sqrt{\frac{2xm}{qE}} \ll 25\ ns$	• Compare bunch-by-bunch measurements with other instruments

Goal #5. Increase event rate

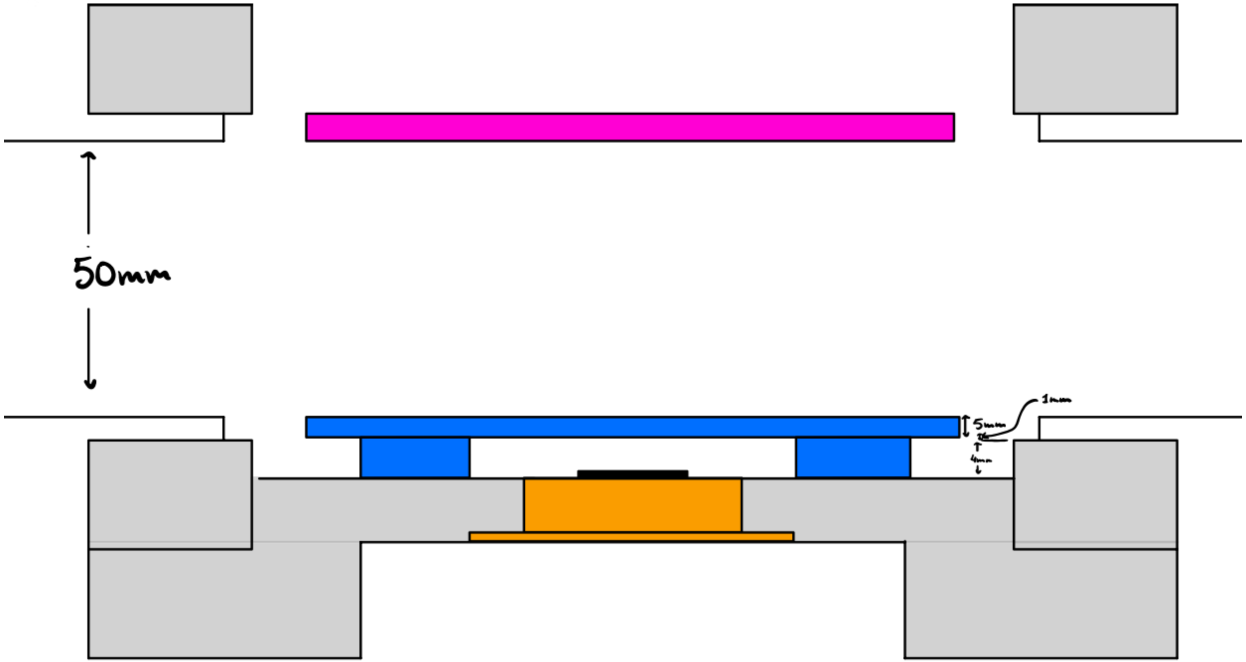
Design Considerations	Pre-Build Testing	Verification
• High electric field integrated over ionised electron path length • Thin entrance window if necessary	• Compare electric field with PS and SPS instruments to predict event rate	• Measurement with < 5% uncertainties integrating over period where beam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

Design Ideas

Design Concept



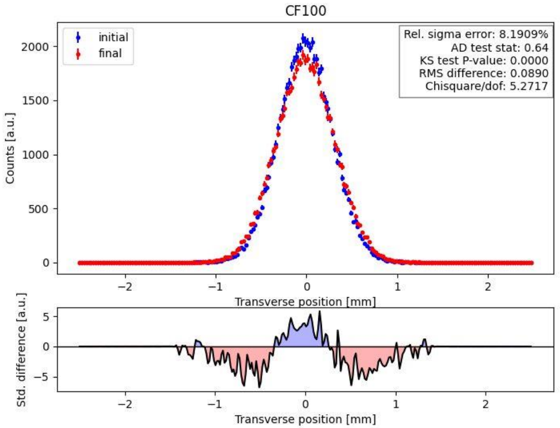
TPX4 Flange

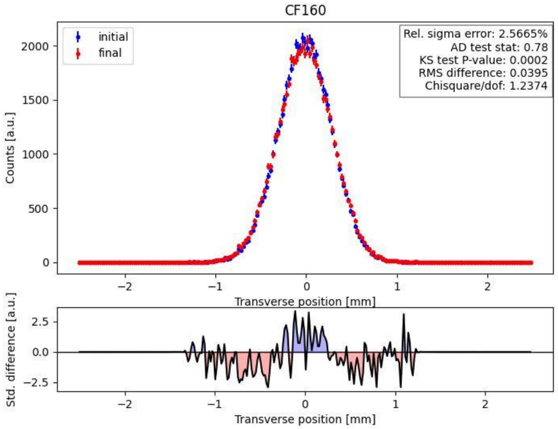


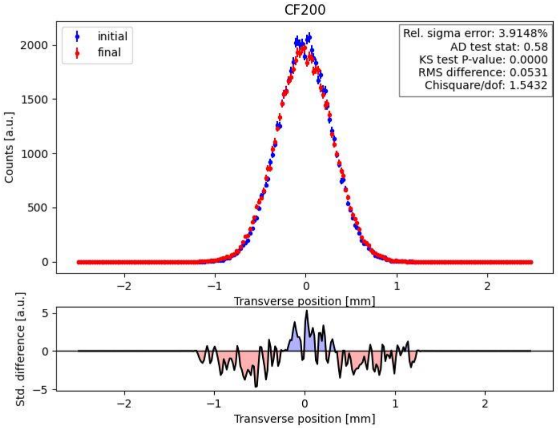
- Minimize distance between TPX4 and flange
- Potentially attach electrode to the tank instead of the flange
- Allow easy replacement of TPX4

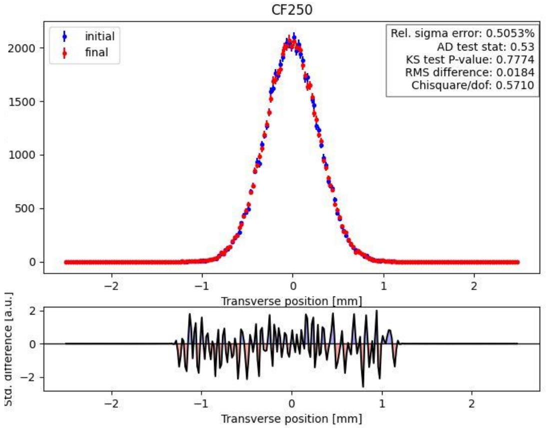
Choosing Flange Sizes and Electrodes

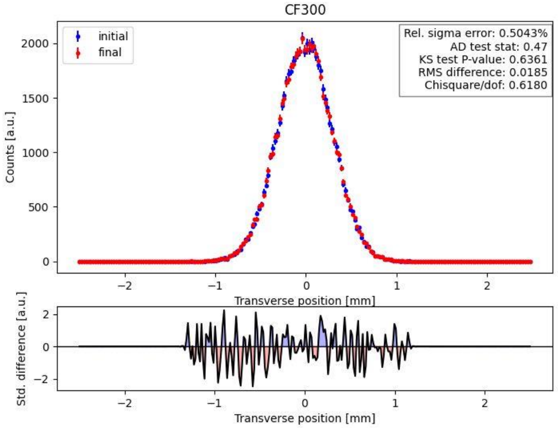
Varying Flange Size











Varying Flange Size Recommendations

Other Considerations

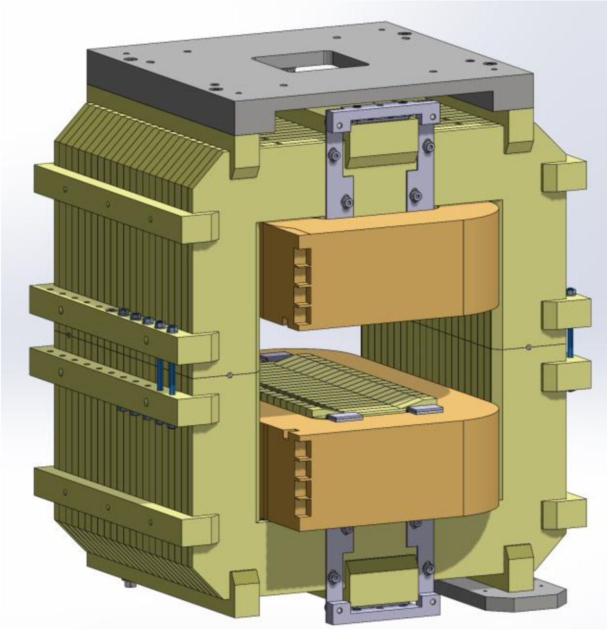
- > CF250 require M10 instead of M8 screws

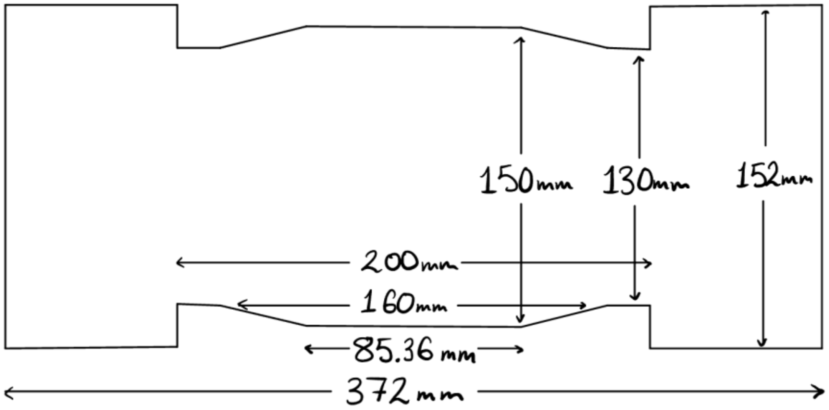
Recommendation

- **Recommend using CF250**, given current information
- Consider investigating electrode geometries
- Must simulate with magnetic field CST file

Considering Mechanical Constraints

Mechanical Constraints from Magnet



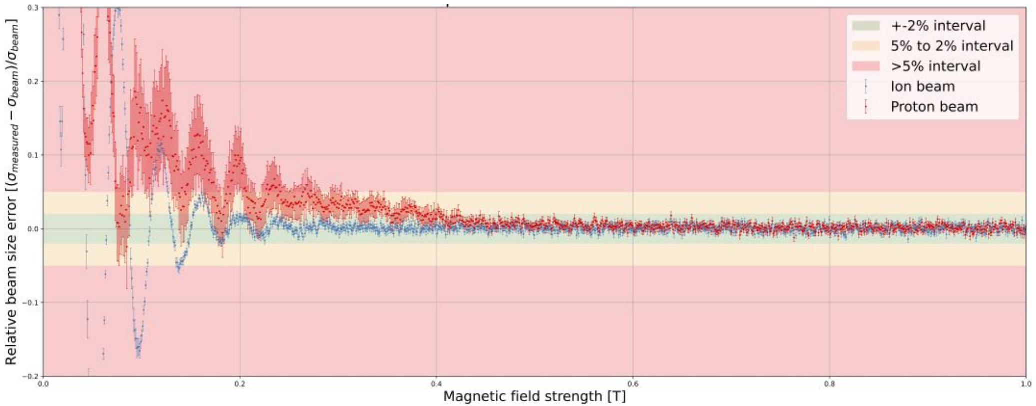


$$(\mathrm{mm})\ \Delta y = \begin{cases} 150 & if\ \Delta x \in (0, 85.36) \\ 150 - \dfrac{\Delta x - 85.35}{3.732} & , if\ \Delta x \in (85.36, 160) \\ 130, & if\ \Delta x \in (85.36, 372) \end{cases}$$

All designs with flange sizes **> CF100** only have **130mm** of vertical space

Potentially Increasing Magnet Size

Simulation from Swann:



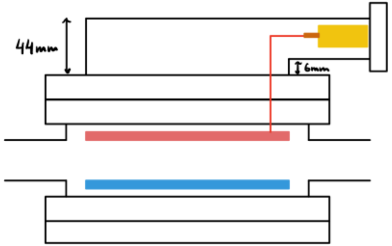
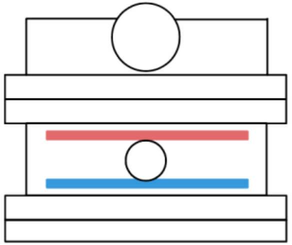
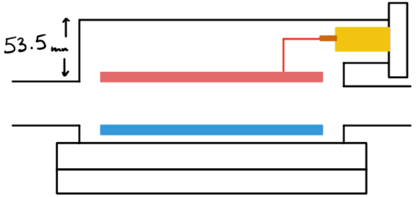
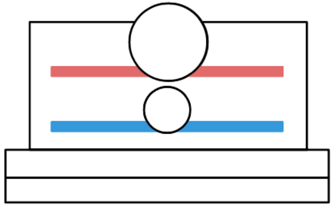
Our Magnet Model:

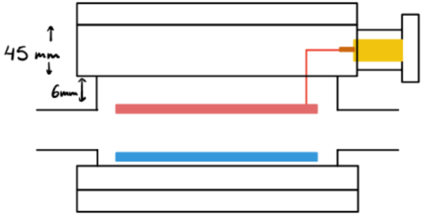
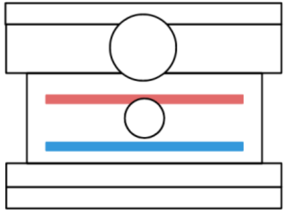
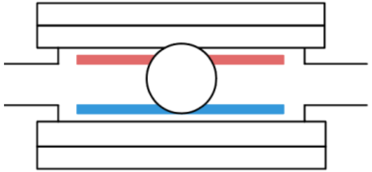
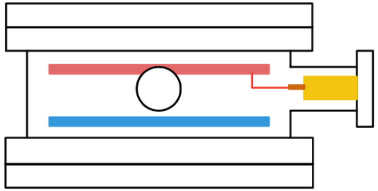
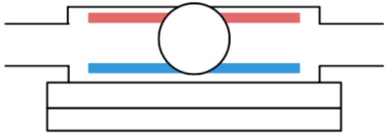
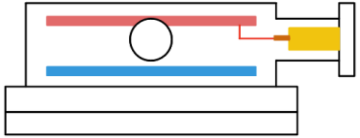
$$\vec{B} = \frac{\mu_0 I R^2}{2} \left(\frac{1}{(R^2+y^2)^{3/2}} + \frac{1}{(R^2+(d-y)^2)^{3/2}} \right) \hat{y}$$

$$\overrightarrow{B_{centre}} = \frac{\mu_0 I R^2}{(R^2 + \frac{d^2}{4})^{3/2}}$$

Conclusion: We can likely increase magnet size by ~20 mm

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

Next Steps

Next Steps

Decisions to be made

1. High voltage feedthrough approach
2. Is the magnet sufficient? What changes should we request?
3. How to hold/secure electrodes

Simulations to be done

1. Beam near the edges of Timepix4 detector
2. Design and simulate ion trap
3. Simulations for tilt tolerances
4. Simulation with final detailed mechanical design

Other

- Talk to magnet group about increasing magnet size

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

Mechanical Constraints with Option 1a

Possible flanges that could be used instead of CF160: **CF63 – CF300**

Estimates include:

- 10 mm for electronics
- 50 mm for LHC beam pipe
- 6x3 mm for bolts
- 44 mm for HV feedthrough

Estimates do **not** include:

- Tolerances
- 15.5 mm for HV feedthrough flange top-edge

Flange Size	Δy-flange	Δy-design	Δy-magnet
CF63	17.3 mm	192 mm	142 mm
CF100	19.8 mm	202 mm	132 mm
CF160	22.4 mm	212 mm	130 mm
CF200	24.6 mm	220 mm	130 mm
CF300	28.5 mm	236 mm	130 mm

Conclusion: ***Will need to expand magnet yoke by 5 to 10 cm***