

## HL-LHC-BGI: Investigating Beam Offset & Time of Flight Clara Fleisig (SY-BI-XEI)



HL-LHC BGI Analysis – 25th March, 2024

#### **New Designs Under Consideration**



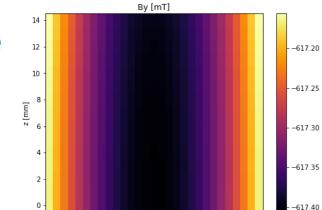
# Rolls-Royce Doublet Magnet

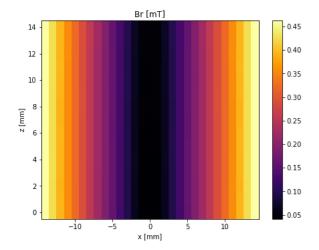
•  $B_y = 617.32 \pm 0.08 \text{ mT}$ 

(0.01% error)

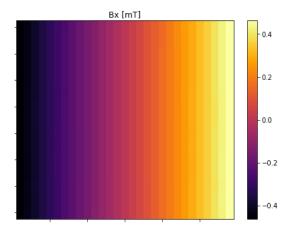
•  $B_r = 0.2 \pm 0.1 \text{ mT} \left(\frac{B_r}{B_y} \times 100\% = 0.04\%\right)$ 

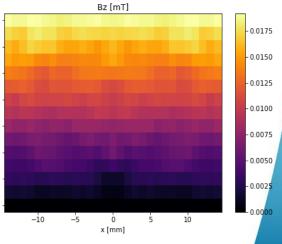
CERN





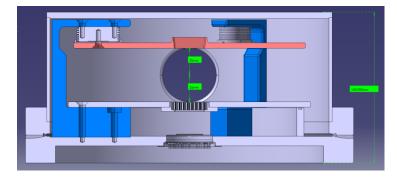


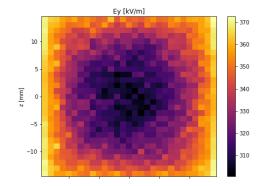


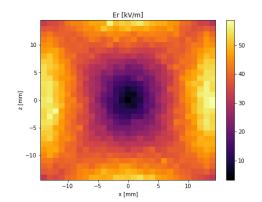


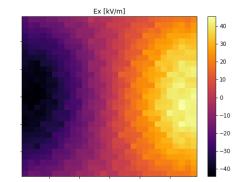
### Latest Iteration of the CF250 Design

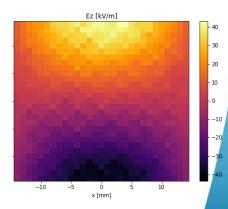
- $E_y = 340 \pm 20 \frac{\text{kV}}{\text{m}}$ (5.3% error)
- $E_r = 40 \pm 10 \frac{\text{kV}}{\text{m}}$  $\left(\frac{E_r}{E_y} \times 100\% = 11\%\right)$













#### **HL-LHC BGI Analysis**

#### Clara Fleisig, 25 Mar 2024

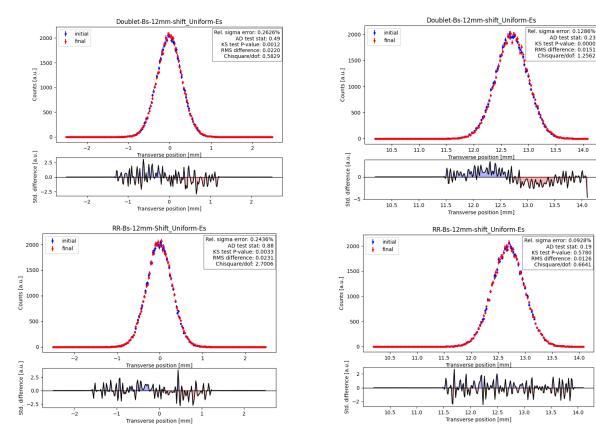
4

### Consider $\Delta y_{e^-}\sim 25~mm$



**HL-LHC BGI Analysis** 

#### **Uniform Electric Field with 12mm Es-Bs Offset**



# Doublet Magnet

Triplet Magnet

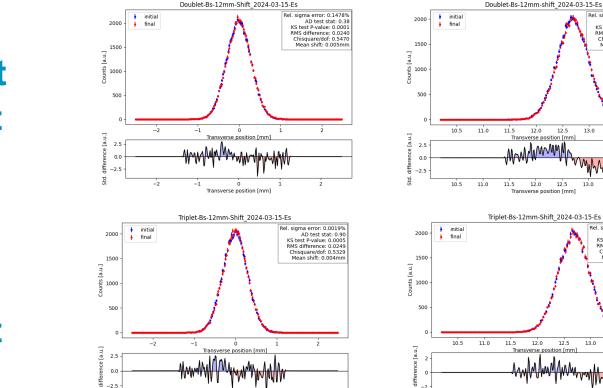


HL-LHC BGI Analysis

#### Latest CF250 Design with 12mm Es-Bs Offset

Std. d

10.5 11.0 11.5 12.0 12.5



# Doublet Magnet

Triplet Magnet

std.

-2

-1

0 Transverse position [mm]



**HL-LHC BGI Analysis** 

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Clara Fleisig, 25 Mar 2024

Transverse position [mm]

13.0 13.5 14.0

Rel. sigma error: 0.2827%

KS test P-value: 0.0000

RMS difference: 0.0174

Chisguare/dof: 1.7935

13.5 14.0

13.5 14.0

Rel. sigma error: 0.2215%

KS test P-value: 0.0015

RMS difference: 0.0113 Chisquare/dof: 0.9341

Mean shift: 0.004mm

13.5 14.0

AD test stat: 0.41

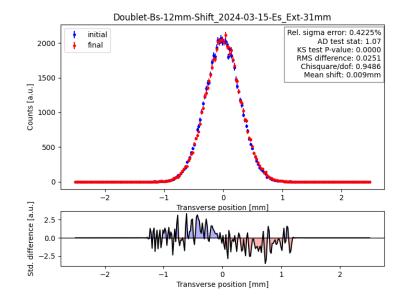
Mean shift: 0.014mm

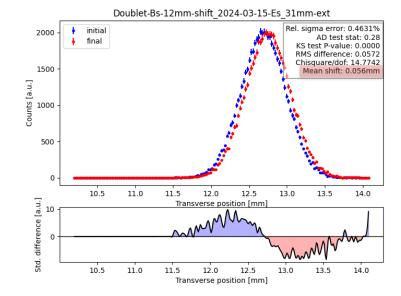
AD test stat: 0.25

### Consider $\Delta y_{e^-} \sim 56 \text{ mm}$



### **Doublet Magnet with Latest CF250 Design**







## Conclusion

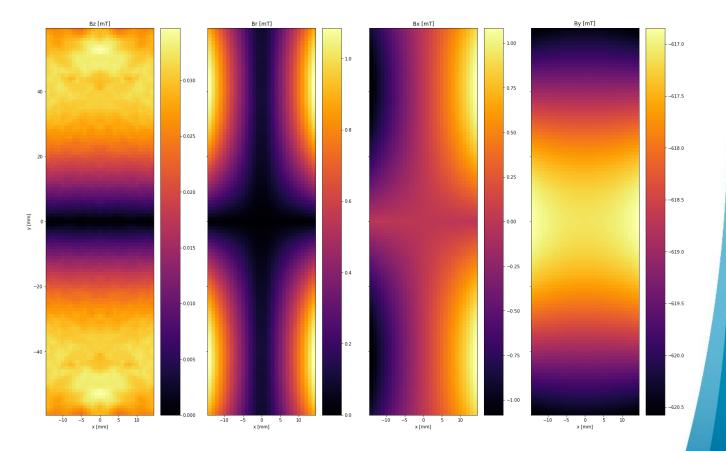
- Triplet magnet performs slightly better than doublet magnet, but all simulations demonstrate <1% relative sigma error</li>
- Shifting effects seen for the doublet magnet when beam is are 12.7mm in the x-direction. These effects are compounded with additional 31 mm gap between the anode and the Timepix3, such that shift is >55um.



# **Appendix**

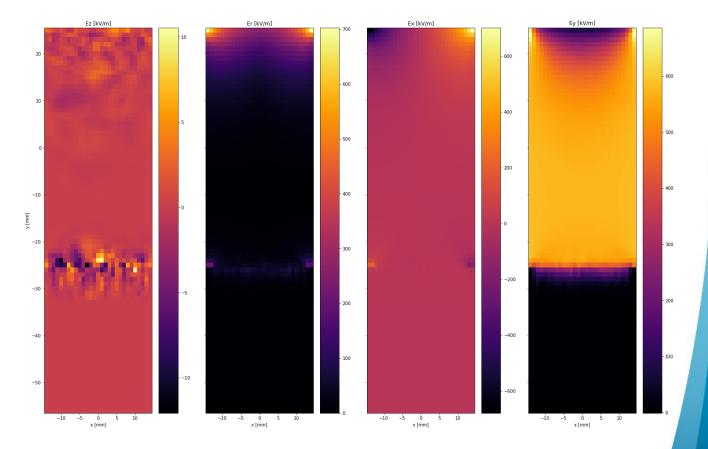


# Rolls-Royce Doublet Magnet





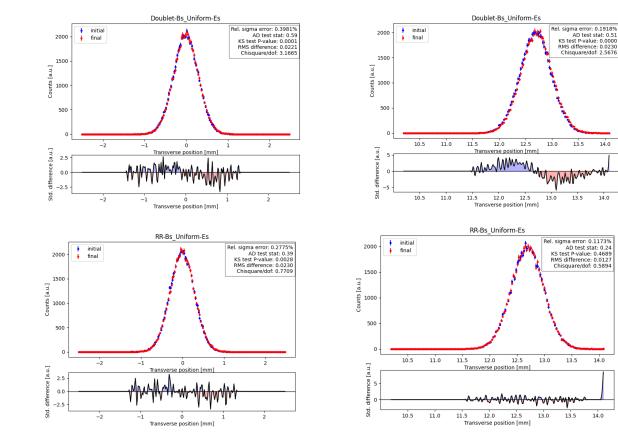
# Latest Iteration of the CF250 Design





**HL-LHC BGI Analysis** 

#### **Uniform Electric Field**



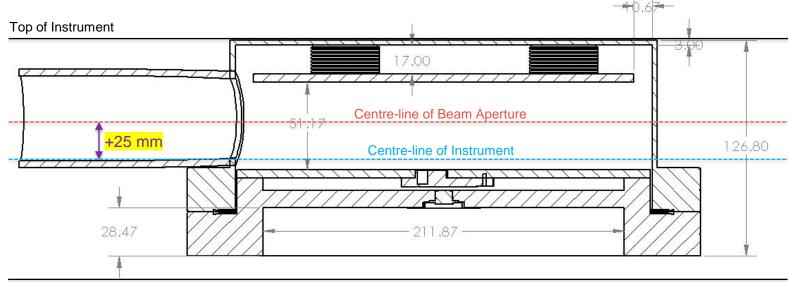
# Doublet Magnet

Triplet Magnet



HL-LHC BGI Analysis

# Aperture-Instrument Offset for Conceptual Design



Bottom of Instrument (accounting for ~15 mm for bolts and wiring)



## **Time of Flight**



**HL-LHC BGI Analysis** 

# **Time of Flight Overview**

- Require < 25 ns spread of time of arrivals (ToAs) per bunch to allow bunch-by-bunch measurements
- Approximate ToA:

Assume negligible space charge and uniform electric and magnetic fields

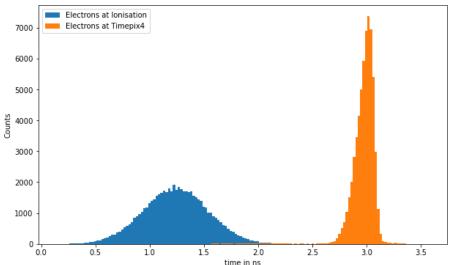
$$y_i = \frac{-qE}{2m} \Delta t^2 - v_y \Delta t \implies \Delta t \sim 1 \ ns$$

• Simulations account for non-uniform electric fields, magnetic fields and space charge effects. They tell us the **spread** of ToAs.



# Time of Flight Evaluation for "Worst Case"

- Simulated with 56mm path length
- Using Doublet magnetic field and latest iteration of the BGI's electric field (30 kV cathode)
- Accounts for off-center beam aperture within magnetic field



**Conclusion:** Spread of electron arrival times is sufficiently small for bunch-by-bunch measurements



#### **Consider Vertically Off-Centre Beams**



# Varying y-position of Beam

- Simulations done beam centered in x, no offset between electric and magnet fields, and triplet magnet
- BSRT estimates beam drifts no more than 1 mm
- Thus, beam should be < 26 mm away from the anode

