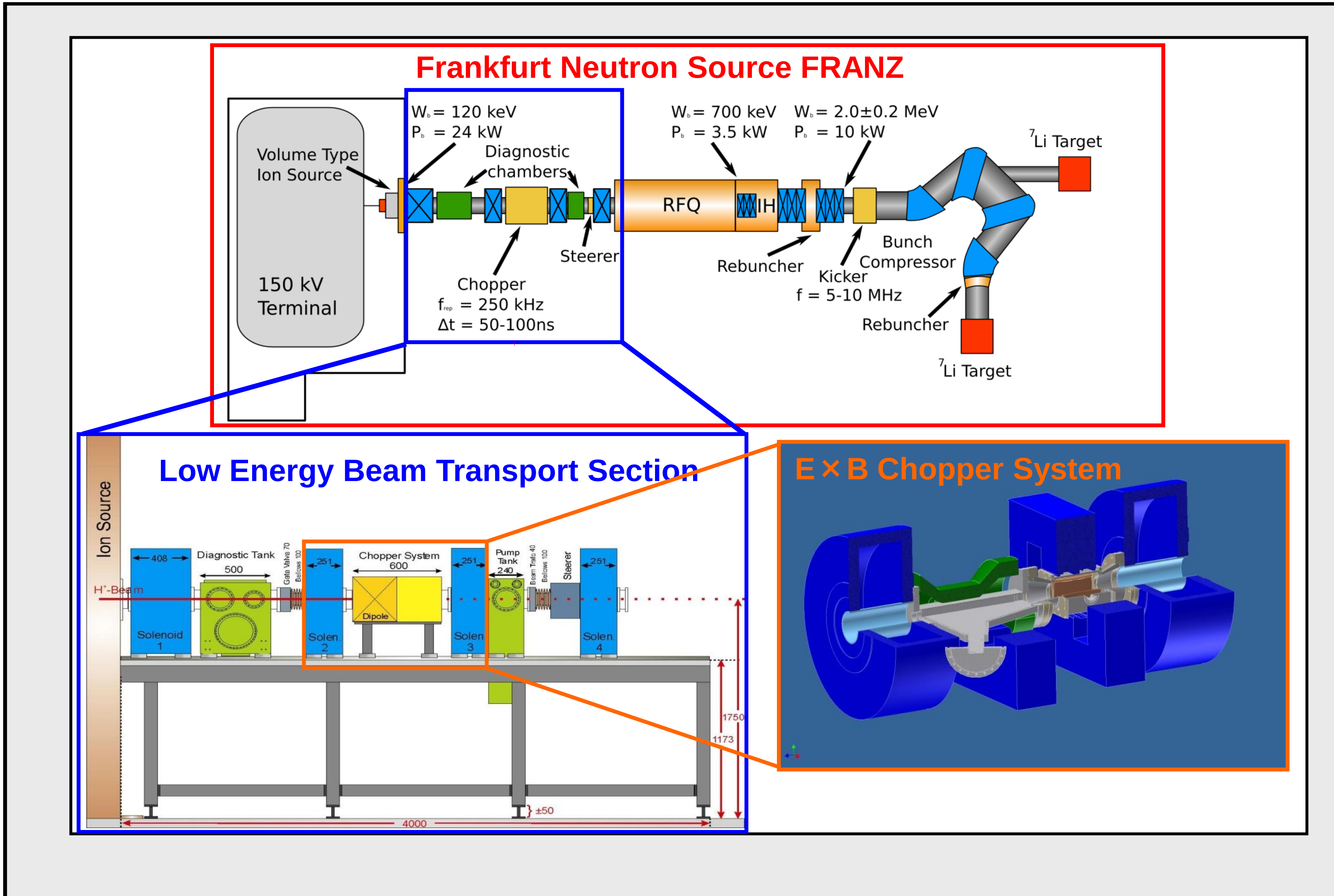
Low Energy Beam Shaping and Transport



2011/03/07

E × B Chopper Development

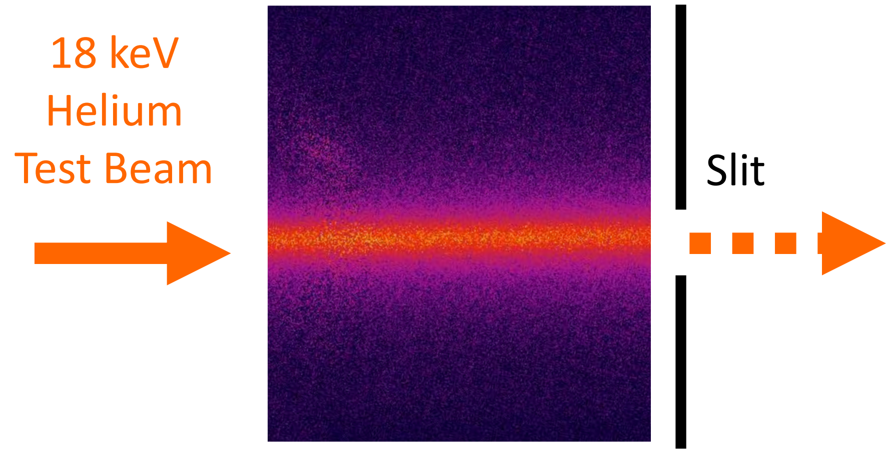
C. Wiesner, L.P. Chau, H. Dinter, M. Droba, M. Lotz, D. Maiberger, O. Meusel, I. Müller, U. Ratzinger

Chopping of High Intensity Beams

Beam Parameters
- I_b = 200 mA
- W_b = 120 keV
- K_b = 2.3e-3

Chopping Parameters
- Pulse Time: 50-150 ns
- Rep. Rate: 250 kHz

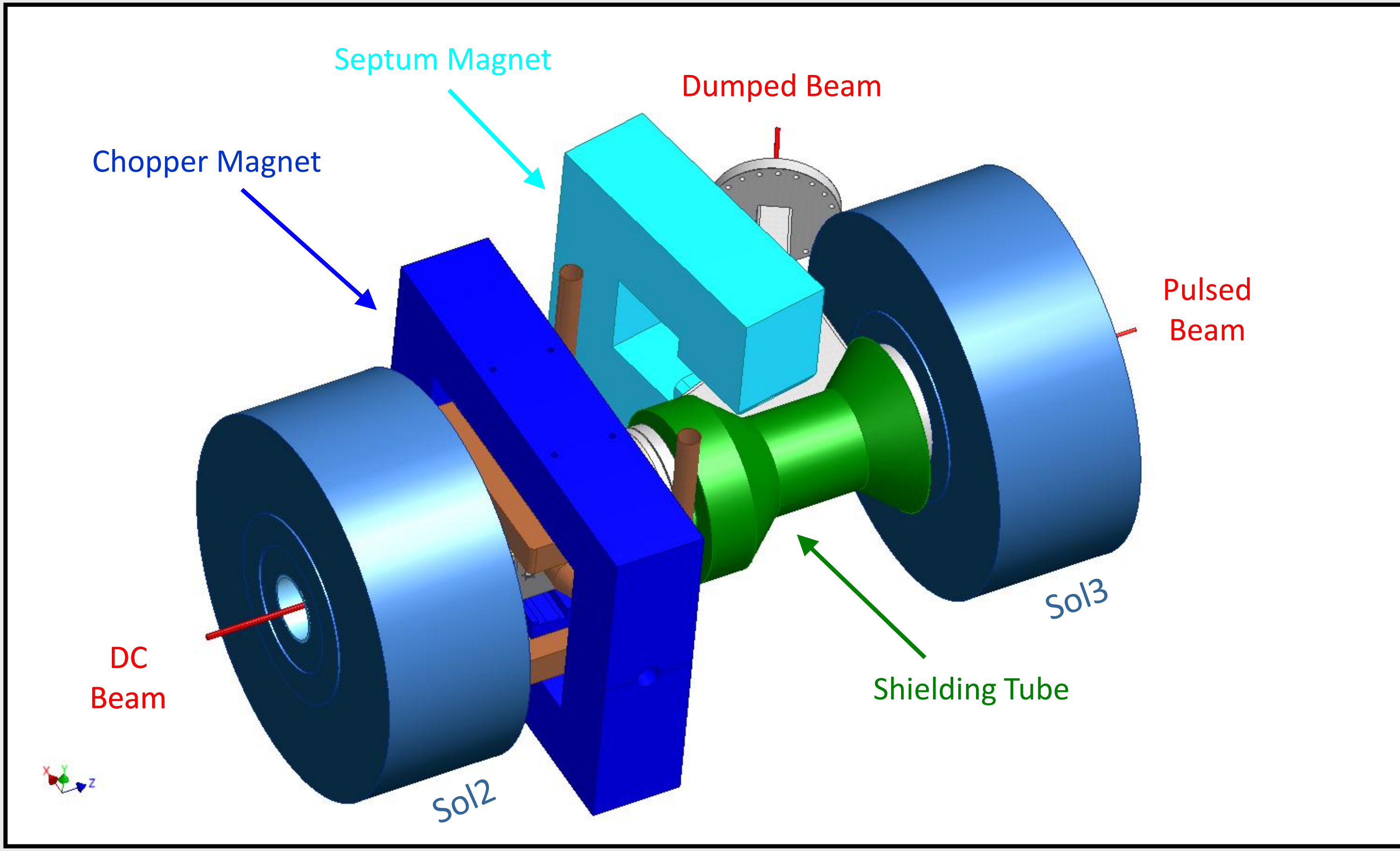
Optical Diagnostics of
Beam Deflection Measurements



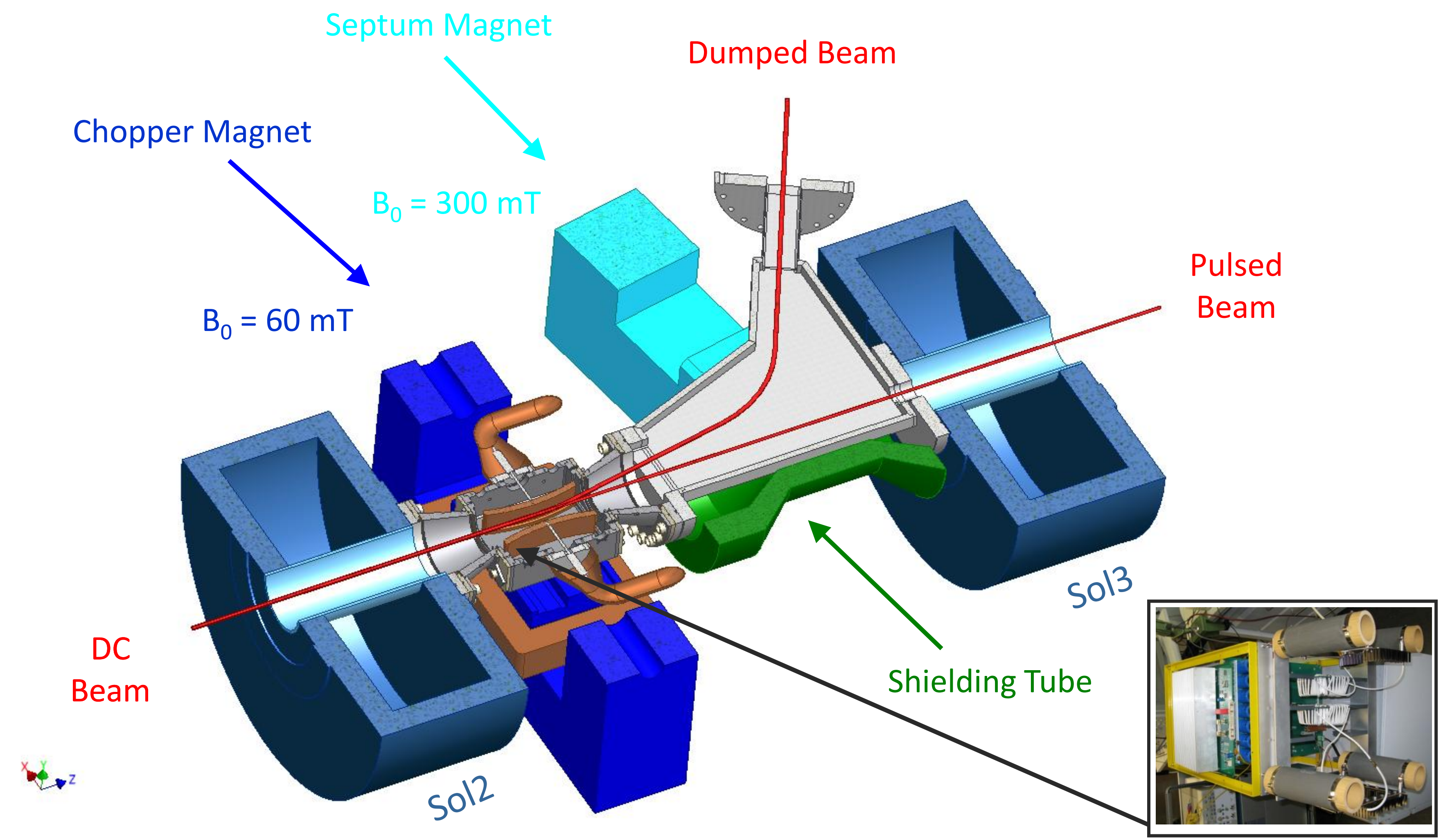
Requirements:

- *Avoiding long drifts.*
- *Minimizing duty factor for electric beam deflection.*
- *Controlled beam dumping outside transport line.*

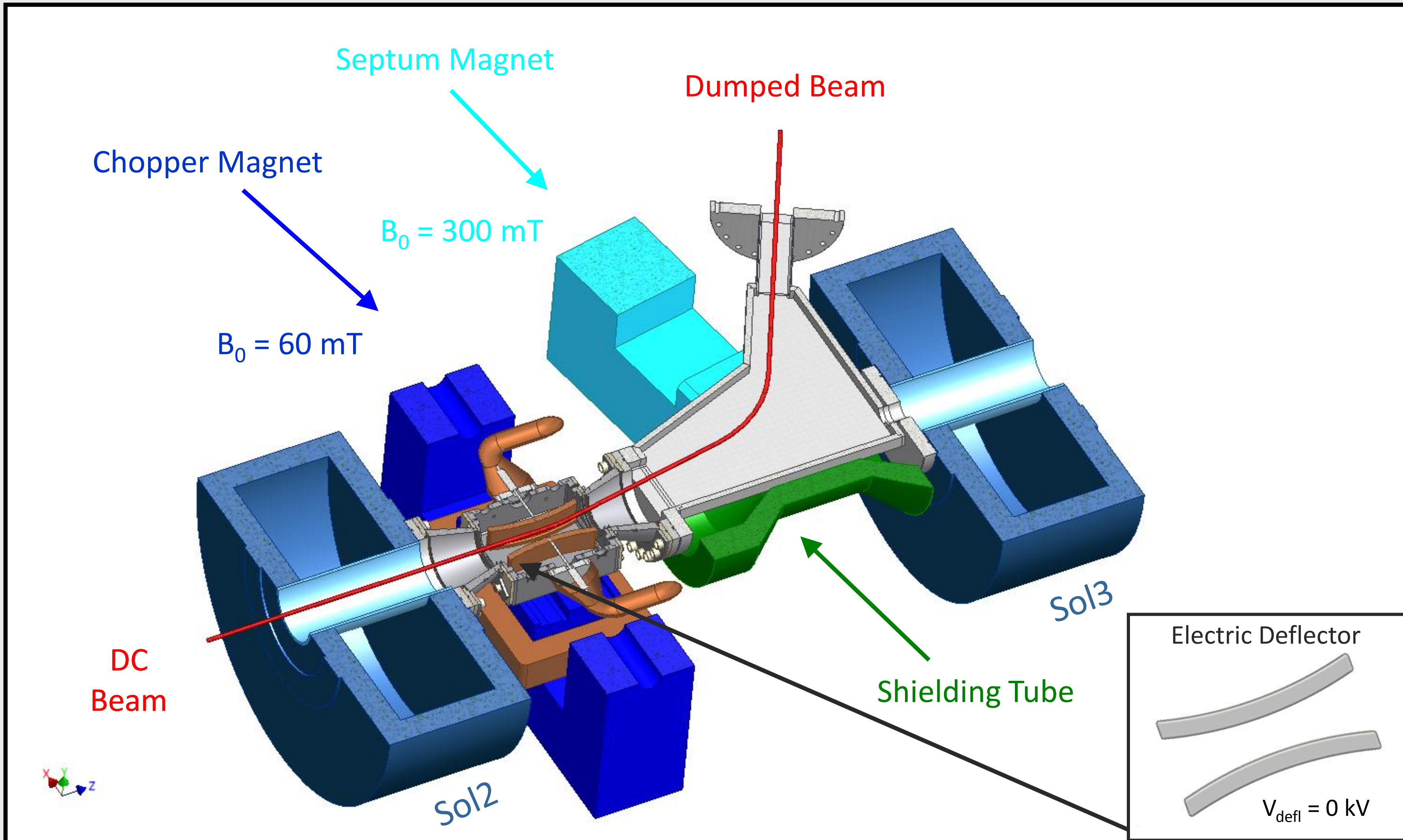
E × B Chopper


Septum Magnet
Dumped Beam
Chopper Magnet
Pulsed Beam
DC Beam
Shielding Tube
Sol3
Sol2

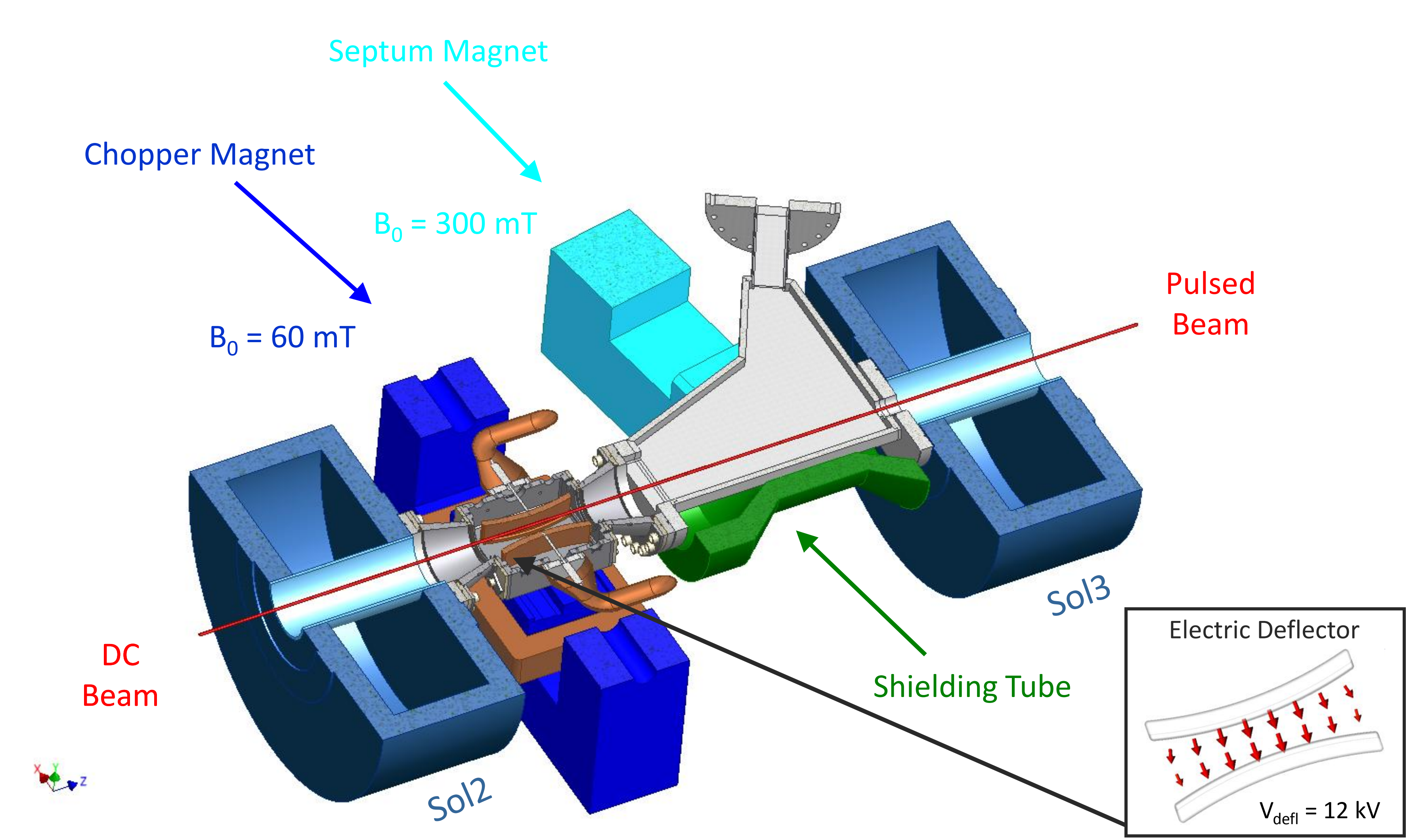
E × B Chopper


Septum Magnet
Dumped Beam
Chopper Magnet
B_0 = 300 mT
Pulsed Beam
B_0 = 60 mT
DC Beam
Shielding Tube
Sol3
Sol2

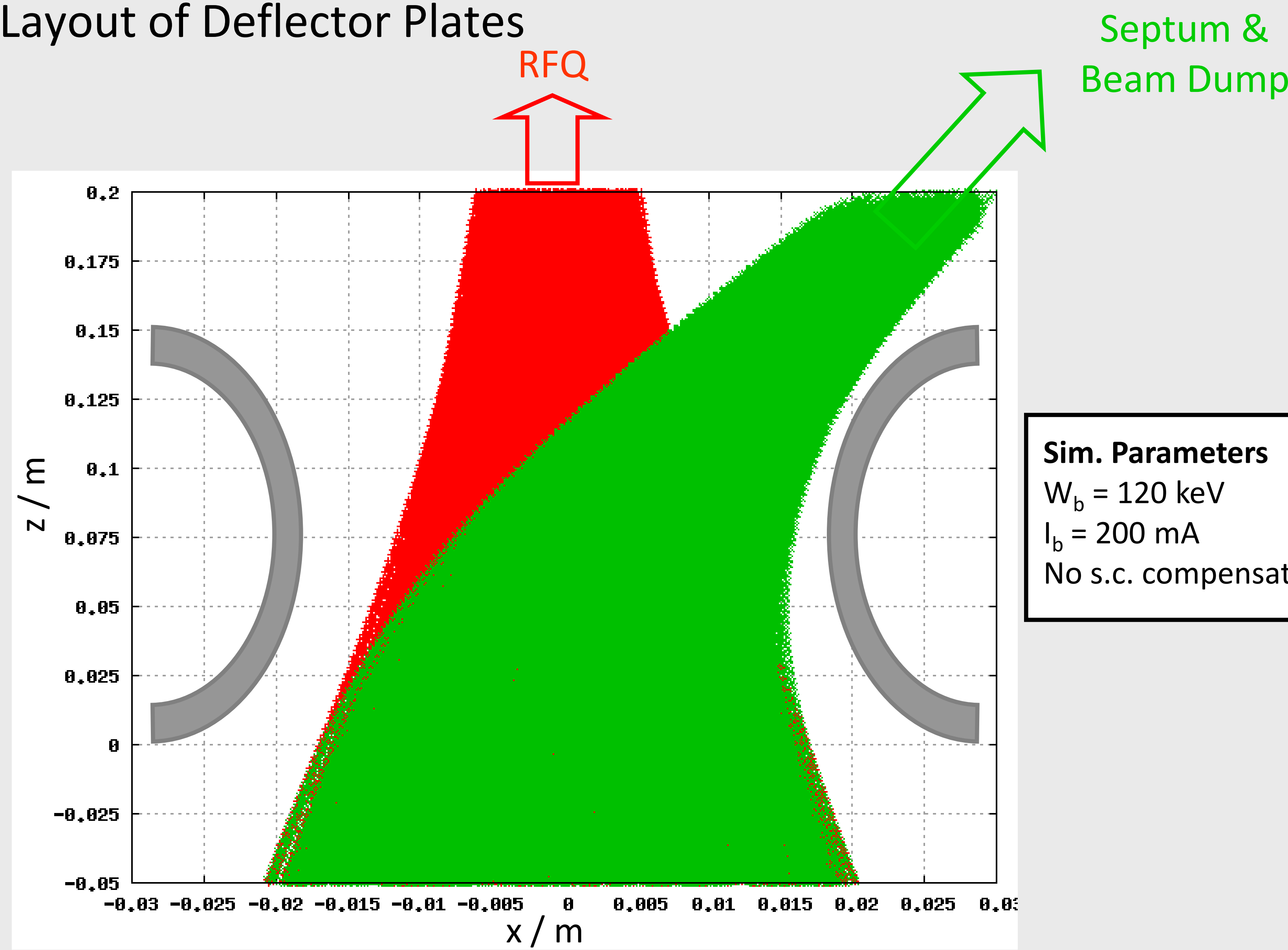
E × B Chopper


Septum Magnet
Dumped Beam
Chopper Magnet
B_0 = 300 mT
B_0 = 60 mT
DC Beam
Shielding Tube
Sol3
Sol2
Electric Deflector
V_{defl} = 0 kV

E × B Chopper

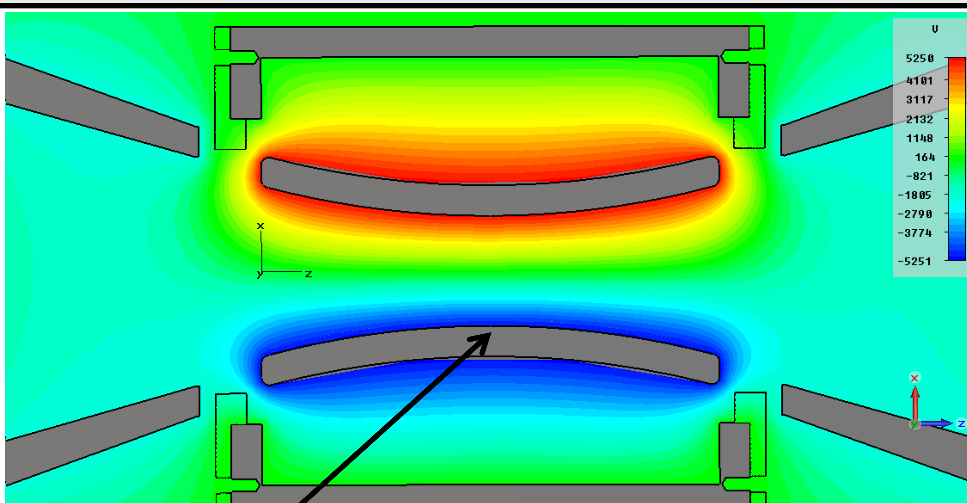

Septum Magnet
Chopper Magnet
B0 = 300 mT
B0 = 60 mT
Pulsed Beam
DC Beam
Sol3
Sol2
Shielding Tube
Electric Deflector
Vdefl = 12 kV

Layout of Deflector Plates

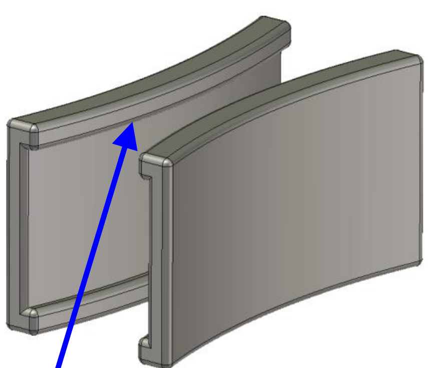


Sim. Parameters
W_b = 120 keV
I_b = 200 mA
No s.c. compensation

Field Optimisation

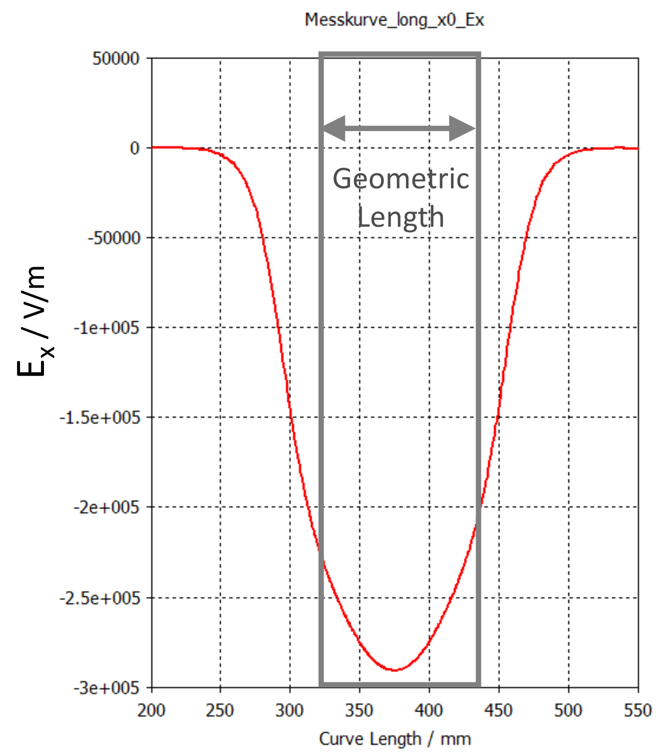


Deflector Plates



Shims for Transverse Field Homogeneity

$V_{defl} = \pm\ 6.0\ \text{kV}$
$= 12.0\ \text{kV}$

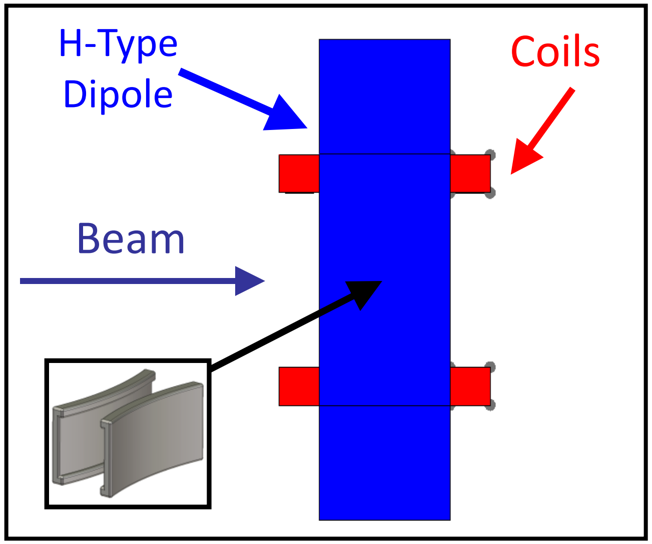


Electric field on-axis

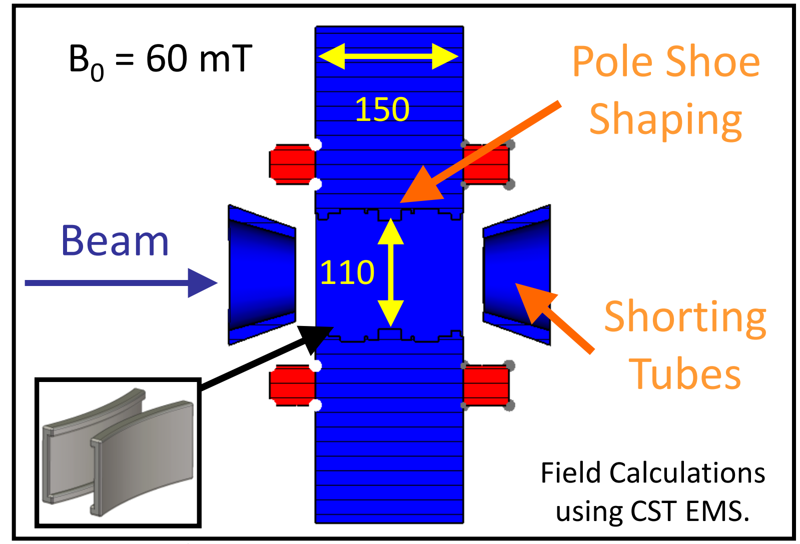
Wien Condition: $$\int q \cdot v_0 \times B_y\, dz = \int q\, E_x\, dz$$

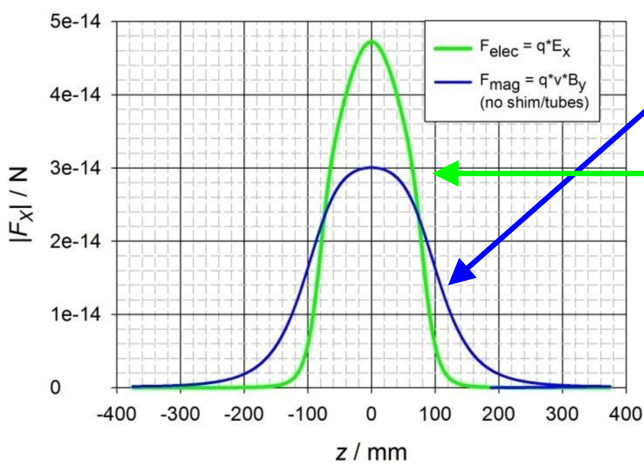
Matching of Deflection Forces

Not Matched Forces



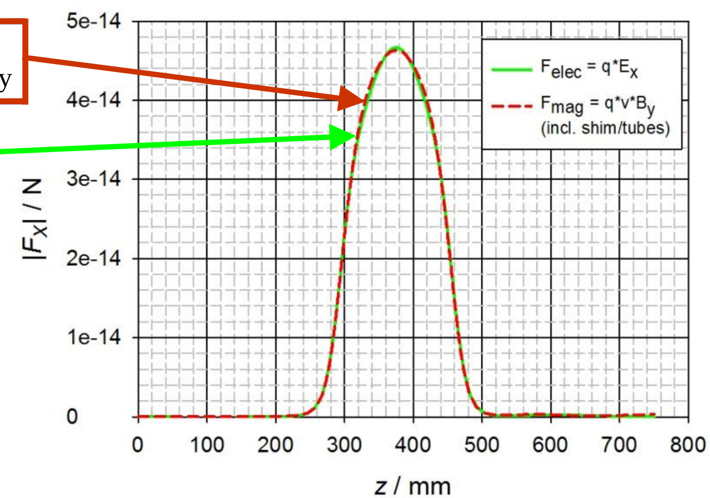
Matched Forces





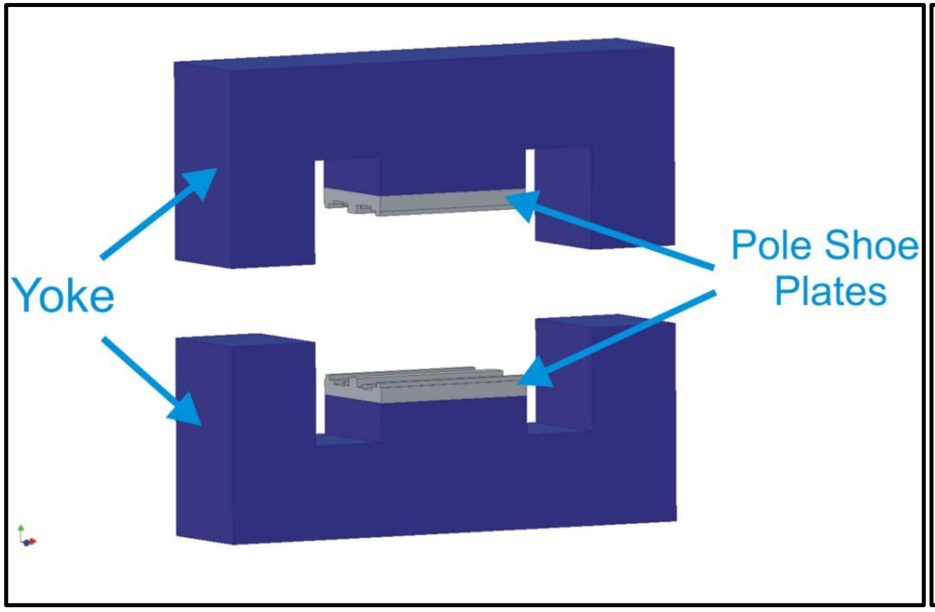
$$F_{mag} = e \cdot v_0 \cdot B_y$$

$$F_{elek} = e \cdot E_x$$

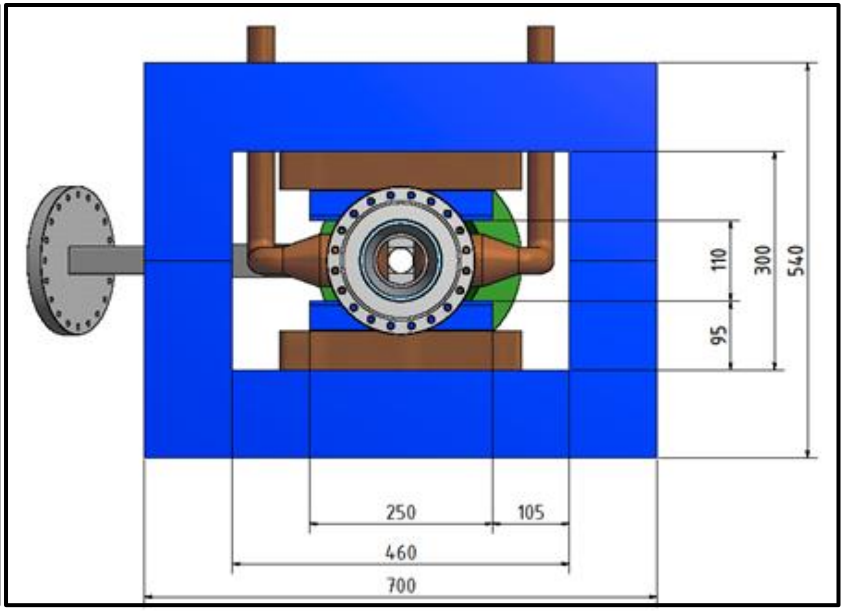


Chopper Magnet

Technical Design



Alterable Pole Shoe Plates required.

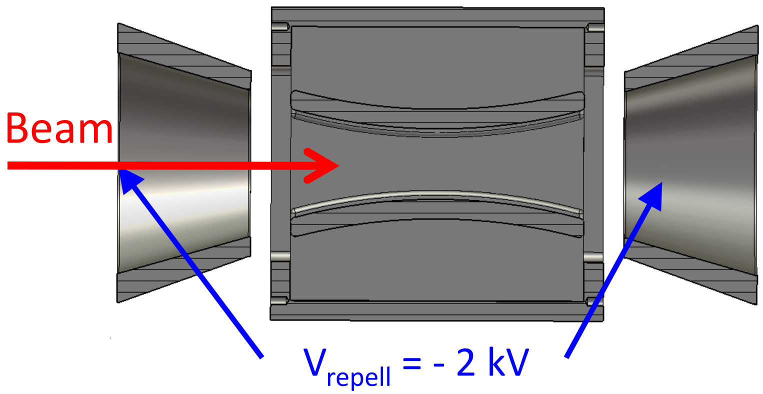


Technical Drawing.

Order has been placed in march 2011.

Repeller Electrodes

Electric Deflection Field:
→ Electron Flux on Deflector Plates
→ Decompensation of Proton Beam



→ Installation of Repeller Electrodes

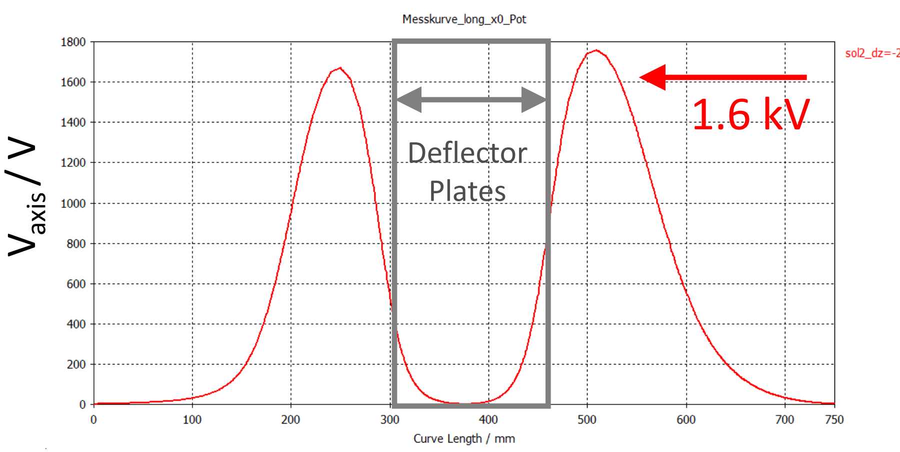
Material: Magnetic Steel

Beam Potential:

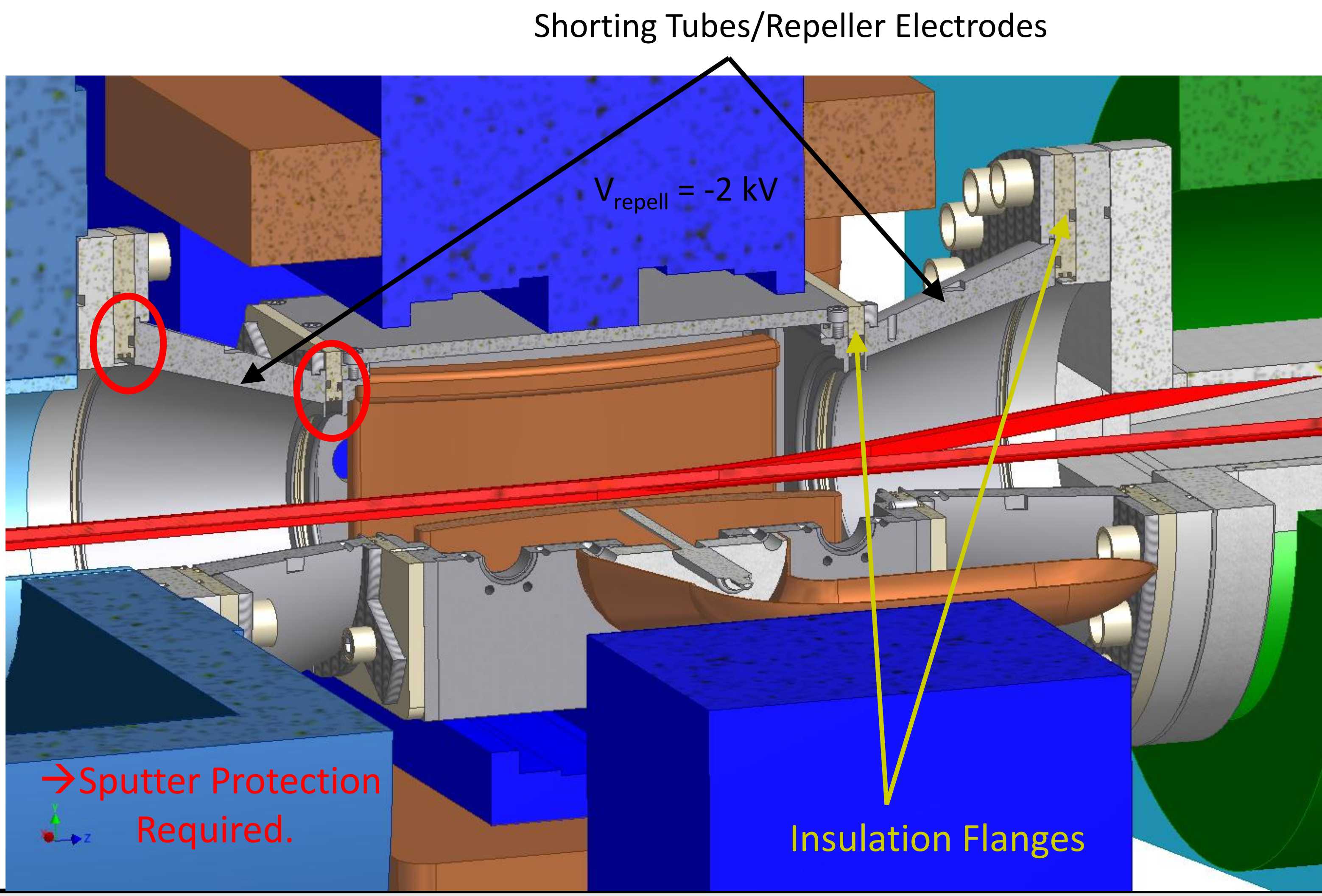
$$\Phi(r) = \frac{I_b}{4\pi \cdot \varepsilon_0 \cdot v_p}\left[1 + 2\ln\left(\frac{r_D}{r_b}\right) - \frac{r^2}{r_b^2}\right]$$

Homogenous Beam, I_b = 200mA, r_b = 10mm →

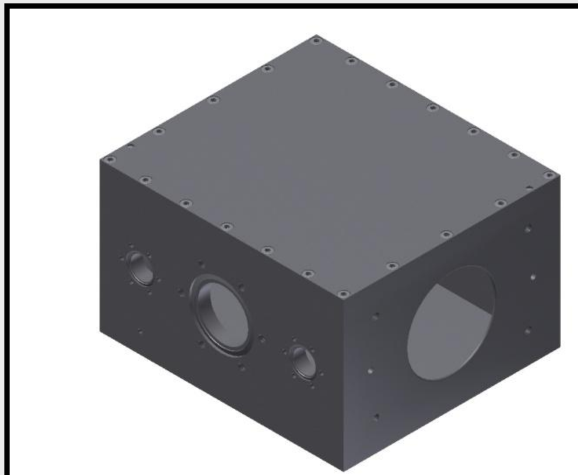
Φ_b = 1.6 kV

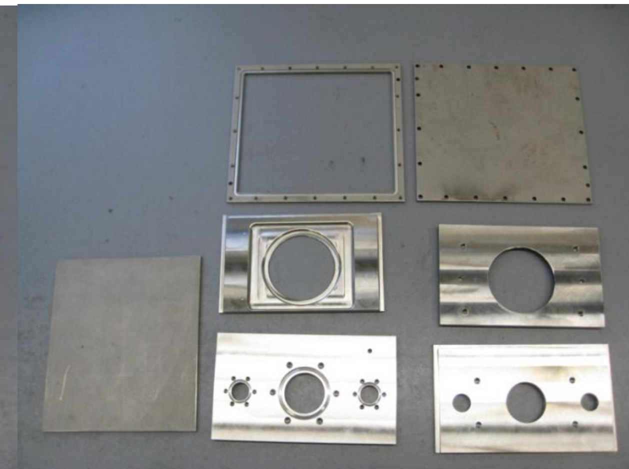


Insulation Flanges

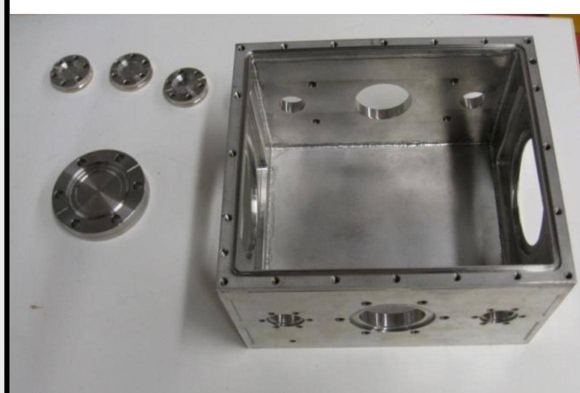


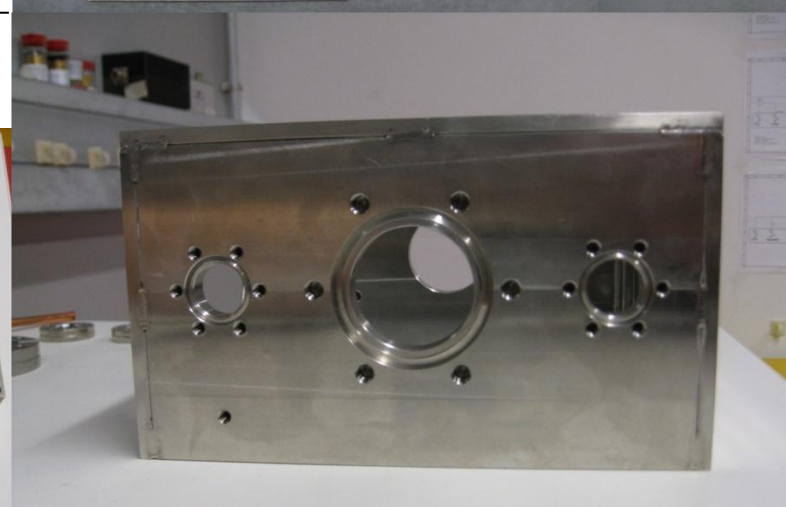
Deflection Chamber: Manufacturing





Material: Steel 1.4435



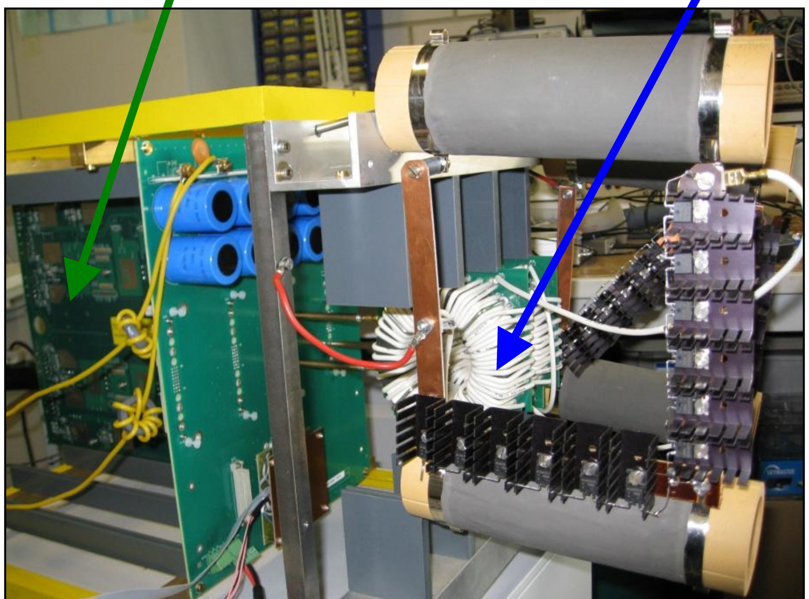


→ Deflector Plates, Mounting, HV Connection

High Voltage Pulse Generator

MOSFETs

Ferrite Cores

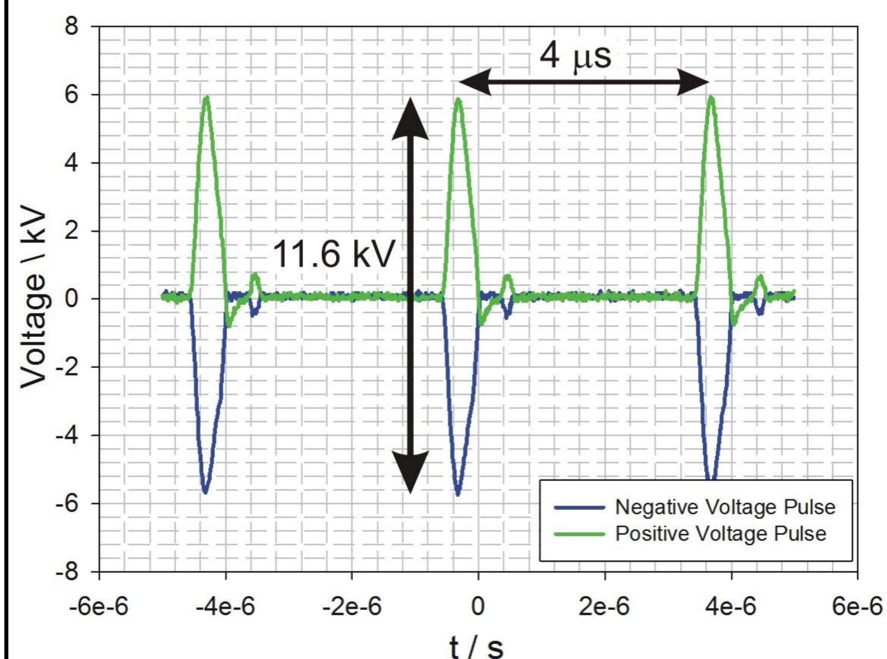


Requirements:

$V_0 = \pm 6.0$ kV

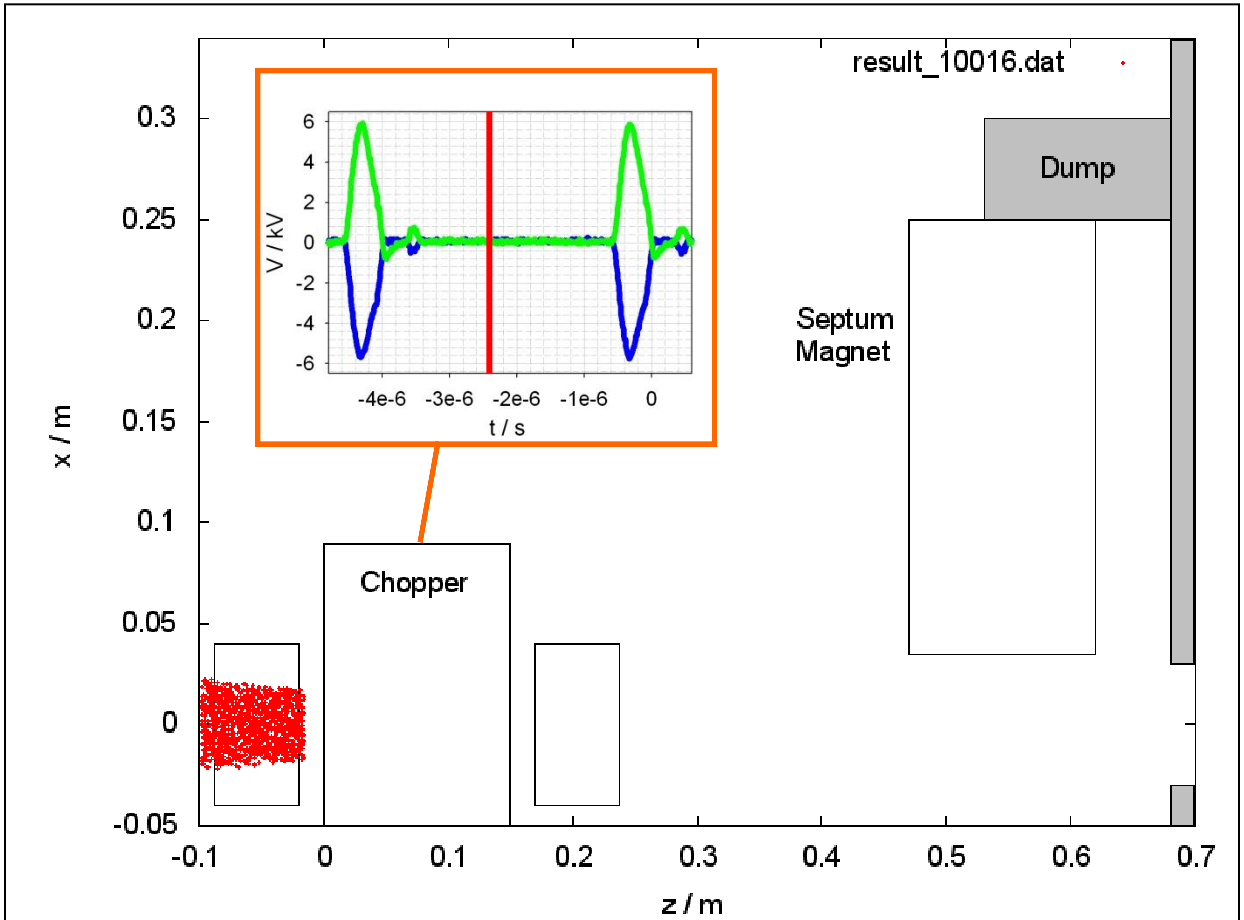
Rep.Rate = 257 kHz

Measured Voltage Pulse



Beam Tests Successful.

Beam Shaping Simulations



PIC-Code

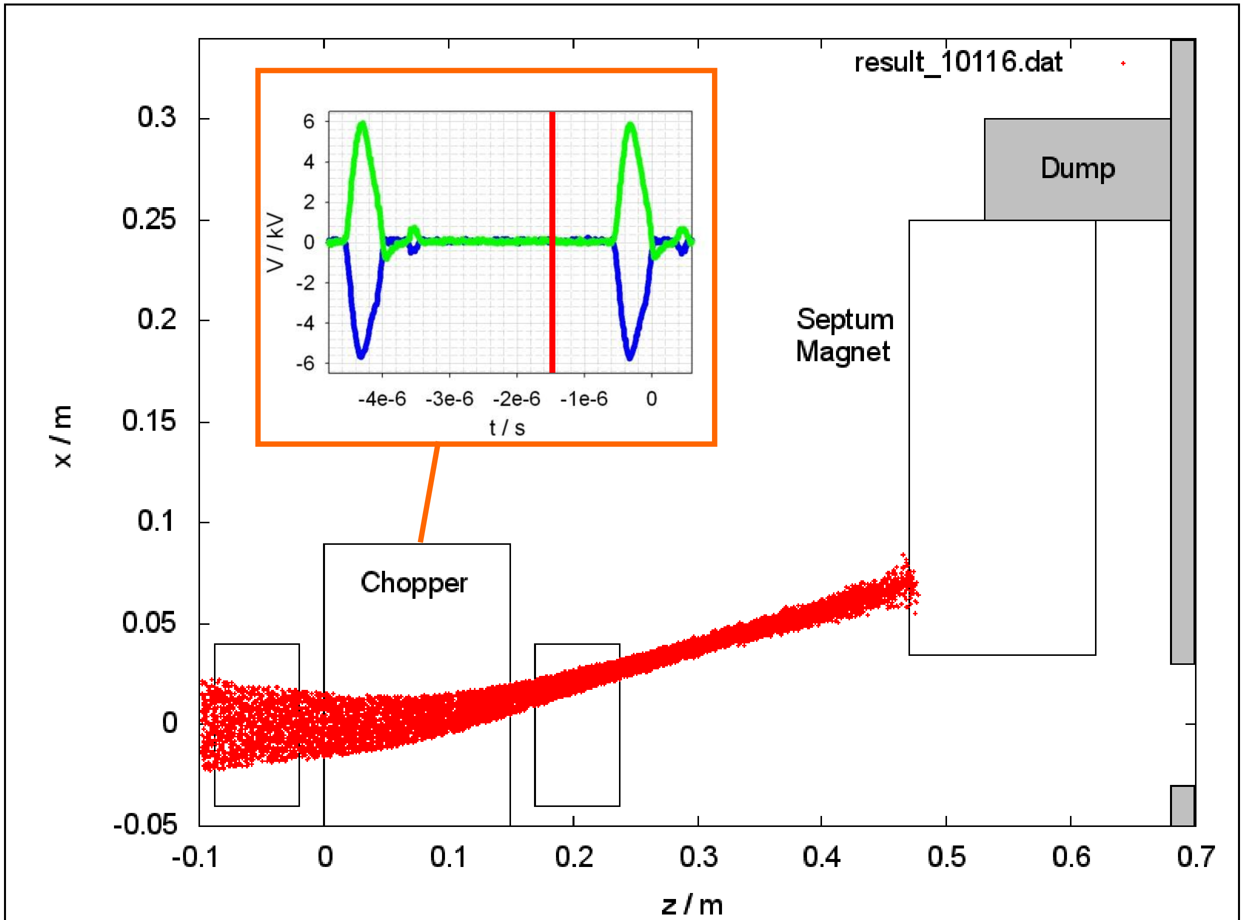
Simulation Input:

- Measured HV Pulse
- Calculated Fields for
  - Chopper Magnet
  - Septum Magnet
  - Deflector
  - Repeller

$B_{Chopper}$ = 60 mT

B_{Septum} = 300 mT

Beam Shaping Simulations



PIC-Code

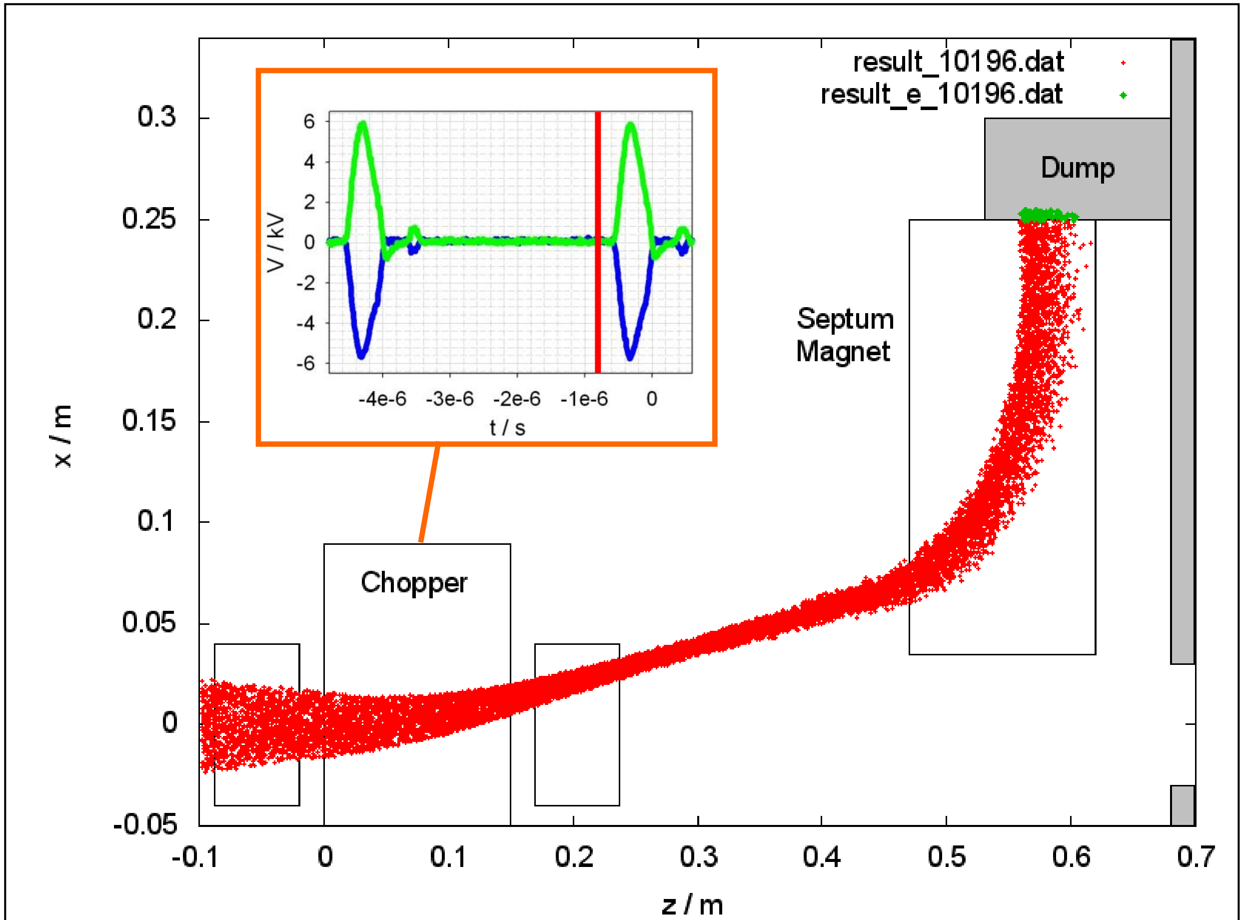
Simulation Input:

- Measured HV Pulse
- Calculated Fields for
    - Chopper Magnet
    - Septum Magnet
    - Deflector
    - Repeller

$B_{Chopper}$ = 60 mT

B_{Septum} = 300 mT

Beam Shaping Simulations



PIC-Code

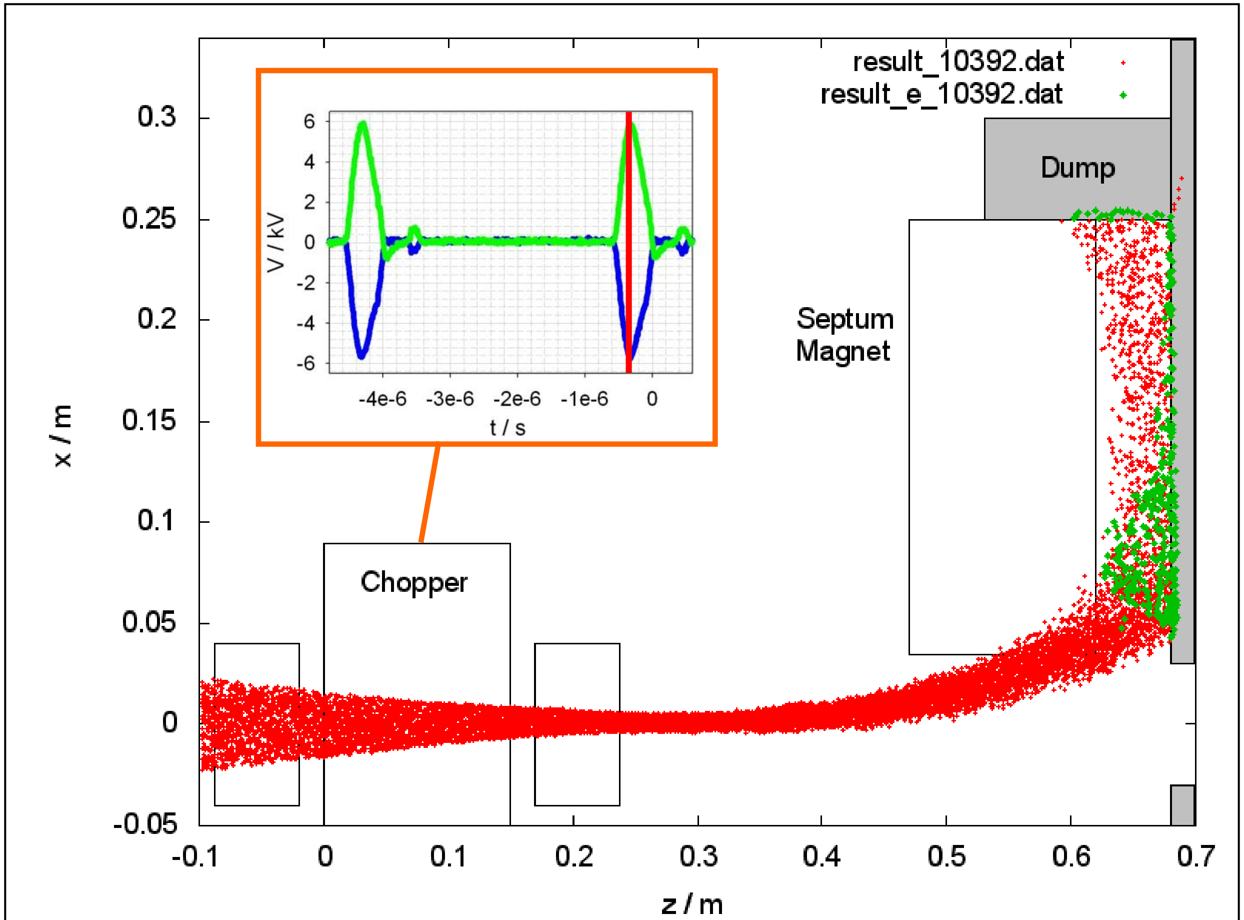
Simulation Input:

- Measured HV Pulse
- Calculated Fields for
    - Chopper Magnet
    - Septum Magnet
    - Deflector
    - Repeller

$B_{Chopper}$ = 60 mT

B_{Septum} = 300 mT

Beam Shaping Simulations



PIC-Code

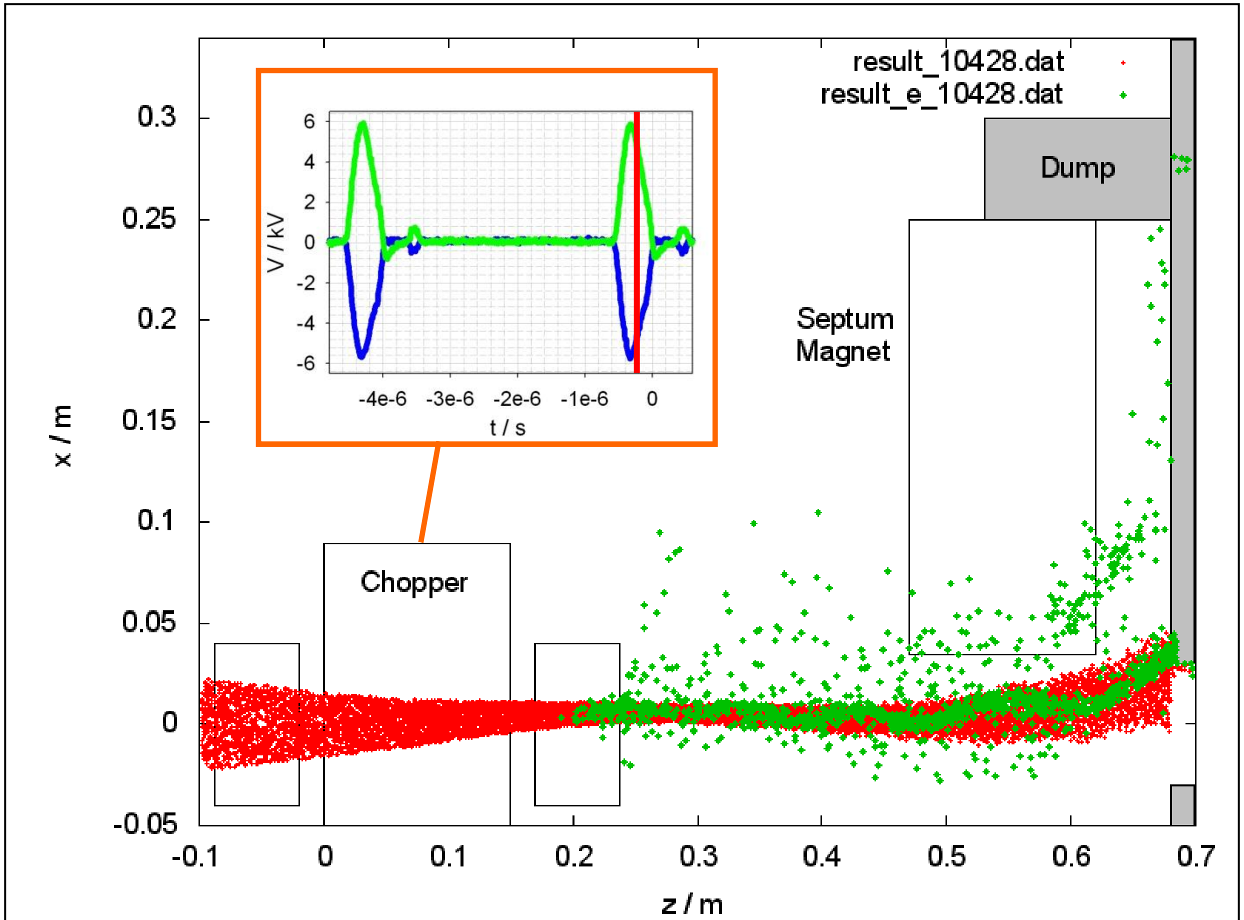
Simulation Input:

- Measured HV Pulse
- Calculated Fields for
  - Chopper Magnet
  - Septum Magnet
  - Deflector
  - Repeller

$B_{Chopper}$ = 60 mT

B_{Septum} = 300 mT

Beam Shaping Simulations



PIC-Code

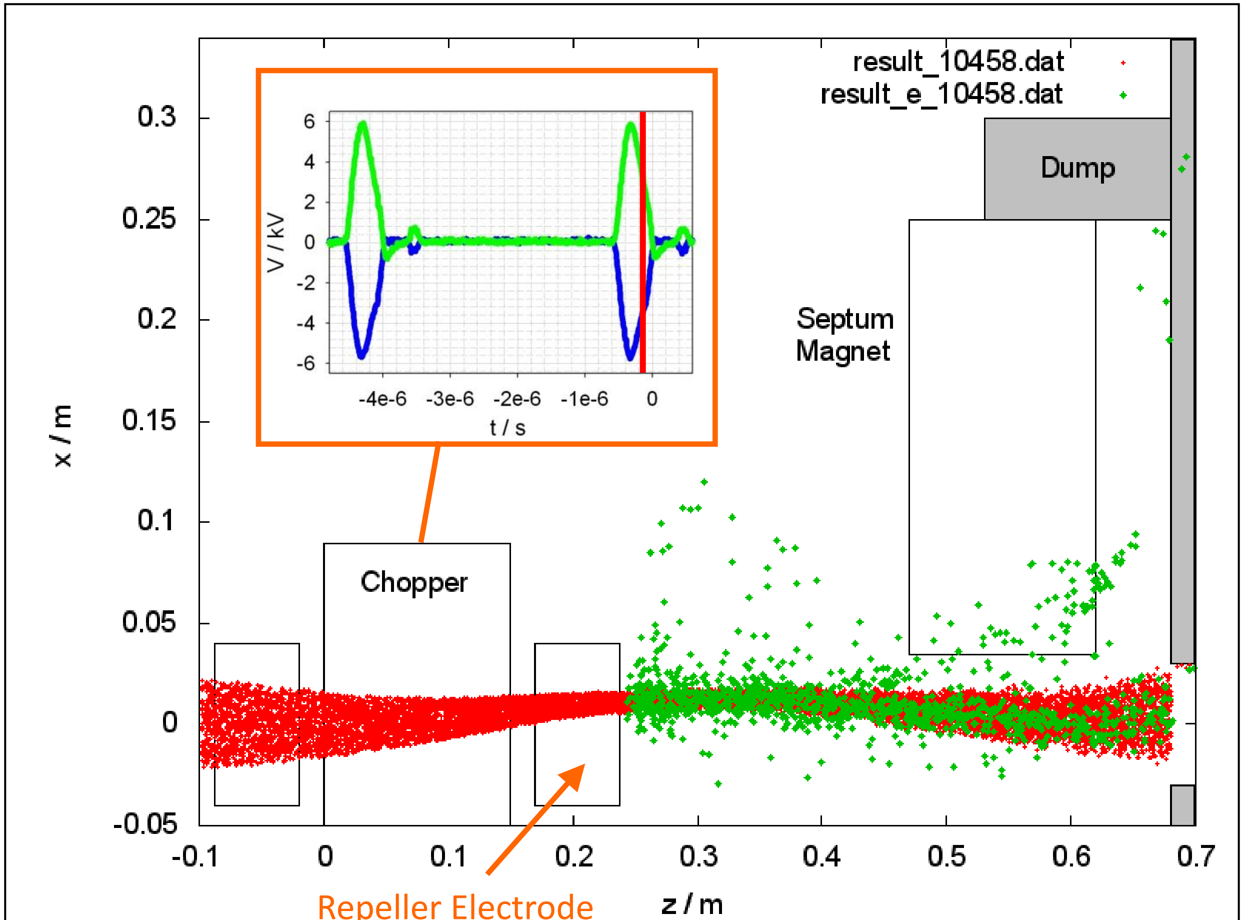
Simulation Input:

- Measured HV Pulse
- Calculated Fields for
  - Chopper Magnet
  - Septum Magnet
  - Deflector
  - Repeller

$B_{Chopper}$ = 60 mT

B_{Septum} = 300 mT

Beam Shaping Simulations



PIC-Code

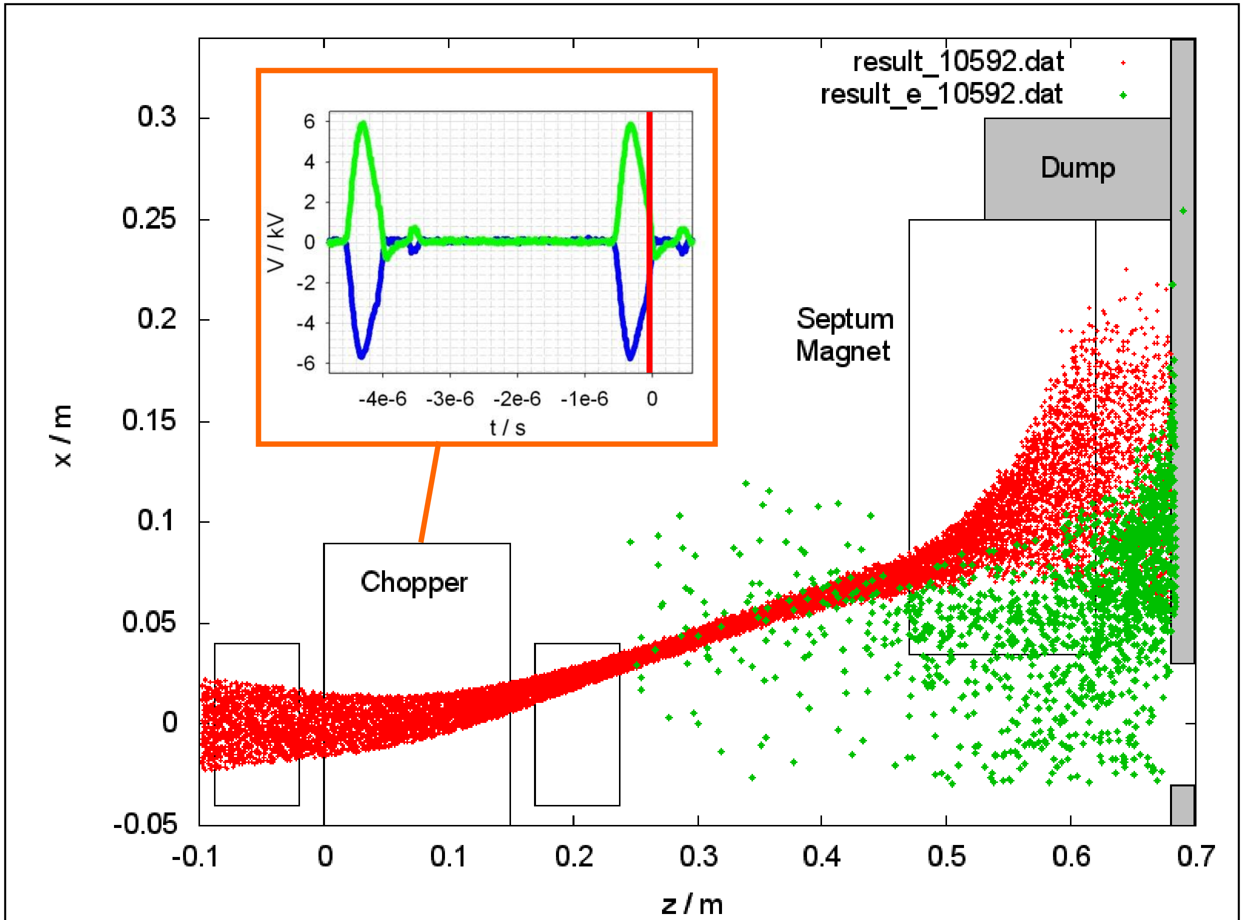
Simulation Input:

- Measured HV Pulse
- Calculated Fields for
  - Chopper Magnet
  - Septum Magnet
  - Deflector
  - Repeller

$B_{Chopper}$ = 60 mT

B_{Septum} = 300 mT

Beam Shaping Simulations



PIC-Code

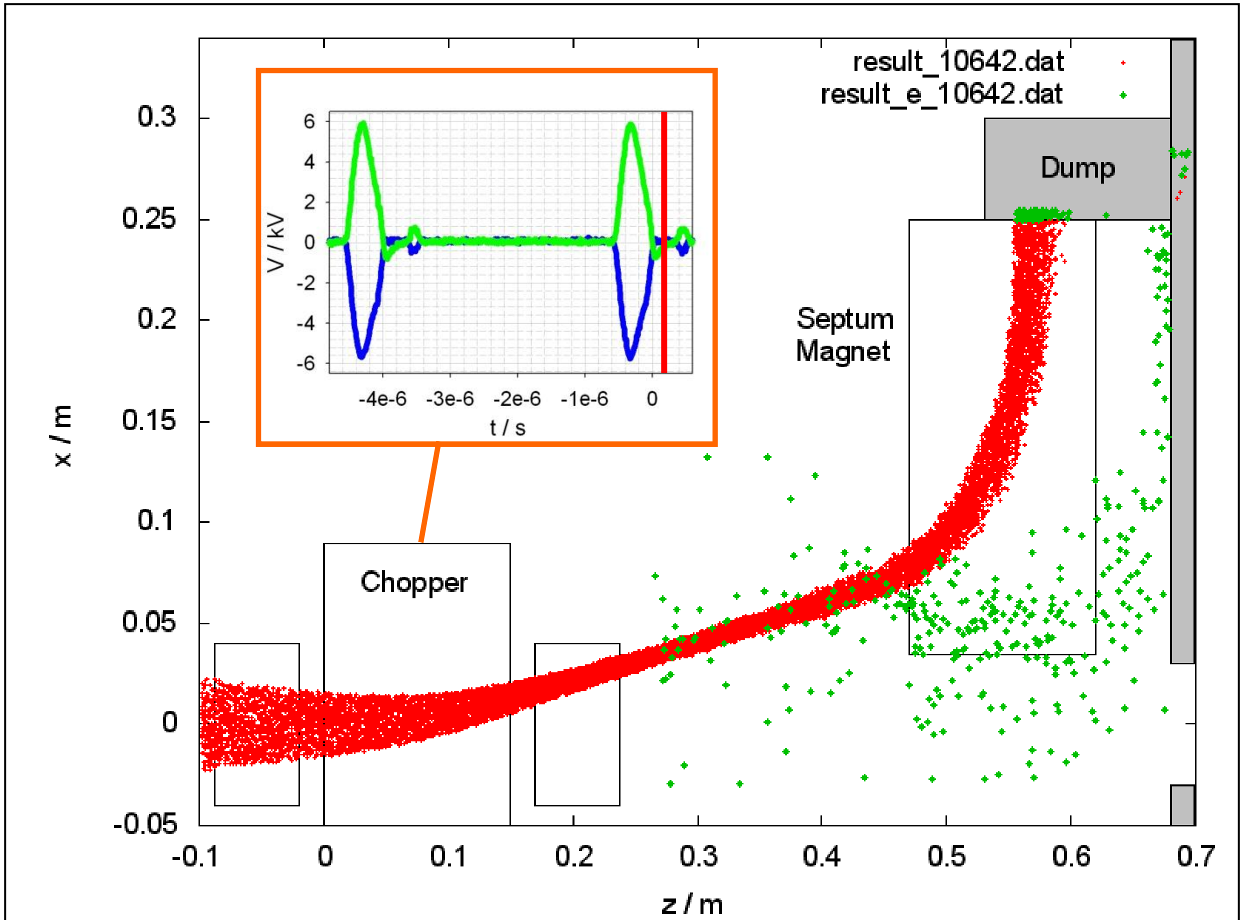
Simulation Input:

- Measured HV Pulse
- Calculated Fields for
  - Chopper Magnet
  - Septum Magnet
  - Deflector
  - Repeller

$B_{Chopper}$ = 60 mT

B_{Septum} = 300 mT

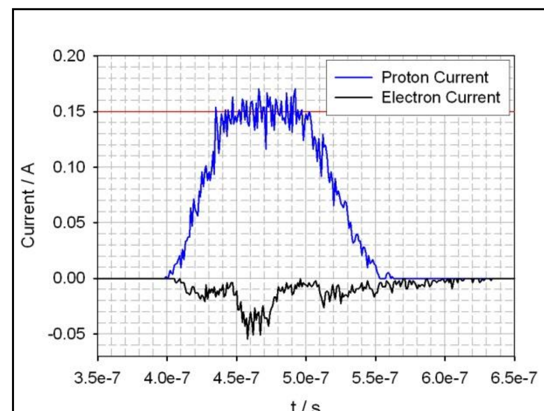
Beam Shaping Simulations



PIC-Code

Simulation Input:
- Measured HV Pulse
- Calculated Fields for
  - Chopper Magnet
  - Septum Magnet
  - Deflector
  - Repeller

Simulated Proton Pulse

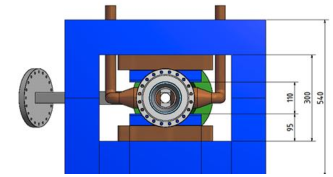


$B_{Chopper}$ = 60 mT

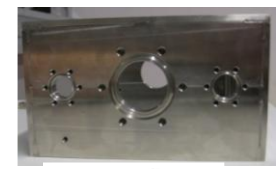
B_{Septum} = 300 mT

Status & Outlook

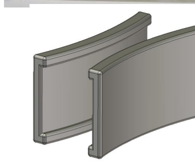
- Chopper magnet: Order placed.



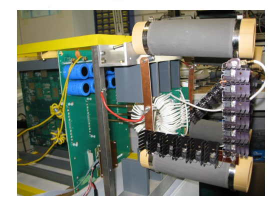
- Deflection chamber: Manufactured.



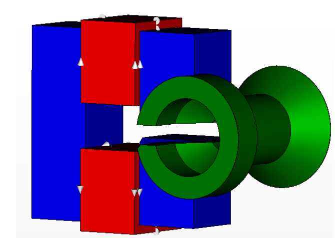
- Deflector/Shorting tubes/repeller/flanges:
  To be manufactured.



- HV pulse generator: Operational.
  - Shielding/HV cables: To be manufactured.

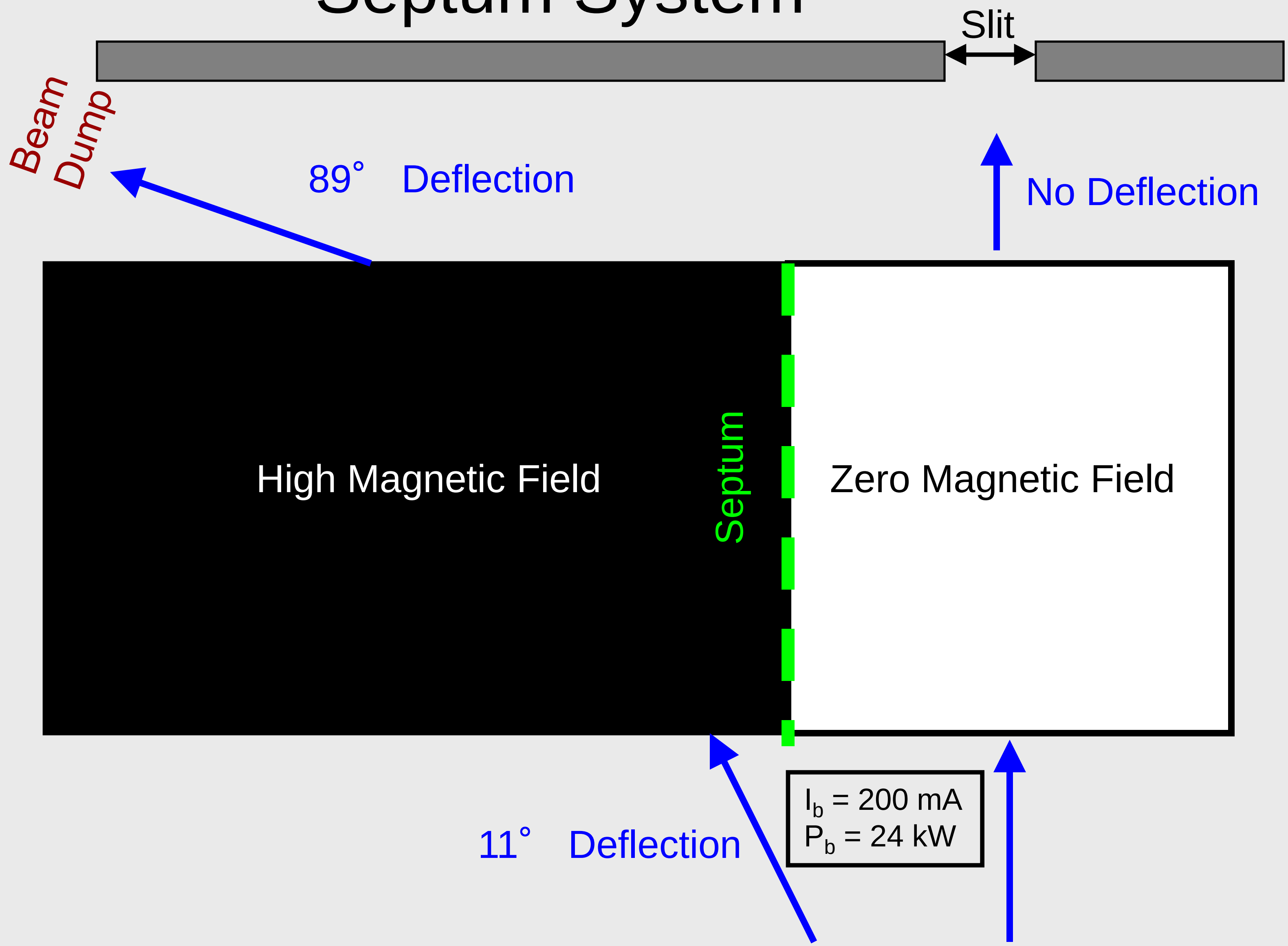


Septum magnet
- Shielding tube
- Separation chamber

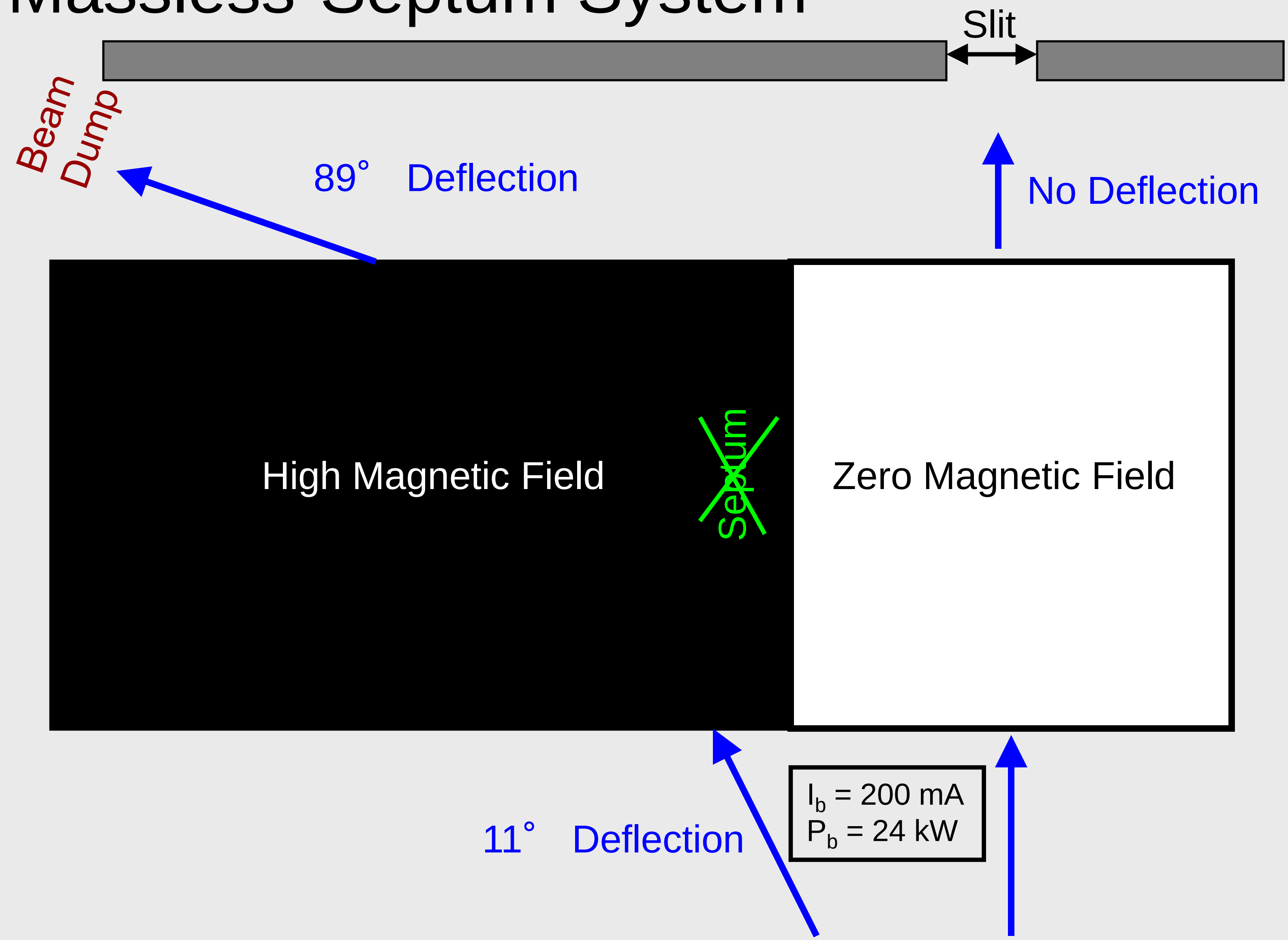



Thank you for your attention

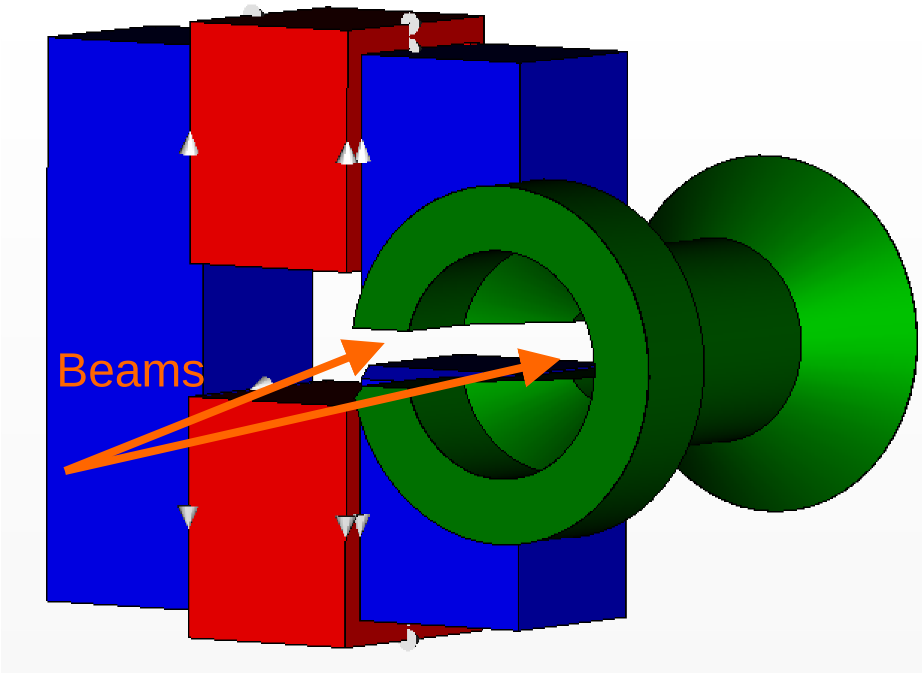
Septum System

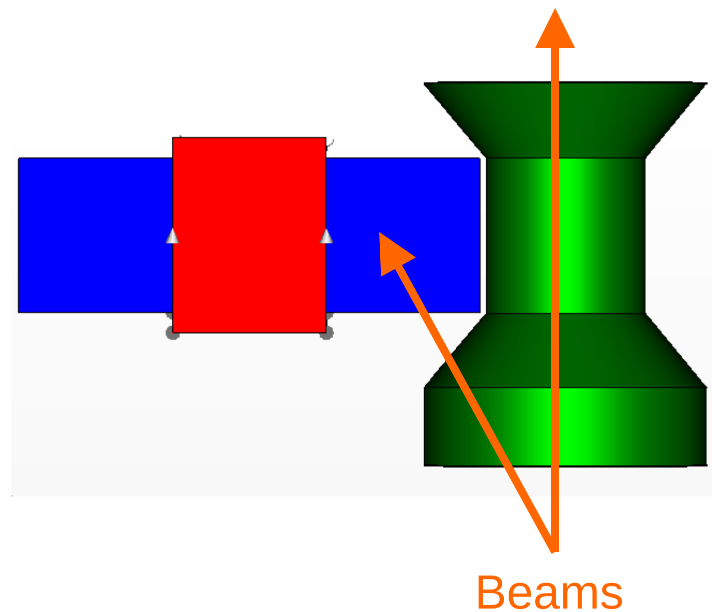


Massless Septum System

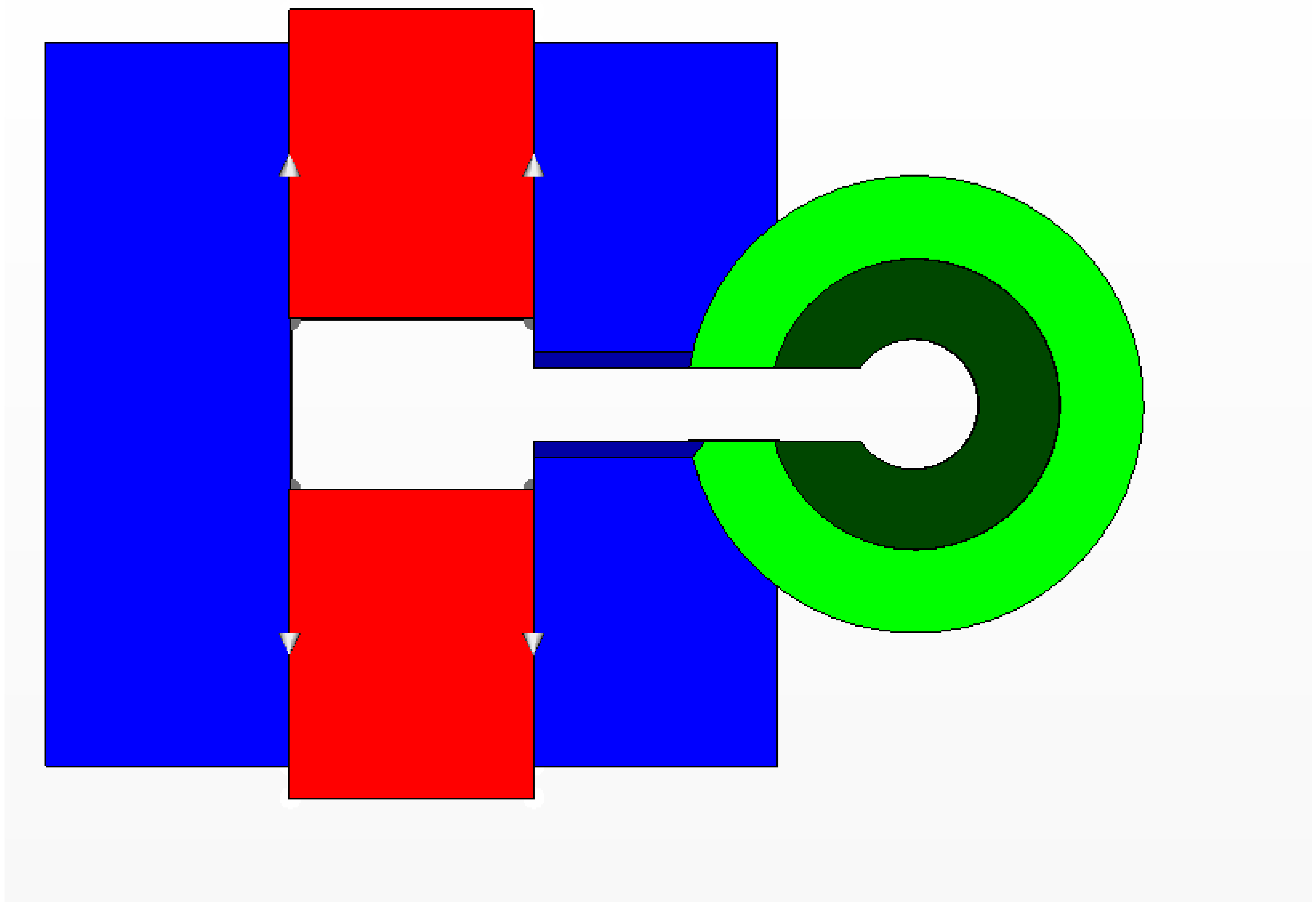


Halfpipe Septum

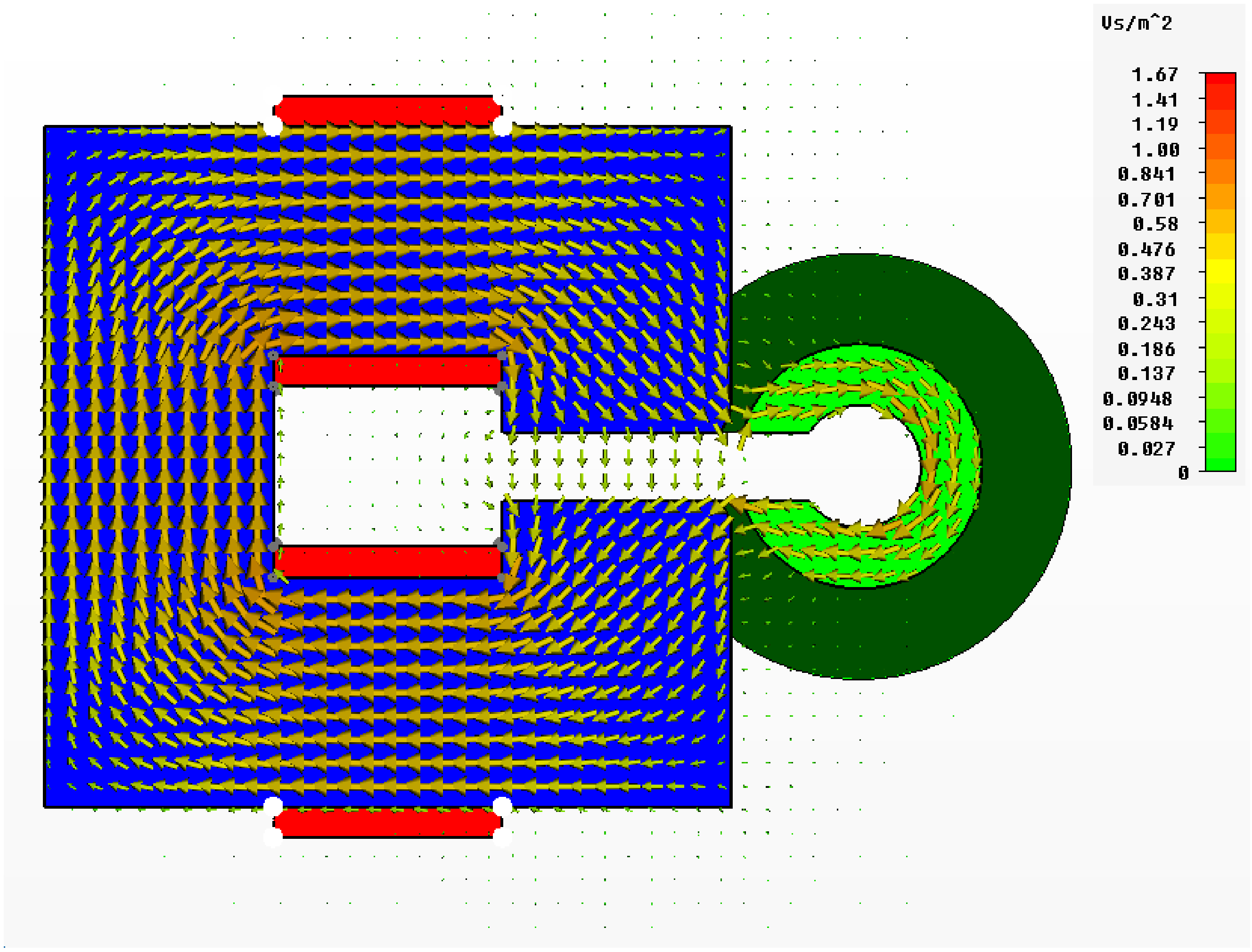




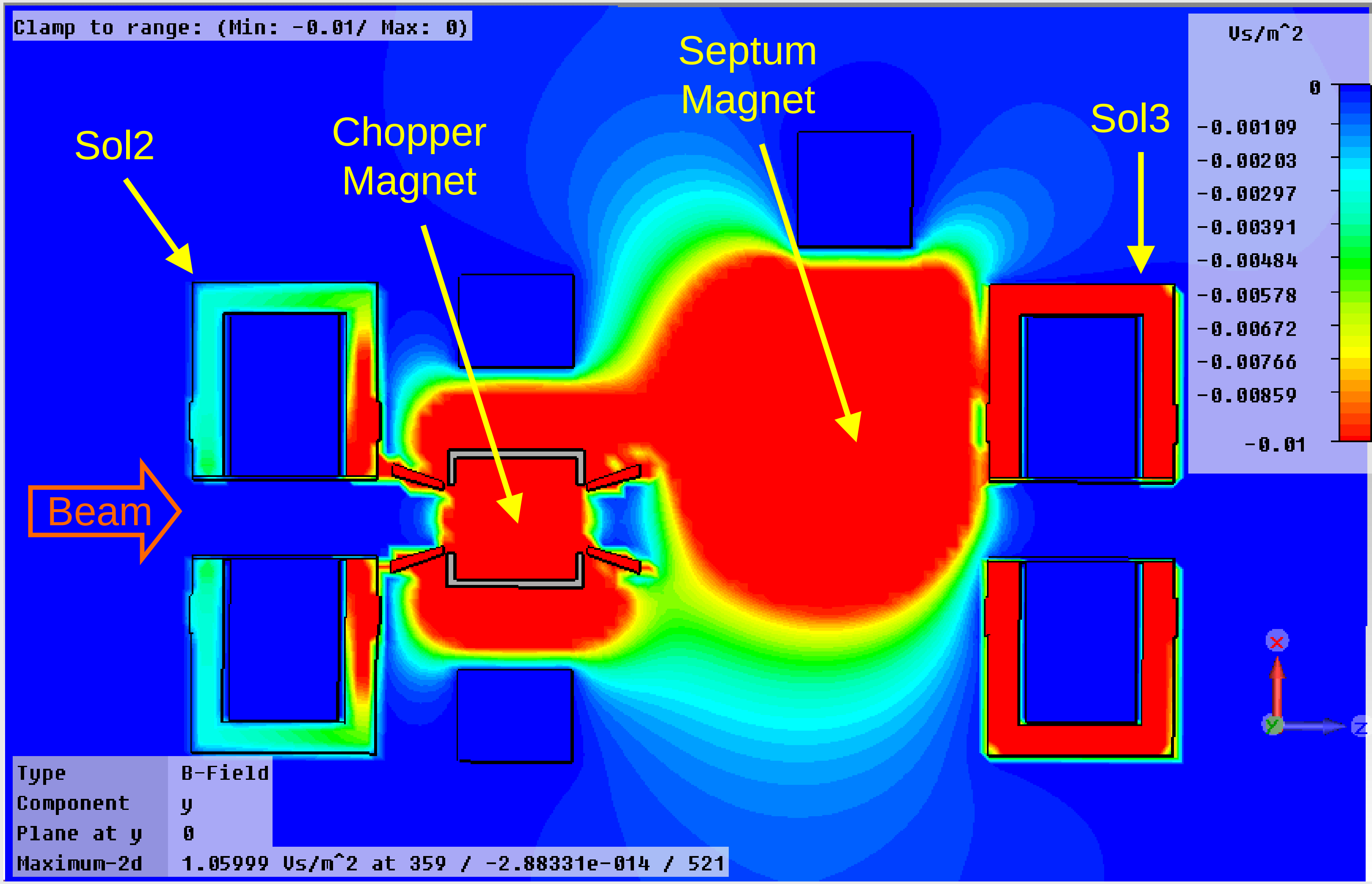
Halfpipe Septum



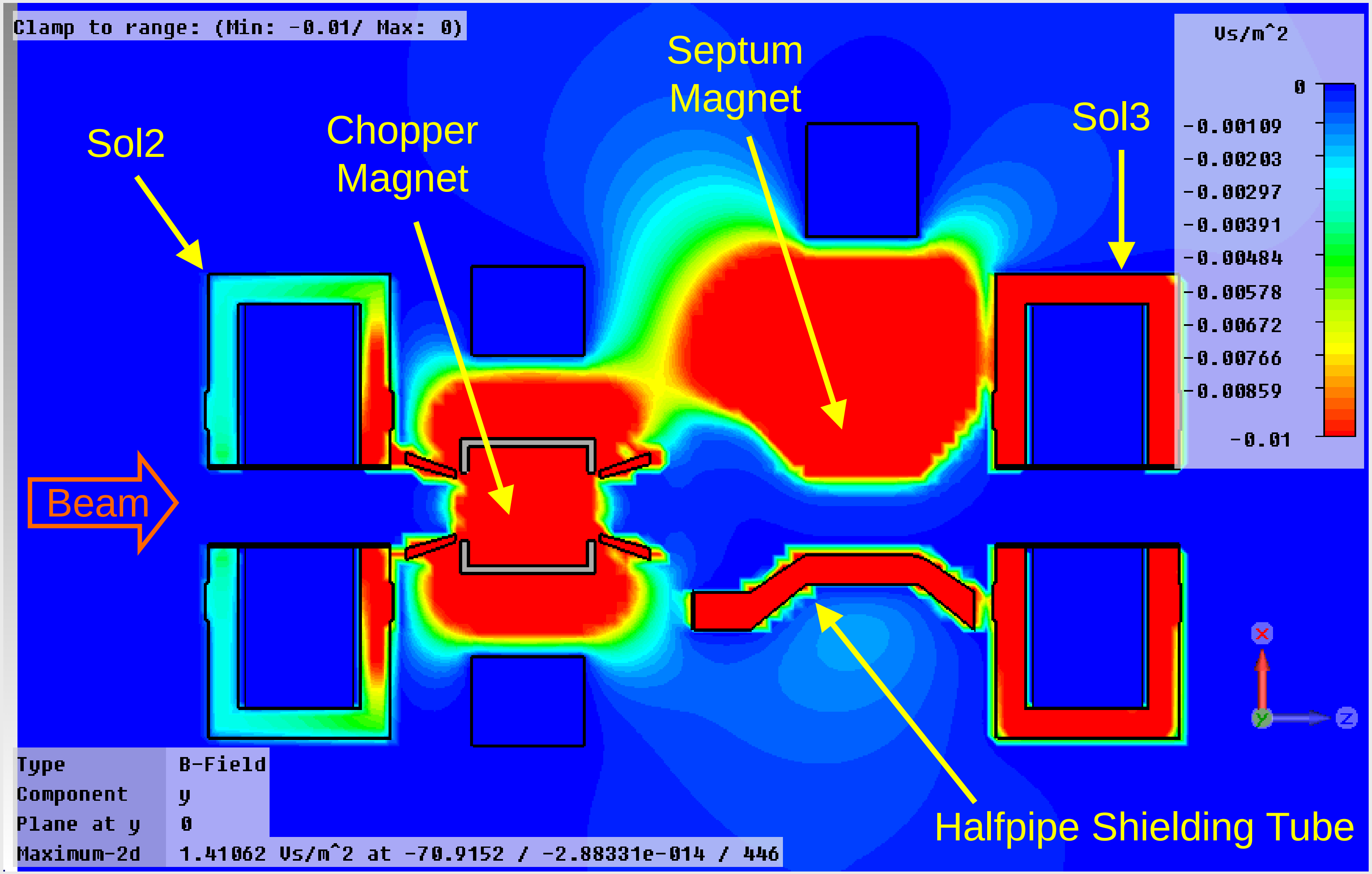
Halfpipe Septum



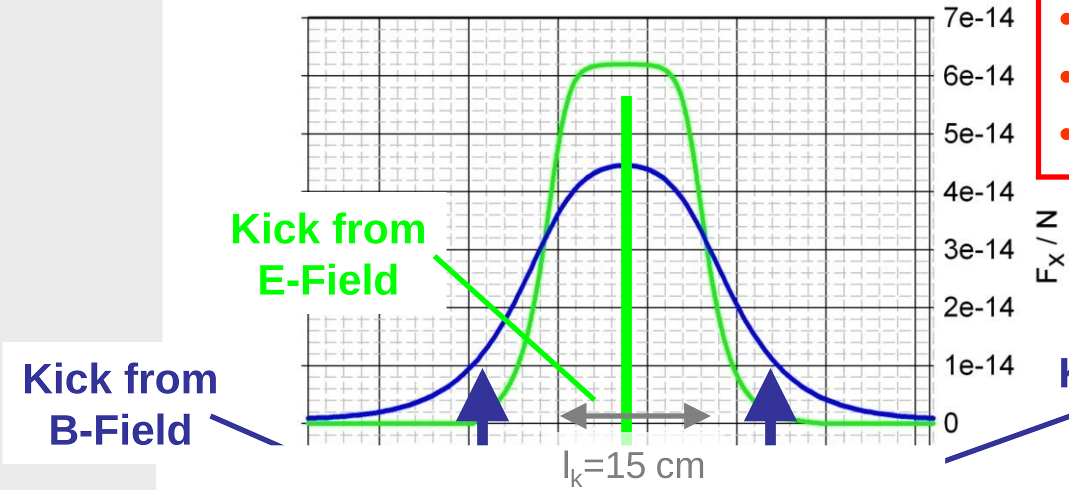
Field Simulation of All Magnetic Components



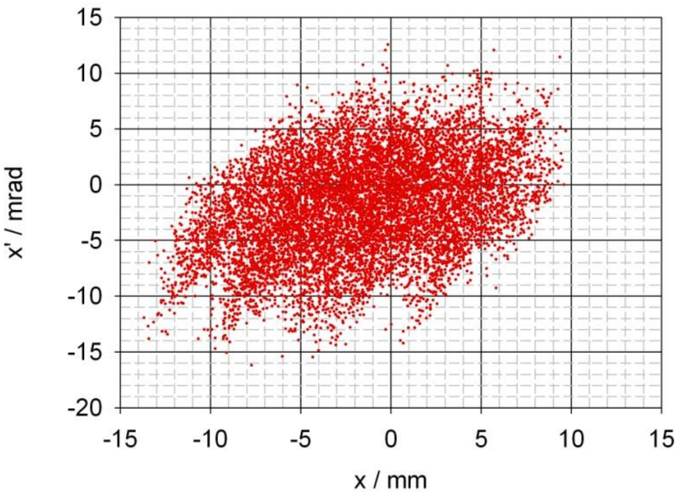
Field Simulation of All Magnetic Components



Homogen. Input Distrib.:
- r_b = 10 mm
- x ‘ = 10 mrad
- no space charge

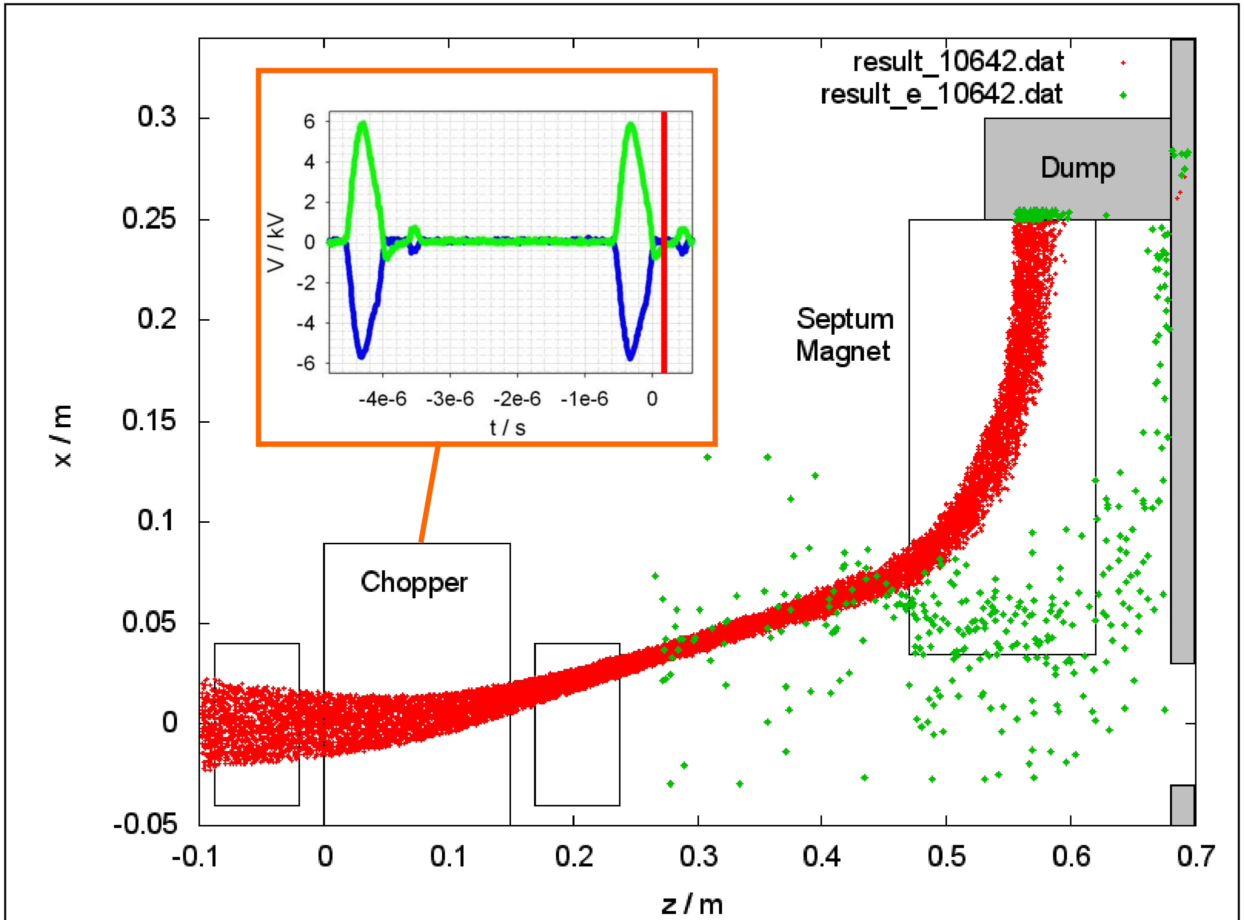


Beam



Output Distribution

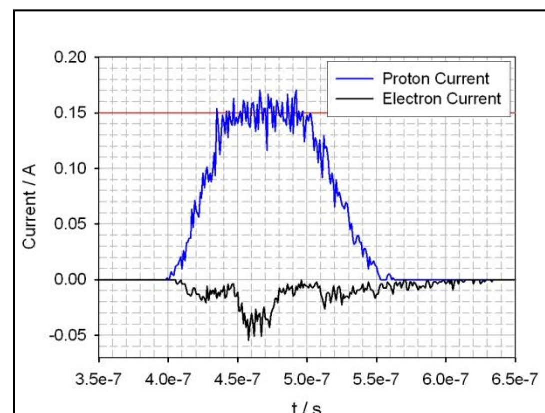
Beam Shaping Simulations



PIC-Code

- Multi-Species (p, e^-, H_2^+, H_3^+)
- Electron Production
- Time-dependent Fields
- External Field Distributions

Simulated Proton Pulse



$B_{Chopper}$ = 60 mT

B_{Septum} = 300 mT

Chopper Magnet

Coil Parameters	
Number of Coils	2
Connection	*Serial*
Number of Turns per Coil	48
Conductor Size	$6\ mm \times 6\ mm$
Cooling Channel Diameter	$3.5\ mm$
Conducting Area	$26.4\ mm^2$
Total Length/Coil	$43\ m$
Resistance at $40\ °C$ (2 coils)	$60\ m\Omega$

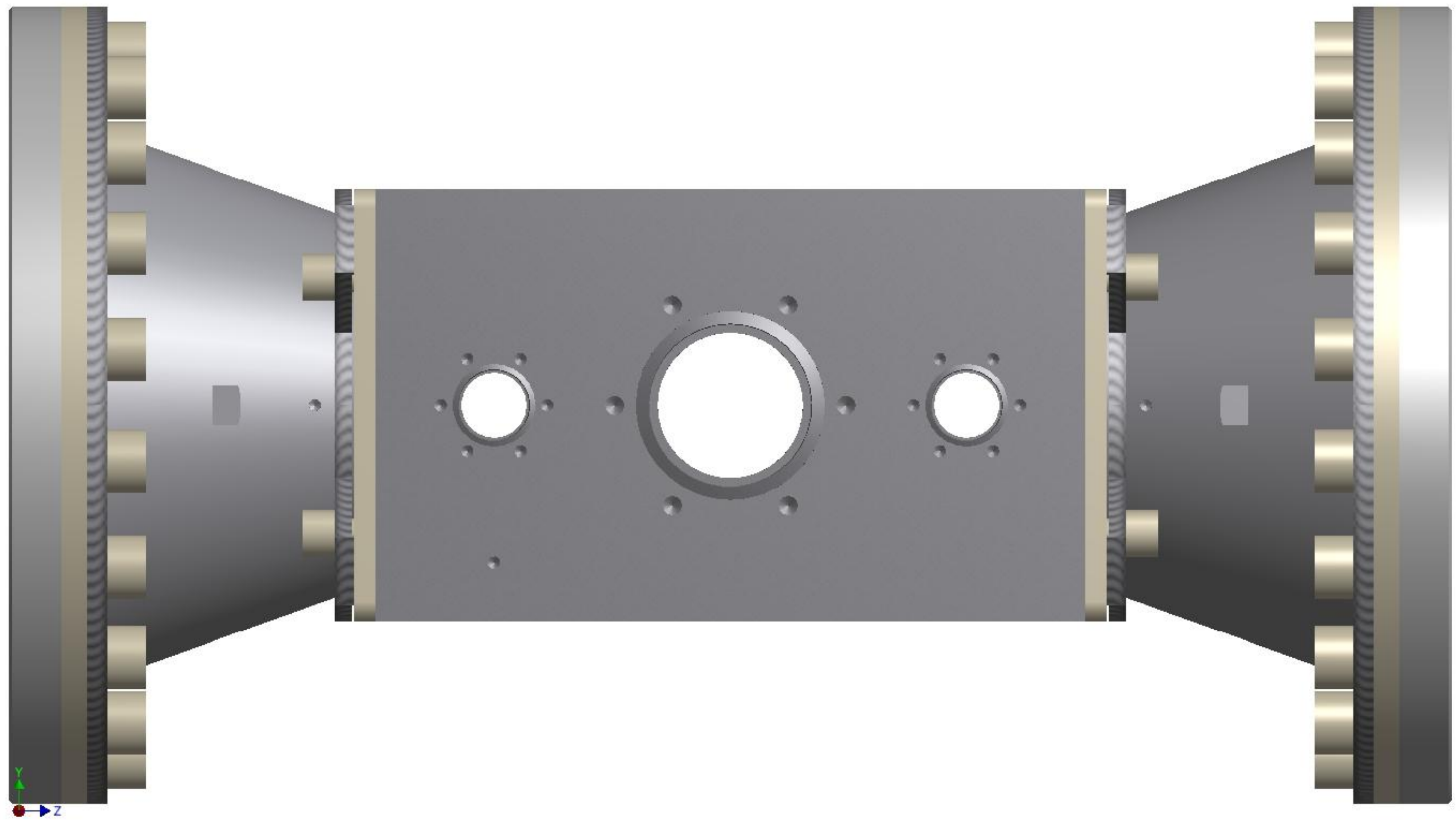
Electric Values – Standard Operation Mode	
Current	$64.6\ A$
Excitation Field	$3100\ A-turns$
Current Density	$2.5\ A/mm^2$
DC Voltage Drop	$3.9\ V$
Dissipated Power (2 coils)	$250\ W$

Cooling System	
Minimum Number of Cooling Circuits	2
Connection	*Parallel*
Pressure Drop Δp	$5\ bar$
Flow Velocity v	$1.5\ m/s$
Reynolds Number Re	4550
Volume Flow q	$0.8\ l/min$
Temperature Rise ΔT, Standard Operation Mode	$4\ °C$
Temperature Rise ΔT, Max. Field Operation Mode	$17\ °C$

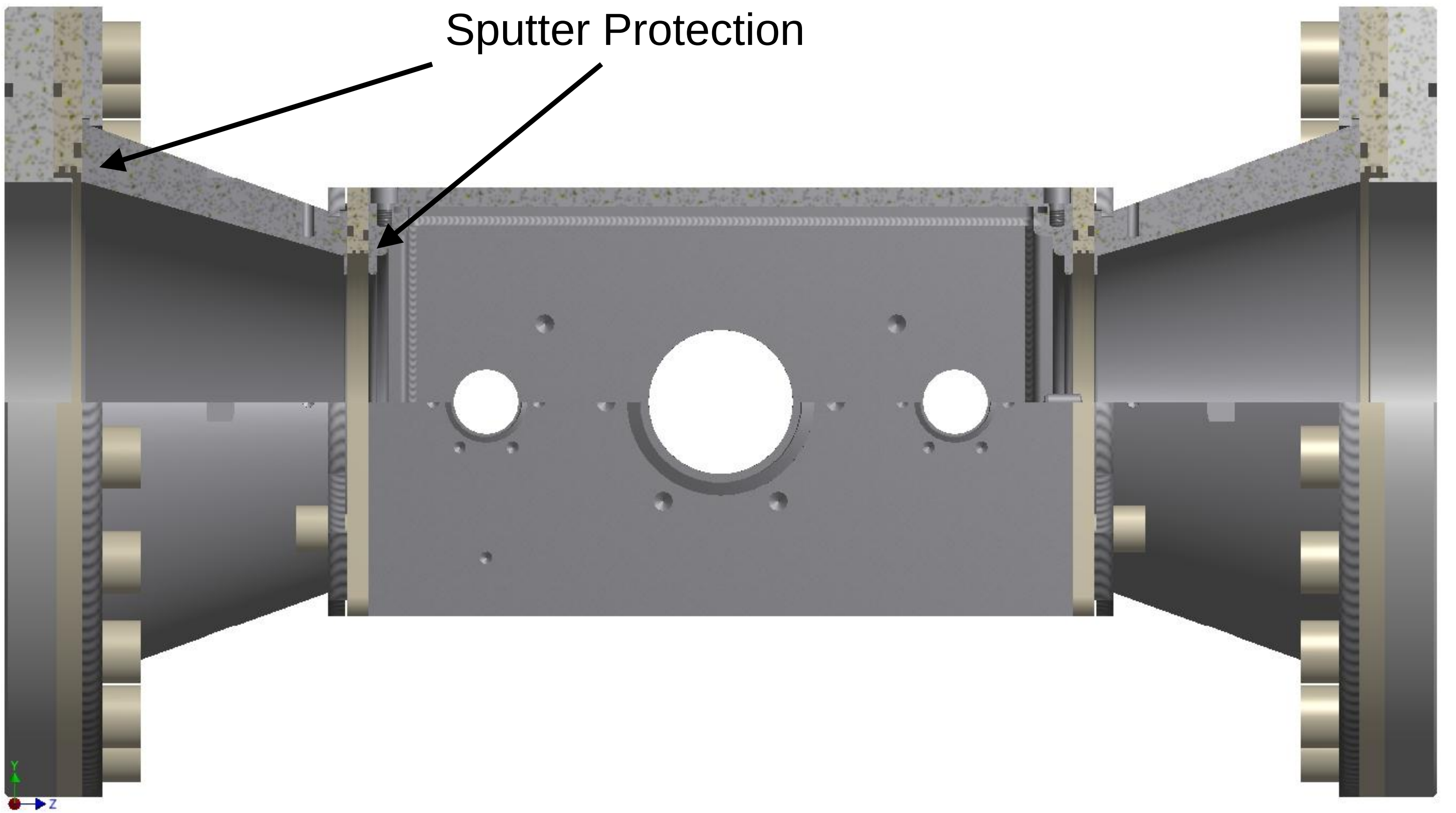
Table 1.5: Design Parameters for Cooling System.

Order has been placed in march 2011.

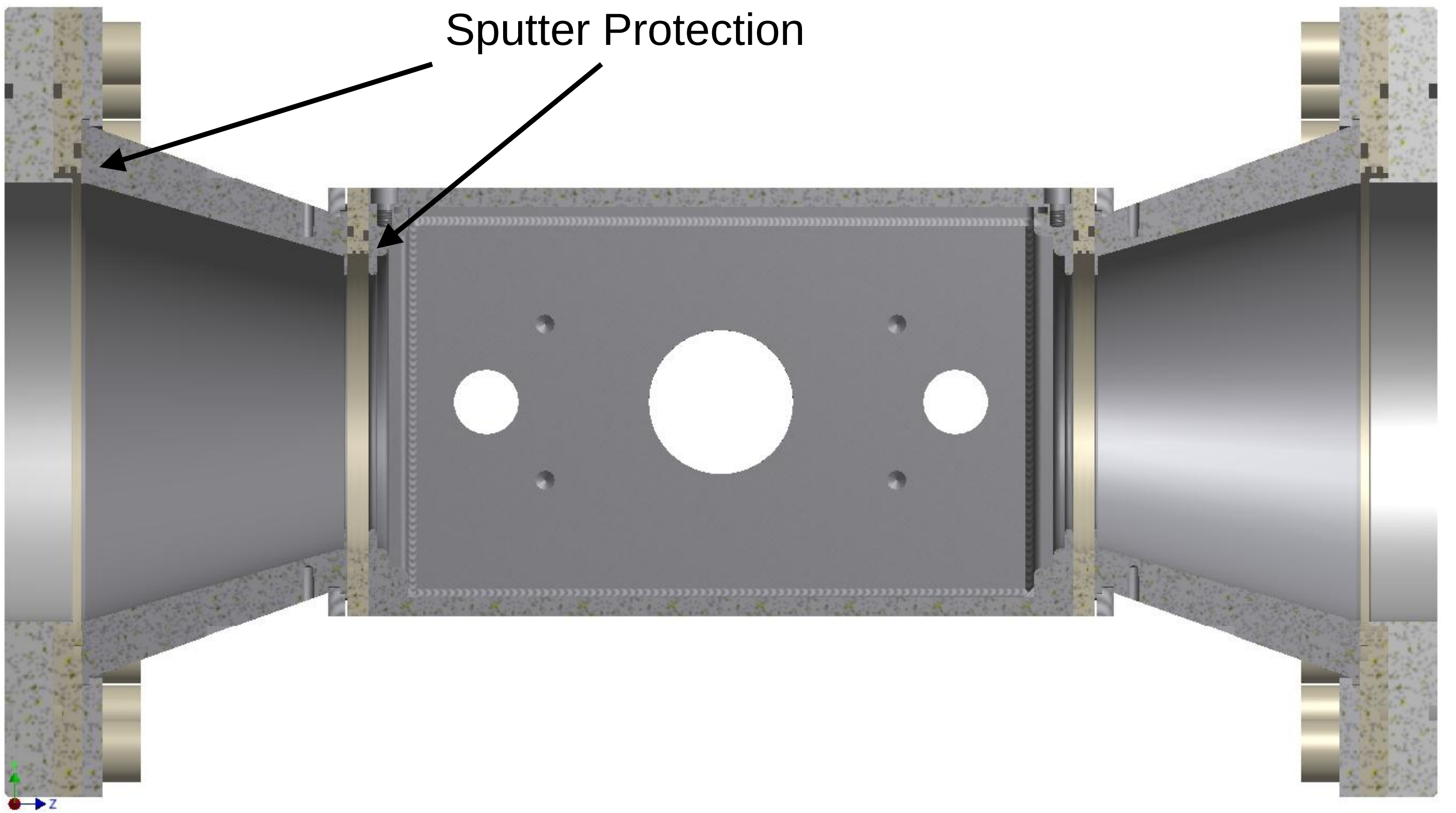
Deflection Chamber: Design



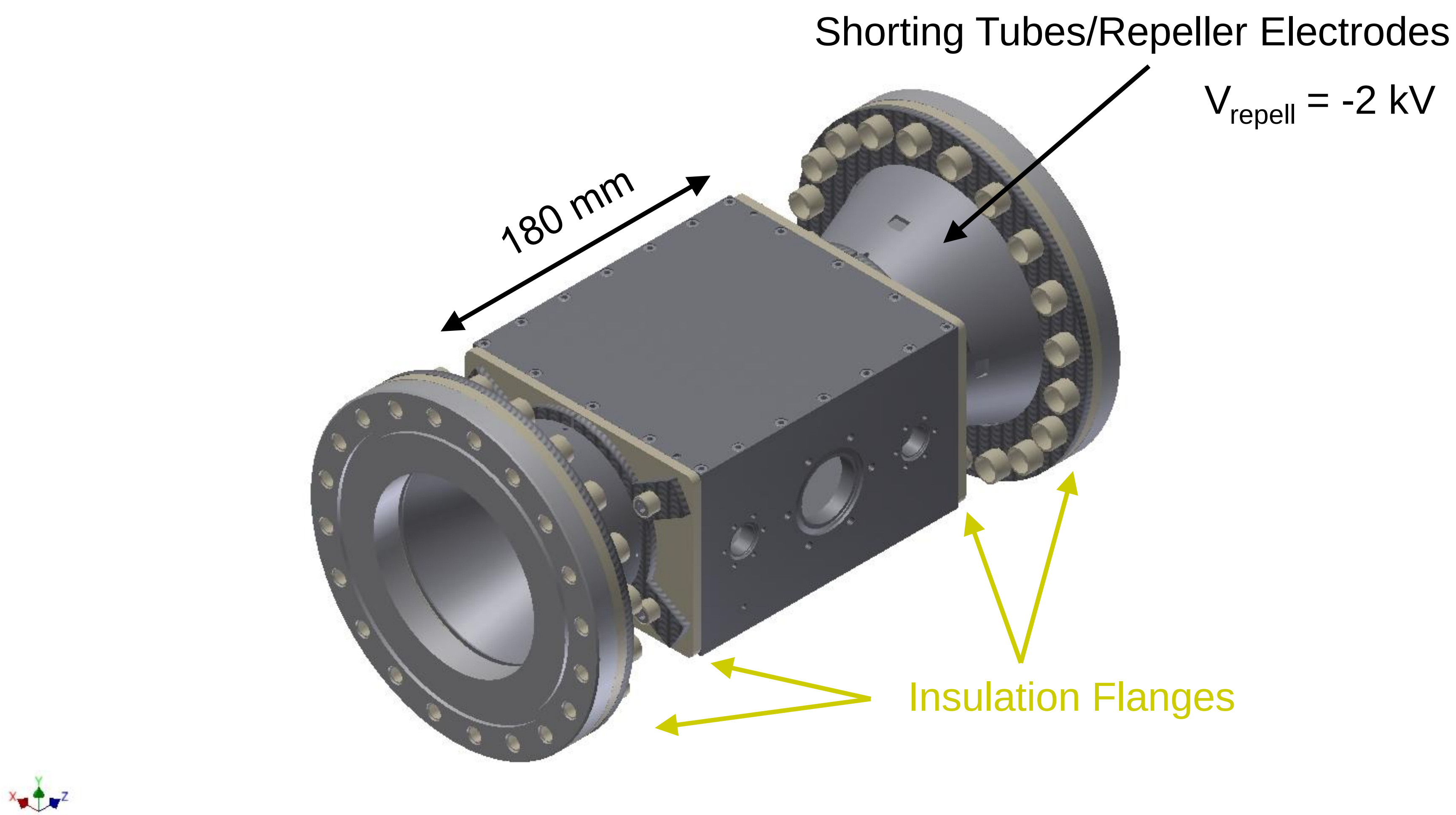
Deflection Chamber: Design



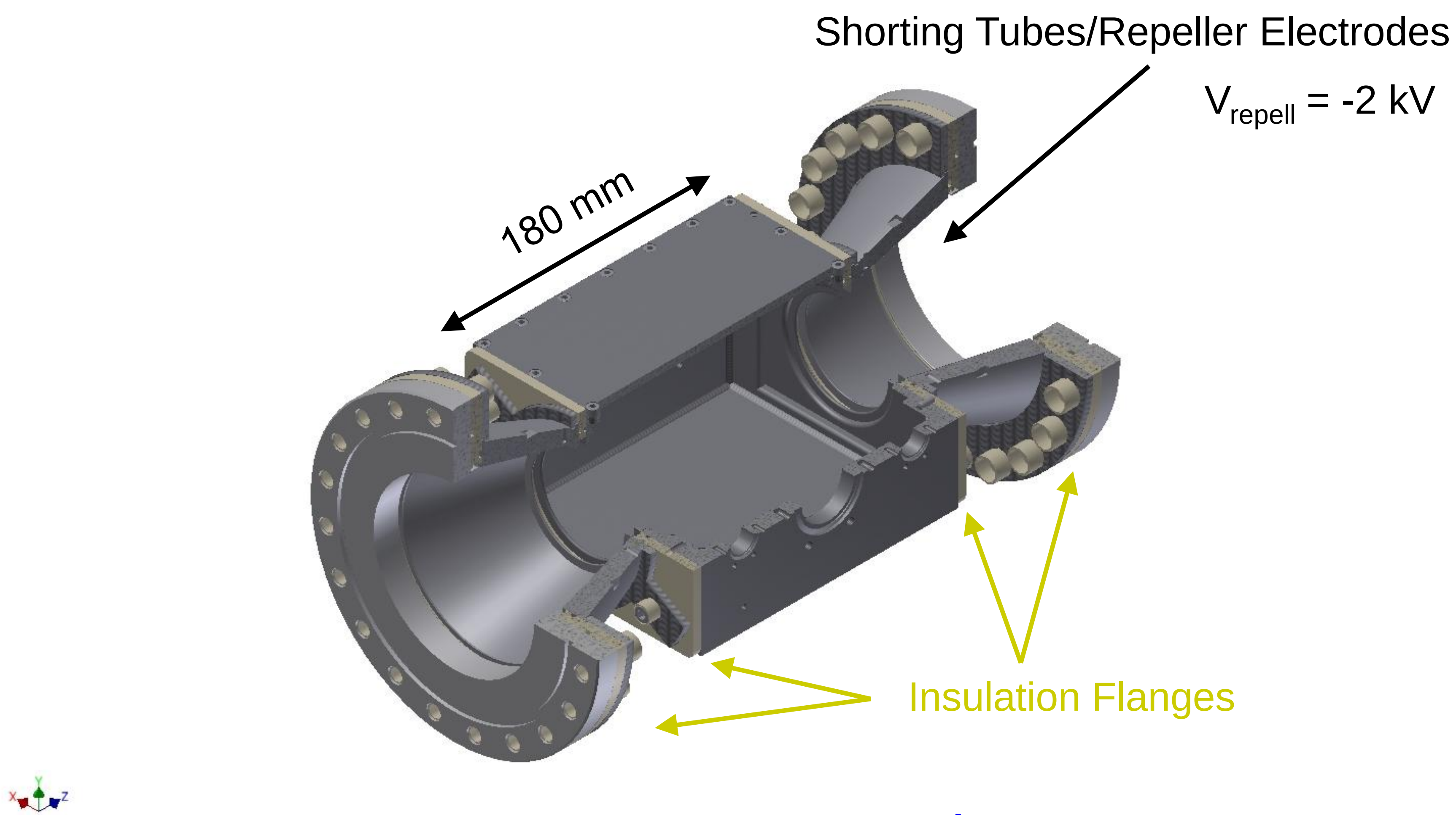
Deflection Chamber: Design



Deflection Chamber: Design



Deflection Chamber: Design



→ Sputter Protection Required.