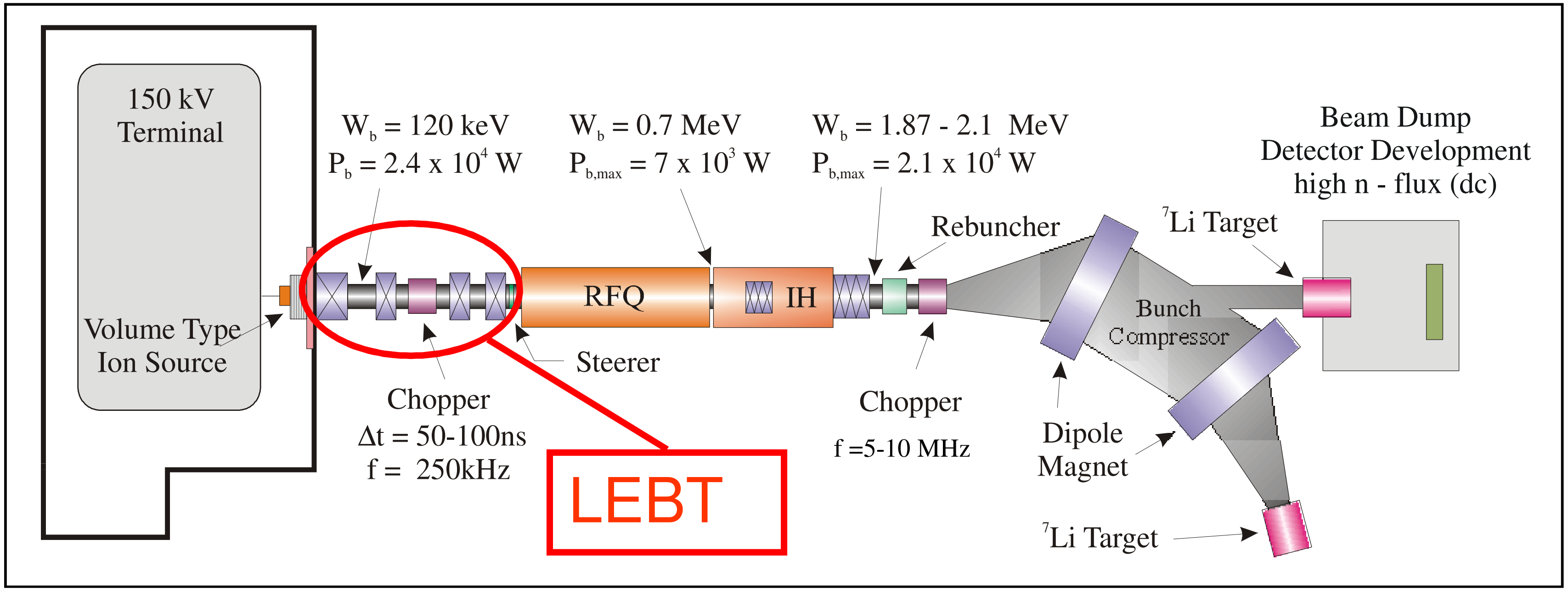
2008/03/04

Fast Beam Chopping for FRANZ

Christoph Wiesner

Contents

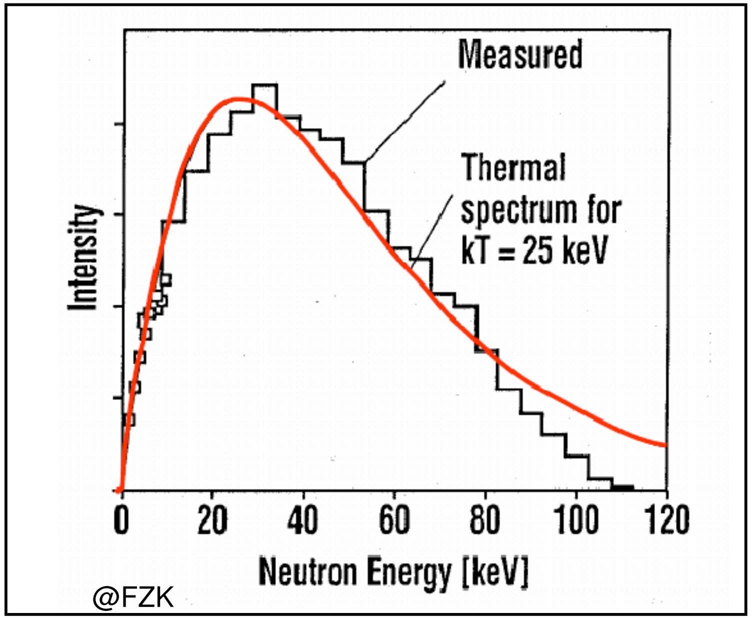
Frankfurt Neutron Source

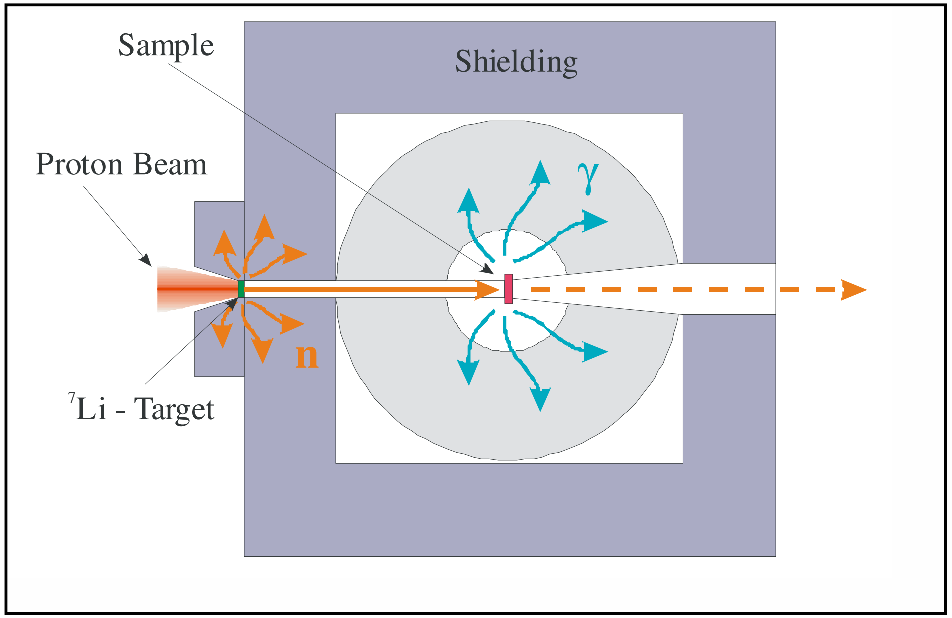


$$p + {}^7\mathrm{Li} \rightarrow {}^7\mathrm{Be} + n - \Delta E$$

Motivation:
- Detector development
- Measurement of Neutron Capture Cross Section for Nuclear Astrophysics and Material Research

Research of s-process in Red Giant Stars





Time of Flight (TOF) requires pulsed proton beam.

Parameters Chopper

- Input: 150 mA dc proton beam, 120 keV
- Output: 50-100 ns bunches, repetition rate f = 250 kHz

Technical Challenge:
- High Repetition Rate
- High Intensity
- Significant Fields
- Short Rise Times (100 ns)

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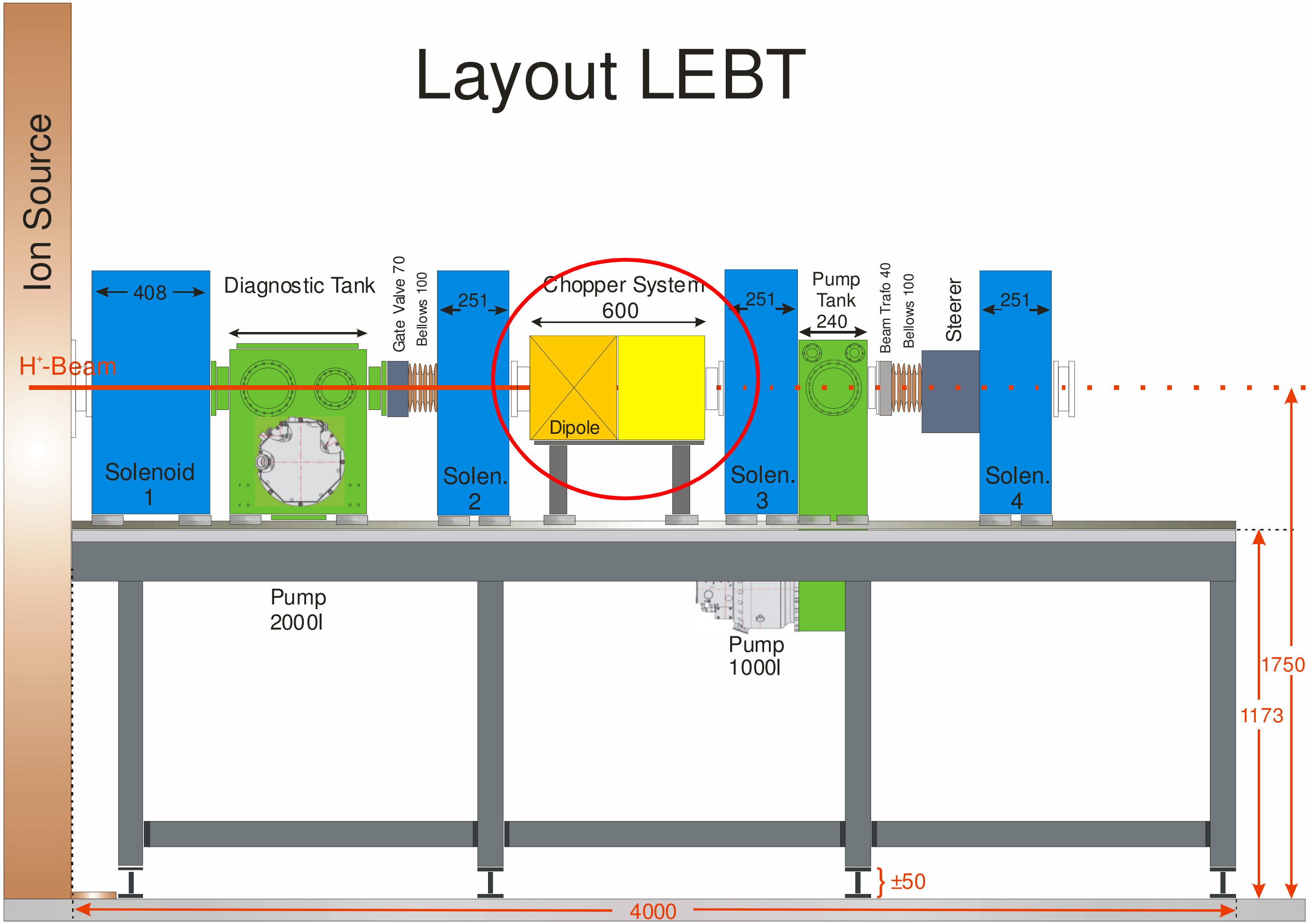
Layout LEBT



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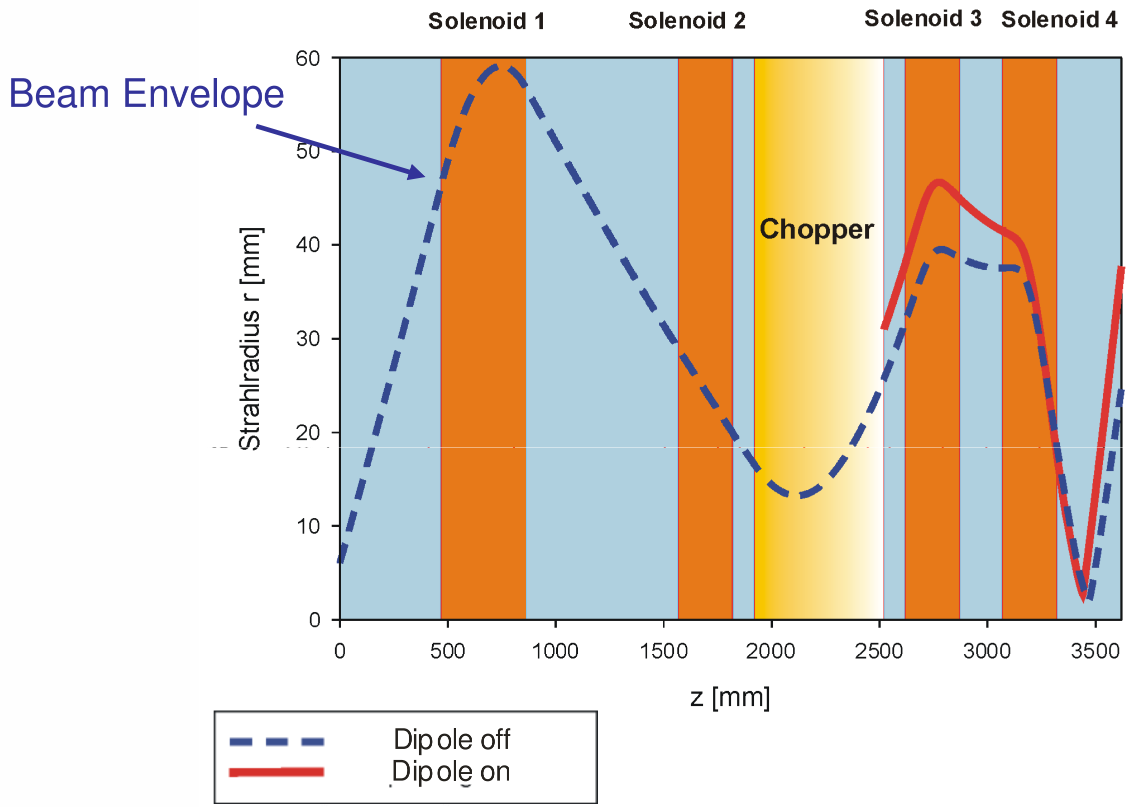
Transport Simulations for 150 mA Proton Beam

1. Introduct.
- FRANZ
- Parameters
- LEBT

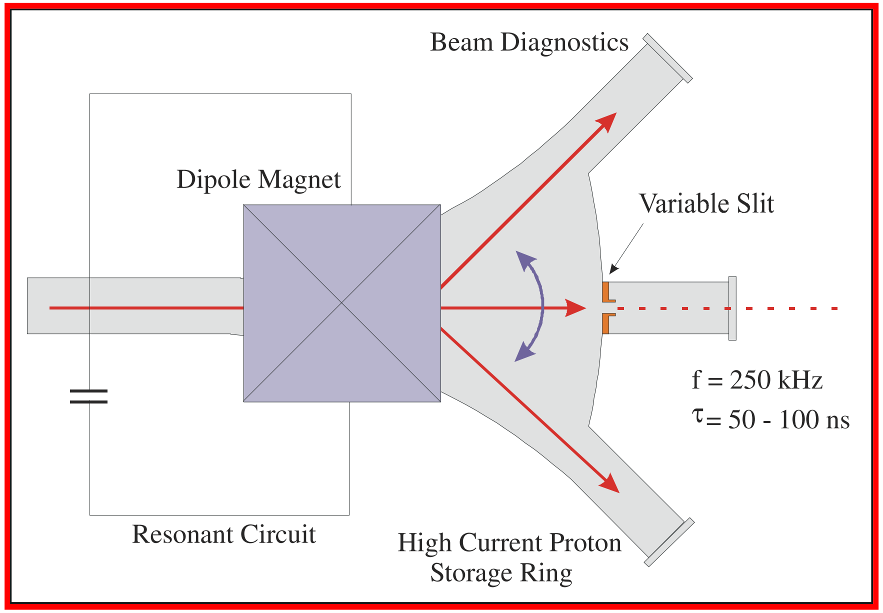
2. Chopper
- **Concepts**
- Kicker
  - Magnetic
    - Simu.
    - Tecn./ Exper.
  - Electric
    - Simu.
    - Tecn./ Exper.
  - Conclus.
- Septum
  - Traditional
  - Massless
  - Simulation

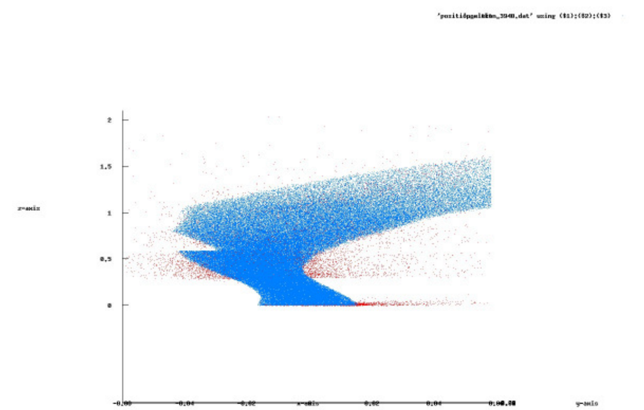
3. Outlook



Sektion	Funktion	von	bis	Länge	B-Feld	Max.Radius	Raumlad.komp
1	Drift	0	470	470	0	75	0.85
2	Solenoid 1	470	870	400	Hom0245	75	0.85
3	Drift (Diagnostik)	870	1570	700	0	75	0.85
4	Solenoid 2	1570	1820	250	Sol0100	50	0.85
5	Drift	1820	1920	100	0	50	0.85
6	Dipol (ohne Feld)	1920	2220	300	0	25	0
7	Drift bis Blende	2220	2520	300	0	50	0
8	Drift	2520	2620	100	0	75	0
9	Solenoid 3	2620	2870	250	Sol0500	50	0
10	Drift	2870	3070	200	0	75	0
11	Solenoid 4	3070	3320	250	Sol0715	50	0
12	Drift	3320	3620	300	0	50	0

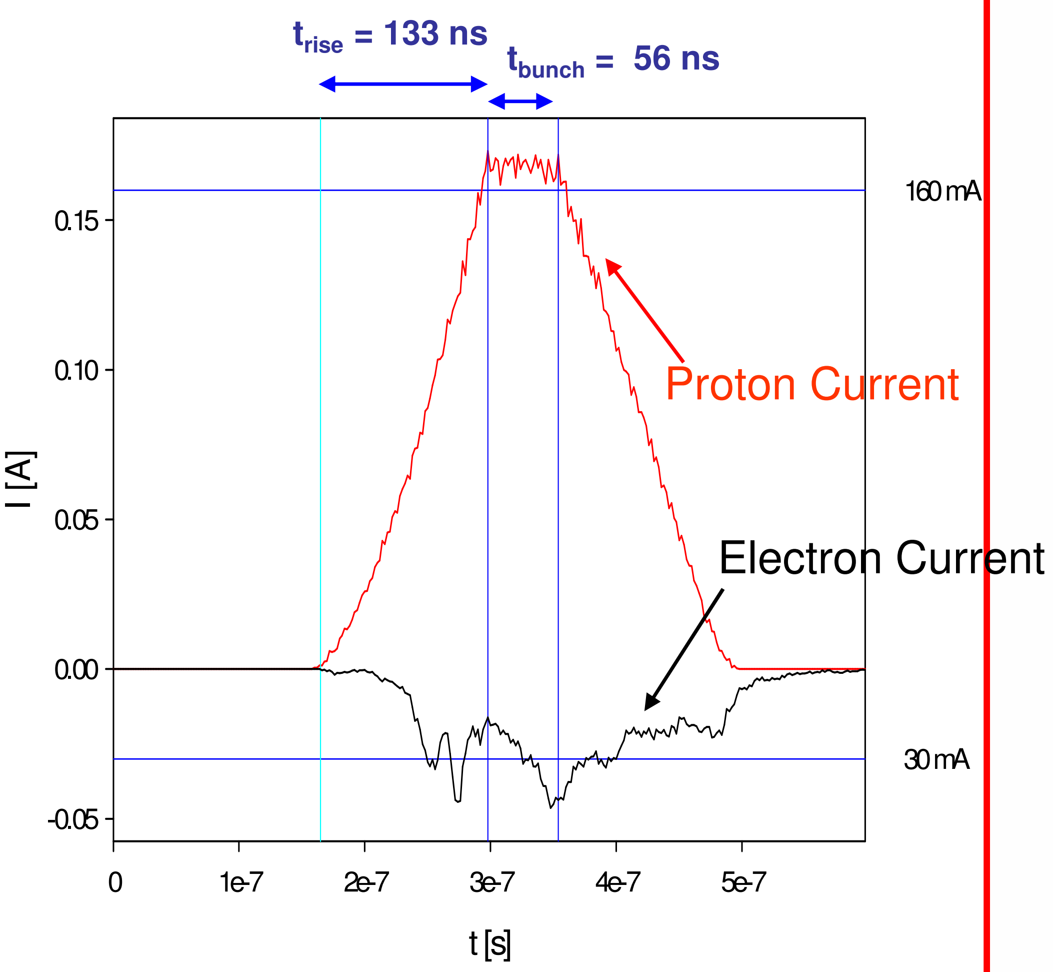
Magnetic Sweeping





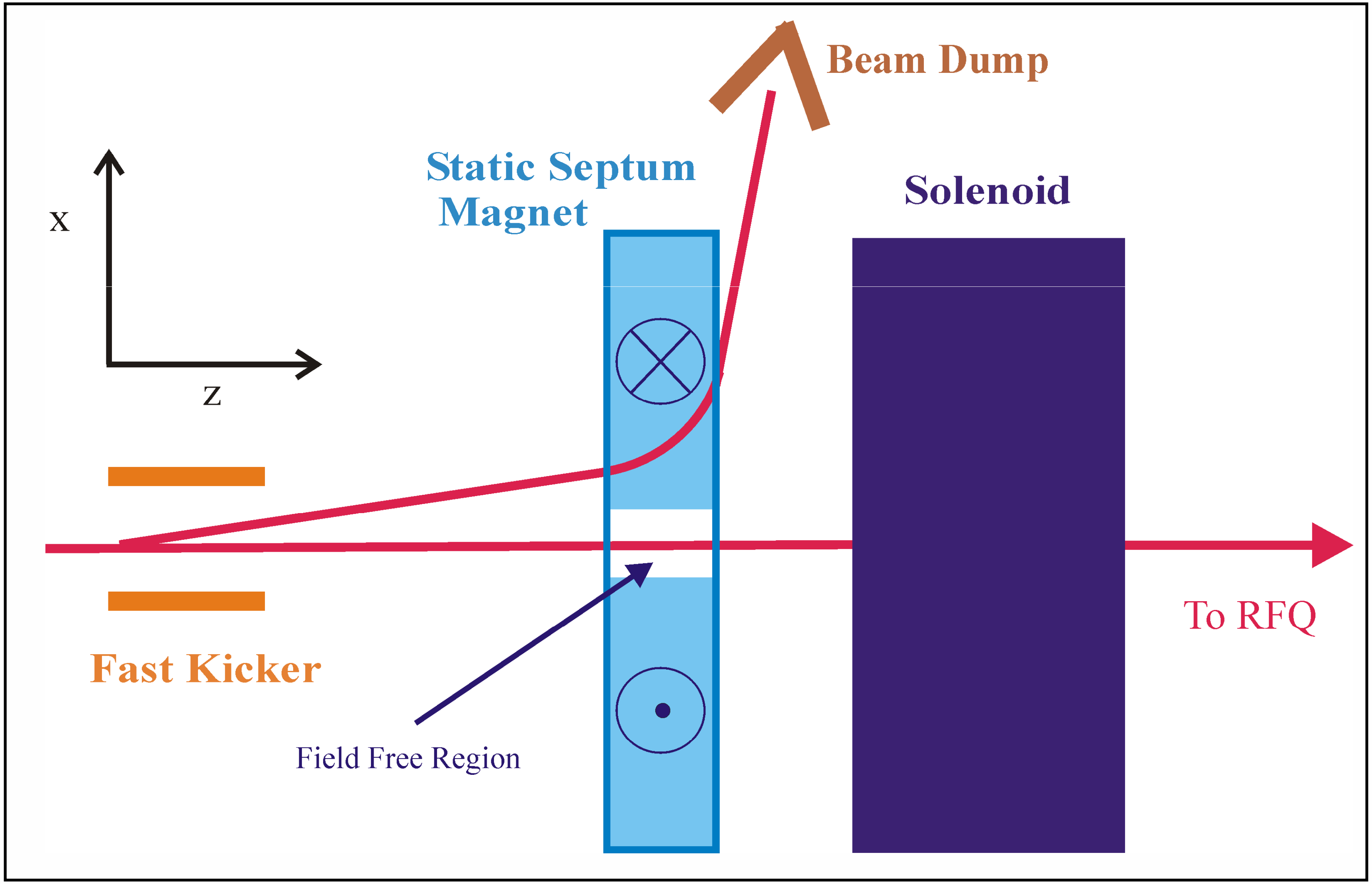
$$B(t) = 0.1T \cdot \sin(2\pi \cdot 125\ kHz \cdot t)$$

Magnetic Sweeping



$$B(t) = 0.1T \cdot \sin(2\pi \cdot 125\ kHz \cdot t)$$

Lower Kicker Field ⇒ Use of Septum Magnet



Trajectory - Magnetic Kicker

Sin_Phase_bei_Einschuss_in_Kicker := 0.5 π

Länge_Kicker := 0.15

B_max_Kicker := -0.0579

Auslenkung_nach_Kicker := 0.01312221339

Länge_Drift1 := 0.35

Auslenkung_nach_Drift1 := 0.07483132529

Einschusswinkel_in_Stat_Magnet := 9.999153574

Länge_Stat_Magnet := 0.1

B_Stat_Magnet := -0.323

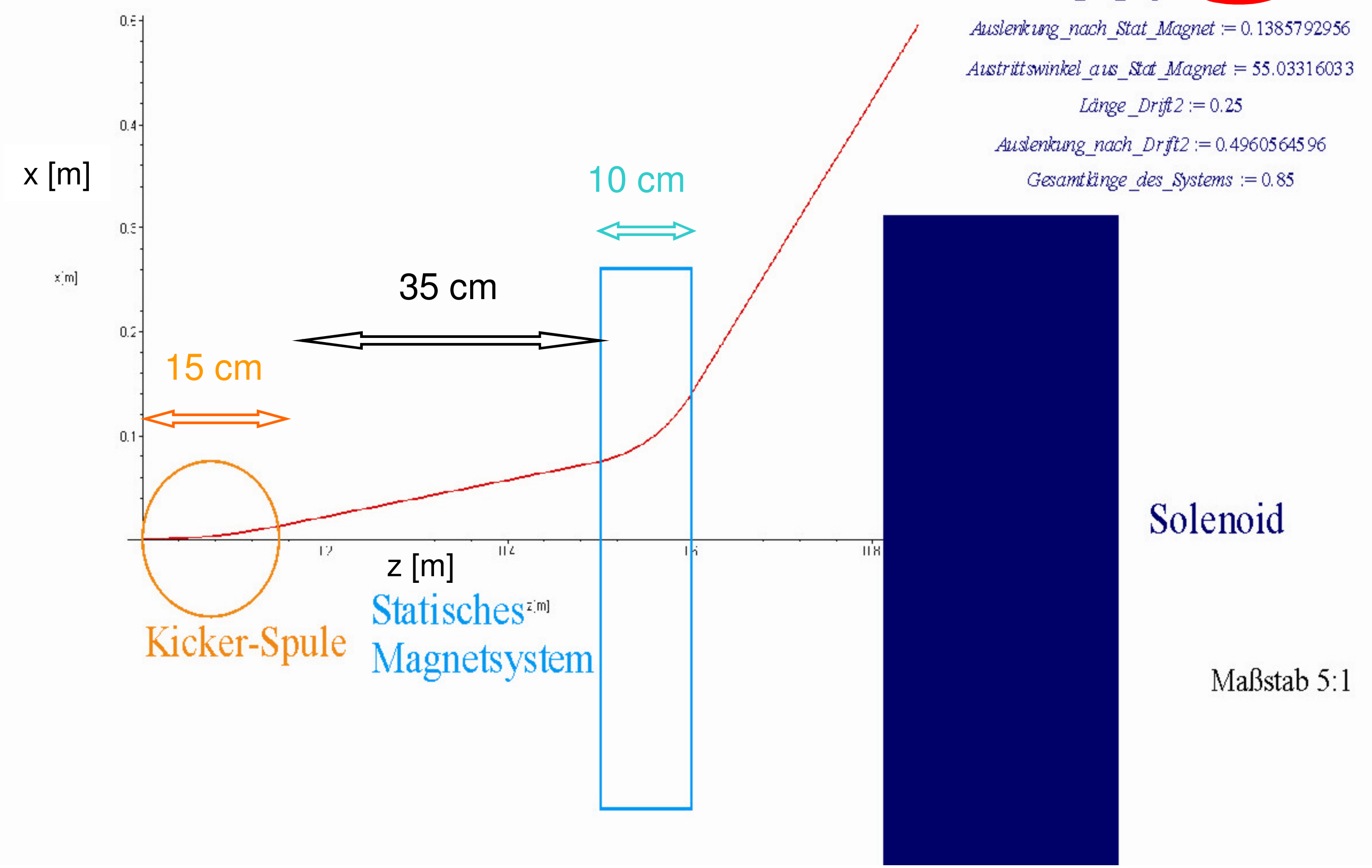
Auslenkung_nach_Stat_Magnet := 0.1385792956

Austrittswinkel_aus_Stat_Magnet := 55.03316033

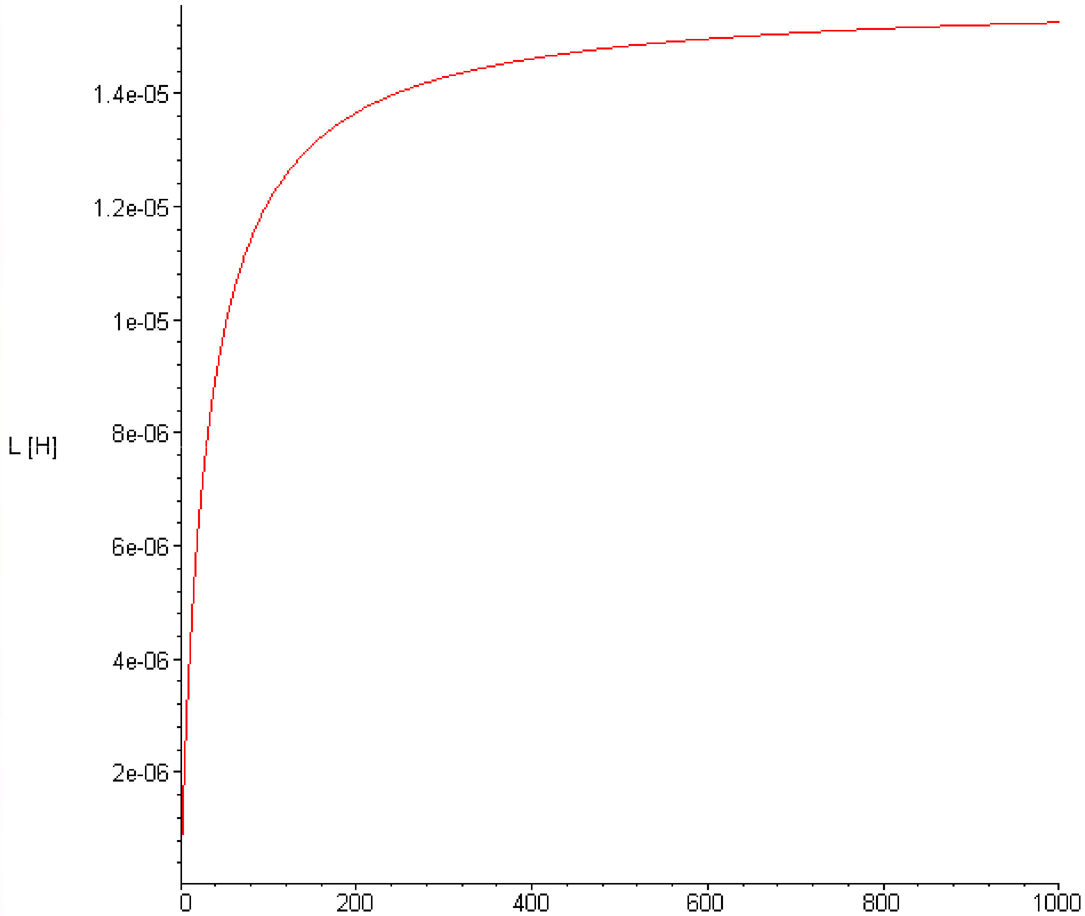
Länge_Drift2 := 0.25

Auslenkung_nach_Drift2 := 0.4960564596

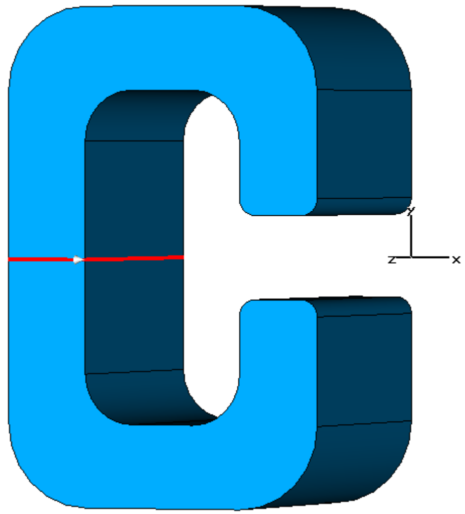
Gesamtlänge_des_Systems := 0.85



Low Inductive Design



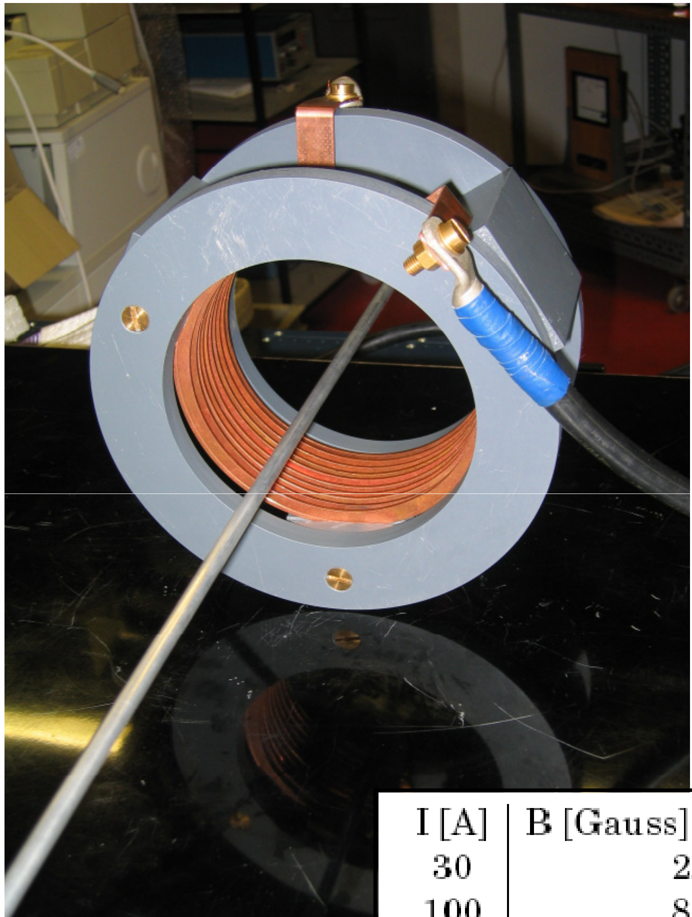
$l_{material}$ = 1.8 m
l_{gap} = 0.06 m
A = 0.03 m²
w = 5
mu_r = 1000



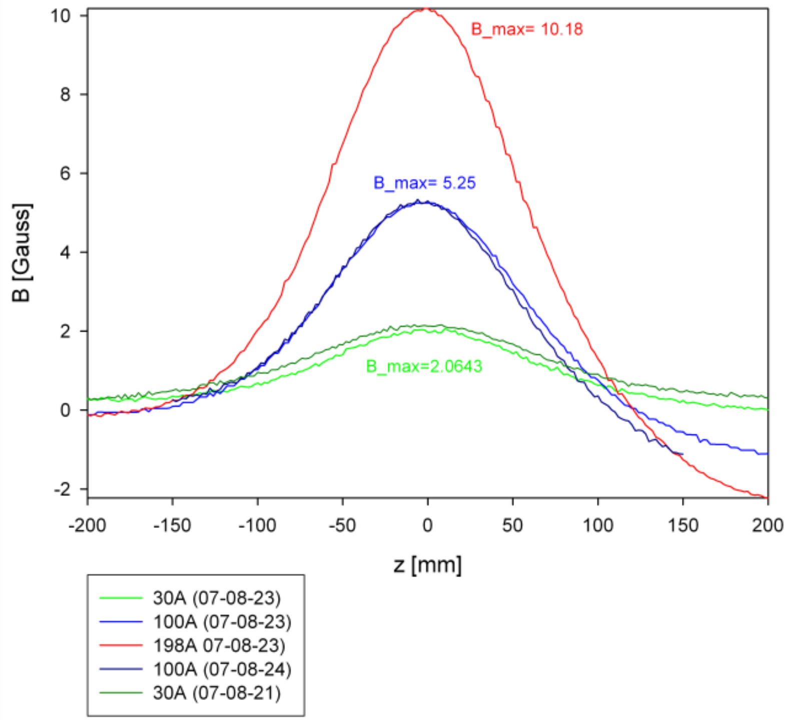
$$L(\mu_r) = \frac{w^2}{\frac{l_{material}}{\mu_0 \mu_r A} + \frac{l_{gap}}{\mu_0 A}}$$

$$|Z_L| = \omega L$$

Test: Cu-Coil



DC-Measurement

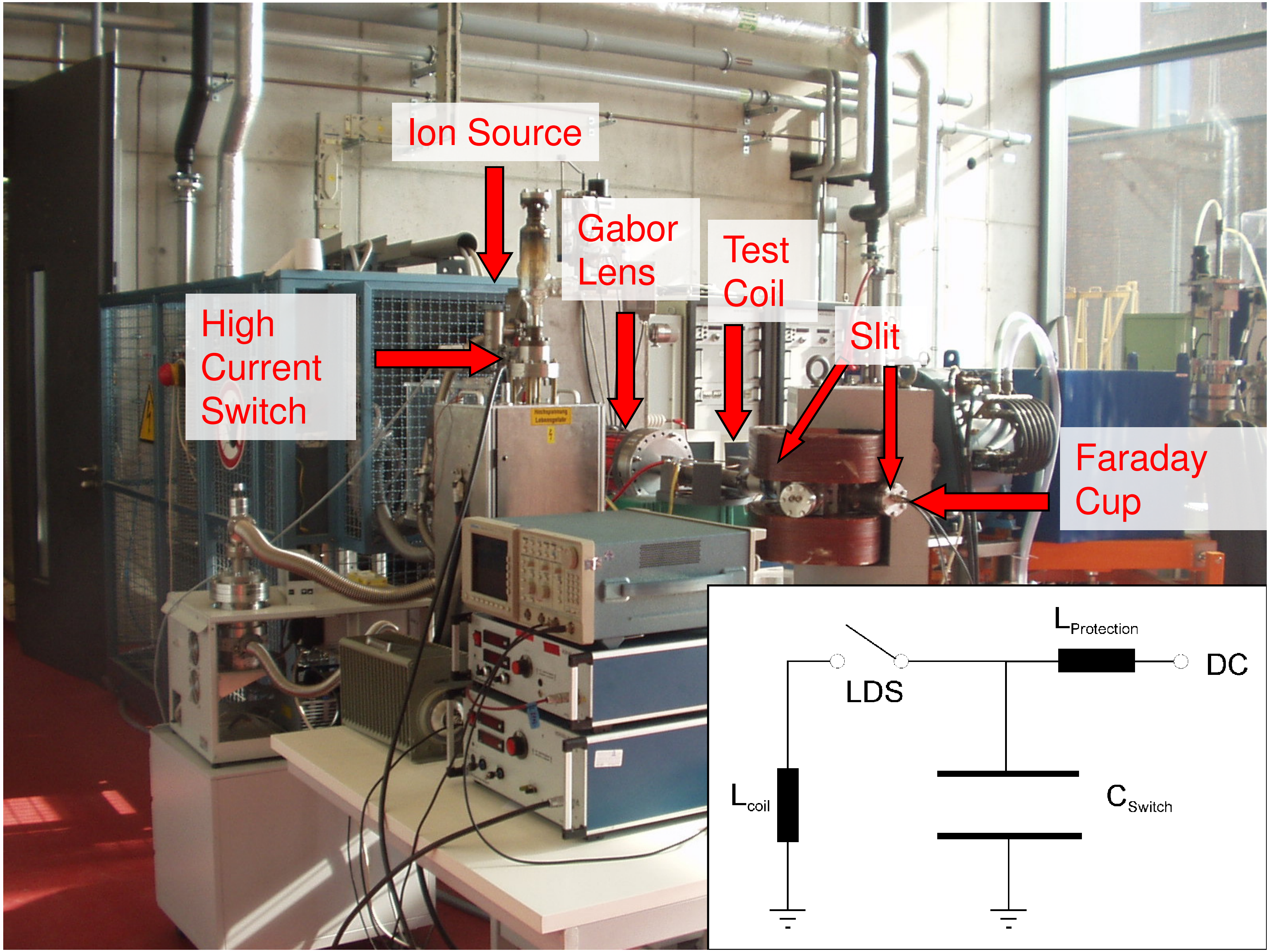


I [A]	B [Gauss] theoretisch	B [Gauss] experimentell	Verhältnis [%]
30	2.47	2.06	83.4
100	8.23	5.25	63.8
198	16.3	10.18	62.4

$$B(0) = \frac{\mu_0 I}{2r}$$

Extrapolation to 58mT
I = 11.3 kA (exper.) resp. I = 7.0 kA (theor.)

Test Stand


Ion Source
Gabor Lens
Test Coil
High Current Switch
Slit
Faraday Cup
$L_{Protection}$
DC
LDS
L_{coil}
C_{Switch}

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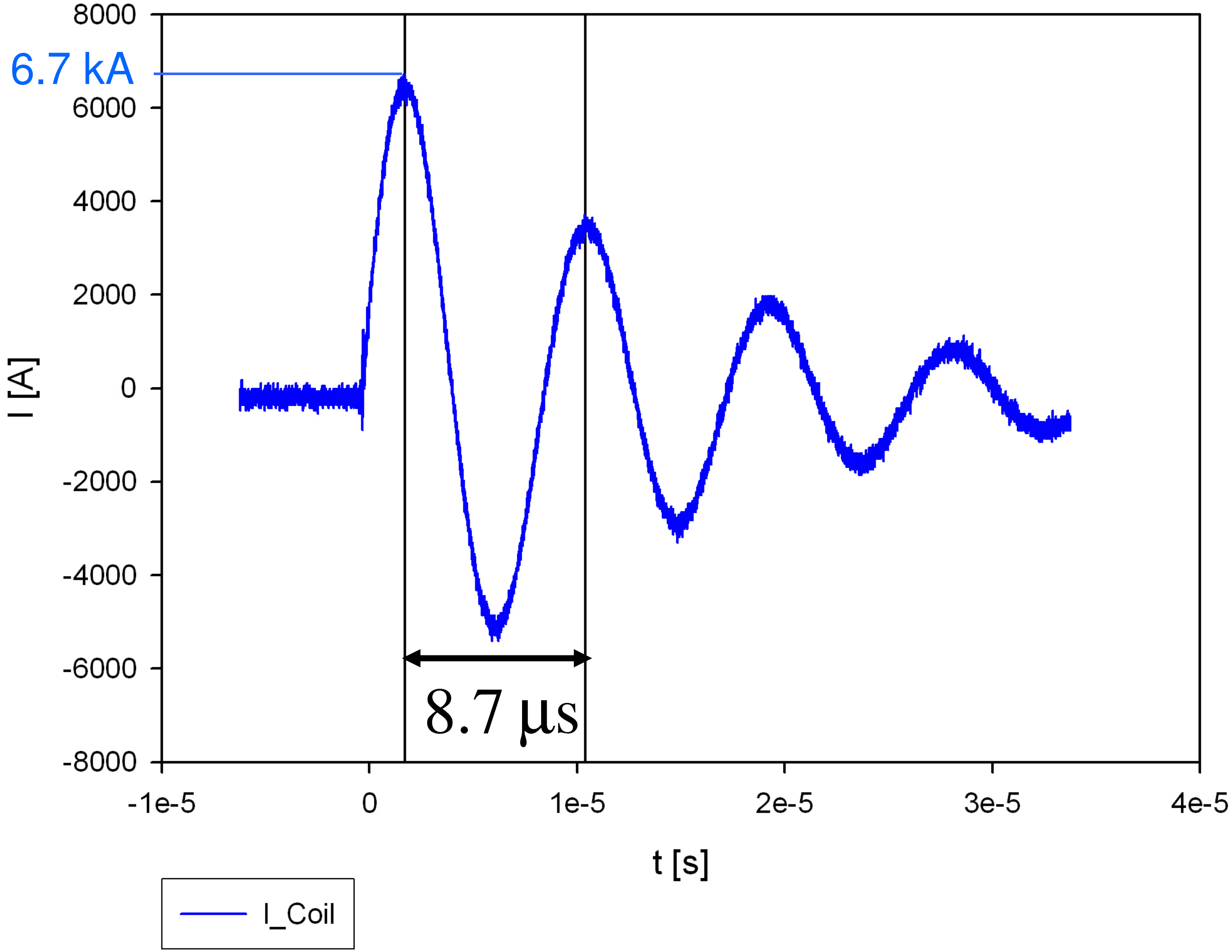
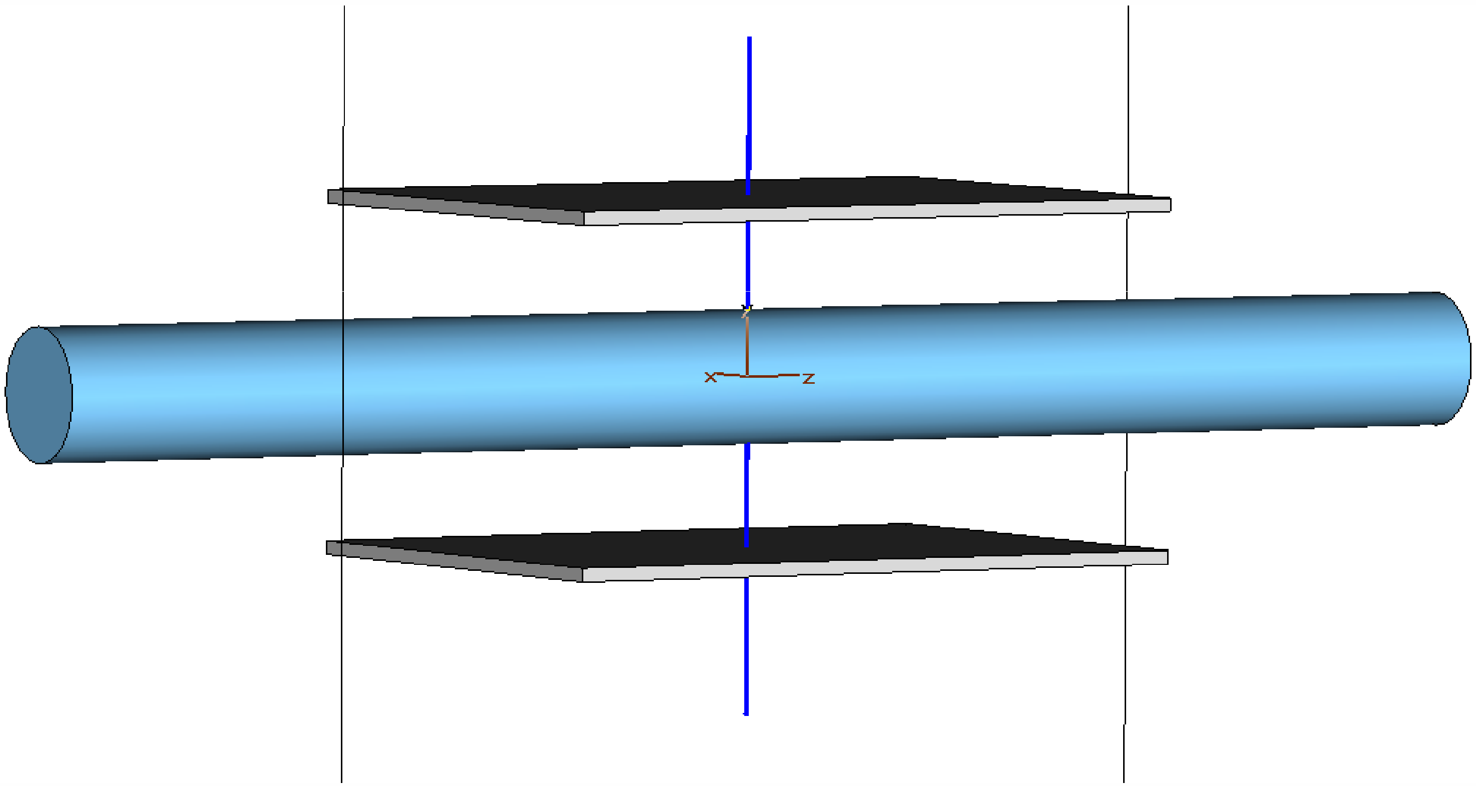
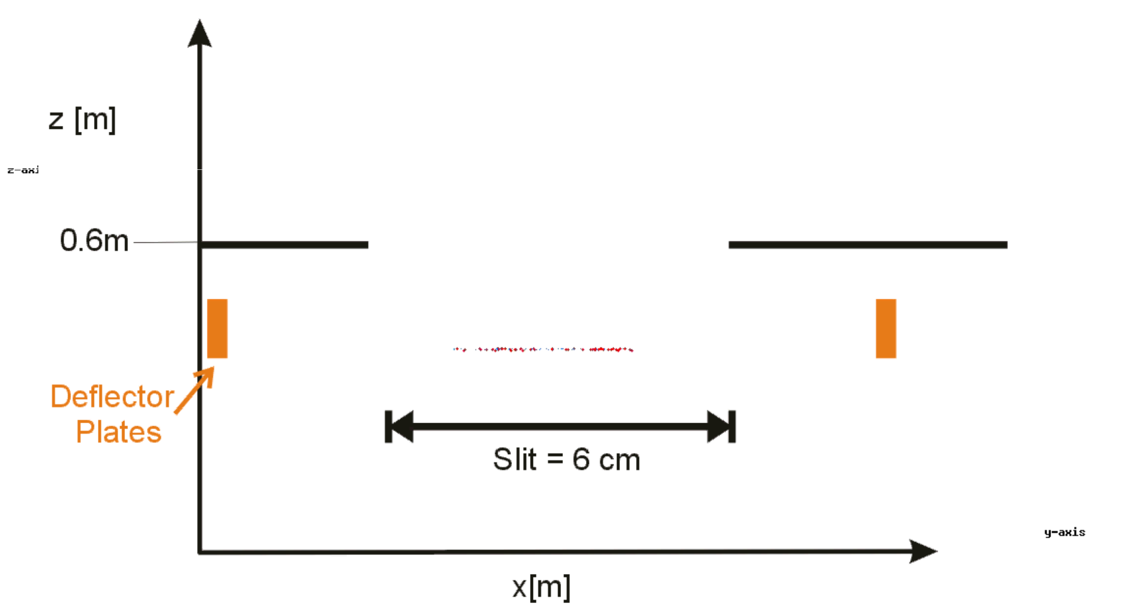
Current Pulse



Electric Kicker



Simulation Electric Kicker (Video)



Blue: Proton Beam

Red: Electrons

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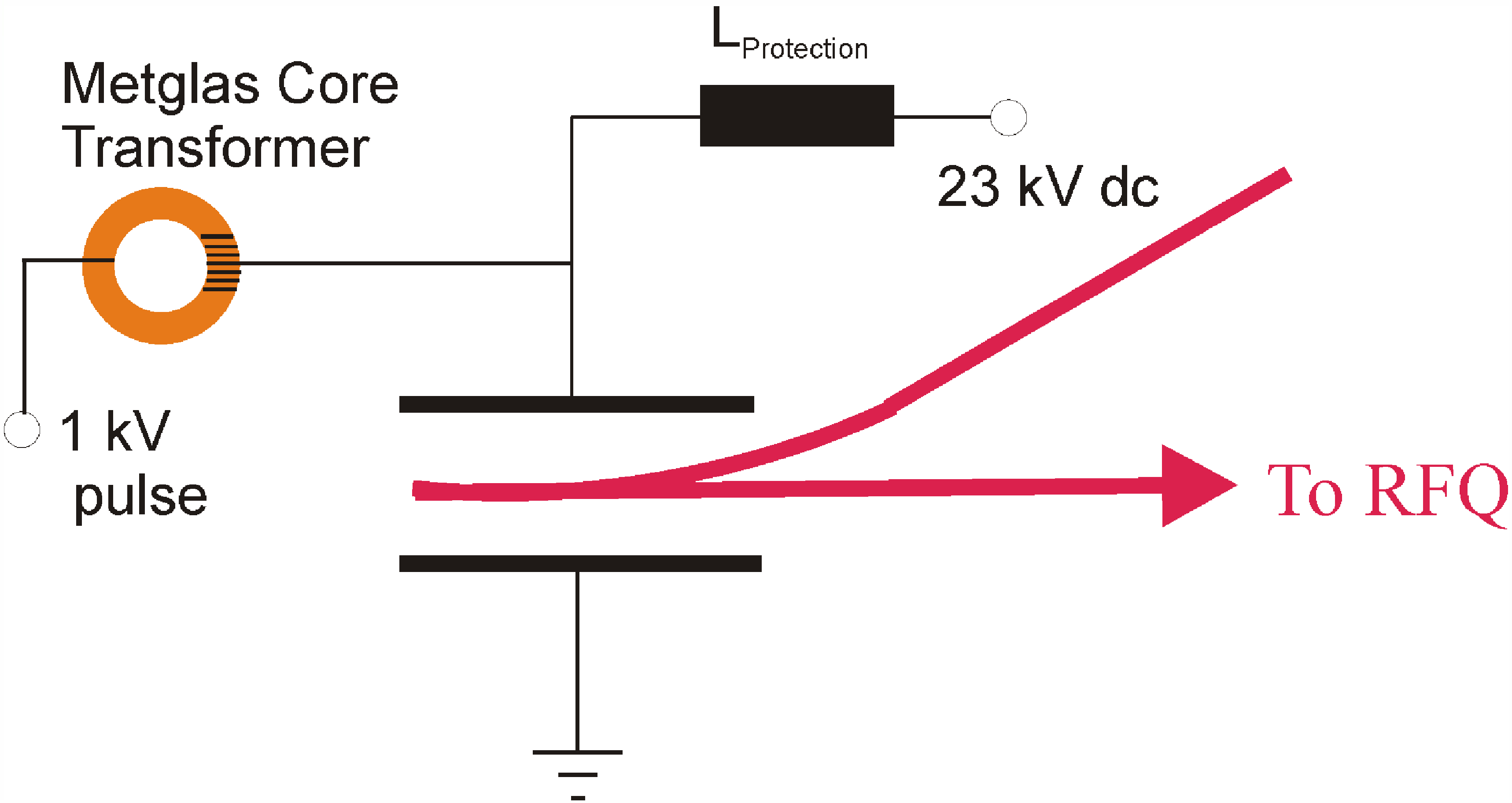
Technical Realization



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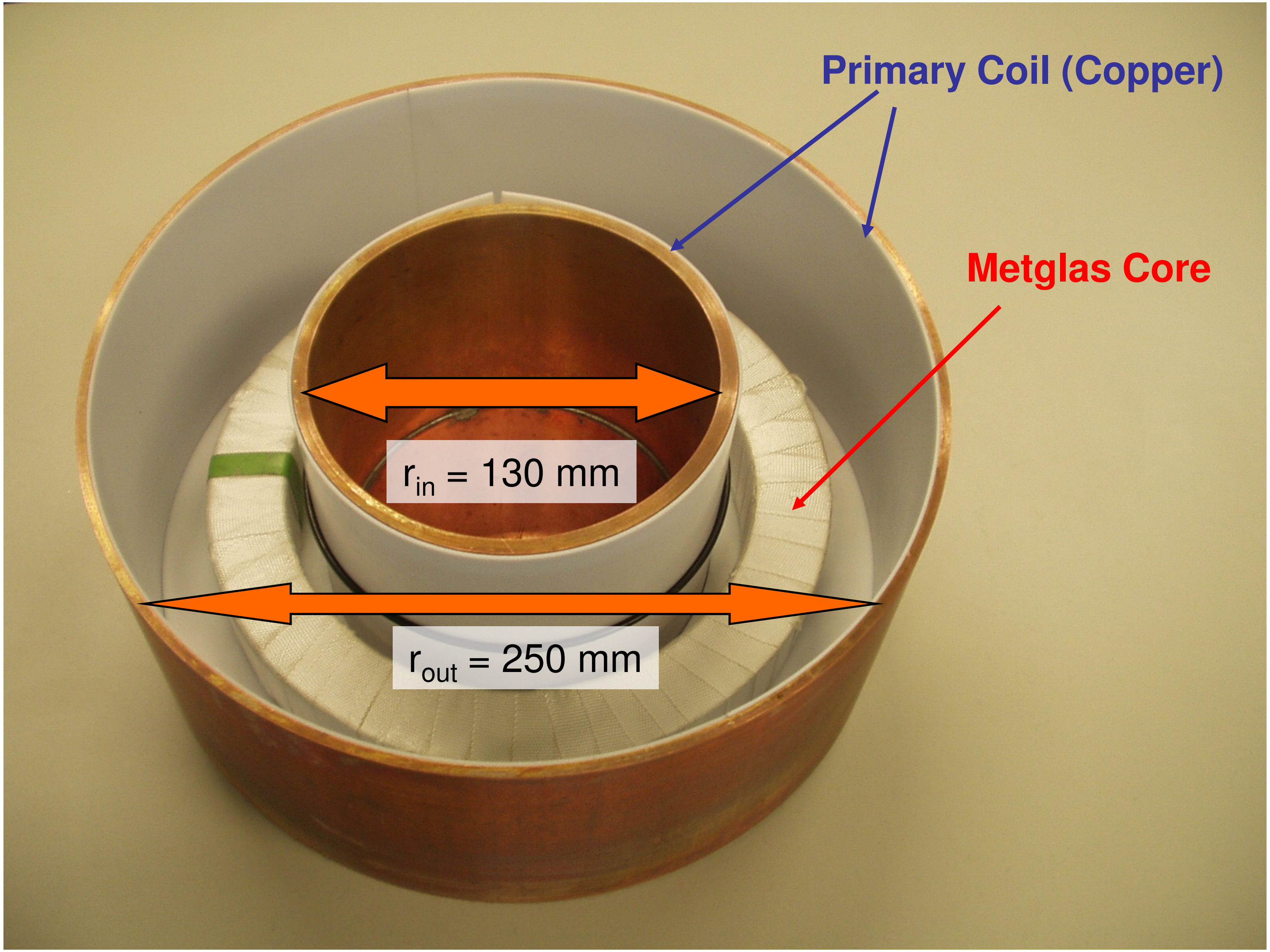
Transformer Experiment



Kicker

	Electric	**Magnetic**
Beam Stiffness	$E\rho \approx 240kV$	$B\rho = 0.05\,Tm$
Proportional to	mv^2	mv
Gap Size	10 cm	6 cm
Length	20 cm	15 cm
Field, alpha=10°	E = 211 kV/m	B = 57.9 mT
Energy Density	0.2 J/m^3	1.3 kJ/m^3
Space Charge Compensation	0%	15-20% ?
Reliability	Sparking? Sputtering? Operation Time?	Power Consumption?

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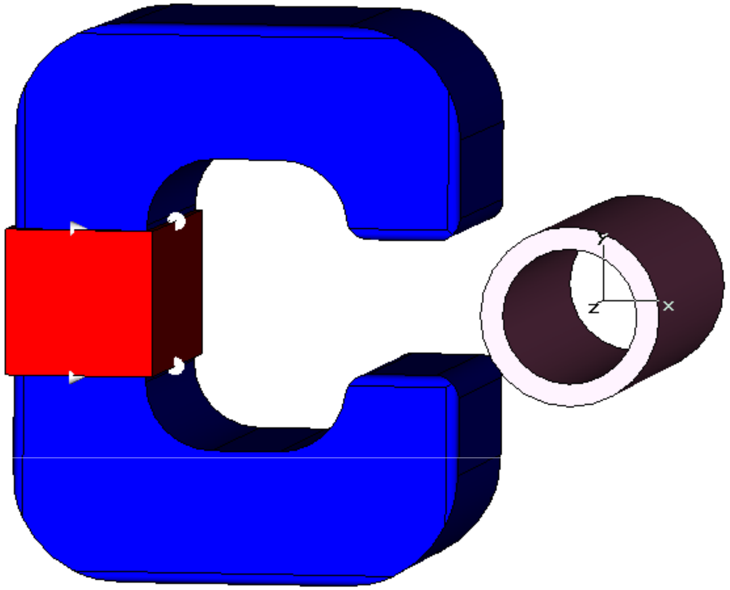
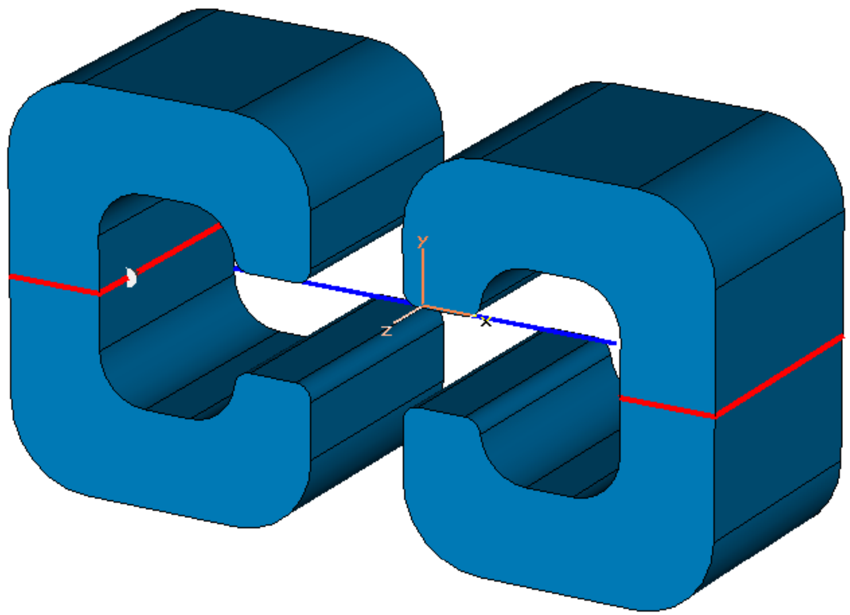
Septum Magnet

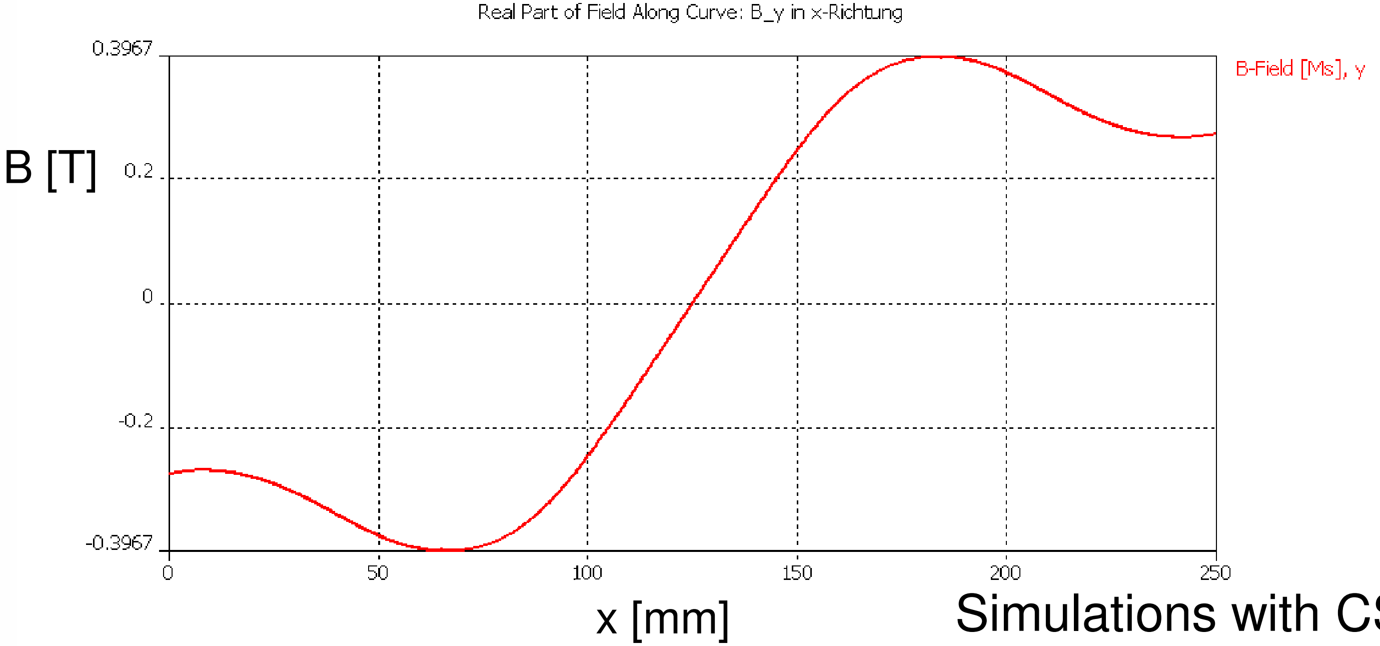


Lambertson Type

Ostiguy et al., **A New Lambertson Magnet for the FNAL 400 MeV Linac,** FERMILAB-Conf-03/115 July 2003

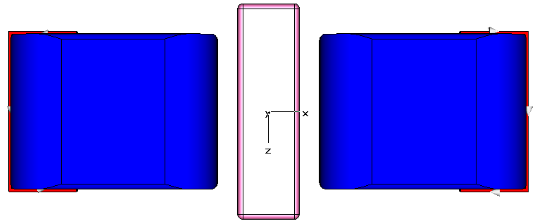
Massless Septum Magnet

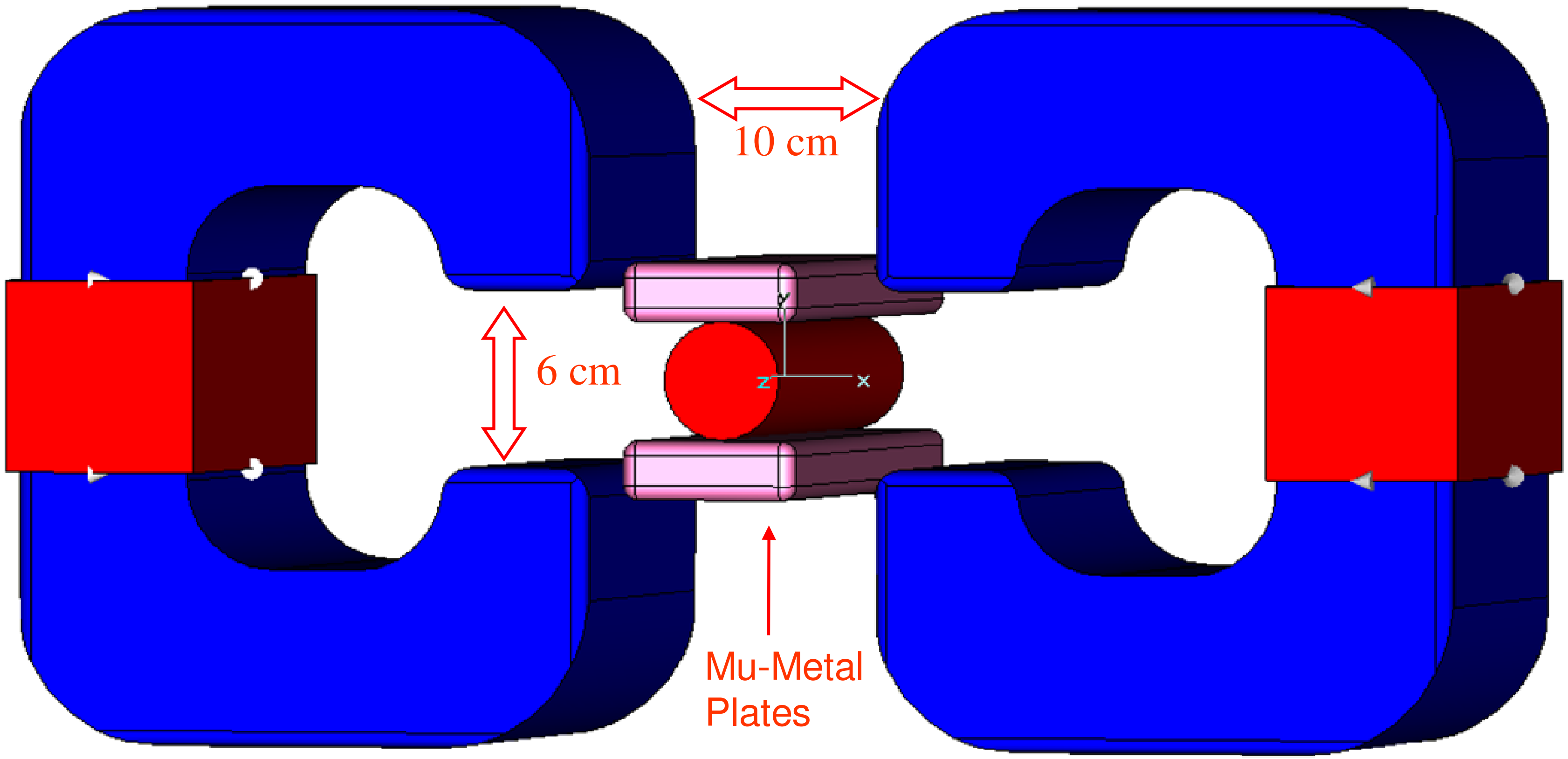




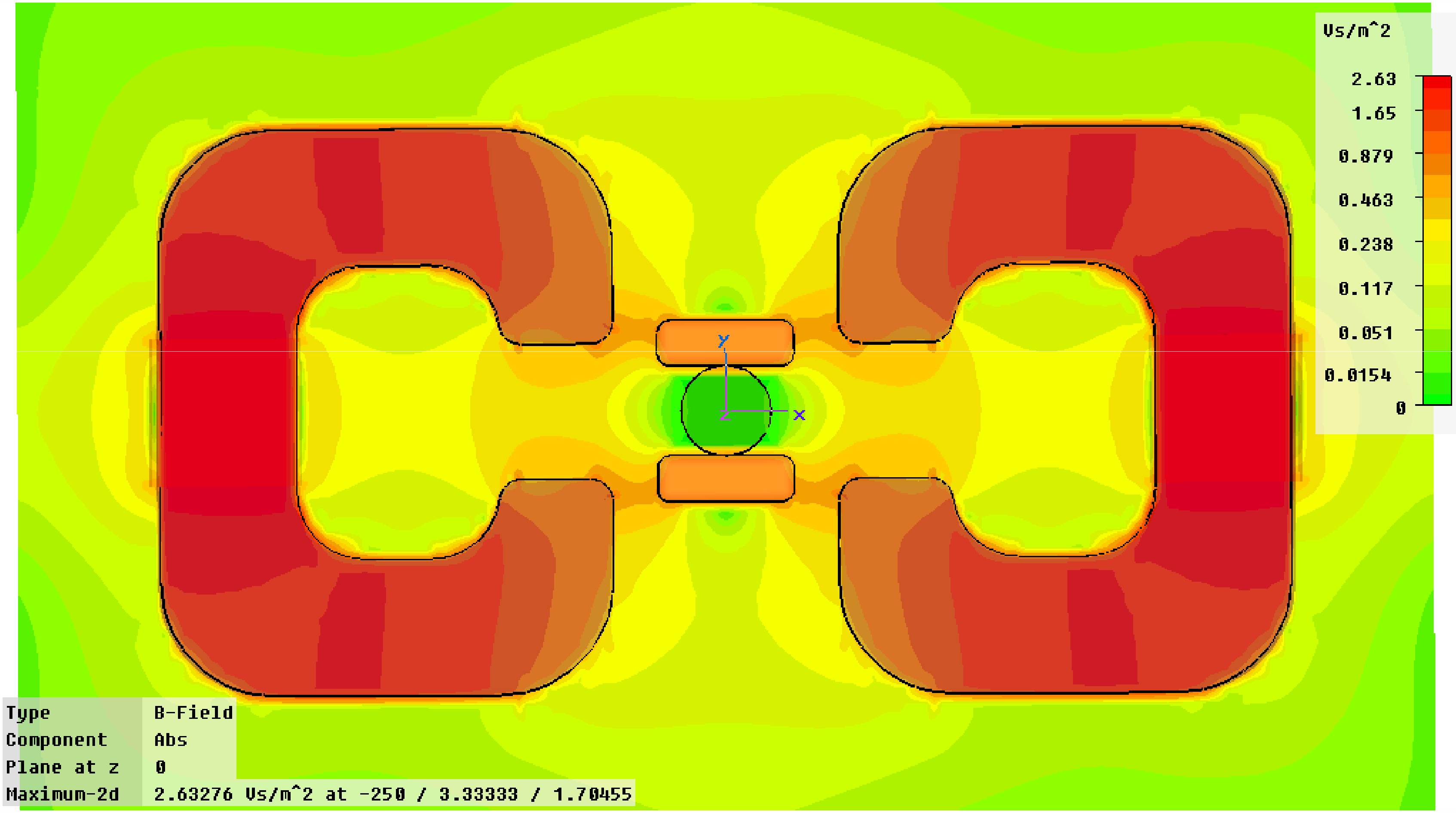
Simulations with CST EM-Studio

Mu-Metal Plates



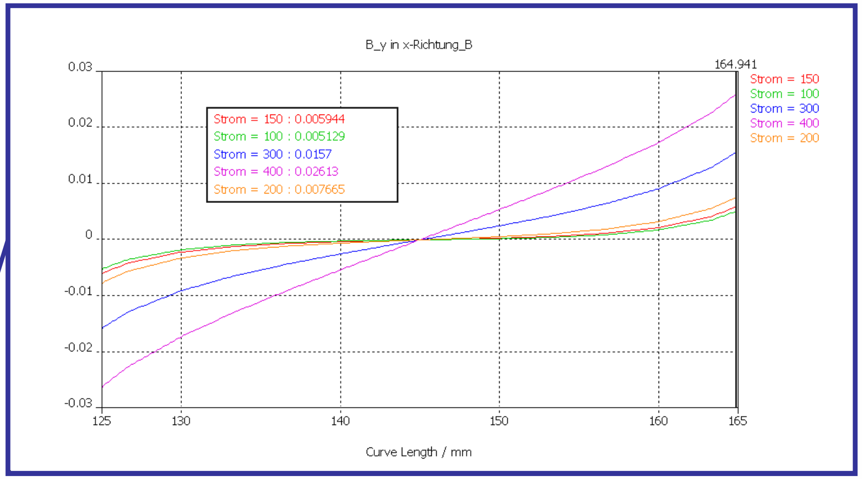


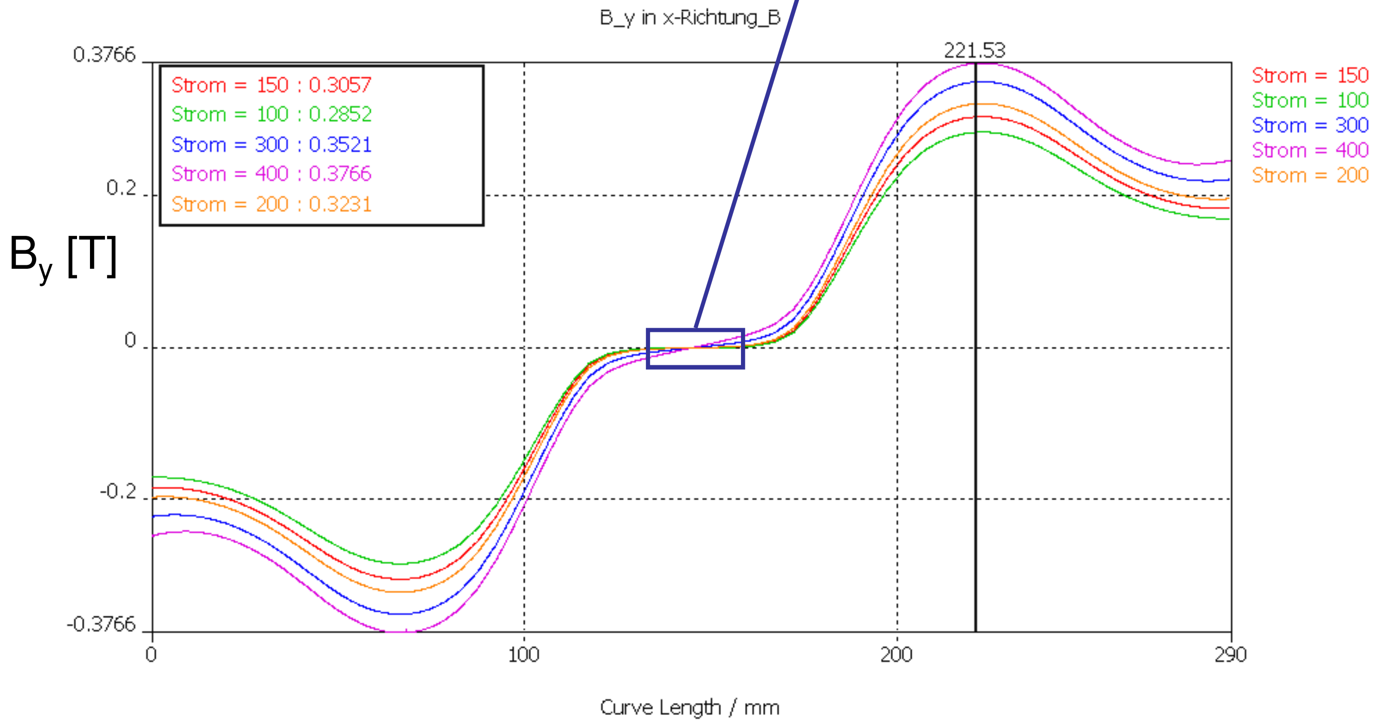
Magnetic Induction



w = 200
I= 150 A

„Good Field Region“





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   - FRANZ
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2. **Chopper**
   - Concepts
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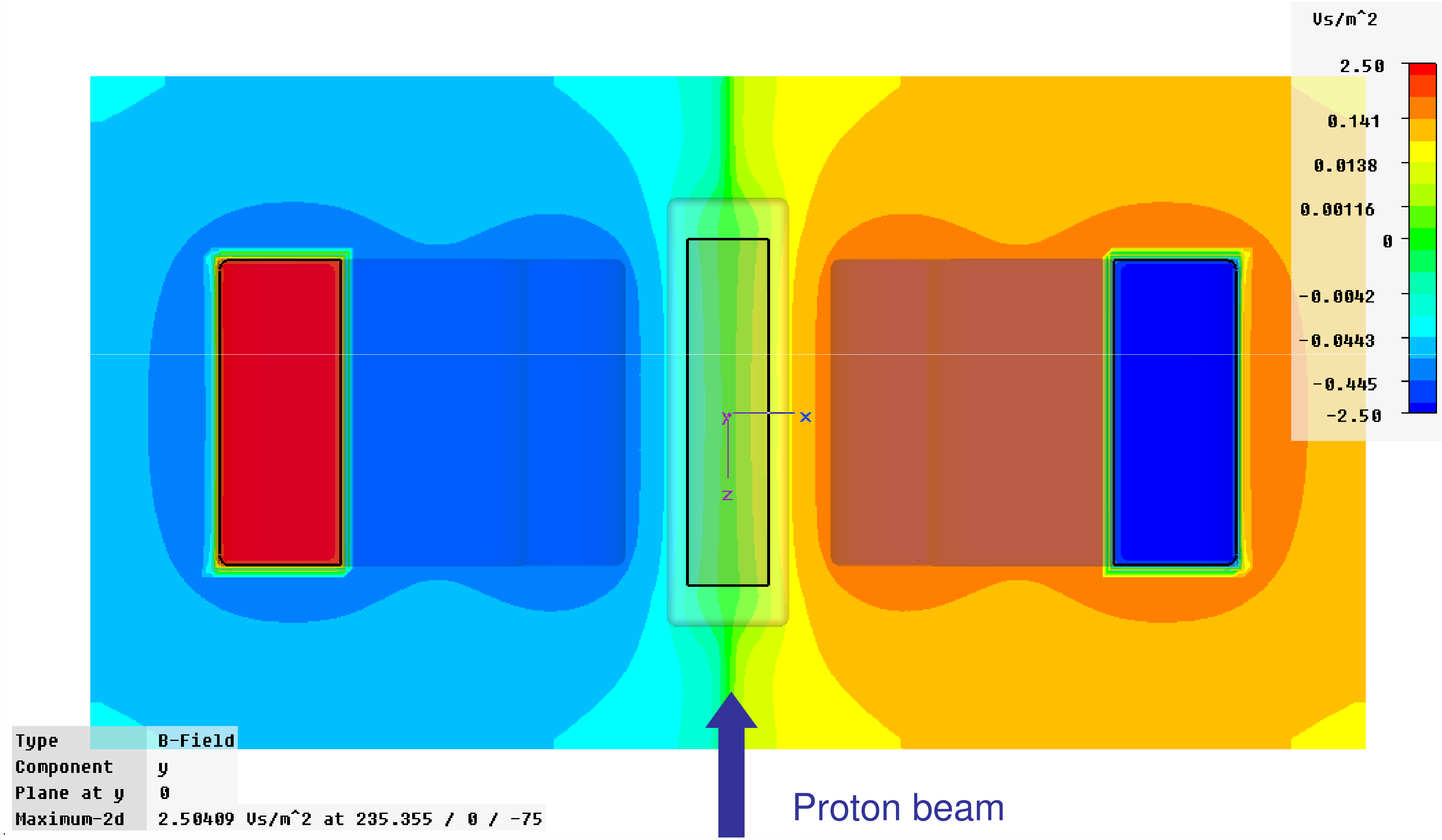
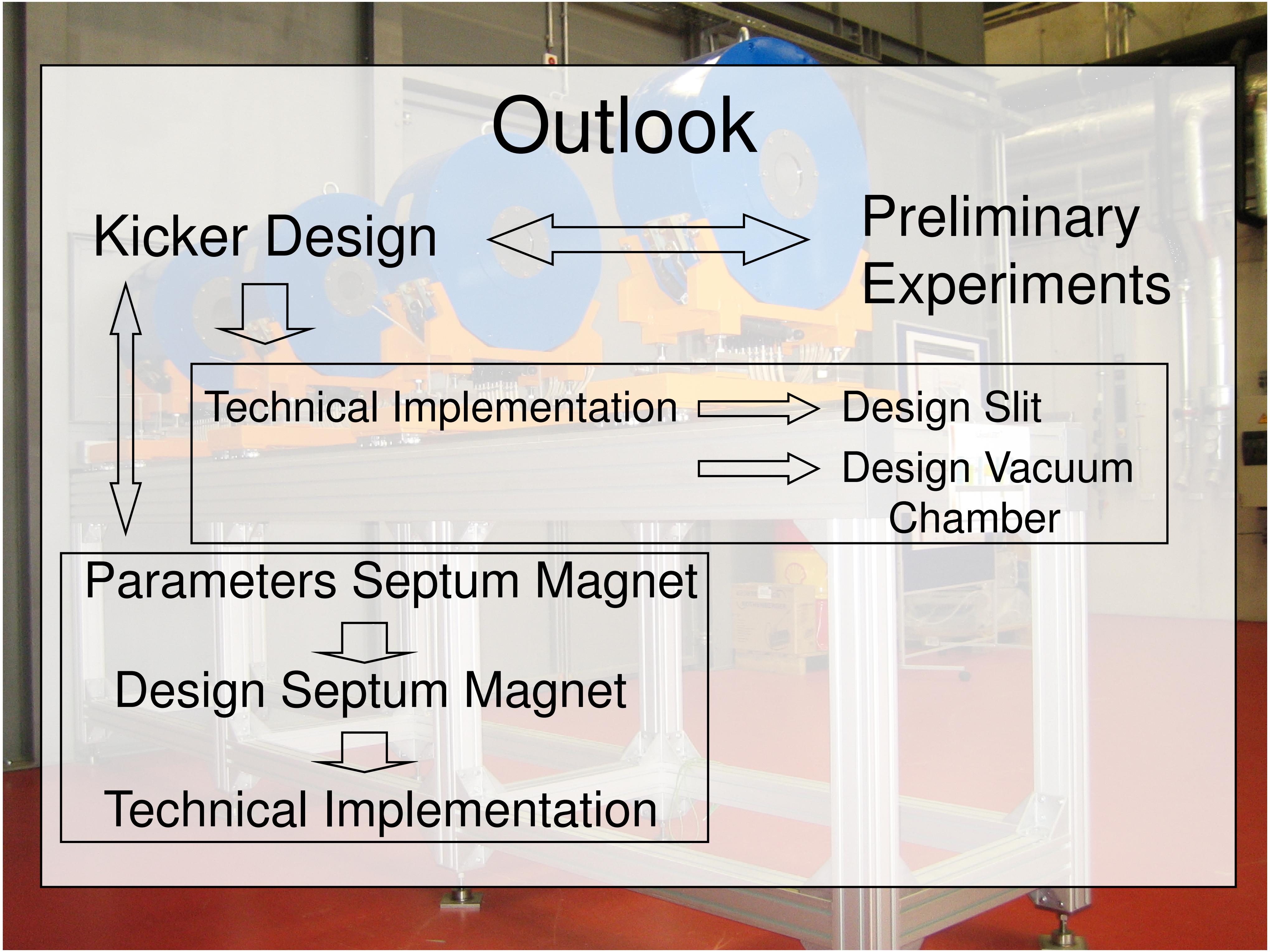
     - Conclus.
   - **Septum**
     - Traditional
     - Massless
     - **Simulation**
3. **Outlook**

B_y Top View



Summary

- Transport Simulations LEBT
- LEBT Installation under Progress
- Multi-Particle Simulations for Electric and Magnetic Kicker
- Development of Chopper Concept
- Preliminary Experiments for Electric and Magnetic Kicker
- New Concept of Massless Septum Magnet
- Optimization of Septum Magnet in Simulations with CST EM Studio


Outlook
Kicker Design
Preliminary Experiments
Technical Implementation
Design Slit
Design Vacuum Chamber
Parameters Septum Magnet
Design Septum Magnet
Technical Implementation