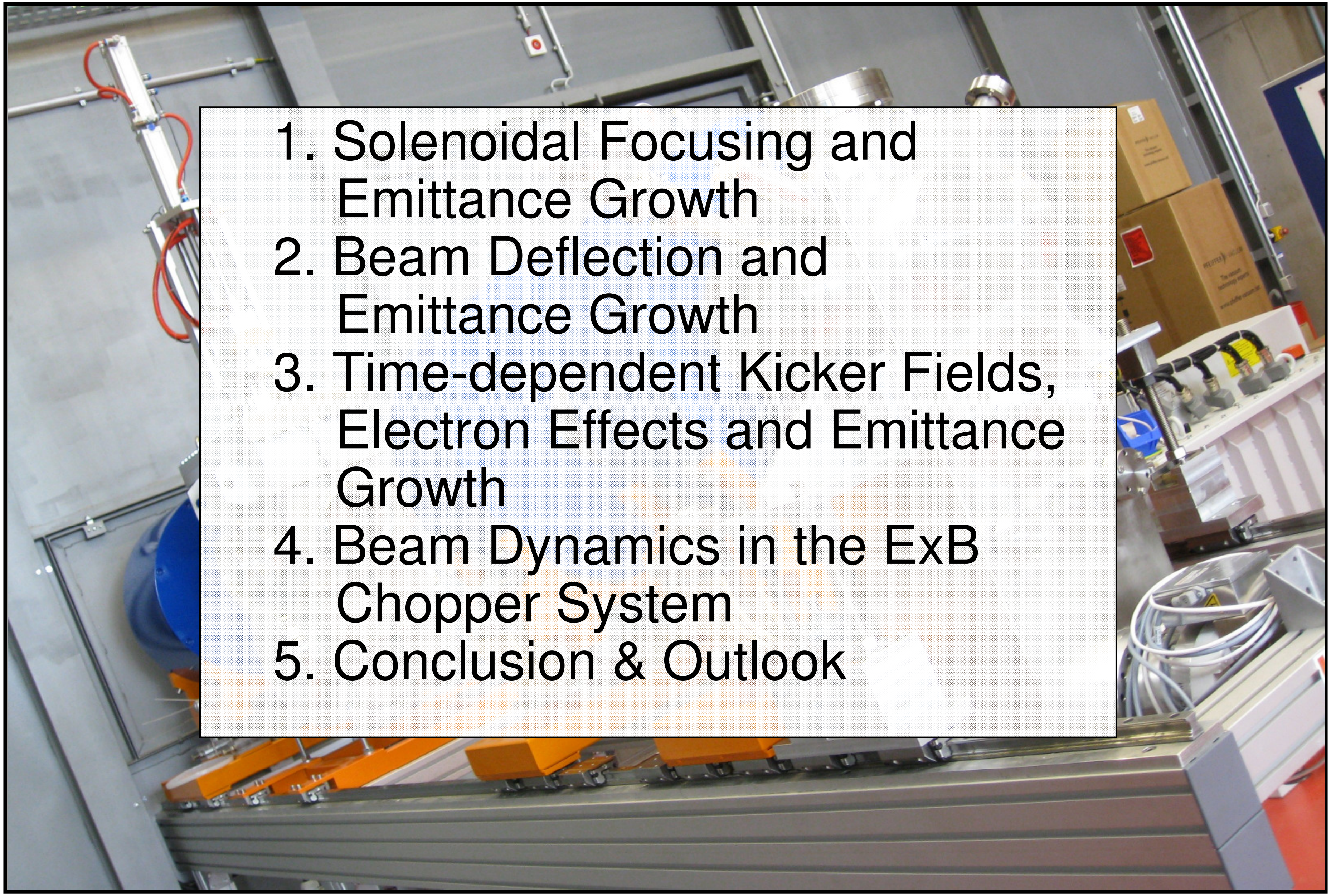
2010/03/09

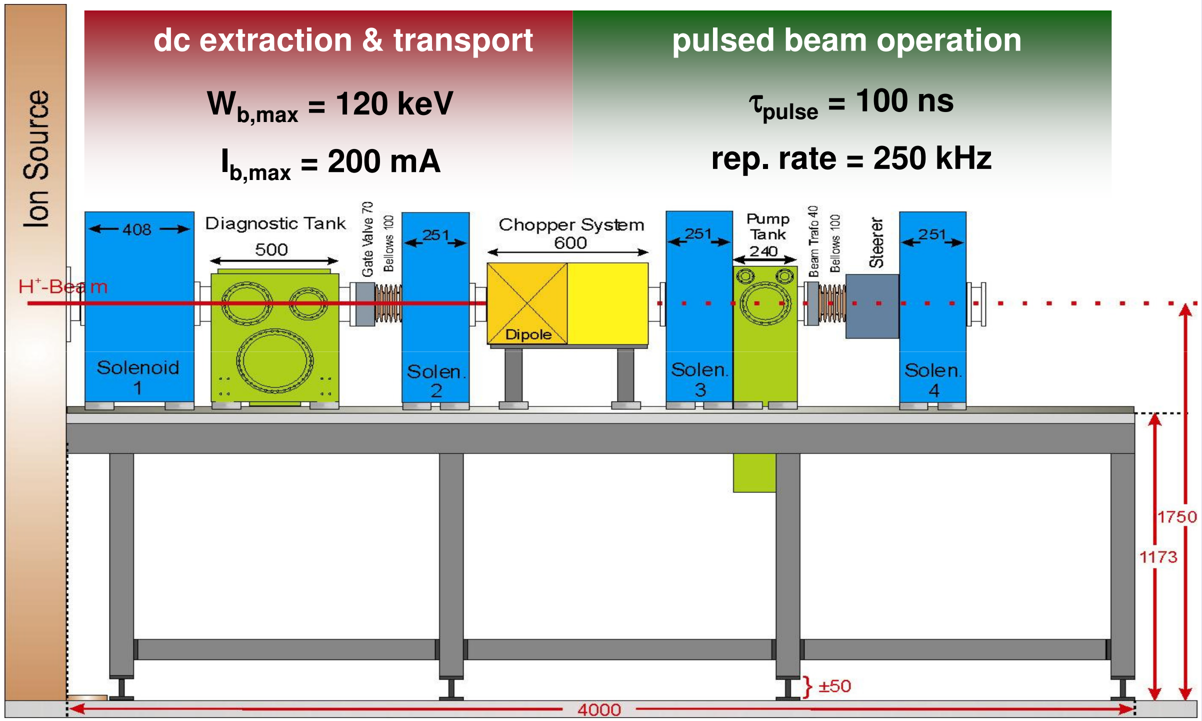
Beam Dynamics and Emittance Growth

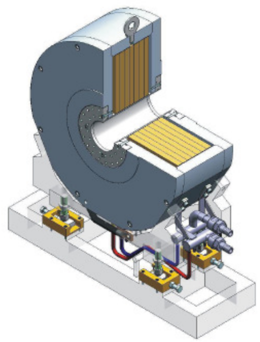
Christoph Wiesner

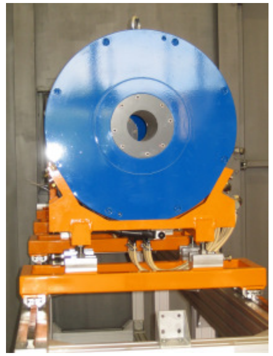


1. Solenoidal Focusing and Emittance Growth
2. Beam Deflection and Emittance Growth
3. Time-dependent Kicker Fields, Electron Effects and Emittance Growth
4. Beam Dynamics in the ExB Chopper System
5. Conclusion & Outlook

Low Energy Beam Transport (LEBT) Section



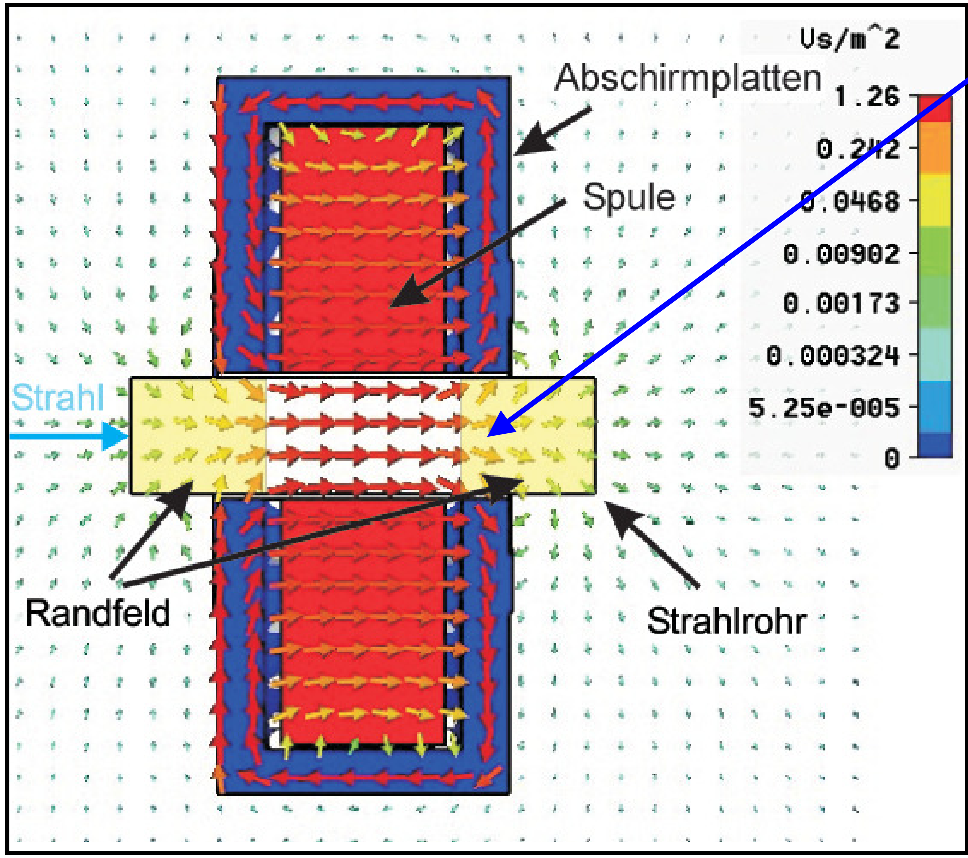


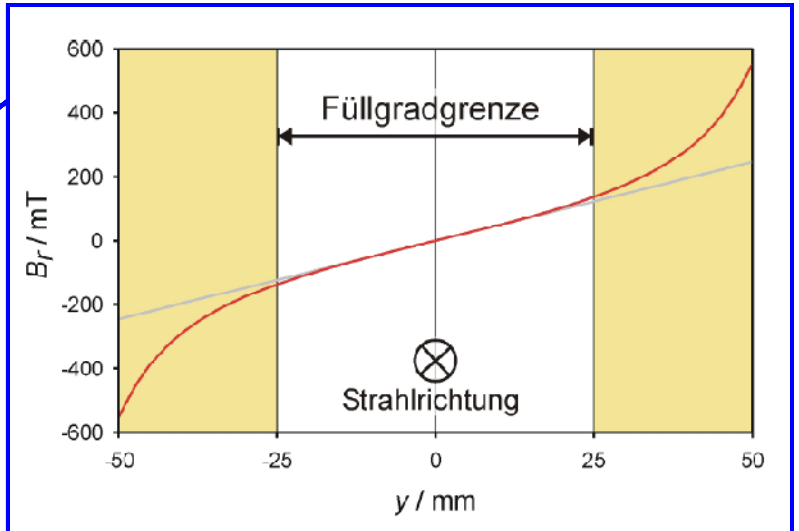


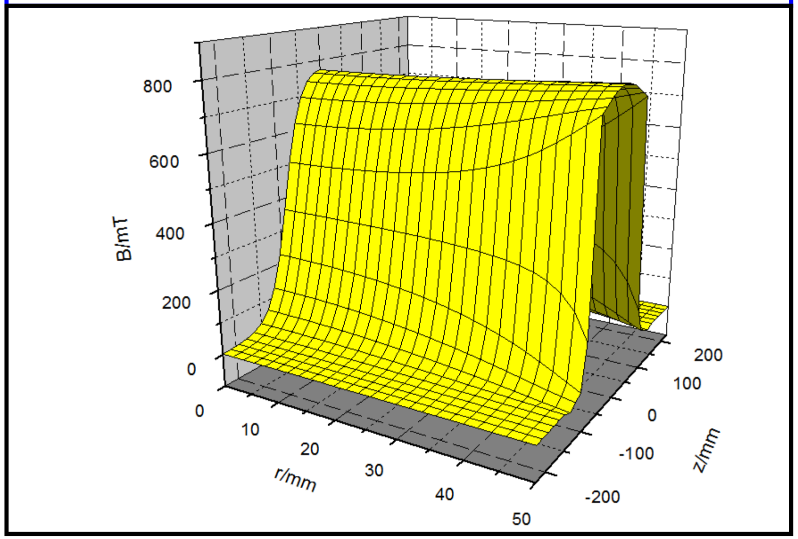
Solenoid Typ I:
Aperture 100 mm, B_z = 0.78 T,
length 251 mm

Solenoid Typ II:
Aperture 150 mm, B_z = 0.66 T,
length 408 mm

Field Distribution

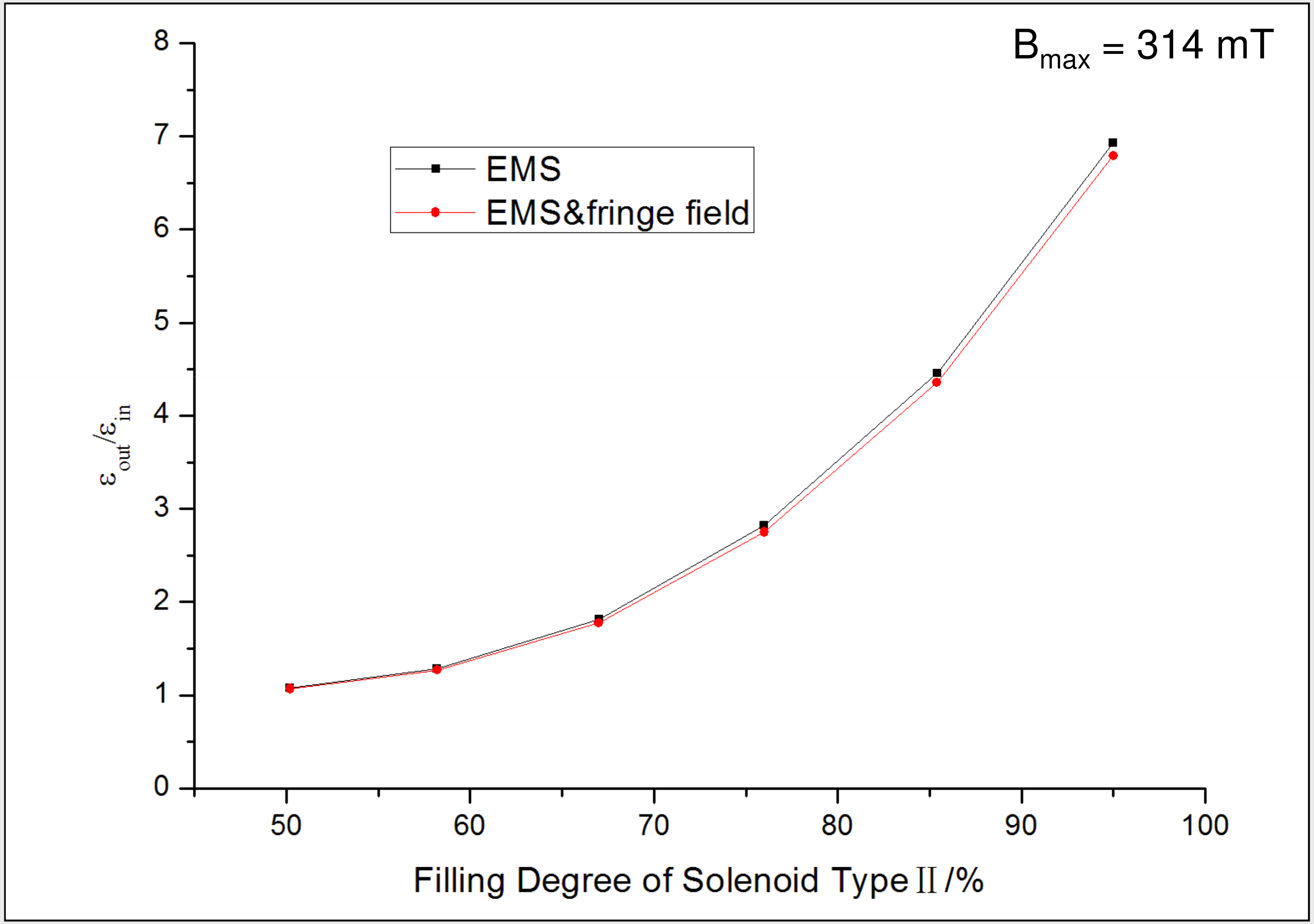




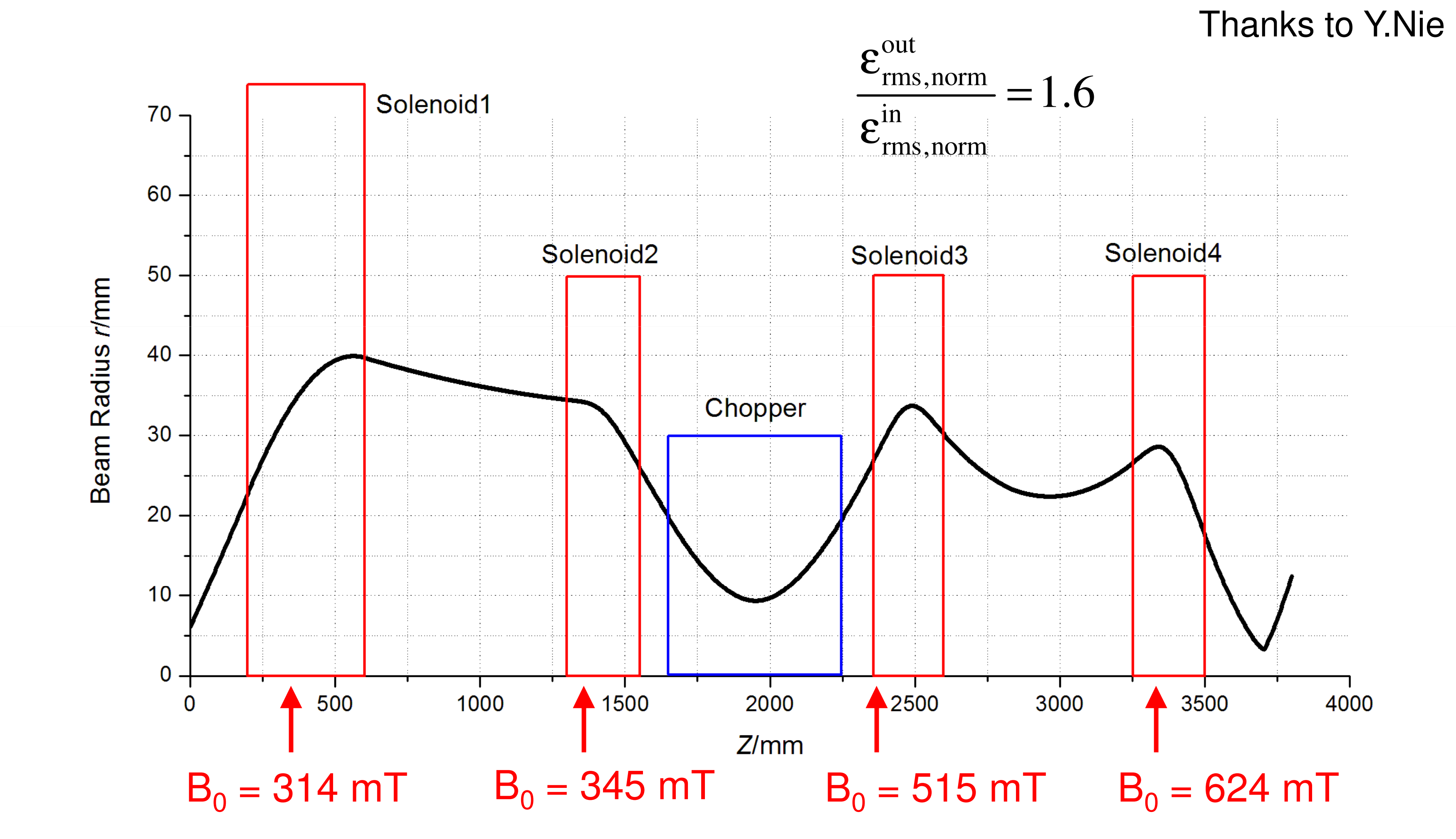


Field Calculations using CST EMS.

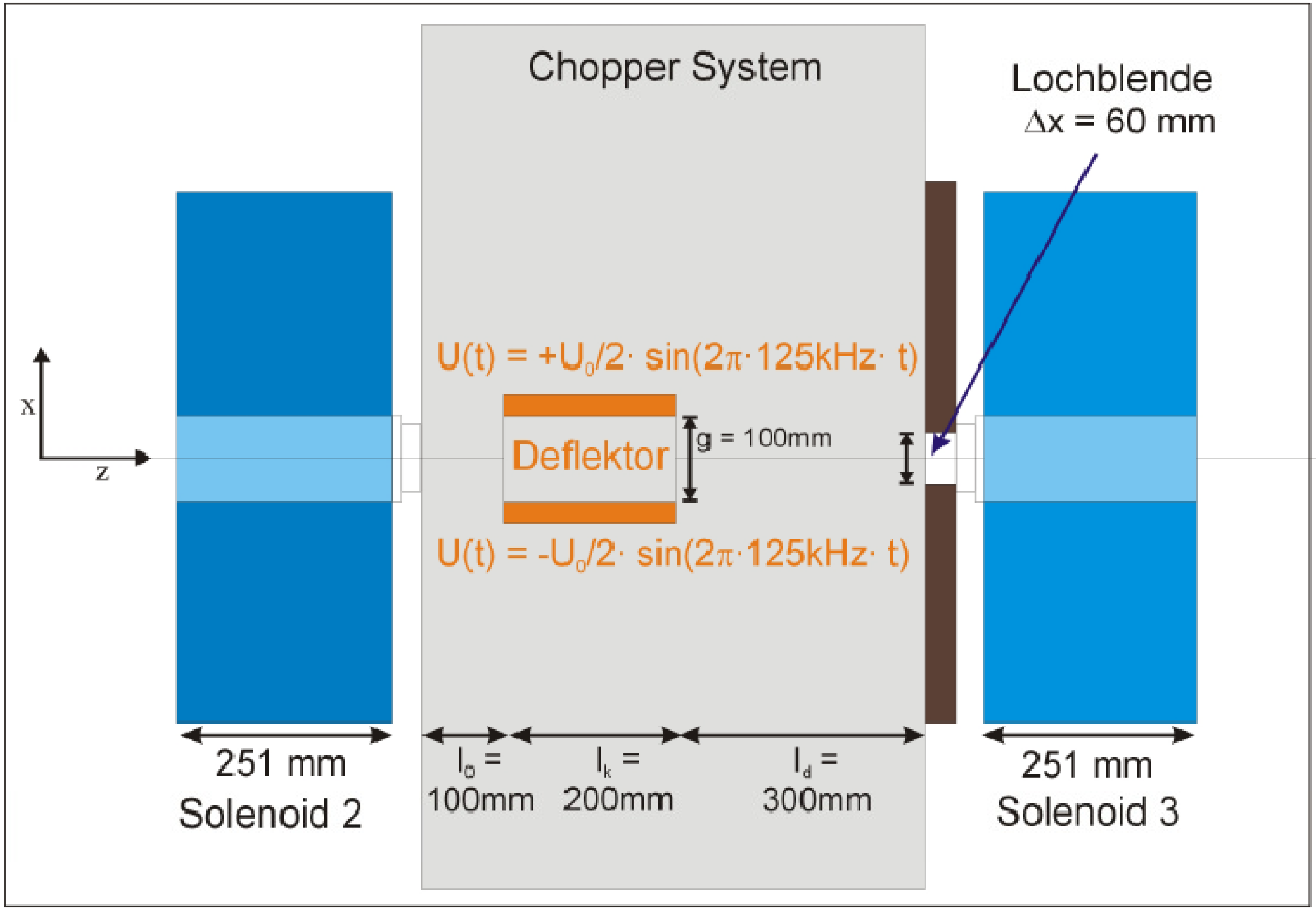
Emittance Growth and Filling Degree



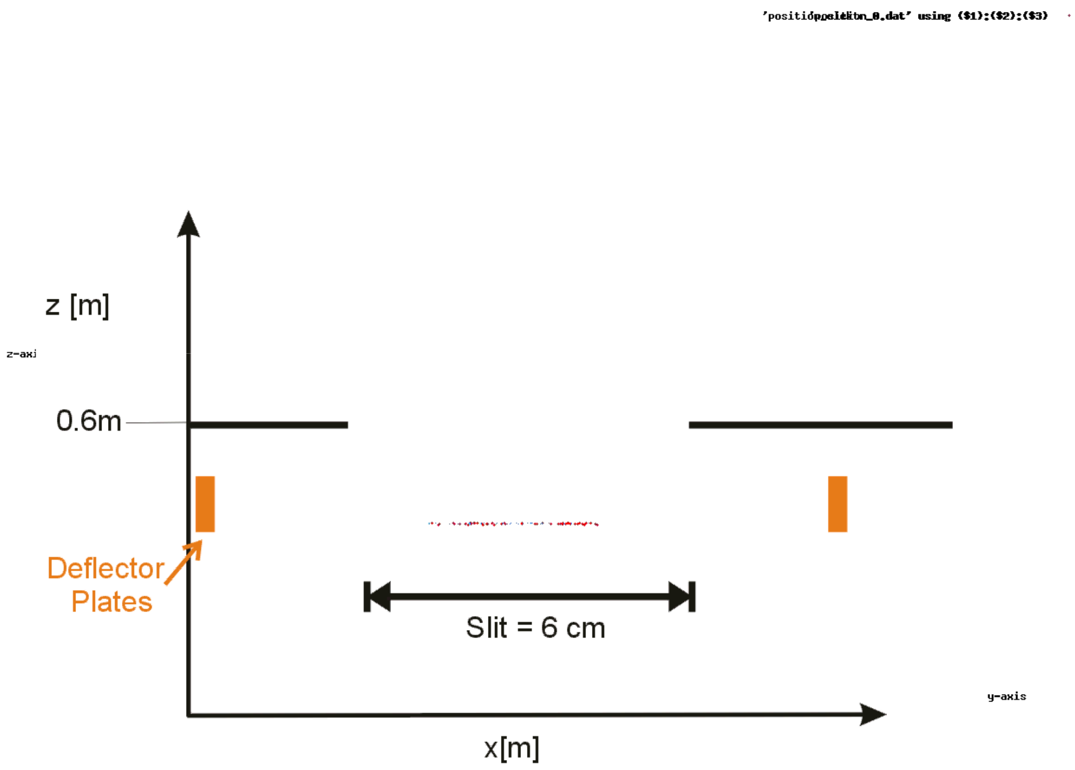
Beam Transport through LEBT Section



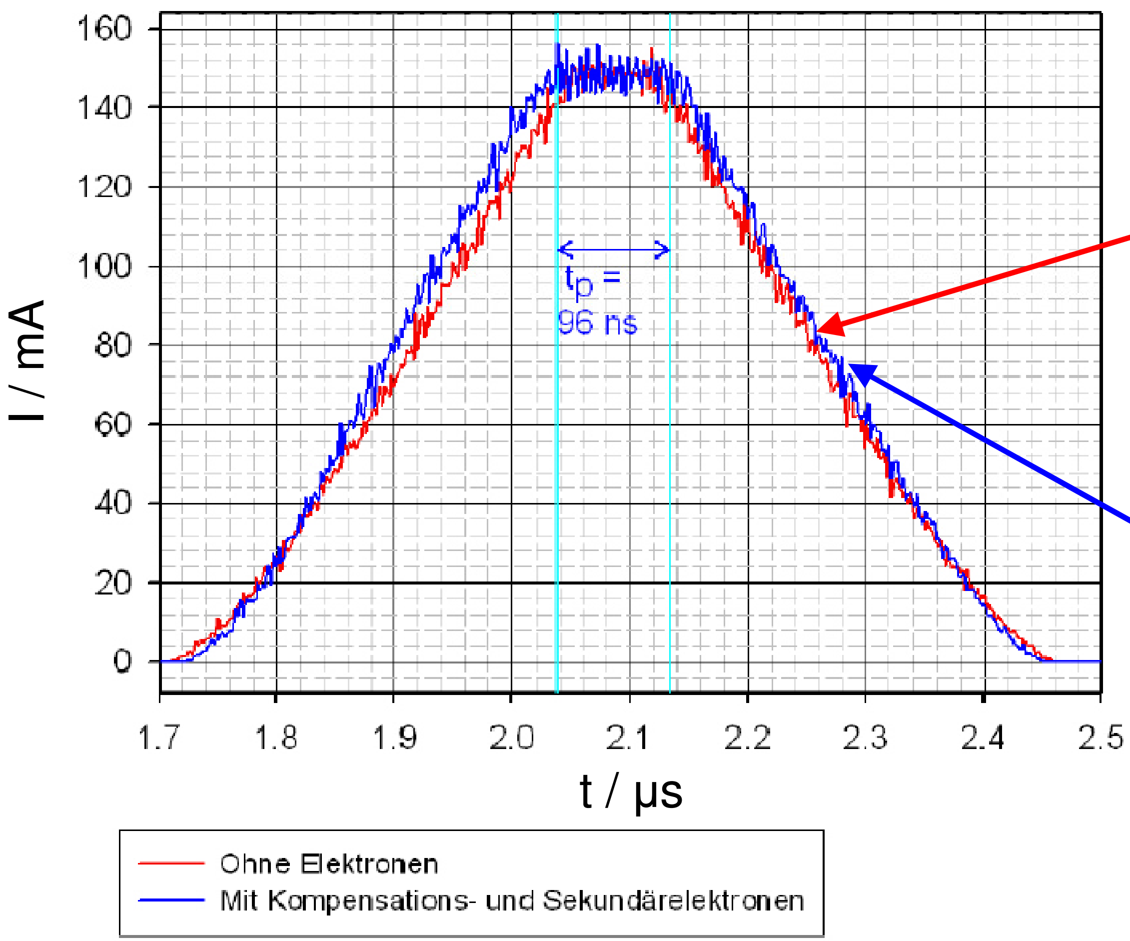
Beam Deflection with Electric Kicker



Beam Deflection with Electric Kicker



Proton Pulse: Current and Emittances



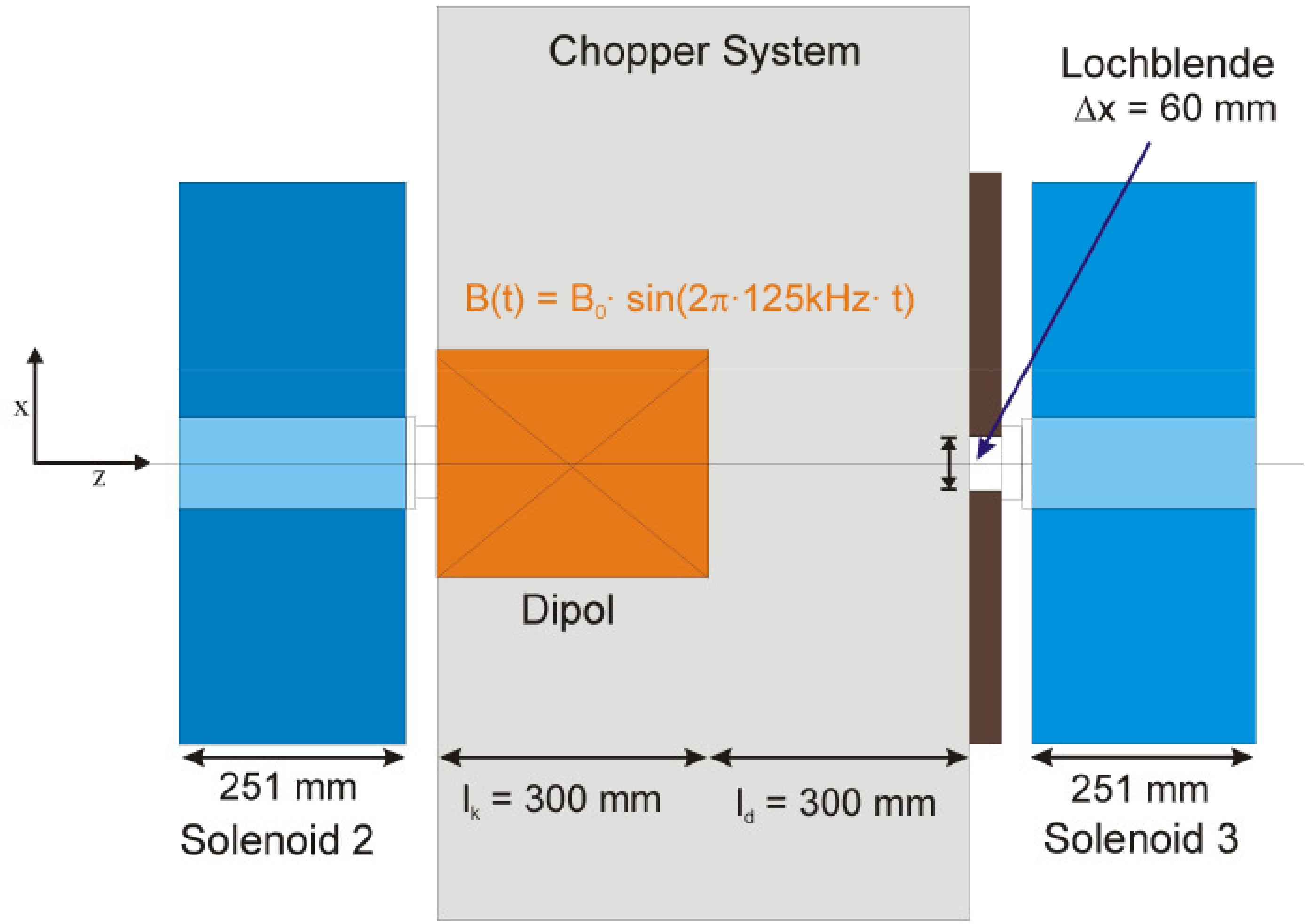
Input Emittance:
$\varepsilon^x_{rms,\ norm} = \varepsilon^y_{rms,\ norm} =$ 0.23 π mm mrad

Output Emittance (no e⁻):
Pulse Plateau:
$\varepsilon^x_{rms,\ norm}$ = 0.50 π mm mrad
$\varepsilon^y_{rms,\ norm}$ = 0.33 π mm mrad

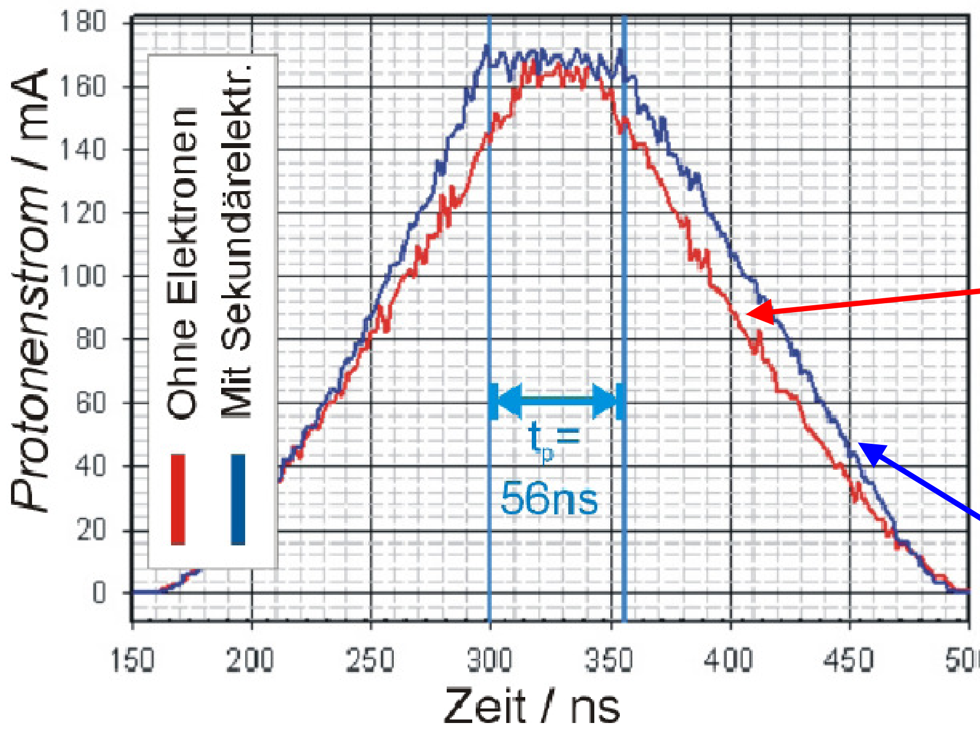
Output Emittance (with e⁻):
Pulse Plateau:
$\varepsilon^x_{rms,\ norm}$ = 0.38 π mm mrad
$\varepsilon^y_{rms,\ norm}$ = 0.46 π mm mrad

Electric Kicker

Beam Deflection with Magnetic Kicker



Proton Pulse: Current and Emittances



Input Emittance:
$\varepsilon^x_{rms,\,norm} = \varepsilon^y_{rms,\,norm} = 0.23\ \pi$ mm mrad

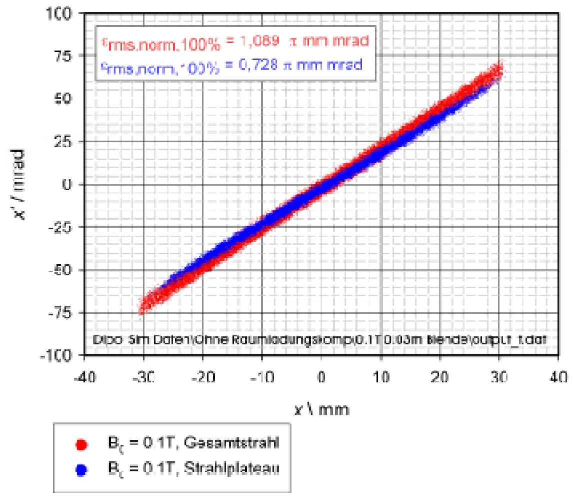
Output Emittance (no e⁻):
Pulse Plateau:
$\varepsilon^x_{rms,\,norm} = 0.73\ \pi$ mm mrad
$\varepsilon^y_{rms,\,norm} = 0.37\ \pi$ mm mrad

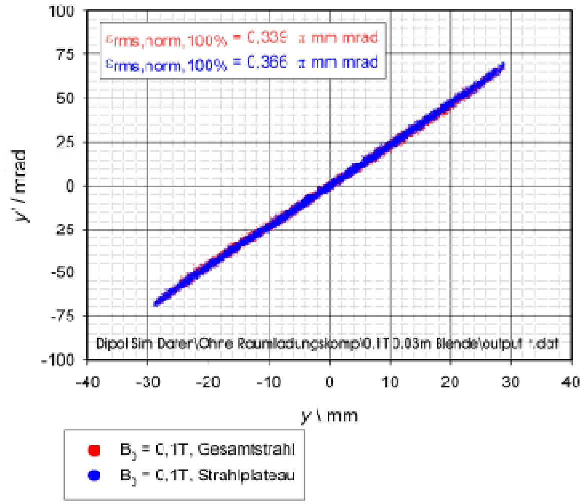
Output Emittance (with e⁻):
Pulse Plateau:
$\varepsilon^x_{rms,\,norm} = 0.66\ \pi$ mm mrad
$\varepsilon^y_{rms,\,norm} = 0.54\ \pi$ mm mrad

Magnetic Kicker

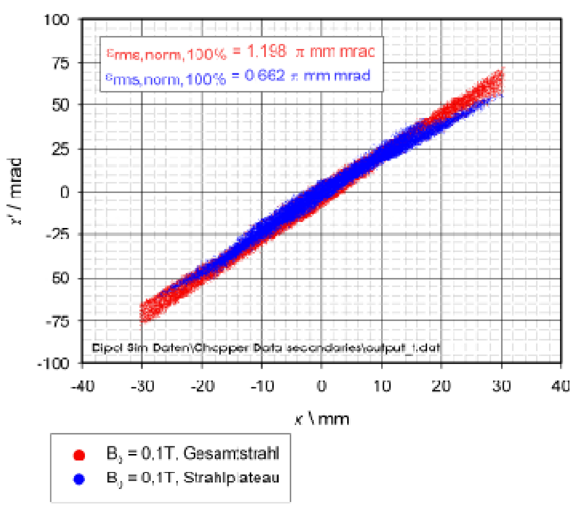
Output Distributions Magnetic Kicker

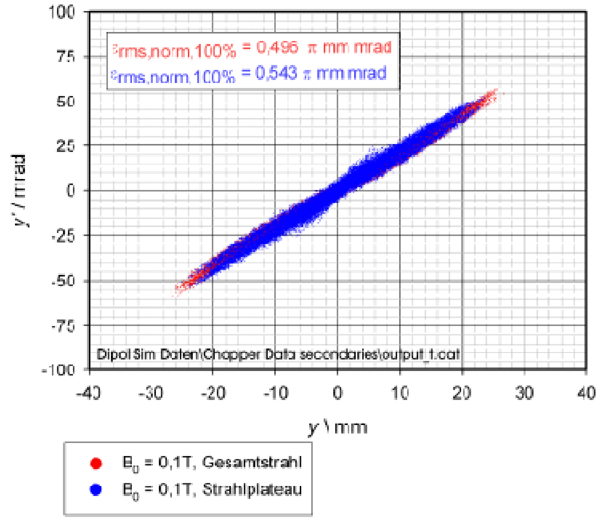
Simulation without Electrons.



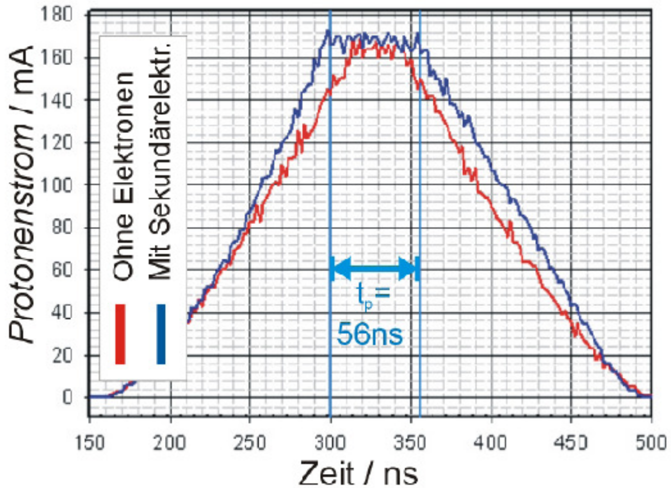


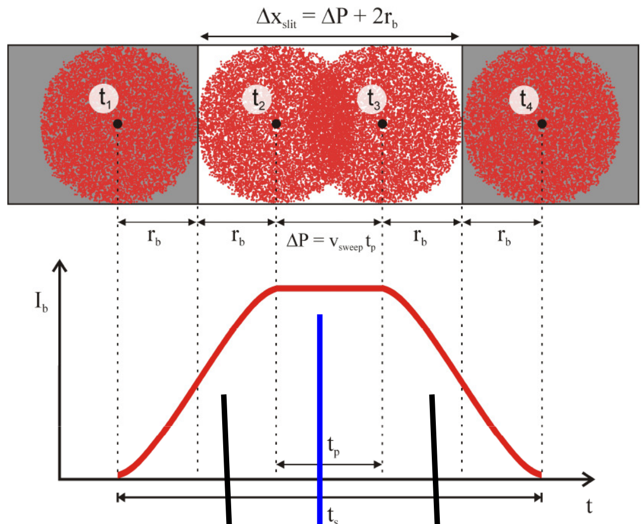
Simulation with Electrons.



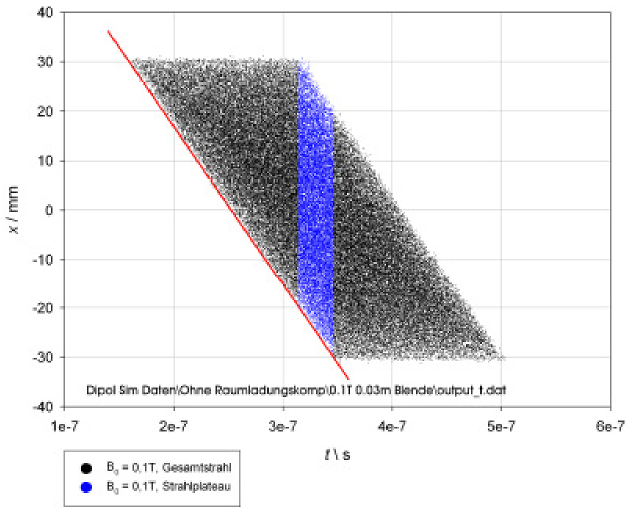


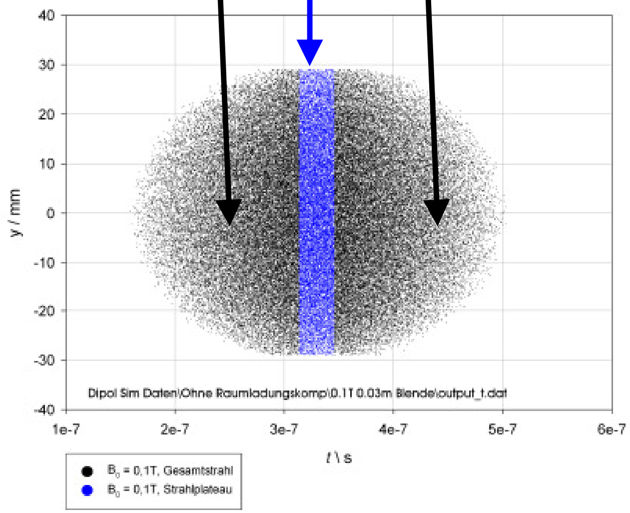
Electron Effects in Time-dependent Kicker Fields



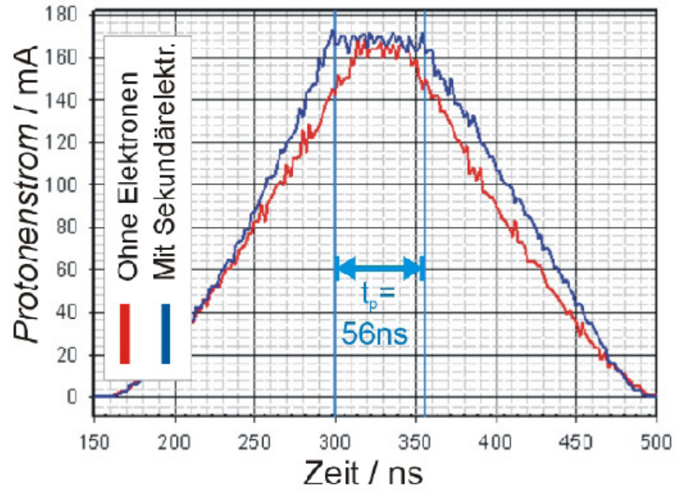


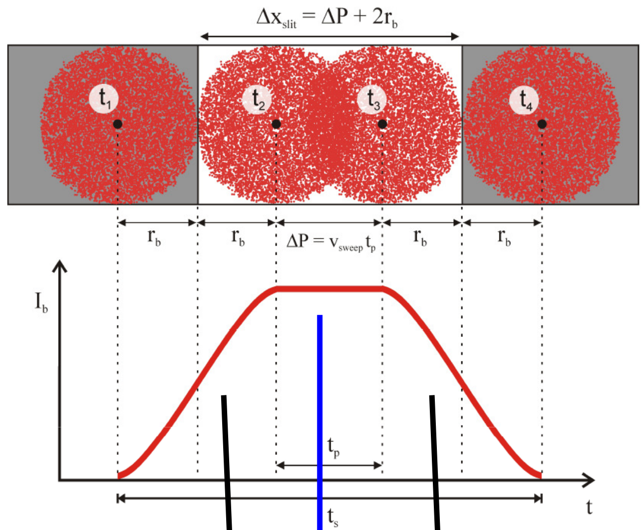
Without Consideration of Electrons.



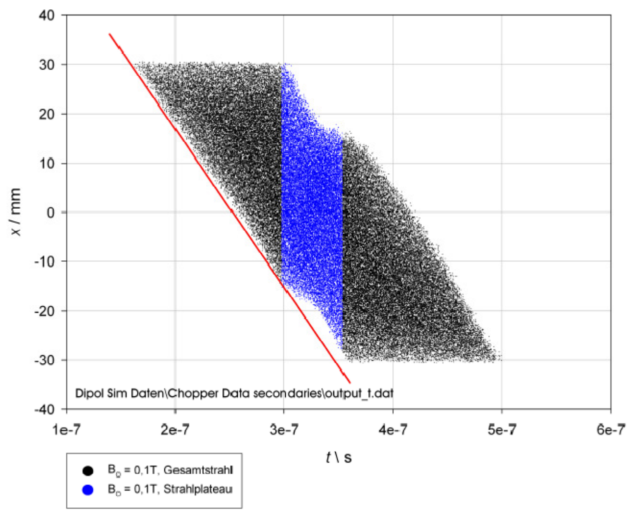


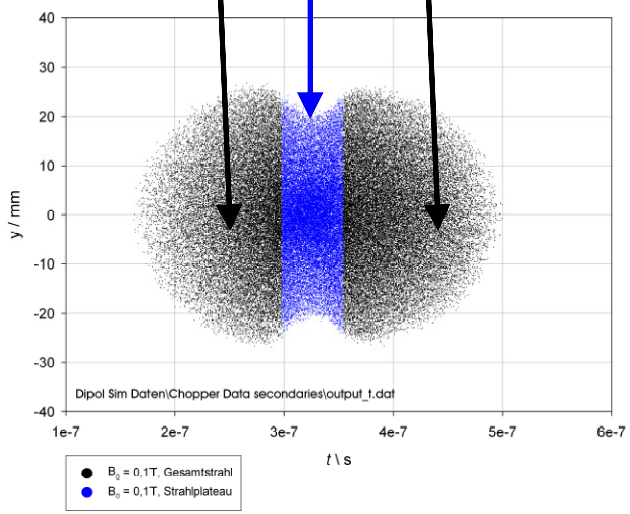
Electron Effects in Time-dependent Kicker Fields





With Consideration of Electrons.

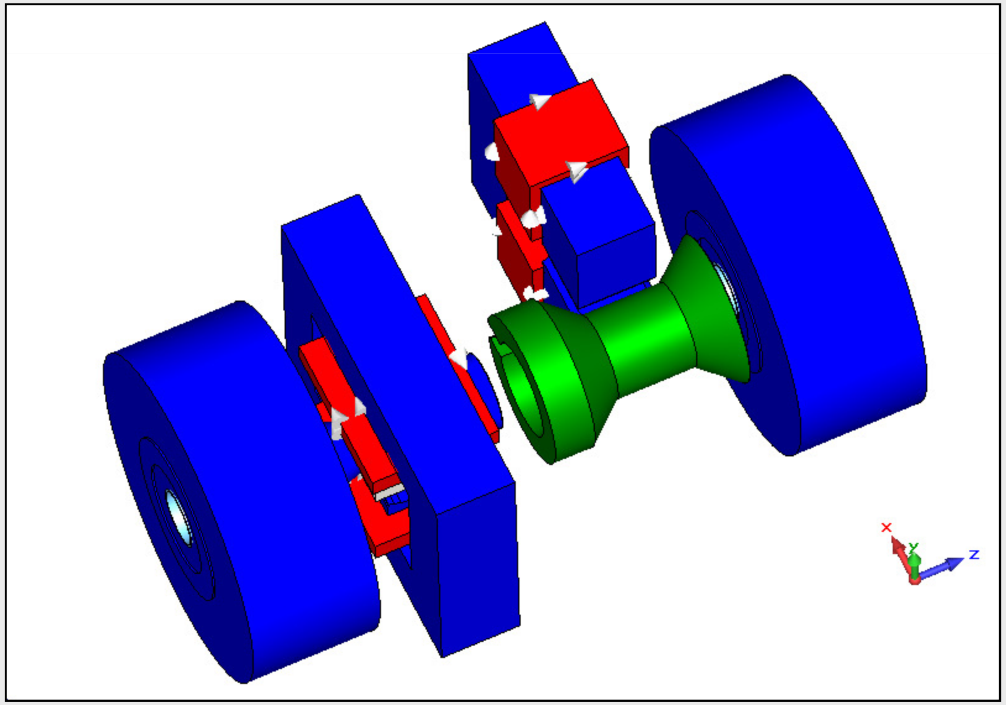




ExB Chopper System

Chopping of High Intensity Beams:

- *Avoiding long drifts* due to high space charge.
- *Minimizing duty factor for electrostatic beam deflection* in order to reduce risk of voltage breakdowns.
- *Beam dumping outside transport line* preferable in order to avoid high power deposition and uncontrolled production of secondary particles.



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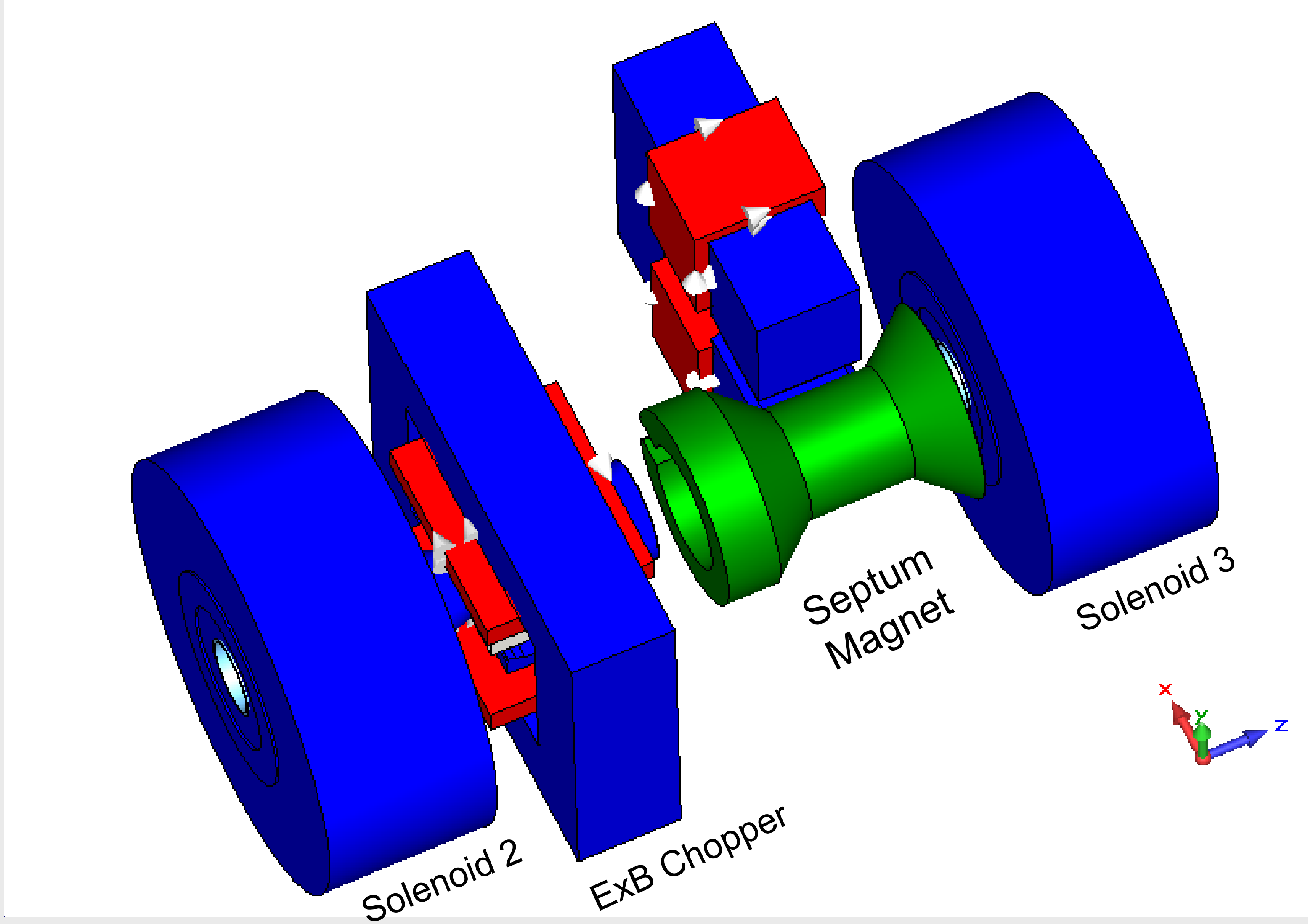
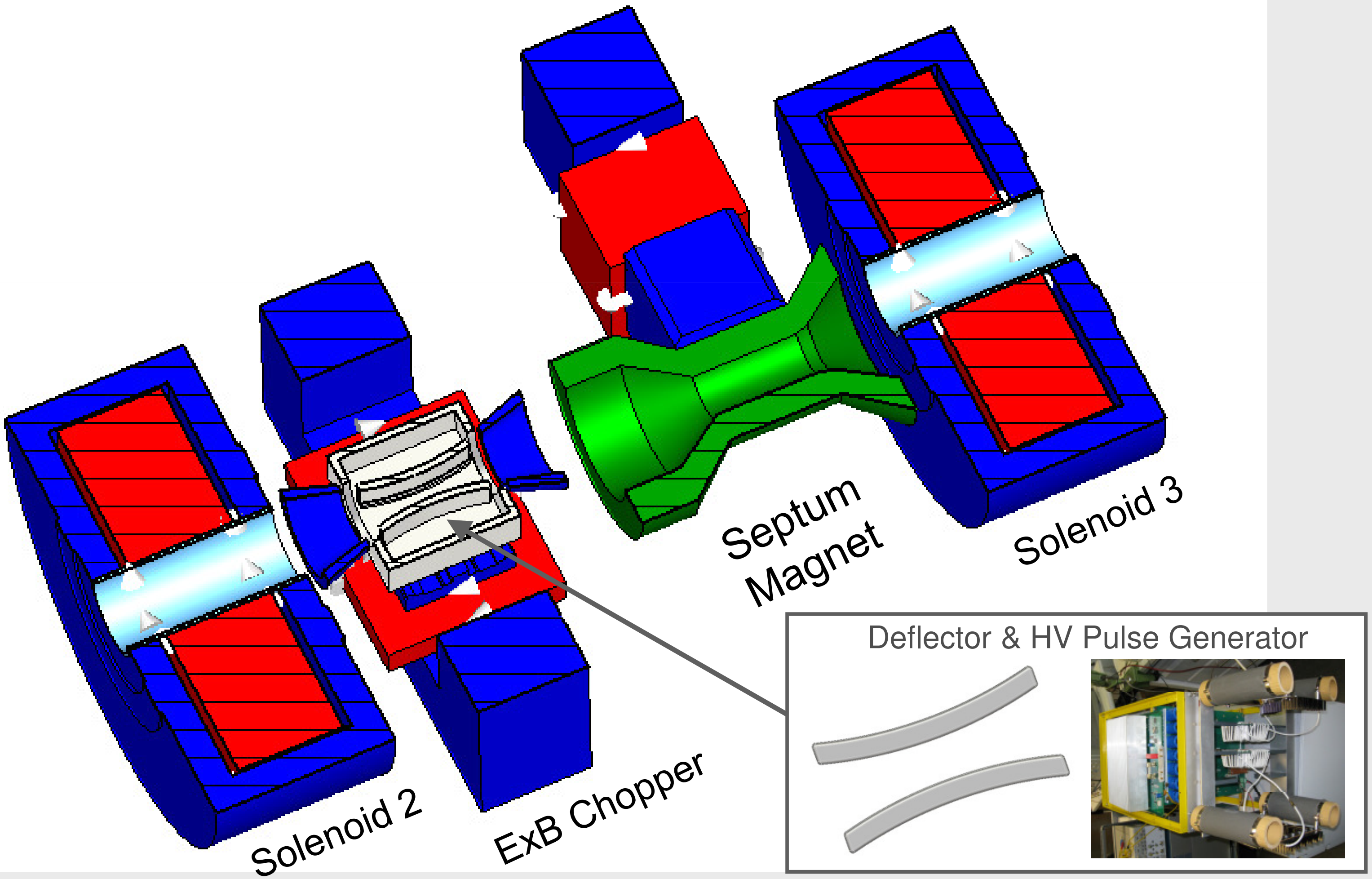
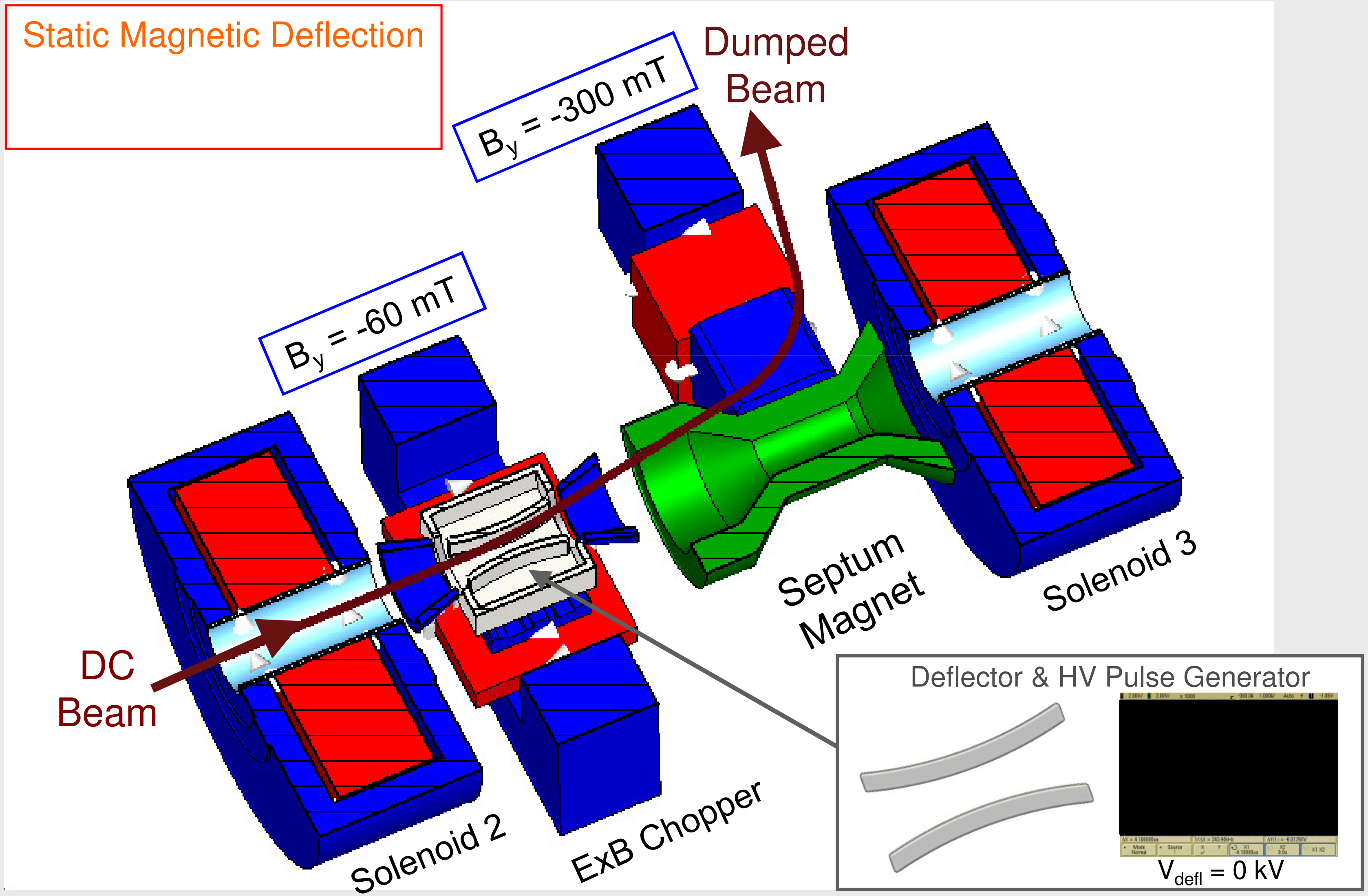
ExB Chopper System



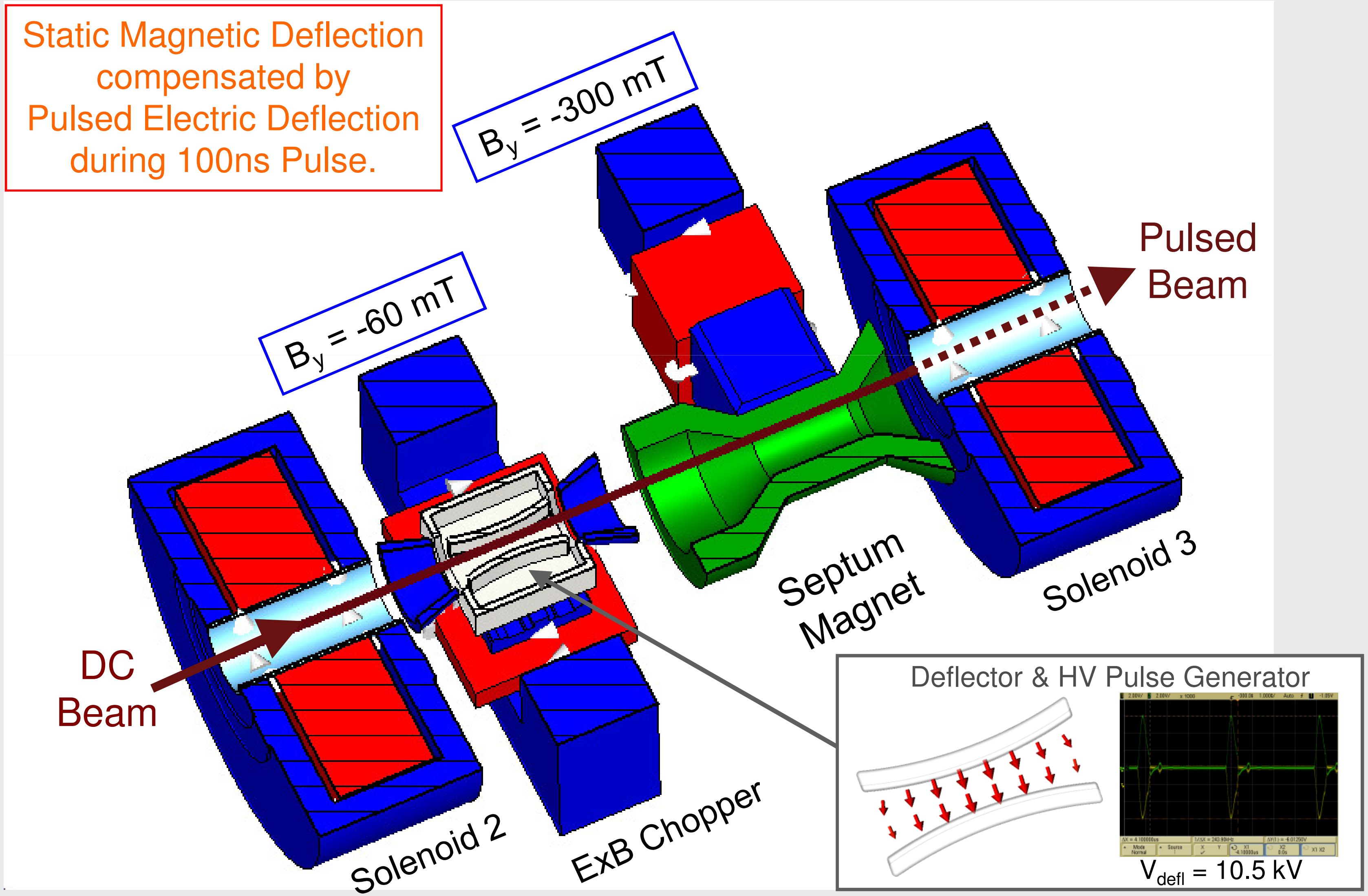
ExB Chopper System



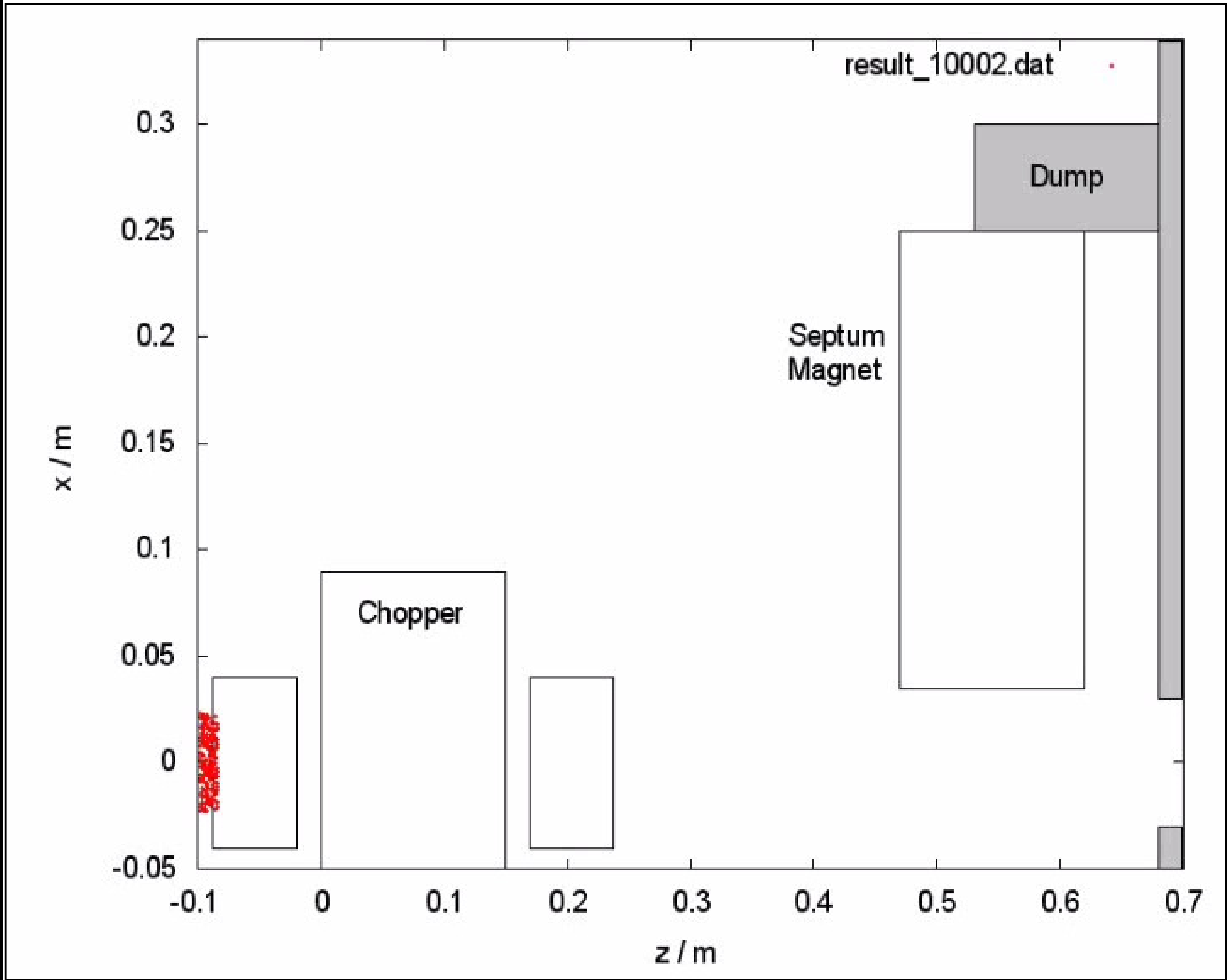
ExB Chopper System



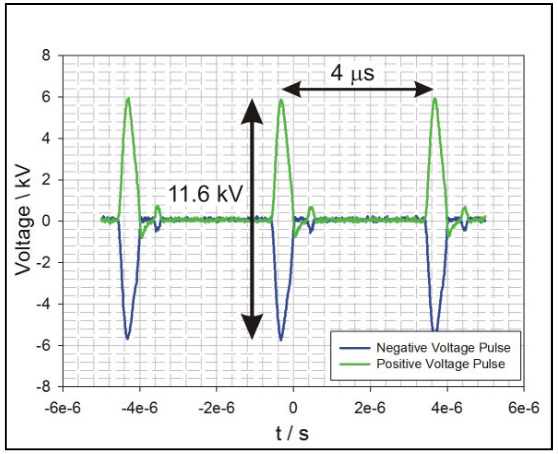
ExB Chopper System



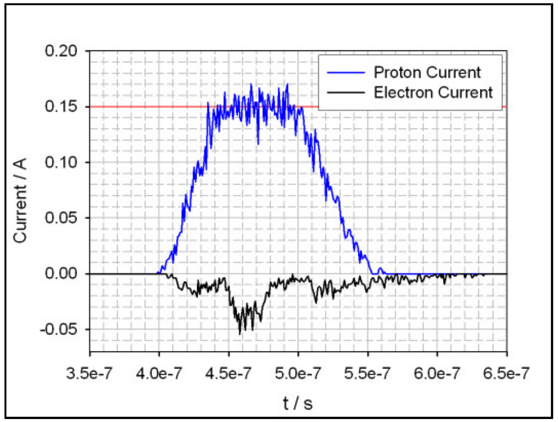
ExB Chopper



Measured Voltage Pulse



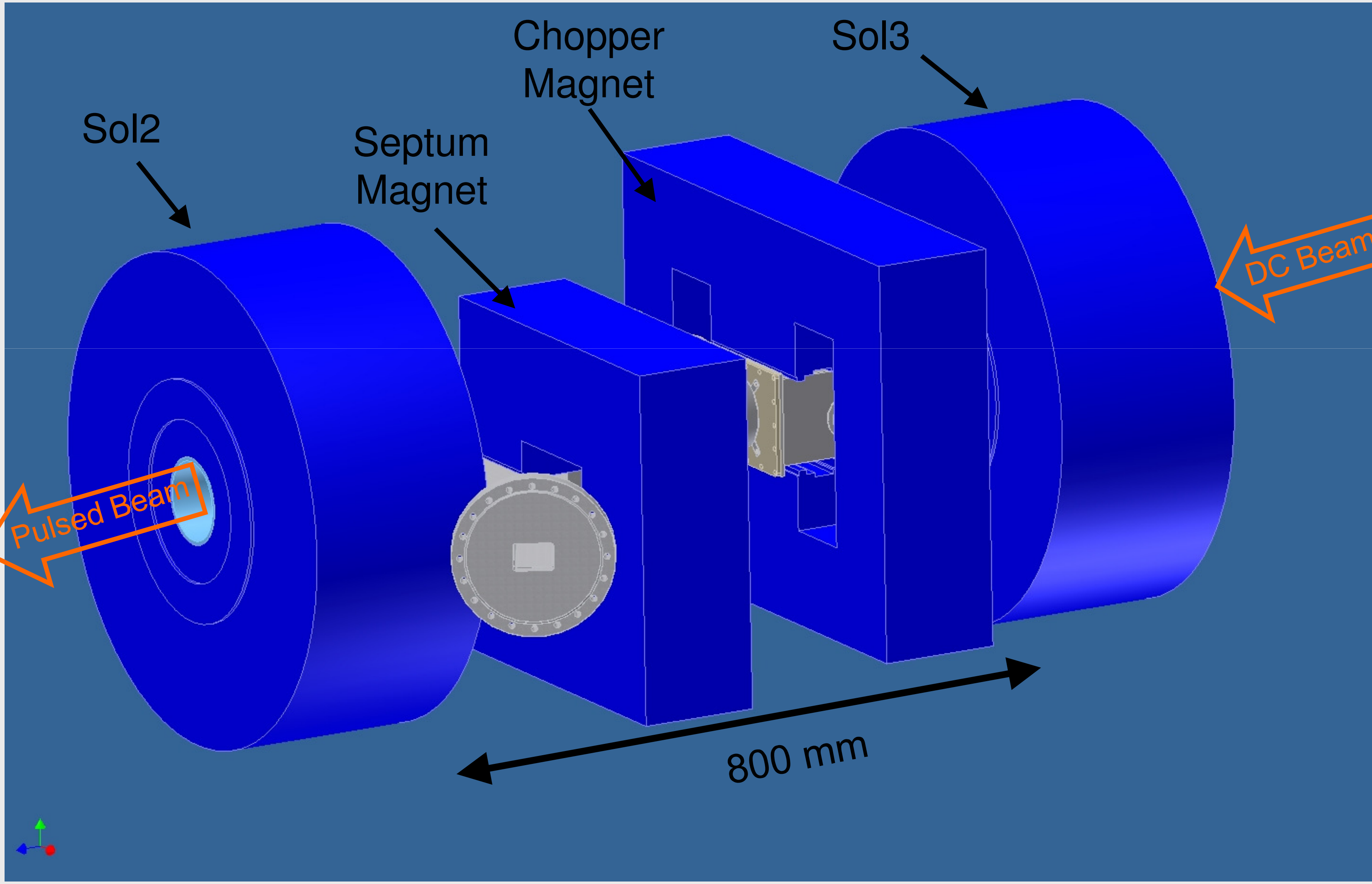
Simulated Proton Pulse



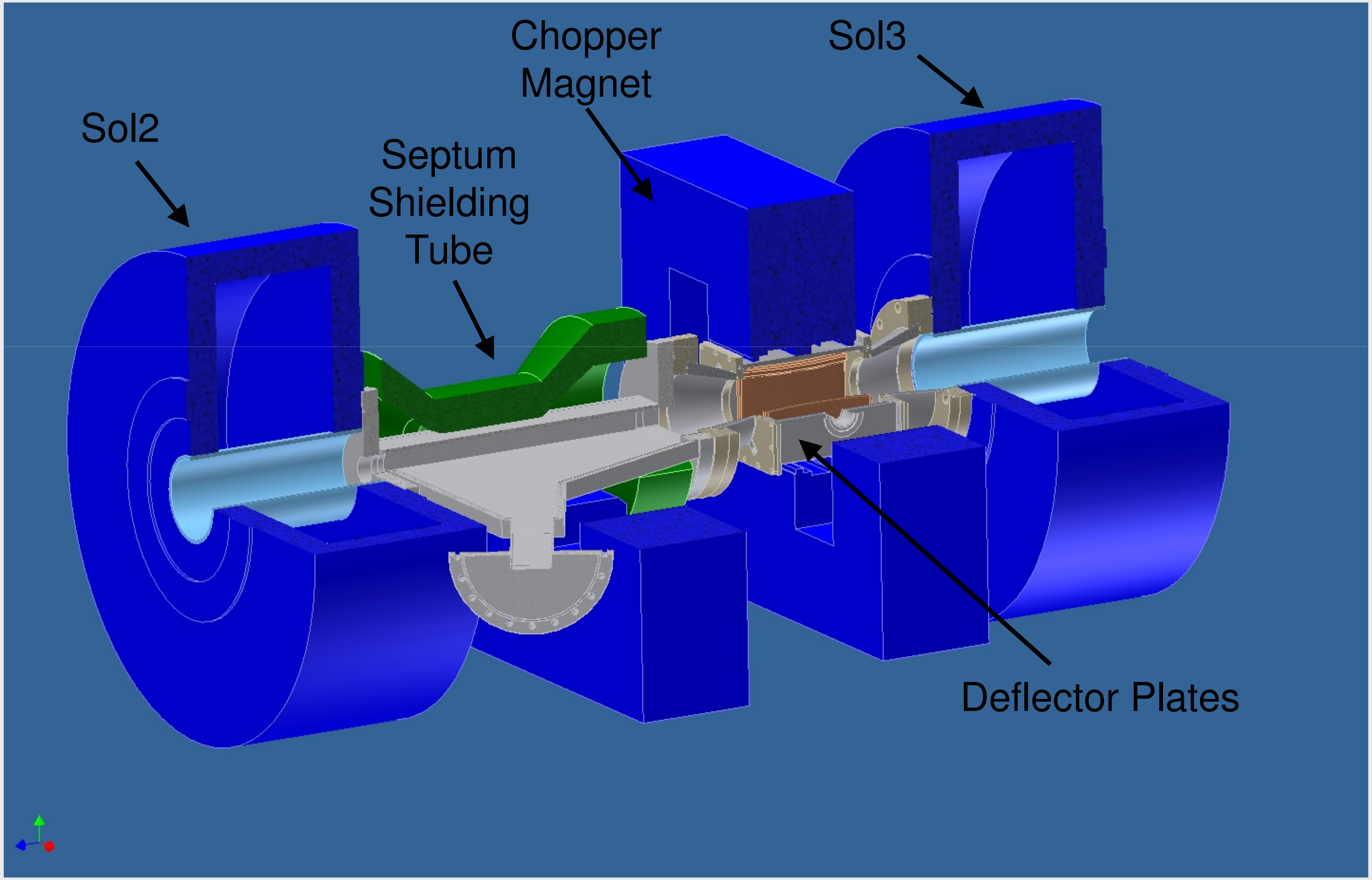
$B_{Chopper}$ = 58 mT

B_{Septum} = 300 mT

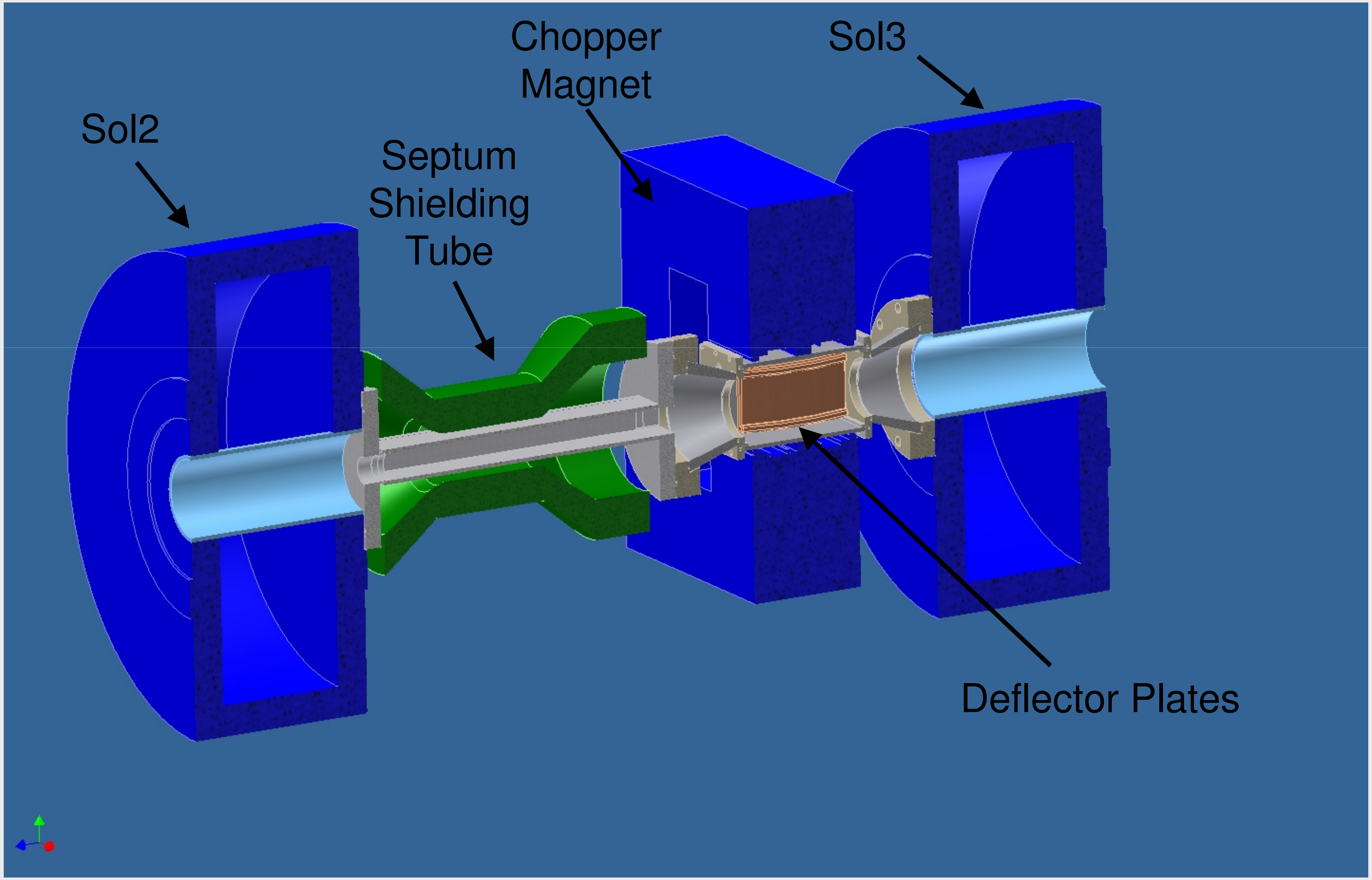
ExB Chopper System



ExB Chopper System



ExB Chopper System

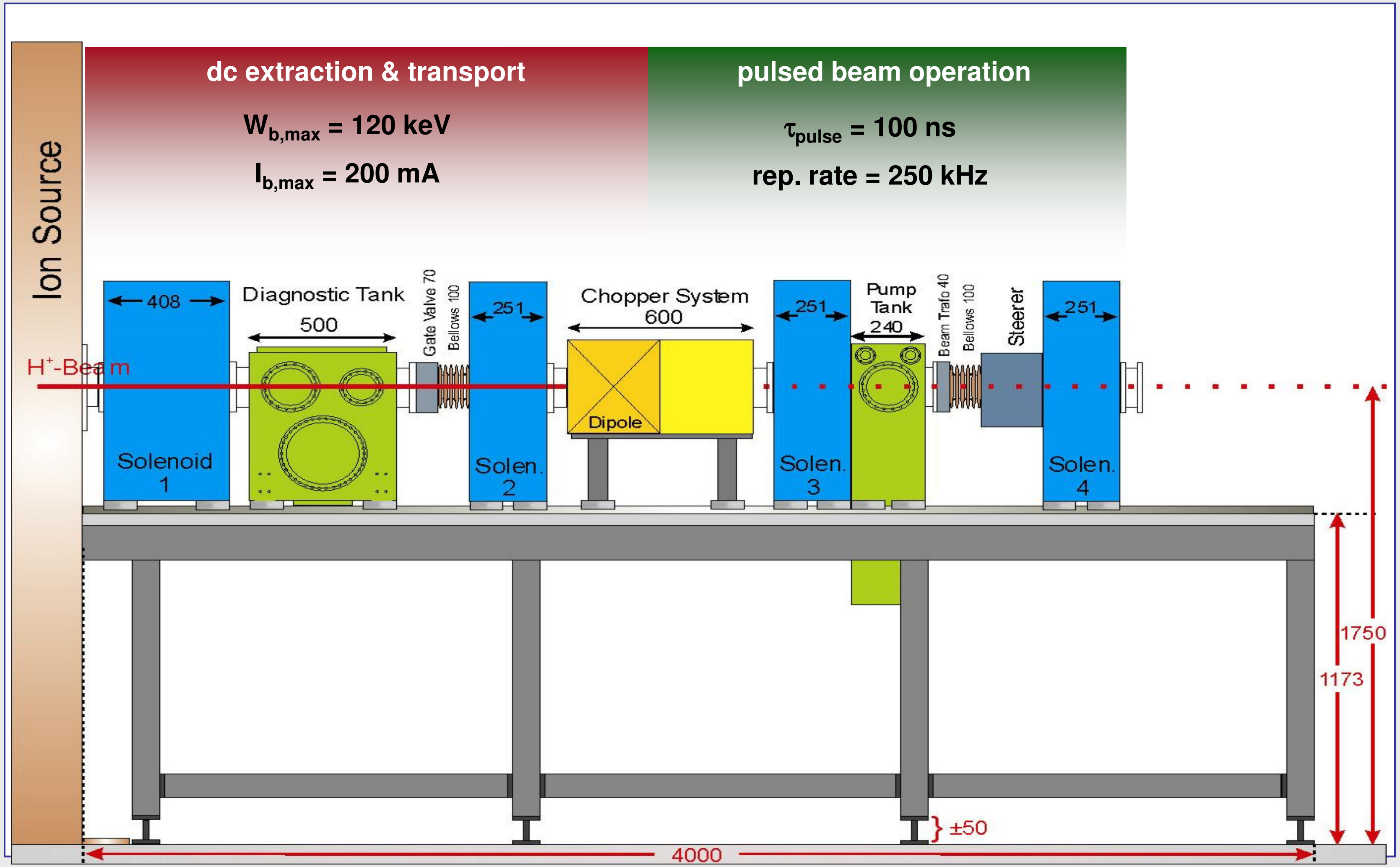


Conclusion & Outlook

- Aberration induced emittance growth must be carefully examined.
- Nonlinear fields are limiting filling degree of solenoidal lenses.
- Time-dependent beam deflection increases emittance in deflection plane.
- Electron effects can significantly influence beam radius and emittance growth.
- Collective effects of beam ions, compensation and secondary electrons must be considered.
- Multi-species PIC codes for simulation of time-dependent kicker fields are ready.
- Deflection test stand for experimental investigations is ready.

Thank you for your attention

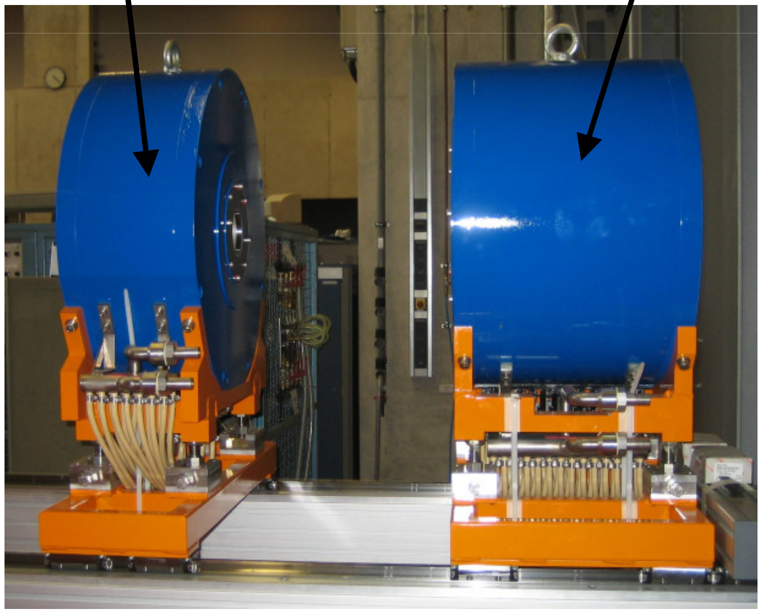
Low Energy Beam Transport (LEBT) Section

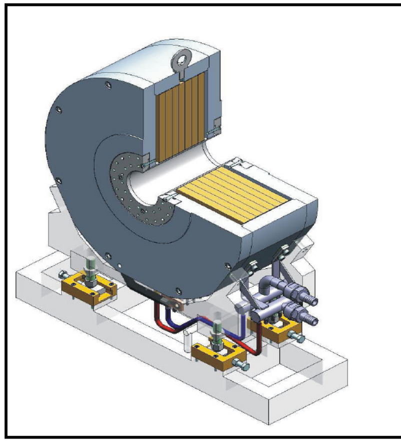


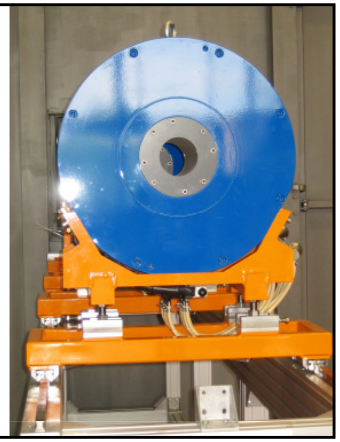
Solenoid Lenses

Type I
- Length: 251 mm
- Aperture: 100 mm
- B_{max}: 0.78T

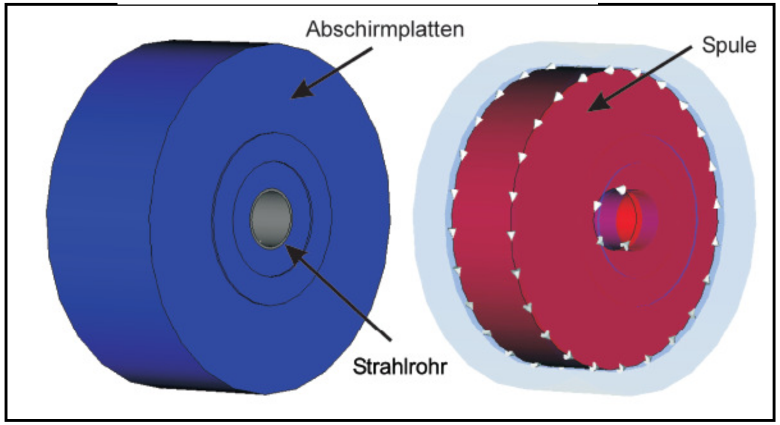
Type II
- Length: 408 mm
- Aperture: 150 mm
- B_{max}: 0.66T



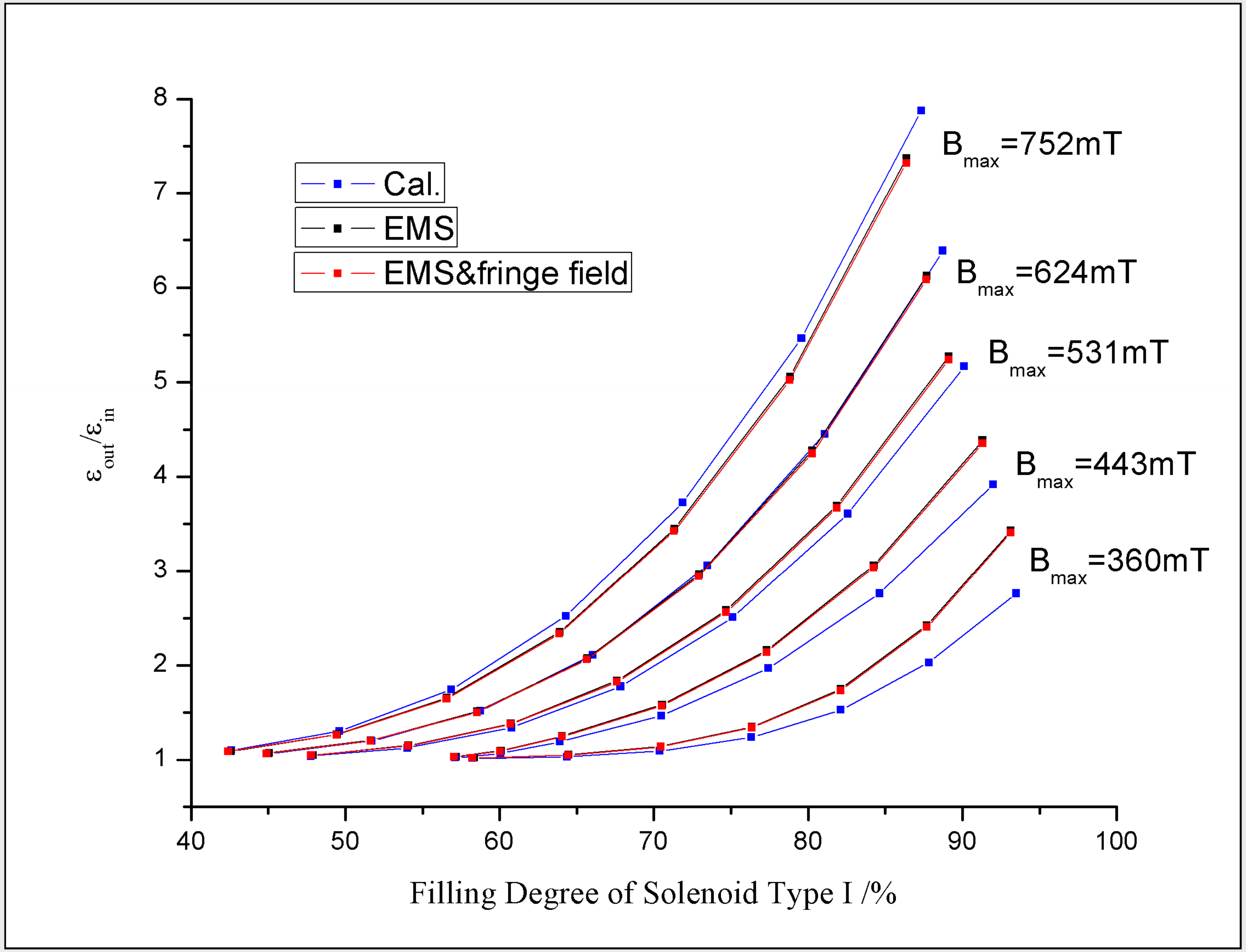


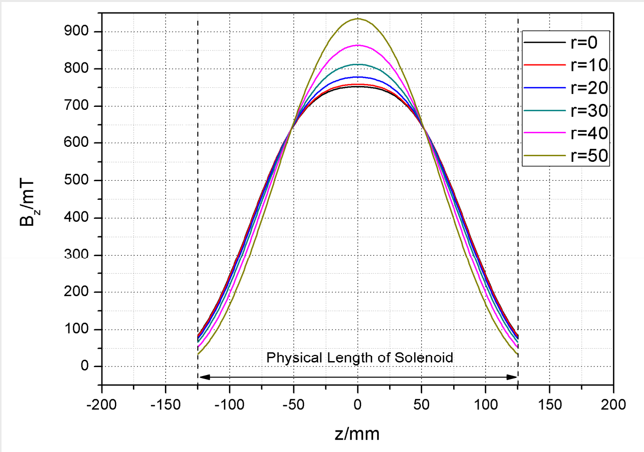


$$k_{sol} = \frac{qB_0}{2m\beta c}$$

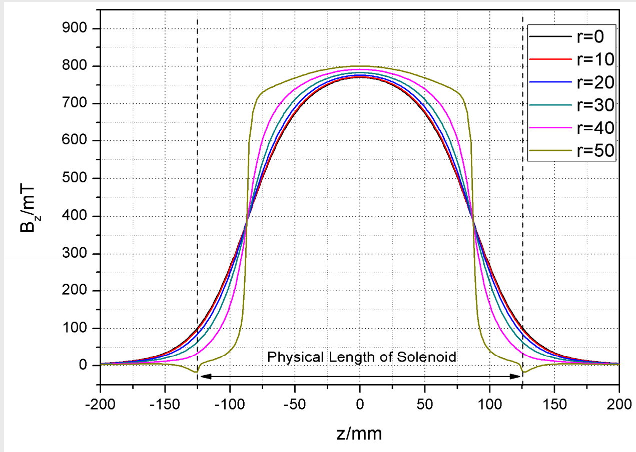


Emittance Growth



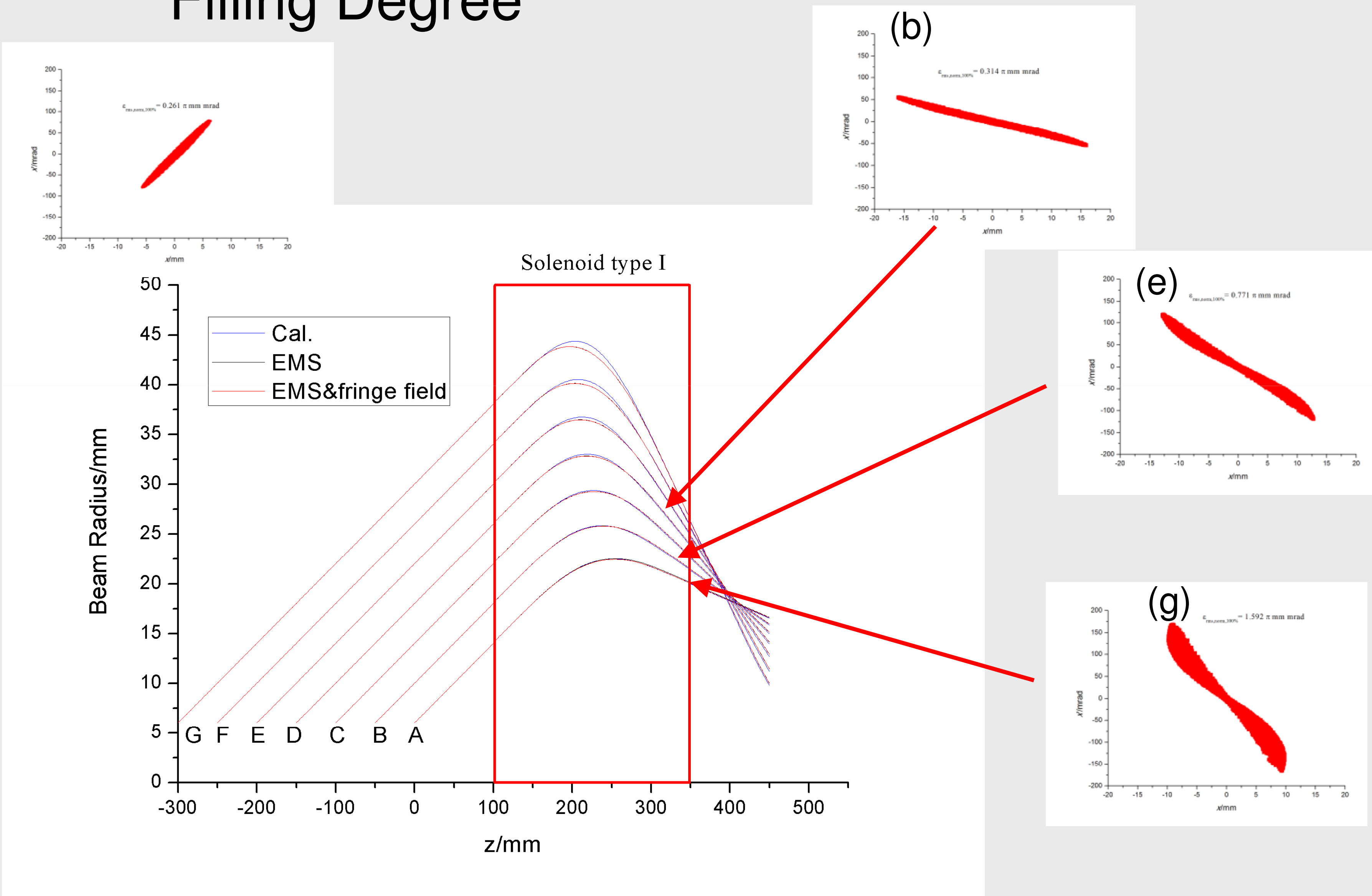


Calculated B-Field



EMS-Sim B-Field

Filling Degree



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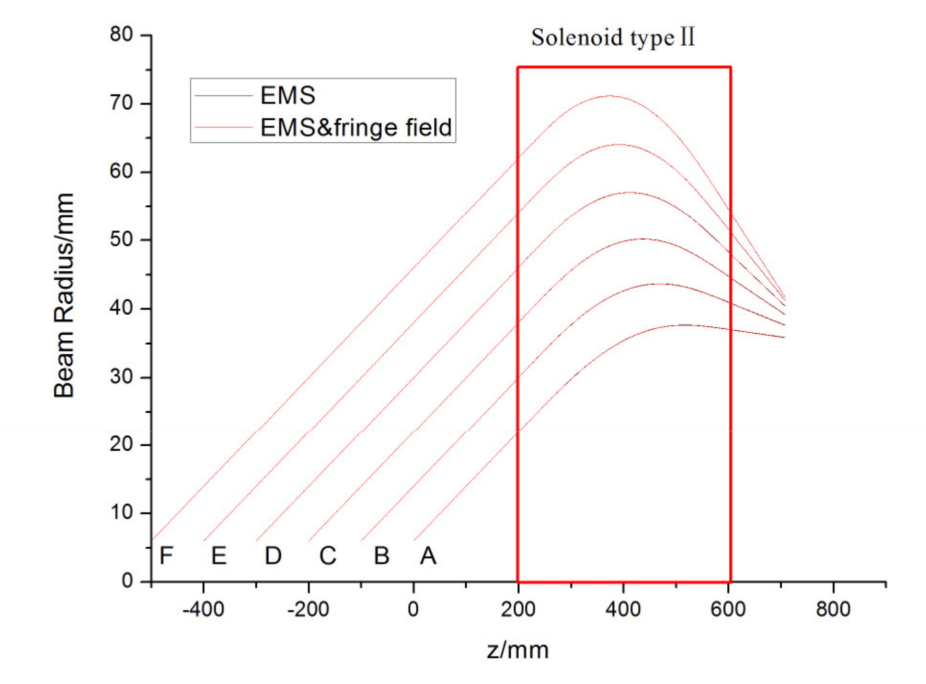
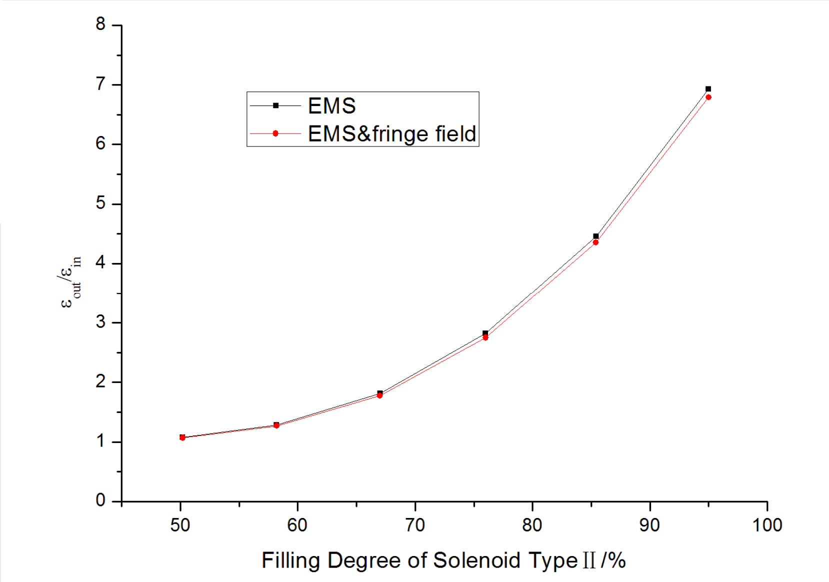
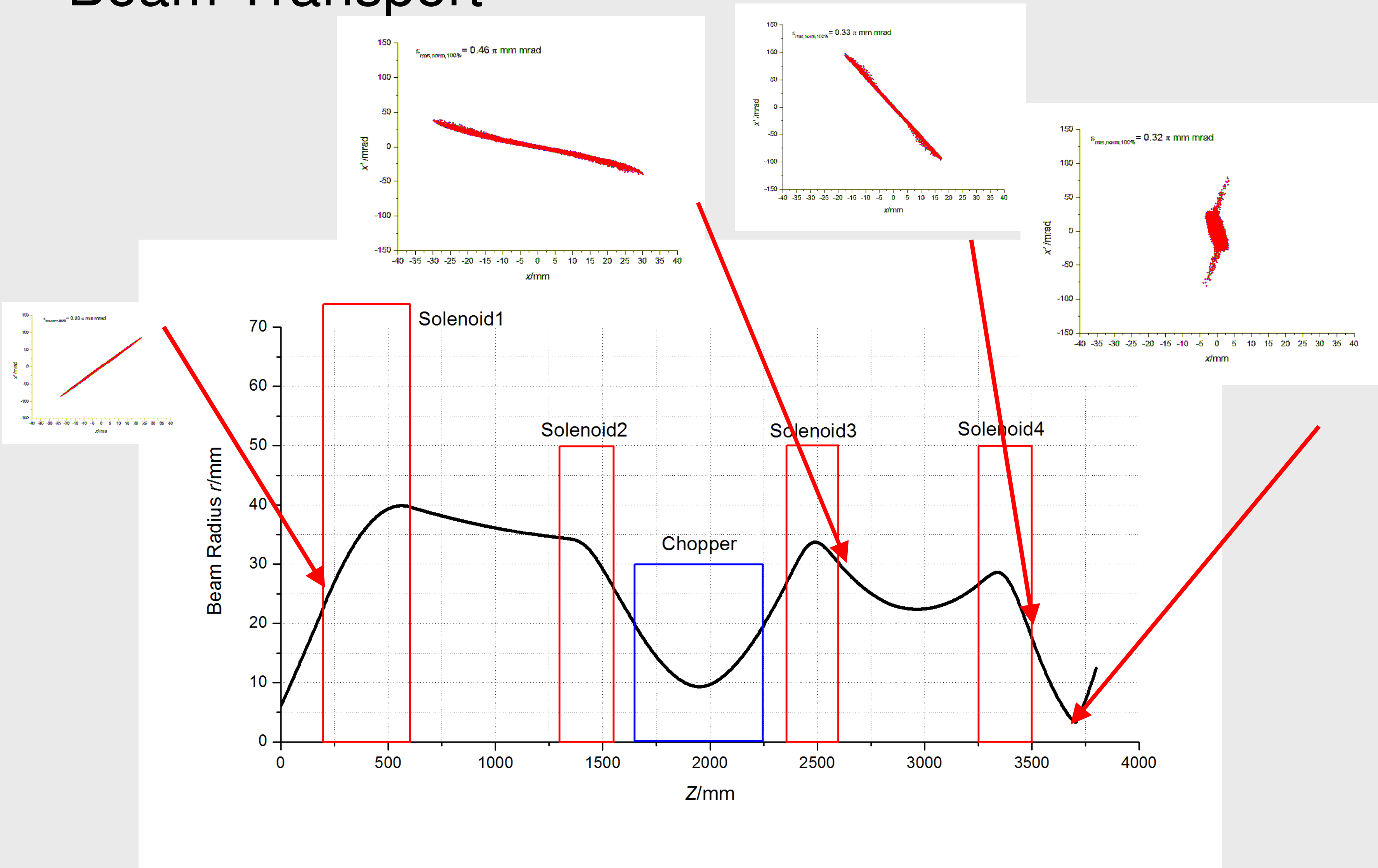
Filling Degree Typ II

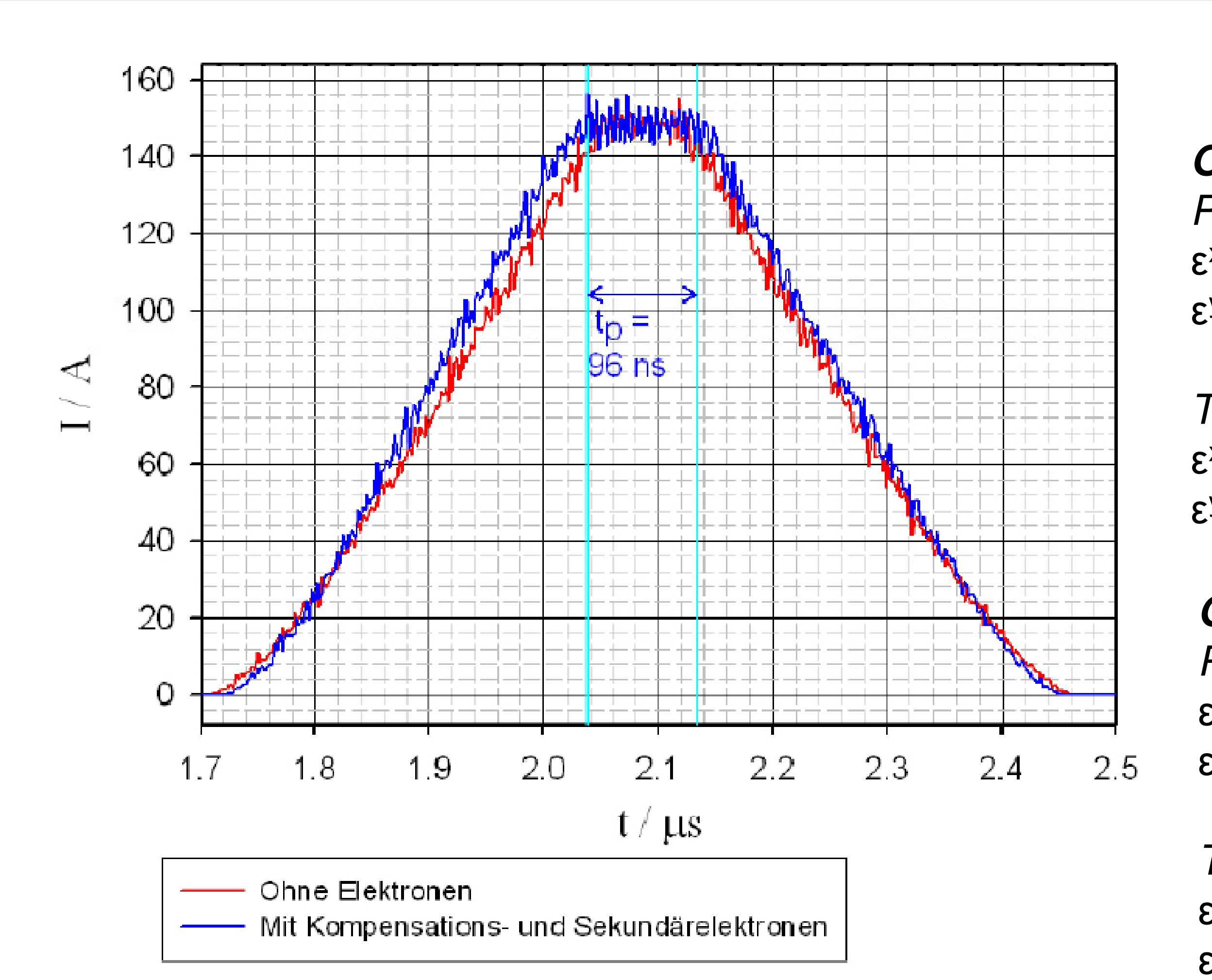




Beam Transport



Proton Pulse Current (Electric Kicker)



Input Emittance:

$\varepsilon^x_{rms,\ norm} = \varepsilon^y_{rms,\ norm} =$ 0.23 π mm mrad

Output Emittance (no e⁻):

Pulse Plateau:

$\varepsilon^x_{rms,\ norm}$ =0.50 π mm mrad

$\varepsilon^y_{rms,\ norm}$ =0.33 π mm mrad

Total Pulse:

$\varepsilon^x_{rms,\ norm}$ = 1.52 π mm mrad

$\varepsilon^y_{rms,\ norm}$ = 0.32 π mm mrad

Output Emittance (with e⁻):

Pulse Plateau:

$\varepsilon^x_{rms,\ norm}$ =0.38 π mm mrad

$\varepsilon^y_{rms,\ norm}$ =0.46 π mm mrad

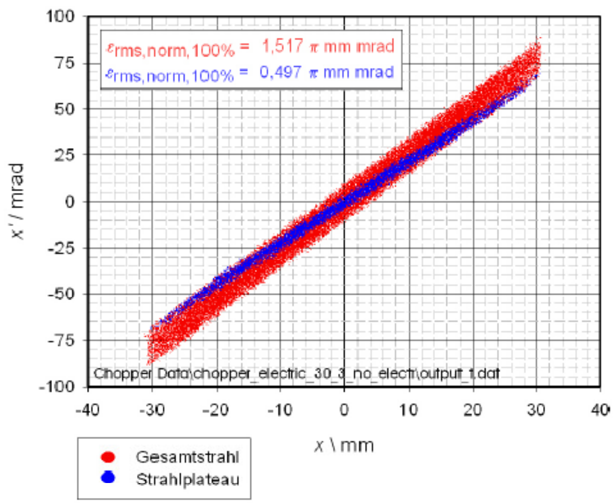
Total Pulse:

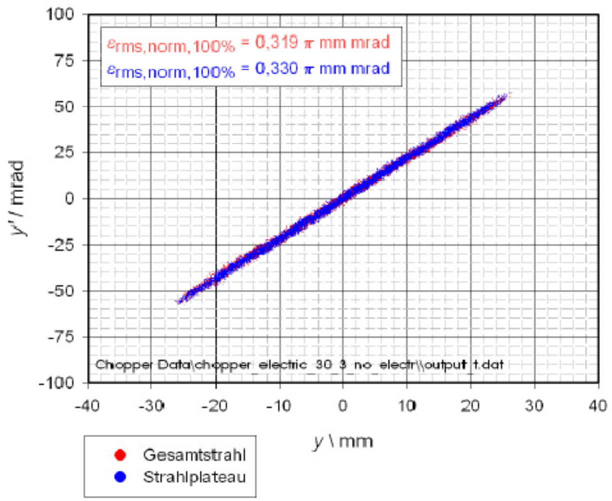
$\varepsilon^x_{rms,\ norm}$ = 1.28 π mm mrad

$\varepsilon^y_{rms,\ norm}$ = 0.46 π mm mrad

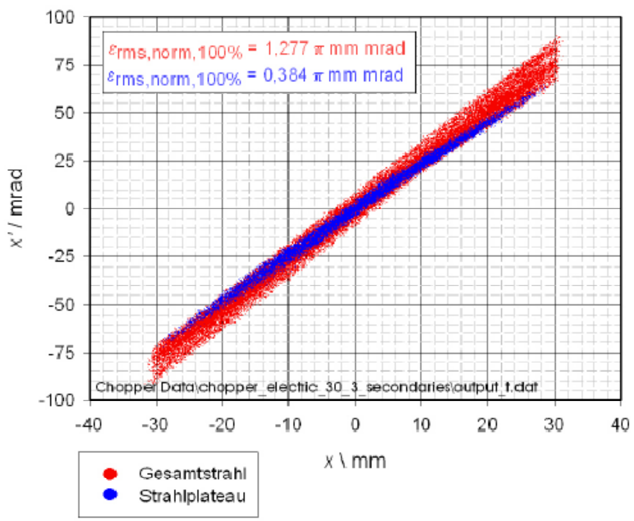
Output Distributions Electric Kicker

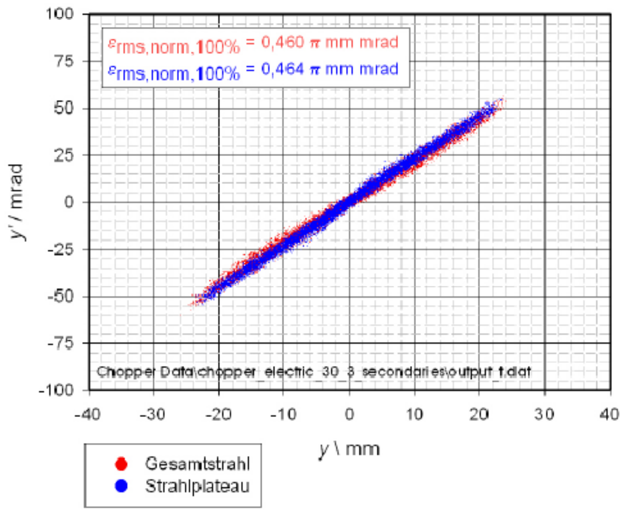
Simulation without Electrons.



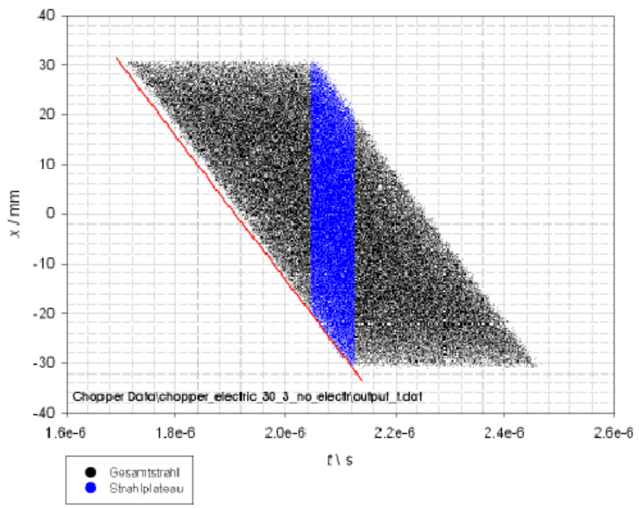


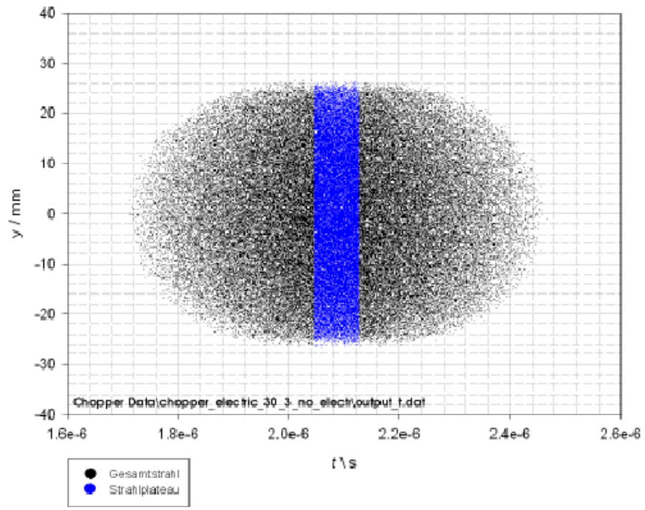
Simulation with Electrons.



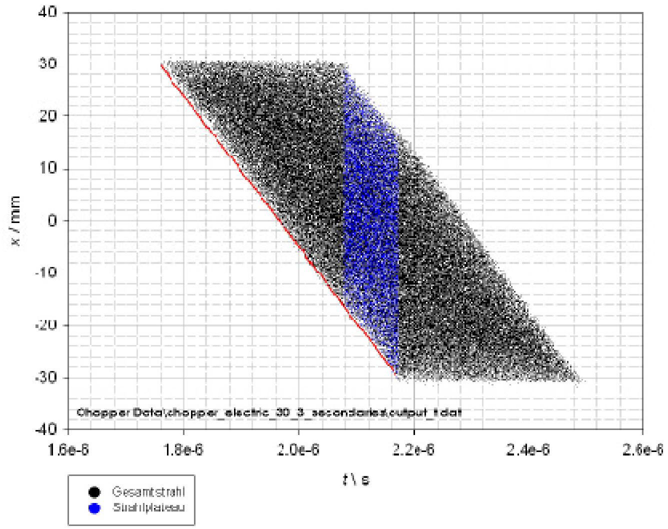


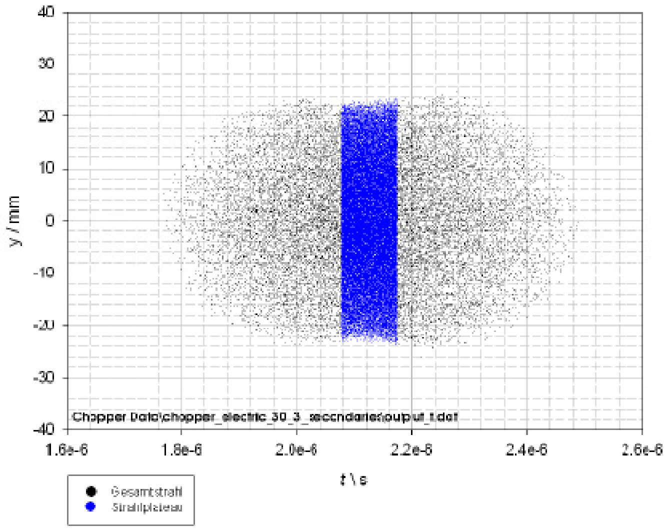
Electric Kicker (no electrons)



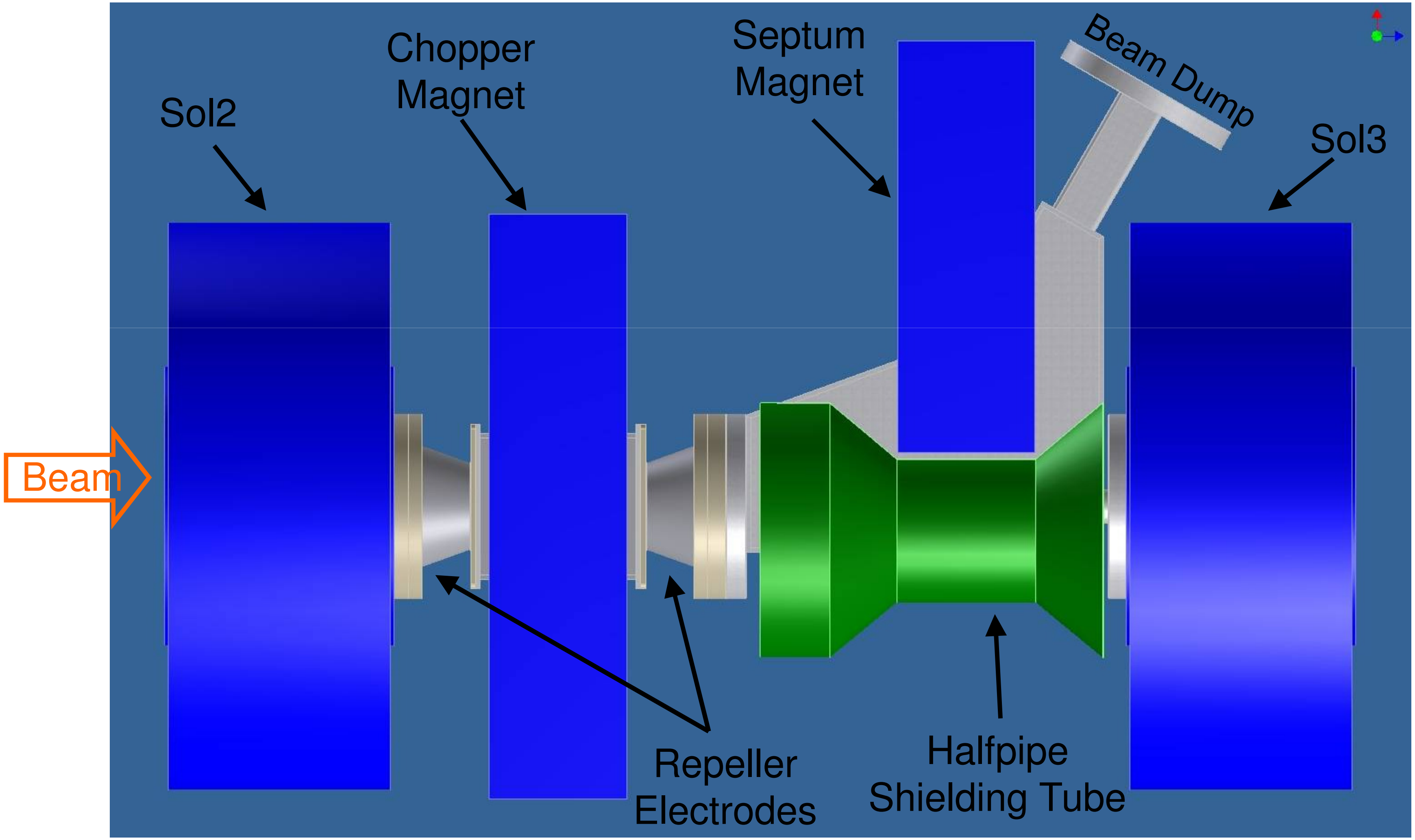


Electric Kicker (with electrons)

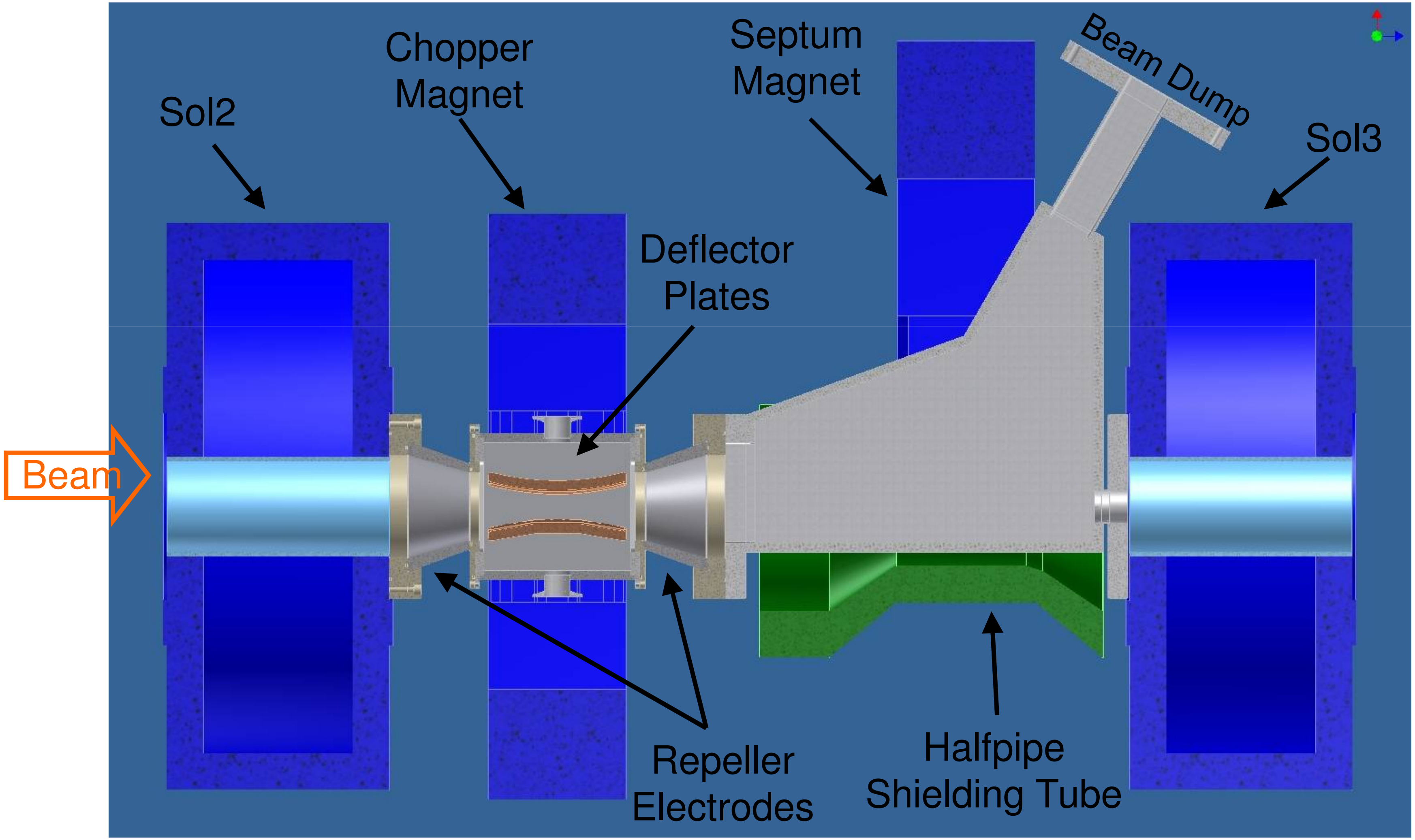




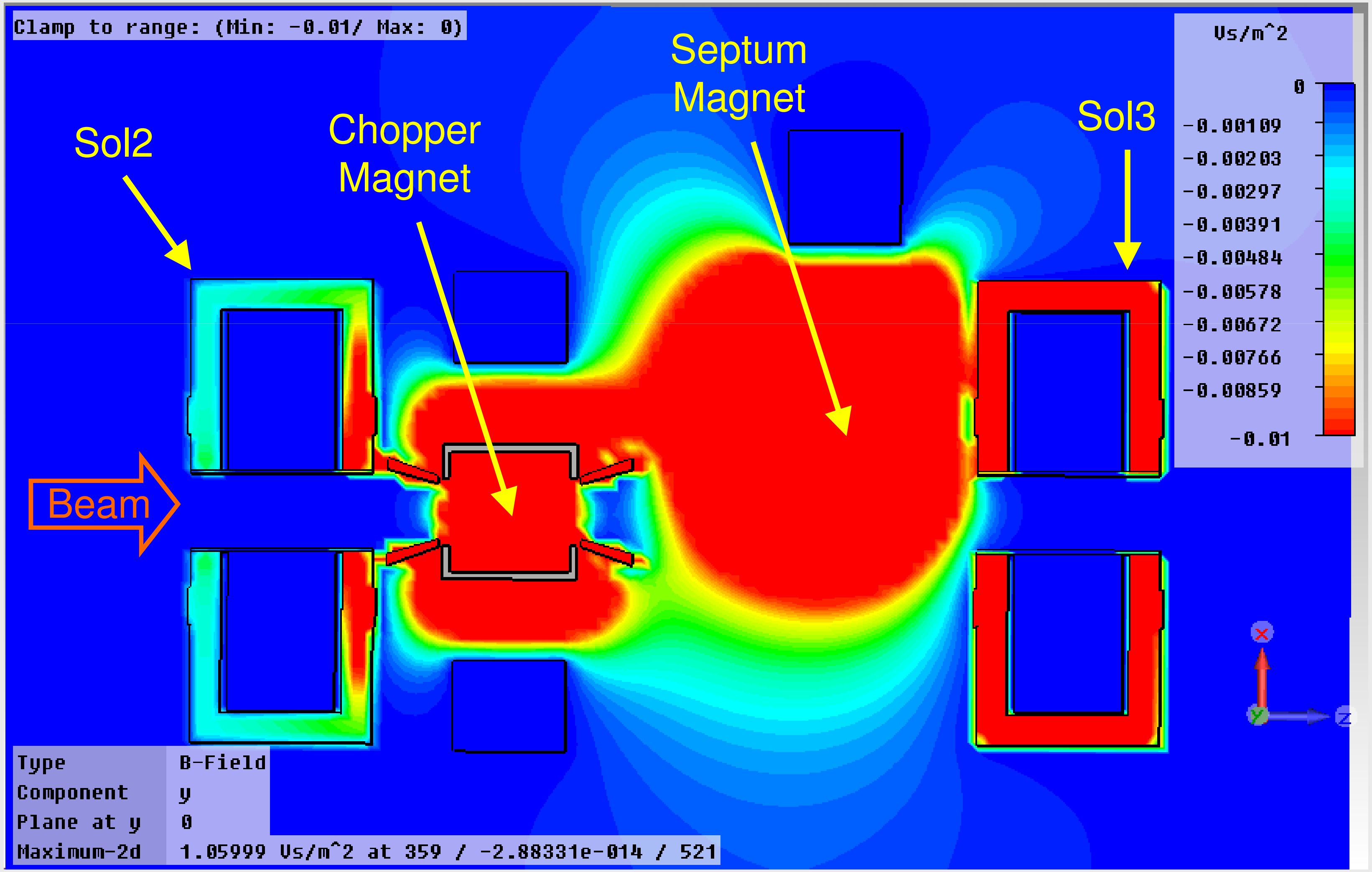
Separation Tank



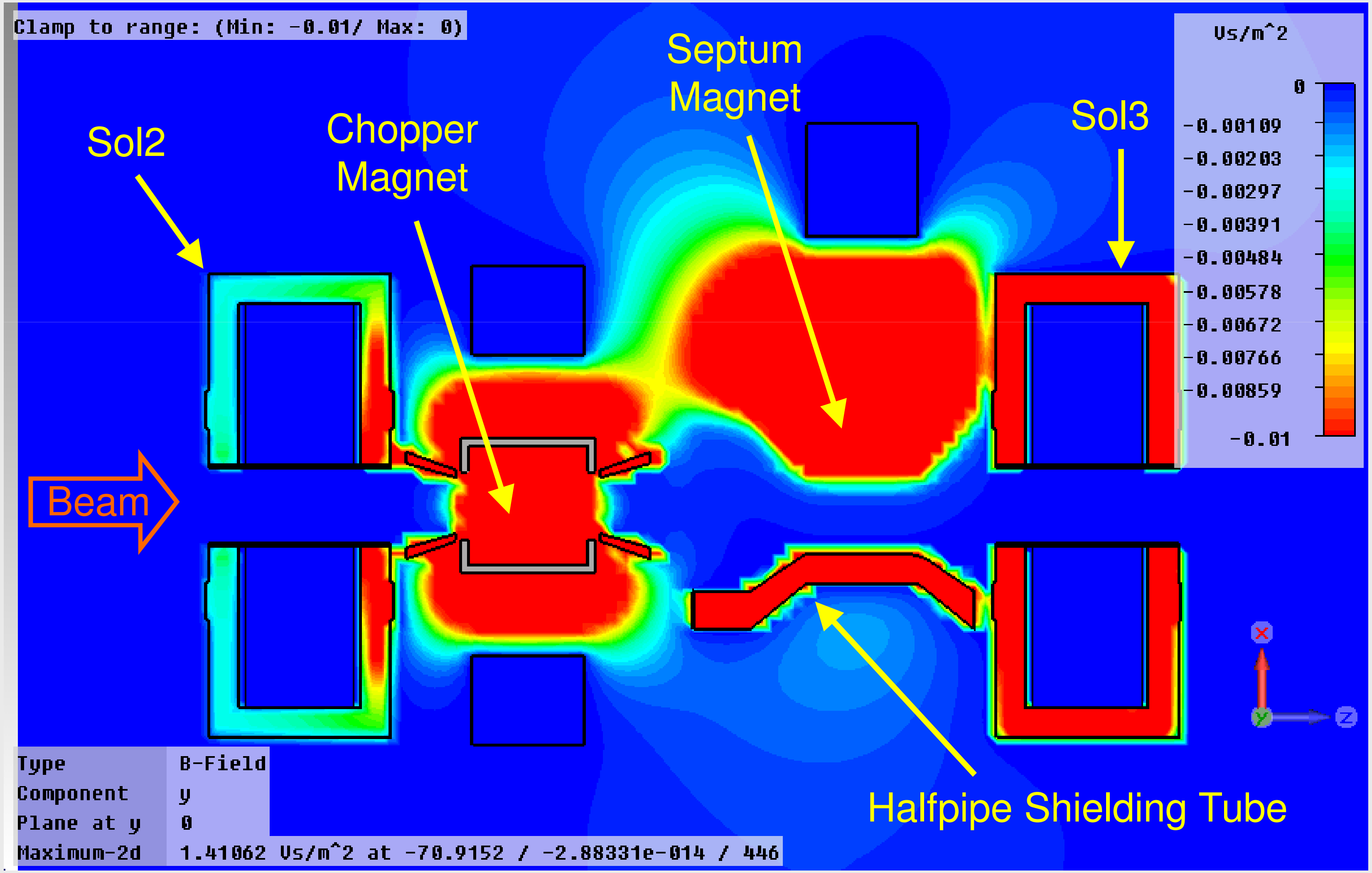
Separation Tank



Field Simulation of All Magnetic Components



Field Simulation of All Magnetic Components



Proton Pulse