Beam transport experiments in toroidal magnetic field

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Riezlern 2009

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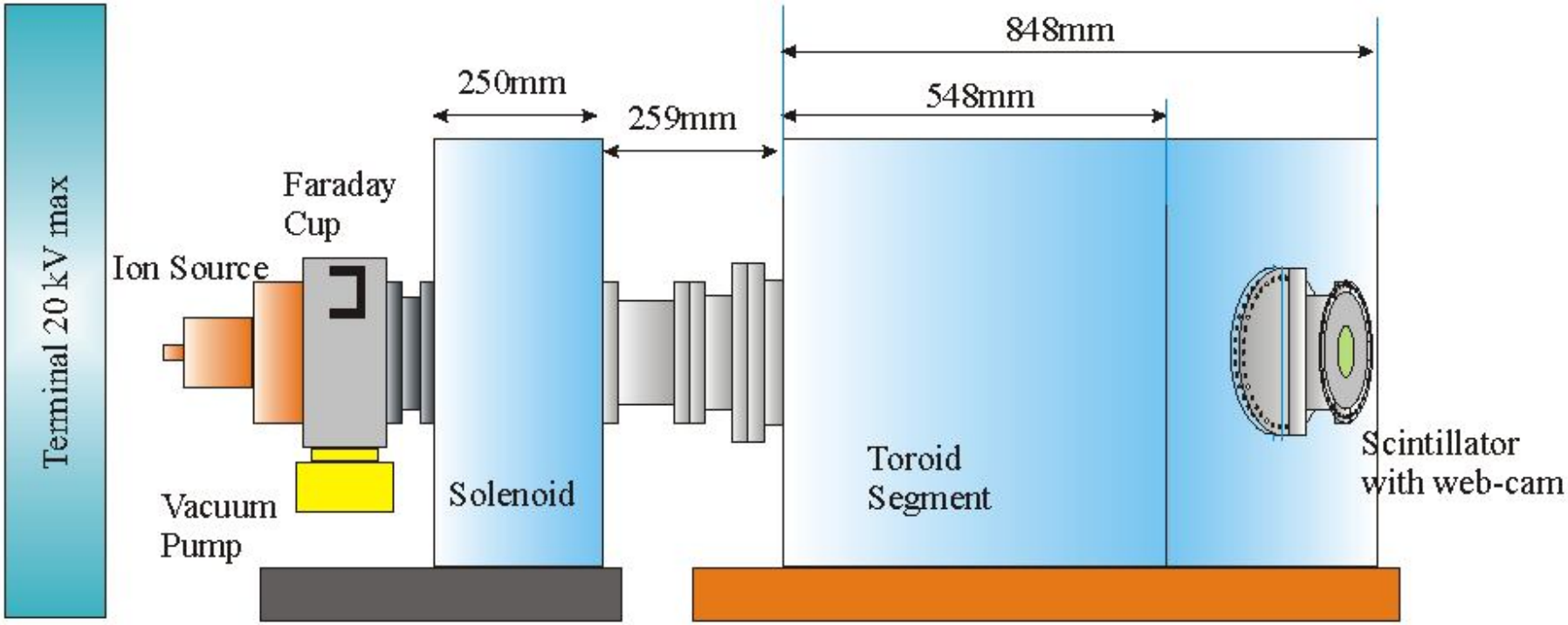
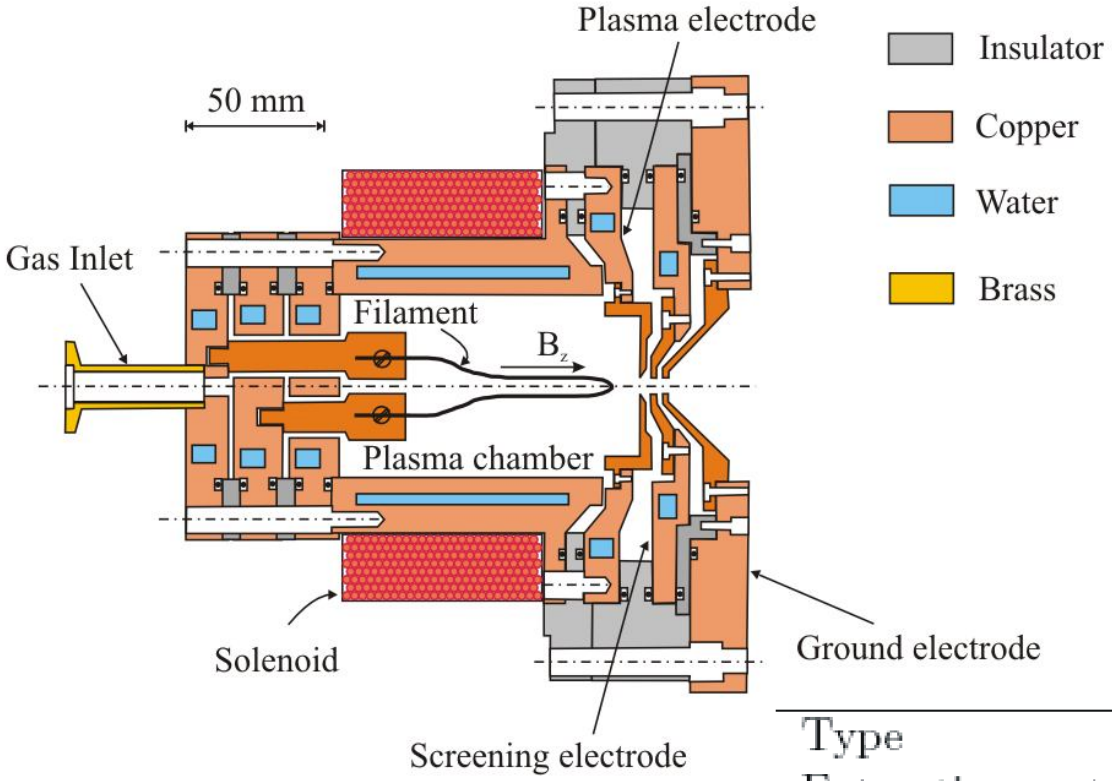
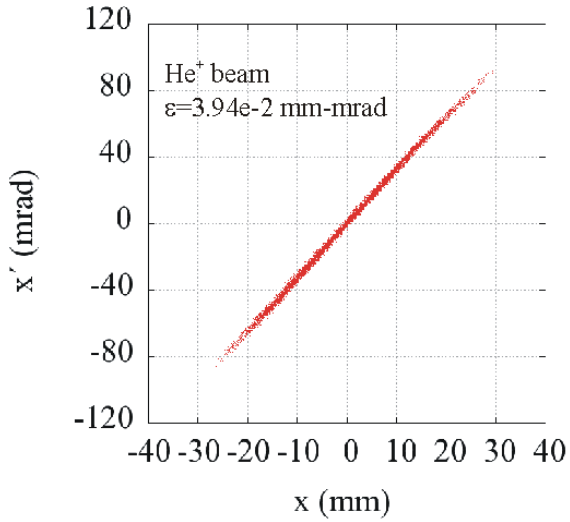
- Observations and Measurements
- Comparison with simulations
- Further experiments

Experimental Setup



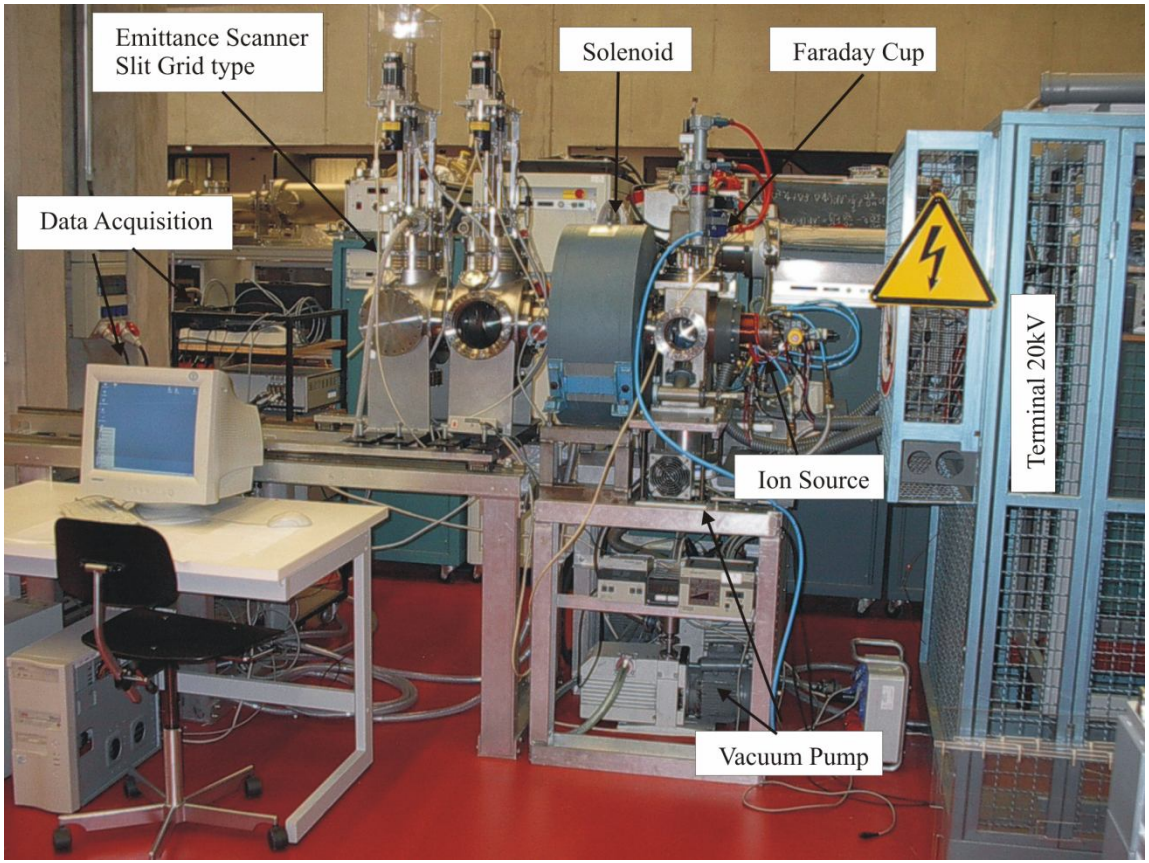
Ion beams



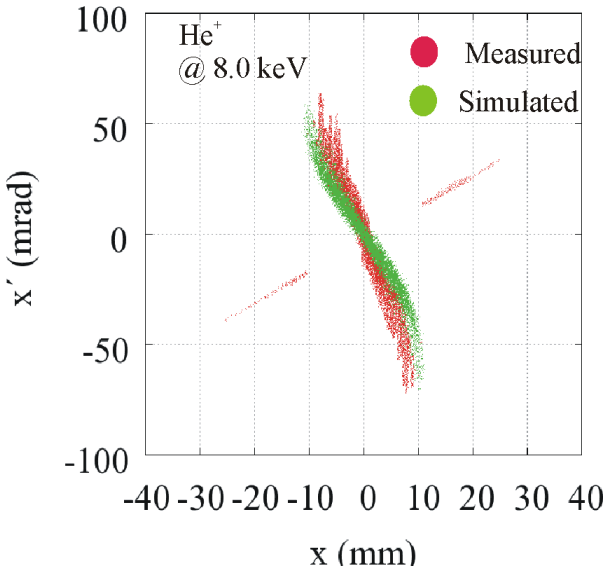


Type	hot filament volume type
Extraction system	triode
Ion Specie	$He^+, composite(H^+, H_2^+, H_3^+)$
Energy	$20\ keV max$
H^+ max	$\sim 45\% \Longrightarrow 2.8\ mA$ @ $10\ keV$
H_2^+ max	$\sim 91\% \Longrightarrow 2.84\ mA$ @ $10\ keV$
H_3^+ max	$\sim 95\% \Longrightarrow 3.05\ mA$ @ $10\ keV$
He^+ max	$2.0\ mA$ @ $10\ keV$

Solenoid



No. of winding	280
Maximum Magnetic on axis field	0.72 T
Maximum Voltage and Current	32.5 V, 360 A
Length	250 mm
diameter of aperture	106 mm
Magnetic Shielding	present



Phase-Space measurements from source

↓

Simulations transport through solenoid (LINTRA)

↓

Comparison with experiments

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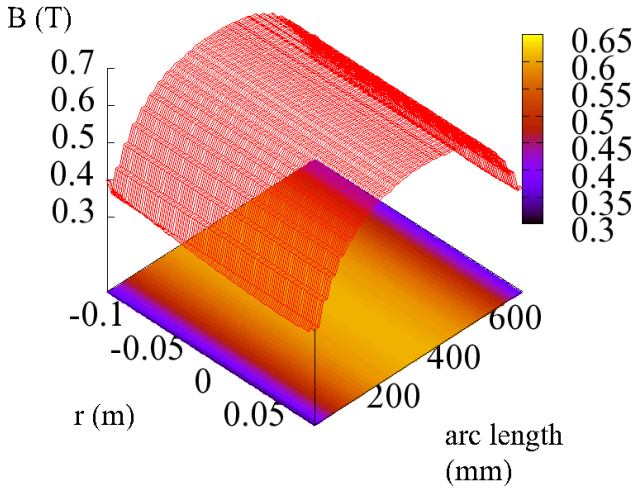
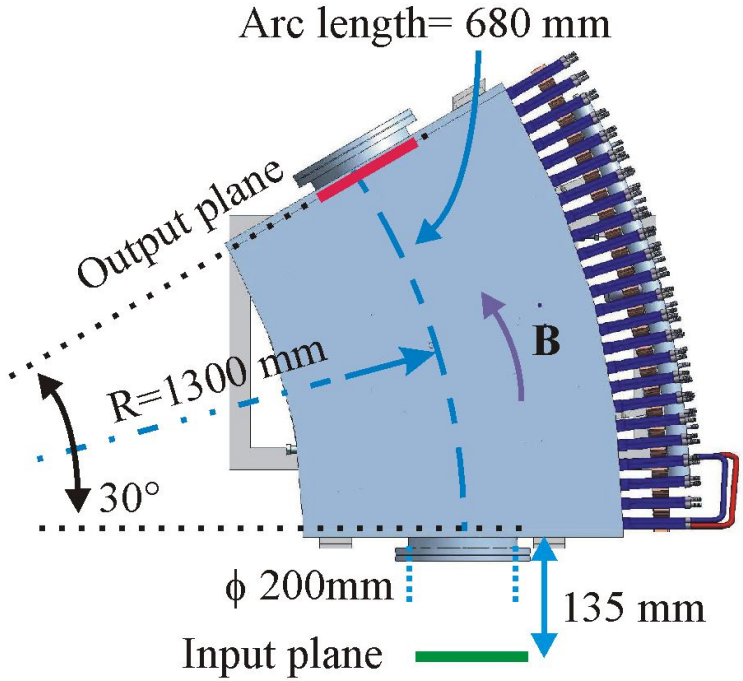
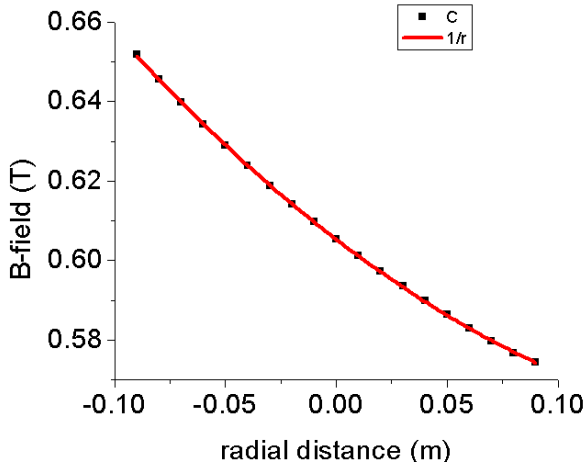
Calculation of phase-space for injection into toroid

Toroidal magnetic field

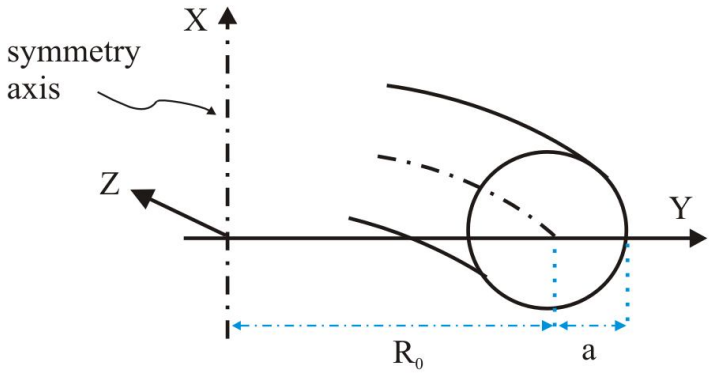




No. of winding	33×24
Maximum Magnetic field on axis	$0.6\ T$
Maximum Voltage and Current	$140\ V, 480\ A$
Major Radius R_0	$1300\ mm$
Arc angle	$30°$
Arc length	$680\ mm$
Diameter of aperture	$200\ mm$
Magnetic Shielding	absent
Cooling water	$70\ l/min$
Weight	$1050\ kg$

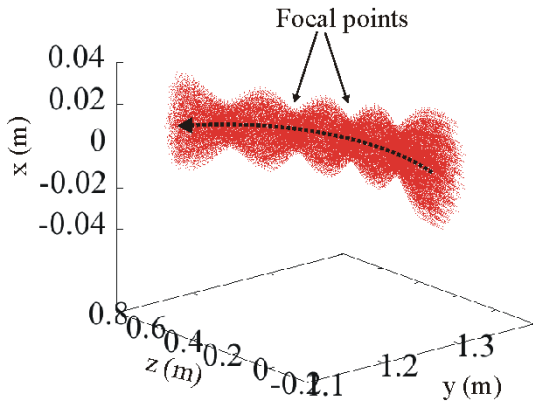


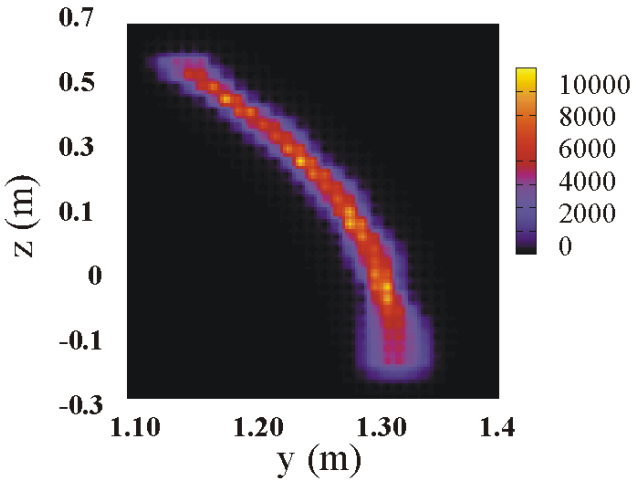
Proton beam transport in curved fields

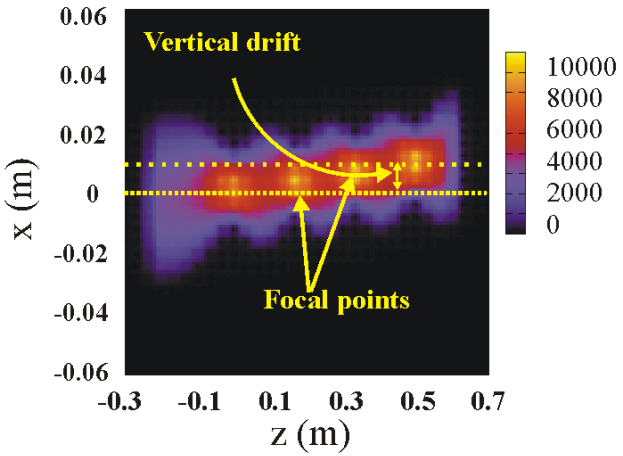


- Code for beam transport
- PIC subroutine
- Real field configuration, measured phase space distribution
- Up to 10^6 particles can be simulated on the CSC cluster
- 50*50*180 Grid points

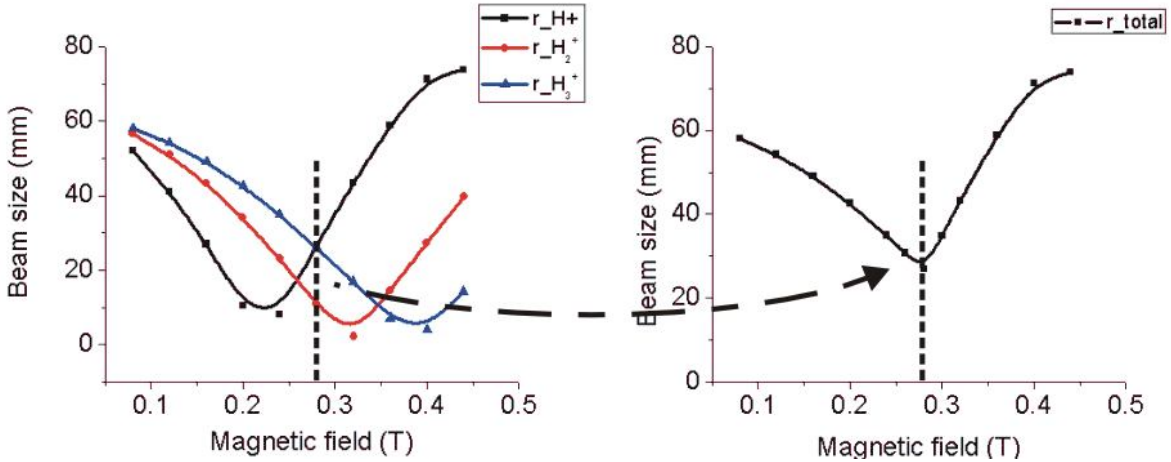
Example : proton 10keV into 0.6 T vertical drift ~15 mm

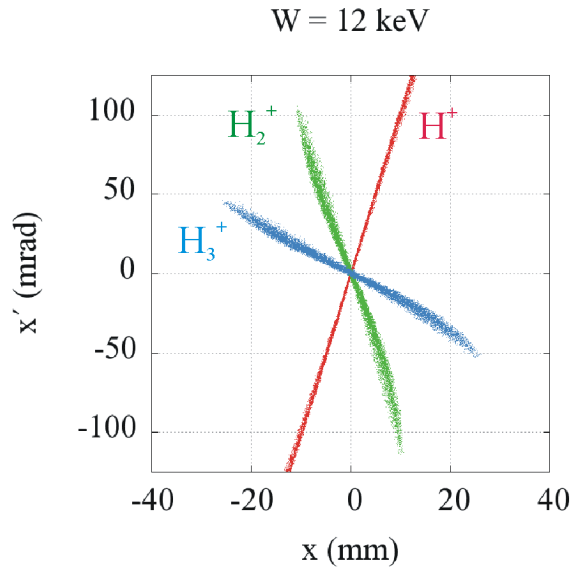


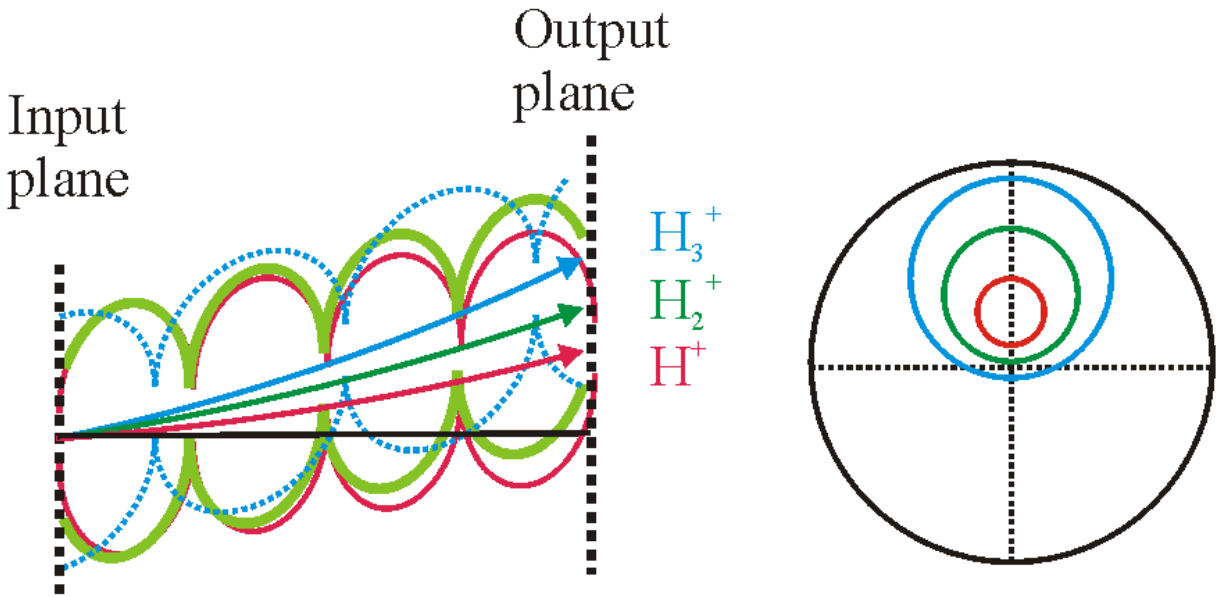




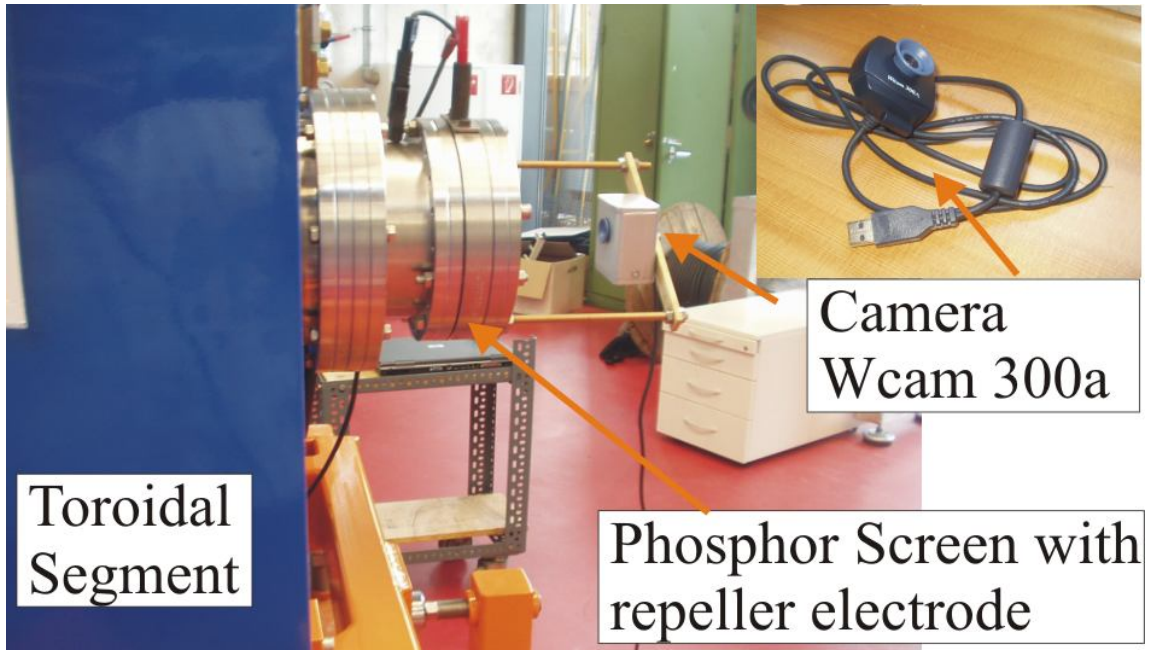
Composite beam transport



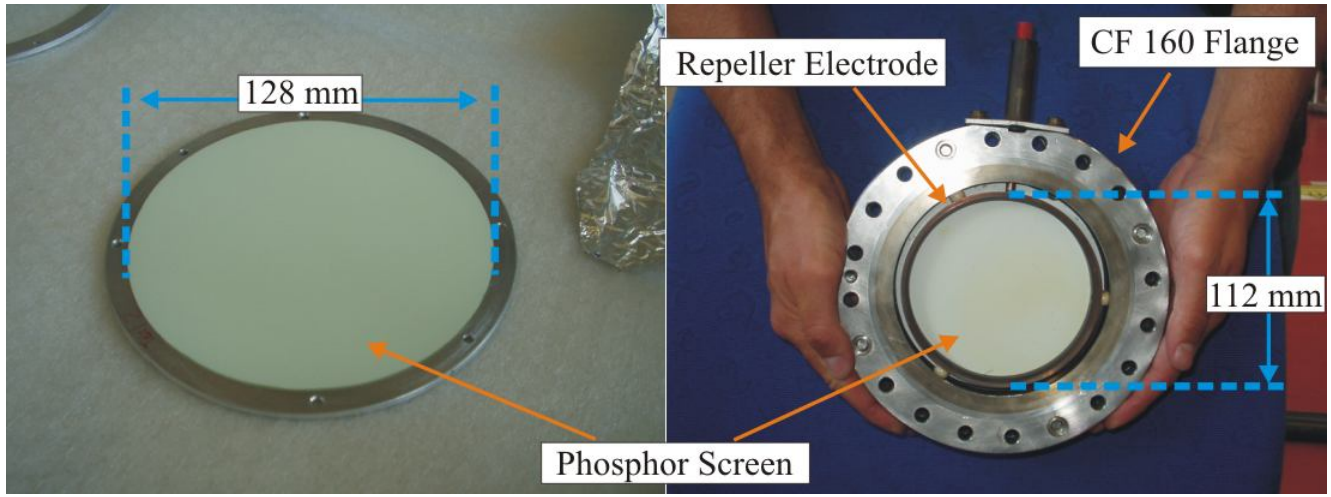




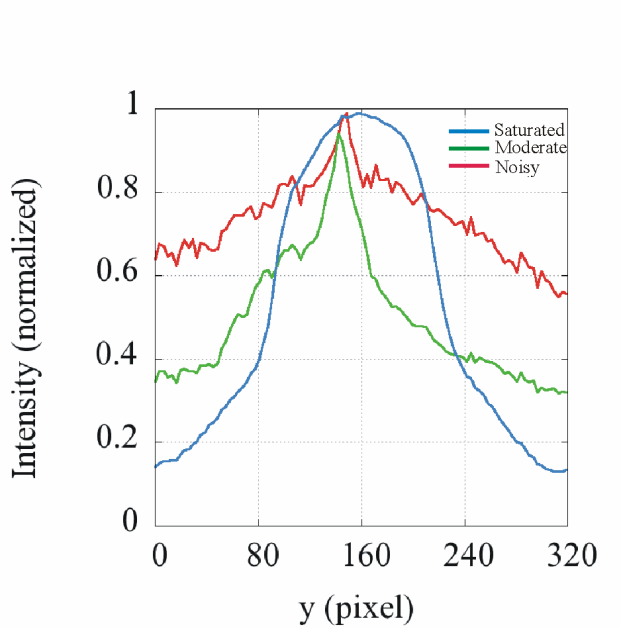
Optical diagnostic



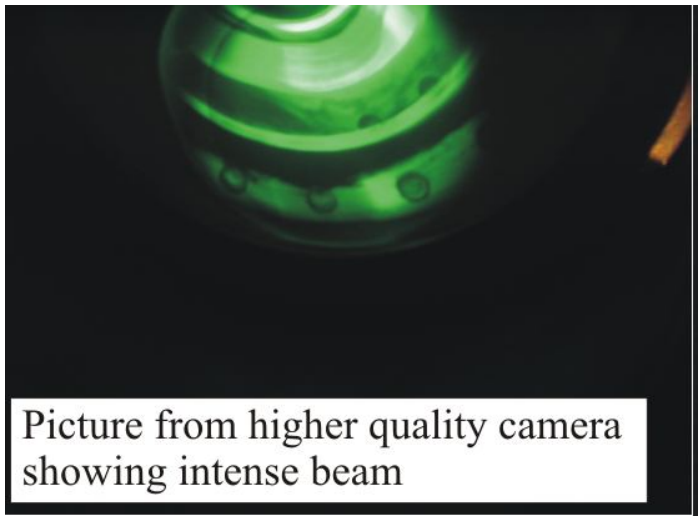
- Phosphor screen P20
- max 1 W/cm^2
- Repeller electrode 1.2kV max
- Digital camera (8-bit)
- Position of screen is in fringe field region

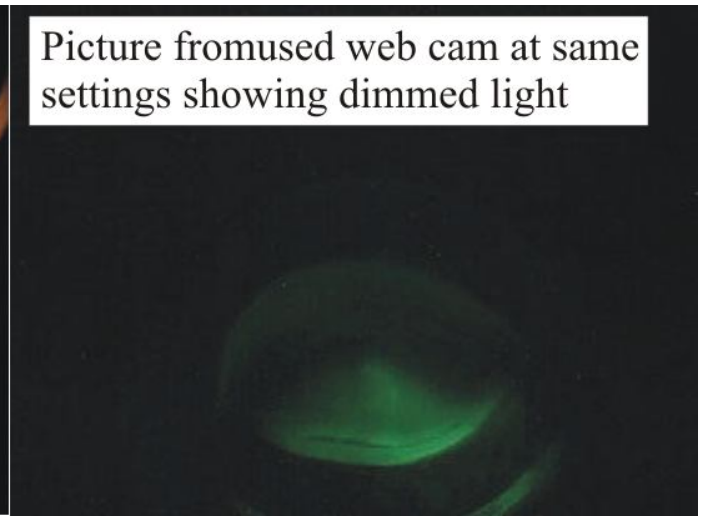


Limitations on optics

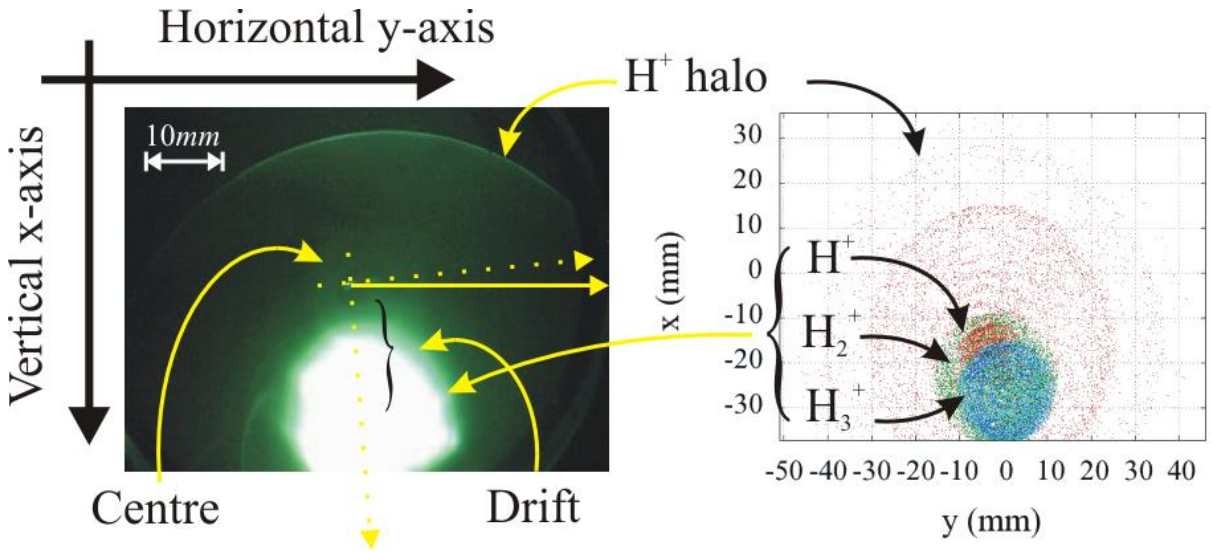


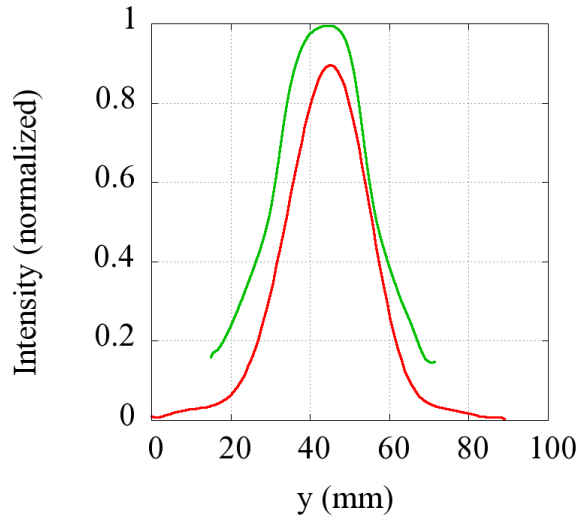
- Camera to be operated in high magnetidc field
- Magnetic shielding required
- Low light conversion efficiency
- Secondary electron production

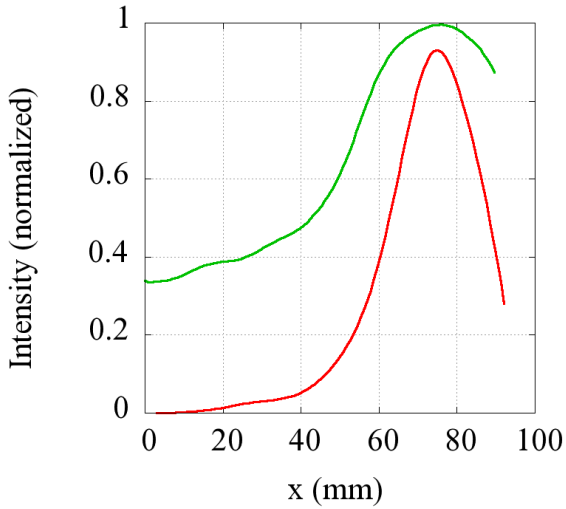




Comparision with simulation

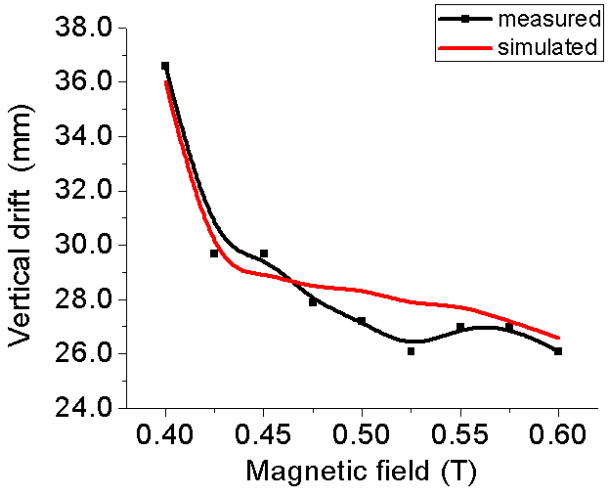


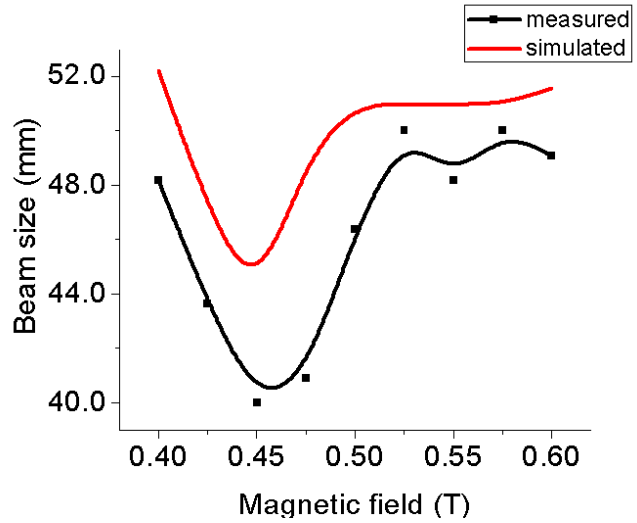


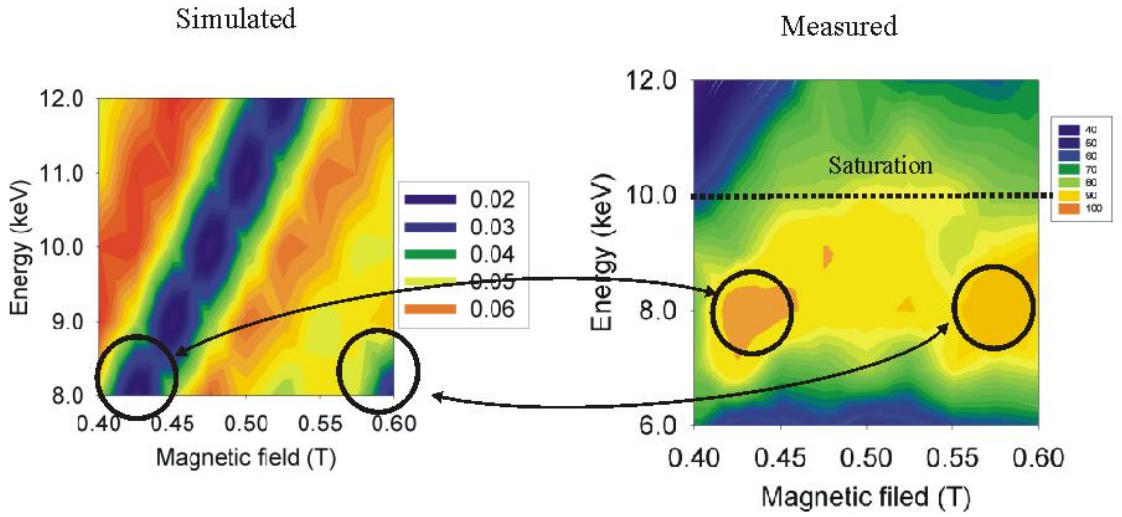


- Magnetic field in opposite direction hence curvature drift downward
- Drift, beam size
- Image processing code

Example : composite proton beam at @ 8keV



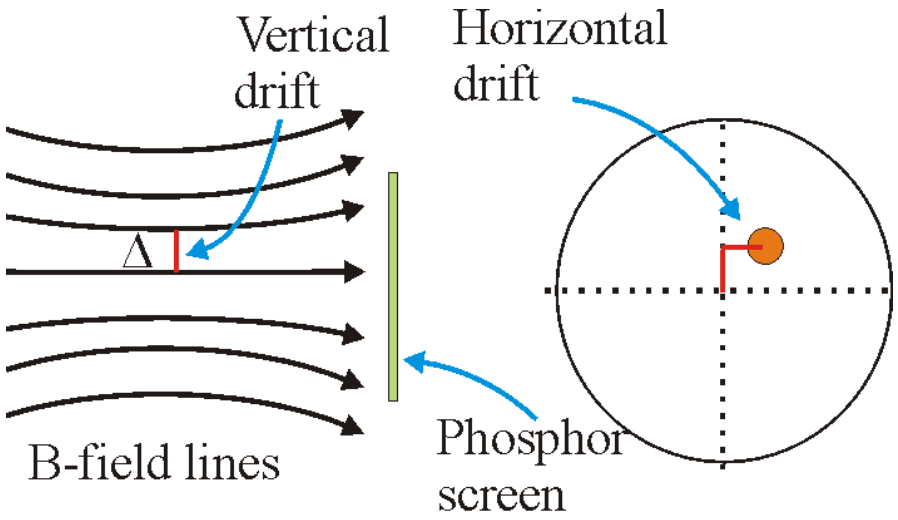




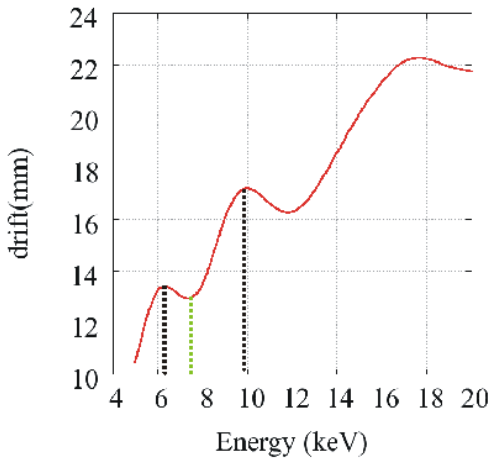
Beam size colour coded

Intensity averaged

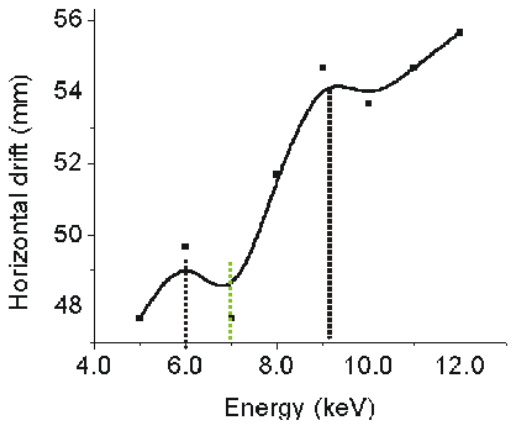
Effect of fringe fields



Simulated Vertical drift

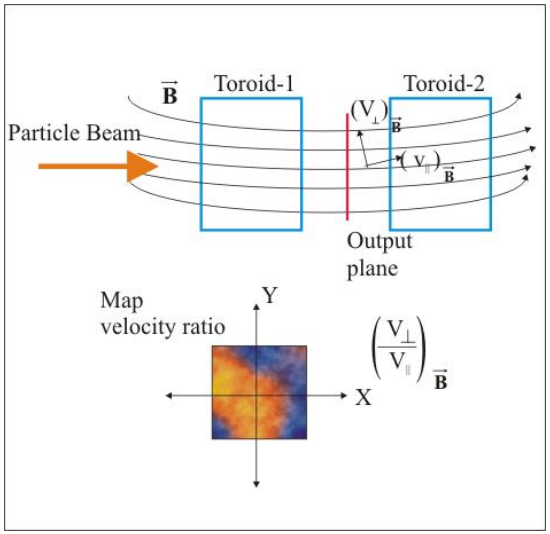


Measured horizontal drift

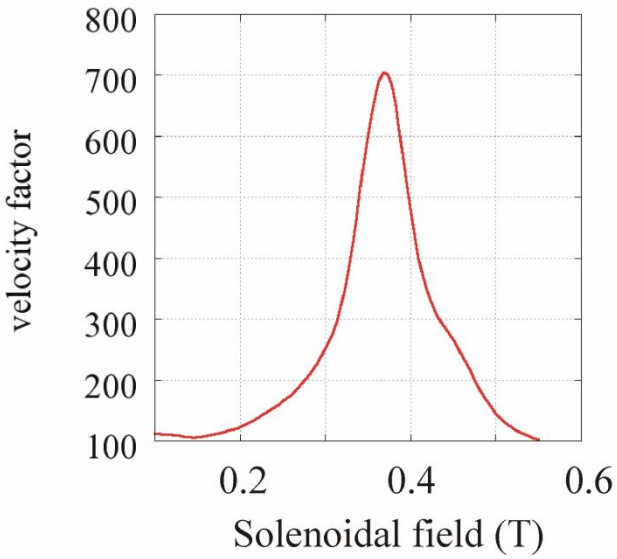


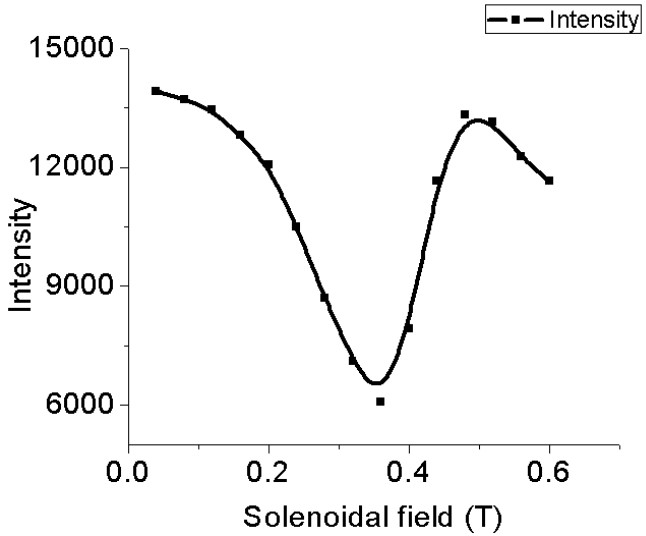
Proton beam
B=0.6T

Beam Guidance



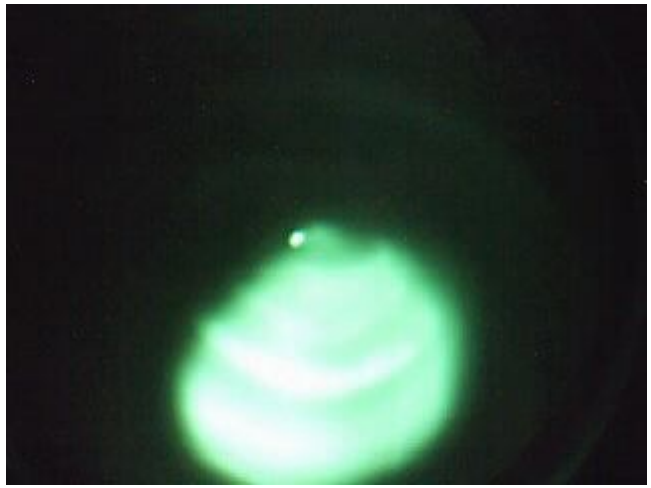
- Beam guidance is defined in terms of v_λ and velocity factor v_f
- low v_λ and high v_f is prefered

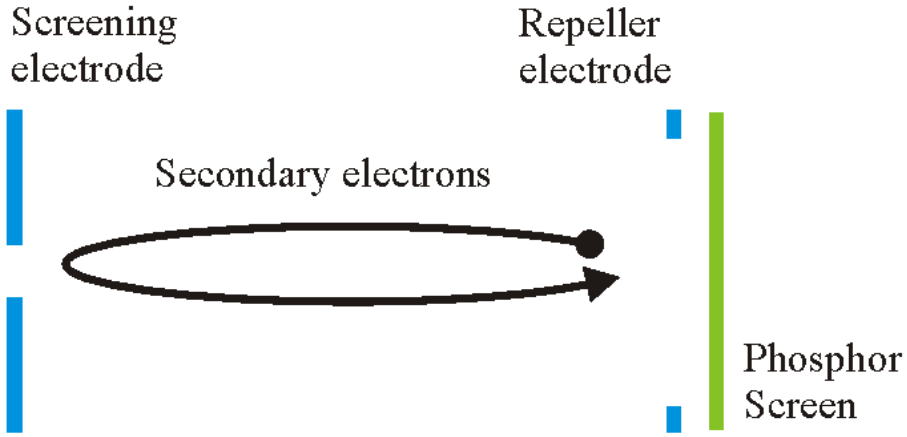




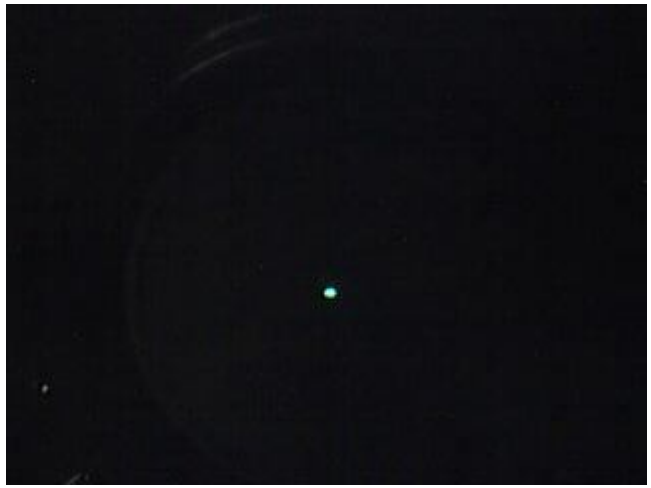
Electrons

Proton beam

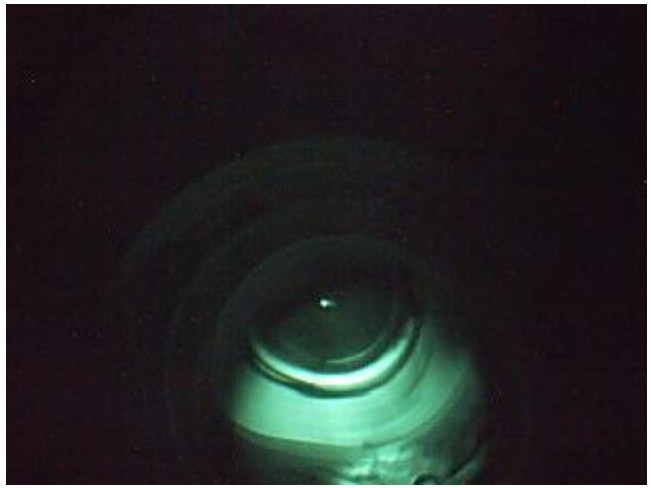




Electron beam 3kev



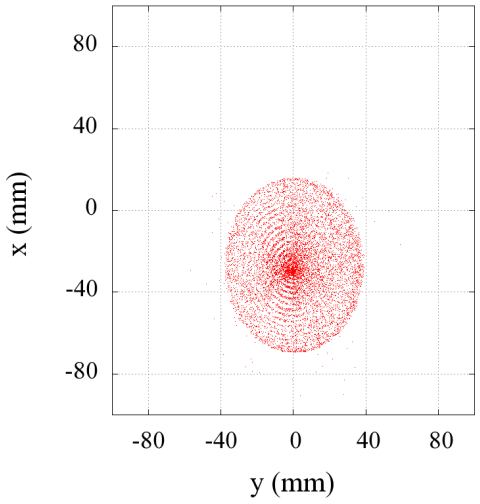
Secondary electrons

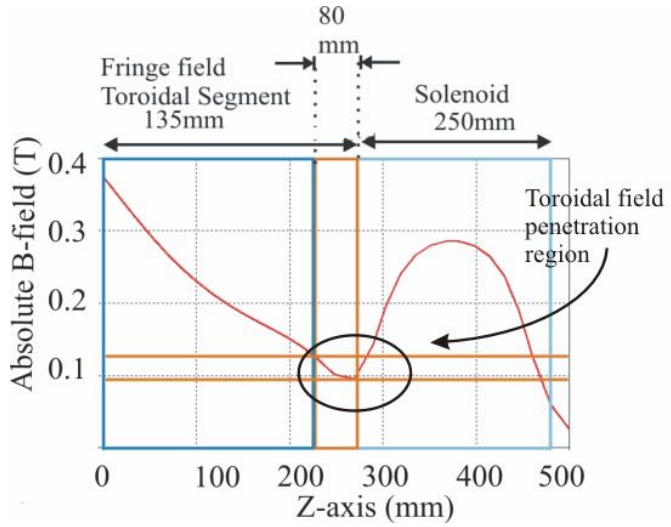


Success and failure

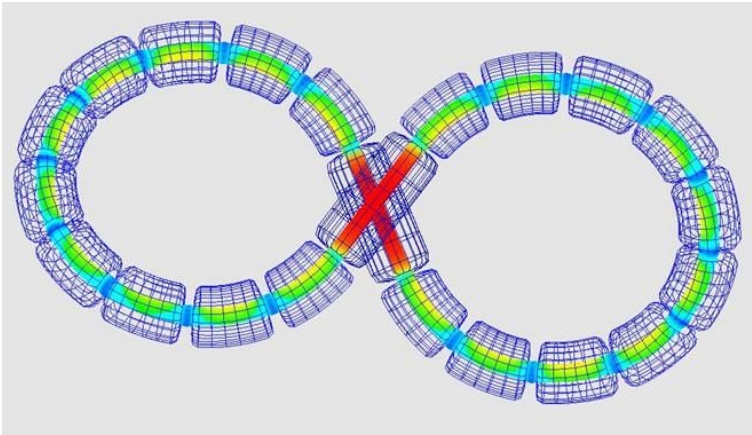
- In the case of composite proton beam the simulation results are in well agreement with experiments
- Helium beam can not be compared well as in most cases it hits wall or repeller electrode producing electons.
- Space charge effects observed still to be compared
- Necessity of measurements inside field

Example : He-beam @ 8 keV into B=0.5T

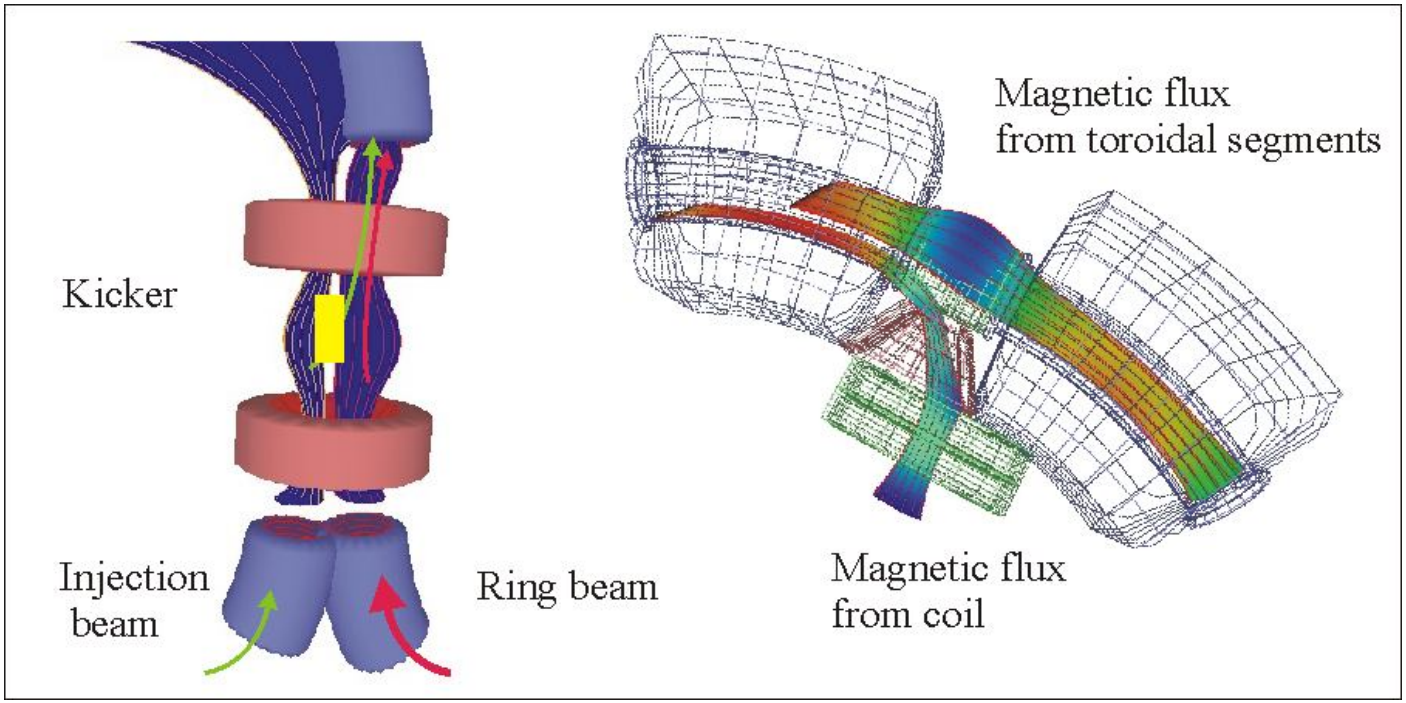




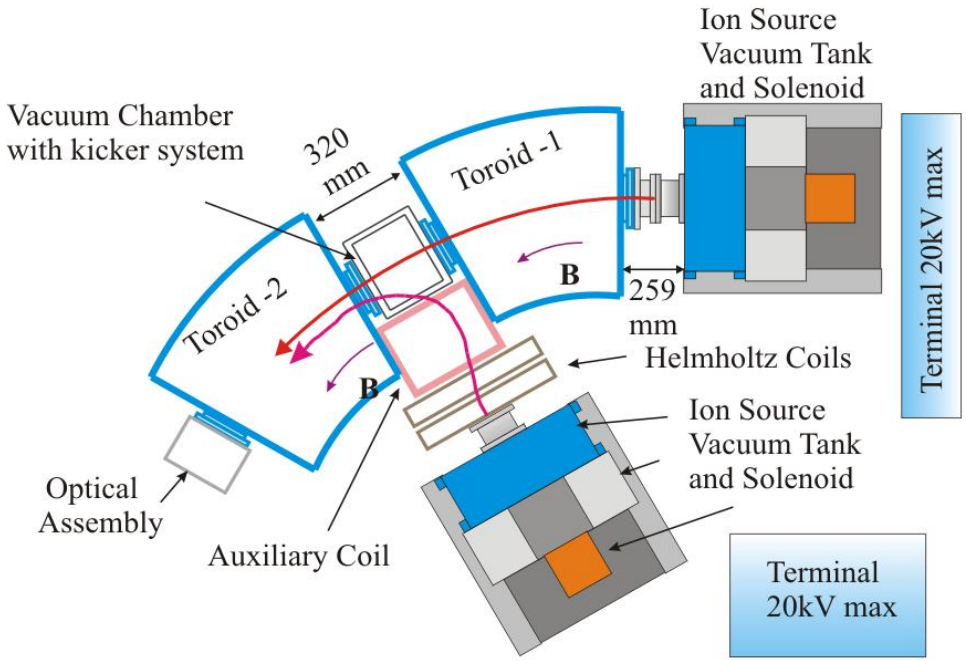
For storage ring



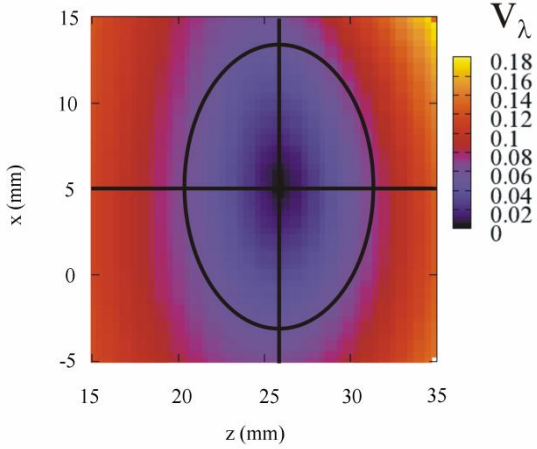
- Storage ring for proton
- Magnetic surface due to 3d geometry
- Two beam experiments with two segments
- Electric kicker with extra coil

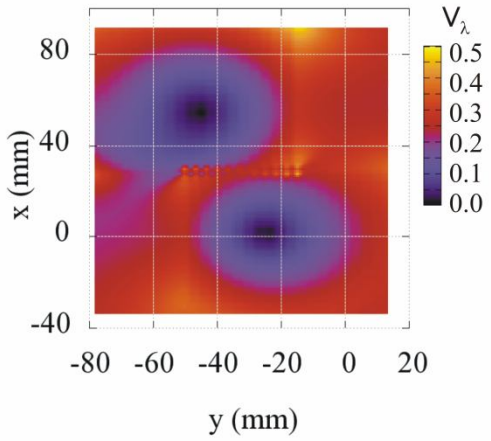


Experimental setup



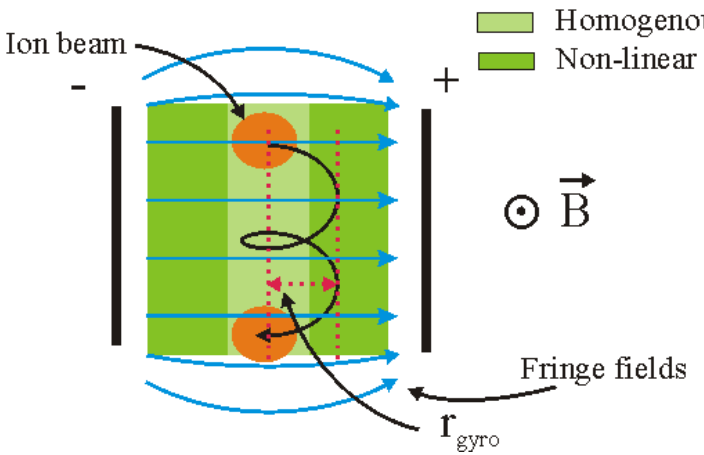
$$v_\lambda = \left(\frac{v_\perp}{v_\parallel} \right)_B$$

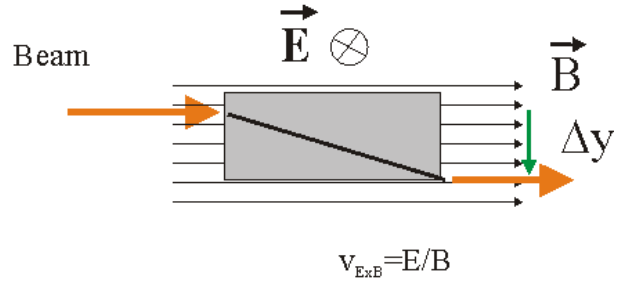


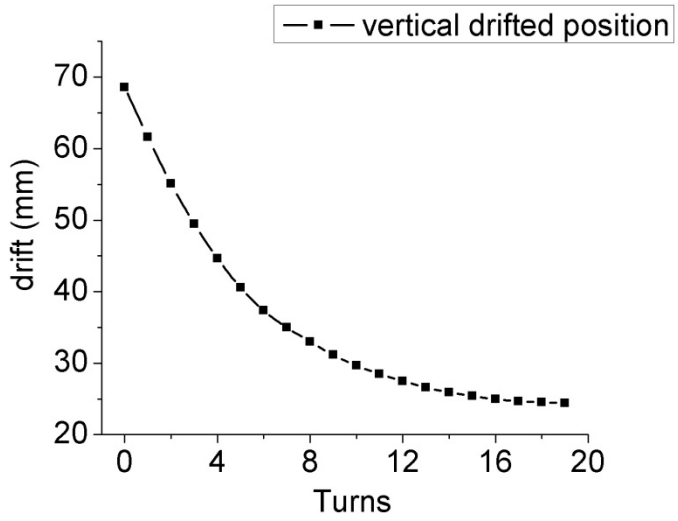


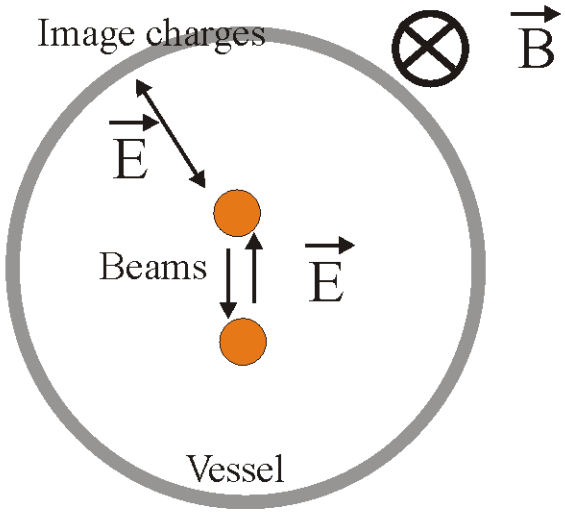
- B = 0.6 T, W = 10 keV, proton beam
- For ring 5T, 150 keV, E= 1.2MV/m required

Kicker and multiturn type phase-space filling









Concluding remarks

- Beam transport experiments were performed to compare simulation tools and investigate drift dynamics
- Further experiment to investigate coupling properties of two magnetic segment are planned with different geometry and extra coil to control ripple in the fields
- Injection experiments are designed
- For experiments more improvement is needed for detection systems
- Mass separator may be recommended to avoid unwanted beam fractions
- Effect of electrons can be studied in detail

The End

- Thank you