



Low Energy Beam Transport and Diagnostic

Gabor - Linsen: Abriß einer Entwicklung

C. Gabor, A. Jakob, O. Meusel*, J. Pozimski, U. Ratzinger, J. Schäfer

Riezlern 2002

[Vorläufige Mitteilung¹⁾ aus dem Hochspannungslaboratorium der Technischen Hochschule Berlin²⁾.]

Das kurze Raumladungsfeld einer Hilfsentladung als Sammellinse für Kathodenstrahlen.

Von Bodo von Borries und Ernst Ruska in Berlin.

Mit 3 Abbildungen. (Eingegangen am 22. April 1932.)

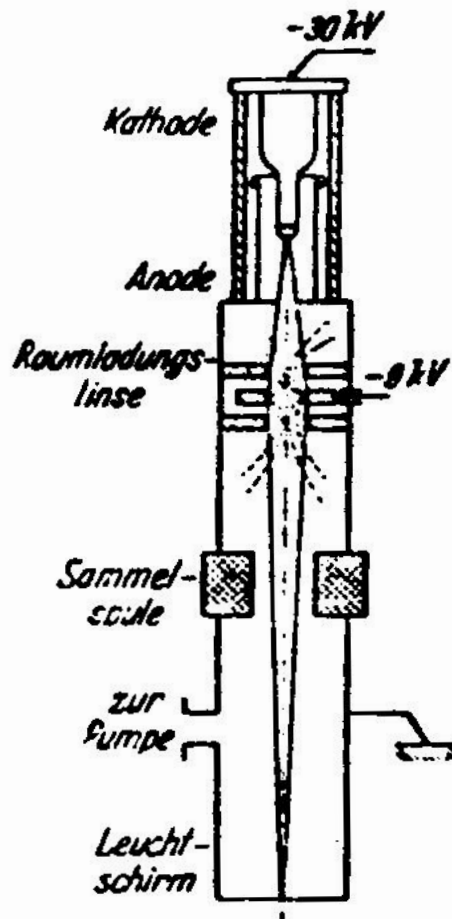


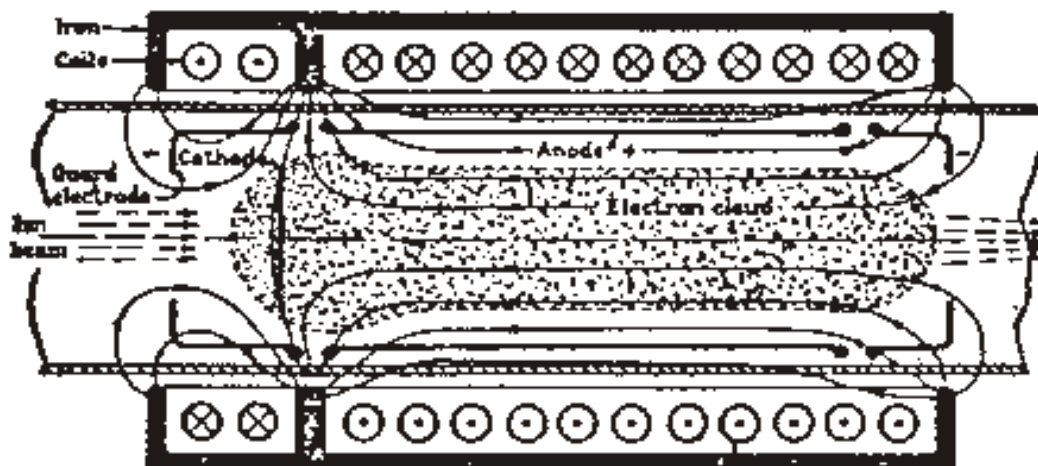
Fig. 2.

Abbildung durch eine kurze Raumladungssäule (Fremdionisation).

D. Gabor

A Space-Charge Lens for the Focusing of Ion Beams

SOME time ago I proposed a magnetron of special design as a divergent lens for electron beams¹. It now appears that the same device may become useful as a very powerful concentrating lens for positive ions, particularly for ion beams of extreme energy.



MAGNETRON LENS FOR ION BEAMS

According to the theories of Hull² and Brillouin³, in the steady state the electrons rotate around the axis in equilibrium orbits, such that the electrostatic repulsion of the electrons inside the orbit together with the centrifugal force balance the radial Lorentz force produced by the magnetic field. The electron distribution in the cloud is uniform, with a space-charge density

$$\rho_H = - \frac{eH^2}{8\pi m_e c^2} \quad (1)$$

IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

GABOR LENSES*

R. M. Mobley, G. Gammel, and A. W. Maschke[†]

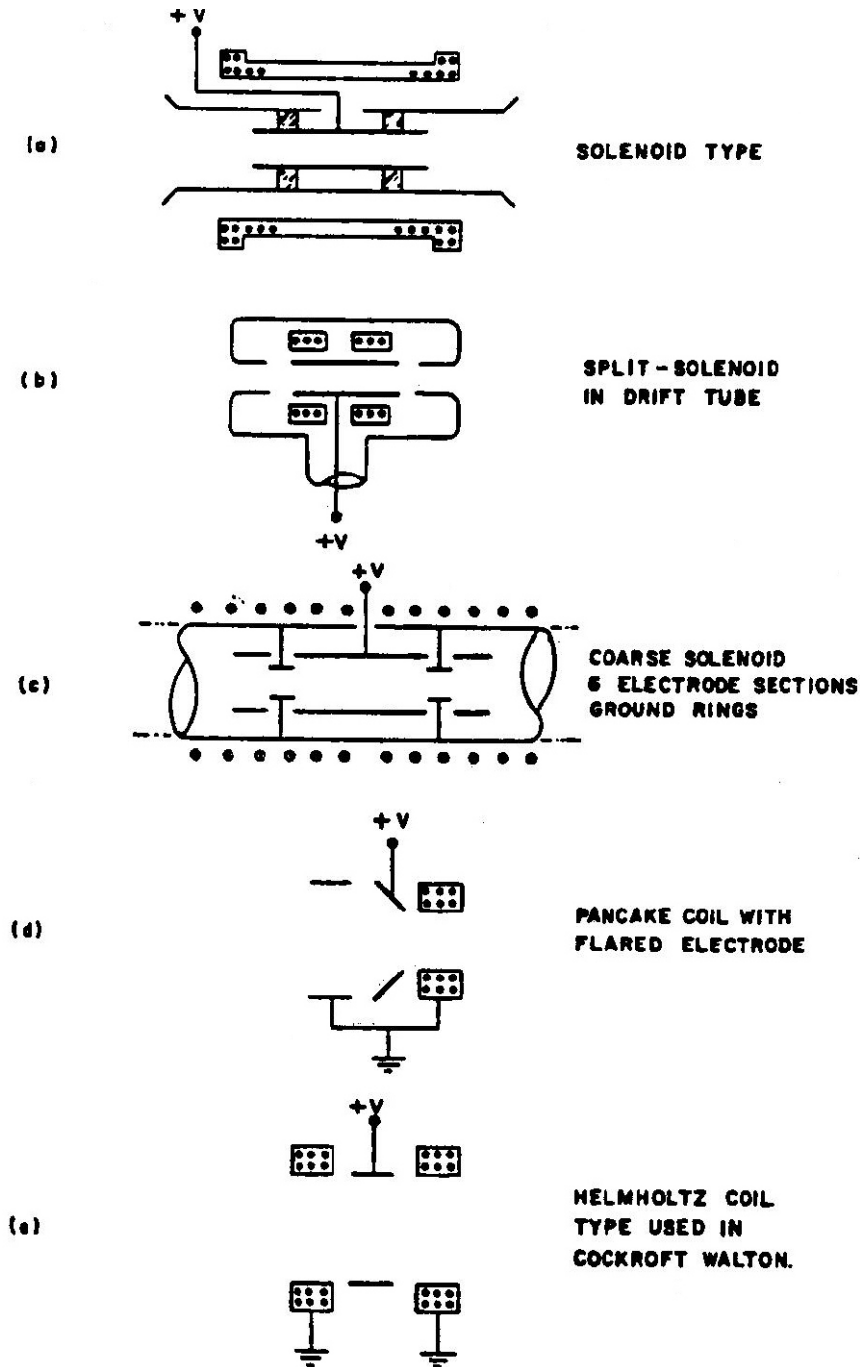


Figure 1. Schematics of lens types successfully operated. Electrode materials are stainless steel or copper.

Erste Ergebnisse für den Transport von Ionenstrahlen durch Gabor - Linsen

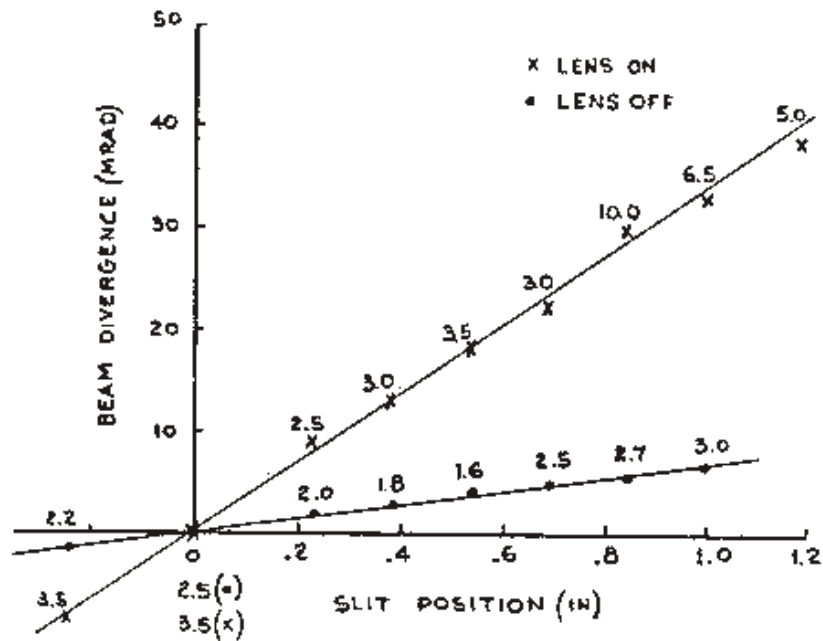


Figure 4. Emittance measurement of 500 keV Xe^+ beam using a moveable slit and moveable pickup wire. Lens (b) was used to produce a crossover halfway between lens and slit for the lens on case. The lines indicate the tilt of the emittance "ellipses", and the associated numbers are full width divergences in mrad. This shows that the focusing is linear across the lens aperture within 5%. The increase in the divergence widths may be due to fine noise.

IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

PROGRESS IN SPACE CHARGE LENS DEVELOPMENT*

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Rex Booth

Lawrence Livermore Laboratory, Livermore, California 94550

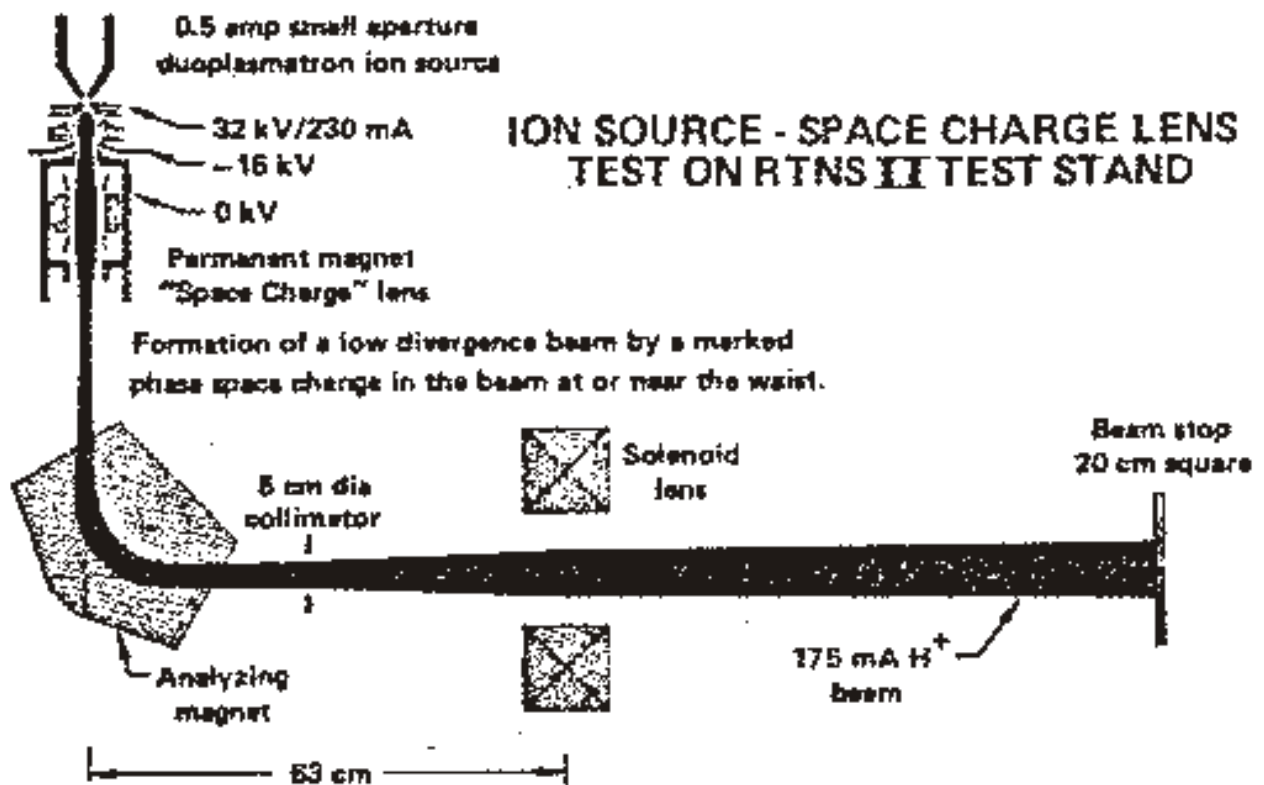
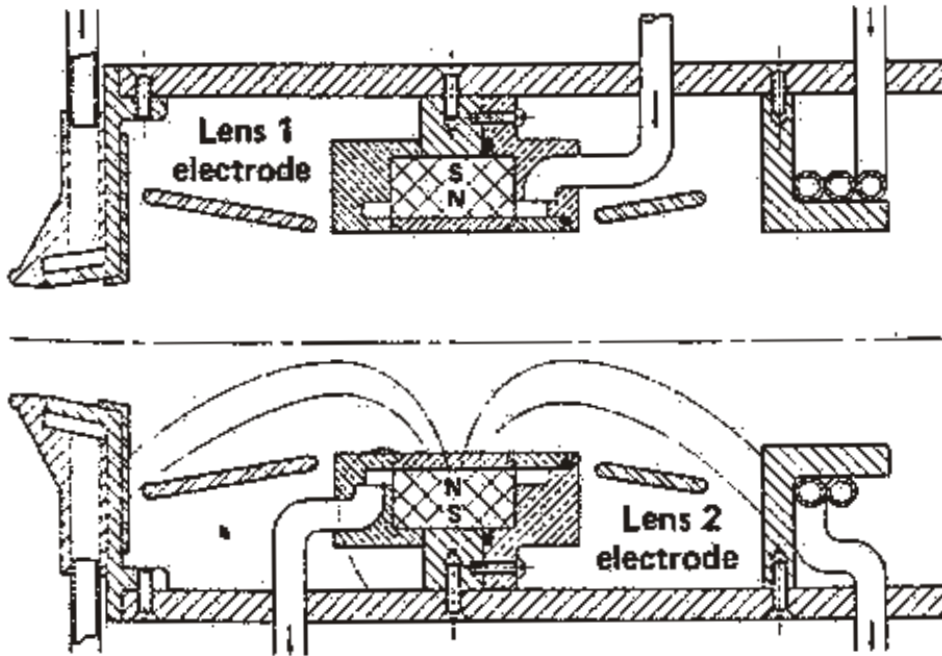


Fig. 2. The permanent magnet lens on the RTNS-II test stand.



. 1. The LLL permanent magnet lens. Overall gth is approximately 18 cm.

Erste Diagnose der Linsenparameter

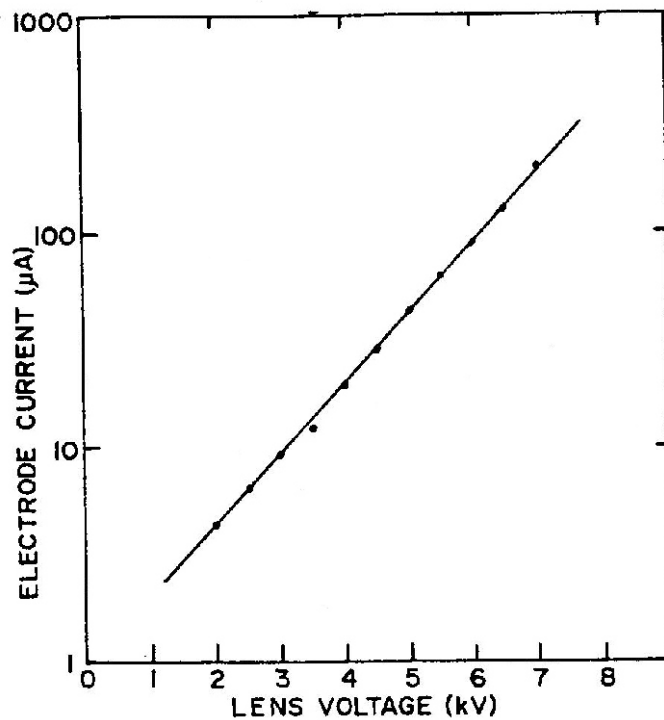


Fig. 4. Current vs voltage characteristic of the nine ring lens after outgassing. The solid line is given by $i = 10^{-6} \exp(V/1320)$.

MEASUREMENTS ON A GABOR LENS FOR NEUTRALIZING AND FOCUSING A 30 KEV PROTON BEAM

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University of Wisconsin, Madison
 R.Hren, G. Lee, F.E.Mills, C.W. Schmidt, J.Wendt, D.E.Young
Fermi National Accelerator Laboratory†

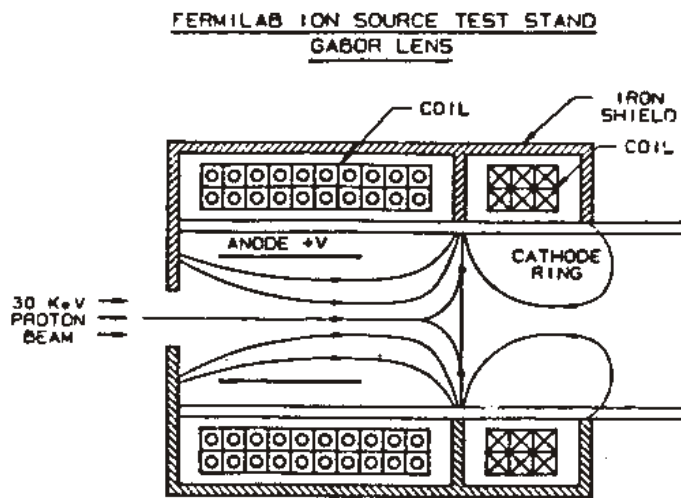


Figure 1: Gabor lens with cusped magnetic field

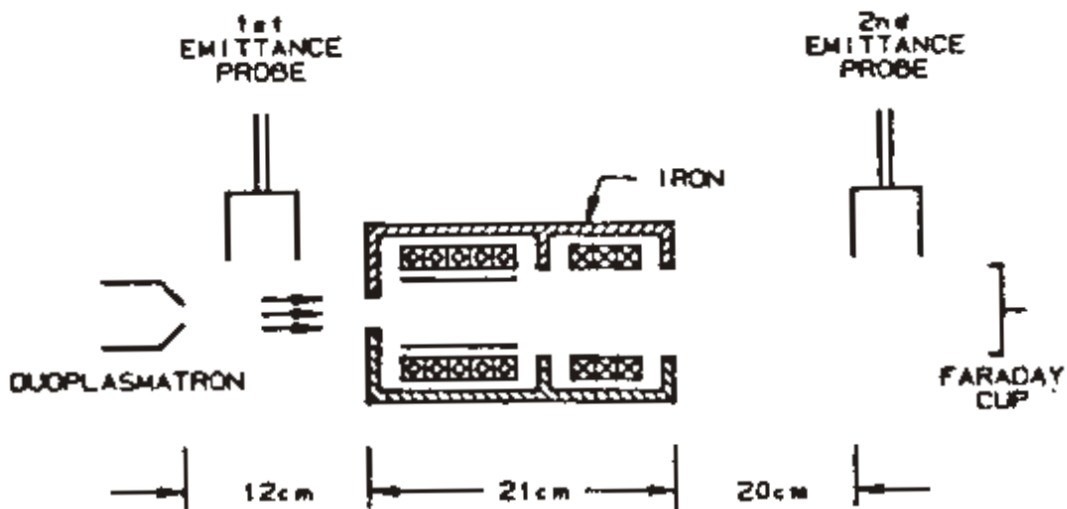


Figure 2: Experimental layout for Gabor lens Measurements

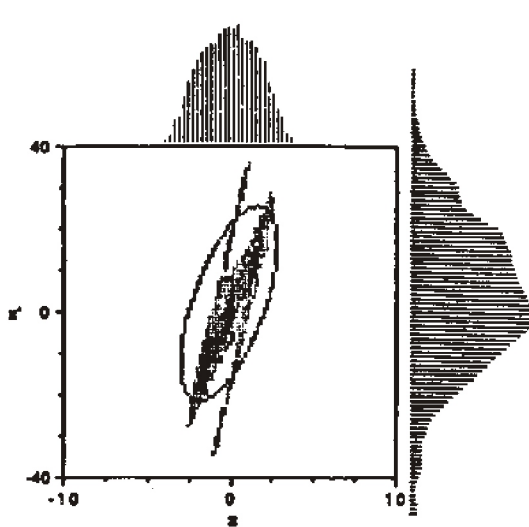


Figure 3: Source emittance; $\alpha = -.77$, $\beta = 0.15$, $\epsilon_{rms} = .56$, $\epsilon_{90\%} = 0.247$, $I = 11$ mA. The projection of the distribution on the x and x' axes are shown. Units are mm and mrad.

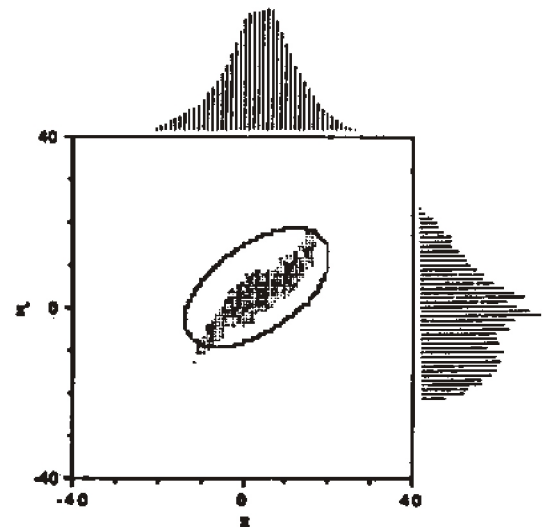
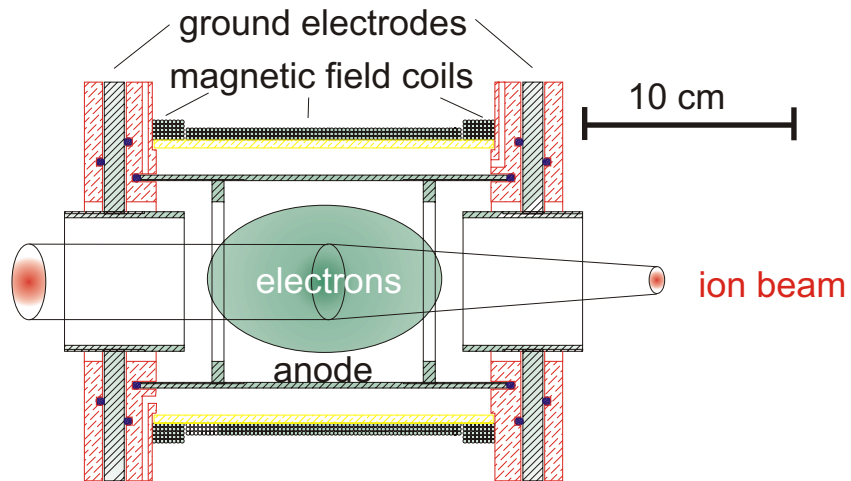


Figure 4: Downstream emittance; $\alpha = -.64$, $\beta = 1.3$, $\epsilon_{rms} = 1.93$, $\epsilon_{90\%} = 0.629$, $I = 17$ mA.

Measurements have been made on a Gabor lens at a beam energy of 30 keV and proton beam currents of 10 to 30 mA. The emittance is observed to grow by a factor of three to four as the beam propagates through the beam line. No significant time dependence of the emittance at the end of the beam line has been observed. Further study is planned to determine whether smaller emittances can be obtained and whether or not Gabor lenses are suitable focusing elements for a LEBT to match a 30 keV H⁻ beam into an RFQ.

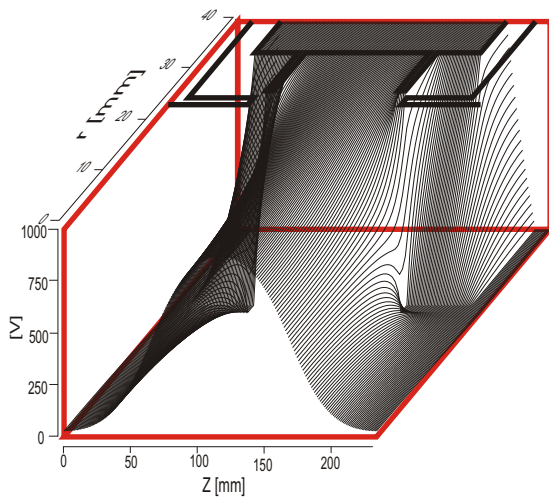
Diplomarbeit
Messung an einer Gabor-Plasma-Linse

Jürgen Pozimski
IAP Uni - Frankfurt
Oktober 1990

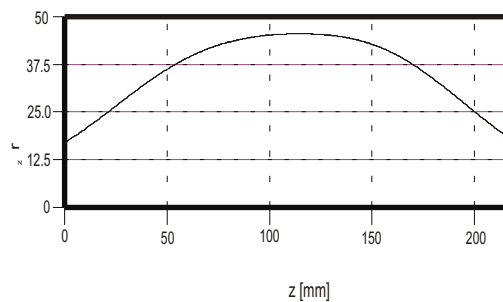
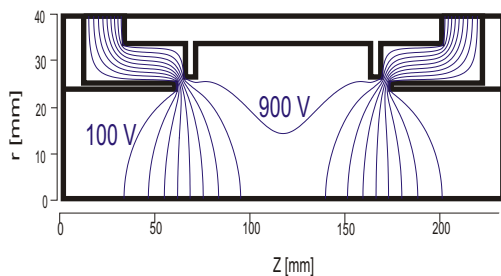
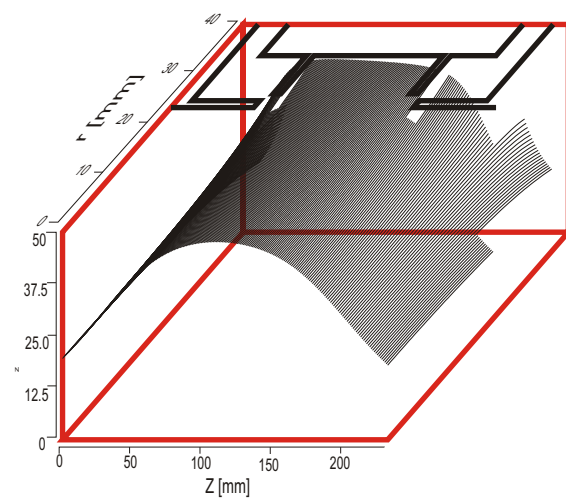


Distribution of the external fields

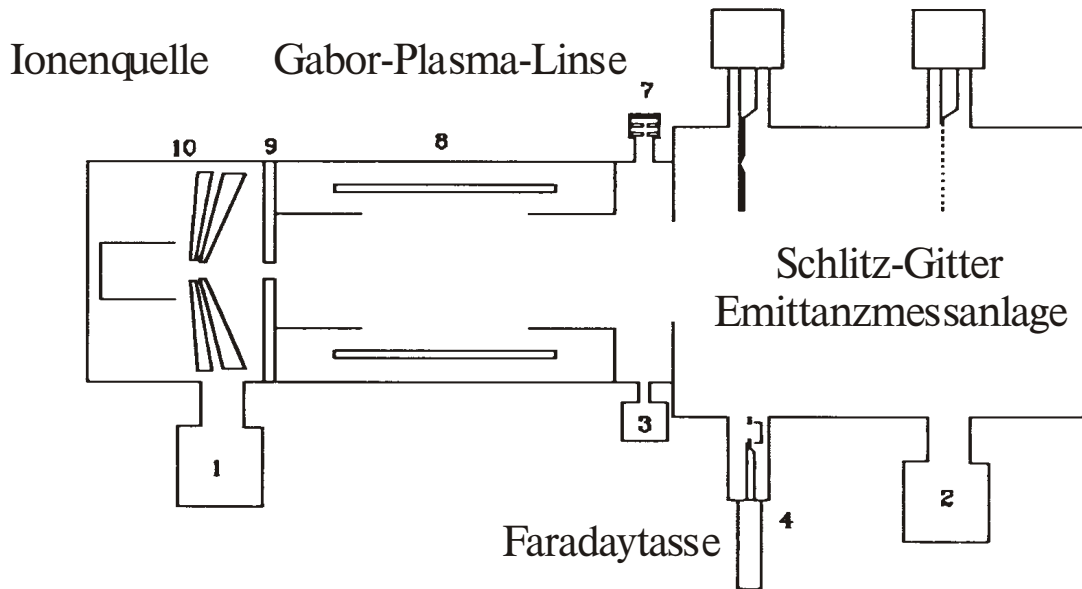
potential distribution



magnetic field

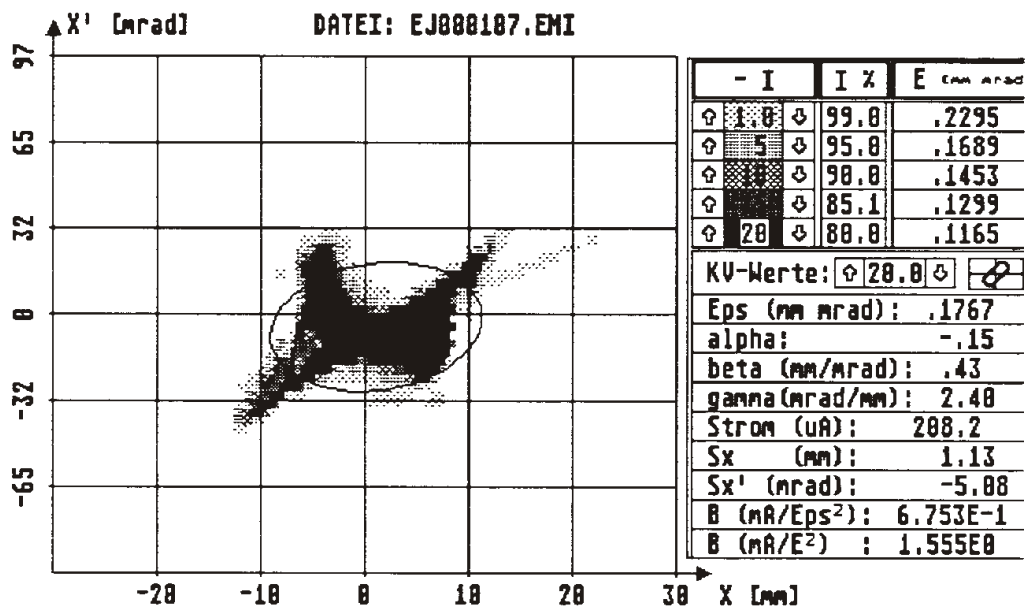


Schematischer Versuchsaufbau



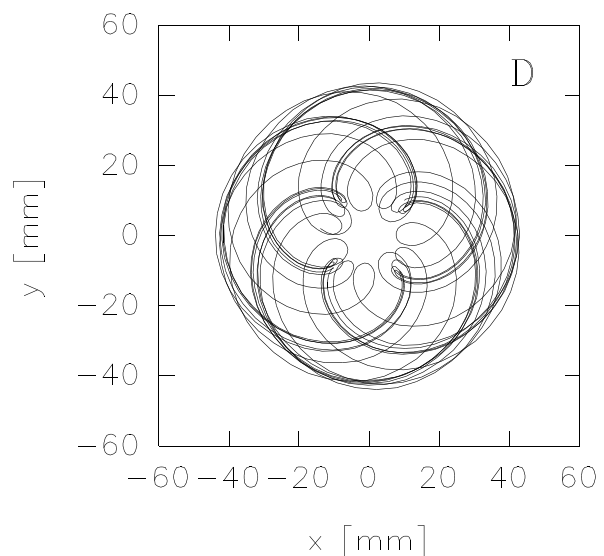
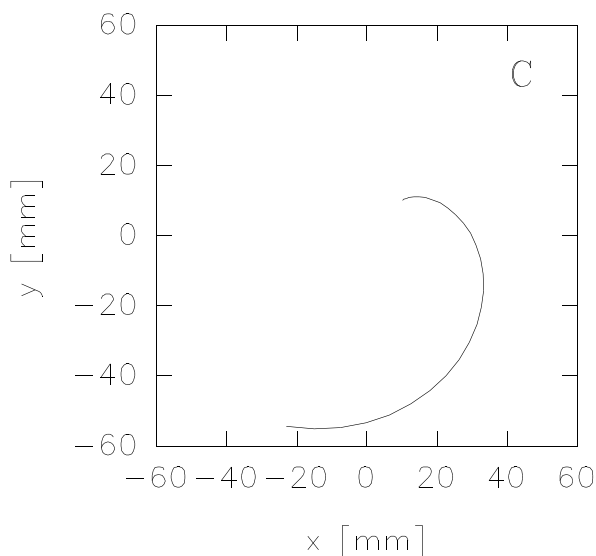
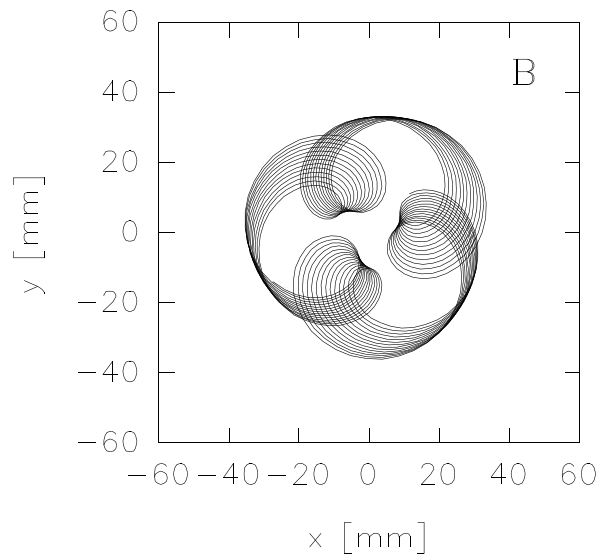
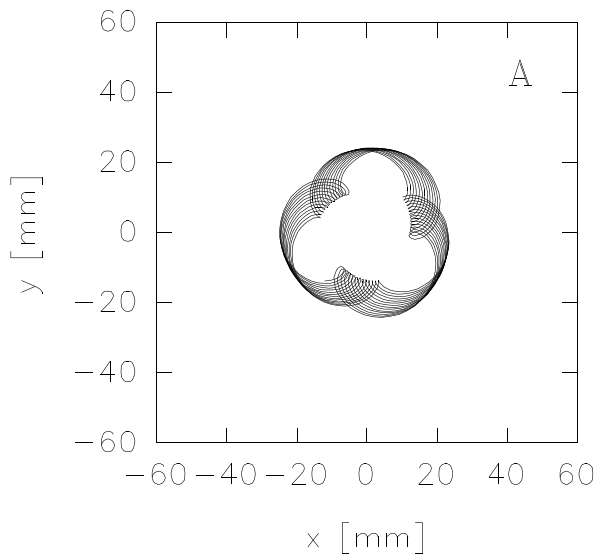
Emittanzmessung

Ar⁺, $I_{\text{FDT}}=280 \text{ A}$, $U_{\text{ex}}=10 \text{ keV}$



Erste numerische Analyse der Einschlußbedingungen

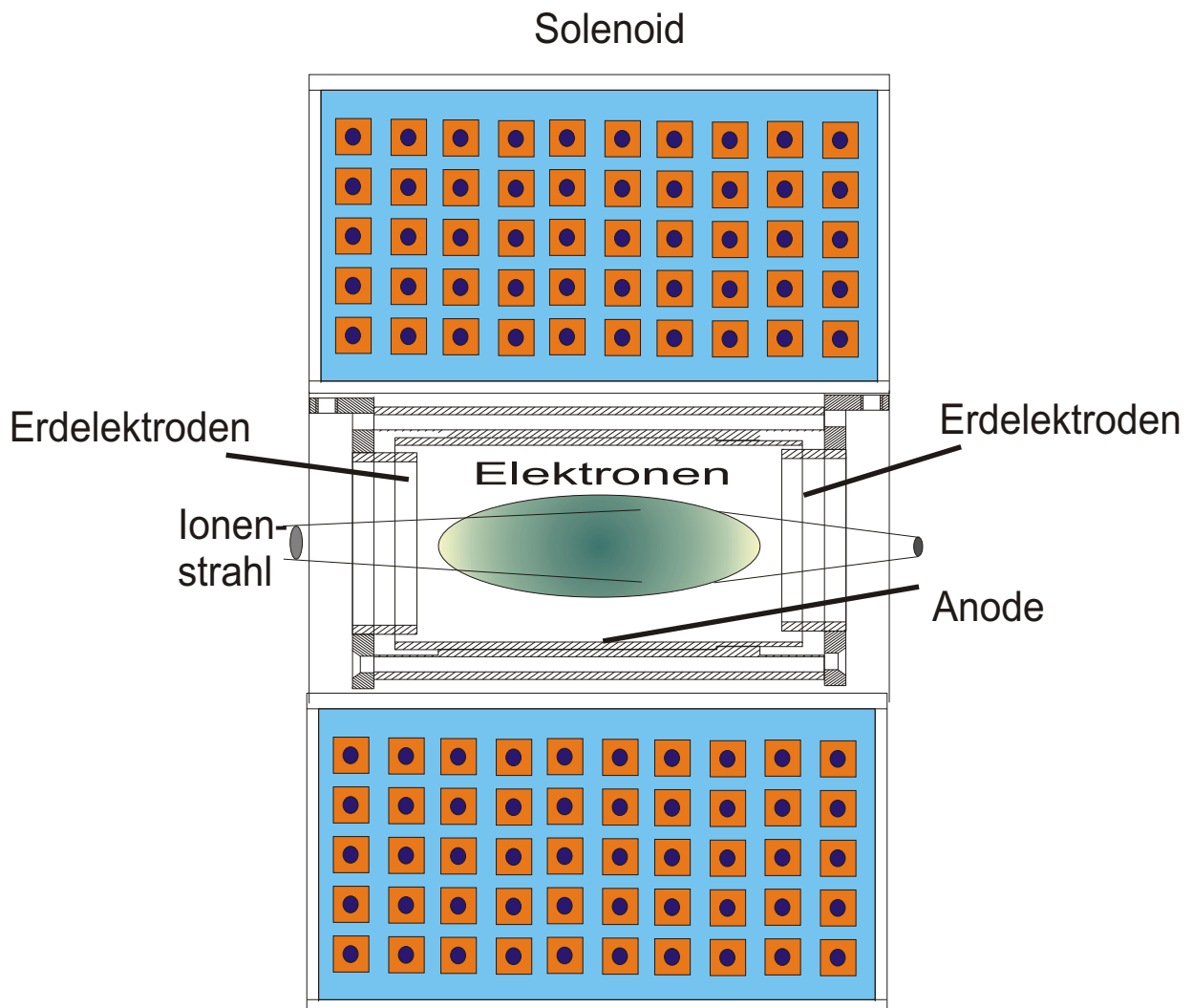
<p>radialer Einschluß</p> $e_{,max,rad} = \frac{e_0 B_z^2}{2m_e}$	<p>longitudinaler Einschluß</p> $e_{,max,long} = \frac{4U_A}{r_A^2}$
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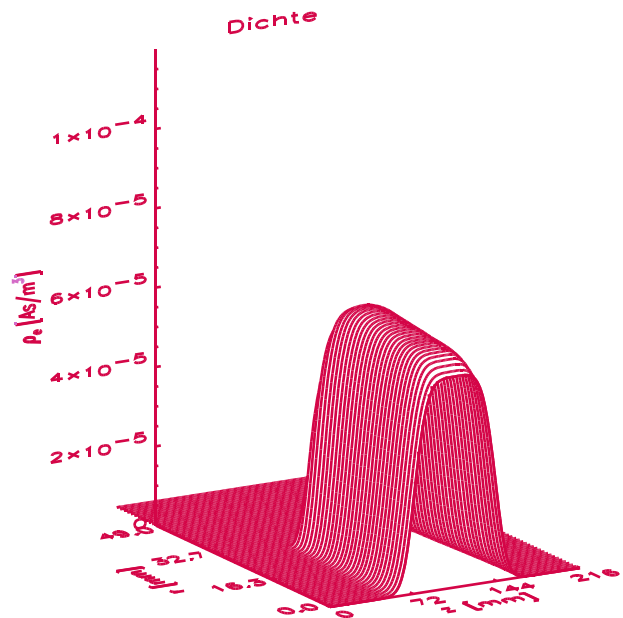
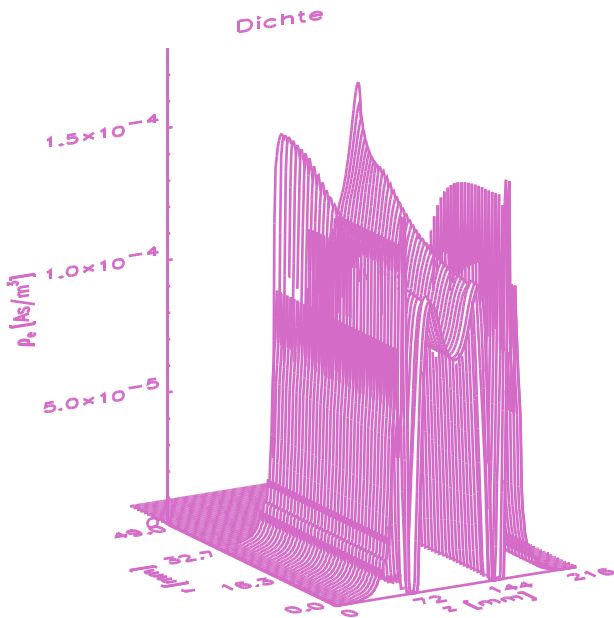
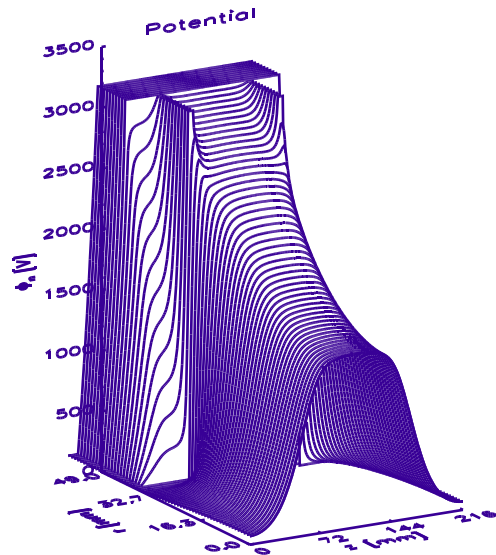
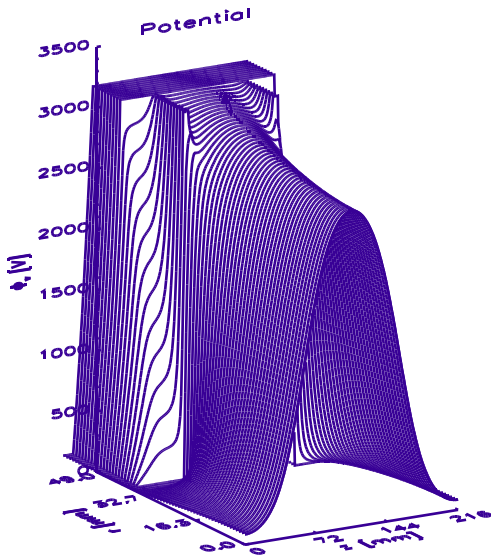
Simulation von Elektronentrajektorien in der x-y Ebene einer GPL für verschiedene Anfangsbedingungen

Jürgen Pozimski, IAP Uni - Frankfurt, 1997, Dissertation

Untersuchung zum Transport
raumladungskompensierter
niederenergetischer und intensiver
Ionenstrahlen mit einer
Gabor-Plasma-Linse



Entwicklung einer numerischen Simulation der Elektronendichteverteilung

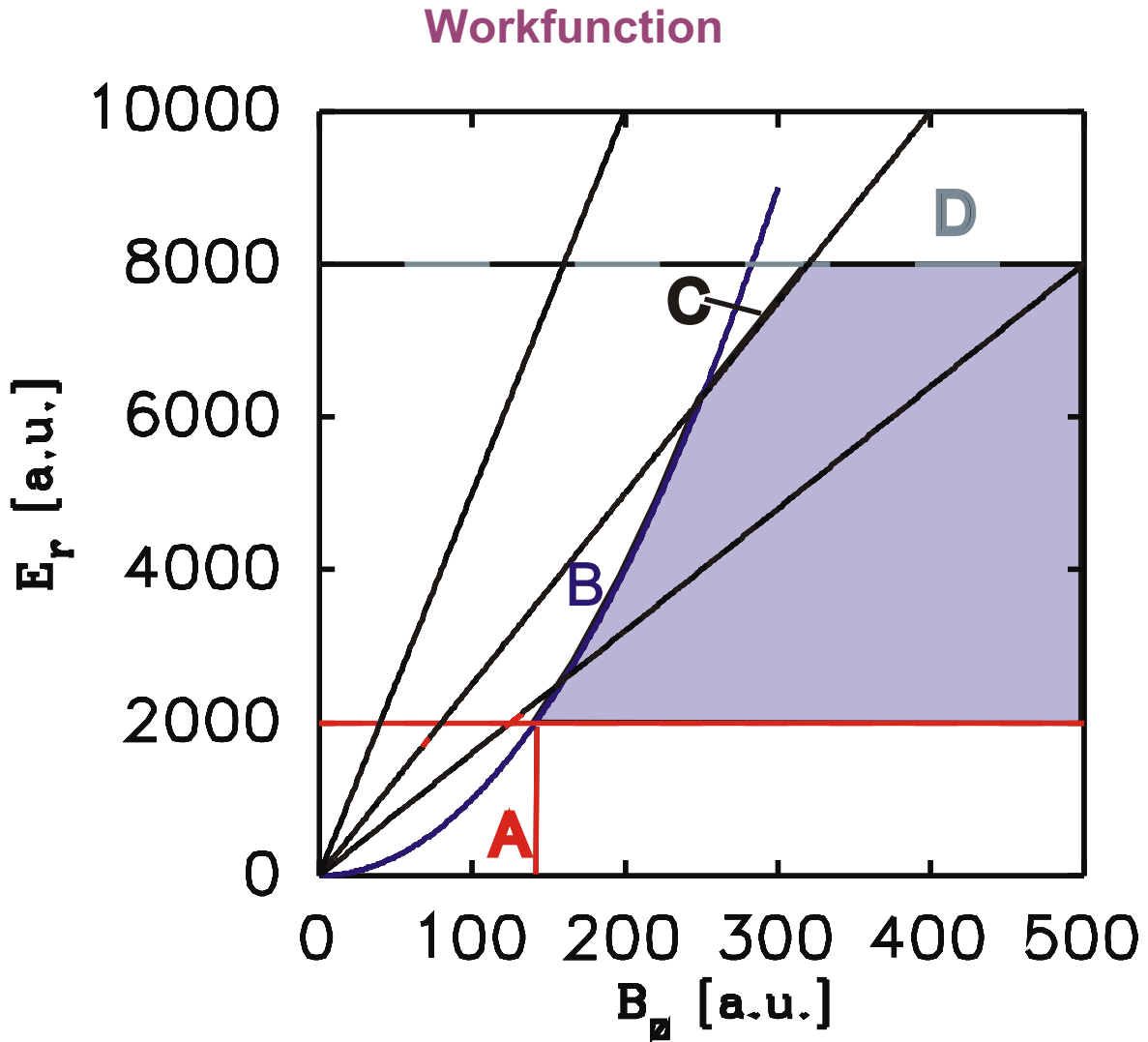


GABORITC: Berechnung der Elektronendichte für ein äußeres B-Feld und Potentialverteilung

GABORM: Berechnung der Elektronendichte für gegebene externe Felder unter Berücksichtigung der Thermalisierung der Elektronen

$$e(r,z) = e_{,\max}(r) e^{-\left(\frac{\max(r,z)}{k_b T_e(r)}\right)}$$

Theory on Gabor lens



A) minimal magnetic field for enclosure
(depending on electrode geometry)

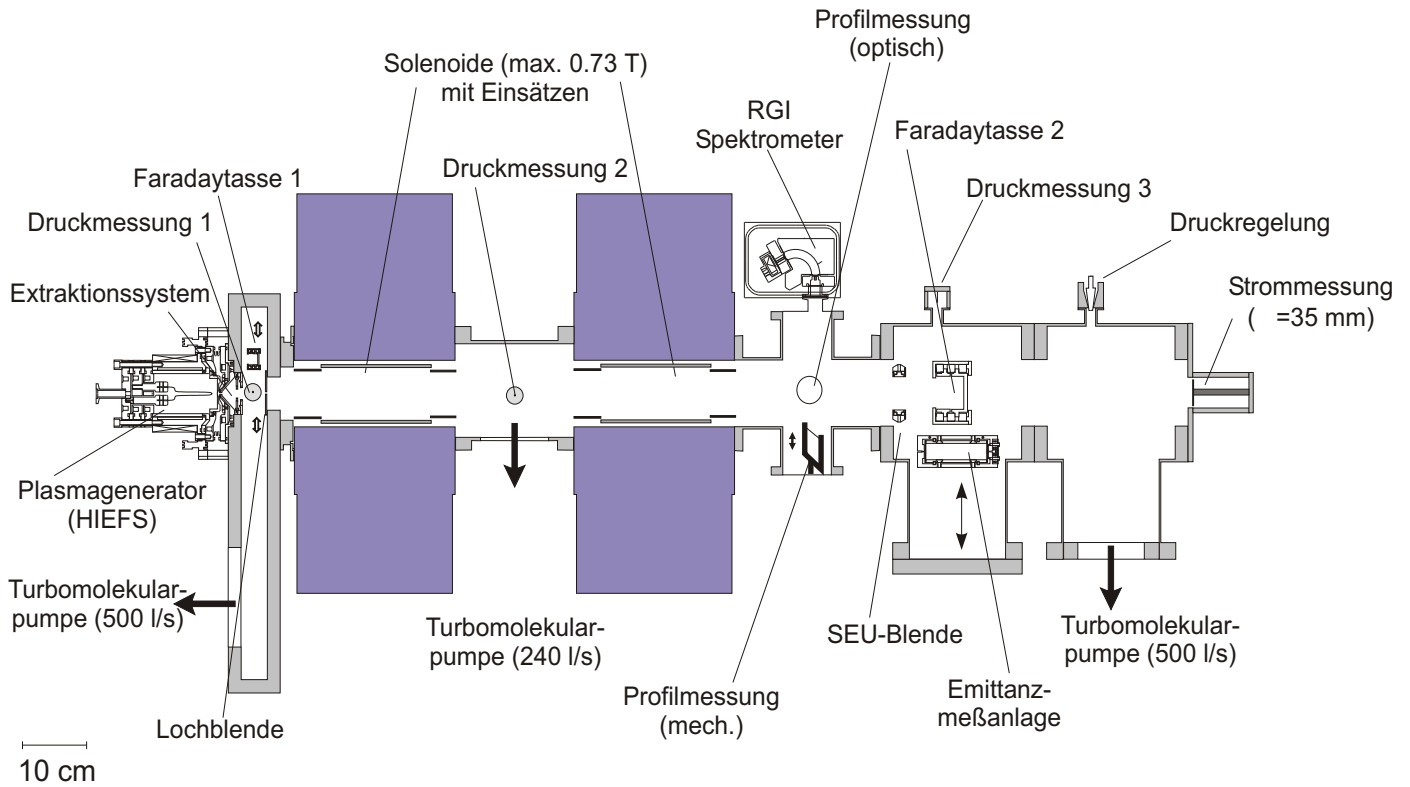
B) radial enclosure criteria
(Brillionflow / Gabor: $n_e B^2$)

C) radial losses by diffusion across fieldlines

D) maximum longitudinal enclosure (anodepotential)

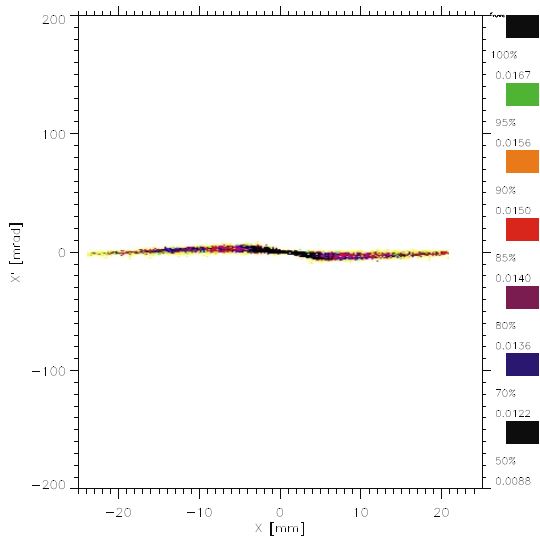
Transportmessungen an einem Argon-Strahl

Ar^+ , $I_{\text{FDT}}=600 \text{ A}$, $U_{\text{ex}}=10 \text{ keV}$

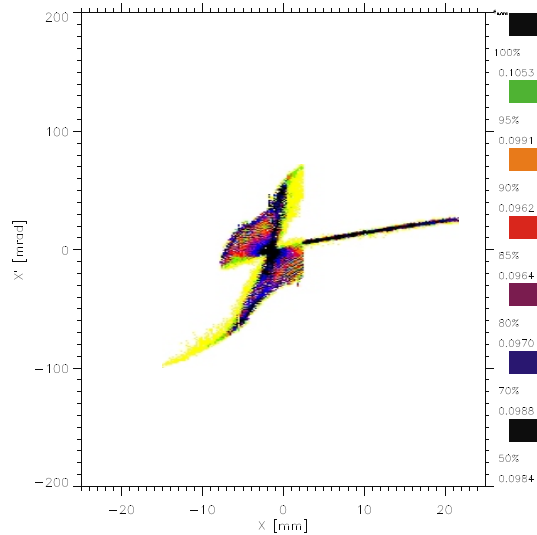


Ergebnisse der Messungen

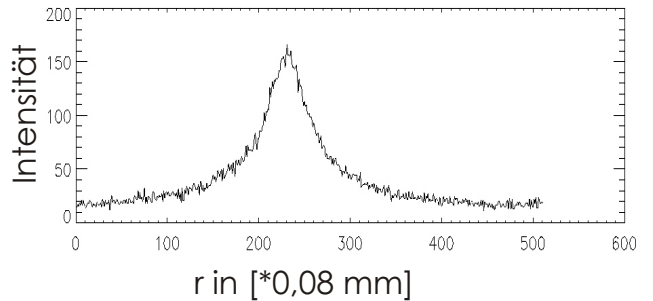
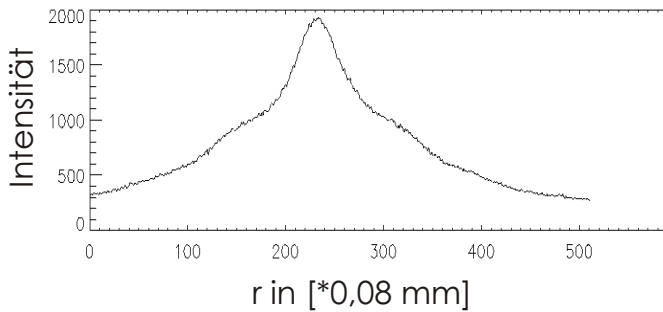
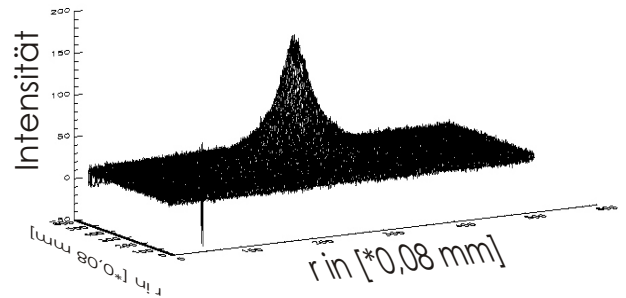
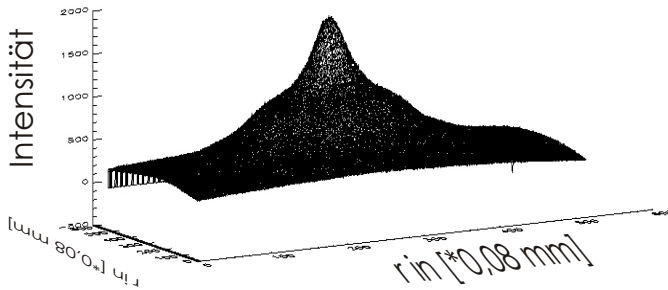
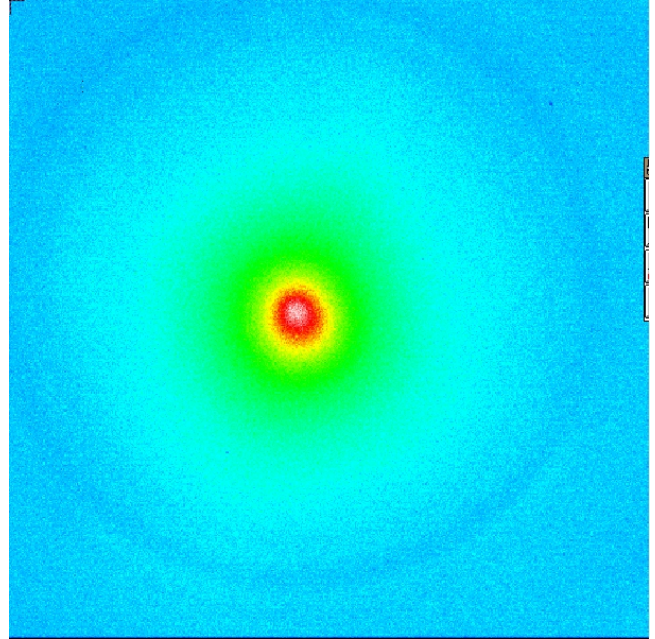
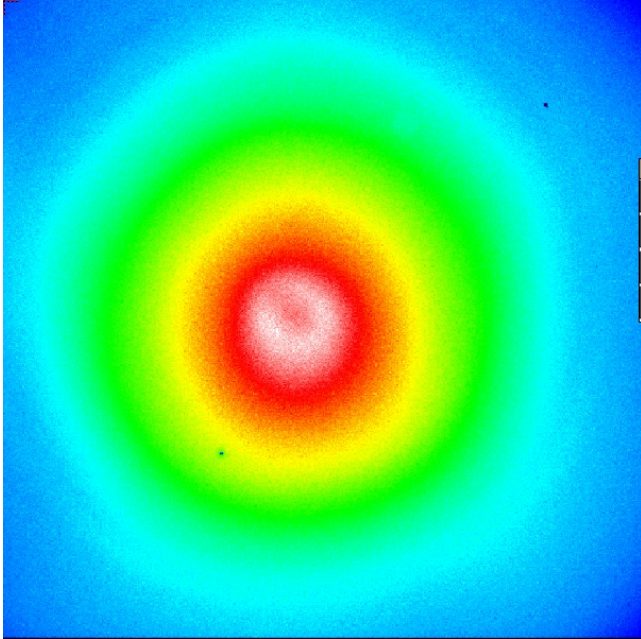
$B_z=40\text{E-}4 \text{ T}$, $U_A=2 \text{ kV}$



$B_z=80\text{E-}4 \text{ T}$, $U_A=4 \text{ kV}$



Eignet sich die Gabor-Plasma-Linse zum Transport von H⁺ - Strahlen?



Elektroneneinschluß

$U_A = 5 \text{ kV}$
 $B_z = 0,09 \text{ T}$
 $p = 4,0E-5 \text{ mbar}$

Protoneneinschluß

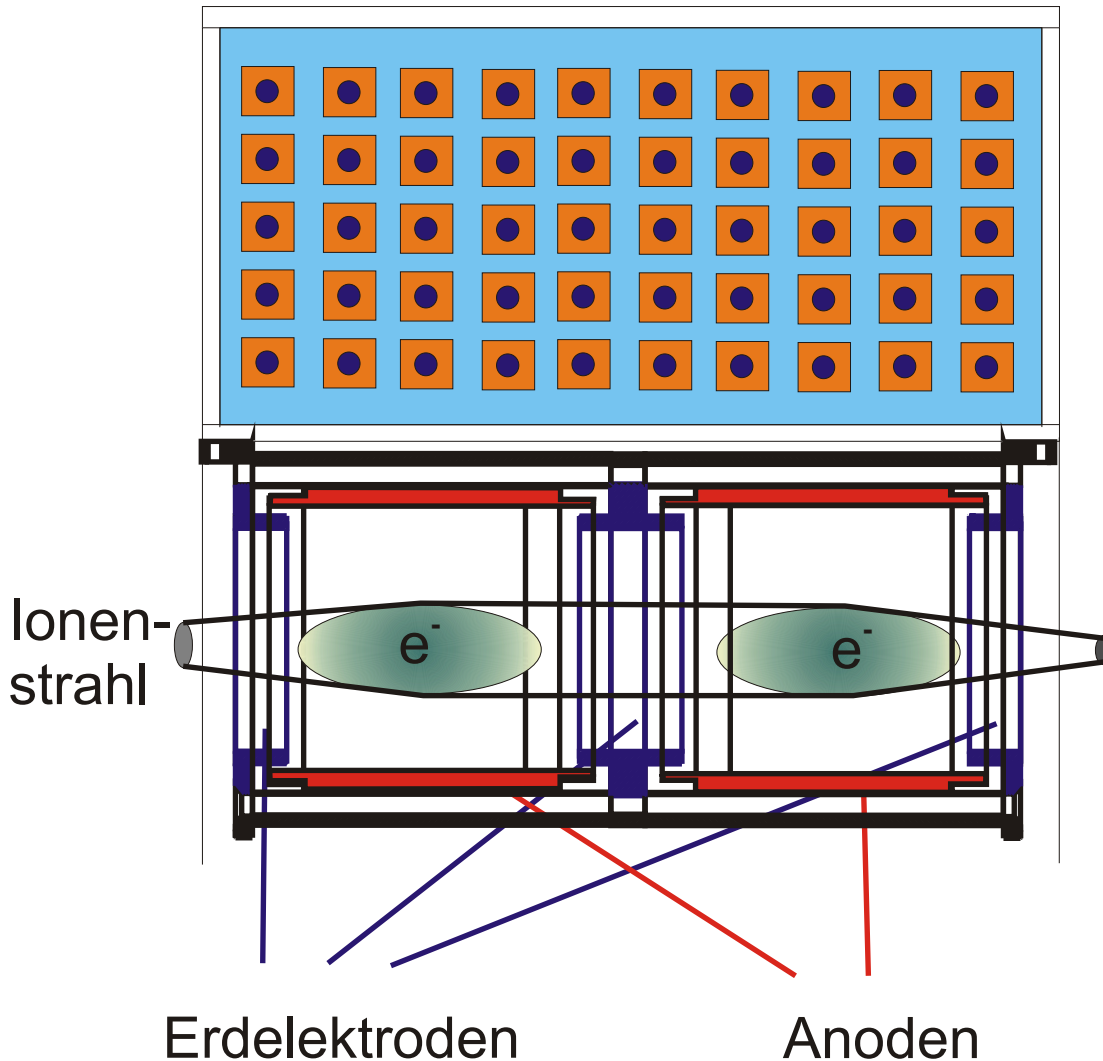
$U_A = 5 \text{ kV}$
 $B_z = 0,09 \text{ T}$
 $p = 9,9E-3 \text{ mbar}$

Diplomarbeit

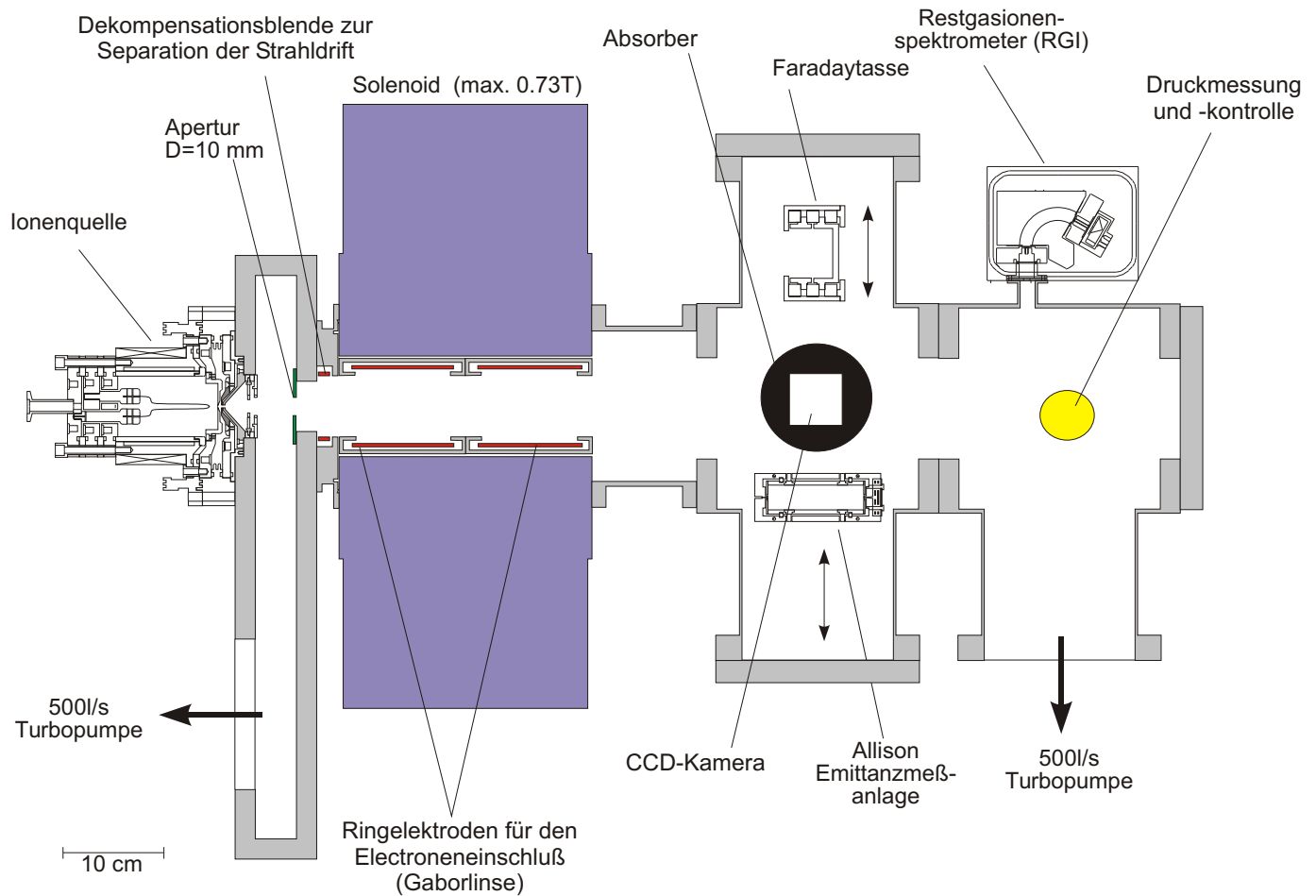
Untersuchungen zum Transport
niederenergetischer und hochperveanter
Strahlen schwerer Ionen
mit einer
Doppel-Gabor-Plasmalinse

Oliver Meusel
IAP Uni - Frankfurt
November 2000

Solenoid



Transportmessungen

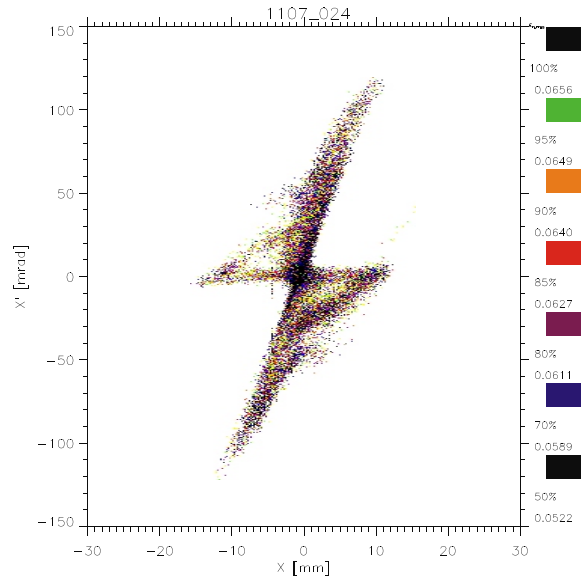
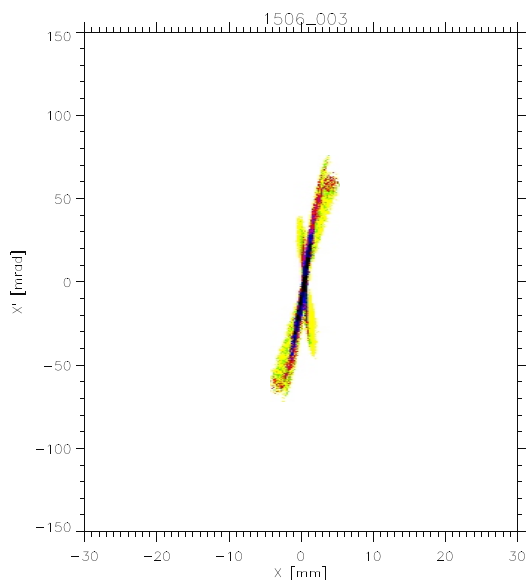


Ergebnisse der Messungen

$$B_z = 0,021\text{T}, \quad A_{1/2} = 3,5\text{kV}$$

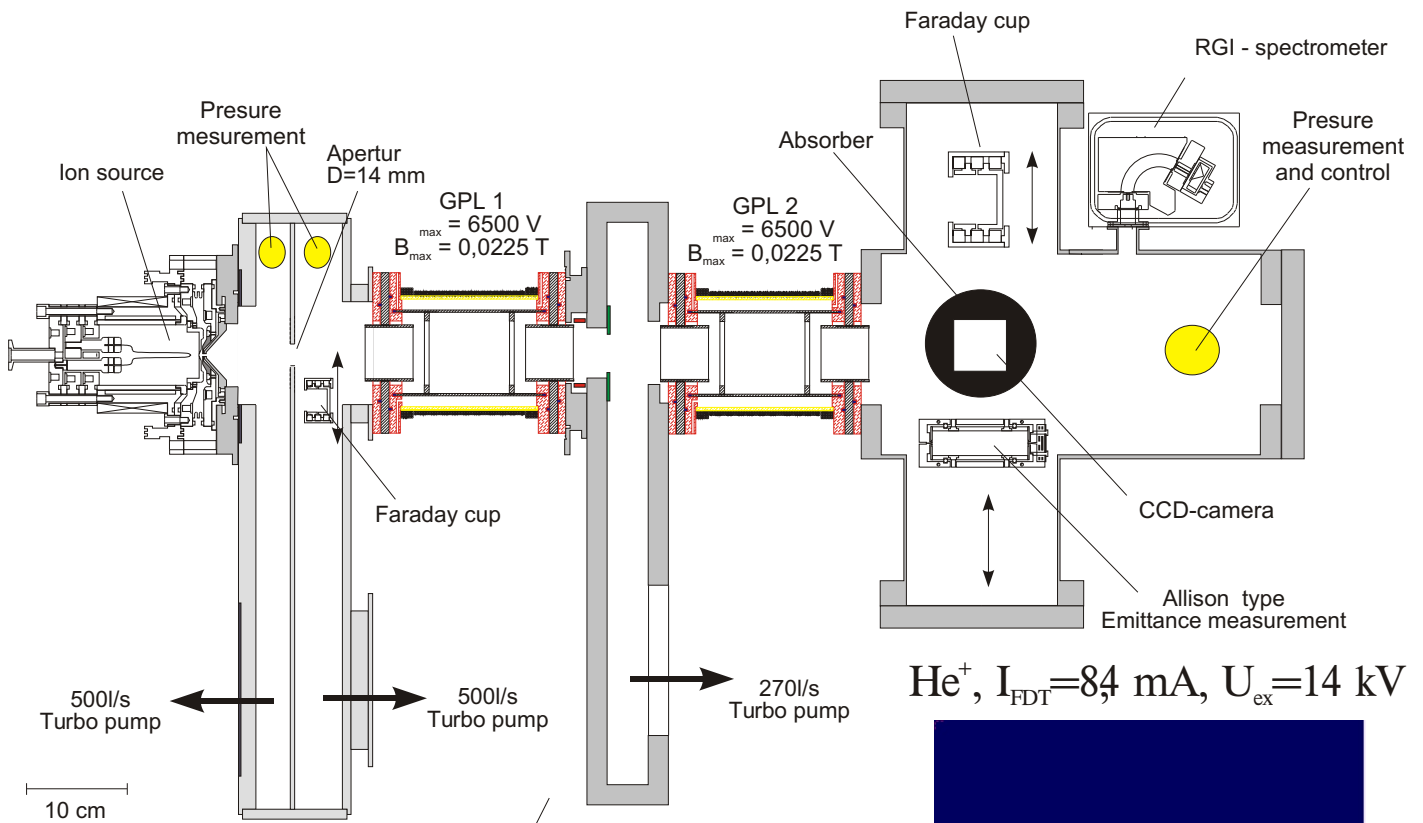
$$\text{He}^+, I_{\text{FDT}} = 3,97 \text{ mA}, U_{\text{ex}} = 12,5 \text{ keV}$$

$$\text{Xe}^+, I_{\text{FDT}} = 0,63 \text{ mA}, U_{\text{ex}} = 12,5 \text{ keV}$$

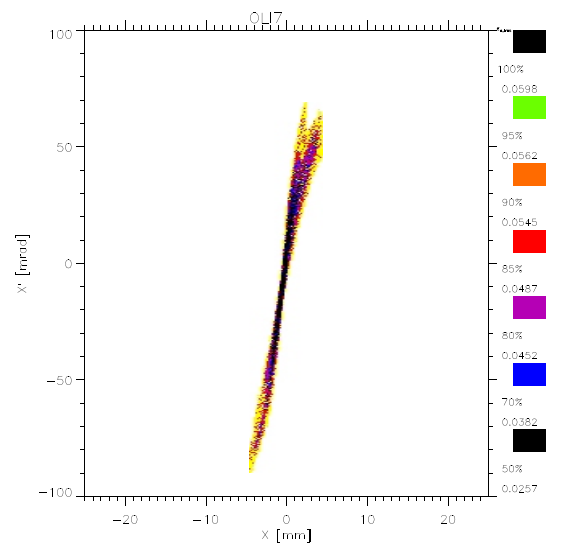
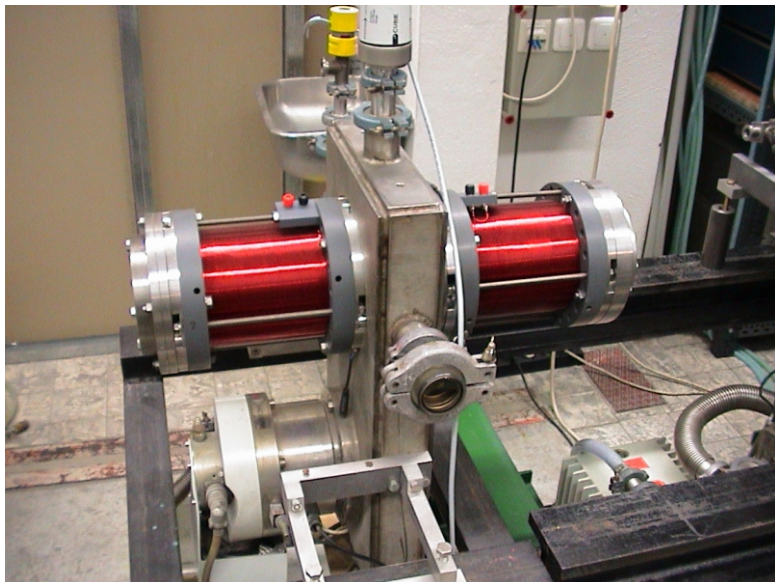
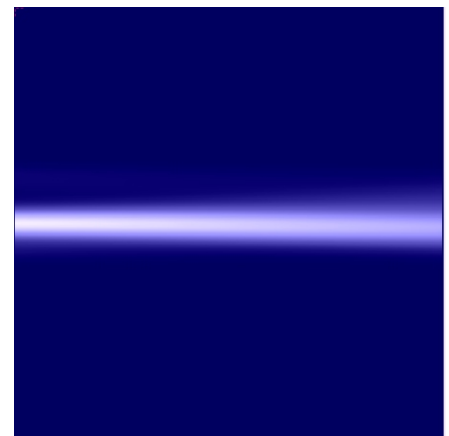


Schematischer Aufbau der He⁺ - LEBT

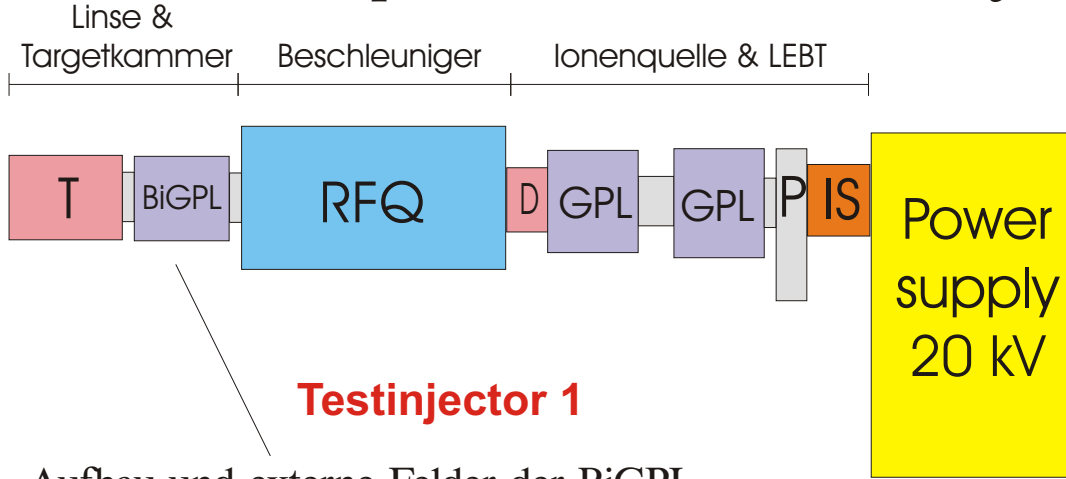
$U_{ex} = 20 \text{ kV}$, $I_{ex} = 10 \text{ mA}$



He⁺, $I_{FDT} = 84 \text{ mA}$, $U_{ex} = 14 \text{ kV}$

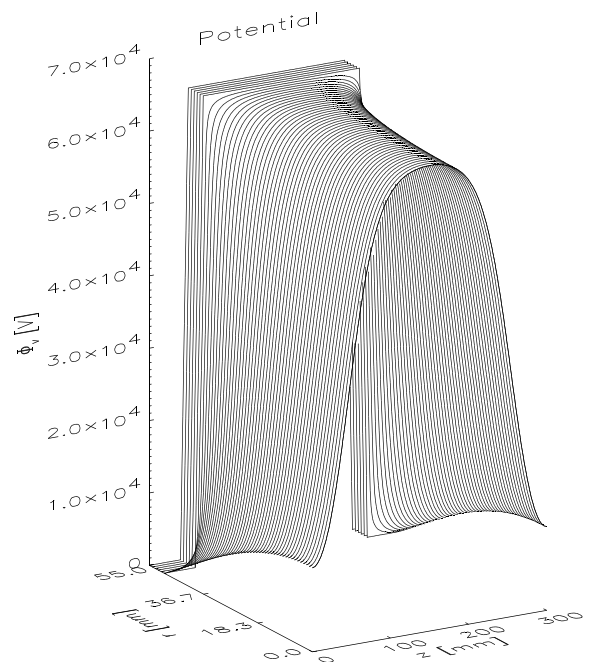
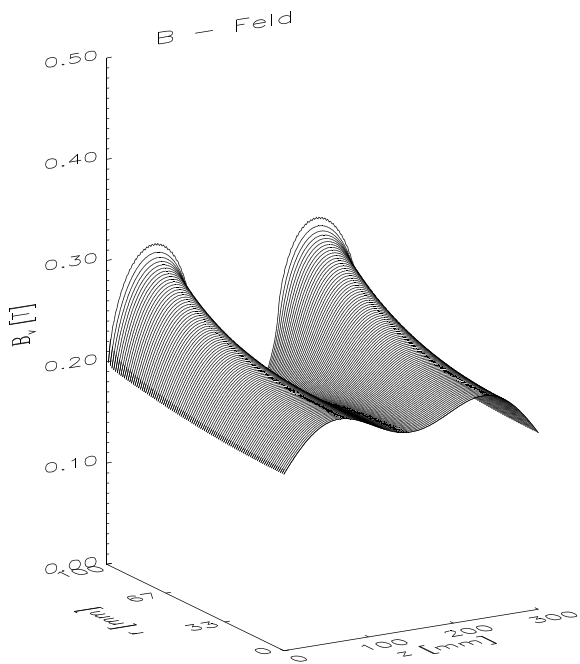
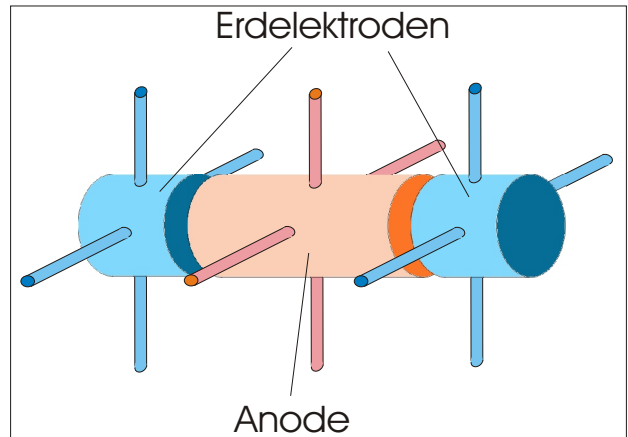
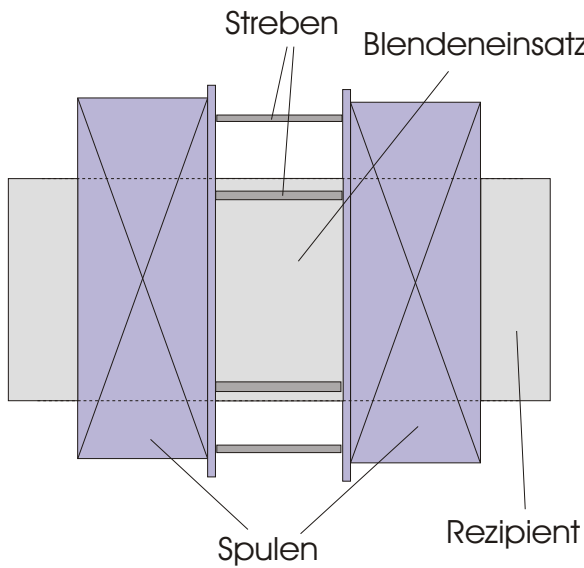


Zukunftsplan: Aufbau des Testinjektor 1



Testinjector 1

Aufbau und externe Felder der BiGPL



Ende des Vortrags und der Entwicklung der Gabor - Linse?

offene Fragen bei der Linsendiagnostik:

- Temperaturbestimmung (opt. Spektroskopie)
- Dichtebestimmung (Mikrowelleninterferometrie)
- Dichteverteilung (Fadenstrahlexperiment)
- Aufbauzeit
- Transport gepulster Strahlen

offene Fragen bei den Einsatzmöglichkeiten:

- Hochstrominjektoren
- MEBT - Sektionen
- Ringe
- H⁻ - Transport
- Fallen für \bar{p} , \bar{e}