# Application of Pulsed Discharges for FAIR


**Joachim Jacoby**

Institut für Angewandte Physik
Johann Wolfgang Goethe-Universität
Frankfurt / Main

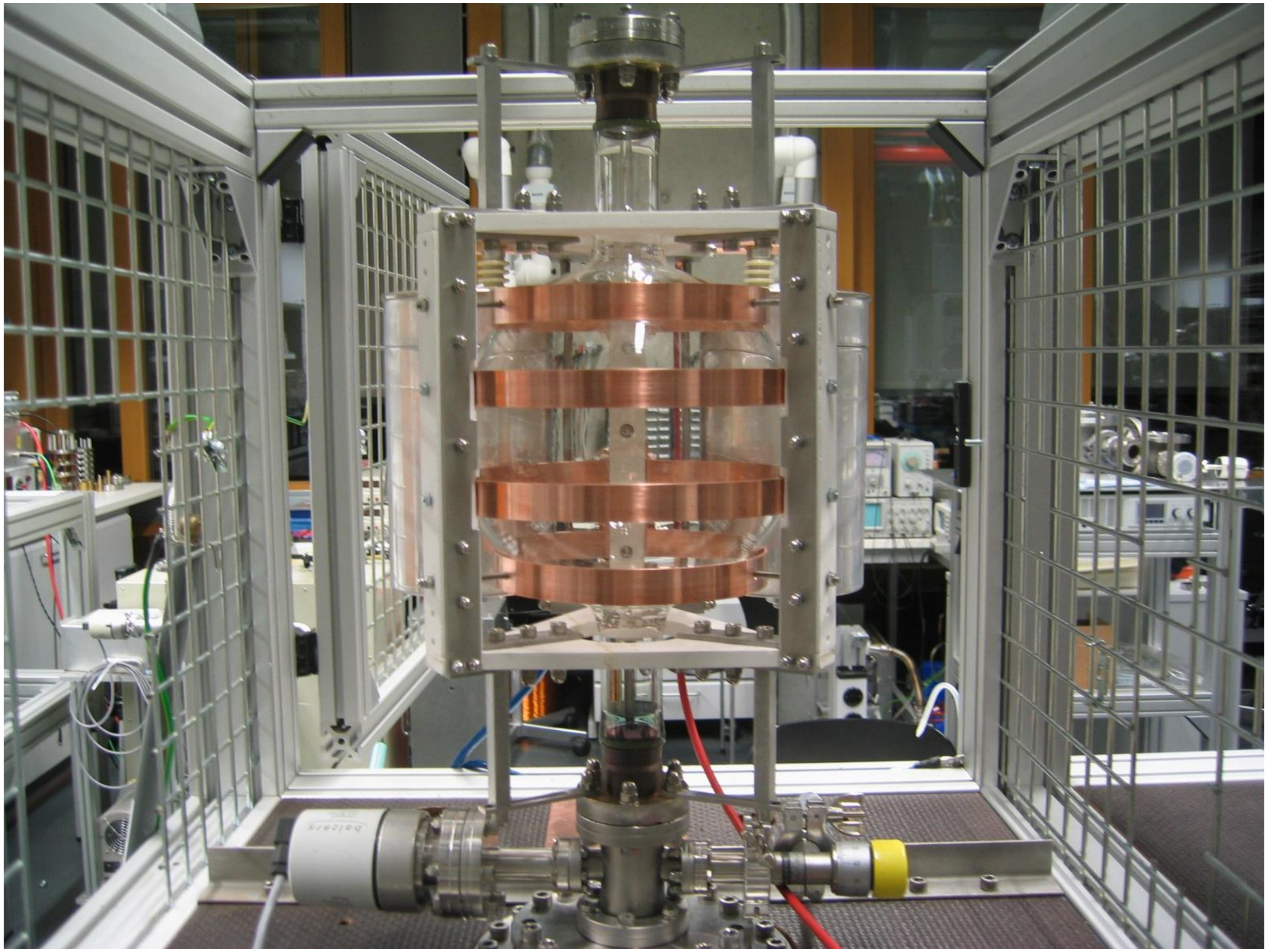

## Outline:

- Theta-Pinch Discharges
- J x B - Collider
- J x B - Switches


**05.07.2012 HICforFAIR PhysicsDay: Accelerator**

# I. Theta Pinch Discharges

# Front View of the Inductively Coupled Plasma



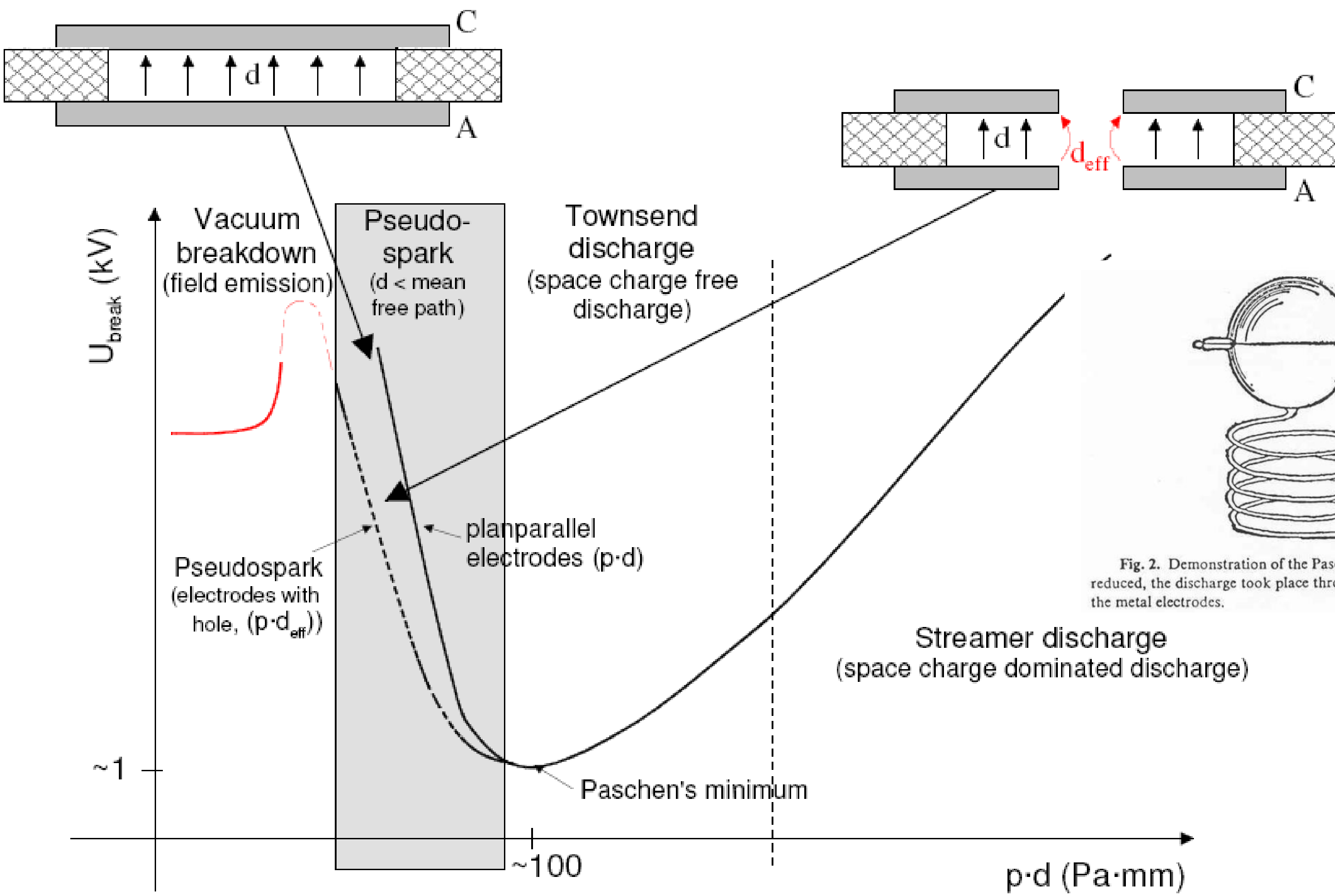
# Possible Applications

## Higher Electron Densities:

$$n_e > 10^{19}\, m^{-3}$$

- Plasmastripper
- Plasmatarget
- Ion Source
- UV Source

# Law of Paschen



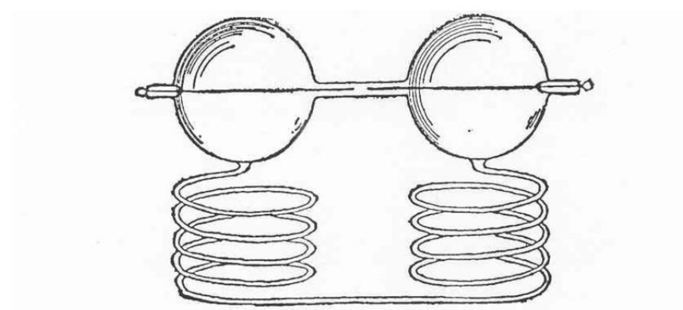
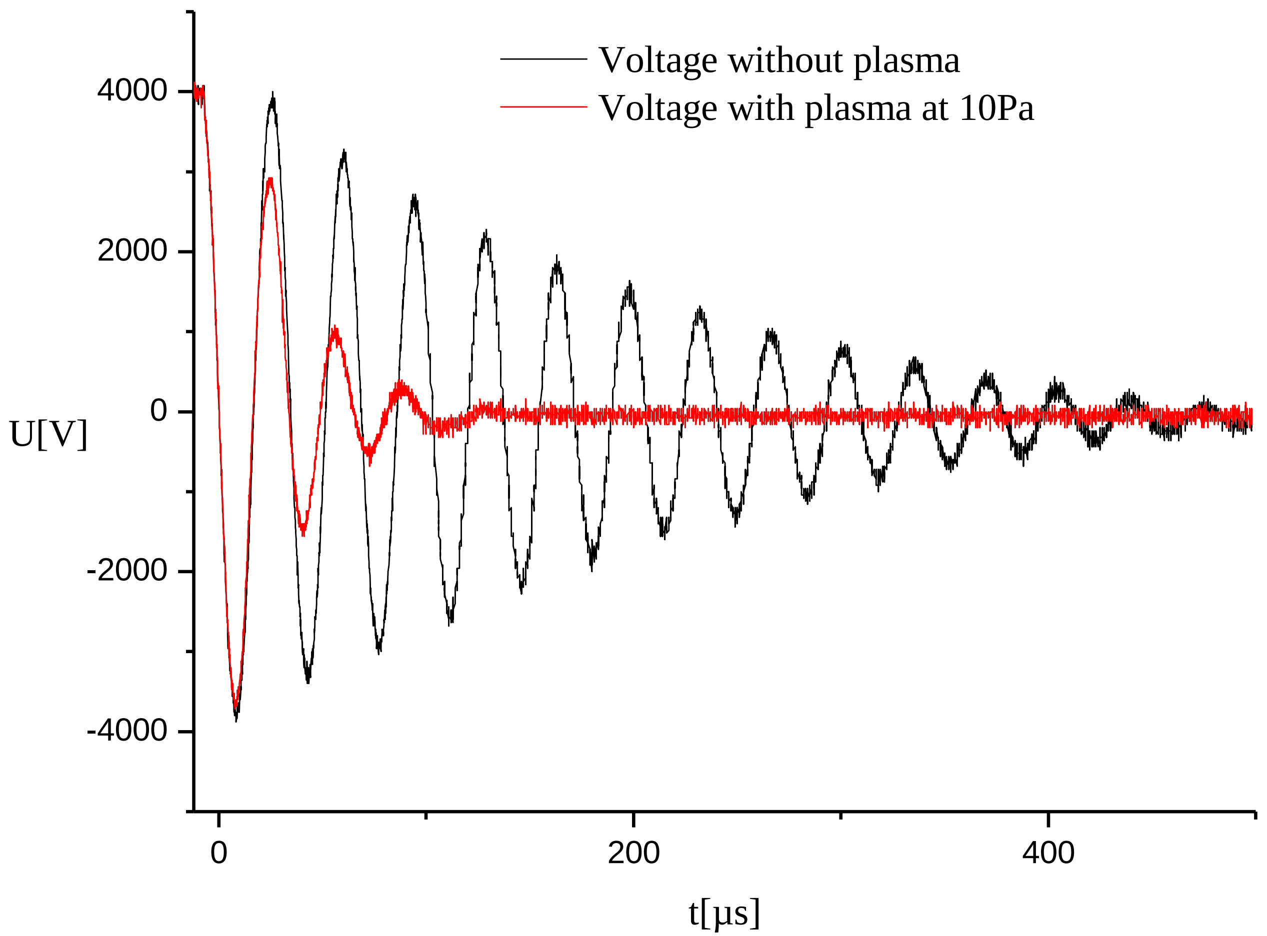



Fig. 2. Demonstration of the Paschen effect. When the pressure of the gas in the bulbs was reduced, the discharge took place through the long tube and not across the small gap between the metal electrodes.

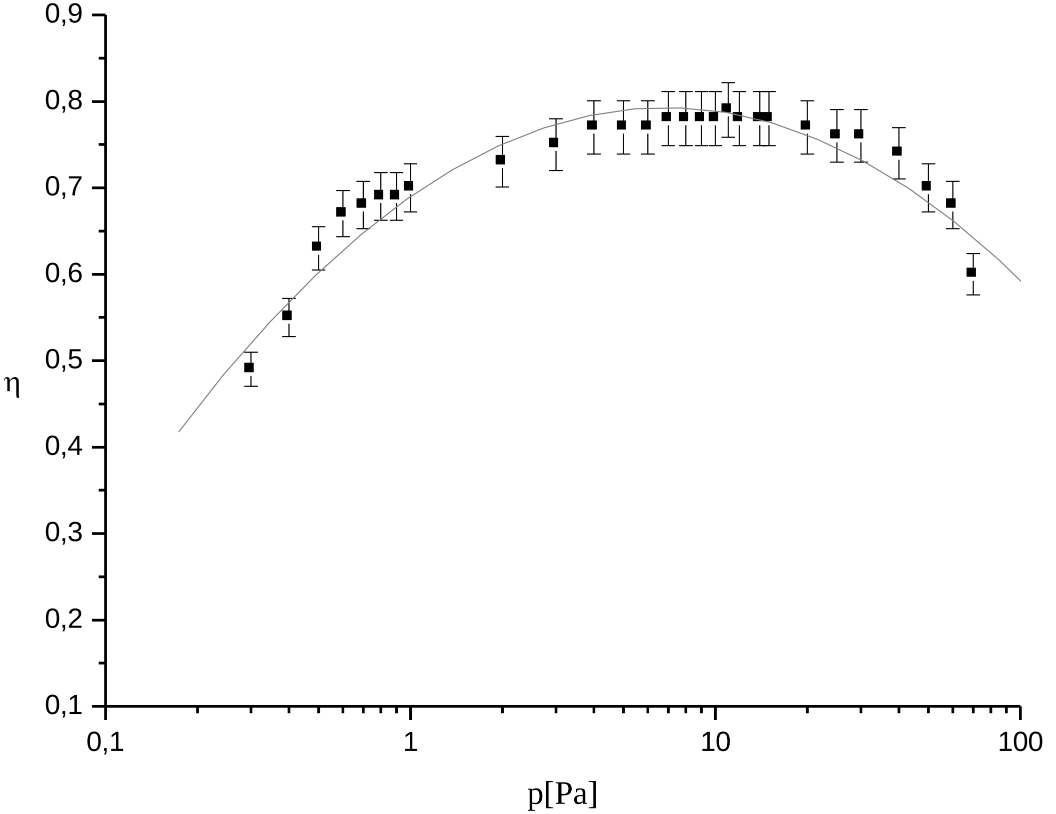
# Technical Data (Setup I)

| | |
|---|---|
| Induktivity: | $L_0 = 2.1\ \mu H$ |
| Capacity: | $C_0 = 12\ \mu F$ |
| Maximum Load Voltage: | $U_0 = 4100\ V$ |
| Resonant frequency: | $\nu = 30\ kHz$ |
| Maximum Current Amplitude: | $I = 9.5\ kA$ |
| Diameter of the Discharge Vessel: | $d = 20\ cm$ |

# Damping of the Circuit through Inductive Coupling

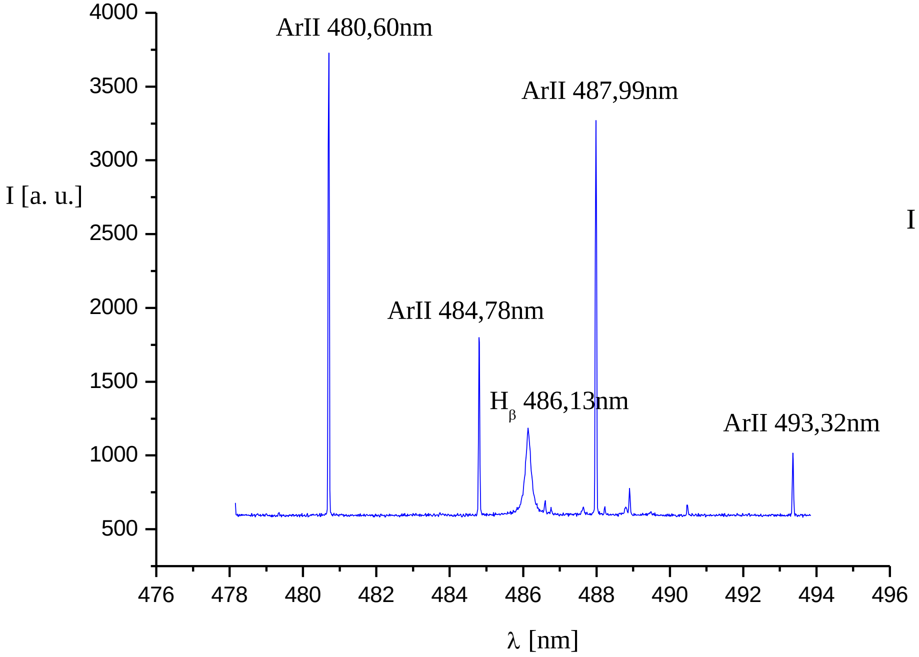


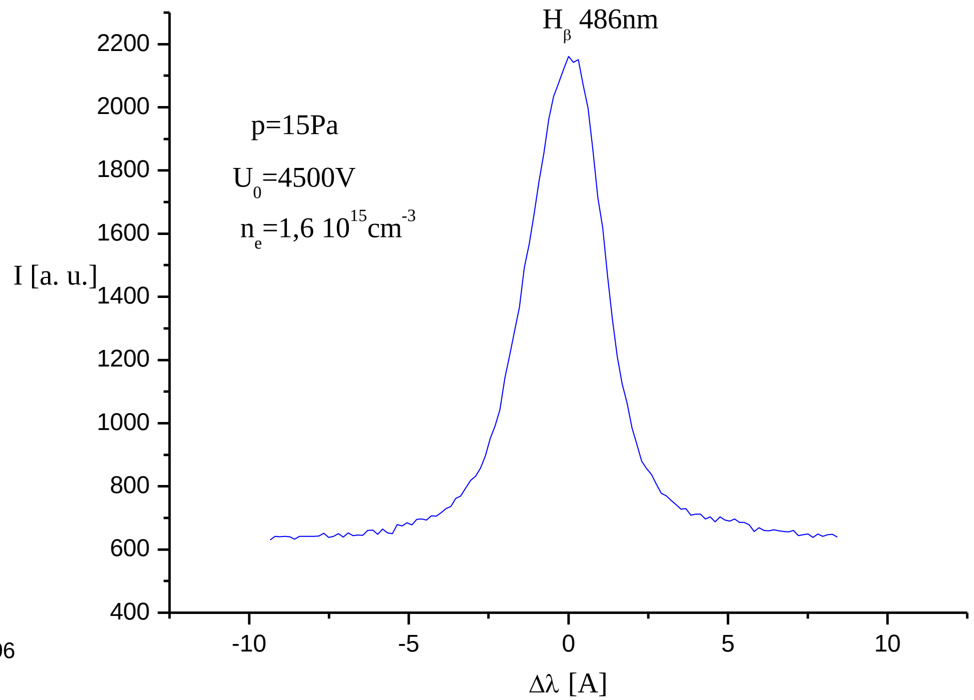
# Energy Transfer Efficiency



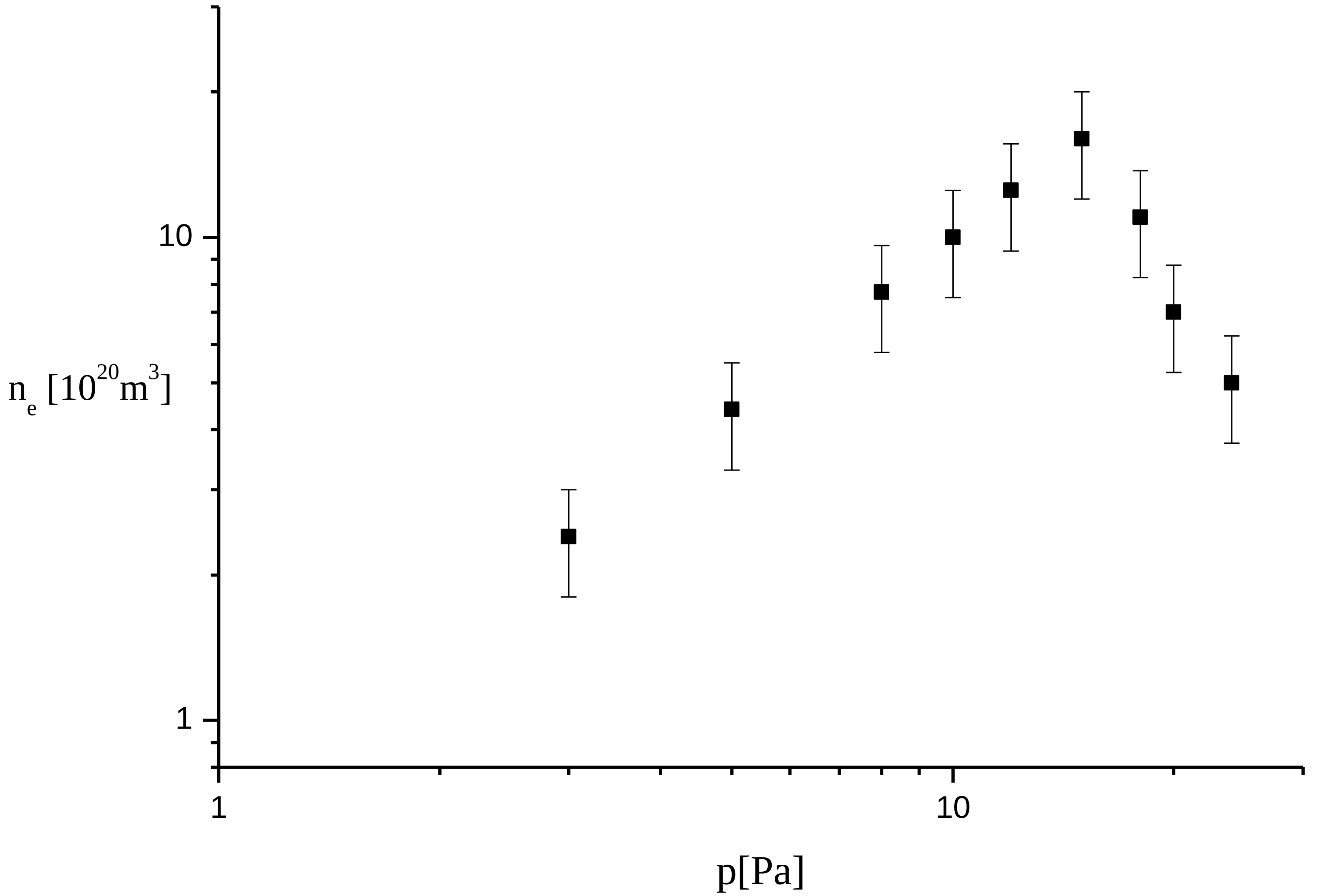
# Discharge Sequence

# Spectroscopic Results



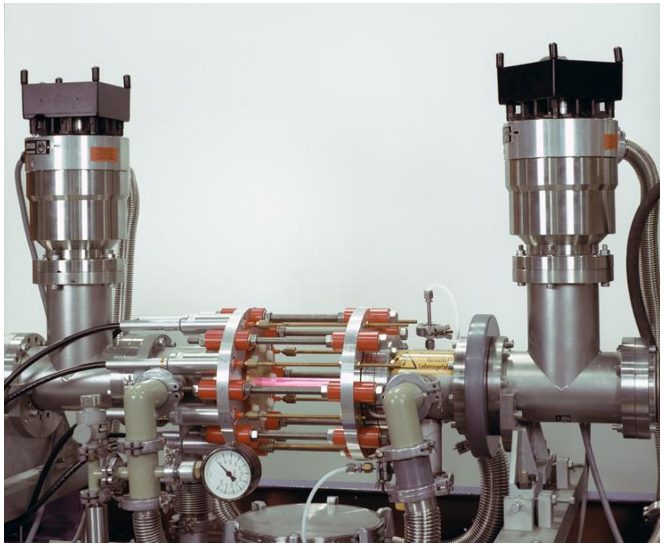



# Mean Electron Density



# Energyloss Measurements with Low Energy Ions (45 keV/u)

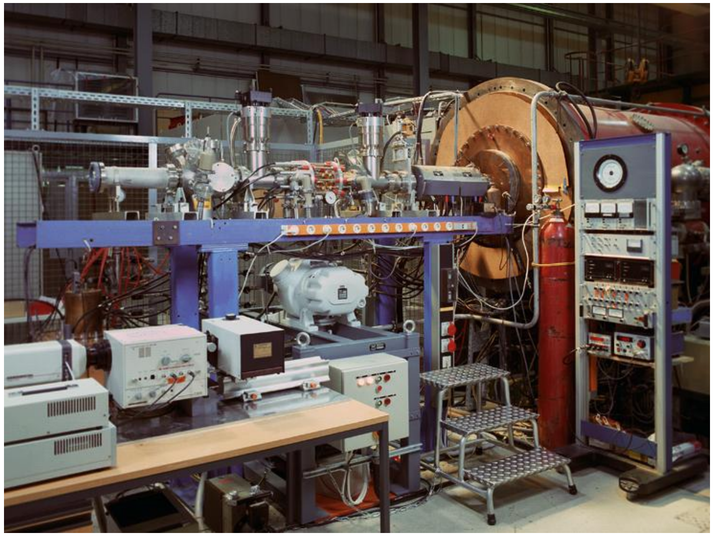
### Compact Linear Discharge Plasma



Discharge vessel: l = 20 cm, d = 2 cm
$H_2$ gas: 0.5 – 2 mbar

2-stage differential pumping
Apertures: d = 3 mm, l = 3 cm

### RFQ-Accelerator MAXILAC and Experimental Set-up



Capacitor bank: 2.6 µF, Charg. voltage: 5 - 10 kV

Ion energy: 45 keV/u, $Kr^{1+}$-ions
$\Delta$E: TOF measurements
Beam microstructure: 13.4 MHz,
74.8 ns between ion-bunches

Fraunhofer ILT
ITEP
IPCP RAS
MAX-PLANCK-INSTITUT FÜR QUANTENOPTIK GARCHING MPQ
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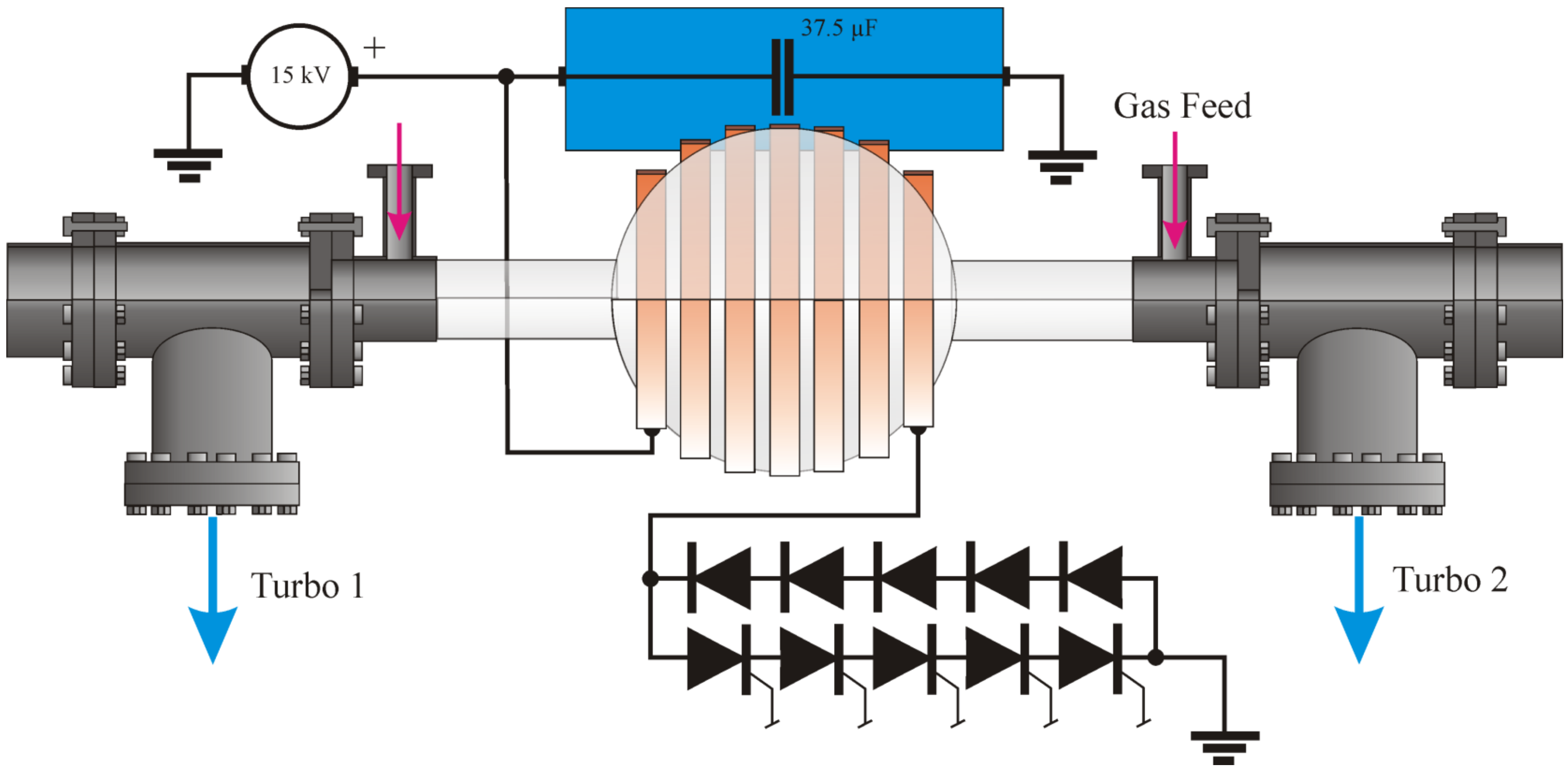
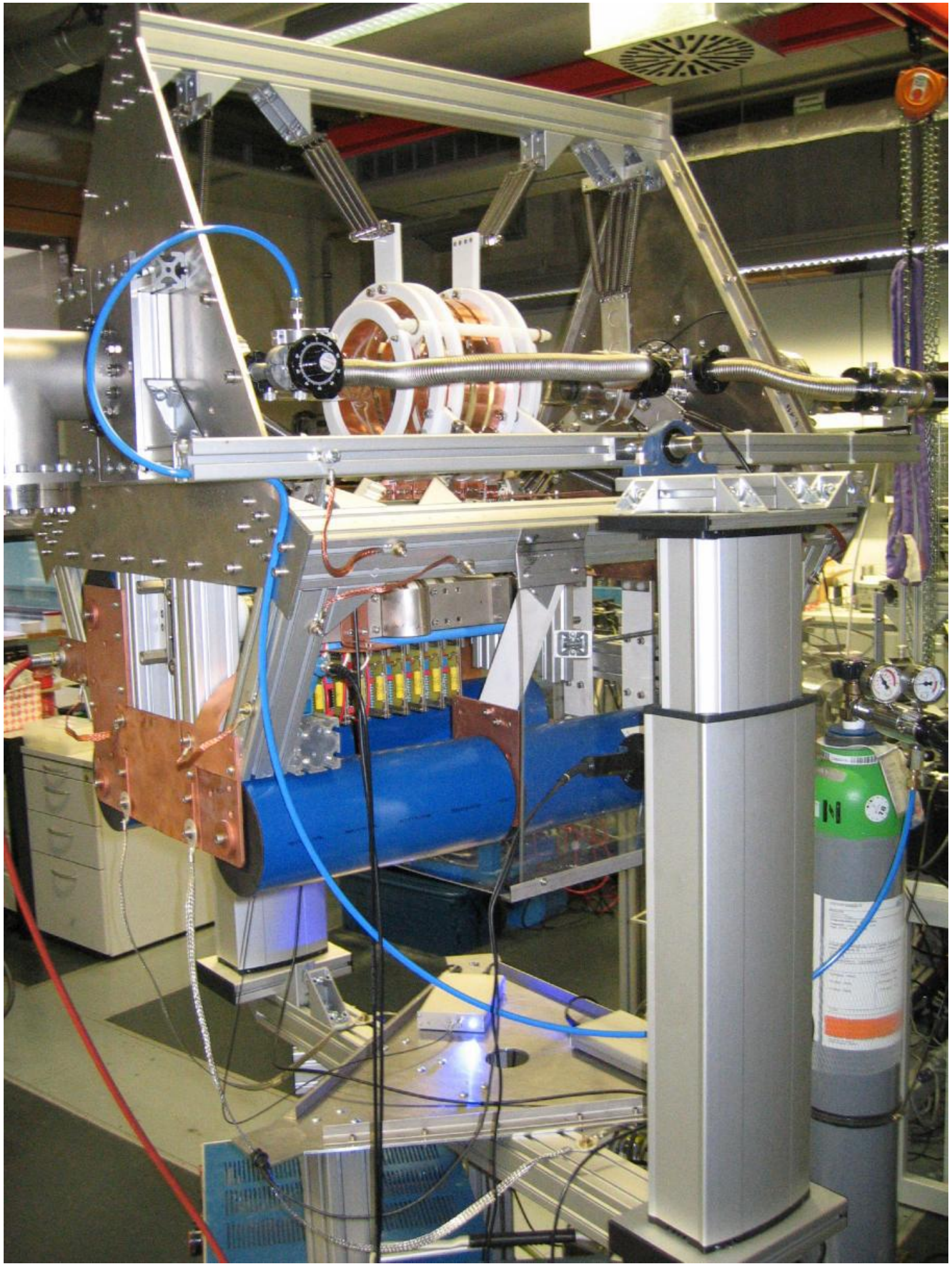
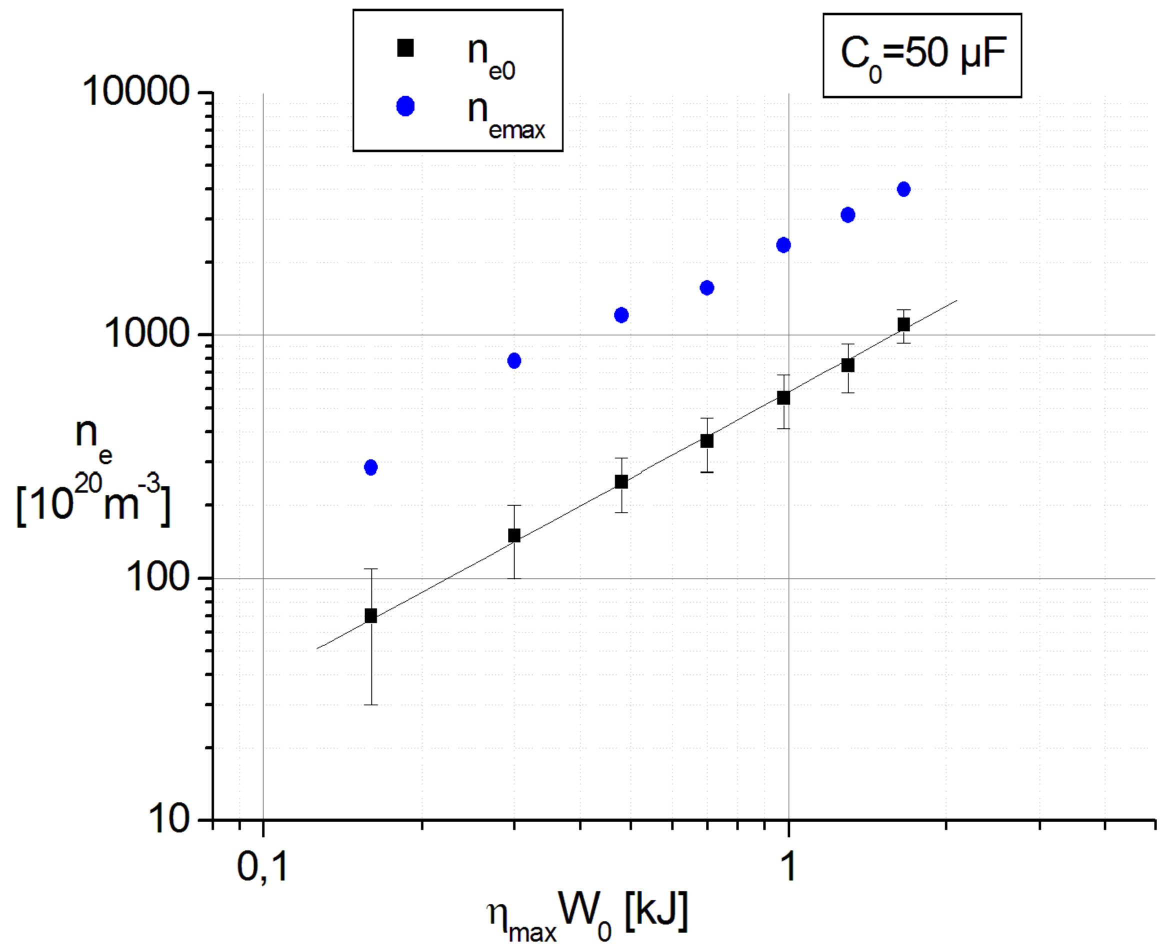
# Setup of the Stripper Experiment

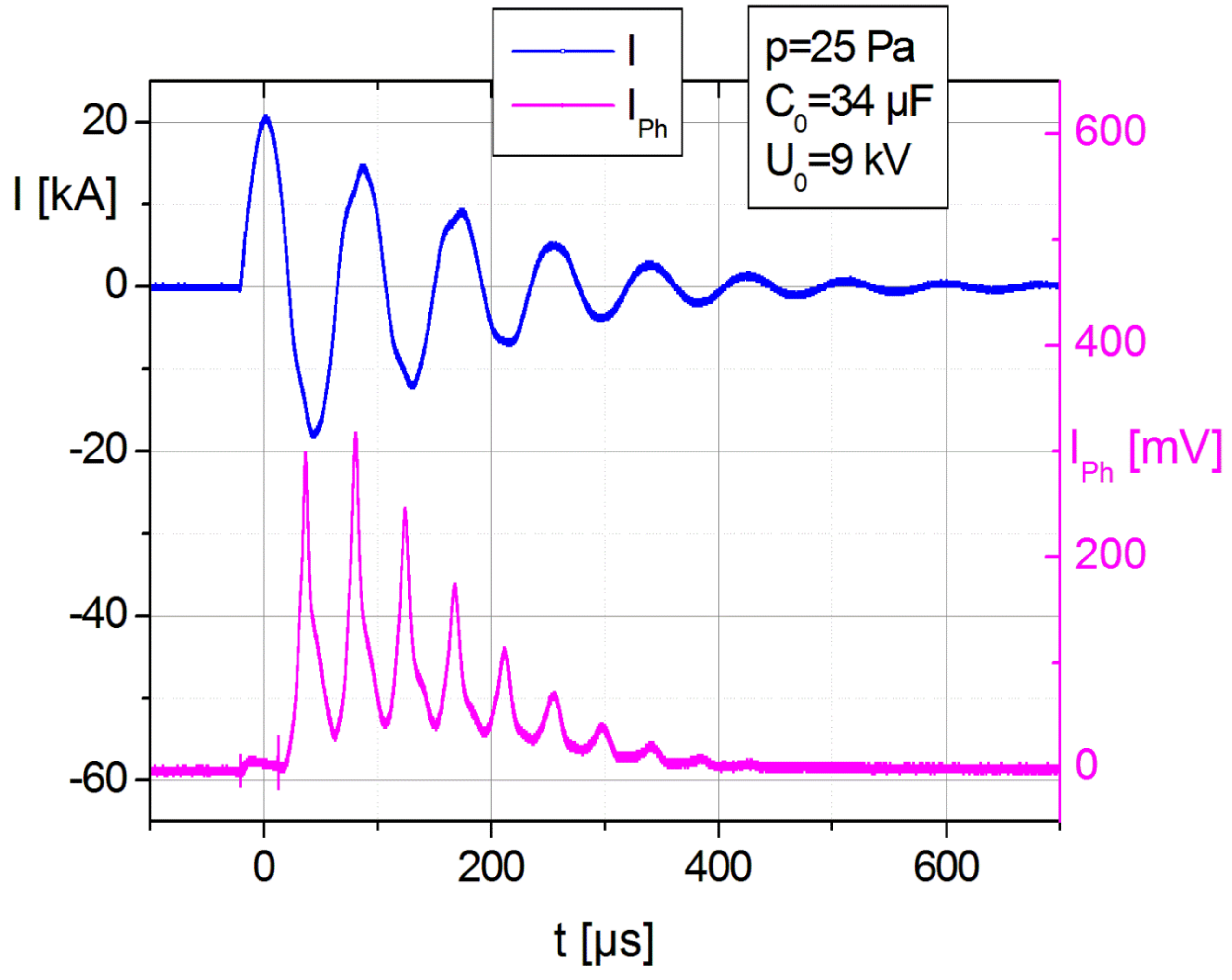




# Plasma Densities Scale with Discharge Energy



# Pinching Sequence



# Screw-Pinchgenerator

- Capacitor (modular design):

C=12,5-100 [µF]

U=9-18 [kV]

E=1250-5000 [J]

- Coil (9 toroidal and 6 poloidal coils ):

L=11,2 [µH]

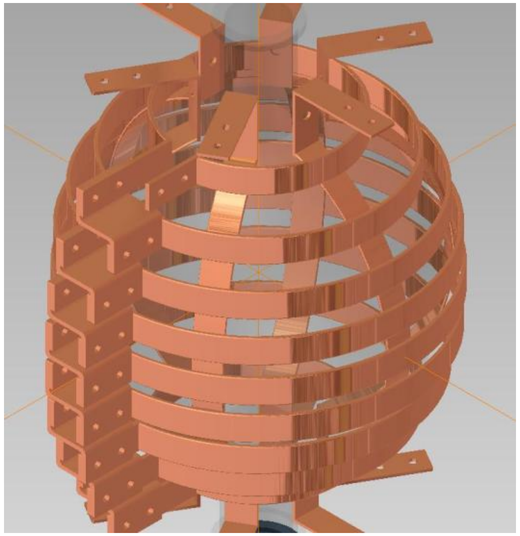
f =4,8-13,6 [kHz]

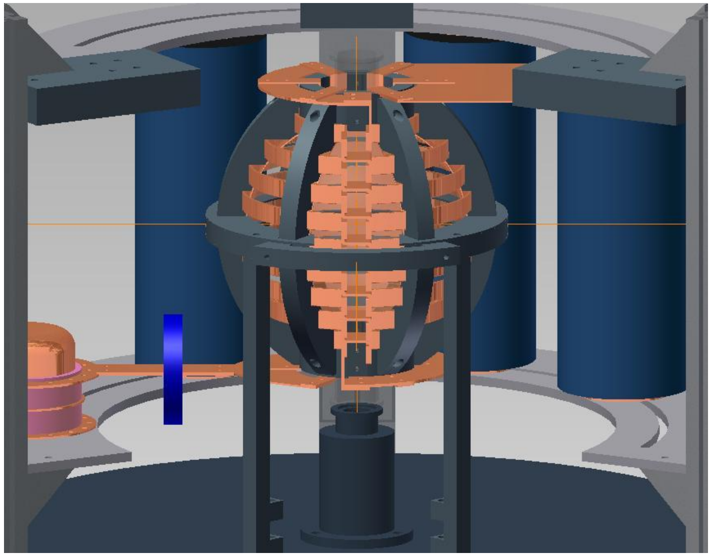
$I_{max}$=27 [kA]

$P_{max}$~50 [MW]

- Gas:

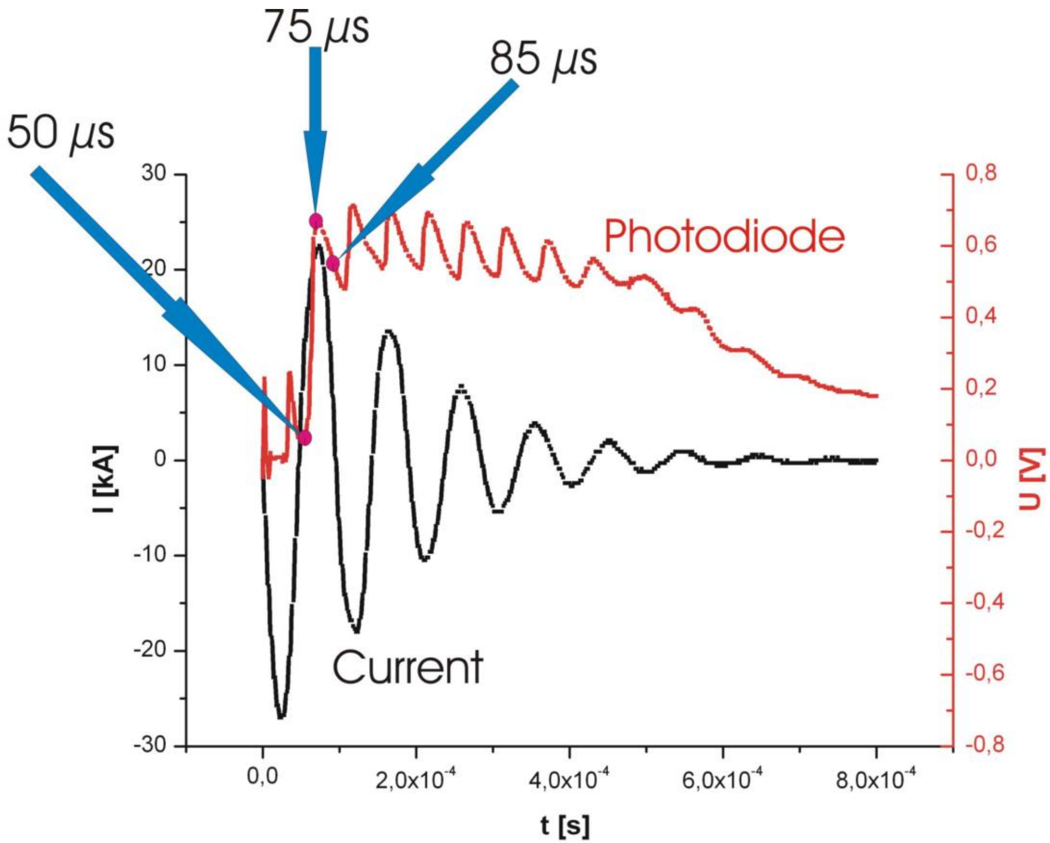
Ar, ArH(2,4%)

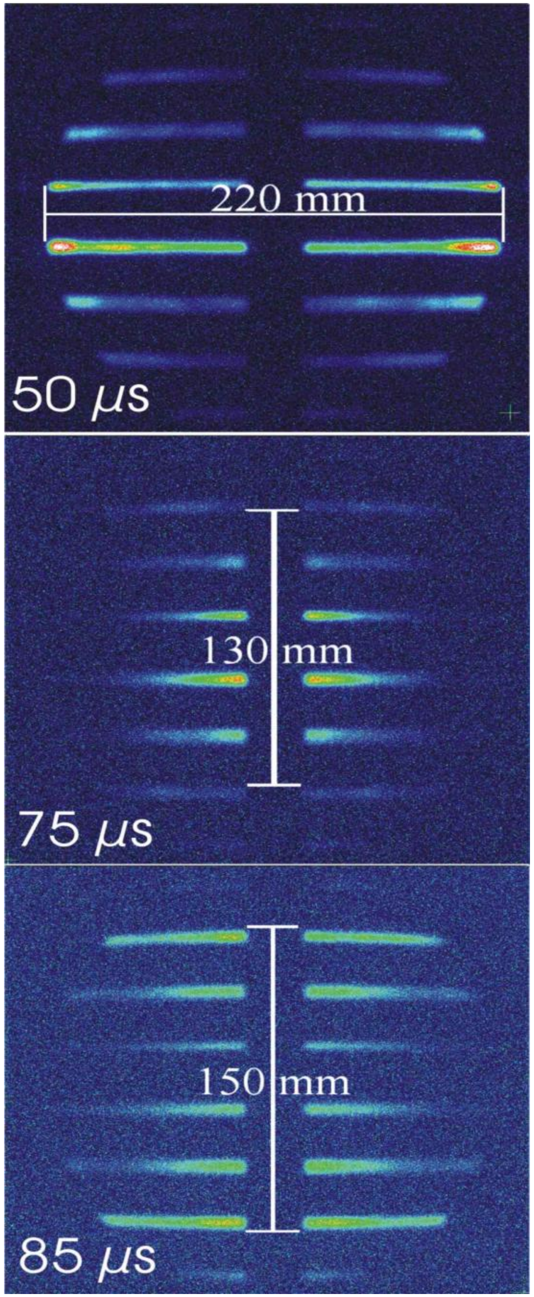




# Results

- 50 µF 18 kV 140 Pa:
- Efficiency: max 60%
- Electron density: max $1{,}38 \cdot 10^{16}$ $cm^3$

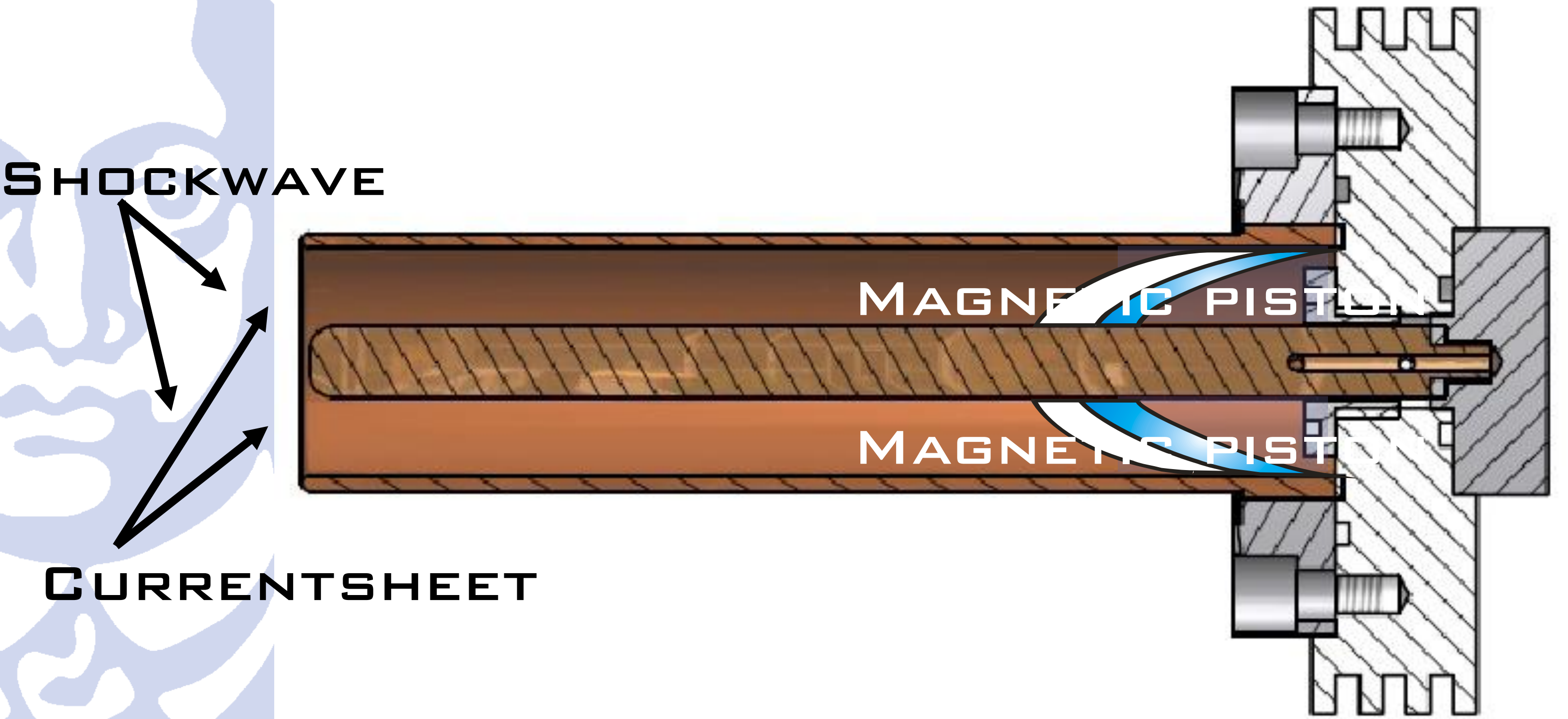


# II. J x B –Collider

A XUV-Source
to study warm dense matter

# J x B - Accelerator



# A Single Discharge

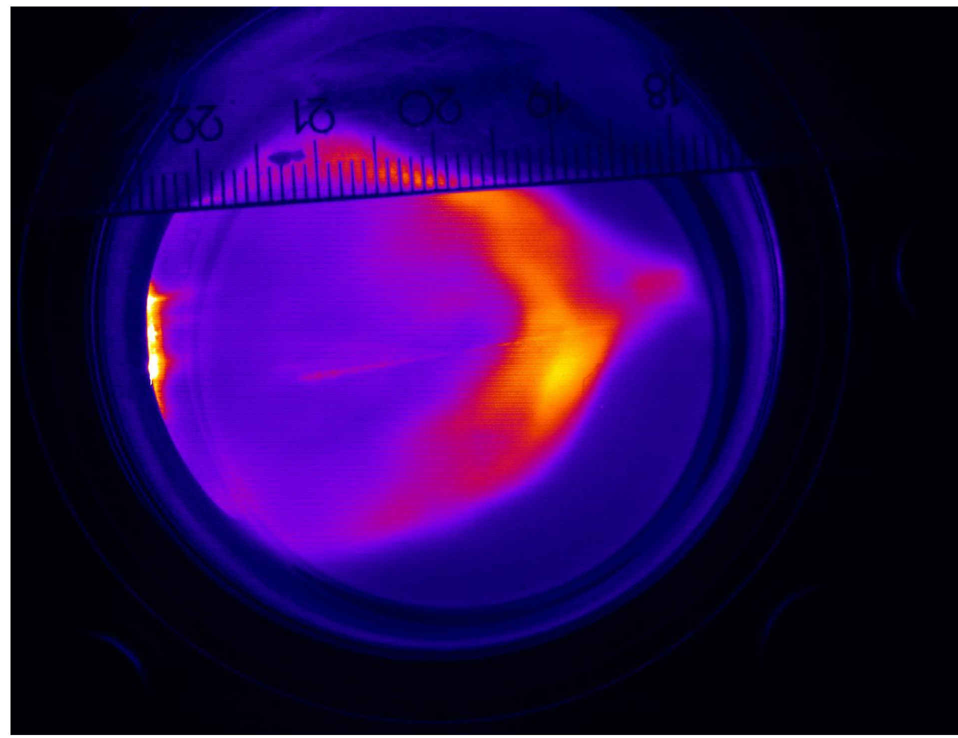
I. voltage: 4kV

II. Current: 35kA

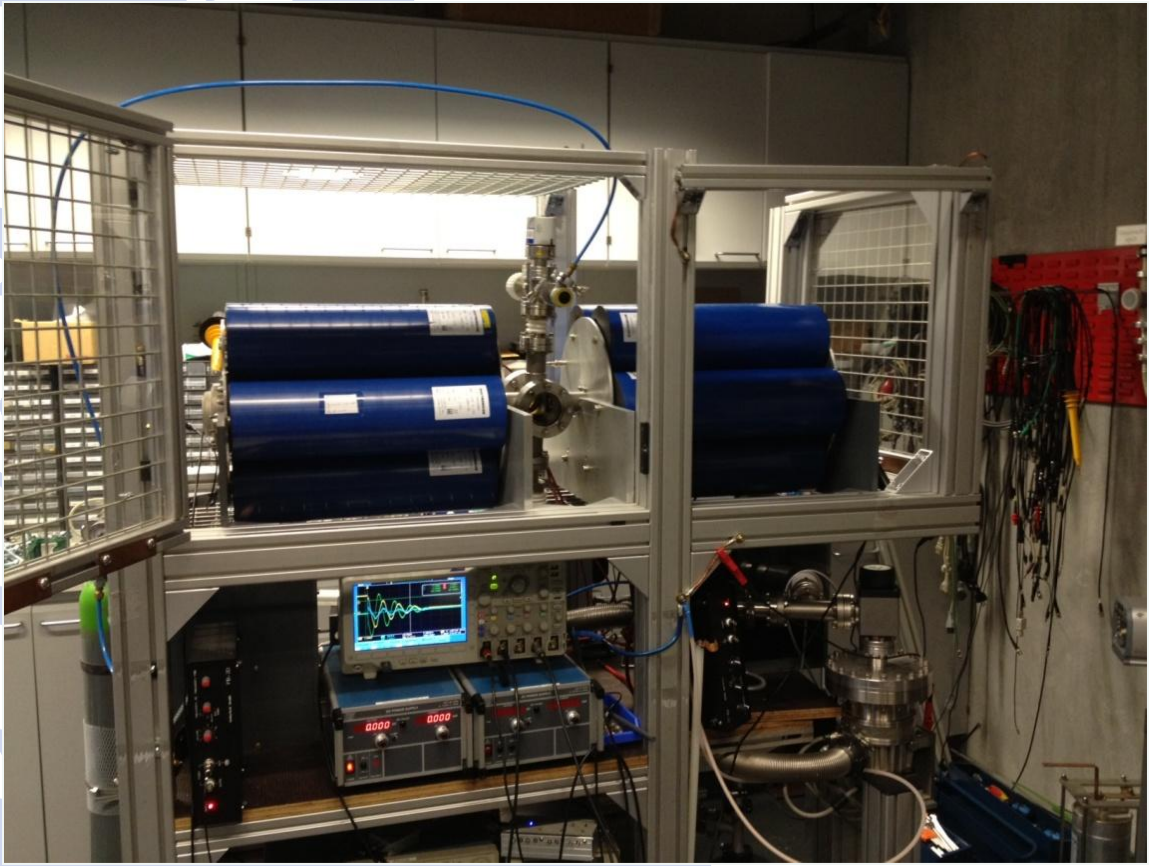
III. Gas-pressure: 8Pa

IV. Stored energy: 72J

V. Velocity: 8,2



# Setup



$$U_0 = 2kV...10kV$$

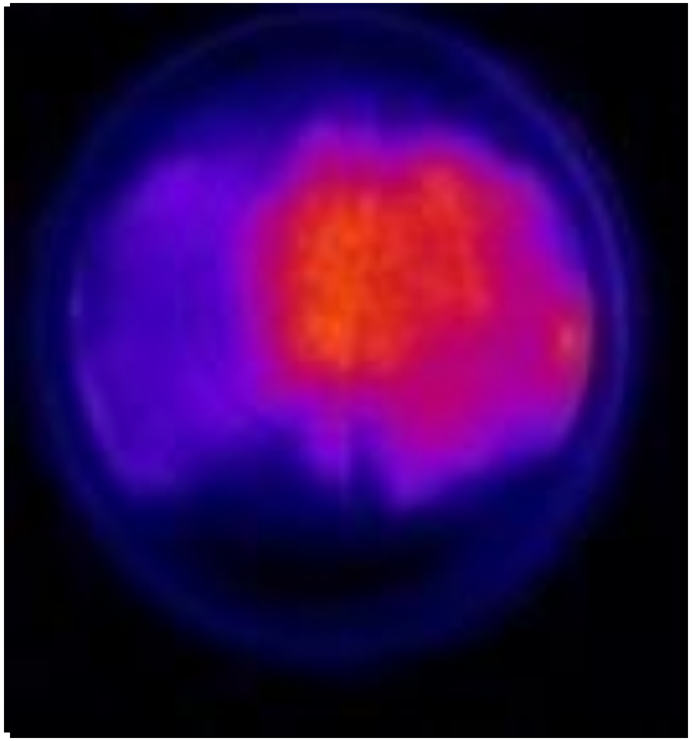
$$C_0 = 27\mu F$$

$$W_0 = 72Joule...1{,}35kJoule$$

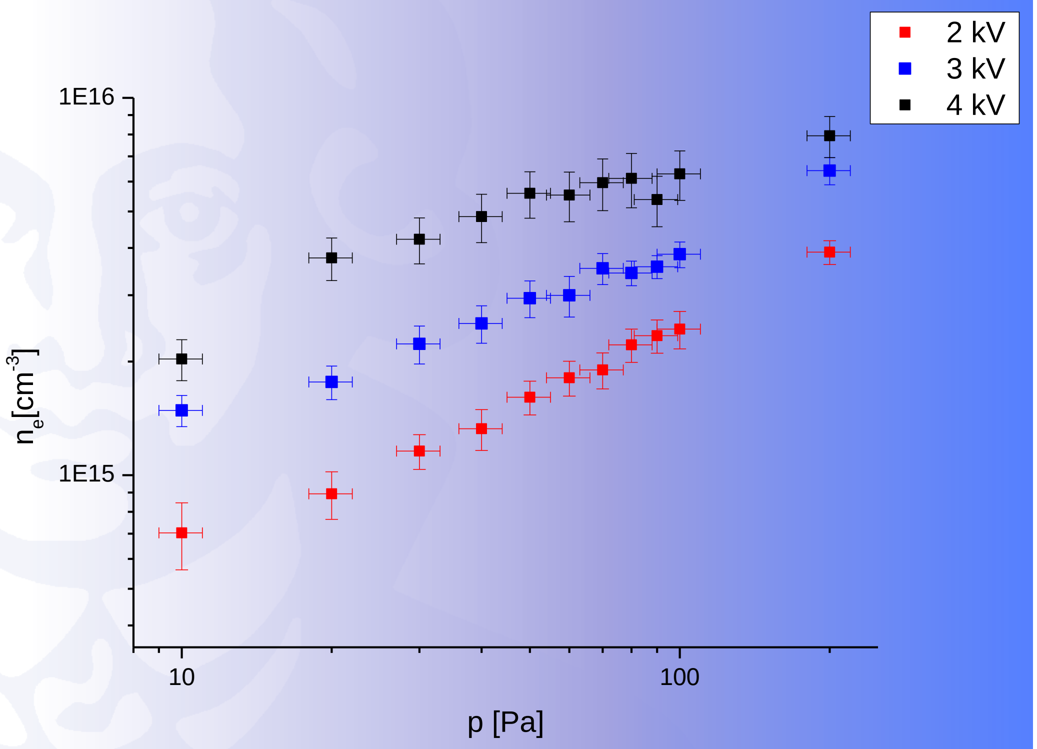
$$I_0 = 20...150kA$$

# Plasma Collider

I. voltage: 2 x 4kV
II. Current: 2 x 35kA
III. Gas-pressure: 10Pa
IV. Stored energy: 2 x 72J



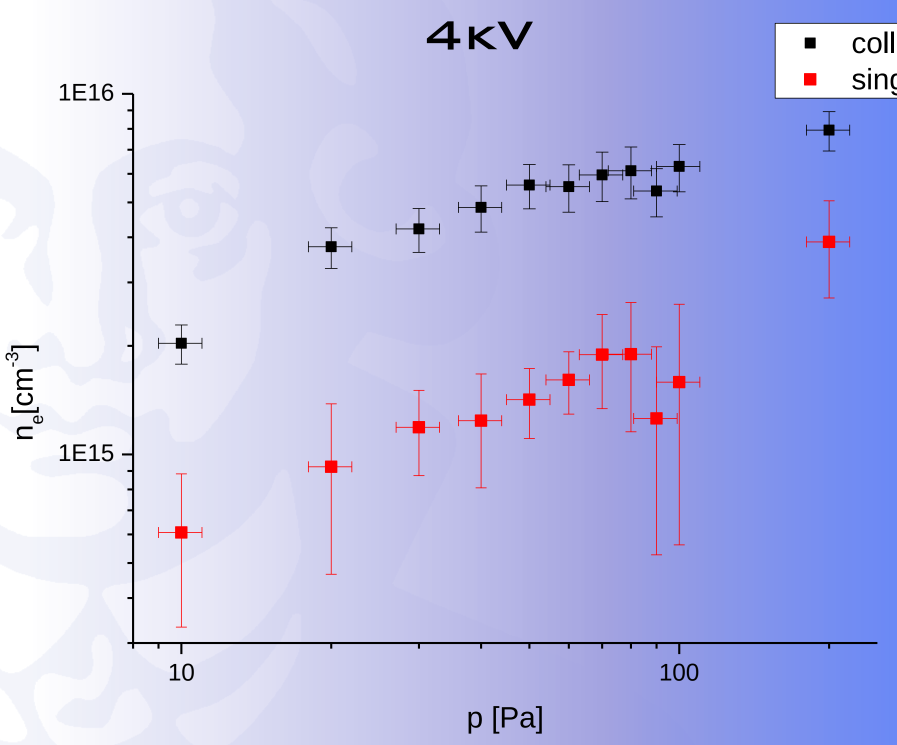
# Density Measurement




$$n_e\left[cm^{-3}\right] = 1{,}03 \cdot 10^{16} \cdot \Delta\lambda^{1{,}488}$$

- Densityprofile shows a linear behaviour
- Density is increasing with increasing gas pressure
- Density is increasing with increasing applied voltage by a factor of 2 per kV

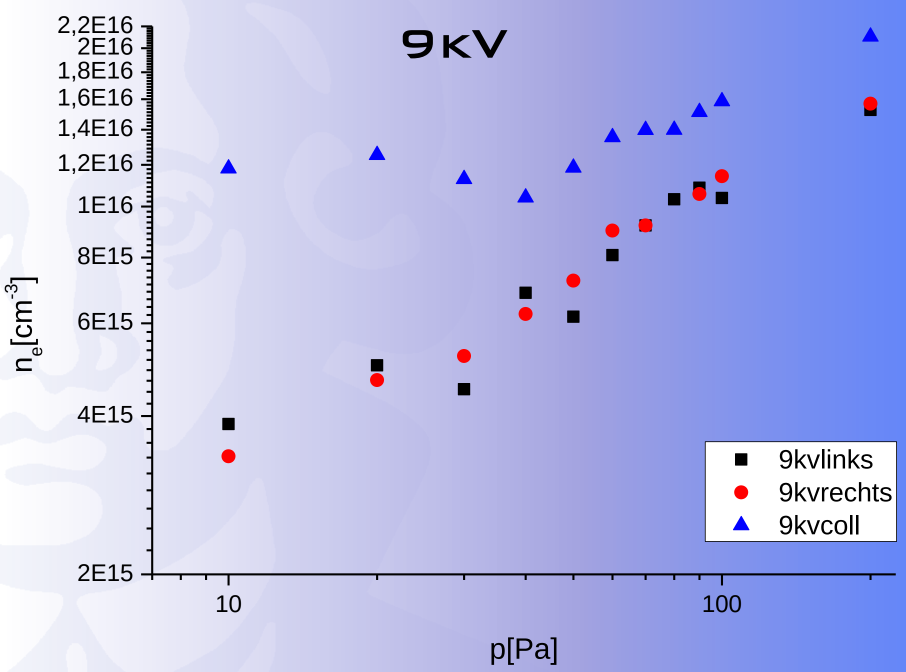
# Density Measurement




$$n_e \left[cm^{-3}\right] = 1{,}03 \cdot 10^{16} \cdot \Delta\lambda^{1{,}488}$$

- the density in the collision case is a factor 4 higher than in the single case

# Density Measurement




- the in the collision the density is up to a factor 3 higher than with a single beam

# XUV/VUV diagnostics of warm dense matter

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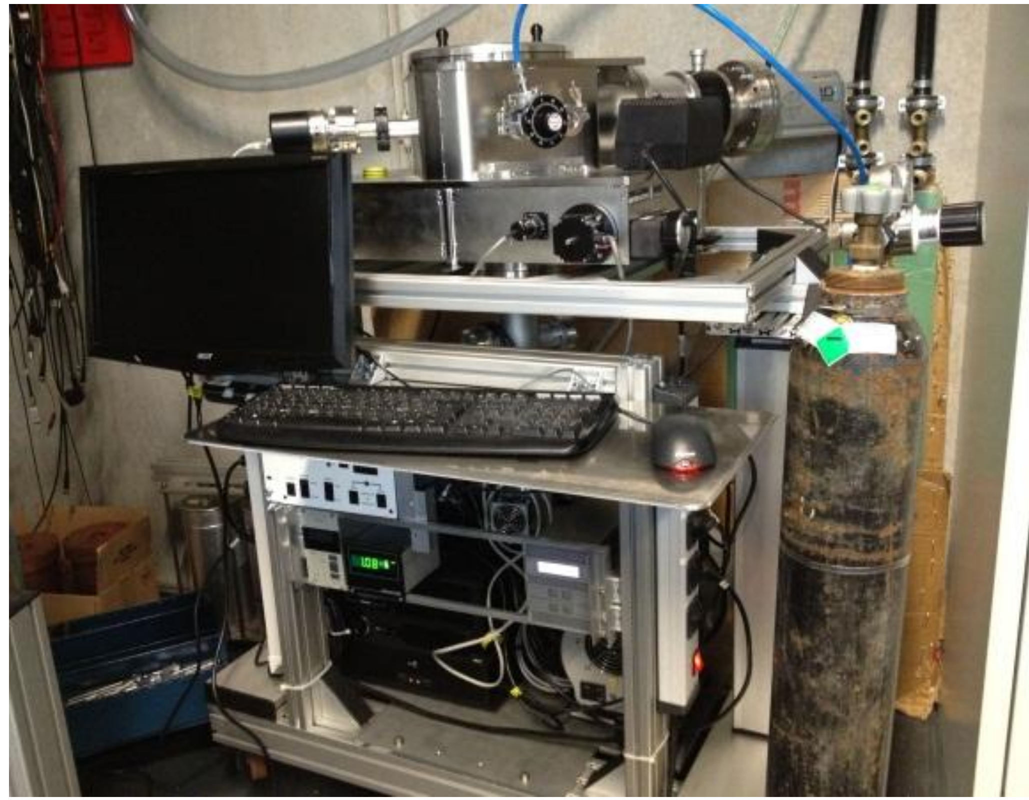
- Setup of a simple to mount VUV diagnostic system
  - Adjustable height (ca. 120-180cm)
  - Self supporting system (one cable solution)
  - AndorBasic coding for automation

- High QE in VUV area
- Monochromator & spectrometer applications



## Experiments:

- Colliding plasma (Uni Frankfurt
- Interaction of matter with an high energy laser (PHELIX)
- Interaction of matter with an  heavy ion beam (GSI / FAIR)

| | |
|---|---|
| Wavelength | 30-300nm |
| Blaze wavelength | 70nm |
| Resolution | 0,05nm |
| Detektor | Andor iKon M |

HGS-HIRe for FAIR Helmholtz Graduate School for Hadron and Ion Research

EMMI

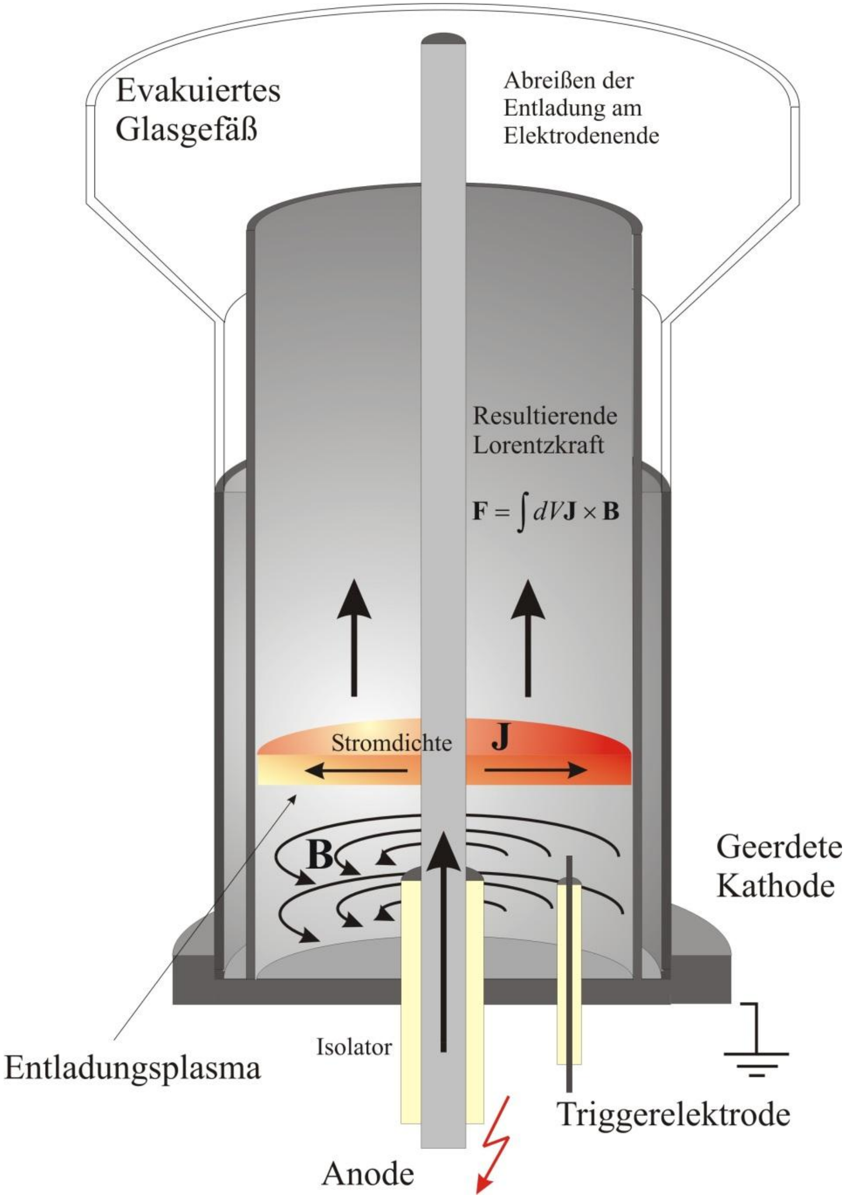
HIC for FAIR Helmholtz International Center

# III. J x B -Switches

Development of a high current plasma-switch

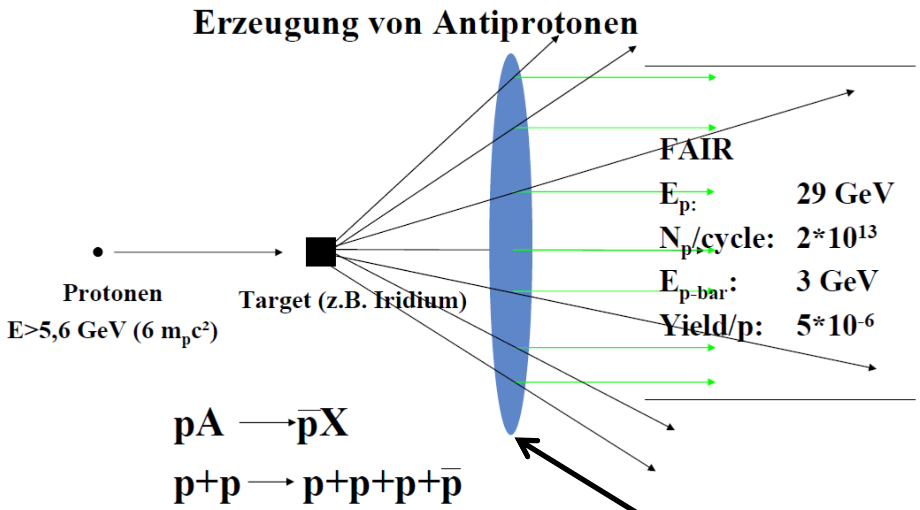
for the FAIR-magnetic-horn

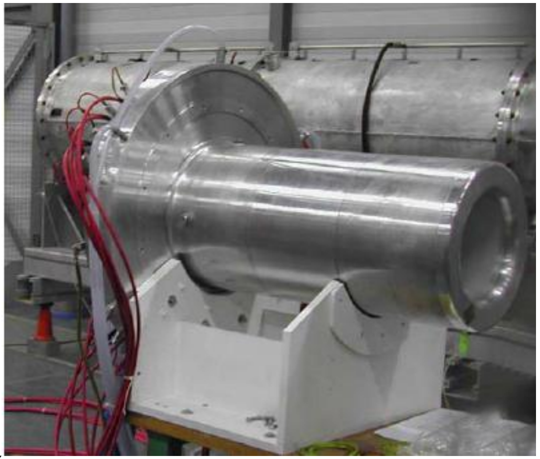
# j x B - Schalter



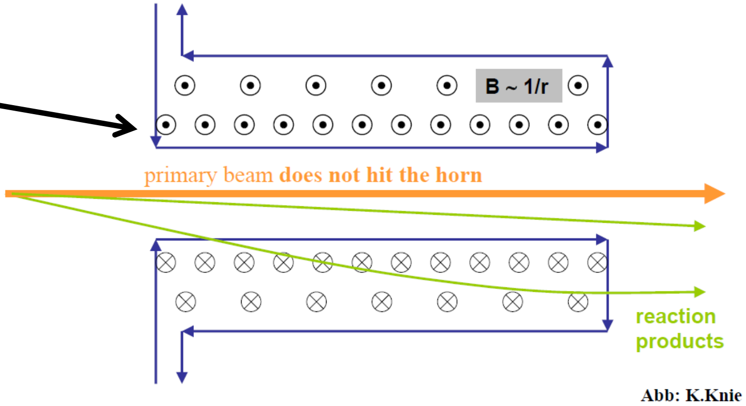

# Introduction

## •Creation and collection of Antiprotons



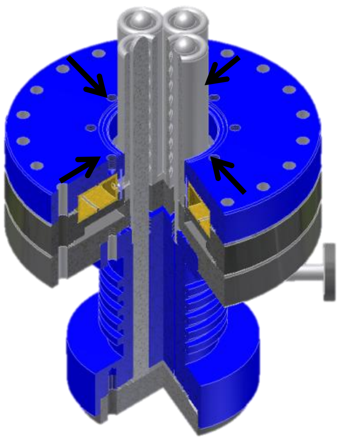



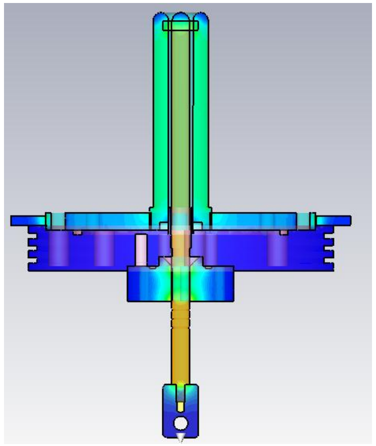
Magnetic Horn




| Requirements for the switch | |
|---|---|
| $U_{max}$ | 20 kV |
| $I_{max}$ | 400 kA |
| T | 2.8 - 40 µs |
| $\Delta A/\Delta t$ | 6E10 – 8.5E11 A/s |
| Dutycycle | 0.2 Hz |

# Concept – HCLDS: High-Current-LDS





- 4 parallel, synchronized LDS‘s:
- Synchronization of the single discharges due to boreholes in the outer electrodes
- Trigger unit:
  - Glow discharge
  - High dielectric Trigger

**Advantages:**

- low inductance → high rise time
- low erosion → long lifetime
- simple setup → cheap
- self quenching → defined pulse length
- mercury free → alternative to Ignitrons

- Problems:
- synchronization of the discharges
- for long pulse length, several single discharges during one “shot” are necessary
- good quenching behavior followed by re-triggering the discharge