Negative Hydrogen Ion density measurement in a permanent magnet based Helicon Ion Source (HELEN-1) using cavity ring down spectroscopic technique

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Presentation overview :

- **Motivation**
- **A brief discussion of the in house developed Cavity Ring down Spectrometer in the Institute for Plasma Research**
- **Description of the experimental setup**
- **Characterization of the negative ion density profile for HELEN-1 with Cavity ring down Spectrometer is presented**
- **Future Plans**

Motivation

- **Negative ion based ion source are important for NNBI system (beam energy >100 keV)**

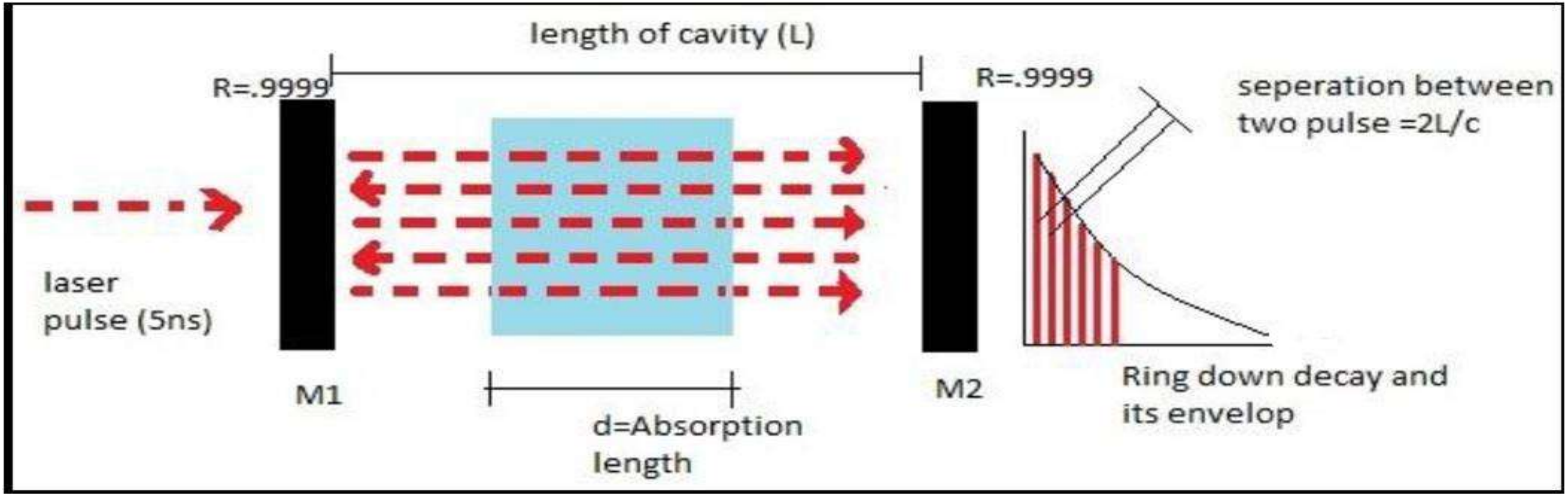
- **Measurement of negative ion density is important for characterization and optimization of any ion source**

- **Cavity ring down diagnostic is a sensitive technique in which the line integrated negative ion density can be measured non invasively**

- **In our experiments, A cavity ring down spectrometer is successfully established and is used to measure Negative ion density in a Helicon device.**

Cavity Ring down Spectroscopy

BASIC PRINCIPLE OF RING DOWN SPECTROSCOPY



- **mean photon life time is increased by multiple reflection**

$$\tau_{ABS} = \frac{L}{c[(1-R)+\alpha d]} \quad , \quad \alpha = Coefficient\ of\ Absorption = cross\ section \times Number\ density$$

CRDS design consideration

System parameters	values
Coefficient of reflection of dielectric mirrors	.9999
Separation between Cavity Mirrors(L)	1.2 m
Radius of curvature of the mirrors	6m
Stability Criteria and g value	$0 < g_1 g_2 < 1 \; ; \; g = 1 - \frac{L}{r}$ $g_1 g_2$=.64
INNOLAS SpitLight Compact 200 (Nd:YAG)	1064nm, Pulse width 5 nm, maxEnergy per pulse 150 mille joule
Photo detector	*p-i-n* photo-detector (InGaAs) ,detection range 400nm -1700nm ,Gain 70 dB
Oscilloscope (Tektronix MSO3014)	Bandwidth 100MHz,Sampling rate 2GHz per sec

Measurement Technique used to extract ring down time

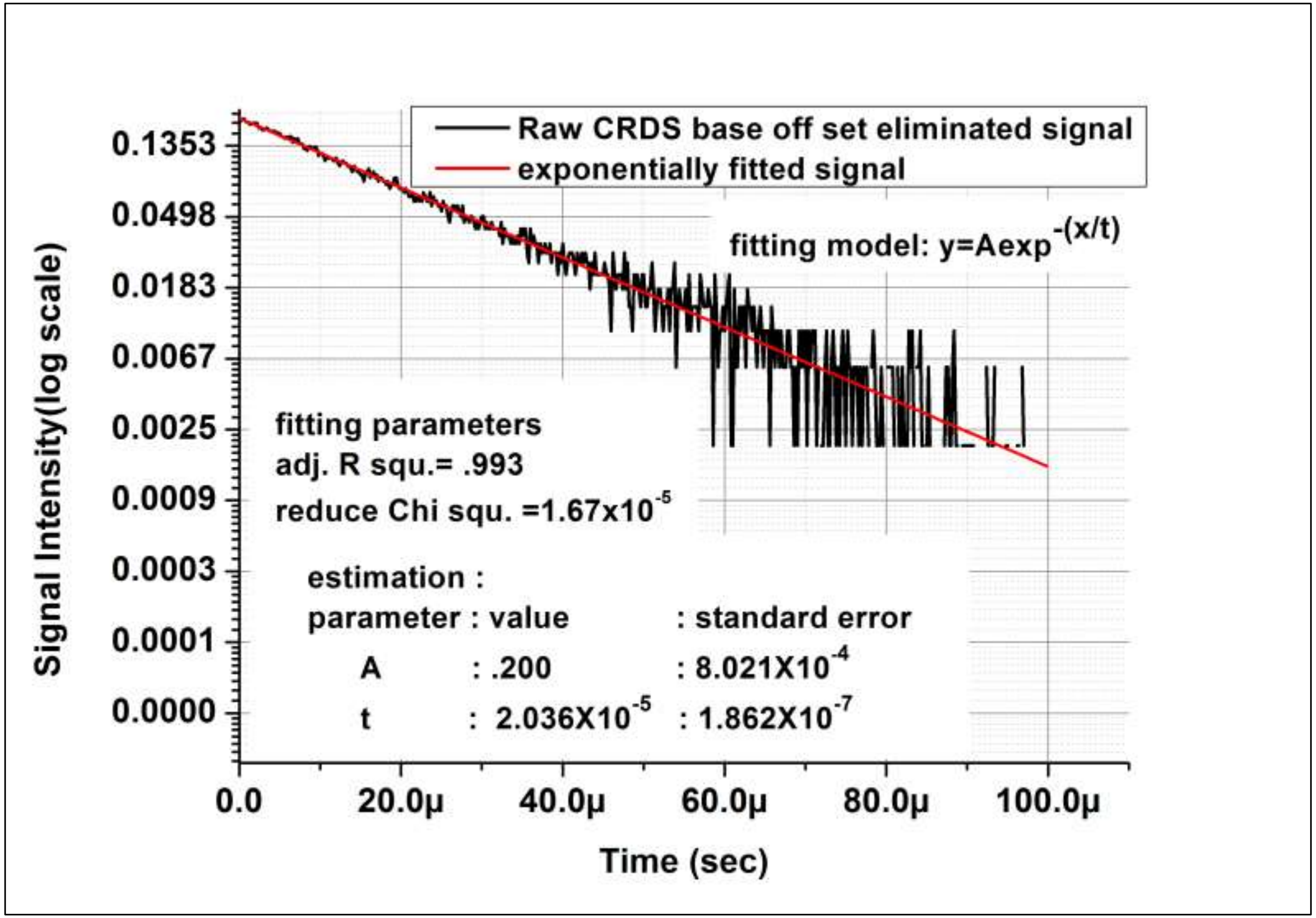
RAW SIGNAL

BASE OFF SET ELIMINATION

LOG SCALE

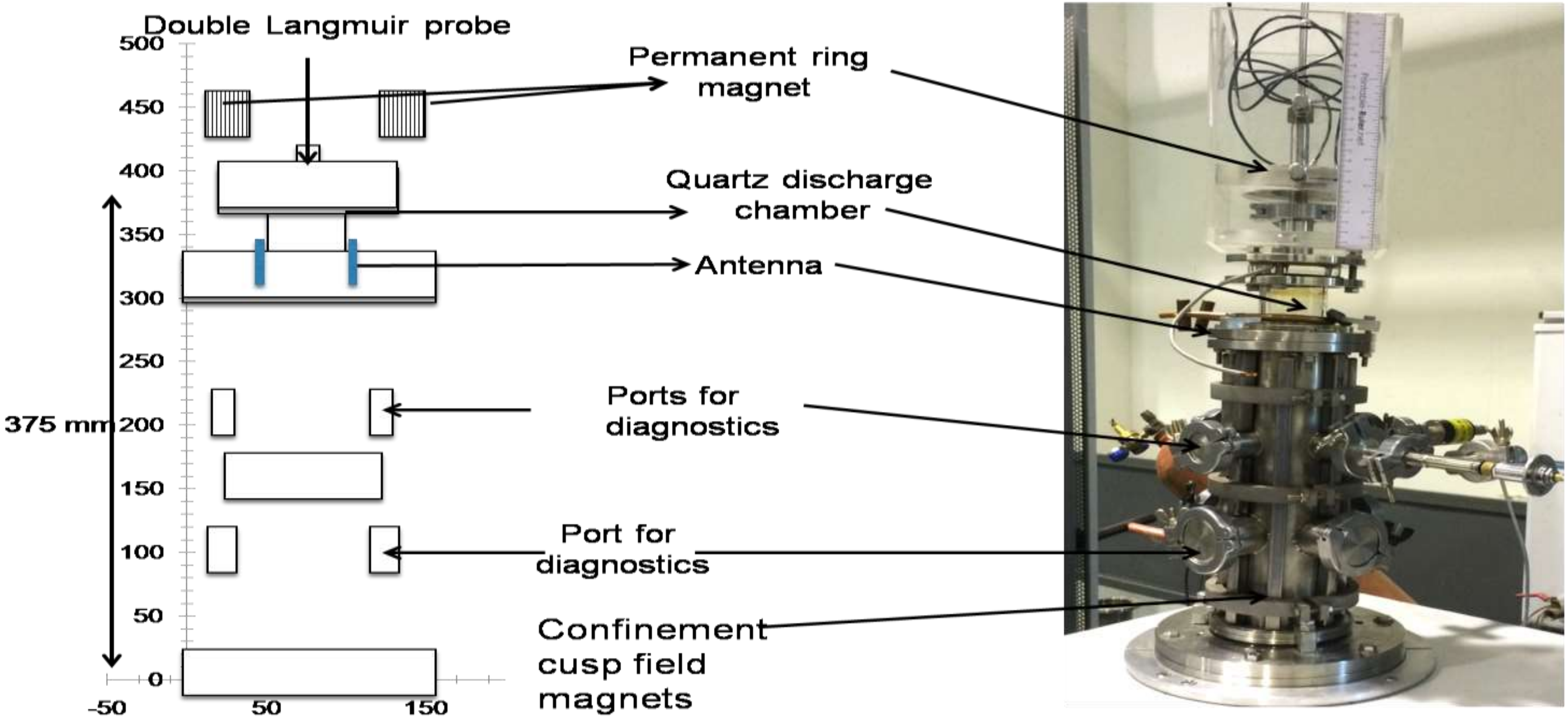
EXPONENTIAL FIT

RING DOWN TIME ESTIMATION



RING DOWN TIME FOR VACUUM AND FITTING PARAMETERS

HELEN -1



Double Langmuir probe
Permanent ring magnet
Quartz discharge chamber
Antenna
Ports for diagnostics
Port for diagnostics
Confinement cusp field magnets
375 mm
500
450
400
350
300
250
200
150
100
50
0
-50
50
150

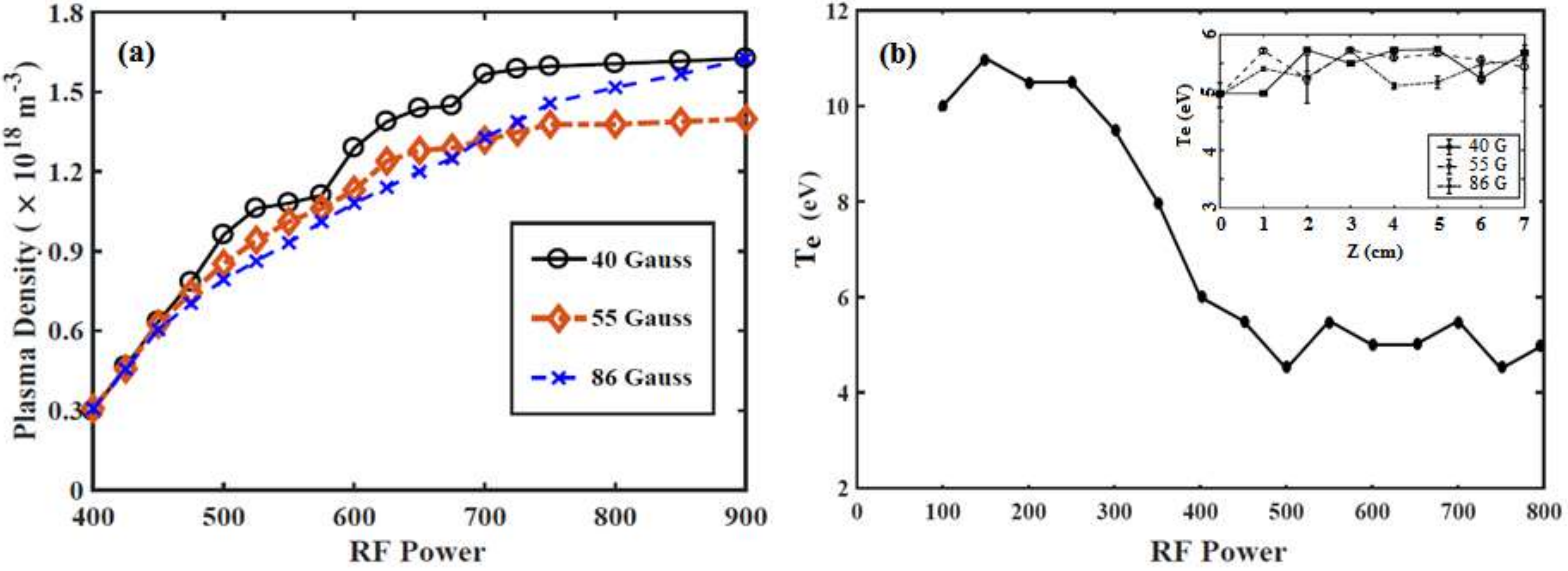
Experimental set up details

Vacuum vessel	Source and expansion chamber
Axial magnetic field	NdFeB permanent ring magnet
RF generator and auto tuning impedance circuit	M/s T&C Power Conversion, Inc. Make
Operating frequency	13.56MHz
Antenna	Nagoya III antenna, of 36 mm length
CRDS installation	CRDS is integrated with HELEN by a vacuum compatible transition flange

Parameters taken into consideration under experiment:

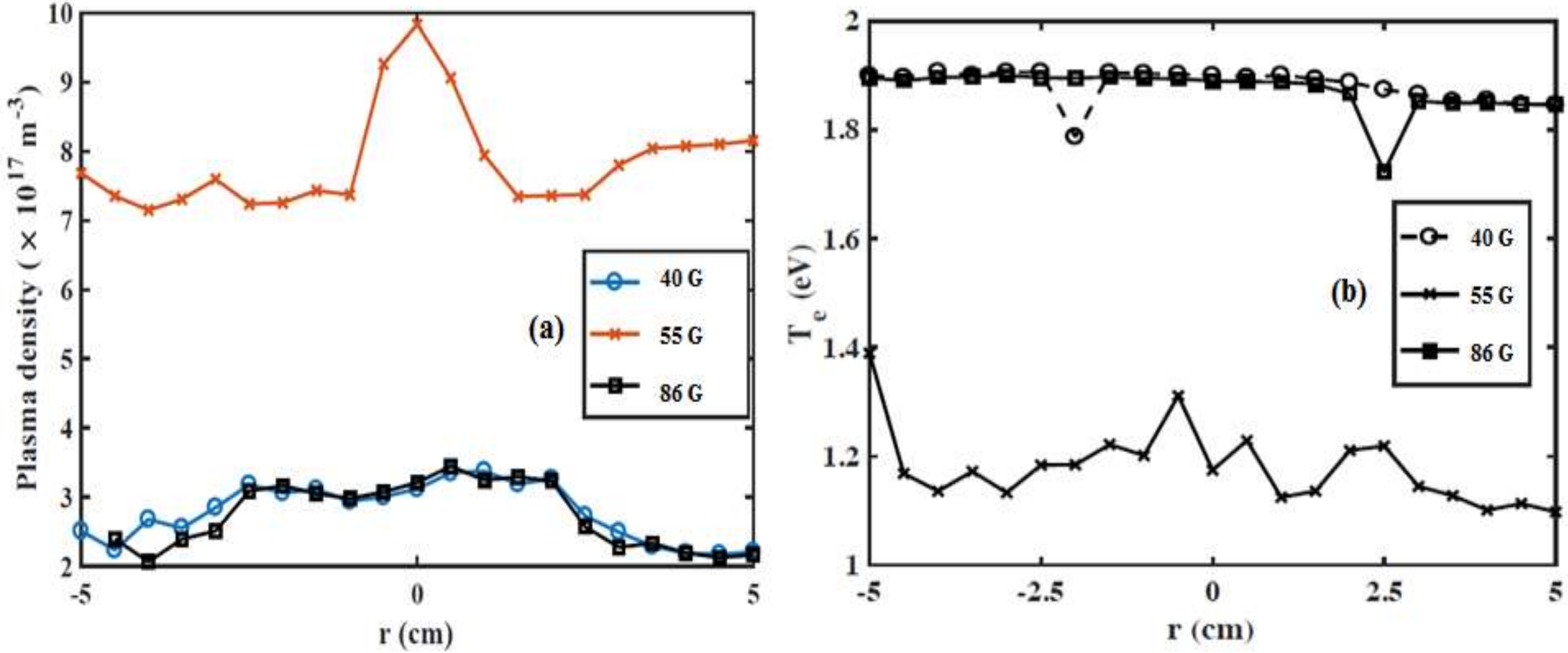
- **Alignment**
- **Deformation of the vessel due to differential pressure gradient**
- **Mirror reflectivity is measured with CRDS setup before experiment**
- **Reflected RF power is less than 1 % for every shots**

Plasma parameters of HELEN



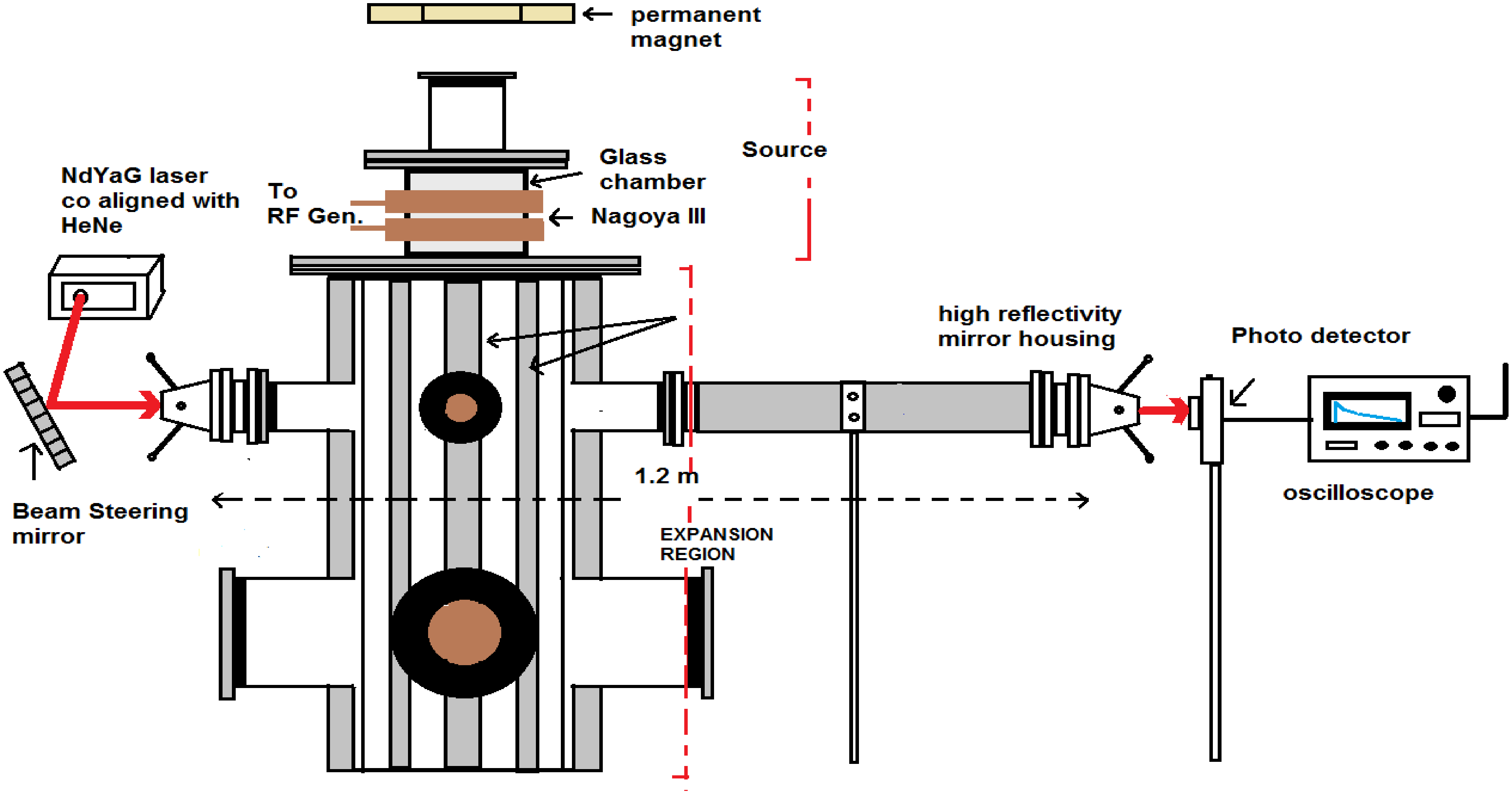
Plasma density and Temperature profile for different RF power and magnetic field in driver

PLASMA PARAMETERS FOR HELEN -1

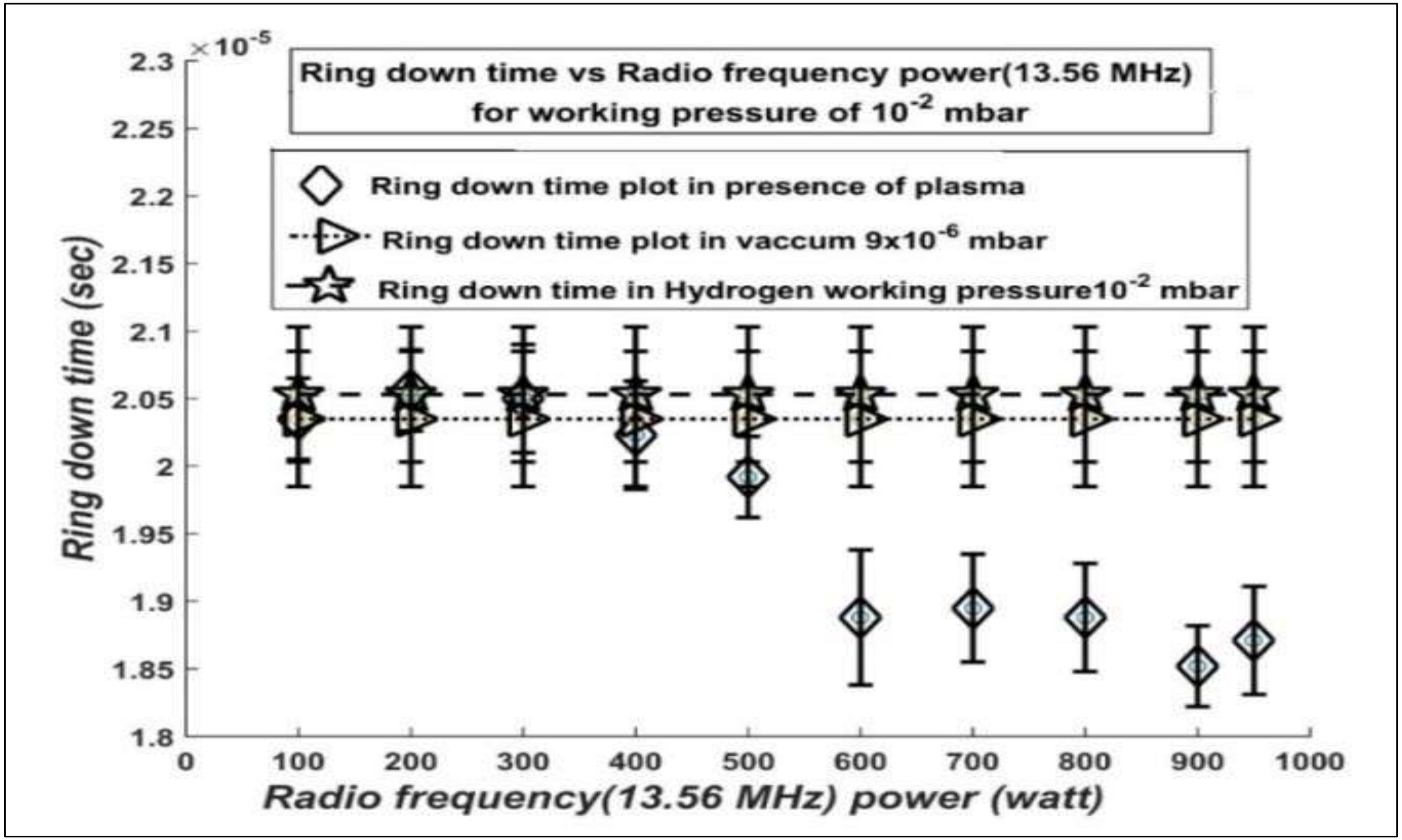


Radial profile of plasma density and temperature at the Probing location of CRDS

Layout of the CRDS system with Helen-1



Characterization of negative ion in Helen-1

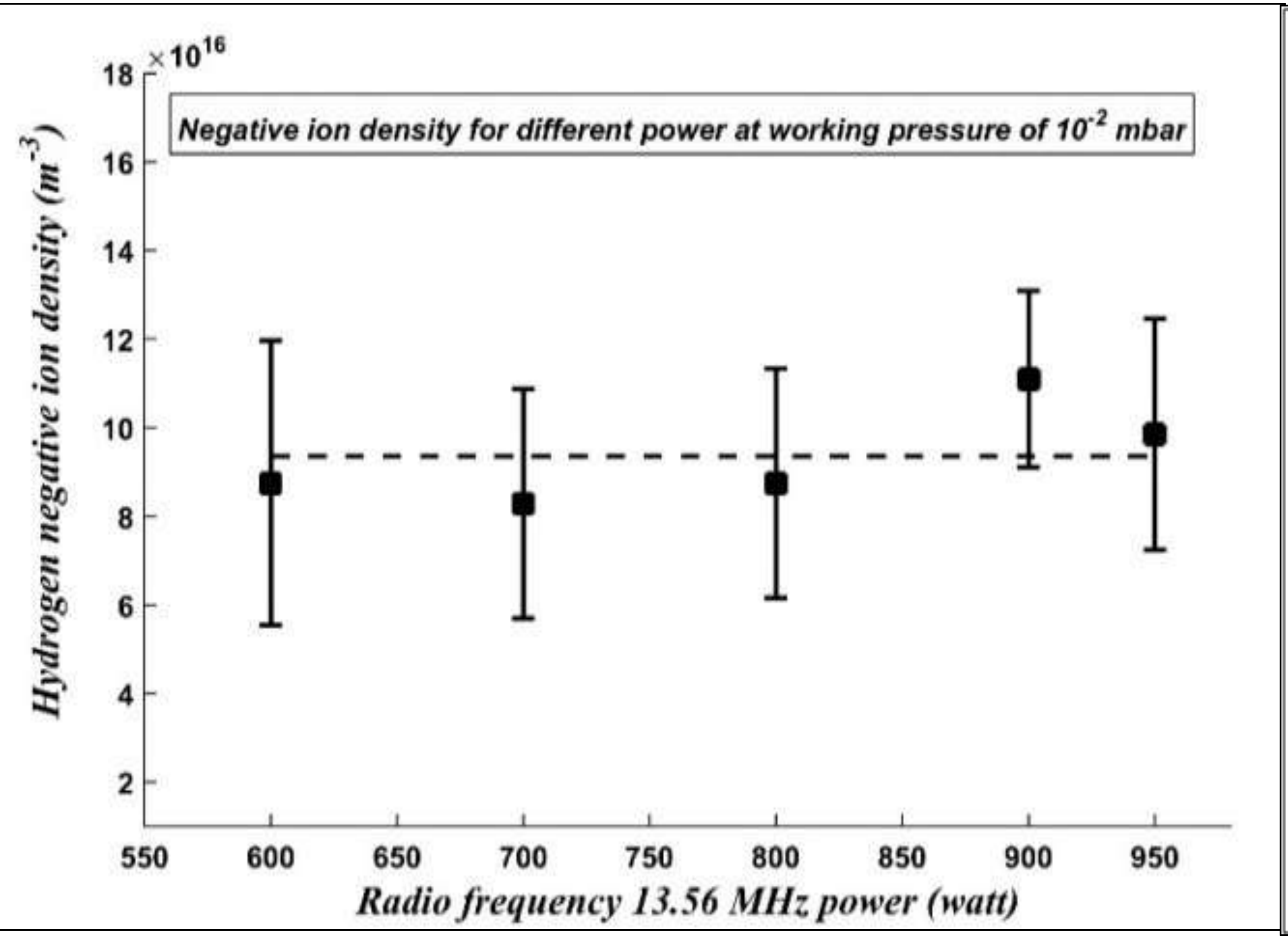


Power characterization of negative ion for HELEN

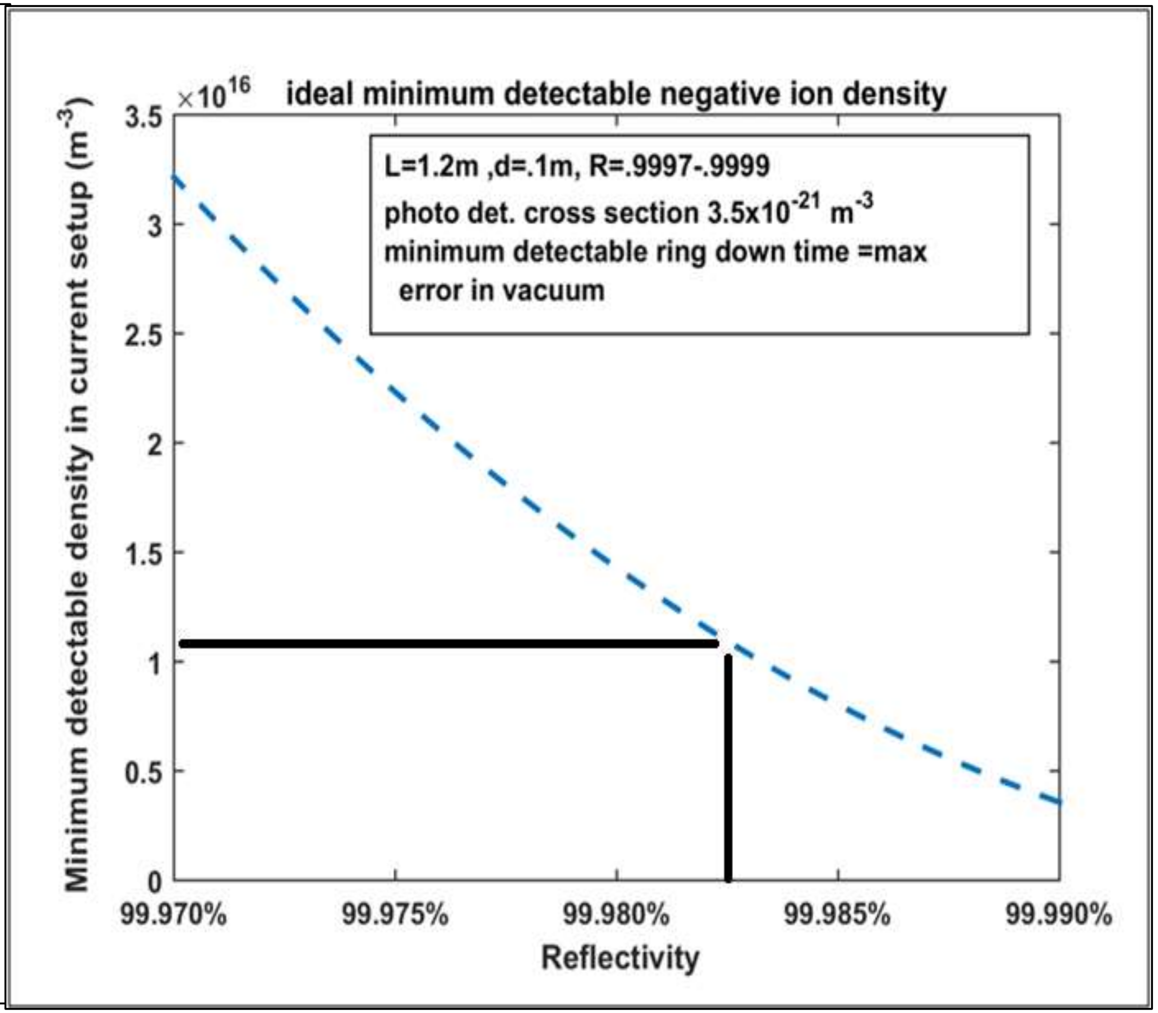
- **RDT is taken in vacuum**
- **RDT is taken in working pressure of 10^{-2} mbar**
- **RDT is taken for different power at 55 Gauss axial magnetic field**
- **The density variation after 600 watt cannot be detected due to sensitivity limit of the present setup**

$$N^{-} = \frac{L}{\sigma_{photo}\, c d}\left(\frac{1}{\tau_{n^-}} - \frac{1}{\tau_0}\right)$$

Negative ion density

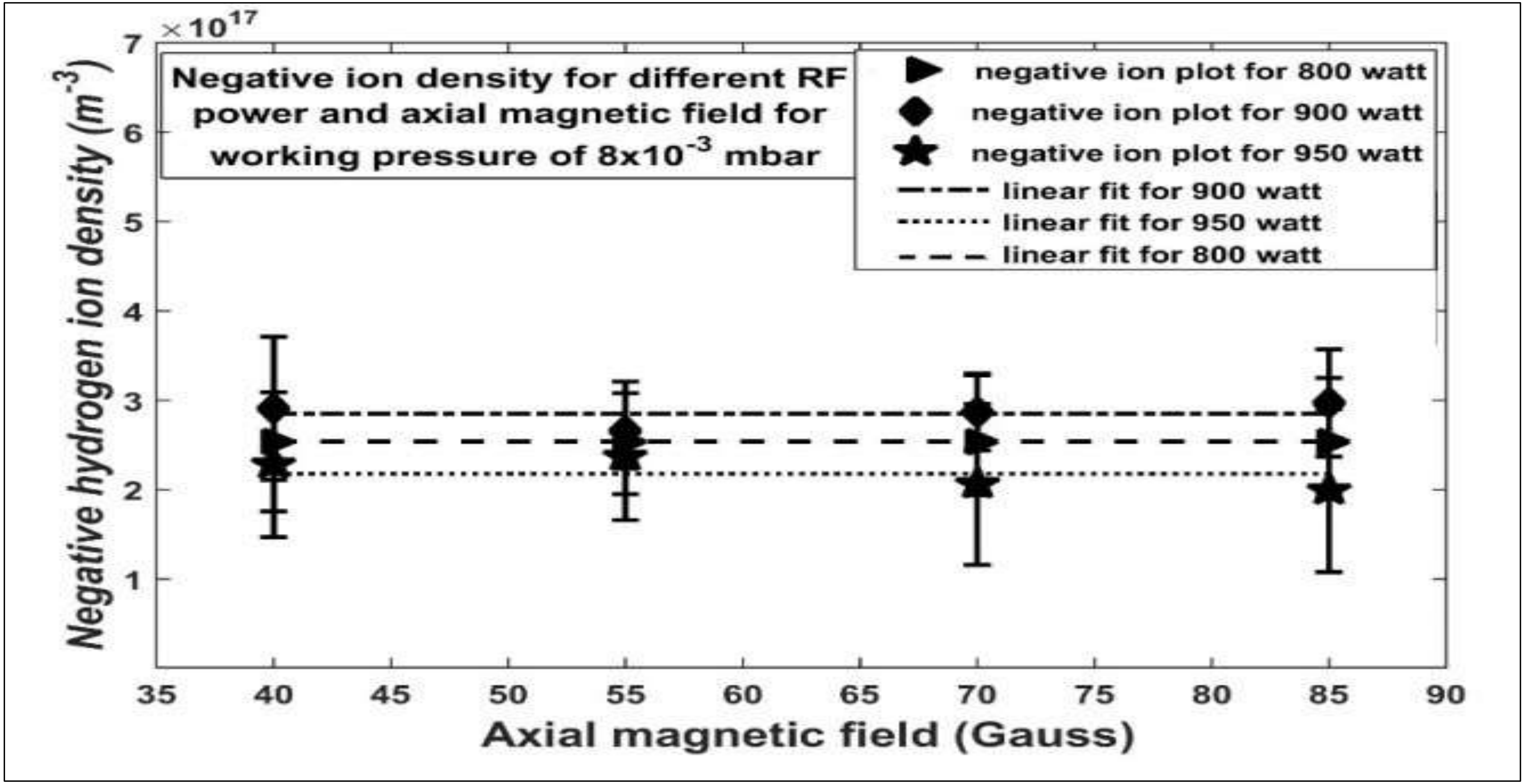


Negative ion density plot for different power



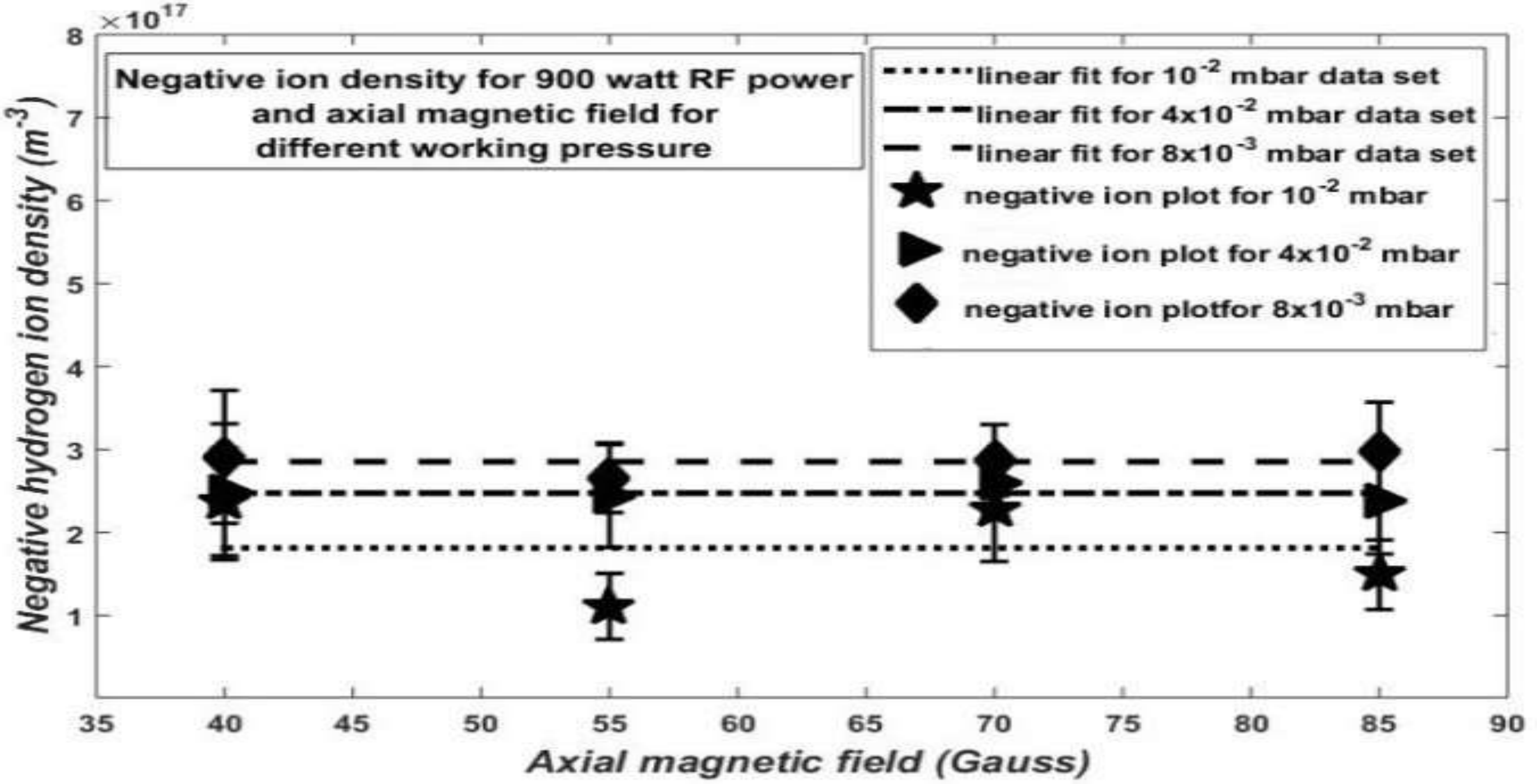
$$\Delta n_{min} = \frac{c}{Ld\sigma_{photo}}(1-R)^2\tau_{min}$$

Characterization continued



The negative ion density plot for different axial magnetic field for different RF powers at constant working pressure of $8x10^{-3}$ mbar

Characterization continued



Negative ion density plot for different working pressure and magnetic field at constant power

Particle balance

$$H_2 + e(fast) \dashrightarrow H_2^*(excited\ state) + e$$

source	loss
EV reaction	Disassociation of excited molecules
	Relaxation by wall collision
	Dissociative attachment
	Ionization of excited molecules

$$n_{H_2^*} = \frac{n_{H_2} n_e}{n_e A + B}$$

$$A = \frac{p < \sigma v >_{DA} + (1-p)[< \sigma v >_{Dis} + < \sigma v >_{ion}]}{(1-p) < \sigma v >_{EV}}$$

$$B = \frac{1}{(1-p) < \sigma v >_{EV} t_{H_2^*}}$$

Particle balance continued

•

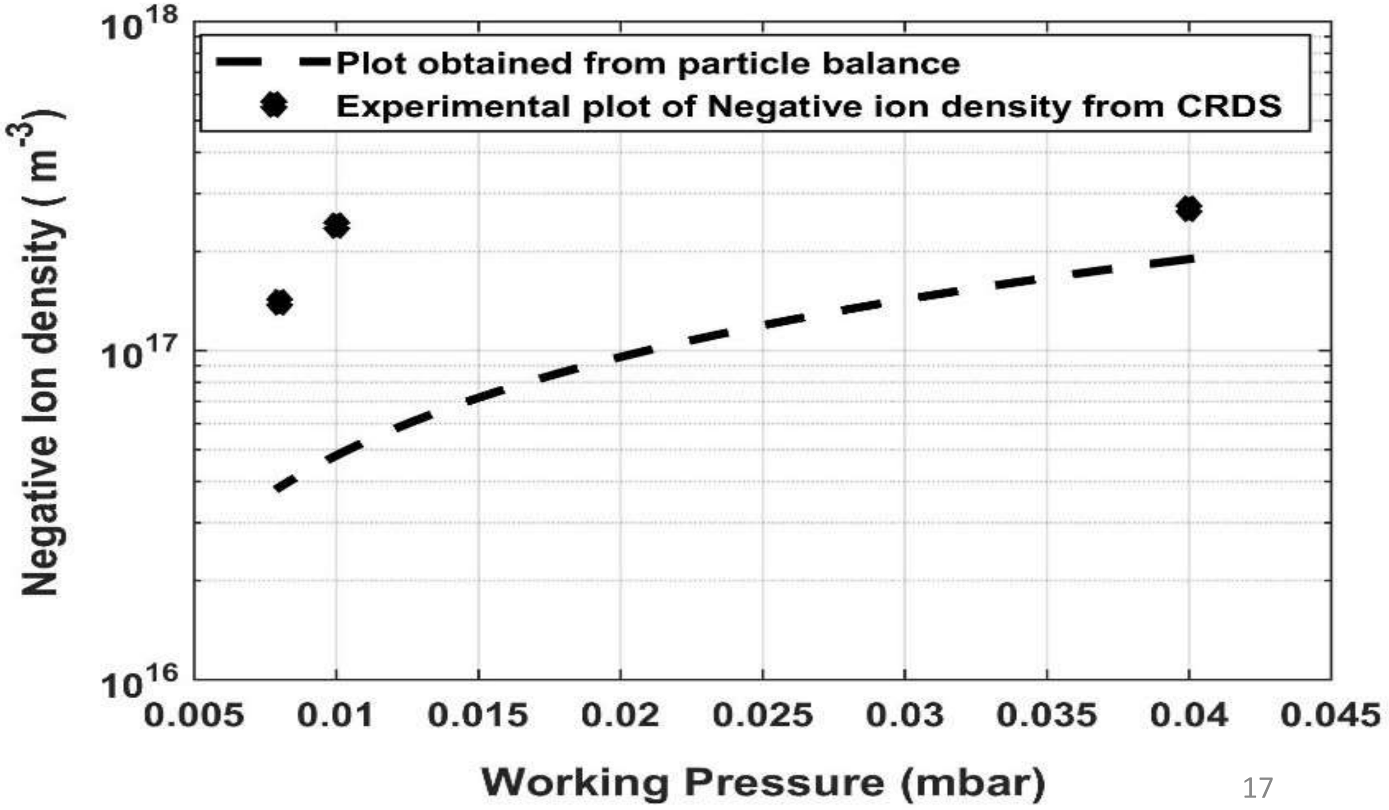
$$H_2^* + e(slow) \dashrightarrow H^- + H$$

SOURCE	LOSS
Dissociative attachment	**Mutual neutralization**
	Loss by collision with wall

$$n_- = \left[\left\{\sqrt{(n_e + C)^2 + 4 n_e n_{H_2^*} D}\right\} - (n_e + C)\right]/$$

$$C = \frac{1}{<\sigma v>_{MN}\, t_{n_-}}$$

$$D = \frac{P <\sigma v>_{DA}}{<\sigma v>_{MN}}$$



summary

•**High negative ion density is can be obtained in the Helicon setup even without cesium injection**

•**No dependence on axial field is obtained in the axial magentic field under consideration**

•**Sensitivity of CRDS need to be increased in order to detect the negative ion density in lower power regime**

•**The variation in negative ion density is negligible in higher power regime and is in the same order**

•**The negative ion density variation with working pressure under consideration is not that much**

Future work

- Automation will be installed for monitering any misalignment during the experimental conditions .
- Much more precise particle balance and monte carlo model will be developed for validation of experimental data
- Other negative ion measurement diagnostics like Laser aided photo detechment method is under development.
- CRDS will be intregtared in TWIN source ,ROBIN and INTF

THANK YOU