Exploration of the Neptune vicinity using ISRU technology

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Abstract

♣ The **HHeDGM**, a volume averaged **detailed global model**, is used to **characterize Electric Thrusters (ET)** fueled by **hydrogen / helium mixtures** and to **analyze** their functioning.
Here, the Neptune Atmosphere (**NeptAtm**) is used as propellant, aiming to support exploration of the **Neptune vicinity**.
♣ **HHeDGM** evaluates the densities of the **ET** plasma components and the electron temperature. Results are presented in **Plasma Component Composition (PCC)** and **Functioning Diagram (FD)** form.
♣ **HHeDGM** calculates also **spectral line intensities** of **H I** & **He I** / **He II**, allowing for **Optical Emission Spectroscopy (OES)** diagnostics.

Summary of the Presentation

1. Introduction

Presentation of **HHeDGM** results, consisting in :

2. PCCs containing **densities of species** followed by their **percentages** in concomitant diagrams.

3. FD, illustrating the thruster functioning.

4. Hydrogen H I & **helium He I / He II theoretical emission spectra**, allowing for **OES** diagnostics.

5. Radioisotope Power Systems (RPSs) are also shortly addressed.

6. Conclusions

1. Introduction (1/2)

♣ **HHeDGM** supports the ***In Situ* Resource Utilization** (**ISRU**) disruptive technology for various types of thrusters, when their propellant is harvested from the **Gas Giants** atmospheres, Refs. [1-4], next slide.

We address here propulsion for **satellites revolving around Neptune** and for **spacecrafts** traveling in its vicinity, where the atmosphere allows for direct feed. Whenever the breathed propellant is conveniently stored, **ISRU** technology may also serve for exploration of the **Neptune-Triton** system, see e.g. Rymer *et al.*, Refs. [5, 6], next slide.

♣ Hydrogen in **NeptAtm** is in molecular form, leaving only two important initial components of the propellant, namely **H2** present in about 80 % and **He** in 20 %. This is approximately valid for all the four **Gas Giants**.

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[6] Rymer, A.M. *et al., Neptune and Triton: A Flagship for Everyone, WHITE PAPER FOR PLANETARY AND ASTROBIOLOGY SCIENCE STRATEGY*

[7] Terranova, M.L. (**2021**). *Nuclear batteries: Current context and near-term expectations*

1. Introduction (2/2)

♣ **Electron temperature T_e**, **pressure *p*** and **absorbed power P_{ABS}** are the main parameters in the presented **PCC**s and concomitant diagrams giving the plasma composition and components percentages correspondingly, while **FD** gives the plasma ionization percentages. The latter shows results illustrated by isothermal, isoenergetic and isobaric curves.

♣ The addressed **flow rate Q_{TOT}** is of 10 sccm throughout.

♣ **OES diagnostics** pertains here to **ET** plasma neutral / ionized species created by the propellant harvested from the **NeptAtm**. Extended sets of data belonging to hydrogen and helium main levels have been included in **HHeDGM**.

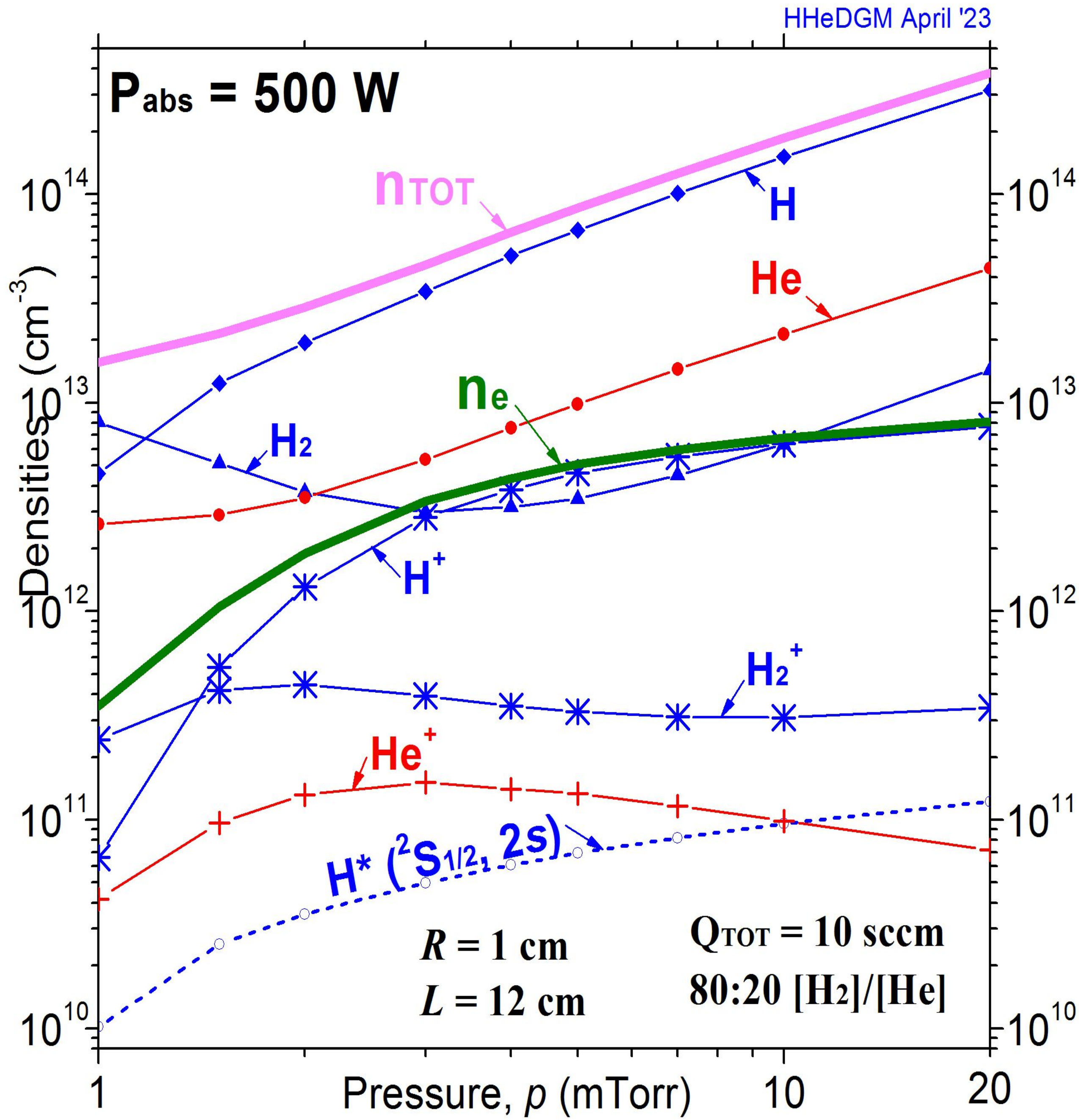
2. Density of Species PCC

Fig. 1. *Pressure dependent* ***PCC***

P_{abs} = 0.5 kW

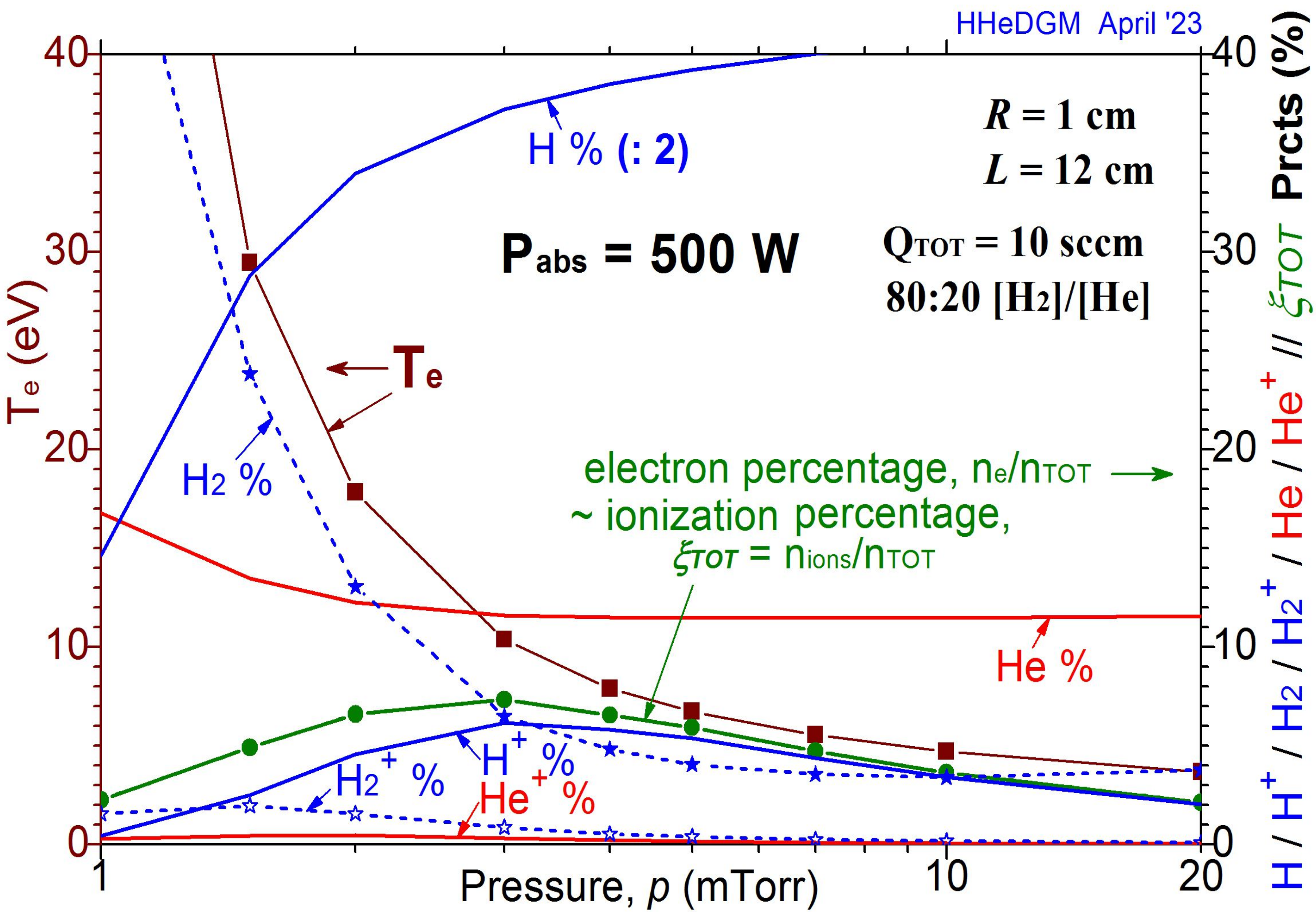
NeptAtm *for 80:20 [H2]/[He] feed of 10 sccm*

Form factor for all figures : R=1 cm, L=12 cm



2. Density of Species PCC

Fig. 2. Concomitant of Fig. 1



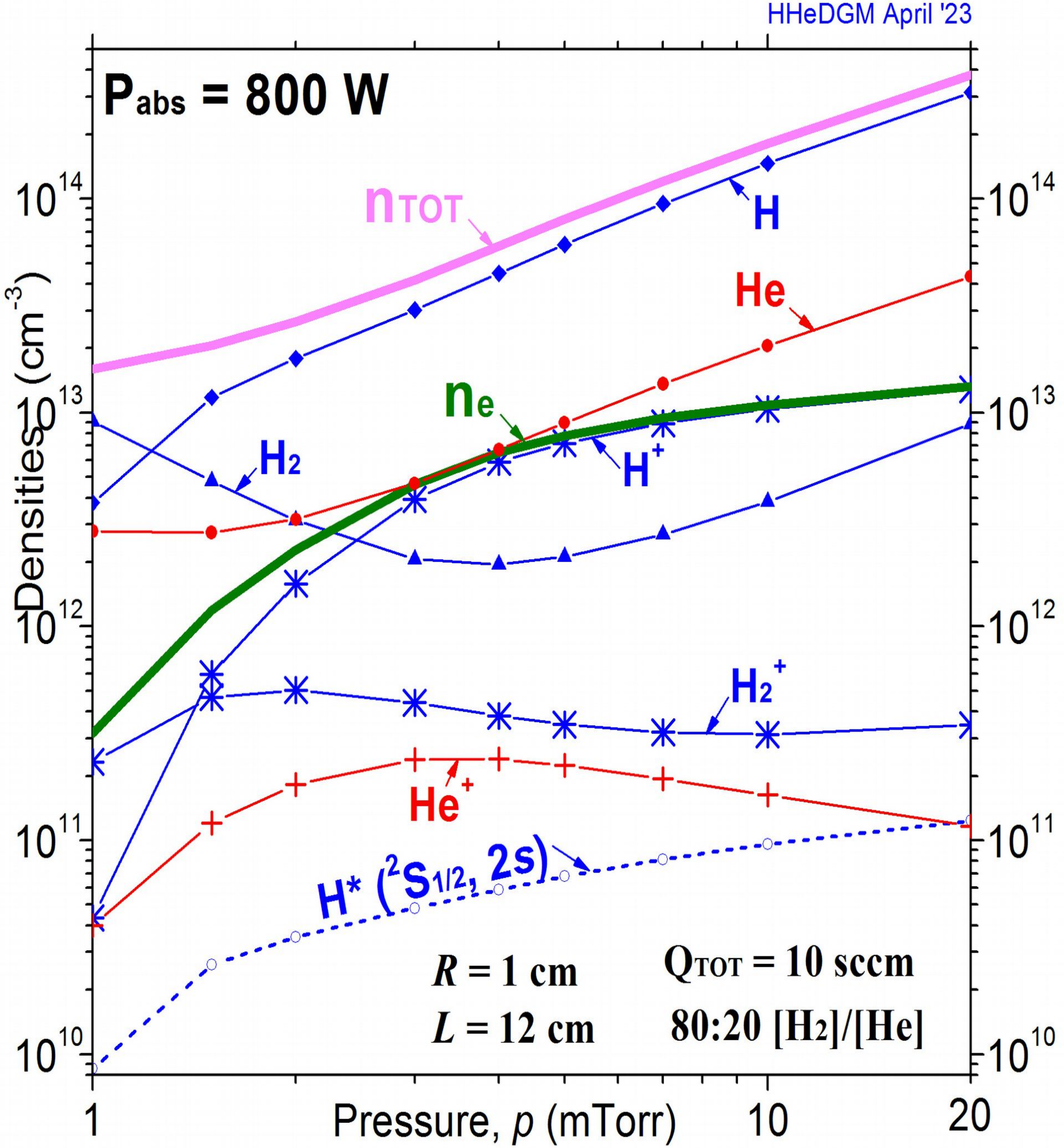
2. Density of Species PCC

Fig. 3.
*Pressure dependent **PCC***

$P_{abs} = 0.8\ kW$

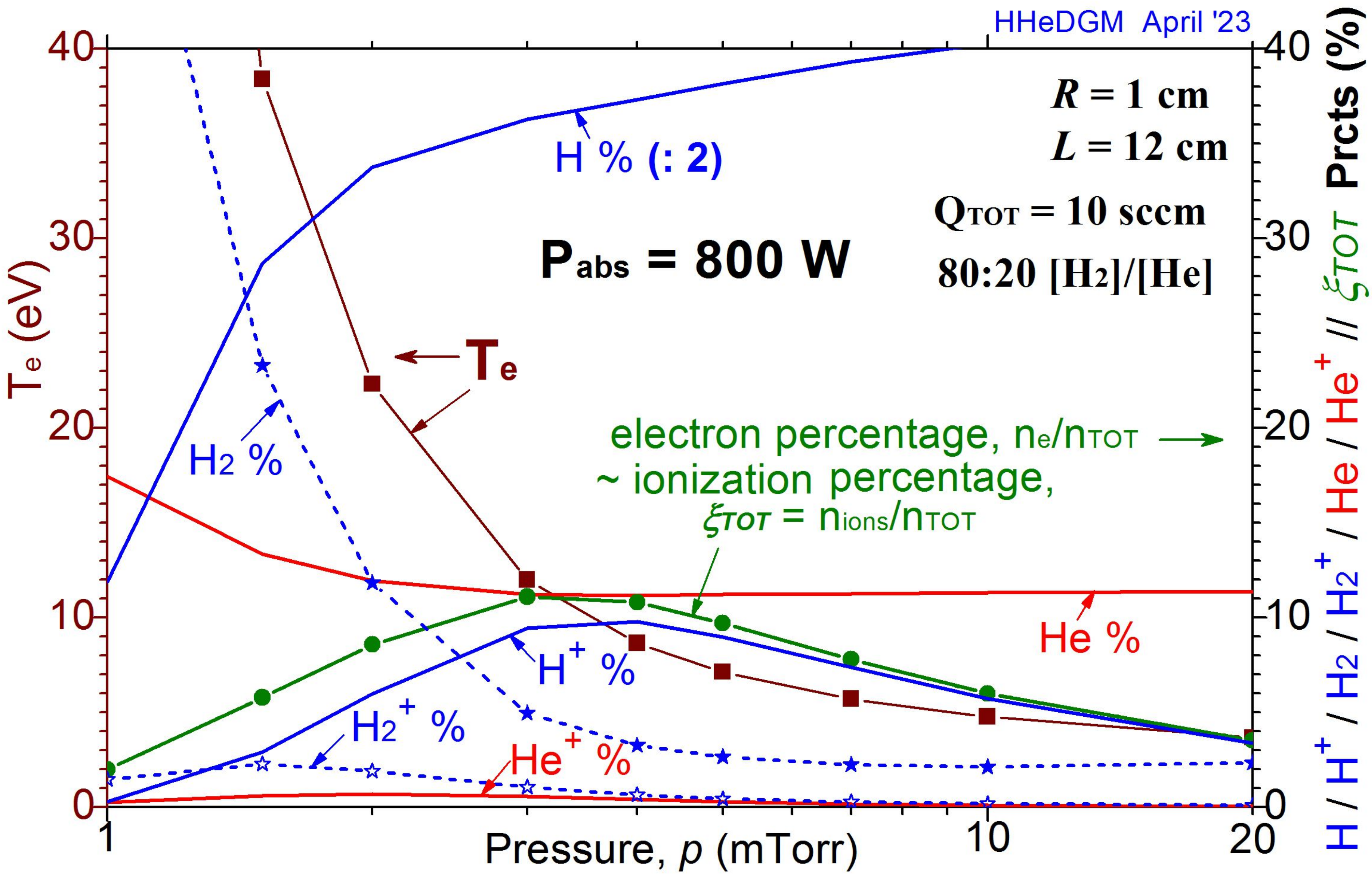
***NeptAtm** for 80:20 [H2]/[He] feed of 10 sccm*

Form factor for all figures : R=1 cm, L=12 cm



2. Density of Species PCC

Fig. 4. Concomitant of Fig. 3



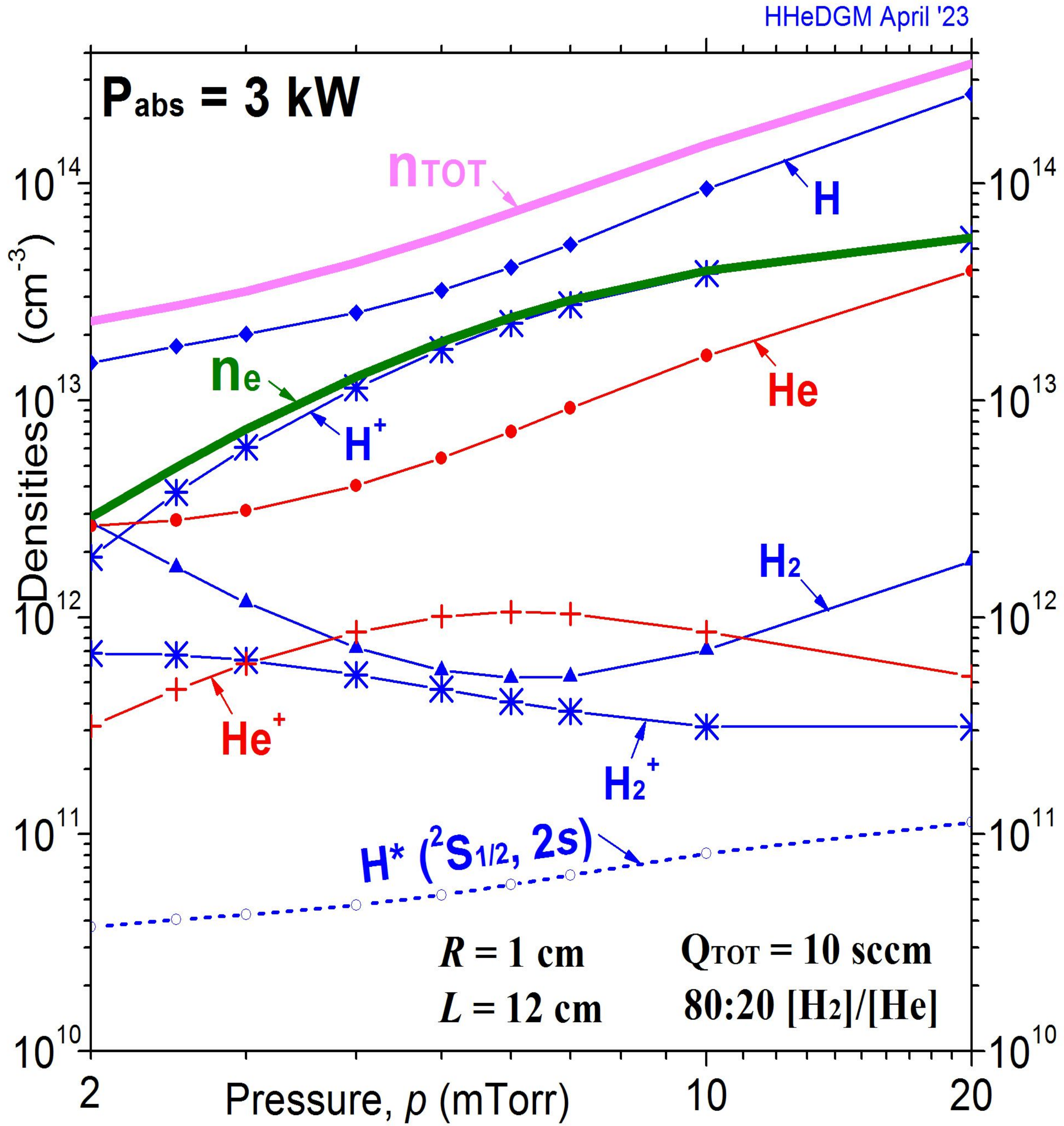
2. Density of Species PCC

Fig. 5.
Pressure dependent PCC

P_{abs} = 3 kW

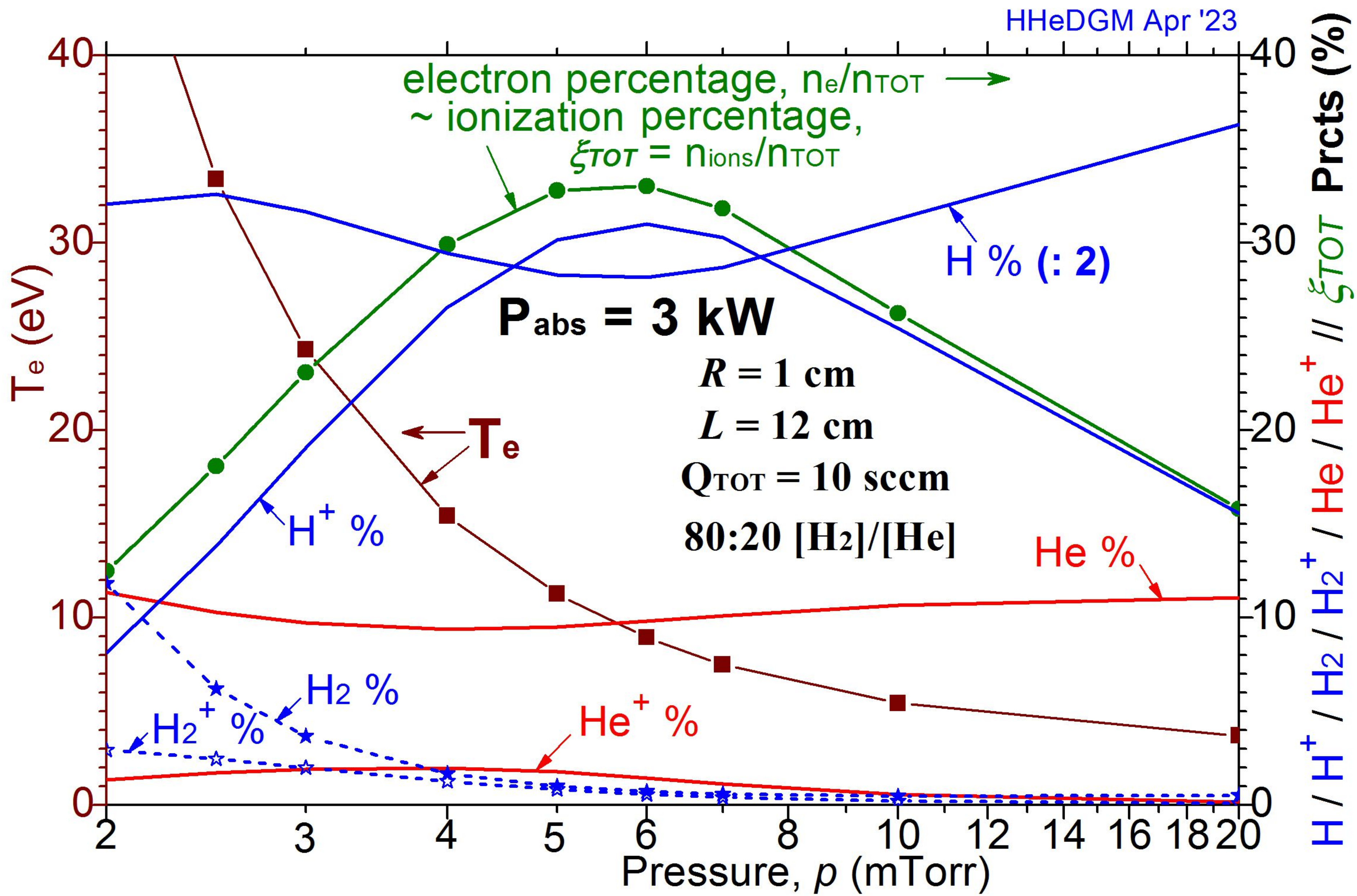
NeptAtm for 80:20 [H2]/[He] feed of 10 sccm

Form factor for all figures : R=1 cm, L=12 cm



2. Density of Species PCC

Fig. 6. Concomitant of Fig. 5



3. Functioning Diagram, FD

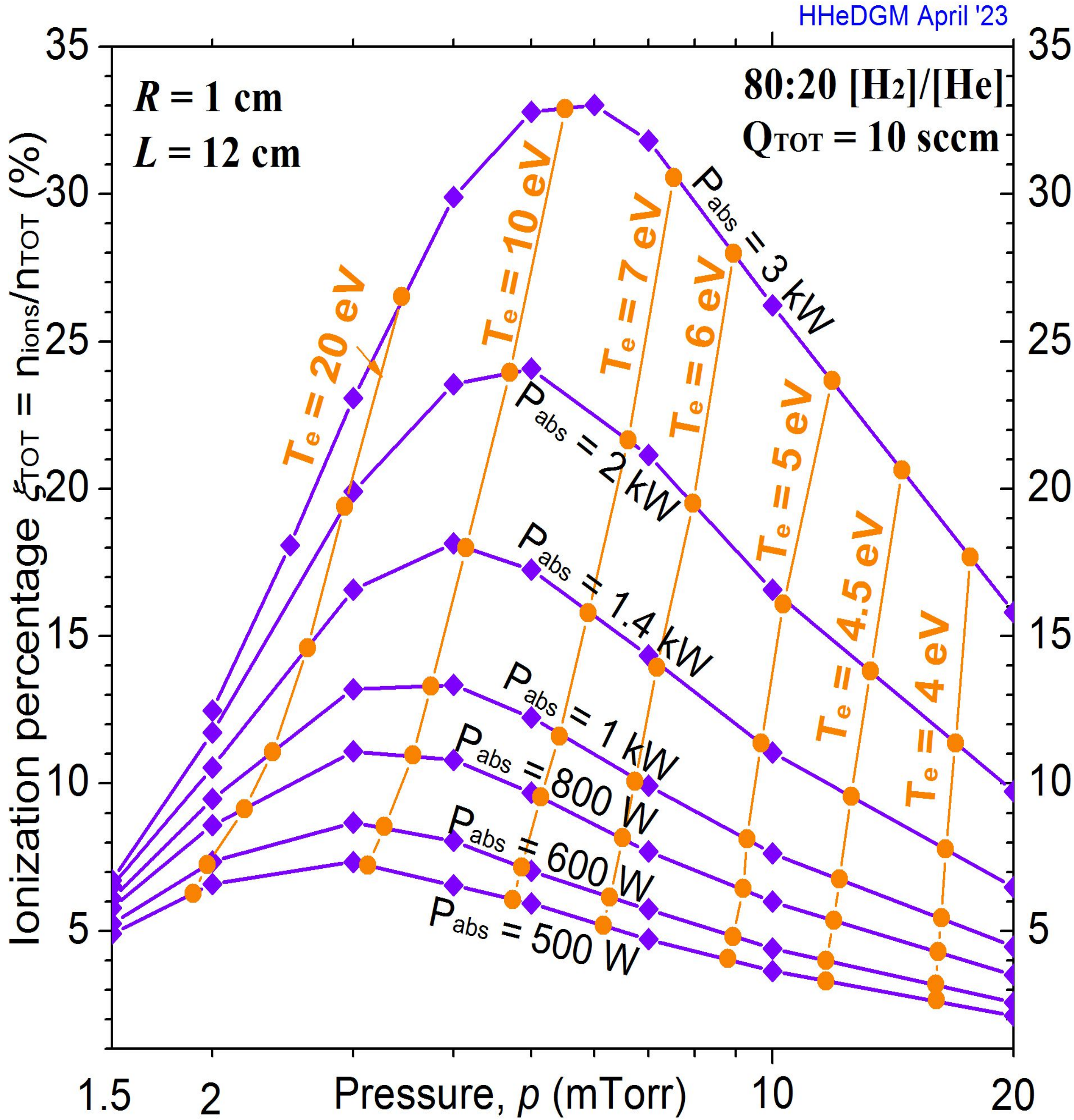
Fig. 7.

FD for

P_{ABS} = 0.5 kW to 3 kW

NeptAtm for 80:20 [H_2]/[He] feed of 10 sccm

T_e = 4 eV to 20 eV



4. Theoretical spectra, OES *H I, He I, He II species*

Fig. 8. NeptAtm, theoretical spectra for P_{ABS} = 3 kW

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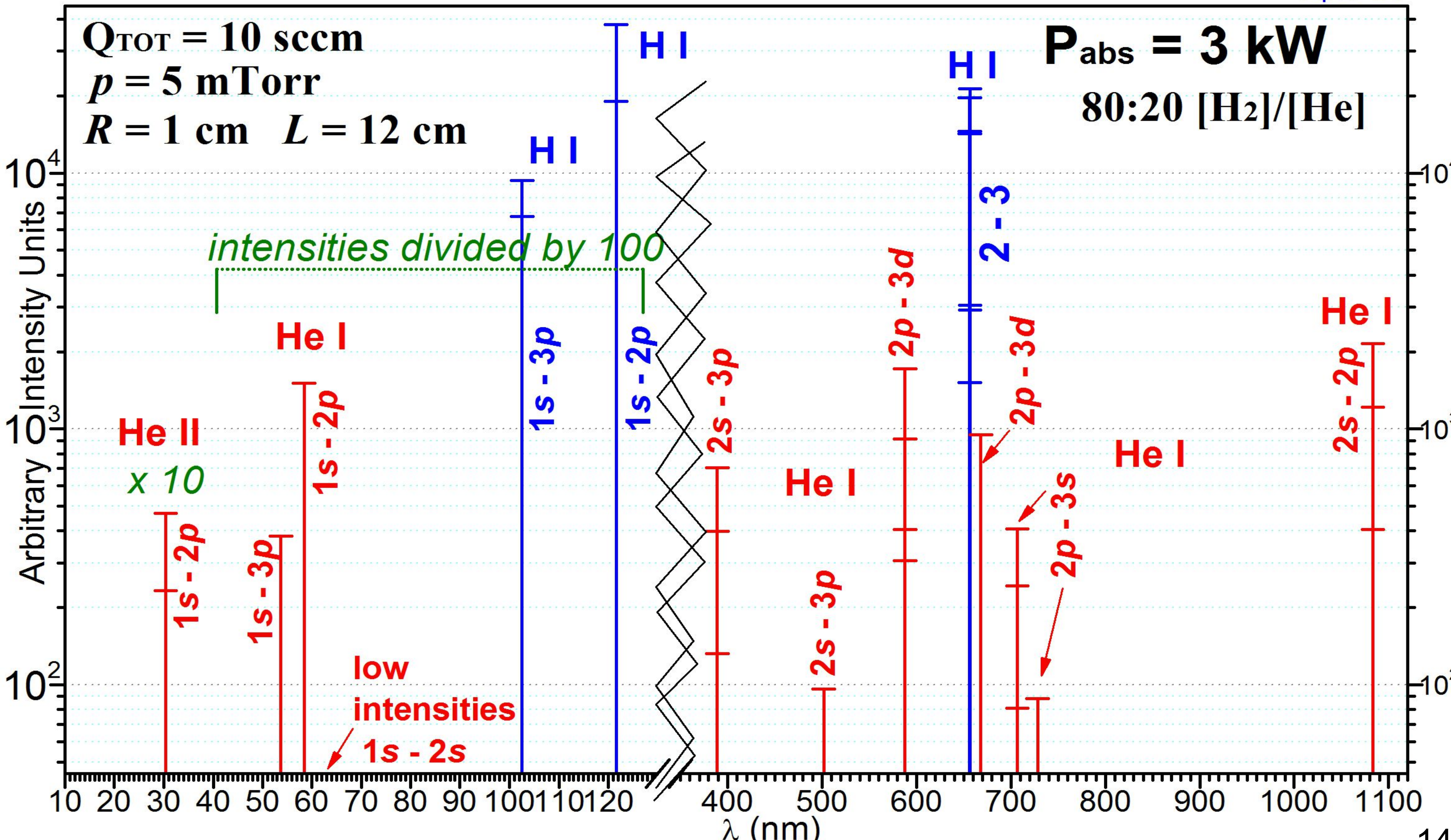

5. Radioisotope Power Systems (RPSs)

Mission concepts and applications are enabled by a **RPS** as is the:

- ♣ Radioisotope Thermoelectric Generator, **RTG** and
- ♣ Stirling Radioisotope Generator, **SRG**

Their use can expand the mission frontiers

MMRTG (Multi Mission **RTG**s) have been now developed.
Stirling technology is applicable for both nuclear and solar powered systems.

RPS technology community profits in assessing the environmental operating requirements of the **MMRTG** and **SRG** units :

1: Study of missions using realistic estimates of **RPS** performance
2: Provide information for review by potential users of **RPS**
3: Identify the possible advantages of each type of standard **RPS** units as a function of mission category and application.

Future s/c, and thus the standard **RPS**s, may encounter potential operating environments (Pressure, Temperature & atmospheric composition, g-load).

Batteries characteristics *play an important role in* ***RPS*** *use*, see Ref. [7], slide 5.

6. Conclusions

♣ Results obtained by **HHeDGM** have been presented, pertaining to **ISRU** propulsion in the Neptune-Triton system.

♣ **HHeDGM** allows for detailed calculation of the ET plasma components densities. It contributes to a better evaluation of the thruster functioning.

♣ **HHeDGM** results also to calculation of theoretical H I, He I and He II spectra, which, together with H^+ and He^{++} are the main constituents obtained in case of **ISRU** type propulsion in the Neptune-Triton region. Comparison of these theoretical spectra with experimental ones, belonging to neutral and ionized species, allows for **OES**.

♣ Availability of electric power provided from the Sun which is in a distance of about 30 au will not be sufficient in the Neptune vicinity.

Thank you for your attention