IPP INSTITUTE OF PLASMA PHYSICS
OF THE CZECH ACADEMY OF SCIENCES

DEVELOPMENT OF SXR DIAGNOSTIC FOR COMPASS-U

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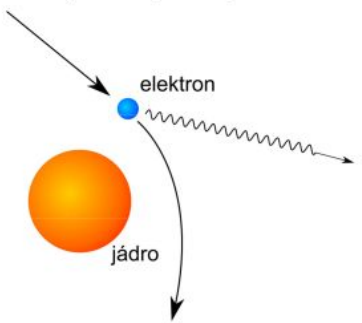
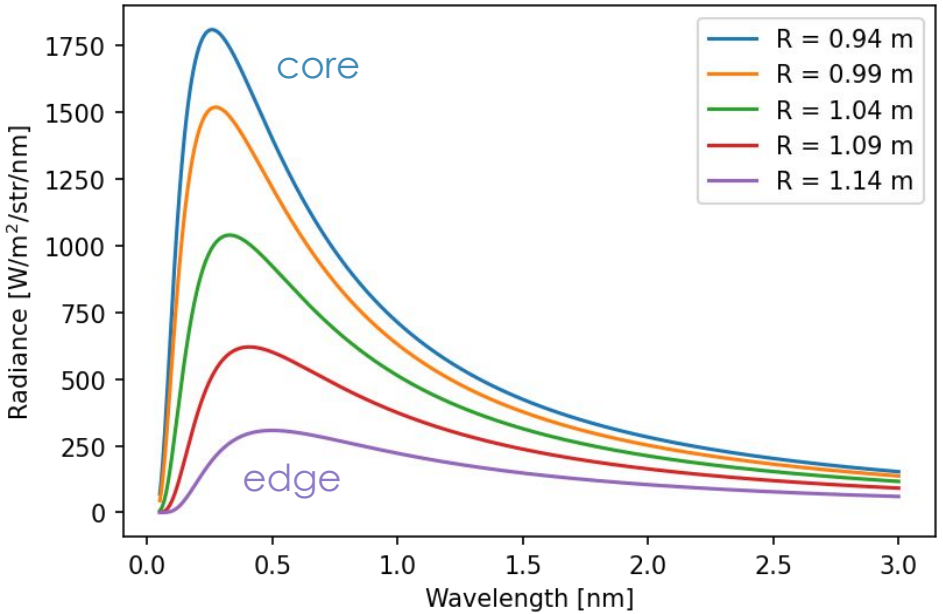
and COMPASS-U tomography team

MINISTRY OF EDUCATION,
YOUTH AND SPORTS

Free-Free radiation (Bremsstrahlung)

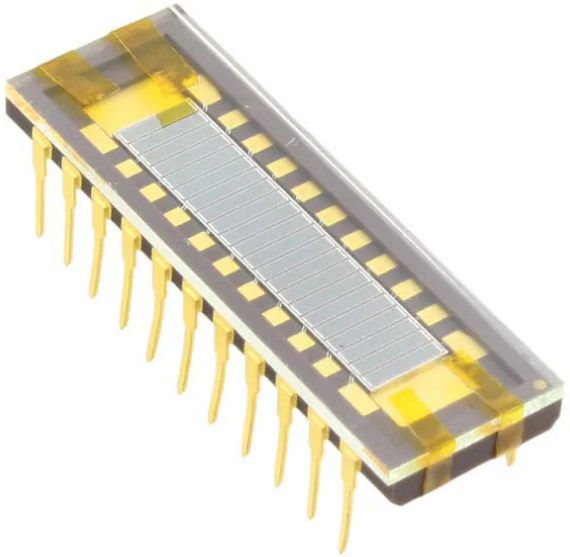


[P. Kulhánek - VKPL]



Detector

- semiconductor photodiode array
- radiated power to electric current
- current to voltage by amplifier close to diode
- **not spectrally resolved**
- combined with a filter for SXR range



AXUV 20 ELG

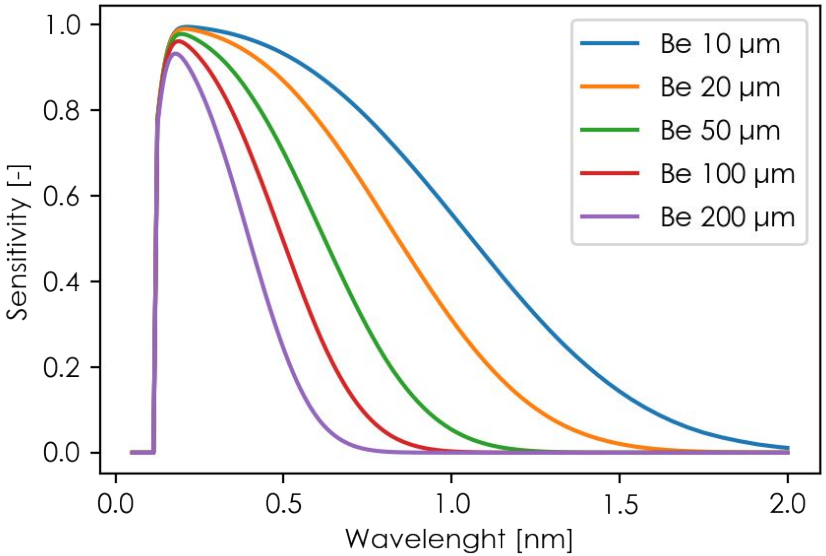
Free-Free radiation (Bremsstrahlung)

$$\mathcal{P} = 5 \cdot 10^{-54} \frac{n_e^2 Z_{eff} g_{ff}}{\sqrt{T_e}} \int e^{-\frac{E}{T_e}} dE$$

P - emissivity [W / m^3 / sr]
n_e - electron density,
Z_{eff} - effective charge,
g_{ff} - gaunt factor,
T_e - electron temperature
E - photon energy

Model signal on detector

$$\mathcal{P} = 5 \cdot 10^{-54} \frac{n_e^2 Z_{eff} g_{ff}}{\sqrt{T_e}} \int e^{-\frac{E}{T_e}} \mathrm{eff}(E) \mathrm{d}E$$

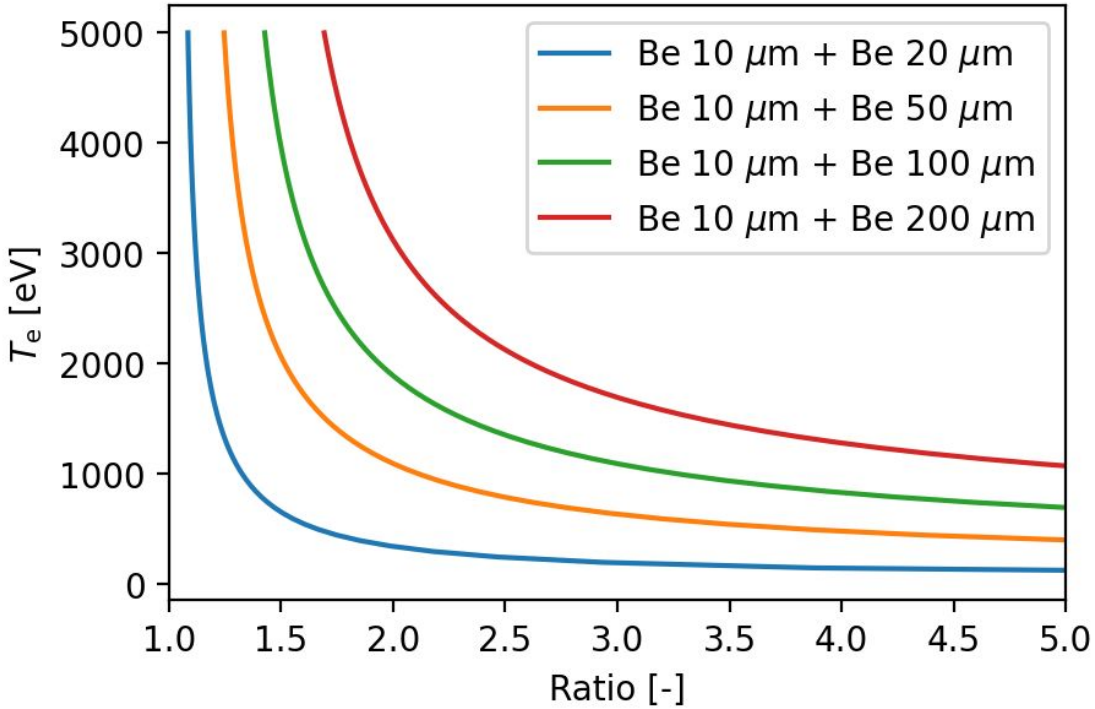


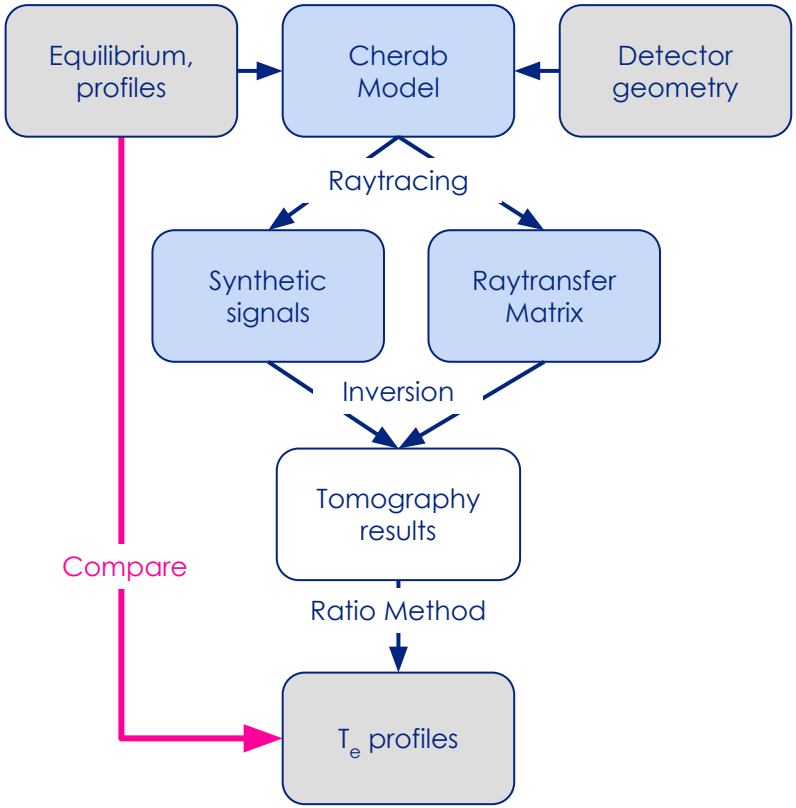
Ratio Method

$$\mathcal{P} = 5 \cdot 10^{-54} \frac{n_\mathrm{e}^2 Z_\mathrm{eff} g_\mathrm{ff}}{\sqrt{T_\mathrm{e}}} \int \mathrm{e}^{-\frac{E}{T_\mathrm{e}}} \mathrm{eff}(E) \mathrm{d}E$$

$$R_\mathrm{P}(T_\mathrm{e}) = \frac{\int \mathrm{e}^{-\frac{E}{T_\mathrm{e}}} \mathrm{eff}_1(E) \mathrm{d}E}{\int \mathrm{e}^{-\frac{E}{T_\mathrm{e}}} \mathrm{eff}_2(E) \mathrm{d}E}$$

Ratio Method



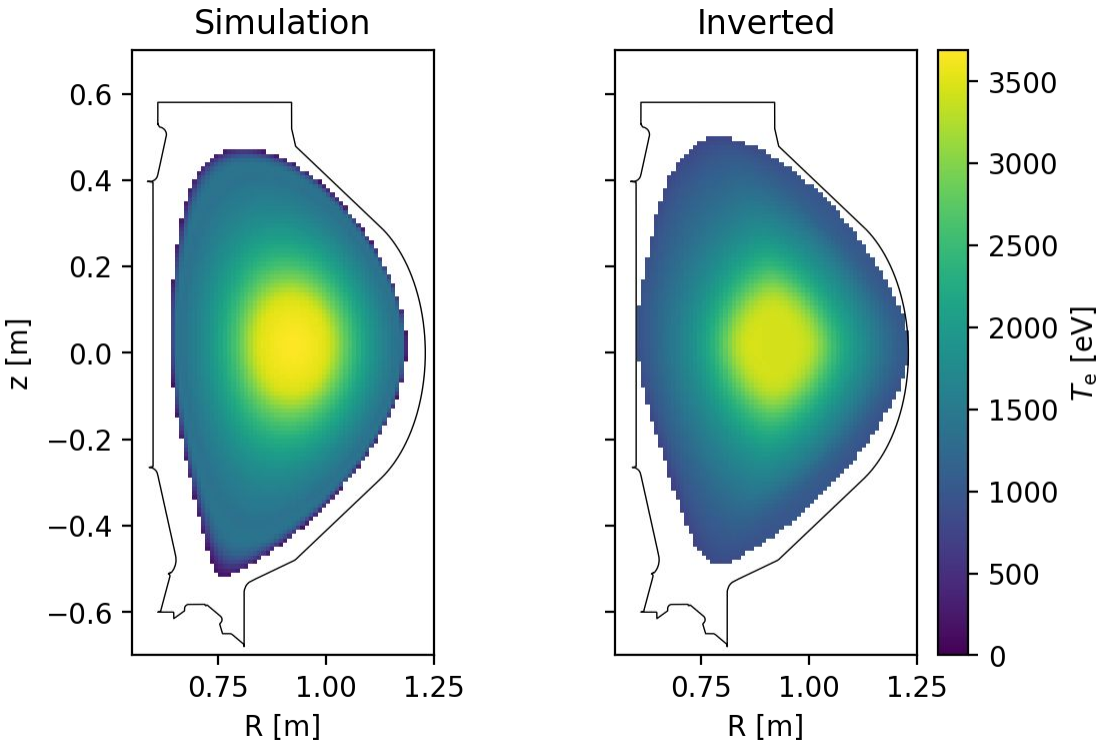


Synthetic diagnostic workflow

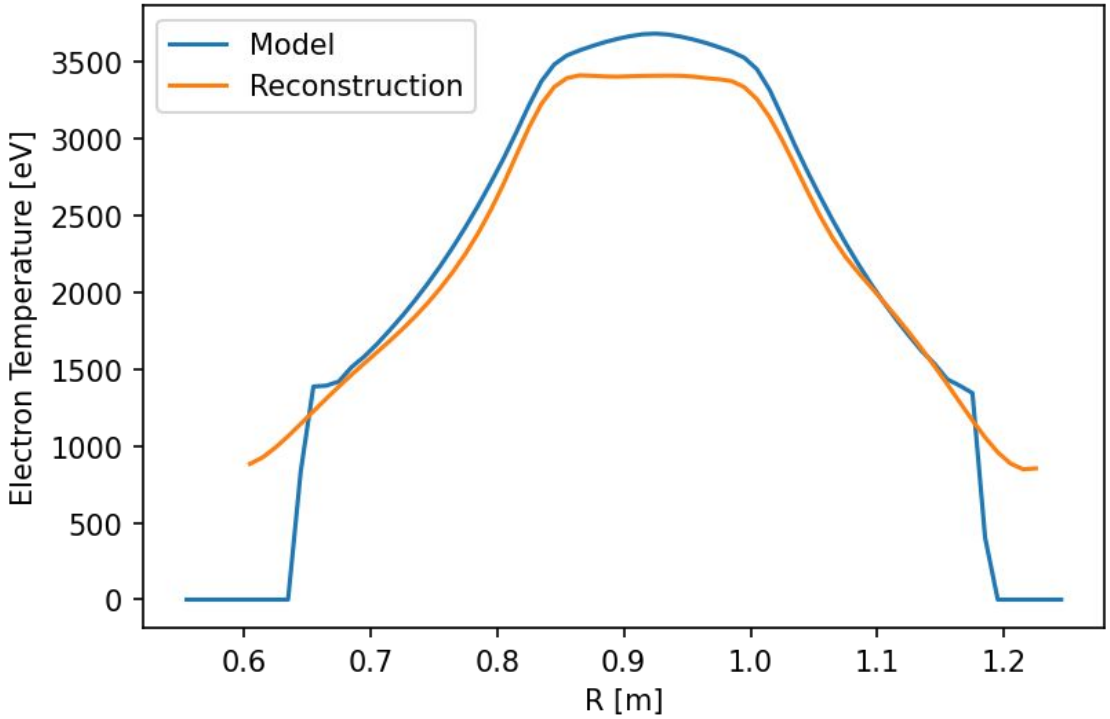
Ryasect + Cherab

Tomotok

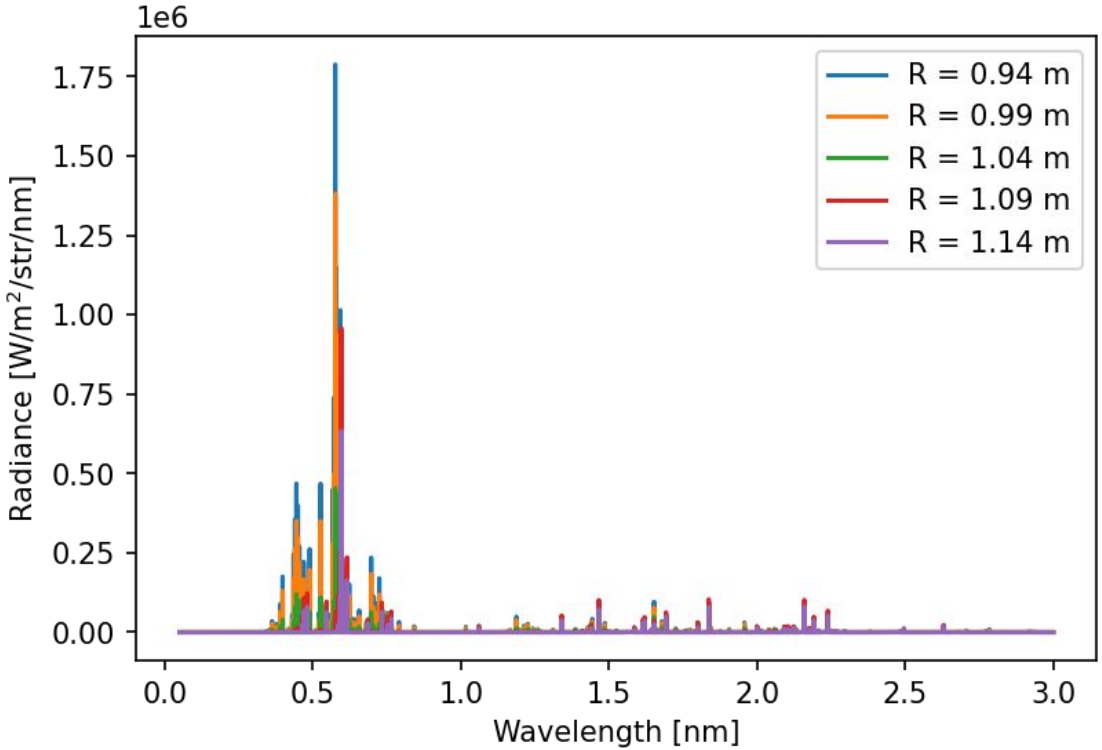
Ratio Method



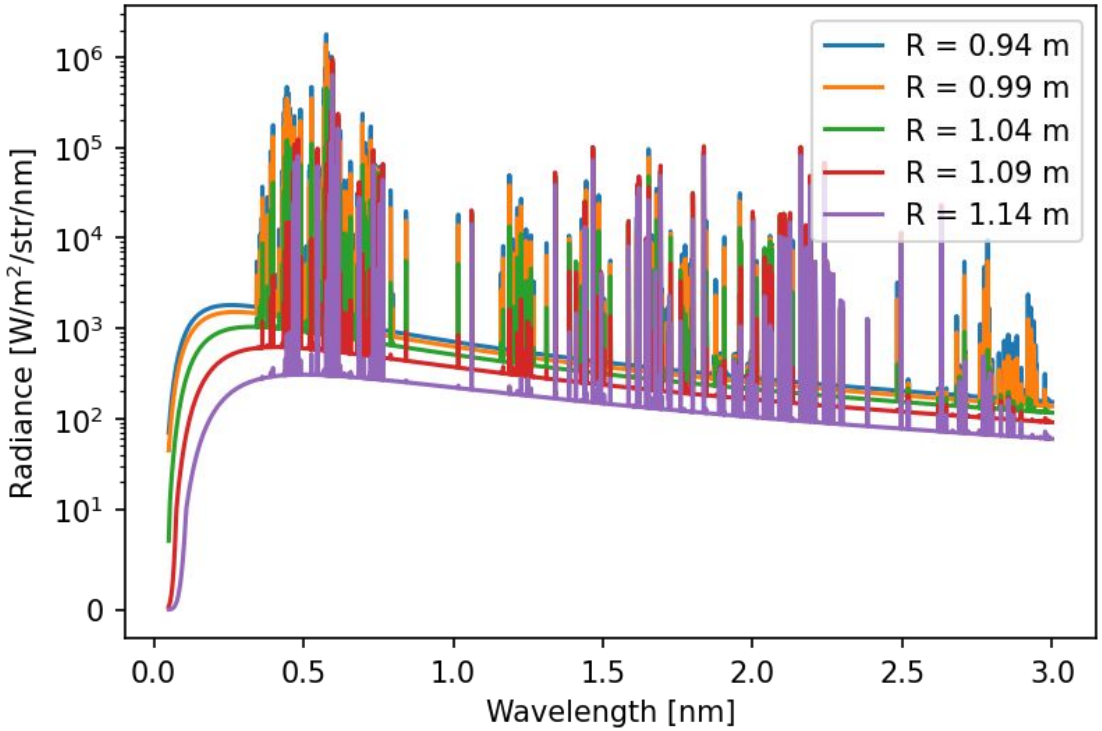
Ratio Method



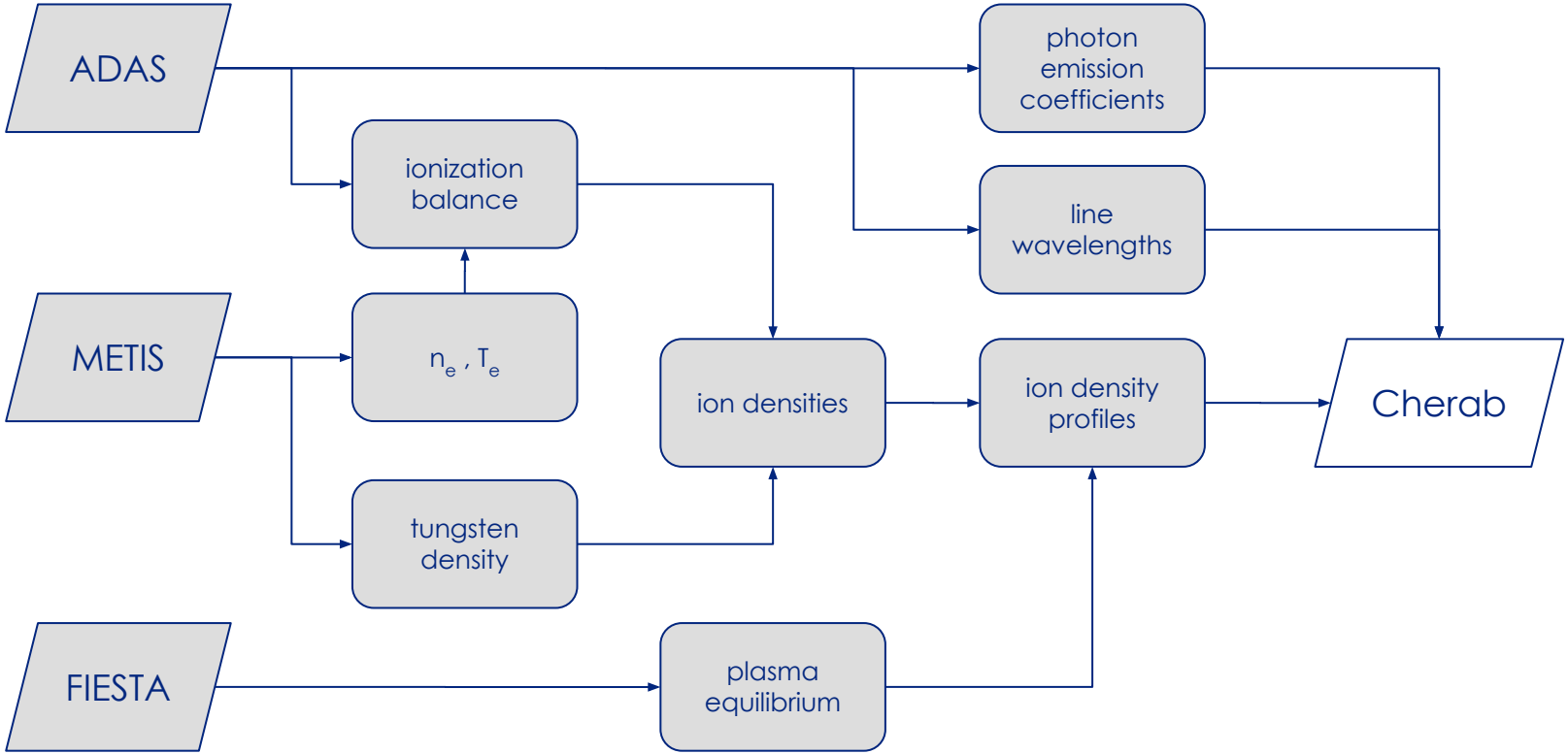
Line Radiation



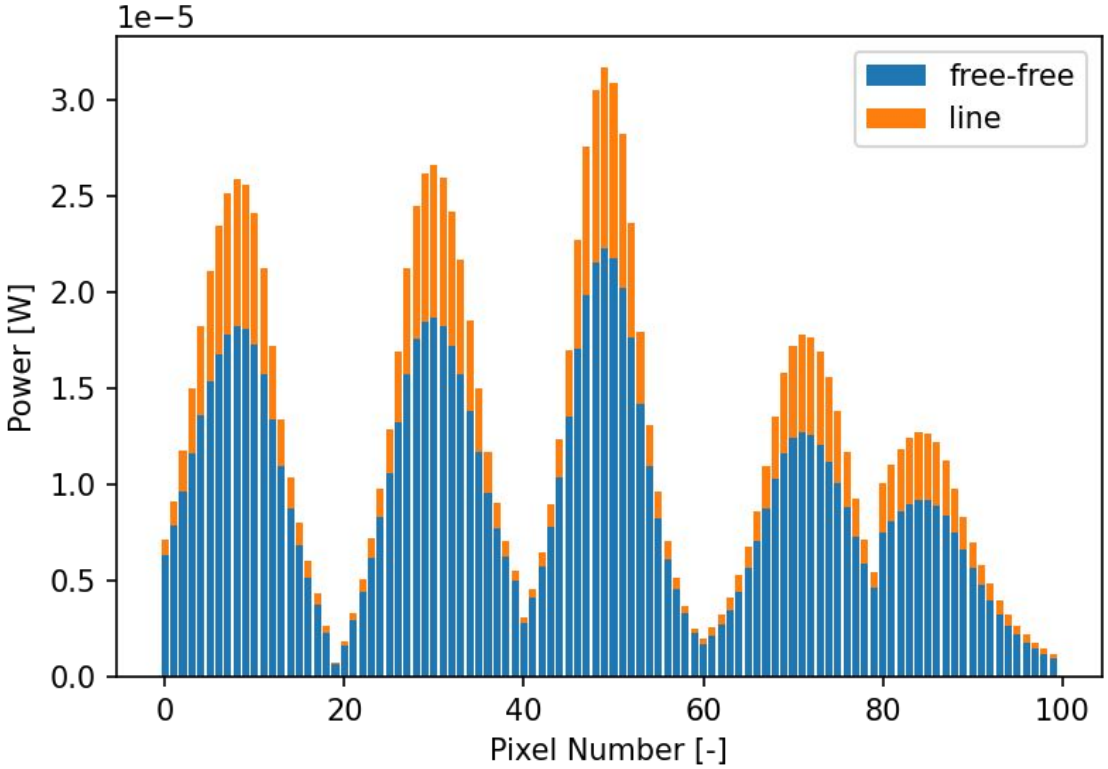
Line Radiation



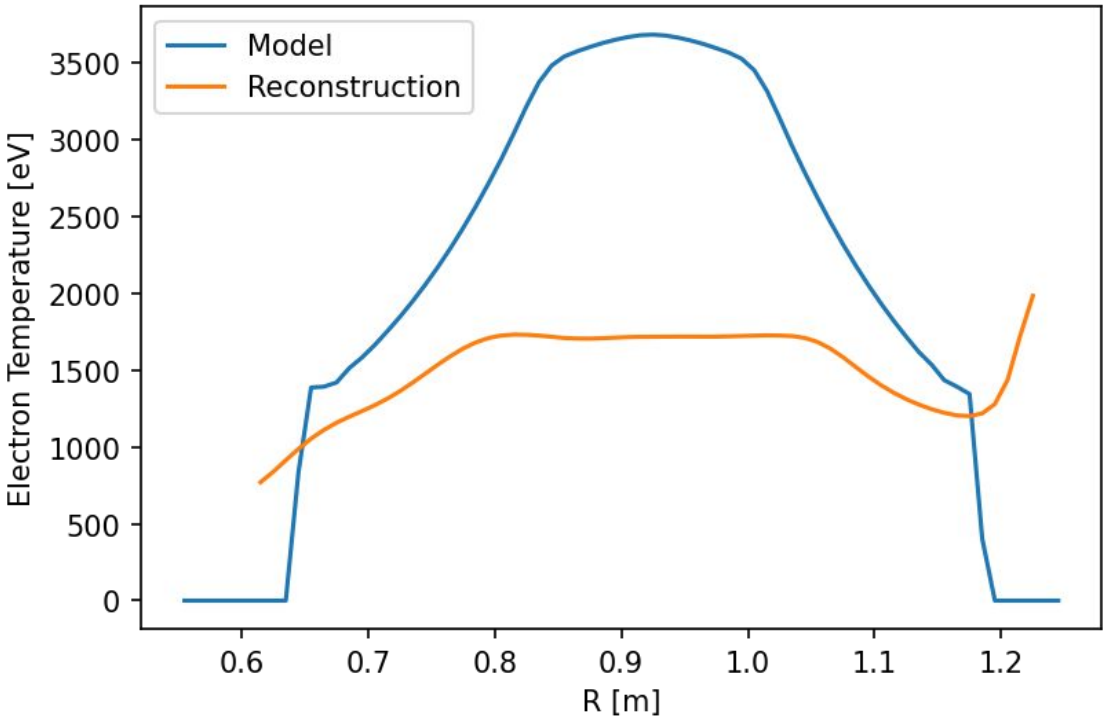
Impurities model



Signal with line radiation

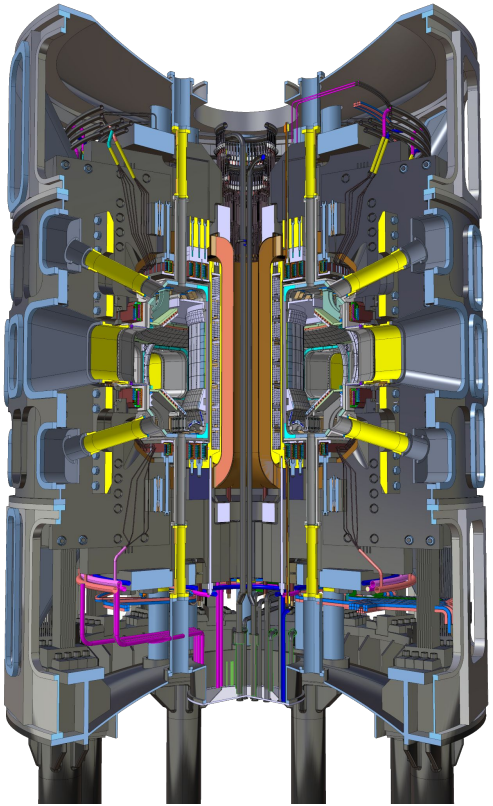


Ratio method with line radiation



COMPASS-U

- compact and flexible
- high temperature vacuum vessel
- high magnetic field (~5 T)
- high plasma current (~2MA)
- testing liquid metal divertor



The Task

General aims

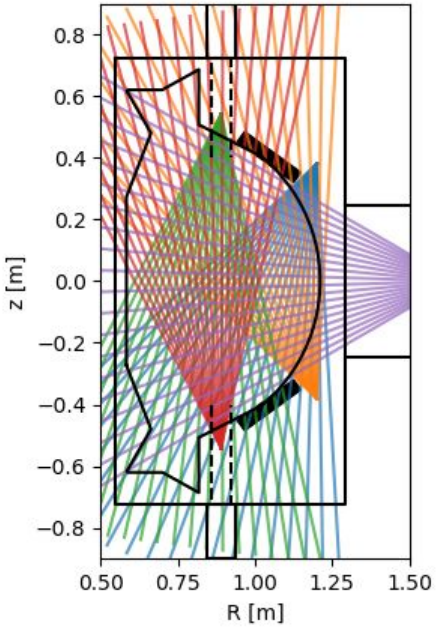
- good tomography performance
- possibility to use ratio method
- survive high temperatures (up to 500 ℃)

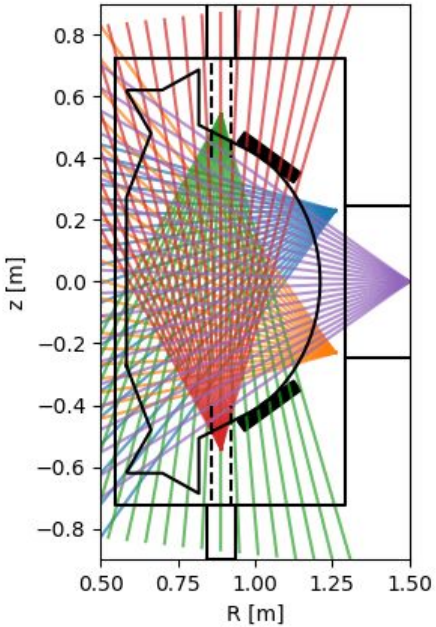
Design Requirements

- Easy in lab calibration
- Easy detector change
- Easy amplifier change
- Removable filters
- Unified detector housing
- Shutters

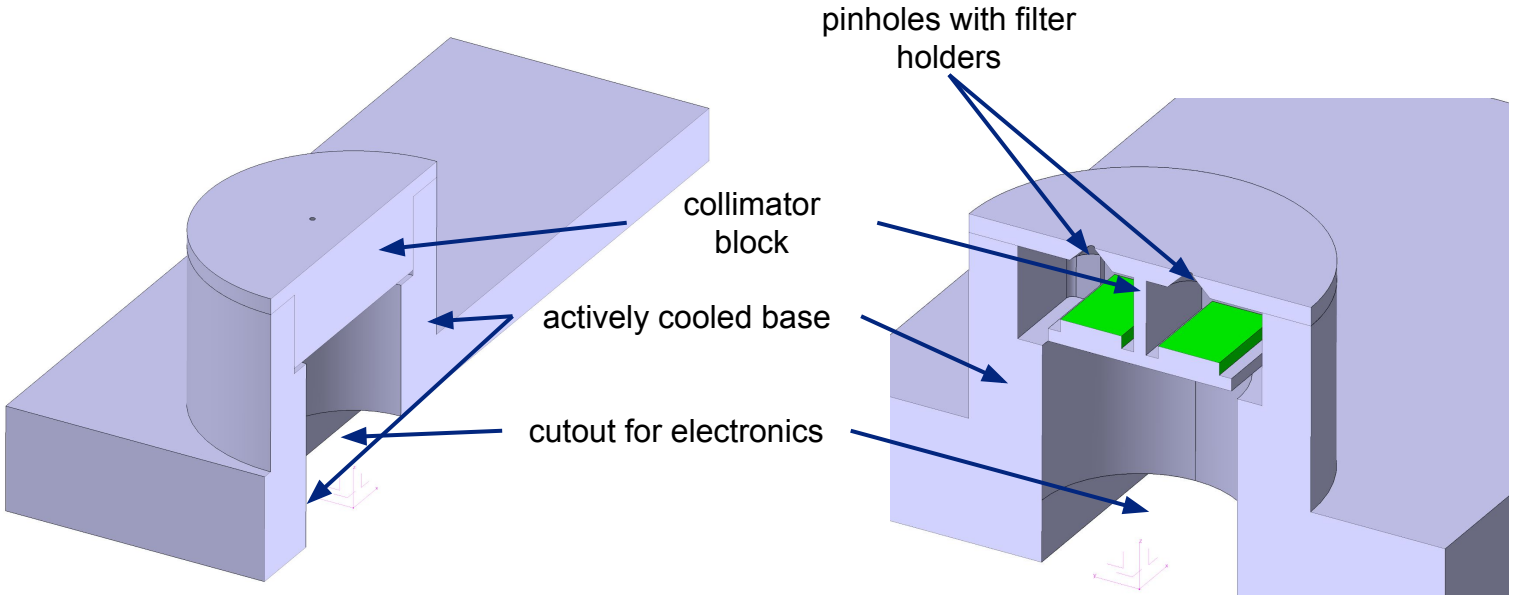
Initial concept - layouts

- use unified detector housings
- 5 position considered
- **purple**, **blue**, **orange** can be further optimised
- **red** and **green** limited by PFC shape and can be only slightly modified

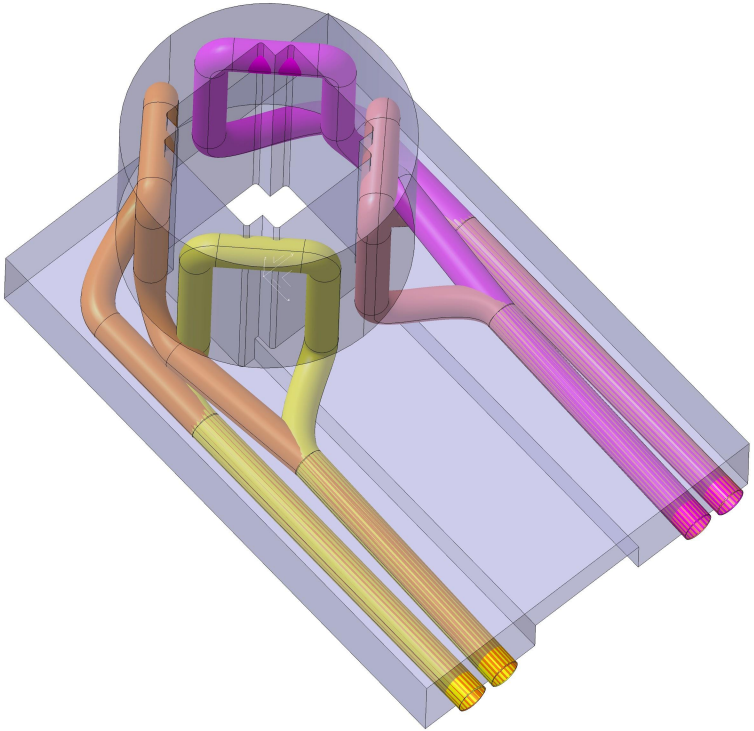




Initial concept



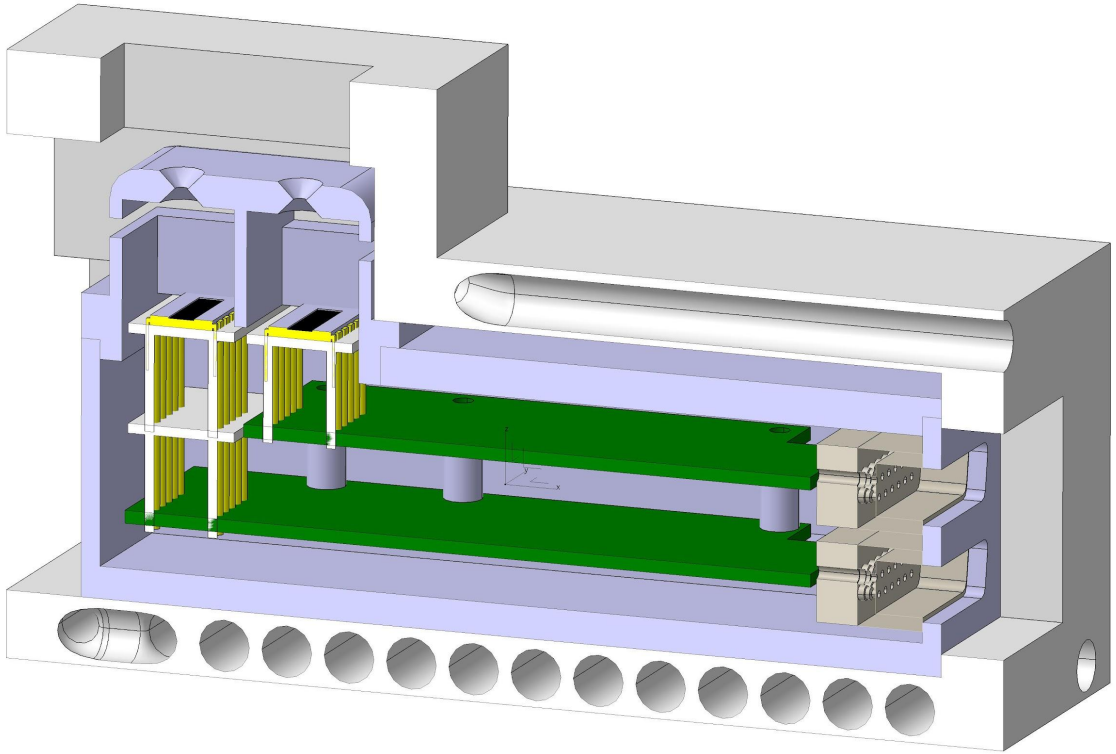
Initial concept



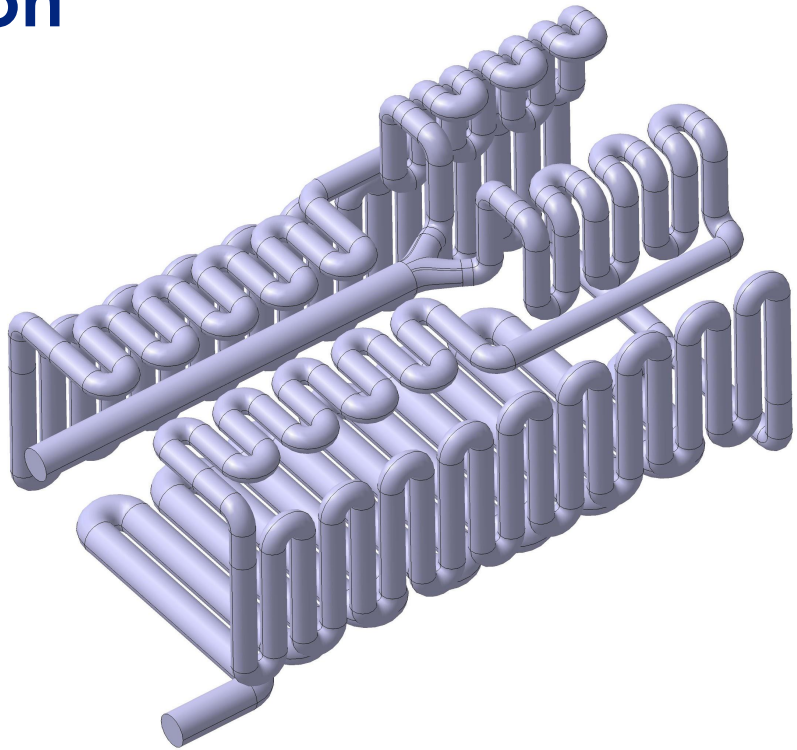
Initial concept - evaluation

- early engineering design
- simple cooling channels
- **complicated connection of photodiodes with amplifier board**
- acceptable size

Second iteration



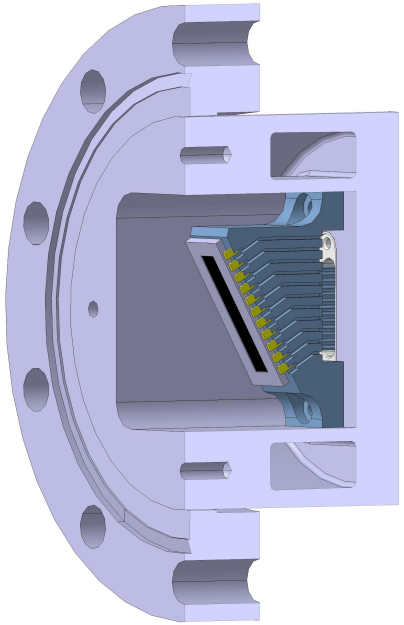
Second iteration

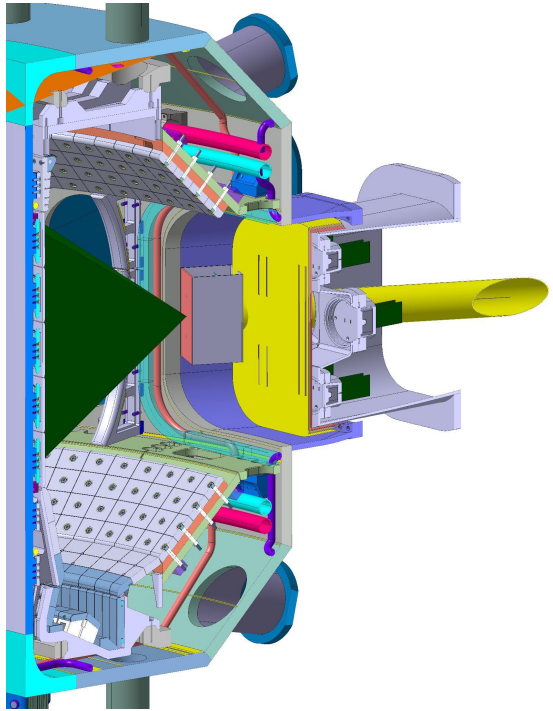


Second Iteration - evaluation

- more advanced design
- complicated cooling design - 3D printing
- might not fit behind PFCs
- no shutter
- **too large for midplane port - can not fit with other tomography systems**

Third iteration





Third iteration - evaluation

- complex port plug design - needs simplifying
- unclear connection of photodiode to feedthrough
- unfinished cooling channels
- filter holder not properly designed

Fourth iteration

Summary

- Sources of SXR radiation
- Synthetic diagnostic workflow
- Line radiation model
- Development of detector housing

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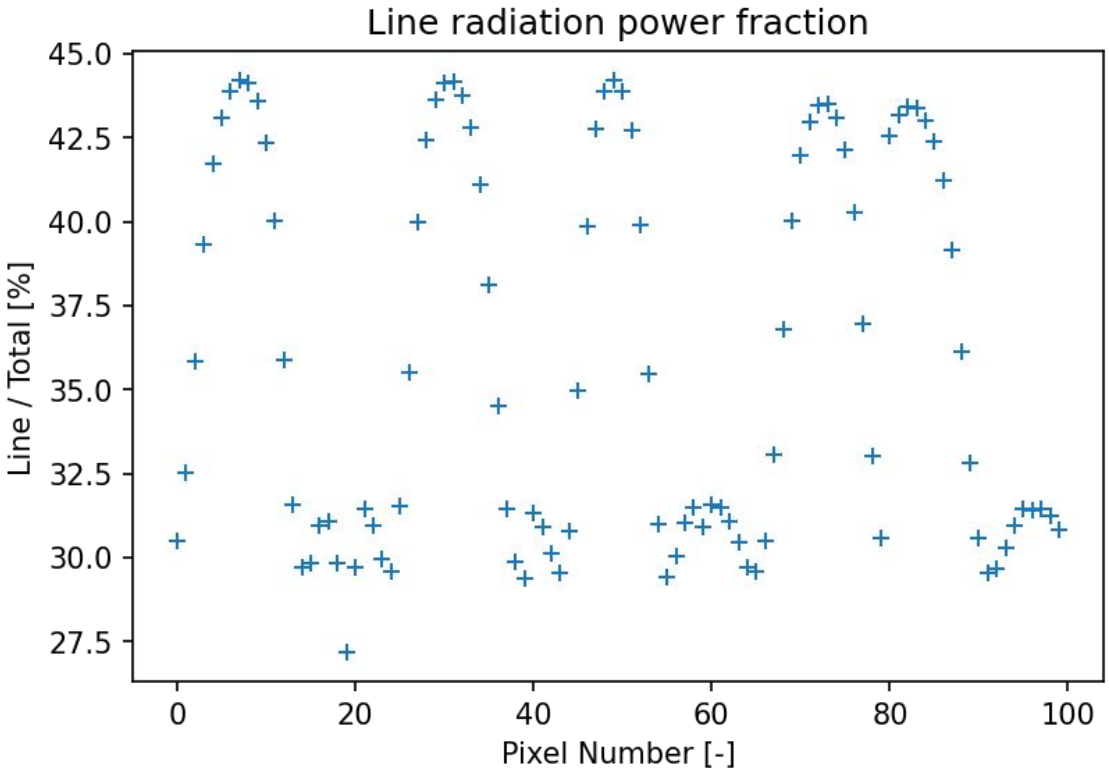
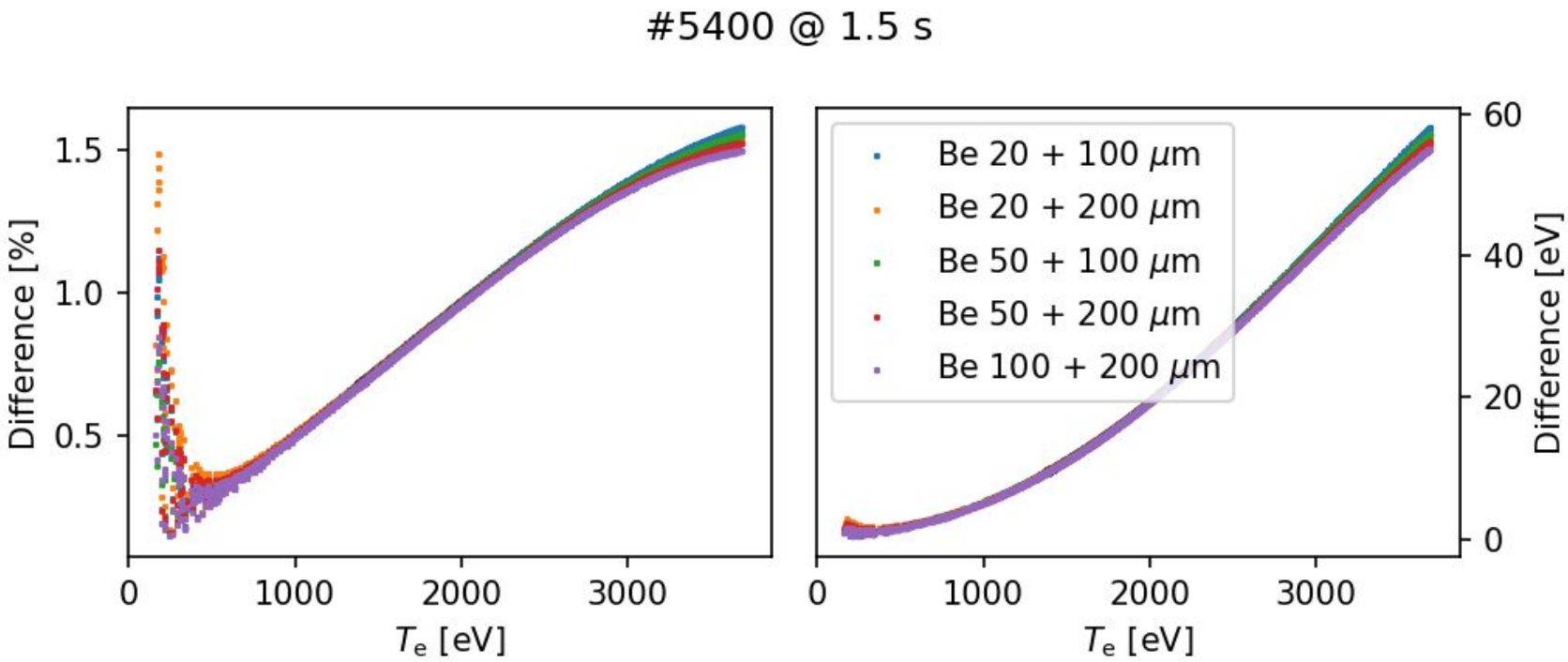
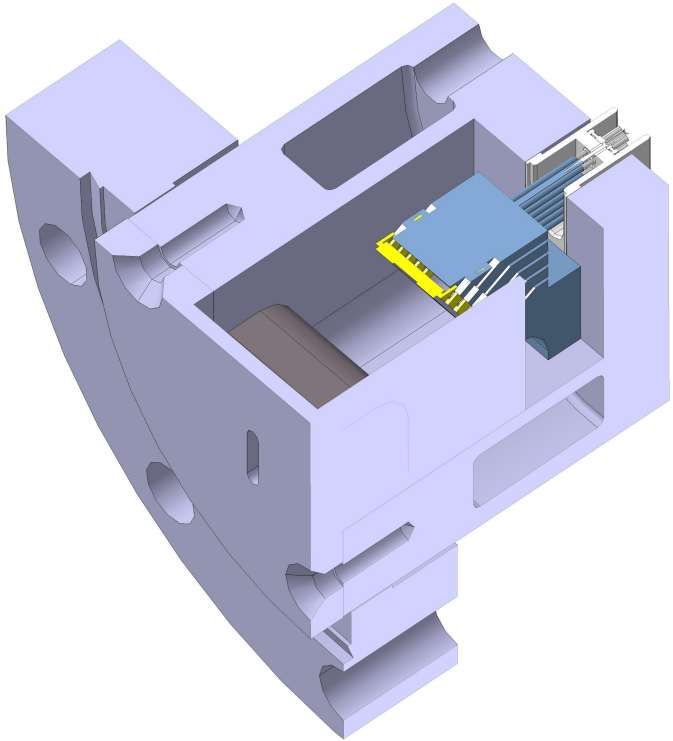
Extras

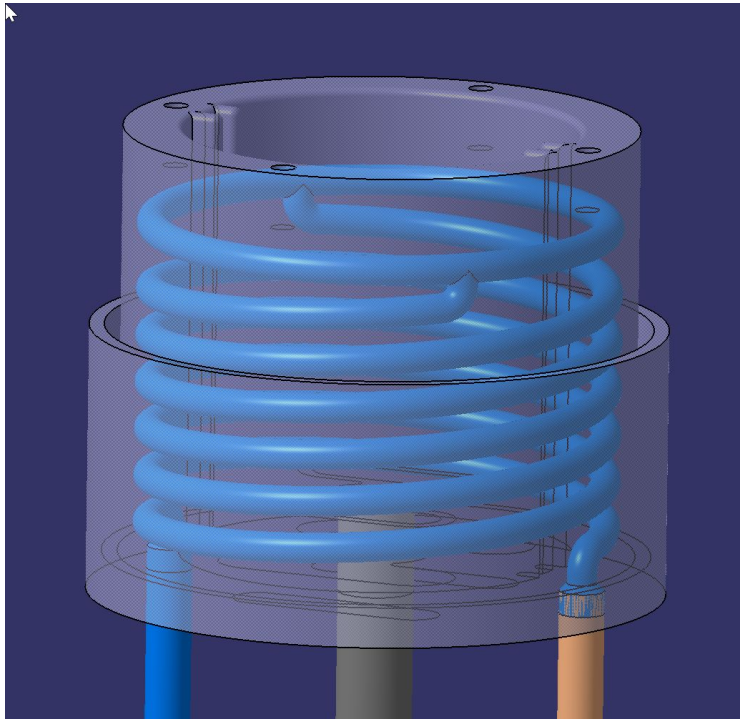

Line radiation power fraction
Line / Total [%]
45.0
42.5
40.0
37.5
35.0
32.5
30.0
27.5
0
20
40
60
80
100
Pixel Number [-]

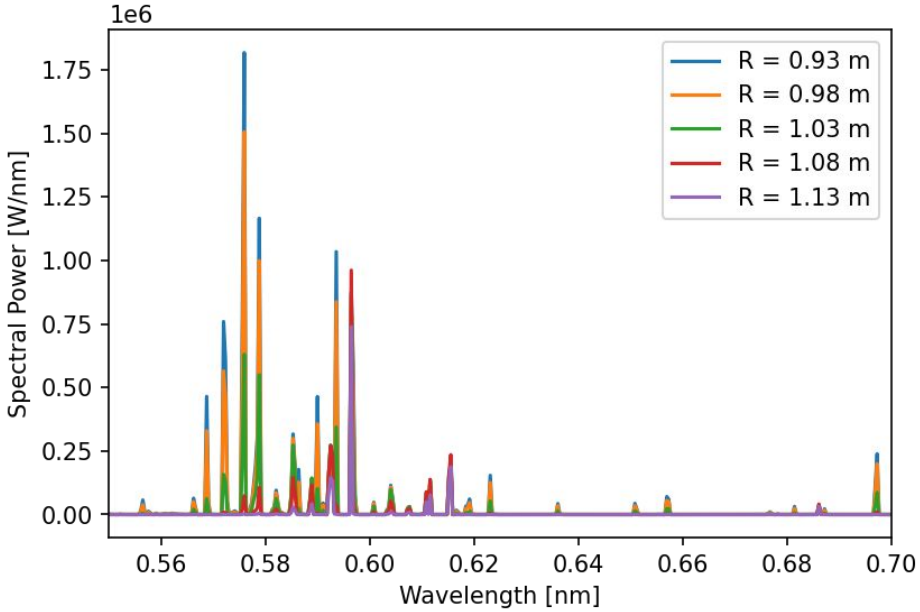

#5400 @ 1.5 s
Difference [%]
1.5
1.0
0.5
0
1000
2000
3000
T_e [eV]
Be 20 + 100 μm
Be 20 + 200 μm
Be 50 + 100 μm
Be 50 + 200 μm
Be 100 + 200 μm
60
40
20
0
Difference [eV]
0
1000
2000
3000
T_e [eV]

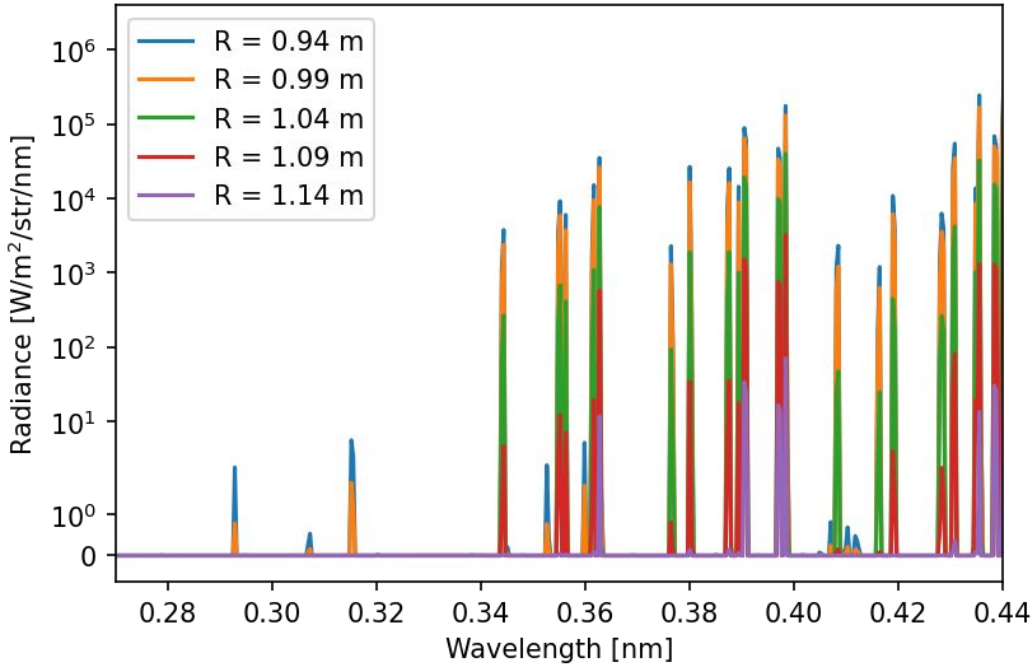
Small Port Plug



Latest Small Plug Design




1e6
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Spectral Power [W/nm]
0.56
0.58
0.60
0.62
0.64
0.66
0.68
0.70
Wavelength [nm]
R = 0.93 m
R = 0.98 m
R = 1.03 m
R = 1.08 m
R = 1.13 m


R = 0.94 m
R = 0.99 m
R = 1.04 m
R = 1.09 m
R = 1.14 m
Radiance [W/m²/str/nm]
10⁶
10⁵
10⁴
10³
10²
10¹
10⁰
0
0.28
0.30
0.32
0.34
0.36
0.38
0.40
0.42
0.44
Wavelength [nm]