MAX-PLANCK-INSTITUT
FÜR PLASMAPHYSIK

Wendelstein 7-X

ECRH power deposition and T_e perturbation investigations using dynamic ECE analysis

HEPP Introductory talk

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N. Chaudhary, R. Wolf, and the W7-X Team

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EUROfusion

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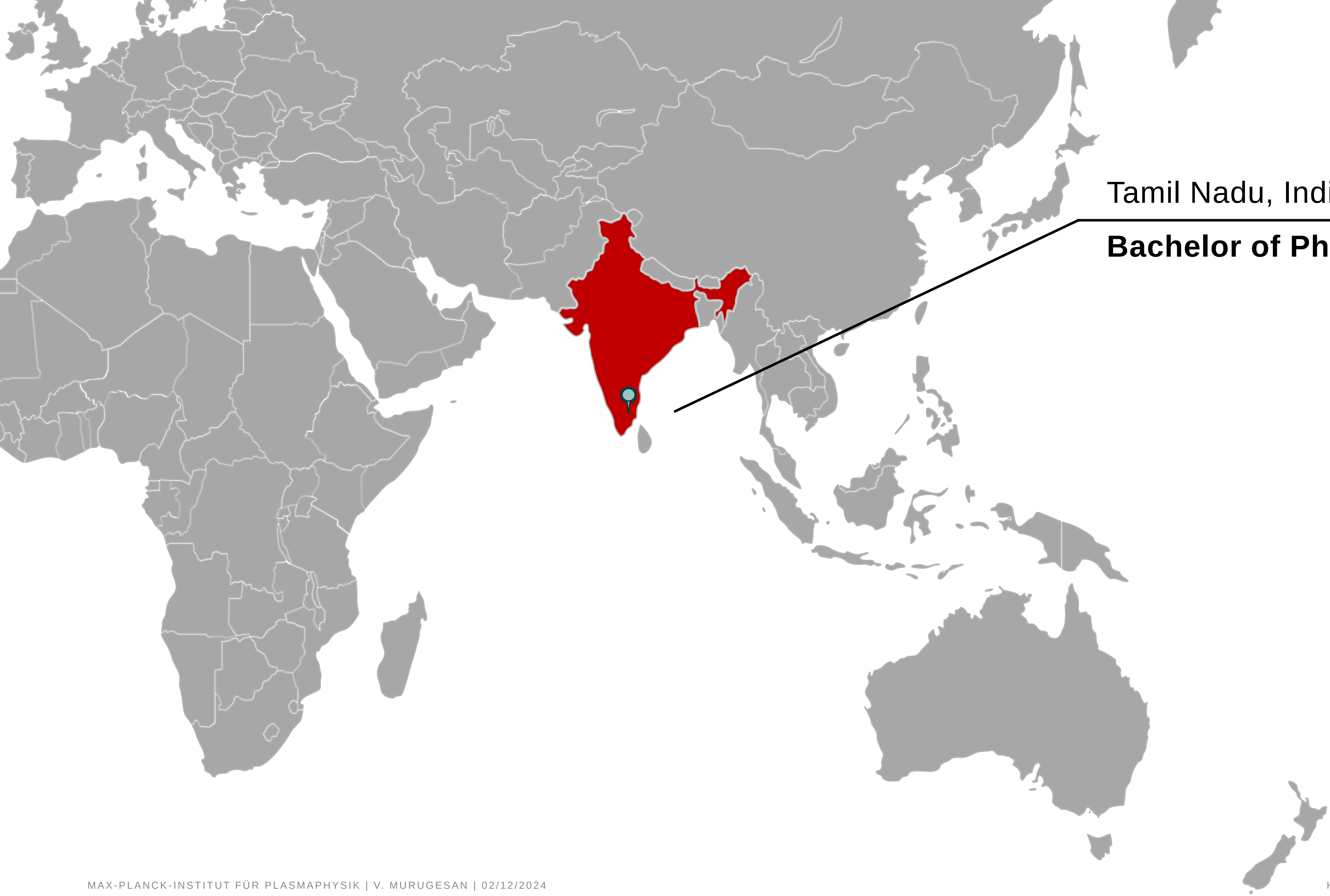
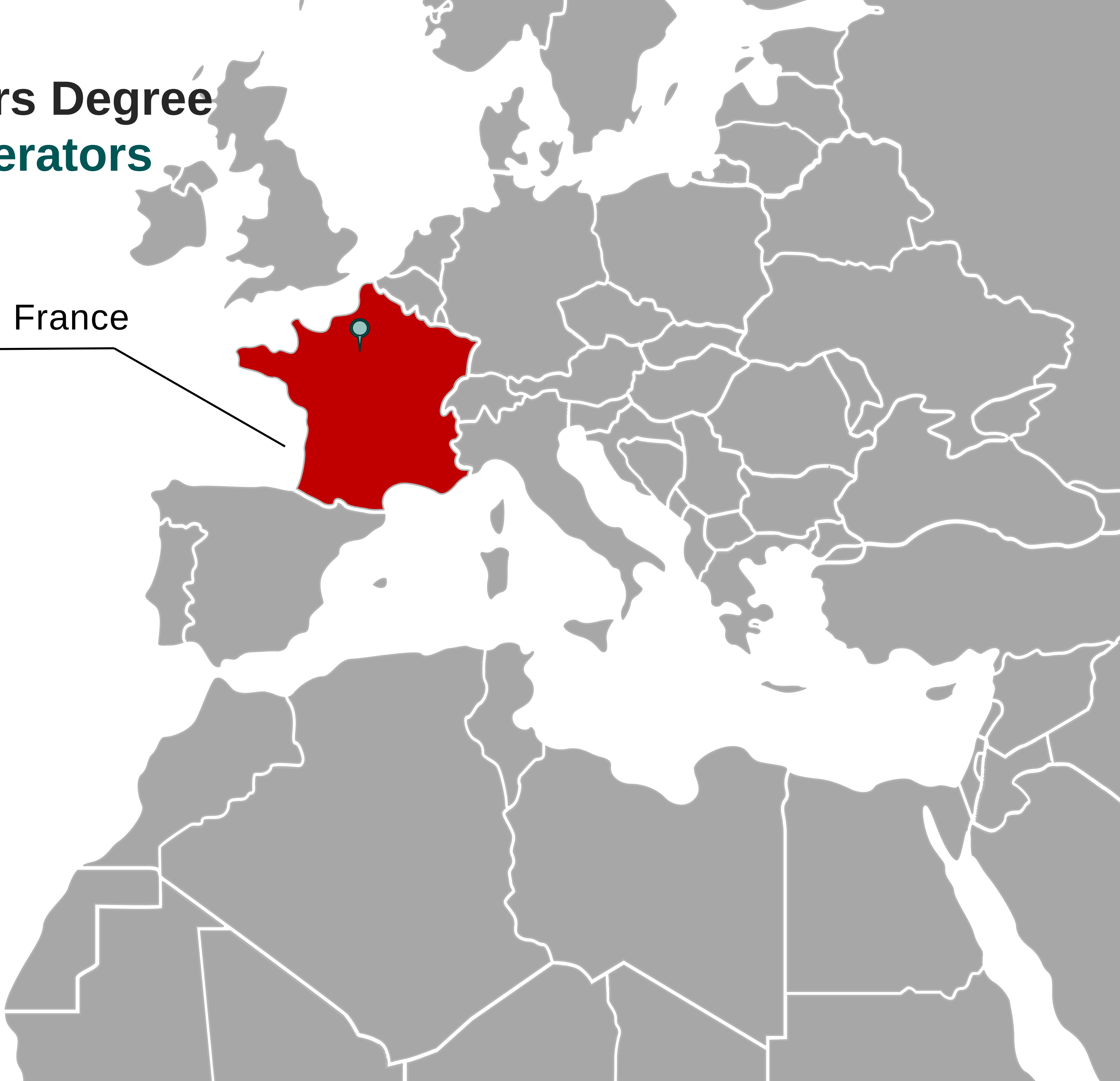


Tamil Nadu, India

Bachelor of Physics

Erasmus Mundus Joint Masters Degree
Lasers and Large Scale Accelerators



Erasmus Mundus Joint Masters Degree
Lasers and Large Scale Accelerators

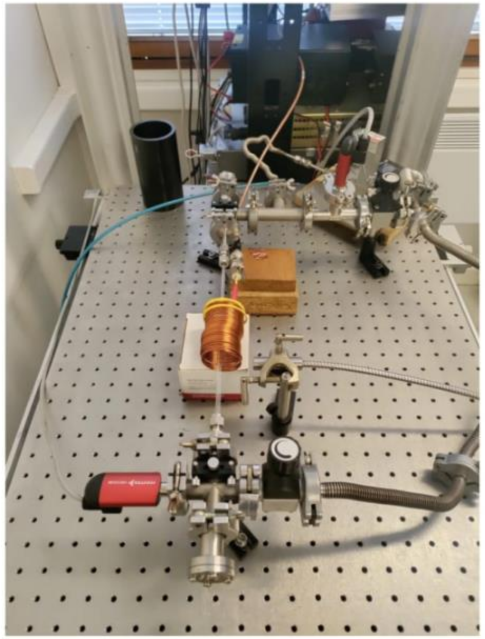
1st semester – Paris Saclay University, France

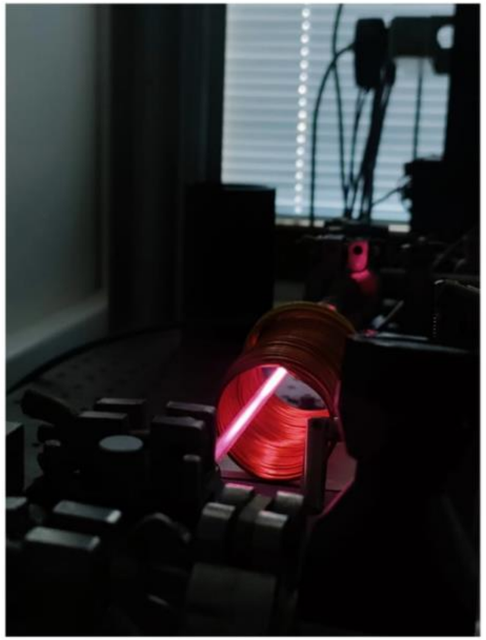
Internship –

Plasma study using

Optical Emission Spectra

- Measured the variation of spectral intensity with pressure in Ar plasma
- Te variation with change of radiofrequency
- Intensity variation with variation of Pressure





Erasmus Mundus Joint Masters Degree
Lasers and Large Scale Accelerators

2nd semester – Sapienza University, Italy

Erasmus Mundus Joint Masters Degree
Lasers and Large Scale Accelerators

2nd semester – Sapienza University, Italy

M1 thesis –

Vector Network Analysis of accelerating cavities

- Characterisation of devices used in an accelerator like a Beam Positioning Monitor, Pillbox cavity.
- Setting up a routine to measure the shifts in the resonant frequency and QF of the cavity overnight, measuring variations due to temperature changes.
- Frequency tuning by volume perturbation.

Erasmus Mundus Joint Masters Degree
Lasers and Large Scale Accelerators

Summer vacation –

- Trip to India,
- Summer school at IPP

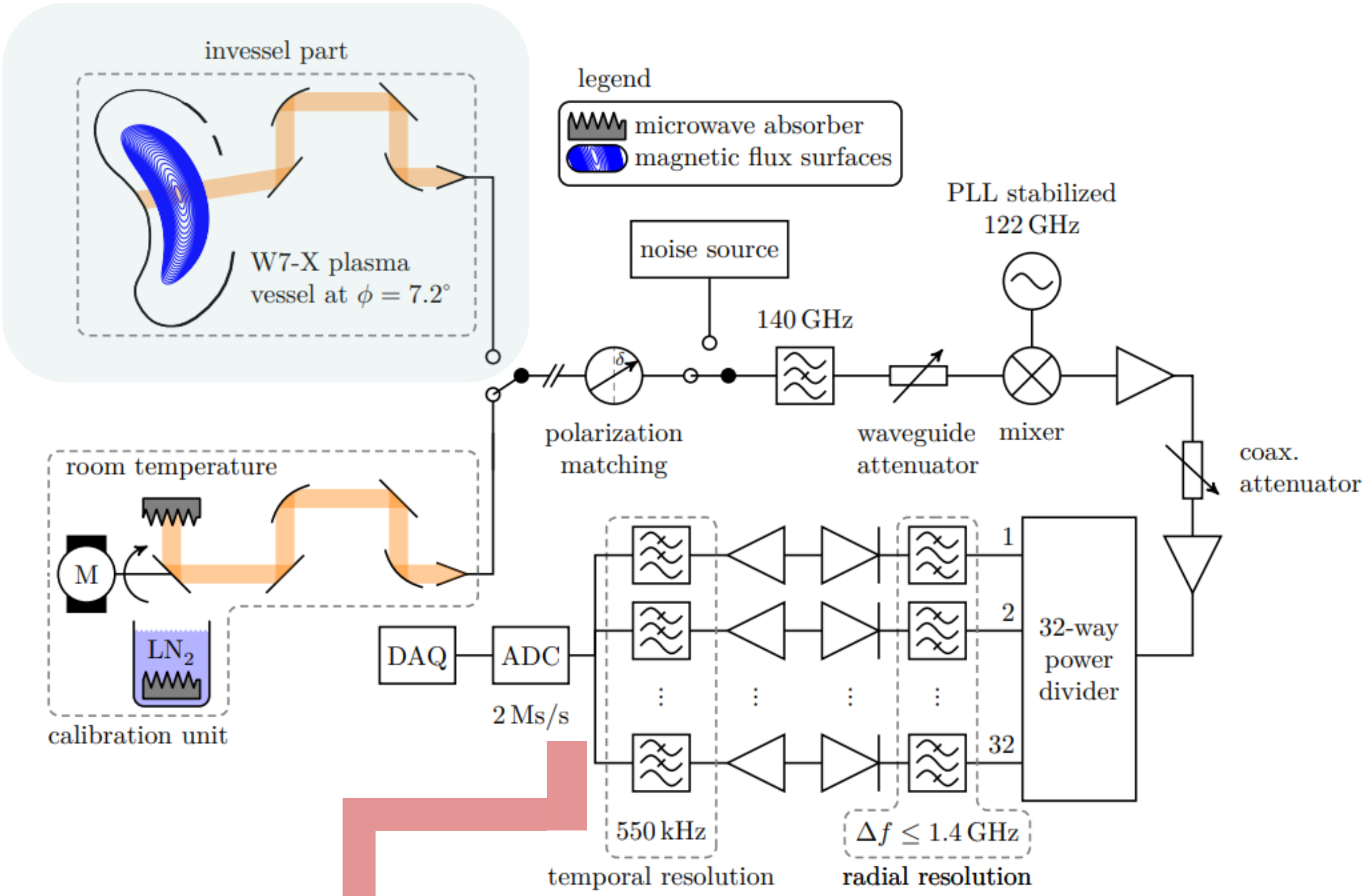
3rd semester – Paris Saclay University, France

Erasmus Mundus Joint Masters Degree
Lasers and Large Scale Accelerators

4th semester – Master thesis at IPP

Characterization and commissioning of an upgraded high-spatial resolution “zoom” radiometer for the study of the dynamic behavior of electron temperature and its perturbations in Wendelstein 7-X

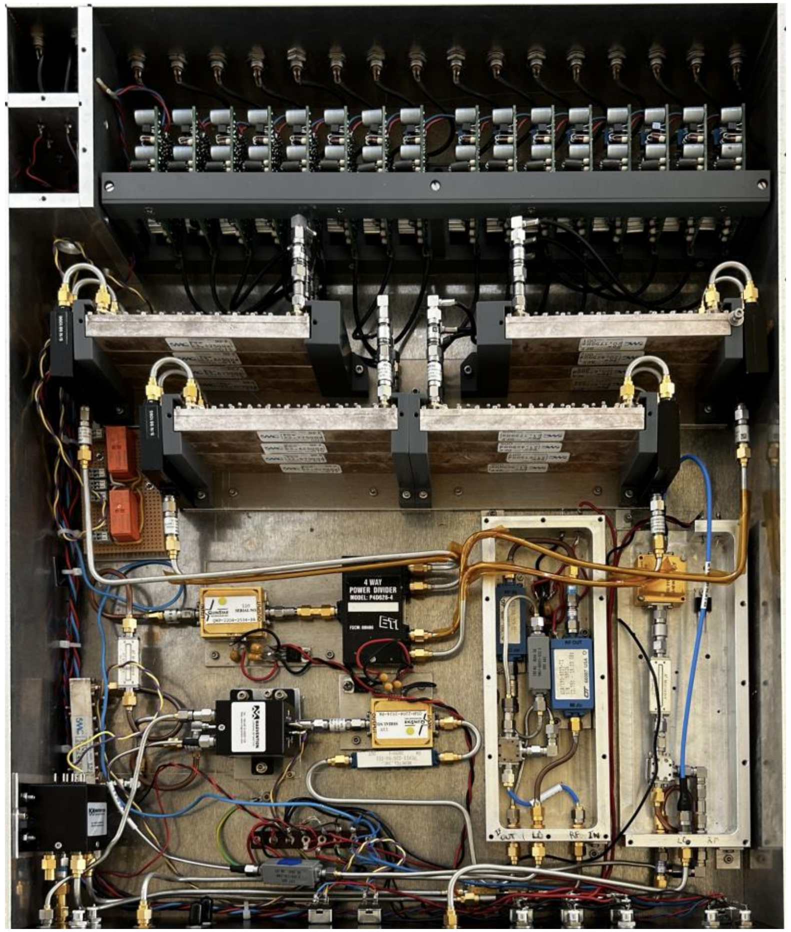
QME - Core Te diagnostic at W7-X:



To ZOOM

Bayesian Modelling of Microwave Radiometer Calibration on the example of the Wendelstein 7-X Electron Cyclotron Emission diagnostic
U. Hoefel et al

M2 thesis: the ZOOM device



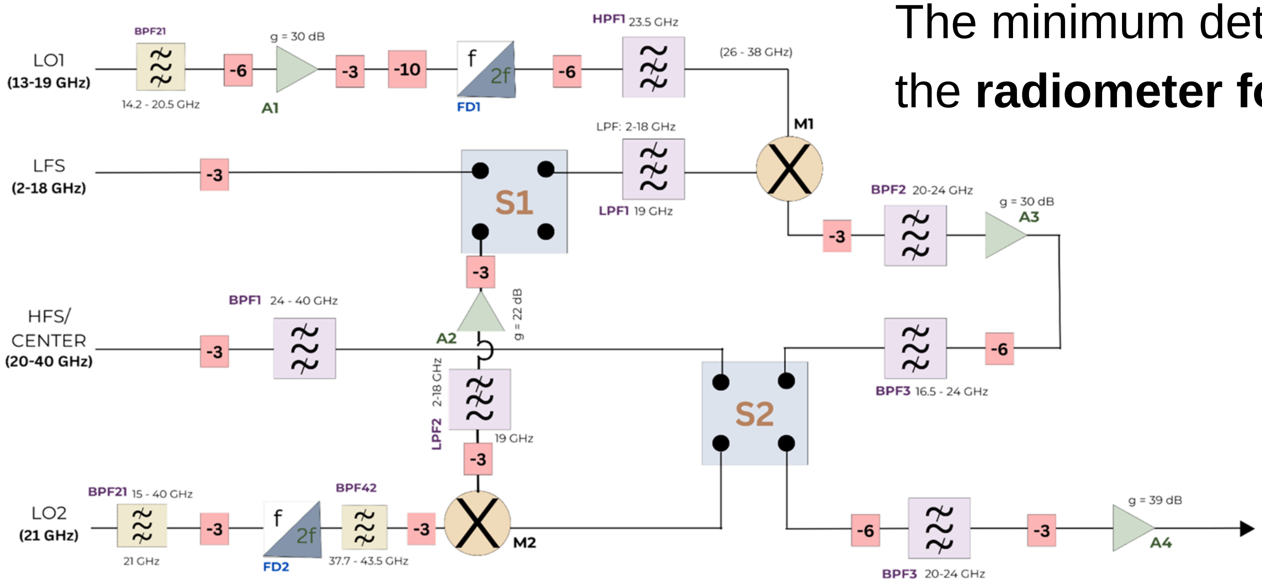
Circuit of the ZOOM system

The minimum detectable fluctuation level is given by the **radiometer formula:**

$$\left[\frac{\tilde{T}_e}{\mathrm{T_e}}\right] > \left[\frac{2B_v}{B_{IF}}\right]^{\frac{1}{2}}$$

- Takes input from the core ECE radiometers
- Detects X2: (126-162 GHz)
- Flexible range of operation
- High frequency resolution

M2 thesis: the ZOOM device



Schematic diagram of the ZOOM system

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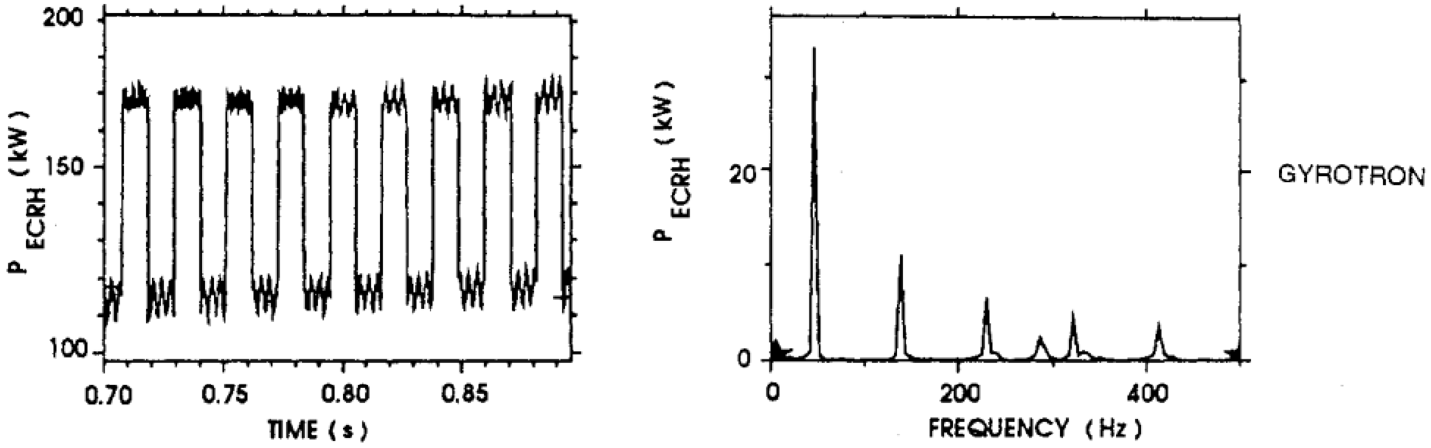
PhD: Power deposition studies

Deposition of ECRH – localised in the plasma centre => power modulation produces heatwaves that propagate away from the deposition volume.



*L. Giannone et al 1992 Nuclear Fusion **32** 1985*

PhD: Power deposition studies

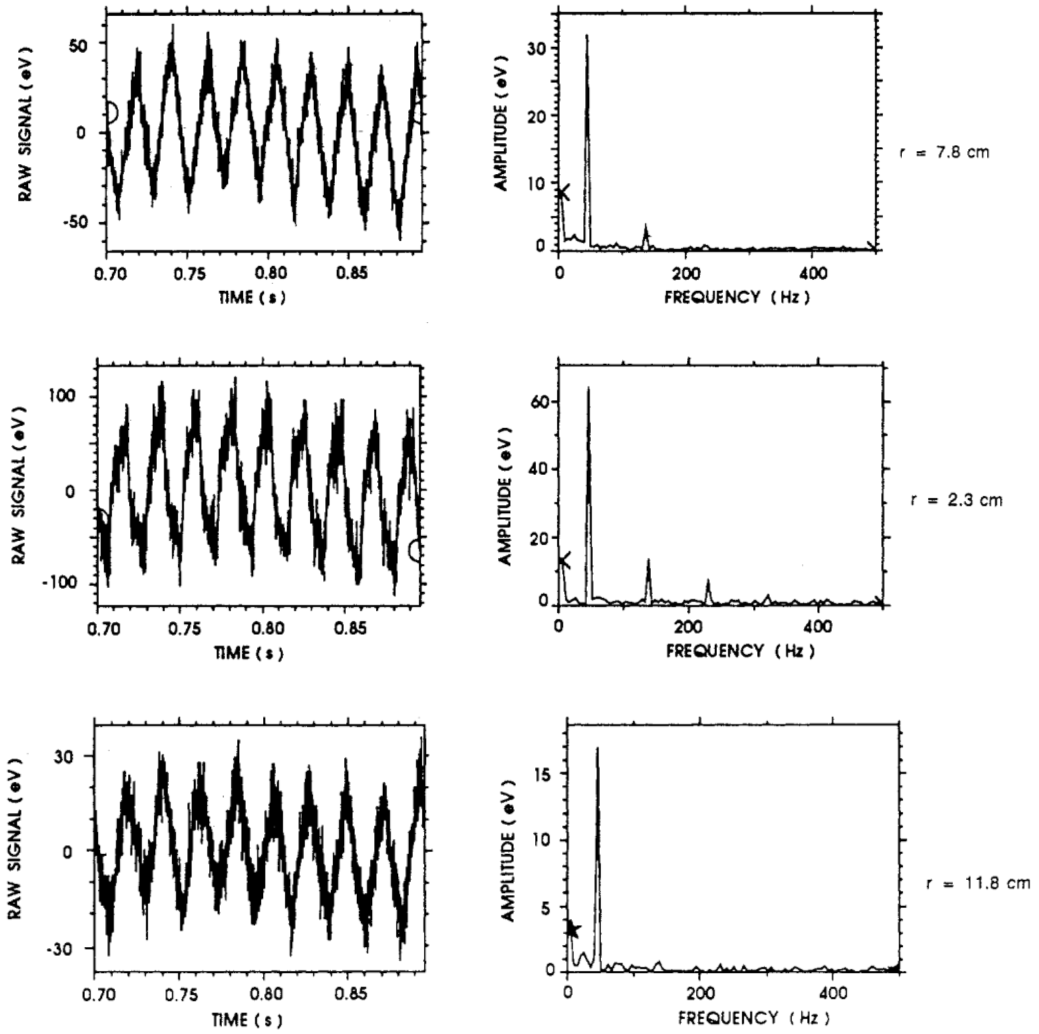
To measure this propagation: ECE signal => FFT

At lower frequencies

Electron diffusivity estimates

At higher frequencies

Power deposition studies



*L. Giannone et al 1992 Nuclear Fusion **32** 1985*

PhD: Power deposition studies

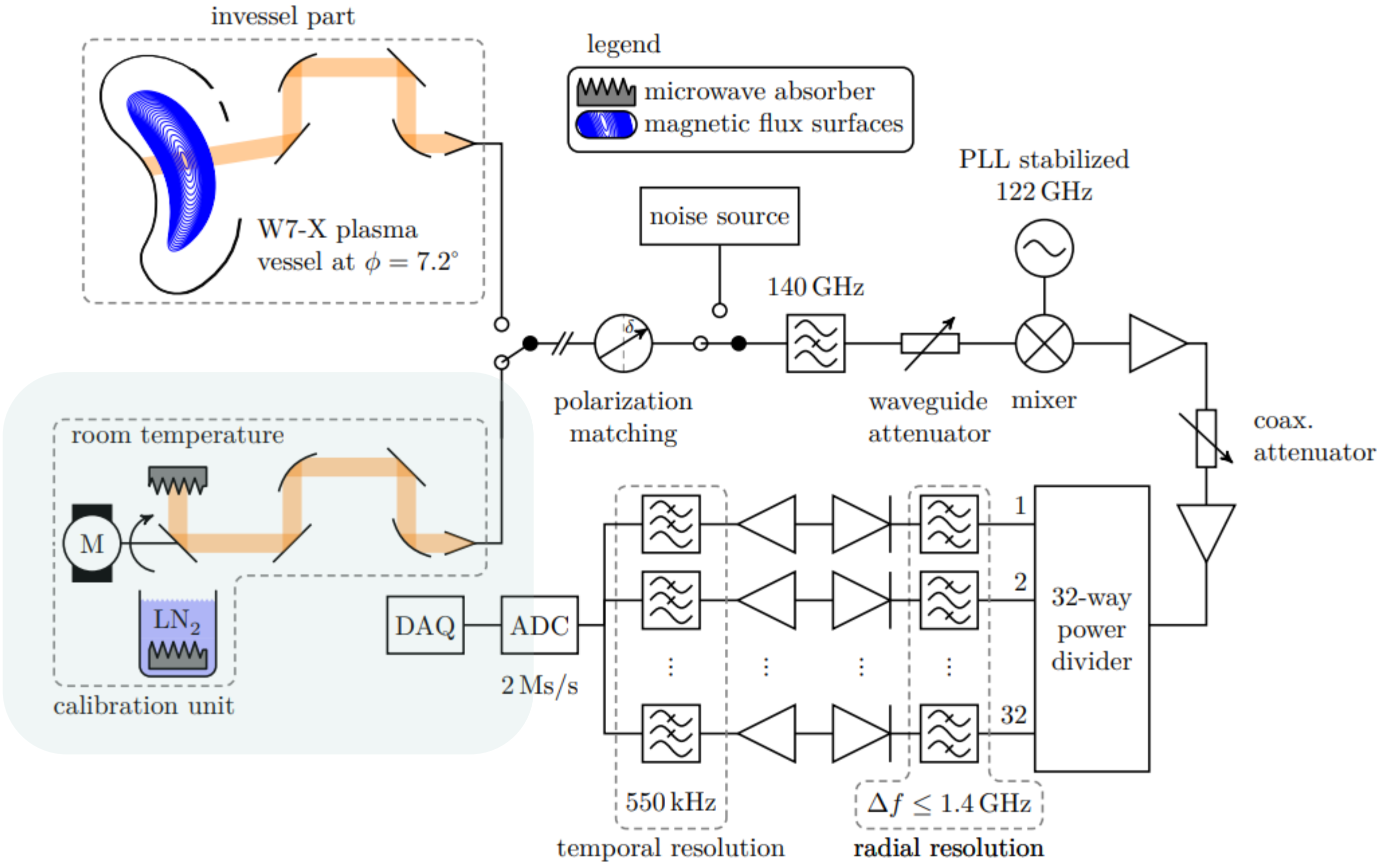
The minimum required sampling rate is set by the e-e collision time.

$T_e (keV)$	$n_e\ (m^{-3})$	$\tau_{ee}\ (\mu s)$	$\nu_{ee}\ (MHz)$
$0.5\ keV$	8×10^{19}	1.6	0.635
$2\ keV$	4×10^{19}	26	0.038
$4\ keV$	8×10^{19}	36	0.027

Requirement:

Calibrated radiometers with sampling rate ~ MHz

Hot cold calibration for ECE



Bayesian Modelling of Microwave Radiometer Calibration on the example of the Wendelstein 7-X Electron Cyclotron Emission diagnostic
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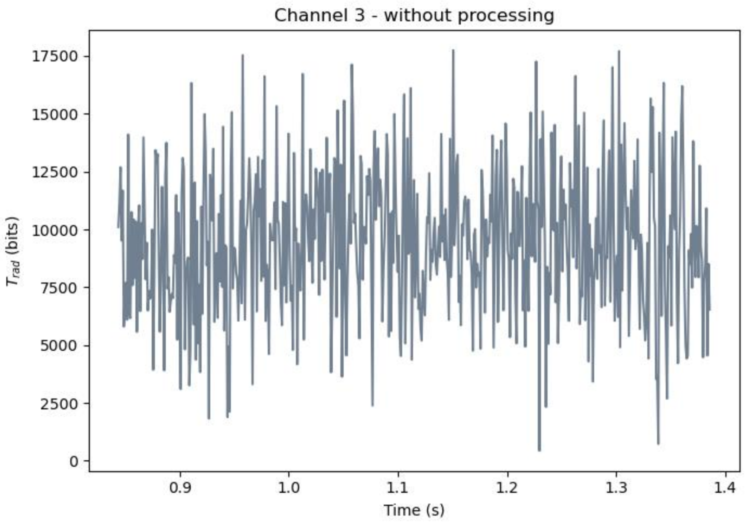
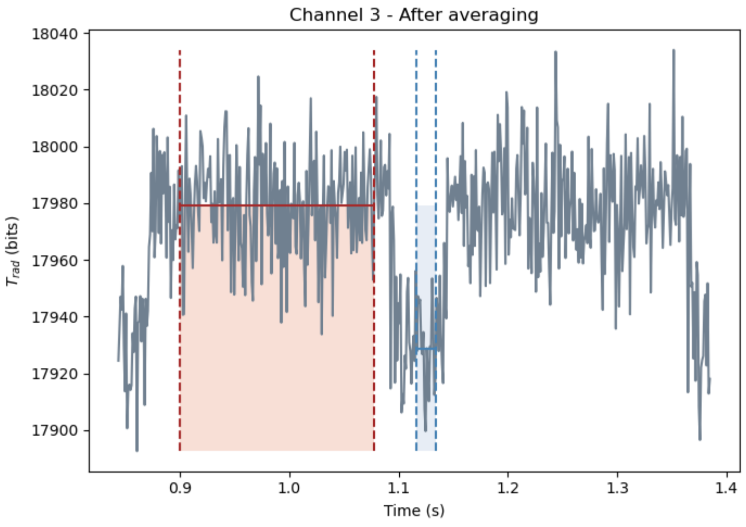
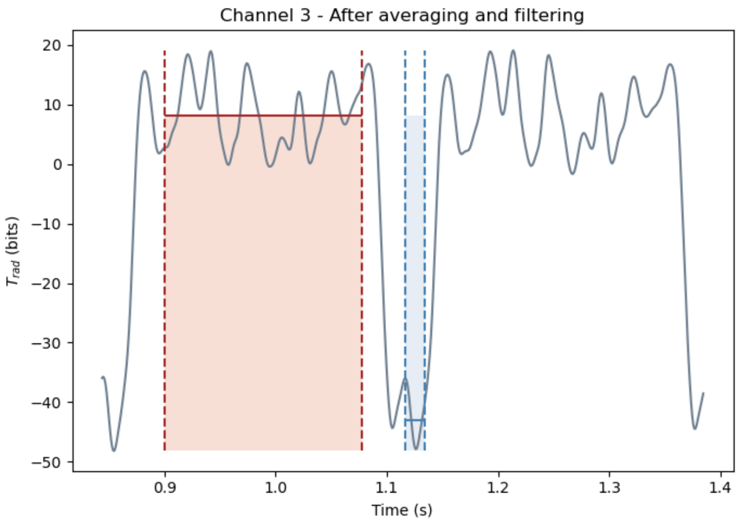
Calibration of ECE with a Hot-cold source

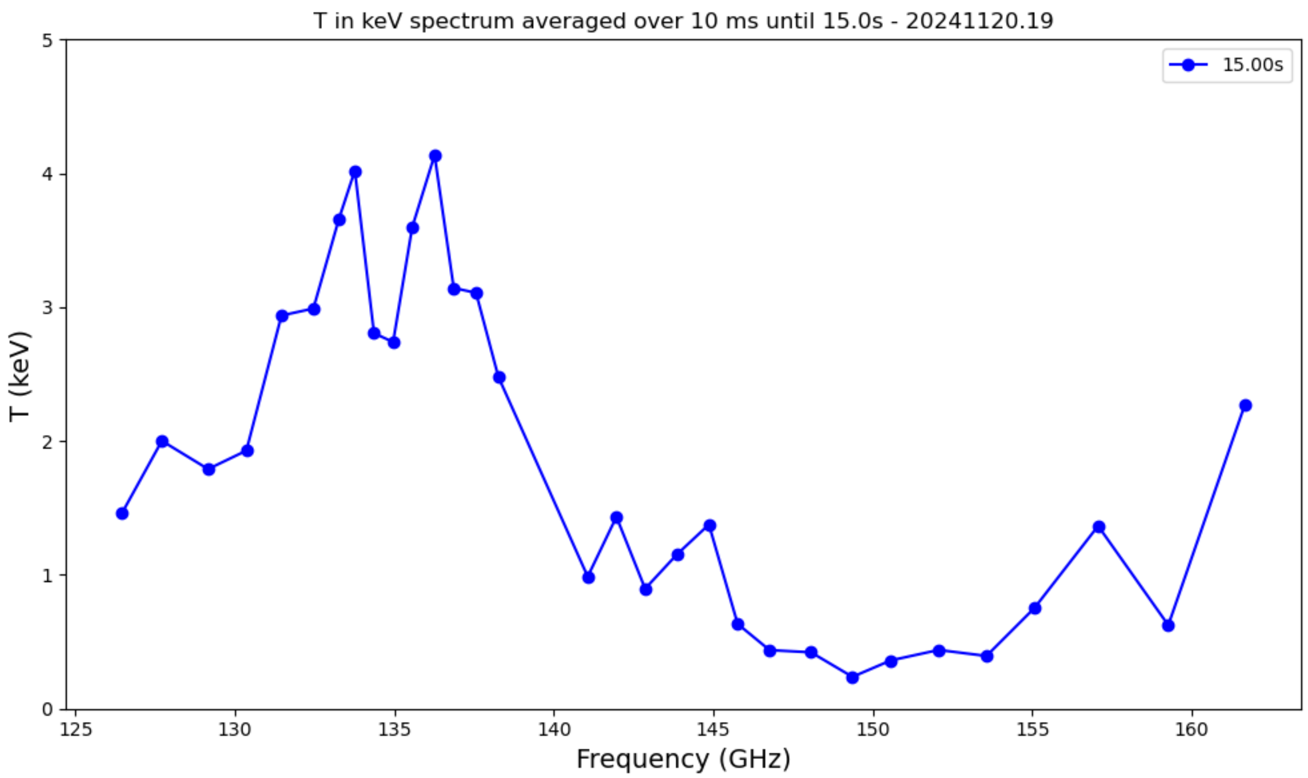




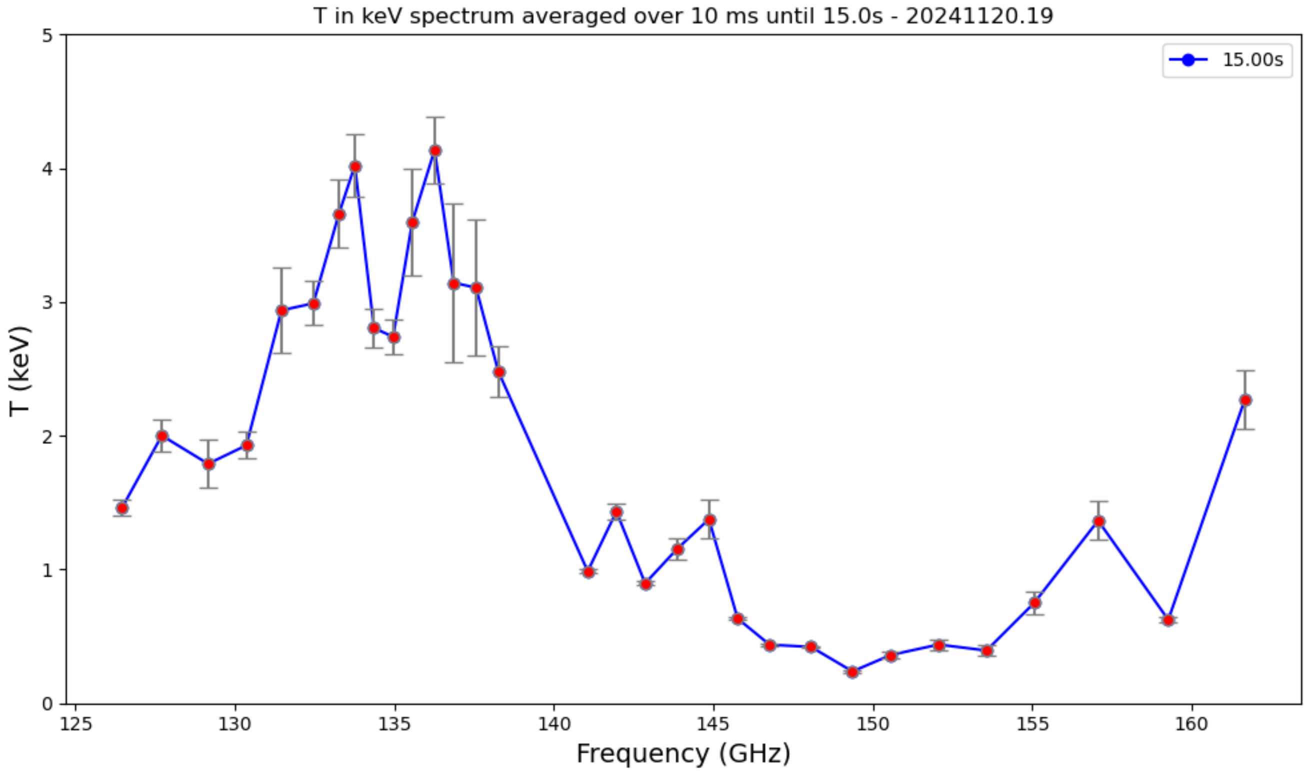


(Averaged for 2 hours over ~30000 periods)

Calibration factors applied to a ECE spectrum



Calibration factors applied to a ECE spectrum (with statistical error bars)



Systematic errors have a significant contribution!

NEXT STEPS:

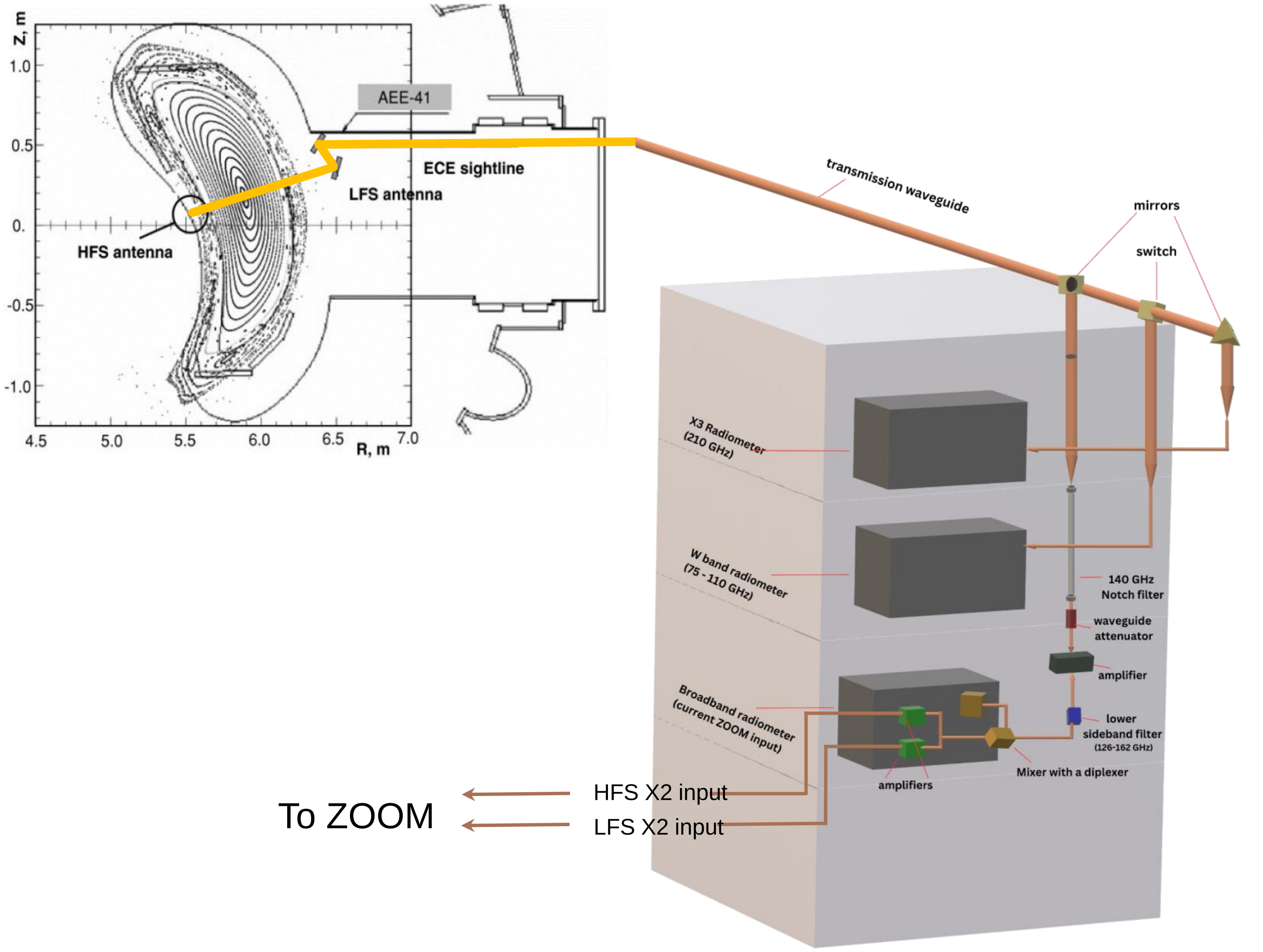
- Estimating errors for the calibration factors: systematic & statistic
- Working on the linearity of channels – especially for ZOOM
- Fourier Analysis of ECE, break in slope analysis
- Using zoom as radial correlation ECE system to study T_e perturbations

Thank you for your attention!

If you have feedback:

BACKUP SLIDES

QME - Core Te diagnostic at W7-X:



ECE & Radiometry

Charged particles in a magnetized plasma emit radiation due to their gyration

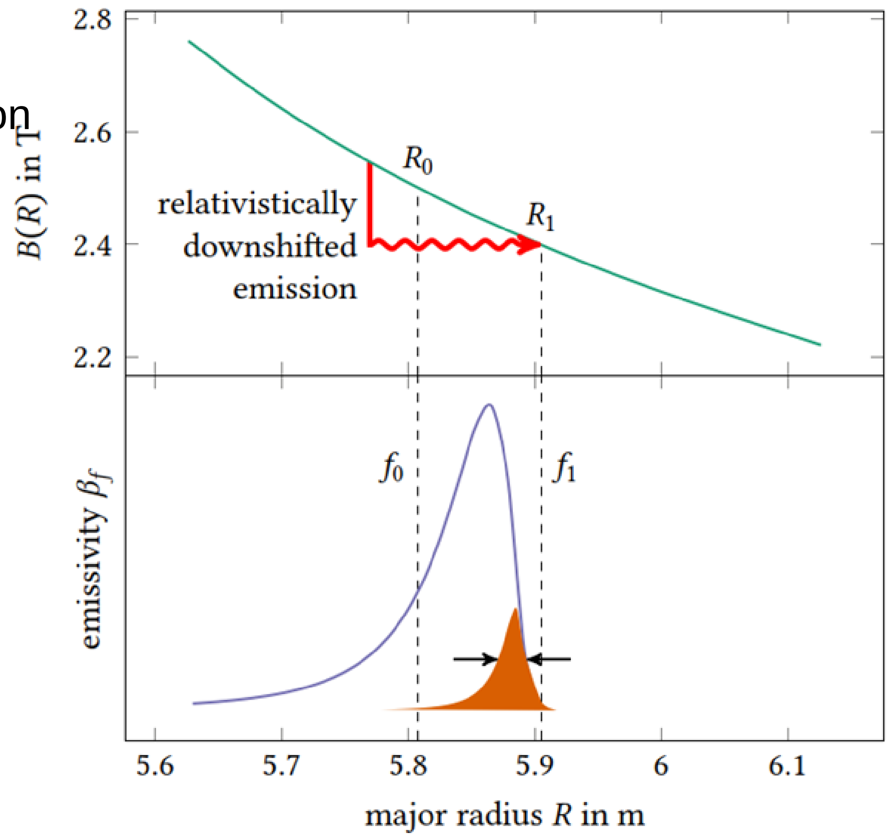
$$r_L = \frac{v_{e\perp}}{\omega_c} = \frac{m_{e0} v_{e\perp}}{e B_0}$$

For $\mathrm{B}(r) = \frac{B_0 R_0}{R_0 + r}$, after taking into account the broadening effects, in a slab geometry approximation:

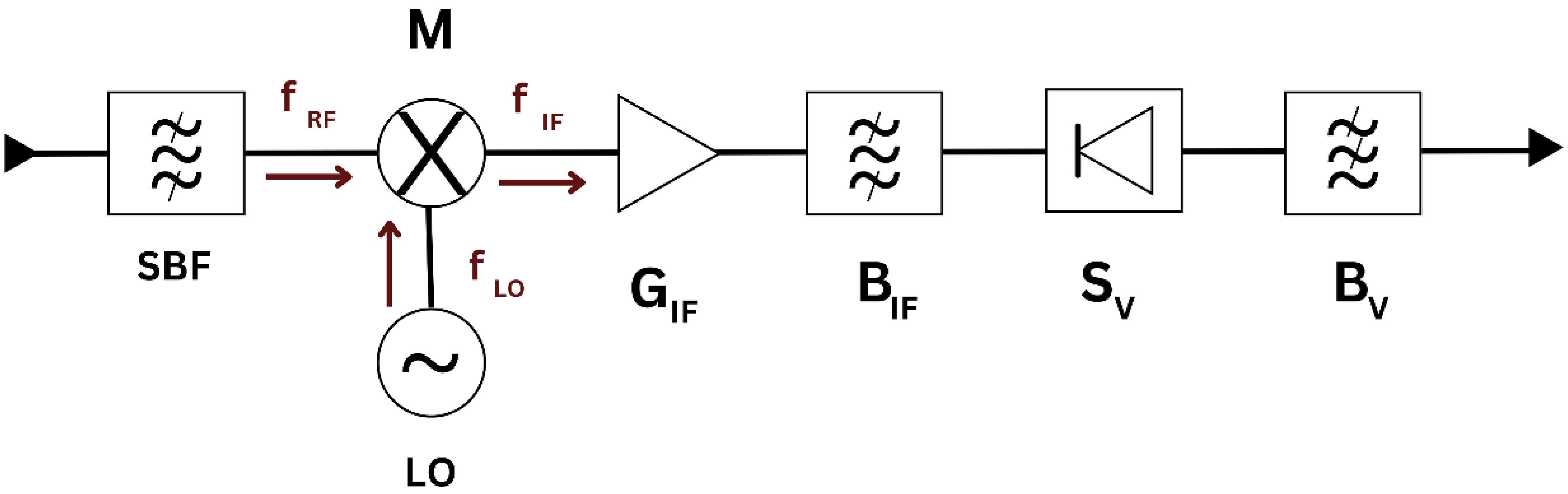
$$\mathrm{T}_{rad}(\omega_0) = T_e\big(s(\omega_0)\big)\left[1 - e^{-\tau(\omega_0)}\right]$$

At high optical depth, T_{rad} approaches T_e →

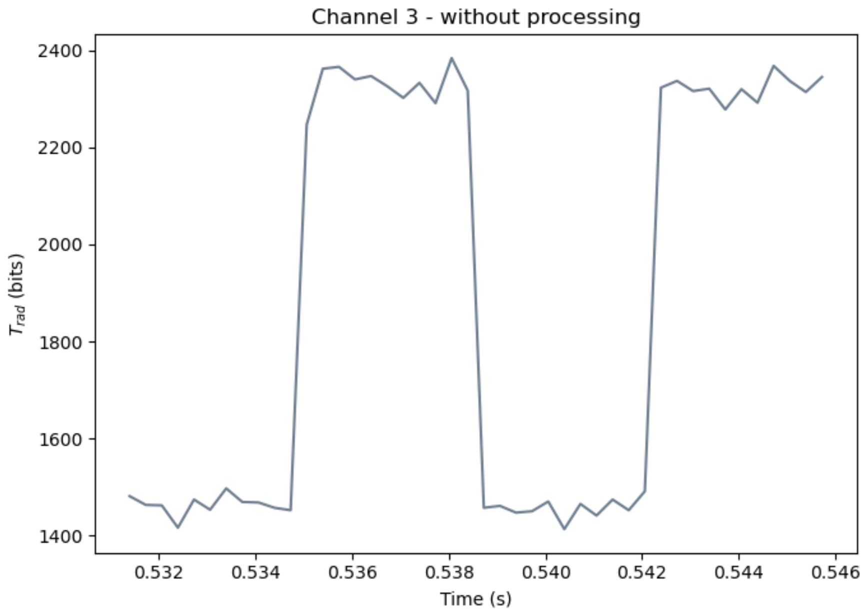
$$\frac{E_e}{K_B T_e} \approx 1 \rightarrow E_e \approx K_B T_e$$

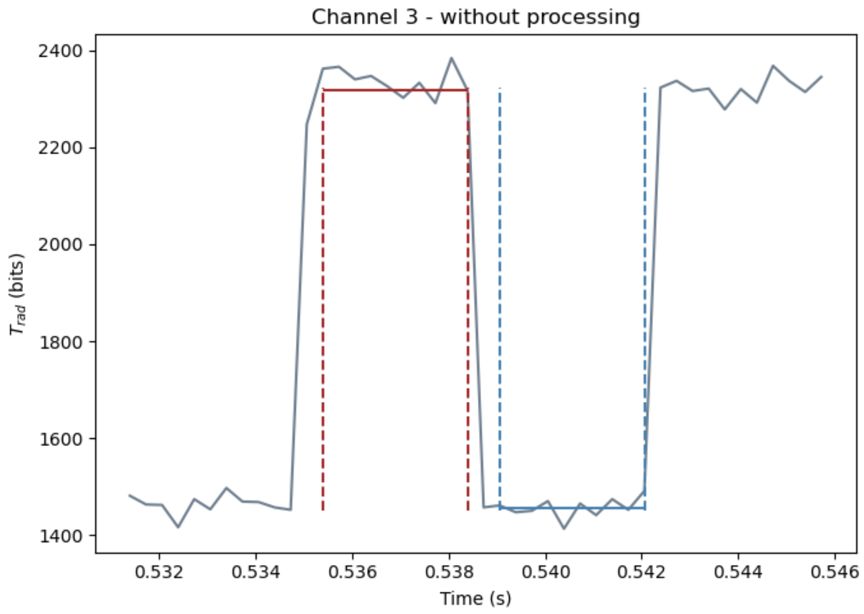


Heterodyne downconversion

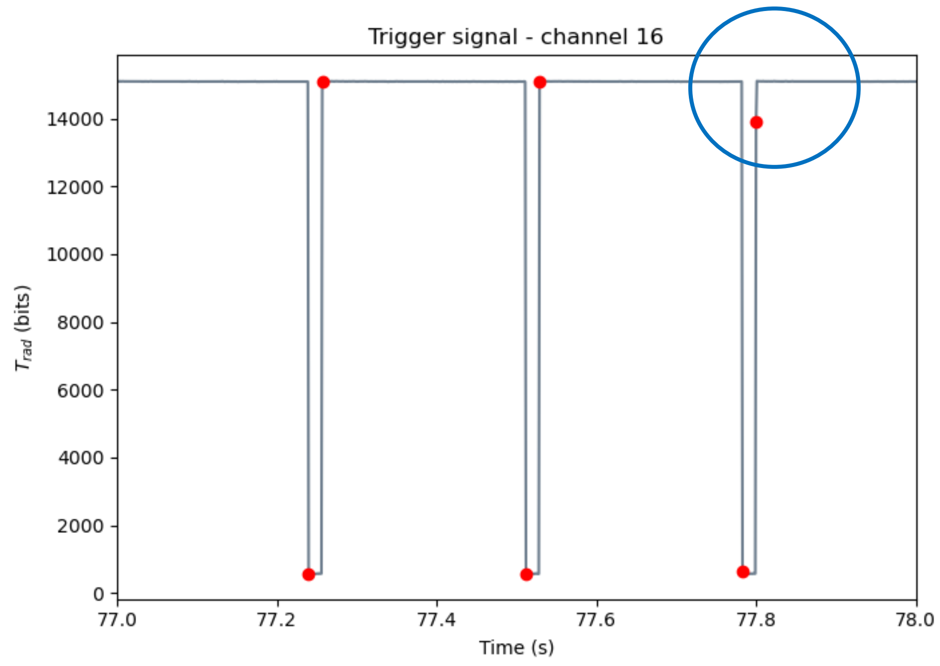


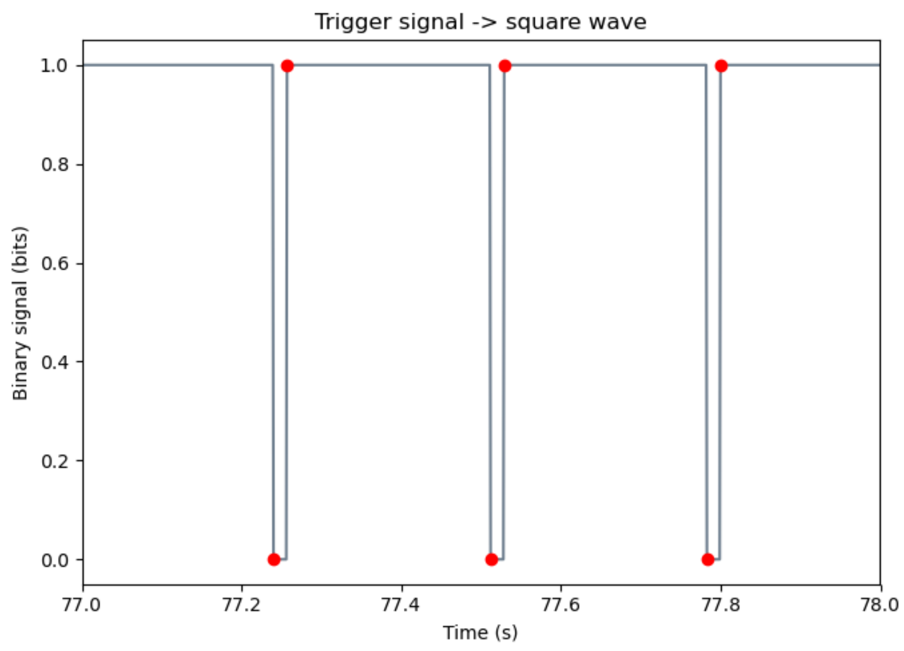
Calibration of ECE with a Noise source



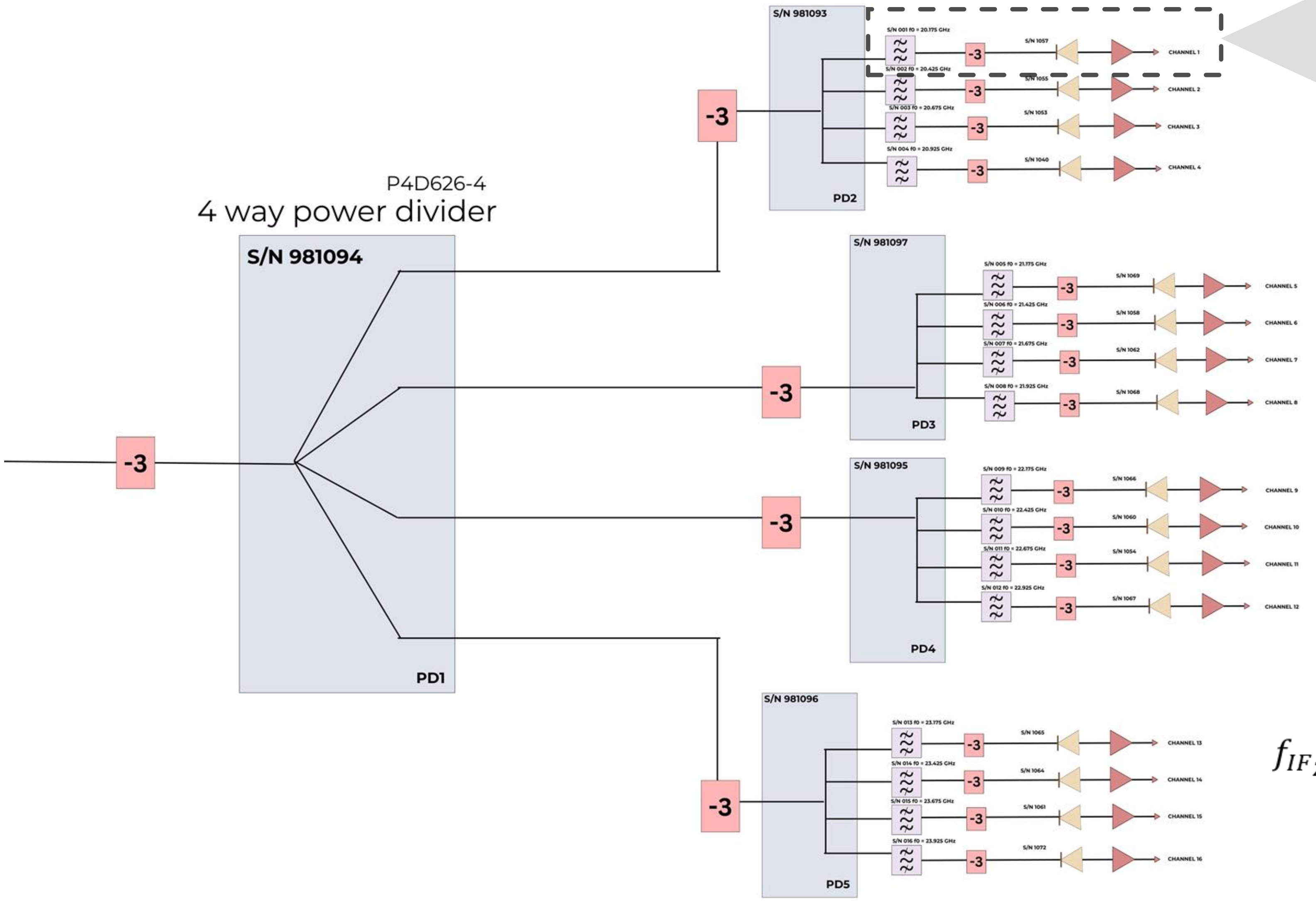


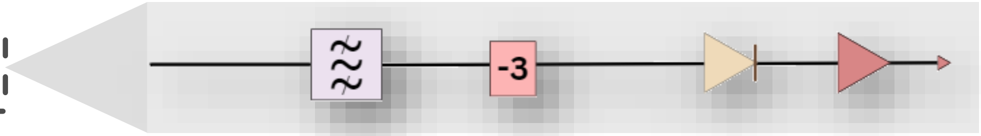
Calibration of ECE with a Hot-cold source

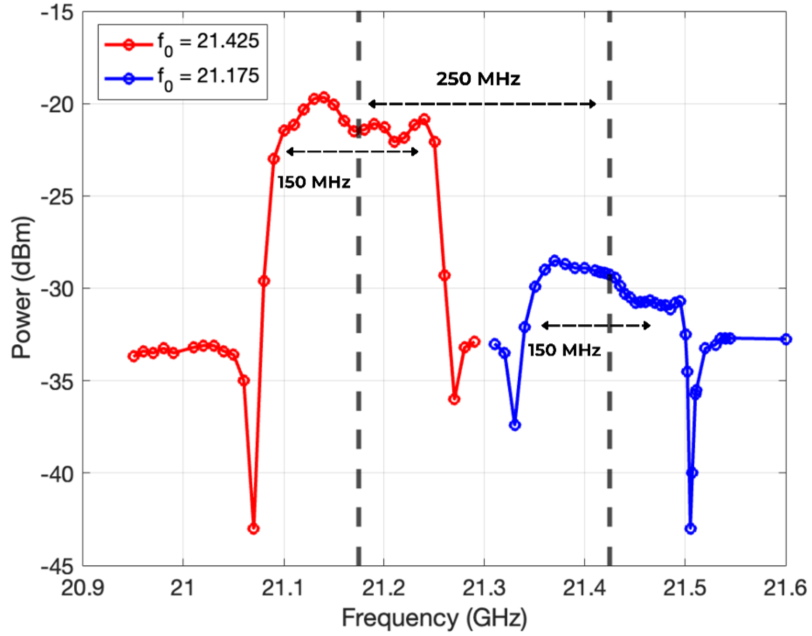




ZOOM circuit design (OP 2.2 onwards)







$f_{IF_{ZOOM}}$: Intermediate frequencies of the zoom radiometer

From 20.175 GHz to 23.925 GHz, 16 channels

Pass bandwidth: 150 MHz Channel separation: 250 MHz