IFAST – 3rd annual meeting
1.3 GHz Cavity Deposition facility progress at UKRI

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16th - 19th April 2024

University of Liverpool

UKRI Science and Technology Facilities Council

iFAST

Overview

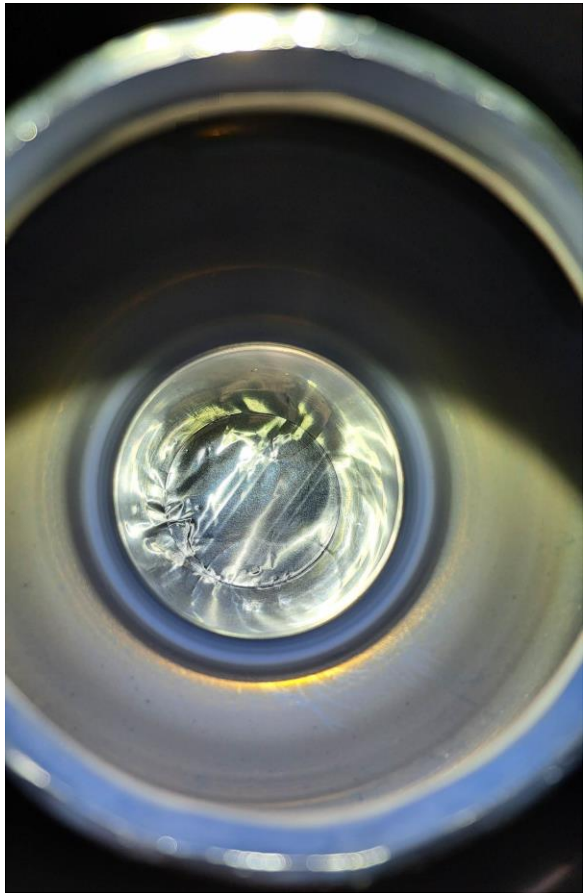
- Coating activities
  - Modified 1.3 GHz cavity - JEFF
  - Preparation for 1.3 GHz cavity - DIVERS
  - Disk samples - JEFF

- Investigation of NbN using HiPIMS and bipolar HiPIMS
  - Mass and energy analysis of the plasma phase
  - Optical emission spectroscopy

Coating activities - Modified 1.3 GHz cavity

- Deposition of Nb using bipolar HiPIMS on a modified 1.3GHz cavity.

- Initial parameters
  - Chamber filled with Kr at $6x10^{-3}$ mbar
  - Bipolar HiPIMS
    - U_{neg} 380 V / 800 mA / 10 A / 300 W
    - neg PW 100 us / Freq 1000Hz
    - U_{pos} 50 V / pos PW 200 us / pos delay 1.5 us
  - Deposition for 6h



➡ No significant variation in pressure or power during the deposition

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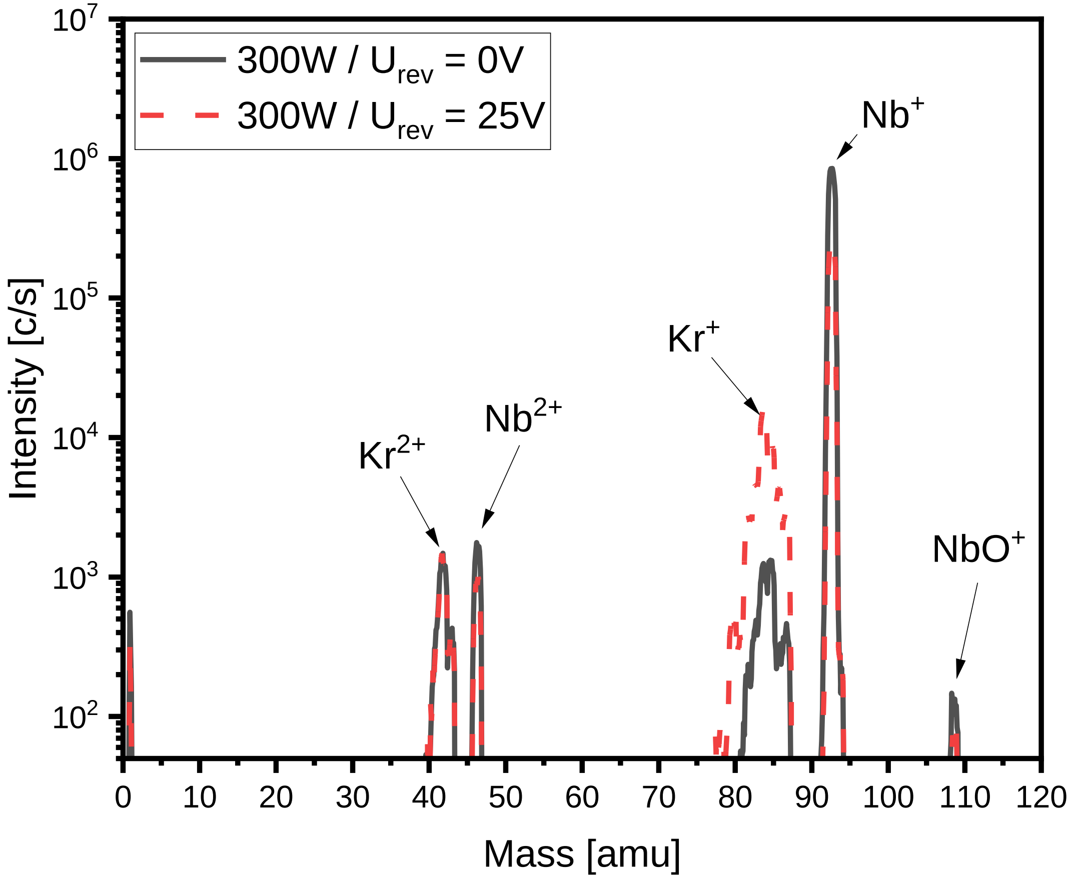
Coating activities – Modified 1.3 GHz cavity

- Mass analysis of the positive ions in bipolar HiPIMS
  - Main ions: Nb^+ (93 amu), Kr^+ (84 amu), Nb^{2+} (46 amu), Kr^{2+} (42 amu), NbO^+(109 amu)
  - Formation of NbO^+ due by recombination with residual H_2O
  - In bipolar mode, Kr intensity increases where Nb intensity decreases. Double charged ions remain stable.



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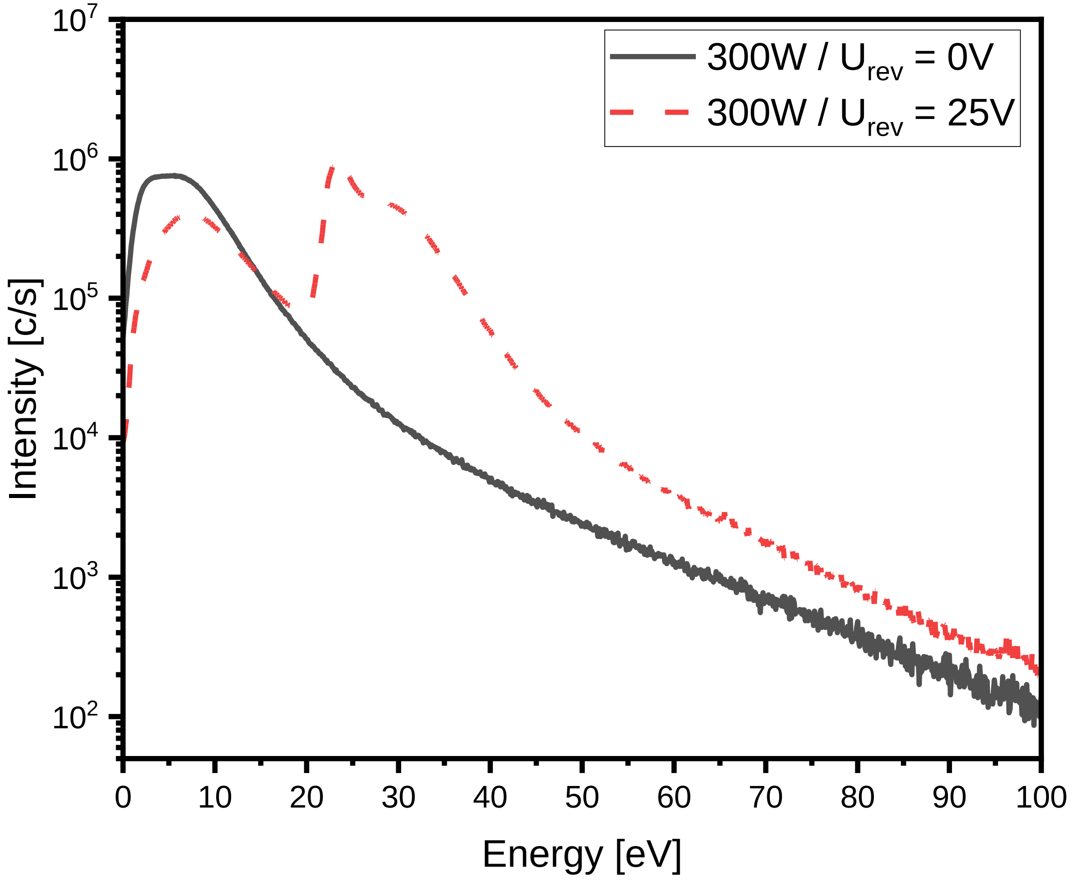
Coating activities – Modified 1.3 GHz cavity

- Energy analysis of Nb^+ positive ions
  - A first peak is observed (~ 5 eV), which decrease gradually in intensity as U_{pos} increases. The ion population is influenced by U_{pos} but not enough to be significantly accelerated by it
  - With U_{pos}=25V, a new peak appears at an energy slightly above eU_{pos}. Similar tail is observed as the HiPIMS case only but up-shifted in energy by eU_{pos}



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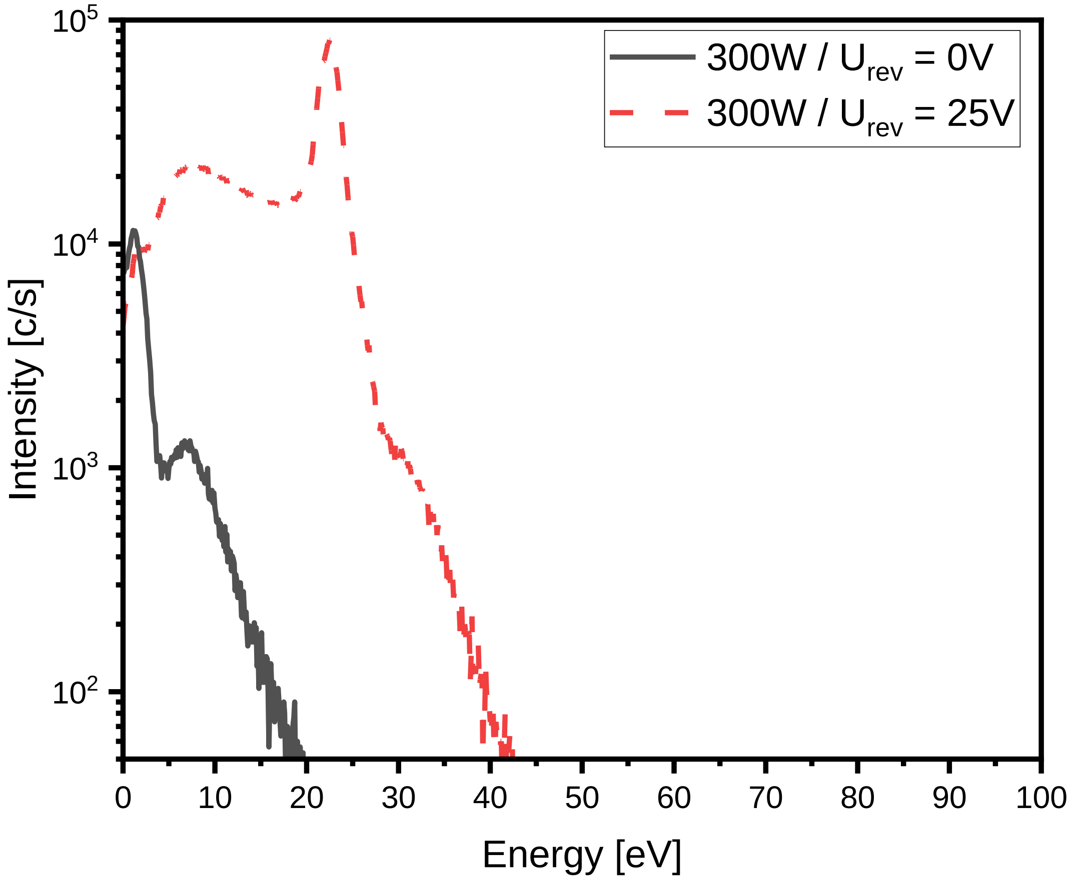
Coating activities – Modified 1.3 GHz cavity

- Energy analysis of Kr^+ positive ions
  - Similar to Nb^+ - Up-shift to the right with an increase of intensity, slightly above eU_{pos} and followed by a drastic decrease. One assumption could be that the Kr^+ ions are accelerated but do not gain the full energy eU_{pos}

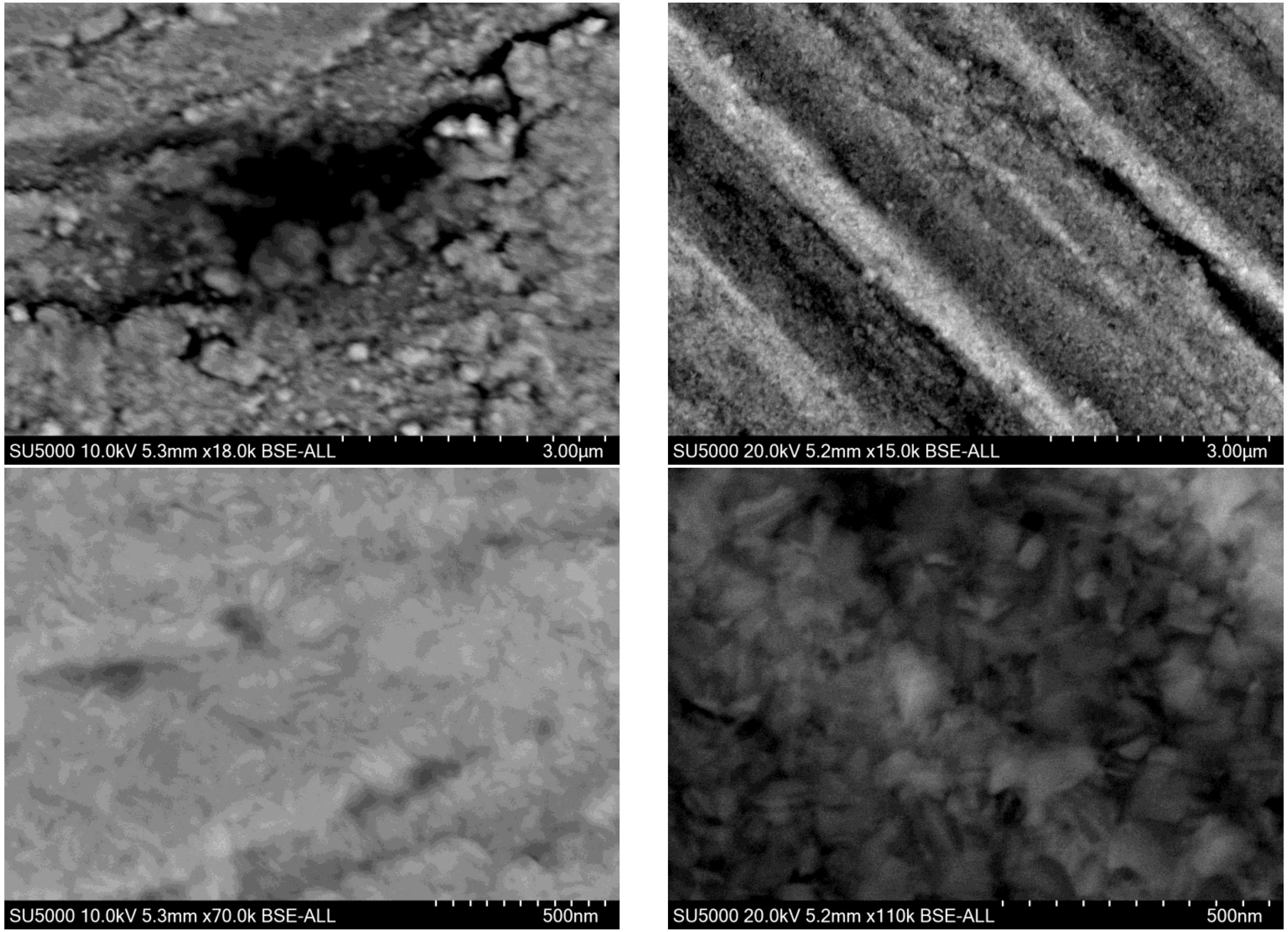


Coating activities – Modified 1.3 GHz cavity (reminder)

- Influence of bipolar HiPIMS on the film structure
  - Bipolar HiPIMS produces a denser film
  - Simiar Tc (~9.2K)

HiPIMS – 100W

Bipolar HiPIMS – 100W



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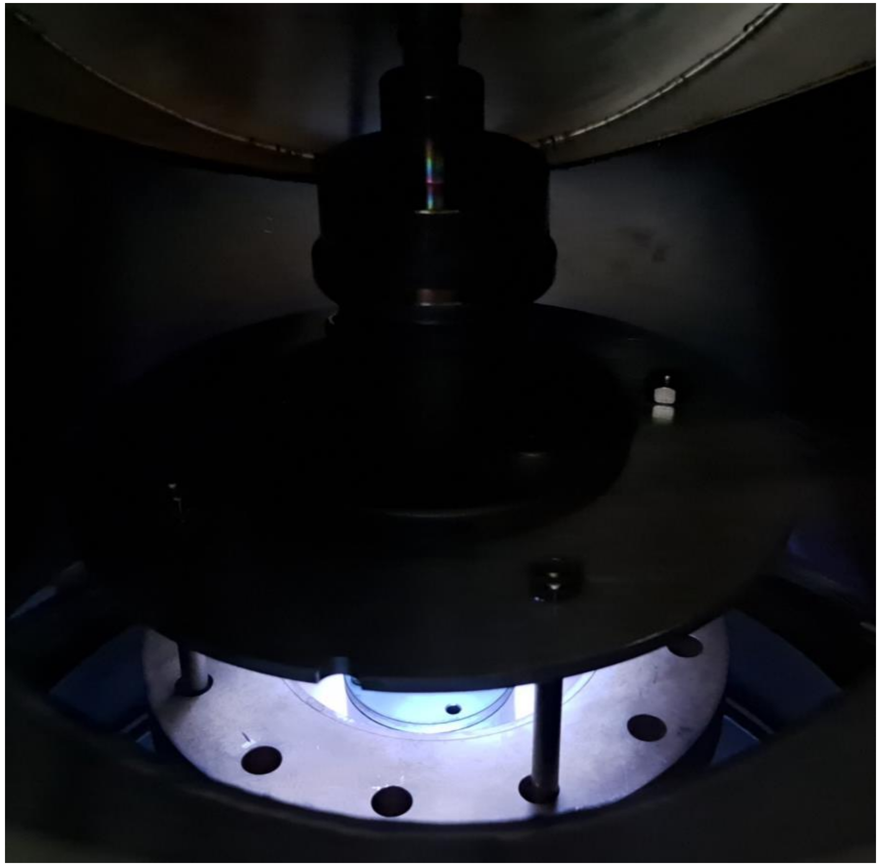
Coating activities - 1.3 GHz cavity

- DIVERS' Rig
  - Modification of the magnetron (between JEFF and DIVERS)
  - Chamber filled with 15 sccm of Kr, base pressure of $2x10^{-3}$ mbar
  - Deposition done for 6 hours in HiPIMS (480V / 830 mA / 400W / 9A / 1000Hz / 100us)

➡ Technical issues: the cavity was not getting coated at the bottom



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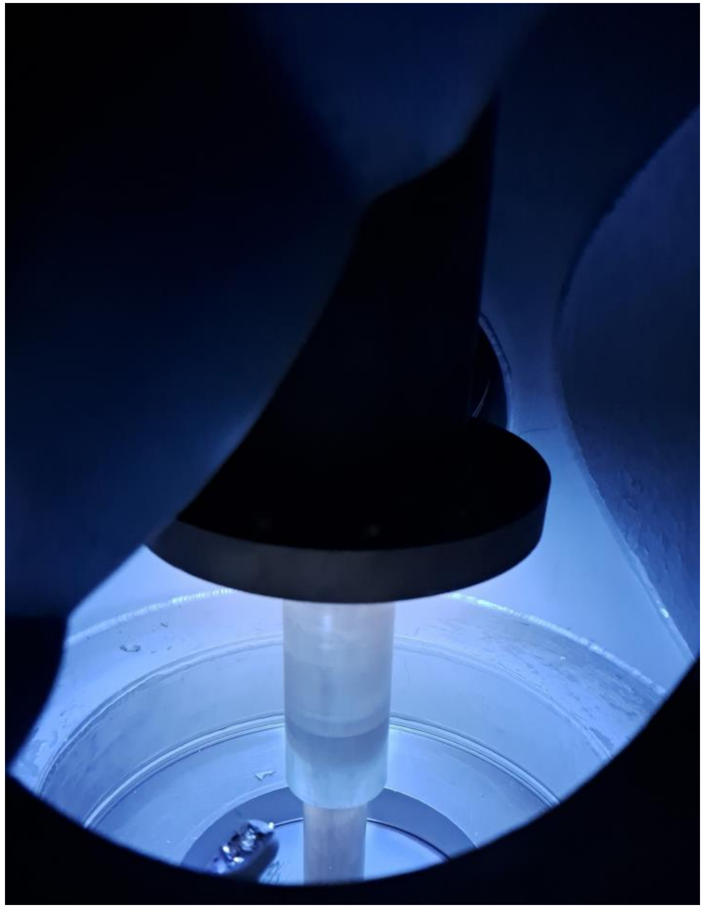
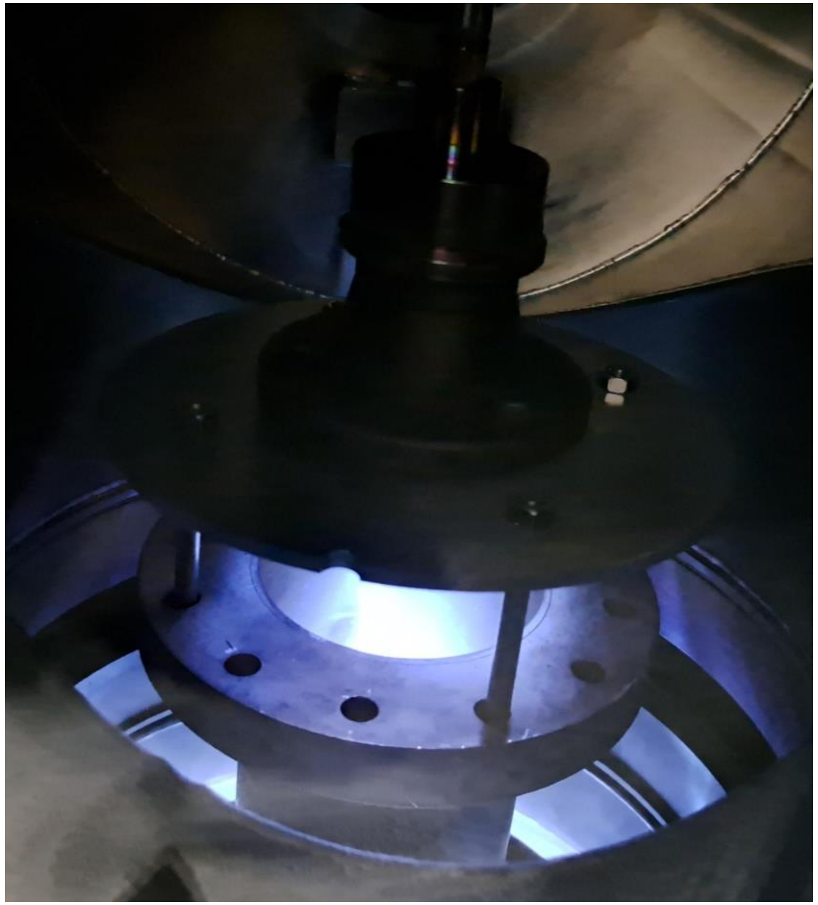
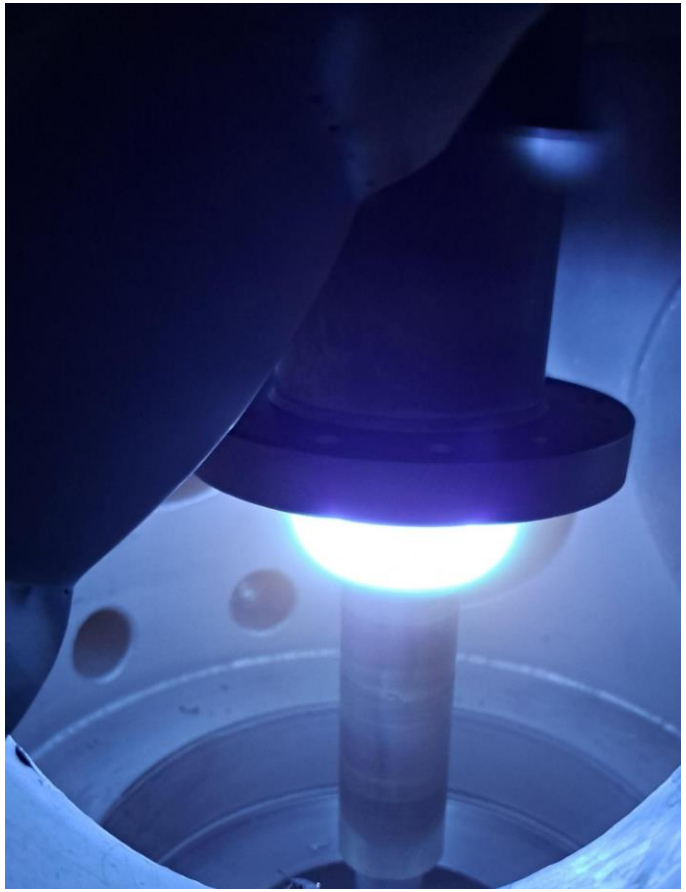
Coating activities - 1.3 GHz cavity







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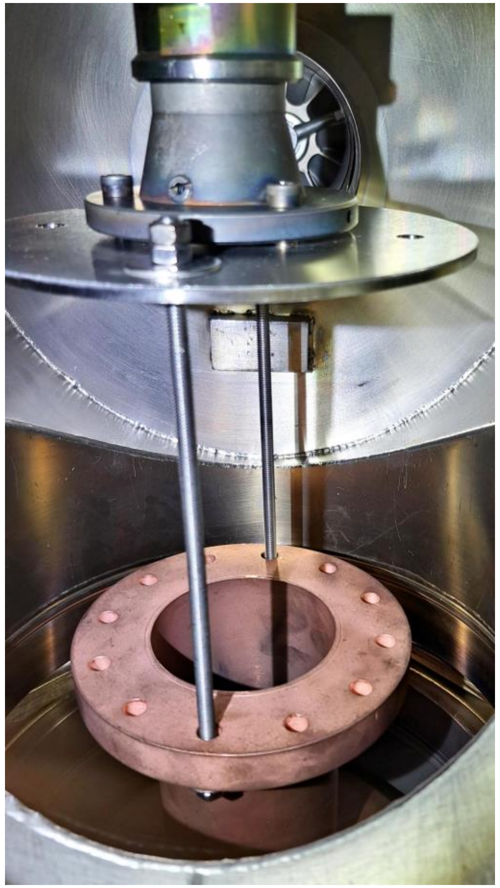
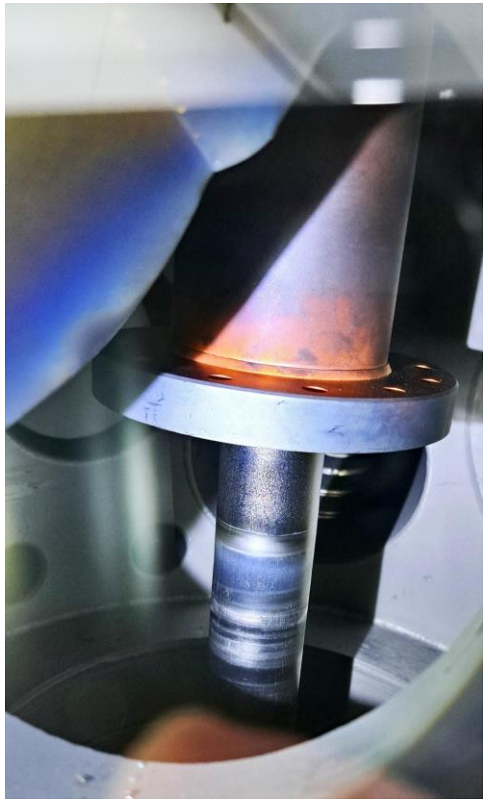
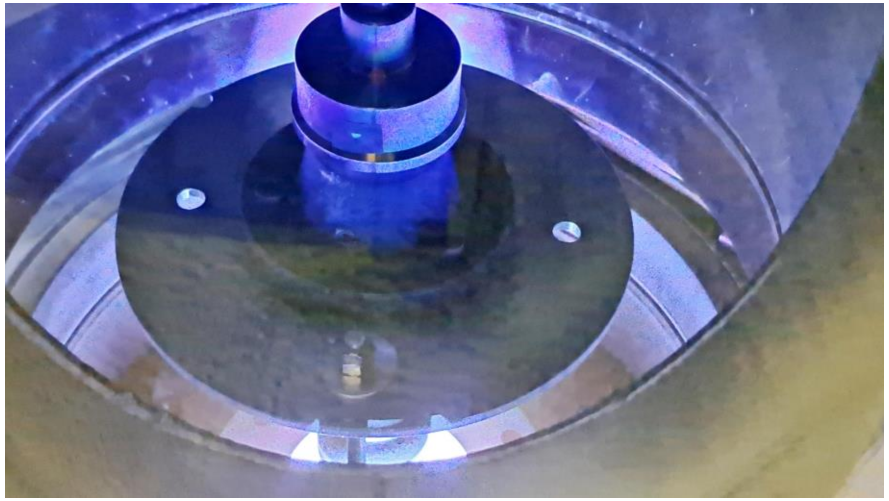
Coating activities - 1.3 GHz cavity

- DIVERS' Rig
  - Upgrade of the holder (top part), allows the cavity to go further down during deposition
  - New deposition for 4 hours
  - 15 sccm Kr, 2x10^{-3} mbar
  - 480V / 830 mA / 400W / 9A / 1000Hz / 100us







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Coating activities - 1.3 GHz cavity

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Coating activities – Disk samples in JEFF

- Study for IPAC'24
  - Samples coated using HiPIMS at 300W for 4 hours at a pressure of $6x10^{-3}$ mbar
  - Parameters: 370V / 805mA / 300W / 11A / 1000Hz / 100us

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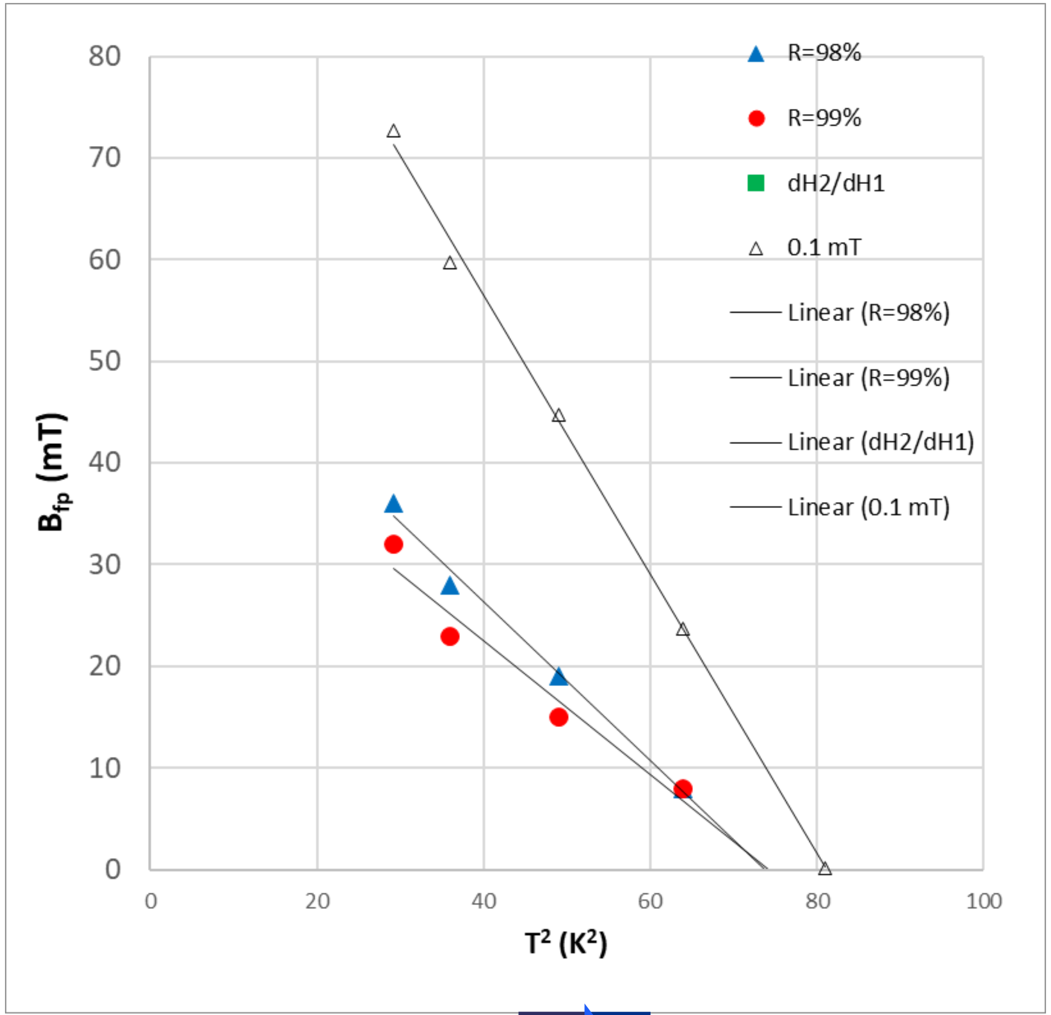
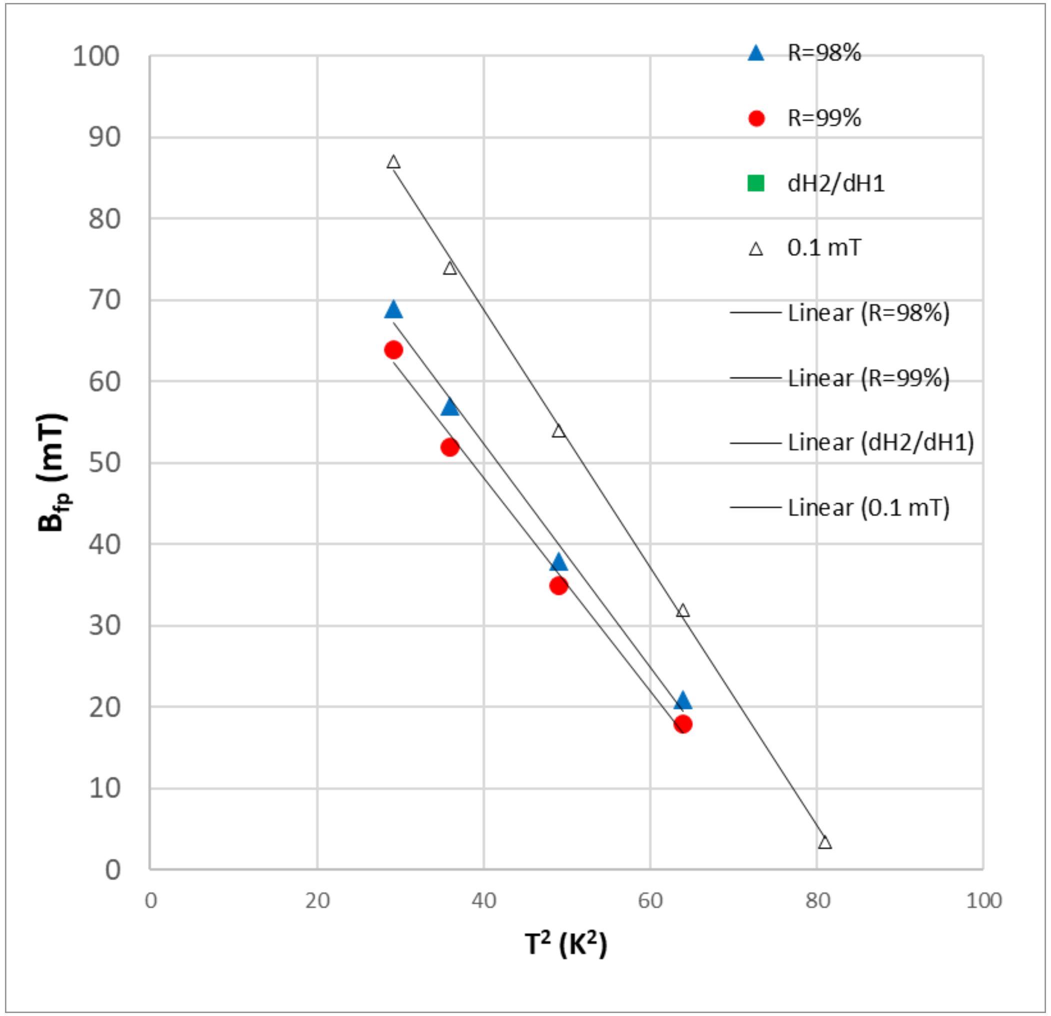
Coating activities – Disk samples in JEFF





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➡ Tc respectively 9.0 and 9.1K

Investigation of NbN: influence of HiPIMS power

- Mass analysis and energy analysis in HiPIMS
  - Chamber filled with a 20 sccm flow rate of Kr and 2 sccm of N_2. Base pressure of 3.7×10^{-3} mbar
  - HiPIMS parameters:

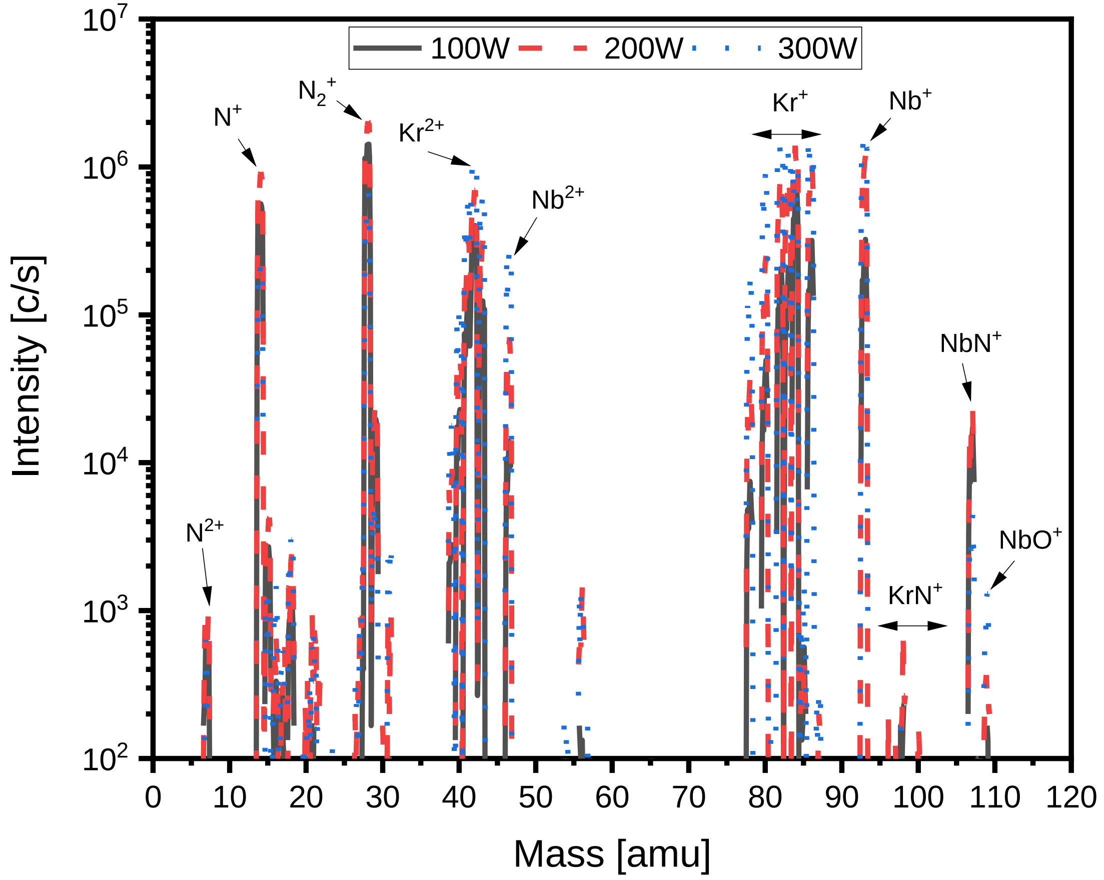
neg PW 100us / Freq 1000Hz

100W: 721V / 139mA / 12A

200W: 730V / 275mA / 12A

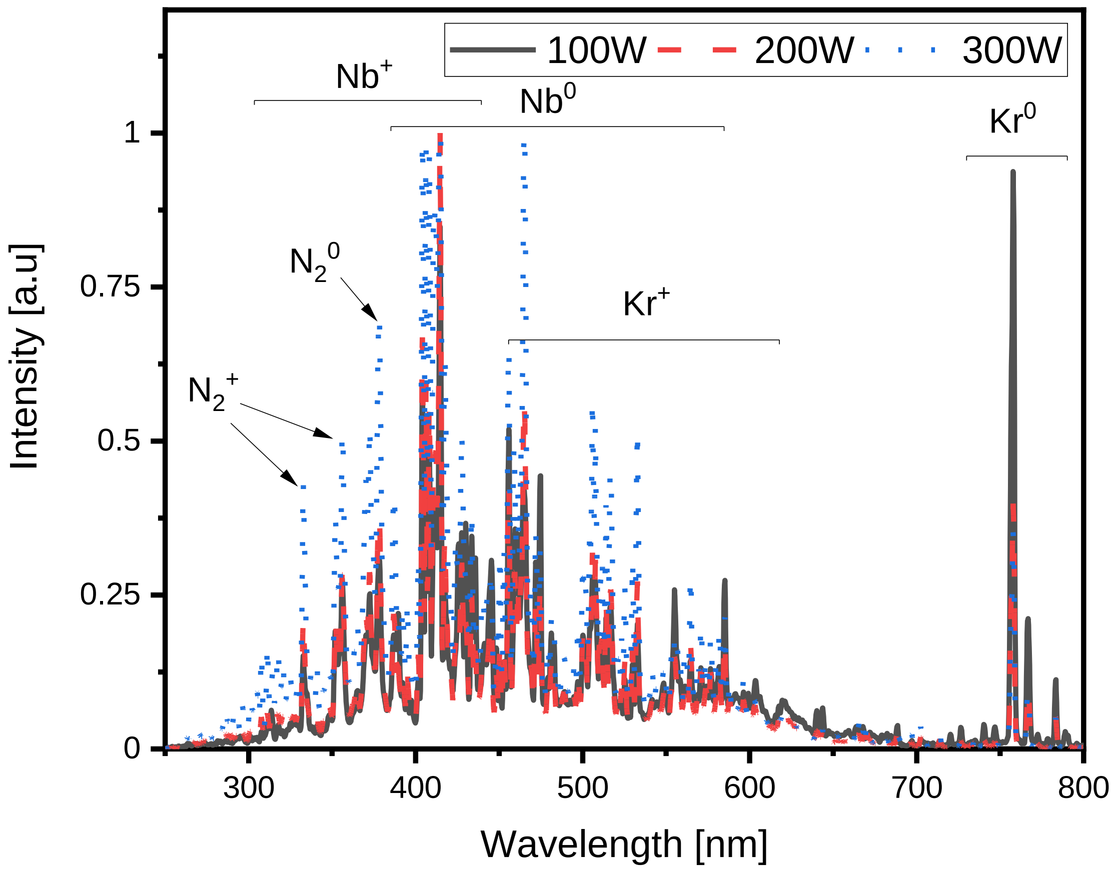
300W: 567V / 530mA / 11A

➡ High reactivity with multiple recombinations

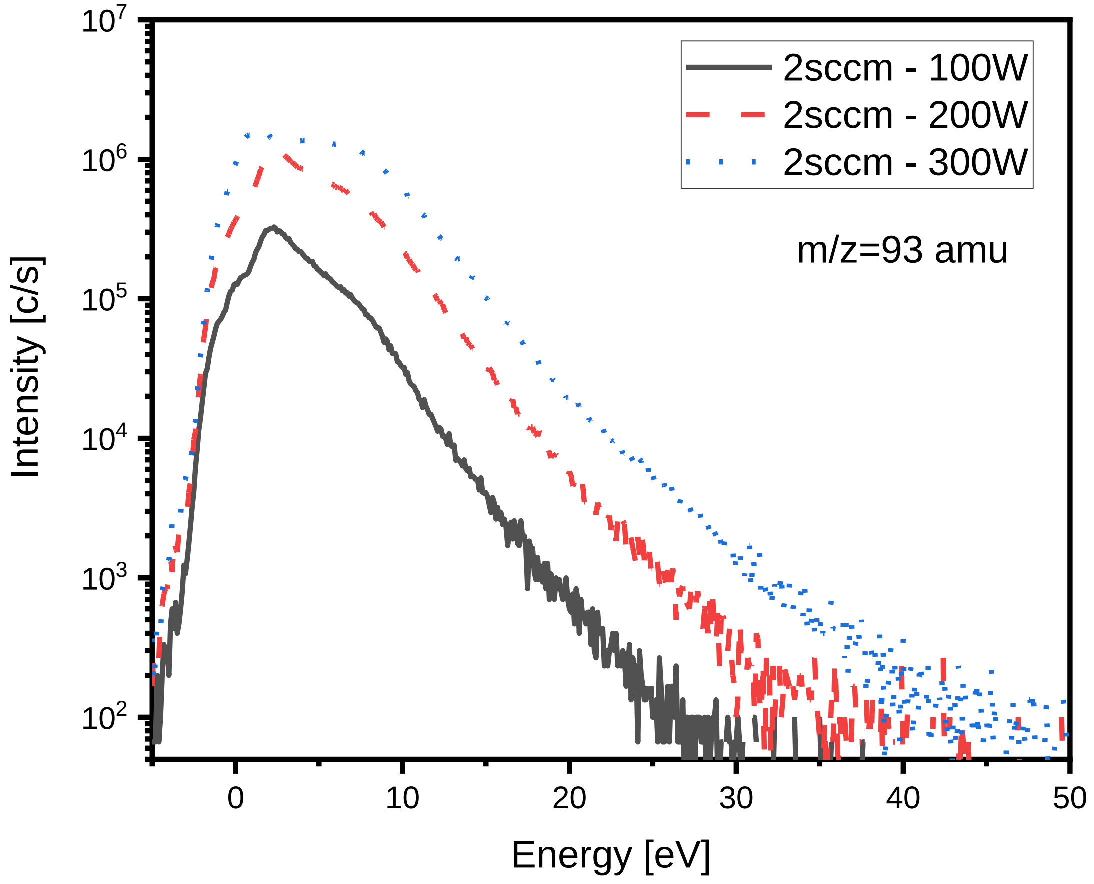


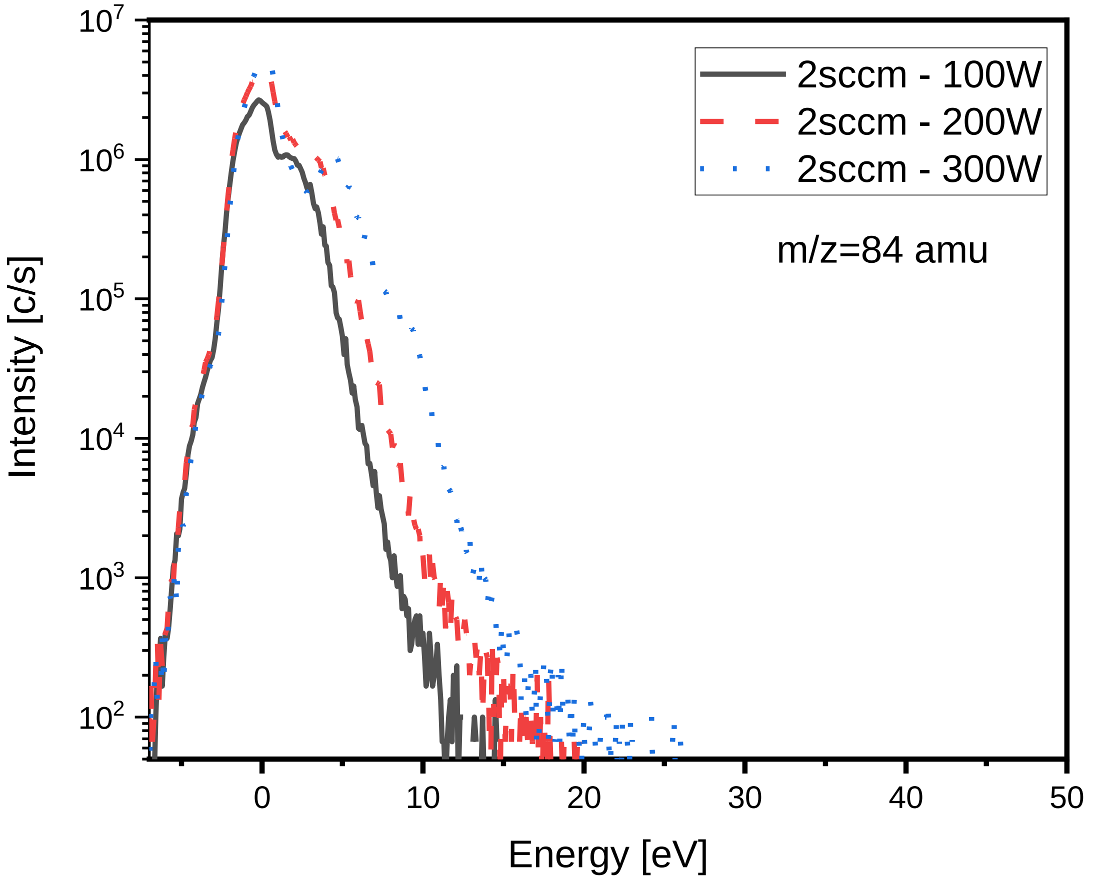
Investigation of NbN: OES for different power conditions

- Overlap of Nb^+, Nb^0, Kr^+, N_2^+ and N_2^0 lines
- Increase of power lead to an increase of line intensity which benefits mainly Nb^+, Nb^0, Kr^+, N_2^+ and N_2^0



Investigation of NbN: IEDF of Nb^+ and Kr^+





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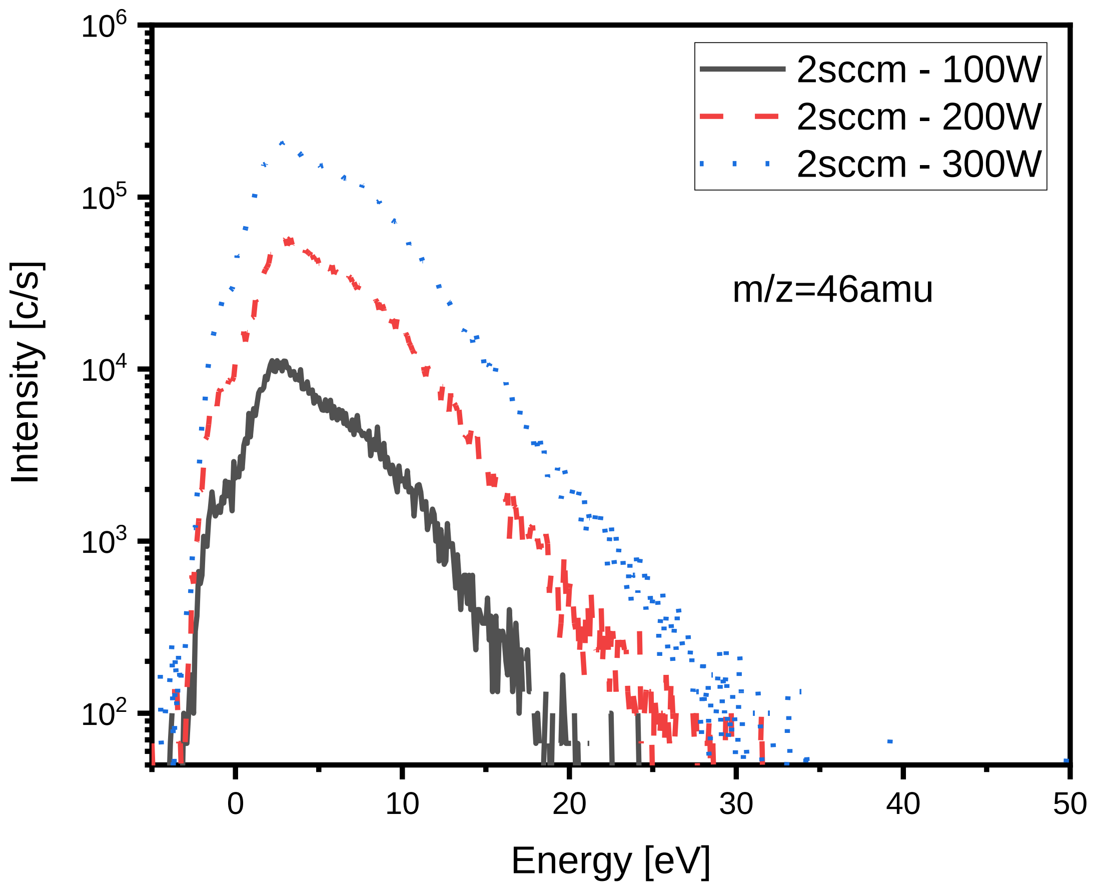
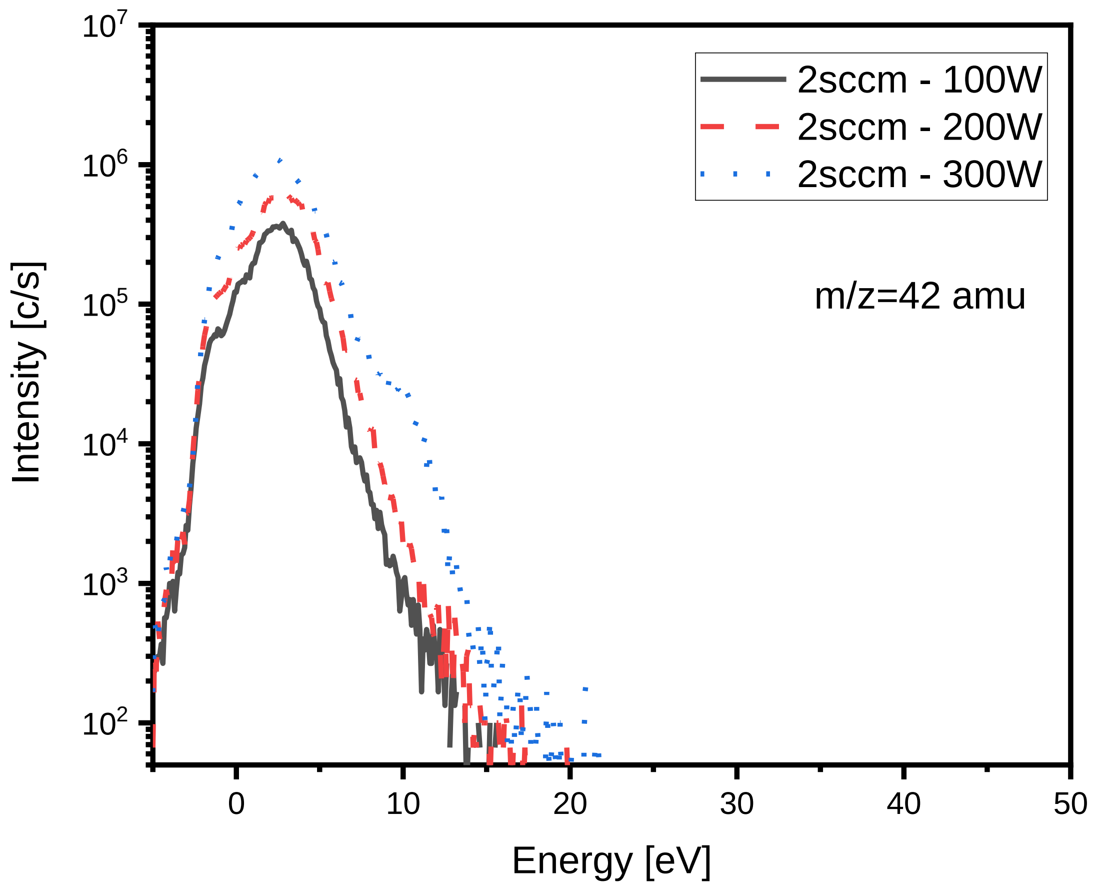
Investigation of NbN: IEDF of Nb^{2+} and Kr^{2+}





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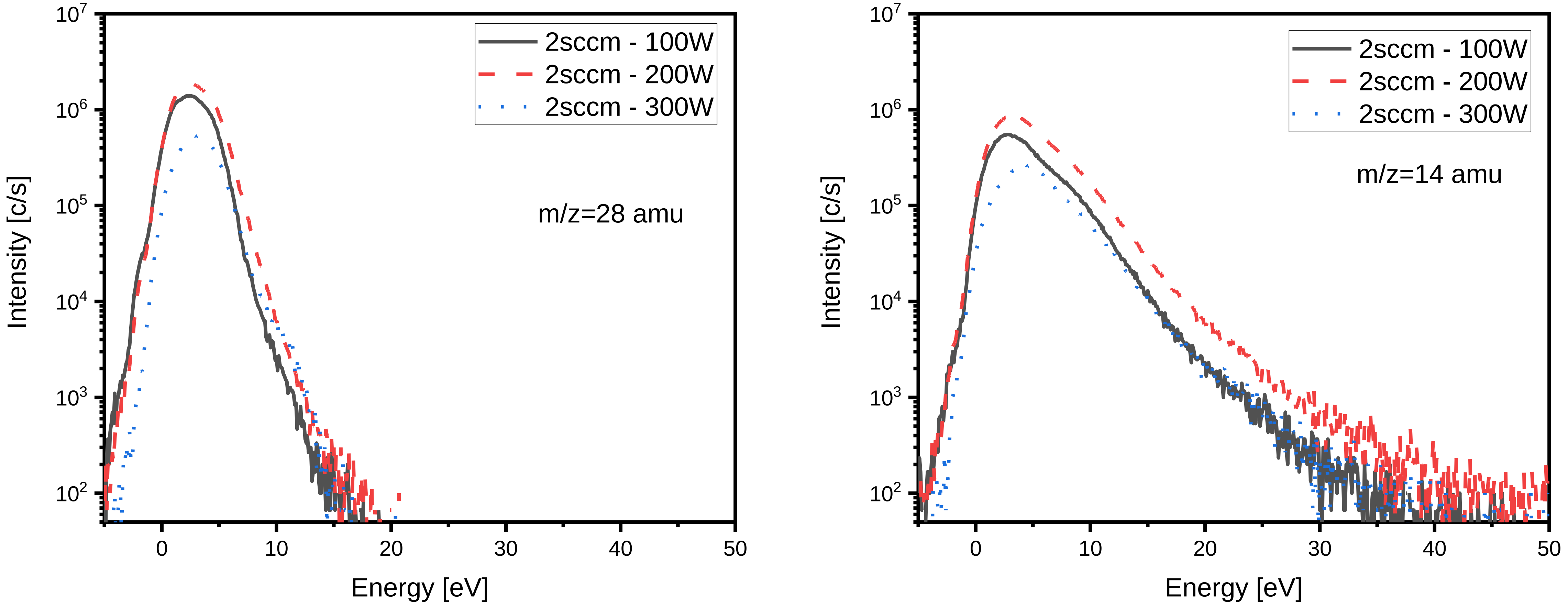
Investigation of NbN: IEDF N_2^+ and N^+



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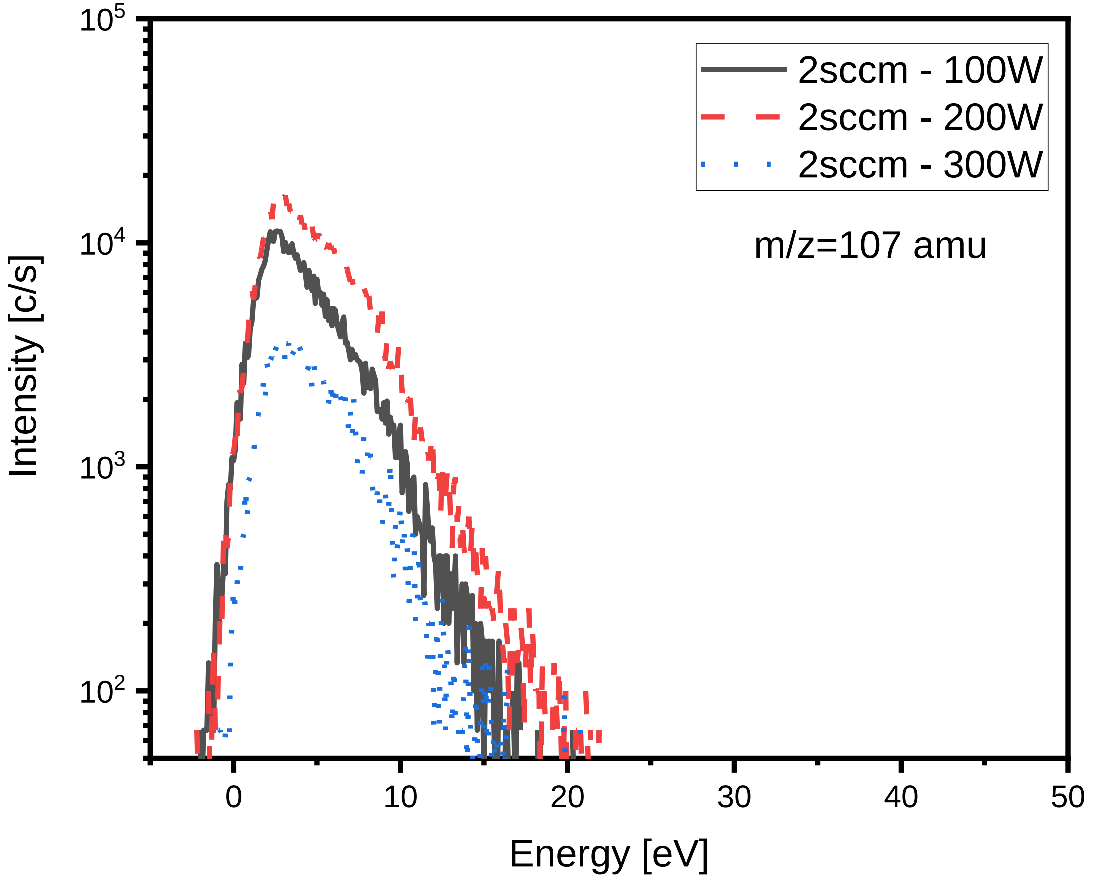
Investigation of NbN: evolution of NbN^+

- 100W and 200W case are roughly similar. 300W seems to increase the intensity of NbO but not NbN.
- System not baked before measurements, oxygen comes mainly from residual water present in the chamber.
- Mass at 56 amu ?



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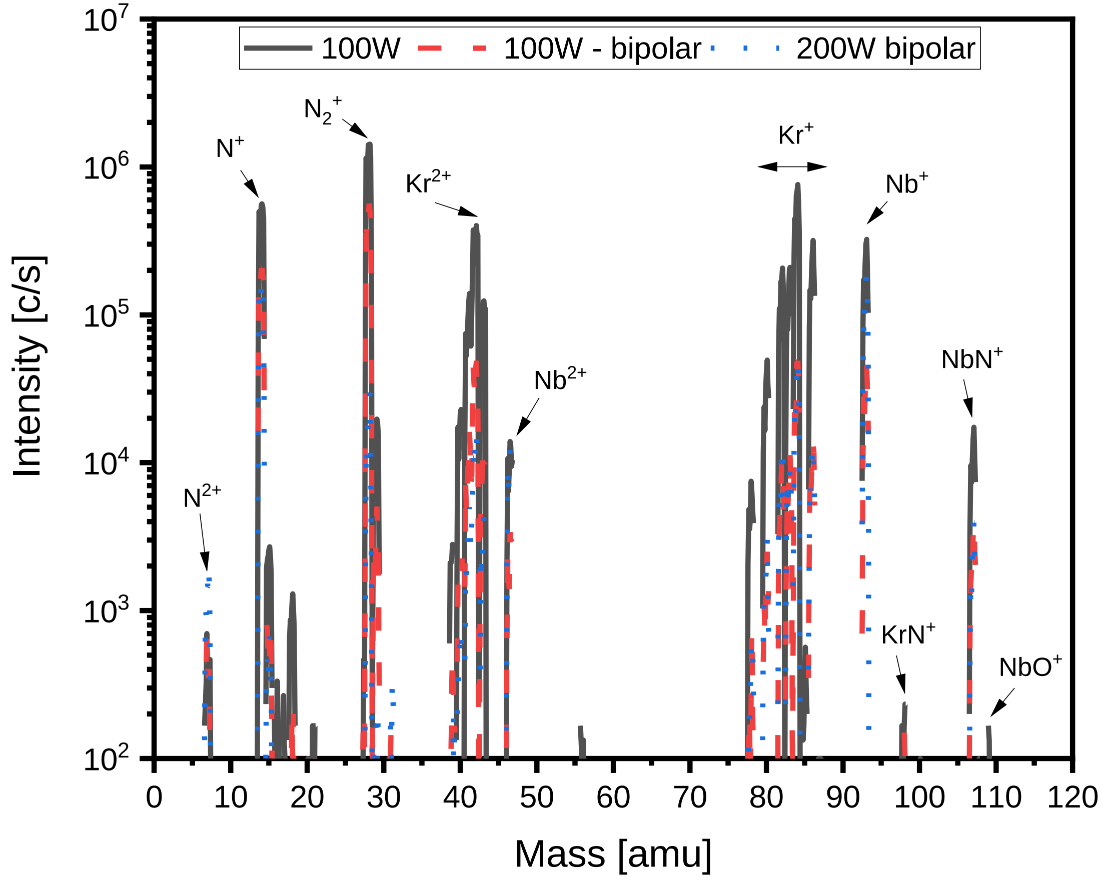
Investigation of NbN: comparison HiPIMS and bipolar HiPIMS

- Comparison between unipolar and bipolar HiPIMS
- For positive kick, pulse width of 200us and U_{pos} set to 25V
- 56 amu drastically reduced, likely to be a contaminant outgassing during the run



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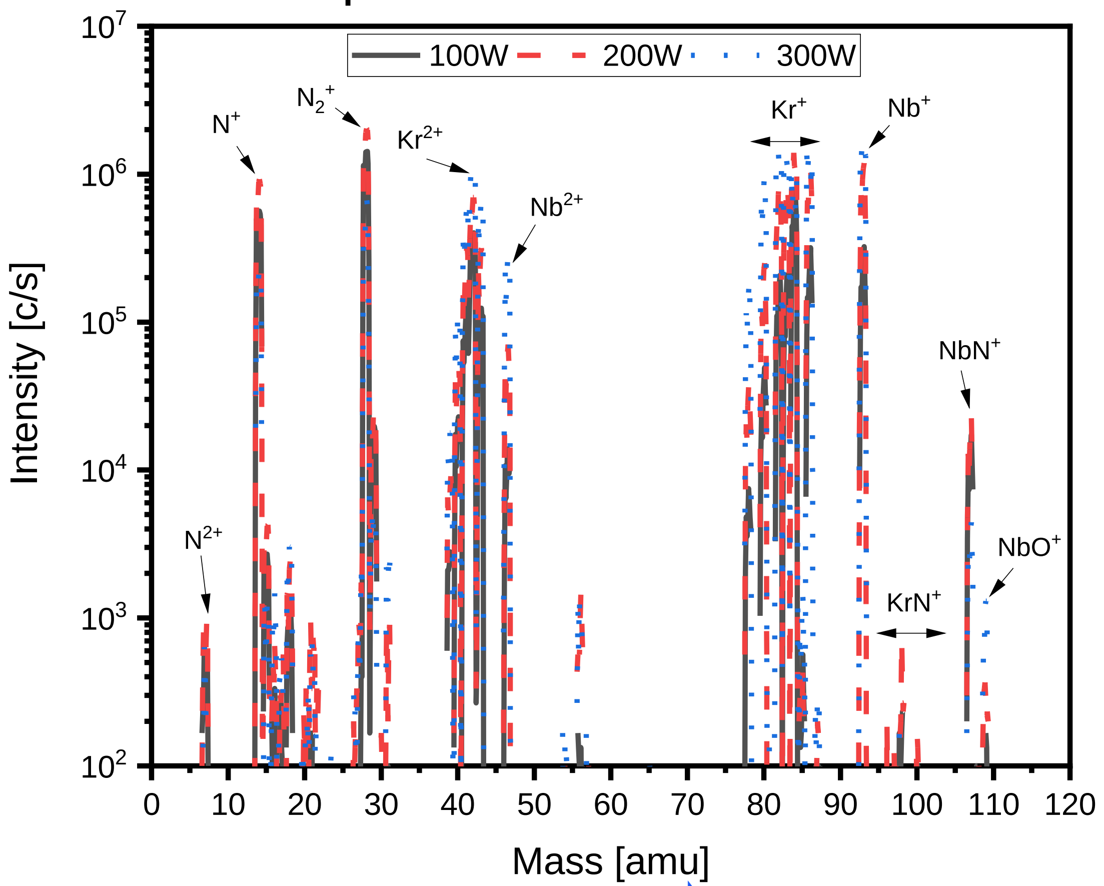
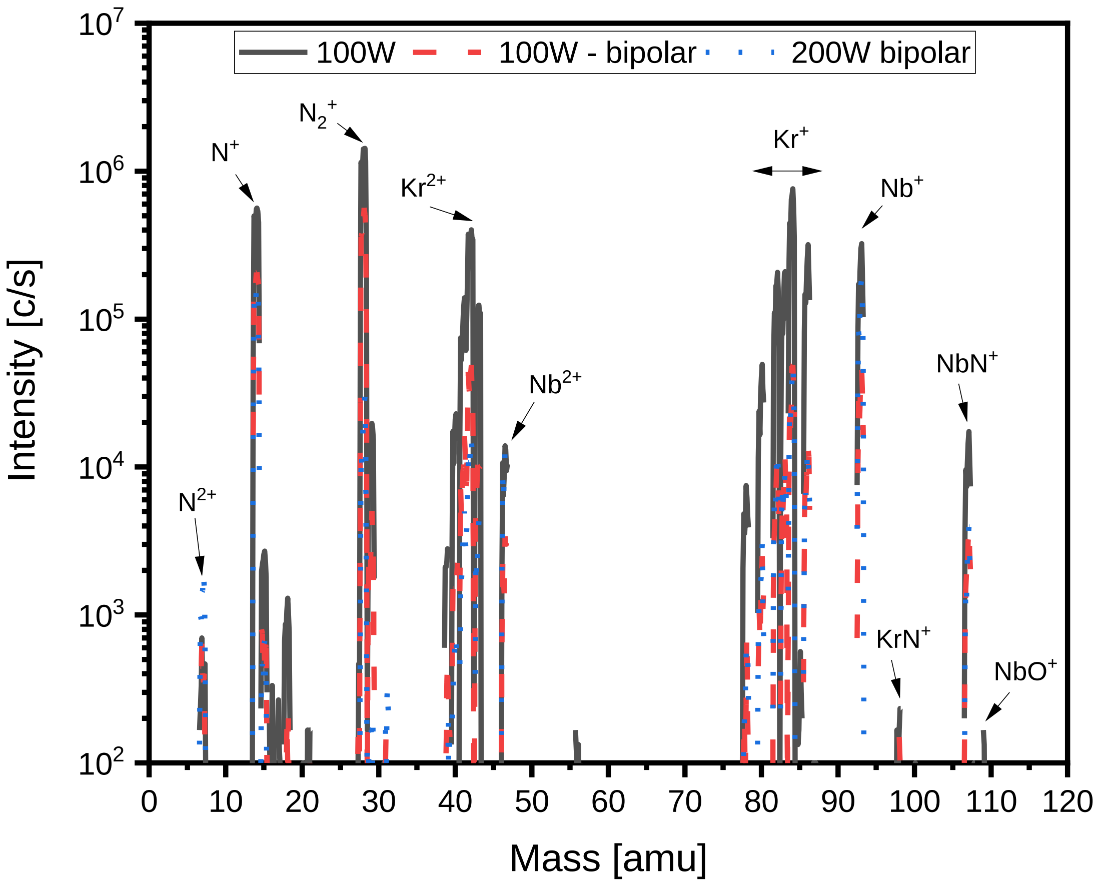
Investigation of NbN: power influence between HiPIMS and bipolar HiPIMS

Unipolar – Power influence



Bipolar – Power influence



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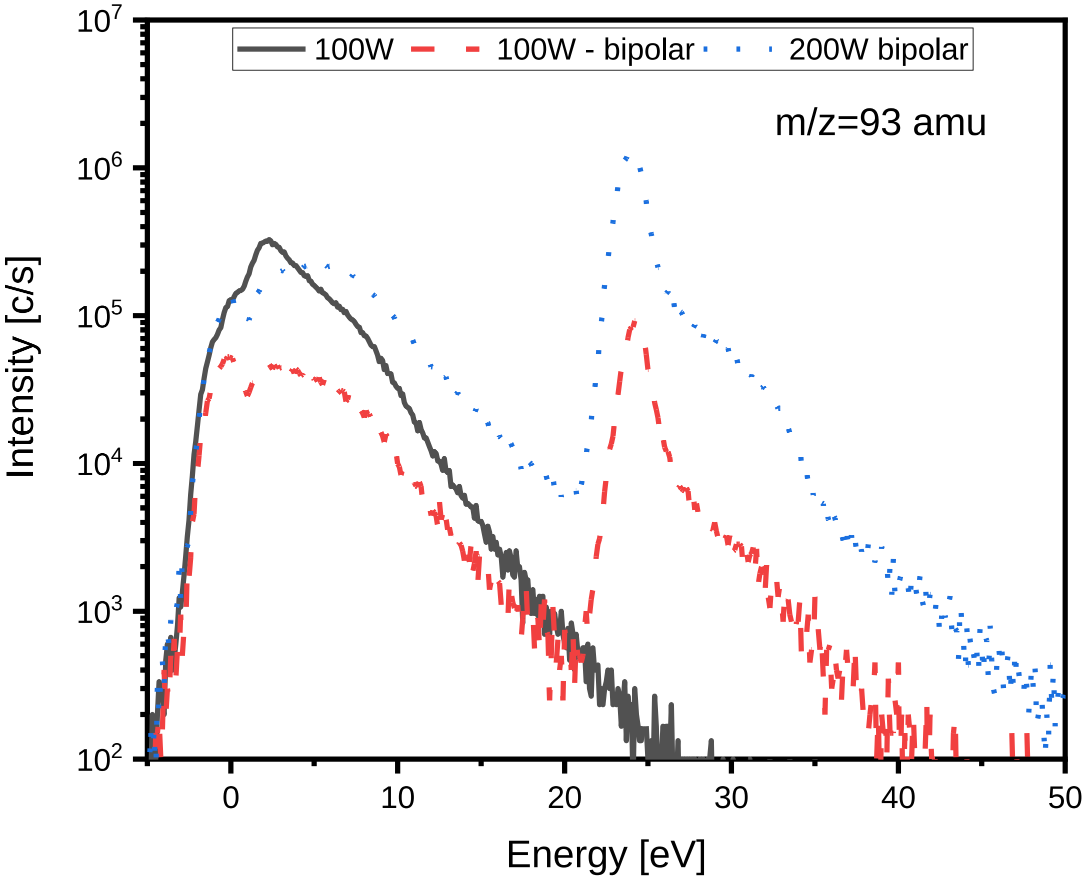
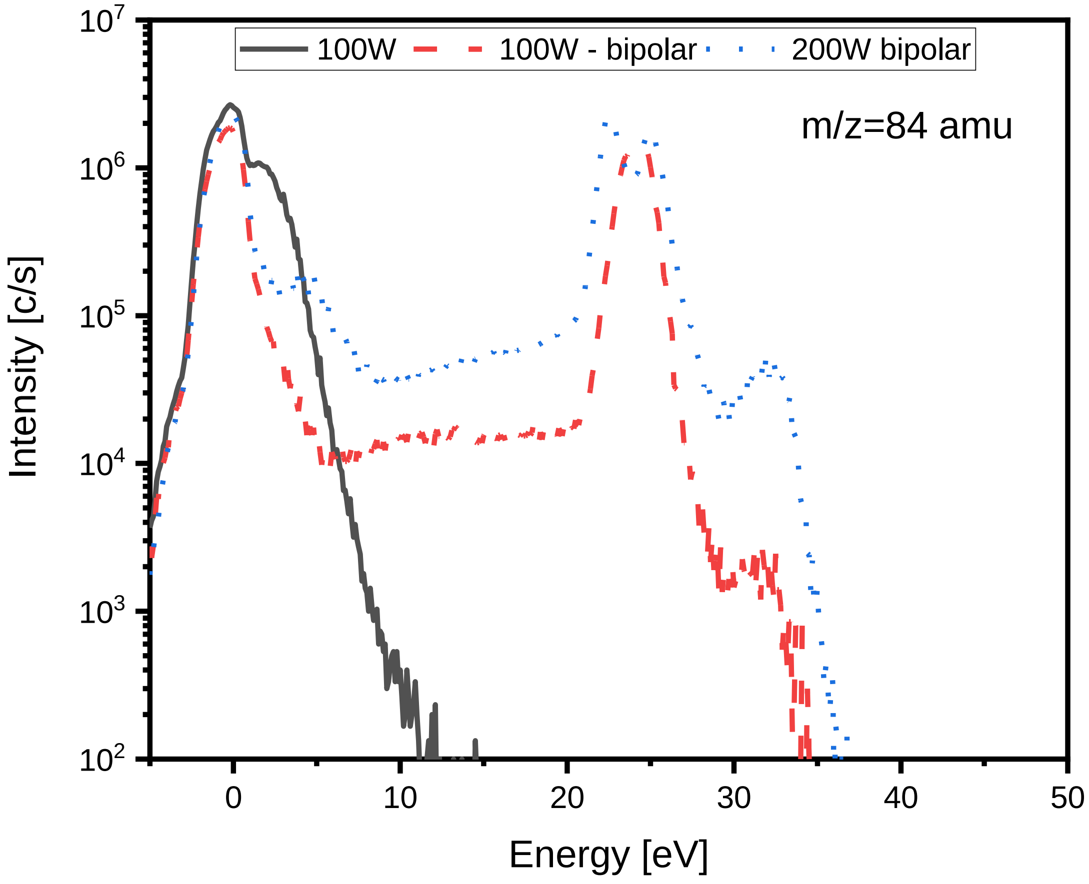
Investigation of NbN: IEDF of Nb^+ and Kr^+





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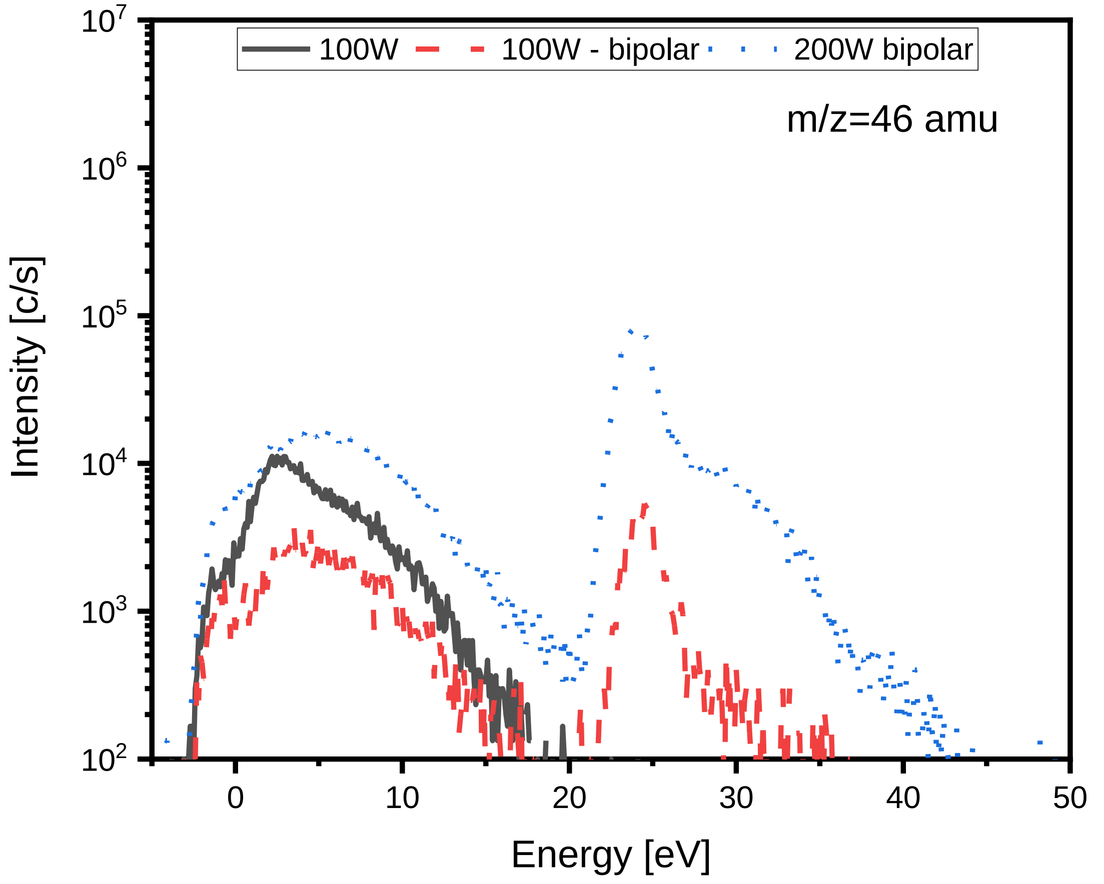
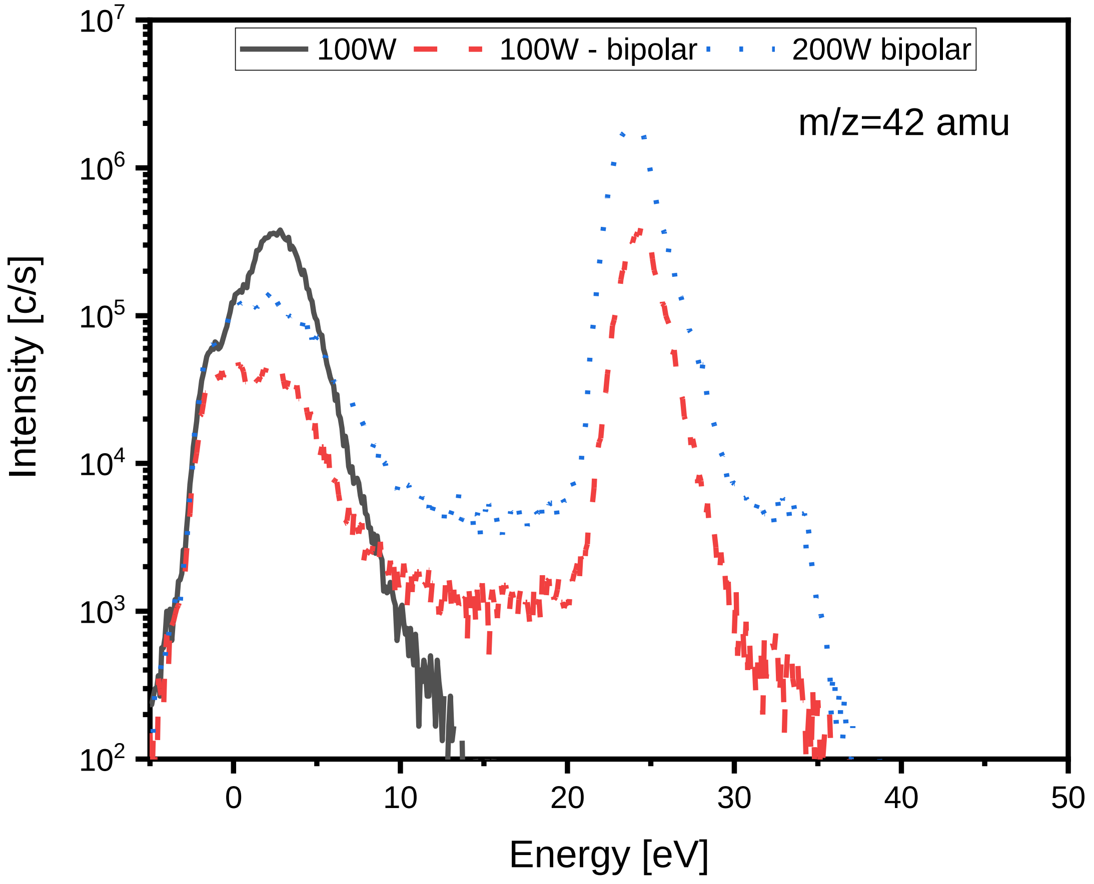
Investigation of NbN: IEDF of Nb^{2+} and Kr^{2+}





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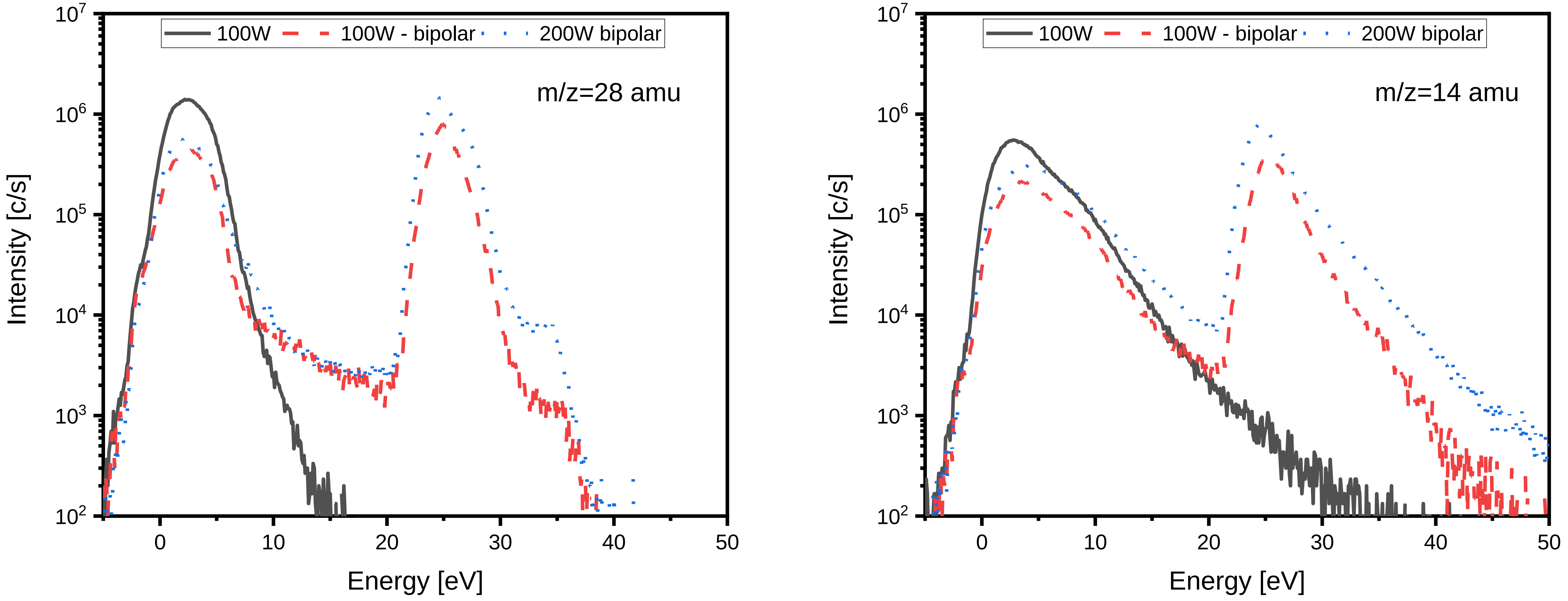
Investigation of NbN: IEDF of N_2^+ and N^+

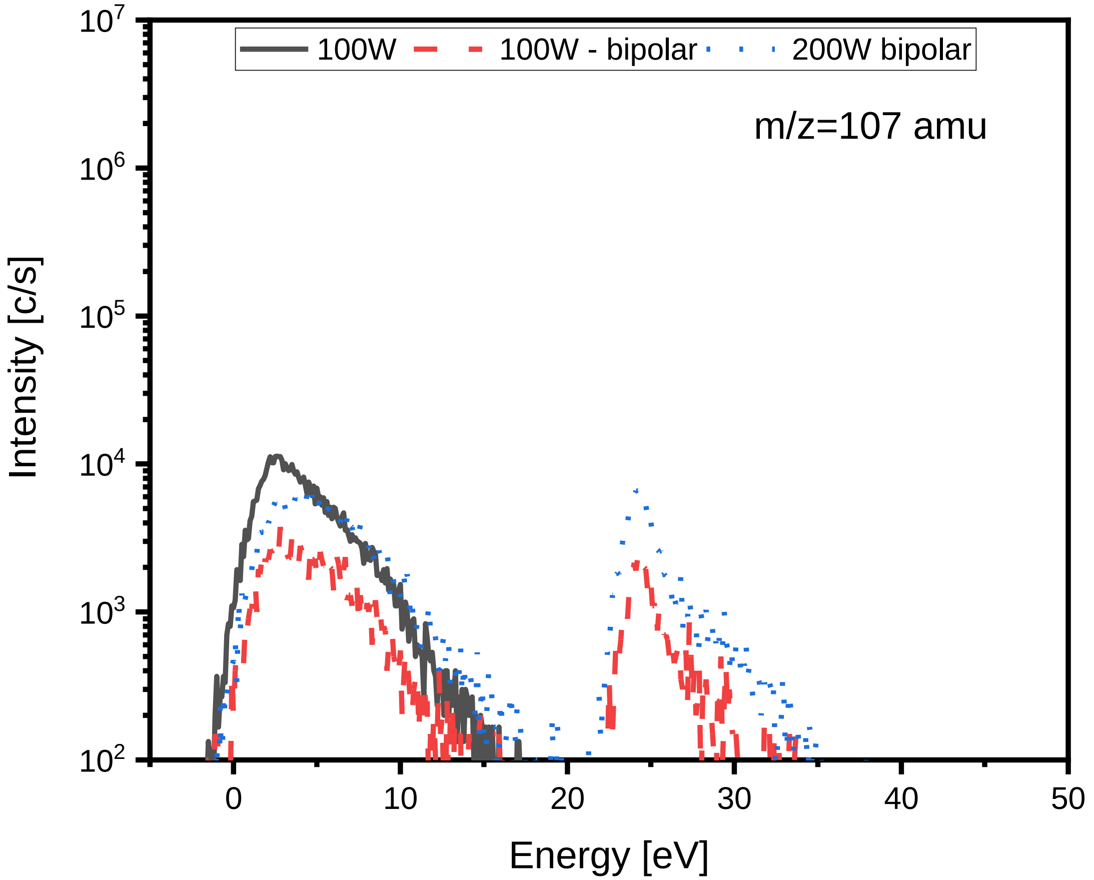


Investigation of NbN: IEDF of NbN^+

- As seen in previous results, initial peak intensity is reduced for the same in put power. Increasing the power balance the peak drop

- Shift according to eU_{pos}

- N_2 follows a similar trend as Kr



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Investigation of NbN: flow rate influence in HiPIMS

- Influence of N_2 flow rate
  - Flow rate: 1, 2, 5, 7 sccm
  - HiPIMS parameters (100us / 1000Hz)

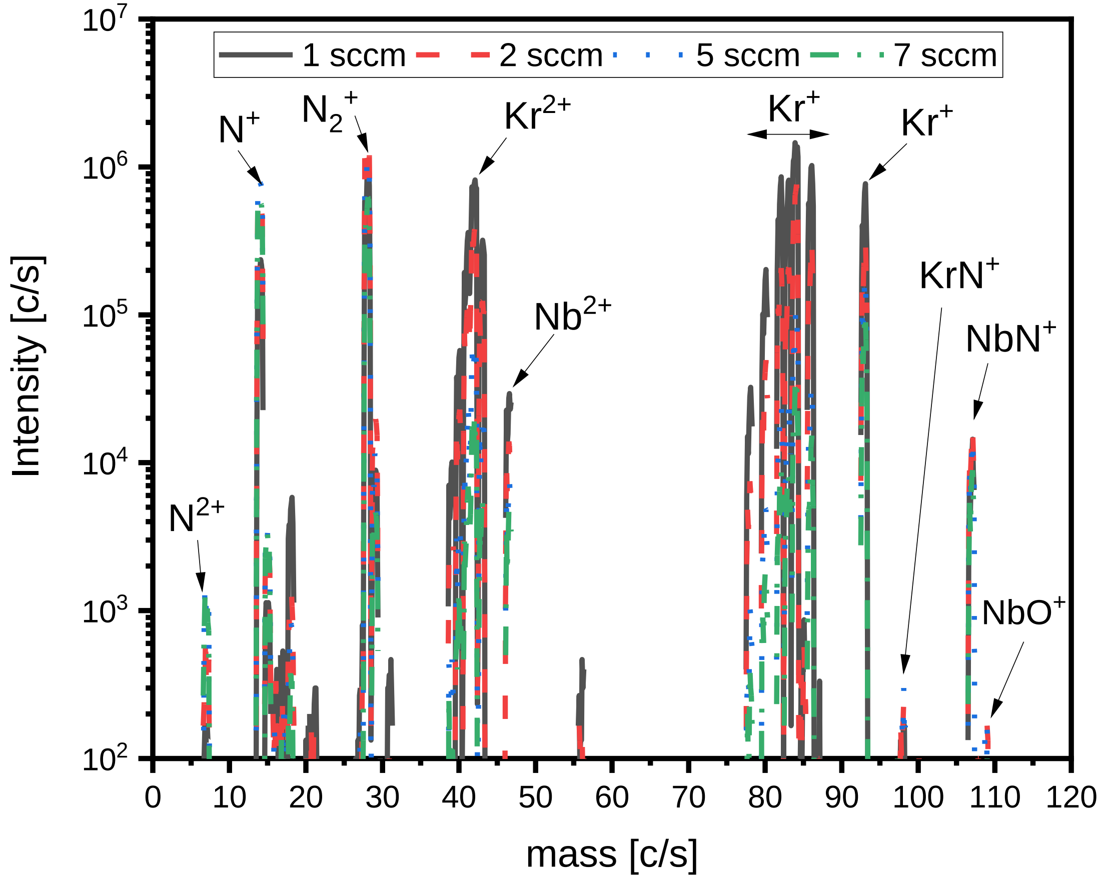
  1 sccm: 595V / 168mA / 10A

  2 sccm: 721V / 139mA / 12A

  5 sccm: 766V / 127mA / 13A

  7 sccm: 806V / 124mA / 13A

  Pressure stabilized at 4×10^{-3} mbar



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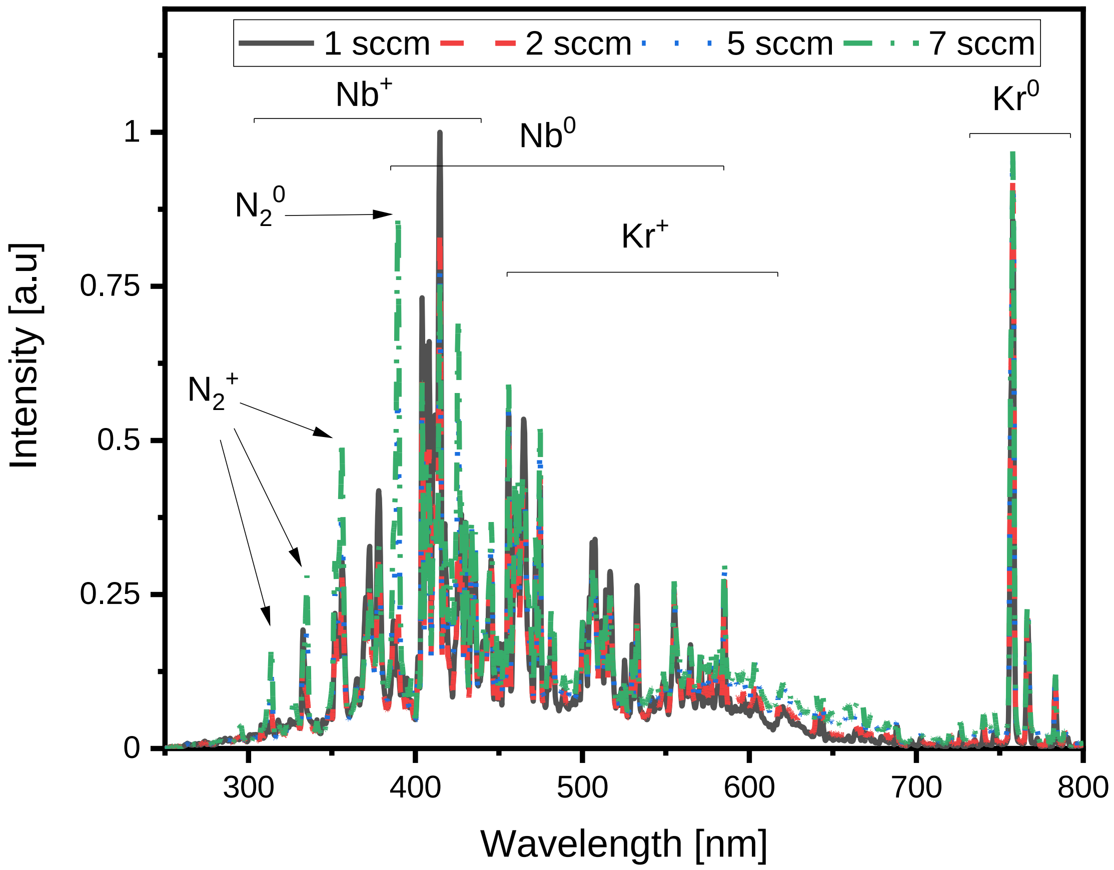
Investigation of NbN: OES at different flow rate

- Overlap of Nb^+, Nb^0, Kr^+, N_2^+ and N_2^0 lines
- Increase of flow rate promote N_2^+ and N_2^0
- Impact on Nb^+ and Nb^0 lines intensity also observed by mass spectrometry



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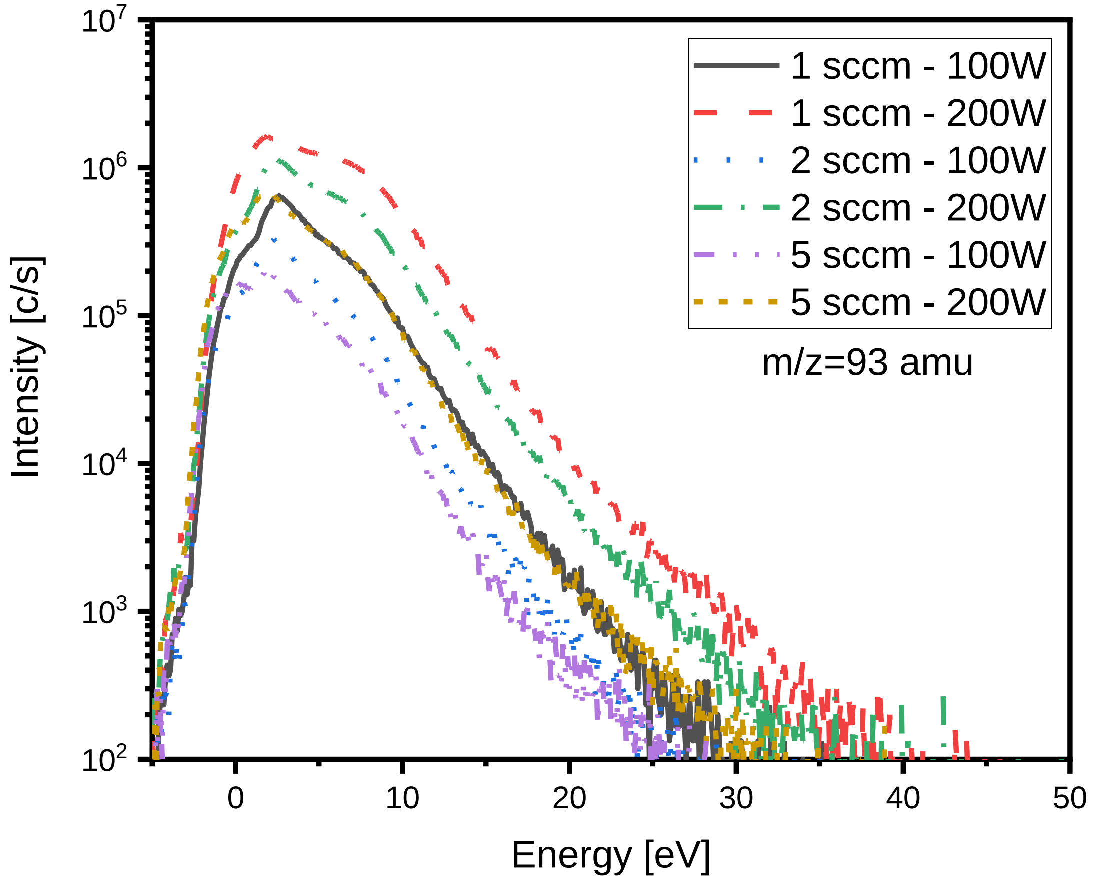
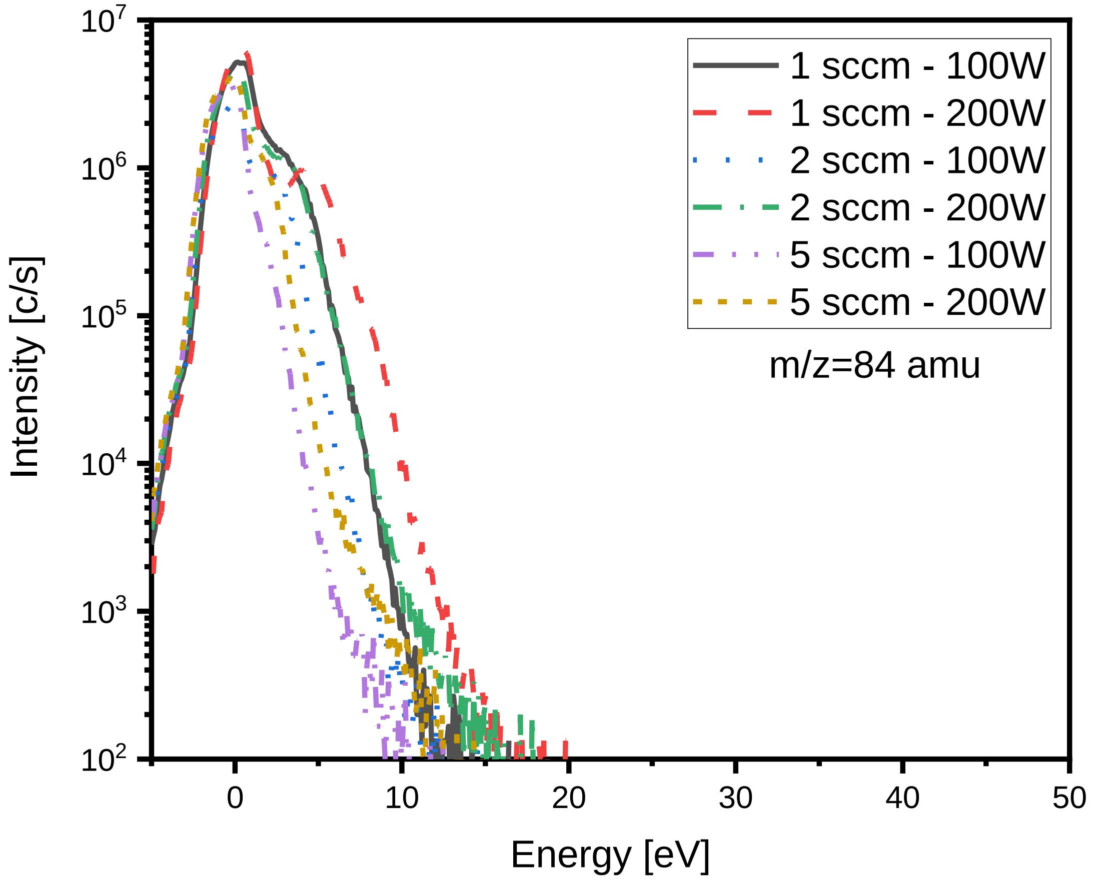
Investigation of NbN: IEDF of Nb^+ and Kr^+





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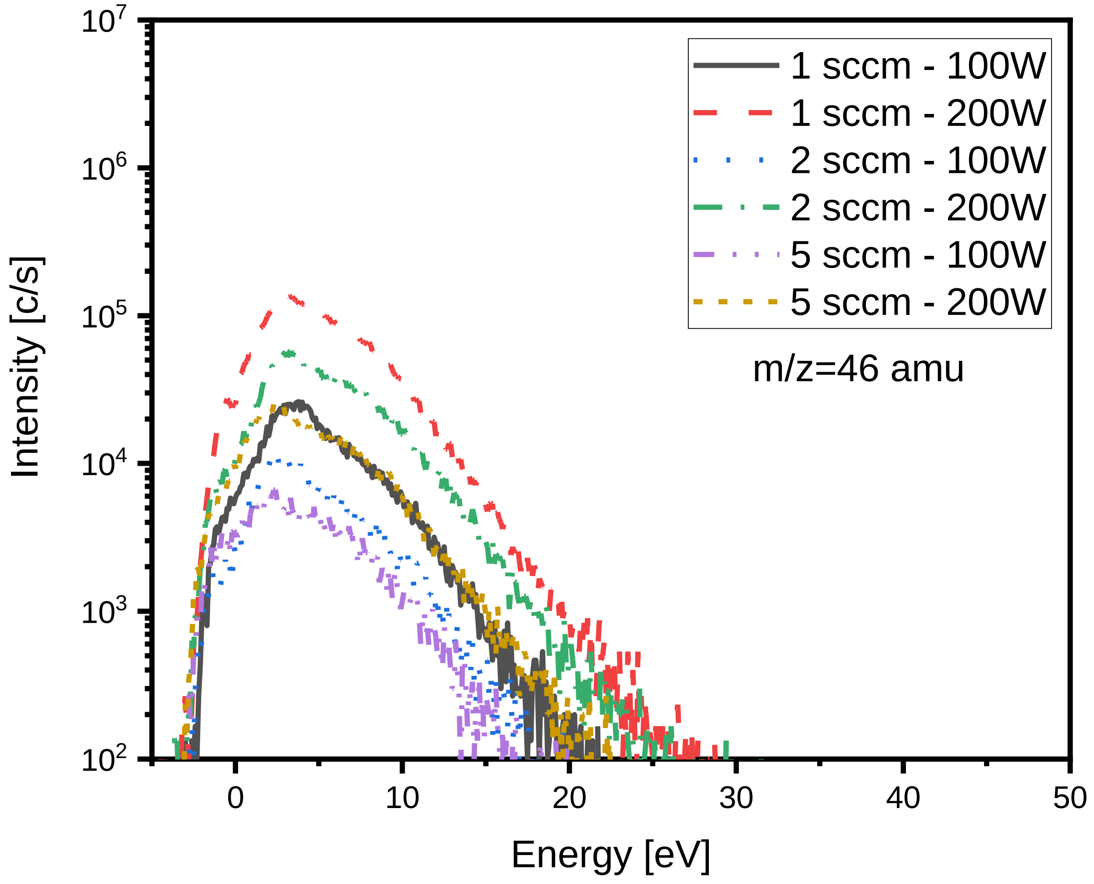
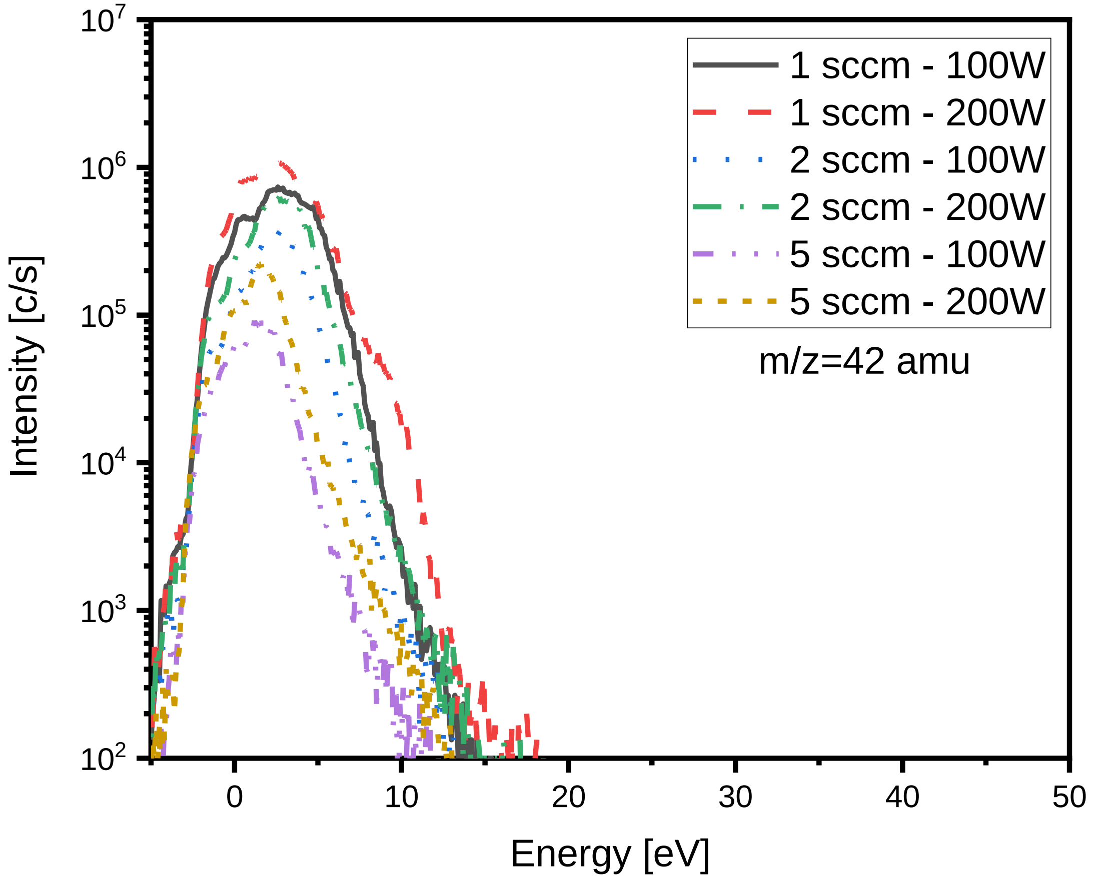
Investigation of NbN: IEDF of Nb^{2+} and Kr^{2+}





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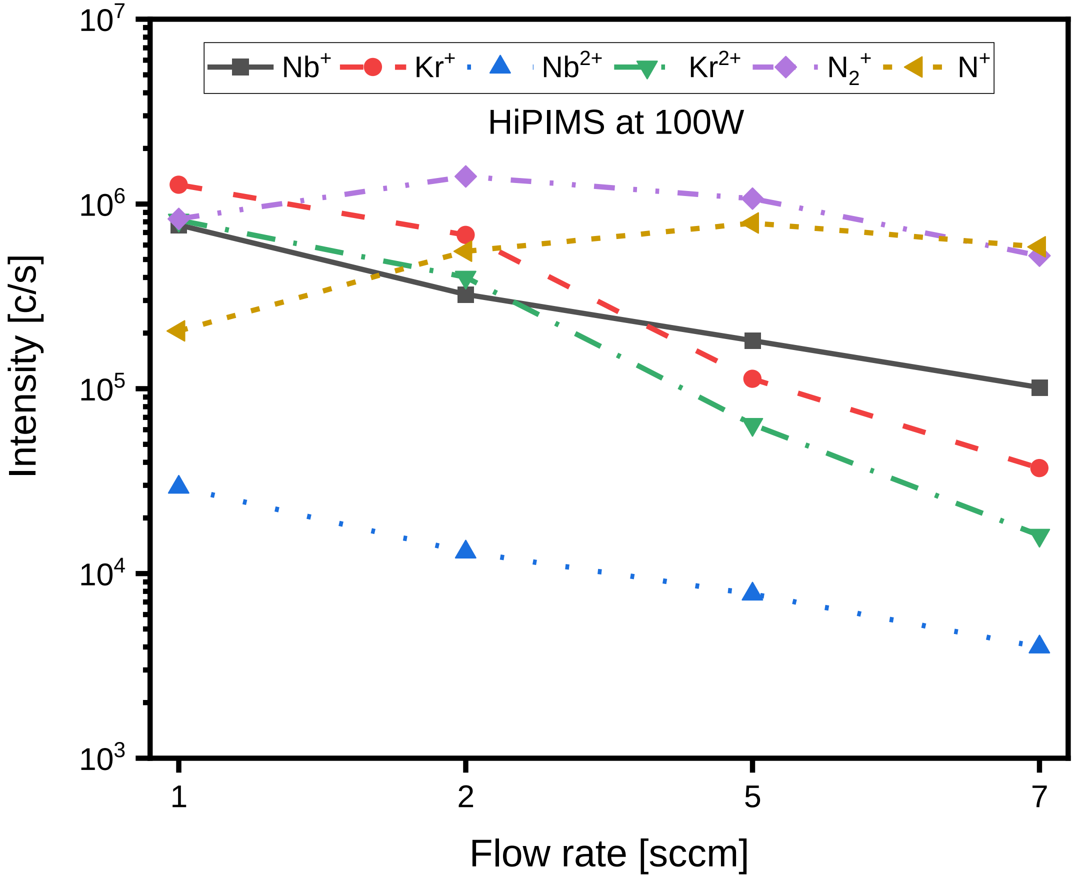
Investigation of NbN: summary

- N_2 flow rate plays a crucial role for the formation of NbN
- Similar studies using Ar or Kr reported that low flow rate was favoured for the production of NbN thin films
- Increase of N_2, reduces ion intensity and peak energy
- Correlation between flow rate and power



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Future work

- Deposition of NbN on Cu samples using results obtained. Focus mainly on HiPIMS and bipolar HiPIMS
- Investigation of NbTiN using similar parameters as NbN
- Investigation on other HiPIMS properties to improve film quality
- Complementary investigation using Langmuir probe to get plasma properties

Acknowledgements

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