Time-Dependent Modeling of Laboratory Photoionized Plasmas

University of Nevada, Reno

Jeffrey Rowland, Roberto Mancini
University of Nevada, Reno

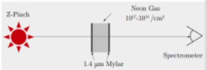
University of Nevada, Reno

Motivation

- Our understanding of the universe is largely based on the spectroscopic interpretation of astronomical observations
- We need to test our interpretations in controlled laboratory experiments

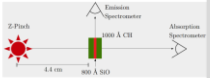
Neon Gas Cell:

- Predominantly K-shell Ne ions
- Temperature measured via line ratio method[2]
  - T_e=26 ± 5 eV



SiO Tamped Foil:

- Predominantly L-shell Si ions
- Temperature measured via line ratio method[1]
  - T_e=33 ± 7 eV



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- Our first efforts to benchmark astrophysical codes used a steady state physics model
- Significantly overestimates the measured T_e
- Latest versions have reduced the error
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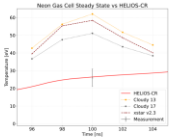
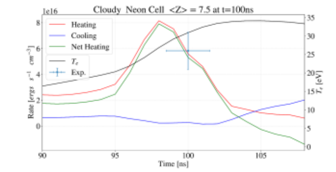


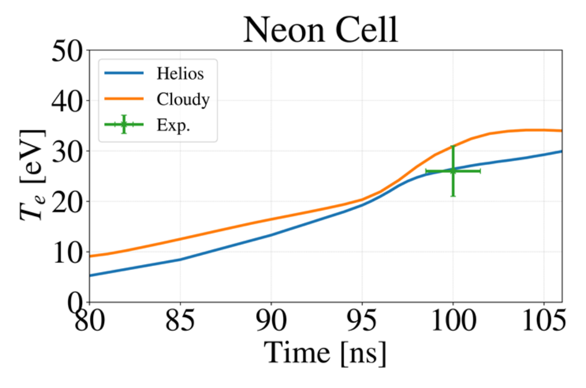
Method:

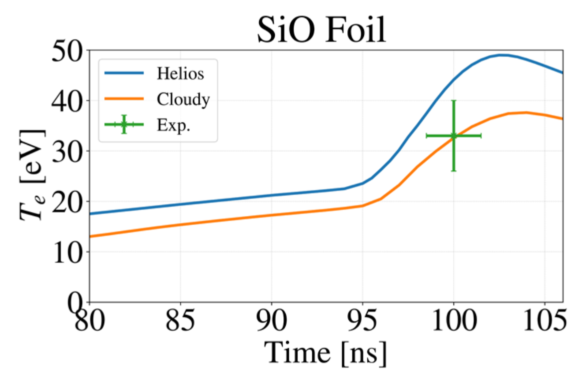
- The incident radiation was modeled with the view factor code VISRAD[5] constrained by x-ray power, pinch size, & source brightness
  - We propagate this radiation through the window material with HeliosCR to get the drive for the Ne/SiO slab in our Cloudy model
- Time history of the radiation drive is handled with a multiplicative scale factor
  - Cloudy does not allow changes to the spectral distribution between timesteps
    - Smallest timesteps available are 1ns
- We have chosen the spectral distribution at the peak of the x-ray drive (t=100ns) and scaled it to match the spectrally integrated intensity at each timestep

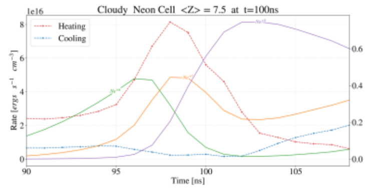


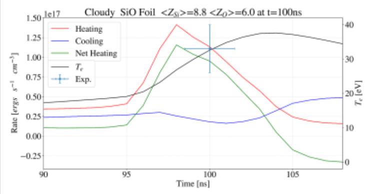
- We report recent efforts to apply the new time-dependent capability of Cloudy[6] to two photoionized plasma experiments performed at the Z machine at Sandia National Laboratory. [1,2,3]
- We plot the results alongside a full radiation-hydrodynamic simulation performed with Helios-CR[4]
- Time-dependent models demonstrate a significant improvement over steady state

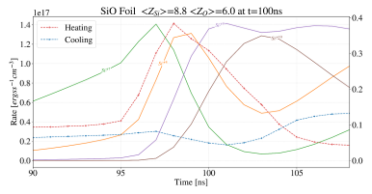
Experiment	Measurement	Steady State	Time Dependent
Neon Cell[2,3]	T_e = 26 ± 5 eV	T_e = 51 eV	T_e = 30.8 eV
SiO Foil[1]	T_e = 33 ± 7 eV	T_e = 53 eV	T_e = 32.6 eV











References

1. G. P. Loisel, J. E. Bailey,1 D. A. Liedahl, C. J. Fontes, T. R. Kallman, T. Nagayama, S. B. Hansen, G. A. Rochau, R. C. Mancini, and R. W. Lee. Phys. Rev. Letters **119**, 075001 (2017)
2. R. C. Mancini, T. E. Lockard, D. C. Mayes, I. M. Hall, G. P. Loisel, J. E. Bailey, G. A. Rochau, J. Abdallah, I. E. Golovkin, and D. Liedahl. Phys. Rev. E **101**, 051201(R) (2020).
3. D. C. Mayes ,R. C. Mancini ,T. E. Lockard, I. M. Hall, J. E. Bailey, G. P. Loisel, T. Nagayama, G. A. Rochau, and D. A. Liedahl. Phys. Rev. E **104**, 035202 (2021)
4. J. J. MacFarlane, I. E. Golovkin, and P. R. Woodruff, J. Quant. Spectrosc. Radiat. Transfer 99, 381 (2006).
5. J. J. MacFarlane, J. Quant. Spectrosc. Radiat. Transfer 81, 287 (2003).
6. Ferland, G. J., "The 2017 Release Cloudy", *Revista Mexicana de Astronomia y Astrofisica*, vol. 53, pp. 385–438, 2017.

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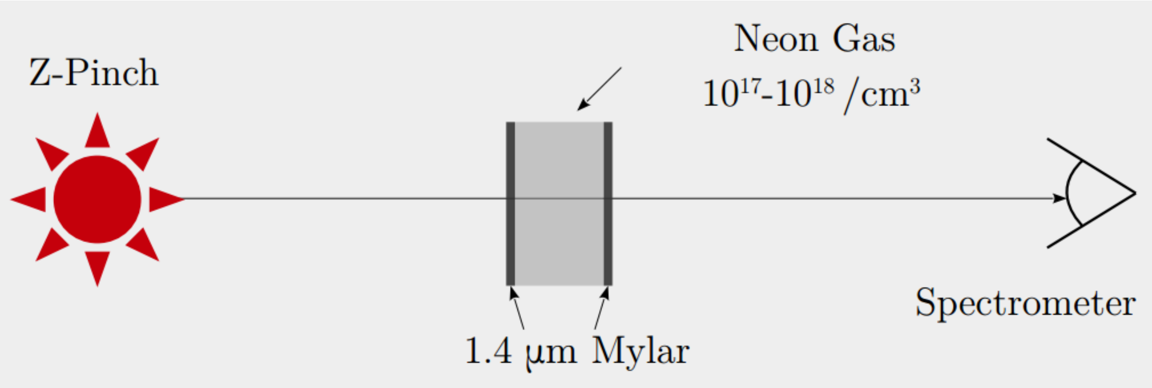

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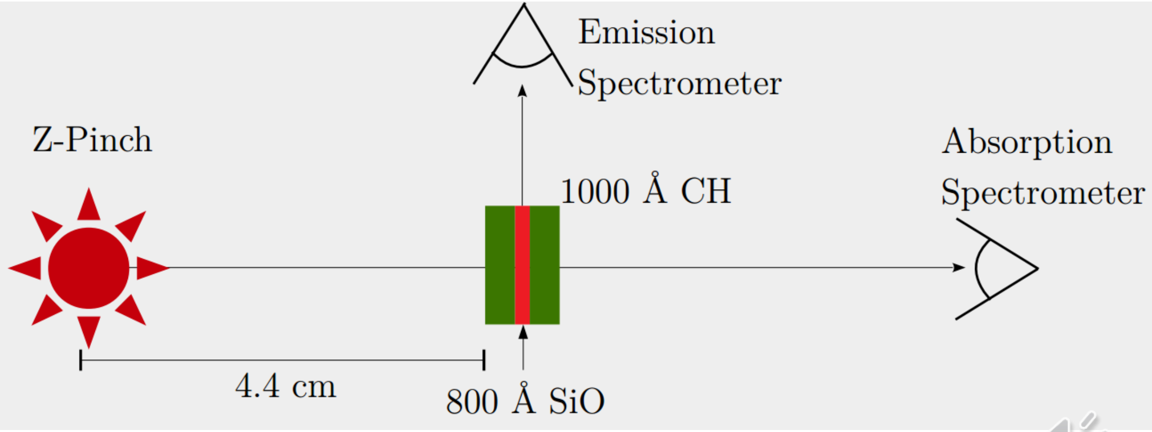

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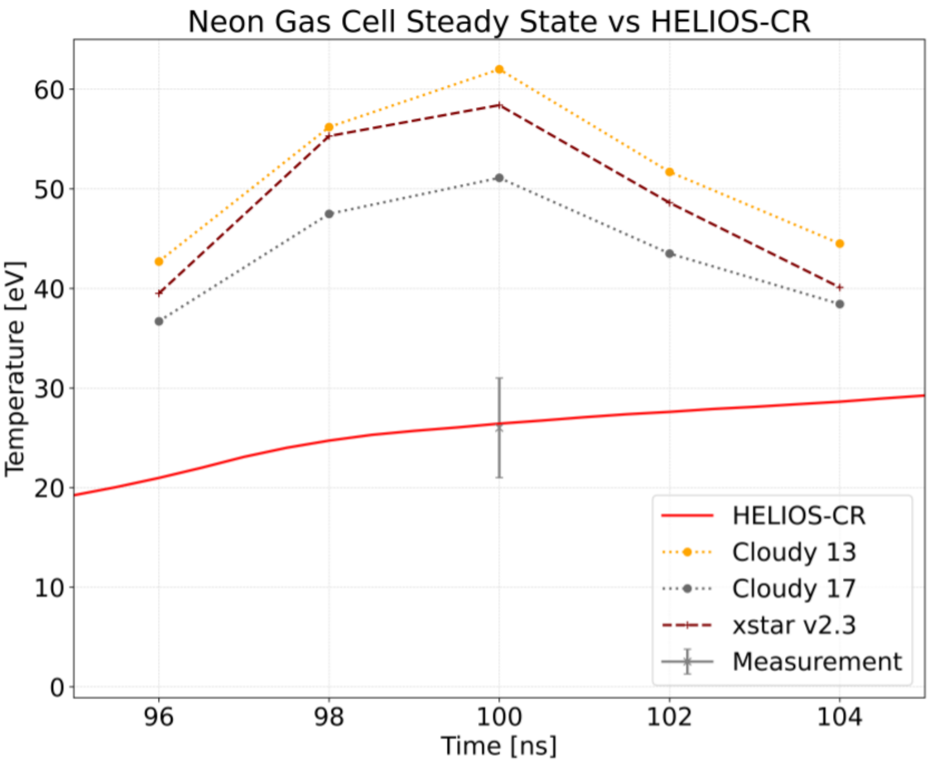

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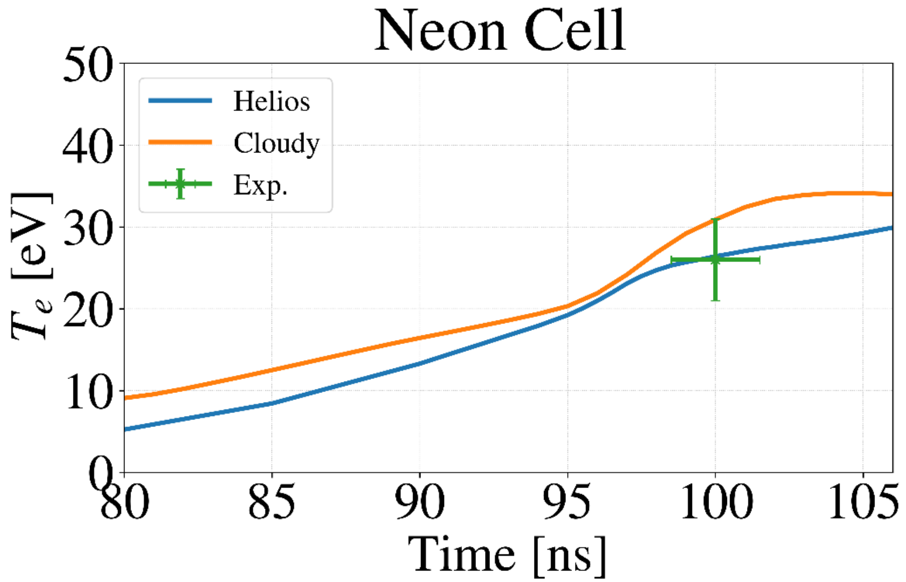
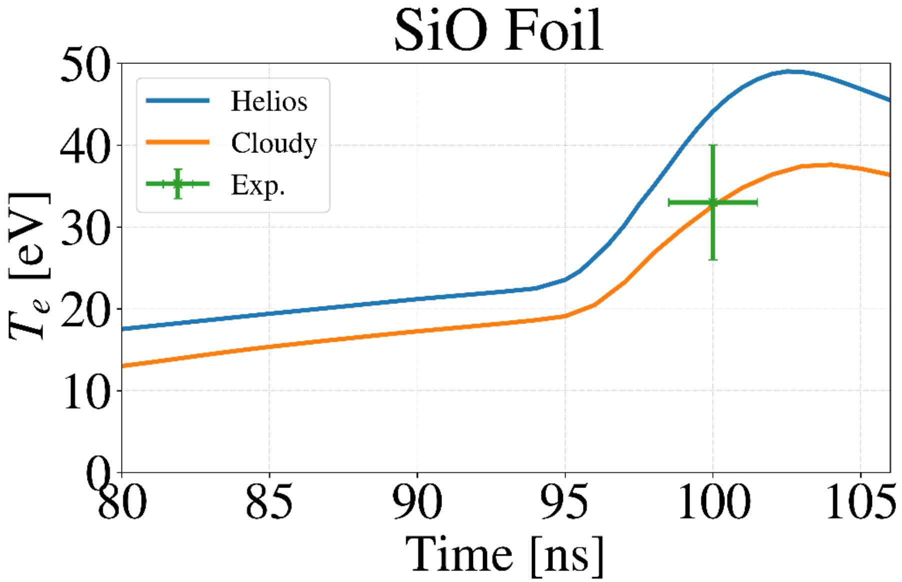
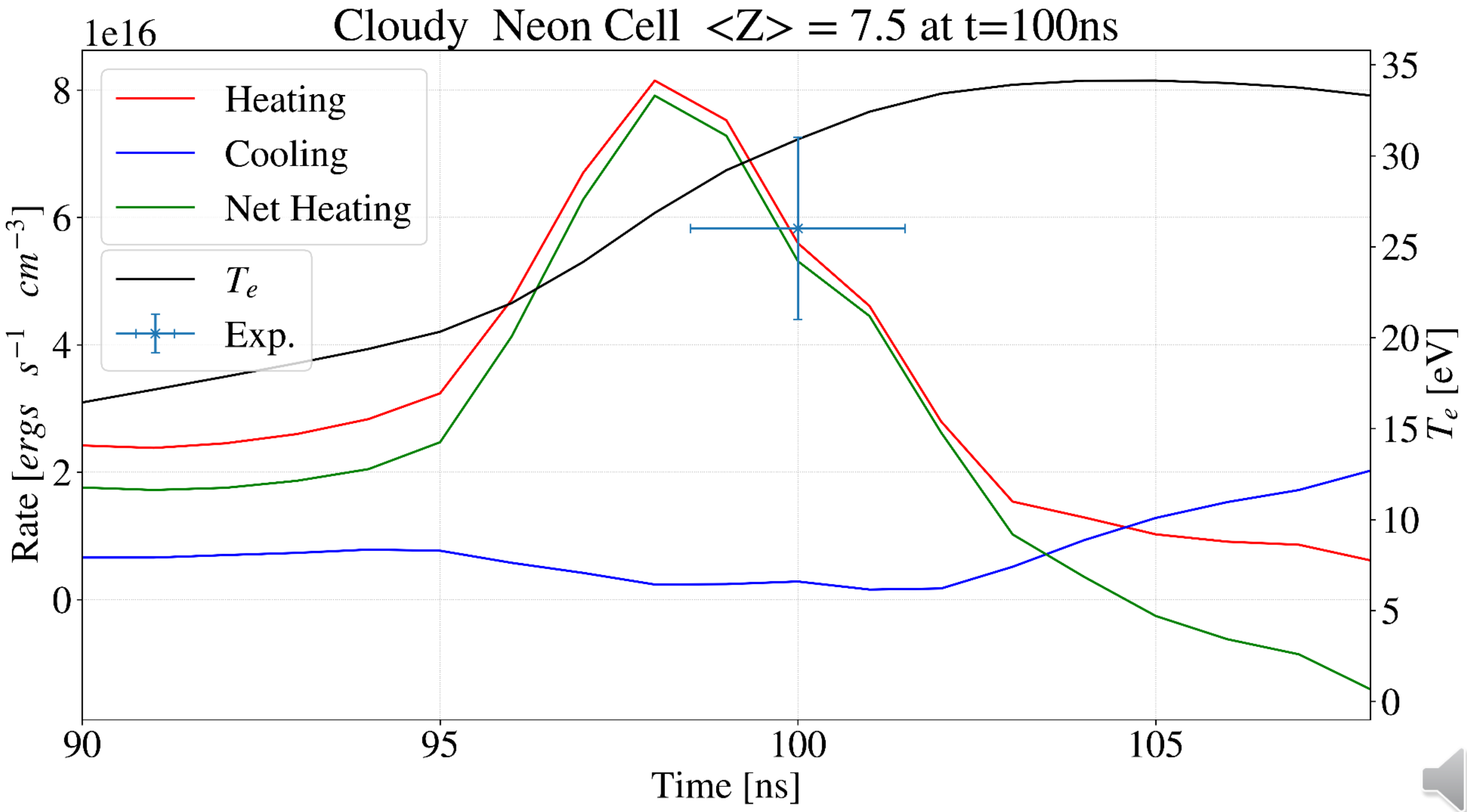
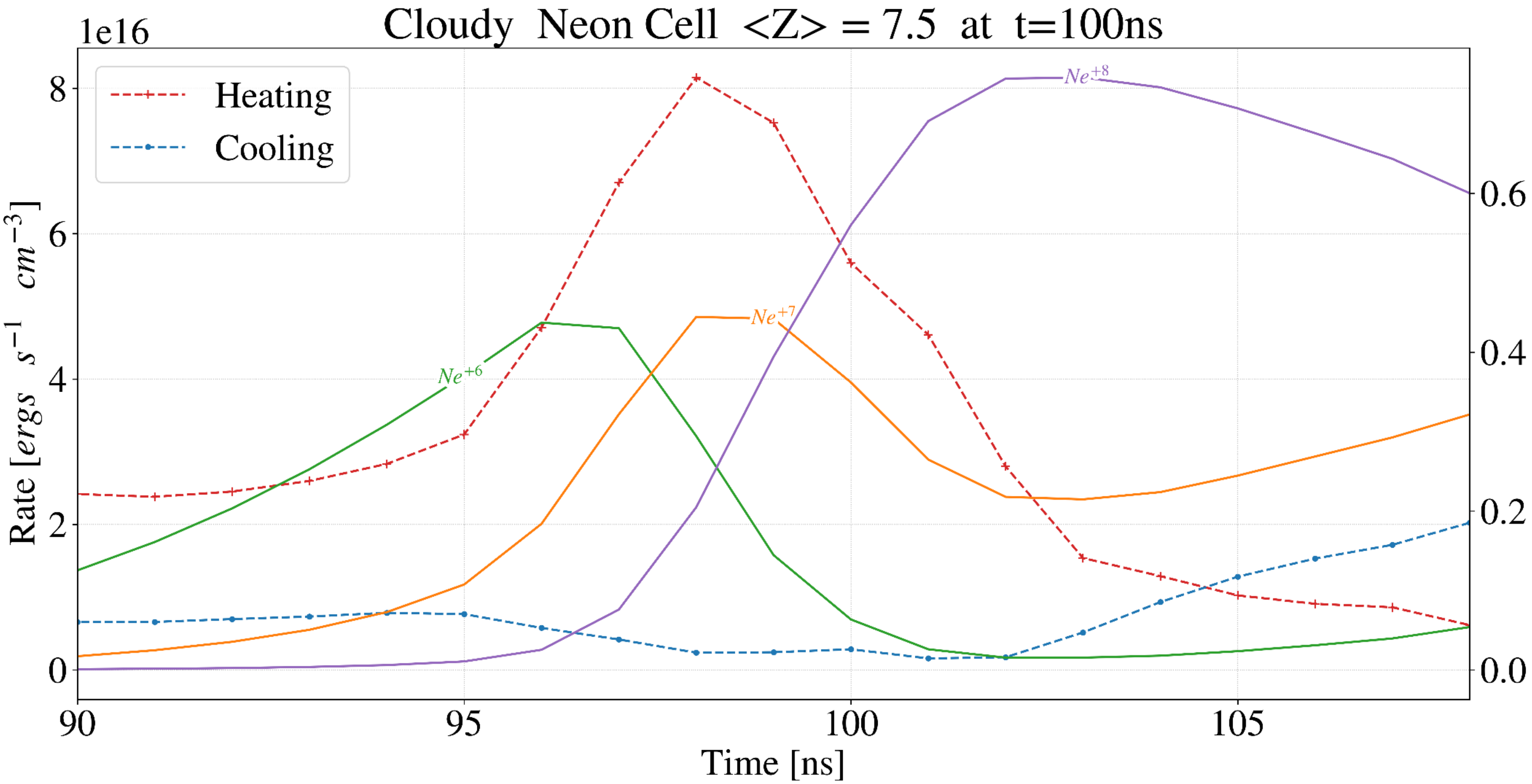
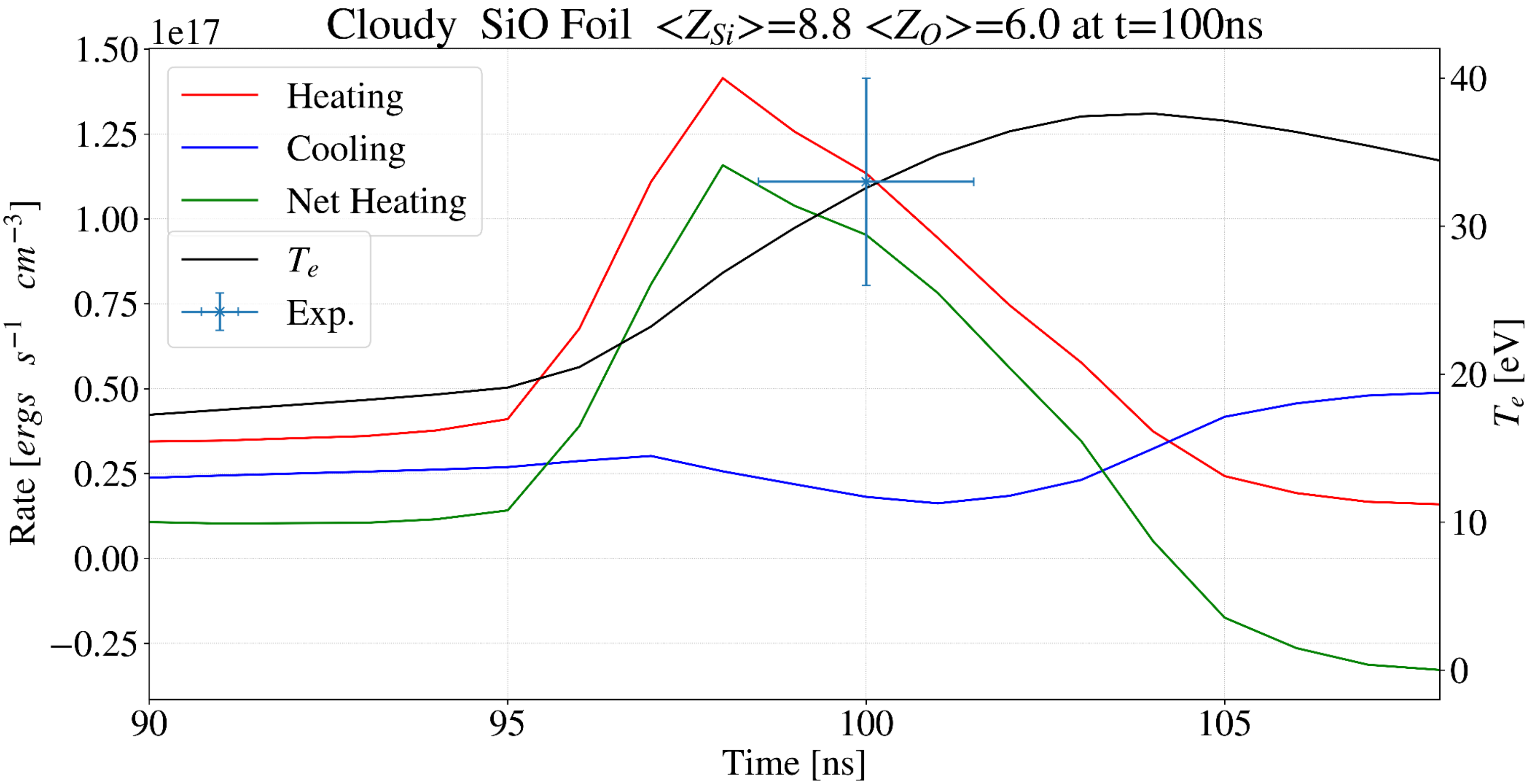

Neon Cell
Helios
Cloudy
Exp.
T_e [eV]
Time [ns]
0
10
20
30
40
50
80
85
90
95
100
105


SiO Foil
Helios
Cloudy
Exp.
T_e [eV]
Time [ns]
0
10
20
30
40
50
80
85
90
95
100
105

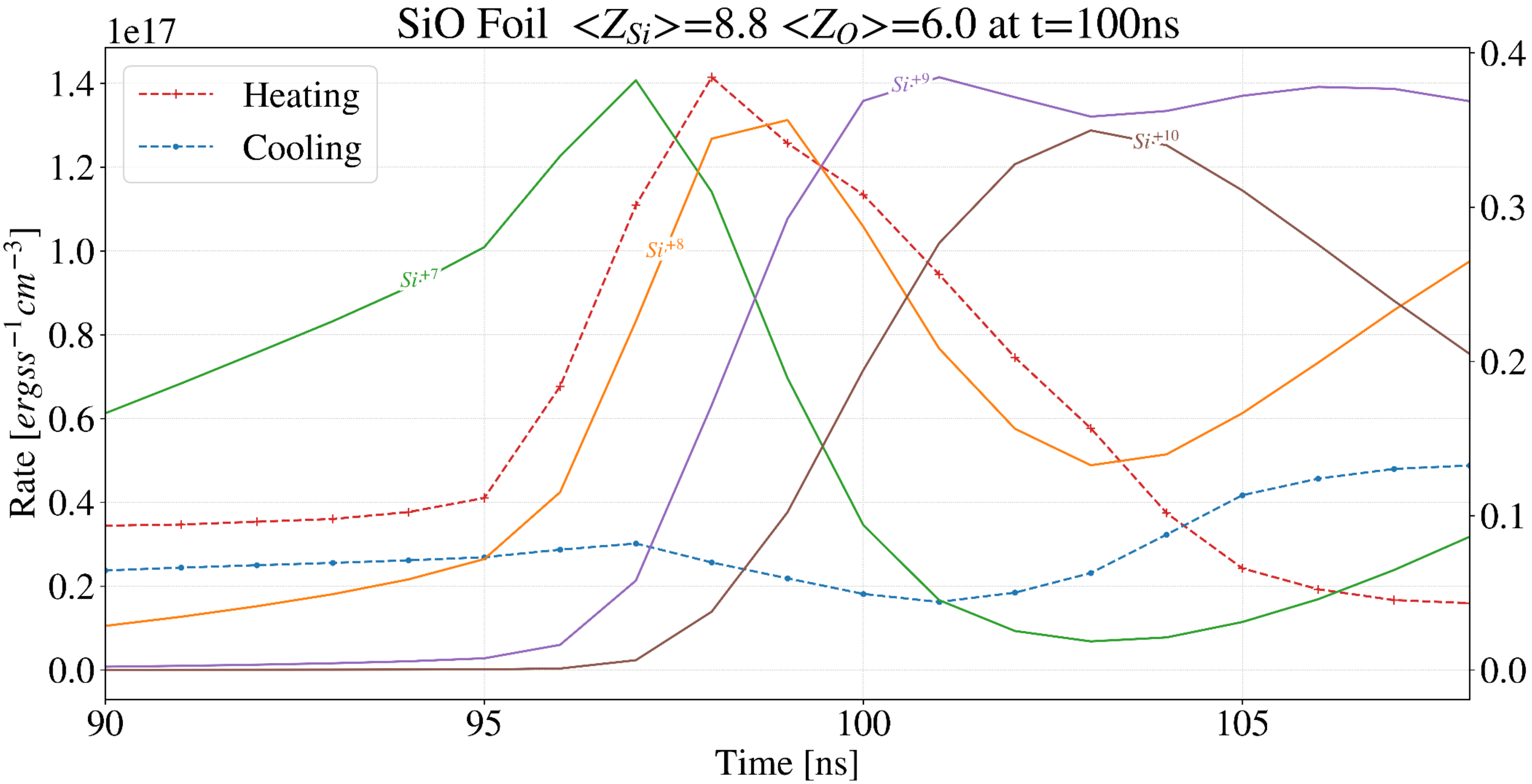

Cloudy Neon Cell <Z> = 7.5 at t=100ns
1e16
Heating
Cooling
Net Heating
T_e
Exp.
Rate $[ergs\ \ s^{-1}\ \ cm^{-3}]$
T_e [eV]
Time [ns]
0
2
4
6
8
90
95
100
105
0
5
10
15
20
25
30
35



Cloudy Neon Cell <Z> = 7.5 at t=100ns
1e16
Heating
Cooling
Rate [ergs s^-1 cm^-3]
Time [ns]
Ne+6
Ne+7
Ne+8
8
6
4
2
0
0.6
0.4
0.2
0.0
90
95
100
105



Cloudy SiO Foil <Z_{Si}>=8.8 <Z_O>=6.0 at t=100ns
1e17
Heating
Cooling
Net Heating
T_e
Exp.
Rate [$ergs\ s^{-1}\ cm^{-3}$]
T_e [eV]
Time [ns]
1.50
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
40
30
20
10
0
90
95
100
105



SiO Foil $<Z_{Si}>$=8.8 $<Z_O>$=6.0 at t=100ns
1e17
Heating
Cooling
Rate [ergss^-1cm^-3]
Time [ns]
Si+7
Si+8
Si+9
Si+10
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.4
0.3
0.2
0.1
0.0
90
95
100
105

References

1. G. P. Loisel, J. E. Bailey,1 D. A. Liedahl, C. J. Fontes, T. R. Kallman, T. Nagayama, S. B. Hansen, G. A. Rochau, R. C. Mancini, and R. W. Lee, Phys. Rev. Letters **119**, 075001 (2017)
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