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Fast T_e and n_e Diagnostic for the NSTX-U Edge-SOL Using He I Line Ratios

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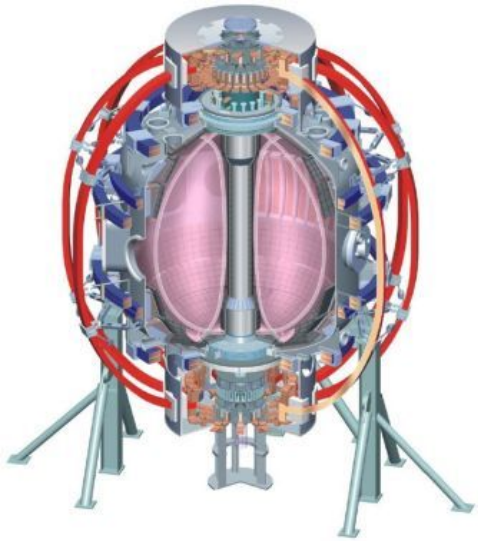
PPPL



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Motivation

- **Extension of the fast ME-SXR measured profiles by implementing a He I line ratio system to cover the edge-SOL region.**

- **Study of plasma phenomena such as ELMs, MHD instabilities, impurity and perturbative electron transport, and measurement of electron temperatures and densities on fast time scales.**

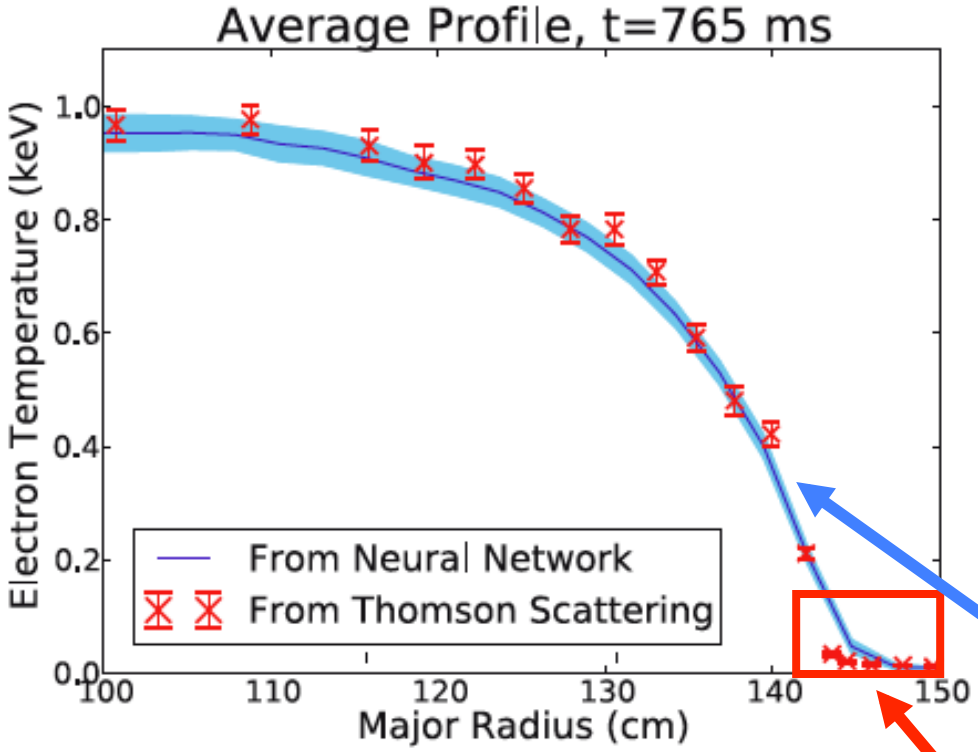
- **Present proposal:**

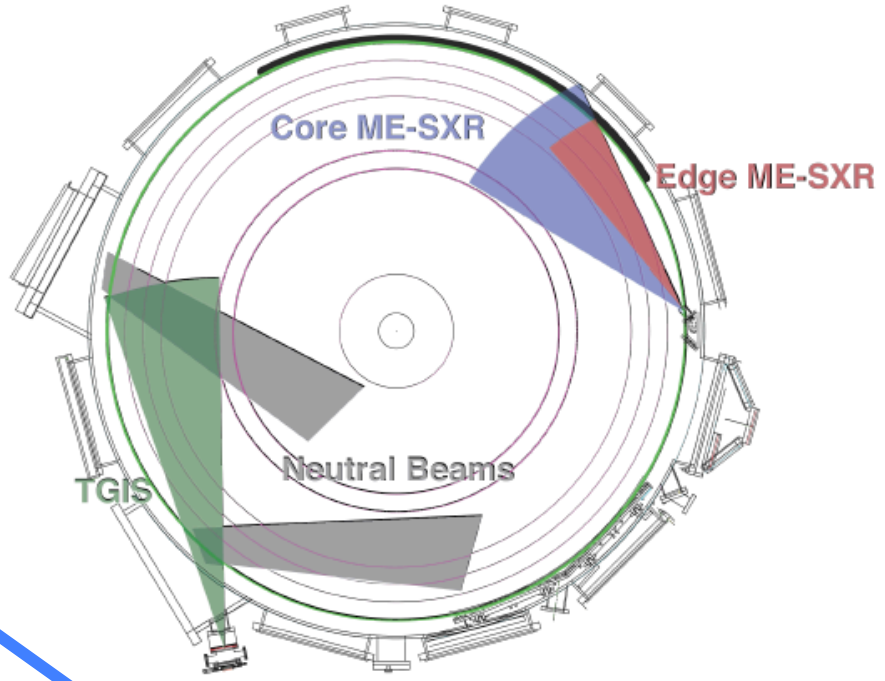
  Add a state-of-the-art He I line ratio measurements and atomic model for T_e and n_e diagnostic to ME-SXR

  - Additional, independent fast $T_e(R)$, $n_e(R)$ measurements for edge studies

  - Validated on TEXTOR (J. M. Munoz et al, Phys. Plasmas 2012)

He I line ratios can complement the fast ME-SXR diagnostic





MPTS available for validation (60 Hz)

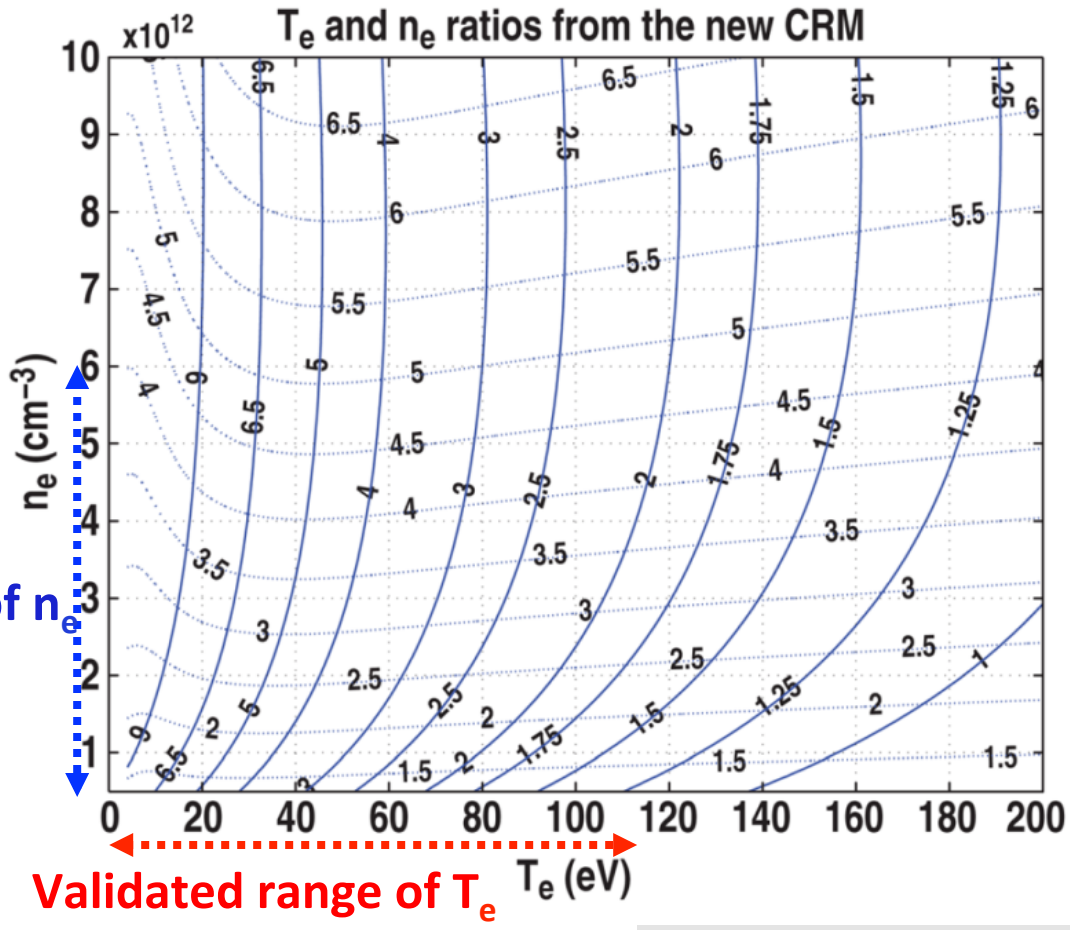
- **The ME-SXR system is limited to T_e > 100 eV (10 kHz)**
- **He I line ratios is ideal to provide T_e and n_e profiles for the Edge-SOL region**

D. Clayton et al PPCF 2014

LTX: K. Tritz et al PPCF 2014

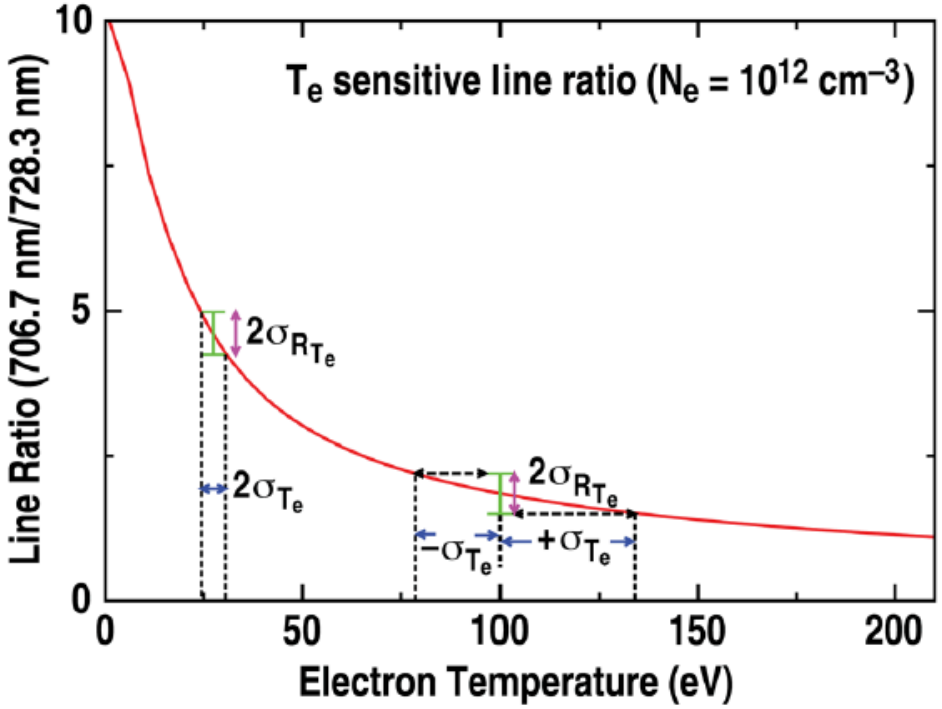
He I line ratio diagnostic for T_e and n_e measurements

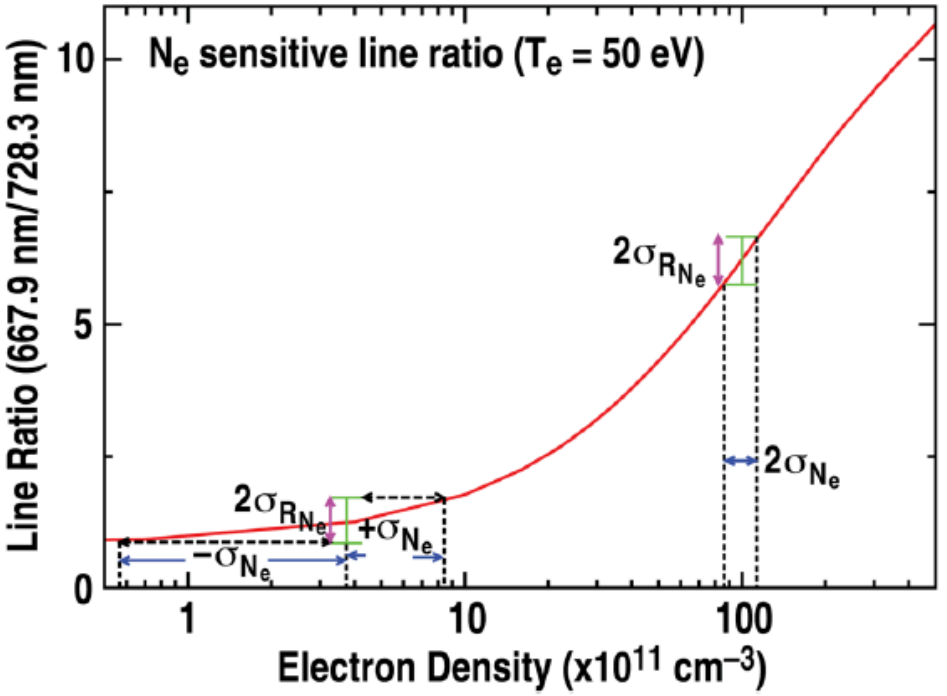
He I line ratios are very sensitive to T_e and n_e



J. M. Munoz Burgos et al Phys. Plasmas 2012

He I line ratio diagnostic ideal for NSTX-U edge conditions





Ideal range of T_e

(0 to ~100 eV)

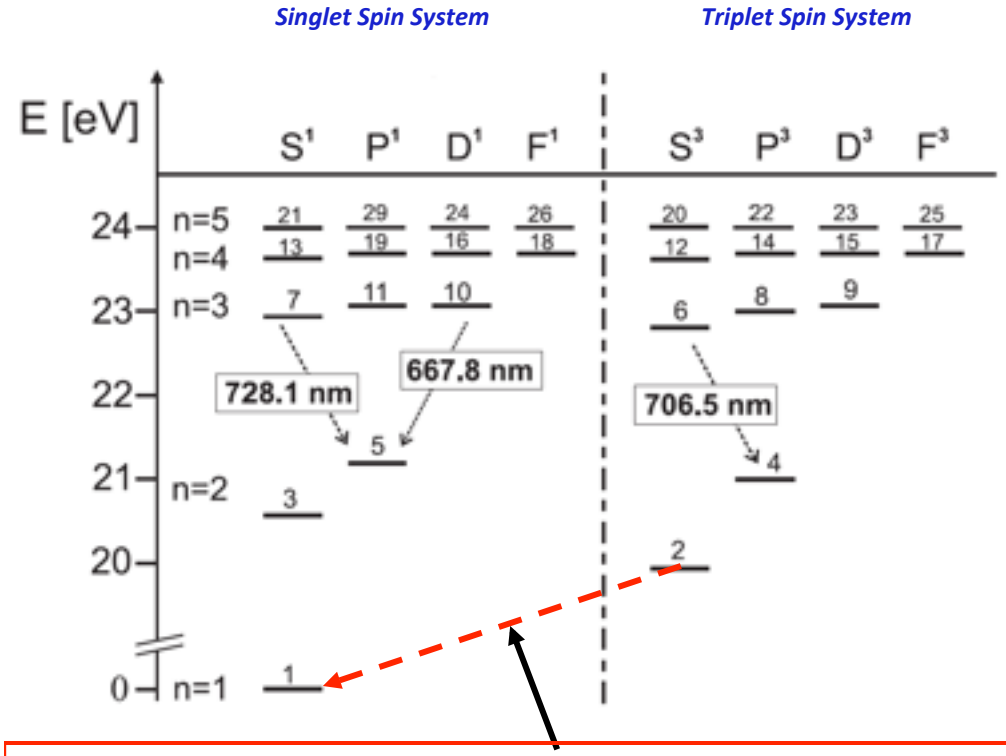
Textor validation up to 120 eV

Ideal range of n_e

(10^{11} to 10^{14} cm^{-3})

How the technique works

He I spin systems (visible lines)



Due to the energy differences between the ground and metastable, the ratio between the triplet and the singlet states is very sensitive to T_e

Suitable Transitions for Electron Temperature and Density Diagnostics

$3^1D \rightarrow 2^1P$ @ λ_1=667.8 nm → $\bullet n_e(r,t)$

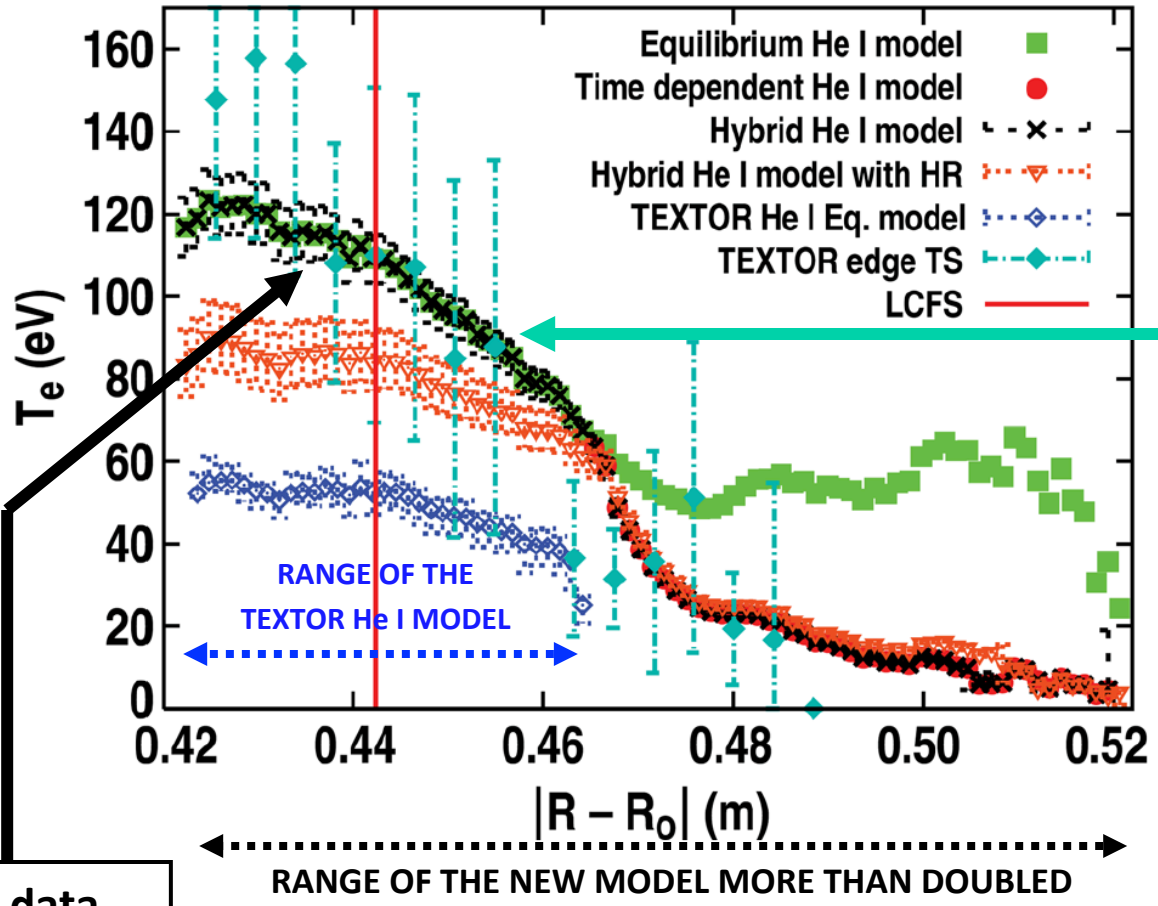
$3^1S \rightarrow 2^1P$ @ λ_2=728.1 nm → $\bullet n_e(r,t)$, $\bullet T_e(r,t)$

$3^3S \rightarrow 2^3P$ @ λ_3=706.5 nm → $\bullet T_e(r,t)$

- Technique first proposed in the sixties
- Newly calculated state-of-the-art electron impact excitation data greatly improves the accuracy of the diagnostic

J. M. Munoz Burgos et al Phys. Plasmas 2012

New, improved He I line ratio model validated at Textor



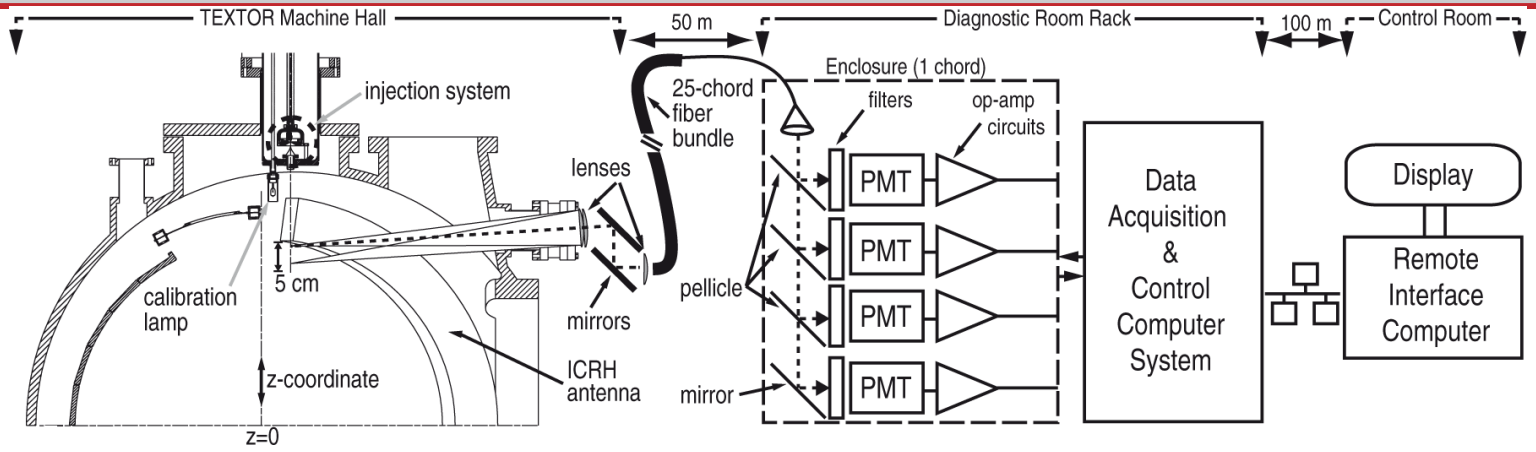
New solution agrees with Thomson data

New atomic data improves T_e measurements inside the LCFS

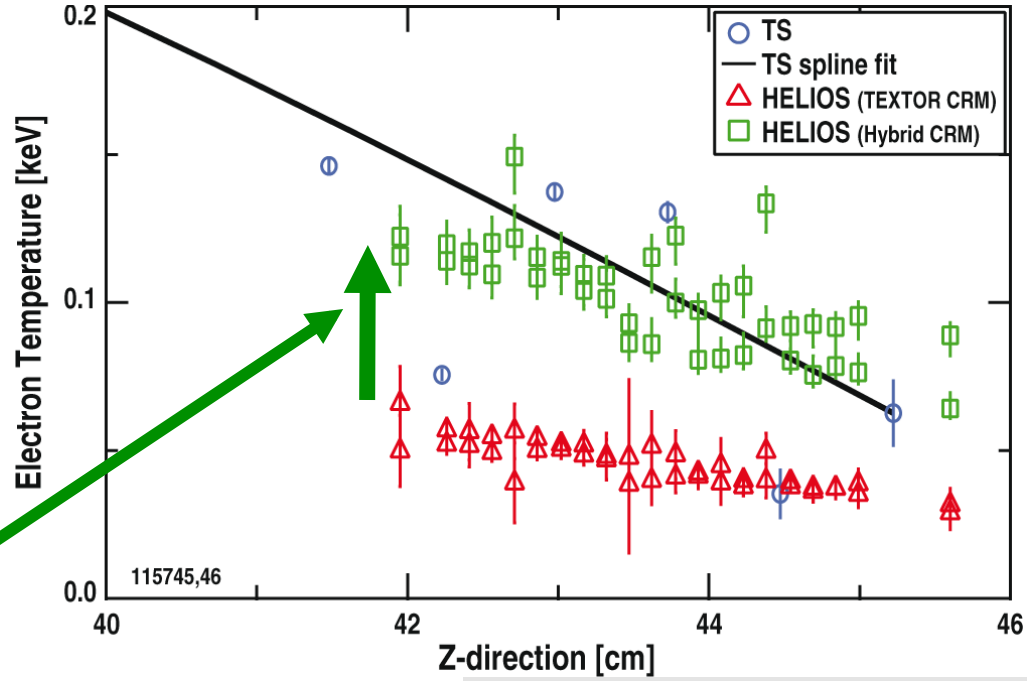
Line ratio model can also be compared to mid-plane Thomson at NSTX-U

J. M. Munoz Burgos et al Phys. Plasmas 2012

He I line ratio model validated at Textor using a new filter-scope system (HELIOS)



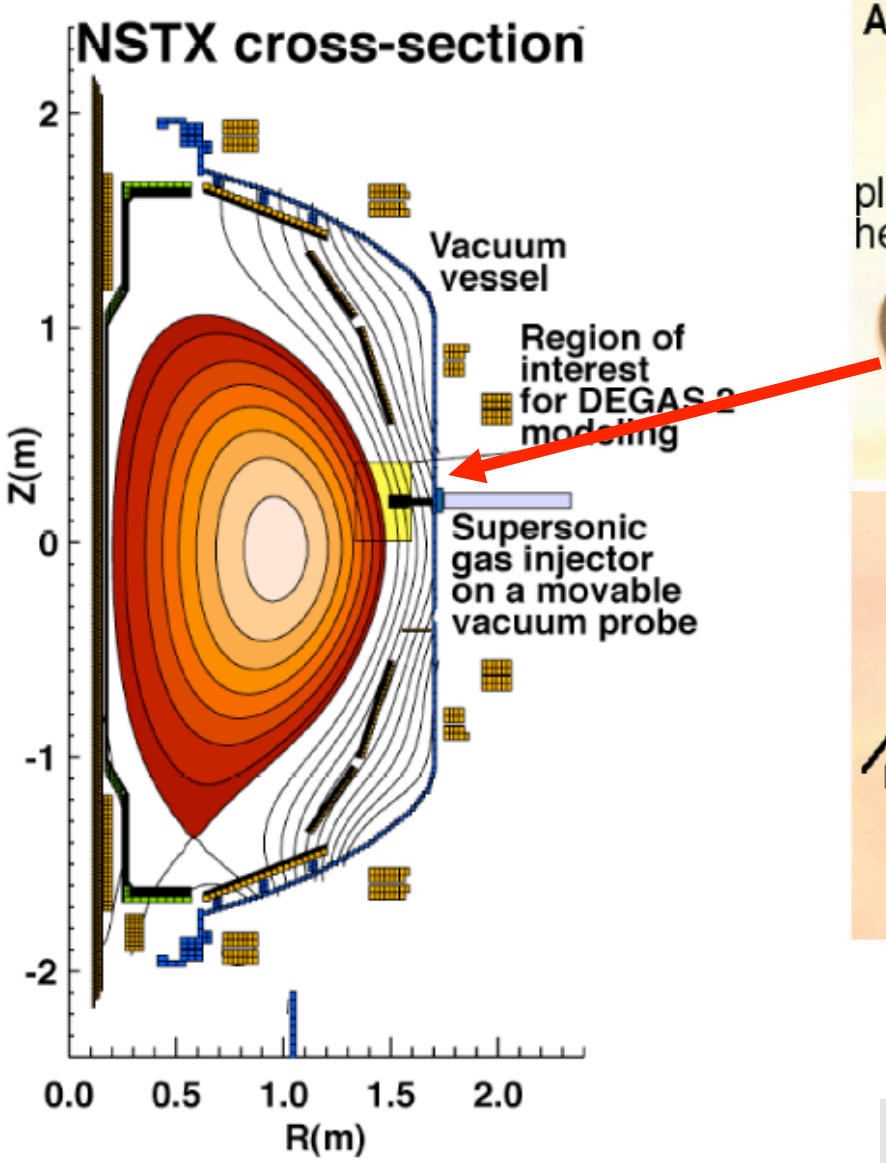
HELIOS system may be available for JHU use

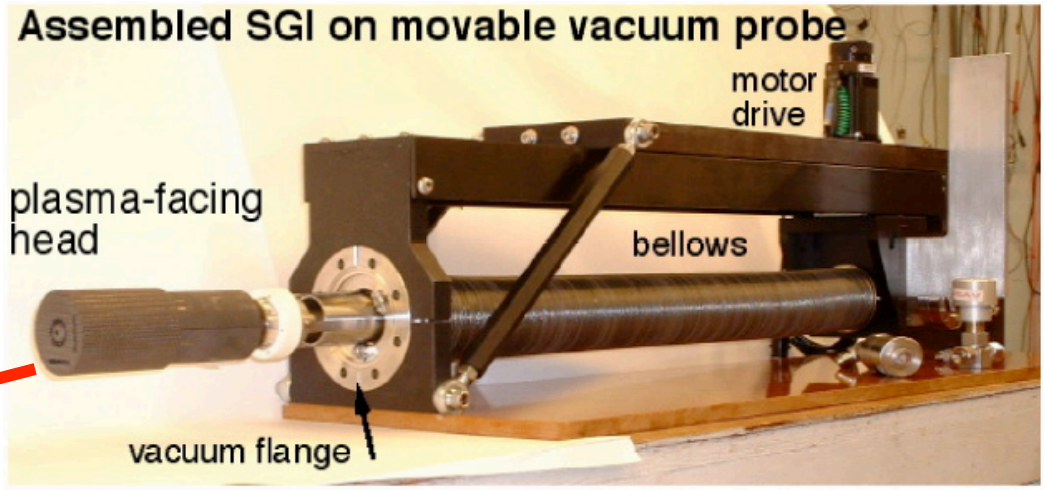


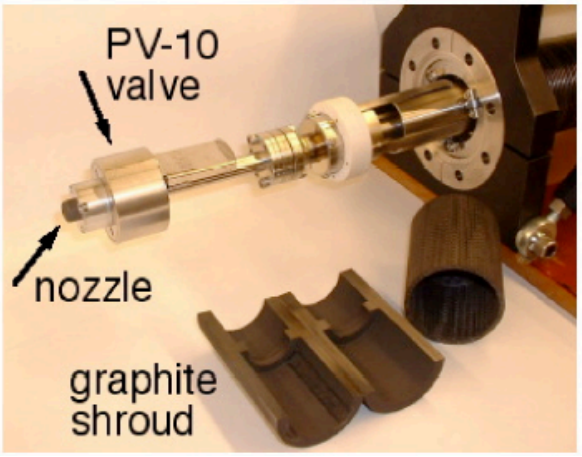
New atomic data improves T_e agreement with TS

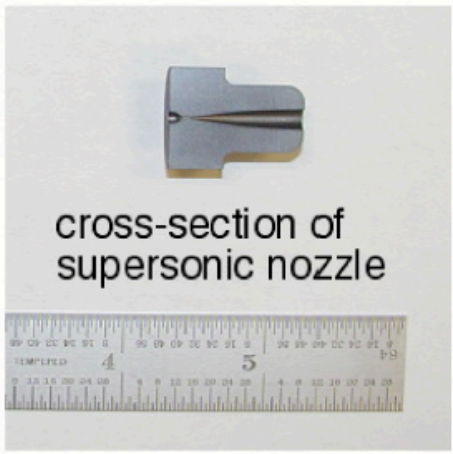
E. A. Unterberg et al Rev. of Sci. Instruments 2012

The supersonic gas injector system installed at NSTX-U is ideal for He I line ratio diagnostic





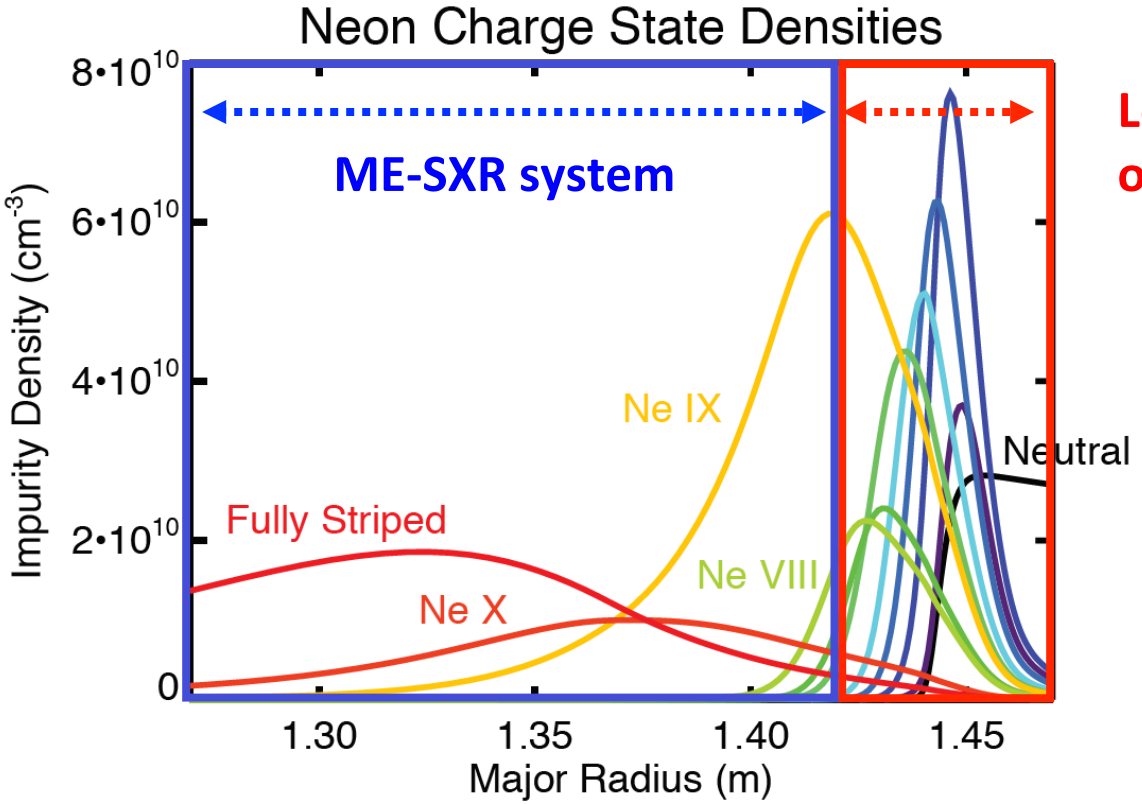




Similar to the Textor system

V. A. Soukhanovskii et al Rev. of Sci. Instruments 2004

Ne and Ar line ratios are also being explored for T_e and n_e profiles and impurity transport studies



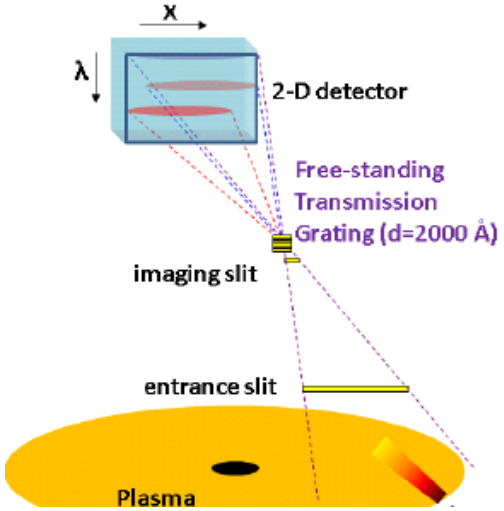
Typical radial distribution of neon charge states (calculated by STRAHL)

Lower charge states of neon or argon

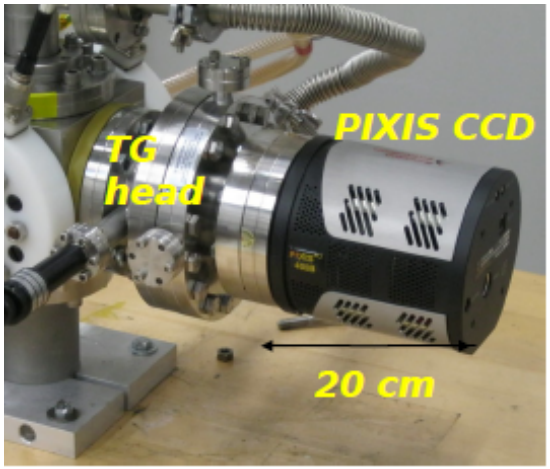
- **Source term constraints for STRAHL**
- **Improved accuracy/ resolution in pedestal**

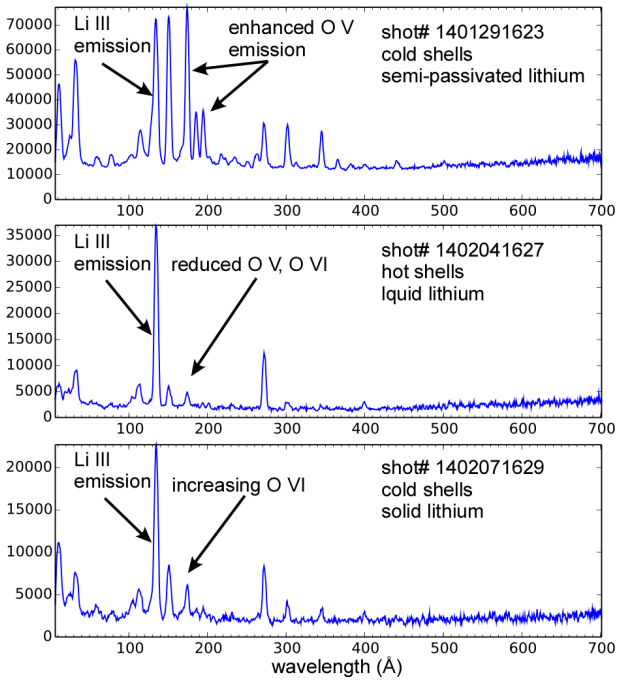
Technique can also be used for divertor spectroscopic 2D T_e and n_e

- XUV (50-1200 Å) TGIR on the NSTX-U divertor, for impurity transport and quantification of metals



LTX: K. Tritz et al PPCF 2014

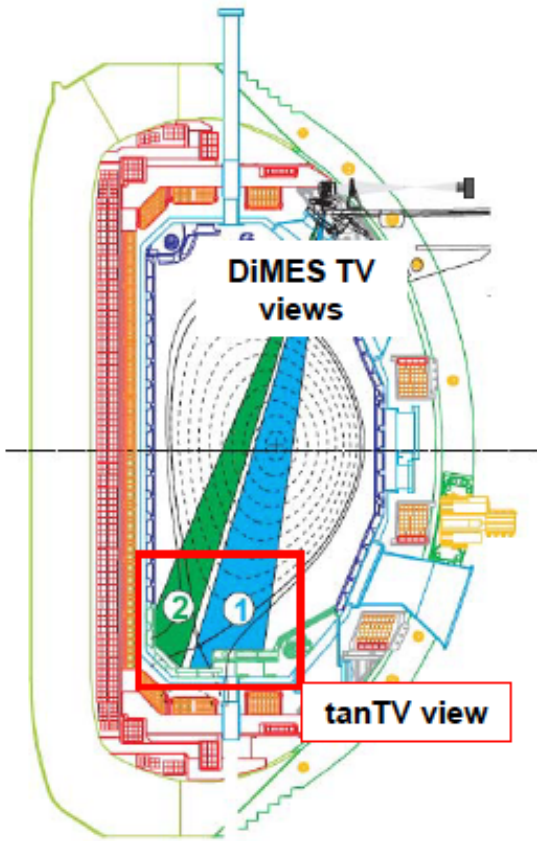


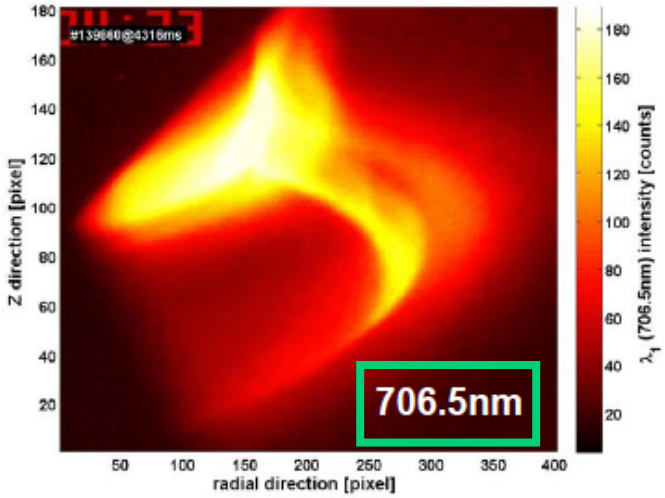


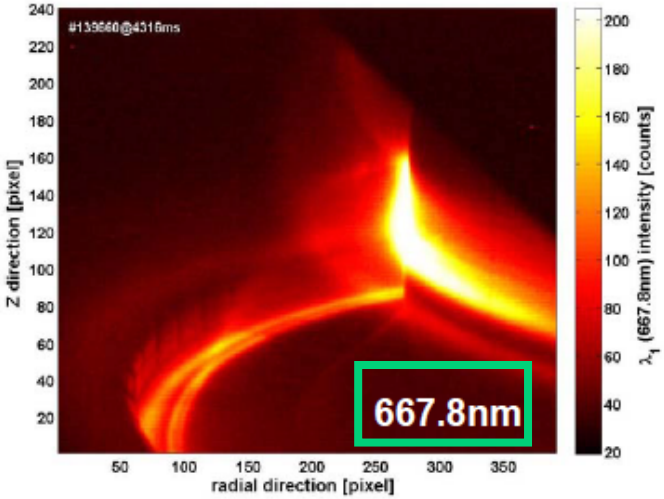
- Improved He I line ratio diagnostic with new state-of-the-art atomic data for 2D-divertor T_e and n_e profiles
  - Isolate transport variables
  - Absolute impurity content (including metals)
  - Improve code validation

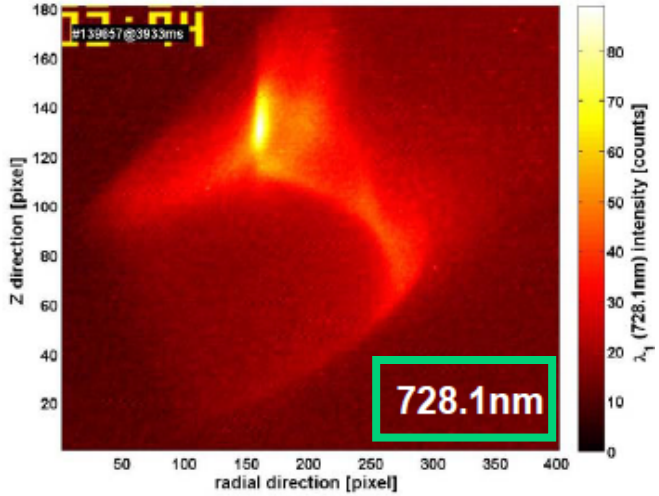
He I line emission divertor measurements at DIII-D

Divertor video cameras









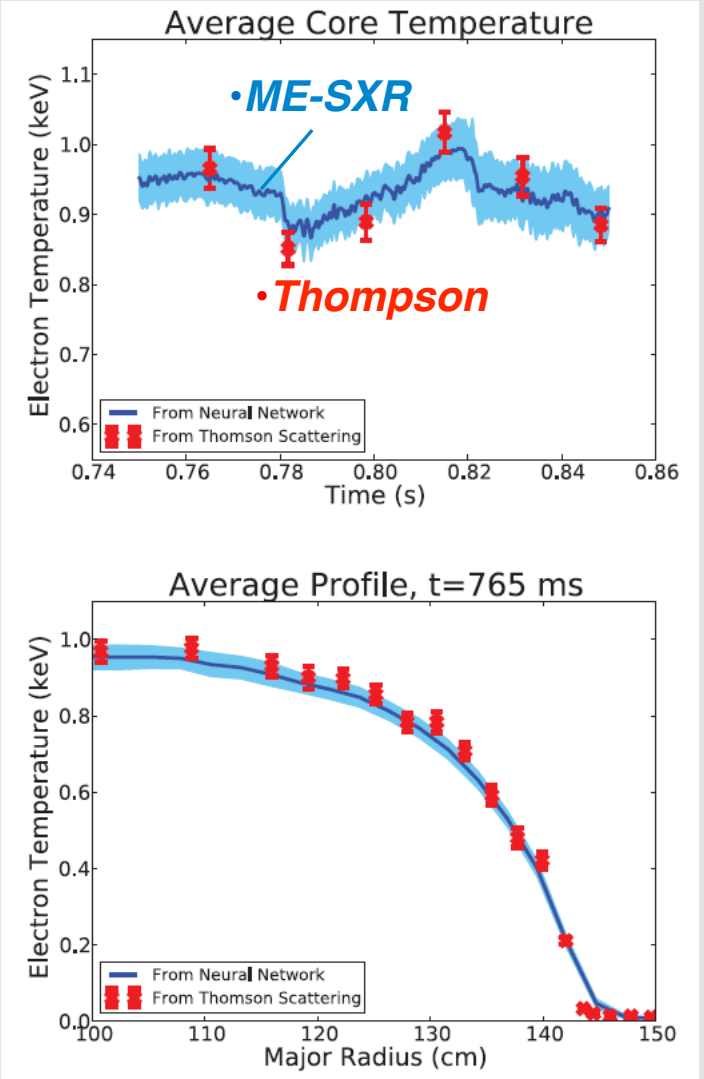
- Quantitative 2-D T_e and n_e profiles on shot to shot basis
- Tomographic inversion obtains local emissivities

Pictures courtesy of O. Schmitz TEXTOR

Neural networks can include He I line ratio measurements with ME-SXR

- Neural networks have been implemented to provide routine fast multi-energy soft-x-ray (ME-SXR) T_e profiles
  - 10 kHz $T_e(r)$ diagnostic.
- Neural networks can also be applied for:
  - Determining fast T_e and n_e profiles in the edge from helium line ratio emission (or from other ions).
  - (Future) Determination of transport quantities and radiated power from the Transmission Grating Imaging Radiometer (TGIR) in the divertor.

D. Clayton et al PPCF 2014



Summary

- Add He I line ratios T_e and n_e diagnostic to complement the ME-SXR.
- Can be implemented using NSTX-U supersonic gas injector (SGI).
- ME-SXR + mid-plane TGIS + He I T_e and n_e + neural networks.
- Fast simple He I line ratio + neural networks measurements can be applied for real-time feed-back control.