Update on PFC and PMI testing possibilities in a Plasma Material Test Station

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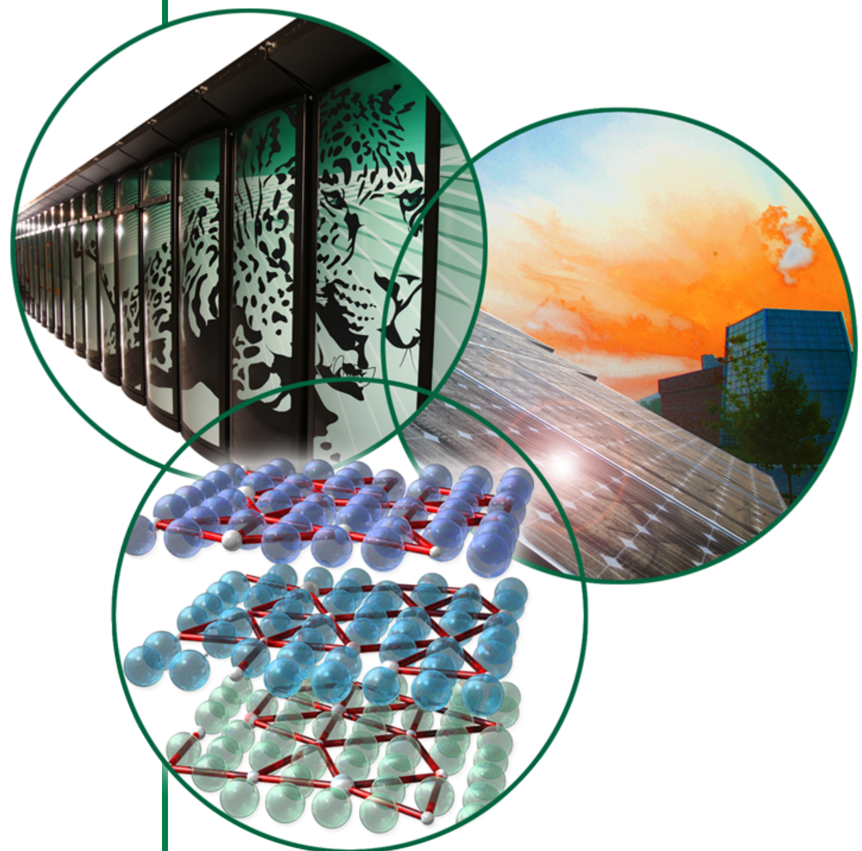

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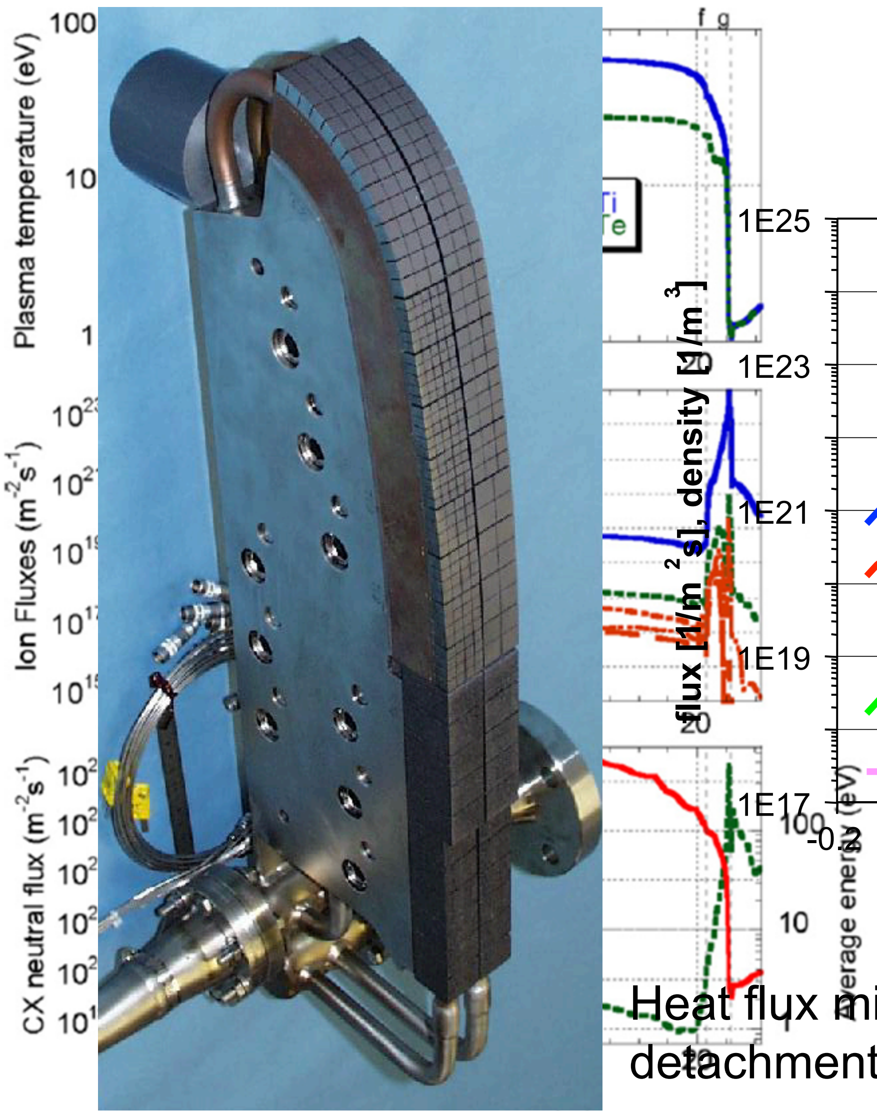
Overview of the Plasma Material Test Station development at ORNL

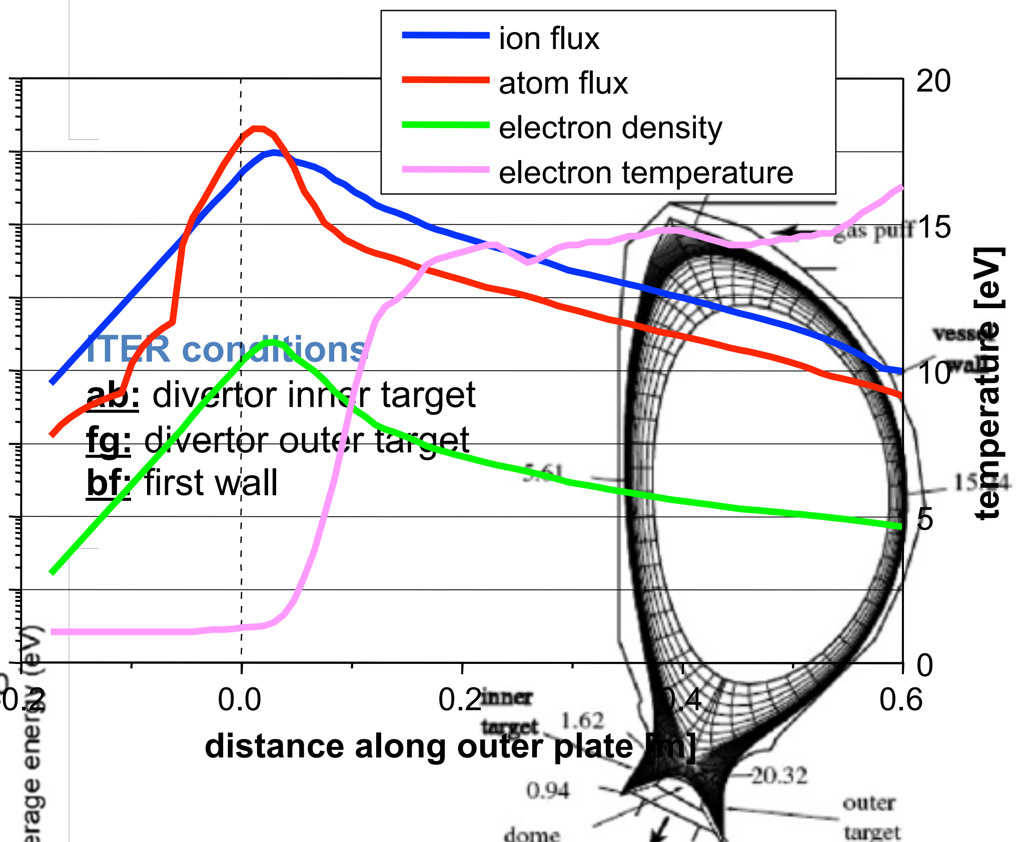
- Background
  - ITER divertor parameters inform about goals of PMTS
  - Ensuring access to the strongly coupled PSI regime

- Plasma Material Test Station (PMTS)
  - Helicon-based source augmented by RF heating
  - ITER-relevant densities and heat fluxes appear achievable
  - High density (D), high magnetic field (He) operation demonstrated in ORNL helicon
  - Near term facility upgrades should provide research-grade plasmas

ITER: unprecedented flux and fluence

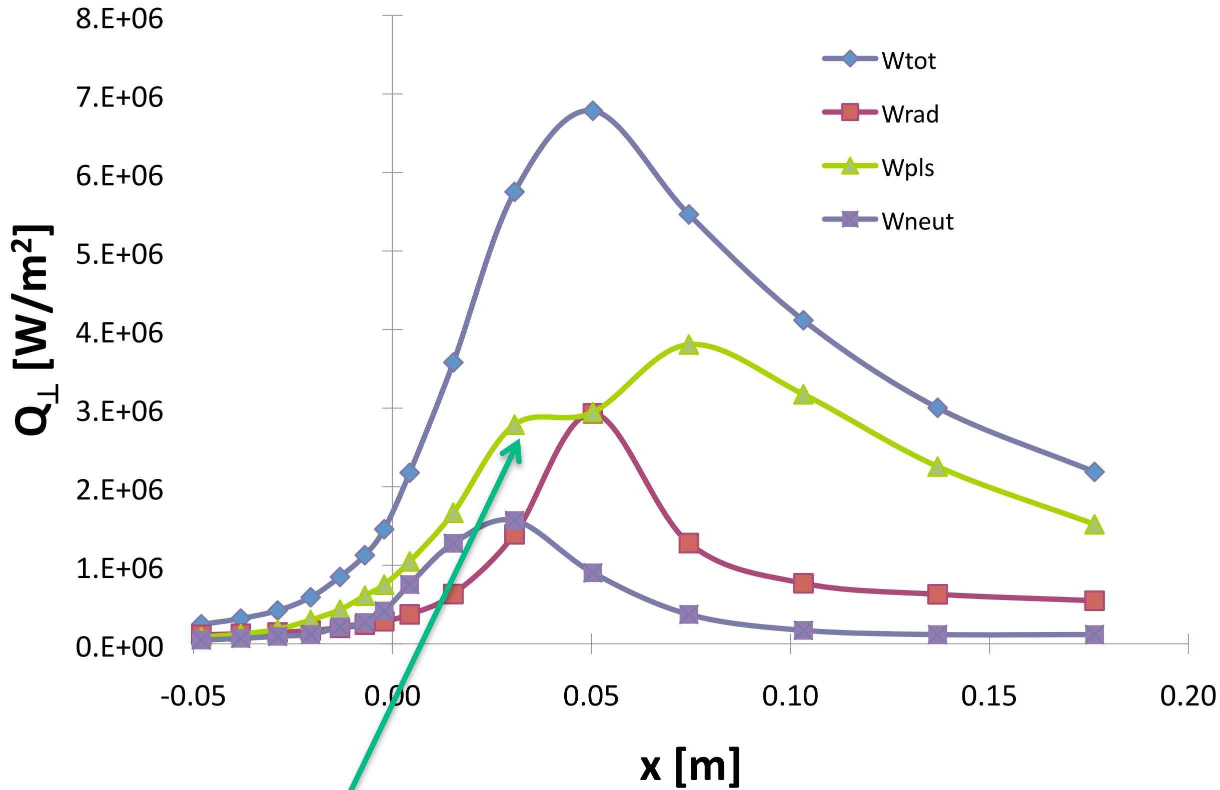


B2-Eirene simulation for ITER, including impurities (A.S. Kukushkin)



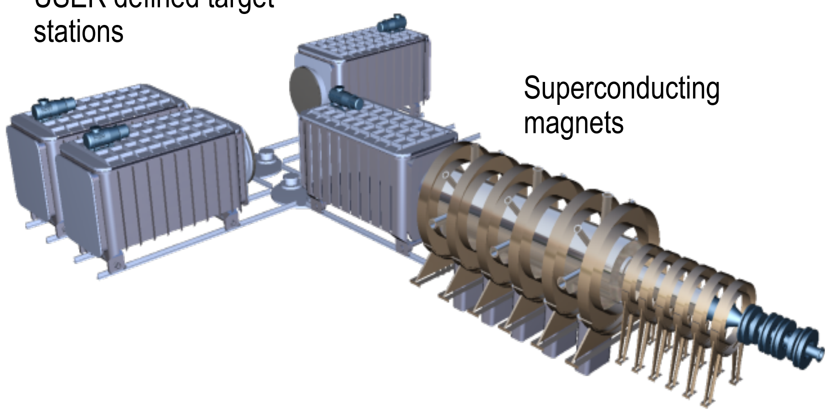
Heat flux mitigation requirements require partial detachment operation: low T_e (~eV), high n_e (~10^{21} m^{-3})

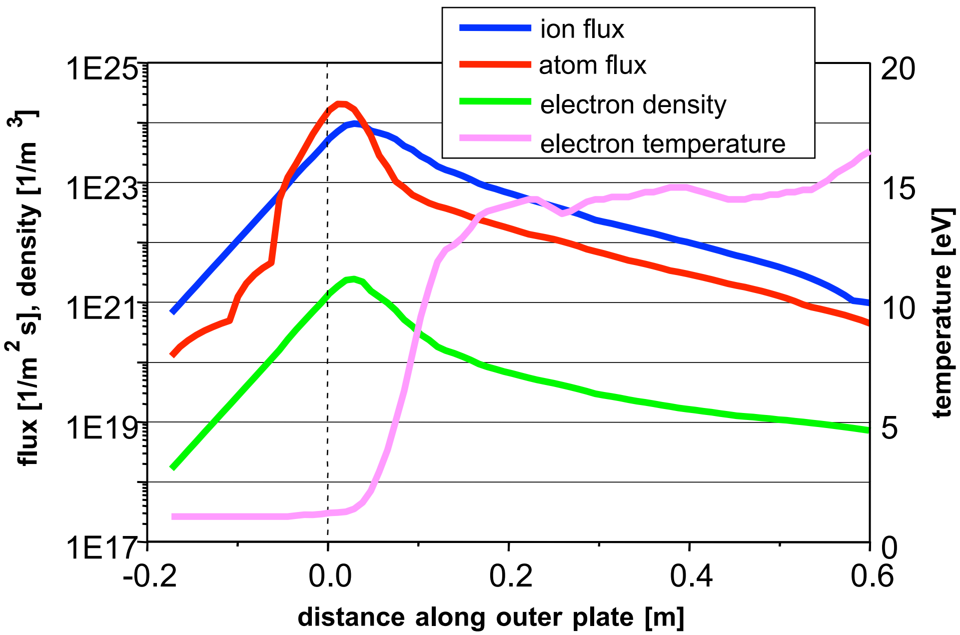
Power fluxes on target in ITER



- Peak **plasma** heat flux is < 4 MW/m^2
- Parallel heat flux of ~ 30 - 90 MW/m^2

New advanced plasma generator PMTS





Concept:

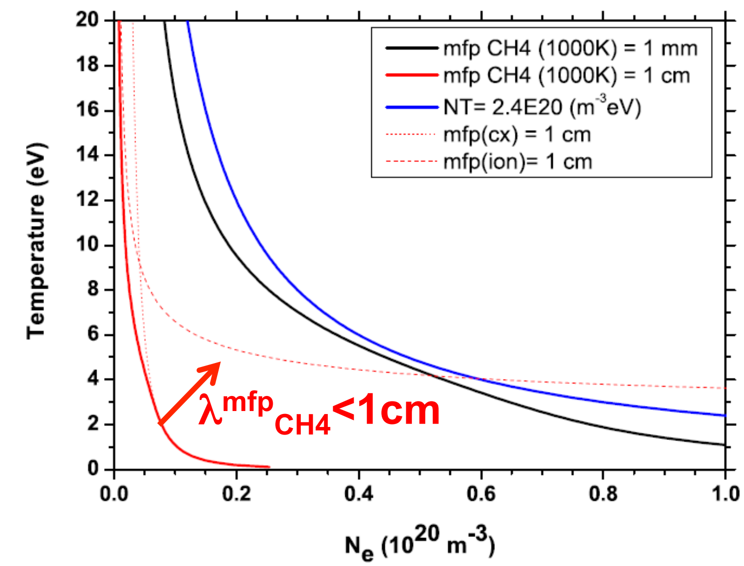
- New RF source system (Helicon wave plasma production, Electron Heating and Ion Heating) for independent control of T_e and T_i for entire divertor plasma parameter range
- High densities at target, require high plasma production in source
- R&D USER defined target station containers

Hydro-carbons and dust should be confined in plasma column at anticipated n_e, T_e, B

For plasma diameters of 5 – 10 cm

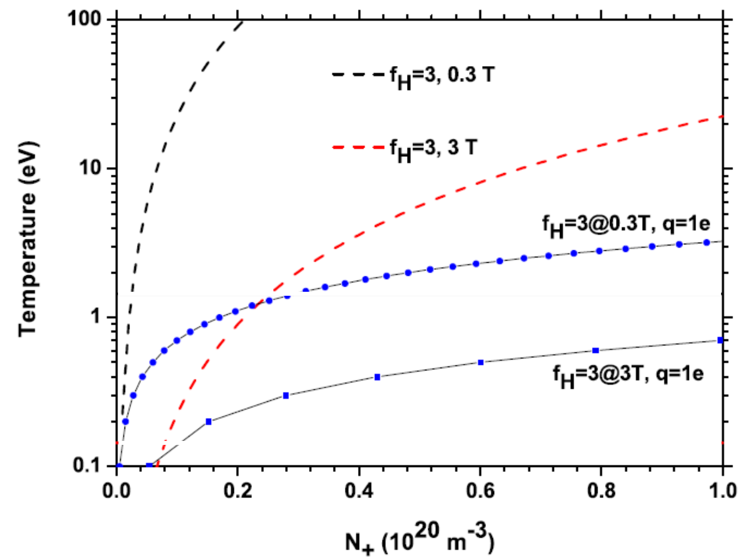
- CX processes will determine mean-free path at high density plasmas

➢ Confinement of hydro-carbons is ensured at high densities



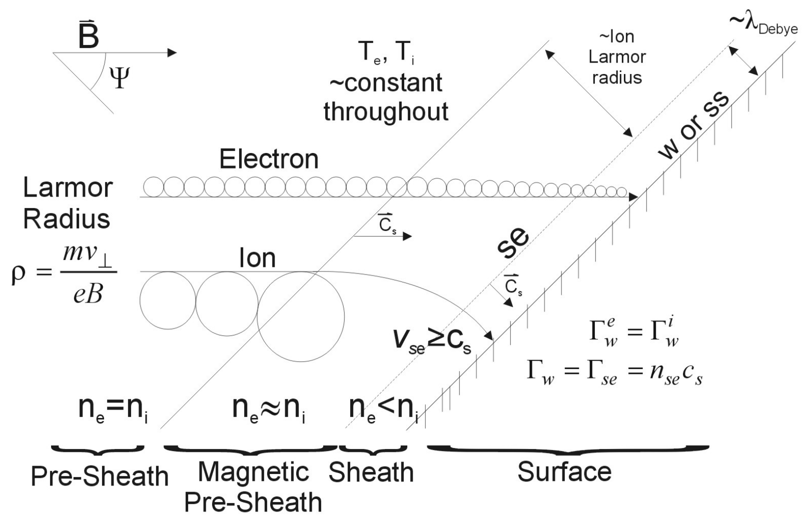
- Hall factor calculated for spherical particles with diameter of 20 nm with floating potential of twice T_e
- For temperatures higher than dashed lines, dust particles are confined

➢ High field of several T is necessary at target to confine dust particles with diameter of 20 nm



Fluxes to target at shallow angles

– Sheath effects (classical Debye vs Chodura sheath)



– Investigation of melt-layer dynamics needs realistic geometry and relevant plasma pressures and fields

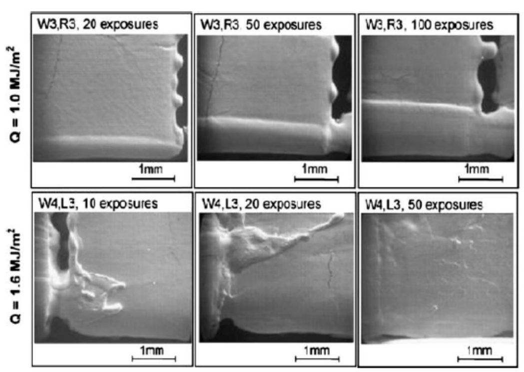
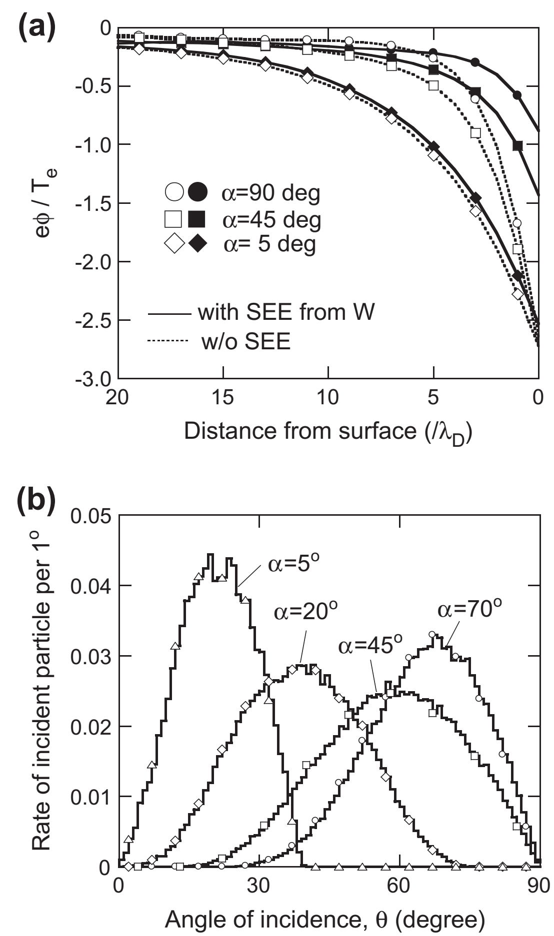


Fig. 1. The SEM view of the tungsten tile surface.

Results from QSPA (plasma gun) shows bridging of gaps, but pressure is too high

– Erosion and Re-deposition (effect of secondary electrons on plasma sheath; gyro-motion of ions)

K. Ohya J. Nucl. Mater. 415 (2011) S10



Potential distribution from a W surface for shallow and perpendicular angle between B and surface

Angular distribution of incident H ions for shallow and perpendicular angle between B and surface

PMTS requirements

Parameter	Aimed value
n_e source	up to 6 x 10^{19} m^{-3}
n_e target	up to 10^{21} m^{-3}
T_e source	up to 35 eV
T_e target	down to 1 eV
T_i source	up to 20 eV
T_i target	down to 1 eV
B target	1 T (maybe 3 T)
Plasma diameter	up to 10 cm
Γ_i target	10^{24} $m^{-2}s^{-1}$
P target, parallel	up to 40 MW/m^2
P target, perpendicular	10 MW/m^2

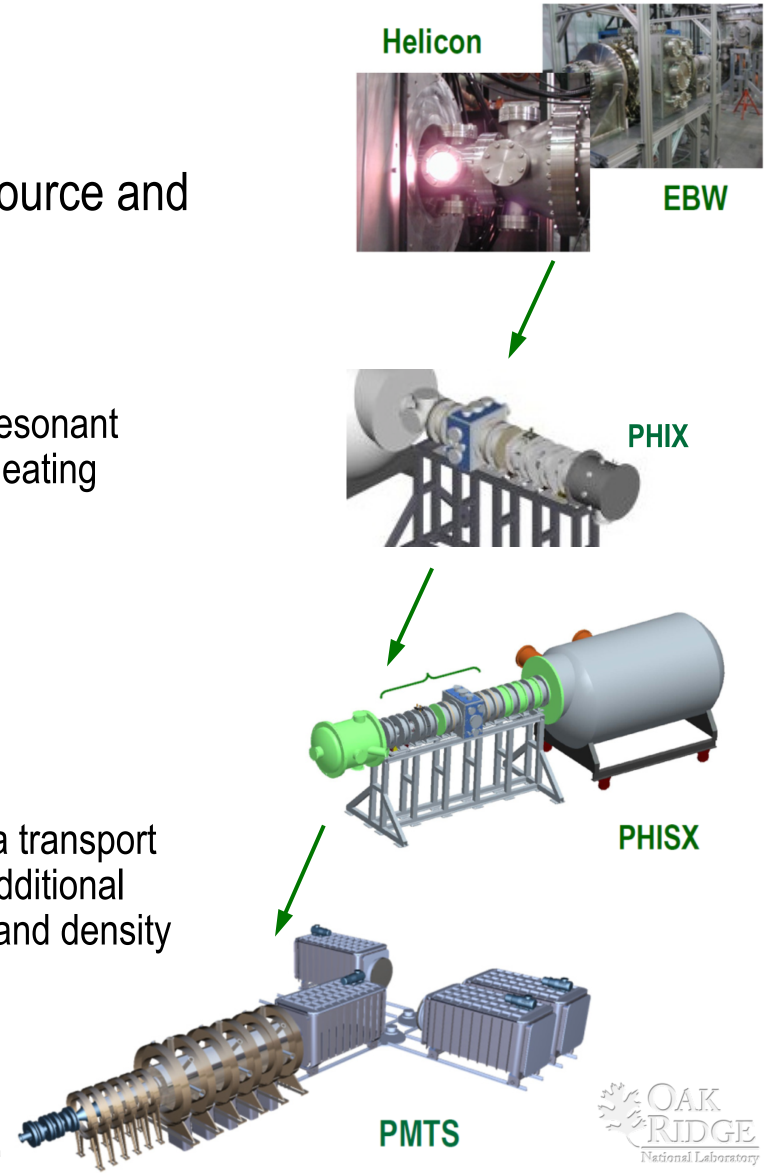
With those PMTS requirements normalized PMI parameters should be within factor 2 matched to ITER values:

- D ionization mean free path / pre-sheath thickness
- MFP of CH_4 / sheath width
- MFP of W / sheath width
- Hall parameter of ions

Path to PMTS supported by strategic ORNL funding

Source development:

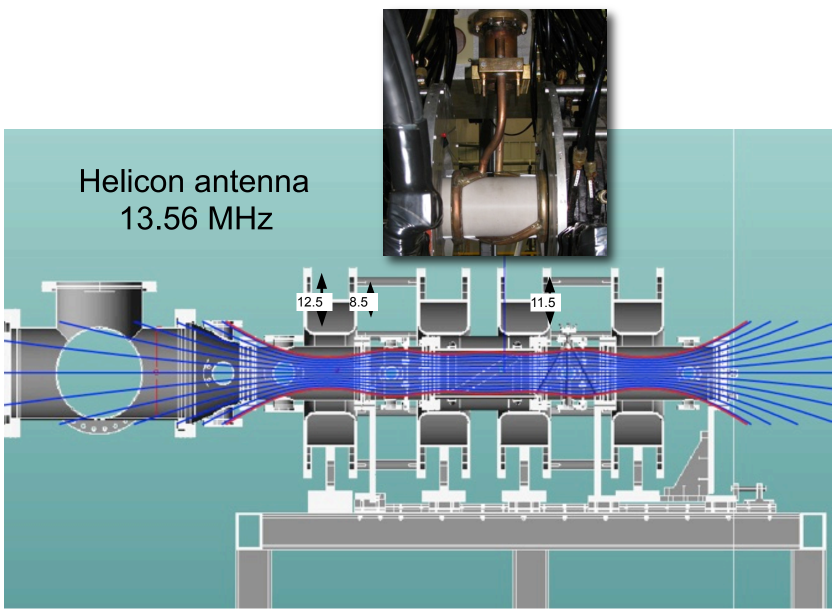
- Individual high density production with Helicon source and electron heating experiments
- PHIX
  - Combine helicon high density plasma production and resonant (whistler wave and Electron Bernstein wave) electron heating experiments
  - Proof of principle of PMTS source
- PHISX
  - Integrated prototype plasma source test
  - Effect of recycling at target on open system and allow a transport region to be added between the source and target (4 additional magnets) to examine creation of electron temperature and density gradients between source and target

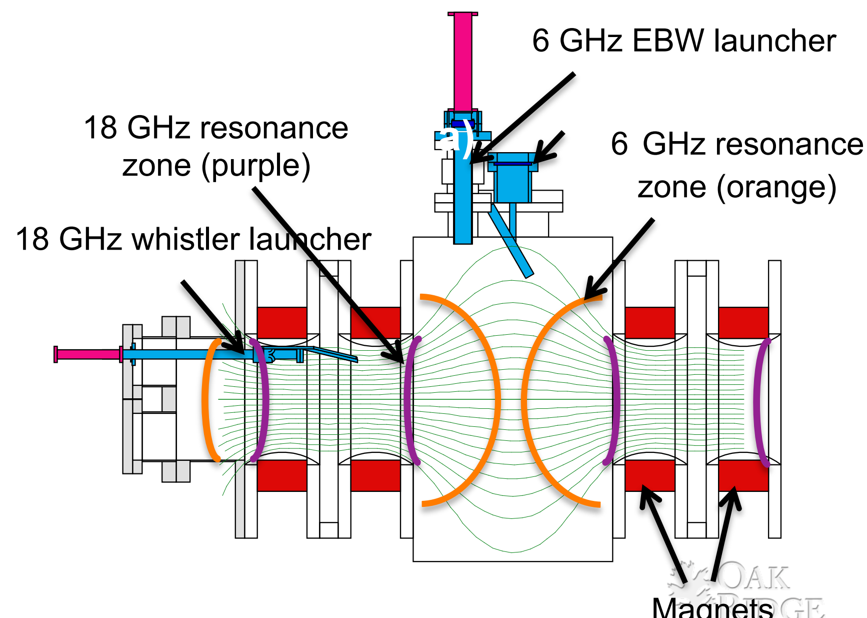


Power is raised in steps to required value

Heating power in kW

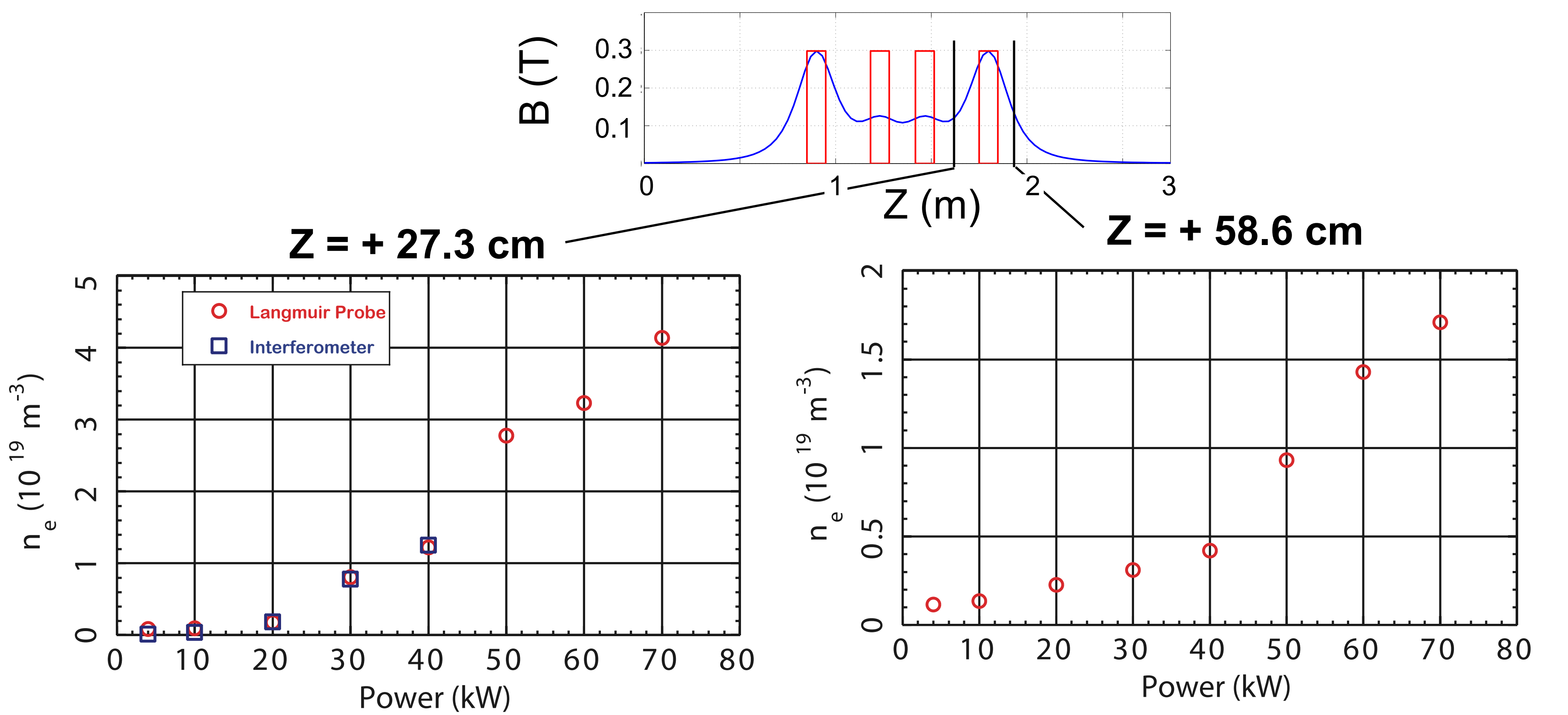
	PhIX (2s)	PHISX (2s)	PMTS	PMTS-U
Helicon	100	100	100	100-200
Whistler/EBW	20 (18 and 15.3 GHz)	200 (28 GHz)	200 (28 GHz)	200 (28 GHz)
ICH		30 - 200 (2s)	30 – 200	400
TOTAL	120	330 – 500	330-500	700-800



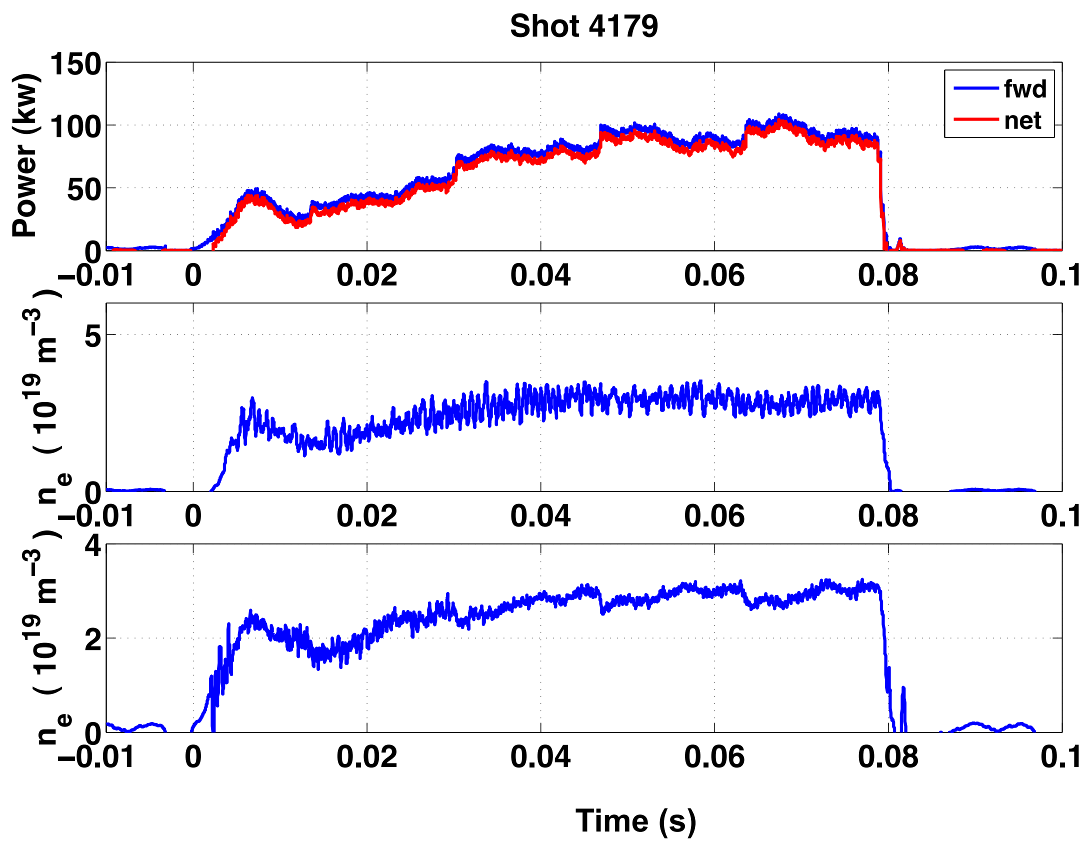


Results: Helicon has delivered high density deuterium plasma (> 4 x 10^{19} m^{-3})

- Suggests that higher density is achievable at higher power



Results: Helicon achieved high density He plasmas with high magnetic field (~0.5 T)

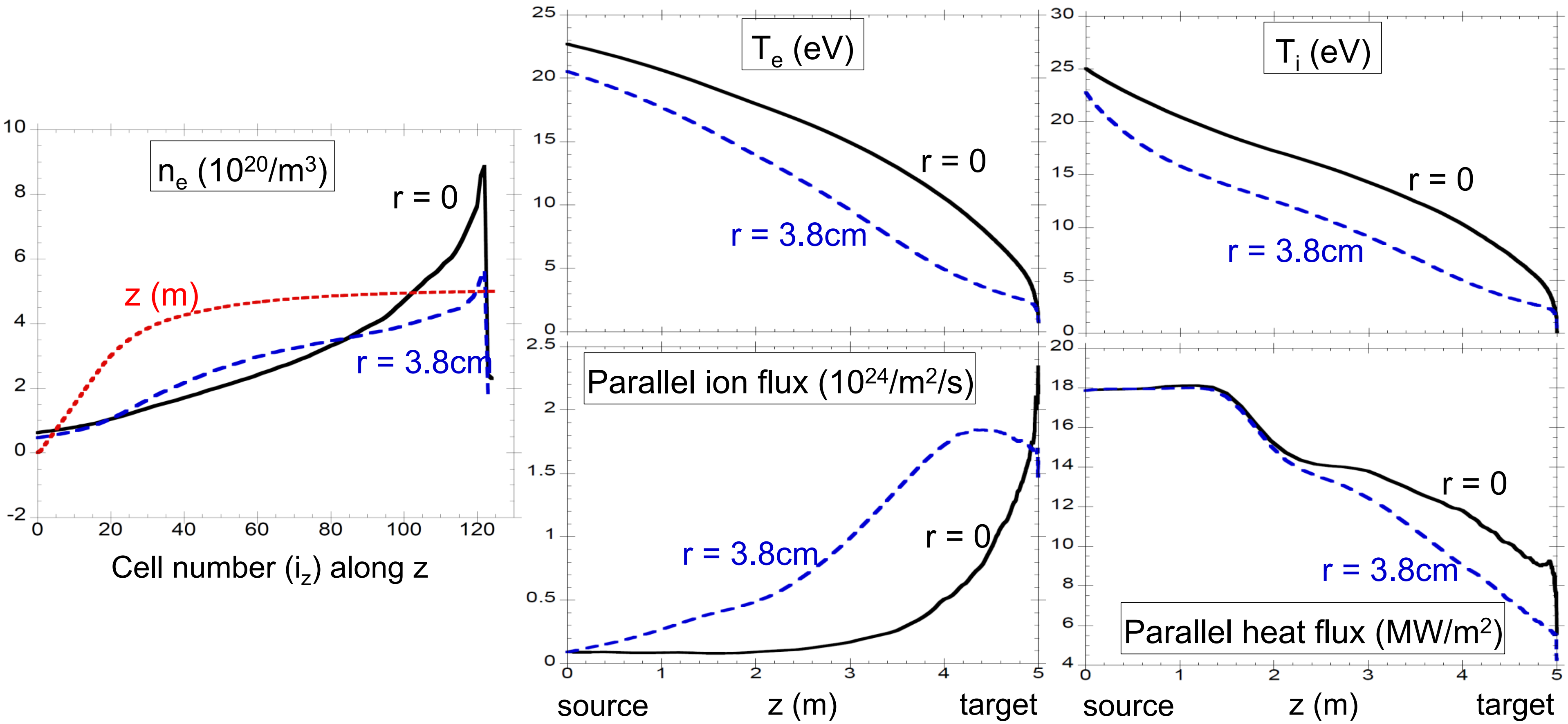


Power

n_e (inside helicon)
(radius = 2 cm)

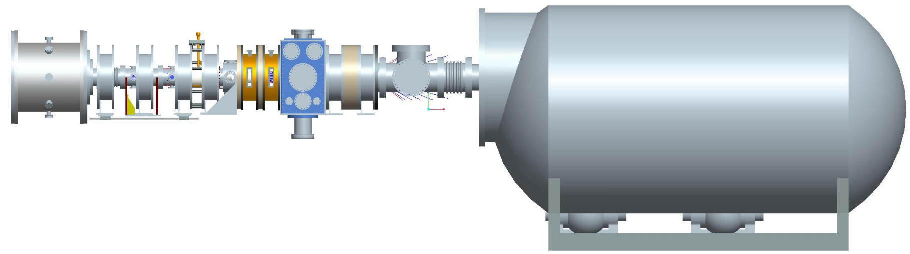
n_e (outside helicon)
(radius = 2 cm)

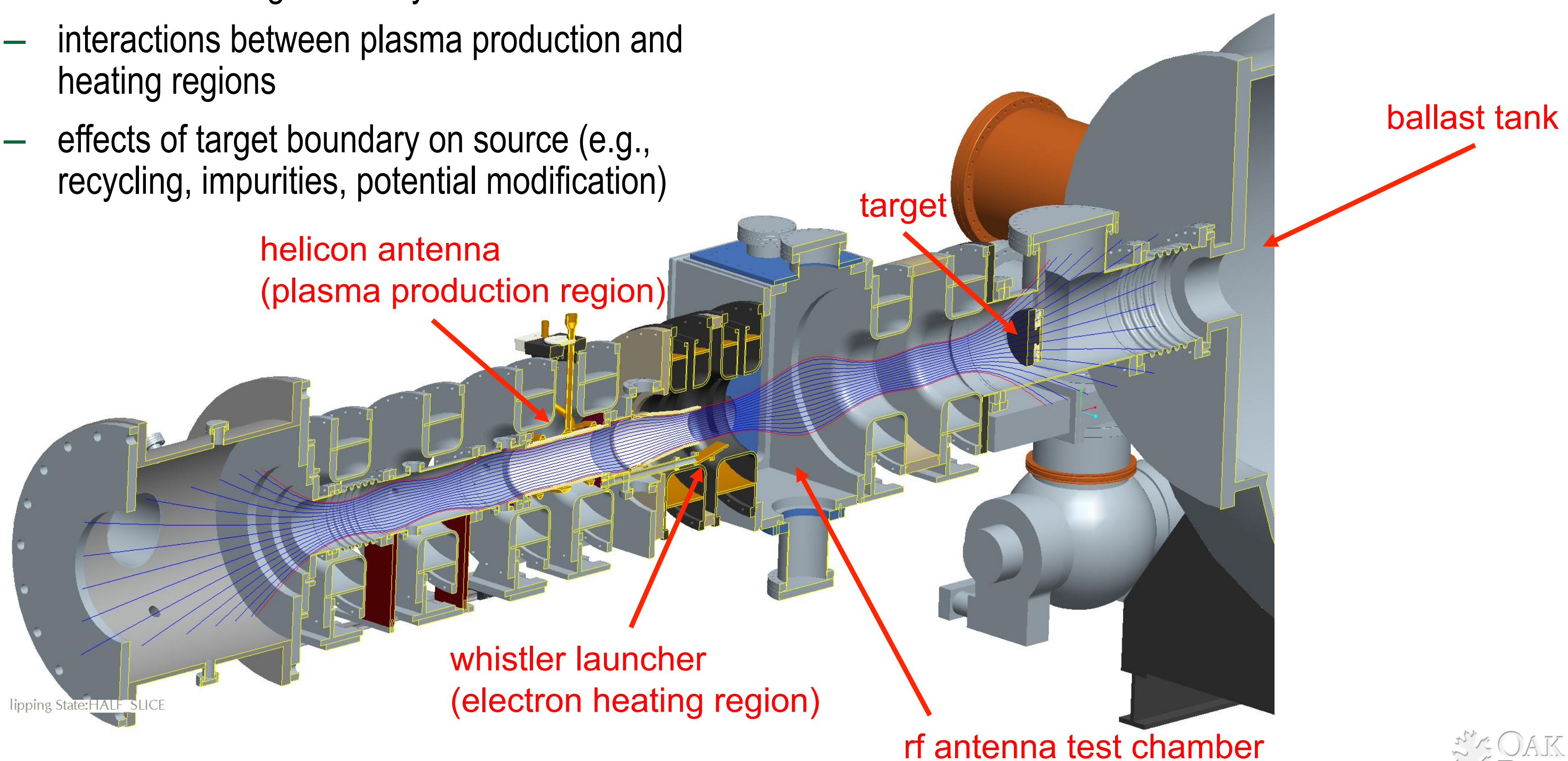
B2-Eirene results: L = 5m, source plasma r_p = 5.65 cm, P = 200kW, peak heat flux = 18MW/m², ion flux = 10^{23}/m²/s, $\chi_\perp$ = 3 m²/s, $D_\perp$ = 1 m²/s



PhIX (Physics Integration eXperiment)

- Investigation of production (rf-helicon) and heating of an overdense plasma by whistler and electron Bernstein waves (EBW), including:
  - ionization cost, gas utilization efficiency
  - electron heating efficiency
  - interactions between plasma production and heating regions
  - effects of target boundary on source (e.g., recycling, impurities, potential modification)

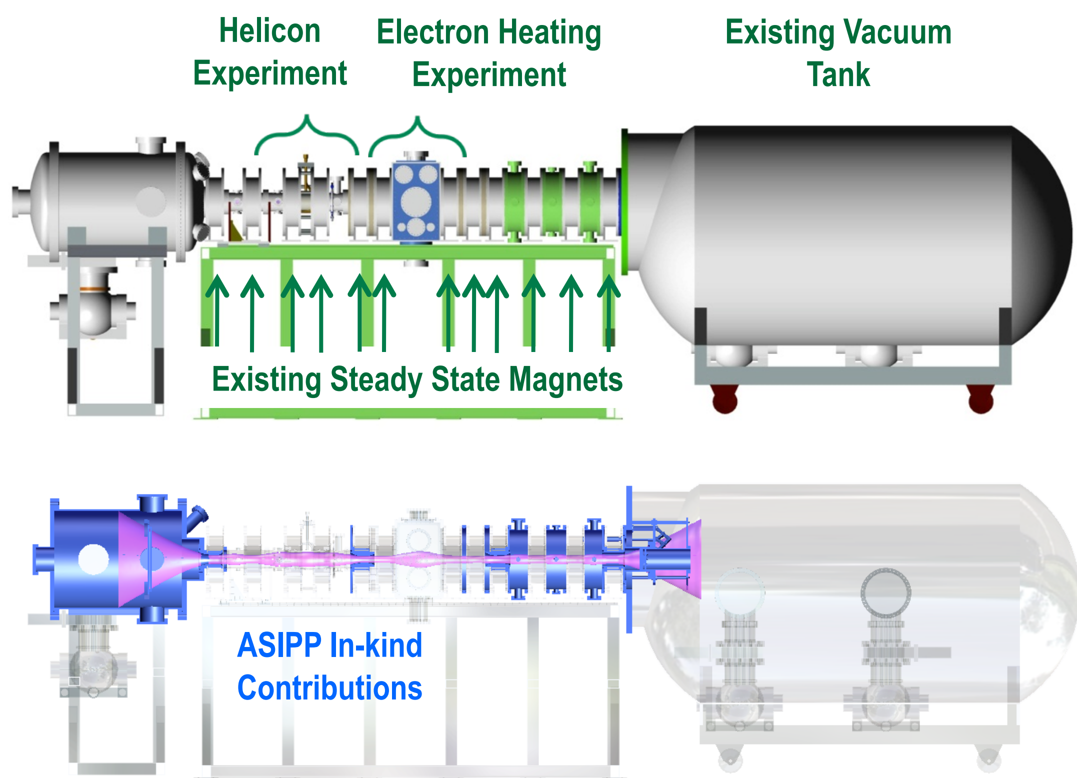




ORNL-ASIPP collaboration on PHISX

Schedule

- Design of parts completed
- FY 2012
  - Fabrication pf parts by ASIPP and delivery to ORNL
- FY 2013 plans
  - September: Assembly of PHISX
  - ASIPP research participation

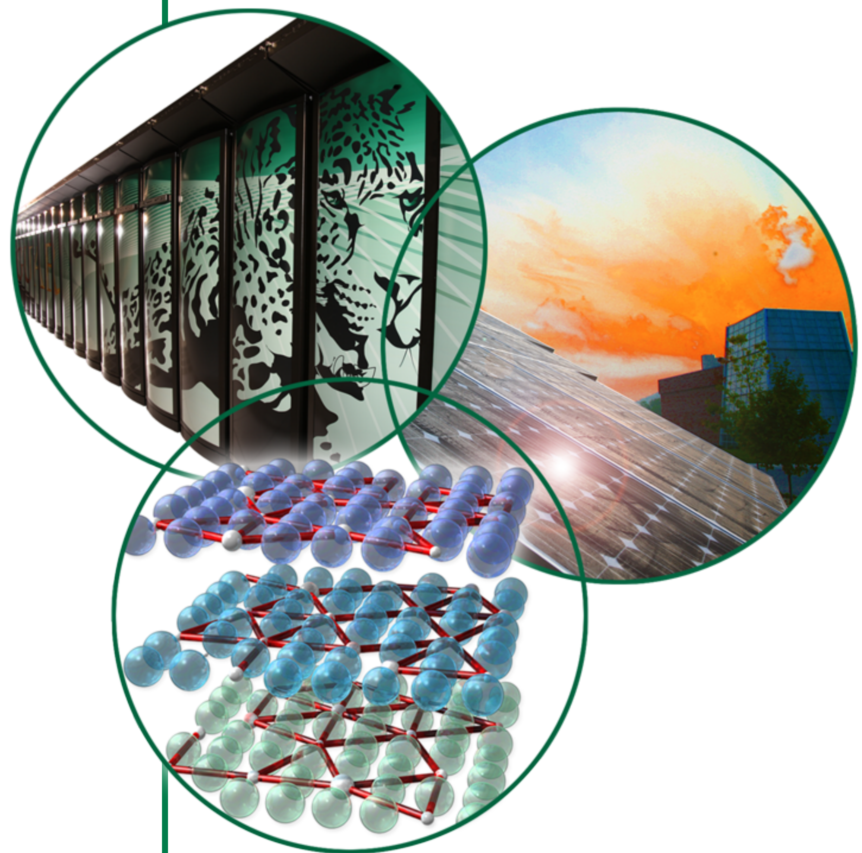


PMI/PFC research possibilities

by end of 2013, 2014 PhIX and PHISX might allow

- Pulsed operation (2 s) with P = 4-10 MW/m^2; Γ_i ~ 1-4 x 10^{23} $m^{-2}s^{-1}$
- Investigation of targets samples up to a diameter of 6 cm
- Investigation of strongly coupled PSI regime at low fluence
- Observation of pre-cursors of surface morphology changes
- Investigation of shallow angle of incidence on target
- Investigation of…….

BACKUP



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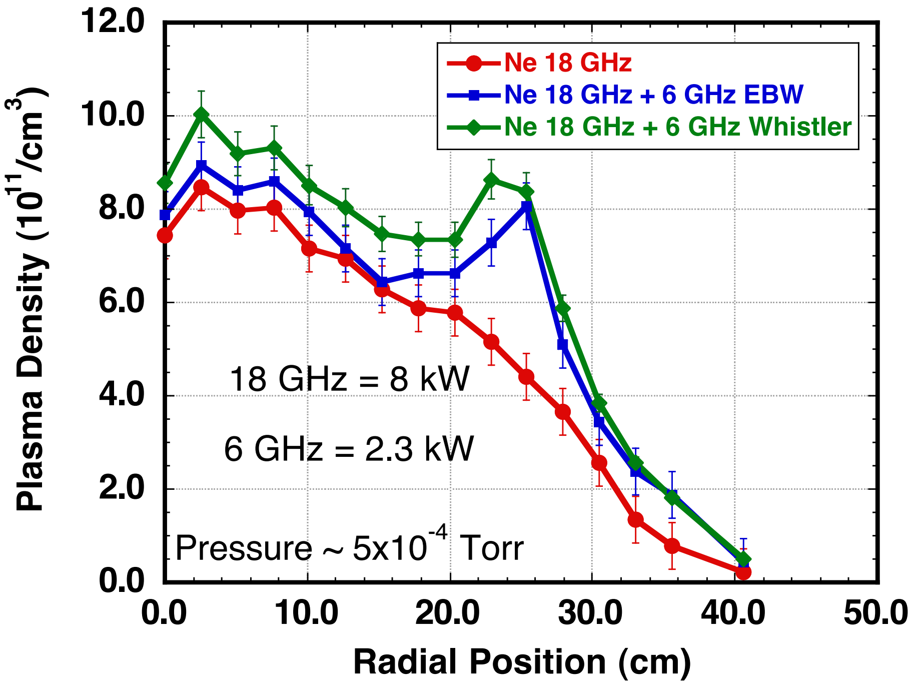
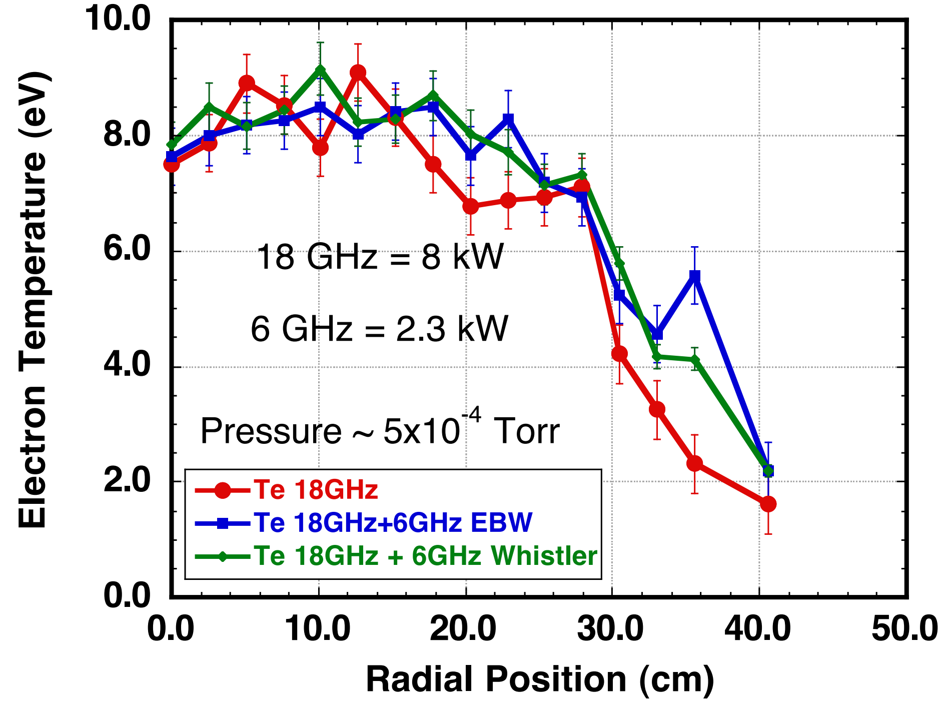
Initial experiments show microwave power coupling to over-dense plasma





- Density increases with the addition of 6 GHz power to above the 6 GHz cutoff density of ~4.5x10^{11}/cm^3 for both whistler and EBW launch
- Electron temperature is 7 – 9 eV for this pressure, increases to > 10 eV at lower pressure