U.S. Collaborations on WEST

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Fusion Energy Sciences Program

U.S. DEPARTMENT OF
ENERGY
Office of Science

WEST Governing Board Meeting
Cadarache, France
May 17, 2019

U.S. DEPARTMENT OF ENERGY
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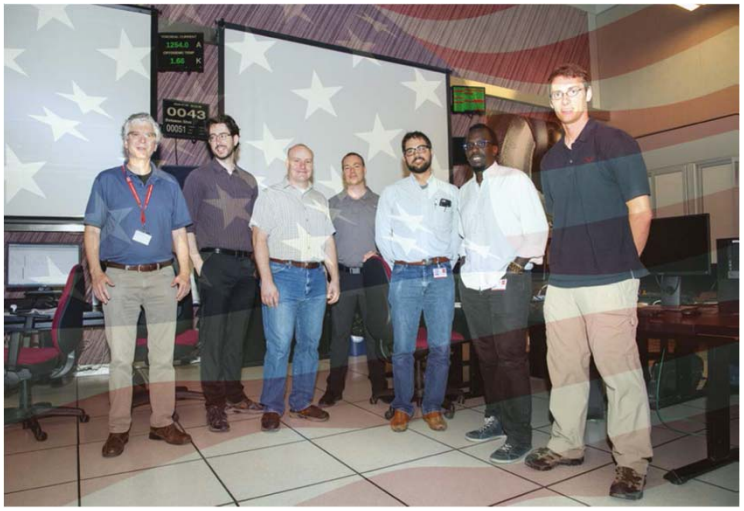
DOE-CEA joint activities aim at addressing top priority issues for WEST

- **ORNL**
  - New spectroscopy system to measure LH wave directivity and scattering
  - Fast filterscopes measure W erosion with poloidal distribution, used to document changes to W gross erosion due to N_2 seeding
  - Proto-type fusion wall evaluation device used to measure W in tokamak edge
- **MIT**
  - U.S. codes (ALOHA) used to assess performance of MIT antenna design, compared with results from COMSOL with plasma model
  - B-field analysis script updated for WEST geometry and data access
- **PPPL**
  - Plan to deploy three x-ray diagnostics to support WEST research program:
    - Compact X-ray Imaging Crystal Spectrometer (cXICS)
    - Multi-Energy Soft X-Ray (ME-SXR) diagnostic
    - Multi-Energy Hard X-Ray (ME-SXR) diagnostic
- **ORNL / UTK / UIUC (*new*)**
  - Coupled PMI modeling of He plasma operation in WEST



WEST Newsletter #22 – October 2018

OAK RIDGE National Laboratory

ORNL Contributions to WEST Collaboration

Assembled by Chris Klepper on behalf of the ORNL WEST collaboration team

C. Lau, E.H. Martin, A.L. Neff, E.A. Unterberg, C.C. Klepper & J.H. Harris

18-Apr-2019

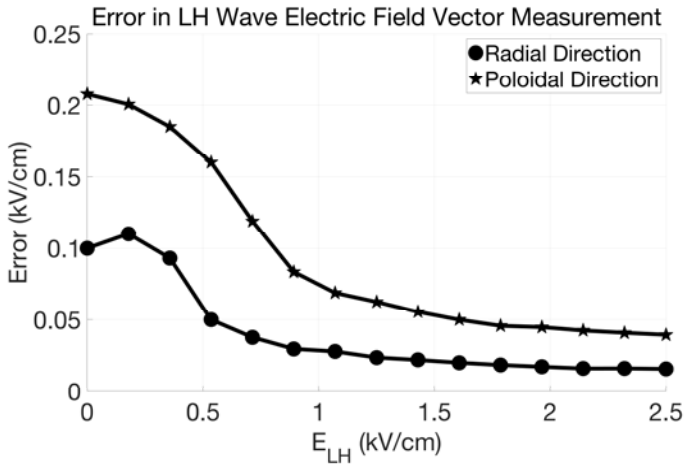
Ahead of WEST GB Meeting of (17-May)

New Spectroscopic System and High Field Side Optics Enable x5 Increase in LH Wave Electric Field Resolution

Accomplishment

New spectroscopic system and high field side (HFS) polarizers increase resolution of LH wave electric field (E_{LH}) measurement by a factor of 5 when compared to the C-Mod experiments.

E. Martin et al., NF (2019), in press
https://doi.org/10.1088/1741-4326/ab16a2

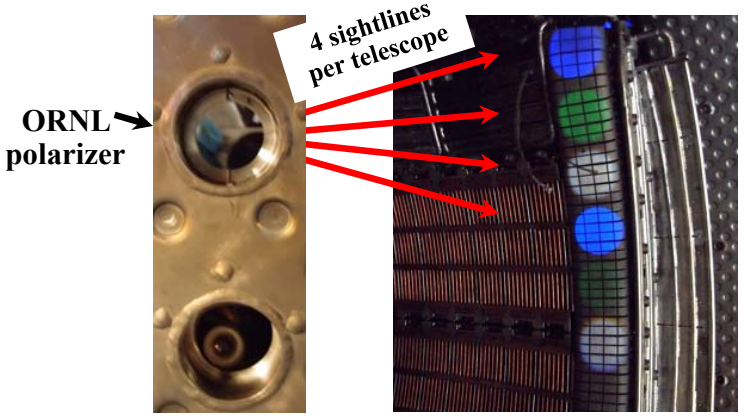


ORNL polarizers, qualified for high vacuum and harsh environment, installed on three high field side (HFS) telescopes, resulting in 12 sightlines.

Scientific Impact

Will enable measurements having an increased sensitivity to LH wave directivity and scattering.

CRITICAL FACTORS DICTATING CURRENT DRIVE EFFICIENCY



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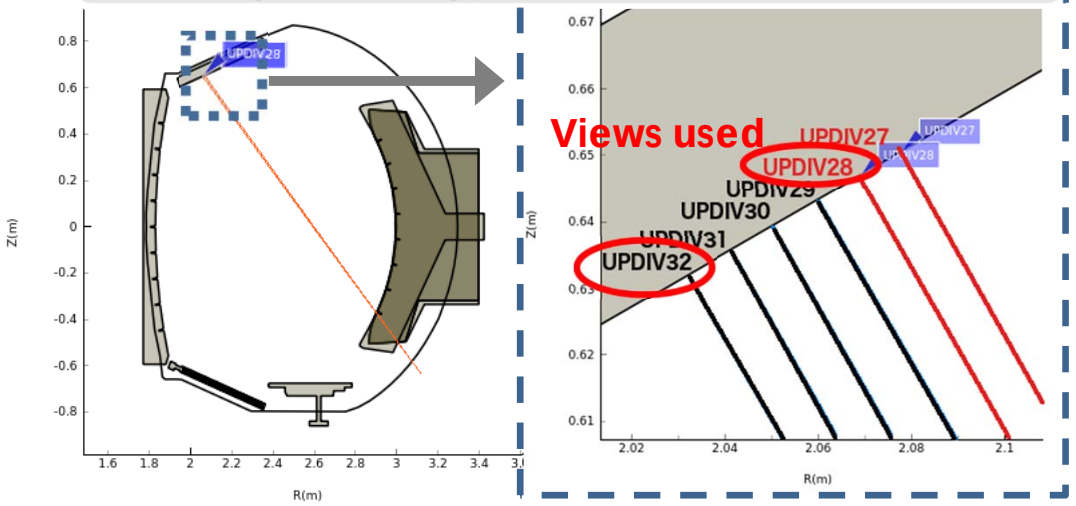
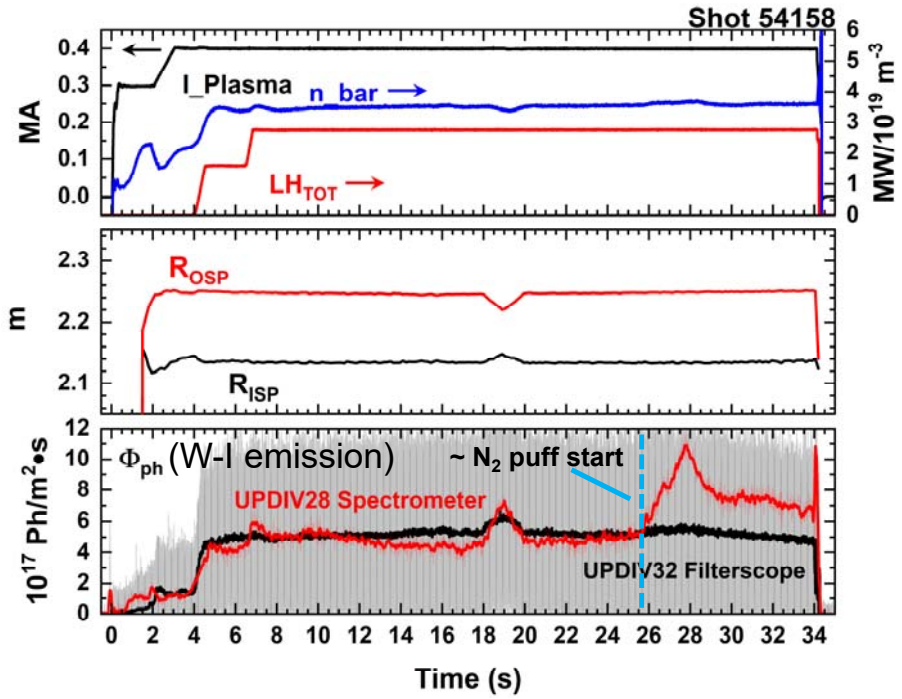
E. Martin + C. Klepper + C. Lau

W Source Spectroscopy Used during recent 30+ second Plasma Pulses on WEST Upper-single-null Discharges

- W erosion measurements available with poloidal distribution and fast-time resolution (*filterscopes*)
- Measurements made during WEST PMI experiments using nitrogen (N_2) seeding in December 2018 → Indications of local changes to W gross erosion due to N_2 seeding
  - *Analysis on-going with planned presentations at PFMC workshop and European Conference on Plasma Diagnostics in May 2019*

WEST Cross-section & Spectroscopy View-chord Location





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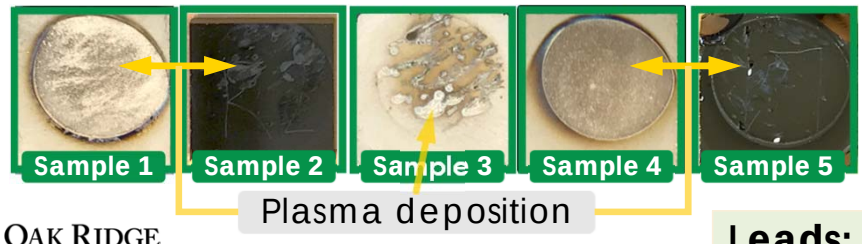
Leads: Unterberg, Klepper, Neff

Reminder: ORNL Deployed Prototype Fusion Wall Evaluation Device on Long-pulsed WEST Tokamak in December 2018

- Sampling device consists of molybdenum (Mo) heat shield & 10 carbon-based samples
- Proto-type tests demonstrate ability to sample tungsten (W) within tokamak edge but limited to ~12 seconds of exposure
- Future work foresees minutes of exposure to plasma aiming to optimize W evolution by plasma-wall interactions which is needed for high-duty-cycle tokamak sustainment

Mo-coated CFC heat shielding showing sample exposure holes

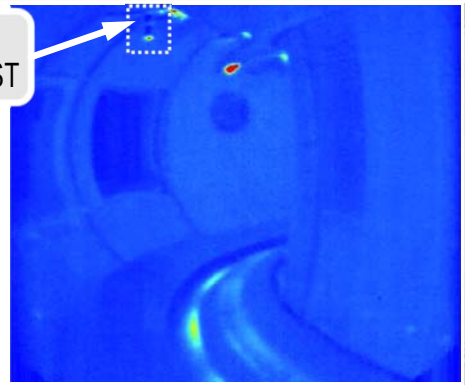
Samples show surface deposition due to exposure; Analysis on-going to determine deposit composition



Inside WEST Vessel showing wall 'hot spots' & cartoon of tokamak shape

Wide-angle infra-red image within a long pulse

Heat shield location in WEST

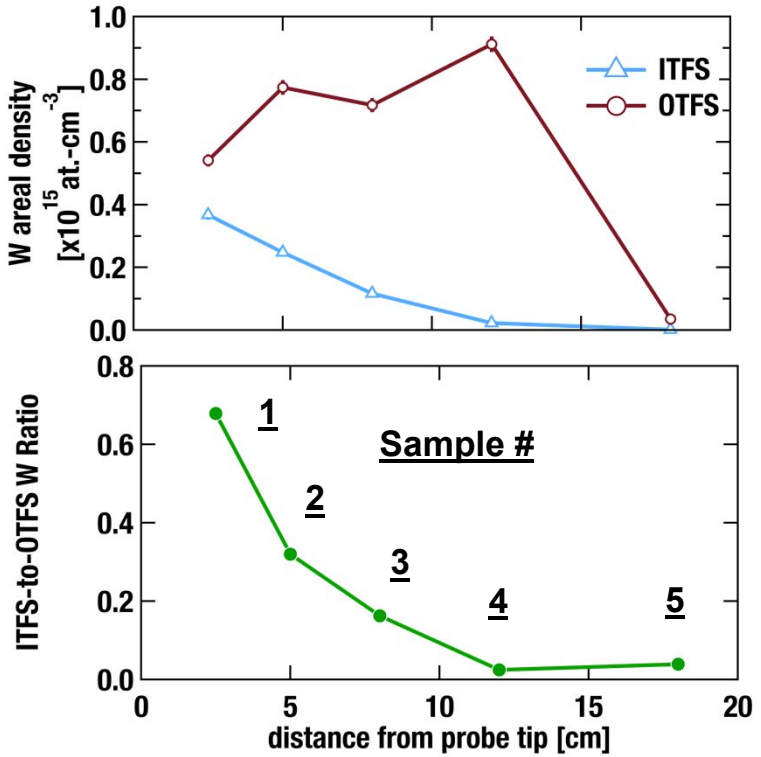


Leads: Unterberg, Klepper, Neff

Initial W Areal Density Profiles from WEST Prototype Collector Probe Indicate W Transport has Preferential Direction along SOL Flux Surface

- DIII-D Collector probes experience during 2016 metal tile campaign used initial interpretation
- Difference between inner target facing side (ITFS) & outer target facing side (OTFS) suggests dominant SOL W source is from LFS
  - *Also suggests no/little W accumulation at 'crown region'*
  - *Probes exposed to L-mode discharge with B x grad-B toward outer target*
- Further analysis is on-going and will use W source spectroscopy measurements to determine main source location(s)

W Areal Density (via RBS) from samples taken from December 2018 exposure



Leads: Unterberg, Klepper, Neff

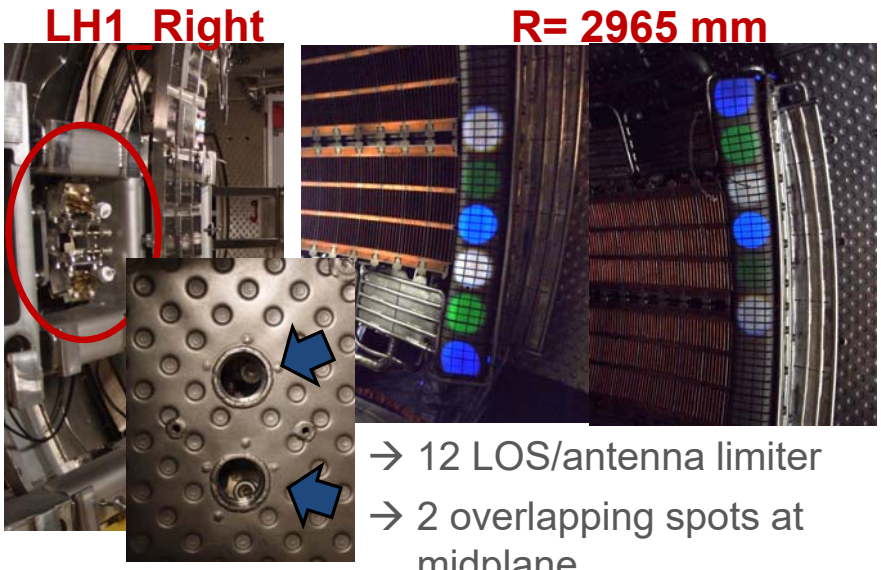
PSFC Plasma Science and Fusion Center
Massachusetts Institute of Technology

JOINT MIT-CEA ACTIVITIES ON LHRF

G. Wallace, 2019-04-16

Ongoing collaboration between CEA/ORNL/MIT to measure LH E-field on WEST

- Successor to SELHF diagnostic on C-Mod
- MIT B-field analysis script updated for WEST geometry and data access
- Spectrometer and polarizers from ORNL
- In-vessel optics from CEA

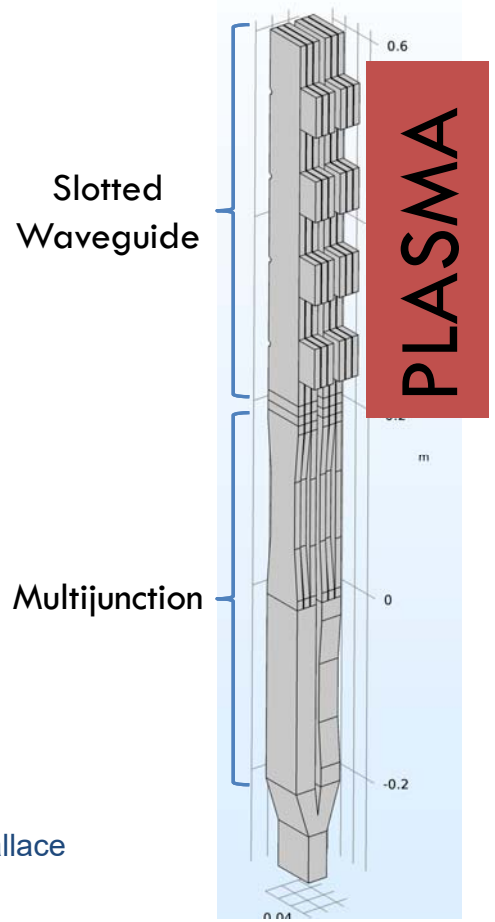


→ 12 LOS/antenna limiter

→ 2 overlapping spots at midplane

CEA/IRFM staff assist with evaluation of MIT HFS antenna design for DIII-D

- Collaboration with W. Helou, RF engineer at CEA/IRFM
  - Previously designed and tested (at low power) slotted waveguide on COMPASS
- Used ALOHA to assess performance of MIT antenna design, compared with results from COMSOL with plasma model
- Results presented in invited talk at 2018 IAEA Fusion Energy Conference



X-ray Crystal Imaging Spectrometer

J. Rice and A. Hubbard

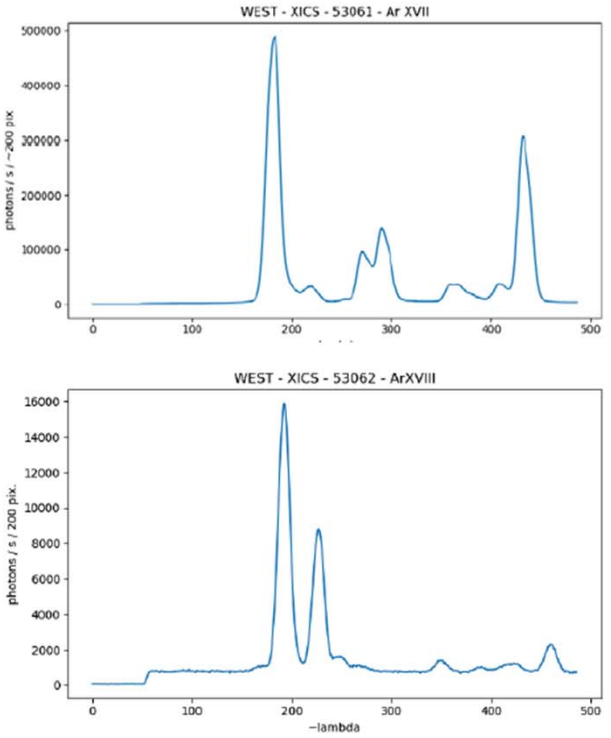
XICS Commissioning

WEST contacts: Didier Vezinet, Christel Fenzi, Gilles Colledani
US participants: Matt Reinke, John Rice

Purpose of collaboration: to assist in interpretation of x-ray spectra to provide time resolved T_i, T_e and V_ϕ profiles, impurity transport coefficients and estimates of tungsten densities.

Current status: central spectrometer operational, He- and H-like Ar spectra obtained (see figures).

Next step: Reinke and Rice will visit WEST for around 2 weeks some time in July-August during the C4 campaign to import x-ray spectral tomographic inversion software (THACO) to provide spatial profiles of ion and electron temperature, as well as toroidal rotation.

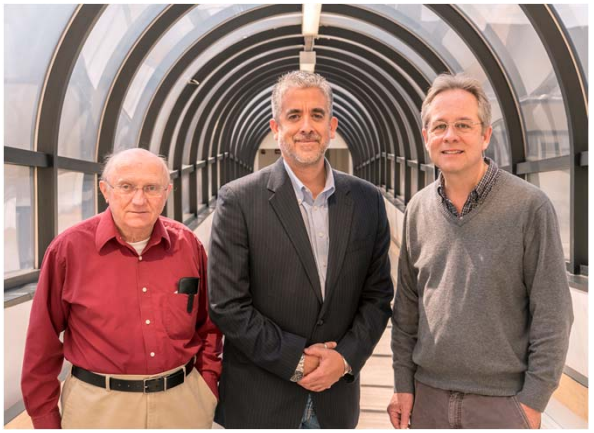


J. Rice

Overview of PPPL x-ray collaboration at WEST

- PPPL plans to deploy three x-ray diagnostics on WEST and use them in support of the WEST research program:
  - Compact X-ray Imaging Crystal Spectrometer (cXICS)
  - Multi-Energy Soft X-Ray (ME-SXR) diagnostic
  - Multi-Energy Hard X-Ray (ME-SXR) diagnostic

- Diagnostics will make significant contributions to the WEST physics research program (e.g. support all divertor scenarios at WEST and work towards extending its H-mode up to 10^3 s)



PPPL x-ray group: K. Hill, L. F. Delgado-Aparicio, B. Stratton, N. Pablant, M. Bitter and P. Efthimion

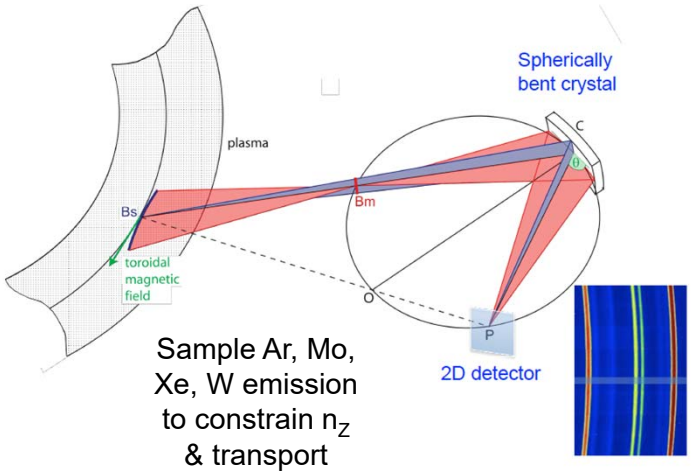
- PLAN:
  i. Complete designs and hold FDR by 09/2019
  ii. Fabricate/ship to WEST by 3/2020. Plan to install diagnostics during shutdown to install actively cooled divertor - to be ready for C5 campaign
  iii. PPPL will provide two postdocs stationed at WEST in 2020-2021
  iv. Exploit the diagnostics and physics during campaigns C5-C8

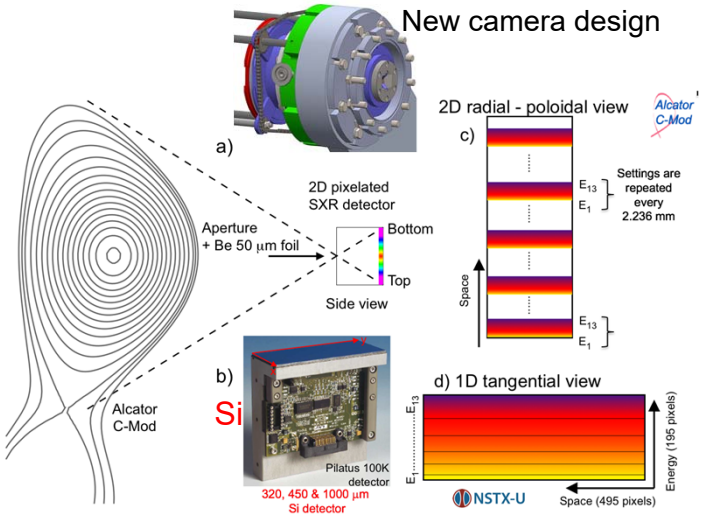
After visits in 2018-2019 successful CDR was held for three PPPL x-ray diagnostic to be implemented on WEST

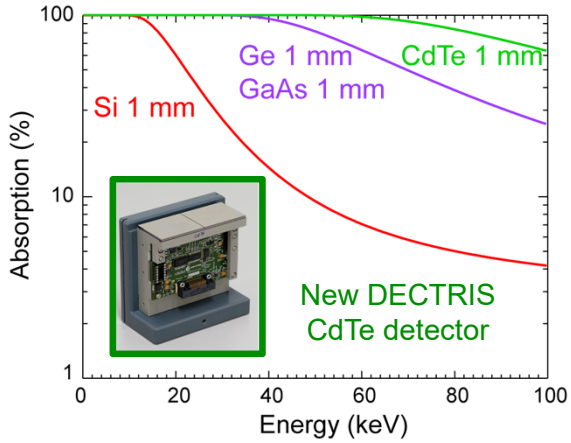
① Modest-resolution compact x-ray imaging crystal spectrometer (cXICS) for n_Z & δZ_{eff} profile measurements

② Broadband multi-energy SOFT x-ray (ME-SXR) for n_Z, δZ_{eff} and T_e profile measurements

③ Broadband multi-energy HARD x-ray (ME-HXR) for T_e & $n_{e,fast}$ measurements







Successful CDR was held on April 4 and suitable port options were agreed upon

Detectors for cXICS and ME-HXR are ordered and one post doc is hired

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Coupled PMI modeling of He plasma operation in WEST

Brian Wirth & the PSI SciDAC-4 Team

ORNL

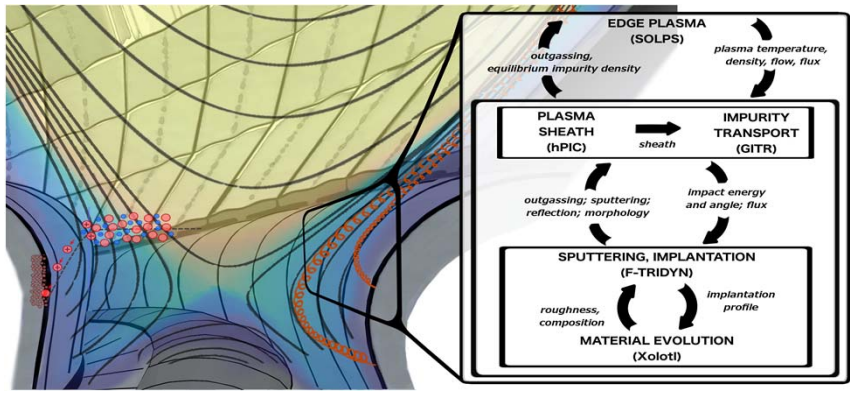
ORNL is managed by UT-Battelle, LLC for the US Department of Energy

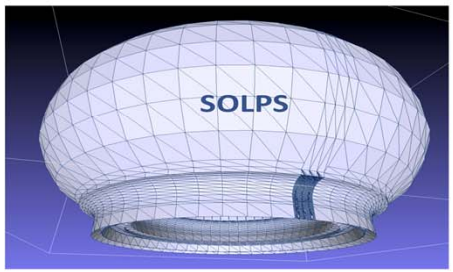
U.S. DEPARTMENT OF ENERGY

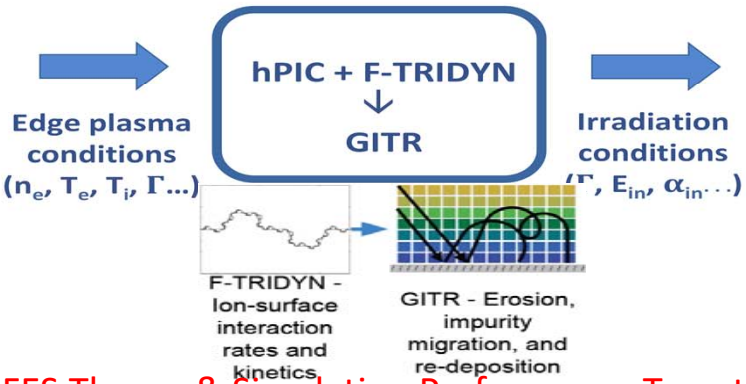
Objective – validate He plasma exposure of integrated PSI modeling capability

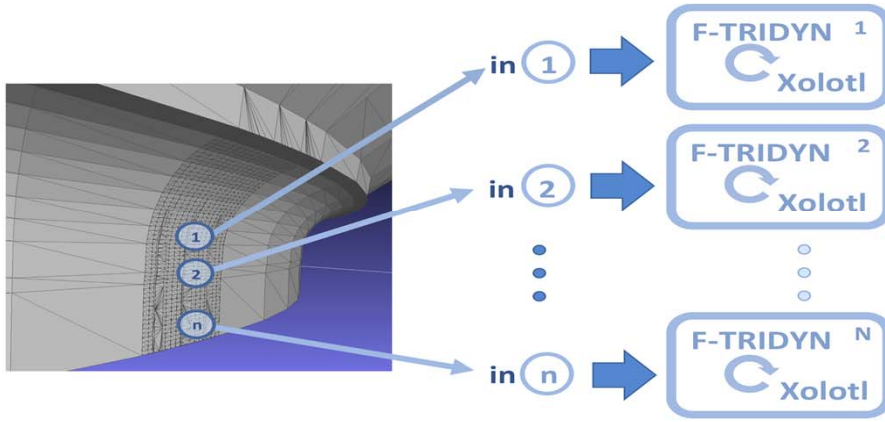
Includes models for

- Background plasma transport (SOLPS)
- Near-surface sheath (hPIC)
- Erosion and transport of wall material (GITR)
- Implantation of ions into the material (F-TRIDYN)
- Dynamics of the subsurface (Xolotl)





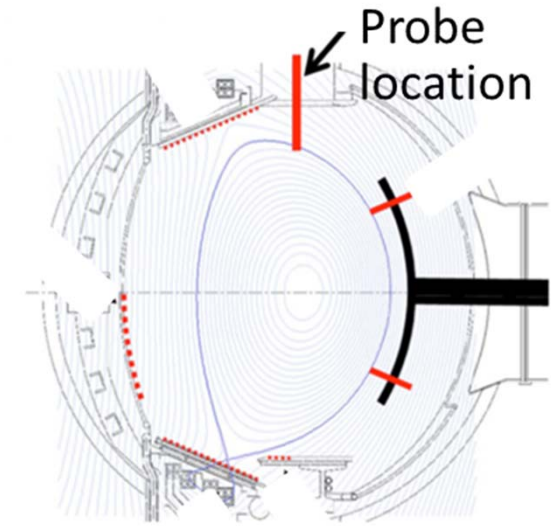




*Subject of 2018 DOE-FES Theory & Simulation Performance Target: full report can be found at https://science.energy.gov/fes/community-resources/

Overall objective: Exposure single crystal W to He flux as near to divertor conditions as possible

- Propose to use same probe setup as was done in Dec. ‘18 but to expose sample not collect
  - *i.e., aim for ~20 eV for background plasma condition*
- Expose 10 samples for up to 100sec in pure helium (may be revised to incorporate some samples to assess tungsten implantation, as well as study influence of pre-exposure surface conditions)
- Post-exposure characterization to be done at ORNL & compared with the US PSI modeling code Xolotl



Full sample tray