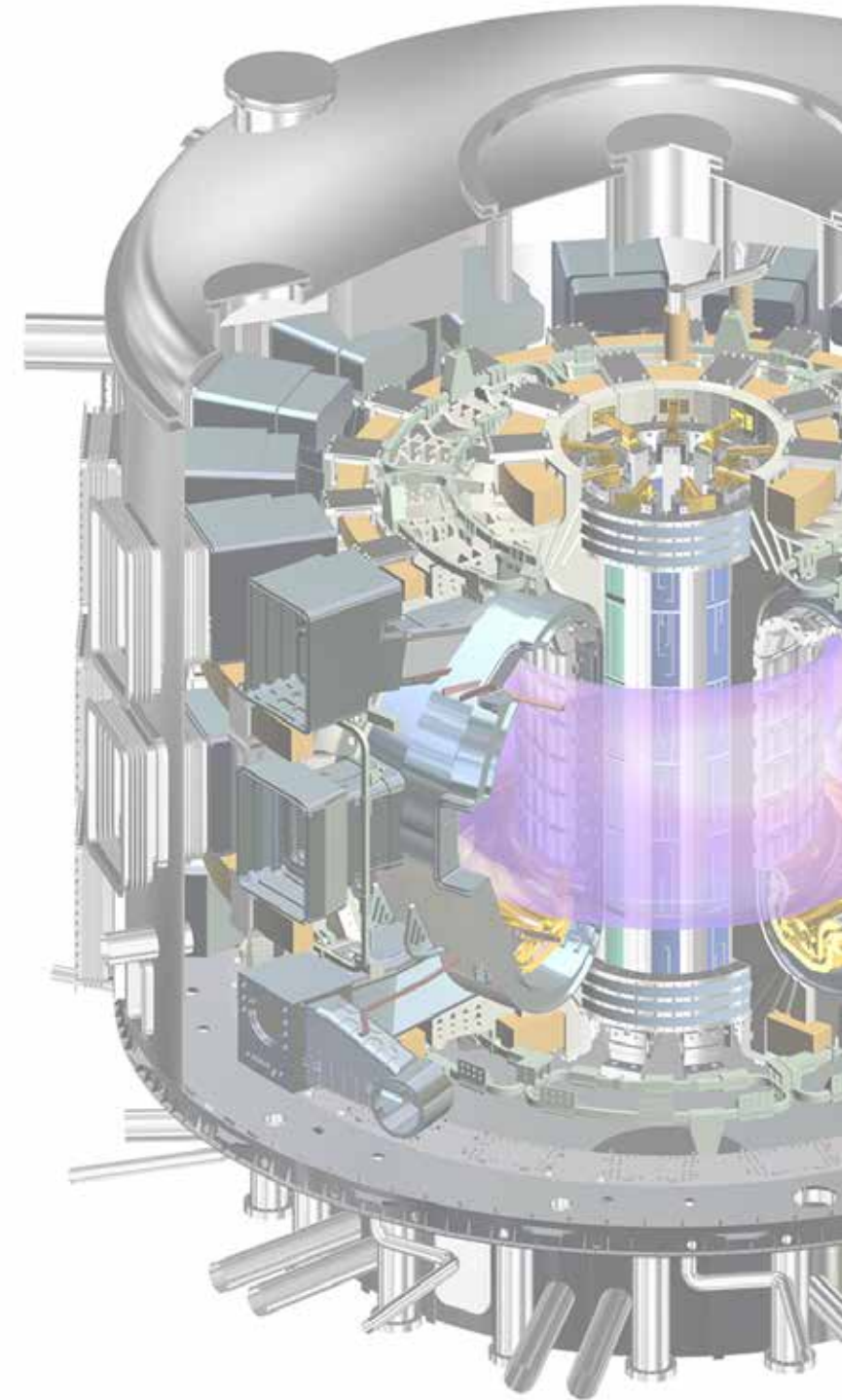


# ITER Diagnostics Work at PPPL

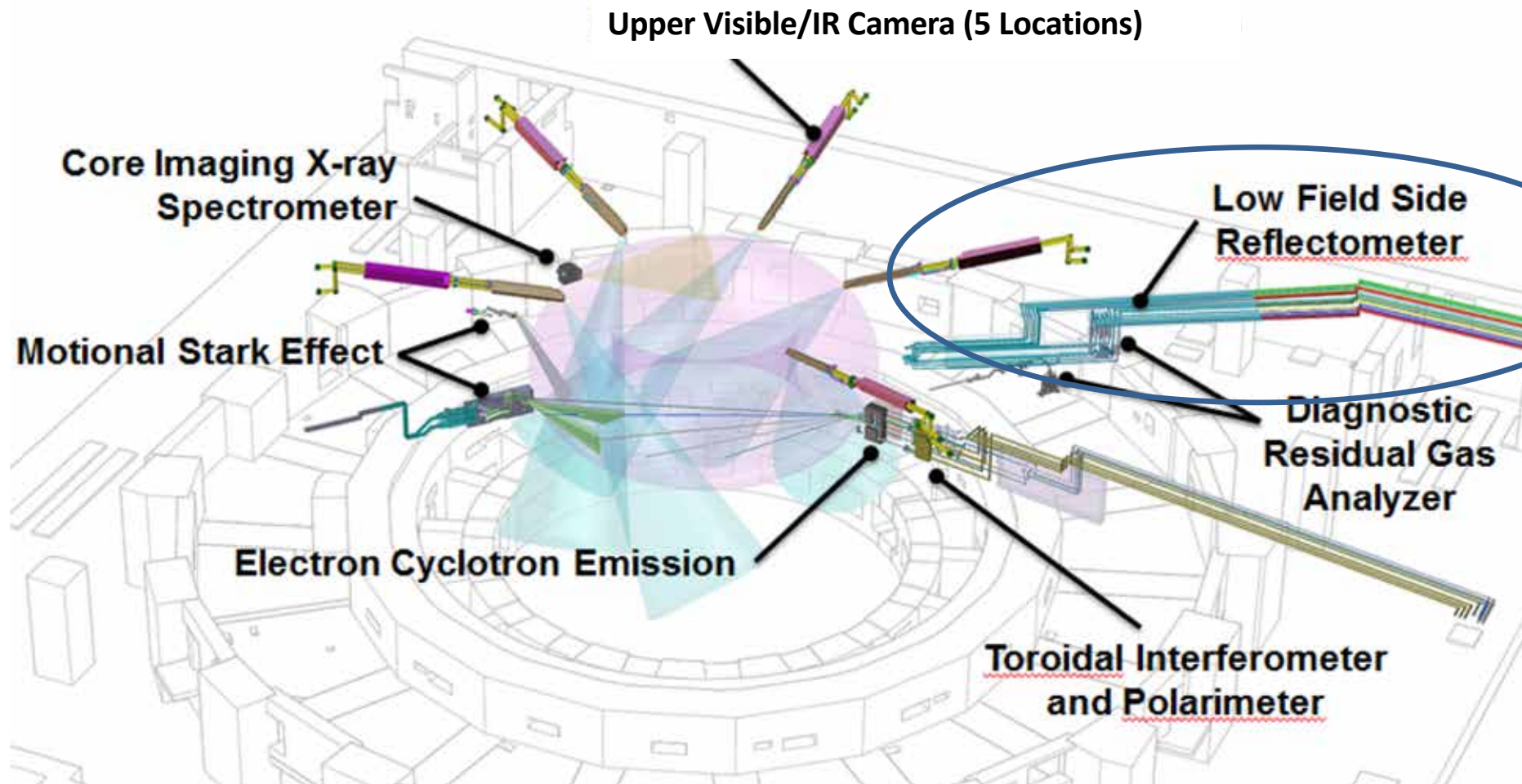
Hutch Neilson  
U.S. ITER Diagnostics Team Lead  
*Princeton Plasma Physics Laboratory*



**NSTX-U / MFE Science Meeting**  
**15 October 2018**



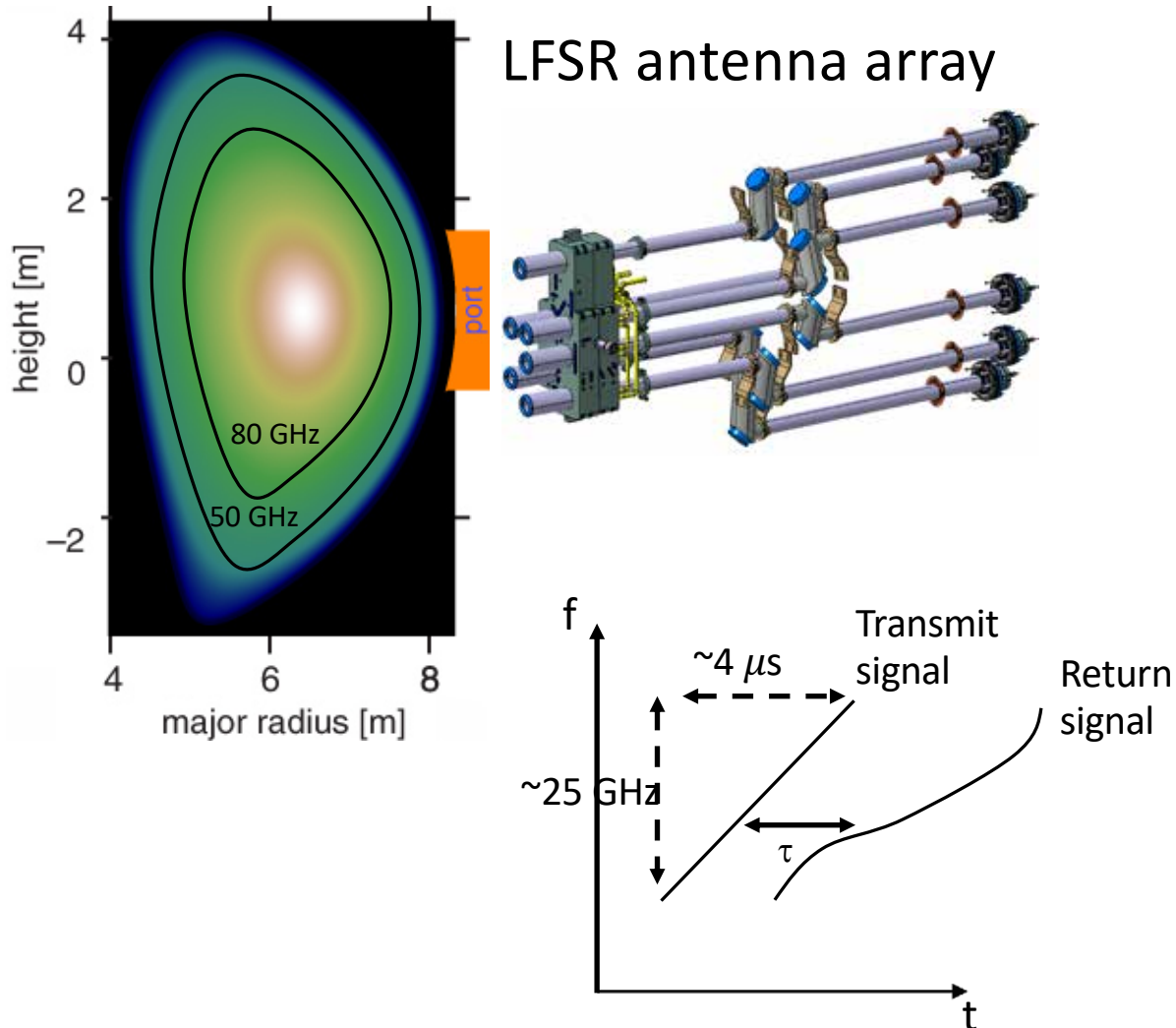
# PPPL is responsible for all 7 U.S. ITER diagnostics



Also port integration for four ports: 2 equatorial and 2 upper.

Low Field Side Reflectometer is the only active project at this time

# Plasma Density Profile Measurement by Microwave Reflectometry

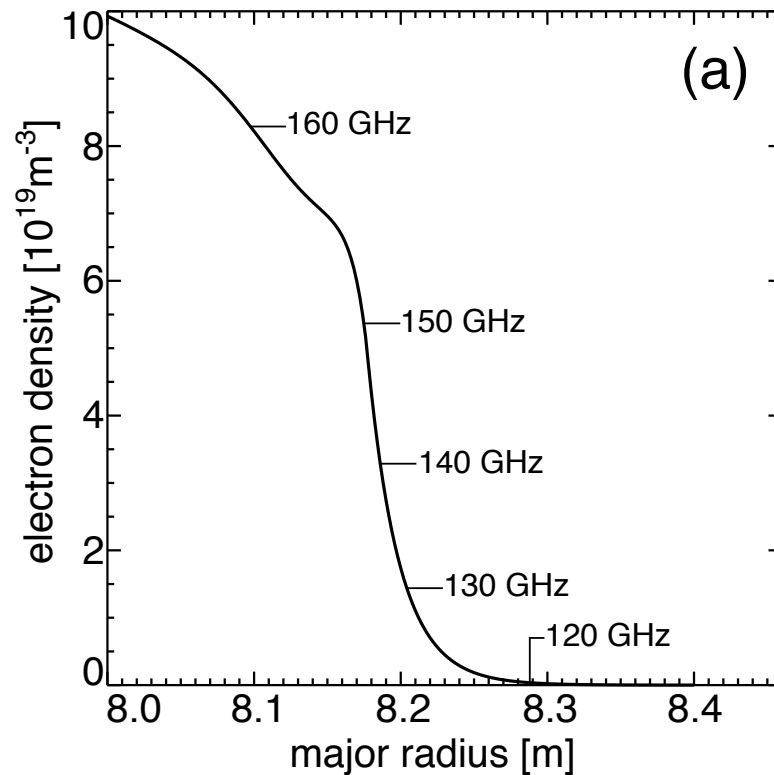


- Reflection layers exist in the plasma depending on density and microwave frequency.
  - A given frequency corresponds to a value of density
- Sweep through a range of frequencies and measure the time delay ( $\tau$ ) of each frequency component  $\rightarrow$  density profile
- Addresses measurement roles:
  - edge  $n_e$  profile
  - H-mode and ELM transients
- System can also measure density fluctuations and poloidal rotation.

# Antenna-plasma coupling has been analyzed for a range of conditions including fluctuations.

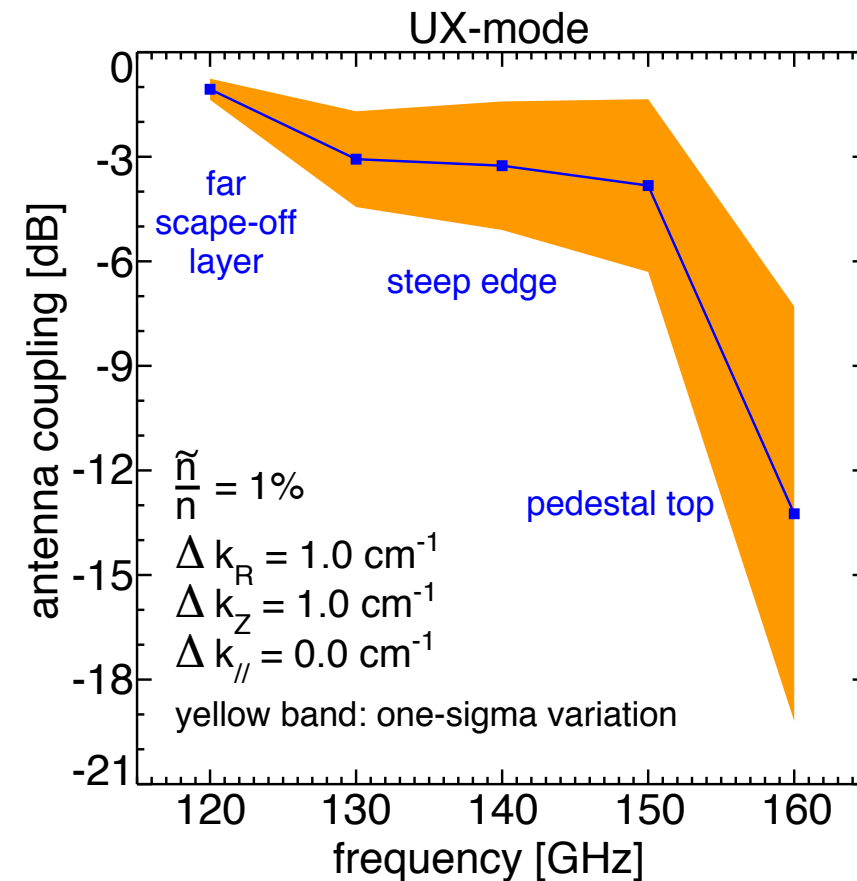


H-mode equilibrium density profile



G.J. Kramer et al 2018 Nucl. Fusion **58** 126014  
<https://doi.org/10.1088/1741-4326/aadea1>

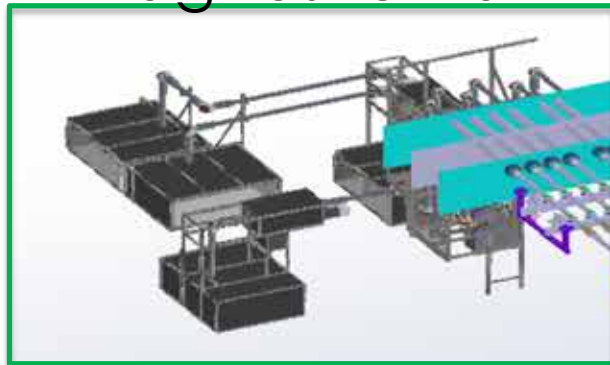
Antenna-plasma coupling vs frequency  
(avg. and  $1\sigma$  error bands over 300 simulations per frequency)



# LFSR extends ~50m from first wall to diagnostic hall

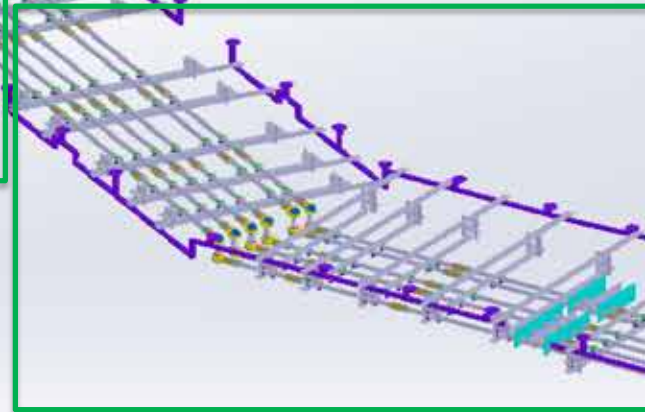


Diagnostic Hall

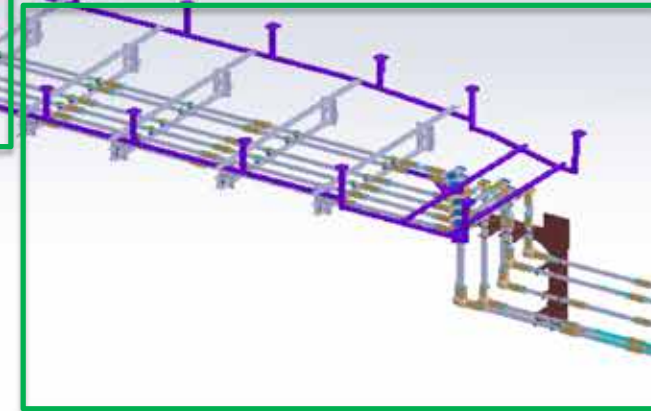


Lintel

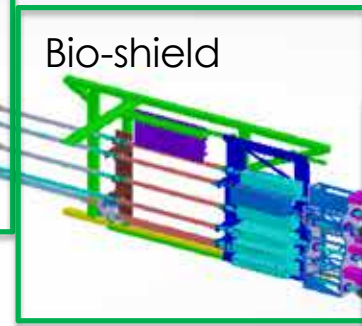
Gallery



Port Cell

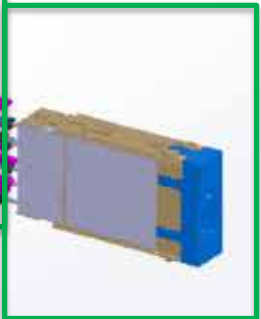


Interspace



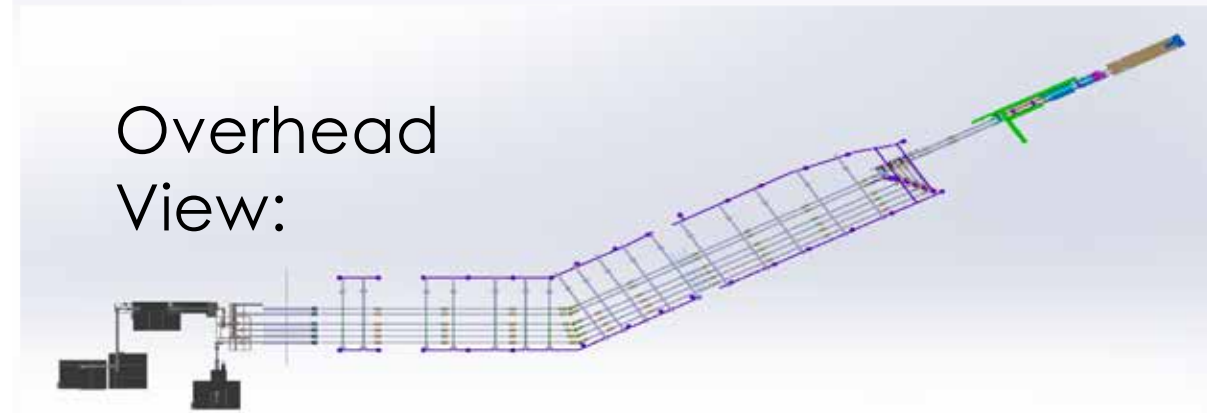
Bio-shield

Closure Plate



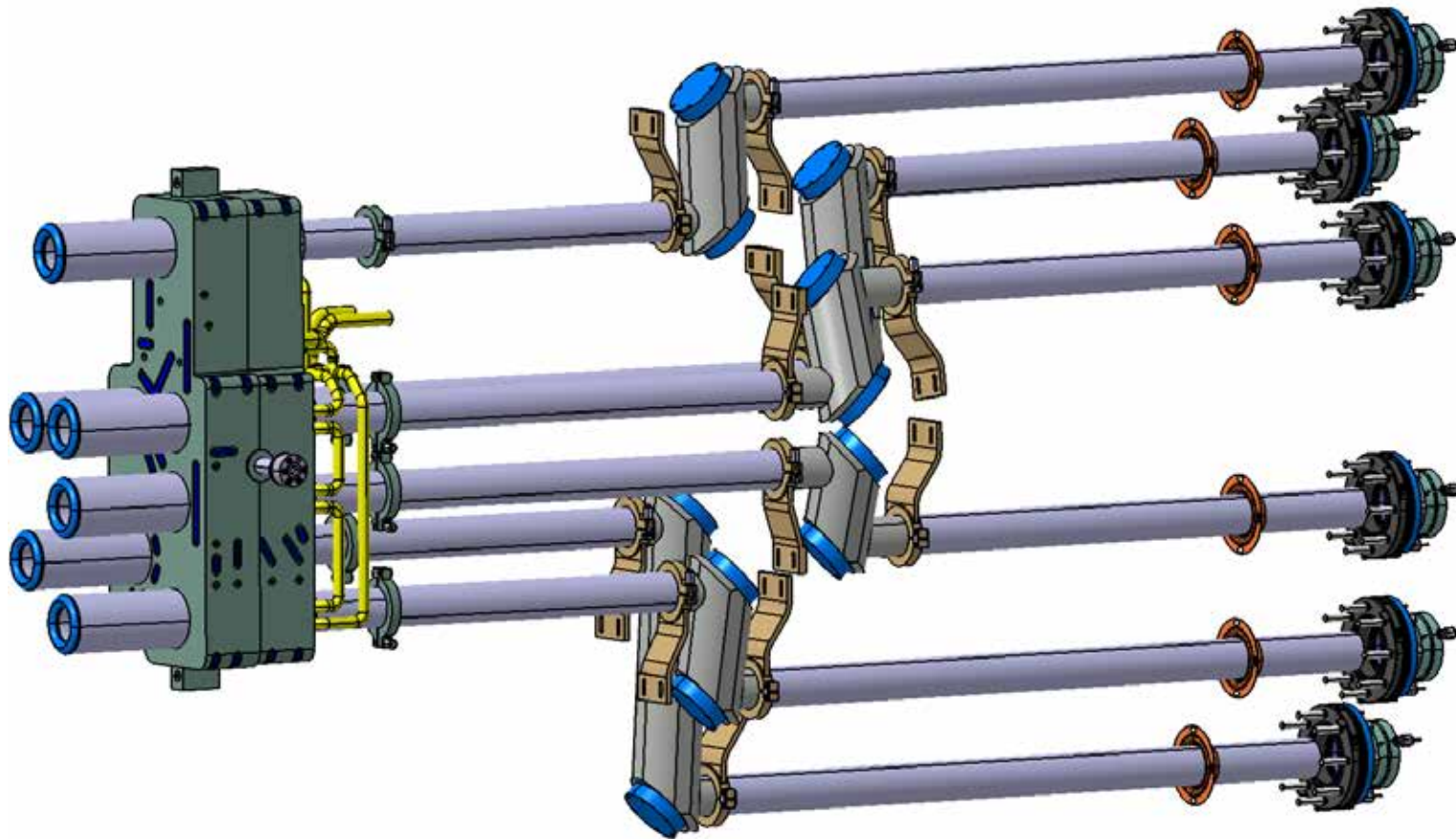
In Vessel

Overhead View:



# In-vessel Equipment

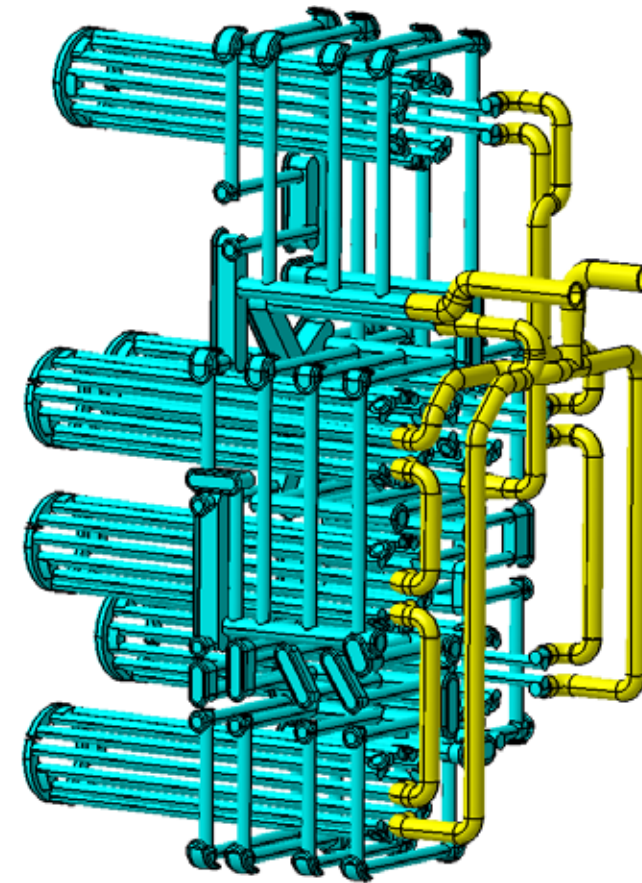
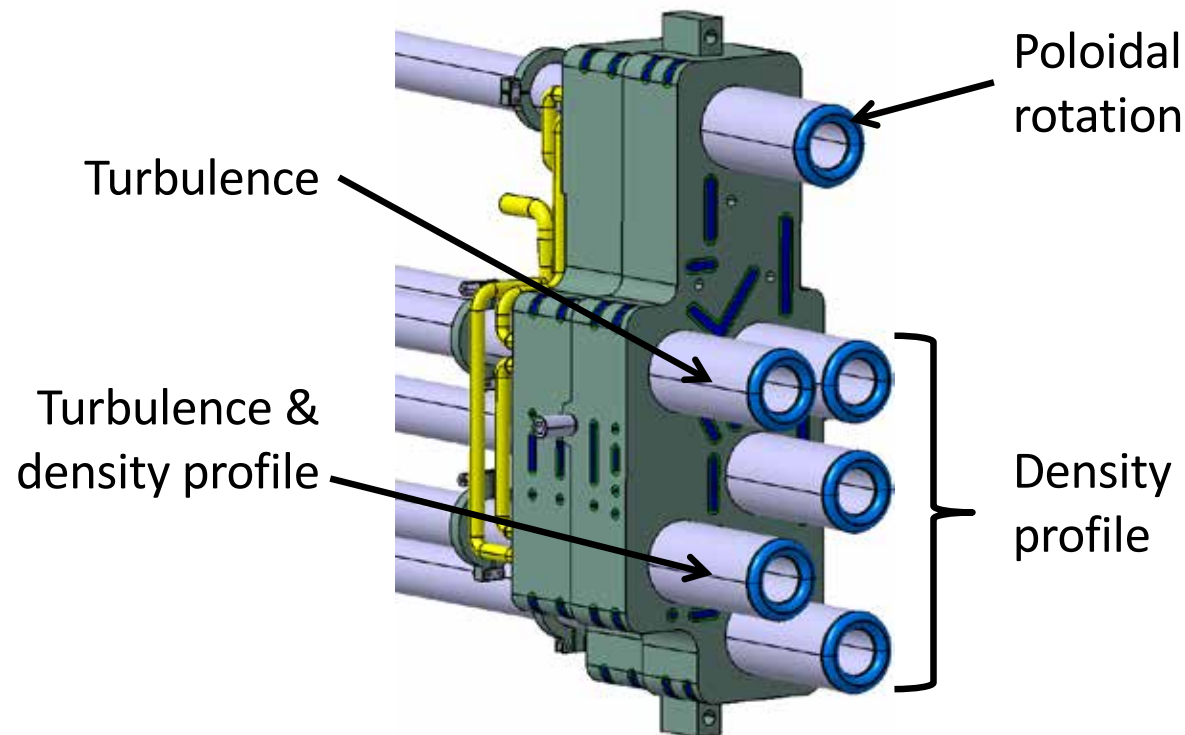
- Stainless steel waveguide with periscope to prevent streaming.
- Support straps attach LFSR equipment to port plug structure.



**First plasma  
scope!**

# Antenna Assembly

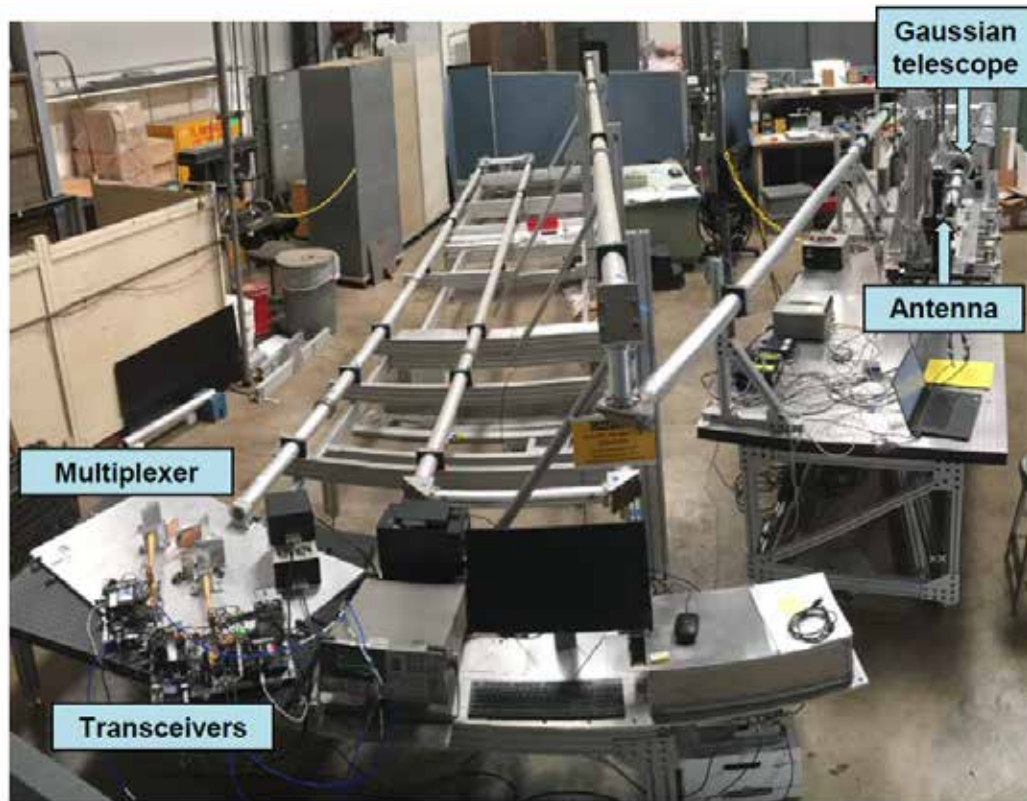
- 6-antenna array provides required measurement functions
- Reflected waves are received by the launching antenna (monostatic)
- Water-cooled antennas and support block receive the main nuclear heat loads.



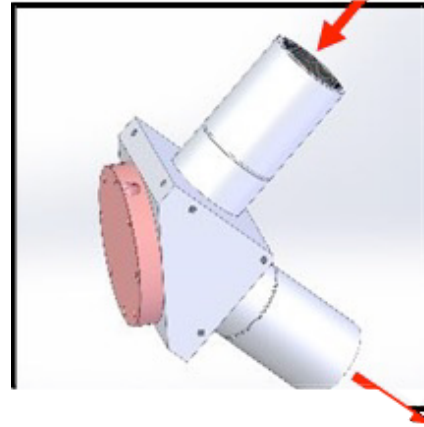
# Transmission line system has undergone extensive performance testing at General Atomics.



## LFSR transmission-line prototype test stand



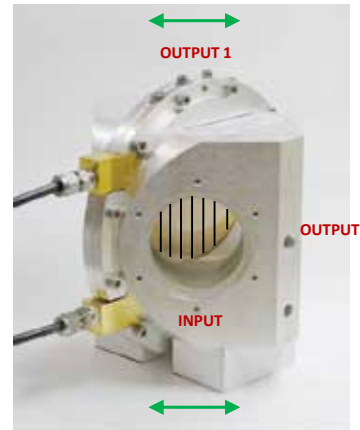
## Bends



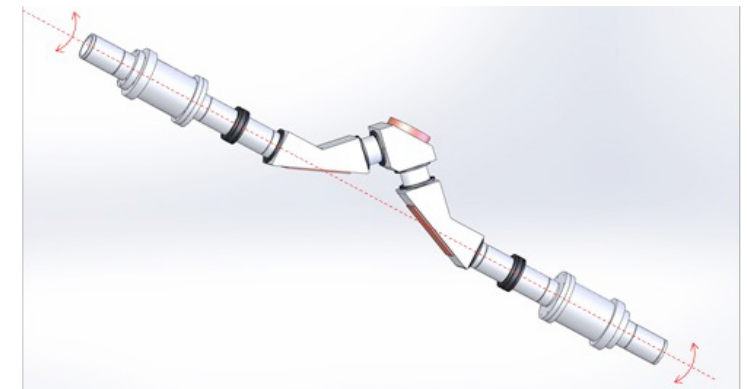
## Switches



## Beam Splitter / Combiners



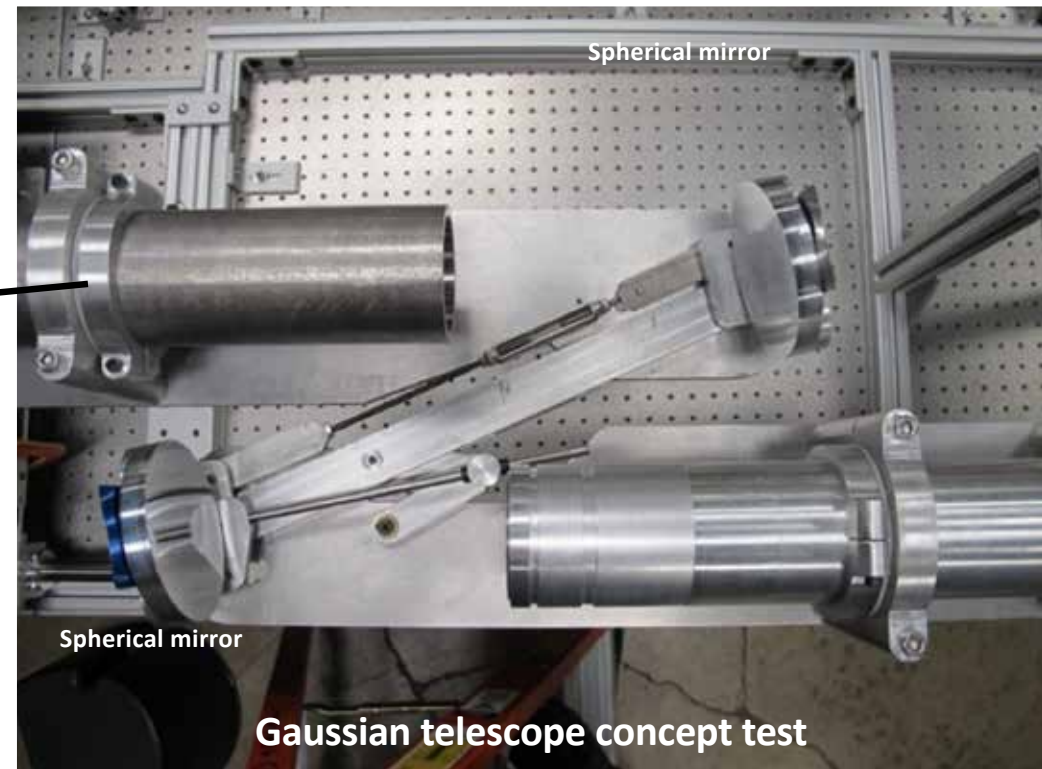
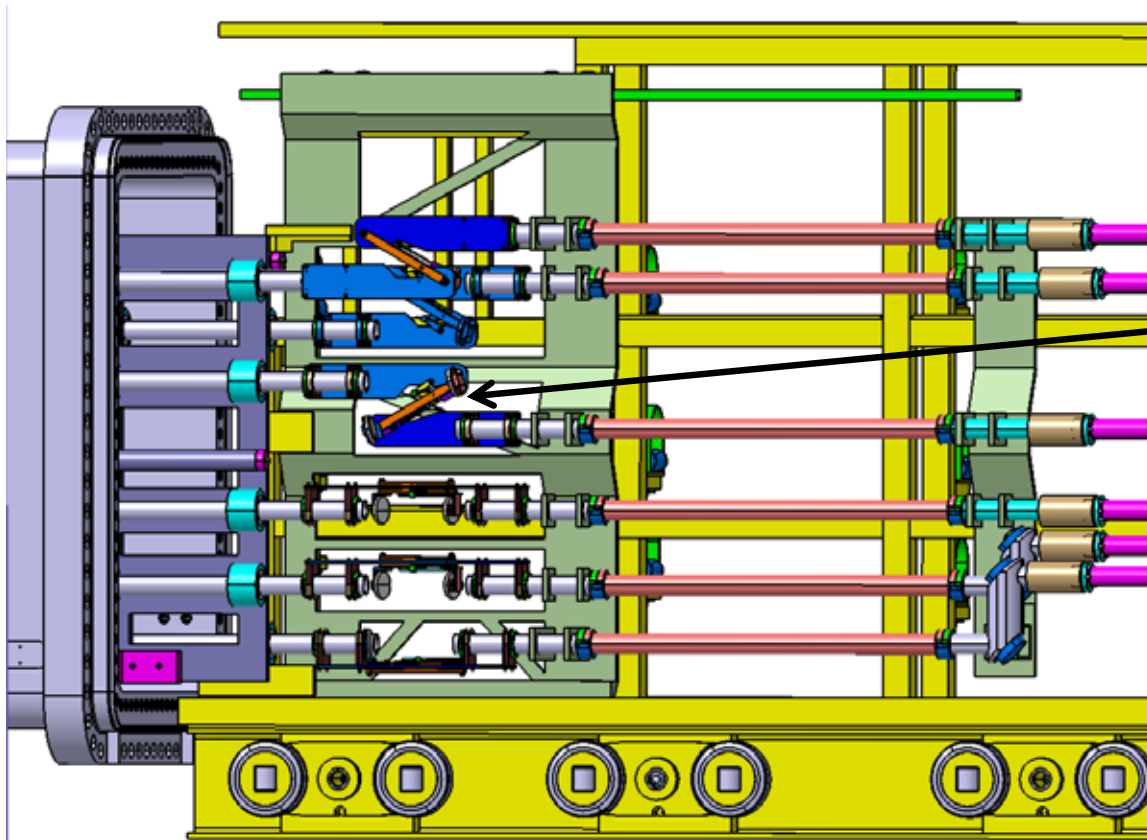
## Polarization Rotators





# Gaussian Telescope

- Maintains beam transmission while accommodating thermal displacements (up to 3 cm) of vessel-mounted waveguides.
- Performance successfully demonstrated in proof-of-concept test.



- Design team: PPPL, General Atomics, UCLA, Palomar Scientific Instruments.
- Preparations for Nov. 7-8 PDR are nearly complete.
  - >280 system requirements defined
  - Design compliance documentation (>100 reports and drawings) submitted and in final review.
  - U.S. ITER status review Sept. 11 affirmed readiness to proceed to PDR.

# Backups

# Required measurement roles: edge electron density (profiles and fluctuations), poloidal rotation



Measurement	Parameter	Contribution	Highest Operation Role	Range Value Coverage	Spatial Coverage	Time Res.	Spatial Res.
Edge electron density profile [1]	Edge $n_e$	Primary	Advanced Control	$5 \times 10^{18} - 1 \times 10^{20} \text{ m}^{-3}$	$r/a > 0.85$	10 ms	5 mm
Toroidal Alfvén Eigenmode (TAE) density fluctuations [2]	$\delta n_e / n_e$	Primary	Physics	$5 \times 10^{-6} - 5 \times 10^{-4}$	TBD	30 kHz – 2 MHz	$N = 10 - 50$
H-mode, ELM and L-H mode transition indicator [3]	ELM / density transient	Primary	Physics	$5 \times 10^{18} - 1.5 \times 10^{20} \text{ m}^{-3}$	$r/a > 0.85$	0.5 ms	3 mm
Plasma rotation [4]	$v_{pol}$	Supplementary	Advanced Control	1 – 50 km/s	$r/a > 0.85$	10 ms	$a/50$ (~4 cm)
Line-averaged electron density [3]	$\int n_e dl / \int dl$	Supplementary	Basic Control	$5 \times 10^{18} - 1.5 \times 10^{20} \text{ m}^{-3}$	$r/a > 0.85$	10 ms	3 mm
Core electron density profile [1]	Core $n_e$	Backup	Advanced Control	$5 \times 10^{18} - 3 \times 10^{20} \text{ m}^{-3}$	$r/a < 0.85$	10 ms	$a/30$ (~7 cm)

## Conditions:

- Full- and half-field
- 52 cm range of vertical plasma displacements

[1] "Measurement 23 and 24, Electron Temperature and Density profiles," SBYVVL  
 [2] "SRD-55 (Diagnostics) from DOORS," 28B39L  
 [3] "Measurement 06 & 14 (line average density and ELMs) Parameter 011, 031," T8FVZ3  
 [4] "Measurement Requirements Flow-Down for MP018.  $v_{pol}$ ," R25ZHM

# LFSR Integration in Port Plug

- Front end components will be installed in a first-plasma port (Equatorial 11) diagnostic shield module (DSM).

