Pegasus-III
Experiment

Development of a Microwave System for Pegasus-III

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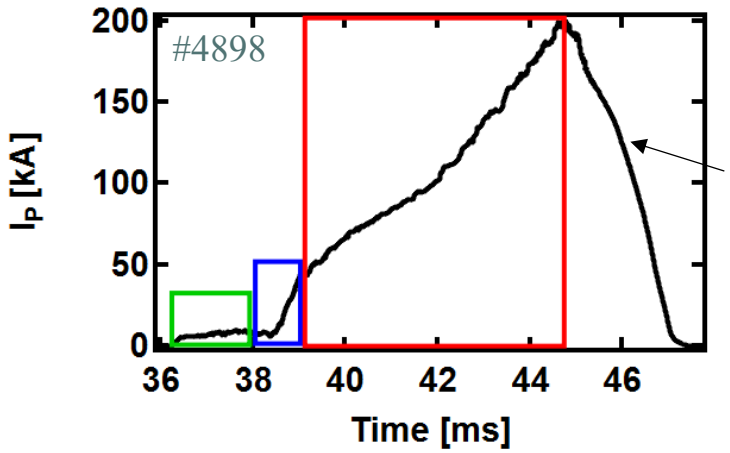
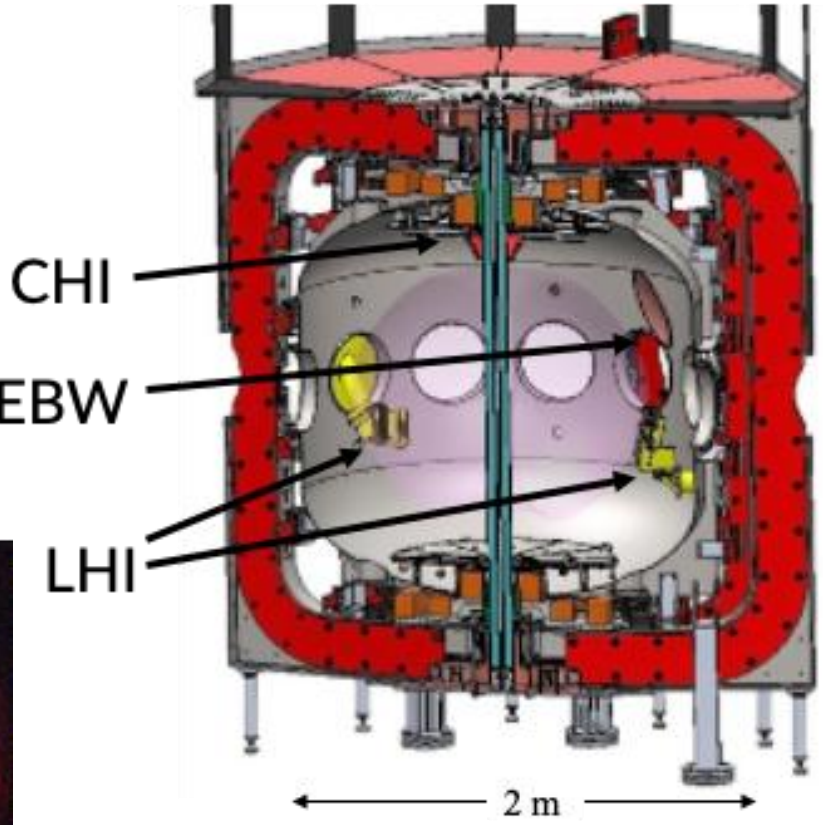
The Pegasus-III Experiment

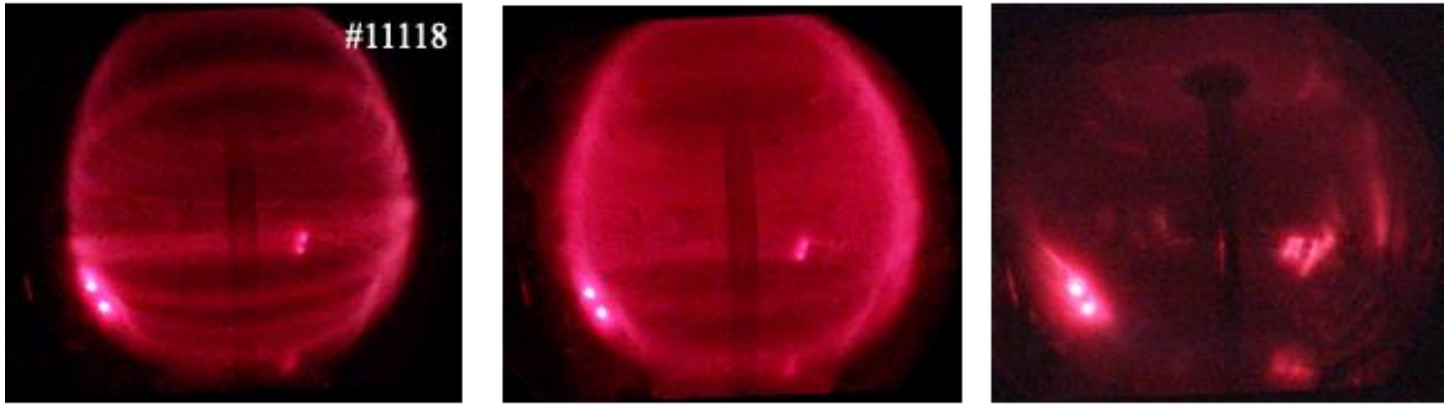


LHI-c I_P Trace

Pegasus-III Machine



Fast Camera Images of LHI Stages on Pegasus-III



$I_p \approx N_{turns} I_{inj}$

1. Injected current follows helical $\vec{B}$

$I_p \gtrsim N_{turns} I_{inj}$

2. Current streams go unstable, reconnect

$I_p \gg N_{turns} I_{inj}$

3. Plasma relaxes to a "tokamak-like" state

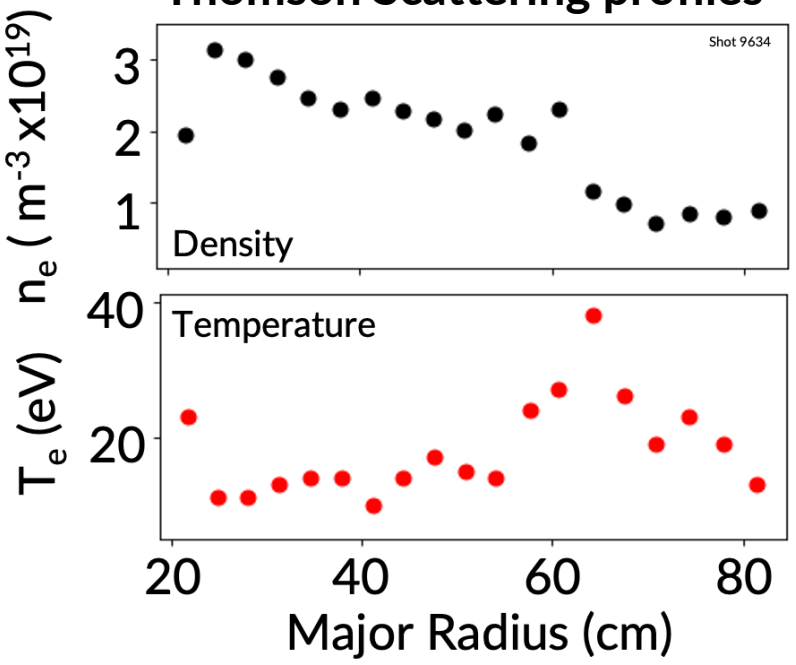
Typical parameters:

- $n_{e0} \sim 2 \times 10^{19}\ m^{-3}$
- $T_e \sim 30 - 100\ eV$

Characteristics of LHI plasmas

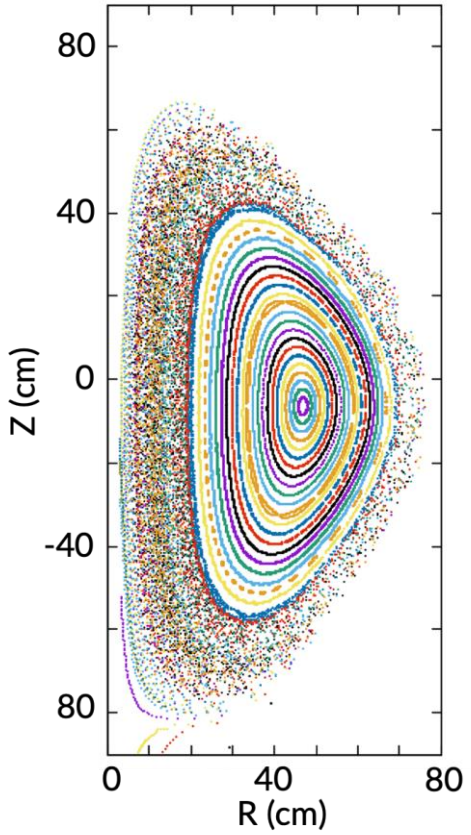
- Hollow electron temperature profiles
- Peaked or flat electron density profiles

Thomson Scattering profiles

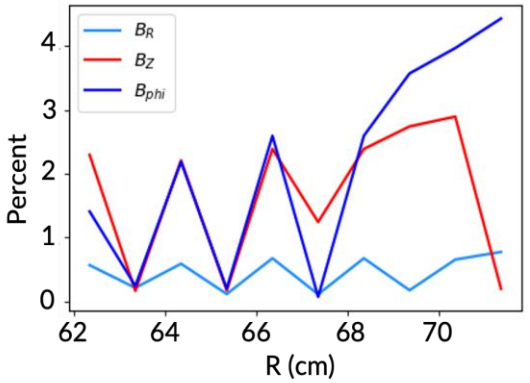


- Stochastic edges, B-field fluctuations ~3%

Poincaré plot calculated with M3D-C1[1]



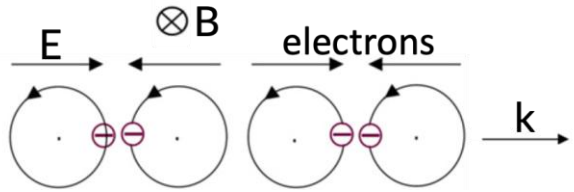
Measured $RMS_{B\sim}/B_T$

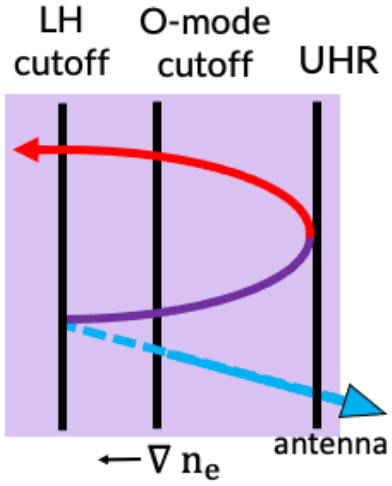


[1]C.E. Schaefer, et al, 2025. [Online]. https://arxiv.org/abs/2511.03930

Electron Bernstein Waves

- For a 28 GHz source, plasmas become overdense at $1 \times 10^{19}\ \mathrm{m}^{-3}$, prohibiting EC use. Instead, EBW can be employed
  - Do not experience n_e cutoffs, are absorbed at EC harmonics

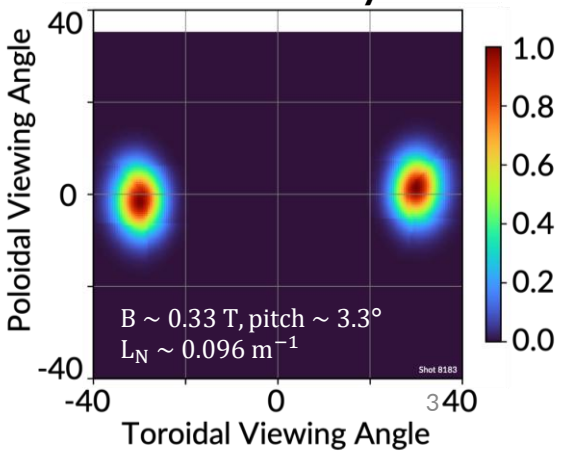




- EBW cannot propagate in vacuum and are launched via OXB mode conversion (MC) scheme
  - Launched O-mode converts to X-mode at LH cutoff, X-mode to EBW conversion occurs at UHR layer
  - Power coupling depends on B field and $L_n = \frac{n_e}{dn_e/dr}$

- When $T_e > 1$ eV and $n_e > 10^{11}\ \mathrm{m}^{-3}$ plasma acts as blackbody EBW emitter.
  - Through BXO MC, EBW are emitted
  - OX conversion occurs at two angular locations in plasma edge
  - Size & angular location of windows estimated with analytical eq.

Calculated transmission efficiency



EBW emission measurements

- Measurements on Pegasus-III have been taken with the SAMI phased-array radiometer
  - SAMI has measured microwave power from a variety of plasmas
  - No MC windows have been conclusively identified yet

Optical thickness and expected power emission from streams (~800 eV)

ω (GHz)	n_{harm}	τ_X	X_{Power} (mW)	τ_O	O_{Power} (mW)	τ_{EBW}	EBW_{Power} (mW)
18	4th	2.3e-3	3.0e-3	-	0	2768.1	1.3
28	6th	5.3e-5	2.6e-4	1.2e-12	0	2715.9	5.0

And from bulk plasma (~30 eV)

18	4th	1.2e-8	3.0e-8	-	0	1455.1	1.7e-2
28	6th	1.3e-12	1.2e-11	-	0	1427.6	6.4e-2

- Optical thickness calculations say emission is EBW, so why are there no MC windows?

SAMI power, I_p, and V_{inj}

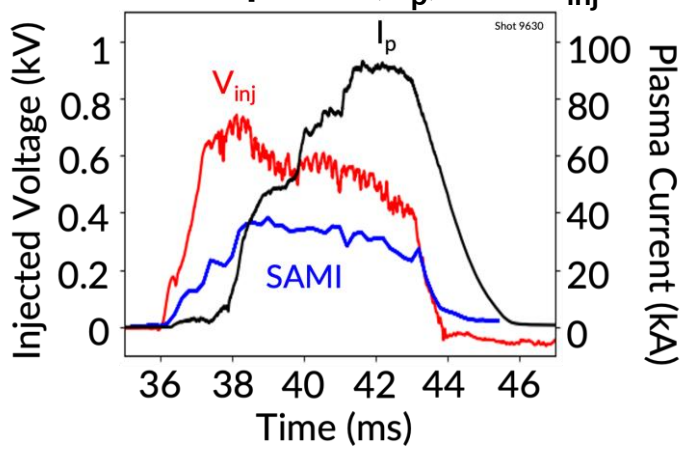
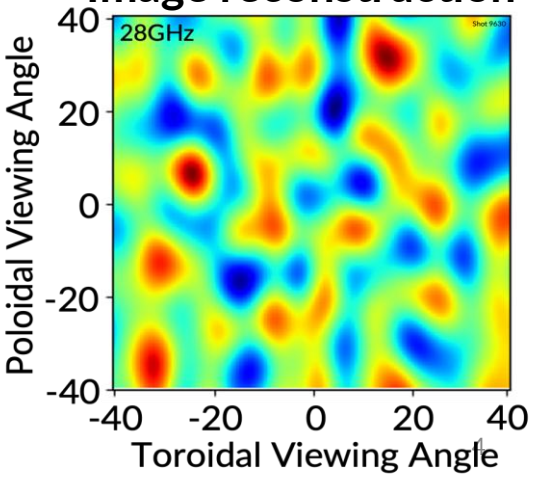


Image reconstruction



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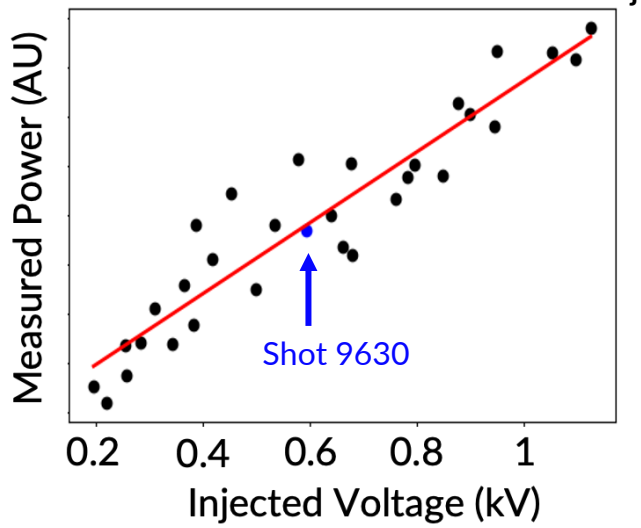
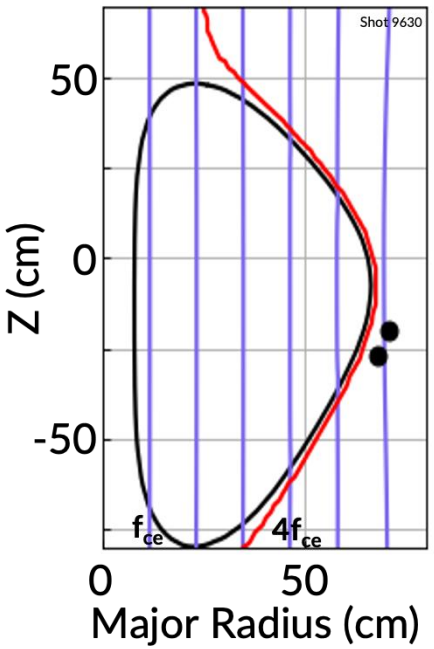
EBW emission measurements from LHI streams

- Scans of injector voltage show measured signal levels are proportional to V_{inj}, suggesting emission from streams dominates measurements
  - EBE is blackbody and directly proportional to T_e for $\tau>1$
  - T_e in streams exiting injectors is expected to be directly proportional to V_{inj} $\rightarrow$ $T_e[eV] = V_{inj}[V]$

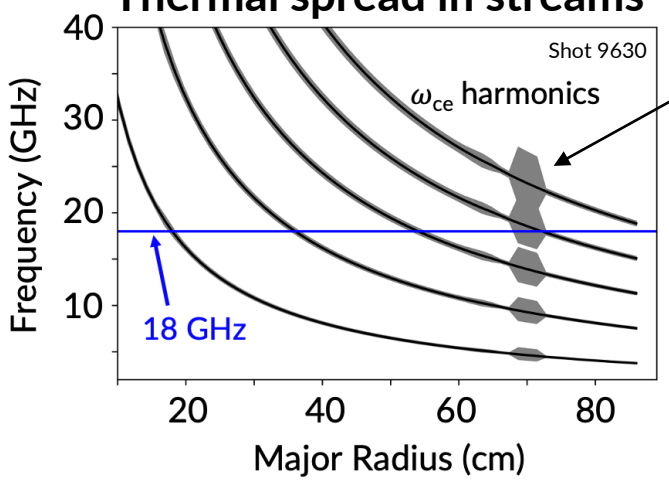
Measured 18 GHz power ∝ V_{inj}



LCFS, MC layer & Harmonics



Thermal spread in streams



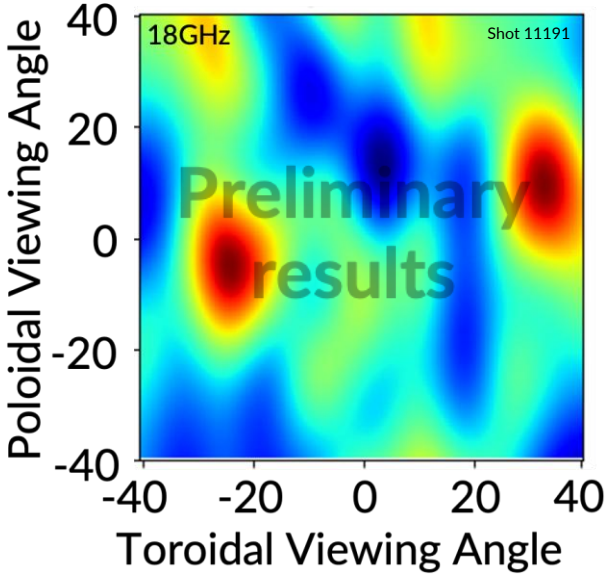
Streams are ~800 eV

- Thermal spread $\omega_{ce}/(1-3N_{\parallel}\frac{v_{th}}{c})$ of streams allows intersection with many harmonics
- Streams are 100x brighter than bulk plasma, limiting search for MC windows to the decay phase

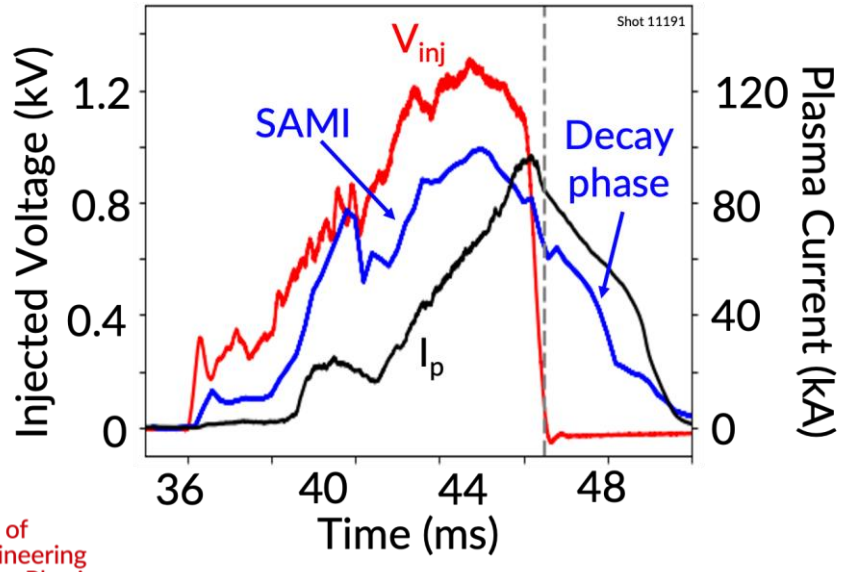
Promising scenario for MC window measurement

- MC windows were potentially seen in SAMI measurements during decay phase
- **NO Thomson Scattering measurements of these shots** -> cannot confirm MC layer or window locations. Results are preliminary only
- What's different about this scenario:
  - Single injector + high V_{inj} -> very low fueling
  - Low fueling -> higher Te, lower edge neutral density & collisional damping

Image reconstruction at 44.7 ms



1-inj SAMI power trace



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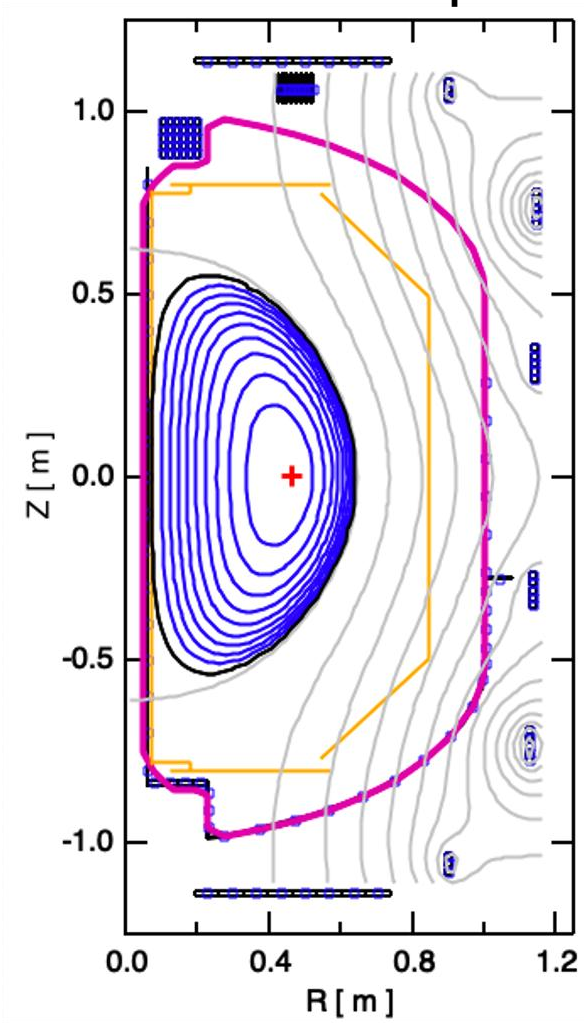
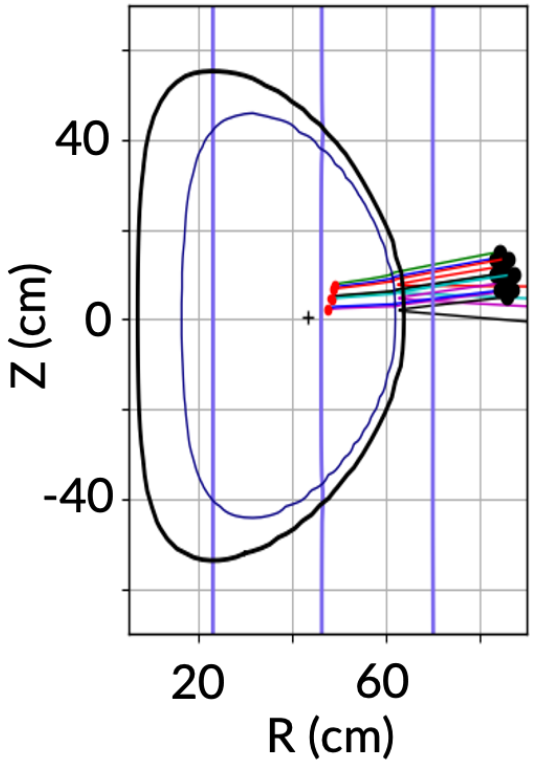
Predictive 0.6 T equilibrium and representative 0.3 T Thomson Scattering profiles

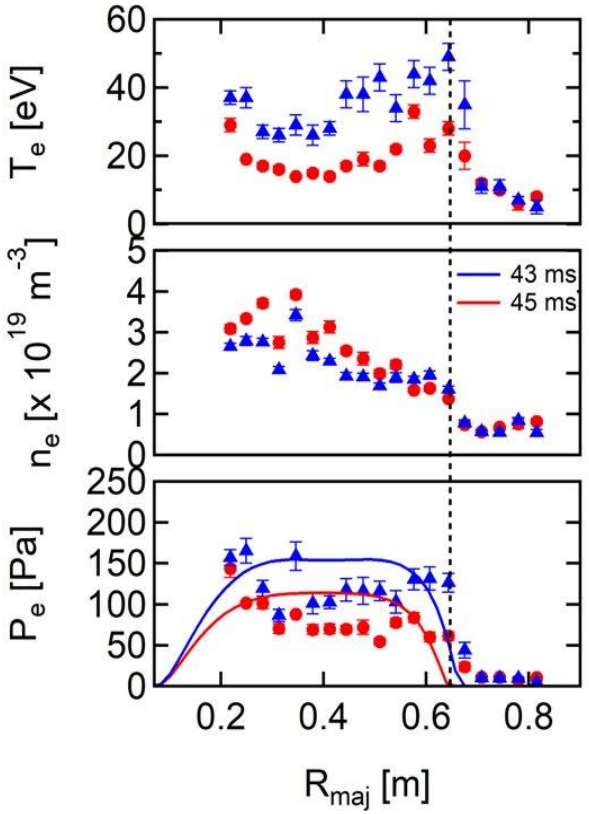
Predictive 0.6 T Equilibrium



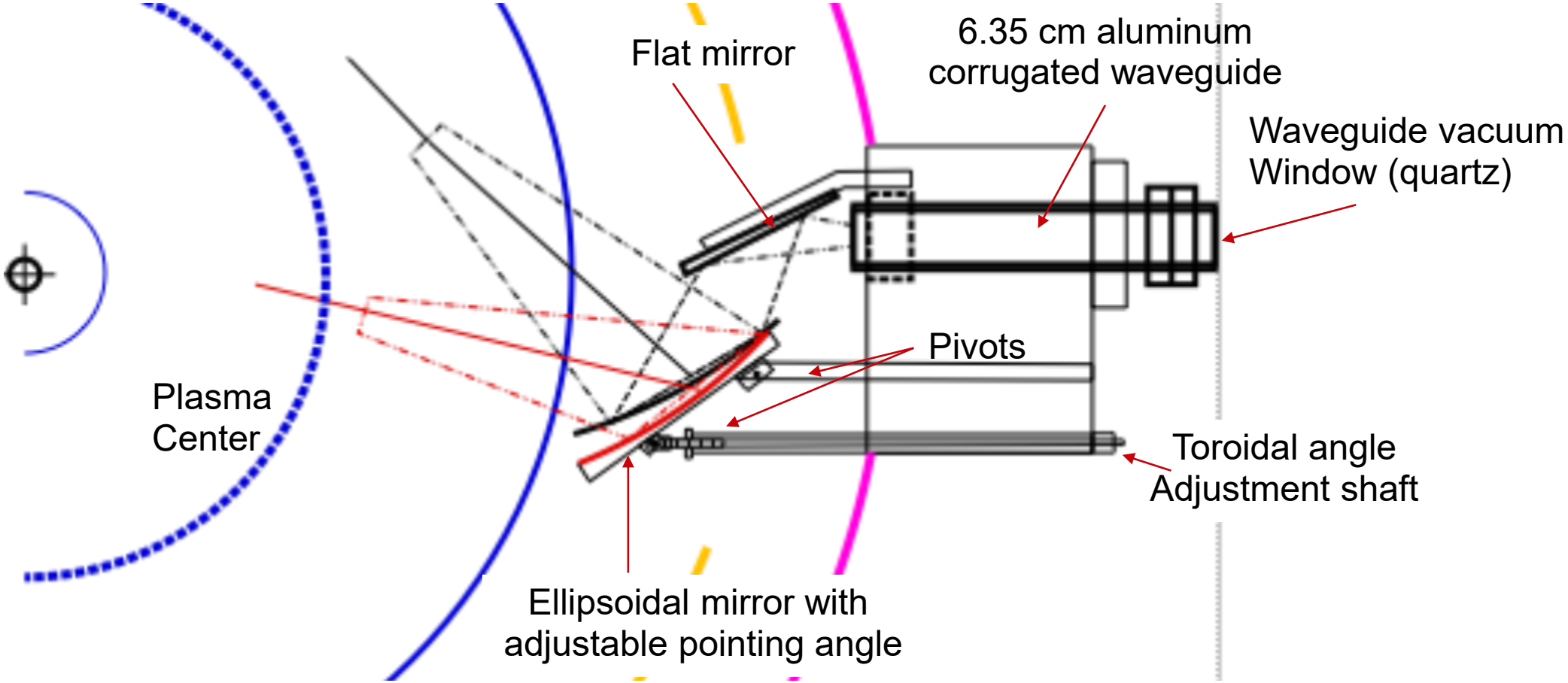
28 GHz harmonic locations



TS Profiles for 0.3 T Shot



Proposed launch system



Proposed equipment layout

- Launch possible from midplane or top ports
- ~ 15 m across the hall
- 85kV power supply for 150 kW, 28 GHz gyrotron