Helically Symmetric eXperiment Upgrade (HSX-U)

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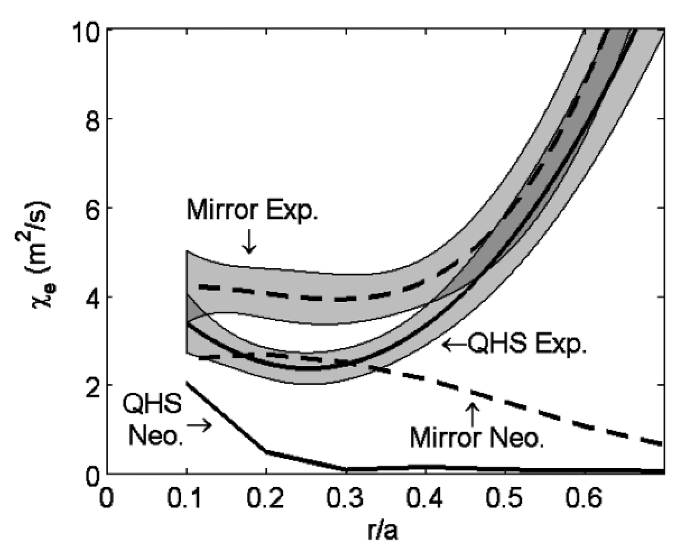
HSX Stellarator

Parameters

- R=1.2 m, a=0.12 m, B=1T, vol=0.44 m^3 and 48 non-planar coils
- Operates with O1-heating at 28 GHz, limiting peak density to 1x10^{19} m^{-3}
- Demonstrated low neo-classical transport [1] and reaches T_e values well above 1 keV



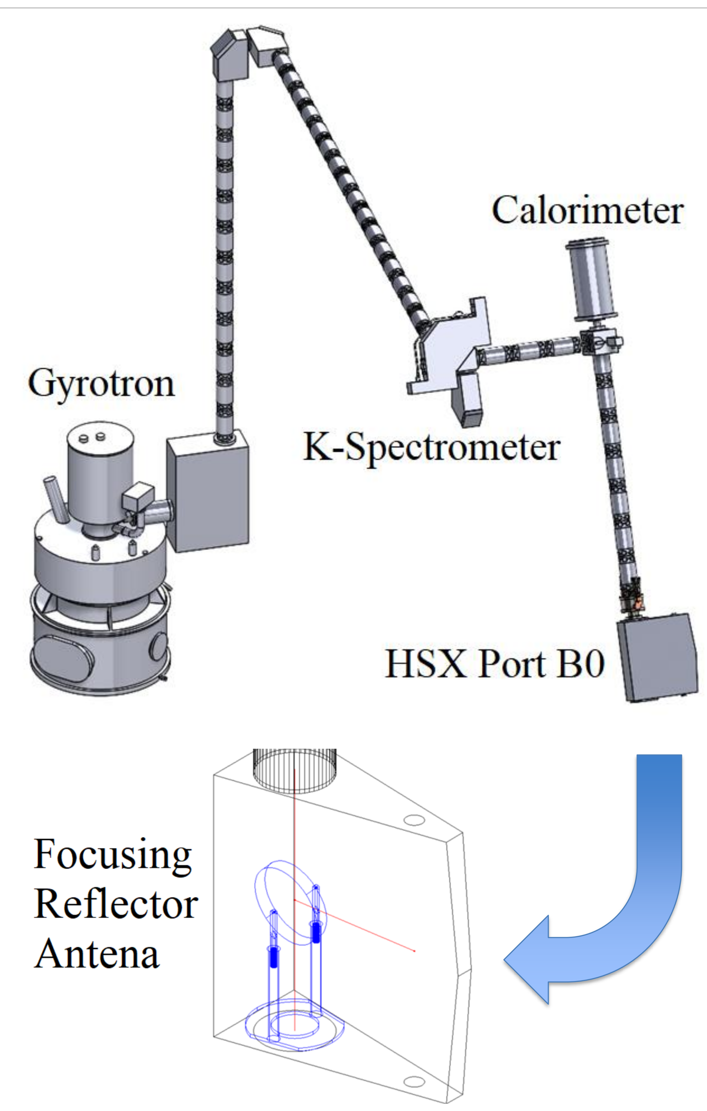
Limitations

- 28GHz ECRH system limits density to to 1x10^{19} m^{-3}, allowing neutral penetration
- Charge exchange losses combined with low electron-ion coupling limit **ion** temperatures to ~60 eV

UPGRADE: New 70GHz ECRH source allows higher plasma density

New 70 GHz ECRH

Frequency	70 GHz
Power	500kW
Pulse Duration	3 Seconds
Collector Depression	25kV
Output Mode	TEM_{00}



- Donation by IPP Greifswald
- Will operate in addition to existing 28 GHz systems
- Transmission line to HSX via oversized corrugated waveguides

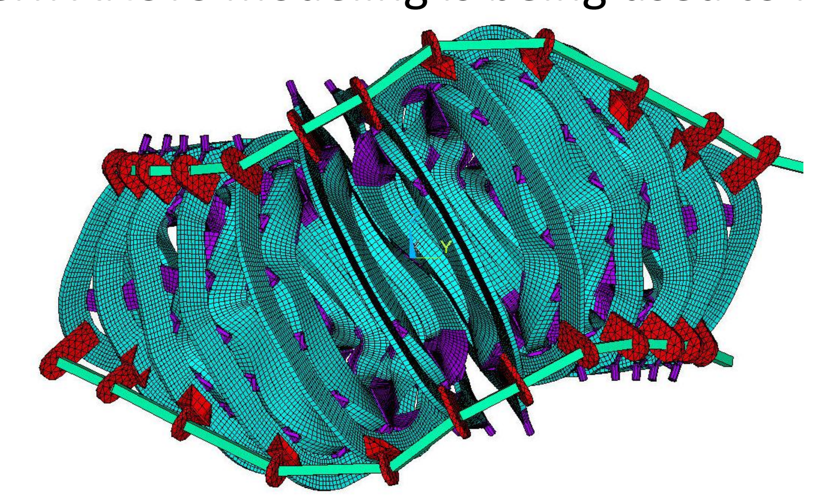
Cut-off densities for kth harmonic [2]:

$n_{cut-off}^{O-mode} = 9.65 \times 10^{18} k^2 B^2$ → ~1 x10^{19} /m^3 with 28GHz, 1.0T

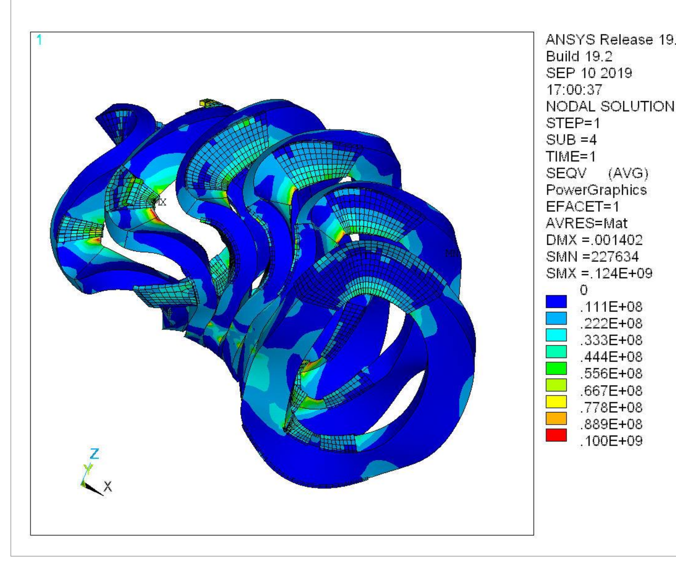
$n_{cut-off}^{X-mode} = 9.65 \times 10^{18} k(k-1) B^2$ → ~3 x10^{19} /m^3 with 70GHz, 1.25T

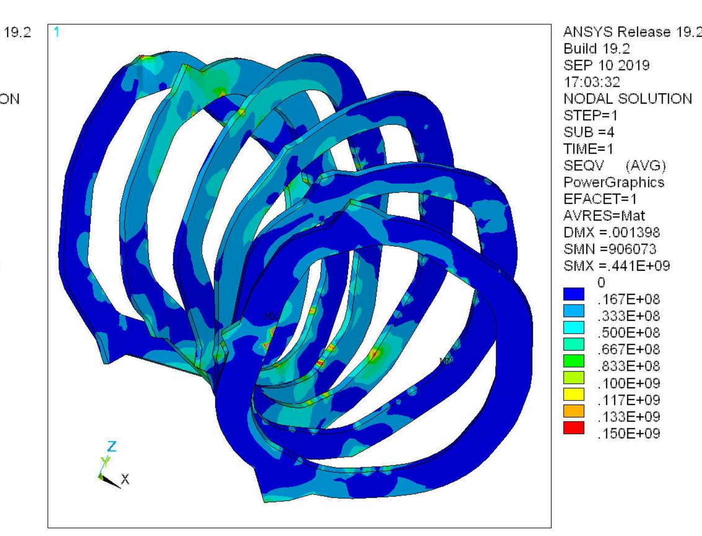
Machine Support Upgrades

- **70 GHz absorption requires 1.25 Tesla field**
- Original coil design assumed maximum field of 1.37 T
- Modern ANSYS modeling is being used to re-examine loads



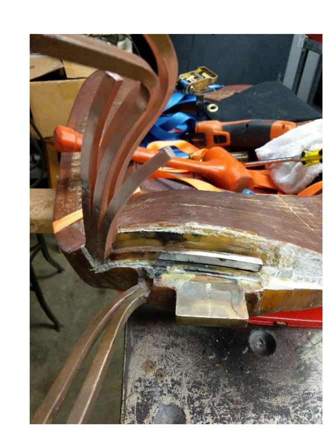
- Max stress is 124 MPa in sharp bends of coil < 50 % yield
- Stress in the coil support rings (304 SS) mostly under 50 Mpa
- Max stress predicted where coils are attached and where rings attach to main support (adjusters)

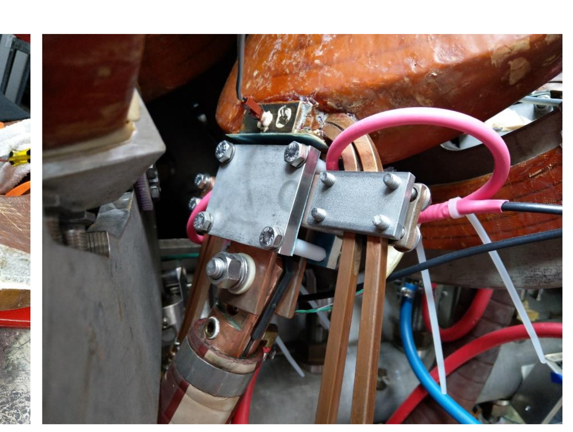




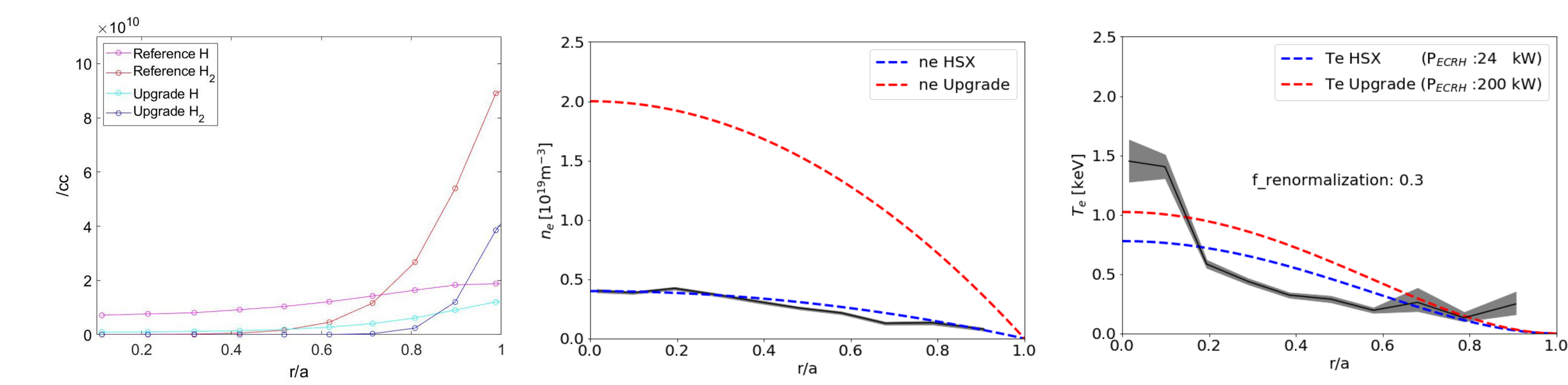
Coil Upgrades

- HSX uses 18 x 1,000HP DC traction motors outfitted with 2,000 lb flywheels which supply the coils with 1 kV, 12 kA.
- 2 motors will be added and flywheel speeds will be increased by 25% to achieve up to 15kA for 1.25 Tesla
- The HSX coil feed connections will be upgraded for better current handling





Expected performance



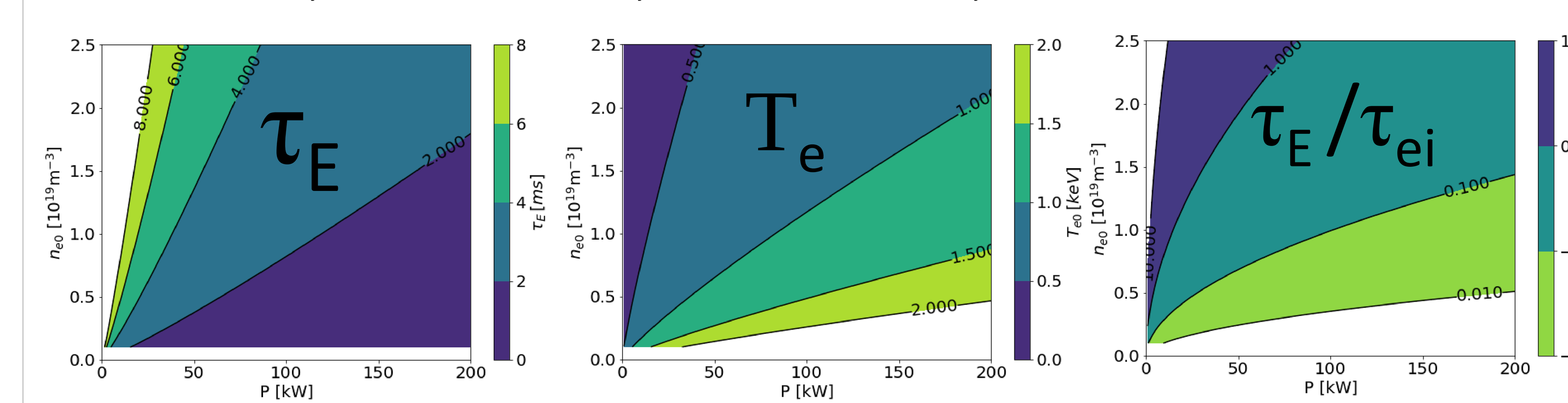
Degas Results by Z. Keith [6]   ISS04 extrapolations by B. Geiger

- **Profiles described using:**

$\tau_{E,ISS04} = f_{ren} * 0.134 a^{2.28} R^{0.64} B^{0.84} P^{-0.61} n_e^{0.54} \iota_{2/3}^{-0.41}$ [3]

with μ_n=1 and μ_T=2 $\quad f(r) = f_0 \left(1 - \left(\frac{r}{a}\right)^2\right)^{\mu}$

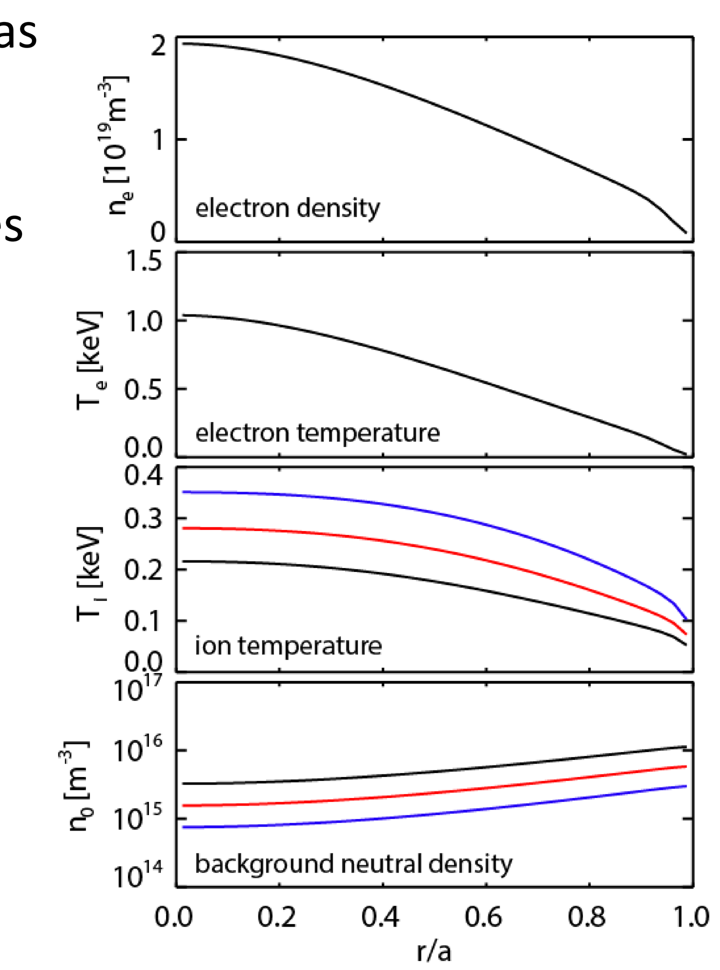
- Renormalization factor for HSX f_{ren}= 0.3
  each device in the ISS04 scaling has a different factor:
  TJII: 0.25, W7-AS: 0.79-1, LHD: 4.48-0.93, HELIOTRON-J: 0.58



- Confinement time will range between 8 ms and 2 ms
- Good coupling between ions and electrons at about **50 kW** of power
- Edge neutral density in HSX can be as high as 2 x 10^{16} /m^3 [4] [6]
- High charge exchange losses and long electron-ion equilibration times result in low (~60 eV) ion temperatures.

$$\tau_{ei} = \frac{3}{2}\frac{(2\pi)^{3/2}\varepsilon_0^2 m_i}{\sqrt{m_e}e^4 \ln\Lambda}\left\langle\frac{T_e^{3/2}}{n}\right\rangle$$

- With the upgrade, higher plasma densities will reduce the neutral population and exchange-time.
- 1D TRANSP [5] modeling yields ~10 kW of collisional ion heating and central ion temperatures >200 eV



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References

[1] J. M. Canik et al, PRL (2007).
[2] Zohm, FED (2007) 134
[3] H. Yamada et al Nucl. Fusion (2005)
[4] L. Stephey, Ph.D. thesis
[5] R. Hawryluk et al., Physics of Plasmas Close to Thrmnclr Conditions (1980)
[6] Zander Keith, Poster session JP13 Abstract JP13.00086