Electron Temperature Evolution During Local Helicity Injection on the Pegasus Toroidal Experiment

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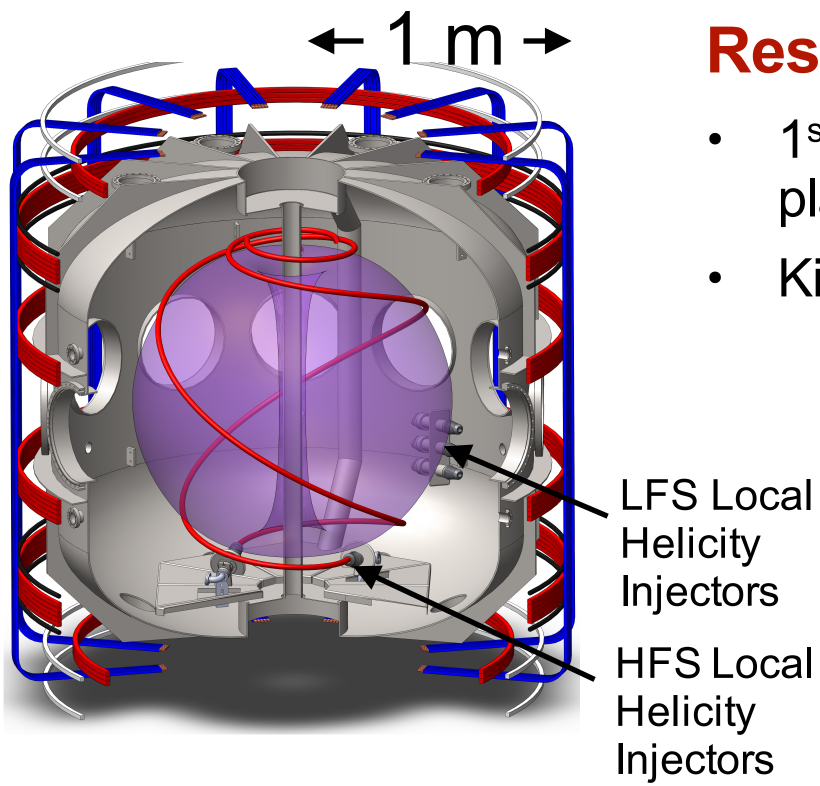
58th Annual Meeting of the APS
Division of Plasma Physics

San Jose, CA
November 1, 2016

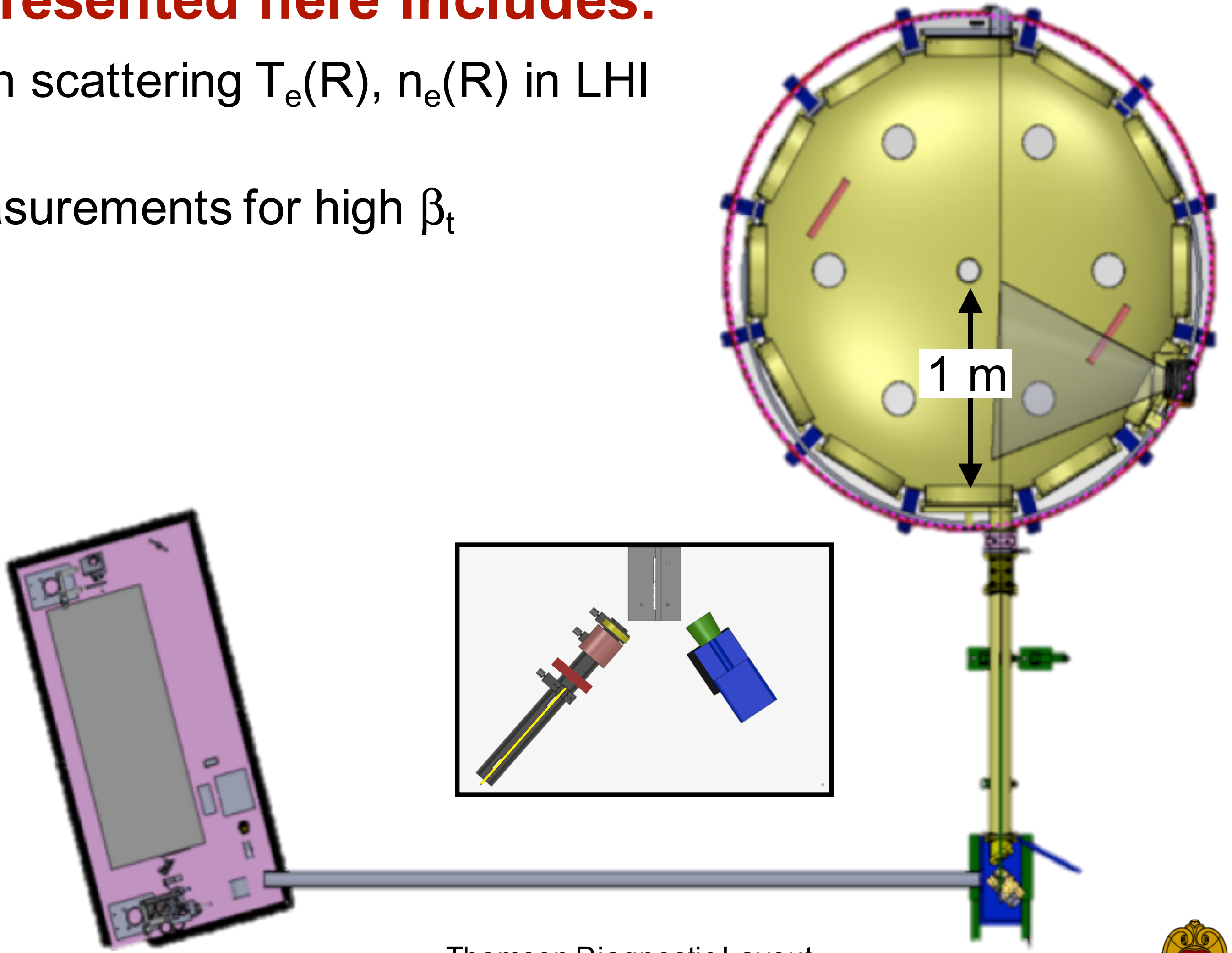
PEGASUS
Toroidal Experiment

Pegasus is a Compact, Ultralow Aspect Ratio Spherical Tokamak



Research presented here includes:

- 1st Thomson scattering $T_e(R)$, $n_e(R)$ in LHI plasmas
- Kinetic measurements for high β_t



Thomson Diagnostic Layout

Experimental Parameters

A	1.15 – 1.3
R(m)	0.2 – 0.45
I_p (MA)	≤ .21
κ	1.4 – 3.7
β_t (%)	≤ 100

I_p Projections for LHI Depend Strongly on Electron Confinement Scaling

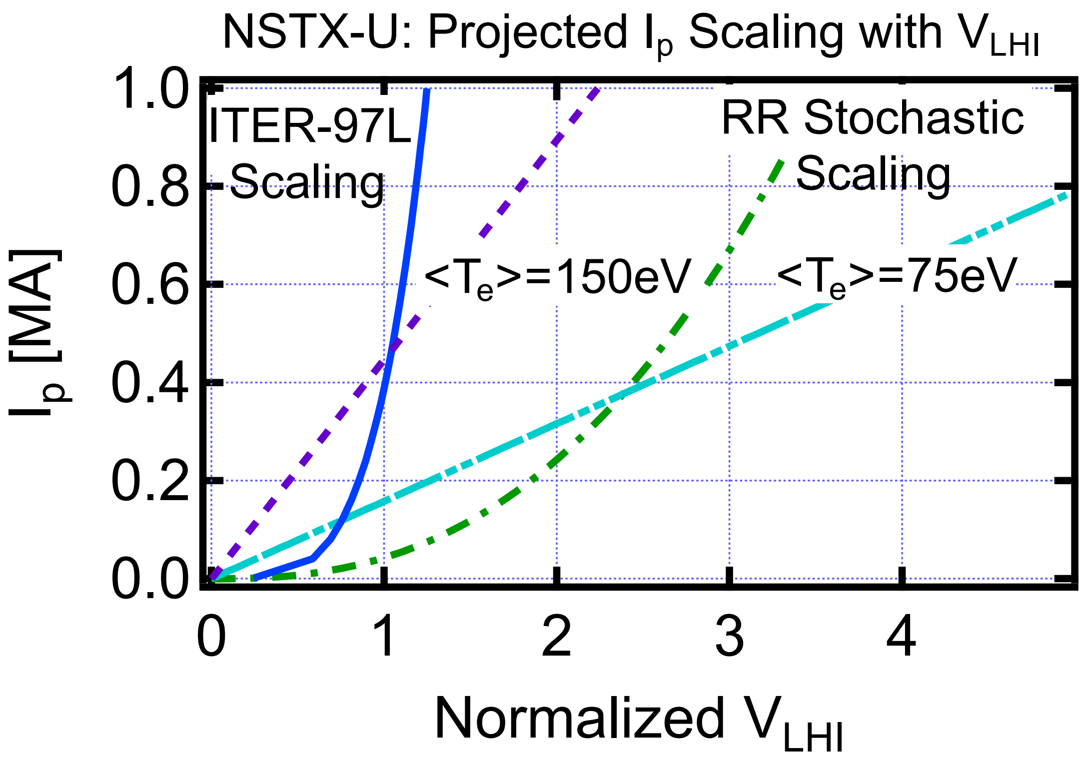
- 0-D power-balance model[1] predicts $I_p(t)$ from Local Helicity Injection (LHI):

$$I_p[\, V_{LHI} + V_{IR} + V_{IND} \,] = 0$$

$$V_{IR} \rightarrow \propto T_e^{-3/2}$$

- Projected T_e, I_p, may vary if:
  - Helicity drive dominates ($V_{LHI} >> V_{IND}$)
  - Inductive drive dominates ($V_{LHI} << V_{IND}$)

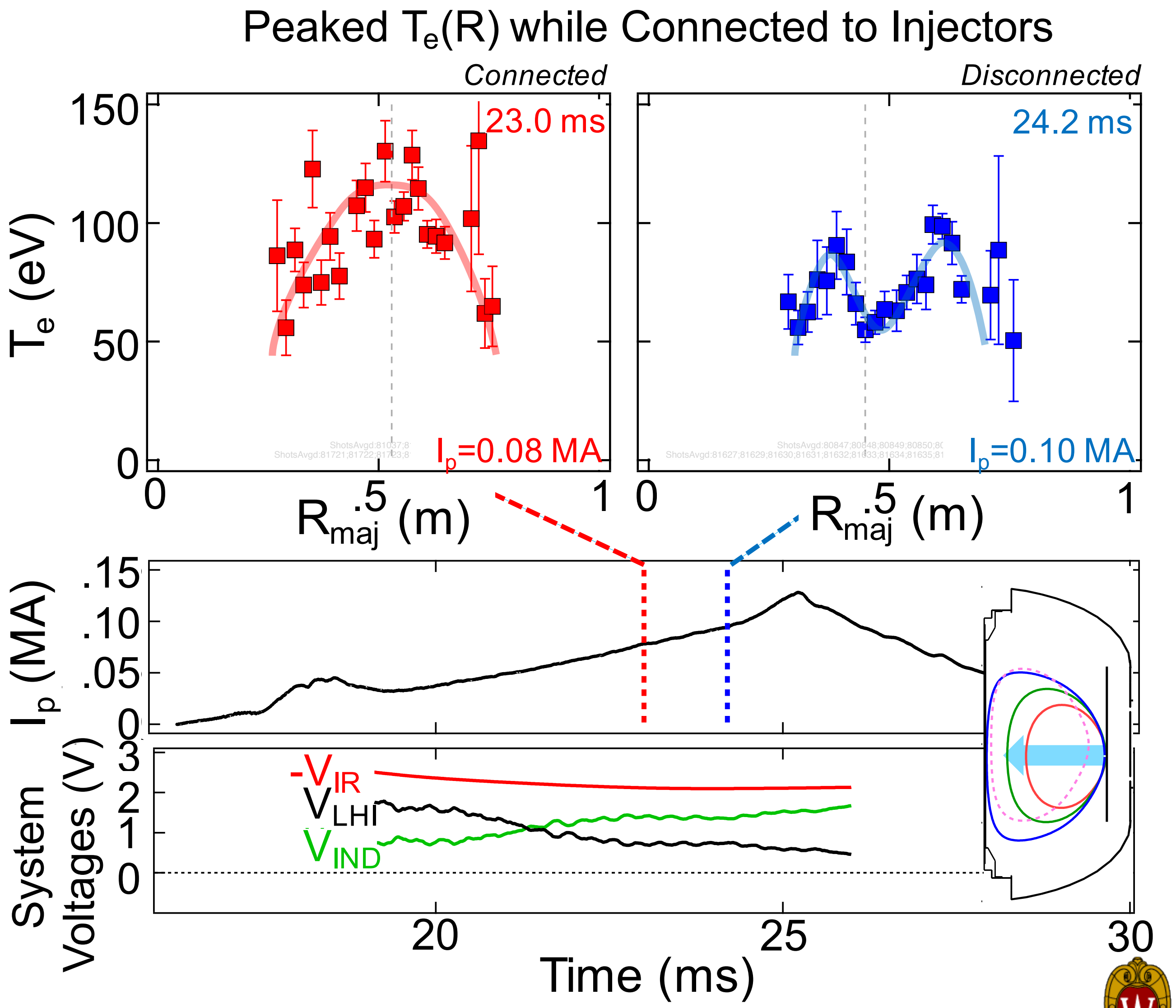
- Exploring T_e behavior as dominant drive mechanism varies



[1] J.L. Barr, et al. NP10.55, Poster session Wed morning

LFS Local Helicity Injection Produces Core T_e > 100 eV

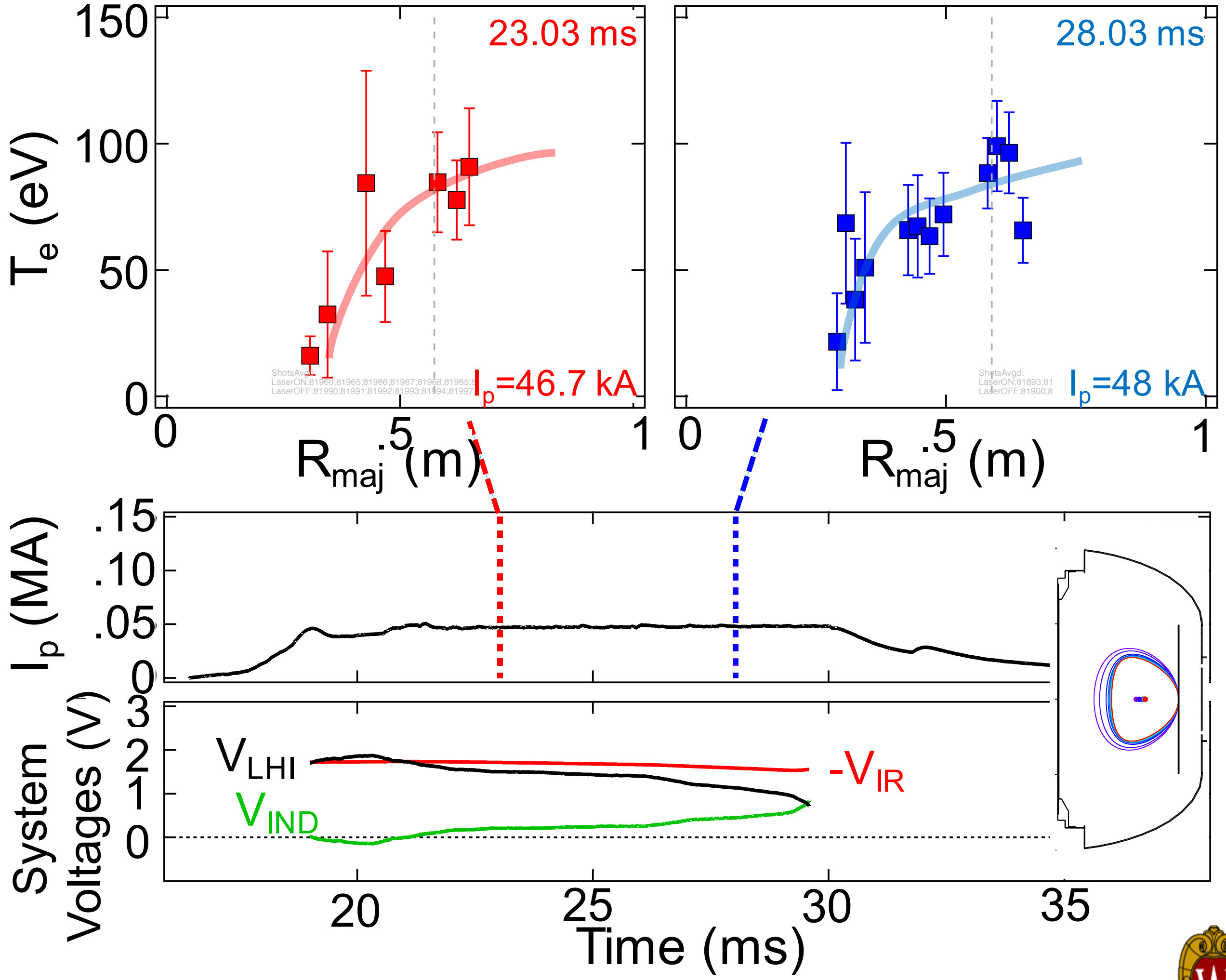
- Plasma position and shape evolve inward from outboard injectors
  - Shape evolution generates V_{IND}
  - $V_{IND} > V_{LHI}$ during high-I_p phase
- Peaked $T_e(R)$ during drive phase (connected)
  - Not strongly stochastic
  - After disconnect radial compression drives skin current
- Core $n_e > 10^{19}$ m^{-3}, $T_e \geq 100$ eV provides target for subsequent CD



T_e (R_{maj},t) Remains Peaked for LFS LHI when V_{IND} Small

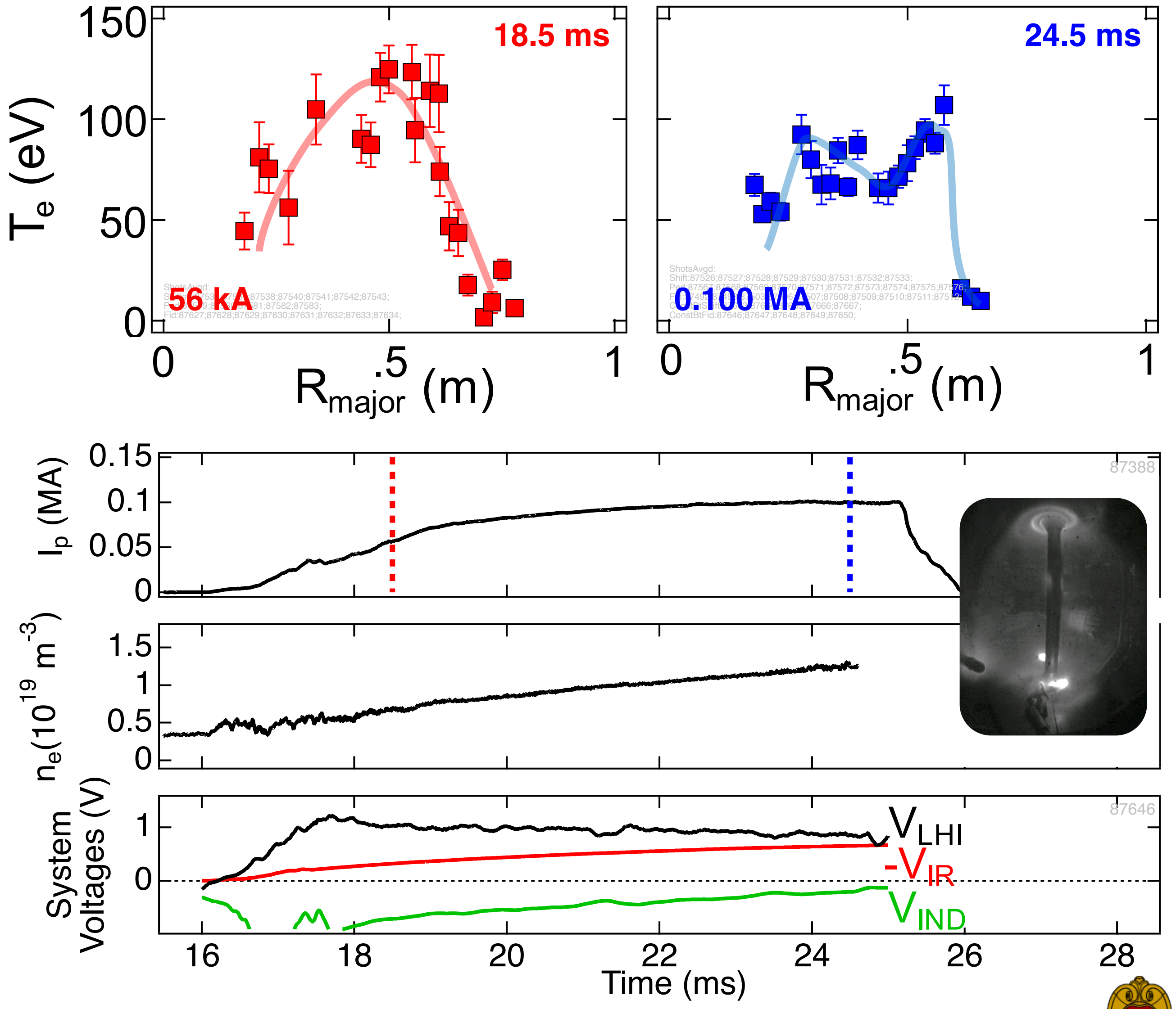
- Same injection location but static, circular plasmas at large R_{maj}
  - Lower performance due to shape constraints
- V_{IND} = 0, $T_e(0)$ ~ 80 eV
- $T_e(R)$ remains peaked while driven solely by edge LHI

$T_e(R)$ > 85 eV with majority LHI-drive



HFS Injection Gives Peaked $T_e(R)$ for Sustained, Highly Elongated Discharge

- $T_e(0) \geq 100$ eV
- $\bar{n}_e$ increasing to ~1.2×10^{19} m^{-3}
- T_e, n_e comparable to Ohmic plasmas in Pegasus
- V_{LHI}-driven throughout

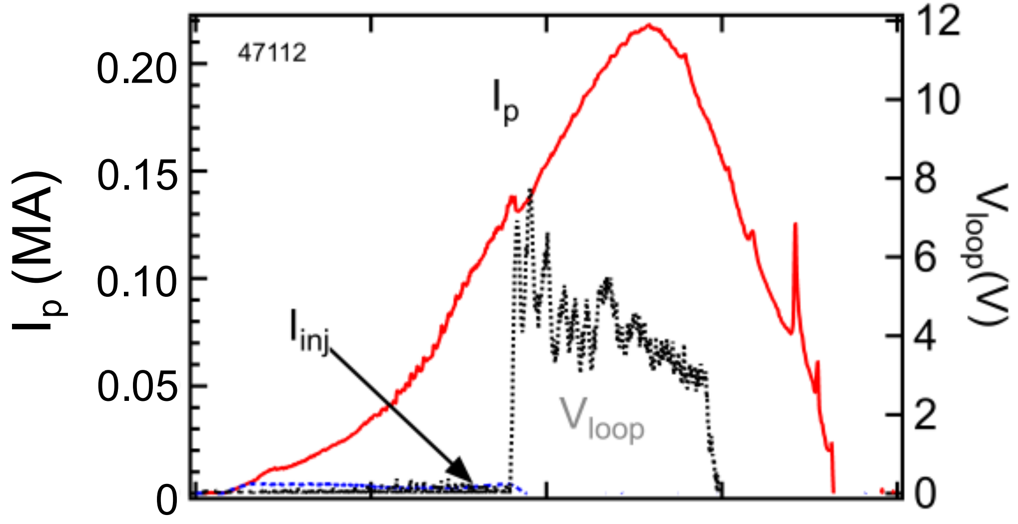


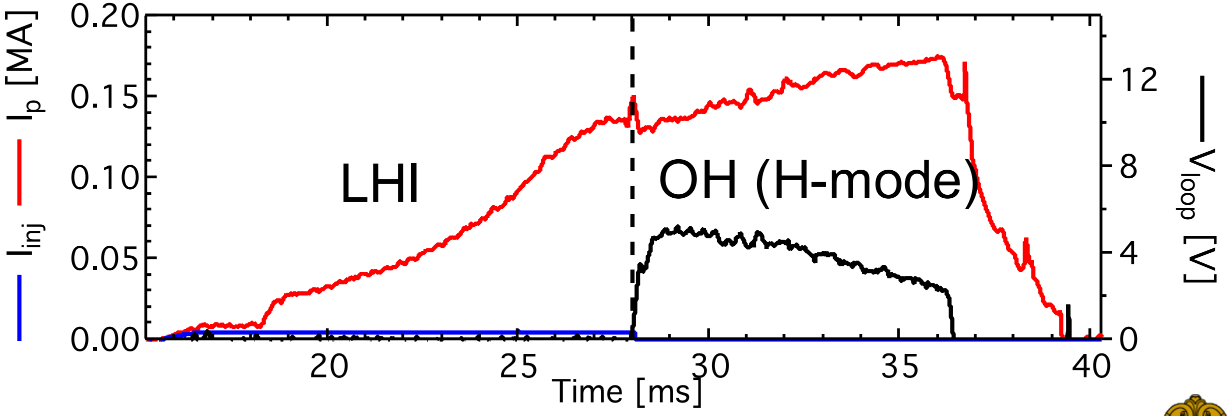
see also: J.M. Perry, et al. NP10.53, Poster session Wed morning

LHI Plasmas Provide Targets for Subsequent Current Drive Schemes

- Coupling to aux. drive is sensitive to I_p ramp-rate:
  - $J(\psi)$ too hollow: ineffective coupling
  - $J(\psi)$ too peaked: MHD unstable
- Pegasus aux. drive = Ohmic
- Upcoming campaign: characterize T_e, n_e through LHI-OH transition

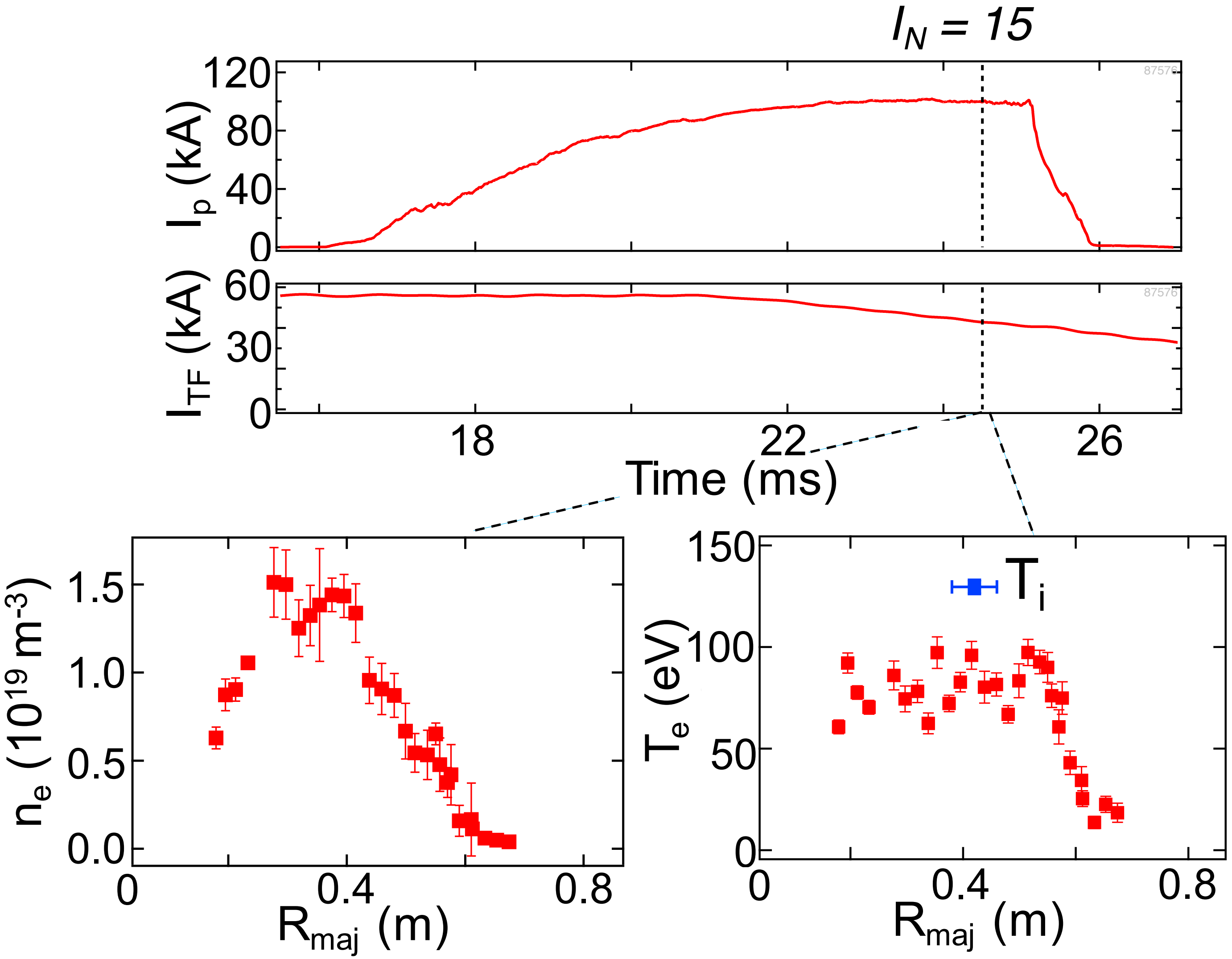
LHI-to OH Handoff Examples
(Pre-Thomson Scattering)





HFS Injection at low TF Provides Non-Solenoidal Sustainment at High I_N

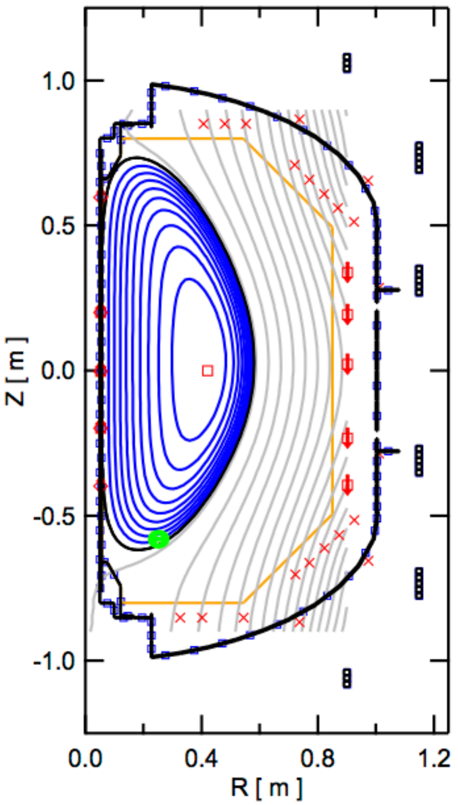
- HFS LHI development campaign provides unique operation space
  - Low $I_{TF} \sim 0.6\ I_p$
  - $I_N = 5A \frac{I_p}{I_{TF}} > 10$ accessible
- Enables high β_t access[1]
  - Aided by anomalous ion heating
- Kinetic constraints on magnetic equilibrium fits[2]
  - $P_{tot}(0)$
  - Edge location defined by T_e profiles



[1] M.W. Bongard, et al. NP10.52 Poster Wed morning
[2] G.M. Bodner, et al. NP10.54, Poster Wed. morning

LHI-Produced Plasmas at low B_t Provide High β_t

- Sample magnetic reconstruction at t = 24.5 ms, using kinetic constraints

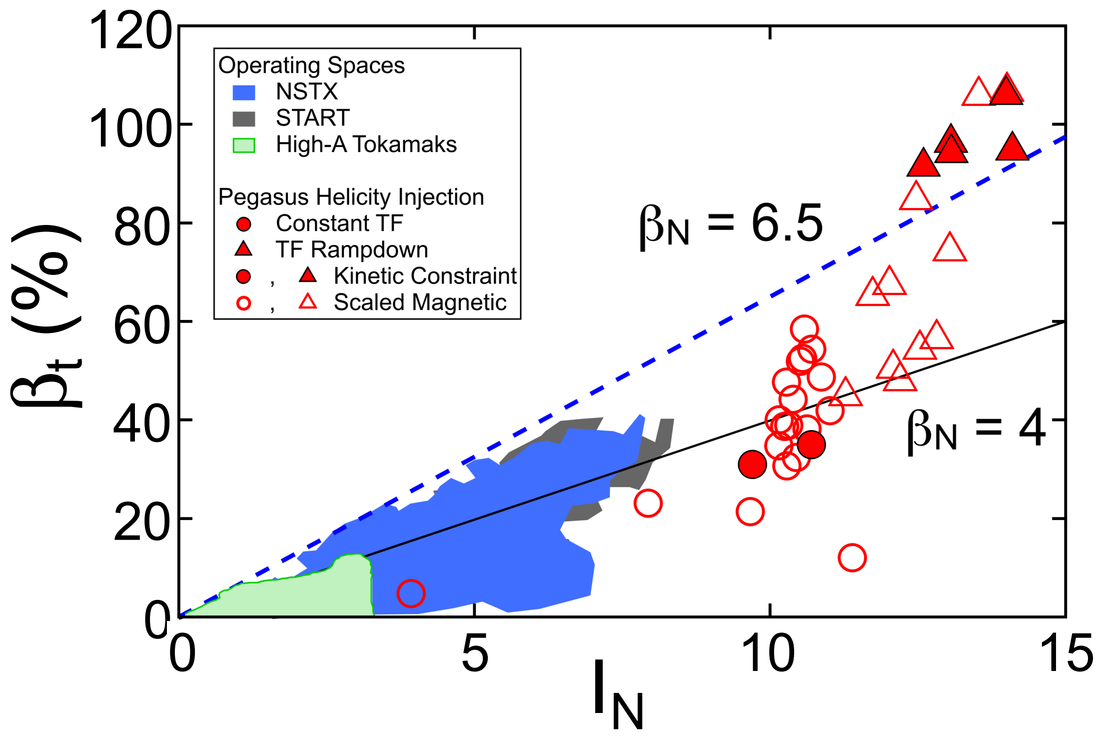


Equilibrium Parameters

Shot 87332, 24.50 ms

I_p	102 kA	R_0	0.317 m
β_t	0.95	a	0.263 m
ℓ_i	0.22	A	1.21
β_p	0.45	κ	2.6
W	545 J	δ	0.54
B_{T0}	0.0249 T	q_{95}	7.24

- β_T for sustained, low-ℓ_i, high-κ, LHI-driven plasmas



[1] *M.W. Bongard, et al. NP10.52 Poster Wed morning*

LHI-Driven Plasmas Have $T_e(0)$ ~100 eV and Provide Access to High β_t, High I_N Operating Space

- Local Helicity Injection (LHI) sustains ~100 eV T_e, moderately-high n_e
- No strong $T_e(R_{maj})$ dependence on LHI location and ratio of LHI-to-inductive drive
- Effective startup target for direct OH coupling (Pegasus); Future to NBI (NSTX-U)?
- Very high β_t confirmed by kinetic measurements