Plasma Initiation and Startup in DIII–D Simulating The ITER Scenario

by

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for

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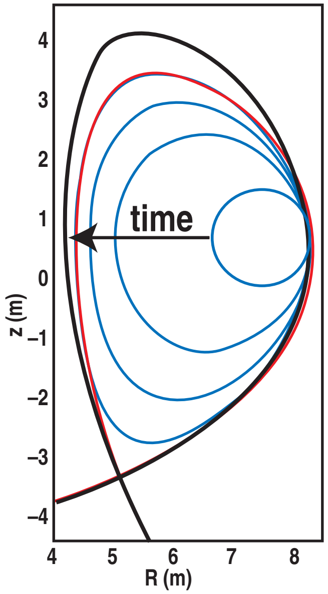
Presented at
Forty-Ninth APS Meeting of
the Division of Plasma Physics
Orlando, Florida

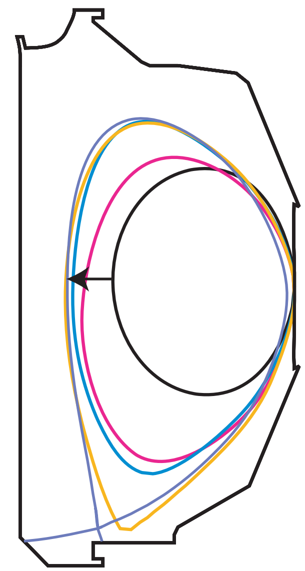
November 12–16, 2007

Plasma Startup in ITER Must Address Several Issues

- Plasma rampup while limiting on outer wall bumper limiters
- Operation near n=0 vertical stability limit (places constraints on maximum ℓ_i)
- Initiation at relatively low toroidal electric field (~0.3 V/m)
- q_{min} > 1 for advanced inductive and advanced tokamak scnearios



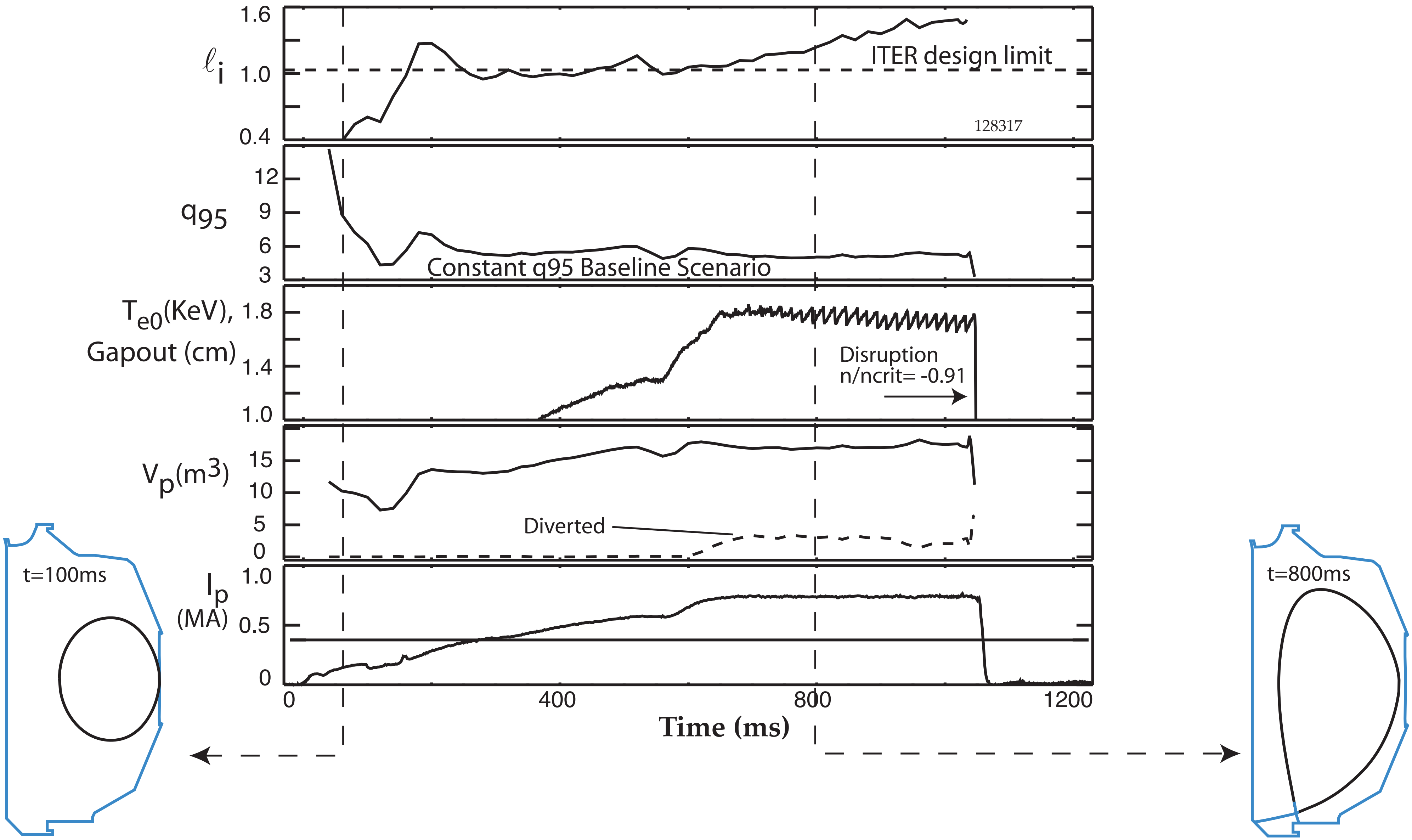
ITER BASELINE STARTUP "SIMULATION"



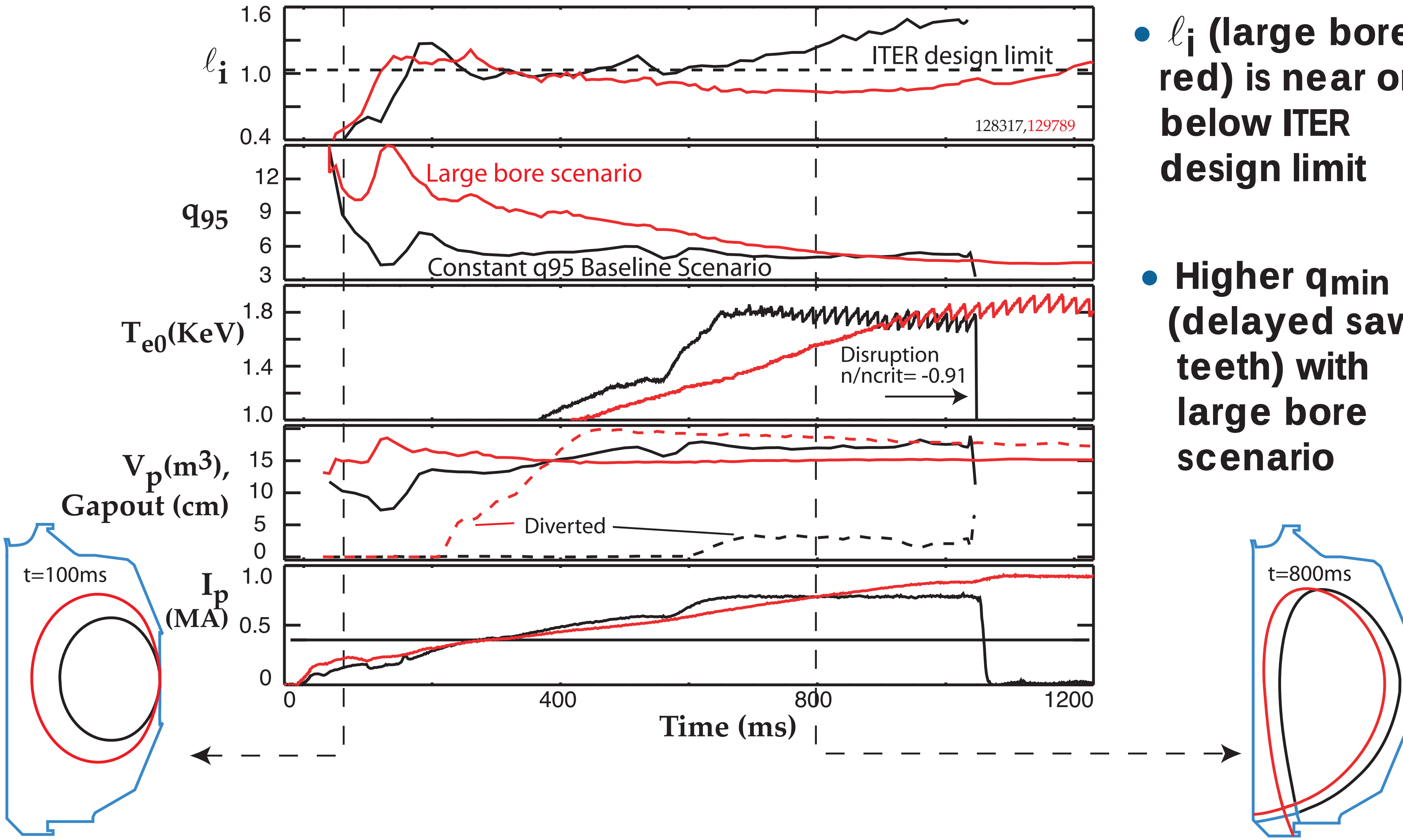
DIII-D INITIAL 2007 EXPERIMENT

DIII-D HAS STARTED EXPERIMENTS AND MODEL VALIDATION SIMULATING THE ITER STARTUP

DIII–D Has Simulated the ITER Baseline Startup Scenario

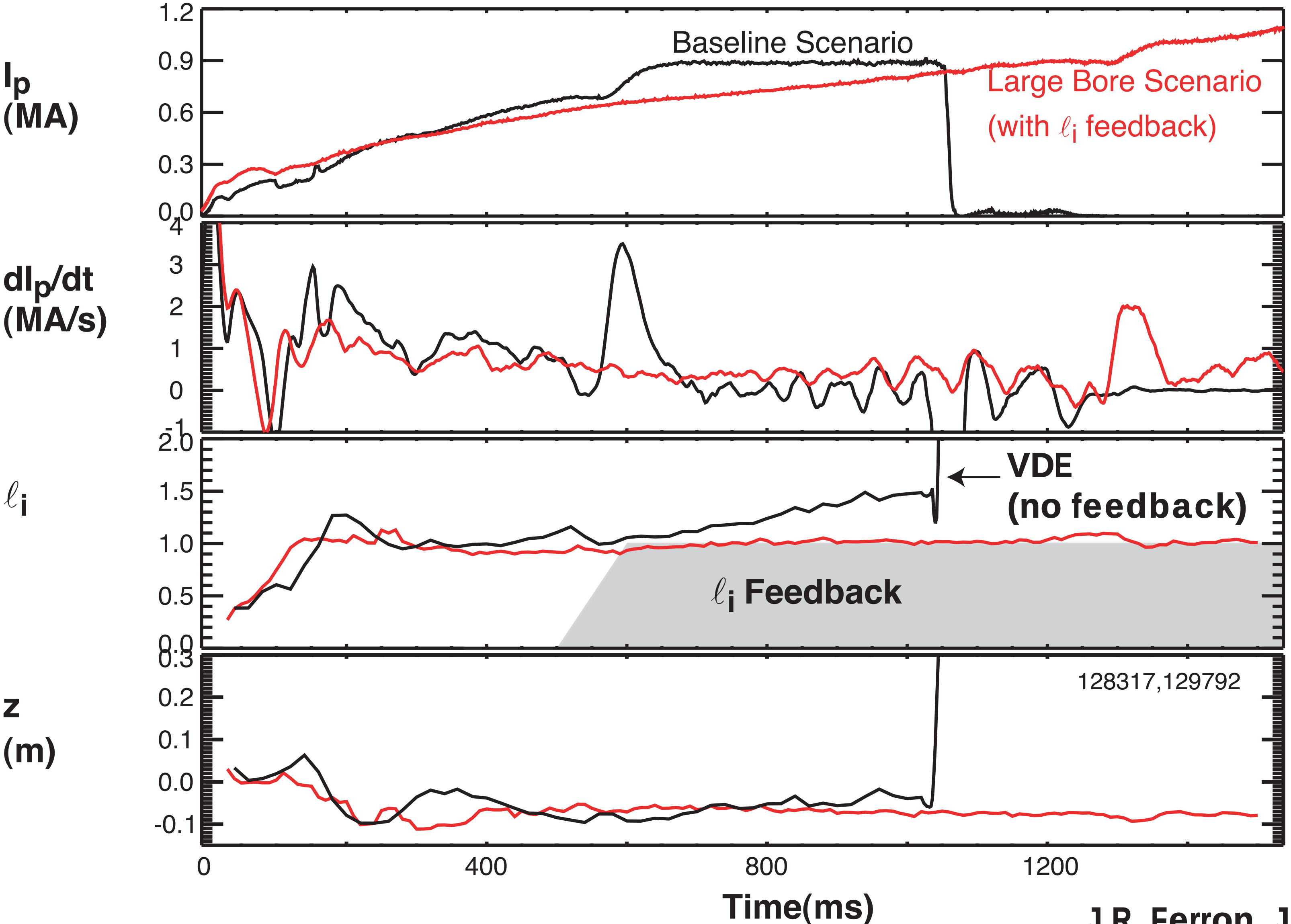


DIII–D has Simulated the ITER Baseline Startup Scenario and Helped Develop an Improved ITER Startup



- ℓ_i (large bore, red) is near or below ITER design limit
- Higher q_{min} (delayed saw-teeth) with large bore scenario

ℓ_i Feedback Enables Operation Below the Vertical Stability Limit

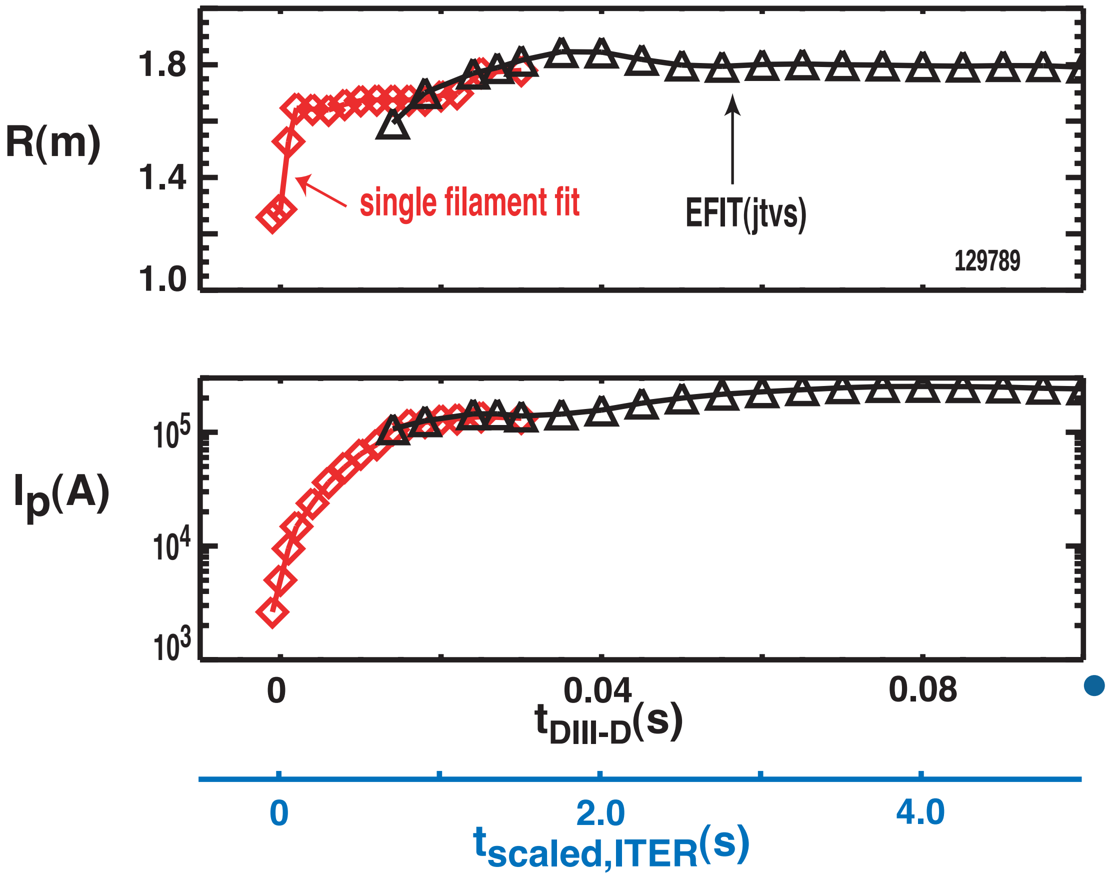


- Useful tool for optimizing current profile in ITER
- dI_p/dt is used as the actuator
- Real time EFIT calculates ℓ_i, PCS compares to target ℓ_i and produces error signal
- Baseline discharges are near n=0 stability limit and sometimes exhibit a VDE

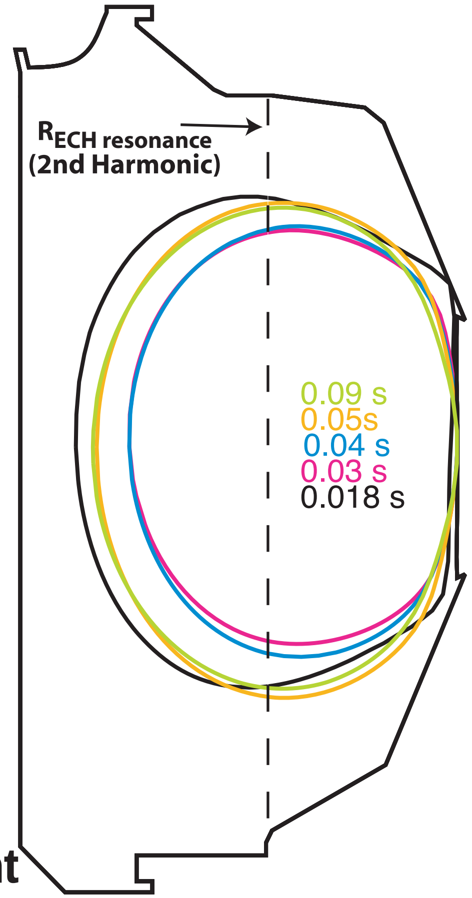
J.R. Ferron, JP8.90 (Tu.,pm)

Plasma Formation in DIII–D is Near the Inner Wall, But Rapidly Limits on the Outer Wall (< 1s on ITER Time Scale)

- I_p always initiates near the inner wall (V_{loop}/R is maximum)
- ITER startup is "planned" to be further outboard

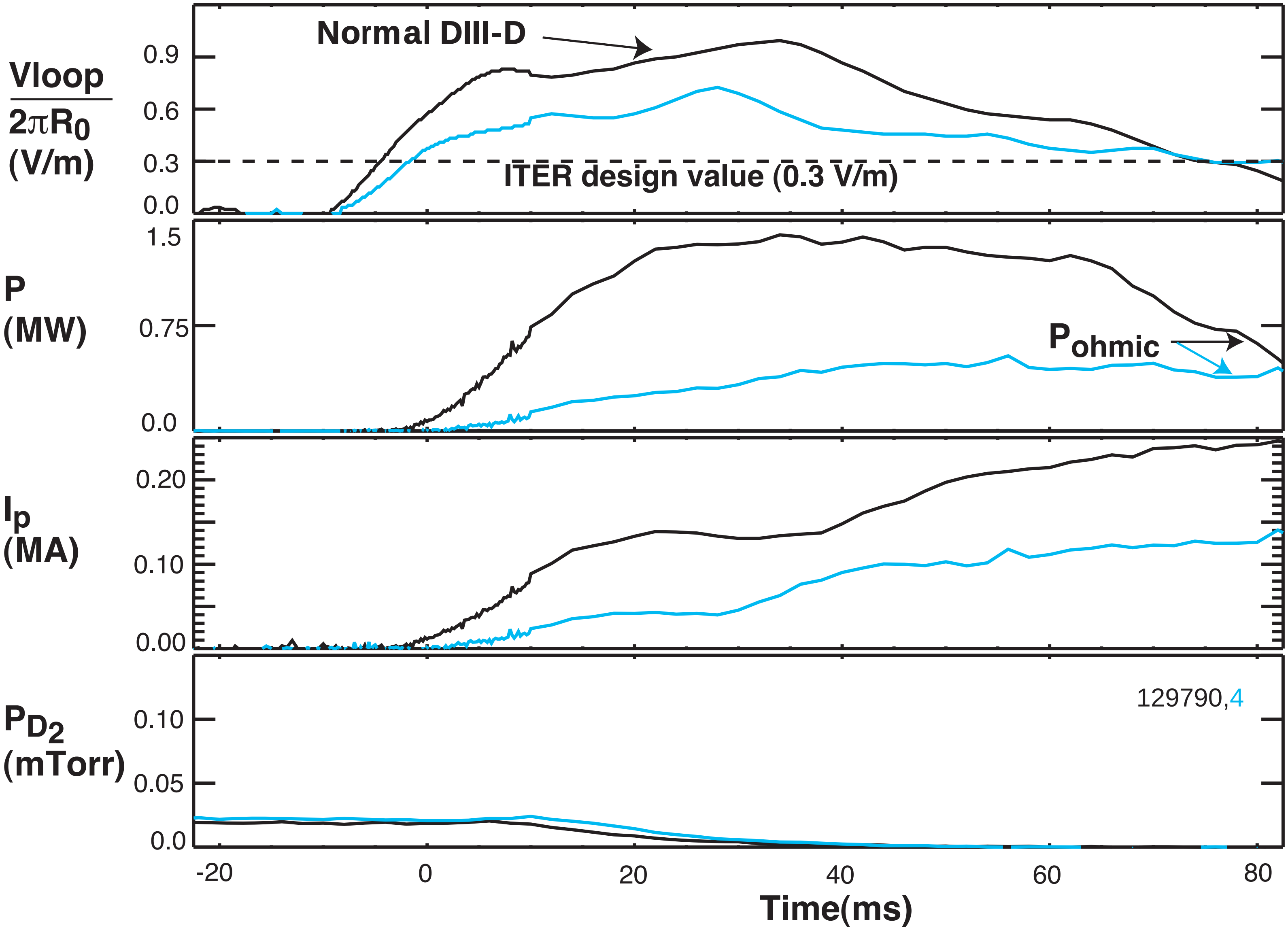


Large bore startup scenario



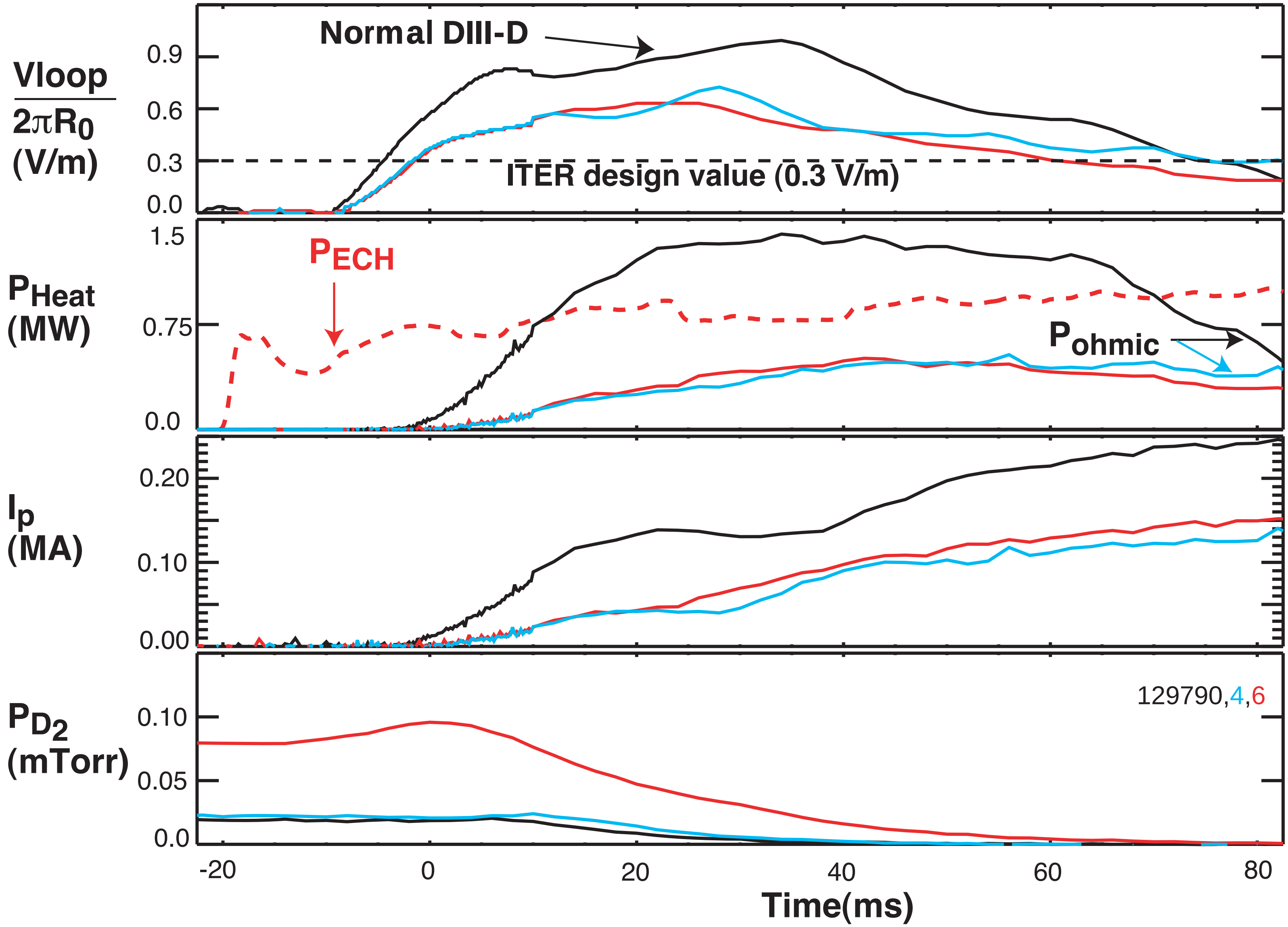
- DIII-D scaled to ITER using resistive current time (1:50)

Reduced V_{LOOP} Startup Was Achieved in the ITER Scenario



- Initial experiments achieved startup on the outer wall at reduced voltage

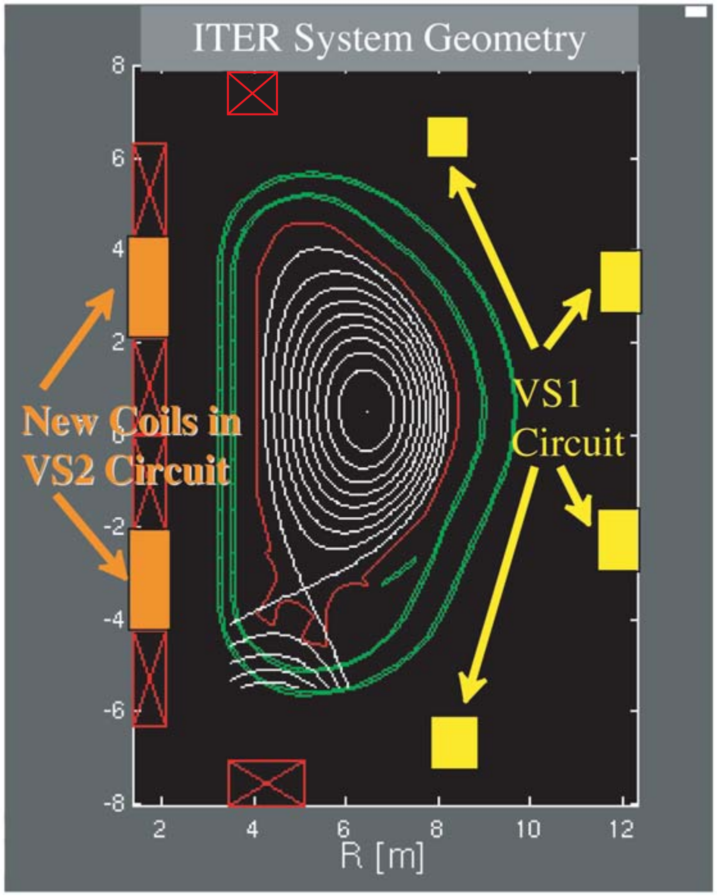
Reduced V_{LOOP} Startup was Achieved in the ITER Scenario
ECH Allows Initiation at A Higher Neutral Pressure



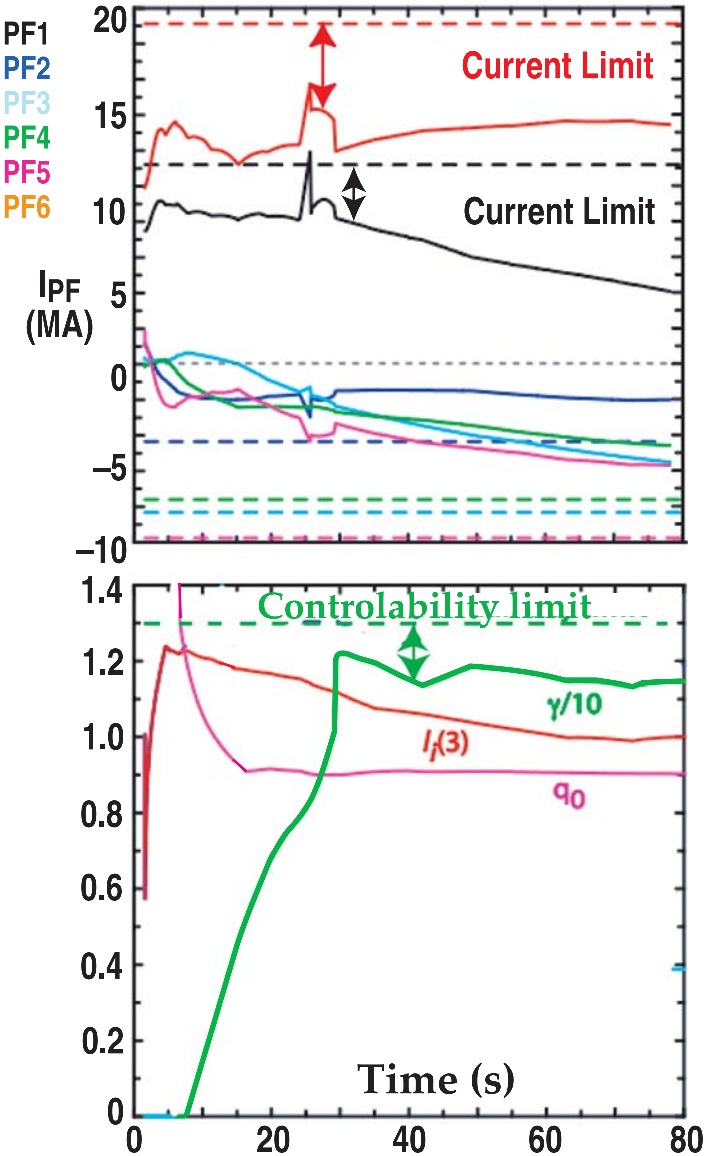
- Initial experiments achieved startup on the outer wall at reduced voltage
- Higher prefill with ECH may provide more flexibility in startup

DIII-D NATIONAL FUSION FACILITY

Modeling Predicts Vertical Stability (n=0) And Coil Currents are Near Limits During the I_p Ramp

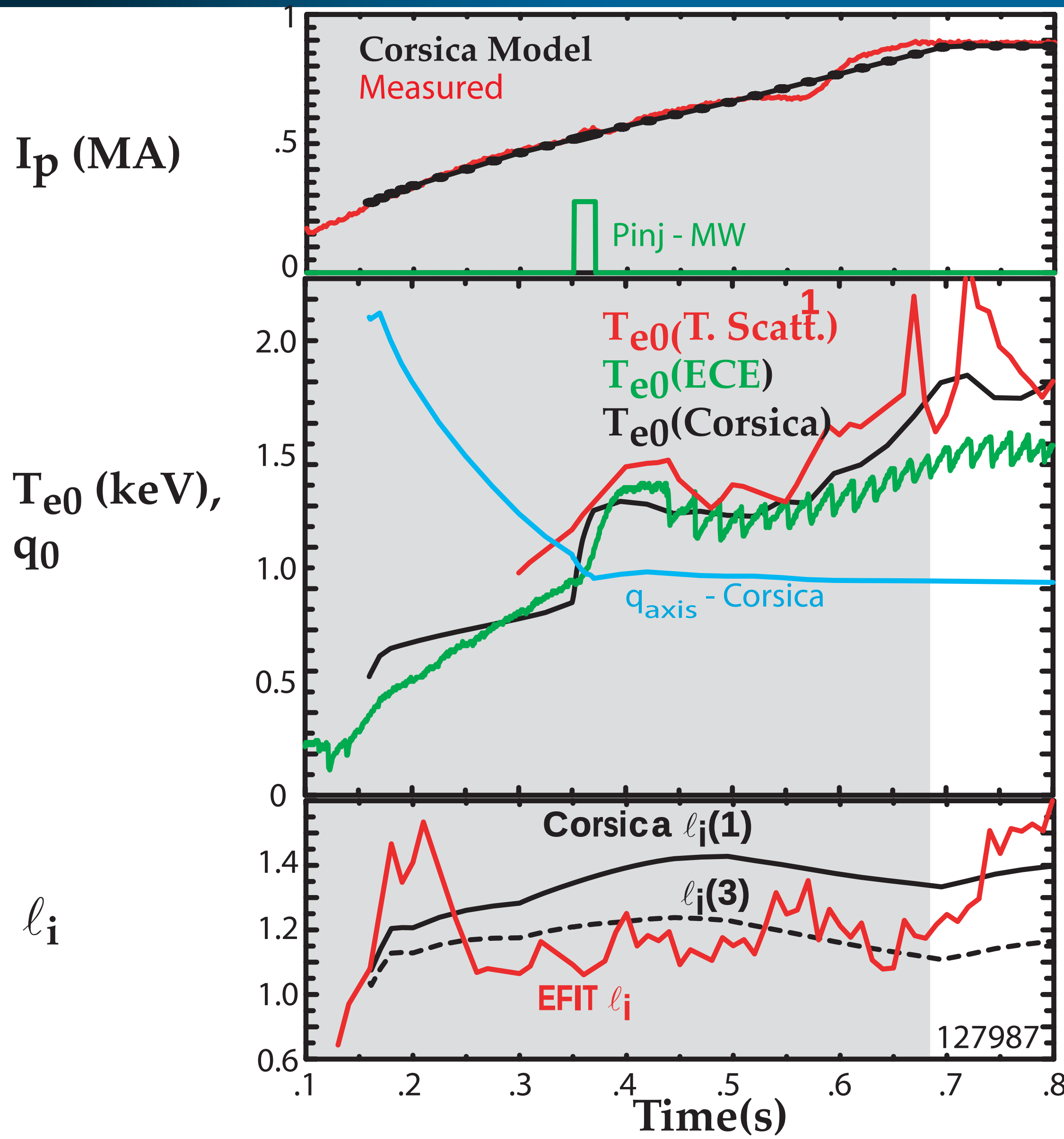


- Inner Coils in vertical control circuit (VS2) can improve stability



- CORSICA simulation models ITER baseline scenario
  - Scenario 2 "small bore baseline startup
  - Maximum $\ell_i(3)$=1.15
- Good control during rampup
- But...
  - poloidal field coils are near current limits
  - Vertical growth rate, γ, is near control limit

Corsica is Being Benchmarked Using the DIII–D Current Ramp Phase



- **Corsica modeling predicts approximate onset time for sawteeth ($q0 \sim 1$)**

- **Corsica predicts ℓ_i higher than ITER design values. Both ℓ_i formulations are included**
  - **-$\ell_i(1)$ used in DIII-D**
  - **-$\ell_i(3)$ is ITER ℓ_i approximation**

Summary

- **DIII-D has simulated the ITER small bore baseline outer wall startup scenario**
  - Measured ℓ_i is above the ITER design limit.
- **A new large bore startup scenario was developed for ITER**
  - Lower ℓ_i and higher q_{min}
- **Real time feedback control of ℓ_i has been demonstrated**
  - Allows control of the current profile (important for AT scenarios)
- **Breakdown in DIII-D always occurs near the inside wall**
  - Occurs at or near maximum E_ϕ
  - ITER breakdown is assumed to occur further outboard
- **ECH and low voltage startup experiments have started**
  - Can provide better simulation of ITER startup
- **CORSICA benchmarking of DIII-D experiments will allow more accurate predictions of ITER startup**
  - ITER coil current and vertical stability are near limits
- **Continuing work in 2008 will extend these initial results**