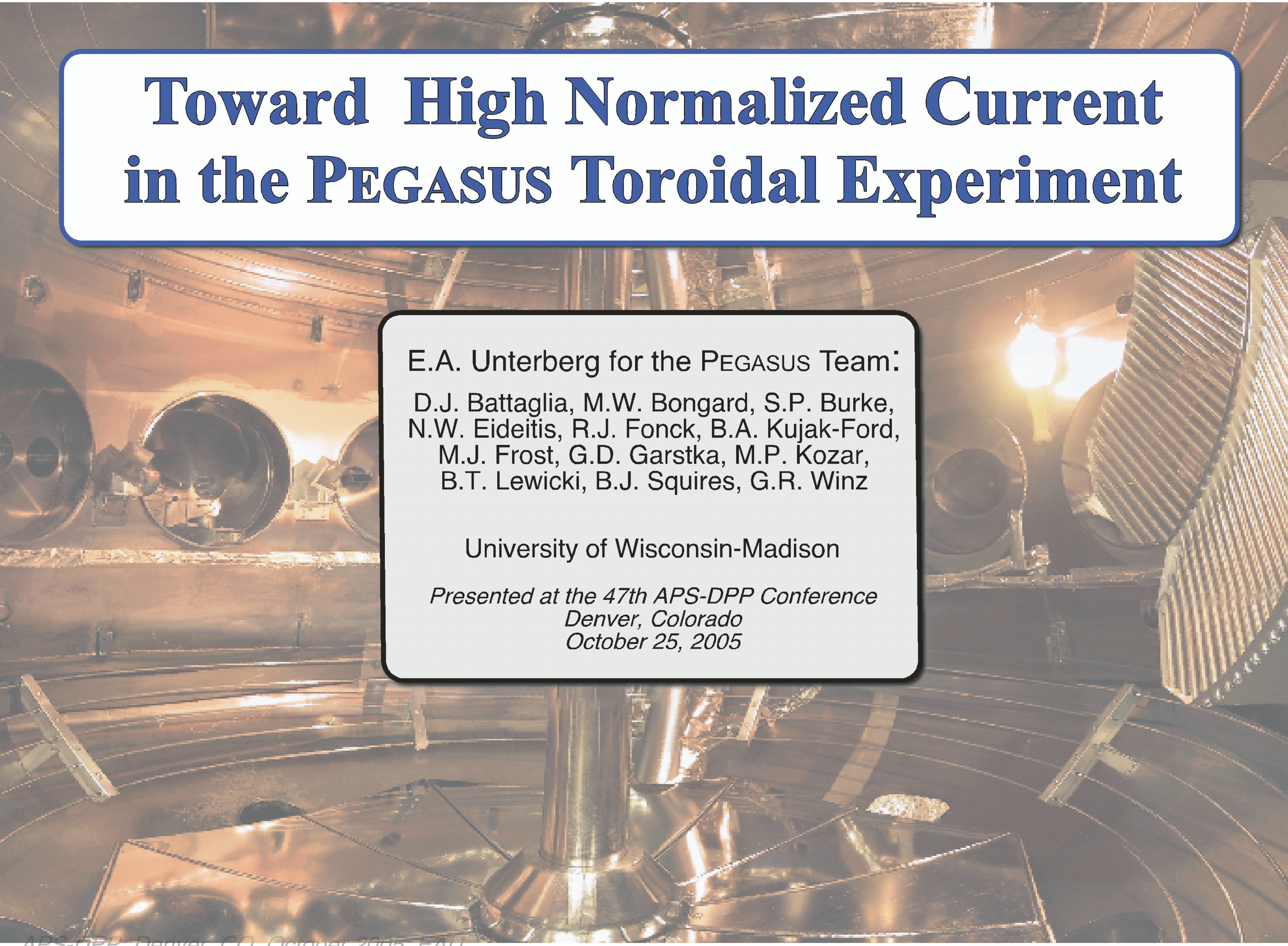

Toward High Normalized Current in the PEGASUS Toroidal Experiment

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Denver, Colorado
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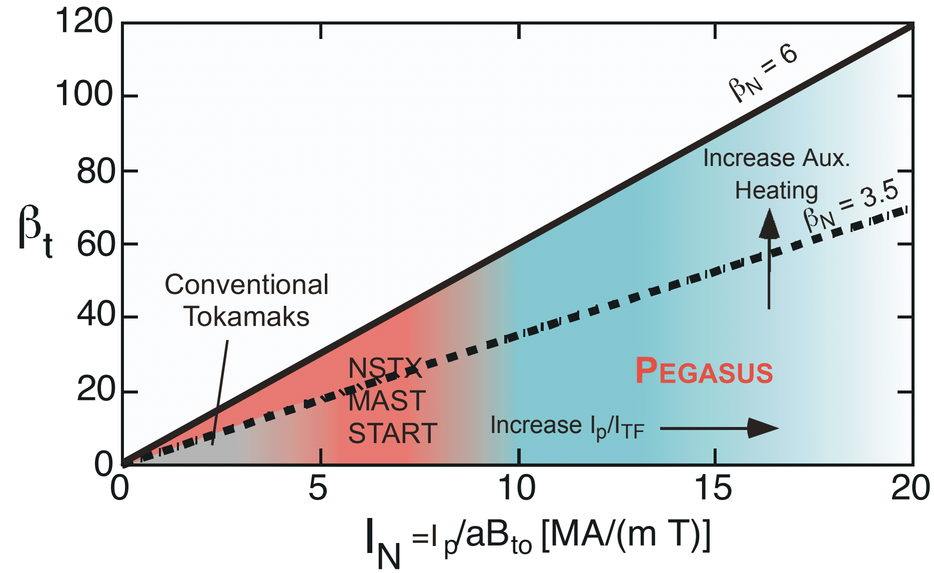
PEGASUS Extends ST Parameter Space

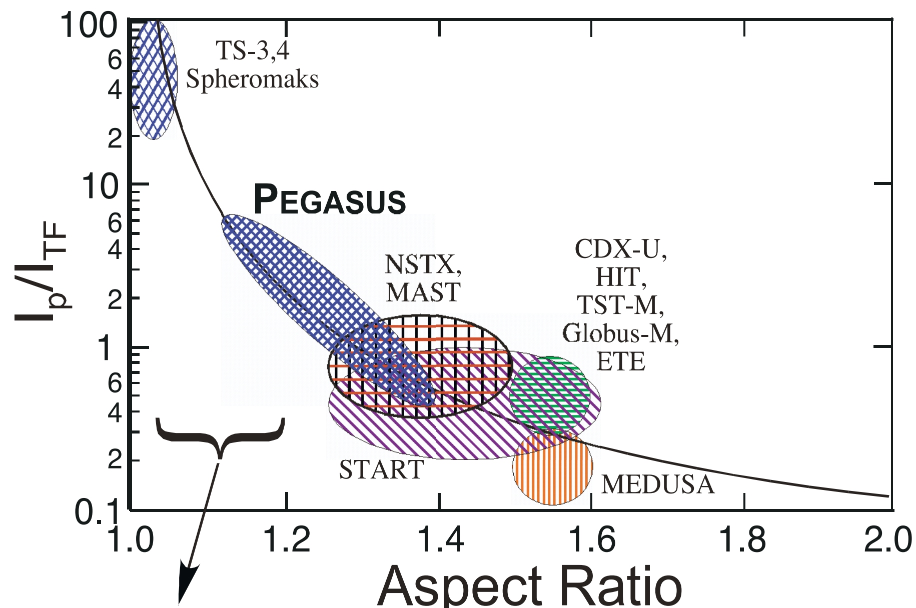
Goals

- Limits on β_t and I_p/I_{TF} (kink) as $A \rightarrow 1$
  - *Overlap between tokamak and spheromak*
- Stability and confinement at high I_p/I_{TF}
  - *Extension of tokamak studies*
- Support ST development to next stage



Campaign Emphases

- Stability at high I_p/I_{TF}
  - *Explore kink stability limit in ULART*
- ST development support
  - *EBW tests for heating and CD (w/PPPL)*
  - *Noninductive startup techniques*



Outline

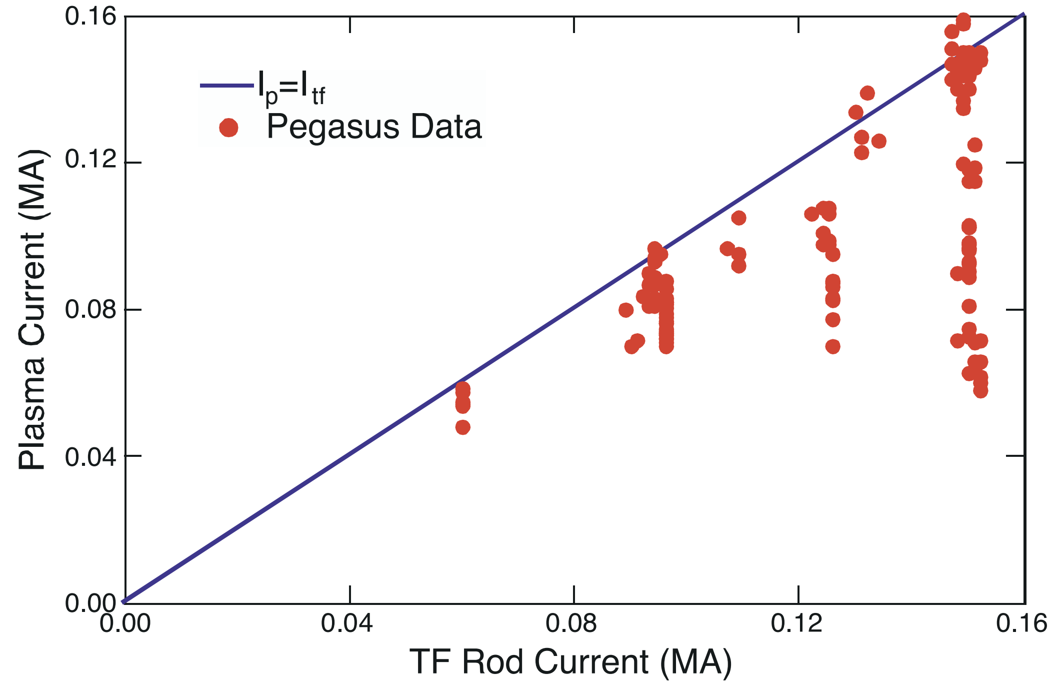
- **PEGASUS Upgraded to Highly Flexible Facility**
  - Phase-I: "soft-limit" in I_p/I_{TF} due to low-A physics and limited discharge control
  - Phase-II: facility upgrade $\Rightarrow$ fully programmable power supplies $\Rightarrow$ discharge control; flexibility

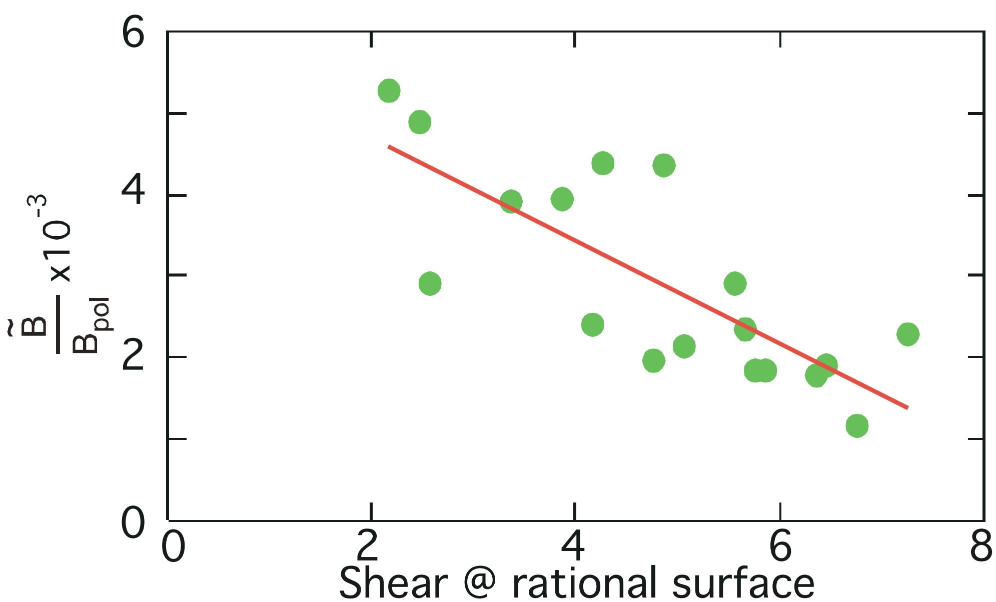
- **Recent Focus: Integration of Capabilities and Tearing Mode Mitigation**
  - Large array of upgraded capabilities nearly complete
  - Phase-I operating space recovered and extended
  - To-date: V-s $\sim$ 30 mV-s $\approx$ 1/3 maximum
  - Mode mitigation experiments ongoing with increased discharge control

- **Phase-II Campaign: Stability in $I_p/I_{TF} > 1$ Regime; ST Development**
  - Goal: $I_p/I_{TF} \sim 2\text{-}3$ ($I_N \sim 10\text{-}20$)
    - *Stability and confinement modelling show attainability in PEGASUS*
  - Electrostatic current injection and EBW heating development ongoing

Phase-I Defined a “Soft-limit” in Ops

- Maximum $I_p \approx I_{TF}$
- Soft limit due to 2 factors:
  - *Tearing modes with rapid growth and large island widths*
  - *Reduced V-sec as TF decrease*





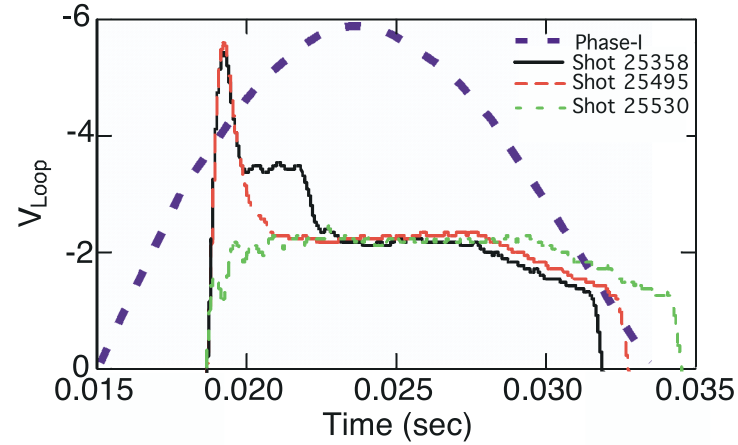
- Crude manipulation of q(r) reduced mode amplitude
  - *Increased shear, $q_0 \Rightarrow$ delay tearing onset*

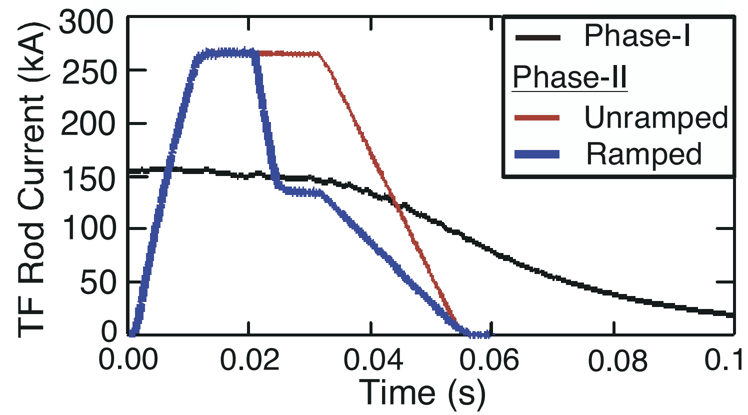
$\Rightarrow$ Access higher I_p/I_{TF} via higher q_0, T_e, shear

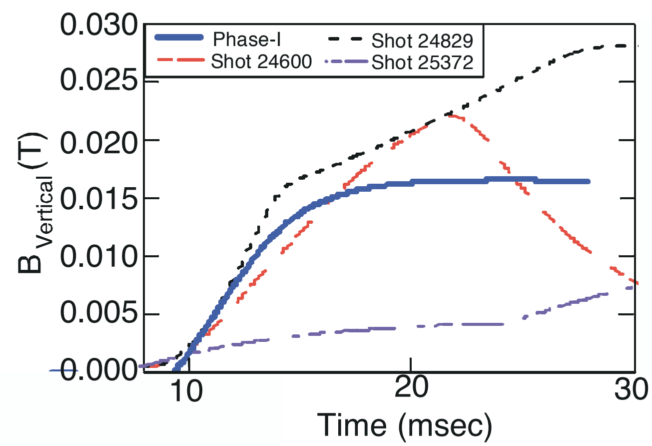
Approaches Developed to Access High I_p/I_{TF}

- **Approaches and tools to increase I_p/I_{TF}**
  - Manipulate current profile
    - *V_{loop} control, position/shape control, $B_t(t)$*
  - Reduce η before low-order rationals appear
    - *V_{loop} control, position/shape control, RF heating (HHFW)*
  - Transiently increase q during startup
    - *$B_t(t)$, V_{loop} control*

- **Main facility modifications**
  - Power Supplies
    - *OH: effective V-s ↑ w/ increased waveform control*
  - Coil Sets
    - *Lower inductance TF set: 60 turns ⇒ 12 turns*
    - *PF Set: monolithic set ⇒ 8 independent sets*
    - *Divertor coil set installed*







Highly Flexible Experiment with Modular Programmable Power Supplies

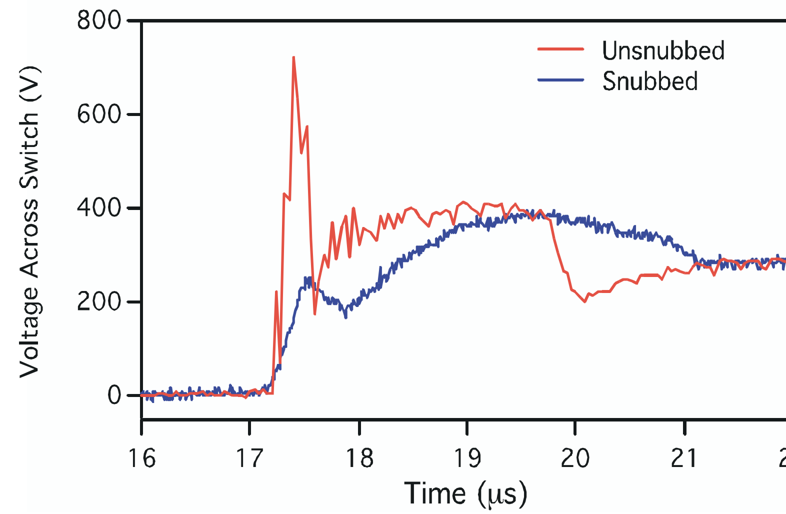
- **250 MVA programmable power**
  - Economical, high-power, solid-state switches
  - Impedence matched for each coil
  - Allows more effective power with less stored energy

- **Large degree of coil arrangement flexiblity**
  - Up to 40 independent subsystems @ 4 kA available
    - *28 @ 900V*
    - *12 @ 2700V*
  - PWM feedback gives msec time response (U.Wash)

- **Allows easy integration to active PCS system**
  - Real-time control under development with GA

Switchyard with the 40 subsystems

Transients across single switch in subsystem

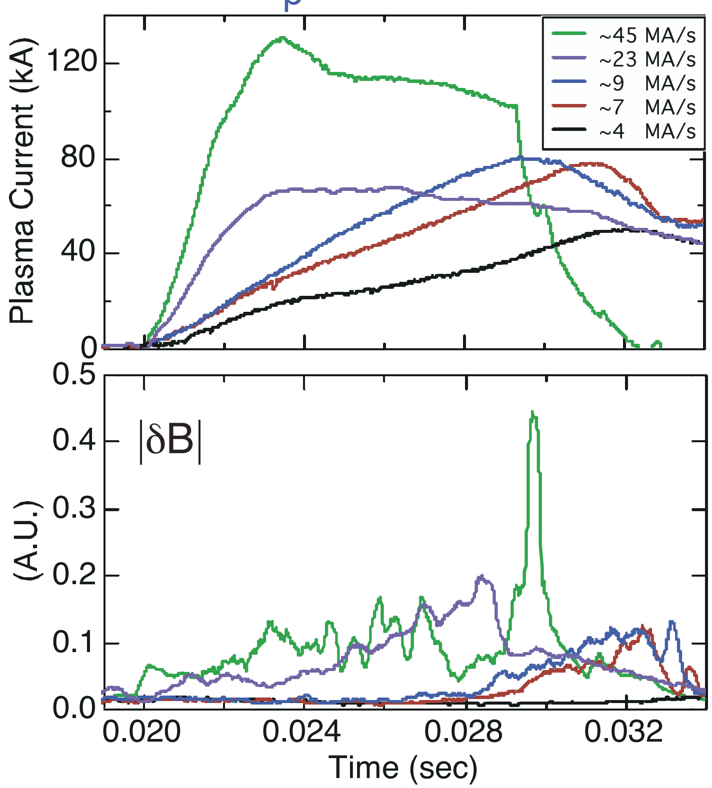


New Tools ⇒ Discharge Control & TM Mitigation

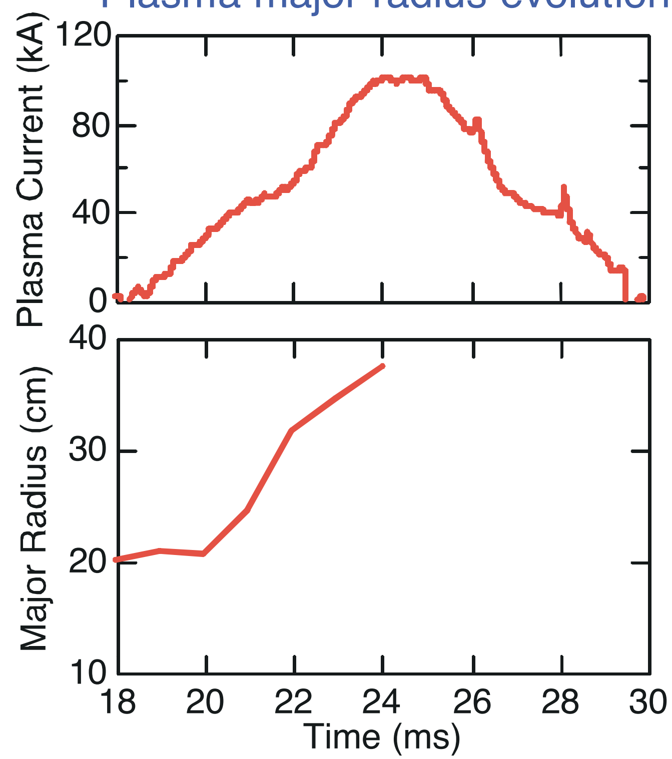
- **Large array of new capabilities developed; deployed into routine use**
  - Pre-programmed coil currents
  - New wall conditioning and fueling
  - Variable PF configurations
  - Increased TF with time-variability
  - Divertor coils

- **Integration underway to access new operating spaces**

Varied i_p & respective $|\delta B|$

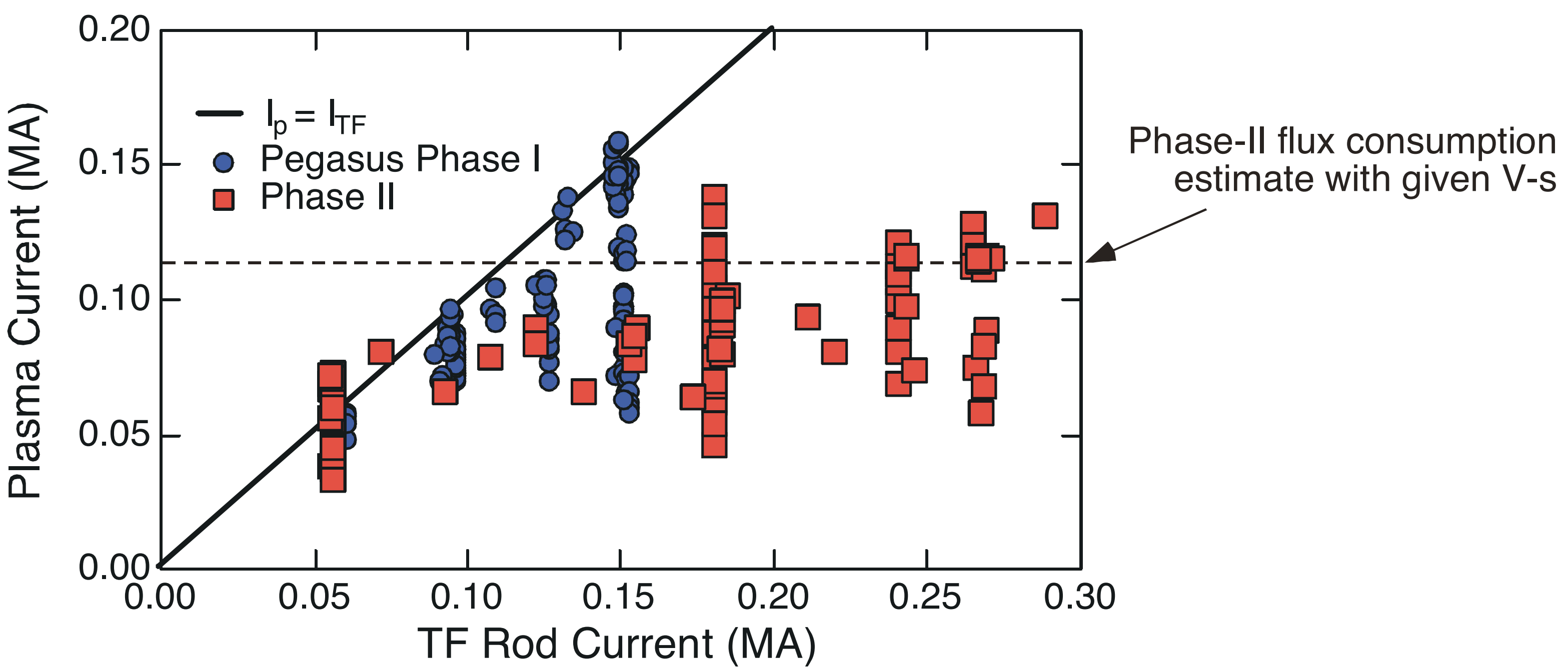


Plasma major radius evolution



Operational Space Expanded

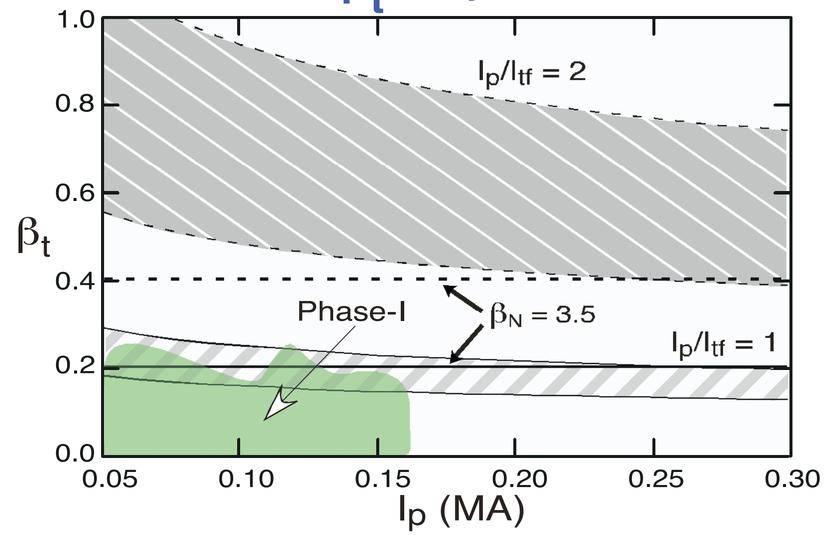
- **Phase-I operational space recovered and extended**
  - $I_p \rightarrow$ ~140 kA ; $I_p/I_{TF} \rightarrow$ ~1
    - *m/n =2/1 mode activity observed with ~ same magnitude as Phase-I*
- **Discharge utilizing all available V-s**
  - ~ 30 mV-s available vs. Phase-I 60 mV-s $\Rightarrow$ 90 mV-s *(full design)*
- **Tearing mode mitigation experiments are ongoing**
  - Optimizing startup to navigate through MHD activity $\rightarrow I_p/I_{TF} > 1$



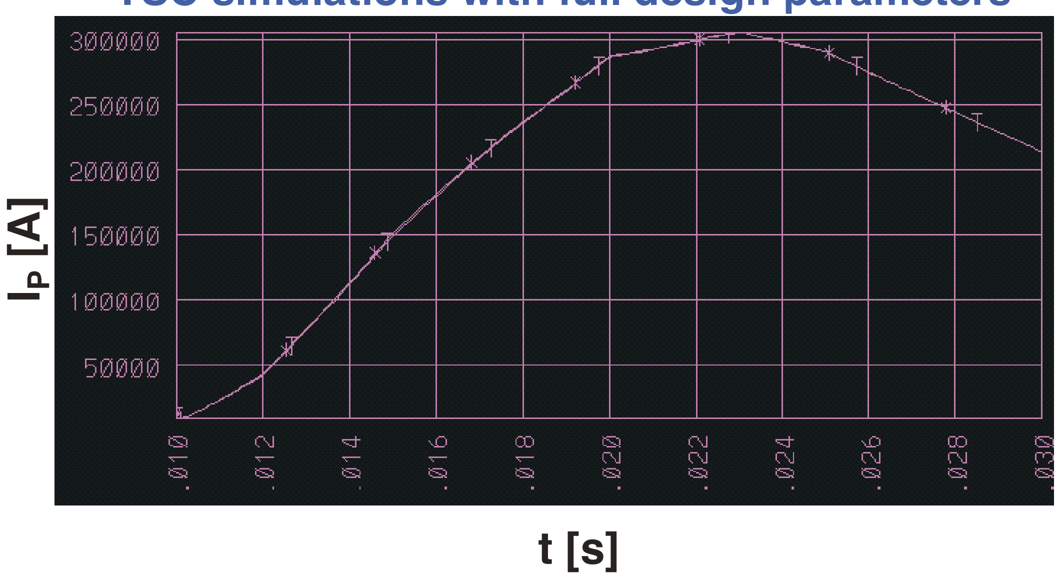
Modeling Gives Path for High I_p/I_{TF}

- **DCON: kink unstable regime ~ q_{95} = 4 and I_p/I_{TF} = 2**
  - Further modelling at higher I_p/I_{TF} ongoing
- **TSC: suggests accessibility → I_p ~ 0.3 MA**
- **Confinement estimates suggest access to β_t > 40%**

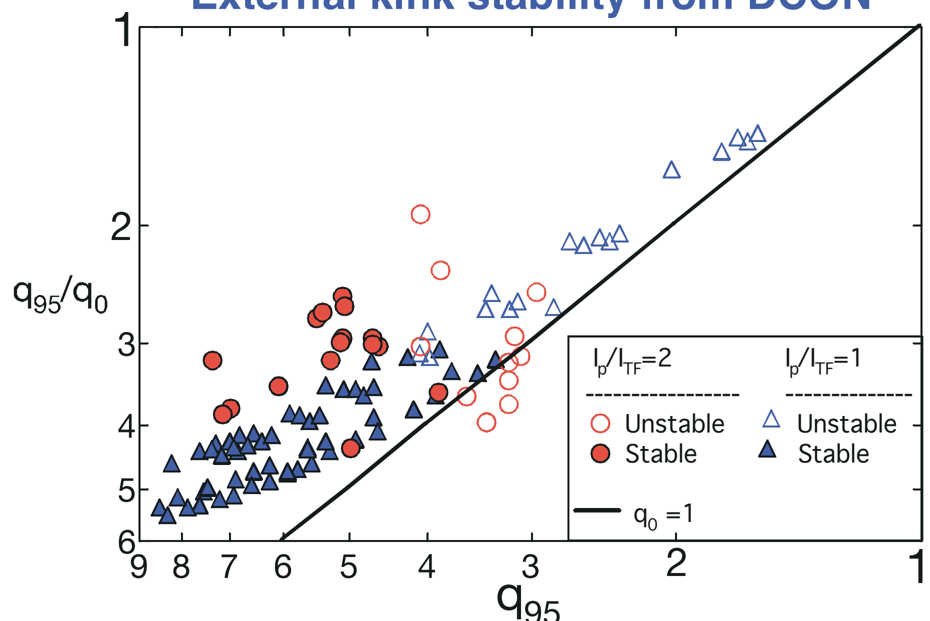
β_t Projections



TSC simulations with full design parameters

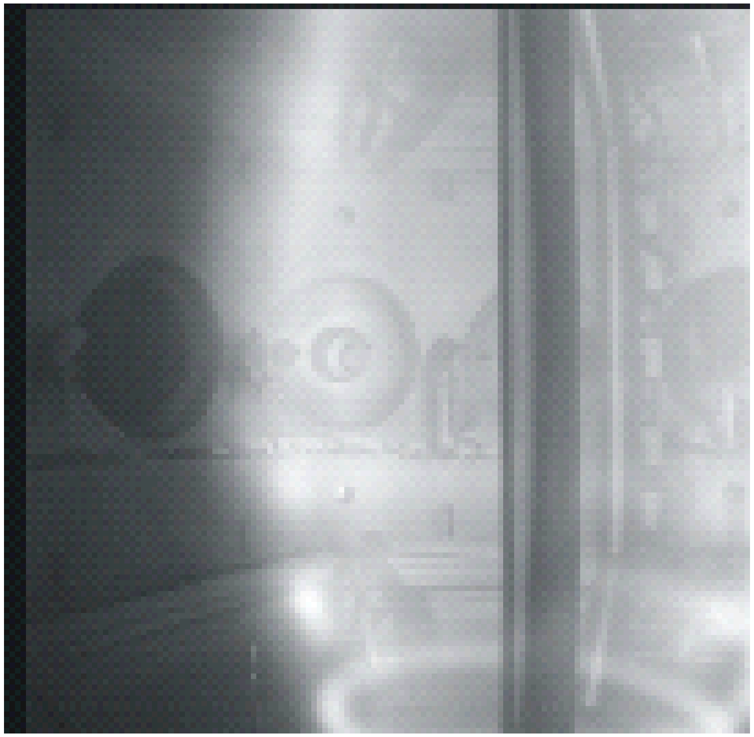


External kink stability from DCON



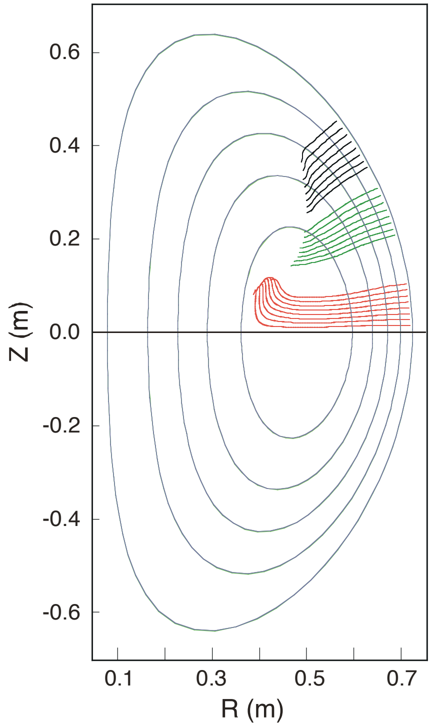
Future Directions: EBW System and Electrostatic Current Injection

Plasma Gun Injection w/ Filament Reconnection



- **Electrostatic Current Injectors installed and being tested**
  - Current amplification → 20X
  - Filament reconnection ⇒ $I_\phi/I_{GUN} \geq$ geometric stacking
  - Closed flux surfaces requires field, gun optimization

EBW Raytracing (GENRAY)



- **0.5-1 MW, 2.45 GHz EBW system under development**
  - Provides convenient test bed for EBW physics in ST
  - Experiments will be a collaborative effort with NSTX & PPPL
  - Planned first heating experiments in 2007

Summary

- **PEGASUS Upgraded to Highly Flexible Facility**
  - Phase-I: "soft-limit" in $I_p/I_{TF} \sim 1$ due to tearing mode activity
  - Phase-II: discharge control $\Rightarrow$ 250 MVA available in H-bridge subsystem

- **Recent Focus: Integration of Capabilities and Tearing Mode Mitigation**
  - Large array of upgraded capabilities nearly complete
  - Phase-I operating space recovered and extended (w/ 1/2 Phase-I V-s)
  - Mode mitigation experiments ongoing with increased discharge control

- **Phase-II Campaign: Stability in $I_p/I_{TF} > 1$ Regime; ST Development**
  - Goal: $I_p/I_{TF} \sim 2\text{-}3$ ($I_N \sim 10\text{-}20$)
    - *Stability and confinement modelling show accessibility*
  - Electrostatic current injection and EBW heating development ongoing

Pegasus Poster Session

RP1 Session Thursday Afternoon

- **RP1.00051:** **Overview of the Phase II Campaign,** *Squires et al.*
- **RP1.00052:** **Plasma Gun DC Helicity Source,** *Eidietis et al.*
- **RP1.00053:** **Active Plasma Control System,** *Bongard et al.*
- **RP1.00054:** **Electron Temperature Diagnostics,** *Battaglia et al.*
- **RP1.00055:** **EBW Heating and Current Drive,** *Garstka et al.*
- **RP1.00056:** **Modeling of EBW Propagation and Damping,** *Diem et al.*