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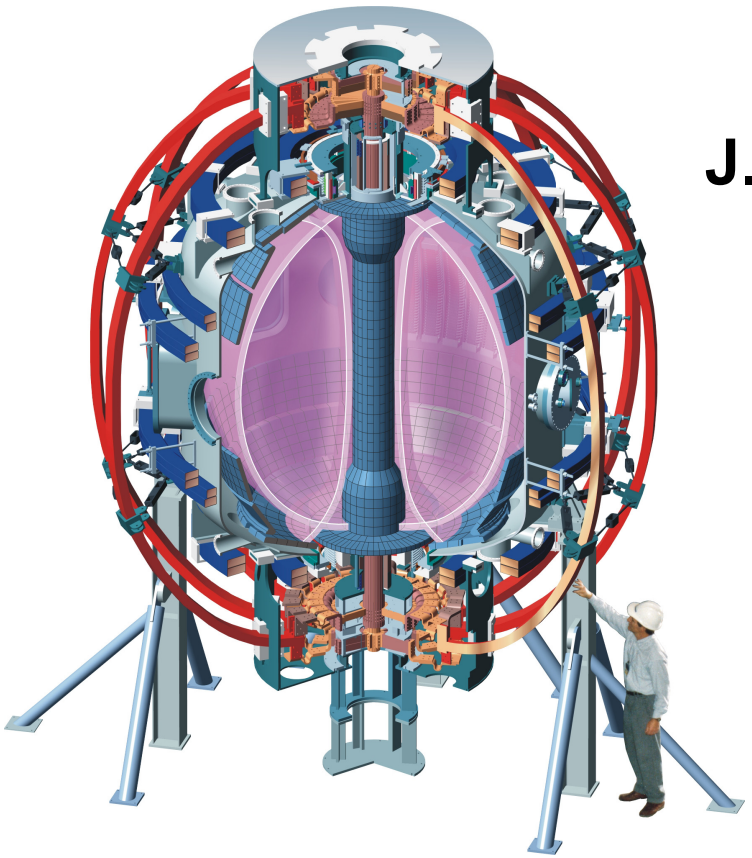
Overview of Integrated Scenario Development (ISD) on NSTX



J.E. Menard and R.J. Wilson

(your fearless ISD leaders)

NSTX Research Forum

November 10-12, 2003

Princeton, NJ

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Hiroshima U
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Ioffe Inst
TRINITI
KBSI
KAIST
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
U Quebec

ISD attempts to combine the following elements:

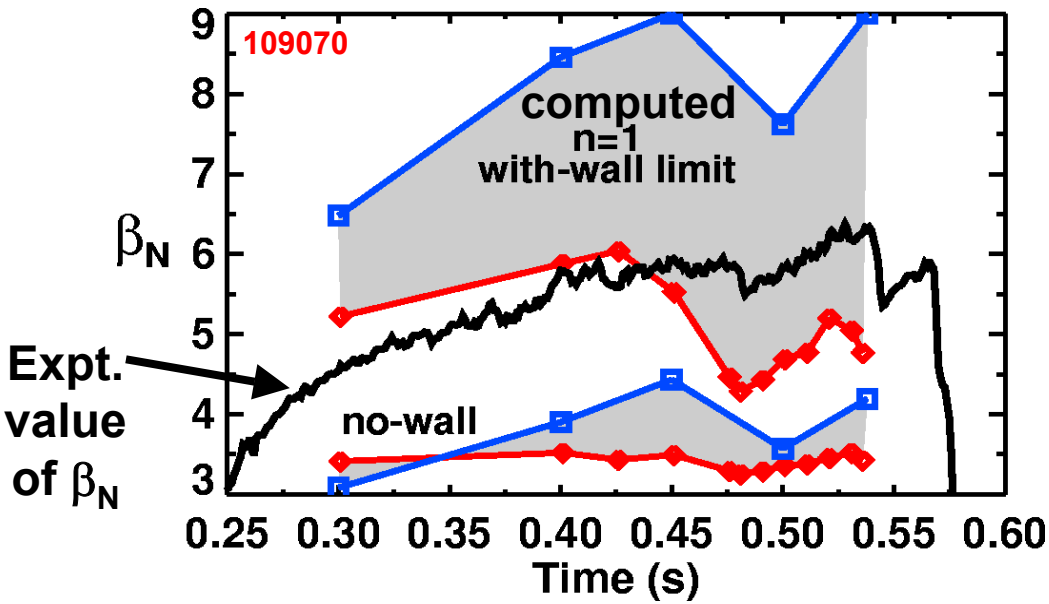
- High β
  - Operate above no-wall limit, near ideal-wall limit
- Long pulse length
  - Pulse lengths of many τ_{CR} where τ_{CR} = 0.2-0.3s
    - Requires high f_{BS} (high β_P), and OH flux conservation
  - Eventual elimination of dependence on OH solenoid
- Good confinement
  - H-mode with H_{98} = 1-1.5
    - broad *J, p* profiles allow high β_N wall-stabilized operation
- Advanced plasma control
  - Shape and HHFW control now
  - Eventually RWM/EF, density, β, and profile control

High β_N operation achieved for long durations

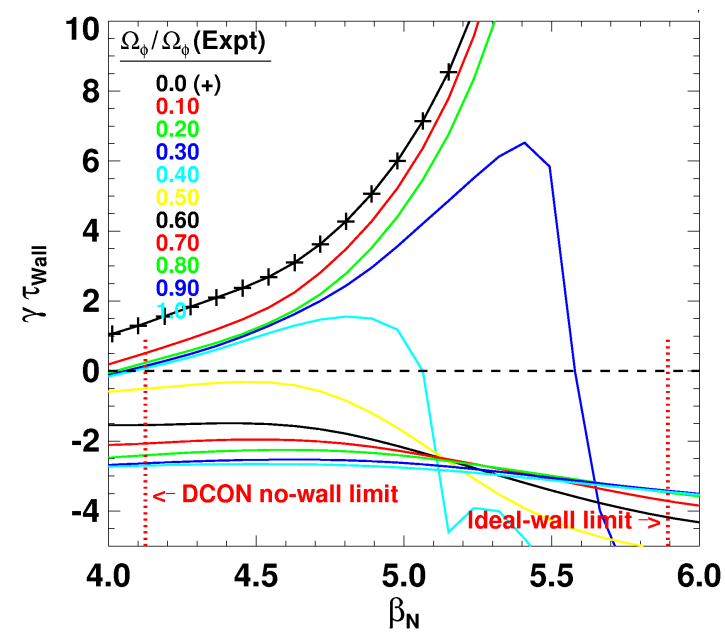
- Recipe: increase *q* the old-fashioned way:
  - Raise field from 0.3T to 0.5T + early H-mode
  - Decrease current to 0.8MA $\Rightarrow f_{BS} \rightarrow 50\%$

β_N > no-wall limit for $\Delta t > \tau_{CR}$=0.25s

Consistent with rotational stabilization of RWM

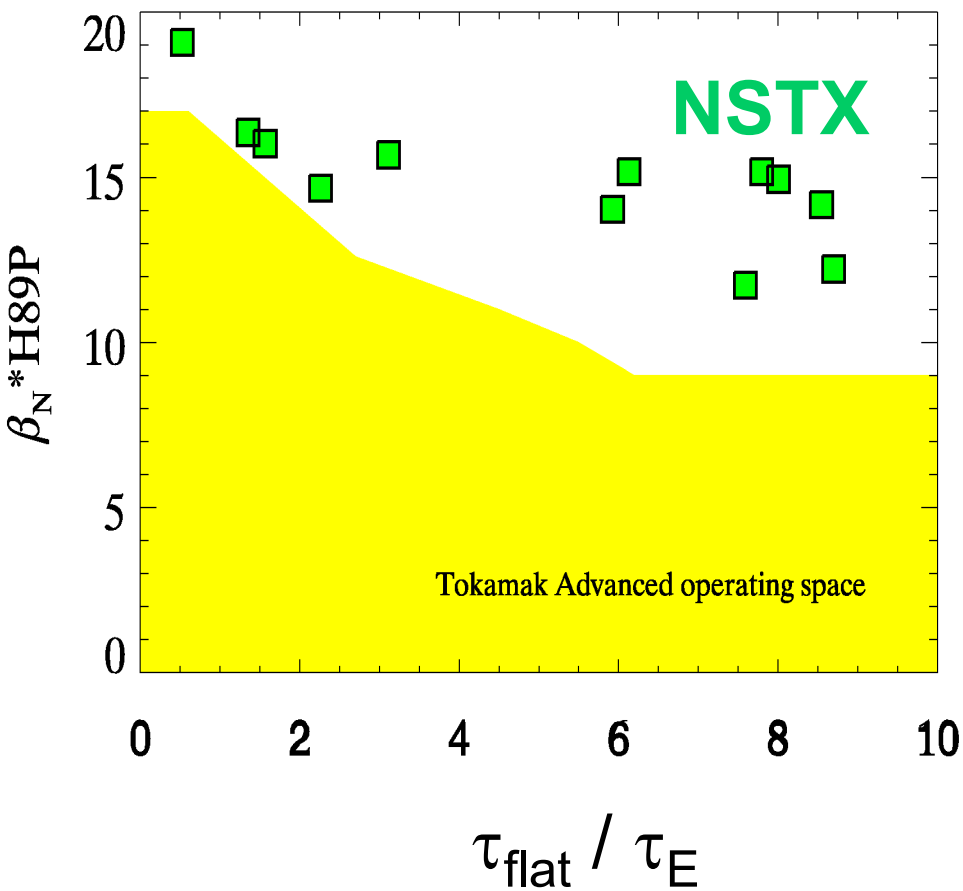


MARS n=1 growth rate
$\tau_w = 10^4\ \tau_A$, η=0, $\kappa_{||}$ = 0.2

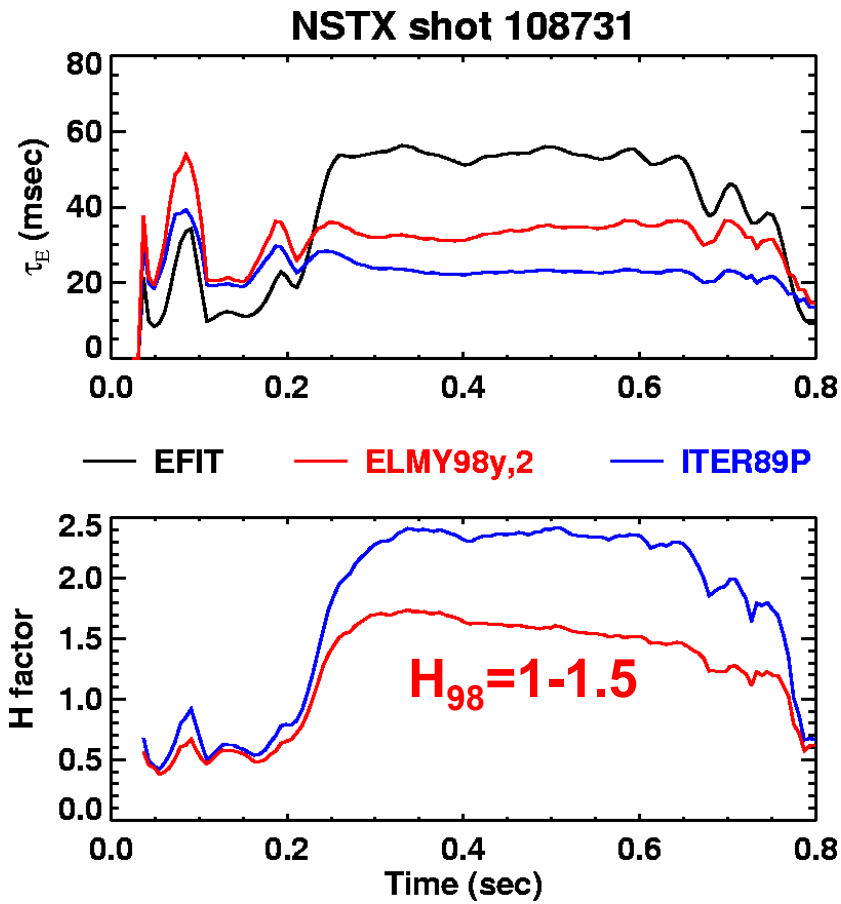


Good confinement obtained at high β for many energy confinement times

Long-pulse H-modes:



NBI A+B at 90kV, 4.0MW, 5.0kG



How do we improve performance further?

- Pulse-lengths > 1s will require B_T < 5kG ($\int I_{TF}^2 dt$ limit)
  - Must operate at 4-4.5kG for significantly longer pulses
  - This will obviously lower *q* if nothing else is done
- Experimentally, lowering B_T shortens high-β_N phase
  - Consistent with $q_{min} \rightarrow$ 1-1.5 sooner(?) $\Rightarrow$ destabilizes *n*=1
  - Plasmas may be at ***n=1 ideal-wall* limit at $\beta_N \approx 6$**
    - **If true, profiles and/or shape must be altered** to increase limit
    - **q_{min} > 2 may increase *n*=1 ideal-wall limit to $\beta_N \approx 8$**
      - **Computationally/theoretically possible with optimized profiles**
- Elevated *q* may be a promising path forward…

  (Just my opinion…)

How do we raise *q*, and try to keep it stationary?

1. Slow current penetration during ramp-up phase:
   - **Faster I_P ramp-rate** **(Gates, Menard)**
   - **Raise T_e early with HHFW** **(Menard, Wade)**
   - **H-mode during I_P ramp** **(Wade)**

2. Increase T_e and control density in flat-top phase:
   - **HHFW with long-pulse NBI** **(LeBlanc)**
   - **HHFW H-modes w/o NBI** **(Wilson)**
   - **Improved density control** **(Maingi)**

3. Increase off-axis BS current drive with higher κ and β_N

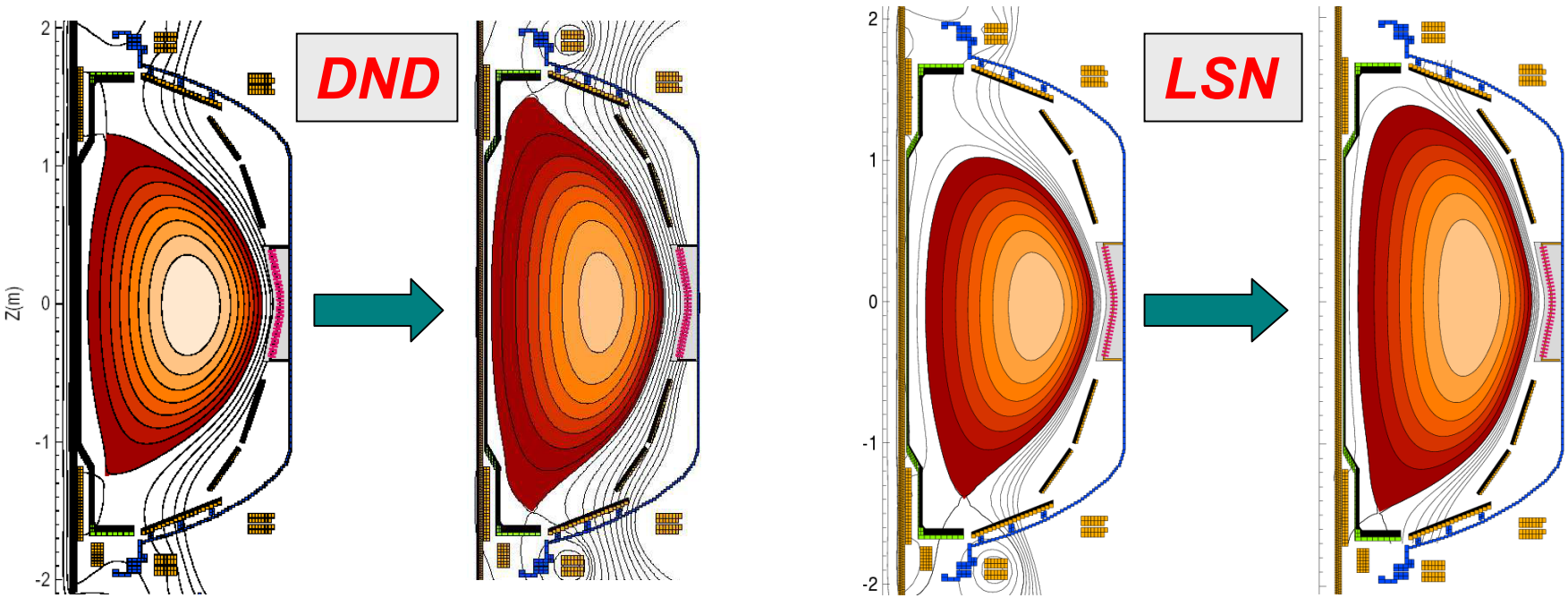
Recall: $\mathbf{f_{BS} \propto (1+\kappa^2) / I_N}$ where $I_N \equiv I_P / aB_T$, so $\mathbf{\beta_T \propto (1+\kappa^2)\, \beta_N^2 / f_{BS}}$

Higher initial q $\rightarrow$ higher β_N $\rightarrow$ higher f_{BS} $\rightarrow$ low l_i $\rightarrow$ higher κ $\rightarrow$ higher q

Longer pulse and/or higher β_T ?

How will we increase elongation?

- Improved vertical control:
  - PCS latency soon to be reduced by up to factor of 5
  - 3 talks on plasma vertical and shape control progress for NSTX ⇔ *strong collaboration with GA control team*
- Experiments proposed to benchmark *n*=0 modeling, and generate strongly-shaped high-κ plasmas:



ISD break-out session agenda

Tuesday 1:30 - 5:30PM B-318

1:30-1:40PM	Introduction and run-time allocation	J. Menard
1:40-2:00PM	Long-pulse high-current plasmas at high kappa	D. Gates
2:00-2:20PM	Strongly-shaped LSN plasmas using PF1B coil	J. Menard
2:20-2:40PM	Advanced shape control development	J. Ferron
2:40-3:00PM	Vertical Stability and Control Study at High Elongation	D. Humphreys
3:00-3:10PM	Vertical Stability and Control	C. Kessel
3:10-3:20PM	Break	
3:20-3:30PM	HHFW Current Drive with hot ions	C. Kessel
3:30-3:50PM	HHFW Heating and Current Drive of NBI Heated Plasmas	B. Leblanc
3:50-4:10PM	Long-pulse HHFW-only H-modes	R. Wilson
4:10-4:25PM	HHFW heating during I_P ramp-up	J. Menard
4:25-4:45PM	Current Profile Tailoring via T_e Control During the I_P Ramp	M. Wade
4:45-5:00PM	Density control techniques in long pulse H-modes	R. Maingi
5:00-5:30PM	Discussion of research prioritization	

ISD FY04 Run Planning Guidance

1. Assume we have a total of 18 run weeks.

2. Assume the following for TF availability:
   1. Day 1, 3.5 kGauss
   2. Start of week 4, 4.5 kGauss
   3. Start of week 12, 5.5 kGauss

   TF commissioning in the month prior to plasma operations.
   The 18 week plan pertains to plasma operations.

3. Plan for 1/3 of your run time to be spent in the first 6 weeks, 1/3 in the second 6 weeks, and 1/3 in the final 6 weeks.

4. Control/shape development, followed by "high performance" work, ought to come quite early. Given the TF limits, this probably means higher beta, as opposed to long pulse, high f_{BS} work.