How Theory Research Motivates and Supports the NSTX Program

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Theory work helps motivate the experimental program on NSTX

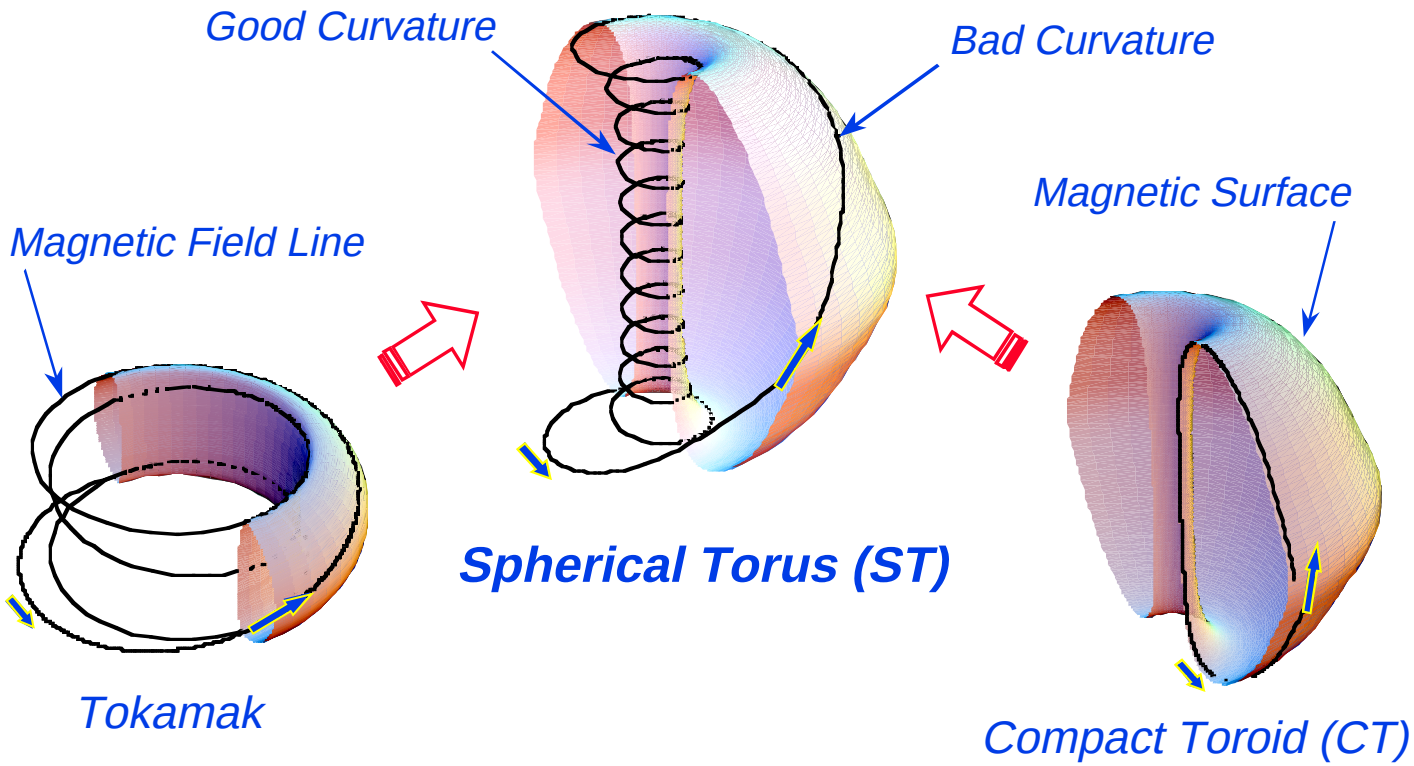
I. Overview: what changes in a toroidal device in going from moderate to low aspect ratio

II. Status of NSTX program

III. Near-term experiment and theory research

a. how theory has helped determine experimental choices
b. how theory is being extended to capture low A, high β

Low aspect ratio changes character of the magnetic field lines

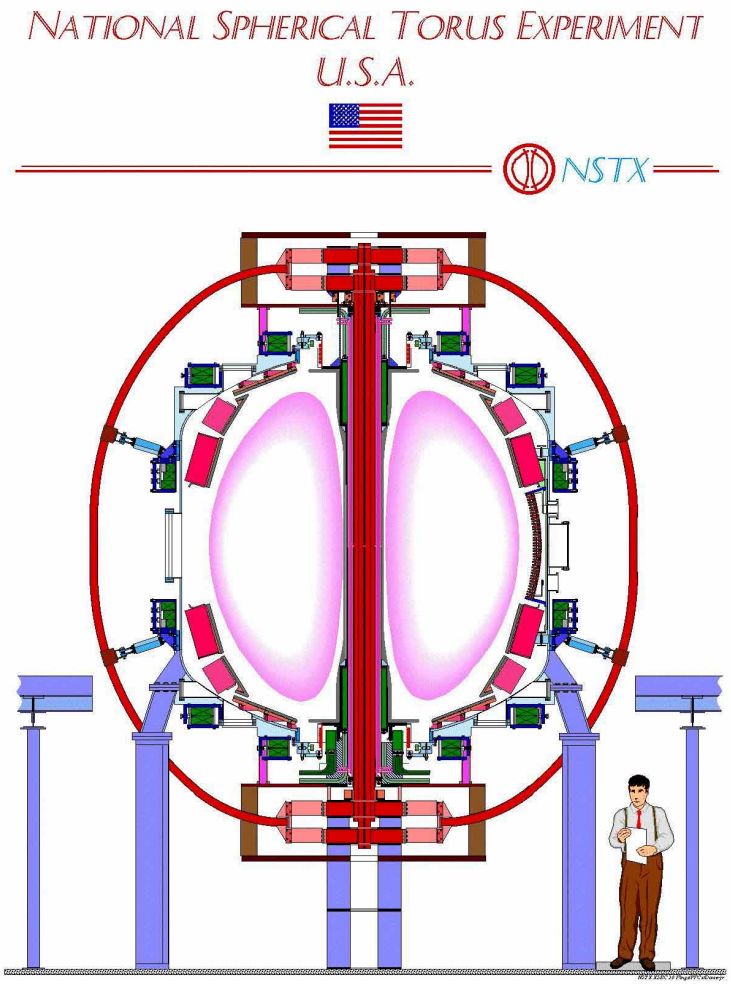


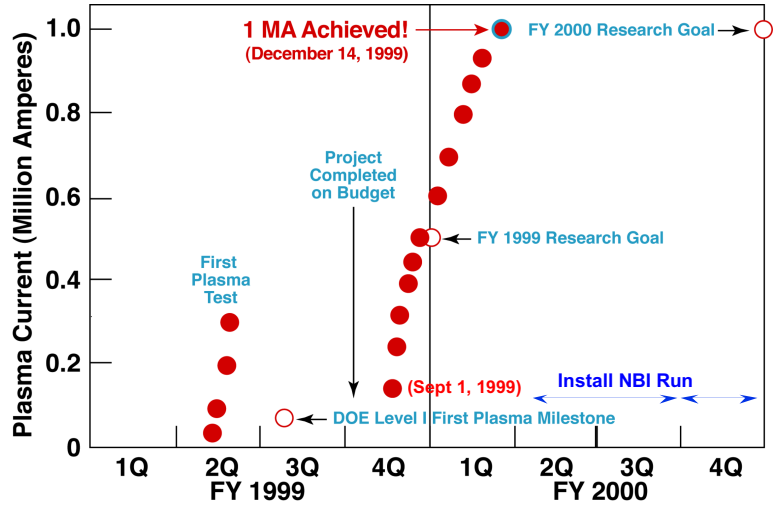
- Most of field line on high field side ⇒ theory suggests fundamental changes in stability and transport
- Theory is pushed to new extremes, and is adapting to interpret upcoming experiments

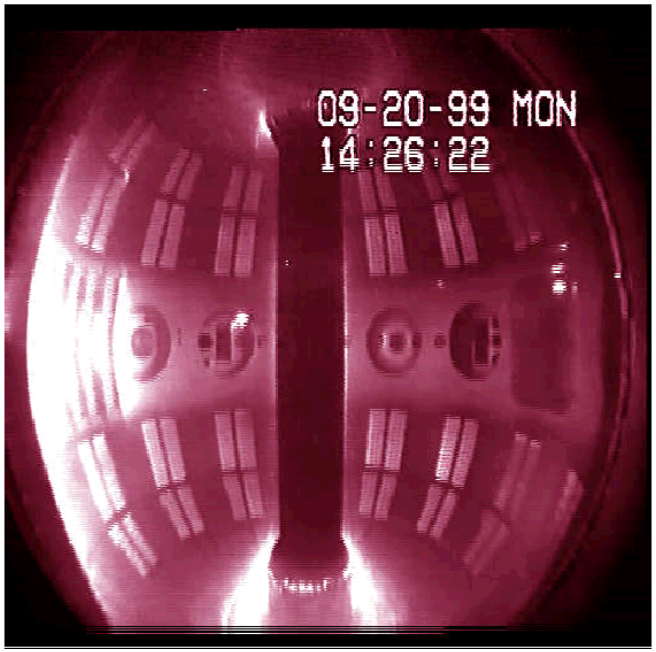
Low aspect ratio forces consideration of new physics

- Field line resides predominantly in high field side
  $\Rightarrow$ possible stabilization of MHD, microturbulence
- High beta: electromagnetic effects in microturbulence
- High beta, low A $\Rightarrow$ less continuum damping of TAE modes
- $V_{Alfven}/V_{sound} \sim 2$
- $\rho_{fast\ ion}$/(system size) ~ 1/3
- Large E$\times$B shearing rates of turbulence
- Non-inductive startup required $\Rightarrow$ reconnection physics key

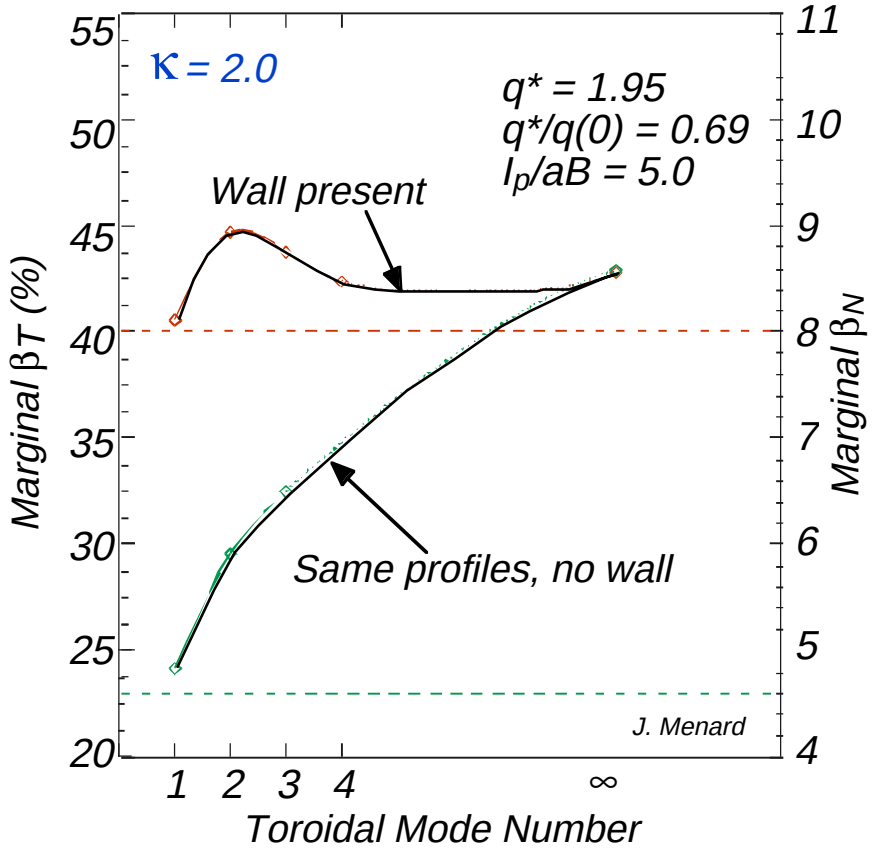
NSTX has had a successful first year of operations

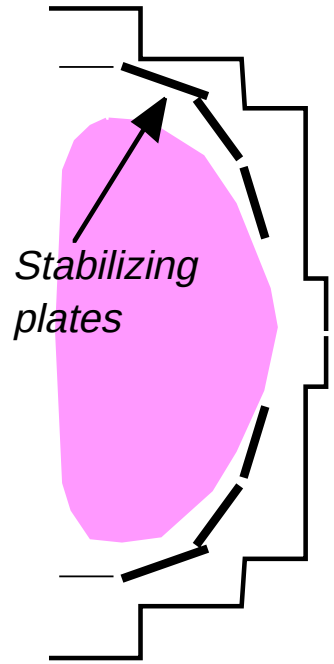






MHD: Theory modelling of wall responses will be used to develop stabilization strategy





Resistive wall mode stabilization

Developing a strategy:

Theory :

- Identify unstable modes, perturbed fields with PEST codes
  - input to VALEN circuit code (Columbia) to quantify plasma-wall response

Experiment:

- Systematic studies near & far from wall
  - improved shape and position control with real-time EFIT

→ *Compare theoretical and measured wall currents* assess required response for stabilization

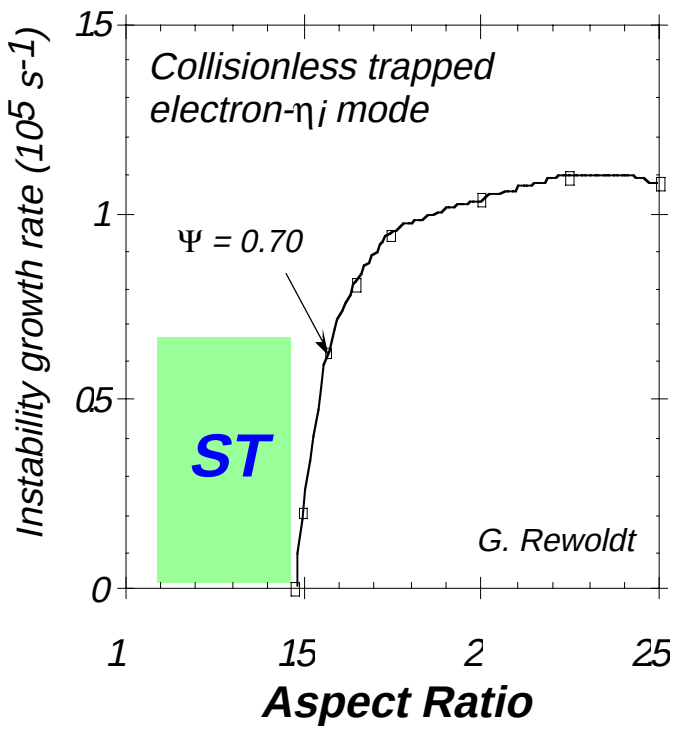
TAE mode studies suggest change in continuum damping at low aspect ratio, high β

- Theory suggests: continuum damping: at low A, high β may no longer damp TAE's (NOVA-k code)
- Building up suite of theory codes to enable prediction of diagnostic signals of fast particle losses
  - ORBIT code, using input from NOVA-k (linear) accounts for large orbit/system size
  - nonlinear kinetic treatment being developed: M3D gives nonlinear growth, redistribution

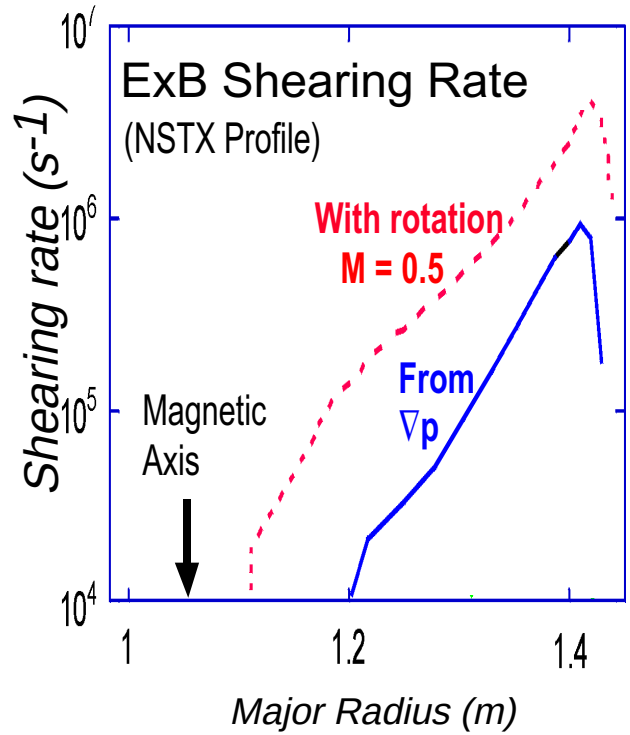
Experimental tools:	particles:	lost ion probes, NPA, neutron scintillators
	instabilities:	reflectometry, FIR, HF magnetics

Local transport focus motivated by theory predictions for low A

Decreased instability drive



Increased stabilization



⇒ Exciting prospects for ST confinement
Theory development aiming to be as complete as possible

Transport: effort requires information from theory at earliest stages of profile measurements

Experimental challenge:

What is the power balance in a moderate β ST?

- Through fall '00: Profile measurements (T_e, T_i, V_ϕ)
  Beam ion orbit improvements in TRANSP

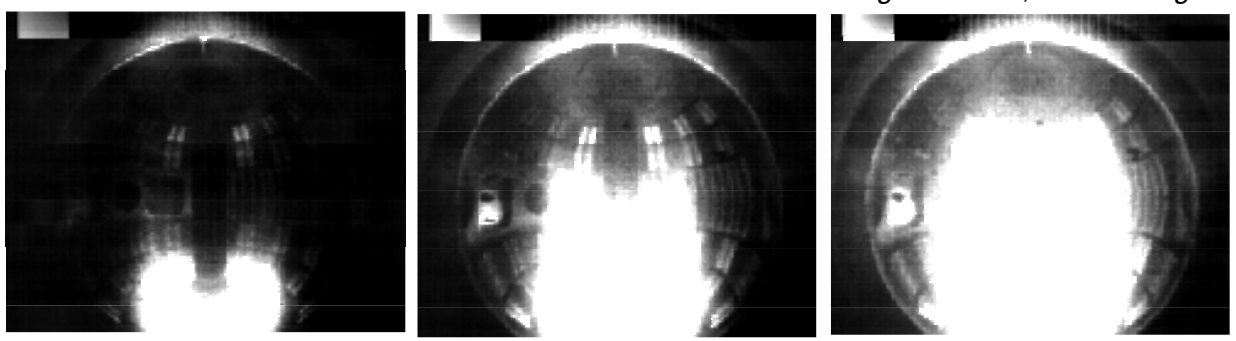
From theory:

1. Neoclassical transport (GTC code without fluctuations)
2. E_r effects: Changes in neoclassical and turbulence
   - Equilibrium E_r in gyrofluid, FULL gyrokinetic code
3. Implementing electromagnetic effects
   - present: gyrofluid, FULL gyrokinetic code
   - under development: GTC gyrokinetic (full torus)

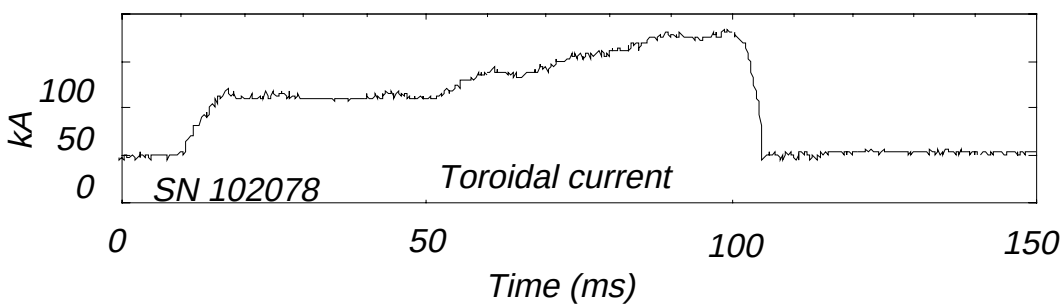
ST startup challenge being supported by theory work in reconnection

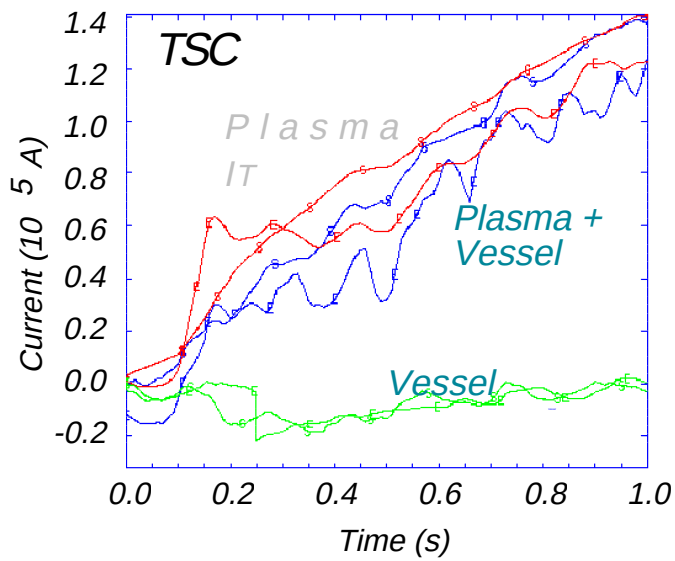
- ST requires non-inductive startup scenario: Coaxial Helicity Injection being developed on NSTX
- Magnetic flux penetrates from edge via reconnection
- Challenging resistive MHD problem. TSC results in -hand M3D being adapted to deal more efficiently with small A

Roger Raman, U. Washington



12 ms *16 ms* *20 ms*





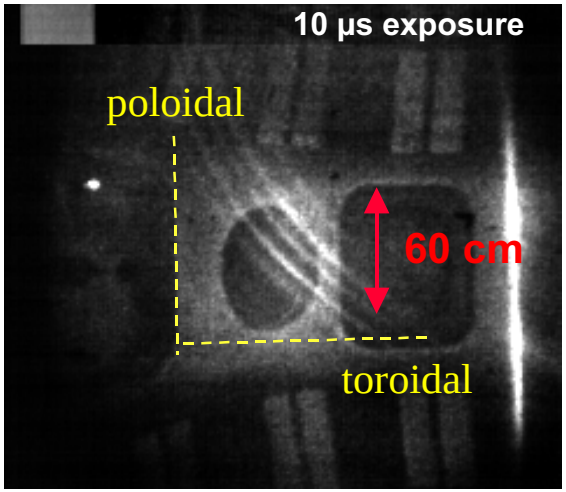
Edge transport & divertor physics program draw on edge modelling tools

- Measure particle influx and heat flux distributions, scalings with n_e, P_{heat}

- Begin detailed comparisons with edge transport (open field line and neutral) modelling

  - DEGAS2 (neutral transport), UEDGE, B2.5 (parallel transport; LLNL) are interfaced

  - Model edge neutral distribution to interpret Gas Puff Imaging (GPI) pictures of turbulence (LANL, PPPL) ⇒



- Impurity transport with short ST connection length

  - use same pair of codes to assess how the core is contaminated, guide strategy for reducing impurity influxes

Summary

- PPPL theory work has helped determine experimental choices for next two years
  - supports program in developing MHD stabilization strategies
  - possibility of exciting local transport physics
  - fast ion theory motivates diagnostic choices

- Theory is adapting to face challenges of high β, low aspect ratio. Examples are
  - finite beta, electric field effects in microstability
  - large fast ion orbits
  - merging of MHD, microstability effects
  - neoclassical transport theory at low A
  - edge transport