Active Feedback Physics Design Study Plan for Global MHD Instabilities in KSTAR

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The Columbia University group could help improve KSTAR plasma stabilization system

- Motivation
  - The steady-state KSTAR device design incorporates global mode stabilization (GMS) hardware for increased performance
  - Full physics assessment of the hardware effectiveness is desired

- Outline
  - Objectives for assessing sustained mode stabilization in KSTAR
  - Supporting research of existing and planned devices
  - Research plan for KSTAR global mode stabilization study
  - Budget

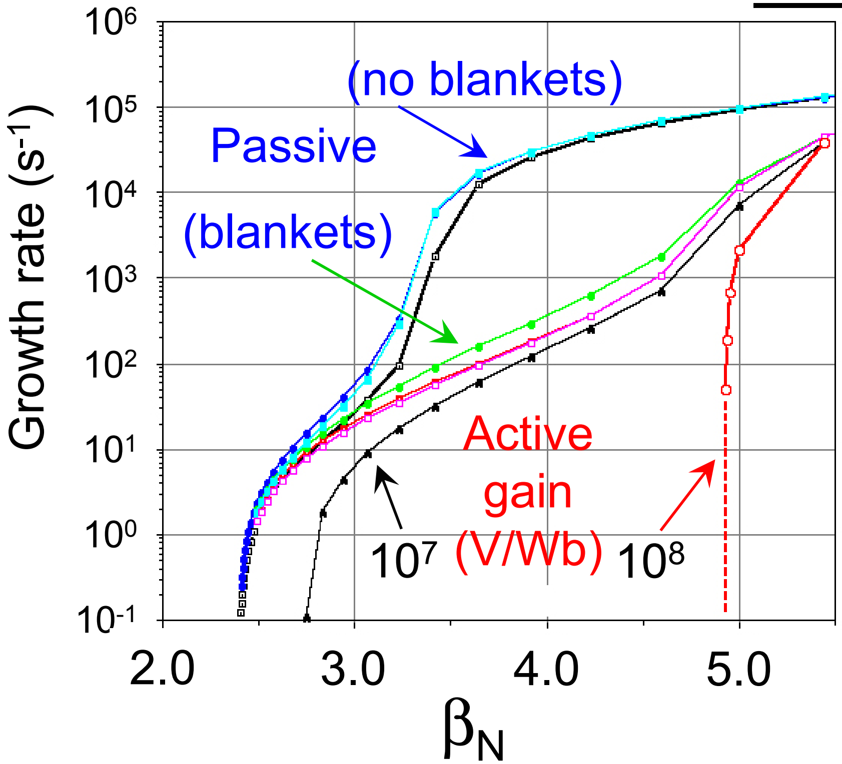
Objectives of GMS physics design study follow required elements

- Equilibrium
  - Use KSTAR design basis equilibria that span operational space (β, shape, q)
  - Perform equilibrium variations as desired in coordination with KSTAR team
  - Use KSTAR equilibrium reconstructions once device produces plasma
- Stability
  - DCON – input to VALEN
    - Analyze stability space vs. KSTAR plasma parameters
- Feedback
  - VALEN
    - Mode growth, time-evolved stabilization, critical feedback time delay
- Simulation development / present experimentation
  - Present upgrades include rotation, multi-mode capability, etc.
  - RWM stabilization physics understanding, critical rotation frequency, etc.

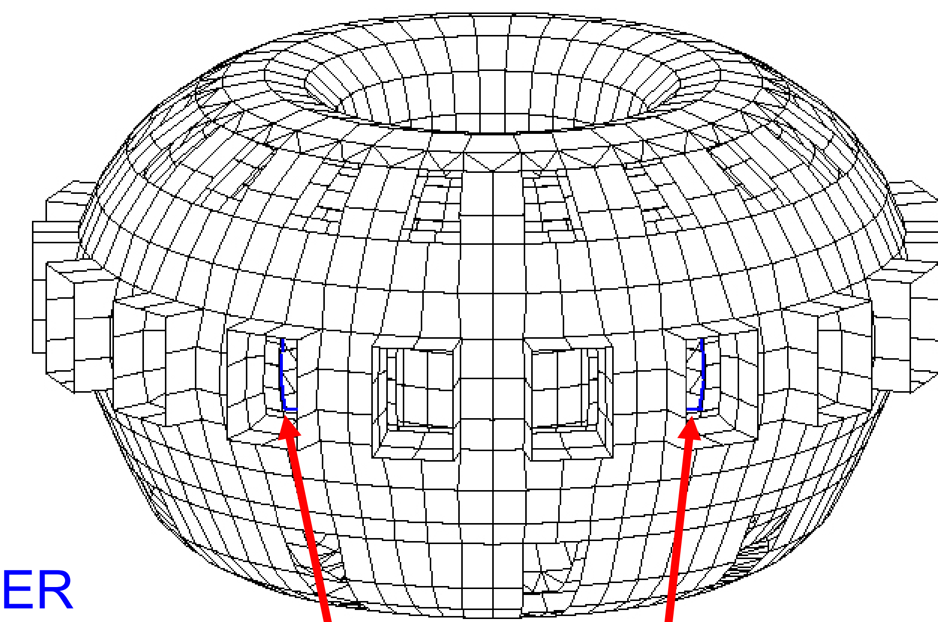
Columbia U. GMS studies closely couple theory & XP

- Applied / Experimental
  - DIII-D
    - Design/analysis of results of active feedback system with internal coils (Garofalo, Navratil, Reimerdes,)
  - NSTX
    - Design/analysis of passive stabilizer system and active feedback system with external coils (Sabbagh, Sontag)
  - HBT-EP
    - Experiment/theory (Navratil, Bialek, Mauel, Boozer)
  - Interactive
    - Common tools, standard (shared) databases, remote meetings
- Theoretical
  - VALEN-3D code design/development (Bialek, Boozer)
- Predictive
  - Analysis of future devices (Bialek, Navratil)
    - ITER, FIRE, JT-60SC design studies conducted

ITER active coil modification can significantly raise stable β_N



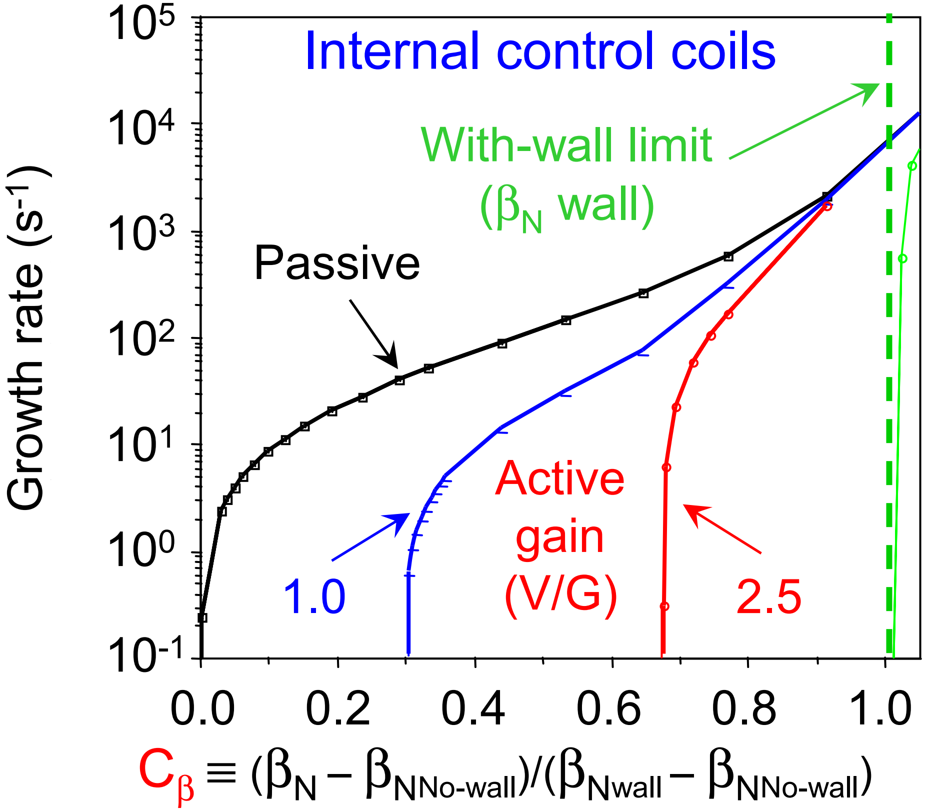
VALEN dual-wall vessel / blanket model
(full view)

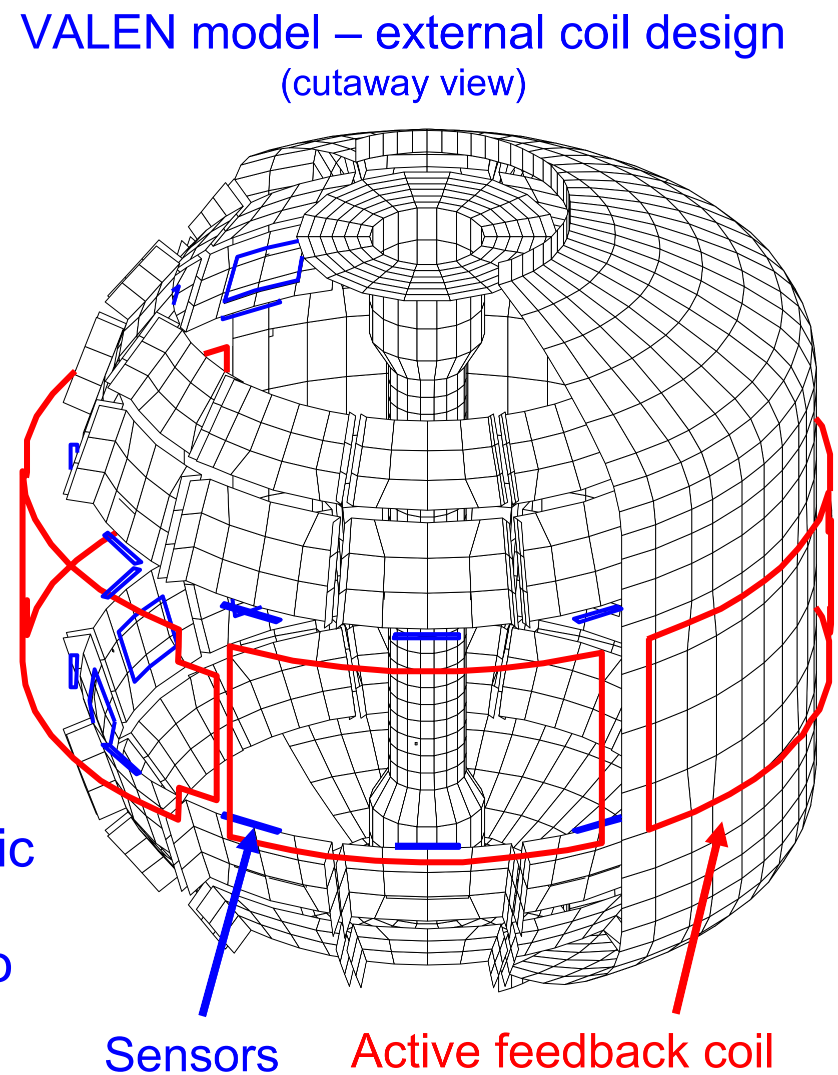


Active feedback coil modification
(coils in ports)

- Original external coil design for ITER stabilizes up to $\beta_N = 2.7$
- Proposed improvement raises maximum stable β_N to near 5
- Dual-wall vacuum vessel and blanket used in VALEN model

NSTX control modeling predicts 68% stable margin above $\beta_{Nno\text{-}wall}$ with initial external coil system

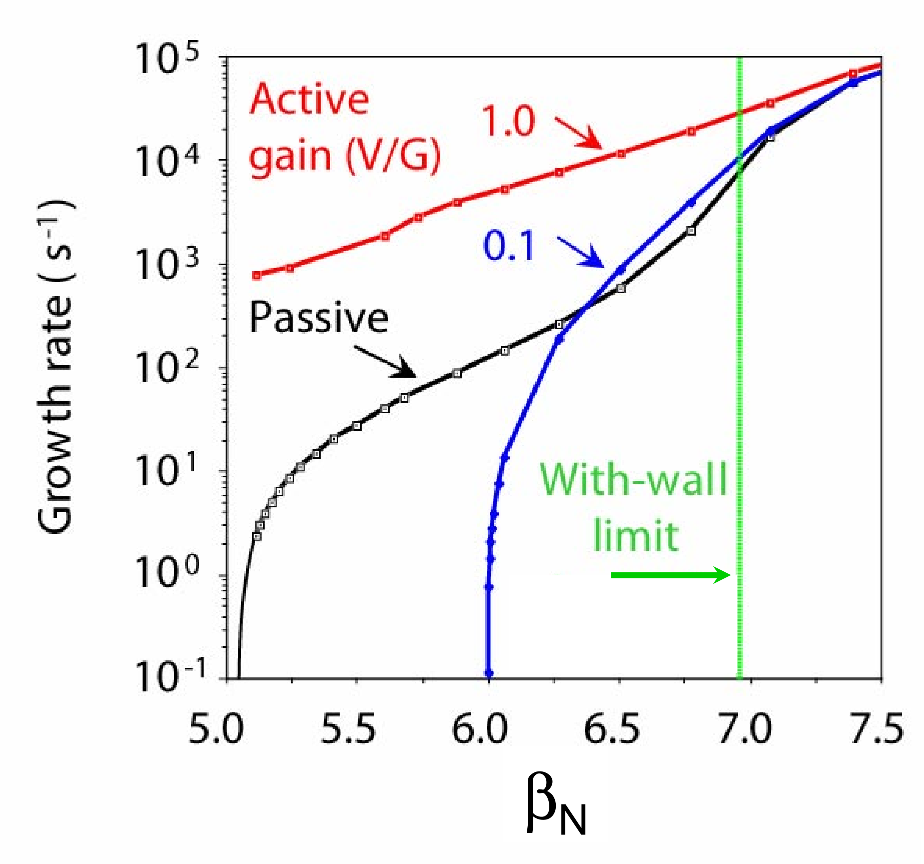


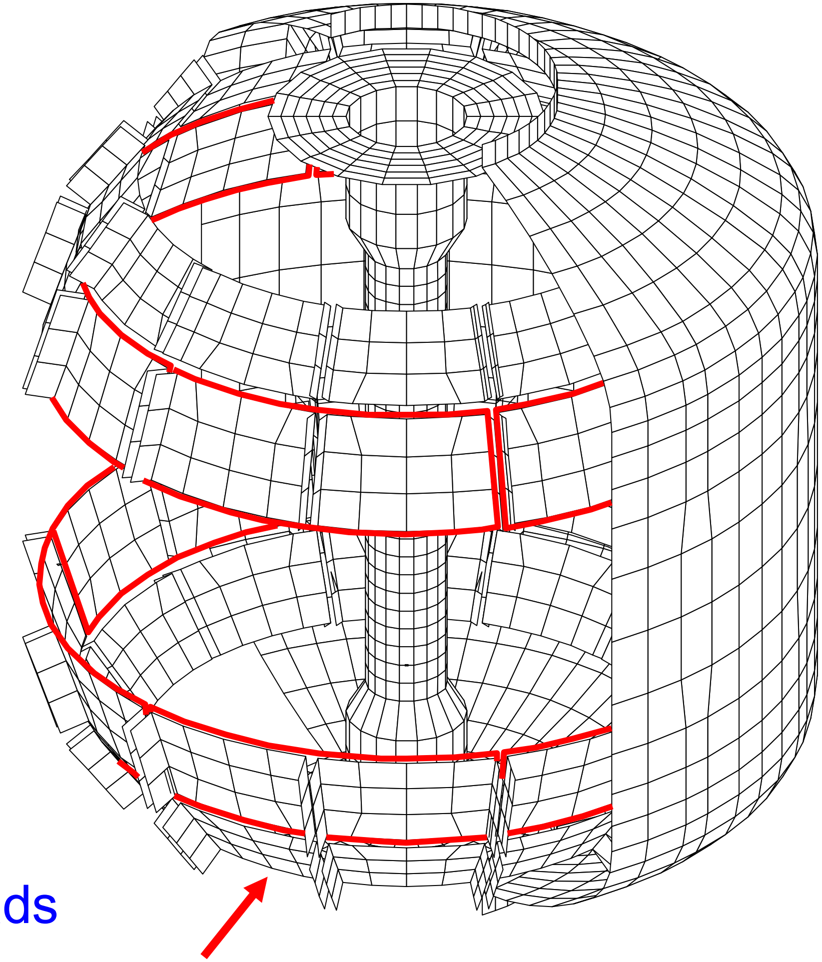


- Control coil / sensor design with realistic geometry
- Internal control coil design computed to reach C_β = 94%

(Equilibria used have $\beta_{Nno\text{-}wall}$ = 5.1; β_{Nwall} = 6.9)

NSTX model with control coils among plates has only 50% stable margin above $\beta_{N\text{no-wall}}$

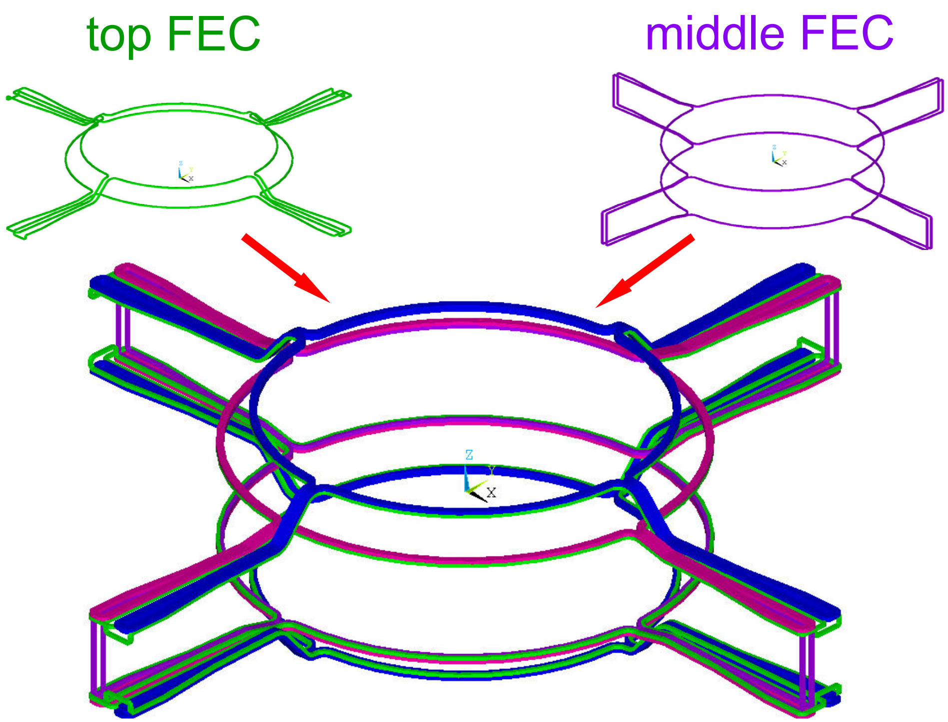


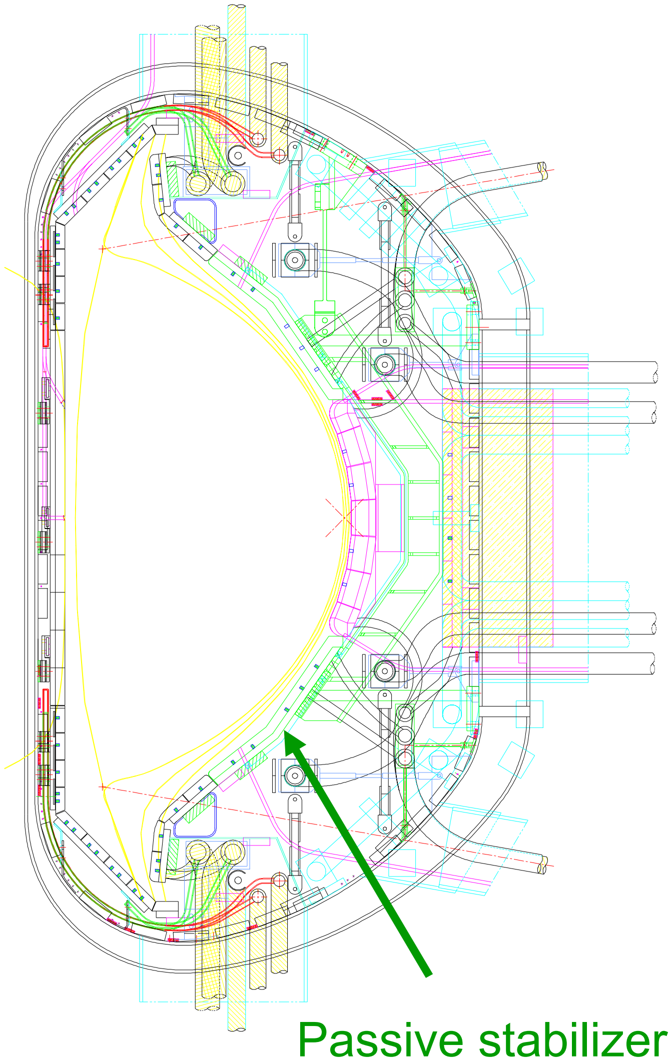


- Active coil / passive plate coupling leads to reduced performance

Modeled active feedback coils

KSTAR active stabilization system might be improved





- KSTAR improvements can be explored as in ITER, FIRE, DIII-D, NSTX, HBT-EP
- Minimizing coil/plate coupling led to improvements in NSTX design
- VALEN can provide correct amplitude and phase relation for KSTAR FEC coil elements to stabilize n = 1,2 resistive wall modes

Timeline for Columbia U. KSTAR GMS Study

- First Year
  - Equilibrium calculations based on present hardware design
    - Use KSTAR design basis equilibria; modify in coordination with KSTAR team
  - Stability / feedback calculations
    - Determine most important stability sensitivity to parameter variation
    - Set up VALEN model; determine performance of present KSTAR design
    - Extend VALEN model to assess possible passive plate improvements
- Second Year (first plasma by end of this year)
  - Assess baseline active feedback system design; project improvements
  - Model time-dependent stabilization, critical time delay for feedback
  - Examine stability of first experimental KSTAR equilibrium reconstructions
- Third Year (high beta plasmas)
  - Stability of high beta experimental KSTAR equilibrium reconstructions
  - Verification of RWM growth rate under passive stabilization
  - Participate in experimental determination of critical rotation profile for stability
  - Investigate improvements for feedback system based on high beta results

Columbia U. Staffing and Budget for KSTAR Study

- CU three year budget
  - First Year (~$150k)
    - 5 months senior research scientists
    - 6 months associate research scientist
  - Second Year (~$200k)
    - 5 months senior research scientists
    - 12 months associate research scientist
  - Third Year (~$200k)
    - 5 months senior research scientists
    - 12 months associate research scientist
- Columbia RWM modeling group presently oversubscribed
  - studies of ITER, DIII-D, NSTX, HBT-EP, JT-60SC, (JET, C-MOD)
  - new staff / new budget resources required to perform KSTAR studies