# Current PPPL Research Challenges & Opportunities in Macroscopic Stability

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# Overview of opportunities and challenges

- Perspective from IAEA/ITPA/ITER/BPO:
  - ELM control - 3D B-field effects on H-mode profiles
  - Role of MHD in J profile of “hybrid” scenario
  - Disruption mitigation physics
  - Resistive wall mode physics at low rotation

- PPPL MHD strengths:
  - Equilibrium & stability of non-axisymmetric plasmas
  - Non-linear MHD simulations – M3D
  - NSTX, DIII-D – test theory against experiment

# Ideas for possible theory contributions (1)

- ELM suppression using 3D coils
  - Use stellarator tools to better understand 3D equilibrium
  - MHD stability and **transport** response to 3D perturbations
  - Observe decreased pedestal density, similar/higher T
  - Are edge field lines really ergodic? Why density pump-out?

  → Head start on transport analysis for NCSX
- MHD effects on current profile in hybrid scenario
  - Extend ORBIT analysis: DIII-D (3/2 NTM), NSTX (core 1/1)
  - Use birth distribution from TRANSP
  - Investigate full orbit effects – is G.C. approximation valid?
  - Reproduce measured NSTX $\xi(r)$ with PEST or MARS?

  → Head start on predictive capability for other modes - *AE

# Ideas for possible theory contributions (2)

- RWM physics
  - Study mode rigidity, RWM control with NMA code
    - Used primarily on DIII-D thus far
    - Extend to NSTX and/or ITER?
  - Longer term – couple GLF closures to C1-MHD code for 2-fluid code with accurate low-collisionality damping models?
    - → Existing RWM damping models need improvement
    - → Develop new linear stability tool with broad applicability & usage…
- ITER disruption mitigation physics understanding
  - Relies on edge cooling, 2/1 & 1/1 island formation, overlap
    - Does this physics extrapolate to ITER?
  - Couple M3D to atomic physics package? (other ideas?)

→ Not just for ITER – may need for any high-$I_p$ next-step

# Ideas for possible NSTX contributions

- ELM suppression
  - Revisit ELM mitigation experiments with RWM/EF coils
    - New understanding of coil current, $q_{edge}$ requirements
- Hybrid scenario physics
  - Complete studies of core 1/1 mode interaction w/ fast ions
  - Extend analysis to NTMs and/or high-f *AE modes
- ITER disruption physics understanding
  - Measure halo current, peaking, contribute data to ITPA
- RWM
  - Test ITER RWM control models using NSTX RWM control tools and codes – compare VALEN, MARS-F, NMA?

# Possible RWM physics contributions from DIII-D collaboration (Michio)

- Assess rigidity of RWM mode structure
  - RFA eigenstructure, and during feedback at low rotation
  - Incorporate poloidal non-uniformity of resistive wall, coils
  - Non-rigidity $\Rightarrow$ MARS / VALEN discrepancy at $C_\beta > 0.7$ ??
  - Assess with NMA code developed by Chance and Chu
- RWM/RFA characteristics at low rotation
  - Rotational stabilization window narrows at low rotation
  - RFA more sensitive to details of plasma properties
  - Reduction of rotation could cause ergodic regions to form
  - Increased interaction of RWMs with ELM, NTM, SOLC
- Simultaneous RWM feedback at minimum rotation
  - Prototype ITER control system

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# Possible SOLC physics contributions from DIII-D collaboration (Hiro/Eric)

- Scrape-off Layer Current (SOLC) studies:
  - Now have good estimates of magnitude, spatial distribution
    - ➔ estimates of error fields arising from these currents
      - Similar in magnitude to fields from coils / intrinsic error fields
  - DIII-D and NSTX ➔ non-axisymmetry of this magnitude demonstrated to influence the stability of RWMs, ELMs
- But, DIII-D tile current measurements disassembled…
  - Should PPPL lead effort to revive & improve this system?
- Physics experimentally & theoretically challenging…
  - 3D current on open field-lines – thermoelectrically driven?
  - Include in RWM/ELM/NTM/EF/etc. (linear) stability calcs?

# Other considerations…

- Why focus on "ITER-specific" issues like this?
  - One answer: We can lead the development of the scientific understanding of issues (thought to be) important for making ITER a success
  - Many of these issues are important beyond ITER
  - Still, should this be our priority?
- Do not want to lose sight of MHD beyond ITER…
  - High $\beta$, high rotation effects, etc. in ST
  - Stellarator-specific MHD physics – disruption free?
  - Advanced tokamak development for DEMO
  - Other concepts – recent high-$\beta$ FRC results
- Suggestions for balancing these are welcome!