Toroidal Asymmetries in Mitigated Disruptions using Two Gas Jets on Alcator C-Mod
*R. Granetz*

Combined Thermal and Magnetic Energy Mitigation Challenges for ITER
*J. Wesley*

Avoidance of Neoclassical Tearing Mode Locking and Disruption by Feedback-Driven Accelerating Electromagnetic Torque
*M. Okabayashi*

*Full-filling ITER mitigation requirements*

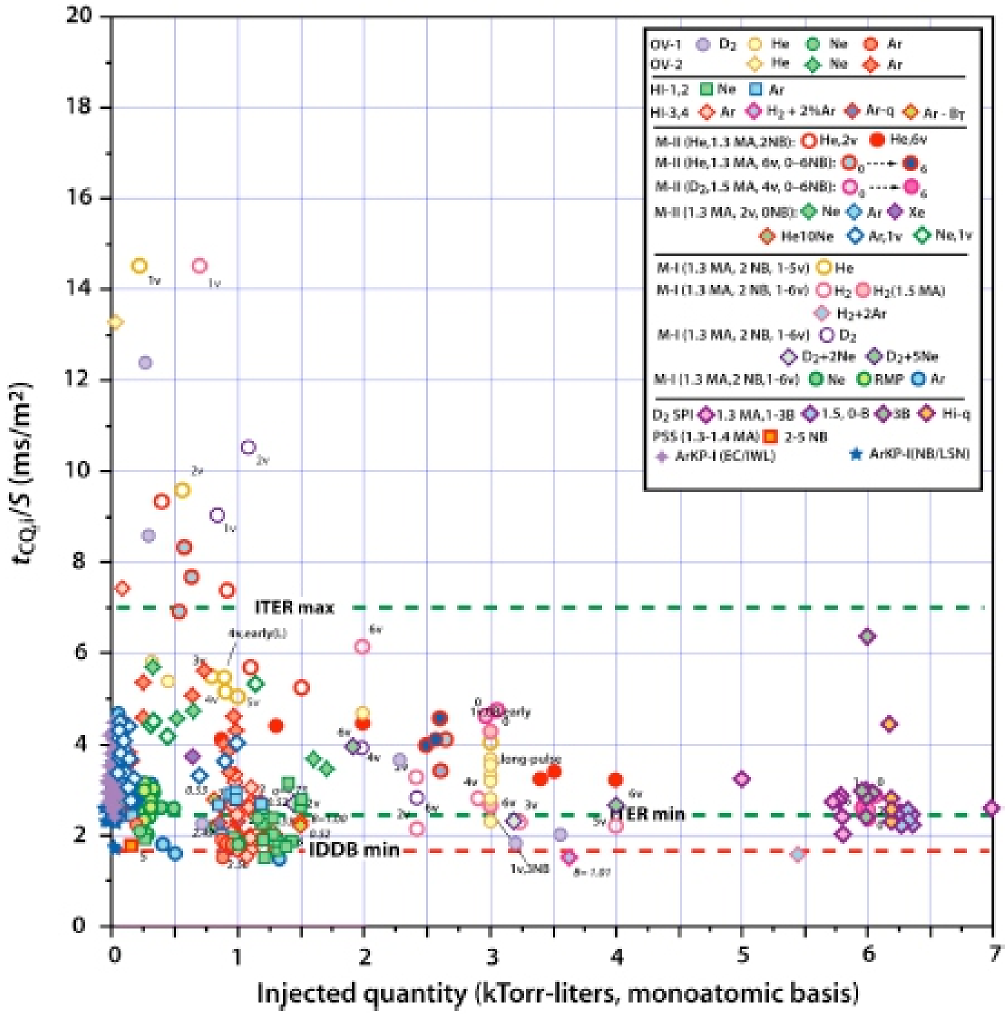
| | | |
|---|---|---|
| radiated 90% of thermal energy<br>reduce halo currents<br>suppress RE | ⇔ | ensure low enough radiation load<br>keep CQ in 50-150ms window<br>consider gas handling capabilities |

*Disruption Avoidance*

- **ITER: Will MGI/MPI that satisfies TE mitigation requirements (later VGs) also meet CQ control requirement?**

many of the DIII-D data points are below or near the ITER limit in CQ time

amount of injected impurities is limited by the CQ requirement




*J. Wesley*

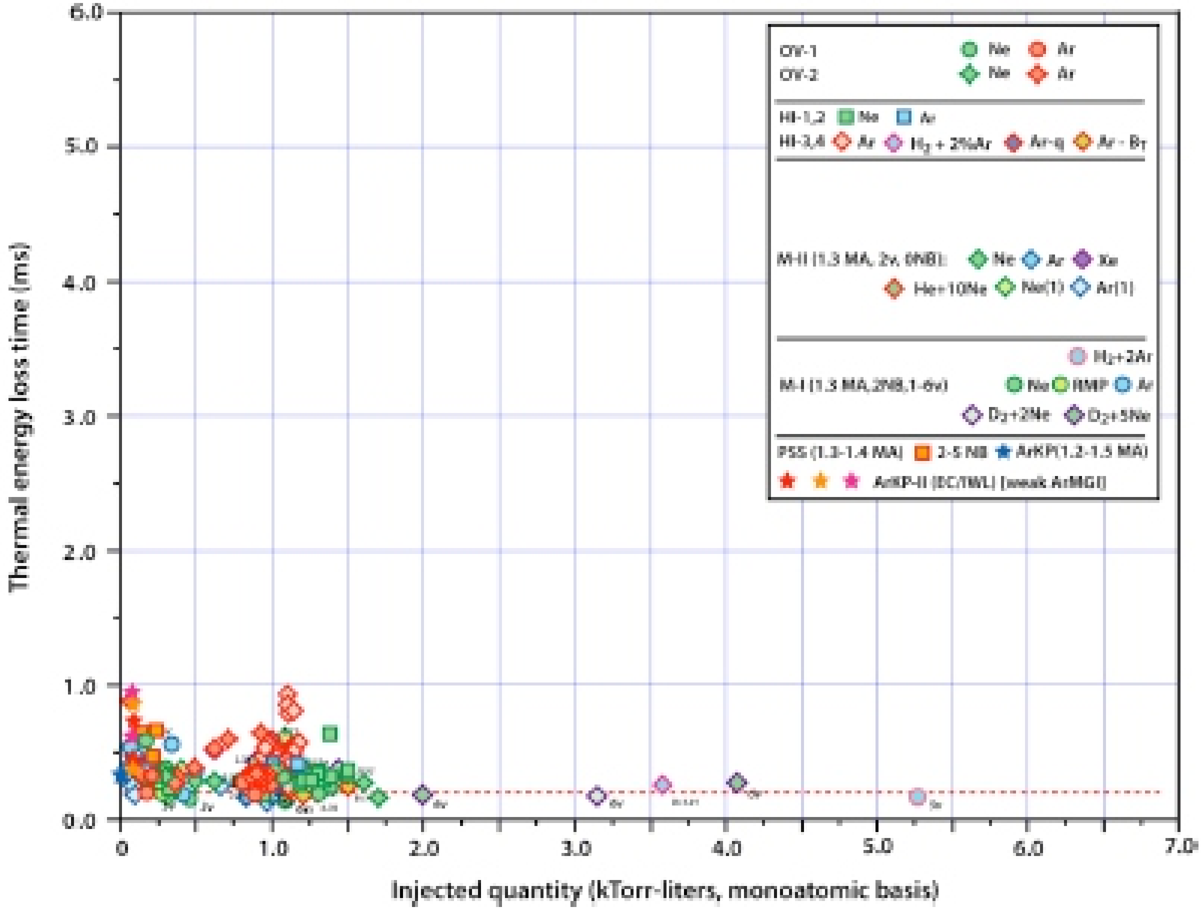
## Thermal Quench

Radiate thermal energy
on short time scale

$t_{rad} < t_{MHD}$

ITER:
TQ: up to 350 MJ in 1-3ms
CQ: ~500MJ in 50ms

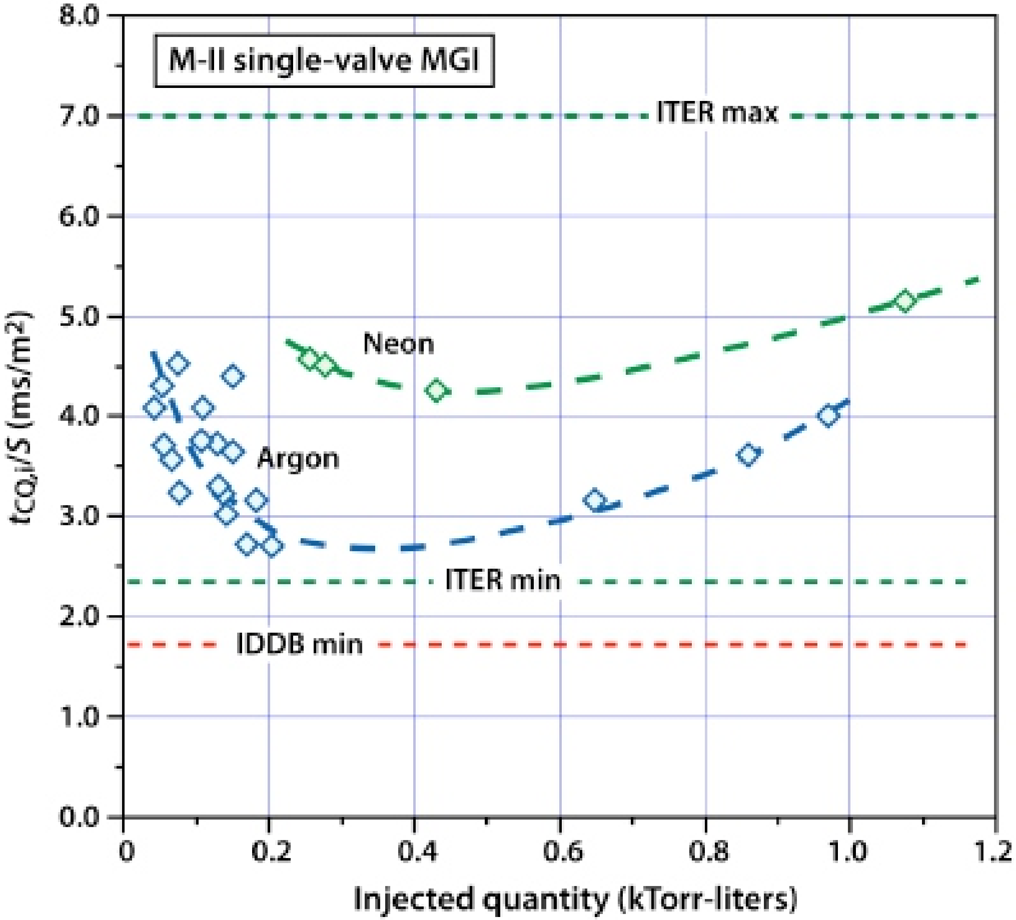
conflict?

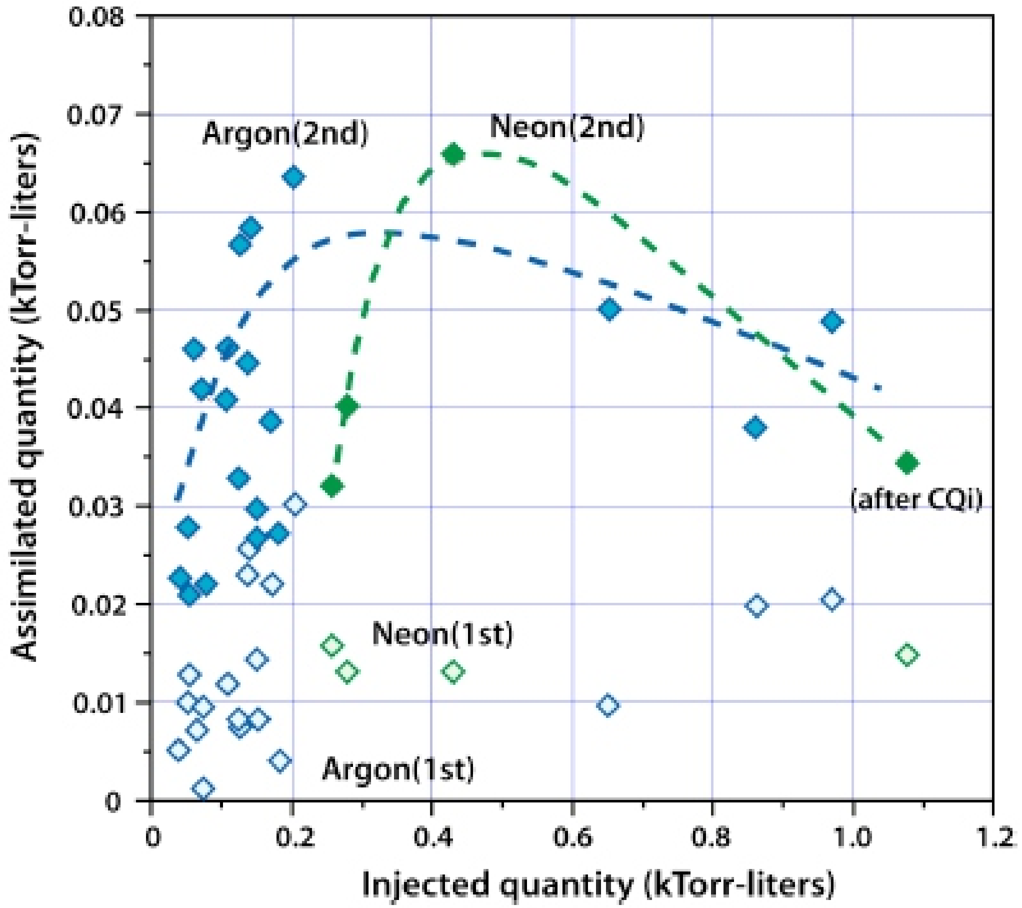



more over:
get the material in before onset of TQ (10ms/1ms?)

*J. Wesley*

## Mixing during the TQ determines $N_Z$ available to radiate in the CQ (and to suppress/mitigate RE)

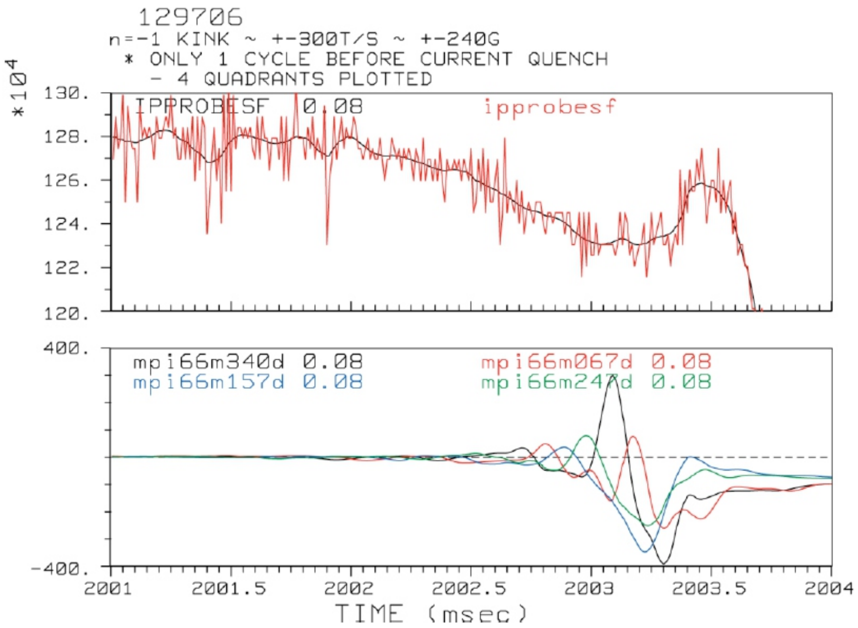


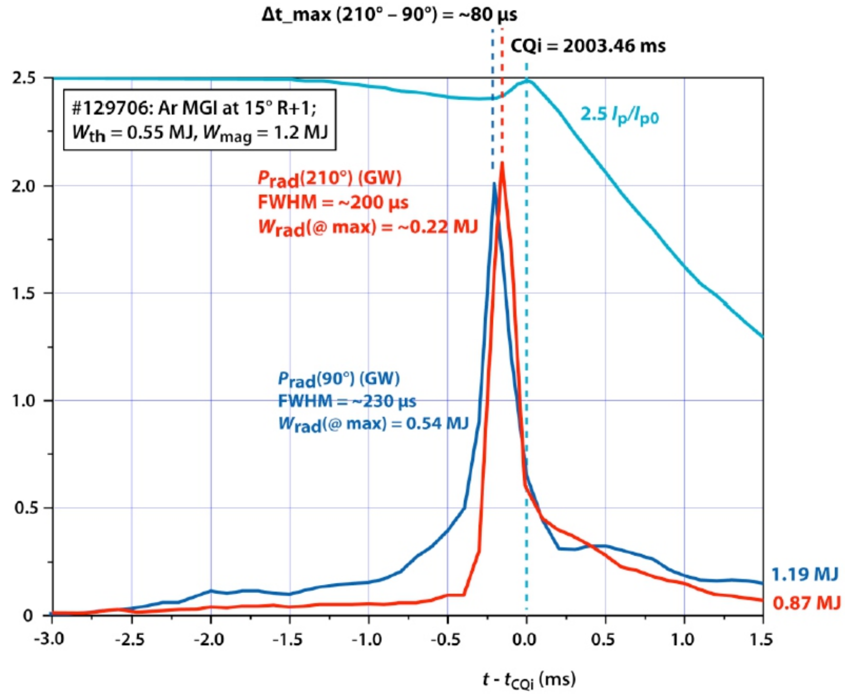




*J. Wesley*

**MHD during TQ**

*DIII-D*
*J. Wesley*




understanding TQ MHD serves two purposes:

*quantifiy (control?) mixing process*

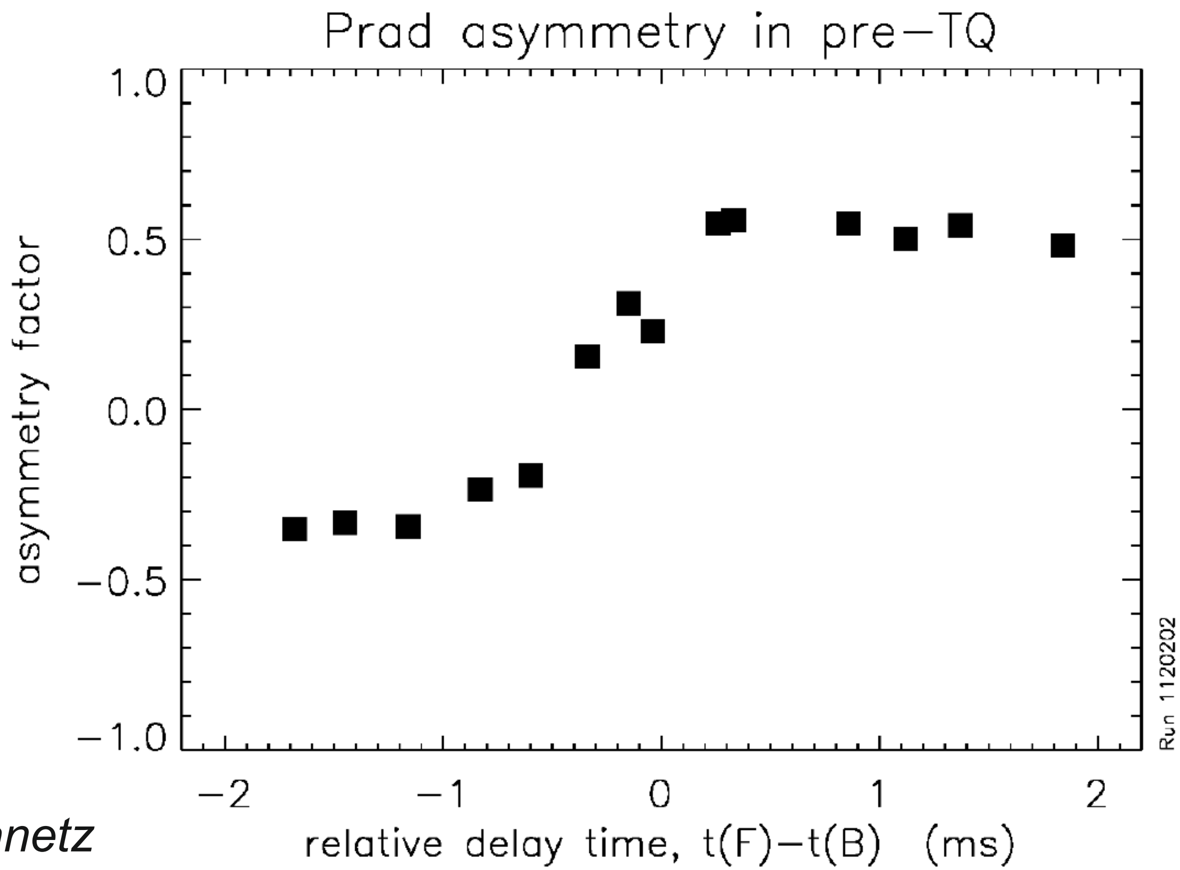
*quantify (control?) radiation peaking*

## *TLM:* 4 injection locations (3 upper , 1 mid-plane)

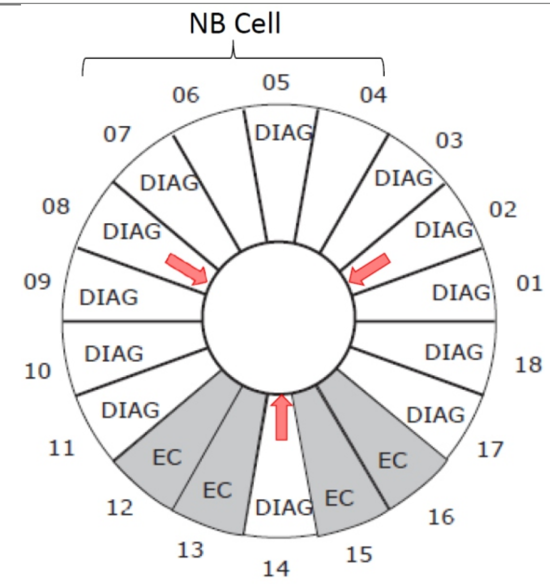
C-mod: pre-TQ appears to be symmetrised with 2 injectors

How many injectors necessary for ITER?

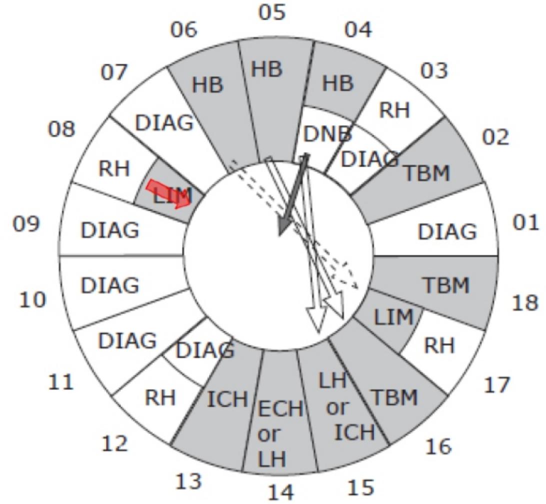
What about poloidal asymmetries?




*R.Granetz*




**Upper port**
**#02, 08 and 14**

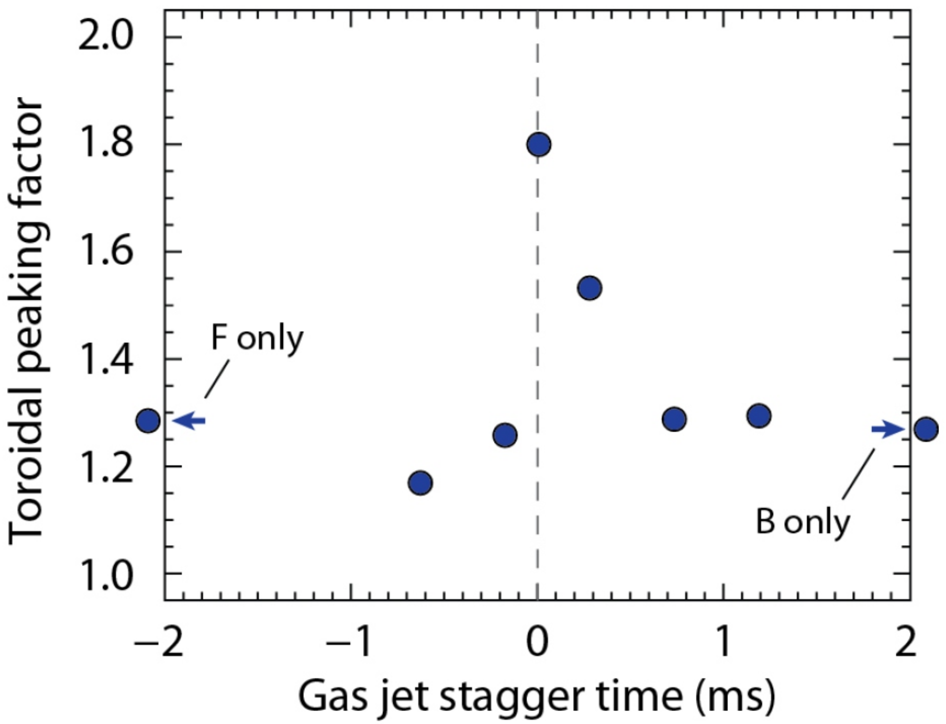



**Equatorial port**
**#08**

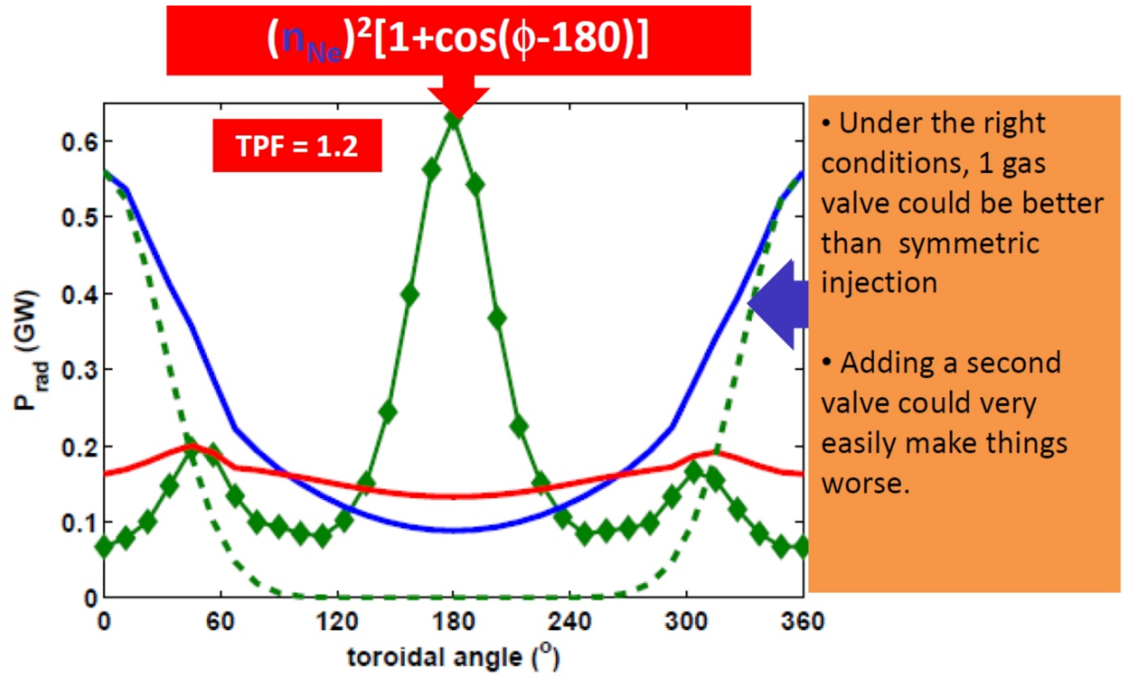
C-mod: symmetric injection > higher TPF

NIMROD calculations show sensitive Prad sensitive on impurity distribution.

ITER injection system is flexible: injectors are independent. Does this help?

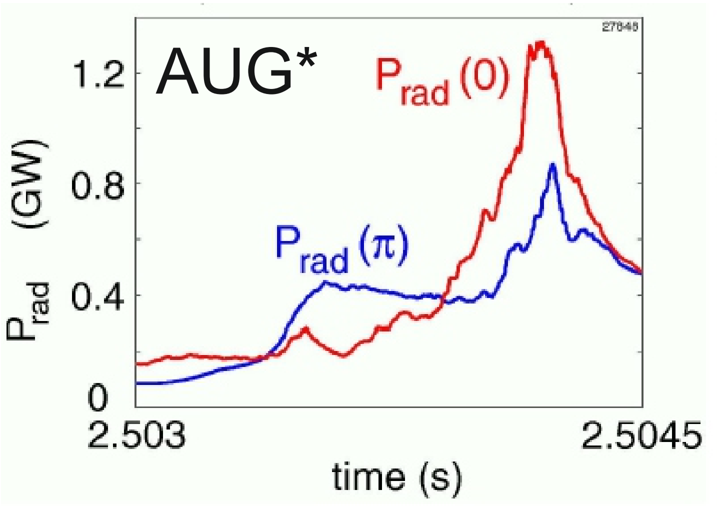


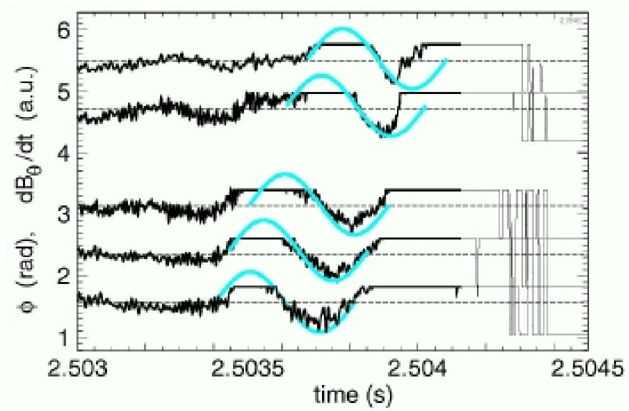

*R.Granetz*



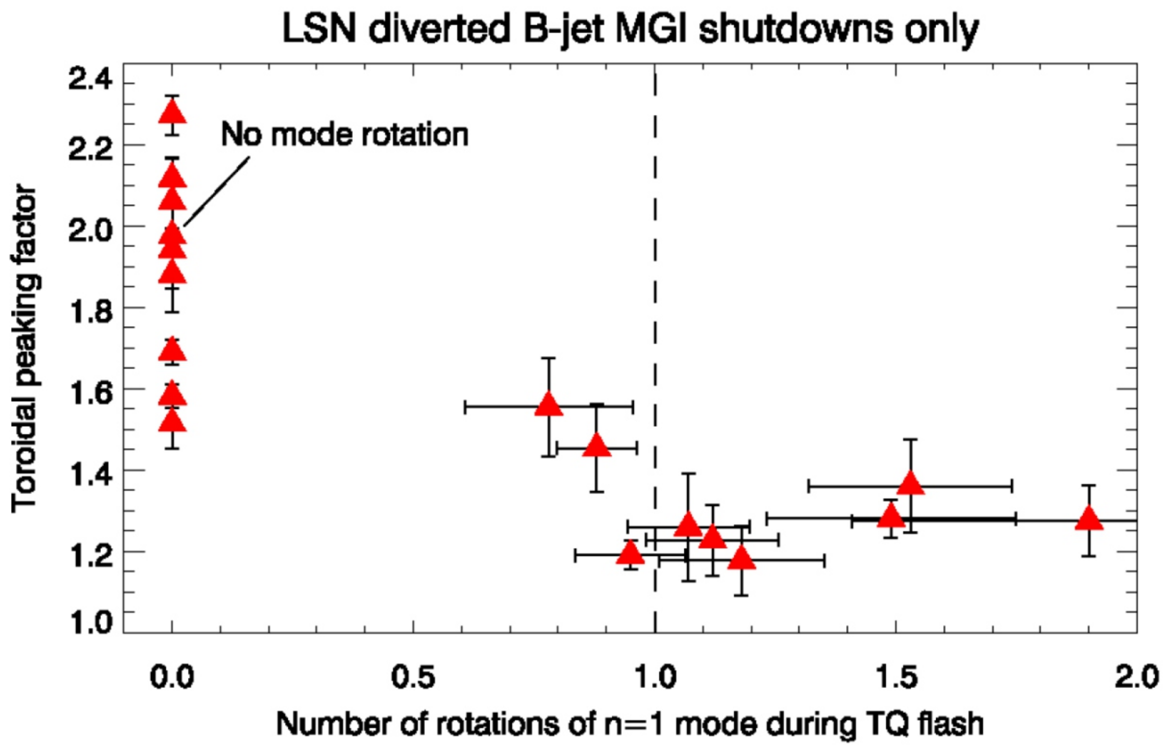

V. Izzo

C-mod: mode rotation reduces radiation peaking.
Similar seen in AUG in pre-TQ




1.5 ms




*R.Granetz*

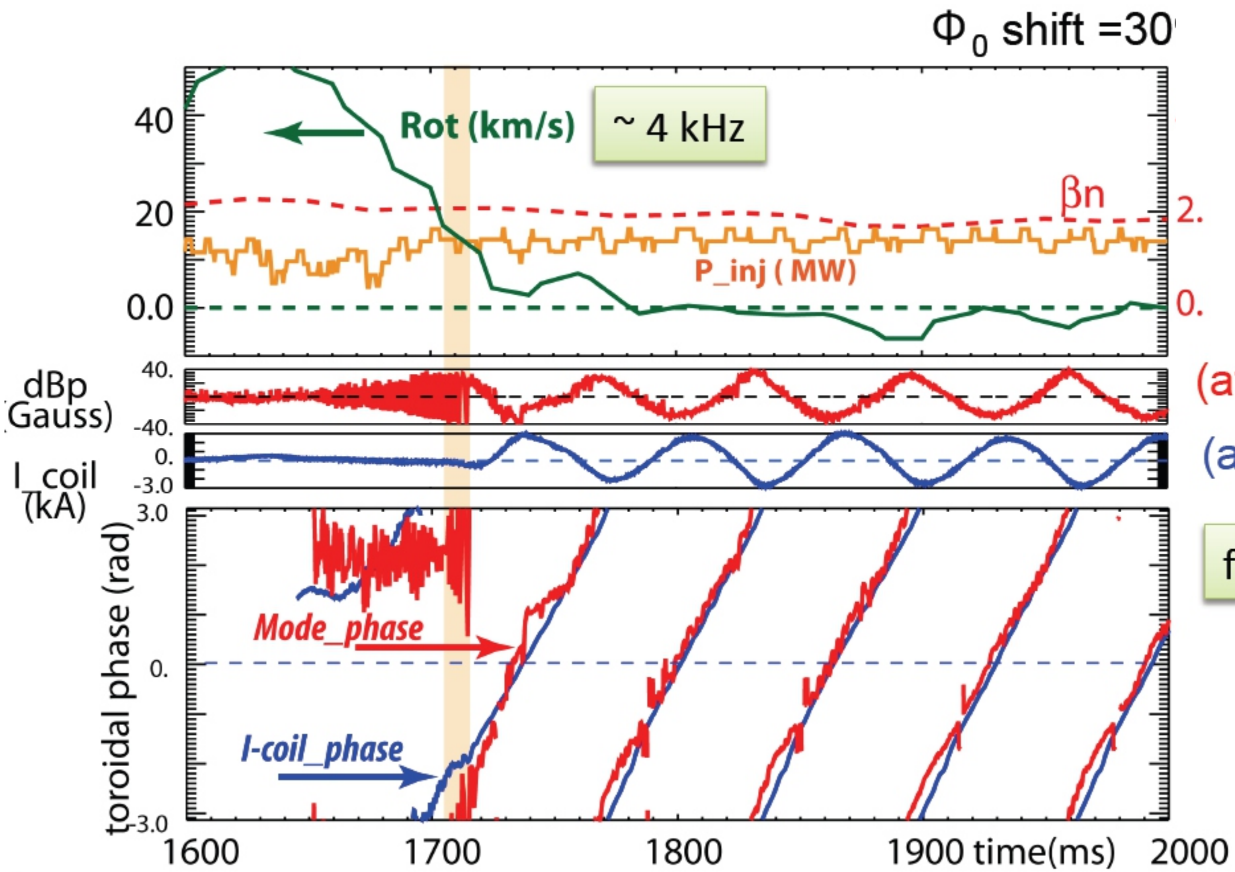
**G. Pautasso, EPS 2013*

# Disruption Avoidance - NTM/TM locking avoidance (M. Okabayashi)

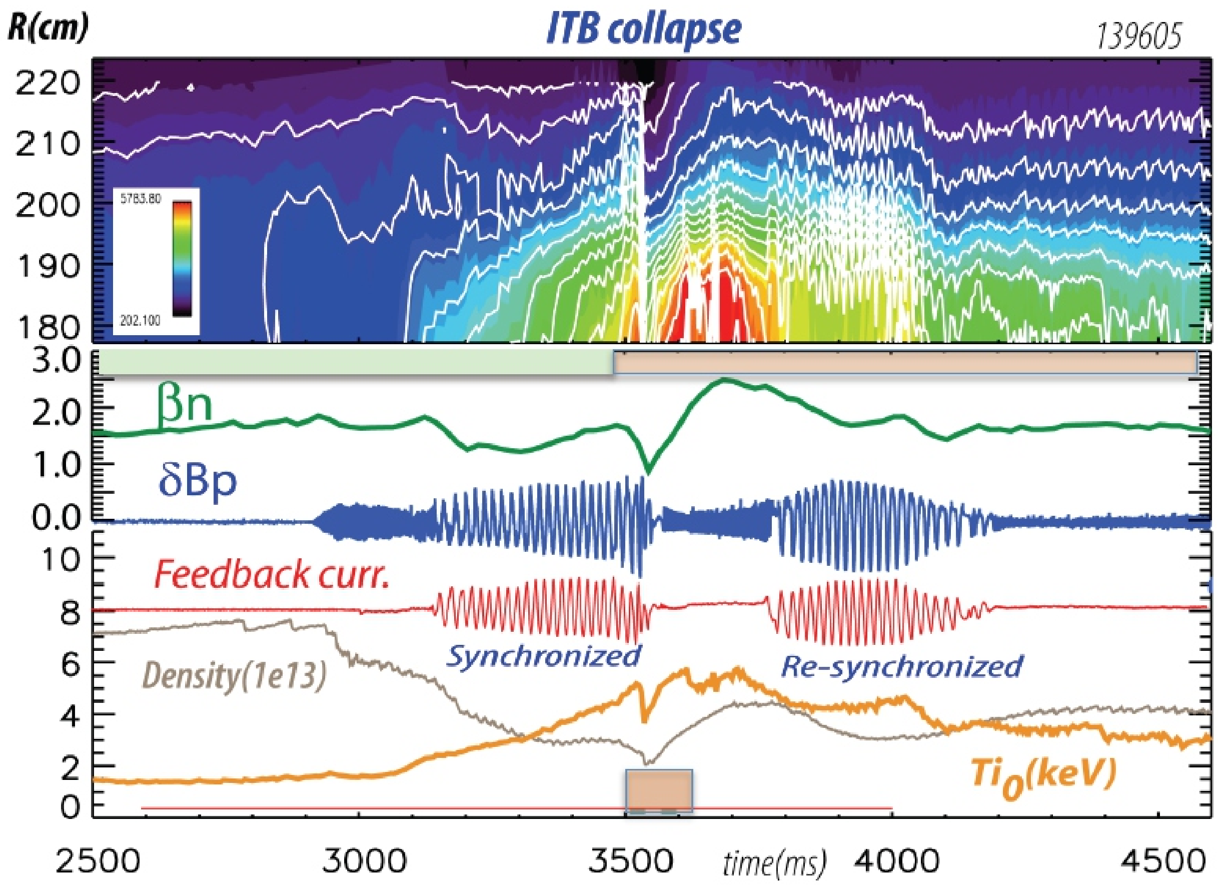
- Assurance of NTM/TM locking avoidance is prerequisite for orderly shutdown such as the termination of hundreds Mega Joules of magnetic stored energy.

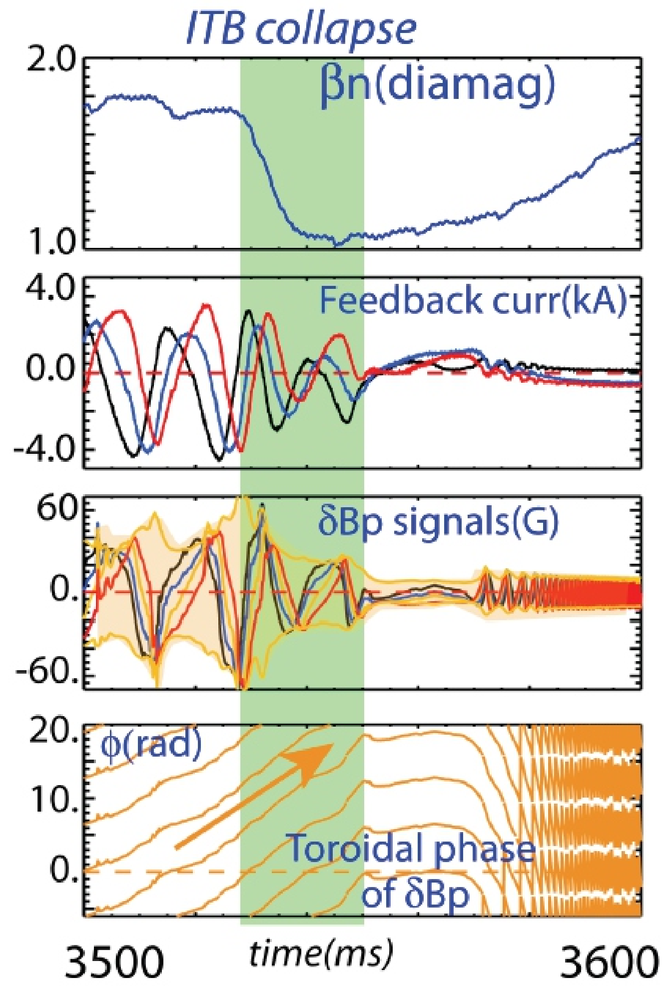
**An Approach:**

- Injection of the electro-magnetic (EM) torque using 3D coils by forcing finite toroidal phase shift between the mode and applied feedback field



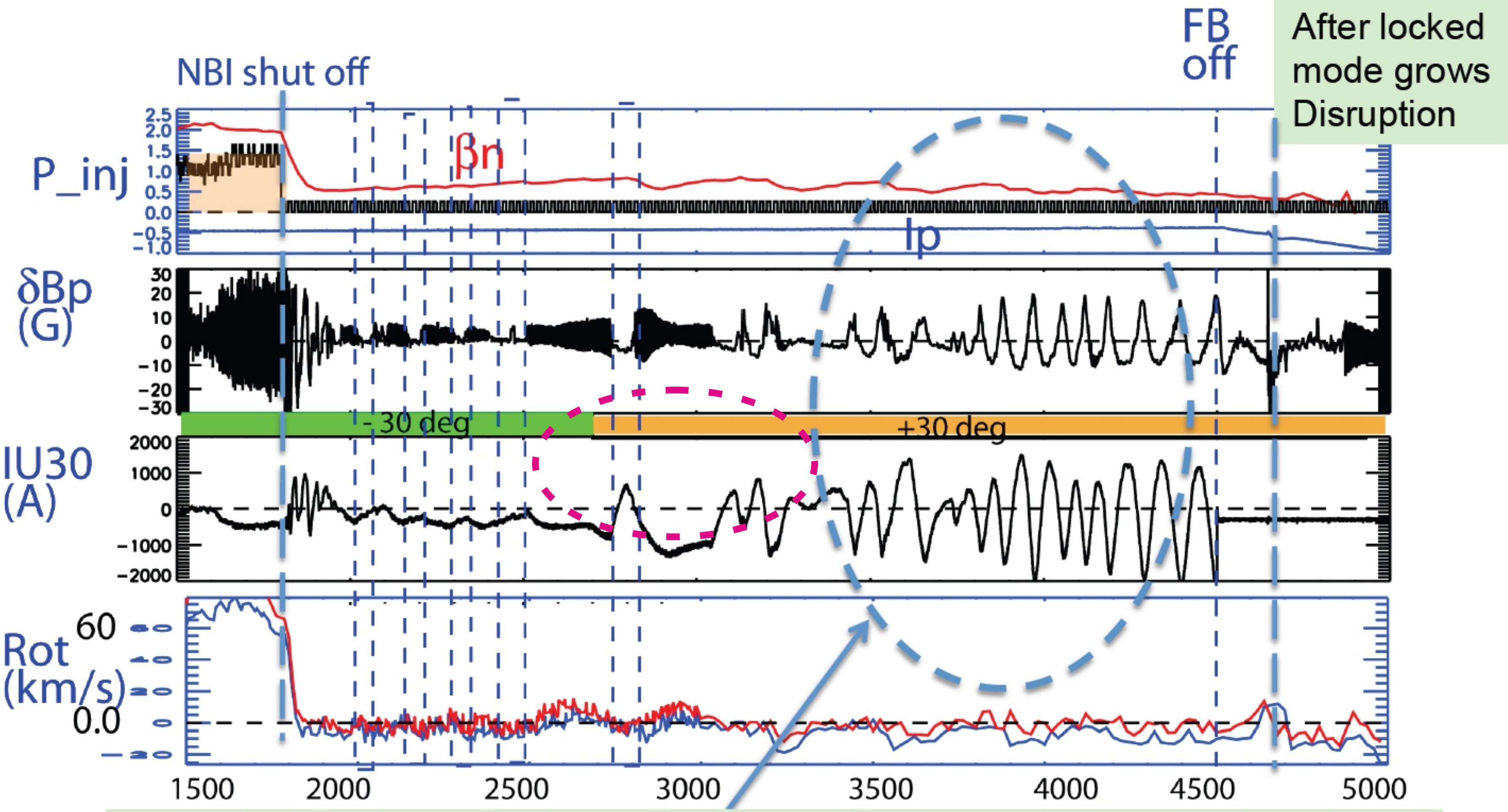
# EM torque input is sufficient enough to avoid ITB collapse disruption even when the density is pumped out by NTM




139605_ti_cont_nrs_ip_prep_4.ai

# Feedback controls the NTM/TM in an orderly shut down process




- EM torque controls the mode by self-adjusting frequency 5- 10 Hz

## Disruption Avoidance

heating/current drive (ECCD)
internal coils (ELM coils in ITER)

but also:

sophisticated plasma shutdown scenarios
(clever combination of heating / current shutdown, shape control, etc.)

this requires knowledge about the type of disruption that is going to occur (*prediction*)

> detection of problem and appropriate reaction (strongly coupled system)

# Disruption Mitigation *issues*

- radiation distribution — *pre-TQ: injector distribution*
  *TQ: MHD dominated*

- radiation efficiency — *> 90% is required for TQ duration 1-3ms*
  *radiation in competition to MHD enhanced transport*
  *dependence on injector location?*

- mass penetration — *MGI: impurity transport on timescale ~10ms*
  *TQ onset in case of MGI or SPI?*
  *Ablation and assimilation of SPI?*
  *Efficiency of penetration into CQ plasma?*
  *Role of MHD for assimilation efficiency?*

- runaway suppression — *densification to Rosenbluth density necessary?*
  *runaway control possible?*
  *role of magnetic turbulence?*