

Multi-mode MHD control scheme in AT plasmas

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Outline



- **Introduction**

- *Multi-mode MHD control*
(NTM, RWM, ELMs, Sawteeth etc)
- *Mode Identification and Feedback Control Algorithms*

- **Concept for multi-mode MHD control**

- *Physics Models (essential and in good progress, but not to be discussed here !)*
- *Theoretical predictions and experimental observations as an example*
- *A “Rough” Suggestion*
 - **Diagnostics**
 - Magnetics/ Photodiode/ Te measurement/ CER for V_{tor}
 - **Actuators**
 - Coils/ ECCD (FW ?)/ NBI (Others: Pellet injector/Ablator/Plume injector ?)
- *Torque vs MHD control scheme in high-beta plasmas*

To harness a multi-mode MHD control is essential to obtain AT plasmas



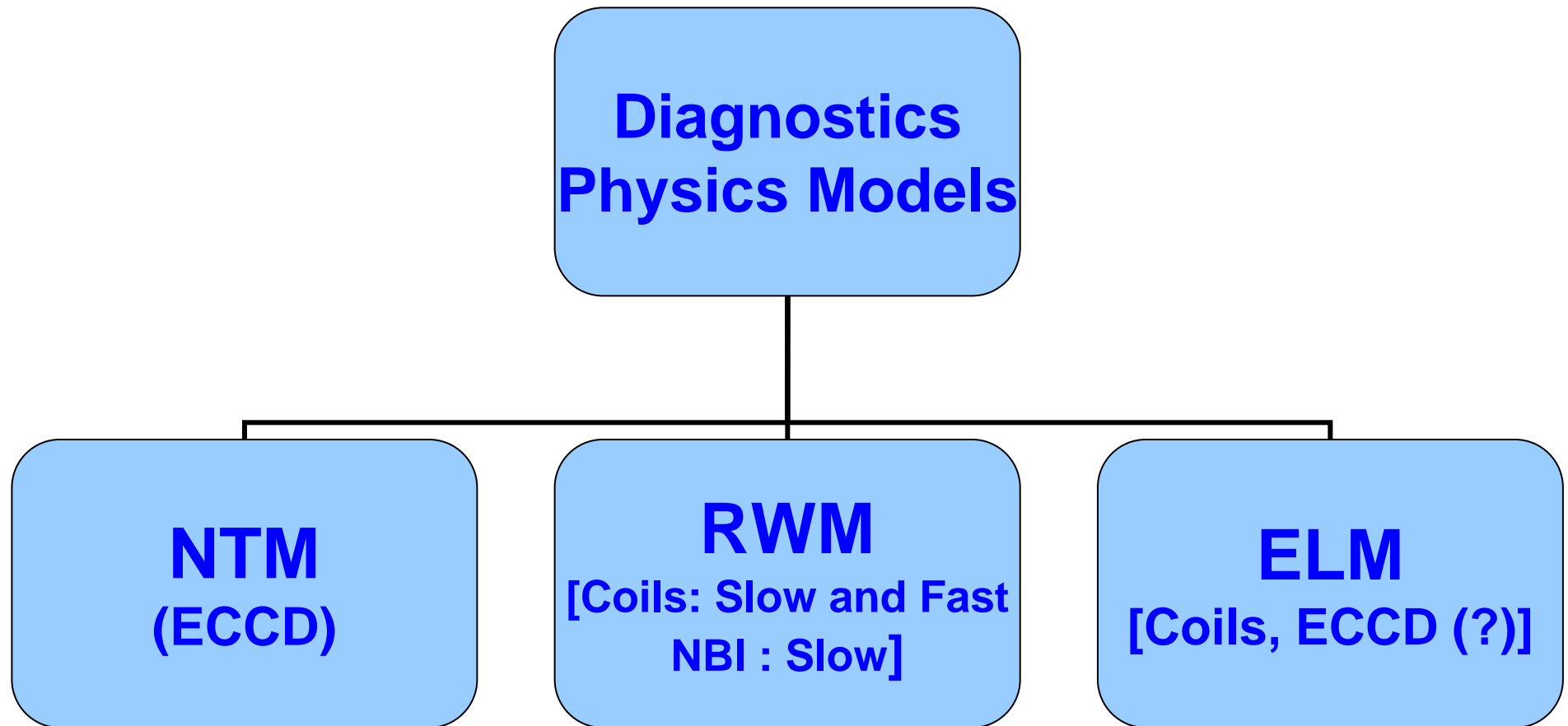
- Integrated operation of various MHD control schemes

Types	Focus	Loci	Time scale	Readiness*
NTM	3/2, 2/1 mode	$\rho < 0.6$	Less than msec	High
RWM	$n = 1$	$\rho \geq 0.6$	~ msec	In progress
ELM	RMP	$\rho > 0.8$ (?)	DC-relevant ?	Empirically high
Sawteeth	Oval or bean shape	$\rho < 0.2$ (?)	10 ~ 100 msec	Avoidable for AT ?

*Completely subjective opinion, no offense!

Desirable to have the capability to mobilize all the mode control simultaneously, if necessary

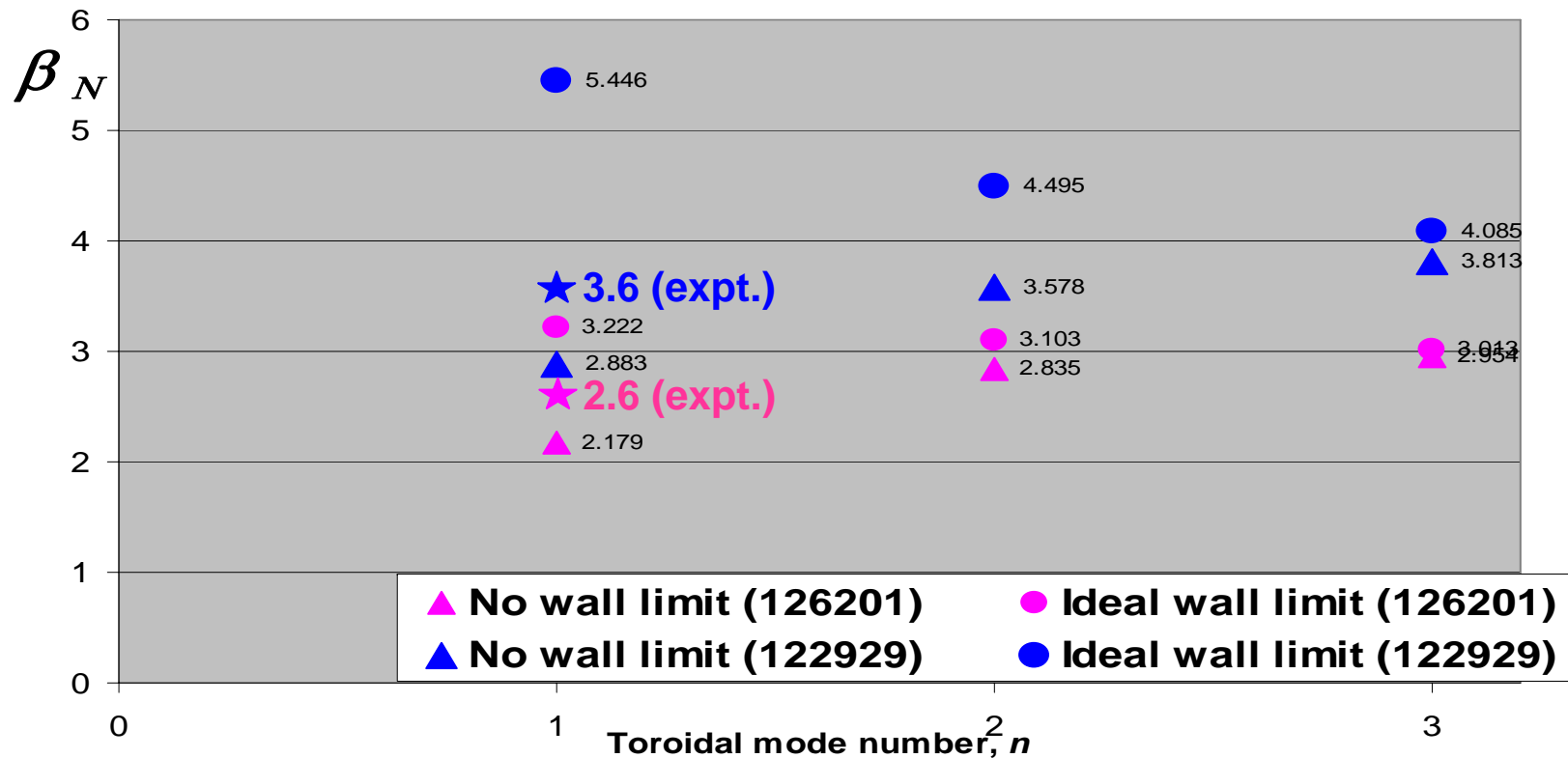
Integrated multi-mode MHD control scheme



Low n RWM modes in high- β plasmas need to be controlled simultaneously.

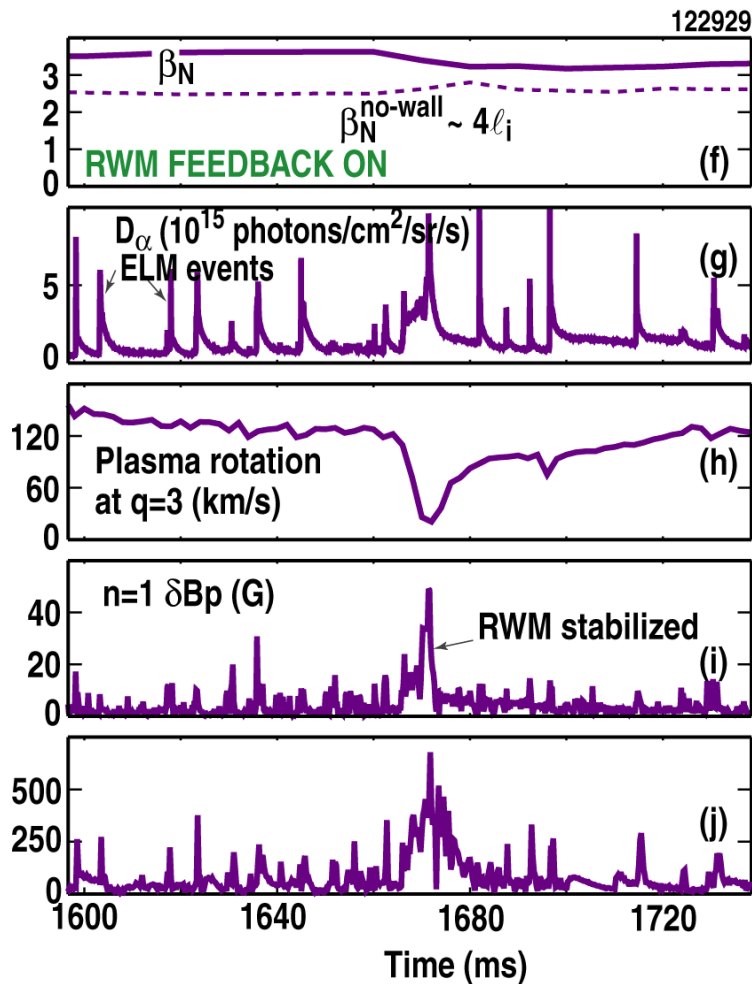


Ideal MHD no-wall and ideal wall betaN limits based on DCON

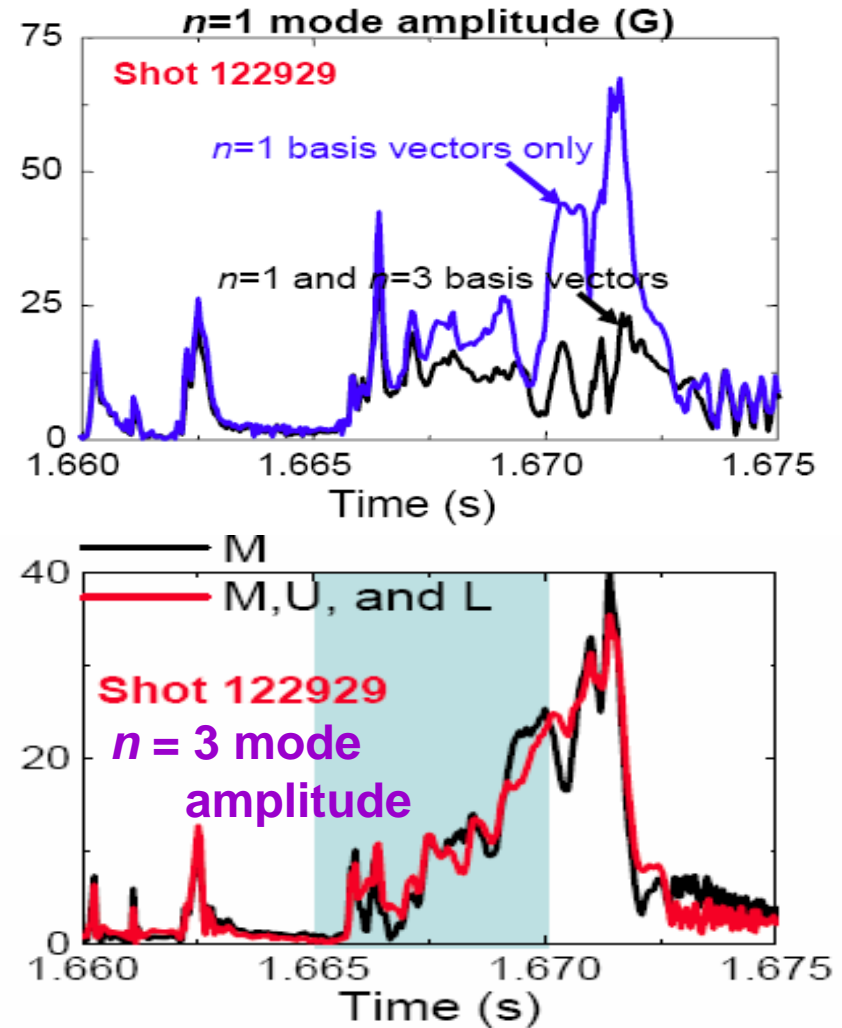


Even after $n = 1$ RWM mode is successfully controlled, the next unstable modes (e.g. $n = 2$ & 3) need to be considered.

Multiple low n mode needs to be considered even for more accurate $n = 1$ mode identification



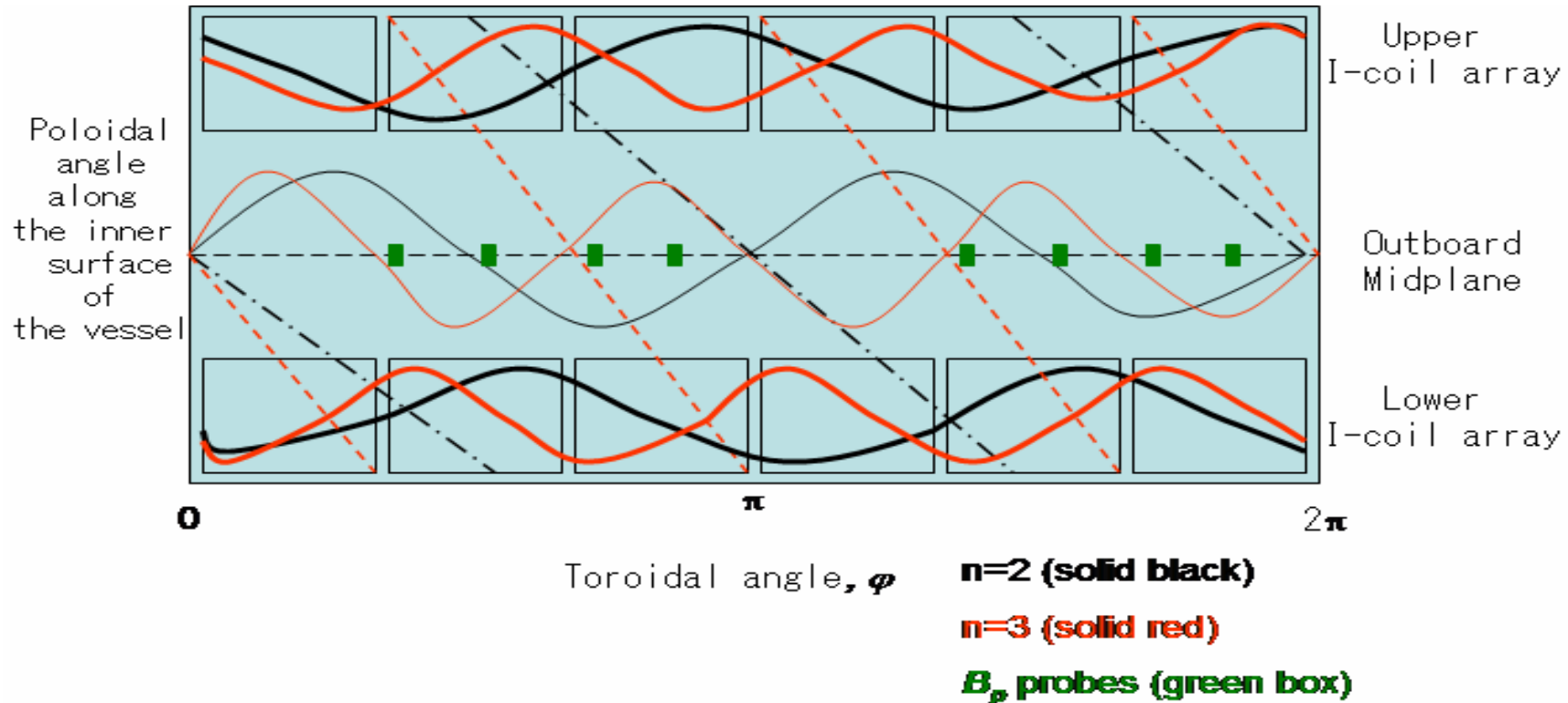
From A. Garofalo et al., IAEA (2006)



From J. Kim et al., APS (2006)

The I-coil configurations would be more appropriate for $n = 1$ and 3 mode than for $n = 2$ mode.

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- The existing configuration of the magnetic sensors and coils can be most effective for odd modes ($n = 1$ and 3)
- To provide low even mode (e.g. $n = 2$) feedback control, a proper set of sensors and coils need to be configured.

A “rough” suggestion



- **Diagnostics**

- *Additional T_e measurement at toroidally displaced location for mode and amplitude to identify island structure (e.g. NTM, RWM (?))*
- *More poloidal sensors to cover various low-n modes [e.g. RWM – low n modes (e.g. $n= 1, 2, 3$)]*
(Presently, N2QUAD1 & 2 are already configured for $n =2$)

- **Actuator**

- *Coils : ‘new’ even-mode feedback coil (e.g. $n=2$), RMP and error-field correction at the midplane*
 - ➔ *This relieves the burden of the existing I-coils so that the odd modes and fast feedbacks are focussed.*
- [SPAs : 7 kA (RMP requires more than ~ 4 kA)*
- AAs: ~ 1kA (limited duration for DC)]*

Multi-mode MHD control scheme for high-beta plasmas may be utilized more effectively, depending on plasma rotation.



• Low torque plasmas

- *Prone to TMs*
- *RWM (low n modes)*

- *Diagnostics*
 - Magnetics
 - T_e , T_i measurements
- *Actuator*
 - Coils/ ECCD

• High torque plasmas

- *Prone to ELMs*
- *Reduced coil current demands*

- *Diagnostics*
 - Magnetics/Photodiode
- *Actuator*
 - Coils/ ECCD