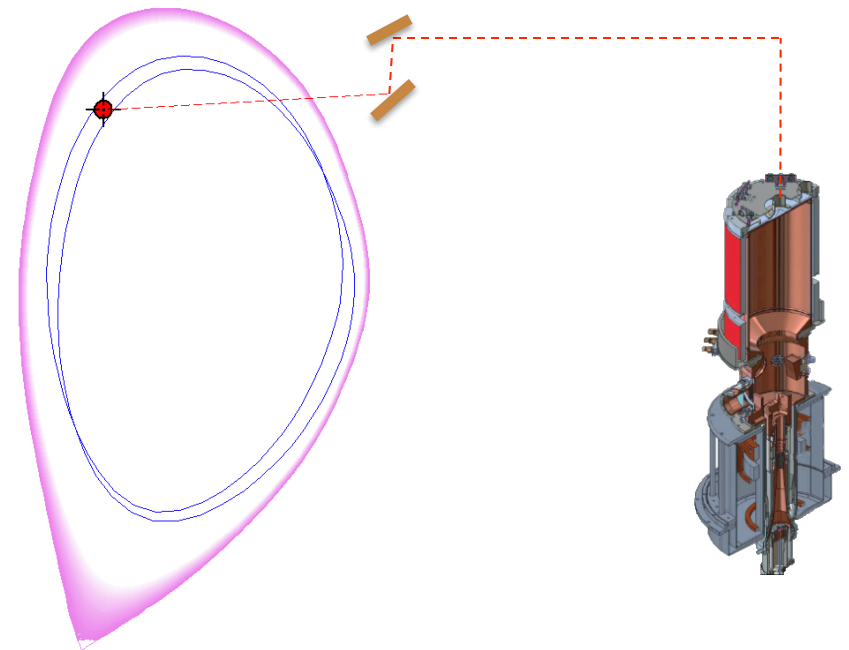# Control of Neoclassical Tearing Modes in DIII-D

A.S. Welander, R.J. La Haye,
B.G. Penaflor, J. Lohr, S. Noraky,
R. Prater, N.W. Eidietis, D.A. Humphreys,
E. Kolemen*, and F. Turco†

* Princeton Plasma Physics Laboratory
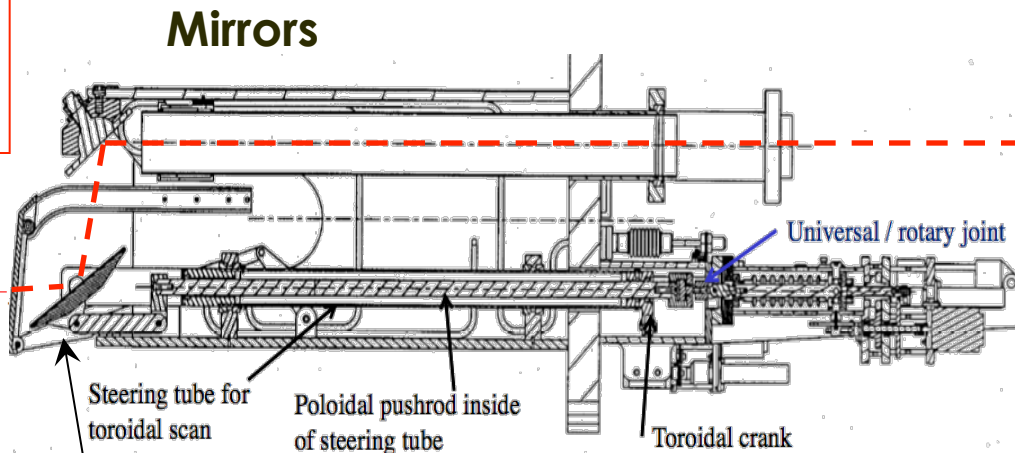
† Columbia University

Presented at the
**54th Annual Meeting of the
APS Division of Plasma Physics,
Providence, Rhode Island**
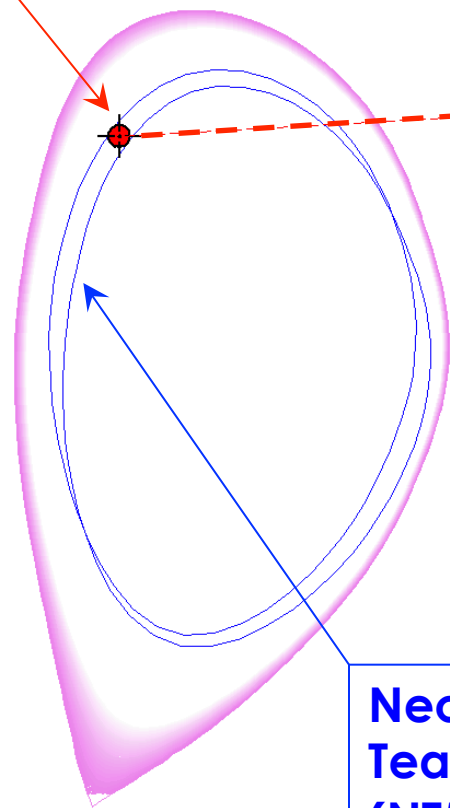
October 29 — November 2, 2012

DIII-D
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AS Welander/APS/DPP/October 2012

GENERAL ATOMICS

Electron cyclotron current drive (ECCD)

Mirrors

RF beam

Universal / rotary joint

Steering tube for toroidal scan

Poloidal pushrod inside of steering tube

Toroidal crank

Mirror controlled to keep ECCD on NTM resonant *q*-surface

Neoclassical Tearing Mode (NTM)

Gyrotron

2

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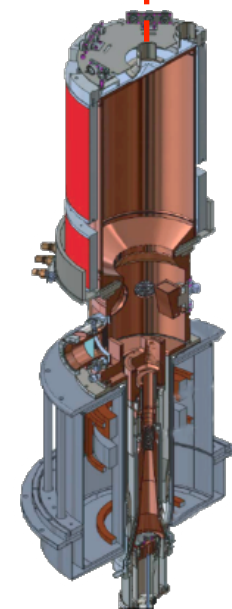
Normally mirror angle is within uncertainty of the command
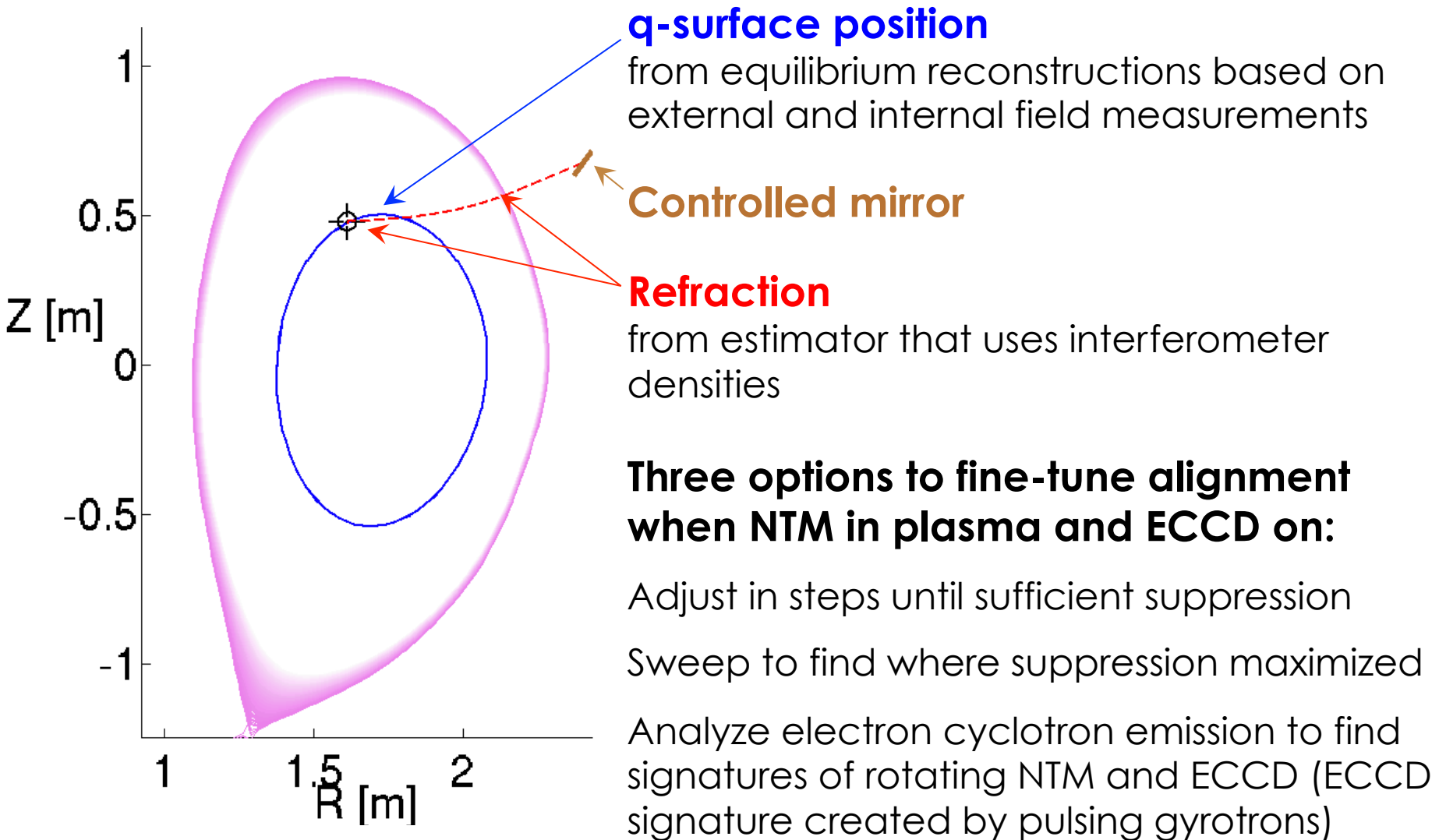
Several layers of safety ensure the mirrors don't move too far

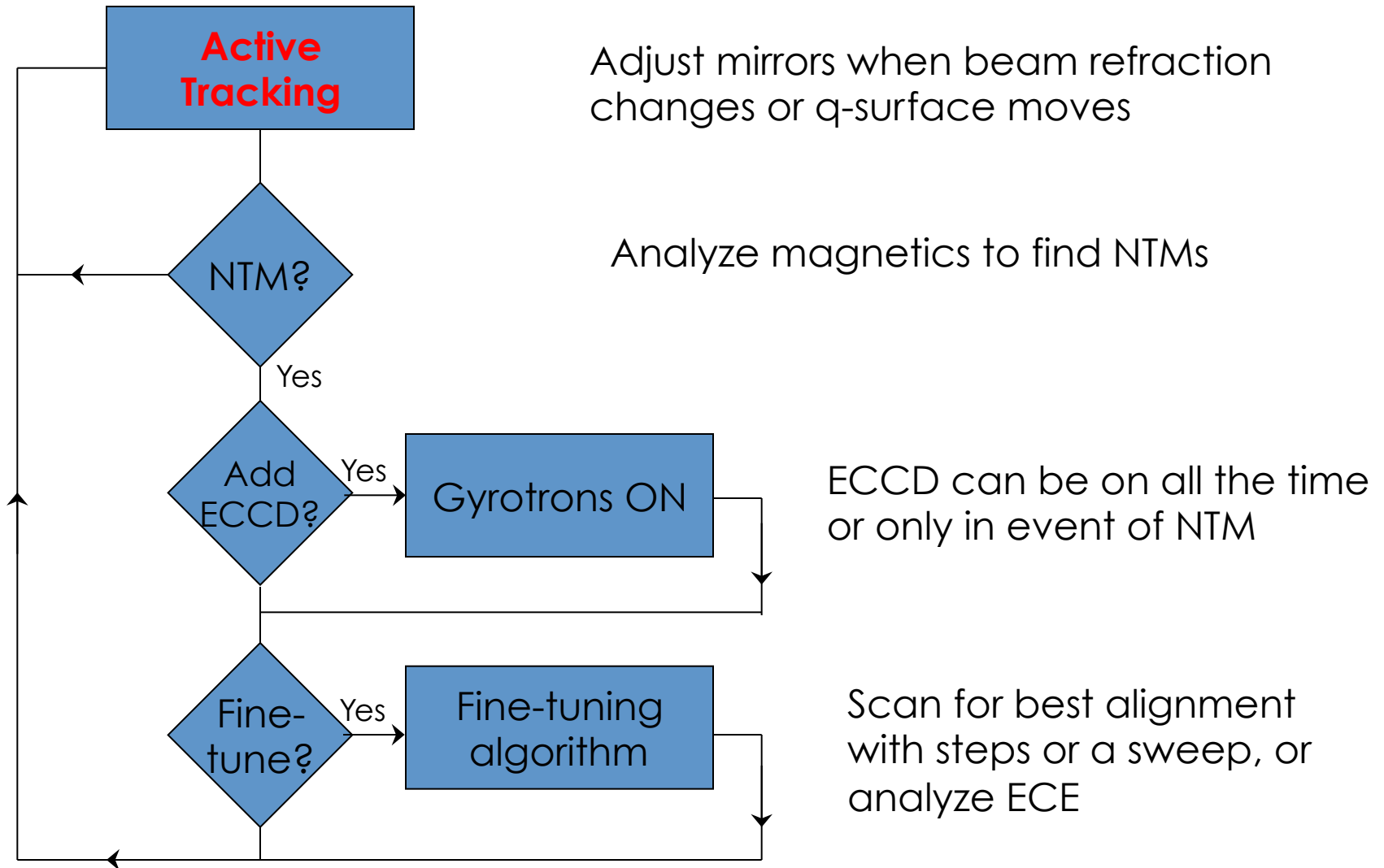Zq is where q=3/2 intersects EC resonance

Safety limit

Z [m]

seconds
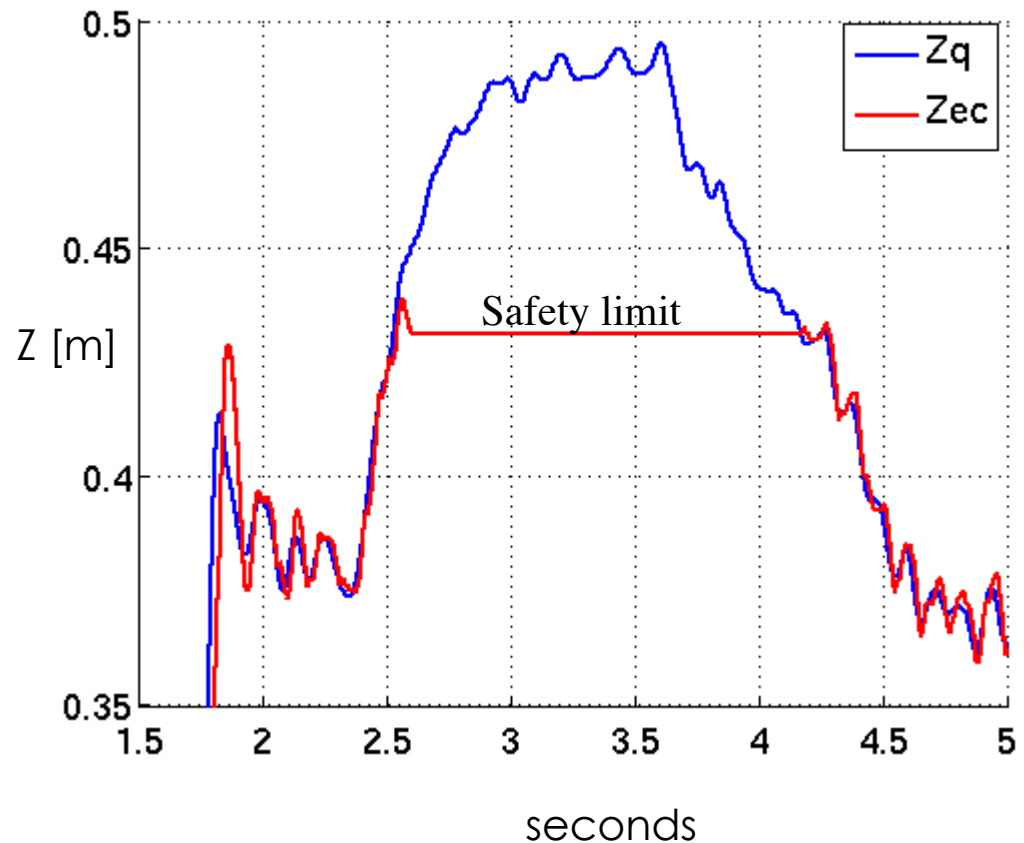
Accurate Alignment Of ECCD Found By Detailed Analysis Of Measurements Combined With Fine-Tuning Algorithm

q-surface position

from equilibrium reconstructions based on external and internal field measurements

Controlled mirror

Refraction

from estimator that uses interferometer densities

Three options to fine-tune alignment when NTM in plasma and ECCD on:

Adjust in steps until sufficient suppression

Sweep to find where suppression maximized

Analyze electron cyclotron emission to find signatures of rotating NTM and ECCD (ECCD signature created by pulsing gyrotrons)

Flowchart For NTM Control

Active Tracking → Adjust mirrors when beam refraction changes or q-surface moves

NTM? → Analyze magnetics to find NTMs

Add ECCD? —Yes→ Gyrotrons ON → ECCD can be on all the time or only in event of NTM

Fine-tune? —Yes→ Fine-tuning algorithm → Scan for best alignment with steps or a sweep, or analyze ECE

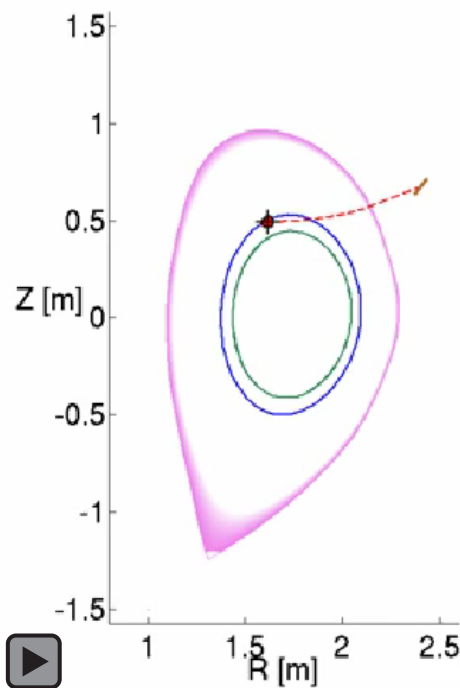DIII-D
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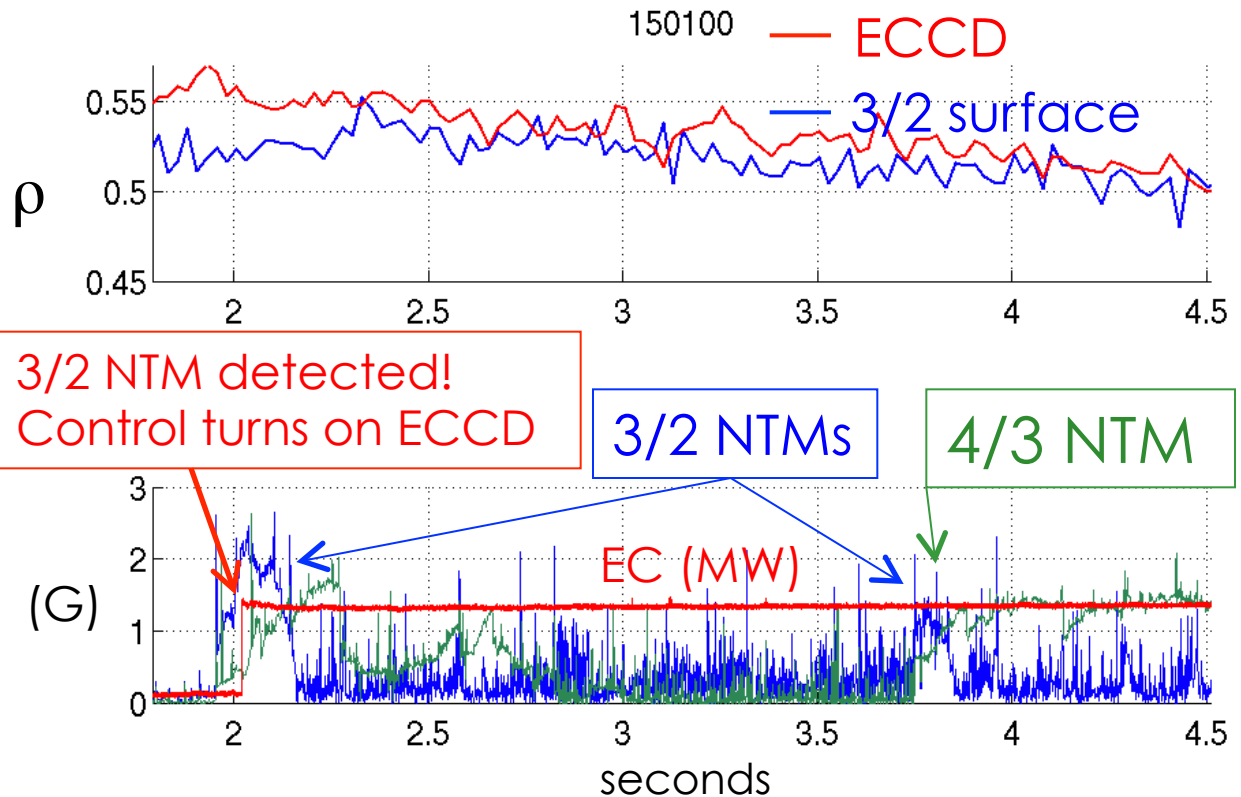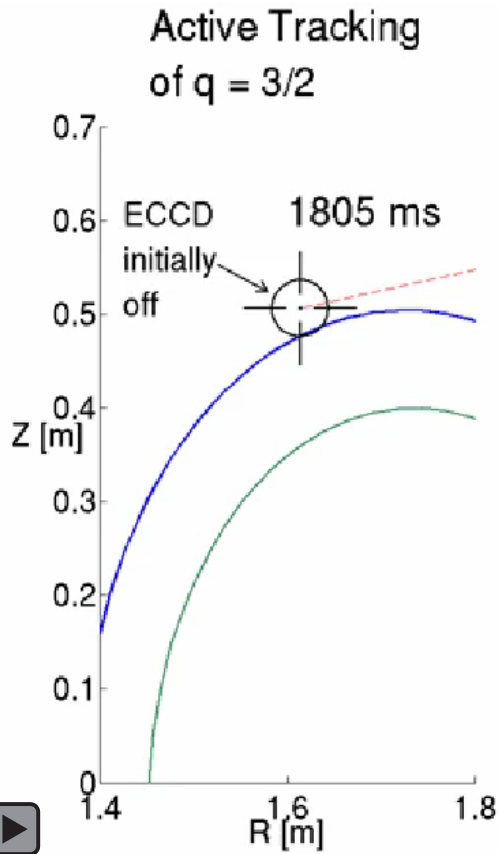
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Preemptive ECCD Promptly Suppresses NTMs

- **3/2 NTMs triggered at 2.5 and 2.8 sec immediately stabilized by ECCD**

- **4/3 NTM at 2.8 seconds <u>not</u> stabilized**

149717
— ECCD
— 3/2 surface

3/2 NTMs

4/3 NTM

EC (MW) on 3/2 surface

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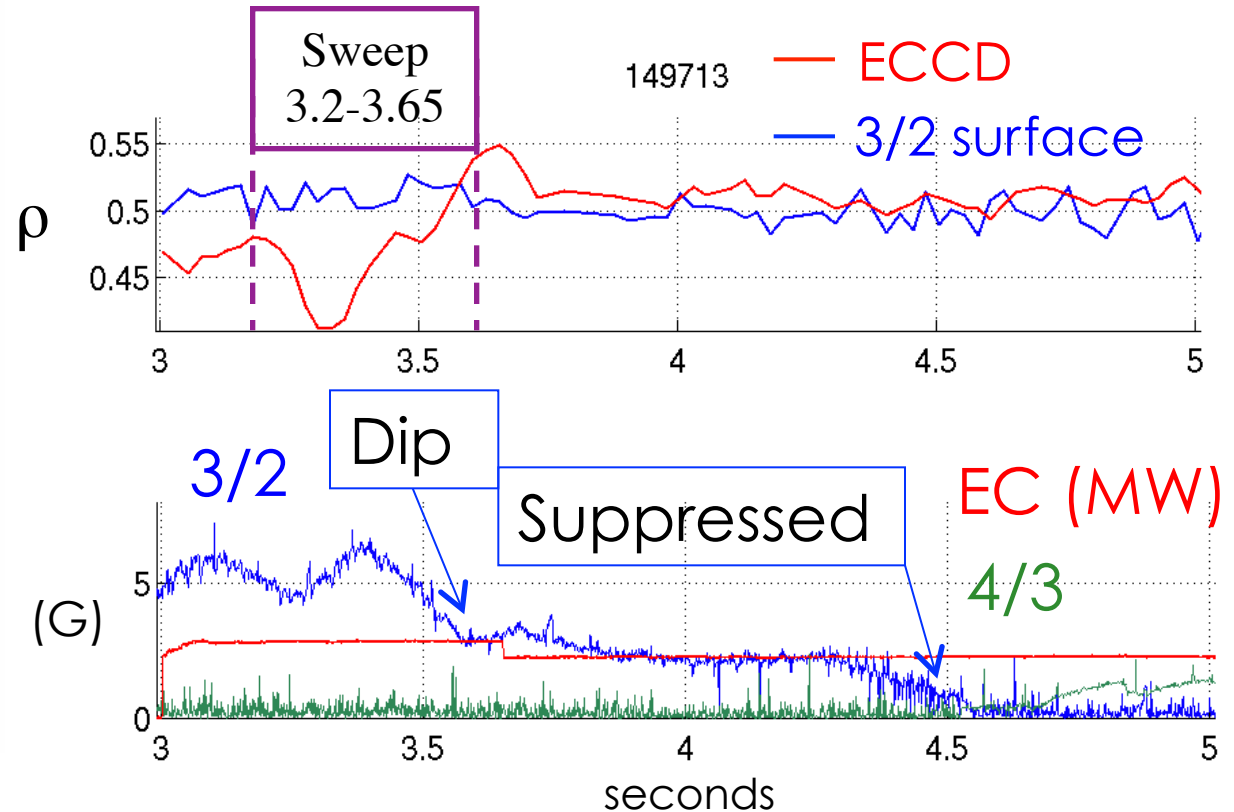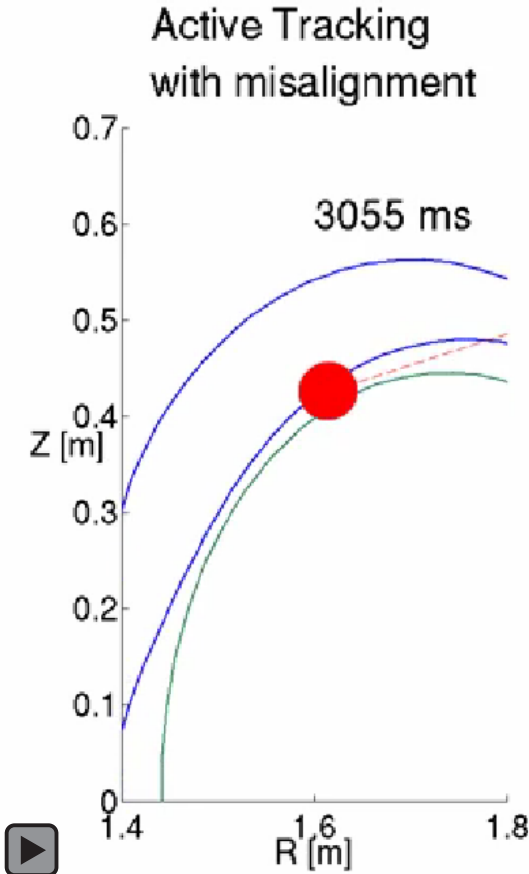
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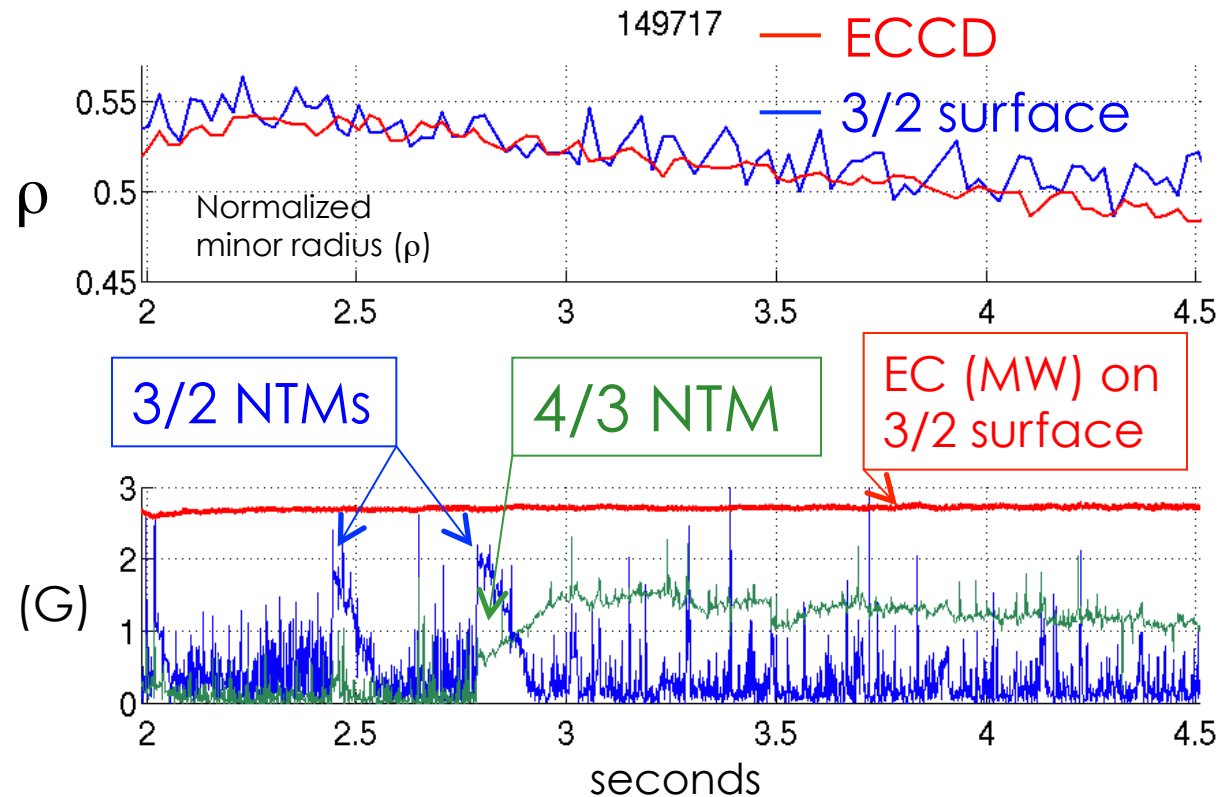
Turning On ECCD When NTM Detected Can Also Give Rapid Suppression (Called Catch & Subdue Method)

- **Early detection critical for rapid suppression**
- **ECCD should be off again after suppression in this scenario but stayed on in this case**
- **3/2 NTMs at 2 and 3.75 seconds**

Active Tracking of q = 3/2

ECCD initially off — 1805 ms

150100
— ECCD
— 3/2 surface

3/2 NTM detected! Control turns on ECCD

3/2 NTMs

4/3 NTM

EC (MW)

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- **Decision to sweep ECCD at 3.2 seconds**
- **Upward sweep 3.25–3.65 seconds**
- **Best suppression found slightly before dip**
- **Correction applied at 3.65 seconds**

Active Tracking with misalignment

3055 ms

Sweep 3.2-3.65

149713

— ECCD
— 3/2 surface

ρ

3/2   Dip   Suppressed   EC (MW)   4/3

(G)

seconds

8

Present Status And Plans For The NTM Control System

- **Status**
  - Mirror steering is fast, precise actuator for aligning ECCD-NTM
  - Alignment maintained as q-surface and refraction changes
  - Automatic fine-tuning of alignment when needed
  - Option to turn on ECCD when NTM appears (Catch & Subdue)

- **Plans**
  - Control of several modes, e.g. 3/2 & 2/1
  - Catch & Subdue to also turn off ECCD after NTM suppressed

See also E. Kolemen U07.00004 Thursday afternoon

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