June 2008 reporting meeting – XP810 and 801 experiment:

Error field and rotation sensitivity of 2/1 NTM onset and decay thresholds

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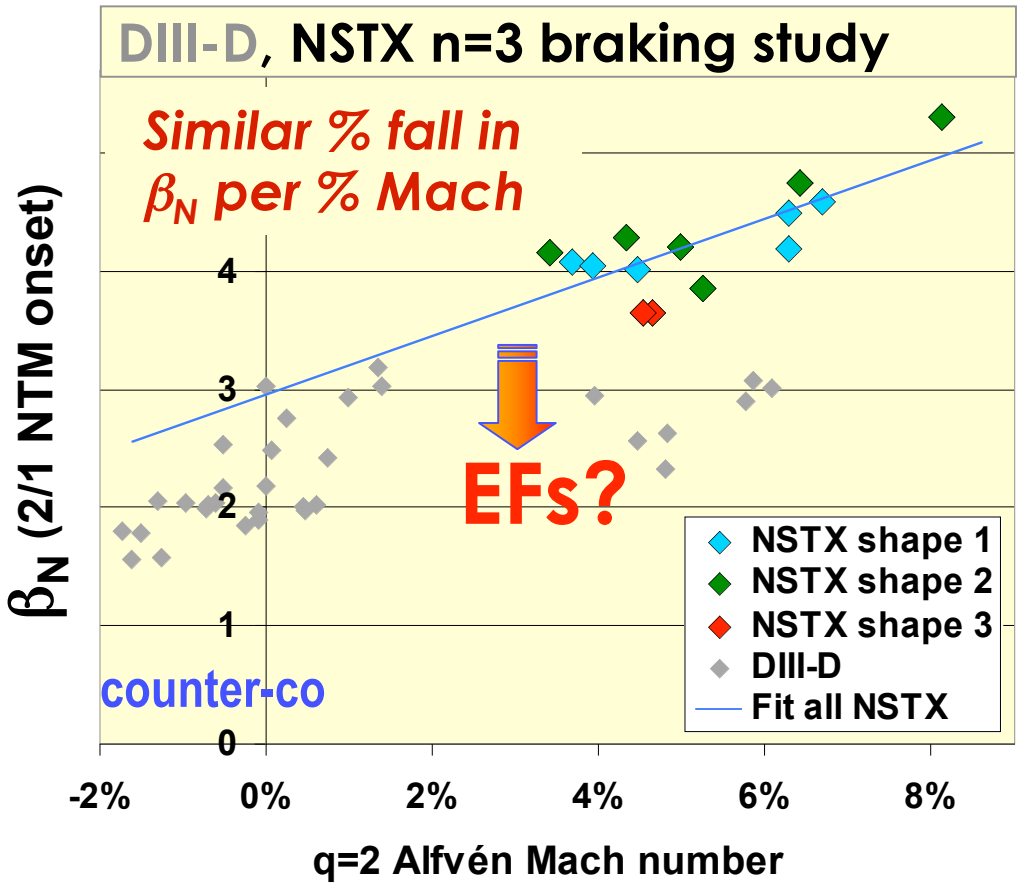
Basis of NSTX NTM rotation experiments…

DIII-D & NSTX show strong rotation dependence in NTM physics:



To explore:

- **Do error fields drop thresholds more at low rotation?**
- **How does rotation impact thresholds?**
  - Rotation or rotation shear?
  - Triggering physics or underlying stability?
- ***Explore with mode onset and decay experiments on NSTX***
  - ***n=1 and n=3 brake plasma differently***

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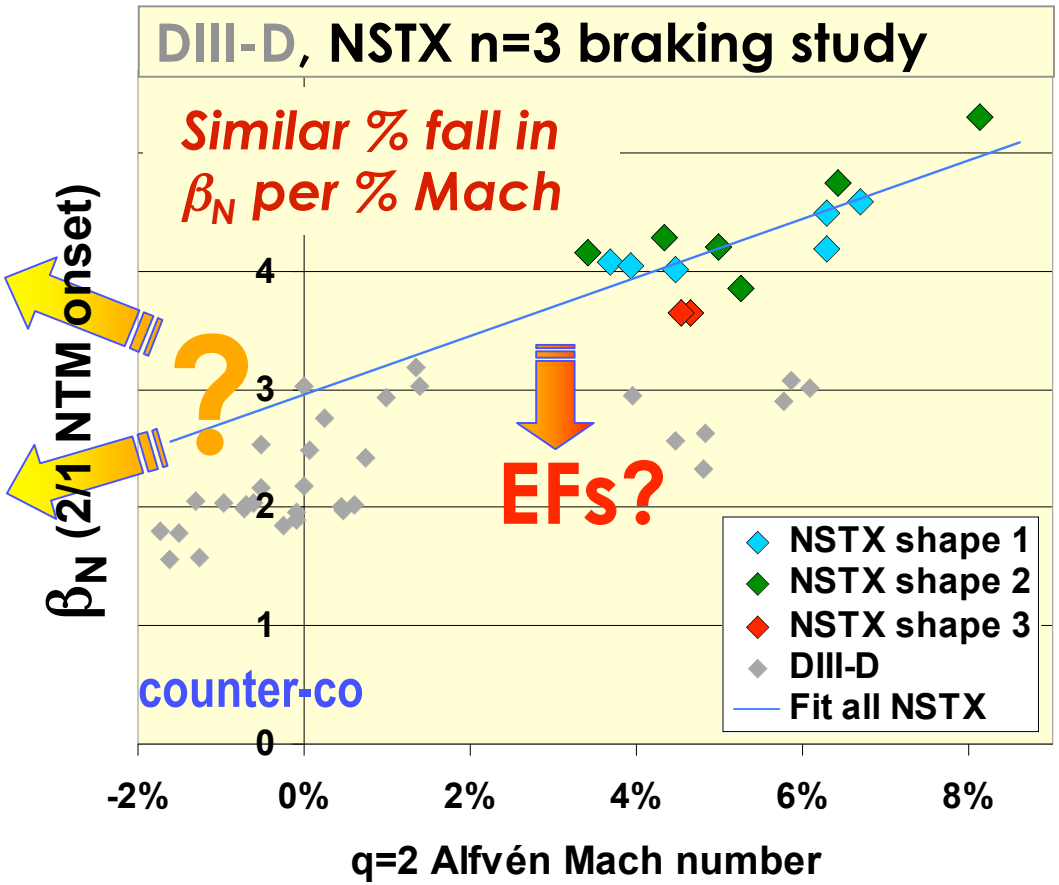

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- *Explore with mode onset and decay experiments on NSTX*
  - ***n=1 and n=3 brake plasma differently***

Later (if reverse Ip operation possible):

- Does counter rotation stabilise mode or not?

Key issues NSTX can shed light on

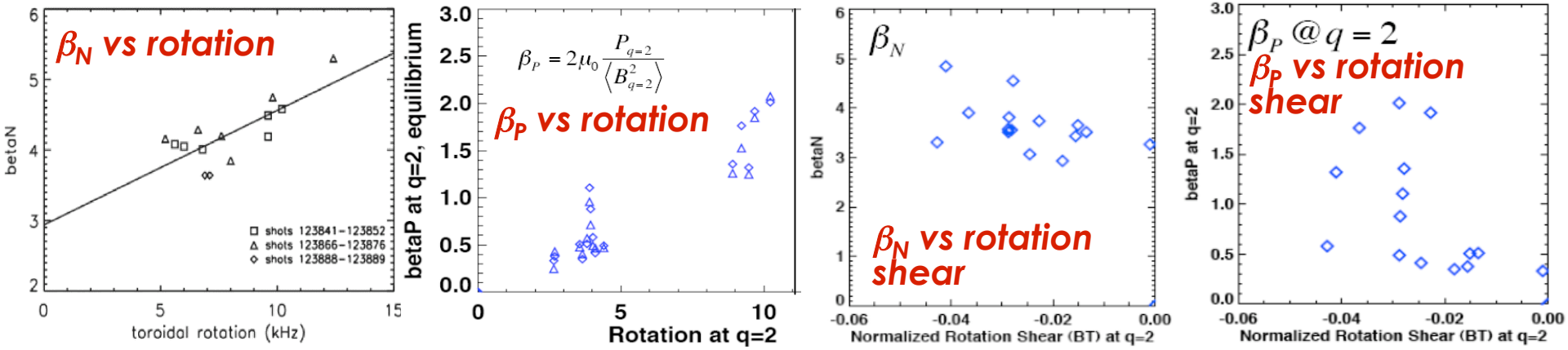
- **NSTX can probe error field effects**
  - To see if increased sensitivity at low rotation
- **NSTX can explore rotation profile effects**
  - Distinguish between rotation and rotation shear models?
  - Assisted by varying mix of n=1 & n=3 braking

Part A

- **NSTX can readily address the counter rotation question**
  - Does trend go up or down in counter direction?
  - *Just reverse Bt and Ip… (later, but covered by this XP)*

Part B

Stefan Gerhardt analysis… :



Lots of problems in February "restart"

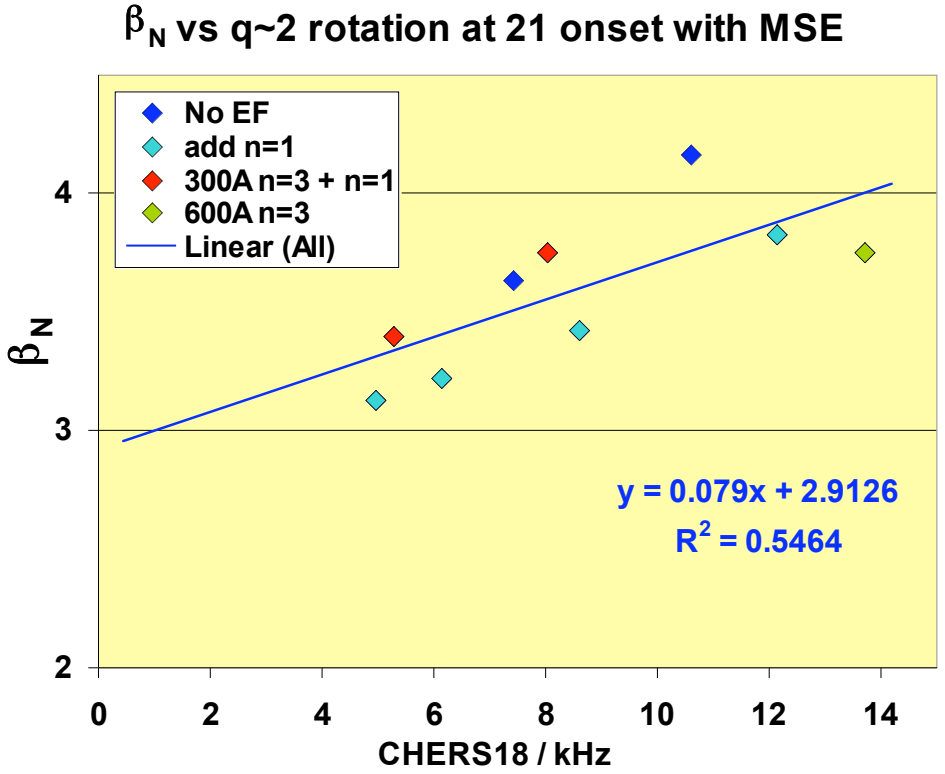
- Poor machine conditions → considerable scatter in results
- Beam C and then A failures
- Central stack problem
- Earth fault
- Error field correction not functioning → modes locked

→ Got about 0.5 days machine time

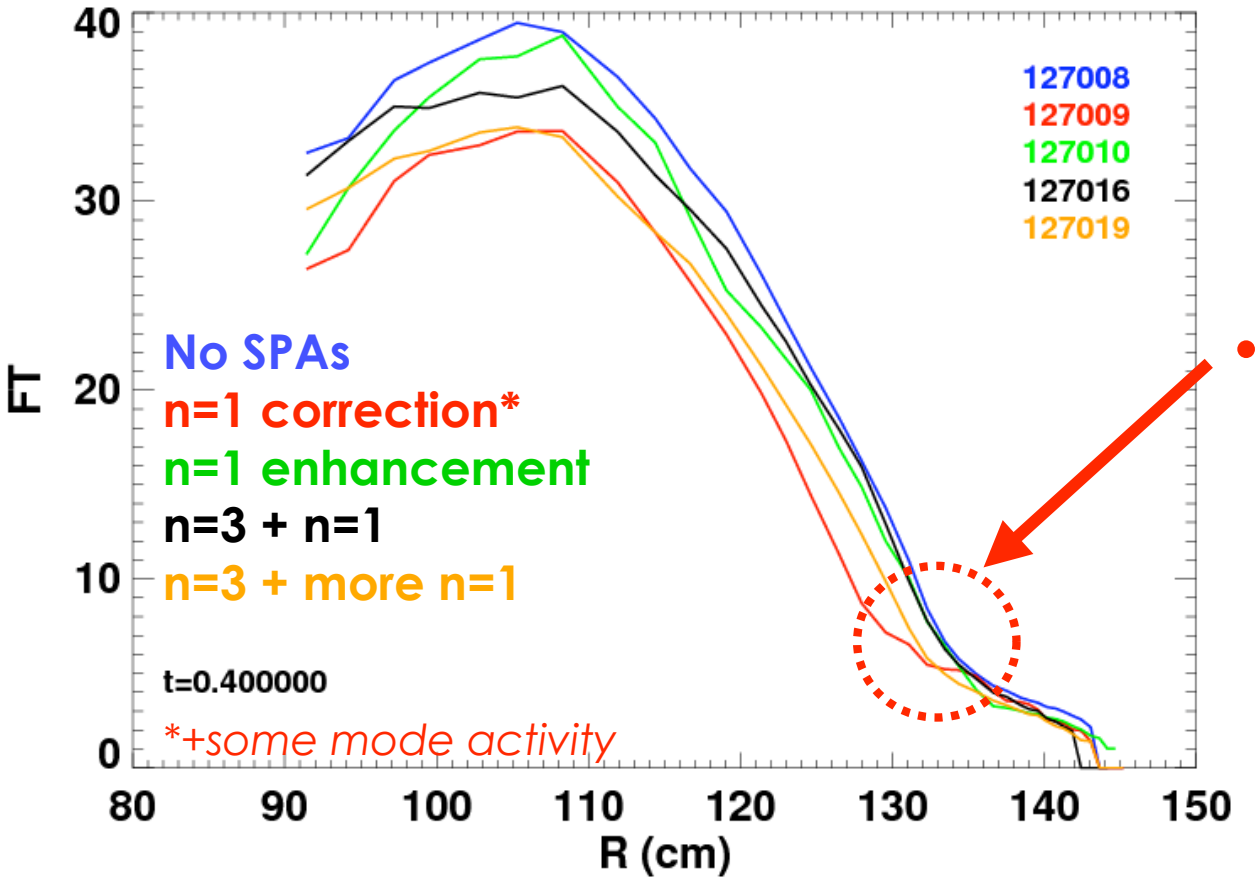
  - Ramp down element unsuccessful
  - Mode onset study 'made a start'
    - 4 point n=1 study
    - 2 points with n=3 but at low level

Preliminary results – mode onset

- **Preliminary onset scan obtained with n=1 fields & 2 beam recipe…**
- **…but very limited data with n=1 applied when lowering rotation from n=3 braking…**
  - *(this was main objective)*
- ***Nevertheless, useful extension of NSTX database to get at rotation vs. rotation shear issue…***



Nevertheless, considerable variation in target rotation profiles before mode…



- Particularly in q~2 region of interest

Although variations in machine conditions and reconstruction proving problematic… (W.I.P.)

New experiments in June

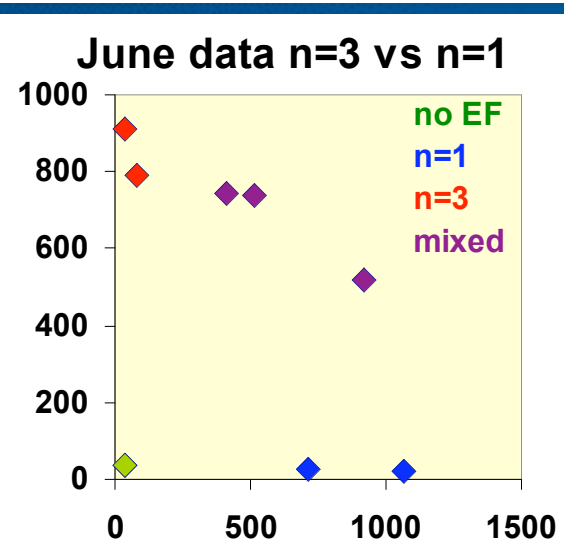
- **Take advantage of improved machine conditions:**
  - **Perform ramp-downs and try to keep mode rotating and in H mode**
    - **+ Explore rotation effect with n=3 braking**
    - **Avoid strong n=1 error fields (locked modes)**
  - **Explore mode onset physics**
    - **Measure n=1 impact on beta limit (='penetration' threshold?) at different rotations (by varying n=3 brakings)**

      ➔ aim for four corners, then fill in if possible

Progress on June day on NSTX

- **Morning focussed on ramp-down:**
  - Troubled by evolving conditions as lithium disappeared
  - Mode threshold raised through morning
  - Did achieve some ramp-downs
    - Mode always locked *(maybe one case?)*
    - Tricks to drop H-L did not help
- **Afternoon switched to onset variation study:**
  - Had to further optimise to strike mode (reduce centre stack gas)
  - Got to reasonable & reproducible target with no braking
  - Started scan with n=3 ramp (after intervention for CS problem)
    - Problems with machine operation to get back n=3 shot
  - **Finally got in the zone**
    - **Reliable 2/1 modes with various n=1 & n=3 fields…**

Results of June study



Got reasonable scan with currents at a level that "did something":

Reference shots

Shot	t21	betan	n=1 A	n=3	chers5	chers18
130210	0.66	4.17	0	0	19.5	6.5
130211	0.65	4.19	0	0	19.5	6.49
130212	0.675	4.02	0	890	12.2	4.5
130216	0.64	3.67	0	800	16.98	4.11
130218	0.697	4.03	1100	0	9.85	2.69
130219	0.692	3.93	740	0	10.8	4.67
130217	0.645	3.23	mix	mix	16.5	2.56
130220	0.525	3.32	500	800	27.87	2.39
130221	0.618	3.86	370	800	18.5	1.59

Pure n=3

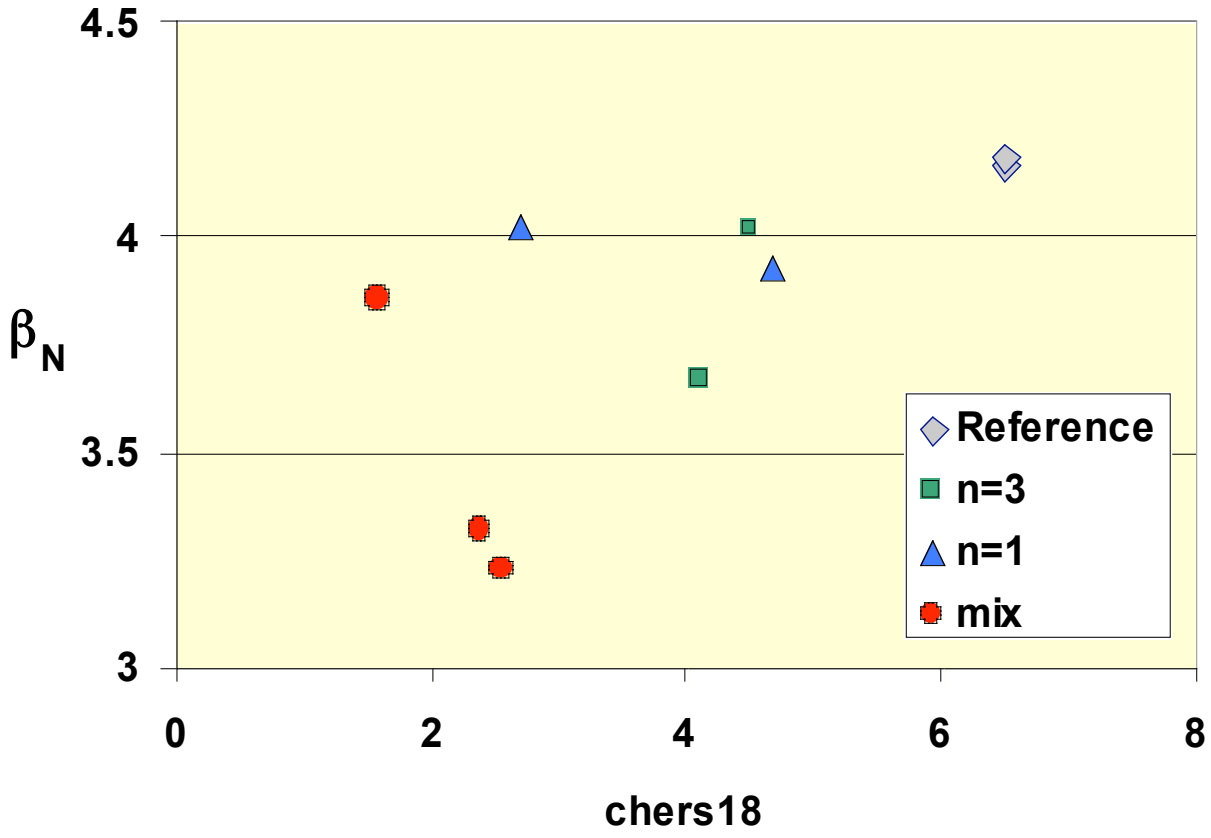
Pure n=1

Mixed n=3 and n=1

- n=1 and n=3 may brake plasma differently
- Work now to deconvolve effects…
  - *The above are 'good shots' for data analysis, please*

Effects observed in raw data

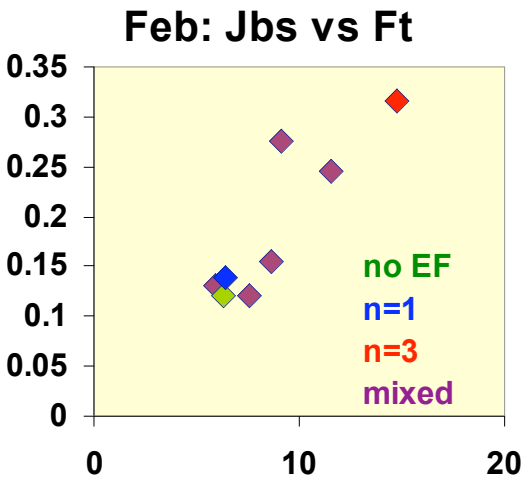
- Key to deconvolve is rotation and rotation shear effects

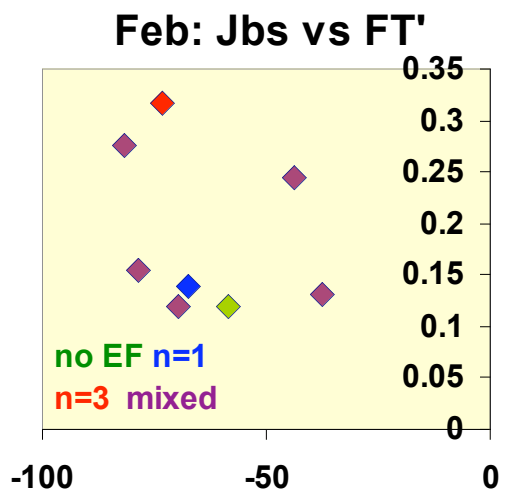


- Also, a simple 'error field threshold' measurement should be possible, and its scaling with plasma braking…

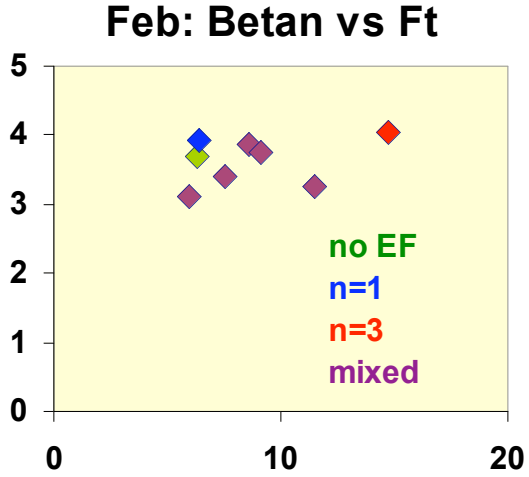
Analysed data just obtained and being processed

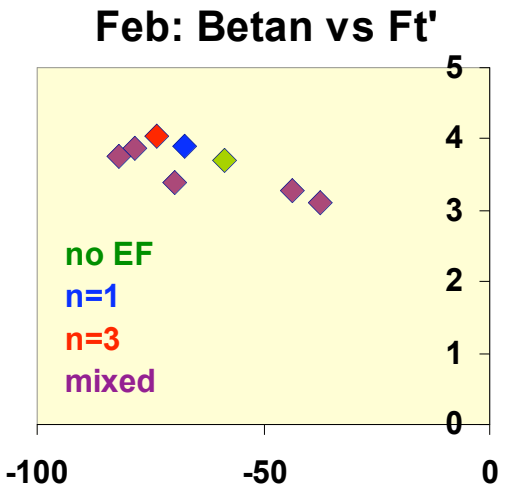
- **Possible trends in Feb data hint at rotation is parameter that matters…**





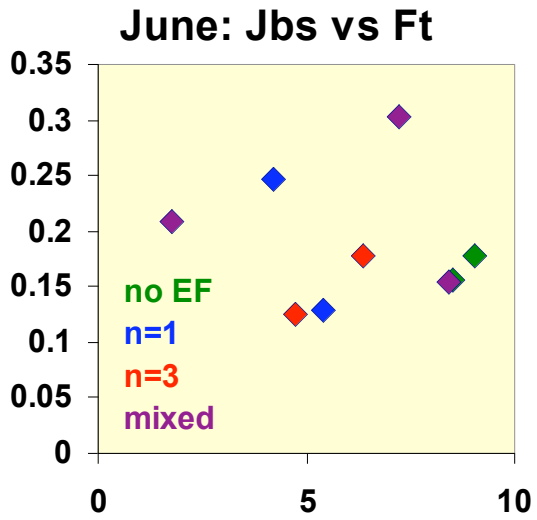
- **But note different trend for β_N**
  – *FT' works best*

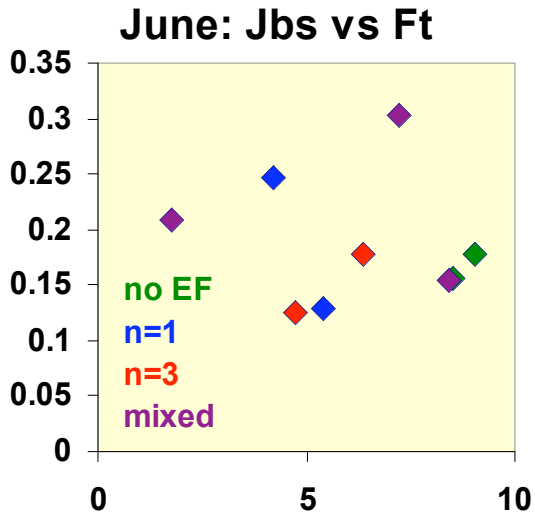


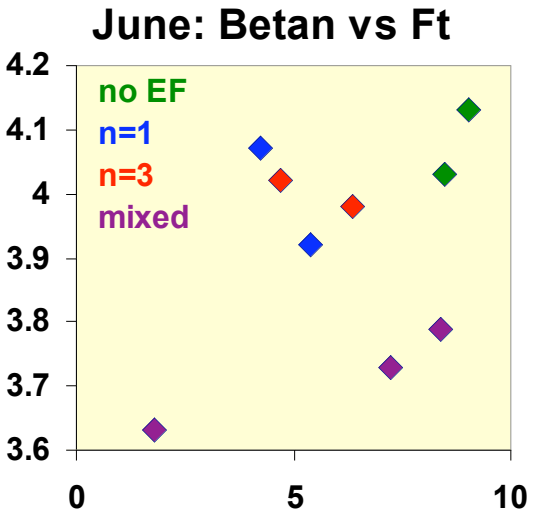


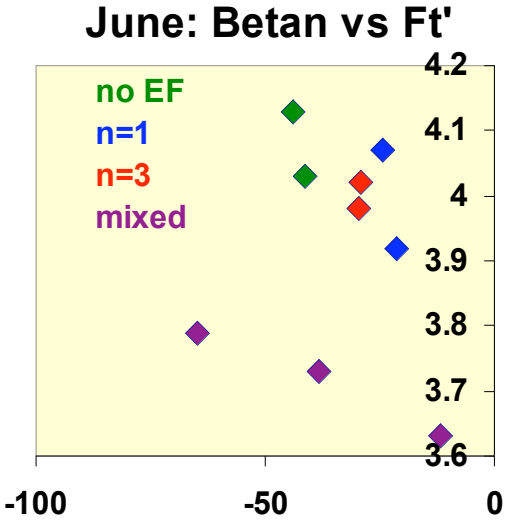
New June data seems to have high scatter

- *Need to check and resolve issues of variability in reconstruction and error field calculation*







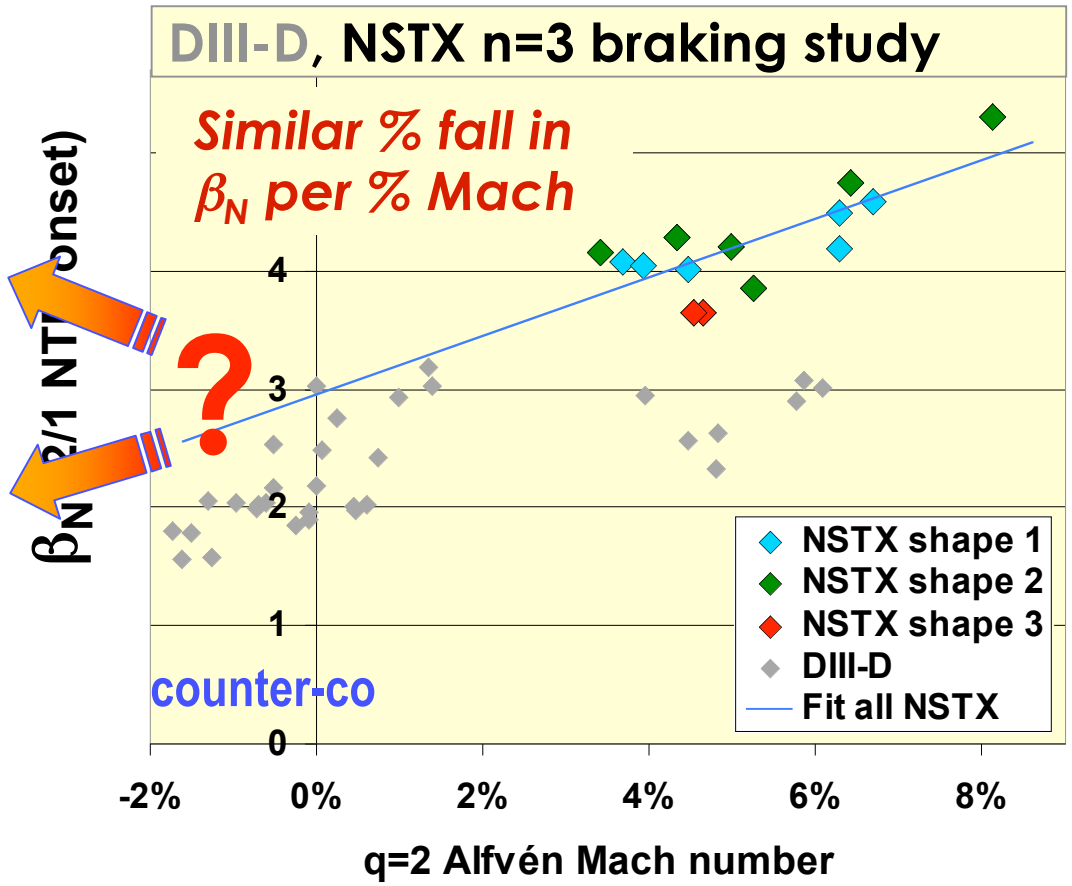


Summary

- **A good data set obtained to test effects**
- **But n=1 and n=3 fields seem to have effects on plasmas and induce/lower thresholds for modes**
  - **'Four corners' of scan obtained**
  - **Considerable scatter in optimised EFIT based data so far**
  - **Some trends emerging – favour rotation rather than rotation shear in physics parameters**
  - **Work underway to resolve trends and noise…**

Part B (later): counter Bt and Ip scans

Recall previous NSTX and DIII-D scans:



- ***Simple technique is to reverse Ip and Bt to get strong counter data***
  - Key test of underlying theory governing rotation dependence

NSTX: about 0.5 shifts, counter B_T and I_P

Apply ramps in β to trigger 2/1 NTM (ref shot 123876)

May need co- comparison, and vary rotation with n=3…

Many thanks to the NSTX team for hosting us and working hard to help our experiments work.

Reference – Feb 2008 in detail

- **Following slides give more detail on problems and achievements in Feb experiments**
  - ***May be useful for longer presentation or if you need to explain these points***

Lots of problems in February "restart" – day 1

- **Lot of problems with machine conditions:**
  - Poor conditions required 3 beam operation
    - Attempts with 2 beams & optimisation of elongation, but mode struck too early…
  - Beam C limited by SPA pick up (**fixed by mid-afternoon**)
    - Got 3 points without SPAs, then 2 more with n=3…
  - Then **central stack problem cost 1.5 hours**
    - Got one final point with 3 beam mode onset…

>> 3 beam target made for ramp-down but not optimised to provide ramp-down data…

Lots of problems in February "restart" – day 2

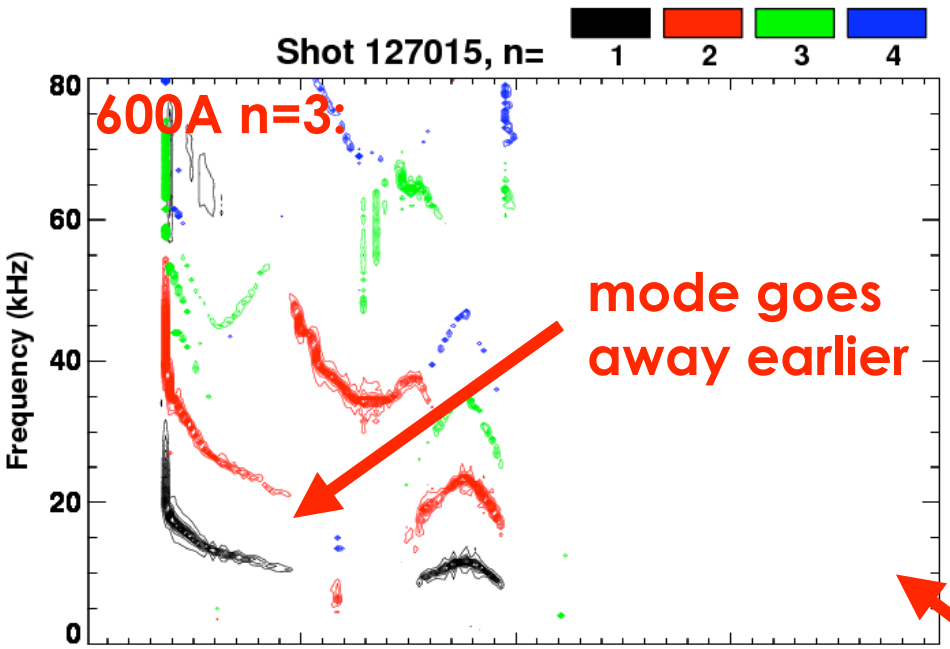
- **Started with target from day 1…**
  - Beam A failed (MSE) for **whole morning**
    - We persevered with development of a lower Ip 2 beam scenario
      - *has limited scope of scans, but allowed us to get scenarios working while MSE beam fixed*
      - *Provided some tests of ramp down techniques for XP801*
    - ✓ **Then obtained 4 point scan with n=1 field**
    - Further tests for ramp-down with n=1 error correction
      - But unknown error field – could not avoid locking
  - Lost 1.2 hours to earth fault on centre column
    - ✓ **Then managed 2 point n=1 scan with n=3 applied**
      - (one or two vertical stability and RTEFIT problems)
- **General point:**
  - Using a lot of flux swing (not yet that well conditioned) and 2 beam mode β_N threshold quite low (limited scan scope)

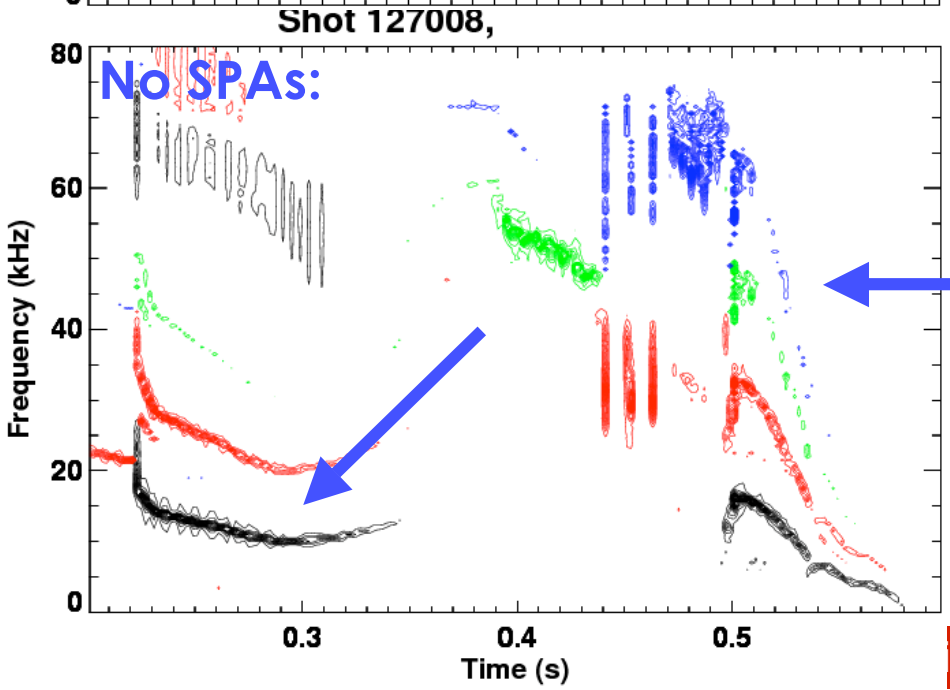
Physics progress summary

- **Scenario redeveloped for 2 beam and 3 beam operation**
- **Ramp-down techniques implemented but mode locking problem**
  - Possibly related to machine conditions and intrinsic error fields
- **4 point 2/1 NTM onset scan obtained vs. n=1 field**
  - Error fields act to lower rotation and decrease NTM β threshold
    - ***Some uncertainties in intrinsic error level***
- **2 point scan of n=1 field obtained while modest n=3 braking**
  - n=1 braking has an effect in lower thresholds here…
  - …analysis required to determine differences cf zero n=3
    - ***scope very limited by available time - higher n=3 & n=1 levels desired to explore key question – is error sensitivity worse at low ω?***

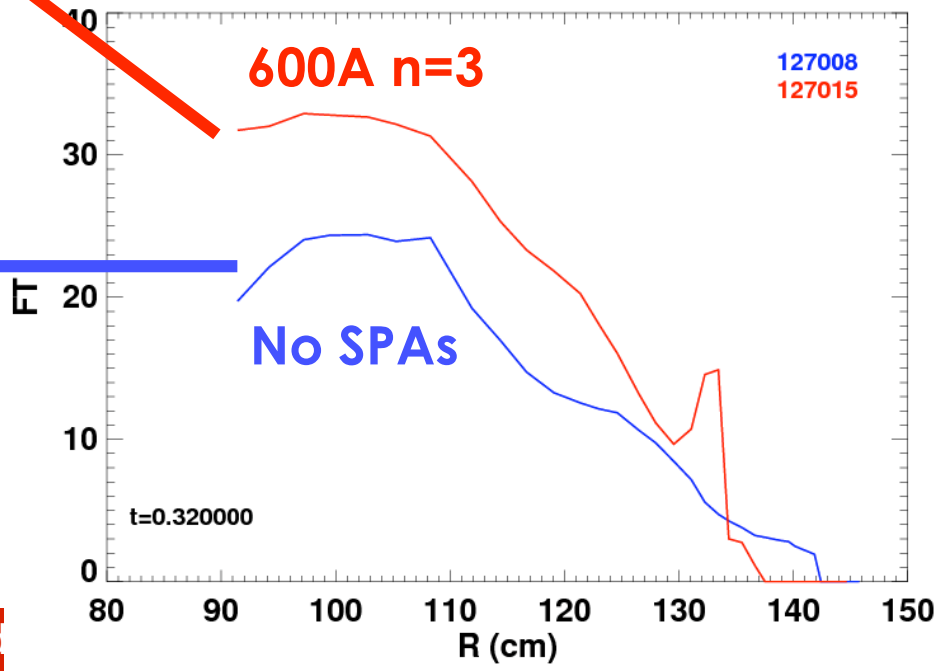
Combined data does provide useful extension of 2007 database to resolve questions of role rotation vs rotation shear…

Machine conditions introduced some scatter…





- **Operating close to early modes as limited time in Ohmic coil swing**
  - These impact rotation
  - Variations in mode time history impacts profiles
  - *Outweighs n=3 braking!*



Key outstanding goals

- **XP 801 – ramp-downs for NTM self-stabilisation point**
  - Need to achieve ramp-down with dynamic error correction
  - Then scan ramp-down vs rotation using n=3 and n=1 braking
- **XP 810 – NTM onset threshold in β_N**
  - Need to resolve issues of intrinsic error n=1 field to understand contribution to that scan
  - Need to extend scan with n=3 braking to get better variation, with higher n=3 braking, and wider range of n=1 fields

This would greatly benefit from improved machine conditions (→ longer time window and higher β threshold) and dynamic error correction (→ to remove / measure n=1 fields)

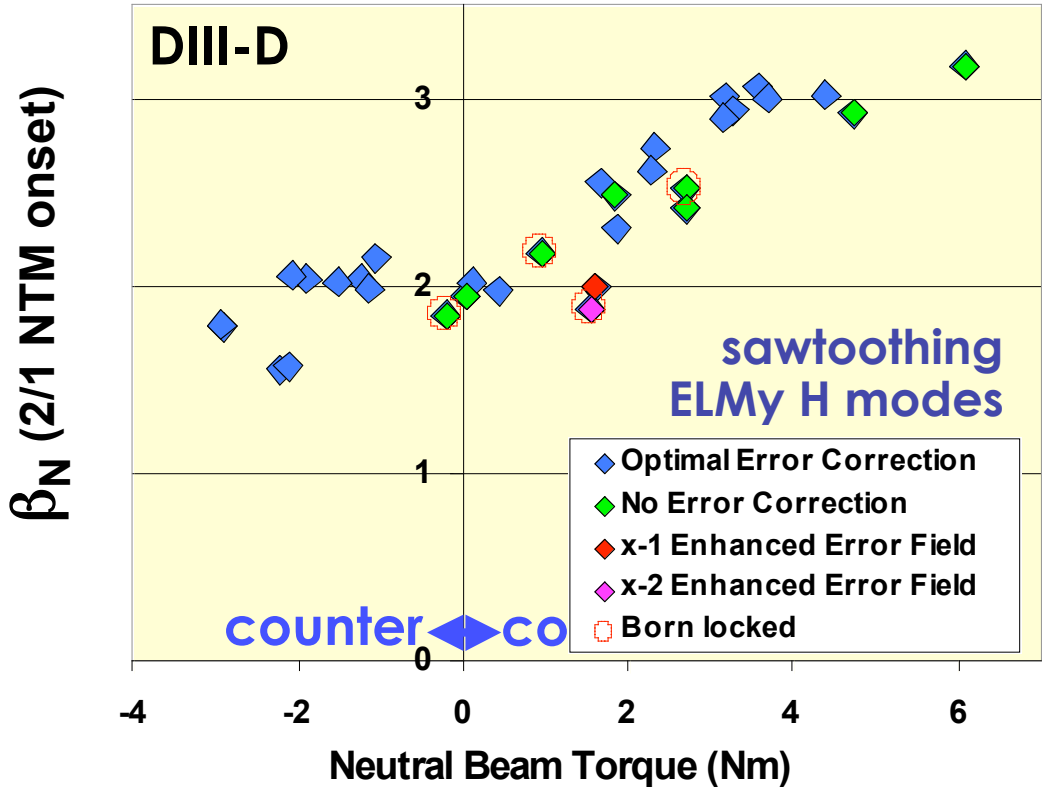
  - *Upcoming XP by SG/JM will provide latter; continued ops – former*

→Propose completion day after that, shared between 801 & 810

- **PREVIOUS MOTIVATIONAL MATERIAL FOR NSTX STUDY**

2/1 NTM co vs counter rotation dependence

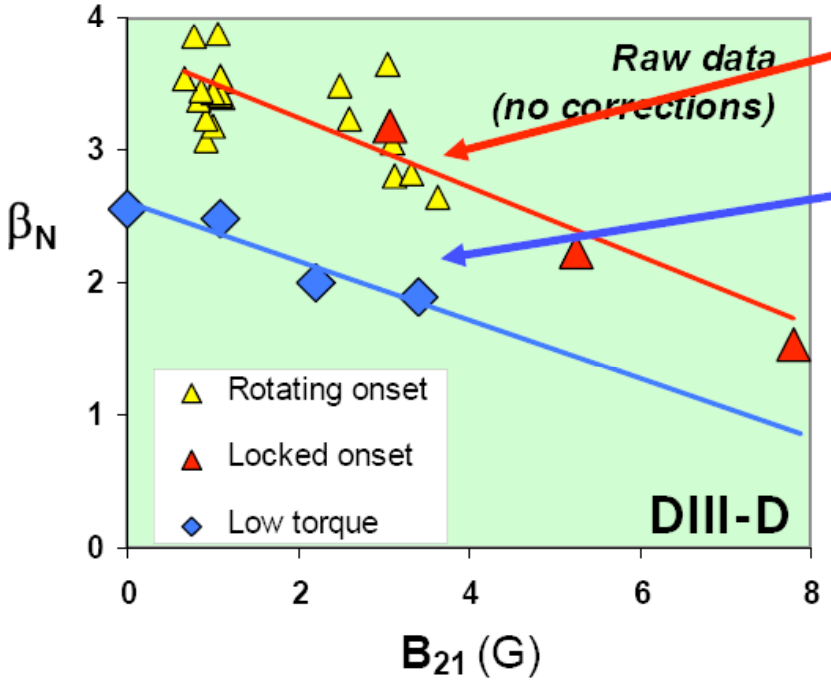
DIII-D: shows strong rotation dependence in 2/1 NTM β_N limit



- **But what is physics?**
- Does counter rotation stabilise mode?
- Is threshold dependent on rotation shear relative to magnetic shear (á la theory)
- ***Need to test and explore this important result…***

Part A: Error field effects on 2/1 NTM β limit

JET and DIII-D show error fields can lower 2/1 TM threshold



- Lowering of β_N limit for 2/1 NTMs with 100%co NBI
- Similar effect on DIII-D with 65:35 mix of co:counter NBI (low torque)

Need to probe further:

- Error field expected to trigger modes more easily at low rotation (???)
- Need to understand correction requirements in medium β_N plasmas
- Helps understand NTM physics & rotation role

NSTX experiment: up to 1 shift

Ramp β_N to trigger modes (ref shot 123876); scan error field level shot to shot.
Repeat scan with high n=3 field applied to explore braking
(May be desirable to compare with an Ohmic version of the experiment… see next)
(Some points with EF ramps at constant β_N also desirable).