Fast ion transport induced by Alfvén avalanches: OP-XP-80?

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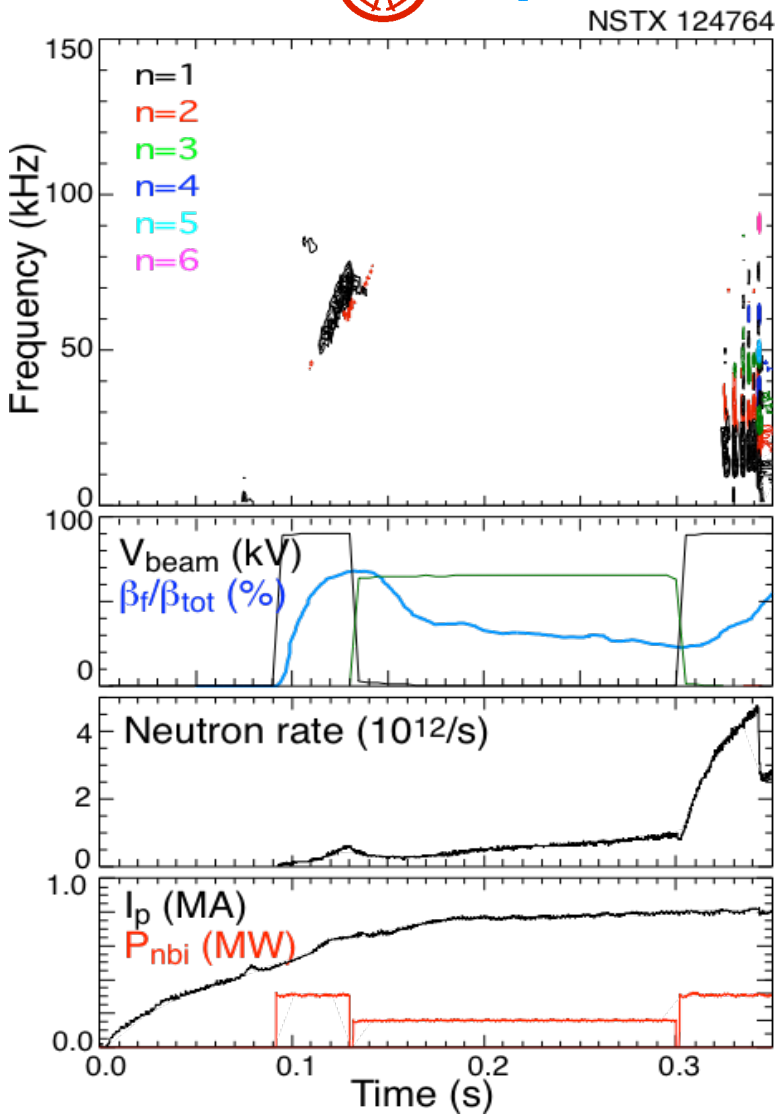
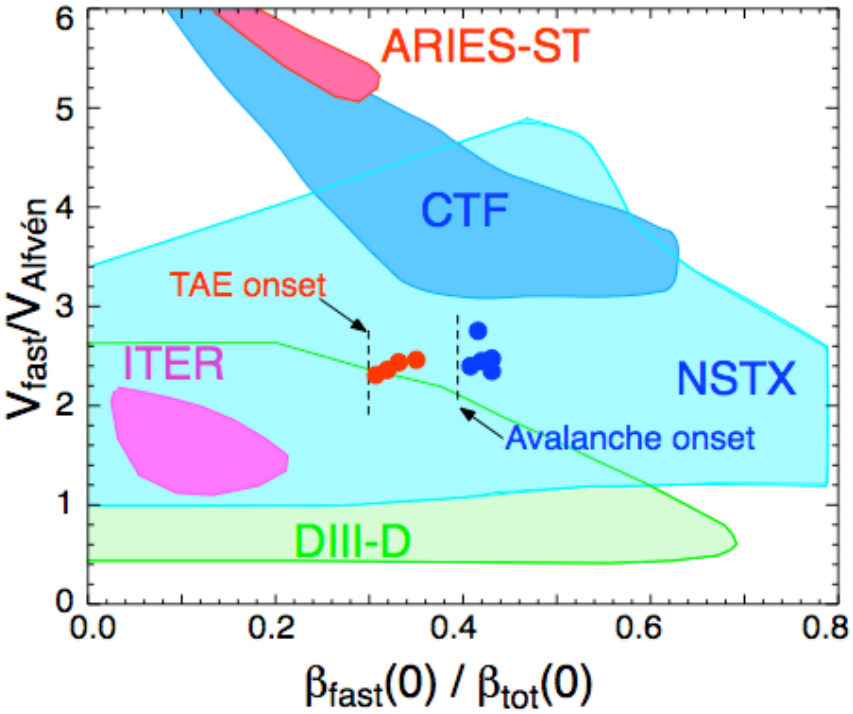
Extend parameter regime for quiescent plasmas - validate FIDA

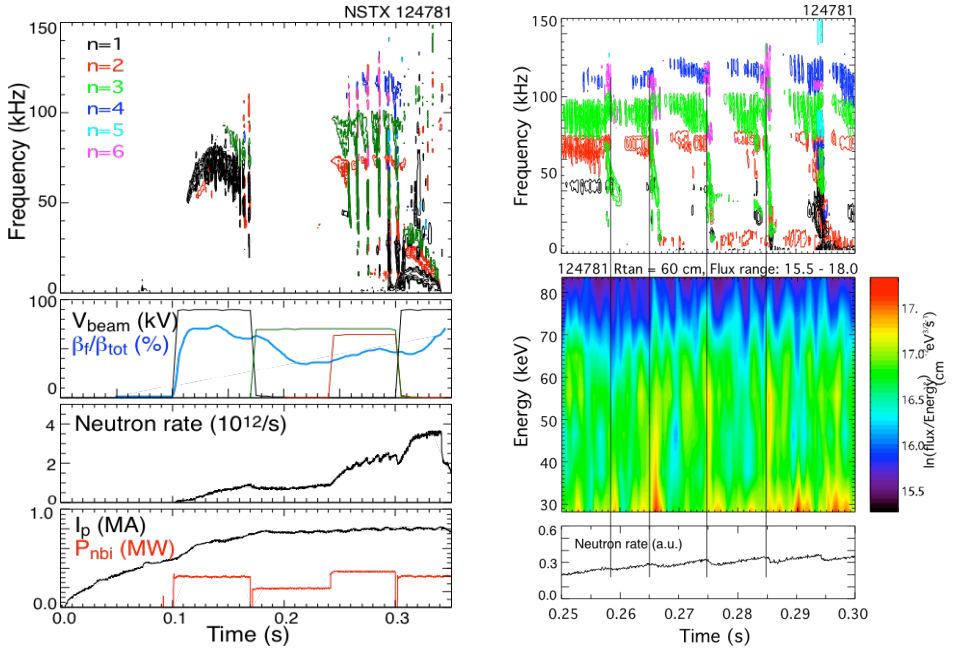
- A high priority is to revisit L-mode quiescent conditions to extend parameter regime
  - Higher density
  - Higher field
  - Beam voltage scan
- Document fast ion distribution with FIDA, benchmark other fast ion diagnostics (beam blips).
- Move to reduce Helium fraction towards D plasma
- Fishbones for sFLIP study of fast ion losses.



TAE avalanche experimental goals

- Scaling of threshold with beam voltage
  - Voltage/power scaling of β_{fast} threshold
- Scaling of threshold with density and toroidal field
  - Also changes V_{fast}/V_{Alfven}





- Extend threshold study to H-mode
  - Density profile affects gap structure
- Use high-k scattering to look for continuum damping
  - Help to sort out γ-dependence of gap structure?

Goal 1: Reproduce quiescent condition
Goal 2: Determine optimum quiescent period
Goal 3: Beam blips to validate FIDA

1. Reproduce density, current, beams, neutron rate evolution for shot 124764.

   IF (plasma quiescent) THEN GOTO 2.

2. Extend source C-to-A swap from 300 ms to 400 ms to determine length of quiescent period, for subsequent plasmas, set source C/A swap accordingly for subsequent shots.

c…Optimize length of quiescent period

3. DO I=1,3

   Start FIDA beam-blip experiments.

c…Make fast ion distribution measurements, optimize FIDA

   ENDDO

Goal 4: Deuterium quiescent plasma? H-mode?

4. Switch to deuterium operation

c…Can we get quiescent D shot for FIDA (improves neutron accounting)

c…Will D shot go into H-mode? (avalanche threshold different in H-mode?)

IF (plasma quiescent) THEN GOTO 5
ELSE
  Raise density
  IF (plasma quiescent) THEN GOTO 5
ELSE
  increase toroidal field
  IF (plasma quiescent) THEN GOTO 5
ELSE
  lower beam power
  IF (plasma quiescent) THEN GOTO 5
ELSE
  Skip quiescent deuterium operation (5)
  GOTO 6
ENDIF

Goal 5: FIDA beam blips in D plasma

5. DO I=1,3

   Repeat beam blip experiments in Deuterium.

c…Make fast ion distribution measurements, deuterium for (absolute) neutron measurements.

ENDDO

Goal 6: Beam voltage scan to Avalanche threshold

6. IF (quiescent D plasmas H-mode) THEN go back to Helium L-mode plasmas
   Adjust density to optimize reflectometer data, if req'd
   Sources B & C should be nominally at 65 kV.
   Use B at nom. 65 kV for quiescent period (until ≈240ms), then source C.
   Start voltage/power scan for C to avalanche threshold
   DO I=1,4
      IF (no avalanche) THEN
         Increase beam voltage by 10 kV increment (maintain target density)
c…Scan of β_{fast} to determine TAE and TAE avalanche threshold.
c…Similar to XP705, but changing beam voltage instead of # of sources
      ELSE IF (avalanche) THEN
         Decrease beam voltage by 5 kV
         GOTO 7
      ENDIF
   ENDDO
c…Approximately 6-7 shots (maintain target density)

Goal 7: q-dependence of Avalanche threshold
Goal 8: fast ion transport study

7. Change C-B swap back to 220 ms

c…is avalanche threshold dependent on q_{min}?

DO WHILE(MHD)

delay swap in 10 ms steps

ENDDO

IF(no MHD AND avalanches)THEN

reduce C voltage by 5 kV steps

ELSE

increase C voltage in 5 kV steps

ENDIF

c…NPA/ssNPA/FIDA documentation of fast ion transport

c…high-k scattering gets radial scan here

8. Start documentation of TAE avalanche condition (either from part 6 or 7)

6-shot NPA scan (tangency radius t.b.d.)

c…4-5 shots for 7

c…6 shots for 8

Goal 9: Avalanche threshold closer to ITER parameters

9. Increase toroidal field to 5.5 kG

IF(no avalanches)THEN

DO WHILE(no avalanches; max steps 3)

Increase source C voltage by 5 kV, repeat

ENDDO

ELSE

DO WHILE(avalanches; max steps 3)

Decrease source C voltage by 5 kV, repeat

ENDDO

ENDIF

c…(low - ITER)$V_{fast}/V_{Alfvén}$ scaling of avalanche threshold

c…try for lower density?

c…less than 4 shots

Goal 10: Avalanche threshold for CTF parameters

10. Reduce toroidal field to 3.5 kG, source C at avalanche threshold for 7.

```
IF(no avalanches)THEN
  DO WHILE(no avalanches; max steps 3)
    Increase source C voltage by 5 kV, repeat
  ENDDO
ELSE
  DO WHILE(avalanches; max steps 3)
    Decrease source C voltage by 5 kV, repeat
  ENDDO
ENDIF
c…(high - CTF)Vfast/Valfven scaling of avalanche threshold
c…add higher density point?
c…less than 4 shots
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Goal 11: Begin study of avalanches in H-modes
Goal 12: Investigation of fishbone transport

11. Switch to D prefill/puffing, attempt H-mode

c…Look for threshold in H-mode plasma

12. Optimize an NPA scan for fishbones after 300 ms

c…Have only started looking at this

Desired Diagnostic/machine capabilities

- 5-channel reflectometers.
- 2 correlation channels in dwell.
- Mirnov HN/HF arrays
- Firetip
- High-k scattering
- FIDA operational
- Scanning NPA
- ssNPA
- sFLIP with PMT channels
- MSE
- Thomson scattering
- CHERS
- JHU Soft x-ray cameras
- Tangential fast SX camera
- Fast neutron detectors

- Source A at 90 kV
- Source C at 60-90 kV
- 4.5 and 5.5 kG operation
- 800 kA (120106/123096)
- Helium prefill/puffing
- D prefill/puffing
- N=3 nonresonant braking
- HHFW at 2 to 3 MW, best phasing for electron heating.

- Probably better before LITER, but may not matter.