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NSTX-U

Inter-ELM and ELM-free divertor heat flux broadening induced by EHO in NSTX

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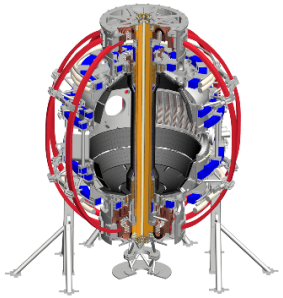
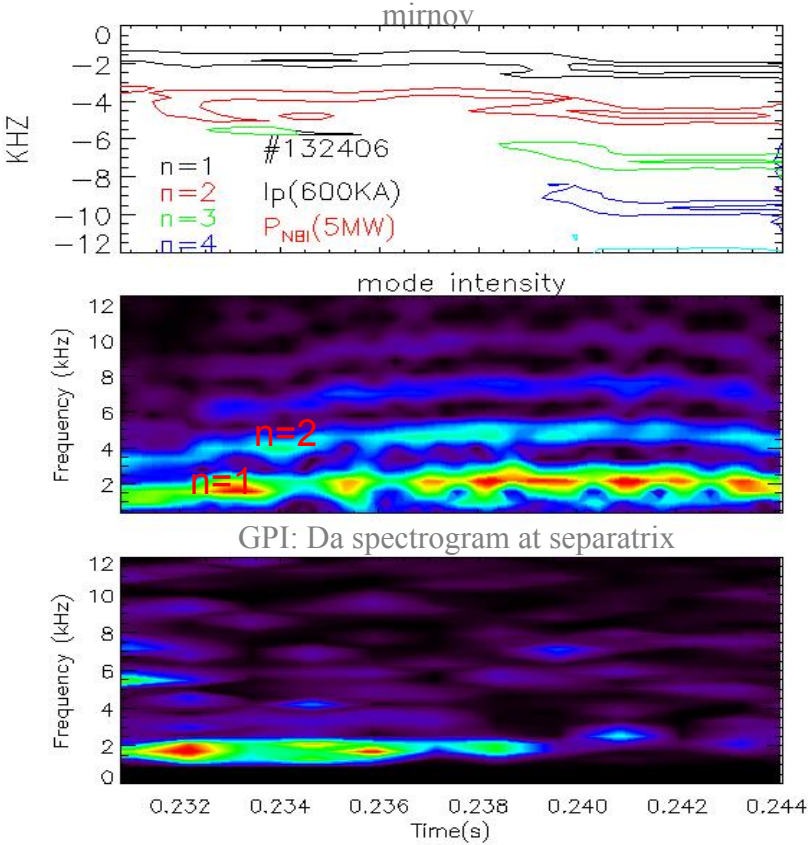
PPPL



EHO Introduction

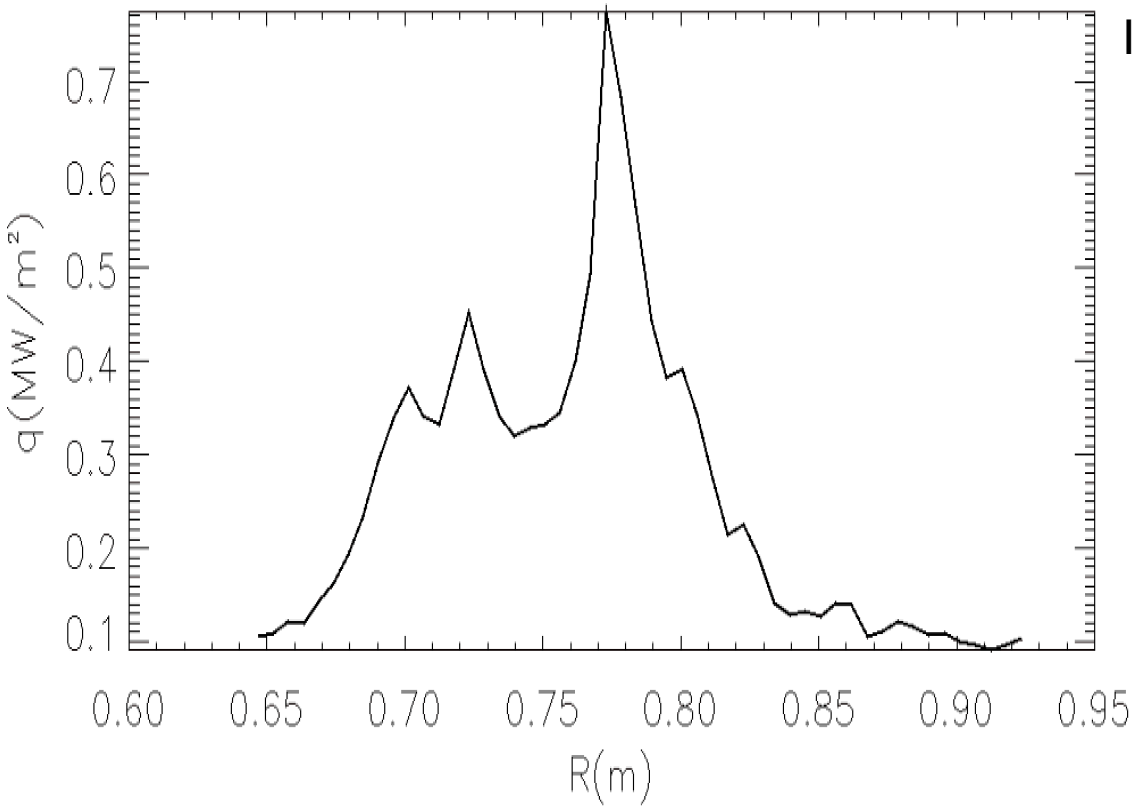
- Edge harmonic oscillation (EHO) is an edge localized, electromagnetic oscillation, accompany by multiple toroidal harmonics n.
  - DIII-D [K.H. Burrell, TTF, 2003], [C.J. Lasnier, 2003JNM]
    - Typically rotates in direction of neutral beam for both co- and counter- injection
    - EHO exists during ELM-free and inter-ELM; increases the divertor peak heat flux.
  - Previous observation in NSTX[J.K. PARK, NF2014]
    - Co-current EHO rotated in the direction of neutral beam
    - Did not generate significant particle transport

New observation of counter current EHO in NSTX



- A counter current multiple harmonics oscillation (n:1-4) was observed to rotate in the opposite direction of the neutral beam
- $f_n \sim n\Delta f \sim nf_1$.
- Gas puffing imaging (GPI) diagnostic observed the same edge oscillation (n=1) due to the harmonics oscillation, indicate this multiple harmonics oscillation might be EHO
- This EHO is n=1 dominated

Definitions of IR related quantities used in this talk



IR diagnostic: 6.3khz (96 x32 pixels)

Peak heat flux: q_{peak}=max(q(R))

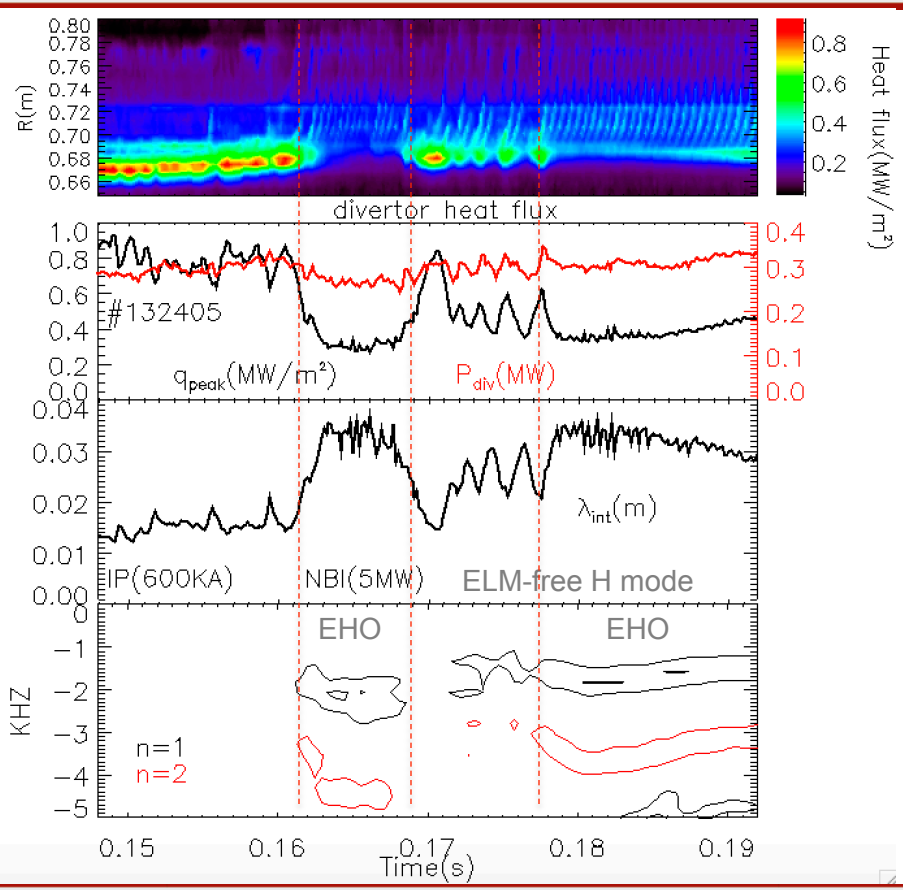
Deposited power on divertor:

$$P_{div} = \int 2\pi R \cdot q(R) dR$$

Integral heat flux width:

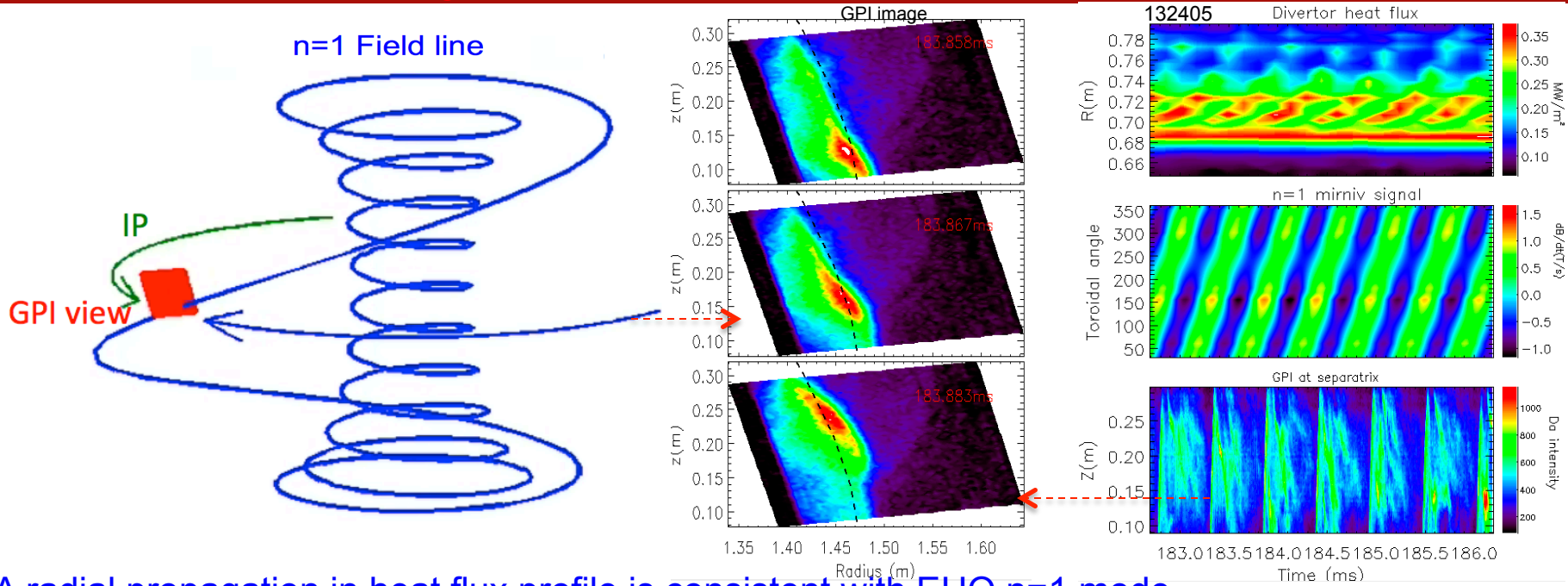
$$\lambda_{\text{int}} = (\int (q(R) - q(background)) dR / q_{peak}) / f_x$$

EHO increases the λ_{int} and reduces the q_{peak}



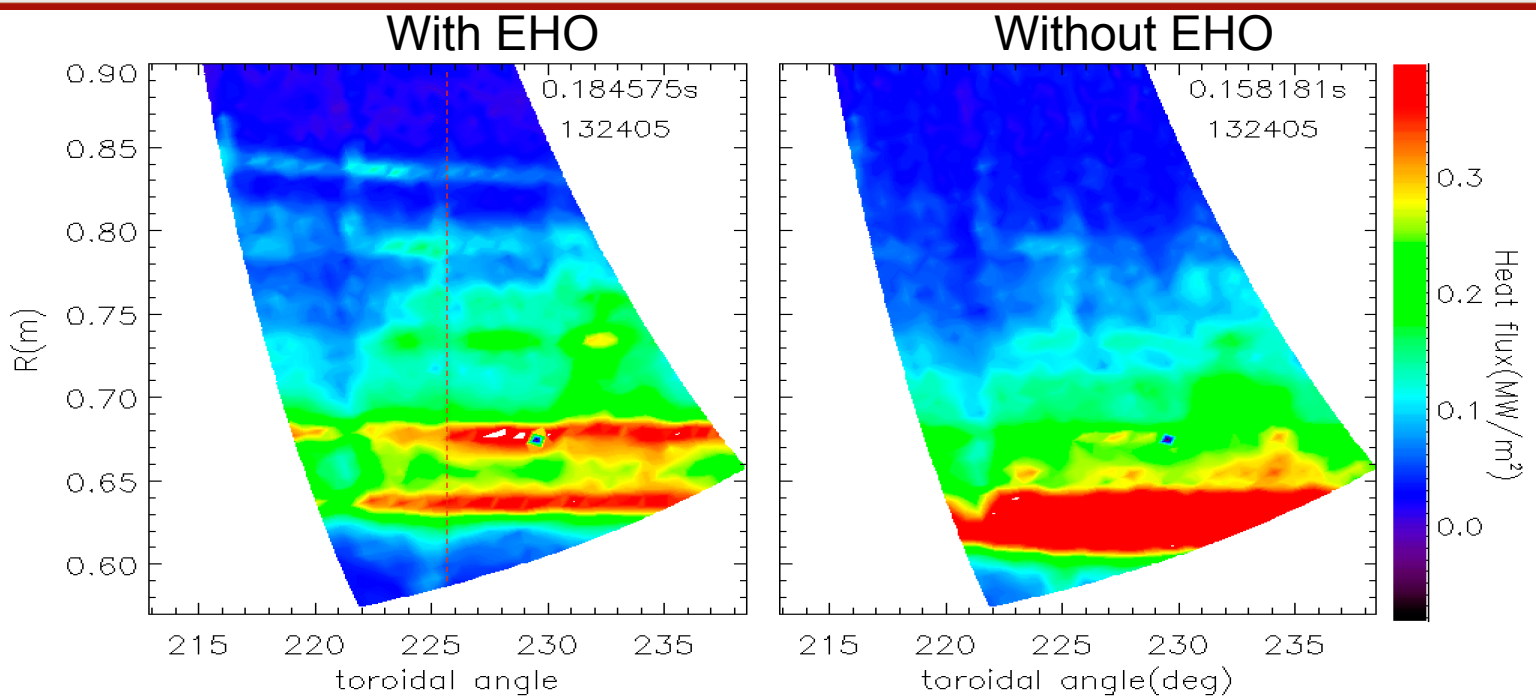
- Counter current EHO could appear during ELM-free H mode (>100ms)
  - *Onset conditions not understood*
- The q_{peak} (λ_{int}) significantly decreases (increases) with EHO
- P_{div} does not change much due to the EHO

Hypothesis: A filament is induced inside the separatrix by the EHO n=1 mode



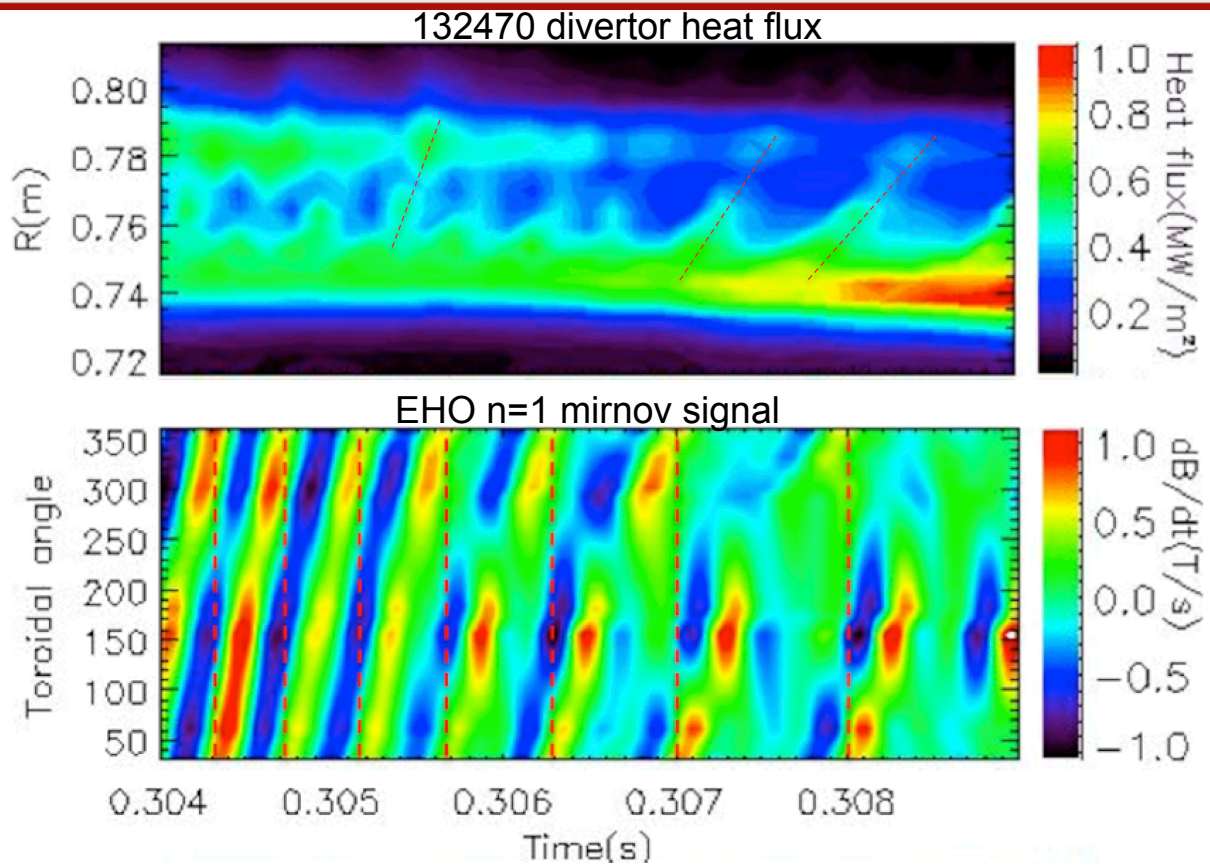
- A radial propagation in heat flux profile is consistent with EHO n=1 mode.
- GPI diagnostic observed the same edge oscillation due to the EHO n=1 mode
- The observation in GPI movie consistent with a filament rotating in the counter current direction.
- A current-carrying filament can induce strike point splitting

Multiple heat flux stripes observed during EHO



- An *EHO-concurrent strike point splitting was observed in the 2D heat flux profiles*
- The *footprints of the split strike line should rotate with the current filament rotation*
  - *Predicted and observed radial propagation of heat flux profile at a given toroidal angle*

The reducing frequency of EHO n=1 mode increases the time for heat flux radial propagation



Hypothesis:

Slow EHO n=1 mode

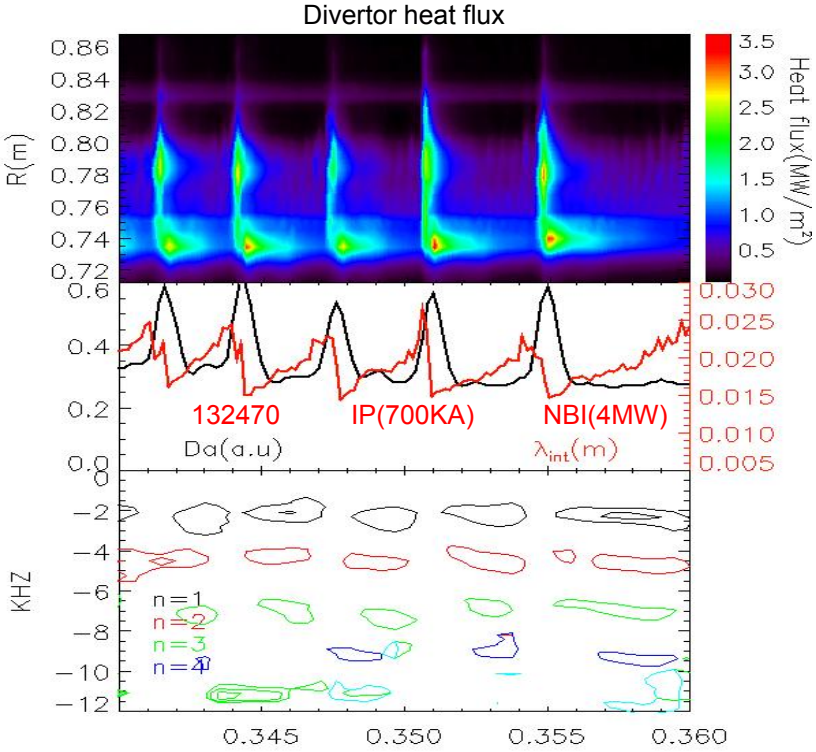
↓

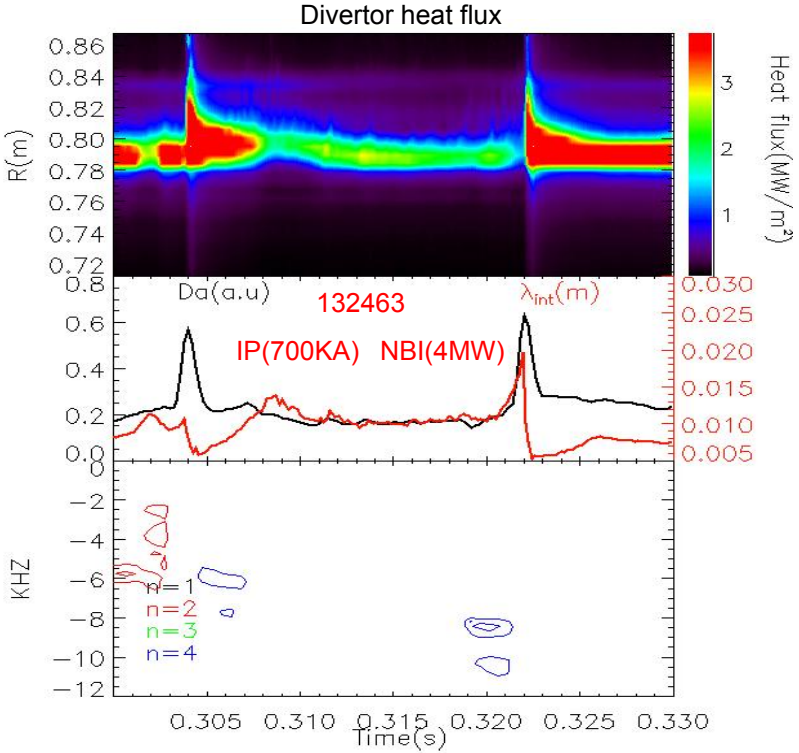
Slow toroidal rotation for footprint of split strike lines

↓

Slow radial propagation of heat flux profile at a given toroidal angle

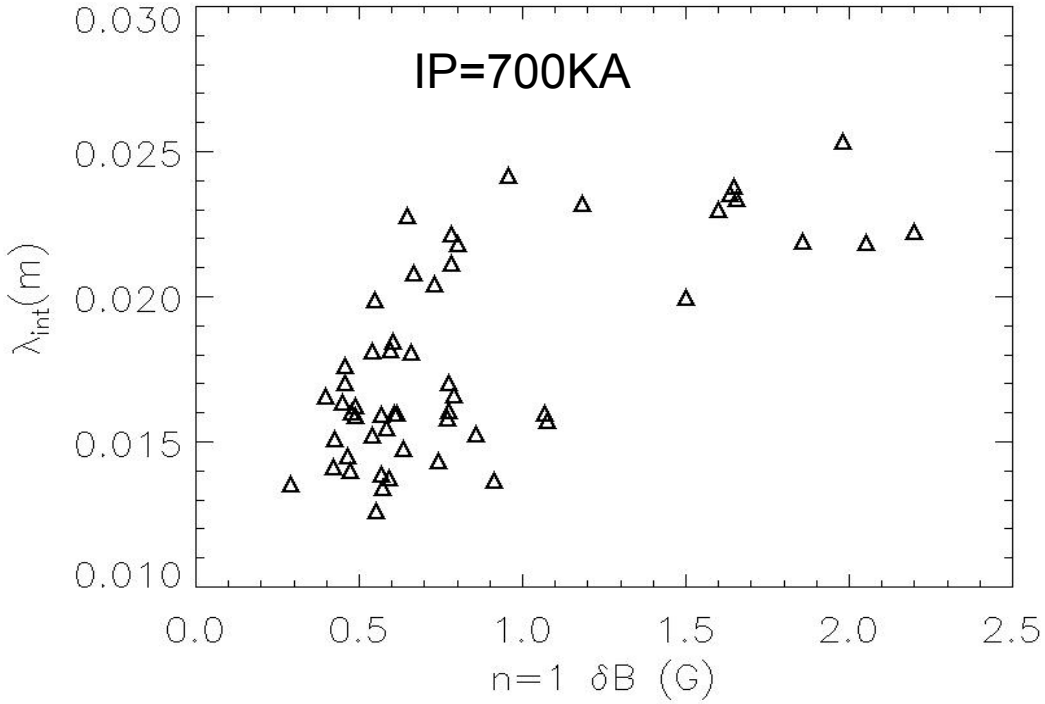
EHO increase λ_{int} during inter-ELM *phases*





- The λ_{int} is much larger with EHO than without EHO
- EHO disappears when ELM appears

The λ_{int} increases with the amplitude of the EHO



EHO amplitude increasing

↓

Increase the intensity of current filaments

↓

Increase the strike points splitting

↓

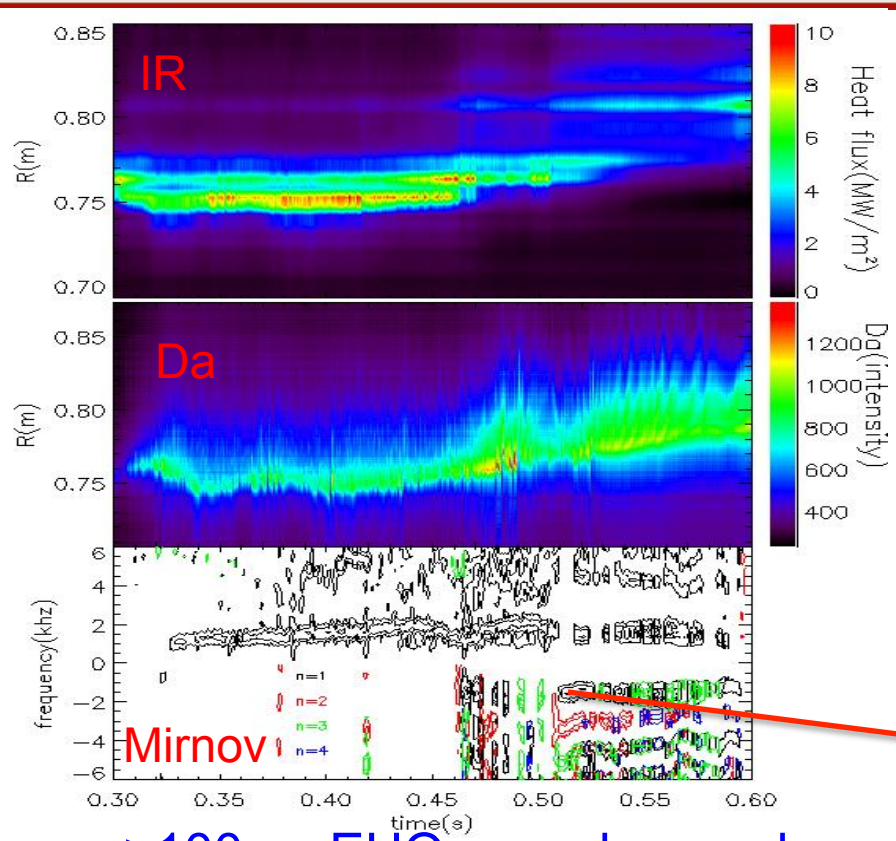
Increase λ_{int}

Summary: a new counter current EHO observation in NSTX

- A counter current "EHO" that rotates in the opposite direction of neutral beam has been identified on NSTX
- This EHO can significantly increase the λ_{int} and decrease the q_{peak} during inter-ELM and ELM-free.
- *Hypothesis: A toroidally rotating filament induced by EHO changes the edge magnetic topology and broadens heat flux profile via strike points splitting*
- The λ_{int} increases with the increasing amplitude of the EHO.

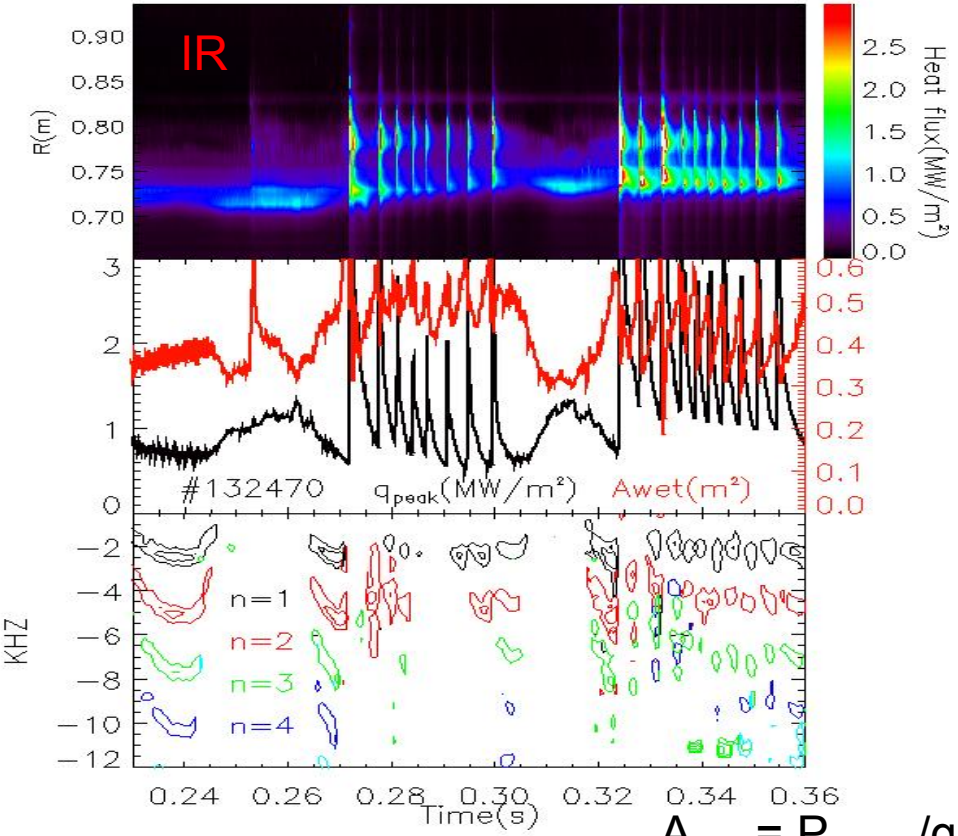
Back up slides

Long-live EHO observation



>100ms EHO was observed

Counter-current EHO observation on NSTX



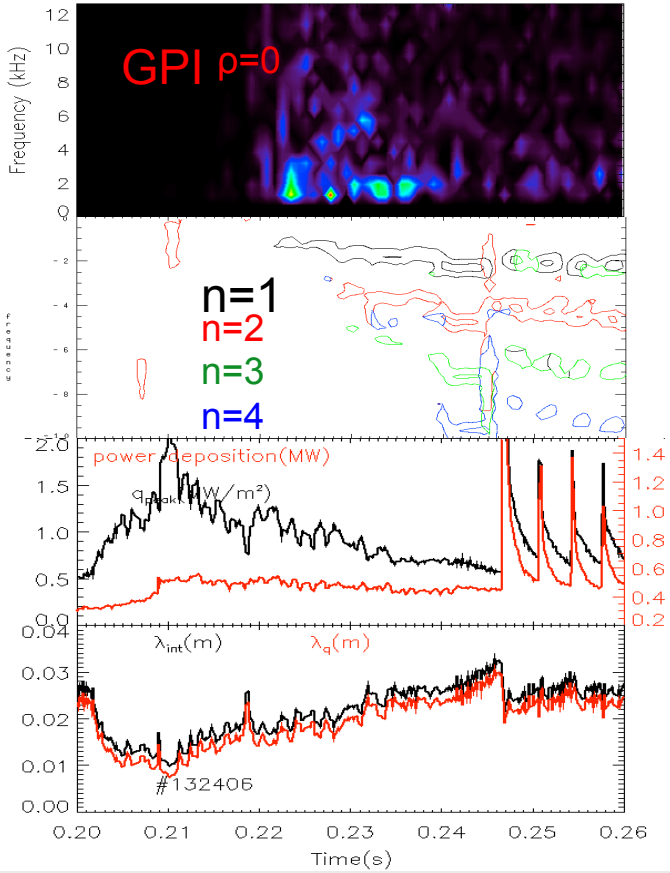
$A_{wet} = P_{div,IR} / q_{peak}$

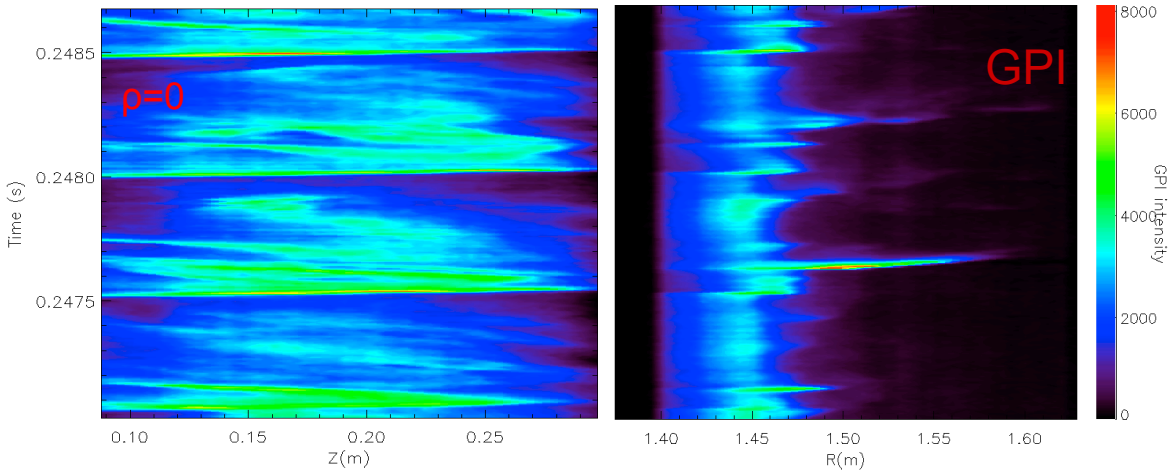
- An counter current EHO with multiple toroidal harmonics n (1-4) was observed to rotate in the opposite direction of the neutral beam

➢ The A_{wet} decreases and the q_{peak} increases when the EHO disappears.

- The A_{wet} is ~0.5m^2 during inter-ELM

EHO induced the 2khz edge and divertor heat flux oscillation?





- The reduced peak heat flux accompanied by EHOs (edge harmonic oscillation)
- The frequency for filamentary divertor heat flux ~2khz is consistent with GPI results and n=1 spectra.
- The GPI movies for single EHOs events is similar as GPI movies during ELM