Structures of Current in Near and Far SOLC Zones during and in-between ELMs

Do SOLC spikes trigger ELMs?

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NSTX FY2010/Early FY2011 Results Review
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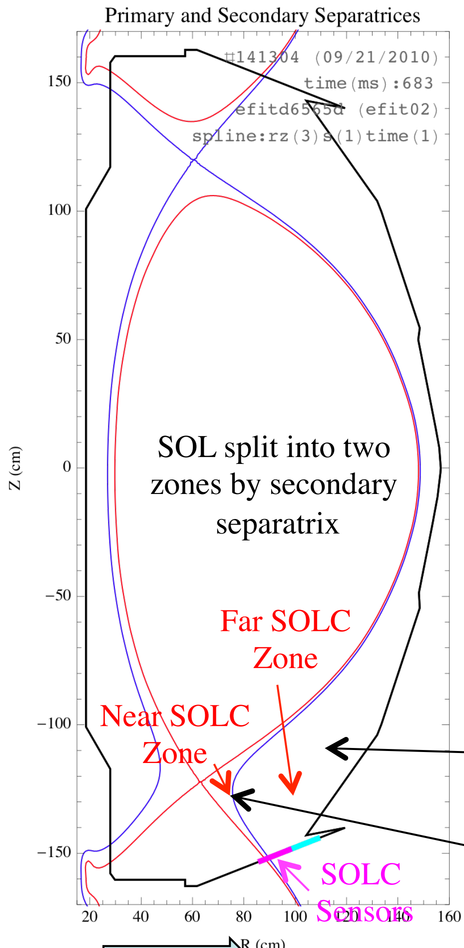
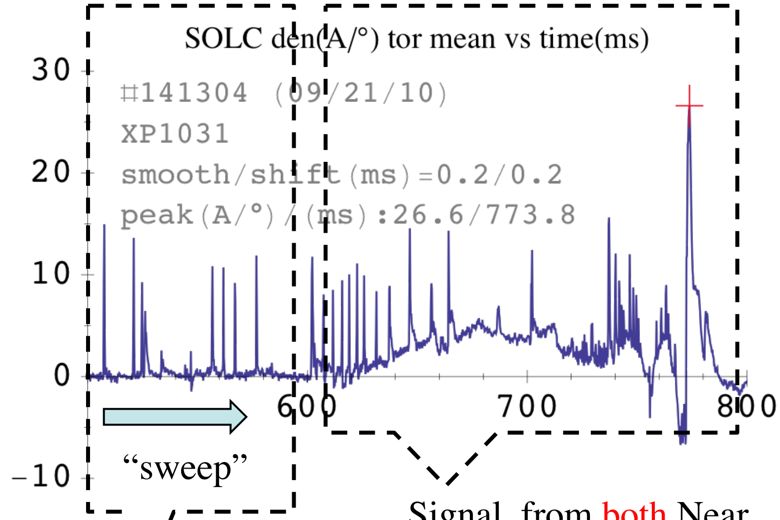
Different SOLC Paths in Near and Far Zones

Near and Far SOLC Zones



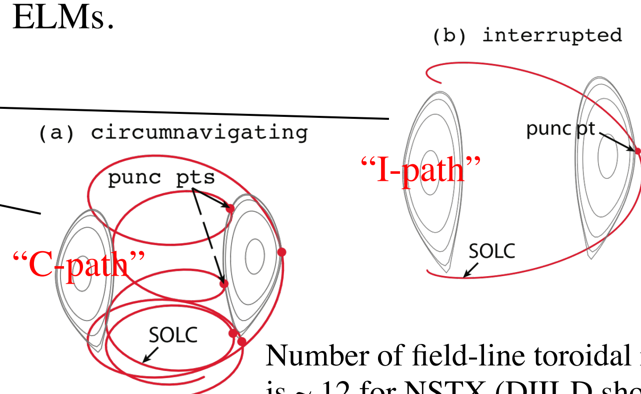
strike points "sweep"

S. Gerhardt



Signal from only Far SOLC Zone, devoid of current except during ELMs.

Signal from both Near and Far SOLC Zones.



Number of field-line toroidal revolution is ~ 12 for NSTX (DIII-D shown here)

In "Near and Far SOLC Zones" SOLC flows along topologically distinct "C-path and I-path" respectively, which have their end points in different pairs of divertors with different thermal environments.

Consequently, thermo-electrically driven SOLC in the two zones may exhibit distinct temporal behaviors as well as magnetic consequences.

Axi-symmetric SOLC in Near Zone, which persists over a discharge evolution time scale, may be driven by Te difference maintained by differential heat flux into in/outboard divertors.

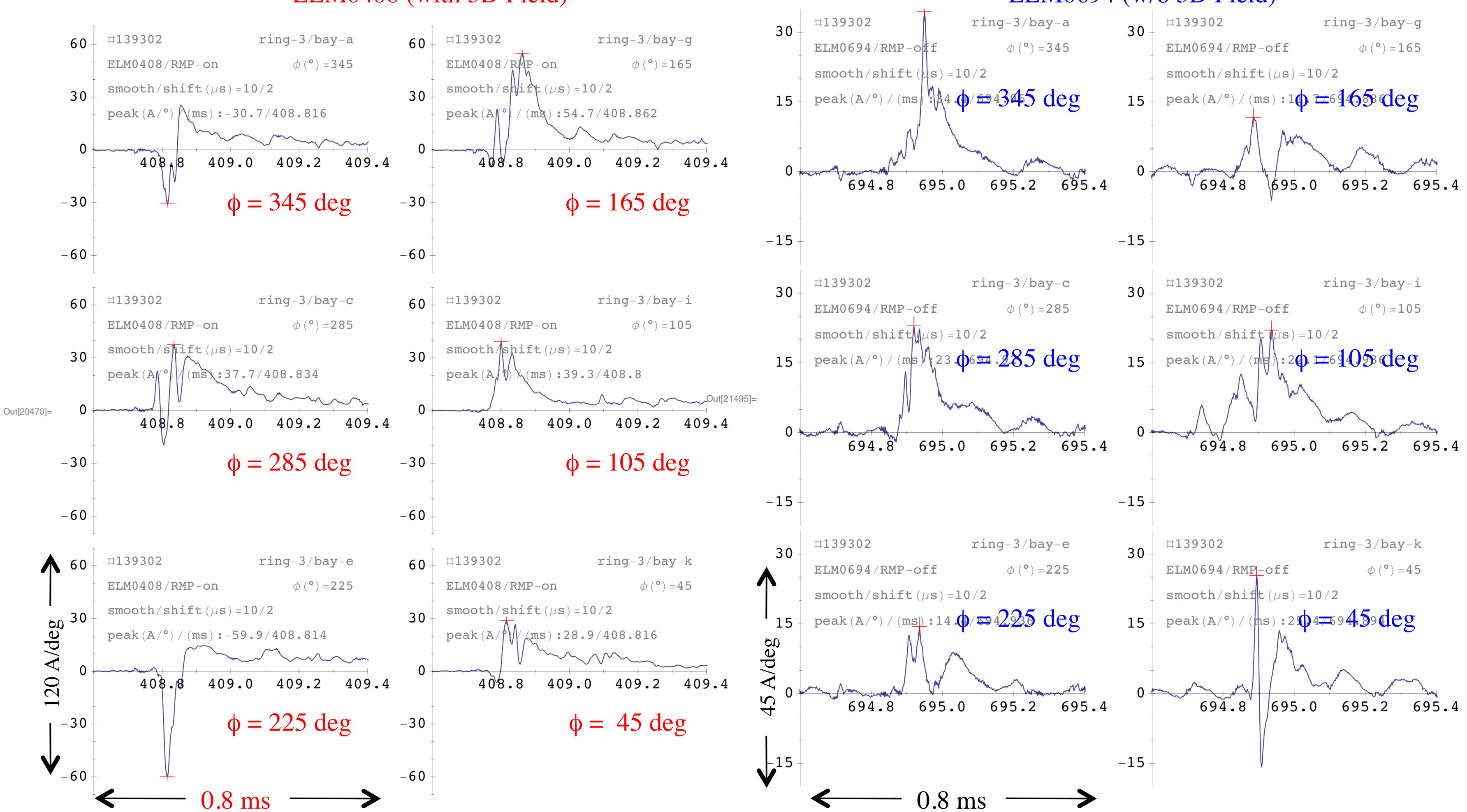
Explosively growing SOLC in Far Zone, spiky in time and non-axisymmetric, may serve as ELMs.

SOLC Manifests as Sharp *Temporal* Spikes in Far Zone

bi-polar in time

SOLC Density (A/deg) vs Time (ms) at Sensors (S. Gerhardt)

ELM0408 (with 3D Field) | ELM0694 (w/o 3D Field)



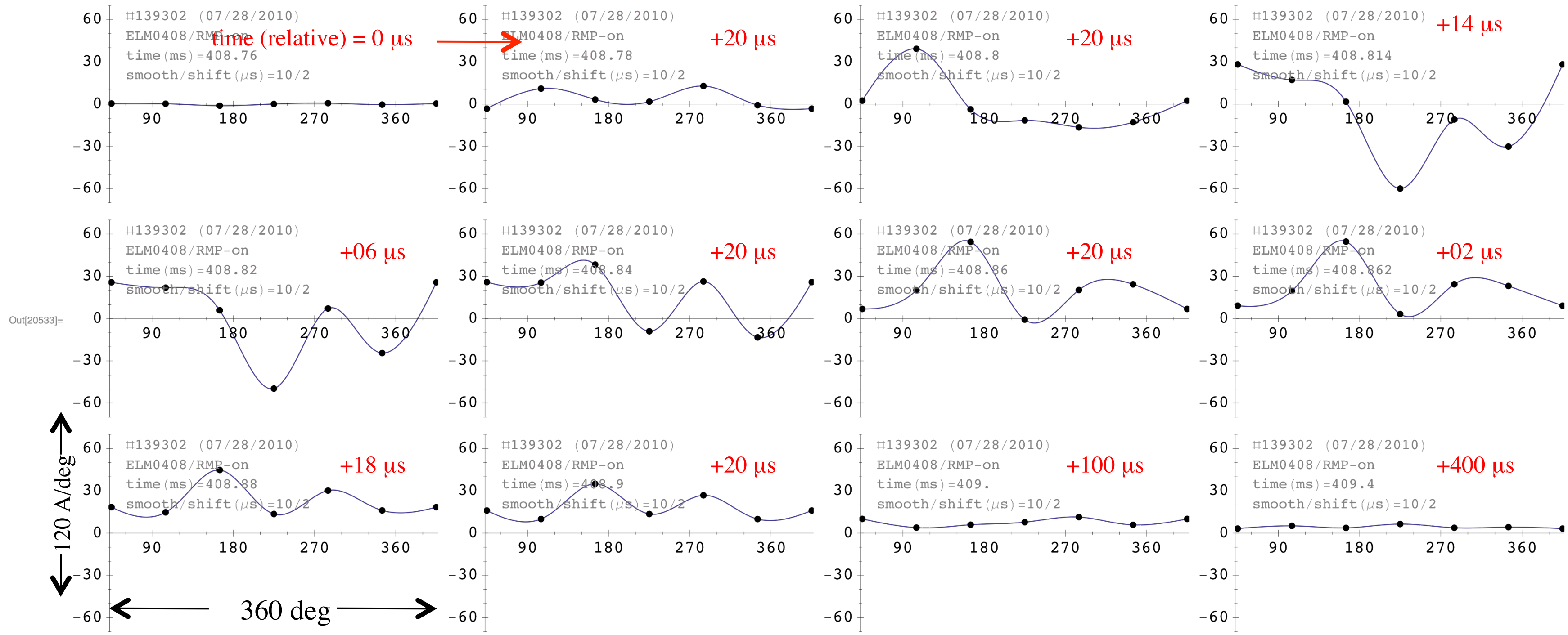
Application of 3D field makes no obvious change in SOLC behaviors in time domain.

SOLC Strongly Non-Axisymmetric in Far Zone - 1

bi-polar in space

SOLC Density (A/deg) vs Toroidal Angle (deg) at Multiple Times

ELM0408 (with 3D Field)

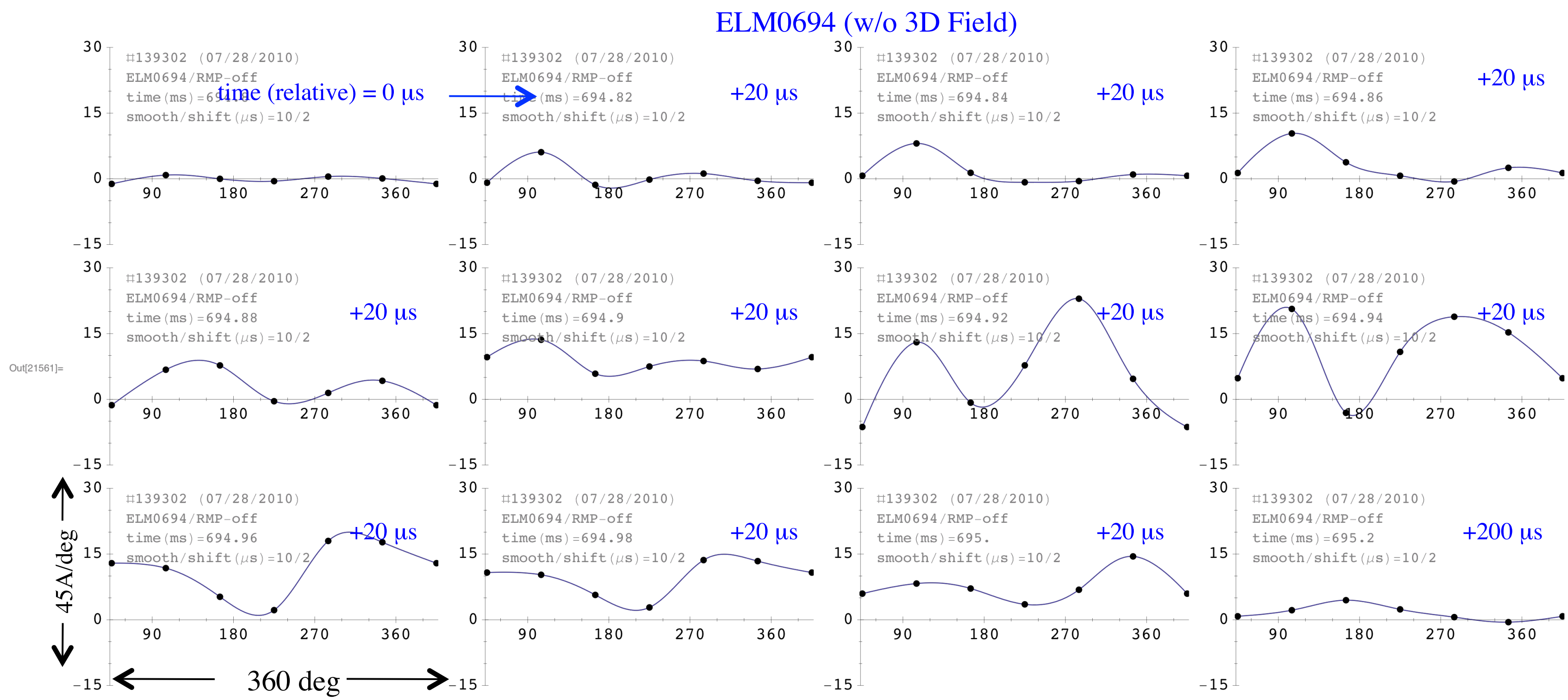


A strongly non-axisymmetric distribution fully develops in ~ 60 μs for this ELM with 3D field (n=3) applied.

SOLC Strongly Non-Axisymmetric in Far Zone - 2

bi-polar in space

SOLC Density (A/deg) vs Toroidal Angle (deg) at Multiple

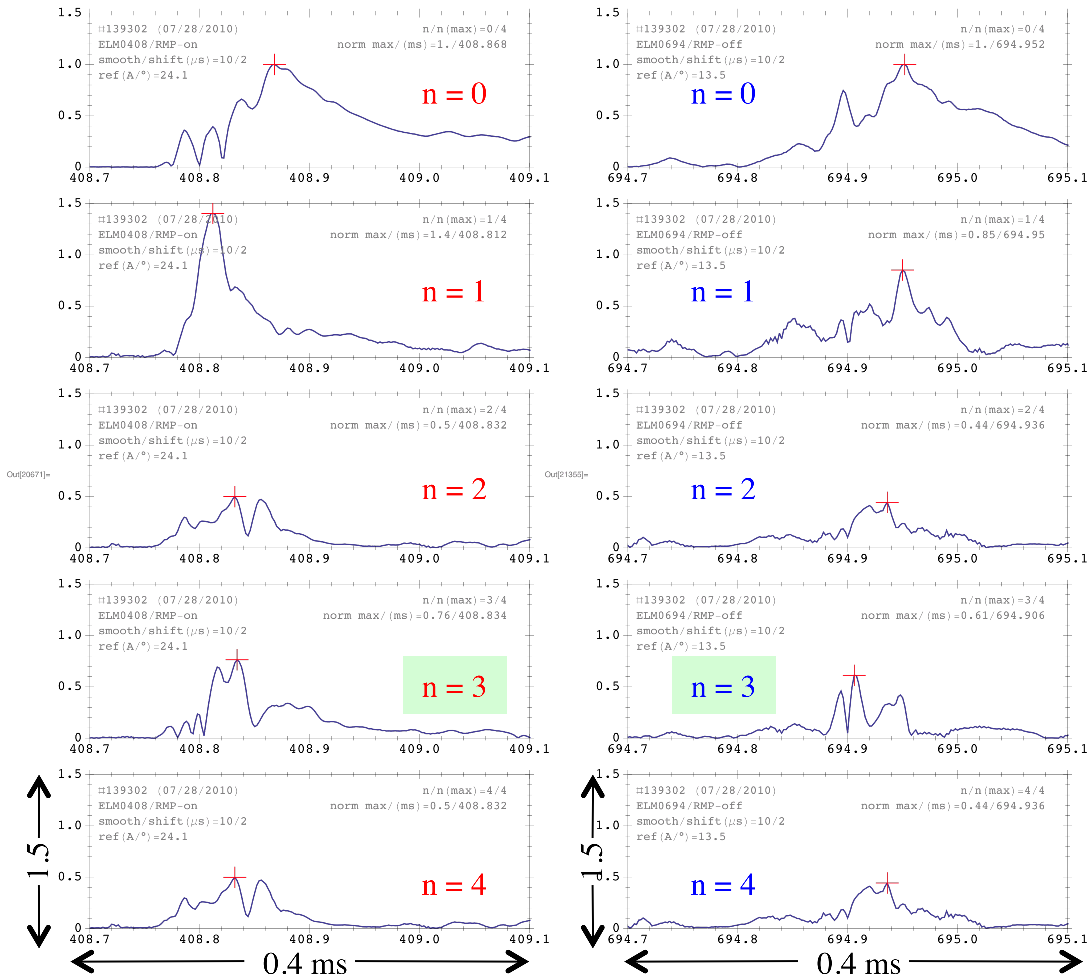


A strongly non-axisymmetric distribution fully develops in ~ 120 μs for this ELM without 3D field applied.

SOLC Toroidal Harmonics in Far Zone

Time Variation of *Normalized* Toroidal Harmonic Amplitude (SVD)

ELM0408 (with 3D Field) ELM0694 (w/o 3D Field)



ELM0408 (with 3D Field)

n = 0 current density reaches 24.1 A/deg, or a total integrated SOLC (*poloidal* current), 8.7 kA (24.1 x 360), much greater, though for a very short duration, than current (1.9 kA) in Near SOLC Zone. (And this, just for Ring-3!)

n = 1 is a dominant non-axisymmetric harmonic (1.4 times n = 0), with RMS amp reaching 8.6 kA (8.7 kA x 1.4 / Sqrt(2)). This is the harmonic that peaks the earliest of all components computed for this ELM (but not universally seen feature).

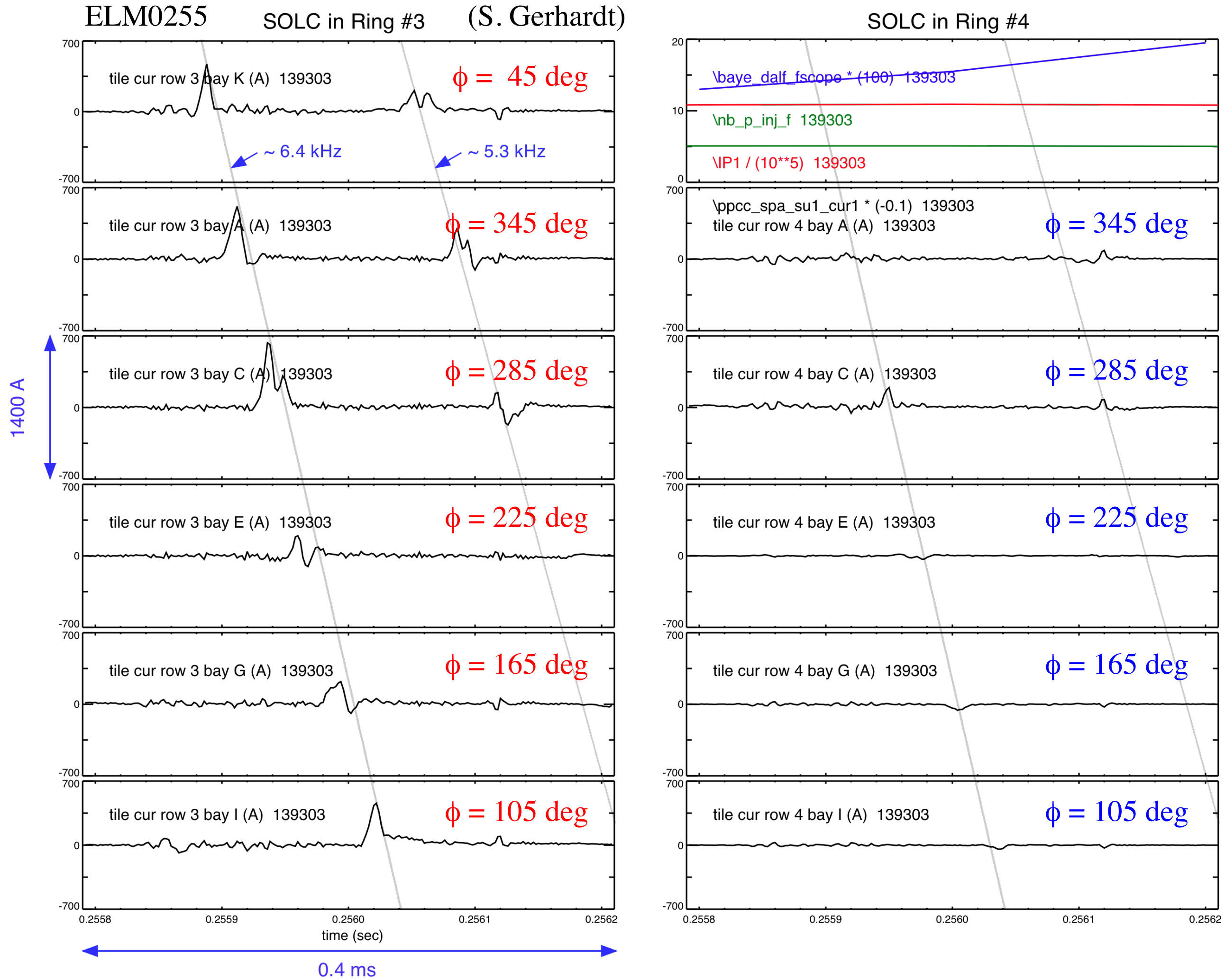
ELM0694 (w/o 3D Field)

n = 0 current density reaches 13.5 A/deg, or a total integrated SOLC, 4.9 kA (13.5 x 360), much greater, though for a very short duration, than current (1.9 kA) in Near SOLC Zone.

n = 1 is a dominant non-axisymmetric component (0.85 times n = 0), with RMS amp reaching 2.9 kA (4.9 kA x 0.85 / Sqrt(2)).

3D Field On/Off Comparisons: Lack of enhancement in n =3 *toroidal* harmonic is in contrast to *radial* striations observed (Ahn, NF 50 045010(2010)) by thermal imaging with 3D field (n = 3) that matched a homoclinic tangle pattern.

Rotating "Current-Carrying Patch" in Far SOLC Zone



A narrow "current-carrying patch," well-defined in its *toroidal* extent, executes, during some *Type-I ELMs* with or w/o 3D field, up to multiple revolutions in clockwise direction at up to several kHz rate - similar to filaments in Type-V ELMs (Maingi, PoP 092510 (2006)).

SOLC emerges on a sensor, just as it disappears from a neighbor. The patch has an estimated *FWHM ~ 25 deg* for this ELM.

SOLC in Ring-3 reached 600 A/tile during this ELM, leading to an estimated total current in the patch of up to 4 kA (triangular toroidal profile over ~ 13 tiles).

As a patch traverses over a succession of sensors, SOLC does not always maintain its temporal waveform, sometimes becoming even bipolar. It is thus the extent of a patch that remains nearly invariant, not current distribution in it.

ELMs Manifest in Far SOLC Zone

•ELMs manifest as sharp *temporal* spikes in Far SOLC Zone, growing explosively on a time scale of a few 10's of μs.

•SOLC spikes arise *in space hitherto substantially devoid of current*.

•SOLC is generally *bipolar* both in temporal and toroidal variations.

•Initial SOLC spikes occur *before* onset of ELM thermal collapse (verified in careful timing measurements in DIII-D) (see EPS '05).

•A toroidally narrow "Current-Carrying Patch" has been observed to rotate up to ~ 14 toroidal revolutions in counter-Ip direction at up to several kHz.

•No obvious differences with 3D field on/off in Far SOLC Zone.

Thermo-electrically driven SOLC may flow (A) along "Double Open-Ended" field lines from a tile in a divertor to another tile in another divertor, or (B) along "Single Open-Ended" field lines in Homoclinic Tangle from plasma interior to a tile in a divertor.

It may be expected in (B) that (i) current be uni-polar, from the plasma to tile, (ii) very large due to a large Te difference, and (iii) exhibit spatial (toroidal) pattern (n = 3 here) of applied 3D field. These expectations have not so far been met, but investigation is still continuing.