I. Optimal Positioning of ELM Triggering Electrodes

II. Validation of SOLC-based ELM-triggering Model

III. Distinguishing between Two SOLC-Based ELM-Models - Inter-Divertor Flux Tube and Homoclinic Tangle

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Related Papers:
APS(2009)PP8.00043
APS(2008)TP6.00033
PRL100(2008)205001
EPS(2005)4.018
NF44(2004)1075-1096
NF42(2002)448-485

Related Papers:
H. Kugel (c.a. 1990)
I. Joseph (IAEA 2010)

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Objectives (3 Proposals)

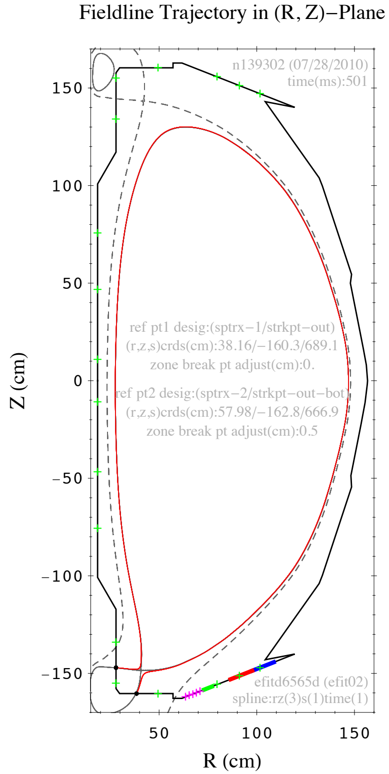
- **Develop a _quantitative_ basis for triggering ELMs on demand using driven SOLC (try out in early phase of NSTX-U?).**
  - **Verify experimentally a "sweet spot" predicted by field-line tracing analysis for optimal non-axisymmetric field generation.**
  - **Develop a field-line tracing technique using injected current (BEaP).**

- **Identify an _elementary_ process that cuts across a multitude of operational recipes for manipulating ELMs.**
  - **Verify space-time separations of pre- and post-thermal-collapse SOLC.**
  - **Distinguish between two SOLC-based ELM models - inter-diverter flux tube and homoclinic tangle models**

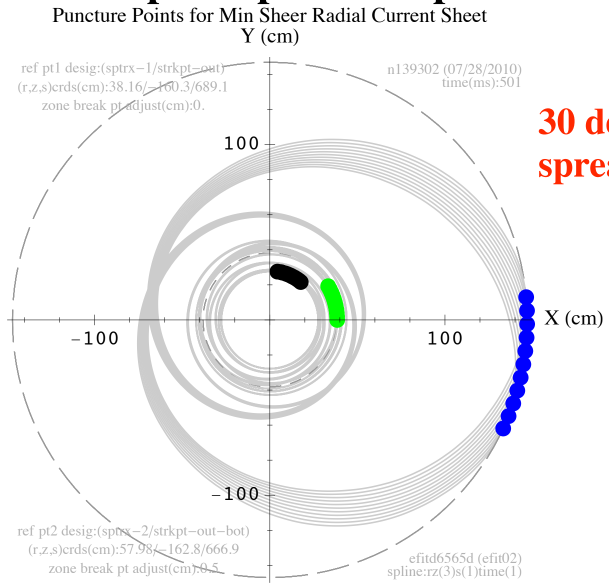
The proposed work is within a broader effort for evaluating the nature and magnitude of error field _dynamically_ generated by SOLC on equilibrium, MHD, and machine operation.

Field Lines in *Toroidal* Sheet Stay Together

field lines in SOL

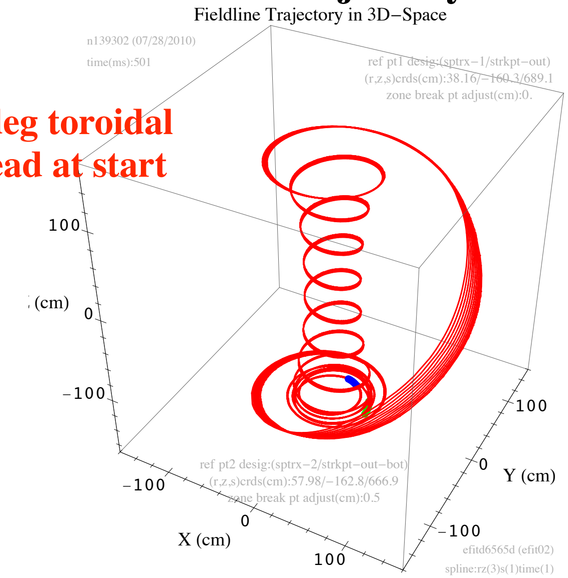


mid-plane puncture points



30 deg toroidal spread at start

field line trajectory

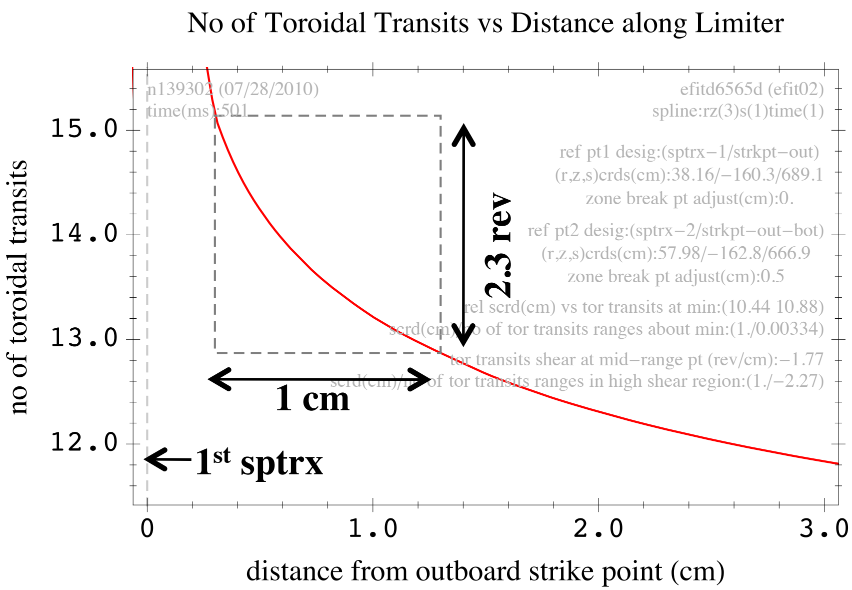


Secondary separatrix plays an important role.

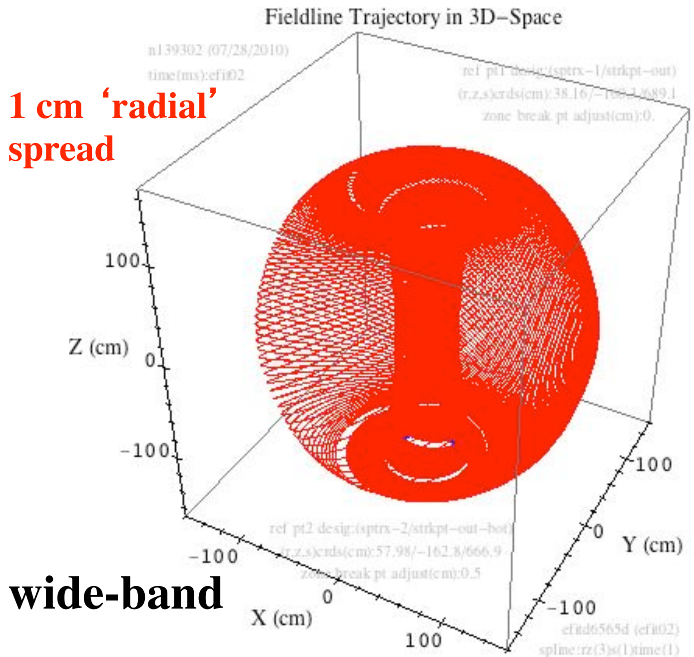
By virtue of symmetry of underlying equilibrium, angular distance between two current filaments (field lines) within a toroidal sheet is invariant: a toroidal profile imposed at divertor is faithfully replicated elsewhere including mid-plane – good for ELM triggering, but slight problem: *there is no such thing as sheet current in real life – current must have radial spread*.

Field Lines *Radially* Distributed Suffer Spreading

no of toroidal transits vs start point 'radius' (diverter-to-diverter)



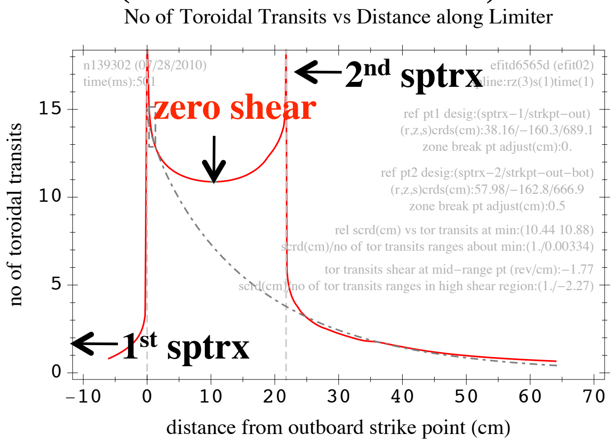
field line trajectory



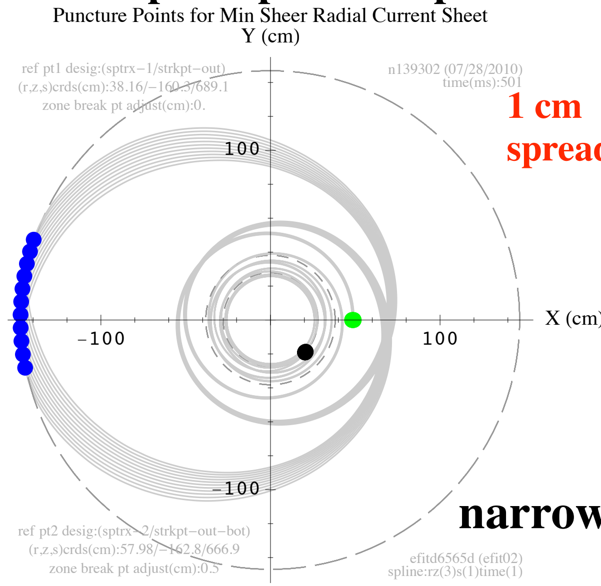
Field lines in a "high shear" region of strong differential revolution arrive in mid-plane with very different toroidal phase, and current along these field lines tend to generate largely axisymmetric field due to "phase-mixing" effect (APS '00 and NF '04). *Not good for ELM triggering, but wonderful for preserving precious axisymmetry.*

Secondary Separatrix Creates Zero Shear Point

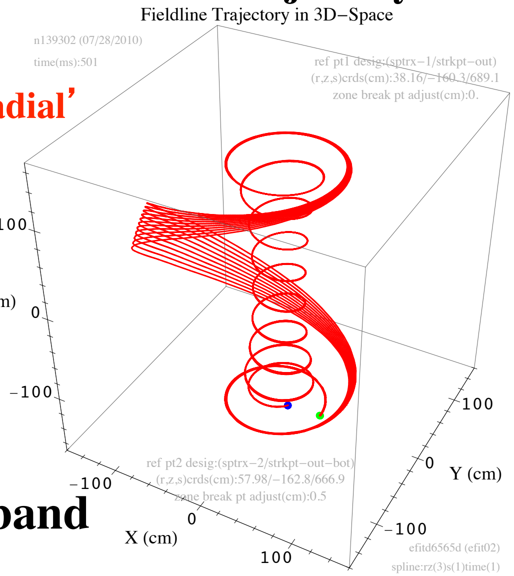
no of transits vs radius (diverter-to-diverter)



mid-plane puncture points



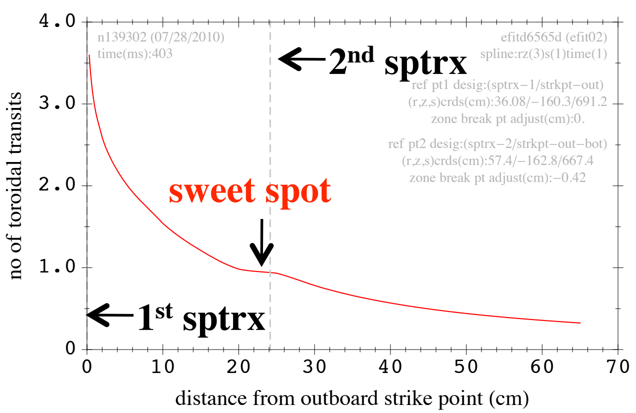
field line trajectory



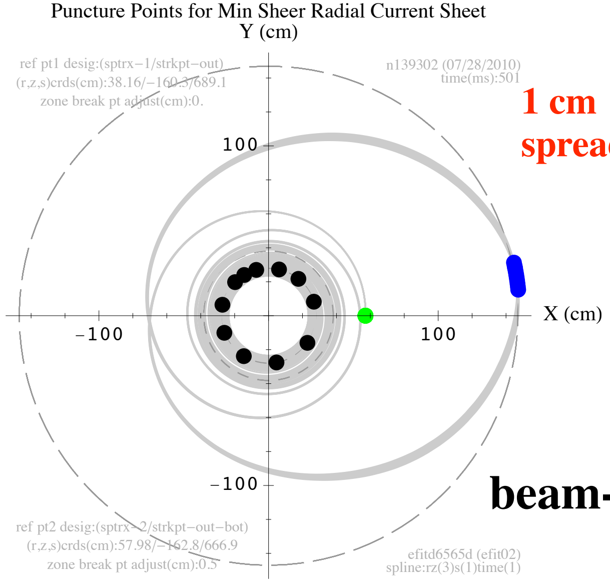
Because of singularity at a secondary separatrix, a high “shear region” next to the primary separatrix gives way to a “zero-shear point” farther away (~ 10 cm) from strike point, whereby a narrow-band toroidal spread is recovered in spite of a radial spread in starting points.

Shoot *Beam-like Bunched Current* from Sweet Spot

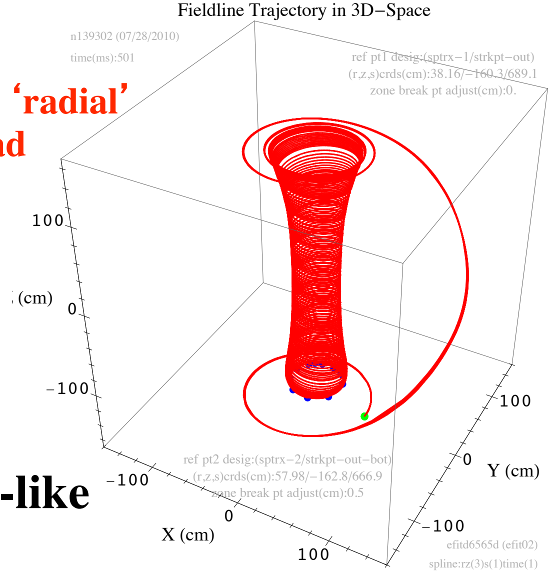
no of transits vs radius (diverter-to-mid-plane)



mid-plane puncture points



field line trajectory



Why bother with "diverter-to-diverter" transits? What matters more is "diverter-to-mid-plane transits.

Extremely narrow beam current could escape detection, if stationary, by widely spaced magnetic sensors.

Optimized on a "divertor-to-mid-plane" transits basis, a zero-shear point is farther away (~ 24 cm), where current suffers minimal toroidal spreading while being radially compressed (current bunching) – sweet, if to trigger ELMs, but dangerous, if to preserve axisymmetry. Natural question arises: *does "triggering current" flow at sweet spot during intrinsic and induced ELMs?*

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Sweet Spot for ELM-Triggering (Prop-1)

DISCHARGES: moderately low triangularity with strike point on inboard of BEaP placed at a sweet spot with intrinsic ELMs (exp-1) or RMP-induced ELMs (exp-2).

ACTUATORS: sinusoidal current through BEaP bay-E electrode(s) driven by BOP amplifier(s) (~ 10 A/10 kHz) – use "two-color" detection if possible

SENSORS: (signals sampled at 200-500 kHz or higher, unless stated)

- Mirnov coils (HF and HN)
- BEaP bay-E probes (swept-voltage mode at 1 kHz sweep rate)
- BEaP bay-K electrodes (grounded and used as SOLC sensors)
- Halo current sensors in rings #3 and #4
- Divertor Langmuir probes (swept at 100 Hz and sampled at 5 kHz)

EXPERIMENT (1/2 day): trace field lines using BEaP-injected sinusoidal current by taking advantage of current bunching caused by sweet-spot and of long-time-series FFT, both for enhancing magnetic signal detection.

Test Key Element of SOLC-based ELM Model (Prop–2)

DISCHARGES: outboard strike point on inboard of BEaP (low triangularity) with intrinsic ELMs (exp-1) or RMP-induced ELMs (exp-2)

SENSORS: (signals sampled at 200-500 kHz or higher, unless stated)

- Halo current sensors in rings #3 and #4
- BEaP electrodes in ring #2 bay-E and K
- Mirnov (HF and NF)
- BEaP Langmuir probes at bay-E and K (1 kHz swept-voltage mode)
- Divertor Langmuir probes (100 Hz swept-voltage mode/sampled 5 kHz)

EXPERIMENT (1/2 day): Capture pre-collapse signals, fast (~ 10 us) and non-axisymmetric (extremely so, if from sweet spot), by halo and Mirnov diagnostics, and post-collapse signals, slow (~ 100 us), delayed, and axisymmetric, by BEaP electrodes (operated as SOLC sensors), and demonstrate existence of space-time separations of two types of SOLC accompanying ELMs.

Inter-Div Flux Tube vs Homoclinic Tangle (Prop – 3)

DISCHARGES: very low but previously produced triangularity (exp-1) with halo current sensors in near SOL, just outboard of strike point, and high triangularity (exp-2) with halo sensors in far SOL and with infrequent or no ELMs and with or without (non-ELM-producing) RMP.

SENSORS: (signals sampled at 200 kHz, unless stated)

- Halo current sensors in rings #3 and #4
- BEaP electrodes in ring #2 bay-E and K (as SOLC sensors in exp-1)
- BEaP Langmuir probes at bay-E and K (1 kHz swept-voltage mode)
- Divertor Langmuir probes (100 Hz swept-voltage mode/sampled 5 kHz)

EXPERIMENT (1/2 day): Search for a pattern corresponding to applied RMP in *toroidal* SOLC profile in near and far SOL, as evidence for current flowing along homoclinic tangle (and possibly correlate with *radial* striations in density). Use RMP n = 1, 2, or 3 to avoid potential aliasing with six-element halo sensor array.