Control of Scrape-Off-Layer Current (SOLC) to Ameliorate Effects of MHD Phenomena

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Motivation

Control coils in ITER are too far away from plasma for generating a well-defined spectrum and/or large enough field for effective control of ELMs and RWMs. SOLC, flowing next to plasma surface, may offer an attractive means of producing required field (old idea).

Resonant Magnetic Perturbation (RMP) has shown its ability to prevent plasma from rebuilding edge pedestal through generation of stochastic field (recent demonstration).

This paper suggests actively driven SOLC can realistically generate requisite stochastic field: field observed during ELMs is likely to have arisen mostly from SOLC comparable to coil current used in generating ELM-free discharges by RMP (new observation).

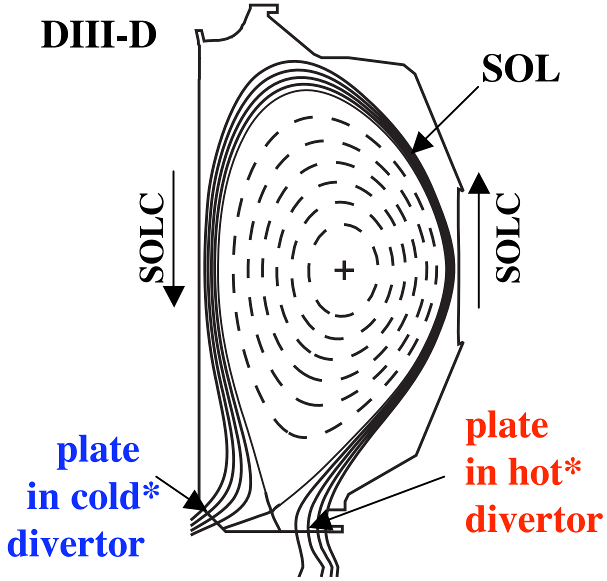
Highlights

B_θ field patterns calculated for model SOLC reproduce prominent features of *measured* field patterns during ELMs:

- **"*Anti*-ballooning," larger on inboard than outboard side.**
- **"Ribbon-like" structure* observable on outboard side.**
- **Peak in divertor, near separatrix strike point.**

***Possibly analogous to earlier observations (E. Strait, Phys Fluids '97; R. Maingi, PoP '06)**

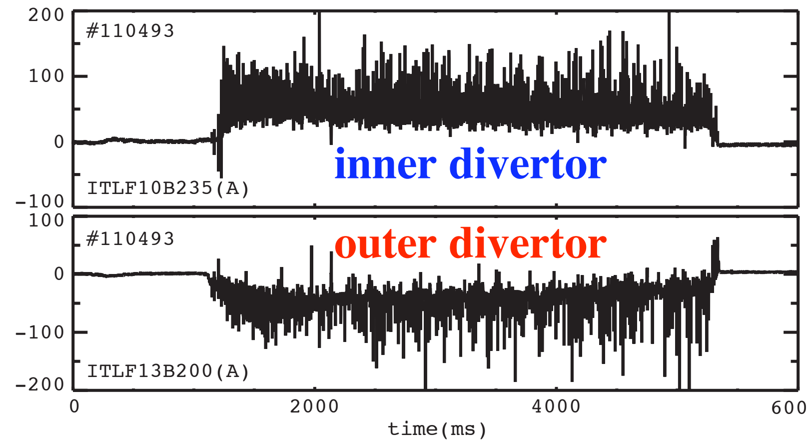
Enhanced Current Flows in SOL during ELMs*



(*Hot/cold may get reversed farther away from strike point.)

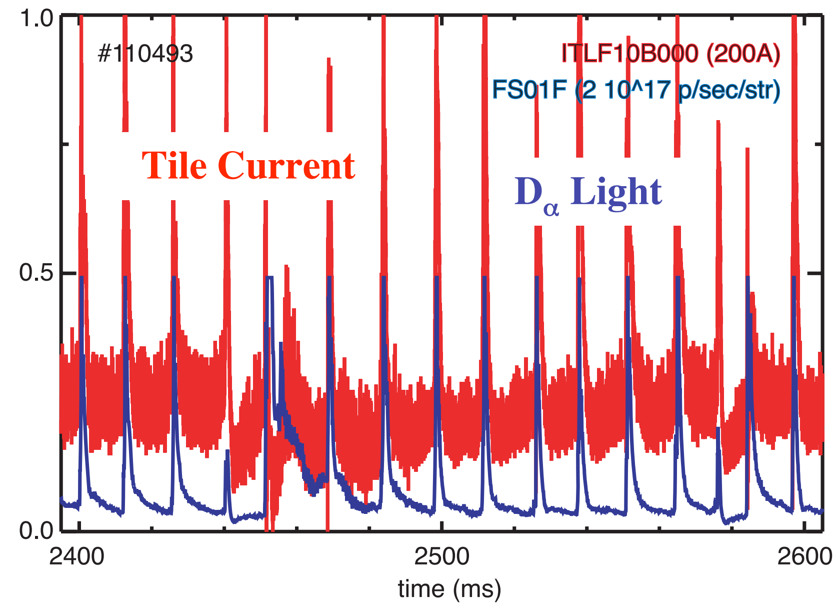
Opposite Current Directions in Two Divertors

Positive signal means current flowing from SOL into tile.



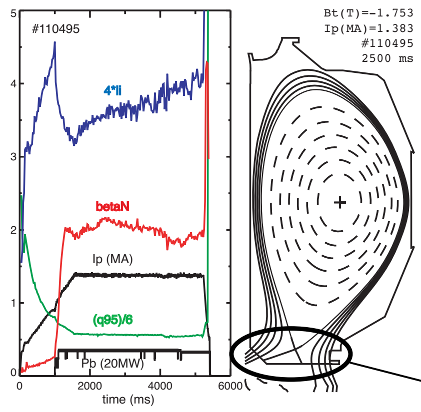
SOLC flows in high β discharges, and becomes large and spiky during ELMs.

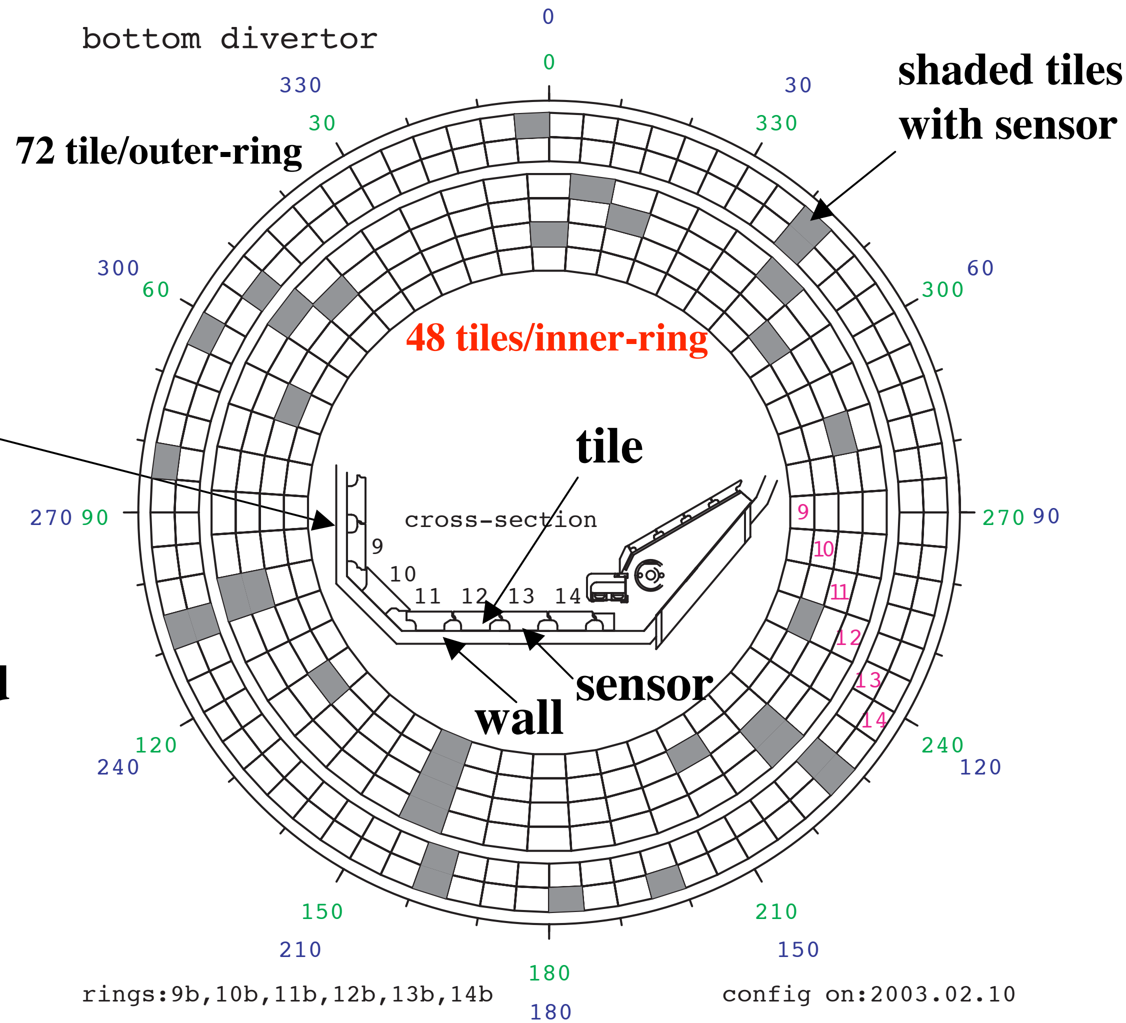
Spikes in SOLC are as good an indicator of ELMs as spikes in D_α.



***Harbour, Contrib. Plasma Phys., 1988**

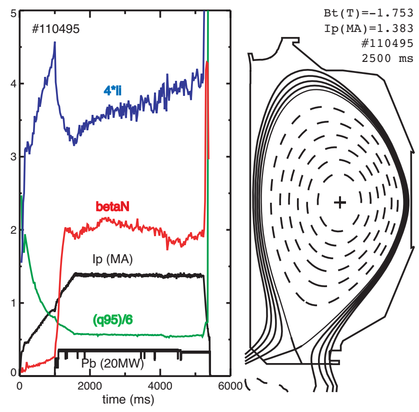
Resistive Sensors Measure SOLC through Divertor Tiles

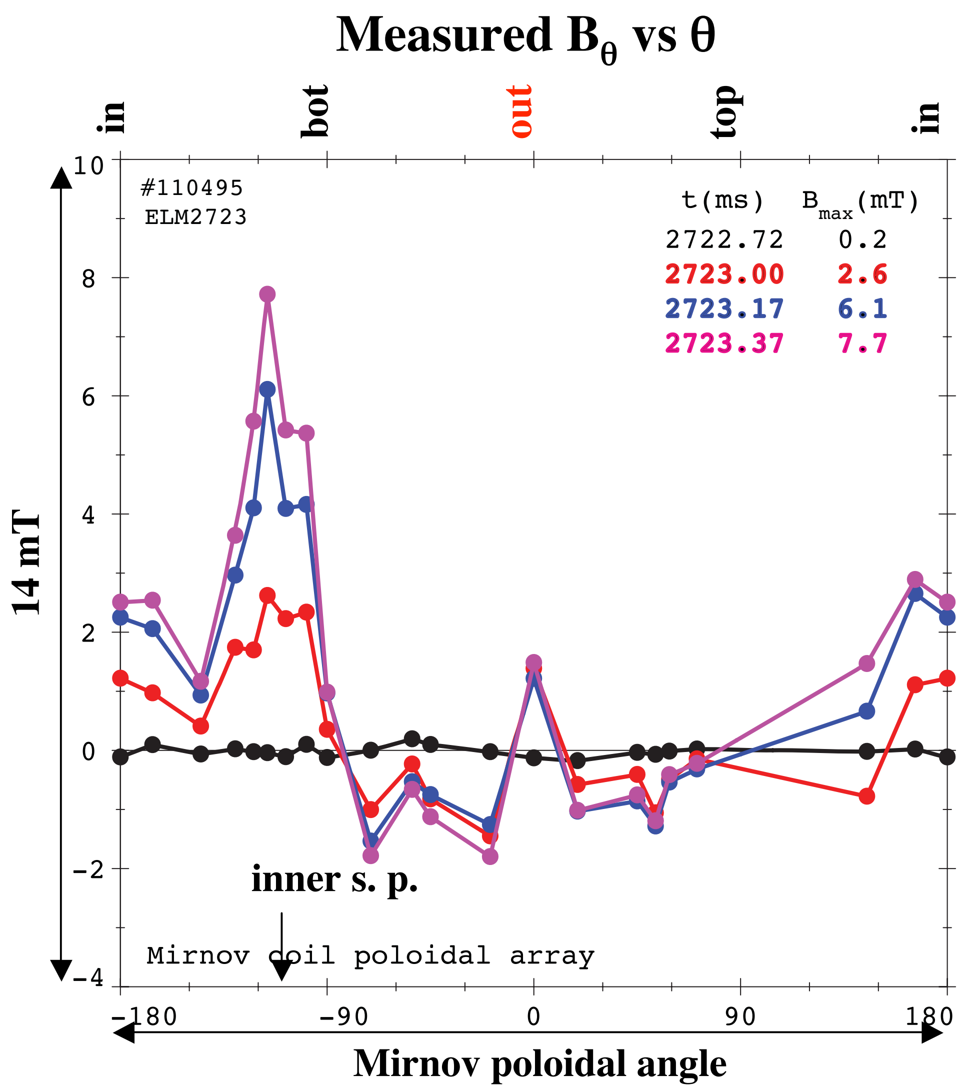




<~10 % of tiles in selected tile-rings have sensors.

B_θ *Poloidal* Patterns Begin to Rise and Peak in Divertor





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From s110495_MagneticsAnalV522_Res.nb

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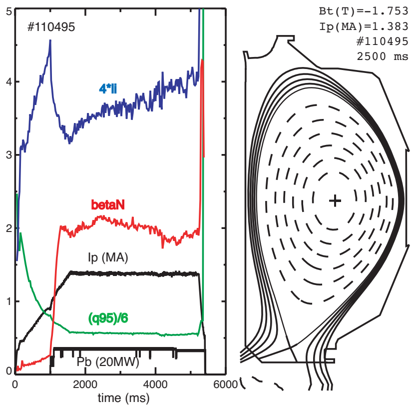
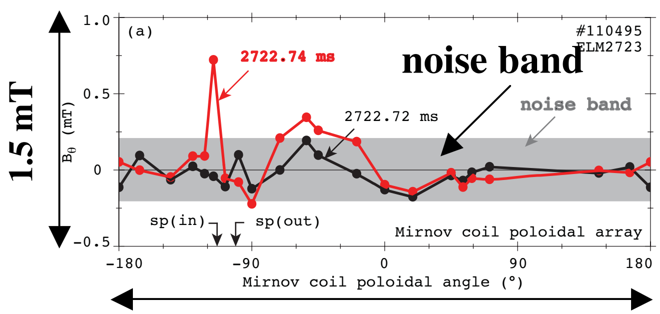


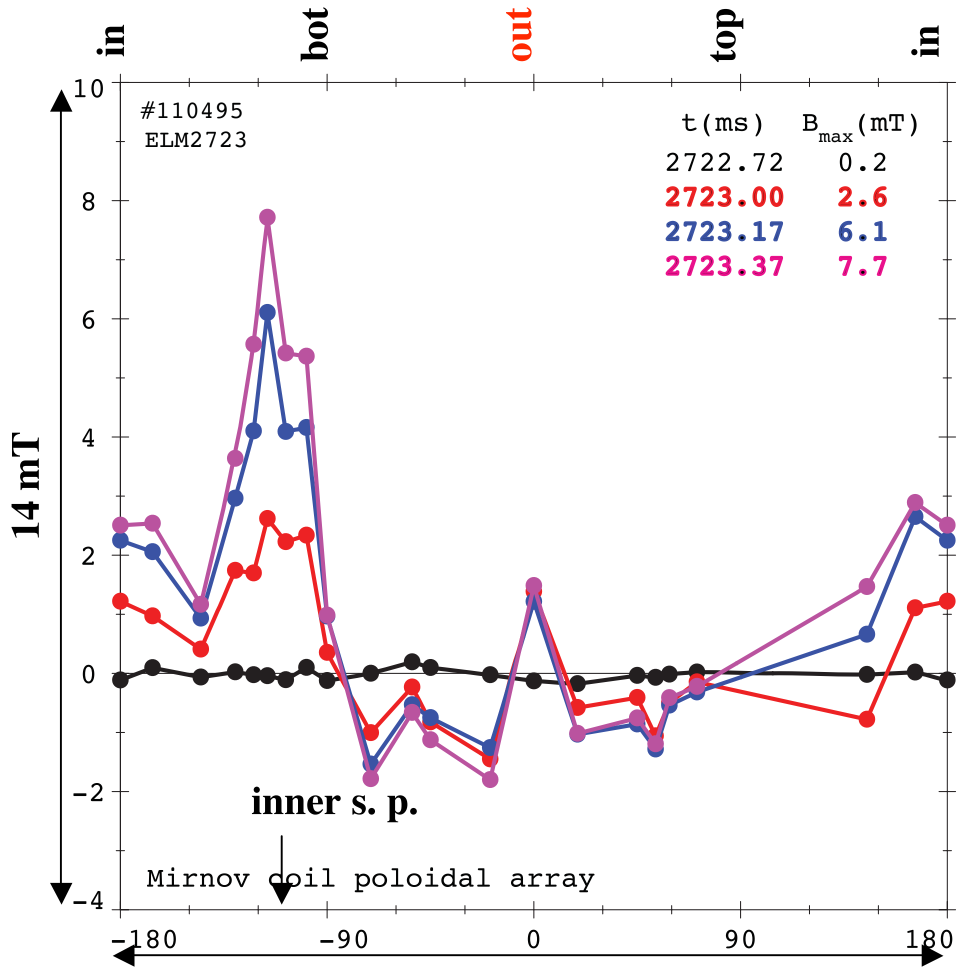
Onset Period



Mirnov poloidal angle

B_θ breaks out of noise in < 20 μs

Measured B_θ vs θ



Mirnov poloidal angle

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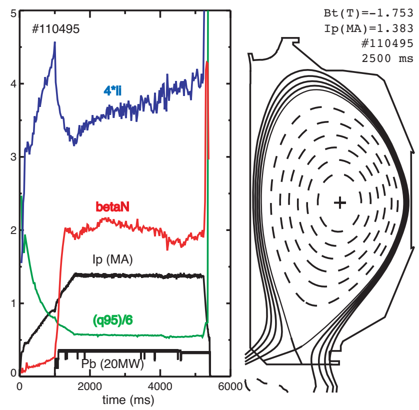

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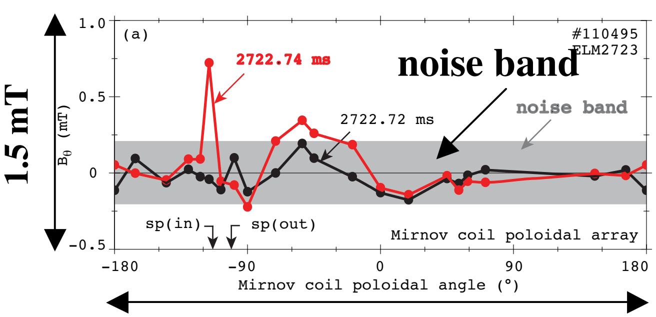

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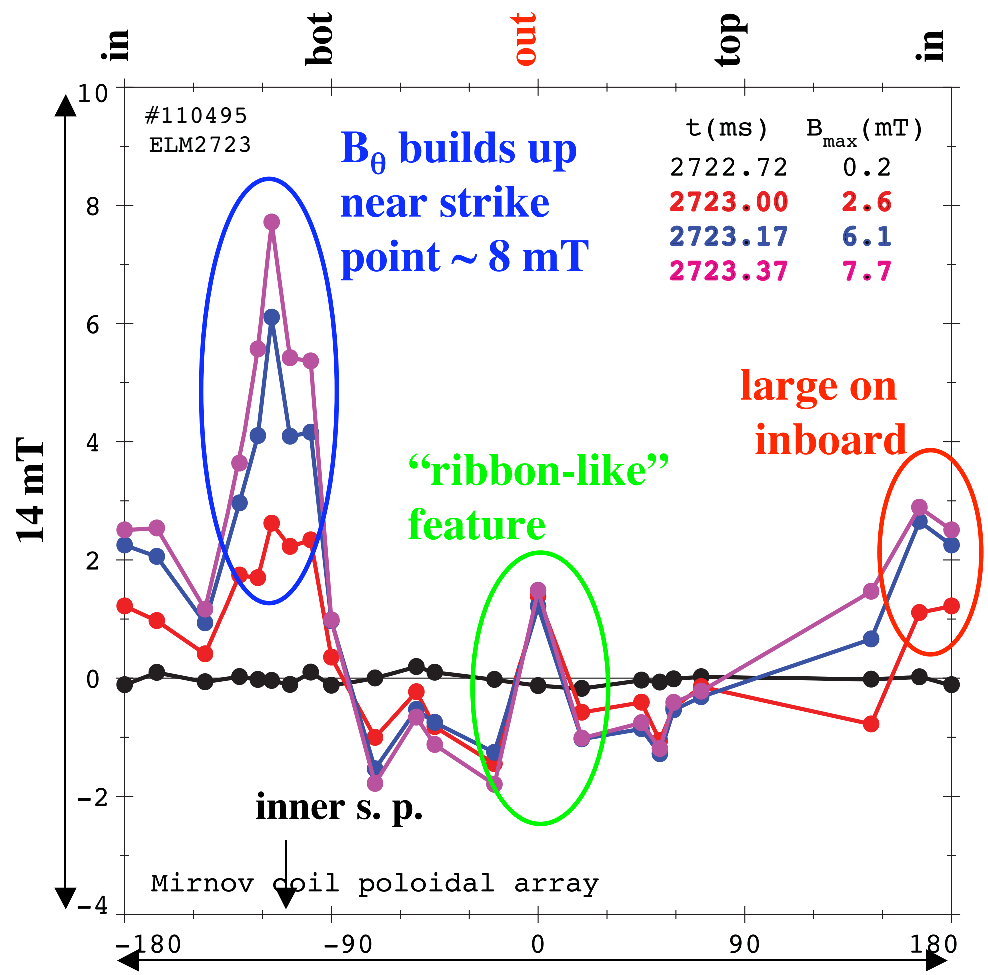

Mirnov poloidal angle

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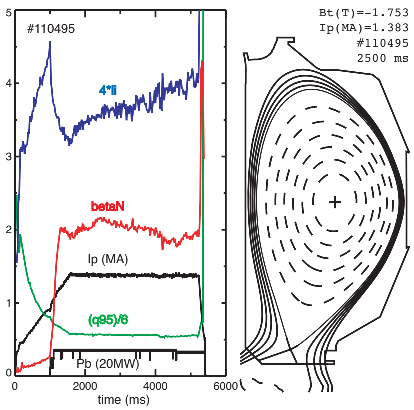
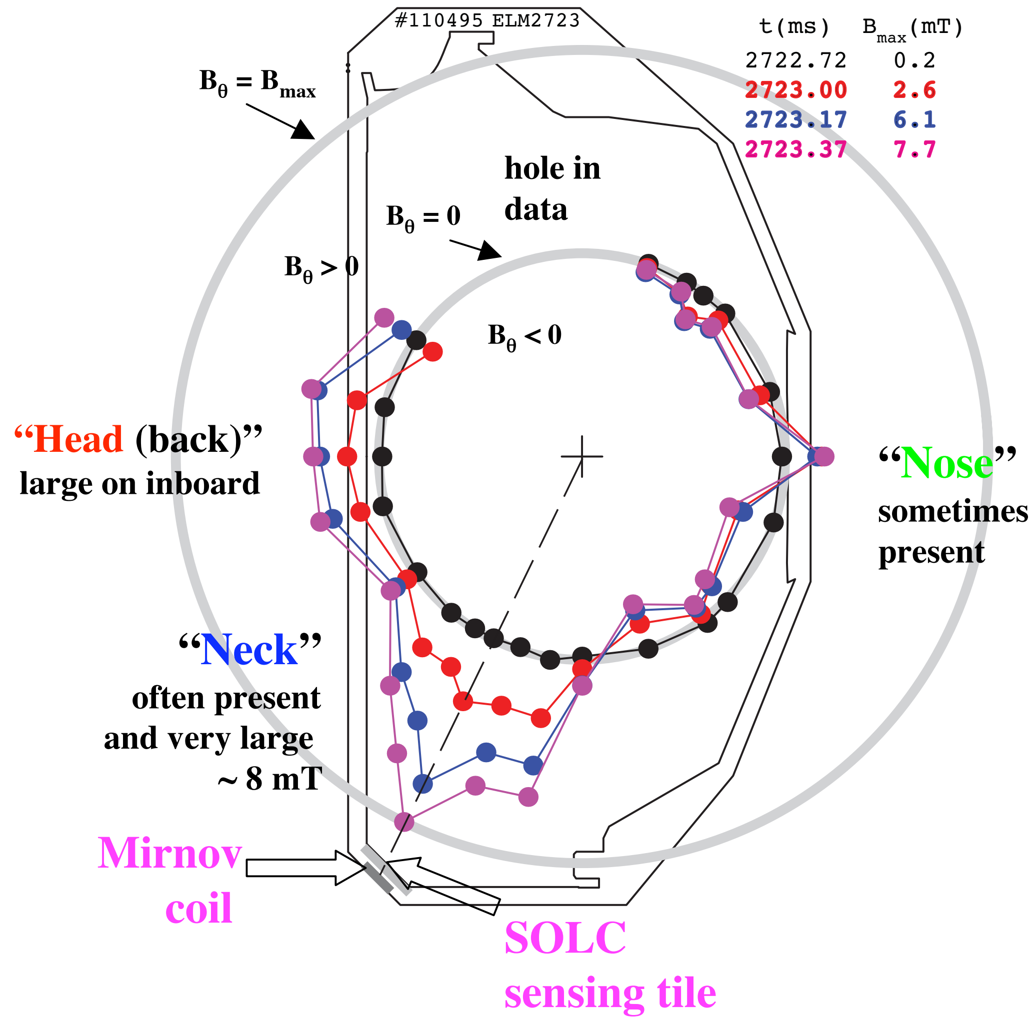
B_θ *Poloidal* Variation Possesses Unusual Features

Same Info as Previous Slide
Presented in "Polar Plot"



B_θ spatial variations set "boundary conditions" in attributing observed field to a possible origin.

Magnetic "Face" of ELM



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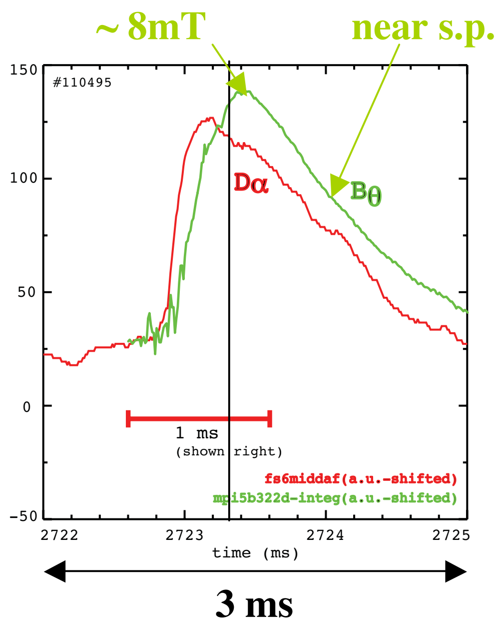
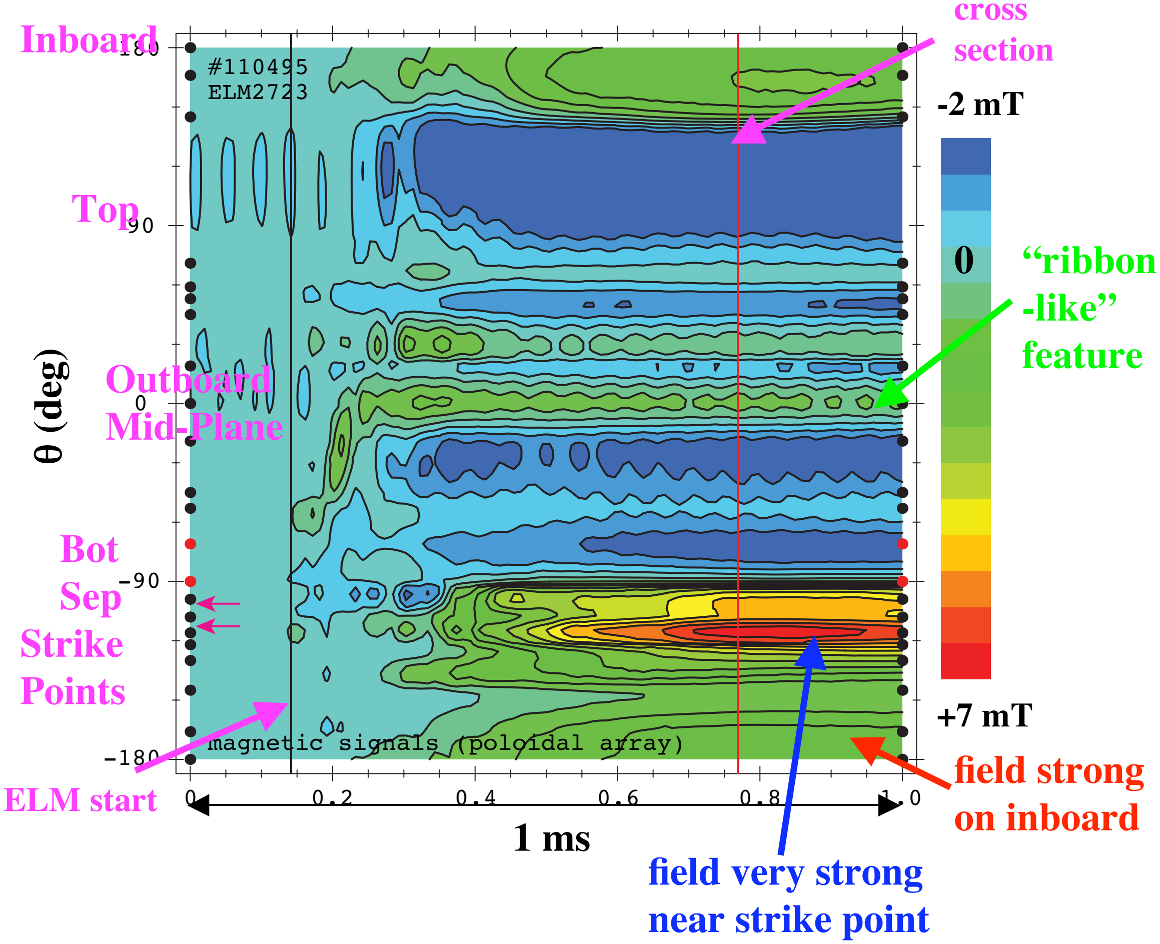
"*Anti-*Ballooning" Patterns Persist during ELMs

Mirnov and D_α



Measured B_θ in Time-vs-θ Contour Plot



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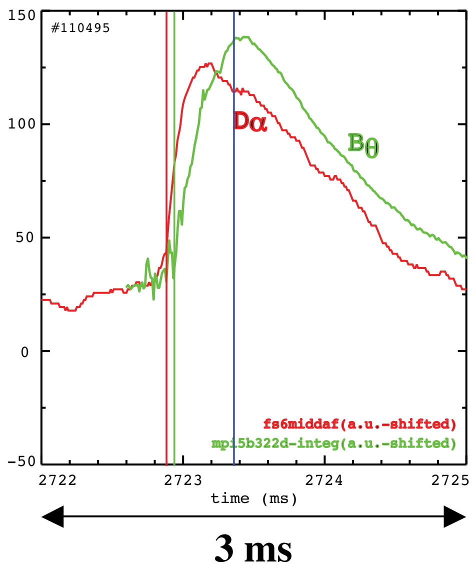
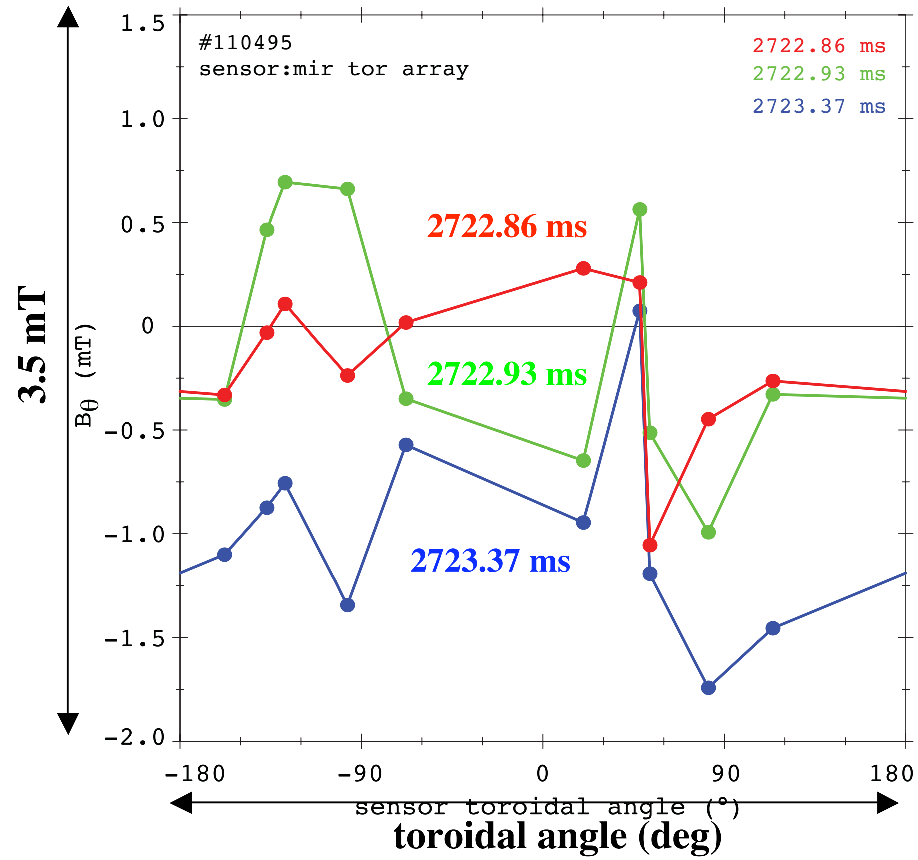
B_θ Non-axisymmetric along Outboard Mid-plane

Mirnov and D_α
(a.u. - shifted)



B_θ Vs *Toroidal* Angle
(along Outboard Mid-Plane)



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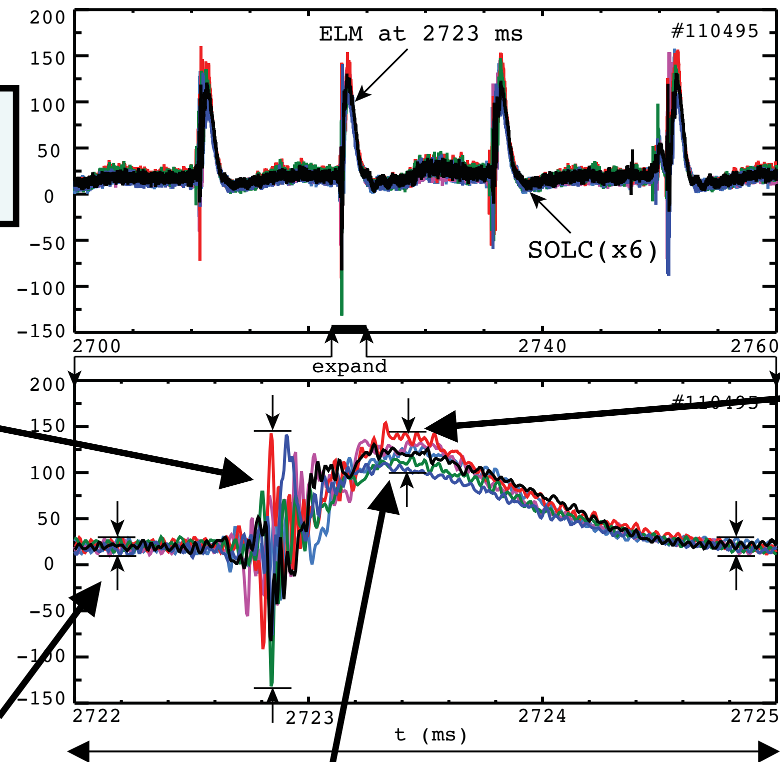
SOLC during ELMs

six SOLC signals in toroidal array overlaid

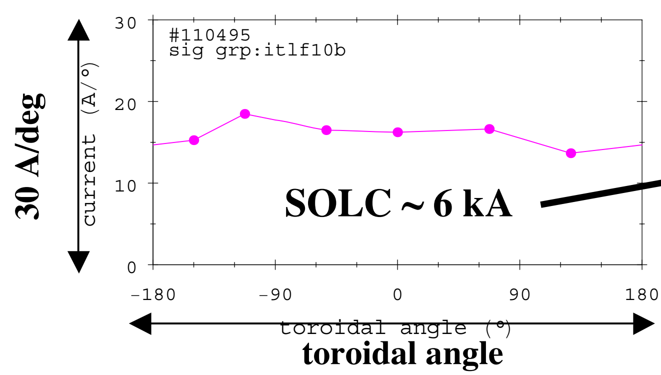
Early ELM phase with strong non-axisymmetric and bipolar variations

"Noise band" between ELMs (mostly due in this case to coherent oscillations unrelated to ELMs, f ~ 23 kHz, n=2)



At ELM peak, SOLC is more axi-symmetric in fractional terms, i.e., variations < 30 % of peak, but possibly still significant in absolute terms.

Some "errant" SOLCs, well outside of the above range, also observed in some cases



Comparable to I-coil current, but circumnavigates plasma at close distance.

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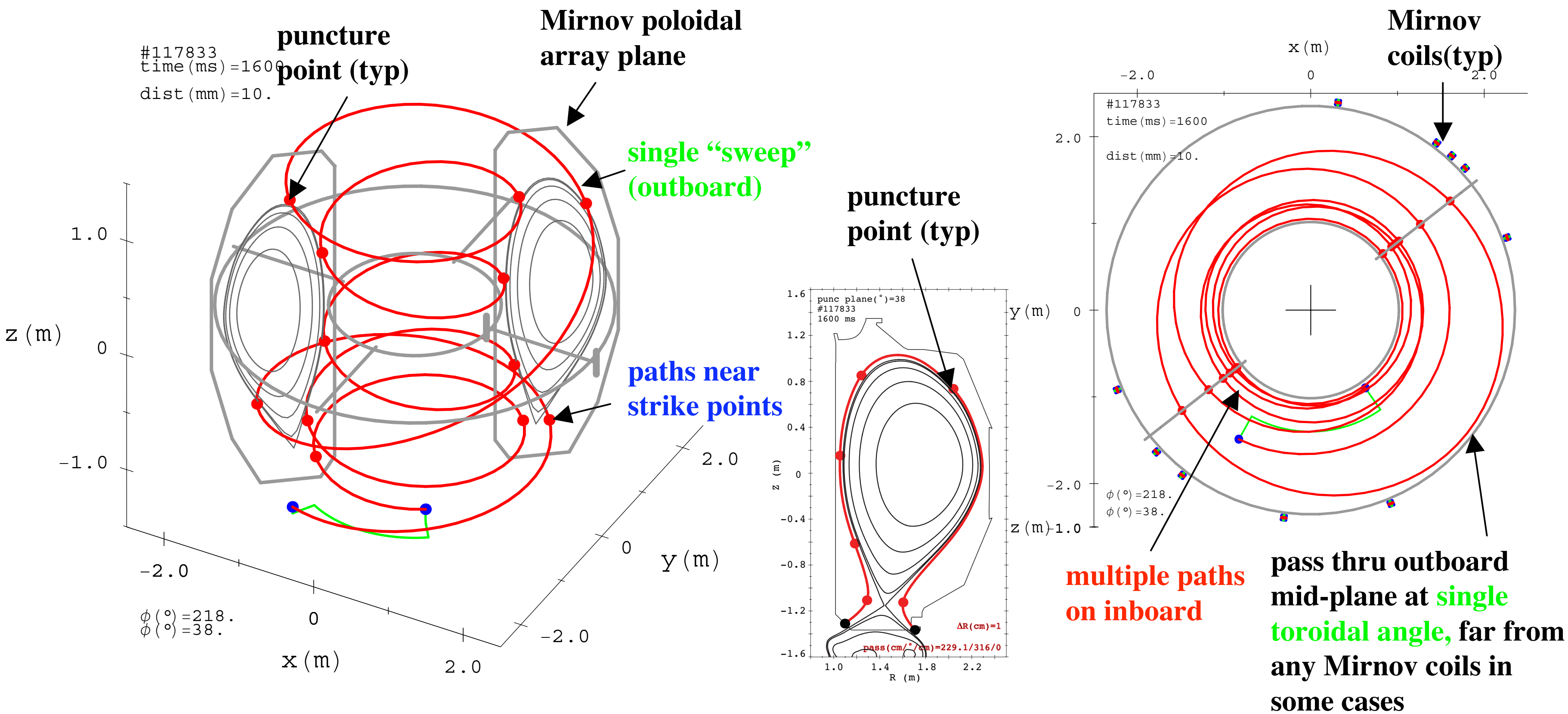
Generic Geometrical Features of Filament SOLC



(a) Multiple paths on inboard side - field observed at all poloidal/toroidal angles.

(b) Single "sweep" on outboard side - sparse toroidal array may miss it.

(c) Paths near separatrix strike points - large field observable there.

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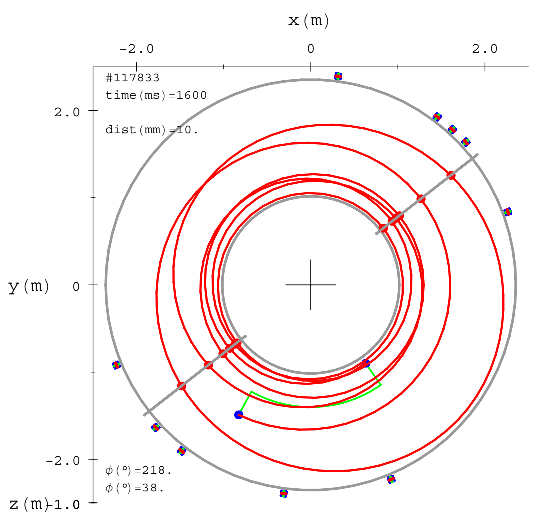
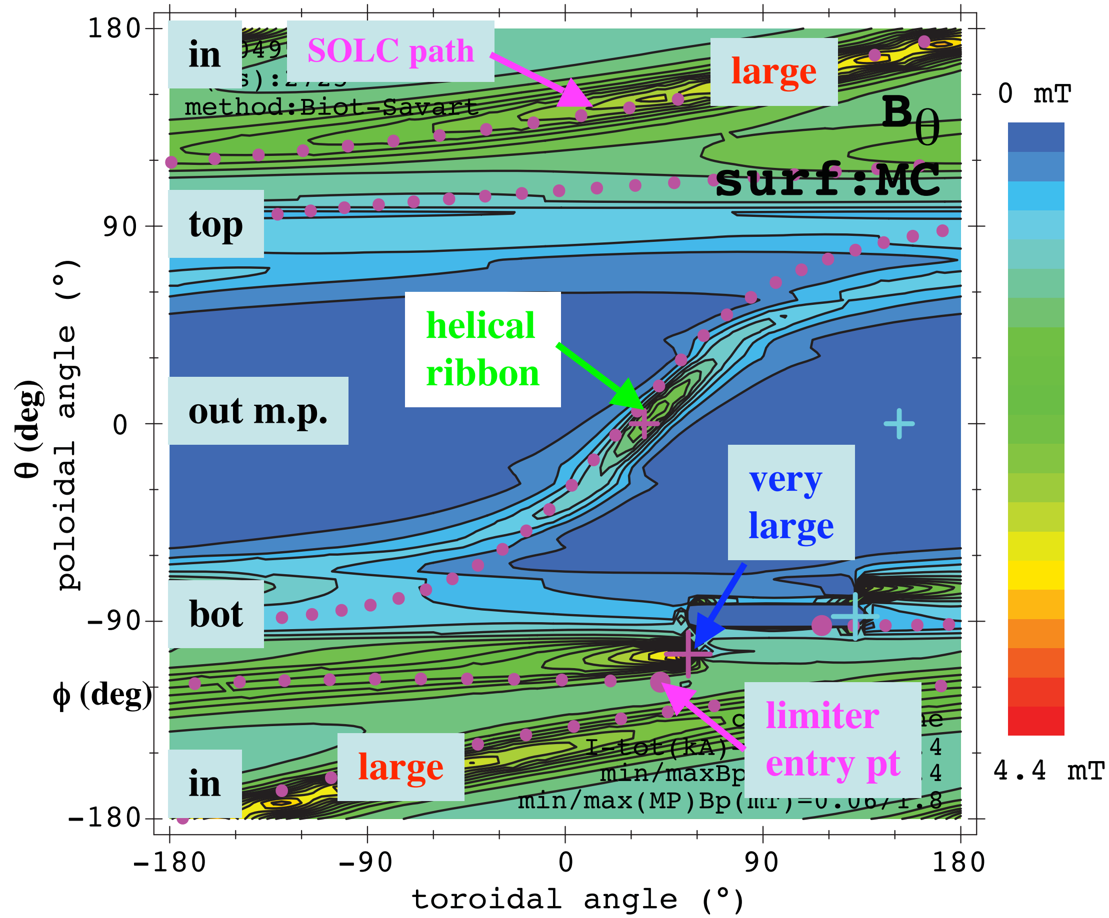
SOLC Filament Model Reproduces Key Features of B_θ Poloidal Variations during ELMs



Calculated **B_θ in φ Vs θ Contour Plot**
(on Mirnov Coil Installation Surface)



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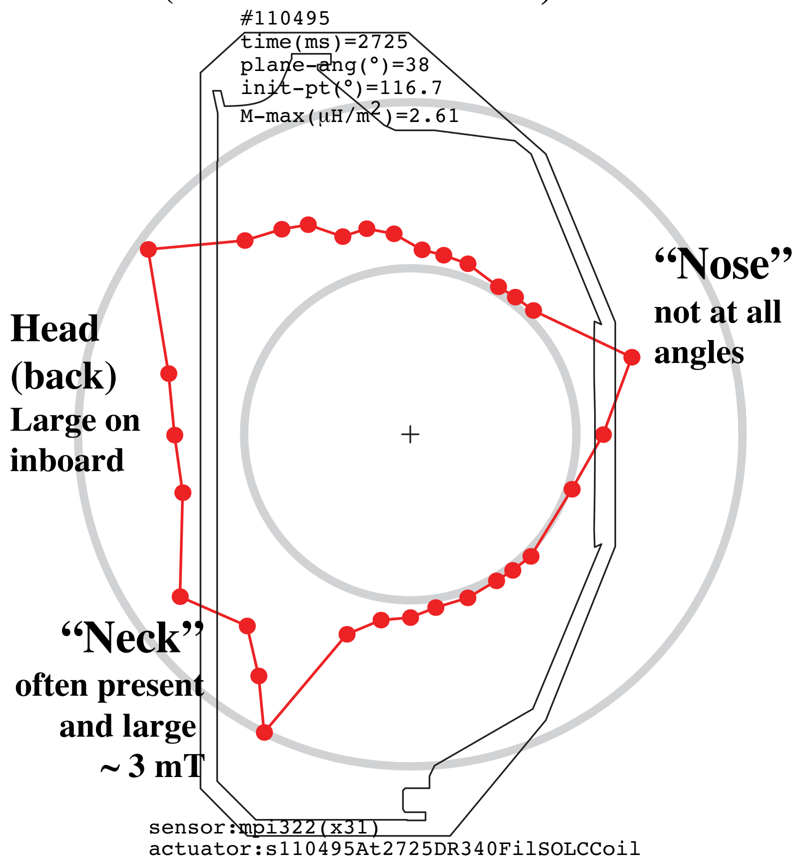
Calculated B_θ Show Key Features of Experiment

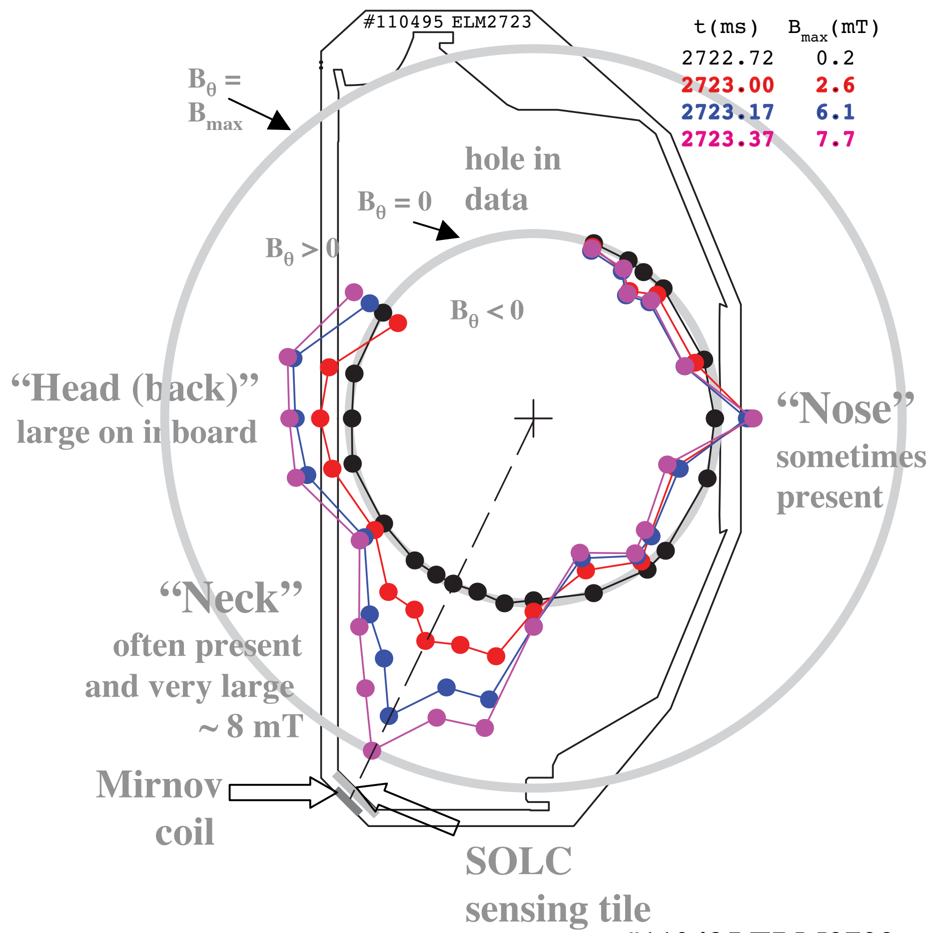
Calculated* **B_θ Vs θ (in "Polar Plot")**

(* for unit current of 1 kA)



Cross Section at ϕ = 38 deg
Mirnov Poloidal Array Plane

Measured **Magnetic "Face" of ELM**



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Summary: *Measured* B_θ Provides "Boundary Conditions" in Identifying Source

B_θ *toroidal* variations are non-axisymmetric along outboard mid-plane.

B_θ *poloidal* variations are:

a) "*Anti*-ballooning," larger on inboard than outboard side.

b) "Ribbon-like*," or poloidally narrow, on outboard side in some cases.

c) Peaked in divertor near separatrix strike point.

*Possibly analogous to earlier observations (E. Strait, Phys Fluids '97; R. Maingi, PoP '06)

Summary: Model SOLC Qualitatively Reproduces Key Features of B_θ Spatial Variations during ELMs

Generic Geometrical **Characteristics of Field Lines in SOL Lead to Features of Calculated B_θ Field:**

a) **Multiple Turns** ⟹ **Larger Inboard B_θ**

b) **Single Sweep** ⟹ **"Ribbon-like" Outboard Structure**

c) **Proximity to Mirnov Coils** ⟹ **Large B_θ in Divertor**

Suggestive that SOLC may be responsible for observed field during ELMs.

Summary

SOLC may be source of the bulk of observed field during ELMs, with its paths next to plasma surface and magnitude comparable to current used in generating stochastic field during RMP experiment. Actively controlling and driving SOLC may be an attractive means of generating stochastic field and affecting ELMs.

SOLC-generated field patterns reflect generic geometrical characteristics of open field lines in SOL, and are expected to be the same in other MHD events, such as RWM, in which SOLC has also been observed. Compensation for SOLC-produced field may help in effective feedback control of MHD modes.