Effects of the second X-point on hot VDE in HL-2M

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26th IAEA Fusion Energy Conference, Kyoto, Japan

SWIP Southwestern Institute of Physics

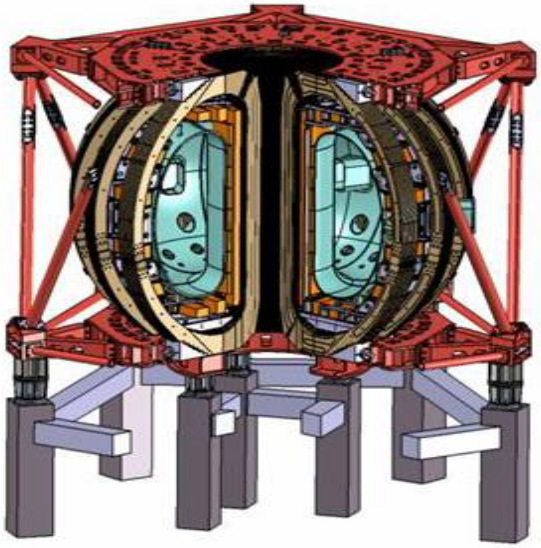
Outline

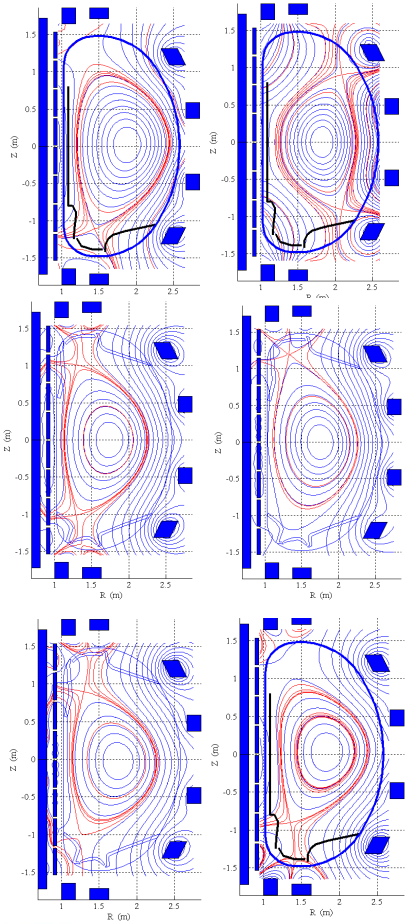
1. Introduction
2. Comparison between advanced and standard divertor configurations
3. Effects of relative locations between two X-points
4. Summary

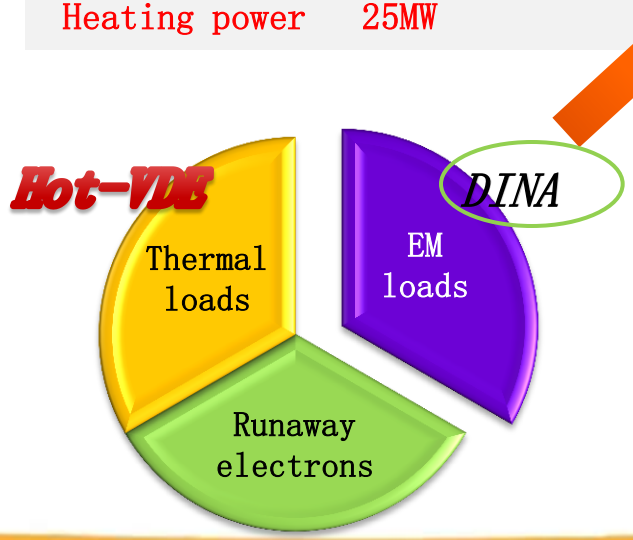
Introduction : HL-2M

Mission: high performance, high beta, and high bootstrap current plasma; advanced divertor (snowflake, tripod); PWI.

Plasma current	I_p = 2.5 (3) MA
Major radius	R = 1.78 m
Miner radius	a = 0.65 m
Aspect ratio	R/a = 2.8
Elongation	K = 1.8-2
Triangularity	δ > 0.5
Toroidal field	B_T = 2.2 (3) T
Flux swing	$\Delta \Phi$= 14Vs
Heating power	25MW

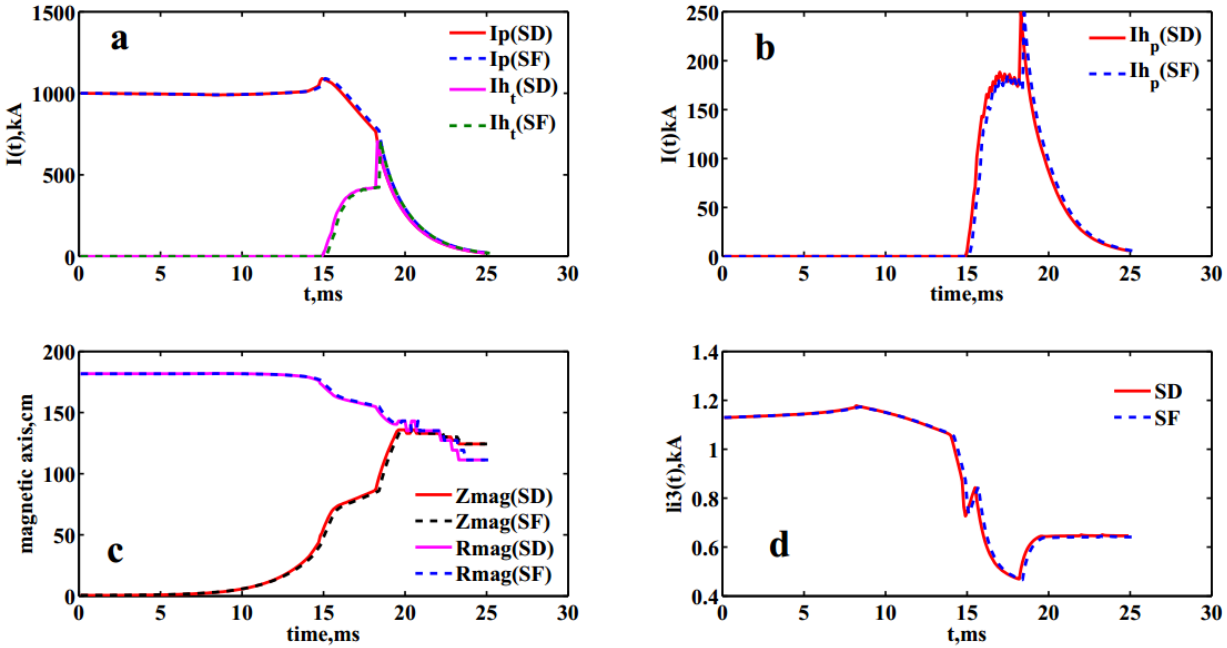


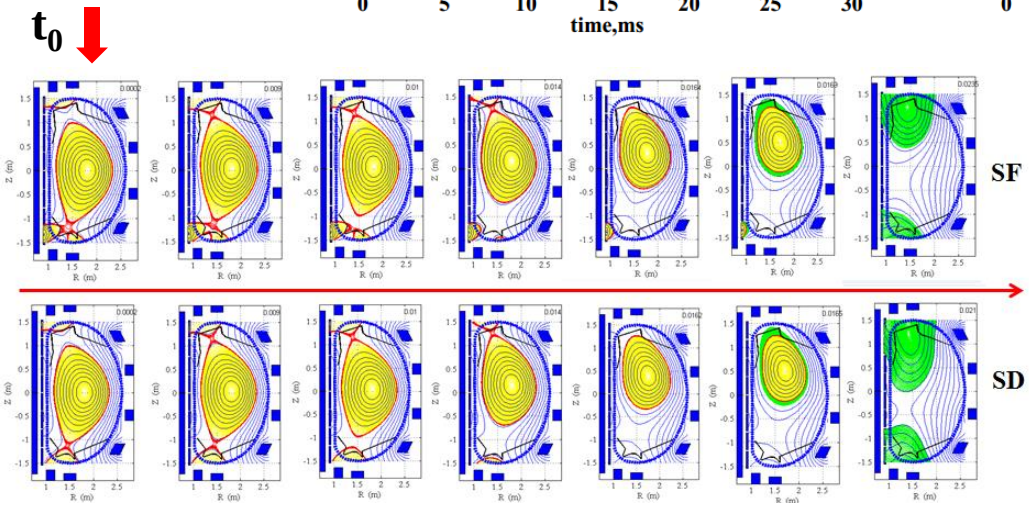




- ✓ High performance operation
- ✓ Disruption mitigation system
- ✓ Advanced divertor experiment

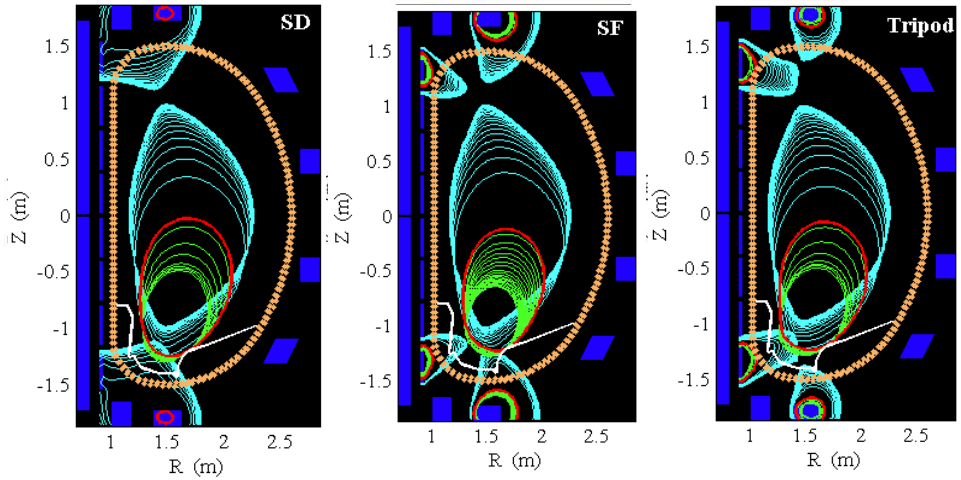
Standard vs. snowflake in single-null

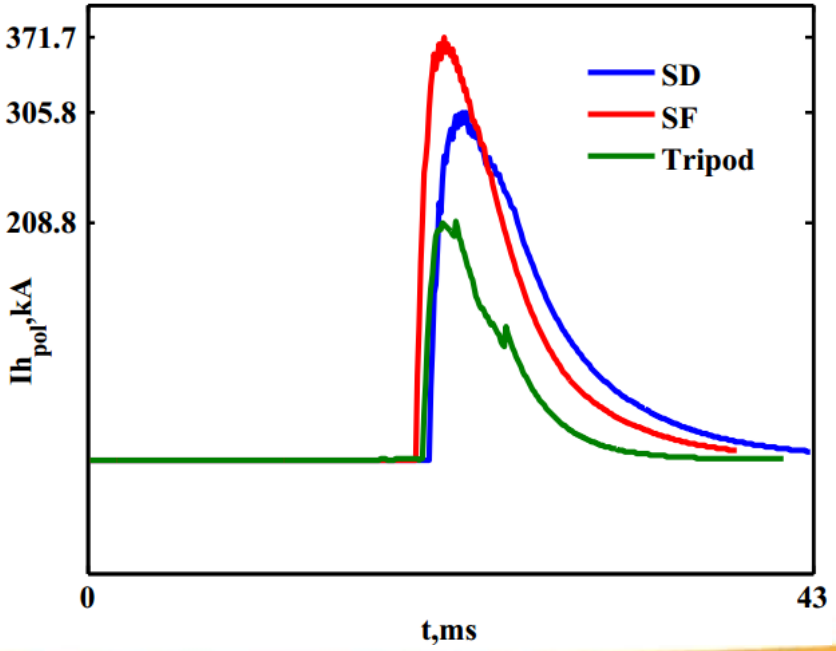


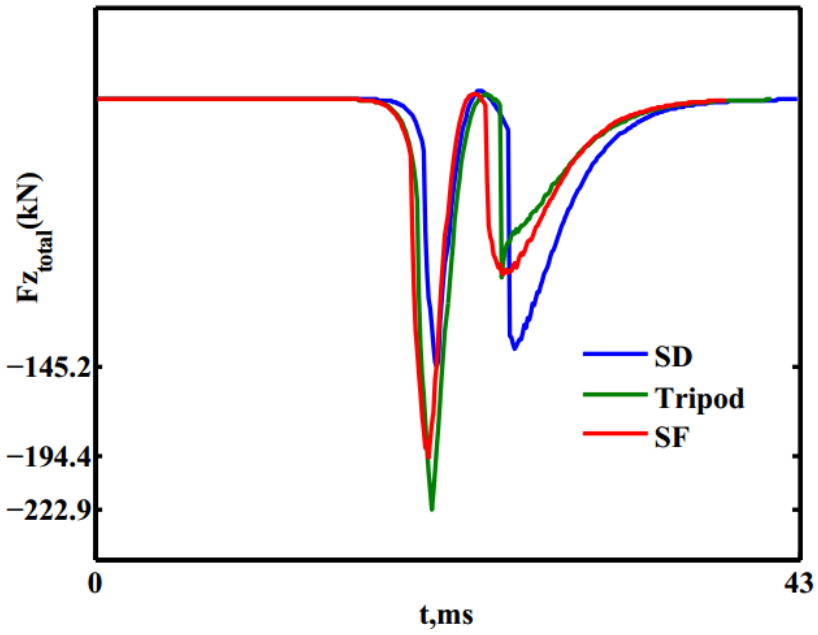


- Magnetic configuration on the path of VDE determines results.

EM loads with SD vs. SF vs. tripod, during hot







- Peak halo current:

$$I_{h,\ SF} > I_{h,\ SD} > I_{h,\ Tripod}$$

- Maximum vertical EM force:

$$F_{z,\ tripod} > F_{z,\ SF} > F_{z,\ SD}$$

Consider three groups of X-points formation

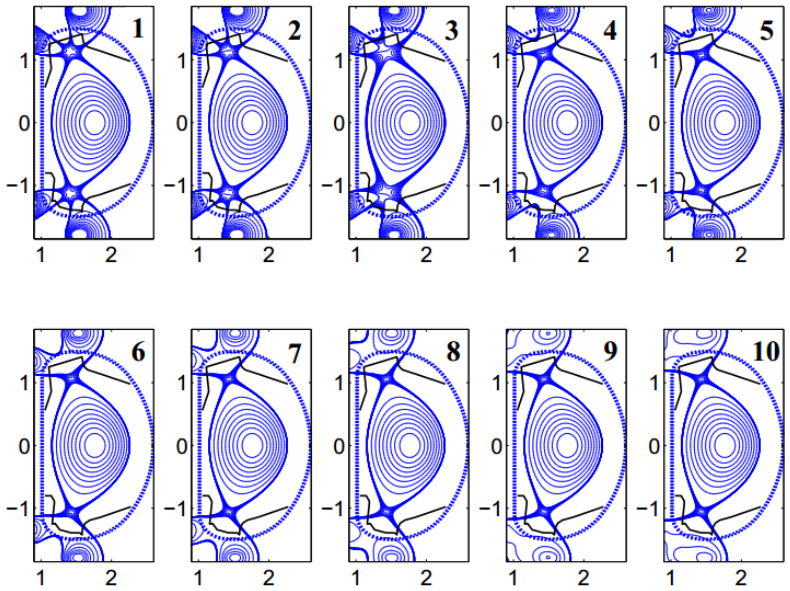
I. Exact SF → Tripod

II. Exact SF → SF minus

II-a. Exact SF → SF left-minus

II-b. Exact SF → SF right-minus

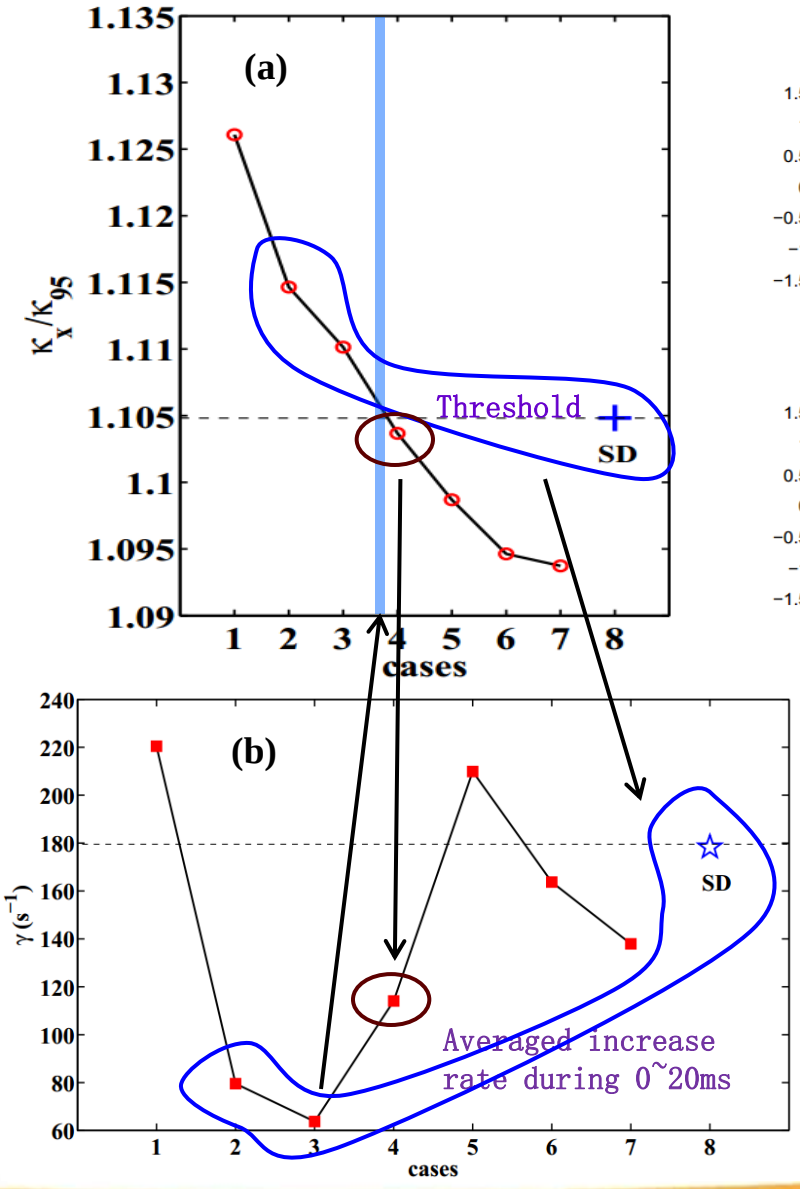
III. Exact SF → SF plus → SD



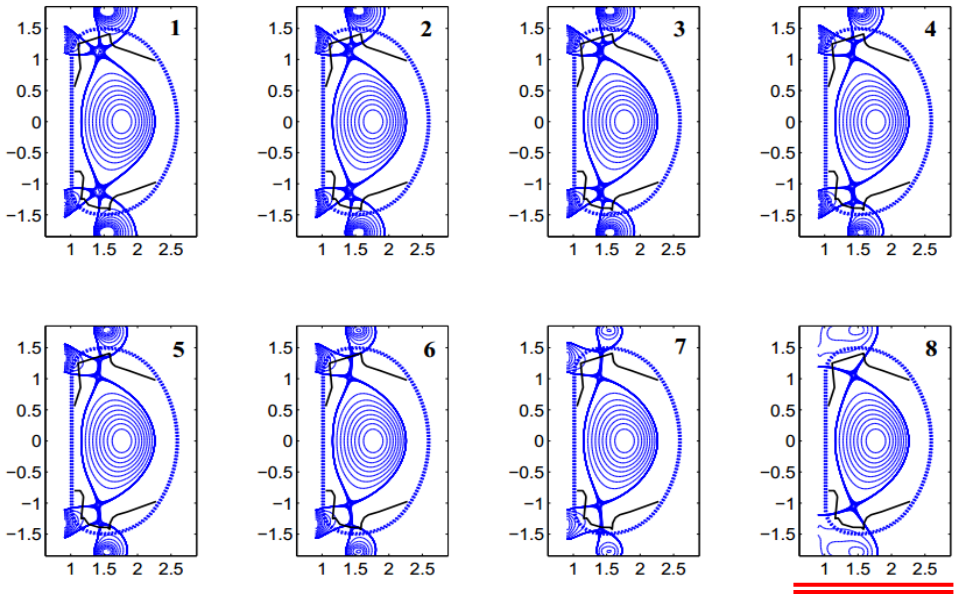
Parameters	Value
I_p (MA)	1.00
R_0 (m)	1.78
a (m)	0.55
K_{95}	1.63
β_p	0.60
l_i	1.10
δ_{95}	0.24
B_T	2.20

- ✓ Initial vertical instability
- ✓ Peak halo currents
- ✓ Maximum vertical EM forces on VV

Initial vertical instability: Group I



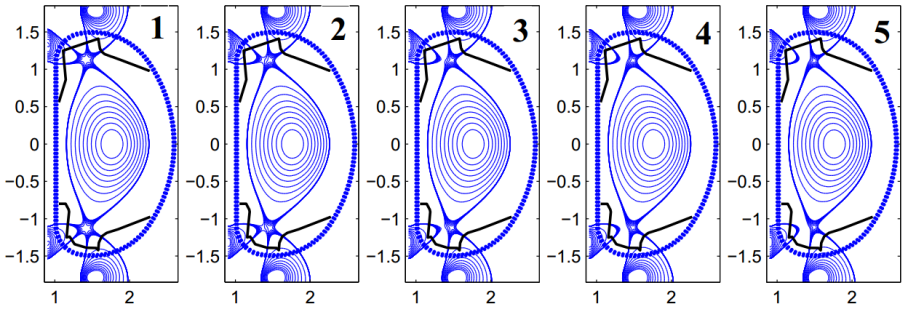
I. Exact snowflake-tripod



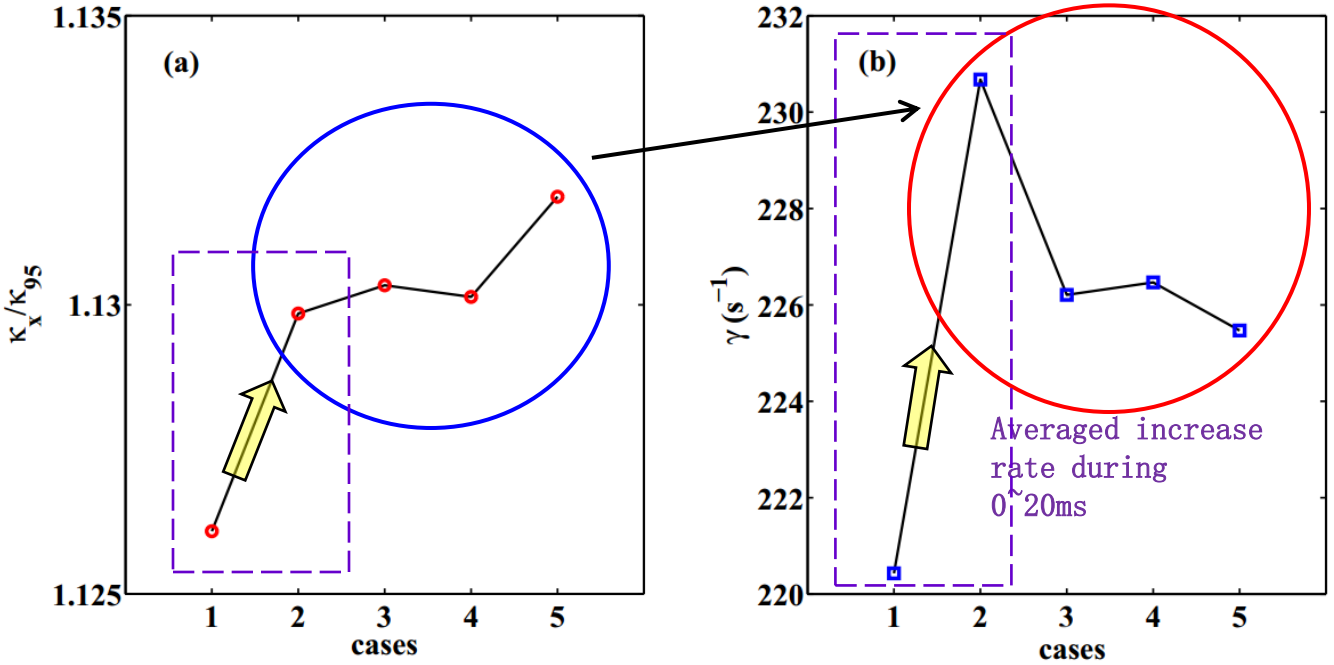
- A properly vertically-elongated weak poloidal field, due to variation of the second X-point in Z direction, can restrain development of vertical instability.
- As κ_x / κ_{95} decreases closer to SD threshold, restraining effect might become more obvious.

Initial vertical instability: Group II-a

II-a: Exact snowflake-SF left minus

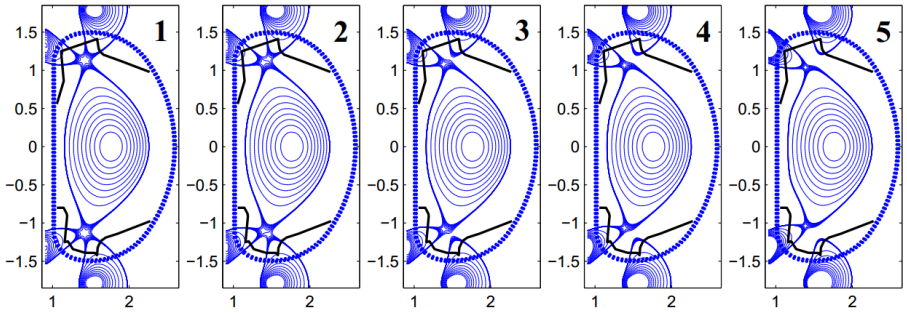


- Horizontally-elongated poloidal weak field can also restrain development of vertical instability.

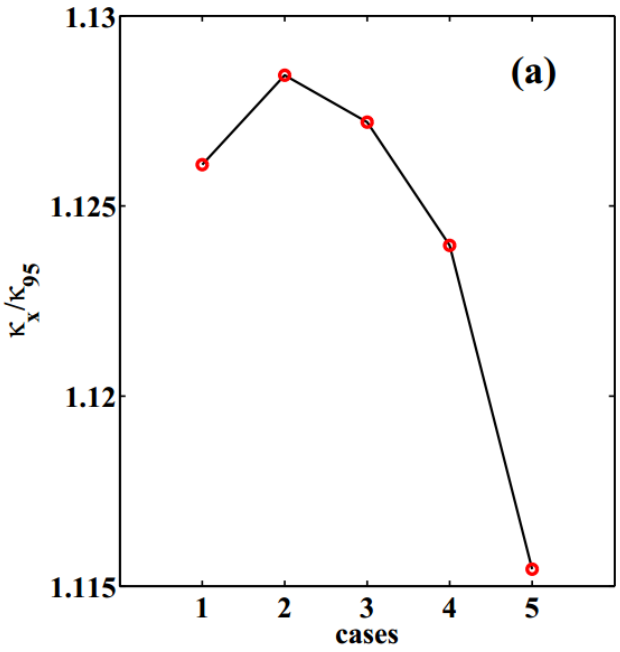


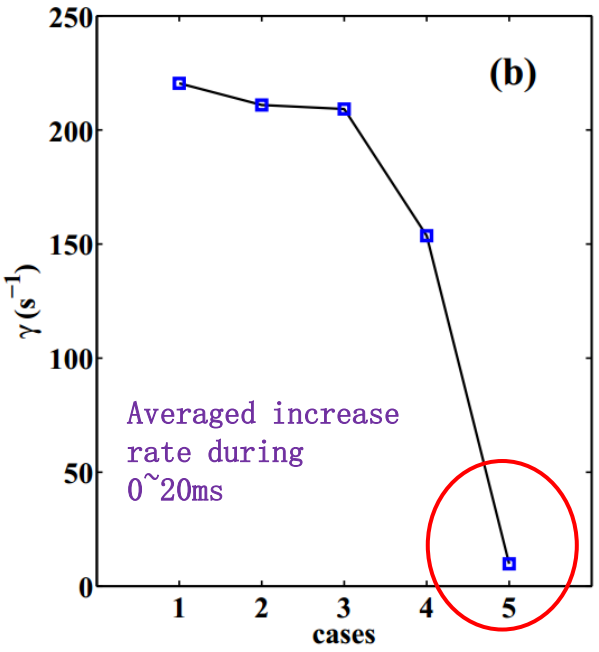
Initial vertical instability: Group II-b

II-b: Exact snowflake-SF right minus

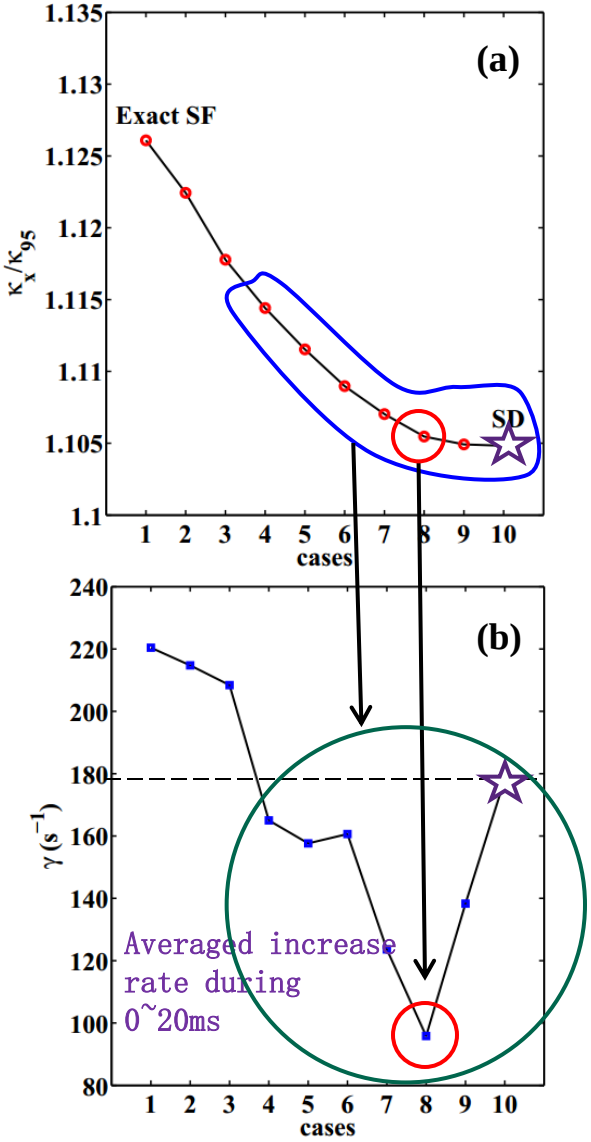


- An obvious restraining effect is observed when the second X-point is sufficiently far from the dominant X-point.

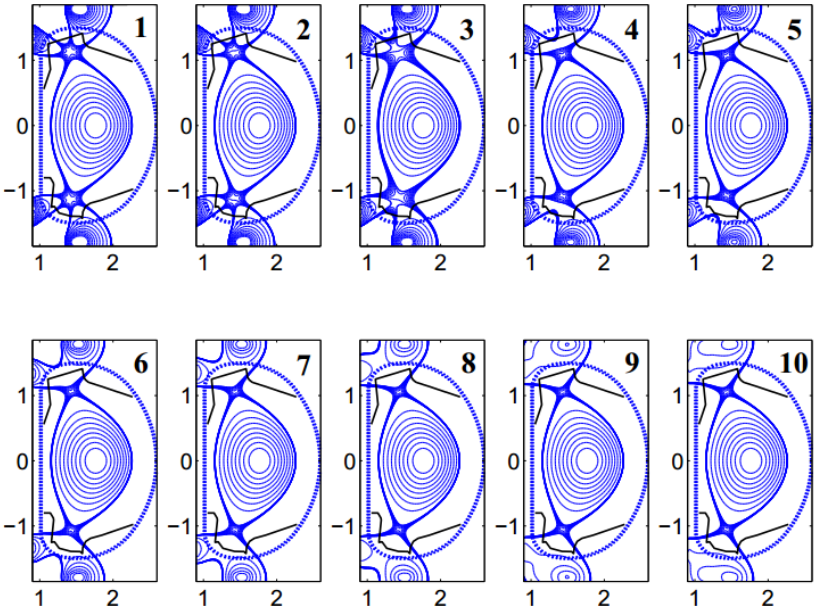




Initial vertical instability: Group III



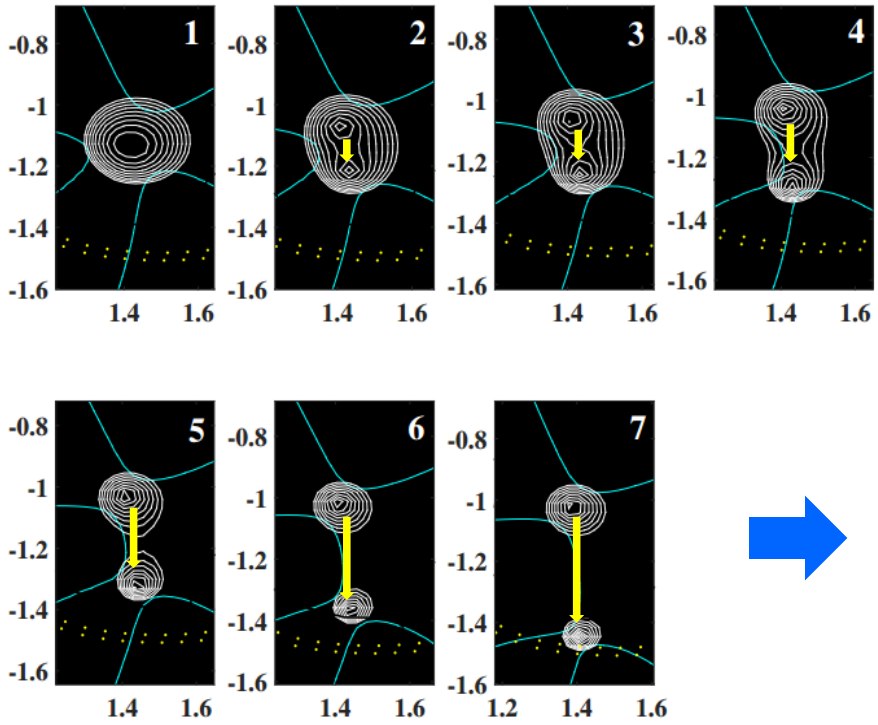
III: Exact snowflake-SF plus-SD

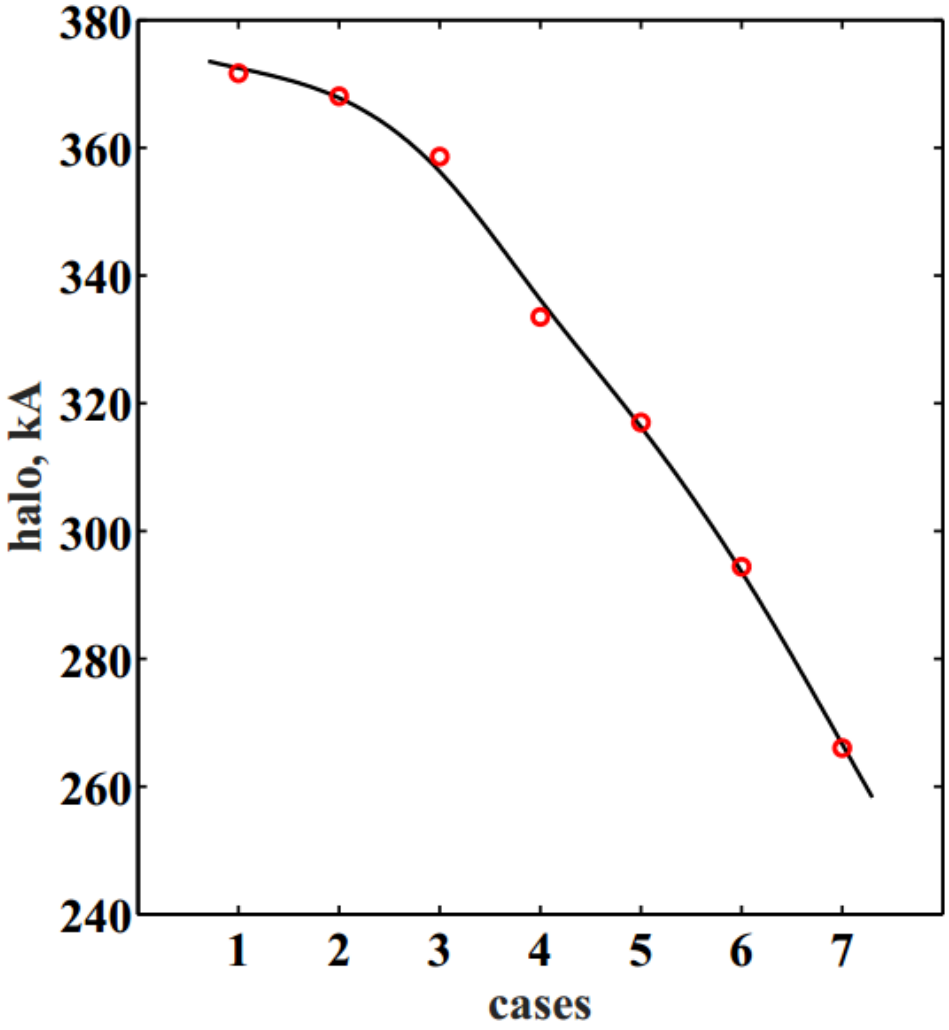


- As the second X-point moves away from the dominant X-point, elongated poloidal weak fields can restrain development of vertical instability.
- Favorable position for the restraining effect exists, when κ_x / κ_{95} is very close to that of SD.

Peak halo currents: Group I

I: Exact snowflake-tripod

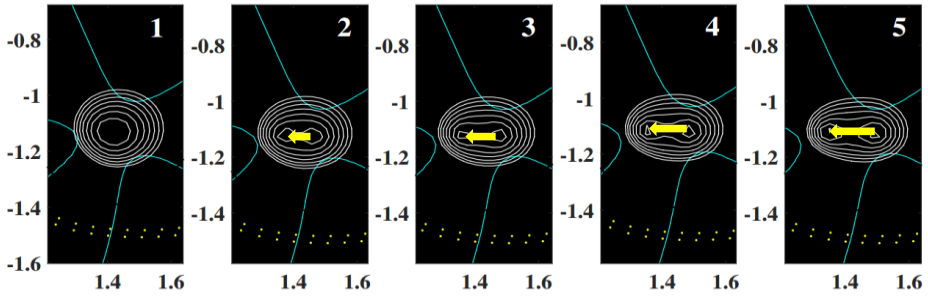


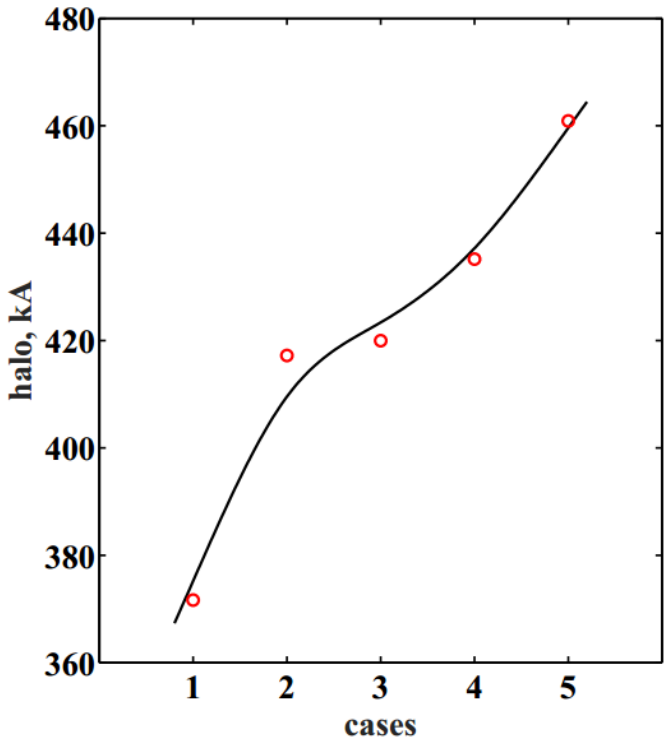


- Peak halo current becomes smaller as the second X-point moves in vertical direction.

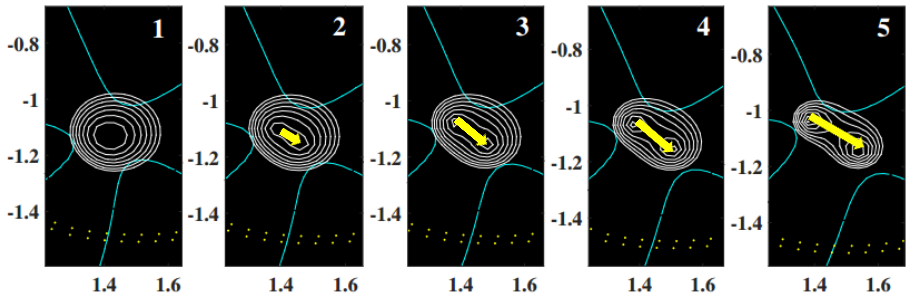
Peak halo currents: Group II

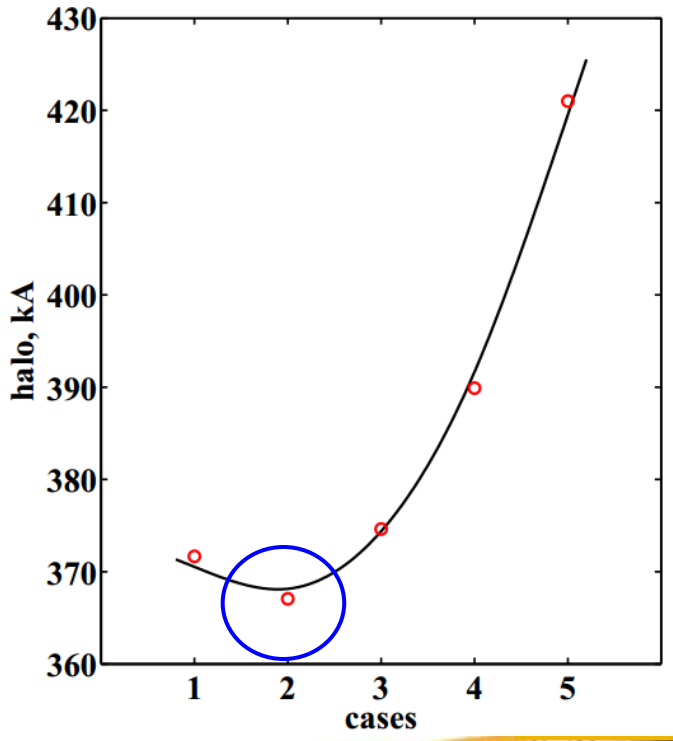
II-a: Exact snowflake-snowflake left minus





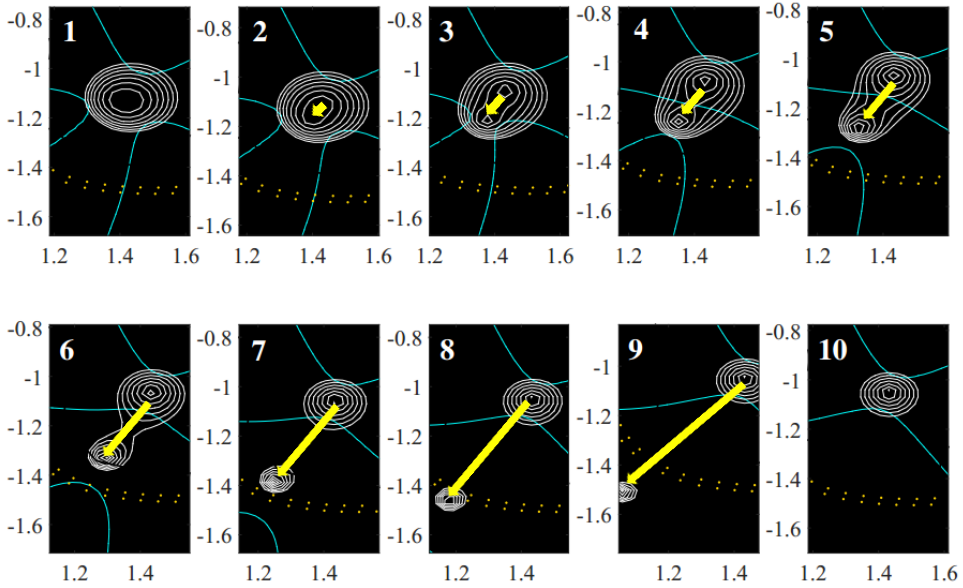
II-b: Exact snowflake-snowflake right minus

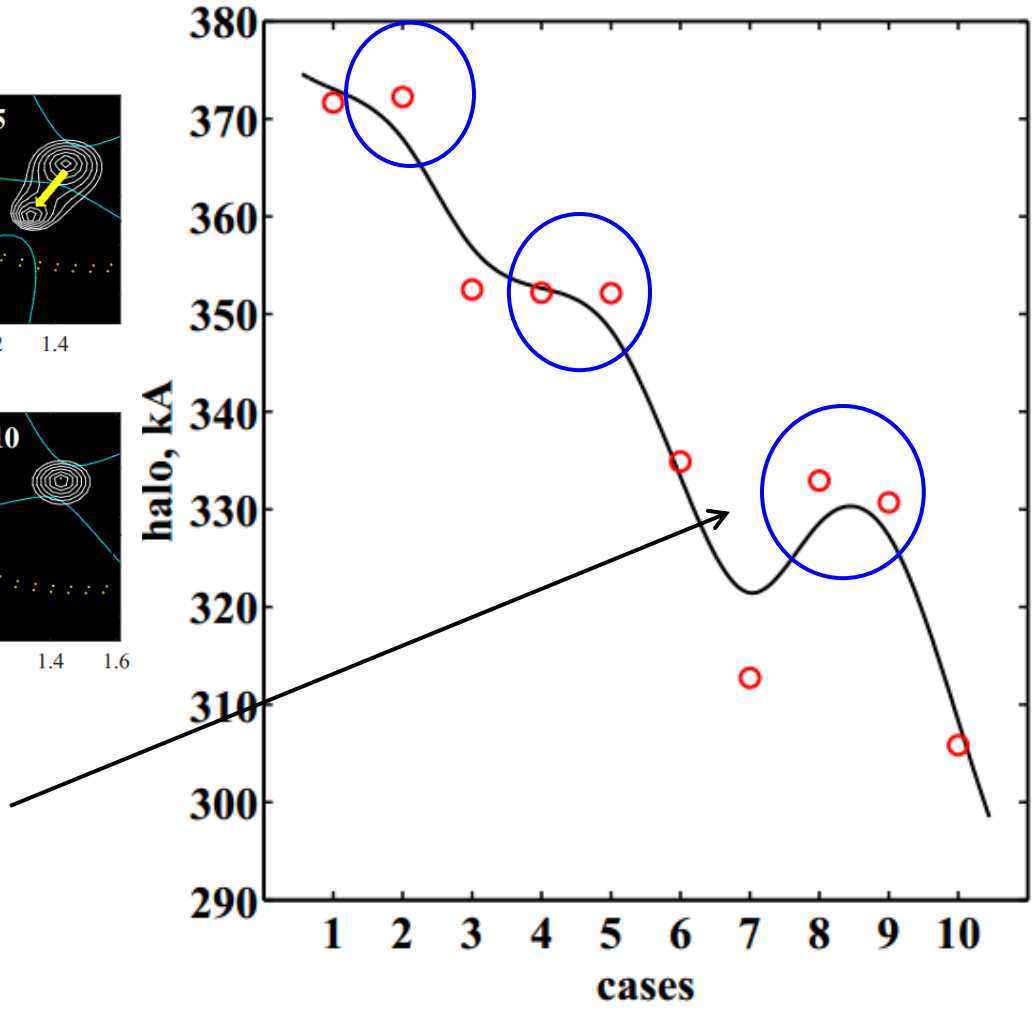




Peak halo currents: Group III

III: Exact snowflake-snowflake plus-standard

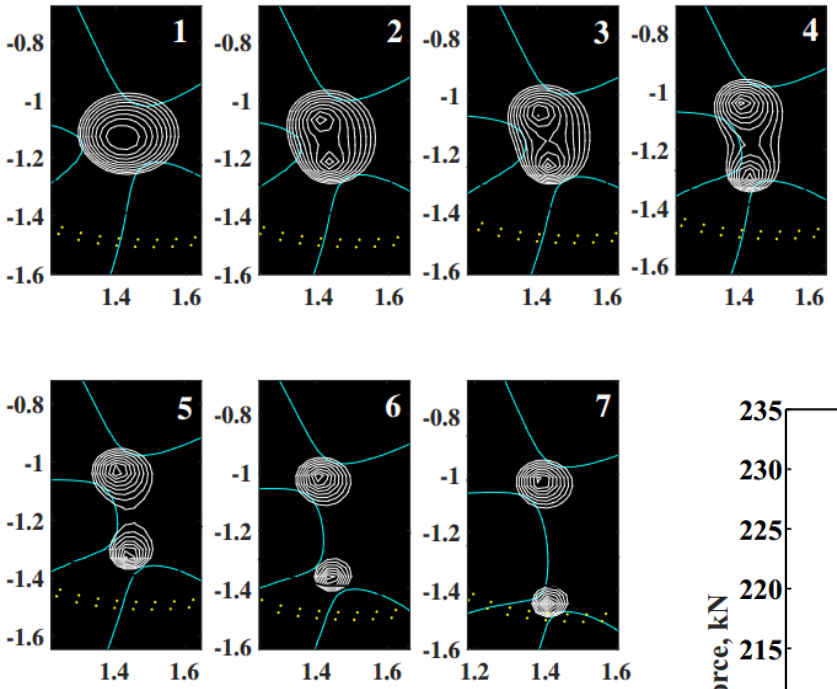




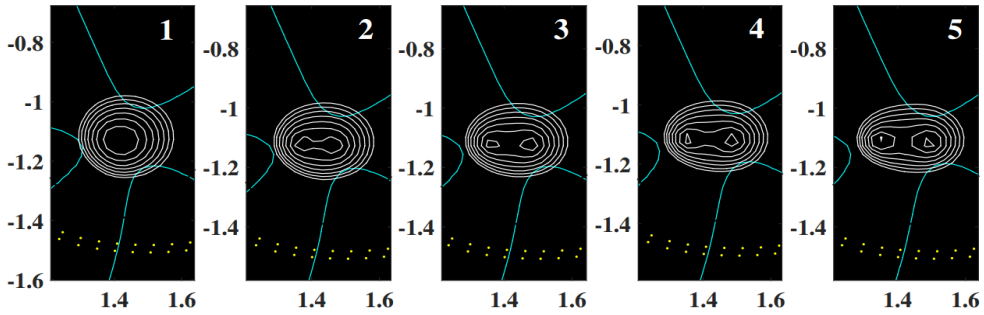
- Abnormal increase of peak halo current in these cases, such as 8 and 9, may be due to the left component of variation of the second X-point.

Maximum vertical EM forces: Group I & II-a

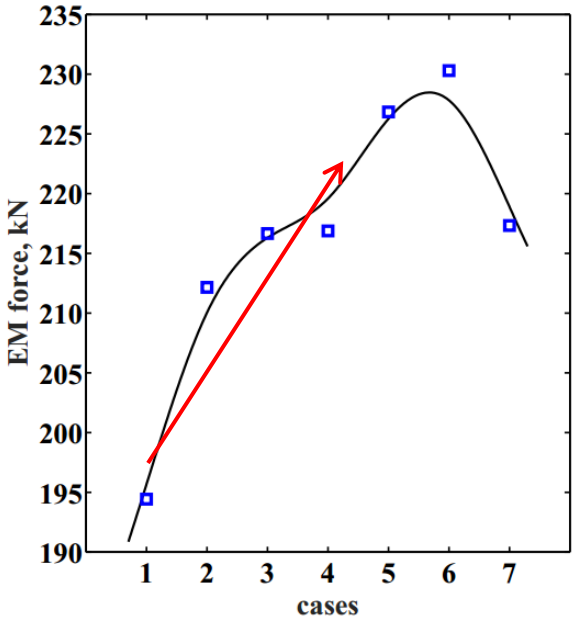
I: Exact snowflake-tripod

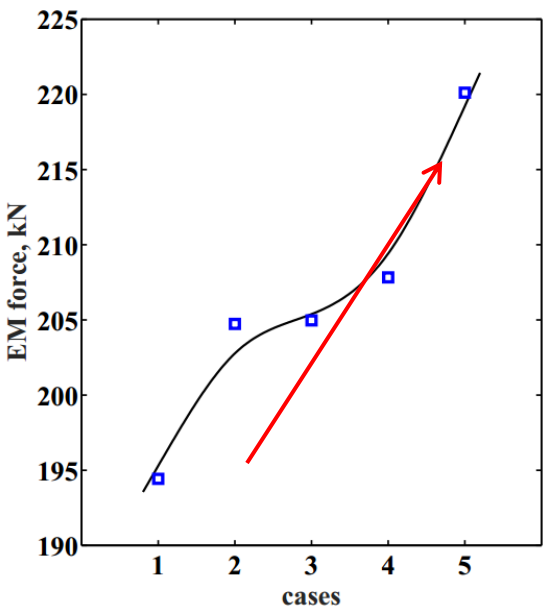


II-a: Exact snowflake-snowflake left minus



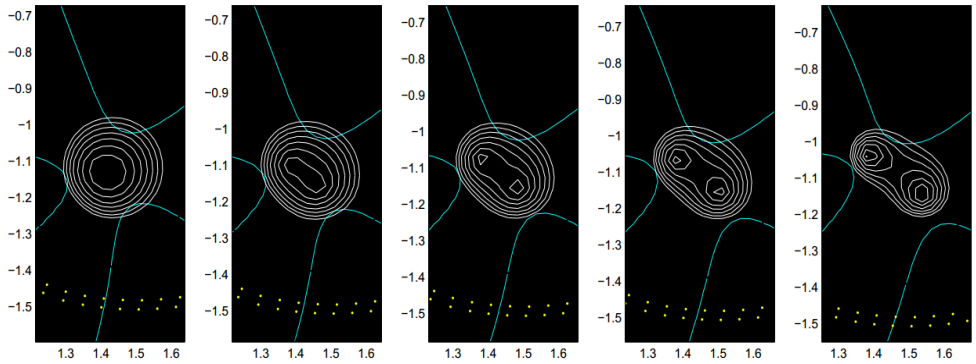
- Maximum vertical EM forces on vacuum vessel tend to increase in both group I and II-a.



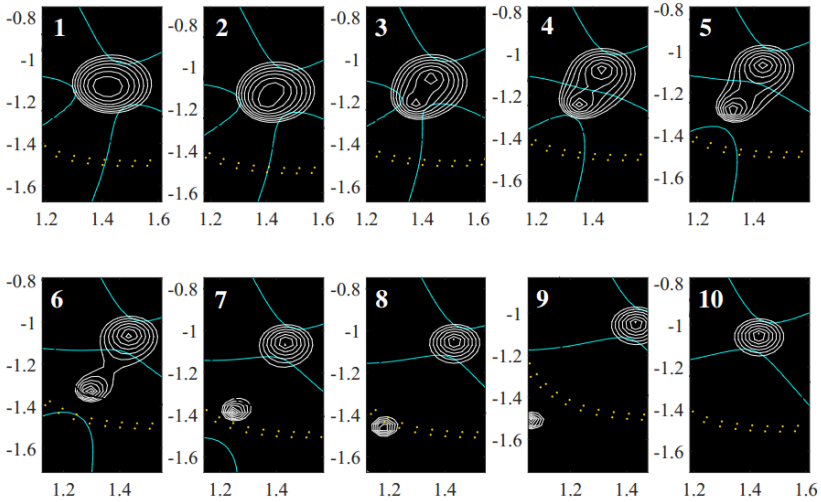


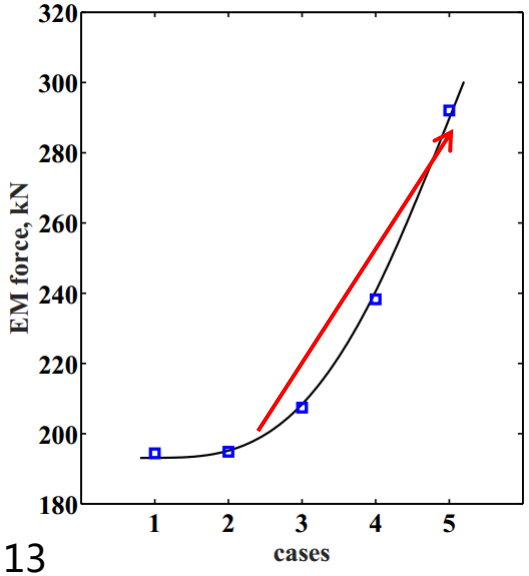
Maximum vertical EM forces: Group II-b &

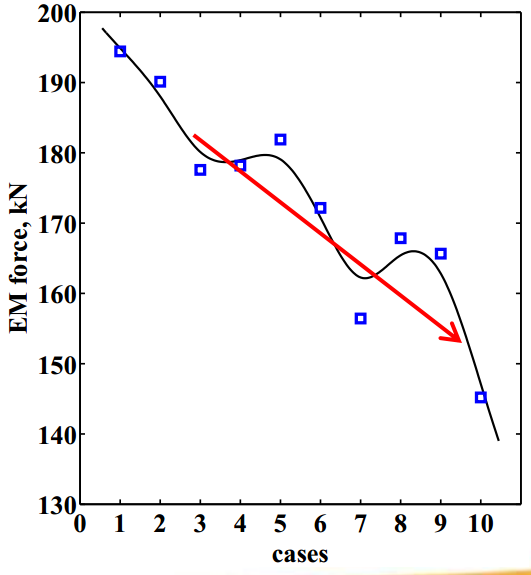
II-b: Exact snowflake-snowflake left minus



III: Exact snowflake-snowflake plus-standard







- In both groups II-b & III, variation of maximum vertical EM forces on VV (vs. variation of initial location of second X-point) is similar to variation of peak halo current.

Summary

- For initial vertical instability, obvious restraining effect is observed when the second X-point is in certain special locations => may be beneficial for hot VDE control.
- Observed a general trend:

  Peak halo current monotonically increases as the second X-point moves in horizontal direction, and deceases as the second X-point moves in vertical direction away from dominant X-point.
- For peak halo current: SF minus > Exact SF > SF plus > SD > Tripod.
- For maximum vertical EM forces: SF minus & tripod > Exact SF > SF plus > SD.

Thank you for your attention !