Part II. Perfect conducting first wall

Recently. Boozer has shown with a simple model that, **even in a perfect conducting ITER first wall limit**:

- a cold VDE could occur (no active controls will be effective in this situation) and
- q(a) could drop down to ~2 even when the plasma current is still large ($I = \sim 0.75\ I_0$ -- 11.25 MA for ITER --), therefore allowing halo currents to emerge.

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Halo currents and vertical displacements after ITER disruptions

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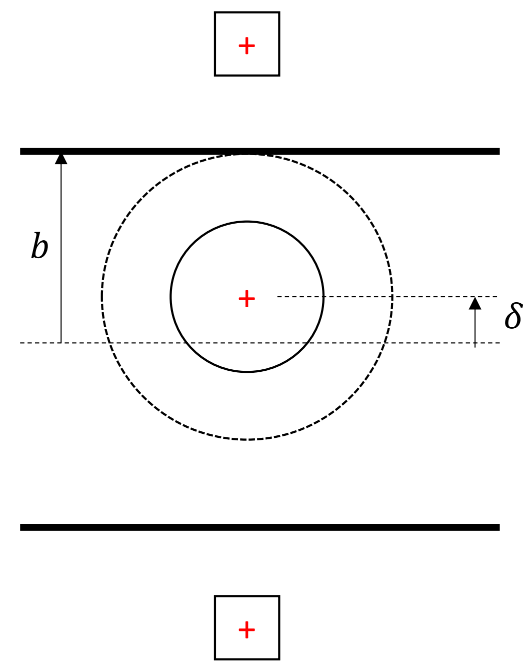
Two features of the walls[6] surrounding the ITER plasma make vertical displacement events different from those in any existing tokamak with a divertor. (1) The first wall, the closest structure to the ITER plasma, has what are called "fingers" to quickly transfer currents—induced or halo—to the blanket modules. This reduces the forces on the first wall but makes the effective conducting wall the blanket modules, which are further from the plasma. If a vertical displacement event pushed plasma into the spaces between the fingers and allowed currents to flow between them, large and potentially unacceptable forces could be exerted on the first wall. (2) The electrical conductivity of the blanket modules is sufficiently great to

Analytical models

We want to compare the safety factor q(t) with analytical models

Circular cross-section large aspect-ratio approximation:

$$q = \frac{2\pi B_t a^2}{\mu_0 R I} \rightarrow \left(1 - \frac{|\delta|}{b}\right)^2 \frac{q_0 I_0}{I} \qquad \delta = Z_{mag}(t) - Z_{mag}(0)$$



Boozer's perfect-conductor-limit model:

Boozer uses this expression in a simplified VDE problem and gets:

$$\frac{q}{q_*} = \left(1 - \frac{|\delta|}{b}\right)^2 \frac{I_*}{I}$$

$I_* q_* = I_0 q_0$ leads to the previous result. But, from the force balance, he gets

$$\frac{I_*}{I} = 1 + 0.8225 \frac{\delta^2}{b^2}$$

And I_* can be expressed as (bx is the x-point position)

$$\frac{I_0}{I_*} = 1.2337 \frac{{b_{x0}}^2}{b^2}$$

We need to define bx/b

Combining all this we can get

$$q = q(|\delta(t)|/b)$$

Or

$$q = q\big(I(t)\big)$$

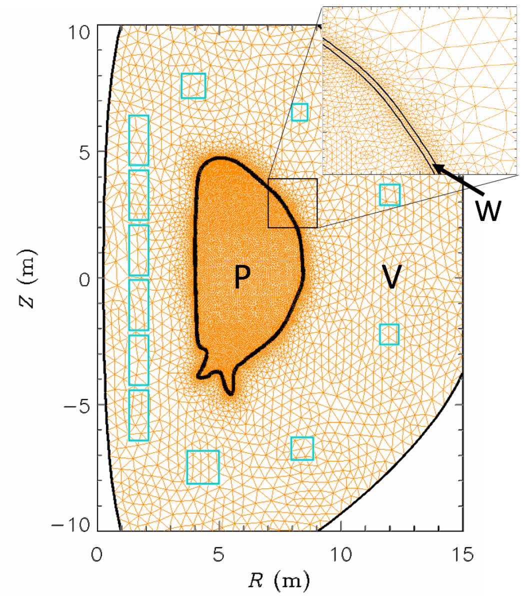
Wall current is calculated with the image method.

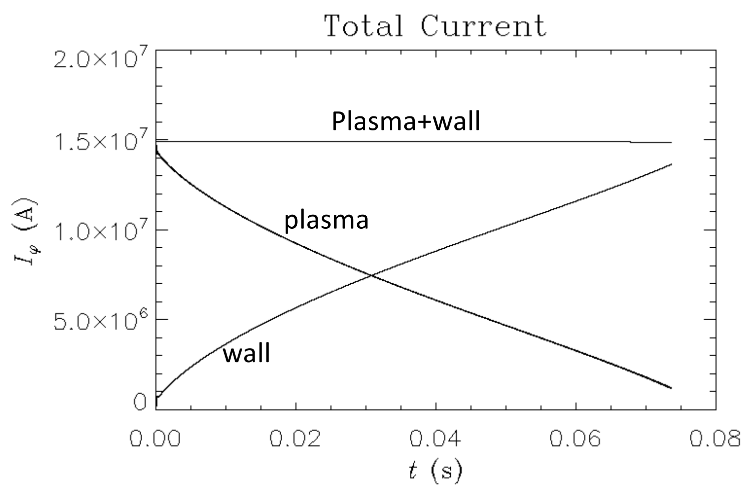
DOES NOT consider CQ induction!

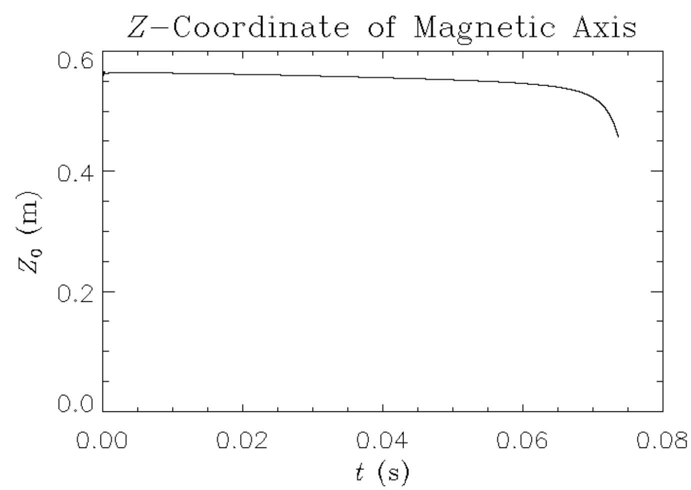
ITER – thin wall – ideal wall limit– Cold VDE

We explore a case in which the first wall acts as an ideal conductor

TQ was initiated at the beginning → Te falls from 25 keV down to 30 eV

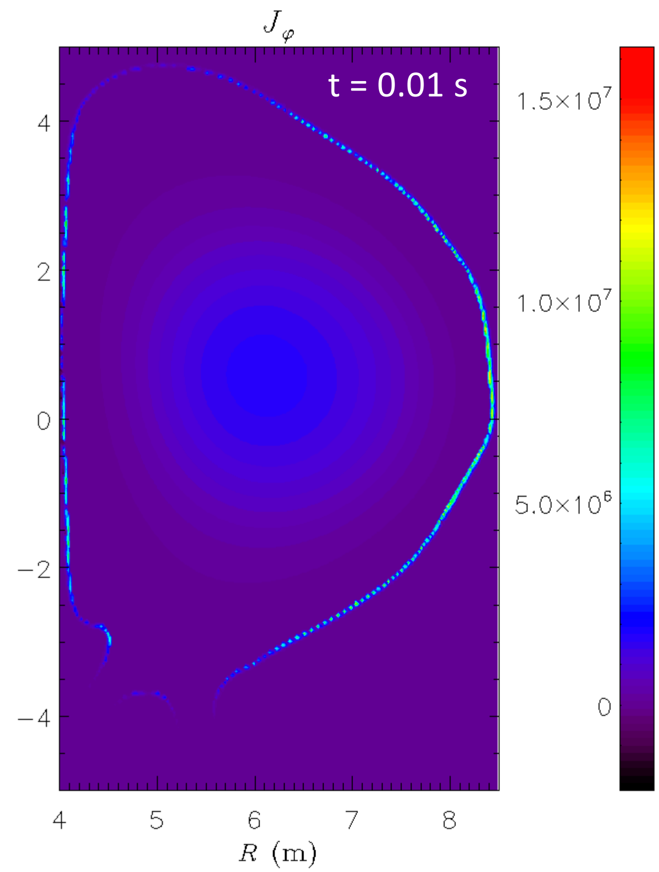






We found that this case is much more stable!

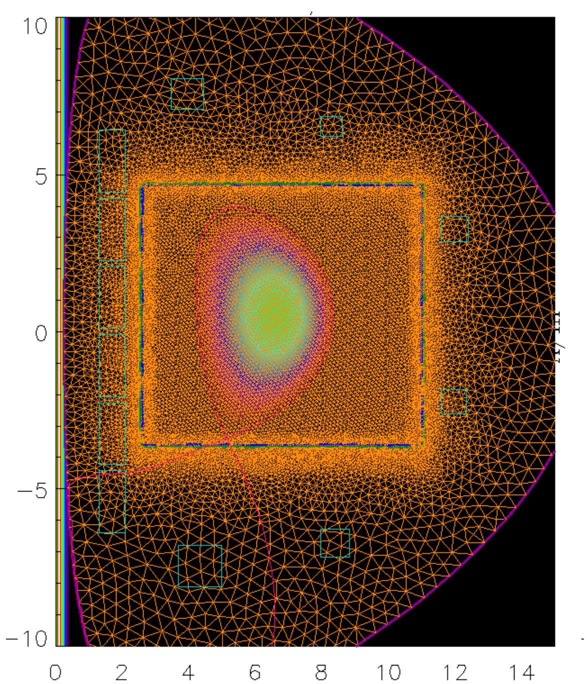
ITER – thin wall – ideal wall limit– Cold VDE



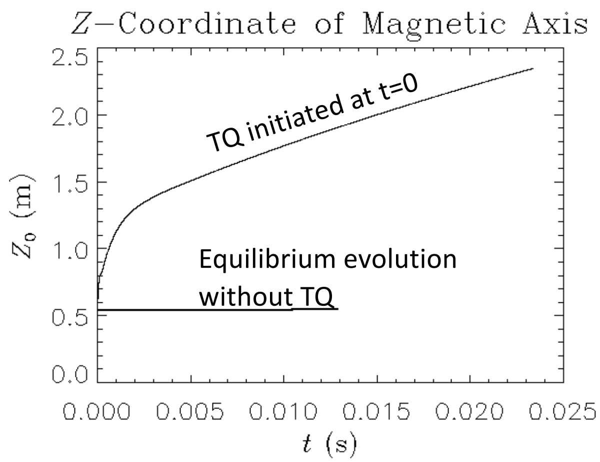
Current quench induction is very important in the side walls

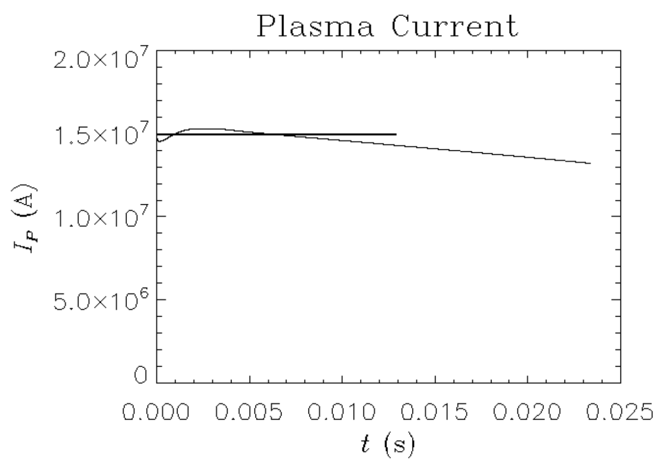
Approaching to Boozer's model: Rectangular wall

To approach the Boozer's model, we simulate a VDE with a very conductive rectangular wall. Side walls are placed as far as possible



- Top/bottom walls are equidistant to the magnetic axis
- Separatrix (bx/b) is ~ 1
  - With this assumption, I_* ~ 0.81 I_0 = 12.1 MA



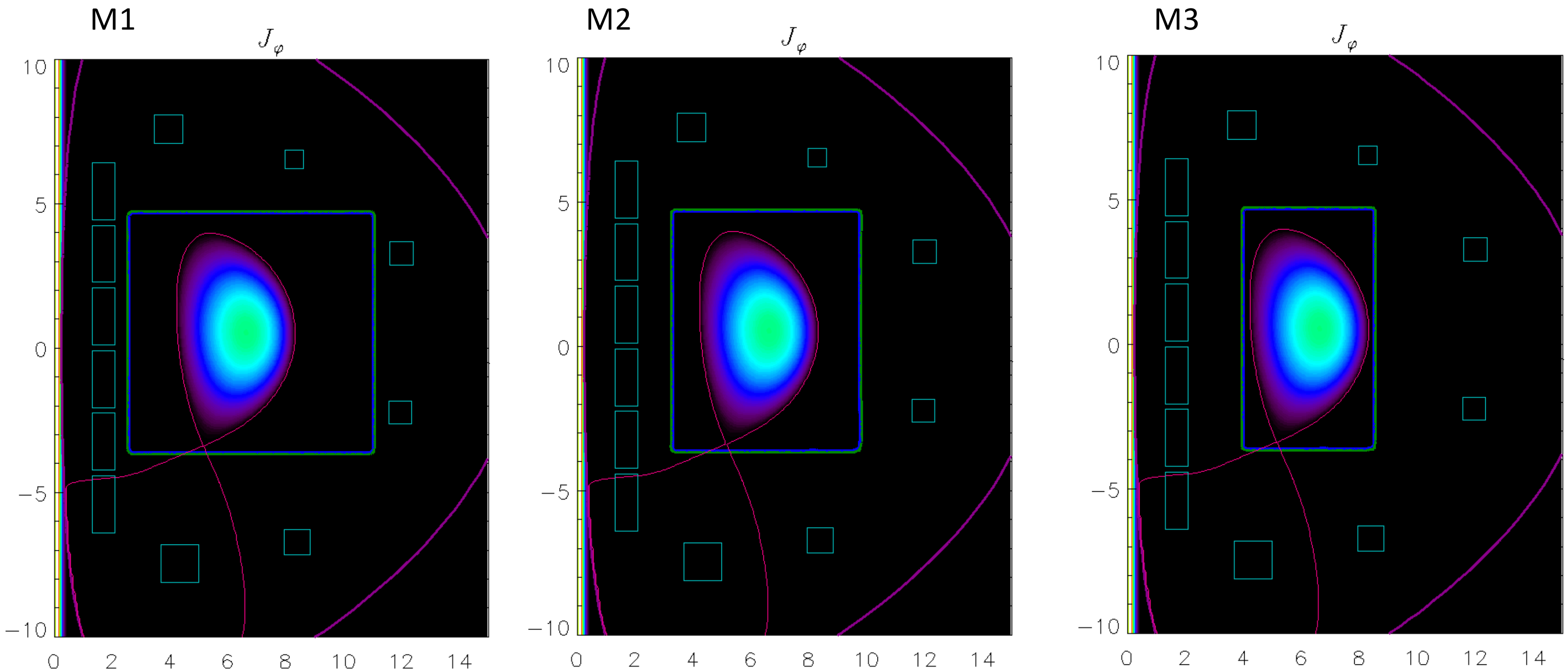


With a TQ, the result is unstable even when 'Ip' > I_*

Elongation seems to play a role even in the ideal conducting wall limit (?)

Approaching to Boozer's model: Rectangular wall

Bringing the side walls closer improves the stability



Approaching to Boozer's model: Rectangular wall