ELM simulations for MAST-U

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Edge localized modes (ELMs)

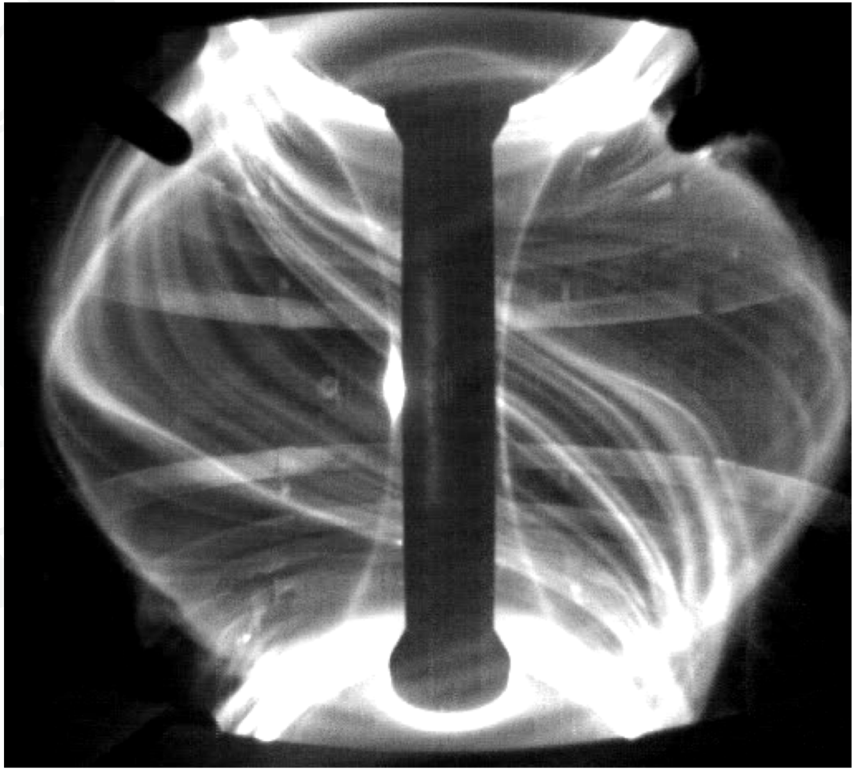

Fig. ELMs in MAST (fast camera)

No TYPE-I ELMs in ITER

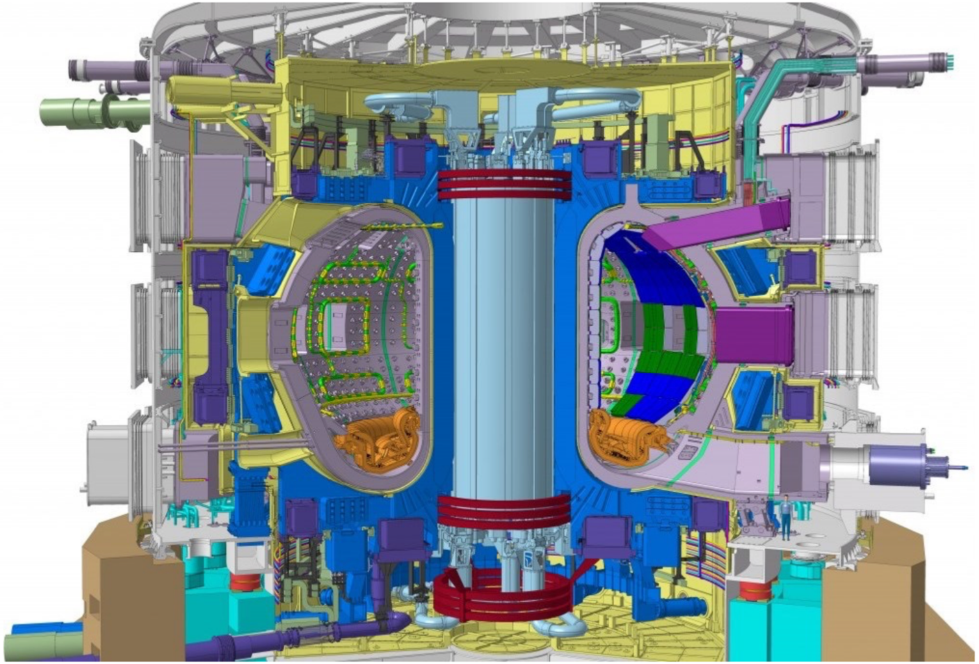

Fig. ITER

Heat flux solution MAST-U Super-X

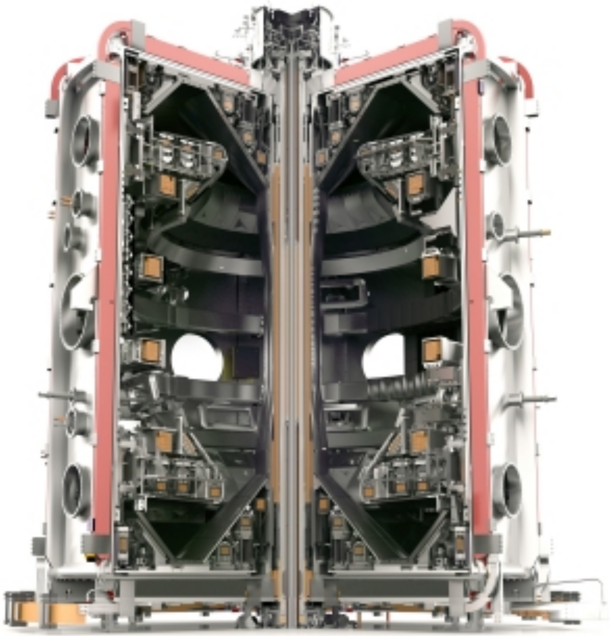

Fig 1. MAST-U design with Super-X divertor

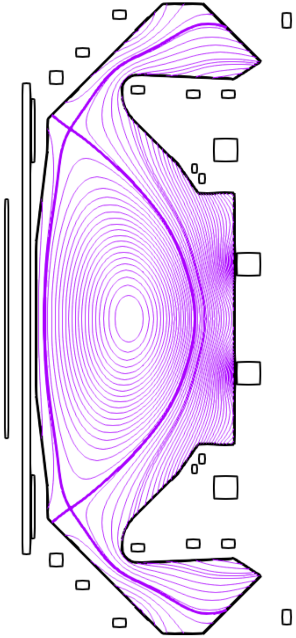

Fig 2. MAST-U Super-X flux contours

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JOREK

$$\rho \frac{d\vec{v}_E}{dt} = - \nabla_\perp p + \vec{J} \times \vec{B} + \mu \nabla^2 (\vec{v}_E) + \mu_{hyp} \nabla^4 \vec{v}_E$$

$$\rho \frac{d\vec{v}_\parallel}{dt} = - \rho \vec{v}_\parallel \cdot \nabla \vec{v}_\parallel - \nabla_\parallel p + \mu \nabla^2 (\vec{v}_\parallel - V_{NBI}) + \mu_{hyp} \nabla^4 \vec{v}_\parallel$$

$$\frac{\partial \psi}{\partial t} = \eta (j - j_A) + R[\psi, \Phi] - \frac{\partial \Phi}{\partial \phi} + \eta_{hyp} \nabla^2 j$$

$$\frac{\partial \rho}{\partial t} = - \nabla \cdot (\rho [\vec{v}_\parallel + \vec{v}_E]) + \nabla \cdot (D_\perp \nabla_\perp \rho) + S_\rho + D_{hyp} \nabla^4 \rho$$

$$\frac{\partial p}{\partial t} = - \vec{v}_E \cdot \nabla p - \gamma p \nabla \cdot \vec{v}_E + \nabla \cdot (\kappa_\perp \nabla_\perp T + \kappa_\parallel \nabla_\parallel T) + \frac{2}{3R^2} \eta j^2 + S_T$$

MAST-U in JOREK

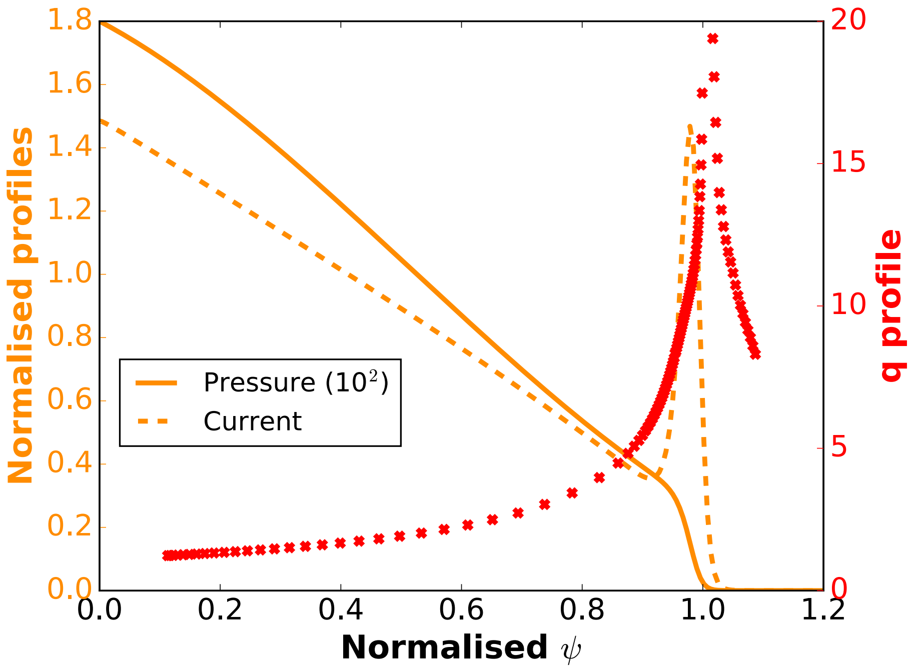


Fig 1. Profiles based on old MAST pulse

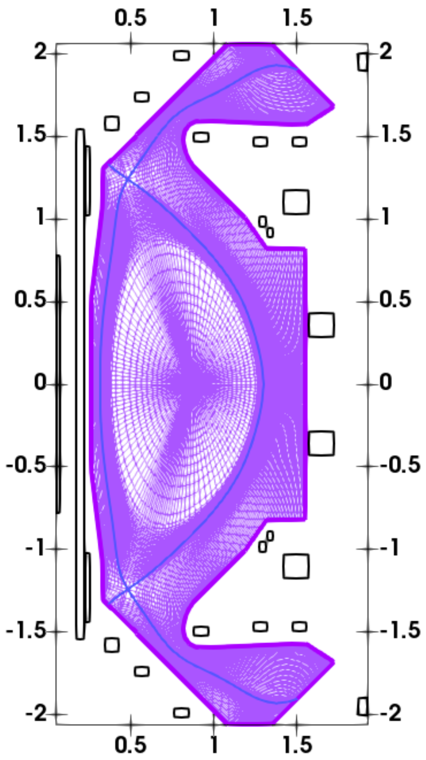


Fig 2. Finite element grid used in simulations

ELM simulation

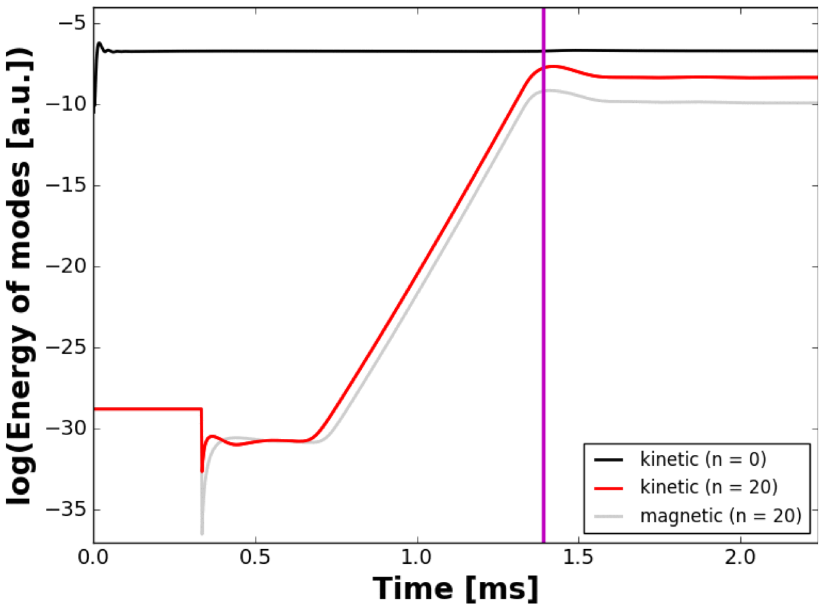


Fig 1. Evolution of the energy of the modes

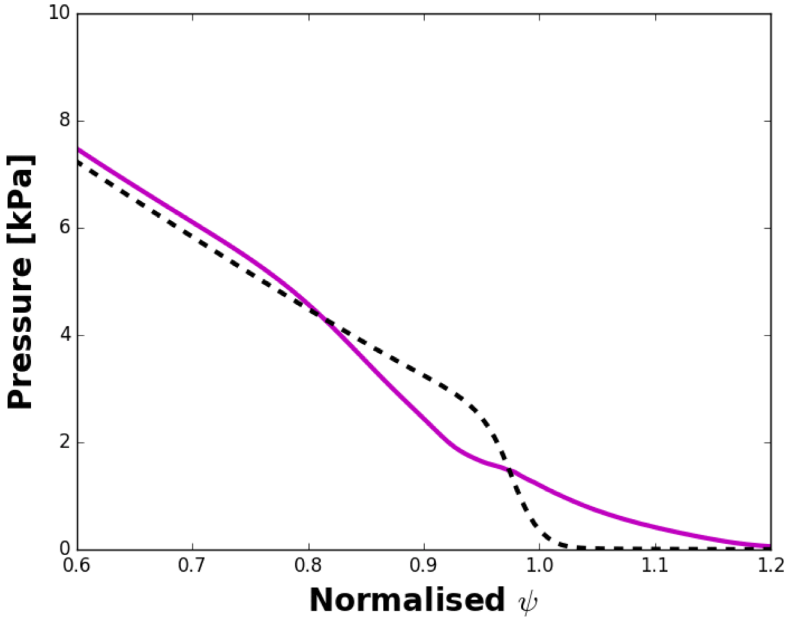
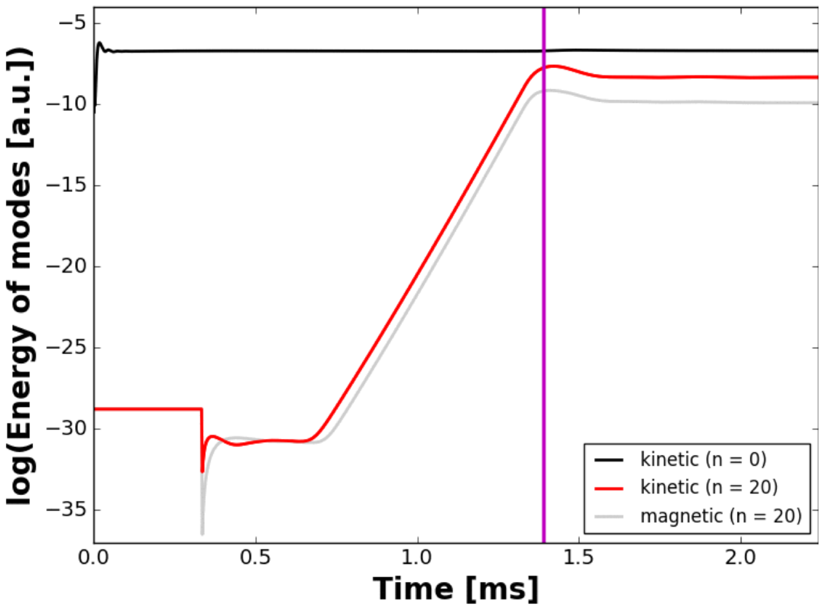


Fig 2. Evolution of the pressure profile

ELM simulation



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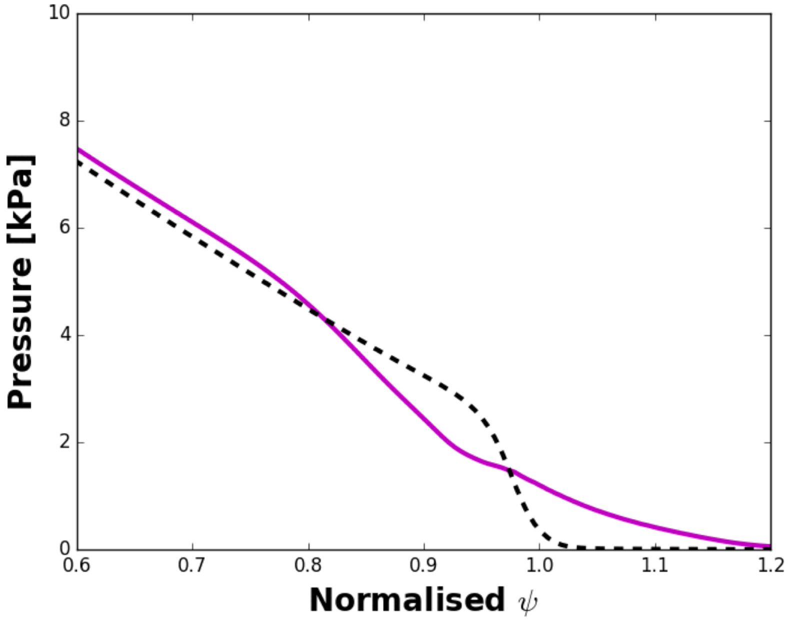

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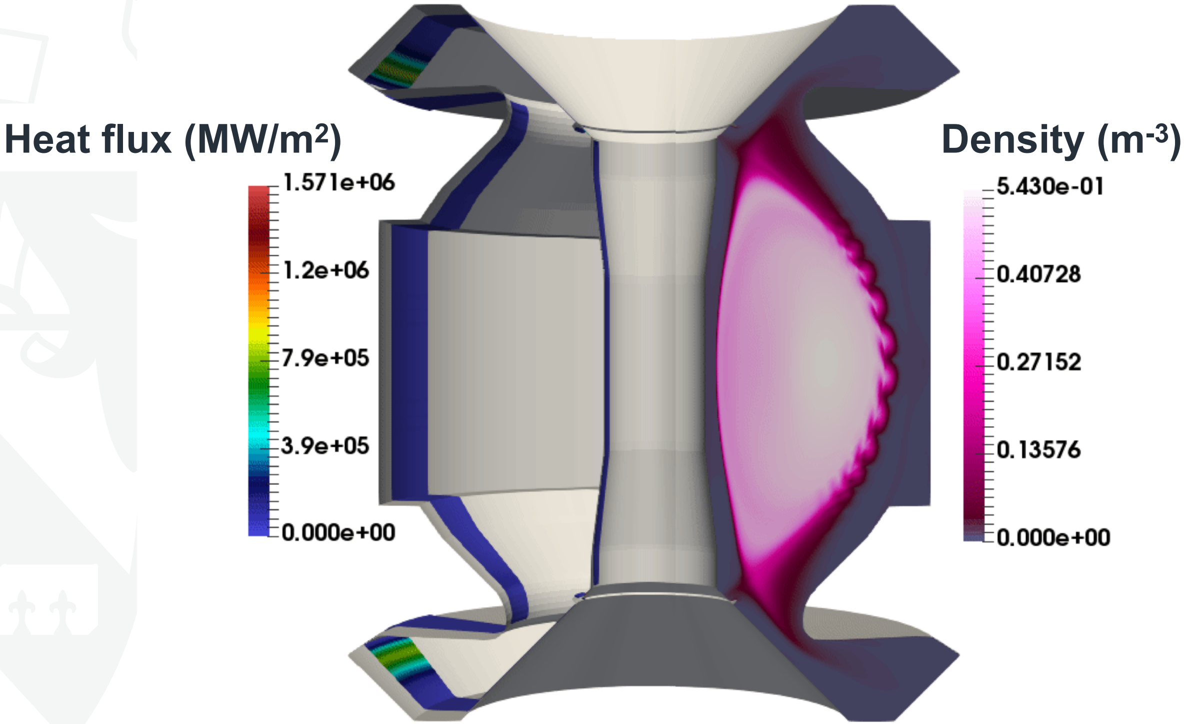

Fig. Evolution of poloidal density and heat flux to the boundary. Peak heat flux is 0.3 MW/m^2

Super-X comparison to conventional

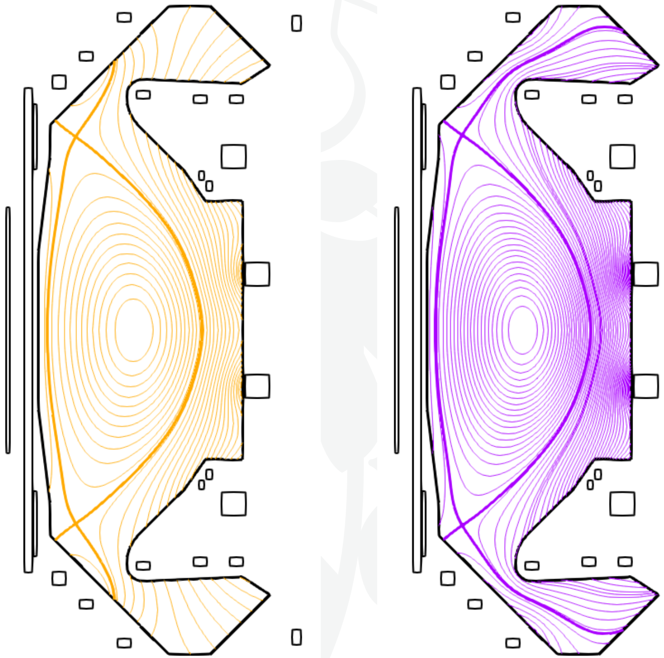

Fig 1. Flux contours for conventional (left) and Super-X (right)

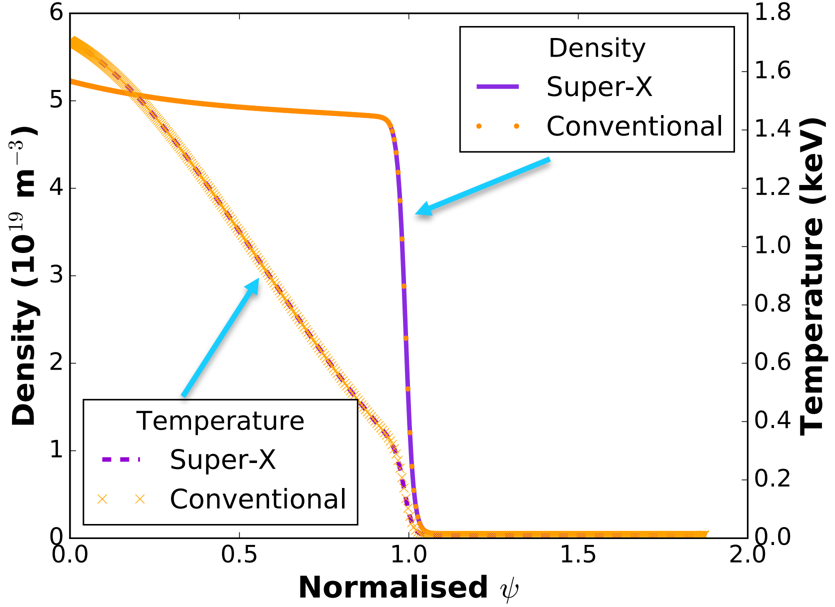

Fig 2. Profile comparison for conventional (orange) and Super-X (purple)

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Super-X comparison to conventional

	Conventional	Super-X
Growth rate (10^4 s^{-1})	3.53	3.45
Particle losses in pedestal	13%	14%
Energy loss in pedestal	10%	11%
Peak heat flux inner target (MW/m^2)	2.2	2.7
Peak heat flux outer target (MW/m^2)	6.9	0.32

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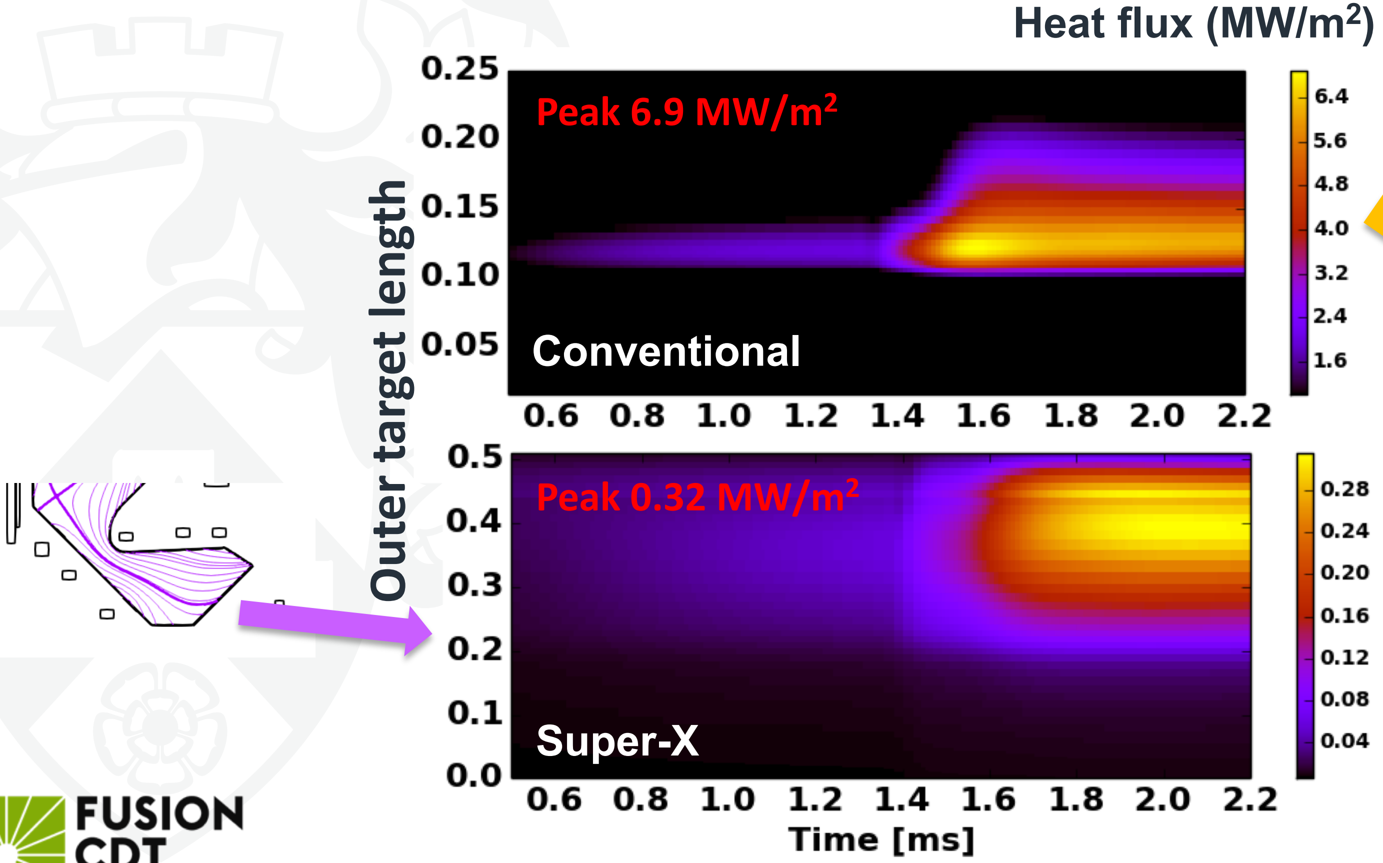
Super-X comparison to conventional



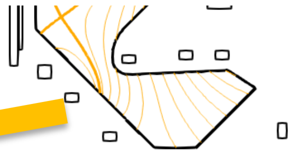


Fig. Evolution of the heat flux for the conventional (upper) and Super-X (lower)

JOREK fluid neutrals model

$$\frac{\partial \rho_n}{\partial t} = \nabla \cdot \left(\vec{D}_n : \nabla \rho_n \right) + S_{\rho_n} - \left(\rho \rho_n S_{ion} - \rho^2 \alpha_{rec} \right)$$

Diffusive neutrals

Neutral source, injection/pumping

Ionisation and recombination rates

JOREK fluid neutrals model

$$D_n \nabla \rho_n \cdot \vec{n} = - \xi_{re} \; \rho \vec{v}_{\|} \cdot \vec{n}$$

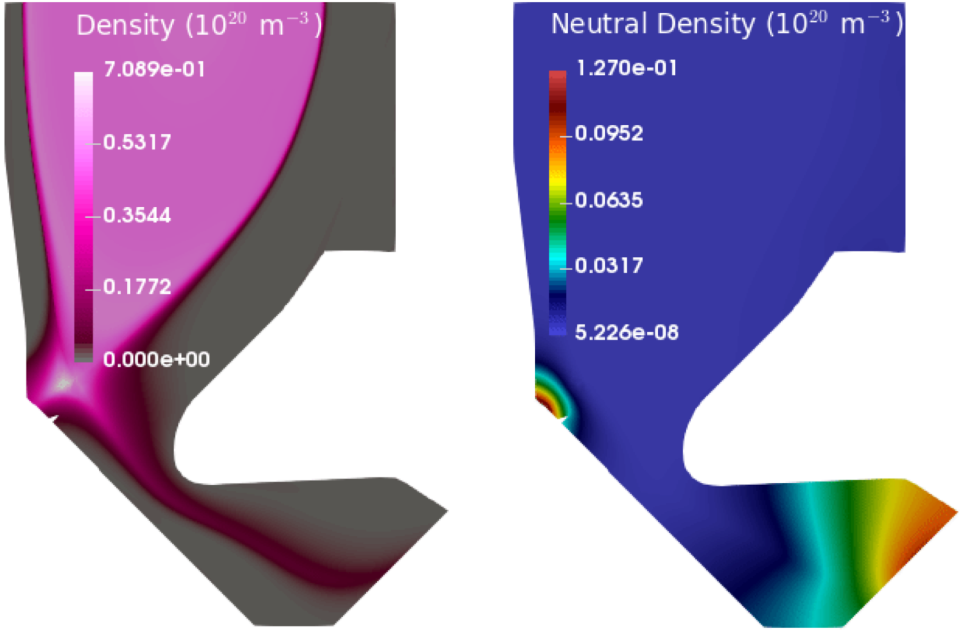
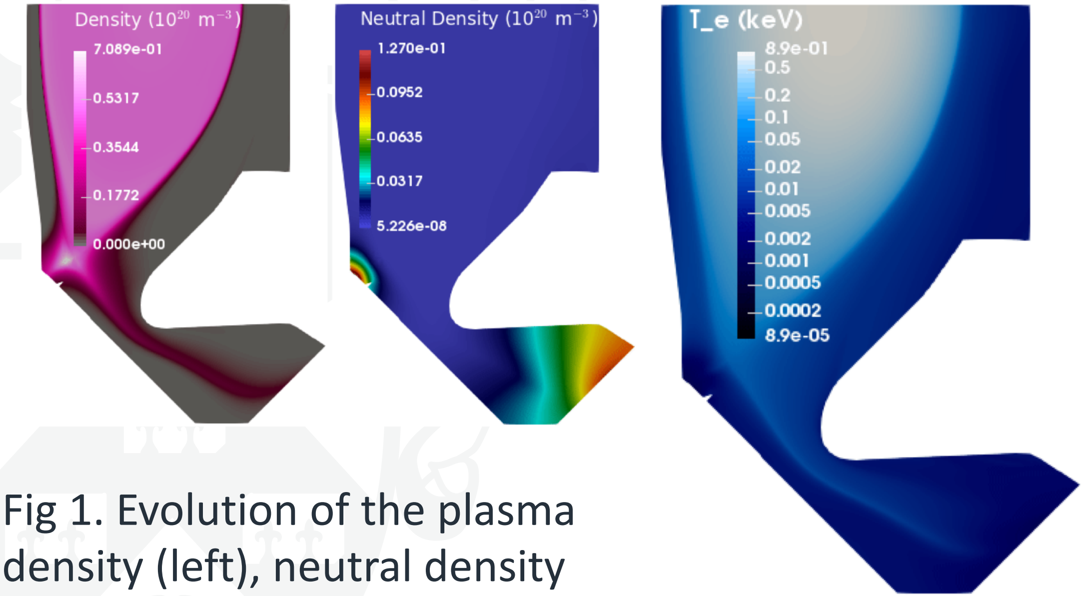


Fig. Plasma density (left) and neutral density (right)

Detachment with neutrals model



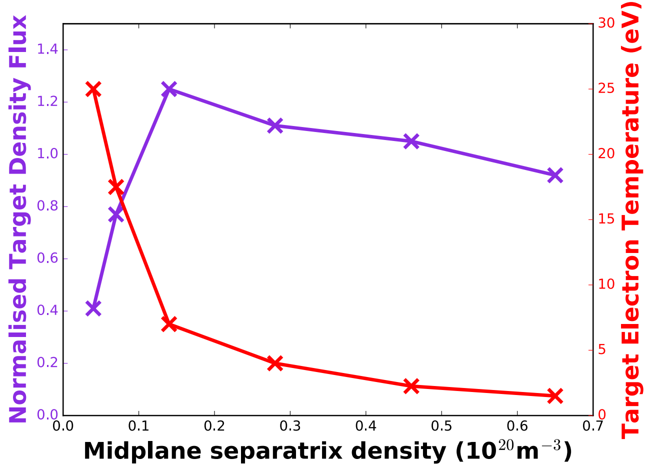


Fig 1. Evolution of the plasma density (left), neutral density (center) and electron temperature (right)

Fig 2. Rollover of target density flux and drop in electron temperature

Detachment with neutrals model

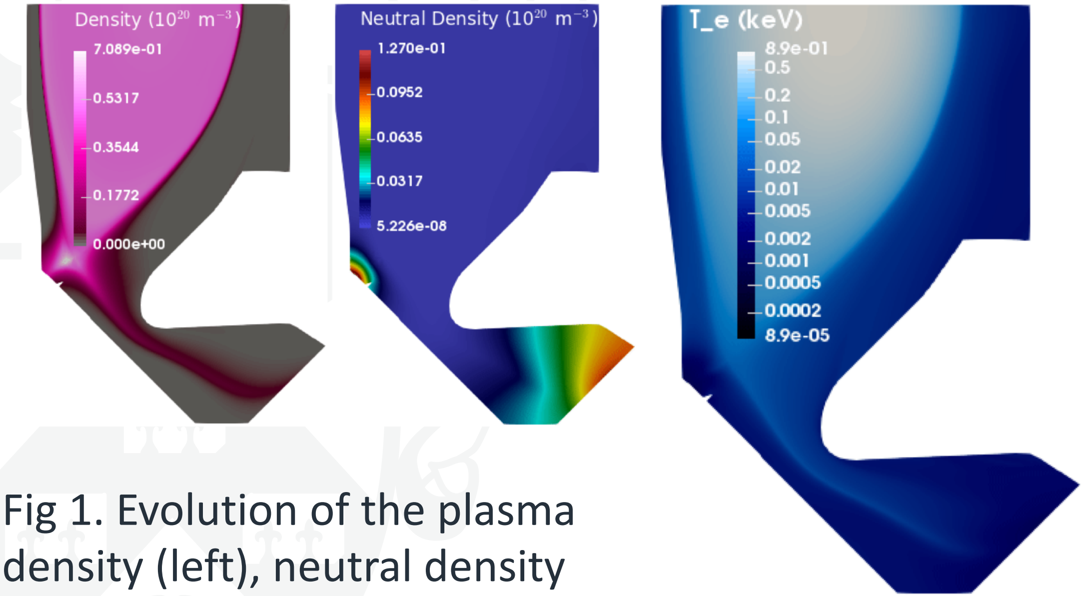


Fig 1. Evolution of the plasma density (left), neutral density (center) and electron temperature (right)

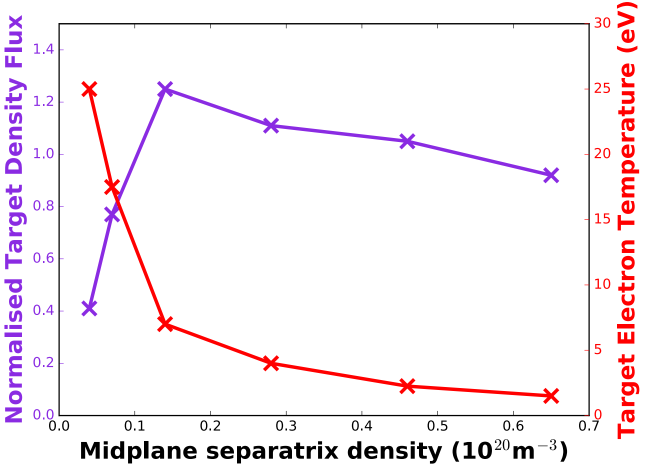


Fig 2. Rollover of target density flux and drop in electron temperature

ELM burn-through

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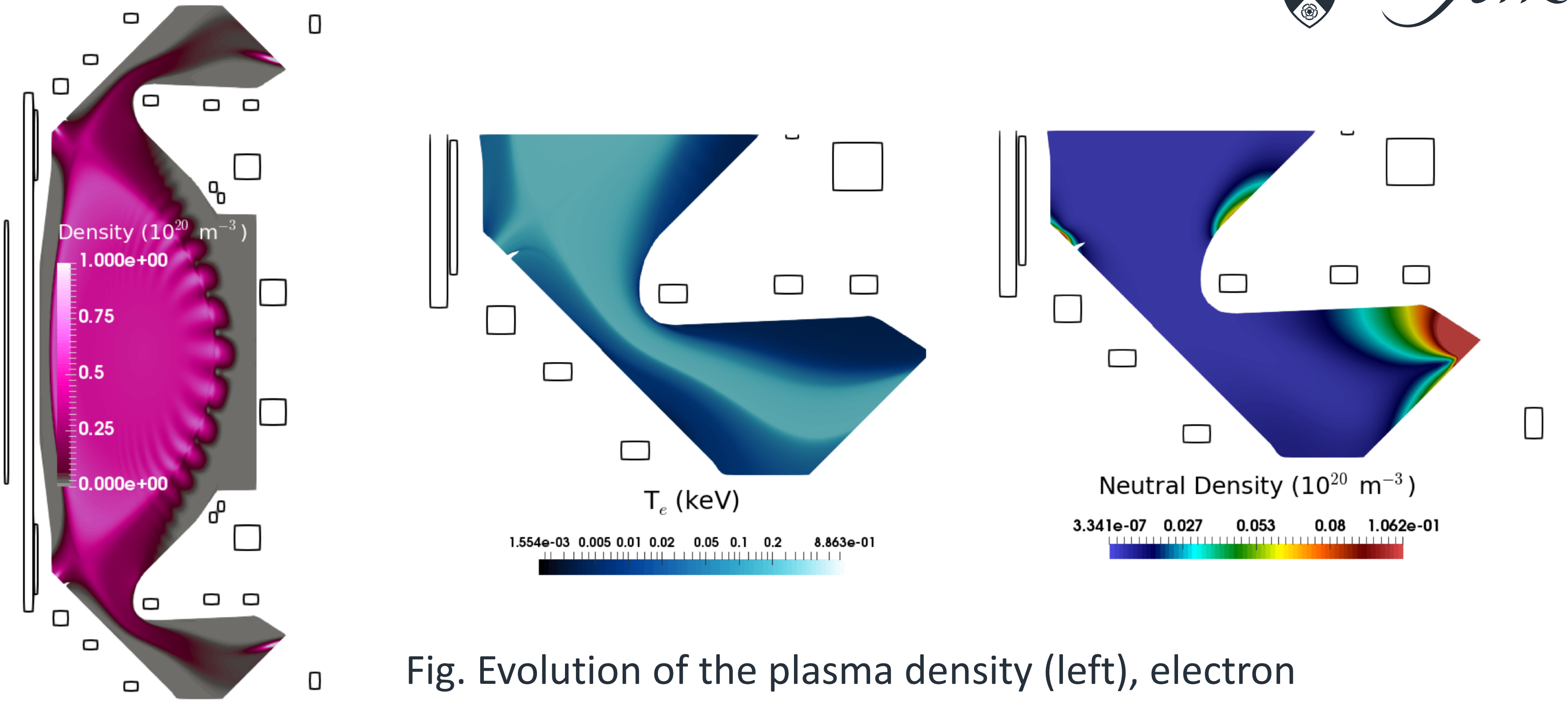

Fig. Evolution of the plasma density (left), electron temperature (center) and neutral density (right)

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ELM burn-through

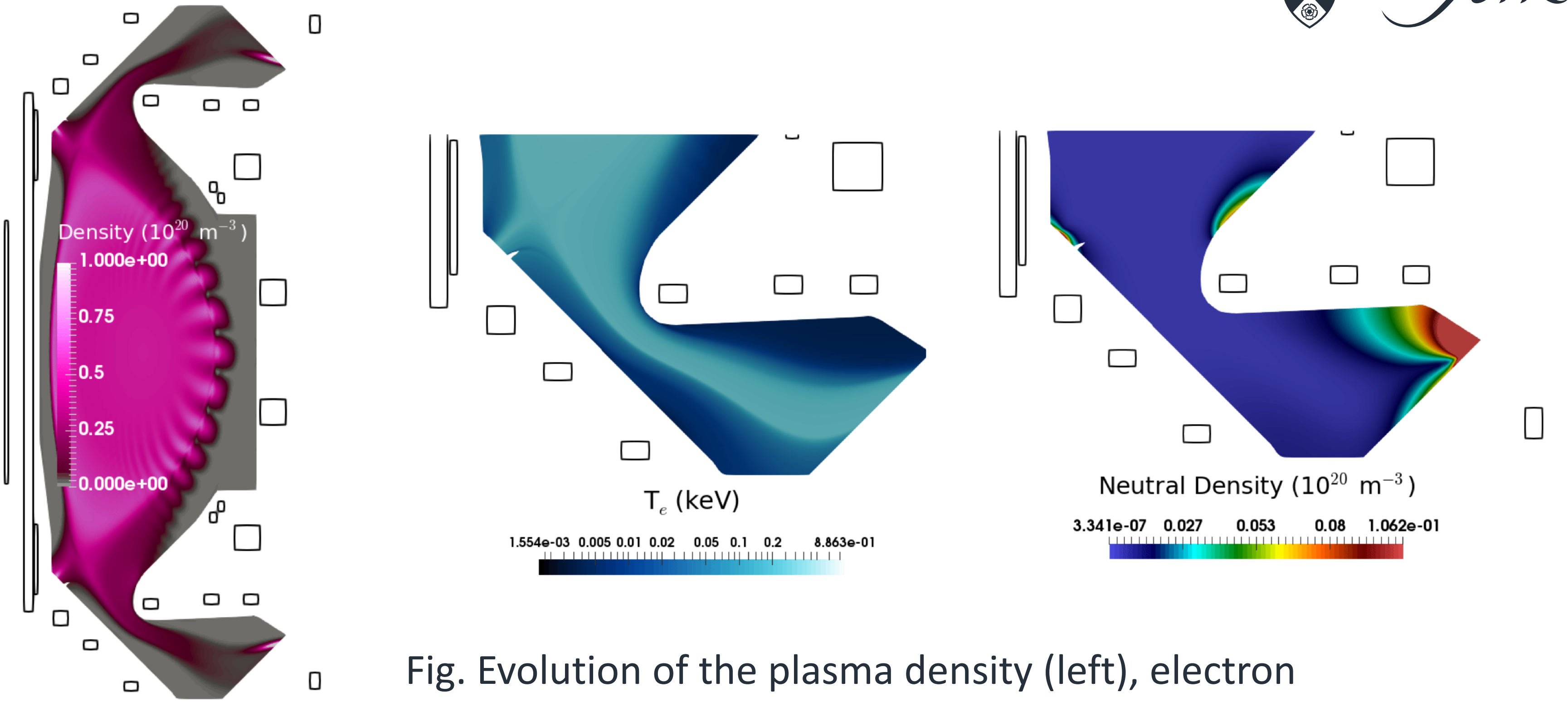

Fig. Evolution of the plasma density (left), electron temperature (center) and neutral density (right)

ELM burn-through

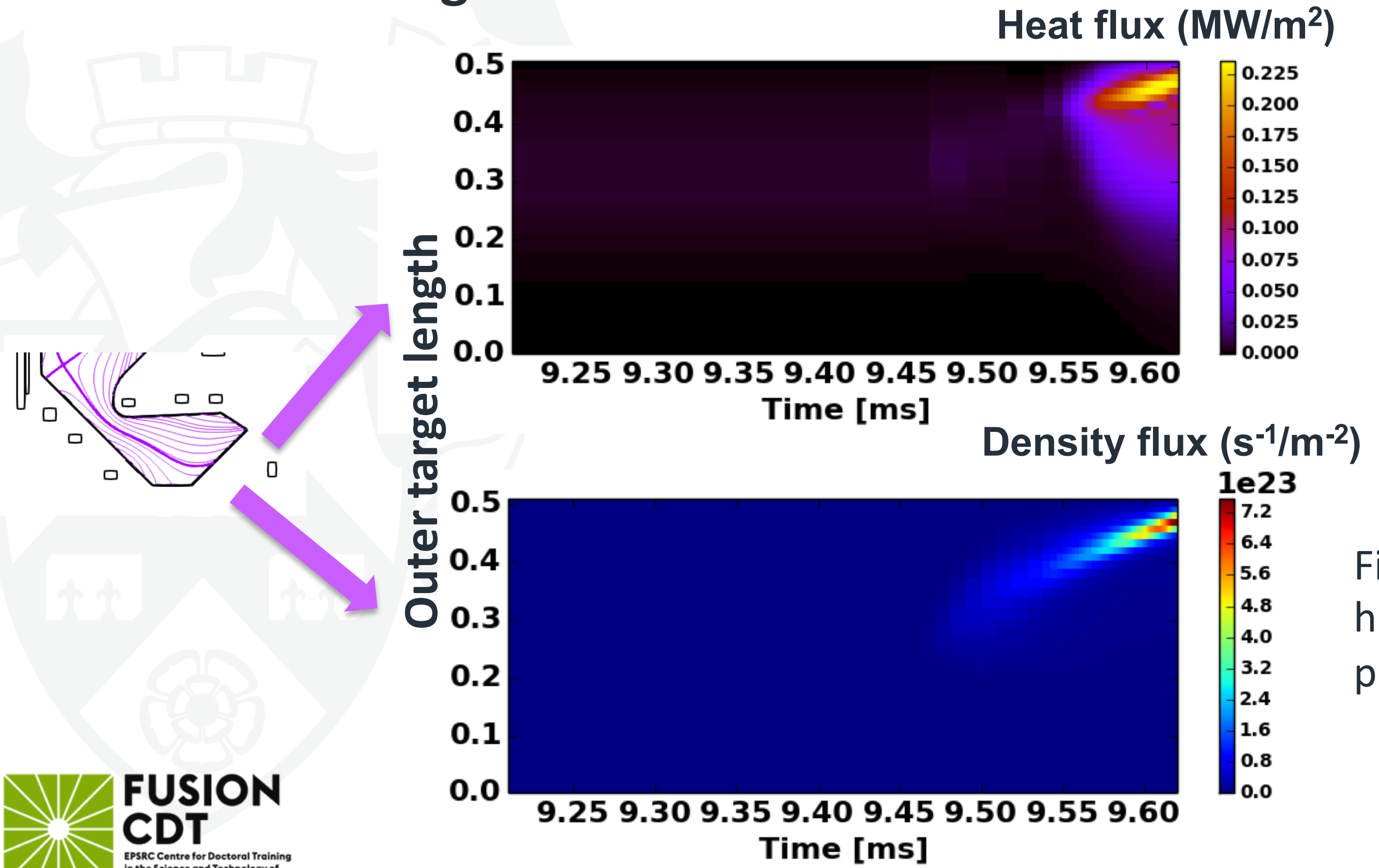

Fig. Evolution of the heat flux (upper) and particle flux (lower)

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Conclusion

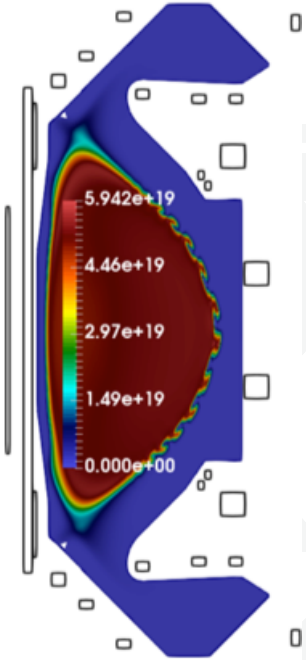

Fig 1. ELM simulation MAST-U lower heat fluxes

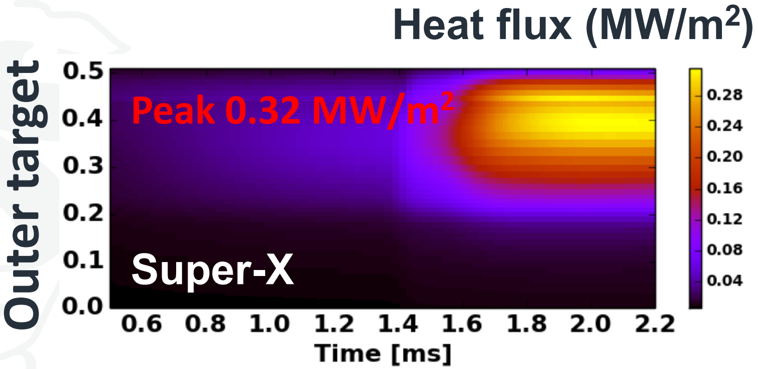

Fig 2. Lower heat fluxes for the Super-X

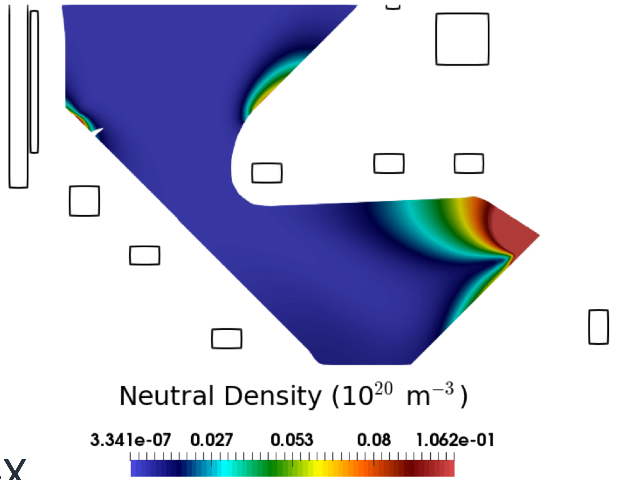

Fig 3. ELM burn-through