INSTITUTE OF PLASMA PHYSICS
OF THE CZECH ACADEMY OF SCIENCES

Modelling of the interaction of RE with PFC

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MINISTRY OF EDUCATION, YOUTH AND SPORTS

STATUS OF 2021 TASKS

2021 Plan

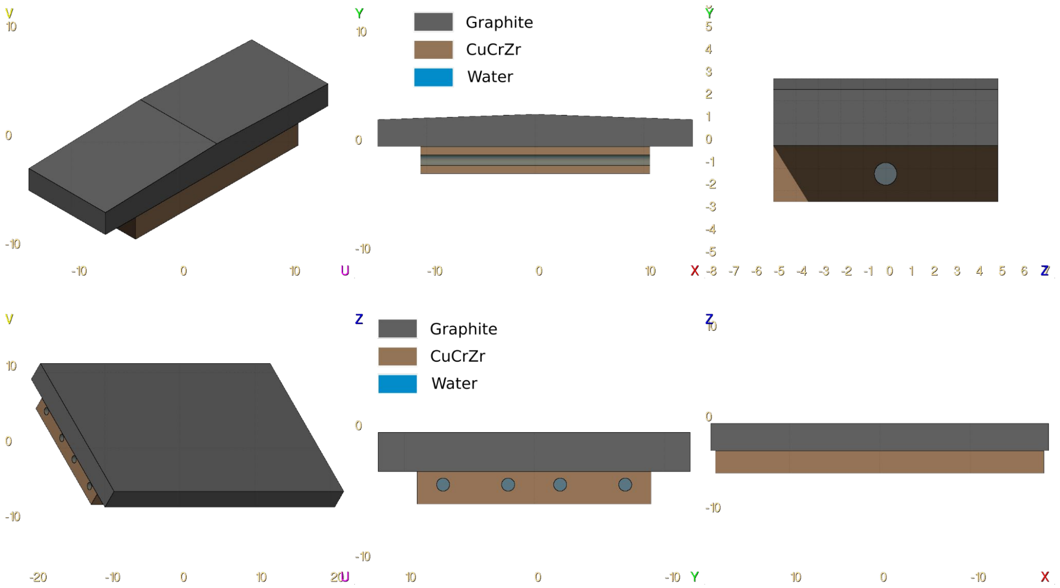
- Design of the simplified combinational geometry of the PFC for use in FLUKA simulations
- FLUKA simulations of deposited energy depth profiles for various RE energy distributions and incident angles of impact

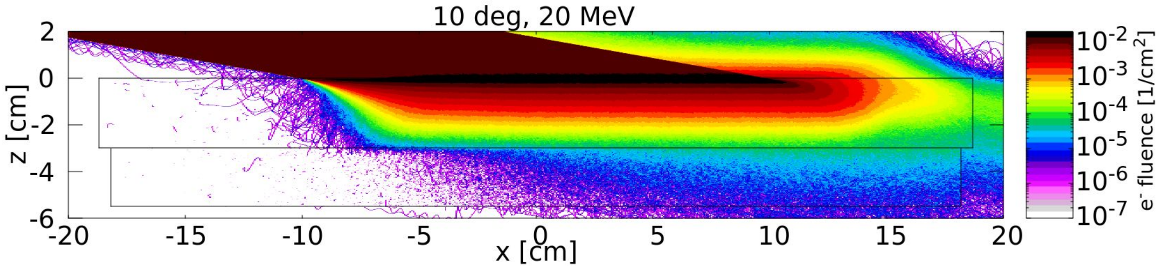
FLUKA

- FLUKA - MC particle transport and interaction code
- Transport of RE from 1 keV in magnetic fields, Interactions with solid materials and energy deposition

Status

- IWL and Divertor dome simplified tiles modelled in FLUKA
- Simulations with monoenergetic RE beams with magnetic field (10^6 particles)
- Scans in RE energy (based on JET data [1]) and impact angle (based on simulations [2,3])

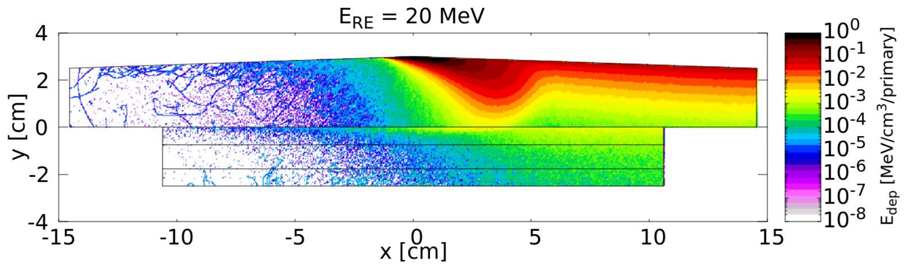


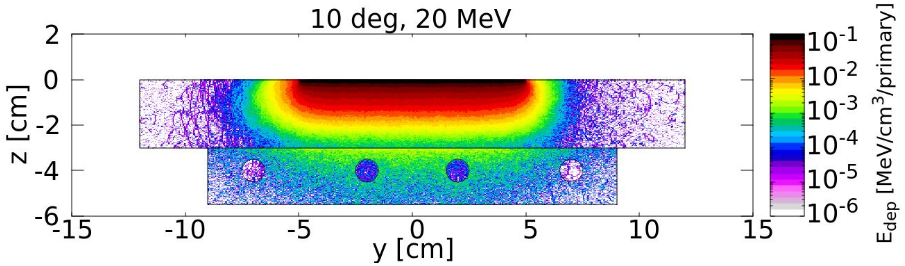


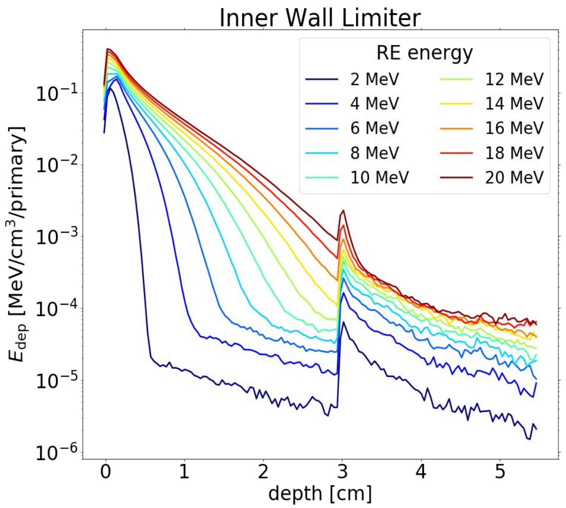
[1] C. Reux et al., Nucl. Fusion 55, 093013 (2015)
[2] G. Maddaluno et al., J. Nucl. Mater. 313 (2003): 651-656
[3] B. Bazylev et al., J. Nucl. Mater. 438 (2013): 237-240.

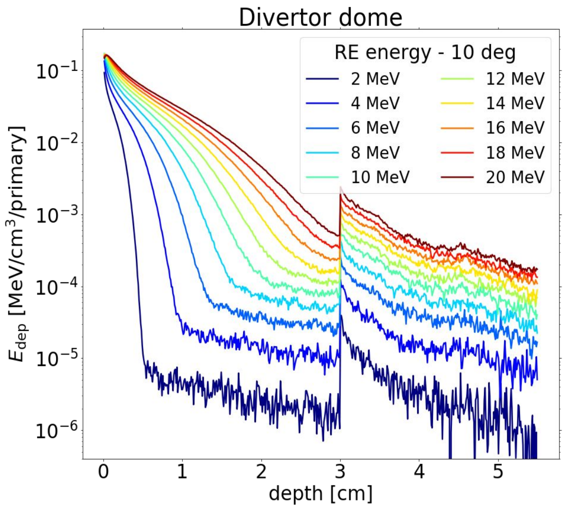
Results

- Simulations of RE beams 2 - 20 MeV with angle 1 - 10 deg
- Deposited energy density decreases exponentially with the depth both for graphite tiles and heatsinks
- For lower energies of RE, energy deposited by radiation deeper into material
- Energy deposited into heatsink is 2 orders of magnitude lower than in the graphite tile
- Energy deposited directly into coolant is negligible









$E_{\mathrm{RE}} = 20$ MeV			
	E_{dep} (Graphite)	E_{dep} (Heatsink)	E_{dep} (Coolant)
DIV (10°)	18.77 MeV	0.38 MeV	3.8 keV
IWL (3°)	14.0 MeV	0.1 MeV	0.4 keV

2022 Plan

- Workflow of particle tracing codes coupled to FLUKA
  - spatial distribution and energy levels of RE heat loads on the JT-60SA PFC
- Simulations with 2 particle tracing codes for selected scenarios - scans over RE energy and pitch angles
  - ORBIT
  - Full orbit particle tracing code developed at COMPASS
- Identification of areas where REs terminate with different energy and pitch angle
- FLUKA/FluDAG simulations with inputs from the particle codes - deposited energy density profiles in simplified and full CAD geometry

Specifications of the code

- Guiding-center particle code which solves the Hamilton equations for the canonical variables $P\theta$, $P\varphi$, θ and φ
- An arbitrary spectrum of magnetic perturbations can be imposed over the equilibrium
- A population of runaways, characterized by energy E, spatial and pitch-angle distribution, can be evolved
- Final spatial and pitch-angle distribution is obtained, as well as the fraction of lost particles, as function of E
- Code is relativistic, but energies must be limited ($E<10$ MeV) because FLR effects are missing

Required inputs

- Initial guess on the runaway distribution (energy, spatial and pitch-angle)
- Magnetic equilibrium in eqdsk format, guess on spectrum and amplitude of MHD perturbations

R. White and M. Chance, “Hamiltonian guiding center drift orbit calculation for plasmas of arbitrary cross section,” The Physics of fluids, vol. 27, no. 10, pp. 2455–2467, 1984

CODE[1] specification

- solves the relativistic equation of motion in **3D** B-field from equilibrium & 3D E-field (toroidal symmetry) with 3D **magnetic perturbation** perturbation toroidally asymmetric
- radiation losses represented by radiation reaction force in the Landau–Lifshitz representation [2,3] included
- relativistic geometry of tokamak with PFC used,
- no collisions (time scale of simulations ≤ 1ms, $\Delta t = 1.10^{-13}$ s)
- validation against ORBIT[4] (w/o perturbation) for < 2 MeV

CODE requirements

- coordinates of first wall
- magnetic equilibria or information about the poloidal and toroidal field in required scenario and time step
- estimation of amplitude and poloidal and toroidal structure of magnetic perturbations
- range of RE energies and pitch angles

[1] Hron et al 2022 NF accepted, [2] Landau and Lifshitz 1971, [3] Carbajal et al PoP 2017, [4] White et al, PF, 1984