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# Preliminary applications of ANET code for the investigation of the Hybrid Soliton Reactor concept

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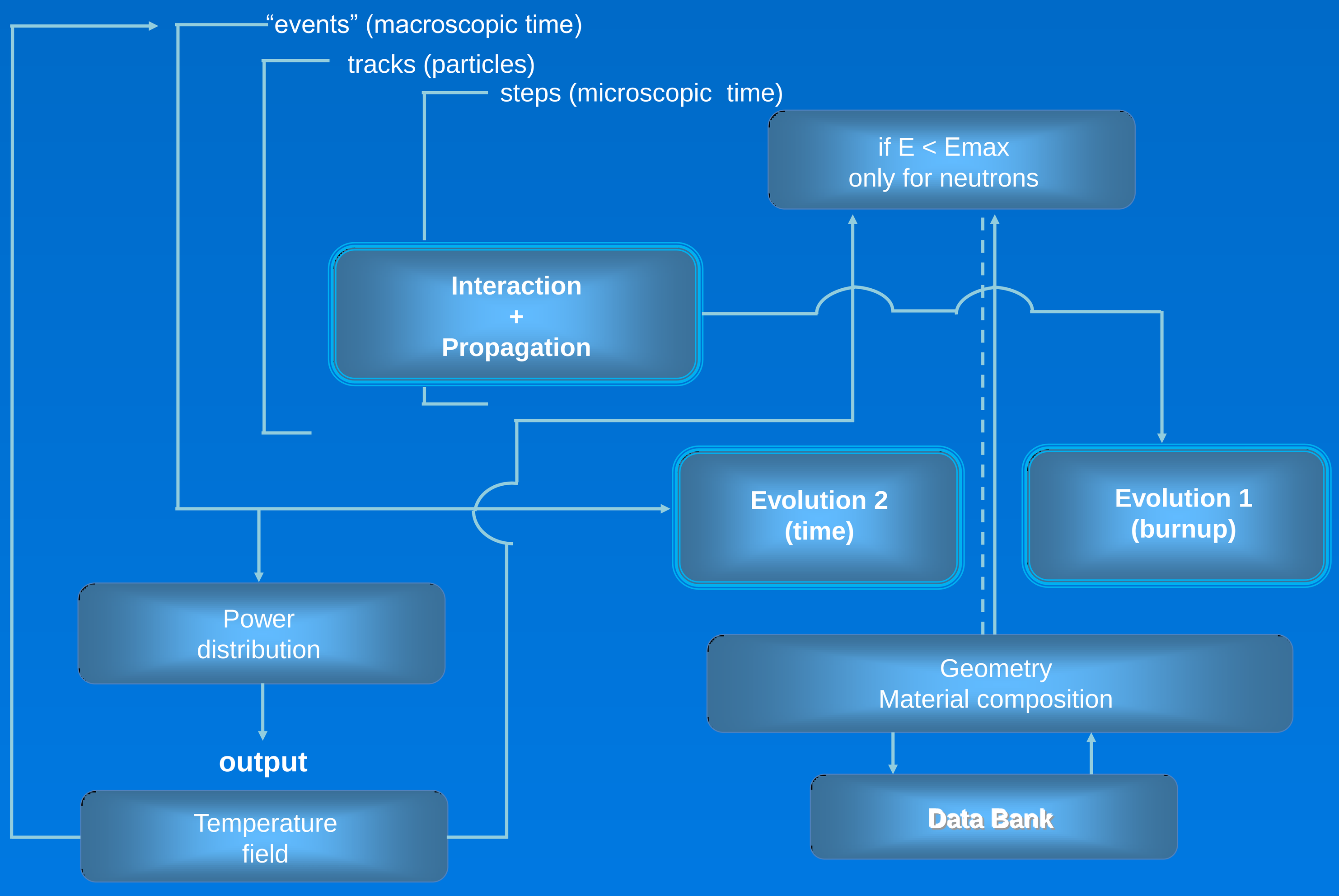
The Monte Carlo code ANET is under development, based on the high energy physics code GEANT3.21 of CERN. The code is being developed aiming at progressively satisfying several requirements regarding simulations of both conventional reactors and innovative nuclear reactor designs such as the Accelerator Driven Systems (ADSs). ANET present version is capable of simulating the spatial distribution of fission, absorption and elastic scattering events in the core of critical and subcritical fission reactors, performing also criticality calculations. On the other hand, the code is capable of performing ADSs simulations accounting for the high energy proton beam interaction with spallation target, the neutrons trajectories in the reactor core and the reaction rates distribution. ANET is being structured to account for core materials modification due to nuclear reactions and to radioactive decay. Preliminary applications of ANET for the investigation of the Hybrid Soliton Reactor (HSR) concept are here presented.



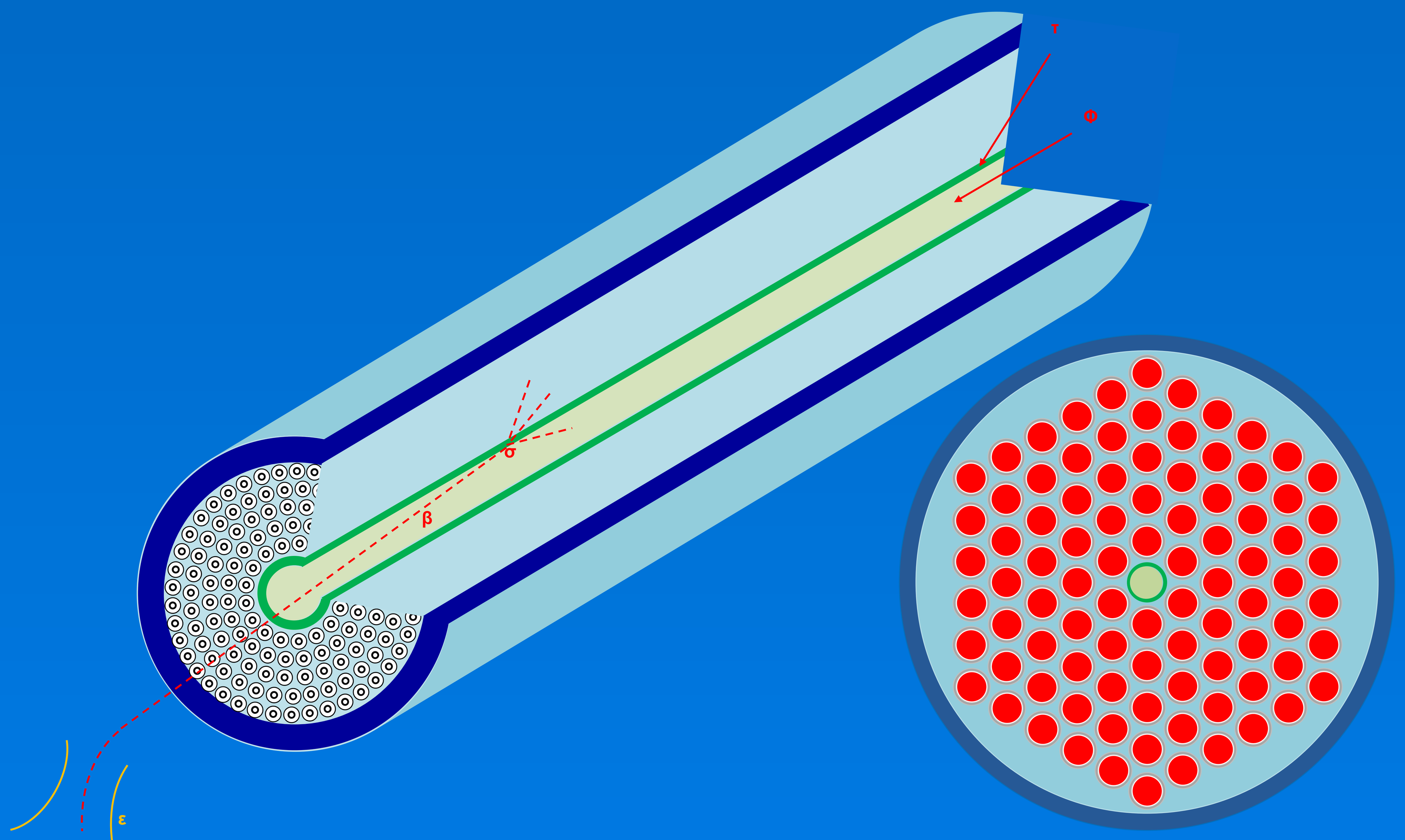

- Architecture typical of a dynamical Monte Carlo transport code.
- Three main loops, on events, particle tracking and microscopic time step.
- If a time is assigned to each event and a quantity of energy is assigned to each fission -> practically continuous simulation of the evolution of reactor composition due to radioactive decay with time and burn up.

Inputs of the program:

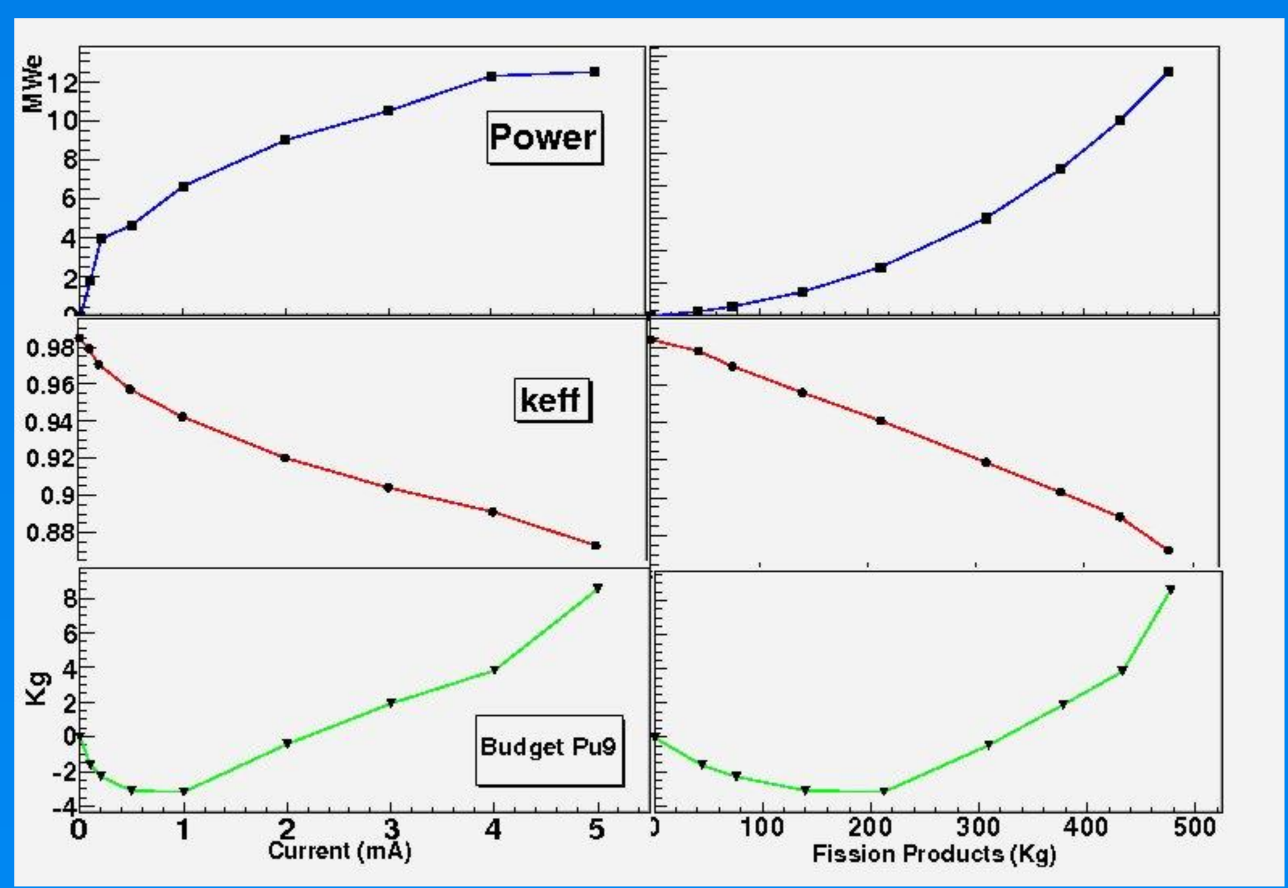
- geometry and initial chemical and isotopic composition of the reactor
- temperature distribution
- source of neutrons or particle beam (e.g. deuteron or proton)
- nuclear data base (cross sections, fission parameters)

- Parameters of the reactor (geometry, inventory, temperature, neutron source) can change during computation, due to reactor evolution, or simply to reactor control (e.g. rods’ movement) or to the accelerator’s beam displacement.

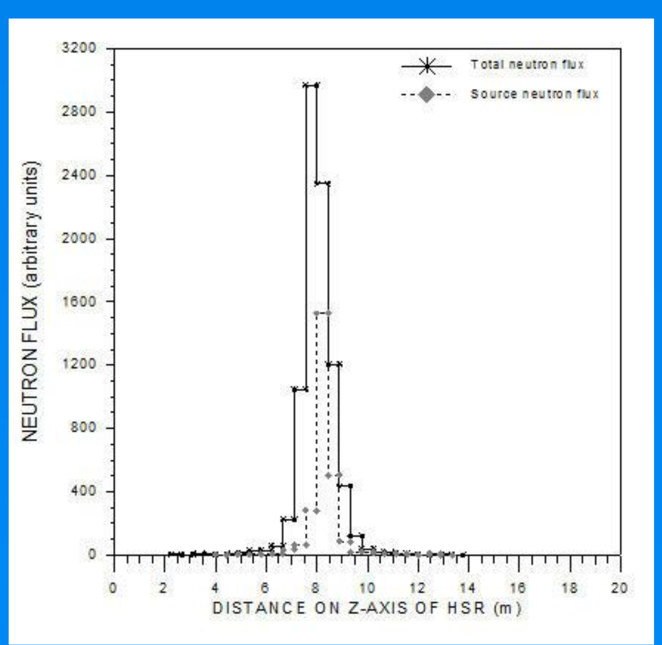
In the code’s flow chart:
“Evolution 1”: core materials modification due to nuclear reactions ; “Evolution 2”: radioactive decay ; “Temperature”: capability of computing neutron cross sections at various temperatures of interest ; “Interaction + Propagation”: capability of simulating particles’ transport and interactions produced ; “$E < E_{max}$ only for neutrons”: code capability to simulate transport of low energy neutrons.



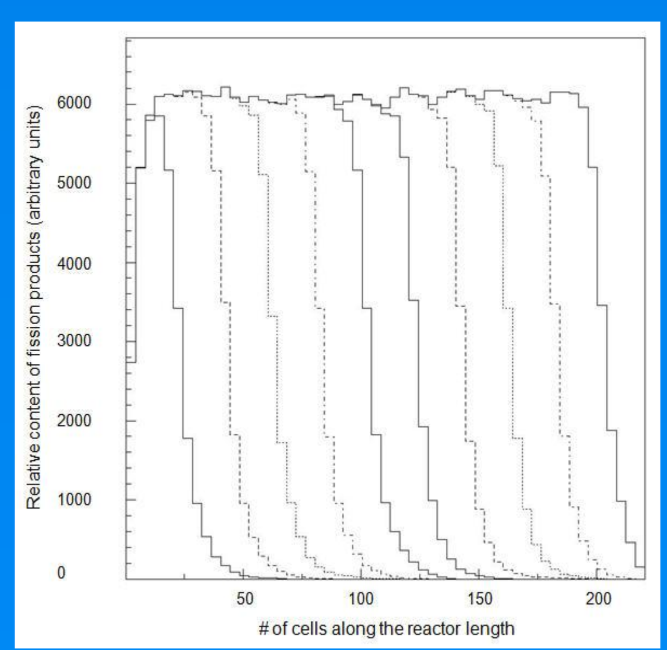

- The HSR concept is schematically described by a long cylindrical vessel Φ.
- The vessel contains the fertile and fissile materials as well as transuranic waste to be destroyed.
- The fuel pins are arranged in a hexagonal geometry.
- The central tube of the vessel is empty, forming a channel through which a source of neutrons moves at a velocity which can be modulated.
- The neutron source σ is a beam of protons β from an accelerator, which hits the target τ (made for example of tungsten) and then produces neutrons.
- The neutron source σ is moving with a constant speed along the axis of the cylinder.




Preliminary results of a conceptual configuration of an HSR, loaded with $^{238}U/^{239}Pu$ fuel pins, show that after an initial decrease, the amount of fissile material ($^{239}Pu$) follows a regular increase, clearly showing the breeding capability. Moreover, the variation of the total amount of fissile material remains limited to a few parts per thousand over a large evolution range (i.e., a few kg for an initial amount of 2 tons). A clear breeding result is obtained for a reasonable beam power (~3 MW). A regular decrease of the multiplication factor $k_{eff}$ , which persists once breeding is established, is also shown. The same concept is currently being studied with $^{232}Th/^{233}U$.




Comparison of the neutrons produced by the spallation source with the total number of neutrons produced in the core after 4000 days of reactor operation and for a given energy of the proton beam. The dispersion of the neutron source is due to the proton’s range of interaction at energies of the order of GeV. This causes neutrons to be produced by proton interactions in a zone of the window material but also with the core materials in the vicinity of the window.




Fission products distribution in the core, varying with time. Each curve corresponds to a reactor operation duration equal to nΔt, where n represents the curve serial number (starting from the leftmost curve) and Δt the computational time step, equal to 1000 days. The reactor stability is also illustrated, since the variation of the fission products distribution in the core remains stable with time. Fluctuations are mainly due to statistical errors.