Centre for Experimental Physics "eLBRUS"
University of Szczecin

Nuclear Physics
at
Extremely Low Energies

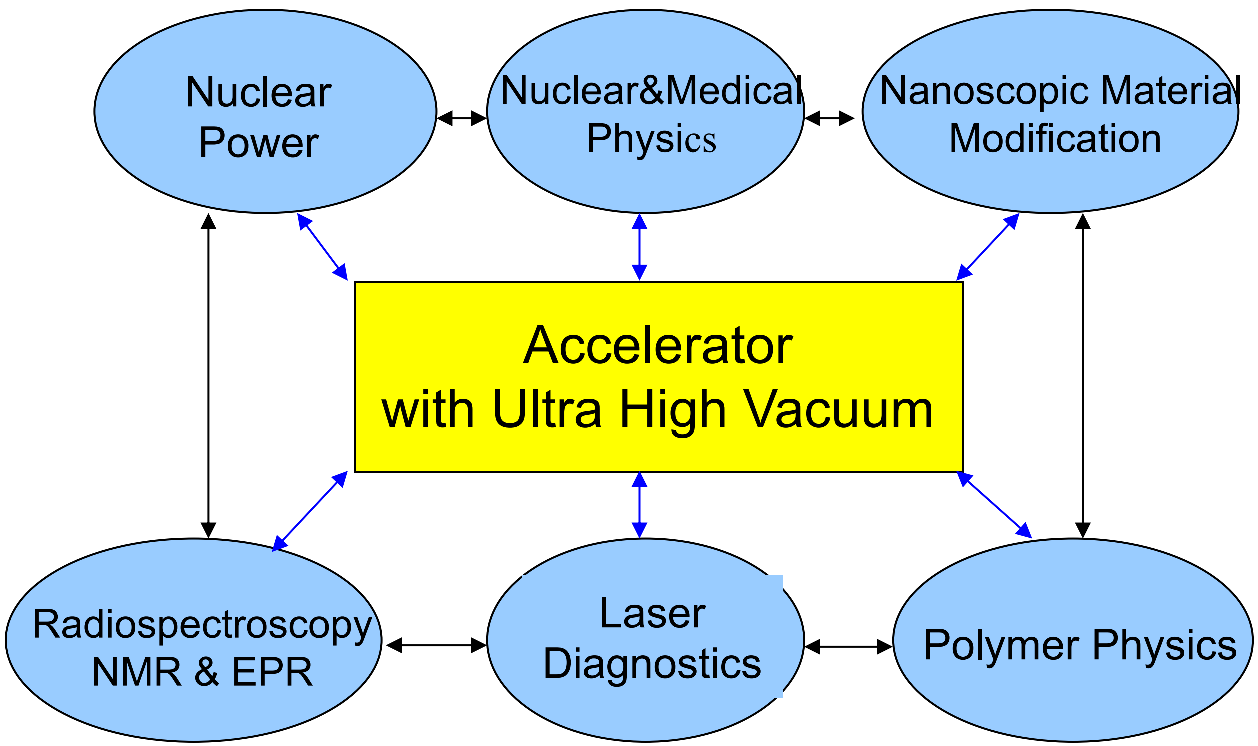
eLBRUS

Otwarte Zebranie Sekcji Fizyki Jądrowej PTF
28.09.2020

Konrad Czerski

eLBRUS: Scheme

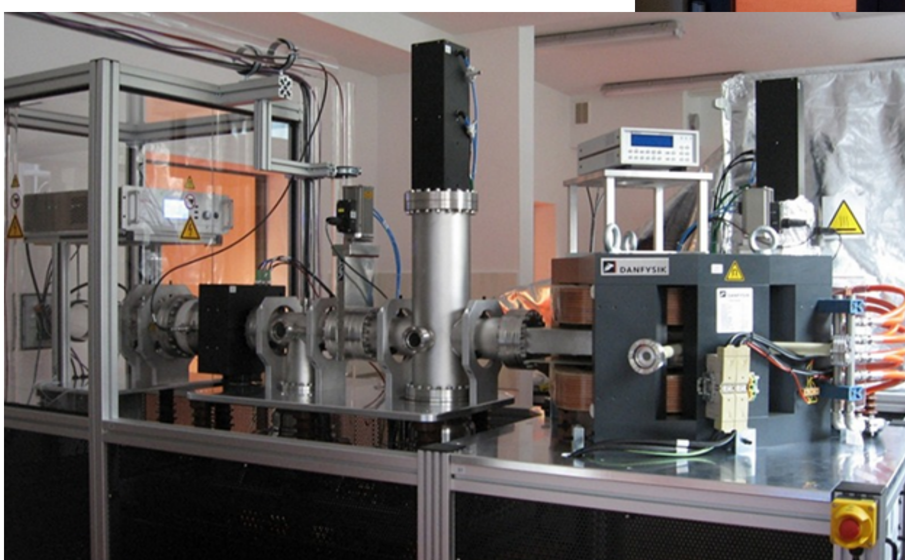
Unique combination of research methods of nuclear physics with methods of solid-state physics and laser optics for study of the condensed hard, soft and biological matter



e
Laboratoria
Badawczo-
Rozwojowe
Uniwersytetu
Szczecinskiego

http://elbrus.usz.edu.pl/

eLBRUS: Realization

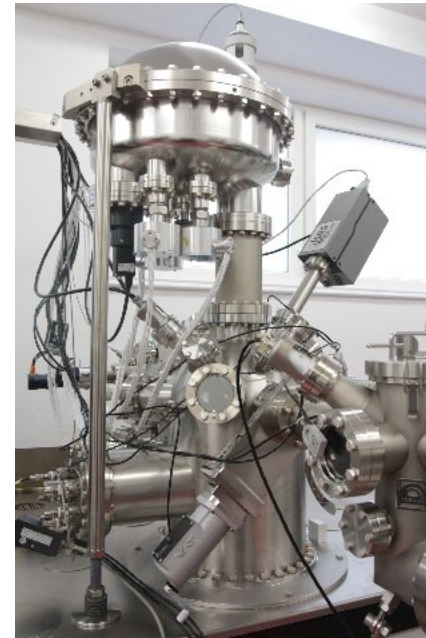


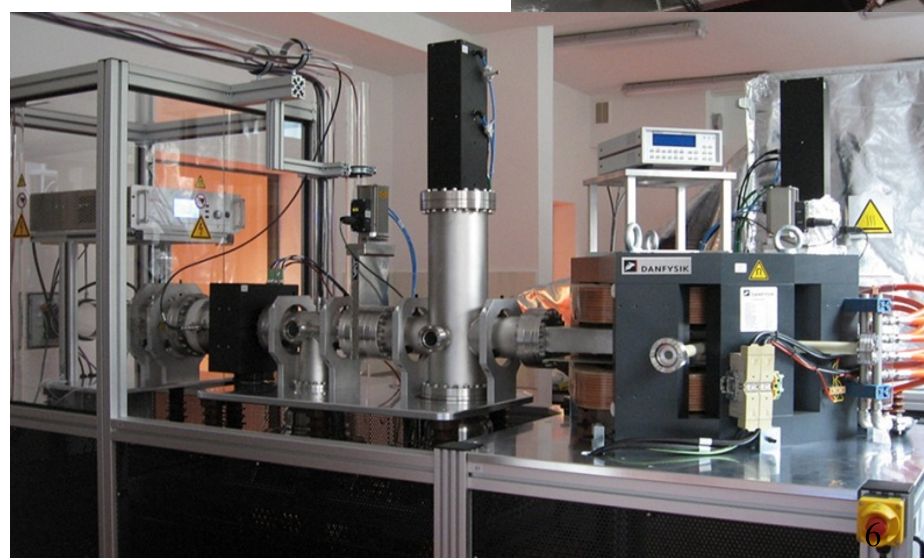
eLBRUS

accelerator with high vacuum

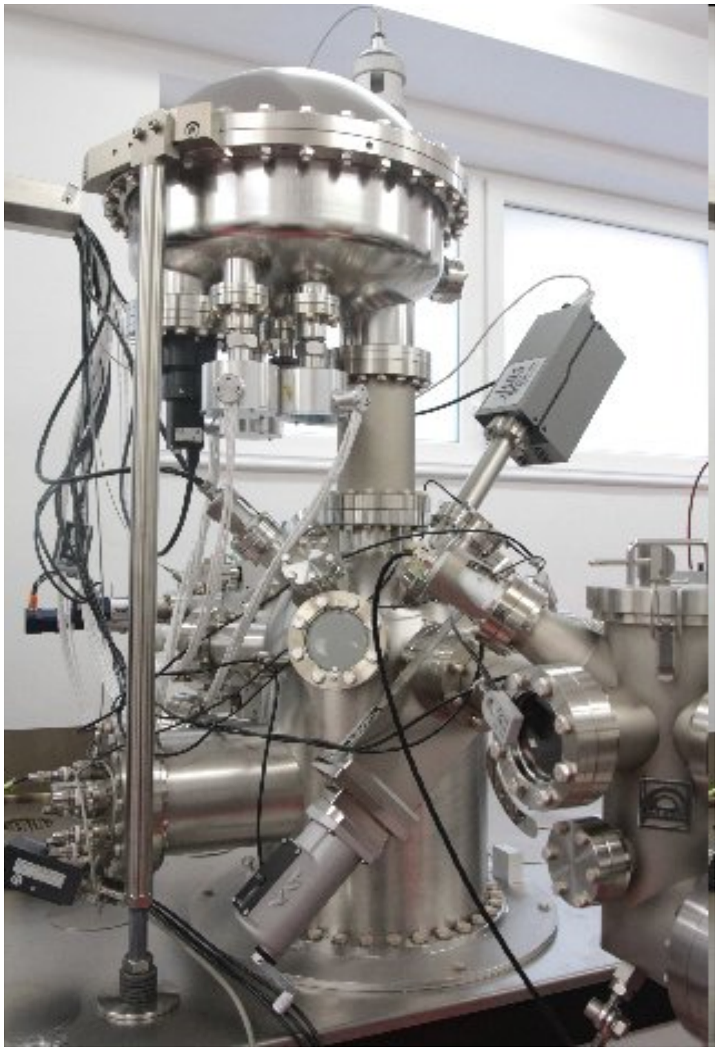
- 4 large Ge detectors
- large NaJ detectors

accelerator with ultra high vacuum





Accelerator with Ultra High Vacuum

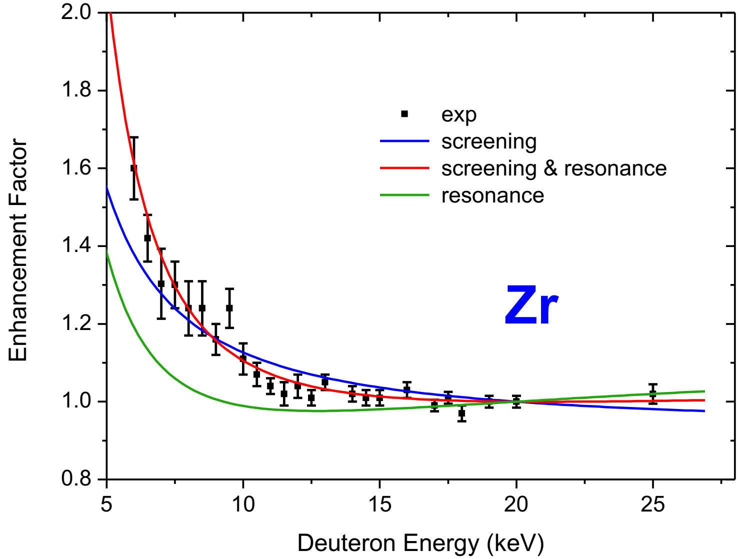


Target Chamber
μ-metal

Detection & Diagnostics:

charged particles
electrons 0.1 eV – 3 keV
electron gun
Argon gun - planned
AES
XPS
UPS
ToF Mass Spectroscopy
Rest Gas Spectroscopy

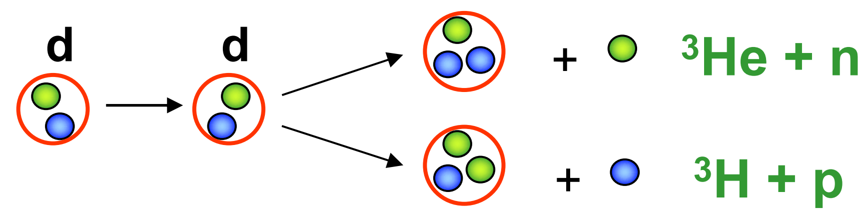
Nuclear reactions at extremely low energies & nuclear astrophyics

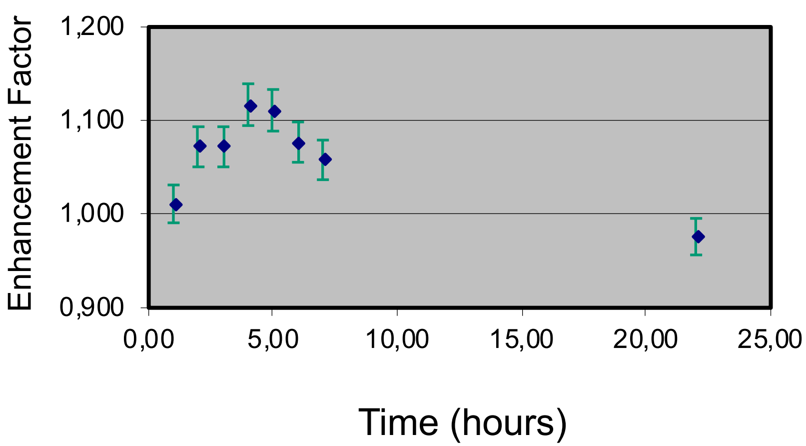


enhancement

of the cross section for the

d+d reactions (neu energy source?)





crystal defects are responsible

for enhancement

of the reaction cross section

Europhys. Lett. 2016

DD Reaction Rates (PdD)
@ Room Temperature

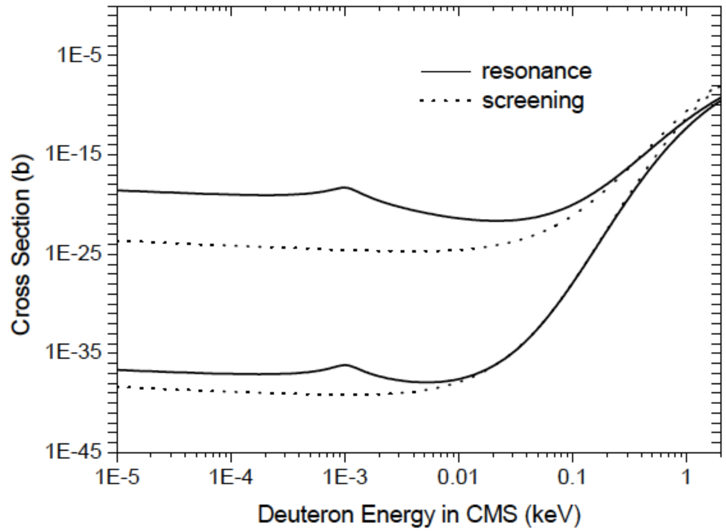
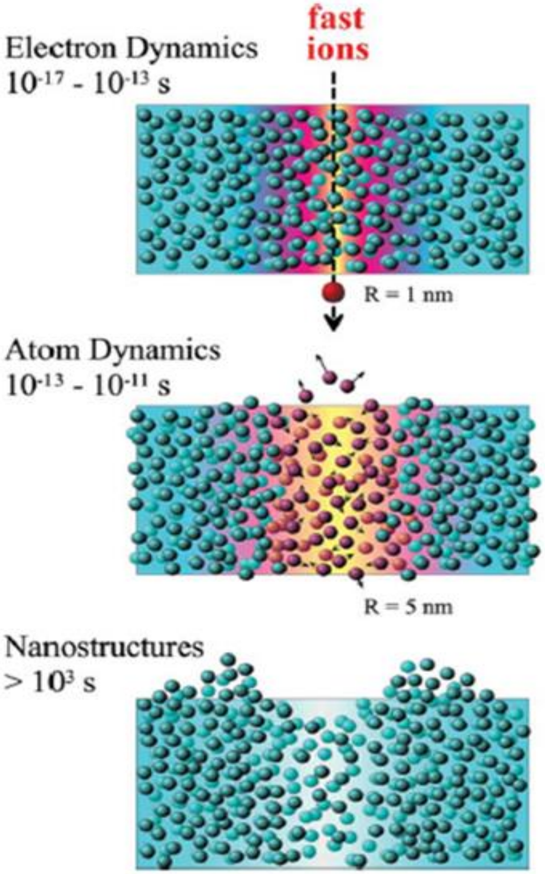


Fig. 3. Nonresonant (dotted line) and resonant (solid line) cross sections for $U_e =$ 110 eV (lower part of diagram) and $U_e = 300$ eV (upper part).

$$R_{scr}(E) = N\sigma_{scr}(E)v_{rel} = N\sigma_{scr}(E)\sqrt{\frac{4E}{M}} \cong \frac{2NS_0}{\sqrt{MU_0}} \exp\left(-\sqrt{\frac{E_G}{U_0}}\right)$$

EPL 2004, APP B 2020

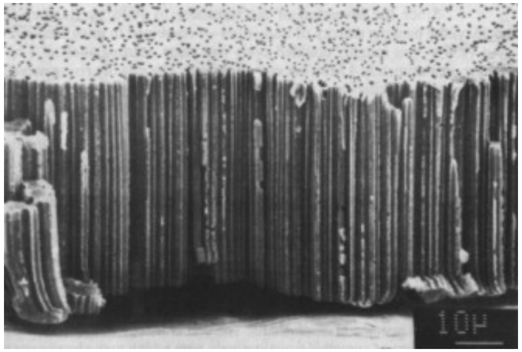
Radiobiology & nuclear tracks



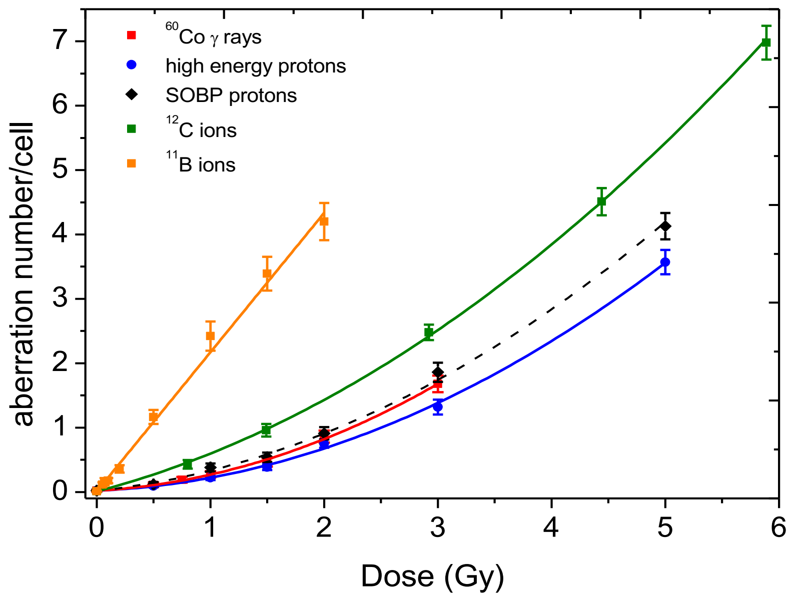
PRL 2007, PRL 2011

Dependent on the electron recombination time:

- Coulomb explosion
- Thermal spike
- Spontaneous lattice relaxation



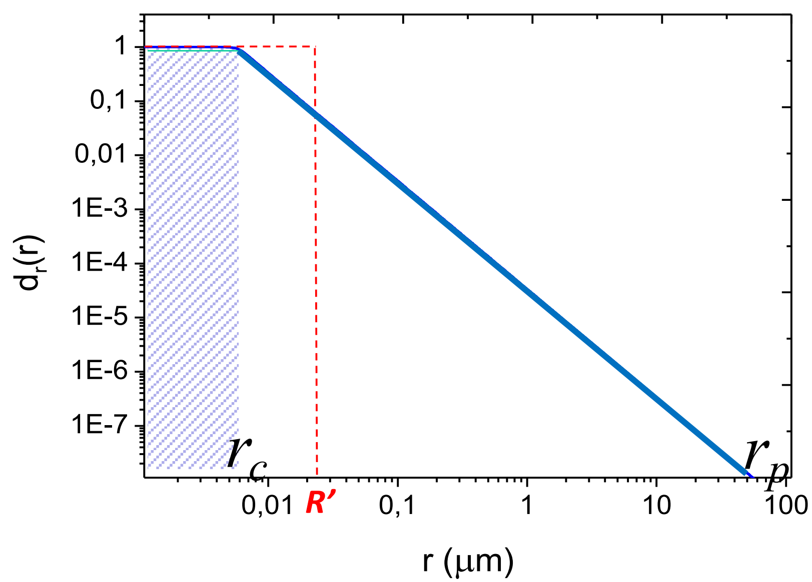
Dose-Effect Curves



Linear-Quadratic Model:

$$Y = \alpha D + \beta D^2$$

LET ↗ { α ↗ ; β=const }

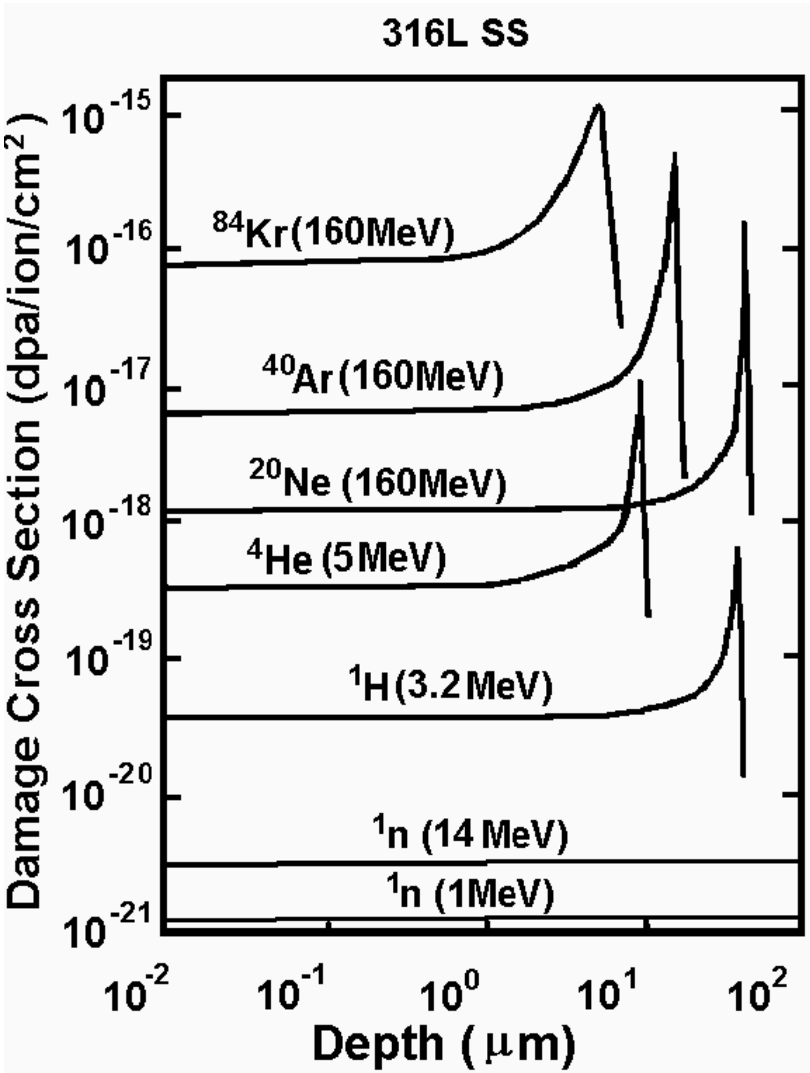


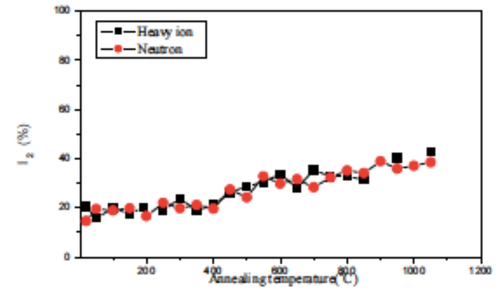
Overlapping Ion Tracks

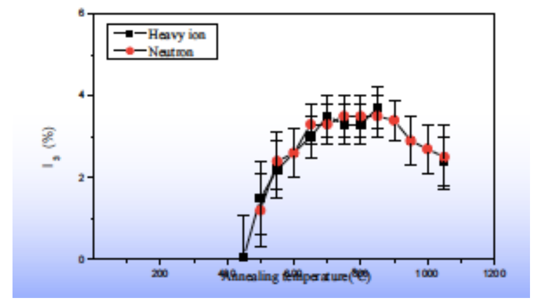
$$R = \sqrt{\frac{3 \cdot LET}{8 \cdot E \cdot \rho_m}} \cdot \sqrt{\ldots}$$

REBS 2018, 2019, 2020

Irradiation of Reactor Materials







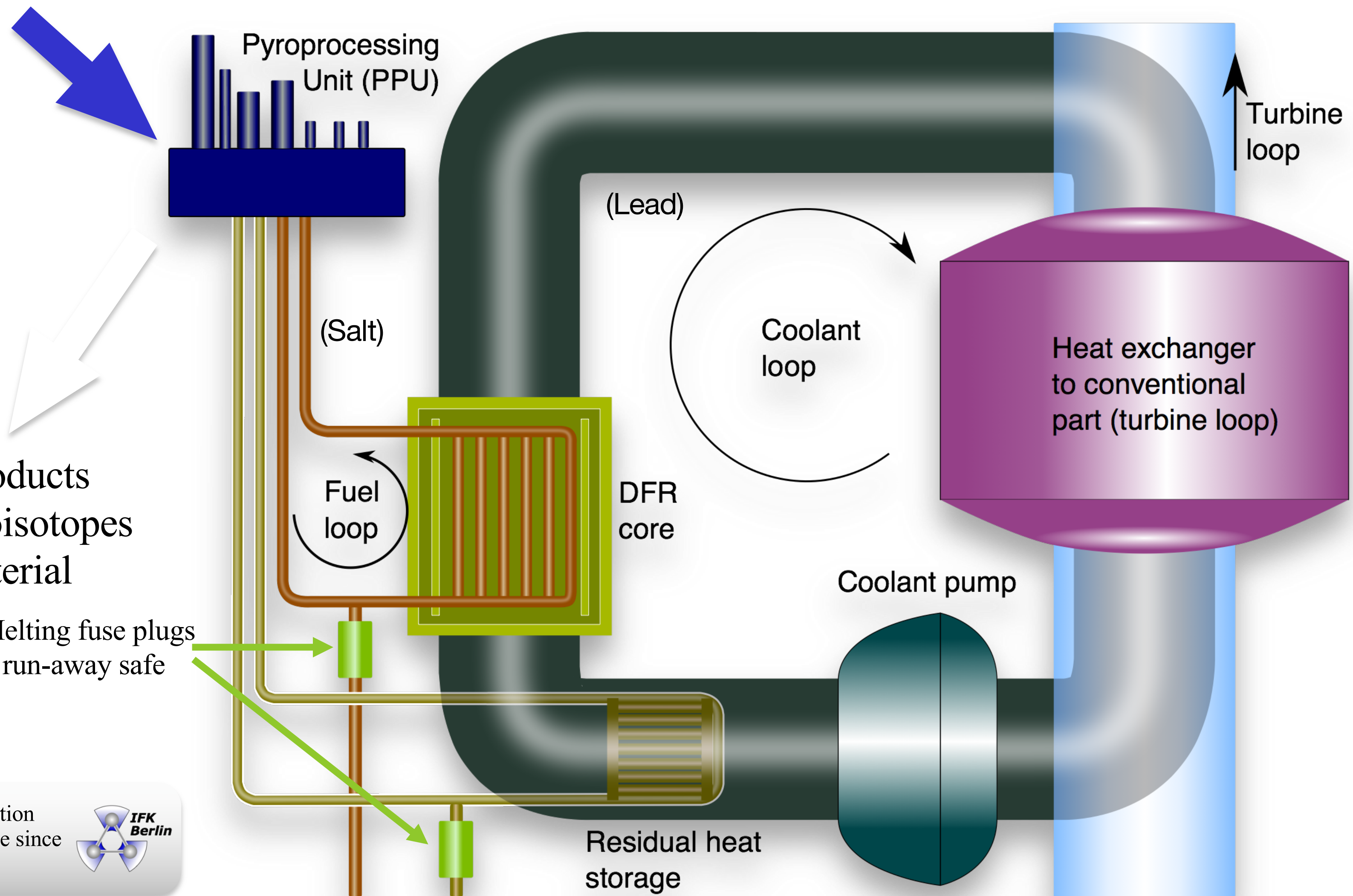
HI	Energy(MeV)	Range(μm)	RD rate(dpa/μAh)
^{12}C	70	41	2.1
^{19}F	80	21	3.9
^{36}Cl	70	7.7	11.7
^{129}I	100	6.6	26.5

fission reactors < 3 DPA/a

heavy ions $\simeq$ 100/a

The Dual Fluid Reactor
A concept beyond Generation IV

- Natural Uranium
- Depleted Uranium
- Thorium
- Used fuel elements



- Fission products
- Med. radioisotopes
- Fissile material

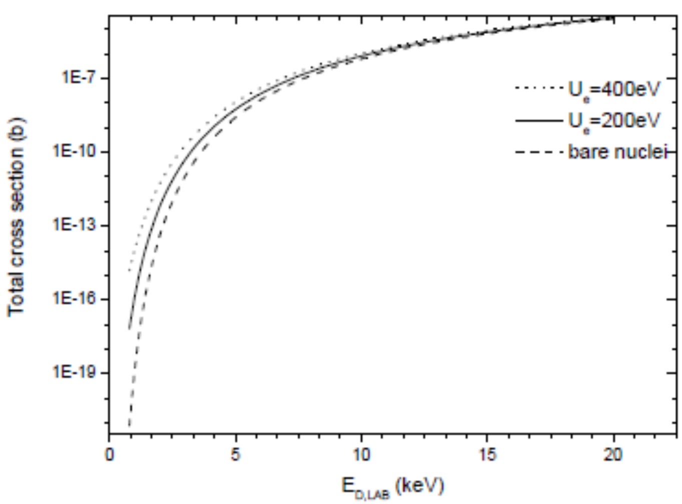
Melting fuse plugs
= run-away safe

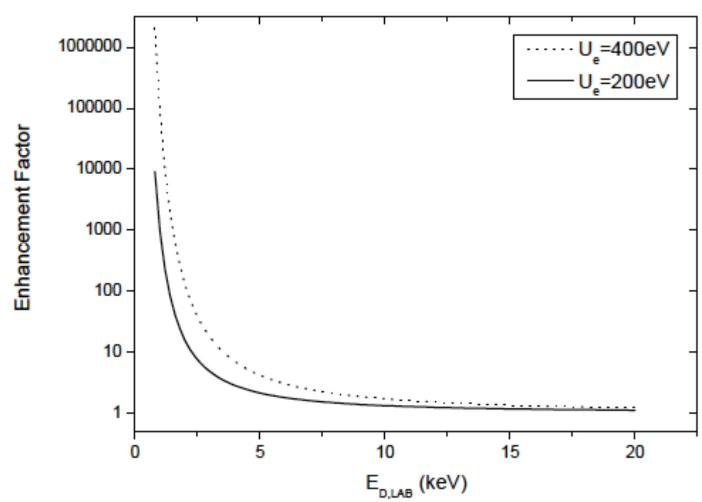
International patent protection for the Dual Fluid principle since Sep. 2011

IFK Berlin

Improvement: Additional accelerating/decelerating unit

- Unit voltage 50kV, focusing lens system
- Acceleration: 70 keV per ion charge: irradiations with HI in the region of the Bragg Peak
- Deceleration: Large deuteron currents for energies below 1 keV possible





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Research topics

1. Nuclear reactions at extremely low energies (K. Czerski)
2. Experimental nuclear astrophysics (N. Targosz- Ślęczka)
3. High temperature plasma physics (M. Ślęczka)
4. Radiobiology and nuclear tracks (A. Kowalska)
5. High temperature nuclear reactors (K. Czerski)
6. Development of the ultra high vacuum accelerator system (M. Kaczmarski)
7. Radiospectroscopy Laboratory – Nuclear Magnetic Resonance (M. Olszewski)

Prof. Konrad Czerski (head, 1,2,3,4,5)
Dr. Natalia Targosz-Ślęczka (1,2)
Dr. Marcin Ślęczka (3)
Dr. Marcin Olszewski (7)
Dr. Mateusz Paczwa (7)
Dr. Agata Kowalska (1,4)
M.Sc. Mateusz Kaczmarski (1,6)
Prof. position, vacancy
Post-doc position, vacancy

M.Sc. Wiktoria Pereira (PhD Student) (4)
M.Sc. Dominik Böhm (PhD Student) (5)
M.Sc. Daniel Weiβbach (PhD Student) (1,5)
M.Sc. Mathieu Valat (PhD Student) (1,6)
M.Sc. Ewelina Kucal (PhD Student, NCBJ) (5)
M.Sc. Hisham Elgendy (PhD Student, NCBJ) (5)
M.Sc. Matusz Nowak (PhD Student, NCBJ) (5)
M.Sc. Michal Komorowicz (PhD Student, NCBJ) (5)

Collaborations

Visiting scientists: Dr. Sergio Bartalucci, INFN, Italy
Prof. Vladimir Visotskii, Kiev University, Ukraine

Nuclear reactions at extremely low energies:	Upssala University, Sweden; MIT, USA INFN, Italy; IFK, Germany; CNRS, France;
High temperature plasma physics:	MPI PP, Germany; NIFS, Japan;
Radiobiology and nuclear tracks:	JINR Dubna,Russia; HIL, Poland;
High temperature nuclear reactors:	IFK Germany; TUM Germany, NCBJ Poland

Clean Energy
from Hydrogen-Metal Systems

Coordination of
17 scientific institutions and commercial companies from Europe, USA, Canada;