D. L. Balabanski

P.-A. Söderström

M. Cuciuc

Yu. Penionzhkevich

Yu. Sobolev

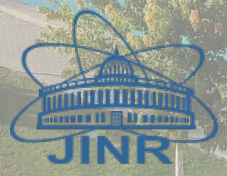
S. Stukalov

Neutron production in (α,n) reactions

presenter: Dmitry Testov

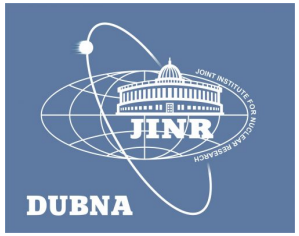
St Petersburg University

NATIONAL RESEARCH CENTER "KURCHATOV INSTITUTE"



JINR

NuPECC

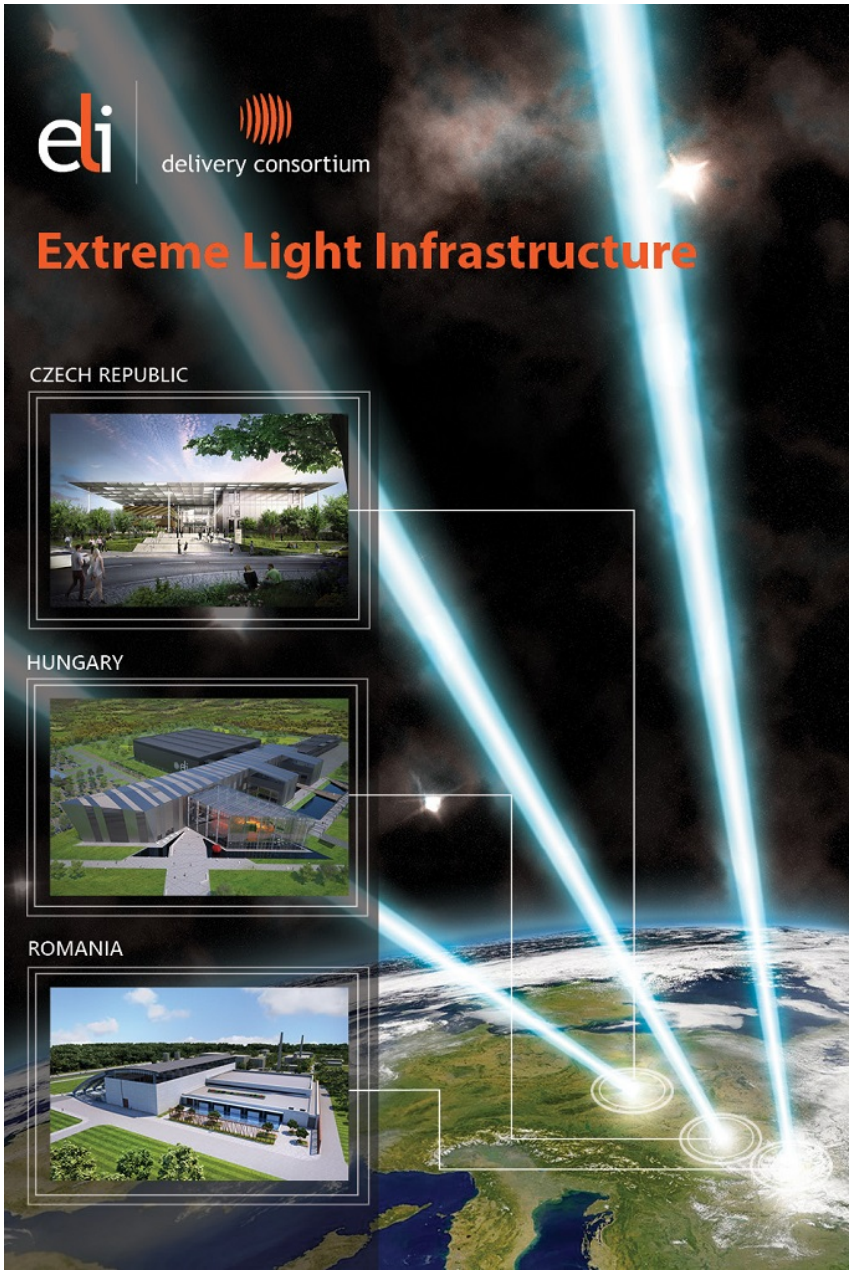


DUBNA

nuclear physics

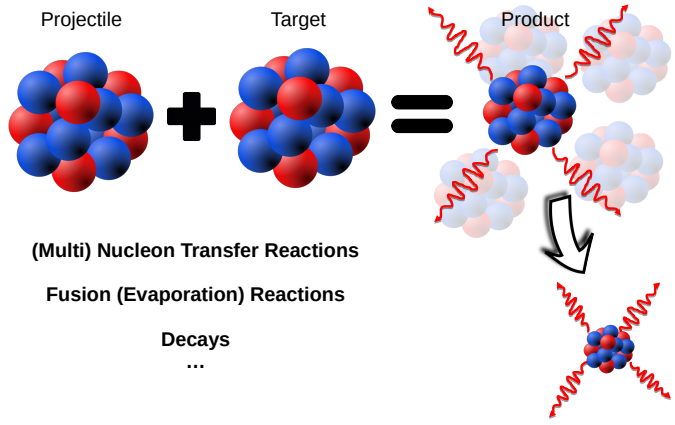
IFIN-HH

The Extreme Light Infrastructure



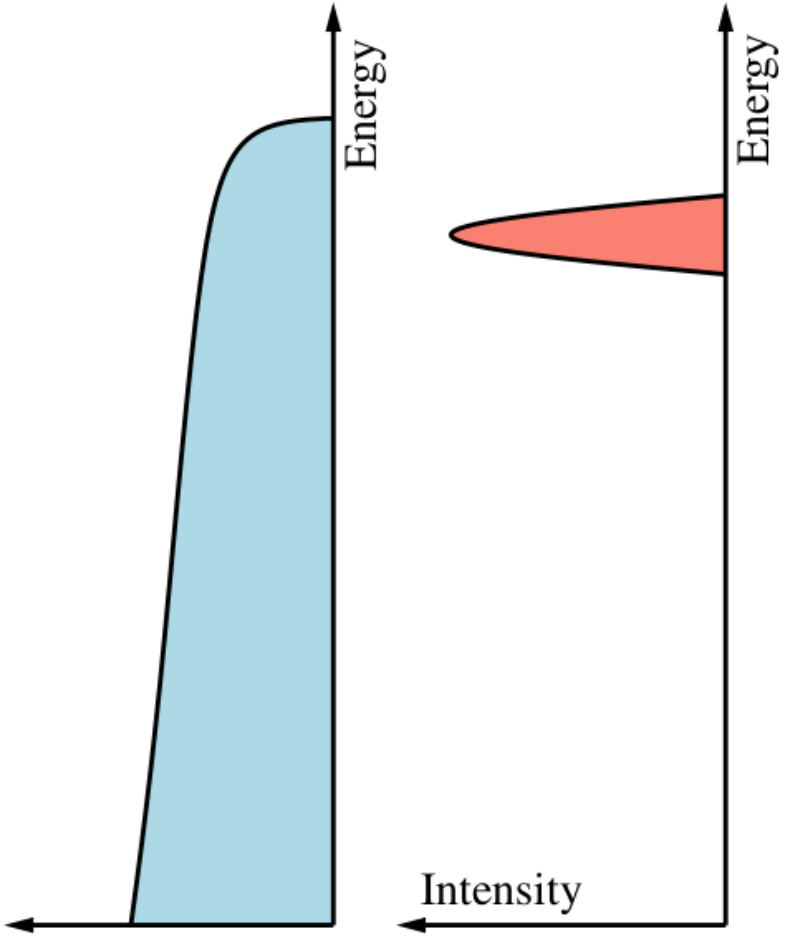
- ELI Beamlines, Dolní Břežany, Prague, Czech Republic, focus on multidisciplinary applications in molecular, biomedical and material sciences
- ELI Attosecond Light Pulse Source, Szeged, Hungary focus on ultrashort pulses with high repetition rate by taking snap-shots in the attosecond scale
- ELI Nuclear Physics, Măgurele, Romania, focus on laser and gamma-beam based nuclear physics

Photo-Nuclear Reactions



Bremsstrahlung

Mono-energetic source



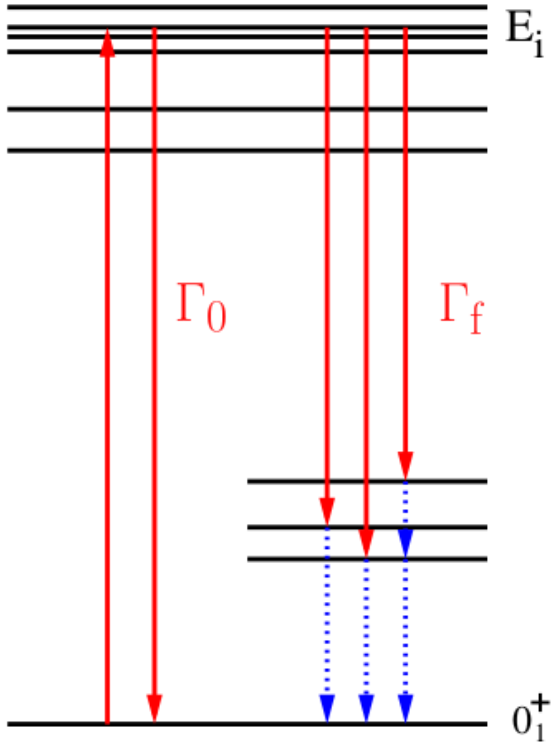
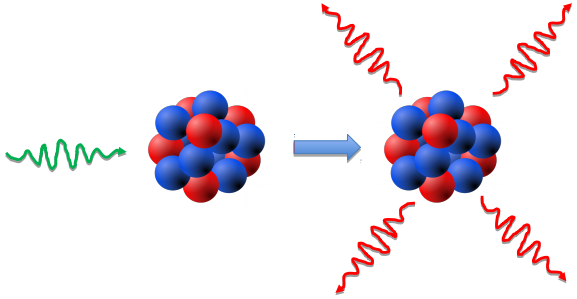
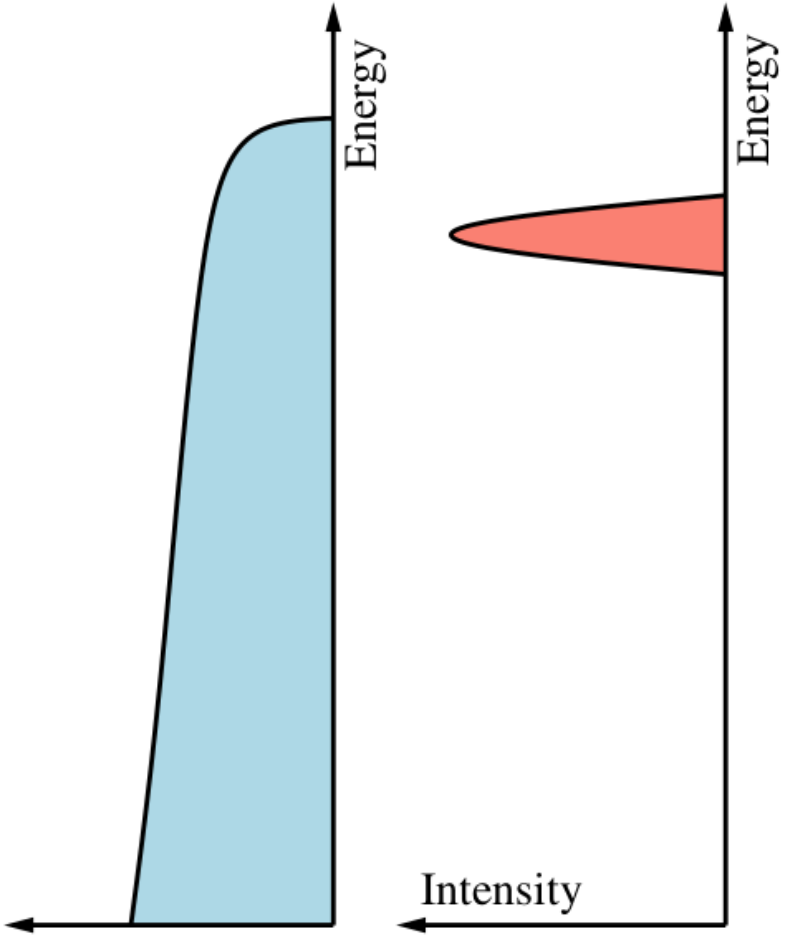


Photo-Nuclear Reactions



Bremsstrahlung

Mono-energetic source



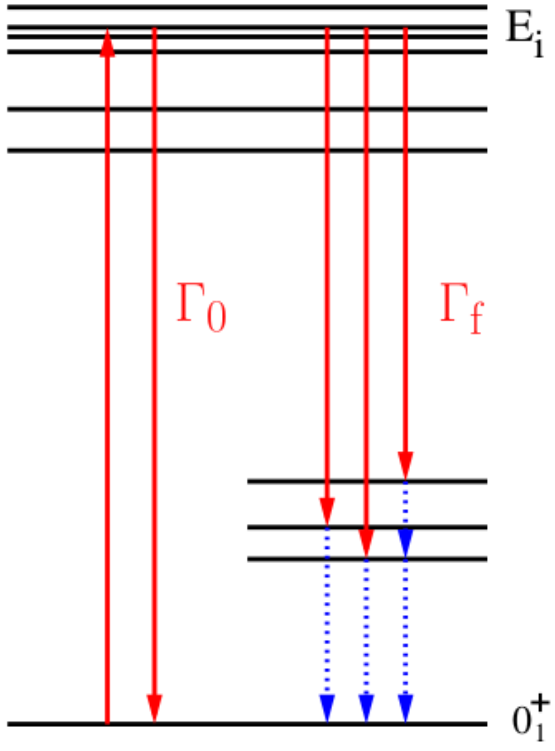
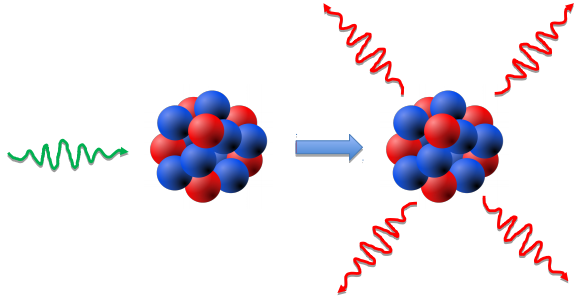
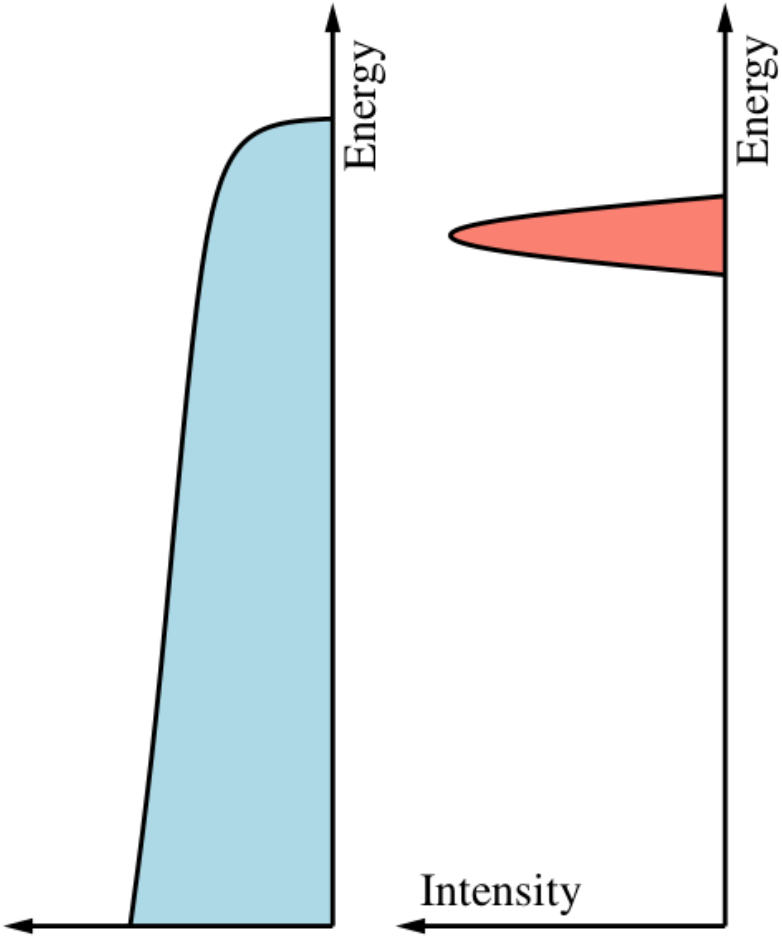
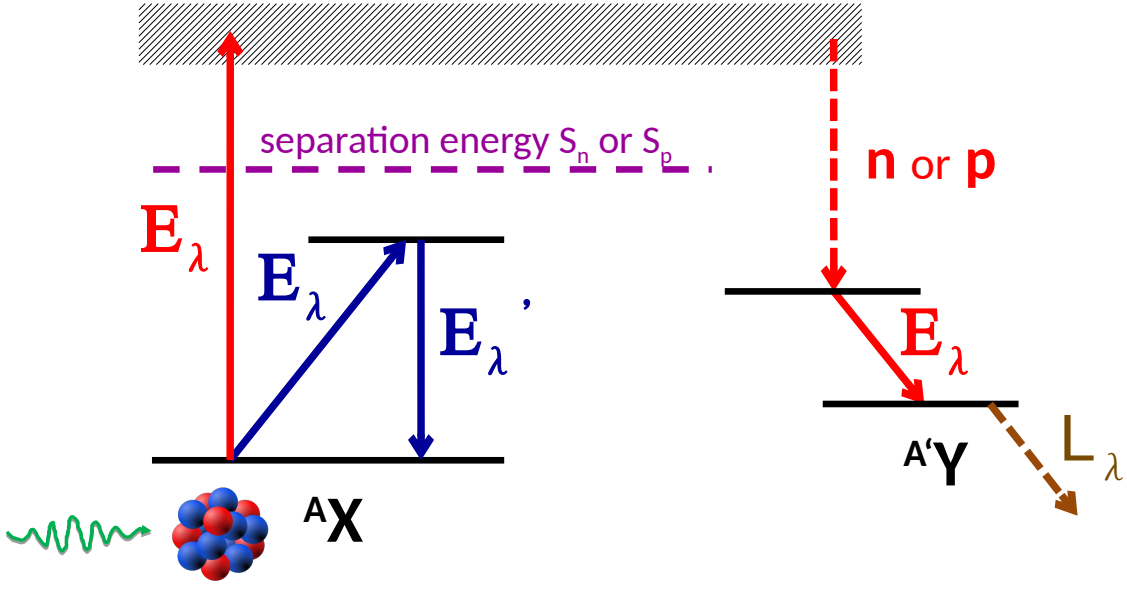


Photo-Nuclear Reactions



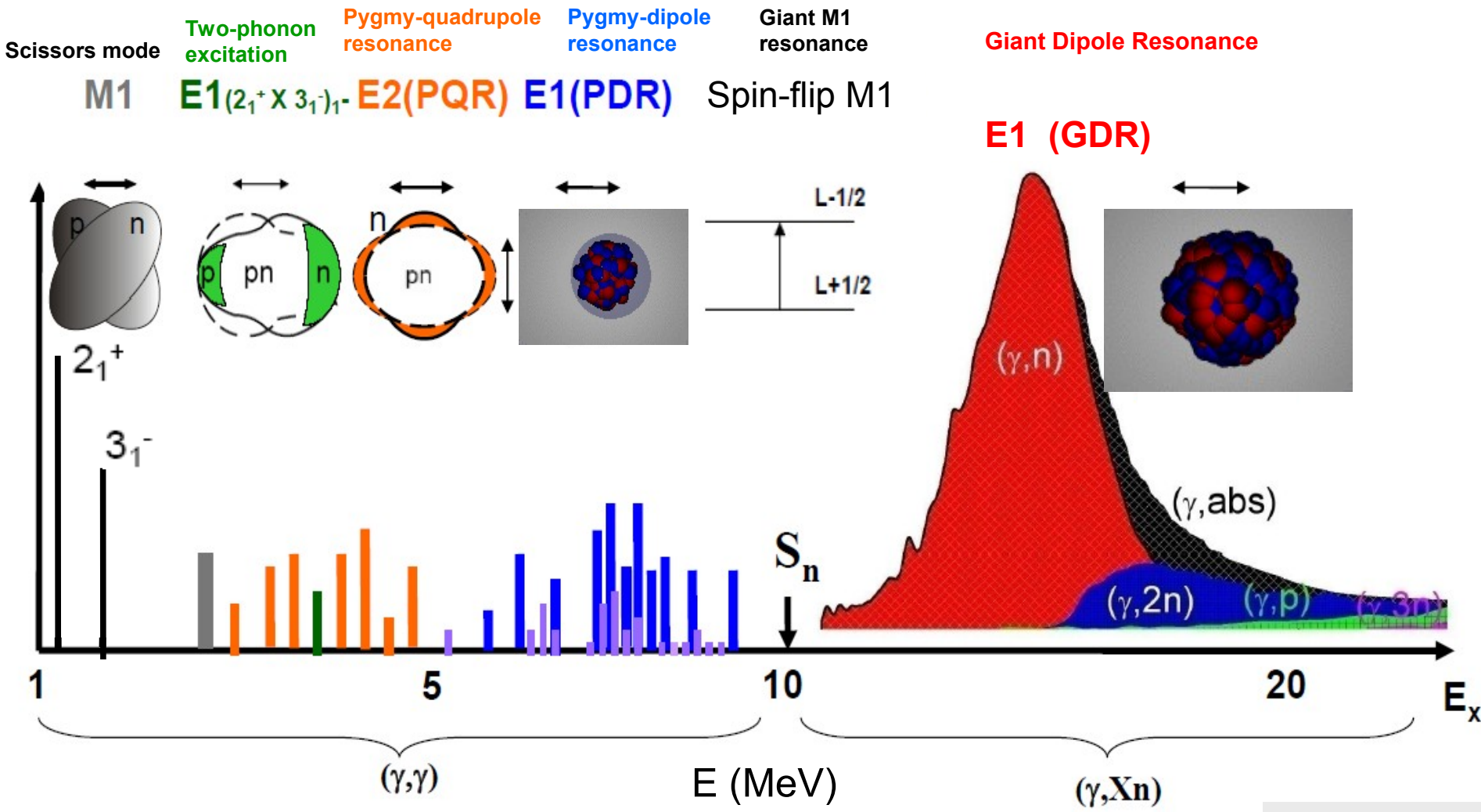
Bremsstrahlung Mono-energetic source





- **Photodisintegration, Photofission**
- **Nuclear Resonance Fluorescence - NRF**

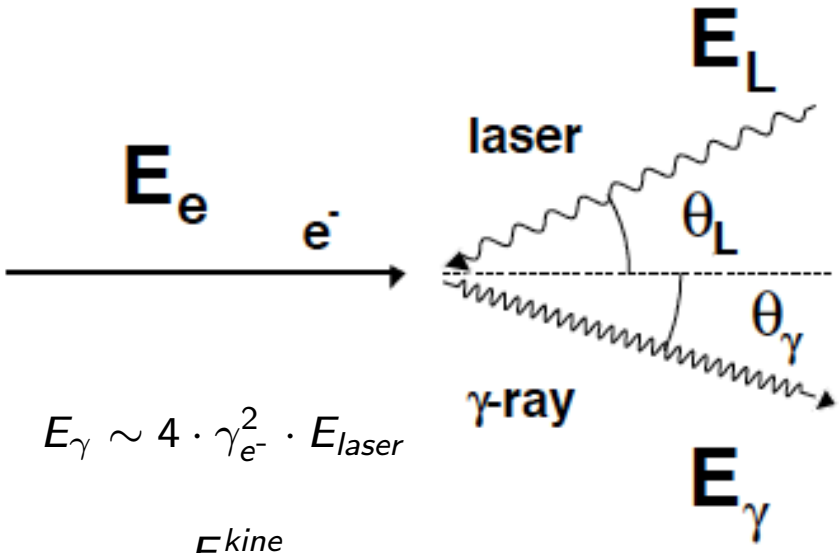
Characteristic Response of Atomic Nucl. to EM Radiation



Moderate and Heavy nuclei

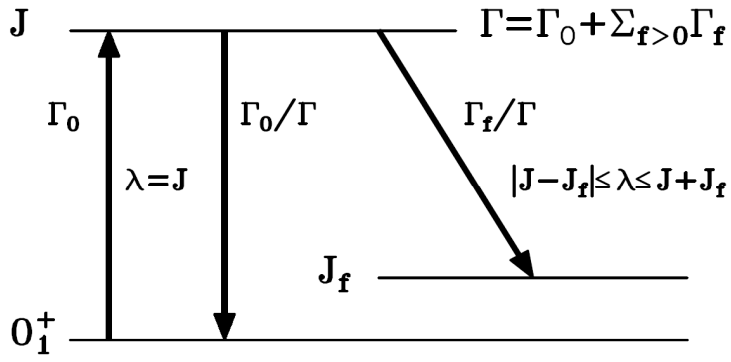
N.Tsoneva, ERICE14

Photons from Laser Compton Backscattering (LCB)



$$E_\gamma \sim 4 \cdot \gamma_{e^-}^2 \cdot E_{laser}$$

$$\gamma_{e^-}^2 = \frac{E_{e^-}^{kine}}{m_{e^-} \cdot c^2}$$



- ,,monoenergetic" photon beam
- tunable energy
- Almost 100% linearly polarized beam

- Populate excited states by resonant scattering of γ rays
- Measure total (Γ) and partial (Γ_f) level widths following γ decay
- Narrow bandwidth: selective population
- Scan for new resonances
- Completely model independent measurements
- Very clean angular distributions for J^π measurements

Physics with the gamma beam system

- Nuclear Resonance Fluourescence spectroscopy using (γ, γ') reactions and the ELIADE γ-ray spectrometer (8 x Clover 32-seg detectors)
- Pygmy- and giant resonances, level population following neutron emission, and neutron resonances, using (γ, n) reactions in ELIGANT-GN (15 x LaBr(Ce), 19 x CeBr, x 37 EJ301, 25 x Li-glass) and ELIGANT-TN (28 ^{3}He-filled tubes)
- Photo-induced fission cross-sections, fragment distributions, and fission isomers with the ELI-BIC and ELITHGEM instruments
- Properties of key astrophysics (γ, p) and (γ, α) reactions using ELISSA Si array and ELI-eTPC time-projection chamber
- High-intensity positron beamline for material research and characterization
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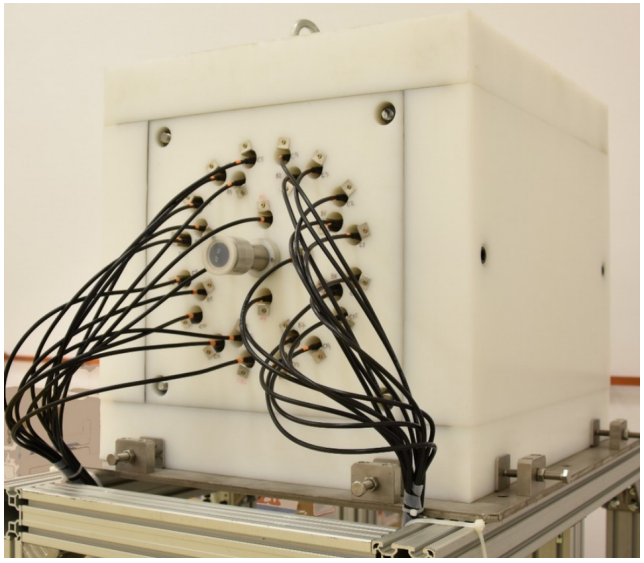
ELIGANT-TN: array of ^{3}He filled counters



High efficiency

Zero energy threshold

Zero cross-talk(multiplicity)

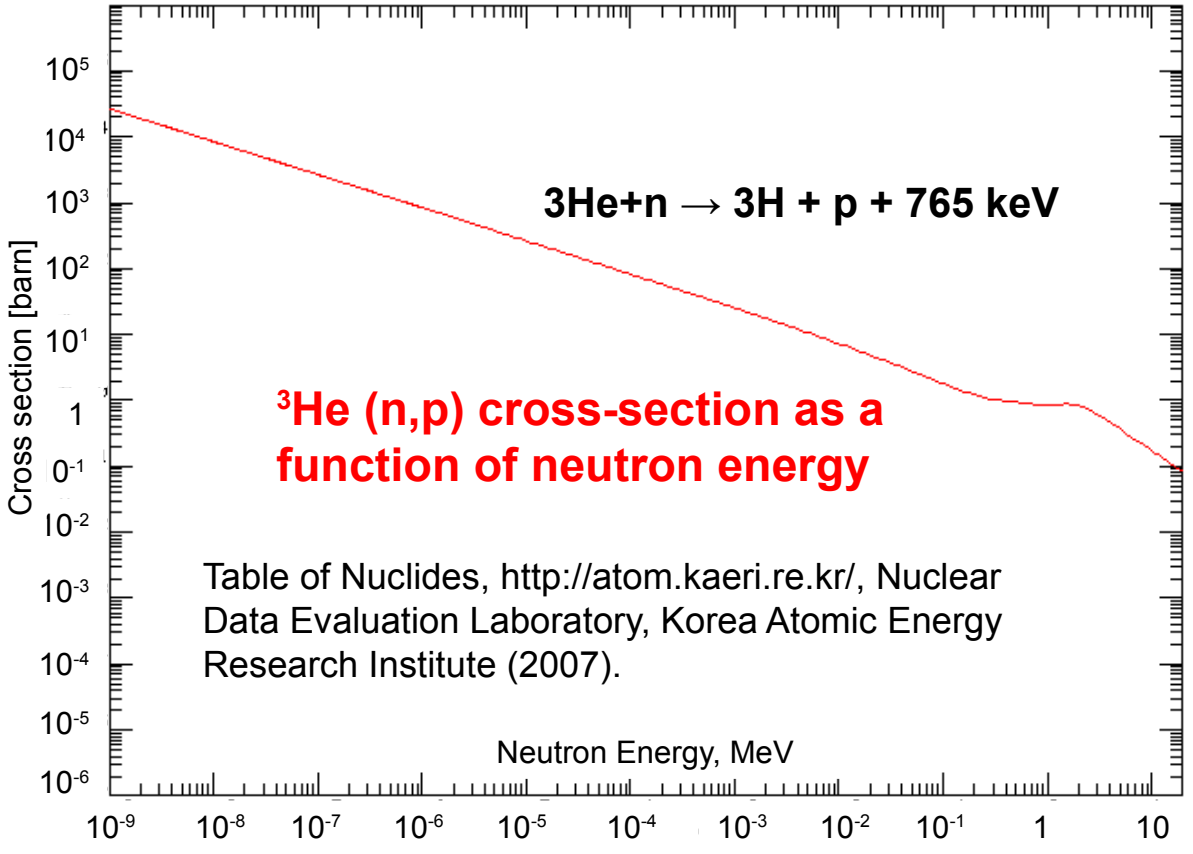
Low internal background

Perfect gamma separation

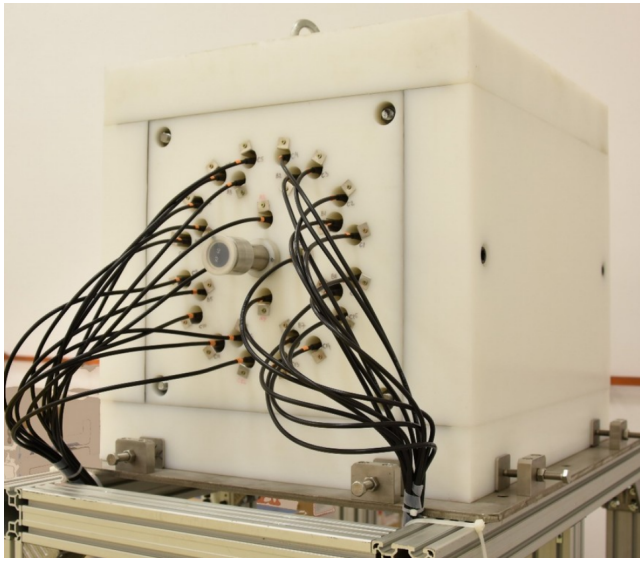
Easy in use/ geometry

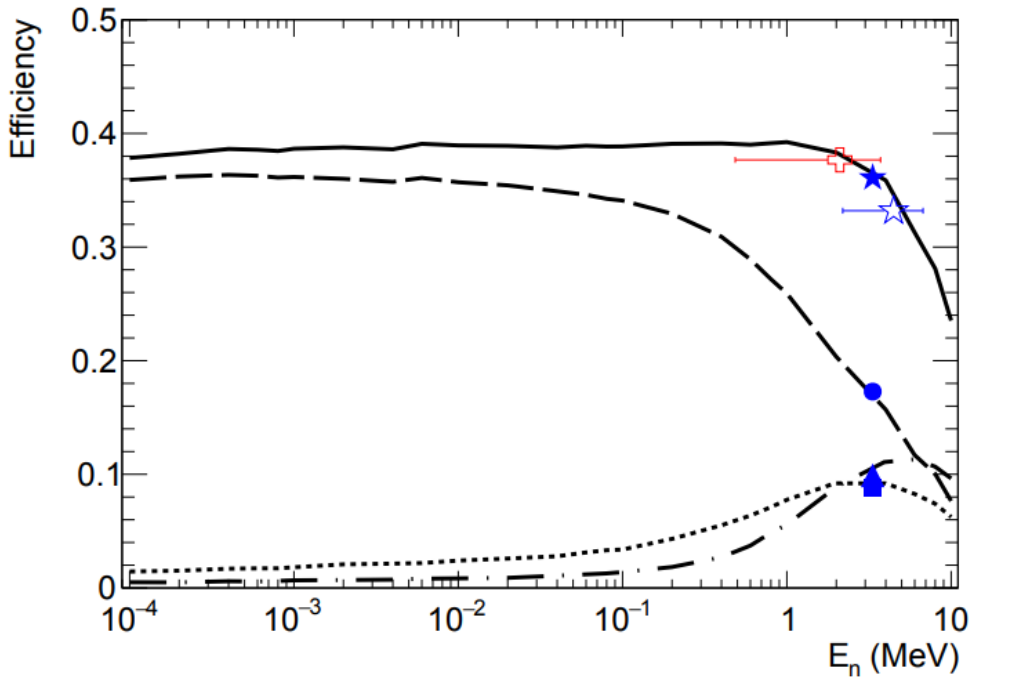
Physics cases

- Nucleosynthesis in the rare astrophysical proton-capture process (p-process)
- Compilation and verification of (γ,n) cross sections for next generation nuclear reactor applications

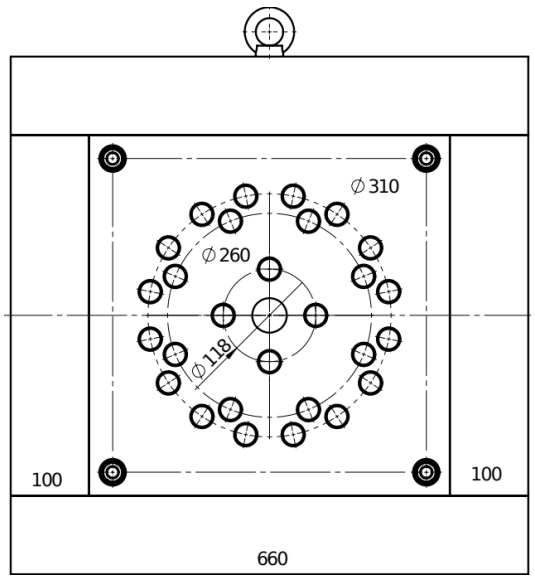


ELIGANT neutron detector

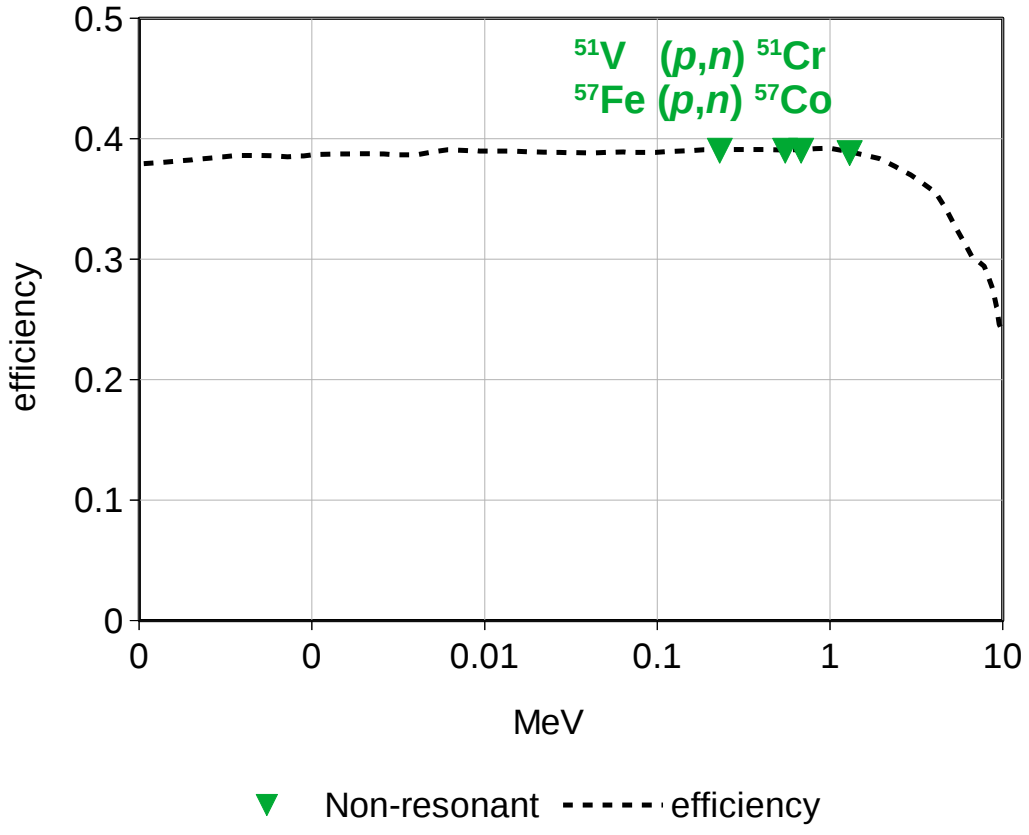




- Moderated ^{3}He counter,of 28 gas tubes
- Pressure in the tubes 12 bar
- Efficiency simulated in Geant4 and MCNP
- Simulations confirmed with a PuBe neutron source (blue)
- Average of neutron spectrum can be extracted from the ring-to-ring ratio



Verification of efficiency curve



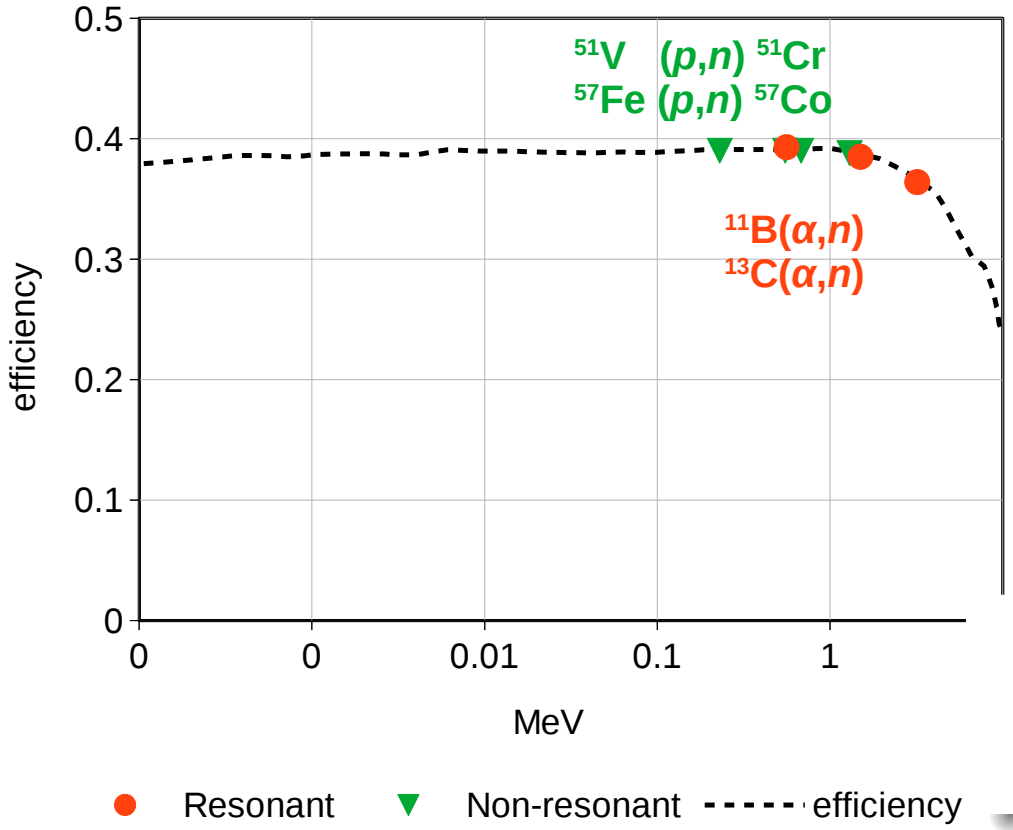
Non-Resonant Reactions

^{51}V(p,n)^{51}Cr

- E_p<3 MeV (one reaction channels)
- $T_{1/2}(^{51}Cr)$=27.7 days
- e-capture, E_γ=320 keV BR=9.91%

$$\epsilon = \frac{Nn \quad online\ ELIGANT}{N(E_\gamma) \quad offline \quad HPGe}$$

Verification of efficiency curve



Resonant Reactions

^{11}B(α,n) | ^{13}C(α,n)

- Resonances are well-mapped
- Γ_R, $(\omega\gamma)_R$, E_x

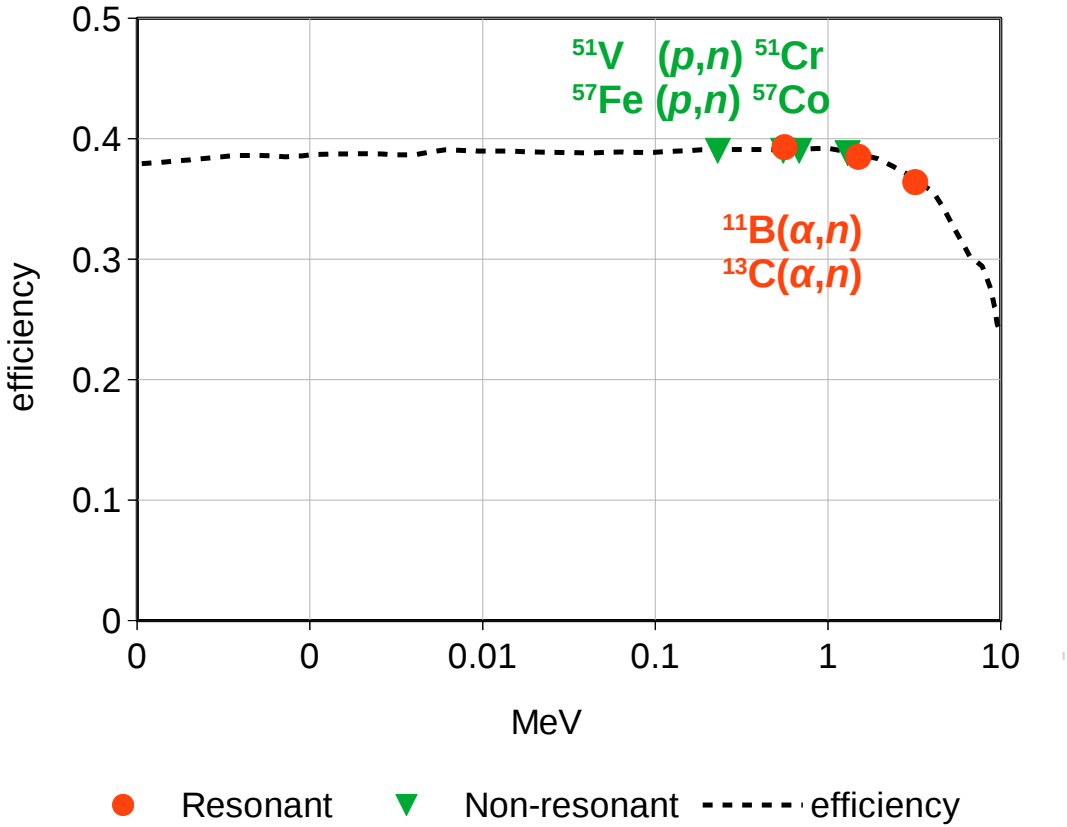
$$\epsilon = \frac{Nn}{N(\Gamma_R, (\omega\gamma)_R, E_x)} \quad \begin{matrix} ELIGANT \\ Resonance \end{matrix}$$

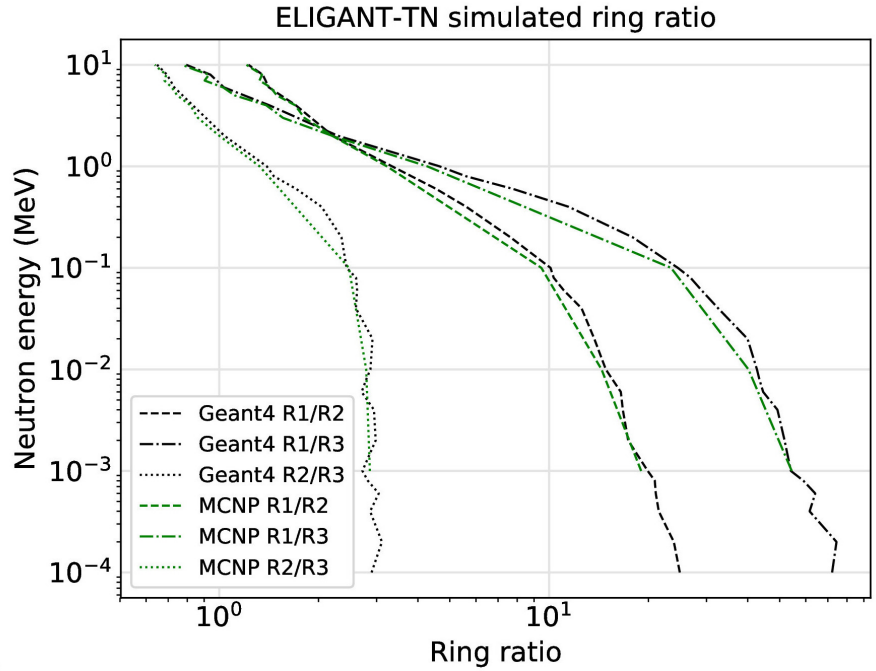
$$N_0 = \frac{I_\alpha \cdot t \cdot \hbar^2 \cdot \pi^2 \cdot (\omega\gamma)_R \cdot N_A \cdot \rho}{\mu \cdot A \cdot E_R} \cdot \left(\frac{dE}{dZ}\right)^{-1}$$

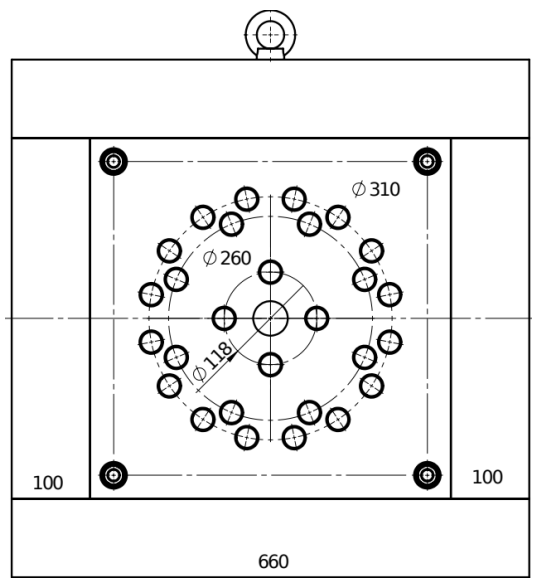
	E_α MeV	E_n MeV	Γ_R keV	$(\omega\gamma)_R$ eV	E_x keV
^{11}B(α,n)	0.606	0.56	$2.5 \cdot 10^3$	0.175	11436
^{13}C(α,n)	1.053	1.5	11.9	0.172	7165
^{13}C(α,n)	1.585	3.2	<1	0.172	7165

C.R. Brune et al, Phys. Rev. C 48 (1993) 3119
T.R. Wang et al, Phys. Rev. C 43 (1991) 883

Verification of efficiency curve

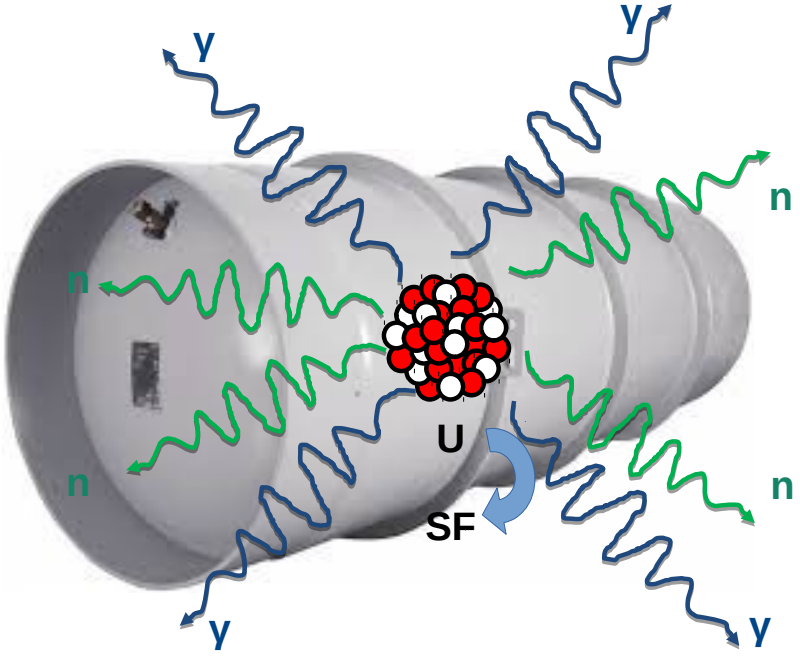




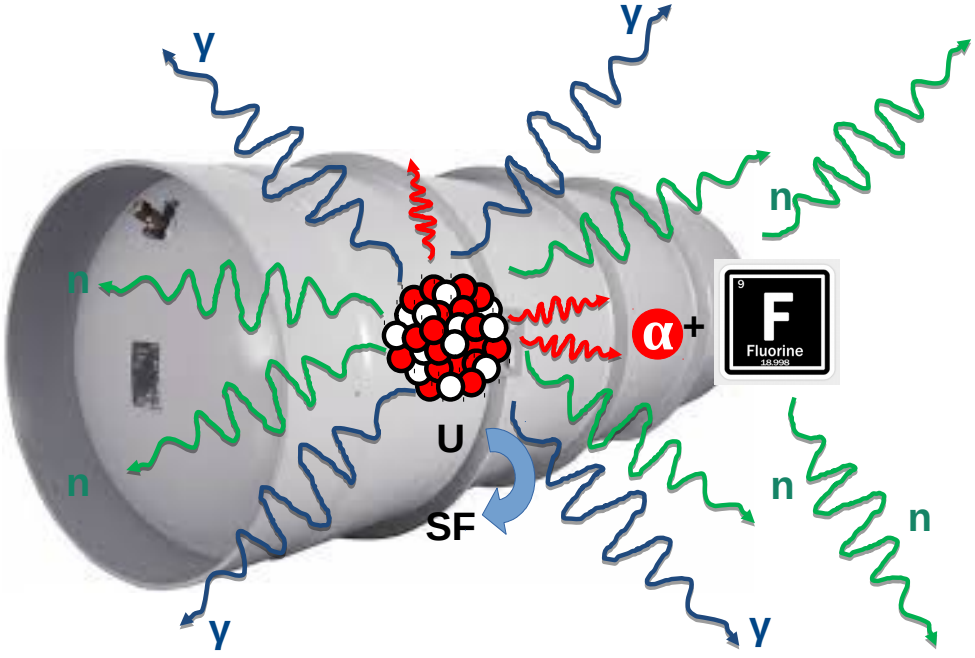


Ring-to-ring ratio method to estimate $\langle E_n \rangle$

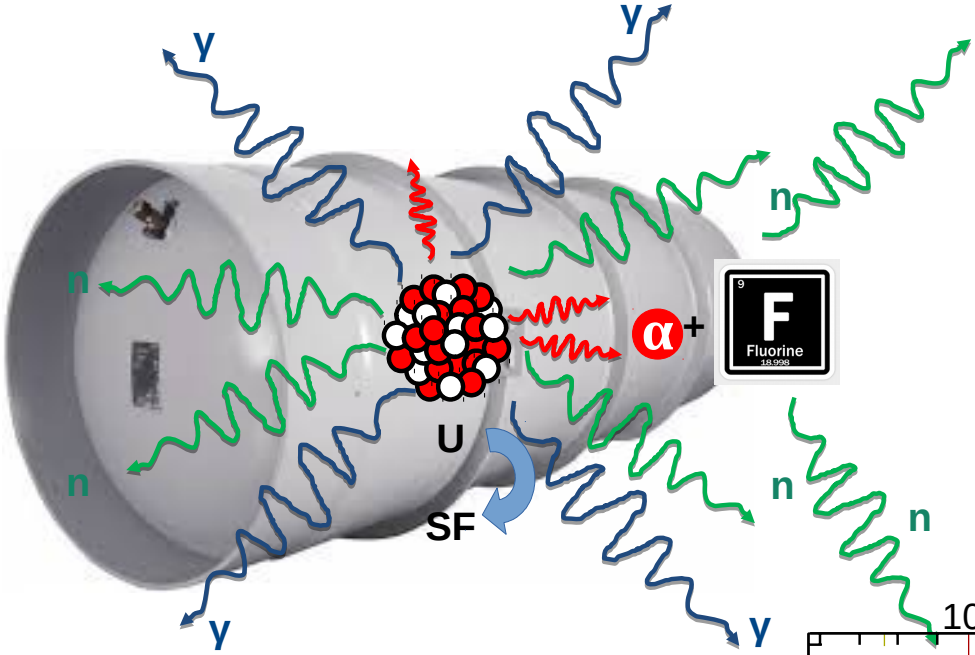
alpha-induced reactions

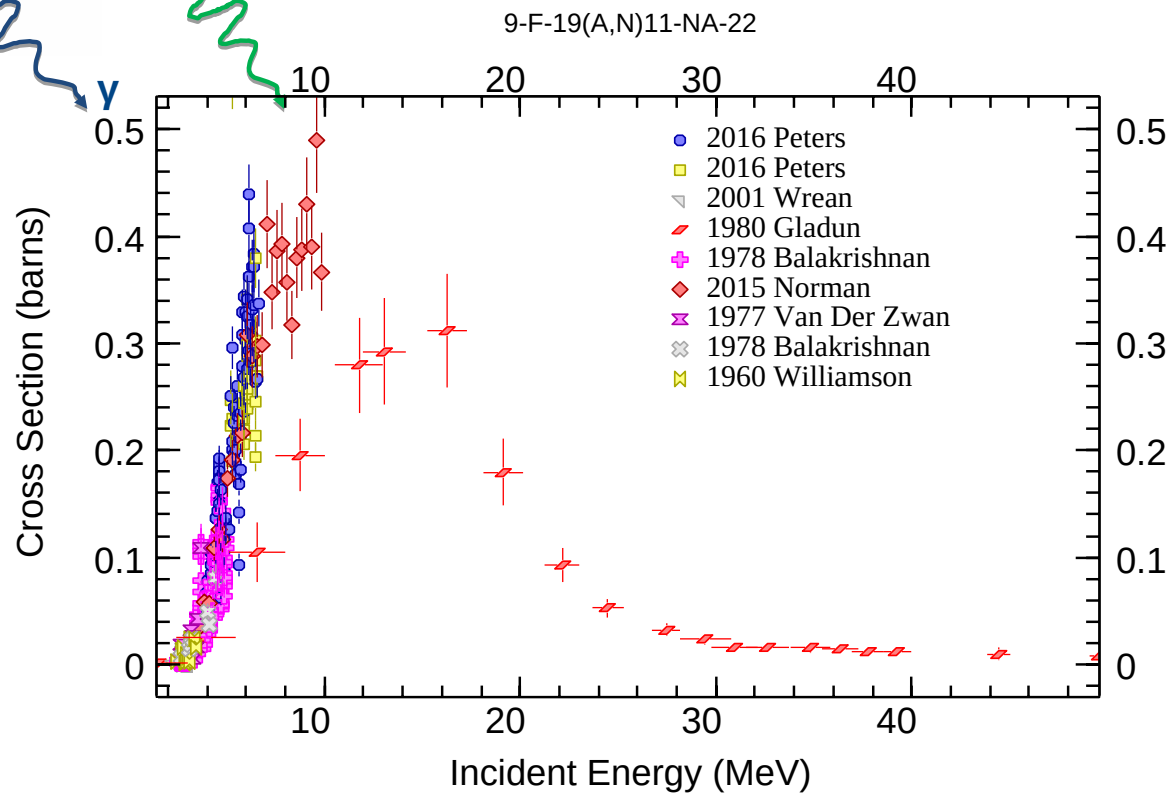


alpha-induced reactions

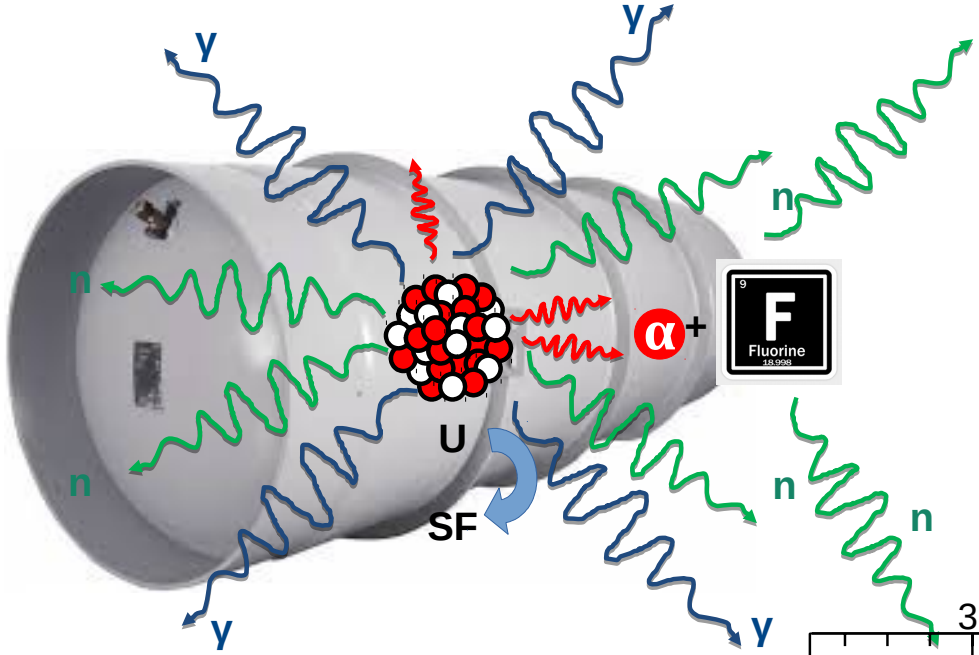


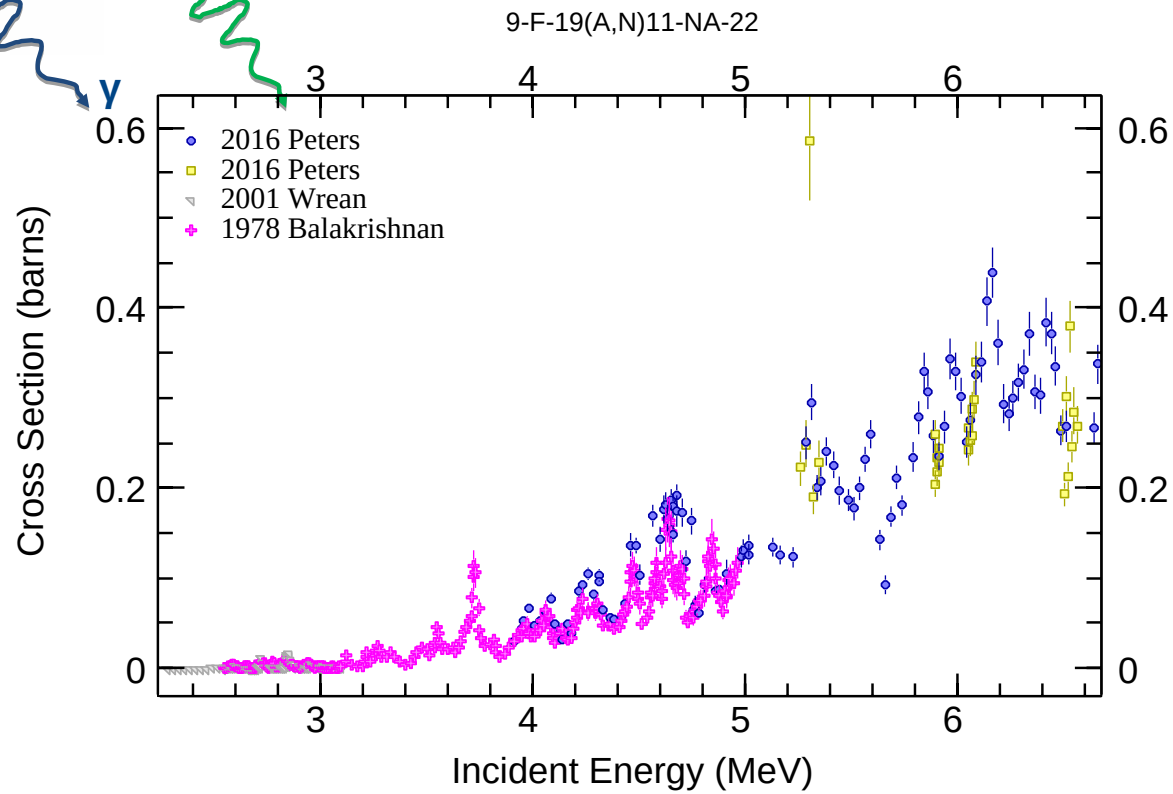
alpha-induced reactions





alpha-induced reactions





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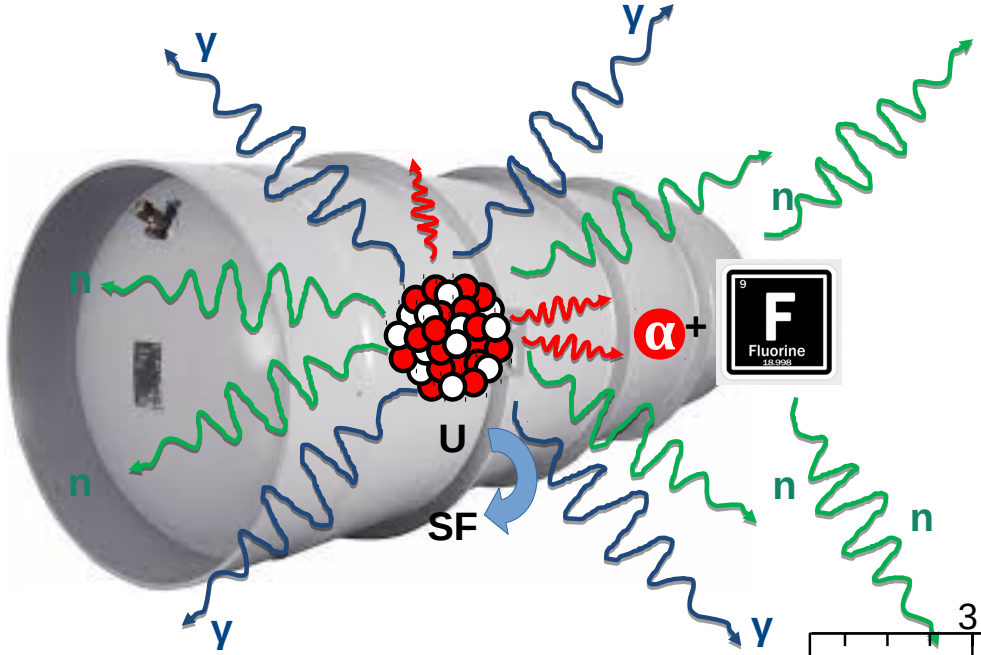
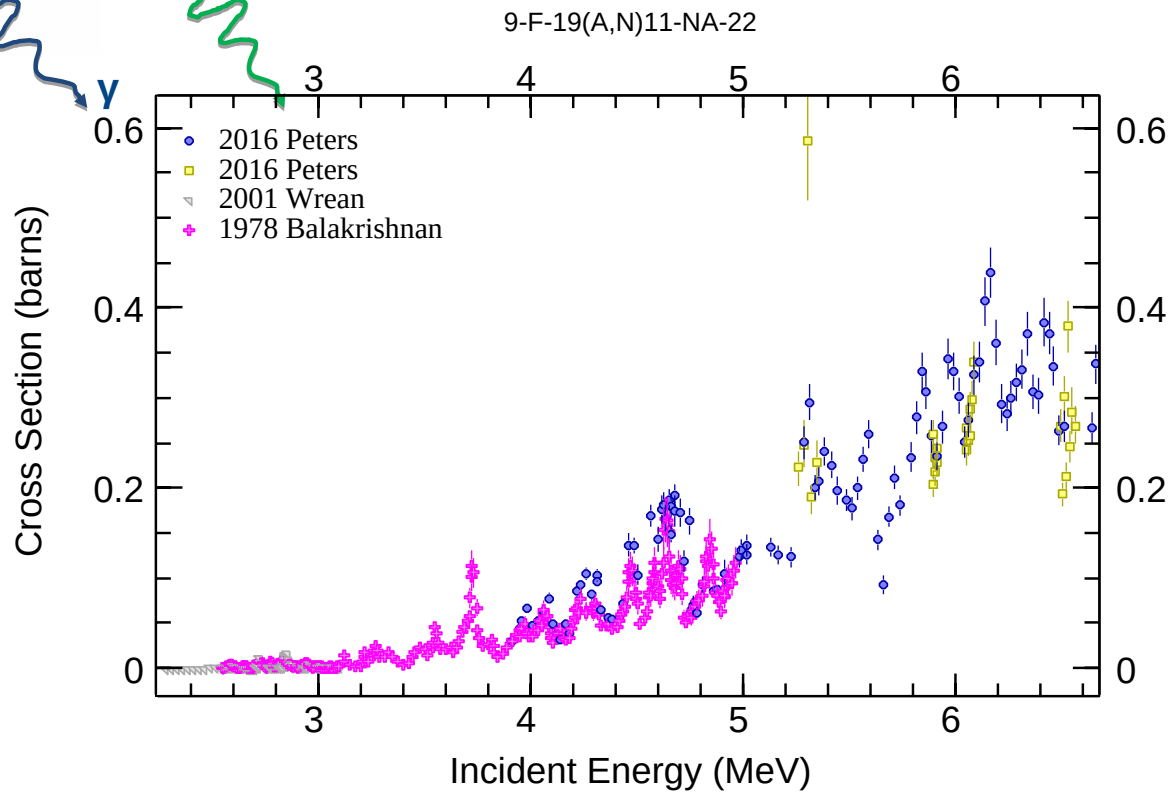


Nuclear fuel management

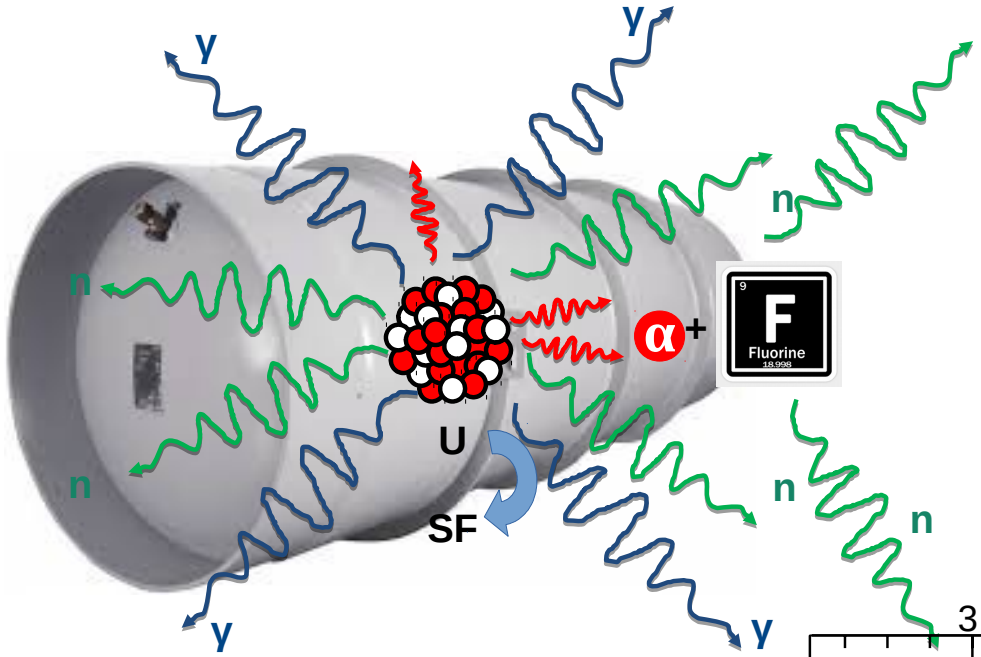
$^{13}_{6}C$ $^{17}_{8}O$ $^{18}_{8}O$ $^{16}_{9}F$

Parameters of the reaction

- Cross-sections
- $\langle E_n \rangle$
- Angular correlations



alpha-induced reactions



Nuclear fuel management

$^{13}_{6}\mathbf{C}$ $^{17}_{8}\mathbf{O}$ $^{18}_{8}\mathbf{O}$ $^{16}_{9}\mathbf{F}$

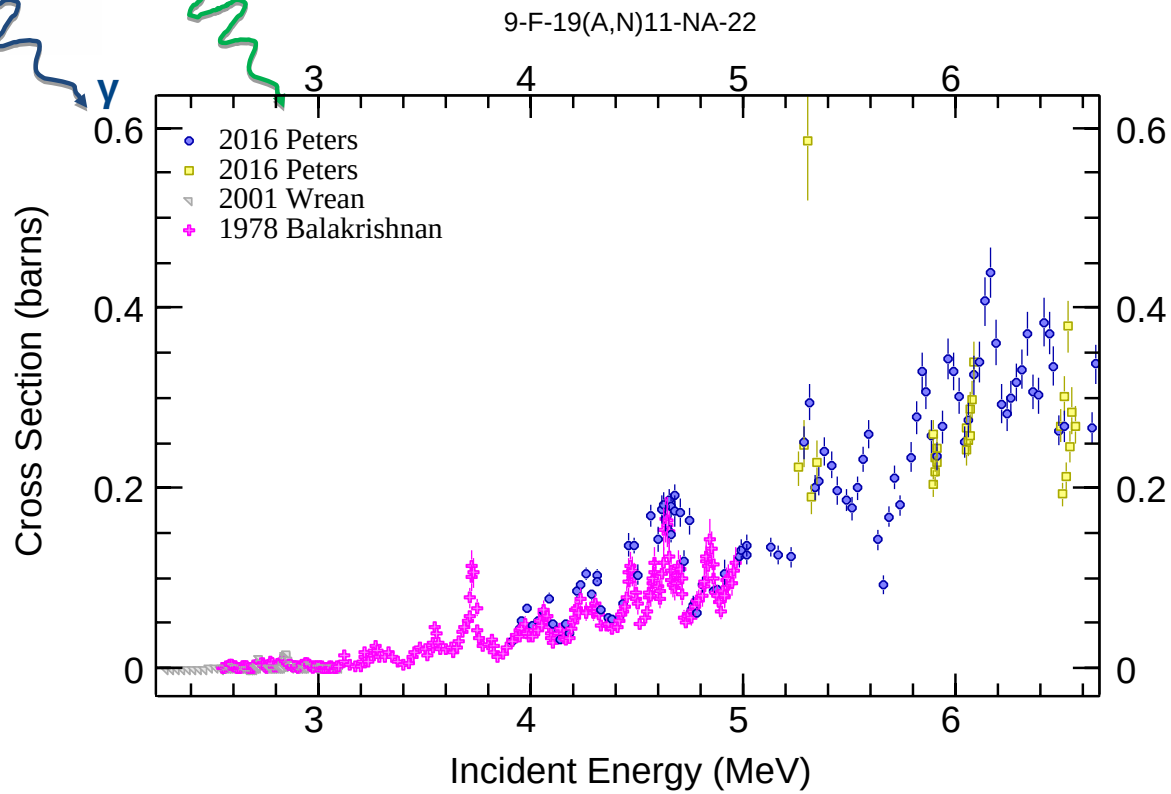
Low background measurements

α-chains $^{238}\mathbf{U}$

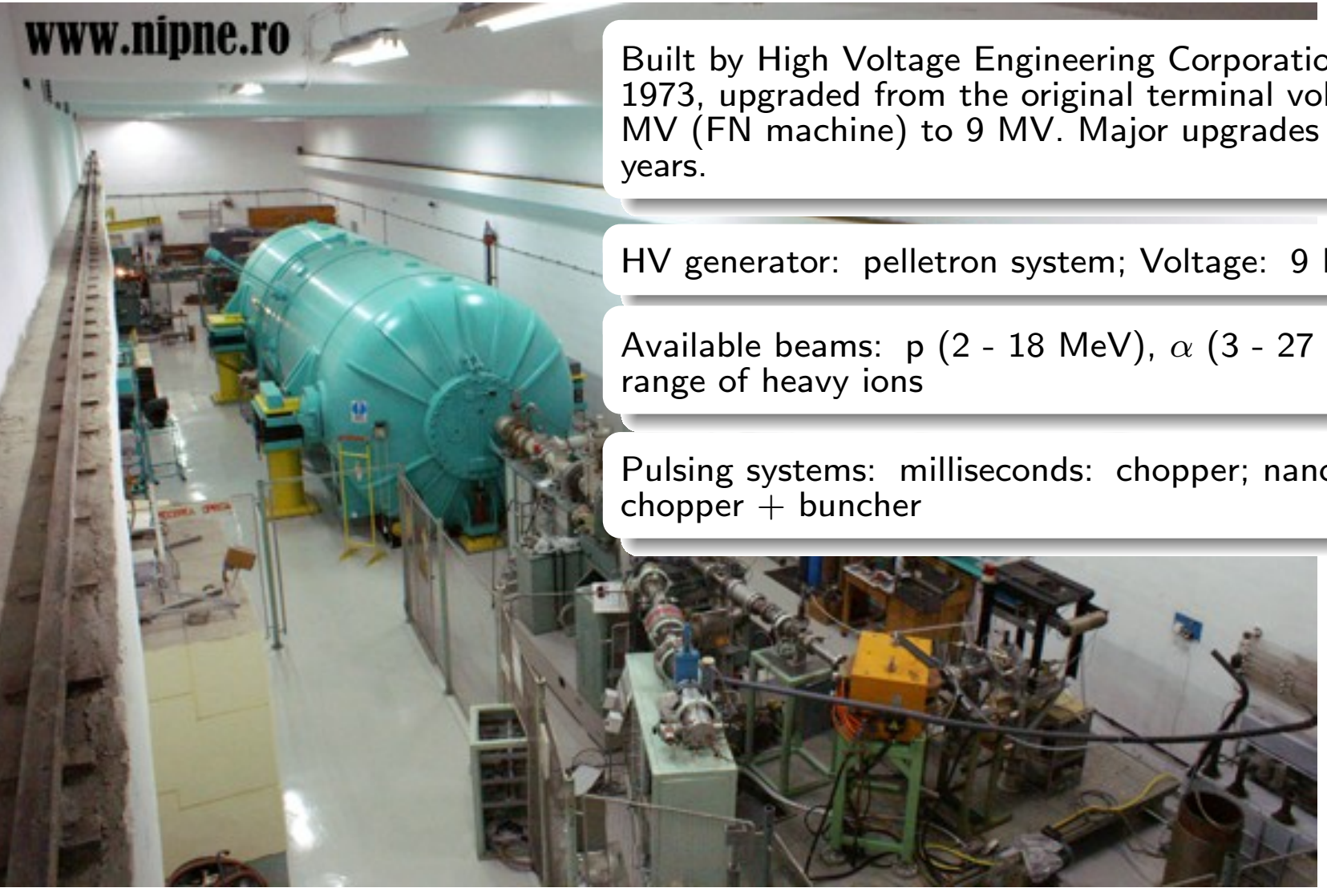
$^{232}\mathbf{Th}$

$^{27}\mathbf{Al}$ $^{28,29,30}\mathbf{Si}$ $^{26}\mathbf{Fe}$

$^{60,62,64}\mathbf{Ni}$ $^{46,48}\mathbf{Ti}$



The 9 MV Tandem accelerator



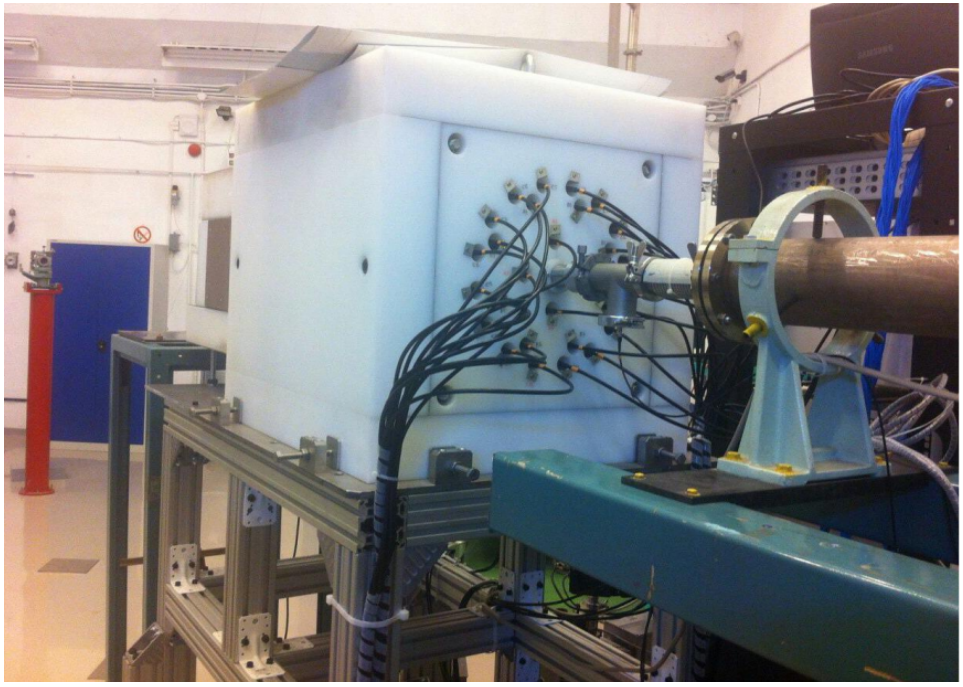
Built by High Voltage Engineering Corporation (HVEC) in 1973, upgraded from the original terminal voltage of 7.5 MV (FN machine) to 9 MV. Major upgrades during the last years.

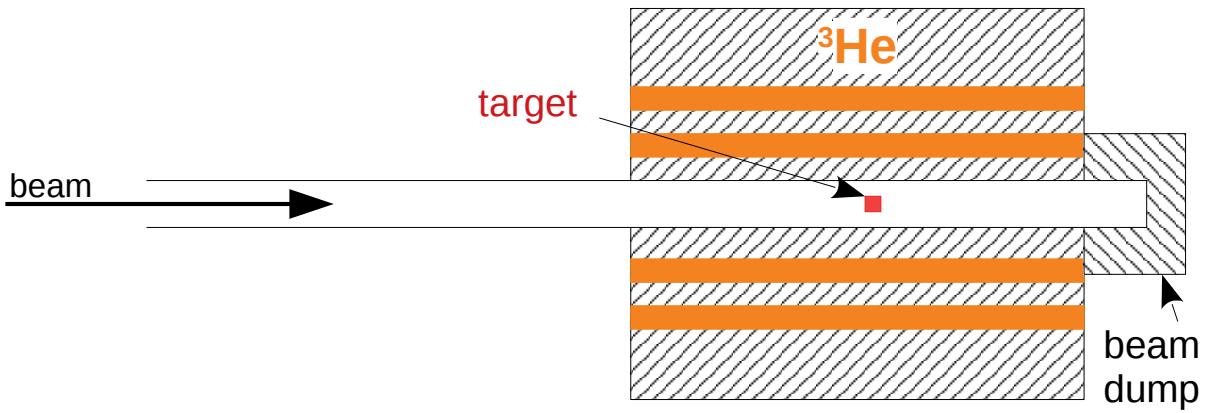
HV generator: pelletron system; Voltage: 9 MV

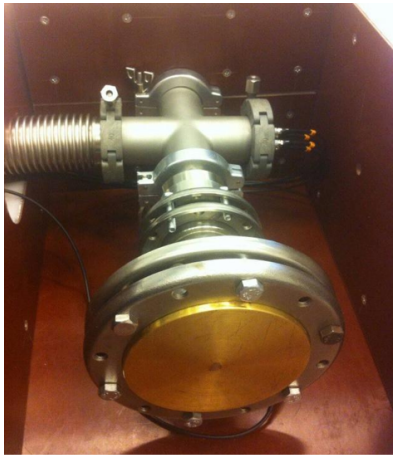
Available beams: p (2 - 18 MeV), α (3 - 27 MeV) a broad range of heavy ions

Pulsing systems: milliseconds: chopper; nanoseconds: chopper + buncher

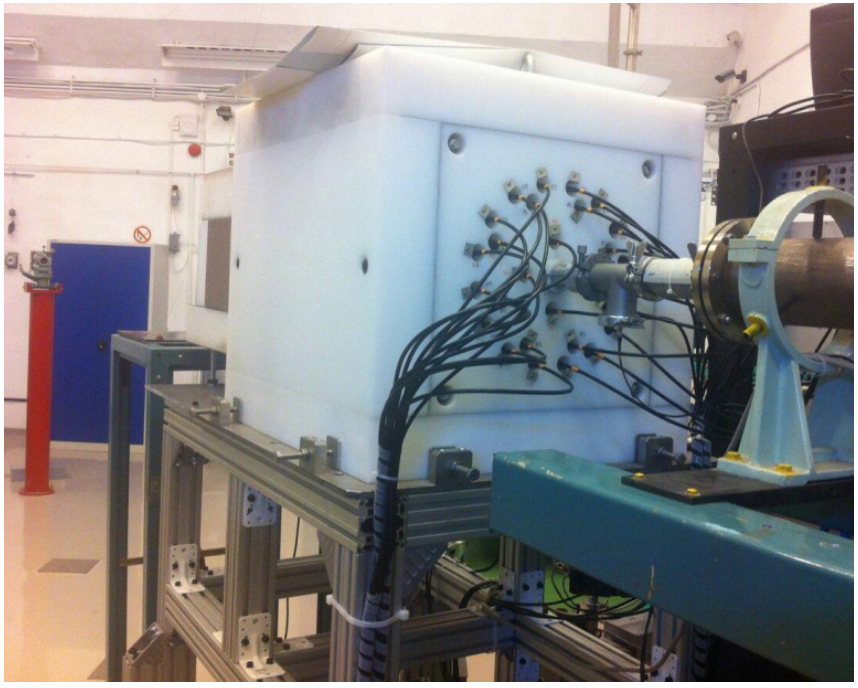
ELIGANT at IFIN

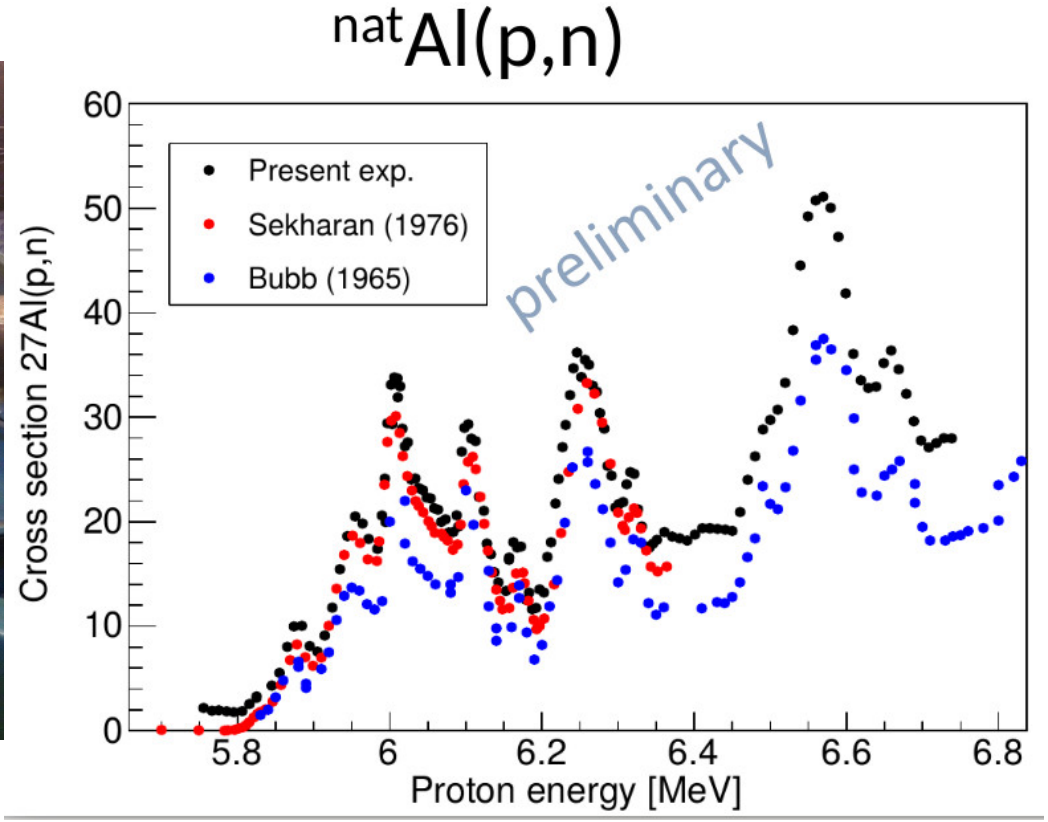


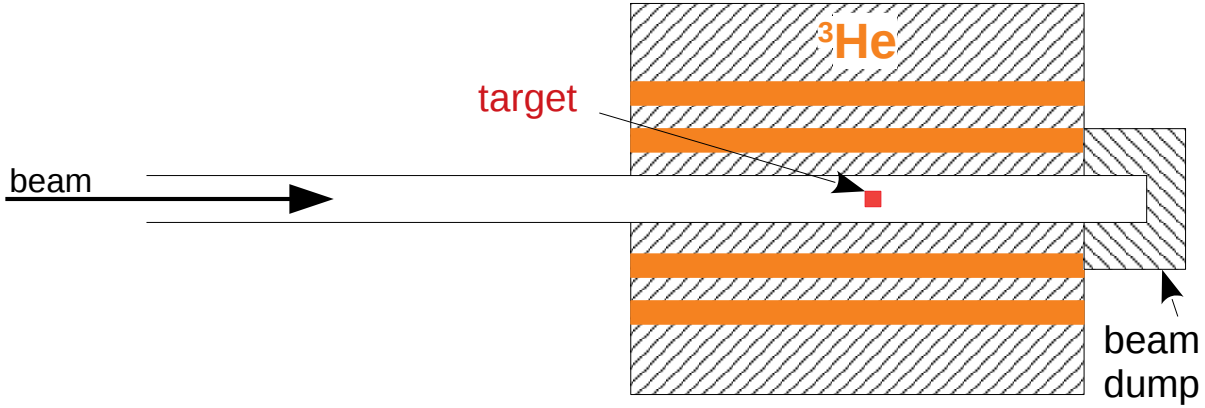


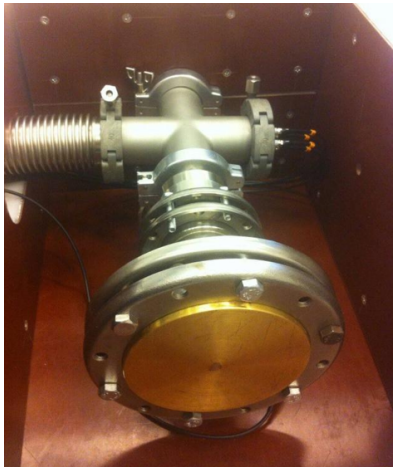


ELIGANT at IFIN









To take home

Neutron production in (α,n) reactions

1. Response of ELIGAN-TN to monoenergetic neutron sources
^{51}V(p,n)^{51}Cr; ^{11}B(α,n), ^{13}C(α,n)

2. alpha-induced reactions for nuclear safeguards and low-background measurements
^{19}F(α,n) ^{27}Al ^{28,29,30}Si ^{26}Fe ^{60,62,64}Ni ^{46,48}Ti

3. (γ, n) reaction cross-sections using VEGA beams
(CS, $\langle E_n \rangle$, N(Θ))

ELIGANT-TN:
28 counters ^{3}He (12 atm.); ~37% (flat 1 MeV<E_n);

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Looking for collaboration

3. (γ, n) reaction cross sections using VEGA beams
(CS, $\langle E_n \rangle$, N(Θ))

Thank you for you attention!

ELIGANT-TN:
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DUBNA

nuclear physics

IFIN-HH

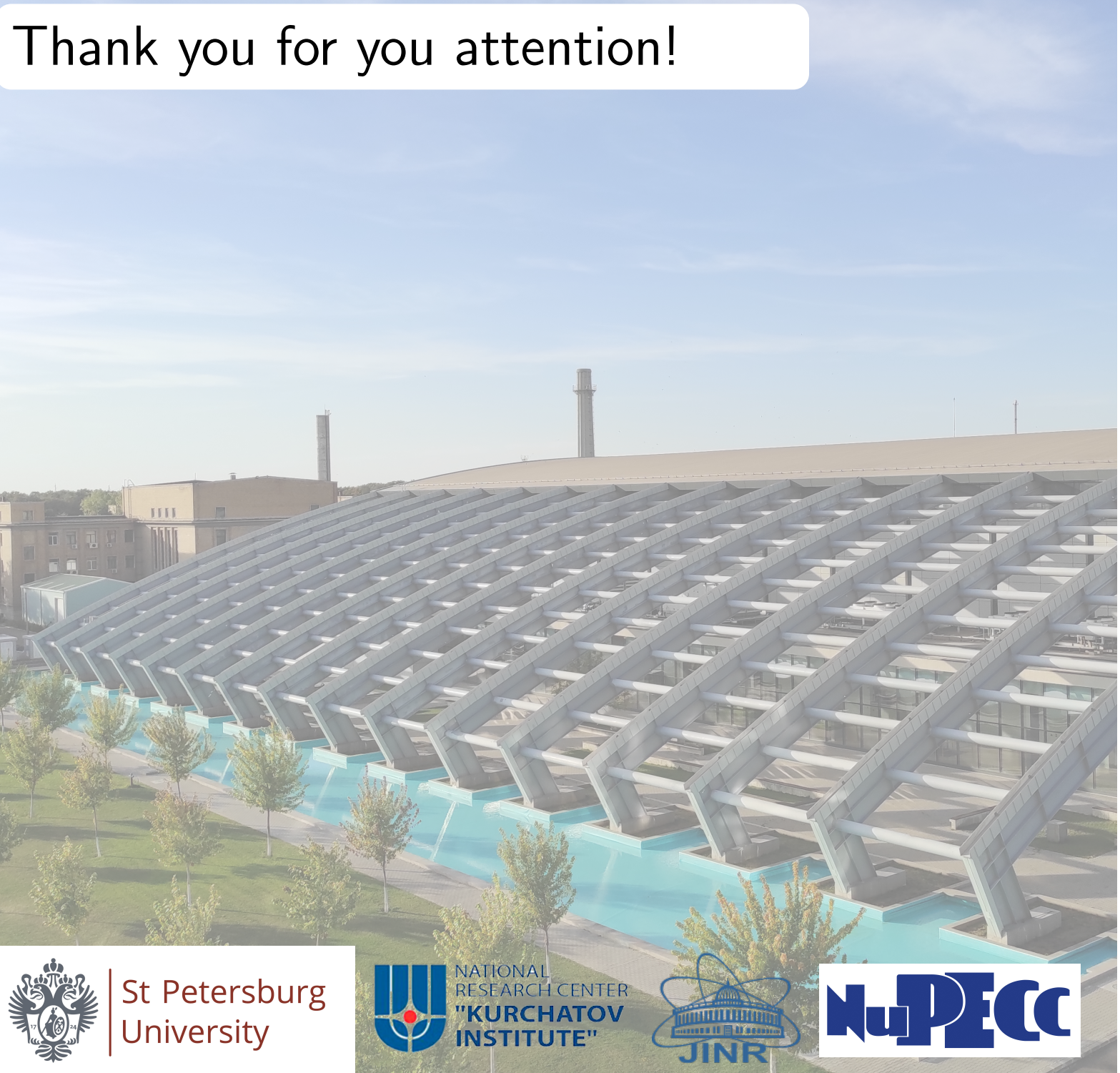
St Petersburg University

NATIONAL RESEARCH CENTER "KURCHATOV INSTITUTE"

JINR

NuPECC

Thank you for you attention!



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eli nuclear physics

IFIN-HH