TECHNISCHE UNIVERSITÄT DARMSTADT

Reactions of neutron-rich Sn isotopes investigated at relativistic energies at R^{3}B

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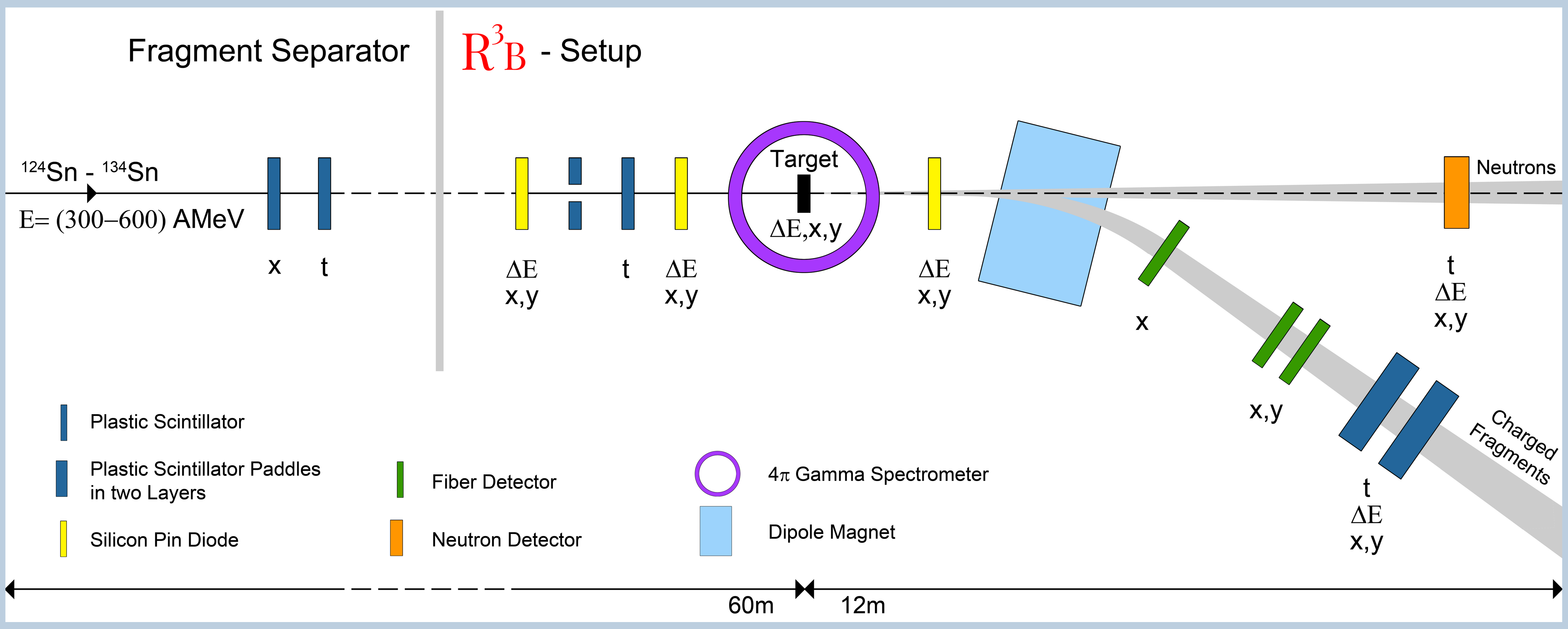
The R^{3}B-Setup (for the S412 Experiment)



Introduction

Reactions of neutron-rich Sn isotopes have been measured in inverse kinematics at the R^{3}B setup at GSI in Darmstadt in 2012.

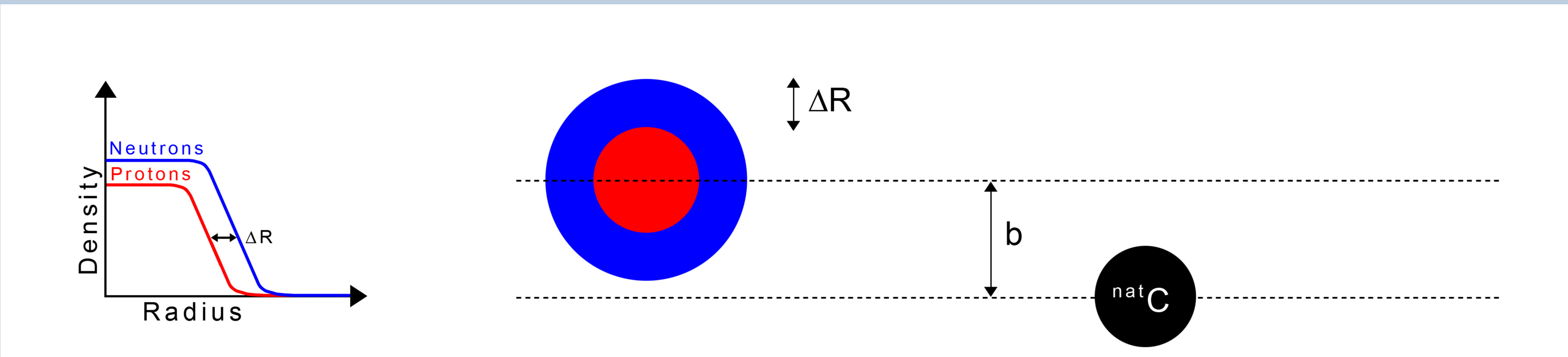
Due to the neutron excess, which results also in a weaker binding of the valence neutrons, such isotopes are expected to form a very neutron-rich surface, which is called the neutron skin. The investigation of this phenomenon is one of the main goals of the experiment.

The reaction products of the isotopes ^{124}Sn to ^{134}Sn have been measured at beam energies of 300 *A*MeV to 600 *A*MeV in a kinematically complete way.

Different reaction channels will be analyzed, therefore informations about the neutron skin can be obtained from different methods. These are in particular the neutron removal cross sections and the dipole polarizability of the nucleus, which are both sensitive to the neutron-skin thickness. The latter will be obtained from the differential cross section of electromagnetic excitation measured in a wide excitation-energy range including the Pygmy and Giant Dipole Resonances.

Investigation of the neutron skin thickness from different reaction channels

NUCLEAR REACTIONS



Probability approach in eikonal approximation

Cross section for the removal of N_X neutrons from a (Z_{Proj}, N_{Proj}) projectile:

$$\sigma_{N_X} = \binom{N_{Proj}}{N_X} \int d^2b \, [1 - P_n(b)]^{N_X} \, [P_n(b)]^{N_{Proj}-N_X} \, [P_p(b)]^{Z_{Proj}}$$

Total neutron removal cross section:

$$\sigma_{\Delta N} = \sum_{X=0}^{P} \sigma_{N_X}$$

Probability distributions P dependent on nucleon density distributions ρ_n, ρ_p

EOS of asymmetric nuclear matter

$$e(\rho,\delta) = e(\rho,0) + S(\rho)\,\delta^2 + \mathcal{O}(\delta^4) \qquad \rho = \rho_n + \rho_p$$

Asymmetry parameter:	Symmetry energy:	Slope parameter:
$\delta = \frac{\rho_n - \rho_p}{\rho}$	$S(\rho) = \frac{1}{2}\frac{\partial^2 e(\rho,\delta)}{\partial \delta^2}\big\vert_{\delta=0}$	$L = 3\rho \frac{\partial S(\rho)}{\partial \rho}\big\vert_{\rho_0}$

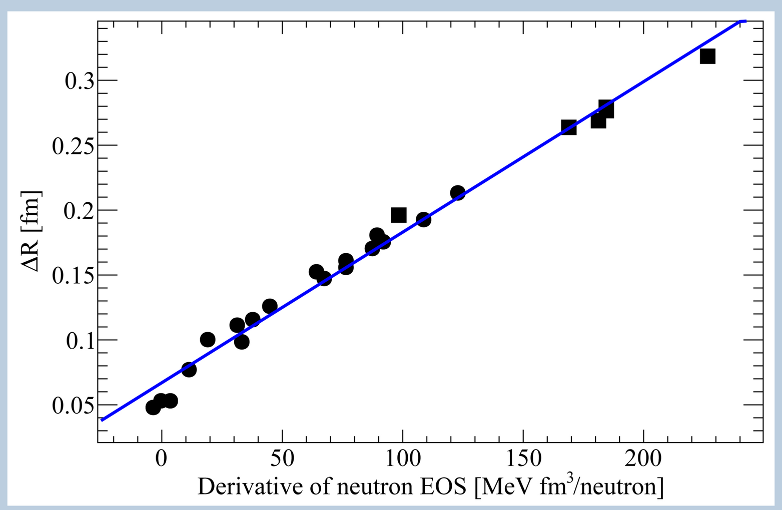
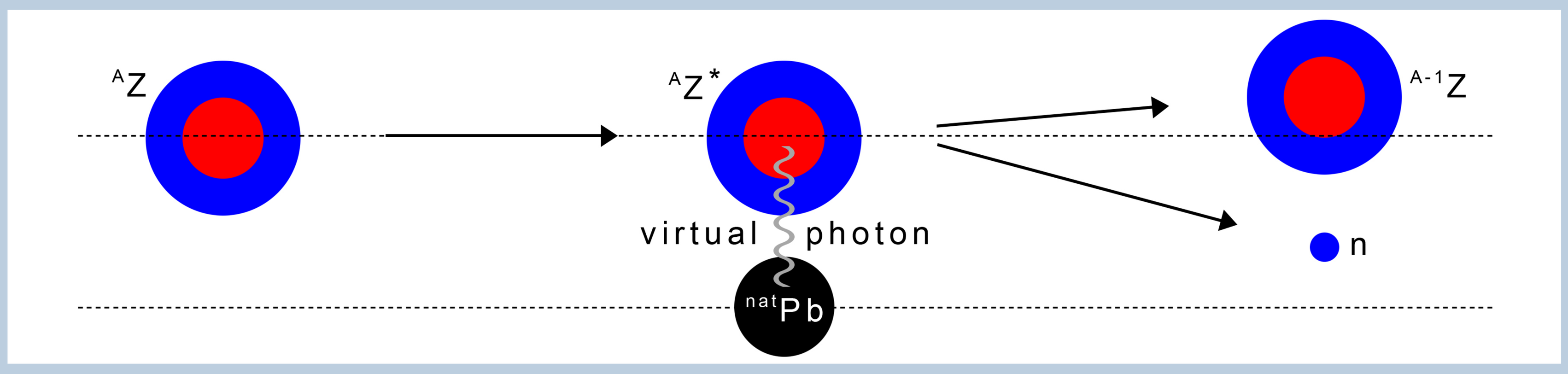


FIG: The neutron skin thickness in ^{208}Pb vs the derivative of the neutron EOS at a density close to saturation for different Skyrme parameter sets (circles) and relativistic models (squares). Data adopted from [1].

COULOMB EXCITATION



Equivalent photon method

Coulomb breakup reaction cross section for the dipole excitation:

$$\frac{d\sigma(E)}{dE} = \frac{16\pi^3}{9\hbar c} N_{E1}(E)\, E \frac{dB(E1)}{dE}$$

- E: Excitation energy reconstructed from invariant mass
- N: Number of virtual photons
- B: Transition probability

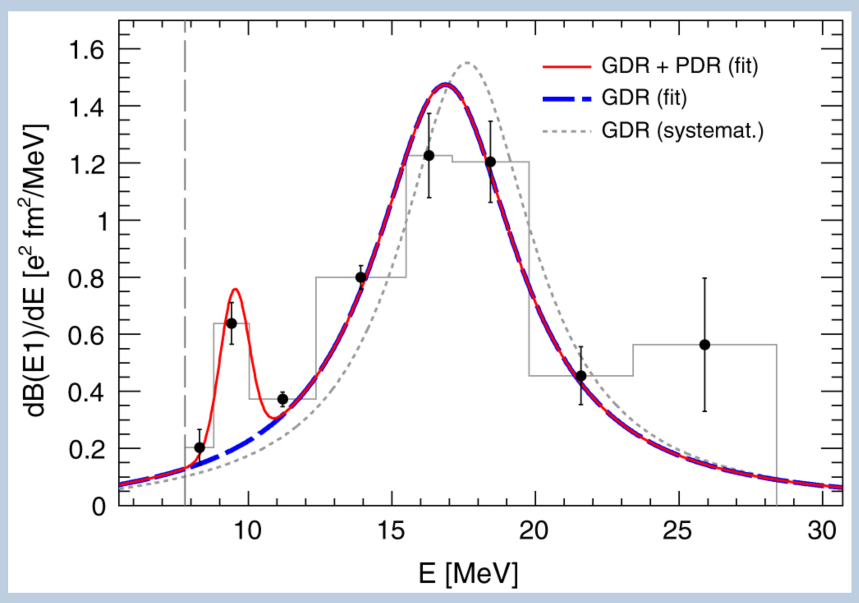


FIG: Experimental E1 strength distribution of ^{68}Ni. Figure taken from [2].

Dipole polarizability

$$\alpha_D = \frac{8\pi}{9}\int_0^\infty \frac{dB(E_1)}{E}$$

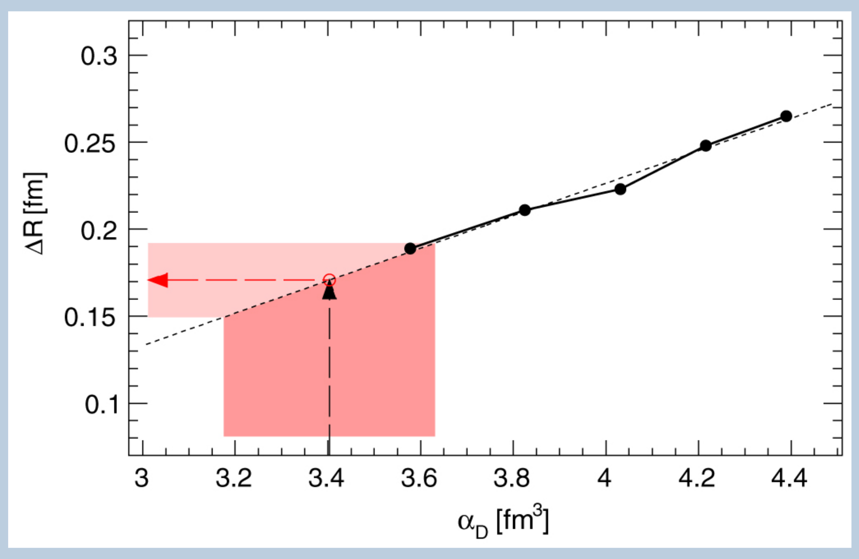


FIG: Correlation between the neutron skin thickness and the dipole polarizability in ^{68}Ni. The experimental result from [2] is compared to mean-field calculations based on FSUGold [3]. Figure taken from [2].

First results and outlook

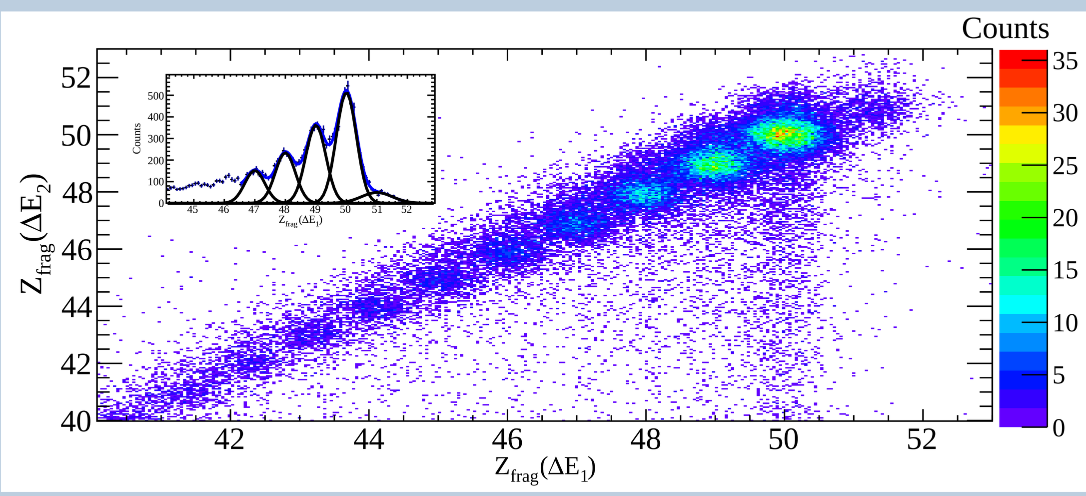


FIG (top): Nuclear reactions of ^{124}Sn with a C-target (μ = 2.67g/cm^2). The two dimensional plot shows the correlation of the fragment charges, obtained from the measured energy loss in two independent detectors. The best charge resolution $\tilde{\sigma}_Z/Z \approx 0.7\,\%$ is achieved by the silicon pin diode (inset).

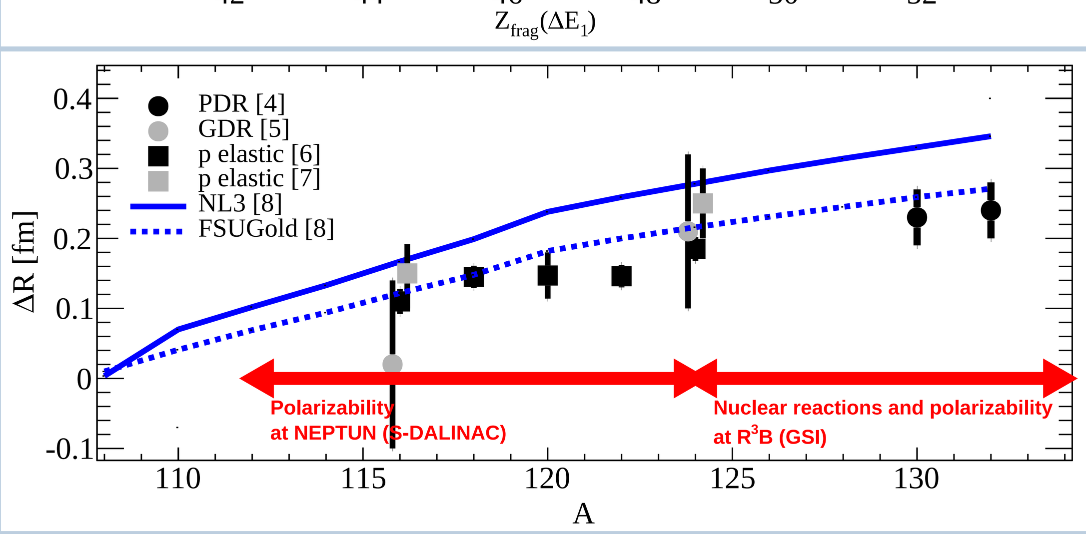


FIG (bottom): Neutron-skin thickness in Sn isotopes from different methods. Results from PDR [4] and GDR [5] data are shown by black and gray circles. The squares correspond to proton elastic scattering at 295 MeV [6] (black) and 800 MeV [7] (gray). Theoretical results from different mean-field calculations [8] are shown as lines.

The stable part of the isotopic chain will be measured via photo absorption at NEPTUN (S-DALINAC, Darmstadt). The experiment discussed above will lead to new results in the mass region A=124-134.

References

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GSI
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