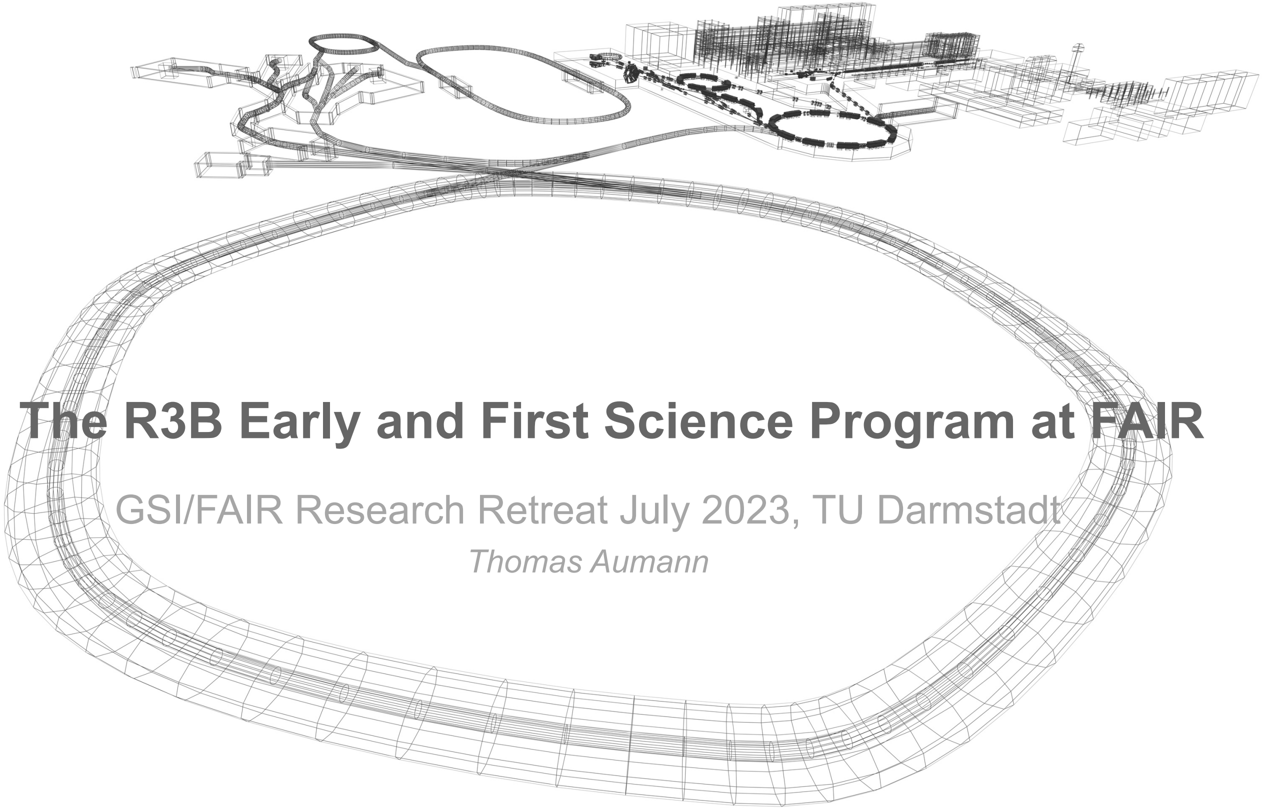


The R3B Early and First Science Program at FAIR

GSI/FAIR Research Retreat July 2023, TU Darmstadt

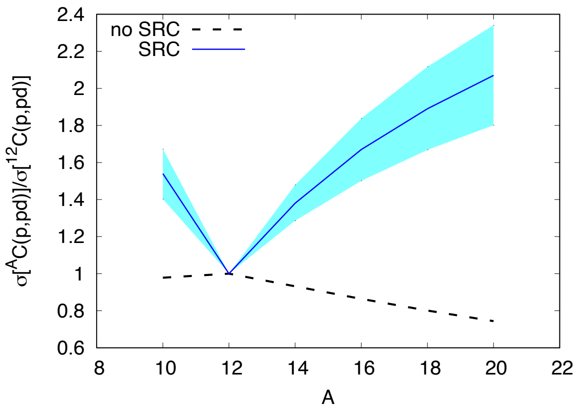
Thomas Aumann

R3B - Phase-0 Remaining program 2024/2025
SRC in (p,pd) reactions, Radius of Hypertriton

New method to study SRC in unstable nuclei in (p,pd) reactions

- Knockout of correlated n-p pair
  (10% of deuteron w.f. corresponds to SRC pairs)
- Exclusive measurement: scattered proton- deuteron, fragment, gamma-rays
- Aim: n-p SRC as a function of neutron excess along isotopic chains

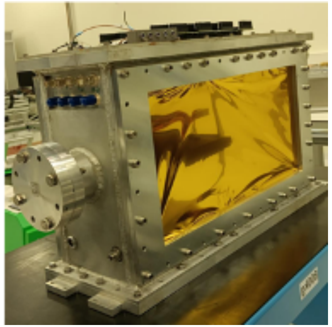
Feb 2024



Radius of hypertriton from total reaction cross section

- Production and reactions of ${}^{3}_{\Lambda}H$ in $^{12}C + ^{12}C$ collisions
- Two targets with different thickness
- New detector: TPC in GLAD to track π^-
- Aim: determine Λ halo of ${}^{3}_{\Lambda}H$ and its binding energy

Feb 2025



Towards R3B in HEC for FAIR Early Science

2025 - Phase-0 Short-range correlations carbon isotopes: $^{A}C(p,pd)$

2025 - Phase-0 Hypertriton radius, decommissioning, move of GLAD to FAIR

2026 - ASY-EOS in Cave C; start installation of R3B at HEC

2027 - installation, first commissioning beams

2028 - extended commissioning and start early science program

Continuation of detector construction:

- NeuLAND: BMBF application for 3 NeuLAND double planes (TU Darmstadt, U Köln)
- CALIFA: completion of acceptance with backward crystals (BMBF application, TUDa)
- Target recoil detector: Si tracker based on ALPIDE sensors
- Active target ACTAF: commissioning and first measurements 2025 at CERN
- Proton-arm spectrometer PAS (Russian in-kind contribution):
  TDR with fiber-based solution in preparation (GSI)

Procedure to define Early/First Science program

R3B internal call for Letters of Intent

(Still some more to be expected)

R3B writing team (part of NUSTAR writing team) prepares document describing the envisaged science program for the first years at FAIR

Ordering according to complexity and readiness of detection devices

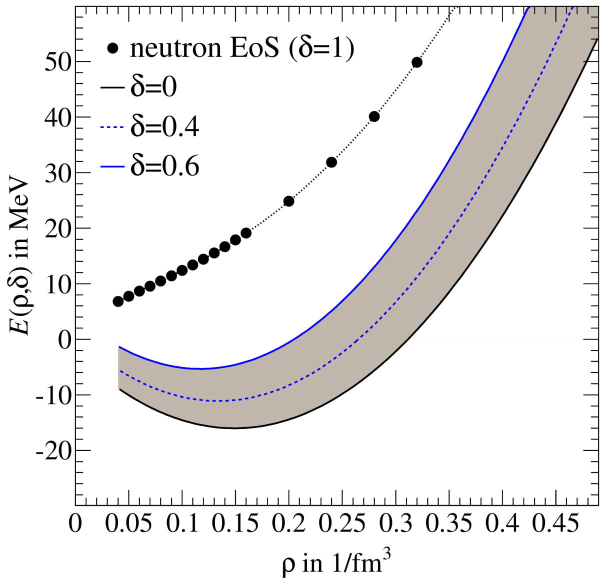
Comprehensive program to constrain symmetry-energy

$$S(\rho) \approx J + L\epsilon(\rho) + \frac{1}{2}K_{sym}\epsilon^2(\rho) \qquad \epsilon(\rho) = \frac{\rho - \rho_{sat}}{3\rho_{sat}}$$

E_{GDR} → J

α_D, Δr_{np} → L

E_{GMR} → K_{sym}



Related programs:

- Neutron-removal cross sections (n-skin)
- Coulomb dissociation cross sections (dipole polarizability)
- Radii of neutron single-particle orbit
- Elastic p scattering (n-skin)
- Inelastic α scattering (GMR)

Neutron skin and dipole polarizability

Total neutron removal cross sections

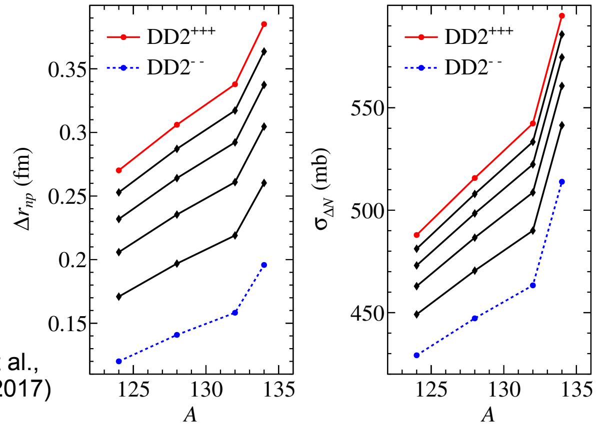
^{114,132}Sn, ^{188,208}Pb

Extension to neutron deficient and heavy beams

Precision measurement for ^{132}Sn

Optimum mass resolution with R3B at the HEC

-> **neutron skin**



Aumann et al., PRL 119 (2017)

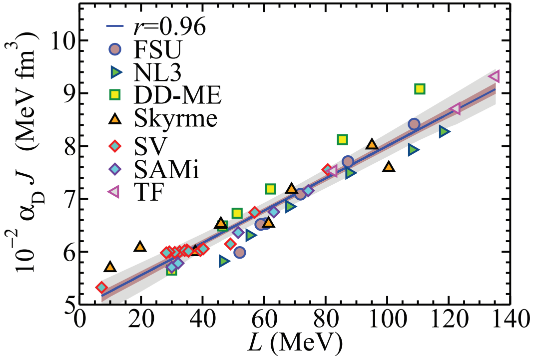
From same experiment with Pb target:

Total Coulomb dissociation cross section

Virtual photon spectrum weights strength distribution with 1/E

-> excellent correlation of total cross section with polarizability

-> **dipole polarizability**



Roca-Maza et al., PRC 92 (2015)

Gernhäuser et al.

Radius of neutron single-particle orbits

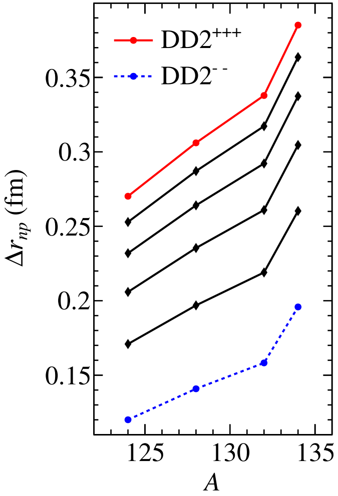
Momentum distributions after neutron knockout

$^{120,128,132,134}Sn(p,pn)^{A-1}Sn$

- Radius of valence neutron orbitals
- directly related to n-skin

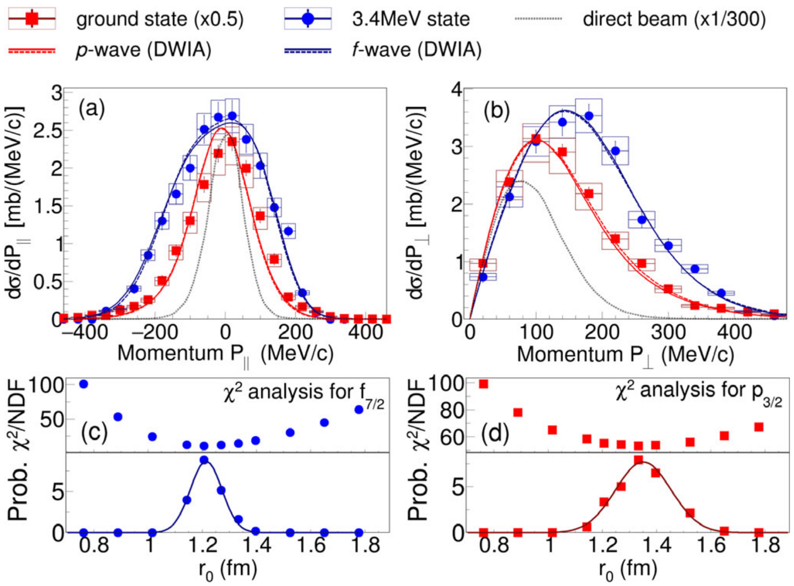
- Including measurement beyond N=82

n-skin
Sn isotopes



Obertelli et al.

$^{52}Ca(p,pn)$



M. Enciu et al., PRL 129 (2022)

Early and First Science Program

Elastic and inelastic scattering with the active target ACTAF

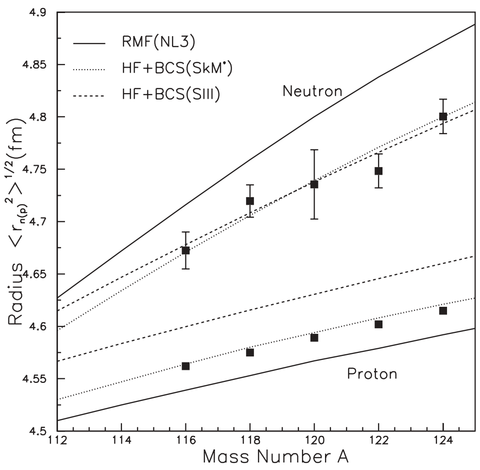
Elastic proton scattering:

^{120,128,132}**Sn** incl. 2nd minimum
-> matter radius, diffuseness

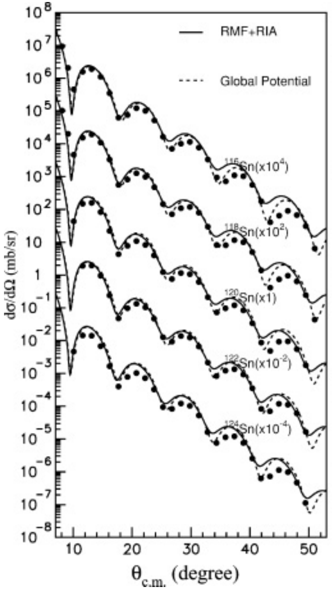
Charge rms radii measured via isotope shift

-> neutron rms radius / **neutron skin**

ACTAF available from 2027



(p,p) RCNP
+ electron data
Terashima et al,
PRC 2019



Kiselev et al.

Early and First Science Program

Elastic and inelastic scattering with the active target ACTAR

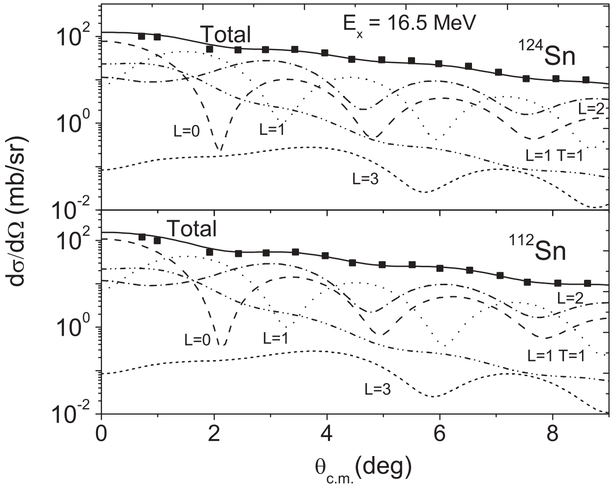
<u>Inelastic alpha scattering:</u>

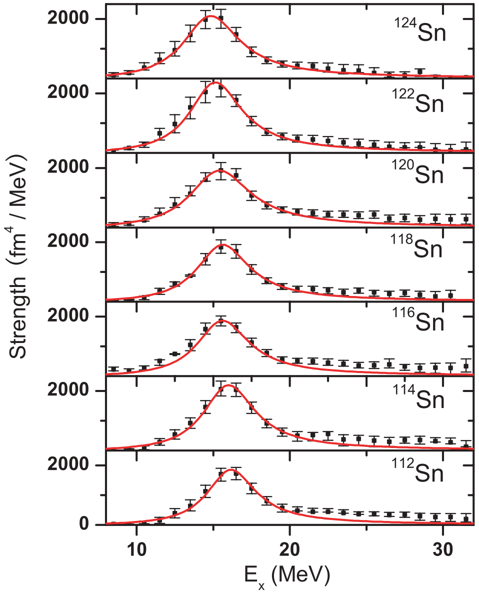
^{120,128,132}Sn at low momentum transfer
-> giant monopole strength

Stable isotopes measured at RCNP

-> centroid GMR -> **incompressibility**

ACTAF available from 2027





Kiselev et al.

Early and First Science Program

Short-range correlations in heavy nuclei

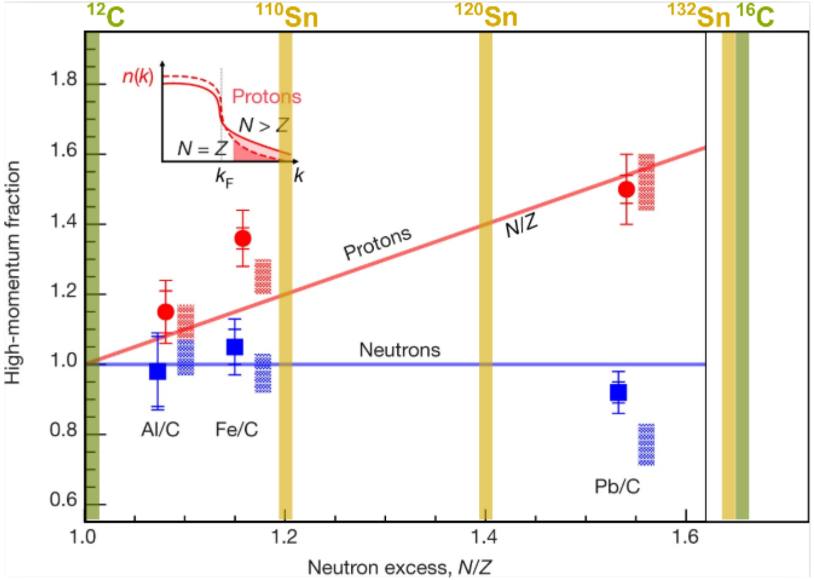
$^{A}\mathrm{Sn}(p,2pN)$

Disentangling asymmetry and mass effects

^{12,16}C measured 2022

Proposed: **^{110,120,132}Sn**

Needs Si tracker



Corsi, Kahlbow et al.

Early and First Science Program

Fission of unstable nuclei:

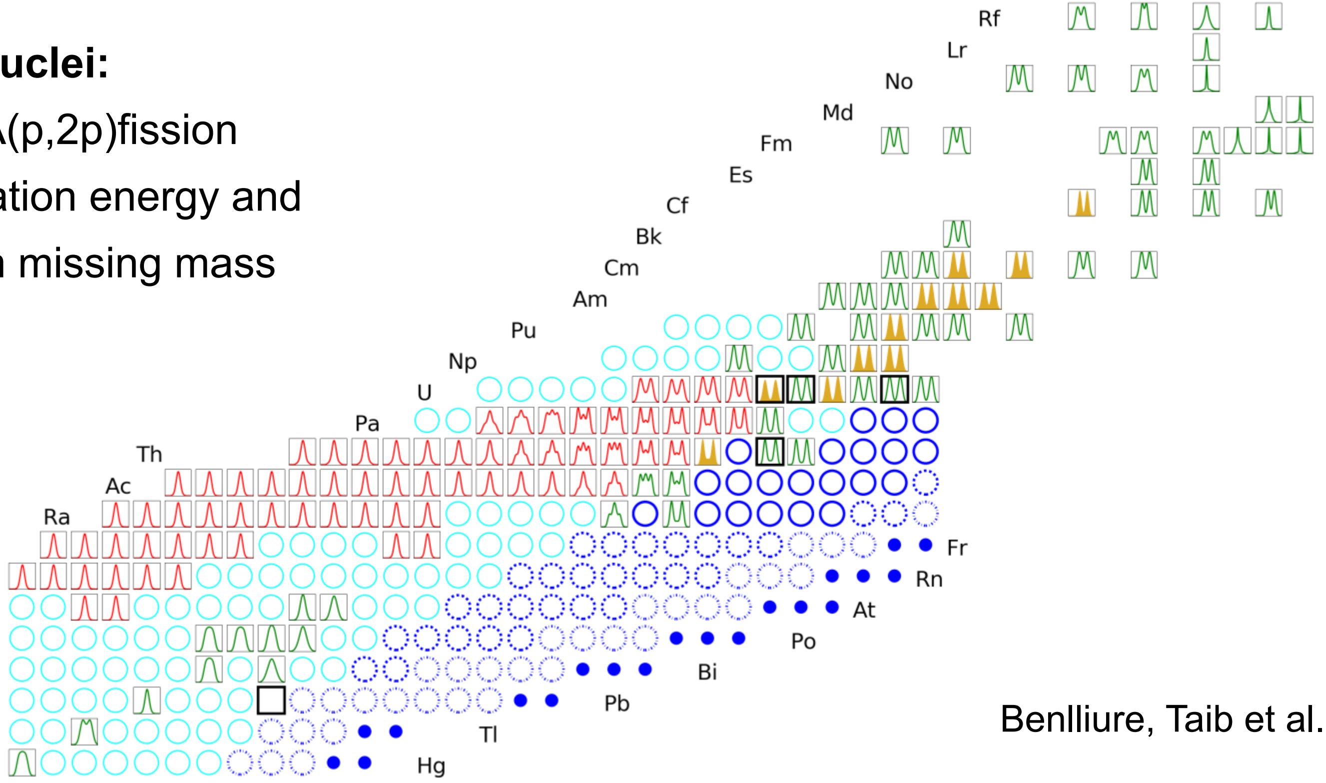
Quasi-free scattering A(p,2p)fission

Determination of excitation energy and

fission barriers from missing mass

-> r-process

Needs Si tracker



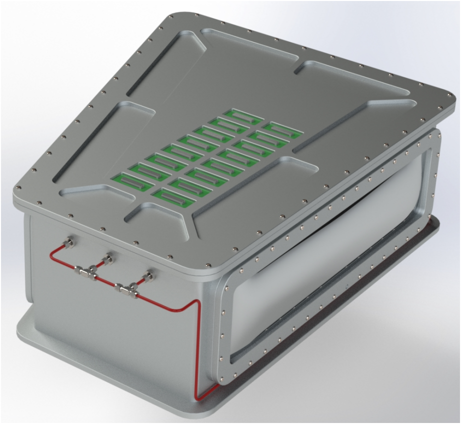
Benlliure, Taib et al.

First Science Program

Follow-up **Hyper-nuclei program with HYDRA**

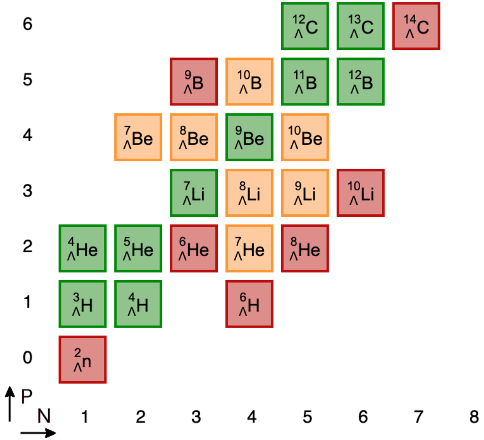
TDR of full-size TPC in GLAD ready in 2024, construction budget not yet secured

Letter of Intent for R3B First Science in preparation



Obertelli, Duer et al.

https://hypernuclei.kph.uni-mainz.de/



E. Hiyama et al., PRC 53 (1996)