"Employing ROC to explore astrophysics milestones: nuclear structure of the N = Z nucleus ^{76}Sr"

and feasibility of ^{75}Sr (ISOLTRAP, RILIS, TISD)

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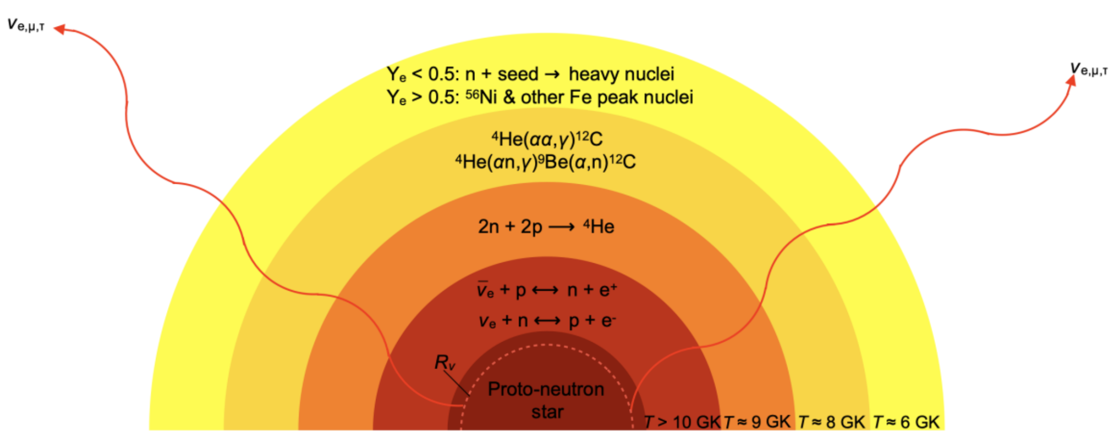


Outline

Physics case

Experimental setup

Beamtime request

Physics motivation – Astrophysics

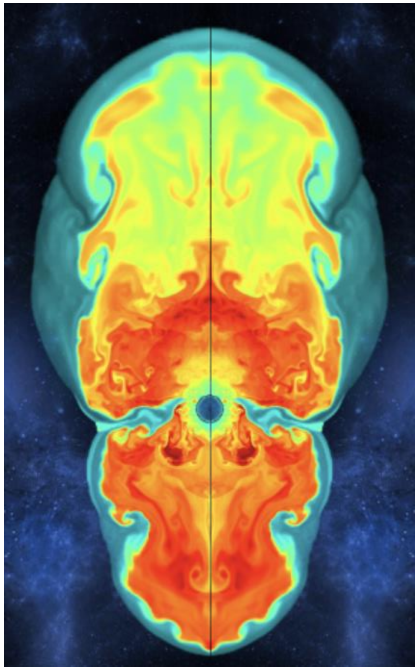
MPIK astrophysics workshop in March 2024

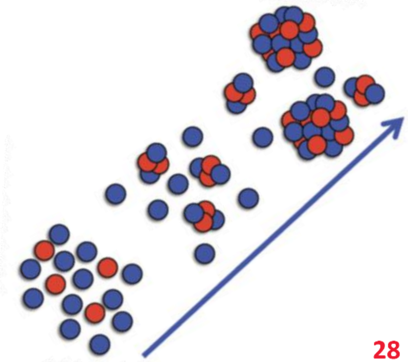
Strong collaboration with the group of Prof. Almudena Arcones (Max Planck's fellow)

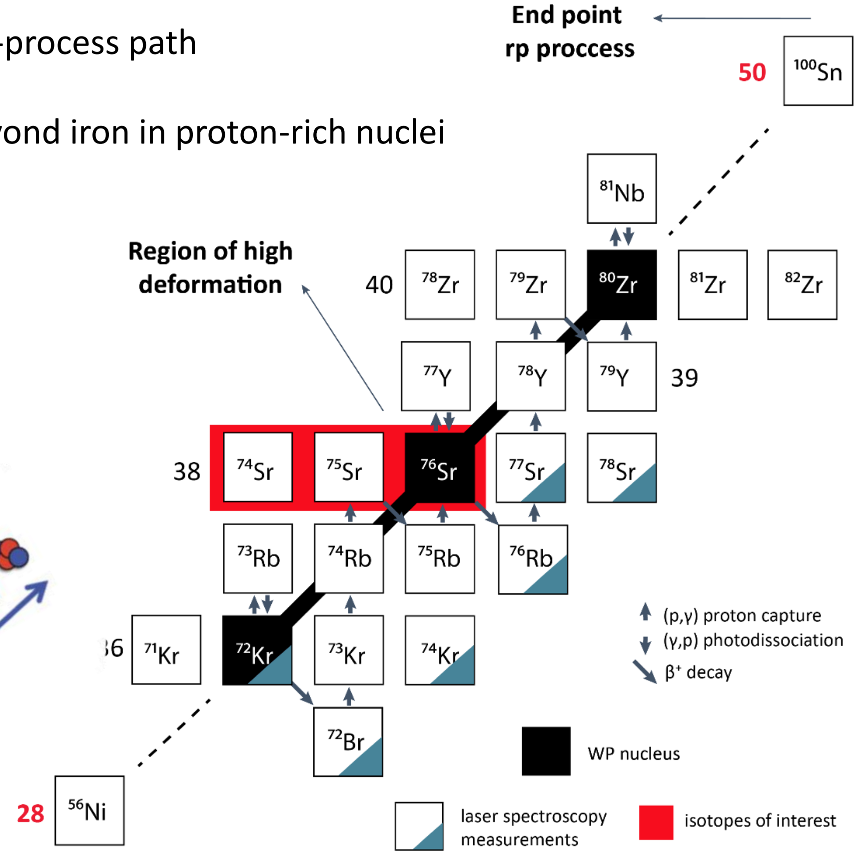
- ^{75}Sr and ^{76}Sr in rp-process path

- rp-process produces elements beyond iron in proton-rich nuclei

Supernovae simulations: proton-rich ejecta







Constraining nuclear physics: abundance observations determine astrophysical conditions, Psaltis et al. ApJ (2024)

Binding energies and deformation as input parameters for the nuclear reaction simulator

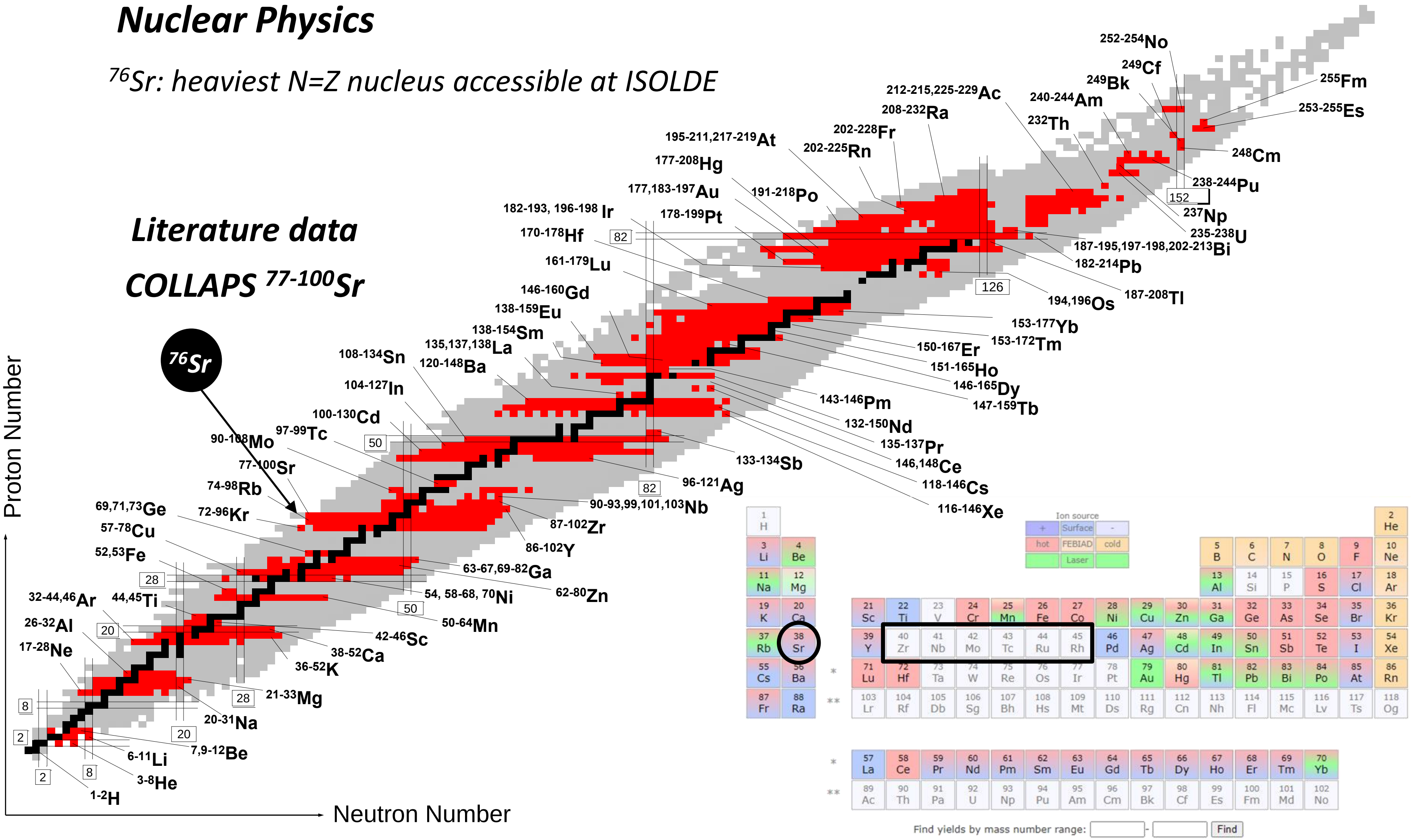
Physics motivation – Nuclear structure

Nuclear Physics

^{76}Sr: heaviest N=Z nucleus accessible at ISOLDE

Literature data

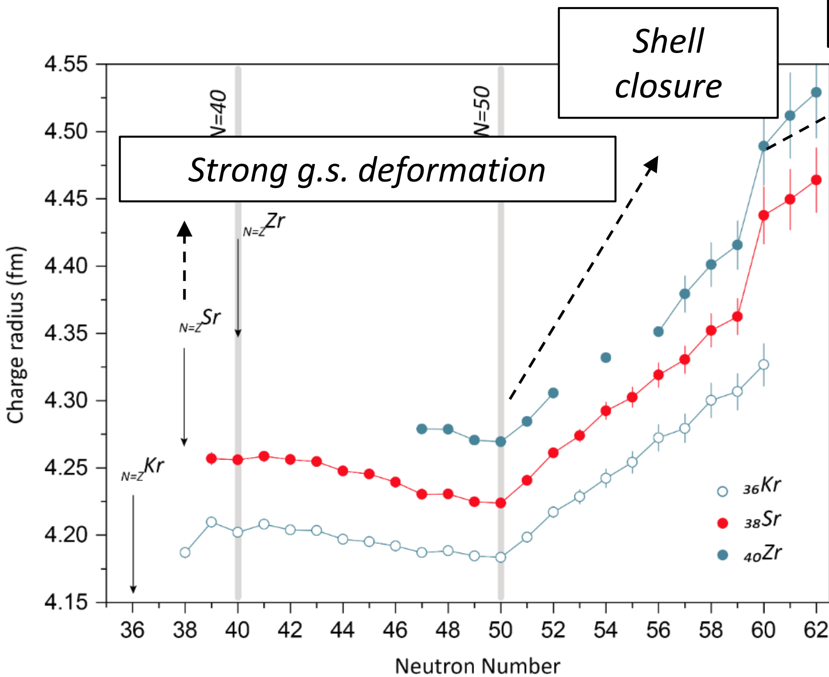
COLLAPS $^{77-100}$Sr

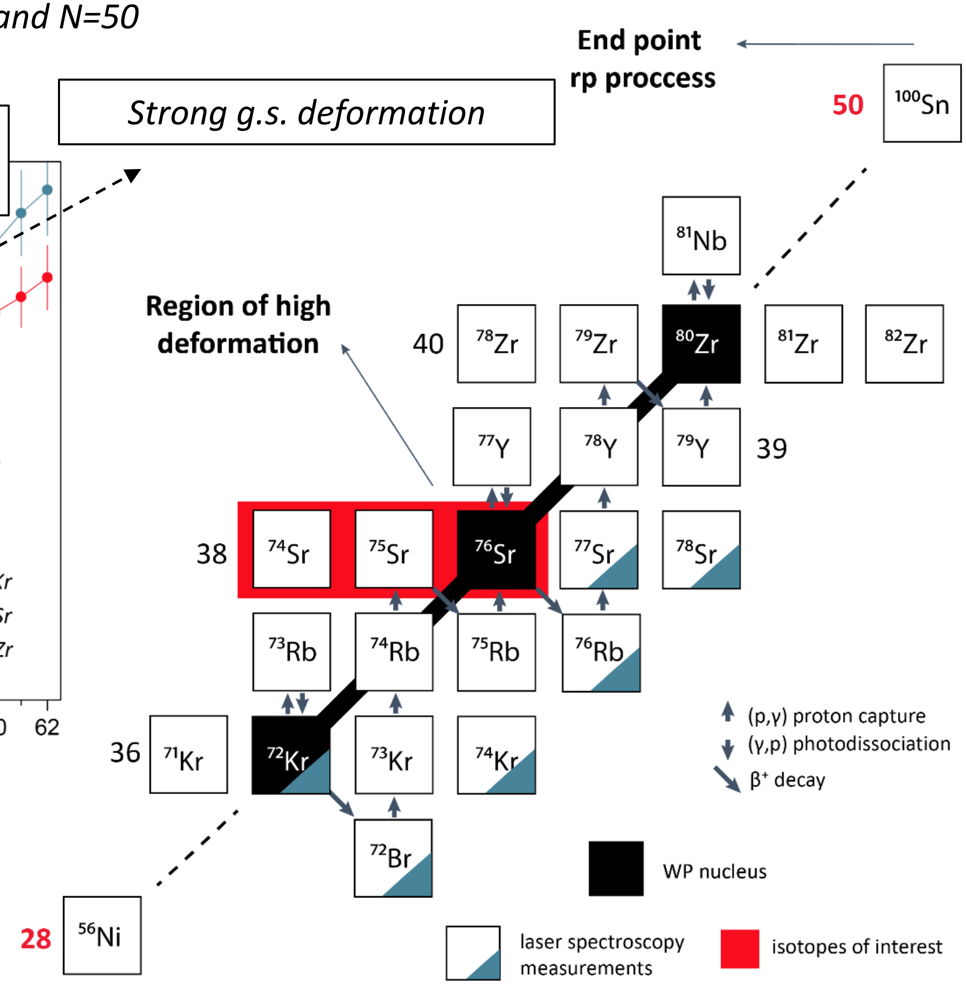


Physics motivation – Nuclear structure

Investigating the N=40 neutron subshell closure

Charge radii of Kr, Sr and Zr between N=40 and N=50



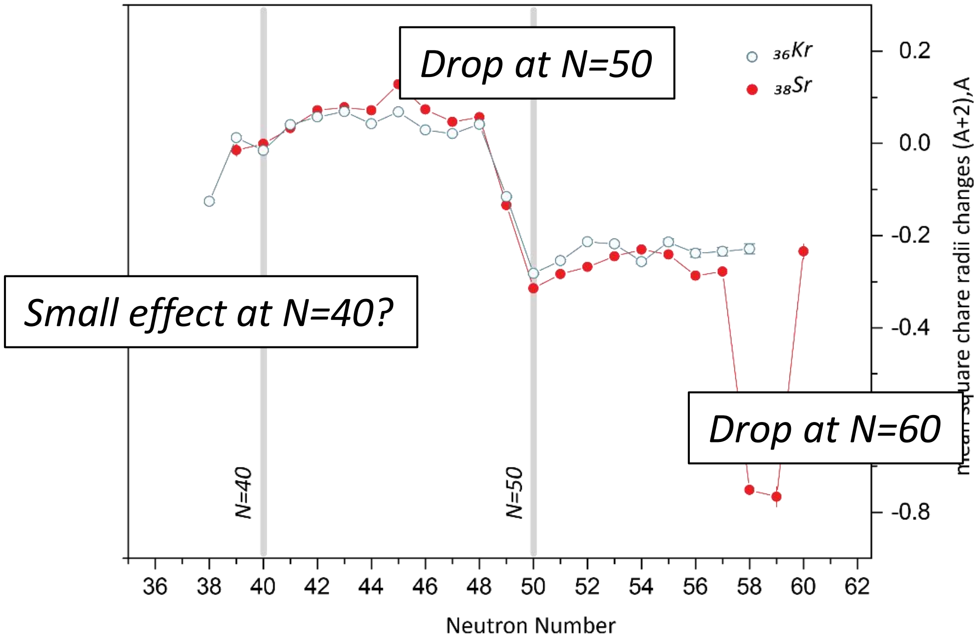


Appearance of a kink at N=40 in Sr ?

Physics motivation – Nuclear structure

Investigating the N=40 neutron subshell closure

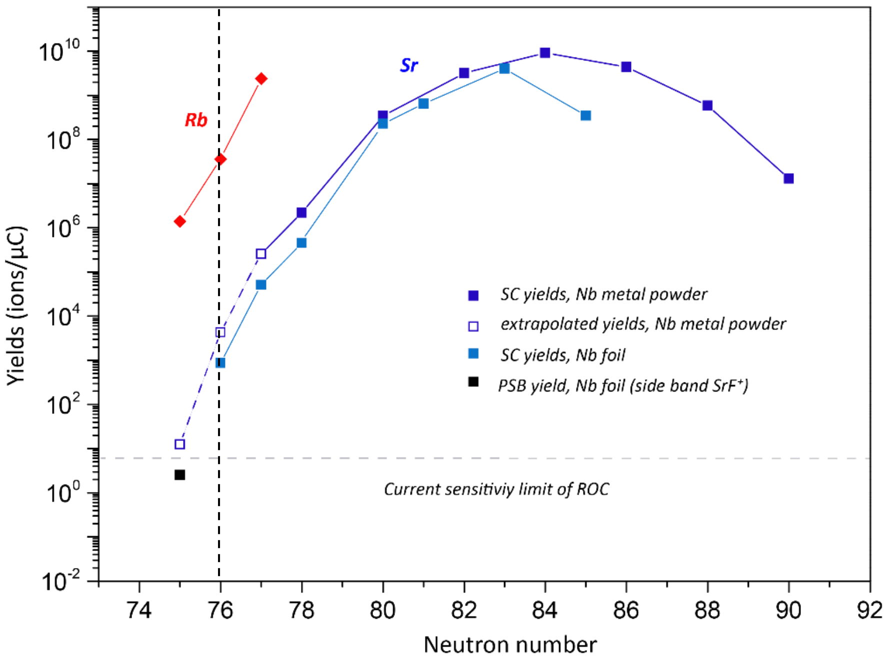
Staggering in Kr, Sr and Zr between N=40 and N=50



neutron – neutron (nn) and proton – proton (pp) pairing correlations expected to be magnified in $N = Z$ nuclei

- crucial for explaining the OES in charge radii

Experimental setup



Sr^+ yields taken from SC

Nb foil (or powder); surface ionized

SrF yields taken from NPA, 763 (2005 45-58)

Nb foil (or powder); surface ionized

RILIS laser scheme available and tested at TRIUMF

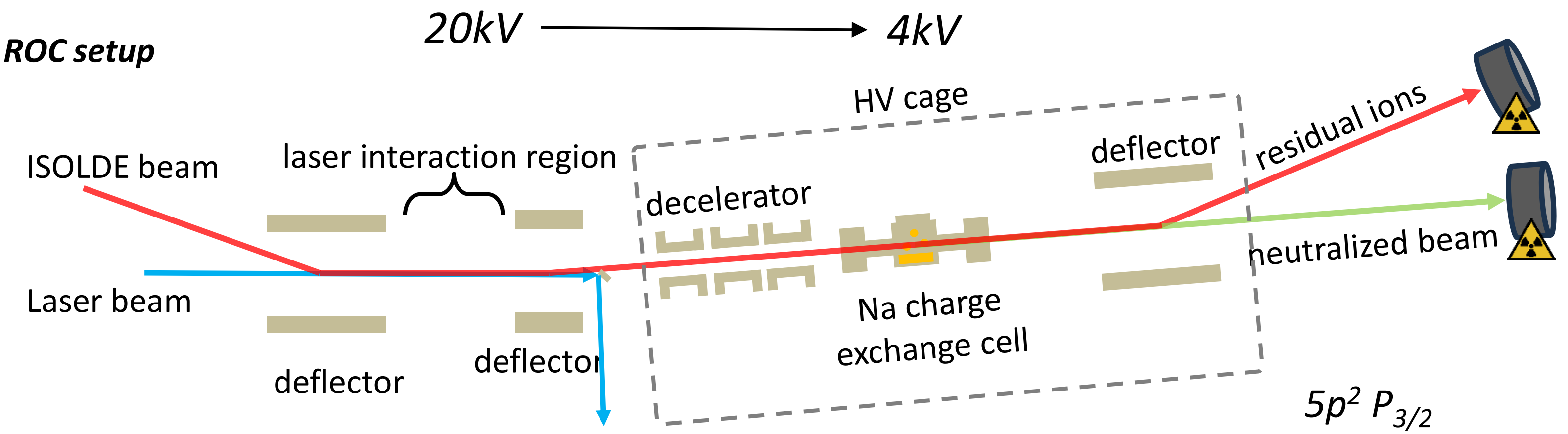
Possible use of a quartz line?

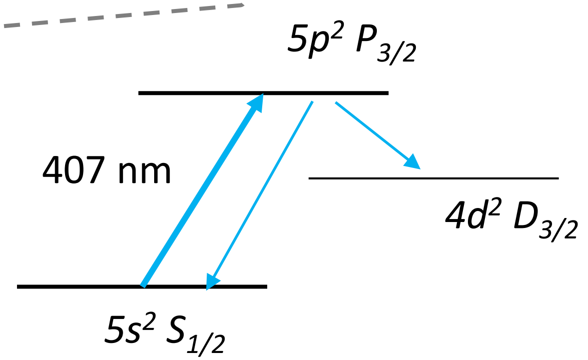
Not possible with conventional CLS but with ROC

Isotope	SC	PSB
^{76}Sr	867 ions/s	-
$^{76}Sr^{19}F$	-	4000 ions/s
Ratio $^{76}Rb/^{76}Sr = 10^3$ (Nuclear Physics A 763 (2005) 45–58)		

Experimental setup

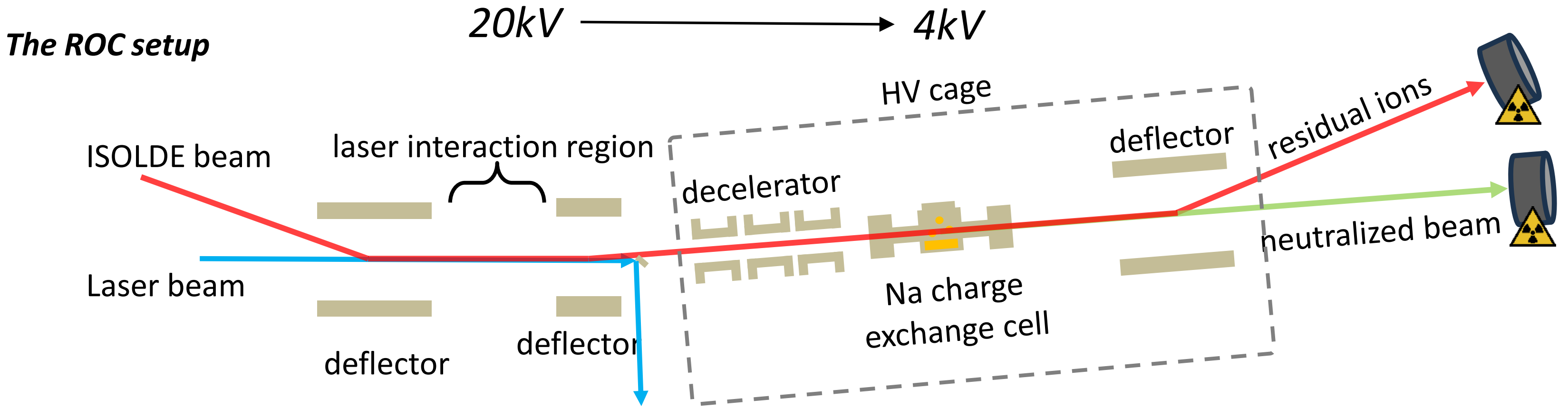
The ROC setup





- ***Very sensitive setup***
- ***Tested with Ca last September, sensitivity limit - 20 ions/s***
- ***Aim to get down to 1 ion/s in July***

Experimental setup



Use of continuous beam from GPS

Can coupe with 10^3 -10^4 more Rb in the beam

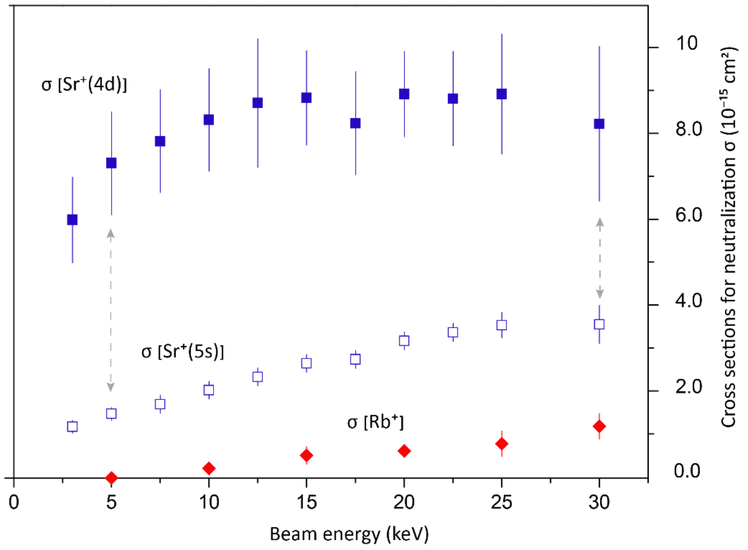
Cross section for neutralization very different at 5keV

Sr: 1.4(4) x 10^{-15} cm^2 ------------ Rb: 0.02(2) x 10^{-15} cm^2

Half live of ^{76}Sr shorter than ^{76}Rb – use it for the measurement interval

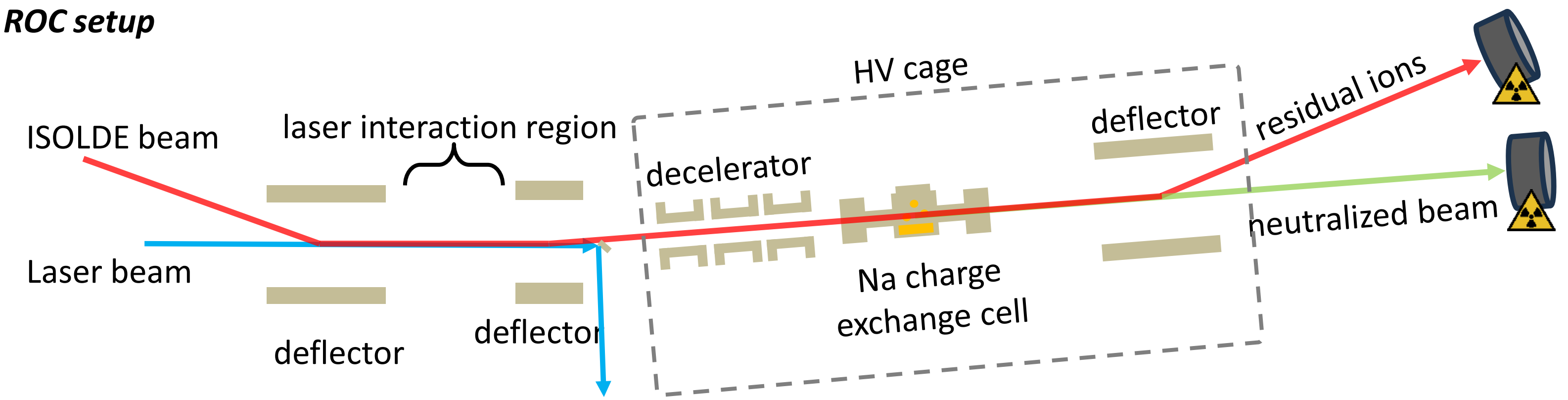
We should expect a signal to background ratio of 1.5

Comparable to our previous ^{52}Ca measurements (1 to 1.2 ratio to ^{52}K)



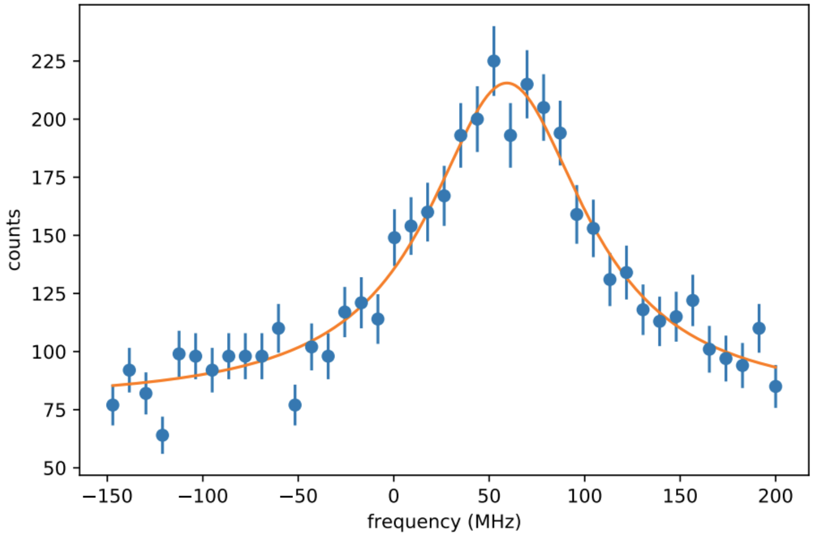
Experimental setup

The ROC setup



Example of ^{52}Ca from 2023

ROC, 40 min



Beamtime request

Summary of requested shifts:

Combined proposal and LoI

- **1 shift for beam tuning and detector optimization**
- **3 shifts to measure the charge radius of ^{76}Sr**
- **1 shift of stable beam (beam tunning and CEC heating)**

- 2 shifts for resonance ionization scheme developments using RILIS
- 2 shift for yield measurements using a Nb powder/foil target with the quartz line and RILIS.
- 1 shift to investigate the beam composition using ISOLTRAP and the feasibility of ^{75}Sr.

In summary, one (or two) experiment of **9 shifts of radioactive beam** and **1 shift of stable beam** are requested for the study of neutron-deficient strontium isotopes.

TAC

Valid point to measure Sr yields from a variety of targets from the PSB. Seeing as the contamination will be an issue on these masses (>1e7 ions/uC reported for 76Rb from SC, this will hardly be less) testing the quartz suppression is crucial to determine feasibility of the experiment. We do not have data on the suppression of Sr from quartz, so if this is not tested before the beamtime there might be an unknown reduction factor in yields making the experiment impossible.

Recommend to decouple yield measurements from scheme development.

- Quantify suppression of Sr from the hot quartz line (can be tested at offline but better test online during Zn run later in 2024
- Do yield measurements to determine of Nb is best choice.
- Scheme development -> Laser enhancement is not fully necessary, yield without would be sufficient.

The TAC notes that more beam development shifts will be necessary than requested in the proposal. If the physics case is deemed interesting, the TAC recommends to grant shift pending successful yield measurements. Alternatively, the proposal could be downgraded to an LOI.

Experimental setup

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Nuclear Physics A 763 (2005) 45–58

NUCLEAR PHYSICS A

Not possible with conventional CLS but with ROC

Mass measurements on neutron-deficient Sr and neutron-rich Sn isotopes with the ISOLTRAP mass spectrometer

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3. Mass Measurements on neutron-deficient Sr- and neutron-rich Sn-isotopes

A 1.4-GeV proton beam was impinging on a niobium target with an average rate varying between 2×10^{12} and 1.3×10^{13} particles per second and created the investigated neutron-deficient Sr isotopes. The ionization took place on a heated tungsten surface, from which also stable Rb isotopes were released and ionized. As mass separator the GPS with a resolving power of $R \approx 2000$ was used. In the case of the most exotic of the investigated Sr isotopes (^{76,77}Sr), the amount of the isobars $^{76,77}Rb^+$ exceeded the quantity of Sr by a factor of 5×10^3 to 5×10^4. Due to space charge limitations, the ISOLTRAP preparation trap is not suitable for removing contaminants of this large ratio in an effective manner. In order to make those isotopes accessible to a mass measurement, CF_4 gas was introduced into the ion source to form SrF^+ molecular ions. In their mass range ($A = 95, 96$) no high-rate contaminants (in particular no RbF^+) were observed. Fluorine was chosen for the molecule formation because of its high chemical reactivity and the fact that there is only one stable F isotope. Furthermore, the mass of ^{19}F is known with a relative uncertainty of $\frac{\Delta m}{m} = 3.9 \times 10^{-9}$ [19]. Hence, this small uncertainty does not contribute