ILIMA/EXL Ring experiments at ESR and further planning

Helmut Weick, GSI, for the ILIMA + EXL collaborations

Research Retreat, TU Darmstadt 18.07.2023

- from CR back to ESR
- Recent ILIMA Experiments
- Future ILIMA Experiments
- Reactions in ESR (Astrum, EXL)

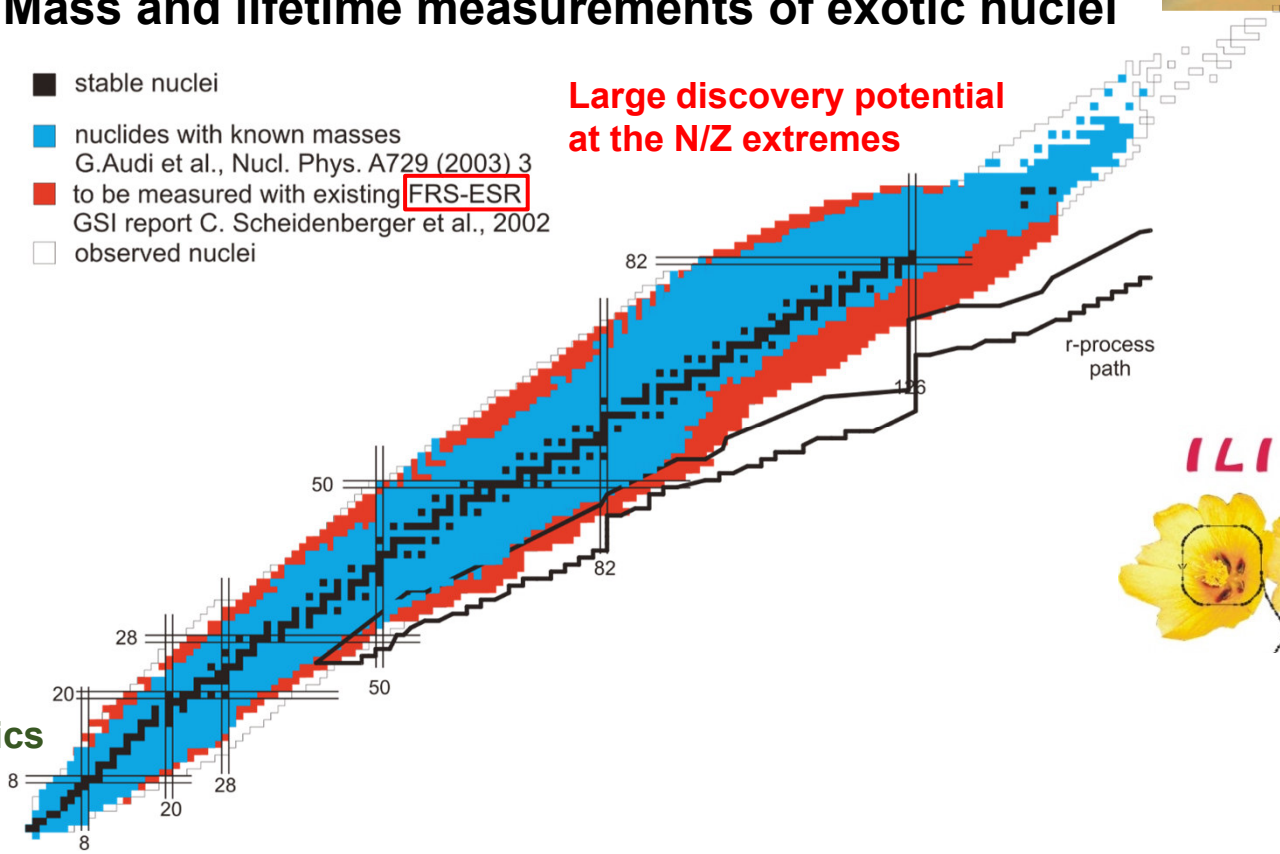
ILIMA

EXL

ILIMA

Mass and lifetime measurements of exotic nuclei

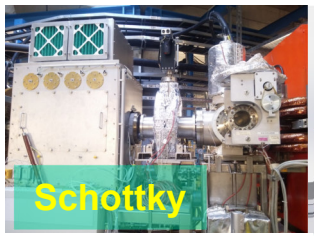
Storage rings:
ESR
CRYRING
with
Schottky detectors
TOF detectors
Particle detectors

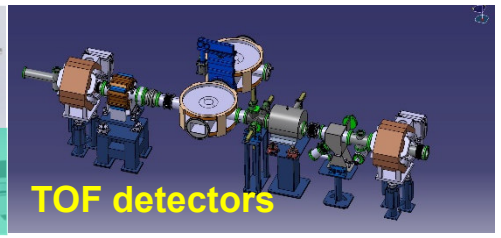


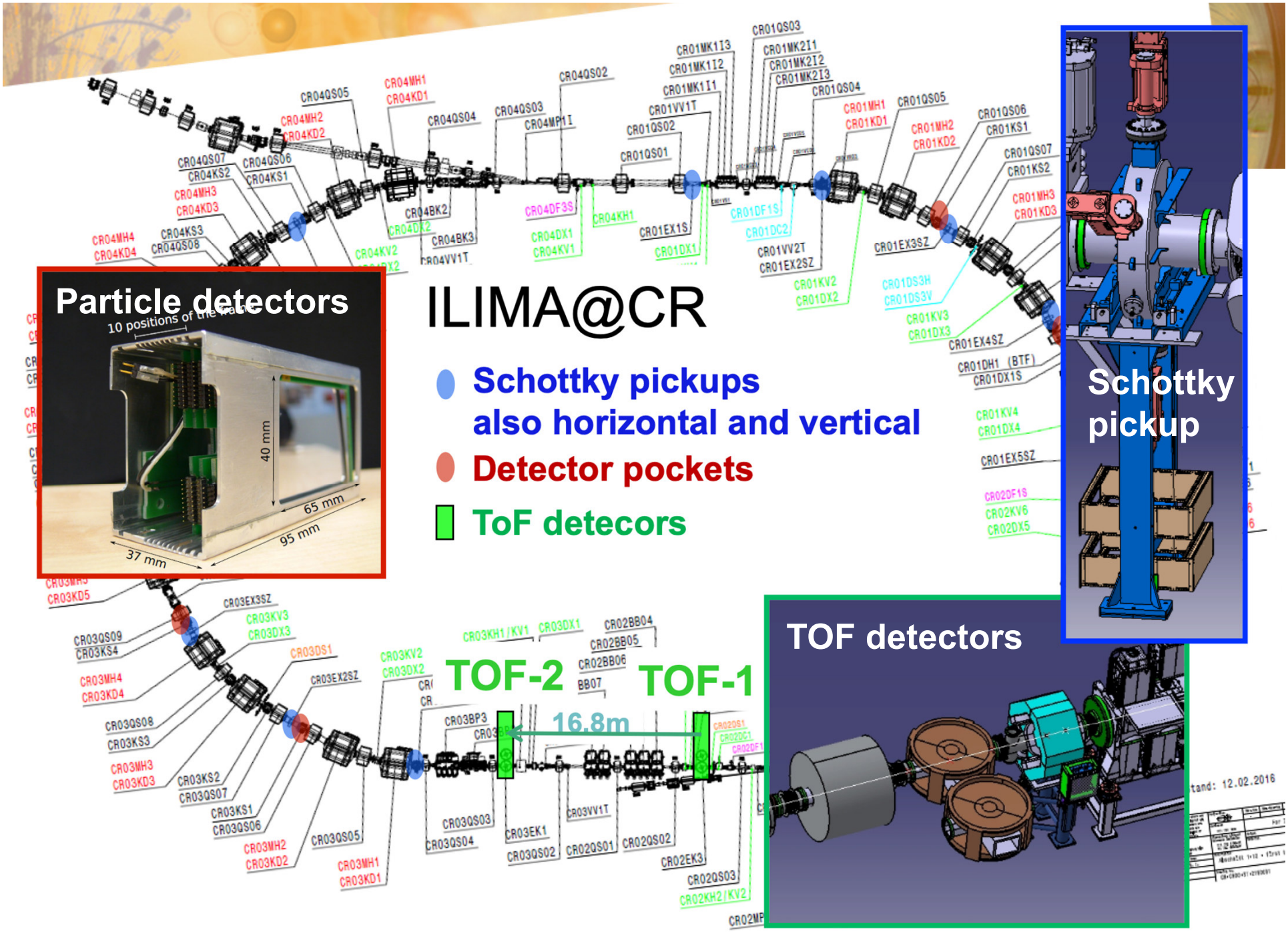
Masses:
- ✓ Shell evolution
- ✓ Deformation
- ✓ Correlation
- ✓ Isomeric states
- ✓ Nuclear astrophysics

Lifetimes:
- ✓ New decay modes
  e.g. Nuclear excitation by electron capture
- ✓ Bound-state beta decay
- ✓ Bound-state pair conversion decay

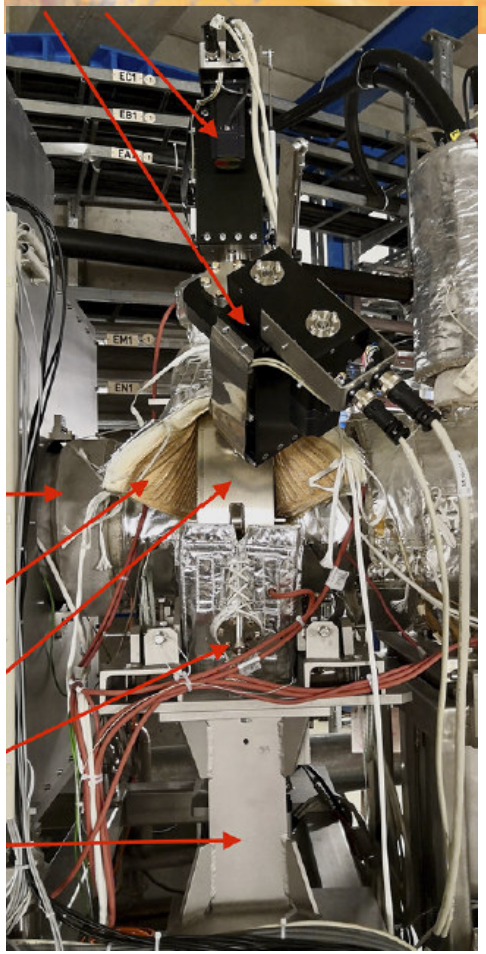
Common technical developments for all rings






Particle detectors
10 positions of the wall
40 mm
65 mm
95 mm
37 mm
ILIMA@CR
Schottky pickups
also horizontal and vertical
Detector pockets
ToF detecors
Schottky pickup
TOF detectors
TOF-2
TOF-1
16.8m

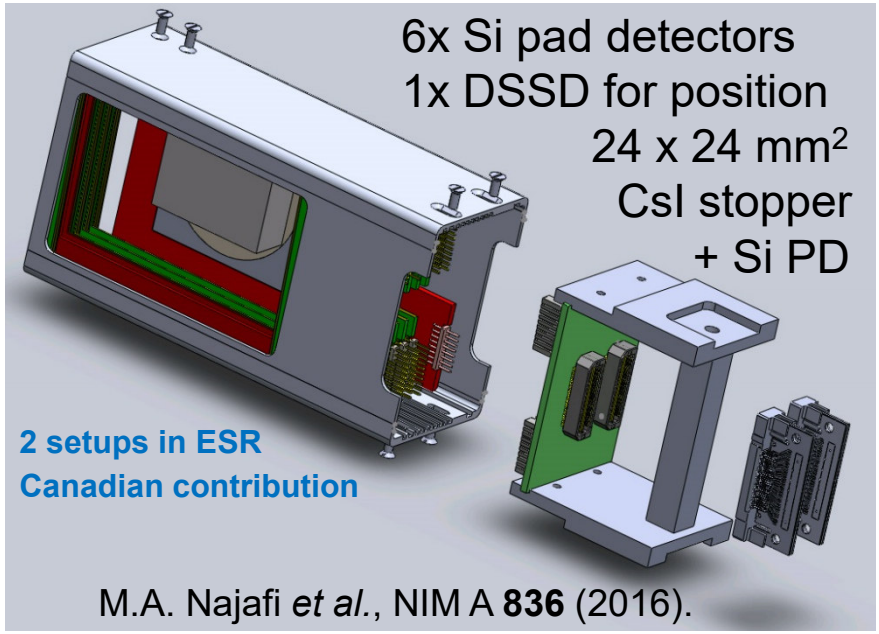
Schottky, Heavy-Ion ΔE-E Telescope



New pickup design
proven in ESR
all metal,
tunable resonance,
high harmonic,

S. Sanjari et al.,
Rev. Sci. Instrum.
91, 083303 (2020).

pocket out during injection
→ fast drive with servo motor



M.A. Najafi *et al.*, NIM A **836** (2016).

Further development of readout,
thesis works (PhD D. Dmytriiev,
and master thesis)

ILIMA Setup and Experiments
approved and planned

Masses

- Isomer masses of n-rich Hf isotopes (PW)
- β-delayed n detection of iodine isotopes + pocket detector (ID)

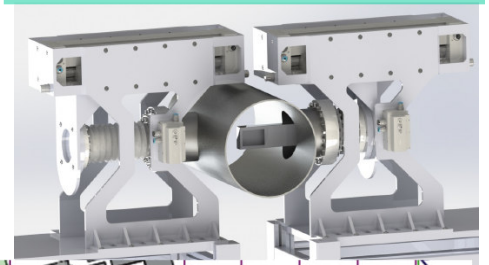
Lifetimes

- 2 photon decay of ^{98}Mo, ^{98}Zr + SMS-IMS

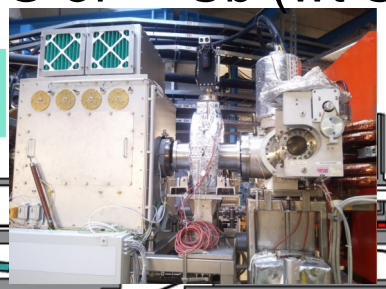
Phase-0
scheduled May 2024

- Bound-state pair creation of ^{194}Pb
- Bound-state beta decay of ^{205}Tl (wt SPARC)
- HFI in beta decay of ^{111}Sn (wt SPARC)
- NEEC@CRYRING of ^{129}Sb (wt SPARC)

In-ring detectors



Schottky

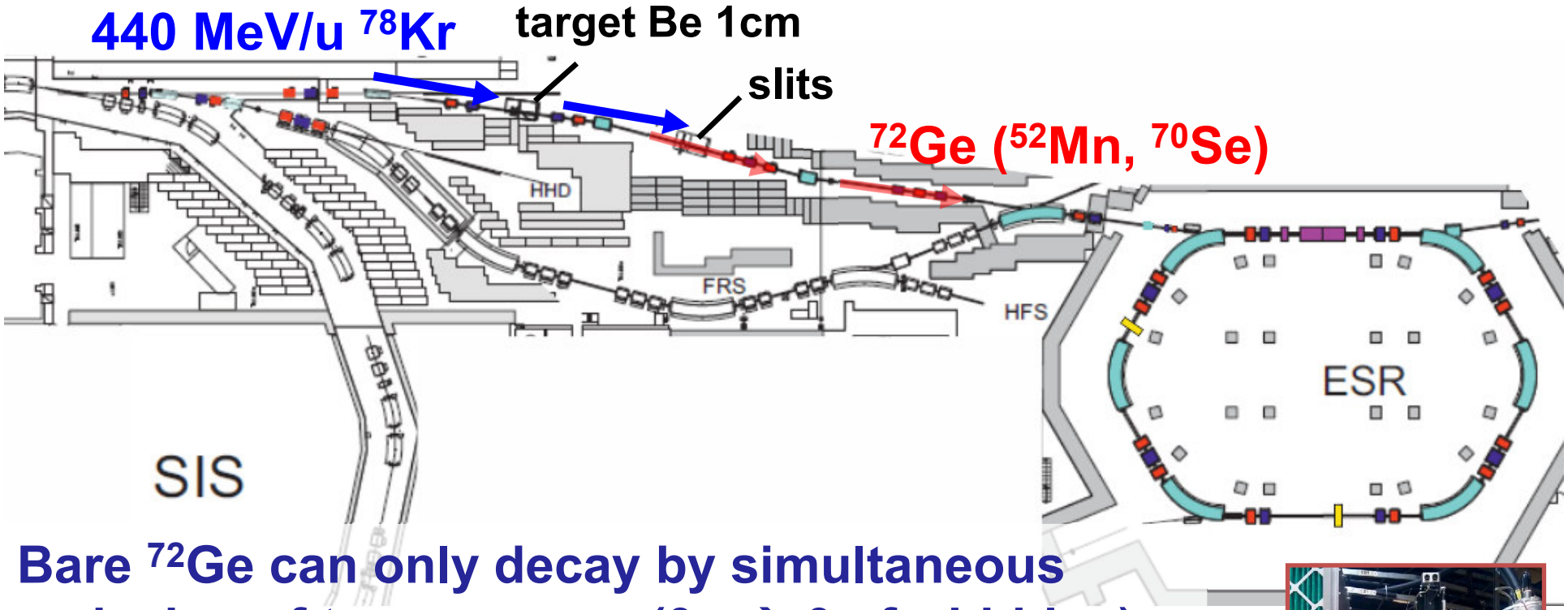


Developments

- **FRS-ESR transmission**
- **SMS+IMS mode**
- **Transverse Schottky** +DAQ
- **TOF detector updated**

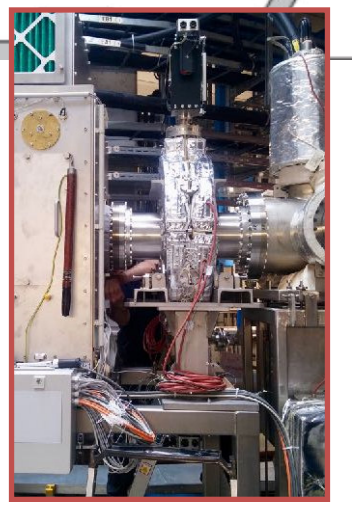
E143: Nuclear two-photon decay

W. Korten



Bare ^{72}Ge can only decay by simultaneous emission of two gammas (0+ → 0+ forbidden).

ESR in isochronous mode (γ_t = 1.3956), used Schottky for detection high production cross section, could use collimators in ESR.



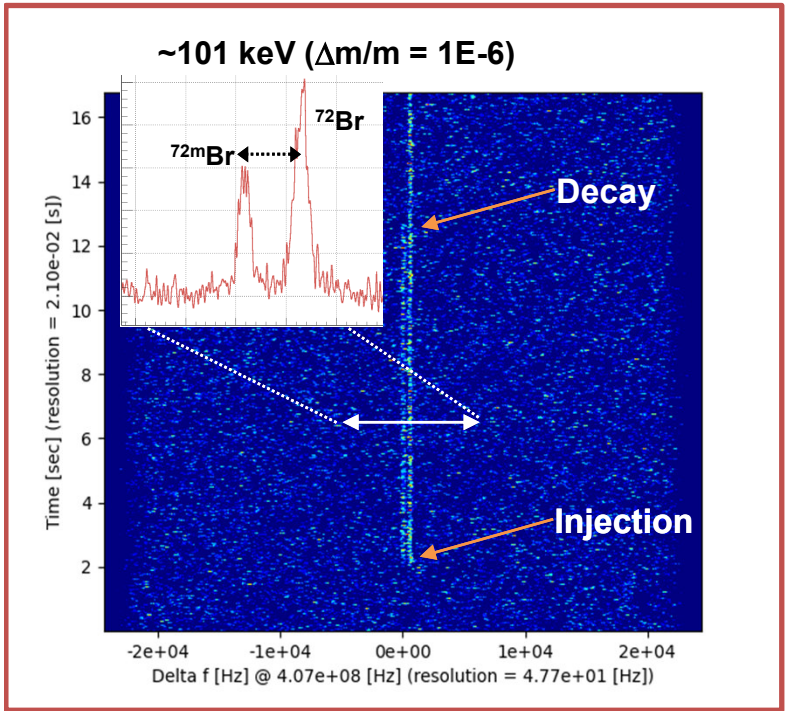
245 MHz Schottky and new 410 MHz resonator

S.Sanjari et al., Rev. Sci. Instr. 91, 083303 (2020)

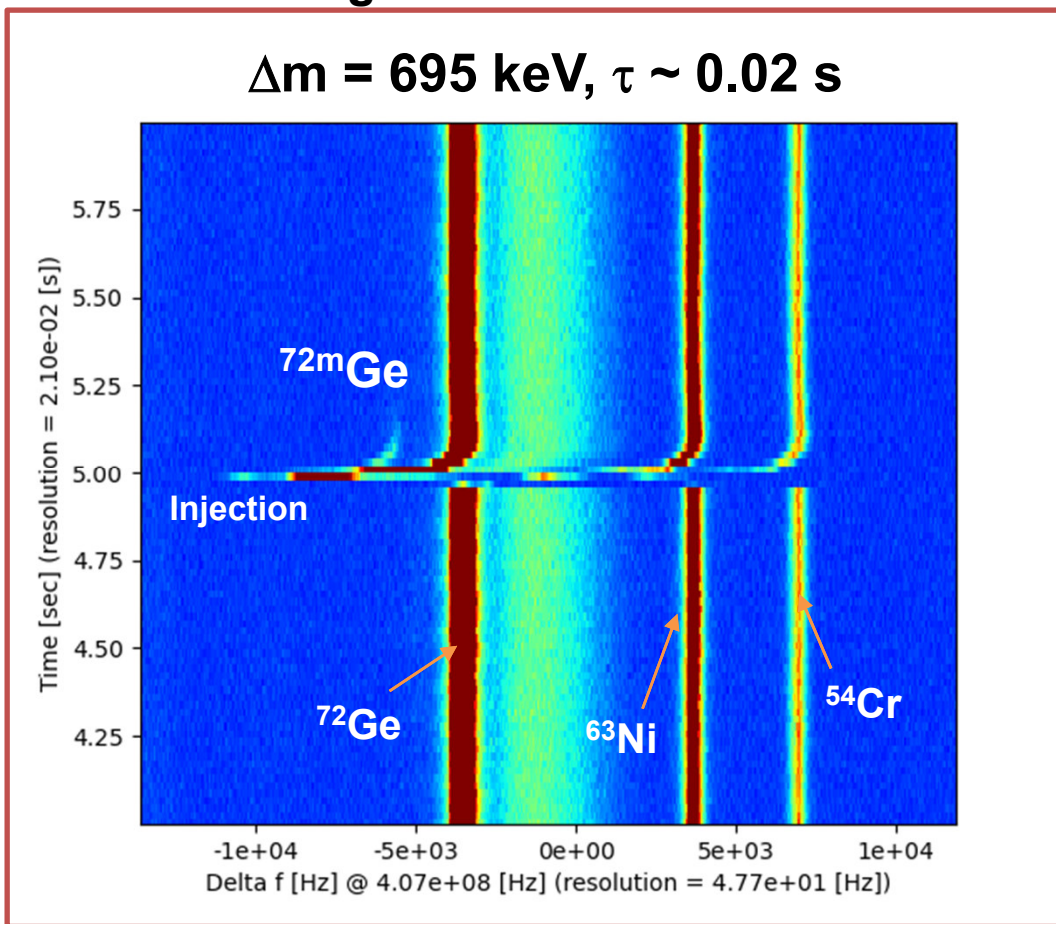
E143 Results

Very good resolution, fast detection time

- Variable resonance frequency: 408-416 MHz
- Variable Q value: approx. 500-3000
- High sensitivity

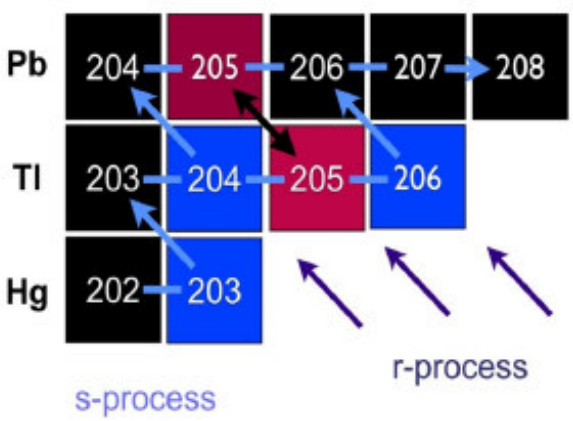


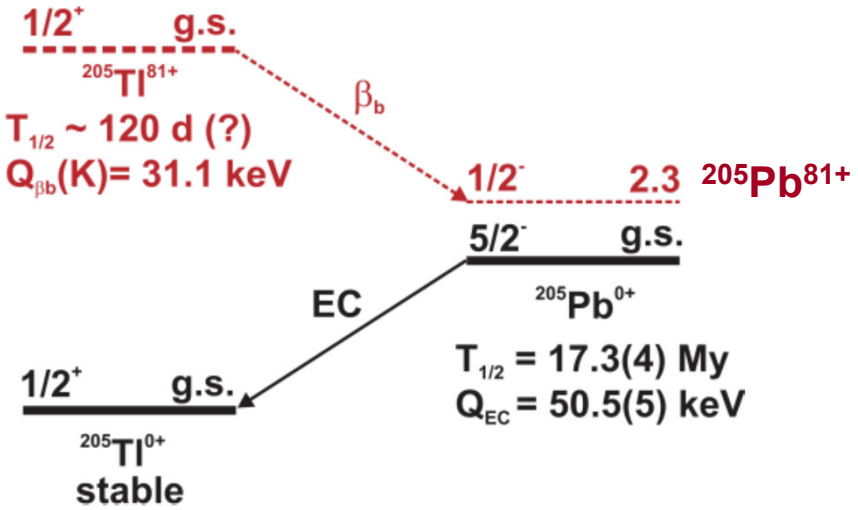
at high harmonic h = 212



E121 Bound-State Beta Decay of bare ^{205}Tl Ions

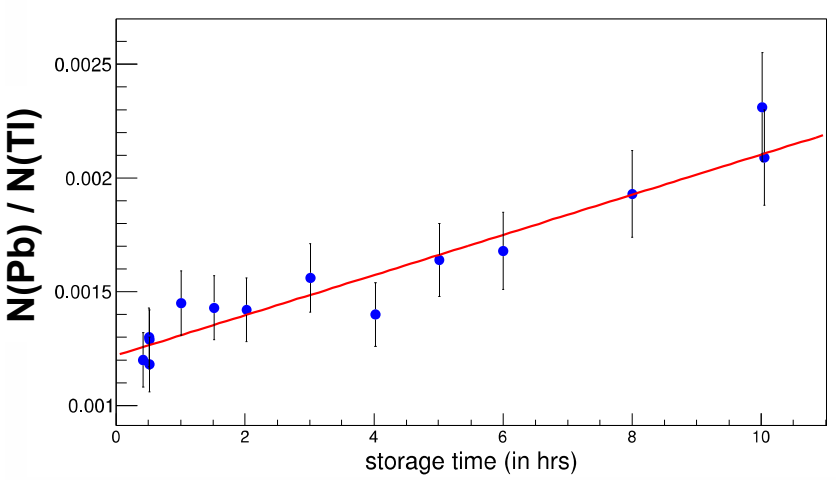
Lifetime of Highly Charged Ion





Key technical points:

- Accumulation of sec. beam from FRS
- Long storage of cooled ions
- Gas jet stripper
- In-ring Particle detector
- Resonant Schottky detector



- **LOREX project: solar neutrino detector with Tl material**
- **Cosmo chronometer of the s-process**

thesis Heidelberg 2021

Y. Litvinov, Ragandeep Sidhu

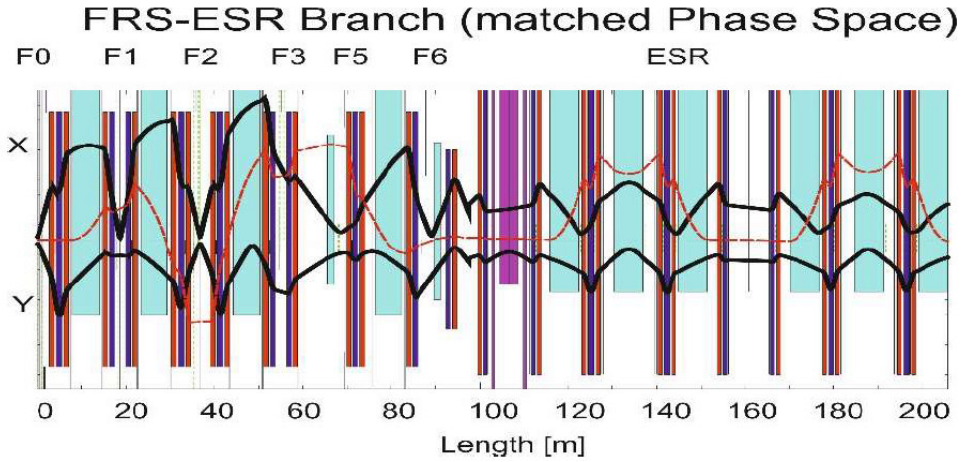
New Experiments

Two γ decay & bound state pair conversion

Resolved in isochronous mass spectrometry with Schottky,

also decay by e^+,e^- pair creation.
When Energy < 2x 511 keV, but can work for bound state,
Cases: ^{98m}Mo, ^{98m}Zr, ($^{194g+m}$Pb). **Mo+Zr scheduled May 2023**

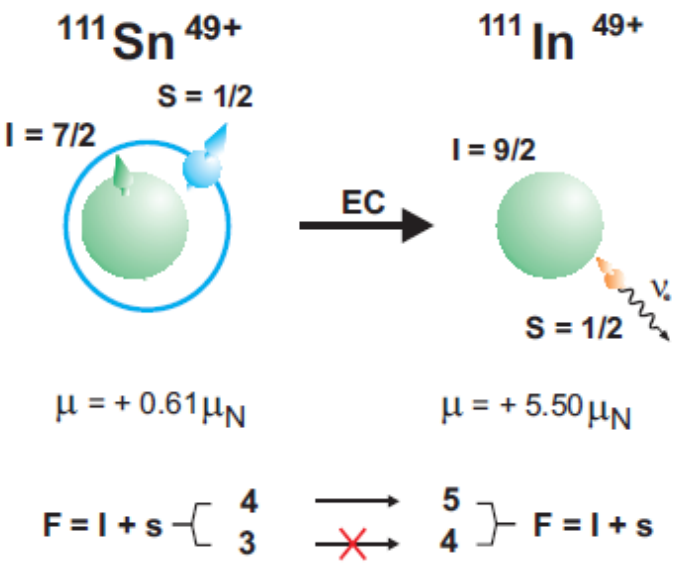
FRS development (beam to ESR, transmisson issue) match phase space ellipses, problem steering



Other Proposals

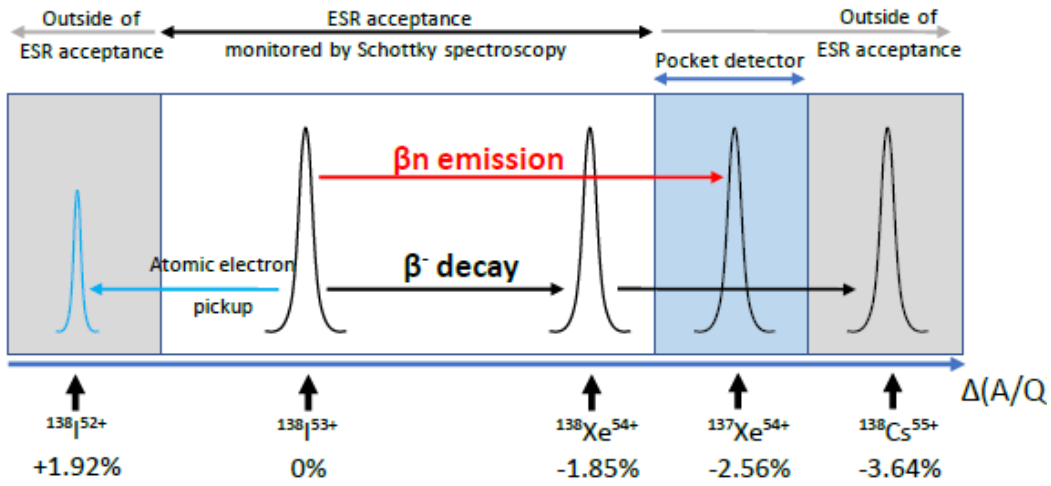
^{111}Sn decay with hyperfine spin coupling

bare ions => only β^+, H-like => no EC,
He(Li)-like => more EC
Store in ring ~1h, measure with Schottky.



Beta-delayed neutrons

Store in ring, daughters
go onto ΔE-E detector,
distinguish β and β-n daughters
=> branching ratio

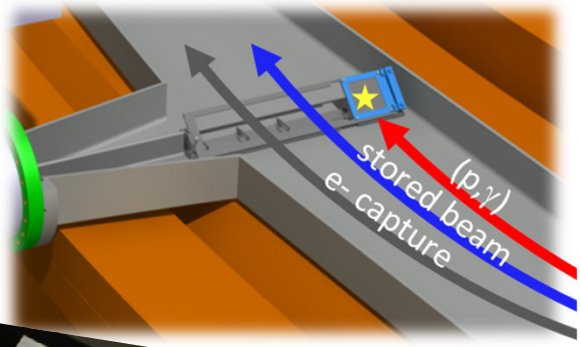


Campaign on Proton-Capture Reactions (p,γ), (p,n)

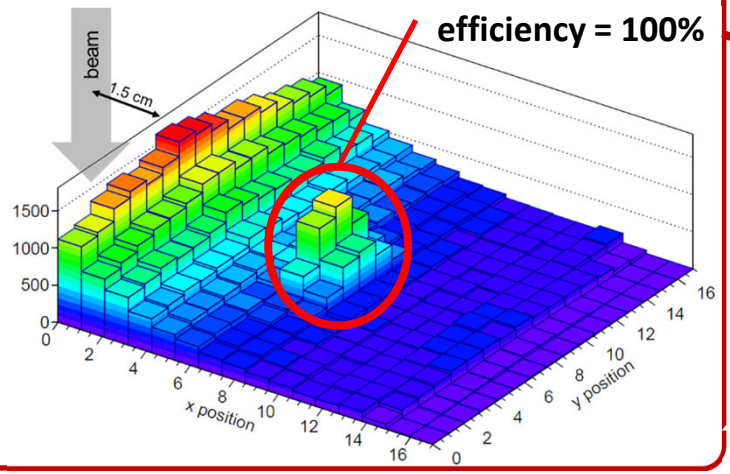
ASTRUm

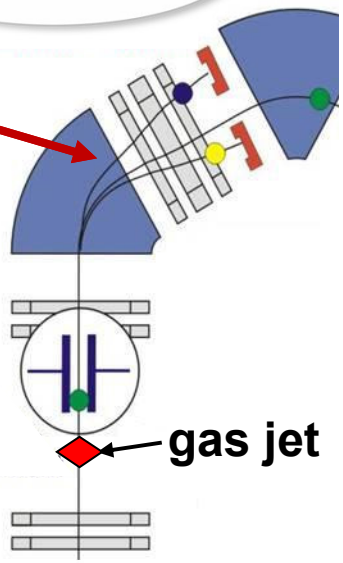
Nuclear recoil separation & detection

UHV compatible detector setup

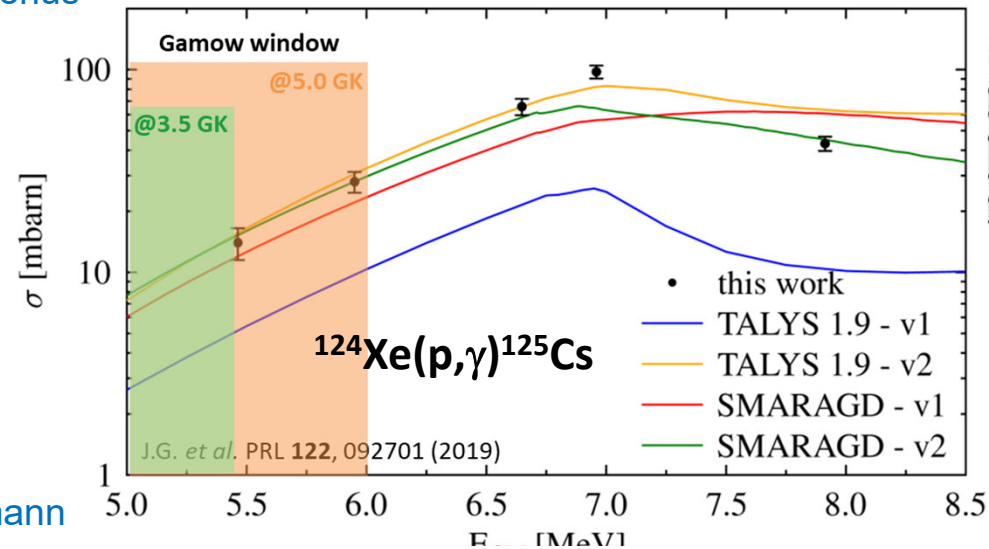


proton-capture efficiency = 100%





Jan Glorius



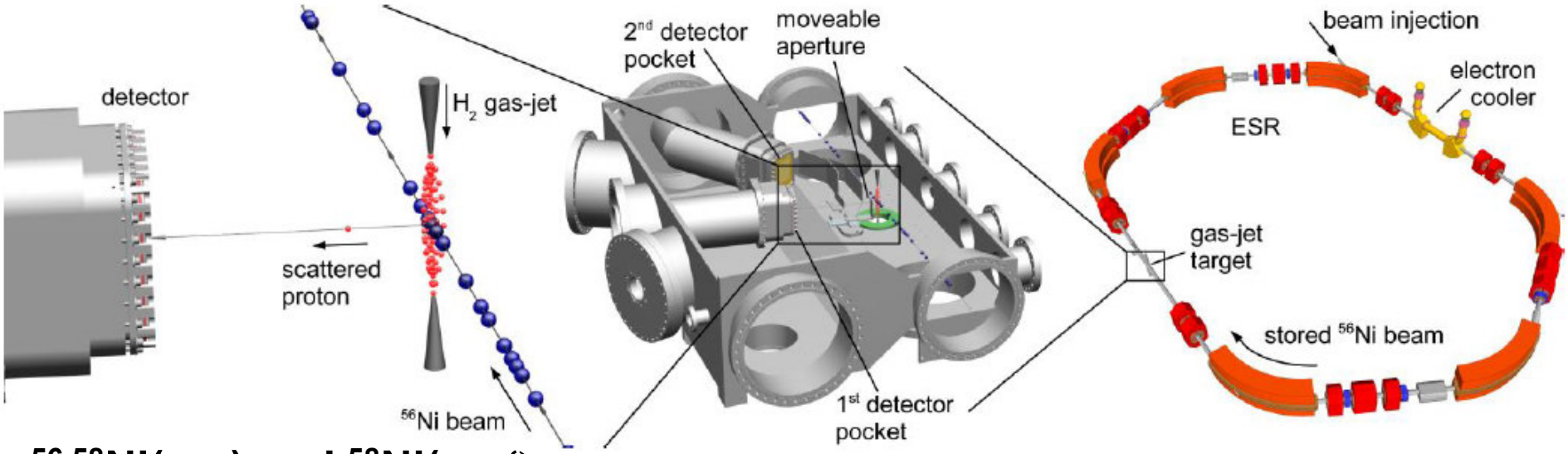
Slowed down rare ions in/close to Gamow window

recent ^{118}Te(p,γ) thesis Sophia Dellmann

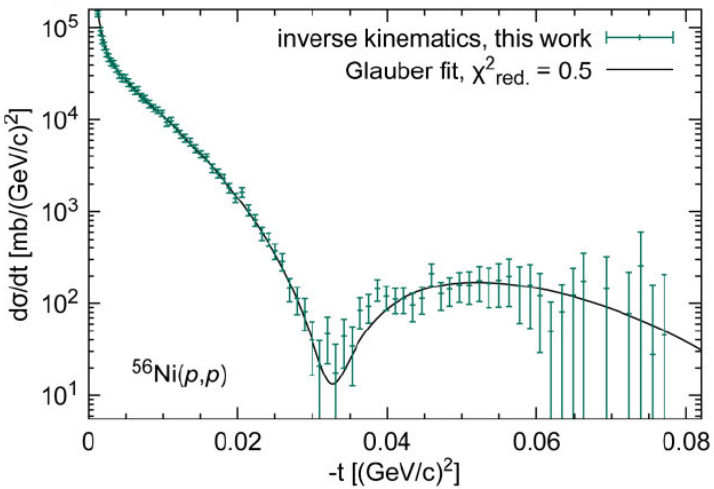
EXL

Exotic nuclei studied with light hadronic probes

Experiment E105, ^{56,58}Ni beams and gas jet target (H and He)

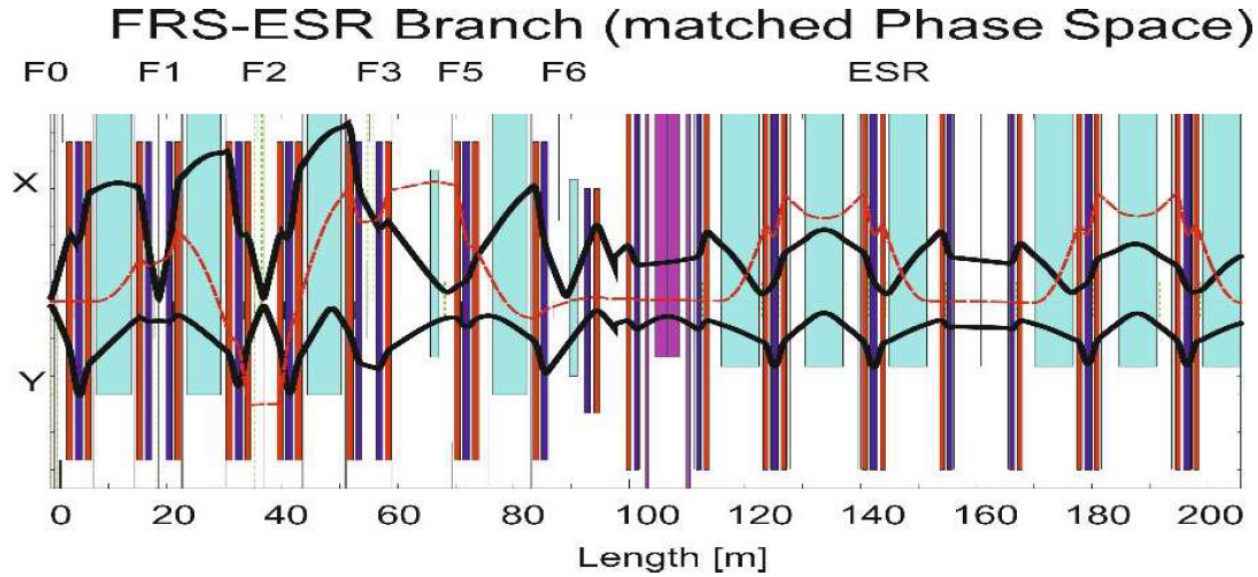


^{56,58}Ni(p,p) and ^{58}Ni(α,α')



Lol 2022 (J. Zamora, O. Kiselev)
next step ^{56}Ni(α,α') for ISGMR
--> compression of nuclear matter

Transmission into ESR



Acceptance into ESR should be ~ 10 times higher !
ε_x = 20 mm mrad --> 8 mm mrad
ε_y = 20 mm mrad --> 7 mm mrad
$\Delta p/p$ = 0.4% --> 0.2%

1998 design values
vs. measured in 2000.

Simulation shows matching is very critical.
Also small shifts in beam position are critcal vs narrow aperture
Injection channel only has 50mm x 50 mm in septum.

--> Better diagnostics for beam parameters, more detectors, and beam time.

Summary / Outlook

Prospects for a CR are very uncertain.

Equipment in ESR also needs funding.
A question is how it is recognized as part of FAIR.

With highly charged ions and special beam preparation still unique experiments in ESR.

For experiments with target the luminosity is an issue.
Target and detector development were successful,
Long term use of ESR needs upgrades,
also for prospects with CryRing.

We have proposals and scheduled experiments.