Physics perspectives with RINGS for NUSTAR

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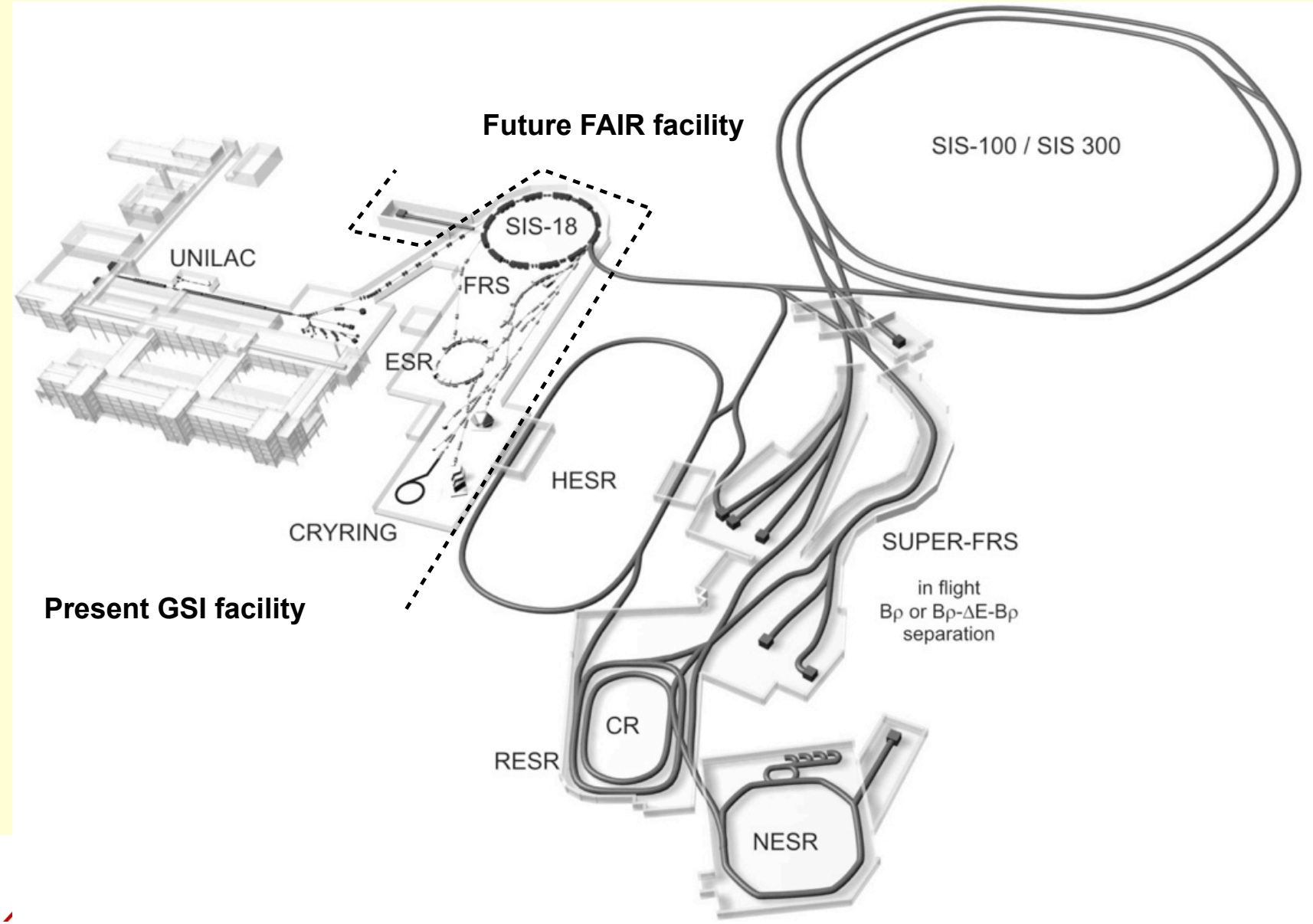
KVI-CART, University of Groningen

Workshop on an Early HESR Physics Case

GSI, Darmstadt, Germany

August 21, 2014

The original plan

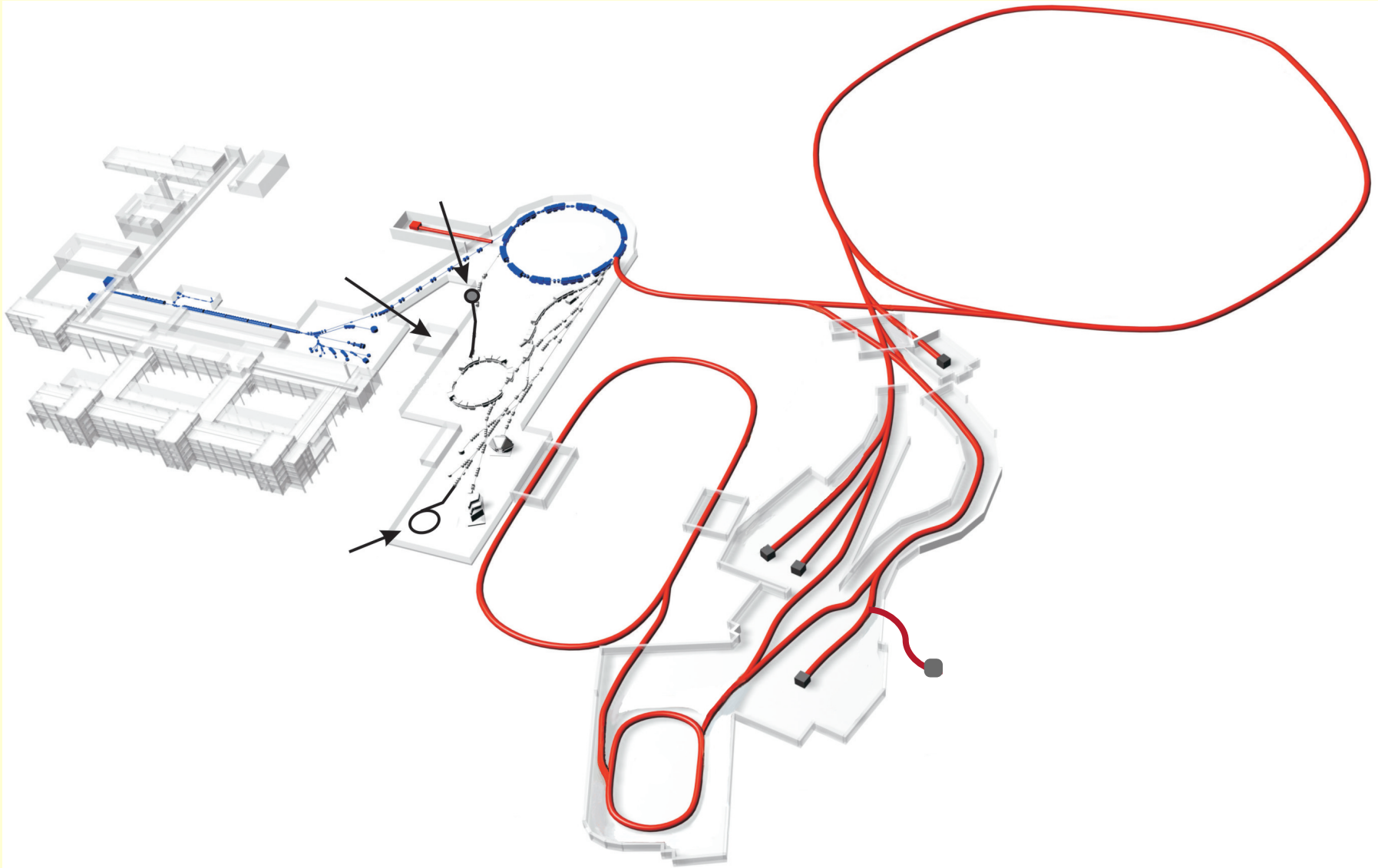


NUSTAR and RING activities

Four major ring experiments:

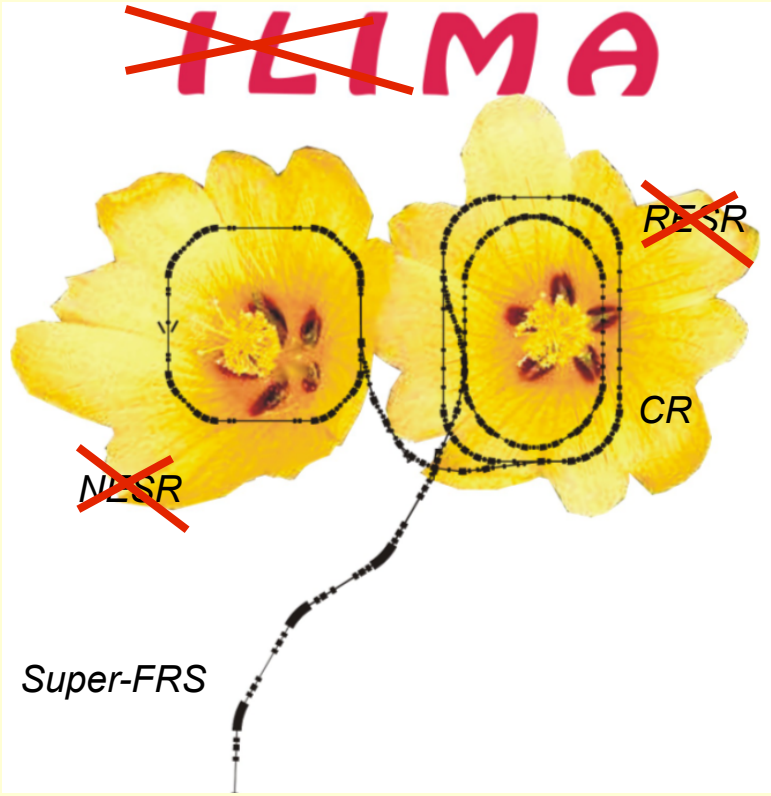
1) ILIMA (Isomeric beams, LIfetimes and MAsses)
2) EXL (EXotic nuclei studied in Light-ion induced reactions at the NESR storage ring)
3) ELISe (ELectron Ion Scattering experiment)
4) AIC (Anti-proton Ion Collider), Presently inactive

Modularized Start Version (MSV)



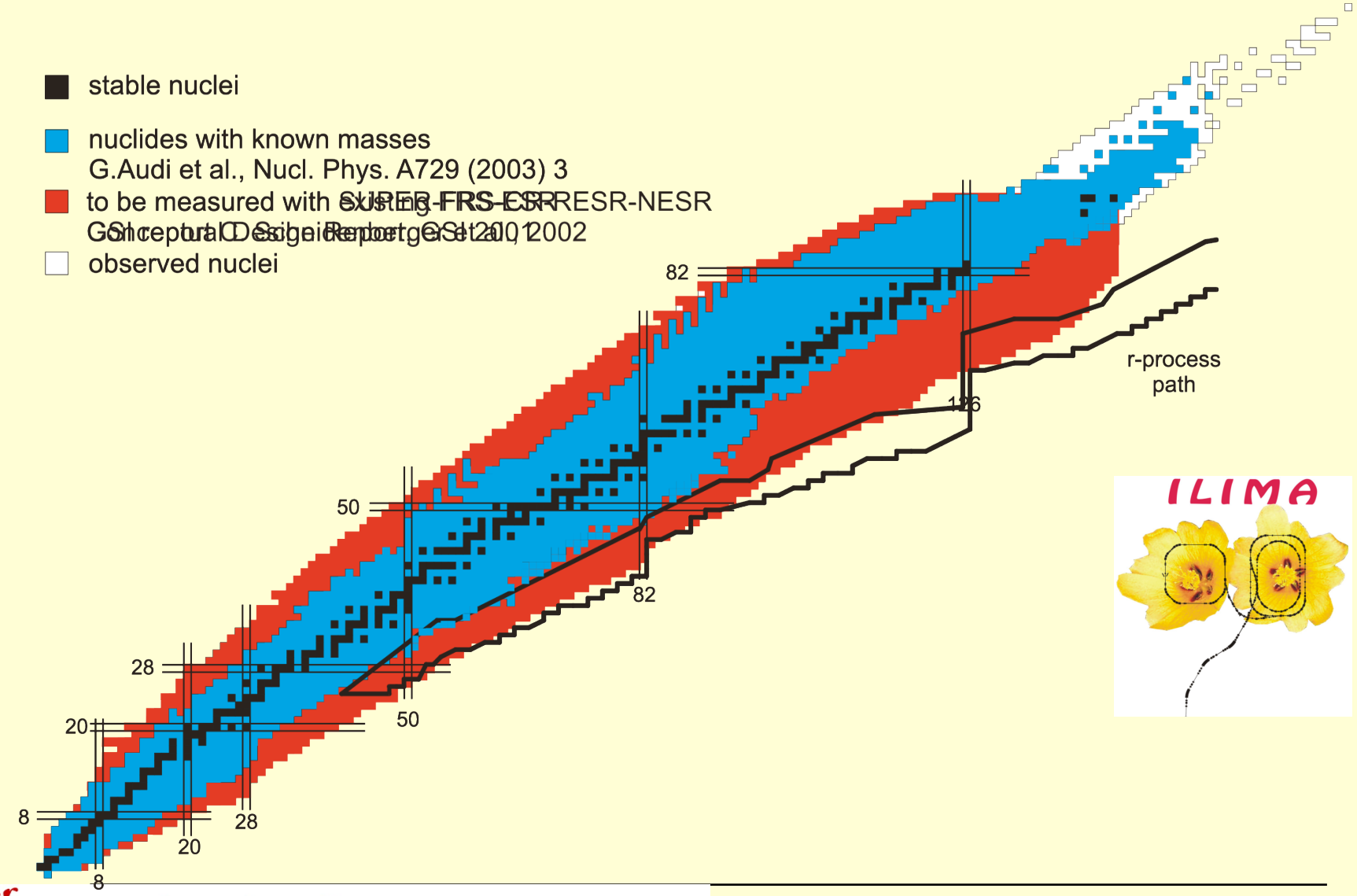
Isomeric Beams, LIfetimes and MAsses

FAIR - CORE Facility



FAIR - Modularized Start Version (MSV)

Mass Measurement Program is NOT affected by the MSV!



ILIMA in MSV-FAIR

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journal homepage: www.elsevier.com/locate/ijms

The ILIMA project at FAIR

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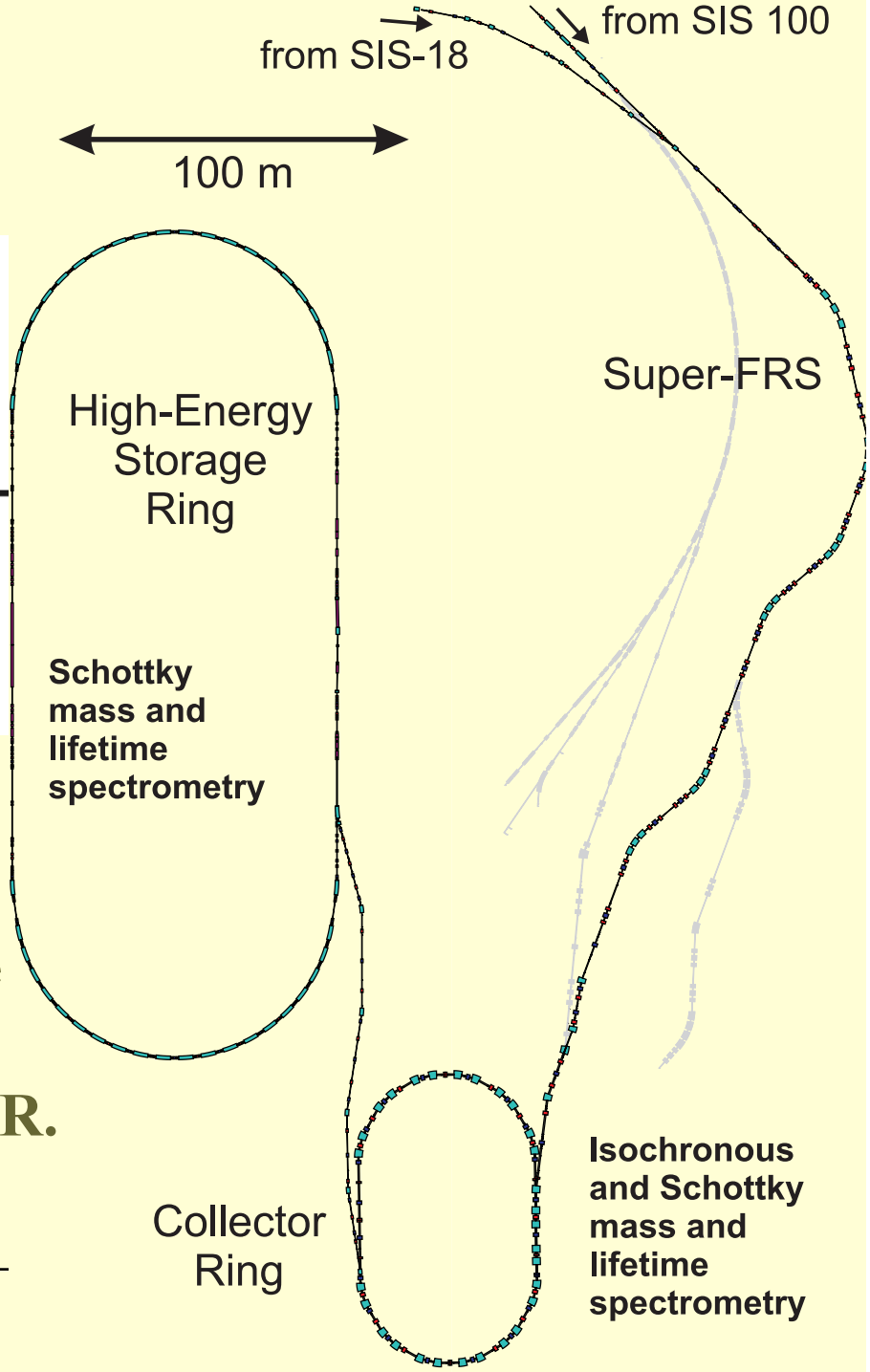
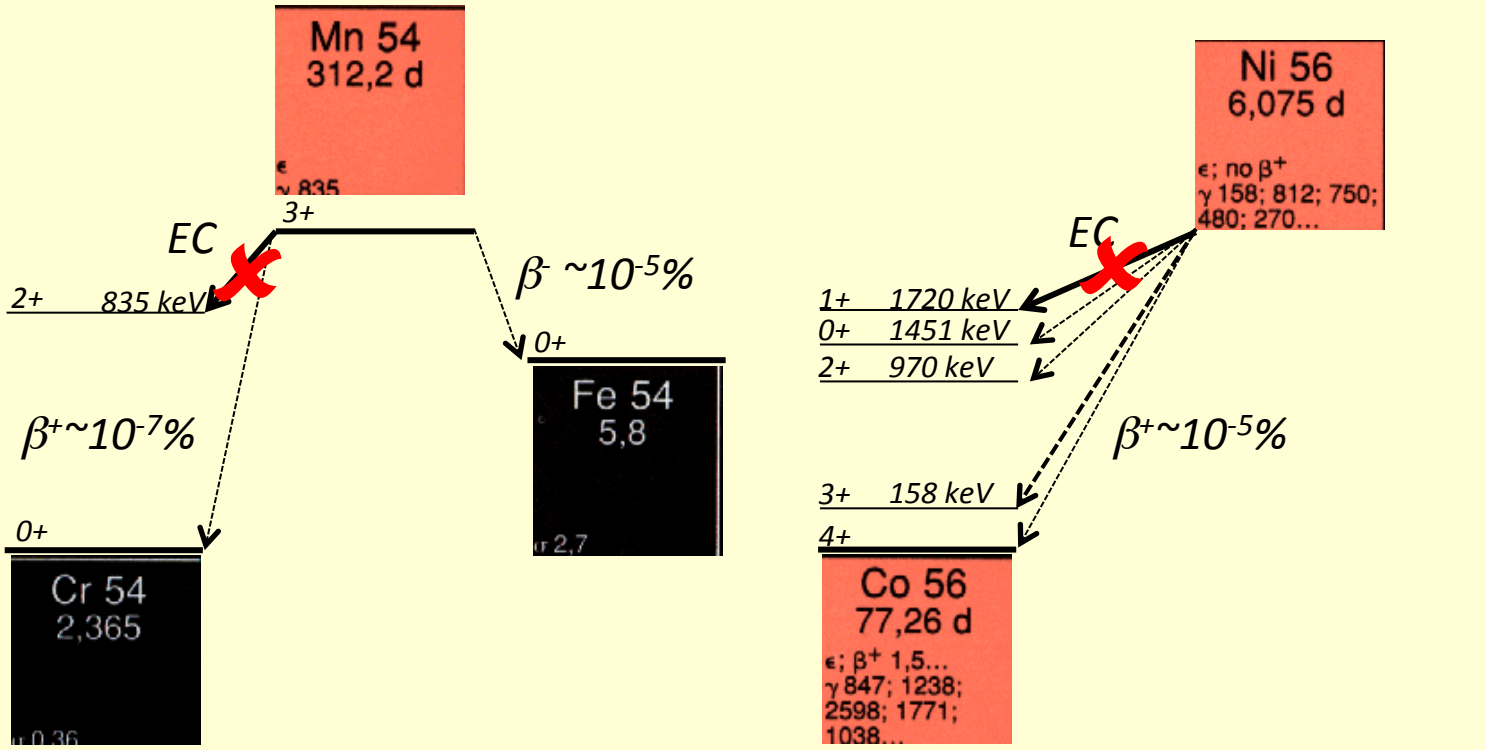


MAIN MESSAGE:
HESR can be employed to measure lifetimes of long-lived nuclides that were originally planned in the NESR.

Physics cases: (1) Galactic clocks

Mixed EC/β-decay isotopes

- Stellar conditions: EC hindered, weak β^+/β^- decay channel determines $t_{1/2}$
- 10^7 pps injected, 30 min measured ⇨ ~1 event/d if partial $t_{1/2}$= 25000 y



Light-ion induced direct reactions and electron scattering (EXL & ELISE)

- Elastic scattering (e,e), (p,p), (α,α), …

  Nuclear matter and charge distributions $\rho_m(r)$, $\rho_{ch}(r)$, skins, halo structures
- Inelastic scattering (e,e'), (p,p), (α,α'), …

  Deformation parameters, B(E2) values, transition densities, giant resonances
- Charge exchange reactions (p,n), (^{3}He,t), (d,^{2}He), …

  Gamow-Teller strength
- Transfer reactions (p,d), (p,t), (p, ^{3}He), (d,p), …

  Single particle structure, spectroscopic factors

  Spectroscopy beyond the driplines

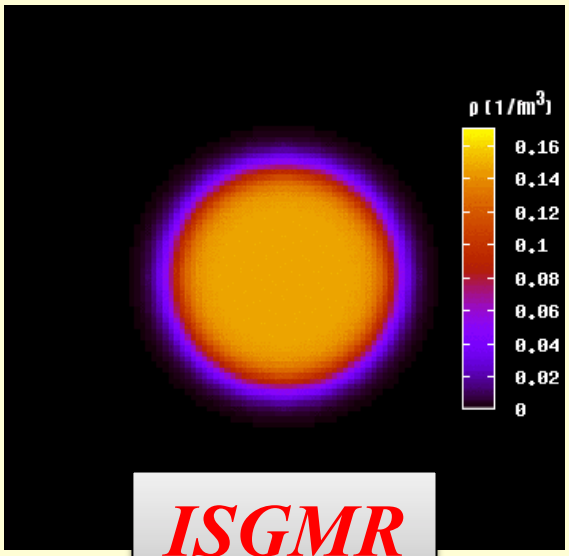
  Neutron pair correlations

  Neutron (proton) capture cross sections
- Knock-out reactions (e,e'p), (p,2p), (p,pn), (p,p^{4}He), …

  Ground state configurations, nucleon momentum dist., cluster correlations

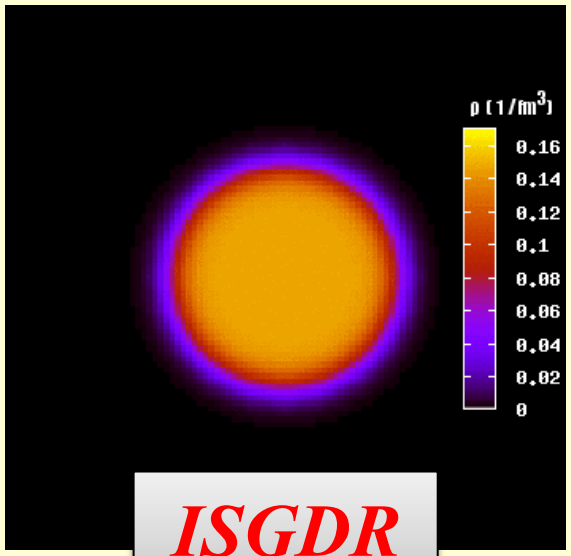
Giant Resonances

Collective oscillations of all neutrons and all protons in a nucleus in phase (isoscalar) or out of phase (isovector)



ISGMR

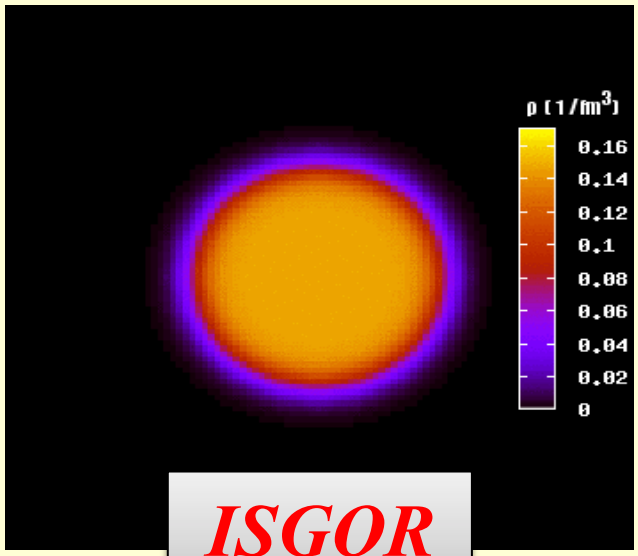
Breathing Mode



ISGDR

Squeezing Mode

M. Itoh

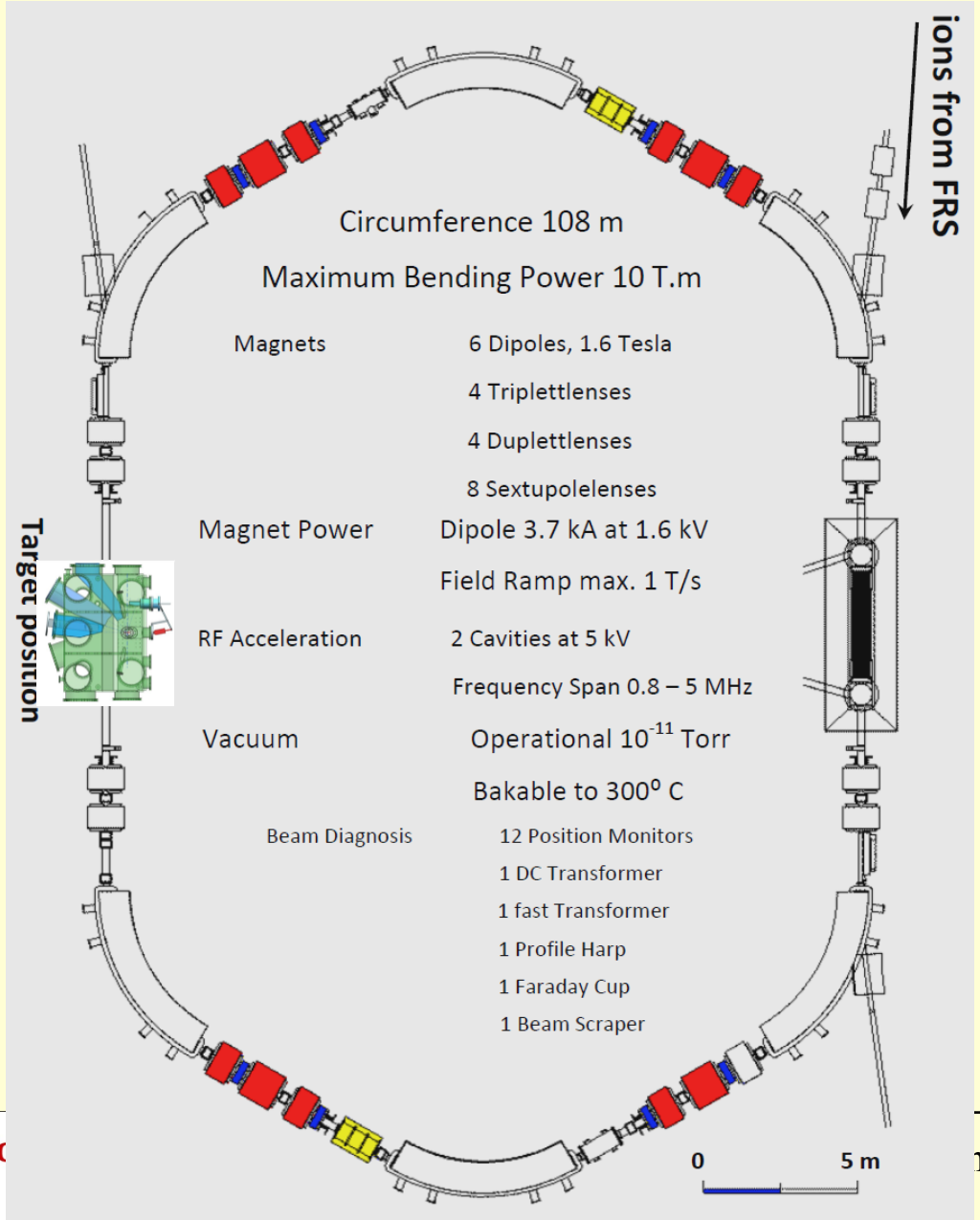


ISGQR

No Density Variation
Shape Change

First experiments with radioactive ions with the existing ring (ESR) at GSI

Setup @ ESR ring



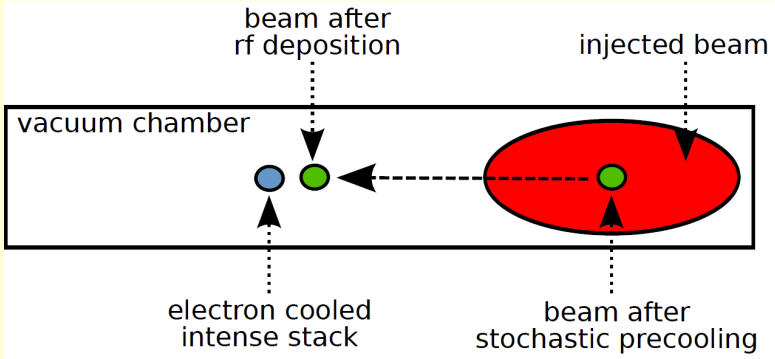
^{56}Ni Beam

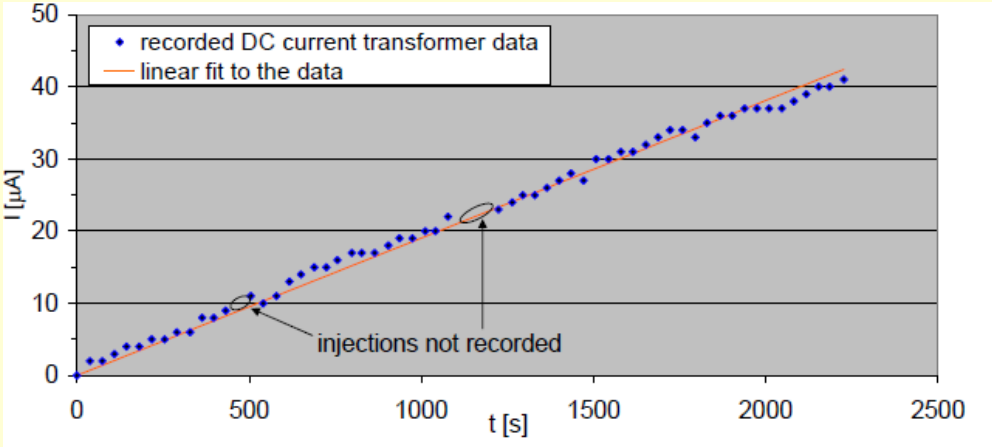
FRS: fragmentation of 600 MeV/u ^{58}Ni beam

injection to ESR: **7 x 10^4** ^{56}Ni per injection

stochastic cooling, bunching and stacking (60 injections):
4.8 x 10^6 ^{56}Ni in the ring

F. Nolden and M. Steck

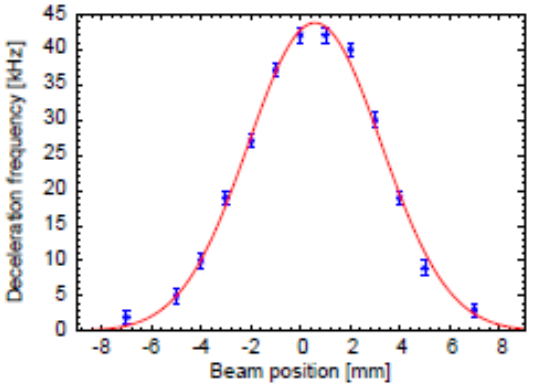




luminosity: H_2 target: 2 x 10^{13} cm^{-2}

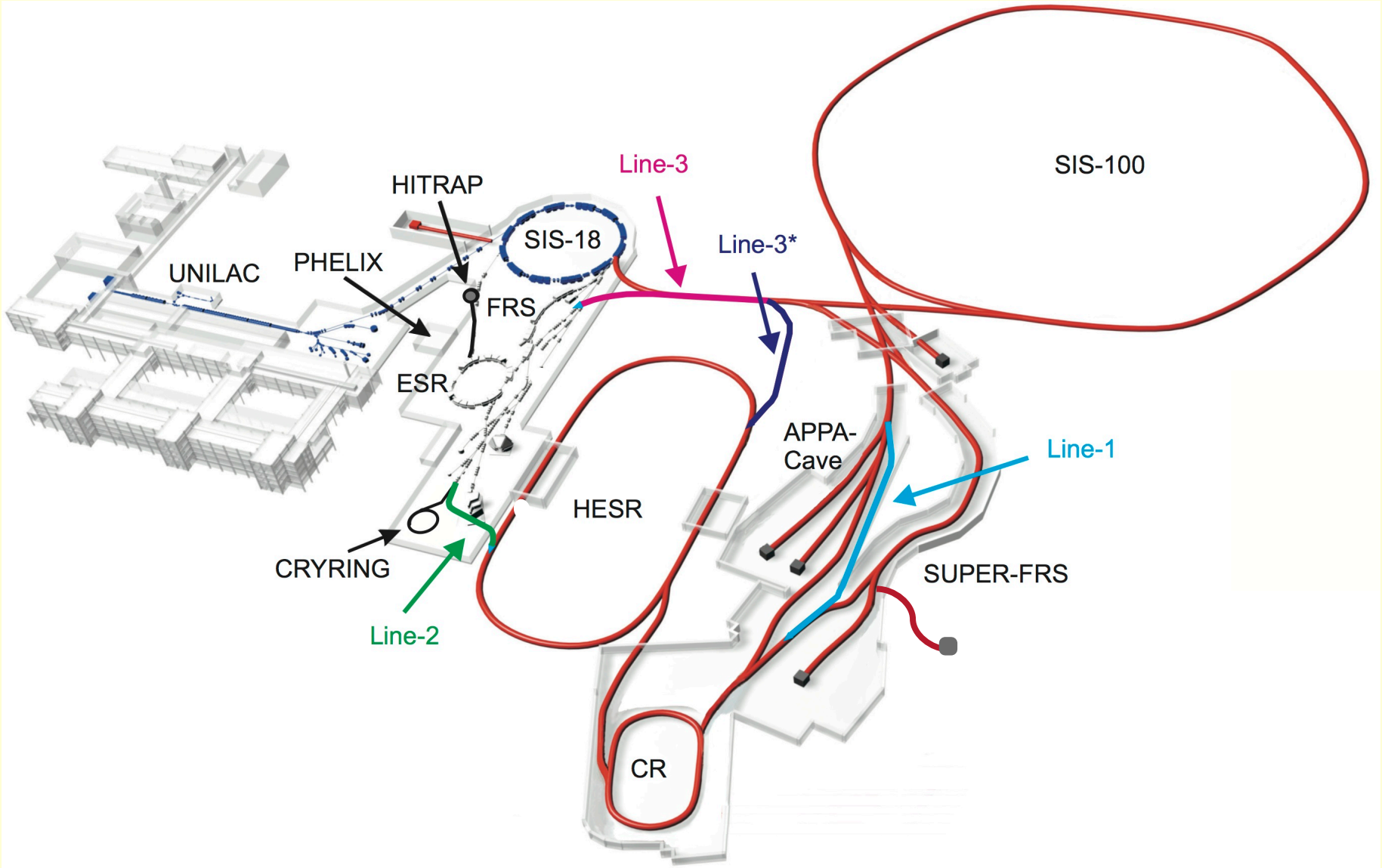
⇒ **L = 2 x 10^{26} cm^{-2} sec^{-1}**
(reduced by aperture)

target profile

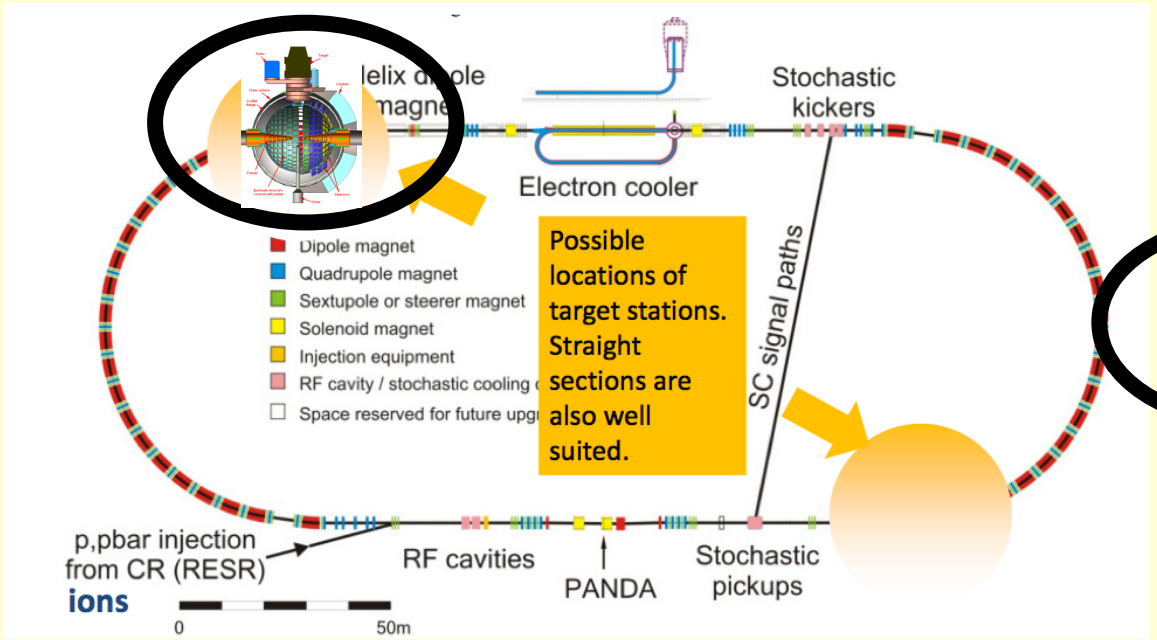


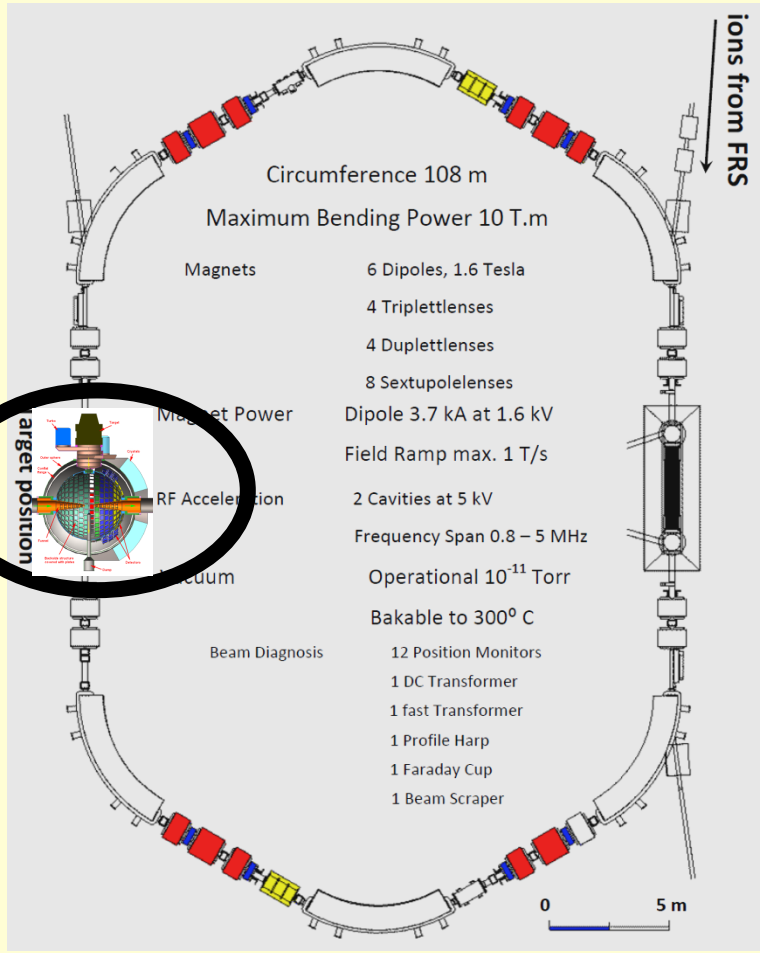
σ = 3.78 mm x_0 = 0.58 mm

Intermediate-range Plans for rings



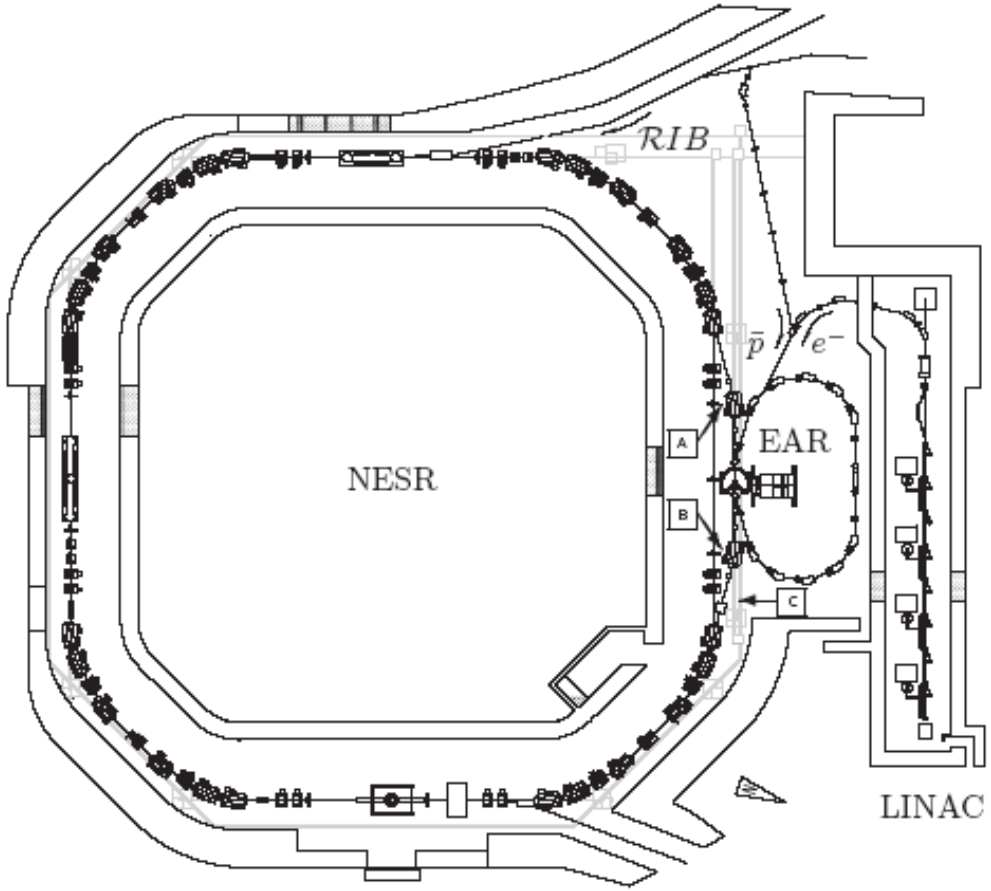
EXL @ ESR or HESR but with Super-FRS beams





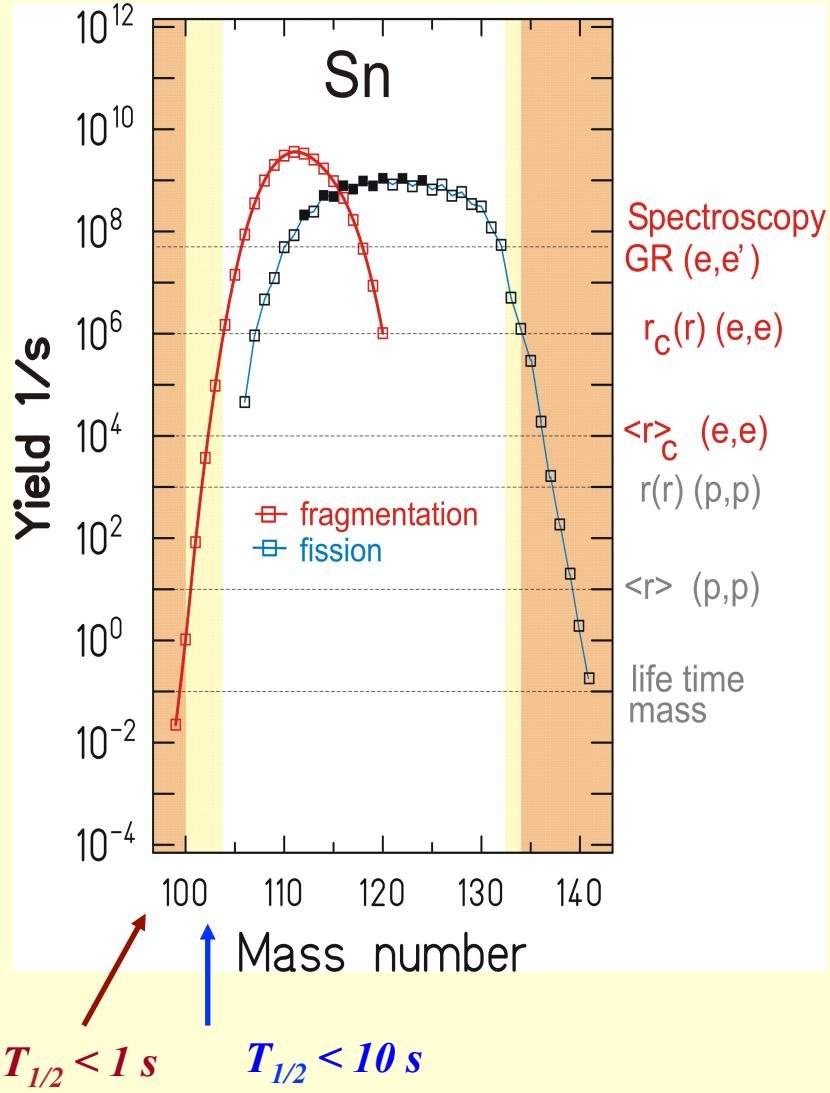
Electron Scattering with ELISe

The eA Collider



- ✘ E_e = 125,250,375,500 MeV
- ✘ E_I = 200-740 MeV/u
- ✘ $\mathcal{L} = f_e n_e \frac{N_e N_I}{4\pi\sigma_x\sigma_z}$
- ☛ $\sigma_{x,z} \approx 100\ \mu m$
  n_e= 5 - 8, f_e=6.6 Mhz
  $N_e = 5 \cdot 10^{10}$
  $N_I = 10^5 \ldots 10^{10}$
- ✔ $\mathcal{L} \approx 10^{26}$ - 10^{31} $cm^{-2}s^{-1}$

- *Electron scattering off radioactive isotopes in a storage ring seems feasible.*
- *Charge distributions can be extracted and compared to matter distributions. Charge radii are already accessible in first generation experiments.*
- *Selective excitation of collective modes in nuclei*
- *Unique tool*



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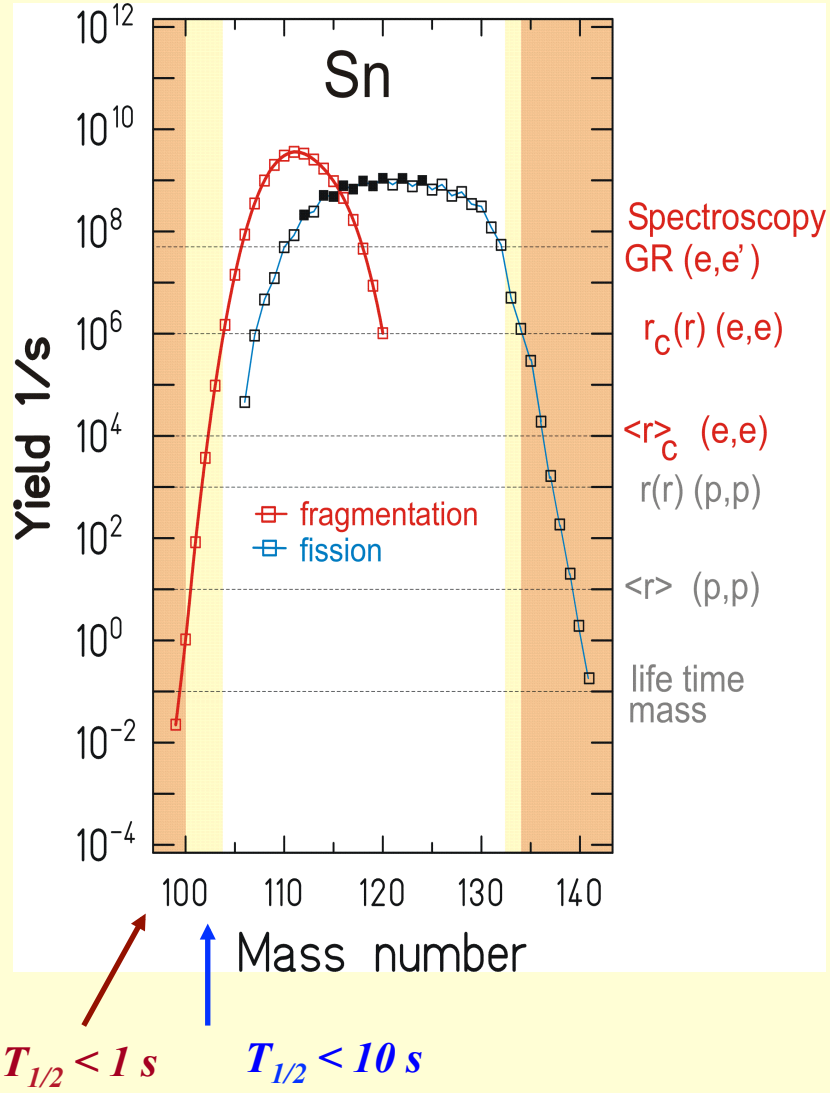
• *Charge distributions can be extracted and compared to matter distributions. Charge radii are already accessible in first generation experiments.*

•*Selective excitation of collective modes in nuclei*

• *Unique tool*

•*FAIR has put this on MSV to be performed at a later stage (after my retirement!!).*



First realization of an RIB electron collider setup at ESR with *high-intensity* beams coming from Super-FRS

Possible Placement at a modified ESR

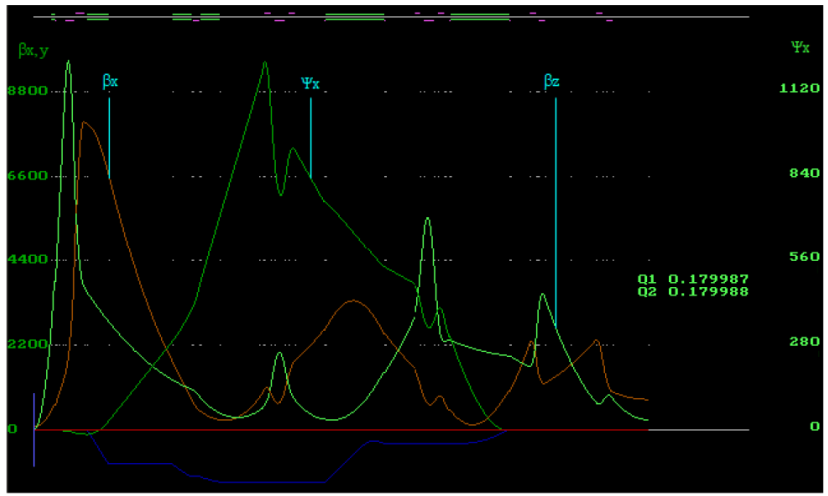
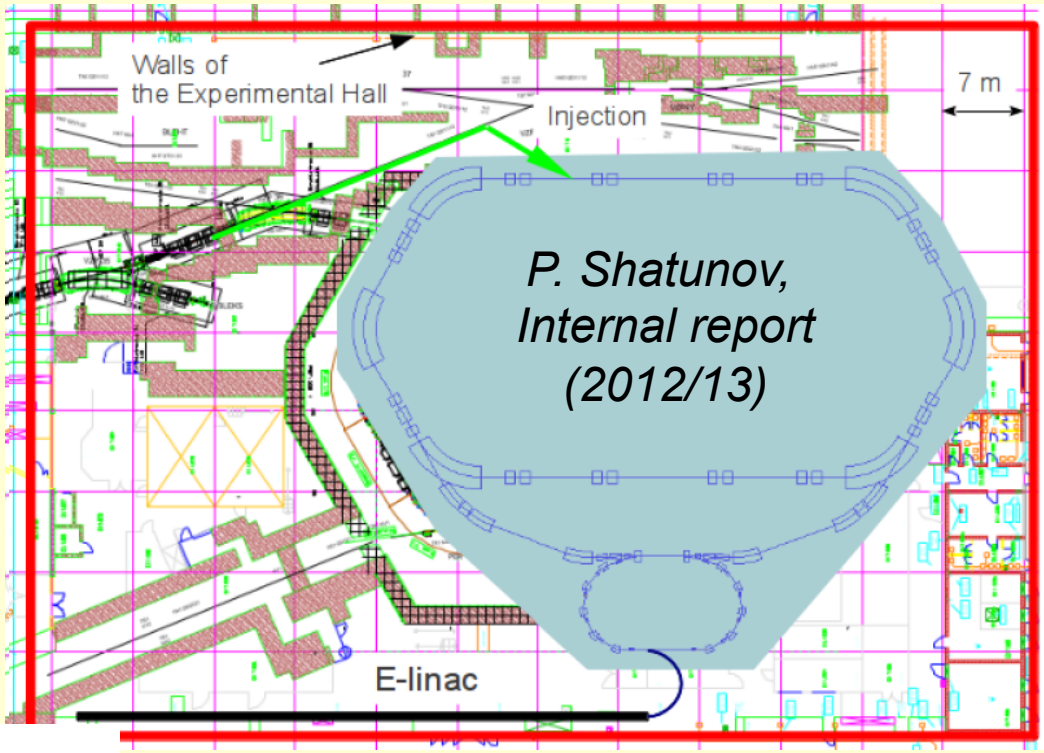
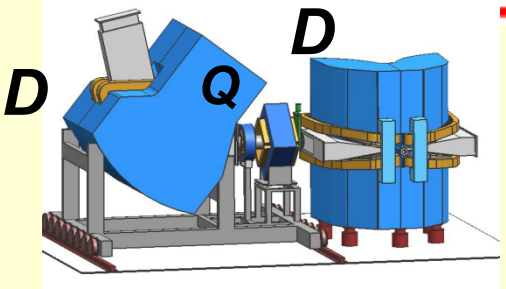


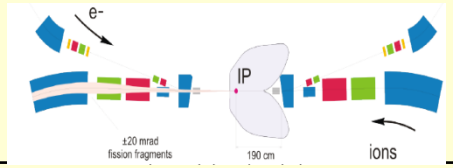
Figure 9. Beta (β, cm) and dispersion (Ψ, cm) functions of stretched ESR (1 half) in the collider mode.



GPA Berg et al.,
*NIM **A640** (2011) 123*
T Adachi et al.,
*NIM **A659** (2011) 198*



ELISe Collaboration,
*NIM **A637** (2011) 60*



Summary

- The exploitation of HESR for SPARC will lower the load on ESR. The SIS18-HESR line also offers the possibility to use Super-FRS-CR combination parallel to SIS18-HESR combination for various FAIR experiments.

ILIMA

Experiments measuring **long lifetimes (part of ILIMA program) are feasible** where beam intensities **from Super-FRS are not required,** and Super-FRS->CR->HESR might be replaced by FRS->(ESR)->HESR. (ESR required for beam purification before accumulation in HESR.)

CAUTION: efficiency FRS->HESR as opposed to FRS->ESR has to be studied.

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ILIMA	EXL	ELISe
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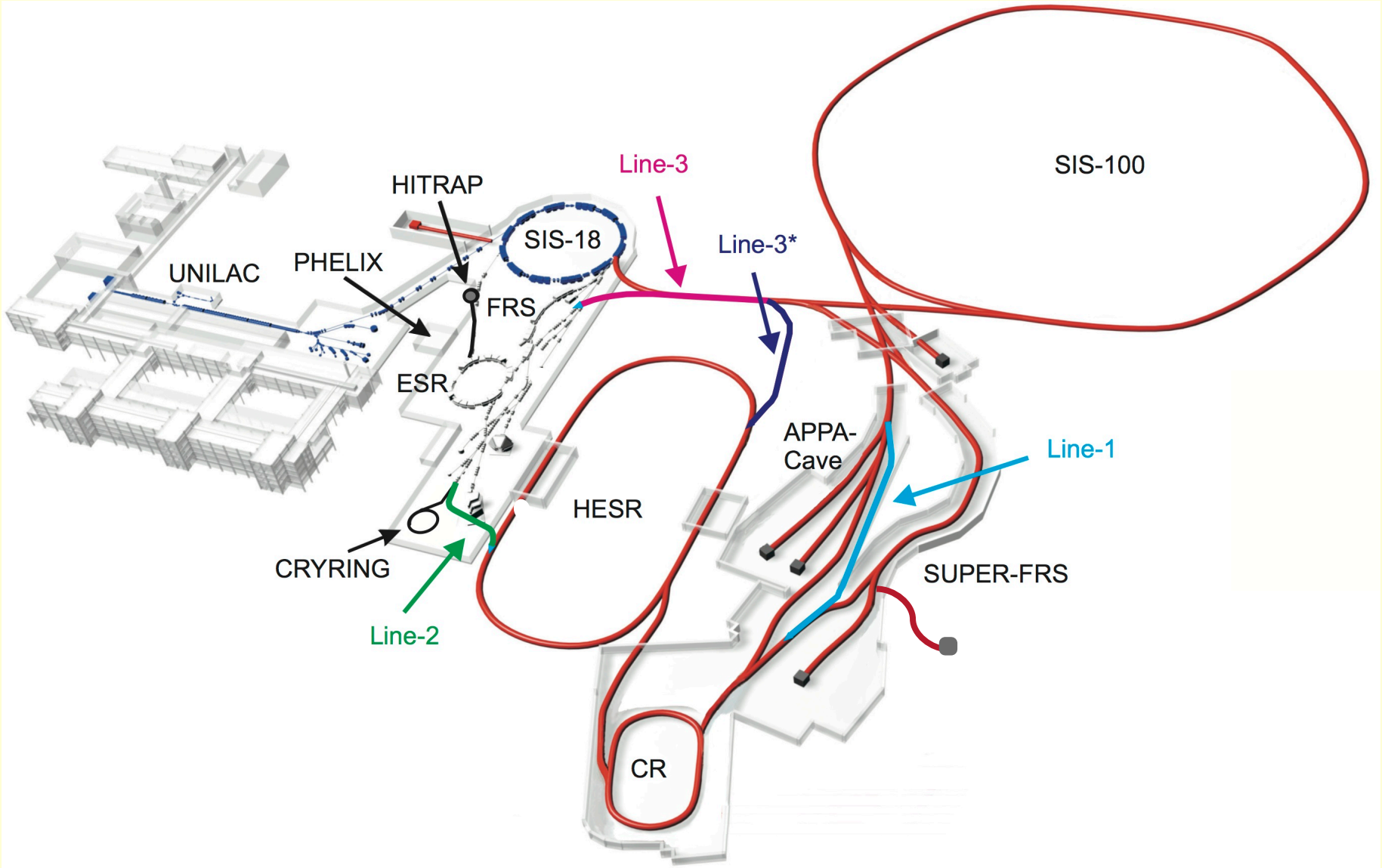
NUSTAR priorities

The priorities of NUSTAR for major projects beyond the MSV are then as follows:

① Realization of Low-Energy Building;
② Realization of the return line from CR to ESR;
③ Modification of ESR and building of the Electron ring.

In case of a transfer line to and from HESR, care has to be taken that Cave-C and the ongoing activities remain intact.

Intermediate-range Plans for rings



Overall conclusions

- APPA would have a large benefit from a direct line from SIS18 to HESR;
- PANDA can use this direct line for commissioning purposes before beams come from SIS100, but not physics;
- CBM has no interest in this line and is worried about delays caused for SIS100 due to this;
- FLAIR and NUSTAR would primarily be interested in the return line to use ESR and CRYRING as well.

Thank you!