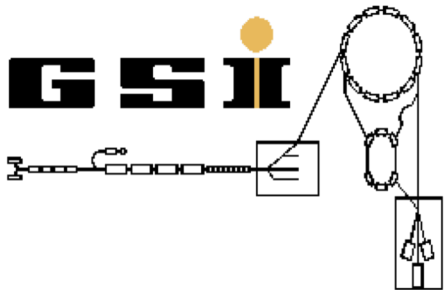
Bound State Beta Decay of ^{205}Tl

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES



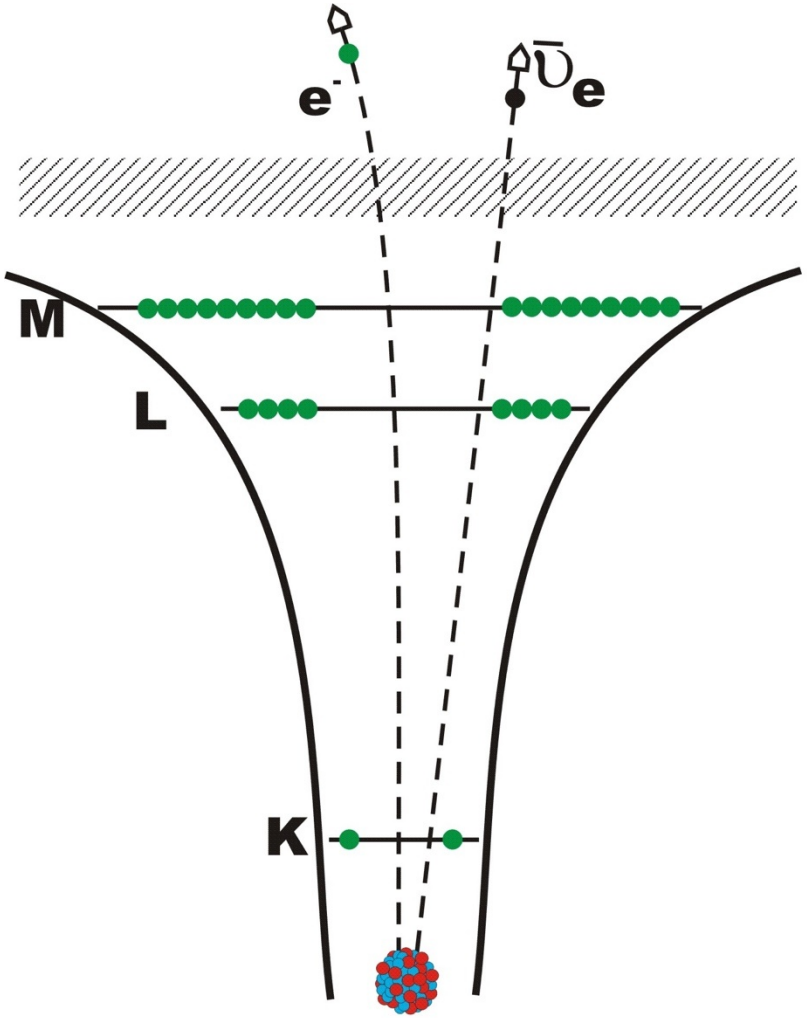
Ragandeep Singh Sidhu

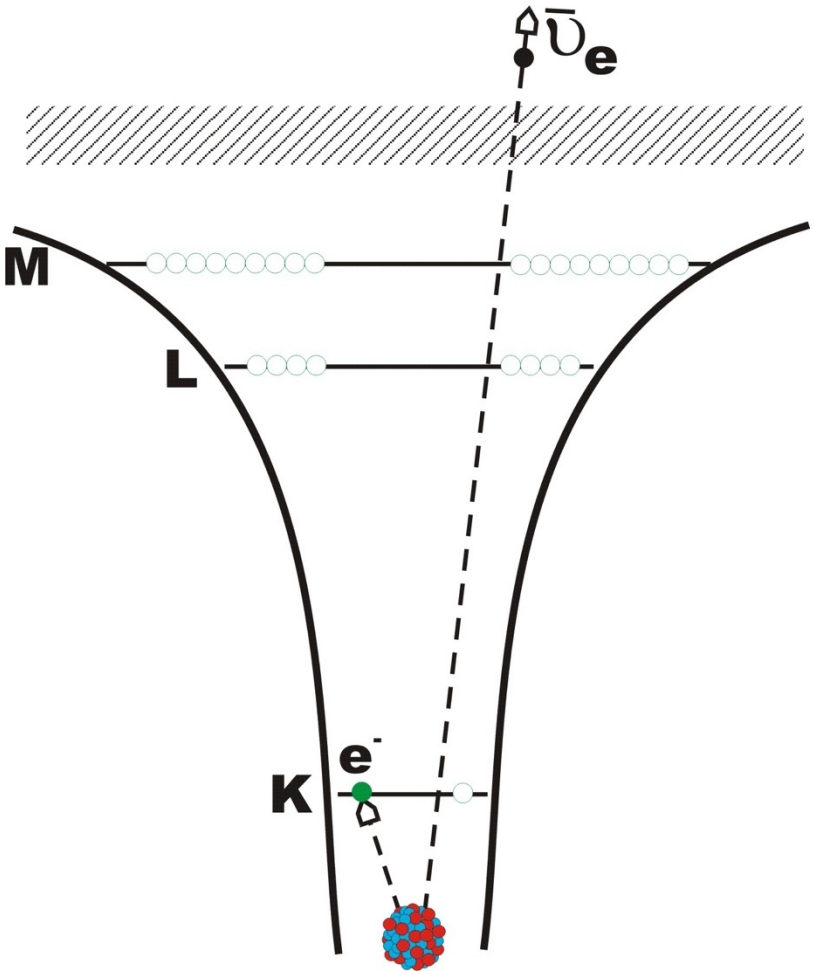
NUCLEAR ASTROPHYSICS AT RINGS AND RECOIL SEPARATORS
13 March – 15 March 2018, GSI, Darmstadt, Germany

Radioactive decays of highly-charged ions

- Few-electron ions
  well-defined quantum-mechanical systems
- New decay modes
  (bound-pair-creation, bound-state beta decay, etc.)
- Influence of electrons on radioactive decay
- Nuclear Astrophysics
  High temperature/density environments → high ionisation

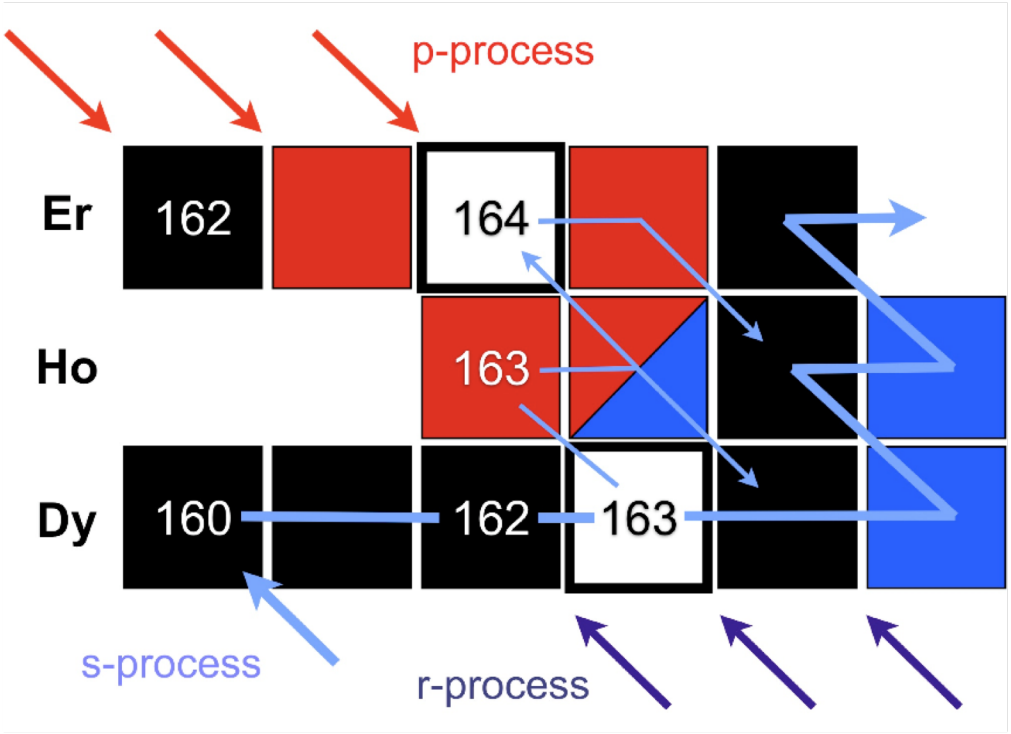
Bound-State β-decay





Bound-State β-decay of ^{163}Dy

s process: slow neutron capture and β- decay near valley of β stability at
kT = 30 keV; → high atomic charge state → bound-state β decay

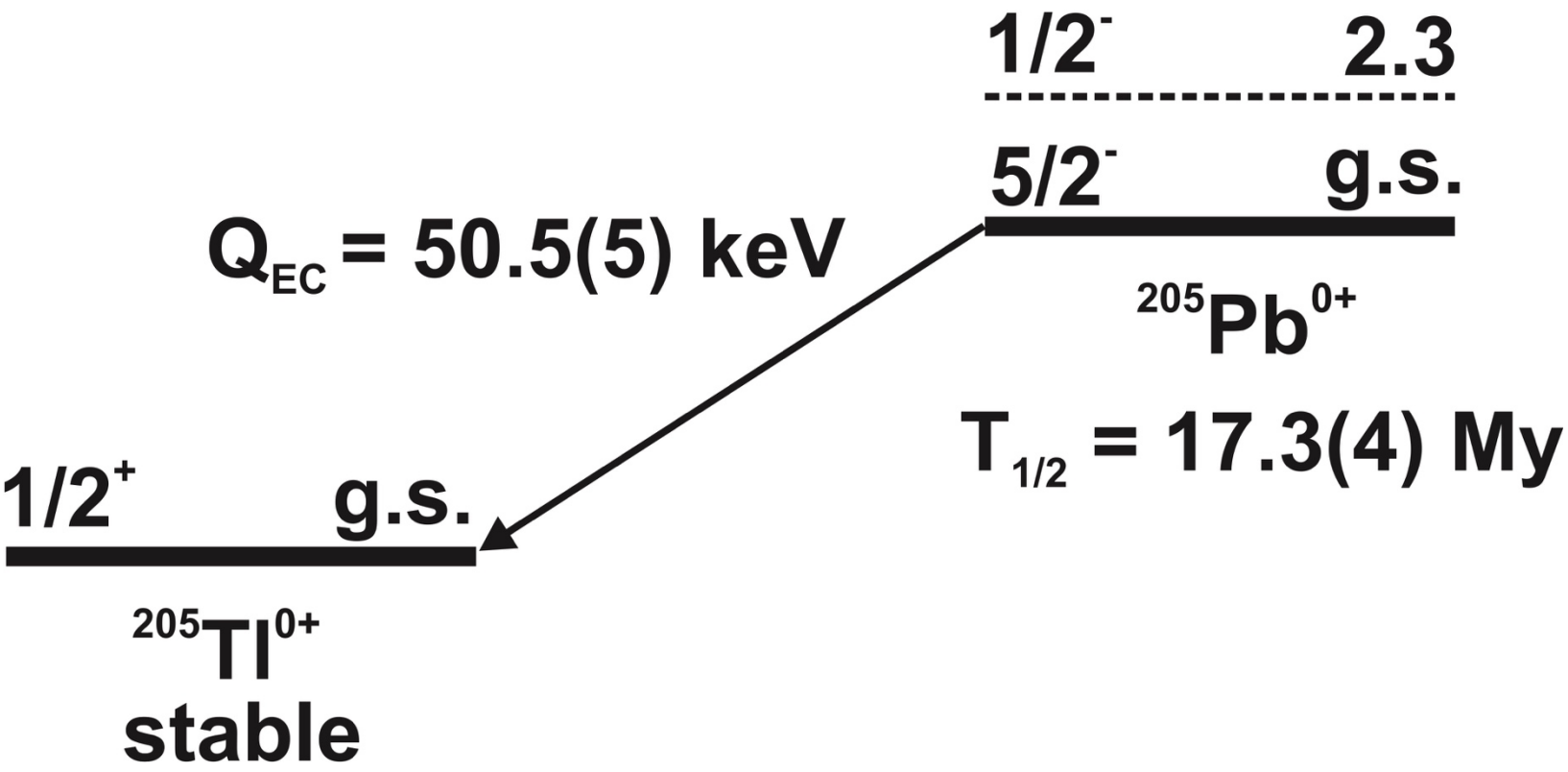


$T_{1/2}$ = 48 days

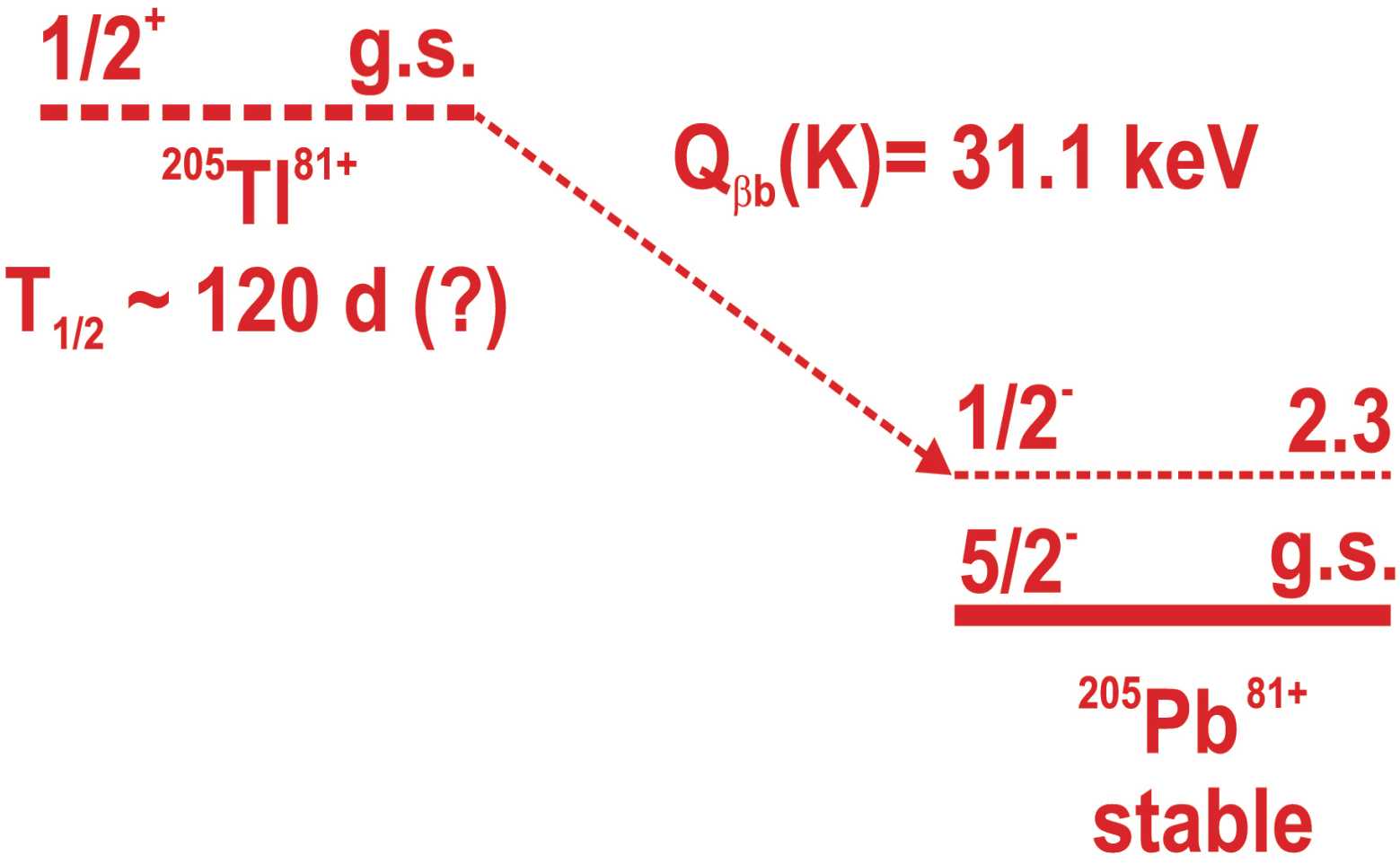
M. Jung et al., Phys. Rev. Lett. 69 (1992) 2164

branchings caused by bound-state β decay

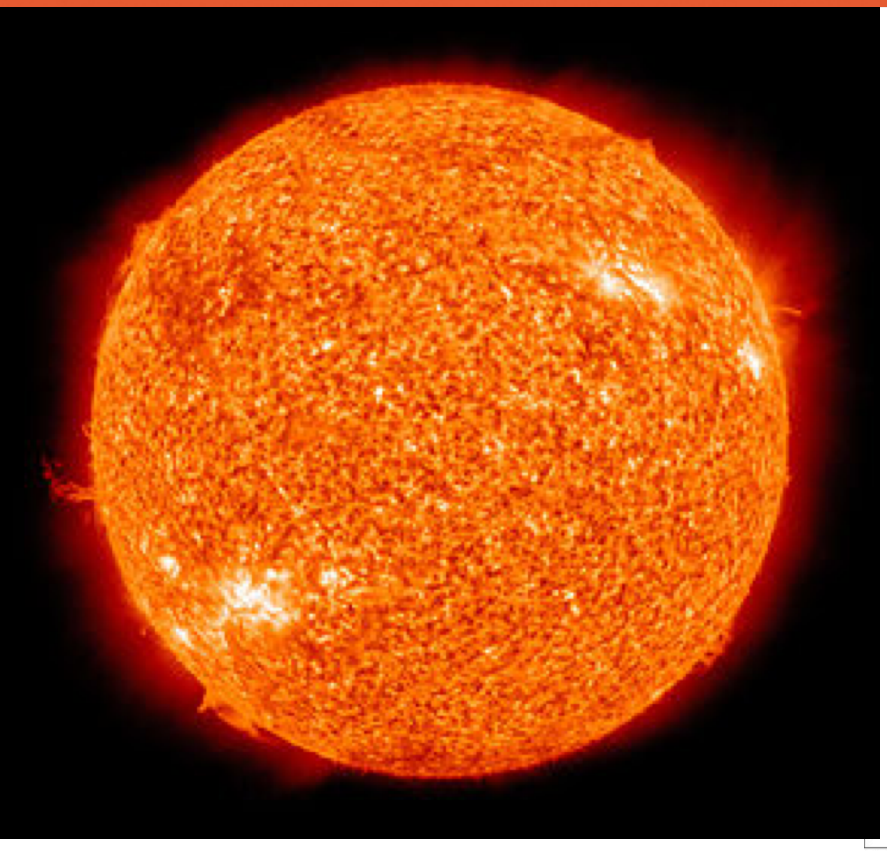
Bound-State Beta Decay of ^{205}Tl Nuclei

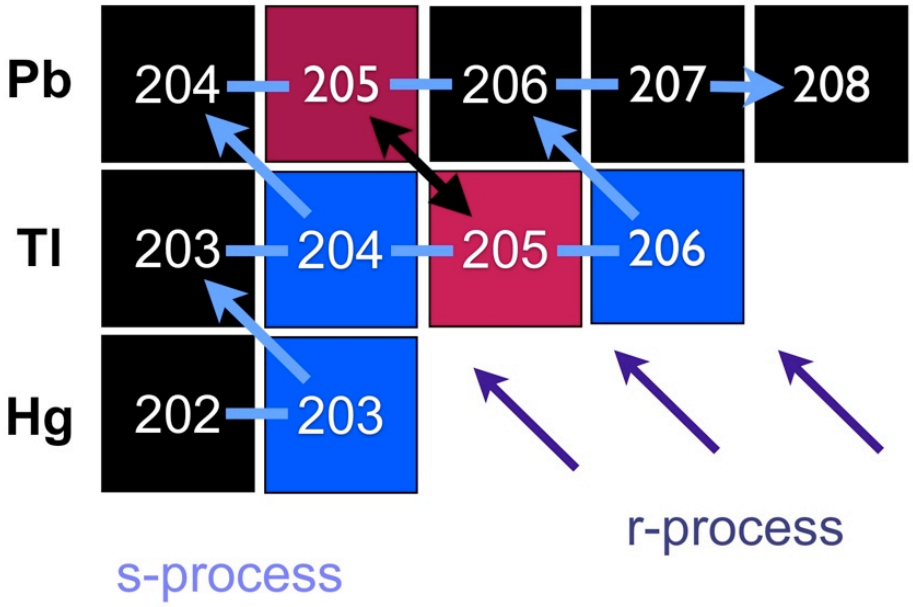


Bound-State Beta Decay of ^{205}Tl Nuclei

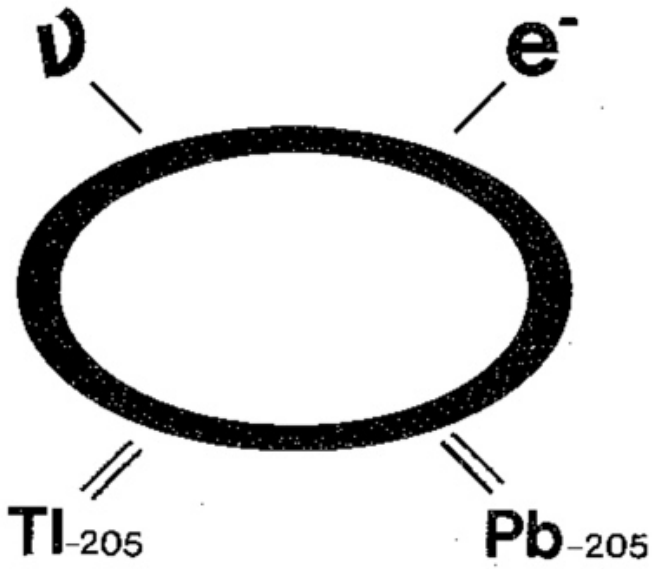


Bound-State Beta Decay of ^{205}Tl Nuclei

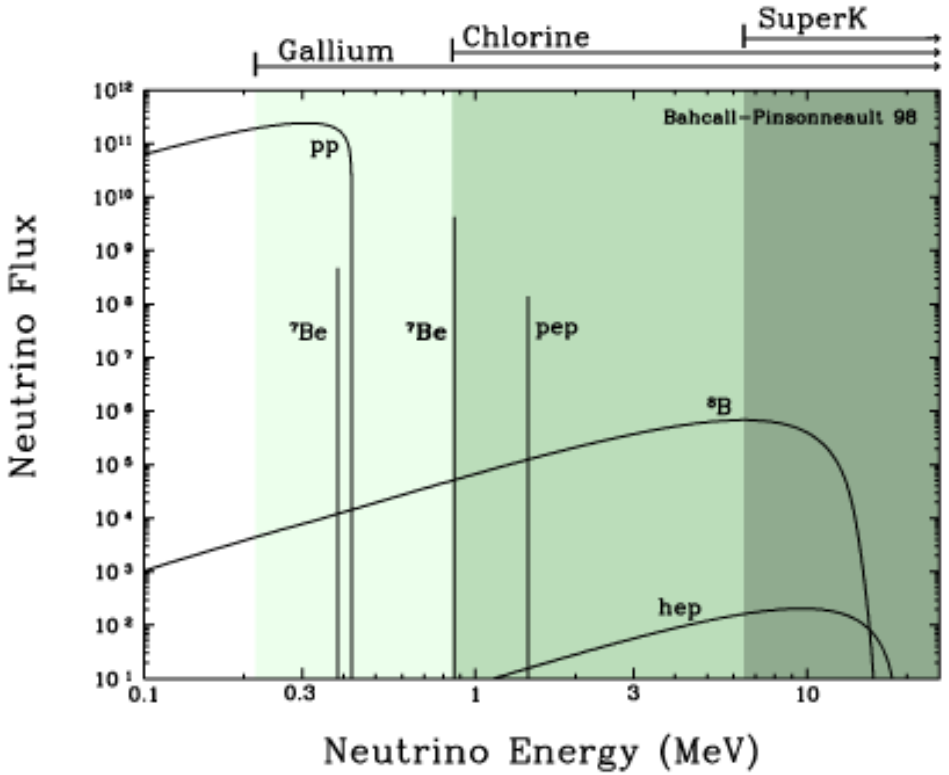




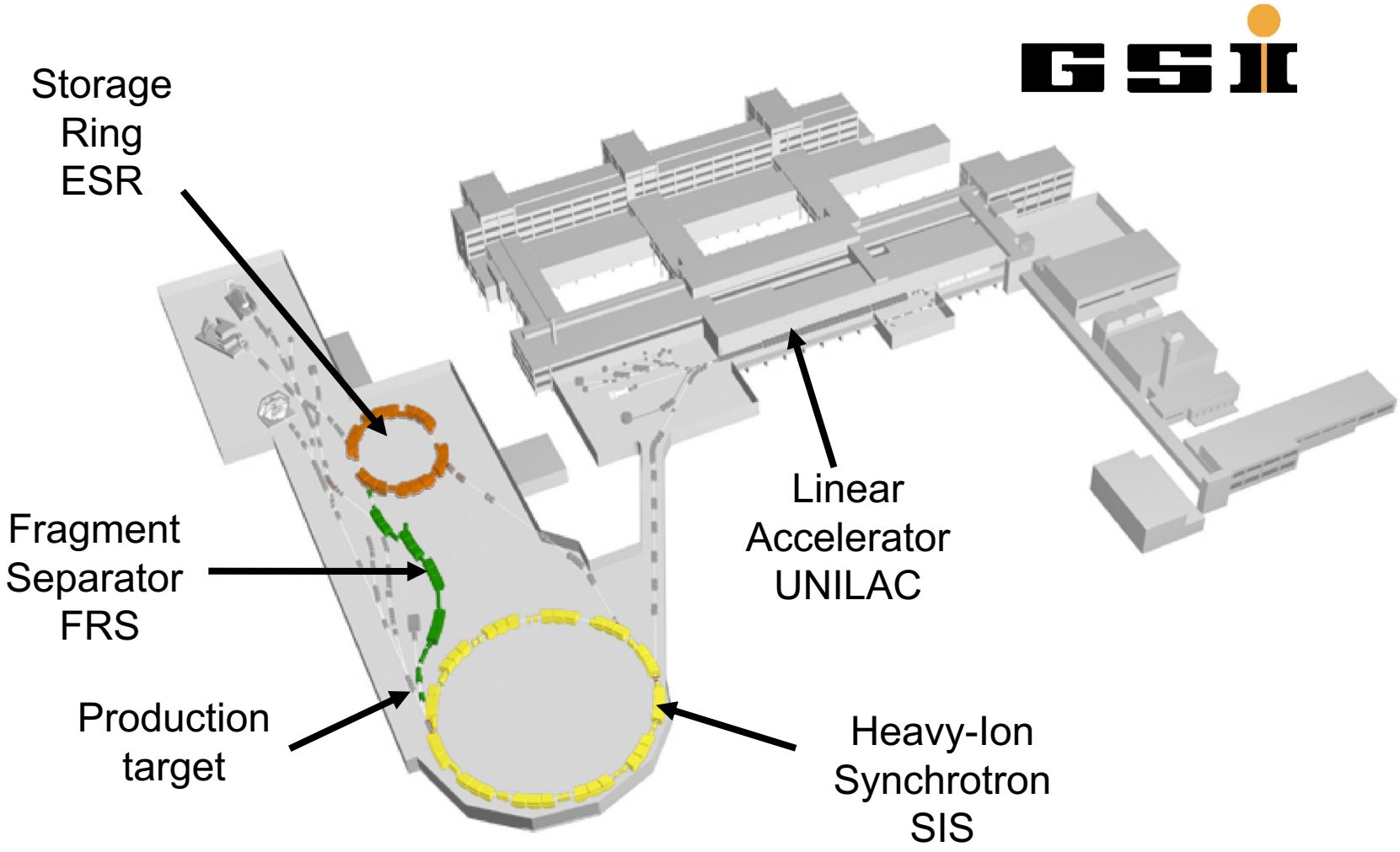
Bound-State Beta Decay of ^{205}Tl Nuclei



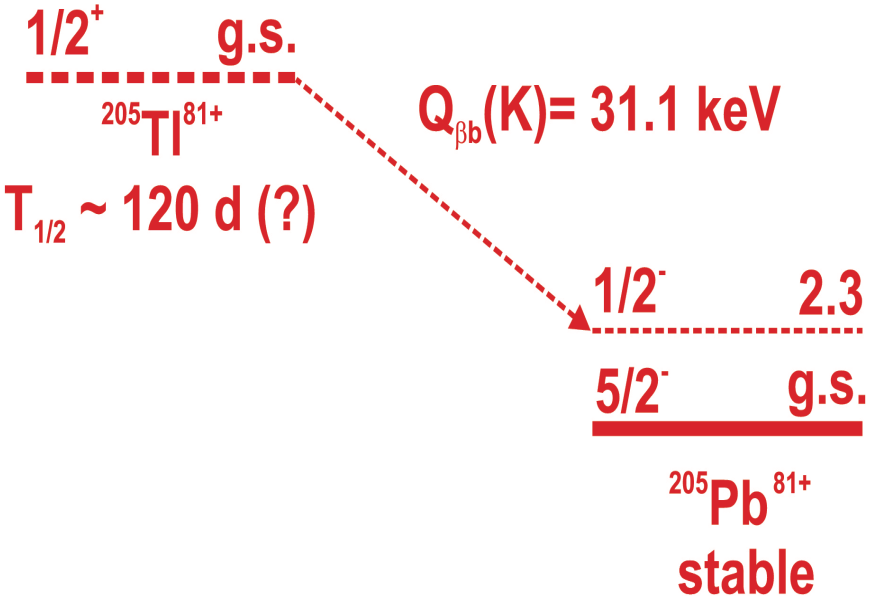
LOREX



Experiment


Storage
Ring
ESR
Fragment
Separator
FRS
Production
target
Linear
Accelerator
UNILAC
Heavy-Ion
Synchrotron
SIS

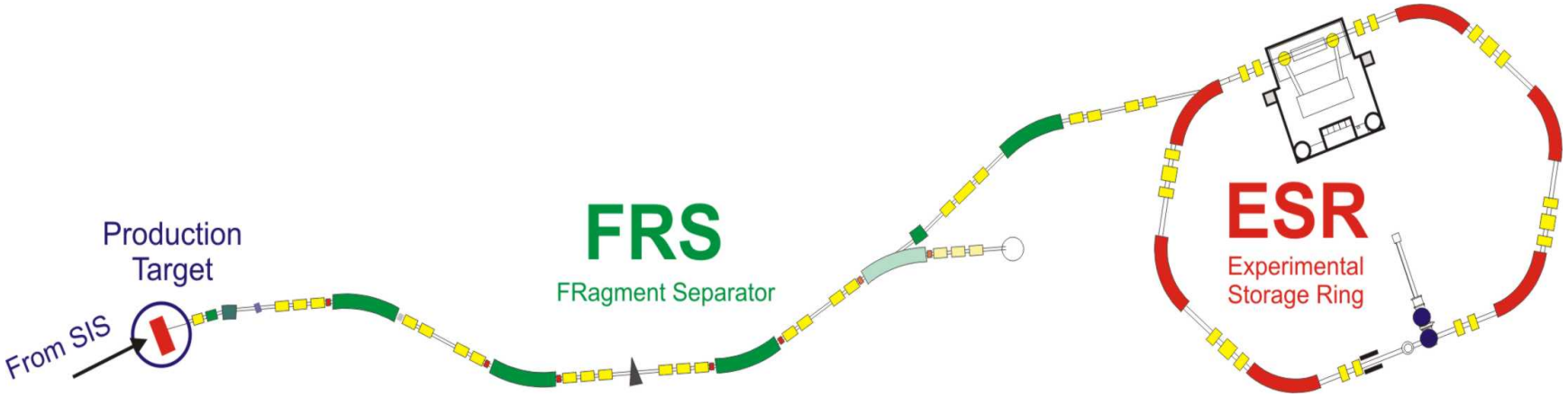
Main Problem



Problem:
The Q-value of 31 keV
Impossible to resolve in the ESR by means of mass spectrometry

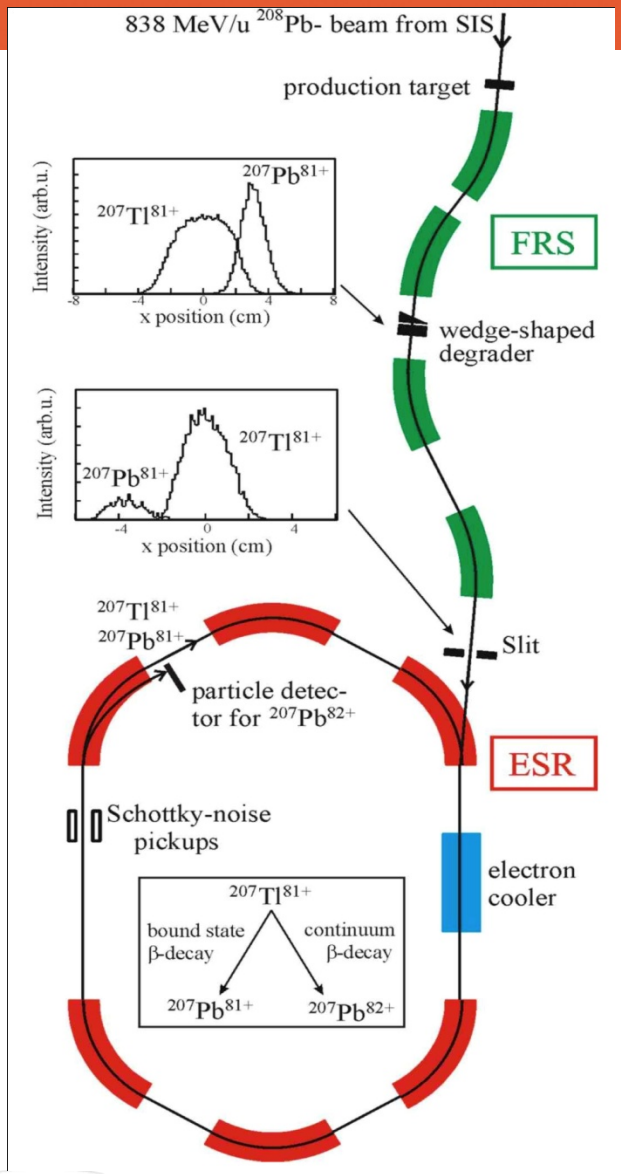
Solution:
No daughter hydrogen-like $^{205}Pb^{81+}$ ions shall be transmitted to the ESR

Monoisotopic separation in the FRS



- Primary beam ^{206}Pb at about 600 MeV/u
- ^{9}Be production target (possibly with Nb backing)
- Energy degrader – about 2 g/cm^2 Al @S2
- Injection of pure $^{205}Tl^{81+}$ beam into the ESR

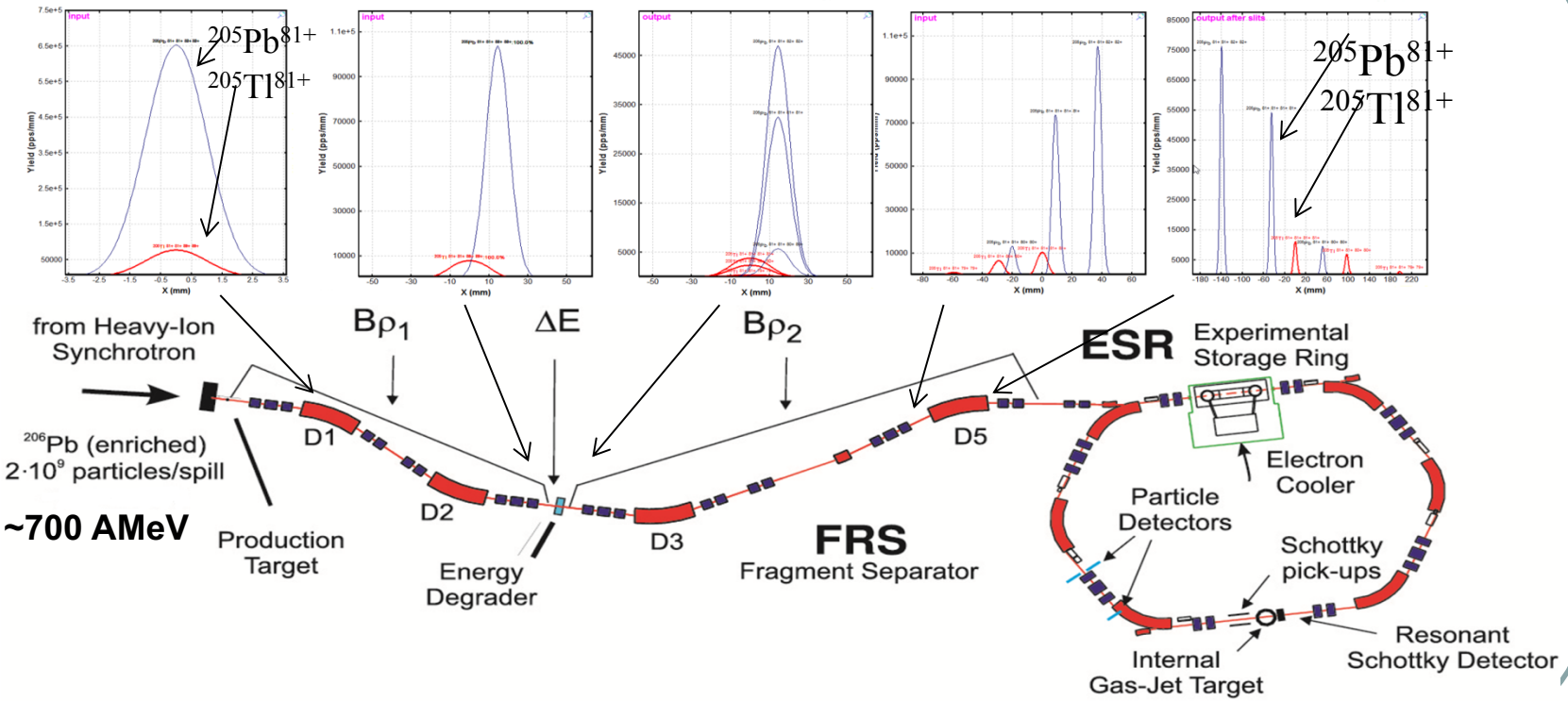
Monoisotopic separation in the FRS



To remind:
A similar separation has been achieved in the ^{207}Tl bound-state beta decay measurements

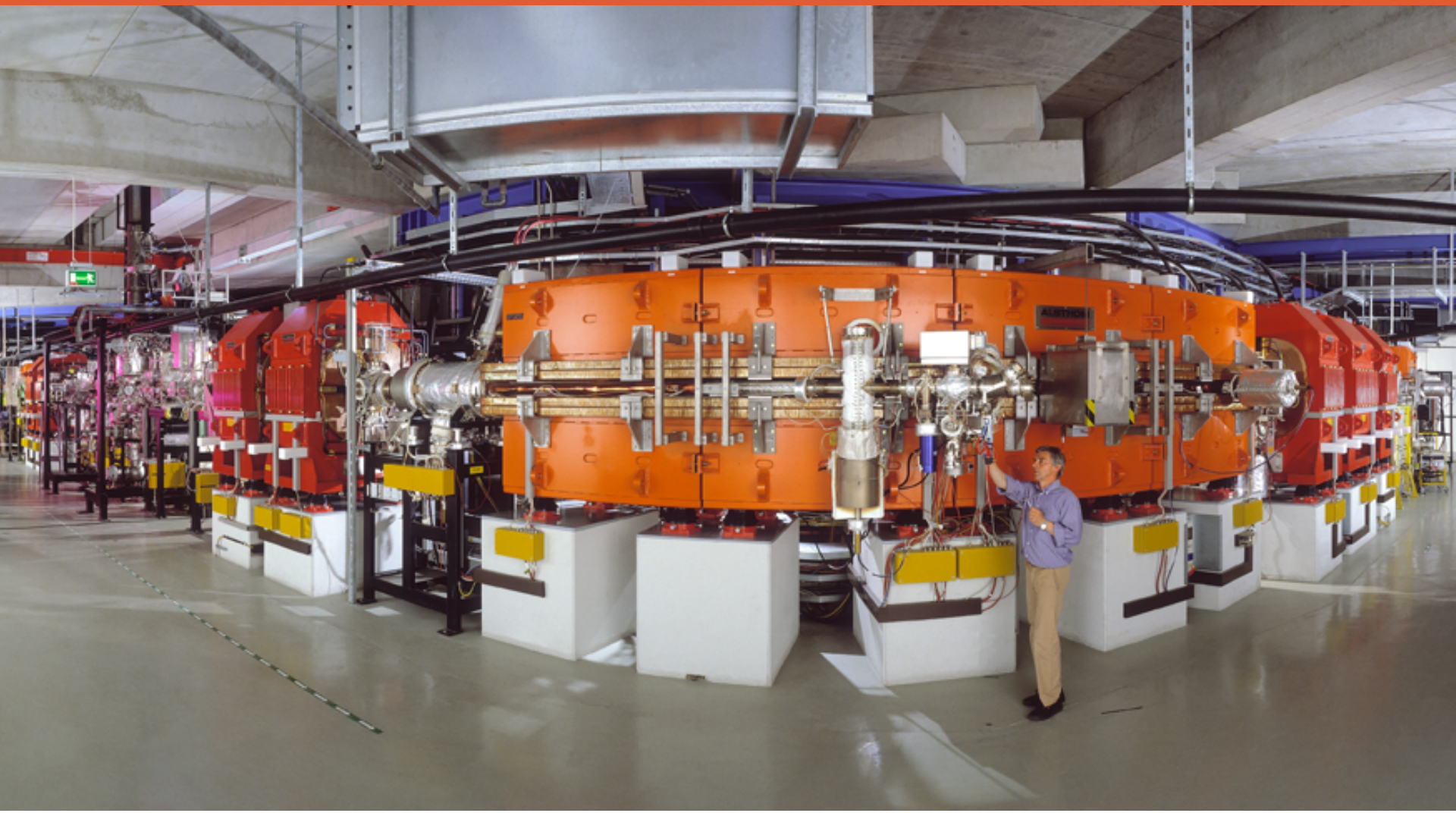
T. Ohtsubo et al., Phys. Rev. Lett. 95 (2005) 052501

Approximate Beam Parameters



- Optimum FRS Target ~2 g/cm^2 ^{9}Be (may be with Nb baking)
- S2: ~2 g/cm^2 Al degrader; otherwise vacuum
- S4: irrelevant
- Energy adjusted such that after the final matter in the ESR the energy of $^{205}Tl^{81+}$ is 400 MeV/u

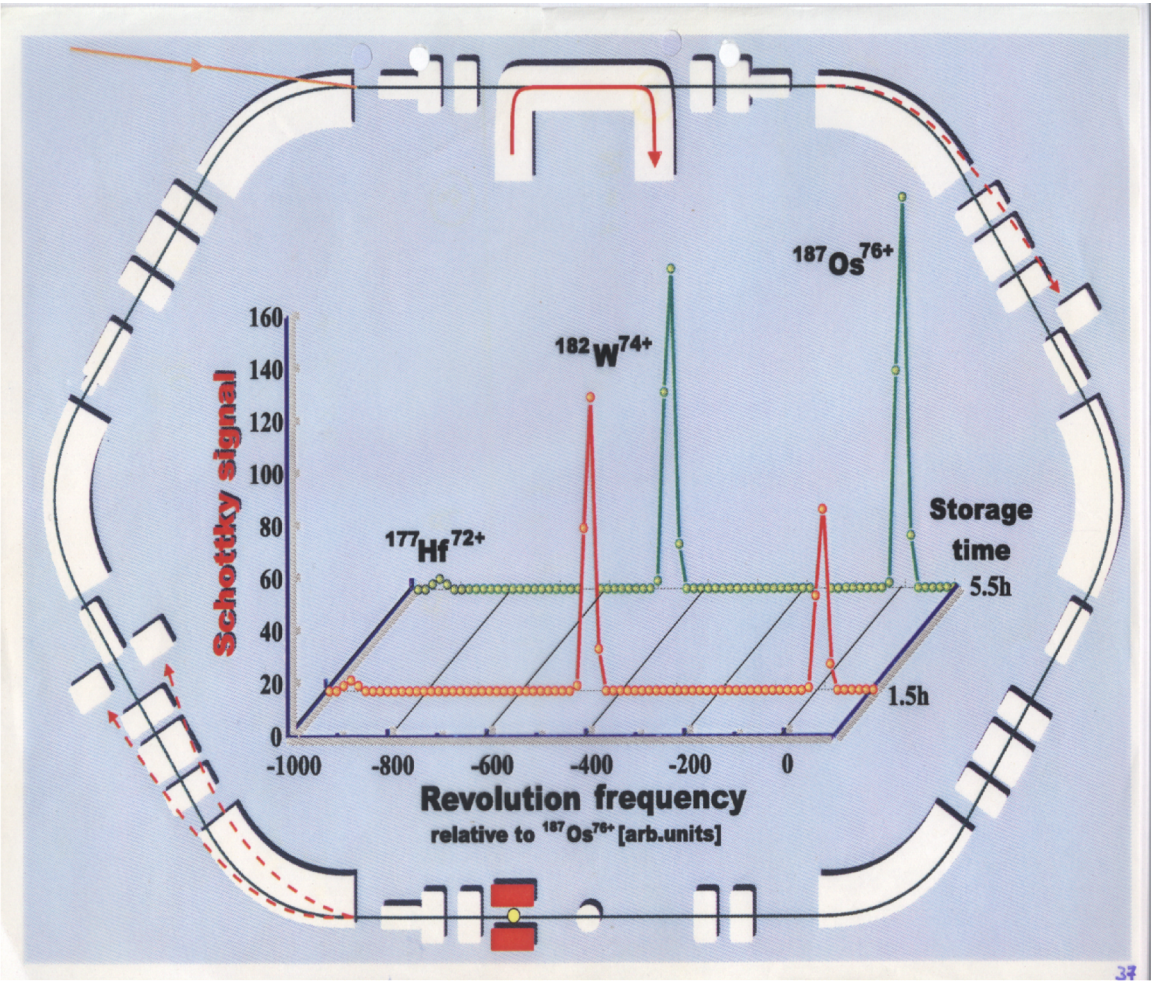
Experimental Storage Ring ESR



Experiment

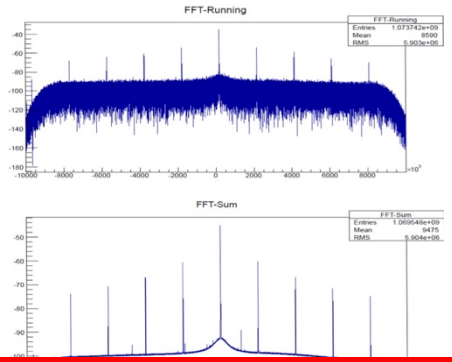
- Stacking in the ESR of at least 10^7 bare $^{205}Tl^{81+}$
- Waiting time (several hours, low electron current)
- Dense Gas-Jet Target (to strip the electron from daughter ions)
- Particle detectors inside the ESR (detection of daughters)
- Schottky spectroscopy (monitoring intensities of all ions)

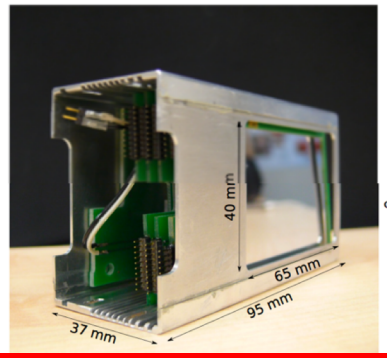
Similar experimental procedure as in ^{187}Re case

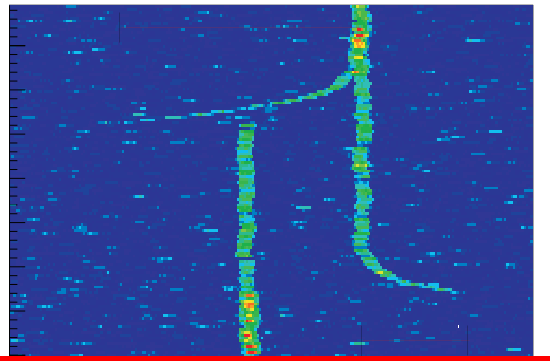


F. Bosch et al., Phys. Rev. Lett. 77 (1996) 5190

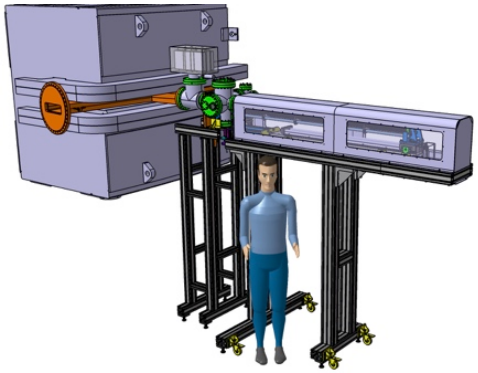
Relevance for FAIR

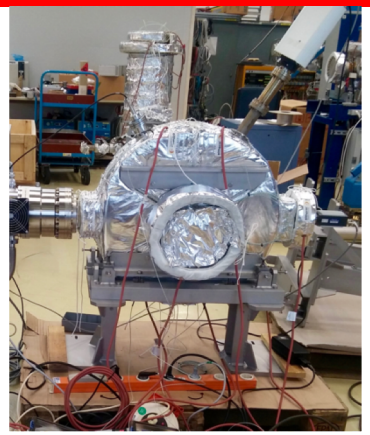


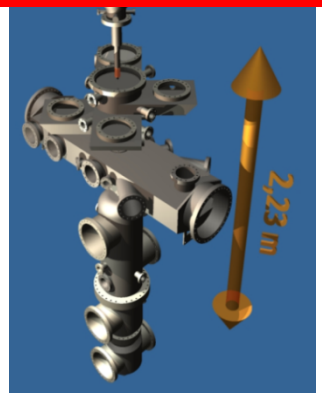




Test of Equipment for FAIR







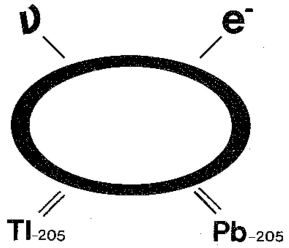
Bound-State Beta Decay of ^{205}Tl Nuclei

Proposal for an experiment to be conducted at FRS/ESR

Measurement of the bound-state beta decay of bare ^{205}Tl ions

Updated from previously accepted proposal E100

For the LOREX, NucCAR, SPARC and ILIMA Collaborations



NucAR

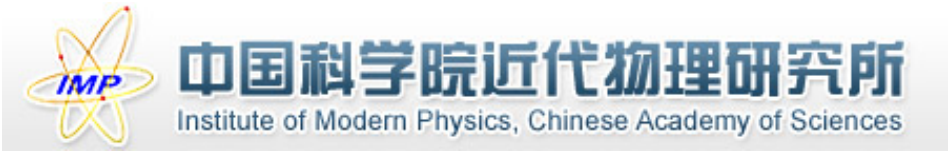
sparc

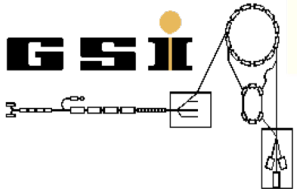
Stored Particles Atomic Physics Research Collaboration

ILIMA

*Regarding the proposal "Measurement of the bound-state beta decay of bare ^{205}Tl ions" (Proposal E121), the G-PAC recommends this proposal with **highest priority (A)** and that **21 shifts of main beam time** be allocated for this measurement.*

Many-many thanks to all colleagues from all over the world !!!





Questions/Comments

Thank you for your attention