Measurements of the spin alignment and g-factor of the 12^+ isomer in ^{192}Pb produced in the fragmentation reaction of a relativistic ^{238}U beam using RISING

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- *CSNSM, CNRS, Orsay, France;*
- *Weizmann Institute;*
- *IKP Koeln;*
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- *UJ Kraków;*
- *Warsaw University;*
- *University of Surrey;*
- *Lund University;*
- *ILL Grenoble;*
- *IF PAN Warsaw*

motivation

- magnetic moments $\mu = g*I$ – probe for investigation of single-particle configuration properties (spin, parity, proton/neutron characters)

- spin aligned nuclei – necessary for the magnetic moments study

Spin alignment of nuclei with isomeric states produced in the fragmentation reaction has been studied so far only in:

- light nuclei
- intermediate energies of projectiles

  - K. Asahi et al., Phys. Rev. C43, 456 (1991) – ^{14}B (beam ^{18}O at 60 MeV/u)
  - W.-D. Schmidt-Ott et al., Z. Phys. A50, 215 (1994) – ^{43}Sc (beam ^{46}Ti at 500 MeV/u)
  - G. Georgiev et al., J. Phys. G28, 2993 (2002) – ^{68}Ni (beam ^{76}Ge at 61.4 MeV/u)
  - I. Matea et al., Phys. Rev. Lett. 93, 142503 (2004) – ^{61}Fe (beam ^{64}Ni at 54.7 MeV/u)

Loss of spin alignment:

- due to pick-up of electron(s) by the fully stripped ion when passing materials in the beam line → hyperfine interaction reduces/cancels the reaction-produced spin-orientation

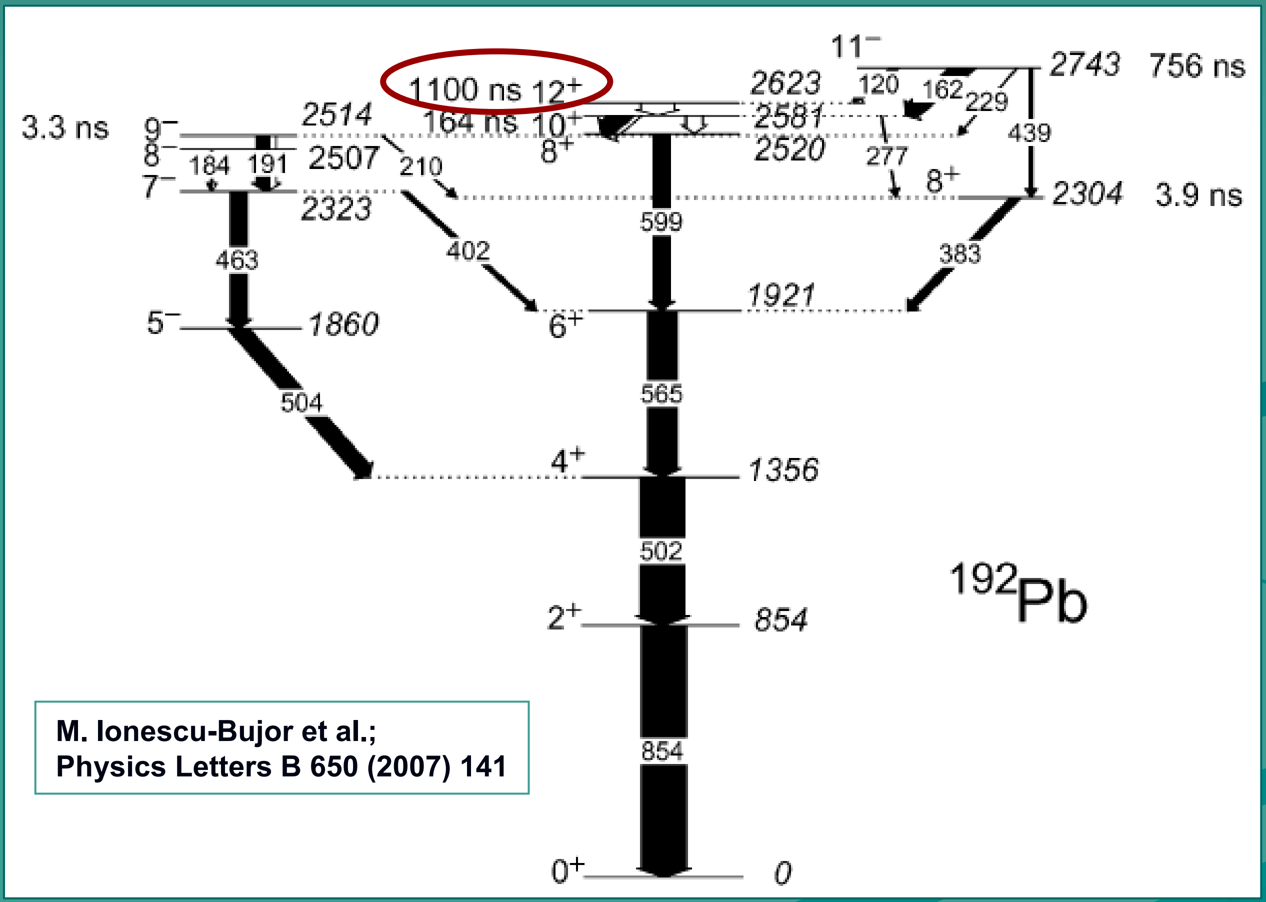
larger probability for heavier nuclei (larger Z)

to minimize: - increase the ion velocity (~ 300 MeV/u)
- reduce material on the way of transported ion

motivation

Do we have alignment in heavy isotopes produced in fragmentation reaction?

^{192}Pb



M. Ionescu-Bujor et al.;
Physics Letters B 650 (2007) 141

known:

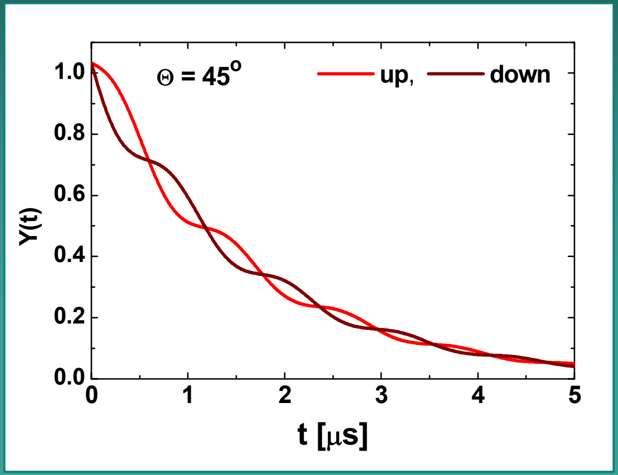
- lifetime: 1.57(6) μs
- g-factor: - 0.173(2)

A	$g_{exp}(12^+)^{a,b}$
192	−0.173(2)
194	−0.167(1)
196	−0.160(2)
198	−0.155(2)
200	−0.151(2)
202	−0.151(2)
204	…

K. Vyvey et al.;
Phys. Rev. C69, 064318 (2004)
Ch. Stenzel et al.,
Nucl. Phys. A411, 248 (1983)

method - g-factor measurement

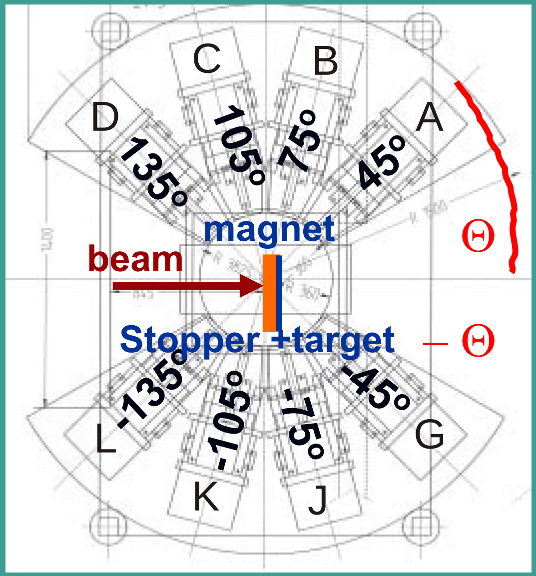
TDPAD (time dependent perturbed angular distribution) method



$$\omega_L = -g\mu_N B/\hbar$$

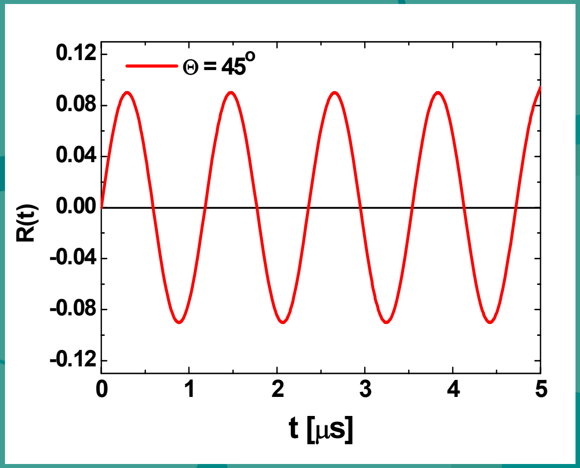
$$I(t,\theta,B) = I_0 \exp(-t/\tau) W(t,\theta,B);$$

$$W(t,\theta,B) = 1 + A_2 P_2(\cos(\theta - \omega_L t))$$



$$R(t) = \frac{I(t,\theta,B\uparrow) - I(t,\theta,B\downarrow)}{I(t,\theta,B\uparrow) + I(t,\theta,B\downarrow)}$$

$$R(t) = \frac{3A_2}{4+A_2}\cos(2(\theta - \varpi_L \cdot t))$$



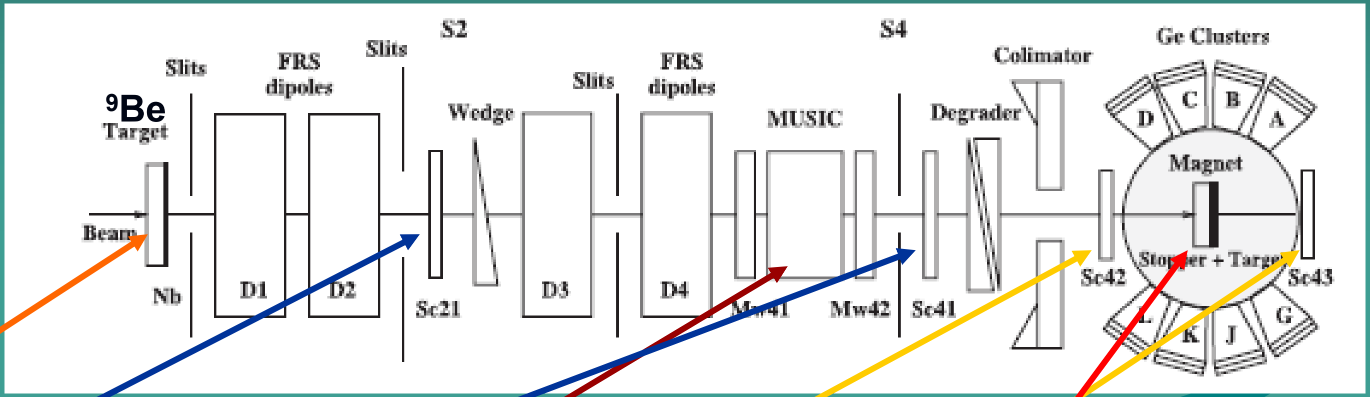
for $\theta = 45°$

$$R(t) = \frac{3A_2}{4+A_2}\sin(2\varpi_L \cdot t)$$

experiment

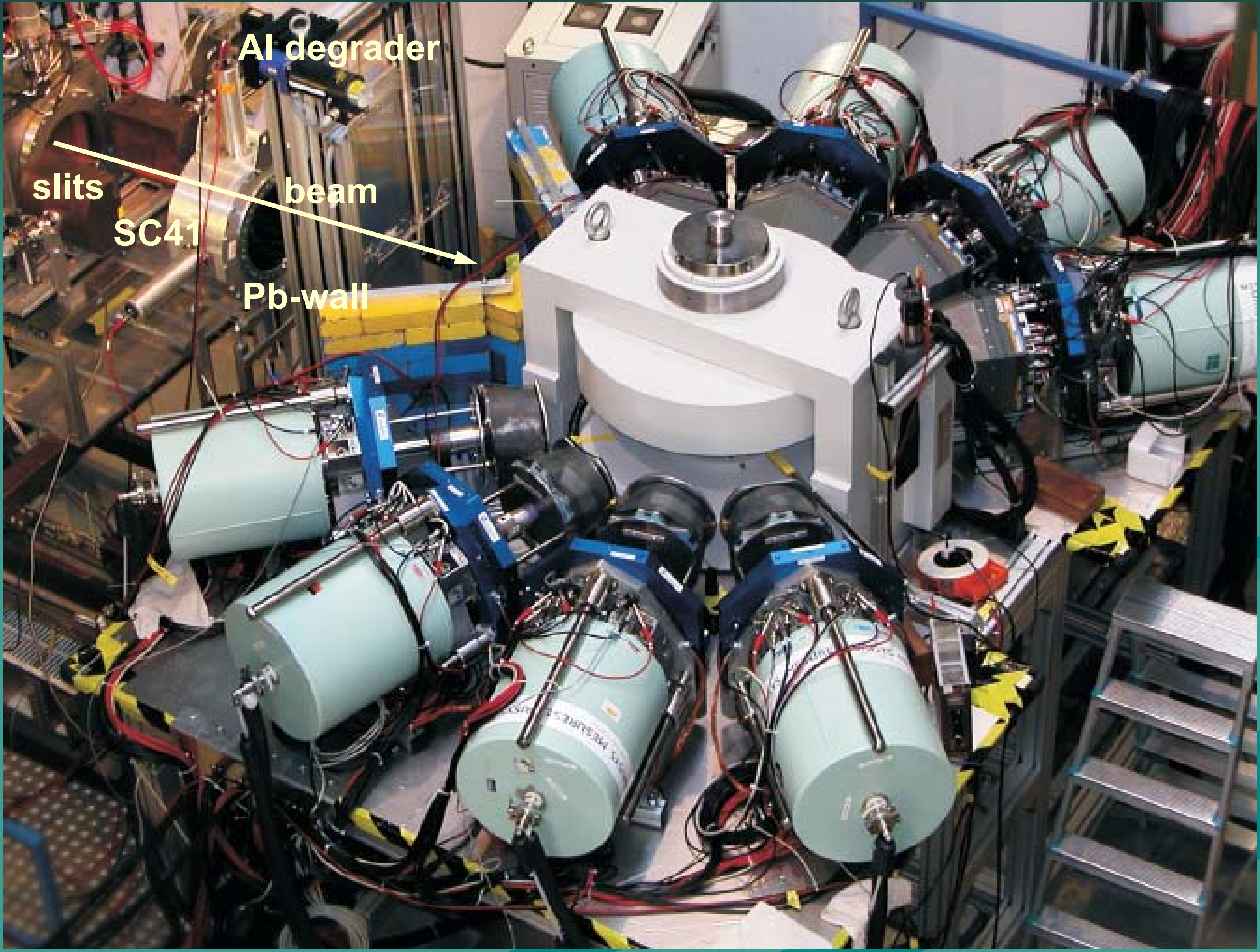
g-RISING campaign at GSI

Reaction: fragmentation of ^{238}U at 1GeV/u



- 1 g/cm² ^{9}Be target
- 221 mg/cm² Nb stripper – to produce fully stripped fragments
- Sc21 + slits – spin aligned secondary beam and position detector (high current, energy not measured)
- Sc41 – t_0 for γ-decay measurement
- Sc42 – validation of the event
- Sc43 – rejection of not stopped particles (veto)
- Stopper + target (plexi + 2 mm Cu (annealed)) – stop nuclei

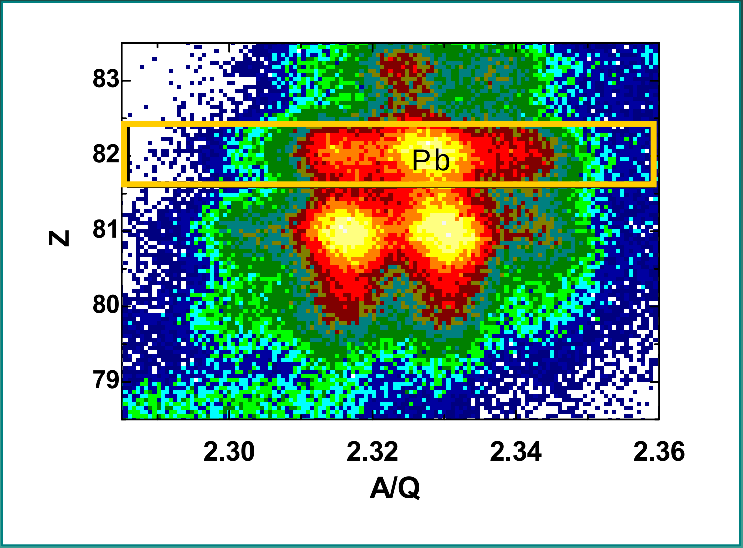
- MW41, MW42 (multiwire proportional counters) – position determination
- MUSIC (ionization chamber) – Z determination
- Sc21, Sc41 (position sensitive fast scintillators) – TOF measurement


Al degrader
slits
beam
SC41
Pb-wall

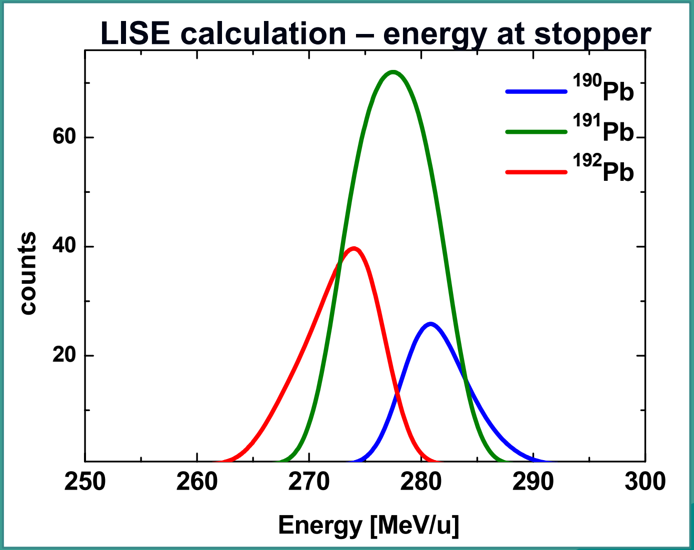
experiment

secondary fragments:

- ^{193}Bi, ^{194}Bi
- ^{190}Pb, ^{191}Pb, ^{192}Pb
- ^{188}Tl, ^{189}Tl

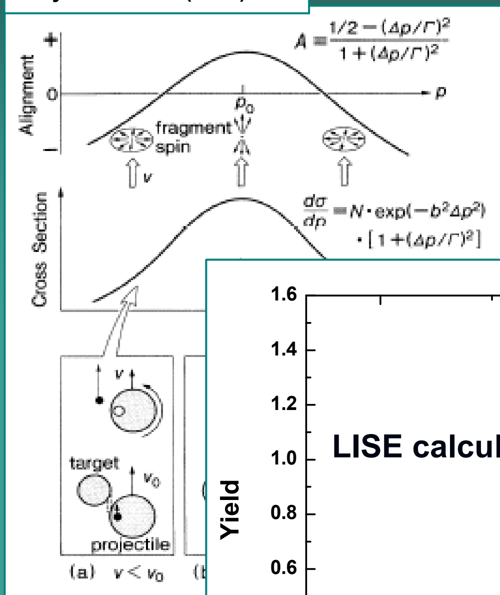


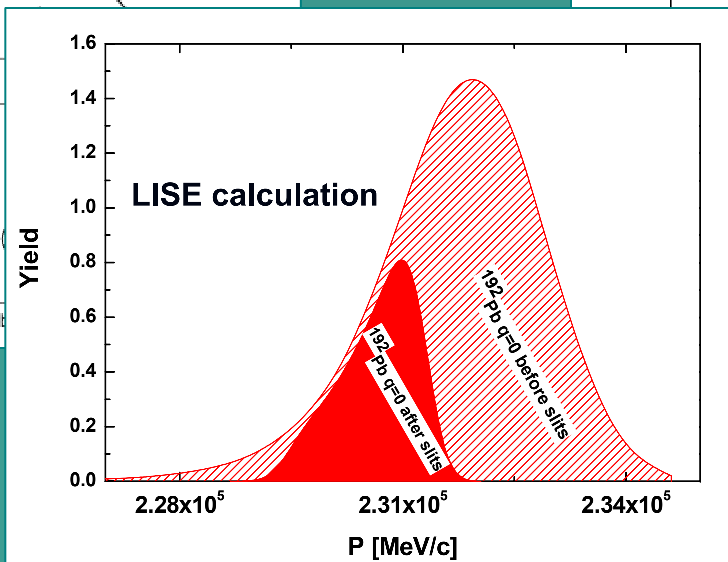
high fragment energy ~ 300MeV/u – less chance to pick up electron
– large prompt radiation

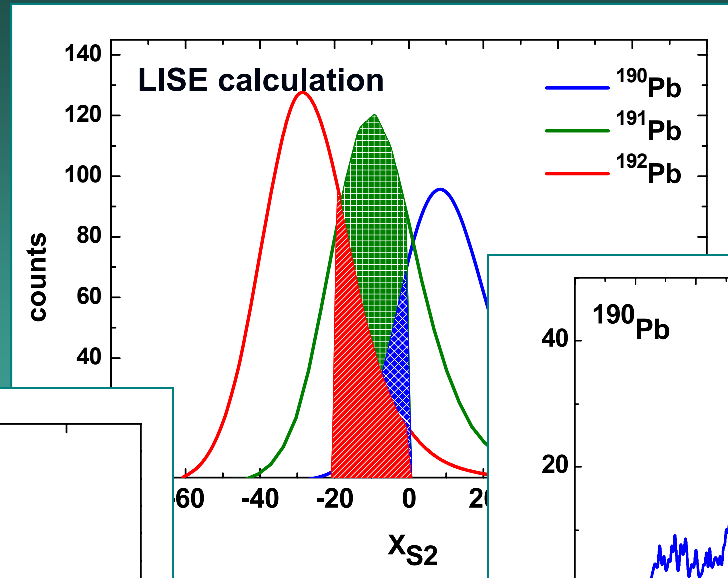


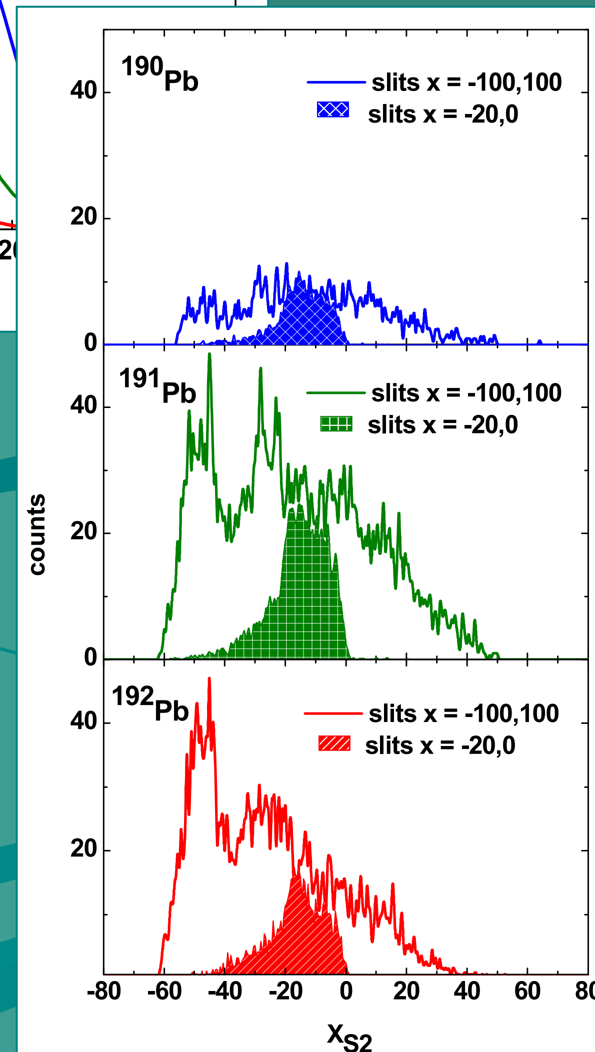
experiment

K. Asahi et al.;
Phys. Rev. C43 (1991) 456

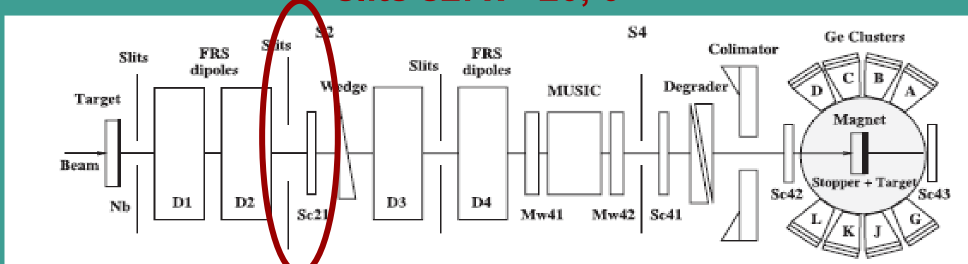




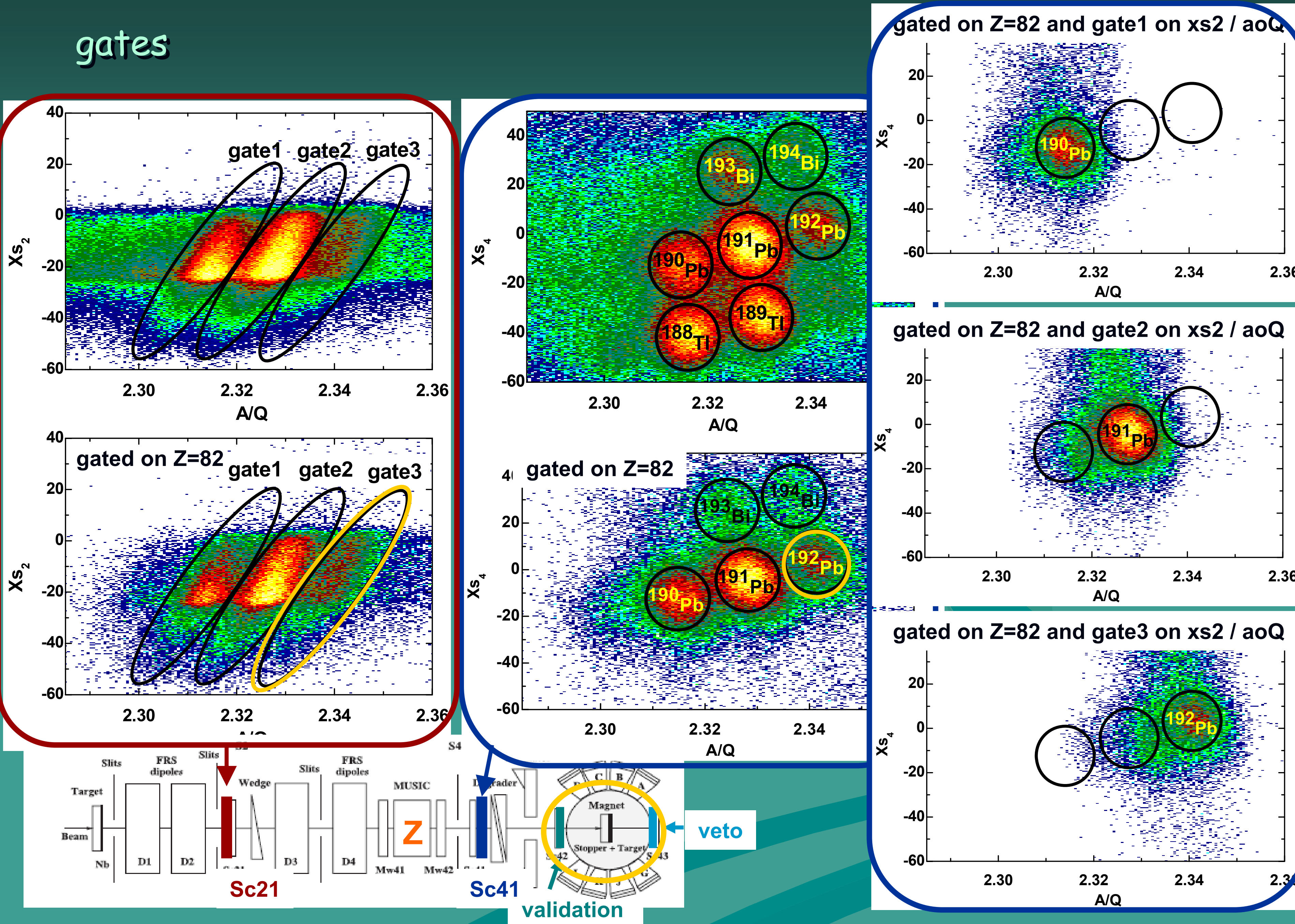




slits s2: x=-20, 0

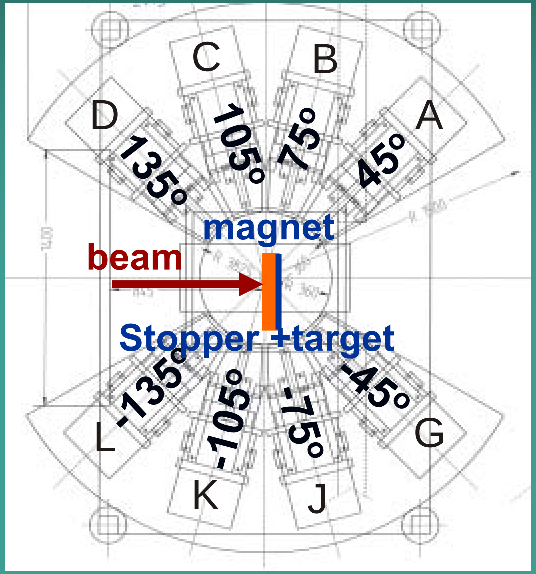


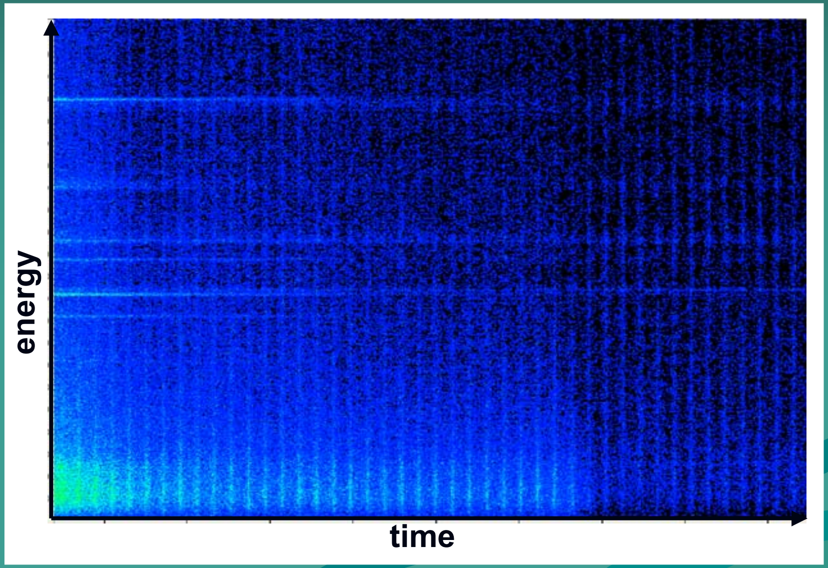
gates

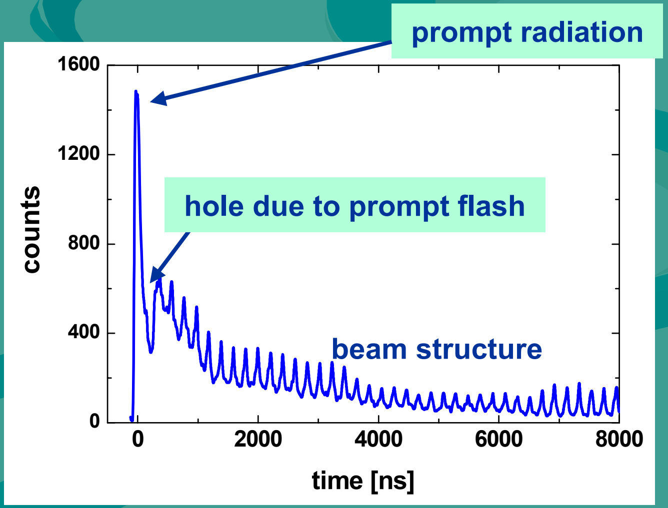

gate1
gate2
gate3
Xs2
A/Q
gated on Z=82
Xs4
193Bi
194Bi
192Pb
191Pb
190Pb
189Tl
188Tl
gated on Z=82 and gate1 on xs2 / aoQ
gated on Z=82 and gate2 on xs2 / aoQ
gated on Z=82 and gate3 on xs2 / aoQ
Target
Beam
Nb
Slits
FRS dipoles
D1
D2
Wedge
D3
D4
MUSIC
Z
Mw41
Mw42
S4
Magnet
Stopper + Target
Sc21
Sc41
veto
validation

analysis

RISING array
HPGe cluster detectors – measurement of γ-ray from isomer decay





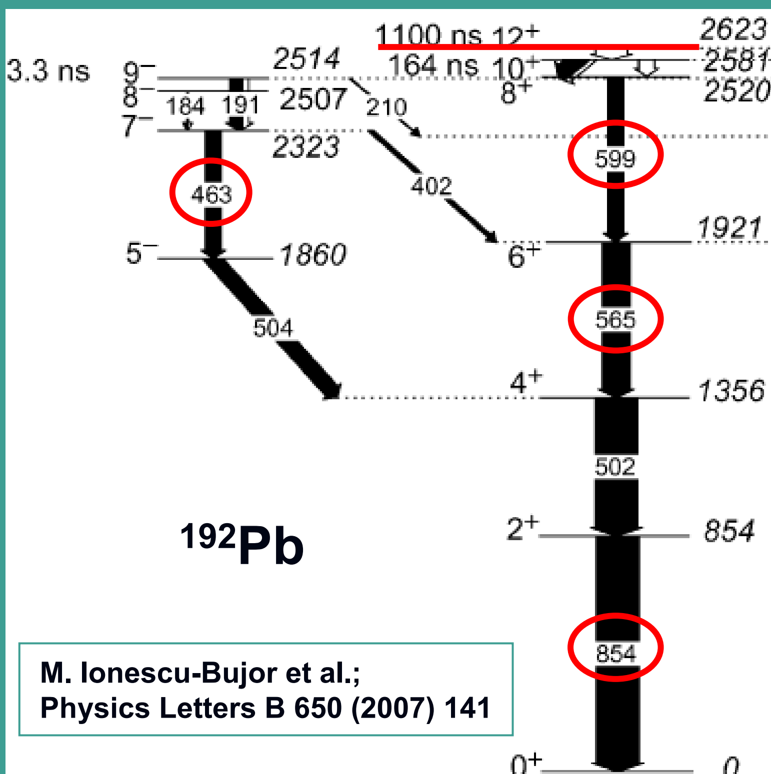


magnetic field of B = 0.16T

γ - spectra

isomeric states 11^- and 12^+
with the lifetime 11 μs and 36 μs

no isomeric states



M. Ionescu-Bujor et al.;
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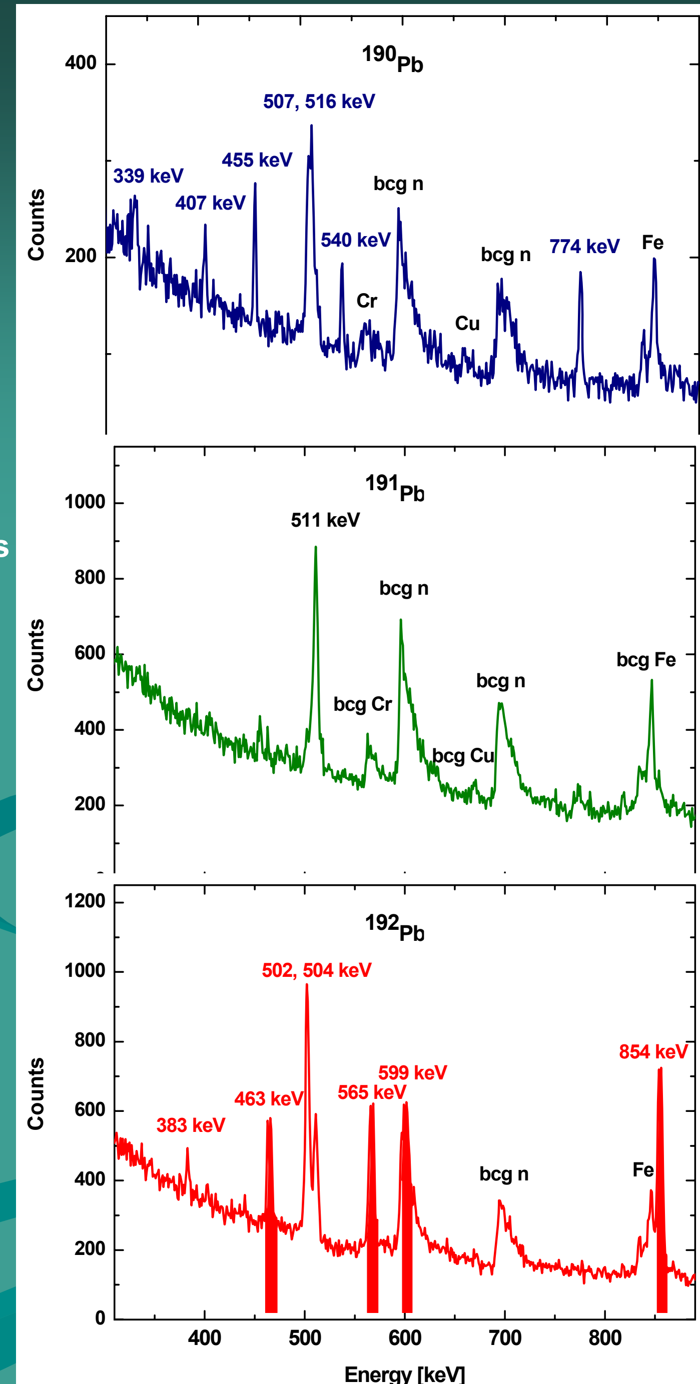
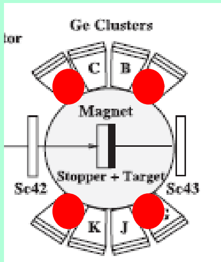


results

for detectors at 90° and 180° with respect to each other:

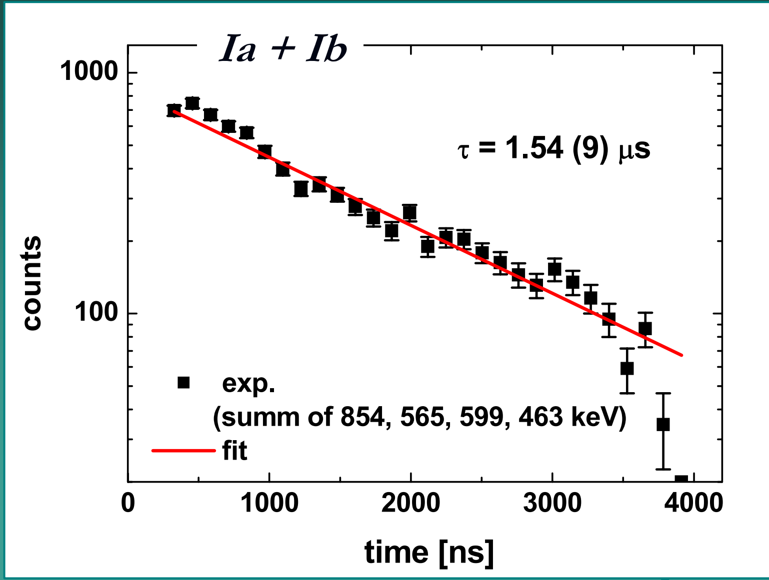


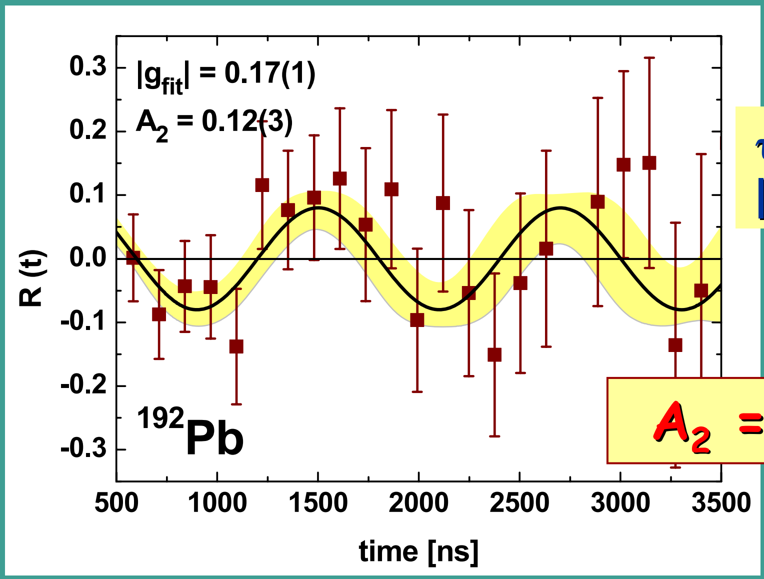
$$Ia = (I_A \uparrow + I_L \uparrow) + (I_D \downarrow + I_G \downarrow)$$

$$Ib = (I_A \downarrow + I_L \downarrow) + (I_D \uparrow + I_G \uparrow)$$

$$R(t) = \frac{Ia - Ib}{Ia + Ib},$$

$$R(t) = \frac{3A_2}{4 + A_2} \sin(2\varpi_L \cdot t)$$





τ = 1.54(9) μs
|g| = 0.17(1)

A_2 = 0.12(3)

Consistent with published values:
τ = 1.57(6) μs
g = - 0.173(2)

fusion-evaporation exp.

Ch. Stenzel et al., Nucl. Phys. A411, 248 (1983);
K. Vyvey et al., Phys. Rev. C69, 064318 (2004);
M. Jonescu-Bujor et al., Phys. Lett. B650, 141 (2007)

$A_2 \sim 0.30$

12^+ state described by configuration $\nu(i_{13/2}^{-2})$

Yamazaki value for fully aligned spins A_2 = 0.40

proven feasibility of g-factor studies in heavy nuclei produced in fragmentation of relativistic beam

conclusions

- *g*-factor in ^{192}Pb nucleus produced via fragmentation of relativistic ^{238}U beam was measured
- obtained life time is similar to the results of previous investigations
- measured *g*-factor value for 12^{+} state in ^{192}Pb is consistent with published value
- extracted A_2 = 12% shows that preserved spin alignment for Pb is large enough for the feasibility of future investigations of properties of isomeric states in more exotic heavy nuclei produced in relativistic fragmentation reactions