Isomer-scope for experiments with neutron-rich radioactive beams

Oak Ridge National Laboratory, University of Tennessee, Vanderbilt University

- *Isomer-scope by Tetsuro Ishii et al.*
- *Population of neutron-rich fragments in deep-inelastic collisions according to the GRAZING_9 code*
- *Test cases considered for measurements with neutron-rich radioactive beams at HRIBF*

Isomer-scope by Tetsuro Ishii et al.

Nuclear Instruments and Methods in Physics Research A 395 (1997) 210-216
T. Ishii, M. Itoh, M. Ishii, A. Makishima, M. Ogawa, I. Hossain, T. Hayakawa, T. Kohno,
Japan Atomic Energy Research Institute (JAERI)

Abstract:
"A new instrument, isomer-scope, has been proposed to observe the ns-μs isomers produced by deep-inelastic collisions."

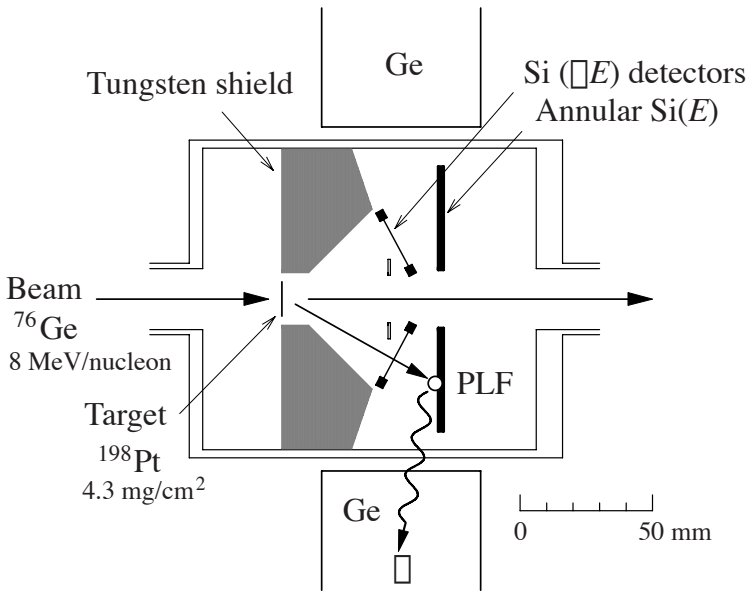


Fig. 1. Isomer-scope: an experimental setup to measure γrays from isomers with $T_{1/2} > 1$ ns of projectile-like fragments produced in deep-inelastic collisions. It consists of an annular-type Si detector working as a stopper of PLFs, four Si ΔE detectors, four Ge detectors, and a tungsten block to absorb prompt γrays emitted at the target.

T. Ishii et al., Acta Physica Polonica B32 (2001) 739-746

- *Experiments at the JAERI tandem booster facility*
- *Neutron-rich nuclei produced by deep-inelastic collisions with ^{70}Zn, ^{76}Ge and ^{82}Se beams of about 8 MeV/nucleon...*
- *... at a 4.3 mg/cm^2 ^{198}Pt target*

- *Projectile-Like Fragments detected by four 20 μm ΔE detectors and one annular-type Si-E detector*
- *The Si-E detector covers angles 21-35 deg. (LAB)*
- *Four 30% Ge detectors surround the Si-E detector and observe γ-rays from stopped fragments*
- *ΔE-E-γ-(γ) coincidences are measured*
- *Flight time between the target and the Si-E detector is about 1.5 ns, the Ge detectors are shielded from the prompt gamma radiation from the target*

Isomer-scope by Tetsuro Ishii et al.

Acta Physica Polonica B32 (2001) 739-746
T. Ishii, M. Asai, M. Matsuda, S. Ichikawa, A. Makishima, I. Hossain, P. Kleinheinz and M. Ogawa
Japan Atomic Energy Research Institute (JAERI)

Abstract:
"Developing a new instrument isomer-scope, we have measured γrays from nano-second isomers produced in heavy-ion deep-inelastic collisions with great sensitivity."

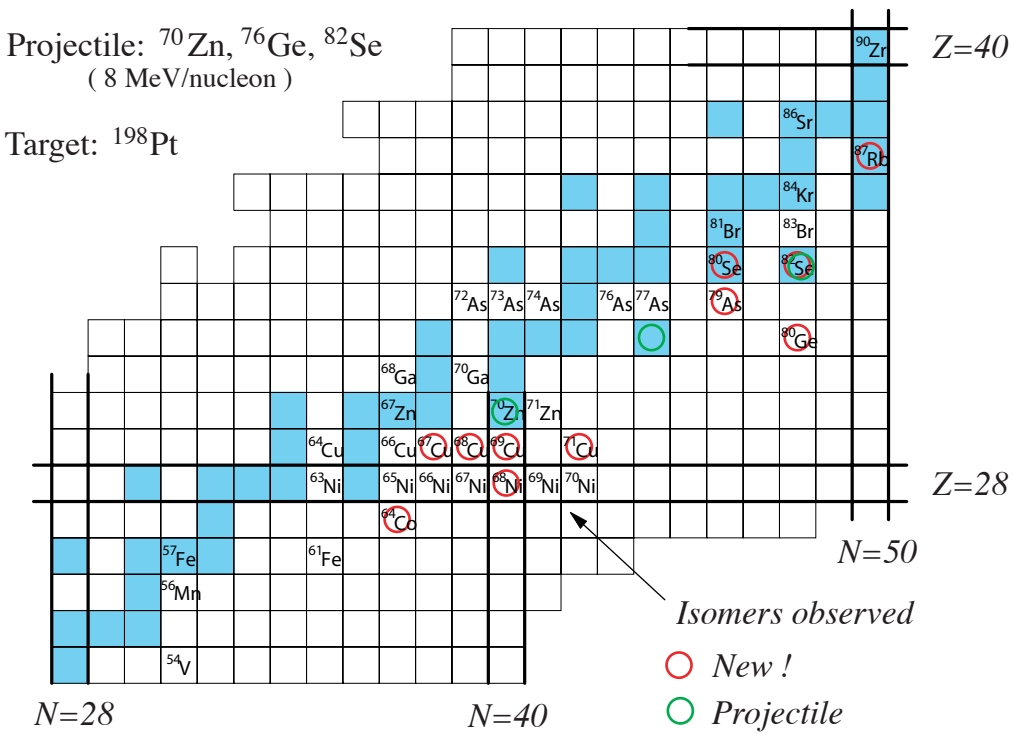


Fig. 3. Distribution of isomers measured with the isomer-scope. Stable isotopes are shown as dark squares. The nuclei depicted in this chart are those whose isomers were observed by the isomer-scope. New isomers we have found are marked with circles.

T. Ishii et al., Acta Physica Polonica B32 (2001) 739-746

Used ^{70}Zn, ^{76}Ge and ^{82}Se beams of very low intensity, about 0.1 pnA

Sensitivity down to about 10 μb for cases with favorable detection conditions (γ-s)

New isomers observed in the neutron-rich region using the isomer-scope:

^{64}Co, M. Asai et al., PRC62, 054313 (2000)

^{68}Ni, T. Ishii et al., PRL84, 39 (2000)

^{67,68,69,71}Cu, T. Ishii et al., PRL81, 4100 (1998) and T. Ishii et al., PRL84, 39 (2000)

^{80}Ge, A. Makishima et al., PRC59, 2331 (1999)

^{79}As, I. Hossain et al., PRC58, 1318 (1998)

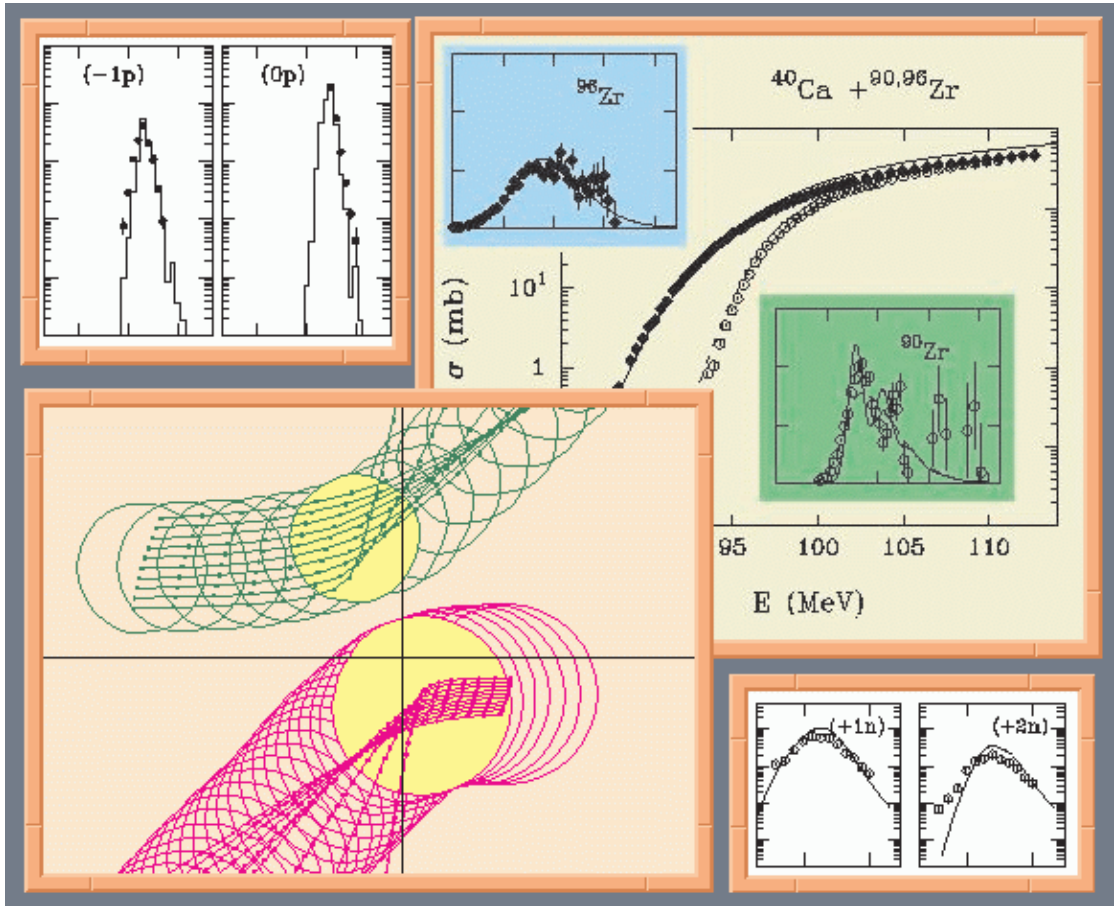
^{80,82}Se, A. Makishima et al., PRC59, 2331 (1999)

GRAZING_9

A Fortran program for estimating reactions in collision between Heavy Nuclei

by Aage Winther
The Niels Bohr Institutet,
Copenhagen (Denmark)

updated by Giovanni Pollarolo
Istituto Nazionale di Fisica Nucleare,
Sezione di Torino (Italy)



Abstract:
GRAZING_9 is an interactive Fortran program that evaluates the reactions to be expected in a collision between two heavy nuclei at moderate bombarding energies. It calculates the cross section for the distribution in mass and charge, kinetic energy and excitation energy of the two scattered nuclei. It also calculates the cross section leading to capture including coupled channel effect in the tunneling of the fusion barrier.

http://www.to.infn.it/~nanni/grazing

A. Winther, "Grazing reactions in collisions between heavy nuclei", Nucl. Phys. **A572** (1994) 191-235
A. Winther, "Dissipation, polarization and fluctuation in grazing heavy-ion collisions and the boundary to the chaotic regime", Nucl. Phys. **A594** (1995) 203-245

Angular distributions for ^{69}Cu and ^{71}Cu produced in ^{70}Zn on ^{198}Pt collisions

Reaction: ^{70}Zn beam at 8 MeV/nucleon on a 4.3 mg/cm^2 ^{198}Pt target

Beam energy loss in the target dE/dx =14 MeV per 1 mg/cm^2

Projectile-Like Fragments detected at 21-35 deg. angle (LAB)

Grazing angle:

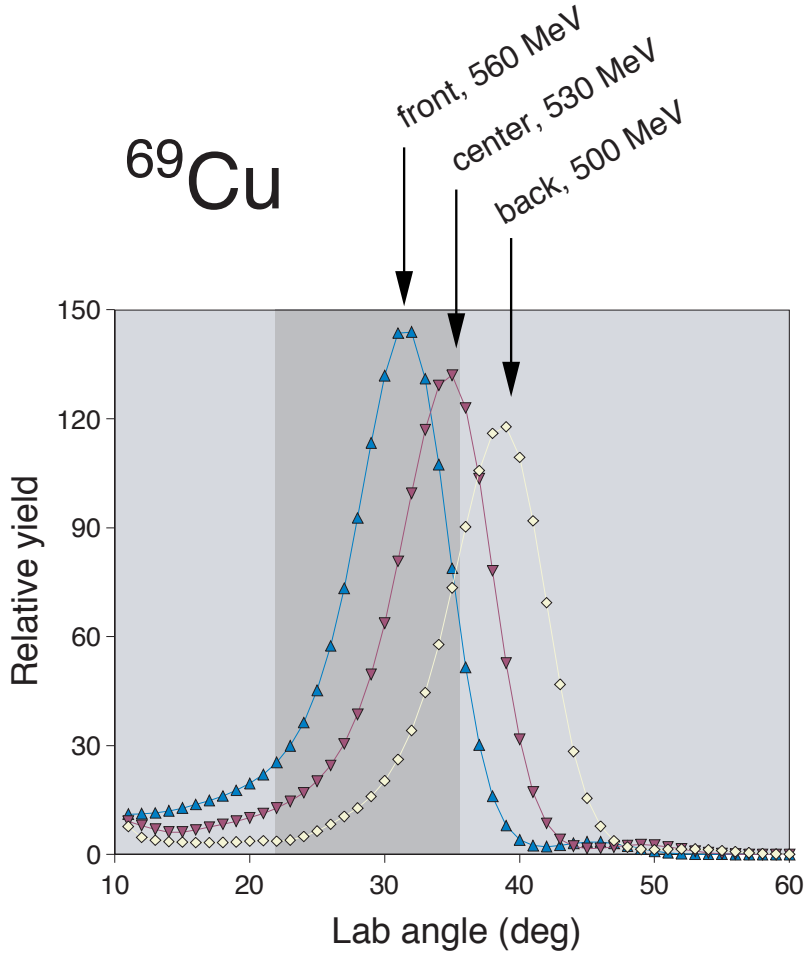
θ_{gr} = 37 deg. at 560 MeV (front of target)

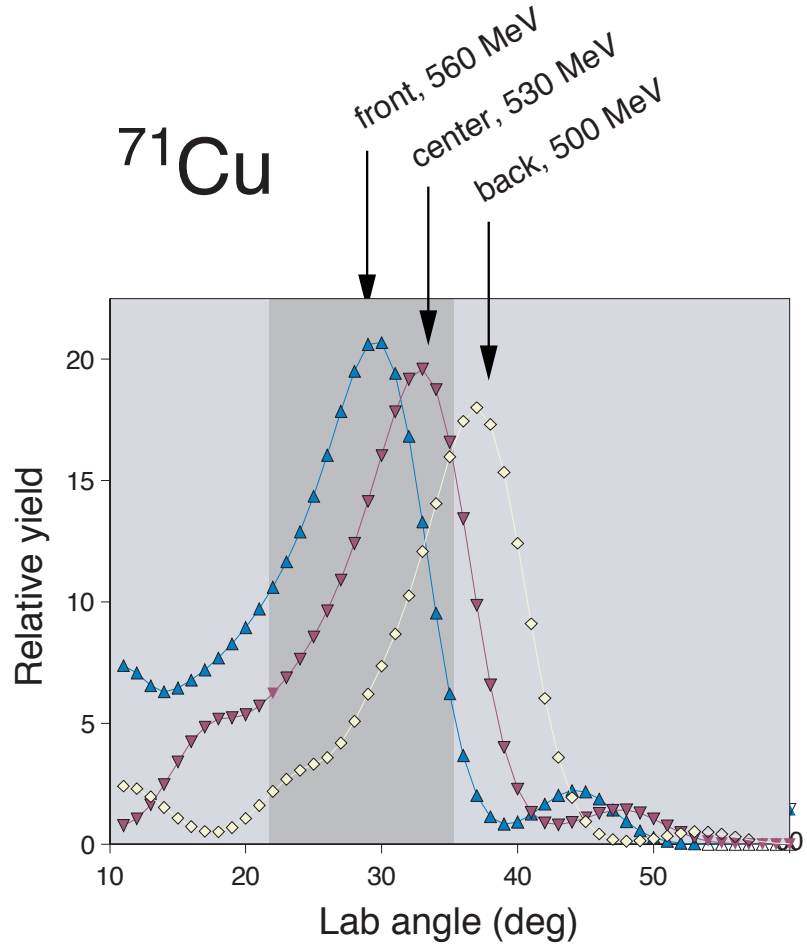
θ_{gr} = 40 deg. at 530 MeV (center of target)

θ_{gr} = 44 deg. at 500 MeV (back of target)

grazing angle formula from R. Bass, "Nuclear Reactions with Heavy Ions", Springer 1980

Angular distributions of fragments according to GRAZING_9 code:





Angular distributions for ^{79}As produced in ^{80}Ge on ^{124}Sn collisions

(+p,-2n)

Reaction: ^{80}Ge beam at 5-6 MeV/nucleon on a few mg/cm^2 ^{124}Sn target

Beam energy loss in the target dE/dx =18 MeV per 1 mg/cm^2

Projectile-Like Fragments emission between 15 and 30 deg. (LAB)

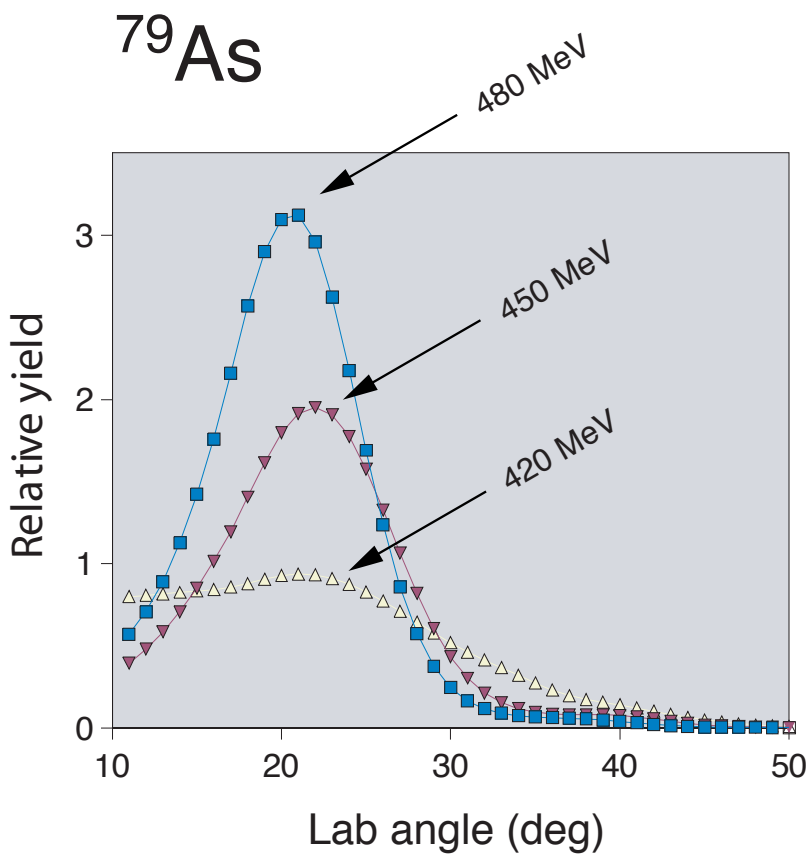
Grazing angle:

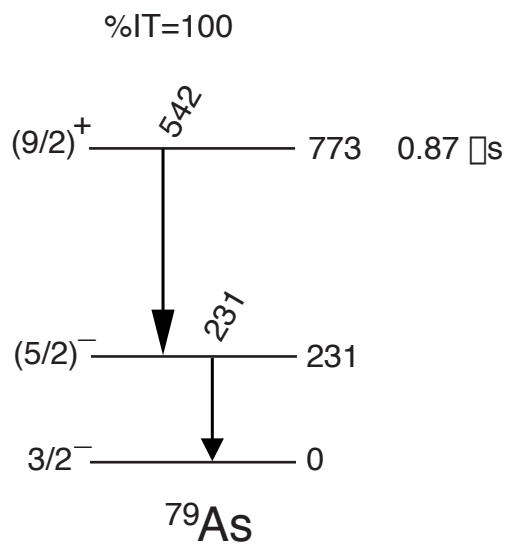
θ_{gr} = 31 deg. at 480 MeV

θ_{gr} = 35 deg. at 450 MeV

θ_{gr} = 39 deg. at 420 MeV

Angular distributions of fragments according to GRAZING_9 code:





R. Grzywacz et al., PRL81, 766 (1998)
I. Hossain et al., PRC58, 1318 (1998)

Angular distributions for ^{78}Ga produced in ^{80}Ge on ^{124}Sn collisions

(-p,-n)

Reaction: ^{80}Ge beam at 5-6 MeV/nucleon on a few mg/cm^2 ^{124}Sn target

Beam energy loss in the target dE/dx =18 MeV per 1 mg/cm^2

Projectile-Like Fragments emission between 20 and 40 deg. (LAB)

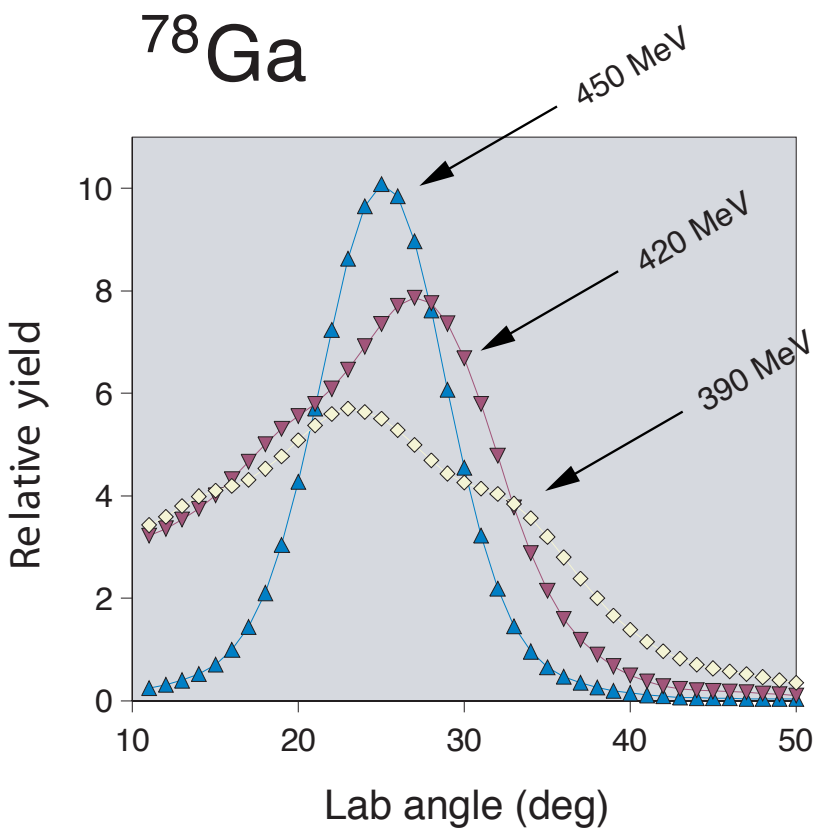
Grazing angle:

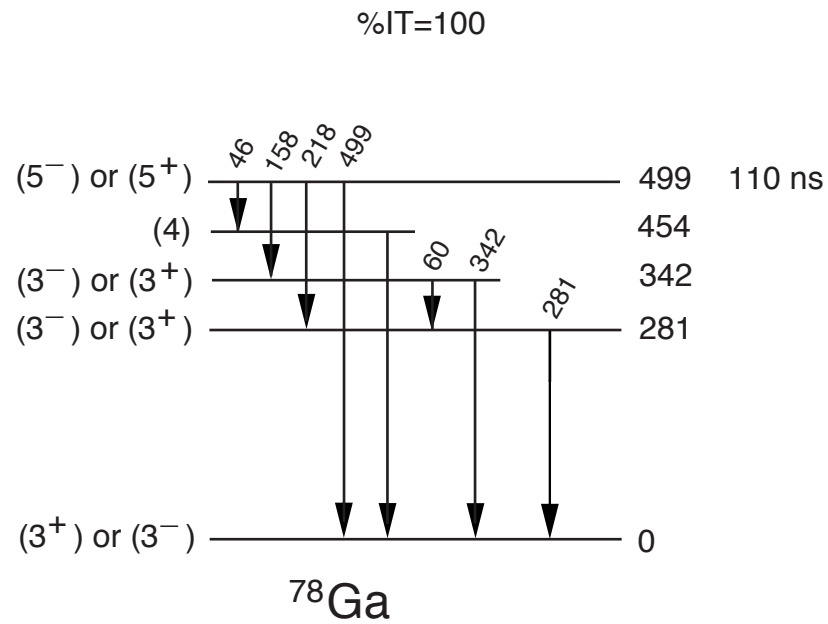
θ_{gr} = 35 deg. at 450 MeV

θ_{gr} = 39 deg. at 420 MeV

θ_{gr} = 44 deg. at 390 MeV

Angular distributions of fragments according to GRAZING_9 code:





J.-M. Daugas, GANIL-T 99 05 (1999)

Angular distributions for ^{88}Br produced in ^{89}Br on ^{64}Ni collisions

Reaction: ^{89}Br beam at 3-4 MeV/nucleon on a few mg/cm^2 ^{64}Ni target

Beam energy loss in the target dE/dx = 26 MeV per 1 mg/cm^2

Projectile-Like Fragments emission between 15 and 40 deg. (LAB)

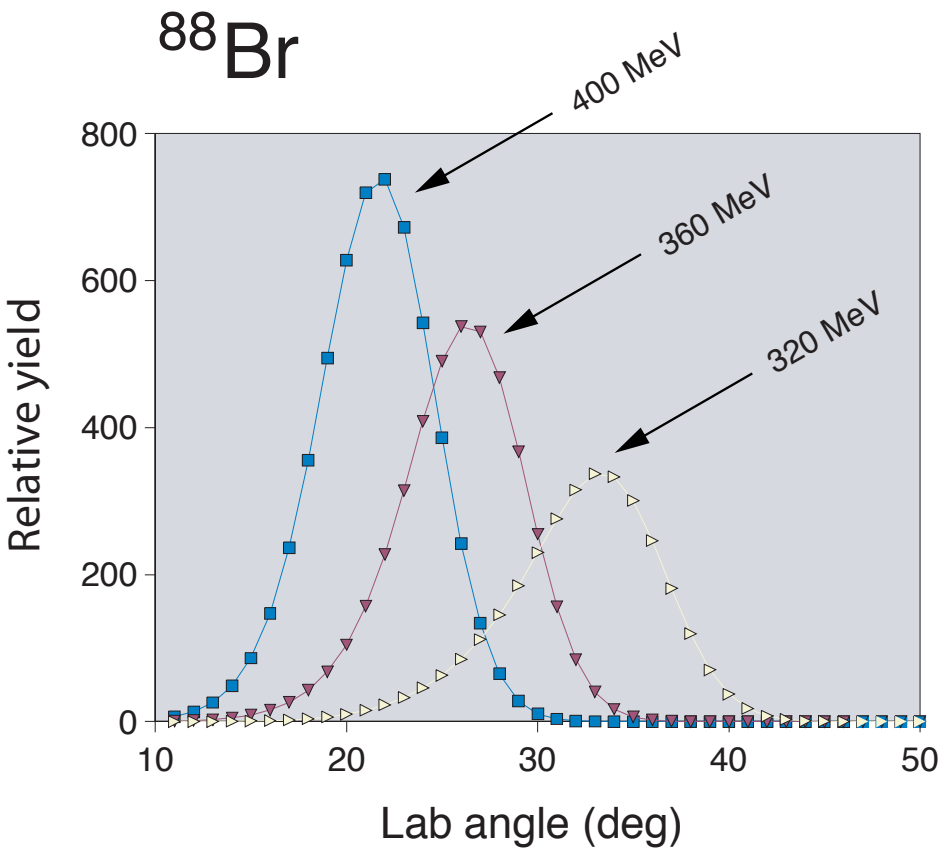
Grazing angle:

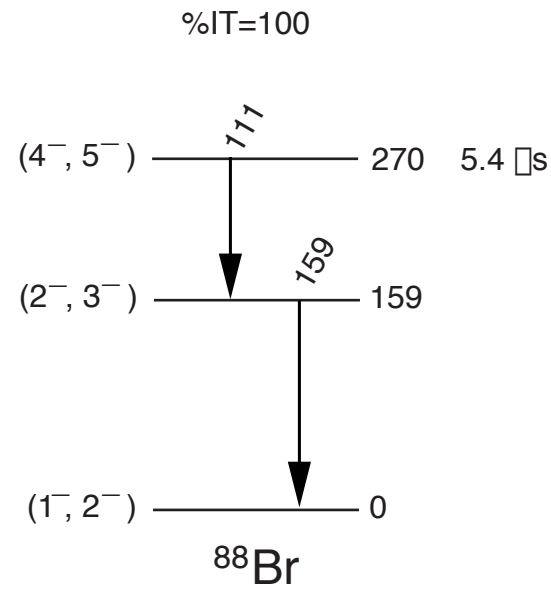
θ_{gr} = 26 deg. at 400 MeV

θ_{gr} = 31 deg. at 360 MeV

θ_{gr} = 37 deg. at 320 MeV

is it possible to inverse the kinematics and detect "heavy" PLFs keeping the same angular coverage of the setup ?





J.W. Gruter et al., PLB33, 474 (1970)

Radioactive beam rate estimates

80Ge	7.2E+06 pps	off platform with a 10 μA proton beam	
	3.9E+05 pps	at 480 MeV	Tandem 24 MV, double foil strip
	4.6E+05 pps	at 450 MeV	Tandem 23.3 MV, double foil strip
89Br	4.3E+06 pps	off platform with a 10 μA proton beam	
	2.0E+05 pps	at 400 MeV	Tandem 23.5 MV, single foil strip
	9.0E+05 pps	at 360 MeV	Tandem 24.0 MV, single foil strip
	1.05E+06 pps	at 320 MeV	Tandem 22.8 MV, single foil strip

Experiments of T. Ishii et al. used beams of 0.1 pnA = 6.25E+08 pps and were sensitive to isomers populated with cross-sections greater than 10 μb

Isomer-scope for experiments with neutron-rich radioactive beams

Oak Ridge National Laboratory, University of Tennessee, Vanderbilt University

- A ΔE-E ionisation chamber - Si detector proposed instead of thin-thick Si ΔE-E setup of T. Ishii.
- GRAZING code indicates that an angular coverage of 20-40 deg. allows measurements of PLFs in both normal and inverse kinematics.
- To reach suitable energies of Ge beam (30-50% above the barrier) double stripping is needed. This means very low beam intensity.
- For Br beams on lighter target (inverse kinamatics) one foil stripper is enough but high Tandem terminal voltage is required.
- By comparison with the Isomer-scope results (beam intensity/sensitivity) the instrument should be sensitive to test-case isomers populated with millibarn cross-sections with currently available RIB intensities.