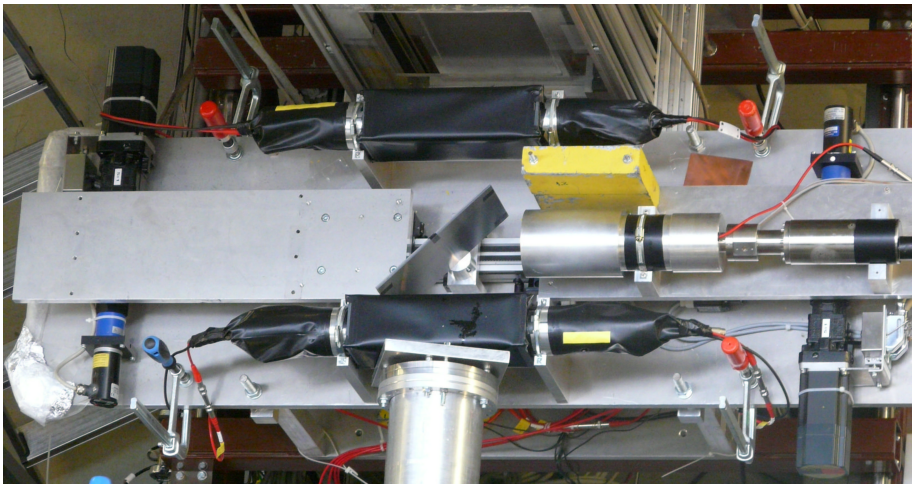
ITAG Manual



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Contents

1 Technical details **2**

1.1 Construction 2

1.2 Electronics 3

1.3 Efficiency 6

2 Operation **6**

2.1 GO4 on-line analysis 8

2.2 SD controller 9

3 Results **9**

3.1 March 2009 9

ITAG (Isomer TAGging detector) is a composite detector developed at the FRagment Separator (FRS) for isotope identification by isomer tagging. It is placed at the final focal plane of the FRS and detects γ-rays emitted from isomeric states in fragments implanted into its stopper. By an on-line analysis, the gamma lines pattern are recognized, allowing to identify the isomers and then all the secondary fragments produced. The identification procedure based on isomers can confirm or supply the standard techniques based on the time of flight and the energy loss.

ITAG was succesfully tested in March 2009 and was used during the S272 (March 2010) and E084 (July 2010) experiments. ITAG is now available as a standard FRS detector.

1 Technical details

1.1 Construction

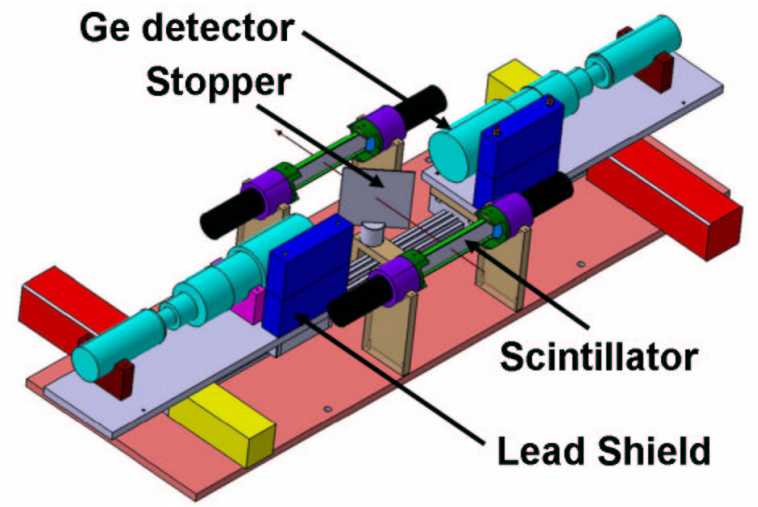

Figure 1: Schematic drawing of ITAG detector.

ITAG consists of two movable Germanium (Ge) detector electro-mechanically cooled, two plastic scintillators and an exchangeable passive stopper (see Fig. 1). The support is 50 cm long and 140 cm wide. A shield made by 50 mm thick lead layer is forseen to protect the Ge crystals from radiation coming from the beam

line. The Ge crystals are mounted on moving tables to get as close as possible to the stopper maximizing the photopeak efficiency, that ranges from $\sim 0.4\%$ at 90 mm to 0.2% at 150 mm for γ-rays of 1.3 MeV (Fig. 6). Each Ge-crystal was installed in a specially developed cryostat (Fig. 2) which replaces PopTop adaptor (not suitable due to its weak thermal connection within the cold finger path) and improves considerably the heat transfer with the electromechanical cooling engine X-Cooler II produced by ORTEC . The cooling system was tested by scanning the whole volume of the crystal with collimated γ-sources. The energy resolution (FWHM $\approx$1.2 keV at 60 keV) was found to be constant and in good agreement with the expectation, proving the uniformity of temperature and sufficient cooling.

The plastic scintillators (BC420, 274 mm x 45 mm and 5 mm thickness) are used to count the particles and to control their implantation in the stopper. The second scintillator acts as veto detector.

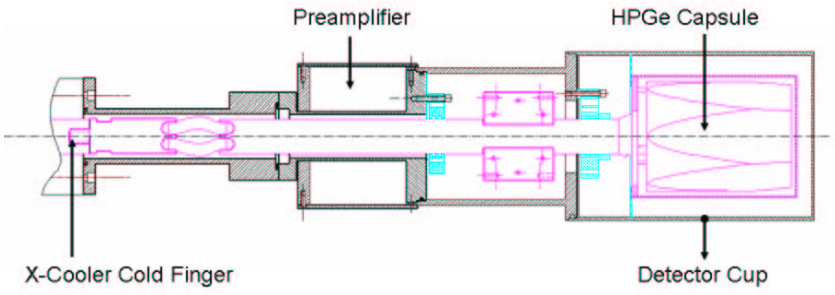

Figure 2: Schematic drawing of the cryostat.

1.2 Electronics

Each individual germanium detector has two parallel pre-amplifier outputs: one provides the energy signal and is sent to an amplifier and then goes directly to a peak-sensing ADC; the gate to the ADC is produced from the FRS accepted trigger. The energy signal is processed inside S4 area in order to preserve the energy resolution of the detector. The second output from the germanium pre-amplifier travels from S4 area to FRS-Messhuette and is sent to an analogue timing branch composed of a Time Filter Amplifier, a Constant Fraction Discriminator and a Time-to-Amplitude Converter. The TAC measures the time interval between the

arrival of a fragment (signal from Scint41) and the detection of a γ-ray. The TAC range is ~ 8 μs. The output of the CFD is also sent to a scaler. Each germanium detector needs a positive high voltage (the exact value depends on the encapsulated crystall installed and is written on the cryostat. Presently the operational high voltage value is +4000 V) and a preamp power supply. The block scheme of the germanium electronics is shown on Figure 3.

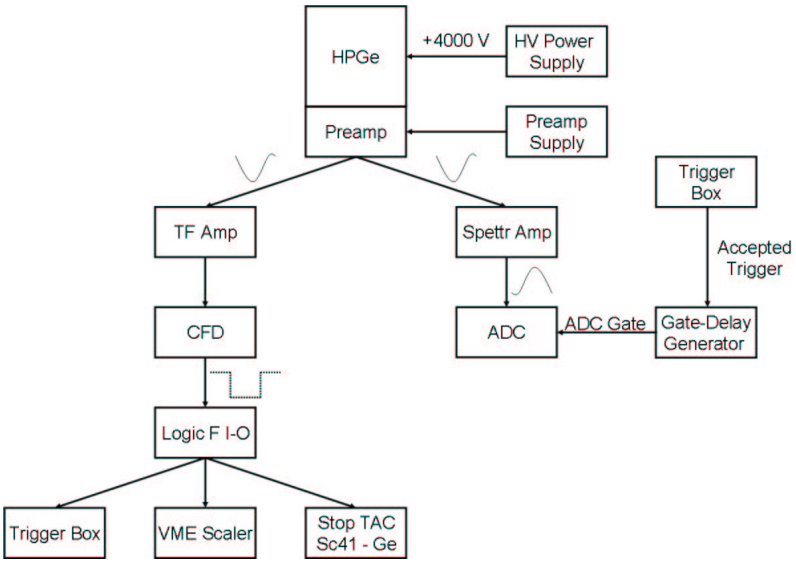

Figure 3: Block scheme of the germanium electronics.

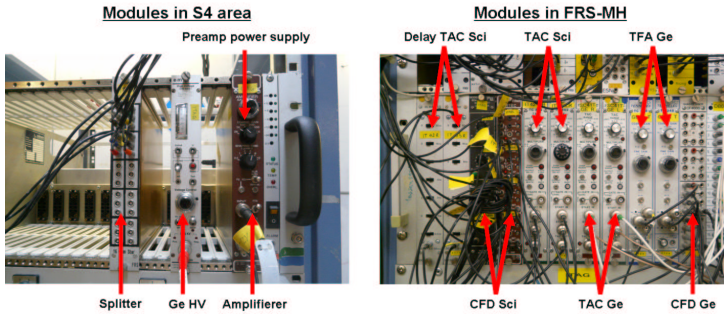

Figure 4: NIM modules used in S4 area and in FRS-Messhuette.

The electronics required for the scintillators is standard: a splitter divides the anodic signal from each photomultiplier tube, then the two signals travel to FRS-Messhuette where one is attenuated, delayed and sent to a QCD to measure the energy loss in the plastic scintillator. The second signal is sent to a CFD, its

outputs produce the coincidence Left-Right. The block scheme of the first plastic scintillator is shown on Figure 5.

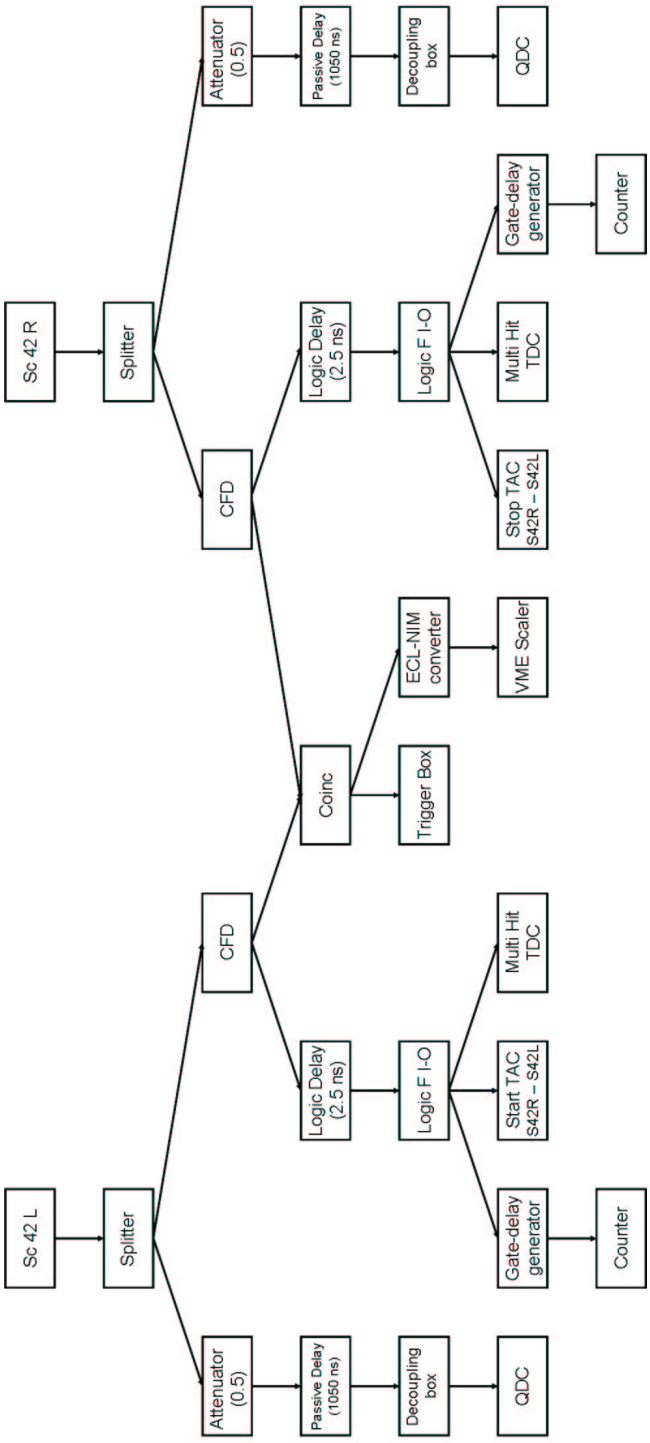

Figure 5: Block scheme of the electronic of the first plastic scintillator.

1.3 Efficiency

To determine the efficiency for detecting γ-rays, an absolute efficiency calibration of the Ge detector is needed. Due to the large size of the beam spot and the varying implantation depth, it is important to take into account the geometry of the setup and the absorption in the stopper material. Calibration spectra were recorded using ^{60}Co source with known activity placed at different positions along the x-direction of a 14 mm thick PVC stopper and then varying the distance detector-stopper (Fig. 6 left panel). The energy dependence of the efficiency was measured using a ^{152}Eu source with known activity. The results are shown in Fig. 6 right panel.

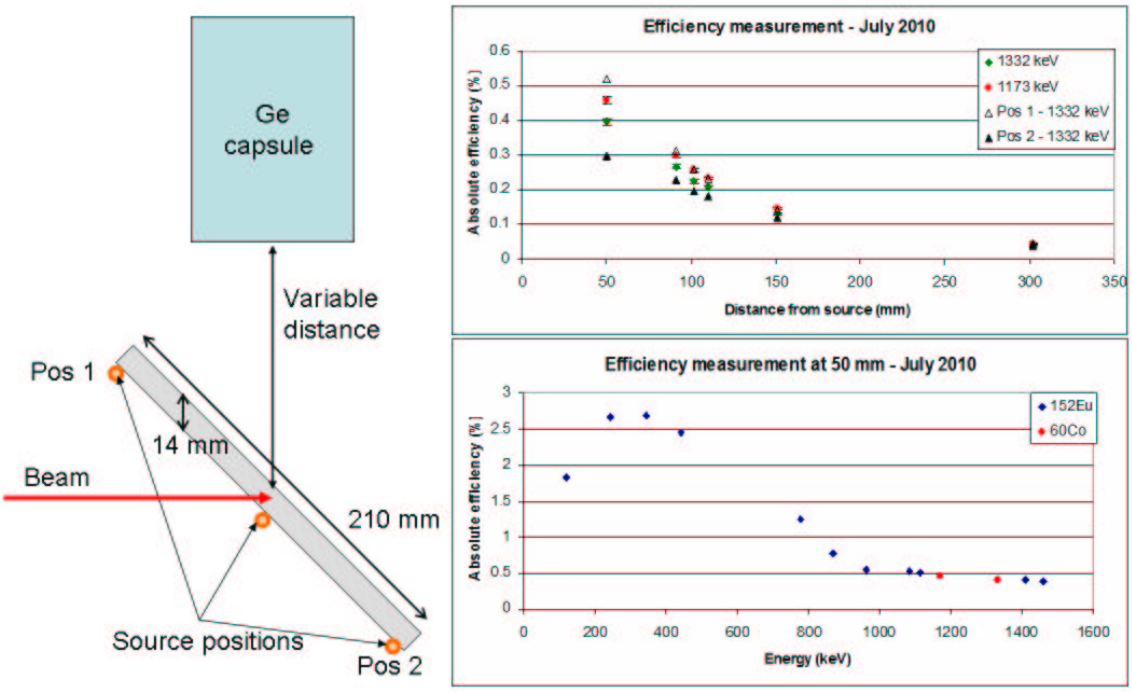

Figure 6: Efficiency measurement setup (left), efficiency vs position (top) and efficiency vs energy at 50 mm from source (bottom).

2 Operation

To operate the Isomer Tagger, before the beamtime starts it is necessary to:

1. Install and cool down the Ge crystal. The Ge detectors have to be handled and held only from marked surfaces (the cryostat cup is a very sensitive part) and have to be isolated from the frame ground. The power supply of the X-cooler II has to go through isolating transformer. After turning on the electro-mechanical cooler, it takes ∼1 day to reach 100 K. The cooler hose should not be bent strongly. Cable the Ge detectors (HV for Ge, power supply for preamp, signals for energy and time branch).

2. Mount the scintillators, stopper and shielding on the support. Cable the photomultiplier for the scintillators (HV for PM and signals).

3. Turn on the HV. Increase slowly, every 500 V wait $\sim$ 30 min, the HV for Ge up to the operational voltage.

4. Perform the energy calibration of Ge with ^{152}Eu source.

5. Calibrate the TACs Scint41-Ge (range $\sim$ 8 μs) and the other TACs (range $\sim$ 25 ns) with a Time Calibrator.

6. Check with the SD program if the Ge moves as expected.

Just before starting beamtime:

1. Move the lifting table to the out position to protect the Ge.

2. Raise HV on PMs (from -1400 V to -1800 V depending on the fragments).

3. Check QDC and TAC signals.

4. Check signals from Ge (energy and time).

5. Scan the degrader thickness to be sure to implant the fragments into the stopper.

6. Only if the rate at S4 is lower than few kHz, move the Ge to the closest position.

7. Start measurements.

To shut down the system:

1. Turn off the HV on PMs.
2. Decrease slowly, every 500 V wait $\sim$ few minutes, the HV for Ge. After the voltage is off wait few more minutes to ensure the complete discharge of the crystal. Then, it is possible to unplug the HV cable.
3. After turning off the HV for Ge, it is possible to turn the cooler off and remove the Ge detector.
4. It is then eventually possible to remove all the other components (scintillators, stopper and support).

2.1 GO4 on-line analysis

Several GO4 versions were prepared to work with ITAG. The latest version (July 2010) is available here: To get a fast identification procedure the analysis steps are the following:

1. Produce the spectrum energy loss in MUSIC vs TOF(S2-S4);
2. Select the expected isomer;
3. Include some conditions to clean the gamma spectrum;
4. Look for γ-lines and eventually for the half-life of the isomeric state;
5. Calibrate the identification matrix Z vs AoQ.

Regarding ITAG, this GO4 on-line analysis shows most of the important spectra:

1. for Ge:
    - energy raw and calibrated;
    - TAC Scint41-Ge calibrated;
    - matrix Ge energy calibrated vs TAC Scint41-Ge calibrated;
2. for scintillator:
    - QDC spectra;

- matrix energy loss in MUSIC vs QDC energy;
- matrix QDC Scint42 vs QDC Scint43.

3. for identification:

   - matrix energy loss in MUSIC vs TOF(S2-S4);
   - reconstruction of position at the stopper.

It is also possible to produce some conditions and cuts on the matrix energy loss in MUSIC vs TOF(S2-S4) and plot the matrix Ge energy calibrated vs TAC Scint41-Ge calibrated only for a specific fragment.

Even if GO4 can be used to perform the analysis of ITAG data, it is faster to produce and analyze *ROOT* files.

2.2 SD controller

The moving tables holding the Ge are remotelly controlled via the SD program. The table are named according to the direction of the beam. The step motor are called HFSEM1GL (left) and HFSEM1GR (right). The position shown in Remote control are in mm. The minimum position usable is 80 mm. At around 75 mm there is a stop position. The motor cannot reach a smaller position. The out position is set at 300 mm.

3 Results

3.1 March 2009

During an FRS000 experiment, a primary $^{96}Ru^{42+}$ beam at an energy of 500 MeV/u and a maximum intensity of $\sim 10^5$ ions/s impinged on a 2.5 g/cm^2 Be target. The FRS was used in achromatic mode and optimised for the transmission of ^{94}Ru ions. The ions were slowed down and implanted into the 3 mm thick Al stopper of ITAG. The identication of the reaction products was performed using the standard time of flight and energy loss techniques and the ITAG.

- Total counting rate at S2 : 4.5kHz

- Total counting rate at S4 : 2.0 kHz

Two isomers (^{90}Mo and ^{92}Tc) were identified using this procedure and the results are listed in the table below.

	Production	γ-counts	γ-lines (MeV)	$T_{1/2}$ (μs)
^{92}Tc	1.3×10^5	95	214.2 ± 2.9	1.04 ± 0.3
^{90}Mo	8.6×10^4	180	809.9 ± 3.0 947.7 ± 3.0 1053.9 ± 3.1	1.13 ± 0.16

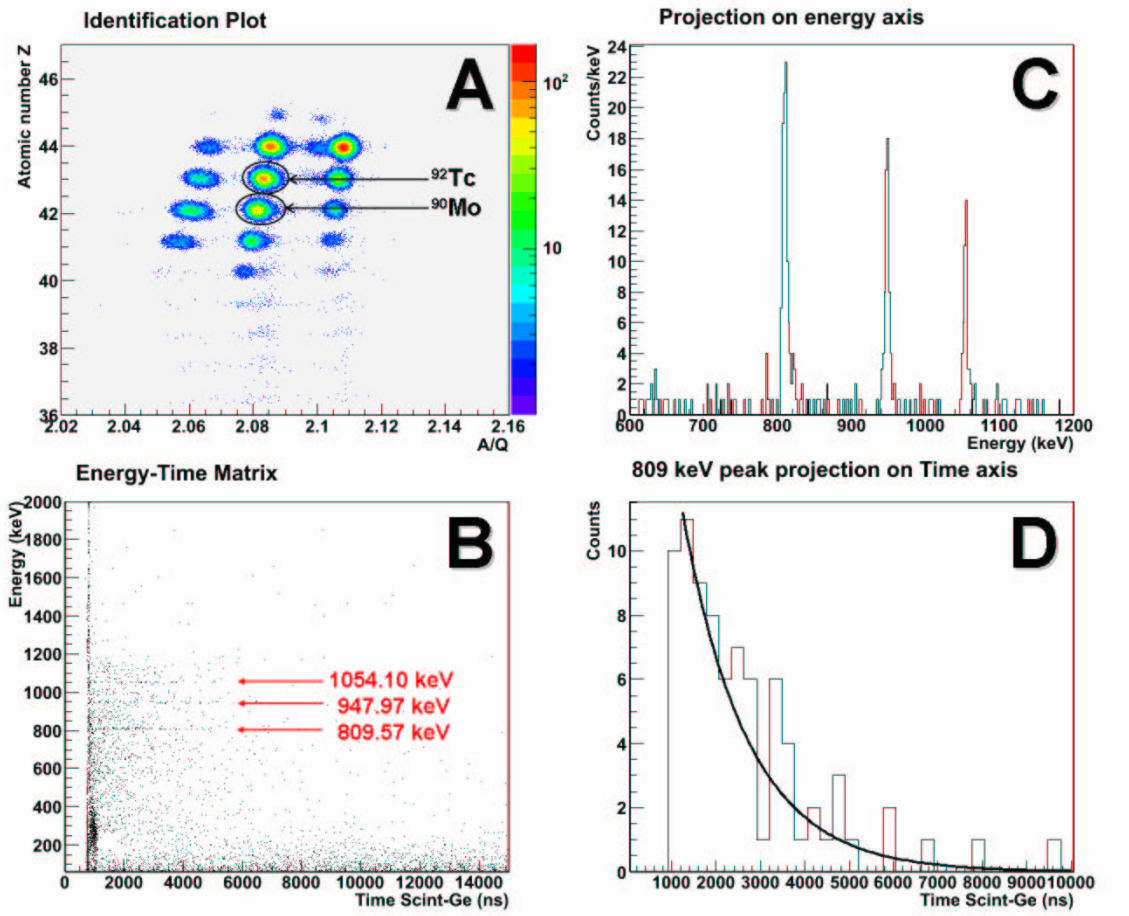

Figure 7: On-line analysis steps: identification matrix (A); ^{90}Mo γ-energy and time correlation matrix (B); ^{90}Mo gamma lines (C) and ^{90}Mo half-life (D).