## TASCA Task Groups

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1 Introduction

TASCA is a gas-filled separator to be built at GSI for chemistry and physics experiments for heavy and superheavy nuclei. It will be served by beams of the GSI heavy ion accelerator UNILAC. The location of TASCA in the UNILAC experimental area and a schematic drawing of its various components are shown in Fig. 1 and 2, respectively.

![Figure 1](https://www-w2k.gsi.de/tasca/)

Figure 1 The UNILAC experimental hall with TASCA at X8/9.

The primary beam will be separated by the magnetic dipole, and the reaction products will be transported to the focal plane by a quadrupole dublett where they will be used for chemistry and physics experiments. More details of the separator you can find on the following webpage [http://www-w2k.gsi.de/tasca/](http://www-w2k.gsi.de/tasca/).

In this document a proposed focal plane set-up for the physics experiments will be discussed on the basis of the experience made with existing set-ups, mainly the GSI velocity filter SHIP and the gas-filled separator RITU at the Jyväskylä accelerator laboratory. In particular, possible detectors and electronics needed for decay spectroscopy experiments will be described. It is meant to serve as a basis for the discussion necessary to produce a final design.
Various detection schemes are presently used to perform nuclear structure studies.

- RDT - Recoil Decay Tagging has proven to be one of the most powerful tools to study the nuclear structure of exotic species. Here the reaction product is identified by its decay after separation. Additional A/q information could improve the background reduction.
- RT- Recoil Tagging uses the Z- and A-information of the reaction product provided by a spectrometer set-up to obtain spectroscopic information in coincidence with the in-beam detected γ-rays.
- DT – Decay Tagging provides spectroscopic information on the decay products of long lived nuclei or isomeric states after separation.

They are applied at various set-ups. At the RITU gas-filled separator the in-beam technique RDT is used as well as the stopped source method of DT. RT including Z- and A-measurement is pursued at large acceptance spectrometers like PRISMA and VAMOS at Legnaro and GANIL, respectively. One of the arguments to favour decay spectroscopy experiments at GSI is that the beam related background limiting the count rate in the γ-detectors for in-beam techniques is absent in the clean environment after separation and the high current beams of the UNILAC accelerator can fully be exploited. The set-up scheme used at SHIP shown in Fig. 3 is together with the GREAT spectrometer built up at RITU (Fig. 4) the basis for the arrangement discussed here for TASCA. The SHIP focal plane detector set-up consists of the following components:
• a position sensitive 16-strip PIPS detector ("stop") for implanted reaction products and subsequent decays (α, sf, protons or electrons)
• a backward box array consisting of 6 Si-chips similar to the "stop"-detector but with lower granularity for escaping α-particles and fission fragments, and to some extend for conversion electrons (CEs)\(^1\)
• a highly efficient germanium CLOVER detector to measure γ-rays and high energy (K) x-rays
• channel plate based transmission detectors for beam related background veto and time of flight (TOF) purposes

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Figure 3: Schematic view of the detector set-up at SHIP, showing the arrangement of α-, γ-, conversion electron (CE) detectors and transmission detectors for time of flight and veto purposes.

The GREAT assembly is similar:

• a double-sided silicon strip detector fulfilling similar tasks as the SHIP "stop" detector
• an array of silicon PIN diodes which in addition are optimized for detecting CEs down to low energies
• a double-sided planar germanium strip detector to measure the energies of X-rays, low energy γ rays and β particles
• a high efficiency segmented germanium CLOVER detector to measure the energies of higher energy γ rays
• a multi-wire proportional counter for veto and TOF purposes

\(^1\) only for special cases with relatively high CE energies
In addition a veto-Si-detector can be mounted after the stop-detector in both set-ups to detect weakly ionizing particles passing through the Si-chip.

2 Detectors

For TASCA the set-up scheme shown in Fig. 5 could serve as a basis for the discussions, certainly necessary to approach the final design. Its components are:

- a position sensitive stop detector
- a backward PIN diode array for escape $\alpha$-particles, fission-fragments, CE and $\beta$-particles
- a highly efficient Ge CLOVER-detector
- two planar Ge X-ray detectors
- transmission detector(s).
Figure 5 Scheme of a possible detector arrangement for TASCA.

2.1 STOP Detector

The stop detector is the first component to be put in place as it is essential for the first tests of TASCA. Therefore, a PIPS detector of the type presently used at SHIP is proposed. Its dimensions are 80 mm × 35 mm × 300 µm. The strips are position sensitive by charge division in the resistive surface layer. It is shown together with the mechanical support structure of transmission type in Fig. 6.
The best achieved energy resolution obtained is 14 keV. The position resolution of the resistive surface layer is of the order of 200 µm. It delivers with the read-out on either side of each strip 32 signal outputs.

A future option is a double-sided silicon strip detector (DSSD) as used in various places. A very compact and promising version is the DSSD detector from the MUST2 array shown in Fig. 7 developed by L. Pollacco et al.\textsuperscript{2} It has a 100 ×100 mm$^2$ surface area divided in 128 ×128 strips (front-back) with 300 µ in thickness. This detector is operated together with other detection components and read out by an integrated ASICS electronics which provides a highly integrated analogue signal elaboration including functions like preamplifier, main amplification and timing discrimination (leading edge discriminator LED). The dynamic range, however, has to be adjusted to the needs of ER, sf and α-particle measurements.

\textbf{Figure 6} 16 strip position sensitive PIPS detector with mechanical support in transmission mounting as used presently at SHIP.

\textbf{Figure 7} MUST2 detector array. Schematic drawing (upper panel) and photos showing the front side of the chip (lower left panel) and the rear view with printed circuit board.

\textsuperscript{2} private communication
At the fragment mass analyzer FMA at the Argonne National Laboratory (ANL) a DSSD is mounted in the focal plane for similar purposes

### 2.2 Backward Detector Array

One possibility for the backward detector array consists of a PIN photodiode solution similar to that of the GREAT set-up. 32 silicon PIN diodes, mounted in the backward hemisphere of the stop detector, serve to measure the energies of conversion electrons emitted by the implanted nuclei and/or their subsequent decay products. Their dimensions are $28 \text{ mm} \times 28 \text{ mm}$ with a thickness of 0.5 mm. Their low intrinsic noise allows for a high energy resolution and a low energy threshold.

The mounting has to be optimized to achieve

- as little as possible dead space for the highest possible efficiency
- as small as possible effective thickness to allow for X-ray detection behind the array (transmission mounting; see section 2.3.2).

This should be taken into account while designing the support structure and for the proper choice of the silicon thickness. In addition to CE, escape $\alpha$'s and fission fragments will also be detected.

![RITU silicon PIN photodiode array. Left panel: PIN diode modules mounted on printed circuit boards. Right panel: PIN diode arrays mounted around the stop detector (top array removed for better illustration).](image)

### 2.3 Photon Detectors

Ge detectors will be used to measure $\gamma$- and X-rays. The $\gamma$-rays emitted from isomeric states of the implanted ERs and/or excited levels populated by $\alpha$-decays in the daughter nuclei will be measured by a Ge Clover detector allowing with its four crystals for $\gamma-\gamma$ interactions.
coincidence measurements. To measure X-rays planar Ge detectors will be mounted in close geometry (see Fig. 5).

### 2.3.1 Gamma-ray Detector

At SHIP a VEGA type Clover has been used (Fig. 9) and it is one option also for TASCA. Some of its main properties are listed in the following:

- 4 crystals, (70×70×90)mm$^3$ each
- energy resolution at 1.3 MeV: $\approx 2.5$ keV
- nominal efficiency per crystal: $\varepsilon_\gamma = 23\%$ at 1.3 MeV
- total efficiency from $\alpha$-\(\gamma\) coincidences $\varepsilon_{\exp} = 15\%$ at $E_\gamma = 150$ keV

![VEGA Clover detector.](image)

The SHIP clover detector with slightly smaller dimensions (50×50×70 mm$^3$) and slightly less nominal efficiency ($\varepsilon_\gamma = 20\%$ at 1.3 MeV) could be used instead as it covers with its 100 mm × 100 mm sensitive surface the whole stop detector area.

### 2.3.2 X-ray Detector

Two crystals 40 × 40 mm$^2$, 20 mm thick are available from SHIP. Their nominal energy resolution is:

- 0.5 keV FWHM at 5.9 keV
- 0.7 keV FWHM at 122 keV
- 1.9 keV FWHM at 1.33 MeV
Both detectors are presently mounted in a common housing with a single dewer so that a new support has to be designed for the mounting proposed in Fig. 5.

### 2.3.3 Transmission Detector(s)

For veto and ToF purposes one or two transmission detectors or planned before the box and stop detector. At SHIP a detector type based on micro channel plates is mounted (see Fig. 10), which uses an electric field for acceleration and a magnetic field for deflection of the electrons created in C-foils by the passing particles. A pair of detectors using electrostatic deflection with an active area of $\approx 57 \text{ cm}^2$ previously used at SHIP is available. Channel plate bases detectors require operation in vacuum so that the gas volume of TASCA has to be separated by a window. A sealed position sensitive gas counter would be an alternative. For low energy particles transmission detectors might not be used at all because of the additional energy loss they introduce.

**Figure 10** Two of the three transmission detectors mounted at SHIP.

### 3 Electronics

#### 3.1 Analogue Electronics

As a first step a copy of compatible parts of the SHIP electronics is proposed. The layout is shown in Fig. 11. The 16 strips of the stop detector and the various elements of the backward array are both processed in 2 branches of different amplification for $\alpha$- particles and ERs/fission fragments, respectively. The 16 strips of the stop detector are organized in groups of odd and even numbers and multiplexed in groups of eight. The strip and box element numbers are sorted in bit patterns. The preamplifiers, amplifiers and mixers are GSI in house developed modules. A complete set of electronics for a 16 strip stop detector set-up is available from RITU.
Figure 11 Scheme of the analogue electronic built up at SHIP for the stop detector and the backward array. Two dynamic ranges (amplification 1 and 10) are created for α- particles and ERs/fission fragments respectively. For both ranges the energy signals as well as both position signals are processed.
3.2 Data Acquisition System

At SHIP a new data acquisition electronics set-up has recently been implemented. It is based on the ADC-multiplexer module AMUX 2 developed by the GSI electronics workshop. Each of these modules can control four Silena 7423 ADCs. It has an onboard time with a granularity of 25 ns. The data handling is including, apart from the list mode data transfer, onboard histogramming and programmable logic operations by an onboard FPGA. The list mode data is transferred to a SAM4 module, also a GSI in house production that serves for event building and communication with the DAQ CPU, a RIO2 power pc processor which transfers the final data stream to mass storage and online analysis. Each SAM module can handle via 2 GTB bus daisy chains 15 AMUX modules for each chain branch. A scheme of the AMUX-SAM architecture is shown in Fig. 12.

The new SHIP data acquisition electronics based on the ADC multiplexer unit AMUX.

This electronics provides a random trigger configuration where the first ADC firing triggers the read out cycle. An alternative approach would be a time stamp based architecture as the GREAT– Triggerless Total Data Readout (TDR) which provides the following features:

- 14bit (16k) ADC's
- triggerless
- 100 MHz clock for timestamping
- metronome for synchronisation

![Diagram of AMUX-SAM architecture]
- DSP technology for data moving
- histogramming possible

A schematic view is shown in Fig. 13.

**Figure 13** Schematic view of the Triggerless Total Data Readout (TDR) of GREAT at RITU.
4. Summary of set-up components

In the following a summary of the set-up components is given. Some of the components are presently already available, at least on a loan basis. For these the source is given on the right:

**source**

1. position sensitive 16 strip-Si-detector
   a. Si-chip \( \text{SHIP/GSI} \)
   b. support structure \( \text{SHIP/GSI} \)
2. Silicon PIN-diode array for the revelation of escape \( \alpha \)-particles, fission fragments and conversion electrons
   a. Si-chips (28+10)
3. highly efficient germanium CLOVER-detector to measure \( \gamma \)-energies \( \text{SHIP/GSI} \)
4. 2 planar Ge-detectors for X-rays \( \text{SHIP/GSI} \)
5. transmission detectors on channel plate basis \( \text{SHIP/GSI} \)
6. electronics
   a. power supplies
   b. analogue electronics (partly \textit{RITU/JYFL})
   c. data acquisition
      i. ADC (10 pieces) \( \text{DVEE/GSI} \)
      ii. AMUX (5 pieces)
      iii. SAM
      iv. VME-crate + CPU
   d. dual-processor computer (for online-analysis)

This list is only a first assumption and is by no means final. I will certainly be subject of the discussion which should be initiated by this document.