EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

(Following HIE-ISOLDE Letters of Intent I-119, I-191, I-194, I-195
and Memorandum INTC-M-020)

The SpecMAT active target

January 13, 2020

R. Raabe[1], A. A. Arokjaraj[1], A. Ceulemans[1], H. De Witte[1], S. Fracassetti[1], M. Latif[1], T. Marchi[2], A. Mentana[1], O. Poleshchuk[1], M. Renaud[1], A. Youssef[1], the ACTAR TPC Collaboration[3], and the ISS Collaboration[4]

[1] *KU Leuven, Instituut voor Kern- en Stralingsfysica, 3001 Leuven, Belgium*
[2] *INFN, Laboratori Nazionali di Legnaro 35020, Italy*
[3] *CENBG, GANIL, INFN-LNS, KU Leuven, University of Huelva, University of Regina, University of Santiago de Compostela*
[4] *University of Liverpool, University of Manchester, UKRI-STFC Daresbury, KU Leuven, CERN*

Spokesperson: [Riccardo Raabe] [riccardo.raabe@kuleuven.be]
Contact person: [Liam Gaffney] [liam.gaffney@cern.ch]

CERN-INTC-2020-013 / INTC-I-214
13/01/2020

Abstract: The SpecMAT active target is being tested at the KU Leuven prior to shipping to CERN, which is foreseen in the early spring of this year. Placed on the second beam line of HIE-ISOLDE inside the ISS spectrometer, SpecMAT will be used to measure direct-transfer reactions for the study of single-particle and collective states in nuclei far from stability.

Requested shifts: —
Installation: SpecMAT inside the ISS magnet

This Letter of Intent confirms the commitment of the research group at the KU Leuven to perform experiments at HIE-ISOLDE using the SpecMAT active target.

The Memorandum INTC-M-020 [1] describes the physics case of the instrument and its characteristics. In the present document we summarise the Memorandum very briefly and we give an update of the progress and current status.

– *Physics* –

The physics aims of the SpecMAT project are concerned with the evolution of the shell structure in nuclei far from stability, studied through the measurement of the single-particle content of selected states populated in transfer reactions.
The first measurements will focus the neutron-rich Ni region and the n-deficient Pb region. In the neutron-rich Ni region the specific motivation relates to the effect of the tensor part of the nucleon-nucleon interaction, that can be measured through the shift in energy of the proton and neutron orbitals on chains of isotopes and isotones towards ^{78}Ni. In the same region and in the neutron-deficient Pb region, the interest lies in the interplay between single-particle and collective degrees of freedom and the origin of shape coexistence. Nucleon-transfer reactions are a well-established tool to study the single-particle structure of states in nuclei, and SpecMAT will allow measurements in inverse kinematics using very weak beams (10^4-10^5 particles per second) at HIE-ISOLDE. The letters of intent I-191 [2] and I-195 [3] address those cases.
In addition to the above, the possibility of studying the pigmy dipole resonance (PDR) in neutron-rich nuclei has also been explored in the letter of intent I-194 [4]. SpecMAT combines detection of γ rays and charged particles, thus potentially allowing the characterisation of the isoscalar and isovector parts of the PDR.

– *Technique* –

SpecMAT is an *active target* [5]: a time-projection chamber, where the detection gas is also the target of the reaction of interest. Tracks of the charged particles traversing the gas volume are reconstructed from the ionisation charges collected on a highly segmented plane. This allows the determination of the reaction vertex and kinematics, ensuring a good energy resolution in combination with a high luminosity.
In SpecMAT the energy of the light charged particles emitted in reactions can be inferred from the length and curvature of their tracks, bent in the magnetic field of the ISS solenoid where the detector is placed. A unique feature of SpecMAT, with respect to other active targets, is the array of $CeBr_3$ scintillators surrounding the active gas volume. The scintillators detect the γ rays emitted in the de-excitation of states populated in the reactions, substantially improving the energy resolution.
Figure 1 shows the components of SpecMAT. The field cage is a cylinder: the electric field, responsible for the drift of the electrons produced in the gas, is collinear with the beam direction. The scintillation detectors surround the field cage in close geometry.

– *Status* –

All the components of the detector are at the Instituut voor Kern- en Stralingsfysica of the KU Leuven. Some pictures are shown in Figure 2.
The array of γ-ray scintillators has been fully characterised and it is up to specifications. As well, the chamber has been tested for vacuum.
The commissioning of the full system and subsequent move to ISOLDE have been pushed back with respect to the initial planning. This was mainly due to a long delay in the production of

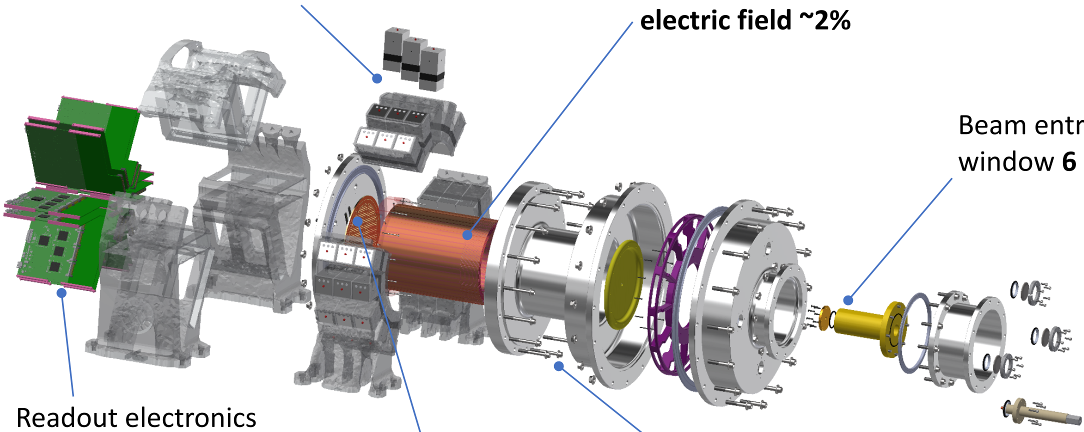

Figure 1: Exploded view of the SpecMAT detector with indication of the main components.

the field cage, which had to overcome technical issues. Additionally, we have decided to realise the full gas handling system in Leuven, based on the safety requirements of KU Leuven and CERN. We intend to bring the SpecMAT detector to ISOLDE in the early spring of this year.

– *Installation at ISOLDE* –

For the move to ISOLDE, all steps are coordinated within the ISS Collaboration.
SpecMAT will occupy the same space inside the solenoid as the array of silicon detectors that is used for reaction measurements in the "pure" solenoidal mode. The two detection systems use different rails, both designed to sit on the existing fittings of the solenoid. Switching between the two rail systems will be validated in January, when the SpecMAT rails will be transported to CERN. Figure 3 show the platform and rail system of SpecMAT. The design has been discussed with the CERN surveyors who will eventually perform the alignment of the detector.
When specMAT is used, the large flanges of the solenoid will not be installed; instead, the beam pipe will reach directly the SpecMAT chamber and the volume inside the solenoid will remain in air.
The footprint of the whole system will not increase with respect to the current situation. There are at present four cabinets placed outside the shield cage of the ISS, of which two are empty and will host the full SpecMAT electronics (integrated GET electronics [6]). The gas handling system will share the cabinet upstream of the solenoid, which already hosts the magnet monitoring system and vacuum gauges and controllers.
Finally, talks have been initiated in December 2018 with the HSE unit of CERN to ensure that SpecMAT complies with the CERN safety regulations concerning all relevant aspects (gas handling, electricity...). We are realising a gas handling system according to the indications of HSE experts of CERN and KU Leuven.

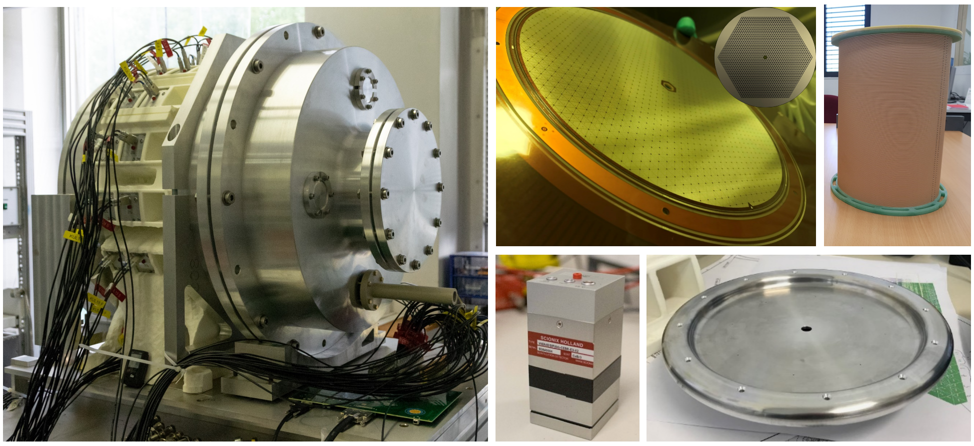

Figure 2: Clockwise from left: The SpecMAT chamber, resting on the platform that will be used to move it inside the ISS, and surrounded by scintillators embedded in their holding structure; the pad plane with triangular pads; the field cage, a bent PCB board with conductive strips printed on it; the cathode; one of the scintillation detectors.

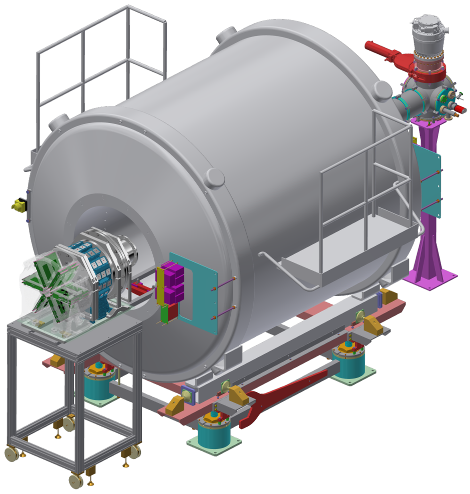

Figure 3: External platform and rails to slide the SpecMAT chamber inside the ISS magnet.

References

[1] R. Raabe, *et al.*, "The SpecMAT active target" (2018).

[2] O. Poleshchuk (spokesperson), *et al.*, "Letter of Intent to the INTC I-191: Single-particle proton states in ^{69}Cu" (2017).

[3] M. Babo (spokesperson), *et al.*, "Letter of Intent to the INTC I-195: Investigating single-particle configurations in deformed Hg and Cd isotopes" (2017).

[4] S. Ceruti (spokesperson), *et al.*, "Letter of Intent to the INTC I-194: Study of the Pygmy Dipole Resonance using an Active Target" (2017).

[5] Y. Ayyad, D. Bazin, S. Beceiro-Novo, M. Cortesi, and W. Mittig, Eur. Phys. J. A **54**, 181 (2018).

[6] E. C. Pollacco, *et al.*, Nucl. Instrum. Methods Phys. Res. A **887**, 81 (2018).