Proposal for TRIUMF Commitment (5YP 2015-2020)

Date:
September 17, 2012

PROJECT/COMMITMENT TITLE: TITAN & ion trap operation and R&D

PROPONENT: Jens Dilling **TRIUMF CONTACT:** Jens Dilling

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PROJECT DESCRIPTION:

Ion traps provide excellent experimental conditions for on-line experiments. The principle of ion traps can be applied to both, the preparation of the sample, as well as the storage and final experimental stage. Currently, there is one major ion trap facility at ISAC: TITAN. It consists of four principle components: a linear Paul trap (RFQ) for cooling and bunching the radioactive beam from ISAC. From there the beam can be further delivered as a bunched ion beam towards the subsequent ion traps or be reversely extracted for collinear laser spectroscopy. The next ion trap component is an electron beam ion trap (EBIT) which is used as a rapid charge breeder or (without the electron beam and charge breeding) as a storage ion trap for decay spectroscopy. After charge breeding the ions are delivered to a cooler Penning trap, where short-lived radioactive isotopes are sympathetically cooled using electrons and/ or protons. The next step is a Penning trap where precision mass measurements can be carried out.
The system is operational (the cooler Penning trap is currently being commissioned) and has a proven track record of being the fastest mass measurement system in the world (hence provides access to the shortest lived isotopes at an ISOL-type facility) and is able to reach very high precision. The decay spectroscopy experiments in the EBIT are set-up, and first on-line measurements have been carried out and have been published.
There are plans to extend the capabilities, to add a Multi-Reflection-Time-of-flight isobar separator system in between RFQ and EBIT, which will significantly enhance the reach of very n-rich isotopes, as well as provide clean samples for the decay spectroscopy.
Moreover, we plan to build a new ion trap system after the EMMA recoil separator, coupled to a gas-filled stopping cell (similar to what is used at SHIPTRAP, GSI, and at NSCL for LEBIT, as well as at ANL and the CPT system). The technology exists and could be coupled to EMMA to provide excess to very n-rich isotopes, which would be uniquely produced from n-rich secondary beams from ISAC and transfer reactions, to go even further n-rich (plus being independent of target chemistry and ionisation issues).

The project is two-fold: 1.) further developments to enhance the performance of TITAN,
2.) development and set-up of a ion trap system behind EMMA (EMMA-trap) including a stopper cell.

SCIENTIFIC JUSTIFICATION:

The atomic mass provides unique access to the nuclear many body system, as all effective interactions are reflected in its value. Moreover, precise and accurate masses are needed for tests of symmetry concepts, for neutrino physics, as well as for nuclear astrophysics, and nucleo-synthesis. Recent developments show the evolution of the classical magic numbers, and detailed theoretical and experimental studies are required to shed light on these phenomena as well as provide explanations.

TITAN is a well established ion trap system, and benefits from the large production yields from ISAC as well as from its sensitivity and ability to reach high charge states to boost the reachable precision. The unrivalled precision and accuracy for light n-rich (halo and island of inversion), as well as medium heavy isotopes (Rb & Sr for r-process path) is currently only limited by unwanted species, that can not be straight-forwardly be dealt with within the existing system. For this we are preparing a new multi-reflection time of

flight isobar separator (R~100.000) to provide clean samples to the ion traps (masses and decay spectroscopy). The technology has been around for some time, and has recently been adopted for on-line work (ISOLTRAP and Oak Ridge). We plan to add this system in between the RFQ and the EBIT for maximal impact on the science program.
In the second half of the upcoming five year plan, and after EMMA is fully operational we plan to add an ion trap system behind a stopper cell at EMMA. Transfer reactions of very n-rich beam will provide unique access to otherwise not accessible isotopes, and moreover, could make them accessible even if they would not come out of an ISOL-type target or ion source. The science motivation is nuclear structure of n-rich isotopes (for which we have a strong track record as well as theory connections), and the r-process path, which, in particular once ARIEL is operational, will become accessible with EMMA-trap. The trap system will consist of a gas-filled stopper cell, an extraction and guide RFQ, and a Penning trap system. The Penning trap could be for spectroscopy (beta and gamma spectroscopy) as well as for mass measurements. More detailed studies are needed.

RELATIONSHIP TO BROADER CANADIAN RESEARCH COMMUNITY:

The unique access of clean samples in a trap system will open up new research possibilities, including mass measurements, decay spectroscopy, and laser spectroscopy of highly charged ions. The Canadian researchers that are interested are coming from the decay spectroscopy group (also involved at TRIUMF), the nuclear astrophysics group, and CKM community.
The EMMA-trap facility will have significant impact, as it opens a new avenue for spectroscopy (decay, mass, and laser) to address a broad field of nuclear physics, primarily for nuclear structure and astrophysics. The details will still have to be planned out, and various options are under discussion.

BROADER IMPACTS:

The TITAN facility and the EMMA-trap facility will have its strongest impact in the HQP sector, with excellent opportunities to prepare undergraduate, graduate-students as well as post-graduate fellows for a career in the academic, scientific, or technical business sector. TITAN has an outstanding track record in terms of scholarships and awards for graduate students; from the last 8 graduate students 6 has scholarships, including a Vanier scholarship. The students went on to positions at Harvard (in combination with the E. Schroedinger fellowship), Stanford, Michigan State University, and as COE of a engineering company, to name a few.

MAJOR MILESTONES:

Description	Date
1.)TITAN upgrades and improvements: Multi-Tof installation and operation	2015
2.)Conceptual design of EMMA trap & TITAN measurements with Multi TOF	2015
3.)design of EMMA trap	2016
4.) manufacturing of EMMA trap system	2017
5.) set-up and commissioning of EMMA trap	2018
6.) EMMA trap operation and first experiments	2019
7.) extensions to EMMA trap for additional spectroscopy	2019

RESOURCE REQUIRMENTS:

CASH FLOW REQUIREMENTS						
\YEAR SOURCE \	ONE	TWO	THREE	FOUR	FIVE	TOTAL
TRIUMF	20k	20k	20k	50k	50k	160k
EXTERNAL	150k	100k	100k	500k	300k	1.15M
TOTAL						
TRIUMF NON-CASH RESOURCES						
\YEAR RESOURCE\	ONE	TWO	THREE	FOUR	FIVE	TOTAL
Design	0	0.2 FTE	1 FTE	0.1 FTE	0	1.3 FTE
Electrical	0.2 FTE	0.2	0	0.5	0.1	1 FTE
Control	0.2	0	0	0.3	0.1	0.6 FTE
Vacuum	0.2	0	0	0.2		0.5 FTE
Machine shop	0.1	0.	0	0.3	0.3	0.7 FTE
Electronic	0.1	0.1	0.1	0.1	0.1	0.5 FTE
DAQ	0.1	0	0	0.1	0.1	0.3 FTE
Beam optics	0.1	0.1	0	0	0	0.2 FTE

EXTERNAL FUNDING INFORMATION:

NSERC (TITAN) ~ 400k/year, NSERC (TITAN-ec) ~ 200k/year for EMMA trap we will ask CFI

ONGOING OPERATIONAL REQUIREMENTS:
1-2 FTE research scientists, 1 technician,

DECOMMISSIONING REQUIREMENT:

Accepted: Date: