The AT-TPC for the study of nuclear reactions induced by secondary beams

1) What is the primary physics motivation and experimental capability of the proposed instrument and why is this important for FRIB science?
The 1995, 2002 and 2007 Long Range Plans for nuclear physics identified opportunities at rare isotope beam facilities to determine the properties of nuclei and nuclear matter in the unexplored domain of extreme isospin asymmetry as priority research areas for the field. The Active Target-Time Projection Chamber (AT-TPC) will be used to study reactions induced by rare isotope beams at the National Superconducting Cyclotron Facility (NSCL) and at the future Facility for Rare Isotope Beams (FRIB). By nature, the intensity of secondary beams is limited, especially for beams composed of species far from stability, which are of primary scientific interest. In this domain, gaseous active targets, in which the detection medium acts as both target and detector, are a novel and essential tool that allow measurements to be made with both high resolution and sensitivity. With the proposed AT-TPC the resolution will be limited only by straggling phenomena. This will allow an unprecedented resolution to be achieved for inverse kinematics reactions, comparable to the best high-resolution magnetic spectrometer experiments conducted in normal kinematics.

2) What are the unique capabilities of this device that are not available in existing equipment? Is this instrument stand alone or is it to be used (solely or partially) in conjunction with other instruments. Could it be used at NSCL or other laboratories before FRIB?
The particle tracking in the magnetic field of the solenoid (2T) allows one to cover a broad range of recoil energies with a good resolution, and this tracking allows one to use thick targets without loss of resolution. Therefore reaction studies with beam-intensities down to 100-1000/s will be possible. This enables studies ranging from low energy measurements at ReA3 and Re12 of transfer and inelastic reactions, as well as fusion, resonance formation and decay, to high energy measurements at 100 - 200MeV/n of charge exchange, and inelastically excited giant resonances. The study with the AT-TPC of the Isospin dependence of the nuclear EOS is discussed in a separate document.

3) Describe the instrument in some detail – how does it meet the scientific requirements and what are the (estimated) performance specifications? Be brief but as detailed as you can. Is the design fixed or are multiple options still being discussed and encouraged?
The AT-TPC is a solenoidal TPC approximately 70 cm in diameter and 120 cm in length. It fits into the TWIST solenoid, allowing momentum analysis of emitted particles. Track information will be read out with approximately 10000 pads, using active target readout electronics that are currently under development. It will be filled with gases such as H2,D2, He, Ar, etc., as required by the reaction to be studied.

4) What is the current stage of development of your project ?
Electronics under development in the GET collaboration
General Layout defined, first localization in ReA3 defined
Reduced Prototype under construction and to be used with beam in autumn this year
Detailed Electromechanical Design to be done
Laser Calibration system to be done
Test of Gems and Micromegas done for some gases, explosive gases (H2,…) to be done
Decision on Gas Amplifying Device (wire, Gem, Micromegas) to be done

5) What is the approximate cost of the project: discuss possible sources of funding.
The AT-TPC is funded as MRI for ~1M$ in cost sharing between NSF(2/3) and NSCL(1/3) not including the solenoid

6) Please provide a brief list of collaborators and institutions. Spokesperson(s) provide contact info.
The AT-TPC MRI project was signed by: Abigail Bickley, William Lynch, Wolfgang Mittig, Fernando Montes and Gary Westfall - Michigan State University Michael Famiano - Western Michigan University Umesh Garg - James J. Kolata, University of Notre Dame Michael Heffner - Lawrence Livermore Laboratory Ritu Kanungo - St. Mary's University I. Yang Lee, Larry Phair -Lawrence Berkeley Laboratory
ATTPC project leader Wolfgang Mittig - Mittig@nscl.msu.edu, (517) 333-6329;
(for EOS see corresponding formulary)

7) Please can you outline how your collaboration has been developing your project and how you are growing your collaboration (How many meetings? Participants?, Circular mailings? Have you a web-site?)
The AT-TPC collaboration formed in 2007 to develop and submit the proposal for the ATTPC. The web site for the ATTPC collaboration is at: http://groups.nscl.msu.edu/tpc/wiki/doku.php, where a list of workshops and collaboration meetings for the AT-TPC can be found. Electronics development for the ATTPC is conducted by the GET collaboration, which held its most recent collaboration meeting at Crepon, France during January 11-15, 2010.
Letters of intent using the AT-TPC at the ReA3 were submitted. The physics programs are resumed below:

Overview of the AT-TPC scientific program.

Measurement	Physics	Beam Examples	Beam Energy (A MeV)	Min Beam (pps)	Scientific Leader
Transfer & Resonant Reactions	Nuclear Structure	^{32}Mg(d,p)^{33}Mg ^{26}Ne(p,p)^{26}Ne	3	100	Kanungo
Astrophysical Reactions	Nucleosynthesis	^{25}Al(^{3}He,d)^{26}Si	3	100	Famiano, Montes
Fusion and Breakup	Nuclear Structure	^{8}B+^{40}Ar	3	1000	Kolata
Transfer	Pairing	^{56}Ni+^{3}He	5-19	1000	Macchiavelli
Resonances	Quasimelecular structures	^{8}He+^{4}He	0-3	1000	Suzuki
Fission Barriers	Nuclear Structure	^{199}Tl, ^{192}Pt	20 - 60	10,000	Phair
Giant Resonances	Nuclear EOS, Nuclear Astro.	^{54}Ni-^{70}Ni, ^{106}Sn-^{127}Sn	50 - 200	50,000	Garg
Heavy Ion Reactions	Nuclear EOS	^{106}Sn - ^{126}Sn, ^{37}Ca - ^{49}Ca	50 - 200	50,000	Lynch

8) Did you consider alternative designs? What alternatives were considered? How did you arrive at a final design?
We considered both dipole and solenoidal designs for the magnetic field. Simulations of the performance of the AT-TPC for structure and reactions programs with CCF and FRIB beams led to the selection of the solenoidal design to be the one best suited to the beam energies available at these facilities. The choice between wires or Micromegas readout technologies is still underway. The AT-

TPC readout electronics is being developed to be self triggering, which is essential for the active target part of its experimental program. The design is not completely final but will be finalized this year. The pad-pattern is still to be defined, triangles and rectangles are considered.

9) What existing equipment exists in the US Community that has similar goals and characteristics, even if inferior in performance.

TPC's exist in the U.S. at BNL, Fermi-Lab, and Jefferson Laboratory, but none are easily adapted to function as an active target. Some active targets exist, but none have the resolution or granularity of the ATTPC. The device ANASEN can be considered as complementary for experiments with high beam-intensity as needed for measurements of astrophysical interest.