An Active Target-Time Projection Chamber (AT-TPC) to Study Nuclei Near the Drip-line

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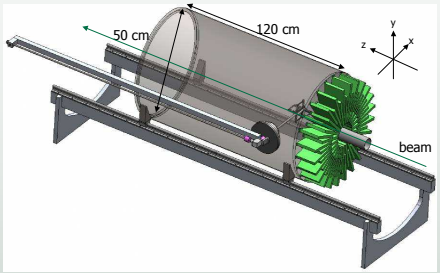
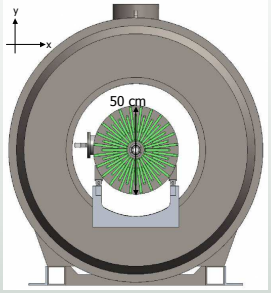
Introduction

- The primary strength of the AT-TPC is the combination of time projection and active target functionality allowing measurements of :
  - rare processes that require high detection efficiency and large acceptance
  - low energy processes that are traditionally difficult to measure due to the short range of the reaction products in matter
- The AT-TPC will address the limitations imposed by low beam intensities by providing a thick target while retaining high resolution and efficiency.

Detector Design





- AT-TPC active volume is a cylinder with a length of 120 cm and a radius of 25 cm.
- The target mount is removable allowing for both active and conventional target experiments
- Charged reaction products will be characterized based upon the ionization track left in the gas.
- The secondary electrons produced in the gas drift towards the readout plane in an electric field gradient
- A solenoidal magnetic field will cause the charged reaction products to spiral along the z-axis.
- Readout is on the entrance plane, with a 2cm radius window for the beam.

Scientific Program

The AT-TPC exploits the full extent of beam species, energies and intensities available with NSCL fragmentation beams and future gas-stopper post-accelerator beams.

Measurement	Physics	Beam Examples	Beam Energy	Min Beam Intensity
Transfer Reactions	Nuclear Structure	^{32}Mg(d,p)^{33}Mg	3 (A MeV)	100 (pps)
Resonant Reactions	Nuclear Structure	^{26}Ne(p,p)^{26}Ne	3	100
Astrophysical Reactions	Nucleosynthesis	^{25}Al(^{3}He,d)^{26}Si	3	100
Fission Barriers	Nuclear Structure	^{199}Tl, ^{192}Pt	20 - 60	10,000
Giant Resonances	Nuclear EOS, Nuclear Astro	^{54}Ni - ^{70}Ni ^{106}Sn - ^{127}Sn	50 - 100	50,000
Heavy Ion Reactions	Nuclear EOS	^{37}Ca - ^{49}Ca ^{106}Sn-^{127}Sn	50 - 150	50,000

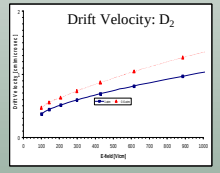
Active Target Gases

- AT-TPC system is designed to accommodate a wide variety of gases:

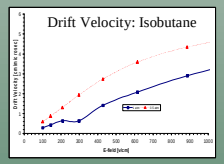
  H_2, D_2, ^{3}He, Ne, Ar, Isobutane, P10

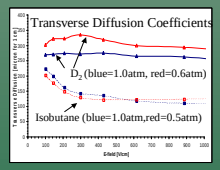
- AT-TPC chamber can operate at reduced pressure:

  0.2 – 1.0 atm



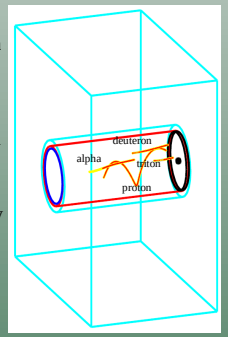
- The interaction of secondary electrons in the wide variety of gases to be used in the AT-TPC determines the requirements for the pad plane design and electronics.
- The properties of D_2 and isobutane are well understood and provide an excellent starting point for studying electron drift.
- Garfield simulations show:
  - Electron in both D_2 and isobutane have an increased drift velocity at reduced pressures.
  - Electrons in D_2 has increased transverse diffusion at reduced pressure
  - The transverse diffusion of electrons in isobutane is less strongly influenced by the gas pressure.

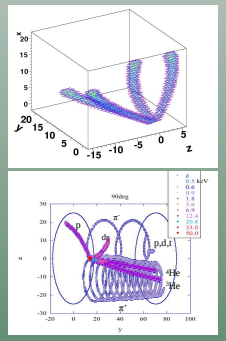




Collision Event Simulation

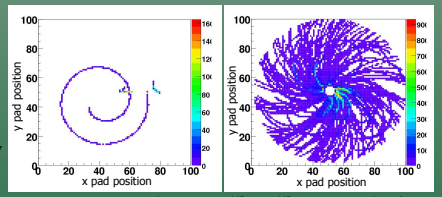
- GEANT4 is used to simulate the interaction of collision products in the materials of the AT-TPC
- Requires input of particle species, energy and momentum vector
- Image shows ionization tracks left by
  - Proton: 5MeV
  - Deuteron: 10MeV
  - Alpha:10MeV





- As the ionization electrons travel through the detector to the pad plane the signal diffuses and is detected on multiple pads.
- The extent of the diffusion is determined by the properties of the gas, and the magnitudes of the E and B fields.

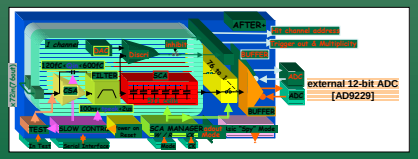
- The occupancy of the detector is simulated using collision-like events
- The detector occupancy in heavy ion collisions is significantly greater than is expected for low energy active target experiments



Active target tracks ^{112}Sn + ^{112}Sn, 150MeV, b=2fm

- A combination of the detector occupancy and the triggering rate determines the data rate that must be sustained by the electronics
- Total Occupancy: 1-10%

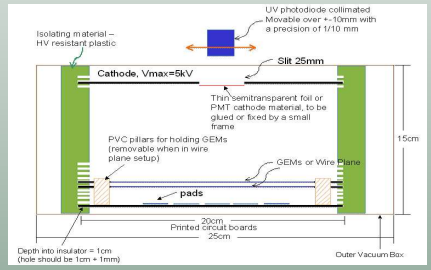
- 1 - 50 MHz sampling frequency
- 2 ns time resolution
- Peak times of 100ns to 2μs (16 values)



AFTER+ Front-end Card

- Trigger Rate: 1kHz/chan
- Data Rate: 5kB/s/chan
- 10,000 channel max
- 511 memory cells/channel

Prototype



- A prototype detector is being constructed to test a variety of electron amplification technologies
  - Wire plane - optimize distance between anode wires and pad plane based on width of image charge.
  - GEMs - stability with respect to sparking; electron amplification advantages for 2 and 3 stacked layers.
  - MICROMEGAS – establish amplification characteristics.

Summary

- The AT-TPC is a powerful tool for studying reactions induced by rare isotope beams.
- The scientific program will exploit the full extent of beam species, energies and intensities currently available with fragmentation and reaccelerated beams.
- Active target reactions will study fusion, isobaric analog states, cluster structure of light nuclei and transfer reactions.
- Scientific program can be conducted with existing rare isotope beams, but requires a high resolution AT-TPC.
- The AT-TPC will allow these measurements to be made prior to the completion of the future rare isotope beam facility.

The NSCL is funded in part by the National Science Foundation and Michigan State University.