

## Design, fabrication and upgrades to the SPiRIT TPC target mechanism

A. B. McIntosh, C. Richers, M. Youngs, and S. J. Yennello

The SPiRIT TPC is a newly constructed Time Projection Chamber to be used to place constraints on the symmetry energy at high density. The symmetry energy impacts nucleosynthesis, properties of neutron stars, and mechanisms of heavy ion collisions. After two decades of active research, headway on the low-density behavior has been made; the behavior at high density is still largely unconstrained. Through measurements of charged pions and light charged particles produced in collisions of exotic tin isotopes at and above 200MeV/nucleon, the SPiRIT TPC (SAMURAI PION Reconstruction and Ion Tracker, to be installed in the SAMURAI dipole magnet at RIKEN) can add constraints to the high density behavior of the symmetry energy and constrain the neutron and proton effective masses through yield ratios as well as directed flow of the light particles.

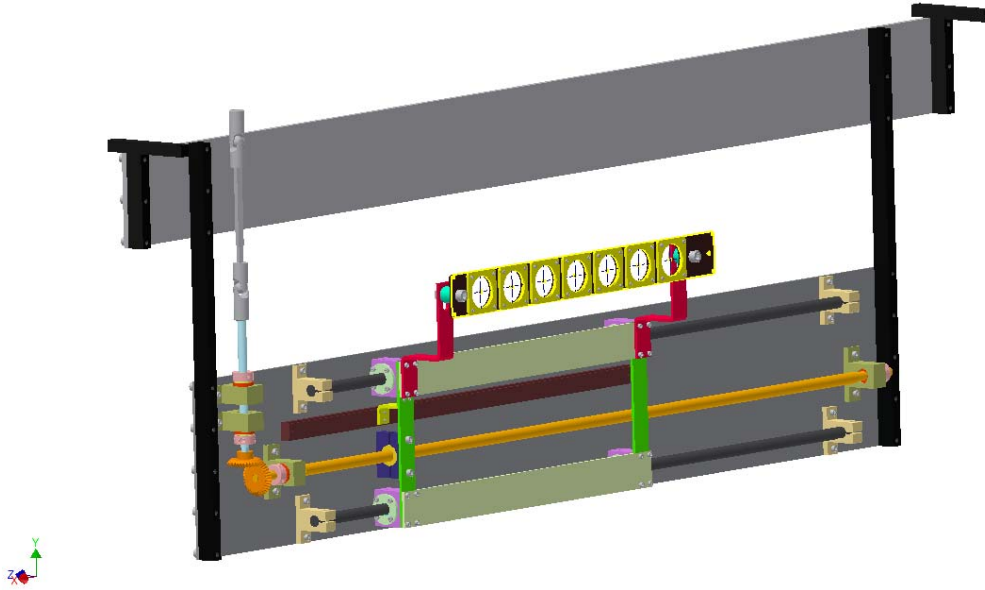
The SPiRIT TPC (formerly referred to as the SAMURAI TPC) was designed at TAMU, with significant contributions from Michigan State University. Fabrication at both institutions over the previous three years is now largely complete. Coupled with efforts at MSU and RIKEN on the electronics, the TPC has recorded tracks of cosmic rays passing through the detector.

The target mechanism for the TPC was subsequently designed and fabricated at TAMU. The requirements, listed below, largely overlap with the TPC overall:

- Made entirely of non-magnetic materials
- Avoid materials that could poison the detector gas of the TPC (such as silicone and halogen-containing compounds)
- Provide a wide range of motion to maximize the number of target positions
- Maximum target diameter of 3cm to accommodate exotic beams at RIKEN
- Allow the target ladder itself to hold a high voltage due to proximity to field cage, while maximizing the distance of the non-biased portion of the assembly from the field cage to avoid discharging
- Avoid blocking the UV laser beams used for position calibration
- External control of the target ladder, even when in a high magnetic field
- Position readout of the target ladder

Fig. 1 shows the 3D design of the assembly in Autodesk Inventor. The target ladder frames (yellow) are held to the target ladder (black). These parts are isolated electrically from the rest of the mechanism with insulating standoffs so that high voltage can be applied. The ladder is attached to a carriage (tan and green assembly) that can slide along one axis of motion, with low-friction plastic bearings sliding along two parallel ceramic-coated rails (dark gray). The lead screw (yellow) and bronze nut are used to transfer rotary motion to translational motion of the carriage and ladder. The rotary motion need to turn the lead screw is transferred via a series of brass miter gears, a telescoping U-Joint, and a hermetic rotary feed-thru from Kurt J. Lesker. The wire used to connect the ladder to the high voltage supply cable was coiled to accommodate the motion of the ladder and minimize sagging of the wire. The position of the ladder is determined using a specialty 500mm linear potentiometer made by ETI Systems.

Low DC voltage is applied to the two ends, and a sliding contact attached to the moving carriage allows a voltage measurement to provide position information.

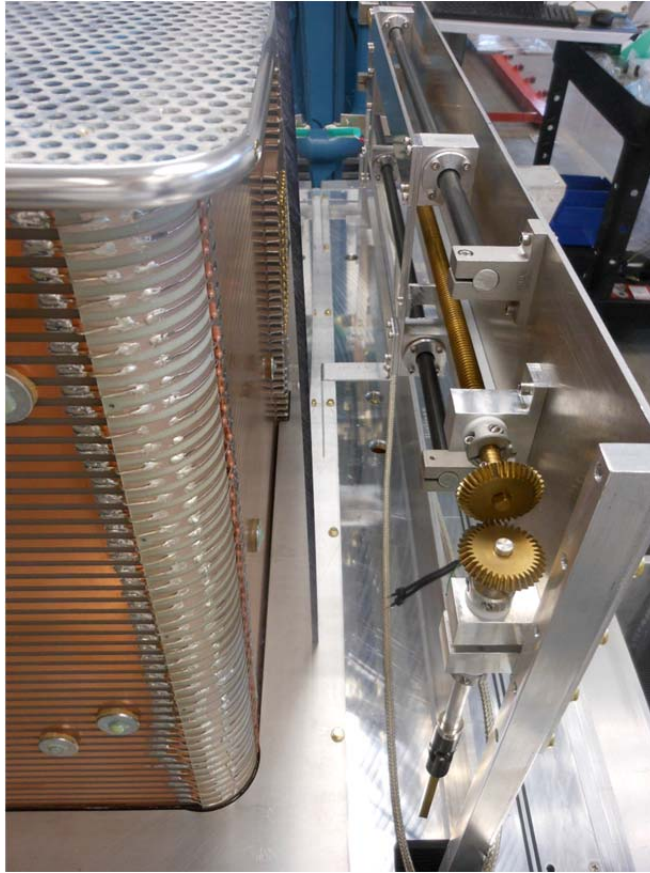


**FIG. 1.** Target Mechanism for SPiRIT TPC drawn in Autodesk Inventor.

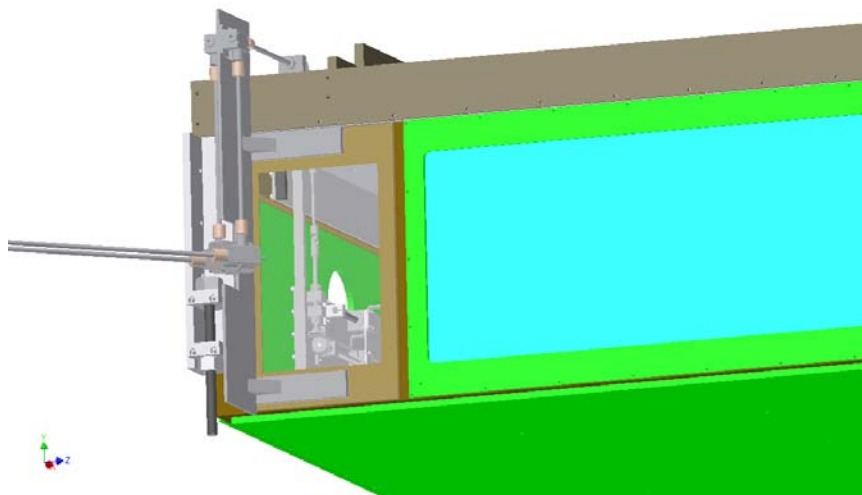
The target mechanism was fabricated at TAMU. Potentially magnetic materials were tested for response to a 0.1T magnetic field produced by the TAMU K500 cyclotron main magnet (fringe field). Assembly and testing revealed quickly that it drives as designed and works well. Alignment can be accomplished by the following procedure: assemble all the parts, leaving the screws slightly loose. Slide the carriage back and forth, tightening the screws one by one while continuing to slide the carriage. Mild binding of the action can occur near one extreme of the range of motion due to the lead screw not being perfectly centered, but this only forfeits an inch of motion if properly aligned, and is not a significant problem. In air, high voltage was applied to the target ladder; up to 9kV applied before discharging to the air, which is a factor of four greater than is required. Discharge to other parts of the assembly did not occur.

The target mechanism assembly was mated with the SPiRIT TPC. Fig. 2 shows a photograph of the successful mating. The ladder can be assembled at the entrance window without damage to the field cage of the TPC. The ladder can be driven back and forth with minimal vibration in proximity to the field cage, and the coiled high-voltage wire does not present a discharge problem.

The external drive train of the target mechanism is designed and will be fabricated at TAMU. Figure 3 shows the 3D design of this assembly. It makes use of simple aluminum rods and custom right-angle enclosed gearboxes from W.M. Berg that use only brass and aluminum components. This will be assembled and tested at RIKEN in the summer of 2014.

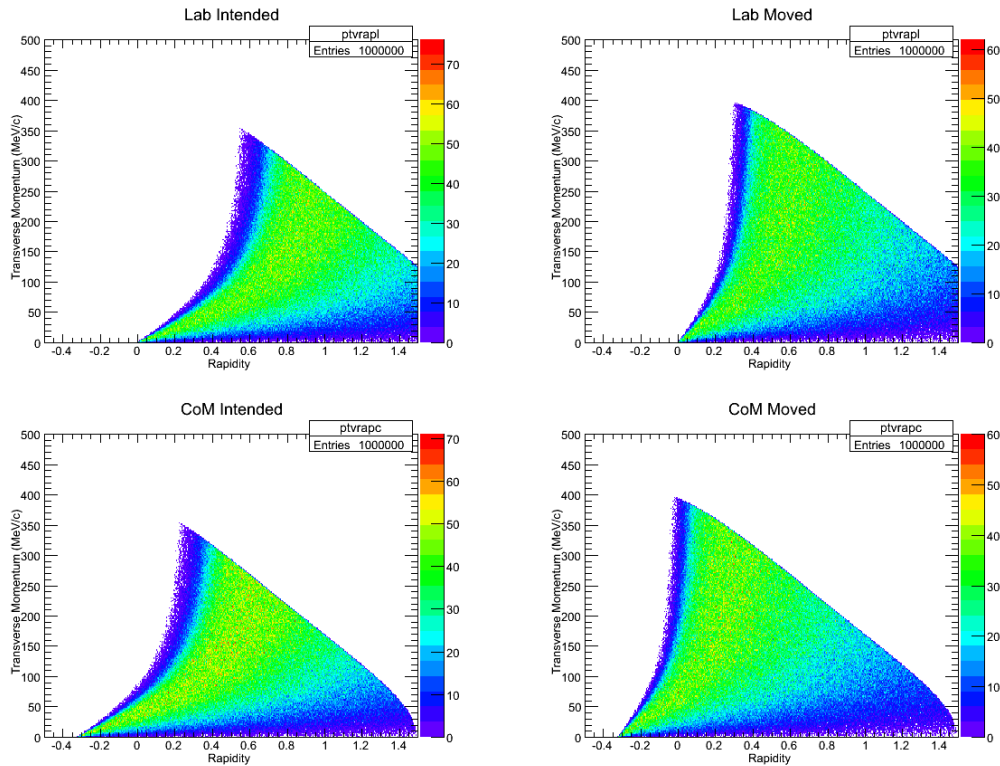


**FIG. 2.** Photograph of the SPiRiT Target Mechanism installed on the top plate of the SPiRiT TPC adjacent to the field cage.



**FIG. 3.** Target Mechanism Extension drawn in Autodesk Inventor. The extension transfers the rotary motion from just outside the TPC to a location upstream that can be more easily accessed during an experiment.

Simple simulations have been performed to address whether the design can be modified to increase the acceptance of the TPC for mid-rapidity pions. A flat energy distribution up to 300MeV pion energy was sampled, with direction isotropic into  $4\pi$ . The beam spot on target was assumed to be 2cm in diameter. The target was positioned at its current location with respect to the field cage entrance window; pions not passing through this window were rejected. The results of this simulation are shown in the left two panels of Figure 4, where the transverse momentum,  $p_t$ , is plotted as a function of rapidity in the lab frame (top) and the center of momentum frame (bottom). In the lab frame, particles going forward of roughly 45 degrees are accepted. This is due to the size of the entrance window and the proximity of the target. The curve in the line is due to the nature of the relation between rapidity and  $p_t$  for relativistic particles. The abrupt drop in intensity at high energy is merely due to the choice of 300MeV as the maximum energy in the Monte Carlo simulation. In the center of momentum frame (lower left), this same data shows that only pions with very low  $p_t$  will be measurable at mid-rapidity due to the geometry. To measure high  $p_t$  pions, one needs to select pions with a rapidity of at least 0.2 to 0.3. Since mid-rapidity pions with high  $p_t$  are predicted to be the most sensitive to the forces in the high-density region of the collision and thus to the symmetry energy, it may be beneficial to move the target closer to the entrance window to increase the geometric coverage of the pions. Theoretically, it should be possible to move the target by 0.632'' from its current distance of 1.248'' from the window. If this can be realized, we would increase our coverage significantly, as shown by the distributions in the right panels of Fig. 4. The slope



**FIG. 4.** Simple simulation of the phase space acceptance for pions accepted by the SPiRiT TPC for the current target position (left panels) and at the closest theoretically possible position (right) in the lab frame (top panels) and in the center of momentum frame (bottom panels).

of the cut-off from the angular acceptance is much steeper, and at mid-rapidity, there is significant yield out to high  $p_t$ , and high-statistics can be obtained from 0.0-0.2 in rapidity. An improvement to the target mechanism to allow the target to be positioned closer to the entrance window seems prudent. Possible solutions to hold the target closer to the window are being explored, including the possibility of adding a second axis of motion to the target mechanism.

The SPiRIT TPC will be installed in the SAMURAI magnet in the summer of 2014, including the insertion, lifting and alignment of the TPC, and the testing of the target mechanism. Concurrent with much of this work will be testing of the electronics and software development. This is in preparation for experiments expected to commence at SAMURAI in 2015.