Proposal
"MECHANICAL STRUCTURE & FRONT END ELECTRONICS
FOR THE RUN-9 STAR MUON TELESCOPE PROTOTYPE "

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We propose to construct equipment for the STAR Experiment at Brookhaven National Laboratory. This equipment is intended for use in the Run-9 prototype of the Muon Telescope Detector (MTD) and includes the main detector mechanical structure, as well as the on-board electronics. A total of seven electronics boards – two (2) “TINO” boards, two (2) “TDIG” boards, two (2) “TTRG” boards, and one (1) “TCPU” board - are needed. The TINO boards close the MRPC gas box and pass the signals from the detectors through to externally mounted TINO boards. The TINO boards pre-amplify and amplify the detector signals and provide the outputs via surface-mount MMCX jacks. These boards also provide the inputs to the two TTRG boards, which form analog multiplicity signals used for triggering. The TDIG and TCPU boards do the digitization and communication with the STAR data acquisition system, respectively, via the existing STAR TOF THUB electronics.

These electronics boards already exist. Engineering support is included in this proposal, part of which is to retest these boards for this project, to provide the necessary cabling, to participate in the commissioning, and to fix any future problems.

These on-board electronics boards mount onto an aluminum mechanical structure that is designed and fabricated as part of this project. This structure holds the internal detectors (long strip Multi-gap Resistive Plate Chambers, “LMRPCs”) inside a leak-less gas volume of primarily Freon R-134a. The structure also provides strain-relief for the external signal cabling, and allows the mounting of the whole detector on the outside of the STAR magnet. Additional non-metallic hardware mounts to the inside of the mechanical structure to hold the LMRPCs with respect to the outer metal enclosure.

The mechanical hardware consists of the following parts:

- One (1) MTD tray “bottom” assembly and one (1) “top” assembly
- Non-metallic internal LMRPC support pieces

The project costs are estimated to be:

Tray Mechanical Hardware	$ 3,800.00
Shipping Crate + Shipping Cost	$ 600.00
Engineering Support	$ 600.00
Total Project Cost:	**$ 5,000.00**

Any money (besides the engineering support) not spent during the fabrication project will be returned to the purchaser.

The fabrication project will begin once the local accounts are open and funded. The delivery schedule will be established once the fabrication project begins. The lead-time for the tray fabrication is unpredictable but is expected to be approximately 6 weeks.

All electronics boards will be tested and qualified before delivery.

The engineering support in the proposed project cost includes project administration, components procurement (electronics cabling, and small hardware for the mechanical structure), board testing, the CADD design of the tray mechanical structure and internal LMRPC support pieces, the tray hardware fabrication order handling and qualification, and assistance with the final assembly of the detector at Brookhaven.

Included in the estimated cost of the tray mechanical hardware are small parts such as nuts and washers, as well as the fabrication of the mechanical pieces that hold the LMRPCs with respect to the tray structure. The tray mechanical structure will be fabricated out-of-house at Oaks Precision Fabricating in Houston, and the internal LMRPC support pieces will be fabricated on-campus in Dwight Dear's machine shop in the Space Science & Technology building.

The bulkhead gas and high voltage fittings, the LMRPC signal pigtails, the internal gas and HV busses, and the DC730 sealant are not included in this proposal and will be provided by the Brookhaven collaborators.

We will ship the tray hardware and the electronics from Houston to Brookhaven as soon as they are available. The large size of the tray mechanical structure, and the fragility of the PEM studs on the top assembly, require a sturdy wooden shipping crate.

Additional technical details are provided on the following pages.

The plan for the MTD in year 2009

Research on a large-area, cost-effective Muon Telescope Detector (MTD) has been carried out for RHIC and for next generation detectors at the future QCD Lab. We utilize state-of-the-art multi-gap resistive plate chambers with large modules and long readout strips in detector design. In the following, we will summarize what have been and will be done and the plan for year 2009.

Intrinsic timing and spatial resolution of long-MRPC from the cosmic ray and beam tests

Each long-MRPC module consists of two stacks of resistive glass plates with ten uniform gas gaps with gap widths of 250 μm. High voltage is applied to electrodes on the outer surfaces of the outer plates of each stack. A charged particle traversing a module generates avalanches in the gas gaps which are read out by six copper pickup strips with strip dimensions of 870×25 mm^2. The MRPC modules were operated at 12.6 kV with a mixture of 95% $C_2H_2F_4$ and 5% iso-butane at 1 atmosphere. The cosmic ray test shows that in the high voltage range $12.5<HV<13.0$ kV, the efficiency is above 95% and timing resolution is about 60-70 ps. In additional to the cosmic ray test, a beam test named T963 was carried out in the MTEST beam line at Fermi National Accelerator Laboratory (FNAL) in May 2007. The results from beam tests using prototype front-end electronics show timing resolution and efficiency are consistent with those from the cosmic ray tests. The spatial resolution of the long-MRPC along the long strip is about 0.6-1 cm. This satisfies the needs for a large-area muon detector. The details of the long-MRPC construction and its performance in the cosmic ray and beam tests can be found in this paper *Y. Sun et al., nucl-ex/0805.2459*, which has been submitted an accepted by NIMA.

Prototype performance of muon detector at STAR

The prototype of the MTD covered $\pi/60$ in azimuth and $-0.25<\eta<0.25$ in pseudo-rapidity at a radius of ~400 cm during the 2007 run in 200 GeV Au+Au collisions. The prototype was placed outside of the magnet steel that serves as hadron absorber. During the 2008 run, the prototype was moved to DAQ1000 sector (sector 16), which covered $\pi/60$ in azimuth and $-0.5<\eta<0$ in pseudo-rapidity at a radius of ~400 cm.

The prototype contained two long-MRPC modules. The front-end electronics are similar to that for PHENIX MRPC-TOF system. The trigger electronics (2 CDB and 1 TAC boards) were used to read out the signal amplitude (ADC) and timing information (TAC). The prototype successfully triggered the data acquisition system. The offline data analysis indicates that offline tracking of particles from the TPC was able to match hits from the Long-MRPC. The tracks of the TPC were extrapolated to the MTD barrel, resulting in position information from tracking. The time difference from two-end readout of the hit strip gave us a position measurement along the long strip of the long-MRPC. The difference of these two position values in the z direction (Δz) shows a interesting feature, where the z direction is the beam direction. Two components were observed in the Δz distribution. A double Gaussian function was used to fit the distribution. The sigma (σ) of the narrow Gaussian was found to be ~10 cm by selecting tracks of $p_T>2$ GeV/c while the other Gaussian is significantly broader. From the GEANT simulation, it shows that muons of $p_T\sim2.5$ GeV/c generated at the TPC center will result in a Gaussian distribution with a sigma of 9 cm in the z direction in the MTD barrel, after traversing the detector material from the TPC center to the MTD. The simulation also indicates that pions will result in a much broader distribution. If we assume the broad distribution is dominated by hadrons and narrow Gaussian is dominated by muons, we obtained the muon to hadron ratio is 1.7

and muon-to-hadron enhancement factor is about 200-300 at $|\Delta z|<20$ cm by requiring track matching only. Additional dE/dx and time of flight cuts significantly enhanced the muon-to-hadron ratio and indicates that the narrow Gaussian is dominated by muons. Further study using the topological decay of V0 indicates that the primary muons dominates the narrow Gaussian distribution and the PYTHIA+GEANT+Reconstruction simulation is on the way to do the final check on this.

The average long-MRPC timing resolution for the two modules used in this analysis was measured to be ~300 ps in Au+Au collisions. The ``start'' timing was provided by two identical upgraded pseudo-vertex position detectors (upVPD), each 5.4 m away from the TPC center along the beamline. After subtracting the start timing jitter (~160 ps) and detector material effect contribution (~100 ps at p_T=2.5 GeV/c), the timing resolution from the MTD was found to be not as good as those from cosmic and beam tests. This is understood by the fact that the electronics we are currently using are not designed for precise time measurement. The simulation indicates that good timing resolution will significantly benefit the di-muon trigger capability in the future. The final R&D on this detector will be done by installing a tray with proper electronics, to take data and demonstrate the timing resolution at STAR.

Plan for the MTD in year 2009 at STAR

We selected the electronics same as the MRPC-TOF at STAR. This electronics use HPTDC technology and have been proved to have the capability to measure the time precisely using the data taken from year 2005 to year 2008.

We plan to retire the old MTD prototype tray and install a new tray with TOF electronics in the coming year 2009 run. The prototype tray will contain: 3 long-MRPC modules with 36 readout channels.

1. Tray will be designed by Bill Llope.

   Since the iron return bar is 57cm and our current long MRPC modules have active area with width of 17cm, we need 3 MRPC modules. However, the PC board extends to be 25.6cm in each module, this means we have to design a tray which allows the modules to overlap to maximize the active area.

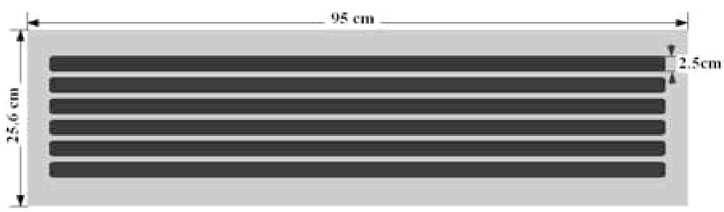
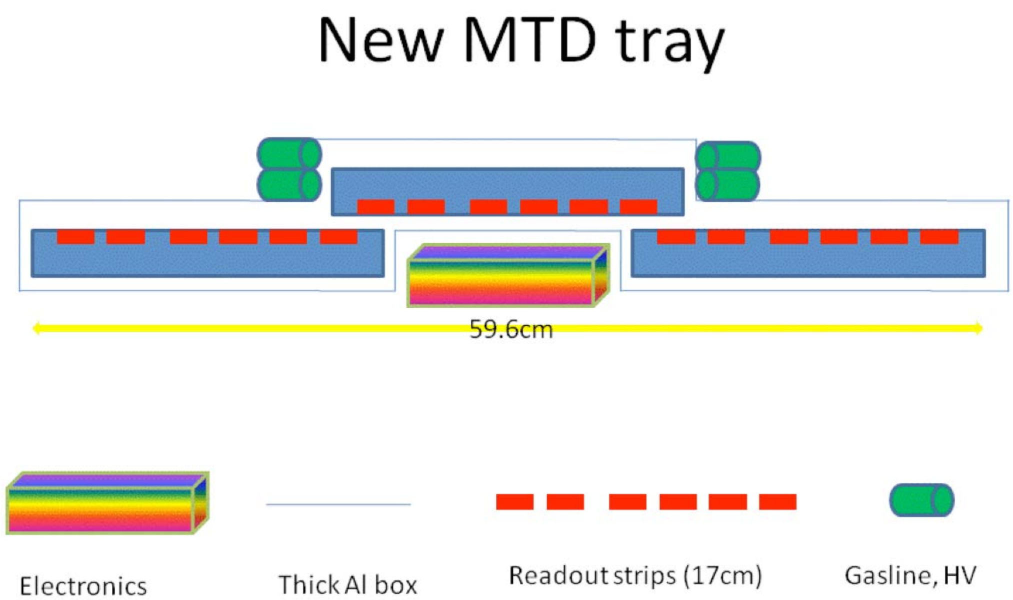


Figure 1 long MRPC module with 6 trips

We only have 3 long MRPC modules, therefore, a tray length (~100cm) will be half of what we have in run7 and run8. The Aluminum box should have much thicker wall than what we have now because of more modules and because we may need to mount and dismount frequently for BEMC to access their PMT HV boxes. There is no concern about radiation length, so a thick and rigid box should be designed.

A possible design is as follows:



2. We need 2 TINO, 2 TDIG boards, and 1 TCPU Board. Electronics use fan cooling.

3. We need TTRG card for providing the analog multiplicity output to trigger system, therefore need analog multiplicity cable as well.

4. 1 canbus cable, 1 CAT6 cable, one LV cable and 2 pair HV cables needed.

5. 1 HV distribution box needed.

6. HV power supply, one pair of positive/negative UNIT needed from CAEN-TOF HV system.

7. LV supply, using one channel from TOF weiner LV system.

8. One channel from THUB (0-31), we will use 0 position in the THUB. Tray will be located at 10 o'clock position, No additional firmware support needed.

9. The analog signal needs to be digitized. We can cut on valid TAC as our Level 0 MTD trigger.