R&D proposal for an Endcap TOF and TRD for Identifying electrons at EIC

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DEPARTMENT/DIVISION	**BNL/USA and USTC/China**	**DATE**	**09/08/2011**

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Joint R&D with GSI and other EIC R&D groups?

TITLE OF PROPOSAL	**Endcap TOF and TRD for Identifying electrons at EIC (ETTIE)**
PROPOSAL TERM (month/year)	From **01/2012** Through **09/2013**

SUMMARY OF PROPOSAL

Description of Project:

Electron identification is crucial in an EIC detector for identifying the out-going scattered electrons from the incident electron beam. Furthermore, precise kinematics from these electrons are necessary to determine the (x, Q^2) of the interaction. We propose to study the combined functionality of a Time-of-Flight detector (TOF) and a Transition Radiation Detector (TRD) at forward direction ($-3<\eta<-1$) behind low-material tracking detector to provide electron identification with high hadron rejection ($\sim>10^3$) over a wide momentum range (0.2 GeV/c<p<~10 GeV/c). In addition, the configuration also provides start time for the produced hadrons in TOF detectors in other locations and additional precise tracking points for hadron reconstruction in the case that the struck particle is a hadron.
We propose an R&D project to use GEM detector with Xe+CO_2 for detection of transition radiation and multi-gap resistive plate chamber as TOF detector. The goals are: a) study the GEM readout performance for dE/dx (TR) signals and its position resolution in the TPC-style readout with 3-4cm ionization chamber; b) to study the TOF and converter combination for hadron/photon rejection and as start timing detector.

Expected Results:

We plan to build a prototype GEM chamber of $10x10cm^2$ sensitive area filled with $Xe+CO_2$ gas mixture and with an ionization chamber of 2-4cm. Different readout electronics will be investigated and should be able to provide multiple time bins in sequence along the drift direction. The study should provide dE/dx measurement for such a GEM chamber and assess whether it is sufficient for electron identification for EIC when combined with transition radiation signal and Time-of-Flight detector. We also plan to optimize a high precision TOF detector with convertor and the requirement for such a detector in the forward rapidity coupling with TRD and other gas tracking systems. This requires major simulation work with realistic detector information, material budget in a realistic EIC environment.

Funding Requests estimated for the period from 01/01/2012 to 09/30/2013 (1.5 years)

Item	Description	Fund (K$)
Detector material/DAQ	Detector components, computer, gas, test beam	8.3+10+10=28.3
Engineer	Electronics and mechanics design	21.4
Postdoc	½ postdoc for simulations and prototype tests/analyses	75
Travel/test beam	Collaboration and meetings	30
International collaboration/student	Joint effort with prototype tests and simulations by international collaborators	40
Total		195

PROPOSAL

1. Introduction

The proposed electron-ion (ep and eA) collider (EIC) will enable us to study the gluonic structure confined inside subatomic matter and its role in defining the fundamental properties of visual mass in the universe. Figure 1 provides an example of the kinematics of the deep inelastic scattering of an e+p collision at electron and proton energies of 5 and 100 GeV, respectively. In panel a), the red lines depict the scattered electron out-going angle with respect to the incident electron angle. Also shown in the figure panel are example detector components of the Solenoidal Tracker at RHIC (STAR) to illustrate the acceptance of a typical collider detector and the missing fiducial coverage necessary for a collider DIS detector. The other panels of the figure show the scattered electron and struck quark energies (panel b and d) and out-going angle of struck quark (panel c).

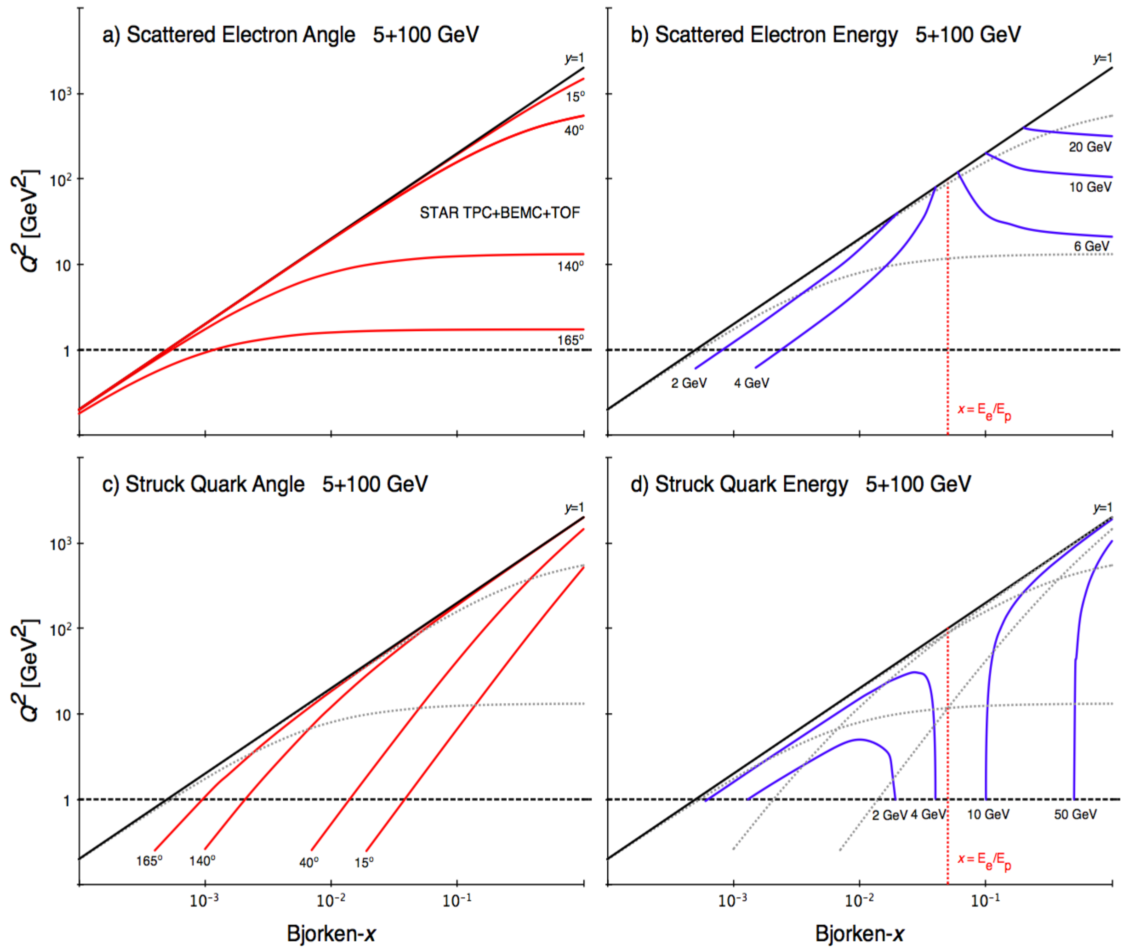

Figure 1: Example of DIS Kinematics with a collider-like detector configuration around mid-rapidity.

One of the major experimental challenges is to cleanly identify the scattered electron and to provide precise kinematics of the interaction. Figure 2 shows the momentum distribution and abundances of electrons (blue), hadrons (red) and photons (black) from such collisions at the forward electron scattering. In general, detector should provide low-material tracking to eliminate photon (conversion) background, which may subsequently be misidentified as electrons. Precise angle and energy determinations are necessary at small scattering angle (Y<-

3). In addition, good hadron rejection is required for -3<~Y<-1 in the order of a factor of a 1000 over a wide momentum range (0.1<pt<~5 GeV/c) while the demand is less for more forward scattering.

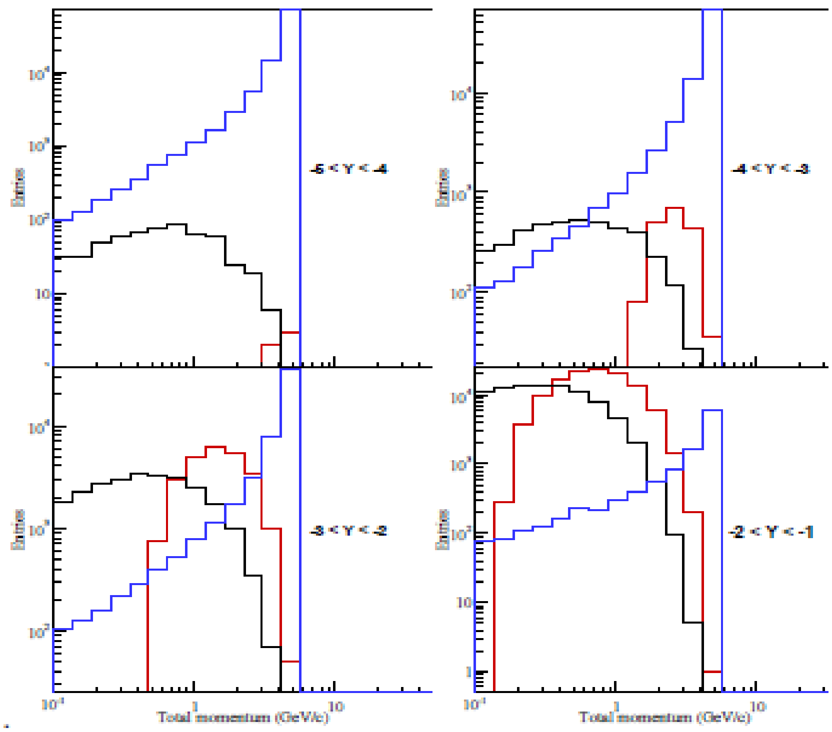

Figure 2, Hadron (red) and electron (blue) distributions vs momentum for given rapidity (Y) in 5x100 ep collisions. Significant photon background (black) exists in all kinematics. Figure is from INT report (arXiv:1108.1713) Fig.7.18.

In this proposal, we focus on developing a detector complex to separate cleanly electrons from hadrons at -2<Y<-1 although some of the components may be suitable for situating at more forward angle as well. We propose a compact transition radiation detector (TRD) followed by a Time-of-Flight detector with additional converter. The TRD is similar to ALICE TRD with dE/dx information in addition to the transition radiation signal and tracklet capability. The novel component of TRD is based on GEM (Gas Electron Multiplier) detector rather than the multiple wire proportional chambers (MWPC). The low-material tracking detector in a solenoidal field in front of TRD, such as Time Projection Chamber (TPC), provides tracking, momentum, dE/dx and photon rejection. Figure 3 illustrates a schematic of fraction of a detector configure relevant to this proposal. The combination of TOF and TPC dE/dx measurements have been proven to provide powerful electron identification at electron momentum p<~3GeV/c as discussed in section 4. The combination of TOF and TPC for electron ID is simple: TOF eliminates slow hadrons which produce large dE/dx signal while the relativistic rise of dE/dx at high $\beta\gamma$ separates electrons from fast hadrons at the same momentum. In addition, TOF provides hadron identification in the case that both interested hadron and scattered electron strike the Endcap TOF. It also provides start-time for barrel TOF in the case that the struck particle is only the scattered electron.

The TRD serves two additional functionalities:
a) It provides additional dE/dx measurement with Xe+CO_2 gas mixture at all momentum. This is essential for small angle scattering where only small section of the particle trajectory falls within the cylindrical TPC acceptance, resulting in few hits in TPC and worse dE/dx resolution (1/sqrt(N) rule).

b) It adds necessary TR signal to the electrons for high momentum (p>2 GeV/c). The transition radiation happens at around gamma>1000 with the current radiator material (ALICE). From practical stand point, only electrons provide such radiation into the ionization chamber in the TRD boosting the effective electron dE/dx to even higher value from the existing relativistic rise.

Given the possible space constraint and limited resolution at low momentum, an electromagnetic calorimeter behind a TOF wall may be more suitable for $\eta<-2$ in a detector configuration as illustrated in Fig.3. An alternative of increasing electron purity is to add a converter (~4X0) and scintillator behind the TOF for generating and detecting E&M showers from electrons. This converter method also provides a cost-effect approach for detecting/rejecting the large photon background in e+p and e+A collisions (shown in Fig.2). We have preliminary simulation shows that the combination of TRD+TOF+converter can provide electron ID necessary for EIC.

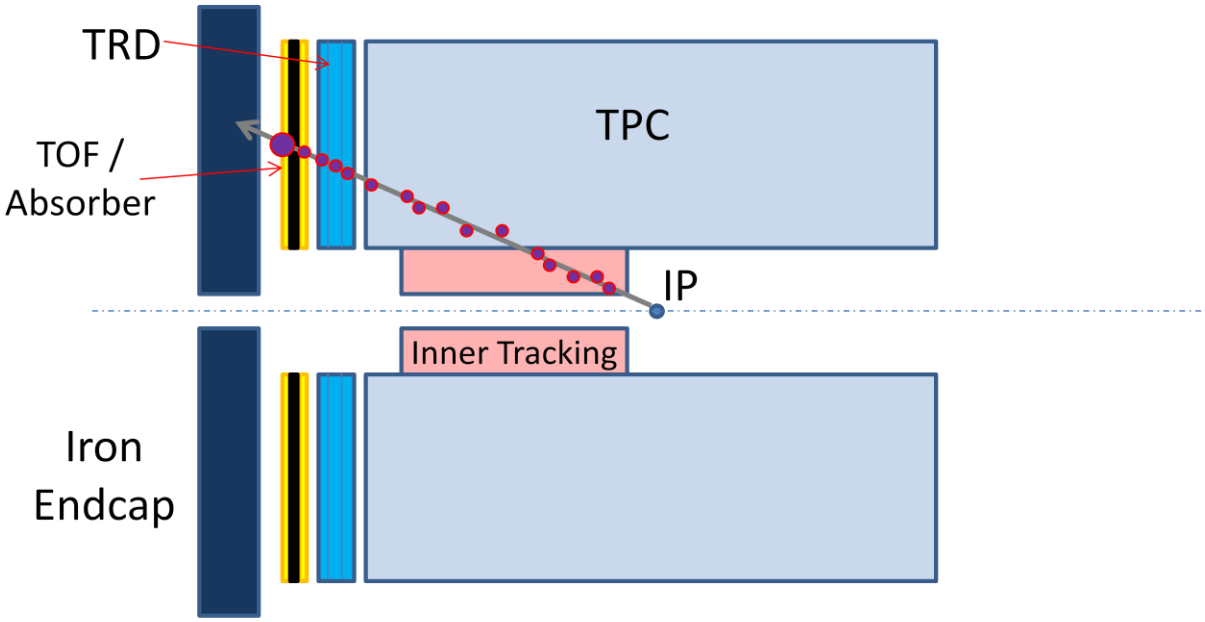

Figure 3: Schematics of a detector with Solenoidal field at mid-rapidity. The proposed TRD+TOF is placed between pole-tip and a low-material tracking gas detector.

2. Transition Radiation detector (TRD) Simulation

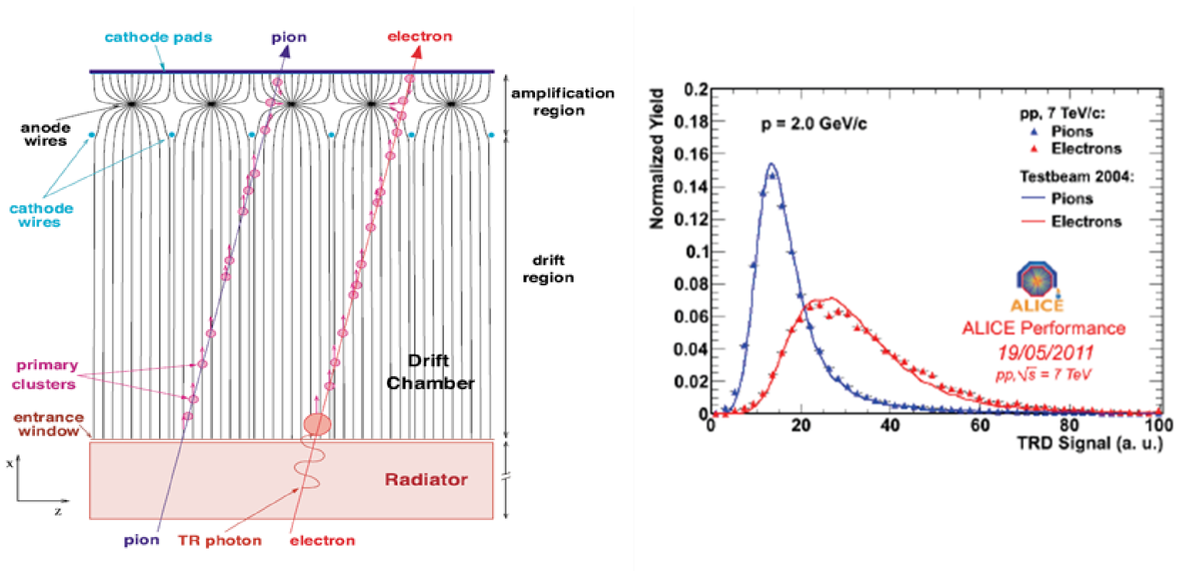

Figure 4: ALICE Transition Radiation Detector schematics (left) and TRD signal of pions and electrons at p=2 GeV/c in pp and test beam. Figures provided by J. Stachel (talk at Krakow, Feb. 25, 2011 and QM2011 poster)

Transition radiation occurs when particle traverses material boundary with different dielectric constants. The radiation depends on gamma factor and usually is effective at gamma~>2000. Figure 4 (left panel) shows a schematic of ALICE TRD. The ALICE TRD is a stack of 6 such components along the radial direction outside of the barrel TPC. The radiator consists of polypropylene fiber mats of 3.2cm in-between two Rohacell forms (0.8cm each) and is reinforced with carbon-fiber sheets (0.1mm thick) laminated onto the outer surface. The fiducial drift chamber is 3cm long filled with Xe+CO_2 (85/15) gas mixing. The signals are readout by multiple-wire proportional chamber (MWPC). Right panel of Fig.4 shows the performance of this detector in pp collisions at 7 TeV center-of-mass energy for electron and pion momentum at 2 GeV/c. Our proposal is to replace the WMPC readout with GEM detectors, which provides higher rate capability and is more radiation hard. This may be crucial for electron and hadron detection at high eta.

As a start of the simulation for this project, we use detector with 3 layers, which is possible to fit inside conventional detector configuration, such as the familiar STAR pole-tip behind TPC readout wire chambers. Figure 5 shows a stand-alone TRD+TOF+converter simulation in GEANT4. An electron with momentum p=3 GeV (red line) incident to the detector from right, producing TR signals and ionization in the 3 TRD drift chambers. These signals are readout by triple GEM detectors with hit position and dE/dx information. The electron also provides signal in the MRPC TOF and creates an E&M shower through the converter behind the TOF. The shower deposits signals in the coarsely granulated scintillators behind the convertors. In the near future, the plan is to put such a detector component into a more realistic detector environment with full ep and eA event simulation.

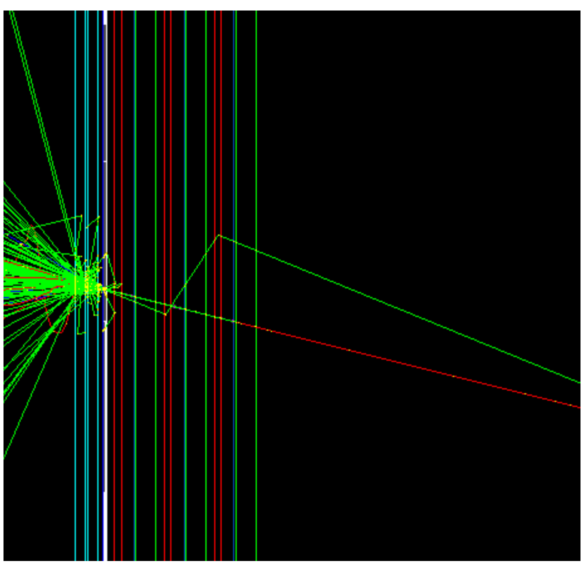

Figure 5: GEANT4 simulation of a 3-GeV electron (red) incident on the TRD+TOF configuration. E&M shower is created at the converter (4X0).

Figure 6 left panel shows the signals from TRD (energy deposition) with (red) and without (blue) transition radiation signals for the same electrons. Right panel shows the signals for pions (blue) and electrons (red) from full-functioning TRD with active transition radiation.

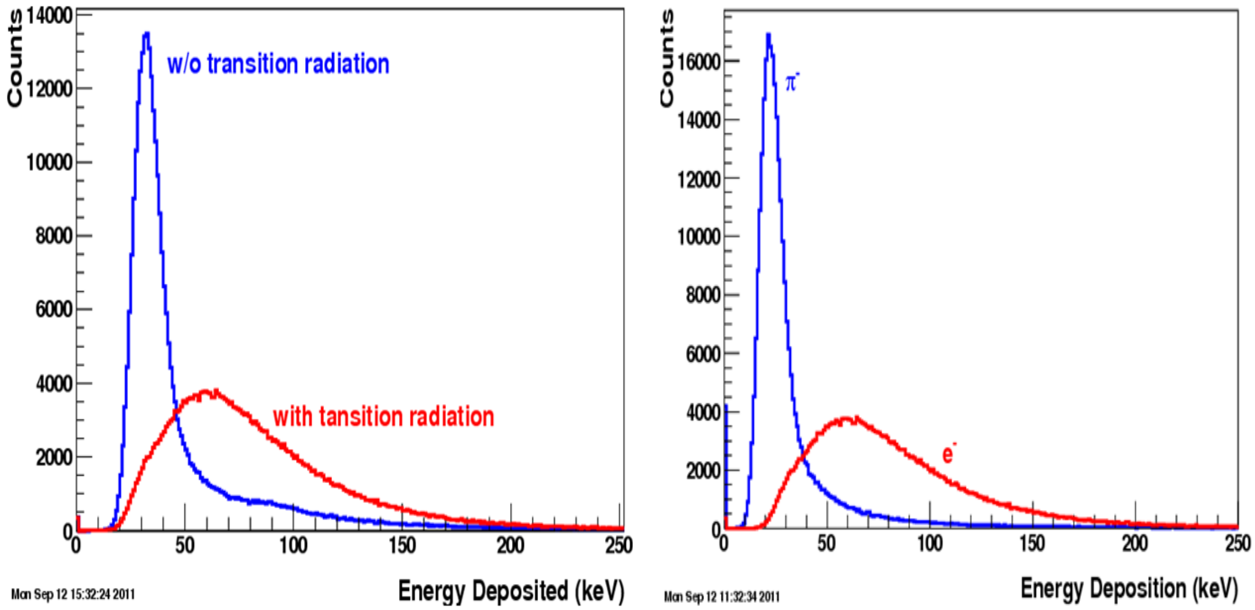

Fig.6: GEANT4 simulation of the TRD performance. The left panel is the energy deposition in the Xe gas sensitive volume for a 3-GeV electron incidents on TRD detector with (red) and without transition radiation. The right panel is the TRD with TR signal for pion (Blue) and electron (red).

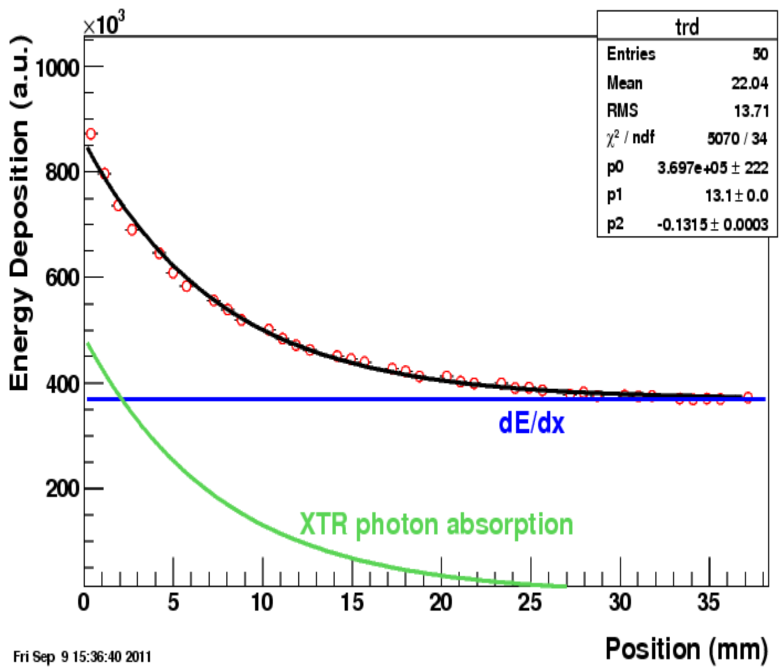

Figure 7: Dependences of transition radiation photon absorption as a function of position inside the drift chamber. Zero is the position of the drift chamber closest to the radiator.

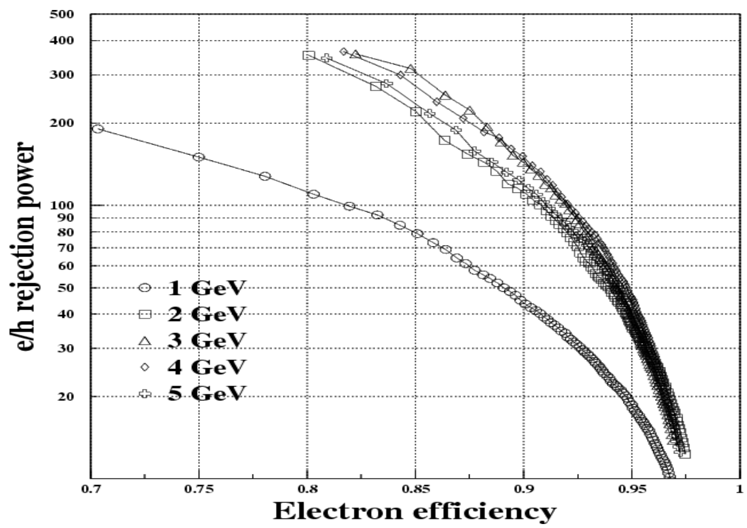

Figure 8: electron efficiency vs hadron rejection for TRD in different electron incident energies. At electron efficiency about 85%, the hadron rejection is about 50.

3. Functionality and simulation of Time-of-Flight Detector and associated converters:

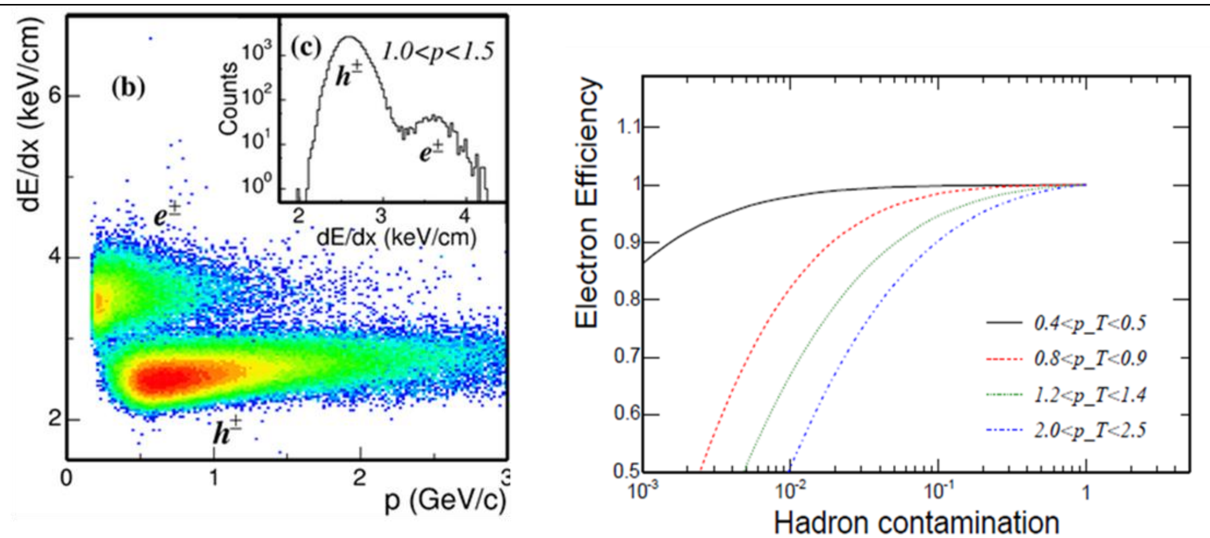

Figure 9. The dE/dx measured by STAR TPC as a function of particle momentum, with velocity cut by TOF, and (right panel) the electron efficiency after dE/dx cut as a function of hadron contamination in different p_T range.

In addition to its hadron PID capability, TOF detector can be used to identify electrons by combining it with dE/dx from TPC, which was proven at STAR at mid-rapidity. The top panel of Fig. 9 shows the 2-D scatter plot of dE/dx as a function of the particle momentum for charged particles with TOF matched hits from d+Au collisions. With a particle velocity cut ($|1-\beta|<0.03$, where β is the scaled velocity), slow hadrons (most protons and kaons, and pions at low momentum range) are eliminated and the electron band is well separated from the hadron band. Electrons can then be selected with further dE/dx cuts in different momentum range. Additional

information about this electron identification and joint US-China TOF project for STAR can are available at:
a) TOF proposal http://drupal.star.bnl.gov/STAR/files/future/proposals/tof-5-24-2004.pdf;
b) Muon Telescope Detector (MTD)
http://drupal.star.bnl.gov/STAR/system/files/MTD_proposal_v14.pdf
c) Electron Identification: Ming Shao et al., Nucl.Instrum.Meth.A558 (2006) 419;
d)High-pT Hadron Identification: Yichun Xu et al., Nucl.Instrum.Meth.A614 (2010) 28.

Hadron contamination to electron identification with TOF velocity cut was studied from the dE/dx distribution in each p_T bin. By varying the dE/dx cuts, electron efficiencies and hadron contamination ratio are estimated, and shown in the right panel of Fig. 9. At low p_T, high electron efficiency and low hadron contamination can be achieved. For higher p_T range, the hadron contamination increases at a given electron efficiency. Taking into account the electron and hadron yields, the hadron rejection power can be evaluated for a specific condition. It was estimated to be at 10^{-5} level at p_T<1.0GeV/c. At higher p_T, the rejection power decreases significantly, which may require additional detectors (such as TRD or EMC) to help reach the required rejection power.

The endcap TOF not only can provides electron identification by combination of dE/dx measurement by other detectors (TPC, TRD), and but also event collision reference time for other particles. With the increase of particle momentum, this method becomes less efficient and help from other detectors (such as TRD) are needed. Unlike TRD, which can provide both energy deposition and tracking information, a calorimeter-like detector can separate electron and hadron mainly by different energy deposition pattern. This also provides additional detection capability for the background photons and may be necessary for identifying event structure. High precision crystal calorimeter (BSO) may replace such a scheme in very forward direction with small required area. Part of this R&D proposal is to do a detailed simulation on the required precise and optimization of a cost-effective approach to a large-coverage photon/electron discrimination. Our initial simulations presented here are from a standalone simulator optimizing the energy deposit in discriminating E&M showers from hadronic showers. The schematic arrangement of such a setup is depicted in Fig. 10. Particles from event vertex fly to the endcap TOF from left side. Two layers of Lead absorber and plastic scintillator are allocated behind the TOF detector. The immediate Lead absorber next to TOF is 3 X0 thick and another one is 1.5 X0 thick. Their thicknesses are chosen to maximize the energy deposition from electromagnetic shower. The thinner scintillator also provides isolation for 2 scintillators so that their measurements of energy deposition are basically independent.

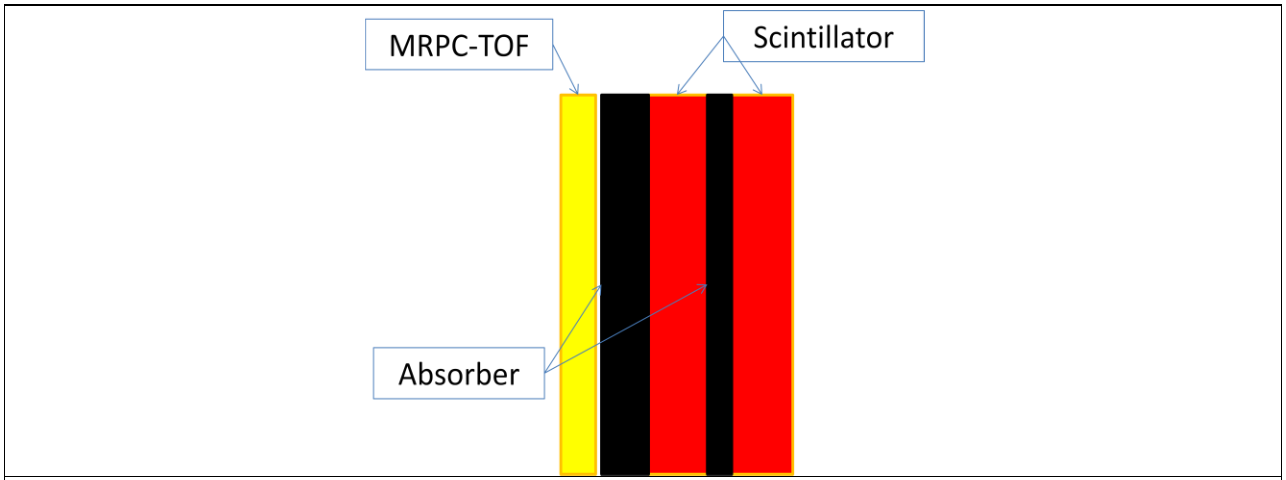

Figure 10. The schematic setup of TOF+convertor detectors at endcap region.

The energy deposited in the two scintillators by electrons and pions are simulated by GEANT4. The particle energy is 3GeV. As shown in Fig 11, the very different patterns are observed. Electrons deposit significant energy in the scintillator and have a peak around 200MeV, while pions deposits less energy with a long tail toward very high energy deposition due to the intrinsic large fluctuation of strong interaction. Furthermore, the energy deposition in the two scintillators does not show significant correlation.

Cut on the energy deposition is applied to separate electrons and pions. Since the energy measurements are independent, 2-D cuts are applied separately to the energy deposited (Although the cuts are the same – they can be different). The pion and electron efficiency at different cuts are obtained and the rejection powers (defined as electron to pion efficiency ratio) are plotted in Fig 12 as a function of electron efficiency. At 90% electron efficiency, the rejection power is ~24 for 3GeV particles. The evaluation of rejection power at other particle energies is also plotted in Fig 12. Generally with the increase of particle energy, the rejection power increases at a given electron efficiency in the range between 1 and 5 GeV.

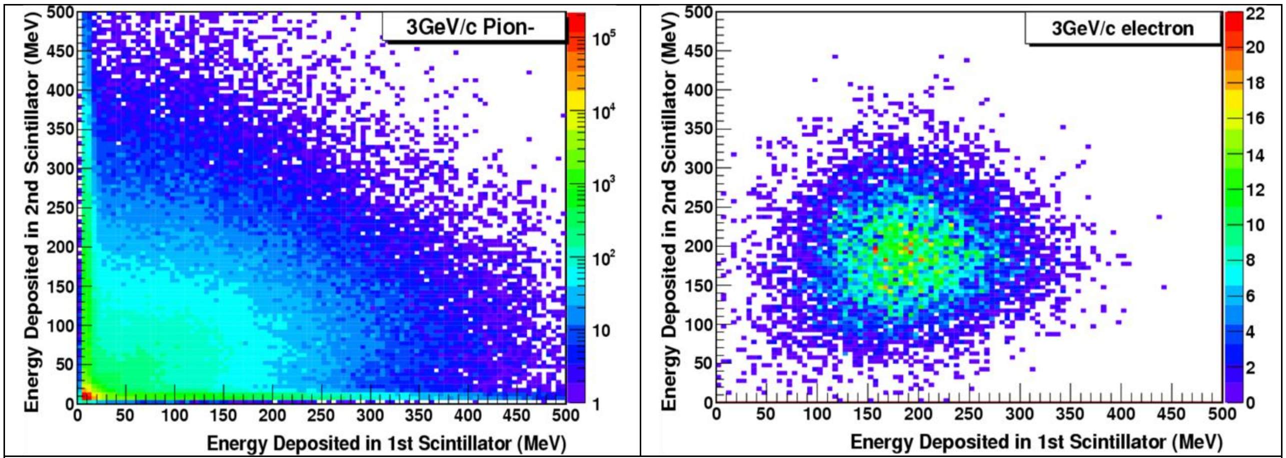

Figure 11. Energy deposition in 2 scintillators by 3GeV pion and electron.

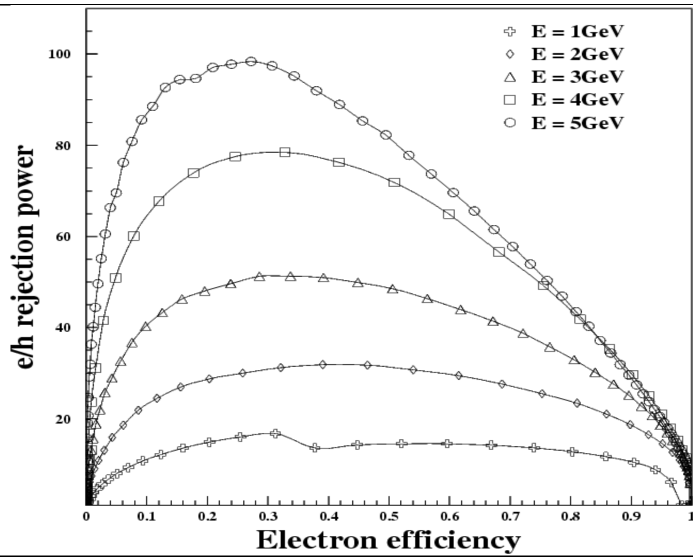

Figure 12: pion rejection of TOF+2 scintilators for different electron incident energy.

4. Performance and Experience of Detector R&D

Collaborators within this group have experiences in R&D and construction of GEM and MRPC TOF detectors. The barrel MRPC TOF project, which is a joint effort of USA-China collaboration, has been successfully carried out from the R&D phase and subsequently to the successful completion of the project in 2009. An R&D project on "novel and compact muon detector" was proposed by us in 2007 and led to the STAR Muon Telescope Detector (MTD), which is designed to cover the barrel for muon identification based on long-strip MRPC modules. The MTD project has been approved and the construction is underway.

Our collaboration also has been active in GEM R&D and detector projects. Two trackers based on triple-GEM detectors have been in construction phase in STAR. One is the Forward GEM Tracker (FGT), which is designed to track and distinguish the electron charge sign from W+- decays in the forward $1<\eta<2$. A few small GEM modules have been proposed to be installed around TPC for monitoring the TPC performance and space charge distortion. This project is expected to complete for this coming run 12.

The proposals of these detectors can be found at:
http://drupal.star.bnl.gov/STAR/future/proposals

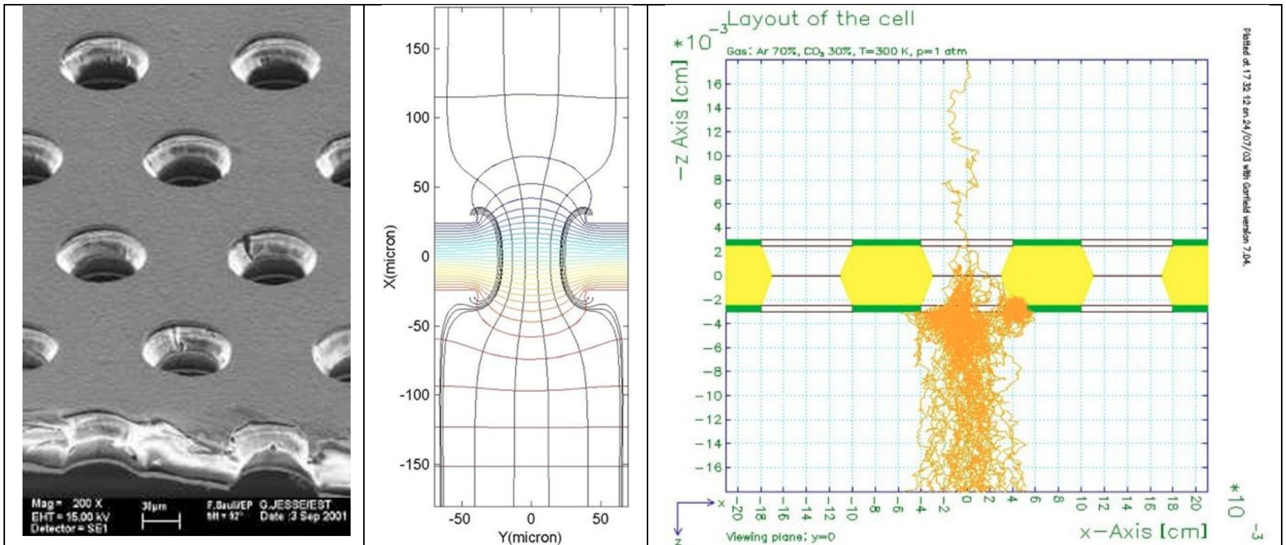

Figure 13. The basic structure, electric field distribution and single electron avalanche simulation of a GEM detector.

Current research activities related to the GEM technology at USTC:

Research on Gas Electron Multiplier (GEM) based detectors for high resolution particle tracking and X-ray imaging applications.

The active element of GEM is a thin, self-supporting composite mesh, realized by photolithographic methods. A thin insulating polymer foil, metalized on each side, is passivated with photo resist and exposed to light through a mask; after curing, the metal is patterned on both sides by acid etching and used as self-aligning mask for the etching of the insulator, opening channels all the way through. When suitable voltage drop is applied on two sides of the foil, high electric field is form in the hole, where gaseous avalanche can take place.

By applying suitable potentials on the GEM electrodes, the effective gain of a single layer GEM foil is at a magnitude of 10^{2-3} and that of a triple layer GEM detector can reach more than 10^{5-6}. Unlike the detectors which consist of wire electrodes (e.g. MWPC), its micro-cell structure endows the GEM detector with very good time responses and high counting abilities. The GEM limits the avalanche process within its holes and separates the avalanches from electron-ion collection, so that the space charge effect is greatly decreased. A GEM equipped with a micro-strip readout electrode and using the Center-of-Gravity (COG) method can reach a spatial resolution of less than 100 μm. Large area GEM detectors have been designed for tracking intense particle beams and for X-ray imaging.

With the funding from the National Natural Science Foundation (NNSF), the high-energy group of USTC had started research on GEM technique since 2000. By actively cooperating with researchers in this field, significant progress had been achieved. These progress include study on GEM foil material, electrode and readout design, GEM test setup. A 2-D new type readout board is developed domestically (in China) and several GEM prototypes are constructed and tested, with excellent performance. Readout electronics suitable to GEM detector is also worked out and a triple-layer GEM structure is developed for X-ray imaging. Several kinds of 2-D delay-line readout circuits are designed and successfully applied to GEM prototype.

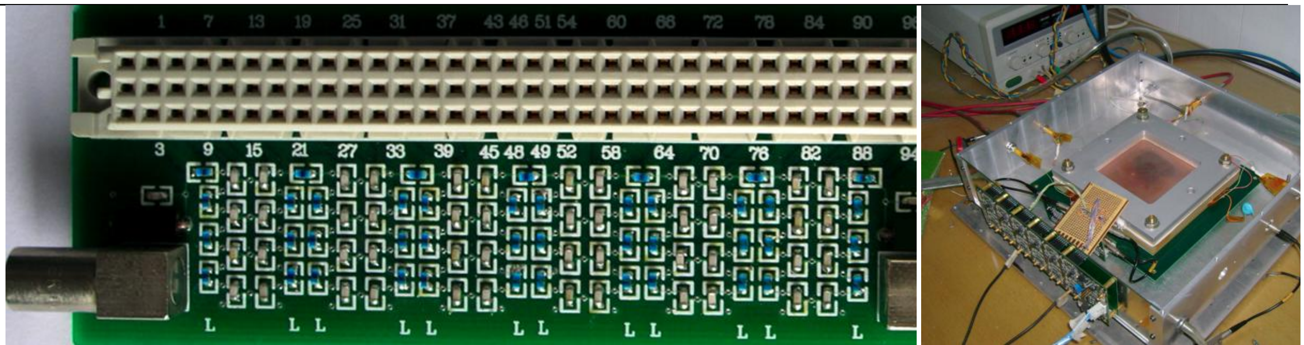

Figure 14. (left) A delay-line readout circuit board and (right) a triple layer GEM prototype equipped with such readout.

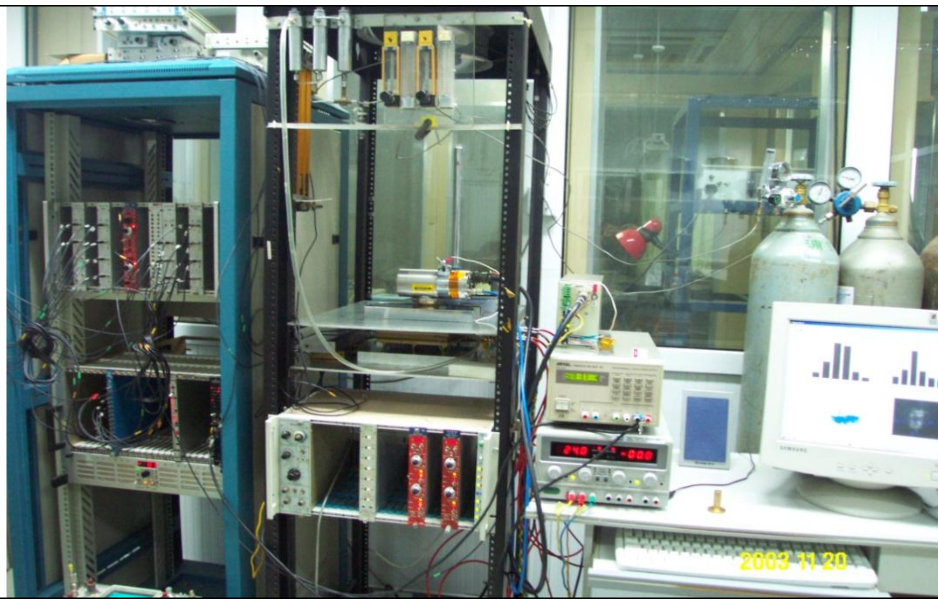

Figure 15. R-ray imaging system with GEM technique.

Activities at BNL and other collaboration institutes in USA

In 2007, we have a test beam experiment at FermiLab meson beam line for the joint R&D projects of MTD and FGT (T963). Technical papers of the test beam results have been published in NIMA 593 (2009) 307 for MTD MRPC and NIMA 598 (2009) 432 for FGT GEM. Fig.16 shows the T963 setup at Fermilab in 2007 with MRPC and GEM test stands together with other detectors (TOF, MWPC stations and Cherenkov counters). Fig.17 shows the correlations between the position calculated from MRPC long-strip and hits from GEM. Fig.18 shows the GEM performance on position resolution and ionization signal.

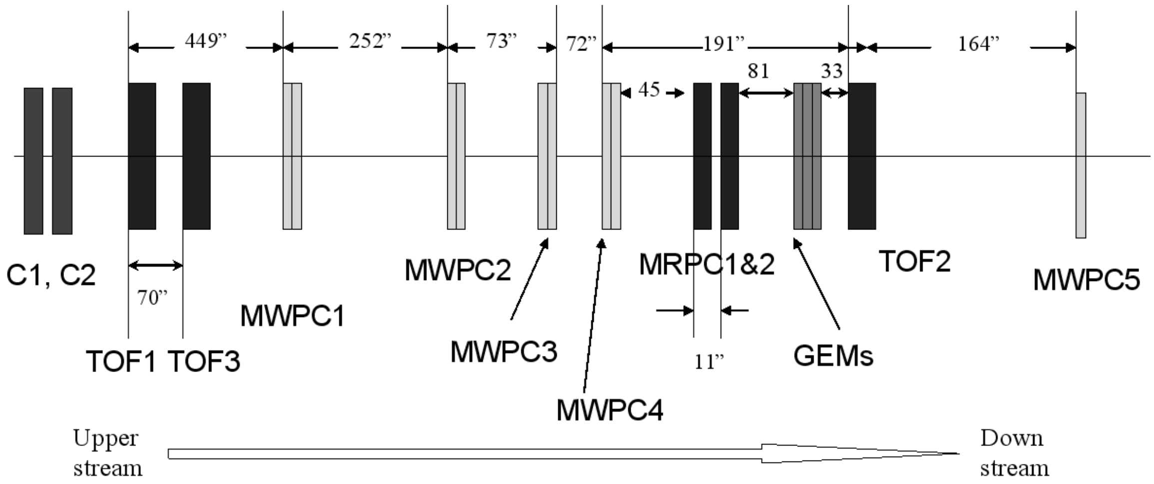

Figure 16: Setup of MRPC and GEM test stand at FermiLab test beam (T963).

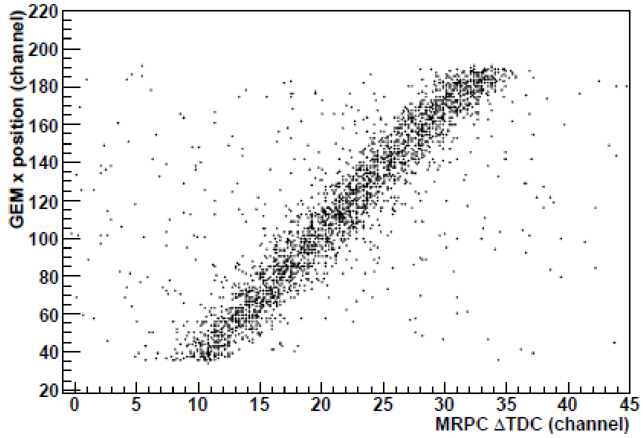

Figure 17: Long strip MRPC position resolution vs GEM position in the test beam.

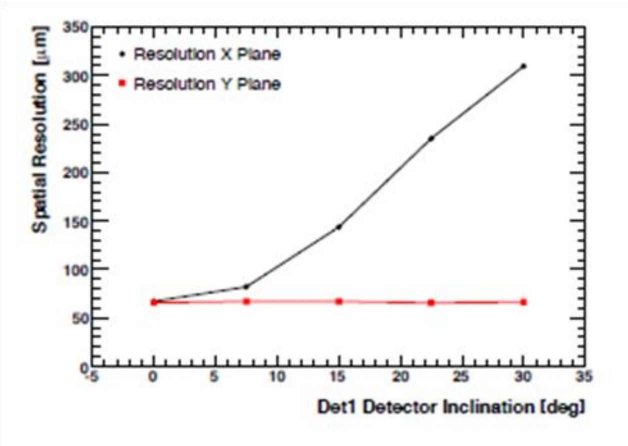

Figure 9: Spatial resolution as a function of the angle of incidence of the particle tracks, for both the projection along the inclination of the tracks (X) and the projection perpendicular to the tracks (Y).

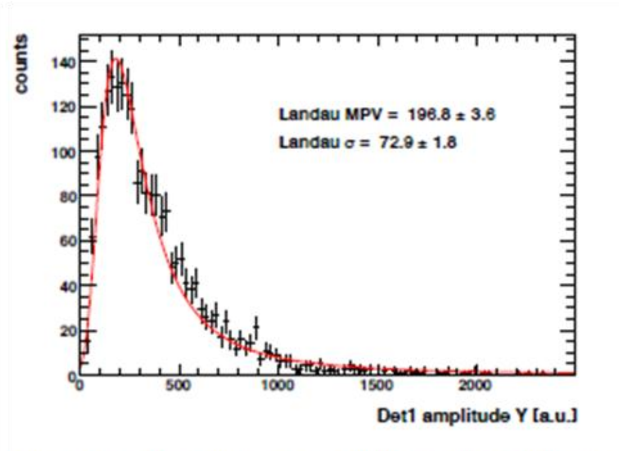

Figure 6: Cluster charge distribution on one detector projection, together with a fit with a Landau function. The charge distribution follows the expected Landau shape for thin absorbers.

Figure 18: Performance of GEM prototype: position resolution (left panel) and dE/dx distribution in the test beam.

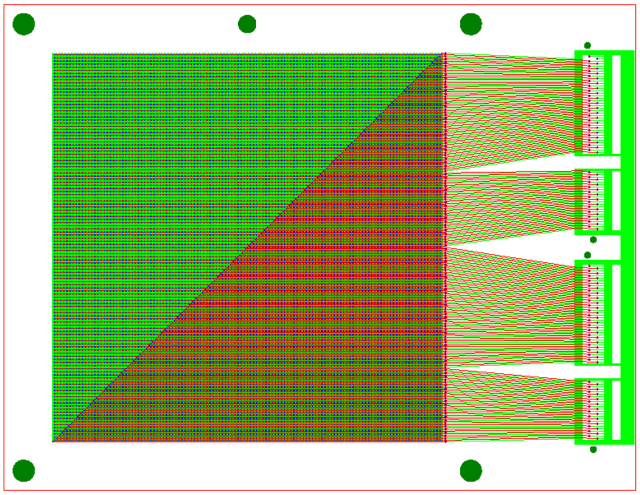

Figure 19: readout design for GMT and same design will be used for TRD prototype.

Figure 19 is the readout pad drawing to be used in a monitoring detector for TPC alignment and distortion correction. Eight modules will be installed in STAR at different azimuthal and eta locations replacing some of the TOF MRPC modules in the coming FY12. We intend to use this design for our TRD prototype. Section 5 provides the details of the electronic readout and DAQ. Prototype assembly and cosmic ray tests will be done at BNL. The same lab space has been used in the past for prototype MTD tests and assembling the GMT into TOF trays.

Activities on Large-area GEM at VECC for CBM

As a part of the development effort for building a muon detection system in the CBM experiment in the upcoming FAIR facility at GSI-Germany, VECC group is involved in R&D work on GEM as tracking chambers. In CBM muon chambers, where tracking will be done inside absorbers, the chambers should cover an area of 20m^2 working at a rate upto 16 MHz/cm^2. Main goal of this R&D is therefore to develop highly efficient large-size GEM modules to be readout by self-triggered readout system with highly granular pad readout.

At VECC so far, several triple GEM modules each of 10cm x 10cm dimensions have been made and tested using radioactive source (Ru-90 and Fe-55), proton beam and cosmic rays. A self-triggered ASIC called n-XYTER has been used for the readout. The ASIC has a fast channel of 20-nsec trigger time for time-stamp determination and a slow channel for charge measurement. All the foils were obtained from CERN fabricated by both types of technology e.g. conventional single-mask and recently developed single-mask. Pad-planes used were of various types, e.g. staggered rectangular pads of 1.8mm x 16 mm, regular square pads of 3mm x 3mm and 4mm x 4mm.
In test beams, well-defined MIP-like ADC spectra and efficiency >95% were obtained. The cluster-size is mostly contained in a single 3mmx3mm pad. Well-defined characteristic ADC spectra were obtained from Fe-55 X-source.
Recently GEM-chambers have been tested at CERN with secondaries produced by proton beams hitting a 10-cm iron converter.

We are in the process of building 30x30cm[2] GEMs to be tested with proton beam in January-2012. Arrangements are being made to procure and build large (1m x 0.5m) sector-shaped GEMs with radially increasing pads.
As a part of exploring other applications of GEM, we are working on testing the GEM with X-rays using Xe-gas. This arrangement might help to get insight towards their applicability in TRD.

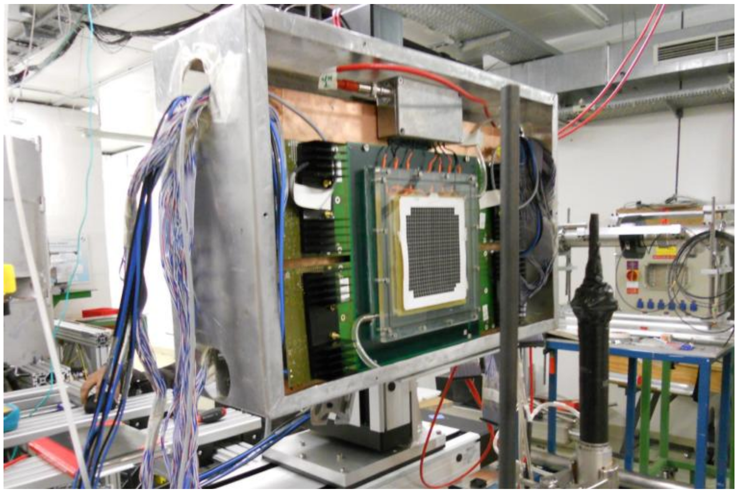

Figure 20: CBM test setup at Jessica beamline at Julich (10/2010)

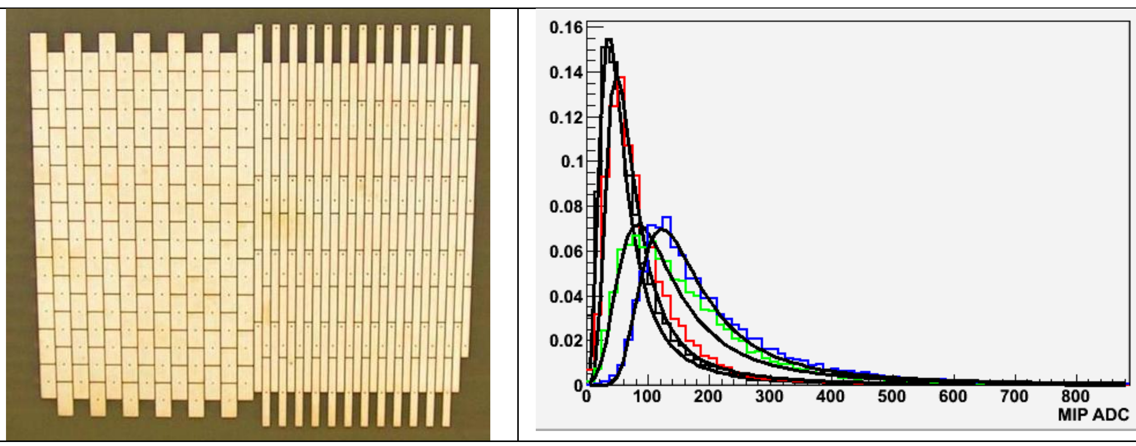

Figure 21: (left) readout pad geometry; (right) MIP for different HV settings.

5. TRD electronics options and stage I goals

Part of the R&D of this Proposal is to gain experience & evaluate a readout electronics chain suitable for the TRD detector at its envisioned position in an EIC detector, potentially an upgrade STAR detector. Members of the team have been responsible to majority of the electronics and upgrades in STAR detectors: TPC electronics upgrades and DAQ system (BNL), EMC readout electronics (IU), FGT GEM readout electronics (IU), TOF electronics (UT/Rice).

We plan to approach this in two stages. In the first stage we will concentrate on the actual detector performance where we only wish to have a working and well-understood readout chain used exclusively for the TRD detector R&D. We call this the baseline stage since we need to provide basic readout of the TRD detector in the lab or in test beams.

In the second stage we would like to concentrate on the evaluation or initial development of the frontend electronics which could be suitable for a production version of the TRD detector.

We expect to complete Stage I during the first 3-6 months of the Project while the remaining time would be entirely spent on Stage II.

Stage I -- Baseline Electronics

For the baseline stage we plan to use the currently existing electronics readout used for the “Forward Gem Tracker” (FGT) at STAR with modifications already made for the “GEM Monitor for the TPC” (GMT) detector also at STAR. This electronics system was designed for FGT’s and GMT’s GEM chambers and is based upon the APV frontend ASIC, custom STAR-specific electronics and the STAR-standard DDL optical link. Such a system is already in use for the QA phase of the FGT detector and will be used in the physics production during the RHIC FY12 run.

Apart from installing the electronics on the prototype detector the 2 necessary modifications and thus milestones of Stage I would be:

Milestone 1: Modifications of the FGT/GMT readout system to enable at least 100 time samples readout.

Milestone 2: Modifications necessary to enable operation at collision frequencies of up to 15 MHz, as required by eRHIC.

The cost estimate of Stage I of the TRD frontend electronics is in Table 1.

ARM board	2700 $
ARC board	1000 $
backplane & cardcage	1000 $
interface cards	1000 $
SIU optical interface card	700 $
engineering (1 man-month)	15000 $
TOTAL	**21400 $**

Table 1: *Cost of the baseline electronics system*

Stage II — Evaluation of TRD Electronics Options

During the first part of Stage II we plan to provide a list of precise requirements for an electronics readout system necessary for a physics production detector. Although some of the requirements are already known and understood we assume that more precise or more stringent requirements will follow from the first initial test of the prototype, as we gain more experience from our R&D. We plan to propose the Stage II R&D next year.

The currently known requirements for final electronics are:

1. Synchronous time sampling suitable for a drift TRD with good energy resolution.
2. Low mass.
3. Efficient cooling.
4. Some level of radiation tolerance.
5. Magnetic field tolerance.

Requirement 1 -- time sampling with good energy resolution

The ETTIE TRD detector is also a small TPC so the readout electronics needs to sample the detector GEM signal at fixed times synchronous to the collision clock. An example of an existing ASIC which was designed for TPCs is the ALTRO chip already used in the STAR TPC.

The electronics also need to provide good noise and energy resolution characteristics for the dE/dx measurement.

Requirement 2 -- low mass

The ETTIE detector is situated in the forward direction and aims to detect electrons. As such the mass of the electronics system through which the electrons pass needs to be as small as possible.

The designs we plan to evaluate will thus attempt to split the electronics chain into a preamplification and shaping analog stage which we presume will be located next to the detector but will be as low mass as possible, and the digitization and signal processing stage(s) which we assume will be outside the critical volume.

Requirement 3 -- power consumption

The proposed ETTIE detector is fully enclosed within the STAR magnet volume and thus the electronics need to be either sufficiently low power or the cooling system needs to be efficient and low in mass.

Requirement 4 -- radiation tolerance

Since at least part of the frontend electronics will be showered by particles produced from eRHIC collisions and other collision debris we need to evaluate the level of radiation and thus the necessary electronics radiation tolerance of our system. This will provide guidelines to the final design and might provide constraints to the available technologies used (i.e. FPGAs or other CPLDs).

Requirement 5 -- magnetic field tolerance

Some part of the electronics will be situated within the STAR magnet and as such need to work reliably in a 0.5T magnetic field. Although we do not feel that this would cause any problems we need to bear in mind this requirement.

During the Stage II of the TRD readout electronics R&D we plan to first evaluate existing ASICs suitable for the TRD detector as well as investigate and potentially partake in new developments throughout the physics experiments in nuclear and high-energy community such as the RD51 collaboration at CERN.

Trigger & Data Acquisition (DAQ) Readout

To enable robust and efficient testing of both the TOF and the TRD components of this Proposal we plan to install a single slice of the existing STAR Trigger & DAQ chain.

The chain would consist of 1 STAR Trigger Clock Distribution board (TCD) with associated fanout boards and cables, 1 STAR-DAQ “standard” Linux PC, 1 dual-channel DRORC optical readout card with associated optical fibers and enough of hard disk space for efficient saving of acquired data.

The TCD card is the same electronics board used to distribute the clock and all of the trigger-specific signals to any of STAR’s detectors and is the standard trigger interface of STAR’s detectors. As part of this proposal we plan to evaluate TCD’s performance for clocks of up to 15 MHz, the assumed clock of the eRHIC accelerator.

The DAQ PC would run all of the standard STAR DAQ detector software, full Run Control & monitoring similar to STAR as well as online plots and Q&A package which currently runs in STAR (so called “pplots”).

Such a setup will allow for very efficient operation during both lab testing and during beam tests since all of the hardware and software components are compact and well known and understood by members of the R&D Proposal group.

The same Trigger & DAQ Readout system would be used throughout the lifetime of ETTIE’s R&D and in both Stages I & II of the electronics development.

The single milestone for the Trigger and DAQ Readout is:

Milestone 1: Modifications to the Trigger & Clock Distribution Board (TCD) to enable it to work with collision clocks of up to 15 MHz.

The cost estimate for this system is in Table 3.

STAR DAQ standard PC	2500 $
2 DDL DRORC fiber cards	3500 $

optical fibers	300 $
network equipment (switches, cables)	500 $
TCD board, chassis and power supply	1500 $
TOTAL	**8300 $**

Table 3: *Cost of the DAQ Readout System*

6. **Summary:**

We propose to build a prototype of Transition Radiation Detector based on $10x10cm^2$ triple GEM detector. We will take advantage of the design of the GMT readout pad and its available GEM foils for building this prototype. The goals are:

i) dE/dx resolution with $Xe+CO_2$ gas in 2-4cm ionization chamber;

ii) hit position resolution for tracklets;

iii) investigating readout electronics options (Stage I).

Part of the R&D support (not requested by this proposal) on large-area GEM readout are conducted in India and China. Possible R&D on endcap-type TOF design and electronics may be proposed to NNSFC/China in early next year.

In addition, we plan to carry out simulations including a realistic simulation for a combination of TPC and TRD tracking, TOF with converter for identifying scattering electrons at the level of better than 1000 hadron rejection and for detecting large background photons in a possible first-stage EIC detector.

We envision a Stage II R&D proposal at the end phase of Stage I R&D (this proposal) to continue the following possible investigations:

a) complete TRD prototype with radiator and tracking capability;

b) TOF prototype detector with the necessary radiation and rate capabilities;

c) Stage II TRD electronics design and new TOF electronics options;

d) install the prototype in realistic magnetic field and radiation environment.