Quarterly Report FY09Q1
Date: February 11, 2009

Project Name: PHENIX Forward Muon Trigger Upgrade
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Report Outline:

Introduction

This report has been prepared as the basis for a quarterly review on February 11, 2009. This report reviews the status of the PHENIX Forward Muon Trigger Upgrade Program. In this document we outline the progress made since the BNL review in September 2008 and present our plans for progress in the next few months. In section A we discuss progress made and plans for the construction of the RPC detectors, the RPC electronics and software and simulations. In section B we present the status of the project budget and in section C we discuss the project schedule.

A. Status Reports and Plans

A.1. RPC Design, Construction and Integration

A.1.a. RPC Gap Production at KODEL

(Sung Park, Korea Univ.)

A major effort at KODEL has been preparation for and production of gaps for the RPC-3 detectors. For the RPC-3a, 3b and 3c gaps, we received all 242 bakelite sheets in October 2008. Most of them were in good condition. Also the design of each of the RPC-3 gaps was finalized in close collaboration with the RPC design group at RBRC, UIUC and ACU. Upon completion of the RPC-3 final designs we prepared all necessary adjustments of the gap production line for mass production of RPC-3. The production started with RPC-3a and now has moved on to RPC-3b. 83 RPC-3a gaps have been shipped to Brookhaven in the first week of February 2009. These gaps were successfully tested at KODEL for 150 hours at the working voltage of 9.4 kV. A total of 64 RPC-3a gaps are required but a total of 83 will be shipped from KODEL. Fig. 1 shows RPC gaps produced at KODEL and in a box ready for shipment to BNL.

In addition to the RPC-3 mass production RPC-1 prototypes were manufactured These prototypes were needed to test the final design of the RPC-1 chambers. The RPC-1 gaps were smaller in overall size than any previously manufactured gas gap at KODEL. It was necessary to develop new procedures for assembling, oiling and testing the gaps. All 10 gaps were shipped to BNL and then RPC 3 production work resumed.

KODEL has started work on the production of the RPC-3b and RPC-3c gaps. The RPC-3b gaps should be ready for shipment as early as the end of March 2009 and shipment of the RPC-3c gaps is expected in early June 2009. This will complete the major portion of the RPC production. Then with completion of the RPC-1 design (see below) KODEL will begin production of the RPC-1 gaps.

A.1.b. RPC Boxes and Signal Plane Production in China

(Xiaomei Li, CIAE)

3 sets of RPC3 support frames arrived and were installed as two prototype D half octants upstream and downstream of the south PHENIX MuID in October 2008. Detector boxes and signal planes for the RPC1 prototypes were manufactured and arrived at BNL in January 2009. They delivery consisted of the readout strips shown in Fig. 2 and the honeycomb boxes shown in Fig. 3. Readout strips for the RPC1 prototype adopted the mylar covered technology which has not been used in any other experiments before. The mylar is a thin layer that can prevent oxidation.

The purchase order for 34 sets of RPC3 module parts from University of California, Riverside (UCR) is in process, and is expected to be approved in the week of February 9th. The factory usually has a 5-10% discount for mass production. Comparing with the prototypes of RPC3 module parts we delivered last May, we achieved a deal of ~14% discount this time after hard negotiation, which has touched their bottom line. We will use sea shipping this time, which costs only 2.5% of the production cost compared to the 23% production cost for air shipping. After receiving purchase order and advance payment from UCR, Chinese factories will manufacture as soon as possible, and deliver in 100 days by sea shipping.

A.1.c. RPC Half-Octant Structure Production in U.S.

(Larry Bartoszek, Bartoszek Engineering)

The extensive hardware needed to connect the individual modules to form half-octants and to connect the half-octants into the various complete RPC detectors has been designed. Drawings were sent out to ISU and CIAE and several commercial shops in the U.S. Bids from these institutions and shops have been received. Prices vary over a wide range. The most competitive prices were obtained from three shops in Illinois and New Mexico. The order will be split into two separate orders, one for large pieces and the second for smaller size pieces. We found that this division lowers the overall production cost. The lowest bidders for both orders were from Illinois. A purchase order will be submitted before the end of February. Pre-assembly of the half octants will take place at UIUC in Urbana.

A.1.d. RPC Prototype-D Installation & Readiness Run-9

(Anselm Vossen, UIUC)

Half octant prototypes in the positions of stations 2 and 3 on the south side of the interaction point where assembled and tested by the Muon Trigger Upgrade Group in the factory on schedule. Fig. 4 shows a RPC half octant after assembly and testing. The half octant prototypes were subsequently delivered to the PHENIX experiment on Oct 29th and Nov 17th respectively. PHENIX technicians and engineers working together with the upgrade group installed, integrated and surveyed the detectors such that no additional access to tunnel or IR is planned. Fig. 5 shows one of the half octants in place between the muon tracker and the muon ID.

Gas lines are laid, branching from the TOF west gas system, with a dedicated RPC gas mixing rack. A rack housing electronics for both RPC prototypes is installed in the south tunnel. Signal cable, low and high voltage cables were routed from the detectors to the respective bins in the rack. Electronics, low and high voltage supplies are functional and tests are ongoing. Gas checks testing the detectors for leakage were successful. Low and high voltage supplies as well as basic electronics tests were also successful.

Since February 4th working gas is supplied to the detector with a plan to add humidity from outside the shield wall as soon as tests in the factory and dry operation in PHENIX establish confidence in a smooth operation of the detector with humidified gas. The front end electronics are integrated in the PHENIX DAQ and form a granule. Currently the stability of the HV on the detector is monitored and test data is taken with a pulser integrated into the front end electronics.

Once the above standalone tests are successful the detector will be ready for integration into the PHENIX DAQ and therefore ready for data taking. LV slow control is provided by PHENIX whereas HV slow control automation software is developed by the group and is expected to be finalized by the time this report is given. Going forward, the next tasks will be the development of online monitoring software based on existing test software and shift crew instructions. Starting with the first collisions in PHENIX the detectors will be timed in. Summarizing, the installation and integration of RPC prototype D is on schedule. There were no major difficulties encountered so that we plan on studying detector performance very soon after the first beam collisions.

A.1.e. RPC Factory Progress and Status

(Young Jin Kim, UIUC)

The RPC group has gained a lot of experiences in QA of RPC gaps, detector parts, and RPC detectors as well as in assembly of RPC modules and half octants for three prototype C RPC modules, nine prototype D modules, and two half octants. The two half octants are currently installed at PHENIX for RHIC Run-9. The assembly of prototype RPC-1 is in progress for the purpose of finalizing the design of RPC-1. This is proof of the capability of our group to carry out RPC mass production and testing.

One of the recommendations from the October 2008 review was the following:

> “Build and instrument a separate “burn in” area where the RPC modules can be located and burned-in after the efficiency study. This activity should not affect the overall schedule since it can be carried out in parallel with the main cosmic ray test stand running activity.” Fig. 6 shows a diagram of the new half octant burn-in and storage area.

Also the schedule of RPC gap production and delivery must be adjusted to accommodate the KODEL schedule for RPC gap production (last gap will be shipped in early June). Thus additional RPC gap, detector part, and RPC module storage is needed.

In order to help fulfill the above requirements a review of the expanded PHENIX RPC factory was held on 2008 December 12th concerning:

- Enlargement of total capacity of current gas system and extension of number of H.V channels at RPC factory for supplying RPC module QA and burn-in test station and related safety issues.
- Design of burn-in test and storage station of RPC half octants.
- Design of half octant transport table. See Fig. 7.
- Proposal of new RPC factory layout. The new factory layout is shown in Fig. 8.

After the review, the RPC group and PHENIX management received the following action items with current status of them:

- Review the mechanical design of the burn-in assembly and the dolly system to be used in moving the ½ octant units. (Mechanical design finished; see supplement, need to update by RPC group and review them by C-AD)
- Update the RPC work plan accordingly (Done)
- Update the RPC high voltage and gas procedures if necessary (Done)
- Add individual output valves to the burn-in unit gas schematics (Done)
- Get a permit for the R134 added consumption (In progress)
- Review the flammable compressed gas system piping (In progress)
- For the burn-in unit, use non-flammable welding curtains (Will be done)

In parallel to the review action items, upgrade of gas system at RPC factory, installation of dark current test stand, setup of climate control for RPC gap storages are in progress.

Assembly of the RPC-1 prototype began in early February 2009. It will be tested and used to determine the final design for RPC-1. Fig. 9 shows the RPC-1 prototype in the BNL factory during assembly and with also with the honeycomb sheets and the preamp/discriminator.

For the near future of the RPC factory, the expanded PHENIX RPC factory review action items have to be finished by the end of March including implement of all safety items. According to the RPC gap production schedule, the first phase of RPC gap storage must be ready by the middle of February and the extension phase of it has to be finalized by the end of May. In addition to this, the storage area for detector hardware has to be set by the end of April.

The RPC group anticipates starting RPC detector mass production around the beginning of May and the first half octant will be produced around July. Thus, the burn-in test and half octant station and the half octant transport table have to ready including gas and H.V distribution systems. Four PHENIX and 1 UIUC technicians are working on these with support from the RPC group.

A.1.f. Status of RPC-3 and RPC-1 Design

(Ralf Seidl, RBRC)

The designs for all the RPC-3 detectors have been finalized and submitted to KODEL for gap production and to Chinese and U.S. vendors for bidding on detector boxes, signal planes and half octant hardware. After the September 2008 review three prototype designs for station RPC-1A and two possible configurations of station RPC-1B have been created. In an early design two stations 1A and 1B were envisioned to increase the redundancy for RPC modules with split gaps. The RPC gaps for these three prototypes as well as the module frames and the readout strips have arrived at the BNL factory and are currently being assembled.

During the production of the RPC-1 prototypes at KODEL it has been found that the small gaps sizes needed in one of the two detectors (3 split gaps) are very difficult to manufacture. KODEL recommends to not attempt mass production of the 3 split gap design for RPC-1.

In response we carried out several tests on the prototype D and we were able to show, that RPCs operated with only one gap under high voltage are still more than 90 % efficient. It therefore becomes possible to move from an RPC-1 configuration with two detector stations to a design with only on station. We have decided to manufacture a full RPC-1 detector set as spares to compensate for the loss of redundancy. It should be also noted that additional redundancy for RPC-1 will be provided through MuTr station 1.

Finally, trigger simulations showed that the trigger rejection will benefit from the additional absorber that can be placed upstream of RPC-1: Space for additional absorber would become available by departing from the design of two stations RPC-1A and RPC-1B. Therefore it has been decided by the RPC group, that one station RPC-1 will be sufficient.

As the design of the RPC-1 needs only minor changes with respect to the RPC-1A prototype design, the design is nearly finished and the cutting of the Bakelite and the subsequent gap production can start directly after the RPC-3 gap production.

As an example the south upstream RPC-1 design is shown in Fig. 10. The full designs of this detector as well as the three remaining detectors (the flower pot opening angle is different for north and south and the octants are staggered in two layers for full azimuthal coverage) can be found on:
{ http://www.phenix.bnl.gov/WWW/publish/rseidl/RPC/FinalDesign/RPC-1}.

A.2. RPC Electronics and Triggering

A.2.a. RPC Front End Electronics

(Cheng-Yi Chi, Columbia Univ. and Ken Barish, Univ. California at Riverside)

The RPC electronics for RPC prototype D has been installed in PHENIX for Run-9 and the TDC system has been successfully read out through the PHENIX Data Acquisition system. On the electronics production, all discriminator and cable adapter parts have been purchased. We are proceeding with assembly of both boards. The first articles are scheduled to arrive soon. The full assembly of those boards will start after the first article is fully tested.

In the next quarter, the production/testing of the discriminator and cable adapter is expected to be at its half way point. We will proceed with TDC system production, and part procurement for the TDC system will be started in the next quarter. The production is expected to last from 6 to 9 months depending on the lead time of the components.

A.2.b. Status of MuTr FEE Electronic (Tsutomu Mibe, KEK)

In this review the emphasis is on the RPC portion of the Forward Upgrade Project but we report here a significant achievement of the MuTr FEE portion of the project which is funded by the Japanese Society for the Physical Sciences. The MuTr FEE group has successfully installed in the north muon arm the complete FEE electronics in muon tracker stations 1, 2 and 3. This consists of amplifier/discriminator boards followed by a merge (MRG) board. This FEE system will be tested during Run-9. The upgrade of the LL1 trigger for the forward spectrometers uses signals from both the MuTr and the RPCs to enhance the signal from muons from W boson decays. Recently a successful test was carried out in which the MuTr FEE signals from the MRG board were successfully communicated to and received by the LL1 hardware (see sect. A.2.c). A picture illustrating the connections between the MuTr FEE system and the LL1 trigger is shown in Fig. 11.

A.2.c. Trigger Electronics (John Lajoie, Iowa State)

Since the last review in October 2008 the Level-1 trigger tile has been sent out for board fabrication, assembled, and tested. We manufactured twenty boards in total, of which nineteen have tested fully functional, and one board appears to have a bad linear power supply. We require sixteen Level-1 trigger tiles for the full Muon Trigger Upgrade (MuTr+RPC's, both arms), which will give us four spare boards for the full system.

Development work was carried out on the "base" board that will hold up to eight trigger tiles (four required for the Muon Trigger Upgrade). The design on this board is complete and this board is currently being manufactured. Parts have been ordered, and it is expected that we will have two fully-assembled boards for testing in the last week of February. The backplanes and transition cards for the full system have also been ordered and are currently being manufactured, and availability is expected on the same timescale. A critical path item at the past review was whether the Agilent HFBR-782BEZ transceivers could be operated at 2.8Gbit/s (they are rated at 2.7Gbit/s). We felt that detailed testing was necessary, despite assurances from the manufacturer and other users. An HFBR-782BEZ was tested in a Bit-Error Rate (BER) setup in the Electrical

Engineering laboratory of Prof. Robert Weber at Iowa State, and it was determined that a conservative upper limit on the BER for at 2.8Gb/s was 10^{-14}, sufficient for trigger operation.

Finally, in January 2009 a second set of testing of the MuTr MRG board communications with the LL1 trigger tile was started. The goals of this testing is to demonstrate proper communications with the LL1 trigger tile and four MRG board data channels. Four data channels is the required number of fibers from the MuTr per trigger tile (per octant) for the full trigger. In addition to robust communication, we have also tested the ability to align the data in LL1 from all four different data streams, so that the trigger can correlate data from the same beam crossing for all four fibers. Some of the results from the January 2009 tests are shown in Fig. 12. This testing is continuing and has currently identified an issue where communication fails with an apparent shift of 1bit in the 8b/10b encoding pattern. Currently we believe that this may have to do with the stability of the reference clock used for the LL1 clock reference, and we are investigating.

During RHIC Run-9 it is our stated goal to attempt to implement and demonstrate at least one octant of the Muon Trigger Upgrade. It is our hope that this will be done in a full trigger tile + baseboard combination, but it can be done in a standalone trigger tile if required. This will require a great deal of FPGA programming to implement the serial communications, channel mapping, and algorithm within the LVL1 framework and integrate the trigger into the PHENIX Level-1 system. Because of the complicated nature of the system and the great deal of work required to achieve this goal we do not anticipate that the trigger will be available at PHENIX to take data, but will be implemented for debug operation that will allow us to get the experience required to set up the full system in time for RHIC Run-10.

A.3. Software, Simulations and Backgrounds

A.3.a. Software and Simulations (Ralf Seidl, RBRC)

Since the review the amount of background data created has been increased continuously in order to get to the statistics needed to test the effectiveness of tighter cuts on the reconstructed high transverse momentum single muons. The previous studies found that tighter cuts would provide a rejection of the dominating background (punch through low transverse momentum hadrons that decay within the MuTr to mimick a high pT muon) by at least two orders of magnitude. This number was given as a conservative estimate as the statistics limited the tests on how multiplicative the rejections of individual cuts were. Previous studies also concentrated only on the effectiveness on muons of pT = 20 GeV, while higher momenta were not considered. It turned out that some of these cuts were too restrictive to real higher momentum muons as the intrinsic position resolutions of the muon tracking system smear those to a larger extent.

For this reason the moment resolution matrices of generated muons with different intrinsic position resolutions of 100,150,300 and 600 μm were studied. We compare in Fig. 13 the results from 100 and 600 μm. It is clearly visible, how the resolution decreases with increasing pT and decreasing position resolution. Obviously, one has to concentrate on improving this resolution from the current 300 μm to the nominal 150 μm and efforts are underway to achieve this by increasing the HV in the MuTr.

As a next step the background rejection properties of several variables tested previously plus a few newer ones were investigated. For this purpose transverse momentum dependent cuts which were 98 % efficient on the real high momentum muons were used to evaluate how they affect the background. Fig. 14 gives an illustration of the different distributions of several kinematic variables for signal and background. The individual rejection factors as a function of the reconstructed transverse momentum are displayed in Fig. 15 for several of these variables.

The geometry of the final RPC detectors has been implemented in the full detector simulation. As a next step the RPC hit information has to be processed and added to the reconstruction software. The RPC information will not provide very precise position information, but RPC3 will create an additional entry in calculating the road of a muon through the MUID detectors. In addition possible beam related hits can be rejected by the precise timing information the RPCs provide and can thus reduce wrong combinatorics of hits in the existing muon reconstruction software. Both of these aspects are expected to significantly improve the rejection of backgrounds, especially for the dominant background of low momentum hadrons which decay within the MuTr. Furthermore, some of the variables that were found to be efficient to reduce the backgrounds in the W->μ analysis have to be added to the default production.

A.3.b. Cosmic Ray Background Determination in Run-9

(Xiaochun He, GSU)

Our effort on making quantitative measurement of cosmic ray background for the W-physics is going very well. The preliminary results from the Run-7 cosmic data have been documented in a PHENIX analysis note 757. A request for a dedicated cosmic run for more statistics before starting the Run-9 physics running was sent to the PHENIX Run Coordinator in December of 2008 and was subsequently integrated into the PHENIX startup run plan for 2009. Xiaochun He is currently overseeing the data taking and analysis in the PHENIX counting house. As an example, a 3-D cosmic ray event display is given in Fig. 16.

The near term plan for the cosmic ray study is to continue the data taking with magnetic field on before the physics run starts. The collected data will be quickly analyzed in order to determine if more data will be needed. The same data set has been used by the MuTr FEE group to commission the newly installed trigger electronics. Because of the relative data file size, the entire data set will be copied to the analysis cluster at Georgia State University. This will allow us to easily access the data and redo the analysis if further fine-tuned analysis is needed.

A.4. Personnel for RPC Production

Recently a number of new people have committed to work on RPC assembly, Q&A and test work in the factory. These people are listed below:

(1) Professor Jianxin Cai of PKU: 5-15-2009 to 5-15-2010
Jianxin Cai has been a Professor for engineering at PKU, he has worked for 3 years in the CMS RPC factories at CERN and has accepted a position as visiting scholar at UIUC for one year. During this time he will be stationed at BNL.

(2) Byeong Hyeon Park 3-15 to 6-15-2009
JeongSuo Kang 3-15 to 6-15-2009
Both are master students in nuclear engineering with a focus on instrumentation at Hanyang University. Hanyany joined PHENIX in December 2008.

(3) Sourav Tarafdor 3-20 to 6-20-2009
Souray Tarafdor is graduate student at Banaras Hindu University.

(4) IhnJea Choi 3-1-2009 to 2-28-2011
IhnJea Choi is a new post doc at UIUC.

(5) Dave Northacker will be not longer stationed at BNL after 5-1-2009
(Dave Northacker will move to FNAL to work for UIUC on E906 and g-2). However, Dave Northacker will be available for 2 week visits to help in the RPC factory.

A.5. Summary and Outlook

Prototyping for the RPC-3 detectors has been completed. A full sized RPC prototype-D was fully tested, installed and integrated in PHENIX for Run-9. Evaluation of detector performance and backgrounds is planned for Run-9.

Mass production of the RPC-3 detectors has begun in the RPC factory at BNL. A RPC-1 prototype has been built and is available to finalize the design for the RPC-1 detectors. Thus mass production of the RPC-1 detectors can start immediately after completion of RPC-3 production.

The RPC FEE + trigger processor design and production are on schedule. Delays have arisen in the detector hardware production through difficulties in the RPC-1 prototyping. An important concern is the engineering work needed for the detector integration. It appears (after the departure of Charlie Pearson from this position) that this work will be not done by CAD liaison engineer

B. Budget Summary (Perdekamp, UIUC)

Item	projected ocst 9-08	projected cost 1-09	Change (decrease, **increase**)	comment
FEE R&D	$ 261,709	$261,709.0	$0.0	
FEE	$ 600,337	$535,332.0	$65,004.8	change in RPC-1
LL1	$ 299,520	$288,920.2	$10,599.8	
RPC Engineering	$ 161,716	$159,248.4	$2,467.2	
RPC R&D	$ 117,562	$143,862.0	**($26,300.0)**	RPC-1 R&D
RPC Production	$ 707,116	$610,606.9	$96,509.1	change in price, RPC-1
Gas System	$ 60,000	$60,000.0	$0.0	
High Voltage	$ 96,000	$96,000.0	$0.0	
Total	$ 2,303,959	$2,155,678.5	$148,280.9	
contingency	$ 183,372	$255,611.4		
committed	$1,086,468	$1,403,364.8		
fraction committed	47%	61%		

We use as reference the budget from September 2008 which reflects the muon trigger configuration with two RPC stations. The projected cost reflects an updated version of the original budget using improved cost estimates based on orders submitted and quotations obtained. The uncommitted contingency has increased by about $70k. The amount of funds committed has increased from about $1.1 million to about $1.4 million.

Significant commitments since the last report include (1) parts orders for the front end electronics and trigger processors for about $100k (2) order of RPC-3 detector boxes and signal planes ($98.3k instead of $150k) and (3) commitment to support for Mr. Cai to lead the RPC assembly team at BNL for one year.

Unbudgeted costs, $26k, arose from the production of RPC-1 prototype gaps. It has been planned that the RPC-1 gaps could be produced in the course of the RPC-3 mass production. However, it turned out that the RPC-1 gaps are too small in size for the production facility at KODEL. In response we now have an RPC-1 configuration that is cheaper, the cost difference have been put included in the updated projected cost.

In the current quarter we expect to order the hardware for the half octant structure and we will continue procurement for the electronics mass production.

C. Schedule Summary (Perdekamp,UIUC)

We believe that the schedule for trigger processors and front end electronics remains as planned. However, in the RPC detector hardware production we have acquired the following delays compared to the project schedule presented at the last review in September:

(1) The **RPC gas gap production for RPC-3 South + North** has started about 4 weeks late and is going to end almost 3 months late:

original schedule	:	12-05-08 - 03-12-09
current schedule	:	**01-02-09 - 06-04-09**

The initial delay of 4 weeks has been caused by technical challenges in the production of the PRC-1 prototype gaps. The additional delay reflects the experience KODEL has gained concerning differences in the manufacturing process for PHENIX gas gaps as compared to CMS gas gaps. An important scheduling constraint arises from a change in production order: KODEL has determined that the highest quality for the gas gap manufacturing does not permit switching the production between different gas gap types. We therefore decided to change to a production sequence in which first all detector modules A (RPC-3 north + south) were manufactured. Next all gas gaps B and then all modules C gas gaps will be build. Finally, we comment that the delay also accommodates the schedule for ongoing RPC factory modifications at BNL: The factory extension results in part from the change in production sequence (requires more storage!) and in part from the decision to build a burn-in station for half octants in the factory. The latter was a recommendation from the September review.

(2) The **RPC-3 detector module north production** schedule is now :

original schedule	:	01-30-09 - 06-18-09
current schedule estimate	:	**04-15-09 - 09-30-09**

(3) The **RPC-3 half octant north production:**

original schedule	:	04-27-09 - 07-20-09
current schedule estimate	:	**07-15-09 - 10-30-09**

The change of schedule impacts the station RPC-3 north installation schedule. It is desirable for PHENIX to split the RPC-3 installation into two steps and to carry out the north installation in the summer shutdown of 2009 and the south installation in the shutdown 2010. The main advantage of a staged integration is the ability to better balance efforts for different detector upgrades within the PHENIX technical support group. We believe that still a major fraction of the RPC-3 north half octants could be installed in the summer of 2009, depending on the shutdown schedule possibly all.

The first polarized proton-proton run with $\sqrt{s}$=500 GeV will not occur before run 11. There is enough float in the schedule so that the change in schedule discussed above does not impact our ability to assemble both detector stations (RPC-3 north and south) in time for an installation in the summer shutdown of 2010.

Fig.1 RPC gaps from KODEL in box for shipment to BNL.

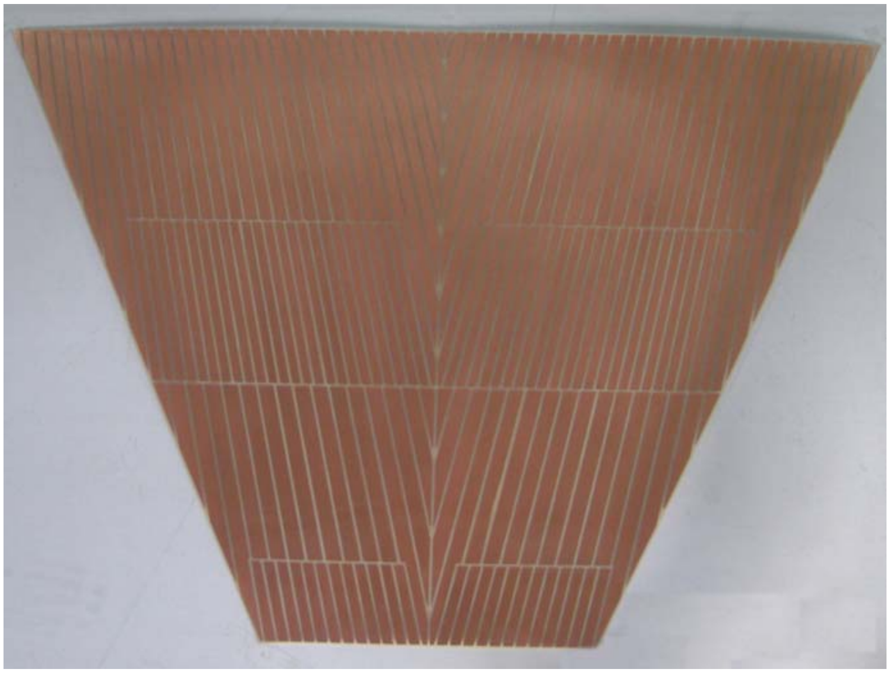

Fig.2 The readout strip of RPC1.

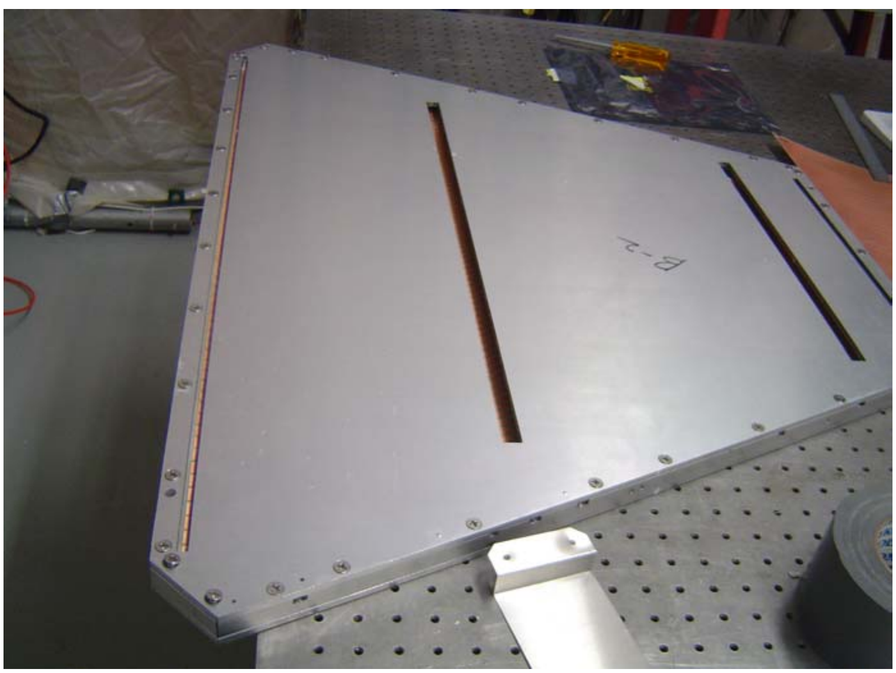

Fig.3 The detector honeycomb boxes of RPC1.

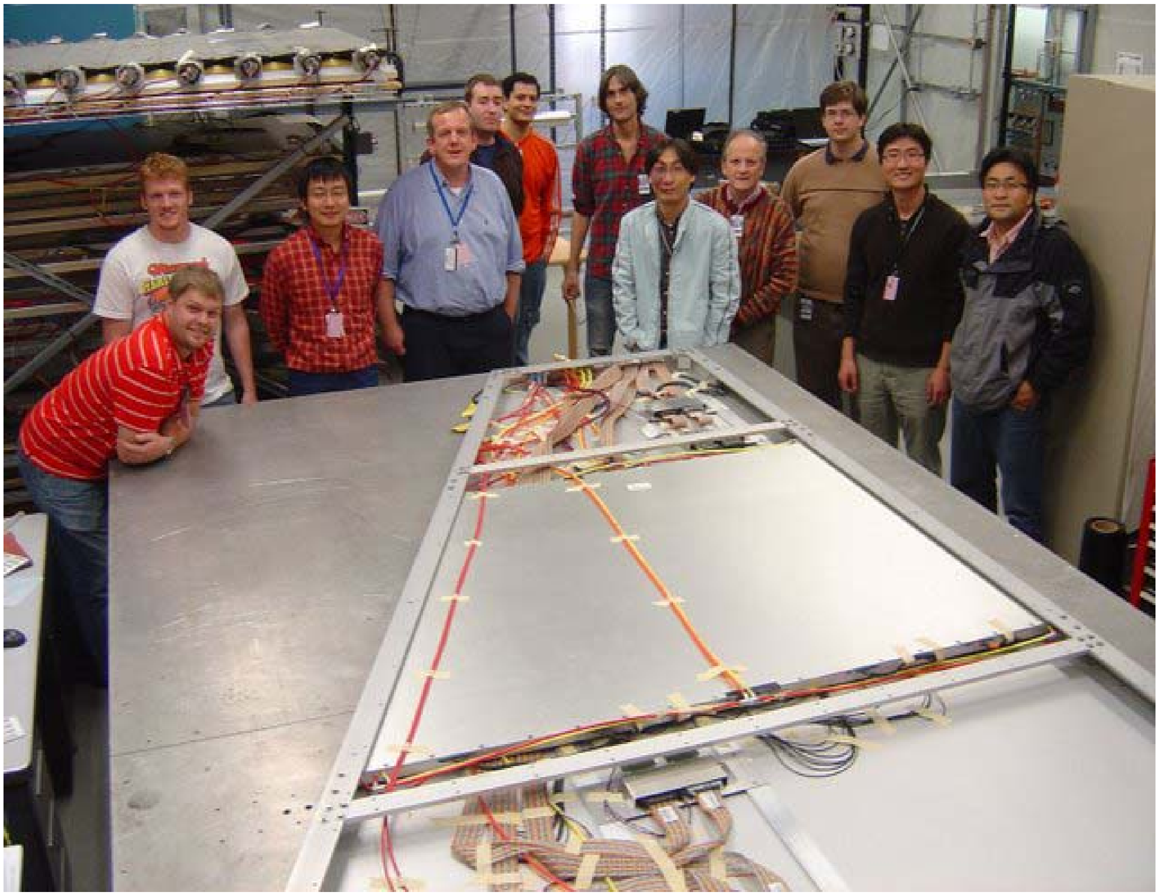

Fig.4 Half octant in BNL factory ready to be sealed and sent to PHENIX I.R.

Fig.5 Half octant installed in PHENIX I.R. between muon tracker and muon I.D.

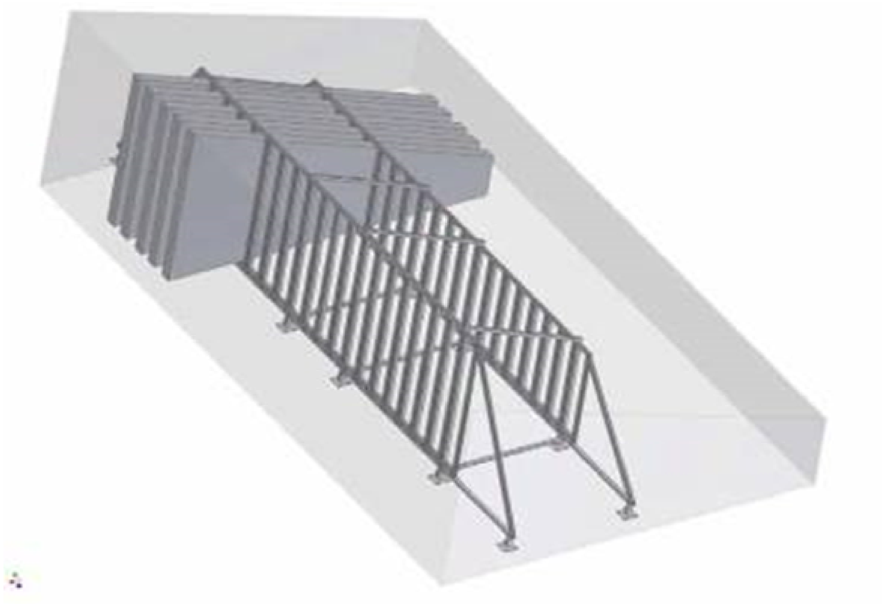

Fig.6 Half octant burn-in and storage station.

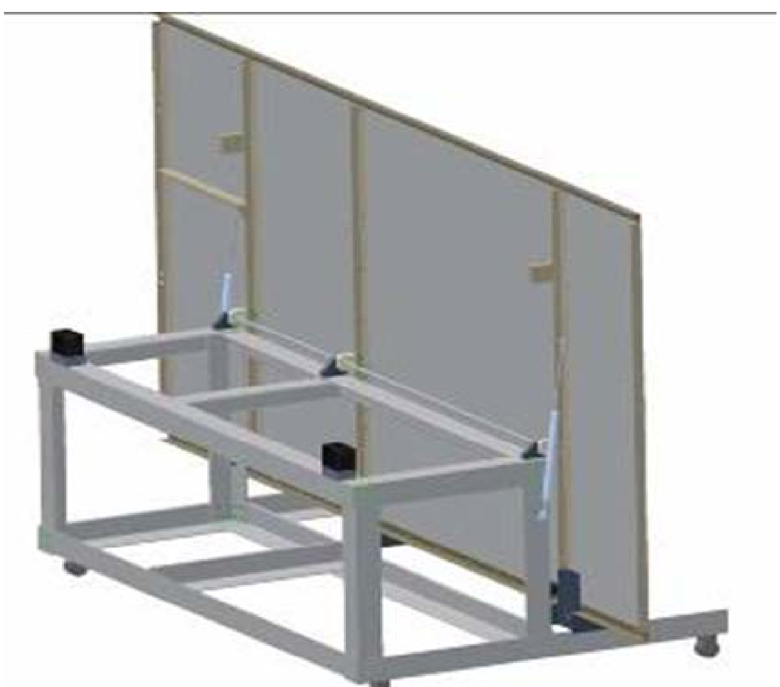

Fig.7 Half octant transport table.

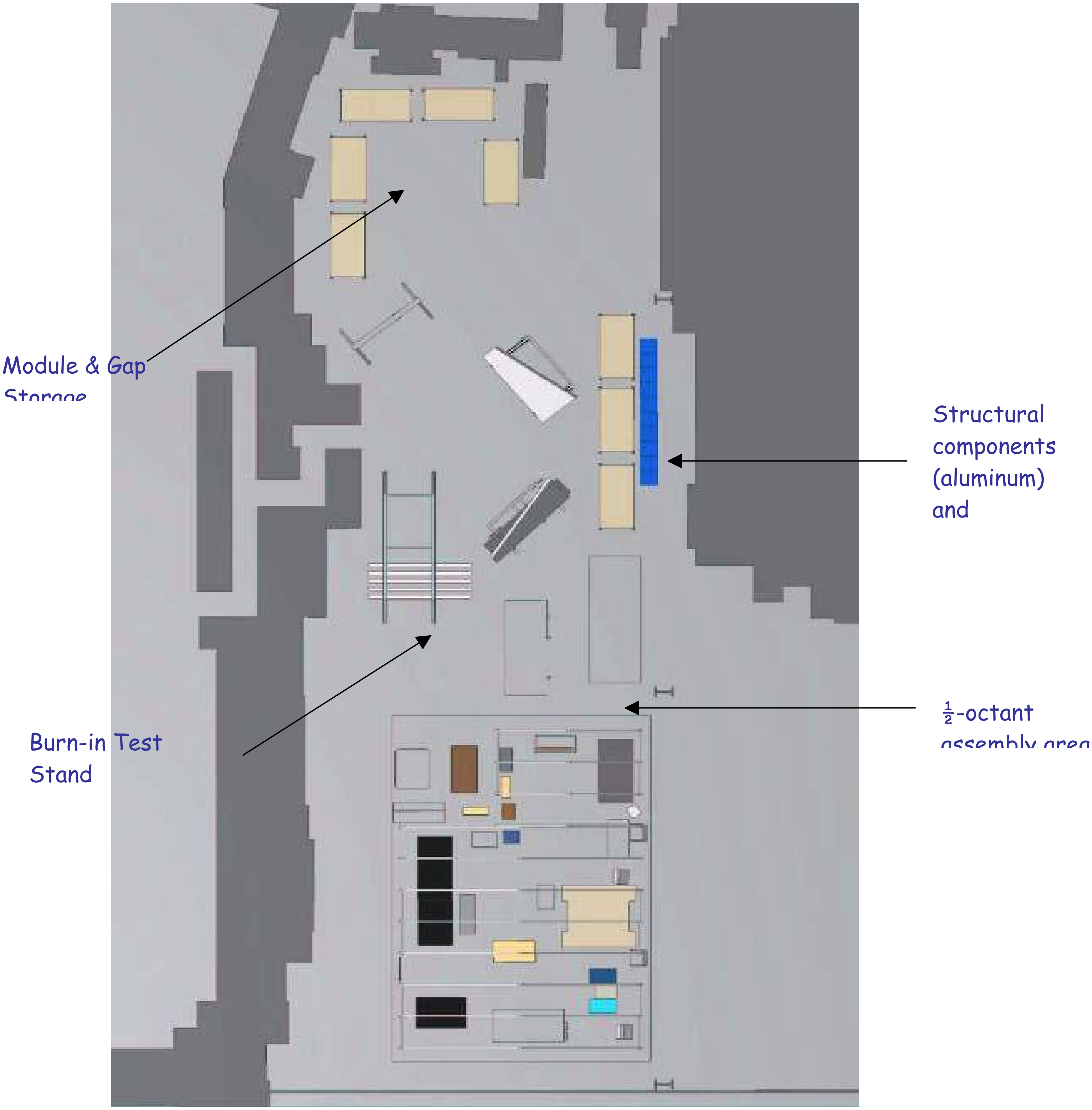

Fig.8 New factory layout.

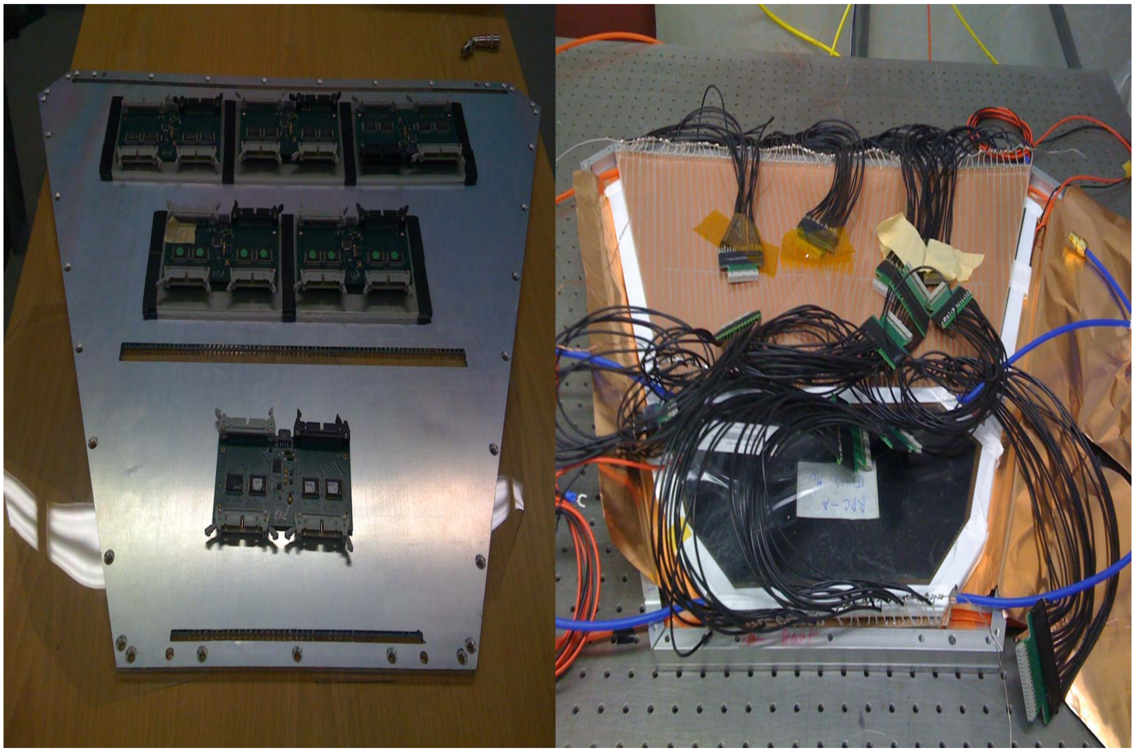

Fig.9. The figure on the left shows the closed detector with honeycomb sheets and preamplifier/discriminator.

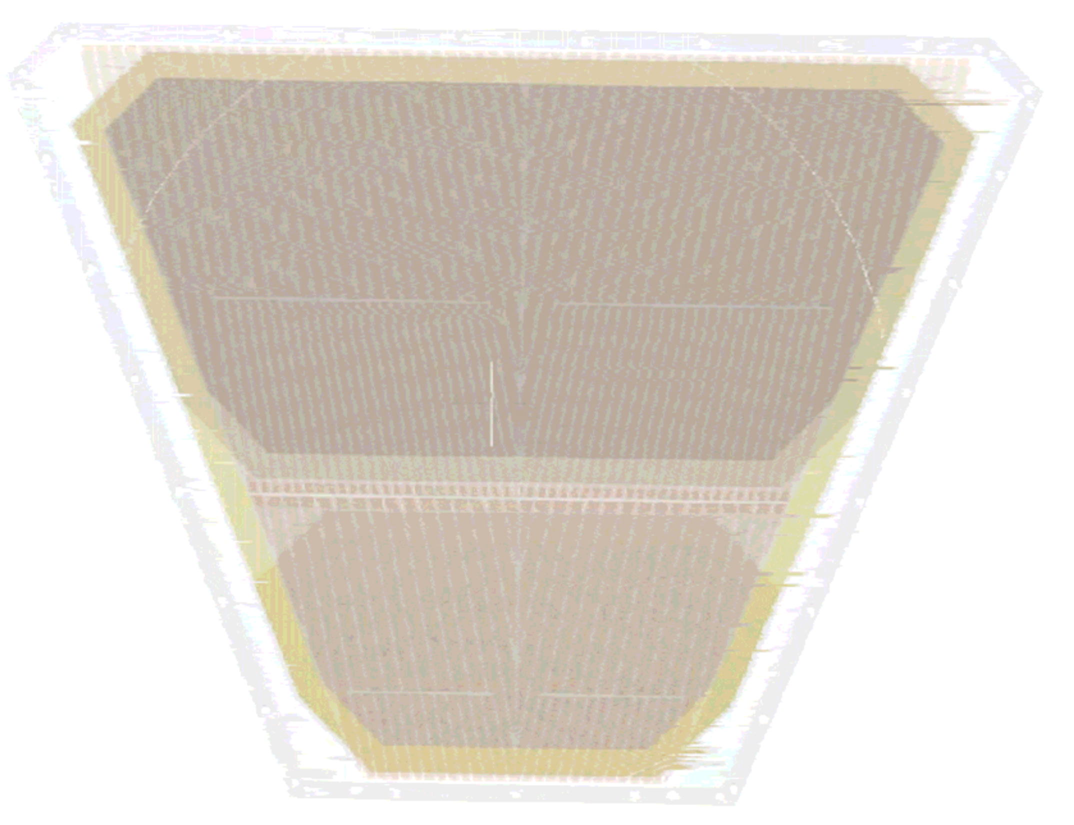

Fig.10.   Design for the south upstream RPC-1.

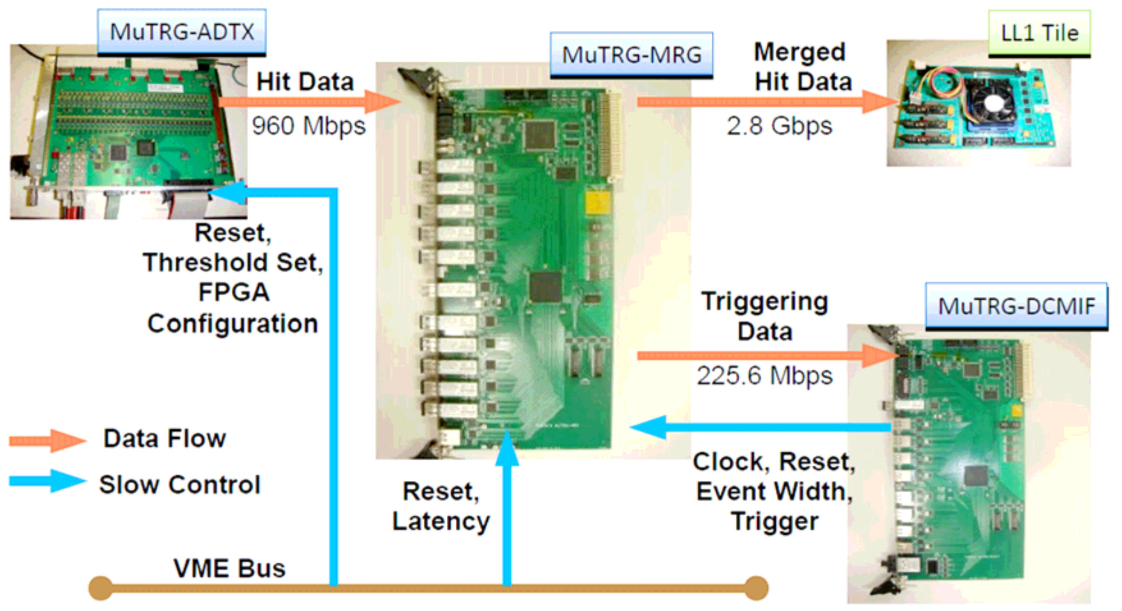

Fig.11. Overall diagram of the upgraded MuTr electronics and communication with the Muon Trigger LL1 trigger tile.

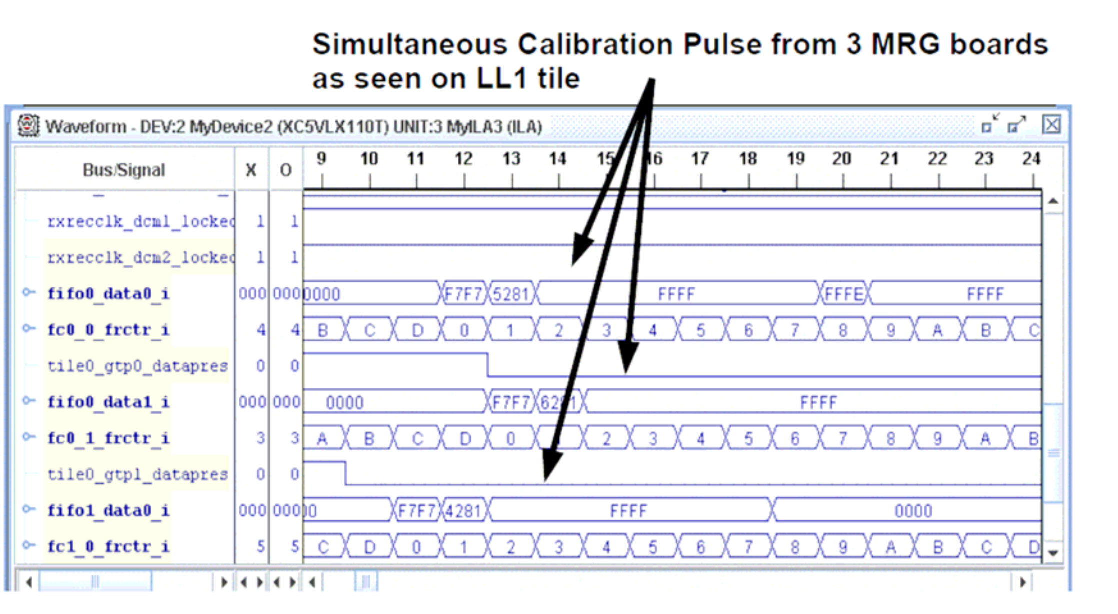

Fig.12. Chip scope output from the MuID LL1 trigger tile tests in January 2009. Simultaneous data from three MRG board inputs to the LL1 trigger tile have been operated, and we can see calibration pulses in the LL1 trigger tile. These calibration pulses can be used to align the data from the three MRG board fibers so that the data from the same RHIC clock is synchronized between fibers.

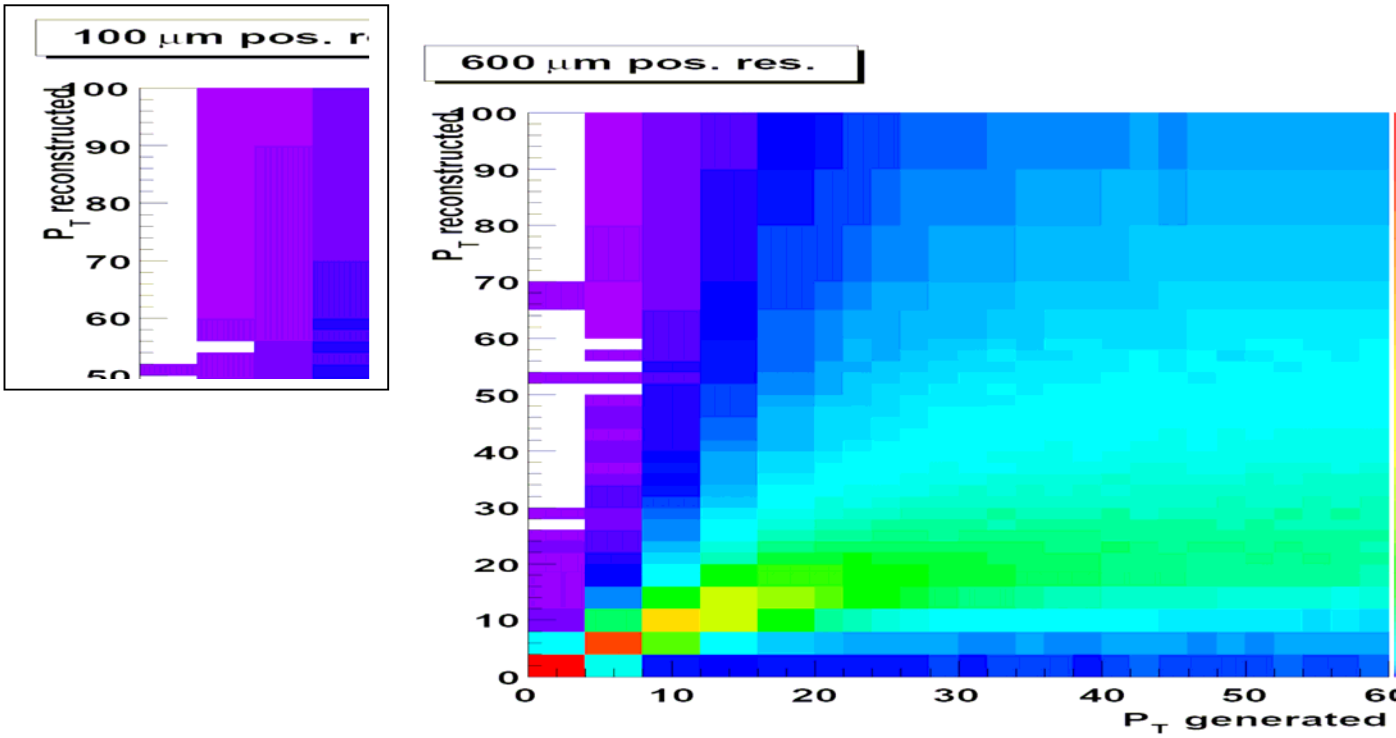

Fig.13. Transverse momentum smearing matrices as a function of the generated muon transverse momentum for intrinsic position resolutions of 100 and 600 μm.

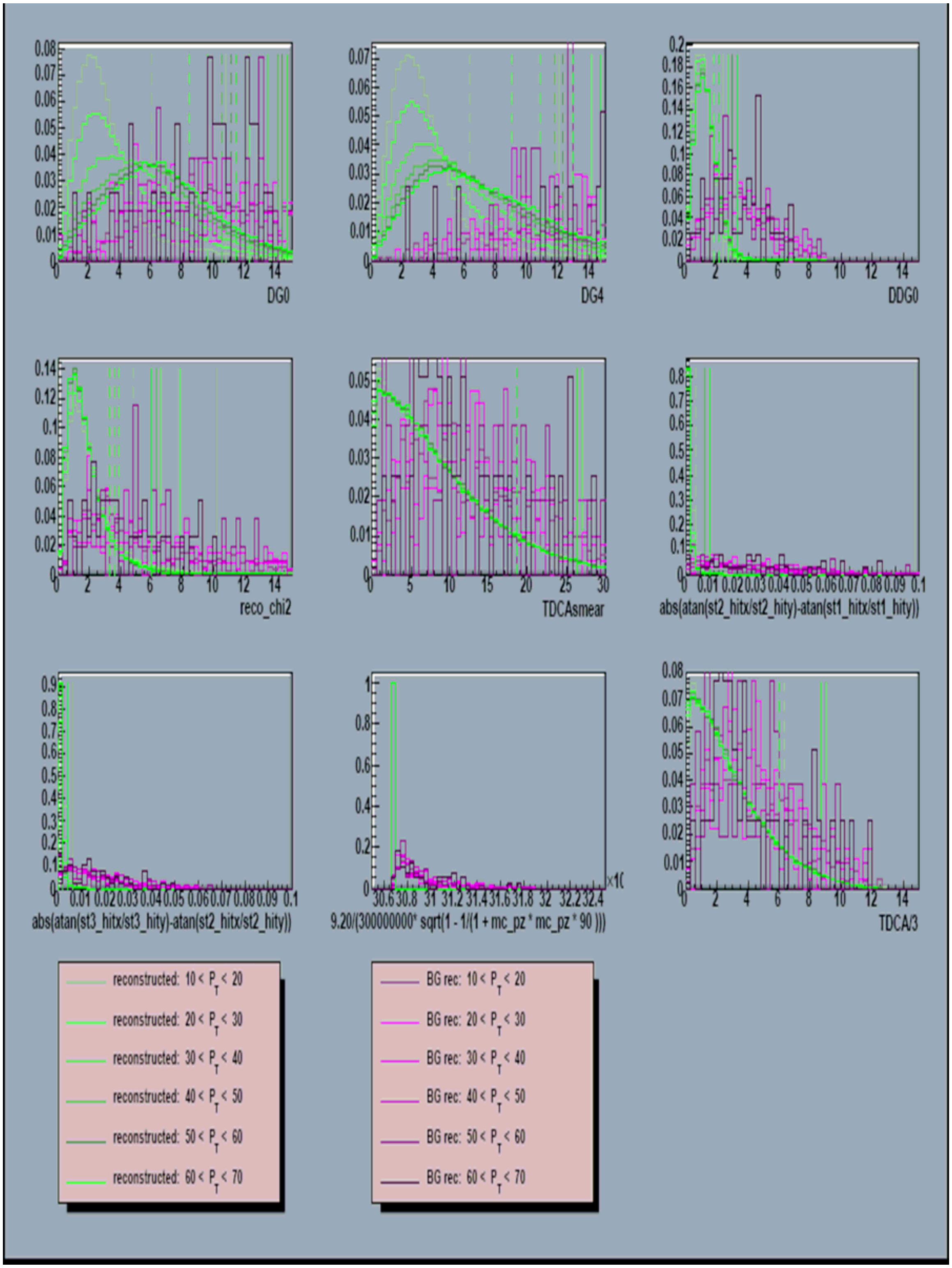

Fig.14. Several kinematic distributions shown for signal muons (green) and fake high-pT background (purple) in several transverse momentum bins.

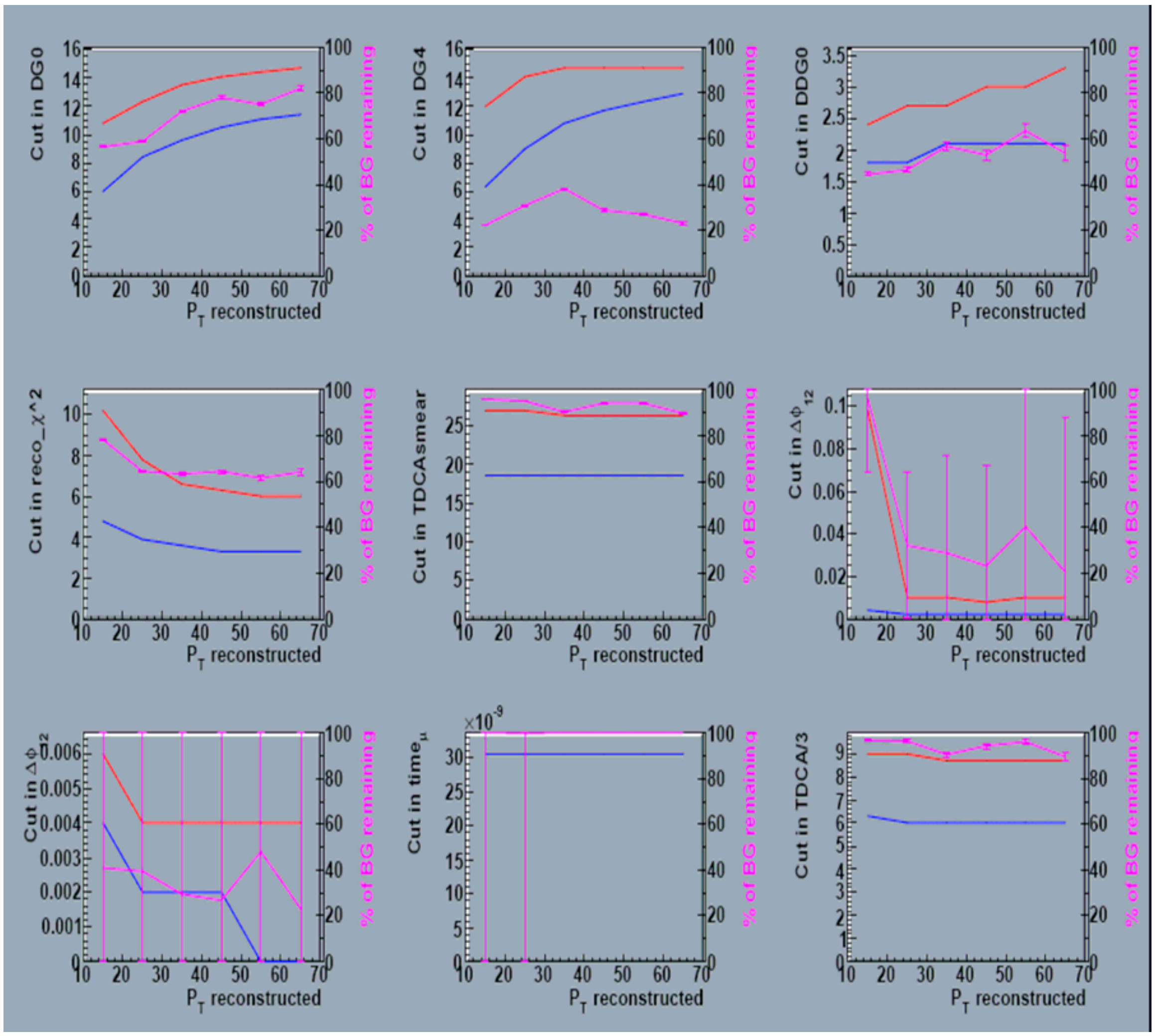

Fig.15. 98 % (red) and 90 % (blue) upper cut values for several kinematic variables as a function of the reconstructed transverse momentum. The amount of background remaining after the 98 % efficient cut as a function of the reconstructed pT is shown in purple.

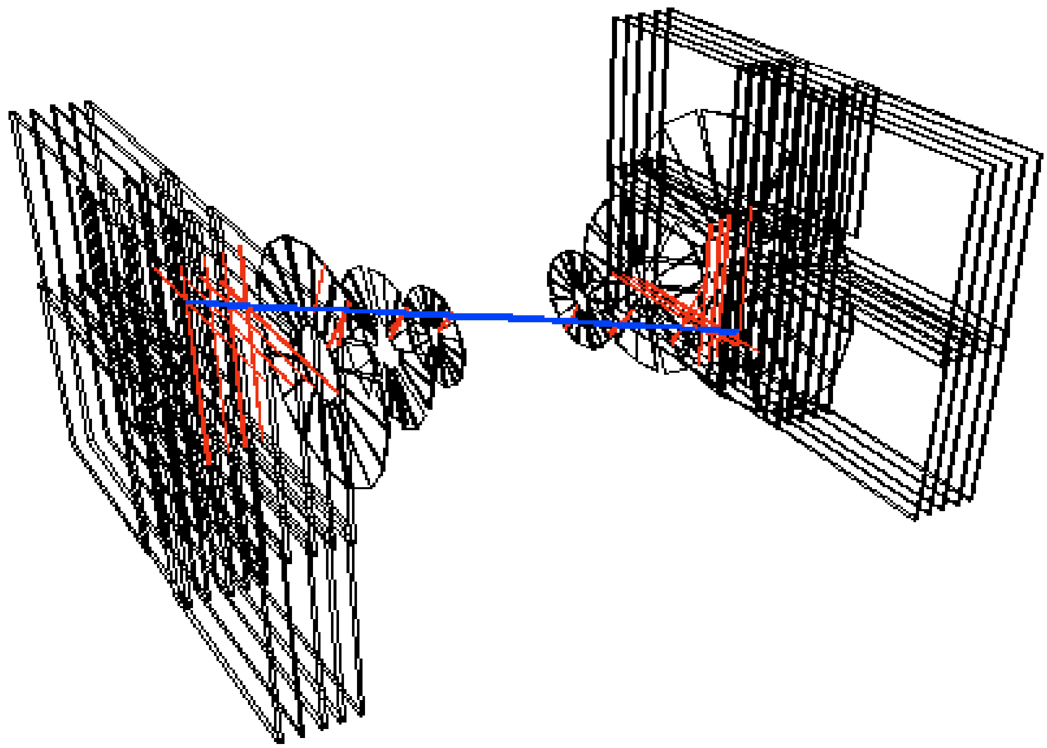

Fig.16. Example of a 3-D cosmic ray event display.