EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
COMPACT MUON SOLENOID COLLABORATION

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Up-scope of the CMS forward RPC low η system Technical Design Report

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1. Introduction

1.1 The CMS muon trigger system

At the LHC, the bunch crossing frequency will be 40 MHz, which, at the nominal luminosity of $10^{34}cm^{-2}s^{1}$, leads to about 800 million proton-proton collisions per second.
The Compact Muon Solenoid (CMS) experiment has put emphasis on the detection and identification of muons. Every 25 ns some 1000 particles emerge from the interaction point into the CMS spectrometer. In less than 3 µs a first level trigger has to reduce this rate to 100 kHz without losing potentially interesting collisions requiring further analysis.
The CMS muon system described in the CMS Muon Technical Design Report [CERN/LHCC 97-32] contains two complementary components:

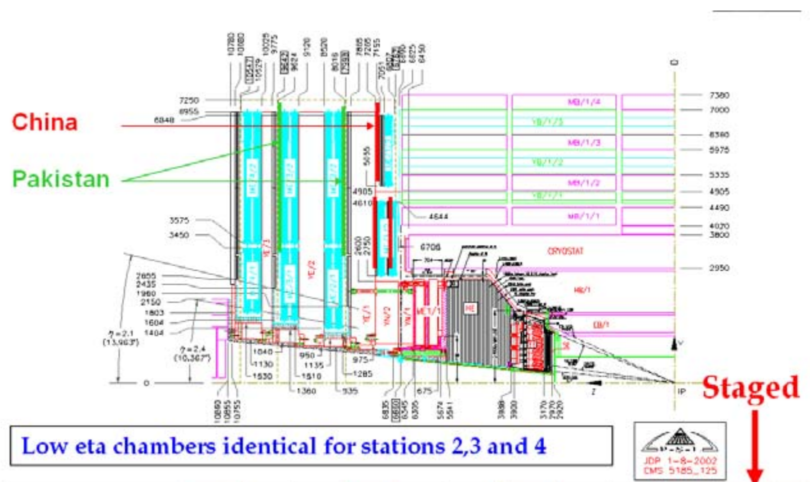
- detectors that track the muons through the iron yoke and return field: Drift Tubes (DT) in the barrel part; Cathode Strip Chambers (CSC) in the end caps. In both cases, four layers are embedded in the yoke;

- detectors that determine precisely the time of passage of the muons: Resistive Plate Chambers (RPC) not only determine the beam crossing from which the muons emerged, but also their transverse momentum.

1.2 Physics motivation for the forward up-scope

The CMS first level muon trigger relies on RPCs. Six concentric layers of chambers are used in the barrel part, while four layers have been foreseen in total for the end caps to cover a rapidity up to $\eta=2.1$.

The Memorandum Of Understanding (MOU) commitment for the forward RPC system was with the Islamabad (Pakistan), Peking (China) and Seoul (Korea) Institutions. Due to insufficient funding availability, only 3 layers per end cap were built with a limited rapidity coverage up to $\eta=1.6$ as shown in Figure 1.1. The remaining chambers were staged until the LHC design luminosity is achieved.



	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*

Figure 1.1: layout and rapidity coverage of the initial forward CMS RPC system.

In Figure 1.2 the simulated trigger efficiency as function of the η region is shown in case of the present 3 layers and compared to a complete 4 layer one. The advantage in extending the detector to include the last foreseen station is clearly evident.

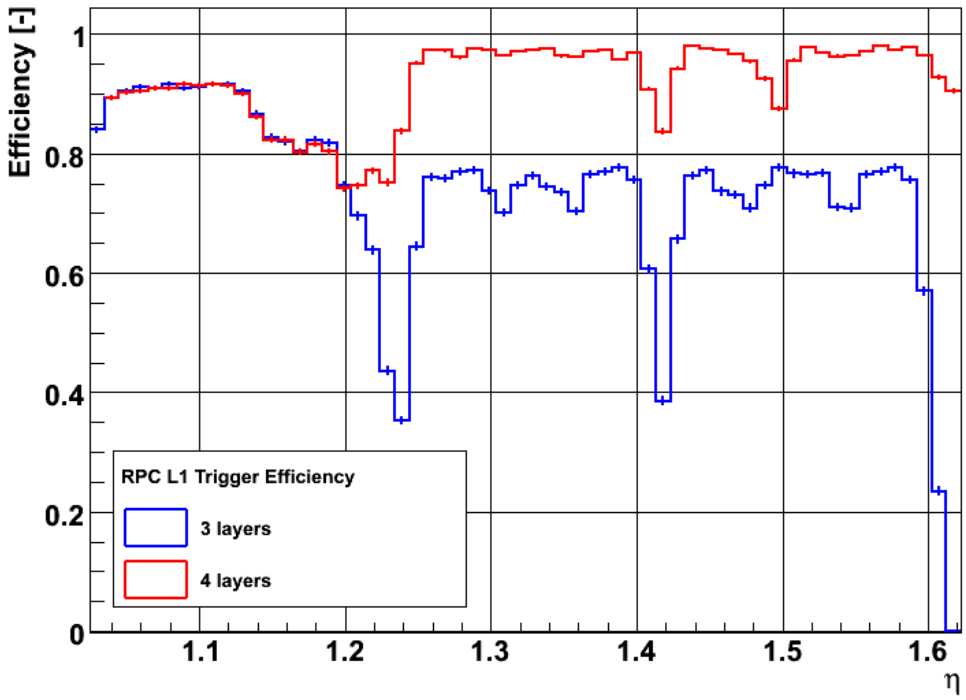


Figure 1.2: simulated trigger efficiency vs. the η region as function of the numbers of layers

The completion of the forward RPC system to 4 layers per end cap is therefore a priority. CMS has decided to split the up-scope project into two distinct phases:

- phase 1: completion of the low η part ($\eta < 1.6$);
- phase 2: completion of the high η part ($1.6 < \eta < 2.1$).

This present document will be focused on the restoration of a full low η system to allow efficient and robust trigger operation at the LHC design luminosity. The involved groups from Pakistan, China and Korea have already committed themselves to this completion. In addition Belgium and India, Egypt, have confirmed their involvement in the project while negotiation with Italy are on the way to assure the off detector electronics. Other countries, although have not committed any financial contribution, will however be involved with their expertise on important aspects of the project (Filand, Poland). Recently interest has been expressed from Iran and Colombia and negotiations have started to define possible contribution and area of involvement.

2. Detector design and layout

2.1 Description of the detector geometry

The forward stations are wedge shaped detectors with a double gap RPC. A schematic layout is shown in Figure 2.1a. The actual system consists of 432 chambers mounted in a staggered way in two concentric rings on the end cap disks to cover its surface (~ 150 m^2 per disk) as illustrated in Figure 2.1b. The RPC third layer on the +z end cap is shown Figure 2.2.
The completion of the forward RPC system for the $\eta \leq 1.6$ region will require an additional layer, in the following named RE4 composed by 144 new chambers.
The new RE4 layer will be composed of two concentric rings (RE4/2 and RE4/3) of RPC. Each ring is therefore composed of 36 chambers. There will be 144 chambers, 72 per end cap. The RPCs chambers will be of the standard CMS forward design.

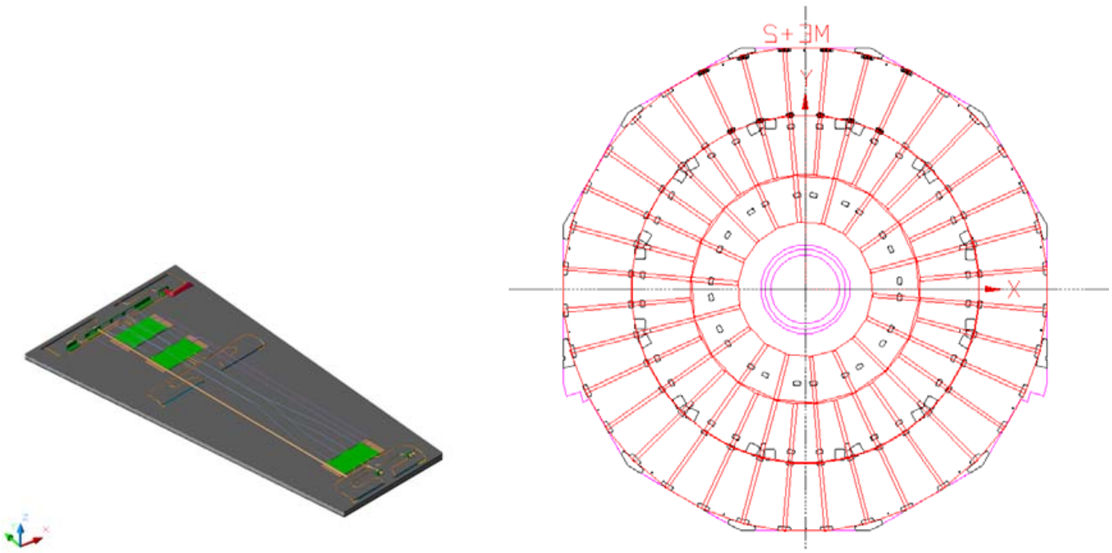


Figure 2.1: a)schematic layout of a forward double gap RPC; b) layout of the an RPC layer on the yoke disk

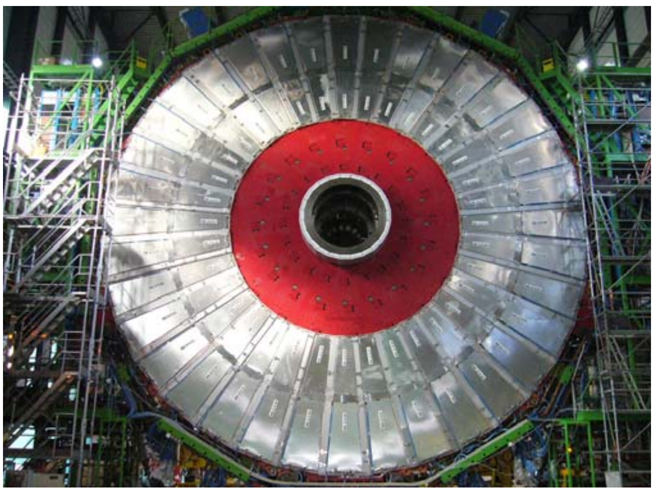


Figure 2.2: RPC third layer on the +z end cap.

2.2 Integration of station RE4

The new RE4 station will be installed on the back of the YE3 yoke, mounted independently of CSC detector. The RE4 detectors will be mounted on an aluminum interface frame, supported on the existing threaded M16 holes at the extension of the CSC mounting posts, as illustrated in Figure 2.3. This solution decouples the installation of RE4 from the existence of the YE4 shielding wall. The nominal clearance to the shielding wall will be 9 mm provided the interface frames have a thickness of 8 mm.

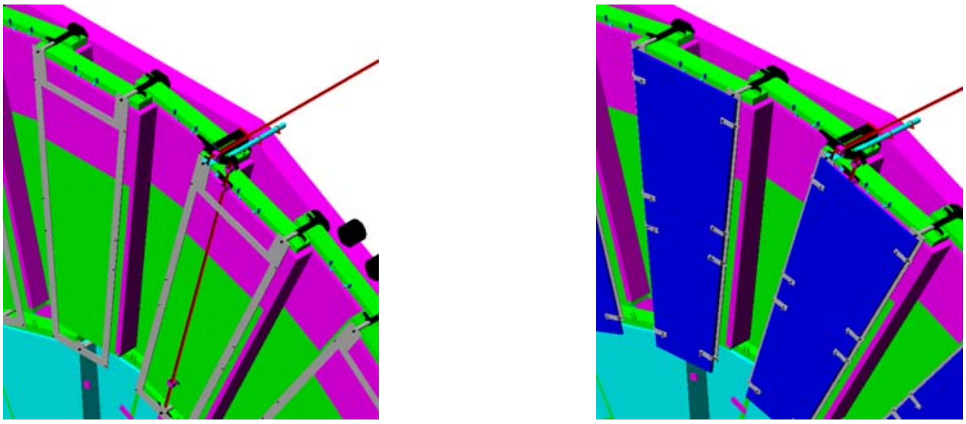


Figure 2.3: mounting of RE 4 stations with the interface frame attached to the CSC posts

The services to RE4 will be housed on the YE3 towers where the infrastructure need to be completed. However no services to RE4 have as yet been installed since they were part of the staging scenario that originally involved YE4. The infrastructure services to be added to YE3 are:

- a gas distribution rack with 72 channels and the necessary pipe work to the adequate bulkheads;
- the manifold and pipe work for the proper distribution of the cooling fluid;
- the LV system including crates and cabling to the power supply system in the YE3 towers;
- the HV cabling to the YE1 Patch Panel (use of minicable chain) and to UCS (use of main cable chain);
- the necessary Link Board Boxes related cables and fibers.

As a consequence the end cap main cable chains will have to be opened to install the missing HV umbilical links to the SX5 cavern (this will be a major intervention of an expert team, possible only when the main cable chain will be accessible, meaning the complete opening of YE1s). Adequate space for this completion has been reserved in the main- and mini cable chains in original design of CMS.

3. Electronics

The layout of the RPC electronics is shown in Figure 3.1. Chamber information are initially analyzed through the Front End electronics Boards (FEB), which forms LVDS digital signal and send them to the Link Boxes located on the balconies at the yoke periphery. Here synchronization and data reduction is performed before transmitting the information via optical fiber to the trigger electronic in control room.

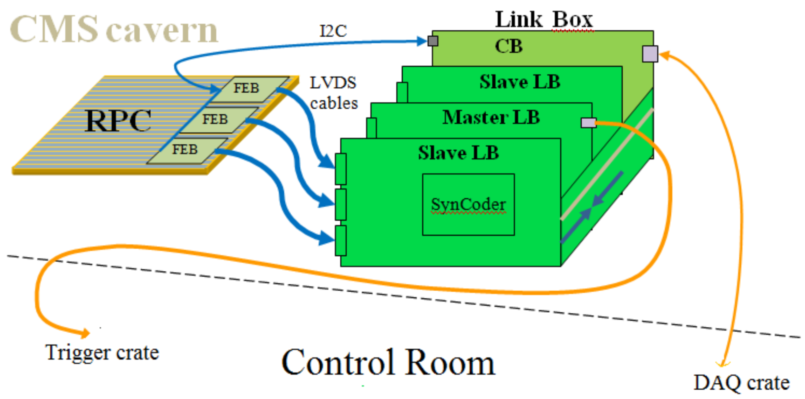


Fig. 3.2: Layout of the RPC electronics

3.1 Front end board

The same RPC Front End Board (FEB) developed in the past and mounted on the chambers in operation will be employed. It contains four 8-channel ASIC Front End Chips (FEC) consisting of amplifier, discriminator, monostable and differential LVDS line driver. The connection between the RPC strips and the FEB is made with 50 Ohm coaxial cables, that are soldered on small adapter boards to be easily pluggable to the FEBs. FECs are available from the past production. About 1000 new boards will be necessary to instrument the new RE4 layer; production is scheduled in Pakistan. Figure 3.2 shows a picture of one 32 channel FEB.

Each chamber contains also one Distribution Board (Fig.3.3) that receives power and slow control communication through power cables and I^2C bus and distributes them to the FEBs using flat cables.

Pakistan will be responsible for FEB mass production in Pakistan. Fifty FEBs will be produced at the end of October. After complete validation of FEBs , mass production will be started at the beginning of 2011. We required 600 FEBs including 10 % of contingency. Required time is approximately three months which include the time of procuring of components, developing of PCBs, components mounting and testing of final FEBs.

Before shipment to CERN, validation tests will be performed in Pakistan, such as voltage threshold setting (VTH), voltage biasing setting (VBIAS), voltage monitoring (VMON) and I2C for quality assurance.

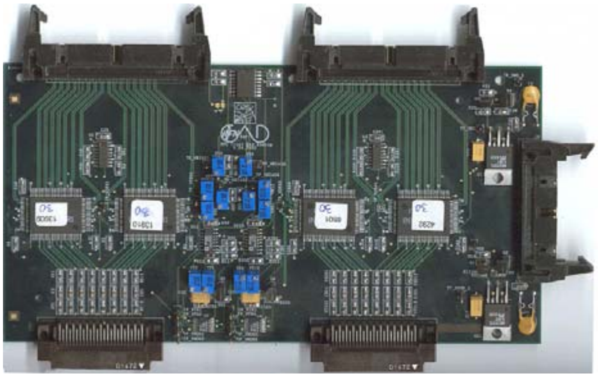


Fig. 3.2: Front End Board

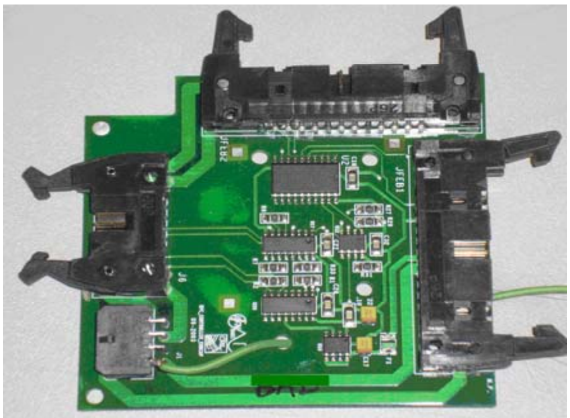


Fig. 3.3: Distribution Board

3.2 Off detector electronics

The output of the FEBs is sent to the Link Board system (LB) where the synchronization with the LHC clock, the optical conversion and the transmission to the Trigger Electronics are performed. The new layer 4 has to be equipped with a complete new set of LBs. Table 3.1 gives the number of additional components needed to complete the LB system on the detector side. The new electronics should include minor design improvements to overcome few problems evidenced during operation, being however fully back compatible with the present system.

INFN is willing to take responsibility for the production and to gain expertise in the run of the new system. The tests and the installation of the new boards should be done in cooperation between Italy and Poland to allow the complete transfer of knowledge especially on software issues

	needed	spare	total
LB mechanics	12	2	14
LB Back Plane	12	2	14
MLB	48	10	58
SLB	96	10	106
CB	24	6	30
FP	24	6	30

Table 3.1: list of LB system components needed for RE4

4 Services

4.1 Gas system

At present no work has been done for the fourth station besides the necessary piping for the control of the intended gas rack. The supply and return piping to RE3 chambers has been designed to allow also RE4 chambers to be connected to it. It will be necessary to find the space for an additional gas rack. Space is available next to the RE3 gas rack, while space above is slightly obstructed with RE3 piping.

4.2 Cooling

The gaps do not heat up by themselves. They suffer a lot the external heating sources. Now we are confident that present cooling setup is adequate to compensate the heating produced by RPC electronics (12 W only) but we know that RPC gaps are still suffering from T increase..

We are asking a cooling connection every 10 degrees (each chamber in ring and not each 3 chambers). Moreover we will have 2 pipes on each side of copper plate. As stated before there are no spigots at present available on YE3 for RE4. Significant reworking of the manifold must be considered.

Also the addition on thermal insulator between the CSC and RPC chambers is under study.

We know that RPC operation is quite temperature sensitive. Best thermal working conditions for RPC are with chambers at 18C. 23C is the maximum temperature where we must switch off the chambers. Given the present performance, the current cooling system in CMS endcap demands relevant revision to secure the best working conditions for RPC. QC procedures in this item will be particularly relevant.

4.3 Signal read out

The data readout and transmission to the trigger crate will need some additional cables that have to be procured, connectorised, labelled, tested and installed:

- 864 signal cables and 72 DCS (I2C) cables between the RE4 chambers and the Link Board boxes;

- 48 fibers from LB boxes to RE3 tower patch panels in UXC;
- 24 single-mode TTC fibers from the Link Board boxes   to the TTCOC
- 84 DCS Ethernet (class 7) cables between the Link Board;
- 96 multimode fibers between the Splitter boards and Trigger Boards in USC.

4.4 High voltage

For the 144 RE4 chambers, a total of 288 HV channels are needed (each gas gap should be supplied separately). However the number of channels will be reduced by using distribution boxes to allow cost reduction maintaining, however, the feasibility to handle problems in case of single gap failure. Each distributor (Figure 4.1) will transform 10 input channels into 40 output channels. A total of 8 HV distribution boxes will be needed. A total of 12 HV CAEN A3512 boards (72 channel in total) will be necessary to complete the system. The existing HV EASY Crates have enough free slots to allow installation of these new boards.

Figure 4.1: HV distribution box

New HV cables need to be pulled from RE4 chambers to HV patch panel (PP) at the YE1 feet through mini cable chains, while additional umbilical cables need to be installed from PP to reach the USC HV racks. The HV cables from chambers to PP will be connectorized and tested before installation, whereas umbilical cables from PP to USC will be connectorized and tested after installation. Extensive quality tests on the cables will be performed prior the installation following the same protocols already developed.

4.5 Low voltage

The Low Voltage (LV) system supplies power to Link Board Boxes (LBBs) as well as Front End Boards (FEBs).   In case of LBB supply, 8 new A3016 boards will be installed in the existing EASY Crate (Figure 4.2). FEB supply would need additional 12 new A3009. In this case 4 new

EASY Crate (3000S) will be installed in each near and far sides tower at suitable X levels. The choice of level depends on available space in racks and cable length.

New cables from the CAEN A3009 power supplies to the RE4 chambers will have to be procured, connectorised, tested and routed in mini cable chains. The FEBs LV Crates will take the 48V from the existing RE3 MAO by using a special type of splitter at PP75 connector. Two new branch controllers are required, each one controlling near and far side LV-FEB EASY Crates of the same yoke.

Figure 4.2: available slots for RE4 LBBs boards

4.6 T/RH sensors

Temperature (T) and relative humidity (RH) are parameters that affect the response of RPC detectors. Several studies on dark currents monitoring carried out during CMS commissioning in 2008 and 2009 have shown that the thermal stabilisation of RPC's in the 21-24°C range is essential for the operation and that the working point depends strongly on temperature variations. The dependance on RH is less crucial, however the stabilization is much more critical due to the dimensions of SGX5 and the cavern humidity variation range. Presently T and RH monitoring is performed with six conventional electrical sensors in each of the existing RE stations, while each Barrel chamber has one T and RH sensor. Typical requested precisions are +-0.2°C for temperature monitoringand 2% for RH monitoring.

The development of optical sensors based on the Fiber Bragg Grating (FBG) technique for T measurement has provided an optimal solution with respect to the electrical sensors such as radiation hardness, insensitivity to magnetic field, precision, lack of electrical noise, ease of installation, minimal cabling, precision (+-0.2°C). Both the Italian Frascati and Naples groups have long lasting experience in the development and deployment of FBG sensors for a variety of measurements.

Each RE4 chamber will be equipped with one FBG sensor for T measurement. Sensors will be purchased bare and enclosed in a thermicalconducting housing. Samples of sensors will be tested in Frascati for radiation hardness, and all will be installed at CERN on RE4 chambers. The design of sensor housings will allow ease of disassembly from chambers prior to chamber disinstallation from disks for maintainance and repair. Clear optical fibers will be routed to the existing CERN interrogation system for readout and integrated in the CMS sensors slow-control framework [3]. RH monitoring will be performed via conventional electronic sensors, homogeneous to those employed in the existing RE disks (4 sensors/disk). Finally, an R&D programme has started in early 2010 for the development of optical sensors for fluoridric acid detection in the RPC gas mixture. Options will be considered in case of positive results to install a few sensors in the USC gas distribution racks, upstream and downstream of the RPC detectors in the closed loop recirculation gas system.

5. Production facilities

In the following the main aspects relevant to the chamber production will be briefly reviewed. All the numbers quoted below refer to the production of 200 new chambers, out of which 144 will be needed for the RE4 station and the remaining 56 will be kept as spares for the RE2/RE3/RE4 forward system.

5.1 HPL production

Production of HPL will follow the same procedure already established in the past. The main steps are: production of the HPL foils, quality check for resistivity measurement and surface quality, cuts of the foils to the required size and finally surface cleaning of the obtained components.
Raw material production will take place at the Puricelli industry near Milan. This company has the necessary expertise and experience to produce low resistivity ($1\text{-}6 \cdot 10^{10}$ Ω cm) HPL as required (they were hiring some expert personnel from PamPla firm, previous supplier of HPL for all particle physics community). Recently a small production with the same CMS specifications has been successfully achieved in Puricelli site, ensuring that the proper production set parameters can be reproduced.
About six hundred 1620 x 3200 mm^2 foils for a total of 3110 m^2 are necessary. A preliminary planning draft discussed with the producer shows that about 2 months are required for the production assuming a 3 week cycle for the production and quality control of batches of 200 foils.
Quality check will be pursued at the Pavia INFN site. Here the resistivity measurement table already used in the past will be re-commissioned and made available for operation. The Pavia group will assure consulting for the running of the device while measurement operations will be under RPC community responsibility.
Successive cutting and surface cleaning procedures will follow according to the scheme already established in the past respectively at RIVA (Milano) and General Tecnica (Frosinone).

5.2 Gap production

The gas gaps for 144 forward upscope RPC chambers will be produced by KODEL at Korea University. A total of 432 gaps are needed for the low eta restoration. However, based on previous experience , abput 10% additional production should be planned to replace gaps which passed the quaklity assuramce test at KODEL but failed after the transportation to CERN. Accounting also 30% contingency, the total number of gaps is 600.
The general production procedures can be divided into several sequential steps.

Initially HPLs will be inspected for defects in color, scratch on the surface and any mechanical damages on the edges and corners. The surfaces of all selected HPLs are cleaned with IPA. After the HPLs are cleaned, the surface is graphite coated. The next step is to insulate the graphite surface with PET film. PET film is glued to the graphite surface by the machine shown in Figure. 5.1a. The gaps are then assembled and placed under a pressing machine (Figure 5.1b) for 24 hours for glue hardening.

All assembled gas gap are treated with linseed oil mixed with heptane. The rate of linseed oil administration into the gas gap placed in its vertical position is 100 cm/hour. After the completion of the linseed oil administration, a small compressor is used to immediately remove the remaining oil in the gas gap. Then, dry air of 30°C is circulated over the oiled surfaces of the gaps. The flow rate of air is from 60 to 100 liters/hour. And the period of the air circulation is from 48 to 72 hours.

A check of the mechanical and electrical quality of the gas gap is finally performed. The criteria for accepting the gas gap are very strict. For the mechanical test, no pop-up spacer should be found when the gas gap is over-pressured with 20 hPa for 10 minutes. In addition, the rate of leakage of the gas gap should be less than 0.2 hPa for 10 minutes. For the electrical test of the gas gaps, high voltage is applied to the gas gap and the amount of current drawn is recorded. First a voltage of 8.5 kV is applied for 12 hours to eliminate the faulty gas gaps which draw high Ohmic currents. Then a voltage of 9.4 kV is applied for 96 hours to select the qualified gas gaps with reasonably low currents. The current limit for accepting small-size, medium-size, and large-size gaps were set to 2.0μA, 3.0μA, and 5.0μA respectively.

For the gas gaps which pass the tests, transportation is arranged. Wooden boxes are specially designed for safe transportations. The gaps inside the wooden box are stored vertically and are clamped by using partially pre-stressed bars.

The transportations are normally done via air-carrier for the safety reason. All gas inlet and outlet pipes of the gas gap should be open for sudden change of the atmospheric pressure during the transportation.

Fig. 5.1: a) electrode insulation machine b) gap assembly machine.

Preparation for the gas gap production is over and ready to produce the 600 gaps in 12 months. In each two months period of production, about 100 gas gaps will be completed and shipped to chamber assembly sites. One scenario is to start the production in the following order: RE4/2 Positive, RE4/2 Negative, RE4/3 Positive, RE4/3 Negative. The total estimated cost, including material and manpower will be 400 kCHF.

5.3 Chamber mechanics

The chamber mechanics is composed of several components:

- honeycomb box;
- auxiliary parts;
- cooling circuit, FEB support and screen box;
- readout strips plane.

Honeycomb box

The box is made of aluminium top and bottom honeycomb plates and four edge bars. The honeycomb plate is 6 mm thick, composed of 0.5 mm thick top and bottom Al covers sheets, and 5 mm thick Al honeycomb core; at the four edges and few other positions (where threaded holes will be located) 5 mm thick solid Al plates will be inserted in the honeycomb core. Slots and cut outs are filled up with foam for a better electronic protection. The cross section of the edge bar is 16 x 16 mm^2. Figure 5.2 shows the layout of a typical RE honeycomb plate.

Production of honeycomb plate proceeds as follows: the 0.5 mm thick Al sheets are cut to shape; additional 5 mm thick Al plates and the Al honeycomb cores are glued at the edges and in the middle foam is introduced at the necessary places; the assembled plates are heated and pressed at 120º temperature to cure the glue and foam; finally the slots and holes are machined. We plan to use a CNC machine to make all parts inter-changeable.

Auxiliary parts

These parts include the front patch panel, the joint pieces for mounting the chamber in the yoke, the inside chamber fixation pieces etc.

Cooling circuit, FEB support and screen box
This part is made of copper pipe soldered onto three copper plates, where the FEB will be mounted. The screen box made of 1 mm thick Al sheets will cover all cooling and FEB system.

Readout strips plane
The readout strip planes are divided into three sections as shown in Figure 5.3, the gap between the strips is 2 mm.

The plane is 0.3 mm thick, with a 0.035 mm thick copper cladding. Strips are produced by an etching method. By request, the factory could heat-cover the strips plane with a 0.15 mm thick Mylar sheets for protection and insulation. The honeycomb boxes and auxiliary parts will be produced in “Beijing Axicomb Technology co., Ltd” (China) and the readout strips will be produced in “Beijing Gaonengkedi SGT co., Ltd” (China). We have a long term collaboration with both companies since they have already successfully provided good quality mechanics for the RE stations built and installed in CMS. For the 144 RE4 chambers, the companies could complete the production of the mechanics within three months after signing the contract. Considering the time needed for the transportation, ordering the mechanics six months before the chamber assembly is recommended.

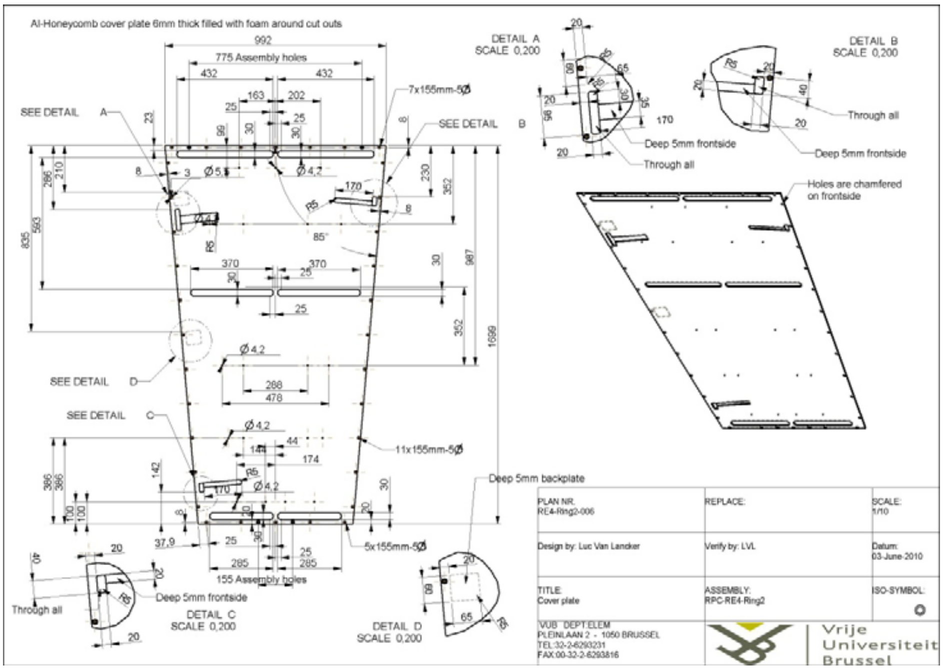


Figure 5.2: layout of a typical RE honeycomb plate

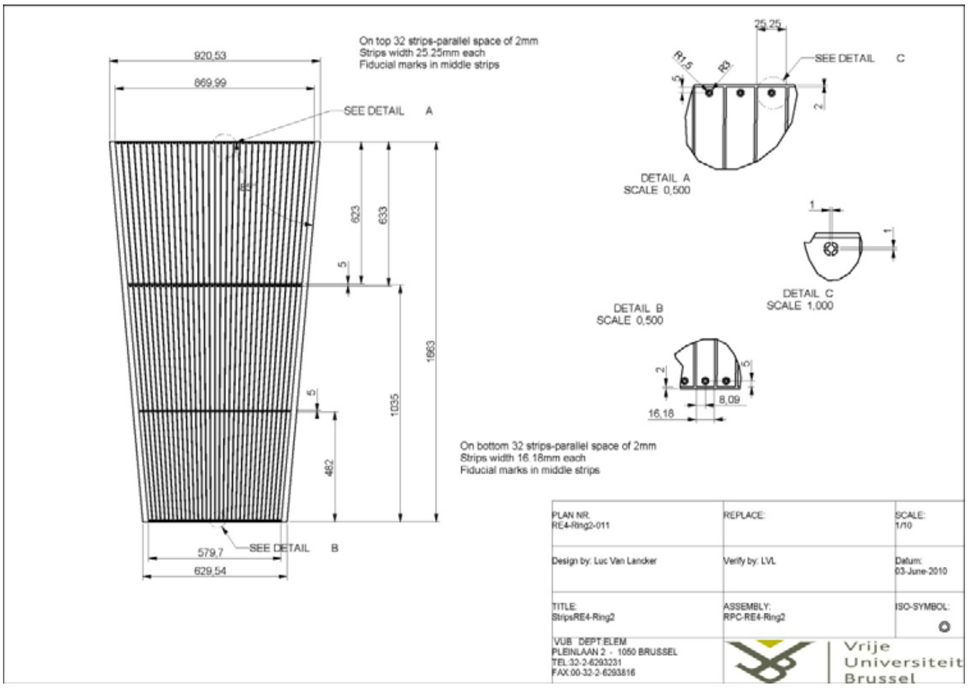


Figure 5.3: layout of a typical RE strips

The plane is 0.3 mm thick, with a 0.035 mm thick copper cladding. Strips are produced by an etching method. By request, the factory could heat-cover the strips plane with a 0.15 mm thick Mylar sheets for protection and insulation. The honeycomb boxes and auxiliary parts will be produced in "Beijing Axicomb Technology co., Ltd" (China) and the readout strips will be produced in "Beijing Gaonengkedi SGT co., Ltd" (China). We have a long term collaboration with both companies since they have already successfully provided good quality mechanics for the RE stations built and installed in CMS. For the 144 RE4 chambers, the companies could complete the production of the mechanics within three months after signing the contract. Considering the time needed for the transportation, ordering the mechanics six months before the chamber assembly is recommended.

5.4 Chamber assembly and test sites

The 200 new RE2 chambers will be assembled and tested at different sites according to the following Table 5.1:

Type of chamber	# chambers	Assembly site
RE4/2	40	Mumbai-BARC
RE4/2	60	CERN - 904
RE4/3	40	Ghent
RE4/3	60	CERN - 904

Table 5.1: chamber assembly scheme

5.4.1 CERN 904 site

On the 904 premises at CERN, an assembly and test laboratory will be set up for the production of the RPC chambers. This facility will include the assembly tables and tooling facilities for gas gaps QC/QA as leak tightness, popped spacers, HV behaviour. A cosmic hodoscope will also be available to test up to 10 detectors at once and determine all physical working chamber parameters. The manpower to run this facility will be provided by the respective institutes when their detectors are being tested. Also the Pakistan, which has an outstanding experience in chamber assembly, will provide qualified manpower for the assembly and test.
A more detailed description of the 904 infrastructure will be given in a dedicated section of the CMS upgrade document.

5.4.2 Belgium

The chamber construction will be the main effort of the University of Gent. At this institute a chamber assembly and test facility is presently being set up. It is foreseen that in Gent 36x2 new RE4/3 chambers will be assembled to instrument an entire new RE4 outer ring station.

To simplify logistics most of the fabrication of assembly tools, small mechanical detector pieces, signal readout cables, storage racks, etc. will be handled by the mechanical workshop in Gent. All commercially available components, e.g. cooling lines, gas tubes, connectors, foils etc. that are required for the chamber assembly will be purchased in common orders with other sites to ensure uniform chamber construction.

The gas gaps will undergo a basic quality control before the assembly. The test procedures will be similar to those performed in the previous construction phase at the CERN ISR test facility. All gas gaps will be tested for unglued spacers and gas tightness using Argon. High voltage behaviour will also be tested with a gas mixture of Freon and Iso-butane (no SF6). Once the chambers are assembled, a complete test with a cosmic hodoscope will be performed before the transportation to CERN.

5.4.3 India

Under India-CMS-RPC collaboration, RPC assembly and testing would be the main effort of Nuclear Physics Division-Bhabha Atomic Research Centre (NPD-BARC) at Mumbai. Panjab University at Chandigarh will contribute with the preparation of component and providing expertise for the assembly and test phase.
The RPC Lab at NPD-BARC, Mumbai, is fully operational and basic quality control procedures have been set up for assembly and testing. Recently ten RPCs which have been assembled and tested there, in collaboration with Panjab University and Delhi University, are at CERN.

The lab has an associated storage area and is backed by a robust workshop for handling all the relevant mechanical jobs. The HV, LV, 4 channel gas mixing unit, 8 channel gas flow system and gas recovery unit are fully operational. The cosmic ray stand can handle eight RPCs of RE4/2 type at a time. Scintillators of the relevant sizes are under fabrication at

BARC, Centre for Design and Manufacture and accordingly the cosmic hodoscope would be set up to study the chamber performance. Efforts are underway to have an independent air conditioning system for controlling the relative humidity at 45-50% level round the clock. Electronics and DAQ have to be upgraded to handle more chambers simultaneously. Expertise from CERN would be required for setting up the cosmic hodoscope to test up to 8 detectors together and determine all RPCs physical working parameters.

6 Project organization

6.1 Responsibilities assignment

Restoration of the low η RPC forward system will involve a large community of physicists around the world. Besides the major responsibilities already discussed in this document for the chamber production, other relevant responsibilities related to important detector components or to infrastructure services should be acknowledged. Table 6.1 gives a complete overview of the responsibilities for all the items related to the RE re-scope.

Item	BL	CH	CN	IN	IT	KL	FI	PK	PL
HPL prod./QA		X			X				
Gap prod.						X			
Chamber. mech	X		X						
Chamber assem.	X	X		X					
Front-end prod.								X	
HV/LV system	X			X					
LB design					X		X		
LB prod./test					X				X
T/RH sensors		X			X				
Infrastructure		X							

Table 6.1: overview of the tasks responsibilities (legend: BL=Belgium, CH=CERN, CN=China, IN=India, IT=Italy, KL=Korea, FI=Finland, PK=Pakistan, PL=Poland).

As already mentioned some of these responsibilities will be related to deliverables and appropriate funding commitment of the funding agencies. In other cases they refer to the coordination of some relevant parts of the projects based on existing expertise and competence already available from the group involved in the design and construction of the initial system.

HPL production and certification

CERN will coordinate the logistic for the HPL production and quality assurance. In this context INFN Pavia will make available the proper tooling for the QA and some expertise will be available for its maintenance during 2010.

Gap production

KODEL has the primary responsibility for gap production, certification and delivery to the chamber assembly sites.

Front-end board

Pakistan has the primary responsibility for FEBs production, certification and delivery to the chamber assembly sites. Fifty FEBs will be produced at the end of October. After complete validation of FEBs , mass production will be started at the beginning of 2011. We required 600 FEBs including 10 % of contingency. Required time is approximately three months which include the time of procuring of components, developing of PCBs, mounting of components and testing of final FEBs. Before shipment to CERN, validation tests will be performed in Pakistan, such as voltage threshold setting (VTH), voltage biasing setting (VBIAS), voltage monitoring (VMON) and I2C for quality assurance.
Pakistan will also take charge of preparing on chamber signal cables and FEB adapter for signal transmission to the off detector electronics.

Off detector electronics

Italy will take major responsibility in the re-design, production and pre-test of the Link Boards and Control Boards. The final validation will take place at the CERN 904 CMS electronic lab with the contribution of Italy and Poland.

HV/LV system

The power system is an obvious extension of the one already installed in CMS, produced by CAEN (Italy). The procurement responsibility will be shared among the Institutions mainly contributing to the chambers delivery. CERN may play a role by centrally coordinating the procurement procedures.

Infrastructure

CERN will have a major role in the infrastructure definition and assessment such as cooling, signal cabling, HV/LV cabling. It will also have the responsibility of the 904 test site running and maintenance.

6.2 Schedule

The overall schedule for the RE up-scope project should foresee as final achievement the chambers installation during the 2011-2012 winter break. The schedule is shown in Figure 6.1. Milestones are indicated in Italic.

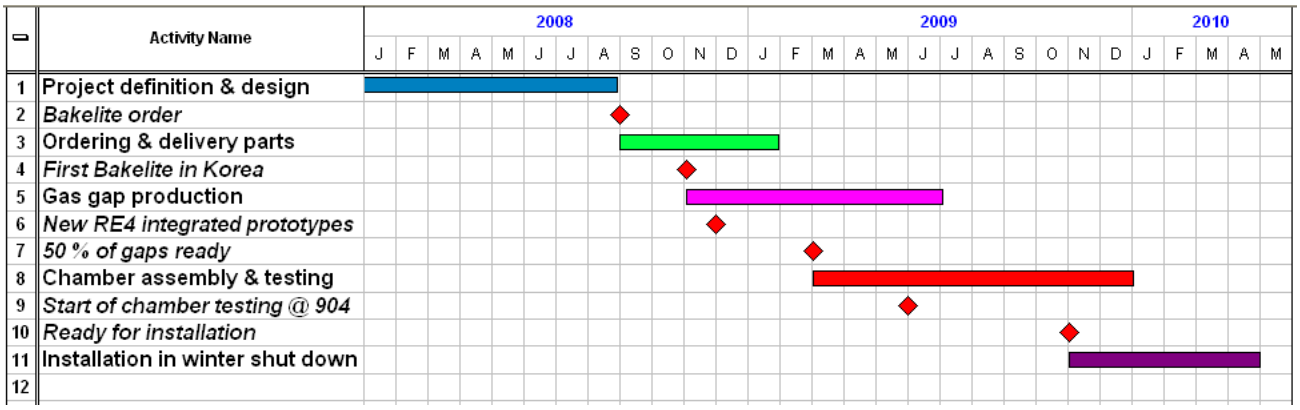


Figure 6.1: schedule for RE4 chamber production and installation in the 2011-2012 shutdown. Milestones are indicated in Italic.

Major milestones for 2010 are:

- start up of the HPL production in summer;
- start up of the gap production in fall;
- start up of the FEB production in fall;
- preparation of the assembly sites in December.

6.3 Cost

The estimated cost of the phase I up-scope is shown in the Table 6.2 where it is broken down into the major categories of expenditures. The expected contributions from the different funding agencies are reported in Table 6.3. In most cases the funds have already been granted. In case of CERN and Italy the figures are only estimates on the basis of the responsibility matrix, but not formal agreement exists.

ITEM	Cost (kCHF)
Detector components	1040
Front-end electronics	170

Off detector electronics	560
HV LV systems	620
Services/ infrastructure	500
Cables	380
Assembly & installation	400
Logistic CERN	400
Travel/subsistence	150
TOTAL	**4220**

Table 6.2: cost subdivided into the major categories of expenditures.

FA	Contribution (kCHF)
Belgium	800
China	500
CERN	700 *
Egypt	200
India	800
Italy	600 *
Korea	400
Pakistan	210

Table 6.3: expected contribution from FA. Figures relative to CERN and Italy are only estimates on the basis of the responsibility matrix, but no formal agreement exists.

6.4 Organization chart

A draft organization chart of the project in shown in Figure 6.2. An overall upscope manager will coordinate the project. A production manger will supervise the production at different sites with the help of local "site managers" who will steer appropriate crews for assembly, QA and logistics. General procurement of component will be coordinated by the production manager, the technical coordinator and the electronic coordinator through appropriate responsible person designed for each given task. This organization will be fully integrated in the present RPC project to allow synergies between "operation" and "upscope" teams to be exploited.

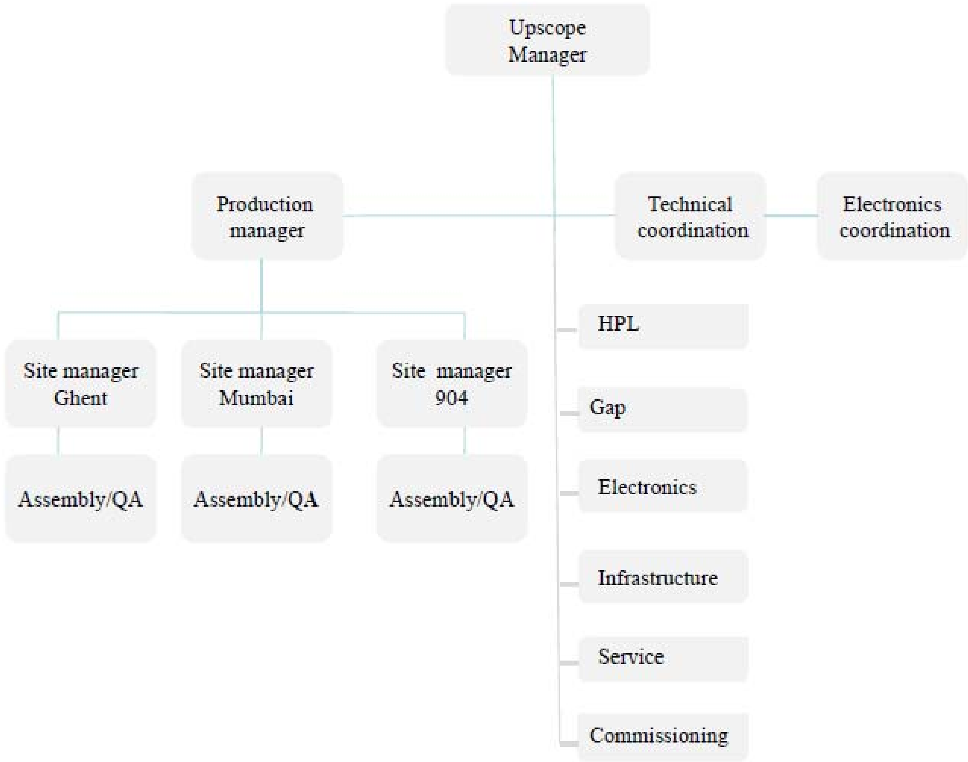


Figure 6.2: draft organization chart of the project

7 RE1/1 upscope

7.1 Introduction

The CMS forward RPC muon trigger system was initially intended to extend its pseudo-rapidity to 2.1. The current installation of forward RPC chambers and future upscope, has however been limited to 1.6 where a background rate up to few hundred Hz /cm^2/gap has to be sustained. In the left-over region between 1.6 and 2.1, the background goes beyond this limit and a different technology should be employed to enable operation at the full design luminosity as forward muon trigger detectors.

It is however proposed to test and improve the current standard bakelite double gap RPC technology to the limit by producing and installing RE1/1 chambers during the current up-scope period.

We want to achieve the twofold goal of testing the current technology to its full limit and study the long-term aging effects. Any data obtained from the RE1/1 during the initial LHC period will become invaluable in accessing the upgrade technology for forward RPCs. As an initial step 4 RE1/1s were already built and installed to study integration issues. We propose to produce the remaining 68 chambers during the up-scope period and fully integrate in CMS during the 2012 shut-down.

7.2 . RE1/1 design and installation

There will be 36 RE1/1 chamber, 10 degree each, to cover one entire forward disk. The signal plane placed between two layers of gaps has divisions according to the pseudo-rapidity range each signal section represents. All RE1/1 chambers have a signal plane divided into four sections from 1.6 to 2.1 as shown in Fig. 7.1.
Figure 7.2 shows the arrangement for gas inlet and outlet, cooling pipes, HV cables and signal cables on the front panel of the chamber.

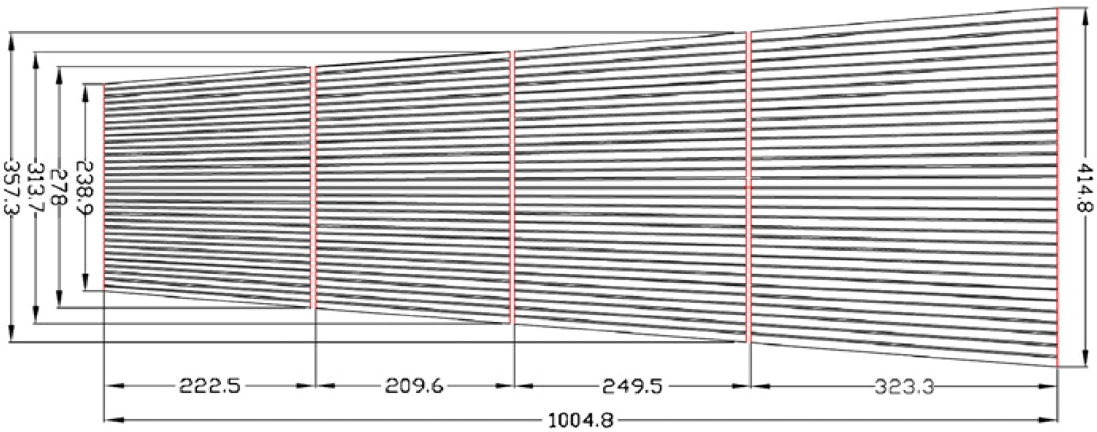


Fig. 7.1. The signal of the RE1/1 strip plane covers a pseudo-rapidity range from 1.6 to 2.1.

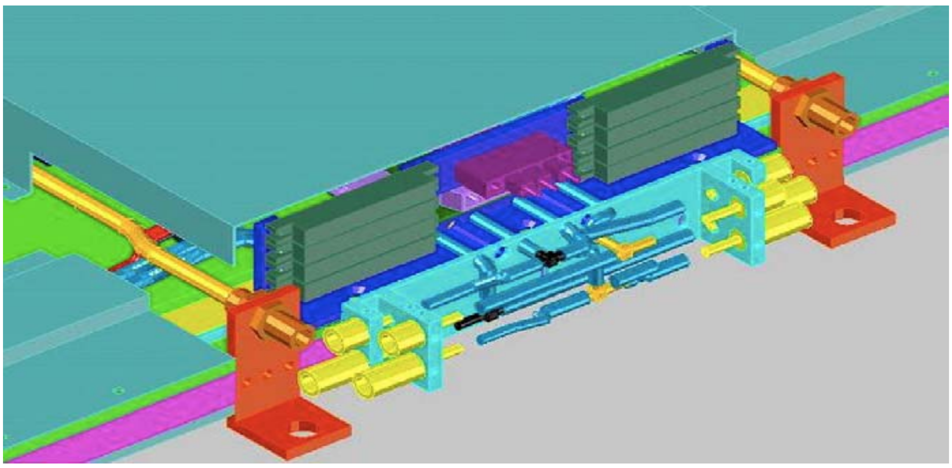


Fig. 7.2. Arrangement for gas inlet and outlet, cooling pipes, HV cables and signal cables.

The 36 RE1/1 in each forward disk will be divided in 6 groups covering a 60° sector .This will represent the unit for servicing power, gas, cooling and signal cables.
Design studies for the installation inside the nose of the YE1 end cap disk (sharing a pocket behind the HE end flange with the ME1/1 CSC detectors) were also pursued.. Since RE1/1 will be the last pieces to be installed with no much space left., we foresees a mounting tip on the back side of the chamber and a guiding rail as shown in Fig. 7.3. This scheme makes installation and positioning of the RE1/1 feasible with the possibility of later retraction for any repairs.

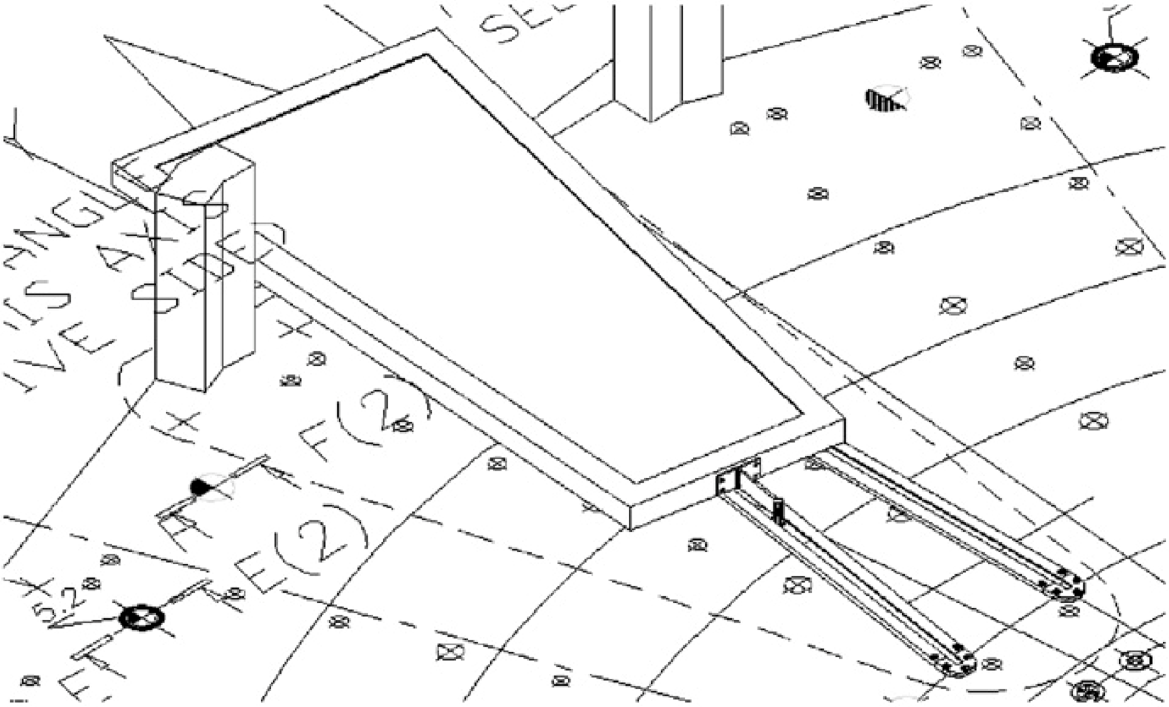


Fig. 7.3. Schematic view of a RE1/1 chamber installed and positioned with a guiding rail in the YE1 nose pocket.

Reference

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NEW :
Session 4.6 modified
Session 5.2 modified
Session 5.3 modified
Session 7 new
Reference new
Figure 1.3 new
Figute 5.2 modofied
Figure 5.3 modified
Figure 6.1 new