Installation and Commissioning of RPCs

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Major Tasks in RPCs Project

Prototyping and Beam Testing

Production & Relevant Tasks are divided in 2 parts

In Pakistan

- Assembling of the RPCs
- Quality Assurance
- Testing of RPCs
- Shipping to CERN

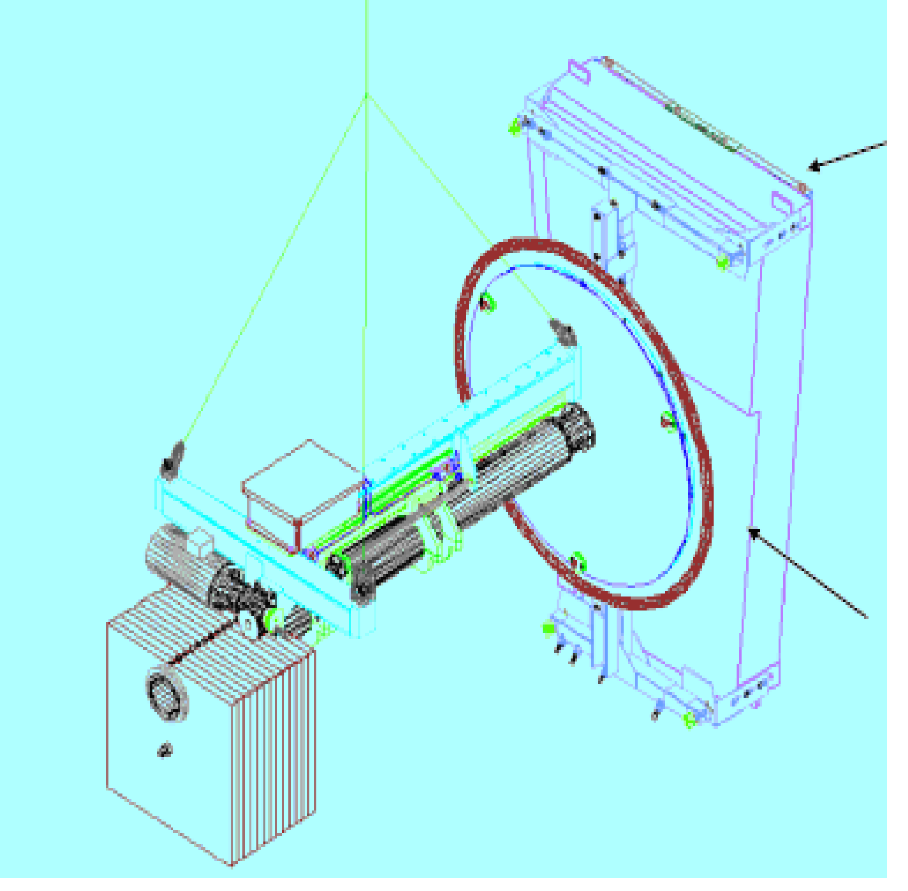
At CERN

- Re-Testing at ISR
- Installation, Pre-Commissioning
- Final Commissioning

Installation

Tools and manpower required

- Installation tool
- 2 cherry pickers
- 1 Crane driver
- 4 persons in cherry picker
- 2 persons at surface



Installation tool

Installation Procedure

- Thread cleaning at yoke
- Stud hammering and fixation
- Installation of cable grid
- Preparation of the installation tool
- Preparing and Placing the chamber vertically

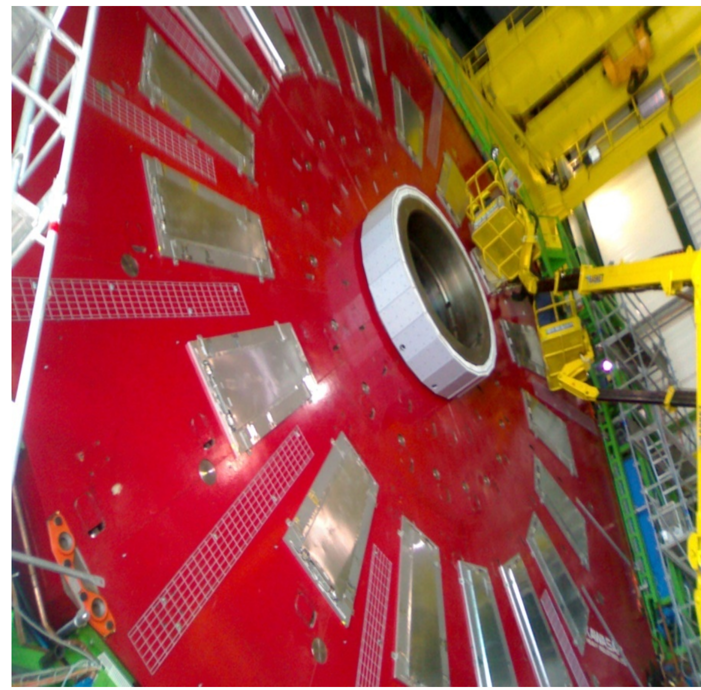
Cable grid

Vertical RPC

Installation Procedure

- Supporting bars adjustment at the both sides of RPC
- With the help of crane bring the tool near the RPC and fix the chamber in the tool
- Crane pick the chamber up and bring it in front of the desired position
- In 2 cherry pickers 4 persons come close the chamber and adjust the chamber in mentioned studs at the yoke

In 2 chary pickers 4 persons



18 On Yoke */2 RPCs

Disk Completion

36

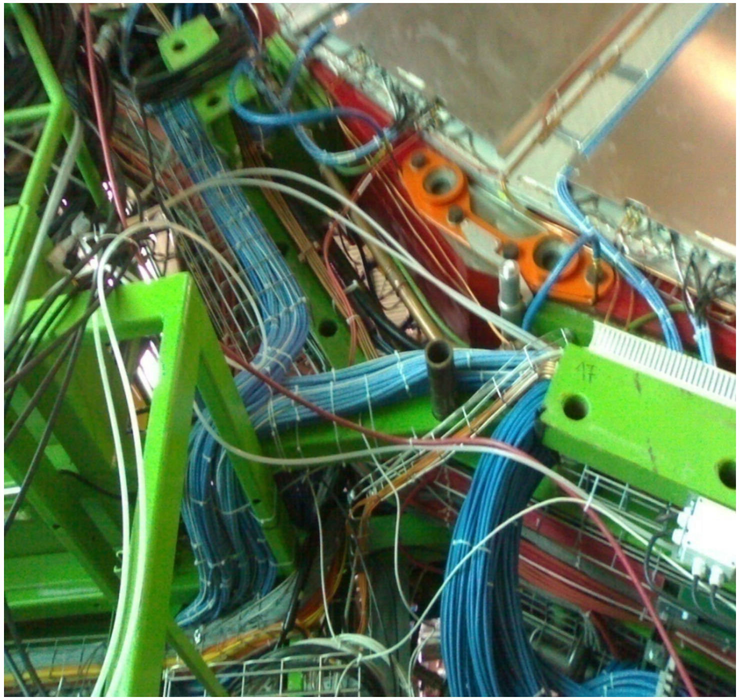
54

72

Cabling

Cabling Steps

- Skew testing and bundling of signal cables
- Installation of link boards in VME crates
- Installation and routing of signal cables, DCS, HV, LV and Temperature cables
- Connection of signal cables and DCS in link boards properly



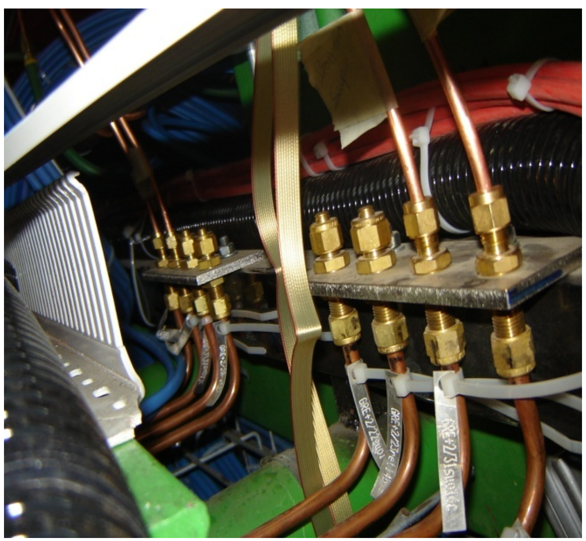
Routing of the cables

Signal + DCS cables in cable tray

Piping

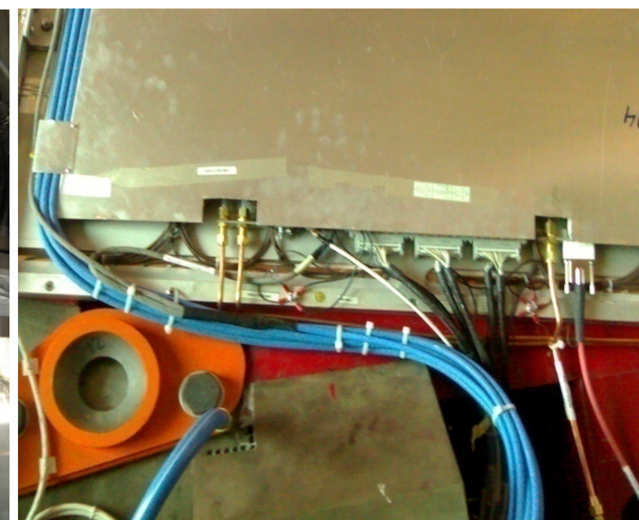
Gas and Coolant

- Preparation of the interconnecting pipes
- Preparation of the flexible pipes
- Interconnection of chambers sector by sector (For Coolant 20 deg, Gas 30 deg)
- Mounting valves at supply and return at each bulk head (18 for coolant and 12 for gas)
- Making connection from chambers to bulk heads



Gas Bulkhead

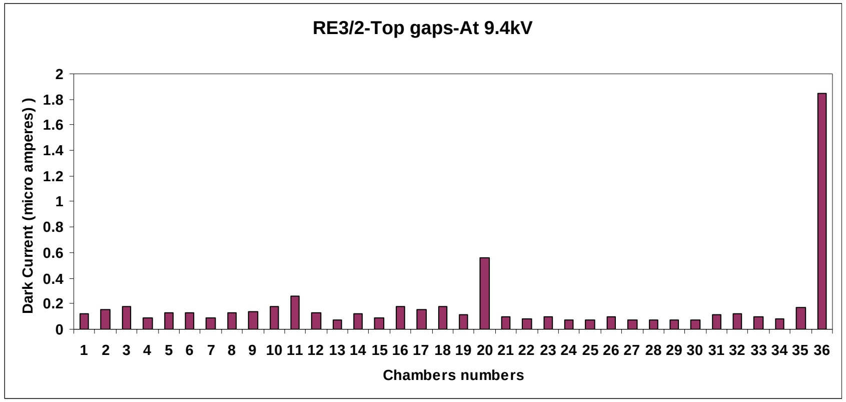
Interconnecting gas and coolant pipes



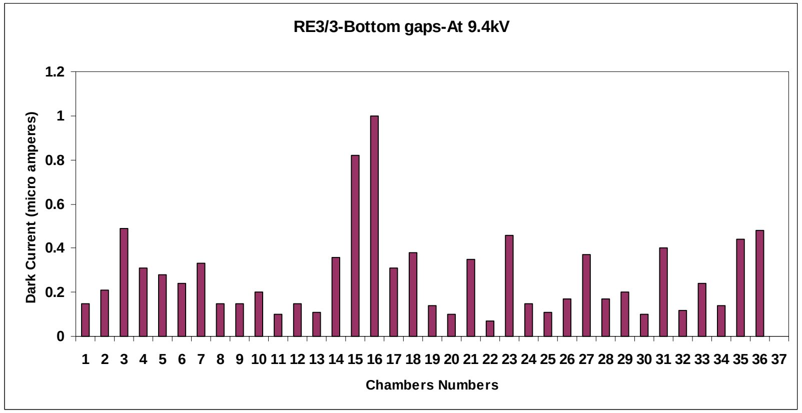
Chamber fully equipped

Pre-Commissioning

- Installation of CAEN Power Supply at two sides of the yoke
- Installation of the gas distribution system
- Flushing gas mixture sector by sector (24 hours for one sector)
- Noting Dark Current at 8.6,8.8,9.0,9.2,9.3,9.4,9.5 and 9.6Kv
- Drawing plots of these results



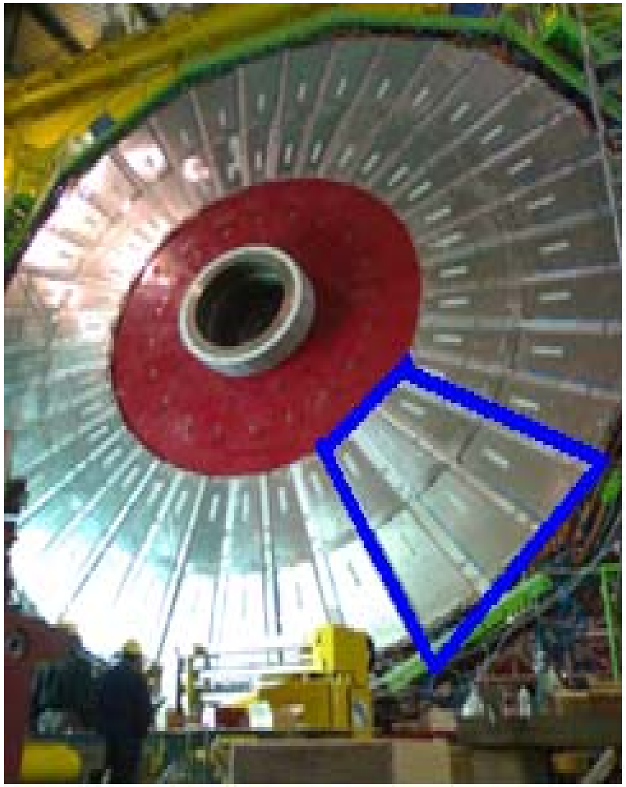
Top gaps */2 at RE-3



Bottom gaps */3 at RE-3

Pre-Commissioning

- In pre-commissioning, we tested:
  - HV connections.
  - Gas connections.
  - Test RPCs for HV Vs Dark current plots.
    - Dark current criteria: maximum 2 Micro Ampere at 9.4 kV.
- Pre- commissioning was done sector by sector.
  - Each sector included 3 RE*/2 type and 3 RE*/3 type RPCs i.e. 30 degree sector.
- Results
  - 1 RPC out of 288 was rejected due to high dark current. RPC was then replaced with the good one.



Work performed at CERN

ISR

Tasks	No. Of RPCs	Persons
Re-Testing	318	3 NCP

Point 5

Tasks	YE+3	YE+2	YE-3	YE-2	Total persons
Installation completed	5 PAEC 1 NCP	6 PAEC 1 NCP	4 PAEC 2 NCP	4 PAEC 2 NCP	19 PAEC 6 NCP
Cabling, Coolant, Gas, Pre-Commissioning completed	1 PAEC 1 NCP	0 PAEC 2 NCP	2 PAEC 3 NCP	4 PAEC 2 NCP	7 PAEC 8 NCP
Final Commissioning	NCP	NCP	NCP	NCP	7 NCP

- **Installation of 288 RPCs on 4 RE Stations is finished by end of 2007.**
  - All services like gas, coolant, cabling are done.
  - Pre-commissioning is done on all 4 stations.
- Next step is Commissioning.

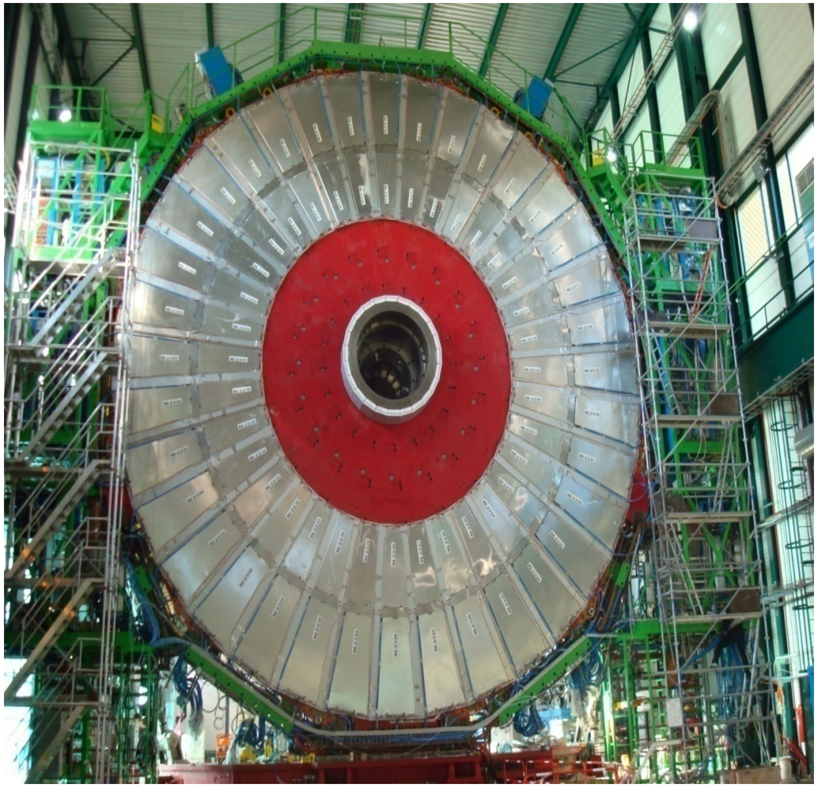
COMMISSIONING

Manpower involved in Commissioning

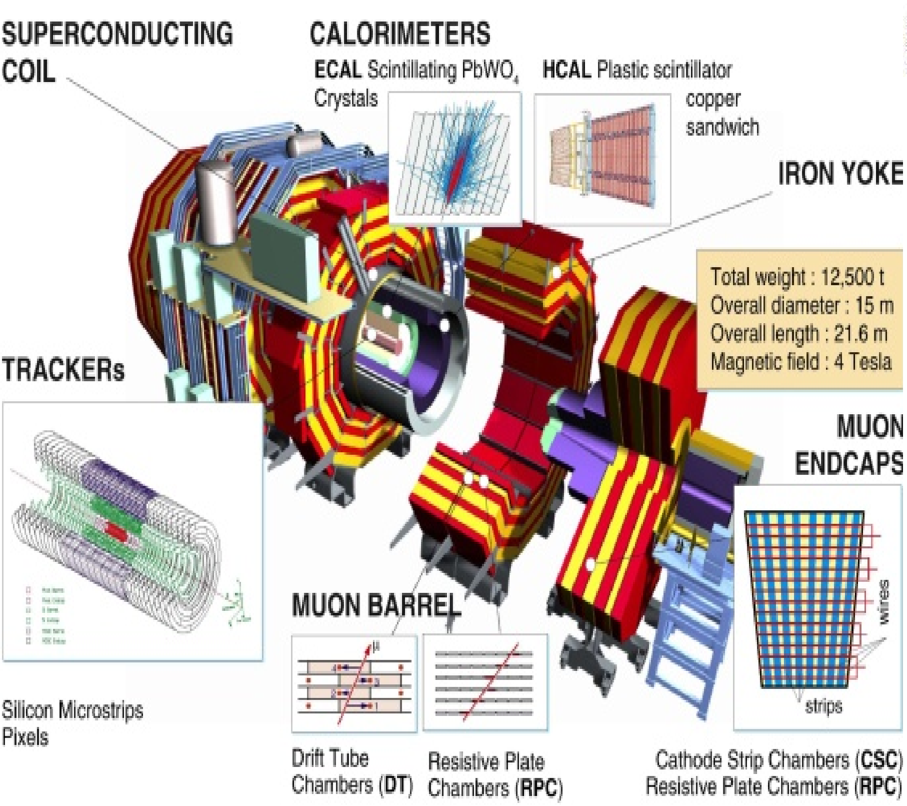
- Following Pakistani group is involved in Endcap RPC commissioning since May, 2008
  - Dr. Jamila Bashir Butt
  - Hassan Shahzad
  - Saleh Muhammad
  - Taimoor Khurshid
  - Muhammad Ahmad
  - Wajid Ali Khan
  - M. Imran Malik

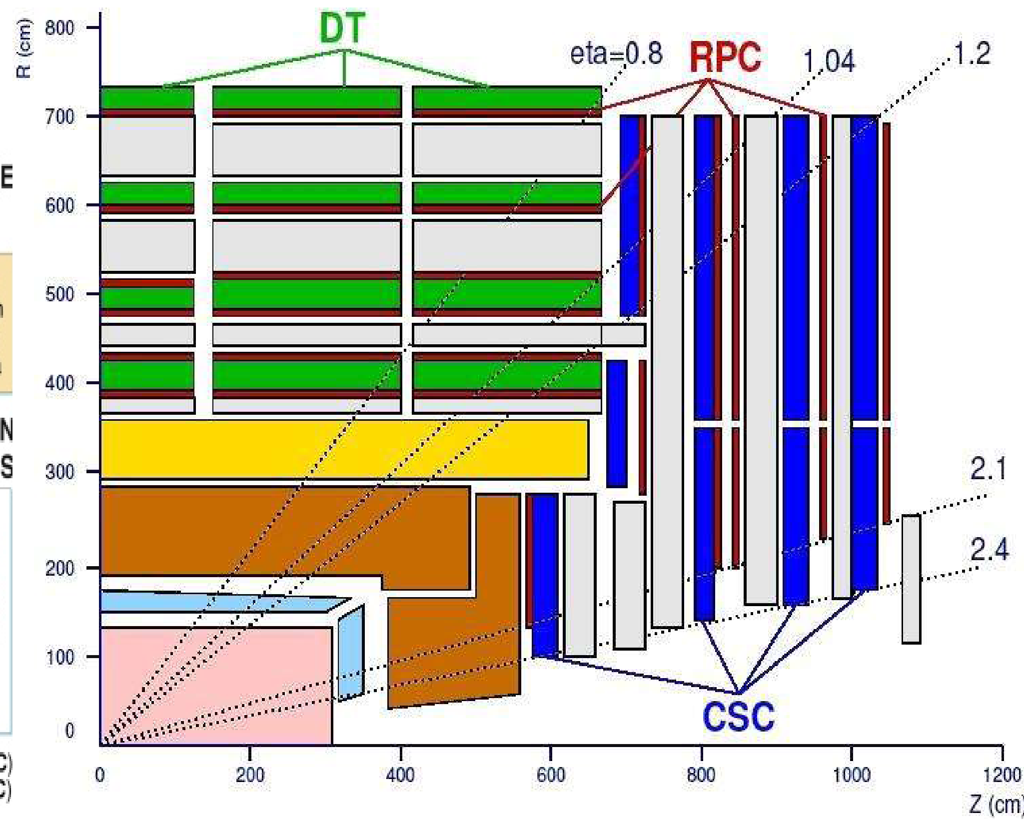
Continued..

- Pakistani group involved in Commissioning From May, 2008 till 1st June, 2009 equals to approximately 5 man years.



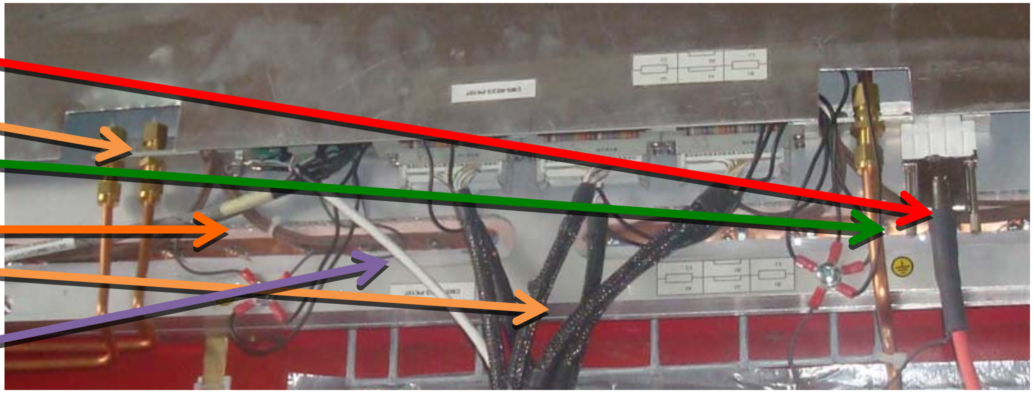
Resistive Plate Chambers at Compact Muon Solenoid





Commissioning

- Commissioning means to ensure that all the service (e.g HV, LV. Gas, cooling, sensors for temperature & humidity and Readout system) needed to operate the chambers are working properly.
- It also certifies that the performance of our detector is still of the same level as during the production and test phase.
- Following system needs to be tested for commissioning
  - HV System
  - Gas System
  - Cooling System
  - LV System
  - Readout System
  - Monitoring System



- The performance of RPC detector is based on following parameter; occupancy, efficiency, cluster-size, dark current.

HARDWARE ORDERED BY PAKISTAN

- Following is the list of hardware ordered by Pakistan.

ITEM NO	DESCRIPTION	SHORT DETAIL	QUANTITY
1	SY1527 HV SYSTEM	HV Main Frame	1
2	SY1527LC-LV SYSTEM	LV Main Frame	1
3	EASY 3000 HV SYSTEM	Able to maintain 6 HV boards	11
4	EASY 3000S LV SYSTEM	Able to maintain 5 LV boards	6
5	A1676- 2 HV, 2LV	Interface b/w mainframe to EASY System	4
6	A3512N HV SYSTEM	HV Board containing 6 channels	42
7	A3485- HV SYSTEM	Power Supply for HV EASY Crate	1
8	A34FU- HV SYSTEM	Fan units for HV EASY Crates	11
9	A3486	Power Supply for HV EASY Crate	1
10	A3009-LV SYSTEM	LV Board containing 12 Channels	36
11	A3486S- LV SYSTEM	Power Supply for LV EASY Crate	6

SCHEDULE OF HARDWARE ARRIVAL

Below is the schedule of the hardware arrival at CERN Electronics pool

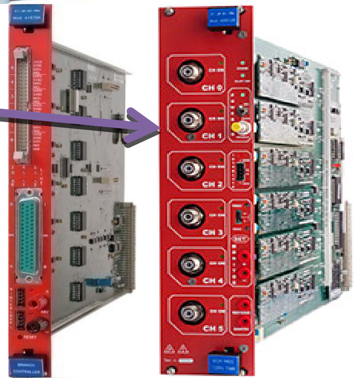
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr		
DC/DC																				
All LHC				90	90	110	120	120	120	0	120	120	120	120	120	120	120	120		
CMS				26	26	32	34	35	34	25	35	34	35	34	35	34	19	0		reqts
	0	25	20	26	26	32	34	35	34	25	35	34	35	34	35	28	19	0	477	
ES	0	0	0	0	0	1	0	0	0	0	3	0	0	9	15	12	17	0	57	57
A3025						1					3			9	15	12	17		57	*57*
RE		**0**	**0**	**0**	**0**	**0**	**4**	**0**	**0**	**0**	**0**	**0**	**11**	**25**	**20**	**16**	**2**	**0**	**78**	**78**
A3009							**4**						**5**	**15**	**10**	**2**			**36**	***36***
A3512N													**6**	**10**	**10**	**14**	**2**		**42**	***42***
DT		25	10	12	14	18	21	26	20	15	28	21	0	0	0	0	0	0	210	210
A3009		15				4	7	10	4	15	10	5							70	*70*
A3050		10	10	10	12	12	12	16	16		16	16							130	*130*
A3100				2	2	2	2				2								10	*10*
HCAL		0	10	2	0	5	5	5	5	3	0	0	0	0	0	0	0	0	35	35
A3016			10	2		5	5	5	5	3									35	*35*
RPC		0	0	12	4	0	4	4	4	4	4	13	19	0	0	0	0	0	68	68
A3016				12	4		4	4	4	4	4	13	19						68	*68*
Align		0	0	0	8	8	0	0	5	3	0	0	5	0	0	0	0	0	29	29
A3006					8	8			5	3			5						29	*29*

CONT..

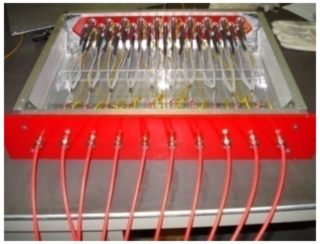
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct		
AC/DC														
All LHC				40	30	30	30	30	30		30	30	reqts	
CMS				26	20	20	20	20	20		20	20	175	175
	6	6	0	26	20	20	20	20	20		20	16		
ES													13	13
A3486											1	12		
RE													**7**	**7**
A3486S											**5**	**1**	**6**	
A3485											**1**		**1**	
DT													41	41
A3486S				8	6	6	6	6	6		3			
HCAL													15	15
A3486	3	3		4	2		1	1	1					
RPC													9	9
A3486S					2			2	1		4			
Tracker													78	78
A3486	3	3		12	10	12	12	10	12		4			
Pixel													6	6
A3486											3	3		
RB													6	6
A3486S				2		2	1	1						

RPC HV Hardware 1

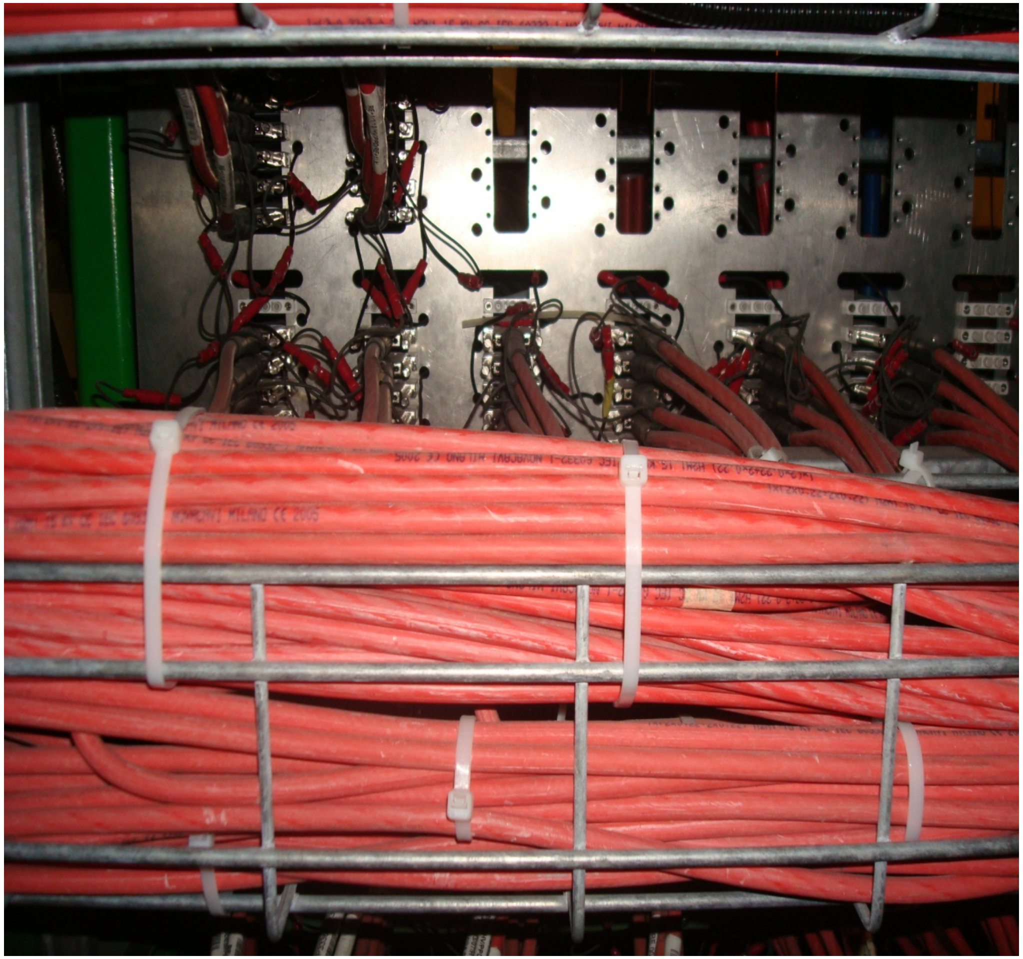
S No.	Model No.	Short Description	Quantity
1	SY 1527	HV MAINFRAME	1
2	A3485N	MAO FOR HV SYSTEM	1
3	A1676N	BRANCH CONTROLLER	3
4	EASY 3000	EASY CRATES	8
5	A34FU	FAN UNITS FOR EASY CRATES	8
6	A3512N	HV BOARDS	36
7	Custom Made	HV Distribution Boxes	24



- Total Channels 864
- Reduced to 216 by using distribution boards



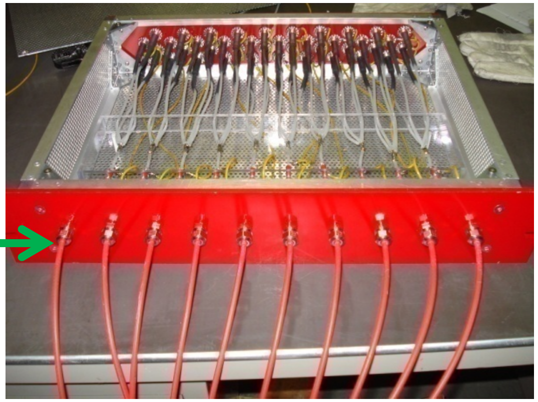
Main Frame



HV Cables connections to PP

RPC HV Hardware Continued

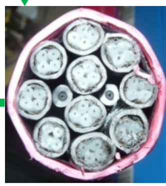
- HV Module



- Distribution Box Input Side

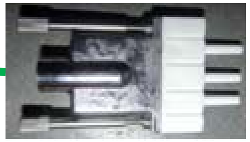
- Distribution Box Output Side

- Jupiter Connector

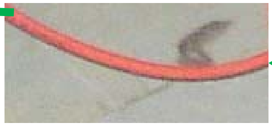


- 200 meter long cable

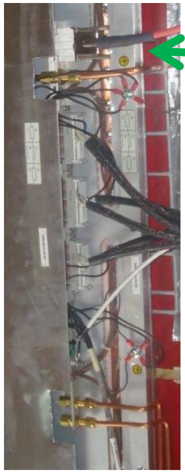
- Patch panel



- Female Tripolar Connector

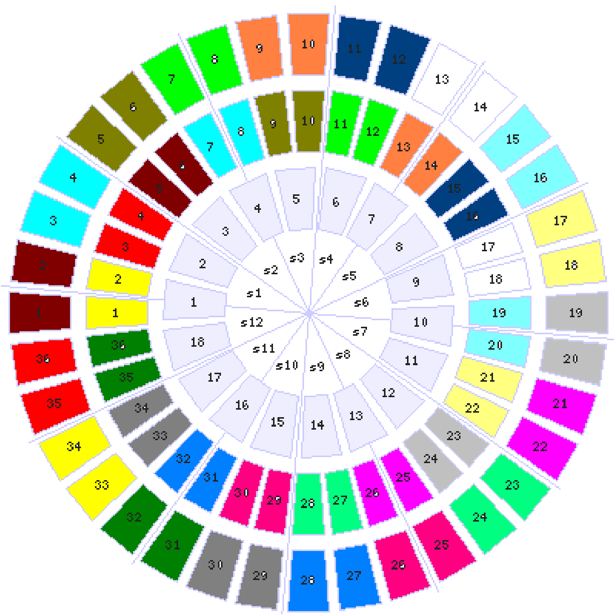


- HV cable

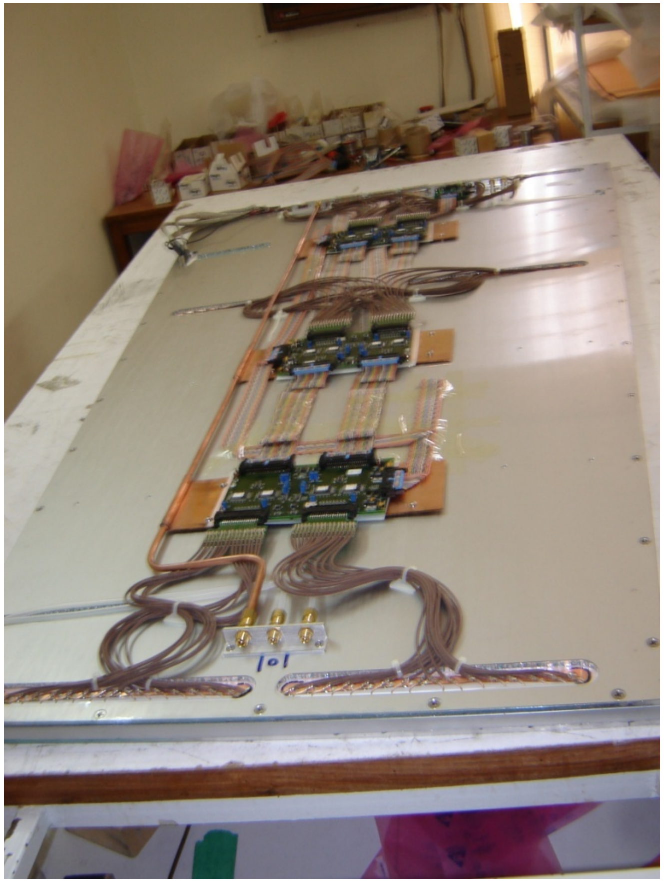


- RPC

HV/LV System Layout

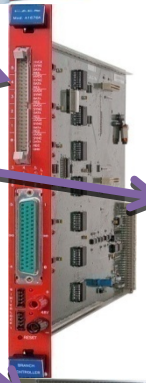


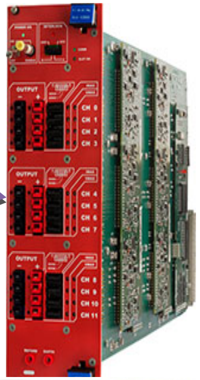
RE+1 from the IP



LV System

S No.	Model No.	Short Description	Quantity
1	SY 1527 LC	LV MAINFRAME	1
2	A3486S	MAO FOR LV SYSTEM	12
3	A1676N	BRANCH CONTROLLER	4
4	EASY 3000S	EASY CRATES	24
5	A34FU	FAN UNITS FOR EASY CRATES	24
6	A3009	LV FEB Modules	36
7	A3016	LV LBB Modules	24

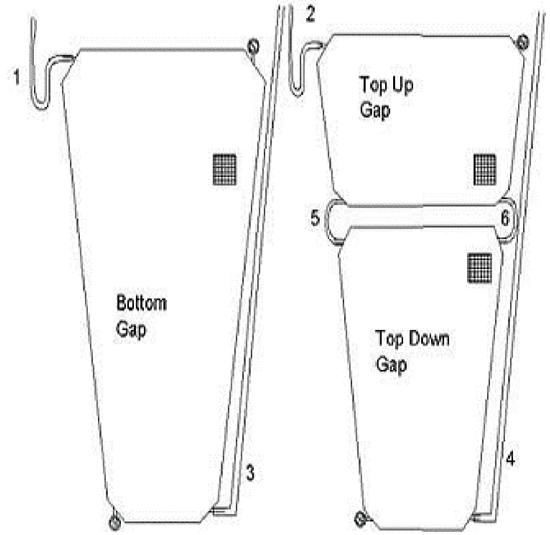


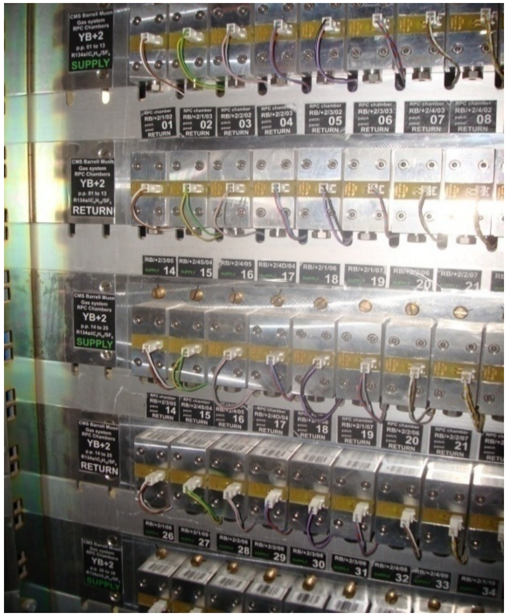


- *Total channels for:*
  - FEBs 432
  - LBBs 144

Gas System Layout

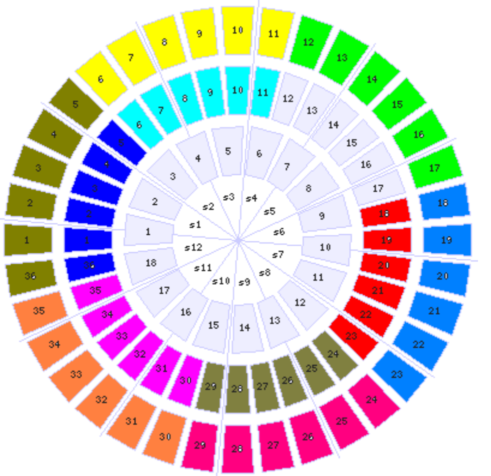
- Needs to provide correct %age of the gas mixture to each chamber. (96% $C_2H_2F_4$, 3.5% iso - C_4H_{10} and 0.5% SF_6)
- Economize as well as optimize the expenditure and efficiency of system
- There are 6 consecutive chambers connected to one gas supply. This set for gas system is called a sector
- Location and geometry of sectors for 3 disks on +ve side are shown below.



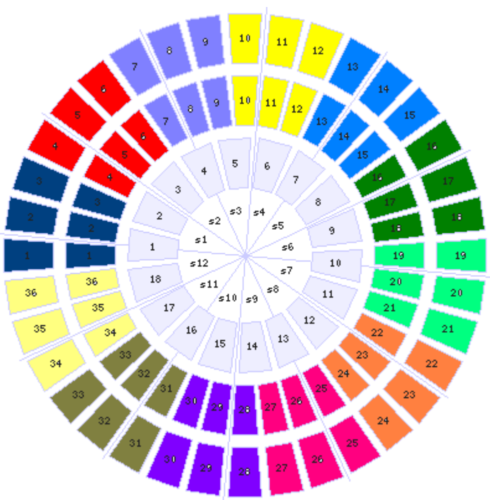


GAS SYSTEM

- 1 gas sector comprises of 6 RPCs and covers 30degree in eta for RE2 and RE3 while 60 degree for RE1. Each sector has 4 channels: 2 supply, 2 return.
- There are 2 pressure sensors (tested) located on each disk.
- For uniform flow of the gas in the chamber all flow cells are equalized.
- 1 rack contain 24 flow cells. Total racks are 6.



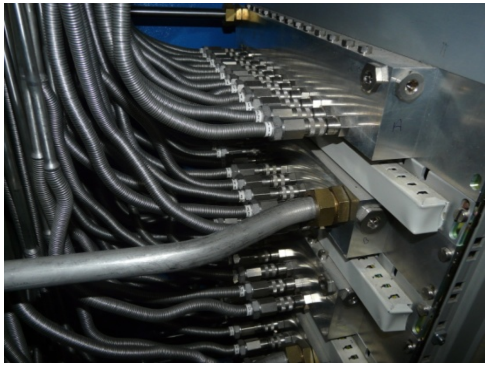
RE+1 from the IP



RE+3 from the IP

Gas Supply

• Gas rack front



• Gas rack back

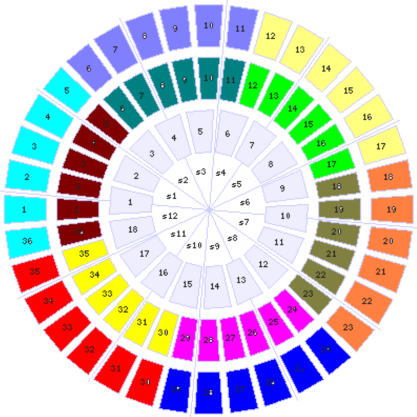
• Gas pipes from rack leading to disk

• Bulkhead at disk

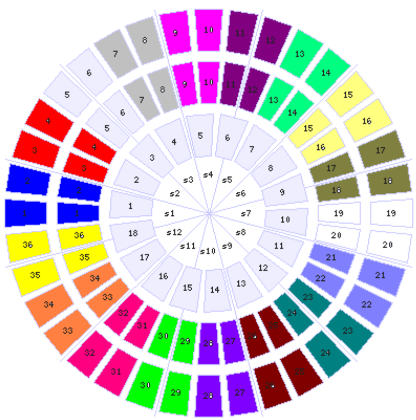
• Gas pipes at chamber patch panel

Cooling System

- Cooling system is installed by ZEC group.
- Pakistani group is involved in testing of coolant system.
- One RE2 and RE3 station has 18 coolant sectors while RE1 has 12 coolant sectors.
  - each sector comprises of 4 or 6 RPCs as indicated in picture.
- Coolant leak test is done on sector by sector followed by full manifold test on all 6 stations.
- It is very important because in case of water leak whole RPC system can be damaged.
- Recent studies showed that a temperature ~ 17C of coolant is needed to avoid current increase which was observed for different endcaps

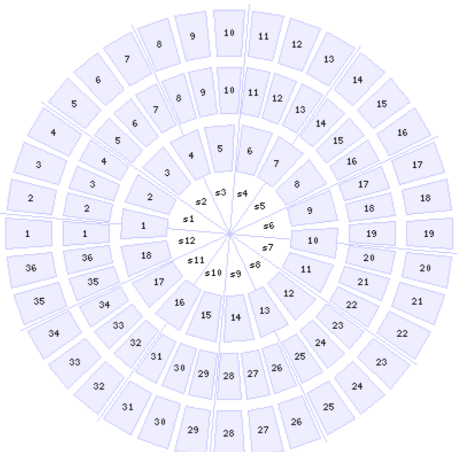


RE+1 from the IP

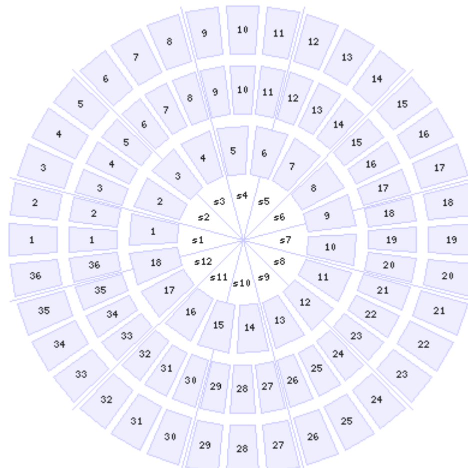


RE+2 from the IP

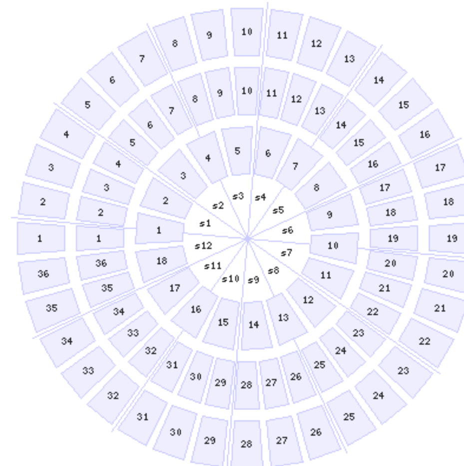
Readout System



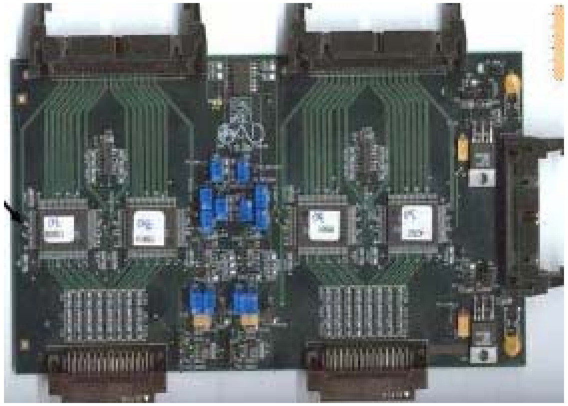
RE+1 from the IP

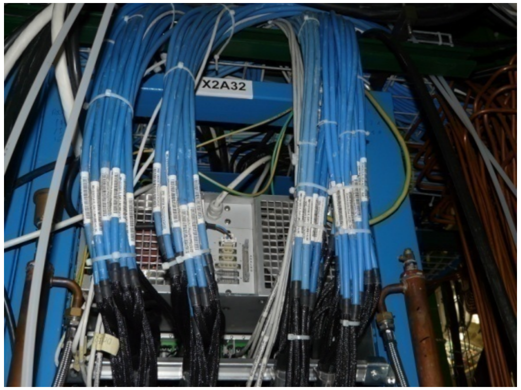


RE+2 from the IP



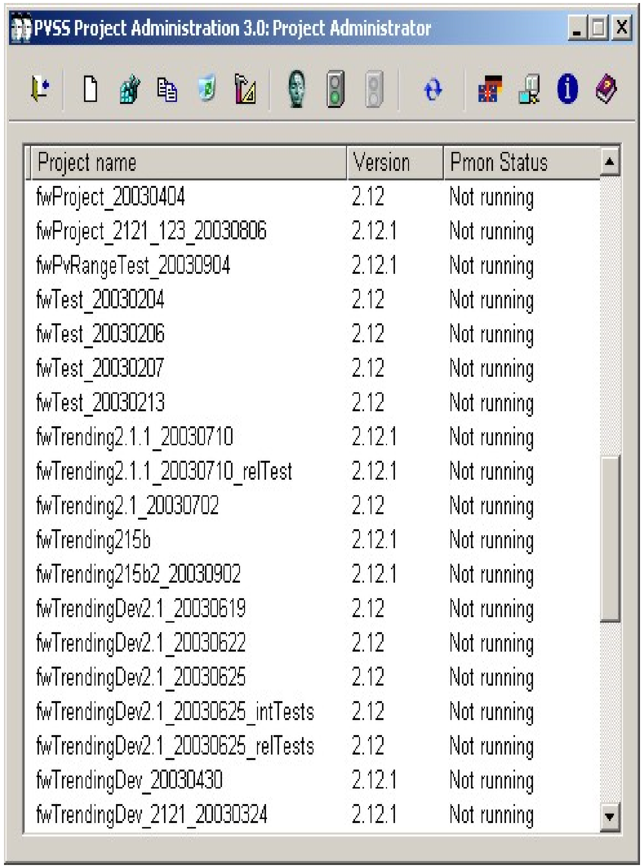
RE+3 from the IP



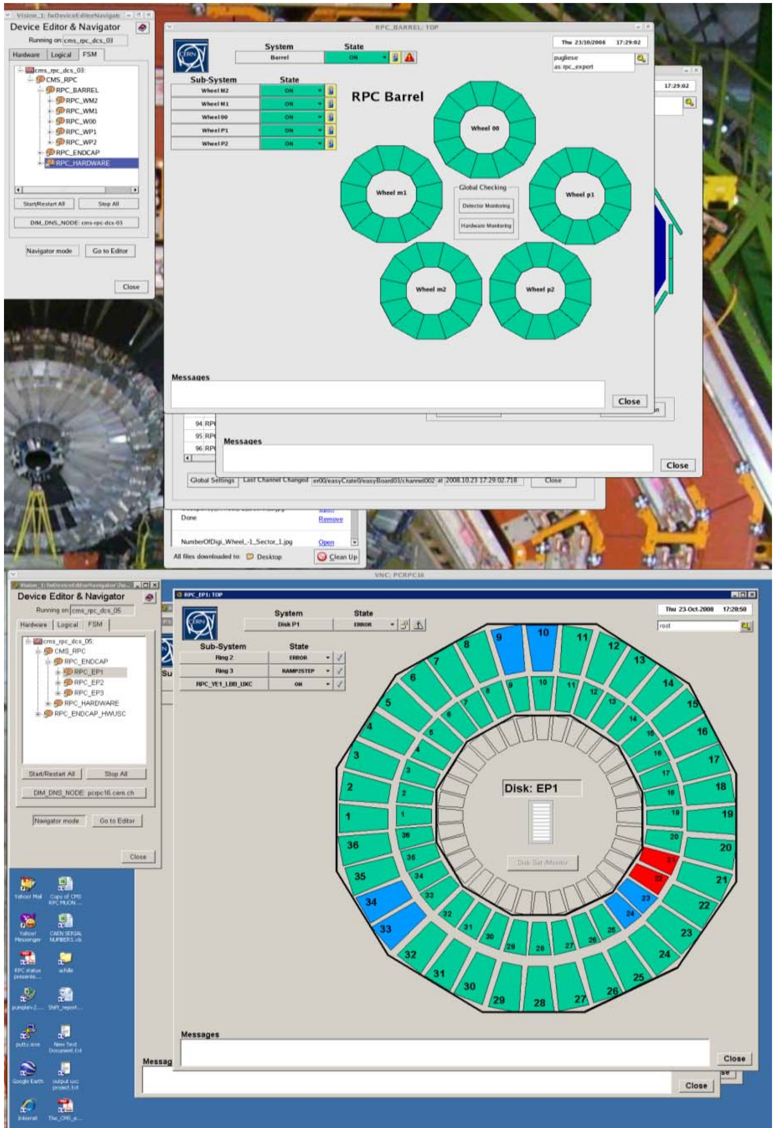


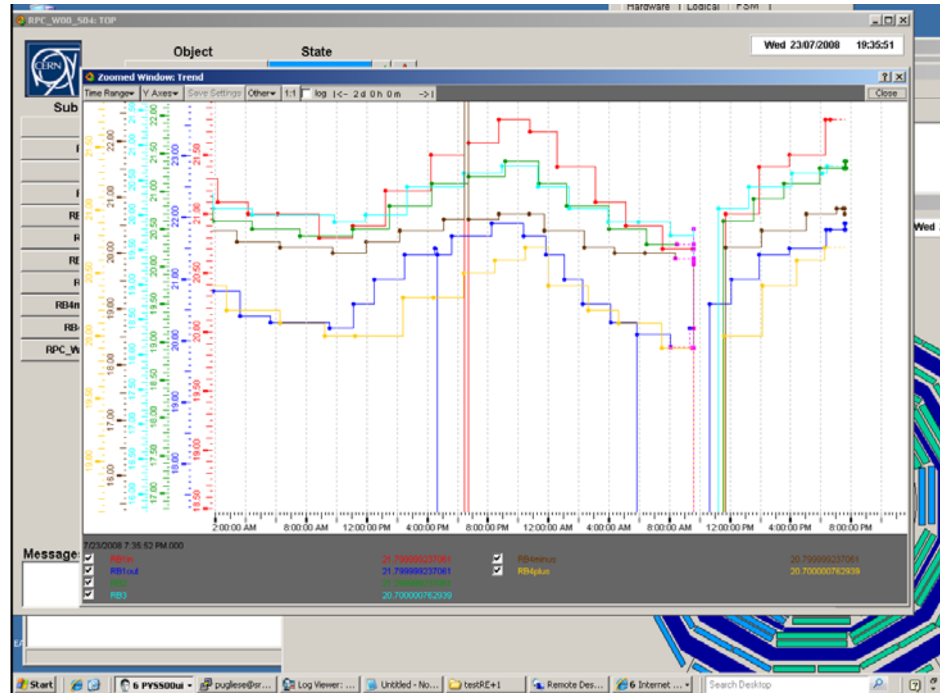
DETECTOR CONTROL SYSTEM (DCS)

- The software used for DCS for RE system is PVSS.
  - PVSS is the Supervisory Control And Data Acquisition (SCADA) system chosen by CERN team.
  - Commercial product from ETM, Austria.
  - Since then, PVSS has been widely adopted across CERN, not just used by the experiments.
- We will monitor the HV, LV and Gas system of RE using PVSS.



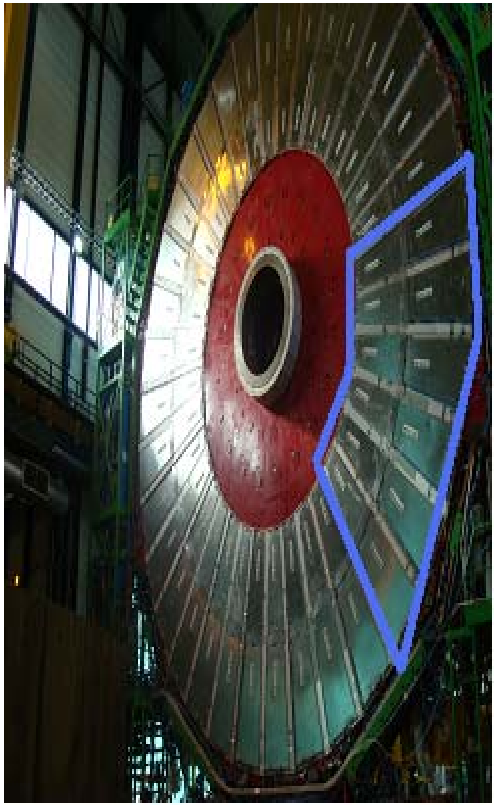
Monitoring System (PVSS)





PROCEDURE FOR RPC COMMISSIONING

- Commissioning was done sector by sector.
  - Each sector is of 60 degree.
- Forward commissioning includes three stations.
  - i.e. RE+1, RE+2, and RE+3.
- Note: same 60 degree slice of all three stations will be active at same time.



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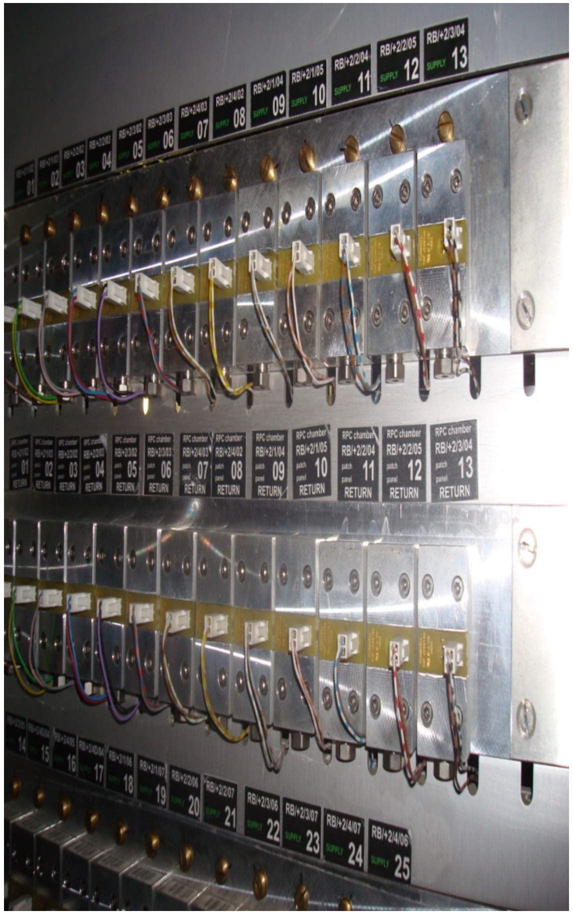
- **Procedure:**
  - Supply gas mixture according to gas rack information to 60 degree sector of 3 stations.
    - If there is leak in the sector, it will be indicated in this step.
    - Solution: find leak and tight the connections.



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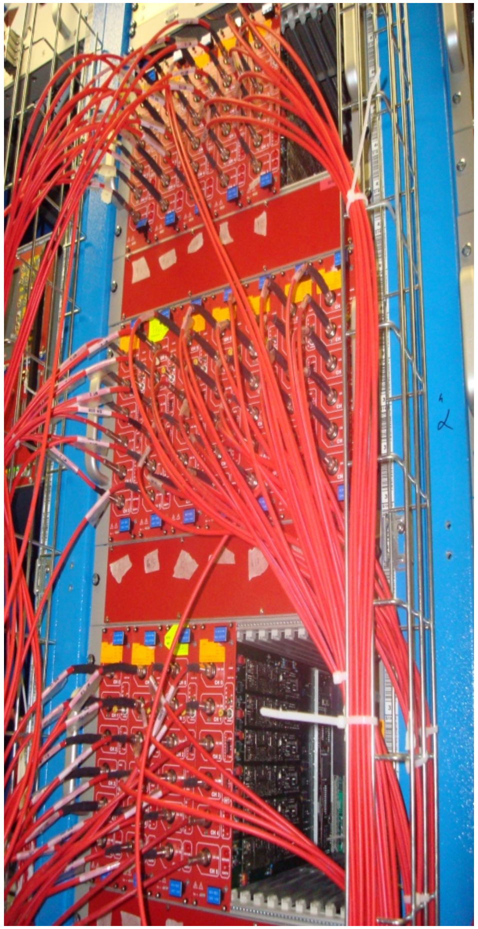
- After sufficient amount of time (i.e. 24 to 30 hours) switch on high voltage of 36 RPCs.
  - Check dark current, if it is in limit then the HV cable and RPC is OK.
  - Else if there is high dark current then there is problem in HV Cable or in Gas Gaps of RPC.
    - Do proper procedure to solve the problem.
    - If problem is not solve in terms of dark current the last step is to remove the faulty RPC.

CONT..

- After sufficient conditioning of HV (app 10 hrs), switch on the LV power supply of 36 RPCs.
  - Check current drawn for each LV channel.
    - If there is some ambiguity in the current drawn by any LV channel check LV Cable and its connection.
    - Normally the problem is only improper connection.



CONT

- At this point, check the HV system, LV system and the gas system.

- If status of everything is OK, then start taking the data from the signal cables / link boards.

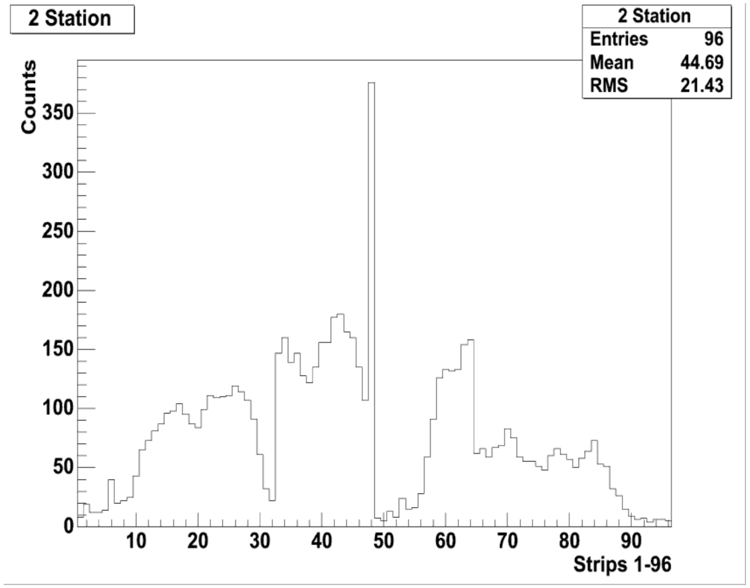
- Take data on 8.8kV, 9.0kV, 9.2kV and 9.4kV.

CONT..

– See the strip occupancy plots generated by the software which is responsible to take data from the link boards.

– If the strip occupancy plot is not OK

- i.e. no of strips are dead or noisy in one RPC.
- Solution: check signal cable connections, FEBs etc.

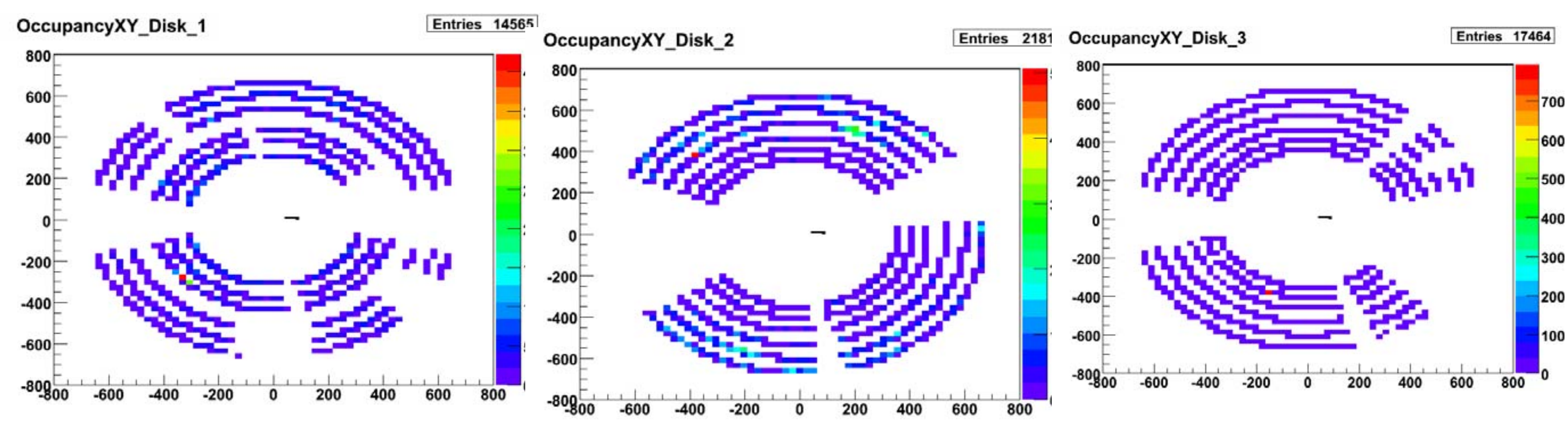


Forward Side Commissioning

- In this way, rest 60 degree sectors will be tested.
  - There are total of 6 sectors in the forward side.
- After completion of forward, backward commissioning will start.
- Commissioning work may continue in shifts.
- Manpower requirement for the commissioning phase is shown in next slide.

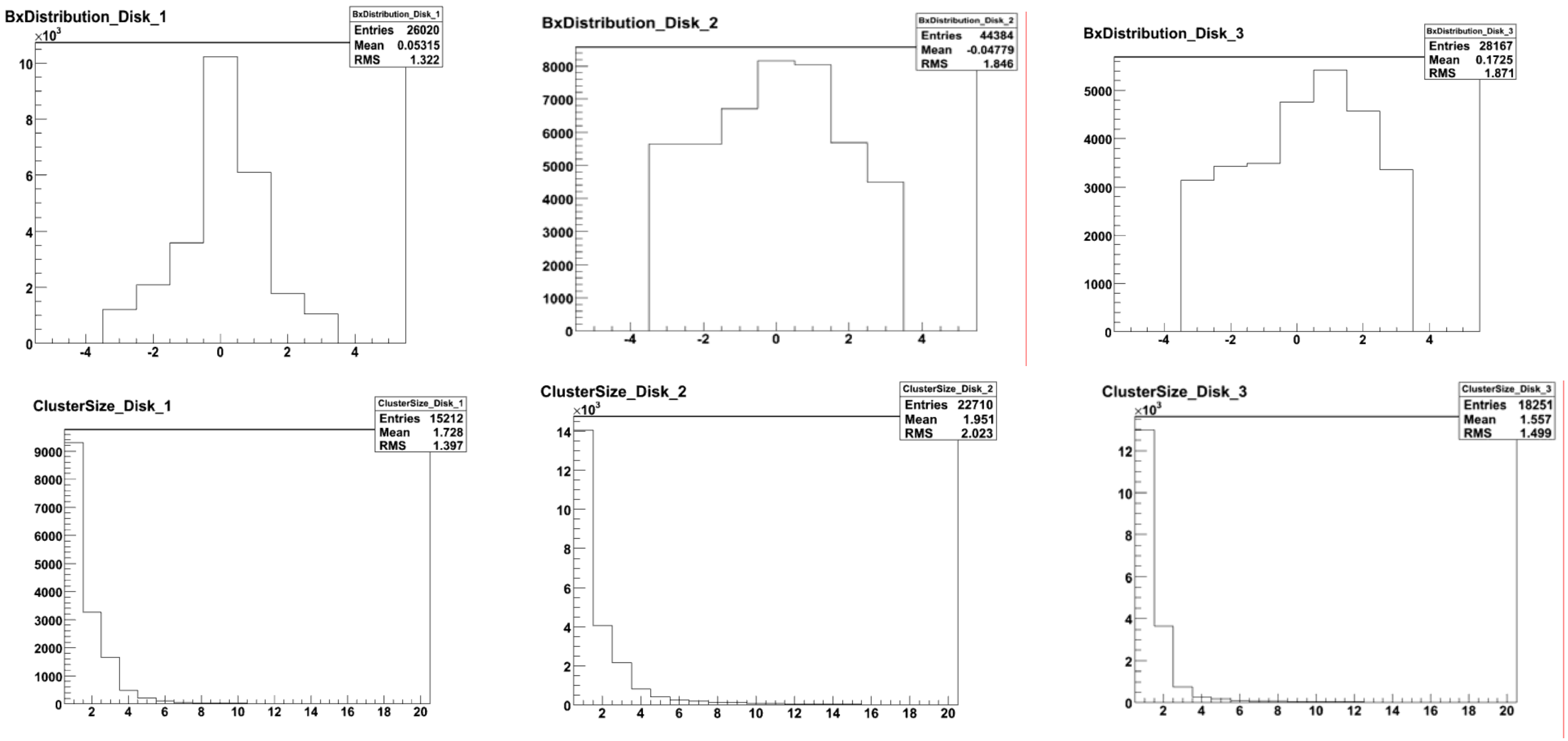
Data Quality Monitoring

- Look at different RPC parameters e.g Bx, cluster-size
- Follow proper procedure to correct it
- Or let RPC team be aware of the situation so problem could be solved
- Occupancy plots for +ve Endcap (RPC)



DQM

- Bx and Cluster size for +ve side of endcap RPC

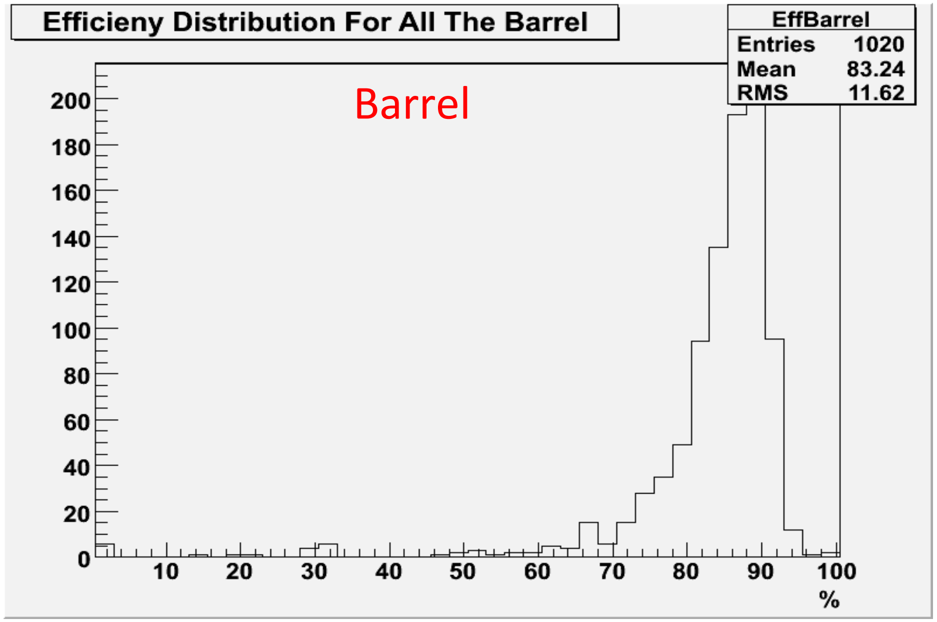


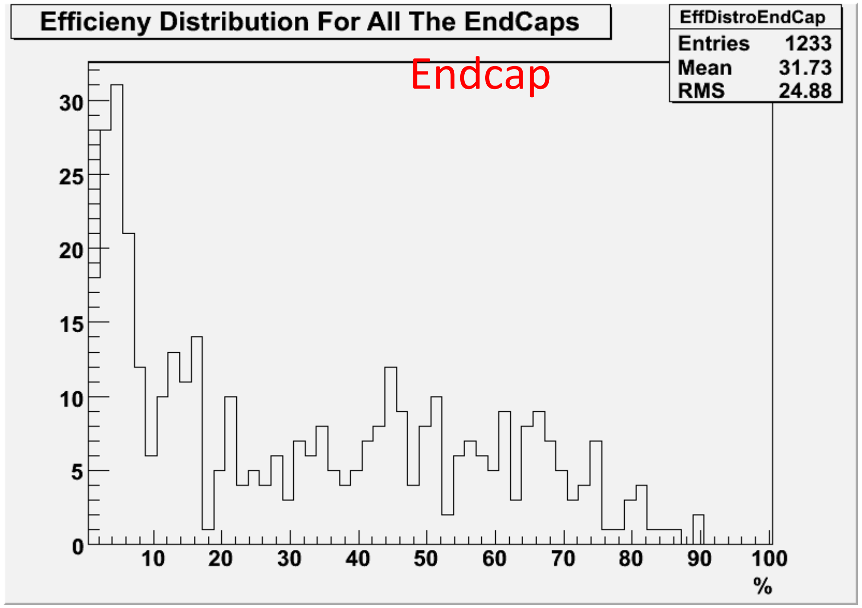
Parameters studied in Global Runs

- A global run (GR) is a mockup of real detector running.
- All sub detectors are turned on together. Magnetic field zero (0 Tesla) data is taken for calibration/correction while Magnetic field Full (4 Tesla) data is taken for real detector studies
- There are no beam from accelerator. The Global Runs use radiations coming from outer atmosphere
- Following parameters are studied and tuned during GRs
  - Efficiency
  - Calribration
  - Alignment
  - Trigger rate
  - Noise

Endcap Efficiency in 2008

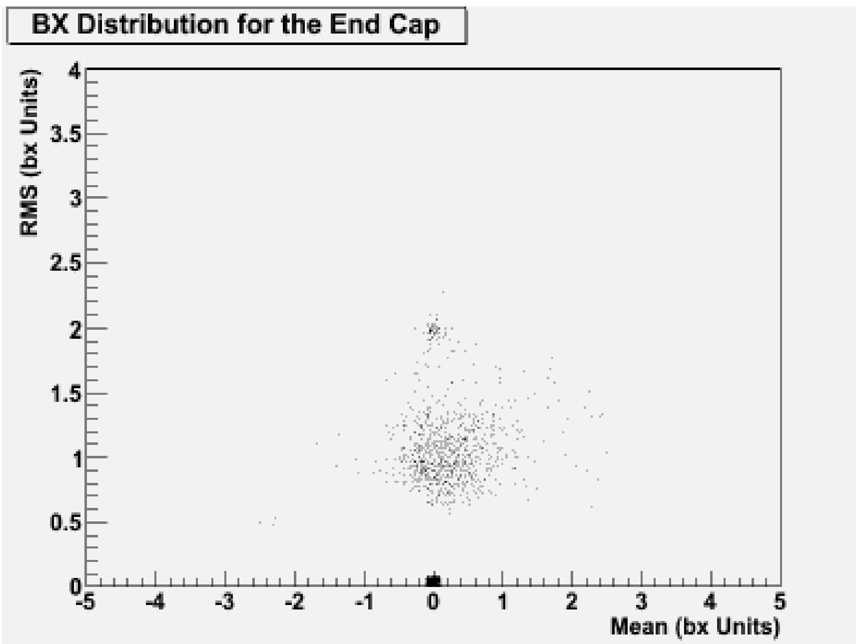
- Lots of work needs to be done for Endcap Efficiency
- Work with RPC group at CAF to understand the problem of endcap

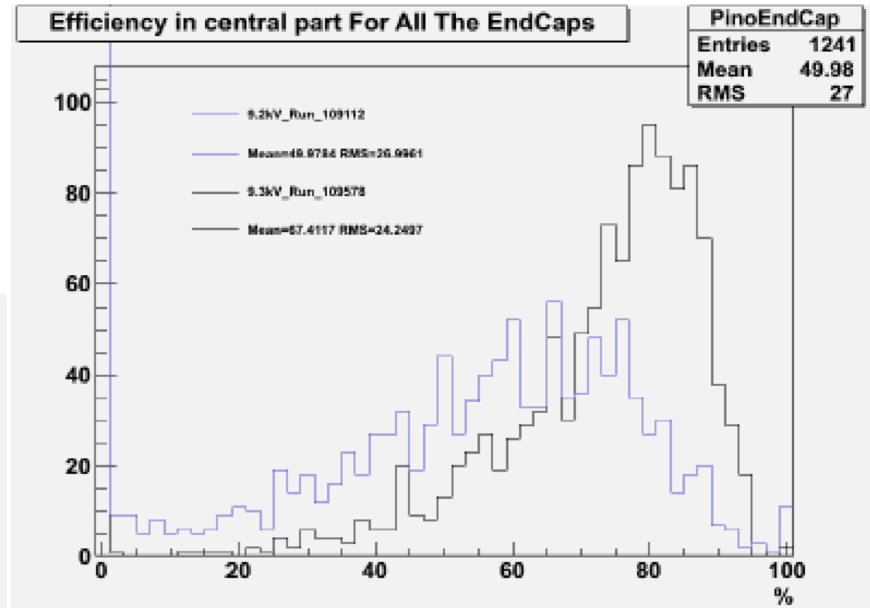




Endcap Efficiency in 2009

Endcaps are now operational, efficiency and noise measurements are being performed

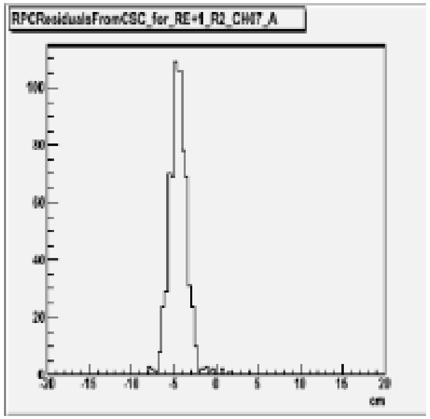


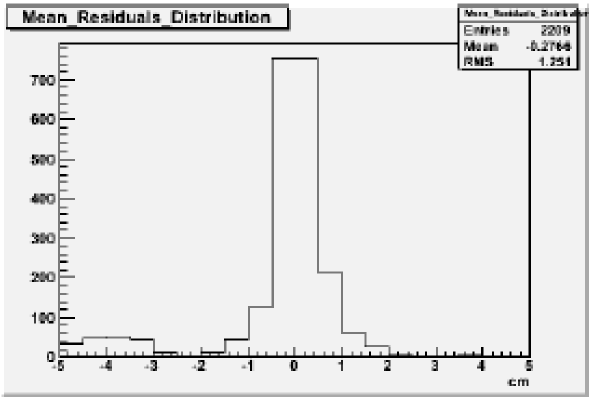


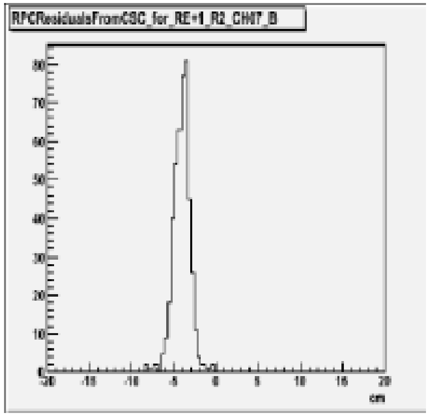
Working point for the endcaps is not yet determined. We are still scanning HV to reach the plateau, that explains the low efficiencies

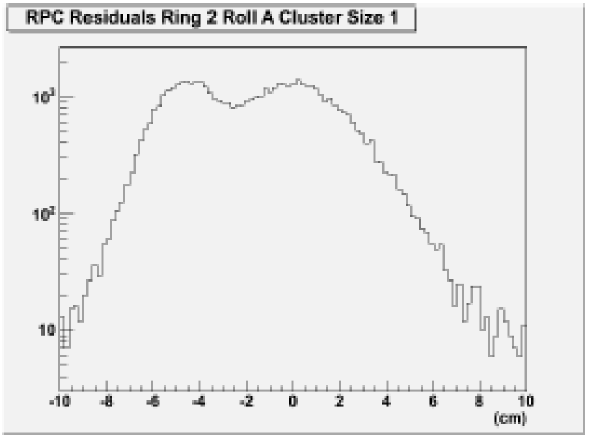
Residuals and Misalignment

Misalignment in endcap is coming mostly from ring 2, in the right top plot, the entire residual distribution for the RPC is shown, the tail at the left is coming from the endcap. In the bottom right plot the ring 2 roll A distribution for endcap residuals shows the misalignment effect. The left plots show a couple of misalignment chambers in the ring 2 roll A and B, chambers seam misalignment in 5 cm.

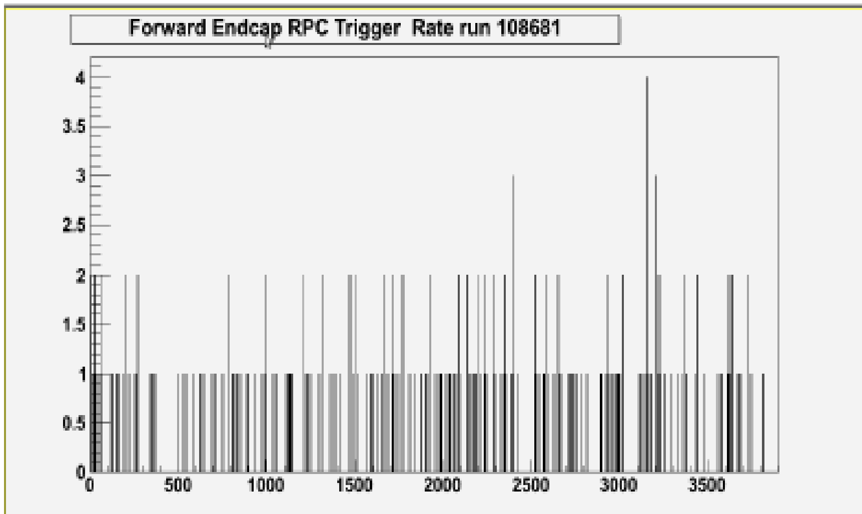


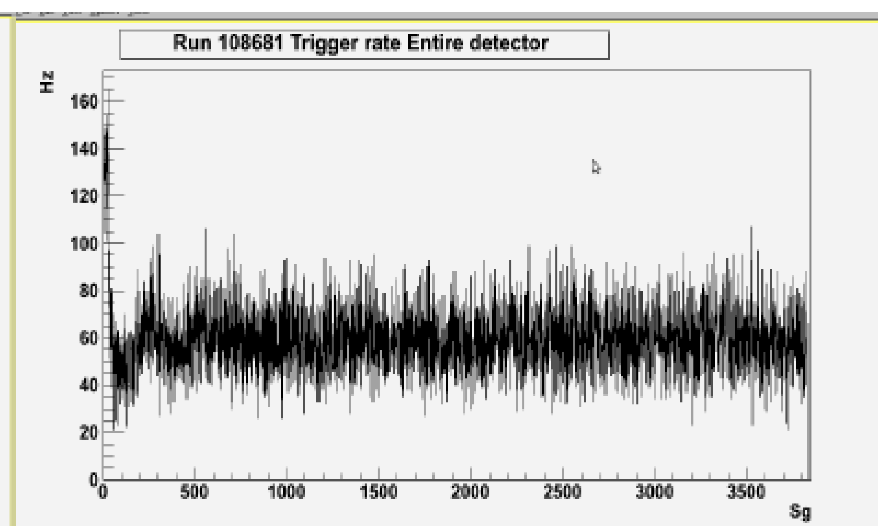






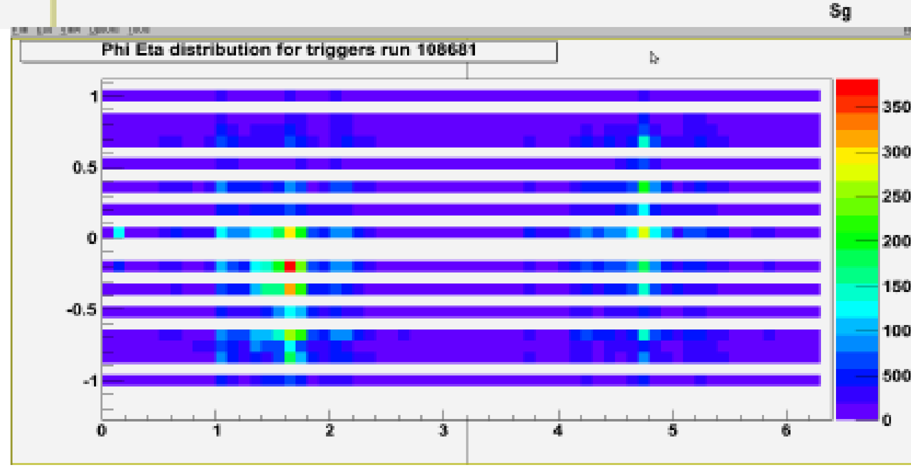
Trigger Rate



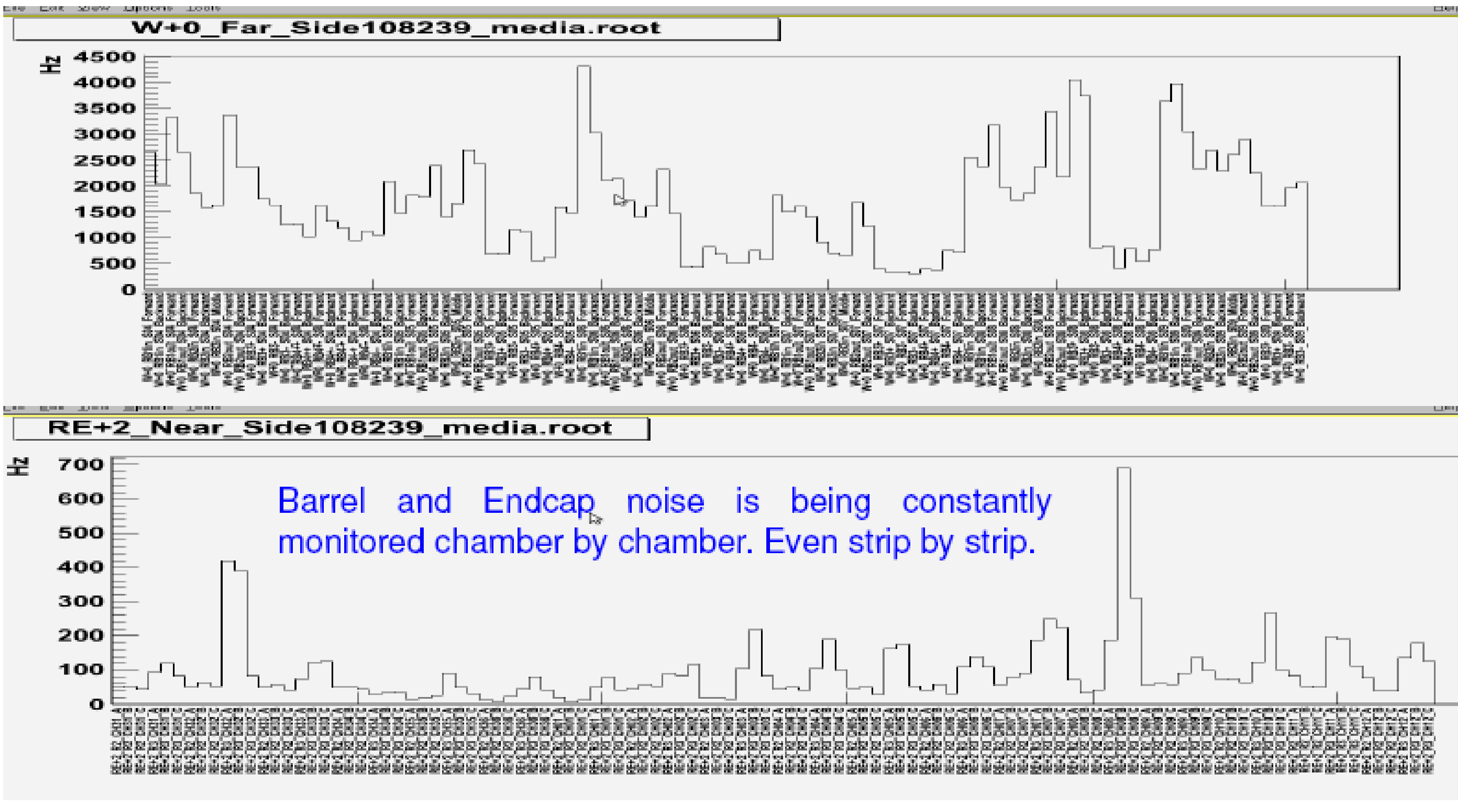


Trigger rate for endcap and for the entire subdetector. Only one sixth of the real statistics is present.

A plot phi vs eta is also shown, normal performances of the detector has been observed



Noise


W+0_Far_Side108239_media.root
Hz
4500
4000
3500
3000
2500
2000
1500
1000
500
0
RE+2_Near_Side108239_media.root
Hz
700
600
500
400
300
200
100
0
Barrel and Endcap noise is being constantly monitored chamber by chamber. Even strip by strip.

September 2008

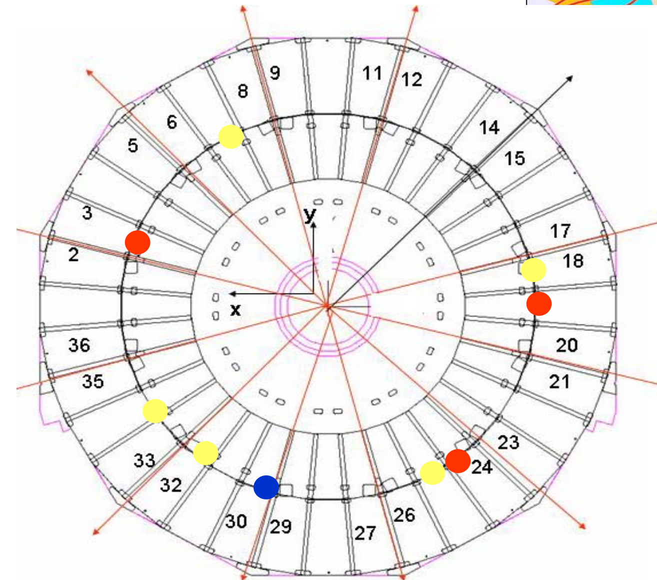
Problems

- Besides some minor problems from time to time the most important one is the Rising of Dark Current

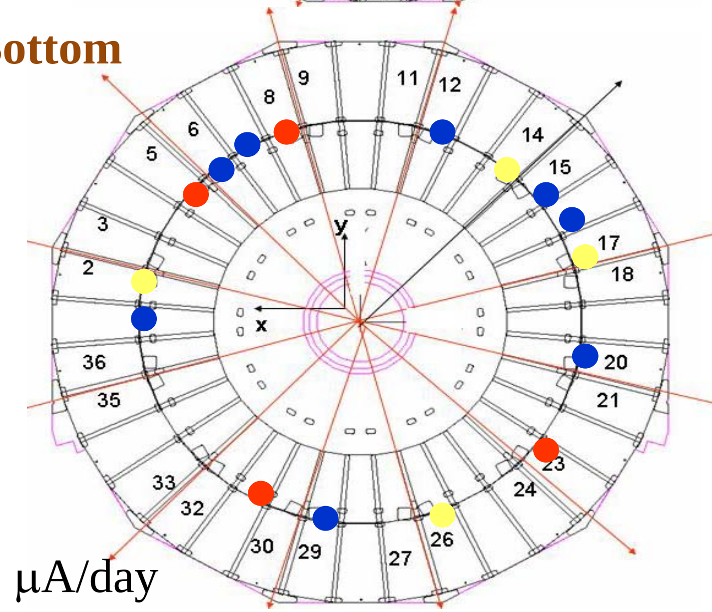
- In Sept 2008 some chambers of RE+2 and RE+3 showed rise in the Dark Current

- Possible reasons could be gas leakage, gas flow, temperature effects, humidity, mechanical reasons etc etc…..

Top



Bottom



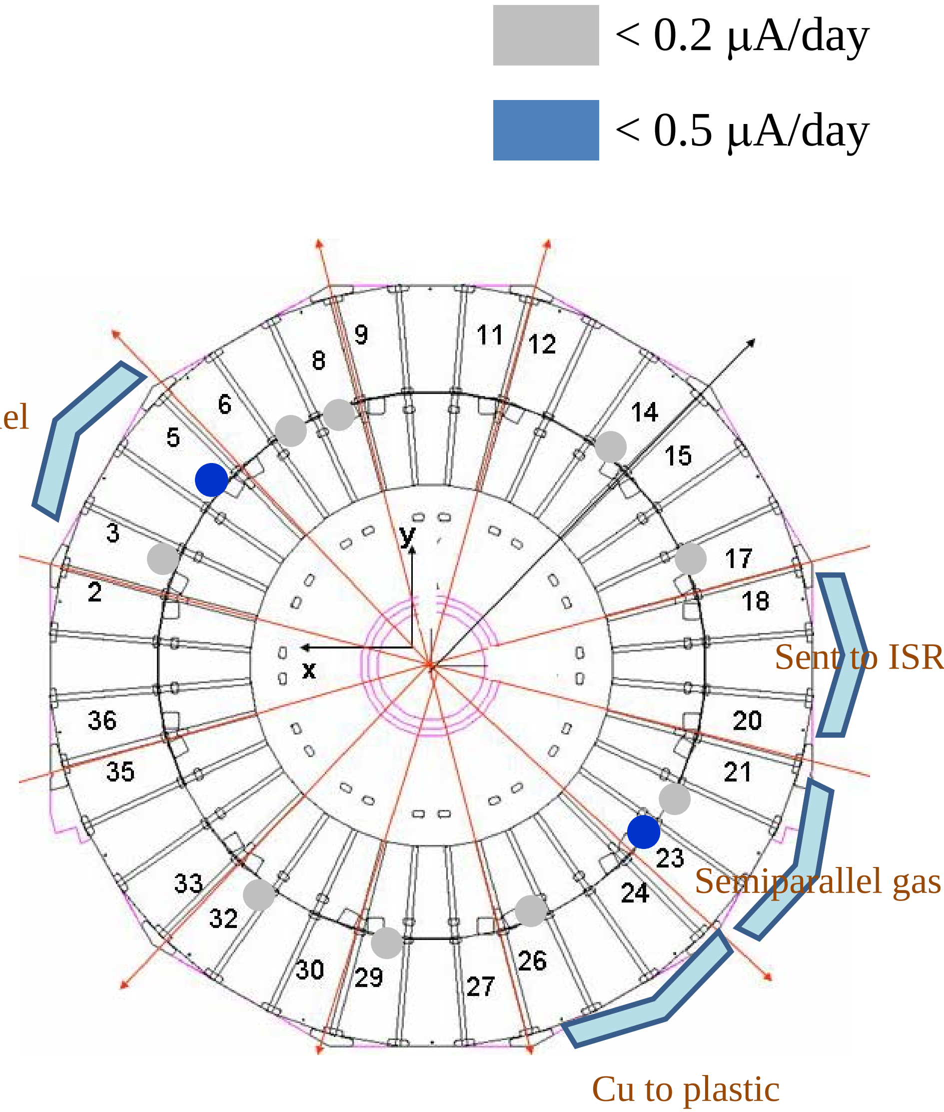
Blue: < 2.0 μA/day

Yellow: < 1.0 μA/day

Red: > 2.0 μA/day

Diagnostic Steps

- Swapping of gas supply in RE+1 and RE+2. No effect was observed
- Reversing the gas flow where outlet was changed to inlet and vice versa. Improvement was observed.
- Parallel and semi-parallel gas flow scheme was implemented for some sector as oppose to present serial flow in a given gas sector. No significant improvement seen
- One sector copper pipes were replaced with plastic to exclude the effects of the copper in the gas in the circuit. No effect seen



Further Gas Tests

- A setup was created in ISR for long term testing with full gas sector.
- Six bad chambers from RE+2 were removed and moved to ISR for further testing.
- Leak test were performed for all RE+1,2,3 and special equipment was used.
- Some leaks were found in chambers which were fixed but the rising current problem could not be correlated with the leak problem.

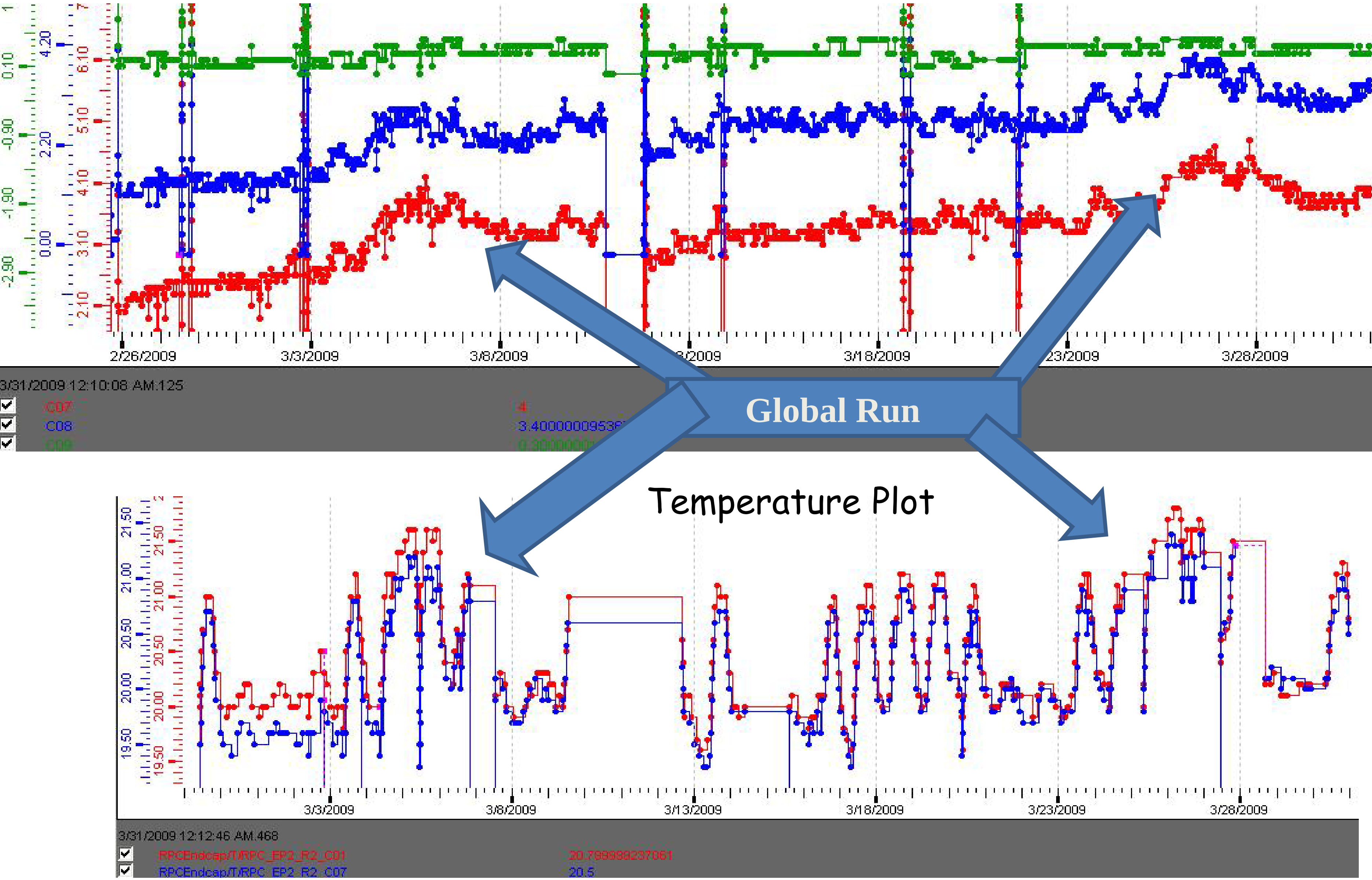
Next Steps

- On close analysis of Current and RPC temperature data during several Global runs showed that the two were correlated.

- The increase in RPC temperature during the full running of CMS is due to many possible reasons e.g. heat generated by FEBs, CSCs etc. which increase the dark current of some chambers.

- Solutions to be implemented
  - The temperature of Coolant will be reduced further
  - If it does not help then insulate FEBs from the chamber

Current Plot



Solution for rising current Problem

- Finally, it was observed this rising current problem is related to the Temperature.
  - After extensive research it is concluded that the outside temperature of RPC must be less than 22.5 degree Celsius to cope with the rising current problem.

Other Problems and Solutions

- HV
  - Tripping problem of HV channels
  - Spikes in HV current
  - Rising in current problem in few channels.
    - Due to change in temperature and humidity in the experimental area.
    - Due to gas mixture.
- LV
  - Communication problem between the EASY crates and MAO.
  - Tripping problem
  - Over current problem
- Solution
  - change /Remake connector, check/change module channel, control board (LV)

Problems and Solution continues

- Gas System:
  - Channel swapping problem.
  - Gas Leak: open the connectors and tight
  - Flow cell calibration problem:
  - Blockage: increase flow rate till blockage is removed
- Cooling System:
  - Leak problem in coolant connections: Open and make tighter connection, introduce oil/white tape to make it tight, leak proof
- Readout System:
  - Signal cable swapping problem:
  - Threshold setting problem: apply a default setting from hardware
  - Link board failure: change link board

Conclusion and Status

- RE hardware troubleshooting almost complete.
- Detector performance parameter are being investigated.
- RE are taking data during Global Runs and CRAFT to get ready for LHC.

Thanks !!!

- Any Question