RPC project
Upgrade

Anna Colaleo (INFN-Bari)
on behalf of
Bari (Resp.D.Creanza), LNF (Resp.S. Bianco),
Naples (Resp.L. Lista), Pavia (Resp.P. Vitulo)

RPC system in the forward region

The forward region of the RPC project consists of: 4 disks equipped with 3 rings of chambers

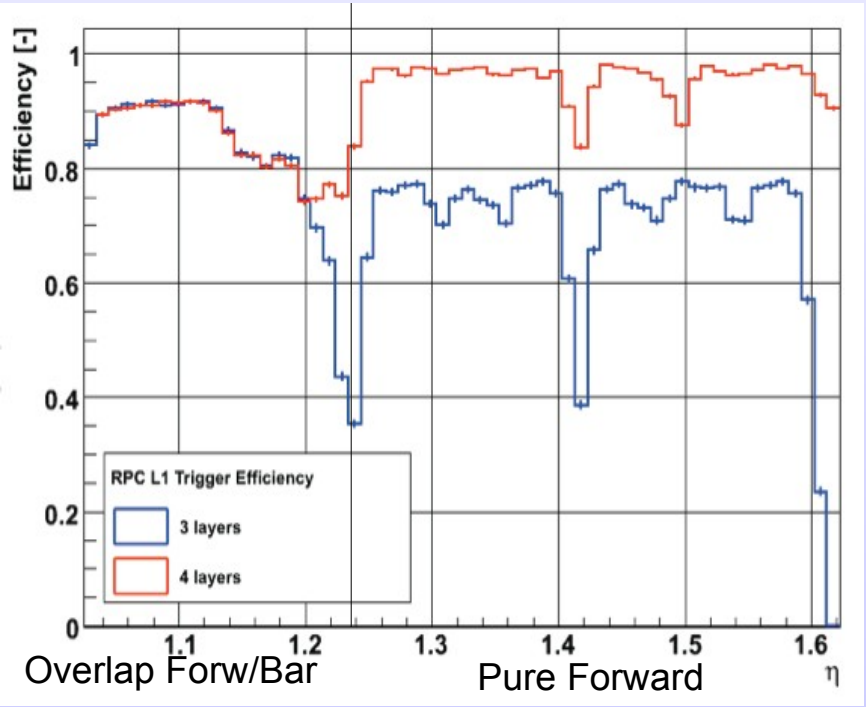
The present system has 3 disks in each endcap equipped with 2 rings of chambers while the barrel trigger is done with 6 layers

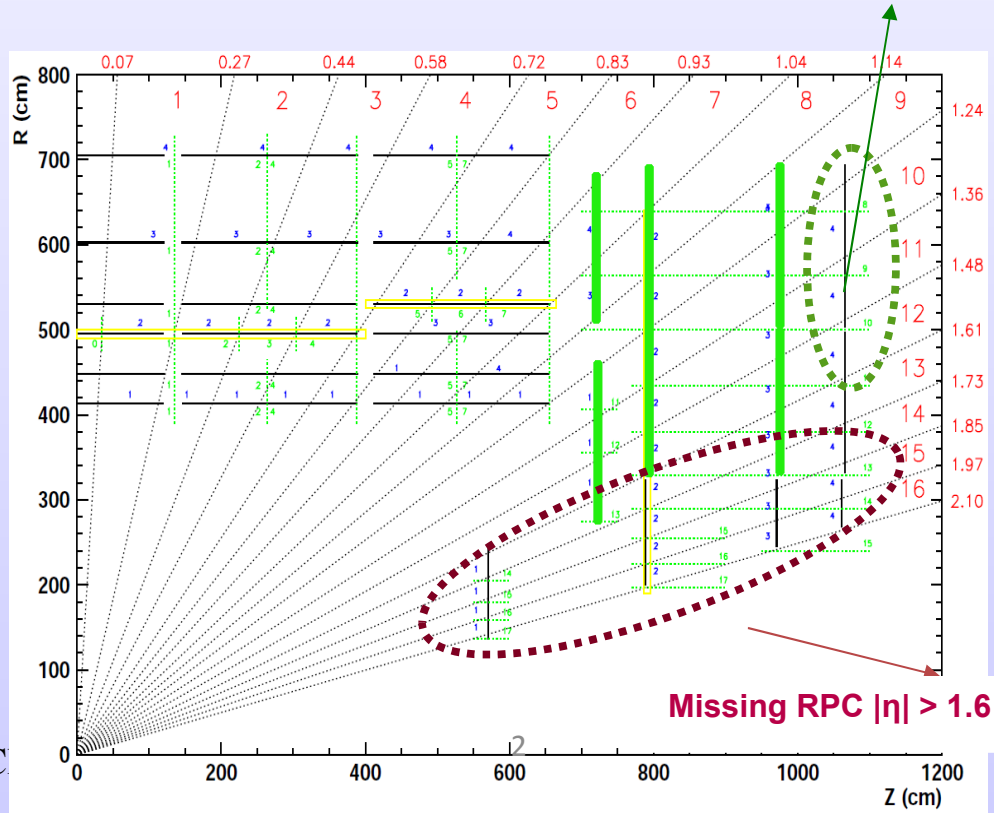
Forward trigger is now descoped :trigger algorithm 3/3 (design is 3 out of 4), |η| < 1.6

Shutdown 2013-2014: 2 rings in disk 4th ==> upscoping

Shutdown 2017-: |η| > 1.6 (R&D on new detectors ongoing)

Missing CSC/RPC 4th layer



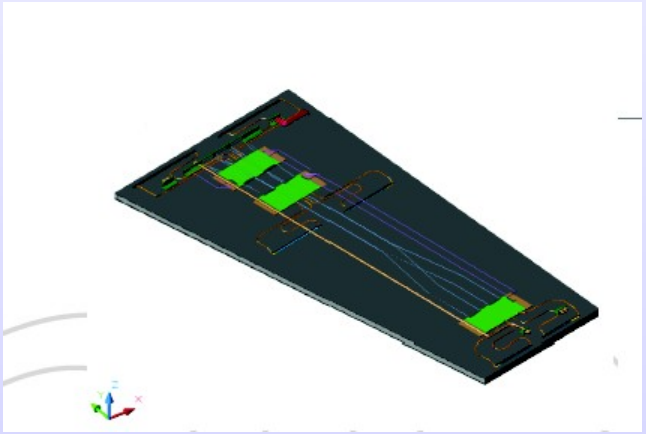


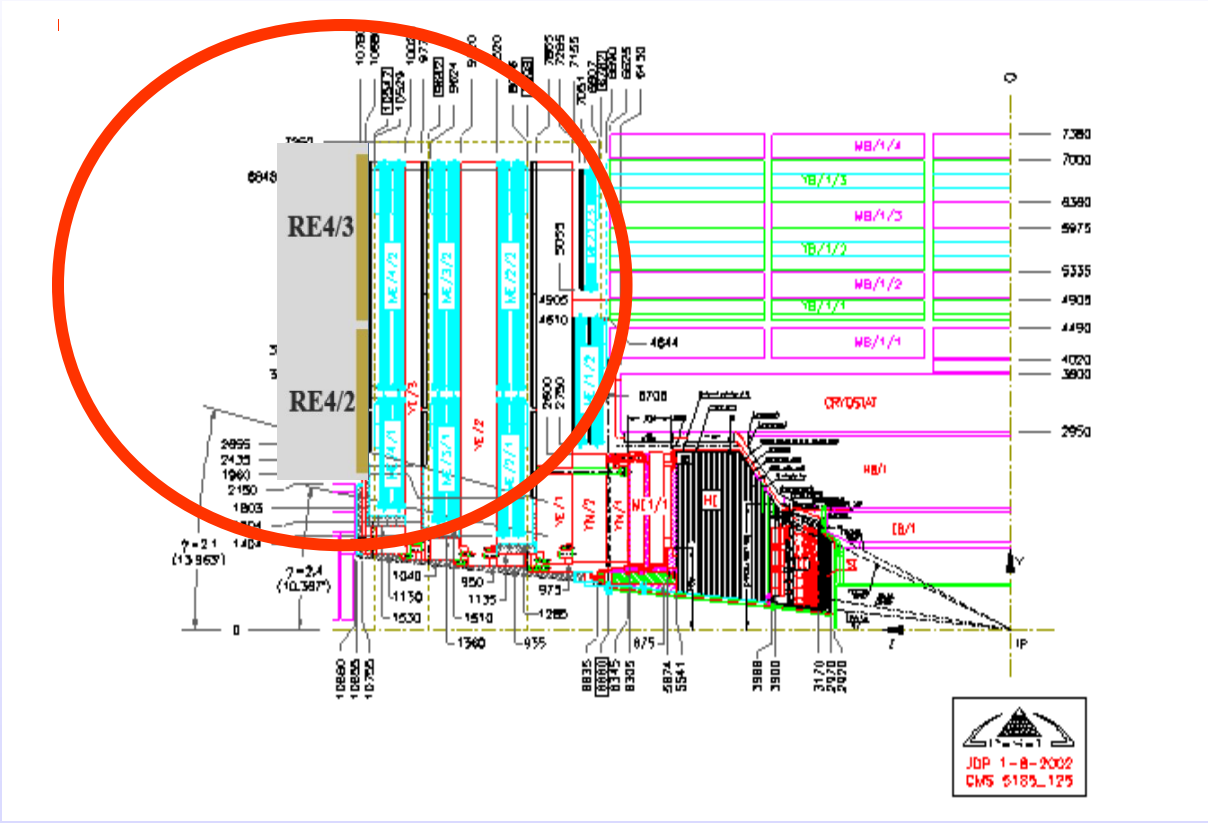
Technical Proposal for upgrade: RPC

Proposal is to construct the 4th layer of RPCs in the endcap in low eta region (shutdown 2013-2014) and infrastructures

The new RE4 chambers will be composed of two concentric rings (RE4/2 and RE4/3) of RPC chambers.

The chambers will have the standard CMS forward design.

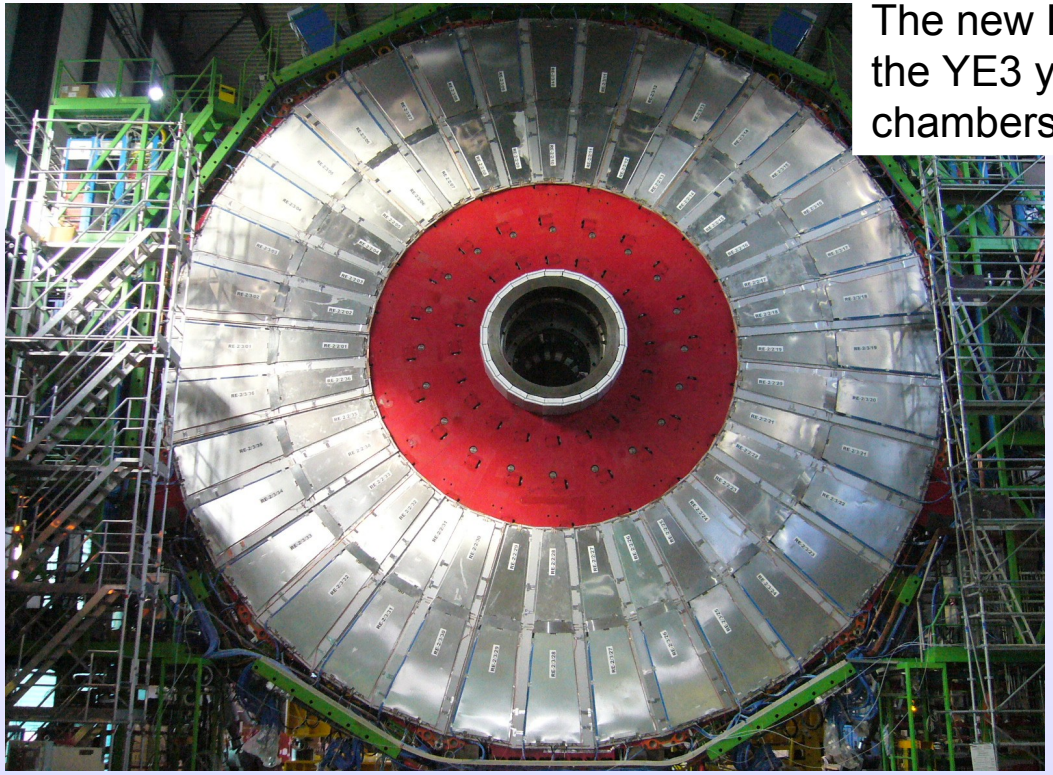




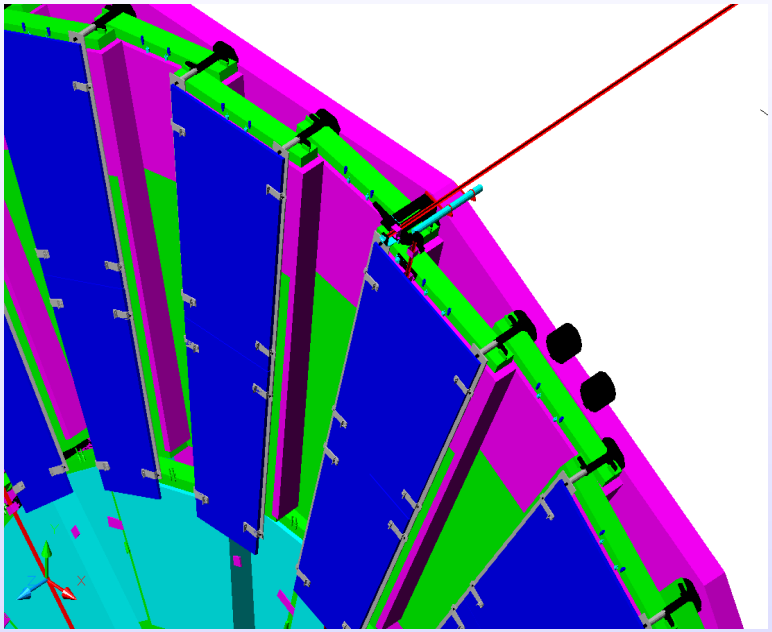
	RE 1/1	RE 1/2	RE 1/3	RE 2/1	RE 2/2	RE 2/3	RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2	RE 4/3
No. of chambers	36*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2	18*2	36*2	36*2

The total number of chambers needed is 144+ spares

Infrastructures



The new RE4 station will be installed on the back of the YE3 yoke, mounted independently of the CSC chambers.



All infrastructure service must be added to YE3:

-Gas and cooling system (racks and manifolds)
-The LV system including cabling to the power supply system.
-The HV cabling to the feet Patch Panel in the YE1 and to USC + power system in USC
-Off detector electronics: the Link Board Boxes with Link boards/control boards and the related cables and optical fibers.
- Temperature and Humidity Sensors

Institutions

The groups from **Pakistan, China, Korea, Belgium, India, and Egypt** have already committed themselves to this completion.

Poland and Colombia have joined the project, although they have not yet committed to any financial contribution.

Recently interest has been expressed from **Iran** and negotiations have started to define possible contributions and areas of involvement.

CERN joined the RPC project

In red the approved

5

INFN

INFN groups has been leading the RPC project since the beginning (Barrel resp.) and gave an important contribution on the commissioning of full system, guaranteeing the success during CMS operation.

We aim to bring our expertize in several part of the Upscope project and also gain further expertize on aspects which are historically not under our responsibility.

- Italian participation in QC/QA during the construction (resistivity meas., QC electronics production, chambers QC) and commissioning phase will be very important

- A further improvement can come with involvement of INFN group in the trigger system:

1) we would like to acquire knowledge on the Link system in order to operate it:

-Design of the board, test and commissioning would be the training and learning phases.
-Involve new people (PhD students) in the link and trigger project

2) we would like acquire expertize on the trigger system in order to participate with a strong group in the design of trigger system for the high eta region.

- Operating experience has proved the importance of temperature and humidity monitoring

1) need to increase the monitoring granularity in all forward system (more sensors)

2) we would like to provide optical sensors with a new technology which we already introduced in CMS for other subsystem.

RPC Project Manager (2011-2012) = P. Paolucci (Naple)
Upgrade Coordinator (2011-2012) = P. Iaselli (Bari)

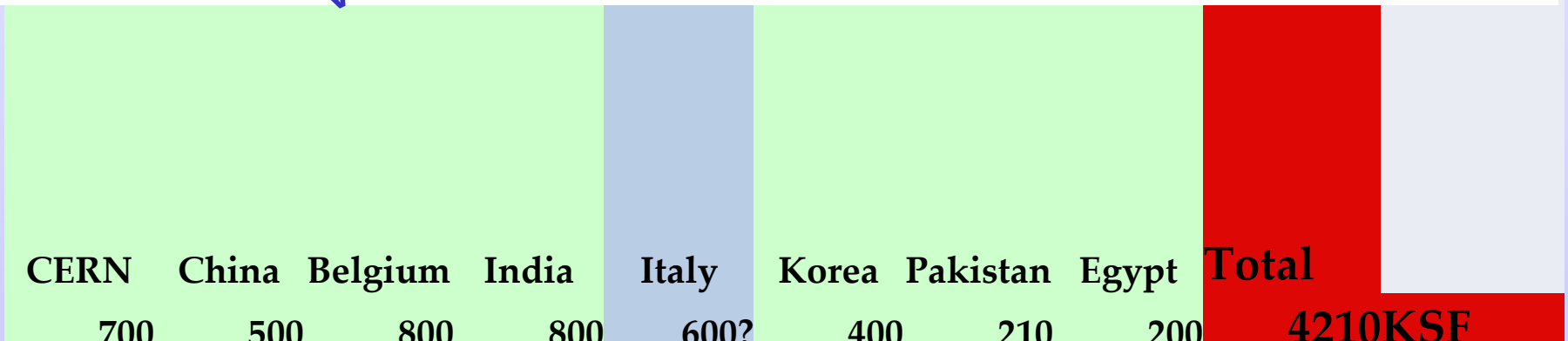
Interests and costs

Technical Proposal 2012-2020

BL=Belgium, CH=CERN, CN=China, IN=India, IT=Italy, KL=Korea, FI=Finland, PK=Pakistan, PL=Poland

Item	BL	CH	CN	IN	IT	KL	FI	PK	PL
HPL production/QA		x			x				
Gap production						x			
Cham. mechanics	x		x						
Chamber assembly	x	x		x					
Front-end production								x	
HV/LV system	x			x					
LB design					x				
LB production & testing					x				x
T/RH sensors		x			x				
Infrastructure		x							

Very preliminary and still under definition



Chamber production and test sites

High Pressure Laminate (HPL):

- Raw material production at the Puricelli industry near Milan
- Quality check and resistivity measurement at **INFN Pavia** and **CERN**

The gas gaps:

180 (144+spares) chambers needed: gaps will be produced by **KODEL** at Korea University. A total of about 660 (432 + spares) gaps are needed

Honeycomb boxes and auxiliary parts will be produced in "**Beijing** Axicomb Technology Co., Ltd" (China)

Readout strips will be produced in "**Beijing** Gaonengkedi GT Co., Ltd" (China)

Gap and chamber test sites:

- **CERN site at 904:** CERN and Pakistan group will provide qualified manpower for the assembly and test (60 **RE4/2-RE4/3**)
- **Belgium site:** The chamber construction will be the main effort of the University of Gent. The manpower to perform the assembly will be provided by both the University of Gent and the Vrije Universiteit Brussel(6**0 RE4/3**)
- **India site:** RPC assembly and testing would be done at two sites: Nuclear Physics Division-Bhabha Atomic Research Centre (NPD-BARC) at Mumbai; and Punjab University at Chandigarh (6**0 RE4/2)**

Production QC and commissioning

- **All people and experts will be involved in the commissioning and integration of the full system.**

Bari and Pavia groups will be involved in the quality control program:

Quality control of bakelite in Pavia and at CERN

- - 1 physicist + 1 technicians (0.3 FTE) – **Pavia**: Vitulo, Torre, Belli (?), Vicini (tec).

Quality control of chamber production at CERN:

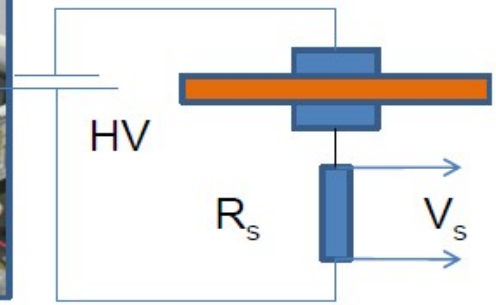
- 1 physicist + 2 technicians (0.3 FTE) **Bari**: Colaleo, Iaselli, Maggi, Pugliese, Lacalamita (tech), Franco (tech)
- 1 physicist + 1 technician (0.3 FTE) **Pavia**: Vitulo, Vicini (tech.)

- **Supervision on FEBs and Distribution boards production**

- - 1 engineer (0.2 FTE) **Bari** : Loddo

Bakelite resistivity measurement and QC

Great experience of Pavia group will be very important in the quality check of Bakelite. Pavia is already checking bakelite pre-production (resistivity values, stability in time..)

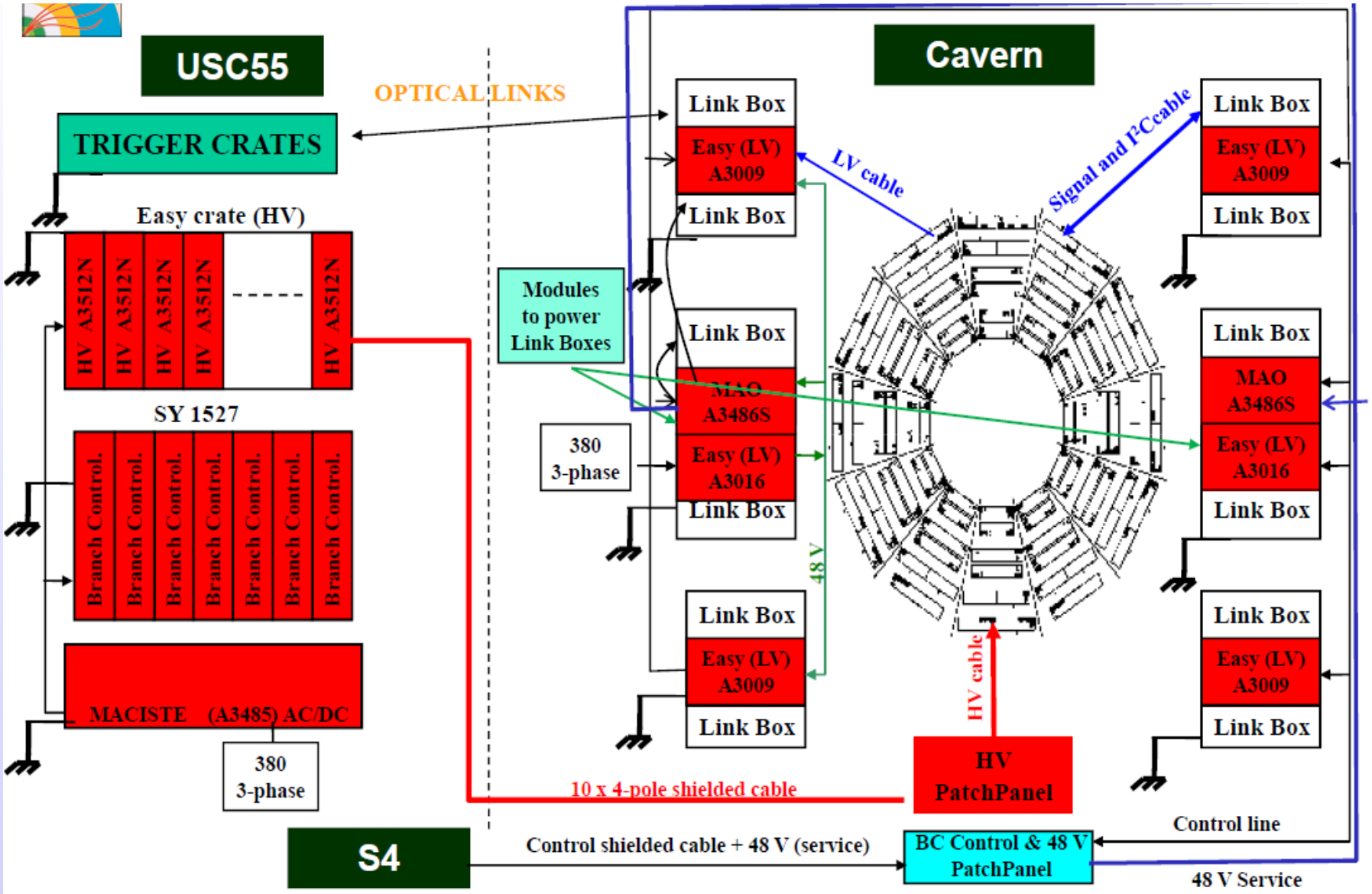


Two instruments used:

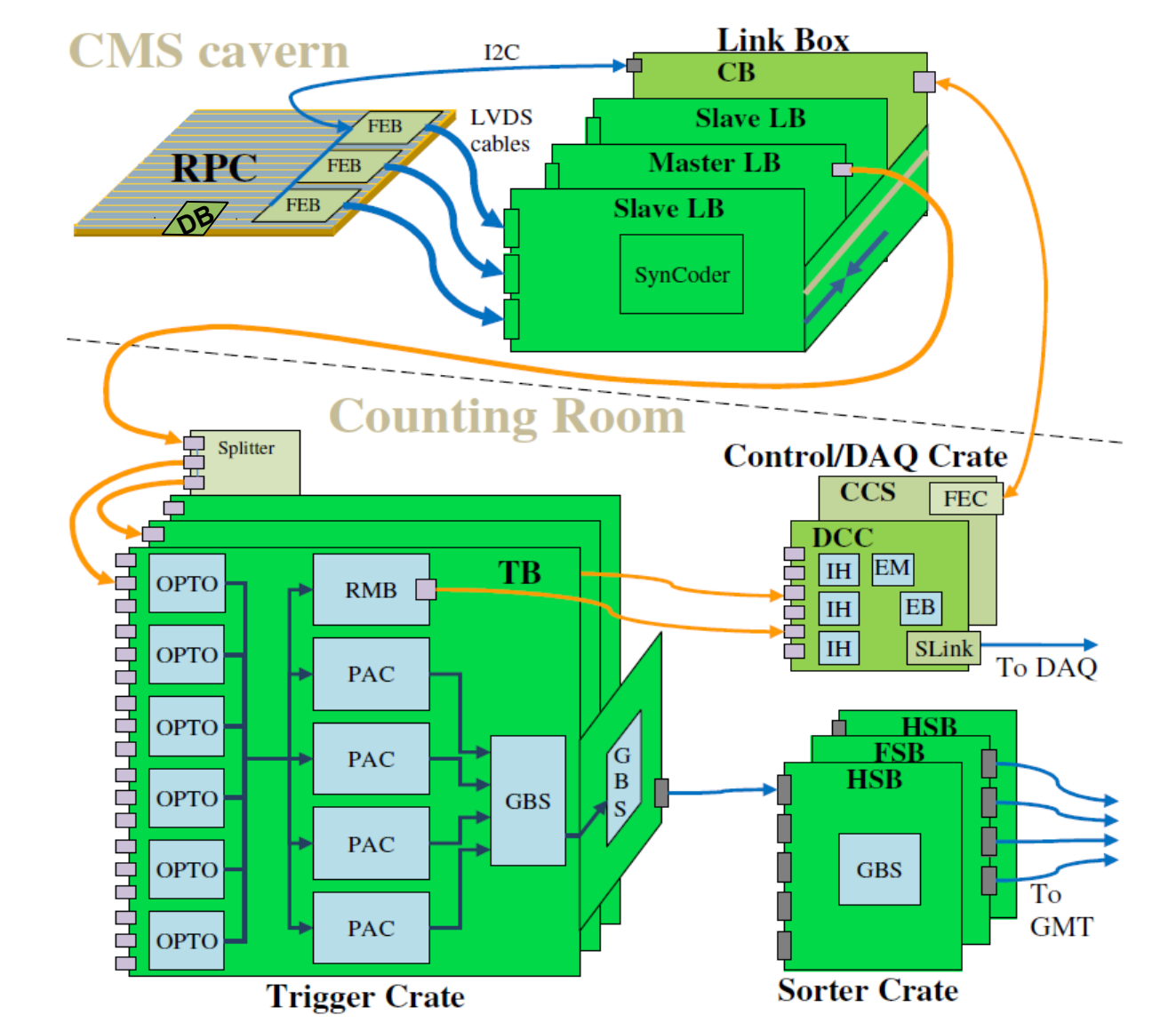
A "Portable" instrument: measurements on 30cmx30 cm (max) samples in INFN lab and Puricelli

A "Fixed " instrument: measurements on an entire panel (9 measurements in 9 different positions across the panel) barrack in INFN Pavia

Electronics: general layout



Electronics: Front-end/Trigger/Readout



More details about the system in **LB_upgrade_costs_and_schema_Febb2011.xlsx**

Electronics

The 144+spares new chambers have to be equipped with FEB, Link board, power systems.

Good opportunity to improve the existing system and built new spares for all system

1) FEB and distribution boards (DB) will be produced under the F. Loddo supervision. Some modifications in distribution board will be implemented.

2) Power system for RE4 will be ordered to the CAEN under the Napoli supervision (India, Belgium budget)

3) Link system:

The CMS electronic/trigger groups have strongly recommended to review to "old" project and to implement all the protections and improvements needed (comes from the experience accumulated in these years).

The main goals are: build an updated and more robust system and involve more groups in the RPC trigger project in order to compensate for the Warsaw dependence and gain experience for the design of trigger system for upgrade at high eta.

New design includes: LV regulators + critical component protections

Back-compatibility:

- **mechanical, electrical and firmware compatibility with the present system.**
- **has to work in both new and old (protected) link box**
- **possibility to have both protected and not protected boards in the same box**

Link system

Warsaw is the group with the expertise in the link board/trigger hardware/firmware and software.

It will ensure the transfer of knowledge and will be responsible for the software integration in the trigger system

- **Naples is designing the board**

  -P. Paolucci, S. Buontempo, N. Cavallo (sabbatical year in the 2011)
  -Electronic Service: 8-7 months in the 2010 and 2011
  - First design ready. Cooling test done (see slides LBupgradeStatus.pdf)

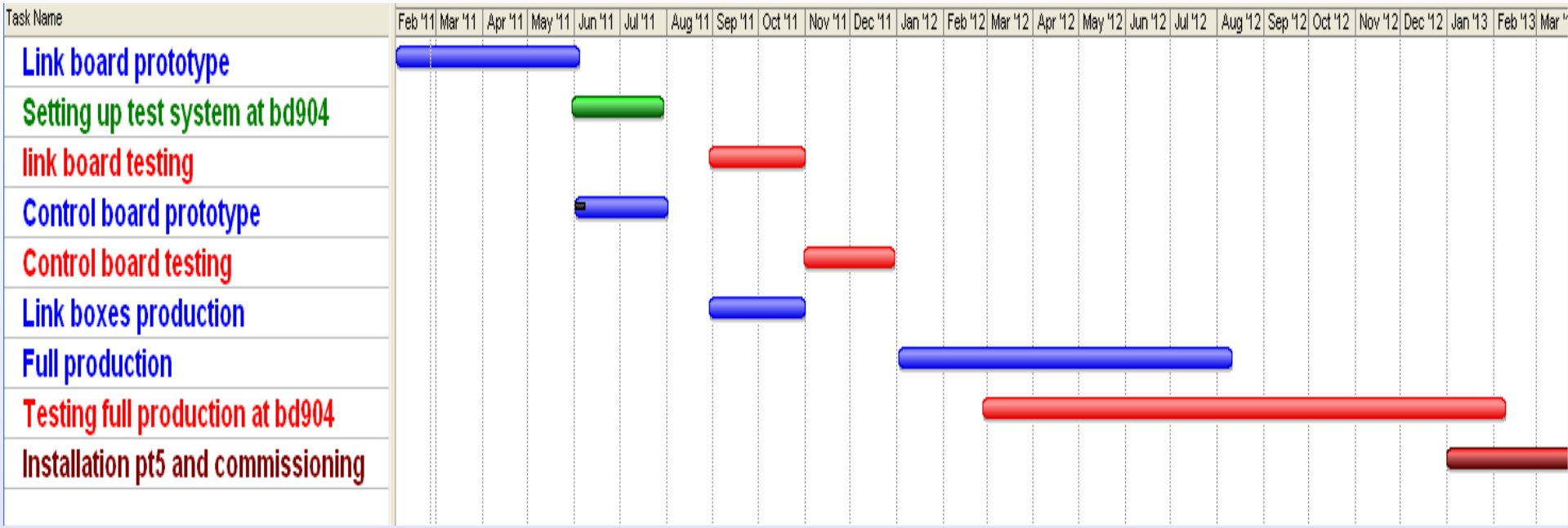
- **Board production in Italy**

  Preproduction 2011, full production 2012

- **Complete test setup at CERN (bd 904):** Warsaw and Italian responsibility
  LNF, Naple and Bari will be involved in test and commissioning
  - Frascati: L.Passamonti (Tech.), D.Pierluigi (Tech.)
  - Naples: Vanzanella, Passaggio, Roscilli
  - Bari: F. Loddo supervision

- **Installation under Italian/Warsaw responsibility**

Preliminary schedule for link project



- Prototypes test and test setup at CERN: 1 tech + 0.5 FTE engineer* (2011) + Warsaw
- Test at CERN (blg 904): 1 tech + 0.5 FTE engineer* (2012) + Warsaw
- Installation 2013: 2 tech + 0.3 FTE engenier* (2013) + Warsaw
- Commissioning 2013: 1 phys for 6 months (2013) + Warsaw

*Need Engenier (PhD student/Post-doc) to work at bd904 and during commissioning phase with Warsaw experts, under F. Loddo supervision

Costs breakdown for link system

	upgrade needed	upgrade spare	barrel & endcap Spare (~2%)	PCB + mount + test	components	total cost	Total
Crates	12	2	2	€0.0	€100.0	€100.0	€1,600.0
ControlBoard	24	4	4	€430.0	€362.0	€792.0	€25,344.0
Link Board Master	48	5	10	€200.0	€550.0	€750.0	€47,250.0
Link Board Slave	96	10	15	€200.0	€400.0	€600.0	€72,600.0
BackPlane	12	2	2	€337.0	€395.0	€732.0	€11,712.0
Frontplane	24	4	10	€99.0	€75.0	€174.0	€6,612.0
Mod APA450	24	4	2	€146.0	€385.0	€531.0	€15,930.0
Frontalini	24	4	0	€37.5	€30.0	€67.5	€1,890.0
							€182,938.0

Link Board Power system + test station + integration in Pt5

	needed	spare	total cost	Total
Schede LV A3016	8	2	€6,000.0	€60,000.0
Test station Bd904	1		€15,000.0	15000
Integrazione PT5				30000
				€105,000.0

TOTALE LINK SYSTEM	€287,938.0	CHF 374,319.40

see details in LB_upgrade_costs_and_schema_Febb2011.xlsx

Temperature and Humidity sensors

Sensors for T and H monitoring in endcap stations (LNF, Napoli and CERN).

Each endcap chamber, RE4 but also RE2, RE3 (each existing ring now is equipped with only 6 sensors) will be equipped with one FBG sensor for T measurement: radiation hard, insensitive to magnetic field, precise, no electrical noise, ease to install, minimal cabling. And costs are similar to the conventional sensor.

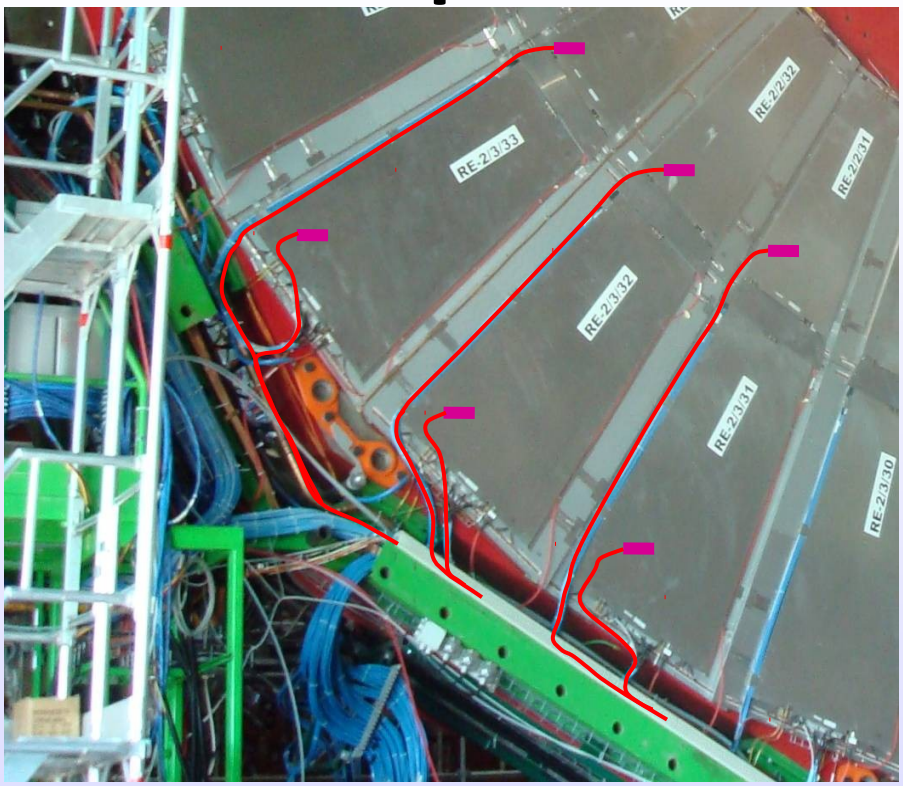
Humidity monitoring will be performed via conventional electronic sensors (4/disk).

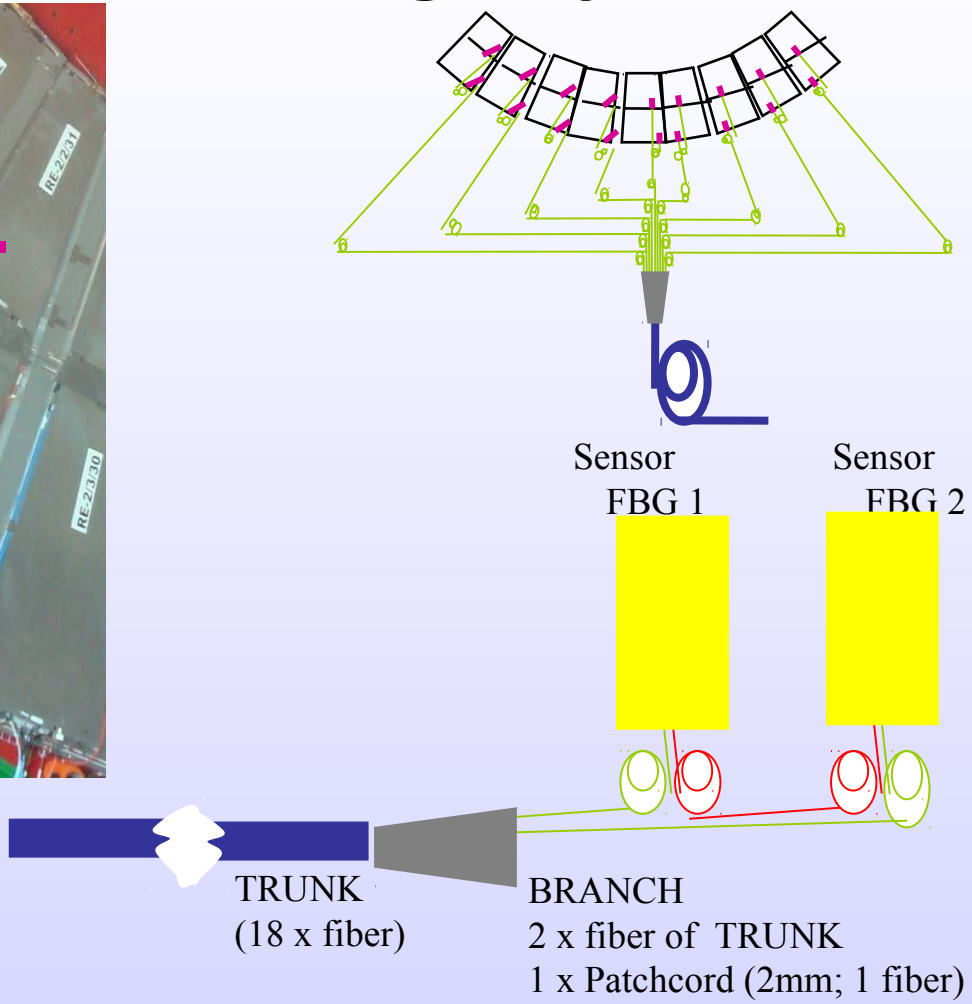
Expertise on FBG sensors in HEP detectors (FINUDA, BTEV, CMS) and industrial applic.:S.Bianco (Frascati), M.Caponero (Frascati and ENEA), S.Colafranceschi (Frascati PhD), G.Breglio (Napoli), S.Buontempo (Napoli), L.Passamonti (Frascati tech), D.Pierluigi (Frascati tech), M. Giordano (Napoli), A. Cusano (Benevento), A. Cutolo (Benevento), A. Saccomanno (Napoli PhD), A. Irace (Napoli).

Explore possibility of using optical sensors for gas contaminants (PRIN funded) F.Felli (Frascati and Roma1), M.Parvis(Frascati and Polito), G.Saviano(Frascati and Roma1)

see more about sensors in slides Sensors4upscopeRev11.ppt

Temperature monitoring: layout





Temperature sensor: optical sensor based on FBG technique
1 sensor per chamber ; 72 sensors per RPC Disk (now 6 sensors/disk)
Cabling will follow existing cable routing

T sensors: layout ans plans

•Tree-like Array cabling: array constructed at Optical Box allows:

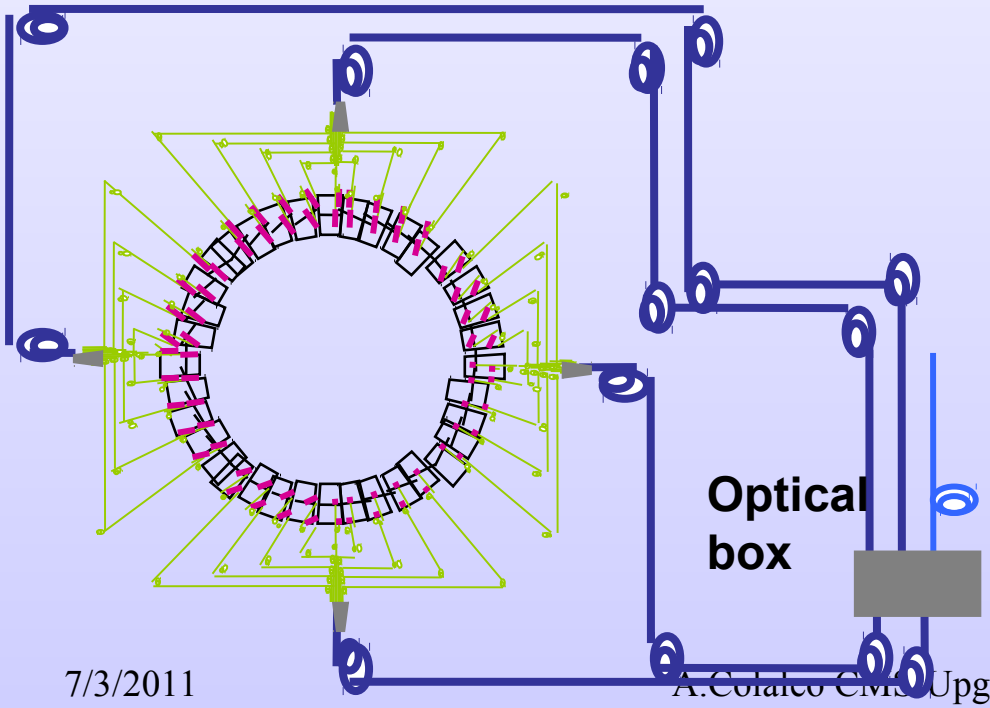
- by-pass of faulty sensors
- following of existing cable routing on RPC wheel

Optical Box in USC: in-serie connection of all sensor of one disk. Placed in UCS in order to have unrestricted access to allow reconfiguration of array

4 x Tree-like Array per RPC Wheel:

•Distribution of Trunk cables in FAR and NEAR cabling chains (already fully packed)

See more about layout in SensingT_CMS_Proposal_rev4.ppt



•Plans of production and installation:

1) Acceptance test of sensors in LNF, packaging and transport to CERN

2) Installation on the chambers
2.a) on new chambers RE4 during production phase
2.b) on RE2/RE3 during shutdown: installation and commissioning

3) routing optical fiber in USX, and from USX to USC

T sensors: tasks and time-line

Sensors certification and packaging (Frascati resp.) at LNF clean room and lab, (possibility of parallelization using labs at Enea, Roma1, UniNa, Unibenevento): S.Bianco (Frascati), M.Caponero (Frascati and Enea), G.Breglio (Napoli), L.Passamonti (Tech. Frascati), A.Russo (Tech. Frascati), Tech. Enea.

• I**nstallation at CERN (Napoli resp.)** S.Buontempo (Napoli), S.Colafranceschi (Frascati phd), M.Caponero (Frascati and Enea), G.Cusano (Napoli), Tech. Frascati, Tech. Napoli

weeks

TASK	SUBTASK	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	Ppower
Sensors Certification and packaging at Frascati																			
	acceptnc test	x	x	x															1
	packaging		x	x	x	x	x												2
	splice		x	x	x	x	x												1
	QA test			x	x	x	x	x											2
Shipment to Cern					x	x	x	x	x										
QA after shipment						x	x	x	x	x									1
Installation of sensors on RE4 chmbrs																			
	Installation						x	x											2
	QA test							x	x										2
Installation of sensors on RE2,3 chmbrs																			
	Installation						x	x	x	x	x	x	x	x					2
	QA test							x	x	x	x	x	x	x	x				2
Cabling																			
	Cabling USX-USC	x	x	x	x														2
	Cabling on Disks							x	x	x	x	x	x	x	x	x			2
	Splicing muffola											x	x	x	x	x			Ext. Firm

Costs breakdown for sensors

Costr. App.	costo/unitario (keuro)	Numero/disk	costo/disk (INFN) keuro	costo CERN
Sistema Interrogazione @ USC	30	1		30
Switch ottico	15	1		15
Sistema interrograzione @Frascat	0	1	0	0
Sensori FBG	0.12	75	9	
Cavo FO 75conduttori	0.4	1	0.4	
Muffola distribuzione	0.4	1	0.4	
Scatola di housing/piastrina	0.03	75	2.25	
Rack	0.4	1	0.4	
TOTALE/disk			12.45	
			INFN	CERN
TOTAL ALL DISKS		disks 6	€ 74,700.00	97,110.00 CHF 45,000.00 EUR

Instrumentation already available at LNF lab and CERN

strumento interrogazione …… 18,0 k€
attuatore piezoelettrico…… 5,0 k€
celle peltier…….. 4,0 k€
Giuntatrice…… 12,0 k€

Total cost completely driven by sensor cost. We will profit from already existing instrumentation in lab

TOTAL= 97000 CHF
Possible solution to reduce INFN budget:
33% Upscope (RE4 only) = (24.7 k€) 32000 CHF
Existing system = (50k€) 65000 CHF M&OB

Costs breakdown full RPC project

Link system
Total = 288k€ ~374500 CHF

Sensors
Total= ~75k€ ~97000 CHF

Assuming 1€ = 1.3 CHF

Total = 363 k€ → 472 kCHF
- 50 k€ (66% of sensor cost moved on MOFB)
= 313 k€ → 406 kCHF
+ 10% (10% contingency)
= 345 k€ → 448 kCHF

Total request to INFN including 10% contingency = 450kCHF
-having moved 65kCHF = 66% of sensors costs to MOFB

Original request was 600 kCHF

Do not include FTE cost and transport

Cost time profile

Task	Cost (k€)	2011	(k€)	2012	(k€)	2013	(k€)
Link board		Crate Test System Pre-production	2 15 21	Production	160	Integration Power	30 60
Link cost	288		38		160		90
Sensors	25	Production	25		0		0
Total cost (link.+sens.)	313		63		160		90
+10%	**345**		**70**		**176**		**99**

66% costs of sensors (-65kCHF => 50 k€) must be shared between RPC institution contribution to M&OB (INFN ~36%, see next slide) over 3 years (2011-2012-2013) = ~18kEuro (over 3 years) from INFN (discussion ongoing inside RPC IB)

M&O B contribution in 2011

M&O 2010	# ESP	Amount KCHF
Peking univ	**2**	6.7
SKK Univ (Korea)	**2**	6.7
Korea Univ (Korea)	**10**	33.6
Chonnam (Korea)	**0**	0.0
Mumbai-Barc (India)	**1**	3.4
Chandigarh (India)	**3**	10.1
Ghent (Belgium)	**9**	30.2
Brussel Univ (Blgium)	**1**	3.4
Uniandes	2	6.7
Pakistan	6	20.2
Asrt-Enhep (Egypt)	3	10.1
Bari	**12**	40.3
LNF	**5**	16.8
Napoli	**9**	30.2
Pavia	**3**	10.1

From 2011 also
CERN group to be included

INFN represent ~ 36% = ~100 kCHF

268.8 / 1.5 = 179.2 Keuro

Conclusions

-Bakelite test – Pavia

-Chamber commissioning – Bari, Pavia

-Electronic production supervision and commissioning – Bari/LNF/Napoli

-T/H sensors – LNF/Napoli

In order to reduce our request to INFN we moved 66% sensor cost on MOFB, and some electronics on Pakistan budget.

Total request to INFN ~ 345 k€ (~ 450kCHF) (including 10% contingency)

We also envisage to involve new people, who has to work at CERN with Warsaw experts in order to be able to form a group that can take part to the design of trigger system for the high eta region project.