India in CMS

CERN/LHCC 93-48
15 October 1993

Status Report and Milestones
by the
CMS Collaboration

Abstract

We present a status report on the overall design of the detector and a new cost estimate. Milestones defined by the LHCC are discussed. The status of the magnet design is reviewed. A mechanical design of the tracker is presented. The average amount of material is about 0.2 X_0 over the rapidity acceptance of the tracking ($|\eta| < 2.5$). Progress in the study of MSGC detectors suitable for CMS is reported. The baseline choice for the ECAL is the shashlik lead/scintillator calorimeter. Projective towers with a preshower in front have been tested in a beam. Several designs of the mechanical support structure for a barrel of shashlik towers with pointing geometry are presented. Radiation hard scintillators and shifting fibres have been selected, which guarantee an induced constant term due to radiation damage of less than 0.7% up to rapidities of 2 for 10 years of operation at high luminosity. A crystal option for the ECAL using lead tungstenate crystals ($PbWO_4$) is considered. Cheap heavy glasses are also considered. Progress has been made in the construction of prototypes and the overall mechanical design of the HCAL and VFCAL calorimeters. The status of the R&D on muon detectors in RD5 is reviewed. The baseline muon detector for CMS consists of DTBX chambers in the central region and of CSCs in the forward region. A detailed description of the muon alignment system is given. The installation time after completion of the experimental area is estimated to be 15 months. Installation at point 1 is the preferred solution. Installation at point 6 is possible if enough time is left for the installation before the start of LHC. The baseline detector costs 407 MCHF. The staged detector costs 339 MCHF and can be funded over a period of 8 years by the present collaboration.

DRAFT
October 31, 1994

Indian Participation in CMS Experiment [1]

Title of the Research Programme:
Search for new particles in Large Hadron Collider at CERN, Geneva

Collaborating Institutions:
[1] Institute of Physics, Bhubaneswar
[2] Tata Institute of Fundamental Research, Bombay
[3] Panjab University, Chandigarh
[4] University of Delhi, Delhi

Names of physicists from Bhubaneswar :

Names of physicists from Bombay :
(a)**EHEP Group**: T.Aziz, S.Banerjee, S.N.Ganguli, S.K.Gupta, A.Gurtu, K.Mazumdar, R.Raghavan, K.Sudhakar, S.C.Tonwar
(b)**HECR Group**: B.S.Acharya, Sudeshna Banerjee, S.R.Dugad, M.R.Krishnaswamy, V.S.Narasimham N.K.Mondal

Names of physicists from Chandigarh :

Names of physicists from Delhi :

Collaborating Institutions outside India:
CMS Collaboration involving 119 laboratories

[1]This is now working DRAFT #2.0. Members are requested to go through it and make addition/deletion etc.etc. Send to S.N.Ganguli or A.Gurtu. Email : ganguli@tifrvax.tifr.res.in, gurtu@tifrvax.tifr.res.in

A. GURTU

CMS HCAL MEETING

3 - DEC - 1995

HCAL BEAM TEST AUG. 95 - EFFECT OF Cu SPACER

- Data Analysis & Simulation

S. Banerjee, A. Gurtu, T. Moulik, R. Raghavan, K. Sudhakar

EHEP, TIFR, BOMBAY

TEST CARRIED OUT TO DETERMINE THE EFFECT OF COPPER SPACER ON THE

- REDUCTION IN $E_{DEPOSIT}$
- DETERIORATION IN ENERGY RESOLUTION

DETECTOR CONFIGURATION

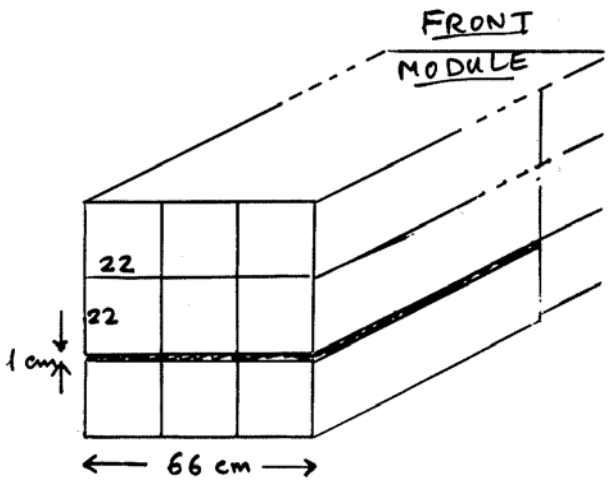
HCAL:

2 MODULES:
FRONT, BACK

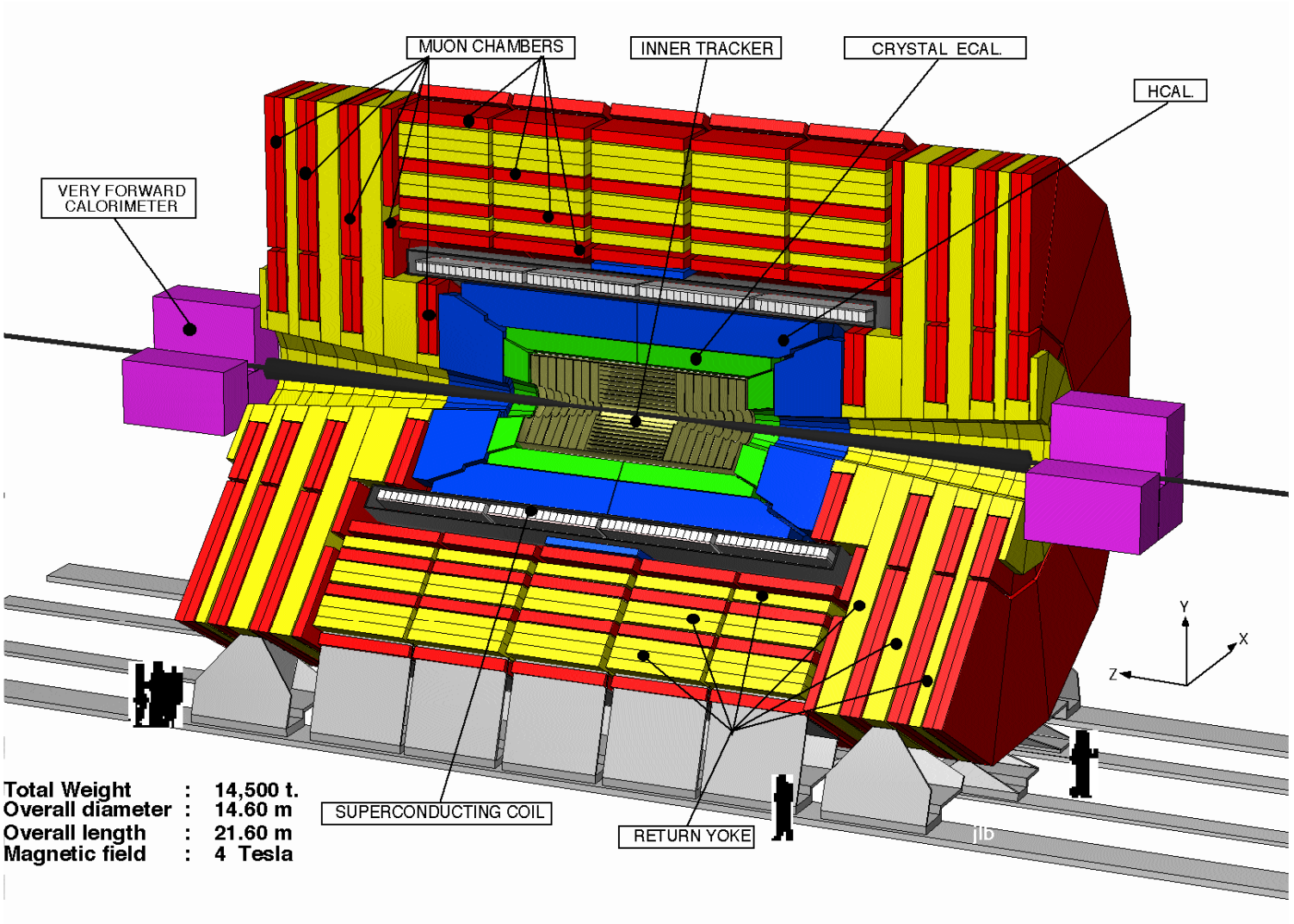
9 X 2 RDMS
TOWERS

ECAL:

IN FRONT OF
HCAL



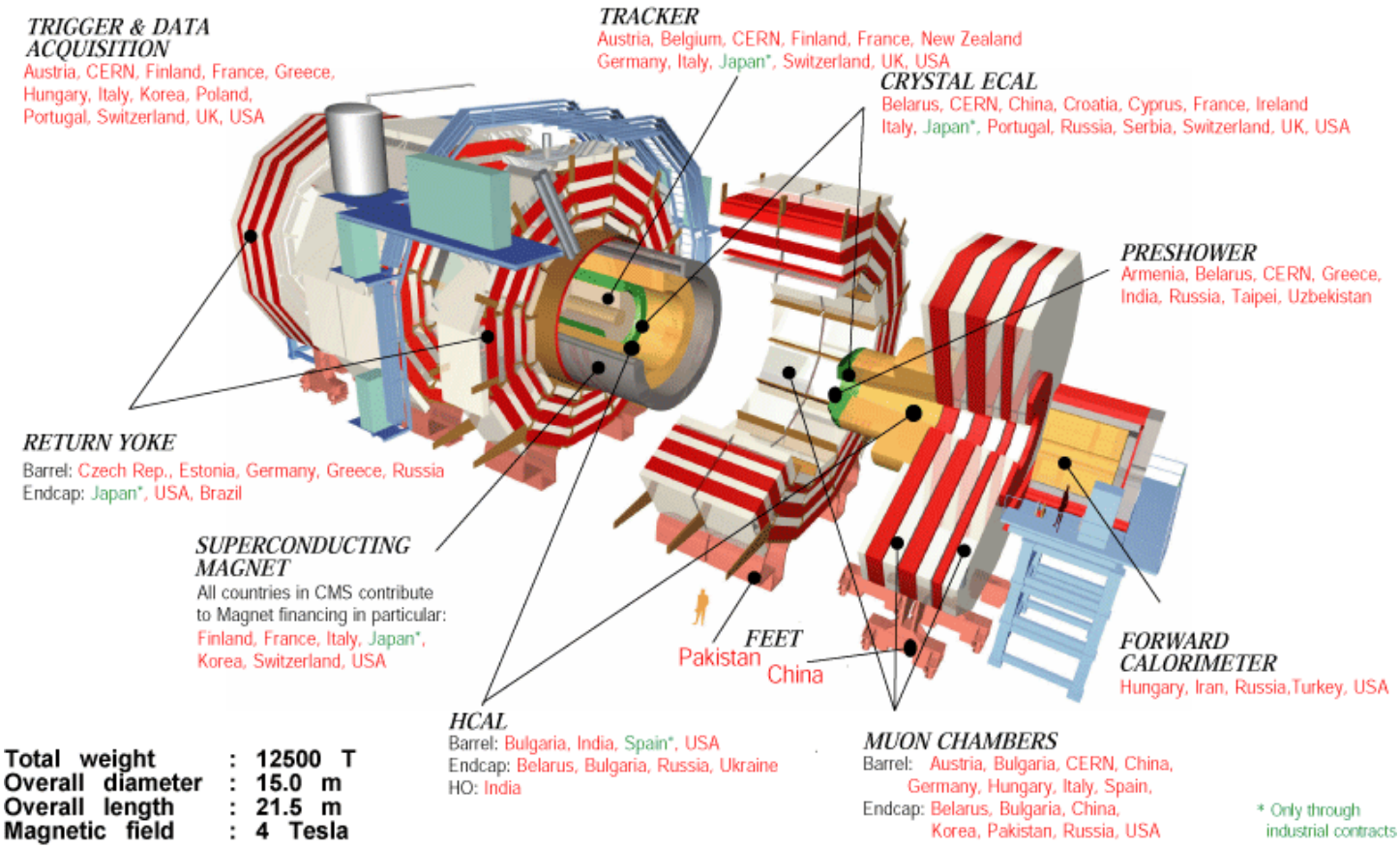
A Compact Solenoidal Detector for LHC



A. Gurtu: "India in CMS", TIFR, Mumbai, 23 October 2009

CMS Collaboration

36 Nations, 160 Institutions, 2008 Scientists and Engineers (November 2003)



Total weight	**:**	**12500 T**
Overall diameter	**:**	**15.0 m**
Overall length	**:**	**21.5 m**
Magnetic field	**:**	**4 Tesla**

October 2009: 182 Institutions with about 3110 scientists and engineers. ~ 2000 Signing Authors (incl. students)

A. Gurtu: "India in CMS", TIFR, Mumbai, 23 October 2009

India-CMS Collaboration

- **Panjab U, Delhi U, BARC, TIFR (2 groups), Visva-Bharati U**
- **Hardware responsibilities:**

- Outer hadron calorimeter.

Physics necessity: ensure more hermetic detector to look for missing energy signals of LSP/ other new physics.

- Silicon Pre-shower Detector.

Physics necessity: discriminate between γ/π^0 to detect the Higgs → $\gamma\gamma$ decay mode (for low mass Higgs favored by existing data)

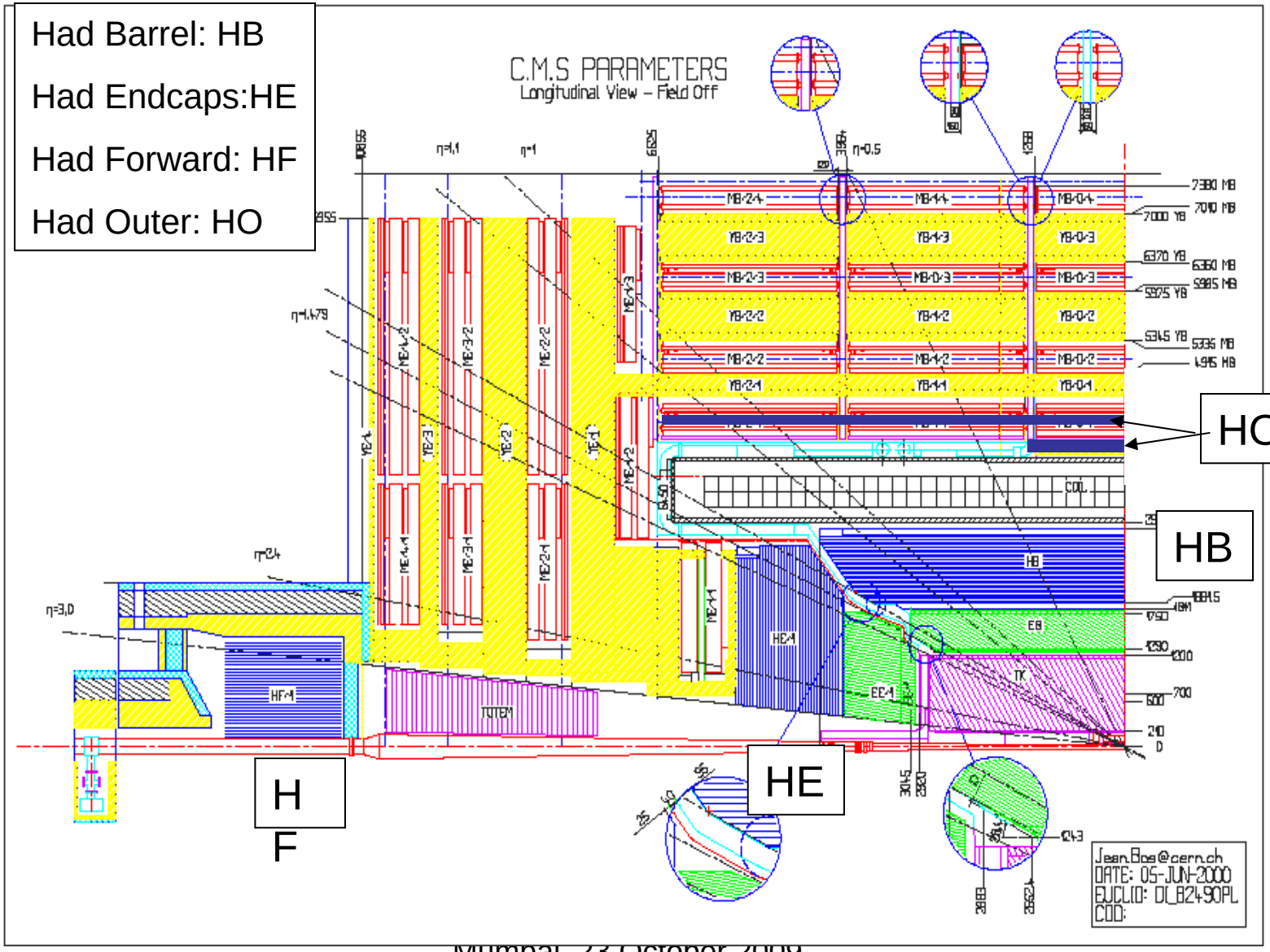
Hadron Calorimeter: HCAL

Had Barrel: HB

Had Endcaps:HE

Had Forward: HF

Had Outer: HO



HO basic design

- Detector element is a plastic scintillator tile which produces light when charged particles pass through it
- This light is collected by embedded WLS fibers (4 sigma grooves/tile)
- Light is transported to HPD detector via clear optical fibers spliced to WLS fibers
- Size and placement of the tiles is matched to geometric towers in the CMS calorimeters
- Tiles are grouped together and packed in “trays” for ease of handling, and 6 trays in each phi sector are in turn inserted inside aluminum honeycomb housings.

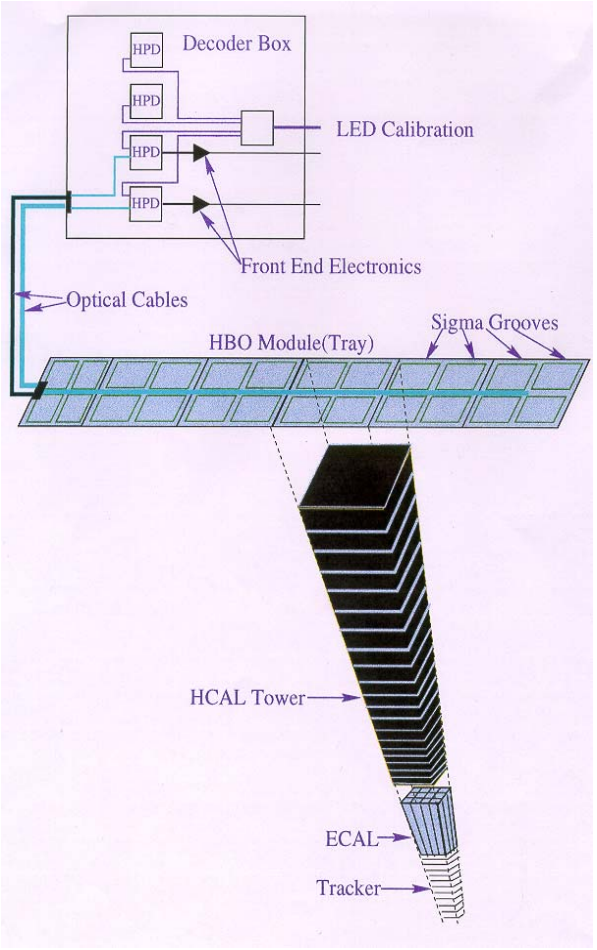
Design Consideration

• **Basic Detector Elements should map the barrel hadron Calorimeter (HB) towers of granularity 0.087 X 0.087 in η and ϕ.**

• **Should be able to see MIPS.**

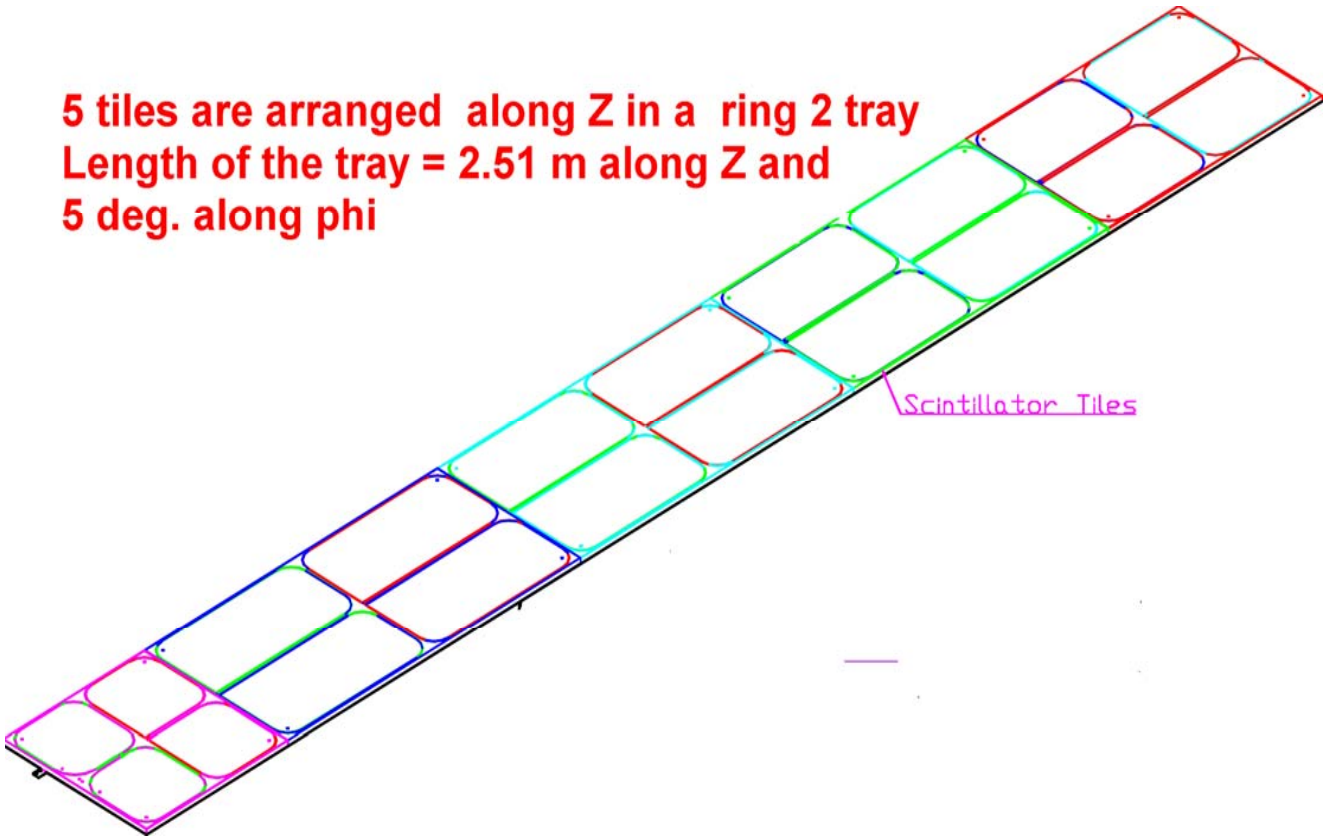
10 mm thick Bicron BC408 scintillator to be used as the active element.

Use 0.94 mm dia WLS Kuraray double clad fibers (in σ shapped grooves), spliced to clear fibers to carry light to HPDs located on the outer edge of the muon system.

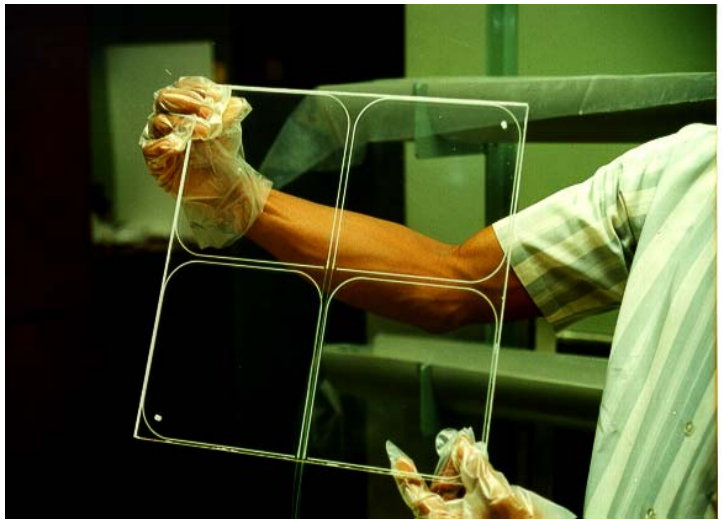


HO Tray Design

- All the tiles in the same ϕ slice of a ring will be packed as a single mechanical unit called the “tray”.
- It will cover the entire length of a muon ring along Z.
- Along Φ, it will only be one tile wide (5^0)



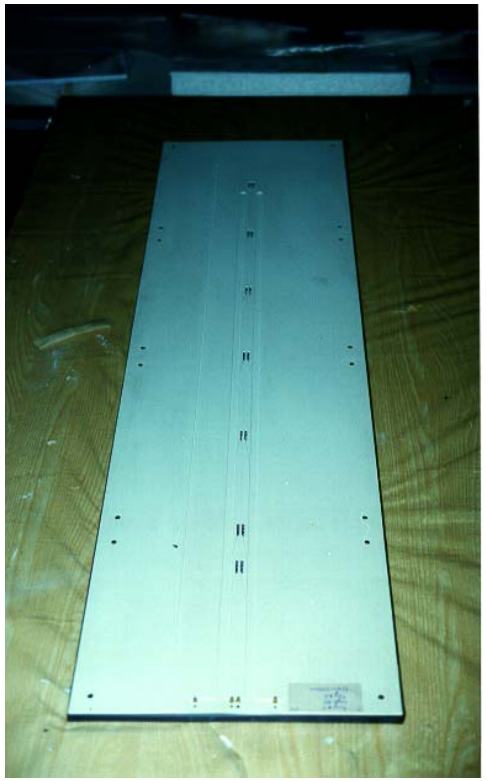
Tile, Tray (one of 432 trays)



⇑

PPP tile with 4 σ grooves visible

⇐ **Pigtail with connector**



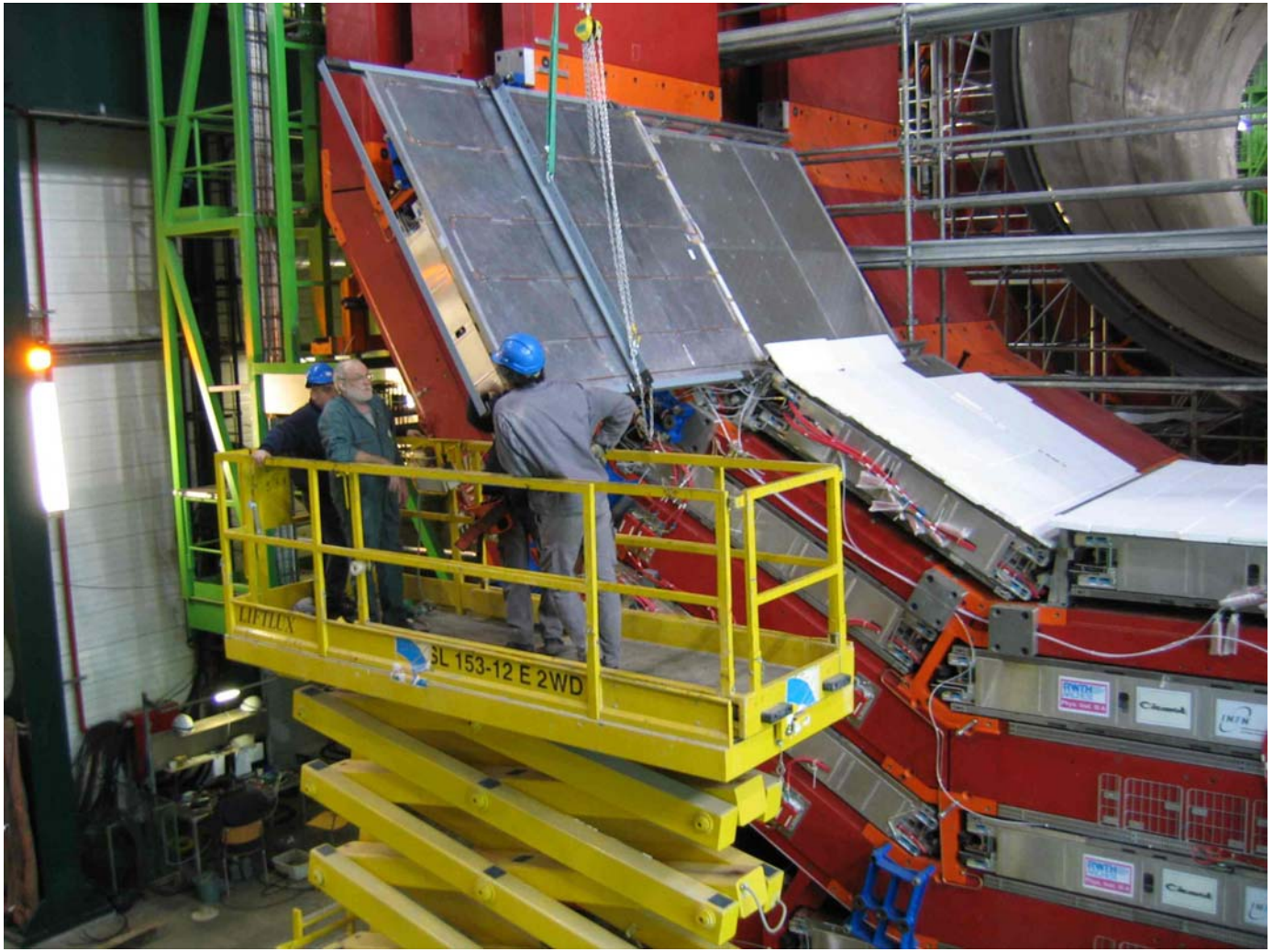
Finished Tray

⇐

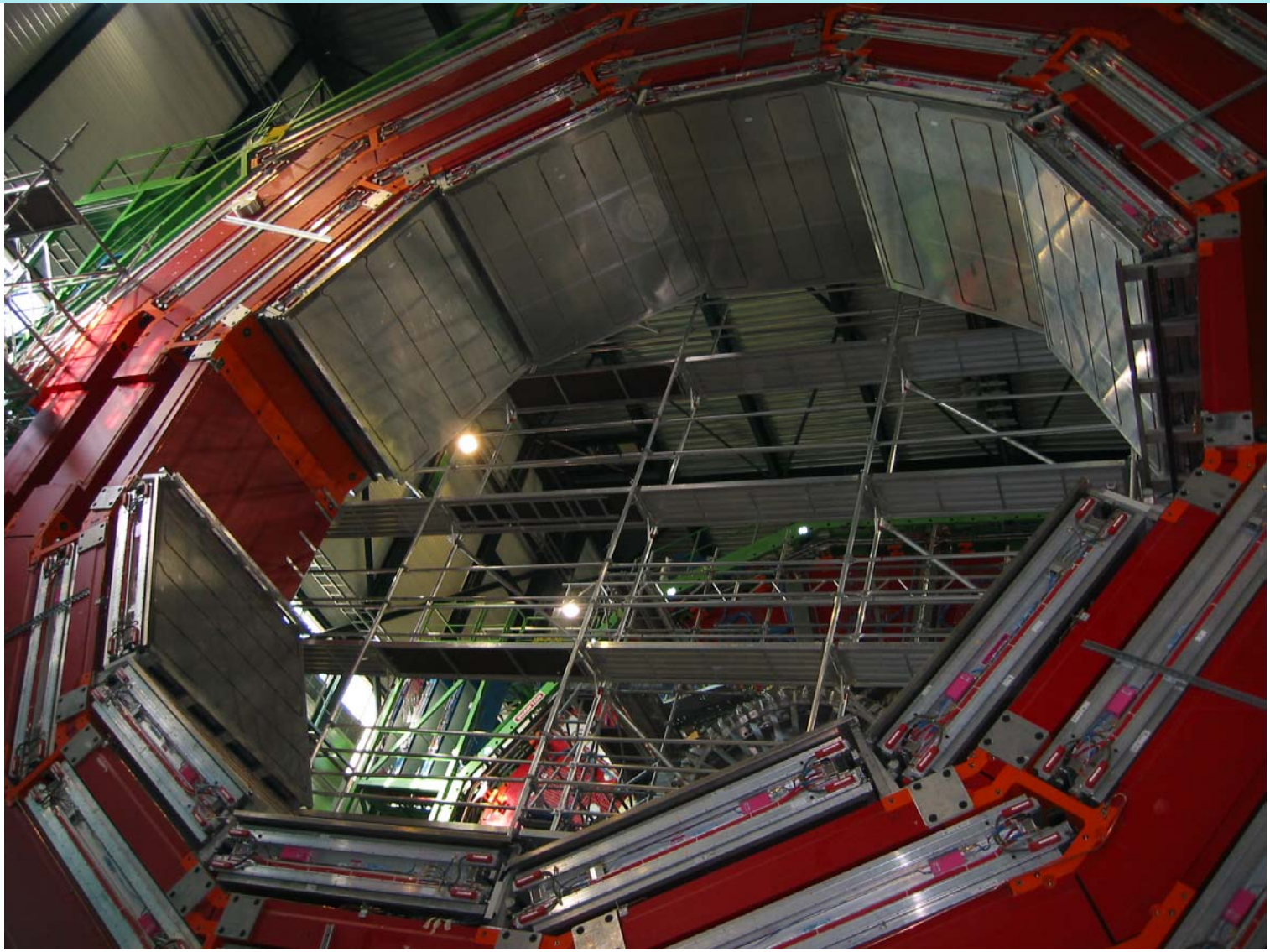
HO hardware status

- **Fabrication of detectors done at TIFR and Panjab University.**
- **Housings assembled in Mumbai industry; Honeycomb panels from Bangalore.**
- **By April 2004 all 432 trays & 72 housings for HO detectors had been sent to CERN.**
- **2005-07: installation and cabling carried out (testing of read-out boxes, cable routing, cable lengths, cable fabrication).**

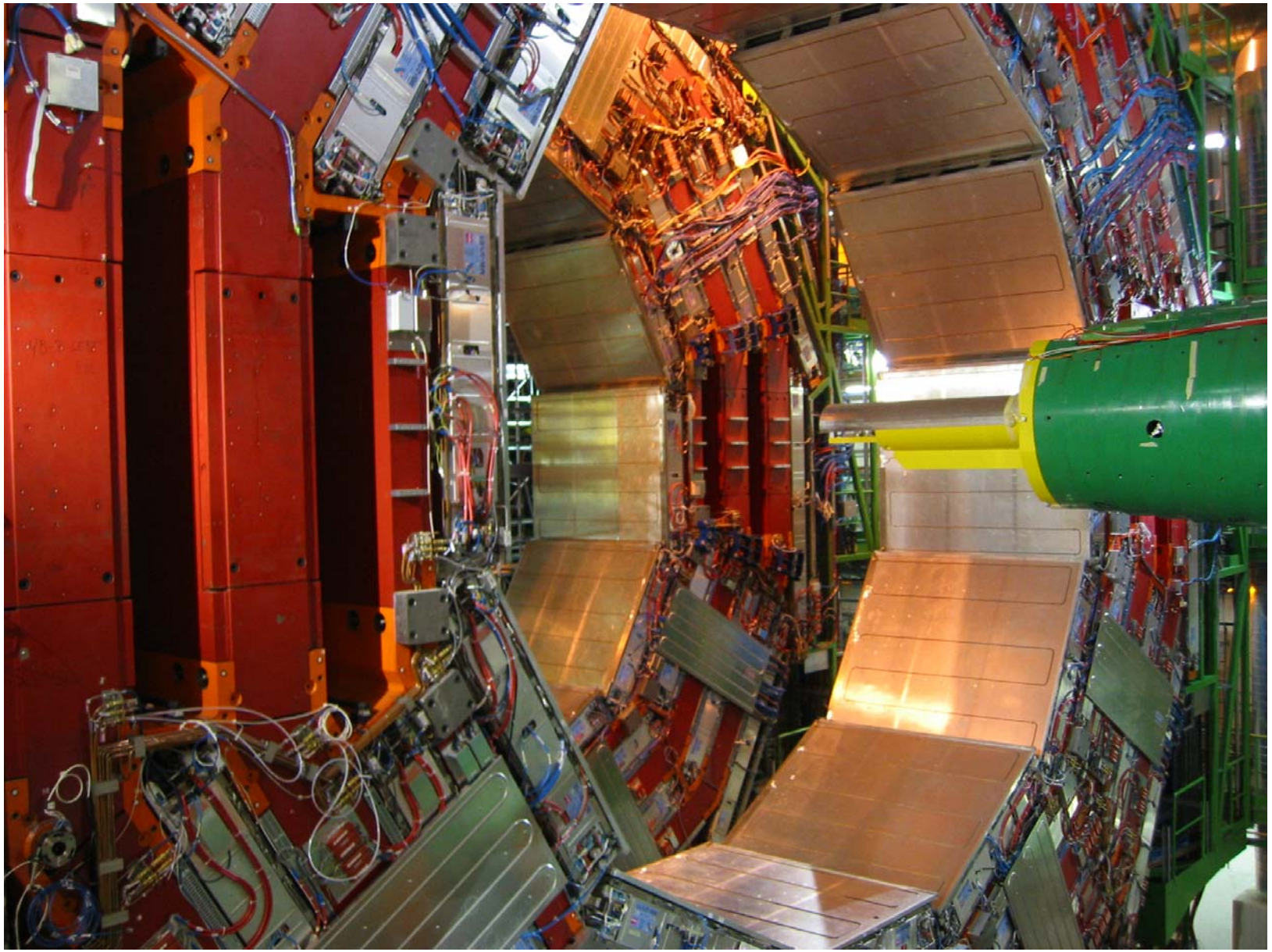
Installation of one HO housing containing 6 trays in CMS magnet



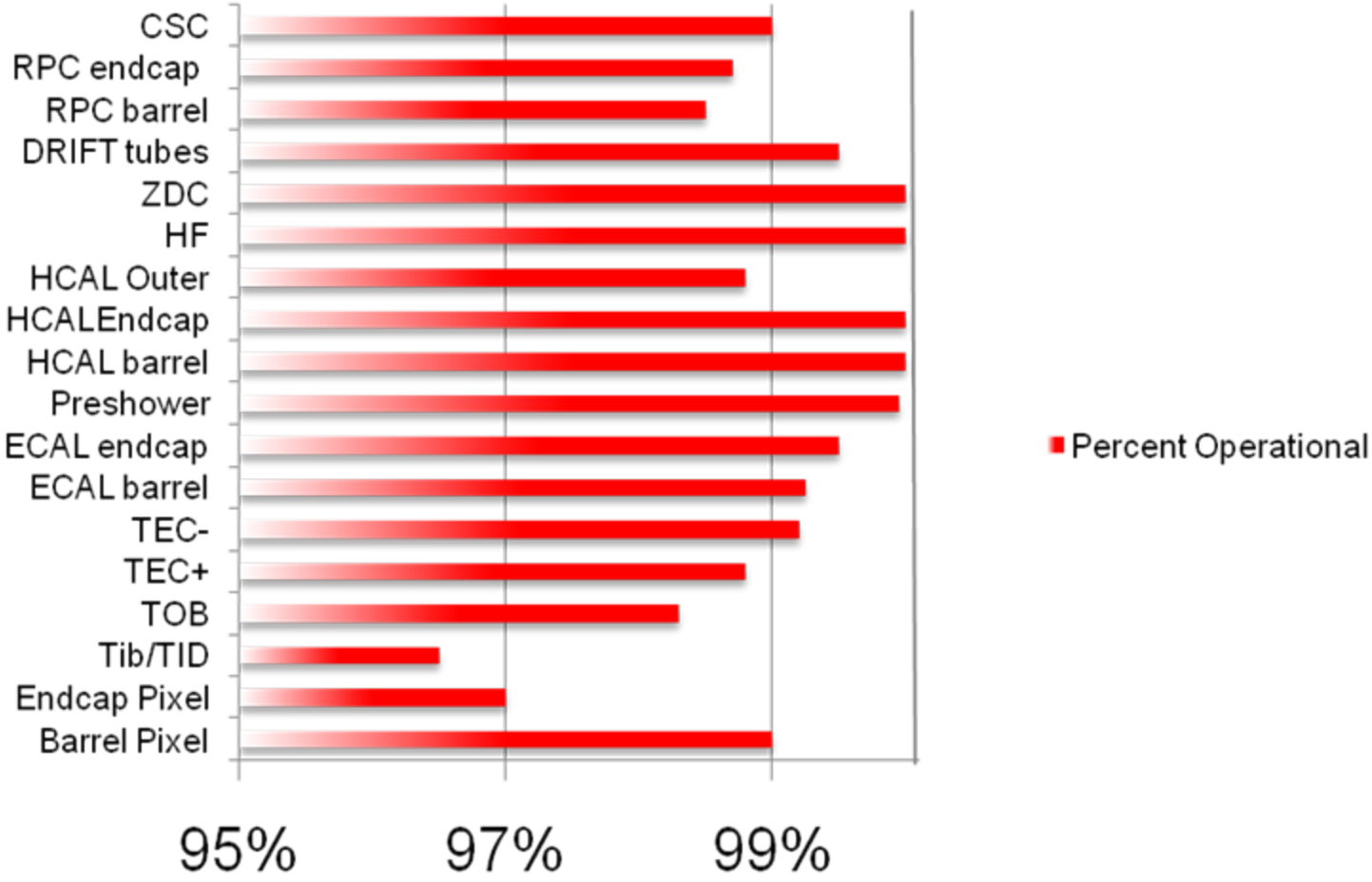
Installation in progress in surface hall



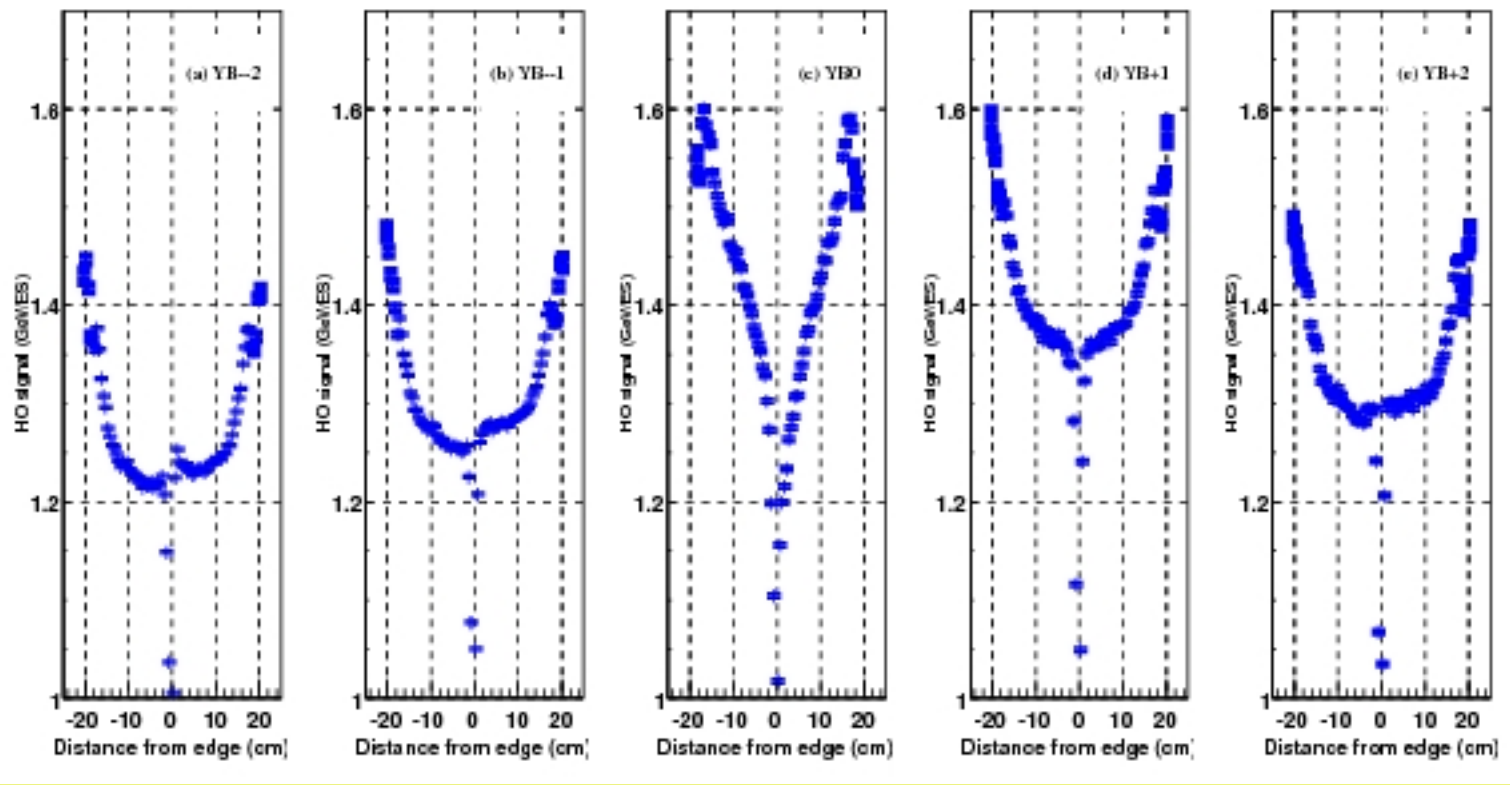
In Underground Pit



CRAFT09


CSC
RPC endcap
RPC barrel
DRIFT tubes
ZDC
HF
HCAL Outer
HCALEndcap
HCAL barrel
Preshower
ECAL endcap
ECAL barrel
TEC-
TEC+
TOB
Tib/TID
Endcap Pixel
Barrel Pixel
95%
97%
99%
Percent Operational

Cosmic muon signal in HO

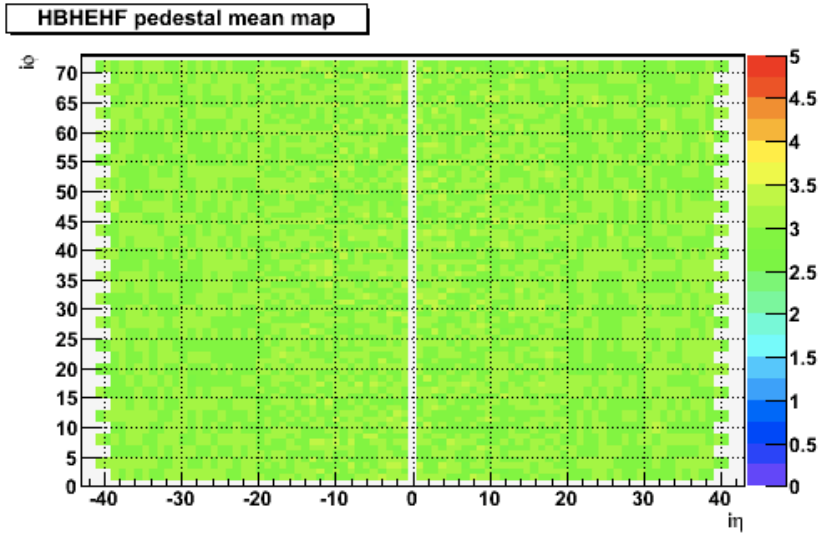


HCAL: Snapshot of what is working (Bologna)

Pedestal maps

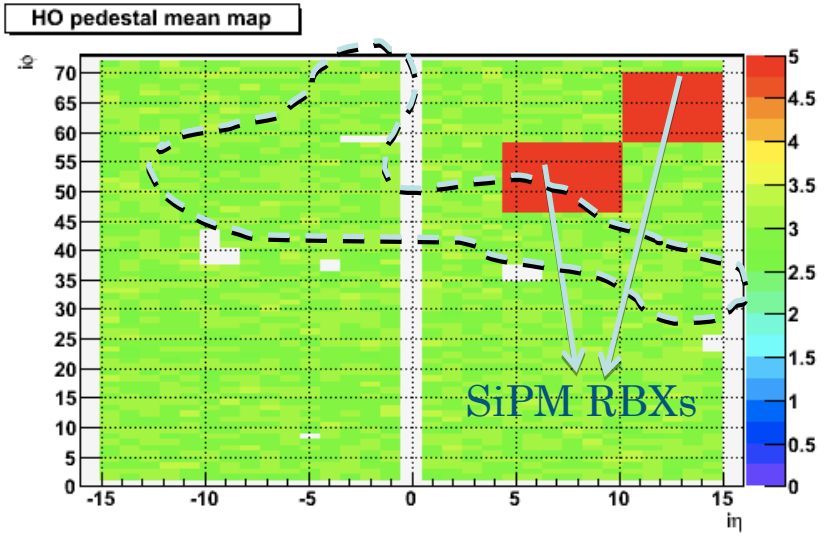
Run 111009 – Normal HCAL conditions

HB/HE/HF



100% of readout channels available in HB / HE / HF

HO



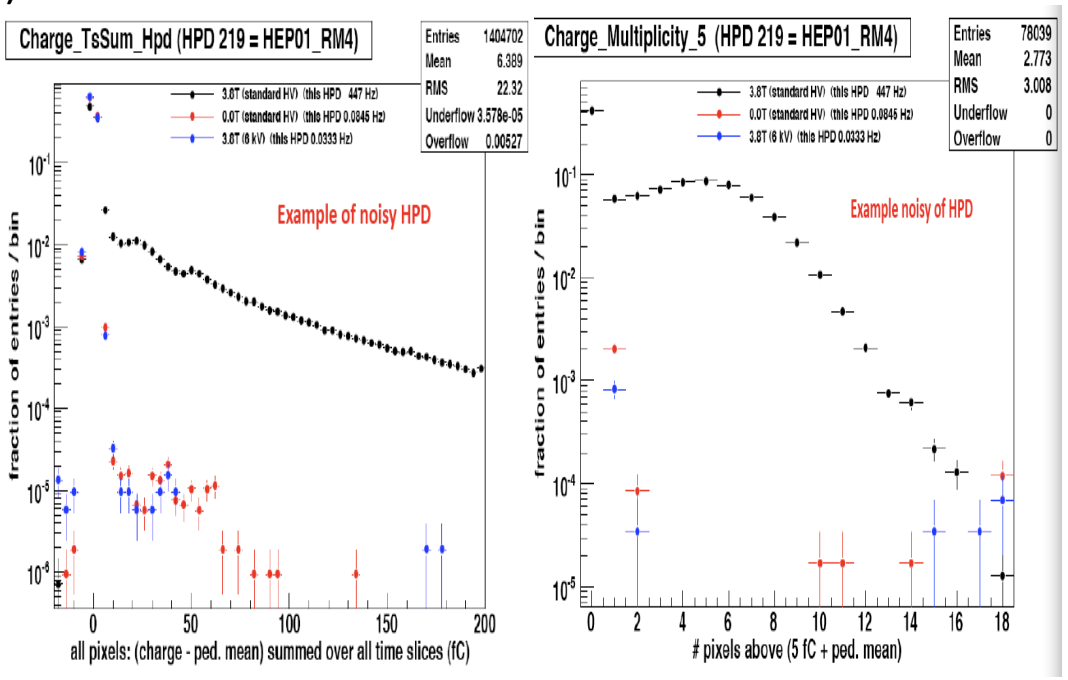
~25 (of 9072, all HCAL) dead channels during CRAFT09

	Channels	|η|
HB	2592	<1.4
HE	2592	1.4-3.0
HO	2160	<1.3
HF	1728	3.0-5.0
Castor	224	5.2-6.3(-end)
ZDC	18	>8.5

(1) HPD Discharge

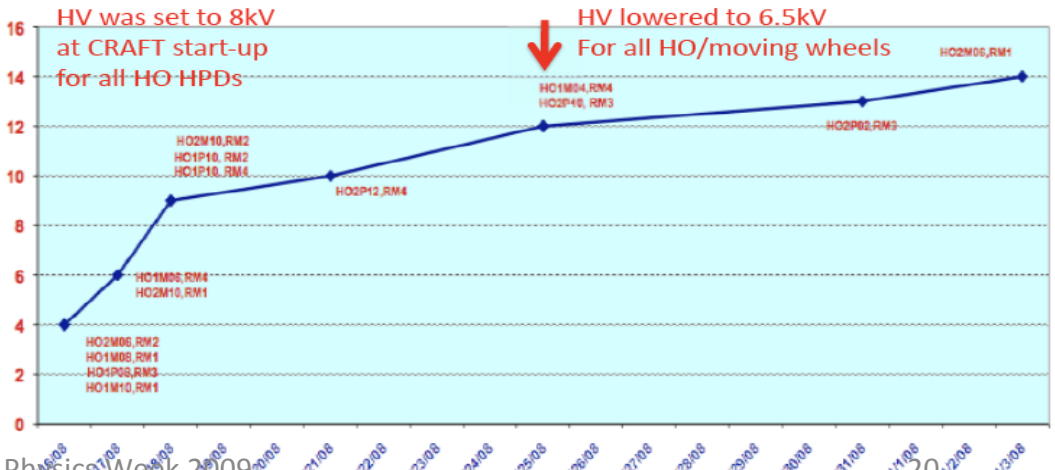
HPD = 18 channels (one ϕ wedge in HB)

- **Flashover discharge when field is not well aligned to the HPD axis – esp. ~0.2 to ~3.0 Tesla**
- **Characteristic signature - large signals in many channels**
- **Once discharge starts it worsens trigger rate unsustainable**



CRAFT08 Experience

- **HB and HE**
  - **Tested down to 3.5T**
  - **11 of 288 HPDs ~discharged**
- **HO**
  - **No discharges in R0 (~0T)**
  - **But 14 in R1/2**
  - **Developed over time**



Plan of action…

- **All CRAFT08 [near] discharging HPDs exchanged in the 2009 shutdown [19 out of 288]**
- **Bias voltage reduced from average of 7.5 kV to 7.0 in HB HE and 6.5 kV in HO R1/2**

CRAFT09 experience

- **Noise was ~2x lower and essentially stable during CRAFT09**
- **Only two (maybe 3) HO HPD's showed discharge – all in R1/2, one at the start**
- **Turning HV off for several days causes a temporary recovery**
- **One HPD in HE showed a brief period of pre-discharge, self-cured**

- **We expect further problems in HO R1/2, hopefully not R0, HE, HB**
- **Develop strategy to monitor behavior closely & plan for long-term**
- **It may be that we can see pre-discharge development and nurse the HPD 'till next shutdown**

Current/future HCAL situation

HPD operation at field

- **HE and HB – the situation is very good**
  - No significant discharges for 288 HPDs
  - Noise rate halved wrt CRAFT08 (due to replacement of discharging/noisy HPDs and operating 500v lower = 10% reduced gain)

- **HO**
  - **1 HPD discharged immediately at field, another started after one week (recovered after a week), a third may have just started @ end of CRAFT**
  - **This is as expected from the experience of CRAFT08**

Long-Term solution: Replace HPDs with Si-PMs (HO Rings 1/2, R0, HB,HE)

Prototype SiPM test in HO – also very successful

- Excellent S/N and no effect of magnetic field

Two lessons learned:

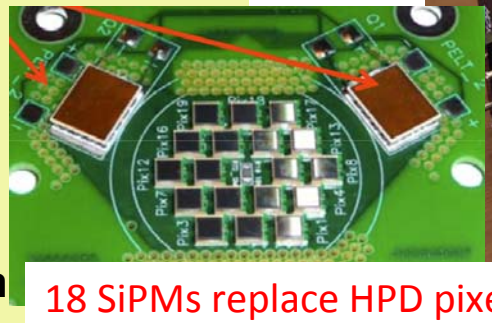
- Gain temperature dependence – want more sensitivity in temp measurement
- Cross-talk for a few individual channels to control lines – likely needs a modification to board layout (under study)

SiPMs in HO

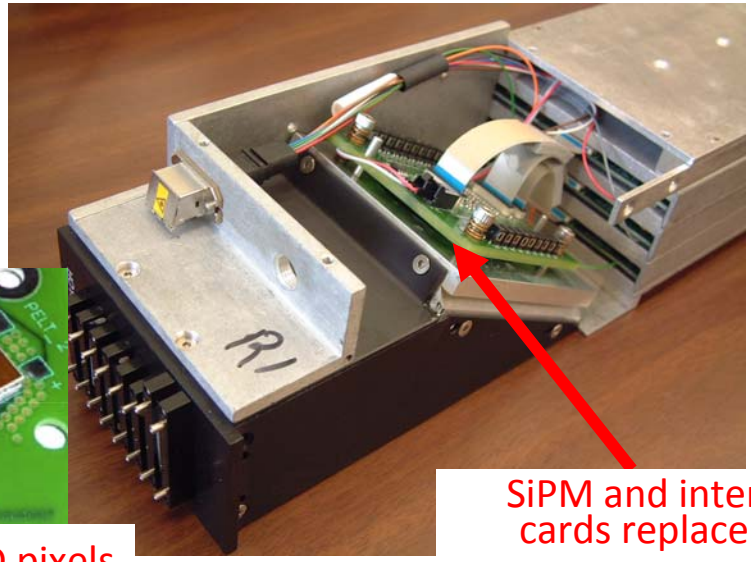
- **2 RBXs (144 channels) are instrumented with SiPMs to confirm suitability for HO**
- **Packaged to replace HPD in existing RM**

Peltier Coolers

- **Two suppliers:**
- **Hamamatsu (400 pix/mm^2)**
- **Zecotek (15K pix/mm^2)**

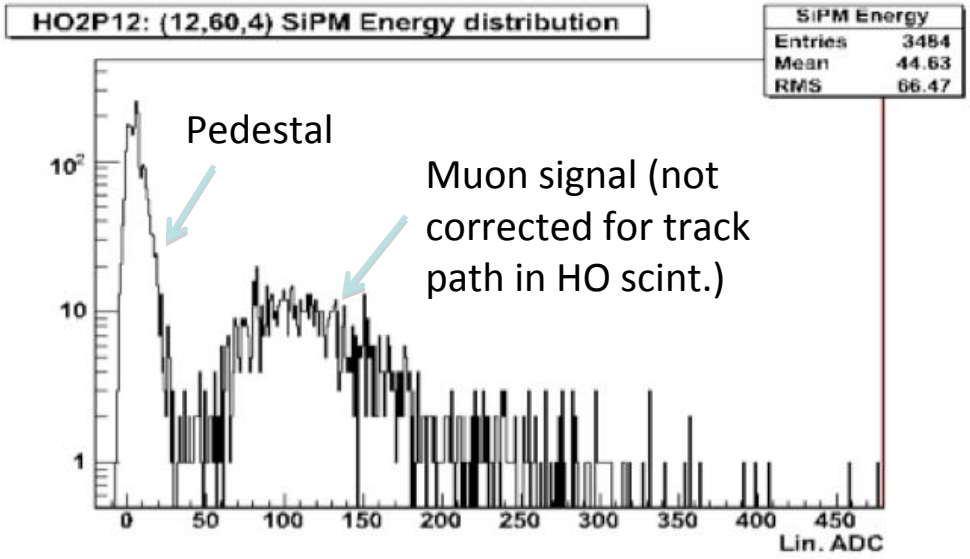


18 SiPMs replace HPD pixels

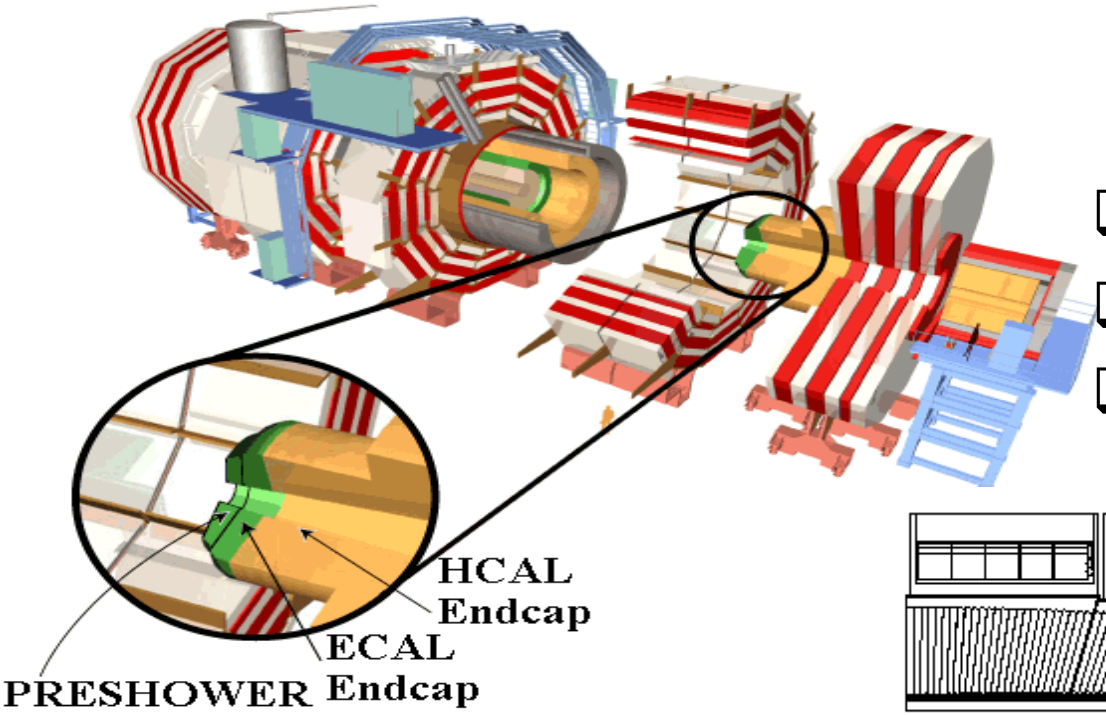


SiPM and interface cards replace HPD

- **Compared in 2009 Test Beam**
- **S/B much higher than HPD**
- **Insensitive to B-field**
- **But gain is temperature-dependent**
  (Hamamatsu: 8-10%,
  Zecotek: 4-5% per deg)
- **Consider replacement for HPDs in R1 during 2011 shutdown**

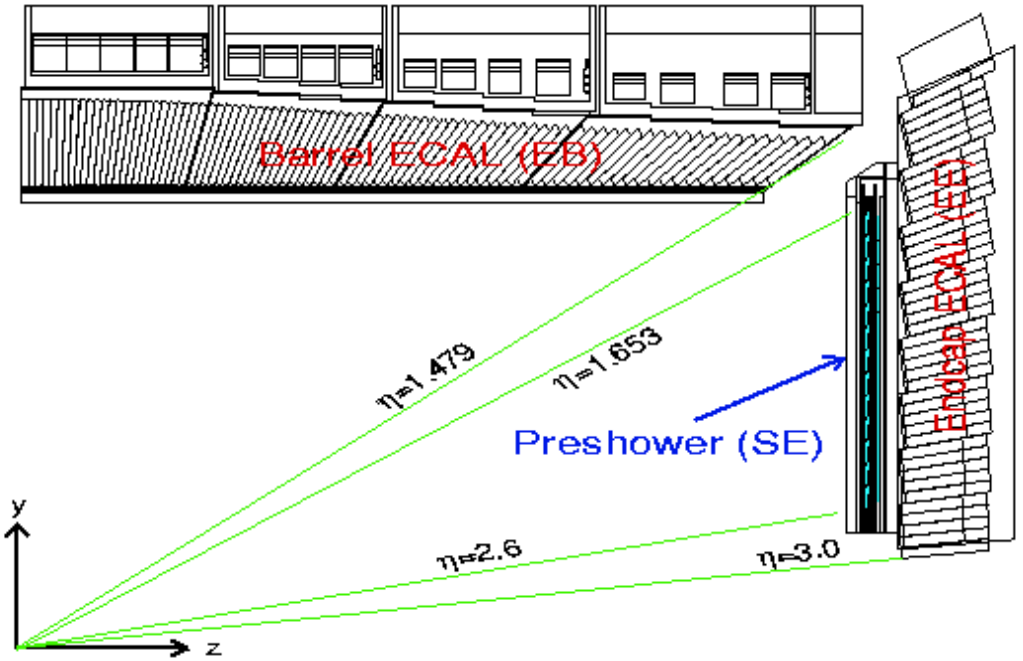


CMS Preshower WHERE?



ECAL

- 1 Crystal BARREL (EB)
- 2 Crystal ENDCAPS (EE)
- 2 Preshower ENDCAPS (SE)



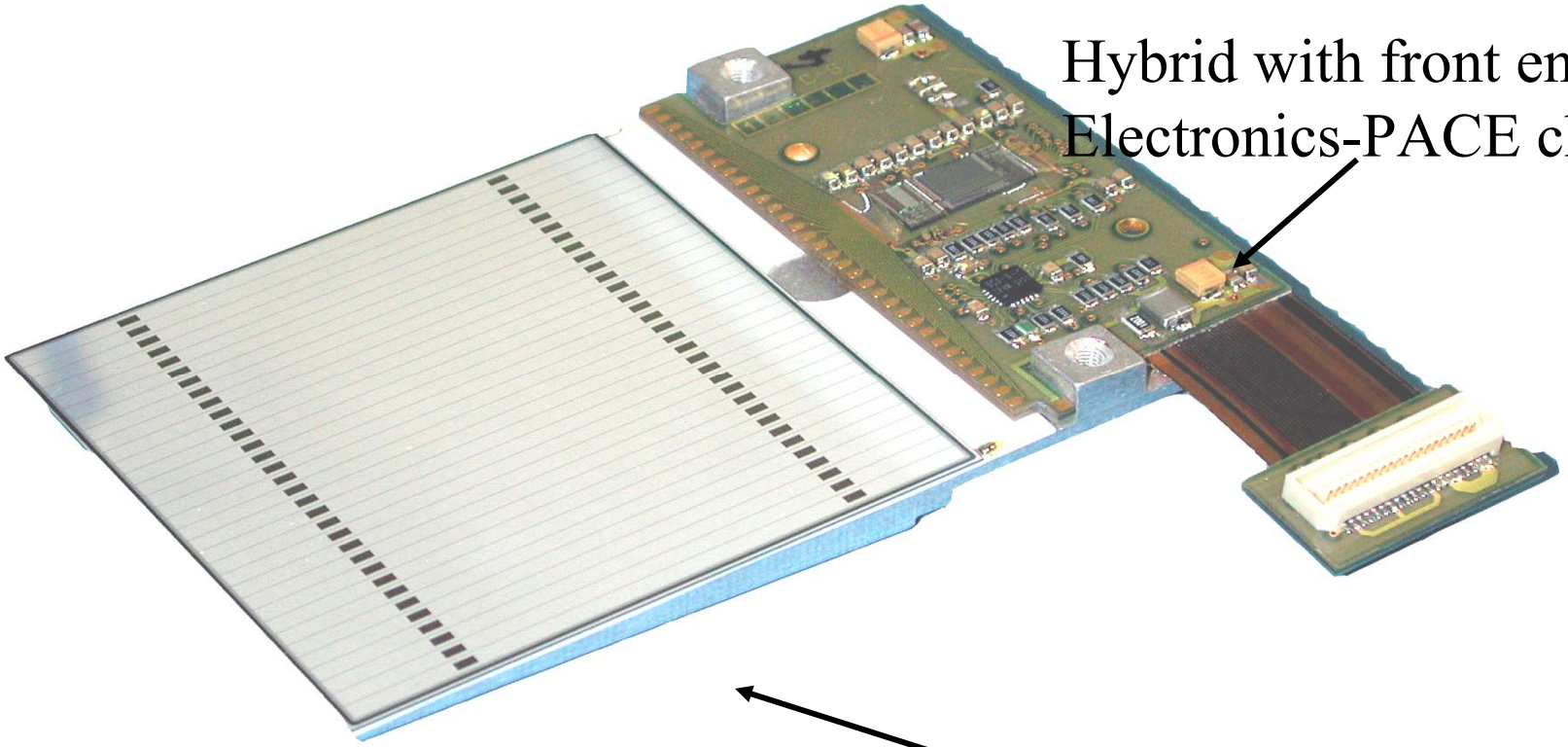
Coverage

- Behind the Tracker and in front of EE
- $1.653 < |\eta| < 2.6$

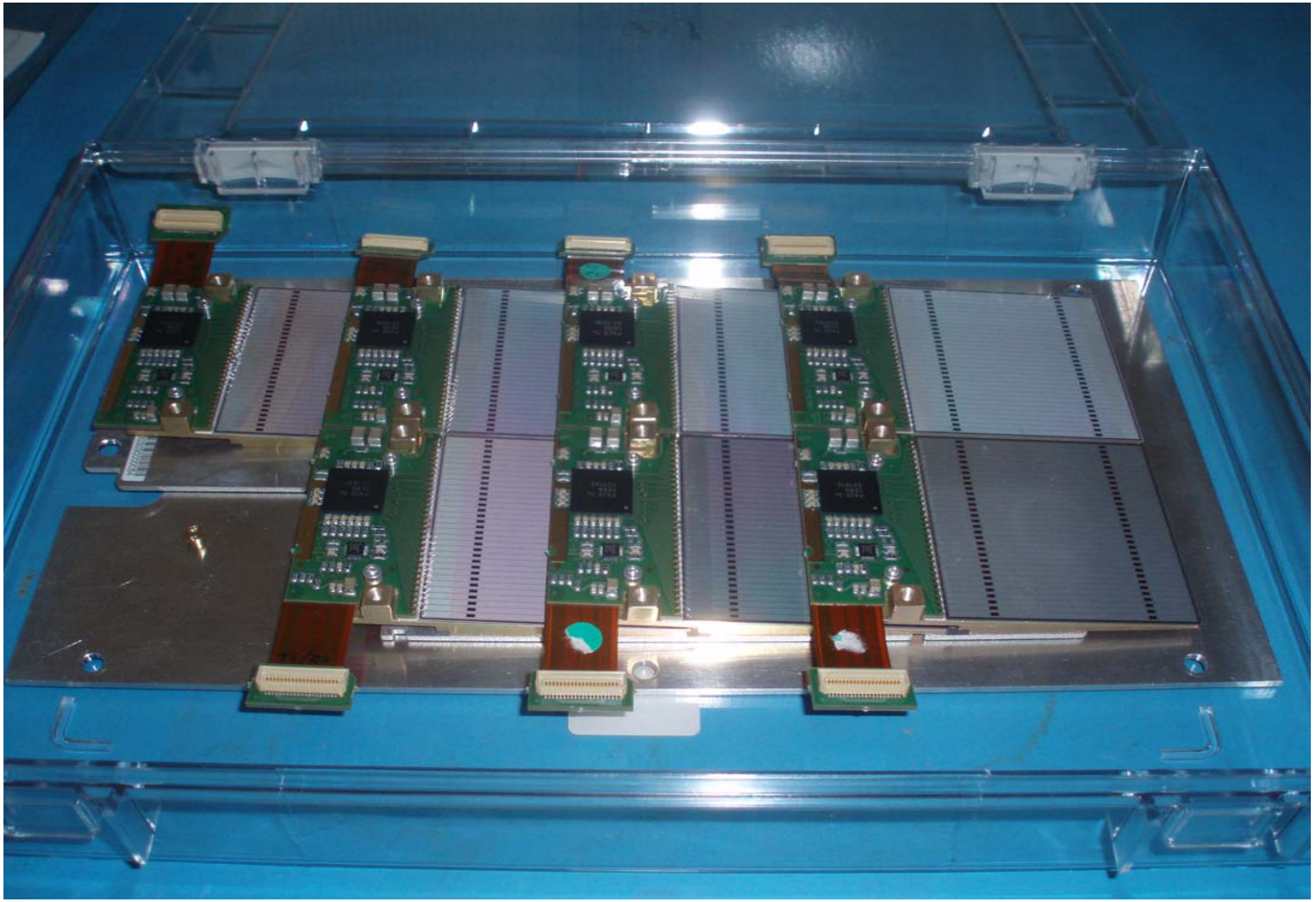
Si-PSD hardware

- **To fabricate 1000 Silicon strip detectors for the pre-shower end-cap of the CMS detector (~25% of total).**
  Plus 10% spares.
- **Carried out at BEL foundry Bangalore. Yield (around 50%) and production rate quite satisfactory.**
- **Mounted them on ceramic supports and then on aluminum plates to complete the module production process in India. Also done at BEL. Shipped to CERN.**
- **Readout chips bonding and other electronics mounting at CERN.**
- **Additionally: CMS ordered a few hundred more sensors from BEL to make up shortfall from other sources.**

Silicon detector micro-module made at CERN



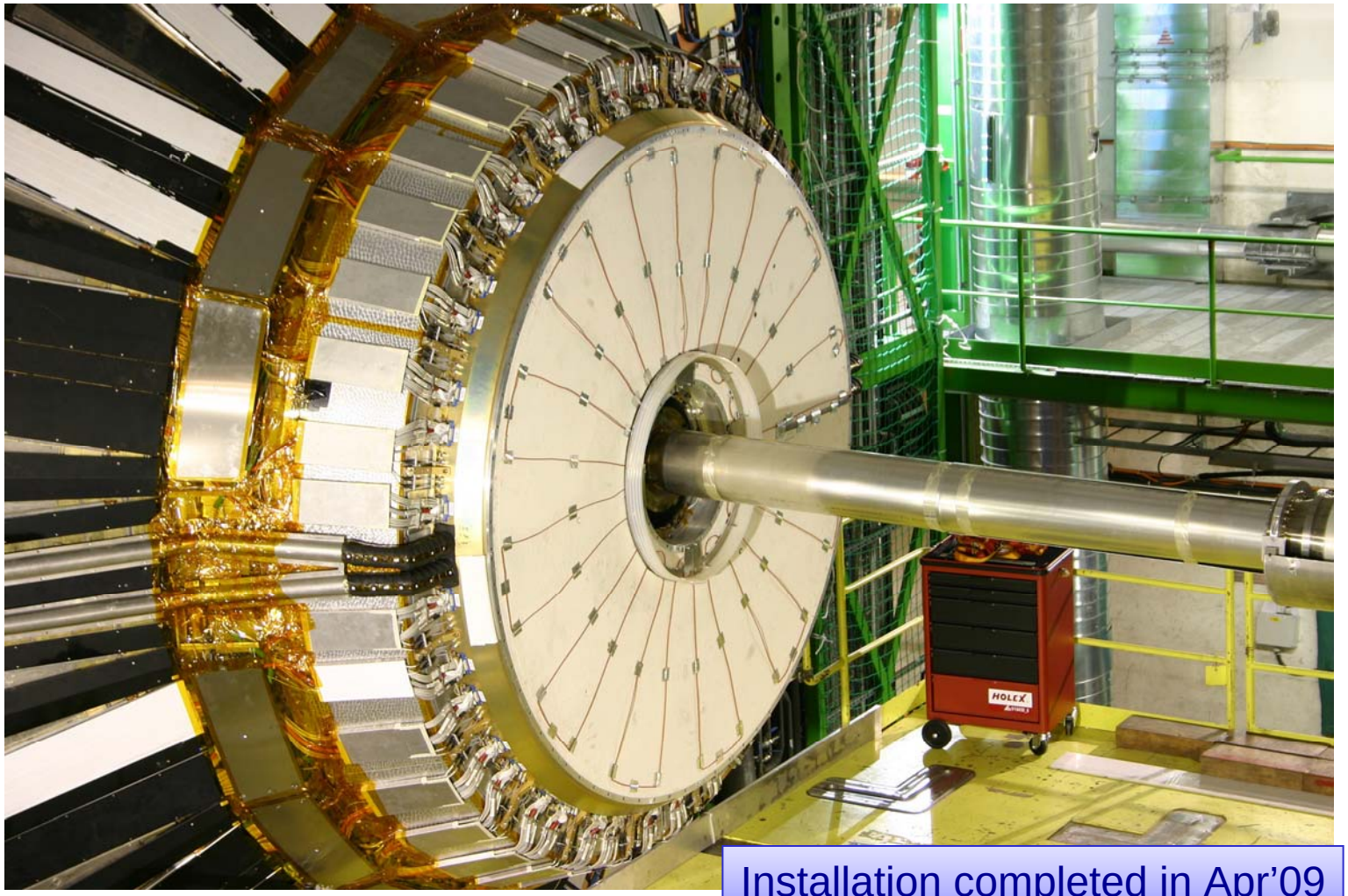
Assembled ladder



Assembly/mounting at CERN

The two separate ES Dees

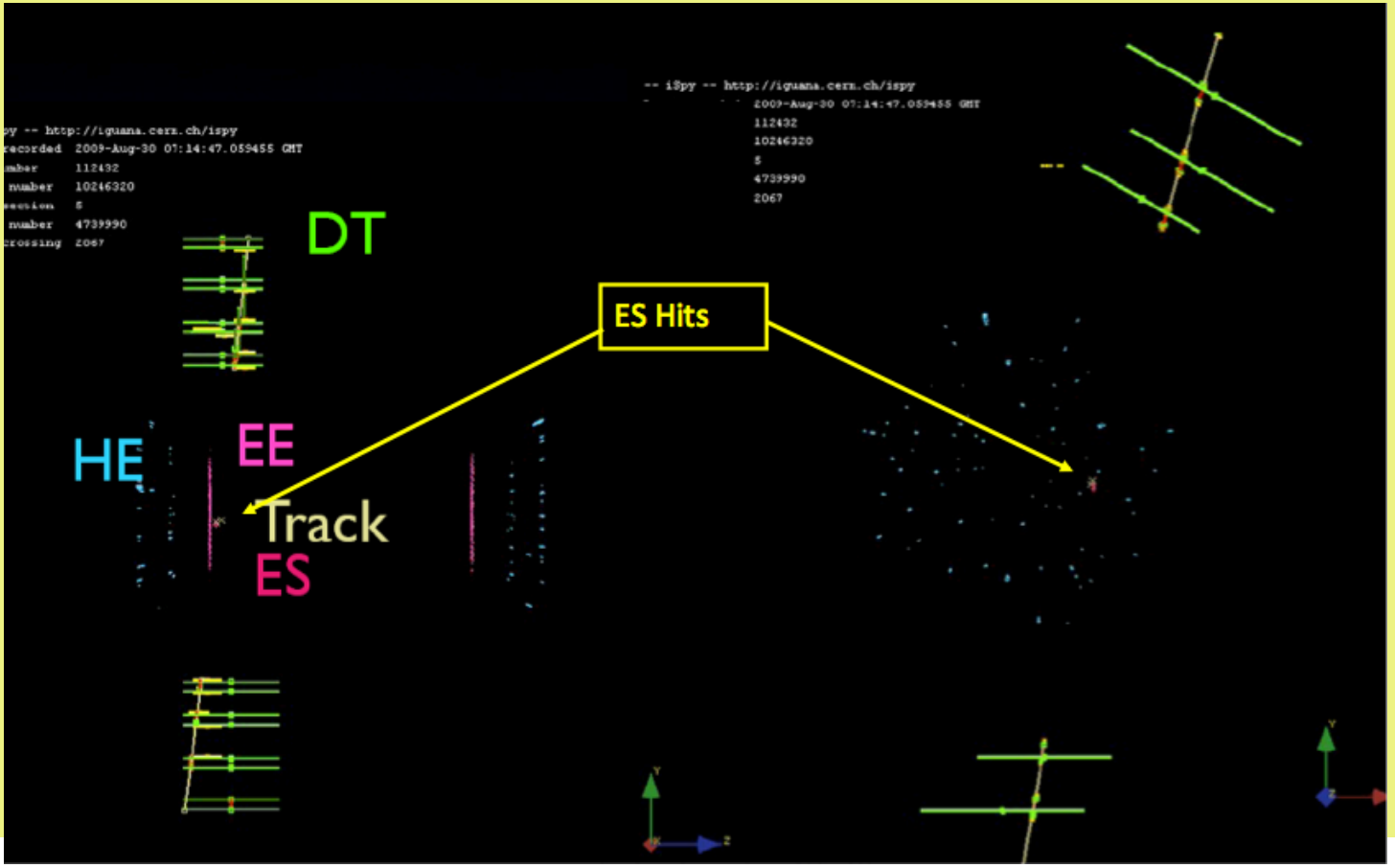
ES Installation Completed in April



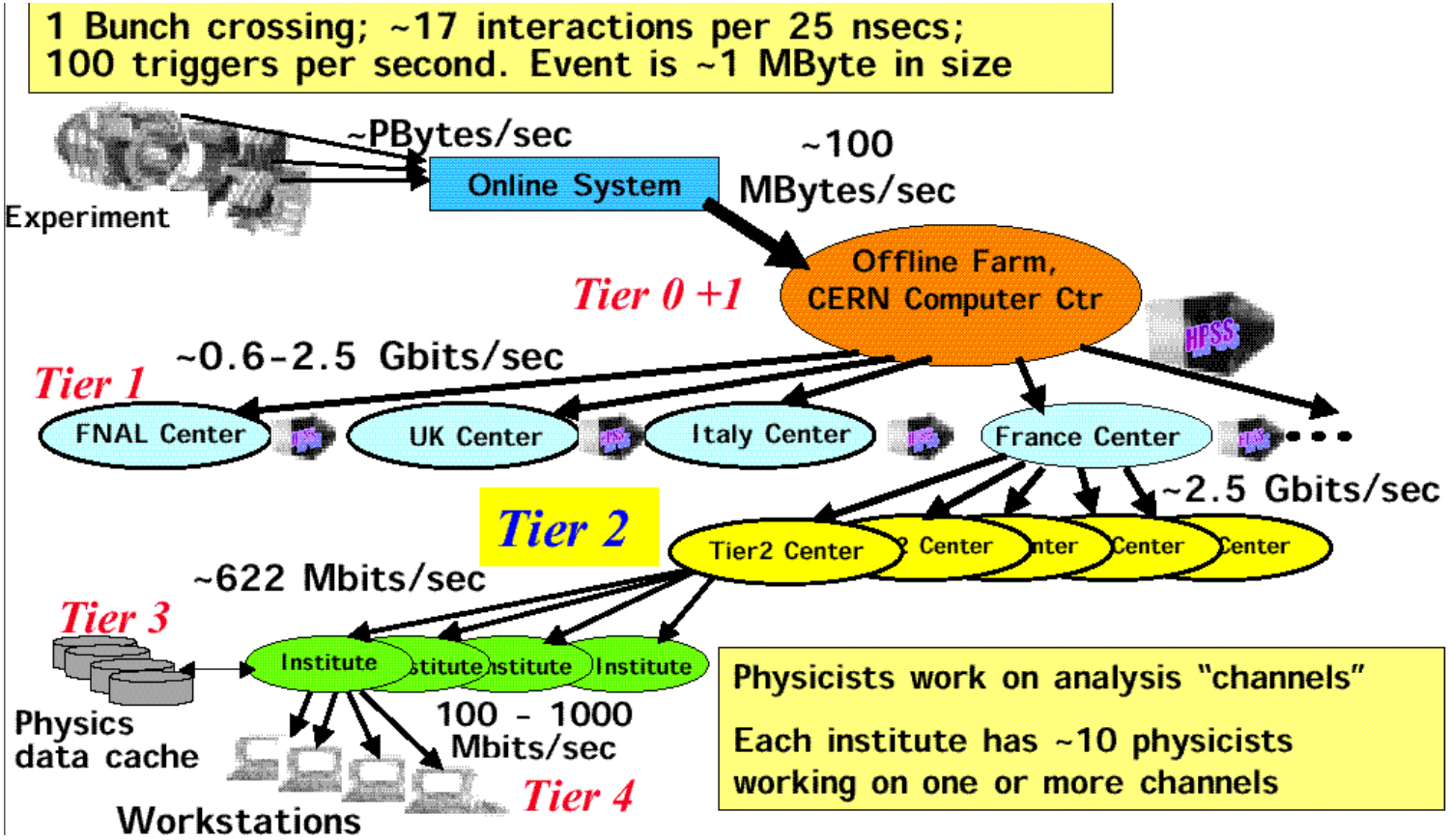
Installation completed in Apr'09

Pre-shower in CRAFT
(Excellent noise performance)

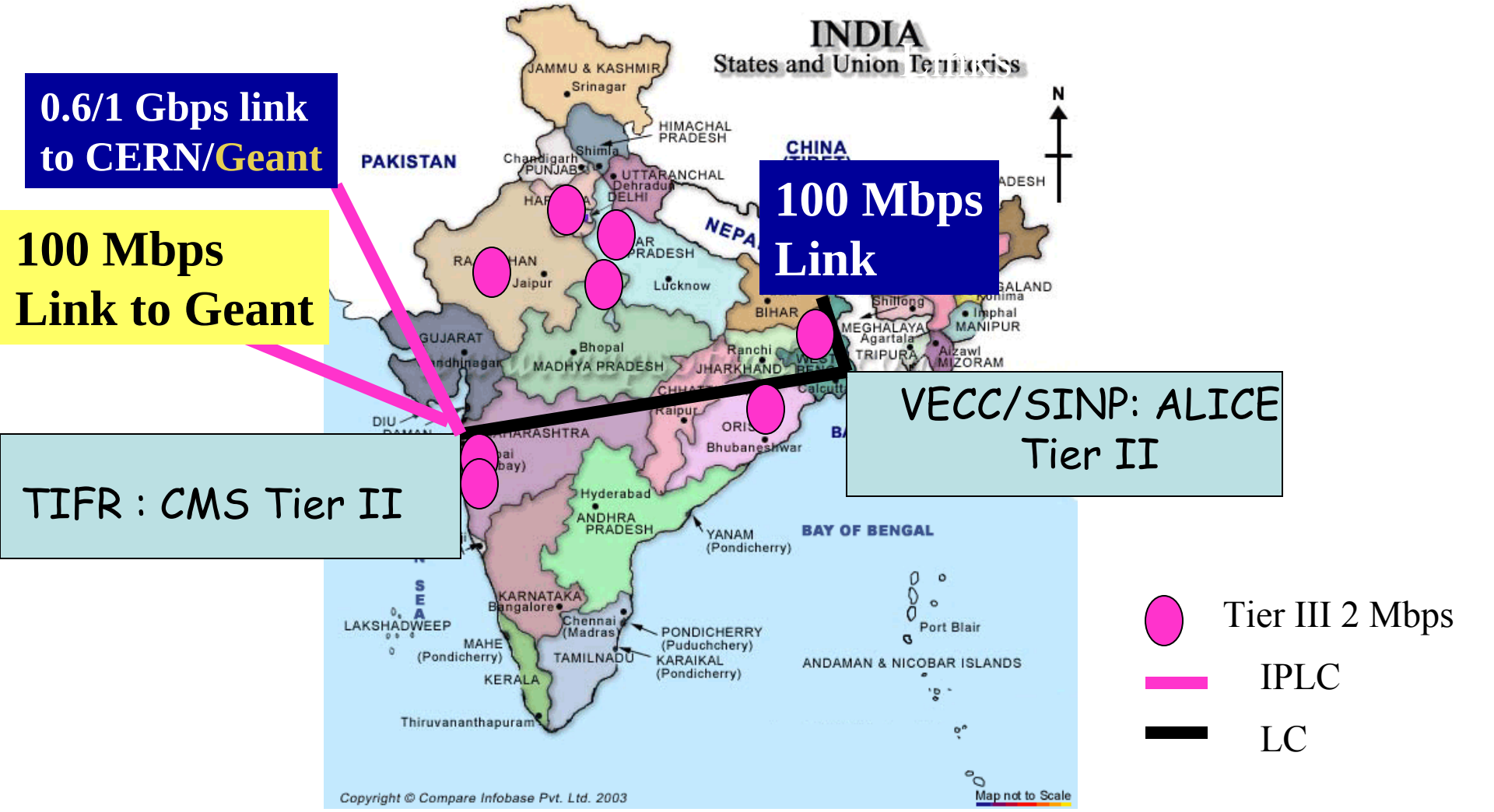
- **Preshower** entered CMS global data-taking. Preshower ran at the end of CRAFT with all four detectors and with all four DCC's installed. These are currently being commissioned.



GRID project, Tier-2/3 CMS, ALICE centers



DAE/DST-WLCG Tier II Grid in India



BARC, IOPB and 14 Universities have been operational since 2007

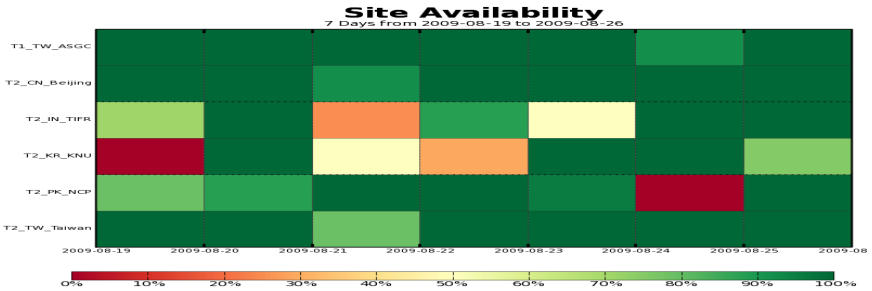
CMS Tier-2 TIFR

Compute power:
45 Blade Servers
Quad Core Clovertown (E5355@2.66 GHz)
2 GB/core memory: 72 GB HDD (15K rpm) + Plus old: 80K equivalent of SI2K
Dual Xeon@3.6 GHz,1 GB/core memory)
Storage: 450 TB (raw) Disk space

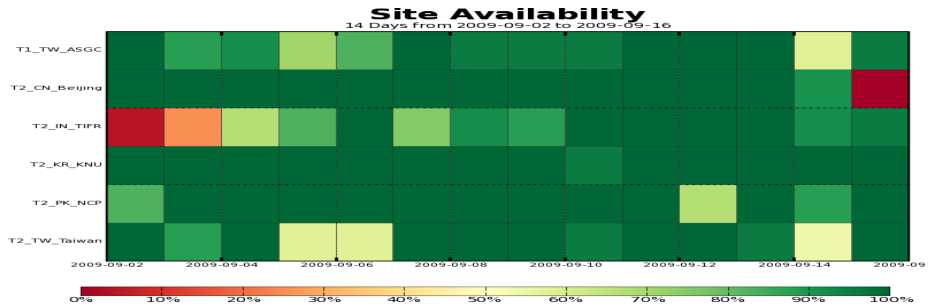
TIFR Mumbai	2009	2010
CPU (HEP-SPEC06)	2400	3200
Disk (Terabytes)	450	600
*CERN Link (Mbps)	400/1000	600/1000

SAM Quality over Last Week (mid-Sep)

Two weeks ago



This week



T2_CN_Beijing : 14 Sept SRM errors: (CGSI-gSOAP: Could not open connection)
Unscheduled downtime on 15-16, Sep.

T2_IN_TIFR : SAM errors for last 2 weeks on CE-cms-frontier (Thu Sep 3 18:13:18 IST 2009 --> DONE CMSSW_frontier.sh: Error. Trying direct connect to CERN server)
cms-prod (Job got an error while in the CondorG queue)
sft-job: shorttime error (the user proxy expired)
SRM errors: on 02, 14 Sept (CGSI-gSOAP: Could not open connection, as same 2 weeks ago)

T2_KR_KNU: **OK**
SRM errors: (CGSI-gSOAP: Could not open connection)

T2_PK_NCP : SAM errors on 02, 12 Sept, SRM error on 14 Sept

T2_TW_Taiwan : 03, 05-06 Sept, SAM error cms-prod, cms-sft-job (both from Condor and from Maradona)
on 10, 14 Sept SRM errors:(CGSI-gSOAP: Could not open connection)

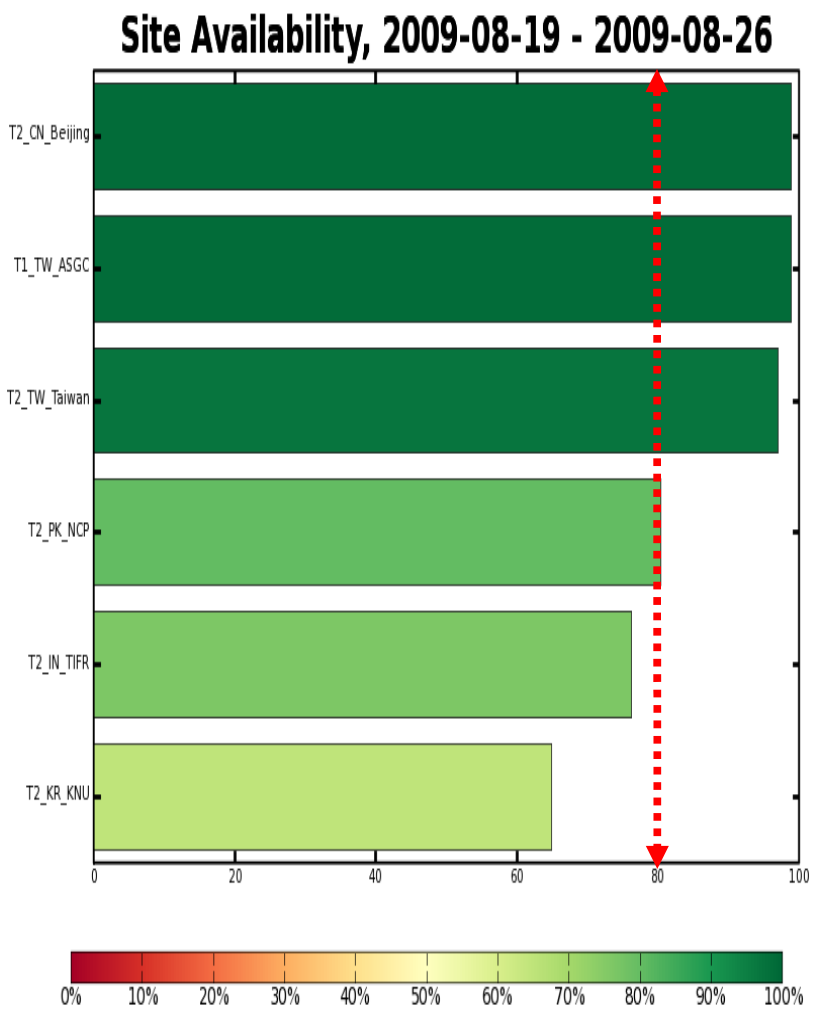
T1_TW_ASGC :**Gang's comments on facOps Monday meeting 14 Sept.**

JR: Maradona errors on Sep 8-9 because some servers were overloaded. SAM: availability 97%.

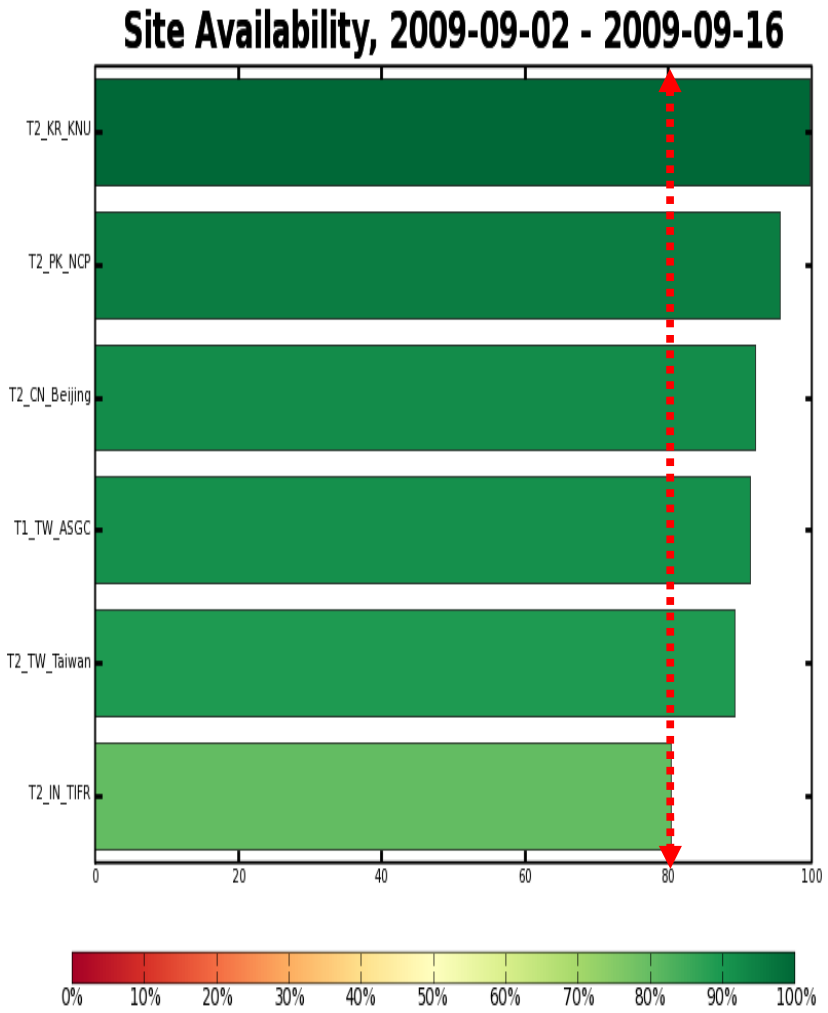
SAM Error: on 14 Sept
"Size Mismatch between local and SE" ERROR: Stage Out Test failed

SAM Ranking over Last Week

Two weeks ago



This week



Sites running MC production (22.7.- 4.9.2009)

Parallel Running Jobs (Average/Maximum)

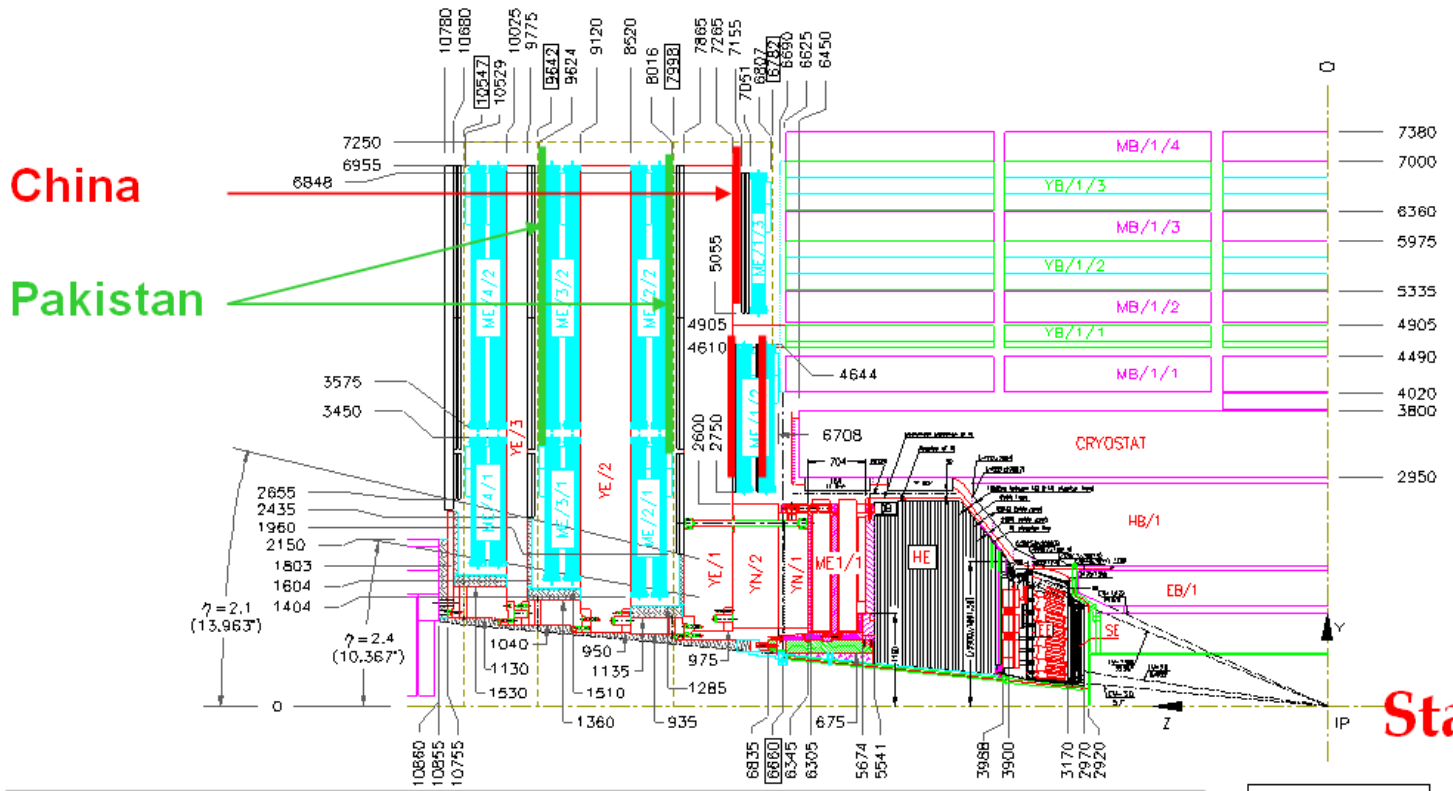
Site	all	production
BEIJING-LCG2	216/455	147/441
BEgrid-ULB-VUB	430/1267	73/160
BUDAPEST	145/373	71/287
BelGrid-UCL	231/441	206/413
CIEMAT-LCG2	404/1039	296/1005
CIT_CMS_T2	753/1611	284/695
CSCS-LCG2	350/1915	162/741
DESY-HH	449/1235	268/967
GLOW	1049/2273	387/1236
GRIF	280/1500	117/435
HEPGRID_UERJ	5/58	0/0
HEPGRID_UERJ_OSG64	16/90	0/0
Hephy-Vienna	311/750	141/404
IFCA-LCG2	672/5417	63/432
IN2P3-CC-T2	391/1264	259/1243
IN2P3-IRES	73/396	27/199
INDIACMS-TIFR	177/354	125/304
INFN-BARI	115/417	51/226
INFN-LNL-2	247/712	45/199
INFN-PISA	732/1544	392/1164
INFN-ROMA1-CMS	145/478	126/472
ITEP	83/264	52/119
JINR-LCG2	201/628	159/554
Kharkov-KIPT-LCG2	32/104	24/53
LCG_KNU	142/333	93/245
LIP-Coimbra	9/77	0/0
LIP-Lisbon	152/532	95/269
MIT_CMS	935/1781	351/1113
NCG-INGRID-PT	75/366	0/0
NCP-LCG2	4/9	0/0
NDGF-T1	55/556	21/283
Nebraska	464/1410	213/637
Purdue-RCAC	1495/5117	1238/5064
Purdue-Steele	205/539	226/539
RRC-KI	36/287	4/14
RU-Protvino-IHEP	40/144	27/79
RWTH-Aachen	1223/2813	773/2711
Ru-Troitsk-INR-LCG2	19/112	40/93
SPRACE	26/102	0/0
T2_Estonia	242/1012	169/1008
TR-03-METU	16/122	14/59
TW-FTT	289/1240	128/472
UCSDT2	403/1696	92/313
UFlorida-HPC	644/2603	273/919
UKI-LT2-Brunel	171/474	106/469
UKI-LT2-IC-HEP	740/2312	434/1082
UKI-SOUTHGRID-BRIS-HEP	17/52	6/15
UKI-SOUTHGRID-RALPP	338/1606	255/1594
WARSAW-EGEE	134/399	87/334
ru-Moscow-SINP-LCG2	65/165	44/123
ru-PNPI	14/125	0/0
ucsdt2-b	454/1693	135/352
Summary	16148/26641	7560/16608

Good production performance:

- Large number of sites participating
- Daily averages
  - 52 active sites with more 0 jobs/day of any kind
  - 45 sites ran MC production: with than 0 MC jobs/day
  - 35 sites with more than 50 MC jobs/day

Endcap RPC completion

Layout & and rapidity coverage of the initial forward CMS RPC system

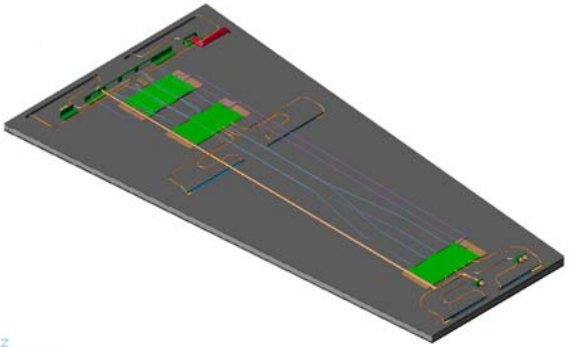


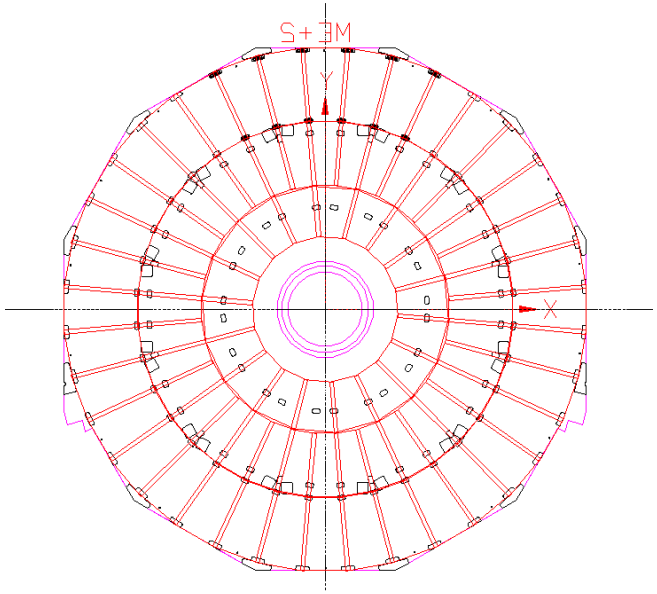
Low eta chambers identical for stations 2,3 and 4

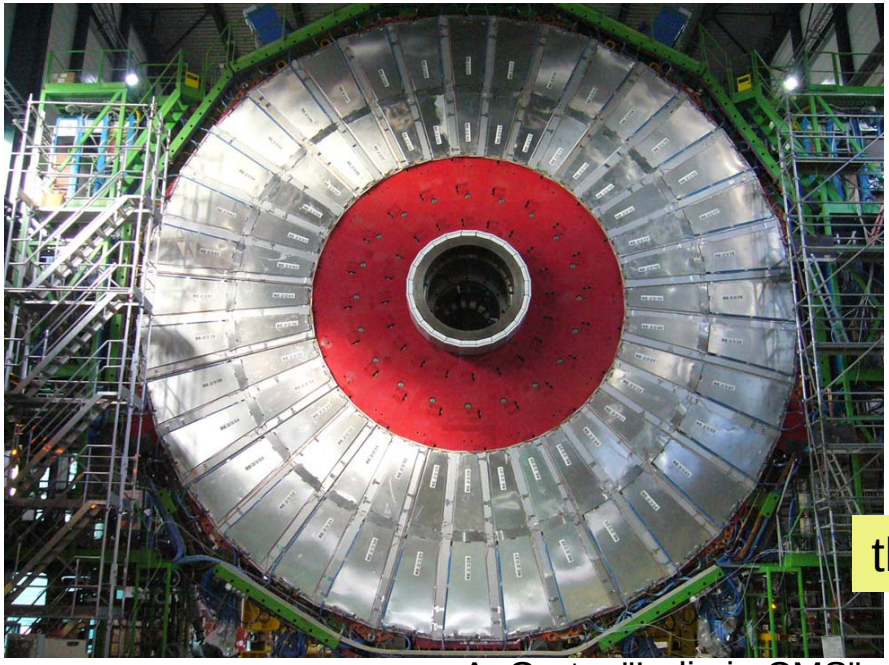
P-S-I
JDP 1-8-2002
CMS 5185_125

	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*

Schematic layout of a forward double gap RPC; layout of the an RPC layer on the yoke disk







third layer on the +z end cap

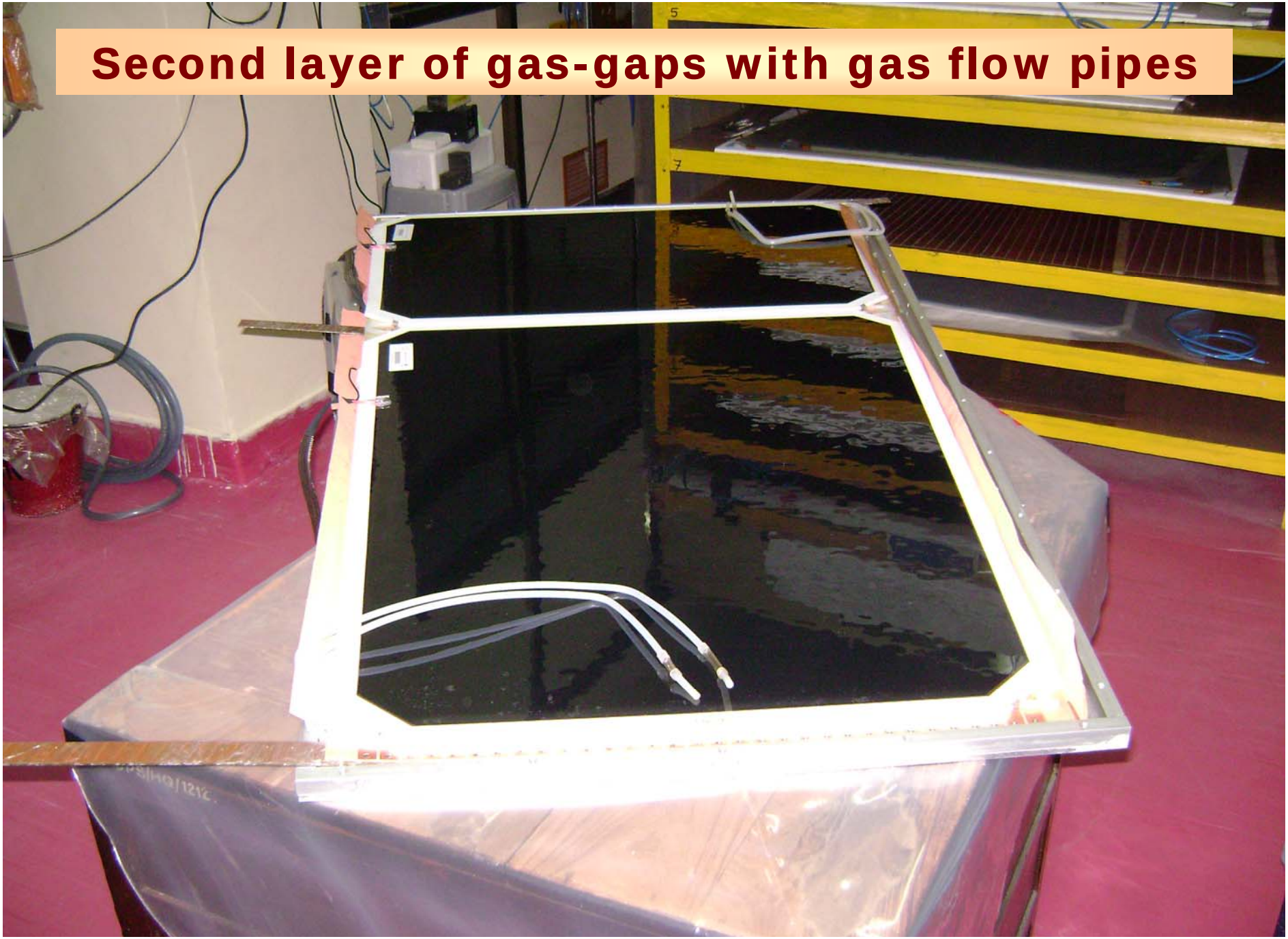
New groups in the CMS Endcap-RPC completion effort

- Belgian groups: Gent, Louvain, Brussels
- **Indian groups: BARC (Mumbai) & Panjab U (Chandigarh)**
- Contribution will be equivalent to providing one side of the endcap (chamber assembly, electronics, etc), approx 0.8 MCHF. The funding has been approved.
- **Assembly of 12 RPCs successfully completed at BARC RPC lab → dispatched to CERN. Validated.**

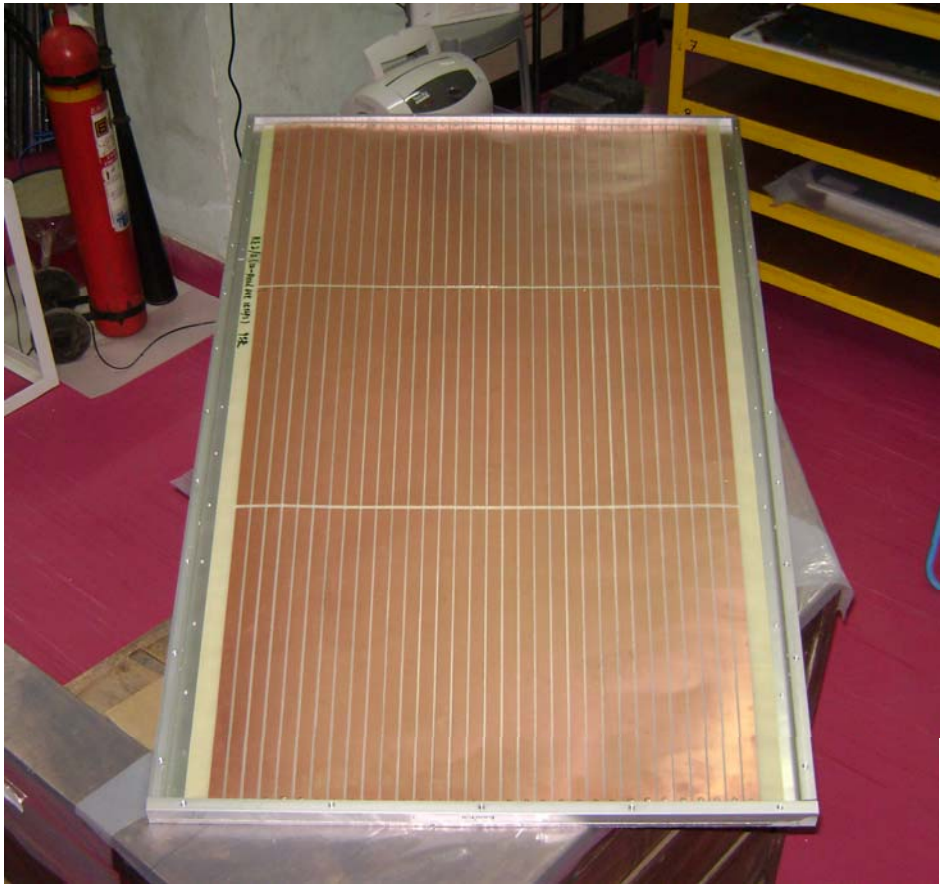
Cu-Faraday cage being cleaned before placing it on the honey comb panel

First layer (bottom) of large gas-gap laid on the honey comb panels

Second layer of gas-gaps with gas flow pipes



Mechanical assembly of RPCs in progress



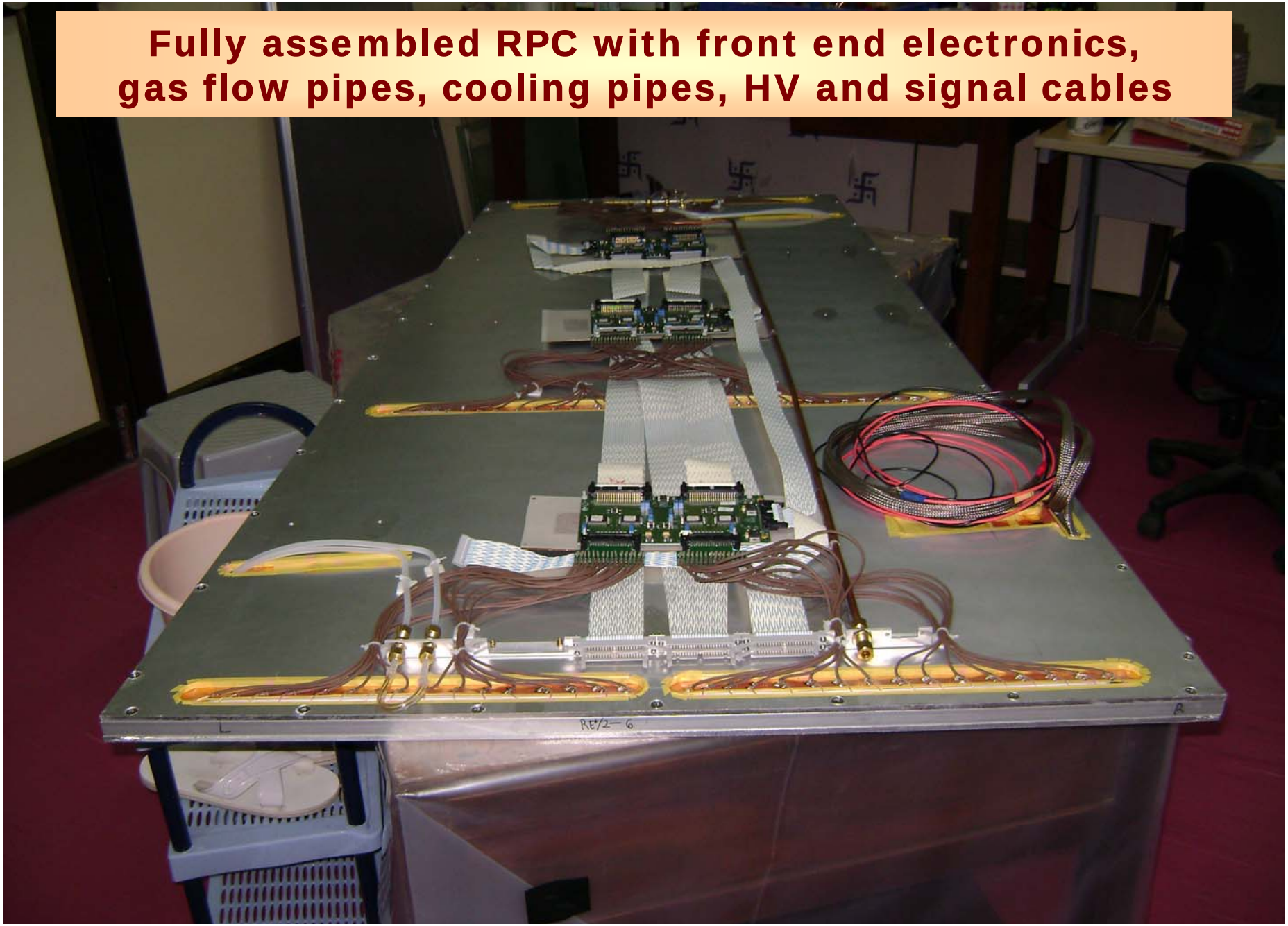
- the double-gap design
- increases signal on read out strip
- sum of two single gap signals

segmented strips	: length, 55 to 70 cm
strip width	: trapezoidal, 2 cm to 4 cm
strip capacitance	: ~ 160 pF/m to 420 pF/m
signal propagation	: ~ 5.5 m/ns

A. Gurtu: "India in CMS", TIFR, Mumbai, 23 October 2009

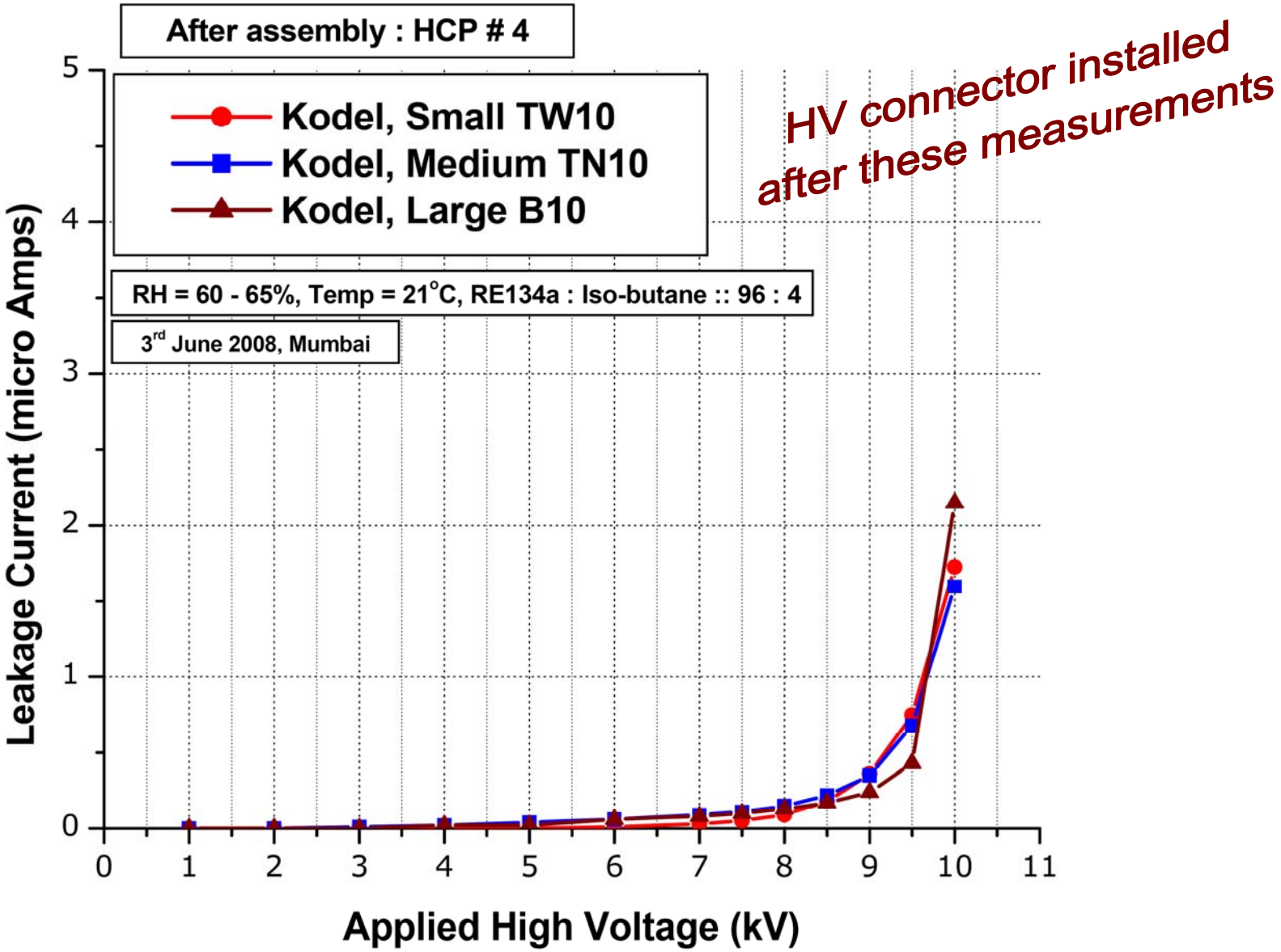
Bakelite gas-gaps enclosed inside the Faraday Cage

Fully assembled RPC with front end electronics, gas flow pipes, cooling pipes, HV and signal cables



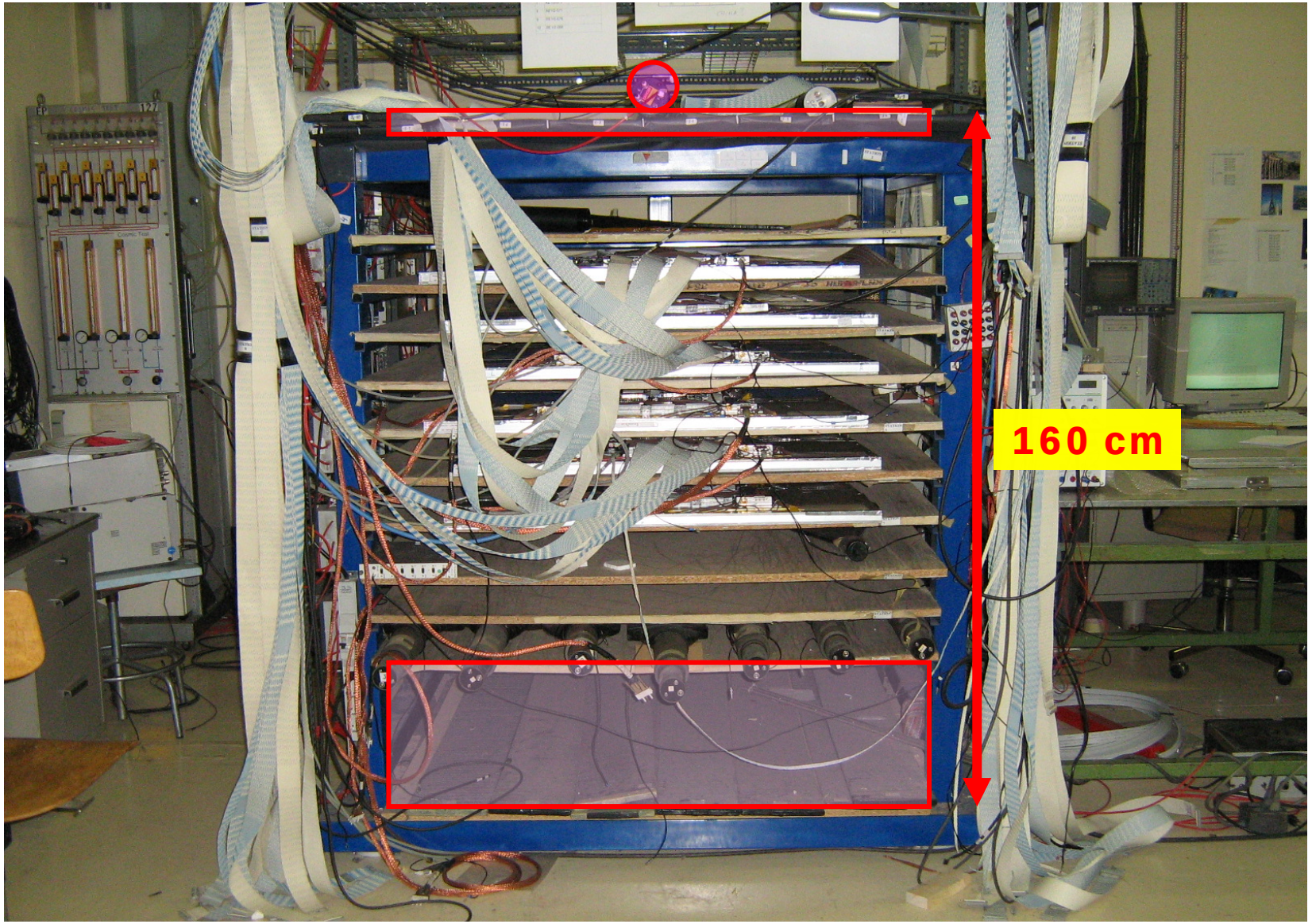
RPC being given final touches

Leakage current vs. HV plot after assembly at Mumbai



Cosmic hodoscope and the DAQ

RPCs in the cosmic hodoscope in the ISR Lab.



Mumbai, 22 October 2009

Trigger from cosmics

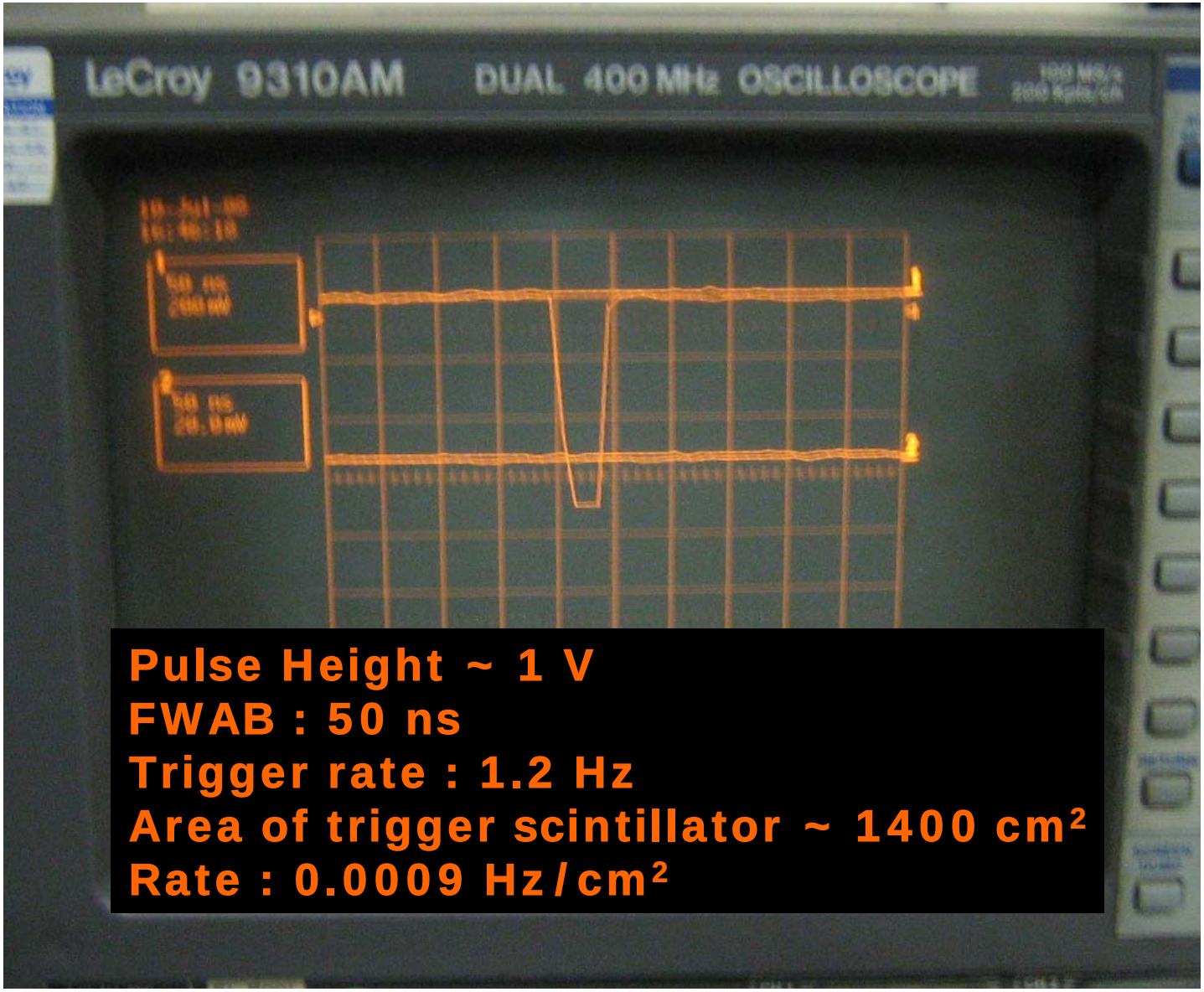


Table 1 : Status summary of ten RPCs from India as on 14th July 2008

SN	Type	RPC #	Gas flow & leakage currents upto 9.6 kV	Efficiency at 9.4 kV	Strip profile & Cluster size	Present status	Remarks	Date of completion of efficiency measurement
1	RE*/2 KODEL Gas-gaps	1	OK	98.00	OK	RPC put back in the crate after tests	Cosmic test OK	12 Jul (run # 5179) at 9.4 kV with 10K triggers
2	RE*/2 KODEL Gas-gaps	2	OK	98.60	OK	RPC put back in the crate after tests	Cosmic test OK	10 Jul (run # 5135) at 9.4 kV with 5K triggers
3	RE*/2 KODEL Gas-gaps	4	OK	97.25	OK	RPC put back in the crate after tests	Cosmic test OK	10 Jul (run # 5126) at 9.4kV with 0.5K triggers
4	RE*/2 KODEL Gas-gaps	5	OK	98.40	OK	RPC put back in the crate after tests	Cosmic test OK	14 Jul (run # 5194) at 9.4kV with 5K triggers
5	RE*/2 KODEL Gas-gaps	6	OK Eff. upto 9.4 kV problem with HV ch # 5	97.00	OK	RPC put back in the crate after tests	Cosmic test OK	10 Jul (run # 5135) at 9.4 kV with 5K triggers
6	RE*/2 KODEL Gas-gaps	7	OK	98.60	OK	RPC put back in the crate after tests	Cosmic test OK	11 Jul (run # 5167) at 9.4 kV with 20K triggers
7	RE*/2 KODEL Gas-gaps	8	OK	95.80	OK	RPC put back in the crate after tests	Cosmic test OK	10 Jul (run # 5135) at 9.4 kV with 5K triggers
8	RE*/2 KODEL Gas-gaps	9	OK	96.80	OK	RPC in the cosmic hodoscope	Cosmic test OK 2 dead channels	11 Jul (run # 5167) at 9.4 kV with 20K triggers FEB changed on 14 Jul
9	RE*/3 GT Gas-gaps	10	Gas flow OK	--	--	RPC in the cosmic hodoscope	High current (in Mumbai too)	14 Jul
10	RE*/3 GT Gas-gaps	11	Gas flow OK	--	--	RPC in the cosmic hodoscope	High current (in Mumbai too)	14 Jul

Please note that RPC#3 does not exist in the above list of ten chambers delivered to CMS

2009-10: LHC startup year

- A new high energy collider is expected to come on-line in 2009, 20 years after the previous one, LEP, in 1989!
- Next many years will be very exciting, entering a new high energy regime.
- Certainly looking forward for new physics and discoveries after many years.

Thank you