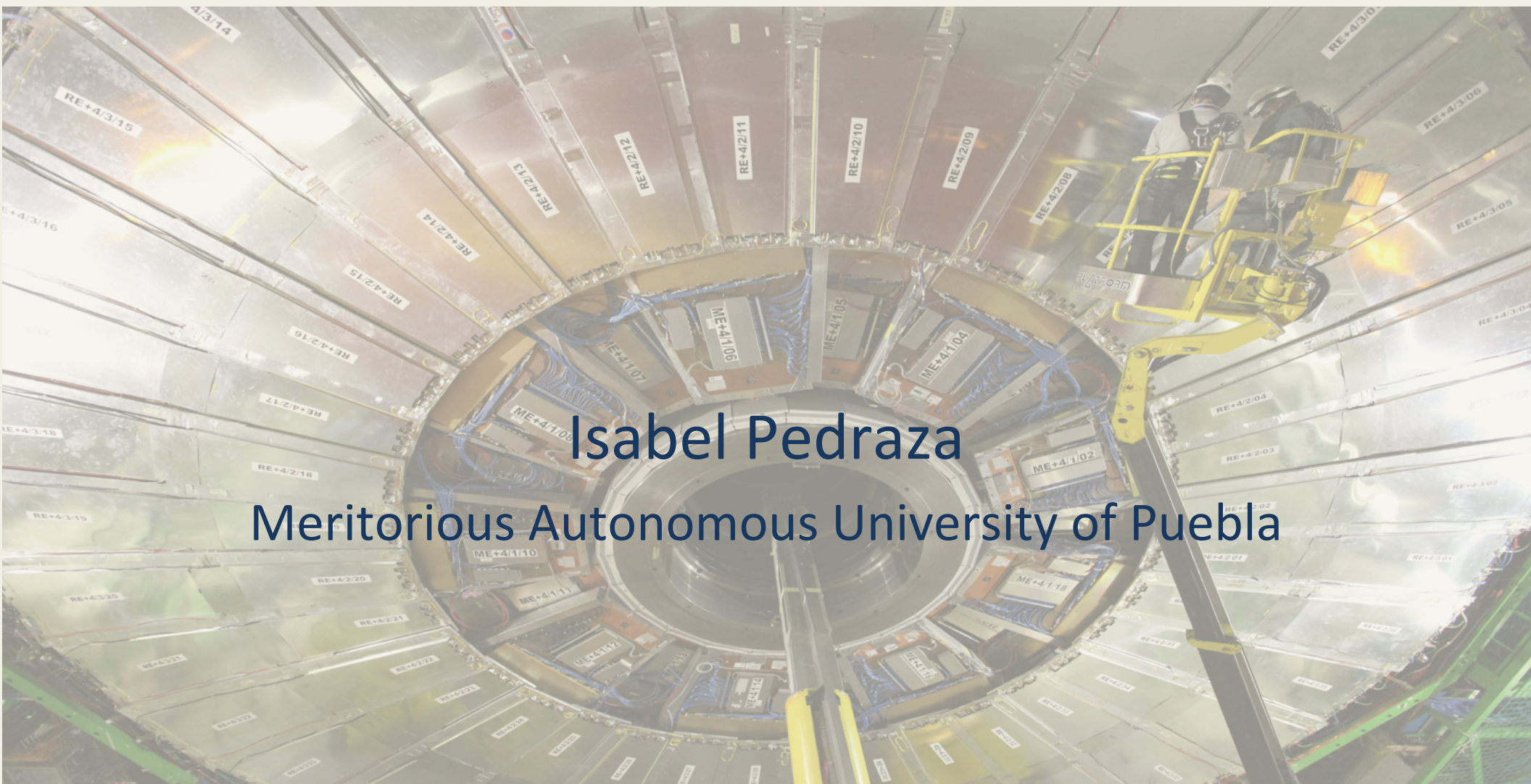


RPC Phase II Upgrade : Project Planning and Execution



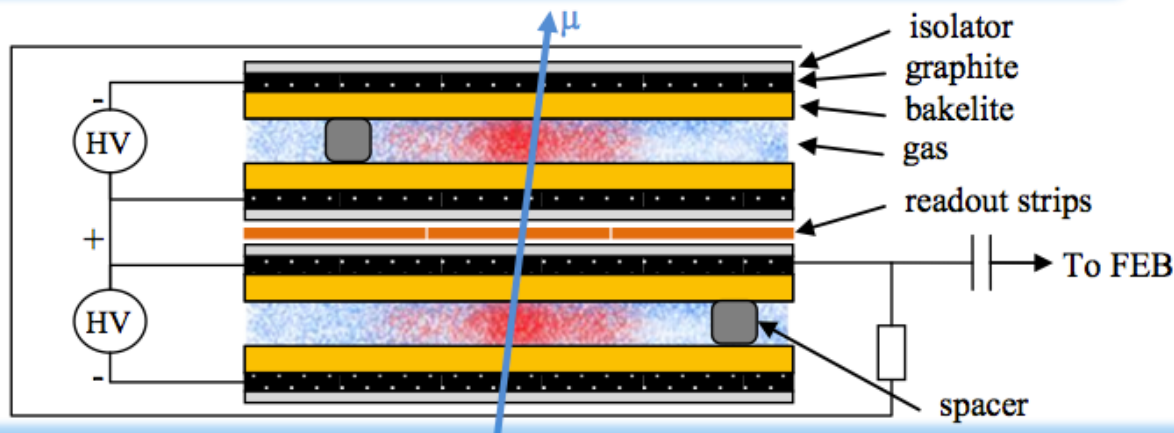
Isabel Pedraza
Meritorious Autonomous University of Puebla

Present RPC System

Robust, efficient and redundant muon system

RPC present system (with RE4 installed in LS1)

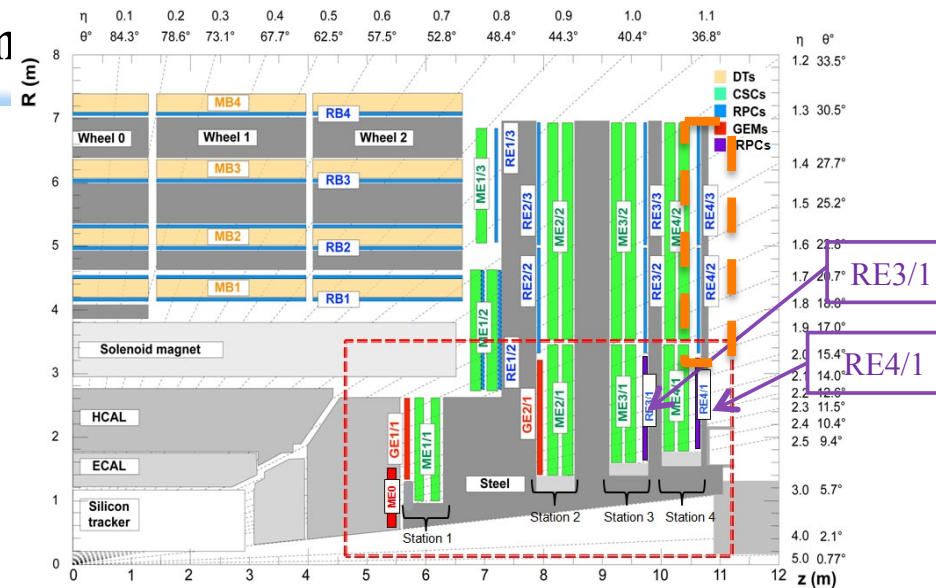
- Covers $0 < |\eta| < 1.6$
- **1056 chambers** (480 in barrel and 576 in endcap)
- 123688 **electronic channels** and 3950 m² **of active area**
- **Double gap chamber**: 2 mm gas width
- **Bakelite** bulk resistivity: $\rho = 2 - 5 \times 10^{10} \Omega\text{cm}$
- **Strip width**: 1 – 4 cm.
- **Gas mixture**: $\text{C}_2\text{H}_2\text{F}_4 + \text{isoC}_4\text{H}_{10} + \text{SF}_6$ (40% of H)
 95.2% 4.5% 0.3%
- Operated in **avalanche mode**



2015 data

Spatial resolution $\approx 1 \text{ cm}$
Time resolution $\approx 2 \text{ ns}$

Av. Electronic Noise $\sim 0.13 \text{ Hz/cm}^2$
Av. Efficiency $\sim 94\%$



CMS muon upgrade

- RPC system completion up to $|\eta| < 2.4$ **in phase 2**

μ RPC system priorities

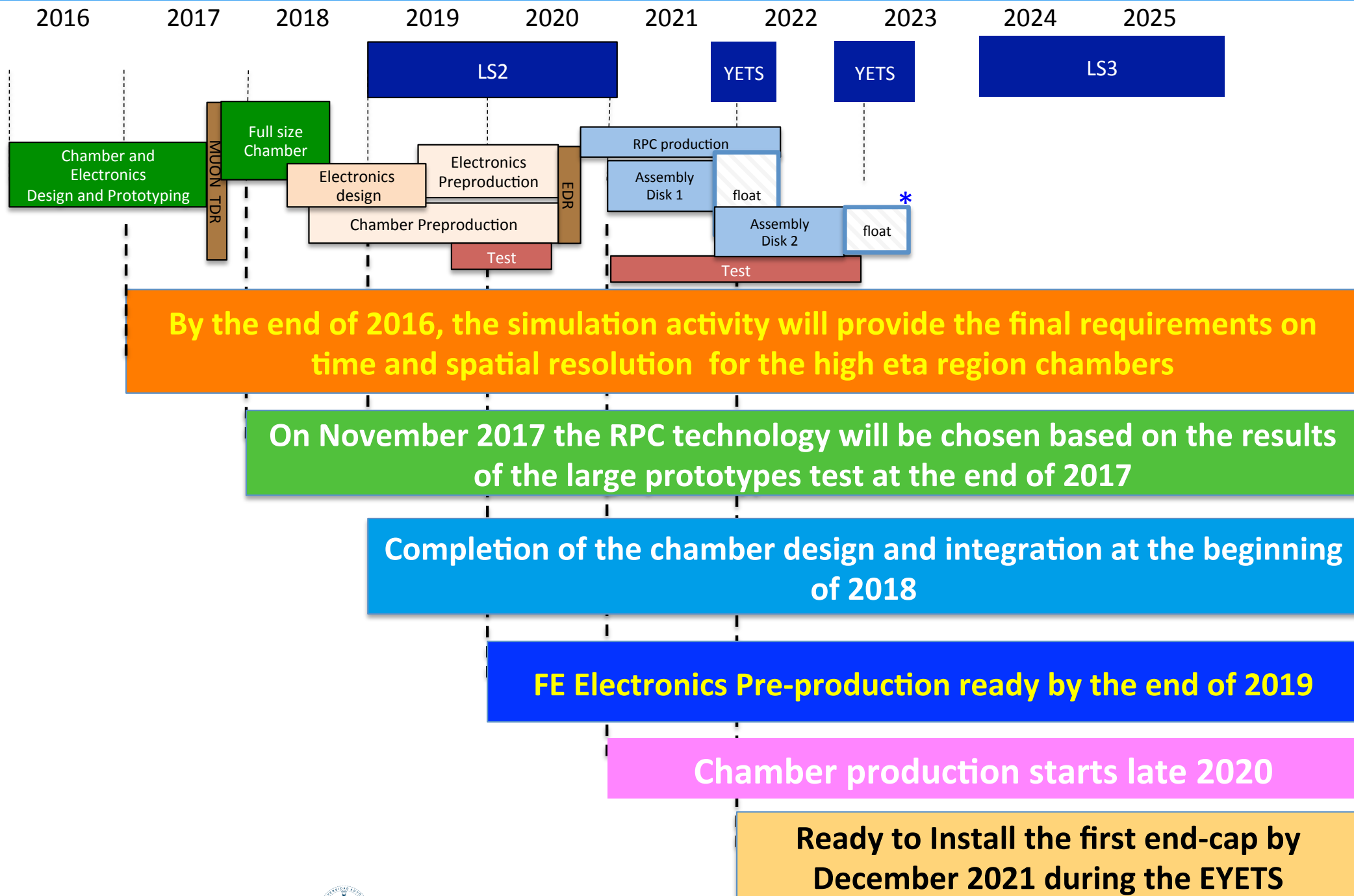
- μ Identification
- Triggering
- Improve High- p_T measurement (inner Tracker dominates up to $\sim 200 \text{ GeV}$)
- Displaced delayed muon reconstruction

Outline

In this talk the following charges for the first Comprehensive Review of the CMS Muon Phase II upgrade is described

- ❖ [charge 8] Time line up to the TDR, EDR, and ESR
- ❖ [charge 8] Project planning and milestones program up to TDR, EDR, ESR
- ❖ [charge 8] Strategy for design decision
- ❖ [charge 8] Draft of construction plan
- ❖ [charge 8] Resources

Project planning and milestones program up to TDR, EDR, ESR



High and Low level milestones up to EDR

High and Low level milestones	Due date	STAGE	YEAR		
RPC Assessment of performance of small prototype (LM)	December 15, 2016	Chamber and Electronics Desing and Prototyping	2016	LS2	
RPC mechanical design and integration in CMS (LM)	December 15, 2016				
RPC simulation: assessment of performance requirements from simulation (HM)	December 22, 2016				
RPC Power system specs ready for TDR (LV) (LM)	July 5, 2017		2017		
RPC FE design finalized (HM)	July 5, 2017				
RPC full size prototypes assembly procedure assessed (LM)	July 5, 2017				
RPC Review L1 and readout design done (LM)	July 5, 2017				
RPC Power system specs ready for TDR (HV) (LM)	August 29, 2017				
RPC full size and FE prototypes tested with beam: preliminary results for TDR (LM)	August 29, 2017				
MUON Technical Detector Review SUBMISSION (HM)	September 14, 2017	TDR			
RPC full size prototypes assembled and tested (LM)	December 5, 2017	Full size Chamber			
RPC Assessment of technology options (HM)	December 5, 2017				
RPC Chamber Cooling : Preliminary Design ready (LM)	December 6, 2017				
RPC Completion of Chamber design and integration (HM)	April 10, 2018	Electronics and Chamber Preproduction	2018		
RPC Chamber ready for pre-production (LM)	September 25, 2018				
			2019		
RPC FE design ready (LM)	February 18, 2019				
RPC L1 and readout desing ready (LM)	February 18, 2019				
RPC FE Close Market Survey (LM)	May 19, 2019				
RPC On-Chamber FE Electronics Pre-production Ready (LM)	December 27, 2019				
		2020			
RPC LV and HV Power Supply pre-production validated (LM)	May 27, 2020				
RPC Electronics System Review (HM)	October 22, 2020				
RPC Engineering Design Review (HM)	October 22, 2020	ESR EDR			

DATES	Beam Status	Goals
-------	-------------	-------

4/15/16 Lyon RE1/1 Chamber to test the CMS electronics at 904 and the RPC with Lyon Electronics for Consolidation

April 18, 2016	Test Beam GIF++ Main Users	Commissioning of DAQ and DCS systems
May 11, 2016		

Data Analysis and results

5/20/16 Lyon RE1/1 Chamber

May 25, 2016	Test Beam GIF++ / RD51	Rate capability study on small GRPC and backelite RPC
June 8, 2016		

Data Analysis and results

7/15/16 Tisinghua Multigap RPC

7/31/16 KODEL 2 Backelite RPC

August 10, 2016	Test Beam GIF++ / RD51	Performance study on MGPC and Backelite RPC (thinner gap & electrodes)
August 24, 2016		

Data Analysis and results

August 31, 2016	Test Beam GIF++ Main Users	Rate capability, test of petiroc, and time resolution
September 14, 2016		

Data Analysis and results

September 28, 2016	Test Beam GIF++ / RD51	Performance study on GRPC large prototype
October 12, 2016		

Data Analysis and results

December 15, 2016 RPC Assesment of performance of small prototype (LM)

December 15, 2016 RPC Review of the mechanical design and integration in CMS (LM)

December 22, 2016 RPC assessment of performance requirements from simulation (HM)

RPC R&D at GIF++ in a HL-LHC like environment



Clear calendar of test and expected results for the different prototypes and configurations

Service	Weeks	Installation LS2 Period
HV Umbilical cables	4	RE+: W16-17 RE-: W47-48
HV power cables	4	RE+: W18-19 RE-: W49-50
LV power cables	4	RE+3/1: W51 RE+4/1: W57 RE-3/1: W38 RE-4/1: W44
DCS cables		
LVDS signal cables		
Gas copper pipes	2	RE+: W17 RE-: W48
Supply Gas copper pipes	4	RE+3/1: W50 RE+4/1: W39-40 RE-3/1: W37 RE-4/1: W20-21
Return Gas copper pipes		

❖ All RE3/1 & RE4/1 service installation activities.

CMX

ZEC

CSC RE

DT+ RB

TK FPIX

Survey

HCAL

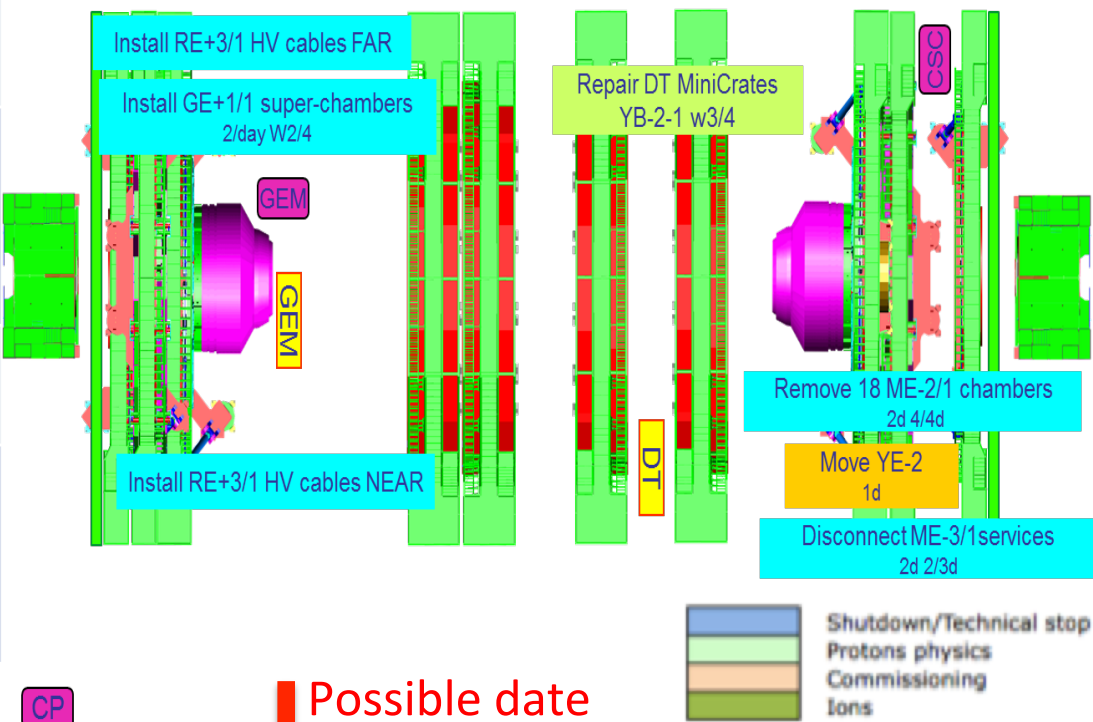
TE-VSC

EN Dept

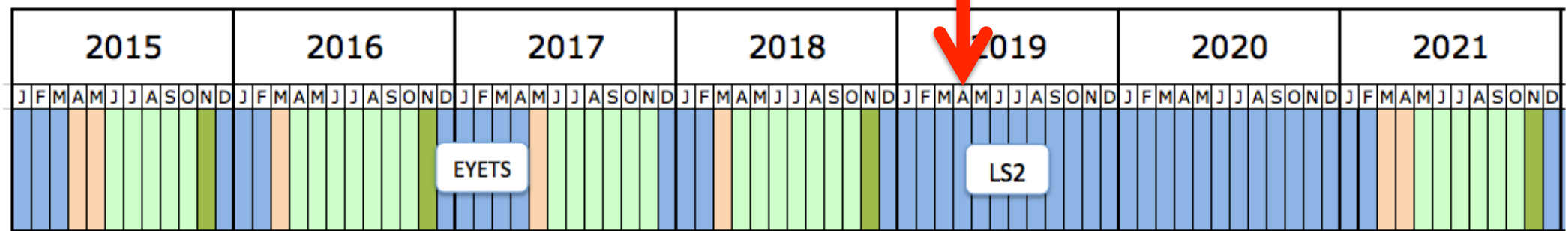
GS Dept

RP

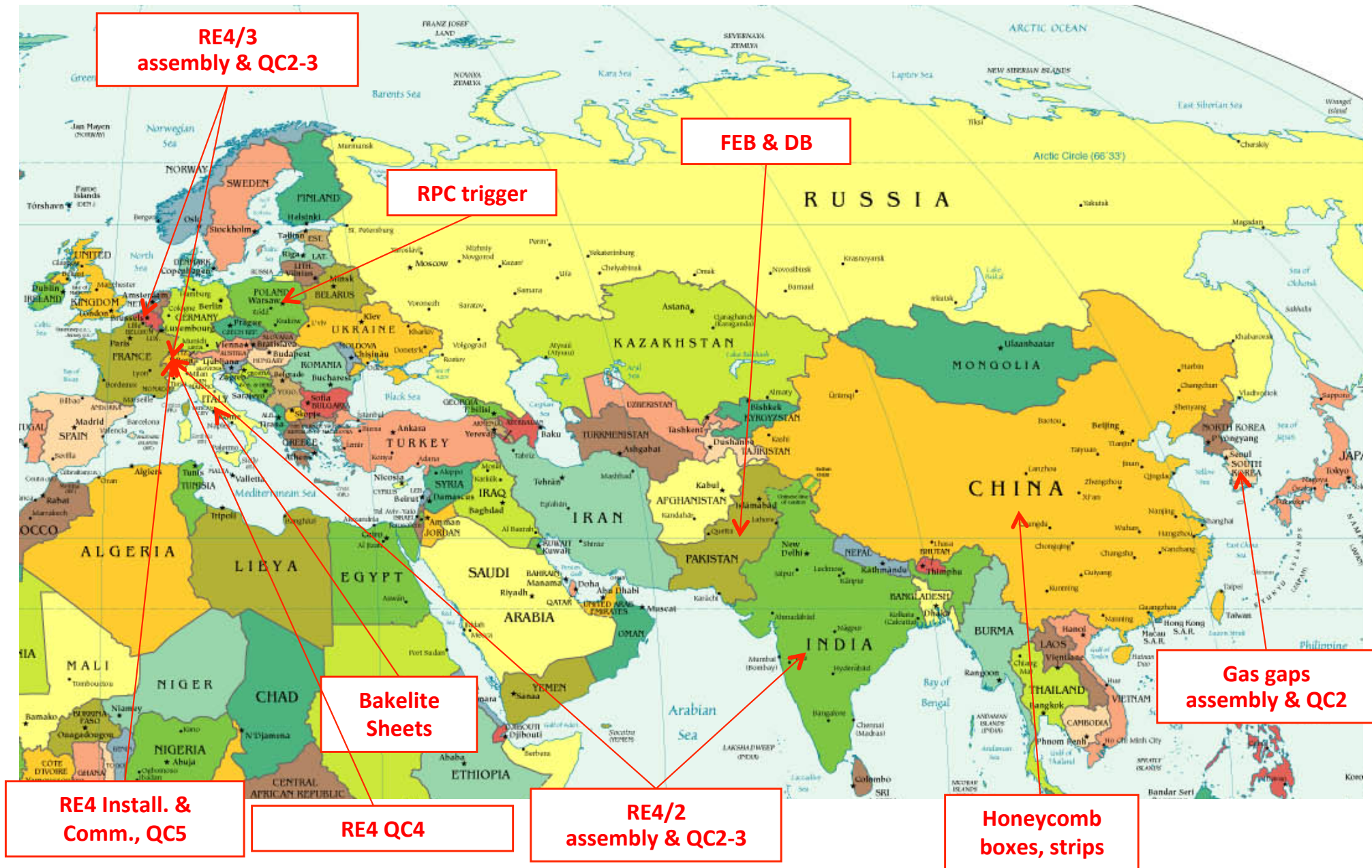
Week 18



CP Possible date



Experience with RE4 Production (ended 2014)



Lessons learned

- Effective interaction with the industry.
- Successful overseas collaboration.
- Meetings every week.
 - Very different time zones
- Day by day calendar of activities.
- Shipments and product safety protocols established.
- Well defined quality controls and acceptance thresholds on components and chambers performance

GTM-6
GMT+1 → Geneva
GMT+8
GMT+9

[CHARGE 8] DRAFT OF CONSTRUCTION PLAN

Draft of construction flow

Slightly modifications can be expected

QC1
(components)

Electrode Production HPL/Glass Production site:

- Panel Cut, surface inspection, polishing (HPL).
- Thickness, roughness, color, labeling/DB, signal cable (Glass)

Chamber Elements Production. At Assembly sites:

- Front End Boards (FEB) testing.
- Cooling system, mechanics and readout strip testing.

QC2
(RPC gaps)

Gaps Production. At Assembly sites :

- Visual Inspection, Gas tightness and spacer test
- Electrical and dark current, resistivity measurement (sample)

QC3
(RPC chambers)

Chamber Assembly. At sites :

- Visual Inspection, Gas tightness, Electrical and dark current
- Connectivity test, Cosmic muon commissioning

QC4
(Final Chamber Test)

At CERN final chamber tests:

- Detector acceptance for CMS
 - Leak test, Connectivity, Cooling circuit tests, Long term detector operation at Working Point, Electric and dark current tests

Electrodes and Gap Production

Chamber production starts late 2020

Production and Qualification of HPL and Gaps

Experience on process reliability and object inside specification ranges from RE4-3/2

Production at Puricelli (Milan)

1

Electrodes Quality Control at INFN (Pavia)

2

Panel cut at RIVA (Milan)

3

Surface cleaning at General-Tecnica (Frosinone)

4

Gap Production (Kodel, Korea)

5

Gap Quality Control (Kodel, Korea)

6



**Puricelli production site
in Costamasnaga
(Milan, Italy)**

Gap assembly tool



**Korea University facility
for gluing and oiling**

Electrodes and Gap Production

Glass RPC (New for CMS) : Production and Qualification

- Multi glass RPC are already under construction by the same group for the CBM (Compressed Baryonic Matter) Experiment

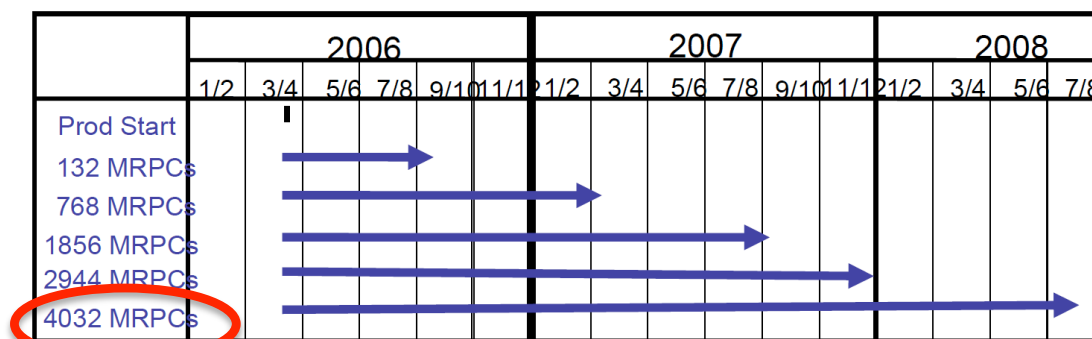
Production at China (Nuctech and Tsinghua)

1

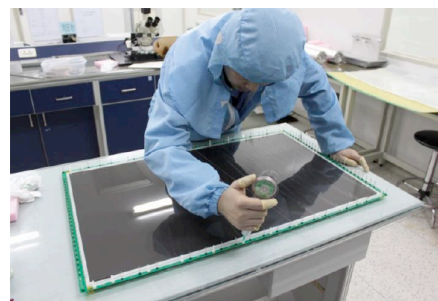
Mass production
yields $>100\text{m}^2/\text{month}$

Electrodes and gap Quality Controls
(Nuctech, Tsinghua)

2



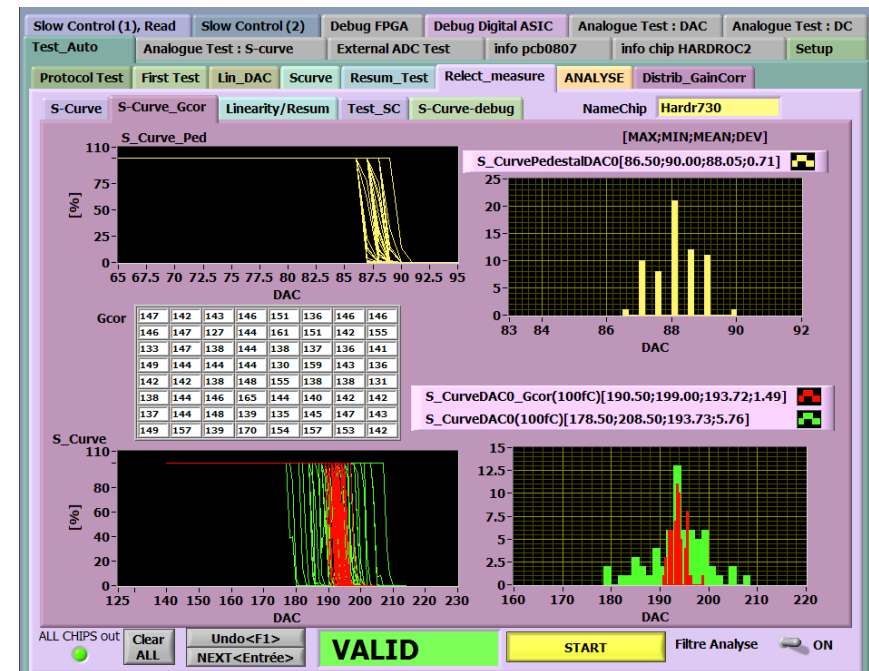
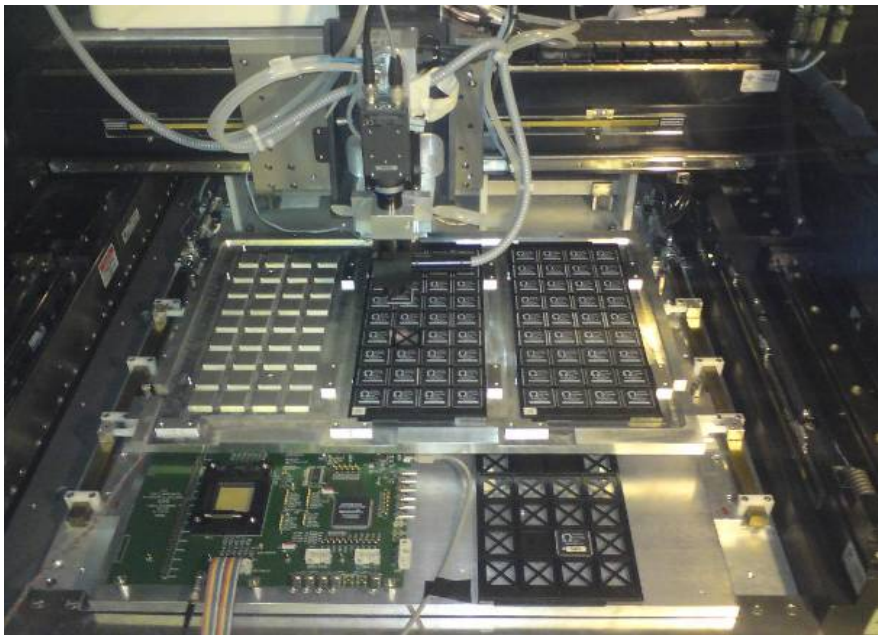
Experience :
**More than 4K
mgaps produced**



The "TUMUTY" (Tsinghua University Muon Tomography)

*<http://www.nuctech.com/en/index.aspx>

- ❑ ~10 500 chips produced and tested at IPNL Lyon for the SDHCAL project (2 months).
- ❑ Dedicated Labview program, USB interface, testboard, programmable generator (GPIB), precise multimeter (Keithley)



- ❑ Measurement of the DC levels and power consumption
- ❑ Test of the Slow Control loading
- ❑ DACs linearity

- ❑ Trigger efficiency measurement
 - ❑ Pedestal for the 3 shapers
 - ❑ 100 fC trigger efficiency measurement for fsb0 + gain correction for each channel
 - ❑ 1 pC trigger efficiency measurement for fsb1 and fsb2

Chamber assembly and test



Cosmic stand at GHENT

- Expect to have more than one assembly and test sites
- There are experienced people in several sites within the RPC collaboration
- Still operational infrastructure for assembly and cosmic test facilities in several sites.
- Recent refurbished RPC laboratory at Prévessin in 904 building.
Cosmic stand and the infrastructure for the stability tests ready.

INSTALLATION

Experience from RE4-2/3

- RE4-2/3 (144 Chambers) is twice the production of RE4-1/3-1 (72).
- The installation negative end-cap end of December 2014.



Preliminary installation schedule

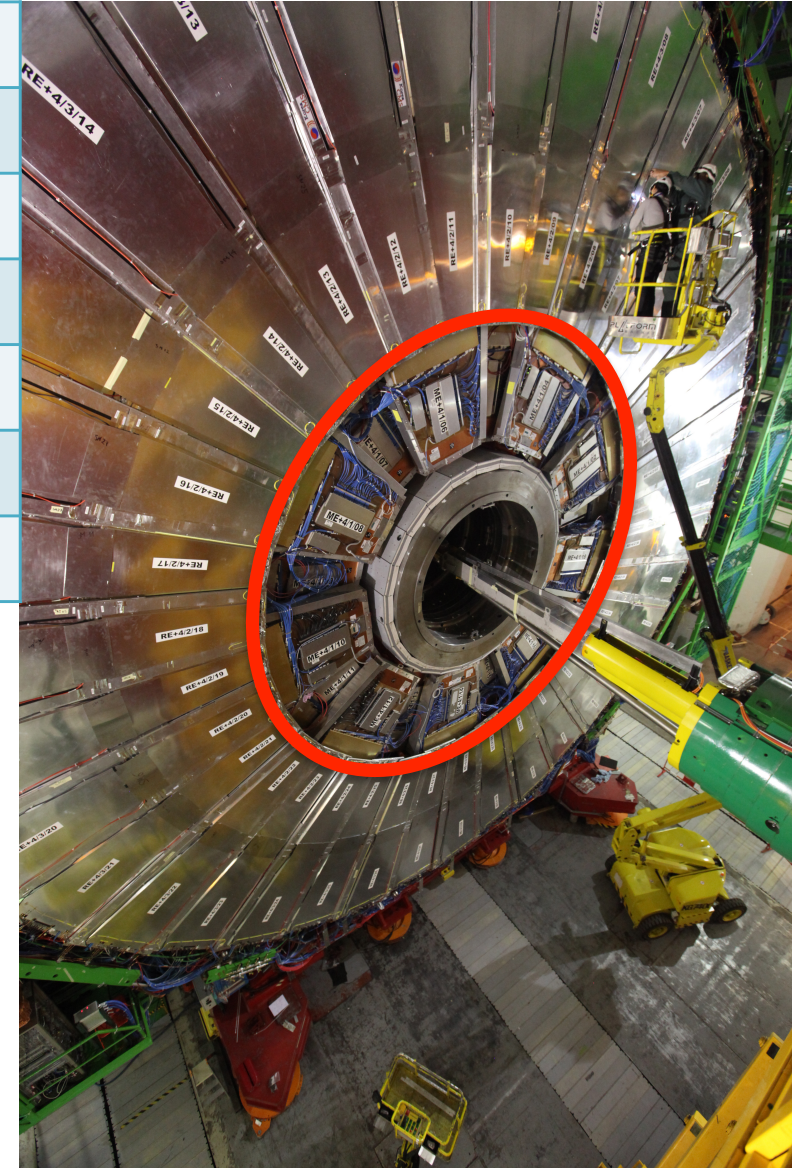
For disk of RE3/1 or RE4/1

Action	Days
Crane needed	Full time
18 (of 72) chambers installed	3
Cable (HV/LV,Signal)	3
Cooling and commissioning at 18 bar with gas	4
Gas	3
Final chamber commissioning	7

**Total installation/commissioning time
~ 3 weeks (including w.e.)**

Job on different disks can be parallelised if
manpower available.

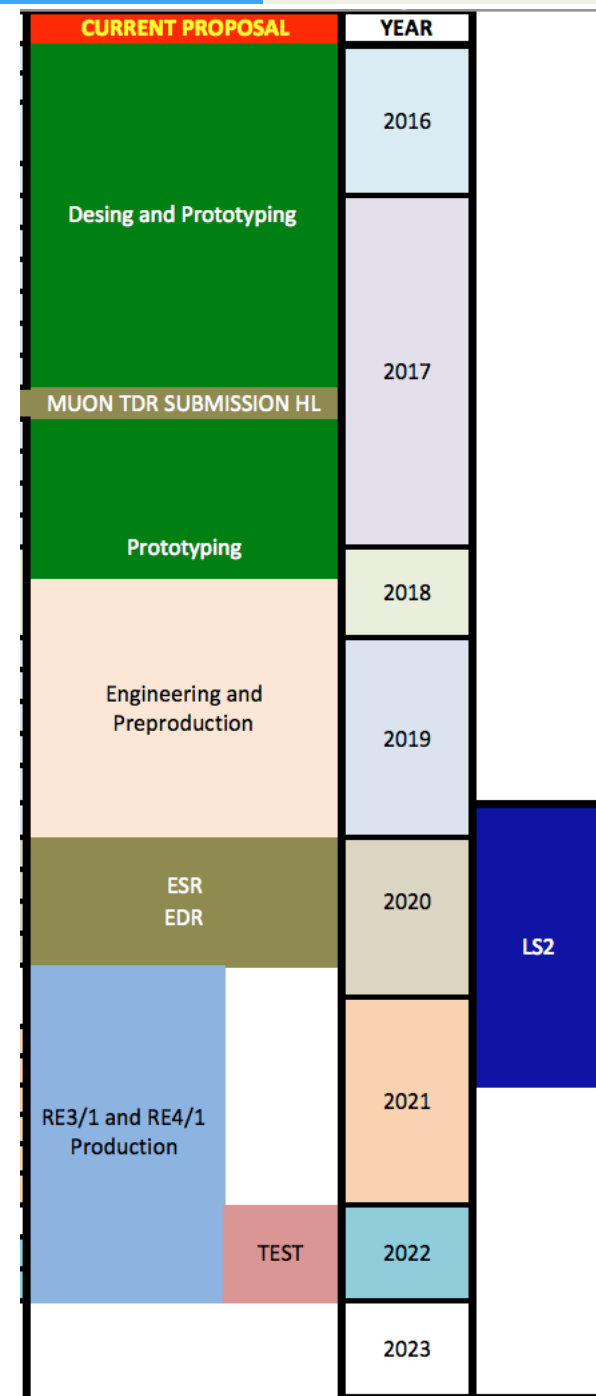
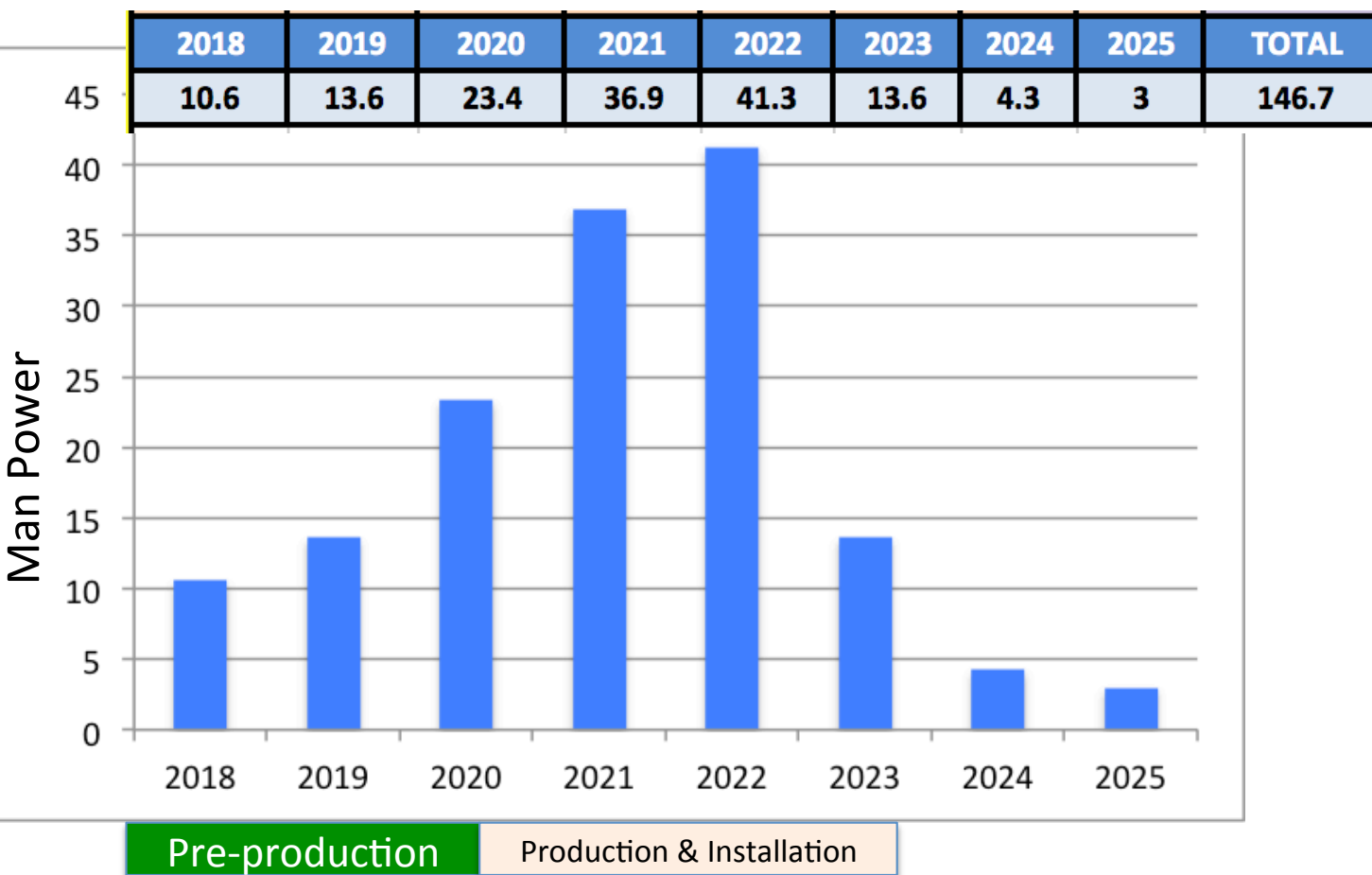
Services installed during LS2 and/or EYETS
Chambers to be installed 1-2 disks during EYETS



DRAFT OF RESOURCES

Expected resources needed: Man power

[charge 8]

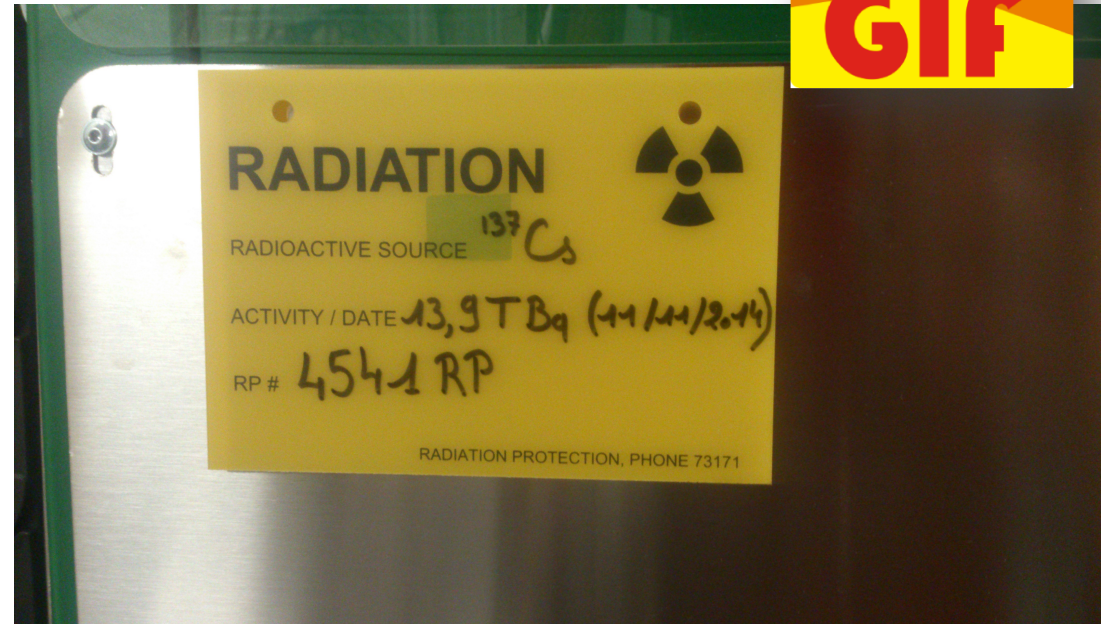


2015 - 19 People

- ✓ Hardware installation and development and commissioning of DAQ, DCS, DQM at GIF++

2016 - 19 people

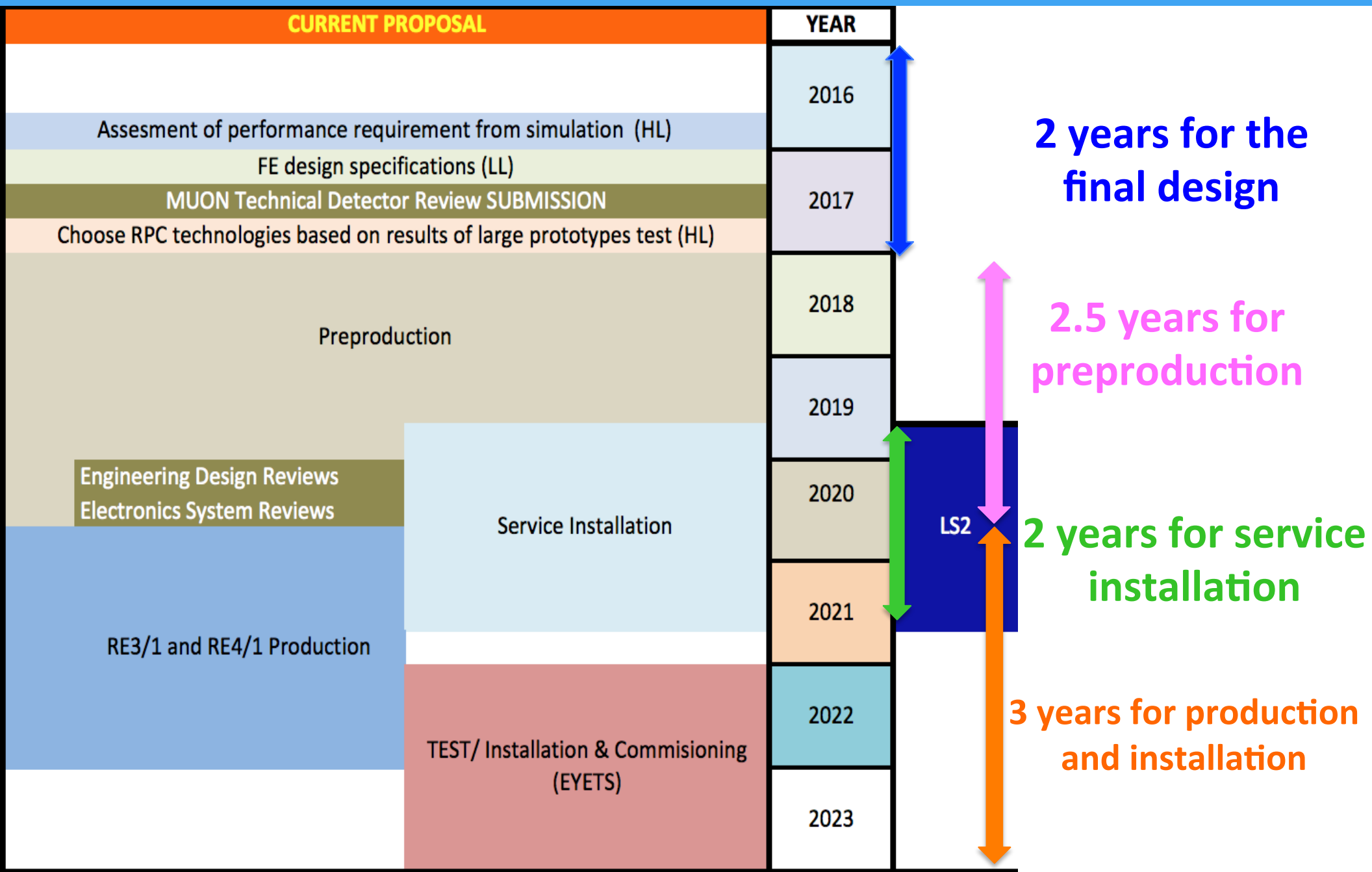
- Test Beam, WebDCS and Offline Data Analysis
- ❖ Test beam outside GIF++



Currently all the institutions interested on the RE4-1/3-1 constructions are actively involved in the GIF++ activities.

GIF++ activities are the starting point for the new institutions that will join the construction and the operations

RPC Timeline and installation plans



Conclusions

- Resources and planning have been established.
- Expected time line :
 - Final performance requirements from simulation end of 2016
 - Mechanical design and integration end of 2016
 - FE design specifications first quarter of 2017
 - Choose RPC technologies based on results of large prototype end of 2017
 - Start pre-production in 2018
 - Service installation in LS2
 - EDR and ESR 2020
 - Production Starts at the end of 2020
 - Installation in EYETS 2022-2023
- The relative cost impact of the different options has been estimated.
- ***We are following a very well consolidated schema of production, test and quality control applied recently for the RE4 construction***

Backup

Current members of the RPC community

[charge 8]



Bari	Ghent	Peking	Tiblisi-IHEPI	Uniandes	Lyon
Napoli	Sofia Univ.	Korea Univ.	New Deli	Nueva Puebla	Tsinghua
LNF	Sofia INRE	SKK Univ.	BARC	Iberoame ricana	Hanyang Univ
Pavia	CERN	Asrt-Enhep	Islamabad - NCP	Chandiga r	(Cinvestav)



13 countries – 23 institutions



Description	Start date
RPC Simulation	01/01/16
RPC Simulation: Local reconstruction	01/01/16
RPC simulation: Sensitivity and hit rate simulation for iRPC detectors	01/01/16
RPC simulation: Adding additional features to RPCDigi (2D position, precise timing, etc.)	01/01/16
RPC simulation: Parallel pseudo-digitization to study the spatial and time resolution of iRPCs	01/01/16
RPC simulation: Adding additional features to reconstructed hit (2D position, precise timing, etc.)	29/04/16
RPC simulation: Development of new digitization model to accommodate different detector technologies (precise timing, 2D strip readout, readout from both sides)	27/05/16
RPC simulation: Developing of new local reconstruction algorithm to work with the new digis (precise timing, TOF information, 2 D readout, etc.)	28/07/16
RPC simulation: Implementation of new detector geometries and realistic digitization	30/09/16
RPC simulation: integration of local reconstruction in the STA muon reconstruction and RPCmuon	24/11/16
RPC simulation: assessment of performance requirements from simulation (HM)	22/12/16

The simulation activity will provide the requirements for the high eta region chambers by the end of 2016

Description	Start date
RPC Developments	01/01/16
RPC Chamber R&D	01/01/16
RPC: Small prototype tests	01/01/16
RPC test with beam and irradiation at GIF++	01/01/16
RPC Assessment of performance of small prototypes (LM)	15/12/16
RPC mechanical design and integration in CMS (LM)	15/12/16
RPC full size prototypes assembly	04/01/17
RPC: full size prototype tests	12/04/17
RPC full size prototype test in lab	12/04/17
RPC full size prototype test at GIF++, beam test	10/05/17
RPC full size prototypes and FE prototypes tested with beam: preliminary results for TDR (LM)	29/08/17
RPC full size prototypes assembly procedure assessed (LM)	05/07/17
RPC full size prototypes assembled and tested (LM)	05/12/17
RPC Assessment of technology options (HM)	05/12/17

Choose RPC technologies based on results of large prototypes test at the end of 2017

Description	Start date
RPC FE developments	24/03/16
RPC FE	24/03/16
RPC FE prototypes design and developments	24/03/16
RPC PCB prototypes design and production	24/03/16
RPC FE prototypes validation with chamber in lab	12/04/17
RPC FE design finalized (HM)	05/07/17
RPC Back-End Systems Developments	24/03/16
RPC Trigger/Readout Development	24/03/16
RPC Review of L1 and readout design	24/03/16
RPC First Review of L1 and readout design done (LM)	15/06/16
RPC First L1 and readout design	15/06/16
RPC Second Review L1 and readout design done (LM)	05/07/17
RPC Power distribution Development	05/07/17
RPC Power system specs ready for TDR (LV) (LM)	05/07/17
RPC Power system specs ready for TDR (HV) (LM)	29/08/17
RPC Chamber Cooling	05/07/17
RPC Chamber Cooling: system design	05/07/17
RPC Chamber Cooling: Demo circuit built	30/08/17
RPC Chamber Cooling: Preliminary Design ready (LM)	06/12/17
RPC final prototype assembly	05/12/17
RPC Completion of chamber design and integration (HM)	10/04/18
RPC: final prototype tests	11/04/18
RPC final prototype tests in the lab	11/04/18
RPC final prototype test with beam at GIF++	08/05/18
RPC Longevity studies from irradiation tests for final prototype	25/09/18

FE design specifications by the beginning of 2017

Description	Due date
RPC Pre-production	05/07/17
RPC FE pre-production	05/07/17
RPC FE proto design	05/07/17
RPC FE design ready (LM)	18/02/19
RPC FE market survey	18/02/19
RPC FE Selection of companies	18/02/19
RPC FE Close Market Survey (LM)	19/05/19
RPC FE pre-production submission	20/05/19
RPC FE pre-production testing	01/11/19
RPC FE pre-production final validation at irradiation facilities (GIF++, reactors etc)	01/11/19
RPC On-Chamber FE Electronics Pre-production Ready (LM)	27/12/19
RPC Back-end System pre-production	05/07/17
RPC L1 and readout design	05/07/17
RPC Power Supply pre-pre-production	18/02/19
RPC LV and HV Power Supply pre-production design	18/02/19
RPC LV and HV Power Supply pre-production order	08/07/19
RPC LV and HV Power Supply pre-production testing	30/09/19
RPC LV and HV Power Supply pre-production validated (LM)	27/04/20
RPC L1 and readout design ready (LM)	18/02/19
RPC L1 and readout demo development	18/02/19
RPC L1 and readout pre-production submission	14/04/20
RPC L1 and readout pre-production testing	01/09/20
RPC L1 and readout pre-production Ready (LM)	23/11/20
RPC Chamber pre-production	25/09/18
RPC Chamber ready for pre-production (LM)	25/09/18
RPC Chamber Pre-production assembly	26/09/18
RPC Chamber Pre-production tests	28/03/19
RPC Chamber Pre-production tests with pre-production electronics	28/04/20
RPC Pre-production Chamber and Electronics Ready (HM)	23/11/20

Pre-production is expected to start at the beginning of 2018

Production & Installation Activities

[charge 8]

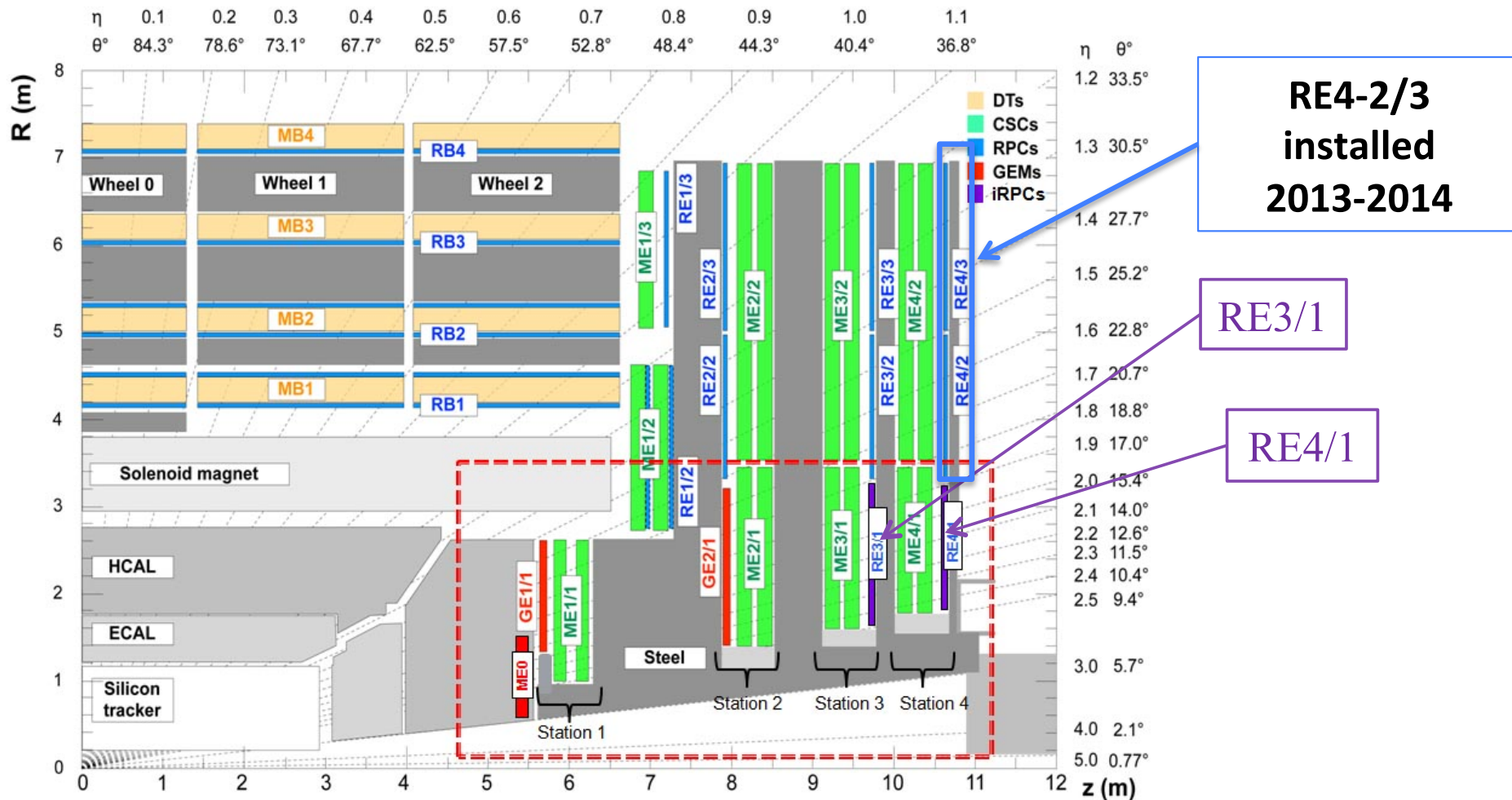
Description	Start date
RPC Production and commissioning	24/11/20
RPC FE Production	24/11/20
RPC On-chamber Electronics (FE) Production and testing	24/11/20
RPC On-chamber Electronics (FE) ready (HM)	11/05/21
RPC Chamber Production	24/11/20
RPC Chamber PRR	24/11/20
RPC Chamber Production and QC 1-2	07/12/20
RPC Back-end System Production	24/11/20
RPC Back-end Electronics Production and testing	24/11/20
RPC Back-end Electronics ready (HM)	01/02/22
RPC Chambers Ready for Assembly Endcap 1 (HM)	13/04/21
RPC Detector with On-chamber Electronics Assembly, Testing and QC 3-4 Endcap 1	14/04/21
RPC Chambers Ready for Assembly Endcap 2 (HM)	07/12/21
RPC Detector with On-chamber Electronics Assembly, Testing and QC 3-4 Endcap 2	08/12/21
RPC installation	25/03/19
RPC Services installation Disk+1 in LS2 shutdown (EM)	25/03/19
RPC Services installation Disk-1 in LS2 shutdown (EM)	01/10/19
RPC Detector Ready for Installation Endcap 1 (HM)	07/12/21
RPC Installation time window from TC Endcap 1	08/12/21
<i>RPC Installation date from TC Endcap 1 (RM)</i>	22/03/22
RPC Detector Ready for Installation Endcap 2 (HM)	06/12/22
RPC Installation time window from TC Endcap 2	07/12/22
<i>RPC Installation date from TC Endcap 2 (RM)</i>	31/03/23

Chamber production starts late 2020
Installation expected during the EYES in 2022 & 2023

Overview

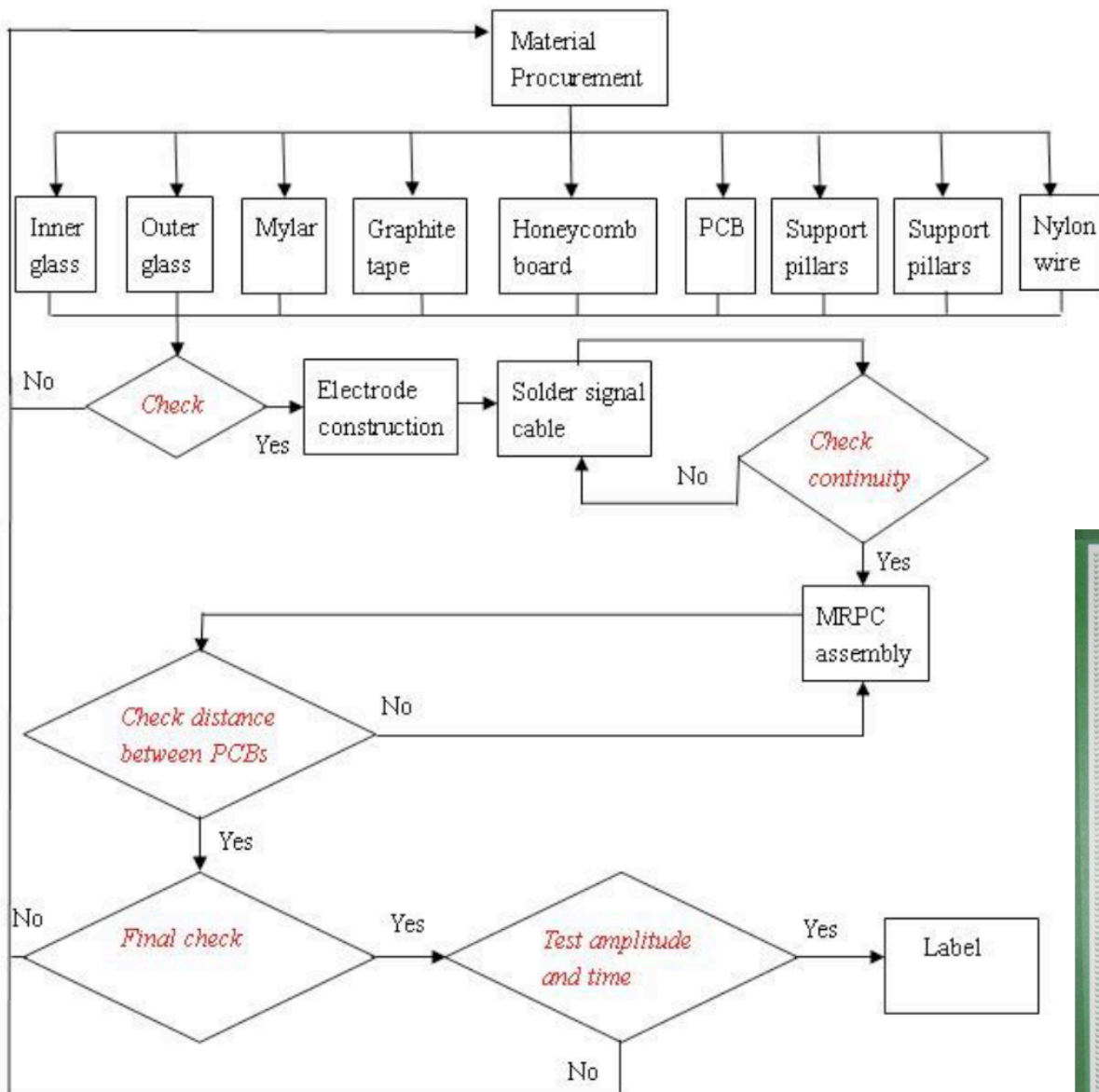
New RPC chambers = “improved” RPC (iRPC):

covering $1.8 < |\eta| < 2.5$; each chamber spans 20° in ϕ



All existing chambers are double gap backelite.

Procedures of construction and QC for MGRPC



6S criterion, **ISO 9000** and **14000** standards are also carried out in MRPC production.

ISO14001

ISO9001



About Nuntech

Manufacturing Ability

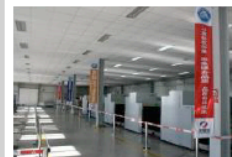
Located in the northeast part of Beijing, the base is 80km away from Tsinghua, which includes

- Accelerator Workshop
- Electronic Workshop
- Assembly Workshop
- Customer Training Center
- ...

The base is equipped with advanced manufacture, installation and testing facilities along with scientific management. The main functions of the base are

- Manufacture
- System research and development
- Professional Customer training

Over 80,000m² Plant Building



01

University of Technology, Austria

RE3/1 & RE4/1 Service Installation

❖ All RE3/1 & RE4/1 service installation activities are well planned and scheduled in the CMS LS2 planning.

Power System Component	Total Quantity	Length/ Diam [m/mm]	Start Point	End Point	Cable chain occupancy	Service Installation Duration	Installation LS2 Period
HV Umbilical cables	8	~90/40	S1H*	X1 YE1 HV PP	Main CC	2 weeks per end	RE+: W16-17 RE-: W47-48
HV power cables	72	~30/6	X1 YE1 HV PP	chambers	18 cables per mini CC	2 weeks per end	RE+: W18-19 RE-: W49-50
LV power cables	72	~15/10	towers	chambers	no	1 week per station & end	RE+3/1: W51 RE+4/1: W57 RE-3/1: W38 RE-4/1: W44
DCS cables	72	~15/5					
LVDS signal cables	1440	~15/10					
Gas copper pipes	4	~110/12	S1L* tbc	X2A51 X2S51	Main CC	1 week per end	RE+: W17 RE-: W48
Supply Gas copper pipes	24	~20/6	X2A51 X2S51	chambers	no	1 week per station & end	RE+3/1: W50 RE+4/1: W39-40 RE-3/1: W37 RE-4/1: W20-21
Return Gas copper pipes	24	~20/8					
Cooling	tbc				no		

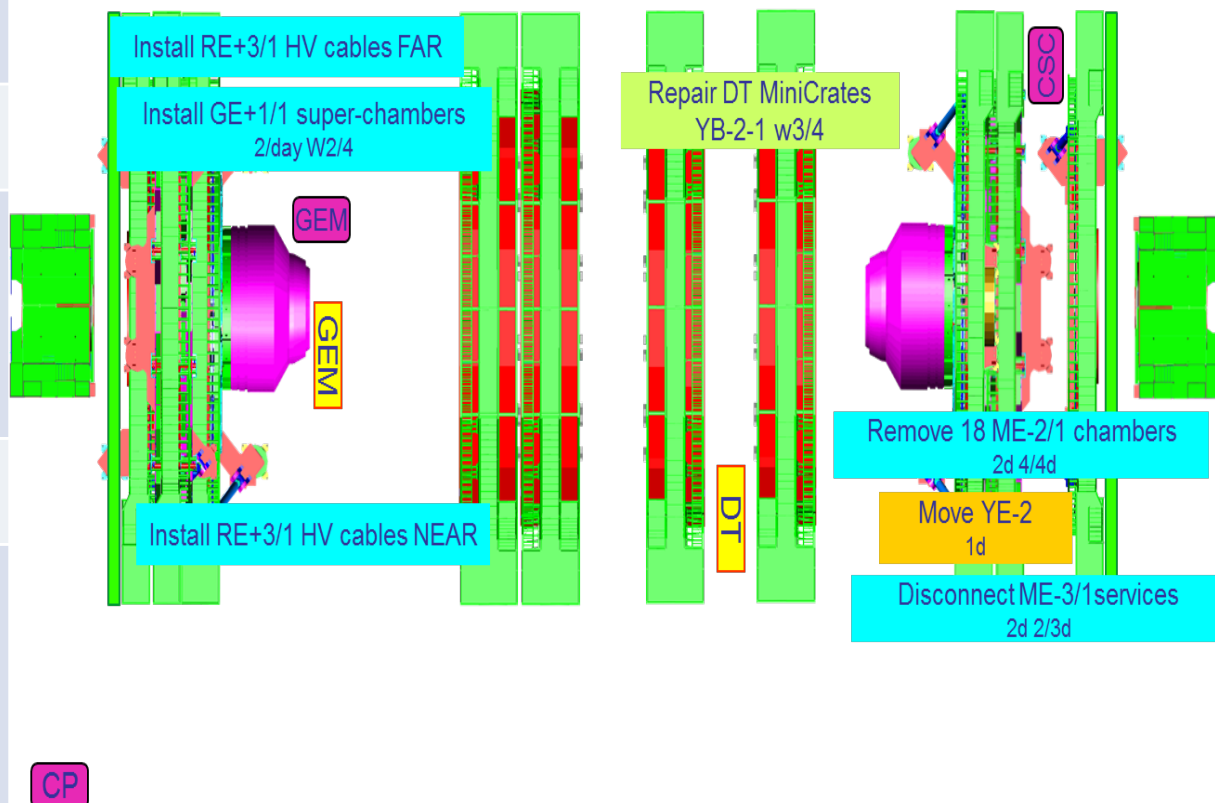
RE3/1 & RE4/1 Service Installation

❖ All RE3/1 & RE4/1 service installation activities are well planned and scheduled in the CMS LS2 planning.

W18

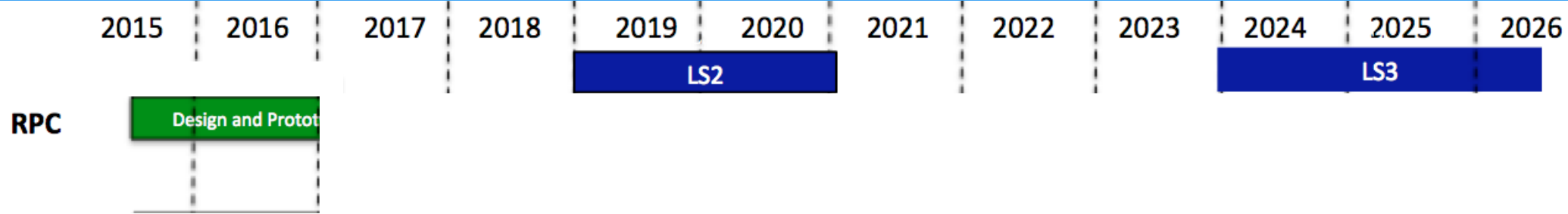
Power System Component	Total Quantity	Service Installation Duration	Installation LS2 Period
HV Umbilical cables	8	2 weeks per end	RE+: W16-17 RE-: W47-48
HV power cables	72	2 weeks per end	RE+: W18-19 RE-: W49-50
LV power cables	72	1 week per station & end	RE+3/1: W51 RE+4/1: W57 RE-3/1: W38 RE-4/1: W44
DCS cables	72		
LVDS signal cables	1440		
Gas copper pipes	4	1 week per end	RE+: W17 RE-: W48
Supply Gas copper pipes	24	1 week per station & end	RE+3/1: W50 RE+4/1: W39-40 RE-3/1: W37 RE-4/1: W20-21
Return Gas copper pipes	24		
Cooling	tbc		

CMX ZEC CSC RE DT+ RB TK FPIX Survey HCAL TE-VSC EN Dept GS Dept RP



High and Low level milestones	Due date	STAGE	YEAR	
RPC Assessment of performance of small prototype (LM)	December 15, 2016	Chamber and Electronics Desing and Prototyping	2016	
RPC mechanical design and integration in CMS (LM)	December 15, 2016			
	December 22, 2016			
RPC simulation: assessment of performance requirements from simulation (HM)			2017	
RPC Power system specs ready for TDR (LV) (LM)	July 5, 2017			
RPC FE design finalized (HM)	July 5, 2017			
RPC full size prototypes assembly procedure assessed (LM)	July 5, 2017			
RPC Review L1 and readout design done (LM)	July 5, 2017			
RPC Power system specs ready for TDR (HV) (LM)	August 29, 2017			
	August 29, 2017			
RPC full size and FE prototypes tested with beam: preliminary results for TDR (LM)				
MUON Technical Detector Review SUBMISSION (HM)	September 14, 2017	TDR		
RPC full size prototypes assembled and tested (LM)	December 5, 2017	Full size Chamber		
RPC Assessment of technology options (HM)	December 5, 2017			
RPC Chamber Cooling : Preliminary Design ready (LM)	December 6, 2017			
RPC Completion of Chamber design and integration (HM)	April 10, 2018	Electronics and Chamber Preproduction	2018	
RPC Chamber ready for pre-production (LM)	September 25, 2018			
RPC FE design ready (LM)	February 18, 2019			
RPC L1 and readout desing ready (LM)	February 18, 2019			
RPC FE Close Market Survey (LM)	May 19, 2019			
RPC On-Chamber FE Electronics Pre-production Ready (LM)	December 27, 2019			
			2019	
RPC LV and HV Power Supply pre-production validated (LM)	May 27, 2020			
RPC Electronics System Review (HM)	October 22, 2020	ESR	2020	
RPC Engineering Design Review (HM)	October 22, 2020	EDR		
RPC L1 and readout pre-production ready (LM)	November 23, 2020			
RPC Pre-production Chamber and Electronics Ready (HM)	November 23, 2020			
		RE3/1 and RE4/1 Production & Installation		
RPC Chambers Ready for Assembly Endcap 1 (HM)	April 13, 2021		2021	
RPC On-Chamber Electronics(FE) ready (HM)	May 11, 2021			
RPC Chambers Ready for Assembly Endcap 2 (HM)	December 7, 2021			
RPC Back-end Electronics ready (HM)	February 1, 2022			
RPC Detector Ready for Installation Endcap 1 (HM)	December 7, 2021			
RPC Detector Ready for Installation Endcap 2 (HL)	December 6, 2022		TEST	2022
				2023
		Instalation & Commissioning		2024
				2025
				2026

Design and Prototyping : Simulation Milestones

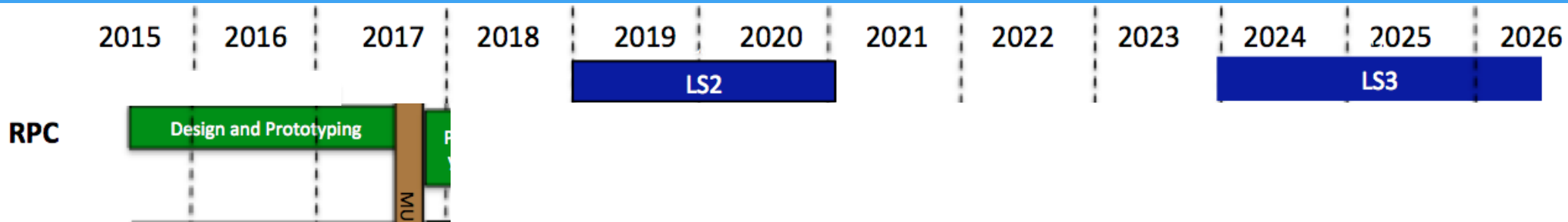


2016 mainly dedicated to simulation studies

RPC First Review of L1 and readout design done (LL)	LL		June 15, 2016
RPC Assessment of performance of small prototype FE (LL)	LL		December 15, 2016
RPC simulation: assessment of performance requirements from simulation (HL)		HL	December 22, 2016
RPC mechanical design and integration in CMS (LL)	LL		December 15, 2016

By the end of 2016, the simulation activity will provide the requirements on time and spatial resolution for the high eta region chambers

Design and Prototyping : Development milestones



2017 mainly dedicated to test the prototypes

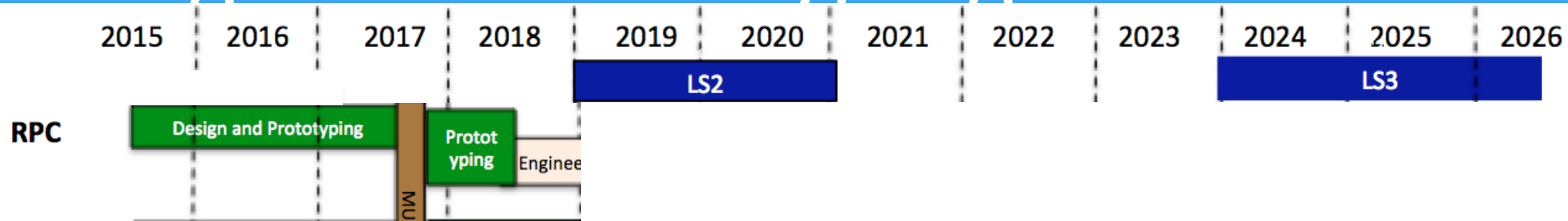
RPC Power system specs ready for TDR (LV) (LL)	LL		June 23, 2017
RPC FE design finalized (LL)	LL		June 23, 2017
RPC full size prototypes assembly procedure assessed (LL)	LL		June 23, 2017
RPC Second Review L1 and readout design done (LL)	LL		June 28, 2017
RPC Power system specs ready for TDR (HV) (LL)	LL		August 17, 2017
RPC full size prototypes tested with beam: preliminary results for TDR (LL)	LL		August 17, 2017
RPC full size prototypes assembled and tested (LL)		LL	November 23, 2017
RPC Assessment of technology options (HL)		HL	November 23, 2017

On November 2017 the RPC technology will be chosen based on the results of the large prototypes test at the end of 2017

FE design specifications by the beginning of 2017

Design and Prototyping

[charge 8]



Completion of the chamber design and integration at the beginning of 2018

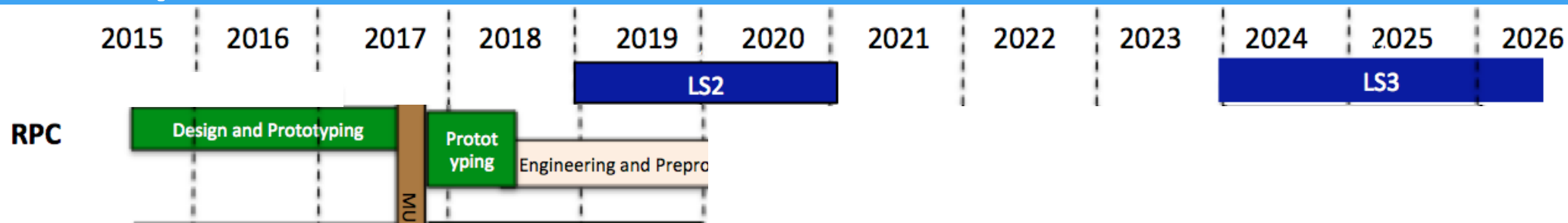
Pre-production is expected to start in the middle of 2018

Final prototype test in the lab and at GIF++

Chambers ready for pre-production

Pre-production Milestones

[charge 8]



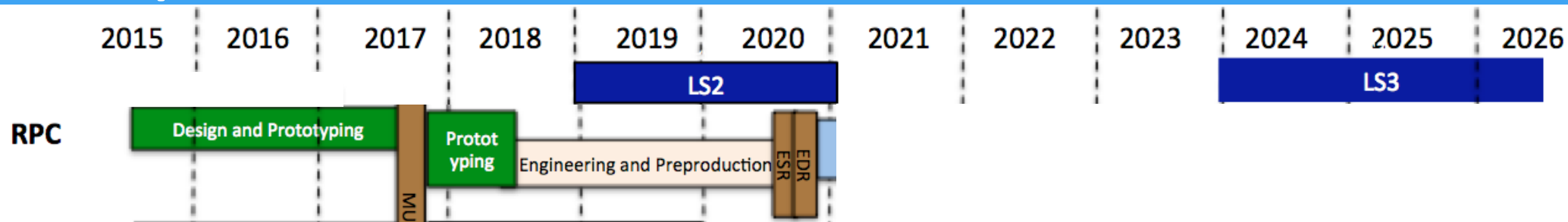
2019 focus to get ready for preproduction

RPC FE design ready (LL)	LL	February 18, 2019
RPC L1 and readout desing ready (LL)	LL	January 9, 2019
RPC FE Close Market Survey (LL)	LL	May 19, 2019
RPC On-Chamber FE Electronics Pre-production Ready (LL)	LL	December 27, 2019

FE Electronics Pre-production ready by the end of the 2019

Pre-production Milestones

[charge 8]



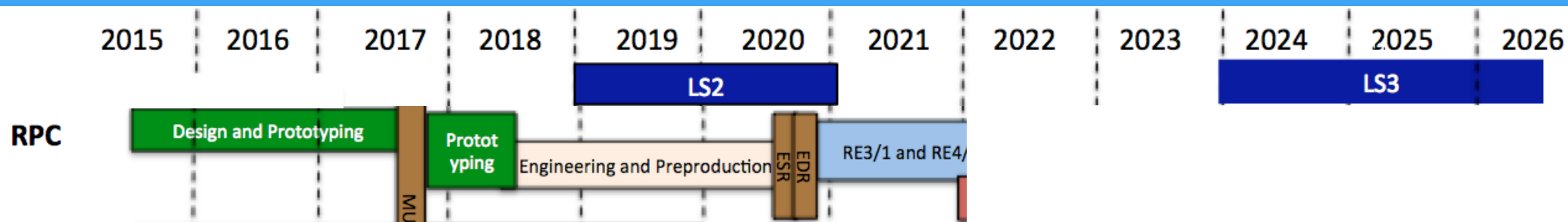
2020 focus on getting ready for production

RPC LV and HV Power Supply pre-production validated (LL)	LL		March 12, 2020
RPC ESR (HL)		HL	October 22, 2020
RPC EDR (HL)		HL	October 22, 2020
RPC L1 and readout pre-production ready (LL)	LL		October 14, 2020

Chamber production starts late 2020

Production Milestones

[charge 8]



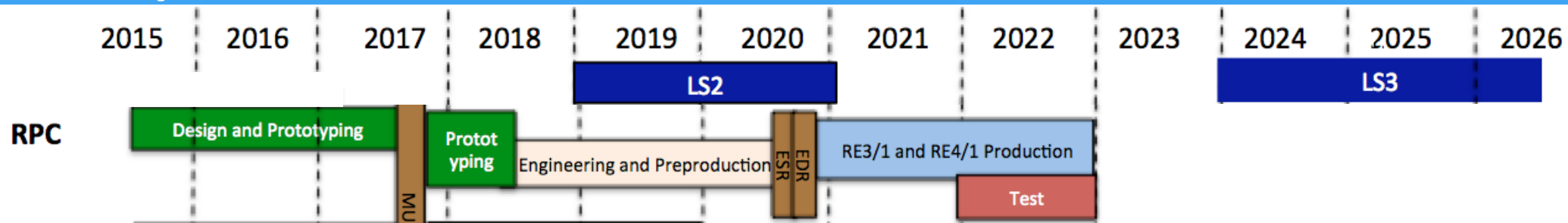
2021 main activity : Chamber Assembly and test

RPC Chambers Ready for Assembly Endcap 1 (HL)		HL	February 25, 2021
RPC On-Chamber Electronics(FE) ready (HL)		HL	March 17, 2021
RPC Chambers Ready for Assembly Endcap 2 (HL)		HL	April 22, 2021
RPC Back-end Electronics ready (HL)		HL	December 16, 2021
RPC Detector Ready for Installation Endcap 1 (HL)		HL	December 17, 2021
RPC Installation time window from TC Endcap 1 (TBF)		HL	December 17, 2021

Ready to Install the first end-cap by December 2021 during the EYETS

Pre-production Milestones

[charge 8]

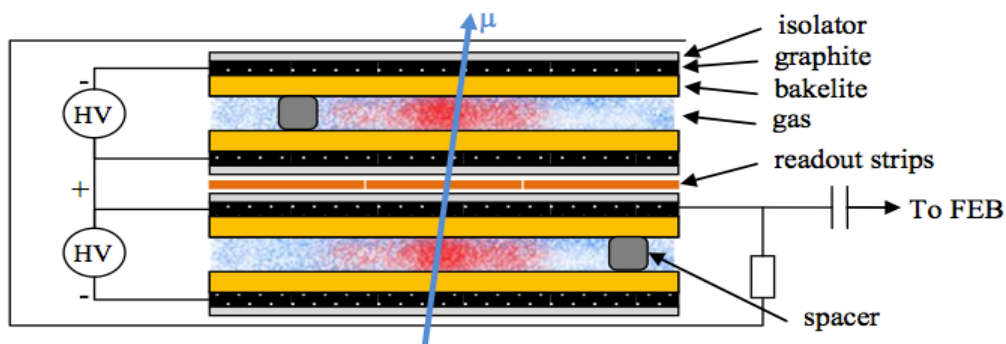


2021 main activity : Chamber Assembly and test

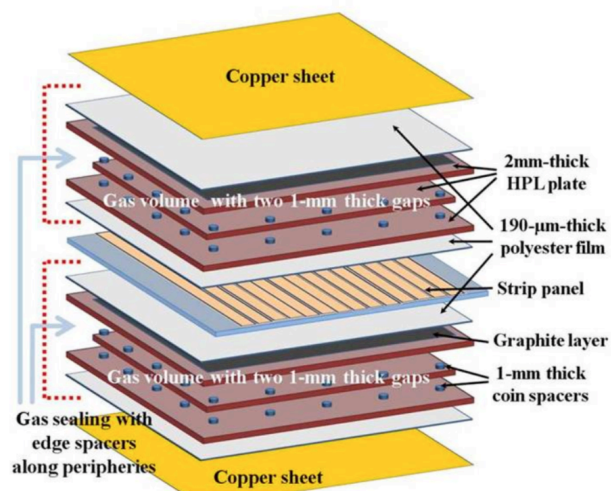
RPC Detector Ready for Installation Endcap 2 (HL)		HL	December 19, 2022
RPC Installation time window from TC Endcap 2 (TBF)		HL	December 19, 2022

Ready to Install the second end-cap by December 2022 during the EYETS

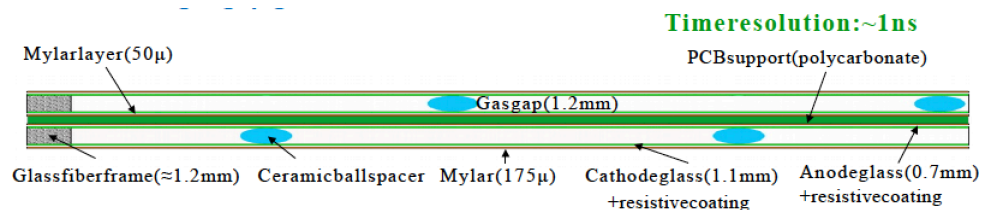
Relative cost impact of options



We expect an increment in the cost due to the **New Electronics**

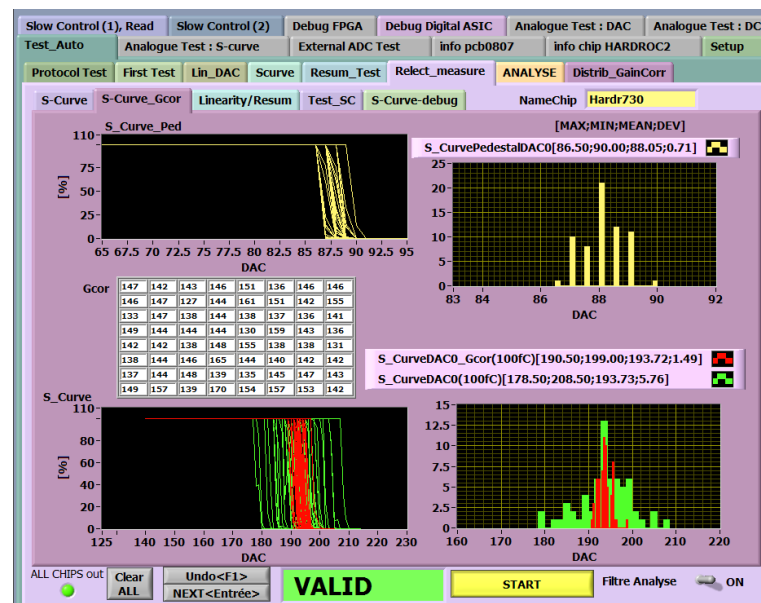
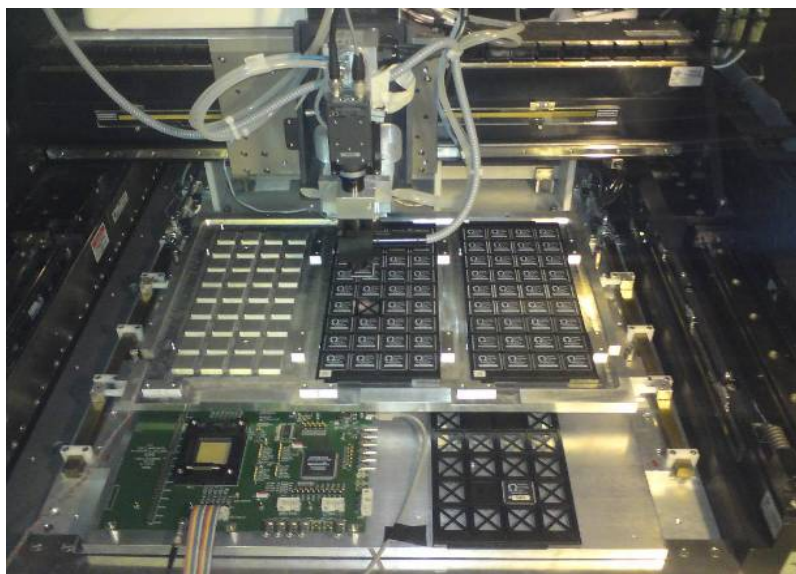


The price of the material used to build the gaps will increase depending if we use **gas or HPL**



HARDROC production

- ❑ ~10 500 chips were produced and tested with a dedicated test bench in IPNL Lyon for the SDHCAL project (2 months). Yield of > 93%
- ❑ Dedicated Labview program, USB interface, testboard, programmable generator (GPIB), precise multimeter (Keithley)



- ❑ Measurement of the DC levels and power consumption
- ❑ Test of the Slow Control loading
- ❑ DACs linearity
- ❑ Trigger efficiency measurement
 - ❑ Pedestal for the 3 shapers
 - ❑ 100 fC trigger efficiency measurement for fsb0 + gain correction for each channel
 - ❑ 1 pC trigger efficiency measurement for fsb1 and fsb2

Draft of construction flow & Quality checks

Slightly modifications can be expected

Electrode Production HPL/Glass Production site:

- Panel Cut, surface inspection, polishing (HPL).
- Thickness, roughness, color, labeling/DB, signal cable (Glass)

Quality tests I

Chamber Elements Production. At Assembly sites:

- Front End Boards (FEB) testing.
- Cooling system, mechanics and readout strip testing.

Quality tests I

Gaps Production. At Assembly sites :

- Visual Inspection, Gas tightness and spacer test
- Electrical and dark current, resistivity measurement (sample)

Quality tests II

Chamber Assembly. At sites :

- Visual Inspection, Gas tightness, Electrical and dark current
- Connectivity test, Cosmic muon commissioning

Quality tests III

At CERN final chamber tests:

- Detector acceptance for CMS
 - Leak test, Connectivity, Cooling circuit tests, Long term detector operation at Working Point, Electric and dark current tests

Quality tests IV