Industrialization of E-XFEL string and module assembly at CEA-Saclay

CEA contribution

- CEA contributes to the E-XFEL Cold Linac construction through String Assembly (WP9), Module Assembly (WP3) and BPM (WP17)
- Accelerator Module Assembly (WP3-WP9) : assembly of 103 accelerator modules with 1 per week throughput ! operated by an industrial contractor on the Saclay site.

Phases of the project

- Phase 1 : 2007-2008 — TTC 2009
  - Preliminary study subcontracted
- Phase 2: 2009-2010 — TTC 2011
  - Preparation of Infrastructure and Tooling
- Phase 3: 2010 – 2012 — TTC2012
  - Pre-industrial study
  - Prototyping : Training and Commissioning at Saclay with XFEL Prototype Modules (PXFEL2 and PXFEL3)

  ⇒ leading to Restricted Call for Tender signed in July 2012

- Phase 4: July 2012→ Q1-2015 — TTC 20xy
  - XFEL module assembly by industry operator

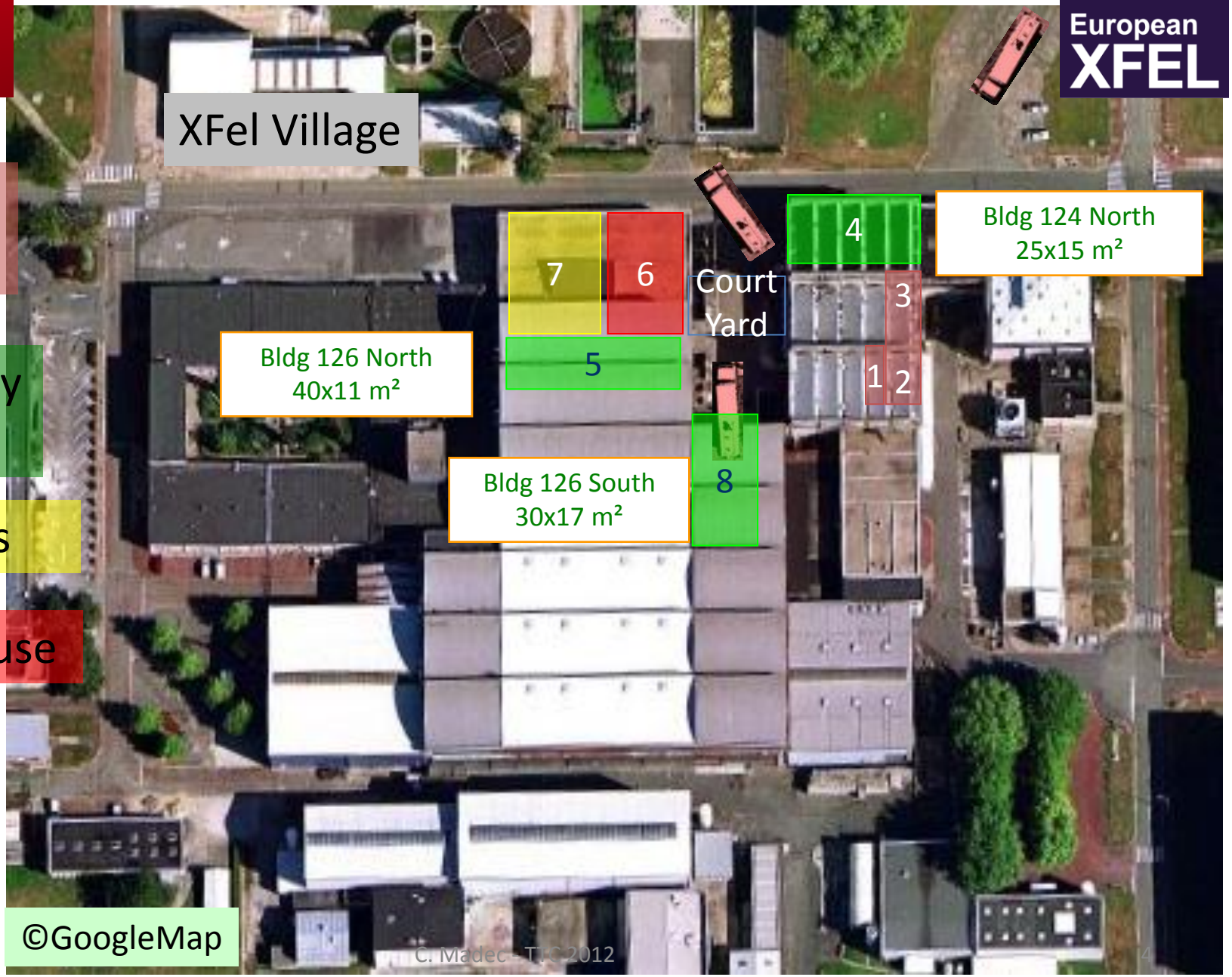
Phase 1 : Overview of the Assembly Buildings

Clean rooms

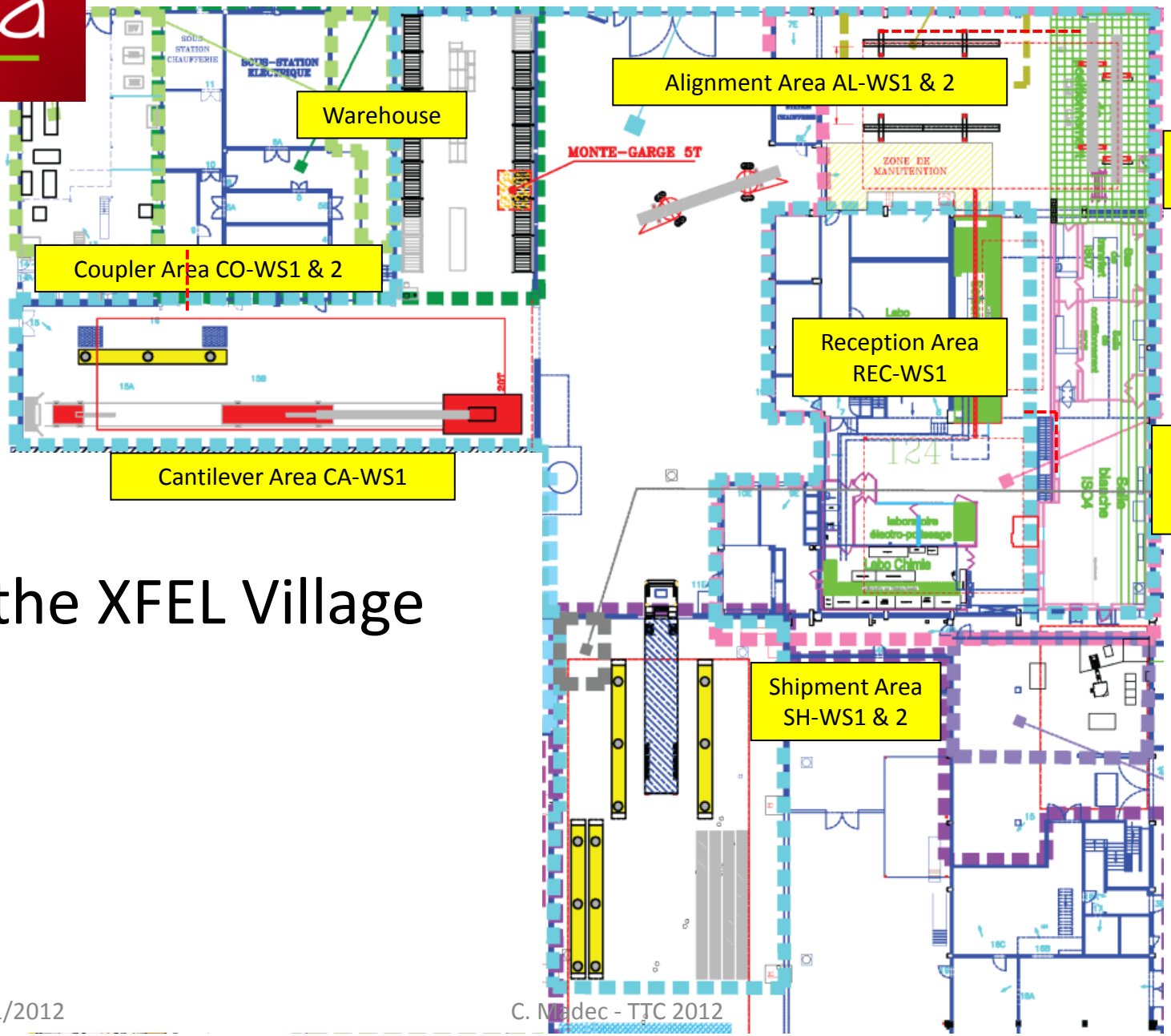
Assembly halls

Offices

Warehouse



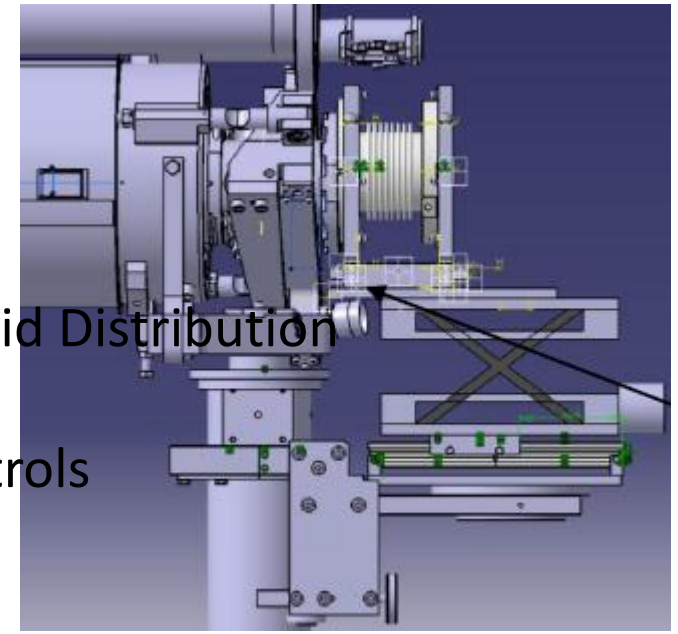
Phase 1 : Assembly Hall : Workstations



the XFEL Village

Phase 3: **Pre-industrial study** and Prototyping

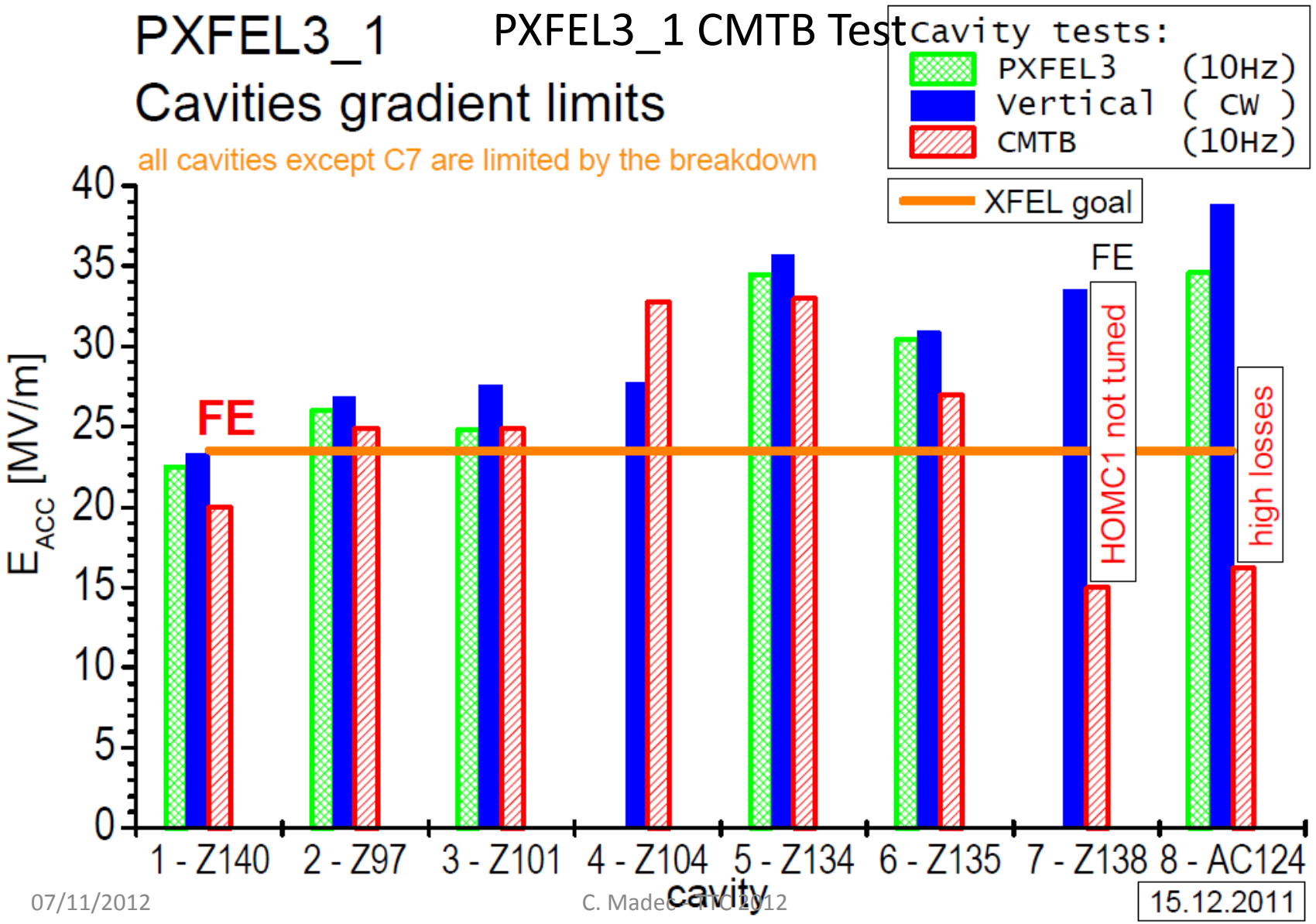
- Ajilon was subcontracted to perform the pre-industrial study
  - Tools Definition
  - Assembly Procedures with the non mechanical operations
  - Schedule
  - PBS – EBOM
  - Risk Analysis
  - Interruption Scenarios
  - Inventory Management
  - List and implantation of Services and Fluid Distribution
  - Listing of Parts and Its Packaging
  - Description of Reception Process & Controls
  - Using experience gained at DESY



Phase 3: Pre-industrial study and **Prototyping**

- Get the « Factory » ready:
  - Implement the pre-industrial study
  - Check the infrastructures
  - Check the tools
  - Check the procedures
  - Train the CEA-IRFU team
  - Prepare all the documentation templates
  - Set-up the QA/QC and MBOM
  - Feedback from the assemblies
- Assembly of 3 cryomodules over 2 years (T0=august 2010) : PXFEL3_1, PXFEL2_1, PXFEL2_2

Phase 3 : Lessons from Assembly Prototyping



Phase 3 : Lessons from Assembly prototyping

- PXFEL3_1 : cavity 1 (FE) and cavity 8 (HL) do not reproduce their VT performances. The causes are not identified:
  - coupler contamination through common conditionning waveguide box ?
  - particulate contamination during string assembly ?
  - shocks during transport CEA-DESY: (4g on frame,1g on cryomodule) + (2g on frame ,2g on CM) events ?

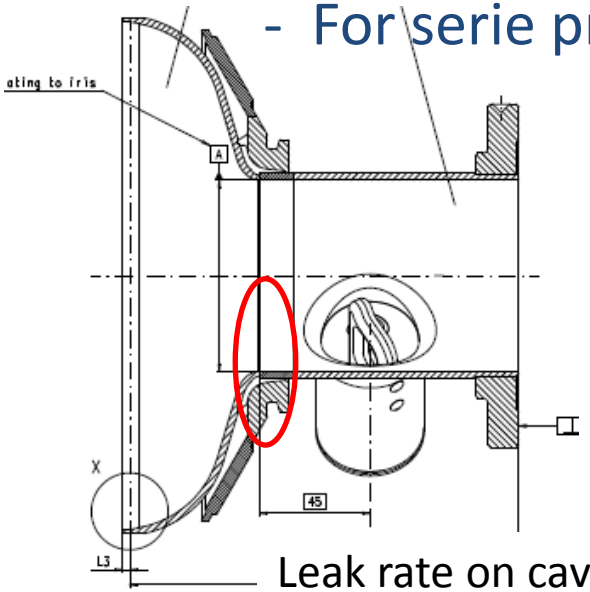
⇒ Still an open question

- PXFEL3_1 : cavity 7 HOM2 badly tuned :

⇒ a successful RF measurement and HOM tuning campaign took place on PXFEL2_2 cavity string during Week 18, with the help of DESY and AMTF colleagues.

Phase 3 : Lessons from Assembly prototyping

- PXFEL2_2:
  - Leak on cavity 6 helium vessel (isolating vac and He circuit)
    - No exchange at CEA because of time constrain for XM-3
    - Not full penetration welding between the cones and the cavity.
    - For serie production, full penetration welding



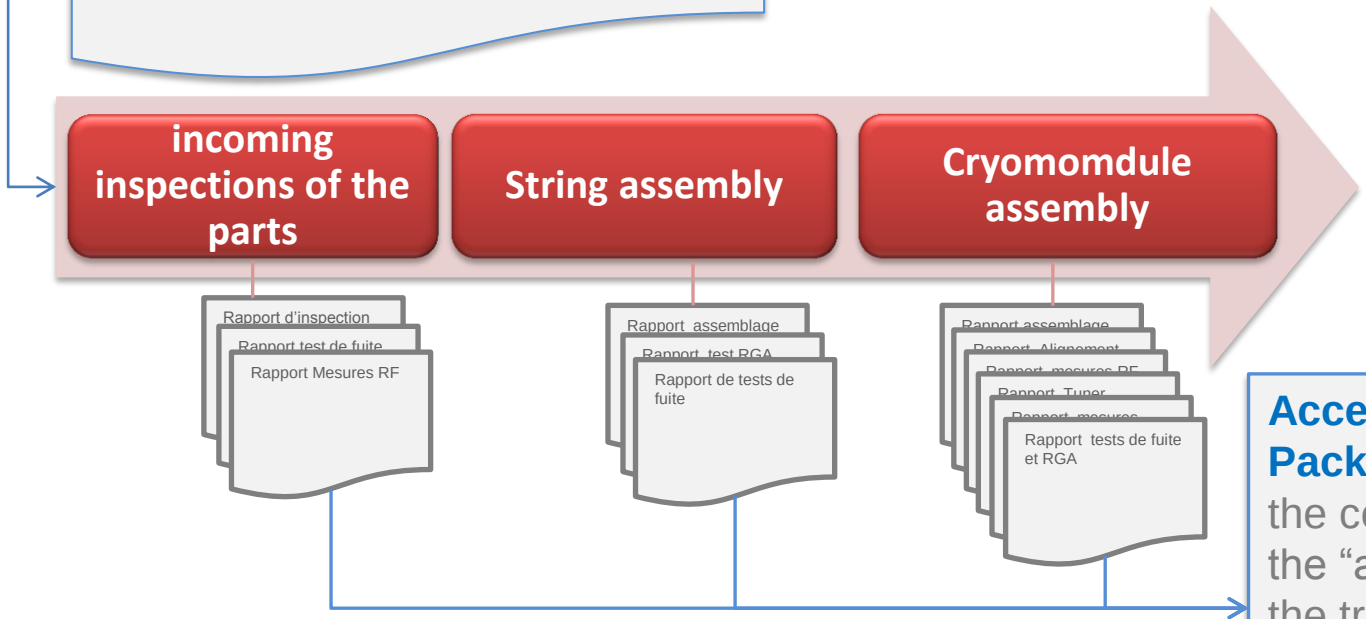
Leak rate on cavity AC121 rises to a value higher than 1 e-5mbar.l.s-1

Phase 3 : Lessons from Assembly prototyping

- PXFEL2_2:
  - In situ leak appeared at the leak test of the cavity string before shipping (acceptance criteria) :
    - leak detection before roll-out 10^{-10} mbar.l.s-1
    - leak rate 7.8 10^{-8} mbar l s-1
    - discovered on cavity 6 CF 16 PU MC leak
    - under investigation at DESY
    - Verification of the tightening on the coming couplers ?

Phase 3 : Acceptance Data Package

- assembly procedures including tests and controls
- traveler
- Templates for controls, tests, reports



Acceptance Data Package :
the certificate of conformity,
the "as-built" configuration,
the traveler,
the test reports
the non-conformities reports.

QA : Non Conformance Reports

Six NCR recorded for PXFEL2_2 string assembly / 14

PROJET XFEL — **ETAT DES NON CONFORMITES - NON CONFORMANCE STATUS**

NCR number	Model	Sub-assembly	Serial number	WS	MAJ /min	Date	Object	Corrective Action Status	Corrective Action Date	Final Decision	Rédactor
CEA-XFEL-RNC-11-011	PXFEL 2_2	Cavity	AC 147	Reception		08/12/2011	Orientation of the angle valve + pin of the HOM2 connector + vacuum above 10-5 mbar @ reception			quarantine	
CEA-XFEL-RNC-12-012	PXFEL 2_2	Cavities	AC150 & AC149	ISO 4 CC		10/02/2012	Water behind the flange of the elbow valve			use as is	
CEA-XFEL-RNC-12-013	PXFEL 2_2	Coupler	AC3C2	ISO 4 CC		20/02/2012	Coupler Antenna tilted			quarantine	
CEA-XFEL-RNC-12-014	PXFEL 2_2	Cavity	AC 150	ISO 4 CC		20/02/2012	Problem on cavity venting with UP34			use as is	C.Madec
CEA-XFEL-RNC-12-015	PXFEL 2_2	Couplers	CP3C45 & CP3C46	ISO 4 CC		22/02/2012	Remise à la PA rapide			use as is	S.Berry
CEA-XFEL-RNC-12-016	PXFEL 2_2	Coupler / cavity	CP3C57 / Z 162	ISO 4 CC		22/02/2012	Outillage monté à l'envers / pour pouvoir démonter l'outillage nécessité d'enlever le coupleur.				B.Visentin

Example:

tilted coupler antenna

Irfu — European XFEL

NON CONFORMANCE REPORT / CHANGE REQUEST

Reference: CEA-XFEL-RNC-12-013 | Page: 1 | Date: 20/02/12

EQUIPMENT:	coupler	SERIAL NUMBER:	AC3C2	FILLED OUT BY:	C. MADEC

Occurrence phase :				Integration level :		Workstation :
Control :		Reception :		Part		CO
Manufacturing :		Acceptance :		Subassembly		
Design/validation :		Destockage :		Equipment		
Integration :	x	Others :		Others		

TITLE : Coupler antenna tilted

DESCRIPTION :

The coupler antenna is tilted in the horizontal plane, the coupler being in the support frame ready for connection to the cavity. The bellow holders were in position and tighten.

Reference documents :

TECHNICAL INVESTIGATIONS : — **Responsible (s)**

The tilt of antenna axis was estimated at the half of the slot flange (for the leak test) i.e. 2.5 mm at the top of the antenna the tilt was about approximately 4 mm (cf. drawing page 4).

CORRECTIVE ACTIONS (equipment concerned by NCR/CR) : — **Responsible (s) :**

On Friday 17th , we dismounted the coupler AC3C2 from the cavity Z141 and checked the antenna (pictures page 2, during disassembly). The coupler is now mounted back on a TWG.

PREVENTIVE ACTIONS (further equipment) : — **Responsible (s) :**

CLASS :	
MINOR :	
MAJOR :	
FINAL DECISIONS :	
USE AS IS	
WAIVER	
DOCUMENTATION CHANGE	
REPAIR	
SCRAP	
MODIFICATION	
ACTION ON OTHER PRODUCT	

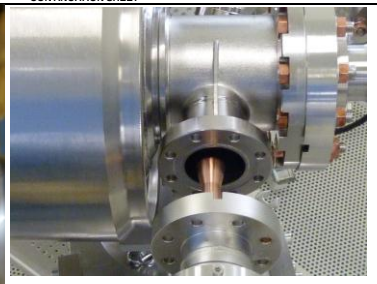
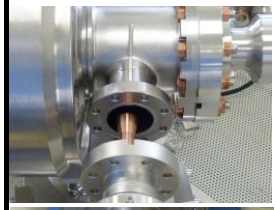
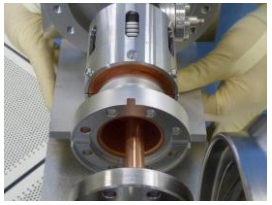
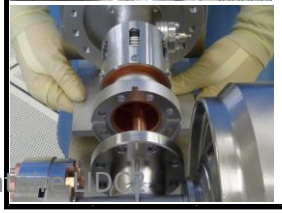
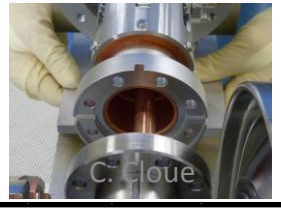
Clearance for actions	Technical Manager	Quality assurance Manager	Project Manager
Unit responsible of involved product :			
Upper level manager :			

Irfu — European XFEL

NON CONFORMANCE REPORT / CHANGE REQUEST

Reference: CEA-XFEL-RNC-12-013 | Page: 2 | Date: 20/02/12

CONTINUATION SHEET

Phase 3 : MBOM

Component assembly			Component Reference							
ISO4 SA WS	ISO4 CC WS	ISO4 CC Workstation (Cavity+ColdCoupler)	EDMS-ID	Rev.	Reference dwg	Position	Quantity	q0SubType	F/N	temporary, modifiable, alternate
Cavity String							1	assembly	1	
	Cavity with Cold Coupler						8	assembly	1	
		Cavity Full Equipped / Measured	D*905747, F	F	03L		1	assembly	1	
		Cavity Beamtube Blank Flange - Long Side	D*905747, F	F	03L	2	1	component	1	temporary
		Cavity Beamtube Adapter Flange - Short Side	D*905747, F	F	03L	3	1	assembly	2	temporary
		HOM Antenna	D*905747, F	F	03L	10	2	assembly	3	
		Pick-Up Antenna	D*905747, F	F	03L	12	1	assembly	4	
		High Q Fixed Antenna	D*905747, F	F	03L	15	1	assembly	5	temporary
		Bellow Clamp								
		Coupler Cold Part Assembly								
		Test Wave Guide								
		Blind Flange for TWG								
		Aluminium Seal NW40								
		Coupler Cold Part Assembly Set								
		Threaded Rods M6x40								
		Washer d=6.4								
		CuNiSi Nut M6								
	Q-pole unit assembly after transport									
		Quad-BPM-Vat main body								
		2Ph Pipe Flange Assembly (C)								
		Dichtdeckel Verschaltungsbox (E)								
		Beam Pipe Flange Assembly (A)								
		Flange Assembly (B)								
		Flange Assembly (D)								
		Cavity Bellows								

It is collecting, recording, and archiving the complete mandatory fabrication information.

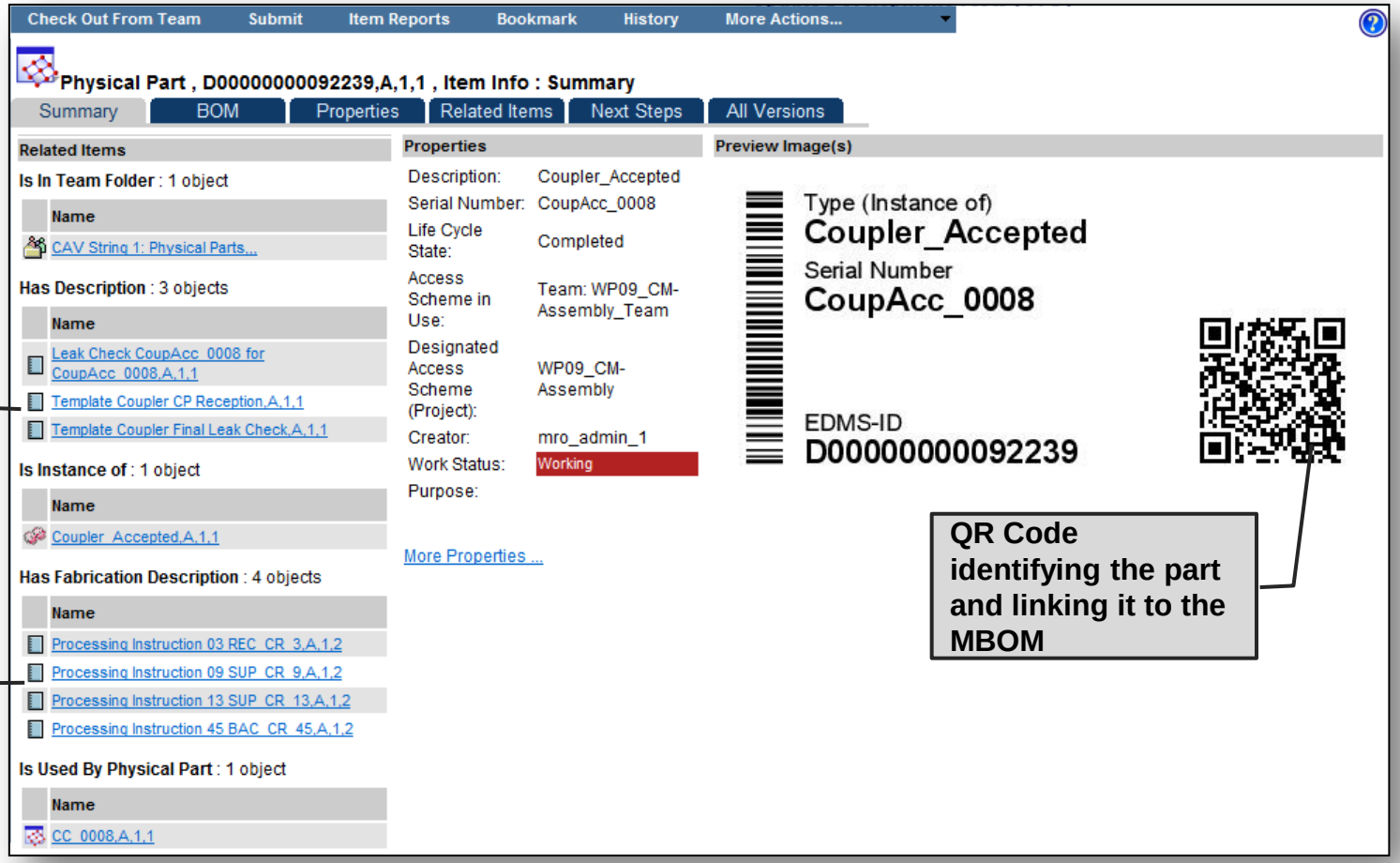
It is focused on the parts that are needed to assemble a CM at CEA. The MBOM also includes information about how the parts relate to each other, the inspection to be performed, the tests to be recorded, the assembly procedures, the documentation etc

Example of information : reference of the drawing, WP leader in charge of the supply serial number … (54 columns, 500 lines)

→ configuration recording of each cryomodule

→ Arborescence documentaire de l'ADP sous EDMS (base documentaire géré par DESY)

MBOM on EDMS



Test report templates

Assembly procedure

QR Code identifying the part and linking it to the MBOM

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- Phase 4: July 2012→ Q1-2015 — TTC 20xy
  - XFEL module assembly by industry operator

Phase 4 : industrial phase

Contract for 103 CM integration awarded to ALSYOM in July 2012.

- The first phase (from Sept 17th, until Dec 2012), consists of :
  - the observation by ALSYOM of the assembly by CEA of the first pre-series cryomodule (XM-3)
  - the deployment of their industrial method based on the outputs of the prototyping
  - the set-up of the storage area,
  - the ERP (entreprise resource planning) parameterization
- The second phase (june 2013):
  - training of the company team attended by the CEA and DESY team on the assembly of the second and third pre-series modules XM-2 and XM-1.
- The third phase : From XM1 on (2013),
  - ALSYOM in charge of the series module assembly.
  - six months ramp-up period to reach the production rate of 1 CM per week.

Cost reductions

- Preindustrial studies
- Team training

- Cavity magnetic shields : proposed some closing improvements and new Cryophy™ material which was qualified on the CM prototypes.
- Precut and assembled multilayer blankets for the 2K and 70K superinsulation have been ordered: they facilitate the assembly and reduce its duration. Cryogenic loss measurements on the prototype modules qualified them for the series.
- Vacuum pumping system in the clean room : reduces time from 3/4h to 1/4h
- Hardware for the clean room assembly : savings in prep time
- Alignement software : savings in time, limit errors
- Rf bench : savings in time, limit errors
- Welding :
  - Welding leak tightness : duration reduced by using the CERN technology (only the detection of the welded area) : reduces pump and purge to lower He backgound
  - « Paint » test crack in the welds TUV vs Xrays of the weldings.

Conclusions

- Factory ready

- Cost reductions
- Alsyom gets started – observation of XM-3

Thanks to

- S. Berry, C. Cloué, JP Charrier, R. Legros, B. Visentin, O. Napoly, Y. Gasser, Y. Sauce, JL Perrin, A. Brasseur, M. Fontaine, C. Simon, D. Roudier, T. Vacher
- Our colleagues from DESY (K.Jensch, S.Barbanotti, W.Maschmann …) , INFN and other institutes for our collaborative work