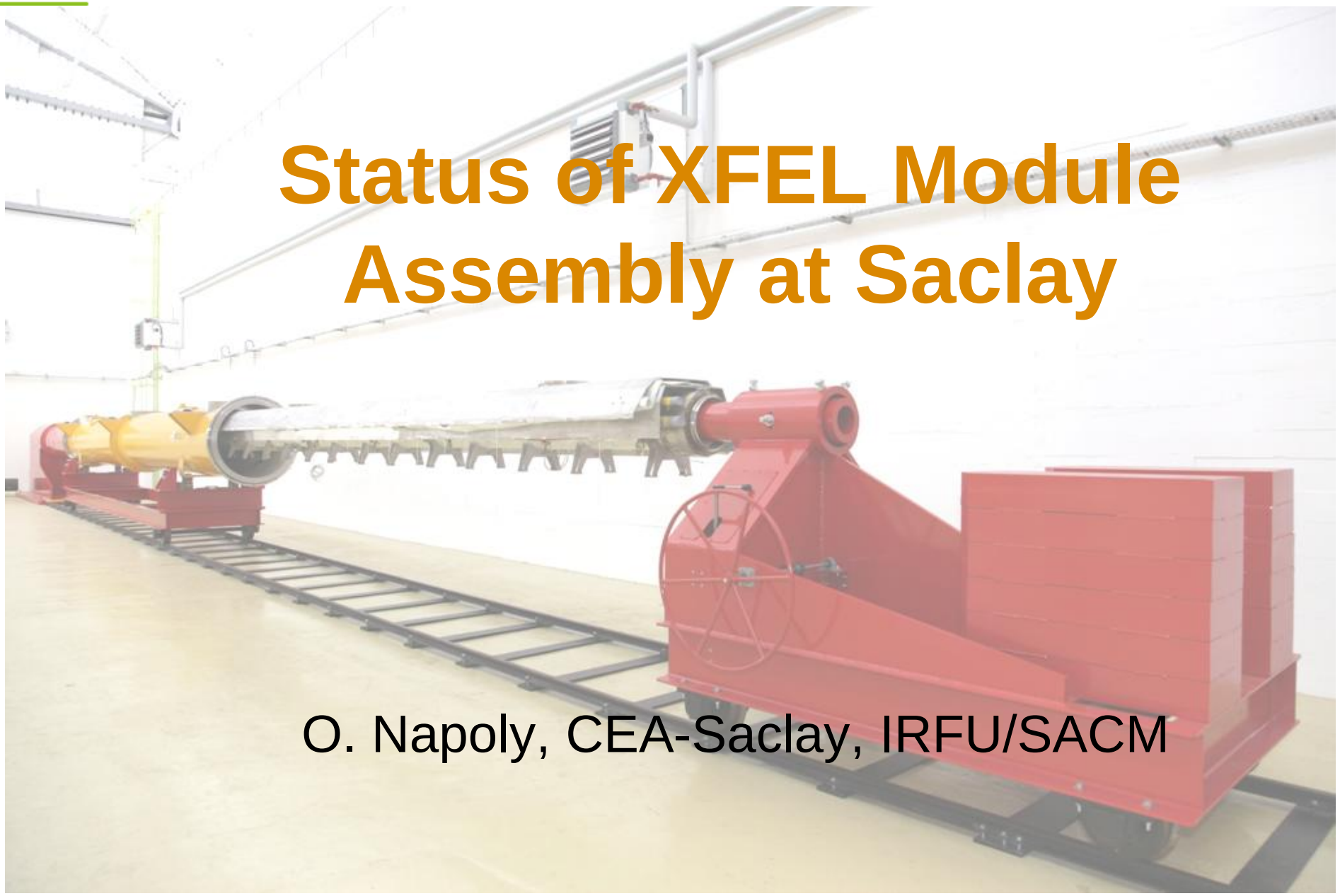
Status of XFEL Module Assembly at Saclay



O. Napoly, CEA-Saclay, IRFU/SACM

CEA contributes to the

XFEL Cold Linac construction

through

Cavity String Assembly in Clean Room

(WP9)

and **Module Assembly** (WP3)

↓

Accelerator Module Assembly

assembly of 103 accelerator modules

with **1 per week throughput** !

operated by an **industrial contractor**

on the Saclay site.

Project Timeline

Our effort develops over the 3 phases:

Phase 1: Preparation of Infrastructure and Tooling

2008 → April 2010

Phase 2: Training and Commissioning at Saclay with XFEL Prototype Modules (PXFEL2 and PXFEL3)

May 2010 → mid-2011

leading to Restricted Call for Tender for Assembly Contract by end 2010

Phase 3: XFEL module assembly by ind^{ial}. contractor

mid-2011 → mid-2014

Industrialization Baseline

- Build the Assembly Tool adapted to the goal of 1 module/week
  - normal mode → 7 workstations for 7 week assembly time
  - degraded mode → doubling of most workstations
- Review assembly procedures to avoid variations and other sources of man errors
  - → long training phase with prototype modules
  - → pre-industrialization phase with pre-series modules
  - → optimize procurement of pre-fabricated parts
- Implement personnel safety regulations ahead of contract
- *Implement reception and control operations in the fabrication timeline (just started)*
- *Optimize operator's incentive vs. technical expertise: one team per module vs. one team per workstation (just started).*

Optimisation Rationale

- Comply with XFEL project schedule and DESY procedures

  → limited room for unproven innovation

- Tailored to Saclay pre-existing hall layout

  → three buildings around a central courtyard

- Optimized for cost (manpower) effectiveness

  → 7 (maybe 6) week total assembly time

- Optimized for assembly fluidity

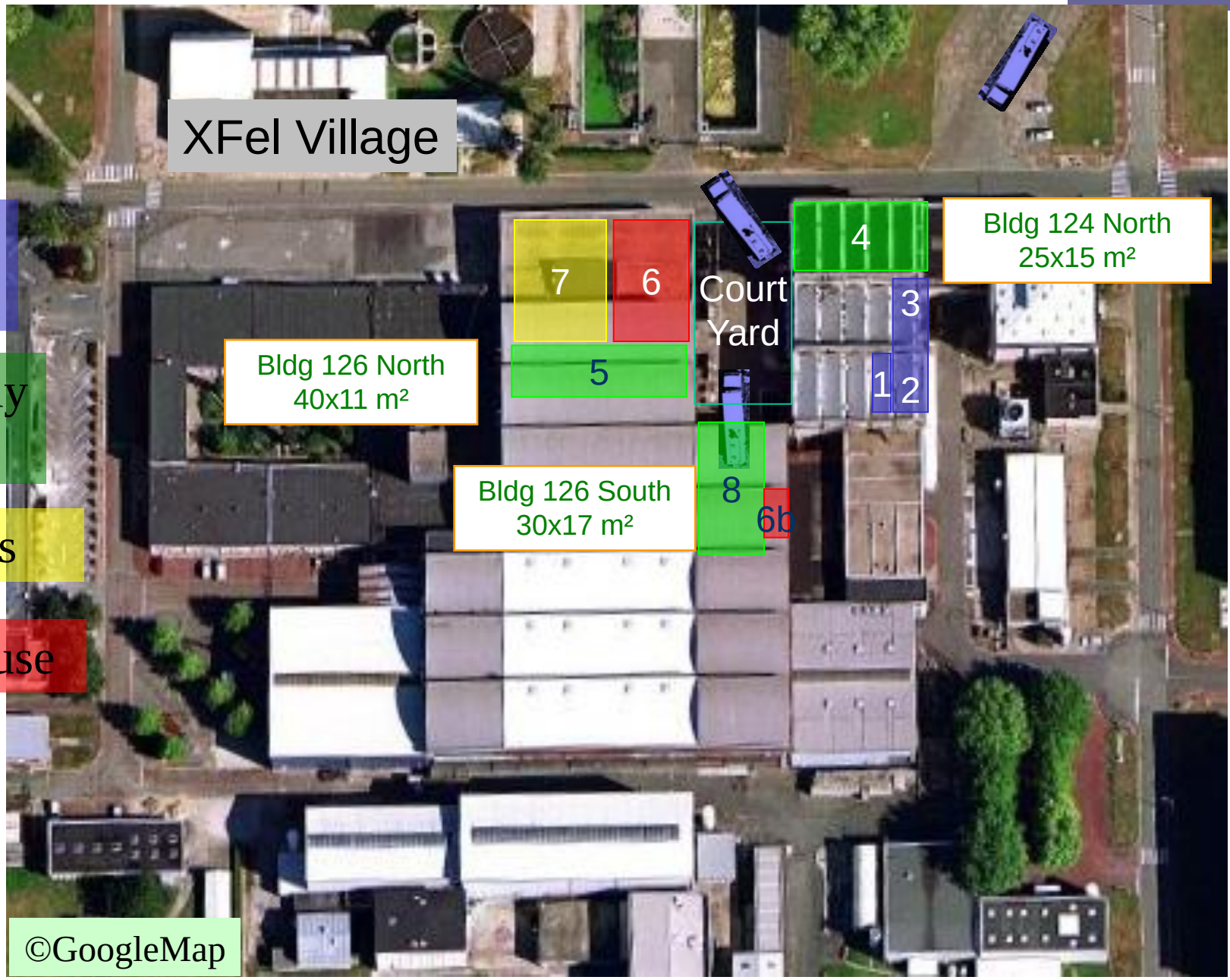
  → alternating workstation occupation

- Adaptive facility towards future projects

  → maximum module length = 15 m

Phase 1: Preparation of Infrastructure and Tooling

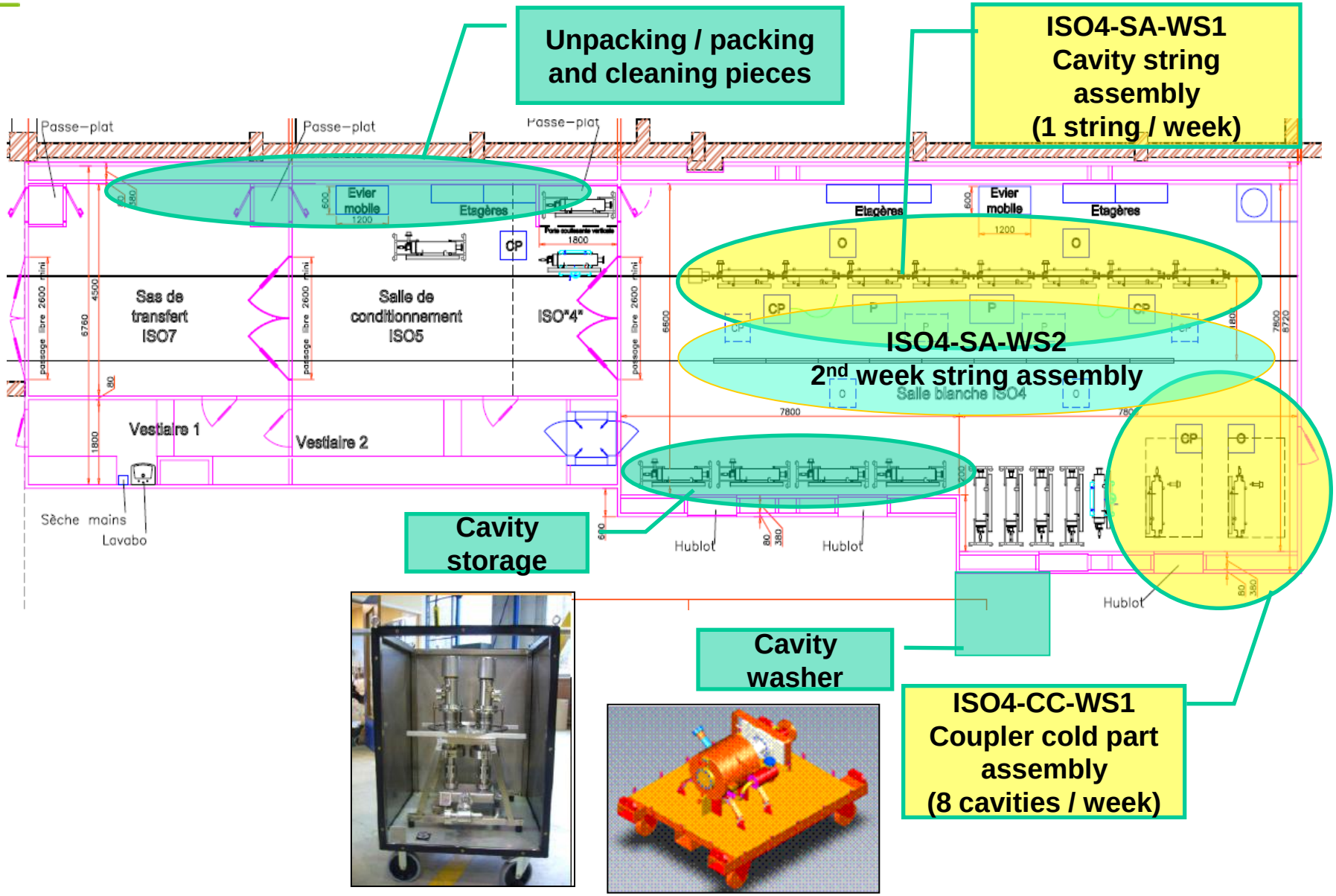
Overview of the Assembly Buildings



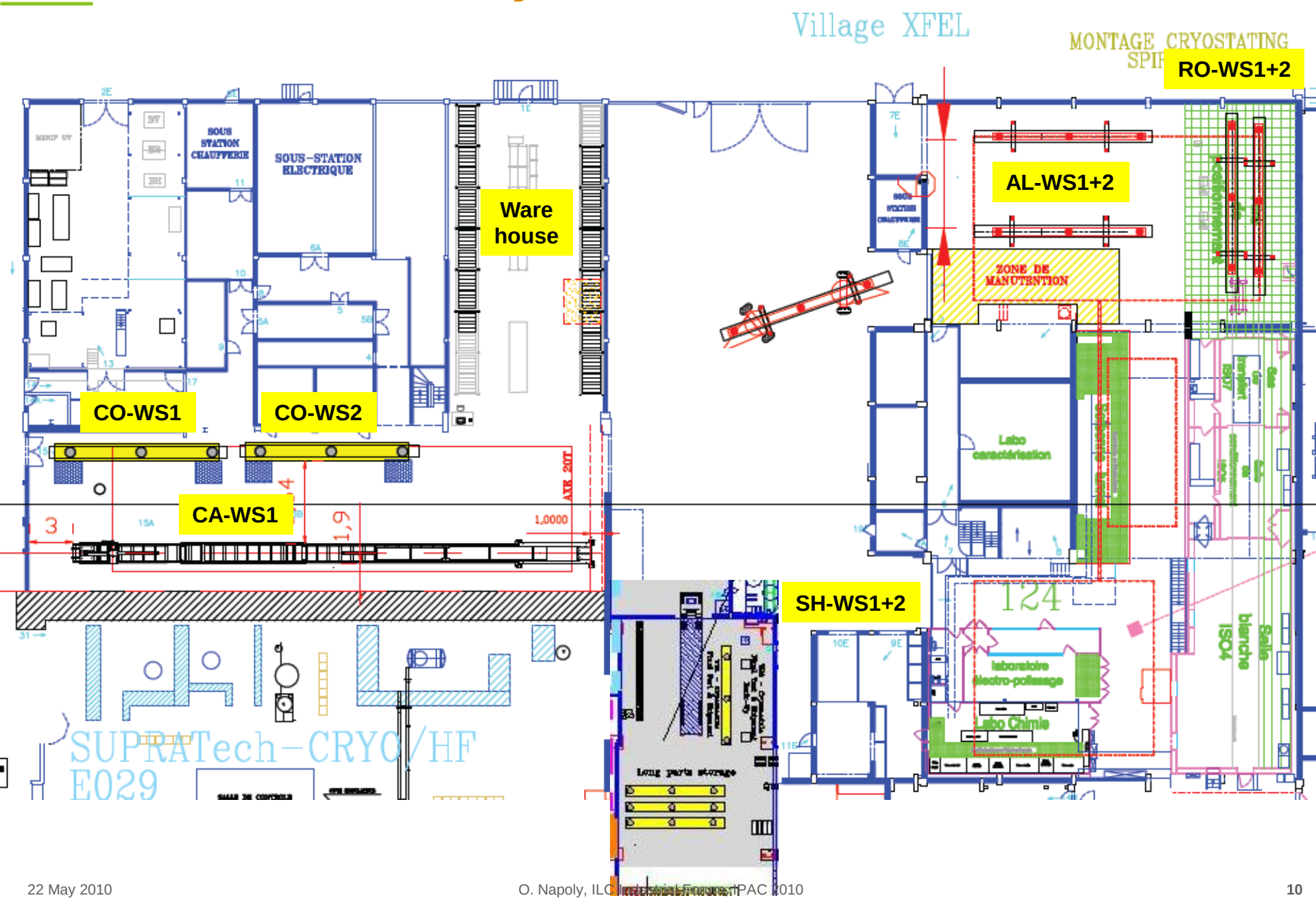
Organisation of Work Stations

1. **Clean Room Cold Coupler Area** (IS04-CC-WS1)
   - Cold coupler assembly
2. **Clean Room String Assembly Area** (ISO4-SA-WS1, ISO4-SA-WS2)
3. **Roll-out Area** (RO-WS1, RO-WS2)
   - HOM adjustment, magnetic shielding, tuners,…
   - 2Ph-tube welding, cold-mass/string connection
4. **Alignment Area** (AL-WS1, AL-WS2)
   - Cavity and quadrupole fine alignment
   - Coupler shields and braids, tuner electric tests
5. **Cantilever Area** (CA-WS1)
   - Welding of 4K and 70 K shields, super insulation
   - Insertion into vacuum vessel and string alignment
6. **Coupler Area** (CO-WS1, CO-WS2)
   - Warm couplers + coupler pumping line
   - Quad current leads
7. **Shipment Area** (SH-WS1, SH-WS2)
   - Instrumentation
   - Control operations (electrical, RF), “acceptance test”
   - End-caps closing, N-insulation, loading.

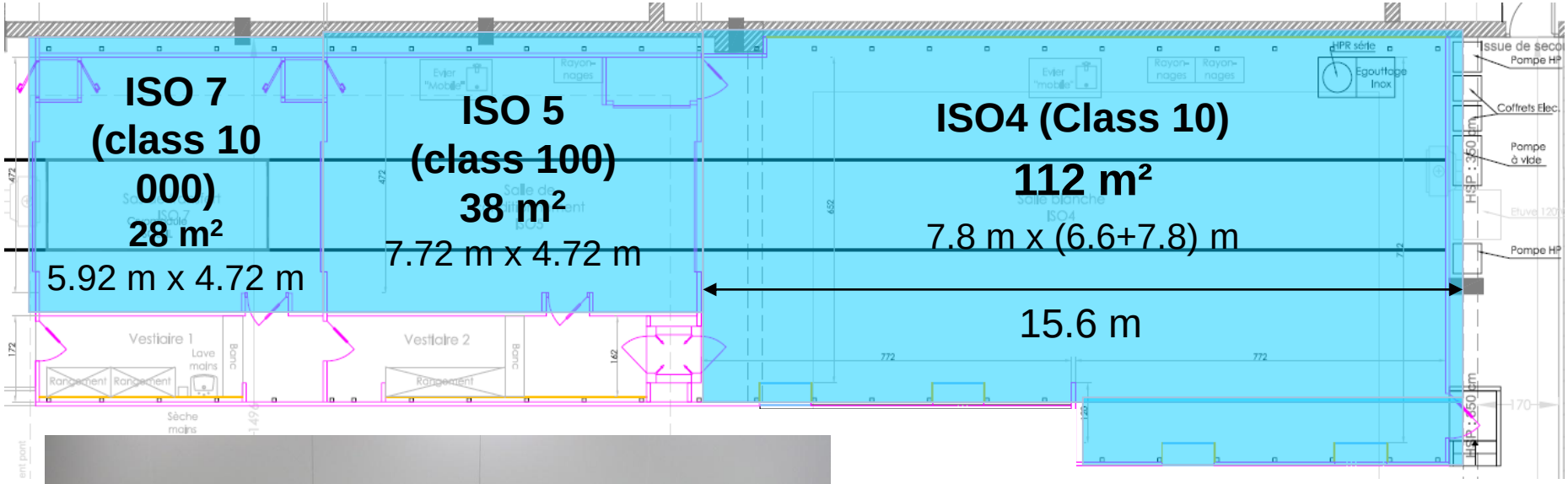
Clean Room : Work Stations



Assembly Hall : Workstations



Clean Room Layout



Clean Room constructed (Sept'09)

Clean room: Washer-Dryer (June ’09)

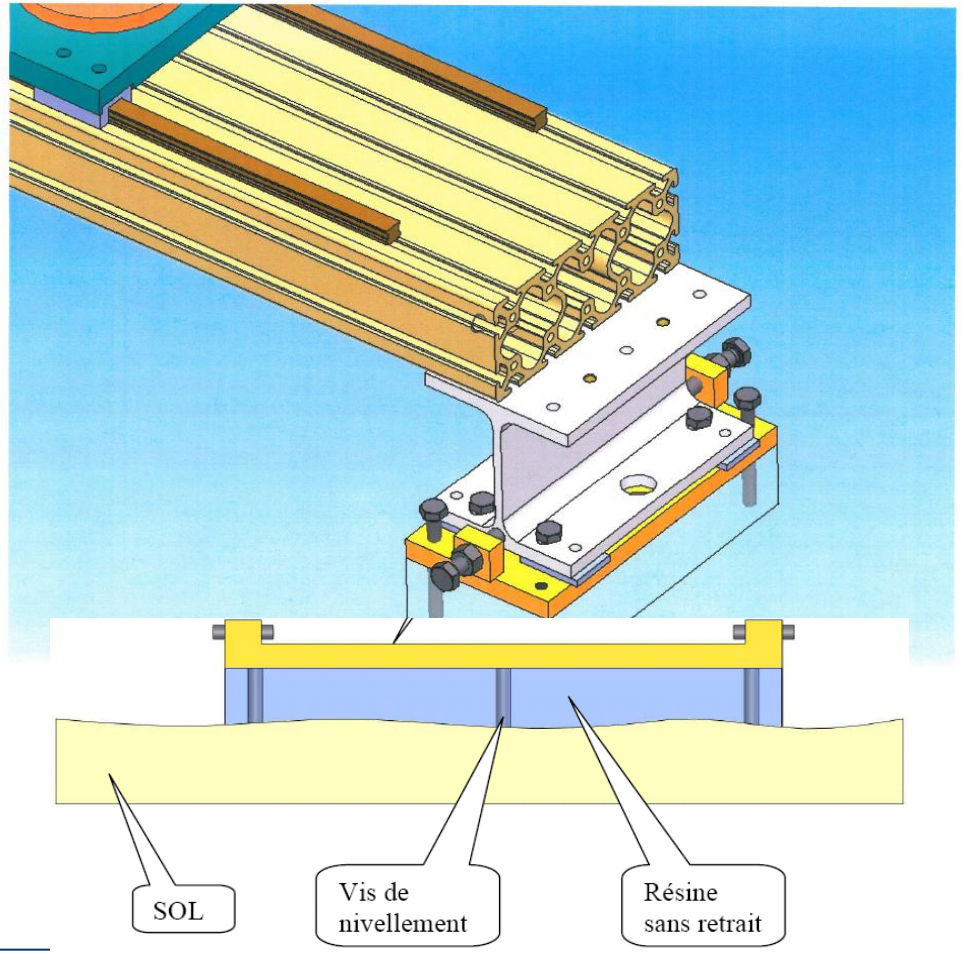
All cavities with He tank, coupler cold parts and quadrupole-BPM units will be cleaned and dried externally before entering ISO4 area

Objective: avoid particle contamination of clean room from external envelopes

Clean Room : Railing System

2 double rail systems, adapted from Fermilab clean room solution:

total length ~45 m, 39 anchors every 1.2m , alignment < 67 µrd



Objectives: ensure a good alignment of the cavities before connecting bellows
ensure a good stability of cavity string during roll-out

Assembly Halls

Three Assembly Halls and Services (offices, dressing rooms, warehouse, central courtyard, etc…) are currently under rehabilitation :

Hall n°1 is ready:

3. **Roll-out Area** (RO-WS1, RO-WS2)
4. **Alignment Area** (AL-WS1, AL-WS2)

Hall n°2 is ready

5. **Cantilever Area** (CA-WS1)
6. **Coupler Area** (CO-WS1, CO-WS2)

+ offices and warehouse

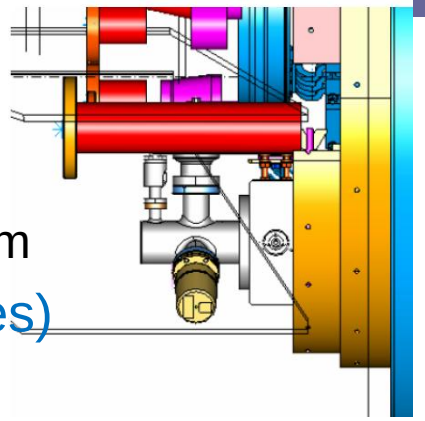
Hall n°3 is ready

7. **Shipment Area** (SH-WS1, SH-WS2)

Assembly Hall and Services ready: April 2010

Central courtyard re-surfaced in June 2010.

Module Dimensions and Placeholder

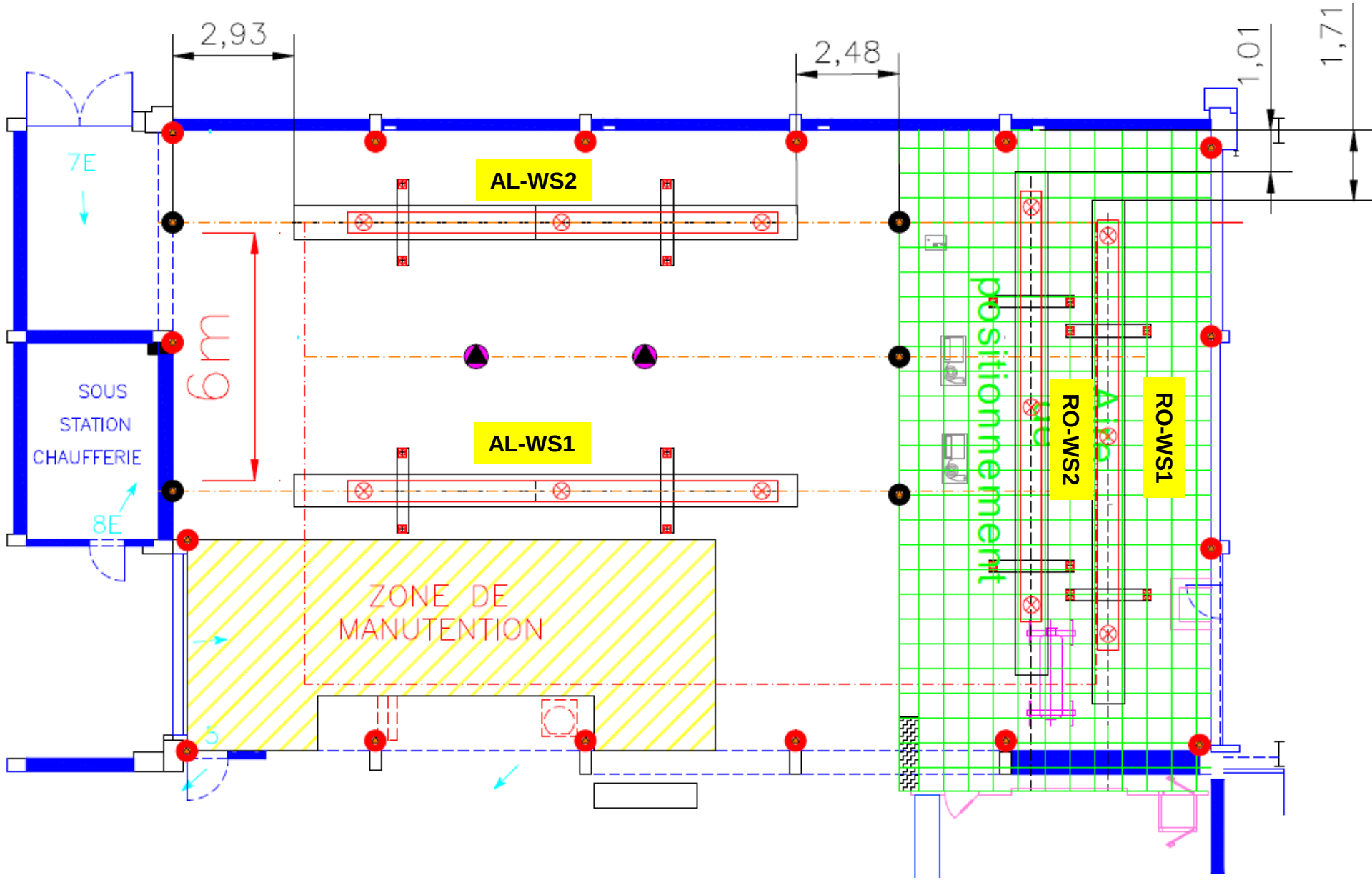


Module dimensions:

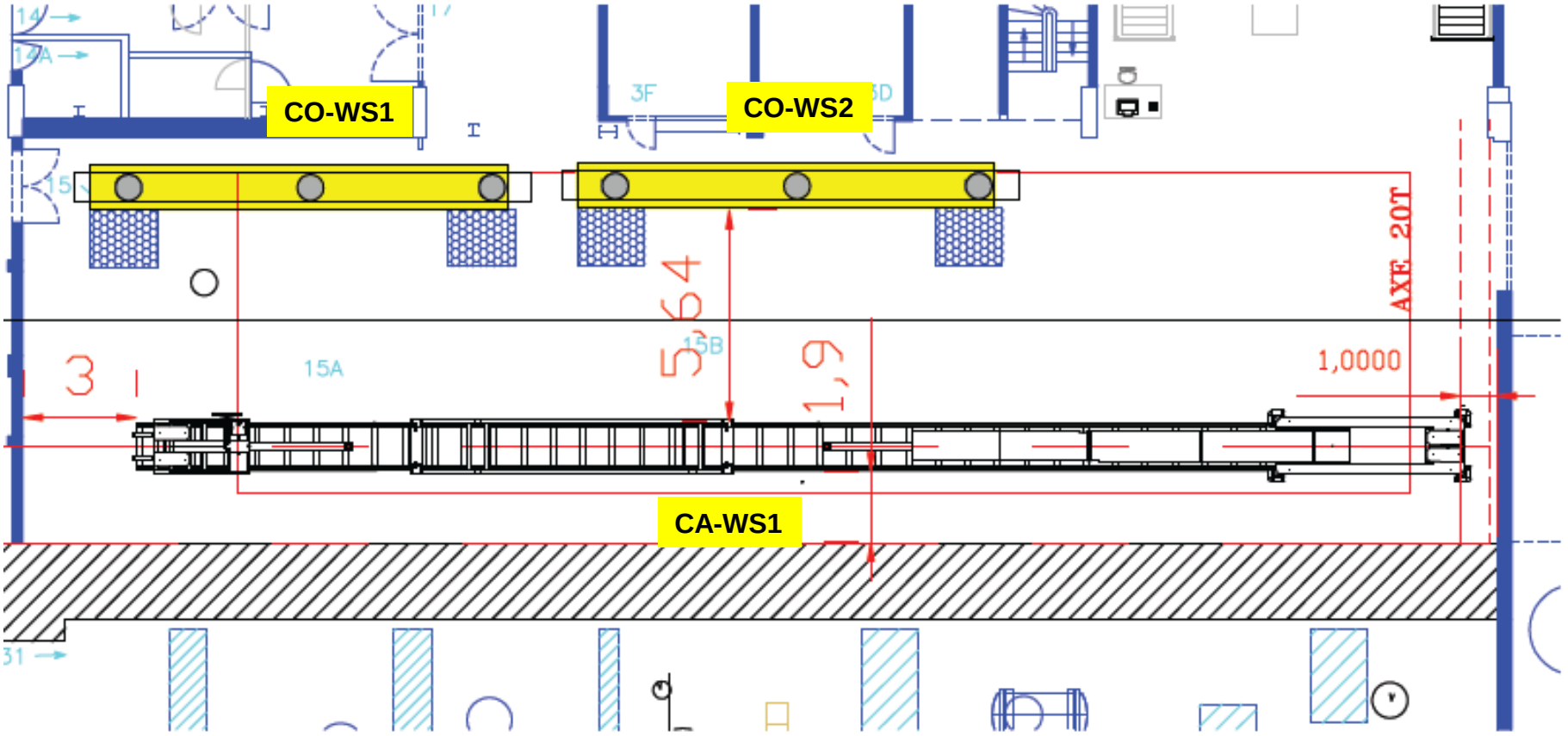
1. Red Girder : L = 10419 (+ 5877, - 4542) mm
2. Cold Mass : L = 12150 (+6374, -5776) mm
3. Cavity string : L = 11692 + 400 (+6132 + 200, -5560 + 200) mm

⇒ place-holder set by the cold mass (with flanges)

Roll-Out and Alignment Areas



Cantilever and Coupler Areas



Big Tools in Assembly Halls: Status

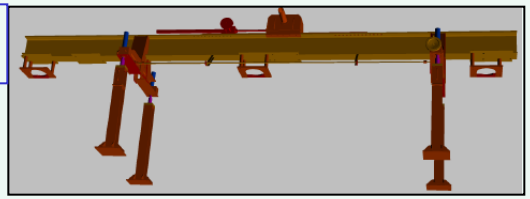
6 

Welding Bladders: 2 units ordered and received by DESY/MKS

5 

Girders for Vacuum vessel: 2 units ordered by DESY/MKS

New drawings, specific to Saclay Plant, generated by DESY/MKS (many thanks !)

1 

Traverse for cold mass: 3 units

4 Pillars: 2 sets over the rails + 2 sets for alignment

FNAL

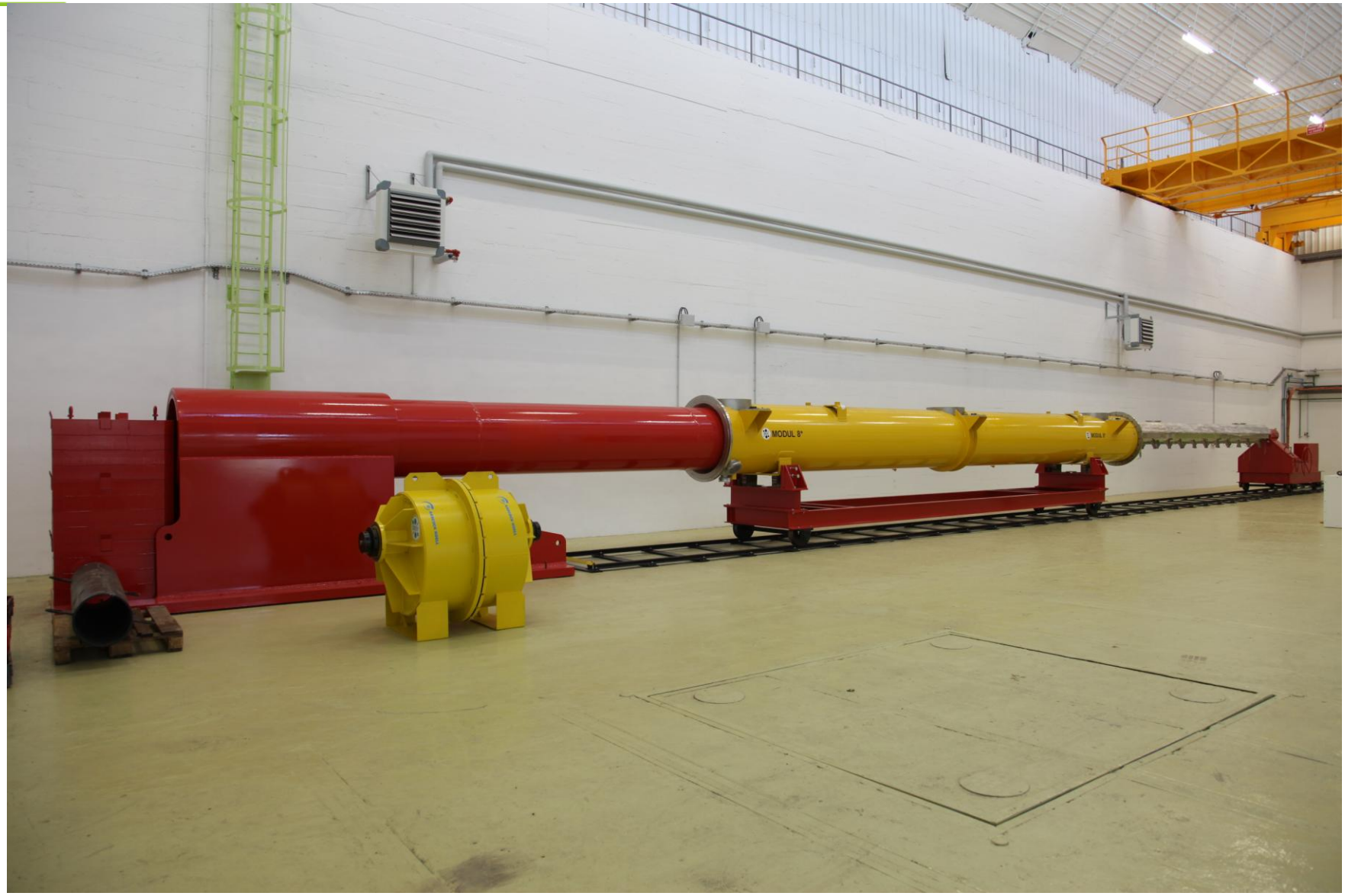
Cold Mass Transfer Frame: 1 unit

3 

Cantilever system: 1 unit

Electrical Transfer Vehicle: 1 unit

Big Tools Fabrication



Cantilever system with M8* (no string) , 21/05/2010

Big Tools Fabrication

Two « yellow » girders, 19/05/2010

FNAL Transfer frame, 17/03/2010

- First Traverse (out of 3 units) + 4 sets of pillars + Frame delivered to Saclay on 1st June (installation ~1 month)

- Electric transfer vehicle delivered to Saclay in October 2010

Phase 2:
Training and Commissioning at Saclay
with XFEL module prototypes (PXFEL 2, PXFEL3)

Plans for Detailed Industrialisation Study

Detailed Industrialisation Study at Saclay (EPPS) launched in March 2010, with the following deliverables:

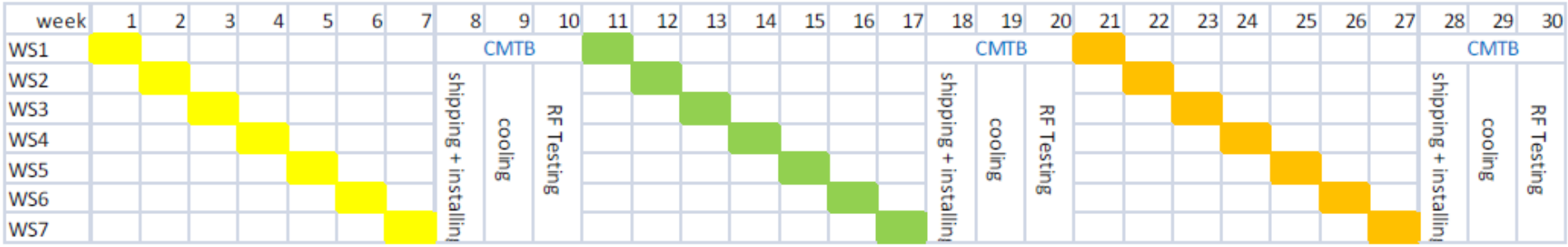
- Review of Saclay hall equipments and assembly tools
- Participation to PXFEL3 assembly at DESY (spring 2010)
- Detailed study of the Clean Room tooling
- Detailed Industrial File (assembly routings, tooling,...)
- Optimization of working weeks per stations (6 weeks ?)
- Commissioning of Saclay infrastructure with 2 module prototypes (starting Q2-2010)
- Control Operations
- QA plans and Risk Analysis
- Specifications for ERP (Entreprise Resource Planning)

Contract awarded to **Ajilon Engineering** (Adecco Group)

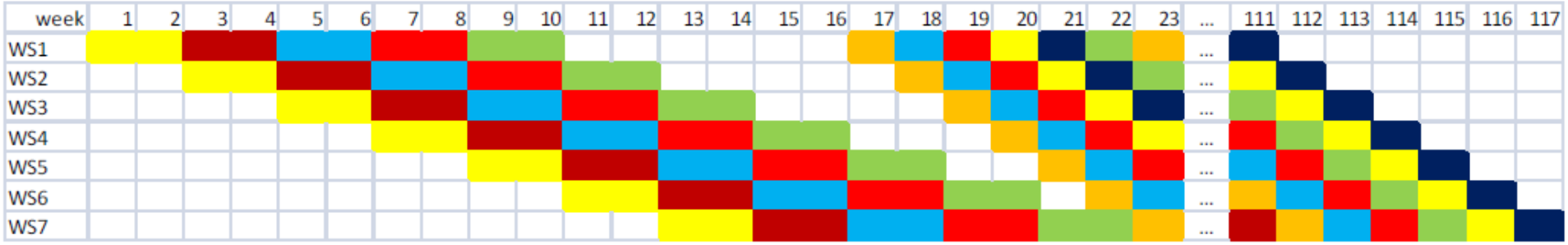
Phase 3:
XFEL Module Assembly by an Industrial Contractor

Ramping up industrial assembly

- P1: assembly of 3 pre-series modules in sequence for training of the first ½ teams by CEA and DESY personnel, assuming 7 week assembly interleaved by 3 weeks for CMTB qualification.
- P2: assembly of 5 modules in parallel during a ramp-up period (P2) for training of the second ½ teams by the first ½ teams, assuming 2 week assembly per module.
- P3: assembly 95 modules in parallel at the rate of 1 module/week.



Period 1: assembly of 3 pre-series modules, in sequence, interleaved with CMTB tests



Period 2: parallel assembly of 5 modules

Period 3: // assembly of 95 modules 1/week

Preliminary Lessons
for the ILC

Rough Figures

• CEA will spend about 6 M€ M&S for the infrastructure, large tooling and preparation work, starting from existing buildings. Most of it is considered a long term investment (ESS, ILC, …) and only the amortization and running costs will be “billed” to E-XFEL.

• The ILC will need at least five such plants to reach throughput of1 module/day:

→ 5 regional clean rooms with 1+1 rails, or a central clean room with 5 + 1 rails with more space in between: economical vs. political optimum ?

• Industrial team for E-XFEL is estimated to about 30 operators and supervisors working on Saclay site. No learning curve in assembly operation is yet assumed (cf. for LHC magnet tests).

Industrialization Readiness

- Two examples of “fuzzy” procedures to be worked out with DESY experts:

  1°) **Particle counting of string hardware**:

  Particle counting is done by one operator shooting ionized Nitrogen “through” bolts, nuts, washer,… with one hand, and “counting” particles with the other hand: highly repetitive and tedious operation, shoot in the air solution !!

  → Investigate procuring of pre-cleaned hardware (vendors ?).

  2°) **Super-insulation** (2K and 80K)

  Foil by foil super-insulation is a manpower pit : pre-cutting is done in parallel, 80 K mdoule insulation requires 7 operators for almost 1 day.
  → Investigate replacing by pre-fabricated blankets (like for LHC SC magnets). There are technical and economical issues.

- **The case of the SC Quadrupole** : For future projects (ESS, ILC, …) I have a VERY strong prejudice against SC quadrupole in the string.

  It is a (*pita*) huge complication to the industrialisation process (procurement, cleaning, transport through clean room, specialized supports, tools, and assembly procedures, string pumping, connection of cryogenic distribution, design and connection of current leads …).

  The alternatives would be 1° warm quadrupoles (cryogenics ?) or 2° a separate cryomodule with a smaller but very technical assembly plant with the BPM (politics).

Summary

Past and Current Activities

Preparation of the Assembly Infrastructure

- Construction of the Clean Room Complex
- Civil Engineering for 3 halls and the central courtyard
- Procurement of the Big Tools (cantilever, girders, etc…)
- Procurement of Transfer Vehicle
- Layout of Alignment Workstations and Instruments

Preparation to the Industrialization

- Preliminary Industrialization Study by Thales (Dec.08).
- “Detailed Industrialisation Study at Saclay” (Mar.-Sept.10).

Assembly Training Operations:

- Observation of M8* string and module assembly
- Reception test of M8* at Saclay
- Participation to M3** and PXFEL1 module assembly
- Observation of M3**, PXFEL1, PXFEL2 string assembly
- Participation to PXFEL3 string and module assembly

Considerable help received from DESY-MKS

CEA-Saclay Milestones for WP3+9

August 2009: delivery of the Clean Room
The 1st user will be Spiral2 (12 QWR) ⇒ qualification of Clean Room.

March 2010: delivery of the assembly halls and buildings

April 2010: start of Detailed Industrialisation Study (EPPS, ~9 months)

April-May 2010: participation to PXFEL3 string and module assembly at DESY

Q2 2010: delivery and installation of the big tools at Saclay

Q2 2010: disassembly and assembly of PXFEL2-3 modules (~12 months)
Interleaved with transport and CMTB tests ⇒ qualification of Infrastructure

End 2010: Call for Tender for String and Module Assembly Operation.

Q3 2011: 3 pre-series module assembly (1 module / 2 weeks) interleaved with CMTB tests ⇒ qualification of Industrialized Production

Acknowledgments

- **Considerable help received from DESY, thanks to C. Engling, K. Jensch, A. Matheisen, M. Schmöckel, H. Weise, …**

  and from FNAL, thanks to T. Arkan, …

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Acknowledgments