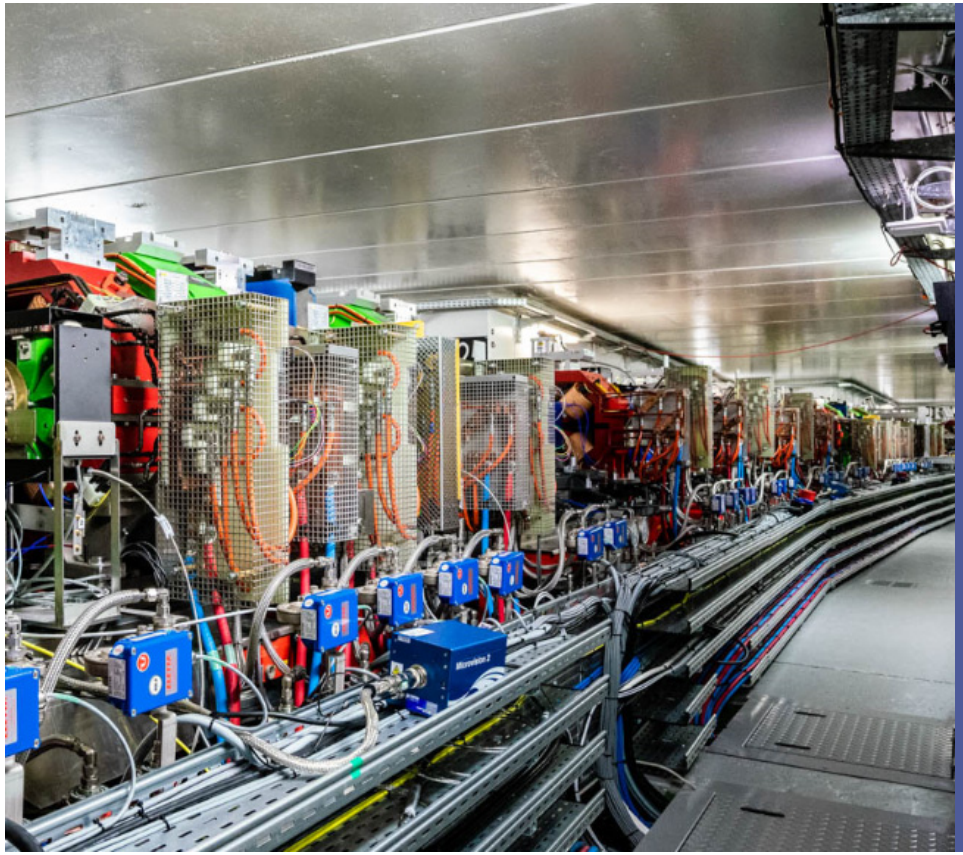


The Extremely Brilliant Source (EBS) Project

Jean-Claude Biasci
On behalf of EBS project team

ESRF-EBS
Extremely Brilliant Source

MEDSI CHICAGO 2020

OUTLINE

The EBS project

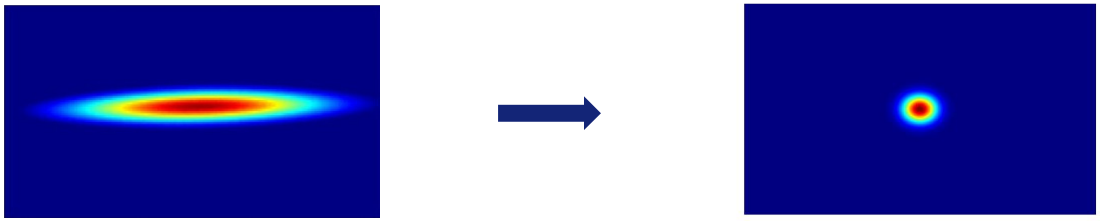
- Context
- Planning
- Organization
- Project phases
  - Technical issues
  - Results/means put in place
  - The positive aspects / lessons to learn
- Conclusion

EBS OVERVIEW

ESRF **E**xtremely **B**rilliant **S**ource

The first high-energy fourth-generation synchrotron

- Substantially decrease the Storage Ring Equilibrium Horizontal Emittance
- Increase the source brilliance
- Increase its coherent fraction



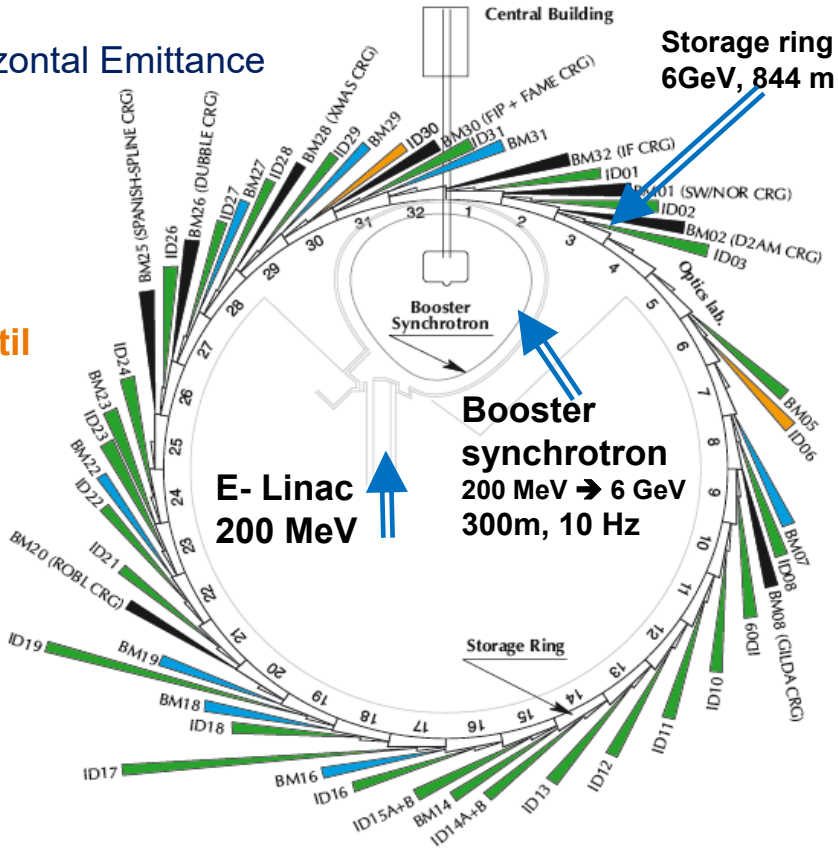
E-beam properties	2018	Now (EBS)
Energy (GeV)	6.04	6
Multibunch current (mA)	200	200
Circumference (m)	844.39	843.98
Horizontal emittance (pm.rad)	4000	140
Vertical emittance (pm.rad)	4	5

EXTREMELY BRILLIANT SOURCE - CONTEXT

The **E**xtremely **B**rilliant **S**ource Project aims to:

- Substantially decrease the Store Ring Equilibrium Horizontal Emittance
- Increase the source brilliance
- Increase its coherent fraction
- Keep the electron energy (6 GeV)

Maintain standard User-Mode Operations until the day of shut-down for installation



- Must fit in the same tunnel
- IDs at same locations: keep Beamlines where they are
- Maintain the existing bending magnets beamlines
- Re-use injector complex
- Preserve the time structure operation and a multibunch current of 200 mA
- Limit the downtime for installation and commissioning to less than 18 months

42 Beamlines (EBS 44)

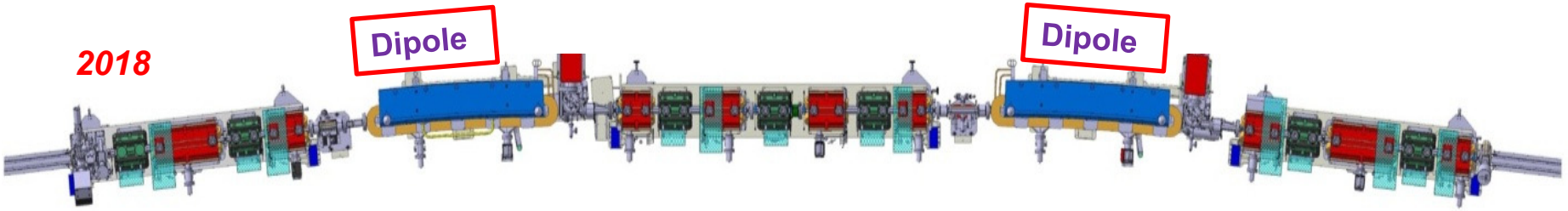
14 on dipoles (EBS 16)

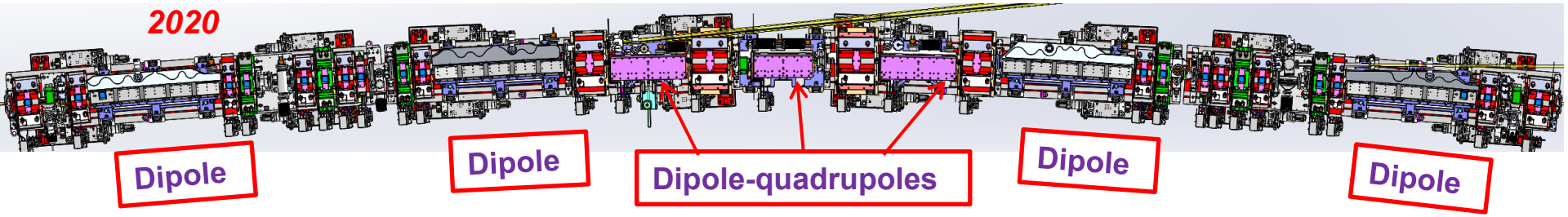
(28 on insertion devices)

EXTREMELY BRILLIANT SOURCE - CONTEXT

- **2018 ESRF lattice**
  Double Bend Achromat = (2 dipoles + 15 quad. sext.) per cell
  ID length = 5 m (standard) / 6m / 7m

- **2020 EBS lattice**
  Hybrid 7 Bend Achromat = (4 dipoles + 3 dipole-quad + 24 quad., sext., oct.) per cell
  ID length = 5 m

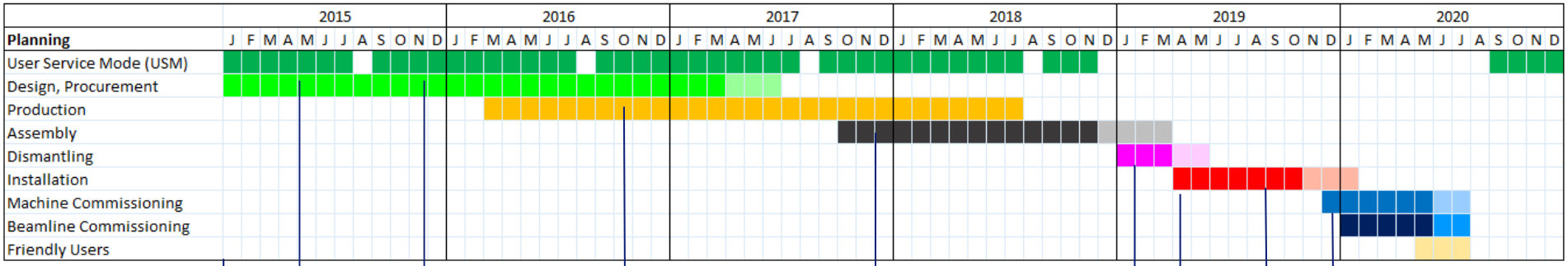




31 magnets per cell instead of 17 currently
Free space between magnets (total for one cell): **3.4m** instead of **8m** in 2018!!

EXTREMELY BRILLIANT SOURCE – PLANNING PHASES

2015 Planning



January 2015
Launch of project

Design

Procurement/Call For Tenders

Production

Assembly

Dismantling

SR Preparation
(civil work)

Commissioning

Installation
- Girders installation
- Fluids
- Electricity
- Vacuum
- Tests
- Alignment

EXTREMELY BRILLIANT SOURCE – ORGANIZATION

APO Accelerator Project Office	APS Accelerator Project Support

WP-01 Beam Dynamics Simone LIUZZO	**WP-02 Magnets** Gael LE BEC *Task coordinator: Chamseddine BENABDERRAHMANE*	**WP-03 Accelerator Engineering** Jean-Claude BIASCI	**WP-04 Power Supply & Electrical Engineering** Jean-Francois BOUTEILLE
WP-05 Radio Frequency Jörn JACOB	**WP-06 Control Upgrade** Jean-Michel CHAIZE	**WP-07 Diagnostics & Feedback** Kees SCHEIDT	**WP-08 Photon Source** Joel CHAVANNE
WP-09 Injector Upgrade Thomas PERRON	**WP-10 Vacuum System** Cristian MACCARRONE	**WP-11 Buildings and Infrastructure** Thierry MARCHIAL	**WP-12 Reliability & Operation** Laurent HARDY
WP-13 Radiation Safety Paul BERKVENS	**WP-14 Injection** Simon WHITE	**WP-15 Metrology** David MARTIN	ESRF-EBS

EBS– ORGANIZATION ASSEMBLY, DISMANTLING & INSTALLATION PHASES

APO
Accelerator Project Office
Project leader
Infrastructure Coordinator
Accelerator Physicist
Safety
Shutdown Coordinator

APS
Accelerator Project Support

WP

Ongoing phases

Assembly
Girders ready for installation

Procurement
Delivery of EBS components

Shutdown Coordination

Task 1: SR Dismantling
SRTU tunnel empty and ready for installation
- Planning follow-up
- Procedures
- Tools
- Equipment recovery
- Disposal
- Storage ring dismantling
  - Front End
  - Arcs
  - Straight sections
  - Injection zone
  - IDs
  - Cavities

Task 2: SR Installation
SR installed in SRTU
- Planning follow-up
- Procedures
- Tools
- Front End
- Arcs
- Straight sections
- Injection zone
- IDs
- TL2
- RF cavities

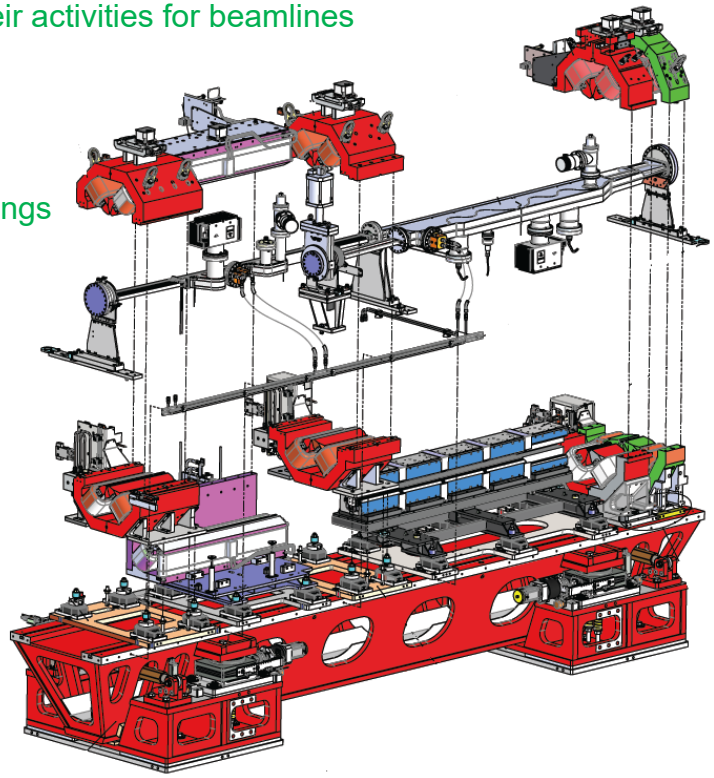
Task 3: TZ Installation and Setup
TZ activities and all subsystems ready for beam
- Planning follow-up
- Procedures
- Quality control & data base
- Controls system
- Interlocks end equipment tests
- Technical gallery tasks
- Waveguide network
- Transmitters
- Booster
- Diagnostics
- Power supplies
- Commissioning

DESIGN PHASE

- Drawing format for existing parts (paper, Autocad, Catia)
- Use of Solidworks with EPDM database anticipated SR tunnel & important components updated to Solidworks.
- Same CAD tool for Accelerator and beamlines.

- Resource: Drafting, FEA, Mechanical Engineers
- Temporary staff recruited and trained. FEA help from neighboring institute. Engineering resource from ISDD Division
- ISDD Engineers have knowledge of new machine on top of their activities for beamlines

- Components identification, lattice iterations, tolerances
- Meetings, reference documents for all Work packages
- Use of EPDM database to share reference documents & drawings

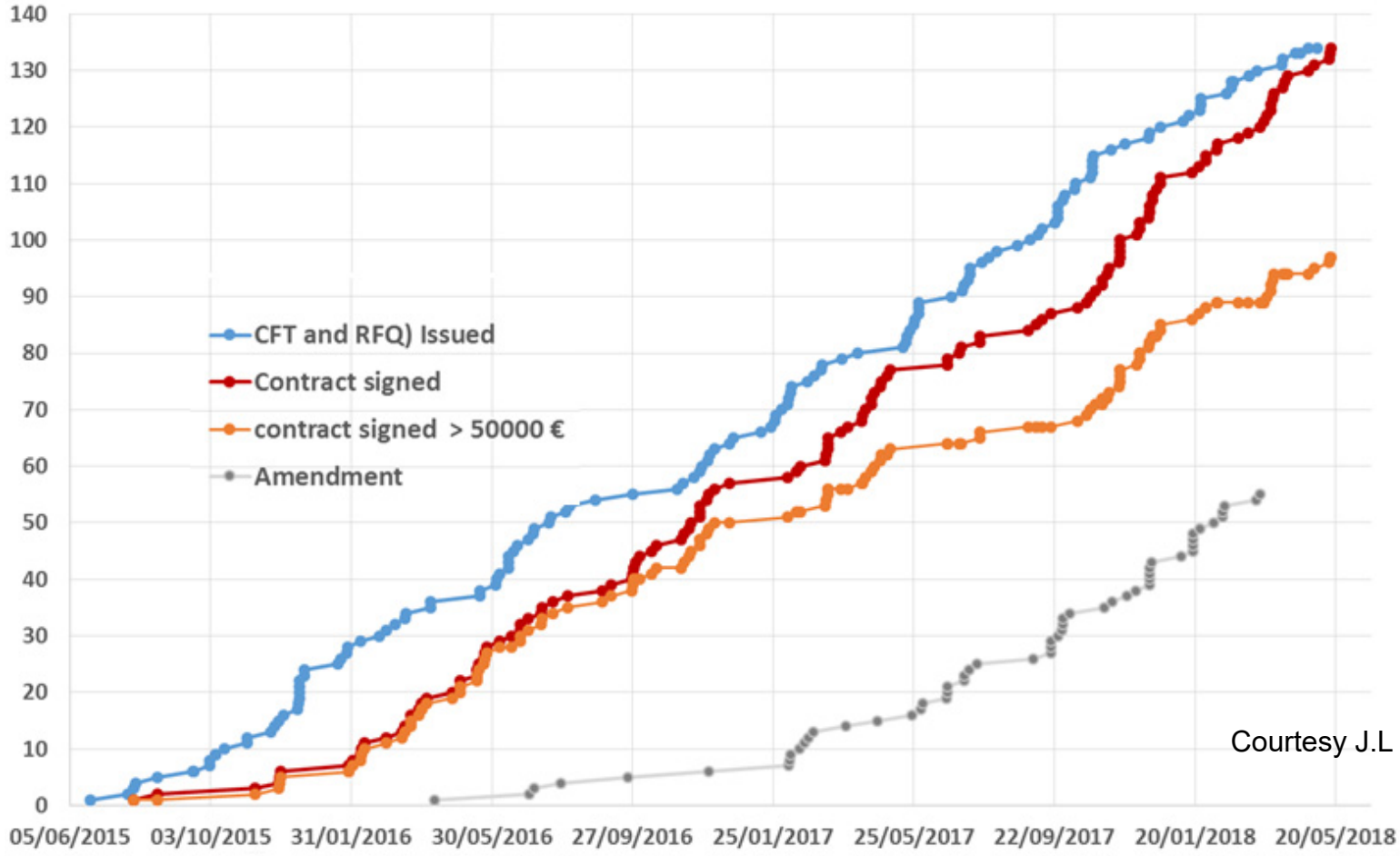


- Design reviews
- Technical meetings
- Change request documents form
- Fruitful exchanges to identify issues and enhance people technical culture & expertise

- Integration
- 3D models review, by different expert people. Reference 3D model regular update
- Only minor issues founds during the cell mockup assembly

PROCUREMENT PHASE

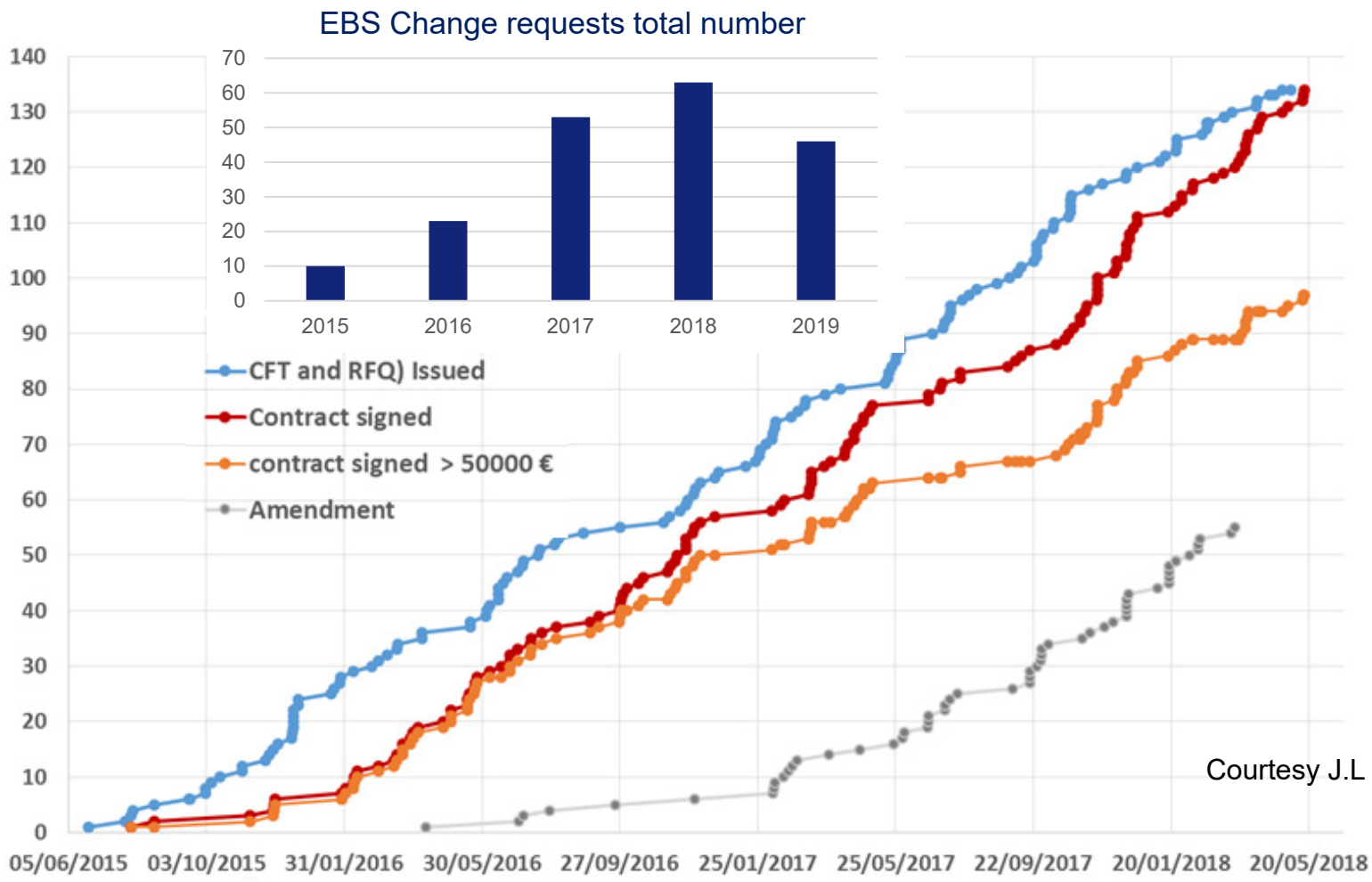
- More than 130 Call For Tender Request For Quotation(<50KEuros) to manage
- Critical and long delivery components identified at design stage
- Template specification used by all work packages to structure the technical content and facilitate the drafting of contracts



Courtesy J.L Revol

PROCUREMENT PHASE

- Additional components, technical or delivery schedule update
- Change requests
- Change request process implemented to for traceability, mandatory for any contract amendment



Courtesy J.L Revol

PROCUREMENT PHASE

Delivery notification:
-Date
-Equipment
-Packaging
-etc…

By Contract responsible

JIRA creation:
-Storage area assigned
-Handling requested

By ESRF1 assembly Logistic team

Delivery:
-Arrival at the Store
-Information to contract responsible & guidance to storage area by Store
-Unloading by ESRF2 Handling unit
-Component check by Contract responsible

Delivery and component recorded in the data-bases

By - ESRF2 handling unit
- ESRF 1 Logistic team

- Procurement process & work flow
- Components and boxes' data bases. Radio tag of boxes.

- Delivery process
- who, what, where, when, why & how

- Storage & Logistics.
- Handling and storage organized before delivery on site
- All received components registered in a database (received date, location, status, quantity, responsible…)

PRODUCTION PHASE

- BPM buttons leaks due to Stainless steel quality.
- All buttons tested before welding on chambers. New buttons produced with qualified material.
- Production inline with vacuum chambers production. (communication!)

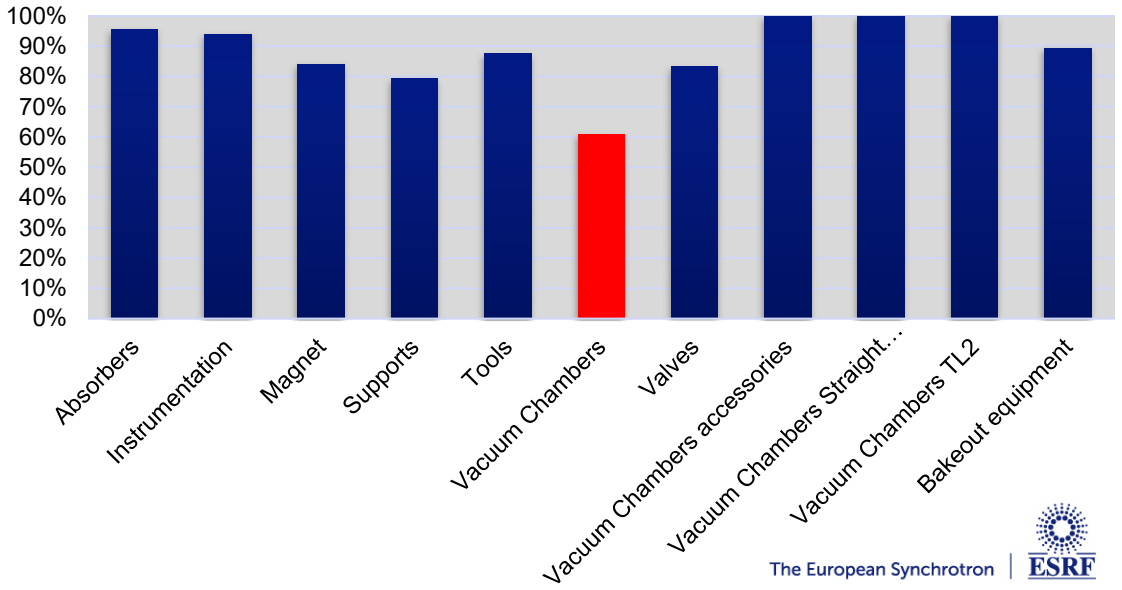
- Vacuum chambers production rate
- Tolerances issues. Evaluation of acceptable tolerances and new schedule to accommodate assembly phase requirements.
- 6 months collaboration period with companies to solve manufacturing issues. (close follow-up, communication!).

- Uncertainties in magnets fiducialisation
- Fiducialization of magnets at the ESRF started in June 2017 and continued until the end of February 2019
- Full control of magnets alignment is necessary

- Late procurement for collimators & diagnostic chambers
- Single component design but complicate
- Close follow-up

- Magnets power supplies shortage in electronic components procurement, design issues.
- Schedule update, interaction with companies
- Efficient test period (Site acceptance test) to minimize impact on installation planning.

Components Delivery (end of April 2018)



ASSEMBLY PHASE

- Vacuum chambers BPM blocks alignment/ tilt problem once chambers installed on the girder
- Alignment procedures, resource
- Pre-alignment of vacuum chambers during chambers assembly. No issue with flange perpendicularity (flange machined)
- Few weeks to find good process
- Better management of assembly time. Collective effort to find a solution
- More teams

- Leak after bake-out (flange, local)
- Adjustment of bakeout parameters (local temperature)

- Heating wire conflict with Dipole-Quadrupole magnet pole
- Modified heating wire routing

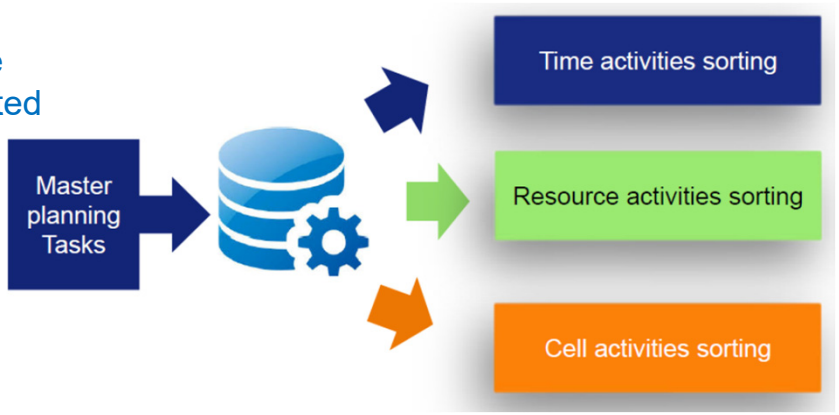
- Magnet rejected during alignment process on the girder
- Very rare (magnet fiducialization improved)

- Chambers delivery schedule
- We receive good chambers but delivery schedule slower than expected. Additional company to produce some critical chambers

- **Involvement of all team members during preparation phase is important**

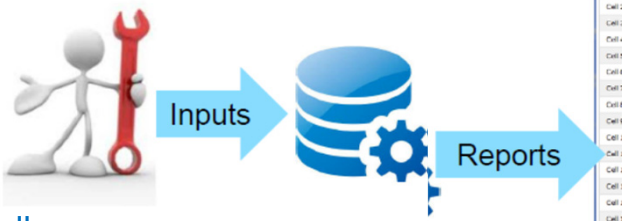
Dismantling installation phases

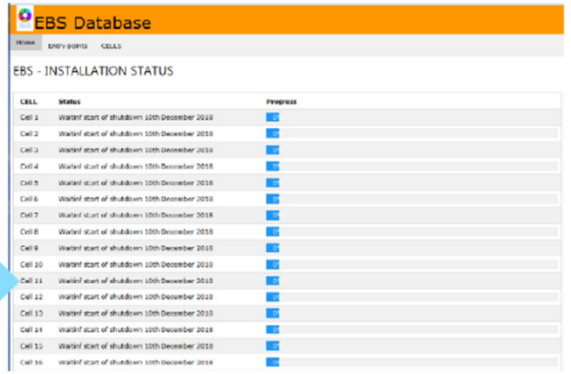
- Planning
- Planning optimization (with resources)
- Regular update to include additional tasks and take advantage of time made available by tasks completed in advance
- Stay tuned to the teams for a better use of time



- Mechanical tools
- Gantries
- Handling tool for assembled girders
- Handling procedure for each case reviewed with Safety group

- Organizational tools
- Database installation follow-up





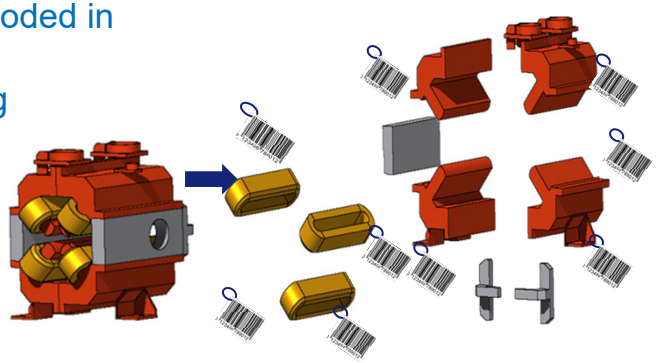
- Procedures
- Detailed drawings for each cell
- Detailed procedure
- Tasks risks reviewed with Safety group. Work in safe conditions

- Collaboration with Safety group is mandatory

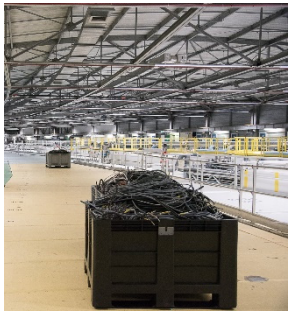
Courtesy T Brochard

DISMANTLING PHASE

- Old storage ring disposal traceability:
- All major components taken out of the tunnel as units, were bar-coded in the tunnel during summer shutdown 2018.
  All major other disassembled components were bar-coded during disassembly in ESRF-12
- Up to date database for old and new machine, traceability during shutdowns



- Organize logistics: Ensure evacuation of removed components.
- Day by day sequence organization
- Organize storage and evacuation
- Sorting of waste
- Good level of information & training. Dismantling completed in advance
- Teams supervisors and Safety people presence all time



STORAGE RING PREPARATION PHASE

- SR Tunnel preparation painting
- Grinding of walls and ceiling not expected
- 7 days without activity during paint drying due to toxicity
- Always have alternative solution, communicate with Safety

- Girder plates installation
- Grinding under girder plates to ensure proper gluing not anticipated
- Procedure and test completed during the 7 days dead period
- Importance to detail tasks to avoid undefined situations

1 plate 250Kg

- Cleanliness before gluing
- Handling (tool)
- Positioning before gluing
- Alignment
- Gluing (procedure)

INSTALLATION PHASE

- Girders installation & gantry height
- Handling tools tests and certification in advance
- Installation sequence & procedures
- Teams training
- Collaborative work with teams.
  Responsibility and role of each person clearly identified

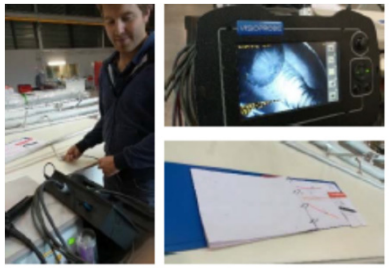
Up to 9 girders installed/day

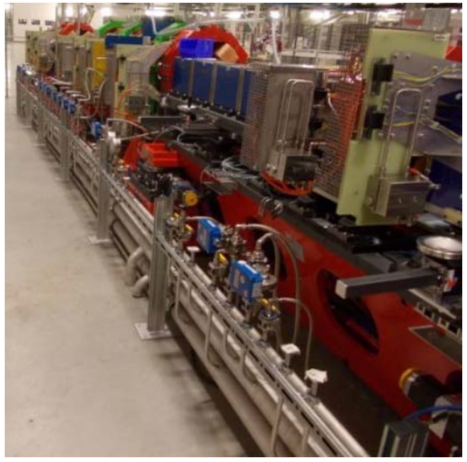
Limited space identified & measured by alignment team for each entry point

INSTALLATION PHASE - FLUIDS

- Local 3D routing in the SRTU (Storage ring)
- Error on 3D model, issue solved easily by local welding.
- Definition of equipment, flow, type of connections for each cell
- All piping equipment prepared in advance and tested.
- Traceability of all installed equipment
- Well prepare phase no bad surprise. (except for total duration which was hopefully less and was an opportunity to do other tasks)

Quality control of welds & endoscopic control



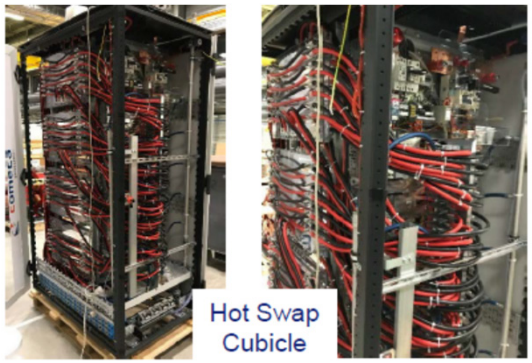


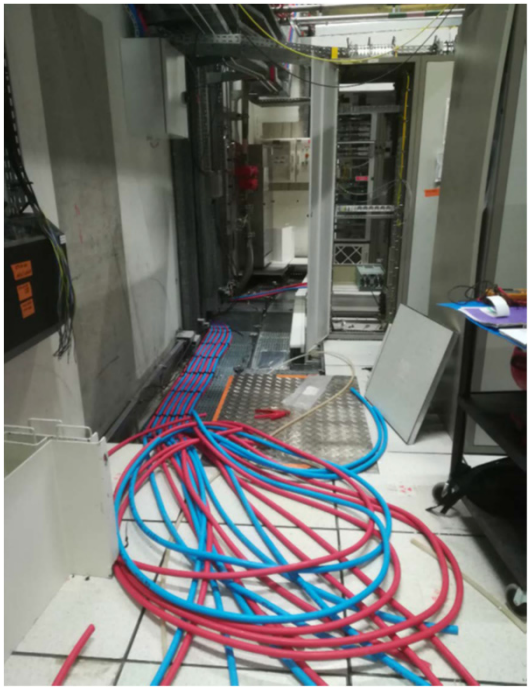
INSTALLATION PHASE - ELECTRICITY

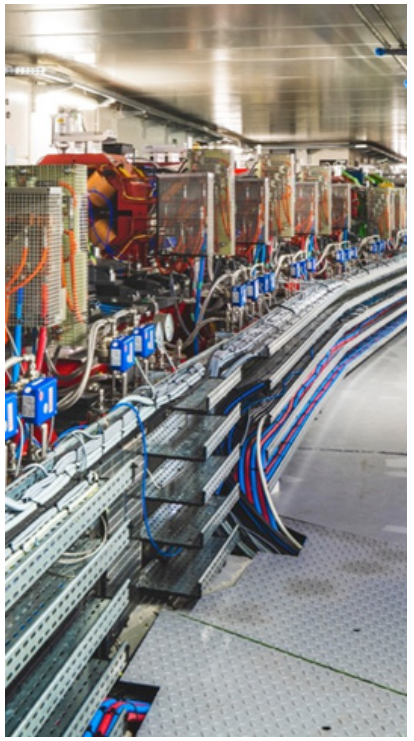
- Installation Planning (long task)
- Some cables desirable for vacuum phase
- Power needed for bakeout.
- Vacuum installation equipment designed to work before Electrical phase.
- Some vacuum tasks scheduled in advance to ease electrical phase
- Electrical work in SR and Technical gallery done in time.
- Anticipated vacuum work made it possible to optimize the process

→

- Electrical activities done with 2 companies
- Supply, installation, labelling, testing of all cables from the cubicles to the various equipment in the SR
- 6.7 Km of cable trays
- More than 12500 cables
- 50 different cables
- >300Km of cables
- > 15000 connectors with >100 connector references



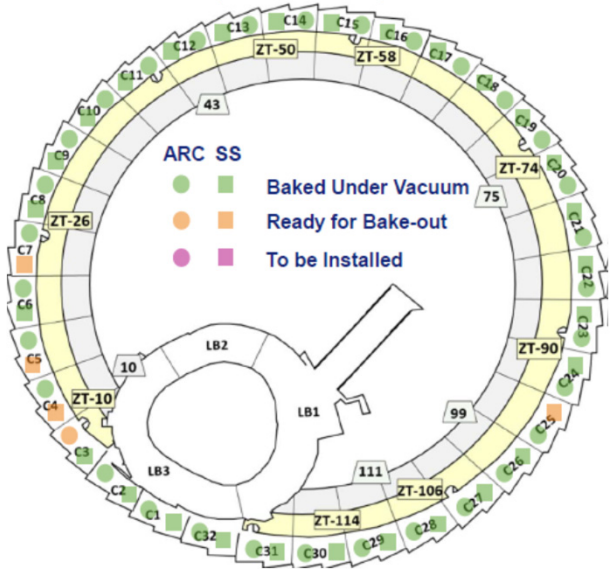


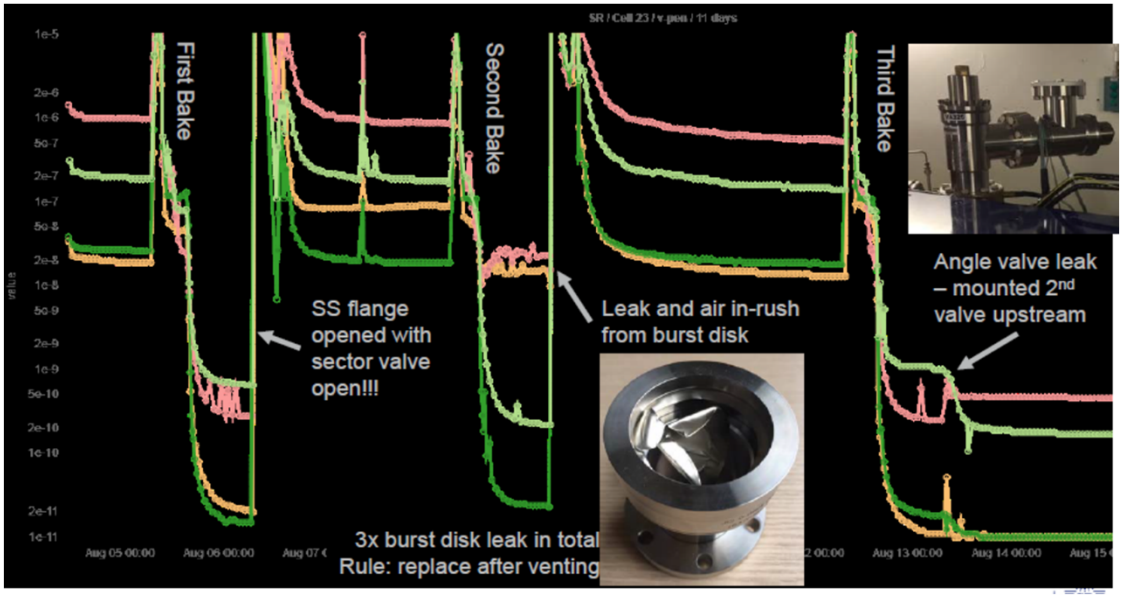


INSTALLATION PHASE - VACUUM

Leak and air inrush from burst disks
Angle valve leak
Sector valve opened after bakeout
Burst disk protected
2nd angle valve mounted to save time
Remote valve electrovalve disconnected until commissioning
Only minor issues without impact on the installation planning

ARC-3 + G0 + 3x RF SS will be baked by week 45 (November 5th)

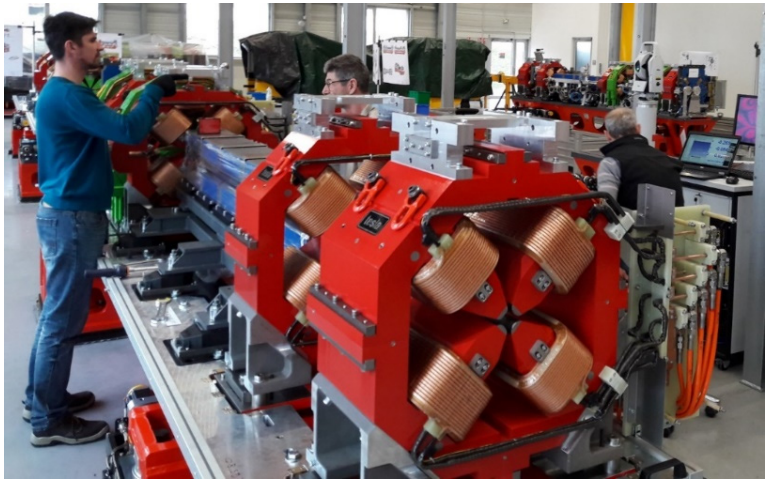




Courtesy C Maccarrone

INSTALLATION PHASE - ALIGNMENT

- Magnets fiducialization, assembly, installation
- Resource intensive for the Survey and alignment Group
- A number of seriously underestimated interventions
- Assembly required a number of steps and 3 weeks of highly organized work.
- More teams and time additional slots
- Additional manpower anticipated. Long discussions to integrate all tasks. Alignment done in time.



Activity	No. Teams Originally Planned	No. Teams Actually Used	Duration
Fiducialisation	Not scheduled	1 ESRF, 1 Ext	06/17 to 02/19
Assembly	1 ESRF	2 ESRF, 2 Ext[1)]	10/17 to 06/19
Installation	2 ESRF, 2 Ext	4 ESRF, 2½ Ext[2)]	02/19 to 11/19

Courtesy D Martin

1) One exterior company team and one Russian/Italian team
2) On average two teams plus a supervisor with regular peaks of four teams

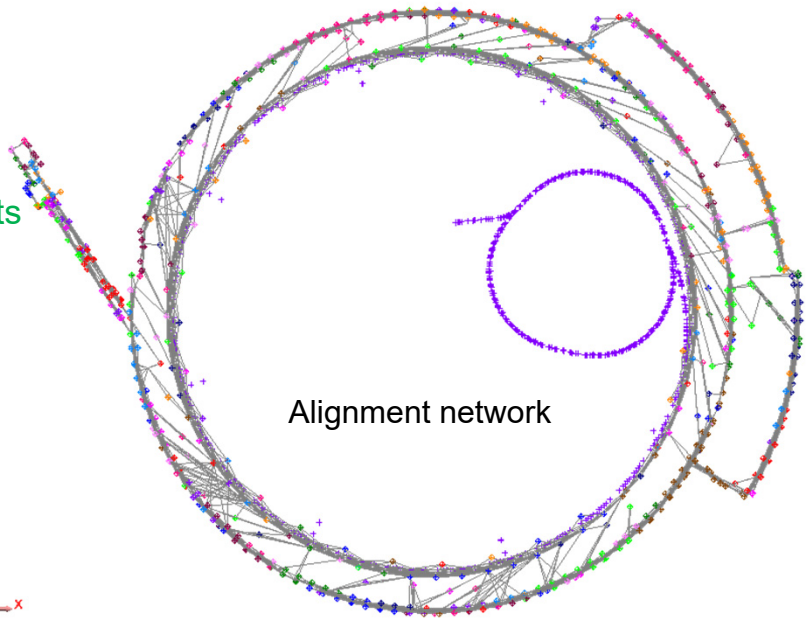
INSTALLATION PHASE - ALIGNMENT

The girders were assembled in ESRF01, moved to storage, moved to their final positions in the SR tunnel
Installing the magnet girders in the machine involves two related constraints; we need to put it in the right place, and second we have to minimize (smooth) the errors between adjacent magnets and girders
Survey network is used to put the machine in the right place

- Uncertainty in our networks well below 100 um. However the dismantling of the machine had a very dramatic effect on them
- Alignment has been one of the most time consuming and demanding activities in the EBS installation
- Conditions were non-optimal but results have been surprisingly good
- 30th Jan 2020 : 26/27 BEAMLINES see Synchrotron radiation at White Beam viewer.
- Very good preparation and a lot of survey/measurements

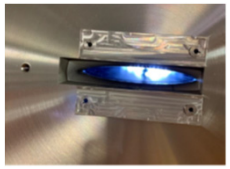
From simulations the estimated SR alignment errors are:
H 30-45 µm
V 20-45 µm
The quadrupole alignment tolerances required where:
H 50 µm
V 50 µm

Courtesy S Liuzzo

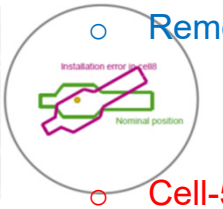


Courtesy D Martin

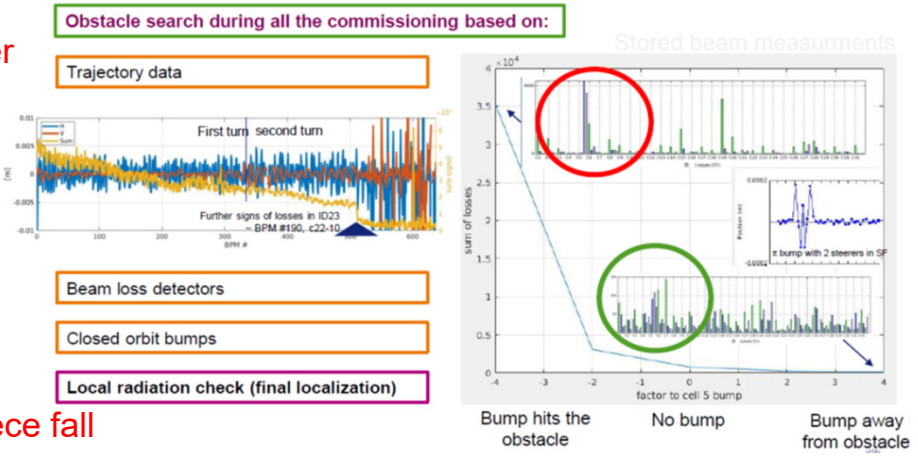
COMMISSIONING PHASE



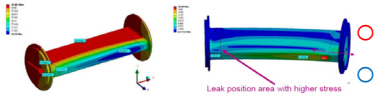
- Obstacle in SS-23 ID chamber
- Chamber replaced



- Cell-8 -Bellow 9-11
- Remounted correctly



- Cell-5 in Chamber-7 Al foil piece fall during installation of DQ2
- Al foil removed



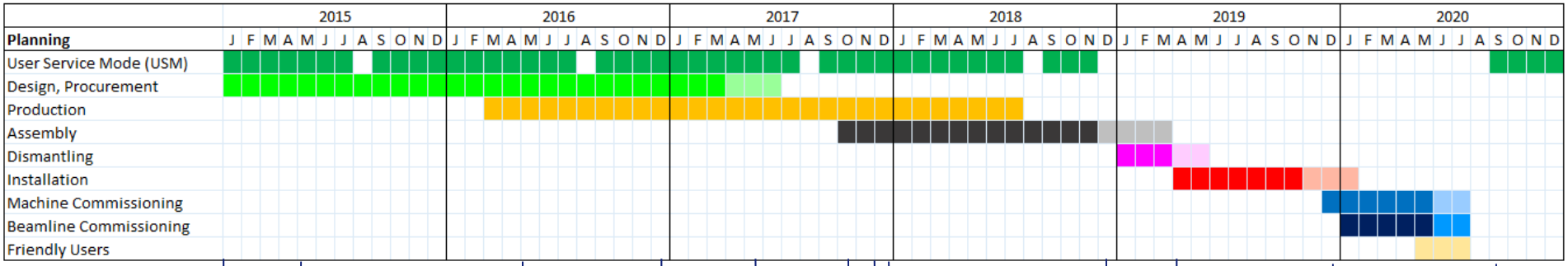
- Air leak from K3 Kicker ceramic chamber while attempting to ramp-up in 16 bunch mode
- leak coming from glazing join (thermal stress)
- Timing mode current limitation
- Replace kickers and shakers ceramic chambers with increased titanium coating thickness
- Redesign of Kickers

- wrong calibration of almost all electromagnets of the storage ring and crosstalk between the magnets
- Magnet excitation curve calibration errors

- Spare, teams responsiveness

EXTREMELY BRILLIANT SOURCE – PLANNING

2015 Planning



January 2015
Launch of project

May 2015
1st Call For Tender

April 2016
Design 90%
Critical prototypes 100%

December 2016
1st Girders, chambers & magnets delivery

May 2017
Completion Storage temporary buildings

November 2017
Start Girders Assembly

October 2017
Completion Assembly building

December 2017
PM Dipole assembly completed

December 2018
Start Dismantling old accelerator

March 2019
Start installation new accelerator

December 2019
Start commissioning new accelerator

25th August 2020
Start USM

Results

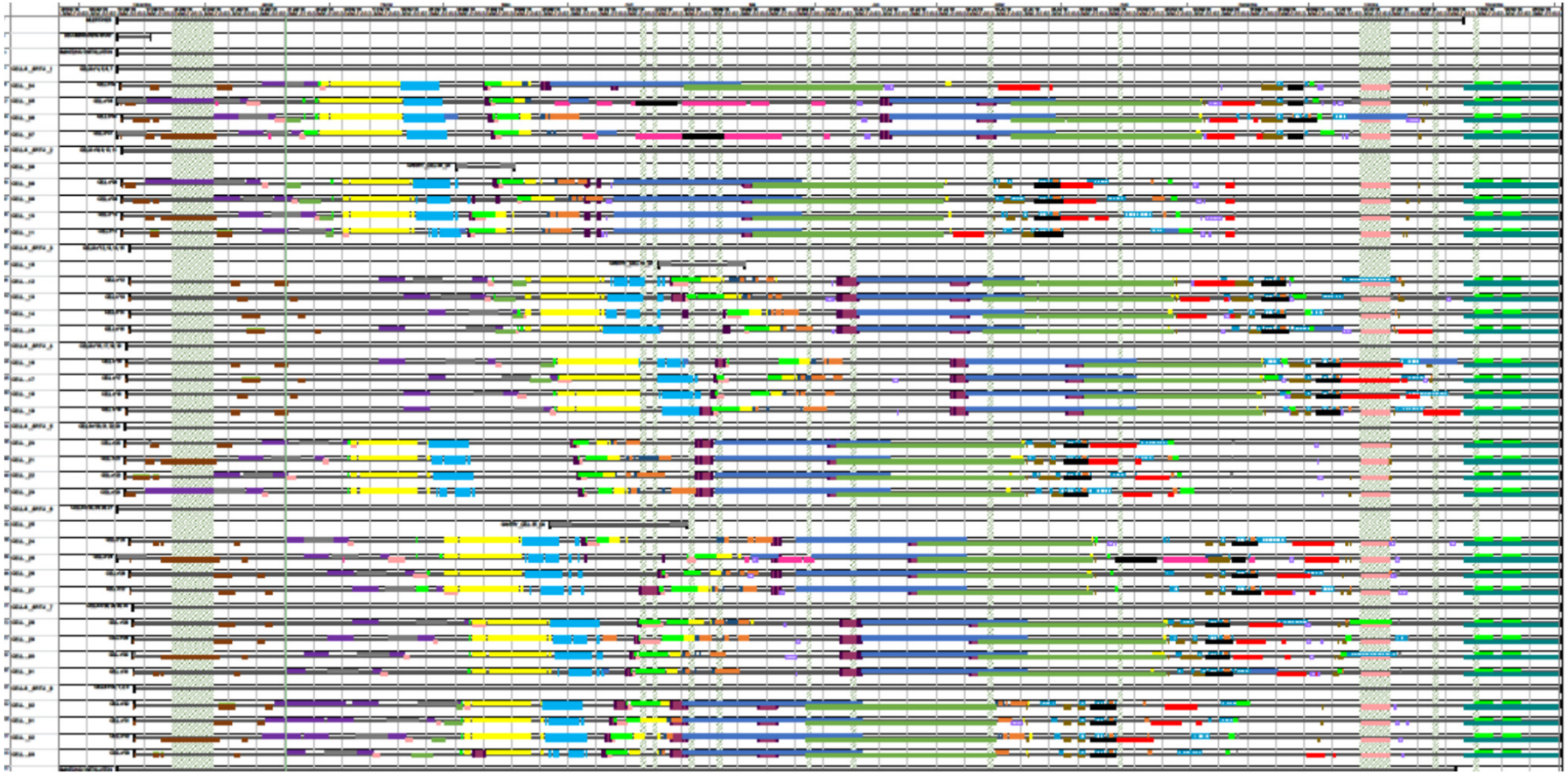
EXTREMELY BRILLIANT SOURCE – SHUTDOWN PLANNING

32 cells divided in 8 independant working zones (coactivity)

Jan 2019

Nov 2019

SR: 32 cells

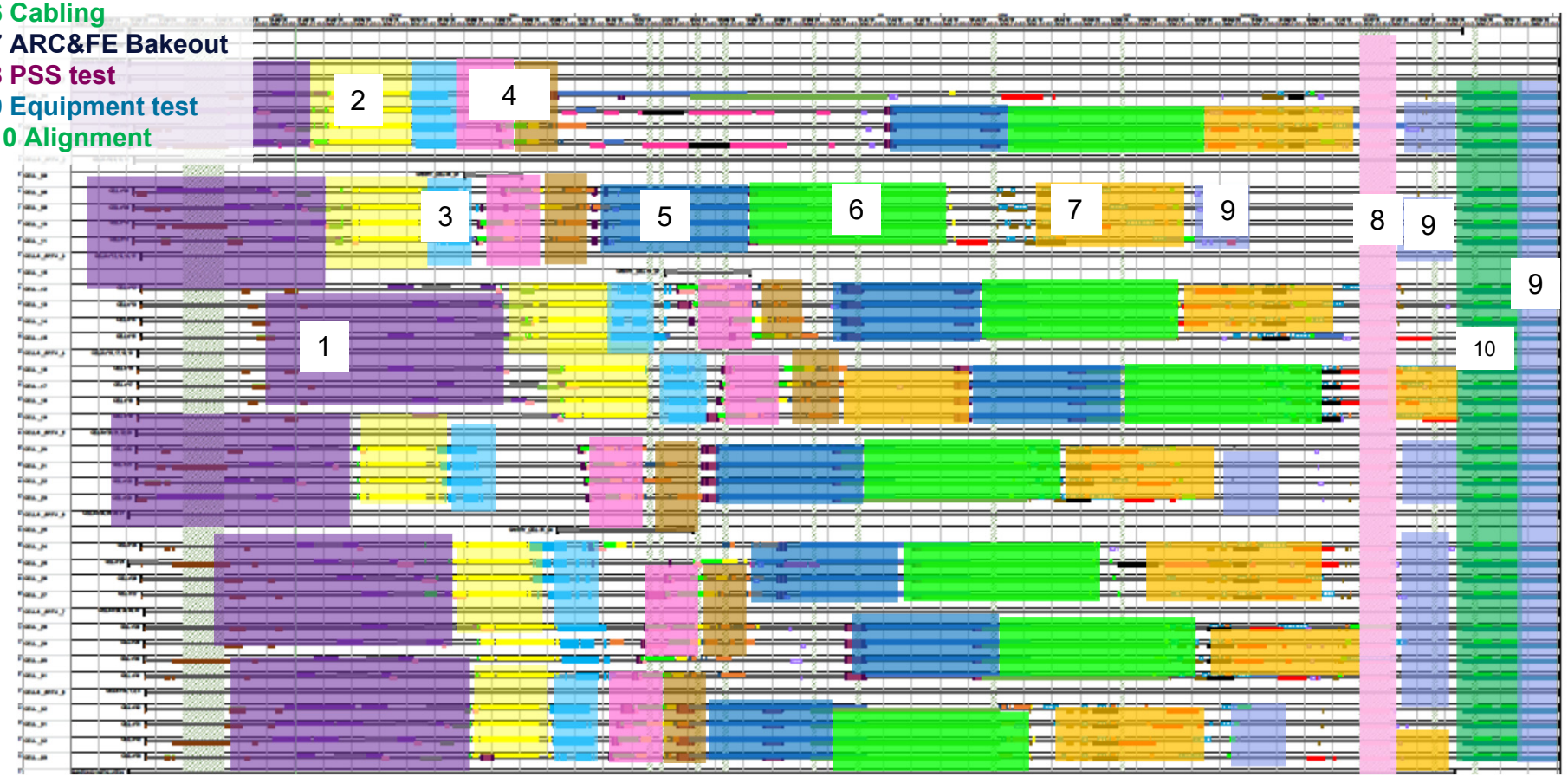


Safety | Coactivity

EXTREMELY BRILLIANT SOURCE – SHUTDOWN PLANNING

EXTREMELY BRILLIANT SOURCE – SHUTDOWN PLANNING

1 Dismantling
2 Civil works
3 Ref plates Girders
4 Girder entry +FE
5 Piping
6 Cabling
7 ARC&FE Bakeout
8 PSS test
9 Equipment test
10 Alignment



CONCLUSION

- Before shutdown
  - All Girders assembled
  - Gantries for girder installation ready & tested
  - RF cavities, Front-Ends, diagnostics pre assembled
  - Magnets power supply long cables pre-installed in the Technical Gallery
  - Timing system upgraded and tested
  - Technical Gallery network cable routing dissociated from signal cables
  - Logistic & tools for all girders movements

Anticipate

- During Dismantling phase
  - Start of In-Vacuum undulator adaptation for EBS

- After Civil work phase
  - All cabling pre assembled & tested
  - All piping system pre assembled , & tested

- Planning
  - Master planning completed and reviewed before the shutdown
  - Detailed planning updated every week (progress, new tasks…)
  - Web based task lists with daily progress status & automatic mailing

Communicate

CONCLUSION – WHAT WE LEARNED

The new EBS storage ring is up and running with design performance
The USM operation restarted on 25 August 2020 despite the COVID-19 pandemic

- Technical issues
- Components delivery issues
- Resource issues

- What is not clearly identified and specified will cause problems
  - (BPM button stainless steel, magnets fiducialization, vacuum chambers tolerances)
- All tasks should be analyzed and assigned
  - (Girder plates gluing)
- Long tasks must be detailed
  - (Fluids)
- Listen to understand
  - alignment additional tasks and underestimated workload
  - Tolerances

- **Safety first**
- **Communication: You know what you say not what the others understand**
  - **(Civil work, Mechanical Engineering, Safety, Beam dynamics, Logistic…)**
- Anticipate and have always a backup solution
- Team work
- Dialogue to move from “who is responsible” to how to find a solution together
- All issues related to debugging and tuning have been fully and timely acknowledged and proper solutions have been successfully applied.
- Involvement of young staff to keep the know-how

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- Accelerator & Source Division
- Instrumentation Service and Development Division
- Technical & Infrastructure Division
- Experiment division
- Administration Division
- Directorate & Safety group

- INFN & BINP

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MANY THANKS FOR YOUR ATTENTION