The ESRF Extremely Brilliant Source

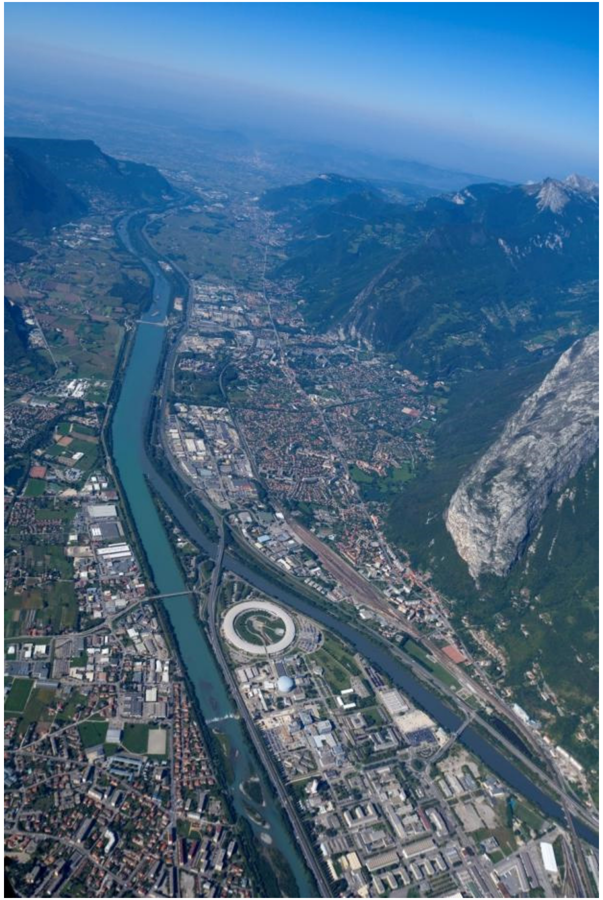
A 4th generation light source

Jean-Michel Chaize on behalf of ESRF accelerator Control Unit

ESRF | The European Synchrotron

ESRF-EBS
Extremely Brilliant Source

Outline



- **ESRF-EBS Project:** goal, characteristics
- **EBS components**
  (from control system point of view)
- **Project management and planning**
- **Accelerator Control system**
  - Hardware infrastructure
  - Software
  - New synchronization system
  - New archiving system
  - Experiment control

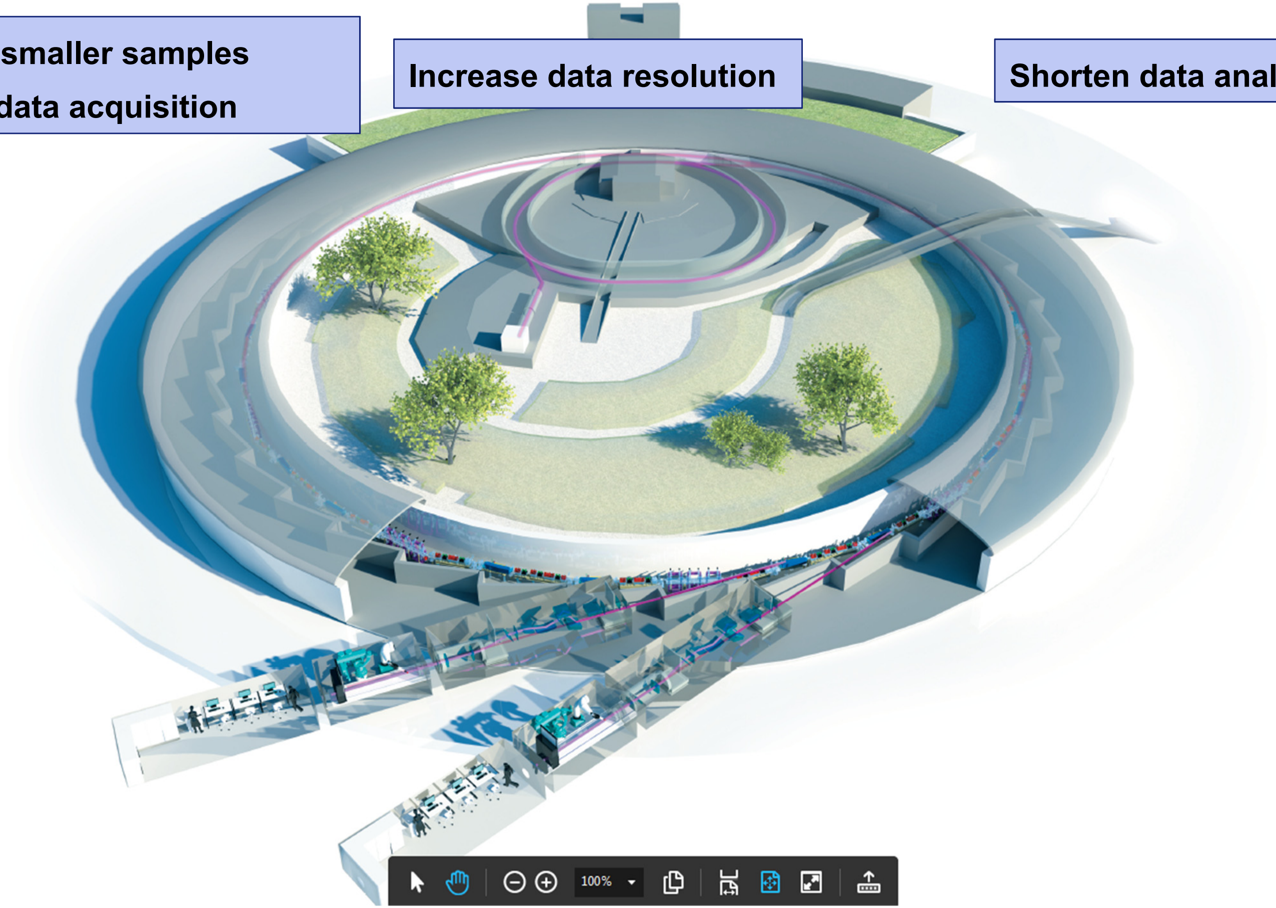
Why EBS? -> Increase the science outcome

Work on smaller samples

Shorten data acquisition

Increase data resolution

Shorten data analysis



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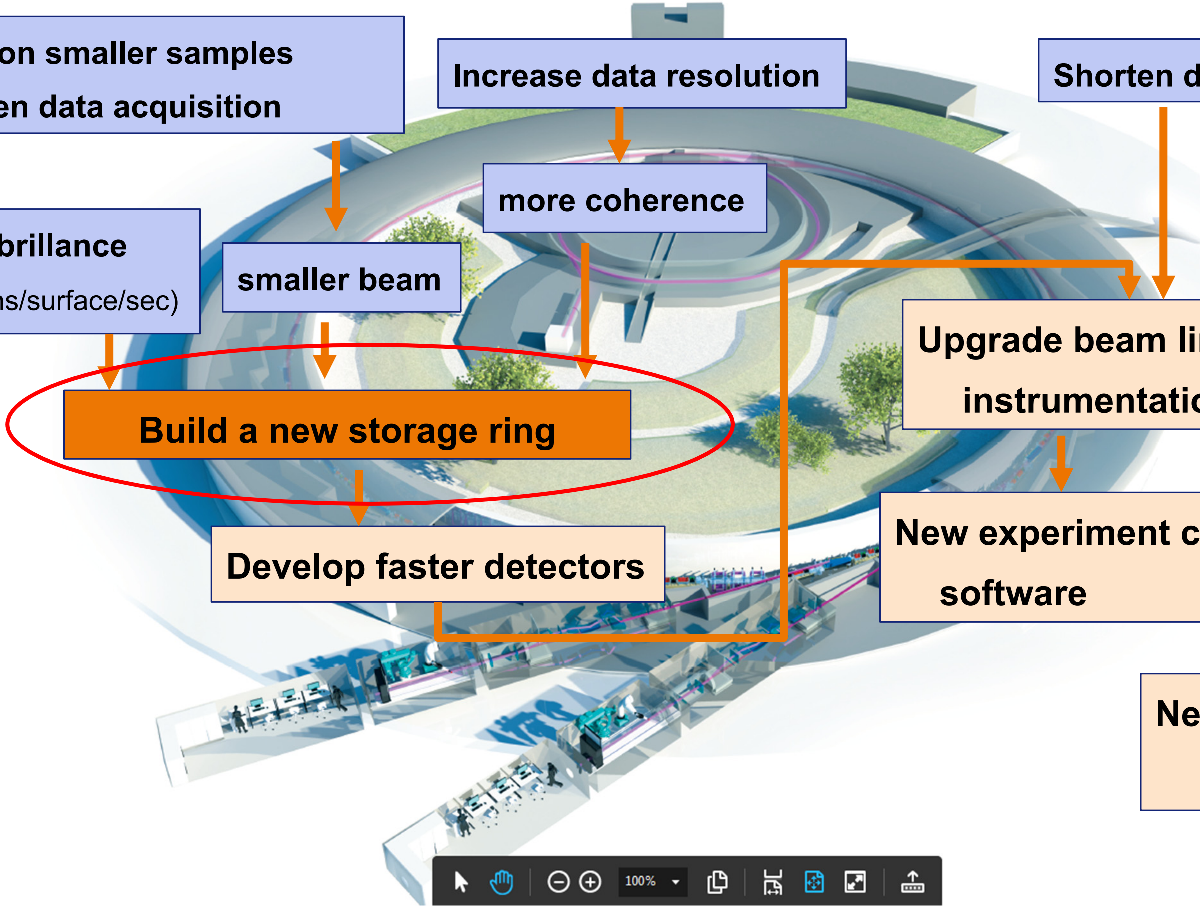


Work on smaller samples
Shorten data acquisition

Increase data resolution

Shorten data analysis

more brillance
(photons/surface/sec)

smaller beam

more coherence

Build a new storage ring

Upgrade beam lines instrumentation

New experiment control software

Develop faster detectors

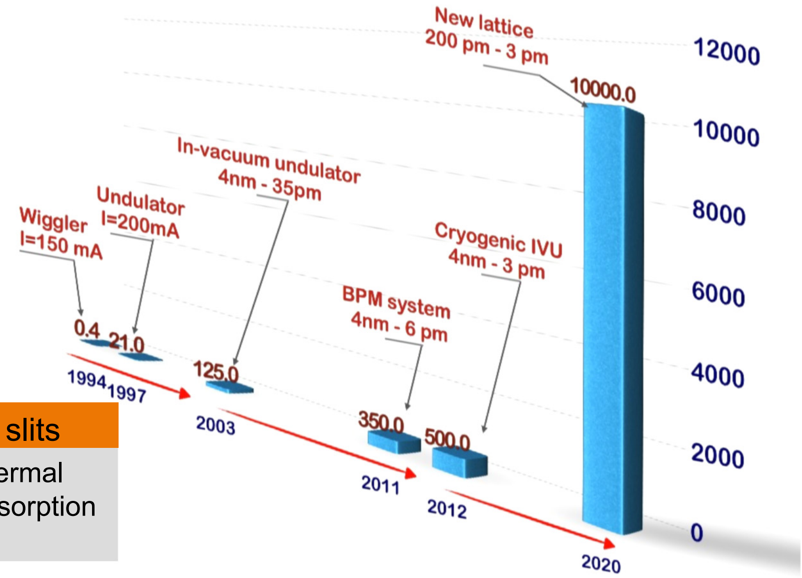
New data analysis software

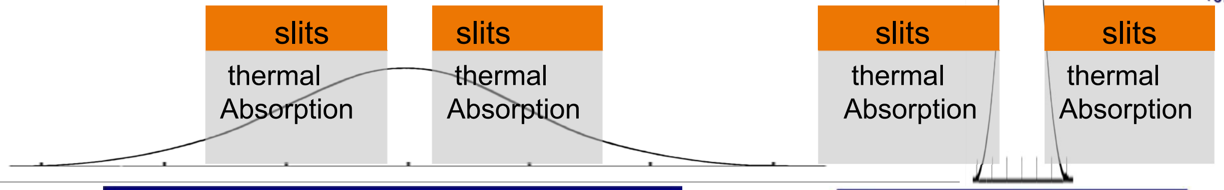
EBS – Reduction of the horizontal emittance -> Increase of brilliance

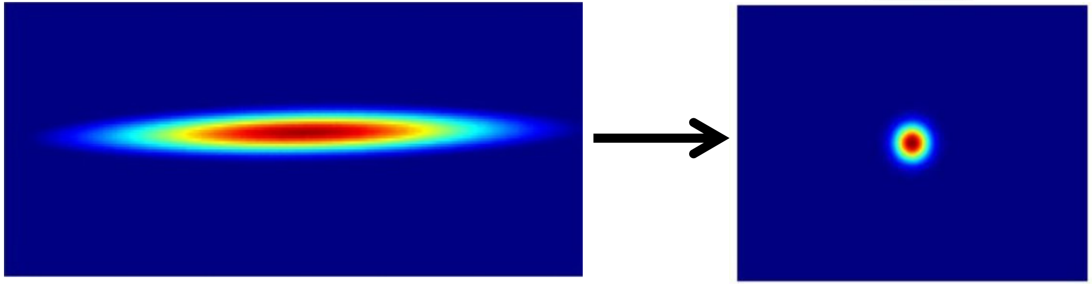
Reduction of the **horizontal** emittance
from **4nm.rad** to **0.14nm.rad**

$$\text{emittance} = \frac{6\pi\left(\text{width}^2 - D^2\left(\frac{\mathrm{dp}}{p}\right)^2\right)}{B}$$

Expected gain on a monochromatic beam:
X100 in number of photons/s/surface on the sample.







Same number of photons on smaller array (x26)
+ Higher monochromatic peaks (x2)
+ Better capture at the sample place (x2).

The EBS Storage Ring characteristics

	Now	EBS
Energy (GeV)	6.04	6
Multibunch current (mA)	200	200
Circumference (m)	844.39	843.98
Horizontal emittance (nm.rad)	4	0.14
Vertical emittance (pm.rad)	4	5
Number of beamlines	43	47

reduced by a factor of 29

14 refurbished, 4 new

Main engineering challenges:

- Reuse 90% of the infrastructure
- Fit new lattice in the same tunnel. Same circumference.
- Insertion devices at the same locations: keep beamlines where they are!
- Re-use injector complex, ID, FrontEnds, Infrastructure...
- High precision & high stability positioning requirements
- Little time for the project and in parallel to the normal operation of the facility

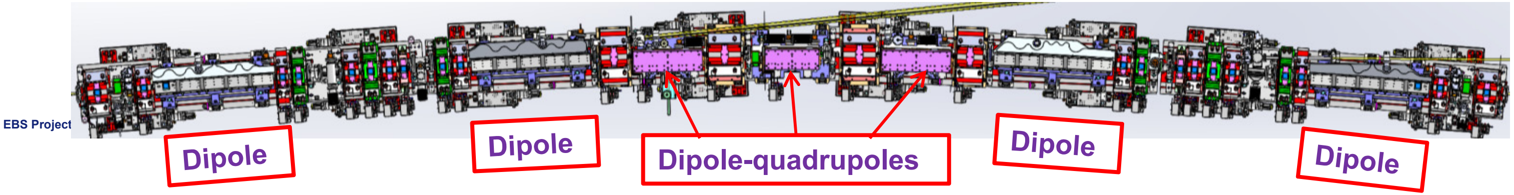
Main EBS accelerator components

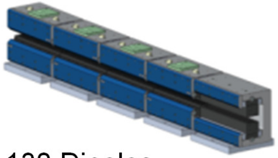
Magnets

➢**EBS magnetic lattice** (32 identical cells of 26m long)

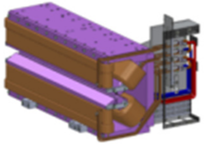
Hybrid 7 Bend Achromat = (4 dipoles + 3 dipole-quad + 24 quad., sext., oct.) per cell

➢+33 corrector channels (24 Inside sextupoles and 9 in corrector magnets)

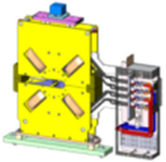




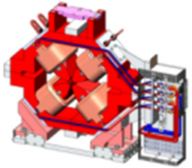
132 Dipoles
Permanent magnets



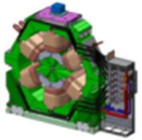
100 Dipole-quadrupoles
Including 1 field corrector



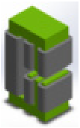
66 Octupoles



524 Quadrupoles



196 Sextupoles
Including 4 correctors channels each



98 Correctors
3 channels each

More than 1000 Magnets to be produced

31 magnets per cell instead of currently 17

864 power supply channels for lattice instead of 17!

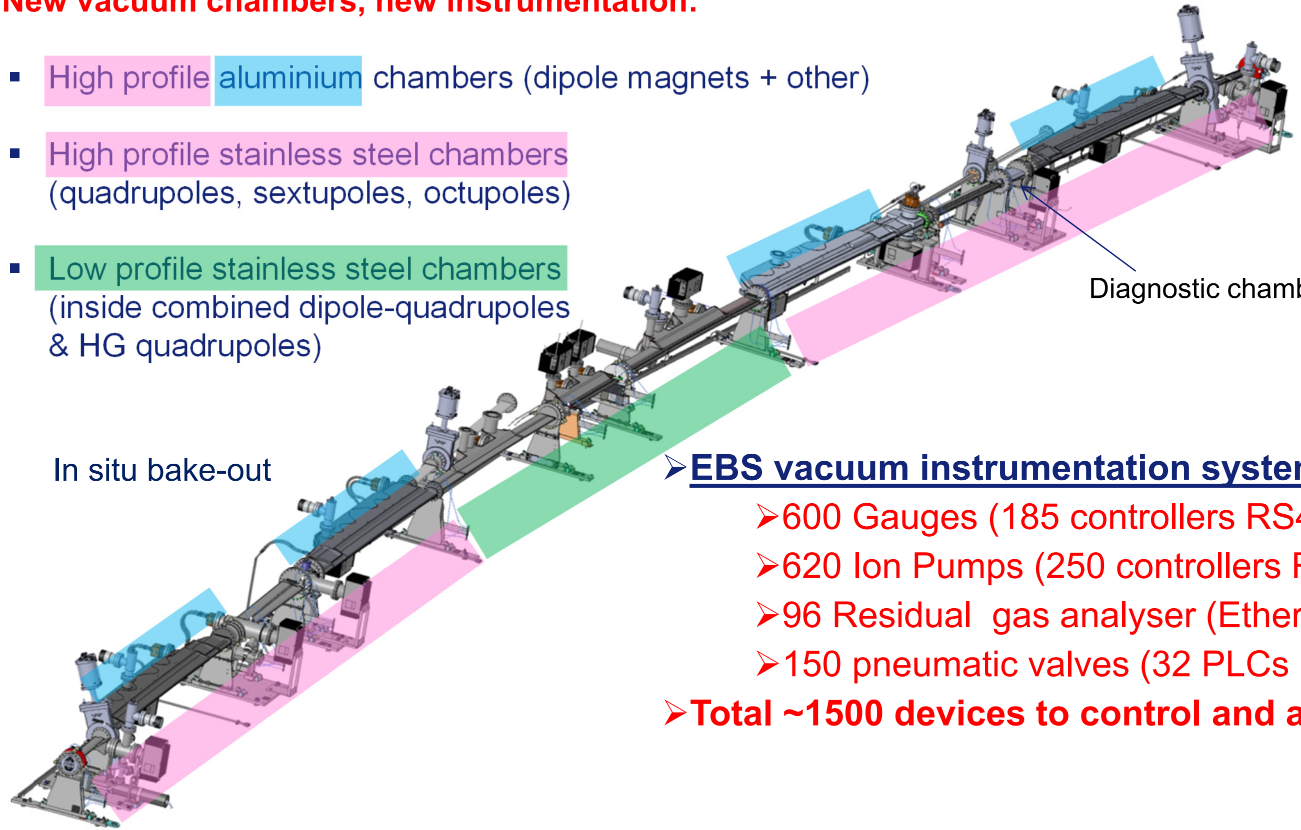
1354 power supplies channels for the correctors

Total ~2300 power supplies to control

Vacuum system

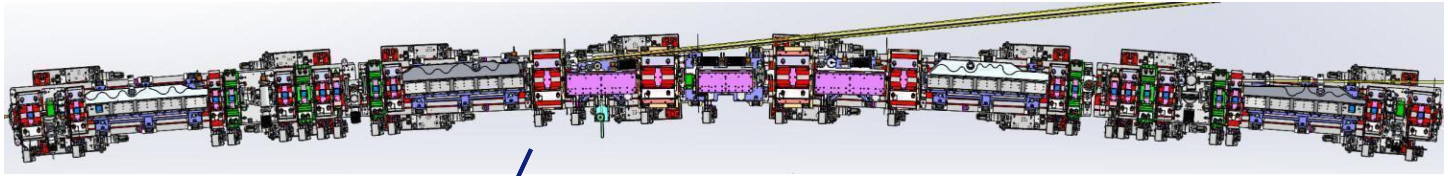
New vacuum chambers, new instrumentation:

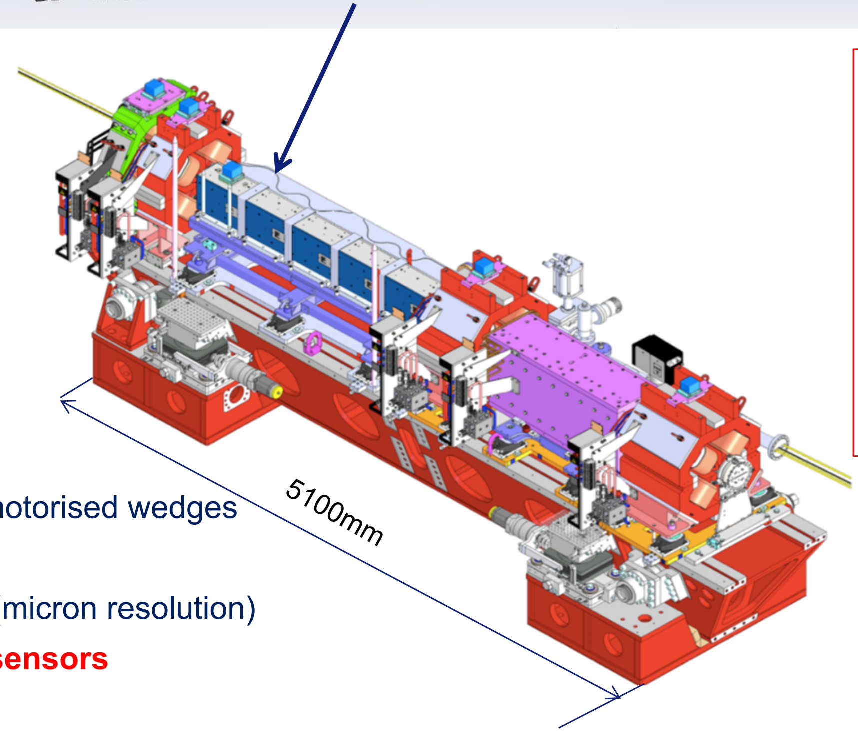
- High profile aluminium chambers (dipole magnets + other)
- High profile stainless steel chambers (quadrupoles, sextupoles, octupoles)
- Low profile stainless steel chambers (inside combined dipole-quadrupoles & HG quadrupoles)



- **EBS vacuum instrumentation system**
  - 600 Gauges (185 controllers RS422 or Ethernet)
  - 620 Ion Pumps (250 controllers RS422 or Ethernet)
  - 96 Residual gas analyser (Ethernet)
  - 150 pneumatic valves (32 PLCs Ethernet)
- **Total ~1500 devices to control and archive**

Girders



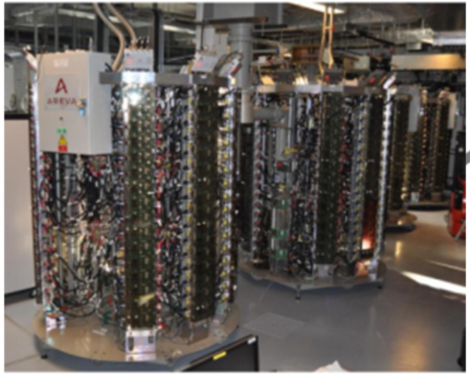


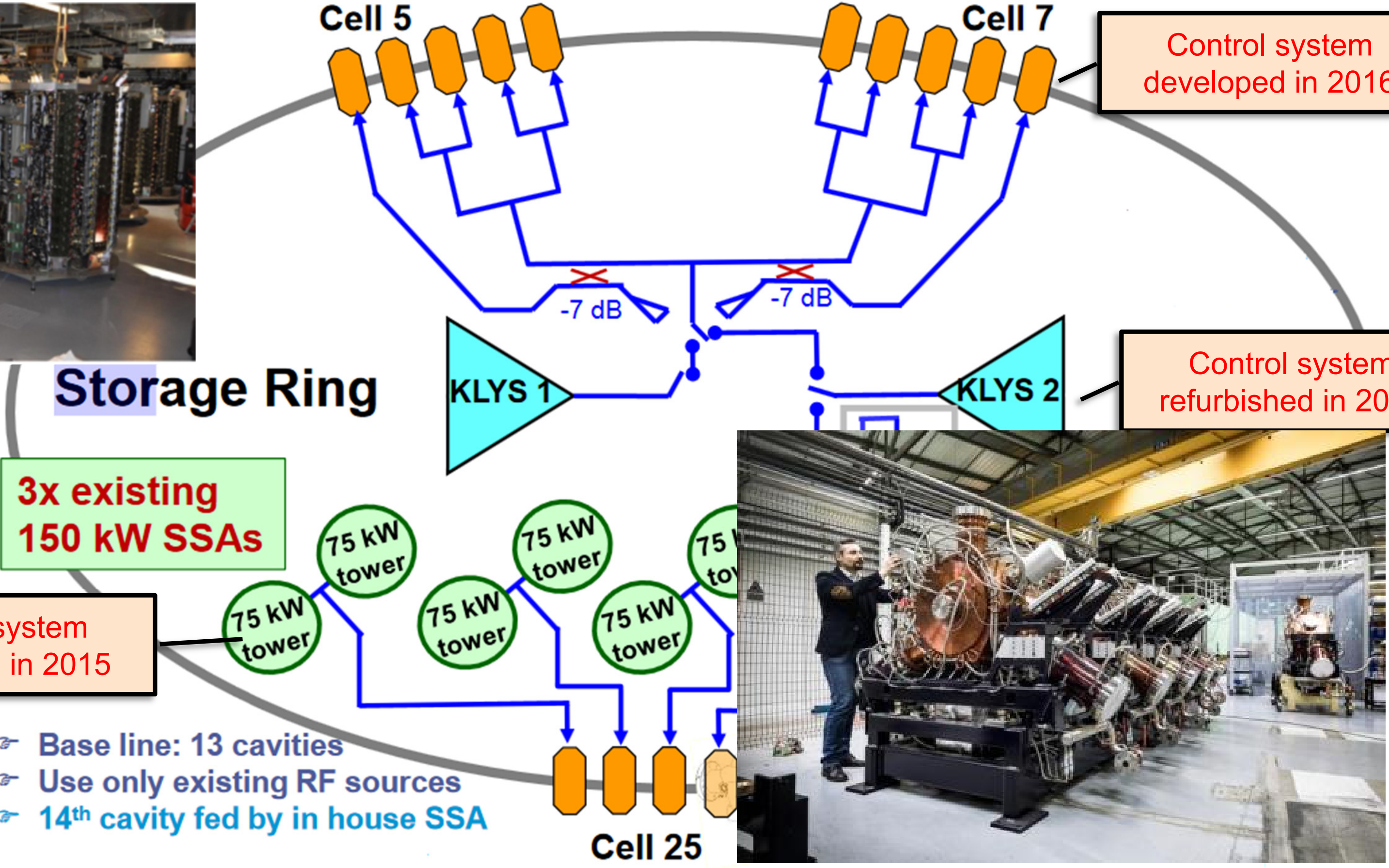
Four girders per cell to install:
- Magnet supports
- Magnets
- Vacuum equipment
- Diagnostics

Bare girder weight: ~6t
Fully equipped girder: ~12-13t
129 girders in total

- 4 adjustable feet with motorised wedges
    - Hyperstatic
- 4 Hydrostatic Sensors (micron resolution)
- **Total: 512 axis + 512 sensors**

Radio Frequency Systems





Control system developed in 2016

Control system refurbished in 2017

Control system developed in 2015

- Base line: 13 cavities
- Use only existing RF sources
- 14th cavity fed by in house SSA

Project management and planning

Main idea: Pre-Assembly the full storage ring on 128 + 1 girders

The Assembly phase takes place during the Operation of the facility!
-Need every pieces, magnets, vacuum chambers,… to start assembly of a girder
-Need storage space for individual pieces and for girders
-Careful management of human resources
-Maintain 24x7 user service of present ring.

- Install magnets on girders & align
- Open magnets
- Install pre-assembled chambers
    - Including pums,gauges,valves
- Back-out
- Align BPM's & chambers
- Close magnets
- Final alignment check

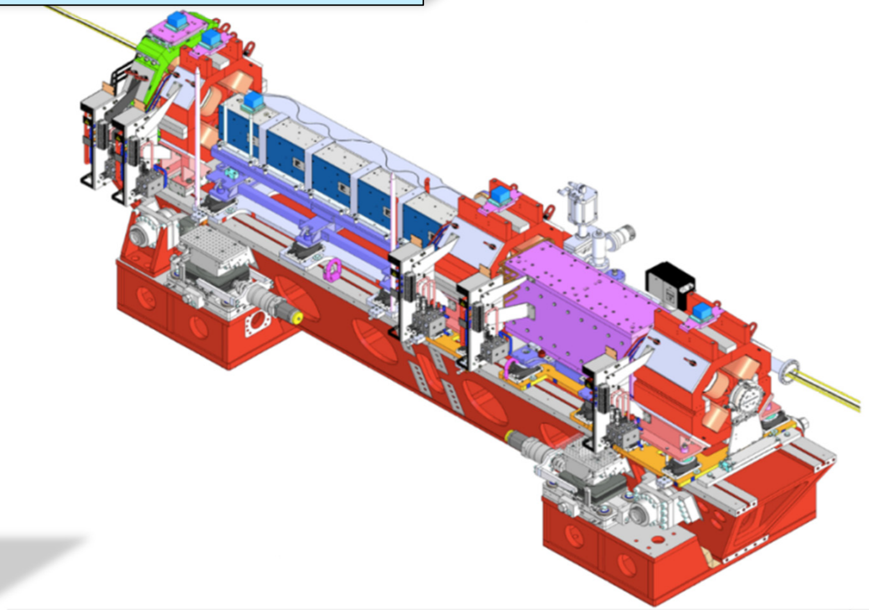
Then:

Dismantle the present ring (including cabling, fluids)

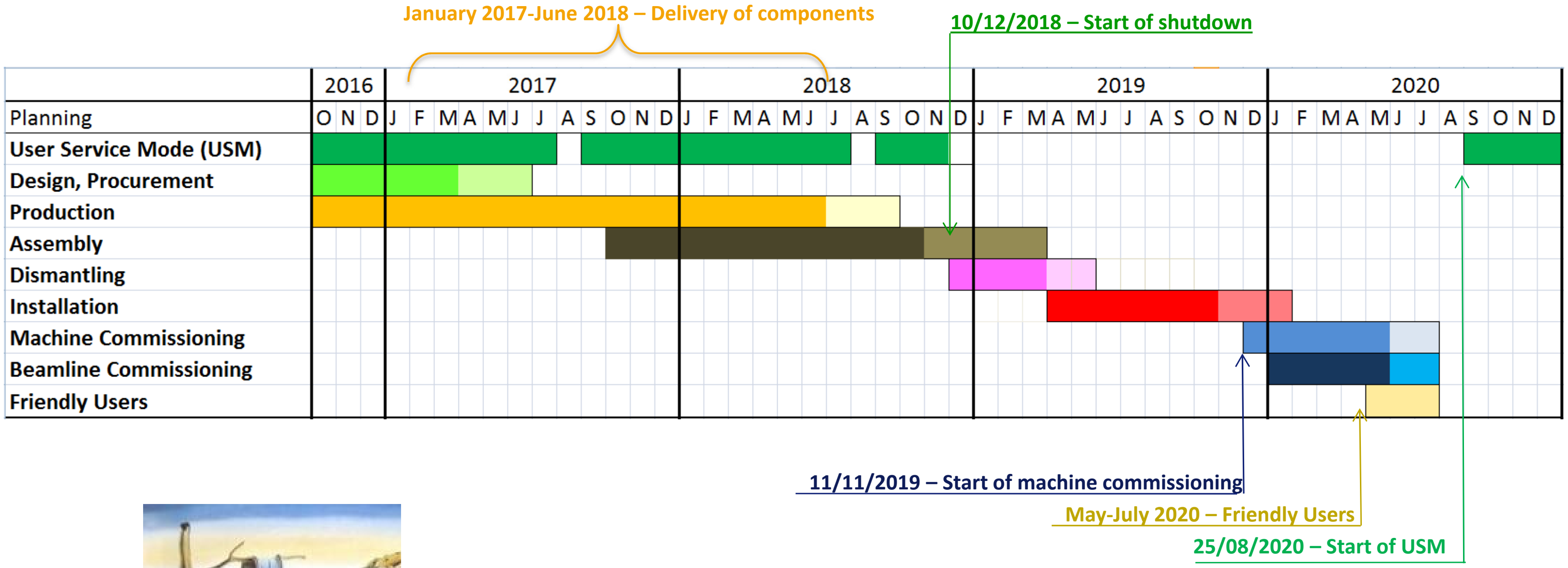
Roll the 129 newly assembled girders in the tunnel

Recable, install cooling and fluids…

Switch ON… and hope…



EBS time line (2016-2020)



Until 10 December 2018	Standard ESRF User service Mode
10 December 2018	Start of the long shutdown,
13 December ->April 2019	Dismantling
11 March 2019 -> October	Installation
11 November 2019	Commissioning starts
02 March 2020	Beamline commissioning starts
25 August 2020	EBS User Service Mode

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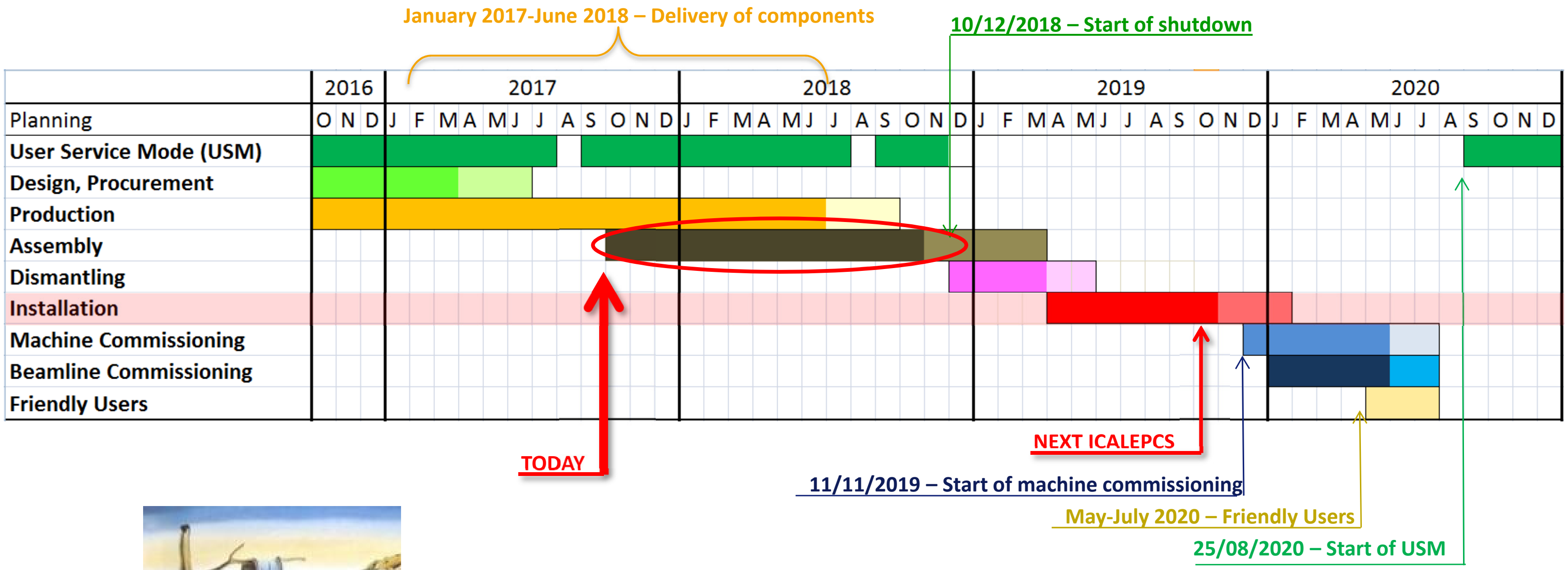

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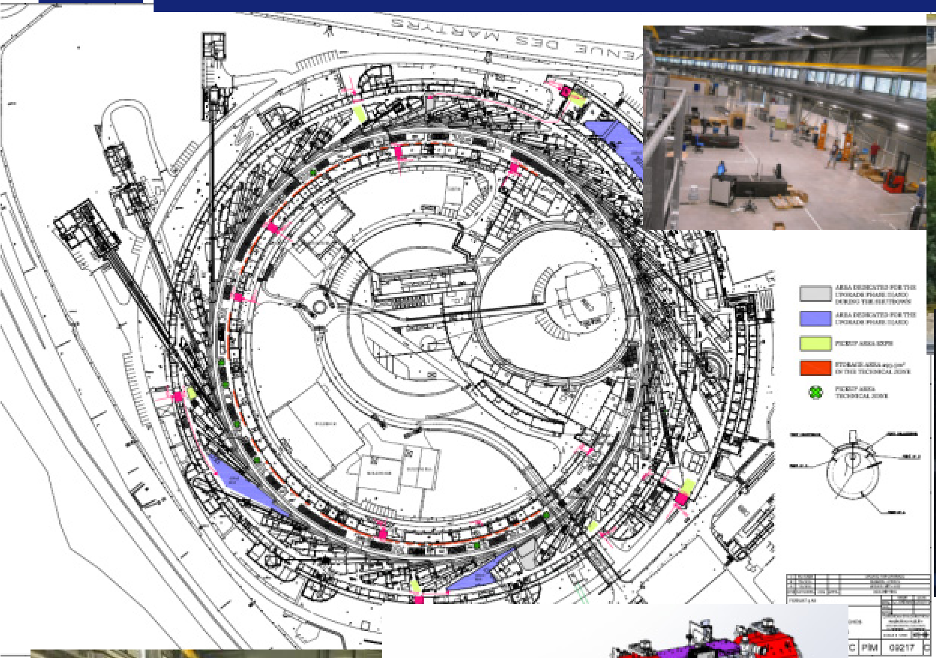
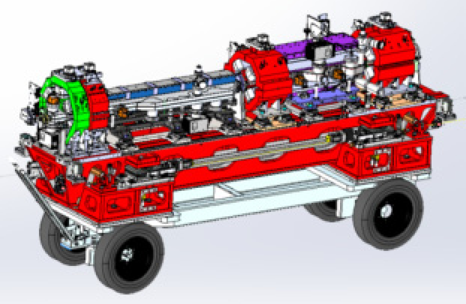
Need huge surface: New Buildings for Assembly, Storage, dismantling.





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The Mock-Up in the Chartreuse Hall

Build and test assembly procedure

Verify good mounting and measure time and resources

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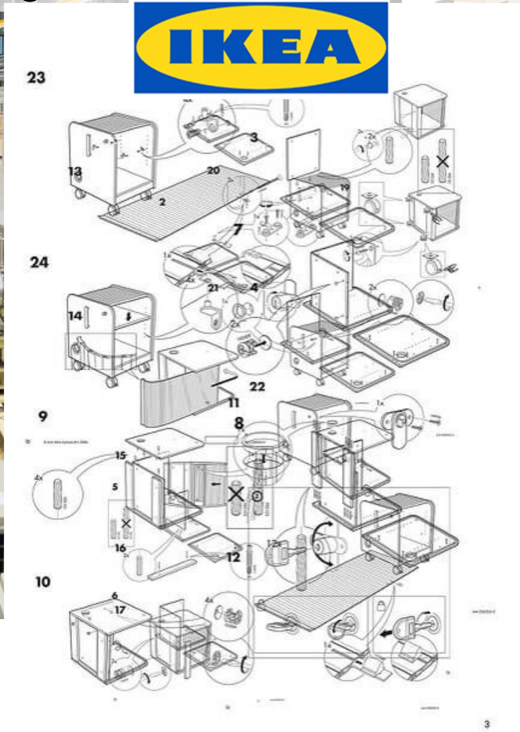

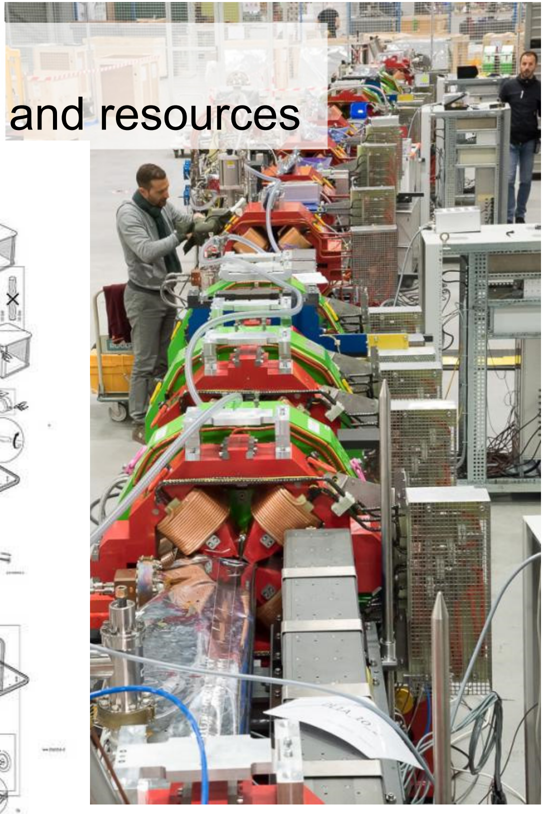

Control system

Management of Obsolescence

- **The EBS new control should be plugged on the injector**
  - A large part of equipment and electronic interfaces reused
    - *Linac, transfer lines, booster, Safety systems, Insertion devices, Vacuum control*
    - *Keep running until end of 2018. cannot be interrupted.*
  - Need a system able to operate old and new devices together
    - *Interconnect different generation of software/hardware*

- **Management of obsolescence is a permanent issue.**
  - There is no way to stay immobile, the landscape is moving
  - Should should go faster than the landscape (at least!)
  - **Hand-shaking necessary between incompatible stuff.**

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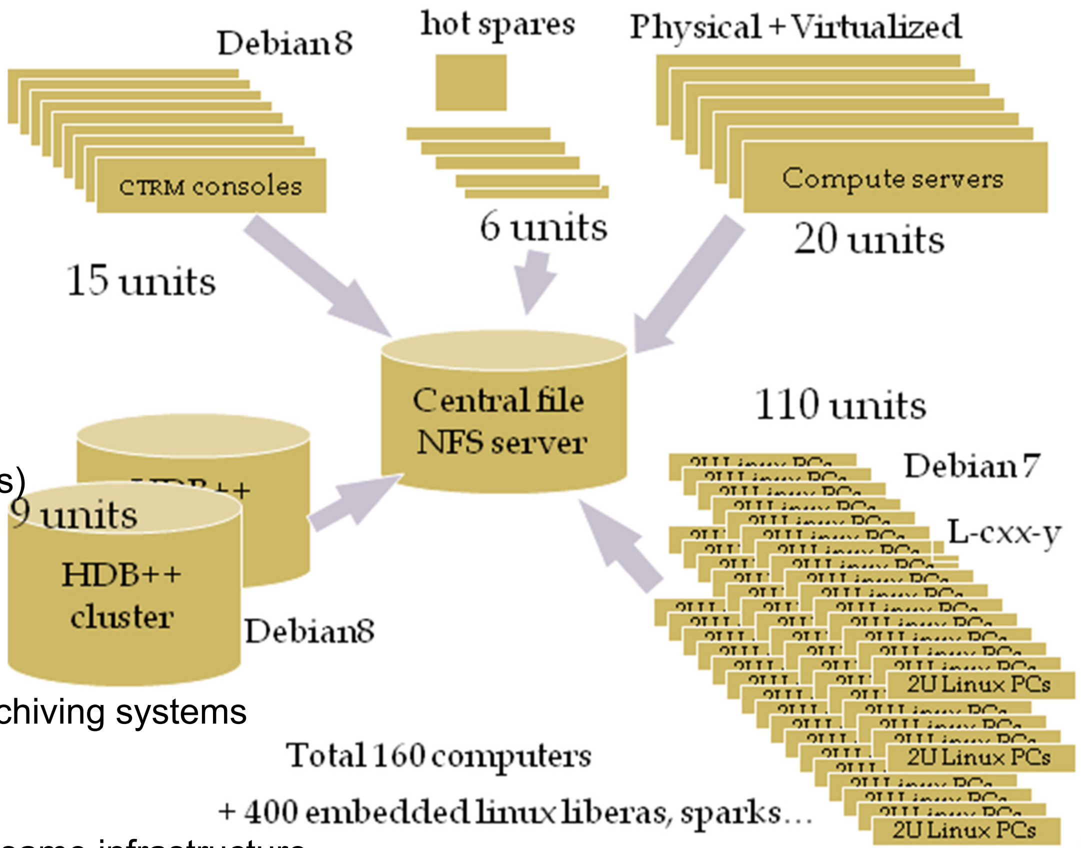
  - Operating systems sometimes imposed by the market
    - No way to install old OS on new hardware
    - No way to change OS when closed source drivers are used
    - Windows-XP systems should co-operator with various linux distrib
- **Choice of a conservative approach**

Control System architecture

Big increase of Ethernet connected devices
Power Over Ethernet ↗
Embedded devices ↗
I/O boards ↘
Field Busses replaced by Ethernet
VME disappears
Only Linux, few units in Windows

Keep physical I/O computers (quasi diskless)
No software packages on it, use NFS
easy exchange with generic spares

Virtualise servers in CTRM (KVM)
No virtualization for CTRM consoles and archiving systems
NFS infrastructure may be conservative
Simple and efficient
Allow old and new hardware to use the same infrastructure



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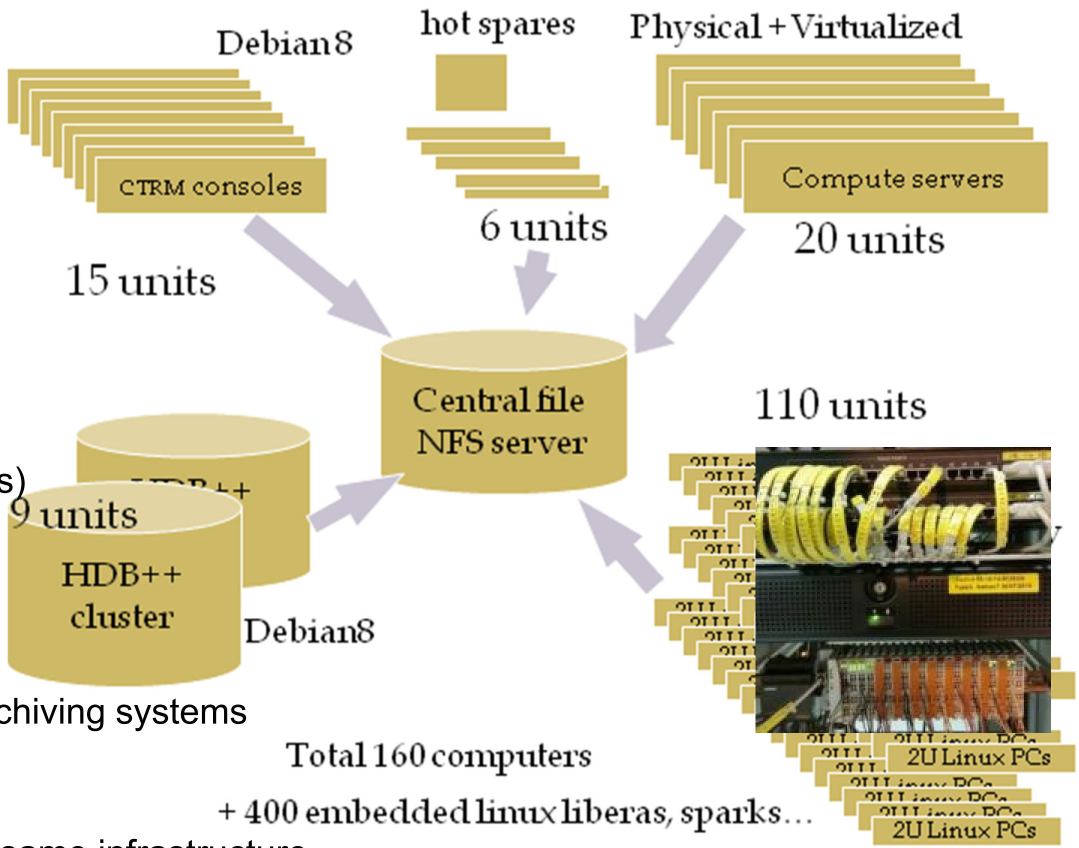
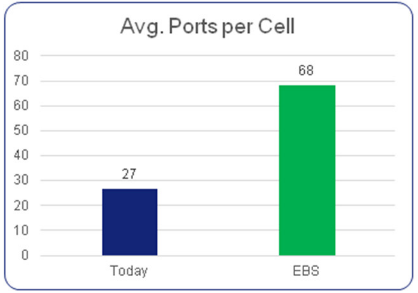


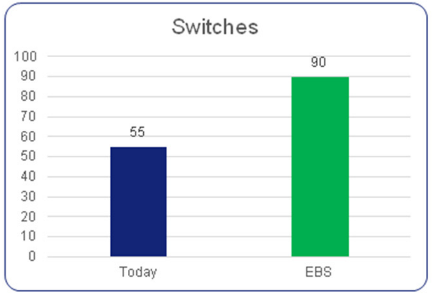
Ethernet becomes more and more critical

The Ethernet network becomes the heart of the control system

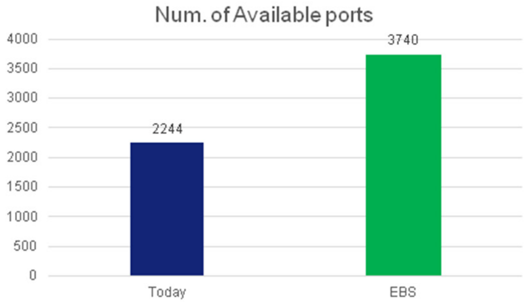
- Field bus -> Ethernet
- I/O boards (e.g. PCI boards) -> Ethernet based remote I/O
- VME systems -> Set of different dedicated embedded systems connected to Ethernet
- Serial lines -> Ethernet
- Many Power Over Ethernet
  - (Gb ethernet cameras, power converters, bpms)

Identified needs (figures)





Ethernet monopoly for communication
must be highly reliable
Choice of Redundant PS, 48VDC + 230VAC
PoE+
PoE management integrated to control system software

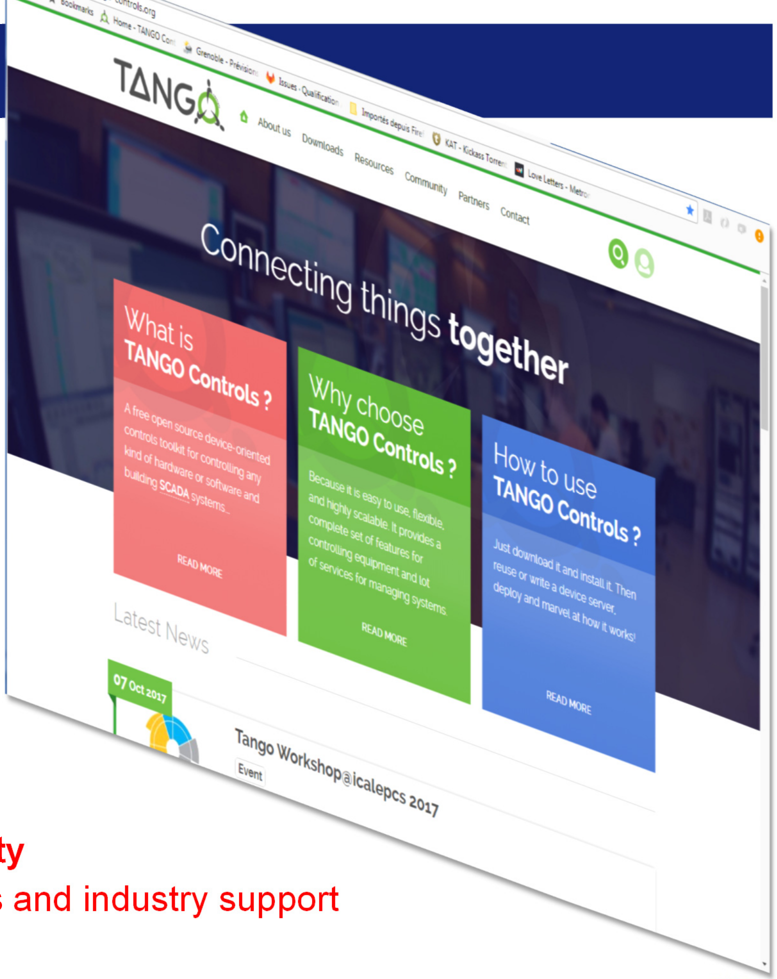


Software framework

Connecting things together

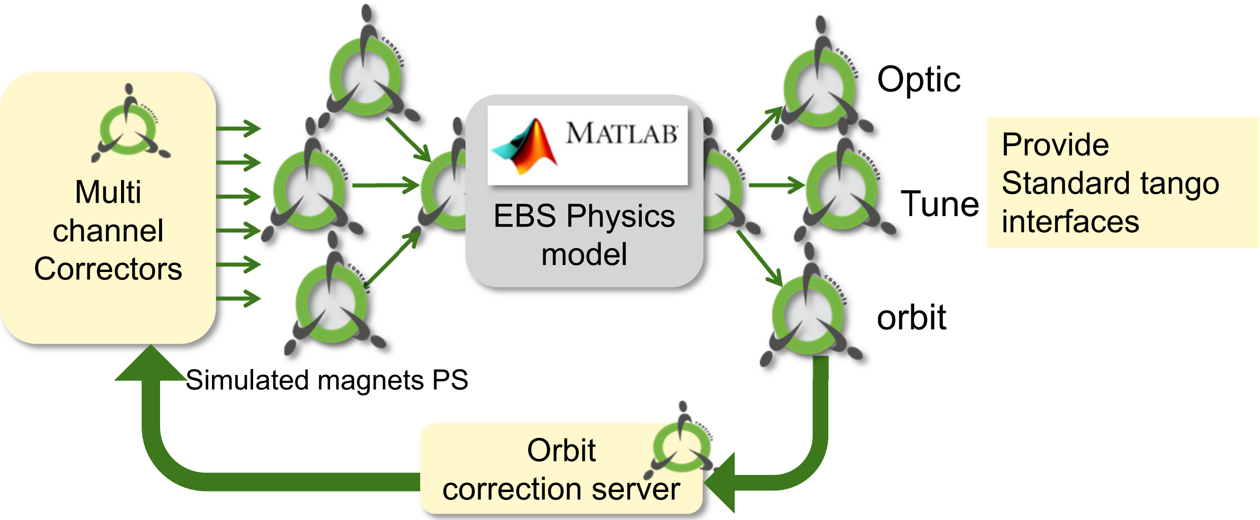
- **Need to manage heterogeneity**
  - Operating systems, software versions, drivers,
- **Need to manage high number of equipments**
  - **> 350000 sensors+actuators**

- **Tango is well adapted**
  - Good scalability
  - No bottleneck
    - Thanks to massive distribution of micro services
  - Excellent management of heterogeneity
  - Live community, well organized, long term **sustainability**
    - Benefit from development done in other institutes and industry support



EBS simulator

Simulates the accelerator and low level control
Integrated to TANGO control system as a real hardware
Middle layer and GUI developed on it



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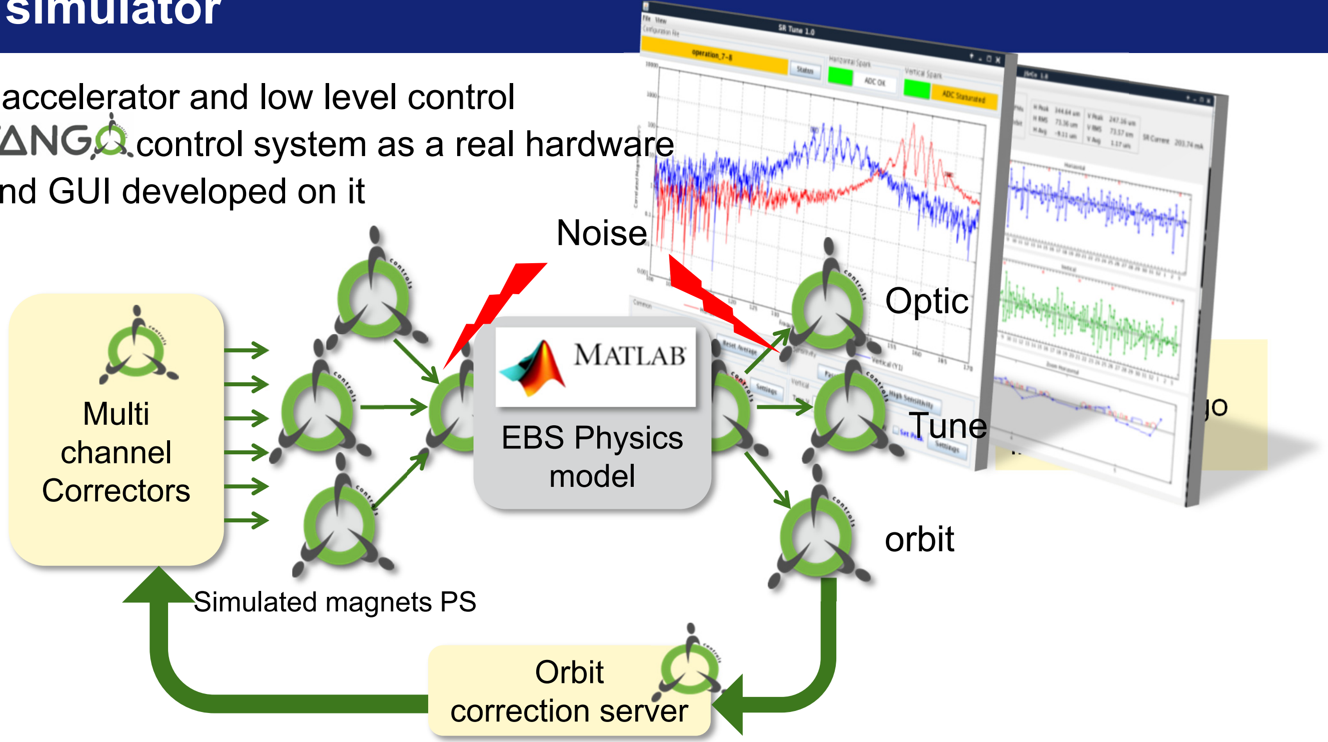

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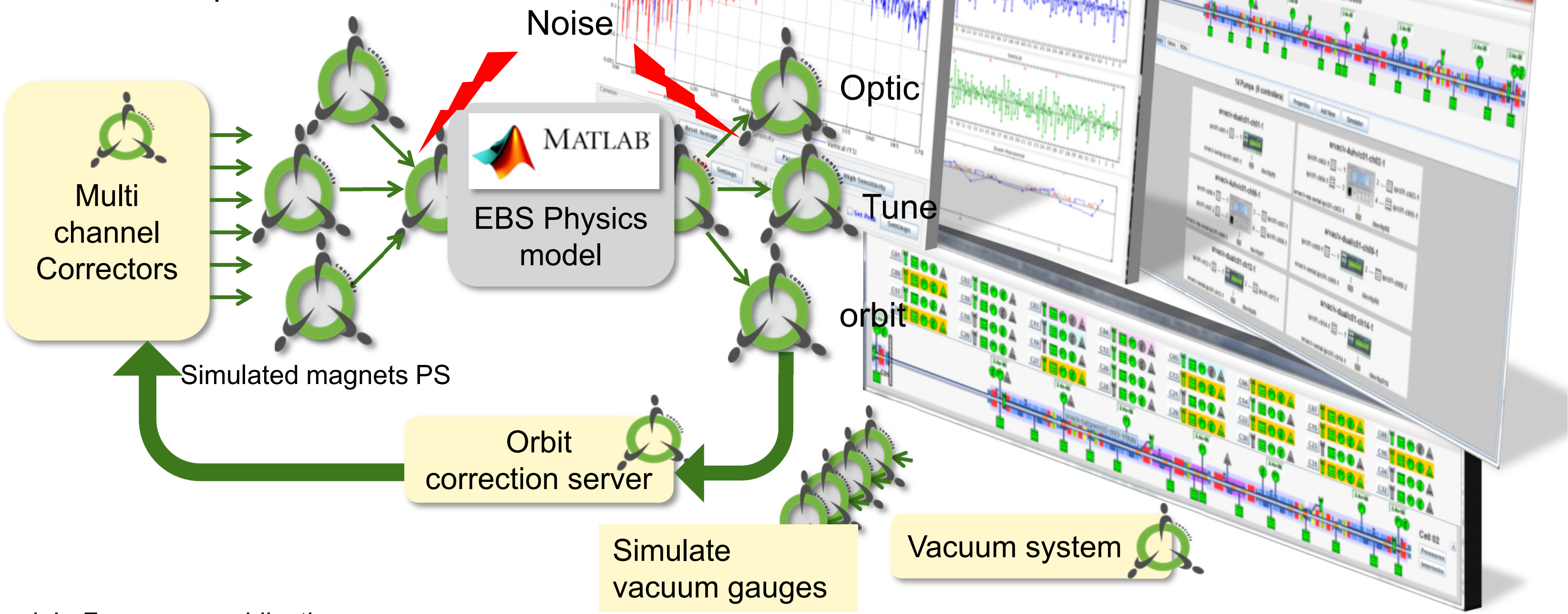

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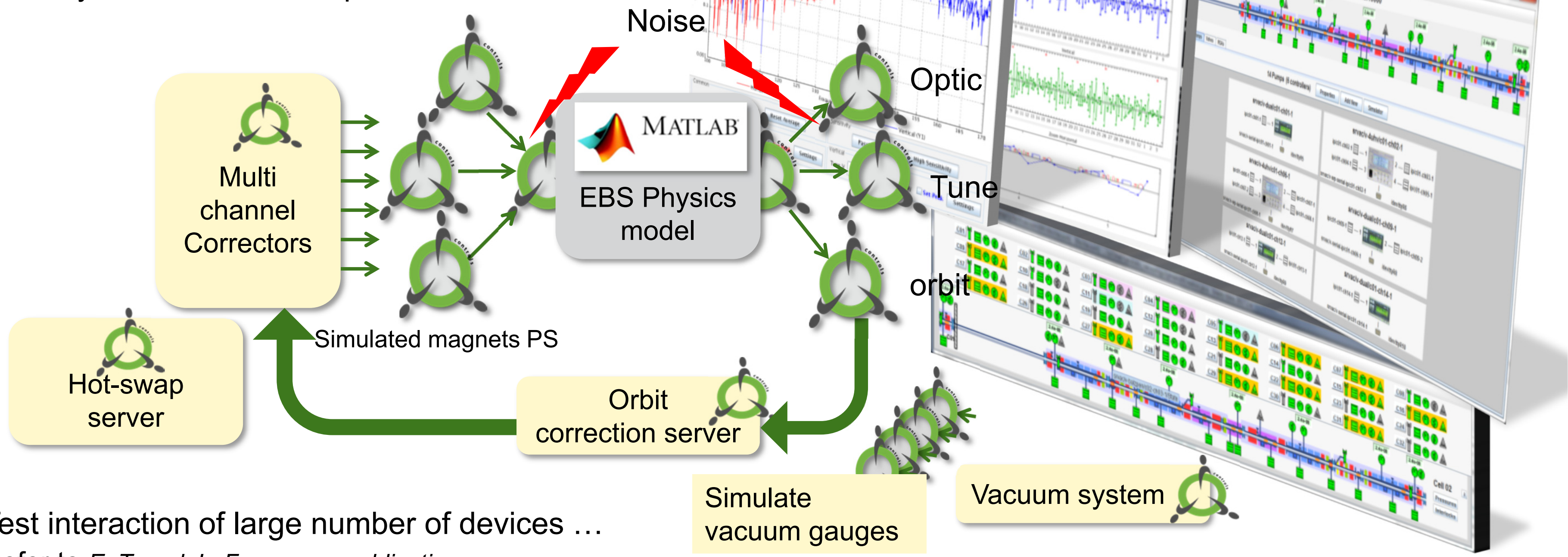

Test interaction of large number of devices …
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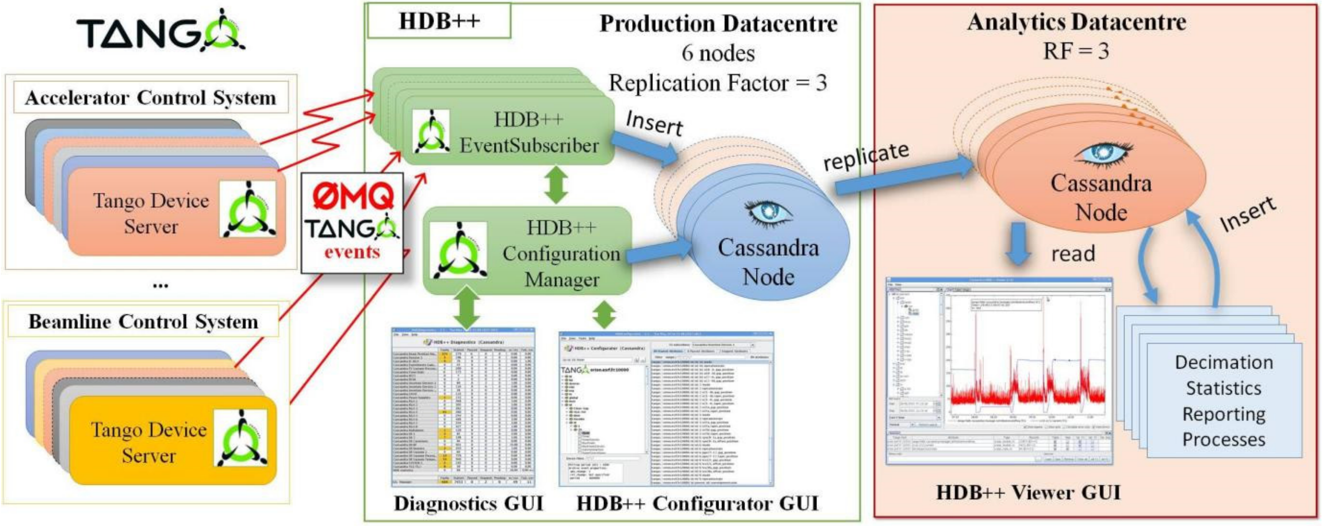
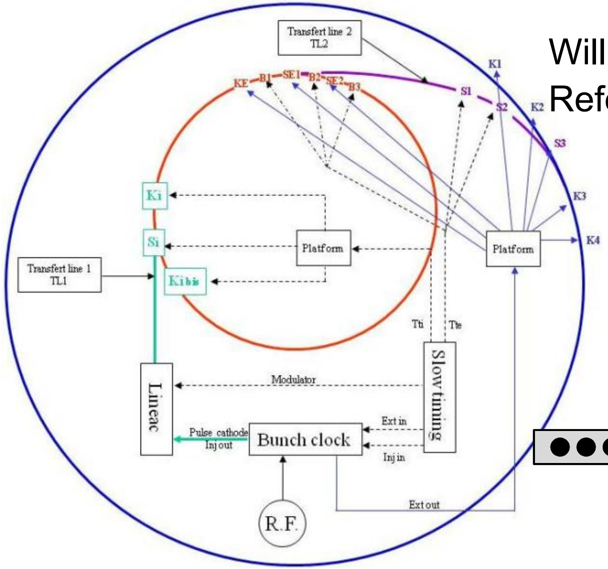
A new New Archiving System

Operational on present ring
Refer to **paper TUCPL01** L. Pivetta

	former HDB	HDB++
Time precision	1 s	1 µs
Insertions/hour	120K	6M
Filling mode	Polling/events	events
No. Signals total	6K	24K/56K
Beam line signals	2K	10K
Extraction tools	C GUI	Java /Python / Matlab / web
Database size	0.5TB/y	20TB/y
Online capacity	9 months	Unlimited
Database	Oracle	Cassandra

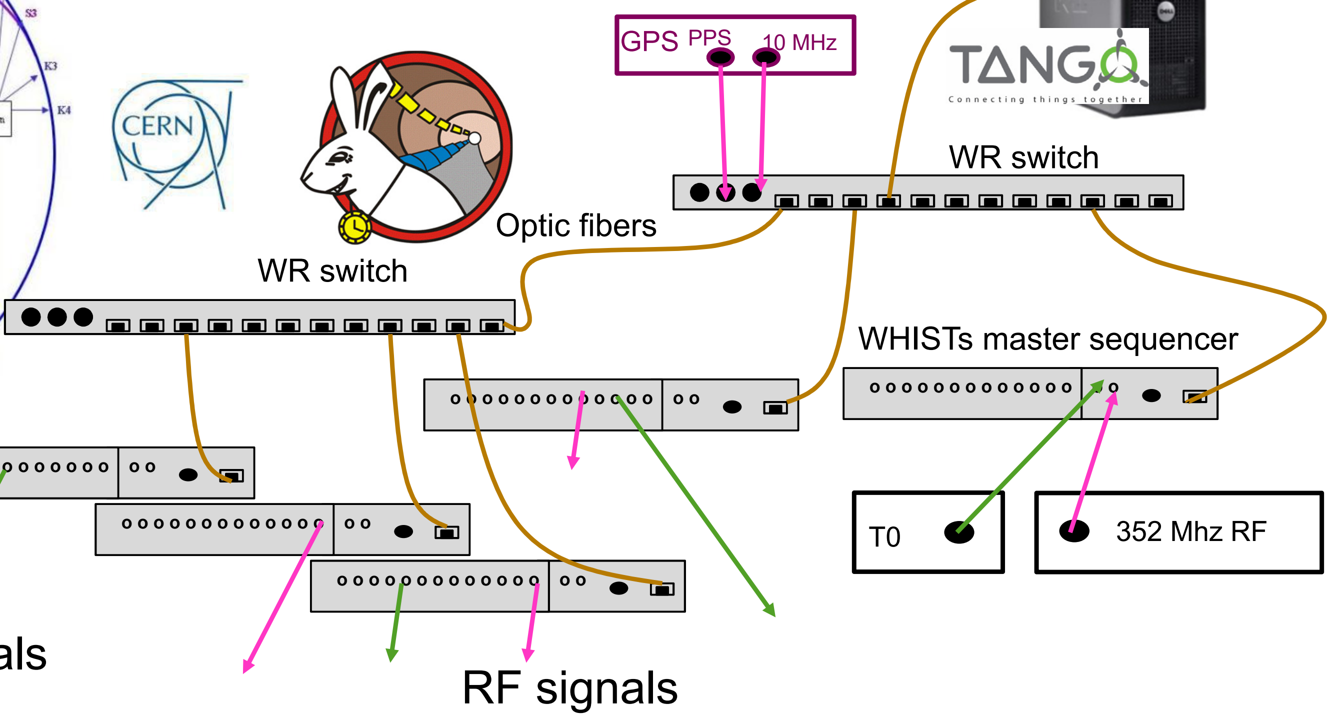


New synchronization system



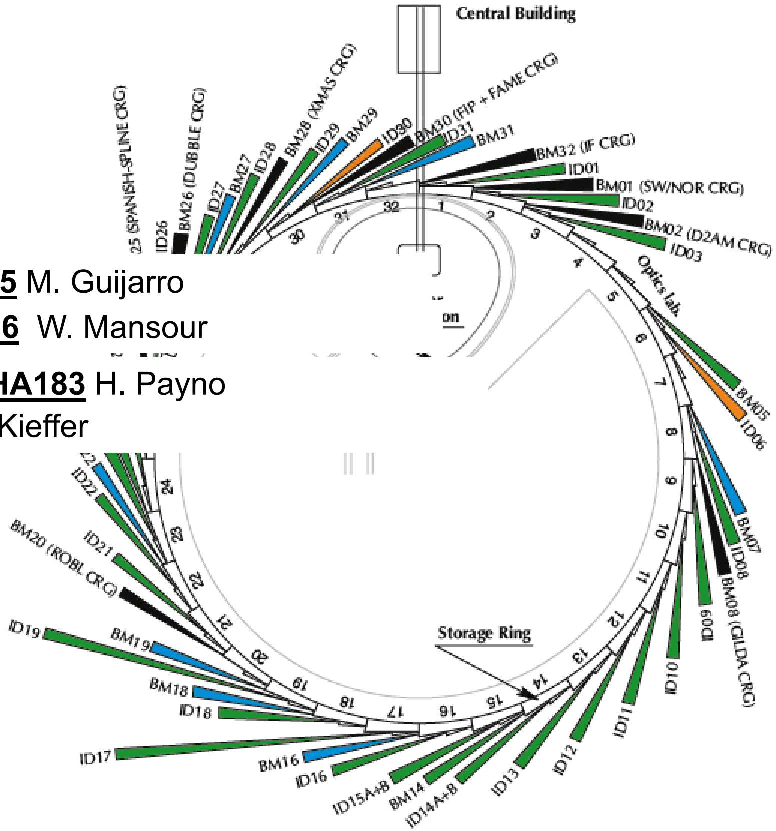
Will be deployed and commissioned on present ring

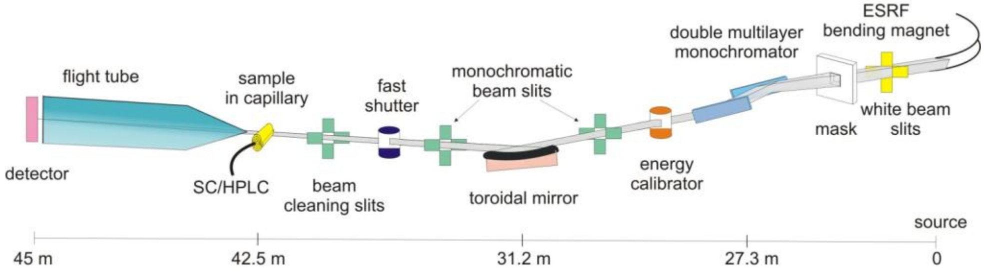
Refer to **<u>paper TUCPL01</u>** G Goujon



Experiment control & detector development

- 14 beamlines refurbished
- 4 new beam lines to construct
- Prepare the acceptance of much more photons
  - Higher data throughput to manage
  - Higher thermal effects
- New experiment control system (BLISS) Refer to **WEBPL05** M. Guijarro
- Ambitious detector development program Refer to **THBPL06** W. Mansour
- Ambitious Data analysis software framework Refer to **TUPHA183** H. Payno **THPHA039** J Kieffer





Many thanks for your attention More news at next ICALEPCS