# European Synchrotron Radiation Facility

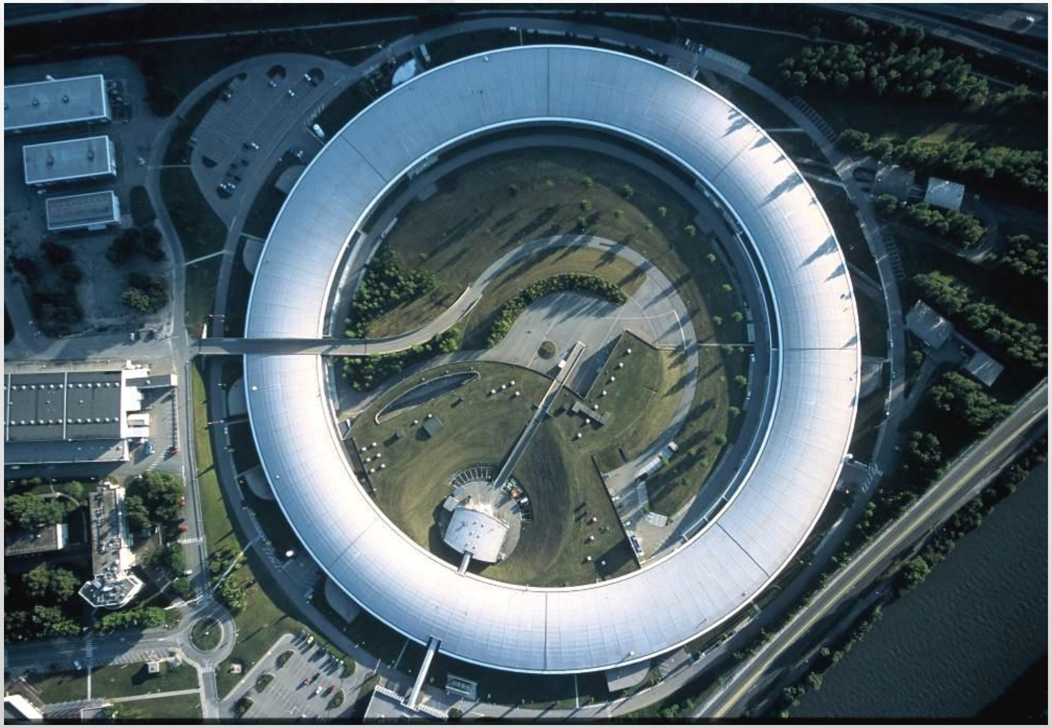
## The ESRF Upgrade Programme & Opportunities for Industry

Harald Reichert

1975 Idea for a European third-generation synchrotron source

1988 Signature between the governments of 12 Member States.

## 13 years pre-history
## 21 years success story



1992 First electron beam in the storage ring. Commissioning phase.

1994 User operations with 15 beamlines

1998 40 beamlines

2008 Upgrade Programme Phase I 2009-2017

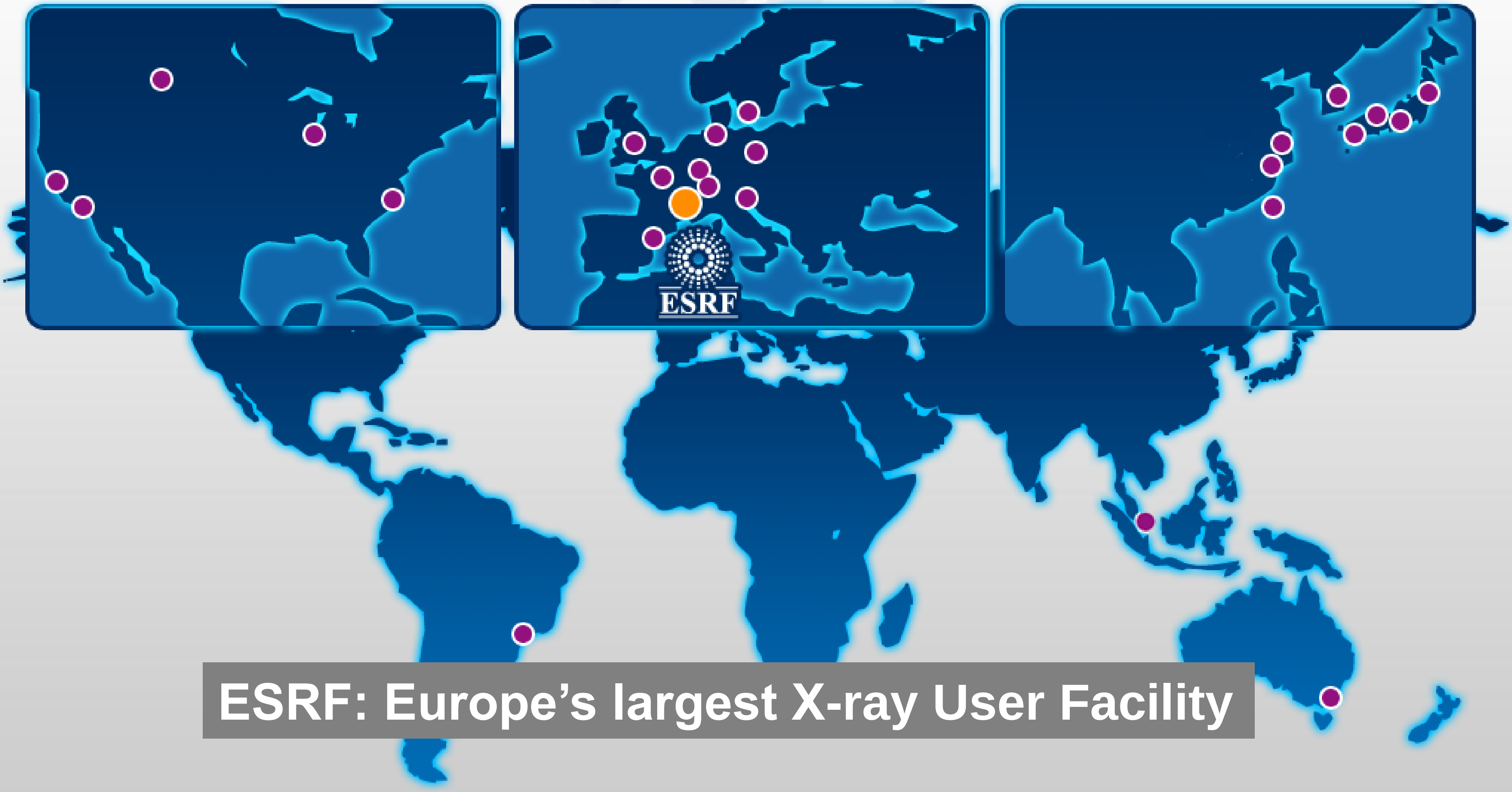

## ESRF Member States

| | |
|---|---|
| France | 27.5 % |
| Germany | 25.5 % |
| Italy | 15 % |
| United Kingdom | 14 % |
| Spain | 4 % |
| Switzerland | 4 % |
| Benesync (Belgium, Netherlands) | 6 % |
| Nordsync (Denmark, Finland, Norway, Sweden) | 4 % |

## ESRF Associates

| | |
|---|---|
| Portugal | 1 % |
| Israel | 1 % |
| Austria | 1 % |
| Poland | 0.6 % |
| CentralSync (CZ, H, SK) | 1.05% |

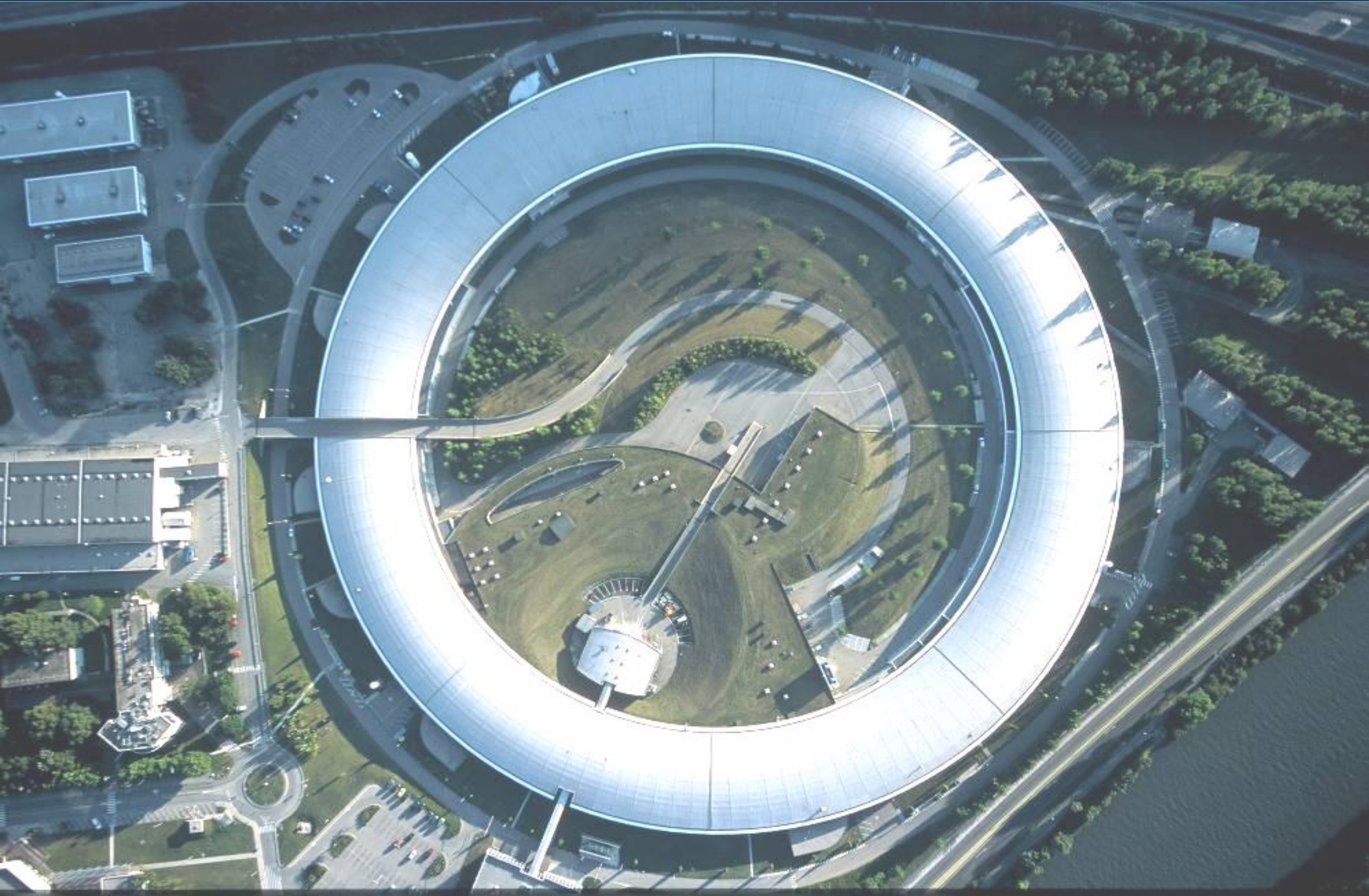
# Major X-Ray sources in the world

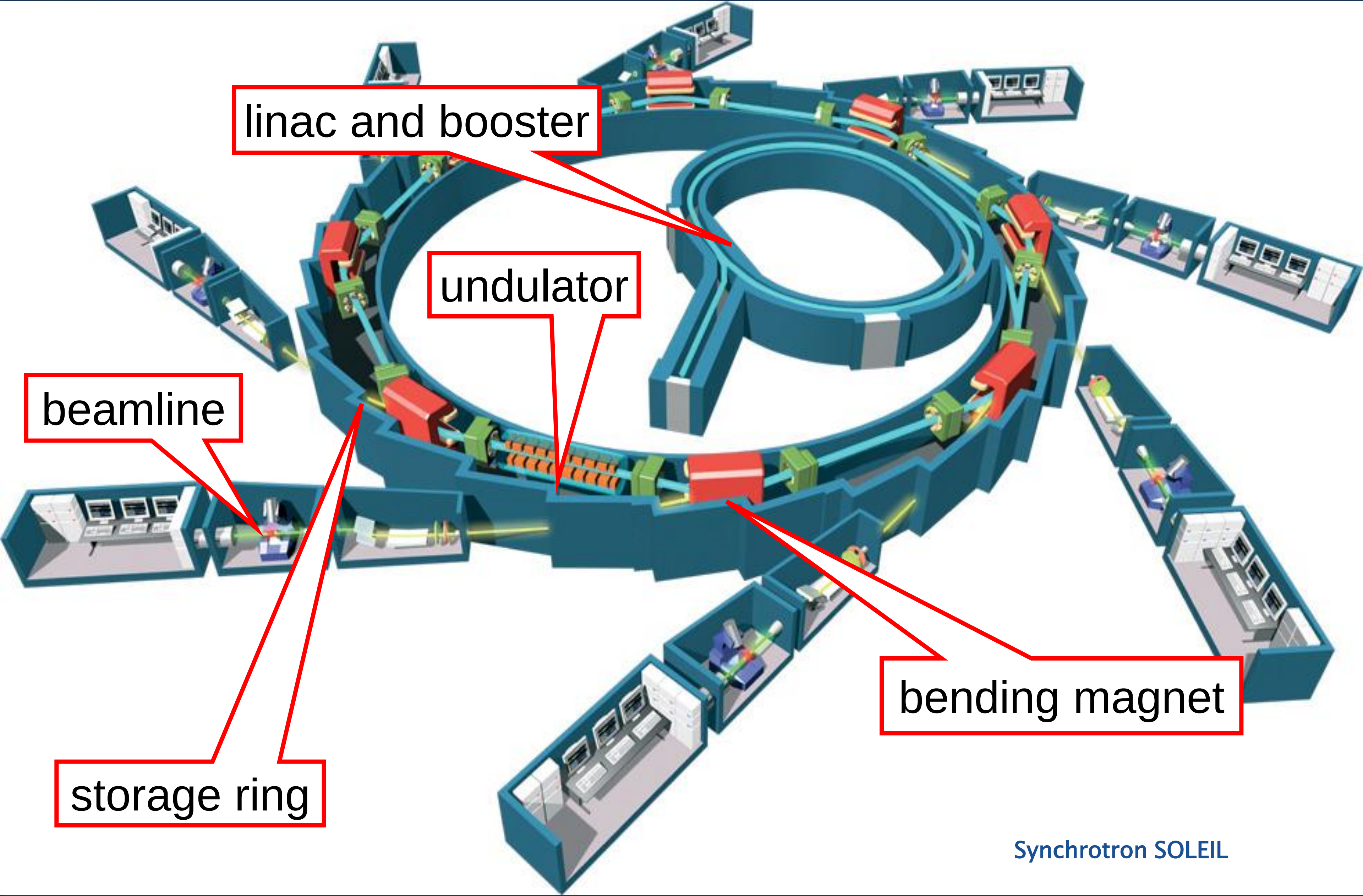


**ESRF: Europe's largest X-ray User Facility**

# What is a synchrotron radiation source?

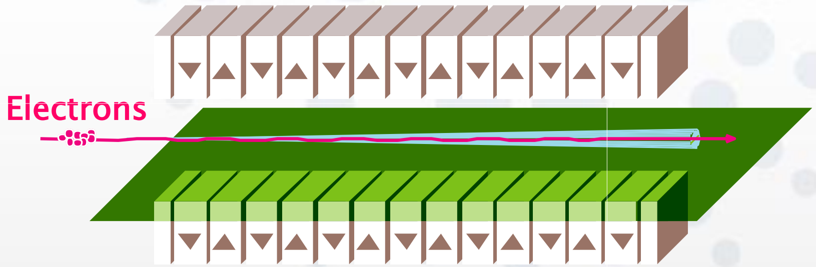


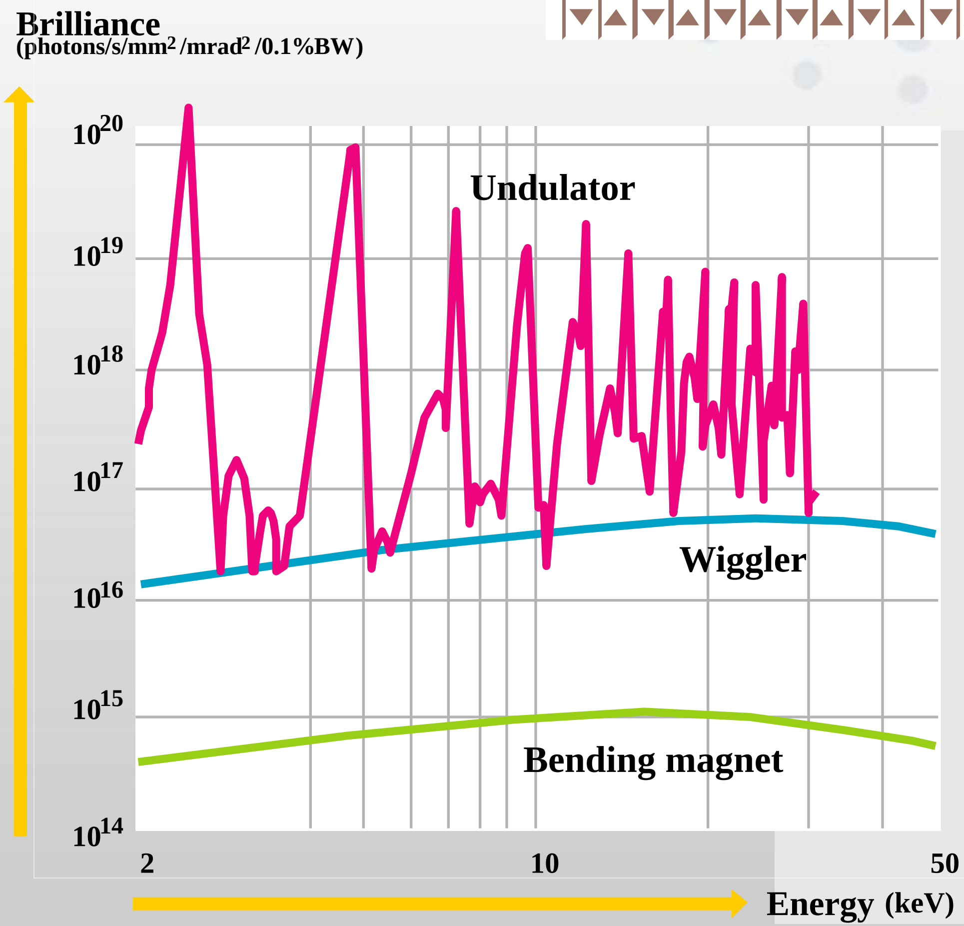


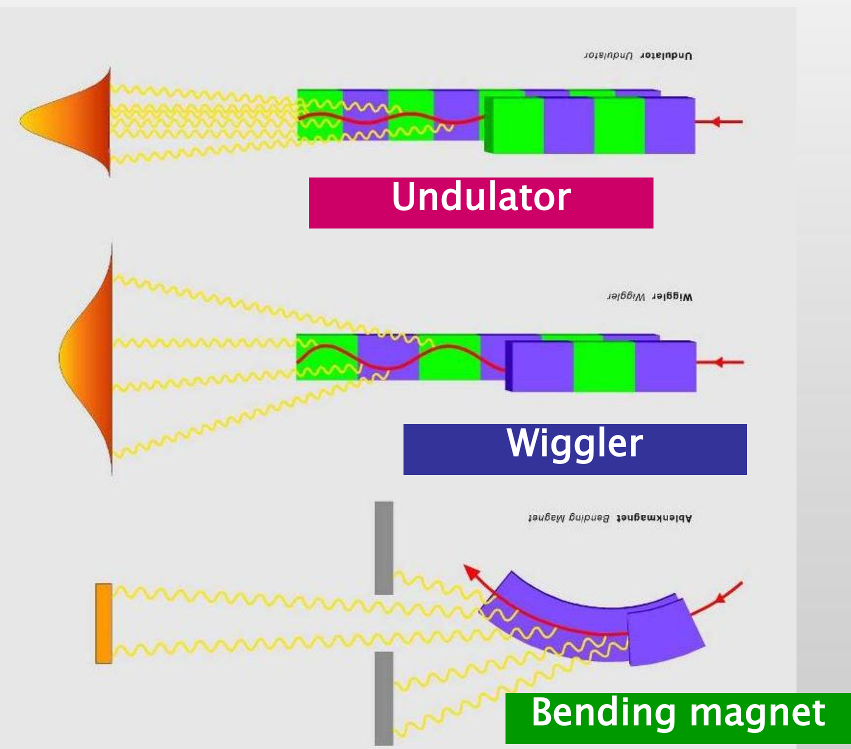


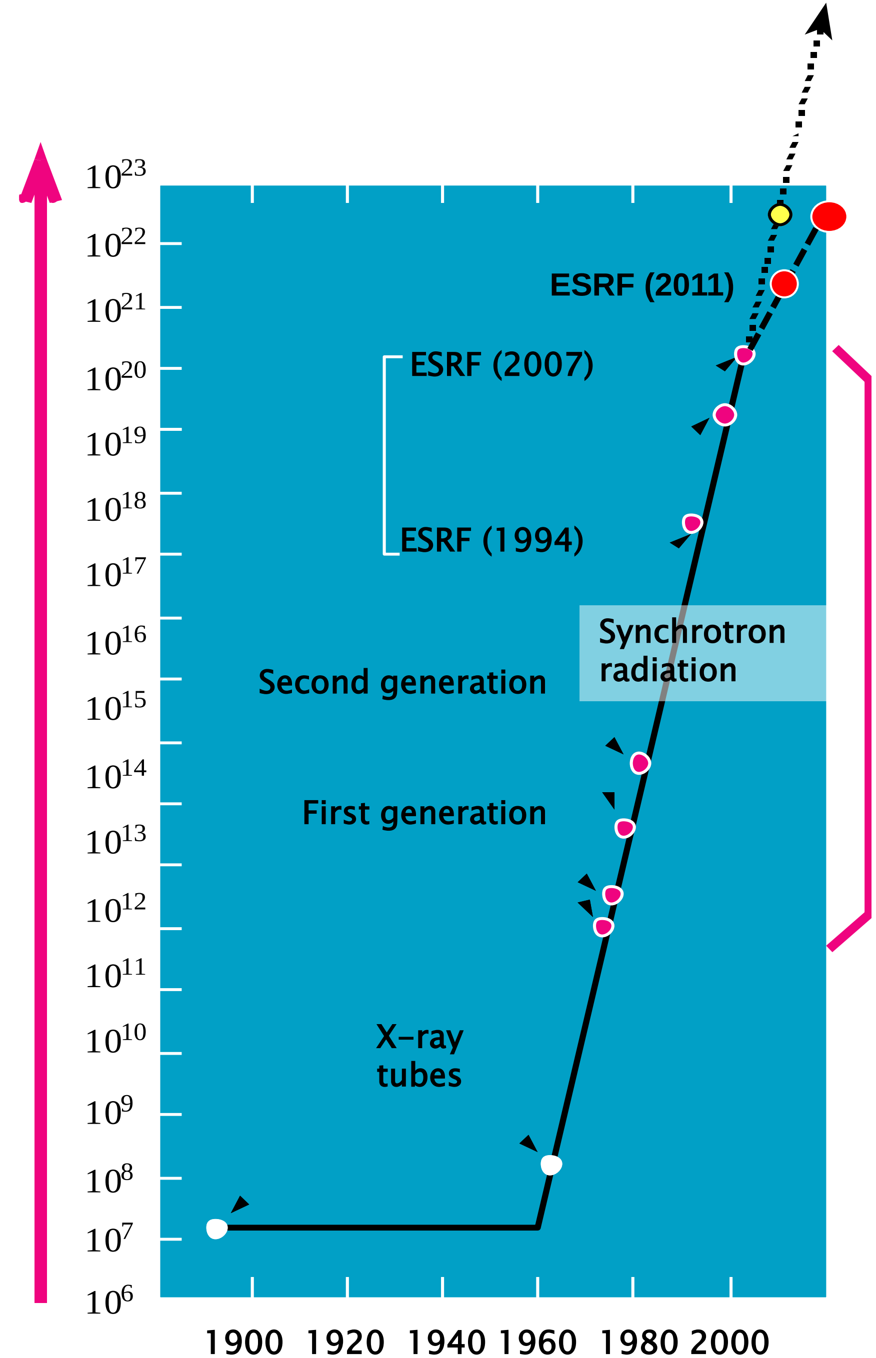

Synchrotron SOLEIL

# Bending magnets and insertion devices

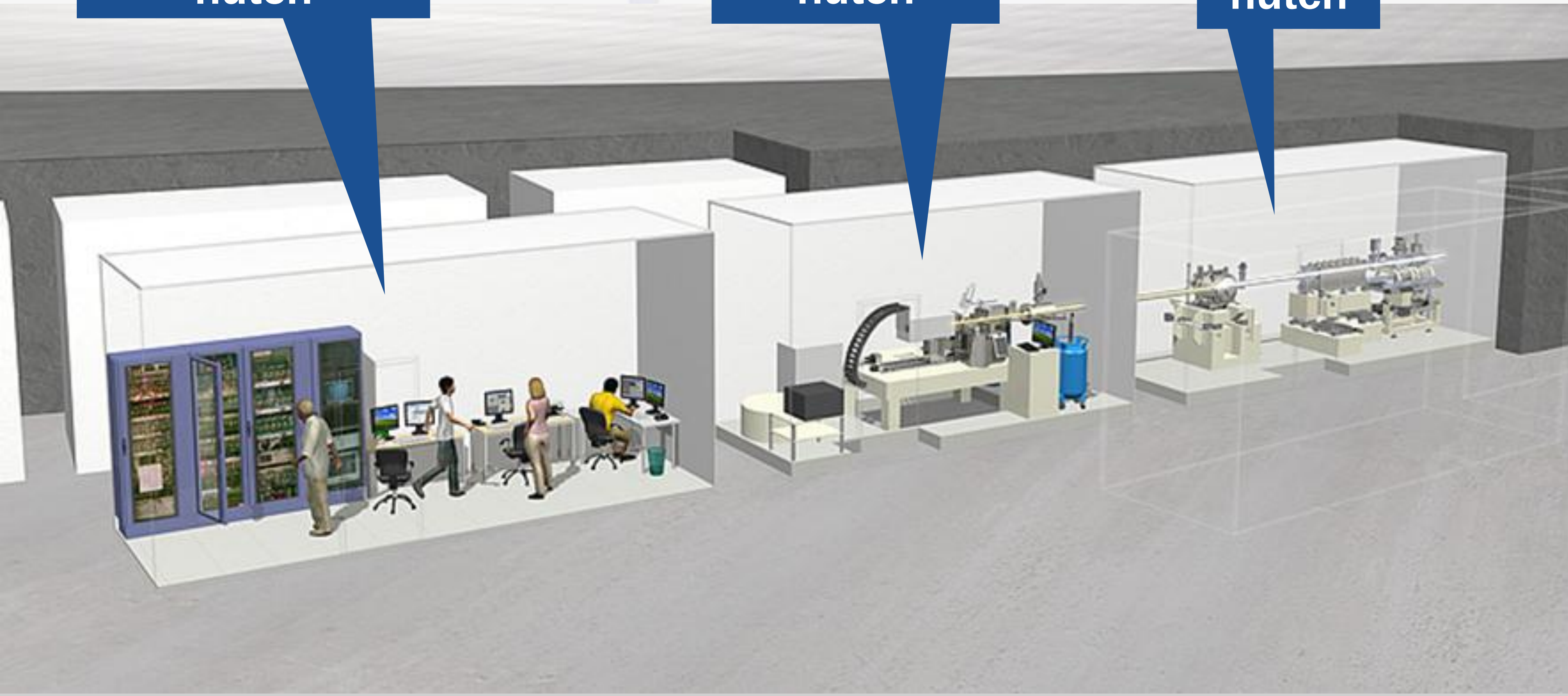


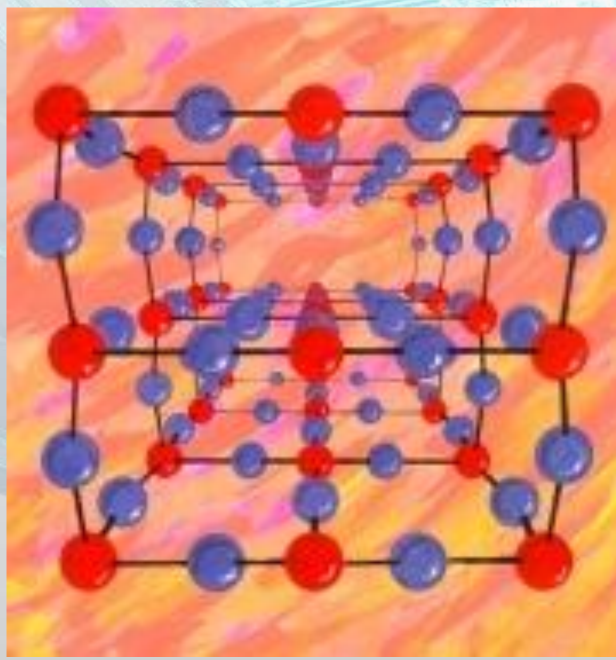



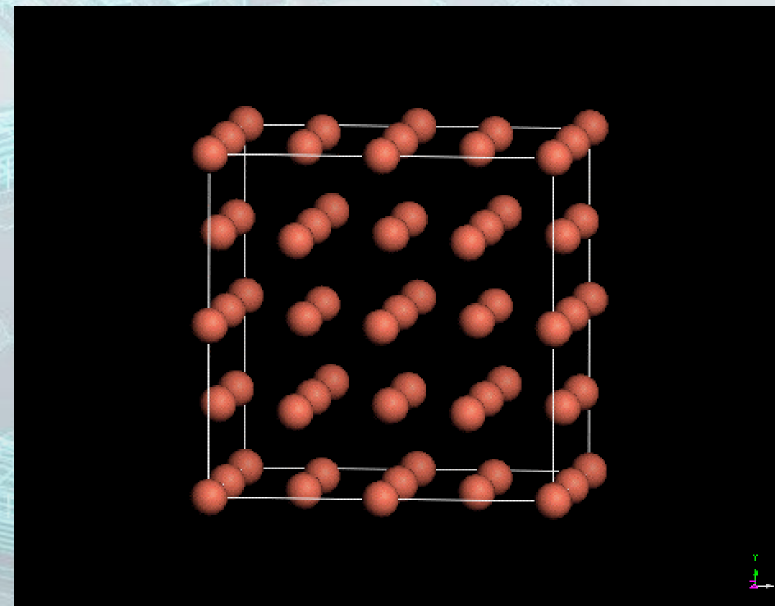

10^23
10^22
10^21
10^20
10^19
10^18
10^17
10^16
10^15
10^14
10^13
10^12
10^11
10^10
10^9
10^8
10^7
10^6
ESRF (2011)
ESRF (2007)
ESRF (1994)
Synchrotron radiation
Second generation
First generation
X-ray tubes
1900 1920 1940 1960 1980 2000

# Beamline Elements



# The ESRF is a User Facility supporting excellence: it provides opportunities for cutting-edge research on the structure and dynamics of matter

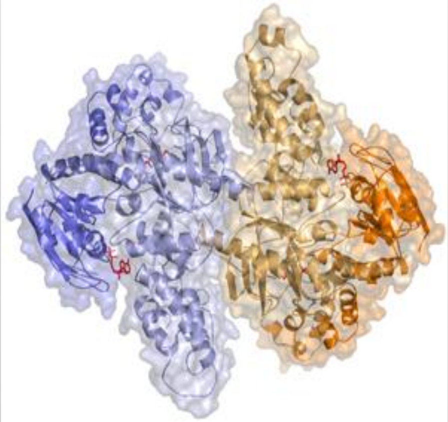


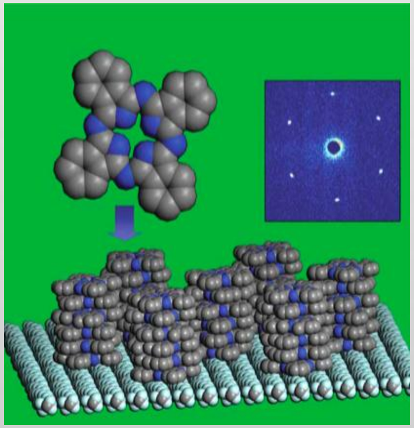


# Investigating matter and materials

Matter is made of atoms – electrons and nuclei.

The ESRF provides tools to understand materials down to the atomic length- and time- scales, answering the fundamental and applied questions on the matter surrounding us.





# An X-ray Swiss Army Knife

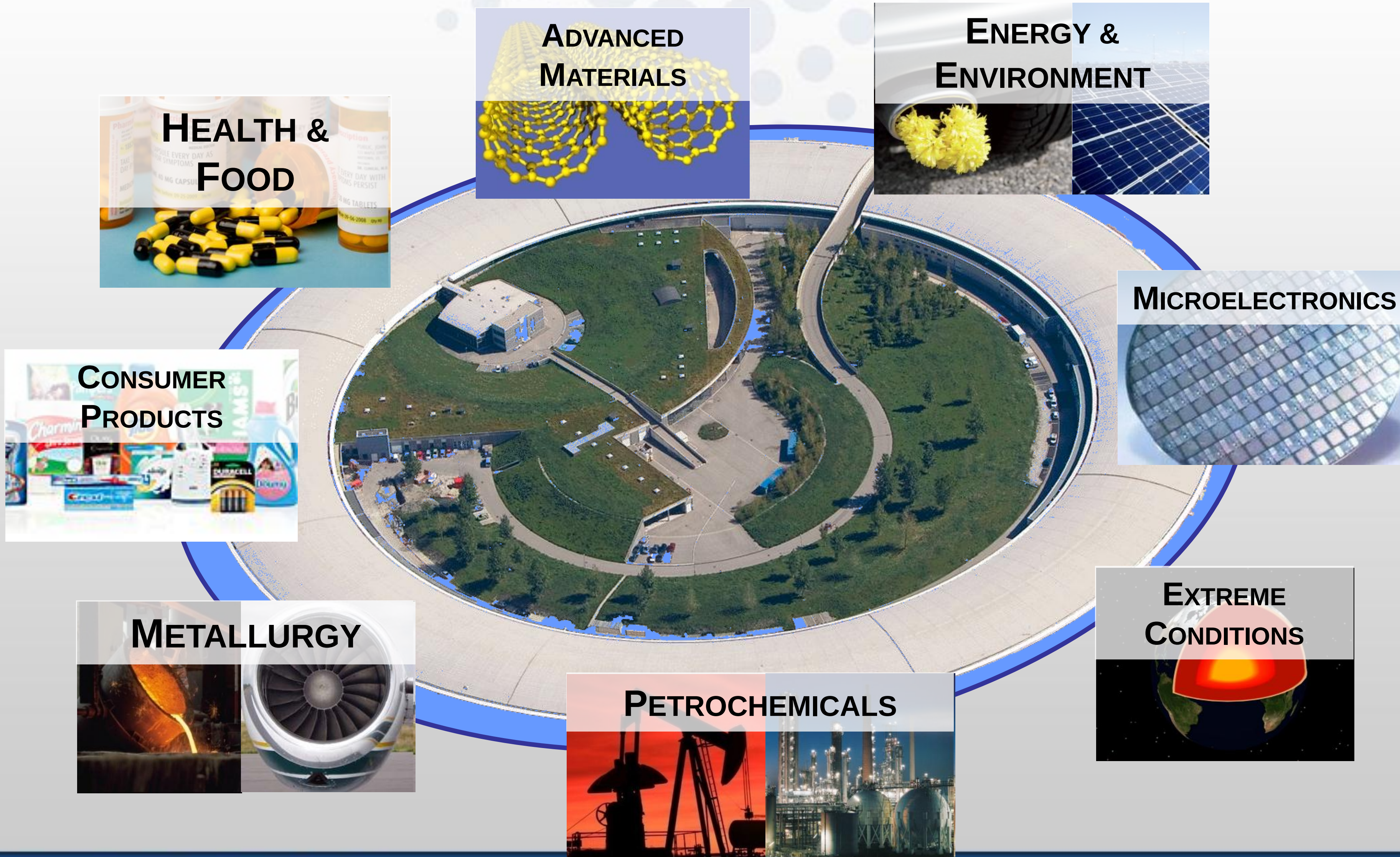
**ESRF serves a huge range of science:**

Biology
Chemistry
Materials
Paleontology
Physics
Archeology
Medicine
Nanoscience
Geosciences
…

**Which is mirrored in industrial beam time applications:**

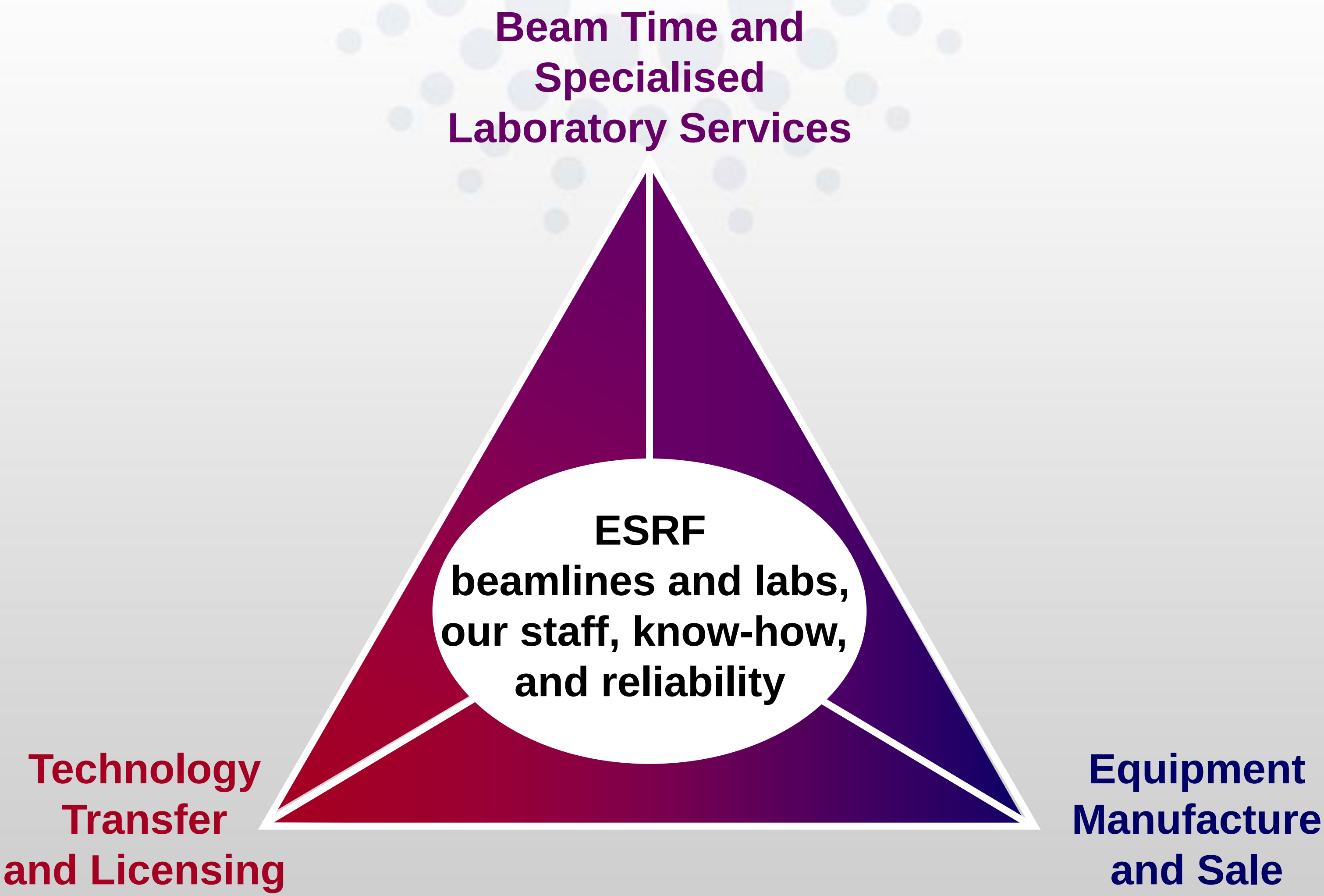
Pharma – drug discovery
Pharma - formulation
Automotive
Food
Aerospace
Petrochemicals
Cosmetics
…

# A versatile tool: from X-rays to applications

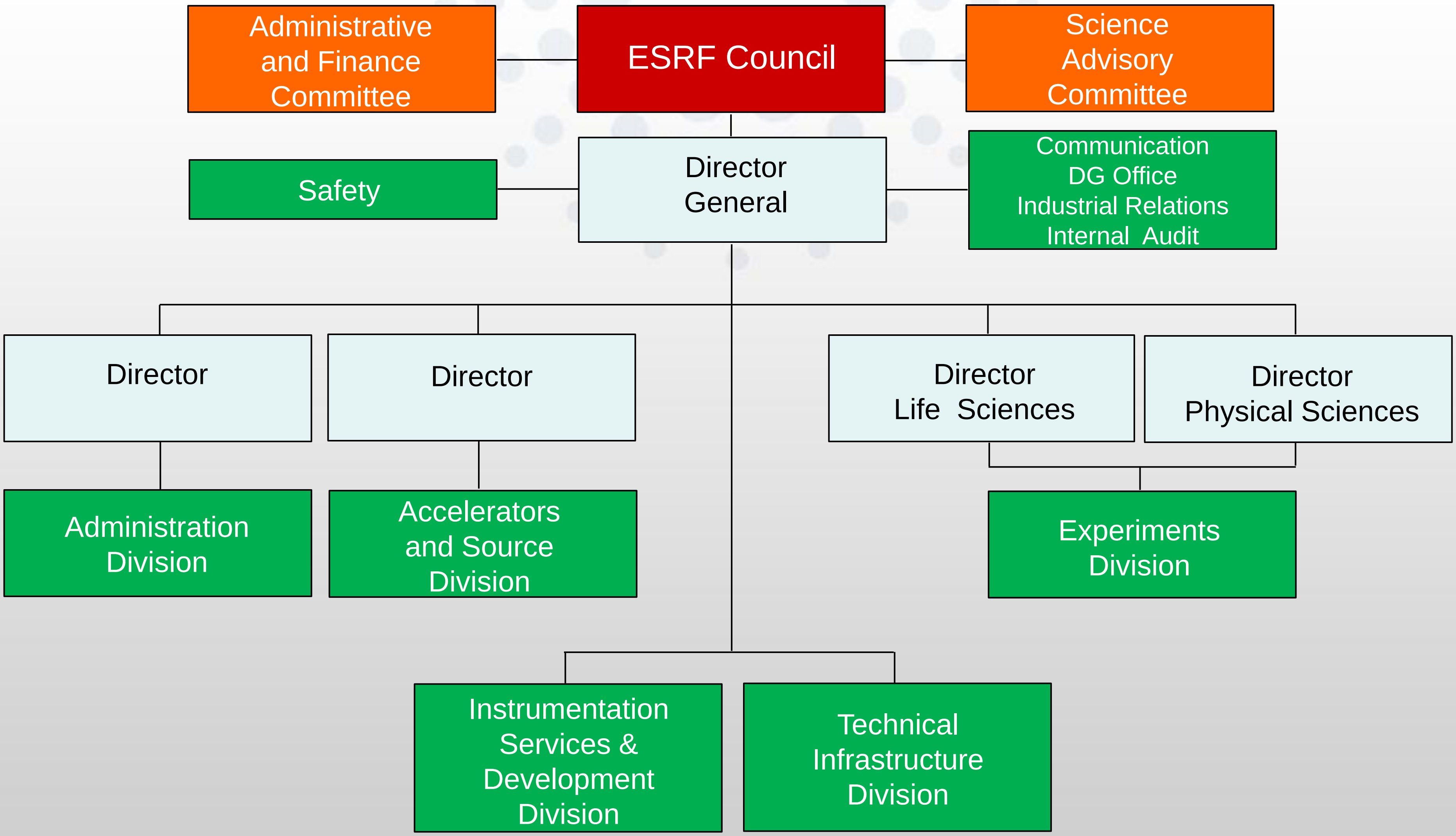


# ESRF relations with Industry





# The ESRF Organisation



# ESRF
# Upgrade Programme

***Preparing the Future***

# Science drivers of the Upgrade Programme of the ESRF


# ESRF Upgrade Programme

## Purple Book (September 2007)

## Key Objectives & Deliverables

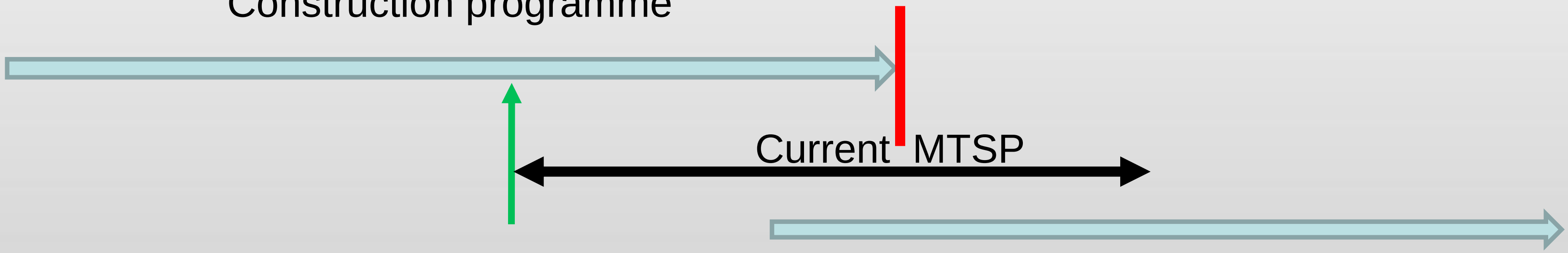
- *Eighteen new and upgraded experimental stations (beamlines)*
- *Delivery of enabling technologies*
- *Enhancement of the X-ray source*
- *Construction of 21,000 $m^2$ of additional space*.
- *Development of collaborations and partnerships with academia, other synchrotrons, and industry*

# ESRF Upgrade Programme
# Phase I and Phase II

**Phase I (~165 M€)**

19 upgraded or refurbished BLs
Accelerator and source upgrade
Construction programme

2009 2015

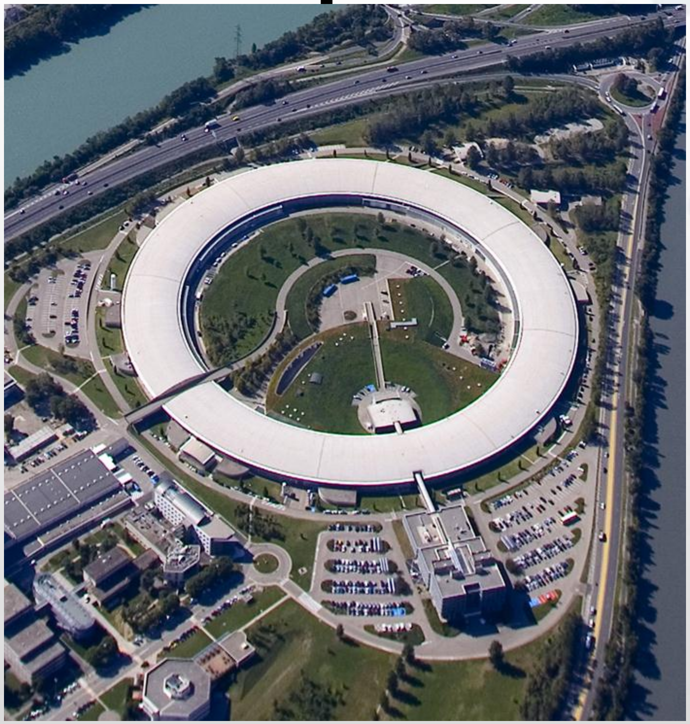



2015 2019

**Phase II (~150 M€)**

**New storage ring**
4 new BLs
Enabling technology

# Experimental Hall Extension (EX2)

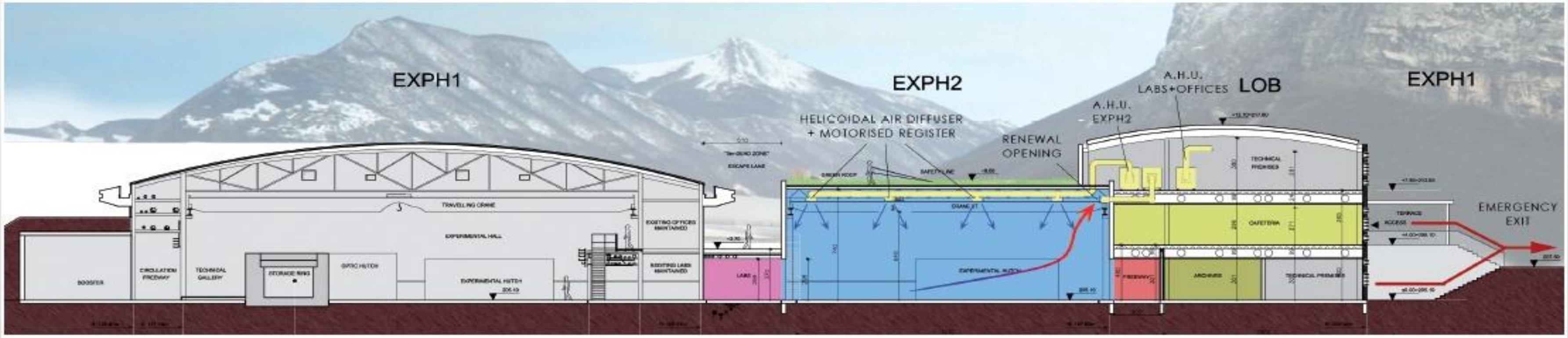


Status February 2013:

- Delivery of satellite building: 10/2012
- Delivery of 1st Hall Extensions & LOB: 6/2013
- Delivery of Science Building: 9/2013
- Start planning for 2nd Hall Extension

# MAJOR TECHNICAL CHALLENGES:

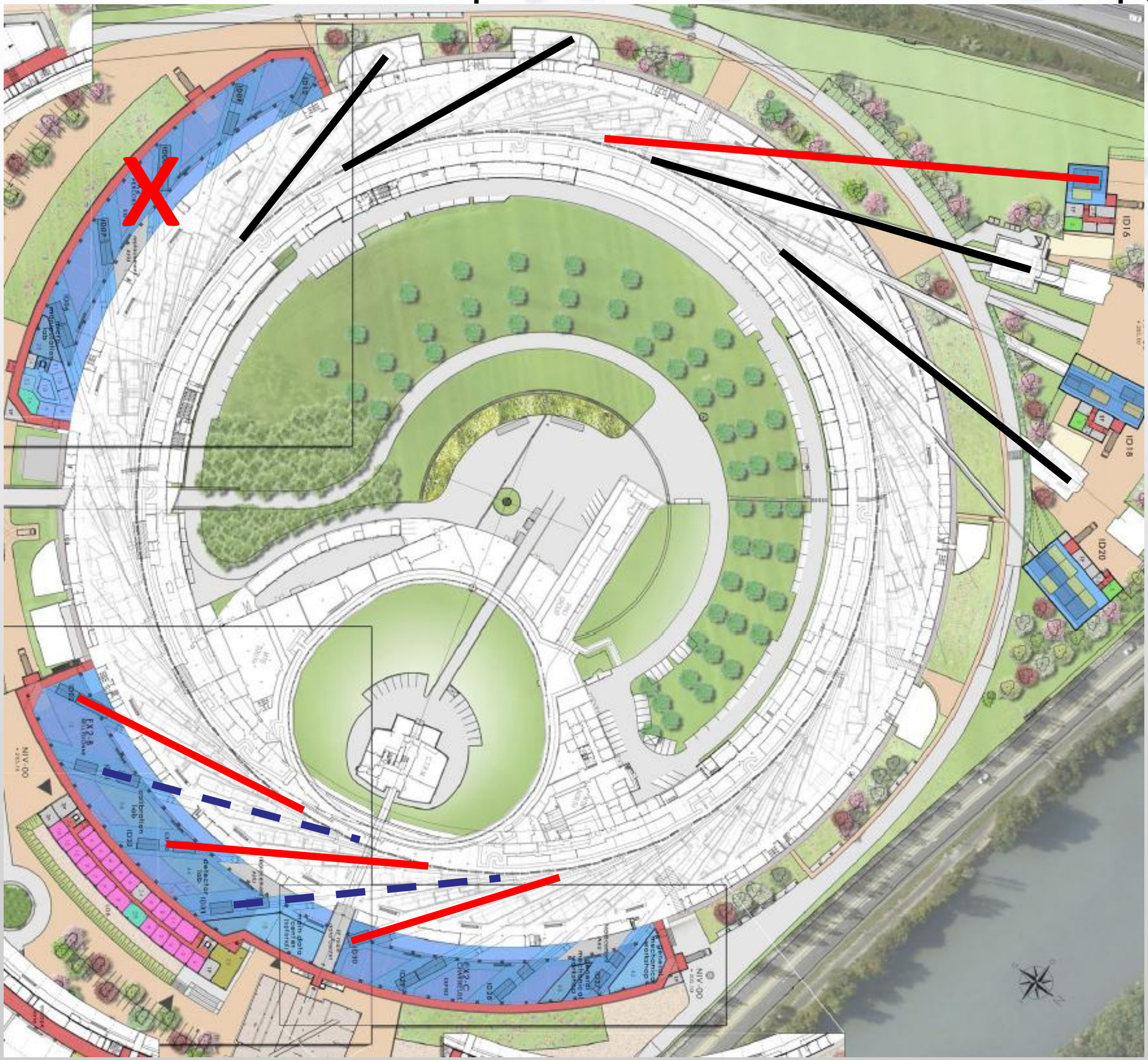
- **Slab design:** Low-level of vibrations
- **T stability:** ±.5°C in the Hall to reach better than ± 0.1°C at the sample.




## SOME FIGURES:

- ~7,500m² of high quality slab
- 13 beamlines at 110m/120m.
- ~4,000m² of labs, offices, multi-purpose areas…
- Satellite building for 200m long beamline

# New floor space – to be filled within the upgrade programme



Existing satellites:
ID11
ID13
ID17
ID19

Hall extension:
ID27 – ID02

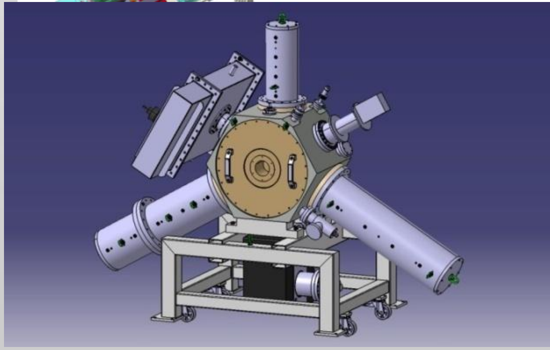
New satellite:
ID16

# Increased Brightness and Improved Stability and Reliability

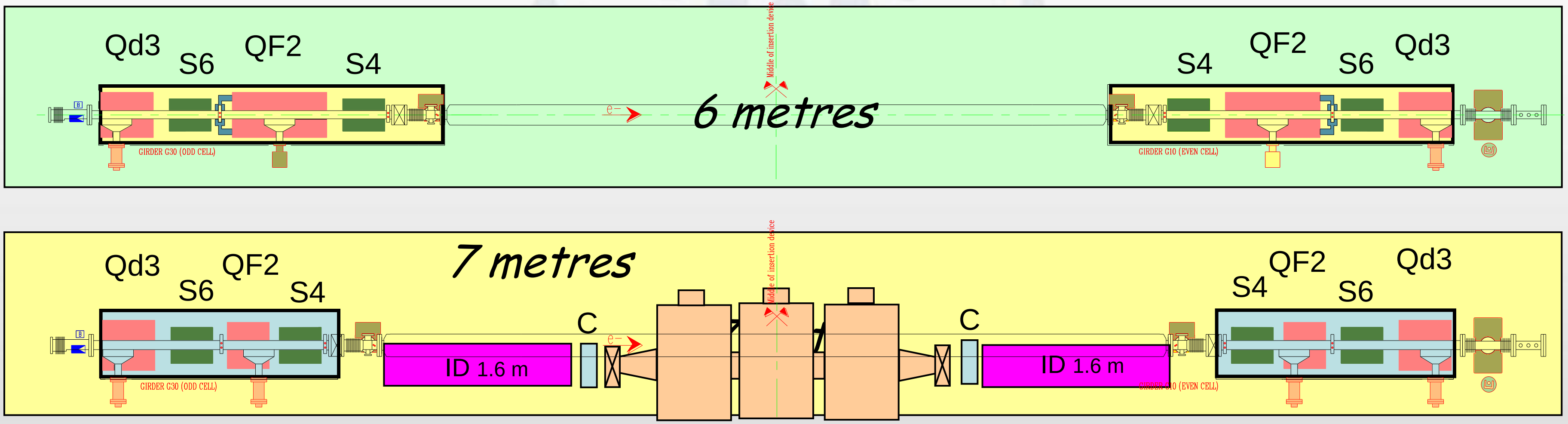
- Solid State Amplifiers based RF Power System
- New Beam Position Monitoring System
- New Cryogenic Undulators

- New 6m ID Vacuum Chambers
- New HOM Damped RF Cavities – Prototypes installed

- Topping-up Capabilities and 300 mA Operation Under Testing and Study
- Canting Options and 7m ID Vacuum Chambers installed



# 7 m ID straight Sections (end of 2012)

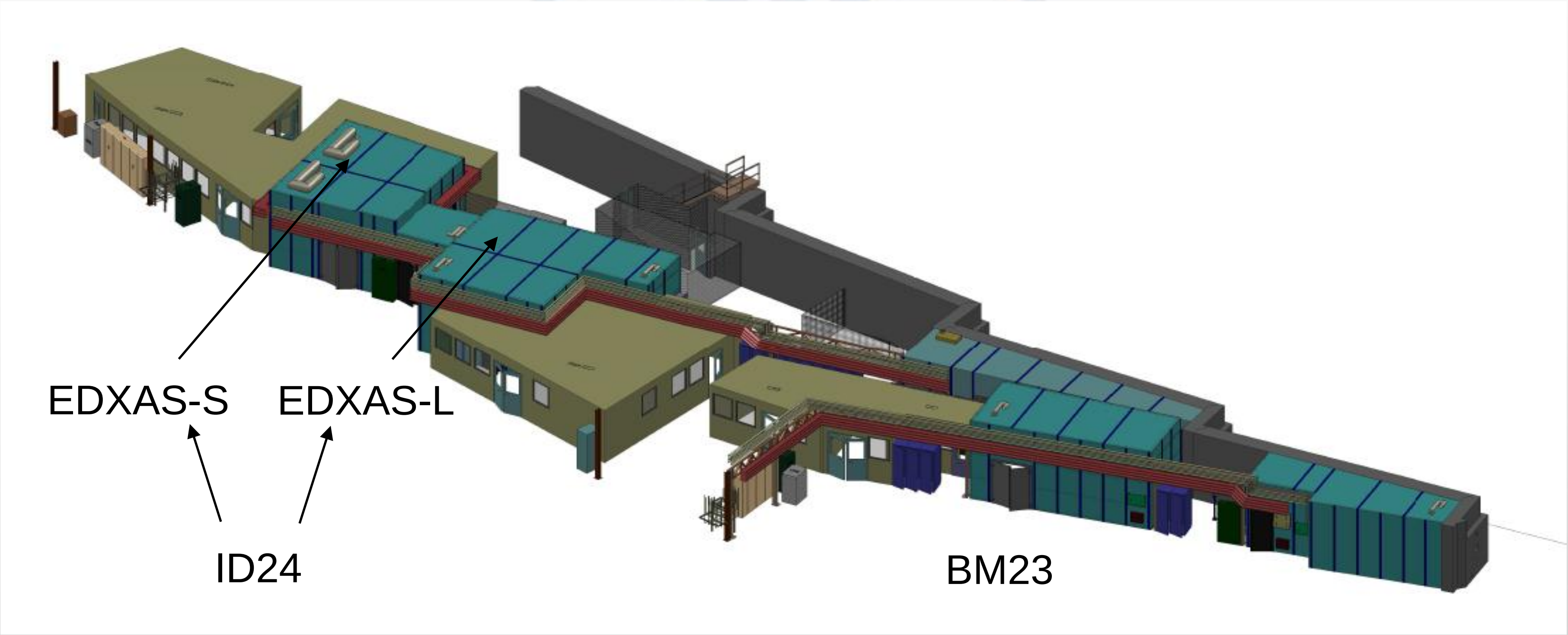



- New girders
- New quadrupoles
- Individual power supplies
- New vacuum chambers
- 1st symmetry breaking

Goal:

- Test low-$\beta_y$ optics
- Redistribute RF cavities to gain useful straight sections

# Infrastructure for beamlines

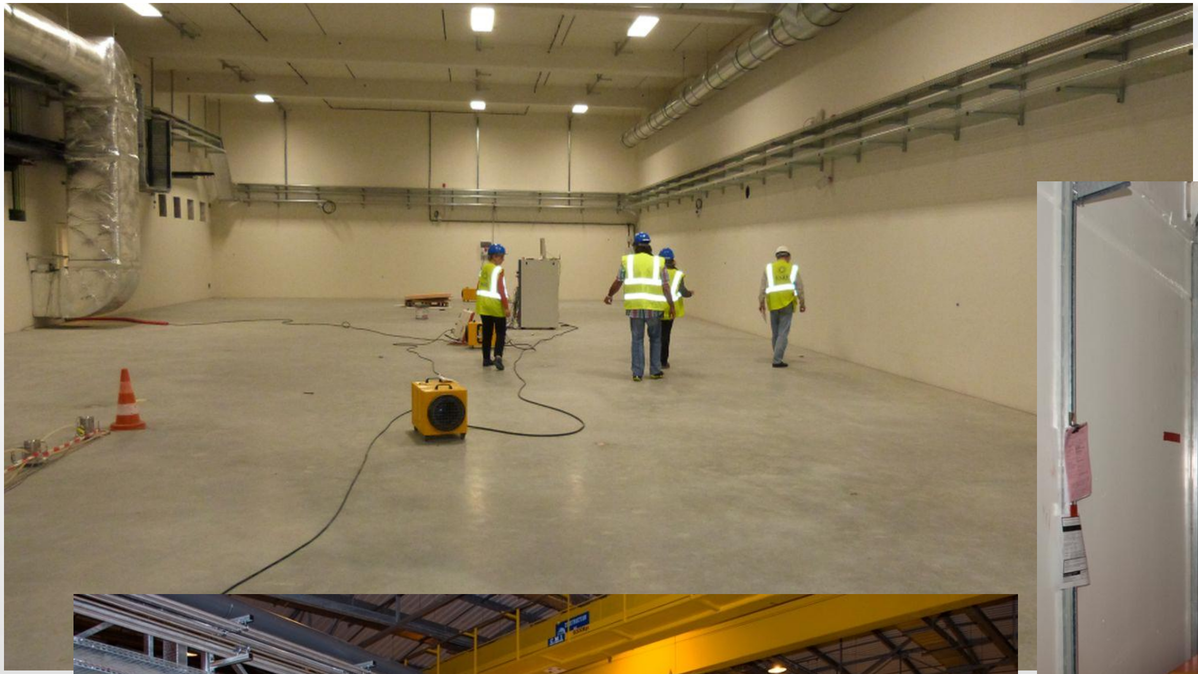


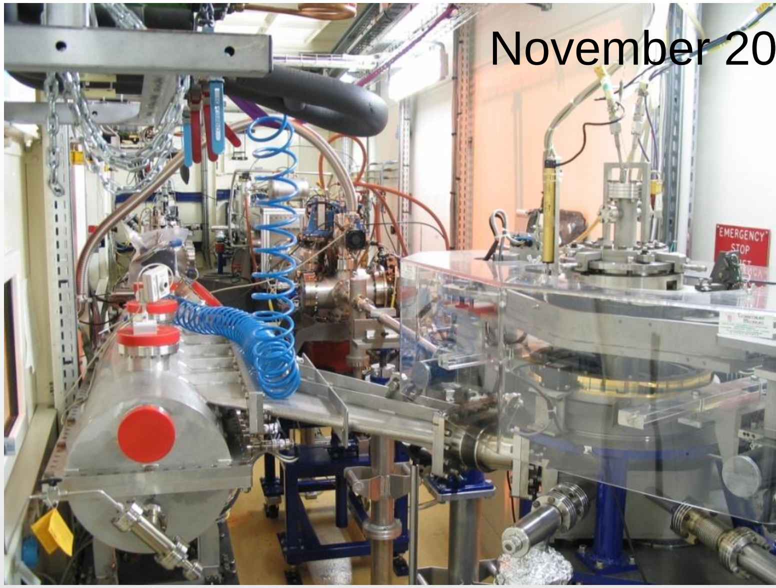

General view of the UPBL11 project

# UPBL4 - NINA
# Nano-imaging & Nano-analysis

# Infrastructure: construction of Pb hutches







November 2011

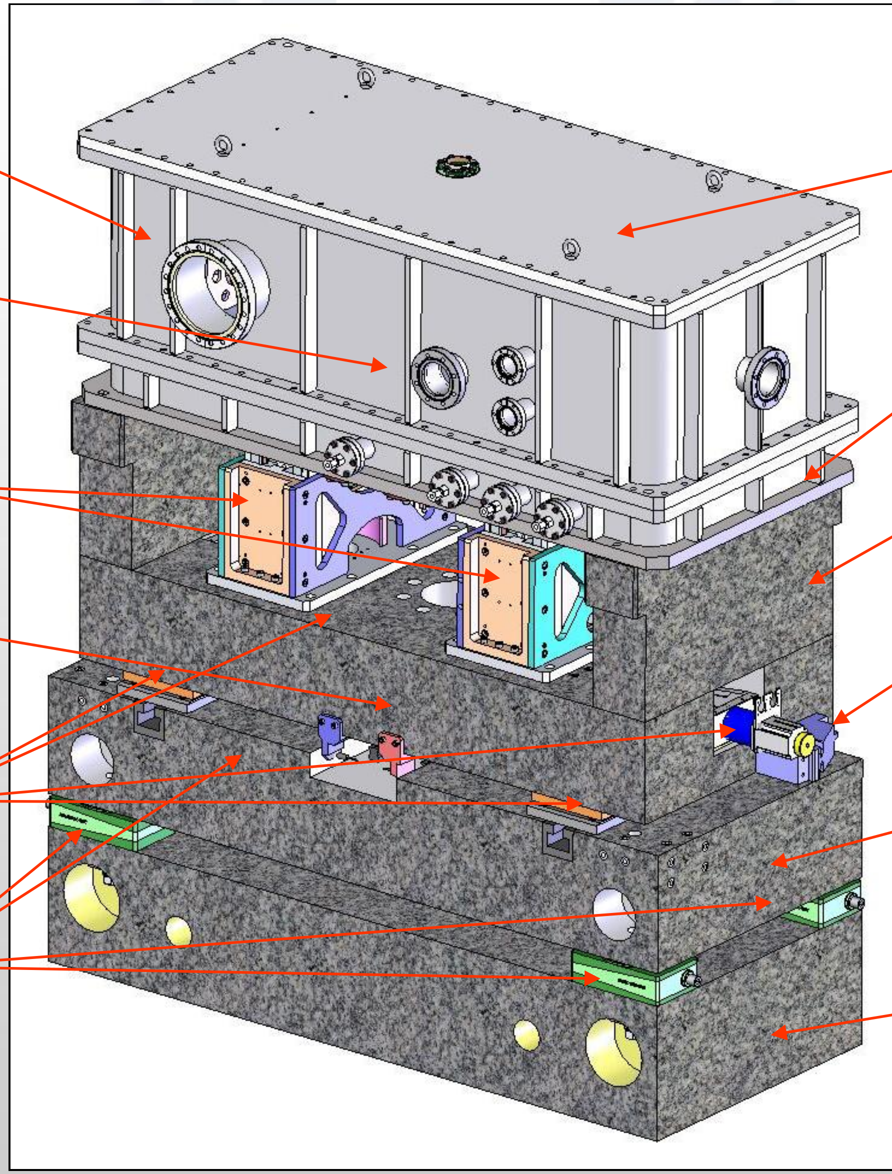
Pimary slits and Photon shutter remain

January 2012

16 May 2012

White beam double mirror (installation Dec. 2012)
Channel cut monochromator with LN cooling
White beam secondary slits and 2xBPM
Transfocator (white beam option)

# New generation of positioning devices for optics



Vessel

Ultra fine $\theta_Z$ (feedback)

$T_Z$ & $\theta_Y$ units

$\theta_Z$ & $T_Y$ guiding

$T_Y$ translation support pads

Manual $T_Z$, $\theta_X$ & $\theta_Y$ pre alignment

Mirror assembly

Vessel base

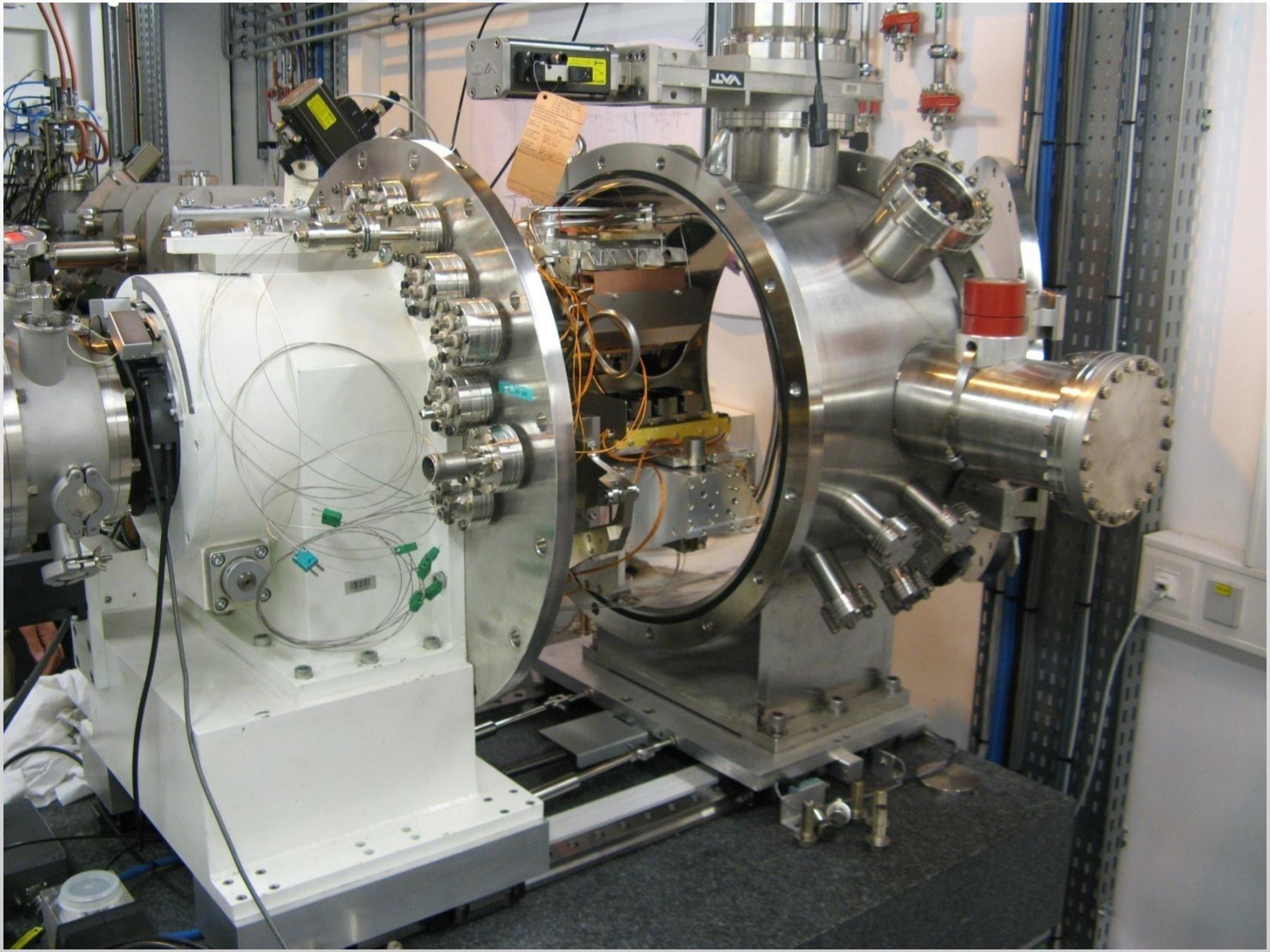
Top granite

Granite clamping

Intermediate granite

Base granite bonded to floor

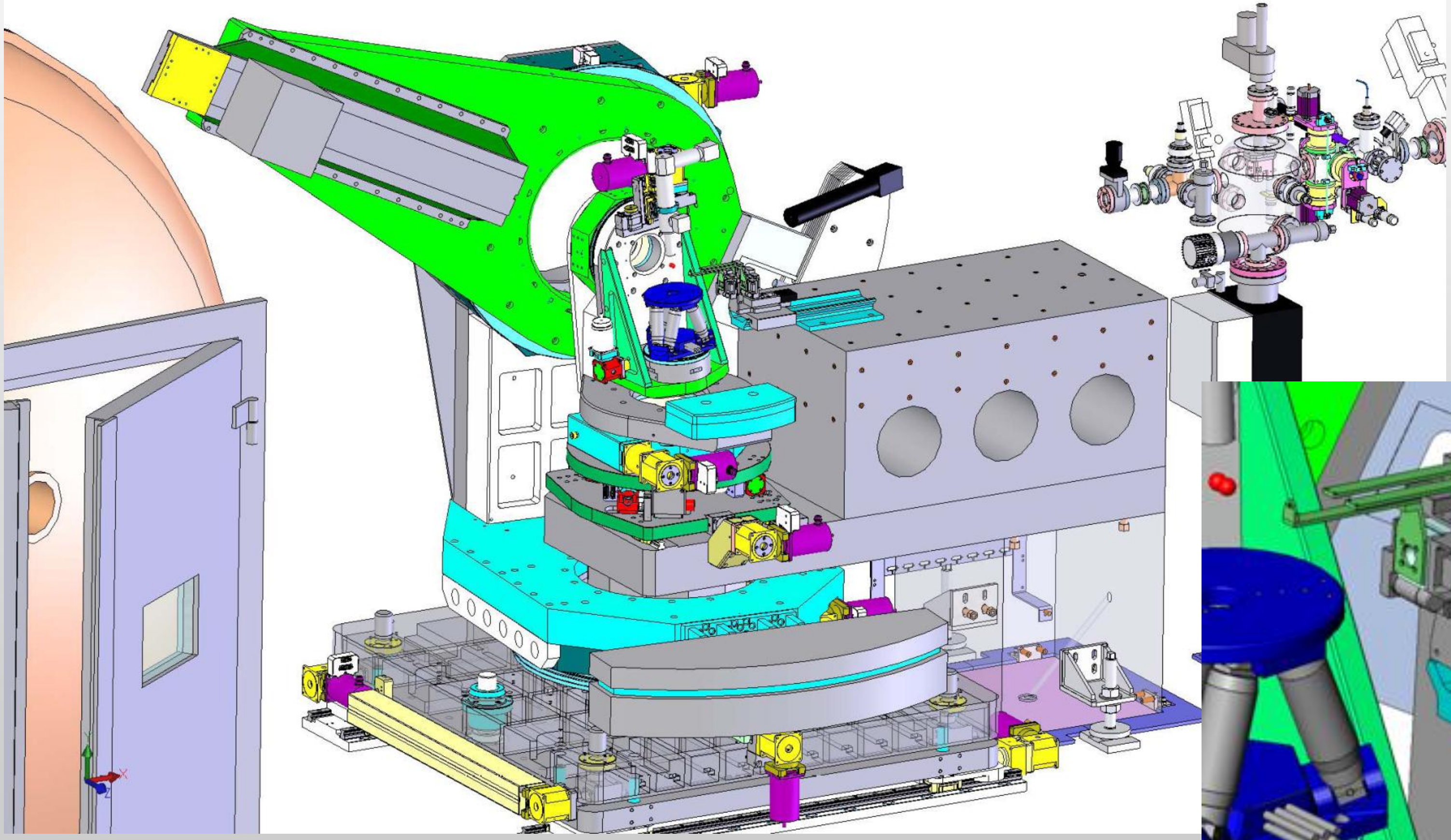
# New Optics: Monochromators, Mirrors, Focusing,….

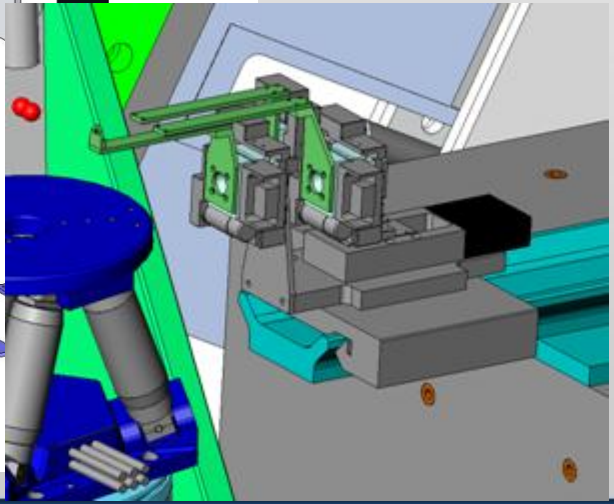


# New generation of positioning devices for samples

## High precision diffractometer for EH1
## UPBL1

beamsize 50 – 100 nm
payload 2…(5) kg
positioning HP ≤ 1 μm
piezo ≤ 20 – 50 μm
SOC ≤ 20 μm (3 axis full )
SOC ≤ 0.2 μm (± 1° for 1 axis)





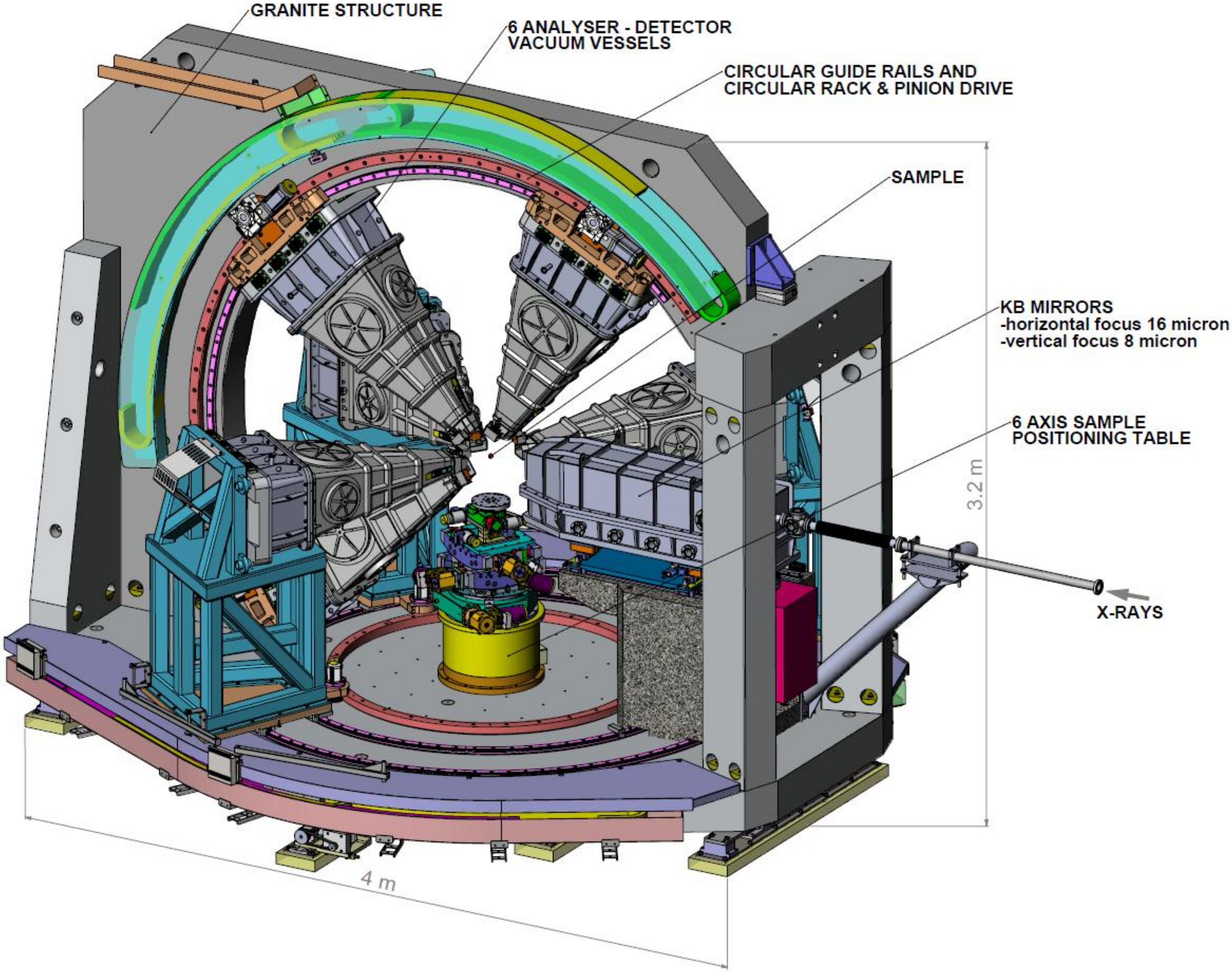
6 units analyser chambers

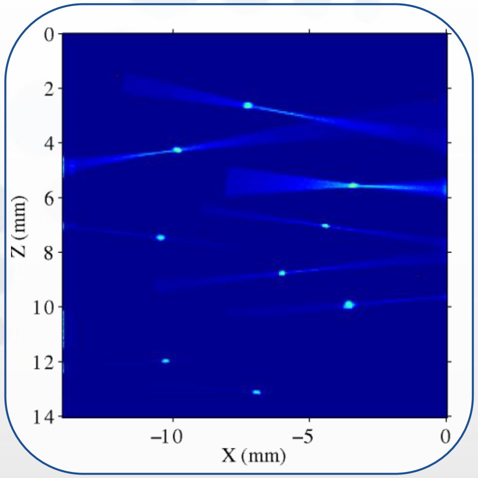
With

12 analyser crystals and 1 detector.

⇒ 72 analyser crystals

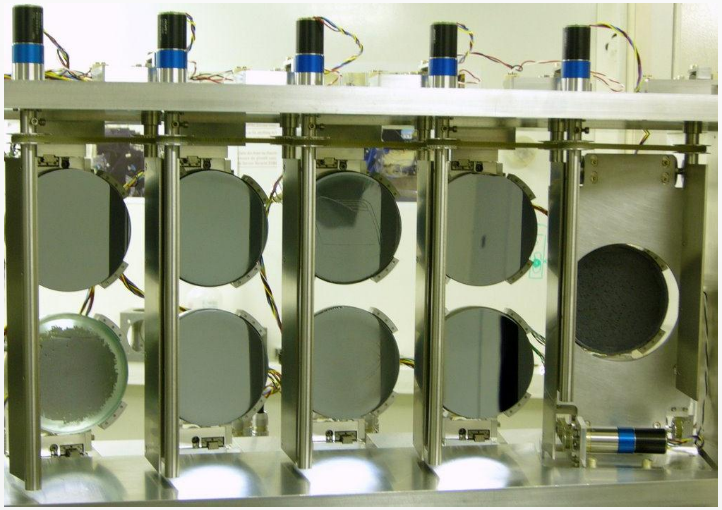
⇒ 6 detectors.






## 2D detector:

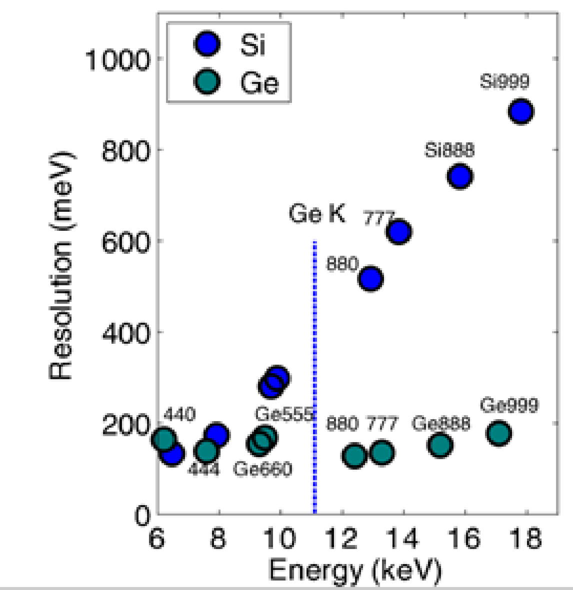
- separate each analyzer
- efficient background removal

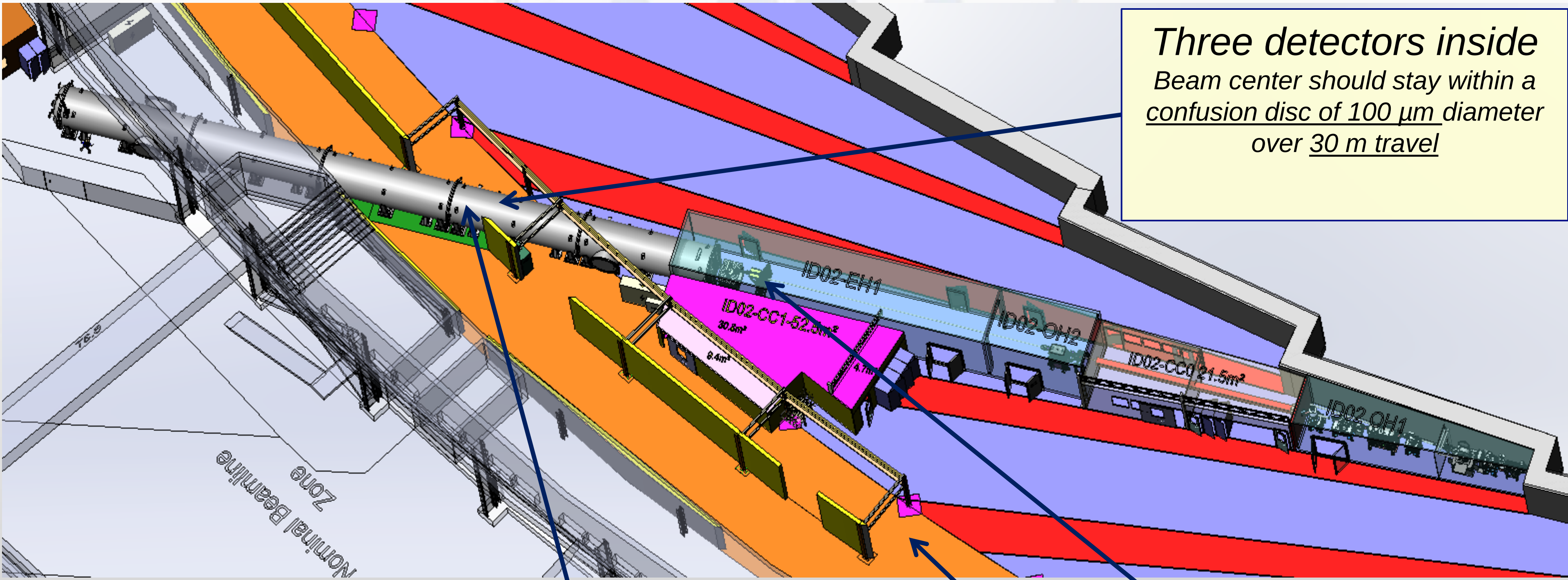


## 9-analyzer spectrometer

- increased count rate and/or multiple q spanning
- spherically bent crystals

## Which analyzers?






## Three detectors inside

*Beam center should stay within a <u>confusion disc of 100 µm</u> diameter over <u>30 m travel</u>*

## *Tube*

*Length = 33 m* | *Diameter = 2 m*

*Weight = 39 T* | *5 sections*

*Material : 304L Stainless steel*

*Thickness = 8 mm*

*Vacuum = $10^{-2}$mbar (in 2hrs pumping, 100m$^3$ )*

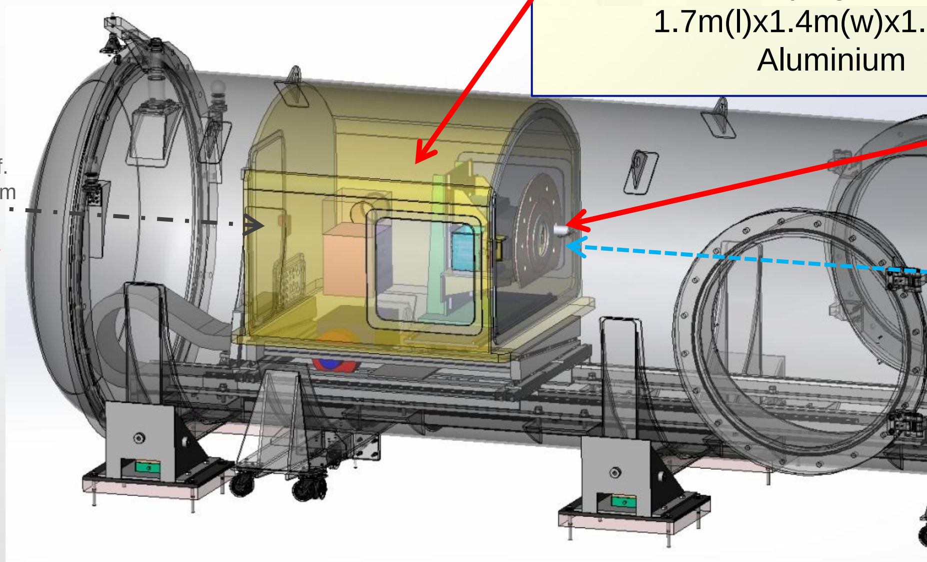
*Freeway*

*Sample*

*Wagon*
In air Carrying 3 detectors
1.7m(l)x1.4m(w)x1.3m(h)
Aluminium

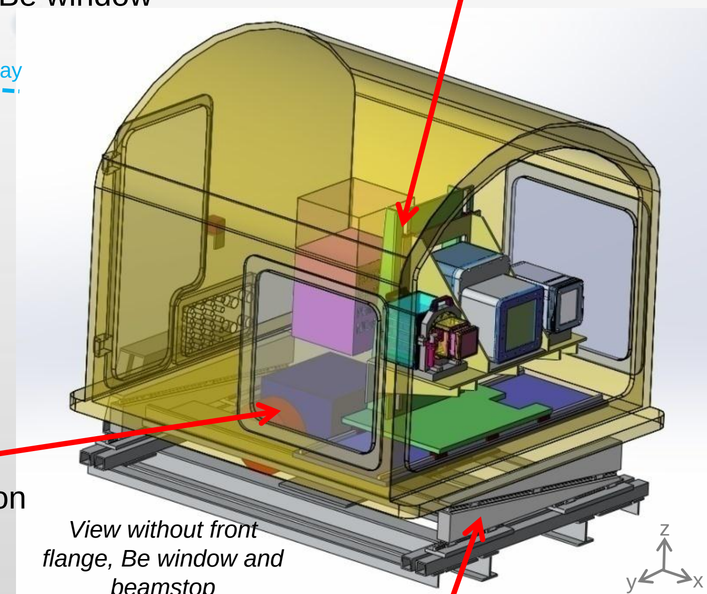
*YZ2 translation table*
Selection & positioning of 1 Detector
Range (resol.) : Y = ±320mm (1µm)
Z = ±87mm (1µm)

Ref.
Beam



*Beamstop*
and Be window

X-ray




*On-line alignment system*
Diode beam parallel to the X beam
(O.Hignette development)

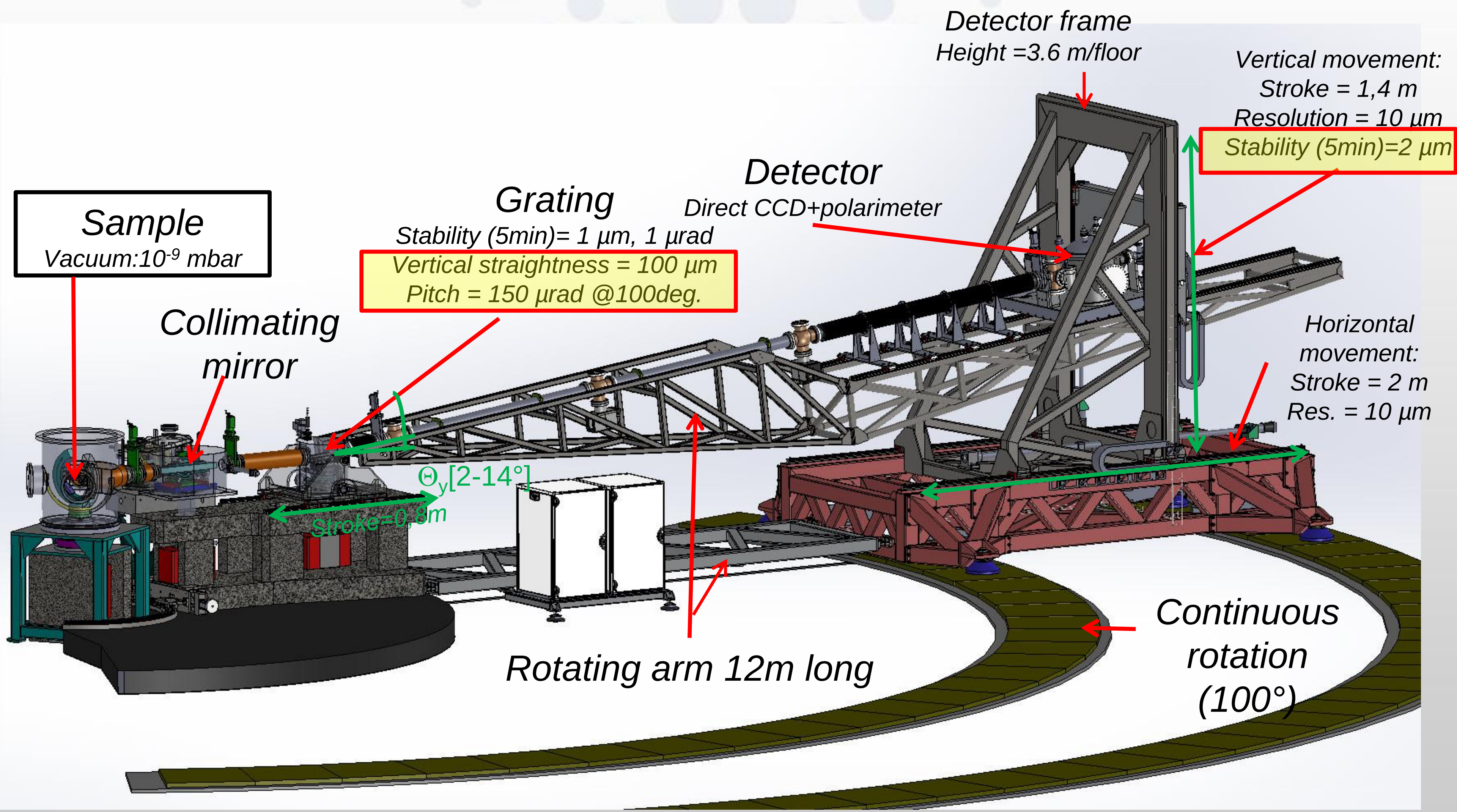
*Motor and encoder*
Central rack and pinion
under the wagon

| | | | | |
|---|---|---|---|---|
| Move Wagon along X | ⇨ | Compare position vs ref. beam | ⇨ | Correct position of Wagon (YZ2) =>Confusion disc of 100 µm over 30 m |

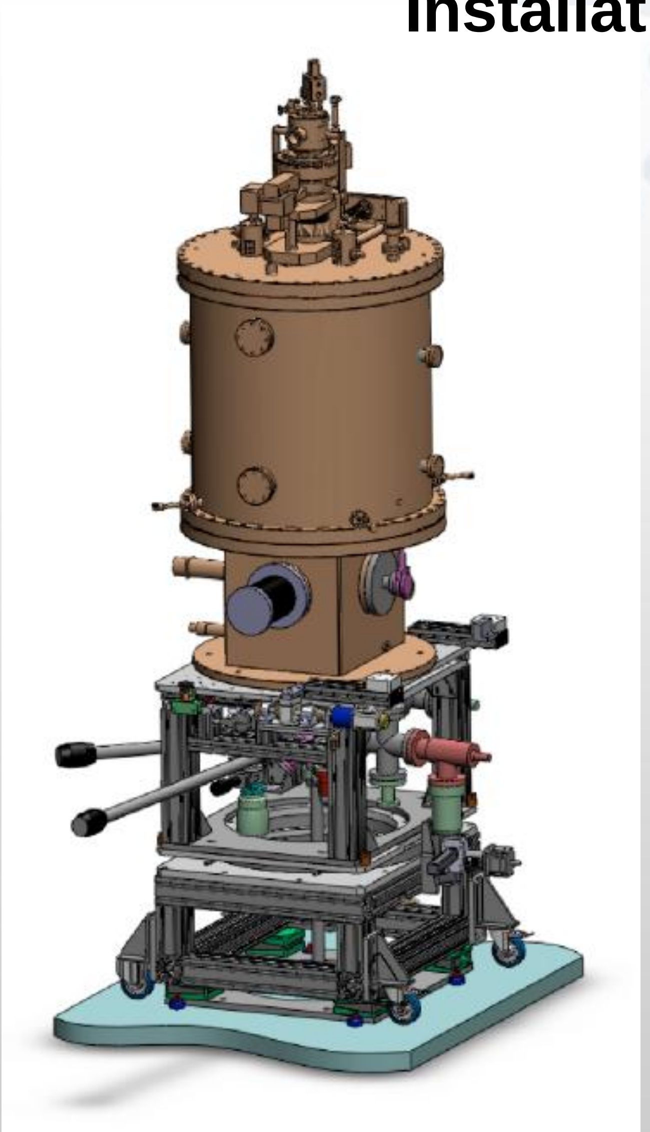
*YZ1 translation table*
Active alignment within closed loop
Range (resol.) : Y = ±10mm (1 µm)
Z = ±10mm (1 µm)

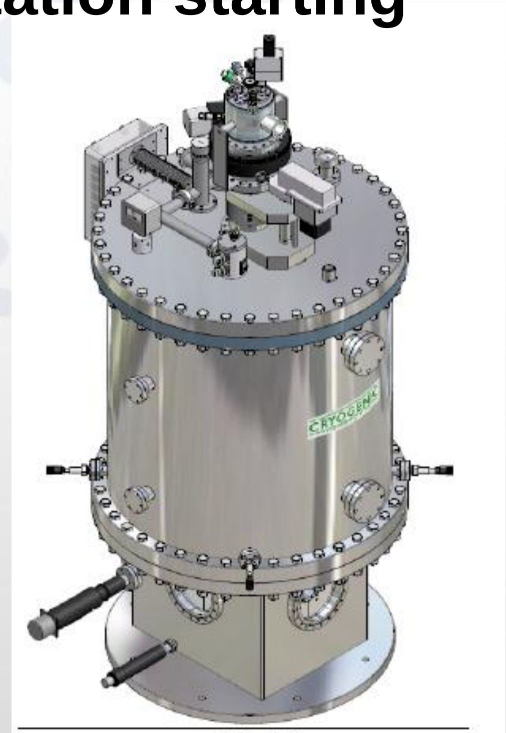
# The 12m RIXS spectrometer in EX2





# Installation of endstation starting





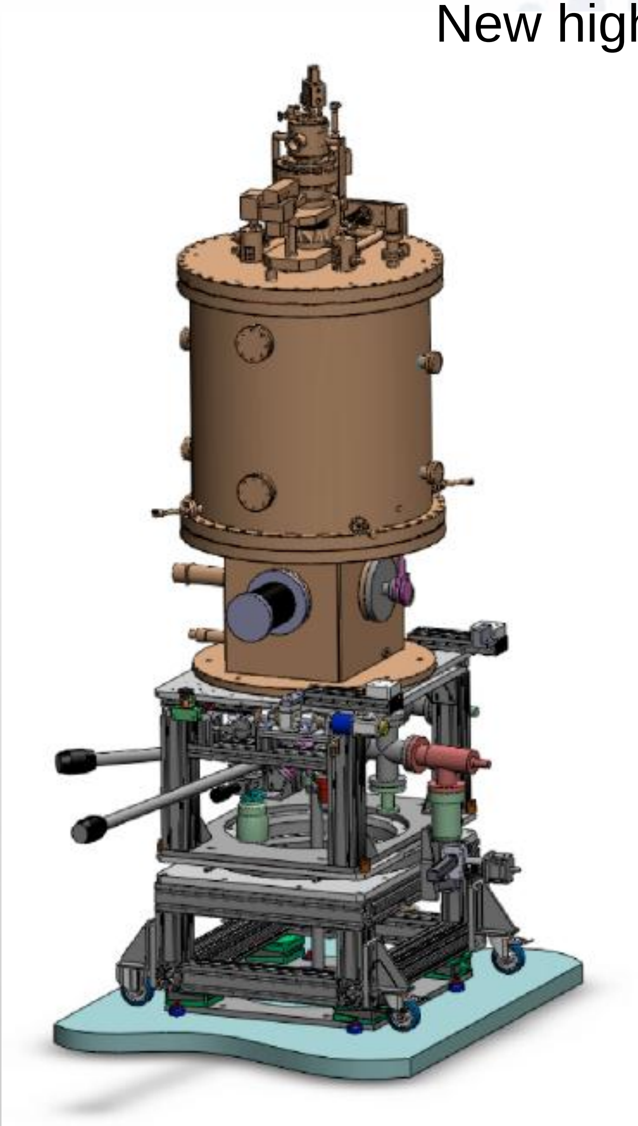
- Ultra high vacuum ($10^{-10}$mbar)
- superconducting magnet
- cold bore
- split coil
- 450-3K sample temperature
- 9T along beam (8T/min sweep rate) fast sweeping
- 4T perpendicular to the beam (2T/min sweep rate)

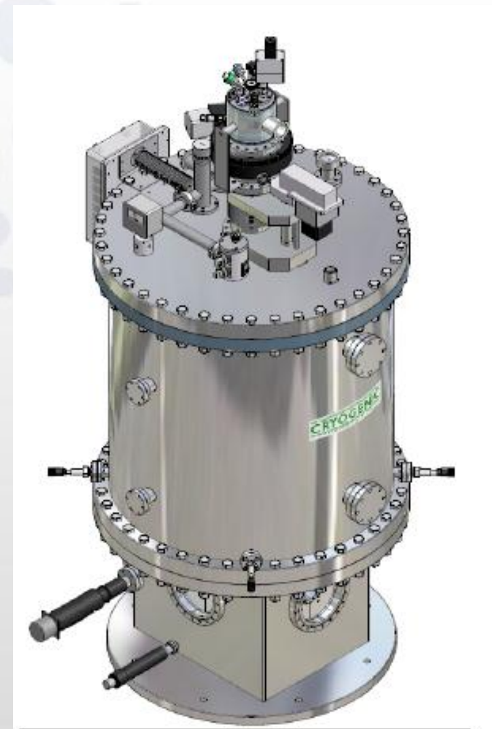
In commissioning on ID08

All specifications have been reached

First official user experiment on ID08 in spring 2013

# New high field magnet in UHV

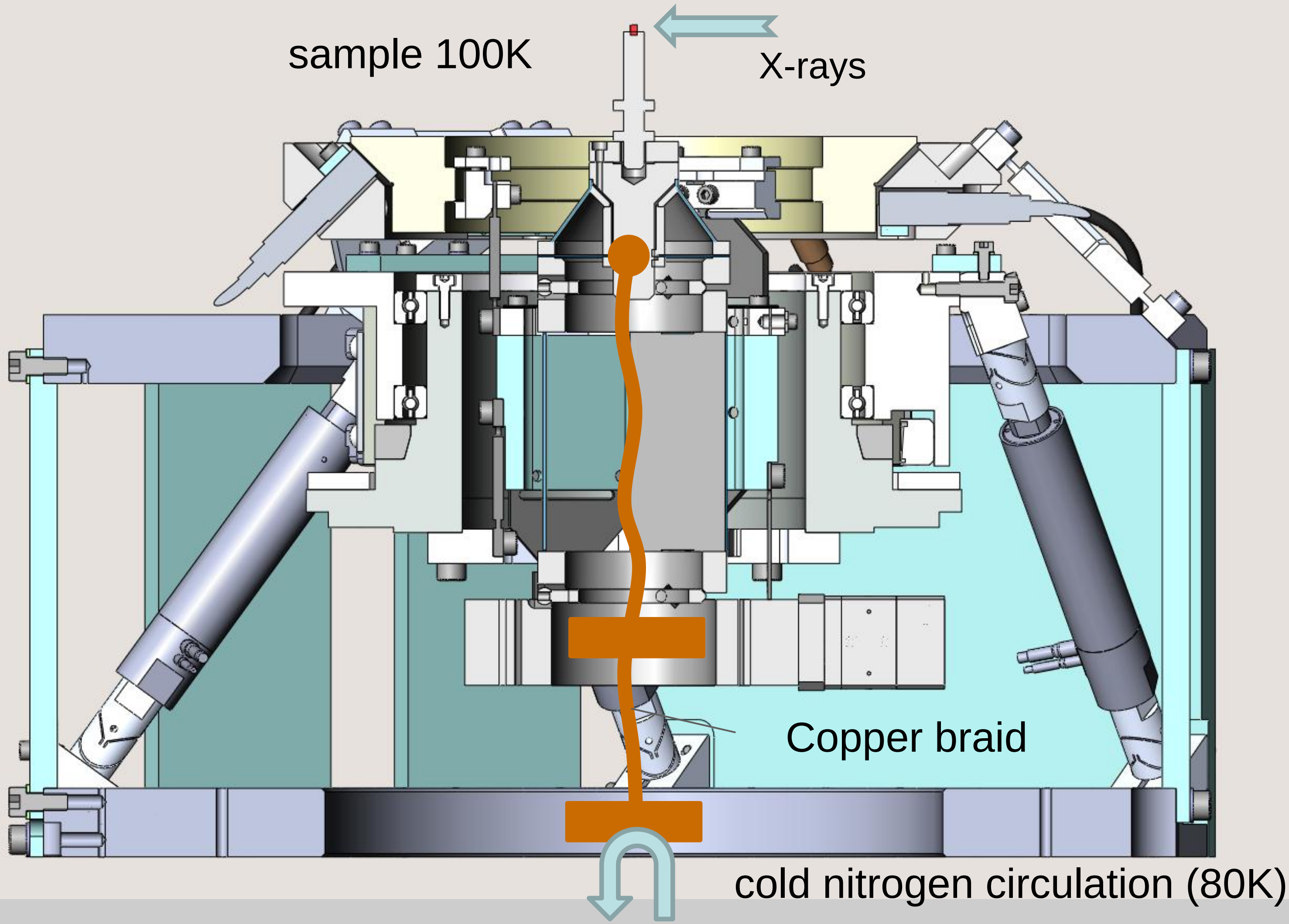




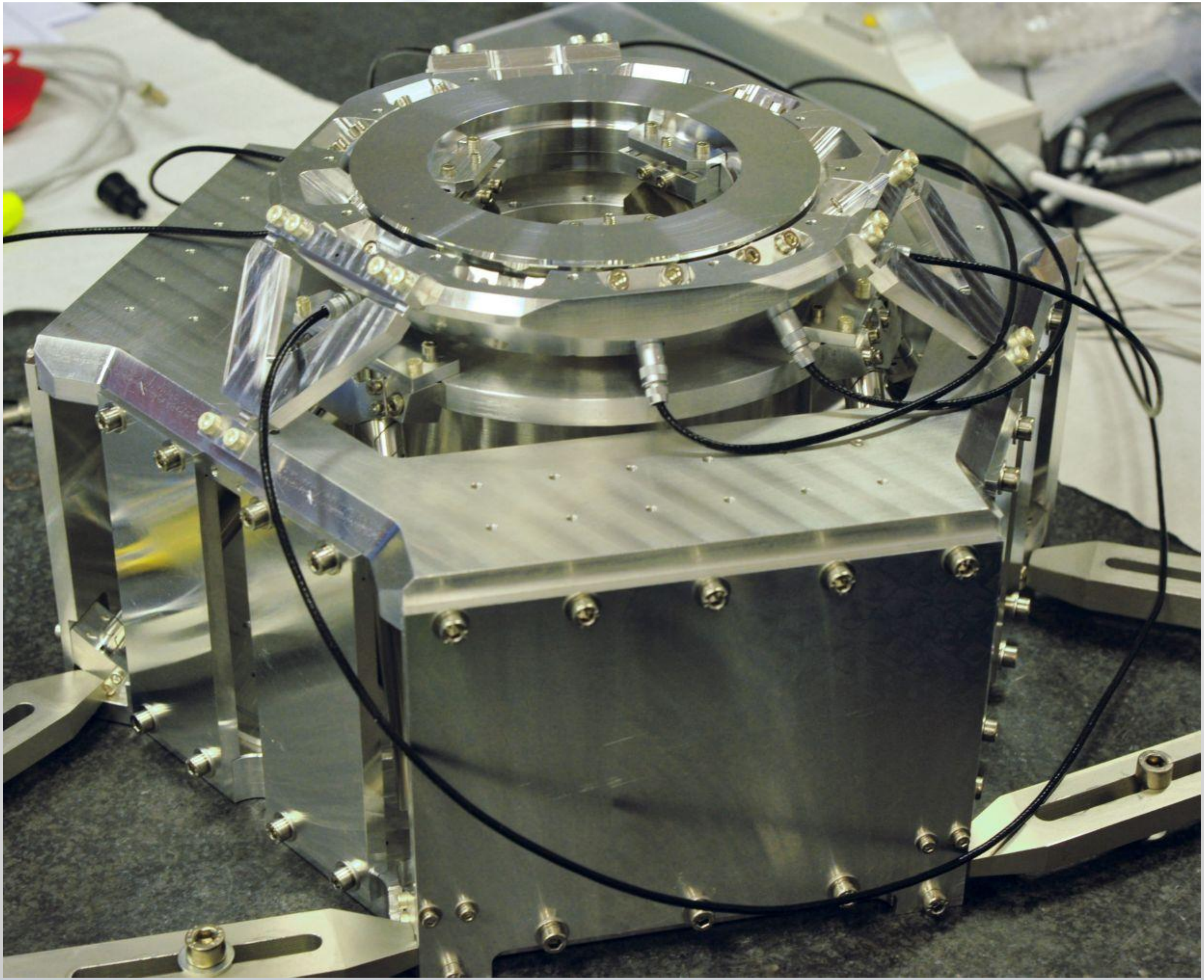
- Ultra high vacuum ($10^{-10}$mbar)
- superconducting magnet
- cold bore
- split coil
- 450-3K sample temperature
- 9T along beam (8T/min sweep rate) fast sweeping
- 4T perpendicular to the beam (2T/min sweep rate)

# 1 nm positioning accuracy

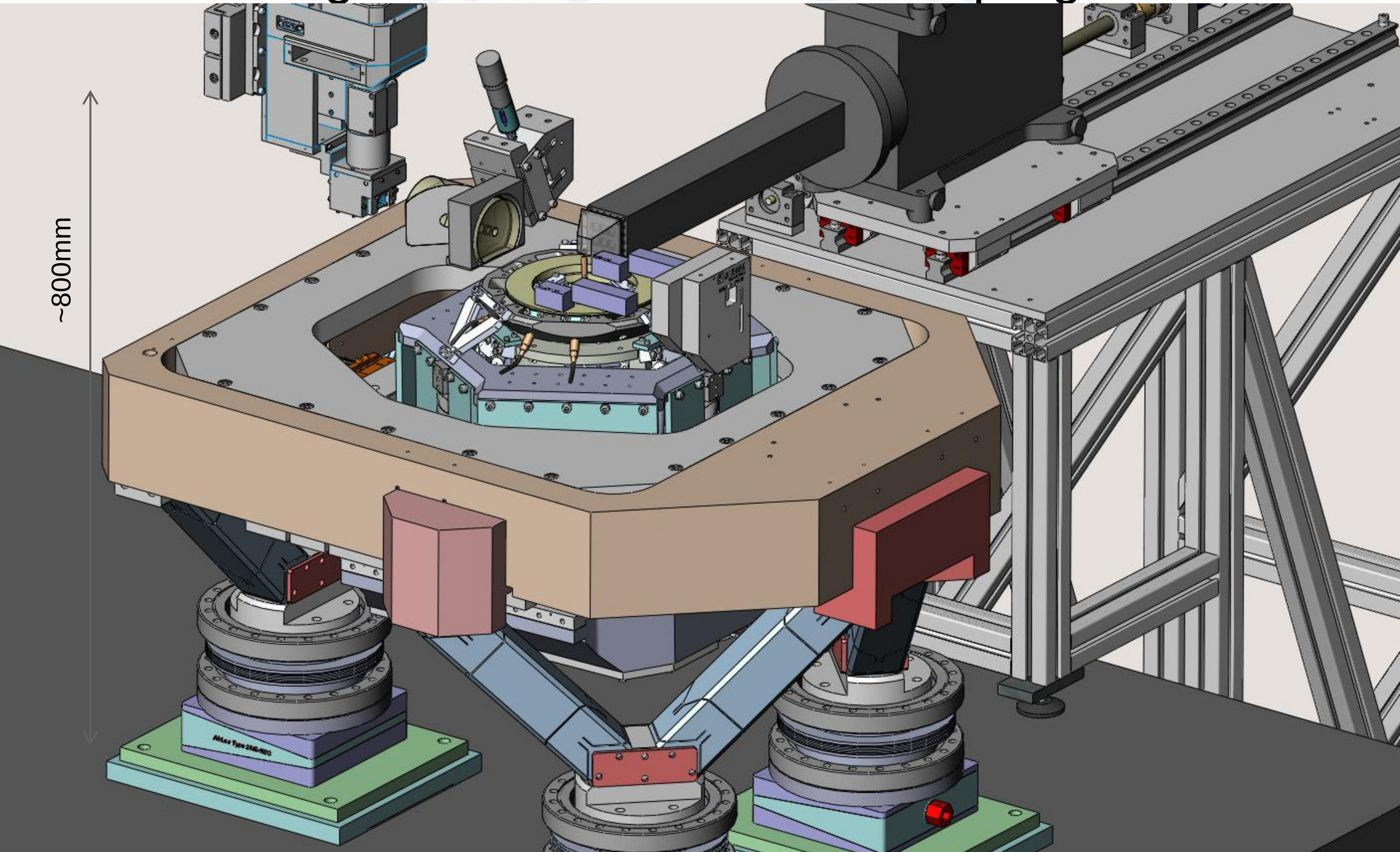
Heat is evacuated by conduction through a cold braid going through a central bore



~240mm



# Design of the endstation under progress

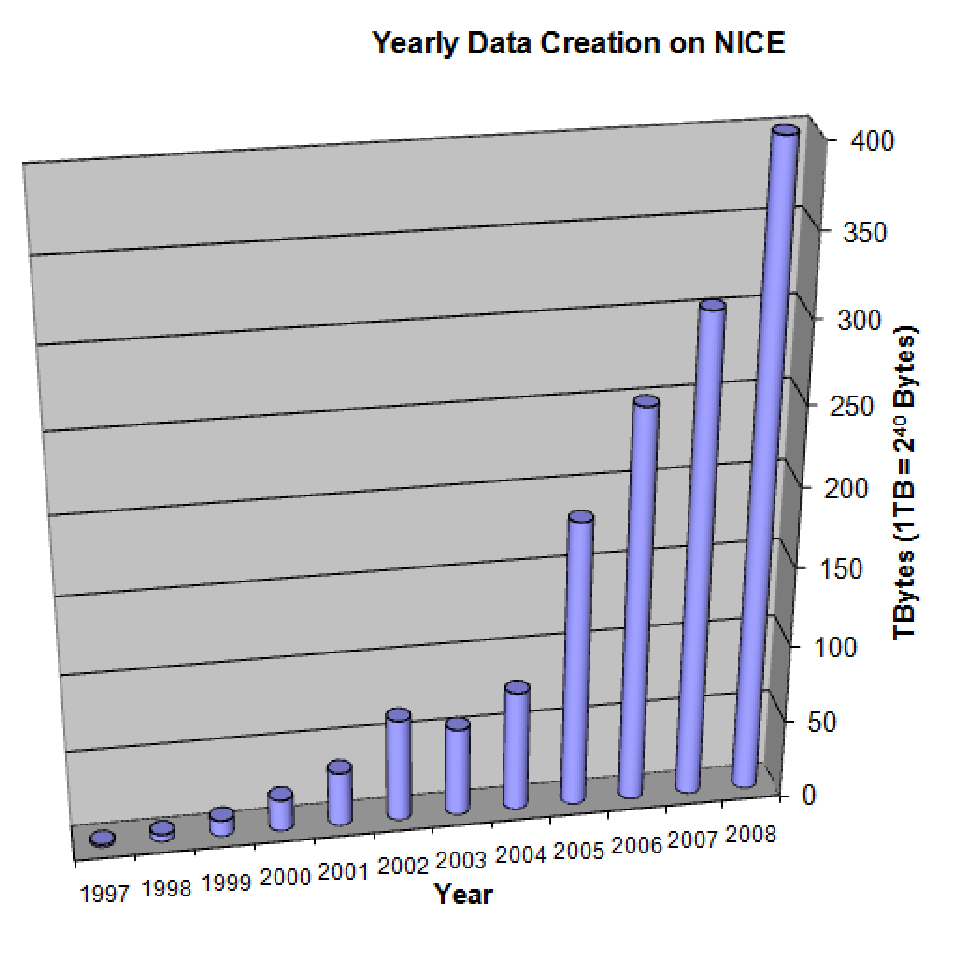


# Computing Infrastructure

# Evolution of the ESRF data production

12 years → data volume x 400.

We managed to provide the necessary network bandwidth, disk space, backup capacity at constant budget



# Extension of the Central Building Data Centre

Creation of a 300 m$^2$ Data Centre in the **Central Building**

## Data Centre in the CB

**ESRF Data Centre Upgrad**

From **150+75 kW** to

**150+350 kW**

**Commissioning 2011**

front

back

# Computing Infrastructure

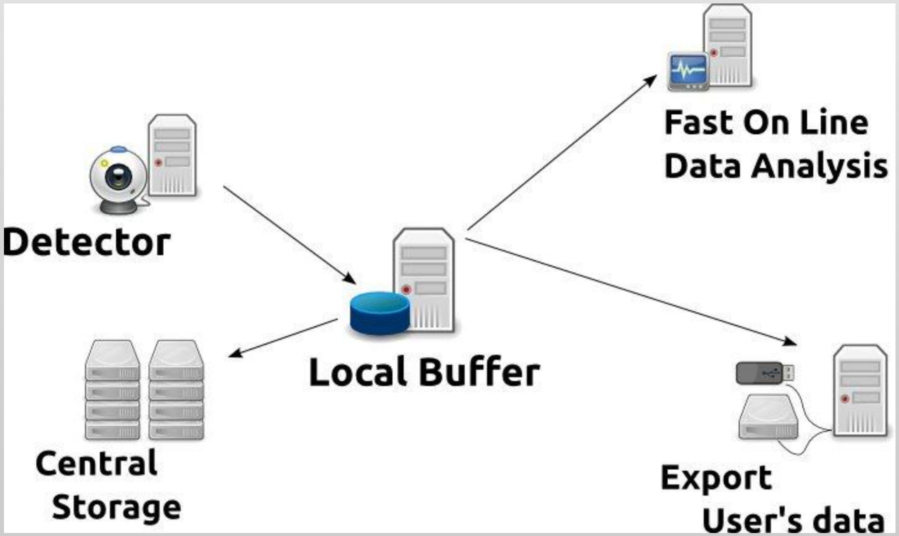
- ESRF computing infrastructure – four pillars:
  - Network
  - Disk base data storage
  - Tape based backup and data archiving
  - Data analysis clusters


- The current infrastructure is well suited for detectors with up to 100 MB/s data output

# Computing Infrastructure

- **Beamlines with high-speed detectors will require**
  - **Local buffer storage** for guaranteed bandwidth allowing simultaneous reading while recording data from the detector
  - Access to **massively parallel computing systems** (multi-core systems, GPUs) for on-line and off-line data processing
  - Large **high-performance data storage**

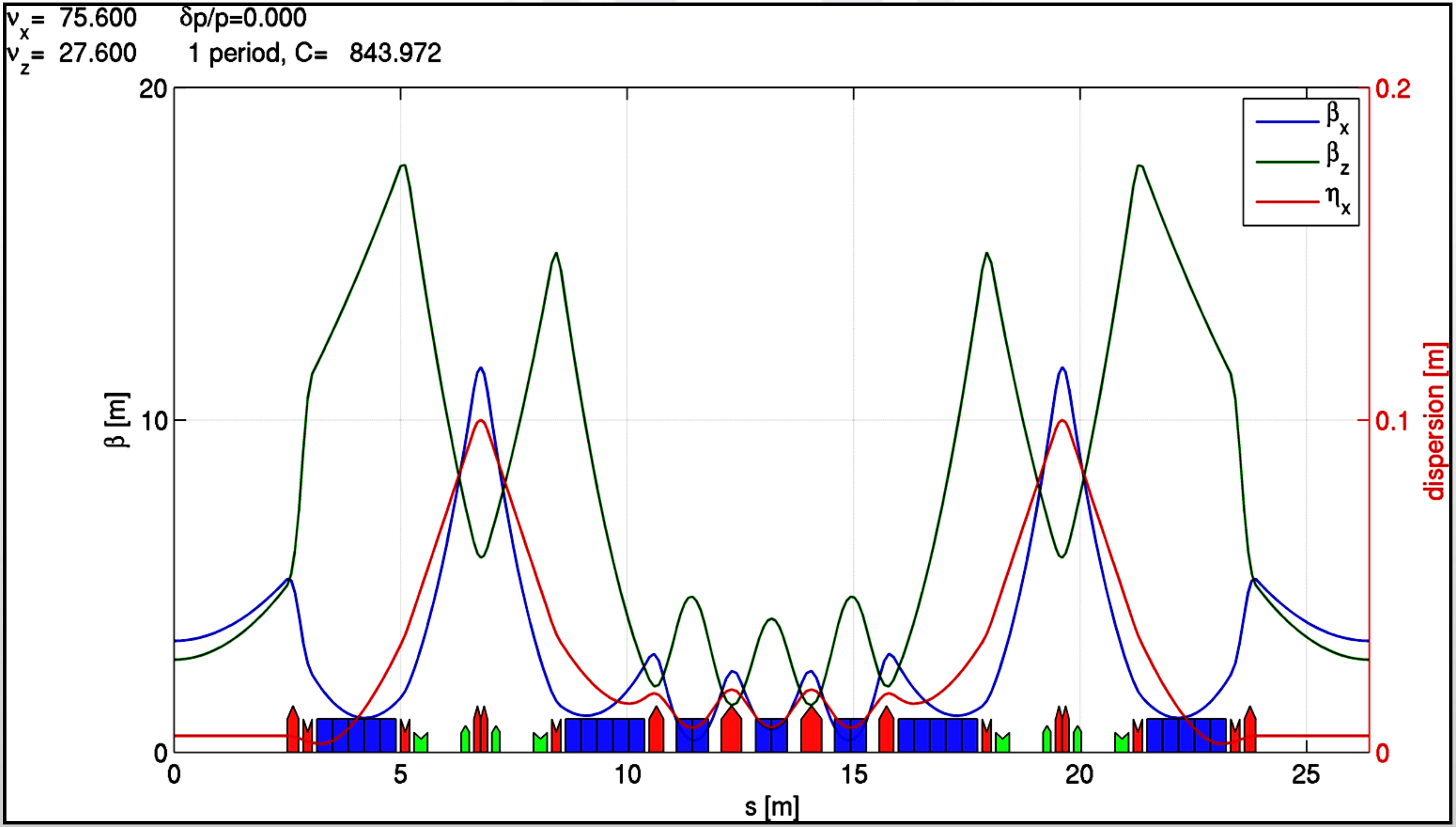
- **Capital investment**
  - significant capital investment is required to implement the proposed strategy



# ESRF Upgrade Programme
# Preparation of Phase II proposal
# 2015-2019

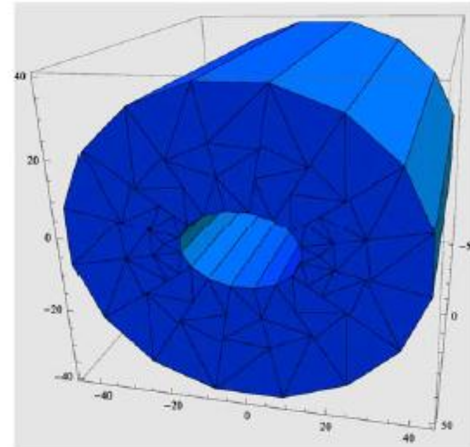
- Accelerator and Source
- Beamlines
- Enabling Technologies

# The ESRF Hybrid Multi-Bend (HMB) lattice

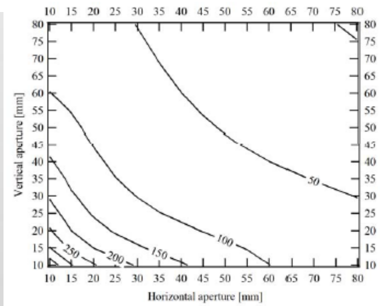


| | ESRF | New lattice |
|---|---|---|
| Dipole [T] | 0.86 | 0.49 |
| Quadrupole [T/m] | 17 (25) | 112 |
| Sextupole [T/m2] | 460 | 1650 |

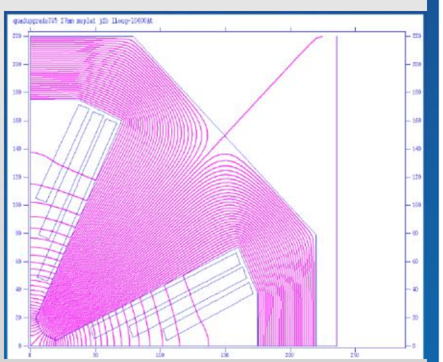
- Weak bending magnet with strong gradient
  - Equivalent to a quadrupole of 33 T/m offset by 1.5 cm
- Strong quadrupoles
- Very strong sextupoles



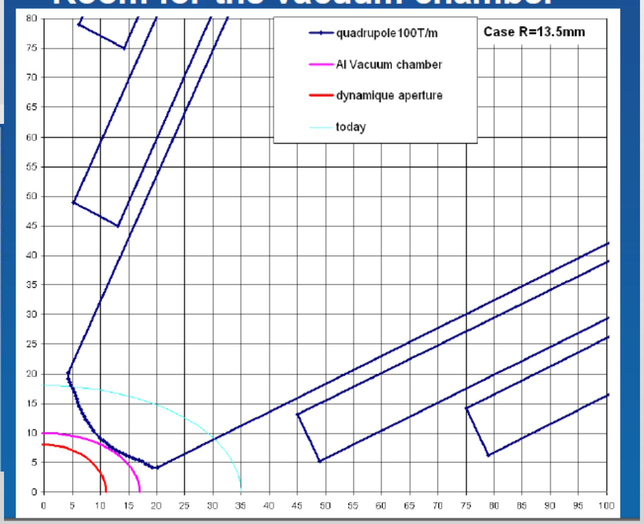
Halbach quadrupole with 20x30 mm$^2$ aperture




Gradient [T/m] vs. aperture



Room for the vacuum chamber




Hardware requirements are very demanding

# Thank You For Your Attention

Ask questions today!

Further Information

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