WORKSHOP ON DFXM

6-7 May 2021

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WELCOME AND

INTRODUCTION TO EBS

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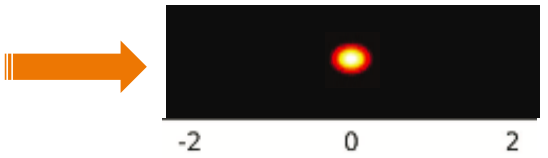
STREAMLINE has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 870313

X-RAY SCIENCE COMMUNITY'S QUEST FOR MORE BRILLIANCE

The quest for more brilliance and coherence to the benefit of Science

3rd generation - emittance H/V ~ 1000

4th generation – H/V ~ 1



SERVING THE LARGEST SCIENTIFIC COMMUNITY IN THE WORLD:
>50 000 TODAY AND GROWING

The aims of the EBS project:

- To decrease the storage ring horizontal emittance (= a factor 100 better than the 3rd SR generation)
- To increase the source brilliance (= a factor 100)
- To increase the coherence of the beam (= a factor 30)
- With the constraints to re-use an existing infrastructure and minimising the impact on the ESRF activity

NEW LATTICE VS. PRESENT ESRF LATTICE: DBA → HMBA

➢ **Previous ESRF lattice (cell)**

Double Bend Achromat = (2 dipoles + 15 quad. sext.) per cell

ID length = 5 m (standard) / 6m / 7m

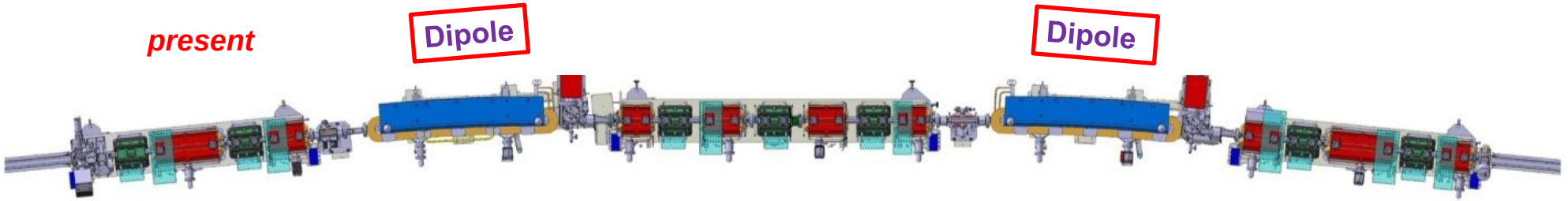
$$\varepsilon \propto \frac{E_e^2}{\left(N_{sect} \cdot N_{dipole}\right)^3}$$

➢ **EBS lattice (cell)**

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

ID length = 5 m

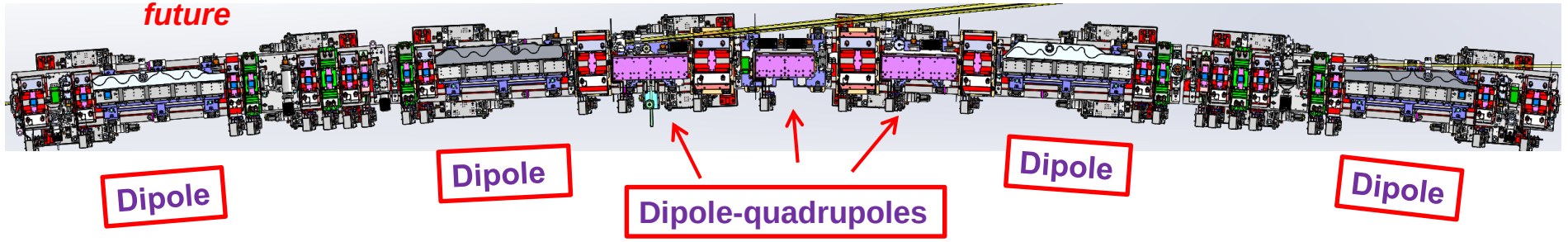
present



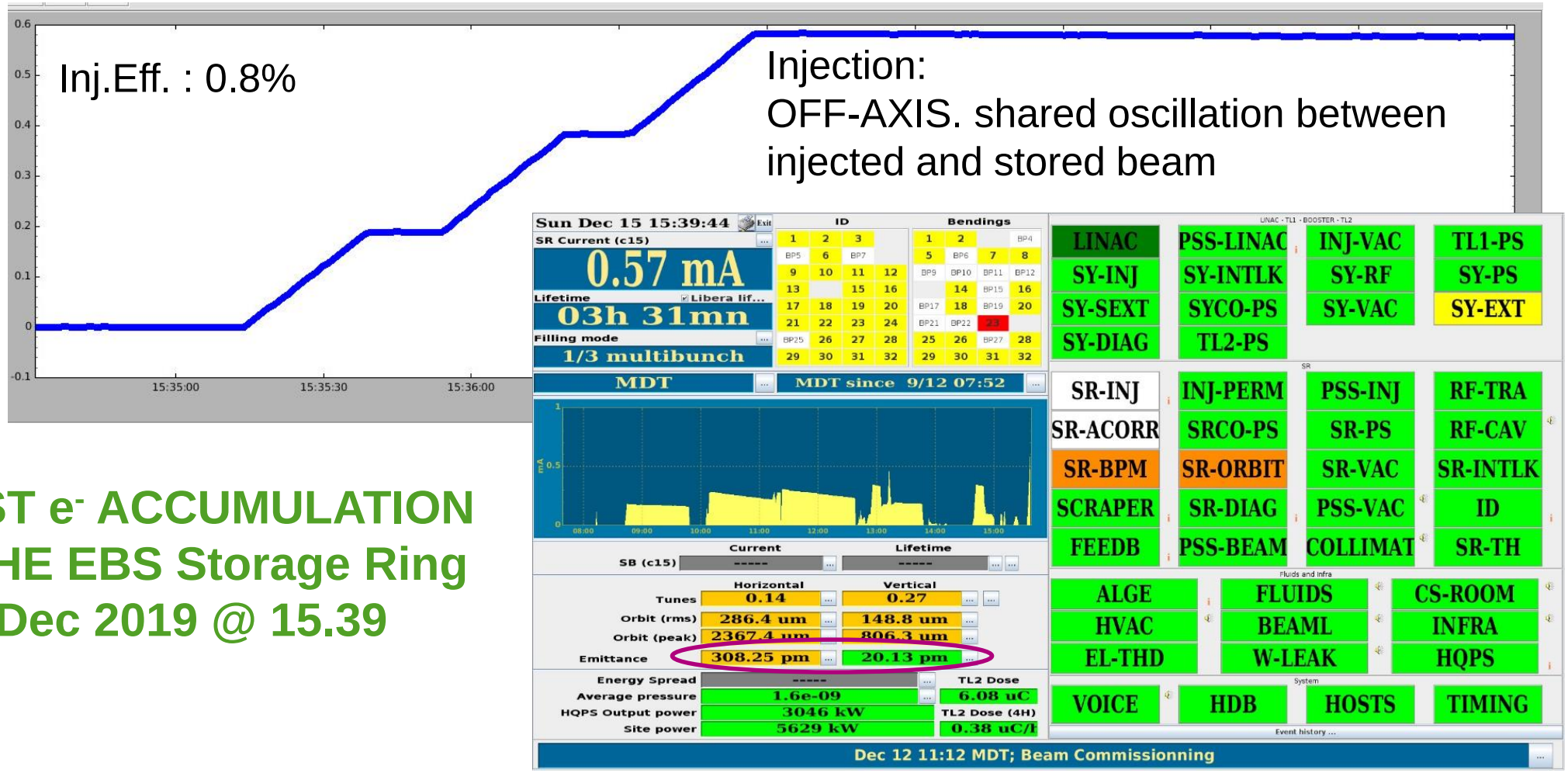
31 magnets per cell instead of currently 17

32 cells (arcs) with 4 girders each

future



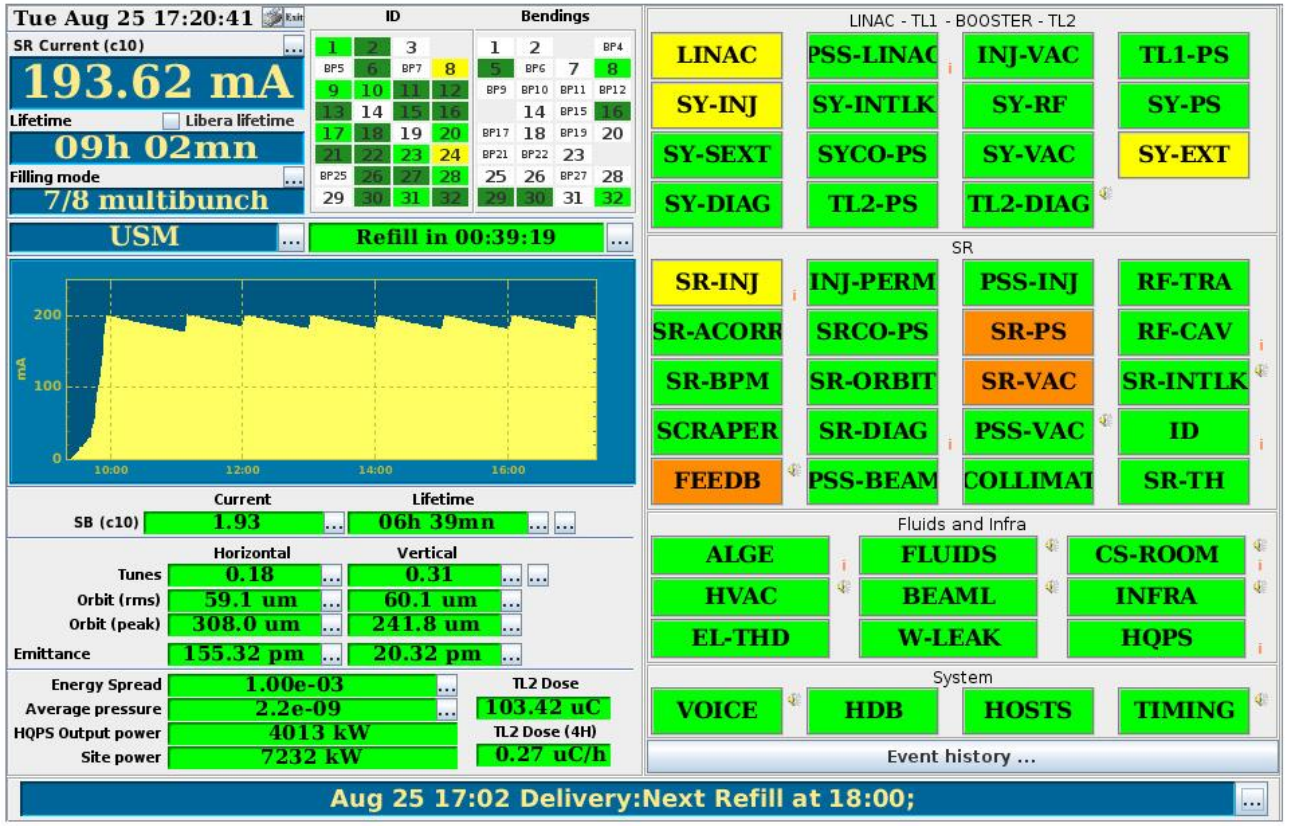
2019 DECEMBER 15TH : FIRST ACCUMULATION



FIRST e- ACCUMULATION IN THE EBS Storage Ring
15th Dec 2019 @ 15.39

25TH AUGUST 2020 : A TIME TO REMEMBER !

The 25th August 2020, first official USM shift starts

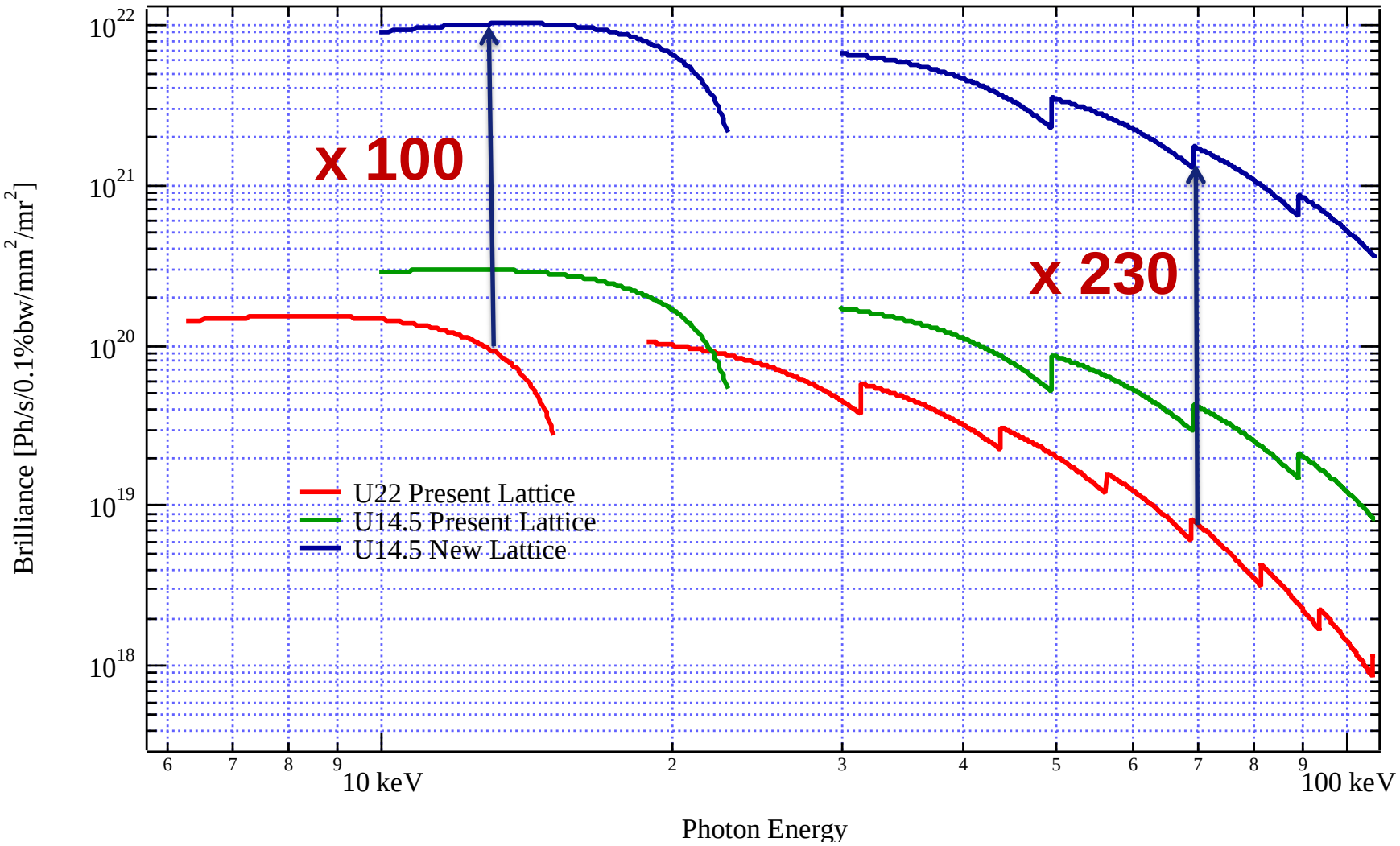


- 28 beamlines take beam
- 200 mA
- $\varepsilon_x = 150\ pm \cdot \mathrm{rad}$
- $\varepsilon_z = \ \ 20\ pm \cdot \mathrm{rad}$

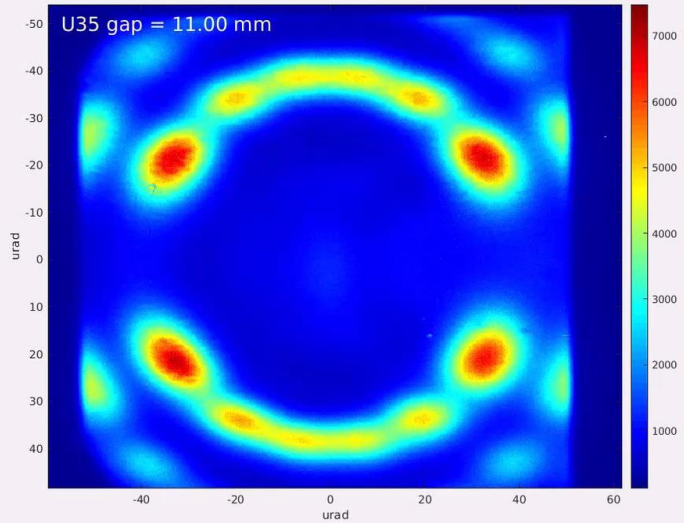
On-schedule beam delivery proofs the very advanced state of the new machine

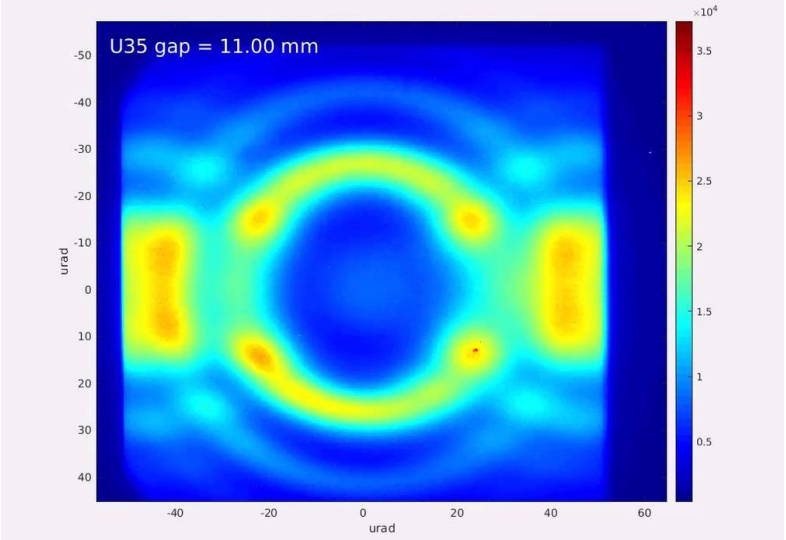
CPMUS AT SMALLER GAP: INCREASED BRILLIANCE

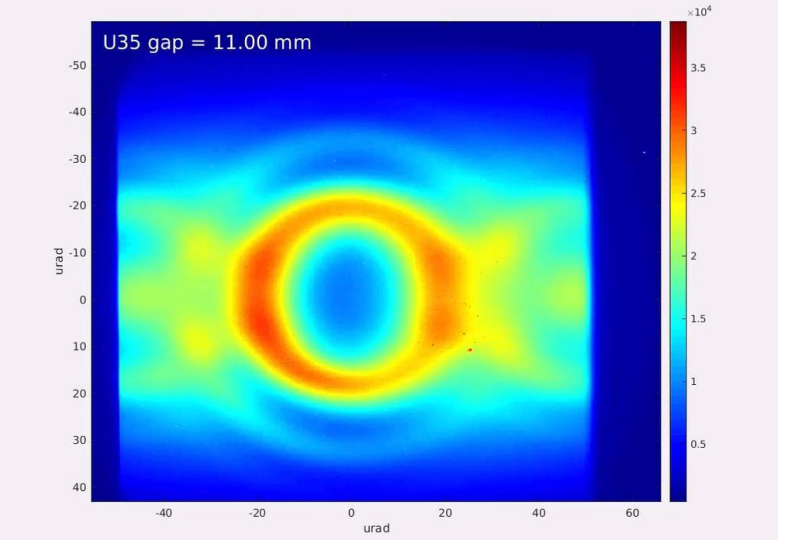
IVUN22 min. gap 6 mm, K_{max}=1.7
CPMU14.5 min. gap 4 mm, K_{max}=1.7



FIRST BEAM AT ID15A







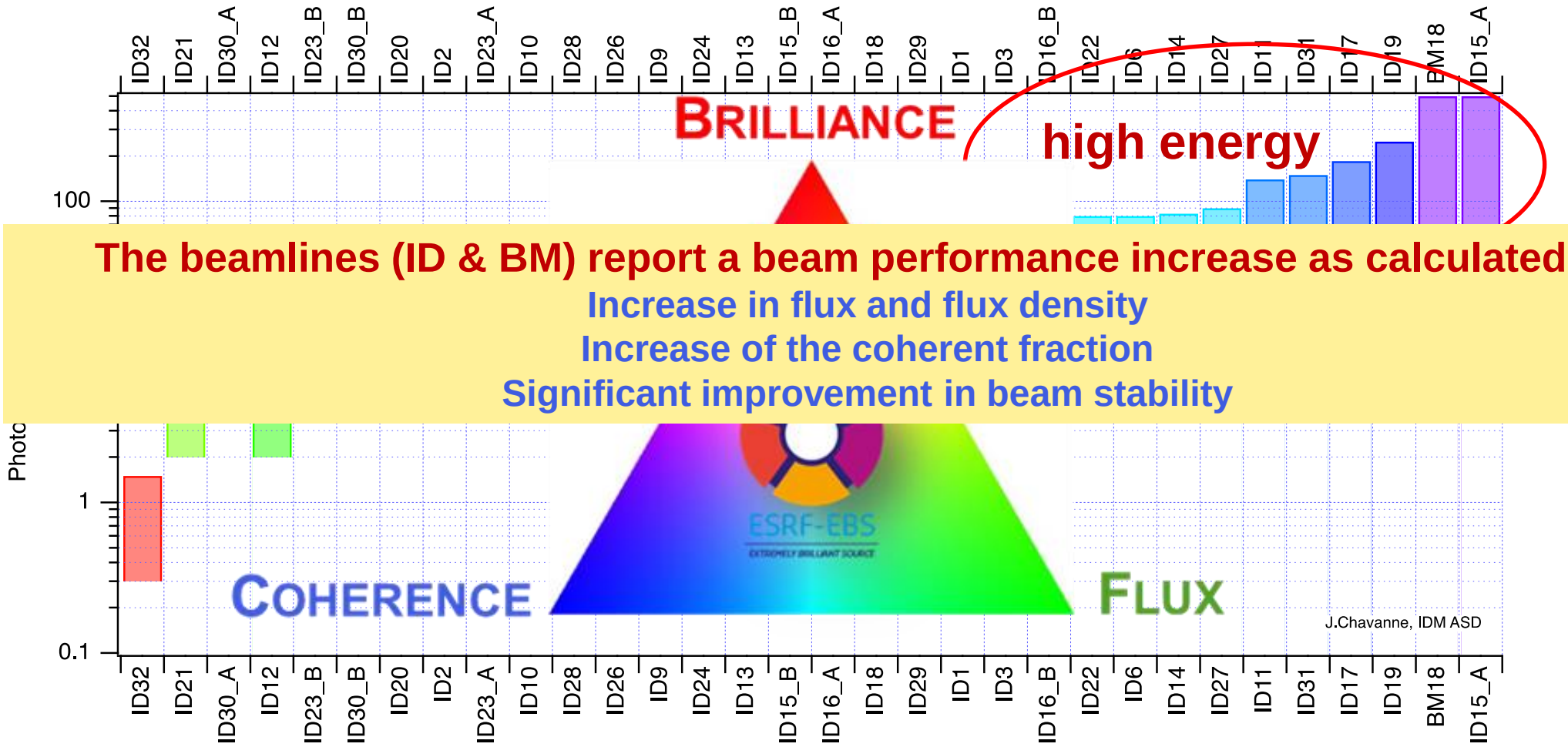
40 keV **70 keV** **100 keV**

monochromatic beam from a U35 [Laue-Laue monochromator with approx. 0.3% energy resolution]

(band width narrower than undulator harmonics)

images taken at ~65 meter with PCO-edge camera with 1:1 optics (6.7 μm pixel size)

EBS – the first 4th generation high energy SR source:
A big step forward for X-ray science



The beamlines (ID & BM) report a beam performance increase as calculated

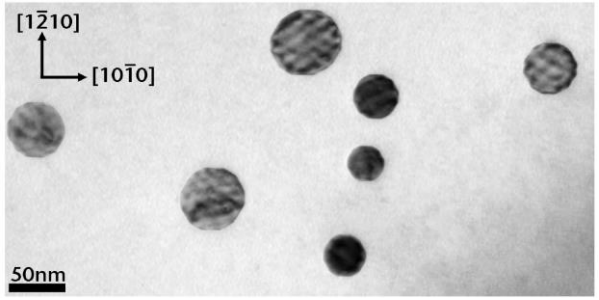
Increase in flux and flux density

Increase of the coherent fraction

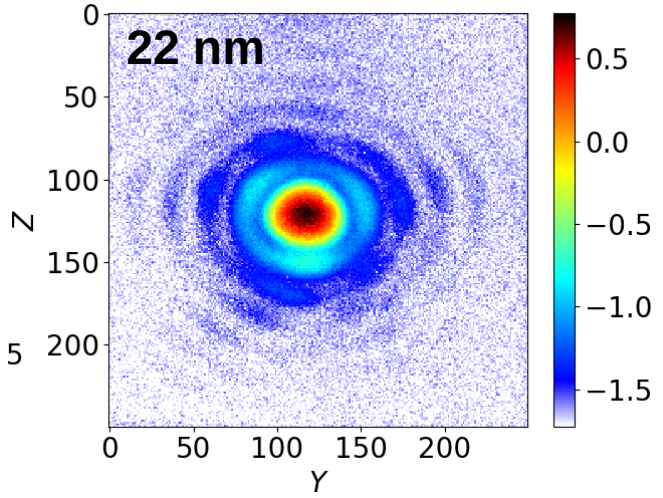
Significant improvement in beam stability

DIFFRACTION @ BEAMLINE ID01: 1ST COHERENT DIFFRACTION PATTERNS OF SMALL PT NANOPARTICLES

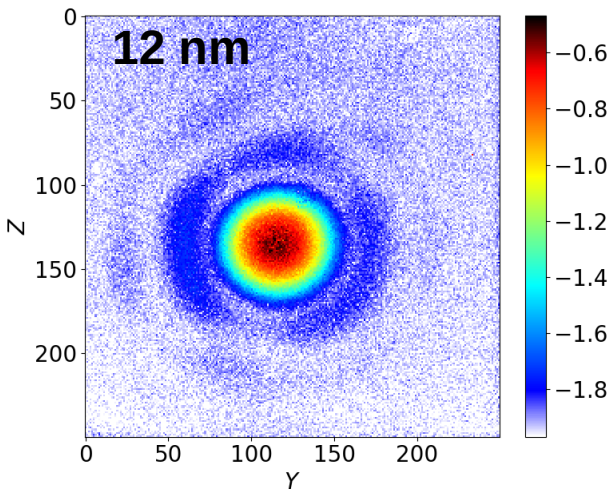
Pt nanoparticles embedded in alumina



Energy: 9 keV
Detector distance = 19.5 cm

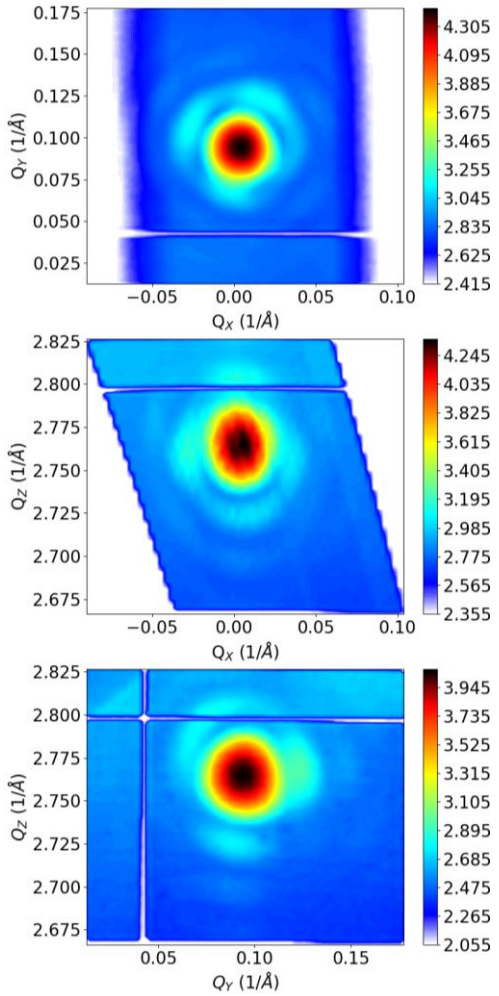


counting time = 1 sec.



counting time = 20 sec.

3D diffraction pattern: 22 nm



ID01
CEA
Oregon Univ.

European Commission

European Research Council
Established by the European Commission
Supporting top researchers from anywhere in the world

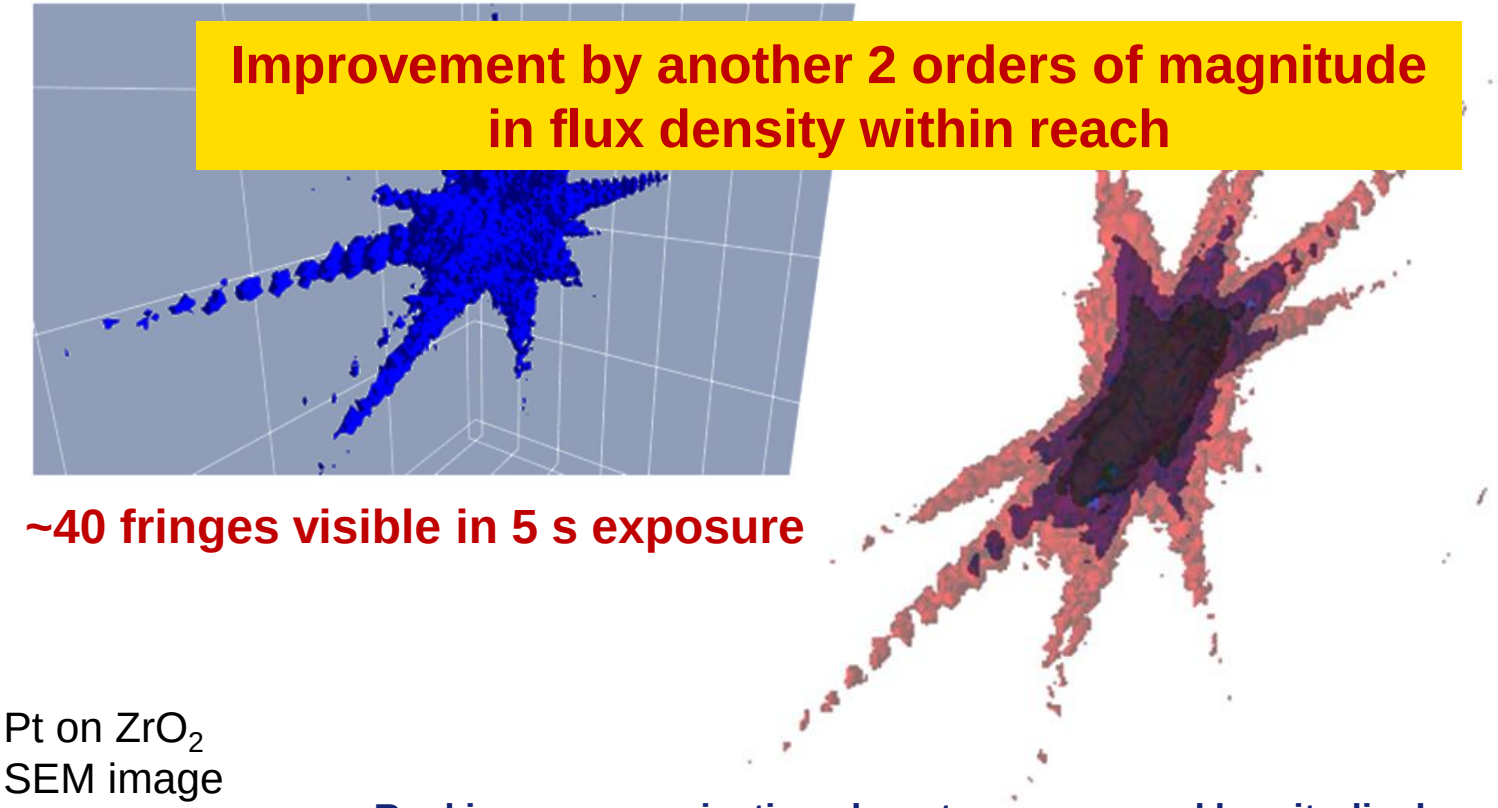
The European Synchrotron | ESRF

COHERENT DIFFRACTION AT HIGH ENERGY @ BEAMLINE ID31

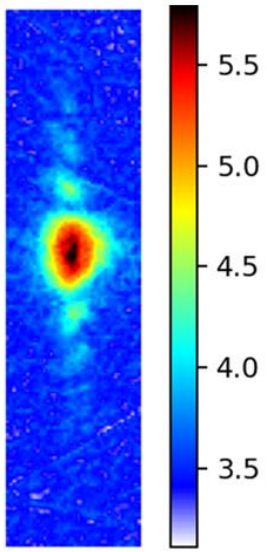
BCDI @ 41keV on ID31

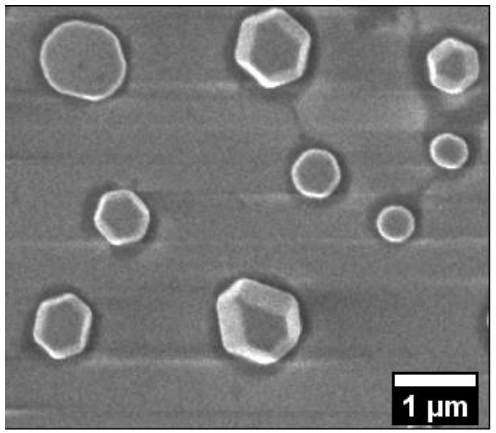
Pt crystals: ~600 nm diameter
Delivered flux: ~ 3 x 10^8 ph/s
Spot size: 9x10 μm
Rocking curve acquisition: 4 min

Improvement by another 2 orders of magnitude in flux density within reach



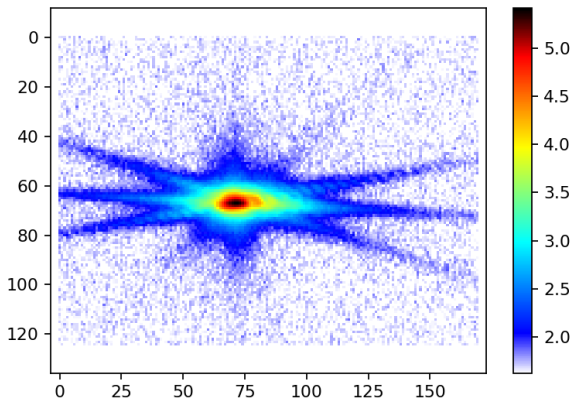
~40 fringes visible in 5 s exposure

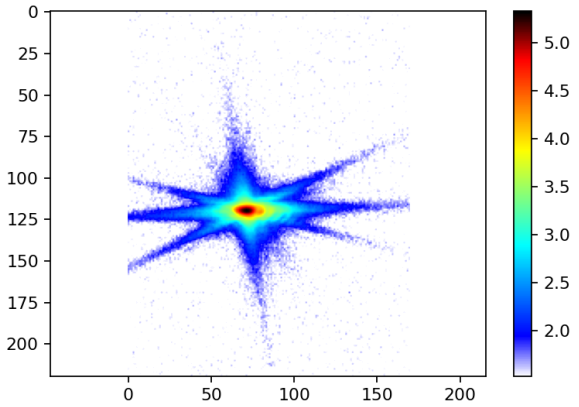




Pt on ZrO_2
SEM image

Rocking curve projection along transverse and longitudinal axes

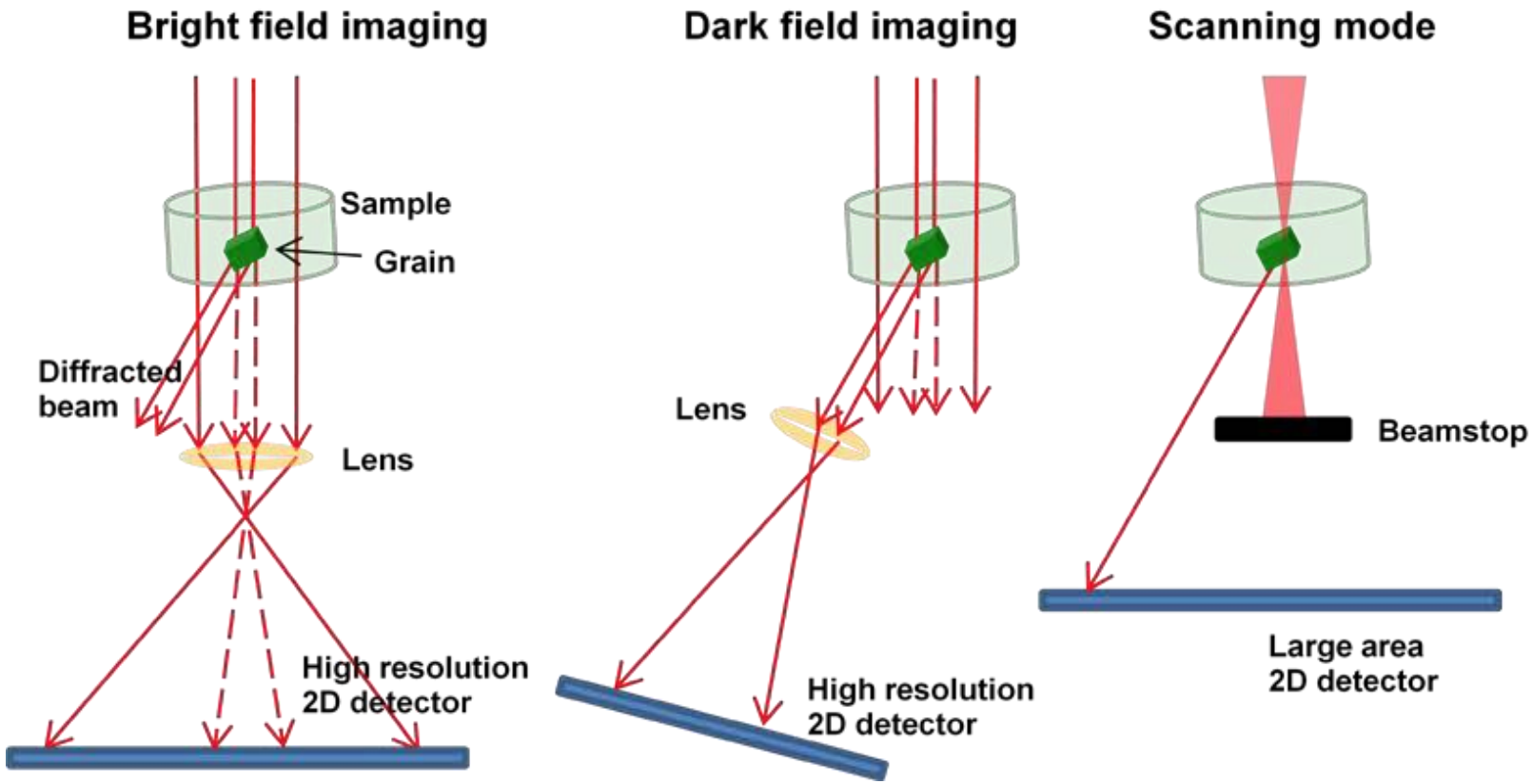




Sufficient flux density for particles 10-15x smaller with penalty to speed (90 min acquisition)

I. Martens, M.-I. Richard, S. Leake, J. Drnec, V. Honkimäki

Diffraction based Transmission X-ray Microscopy

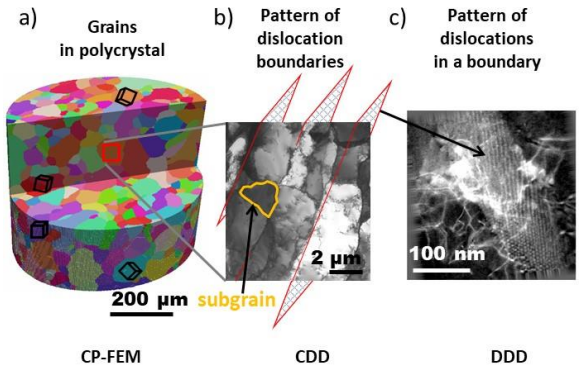


Optics **< 15 keV : zone plates 10 nm**
> 15 keV : compound refractive lenses 100 nm => 20 nm

HXDM ON ID06 – SAC 2018

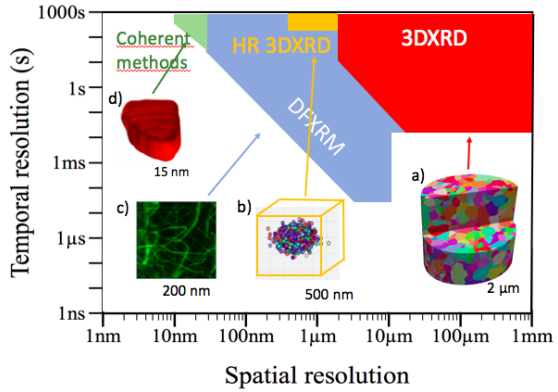
H. F. Poulsen, Technical University of Denmark (DTU):
ERC-Grant “Diffraction-based transmission x-ray microscopy d-TXM (10/2012 – 09/2017)
ERC-Grant “The Physics of Metal Plasticity (2020-2025)
H. Simons, Technical University of Denmark (DTU):
ERC-Grant “3D Piezoresponse X-ray Microscopy (2019-2023)

European Research Council
Executive Agency



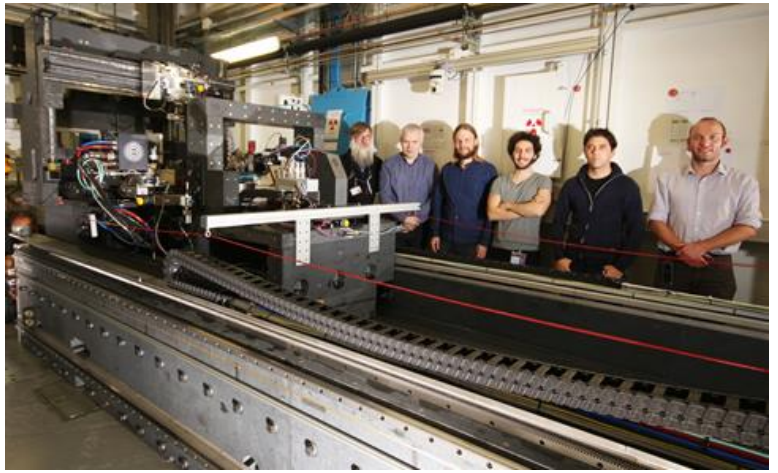
Scientific goal

- Development of multi-scale materials characterization continuously covering length scales from 1 mm to 10 nm.
- Coupling to 3D modeling
- Basic mechanisms underlying plastic deformation & phase transformation in metals



Results

- Development of dark-field X-ray microscopy
- Construction of a dedicated instrument at ID06
- Improvement of the real-space resolution
  from ~3 µm (DCT and 3DXRD) to ~ 100 nm (DFXRM) and ~30 nm (multilayer Laue lenses)
- Demonstration of Bragg CDI in bulk materials to ~ 13 nm @ ID01
- 28 publications

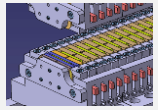


REMAINING EBS PROGRAMME

- Four new beamlines fully optimized for EBS
  - EBSL3-BM18: *High throughput large field phase-contrast tomography beamline*
  - EBSL8-ID29: *Serial crystallography beamline*
  - EBSL1-ID18: *Beamline for coherence applications*
  - EBSL2-ID03: *Beamline for hard X-ray diffraction microscopy*

- **Refurbishment Programme**
  ID18 (ID14), ID21, ID24, BM23, ID27, ID32

- New insertion devices



- ESRF Data Policy on all beamlines

Findable Accessible Interoperable Reusable

- 10 new high-end 2D detectors

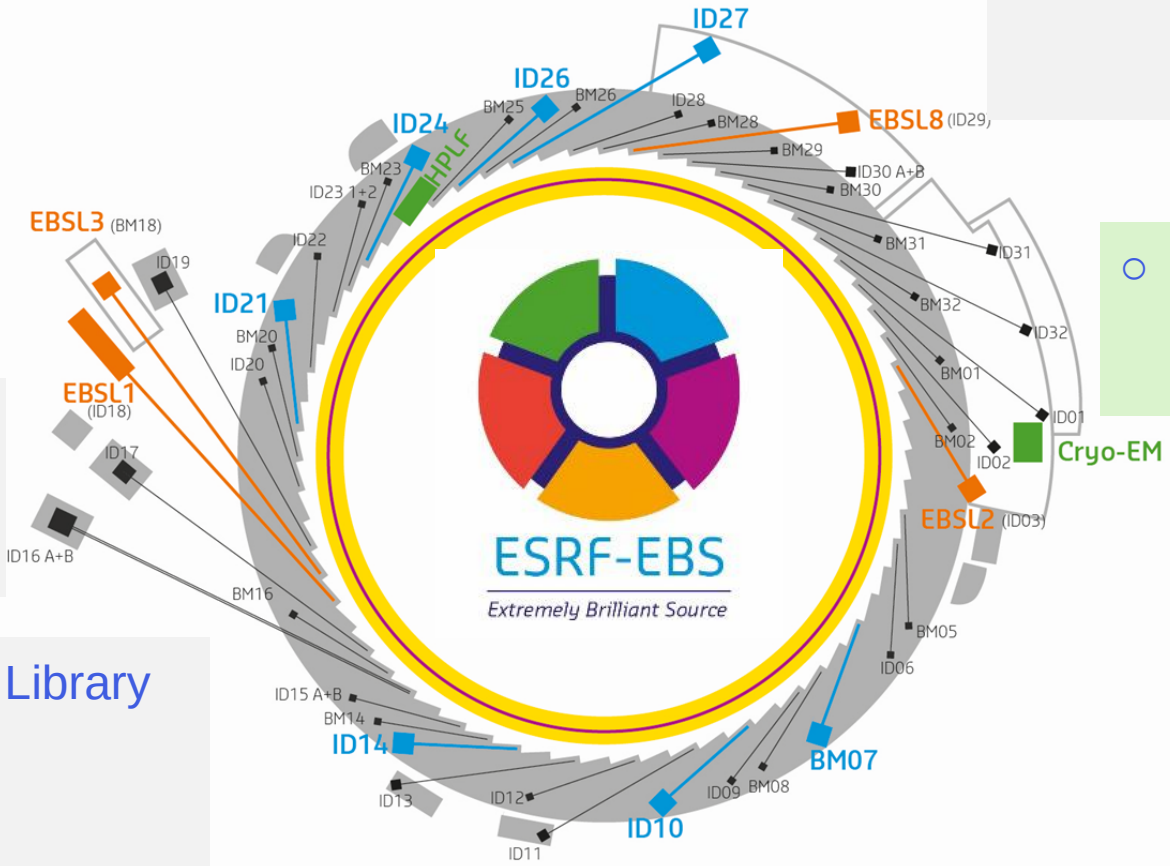
- New beamline control software

Bliss

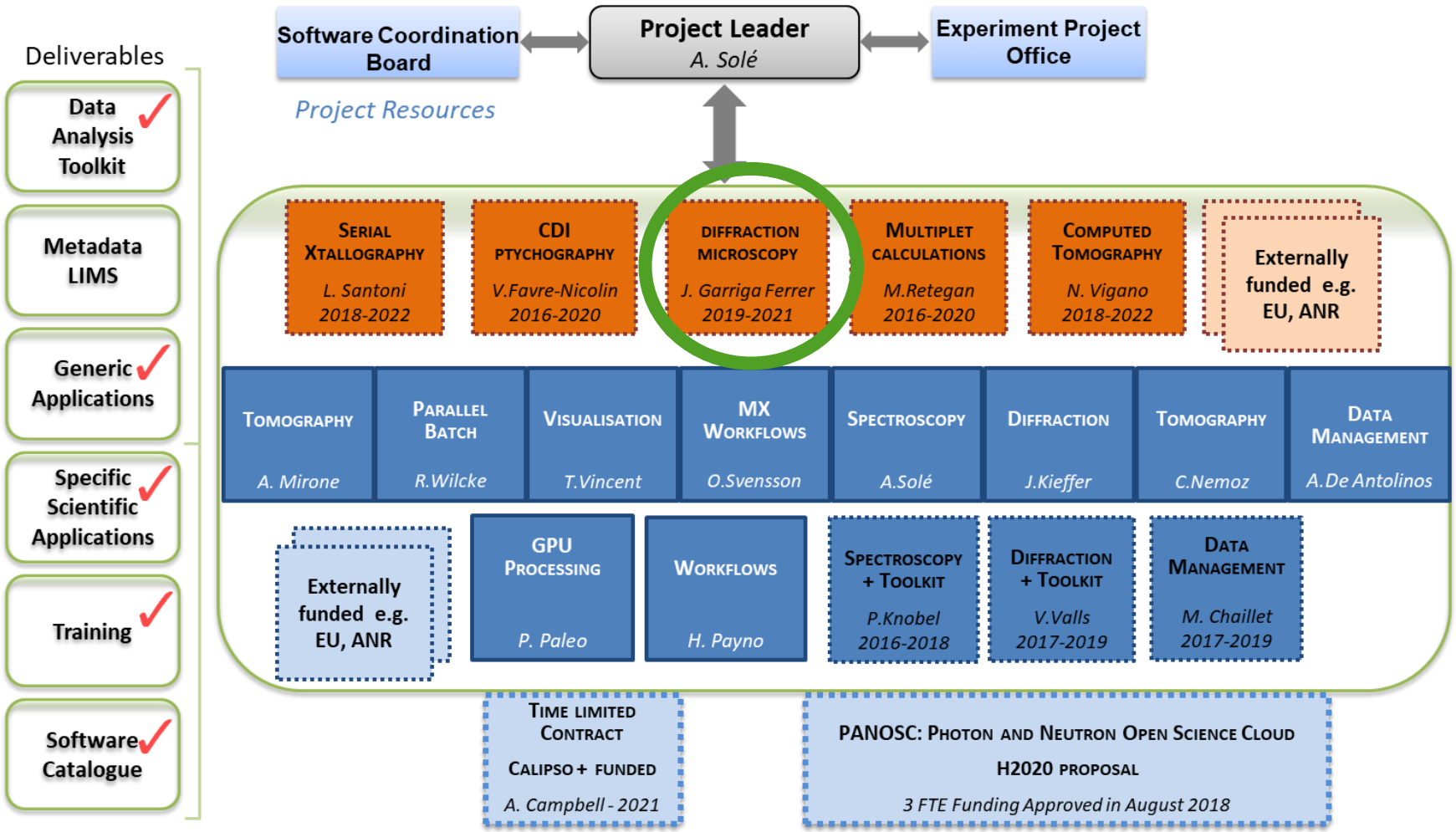
- New access modes
  e.g. BAG, mail-in, etc…

- Scientific software Library

silx



SCIENTIFIC DATA ANALYSIS AND MANAGEMENT FOR EBS – SAC 2019



a big thanks to all colleagues who brought us back into business

It's great to have our user back!!

Thank you for your attention!

STREAMLINE

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