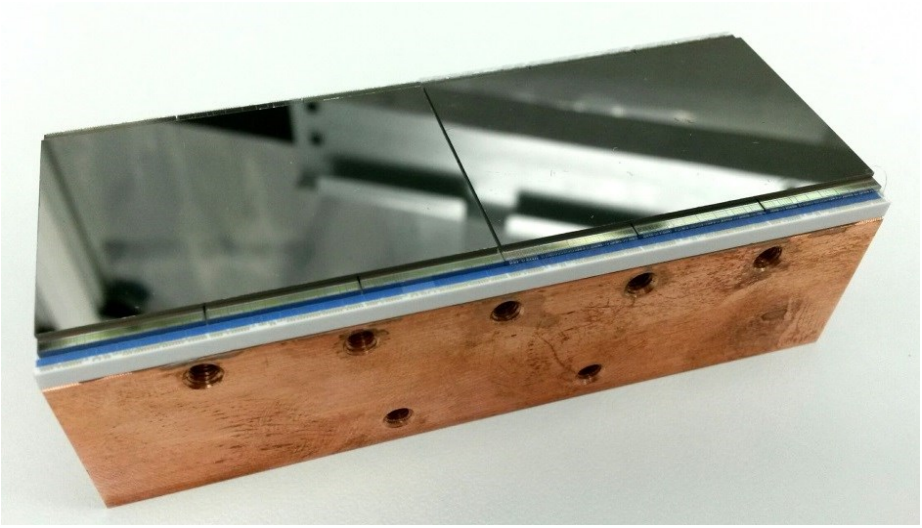
X-ray experiments at synchrotrons

David Pennicard, Andre Rothkirch, Yuelong Yu, Heinz Graafsma – DESY
Julian Becker, Sergej Smoljanin, Florian Pithan, Hagen Stawitz – X-Spectrum
Cyril Ponchut, Marie Ruat – ESRF
Nicola Tartoni, David Omar, Ian Horswell – Diamond
Jean-Marie Polli - LNLS



Synchrotron labs in Medipix collaboration

PETRA-III
Heinz Graafsma
and more…

Nicola Tartoni
David Omar
Ian Horswell

Cyril Ponchut
Marie Ruat

Sirius
Jean-Marie Polli

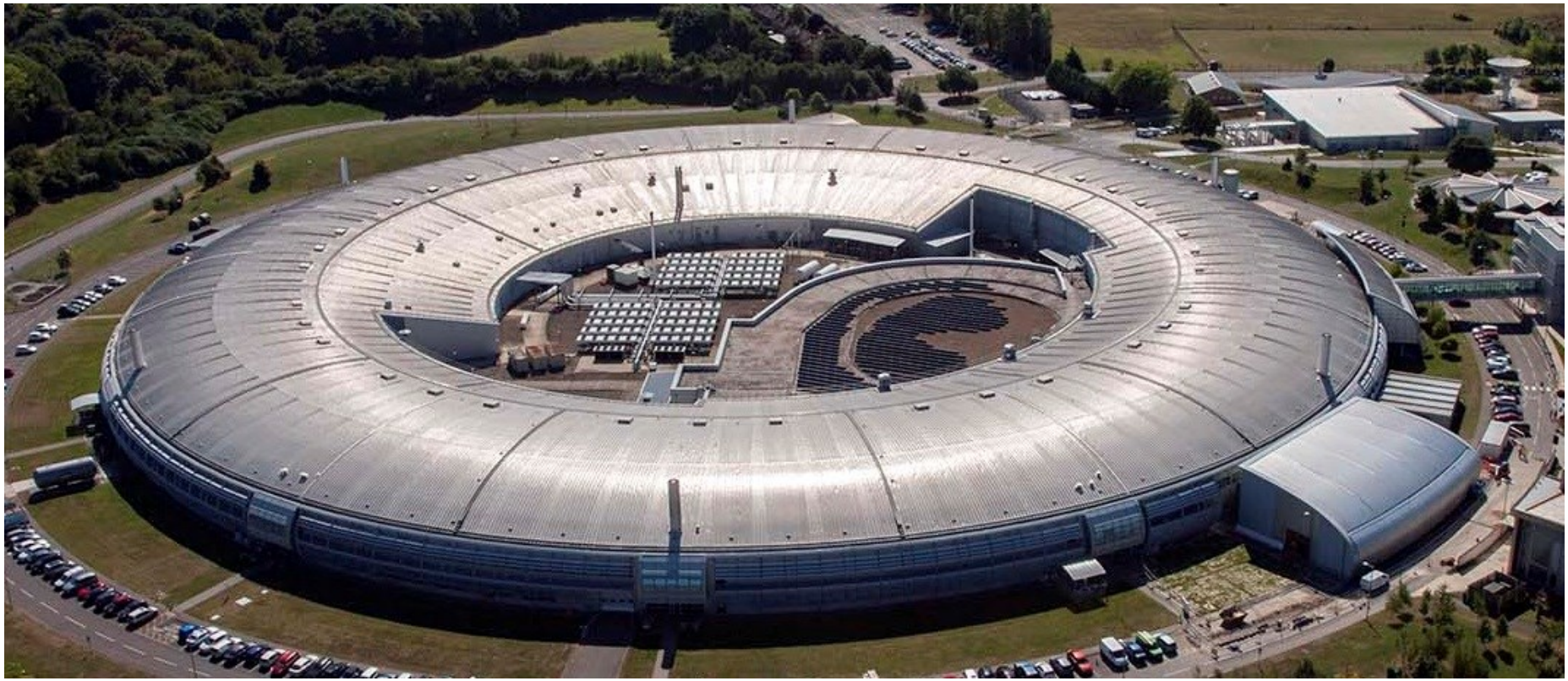
Laboratório Nacional
de Luz Síncrotron

ANKA
Michael Fiederle
Elias Hamann

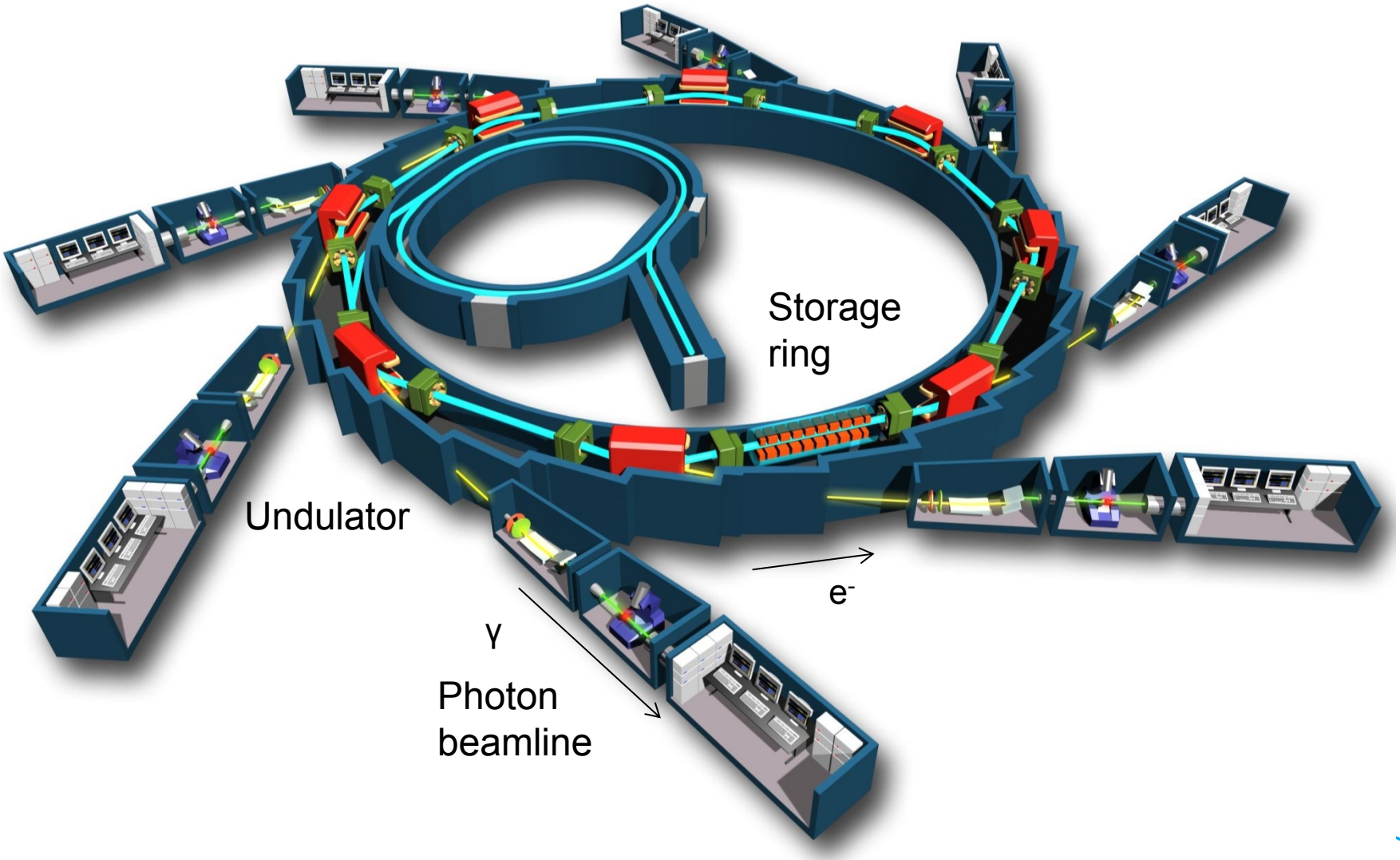
Introduction

- X-ray experiments at synchrotrons
- Medipix developments and applications
- The future

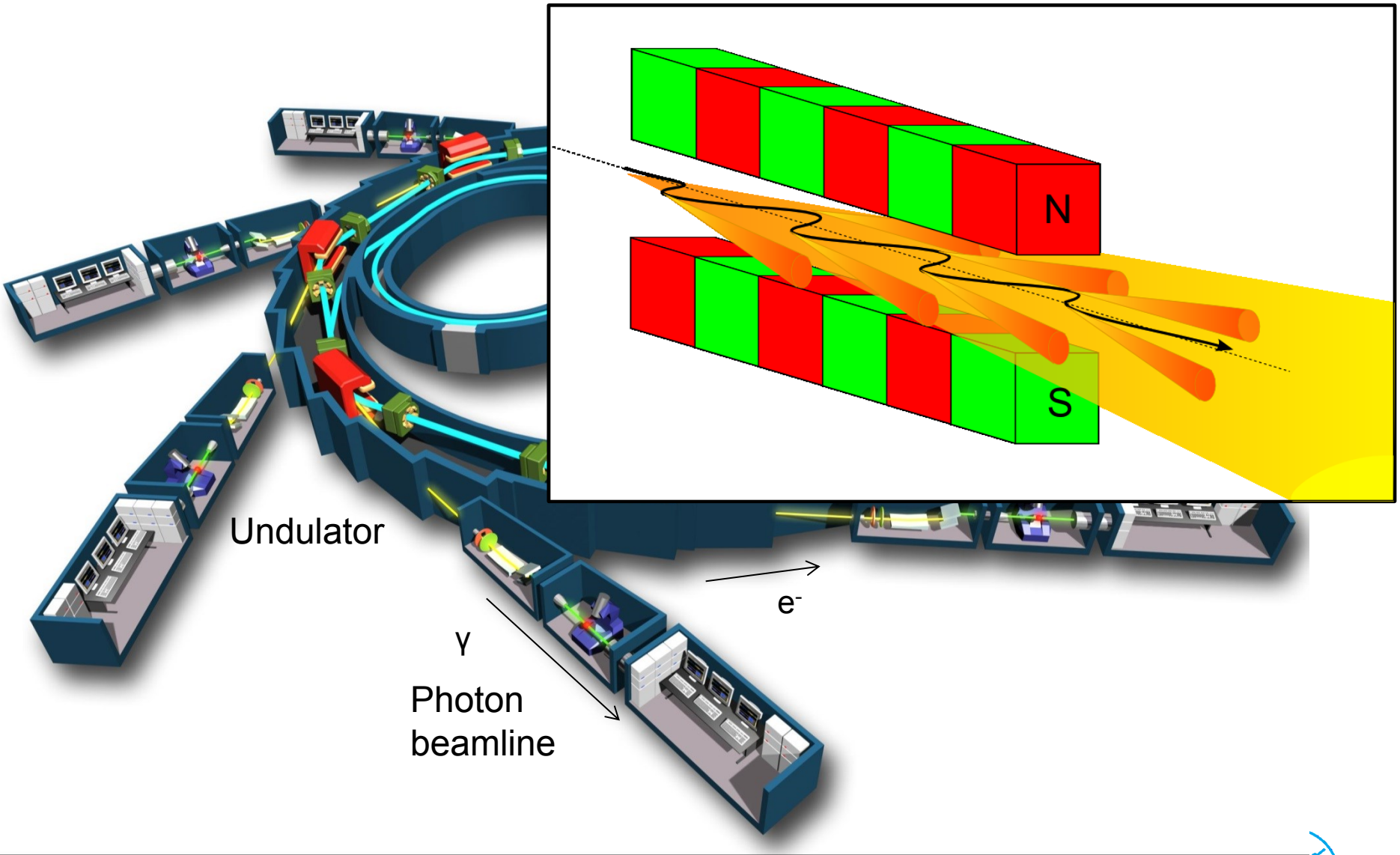
Synchrotron labs



Inside the synchrotron

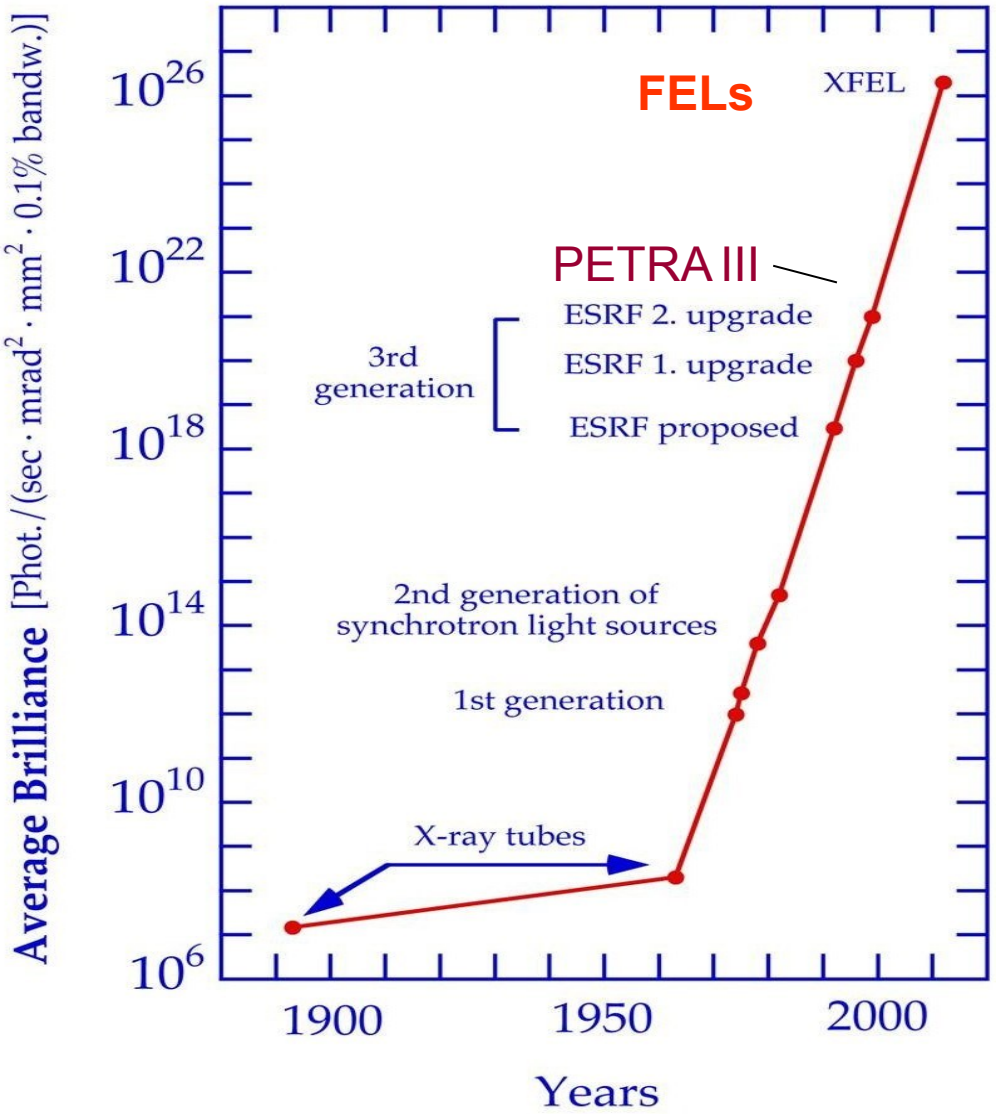


Inside the synchrotron

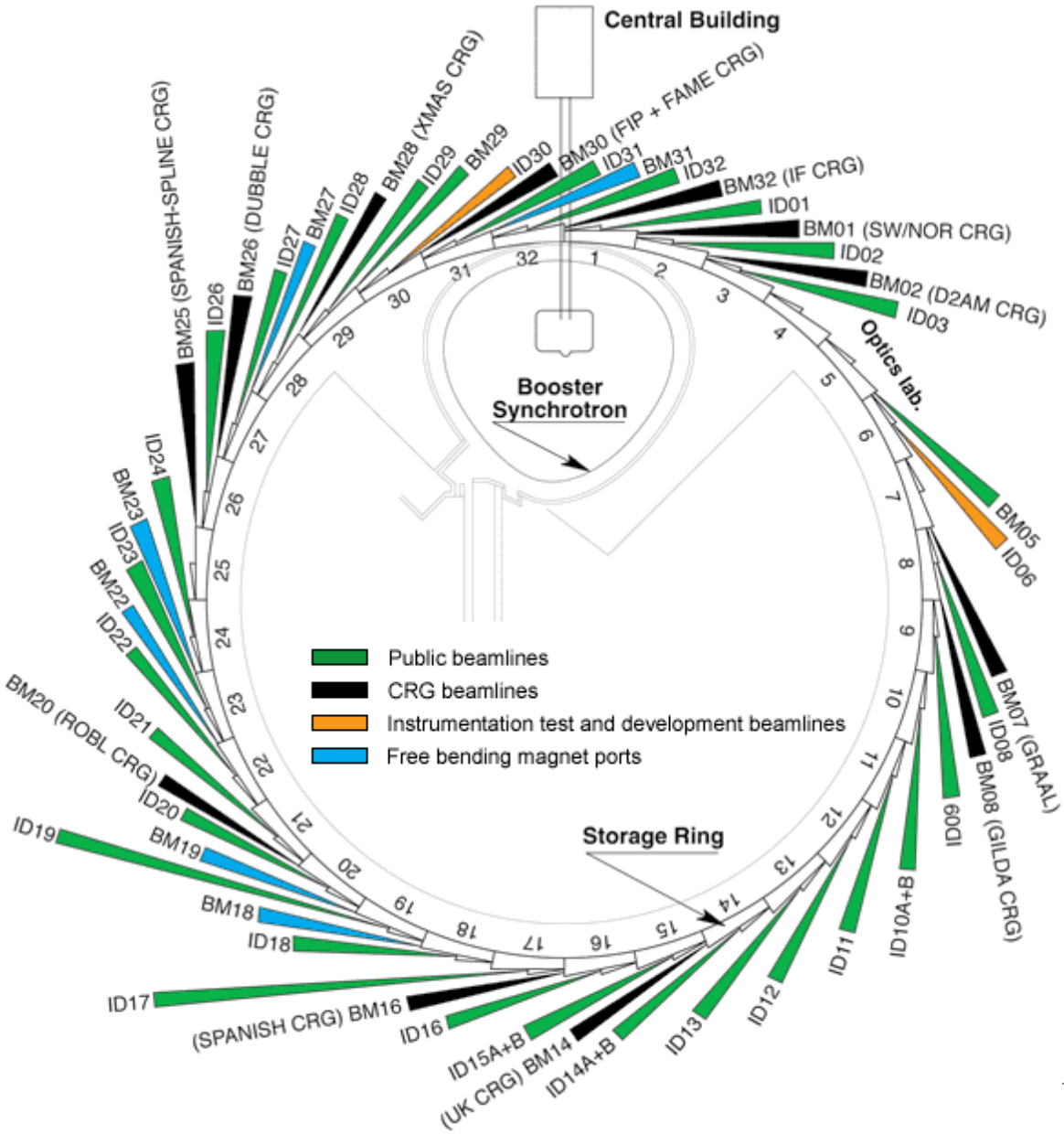


Synchrotron X-ray beamlines

- High brilliance
- Monochromatic
- (Relatively) coherent

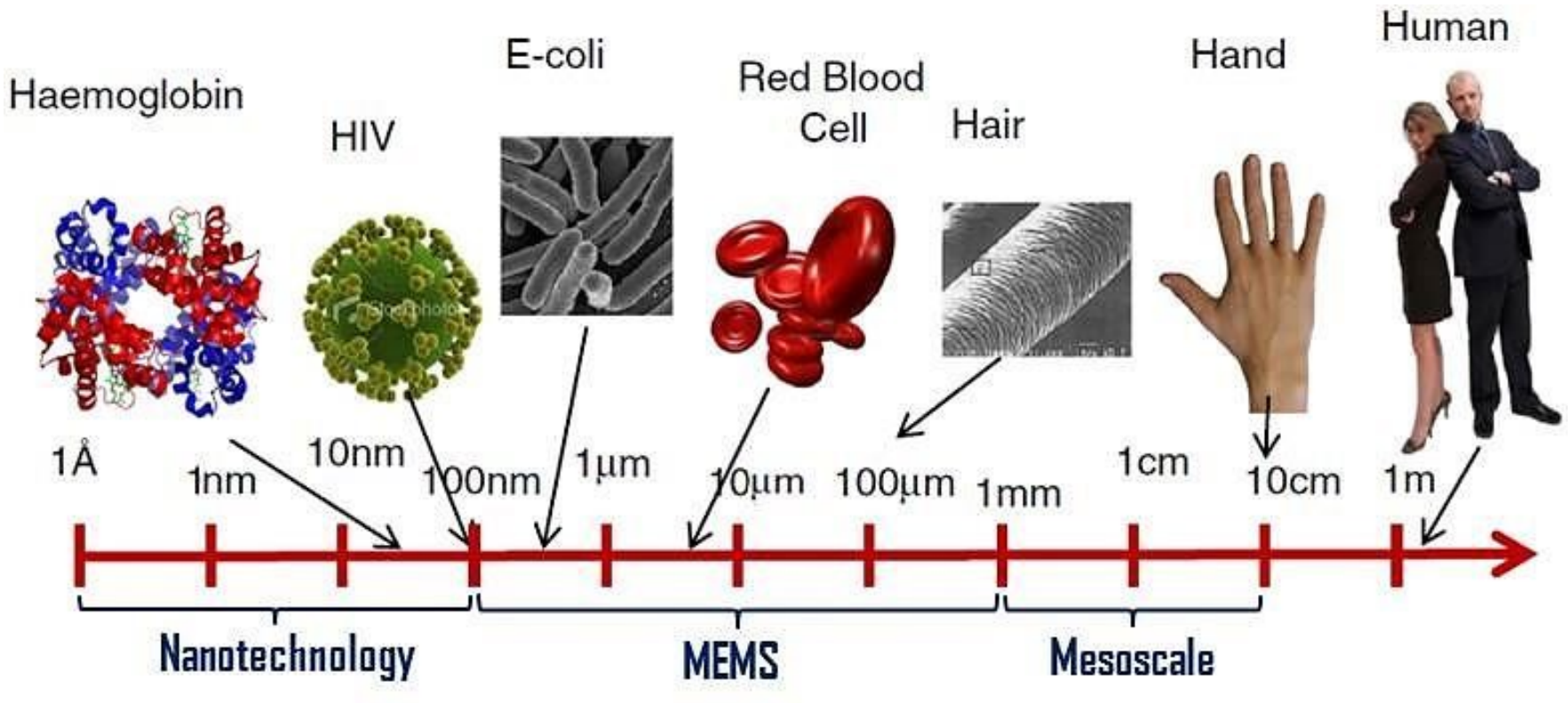


Varied applications!



ESRF, Grenoble
~ 50 beamlines

X-rays as a tool for research



Atomic-scale
X-ray diffraction

Macro scale
X-ray imaging

Introduction

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- The future

Medipix at synchrotrons

Synchrotron sources

- High brilliance
- Monochromatic, tunable
- (Relatively) coherent

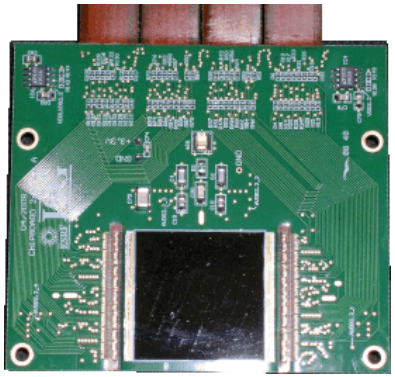
Medipix series

- Single photon sensitivity
- High frame rate
- Spectroscopic capability

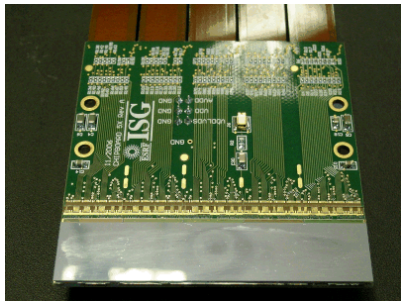
ESRF “Maxipix” detector system

- Medipix2 / Timepix readout
- First complete detector using fast parallel port
- 25+ systems running

Quad (2x2 chips)



Ladder (5x1 chips)



“PRIAM” board

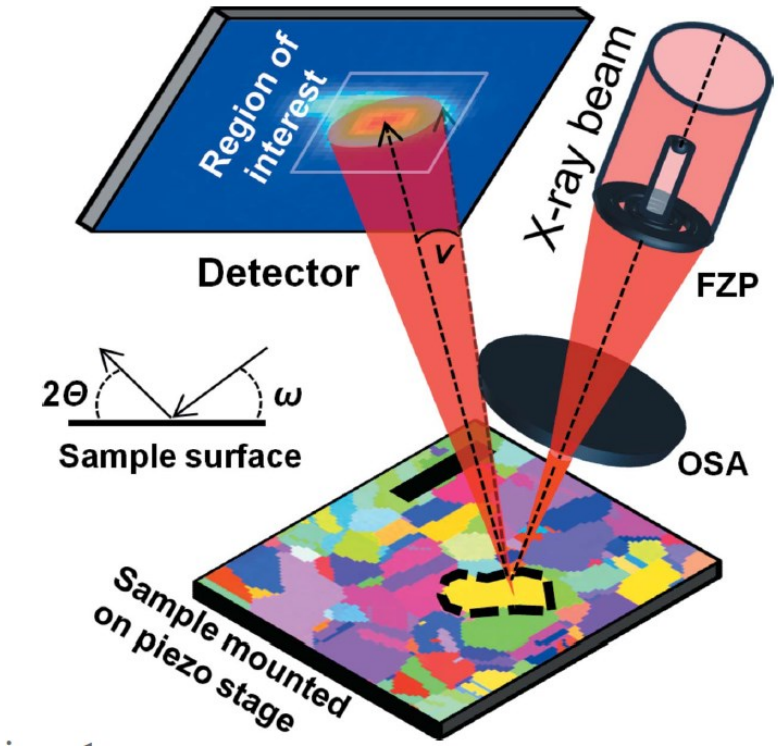
1400 frames per second
4 Gbit/s data output
290 µs readout dead time

maxipix

J. Instr. 6 (2011) C01069

Example – nanodiffraction at beamline ID01

- Scan nanofocused beam across material sample
- Diffraction pattern encodes information on crystal structure

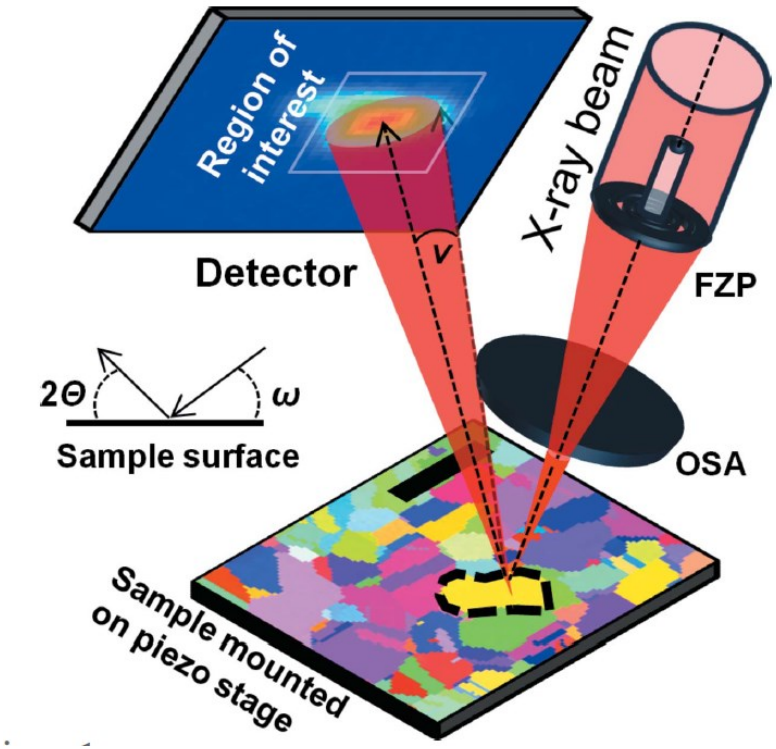


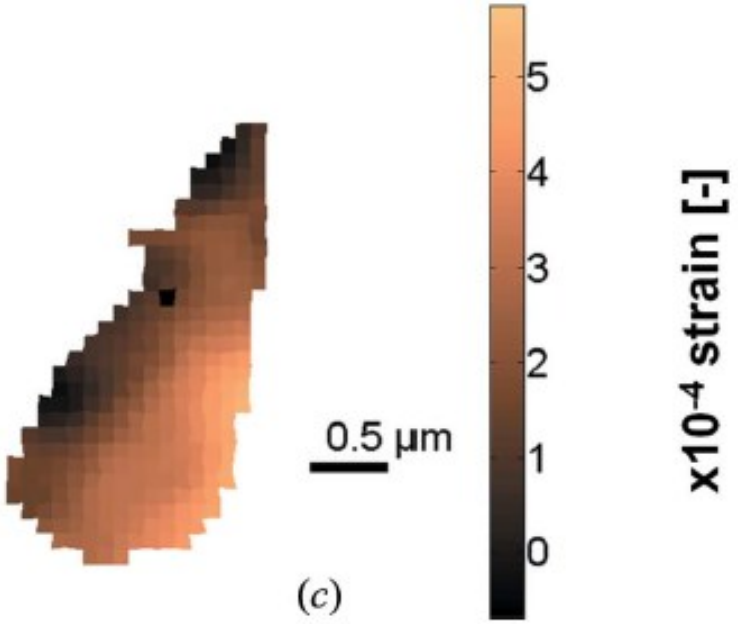
Schäfer et al., J. Appl. Cryst. (2016). 49, 632-635

Leake et al., J. Synchrotron Rad. (2019) 26, 571-584

Example – nanodiffraction at beamline ID01

- E.g. $CuInSe_2$ films for solar cells
  - Measure grain structure and strain within grains





Schäfer et al., J. Appl. Cryst. (2016). 49, 632-635

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Medipix3 and larger systems

- ESRF, DESY, Diamond, KIT and LNLS in Medipix3
- Continuous read-write operation @ 2000 fps
- Total of over 40 systems and 500 chips

LAMBDA – DESY

Excalibur - Diamond

PIMEGA - LNLS

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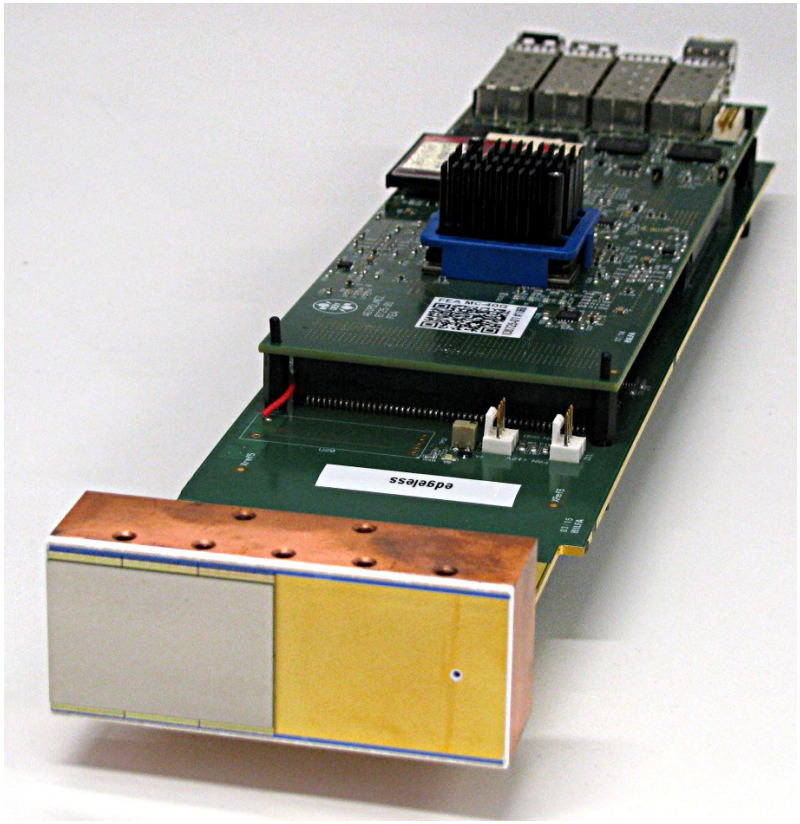
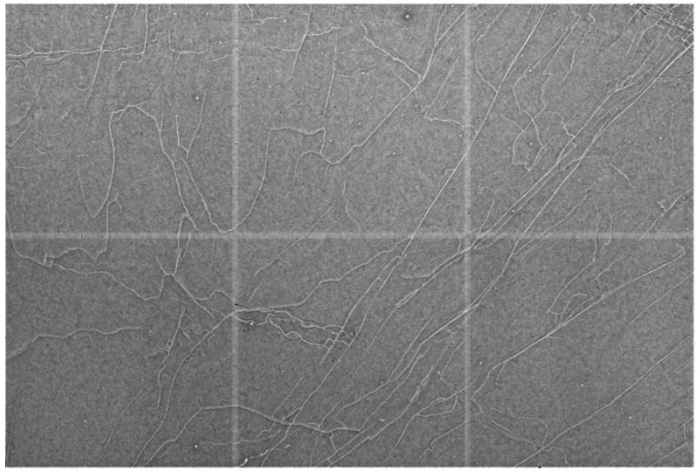


High-Z sensors for hard X-ray detection

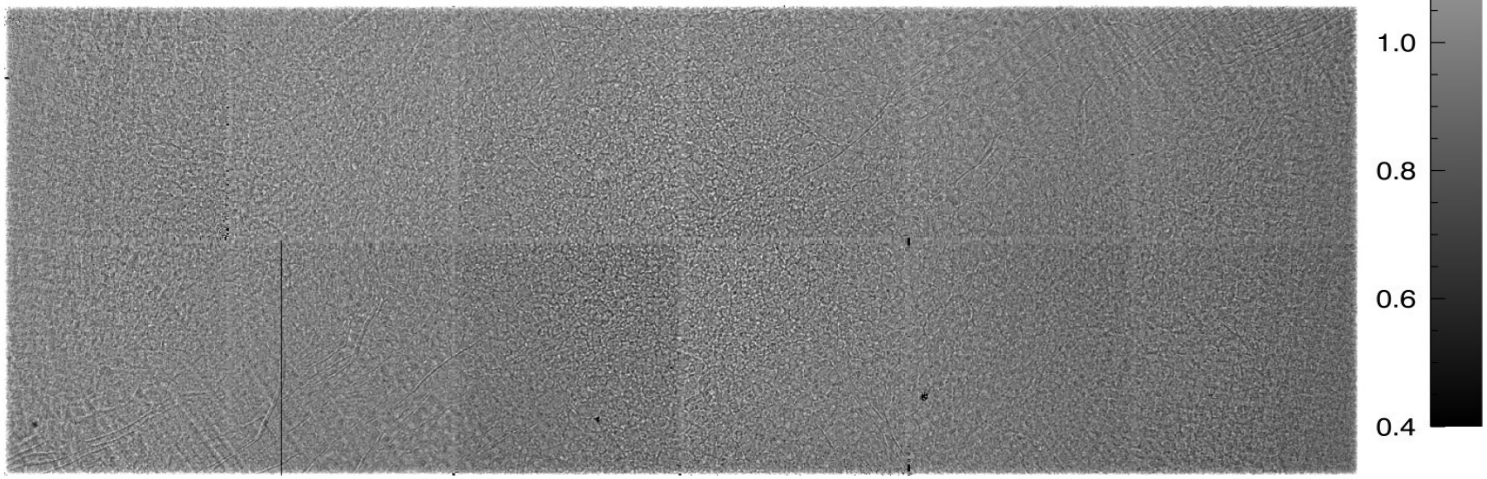
- Medipix compatible with different sensors (CdTe, GaAs)
- Consortium enables collaboration

CdTe, 6 chip (from 3” wafer)



GaAs, 12 chip (from 4” wafer)

Flat field (Mo tube @ 40kV, -300V bias)



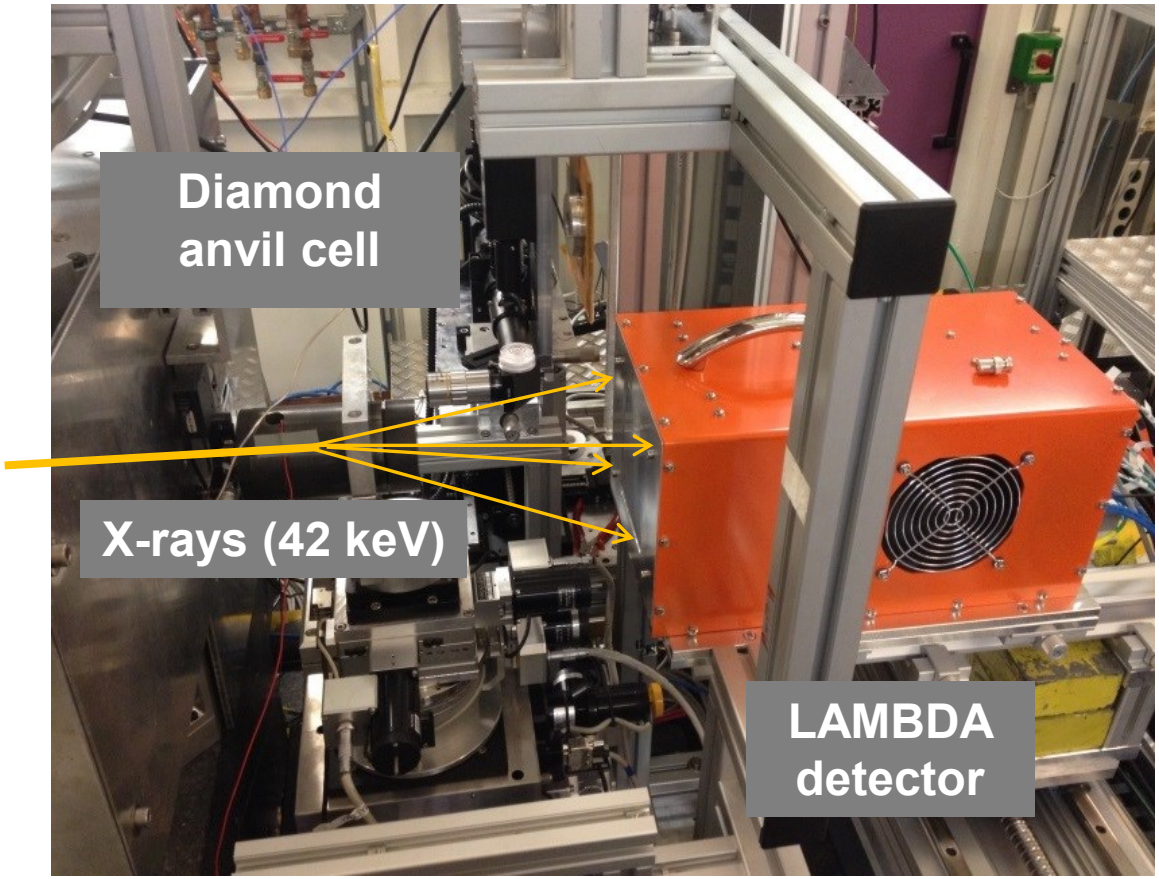
Galapad-2 project: thanks to Tomsk State University and JINR

Example - extreme conditions experiments

Diamond Anvil Cell

Pressure equal to Earth's core (370 GPa)

2 megapixel (36 chip) GaAs detector PETRA-III P02.2



Jenei et al., Rev. Sci. Instrum (2019) 90, 065114

Pennicard et al., JINST (2018) 13 C01026

Example - extreme conditions experiments

Bi sample
Rapid compression
- 30 GPa in 5 ms

Bi-I (As-type, orthorhombic)

↓ 2.55 GPa

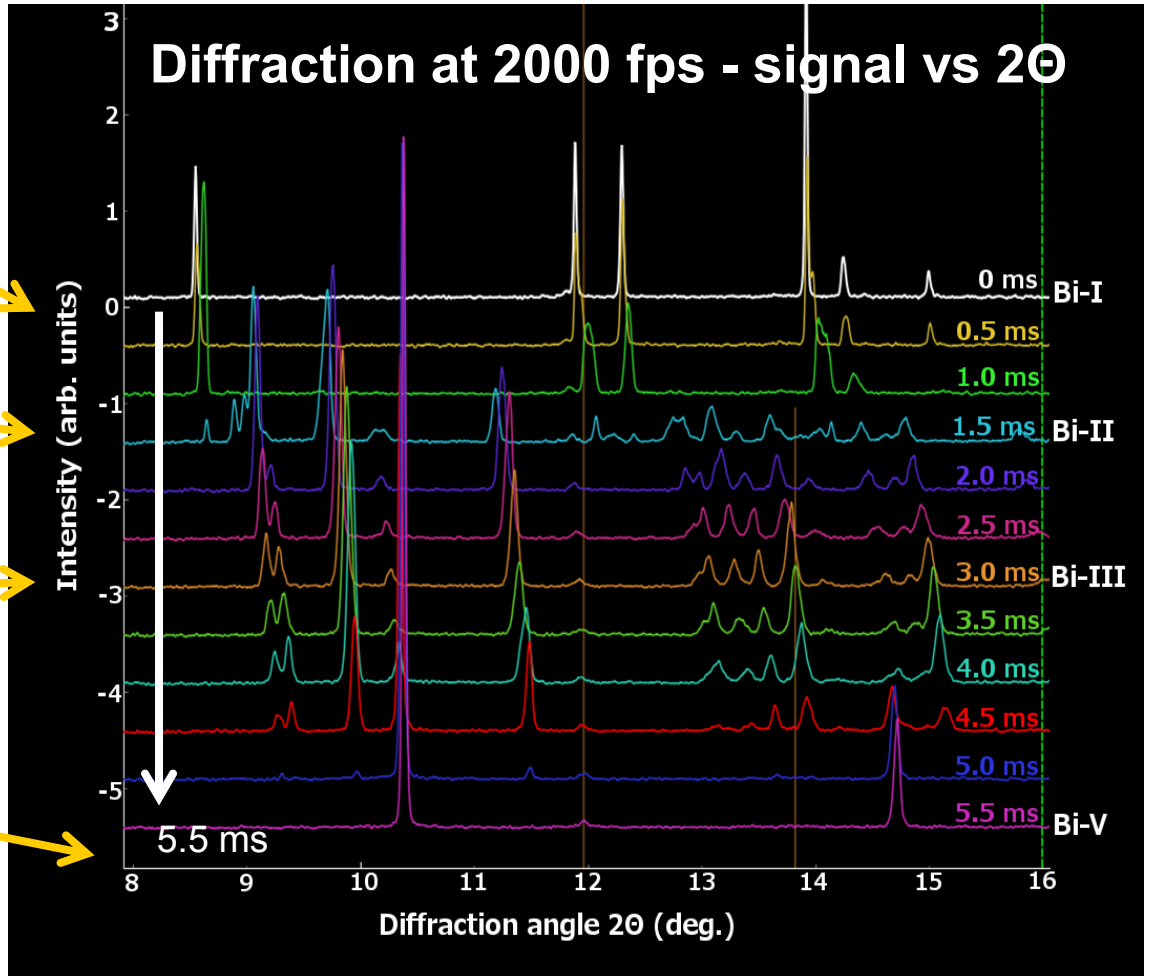
Bi-II (mC4, monoclinic)

↓ 2.7 GPa

Bi-III (incommens. host-guest)

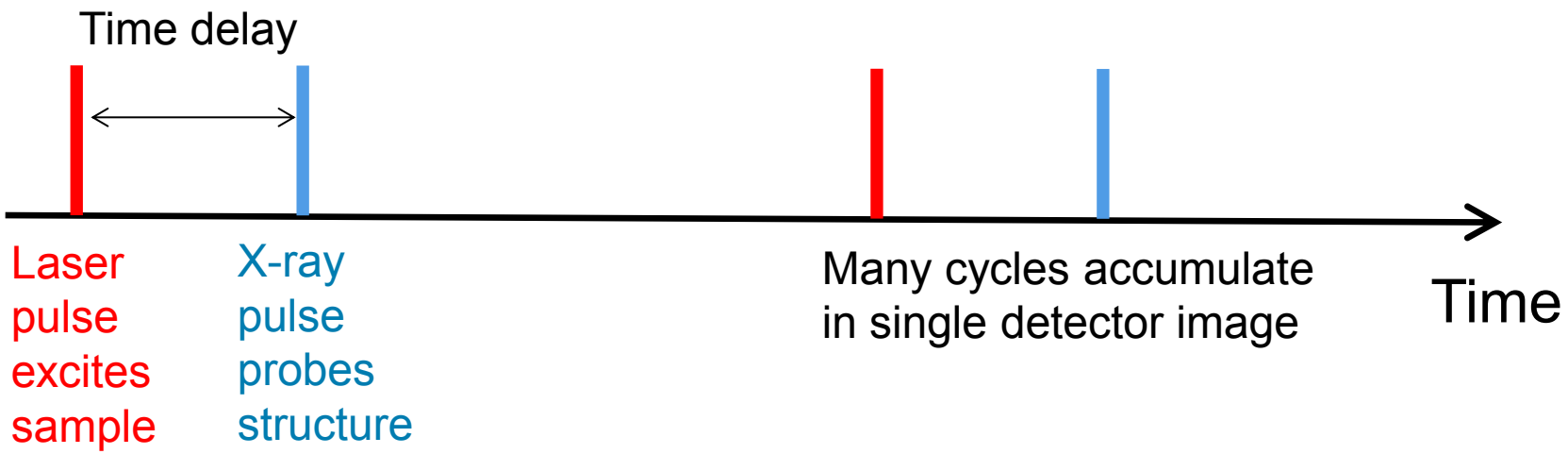
↓ 7.7 GPa

Bi-V (bcc, cl2)



Timepix3 for extreme time resolution

- Pump-probe techniques study repetitive processes with high time resolution
  - E.g. effects of rapid laser heating



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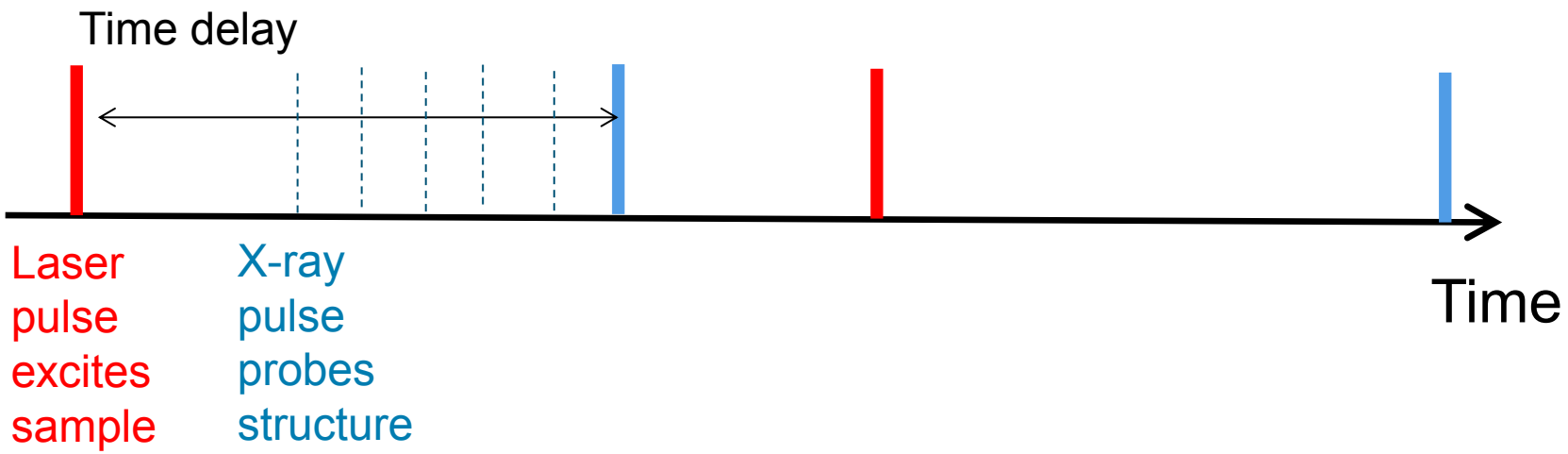
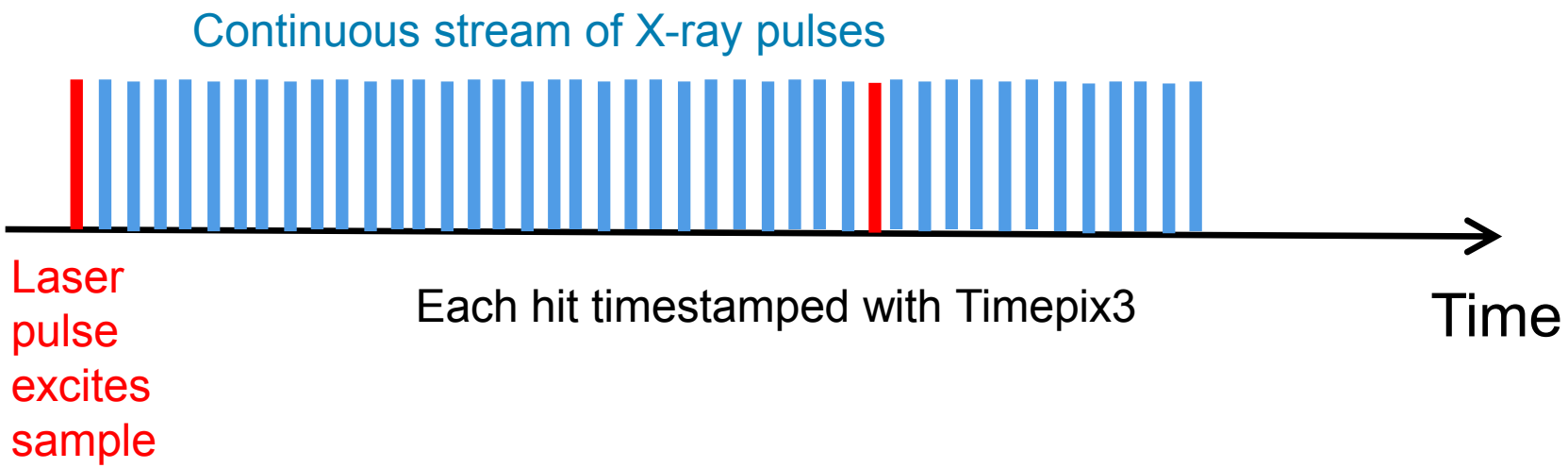


Timepix3 for extreme time resolution

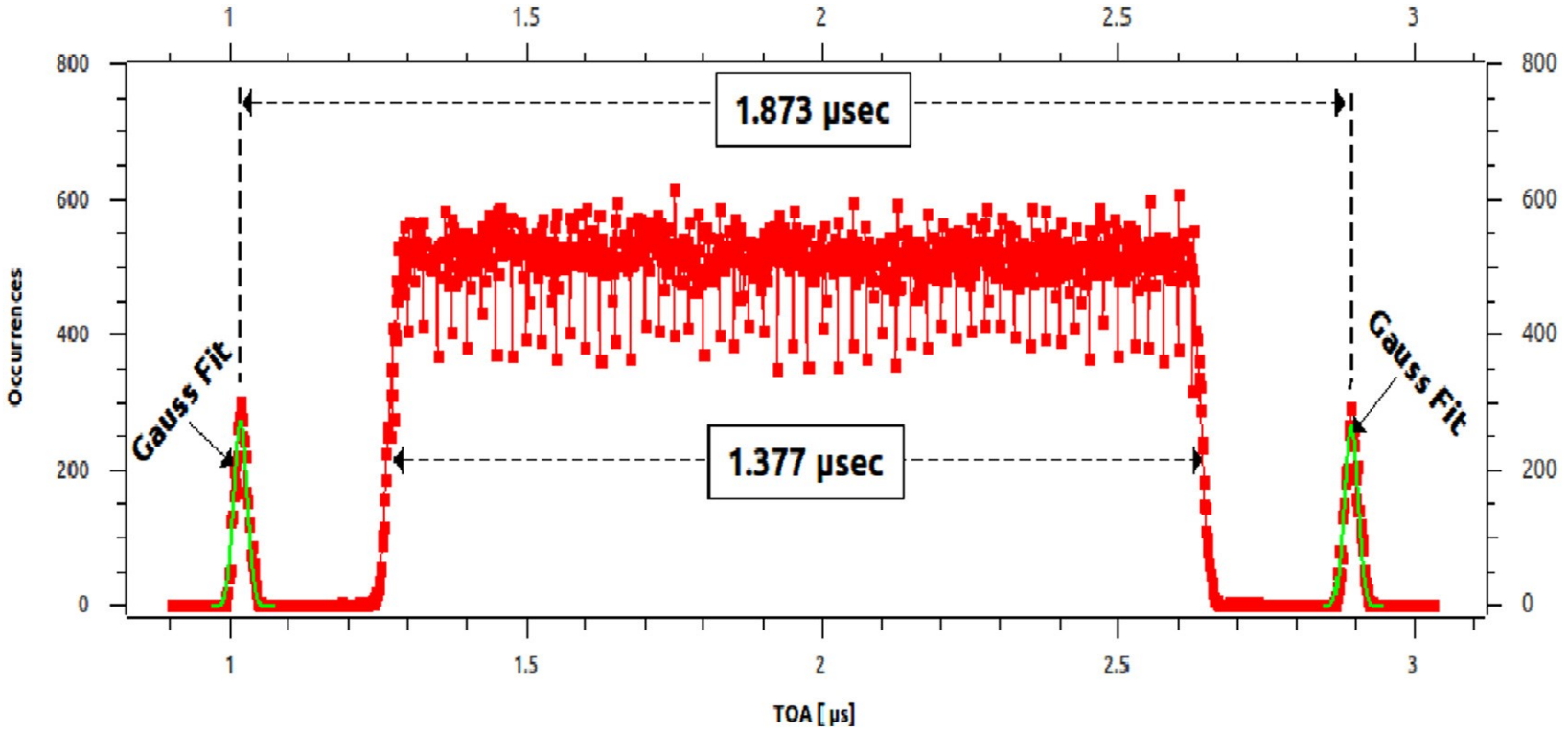
- Timepix3 can time stamp each photon!
  - Rate capability of system is crucial



Timepix3 development at Diamond

- 8 ns RMS time resolution demonstrated
- 10 Megapixel “Tristan” system in development

Measurement of filling pattern in Diamond synchrotron



Yousef et al., NIMA (2017) 845 p639

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4th generation (diffraction limited) synchrotrons

- 4th generation sources – new multibend magnet designs
  - ~ x 100 brilliance
  - High beam coherence

Sirius – New light source

ESRF upgrade ongoing

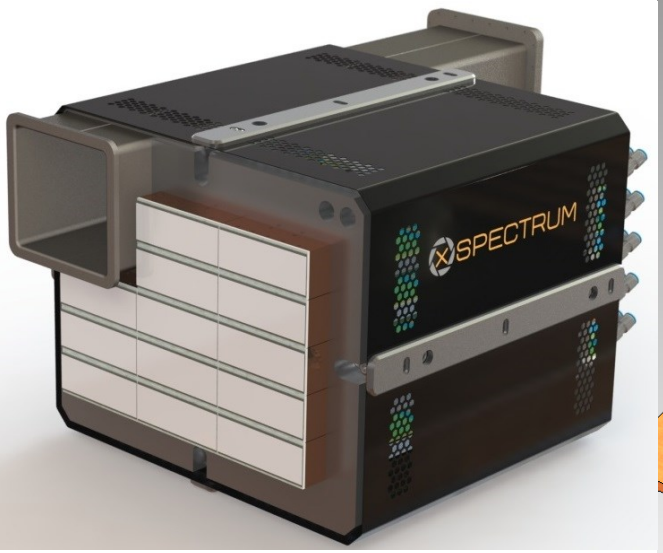
ESRF-EBS
Extremely Brilliant Source

PETRA-IV and Diamond-II in planning

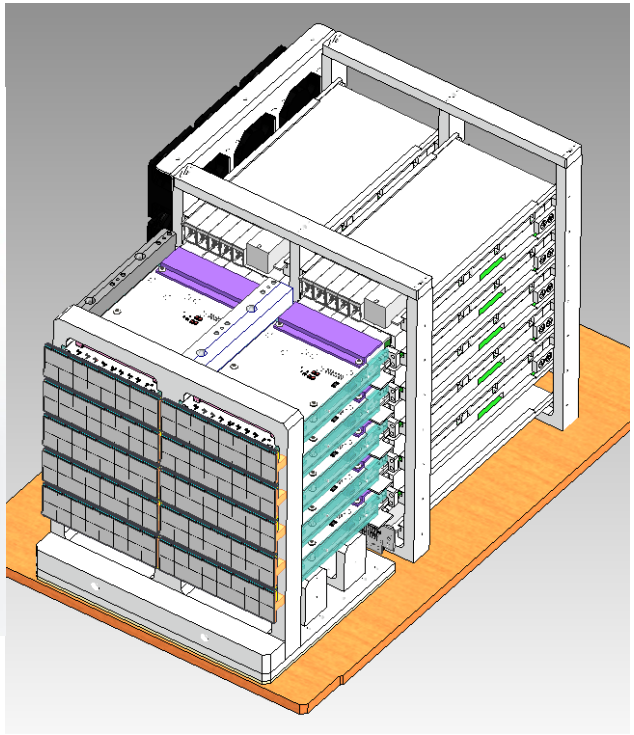
Systems in development

- Systems with 100+ chips in development

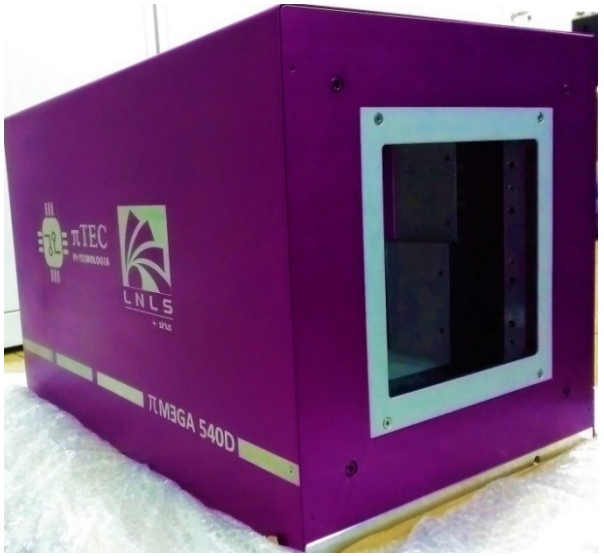
Lambda 10M
- X-Spectrum / DESY



Tristan – Diamond
(Timepix3)



PIMEGA - LNLS



Timepix4

- Better single-threshold frame-by-frame readout than Medipix3
  - ~ x 10 increase in frame rate and count rate
- Better timestamping operation than Timepix3
  - ~ x 5 increase in event rate, better time resolution
- **For synchrotrons, the best of both worlds!**

Conclusions

- Synchrotron applications have driven development of large, high-speed Medipix systems
- Medipix detectors are now widely-used at synchrotrons
- Timepix4 promises to be a versatile system for future experiments

> Thanks for listening!

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