Introduction:
“Photon Science”

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What is “Photon Science”?

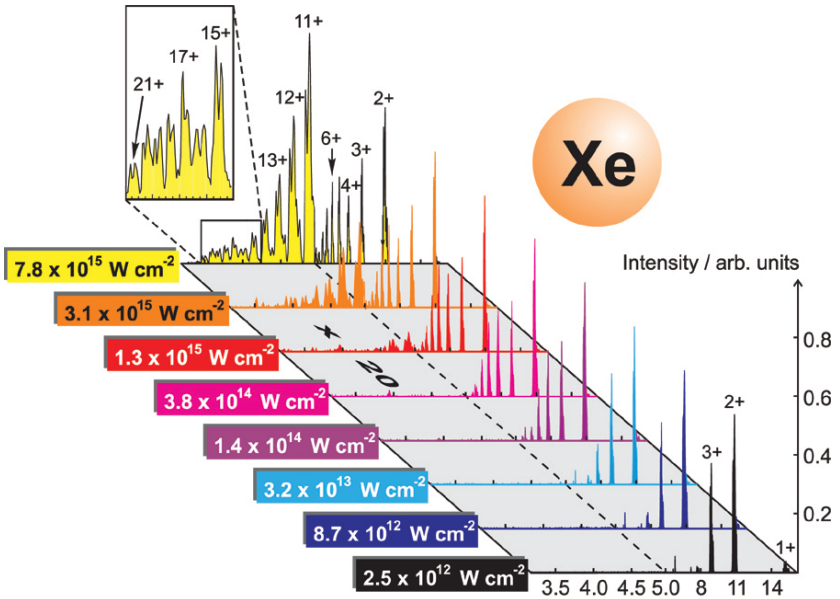
- Exploring Matter, Materials and Life with (X-ray) Photons

- Light sources:
  - Synchrotrons
  - Free-Electron Lasers

- Rapidly advancing sources push detector capabilities
- Rapidly expanding field

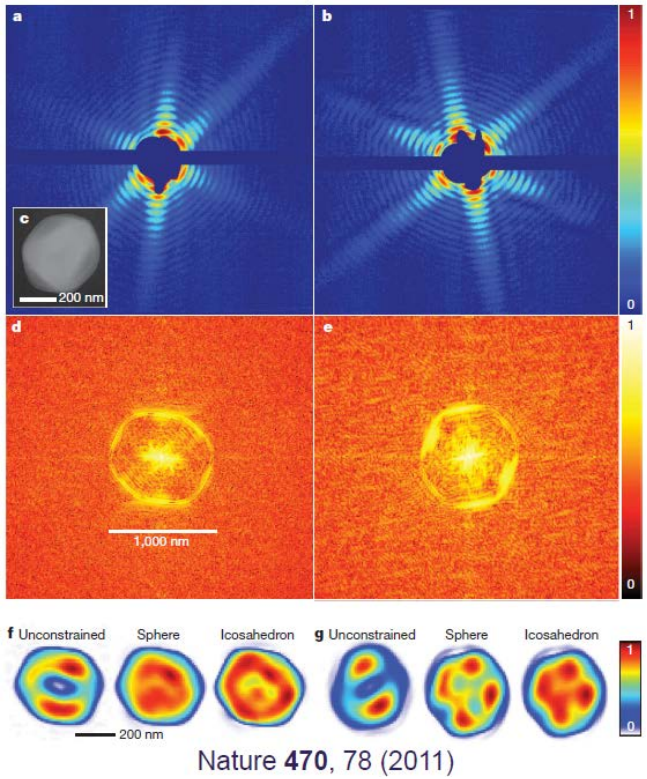
Photon Science: From fundamental to applied science

Study of extremely charged ions



Phys. Rev. Lett. 99, 213002 (2007)

Structure of viruses



Nature **470**, 78 (2011)

Authentication of paintings

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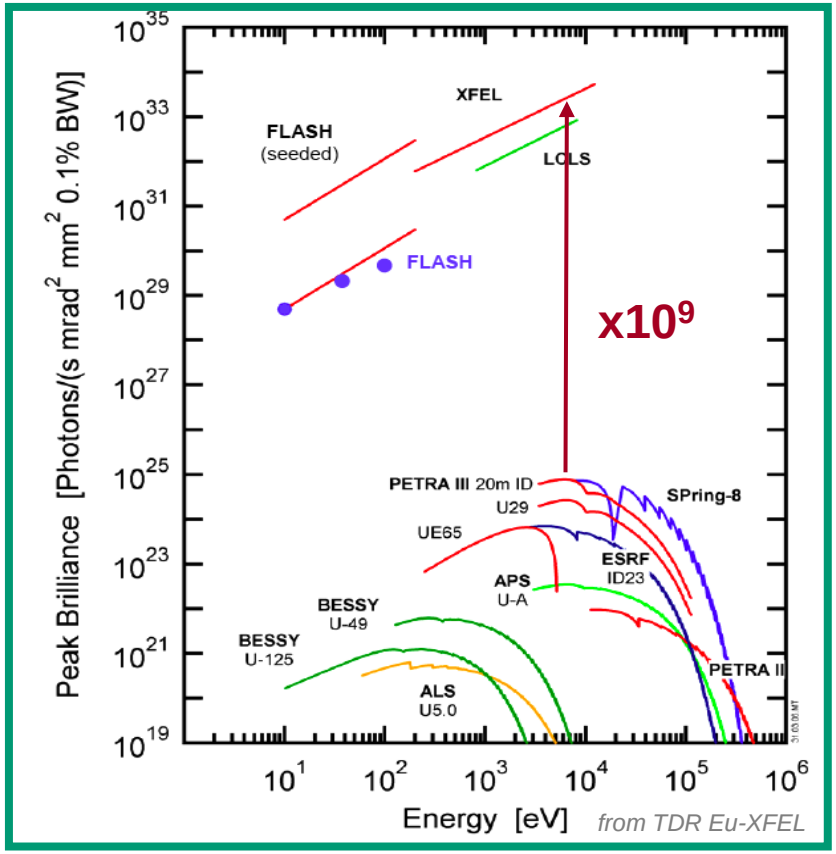
Storage Ring Sources: general observations

- Pulsed X-ray source
- ~ Giga Hz rep-rate
- Treated as a continuous, random source
- Main photon range: 5-30 keV
- Few stations <1 keV
- Few stations > 100 keV
- 30 large synchrotrons world-wide
- ~ 800 end-stations

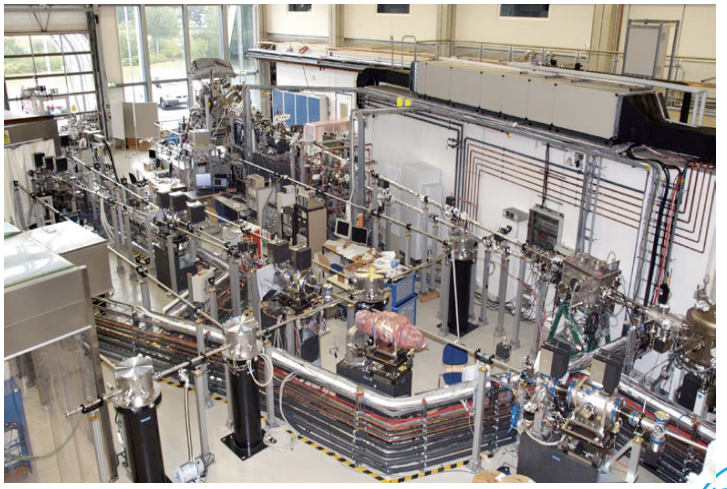
PETRA III

the added challenge from FEL sources



European XFEL

FLASH I + II



- Completely new science
- Fast science: 100 fsec
- “Single shot” science

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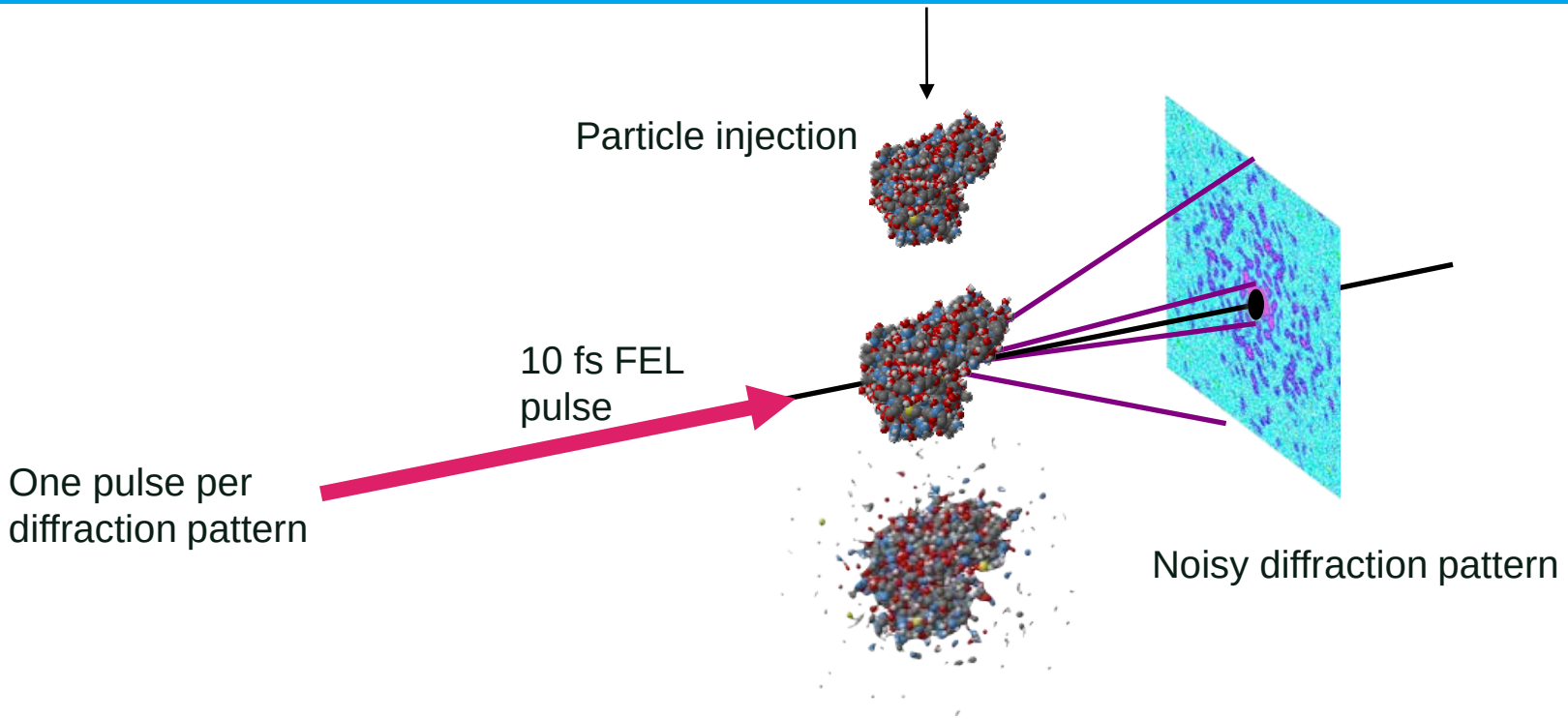
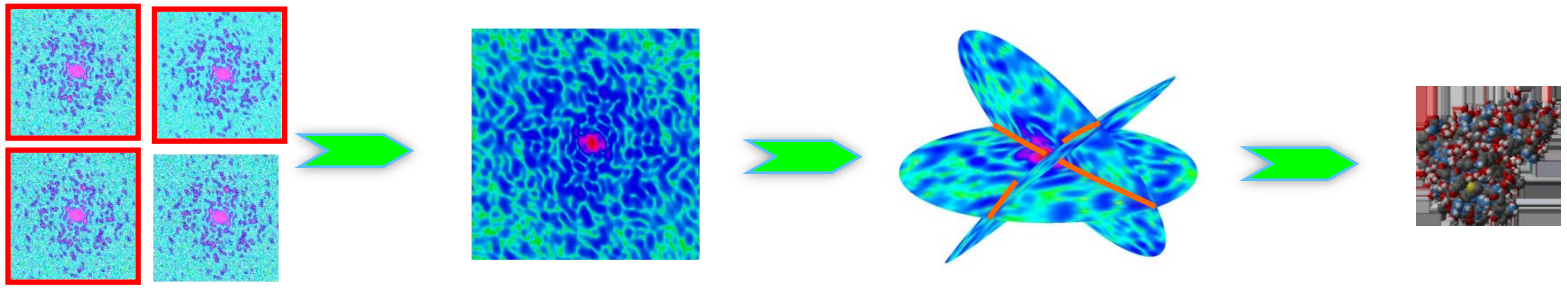
One example of a “holy grail”



Combine 10^5-10^7 measurements



Classification Averaging Orientation Reconstruction

K. J. Gaffney and H. N. Chapman, *Science 8 June 2007*

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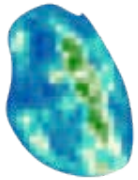
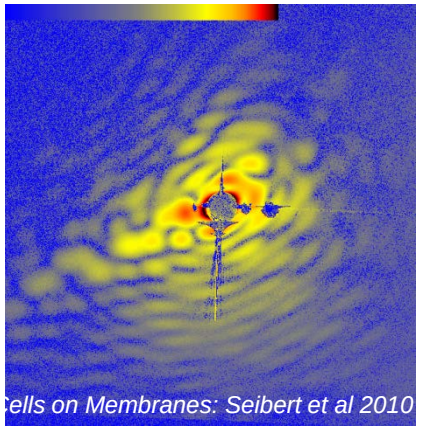
Every image – and every science case – is different

Heterogeneous objects

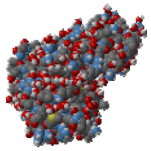


Reconstruct unique objects

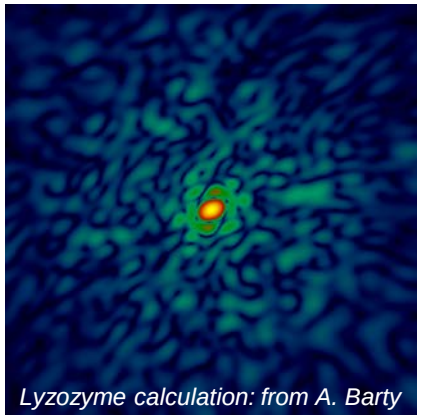


No averaging:
All data in a single shot
High dynamic range

Single molecules viruses, etc



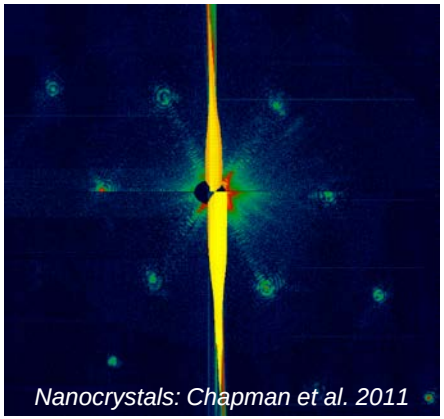
Average weak signal



Very weak:
Must average many shots
Single photon discrimination

Protein nanocrystals

Index Bragg peaks



Bright, isolated peaks
High dynamic range

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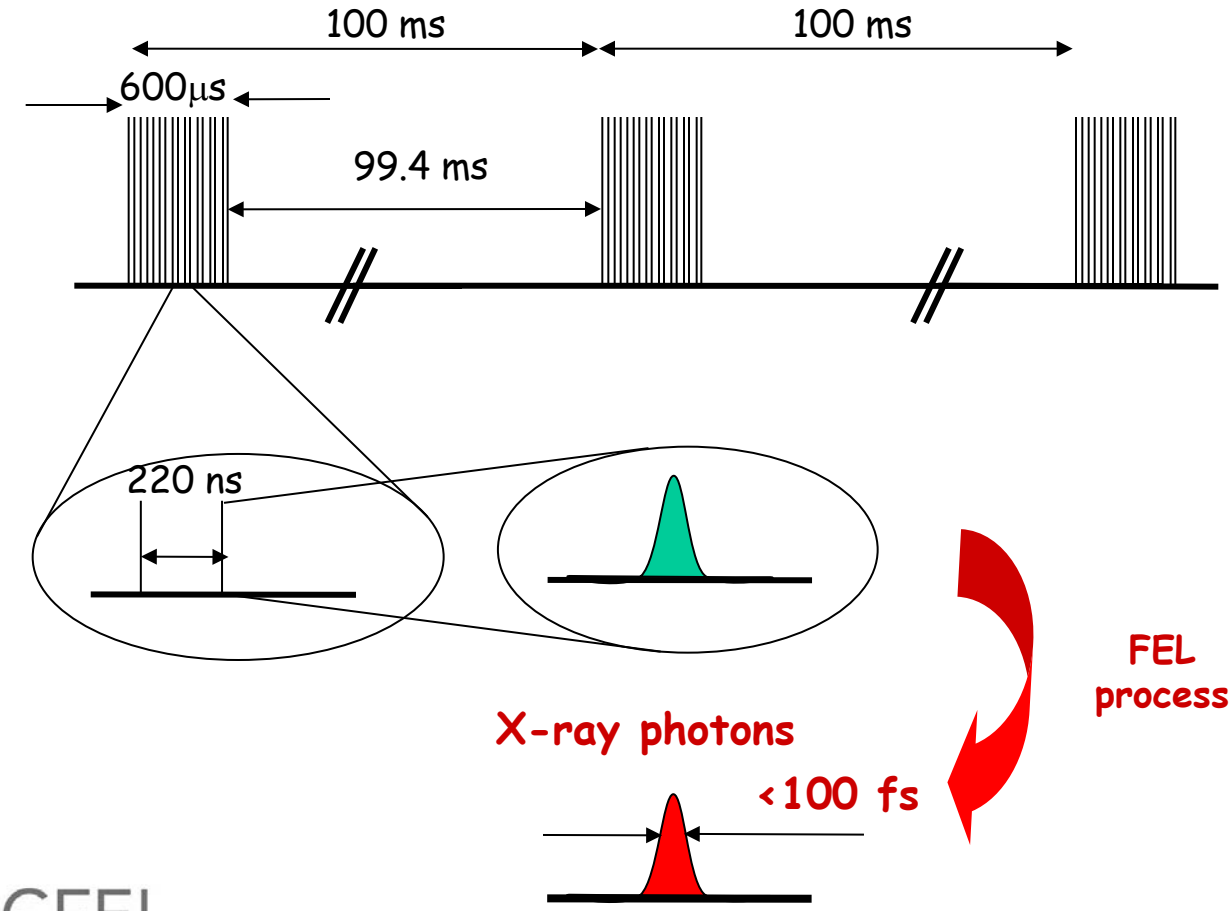
European XFEL Linac: (added) Time Structure Challenge

Electron bunch trains; up to 2700 bunches in 600 μsec, repeated 10 times per second.
Producing 100 fsec X-ray pulses (up to 27 000 bunches per second).



27 000 bunches/s with 4.5 MHz repitition rate

av. Rate:
27kHz XFEL
120Hz LCLS
60Hz SCSS

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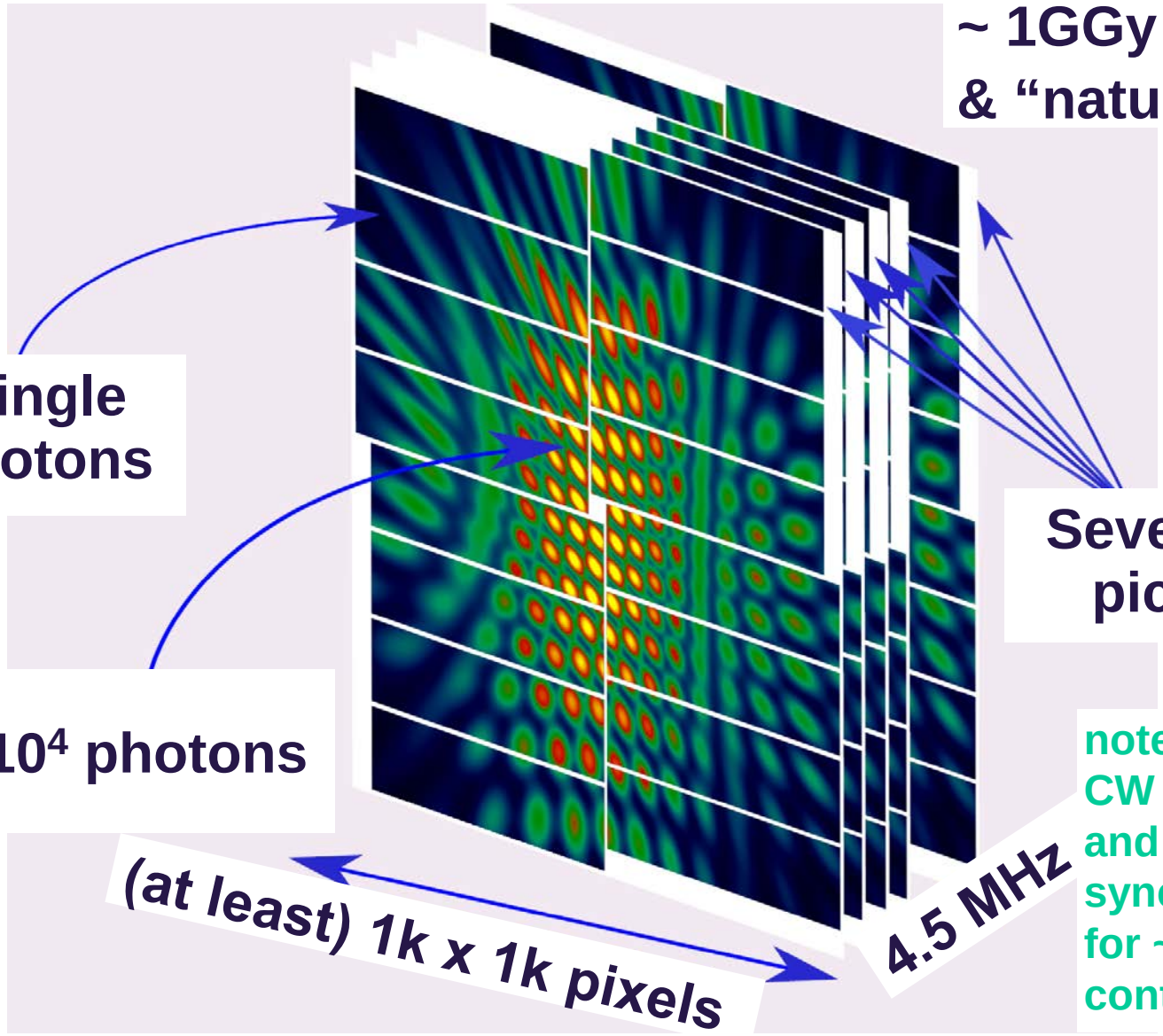
Summarizing the Challenges

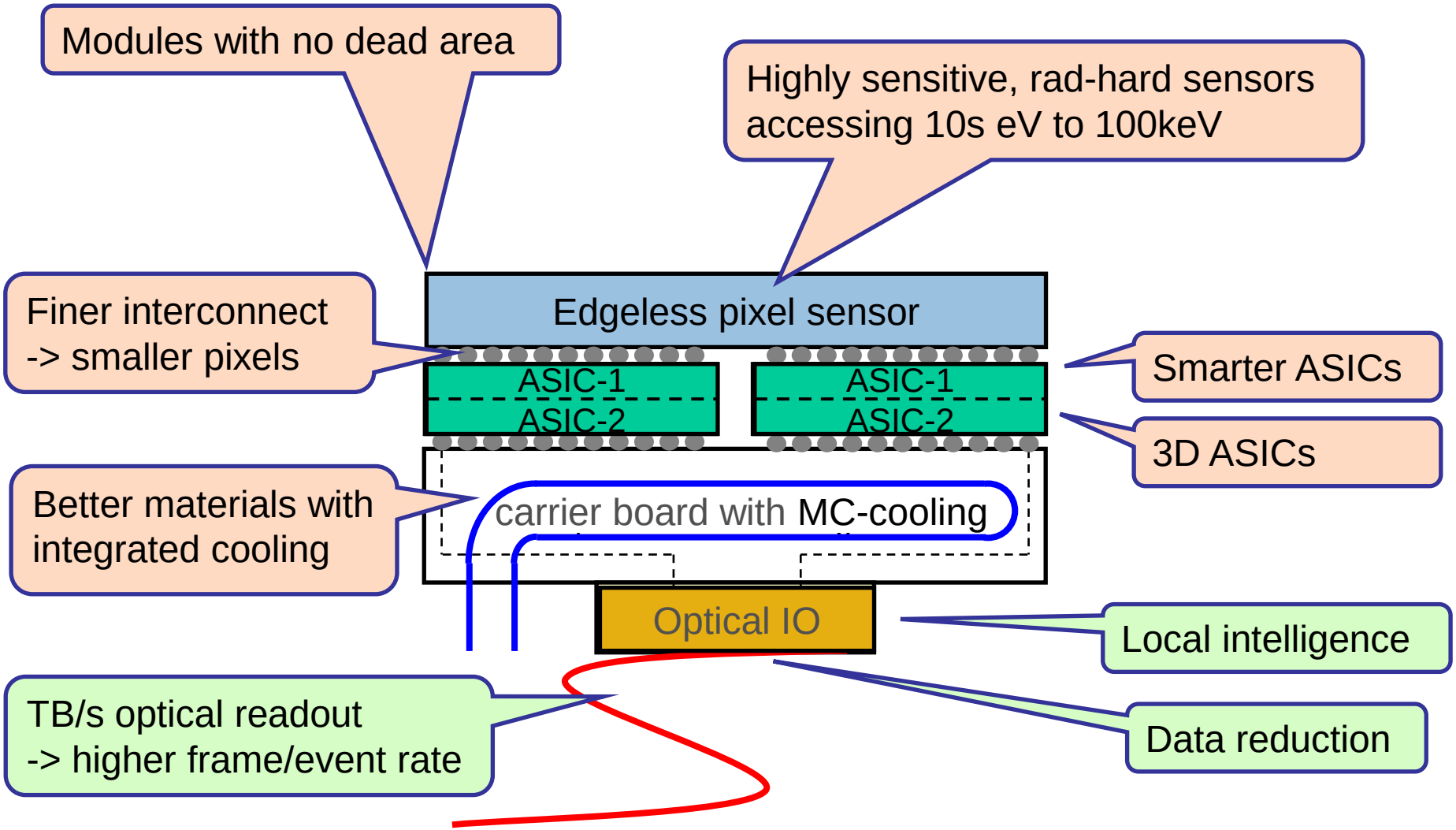


(+ sustained several 10s of Gbit/s data rates → Pbit/day)

More and more dedicated detector developments

- for synchrotron applications (mostly) “photon-counting” systems
- For FELs “integrating” systems as many photons arrive simultaneously
  e.g. for European XFEL
  - Depmos Sensor with Signal Compression
    Non-linear gain, digital storage
  - Adaptive Gain Integrating Pixel Detector
    Automatic adaptive gain, analogue storage
  - Large Pixel Detector
    Three parallel gains, analogue storage
- for soft X-rays – e.g. Percival (CMOS)
- Many other developments ongoing world-wide

Future developments – illustrated on hybrid pixels



Future hybrid pixel technology

This Session

- ***ASICs for next generation imaging calorimetry***
  Christophe de la Taille (CNRS/IN2P3 Micro-Electronics Design Lab)
- **Larger and Faster Imaging Detectors for Science**
  Marcus French (STFC/RAL)
- **Image sensor technology at imec**
  Piet De Moor (imec)
- **The Quest for New and Optimized Sensor Materials**
  Alan Owens (estec)
- **Ultra-fast THz detectors for synchrotron radiation**
  Juliane Raasch (IMS, KIT)