Detectors for Photon Science.

Challenges
Projects
Perspectives

Heinz Graafsma; DESY and European XFEL
DESY Instrumentation Seminar
05 Feb. 2010

HELMHOLTZ
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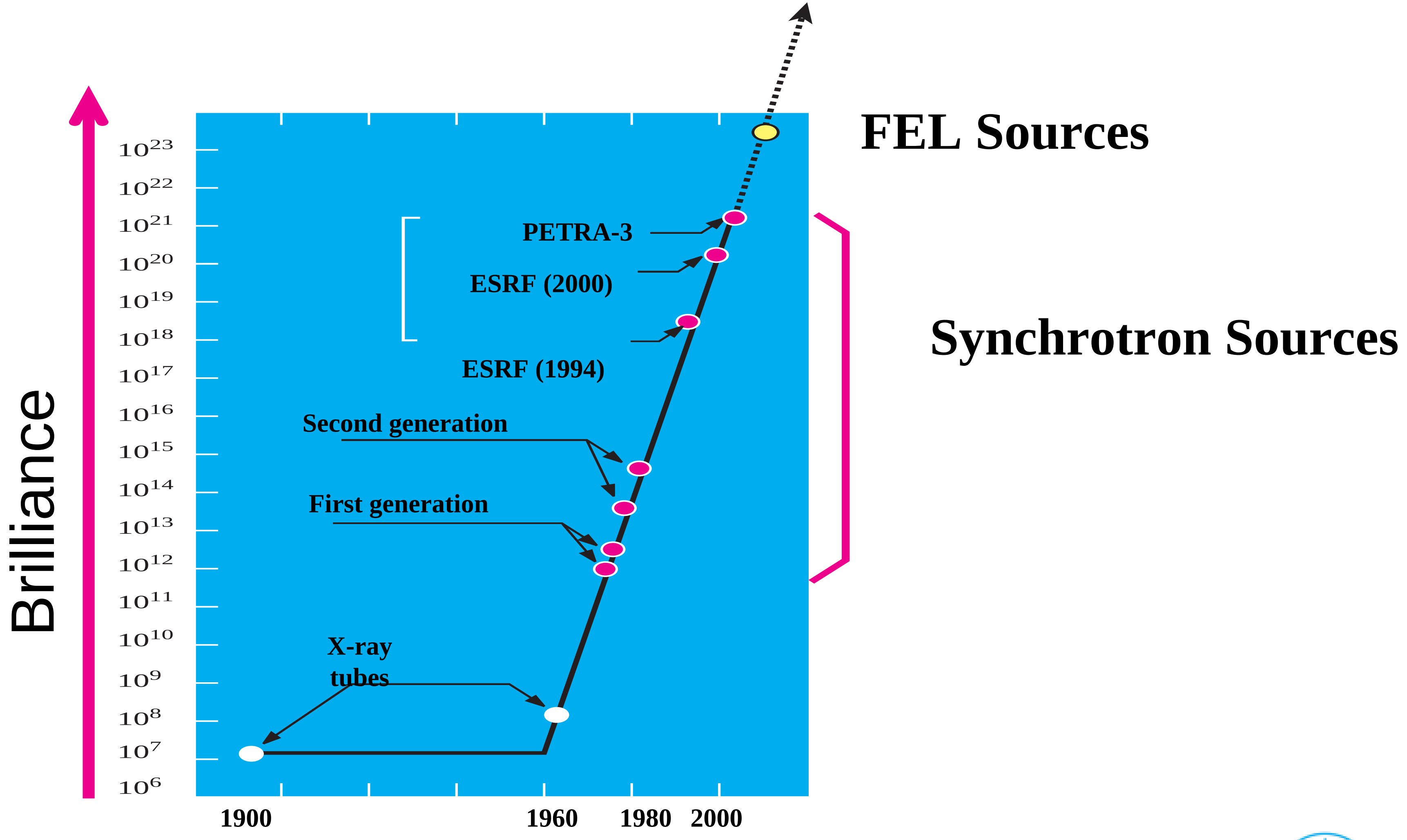
DESY

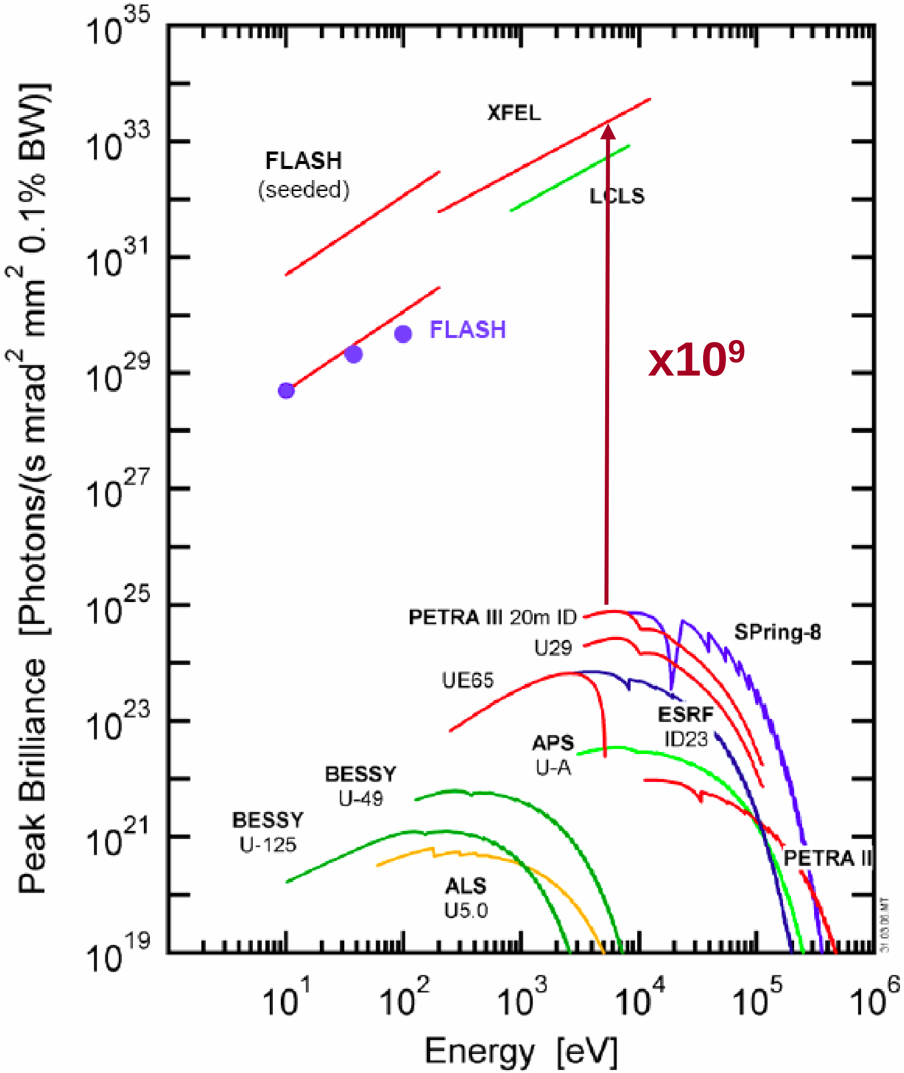
The Challenge #1: a moving target



The Challenge #2: many targets

Number	Name	ID type	Energy range	Contact
P01	Dynamics beamline, IXS, NRS	10 m U32	5 - 40 keV	H. Franz, DESY
P02	Powder and extreme conditions	2 m U23	20 - 100 keV	H. P. Liermann, DESY
P03	Micro and Nano SAXS/WAXS	2 m U29	8 - 25 keV	S. Roth, DESY
P04	Variable Polarization XUV	5 m UE65 (APPLE)	0.2 - 3.0 keV	J. Viefhaus, DESY
P05	Micro- and nano-tomography	2 m U29	8 - 50 keV	A. Haibel, GKSS
P06	Hard X-ray nano probe, imaging	2 m U32	2.4 - 100 keV	G. Falkenberg, DESY
P07	High energy materials science	4 m U19 (IV)	50 - 300 keV	N. Schell, GKSS
P08	High resolution diffraction	2 m U29	5.4 - 30 keV	O. Seeck, DESY
P09	Resonant scattering/diffraction	2 m U32	2.4 - 50 keV	J. Strempfer, DESY
P10	Coherence applications	5 m U29	4 - 25 keV	O. Leupold, DESY
P11	Bio imaging/diffraction	2 m U32	8 - 35 keV	A. Meents, MPG, HZI, DESY
P12	BioSAXS	2 m U29	4 - 20 keV	M. Rößle, EMBL
P13	Macro molecular crystallography I	2 m U29	5 - 35 keV	M. Cianci, EMBL
P14	Macro molecular crystallography II	2 m U29	5 - 35 keV	G. Bourenkov, EMBL

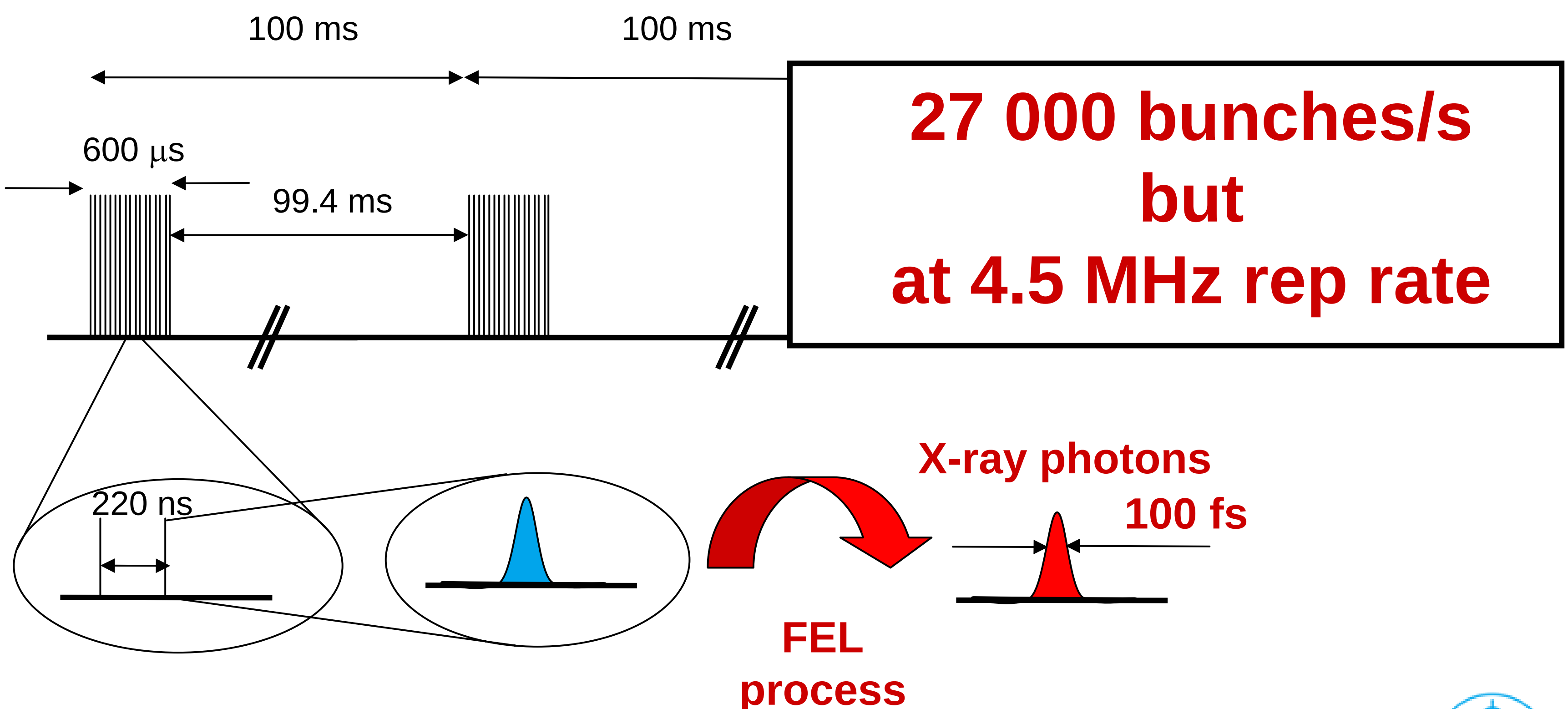
The Challenge #3: different target



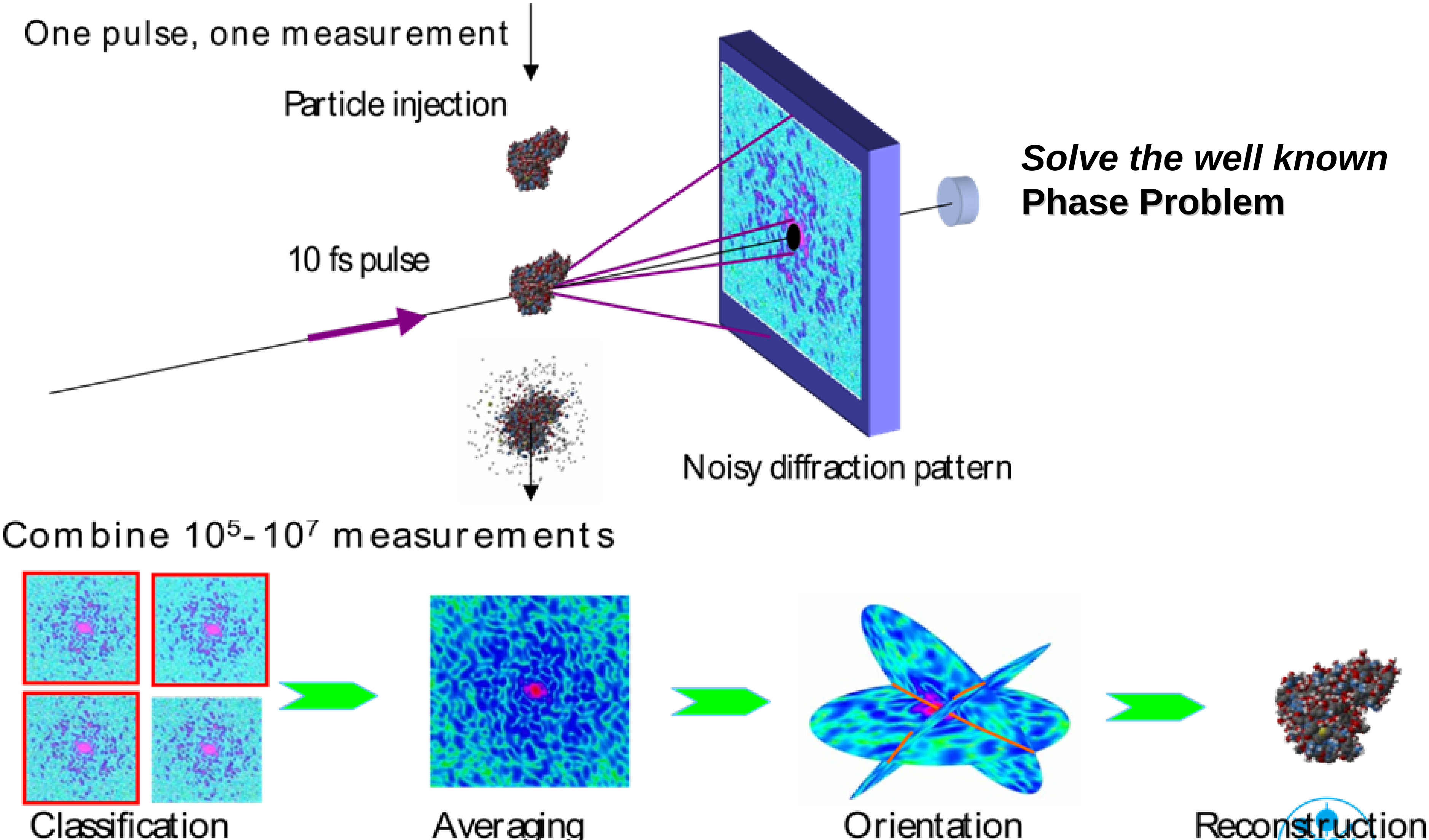
Single shot science

XFEL Challenge: Time structure: difference with “others”

Electron bunch trains; up to 2 700 bunches in 600 μsec, repeated 10 times per second.
Producing <100 fsec X-ray pulses (up to 27 000 bunches per second).



Single shot experiments



Solve the well known **Phase Problem**

The projects launched

Radiation damage study

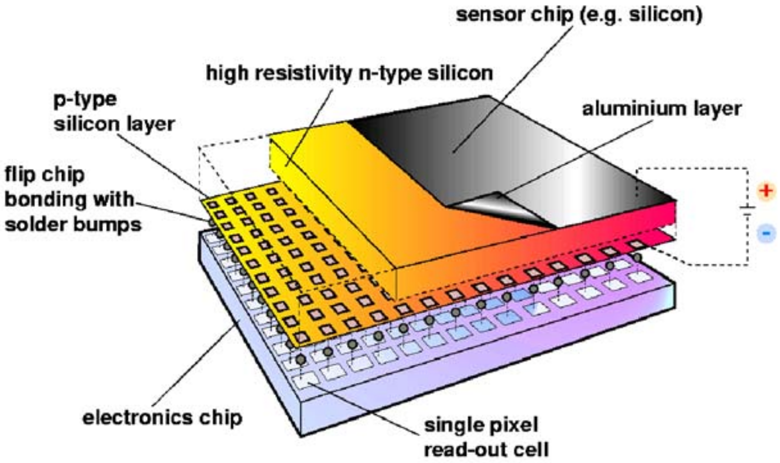
Charge cloud/explosion study

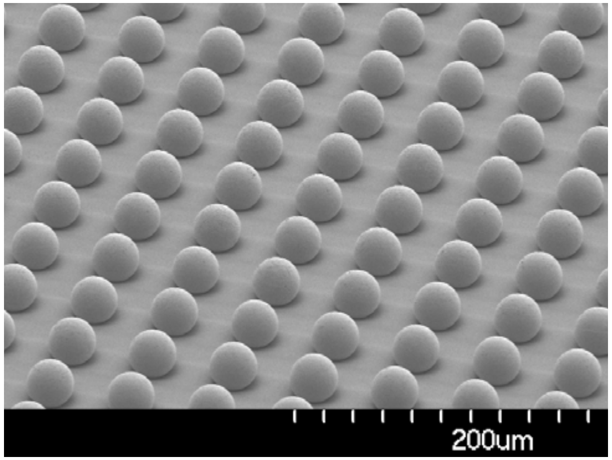
Large Pixel Detector (LPD)

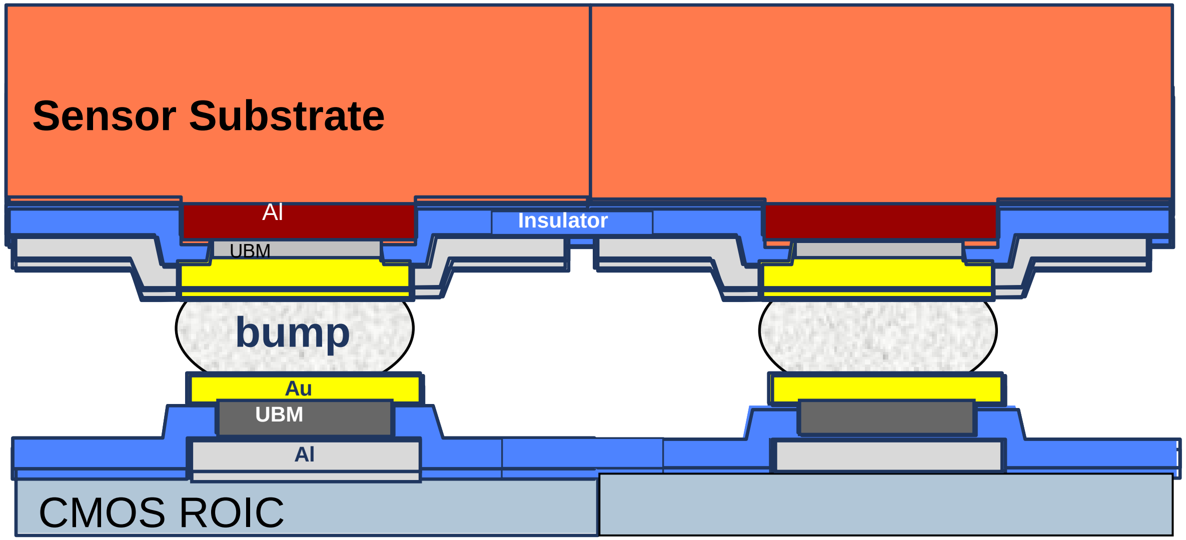
DEPFET Sensor with Signal Compression (DSSC)

Adaptive Gain Integrating Pixel Detector (AGIPD)

Hybrid Pixel Technology







The DEPFET Sensor with Signal Compression (DSSC) project

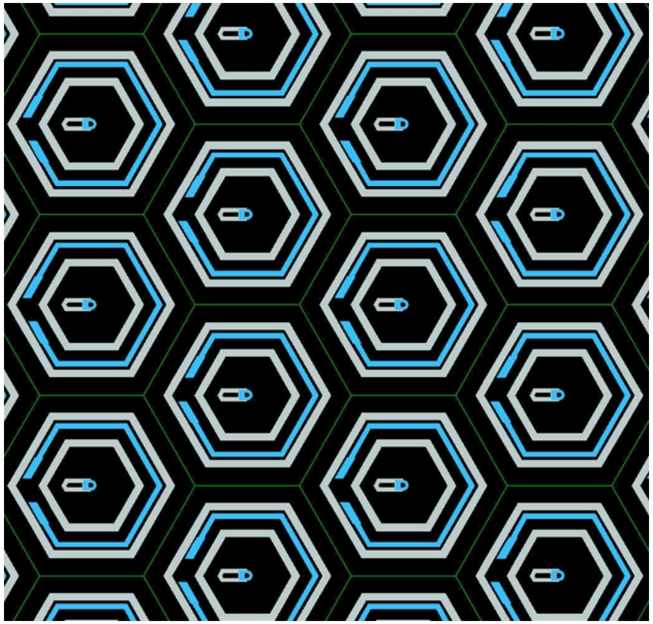
DEPMOS Sensor with Signal Compression

- **DEPFET per pixel**
- **Very low noise (good for soft X-rays)**
- **non linear gain (good for DR)**

- **In pixel ADC**
- ***Digital* storage pipeline**

> MPI-HLL, Munich
> University Bonn
> University Heidelberg
> University Siegen
> Politecnico di Milano
> University Bergamo

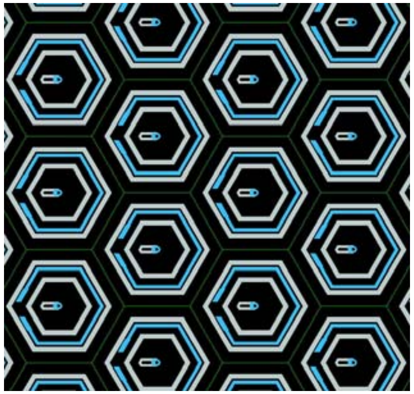
Hexagonal pixels at 200μm pitch combines DEPFET with small area drift detector

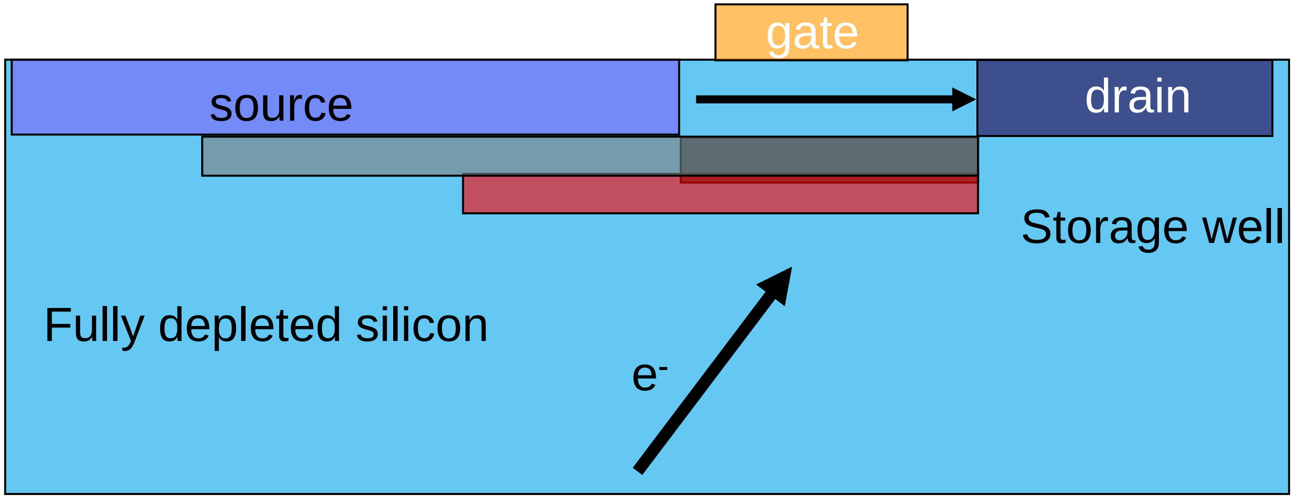


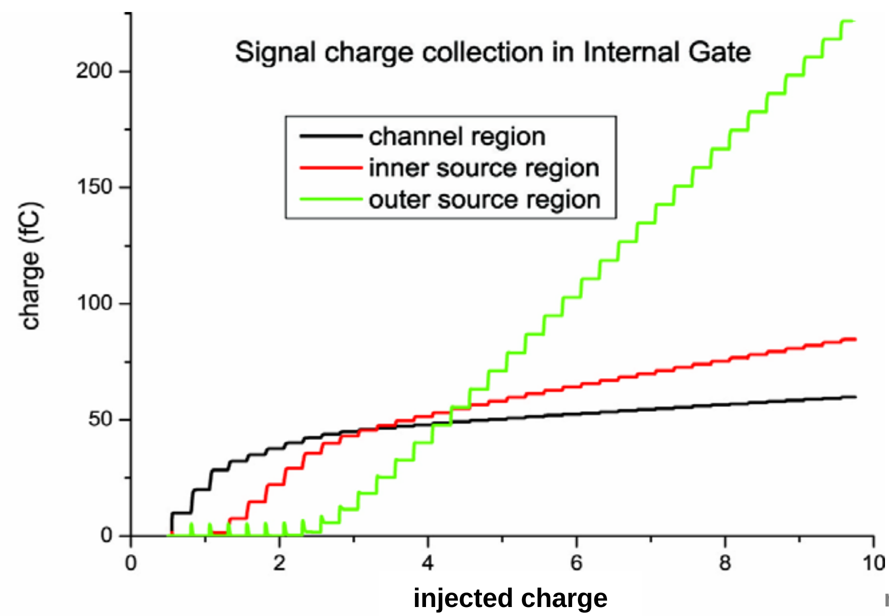
DEPMOS Sensor with Signal Compression

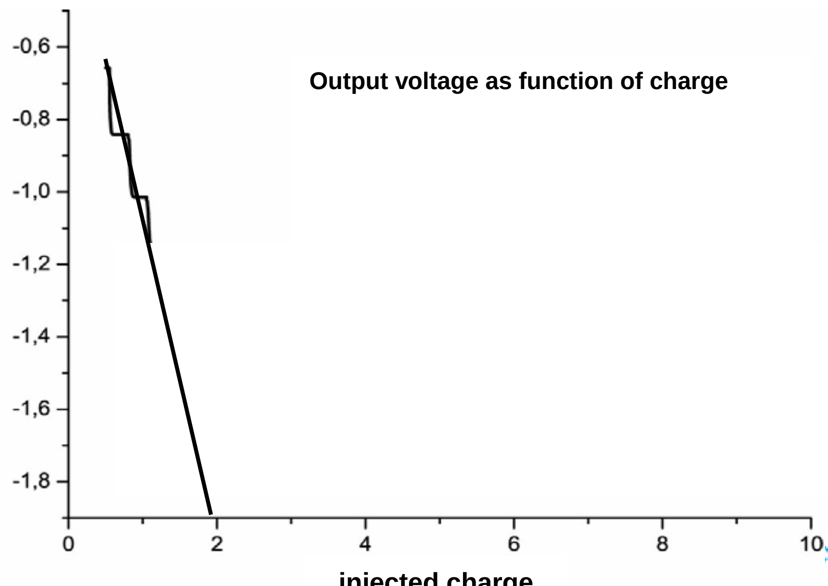
DEPFET: Electrons are collected in a storage well

⇒Trigger current from source to drain









The **A**daptive **G**ain **I**ntegrating **P**ixel **D**etector (**AGIPD**) project

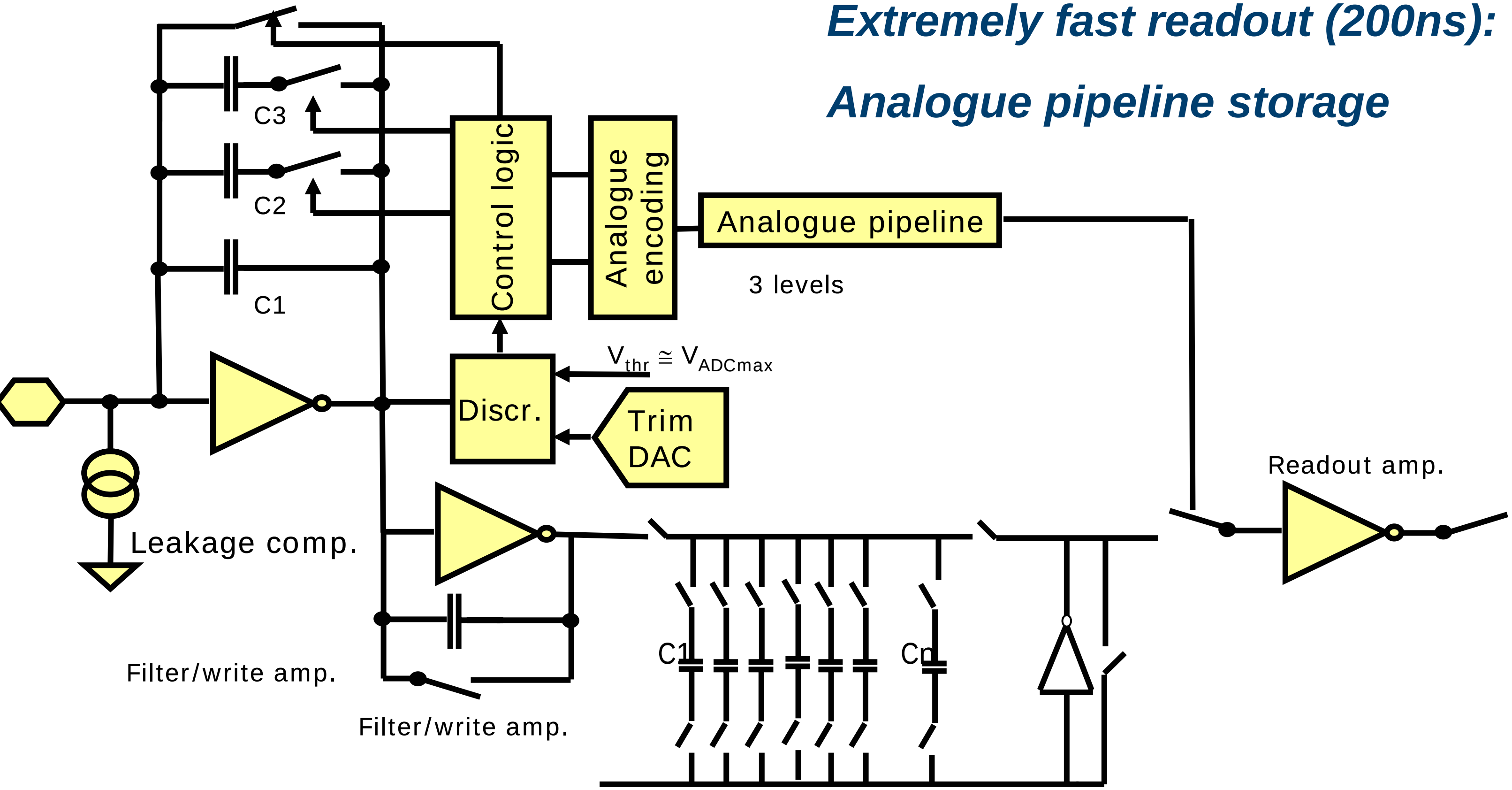
The Adaptive Gain Integrating Pixel Detector

High dynamic range:

Dynamically gain switching system

Extremely fast readout (200ns):

Analogue pipeline storage



Some Thoughts and Perspectives:

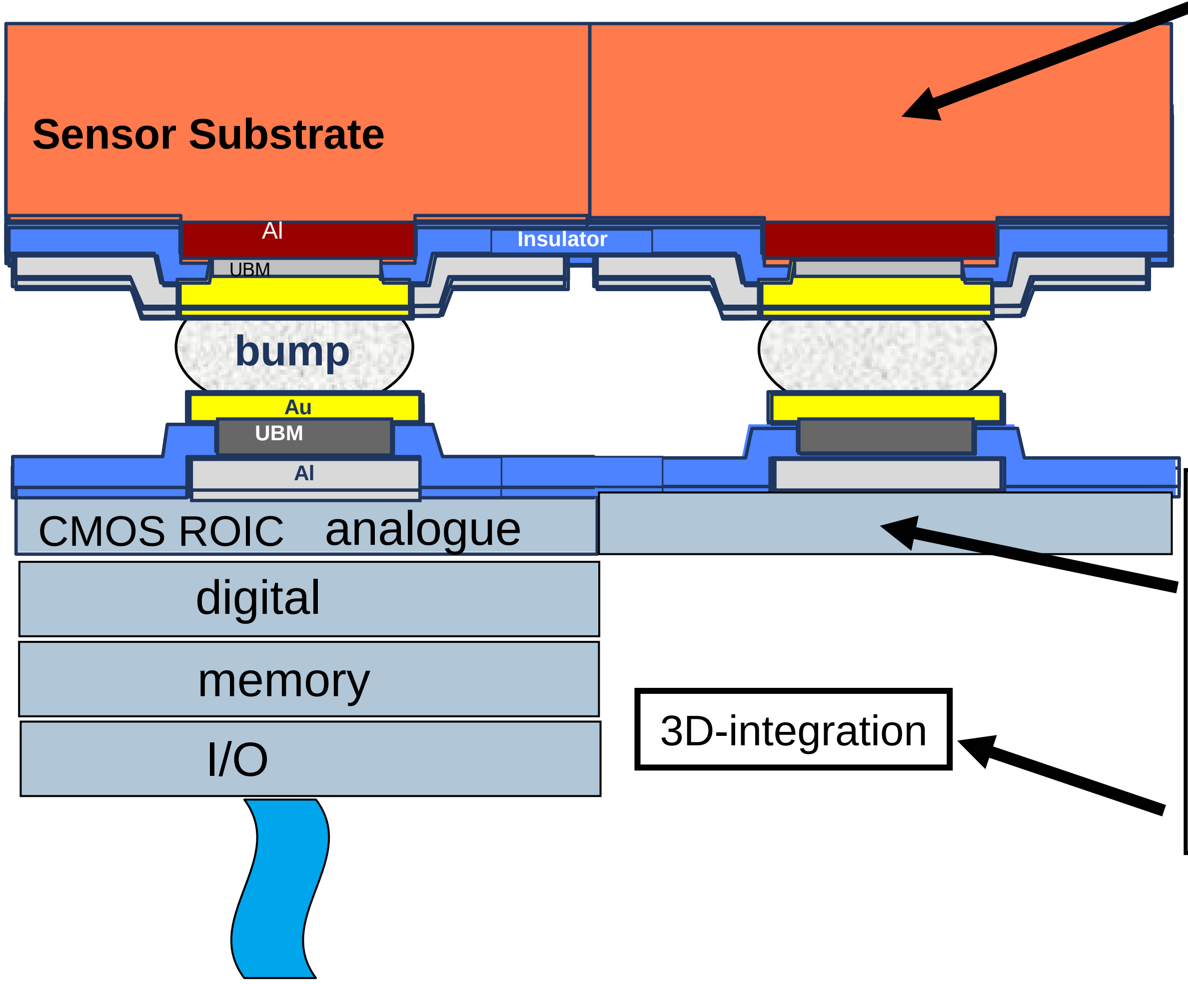
> For every photon measure:
  - Time of arrival (which bunch): ~ nsec time resolution (APD's)
  - Position: ~ micro-meter resolution (center of mass)
  - Energy: ~ few 100 eV resolution (fano-limit)
  - Polarization: few degrees resolution

At SR: "never" more than 1 photon per pixel per bunch

At FEL: often more than 1 photon per pixel per bunch ➔ sum of deposited energy

Note: a photon is either fully absorbed, or not detected at all (no tracks)!

Hybrid Pixel Technology



Other Sensor materials:

- Better at high E:
  Ge; GaAs; Cd(Zn)Te; …
- Better at low E:
  DEPFET; APD's

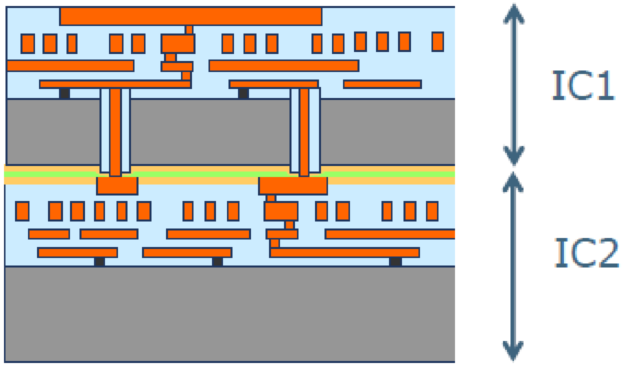
More functionality per pixel:

- Moore's law:
  250 nm CMOS in use
  130 nm CMOS development
  90, 65, 45, ….nm
- Good for digital; bad for analogue

The technology is out there:

Technology enablers:
TSV processing during CMOS process

- Technology:
  - fabrication at device level, i.e. as a part of (CMOS) flow
  - after FEOL, before BEOL
  - will become established in advanced CMOS foundries (core partners, e.g. TSMC, Matsushita, Intel, Micron, ...) participate in 3D IC work at IMEC
- Specifications:
  - Si thickness: 10 – 20 um
  - via diameter: 3 – 5 um
  - via pitch: 10 um
- Applications:
  - Pixel level interconnect
  - imager/processor/logic/memory stacking



imec

Piet De Moor, Workshop on Detector Development

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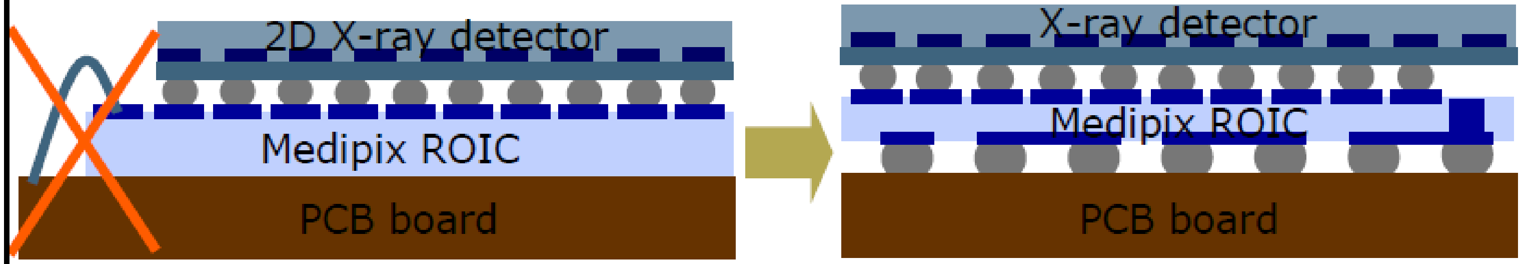
The technology is out there:

Detector systems:

RelaxD: tilable X-ray imagers

- Application: large area X-ray detection by tiling of imager modules
- Using Si X-ray detectors (Canberra) hybridized on Medipix ROICS (CERN)
- Issue: 'dead area' and hence loss of information at imager boundary due to:
  - wiring at > 1 side
- Solution:
  - Vertical electrical interconnections using 3D integration by using TSVs



Summary and Comments

> Full identification of each photon is (probably) possible in the future (like in HEP experiments).

> This needs money (deep sub-micron and 3D chip technology are not cheap), and people (still in developmental phase)

> Photon science needs medium-Z sensors

> Develop detectors for well defined science applications (but choose them carefully)

> Data rates will grow exponentially (need HEP like approaches)

> Storage Ring – FEL – HEP combination extremely powerful!