Overview of the DESY-Photon-Science Detector Group (FS-DS).

Heinz Graafsma
Head of FS-DS; DESY-Hamburg
and University of Mid-Sweden

HELMHOLTZ ASSOCIATION

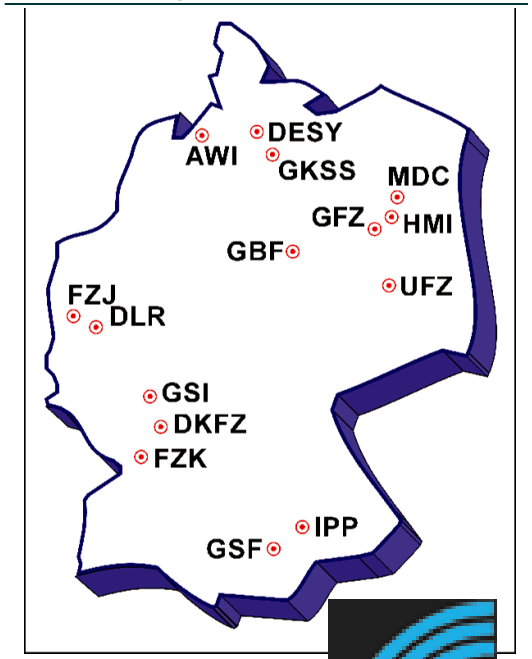
DESY

Research Landscape Germany

Universities
Land 100
Federal St. : Excellence Initiative
Research-Education

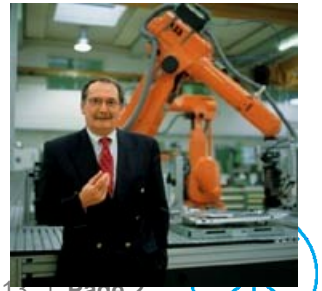
Max-Planck-Gesellschaft
Federal St. -Land 50:50
Fundamental Research
no research policy requirements

Helmholtz Association
Federal St. -Land 90:10
Research Infrastructure
Strategic Research: RPR



Fraunhofer Society
Federal St.-Industry ≈ 65:35
Applied Research
Knowledge Transfer

ISE



Helmholtz-Gemeinschaft Deutscher Forschungszentren

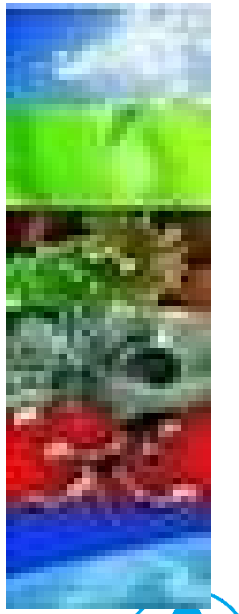
17 National Research Centres

3 billion € budget

30 000 employees

Research fields

- Energy
- Earth and Environment
- Health
- Key Technologies
- **Structure of Matter**
- Transport and Space



DESY: member of the Helmholtz Association

Hamburg

Nationally funded but internationally used research center

Staff: ~1900 (1600 FTE)
Budget: ~183 M€
Users: ~3000 (> 2400 for synchrotron radiation experiments)

two sides of DESY

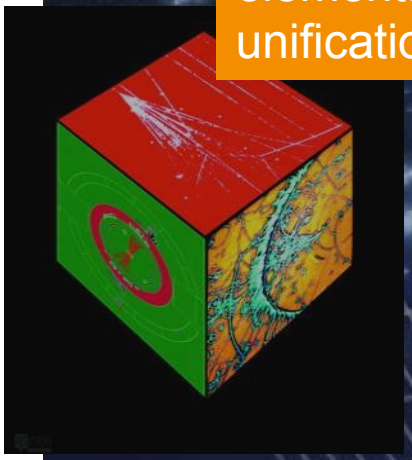
Zeuthen

DESY Research.

∞ small

nano
cosmos

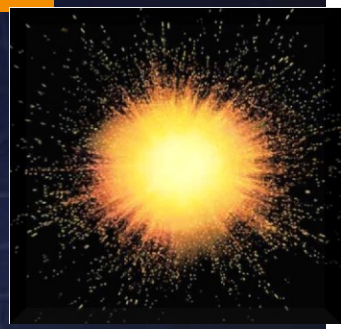
elementary particles
unification of forces



universe

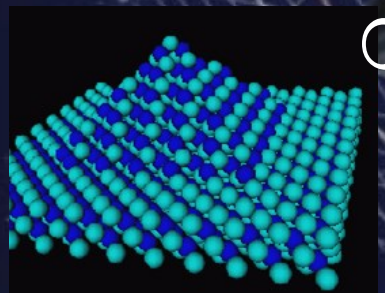
∞ large

cosmology
astrophysics

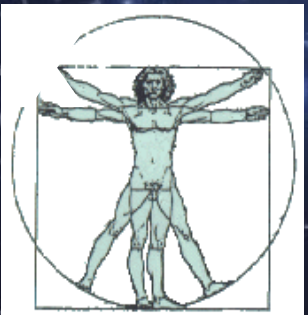


condensed
matter

∞ comple

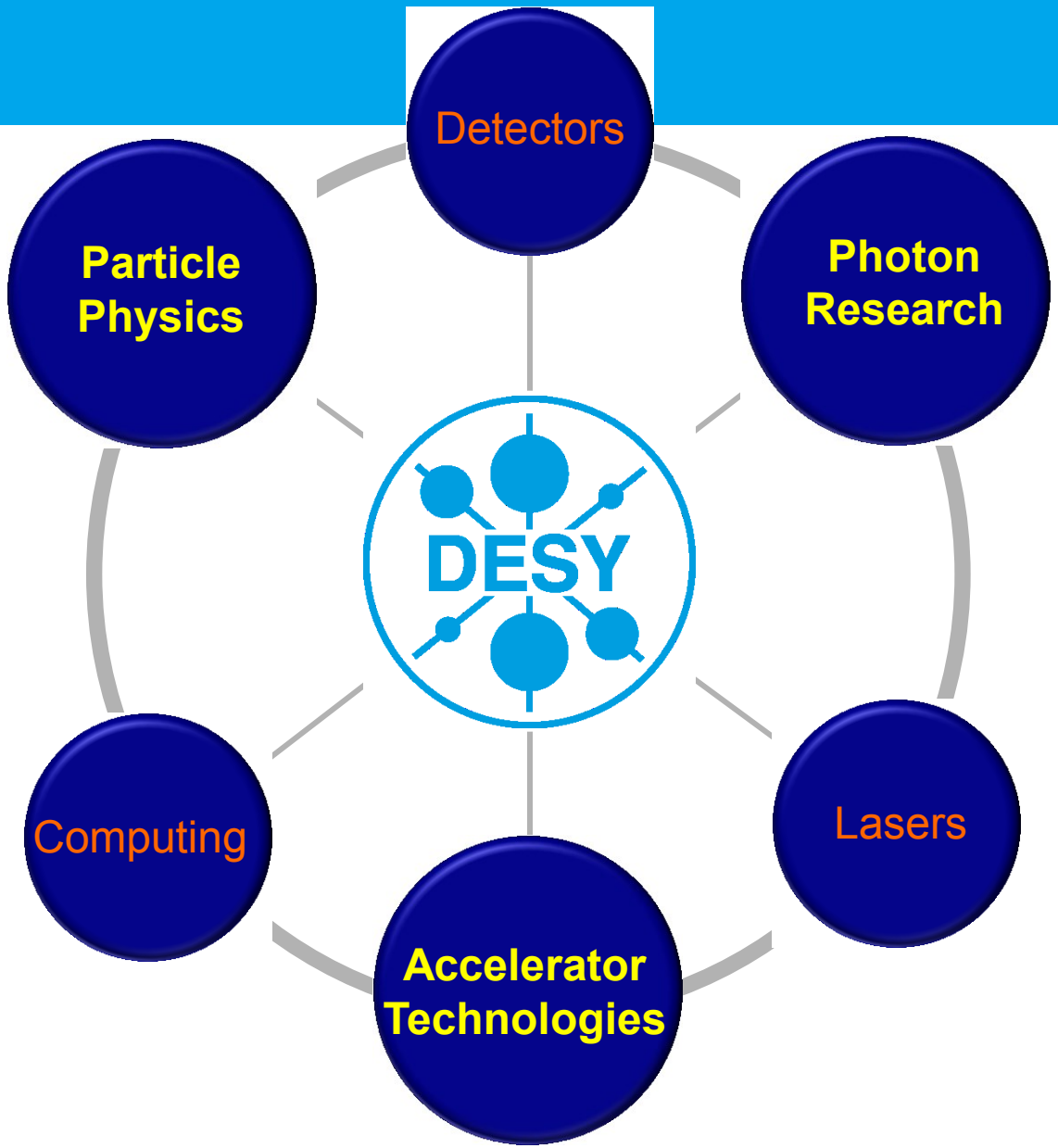


nanoscience, biology
Synchrotron radiation



ASSOCIATION

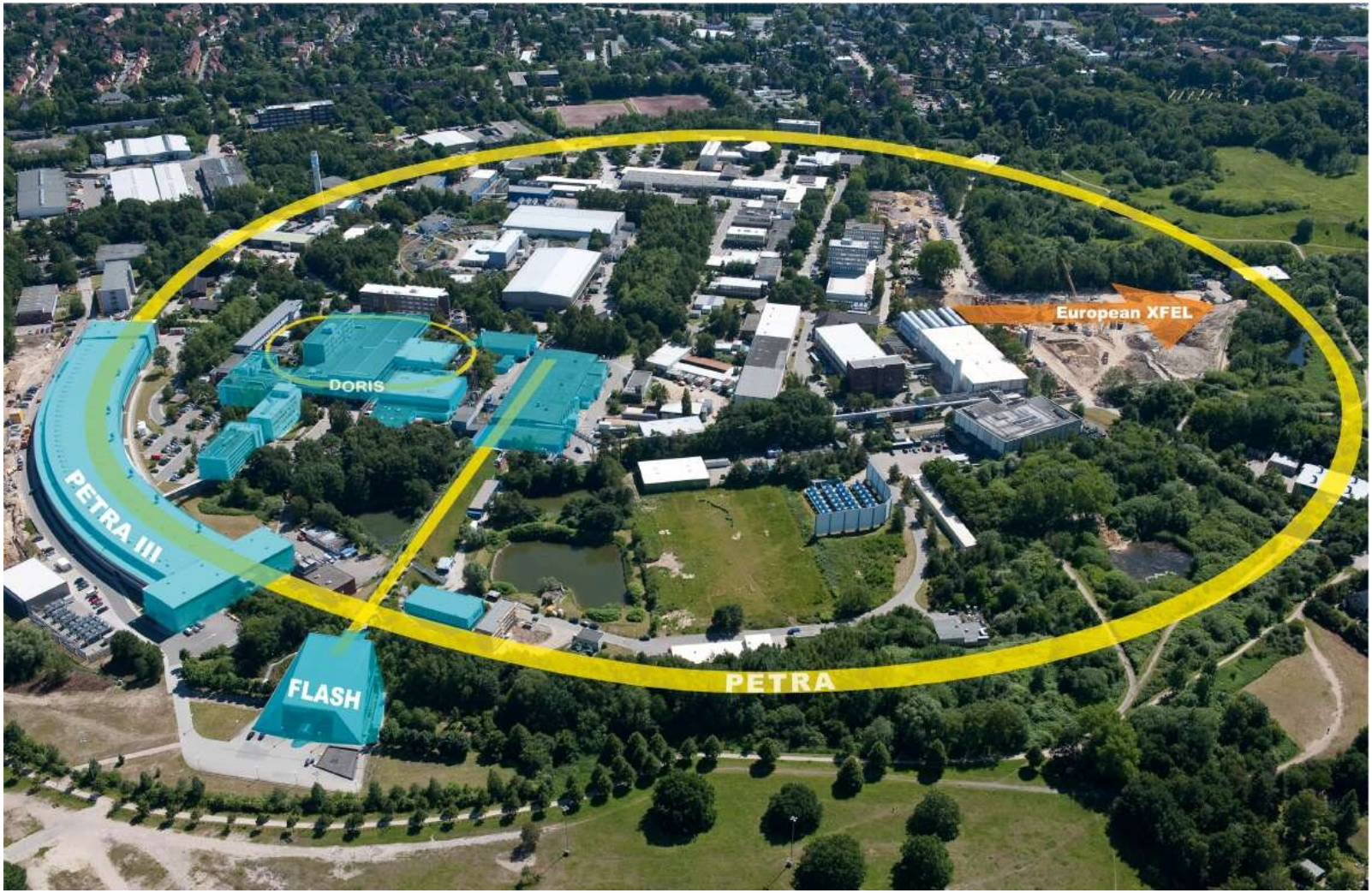
DESY Core Competence.



HELMHOLTZ ASSOCIATION

DESY

Accelerators on the DESY campus



Contributions to many international facilities, including CERN

Development of the DESY Campus ➔ Also new detectors

The Detector Group: Who are we ?

Heinz Graafsma
Group Leader

Stefanie Jack
Project Manager

Michael Lohmann
Detector Scientist

Bernd Struth
Detector Scientist

Ulrich Trunk
Detector Scientist

Trixi Wunderer
Detector Scientist

Seungyu Rah
Detector Scientist

Julian Becker
Postdoc

Laura Bianco
Postdoc

David Pennicard
Postdoc

Alessandro Marras
Postdoc

Michele Viti
Postdoc

Alexander Kluyev
Engineer Physicist

Sabine Lange
Electronic Engineer

Sergej Smoljanin
Electronic Technician

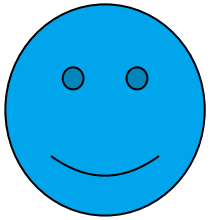
Helmut Hirsemann
Mechanical Engineer

Matthias Bayer
Mechanical Engineer

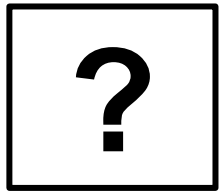
Björn Nilsson
Mechanical Technician

Jiaguo Zhang
Post Doc

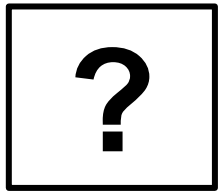
Florian Pithan
Electronic Engineer



Fabian Westermeier
Post Doc



nn
Post Doc



nn
Post Doc

What is our Mission ?

1. Give “detector support” to the experimental stations at DESY and to the DESY scientists

   (e.g.: operate a detector loan pool, purchasing, adaptation)

2. Provide access to the most advanced detectors

   (e.g.: pnCCD, Gotthard for FLASH, Maxipix, Eiger)

3. Develop and build new detectors and detector concepts for PETRA III, FLASH, European-XFEL

4. Deploy new detectors in pilot experiments.

   (e.g.: Rheology, XPCS, Coherence measurements)

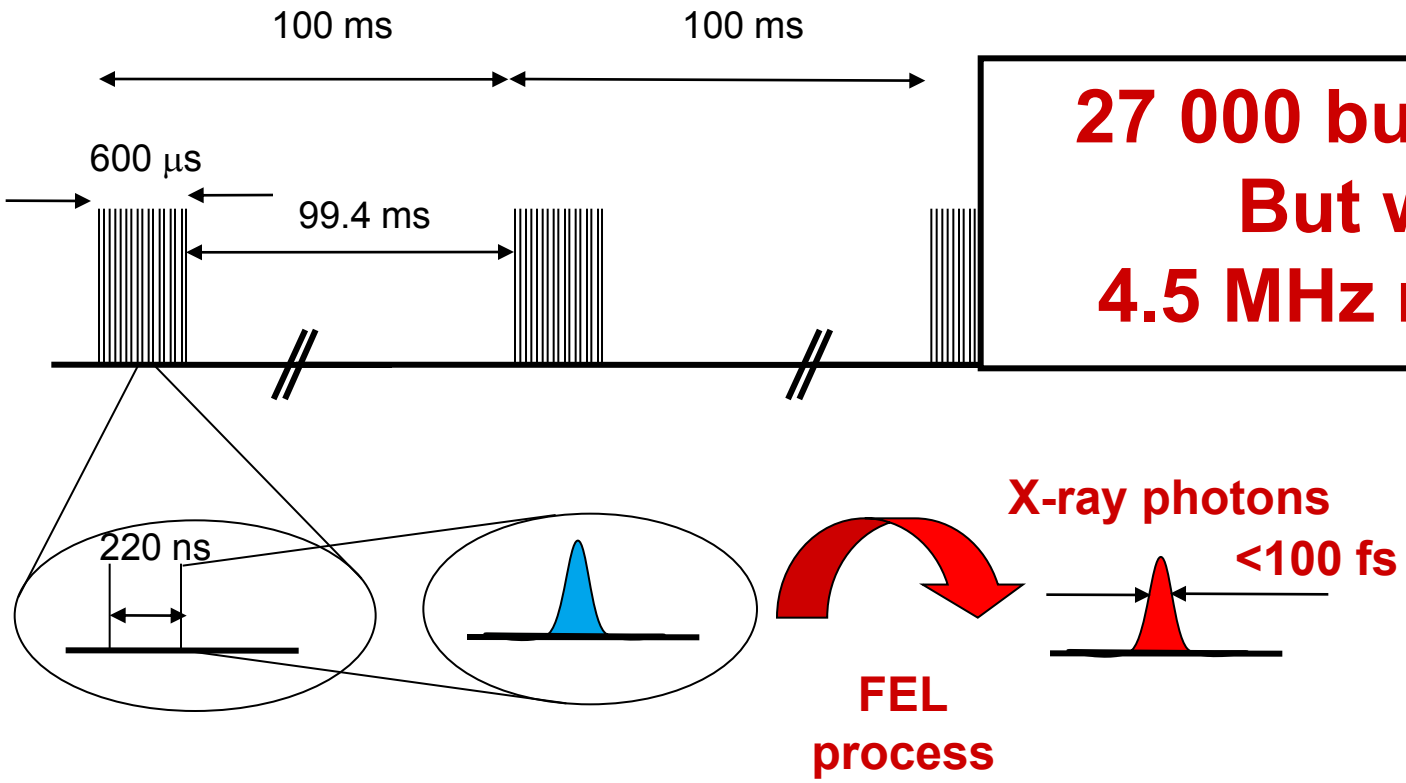
What are our developments projects ?

- LAMDBA (for PETRA III + High-Z) (U-Freiburg, KIT)
- AGIPD (for E-XFEL) (PSI, U-HH, U-Bonn)
- PERCIVAL (for FLASH) (RAL, Elettra, Diamond)
- DSSC (low-E for E-XFEL) (German + Italian partners)
- XNAP (2D APD-array) (ESRF, Mannheim, Excelitas, Spring-8)
- Diamond XBPM (ESRF, I-technologies)
- HGF-Cube (Helmholtz Detector Portfolio)

http://photon-science.desy.de/research/technical_groups/detectors/index_eng.html

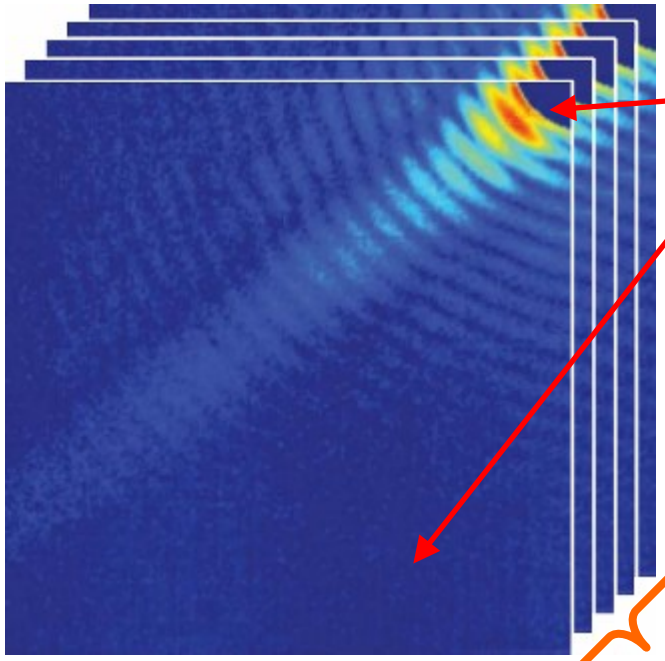
E-XFEL Challenge: Time structure = difference with “others”

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
But with
4.5 MHz rep rate

Constraints



in the same image:
- up to ~ 10^4 photons
- down to 0~1

radiation tolerant!

1-photon resolution!
(or better than poissonian)

single-image experiments!
as many as possible!

many pixels!
small pixels!

4.5MHz x

2700 images

HELMHOLTZ ASSOCIATION

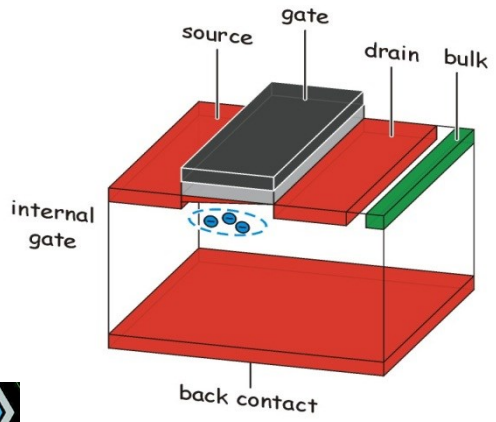
DESY

Three dedicated Projects:

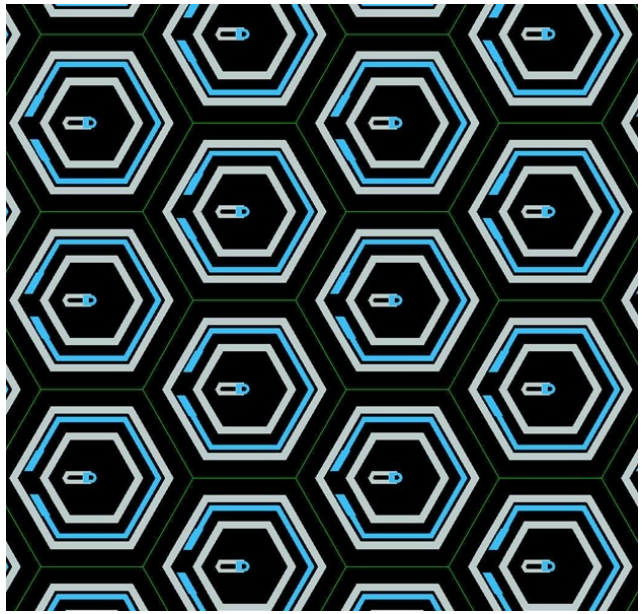
- **L**arge **P**ixel **D**etector
- **A**daptive **G**ain **I**ntegrating **P**ixel **D**etector
- **D**epmos **S**ensor with **S**ignal **C**ompression

DSSC - DEPMOS Sensor with Signal Compression

- DEPFET per pixel
- Very low noise (good for soft X-rays)
- non linear gain (good for dynamic range)
- per pixel ADC
- digital storage pipeline



- **Hexagonal pixels 200μm pitch**



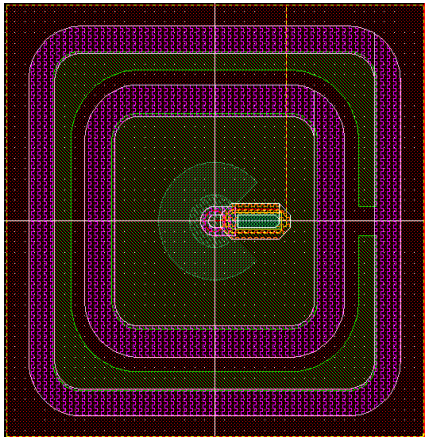
- combines DEPFET
- with small area drift detector (scaleable)

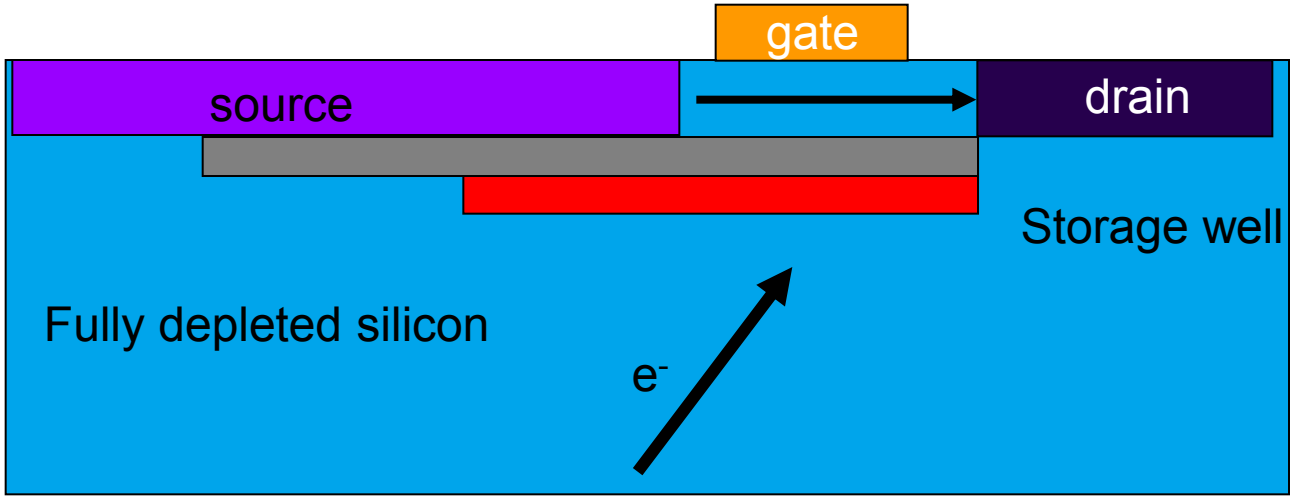
- MPI-HLL, Munich
- Universität Heidelberg
- Universität Siegen
- Politecnico di Milano
- Università di Bergamo
- DESY, Hamburg

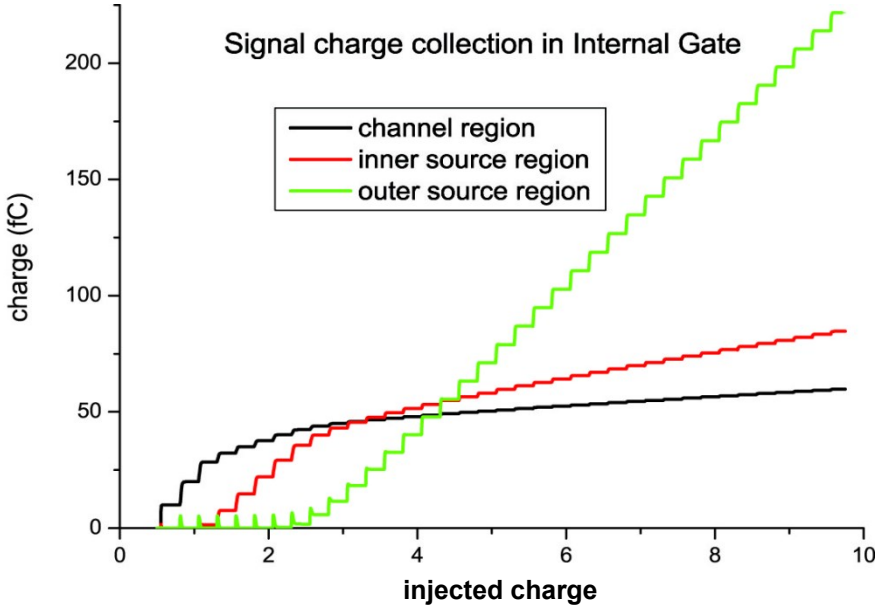
DEPMOS Sensor with Signal Compression

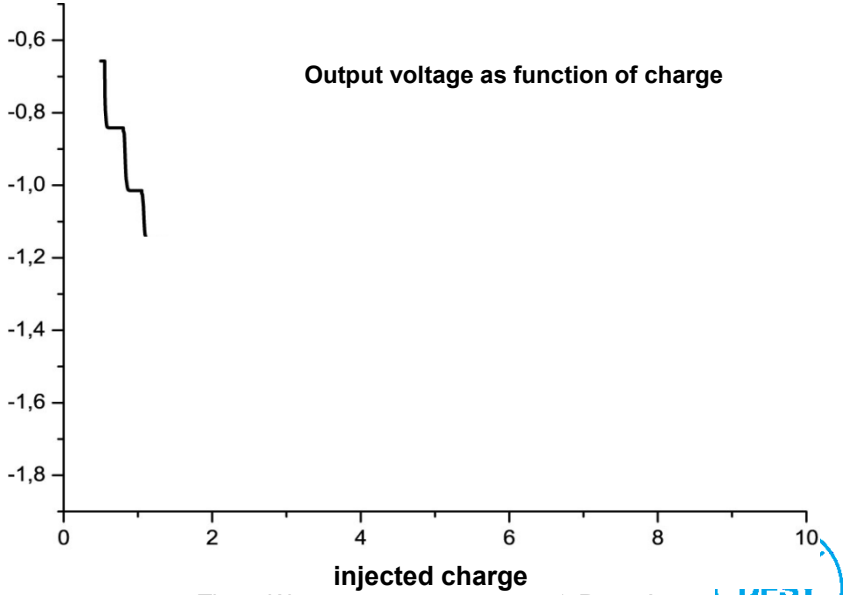
DEPFET: Electrons are collected in a storage well

⇒Influence current from source to drain



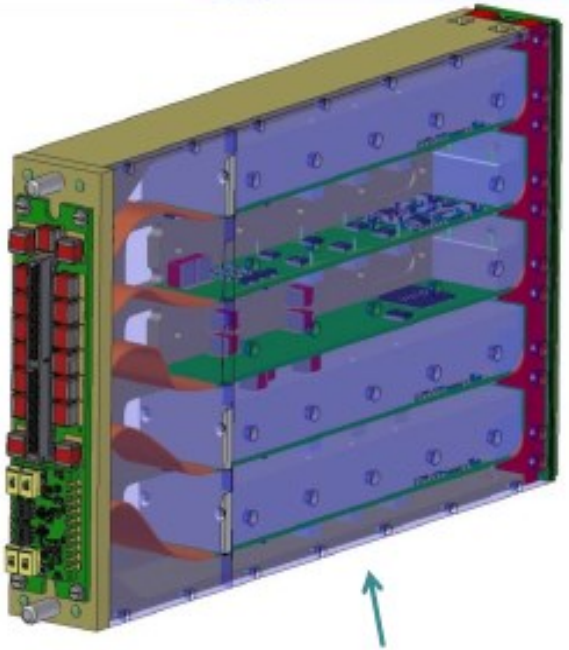




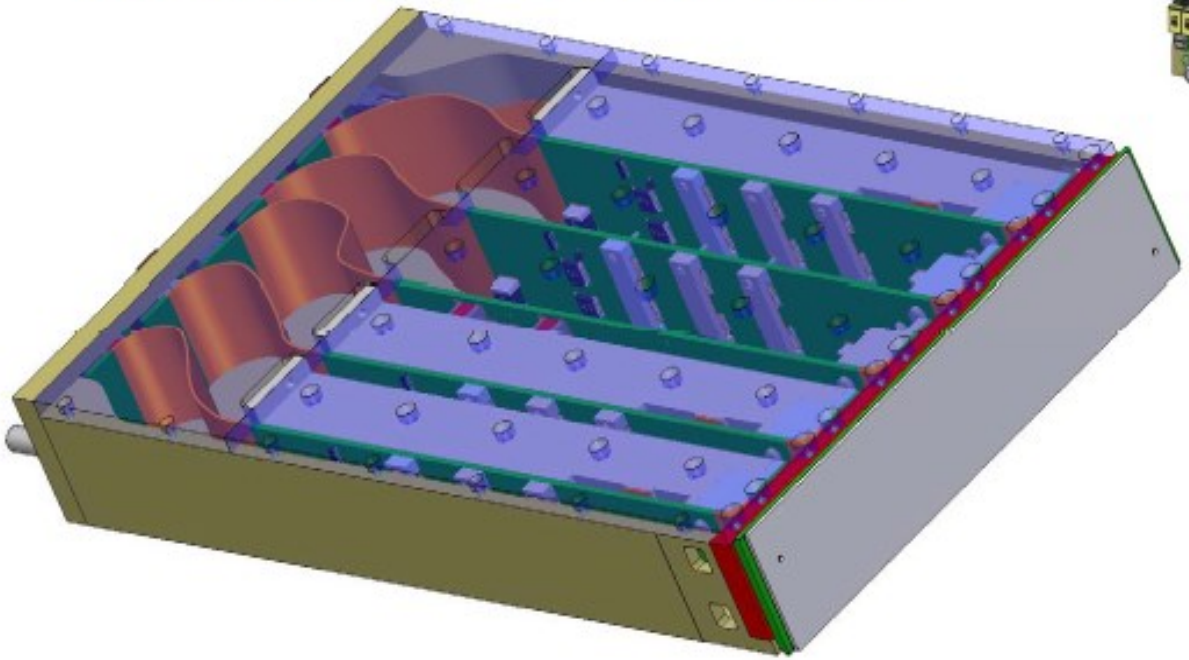


Mechanical Design of Ladder

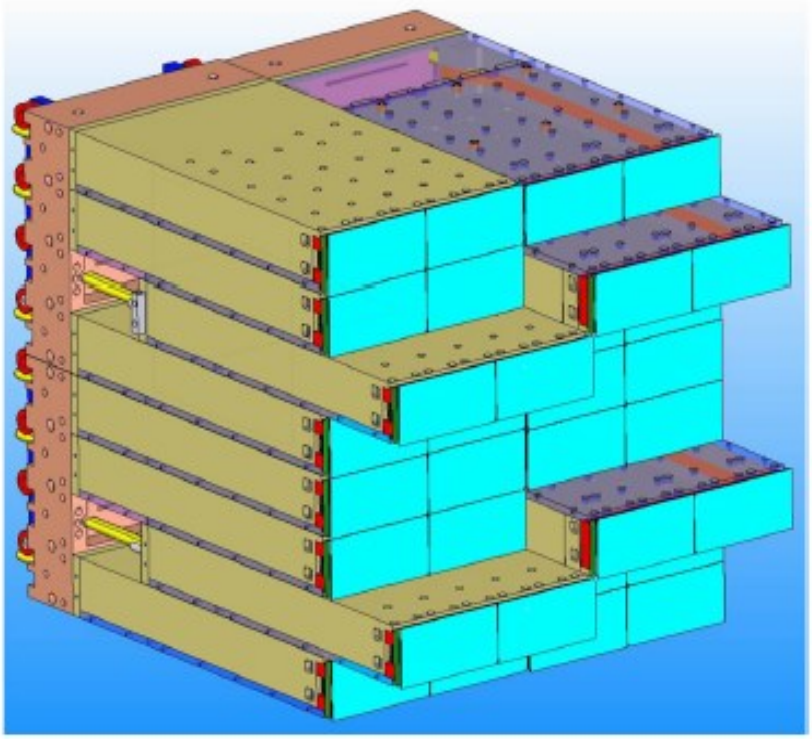
- Care taken to maximize thermal throughput top-bottom
- U-shaped bottom with lid to maximize stiffness
- All screwed connections with indium foil to improve thermal contacts
- All electrical, mechanical, & thermal connections at the back of the ladder



Ladder Box
Ladder Assembly

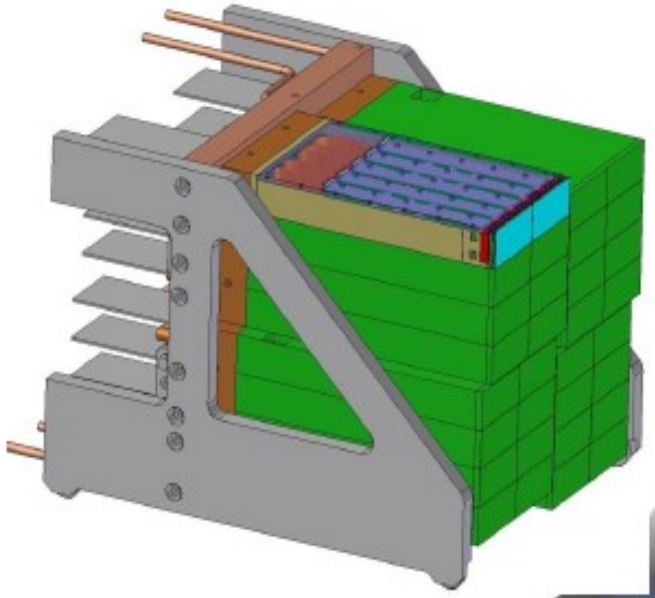


Mechanical Design of 1k × 1k



- Ladders attached to
  - Quadrant plates and XY stages or
  - Common base plate (fixed hole)

  at the back of the assembly,
- Serviceable ladder by ladder



Data Rate … a non-negligible challenge

- LAMBDA: 1536 x 512 pixels per module, 3 modules in total; running at 1000 Hz; 12 bit / pixel

  ➔ 3 module system (2.3 Mpixels) gives up to 30 Gbit/s (3.7 Gbyte)

  (Test operation: 2013, June and August)

- PERCIVAL: 4k x 4k sensor, running at 120 Hz; 15 bits /pixel for each image ADC'd on-chip (x2 for CDS)

  ➔ One sensor (16 Mpixels) gives up to 60 Gbit/s (7.5 Gbyte)

  (Operation: 2014)

- AGIPD: 1 Mpixel, 352 images/pixel x 4 byte: 1408 Mbyte/train; 10 Hz

  ➔ Full system (1 Mpixels) gives up to 96 Gbit/s (14 Gbyte)

  (Operation 2015)

DESY

Helmholtz-Gemeinschaft Deutscher Forschungszentren

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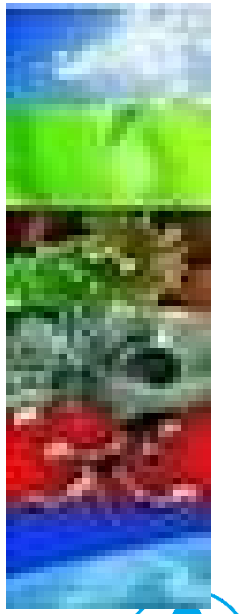
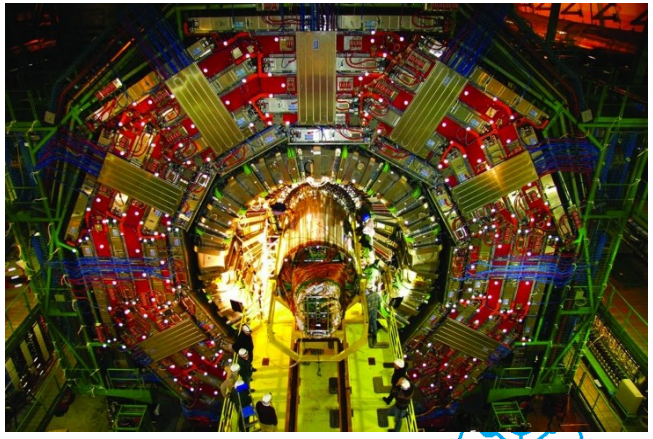
Research fields

- Energy
- Earth and Environment
- Health
- Key Technologies
- **Structure of Matter**
- Transport and Space

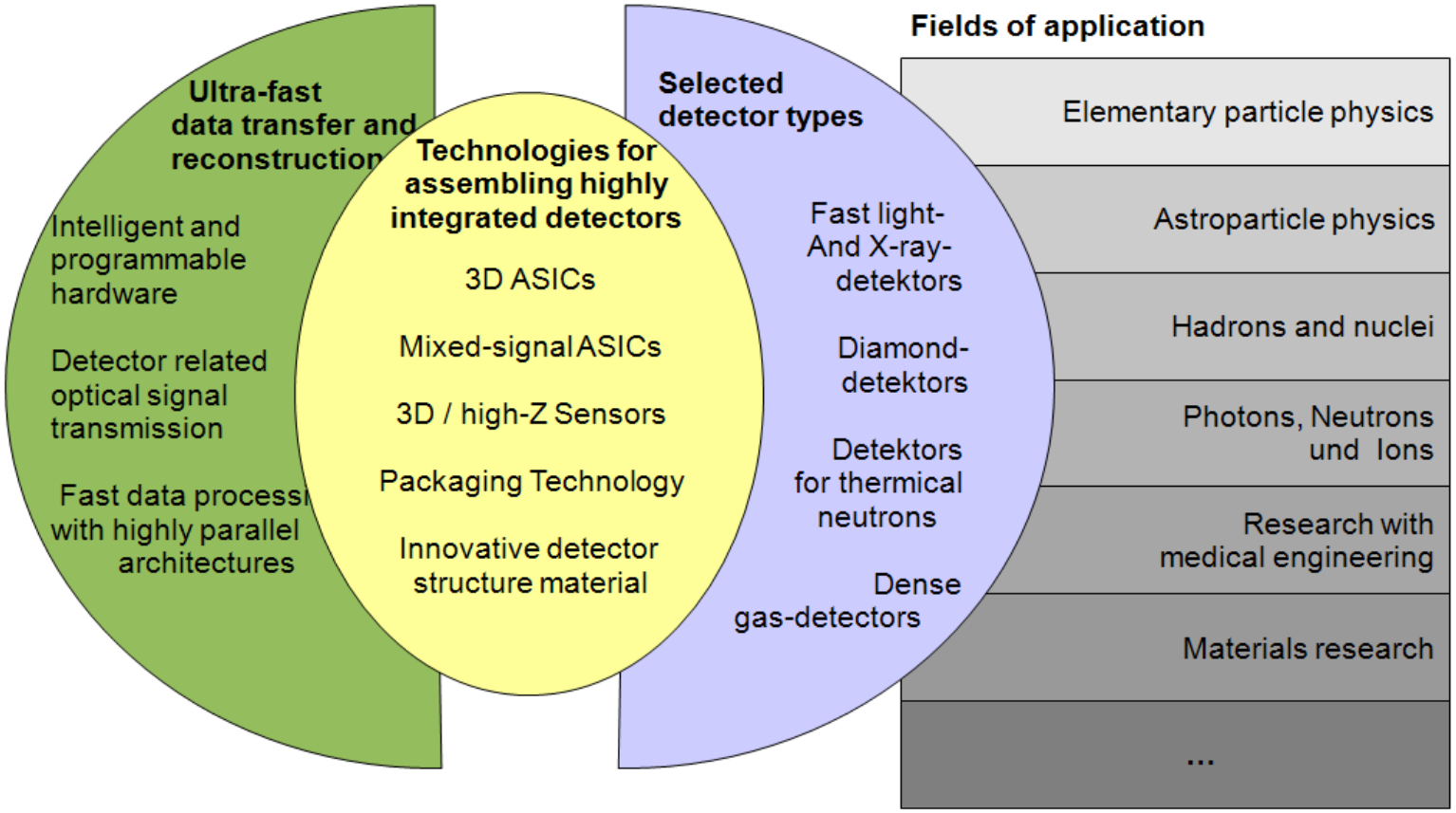


„Structure of Matter“ becomes „Matter“

- Program 1: Matter and Universe
- Program 2: From Matter to Materials and Life
- Program 3: Matter and Technology
  - 3.1. Accelerator Research and Development
  - **3.2. Detector Technology and -Systems**



This is the structure of the current platform



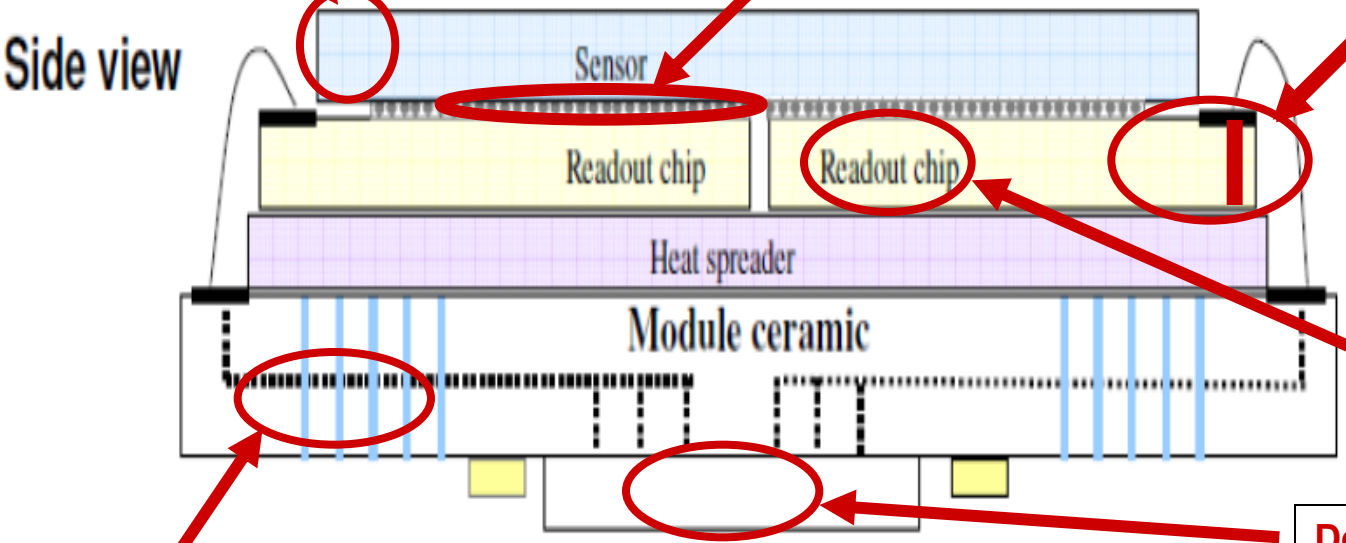
The “Helmholtz-Cube”

Vertically Integrated Detector Technology

Replace standard sensor with: 3D and edgeless sensors, as well as High-Z

Replace standard bump-bonds with new interconnect techniques

Replace standard ASIC and wire bonds with thinned ASICs and TSV as well as ball-grid arrays

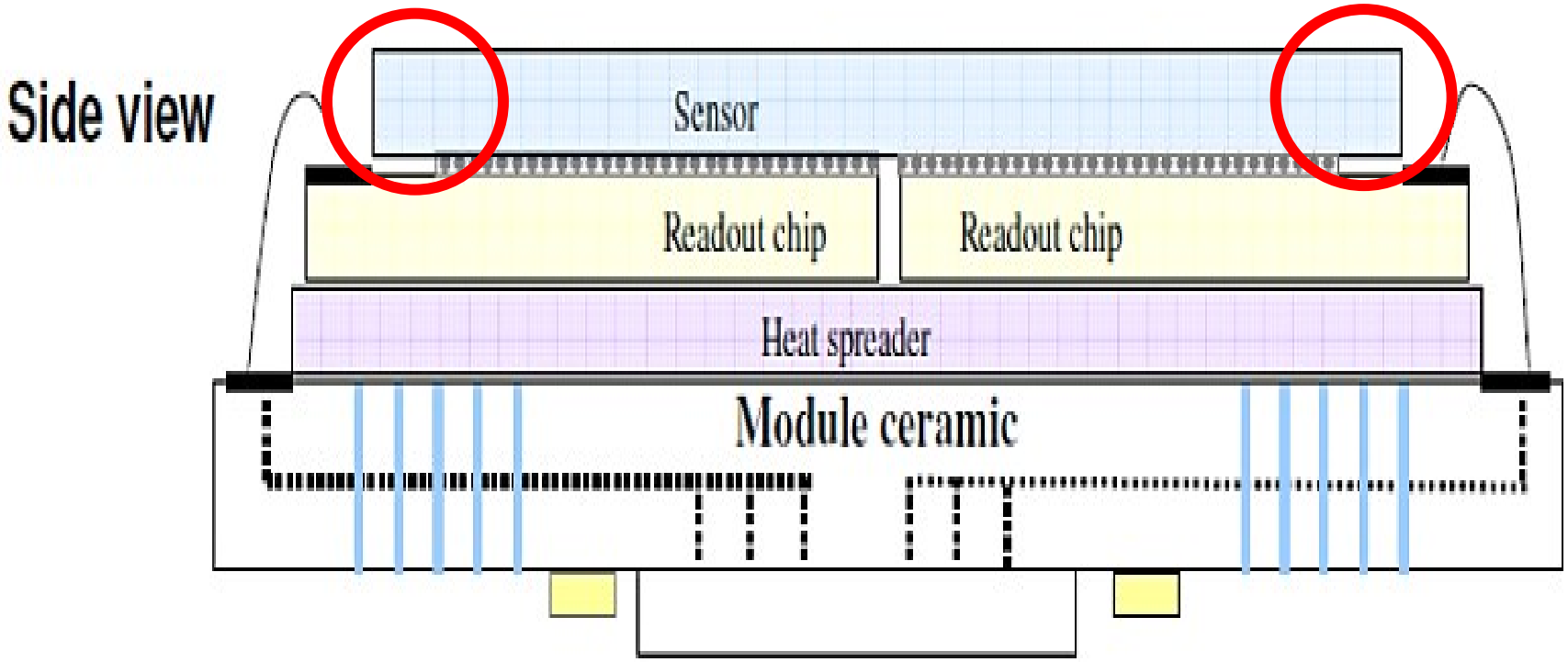


Replace standard ASIC with 3D-ASICs

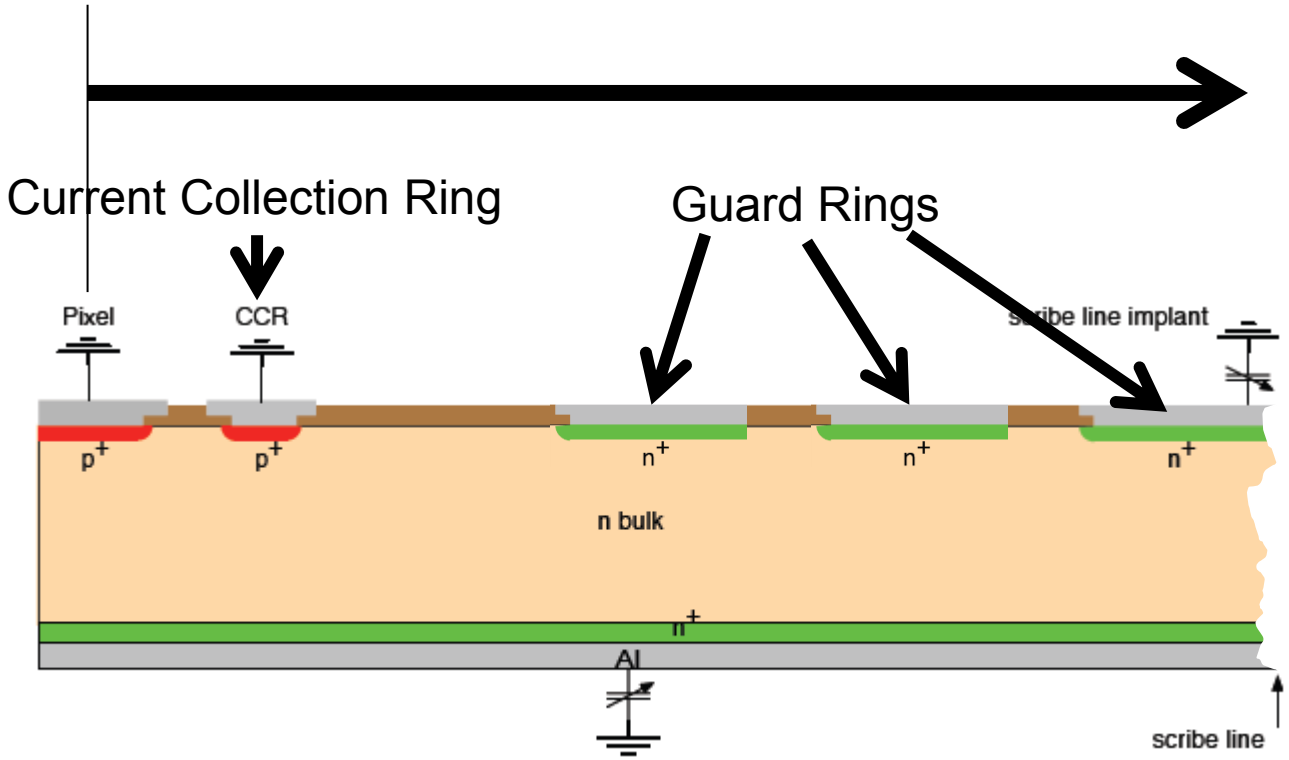
Develop new high speed IO’s

Employ innovative materials

Step 1: remove dead-edge of sensor

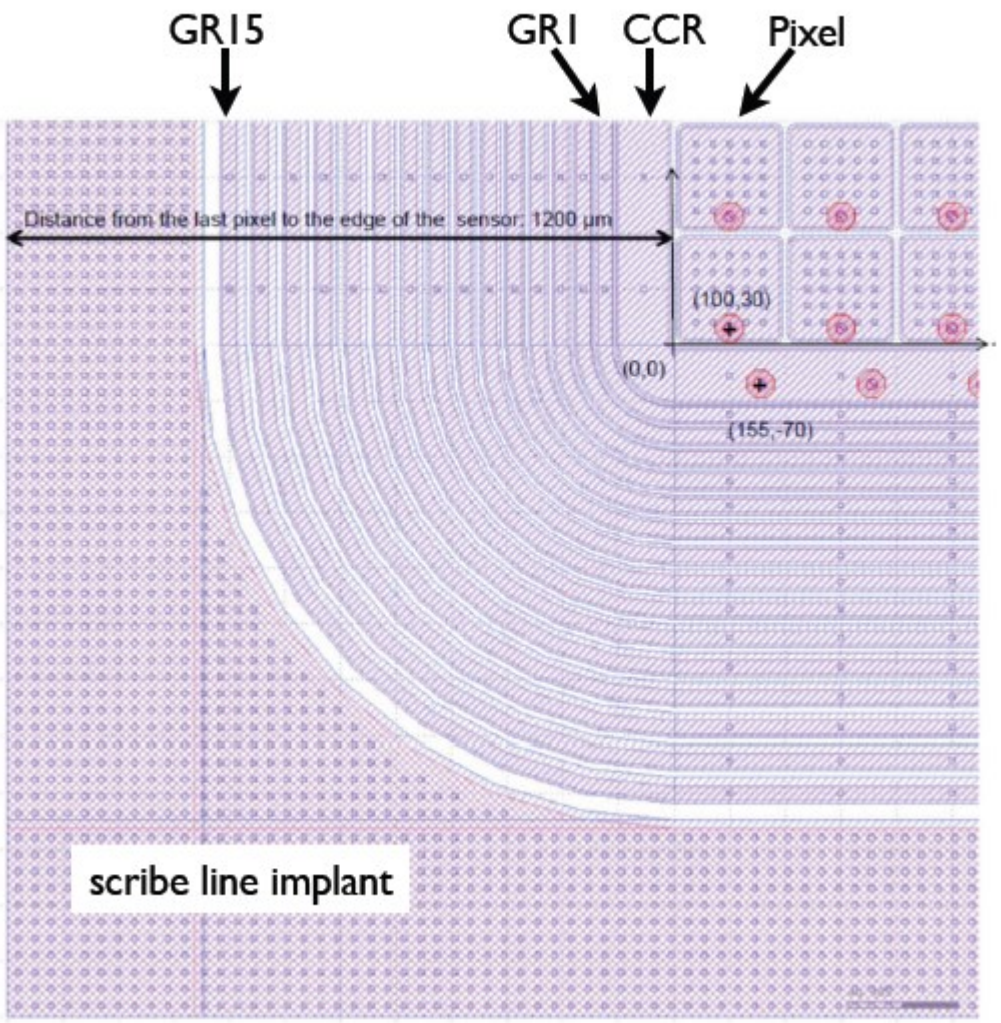


Sensor layout with current collection and guard rings



1) Large distance to the edge
2) Current Collection ring
3) Guard rings to step down voltage

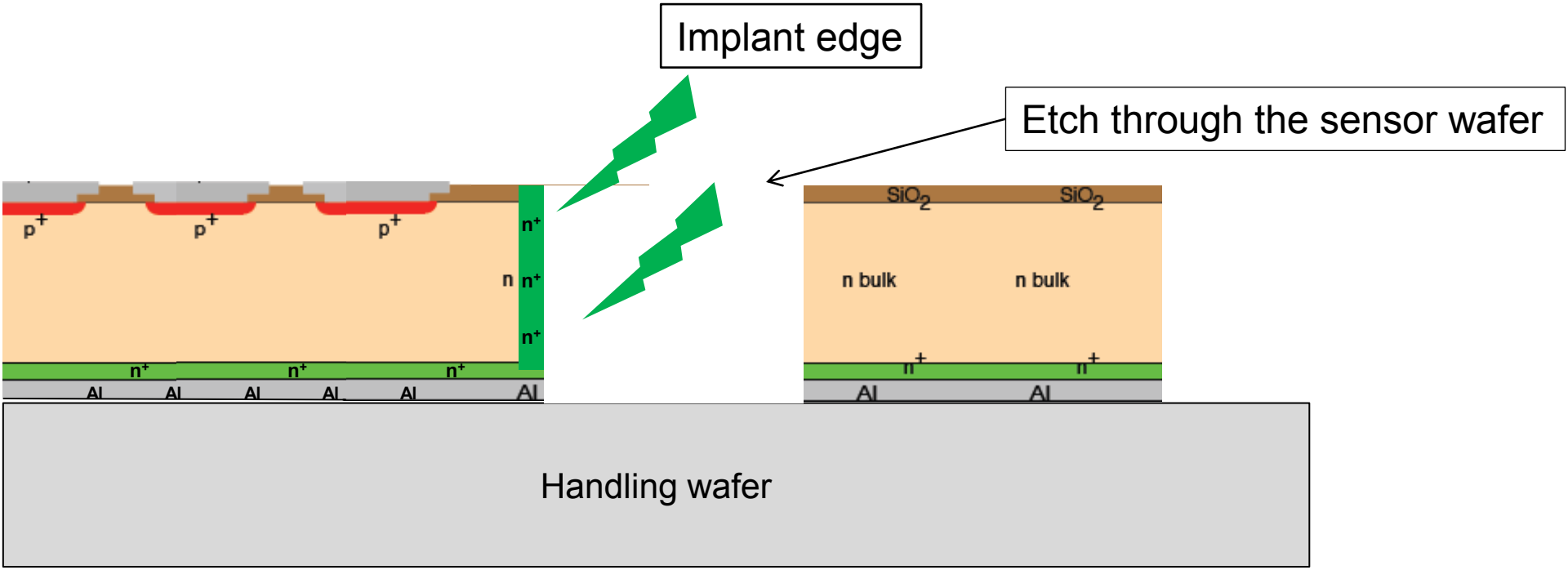
The AGIPD sensor



The AGIPD sensor for the European XFEL.
High Voltage design (900 V):

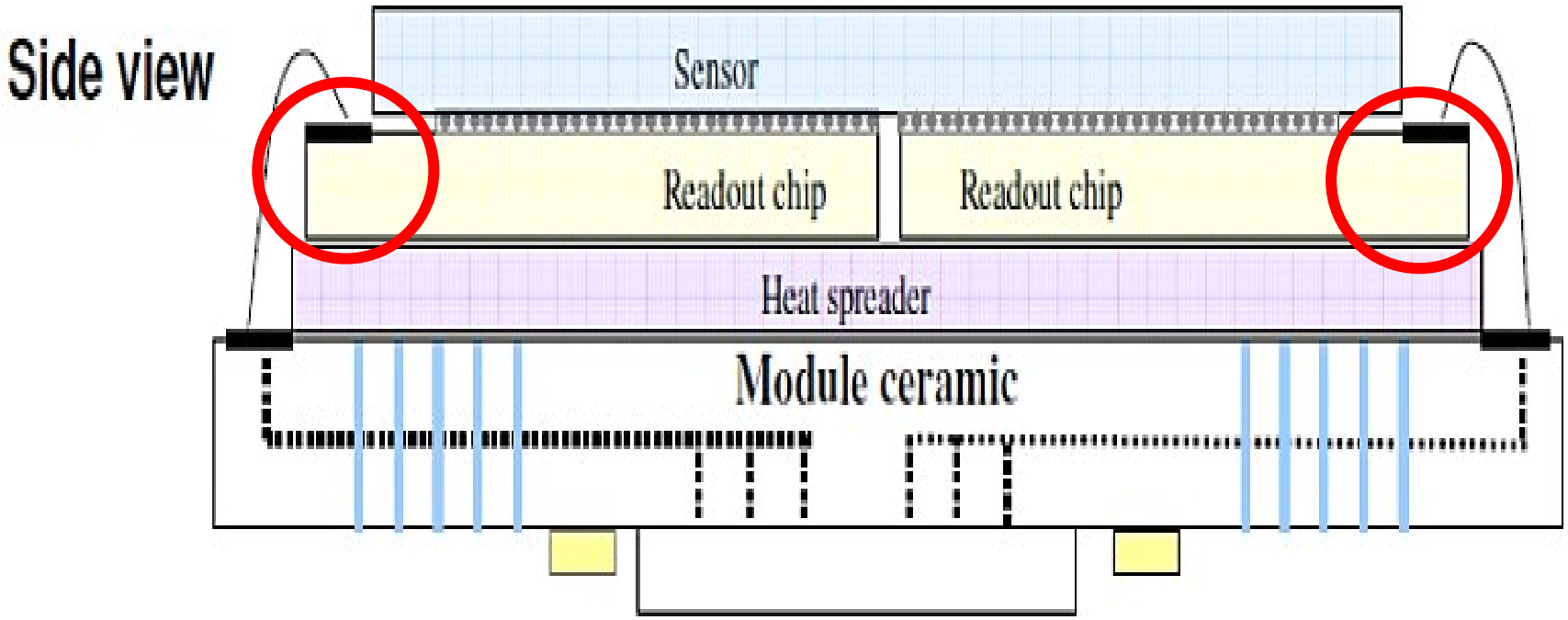
➔ needs 15 guard rings
➔ Large insensitive area

Sensor processing: a better way of doing it

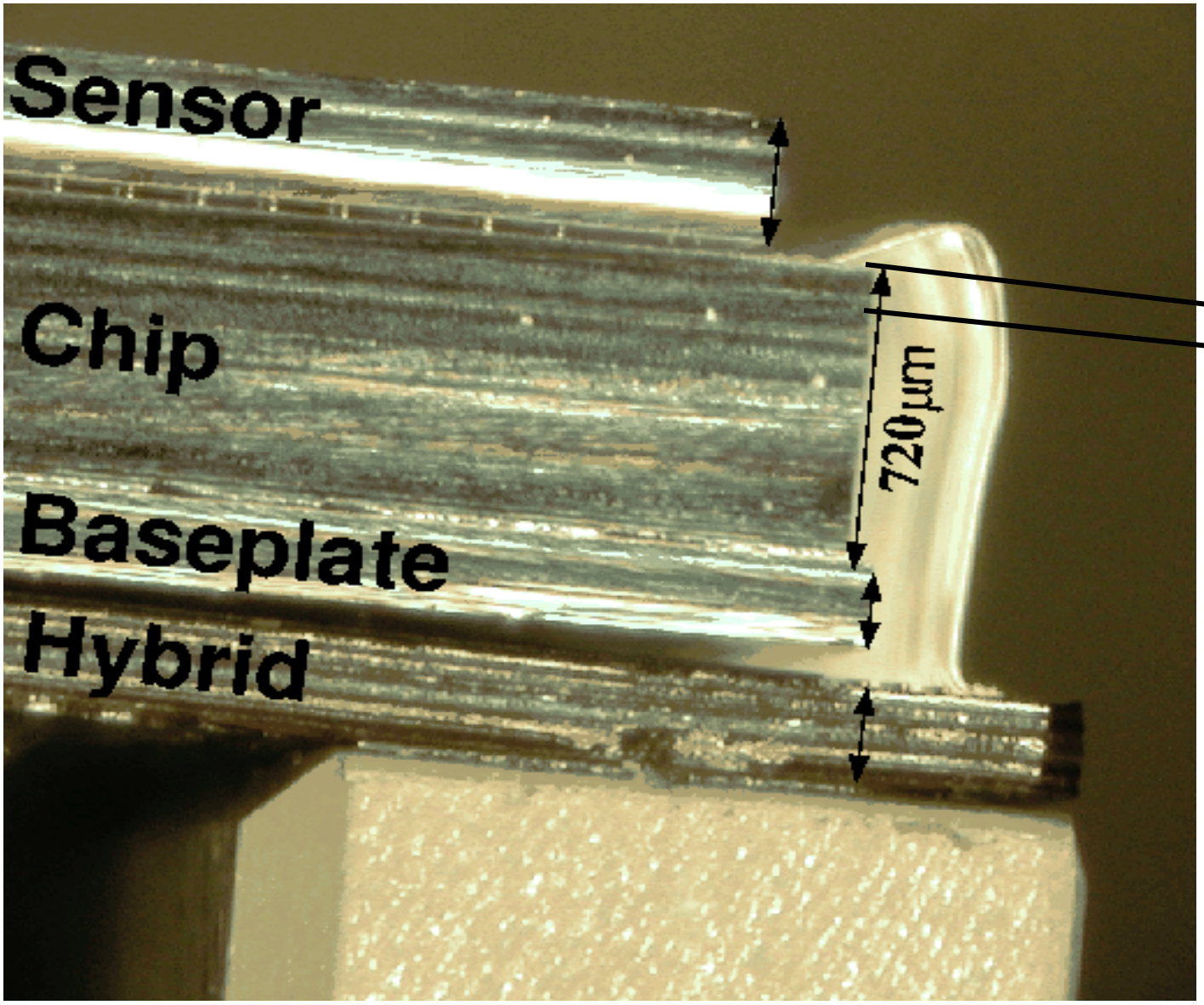


➔ Result: Sensors that are active till the edge (active edge)

Step 2: remove wire-bond region of ASIC



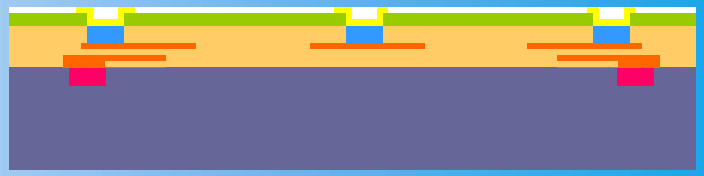
Detector tile the real thing



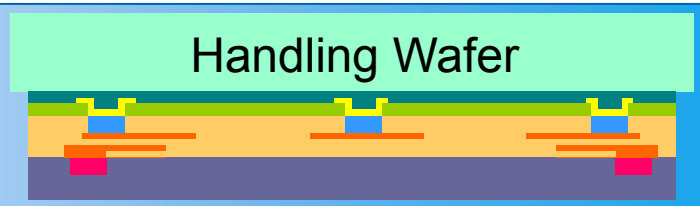
Only ~20 microns
contain circuitry
Rest is support

TSV Process (CEA-LETI with Medipix-3)

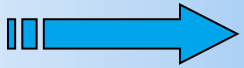
- **Front Side UBM**
  - UBM
    - TiNiAu Deposition
    - Litho UBM
    - UBM etch

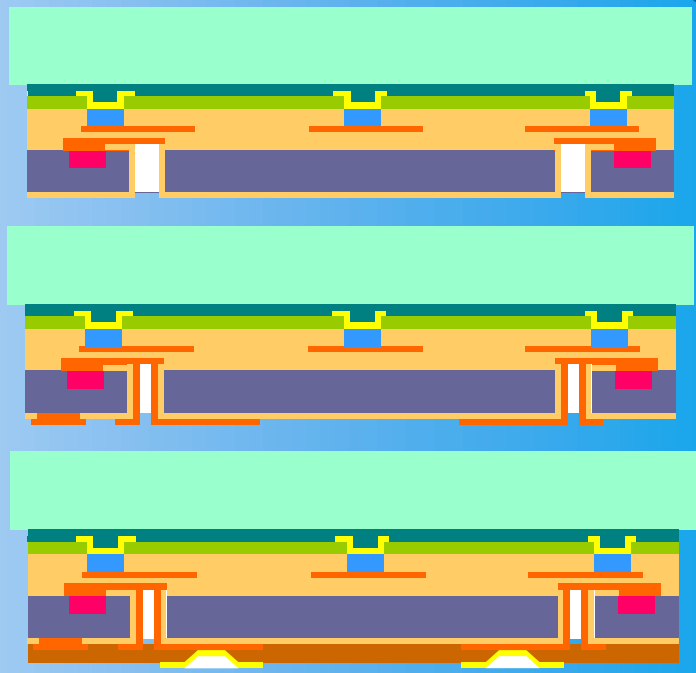


- **Bonding / Thinning**
  - Bonding
  - Grinding/edge dicing
  - CMP Si

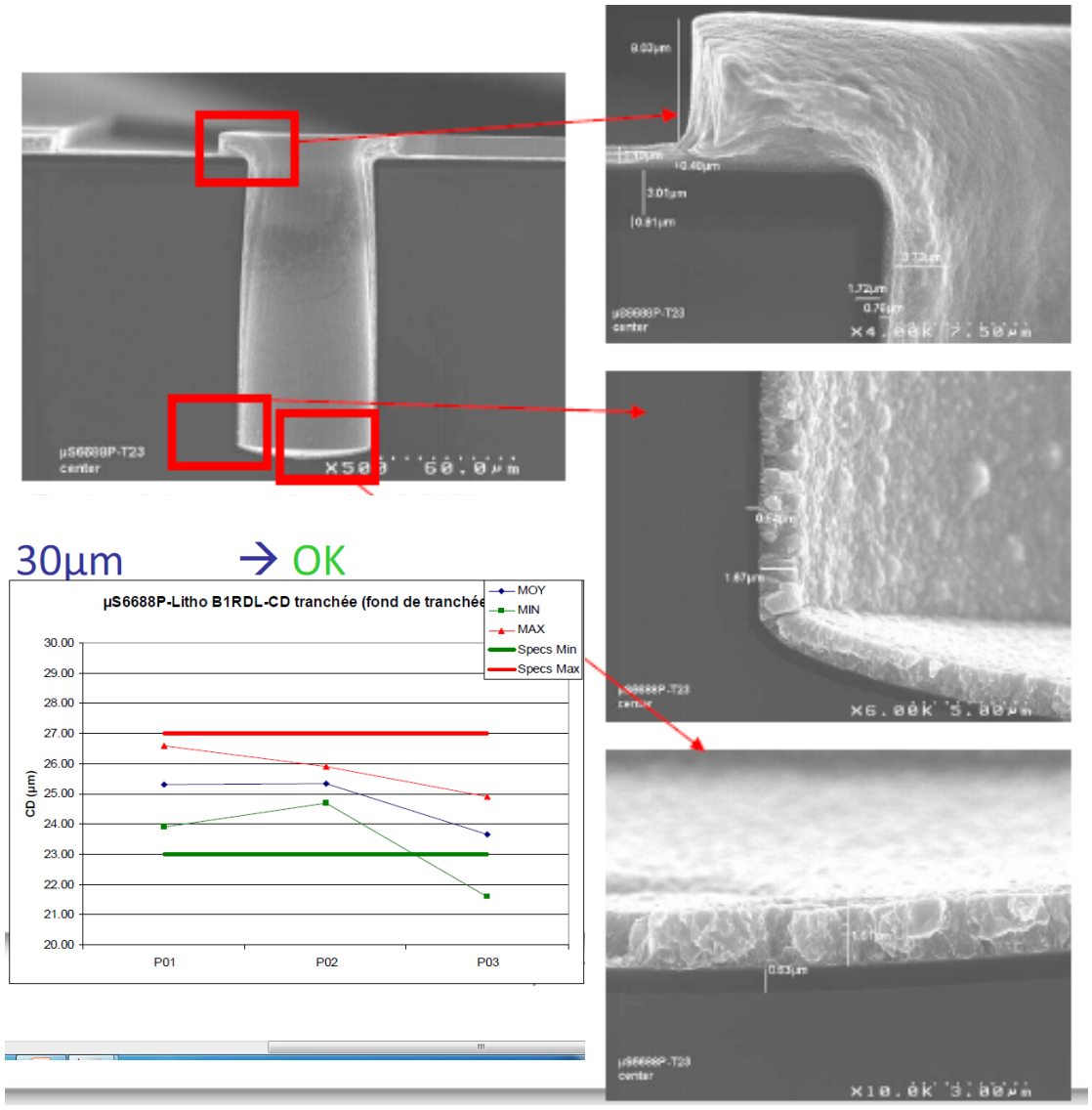


- **Back Side: TSV Last + RDL + Passivation + UBM**
  - TSV
    - Litho TSV
    - TSV AR2 etch
    - SiON conf deposition
    - Etch back
  - RDL
    - SEED TiCu
    - Litho RDL
    - ECD Cu
    - Litho PASSIV
  - UBM
    - TiNiAu deposition
    - Litho UBM
    - UBM etch
    - Debonding / Dicing

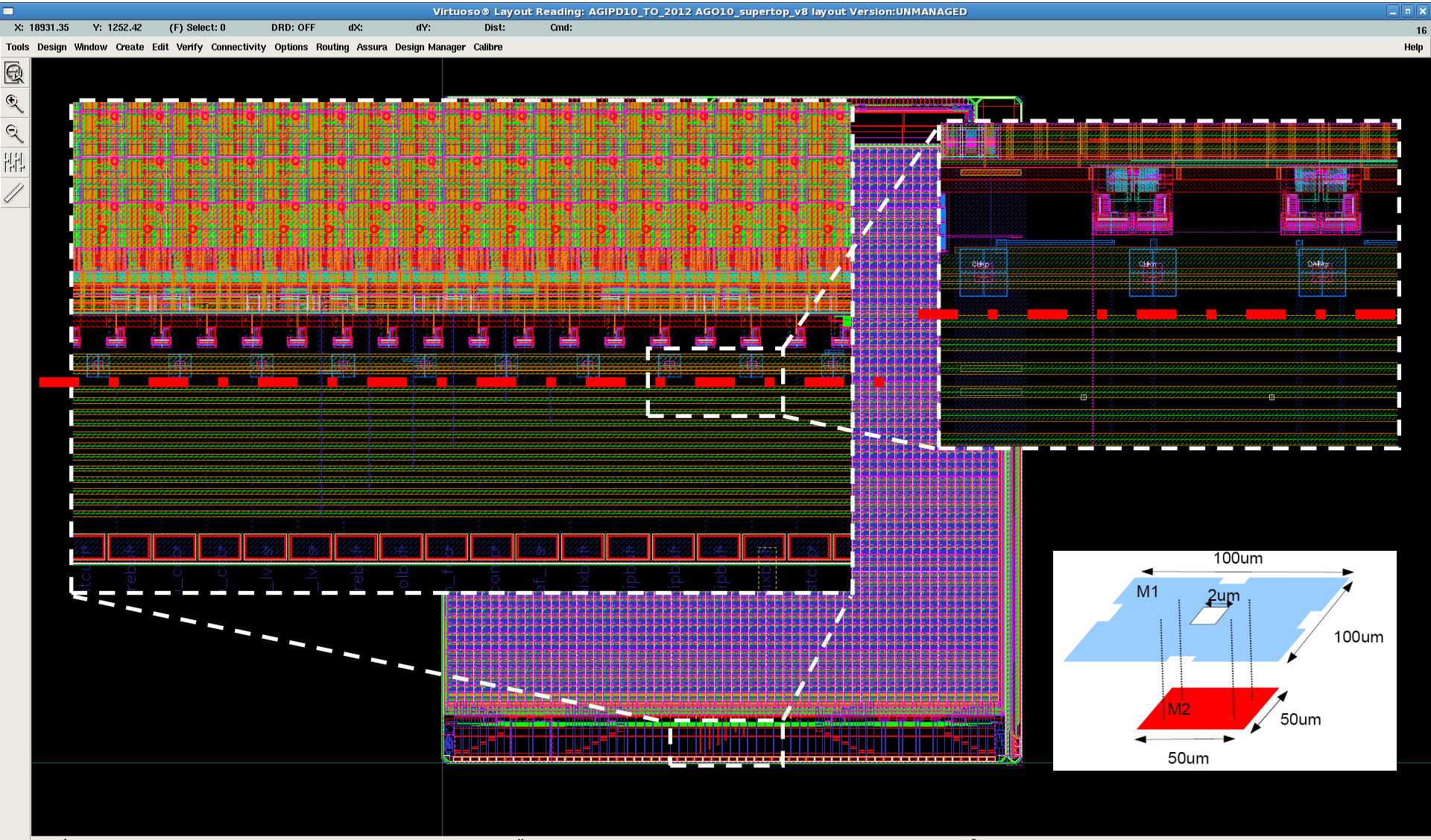




TSV Process (CEA-LETI with Medipix-3)

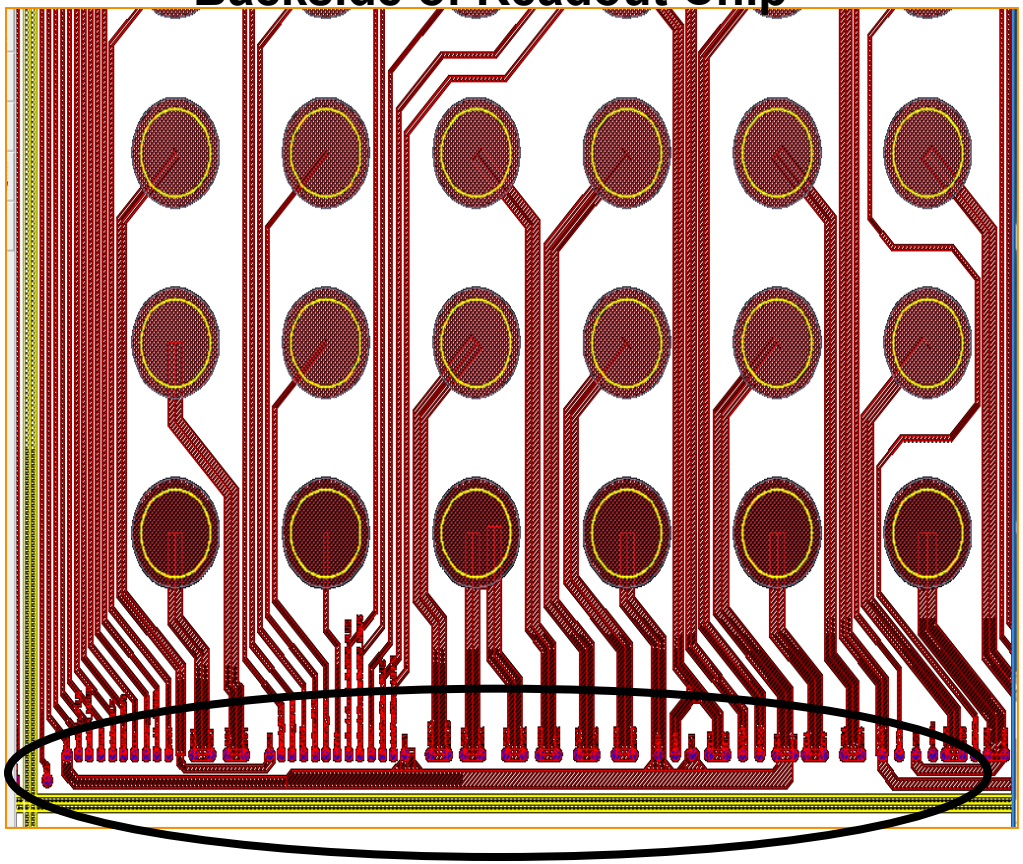


Through Silicon Vias (TSVs): AGIPD



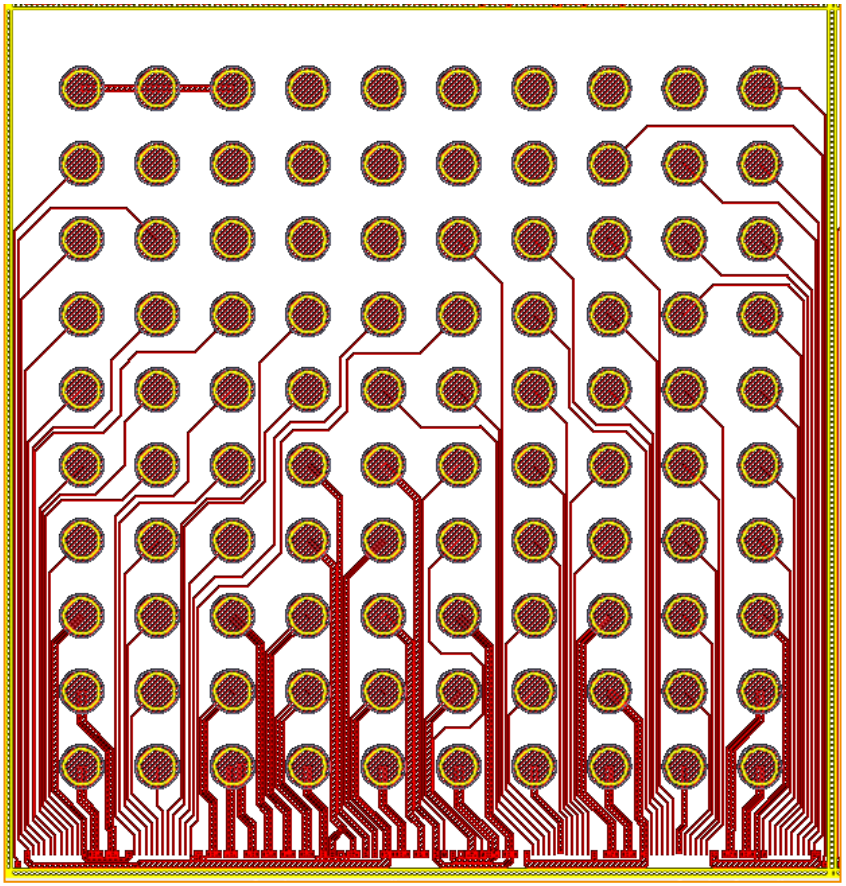
Redistribution layer ➔ Ball Grid Array (like FPGA's)

Backside of Readout Chip



TSVs

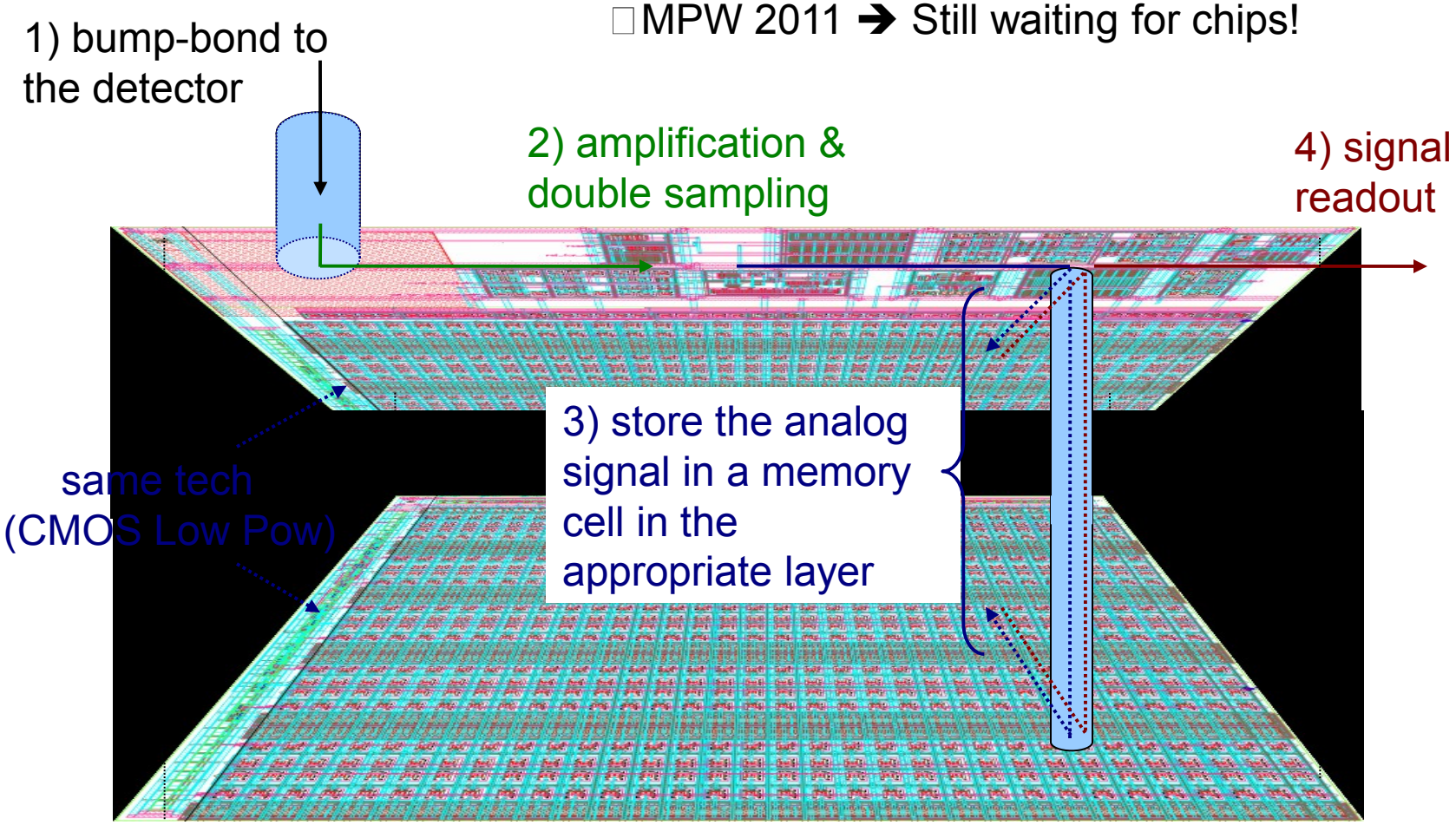
Medipix-3 chip with CEA-LETI TSVs and 10 x 10 BGA



What we really want: 2-tier ASICs

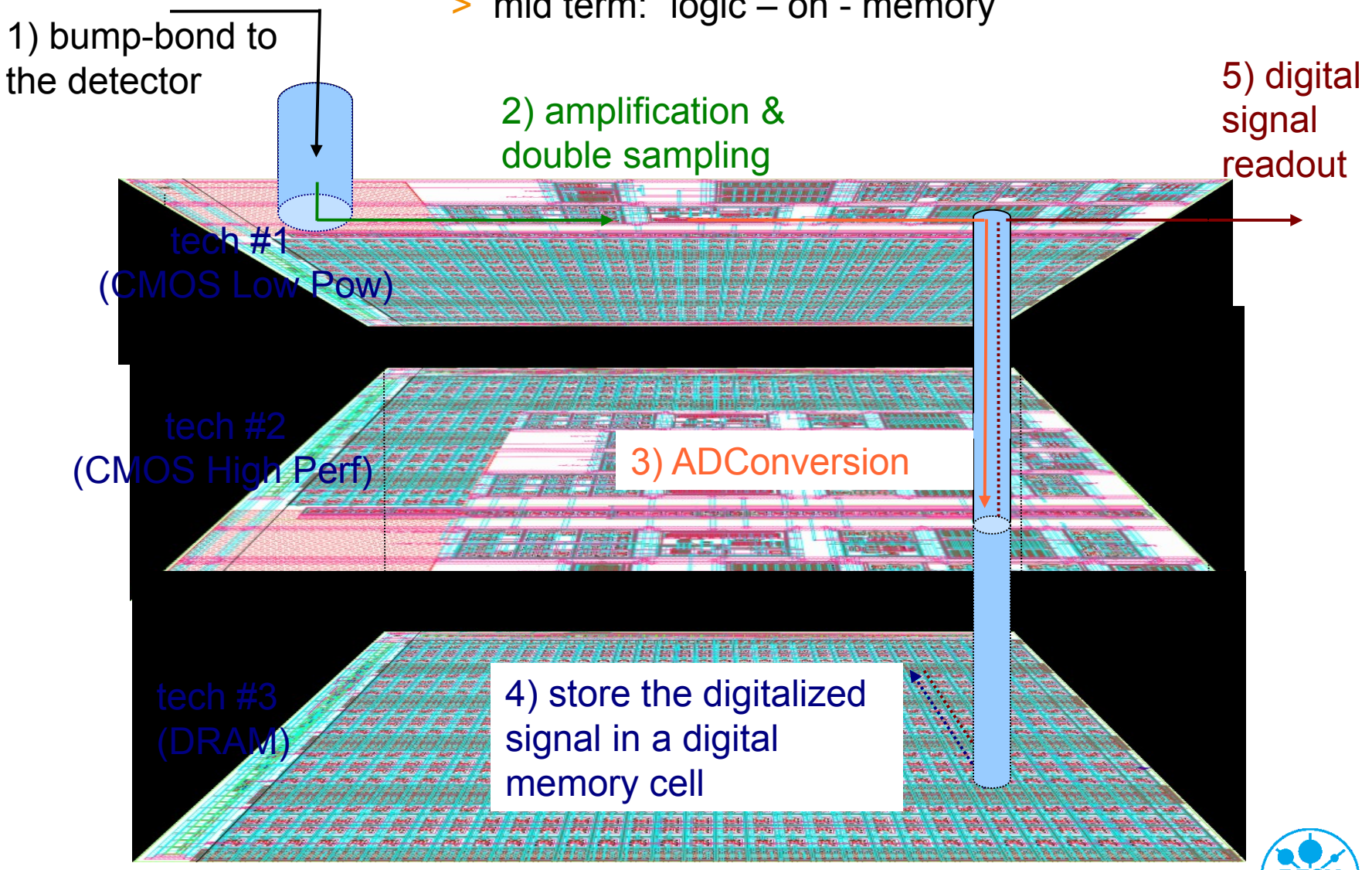
> near future: “logic – on – logic”

- MPW 2011 ➔ Still waiting for chips!



What we really want: 3-tier ASICs

> mid term: “logic – on - memory”



Summary FS-DS Activities

- Work divided between general detector support and development
- Various ongoing developments; AGIPD, LAMBDA and PERCIVAL are the main projects
- First LAMBDA modules being implemented at experiments
- AGIPD progressing well; getting into realization phase
- PERCIVAL progressing well; increasing interest
- All developments are collaborations
- Need for support to experimental stations will increase
- Data rates will have impact on IT infrastructure