Overview of Pillar-1: Technology

Detector Portfolio General Assembly meeting

19-21 November 2012; Karlsruhe

Heinz Graafsma (DESY) / Michael Fiederle (KIT)

HELMHOLTZ ASSOCIATION

DESY

Pillar-1

Reminder of Structure:

- WP-1: 3D-ASICs
- WP-2: 2D-Mixed signal ASICs
- WP-3: High-Z and edgeless sensors
- WP-4: Packaging
- WP-5 Advanced Materials

Meetings:

- Portfolio Kick-off Meeting in Karlsruhe: **21+22 Feb 2012**
- Face-to-face meeting Pillar-1: **13+14 June 2012** in Hamburg
- Face-to-face meeting WP-1 & WP-2 (ASICs) **10+11 Oct 2012** in Heidelberg (increased participation and interest of Universities)

3D-ASICs: technology at a glance (U.Trunk / DESY)

GLOBALFOUNDRIES

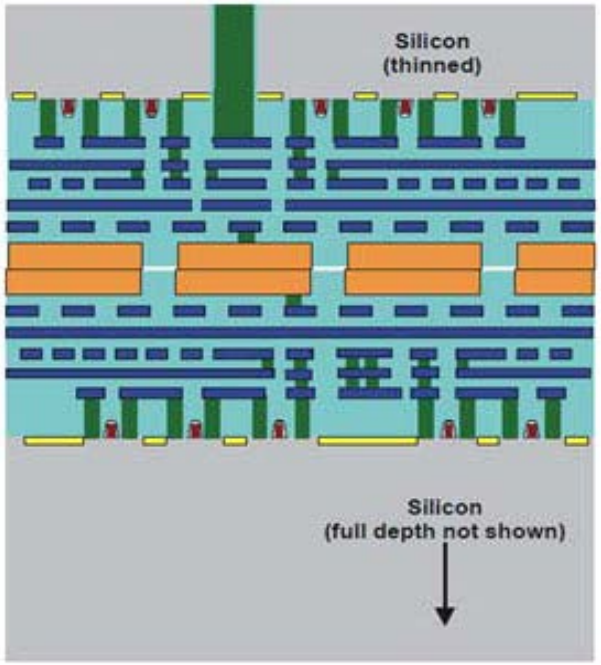
based on GF 130nm CMOS Low Power

1.5 V core, 3.3V IO

including ARM-provided SC library

1 poly, 5+1 metals per Tier

(Metal 6 is used as bond interface)



Tezzaron SEMICONDUCTOR

FaStack

2 tiers, Face-to-Face coupling

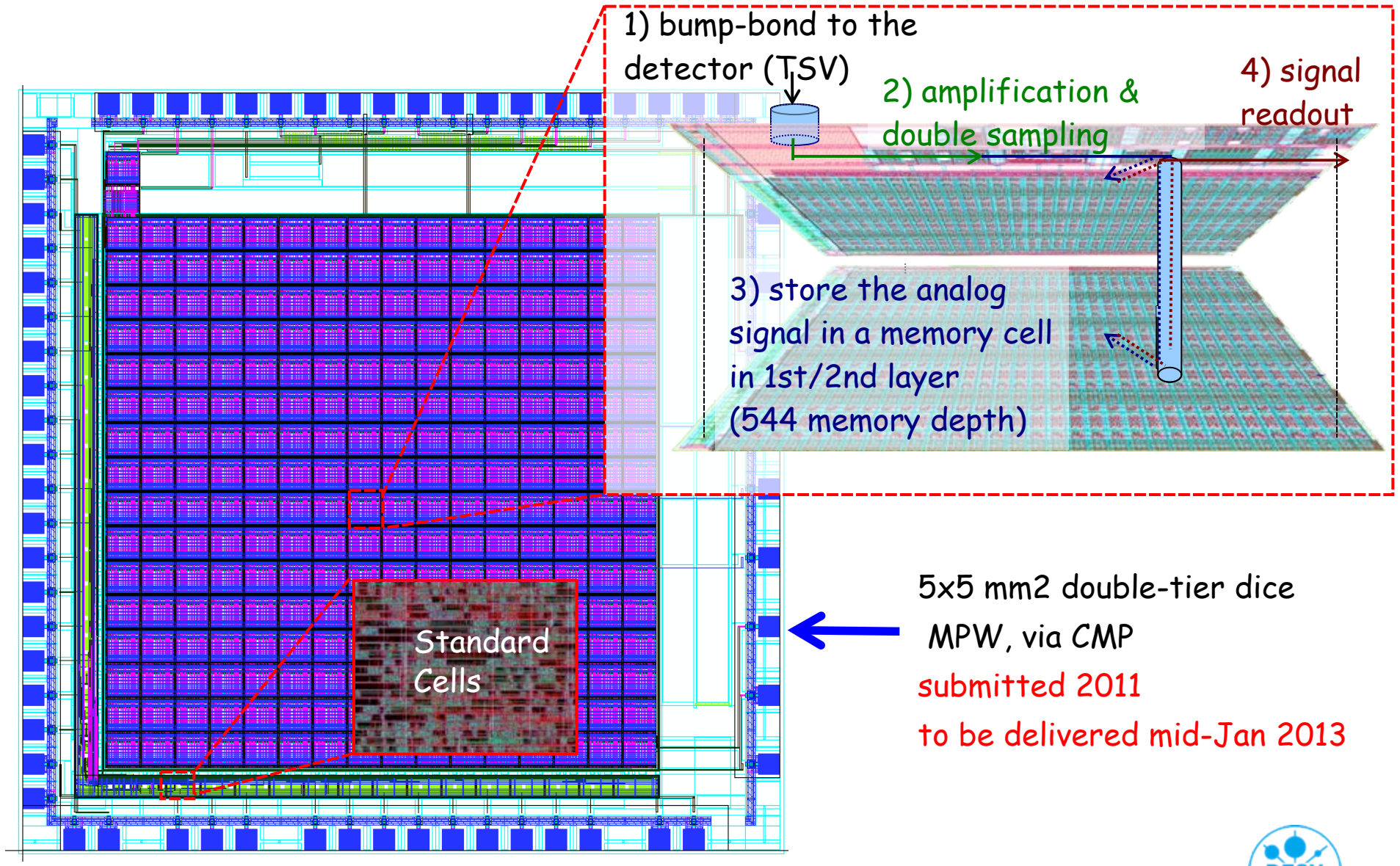
"Via-middle process" (TSVs etched before BEOL)

Cu-Cu bonding (both for mechanical and electrical contact)

upper tier thinned down ~ 6um ; whole stack has ~ordinary wafer thickness

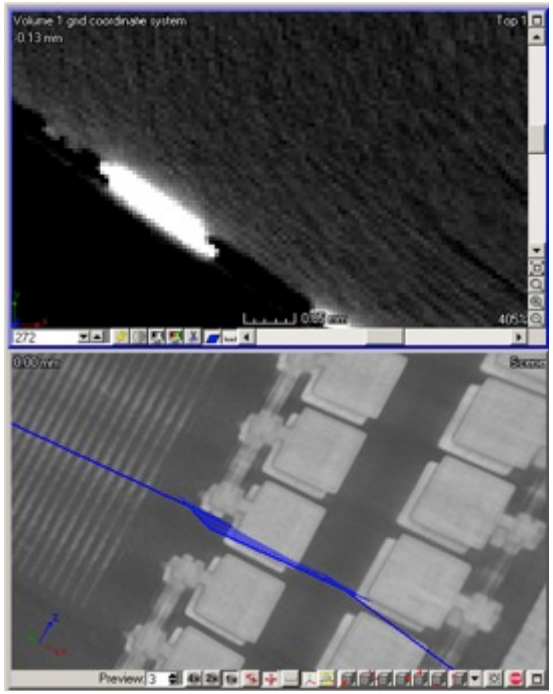
DESY

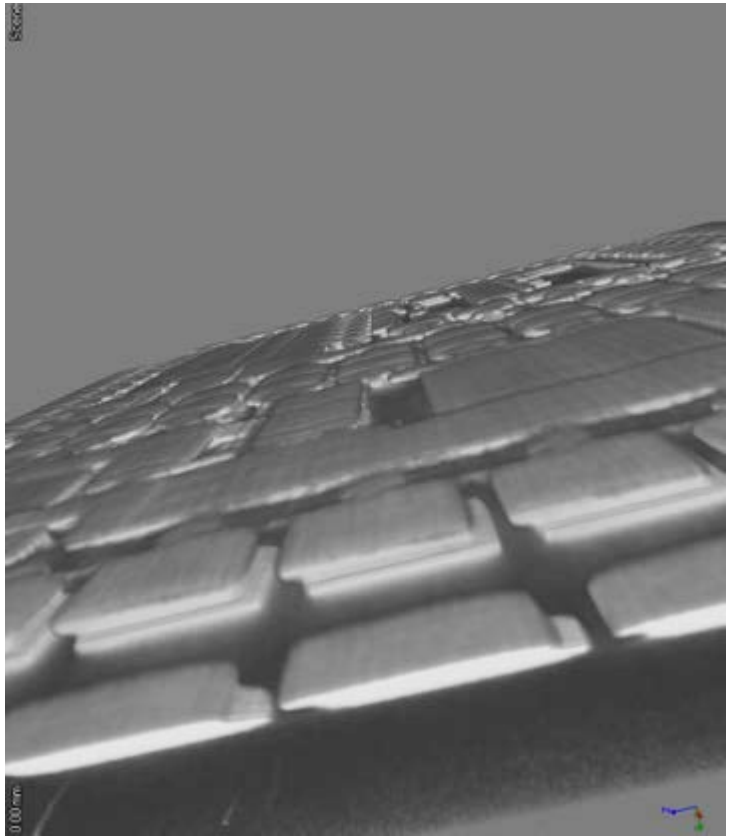
3D ASIC submission: an AGIPD evolution hypothesis

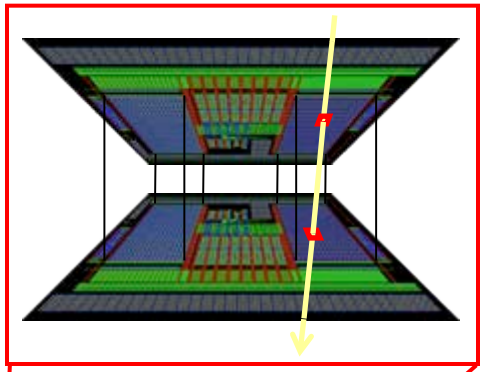


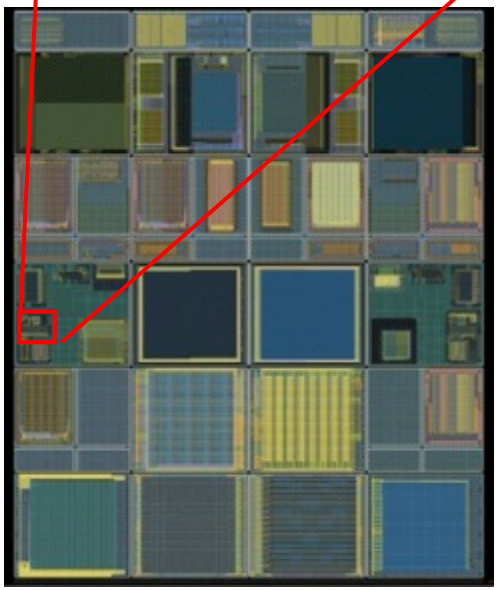
5x5 mm2 double-tier dice
MPW, via CMP
submitted 2011
to be delivered mid-Jan 2013

3D-ASICs X-ray tomography on an “inherited” project









M^{3}APS
MPW, via CMP
submitted end 2009
delivered 2011 & 2012
(courtesy of INFN-Perugia)

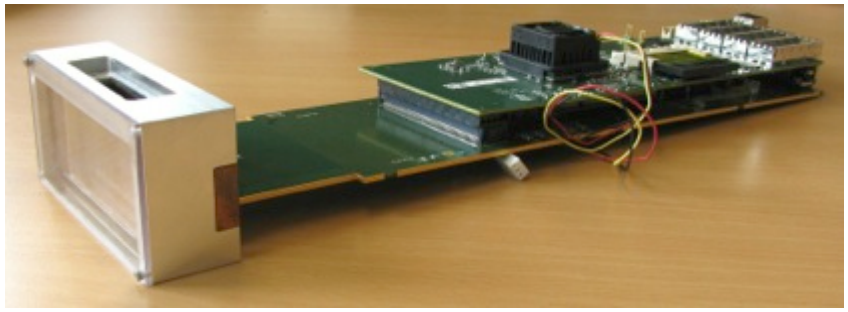
2D-ASICs: Important decisions (C. Schmitt / GSI)

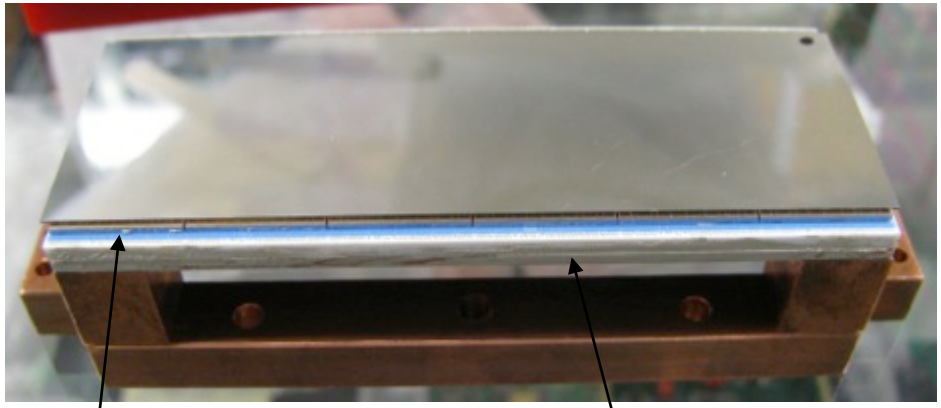
During the face-to-face meeting of the ASIC designer in Heidelberg; it was decided:

- to investigate the possibility to use TSMC 65 nm (low power) as the common technology.
- to create a repository/library of building blocks in order to share designs amongst Helmholtz centers (hosted by DESY).
- to design a common analogue-digital readout chip, that will also be used as a vehicle for evolution towards 3D-integration (using Through Silicon Vias; TSV).
- to consider to create a full-chip simulation tool (together with universities).
- To hold the next face-to-face meeting in January 2013 to decide on the mixed-signal readout chip to be designed.

First version of the Helmholtz-Cube ready!

- 6 by 2 chips (1536 by 512 pixels)
  - Large Si sensor from 6” wafer
    - 300µm Si sensor here
  - 2 x “Hexa” high-Z sensors
- Ceramic circuit board (LTCC)
  - 14 layer board
  - Good match to germanium CTE
  - Cooling through thermal vias
- 500-pin connector on board
  - Full parallel readout (8 LVDS data outputs per chip)
  - ~150 LVDS pairs total





6 x 2 Medipix3 chips

LTCC board

High-speed readout system

- Previously developed prototype system (USB2 readout only)
- High-speed readout with common DESY mezzanine card
  - Virtex-5 FPGA with PowerPC
  - 4 * 10 Gigabit Ethernet links
  - DDR2 RAM (8GB)
- “Signal distribution” board connects to det. head
  - Space for vacuum barrier with germanium detector
- Currently working on high-speed readout firmware

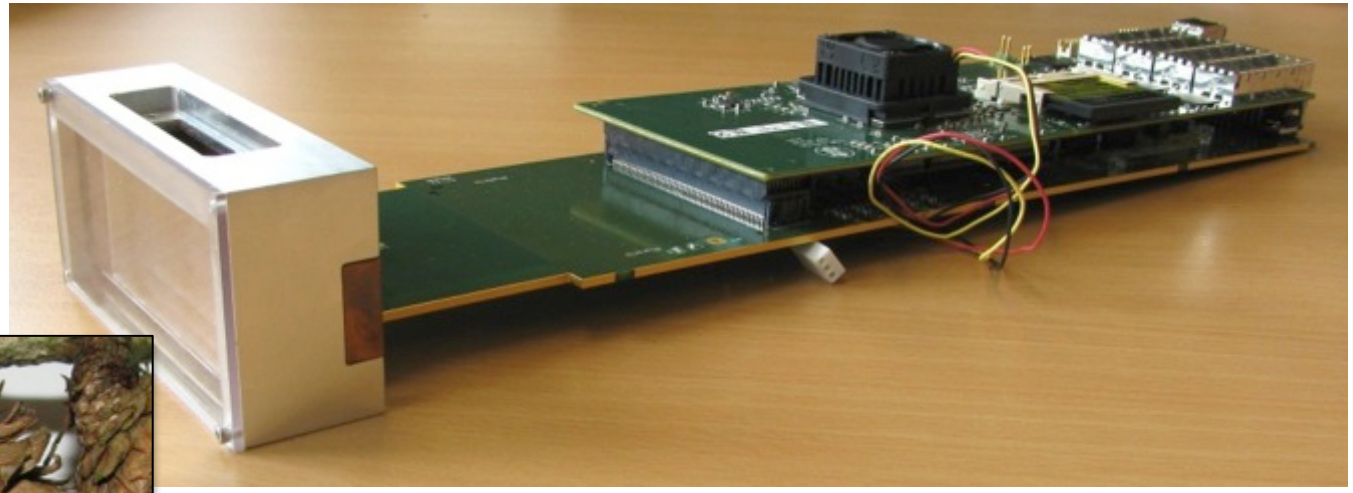
10GBE links

Connector to det. head

Power / trigger in

Test results with Si module

- First full Si module assembled (300µm thick sensor from Canberra)
  - Solder bonding at IZM
  - All 12 chips successfully bonded and functional
  - Small no. of bad pixels on chips and bad bumps on test module



Flat-field corrected image, Mo X-ray tube, 40kV

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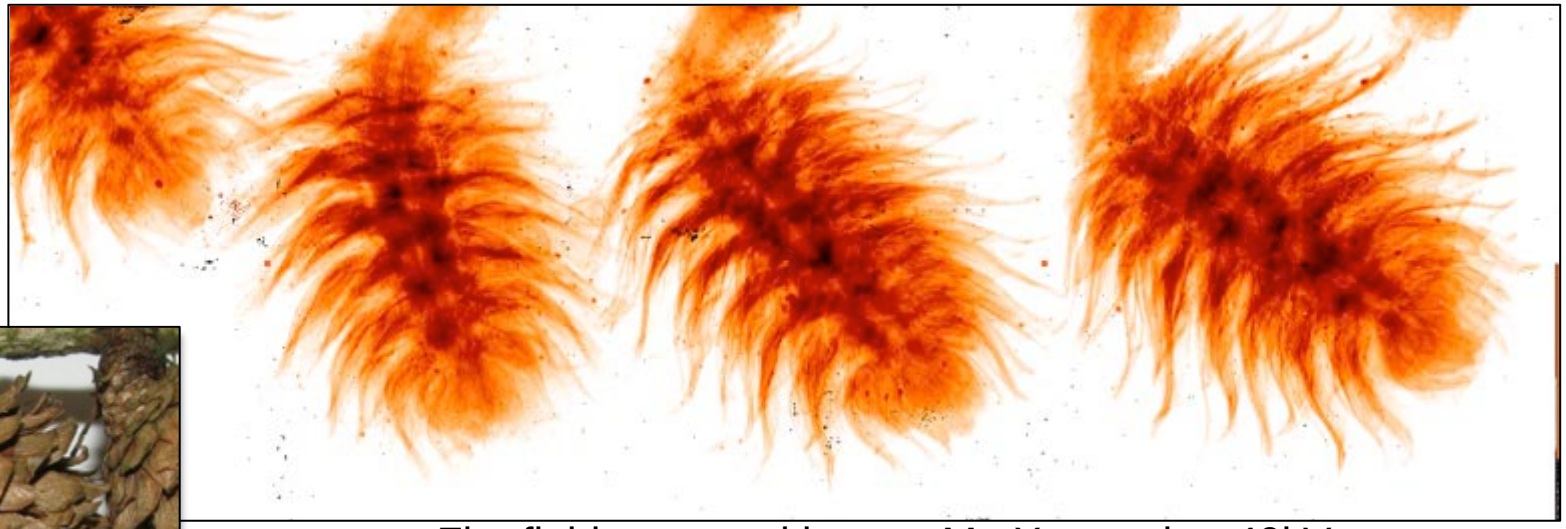


Flat-field corrected image, Mo X-ray tube, 40kV

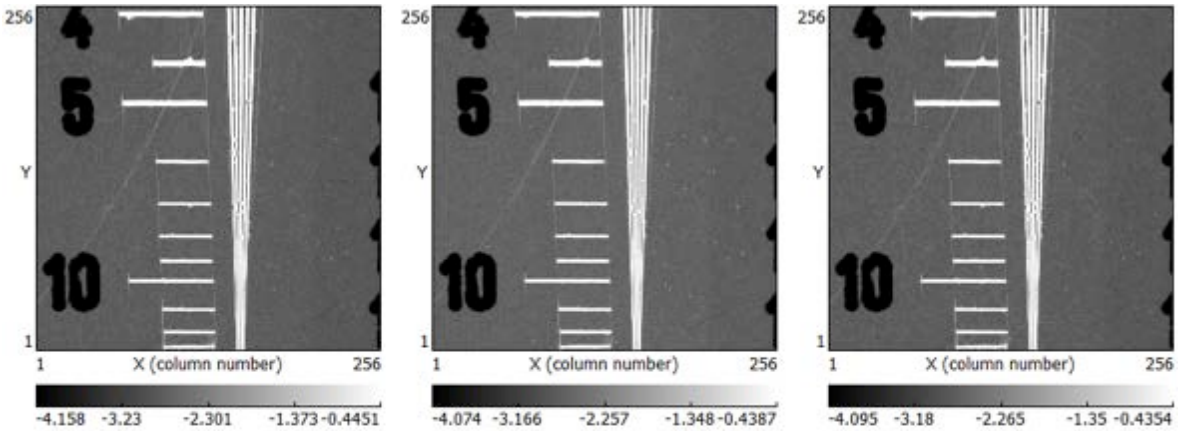
One system delivered to KIT for hybridization with CdTe

High-Z development (M. Fiederle / KIT-FMF)

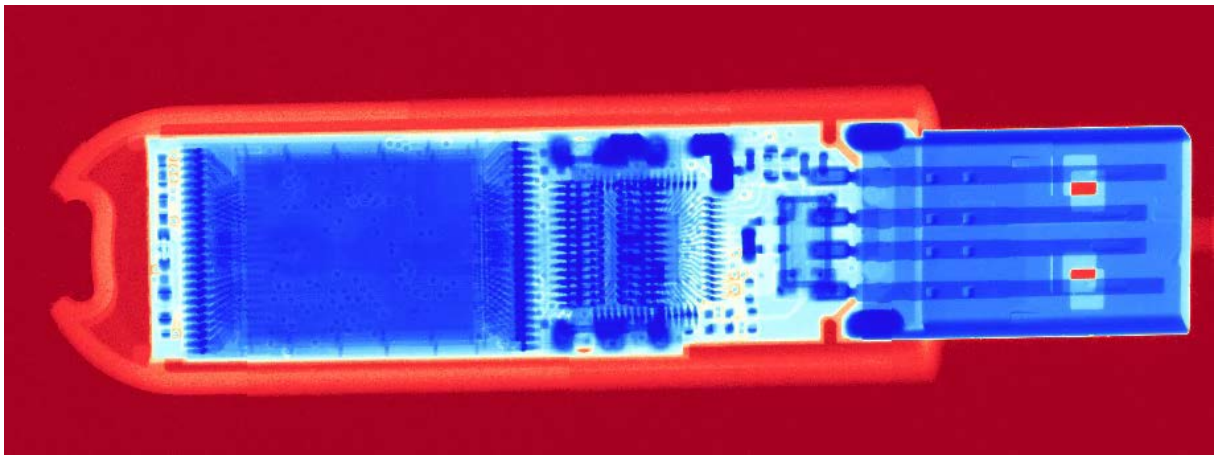
- Processing of High-Z semiconductors: CdTe and GaAs
- Development of monolithic sensors with 165 / 110 / 55 µm pixels
- Active area 28 x 43 mm^2 => maximum size of available material
- Tasks:
  - Wafer level: metallization, passivation, UBM, bump deposition, dicing
  - Sensor level: flip-chip bonding, assembling, wire bonding
- Photon Counting Chip: Medipix3 – Version 3RX (latest):
  - Full functionality: Single Pixel Mode SPM, Charge Summing Mode CPM, Color Mode with Super Pixels 110 µm => 8 (eight) energy tresholds
- First assemblies: CdTe 3RX 55 µm and CdTe 3RX 110 µm

High-Z development (M. Fiederle / KIT-FMF)

> X-ray images with CdTe 55 µm 3RX: **lowest energy < 3keV**

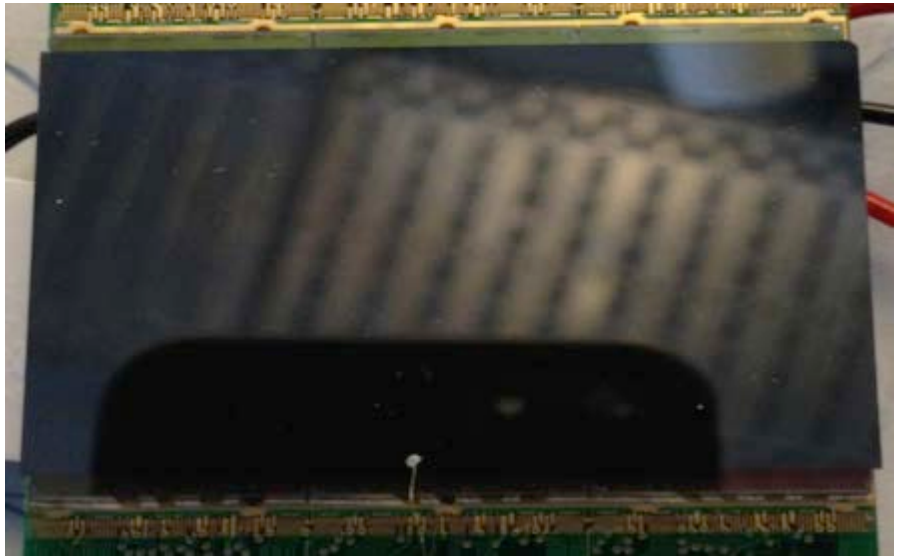


> X-ray images with CdTe 110 µm 3RX:



High-Z development (M. Fiederle / KIT-FMF)

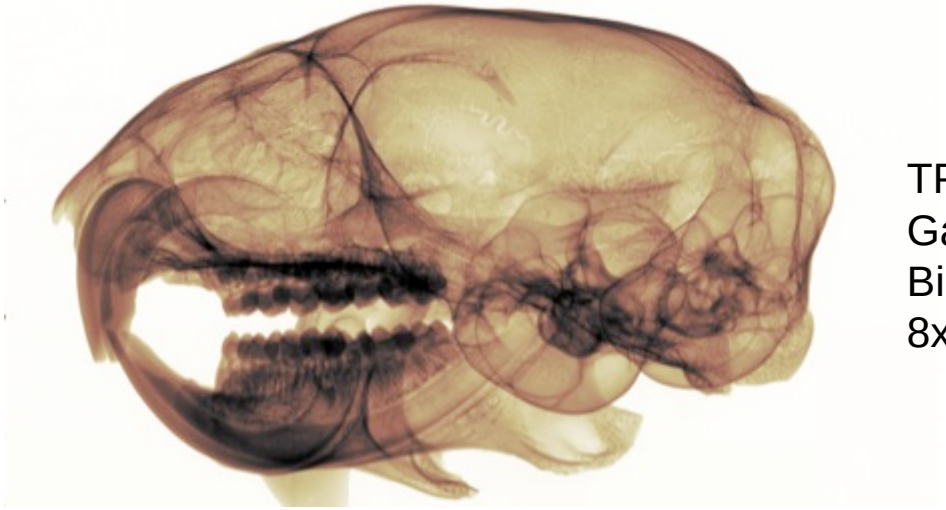
- CdTe Hexa 28x43 mm^2 with Medipix 3RX



- Assembling on HGF-Cube boards:
  - One hexa in the first step
  - Adjustment of back-side contact (gold wire glued to CdTe)
  - Tests in the next two weeks
  - First Cube with one Hexa in December 2012

High-Z development (M. Fiederle / KIT-FMF)

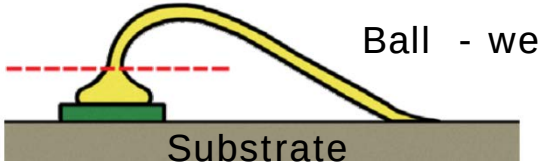
- GaAs Medipix2/3 assemblies: good performance for energies < 40 keV
- GaAs assemblies processed by FMF (first Hexa 1Q 2013)



TPX 55µm
GaAs 500µm
Bias: -230V
8x5 tiles, width 34mm

- 3D sensors structures:
  - Medipix3 layout in collaboration with CNM Barcelona
  - Silicon assemblies with 55 and 110 µm pixels in 2Q 2013
  - Experiments with GaAs and CdTe in 2014

Packaging (Th. Blank /IPE/KIT)

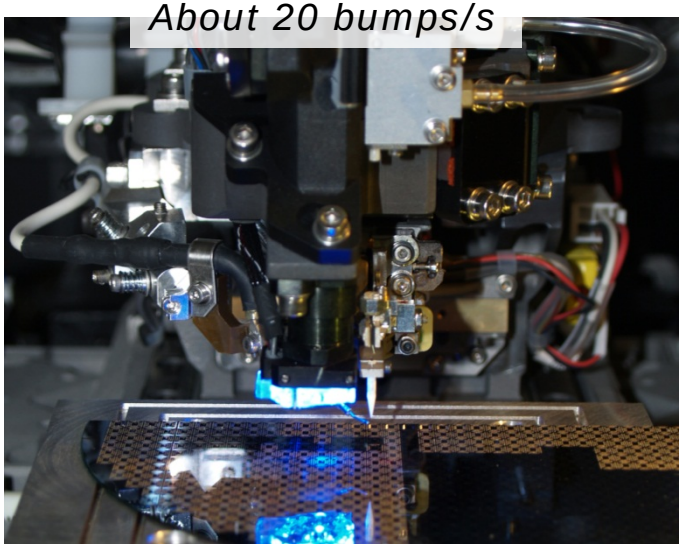


Ball - wedge gold wire bonding

The wire is snapped off after the ball is initially connected to the die

No UBM is required
No chemical process

About 20 bumps/s



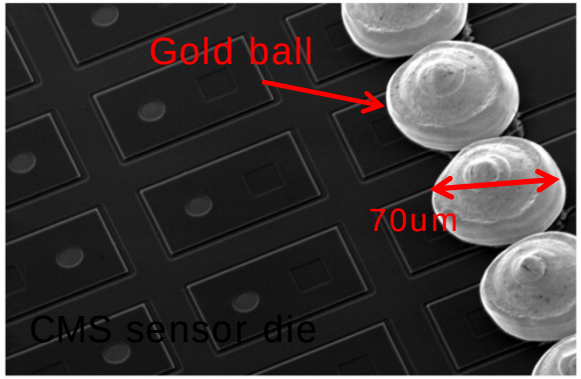
Wire Diameter	Capillary	Bump diameter
30um	Standard	67um
15um	414FE-S108-R35 414FF-V208-R33	37 um
12.5um (Tanaka)	PI-15038-181F- ZP34T	25um

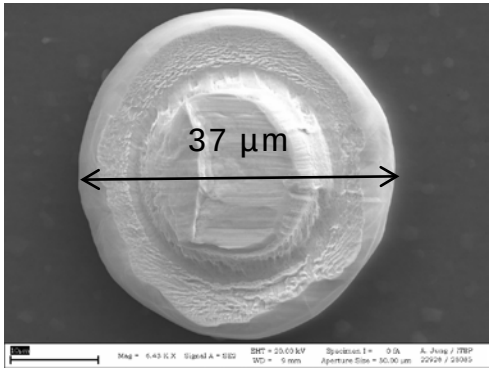
Bump diameter comparable with the traditional bump-bonding processes

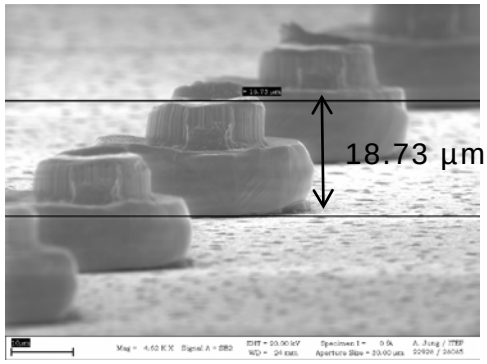
Packaging (Th. Blank /IPE/KIT)

First results...

- Sensor wafer: FZ200N-W4 (*new*)
- Gold wire diameter 30 um & standard capillary





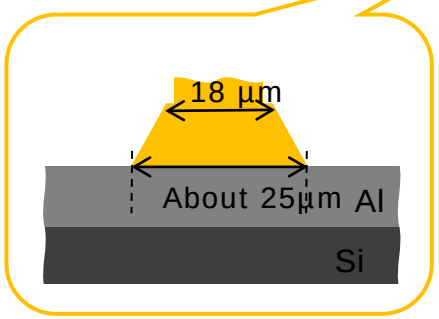


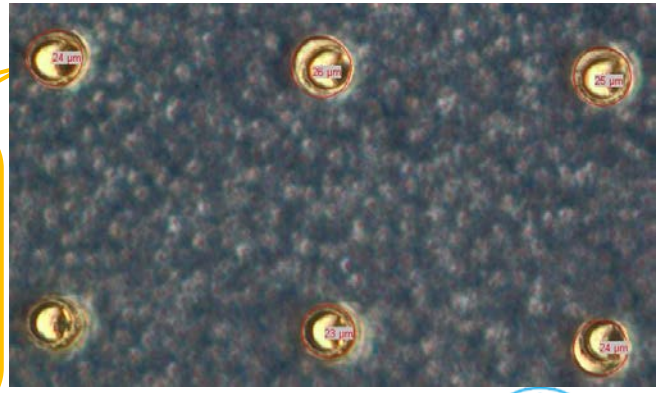
First small gold bumps ...

- 15µm diameter gold wire
- Shear test (mean) = 8.54 ± 1.12 gr/bump

Preliminary results (12.5um wire)

- **Bump diameter 25um**
- Shear test → on-going





Packaging (Th. Blank /IPE/KIT)

> Infrastructure

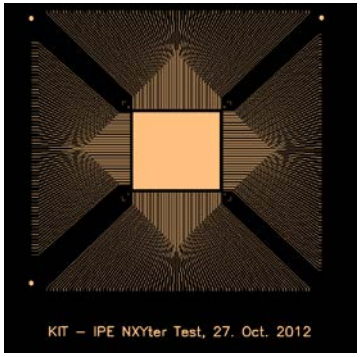
Installation of ISO 6 (Class 1000) Clean Room Area for FC-Processes at the end of December

Flip-chip Bonding process in IPE

Finetech's automated fineplacer FEMTO

- ✓ accuracy < 1 µm
- ✓ Wide-range of the bonding parameters:
- ✓ Several metals bumps (SnPb, In, SAC, gold, ..)
- ✓ Heating chamber with formic-acid atmophere for bumps reflow

- FC-bonding machine ordered, will be installed at the end of this year



Evaluation of Screen & Stencil Printing Processes

- 50µm Lines/ 50 µm Space on Al2O3

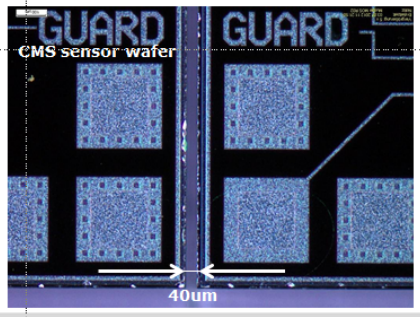
Wafer dicing process @ KIT-IPE

Wafer dicing machine DAD 320

Maximum wafer size: 6 inch (15.2 cm)

Maximum Spindle Speed: 40.000 RPM

Wide available Disco Diamond Blades: silicon, GaAs, GaP, LiTaO3, glass, quartz, crystal, ceramics, etc.



Under investigation an blade upgrade:

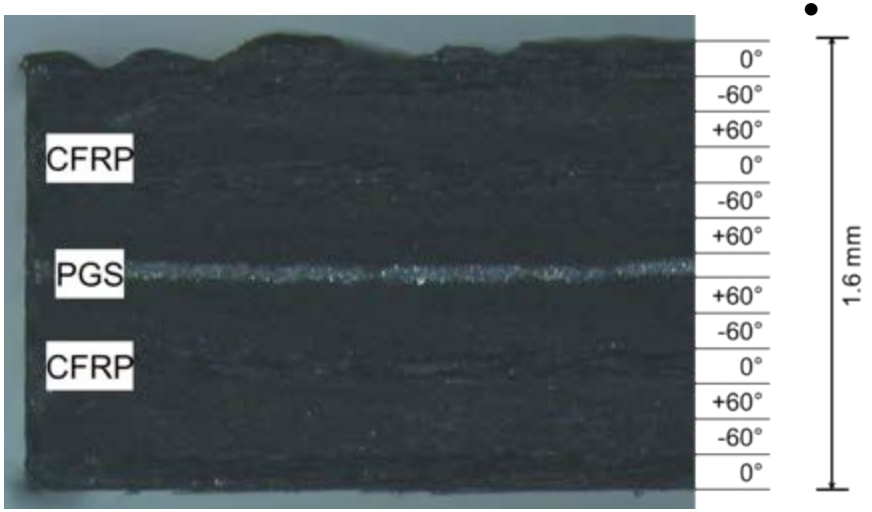
-> cut in the range of 30um
-> reduction of the scratch area

Advanced Materials (A. Mussgiller / DESY)

Special requirement from particle physics: light weight detectors

- Minimize multiple scattering for increased precision
- Good thermal conductivity
- Good dimensional stability

Example: high-tech foil for mechanical stability combined with excellent thermal conductivity.



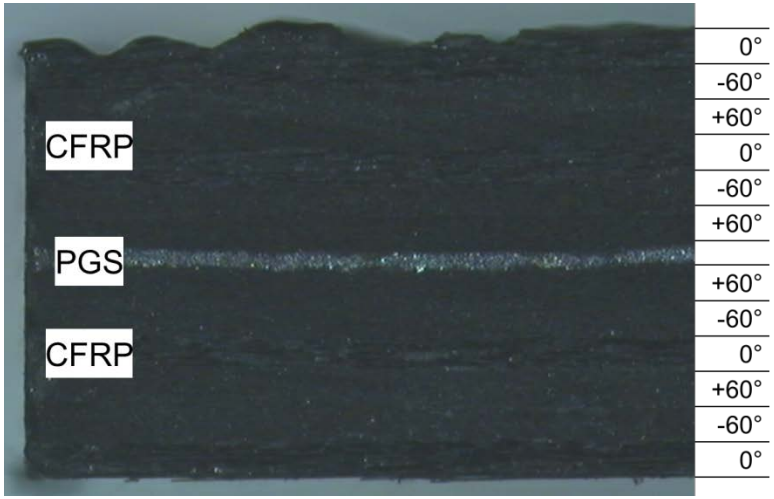
- graphite foil laminated into carbon fibre (CFRP) structure
  - pyrolytic graphite sheet (PGS) has very high thermal conductivity (~700 W/m/K)
  - adhesive bonding PGS sheets to structural elements is challenging
    - shear stress could result in delamination either at glue to foil interface or inside foil

Advanced Materials (A. Mussgiller / DESY)

Special requirement from particle physics: light weight detectors

- Minimize multiple scattering for increased precision
- Good thermal conductivity
- Good dimensional stability

Example: carbon fibre laminate for mechanical stability combined with foil with excellent thermal conductivity.



- graphite foil laminated into carbon fibre (CFRP) structure
- pyrolytic graphite sheet (PGS) has very high in-plane thermal conductivity (~700 W/m/K)
- adhesive bonding PGS sheets to structural elements is challenging
- shear stress could result in delamination either at glue to foil interface or inside foil
- thermal and mechanical characteristics of samples will be tested
- effect of irradiation will be investigated

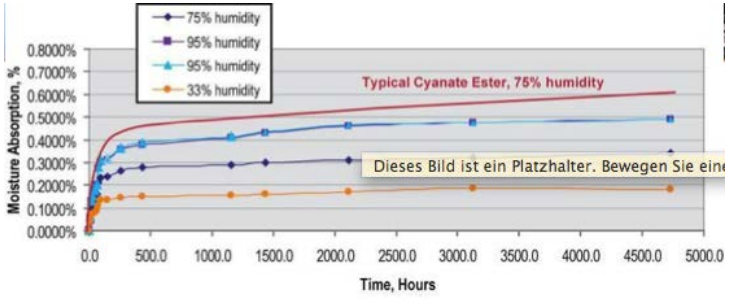
Advanced Materials (A. Mussgiller / DESY)

> Market survey produced a few promising material solutions for HEP

- foams, carbon fibres and resin systems, and glues

> e.g. novel resin system by TenCate

- on the market since 2008 - the standard in satellite structures
- low moisture uptake
- radiation tolerance will be tested
- details will be discussed during this meeting



> PhD position at DESY has been advertised

- next interviews scheduled for early December
- hope to fill position by February

What is next?

- Hybridization of CdTe to current HGF-Cube.
- Distribute more HGF-cubes to centers for testing.
- Come to decisions on ASIC:
  - Common technology; joint readout ASIC; simulation package
- Discuss whether to merge WP-1/3D-asic and mixed WP-2/mixed signal ASIC (discuss in Pillar meeting; decide in EB-meeting).
- See how WP-4/packaging can contribute to next version of HGF-cube. Increase interaction between WP-4 and WP-1,2,3.
- Discuss with Pillar-2 if/how to integrate high-speed I/O into HGF-cube.