Studies on **M**ulti **C**hip **M**odule – **D**eposited Connection Structures

PIXEL 2002
International Workshop on Semiconductor Pixel Detectors For Particles and X-Rays
Carmel Mission Inn Carmel, California, USA
9-12 September 2002

Peter Gerlach

representing

Christian Grah

University of Wuppertal

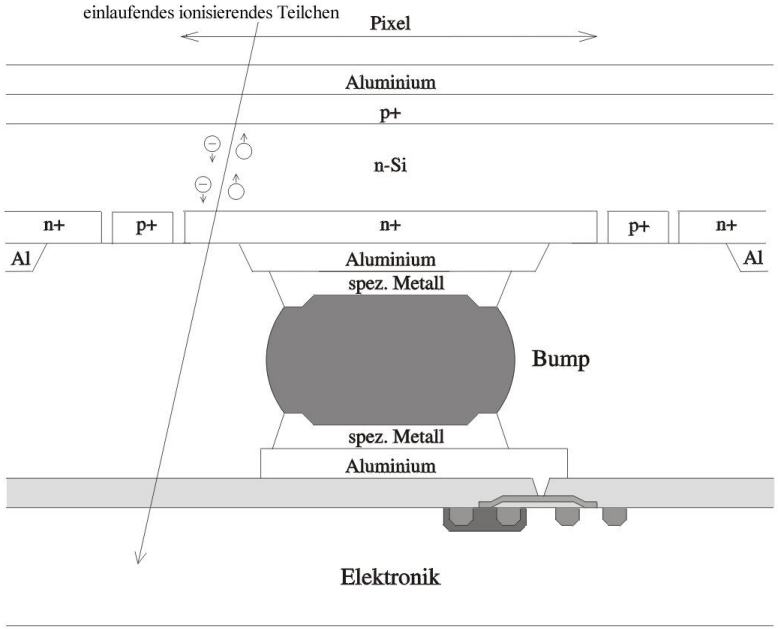
ATLAS Pixel Detector Collaboration

IZM

Contents

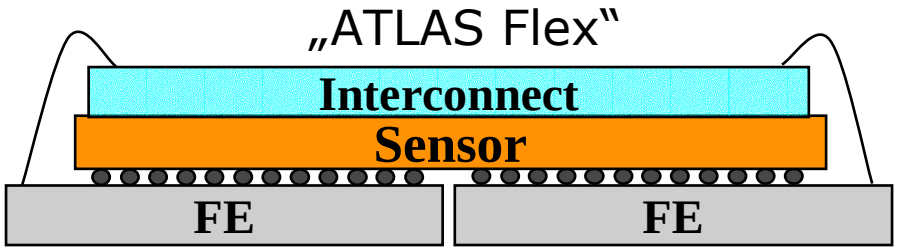
- Idea to build monolithic hybrid pixel detector modules
- MCM-D Technology
- How to realise “equal-sized-bricked” sensors
- Test of hybrids with implemented routing
- First measurements on equal-sized-bricked single-chip hybrids
  - electric
  - Test beam
- Conclusion

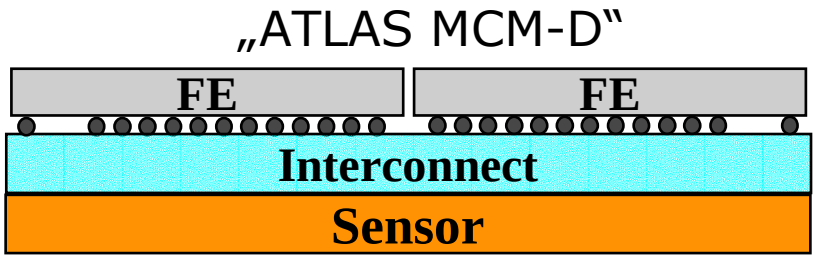
Concept of hybrid pixel-detectors



The concept of a *hybrid pixel detector* requires three parts:

- Sensor
- Electronics
- Interconnect





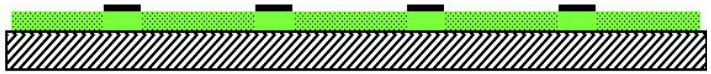
Interconnect includes:

- Bump Bonding
- *Intra Module Connection*

MCM-D Process-Flow

a)

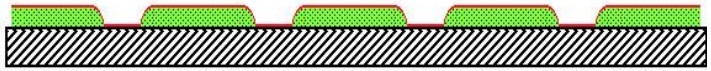
spin on BCB

b) 

expose through mask

c)

develop and **wash away** non-exposed BCB
cure exposed BCB

d) 

sputter copper galvanic seed

e)

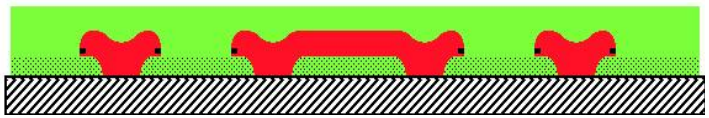
spin on and pattern photo-resist

f)

galvanic growth of copper layer

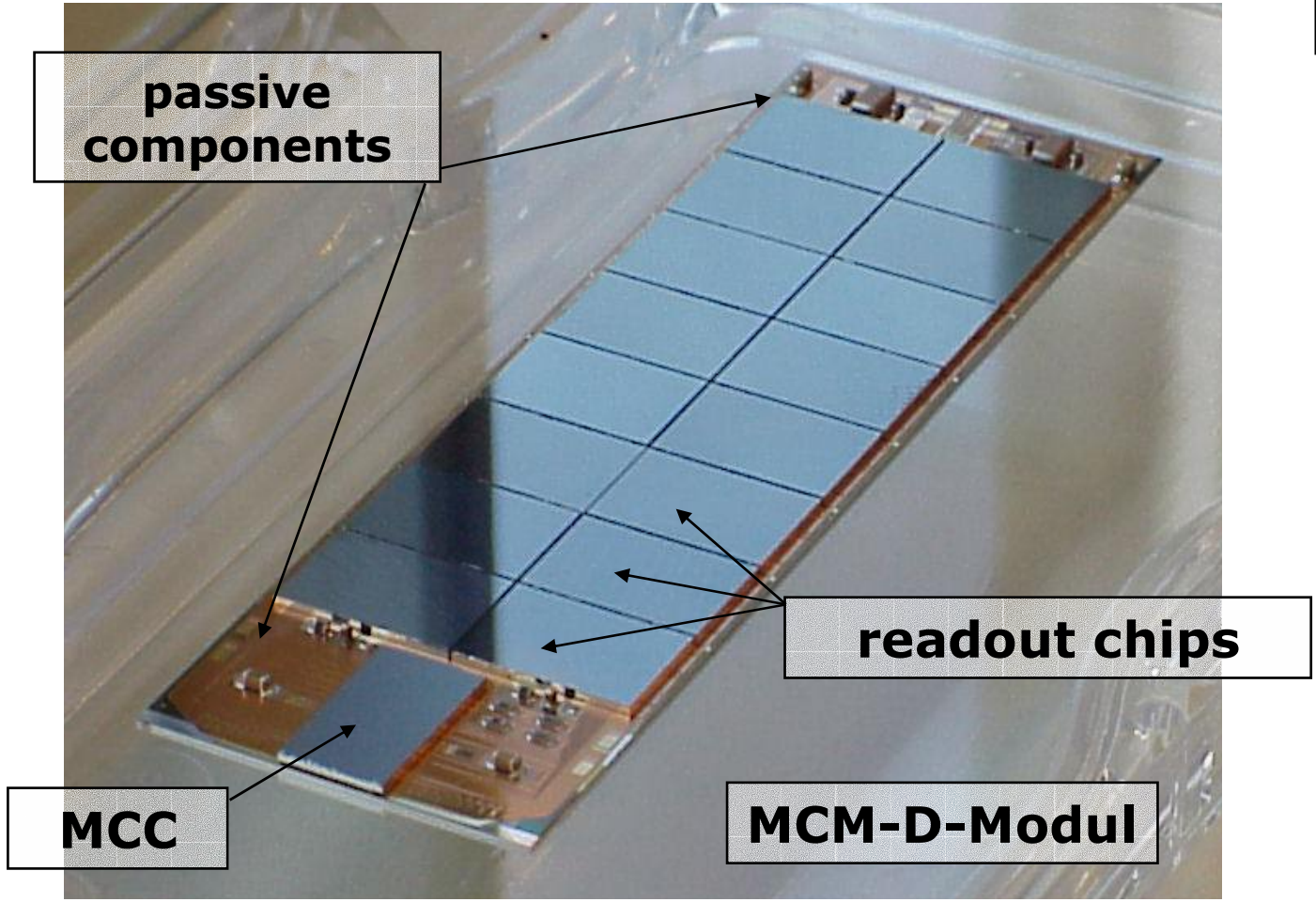
g)

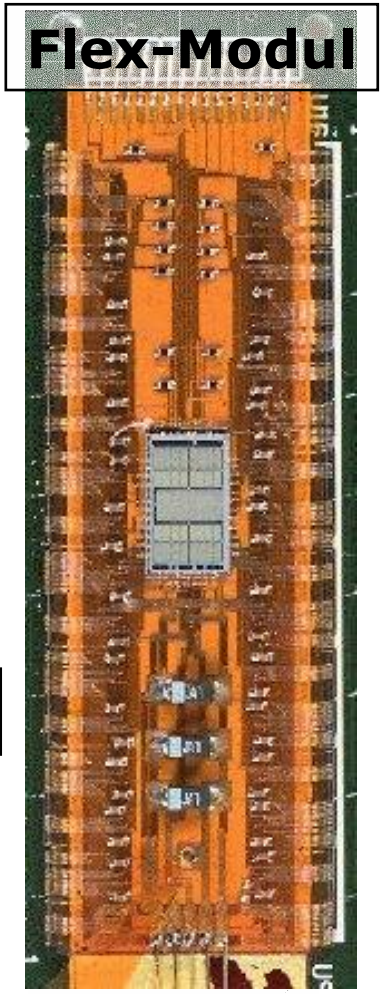
etch photo-resist and seed

h) 

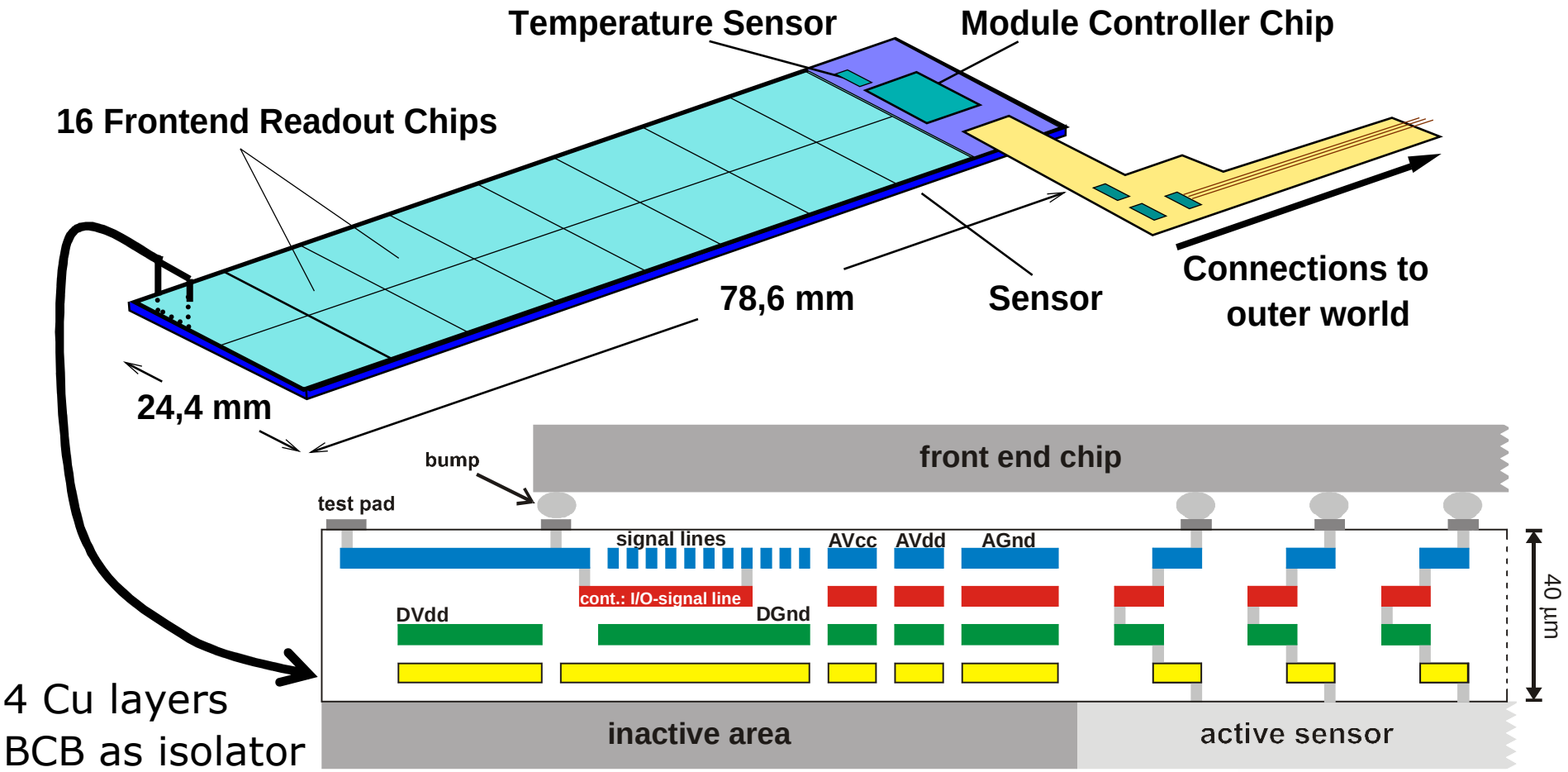
spin on next BCB-Layer [h) = a)]

ATLAS Module Prototypes





ATLAS Pixeldetektor Module in MCM-D



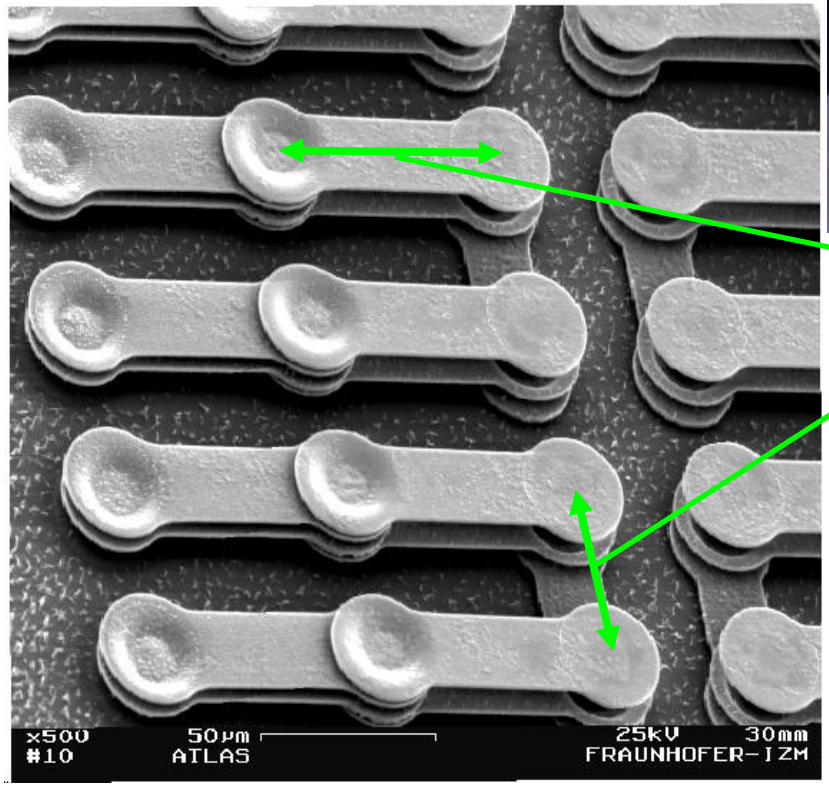
Pro's & Con's of the MCM-D Concept

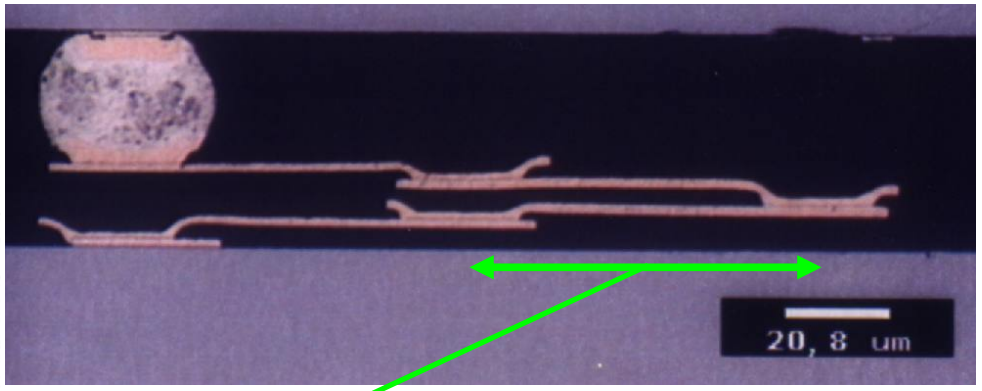
- High quality signal distribution
  (not presented here)
- One assembly technology, compatible with
  - Under bump metallization & flip chip
  - High resistive silicon as substrate
  - Soldering of SMDs
- Easy handling (no damageable wire-bonds)
- Option of routings between sensor- and electronic-cells („equal-sized-bricked" sensors)

- Yield of the interconnect production couples to sensor costs & needs
- No easy prototyping (wafer level process) no "bricolage"
- Long turn around time

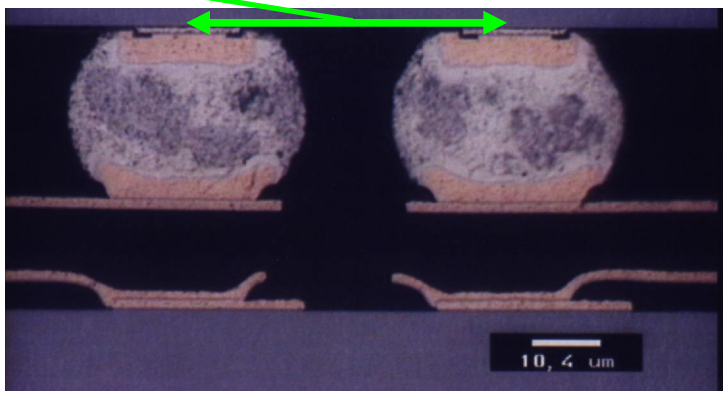
Feed-through's

BCB etched for visualisation





50 µm

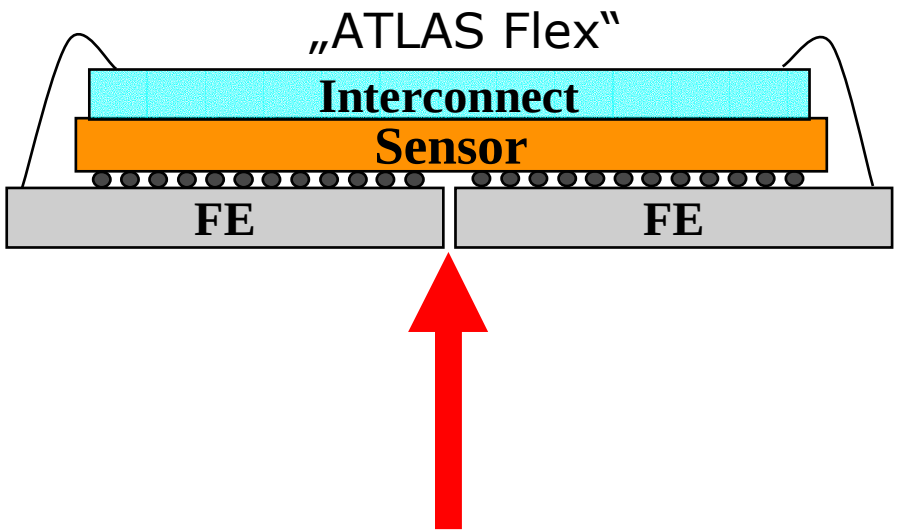


All pictures made by IZM

Covering the Gap

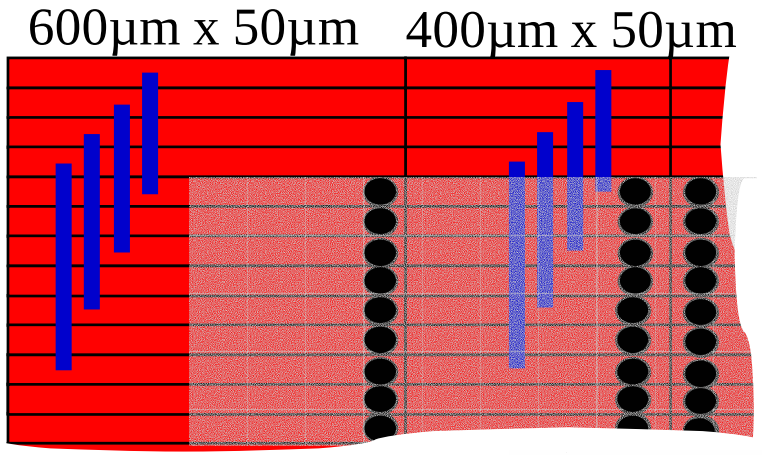
Multi Chip Module ⇒ gap between chips

bump pad positions are determined by the electronic chip



One solution to have no dead area:

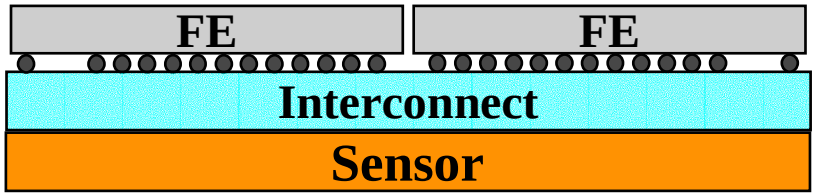
- Different sensor cell sizes
- Connect two sensor cells on the sensor (with the sensor's metallization)



Equal-Sized-Bricked (2)

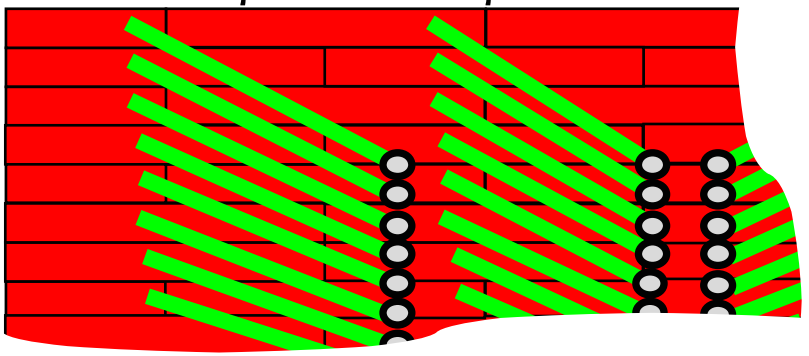
The interconnect structure in between the sensor and the bump bonds allows adequate routing.

„ATLAS MCM-D“

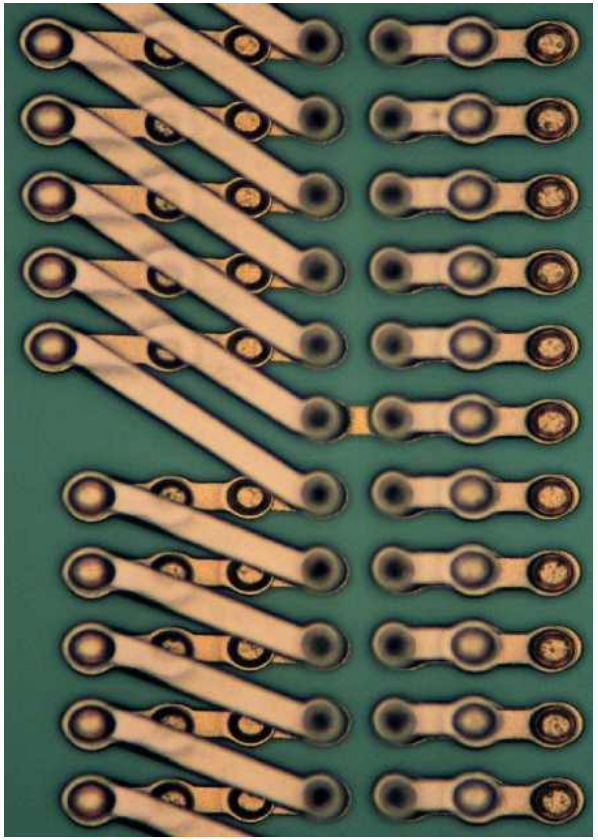


Using MCM-D:

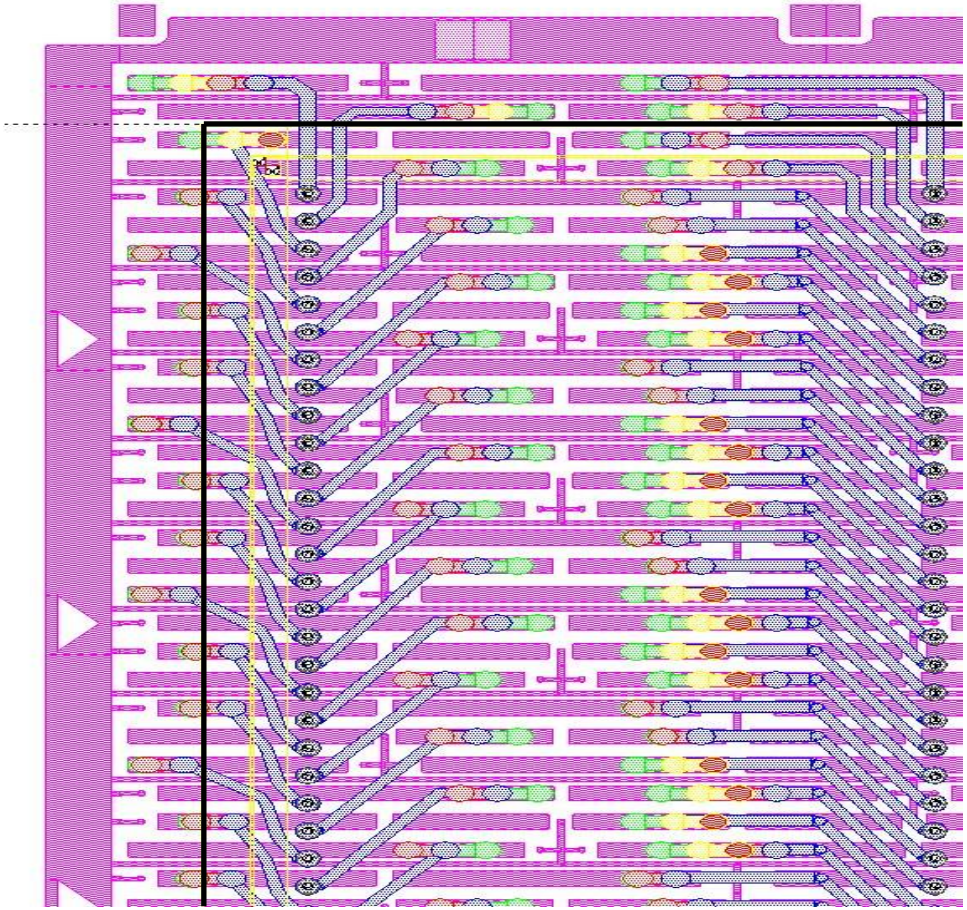
422.22µm x 51.25µm



Equal-Sized-Bricked (3)



First test-structures



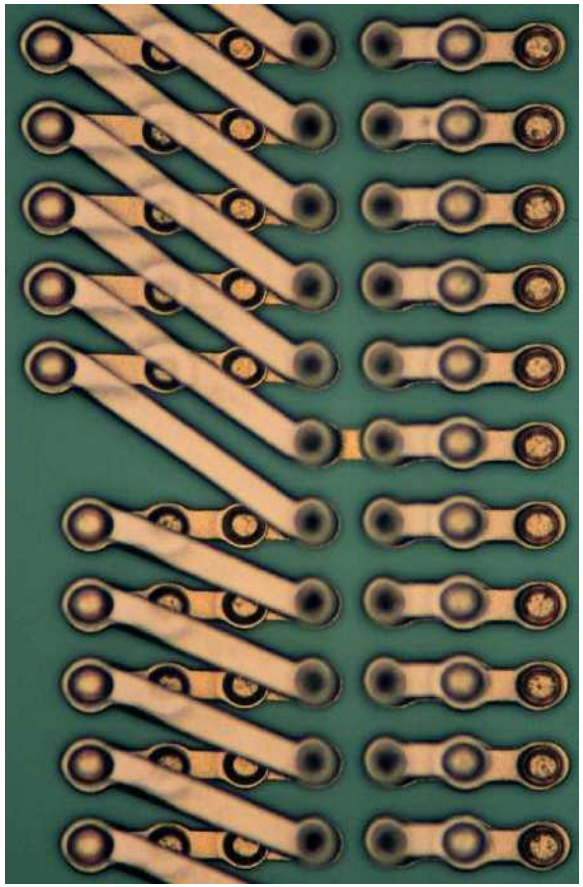
actual design of an „equal-sized-bricked“ detector

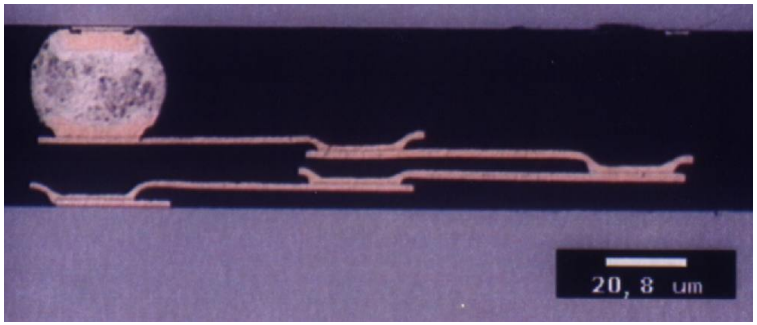
Feed-throughs implementing routing on standard sensor

Class **R_3** (skipping two cells) not shown here

Class **R_2**
skipping one cell

Class **R_1**
to neighbouring pixel cell



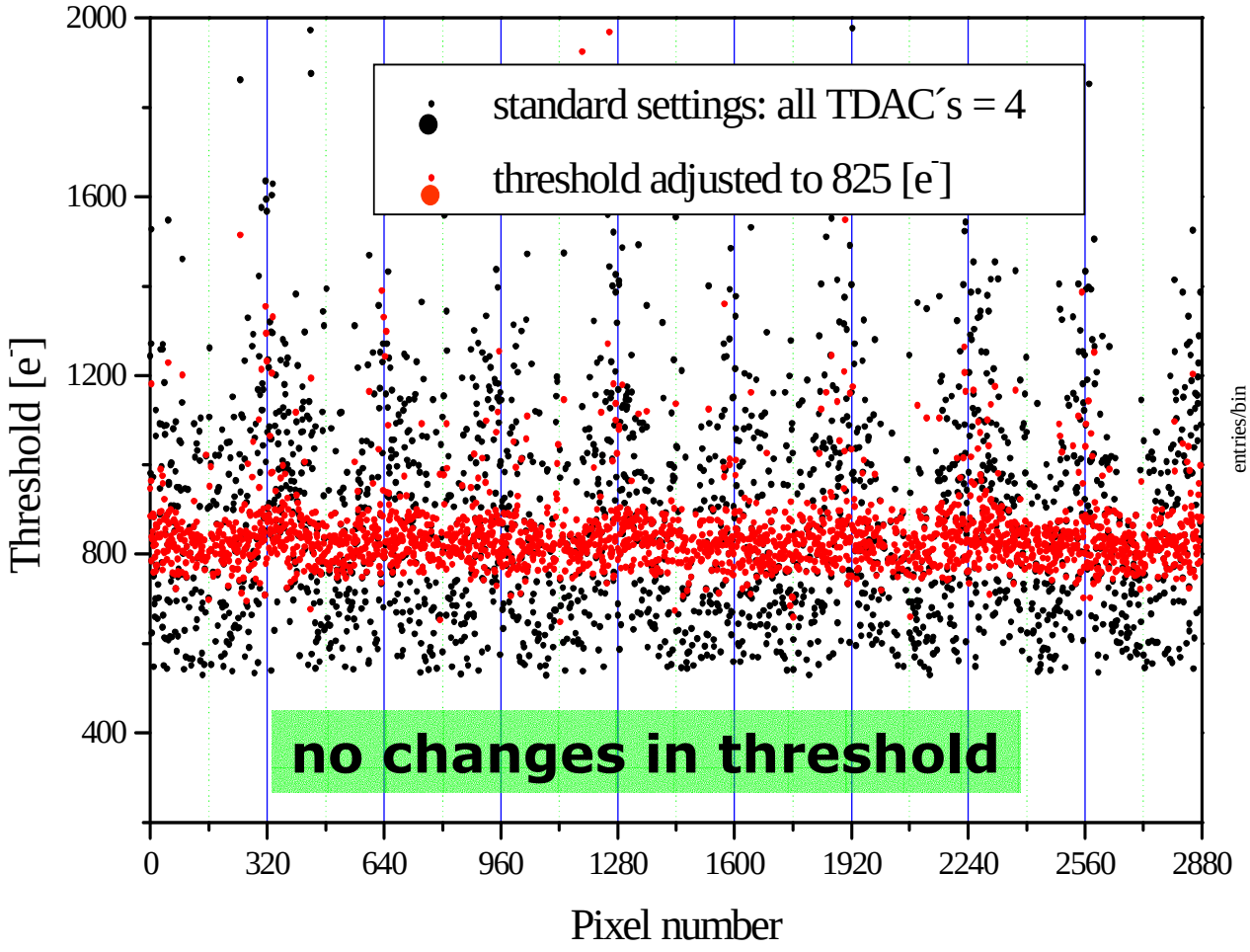


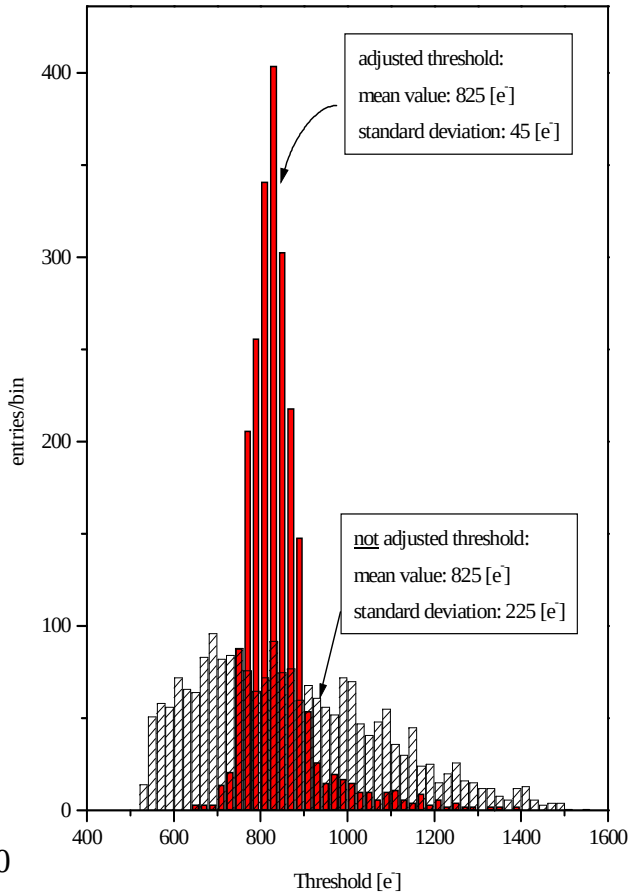
Class **U**

shortest connection to pixel cell

two different sensor cell length
U_{400} & **U_{600}**

Threshold distribution
(Single Chip, standard sensor with routing)

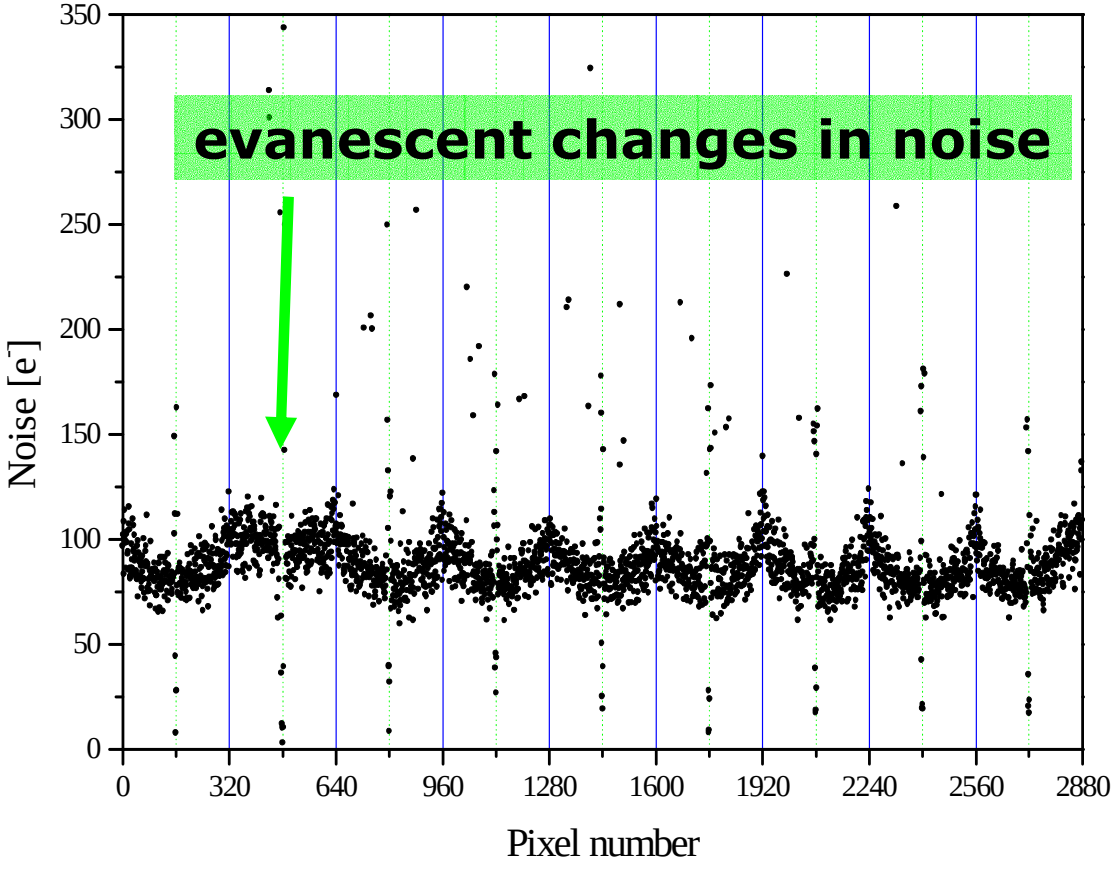


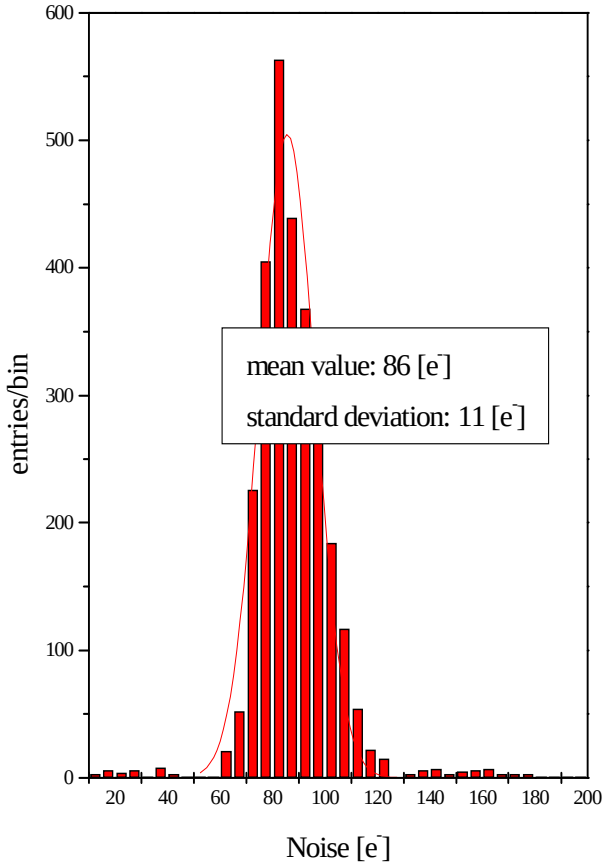


Hybrid: MCM-D ST1/Frontend C

Noise distribution

(Single Chip, standard sensor with routing)





Hybrid: MCM-D ST1/Frontend C

Crosstalk Measurements

Crosstalk = fraction of charge that couples into the adjacent pixel through the interpixel capacitances

Q ⟶ Pixel N (masked to read 0ut)

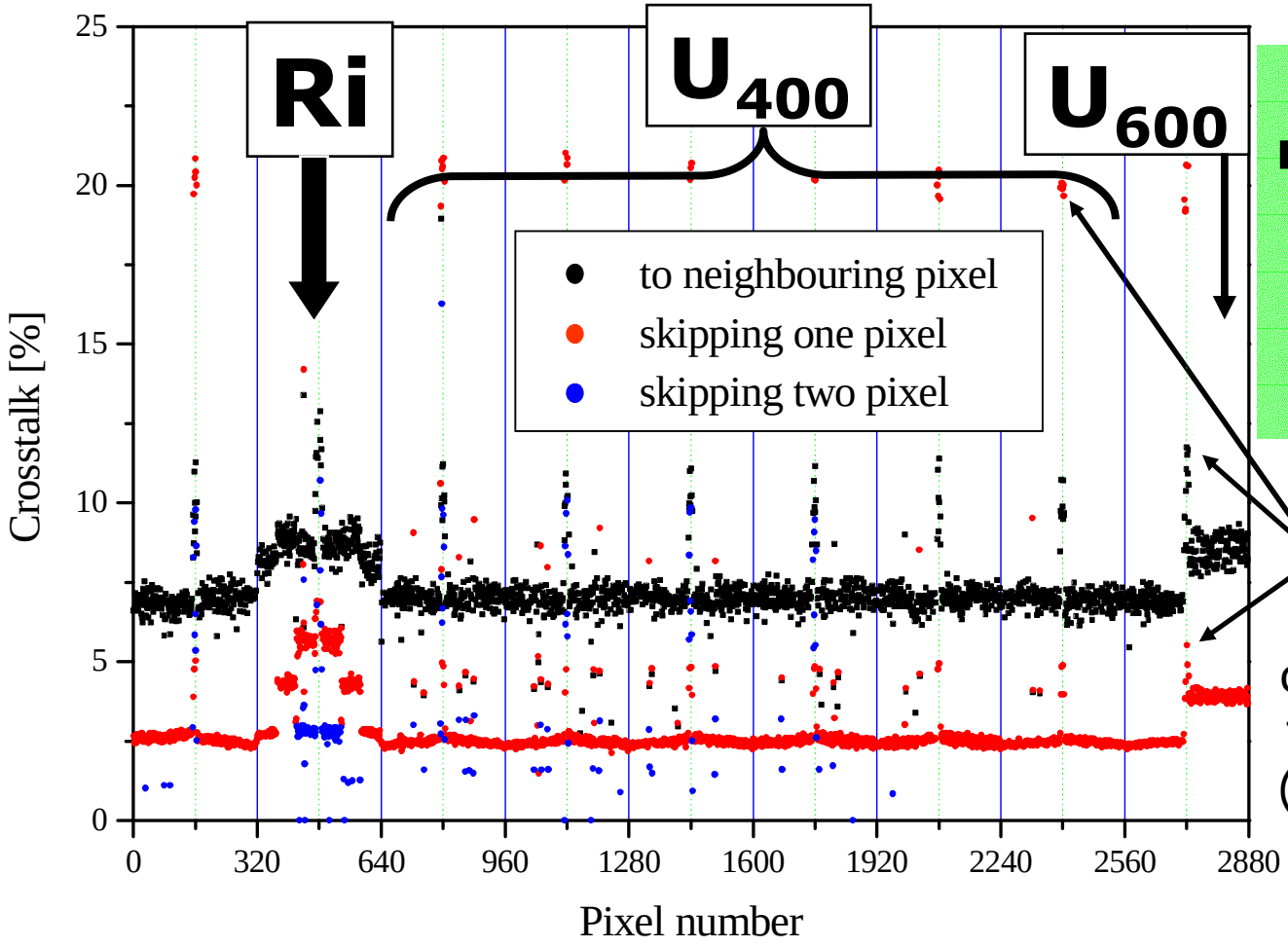
hits ⟵ Pixel N+1 (with threshold T)

Crosstalk = T / Q

Similar for Pixel N+i

Crosstalk distribution

(Single Chip, standard sensor with routing)



Crosstalk due to routing one above the other

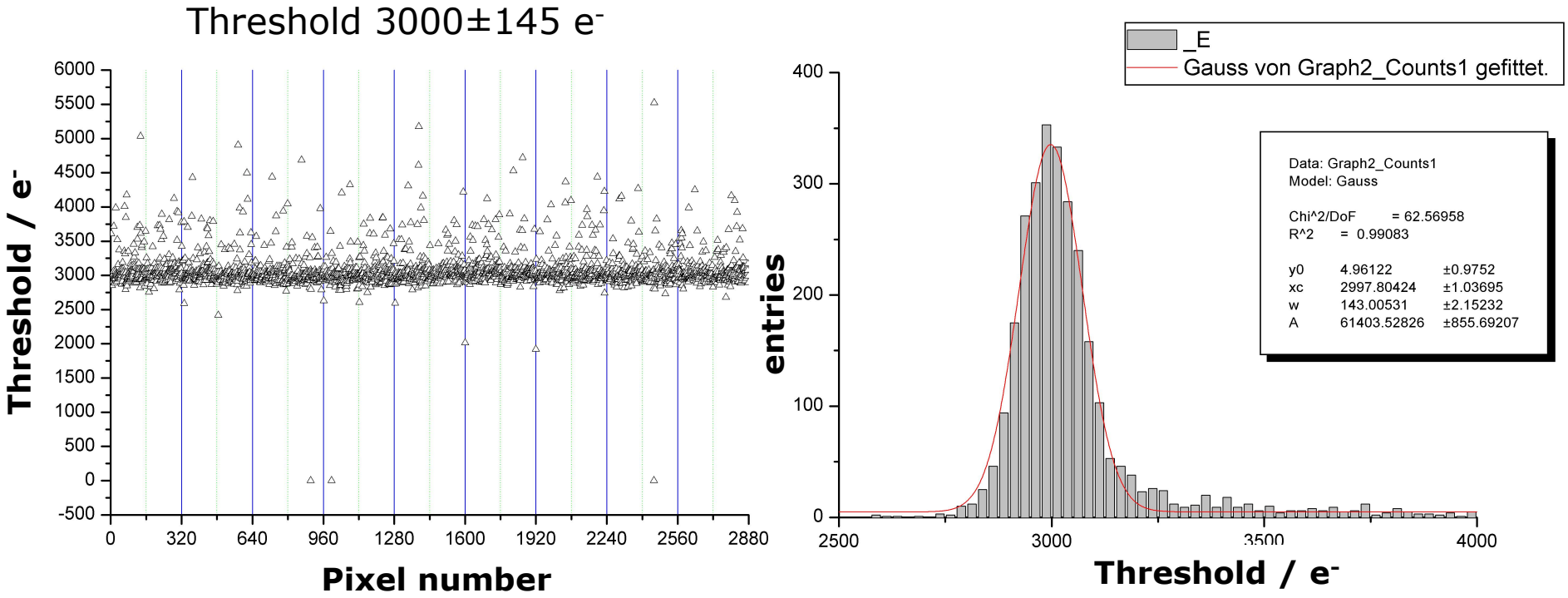
same amount as long pixel

"ganged" Pixel: These electronic cells are connected to two sensor cells (by sensor design).

Aug'02: First equal sized bricked single chip devices hybridised

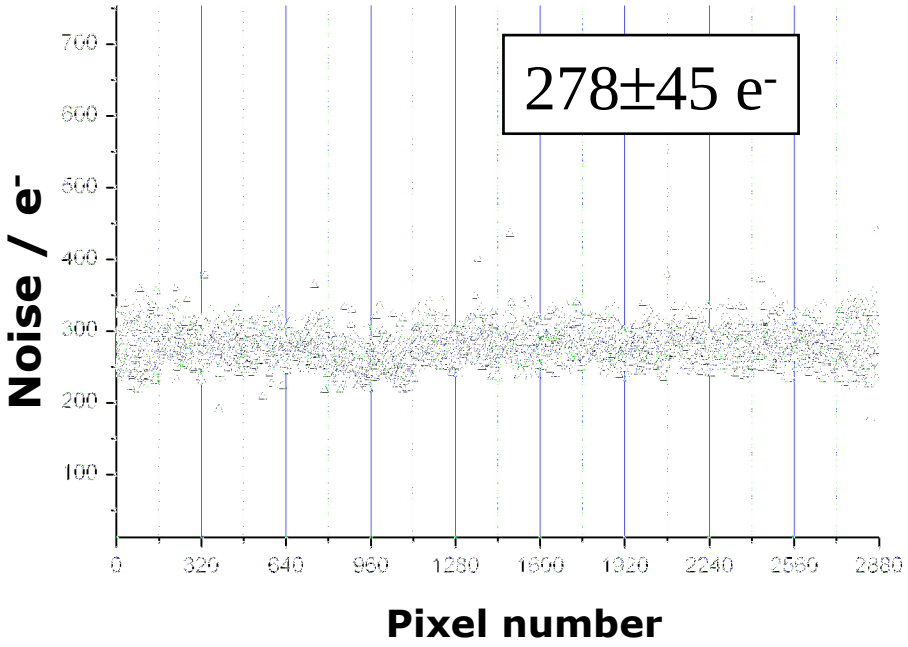
- Sensor and Front-End of the ATLAS pixel project
  - Prototype 2 Sensor (ESB design by T.Rohe)
  - Front End I1, first ATLAS Pixel Deep Submicron Prototype
- MCM-D, bumping and flip-chip processed at IZM, Berlin
- Overlap of routing-structures avoided

Threshold Measurement equal-sized-bricked Sensor

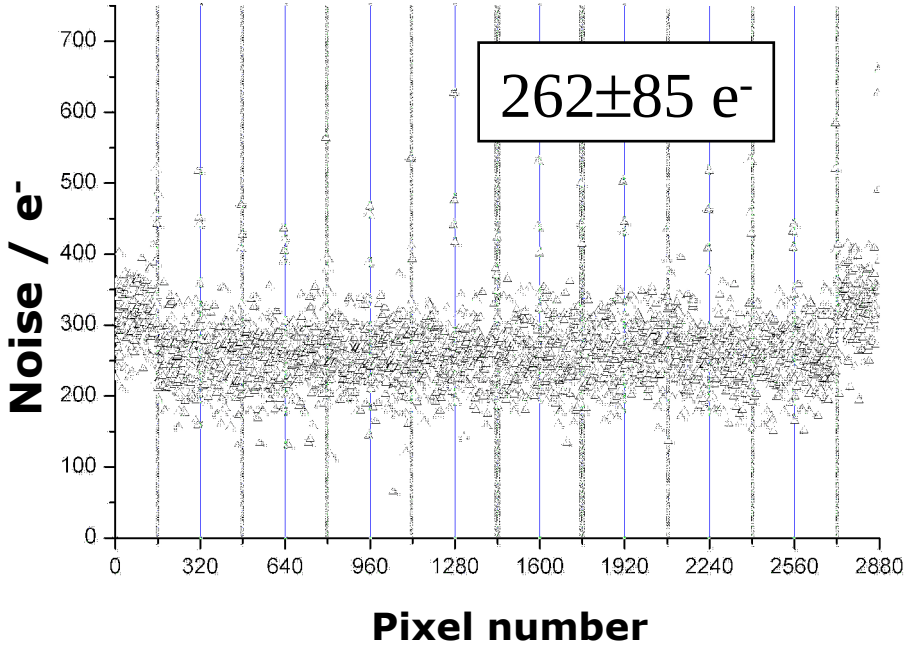


MCMD ESB Sensor, FeI1

Measurements equal-sized-bricked (2)



MCM-D equal-sized-bricked

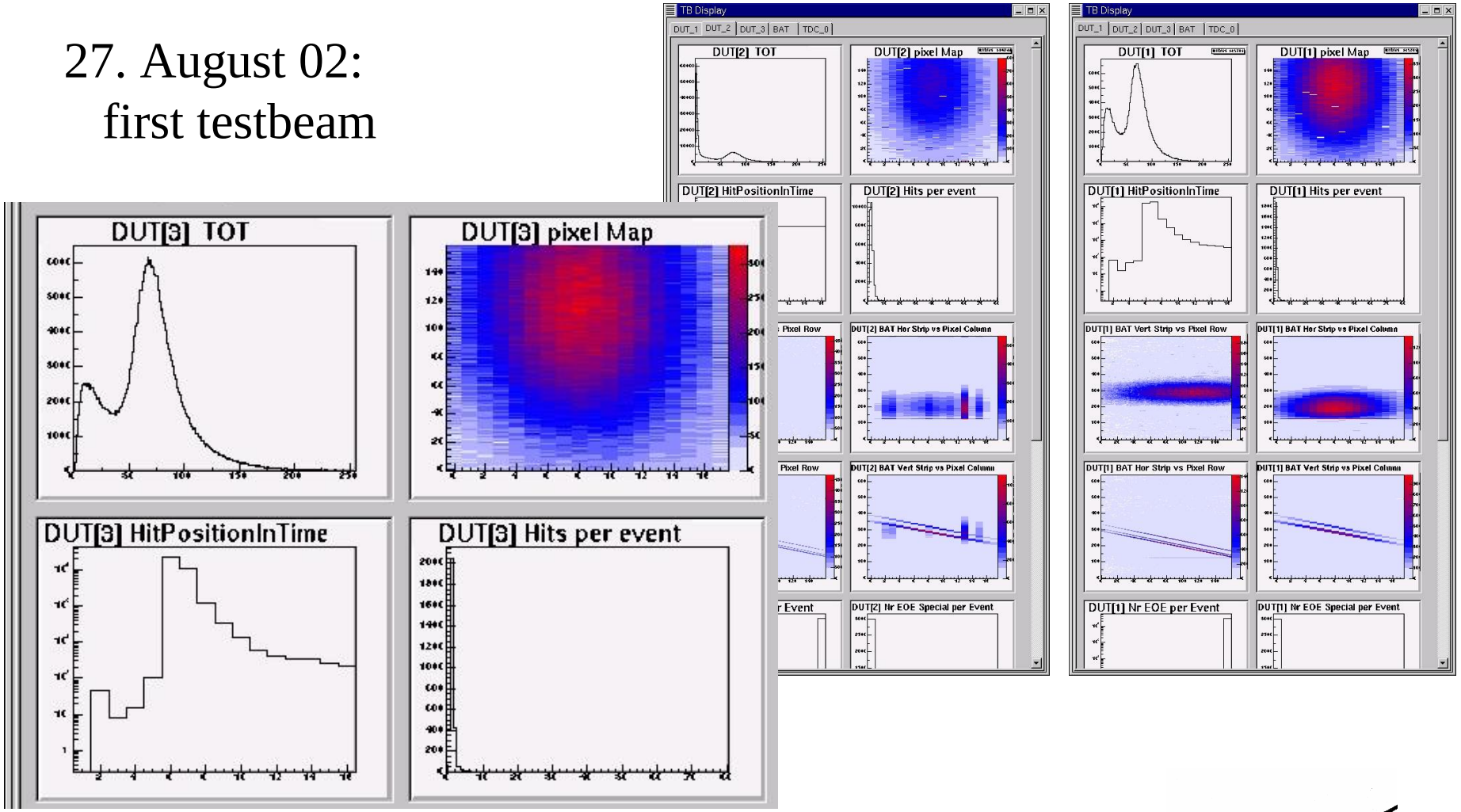


MCM-D standard sensor

MCMD ESB Sensor, FeI1

Test beam: equal-sized-bricked

27. August 02:
first testbeam



Conclusions

- The first devices using all benefits of the MCM-D technology were built.
- These equal-sized-bricked hybrid pixel detectors show very high and uniform performance.
- A more detailed analysis of the test beam data is in progress.
- More electrical measurements will be performed.