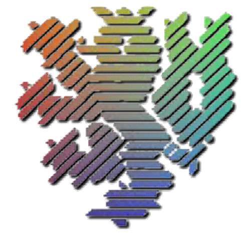
Studies on Multi Chip Module – Deposited Connection Structures

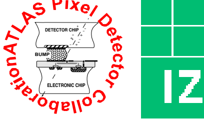
Peter Gerlach

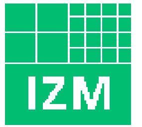
representing

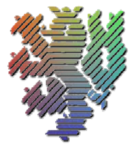
Christian Grah



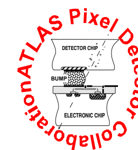
University of Wuppertal



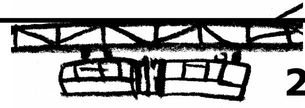


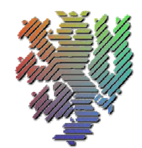


Contents

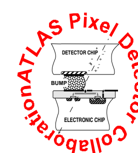


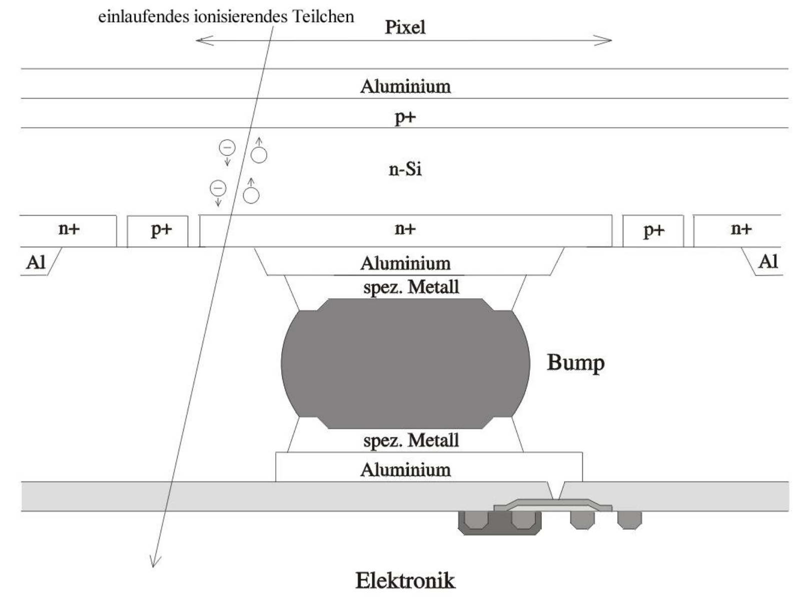
- Idea to build monolithic hybrid pixel detector modules
- MCM-D Technology
- How to realise “equal-sized-bricked” sensors
- Test of hybrids with implemented routing
- First measurements on equal-sized-bricked single-chip hybrids
  - electric
  - Test beam
- Conclusion





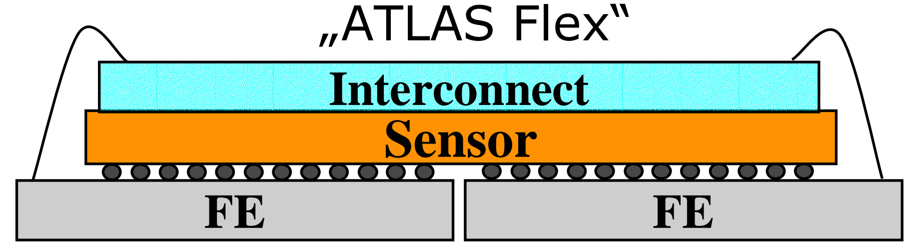
Concept of hybrid pixel-detectors

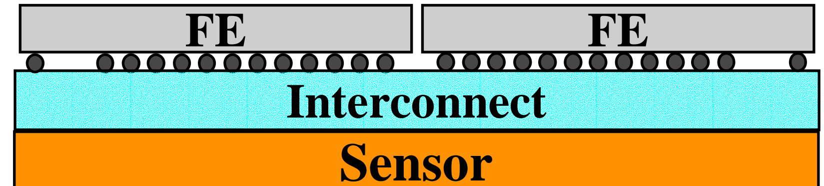




The concept of a *hybrid pixel detector* requires three parts:

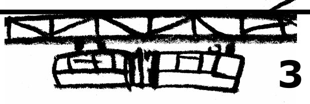
- Sensor
- Electronics
- Interconnect

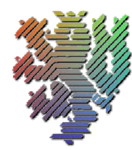




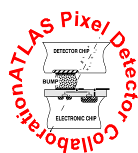
Interconnect includes:

- 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

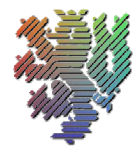
d) sputter copper galvanic seed

e) spin on and pattern photo-resist

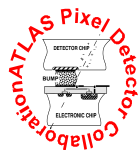
f) galvanic growth of copper layer

g) etch photo-resist and seed

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



ATLAS Module Prototypes



passive components

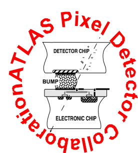
readout chips

MCC

MCM-D-Modul

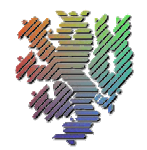
Flex-Modul

ATLAS Pixeldetektor Module in MCM-D

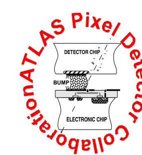


Temperature Sensor
Module Controller Chip
16 Frontend Readout Chips
78,6 mm
Sensor
Connections to outer world
24,4 mm
front end chip
bump
test pad
signal lines
AVcc
AVdd
AGnd
cont.: I/O-signal line
DVdd
DGnd
40 µm
inactive area
active sensor
2 mm

4 Cu layers
BCB as isolator

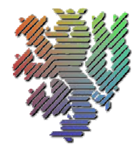


Pro’s & Con’s of the MCM-D Concept

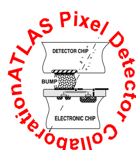


- High quality signal distribution
  (not presented here)
- One assembly technology, compatible with
  - Under bump metallization & flip chip
  - High resistive silicon as substrate
  - Soldering of SMDs
- Easy handling (no damageable wire-bonds)
- Option of routings between sensor- and electronic-cells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

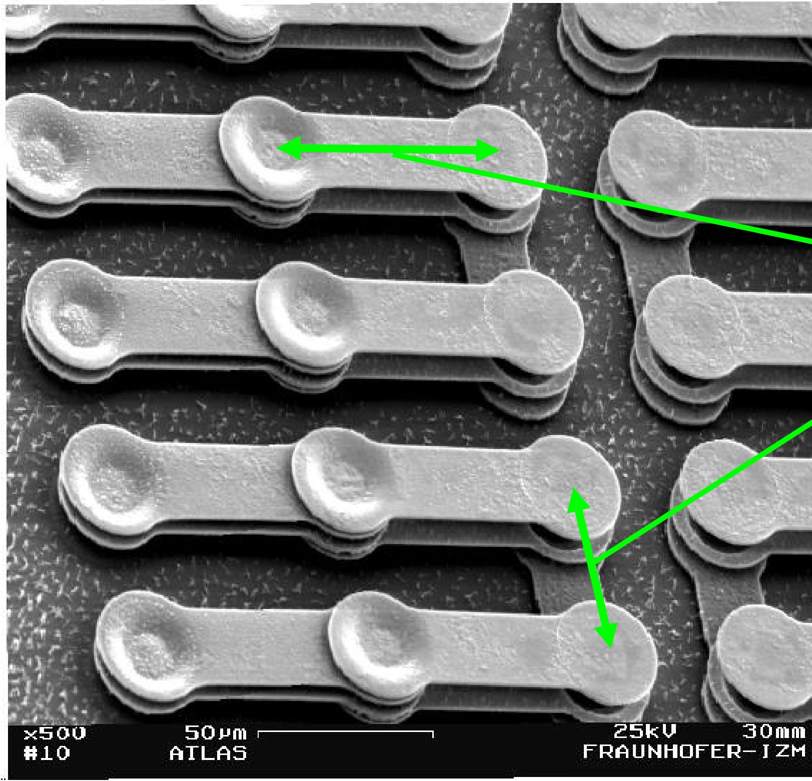
- Yield of the interconnect production couples to sensor costs & needs
- No easy prototyping (wafer level process)
  no “bricolage”
- Long turn around time

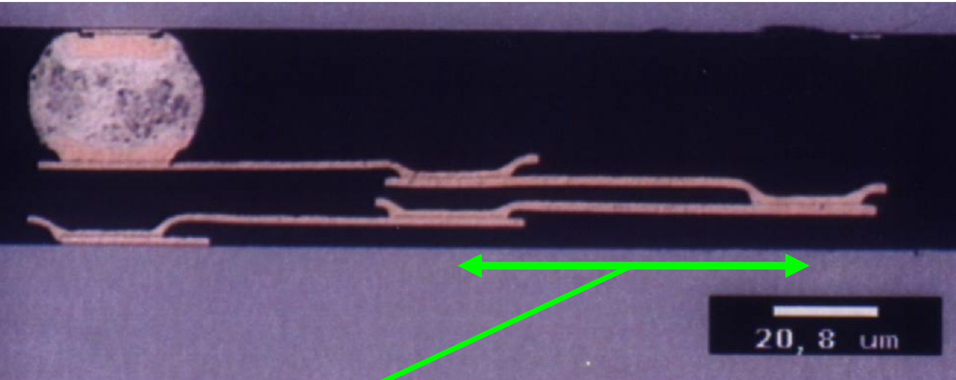


Feed-through's

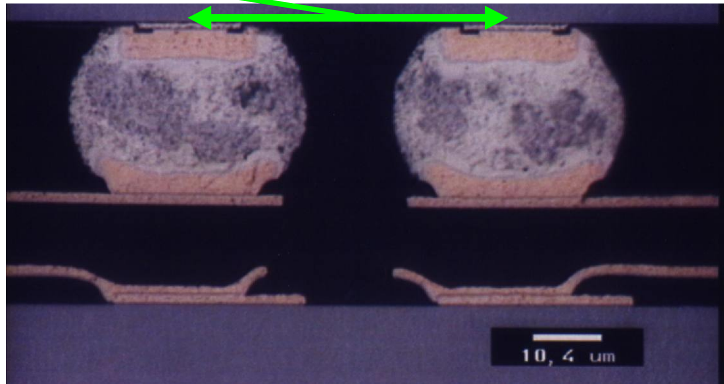


BCB etched for visualisation

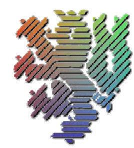




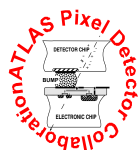
50 µm



All pictures made by IZM

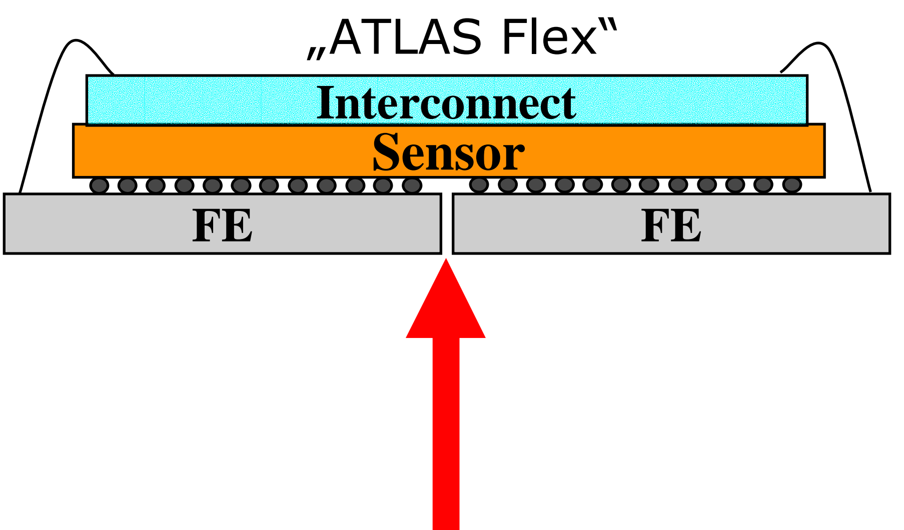


Covering the Gap



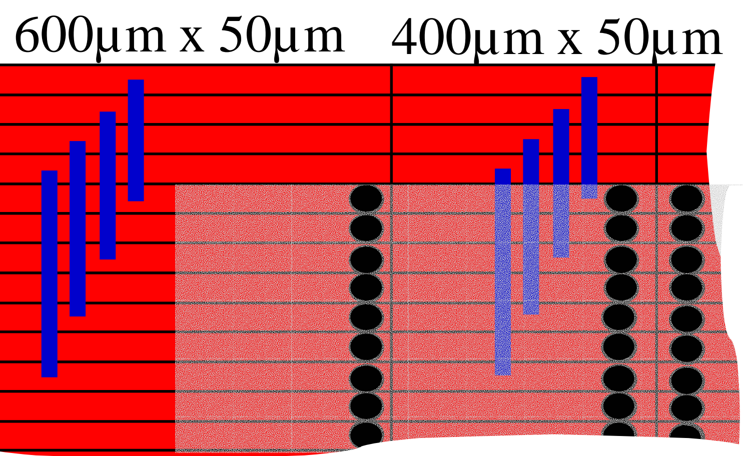
Multi Chip Module ⇒ gap between chips

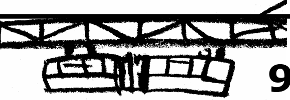
bump pad positions are determined by the electronic chip



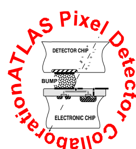
One solution to have no dead area:

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



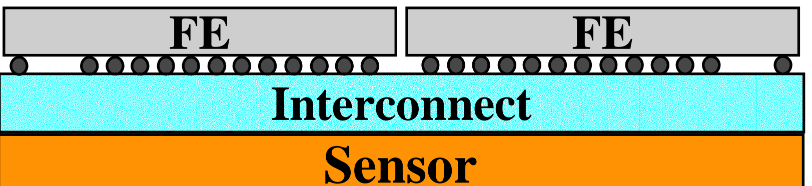


Equal-Sized-Bricked (2)



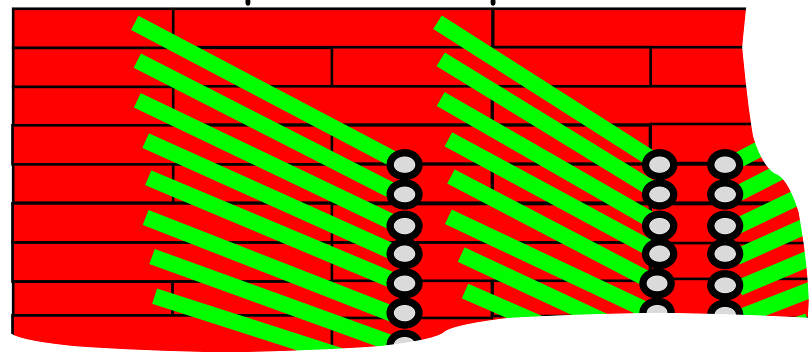
The interconnect structure in between the sensor and the bump bonds allows adequate routing.

„ATLAS MCM-D“

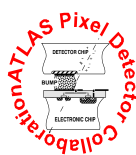


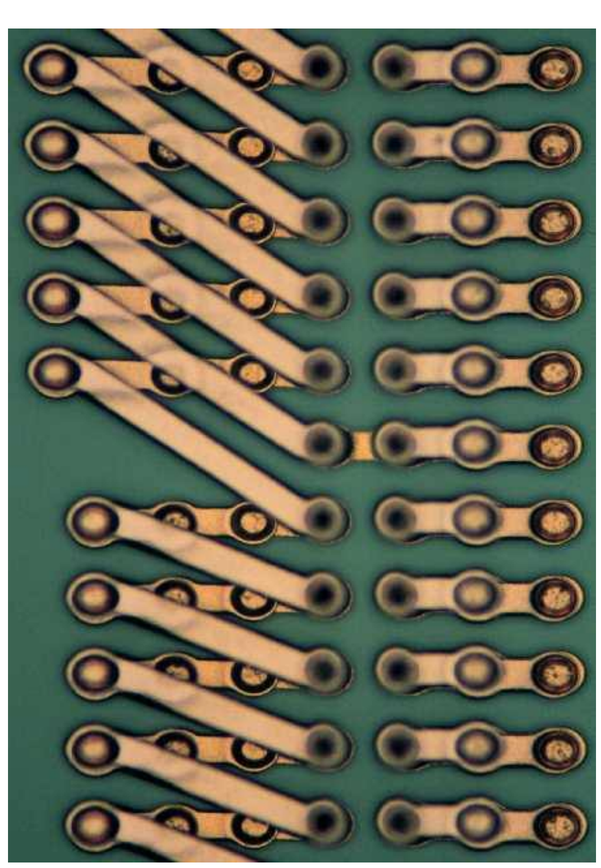
Using MCM-D:

422.22µm x 51.25µm



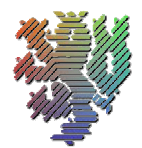
Equal-Sized-Bricked (3)



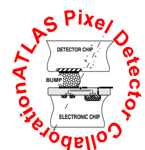


First test-structures

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



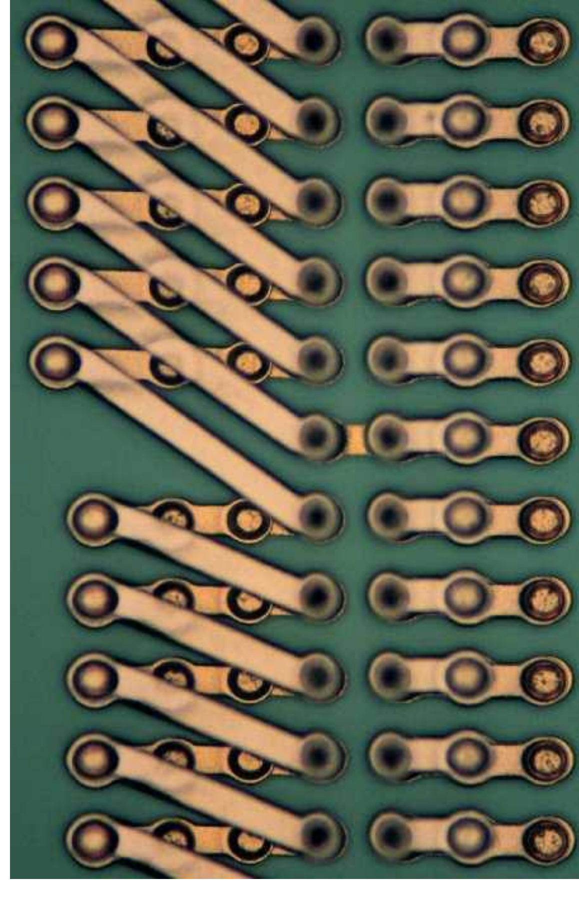
Feed-throughs implementing routing on standard sensor

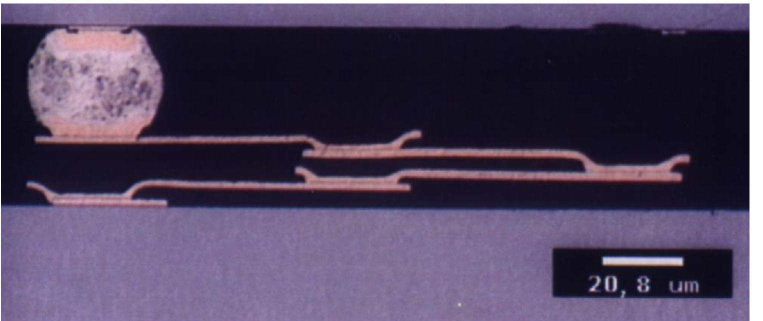


Class $\mathbf{R_3}$ (skipping two cells) not shown here

Class $\mathbf{R_2}$
skipping one cell

Class $\mathbf{R_1}$
to neighbouring pixel cell

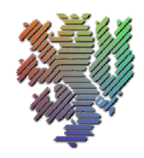




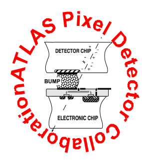
Class **U**

shortest connection to pixel cell

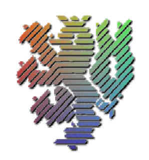
two different sensor cell length
$\mathbf{U_{400}}$ & $\mathbf{U_{600}}$



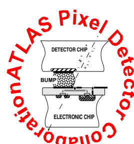
Threshold distribution
(Single Chip, standard sensor with routing)

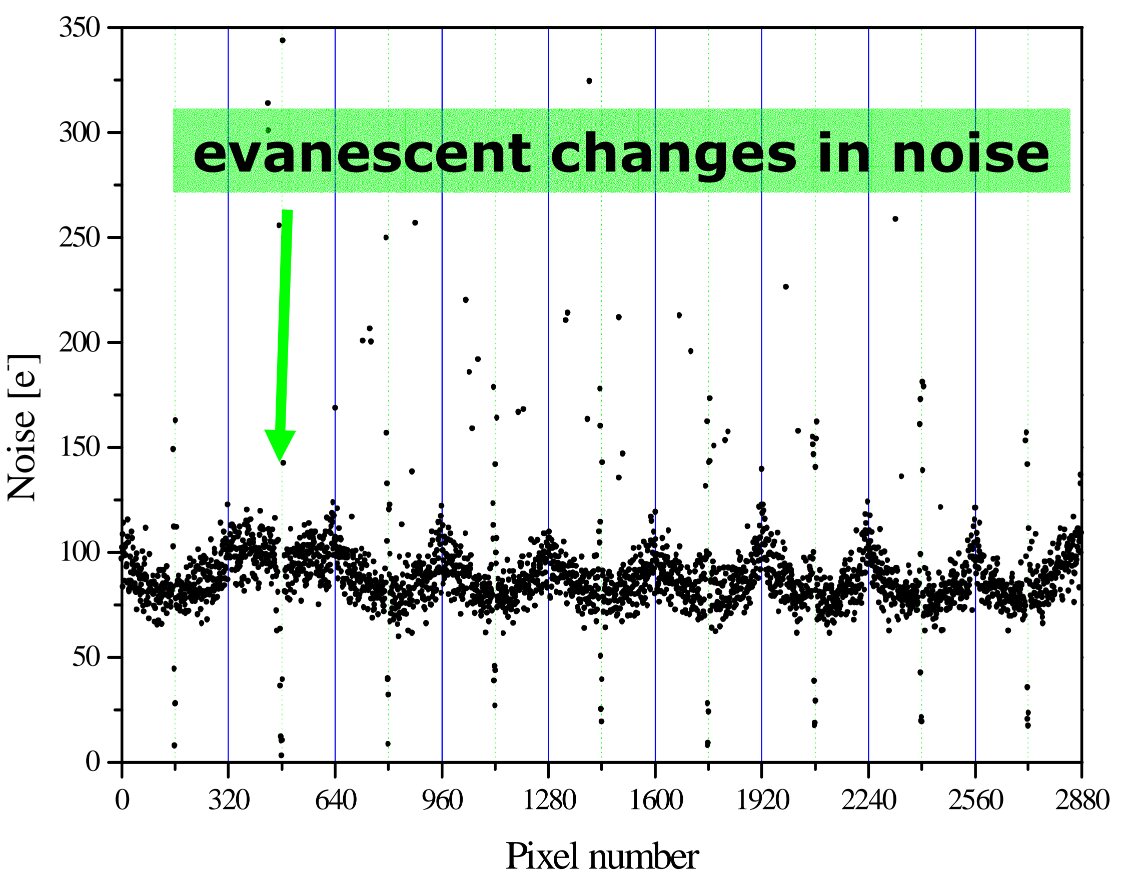


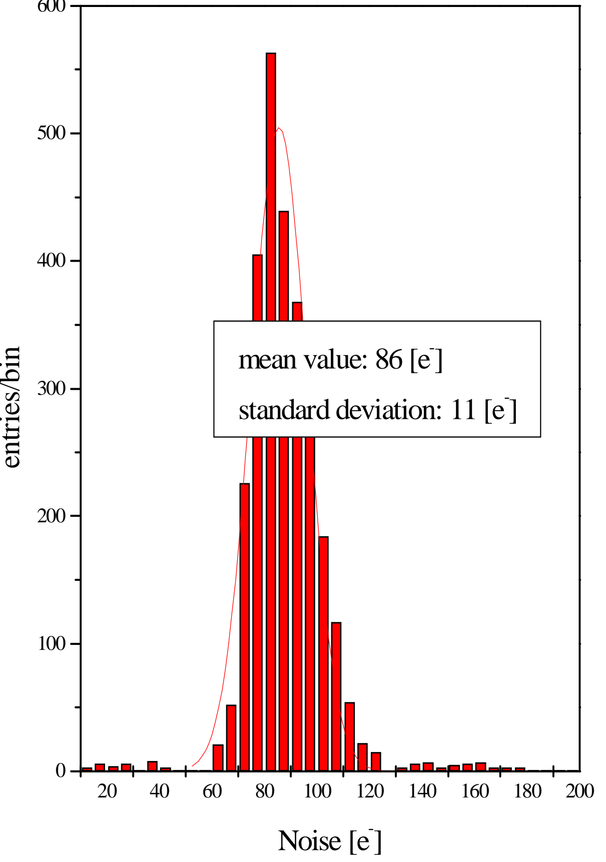
Hybrid: MCM-D ST1/Frontend C



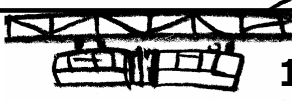
Noise distribution
(Single Chip, standard sensor with routing)

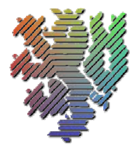




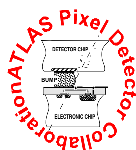


Hybrid: MCM-D ST1/Frontend C





Crosstalk Measurements



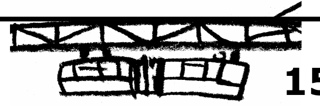
Crosstalk = fraction of charge that couples into the adjacent pixel through the interpixel capacitances

Q ⟶ Pixel N (masked to read 0ut)

hits ⟵ Pixel N+1 (with threshold T)

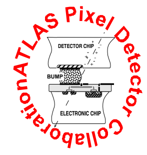
Crosstalk = T / Q

Similar for Pixel N+i



Crosstalk distribution

(Single Chip, standard sensor with routing)



Ri

U_{400}

U_{600}

- to neighbouring pixel
- skipping one pixel
- skipping two pixel

Crosstalk [%]

25, 20, 15, 10, 5, 0

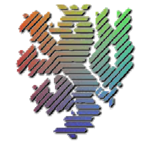
0, 320, 640, 960, 1280, 1600, 1920, 2240, 2560, 2880

Pixel number

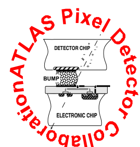
Crosstalk due to routing one above the other

same amount as long pixel

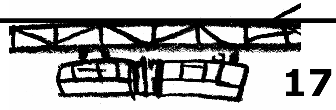
"ganged" Pixel: These electronic cells are connected to two sensor cells (by sensor design).

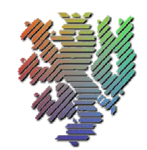


Aug’02: First equal sized bricked single chip devices hybridised

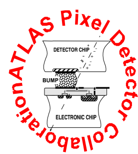


- Sensor and Front-End of the ATLAS pixel project
  - Prototype 2 Sensor (ESB design by T.Rohe)
  - Front End I1, first ATLAS Pixel Deep Submicron Prototype
- MCM-D, bumping and flip-chip processed at IZM, Berlin
- Overlap of routing-structures avoided





Threshold Measurement equal-sized-bricked Sensor



Threshold 3000±145 e^-

Threshold / e^-

6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500

0 320 640 960 1280 1600 1920 2240 2560 2880

Pixel number

_E
Gauss von Graph2_Counts1 gefittet.

Data: Graph2_Counts1
Model: Gauss

Chi^2/DoF = 62.56958
R^2 = 0.99083

y0	4.96122	±0.9752
xc	2997.80424	±1.03695
w	143.00531	±2.15232
A	61403.52826	±855.69207

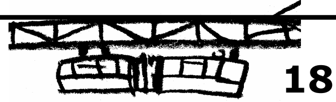
entries

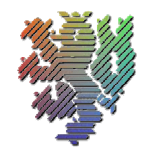
400
300
200
100
0

2500 3000 3500 4000

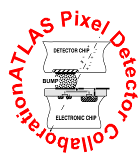
Threshold / e^-

MCMD ESB Sensor, FeI1





Measurements equal-sized-bricked (2)



278±45 e⁻

Noise / e⁻ vs. Pixel number

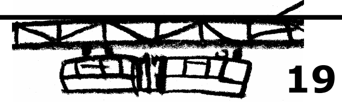
MCM-D equal-sized-bricked

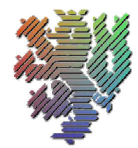
262±85 e⁻

Noise / e⁻ vs. Pixel number

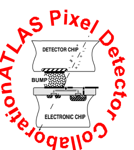
MCM-D standard sensor

MCMD ESB Sensor, FeI1

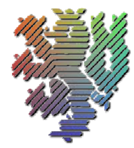




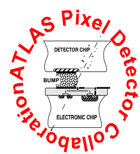
Test beam: equal-sized-bricked



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.