Diamond Pixel Sensors with ATLAS frontend electronics

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SI LAB
Silizium Labor Bonn

Outline

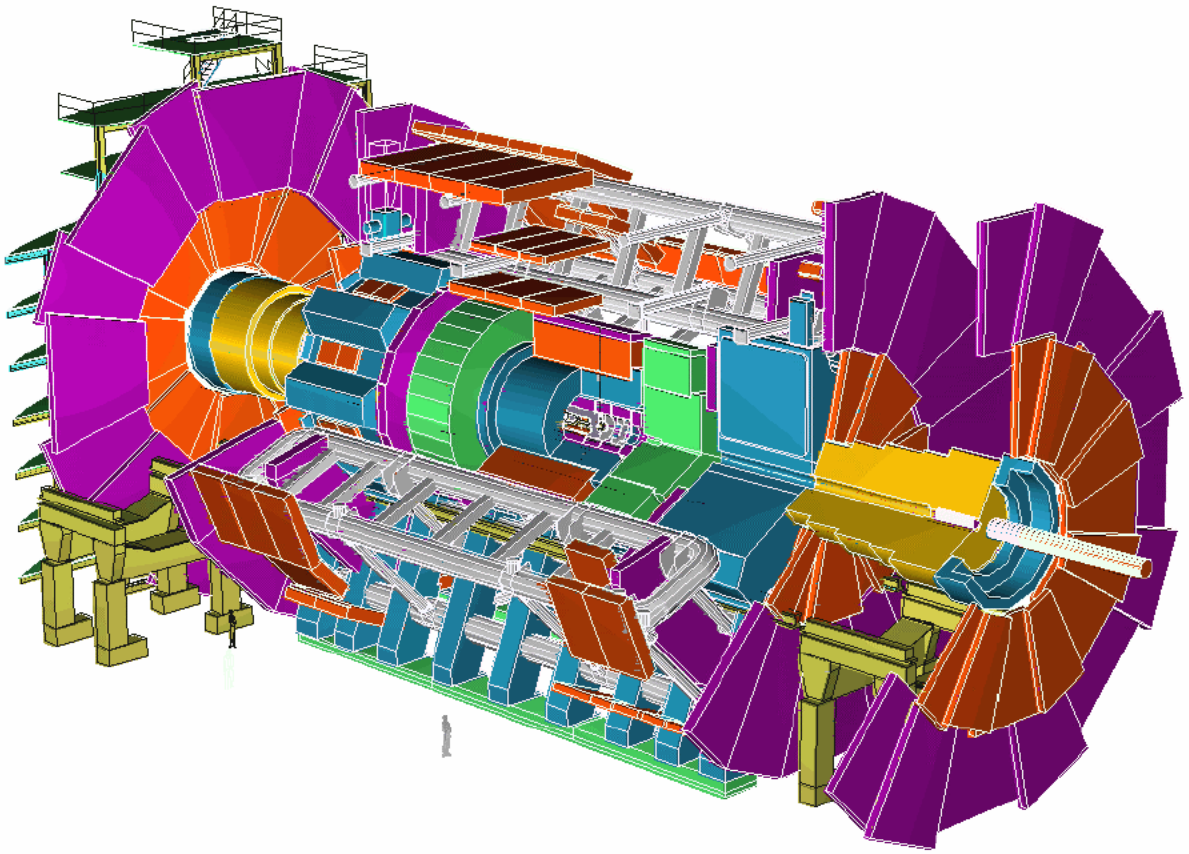
- Motivation
- Atlas Frontend Chip and modules
- Diamond single chip assemblies
- Full scale diamond module

Motivation

Material Properties:

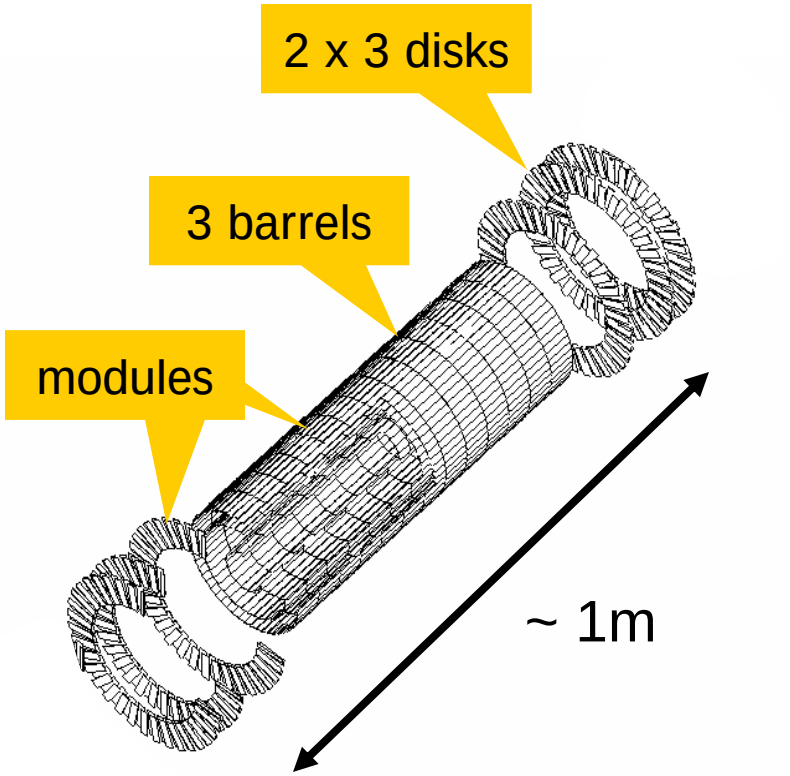
- Radiation hardness
- Low dielectric constant →low capacitance
- Low leakage current → low readout noise
- Fast signal collection time
- Room temperature operation → no cooling

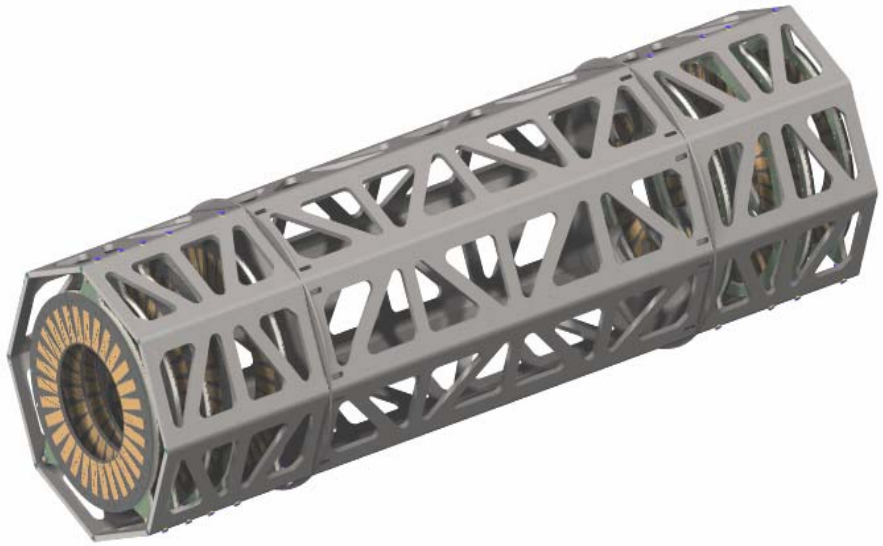
ATLAS Detector



- One out of four large LHC experiments
- Typical onion layout:
  - Myon spectrometer
  - Calorimeters
  - Central tracking device with three sub detectors

pixel detector



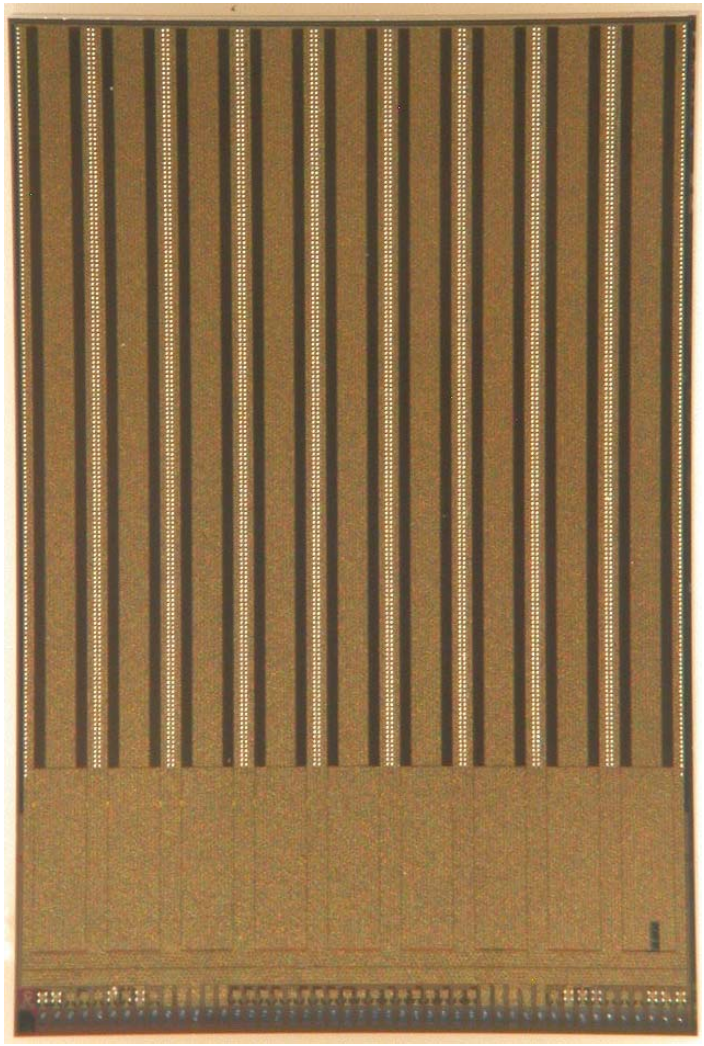


- Global support is a flat panel structure
- Made from carbon composite material
- Total weight is 4.4kg
- 80 Mio. readout channels
- ~1.8 m²

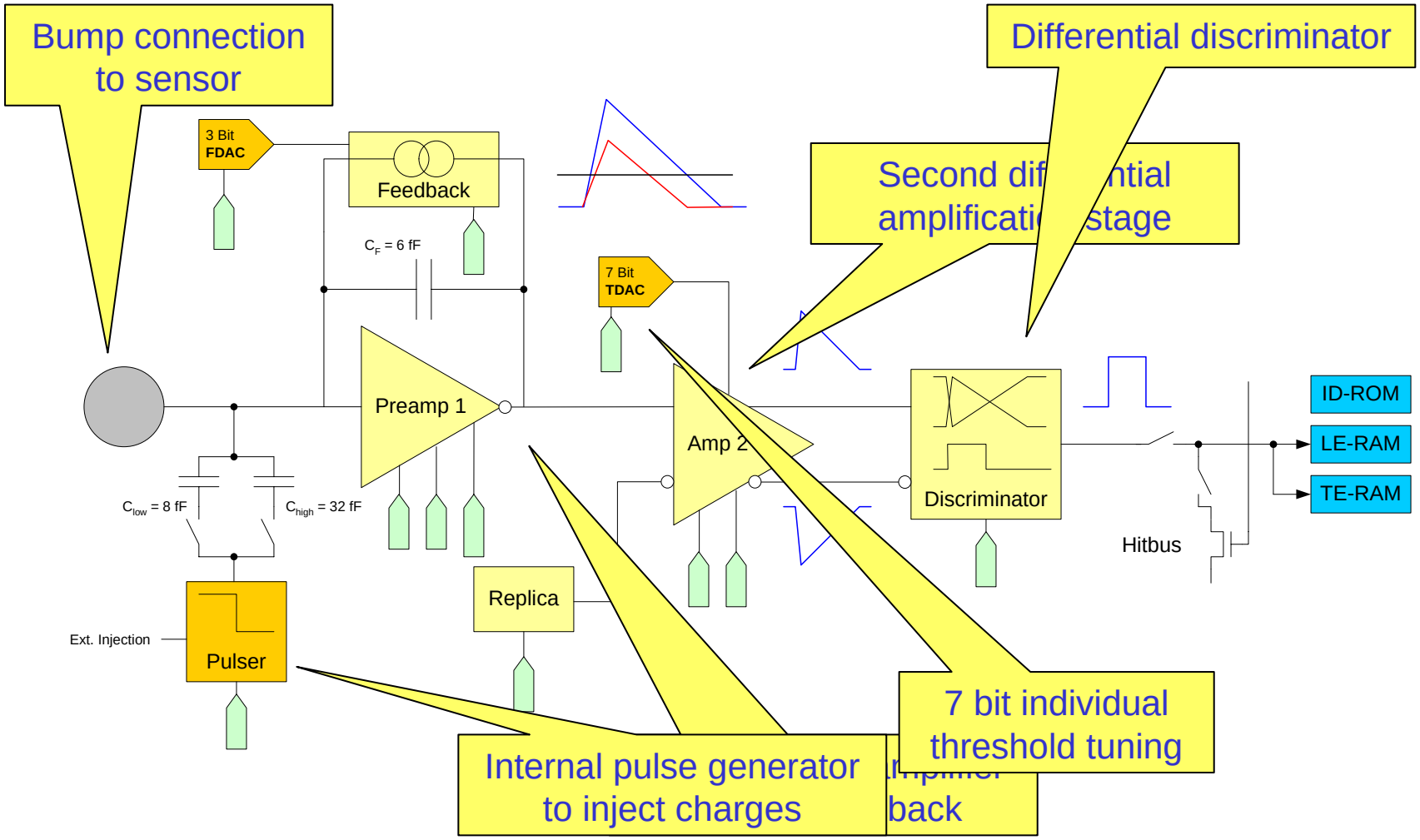
Frontend Chip

Frontend-I3:

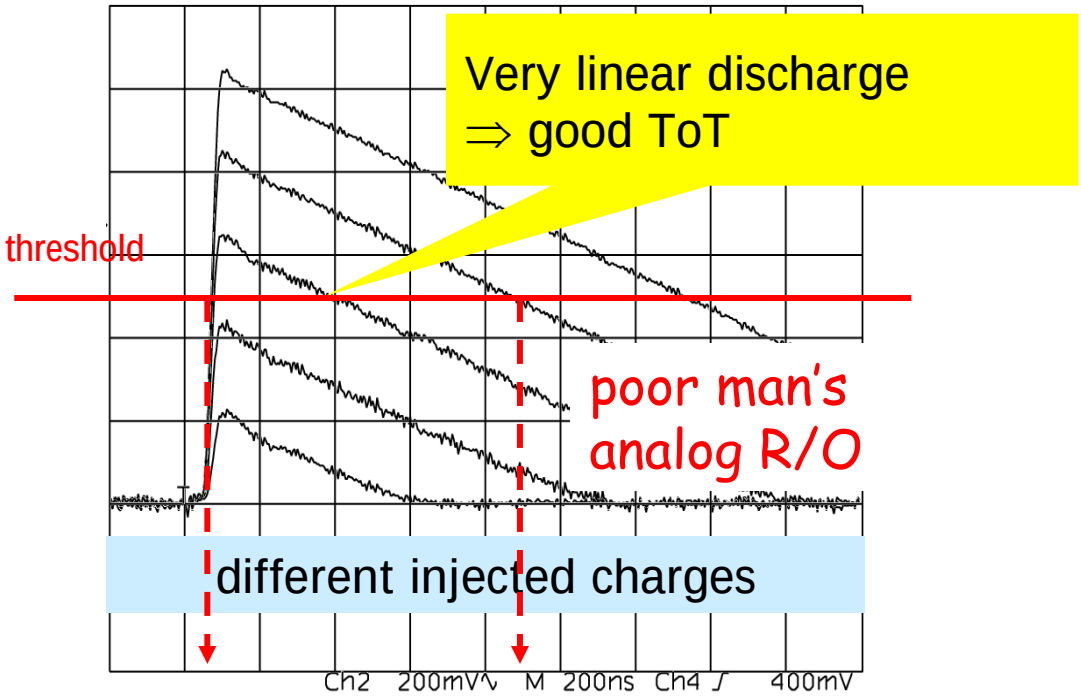
- Production chip for the Atlas Pixeldetector
- 0.25µm IBM
- Pixelsize 50x400µm
- 2880 pixels (18x160)
- radhard @100Mrad
- Wide range of tuning possibilities
- Designed for silicon sensors (capacity, mean charge)



Pixel cell of FE-I2



FE-I ATLAS Analog Performance



Readout

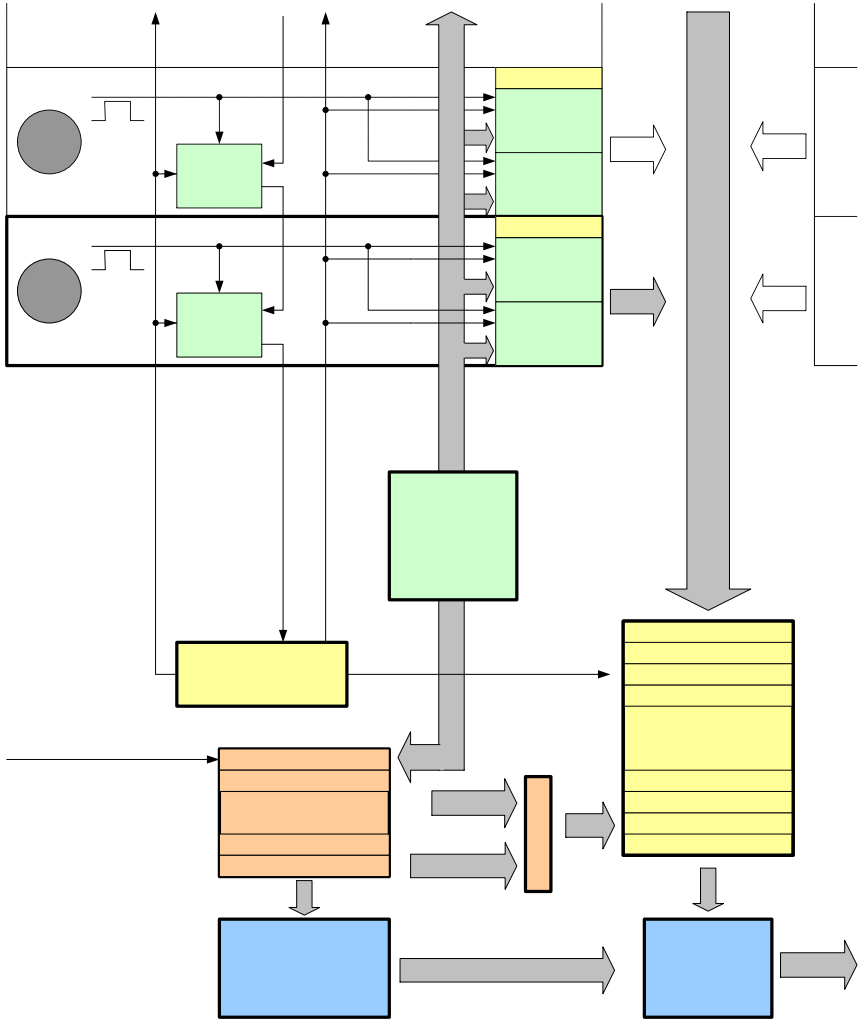
4 simultaneous tasks are running permanently:

- A time stamp (8bit Gray Code) is distributed to all pixels
- When a pixel is hit, the time of rising and trailing edges are stored in the pixel

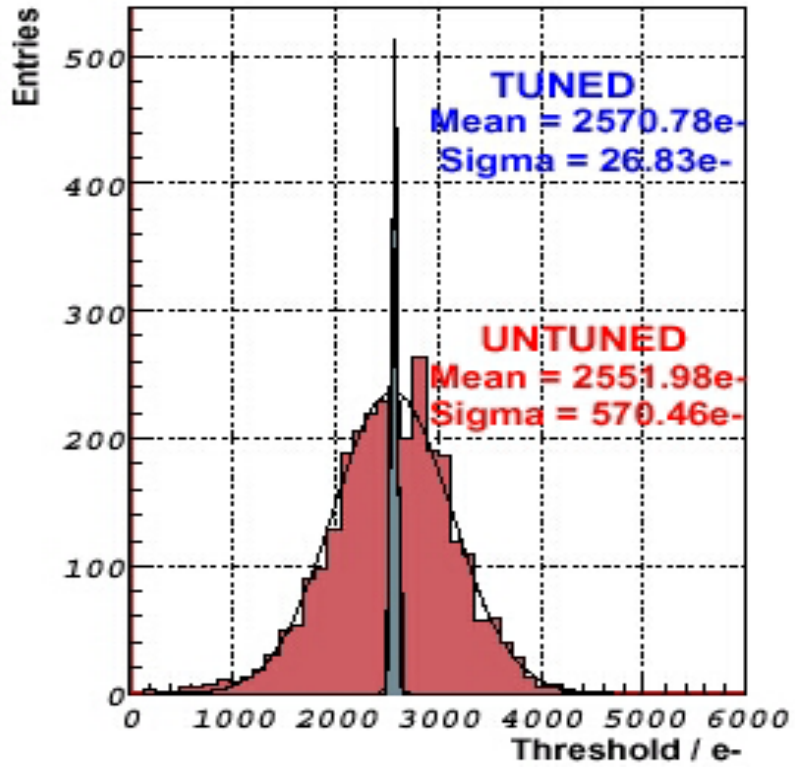
- The hit is flagged to the periphery with a fast asynchronous scan
- Time information and pixel number are written into a buffer pool (common to a column pair)
- The hit in the pixel is cleared

- If a trigger arrives, the time of the hit (leading edge data) is compared to the time for hits associated to this trigger. Valid hits are flagged, older hits are deleted.
- The trigger is queued in a FIFO

- All valid hits of a trigger are sent out serially. All triggers in the FIFO are processed.

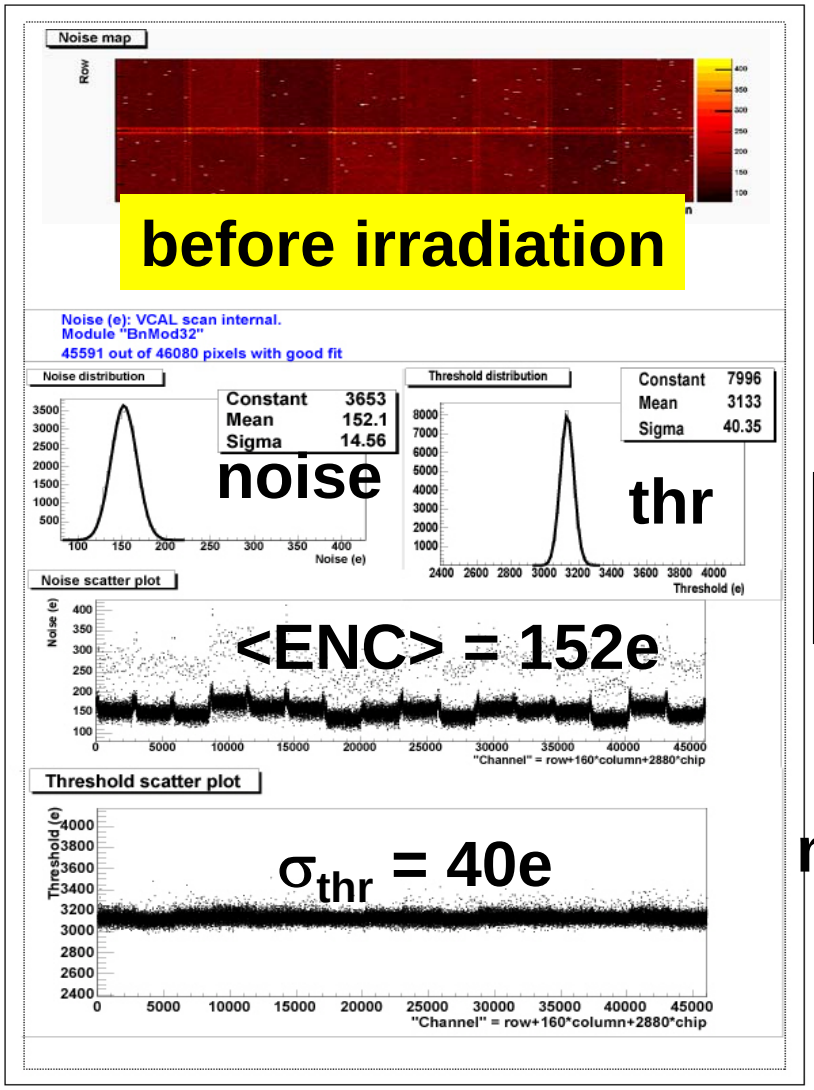


FE-I ATLAS Performance



Threshold tuneable
down to 1500e

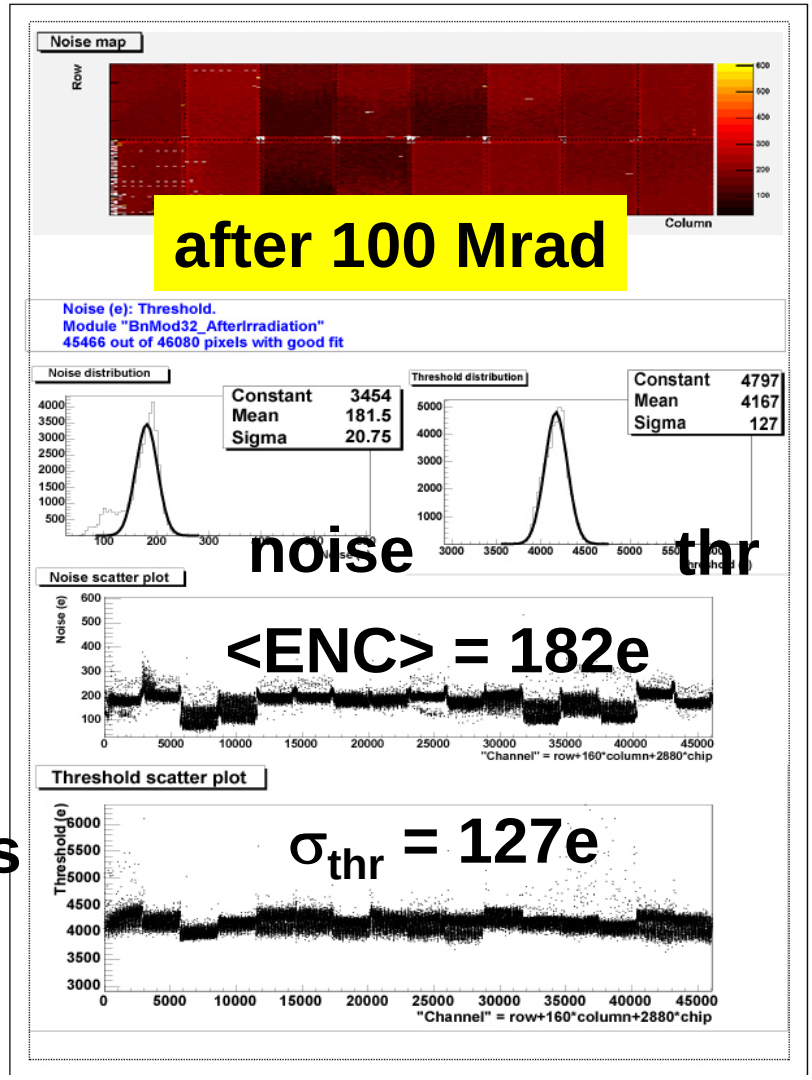
Irradiated Modules after 100 Mrad



ATLAS

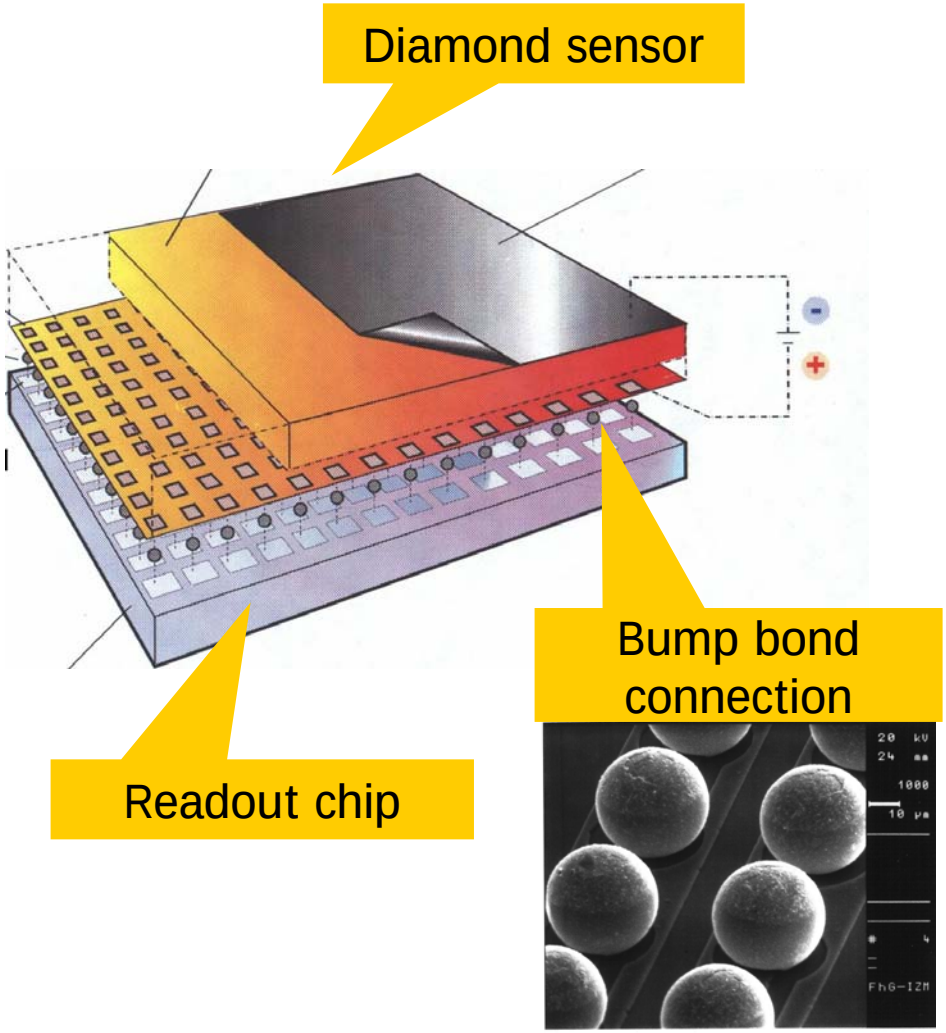
20yrs LHC

lab measm'ts



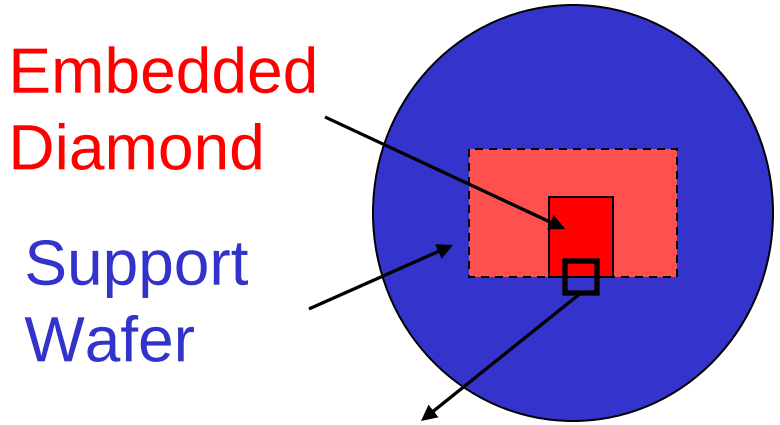
Hybrid pixel detector

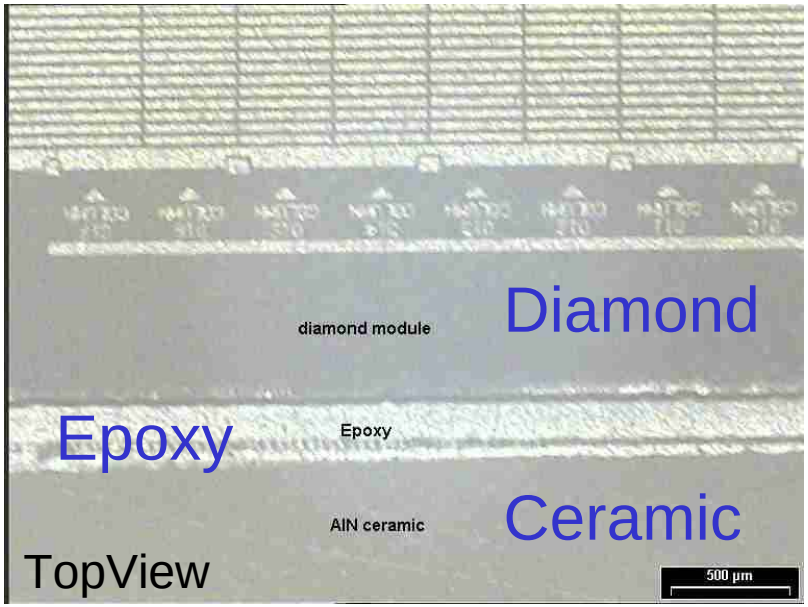
- All Diamond sensors provided by RD42
- Pb/Sn bumping done by Fraunhofer IZM Berlin
- Bumpsize 20µm
  Spacing 50µm



Diamond Bumping

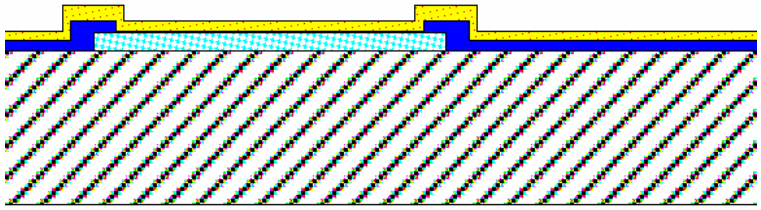
- Challenge: Bumping process is designed for wafer scale IC, not for single die/module
- The diamond has to be glued into a support substrate wafer for underbump metallization (UBM)
- Bump is on FE-Chip side



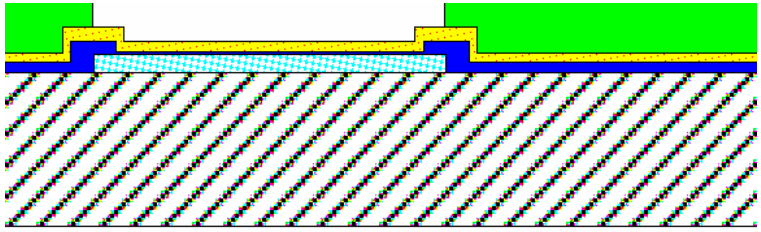


UnderBump Metallisation

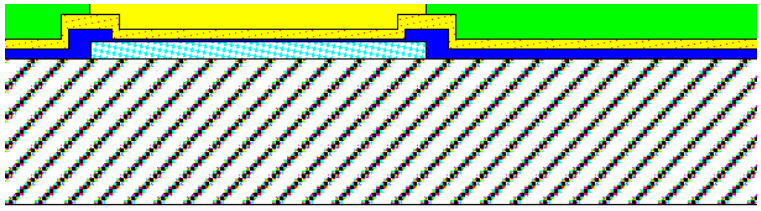
- Deposition of plating base



- Application of photo resist

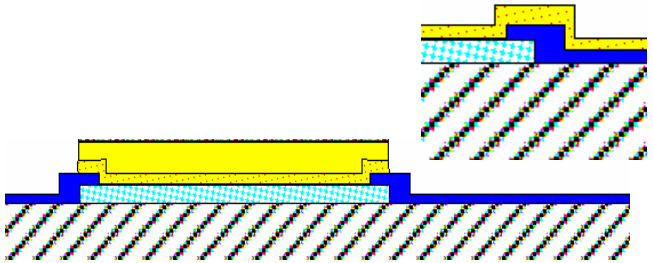


- Galvanic metallization

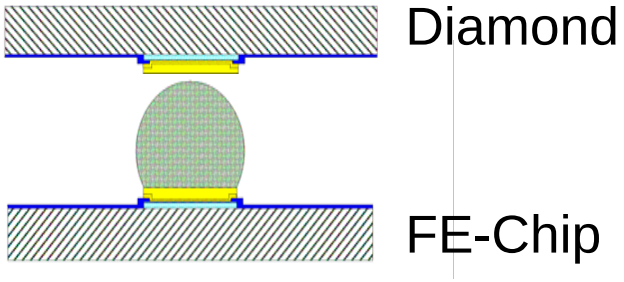


UnderBump Metallisation

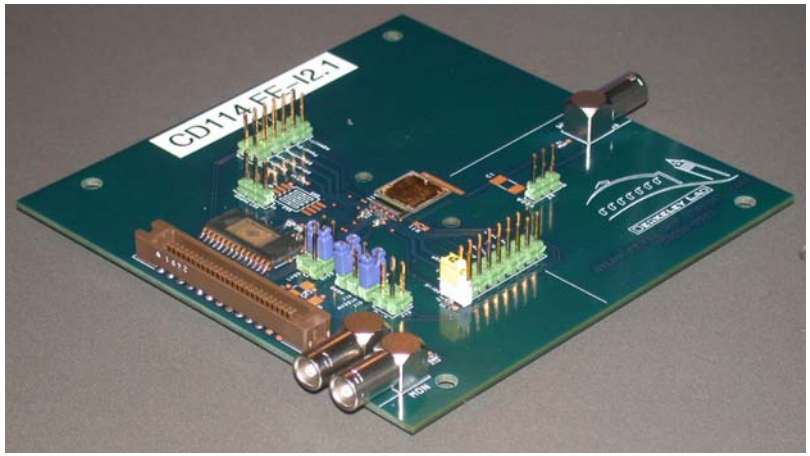
- Removal of photo resist and plating base (if plating base removed only partial shorts between pixels, this has happened)

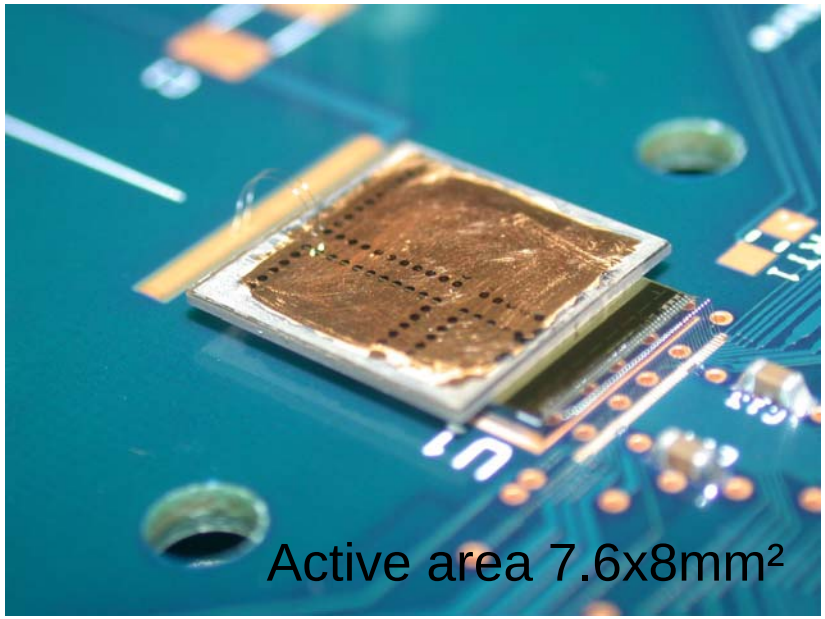


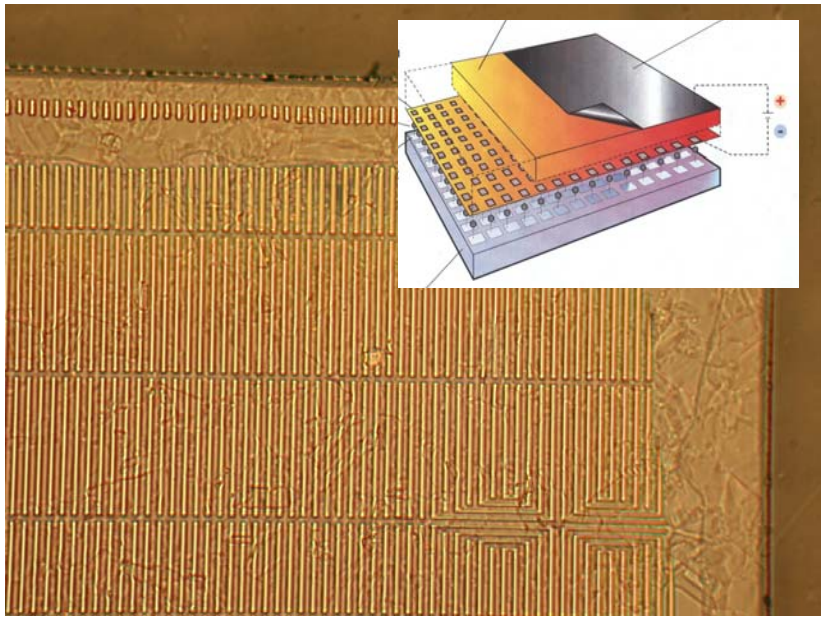
- Cut out of diamond
- Flip Chip bump bonding



Diamond Singlechip Assemblies

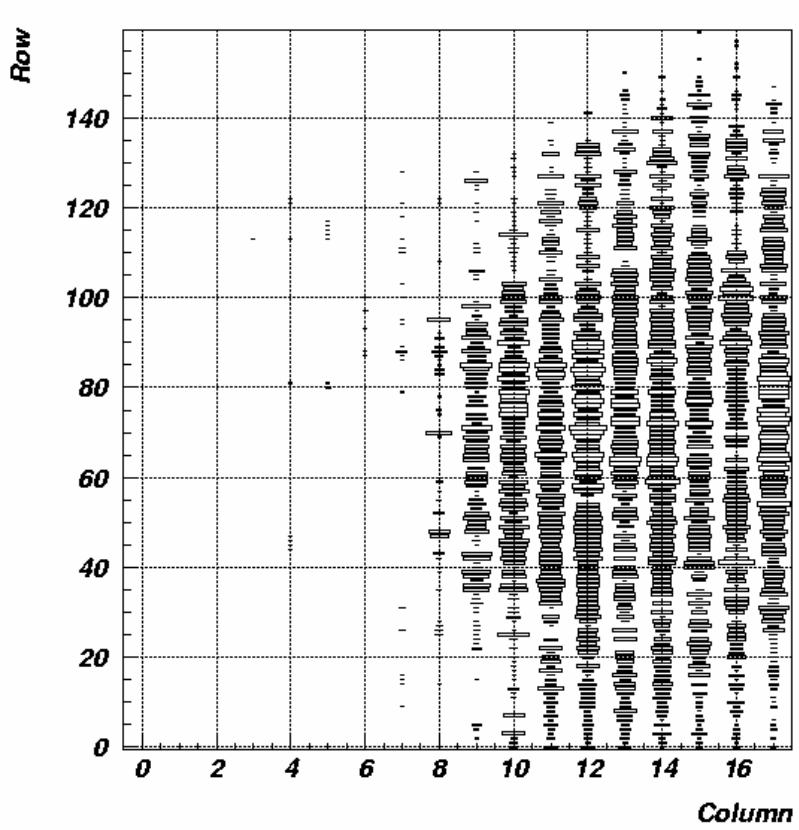






Diamonds at Bonn

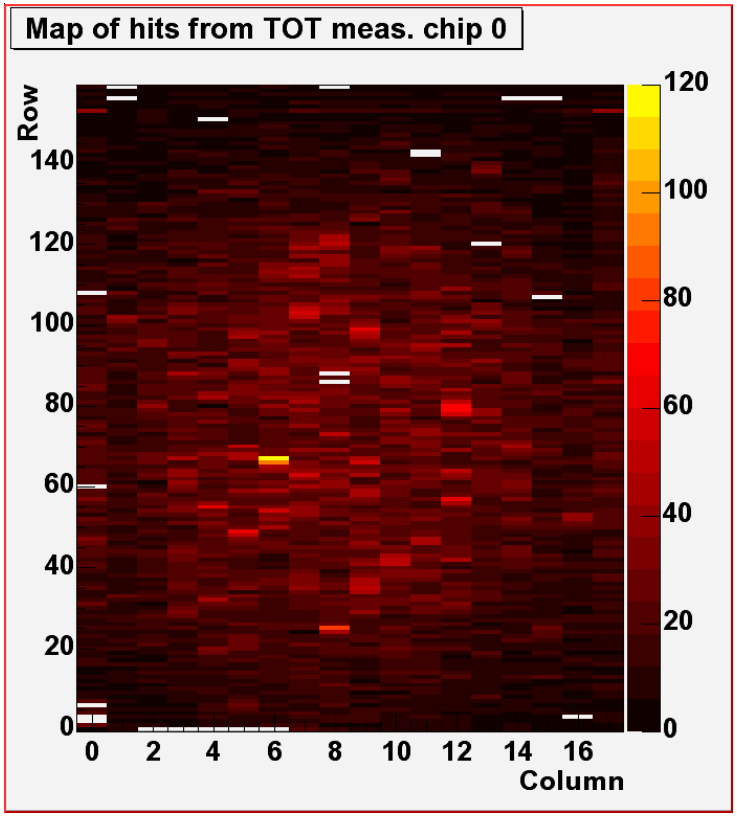
- 2001: UTS5, poor bumping quality, only a corner of good bumps, radsoft FE-C
- 2002: CD91, better bumping, but sensor worked less well than UTS5, radsoft
- 2003: CD109, glue remnants on chip
- 2003: CD114, shorts between pixels due to plating base not etched away
- 3/2004: CD109 and UTS5, fully bumped diamond pixels, FE-I3
- 7/2004: CD114 expected



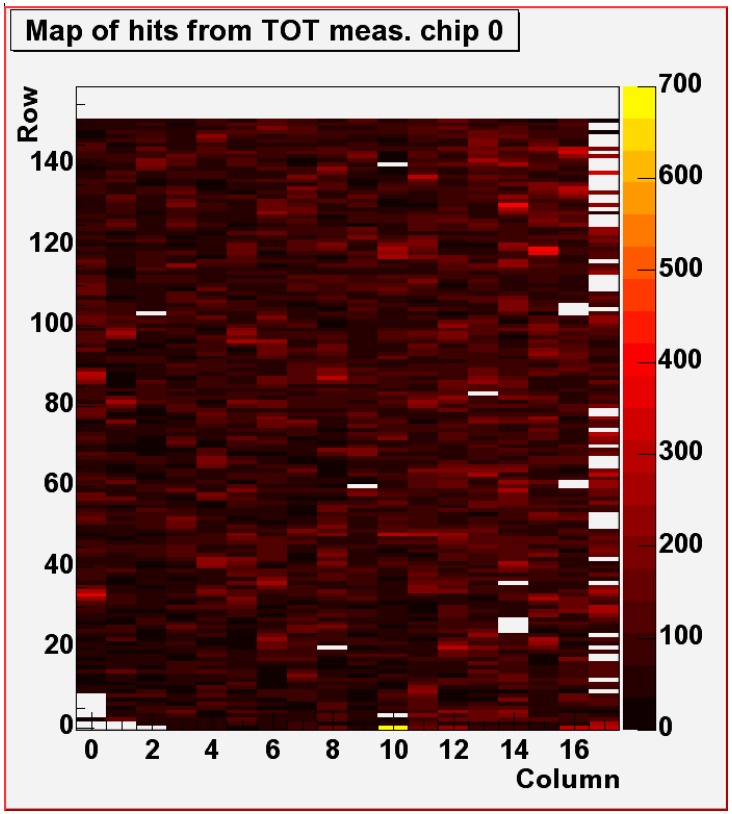
Testbeam HitMap Data
Diamond singlechip UTS5 (2001)

New 3/2004 SC-Assemblies

Source Test

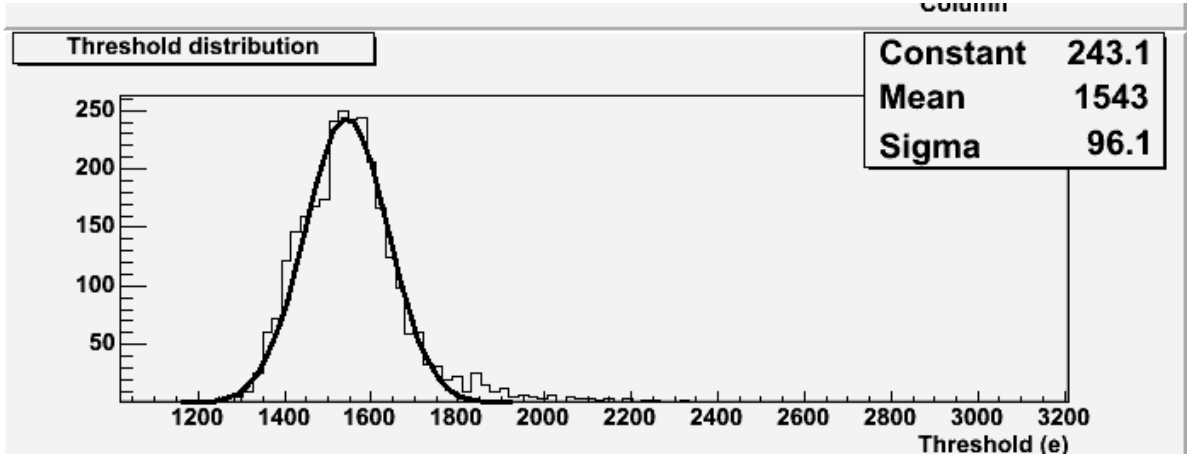


Americium241 source (~4600e)
Diamond singlechip CD109

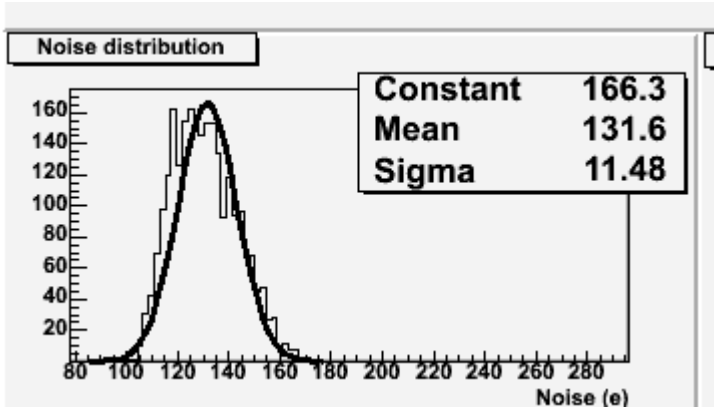


Cadmium109 source (~1500e)
Diamond singlechip UTS5

Diamond Measurements



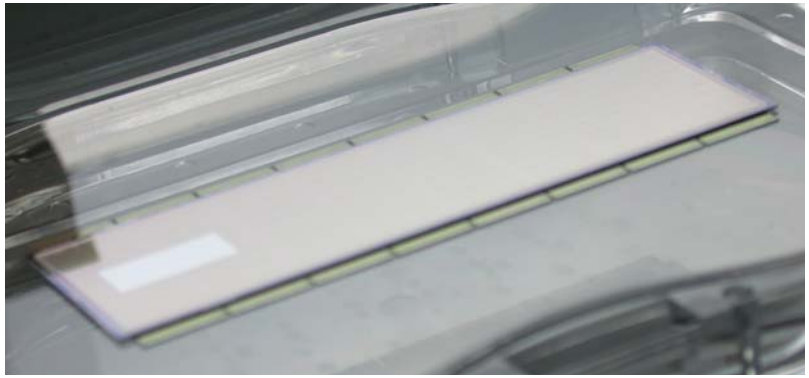
Threshold
~1500e
Dispersion
~100e

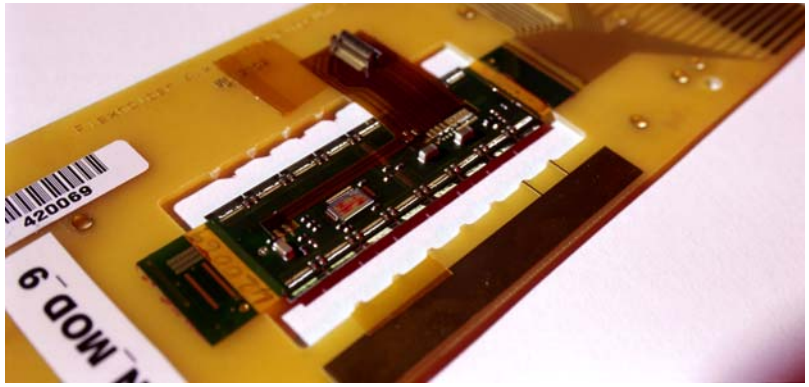


Noise
~130e

Atlas Pixel Modul

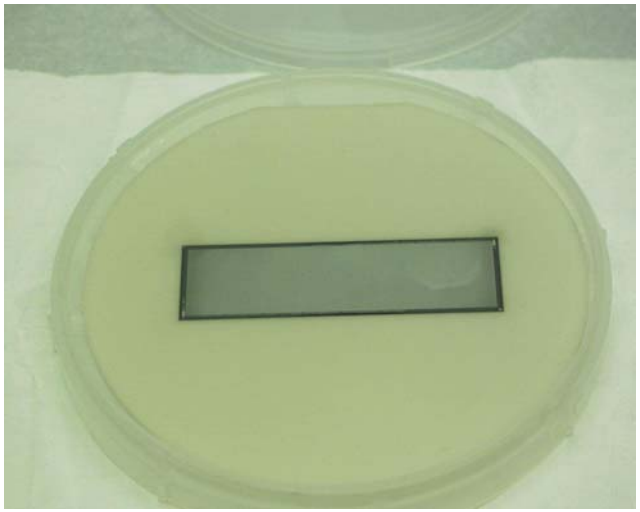
- Sensor ~6x2cm^2
- 46000 pixels
- 16 Altas FE-I3 chips





Full Diamond Pixel Module

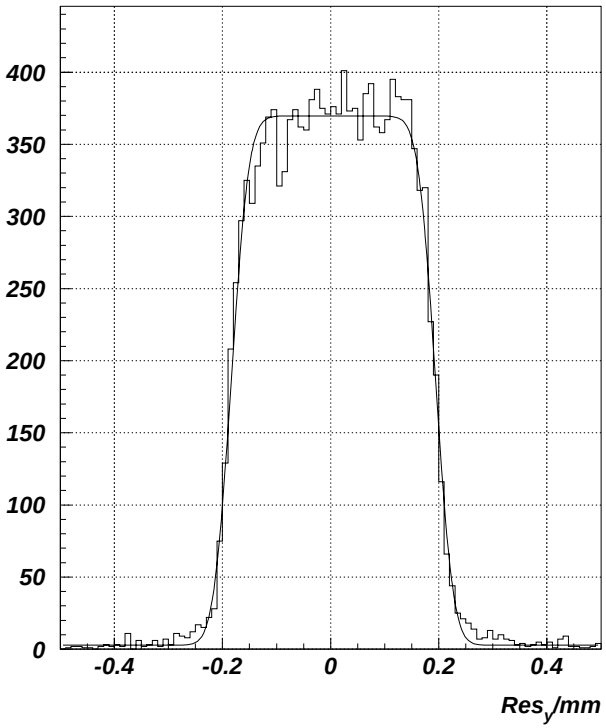
- Practice piece in processing at Fraunhofer IZM
- Full Atlas type Module planed to be ready late summer this year

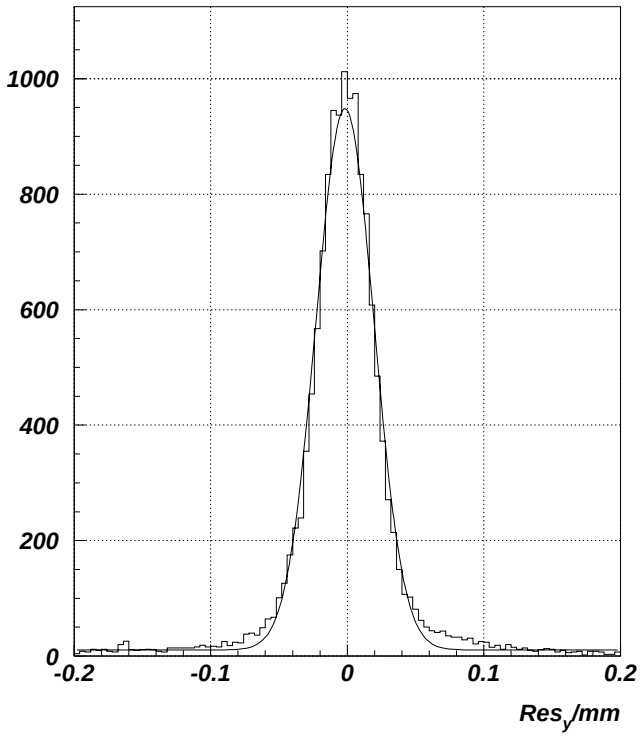


Summary

- Have first assemblies with ATLAS Frontend Chip
- Atlas FE-I3 suitable also for diamond sensors
- Full scale Diamond module in preparation

Testbeam Results

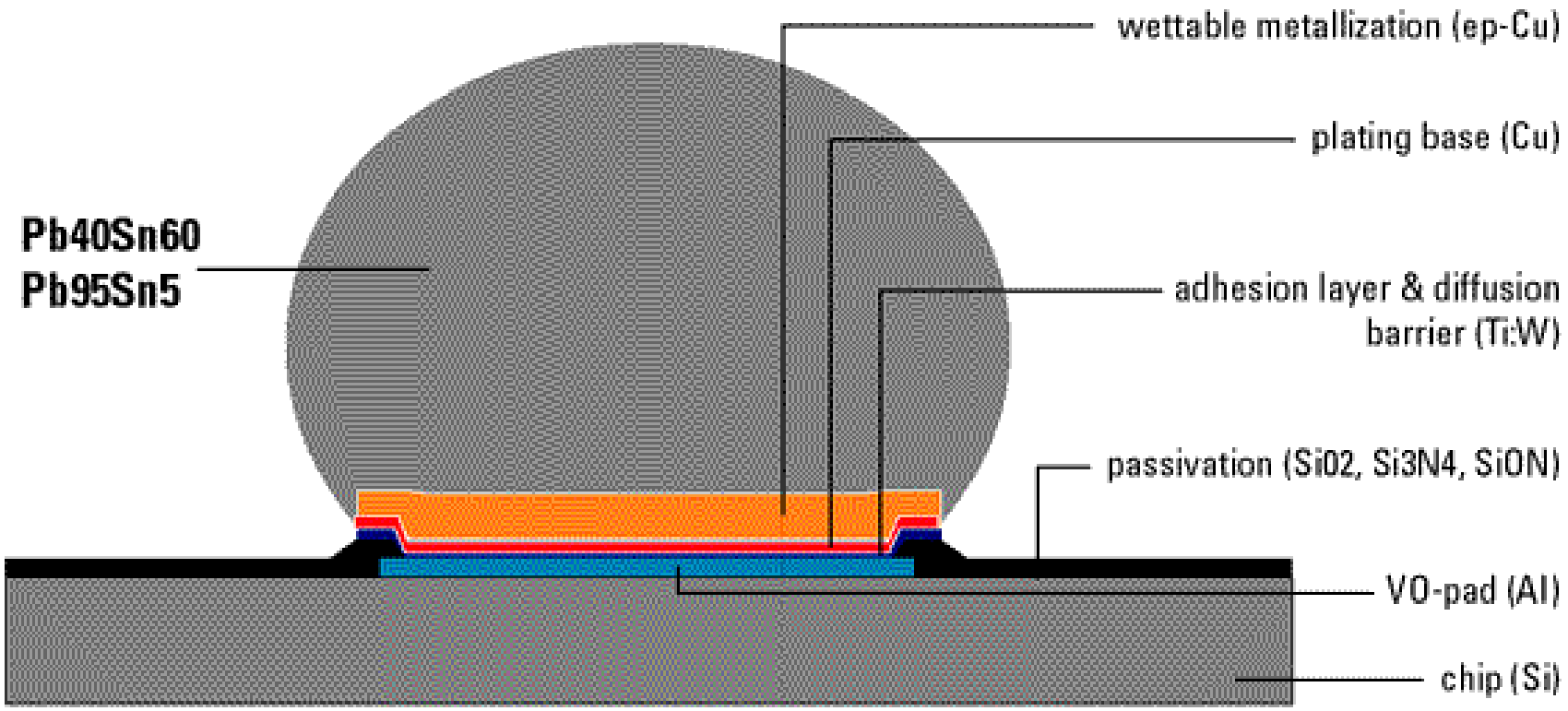




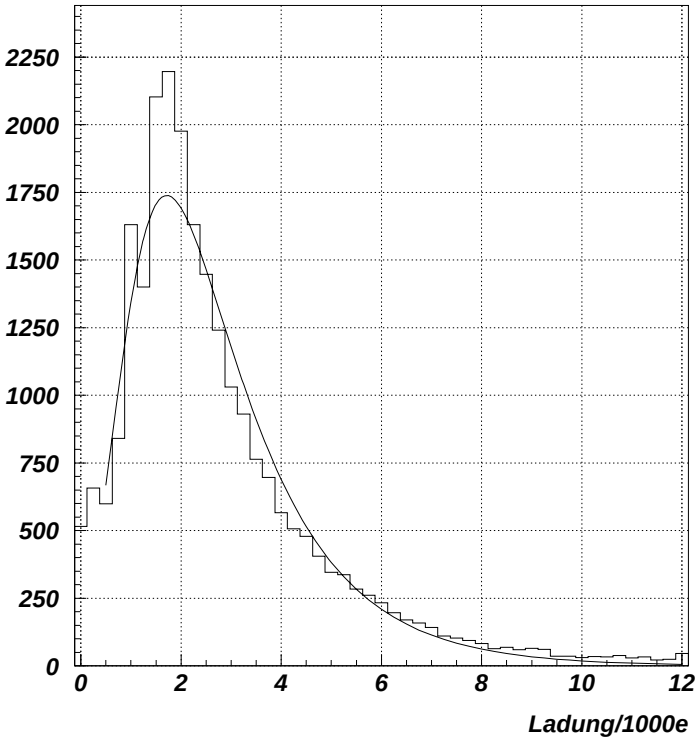
Residual distribution in both pixel dimensions

M. Keil

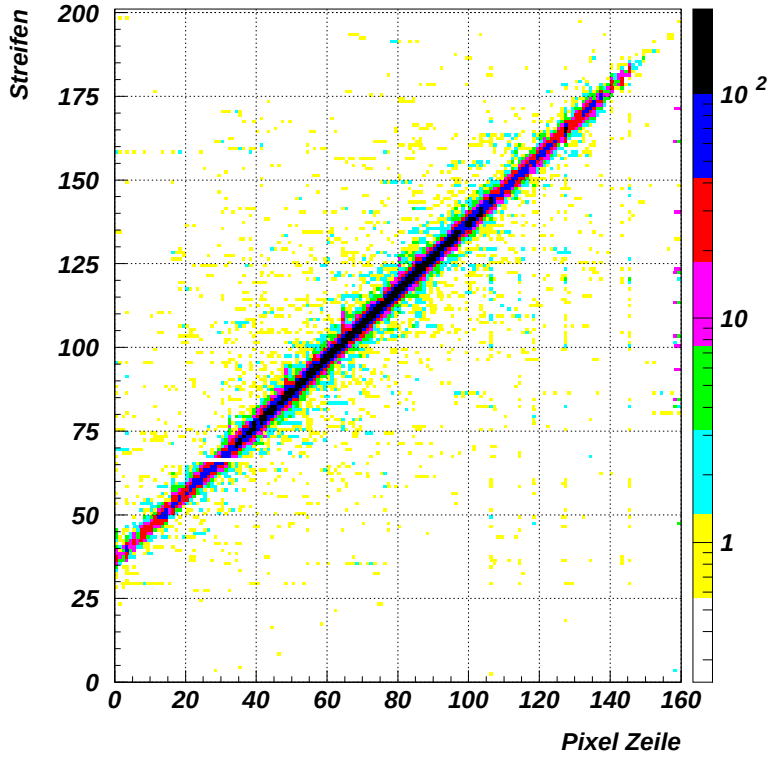
Pb/Sn Bump


wettable metallization (ep-Cu)
plating base (Cu)
Pb40Sn60
Pb95Sn5
adhesion layer & diffusion barrier (Ti:W)
passivation (Si02, Si3N4, SiON)
VO-pad (Al)
chip (Si)

Testbeam Results



Collected charge during testbeam with fitted landau distribution.

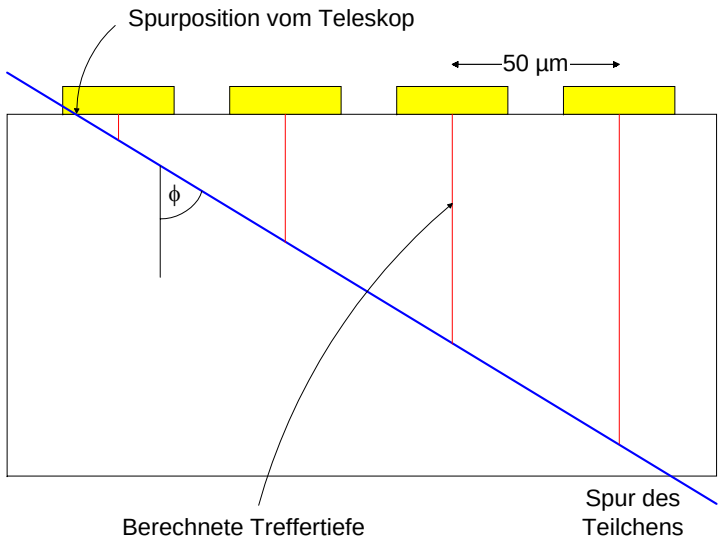


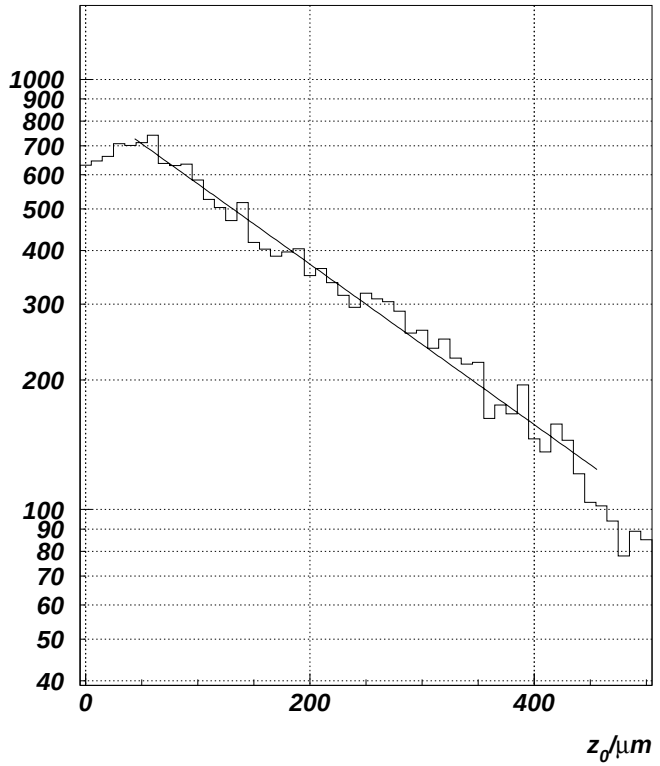
Correlation between hits of diamond detector and beamtelescope

M. Keil

Testbeam Results

Charge collection distance





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Collection distance 228±4µm @20°

M. Keil, in agreement with simulations T. Lari