FANGS

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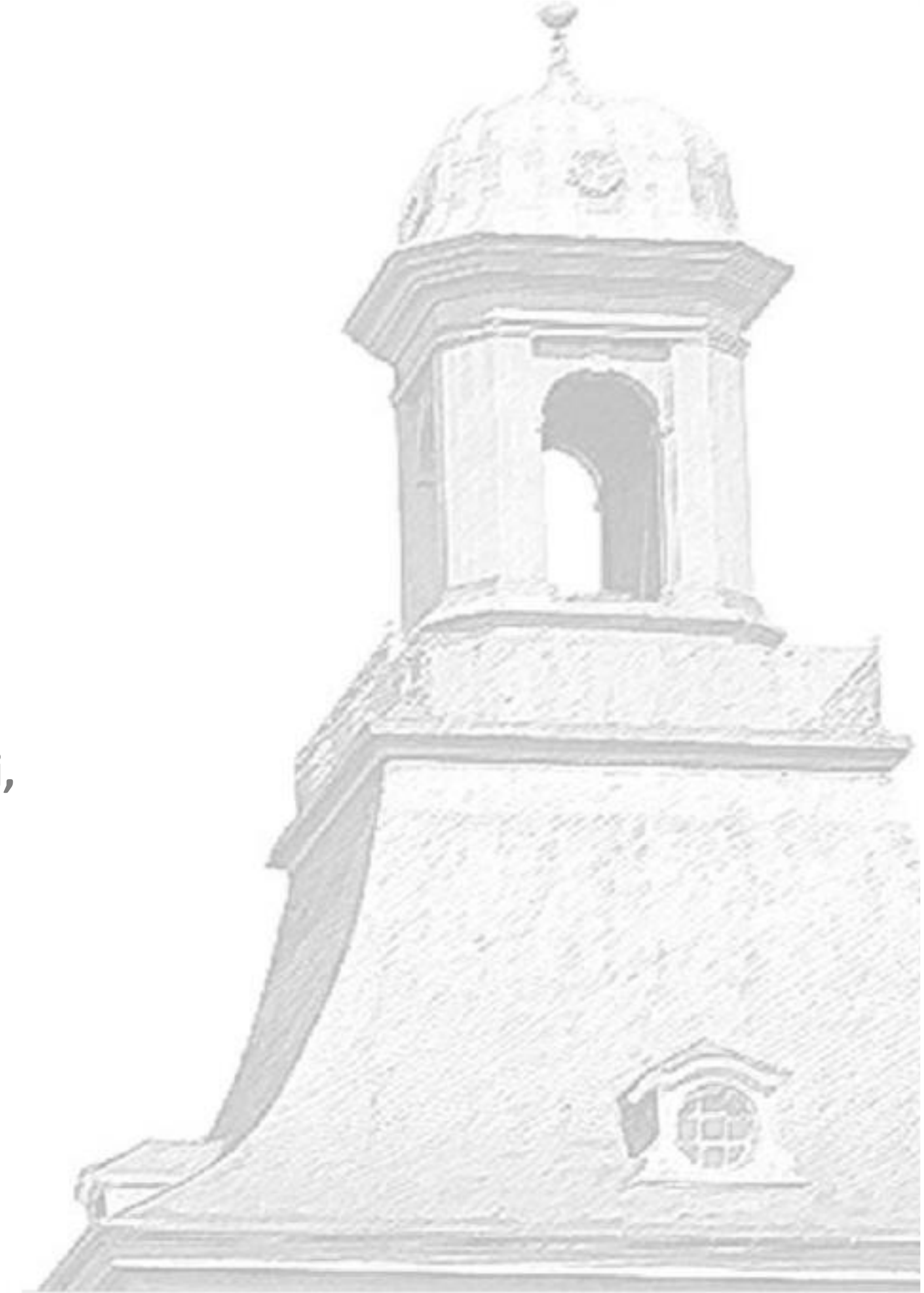

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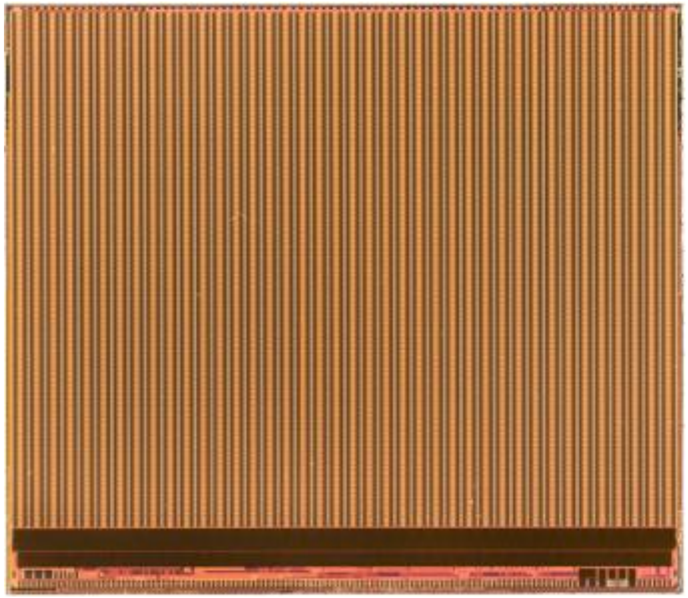
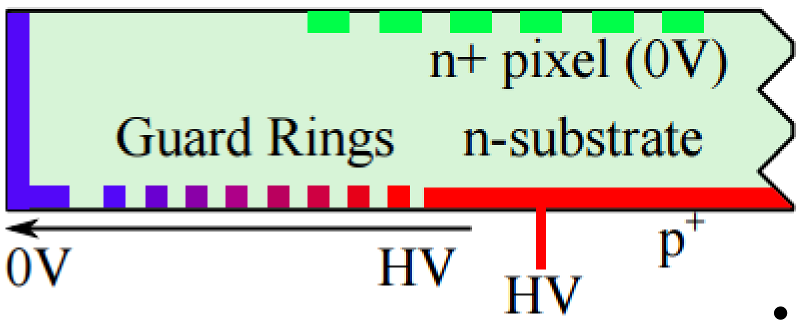
FANGS: FE-I4 ATLAS Near Gamma Sensors



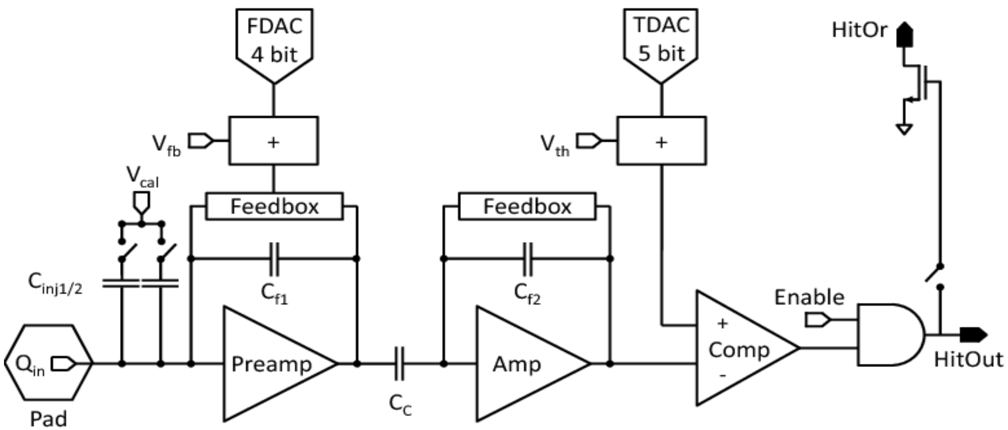
- FE-I4 read out chip
  - **High hit rates and radiation hard**
  - IBM 130 nm CMOS process
  - Provides read out for 80x336 pixels
  - Thickness=150 µm
  - Physical size=**21x19 mm²**
  - Bump bonded to Si sensor

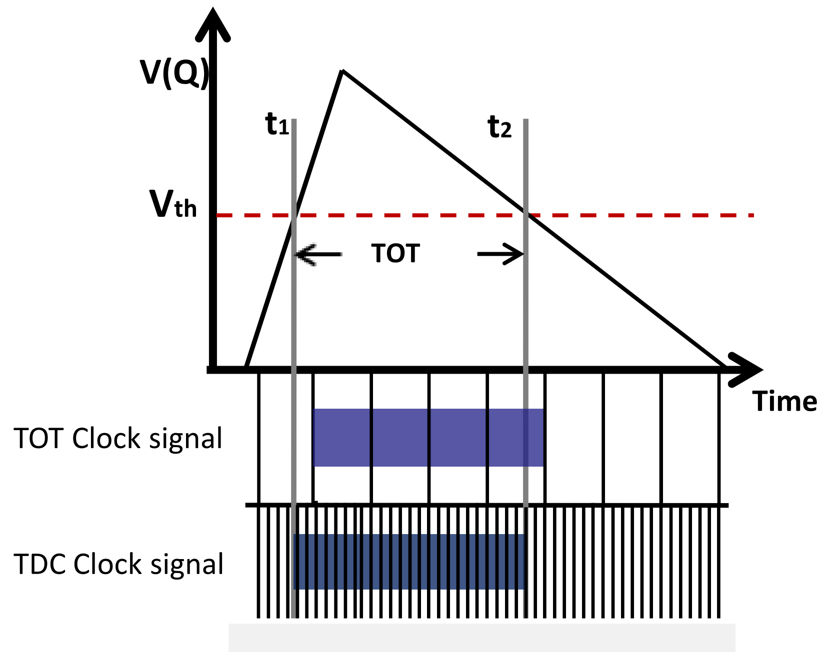
- Sensor:
  - n-in-n planar
  - Pitch=**50x250 µm²**
  - Thickness=200 µm
  - Physical size=19x20 mm²
  - HV=60 V
  - Power=1.2 W



- Background radiation measurements in Phase 2:
  - Sensitive to low keV X-rays
  - Ability to measure high particle rates

TDC Method

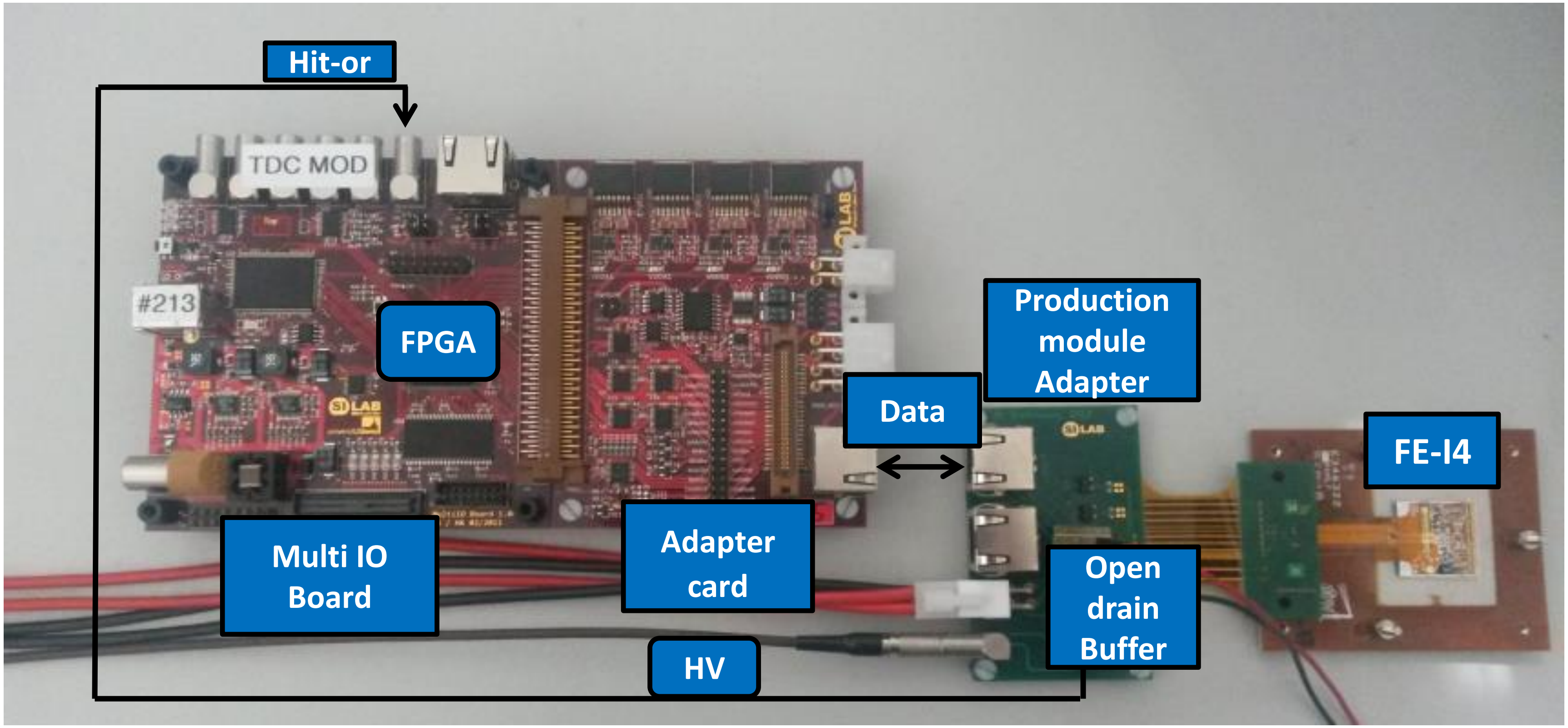




- Two stage amplifier → Discriminator with adjustable threshold.
- Time over threshold **(TOT)** with externally supplied 40 MHz clock.
- Time to digital converter **(TDC)** uses 640 MHz FPGA clock.
- Output of each pixel is ORed.
- Internal charge injection circuit for threshold tuning and calibration

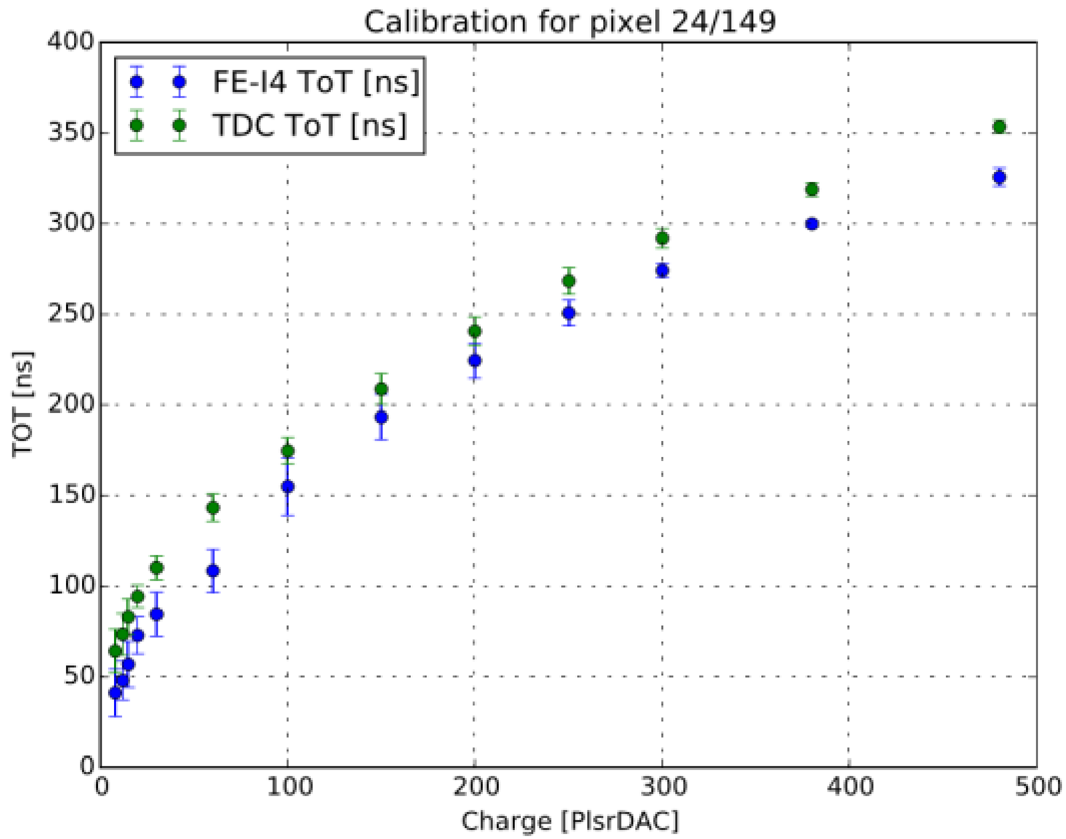
→ Both, high speed and adequate energy resolution achieved at the same time

Experimental Setup



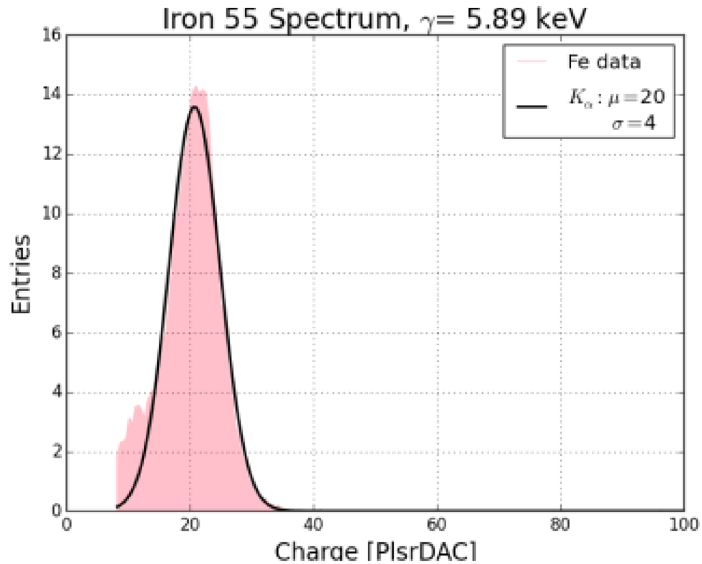
- USBpix used for readout and pyBAR for analysis.
- **Open drain buffer** amplifies HitOr signal on long cables (O(30 m)).
- New USBPix3 readout system being tested at the moment (8 FE at a time).
- Software allows to monitor multiple FE in parallel.

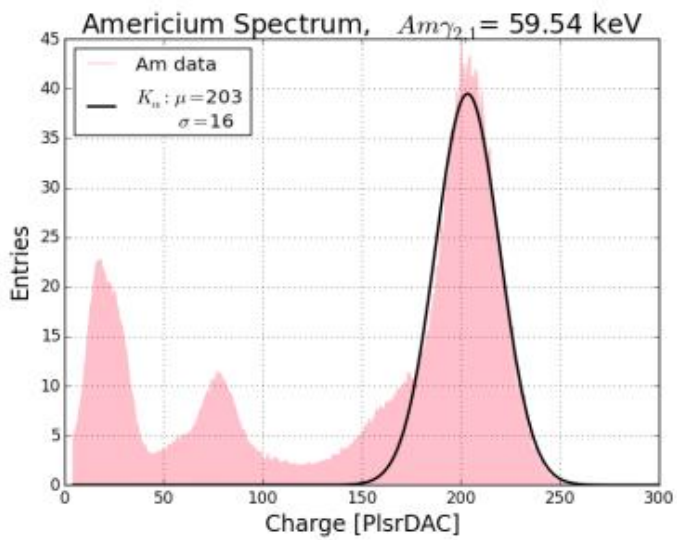
Pixel-per-pixel Calibration

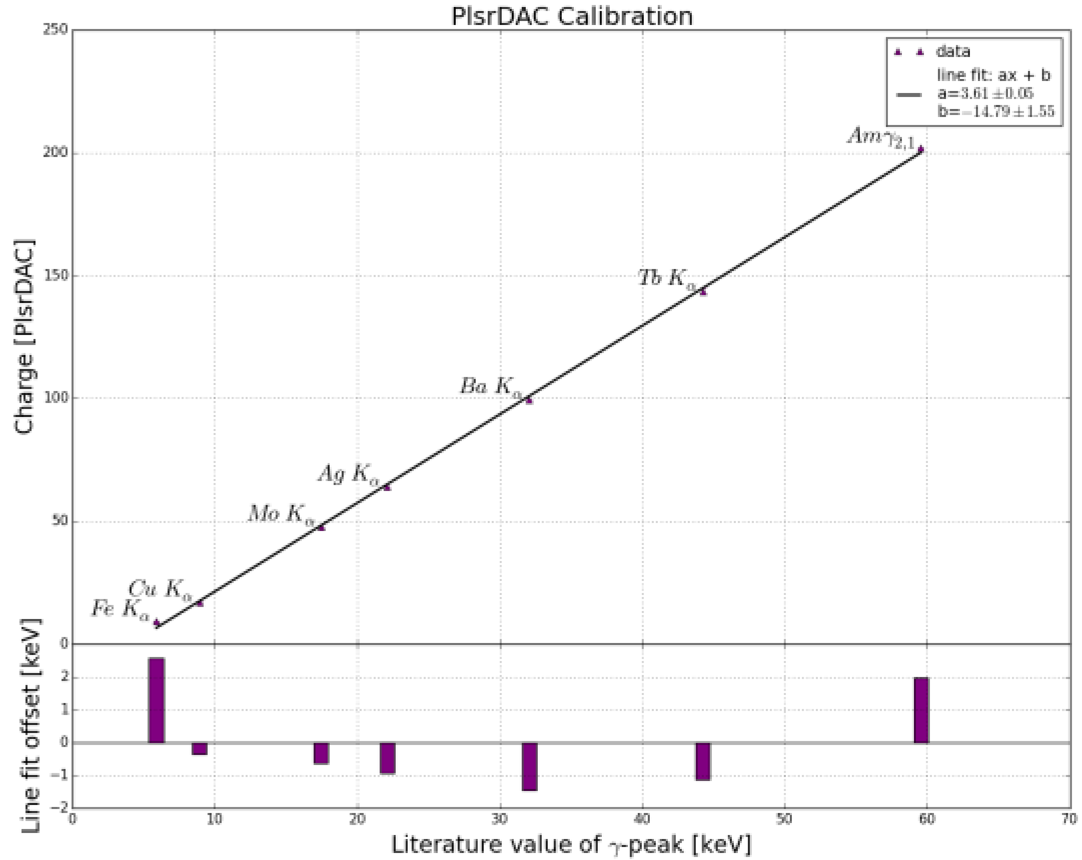


- Threshold tuning noise based
- V_{th} and TDC as a function of charge different for each pixel.
- Pixel per pixel calibration needed.
- Internal charge injection in units of PlsrDAC ~ 55 electrons

Calibration and Dynamic Range

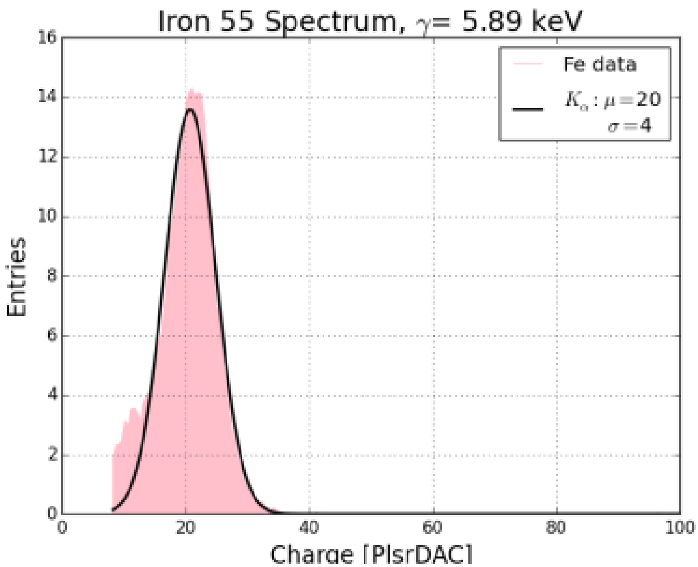


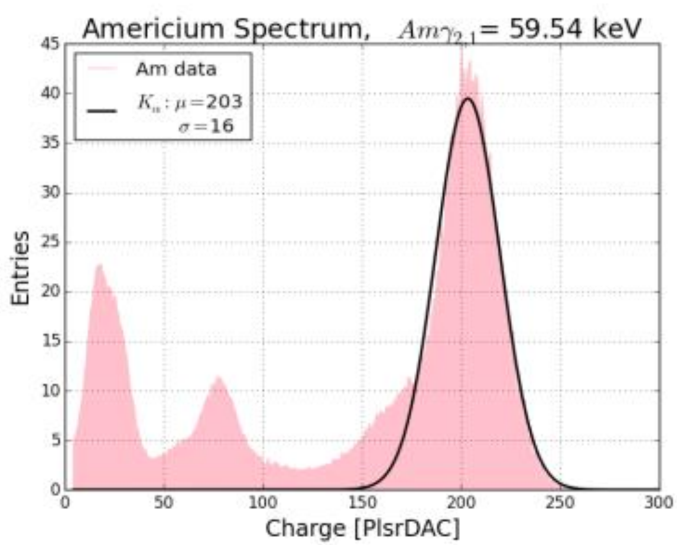


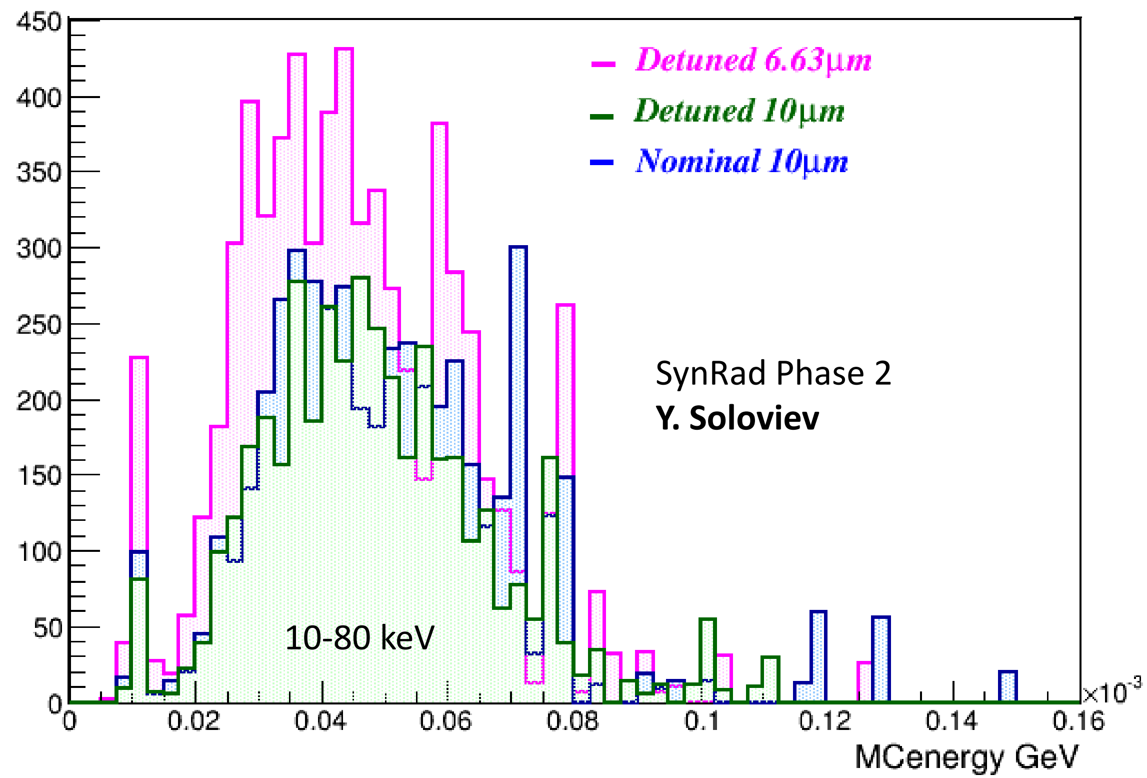


- Dynamic range 6-60 keV (wider also possible)
- Lowest measured plsrDAC value ~ 7
  - Threshold of ~1000 electrons feasible

Calibration and Dynamic Range







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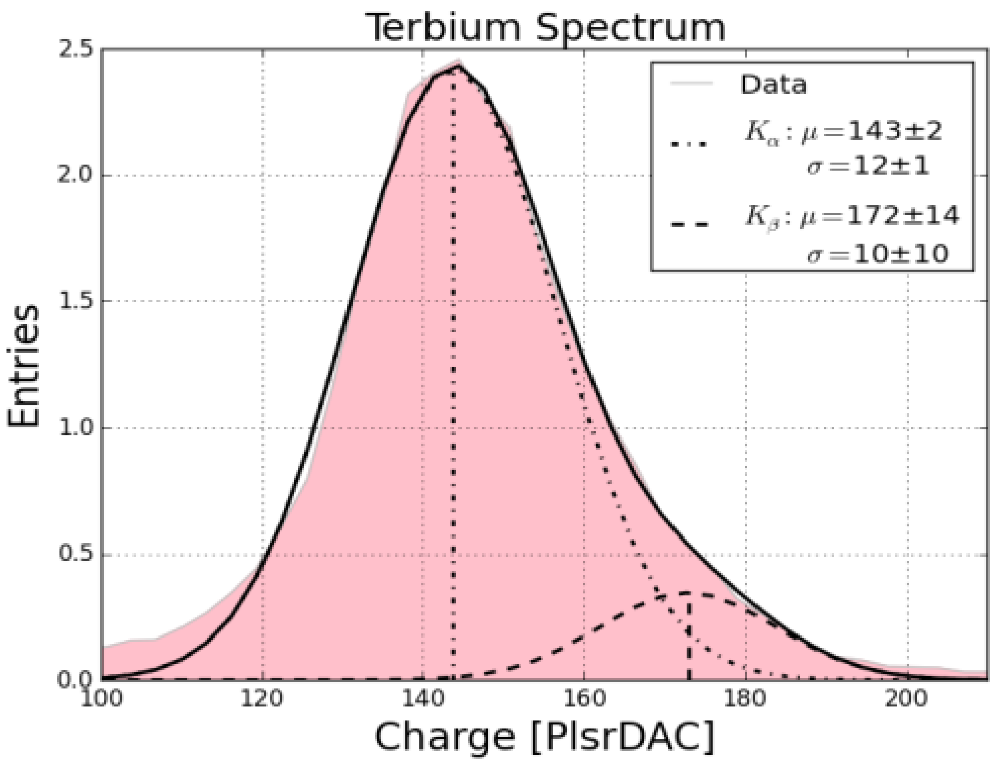
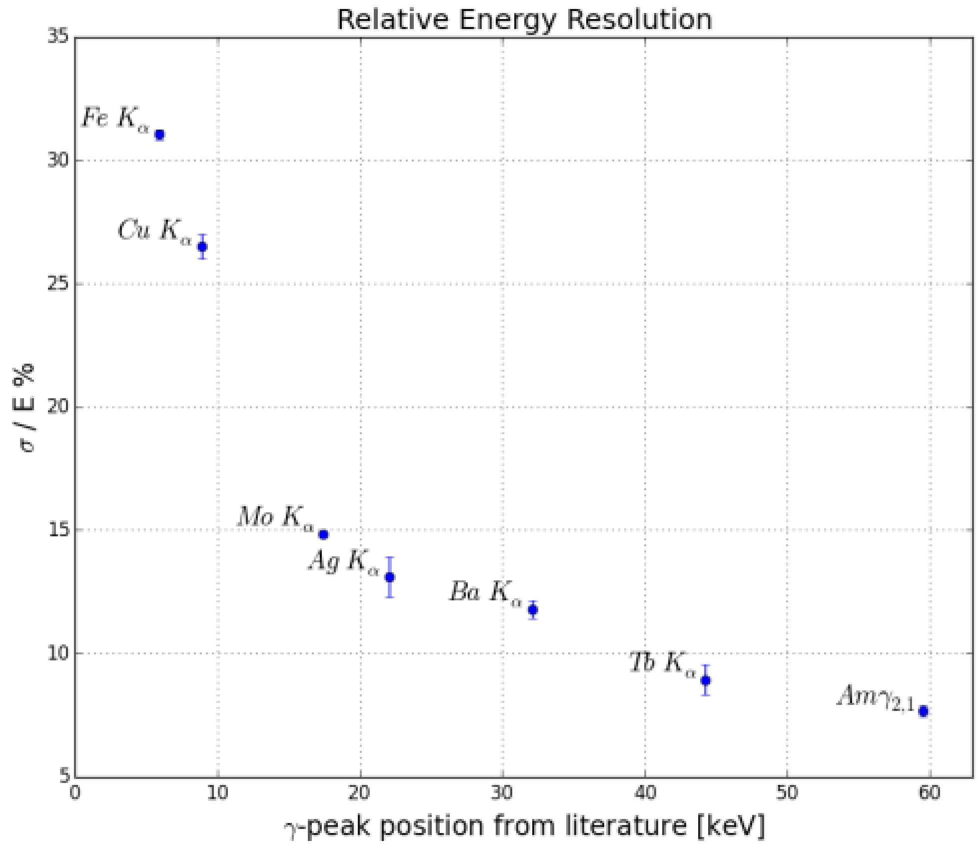
Energy Resolution

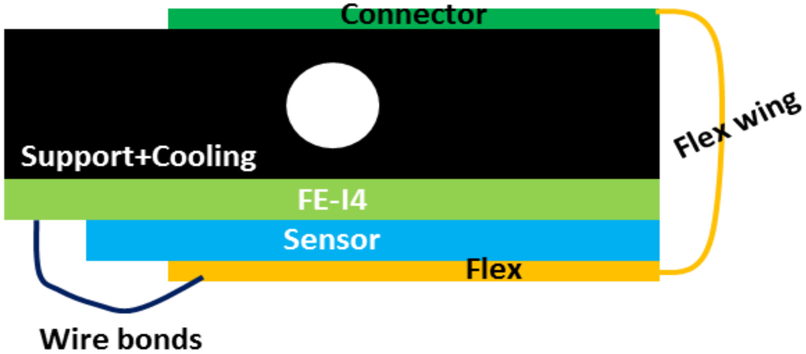


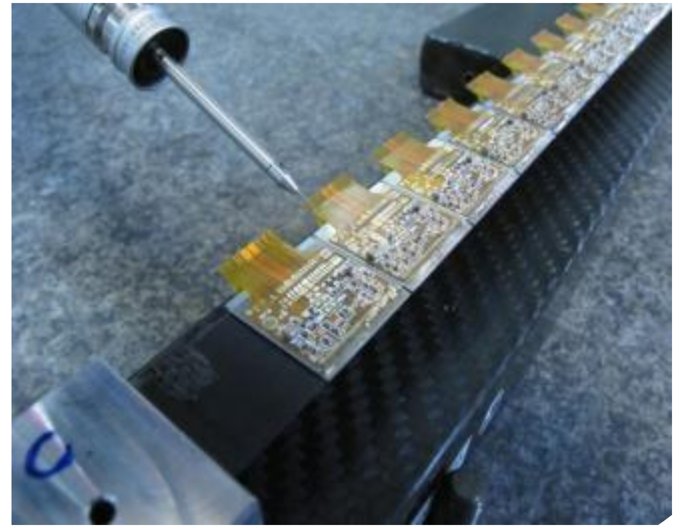


- Terbium K_α=44.2 keV, K_β =50.7 keV
- ΔE = 6.4 keV

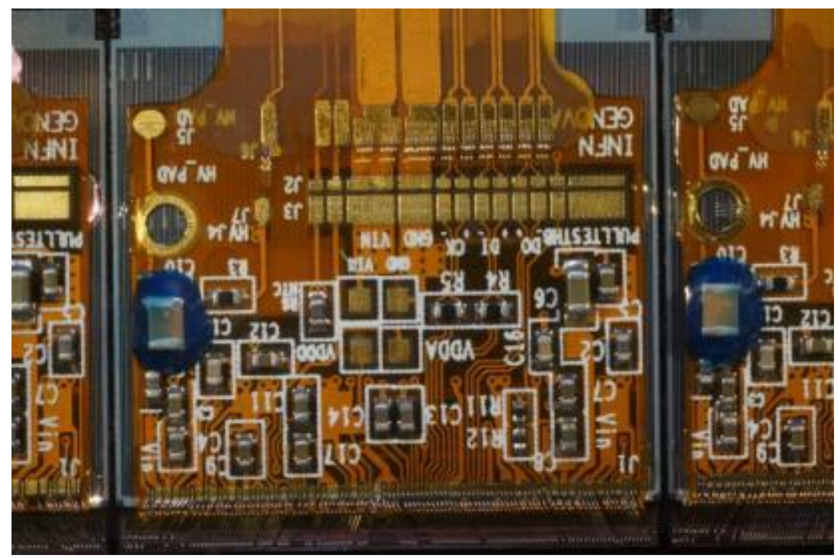
- Adequate energy resolution
- Better than 15 % above 10 keV

Initial Design Concept for Beast II

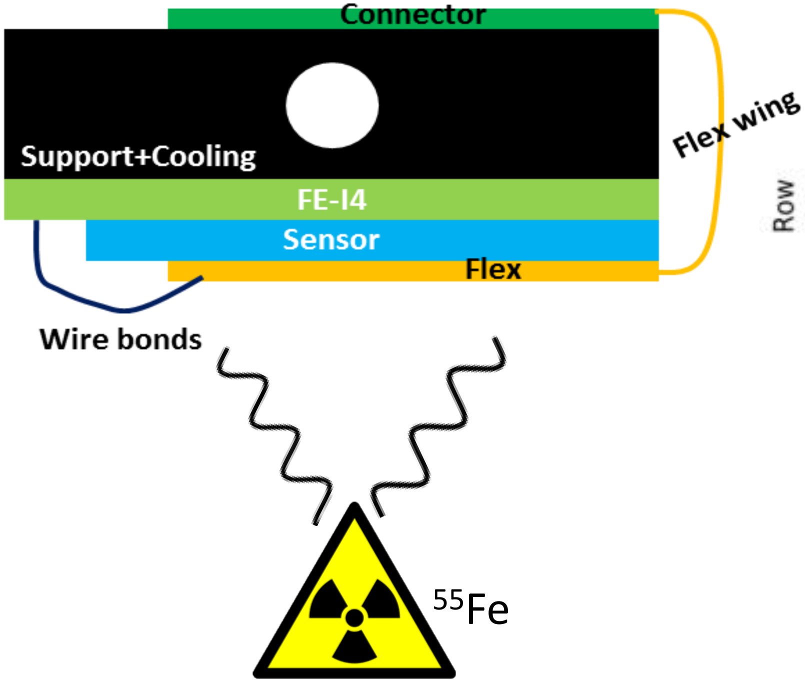


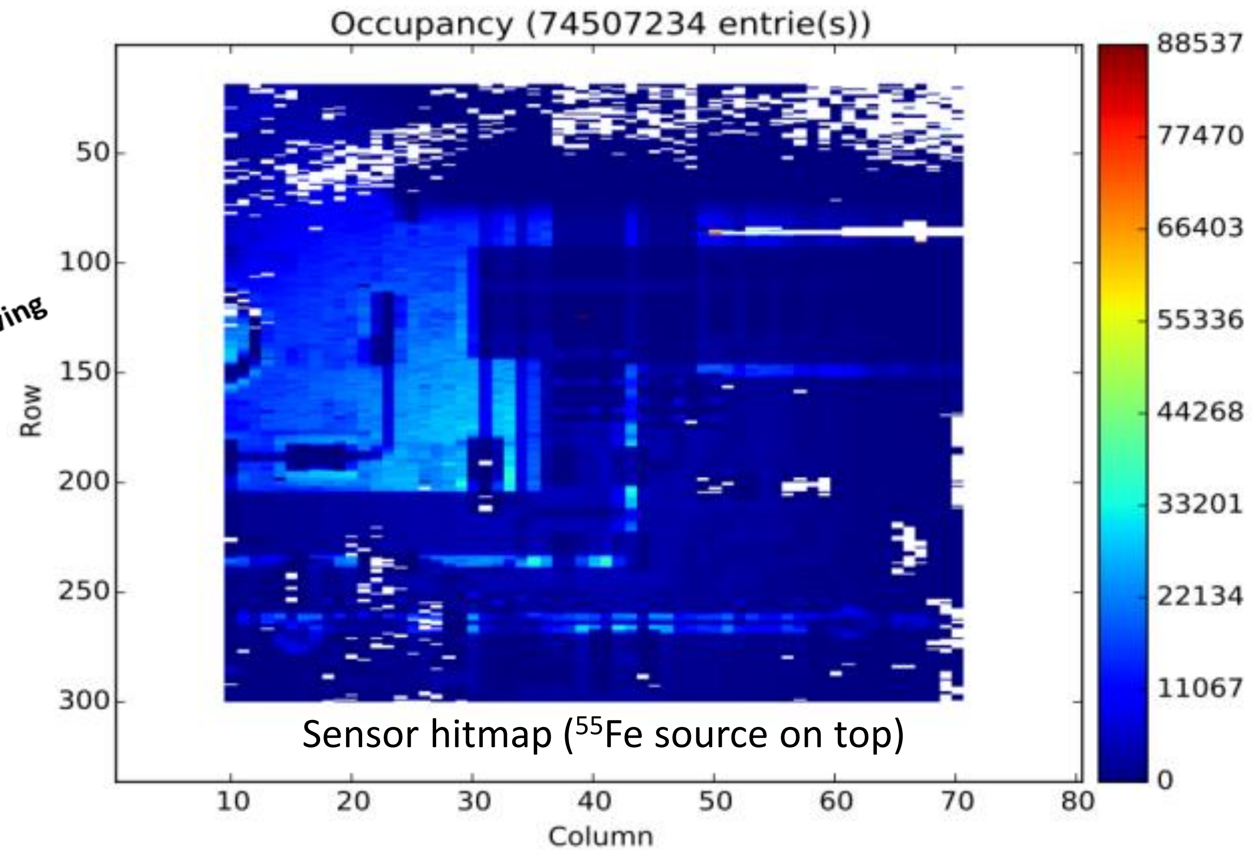


- Stave structure similar to ATLAS IBL.
- 90 µm thick flex attached on top of sensor for read out.



Flex Radiography





Sensor hitmap (^{55}Fe source on top)

Flex Radiography

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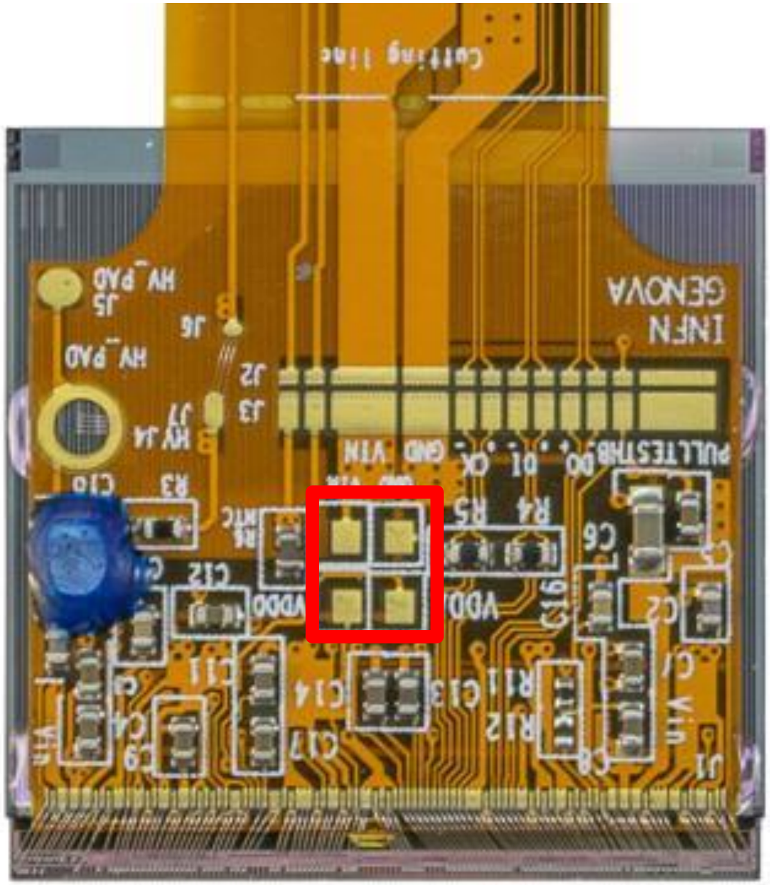
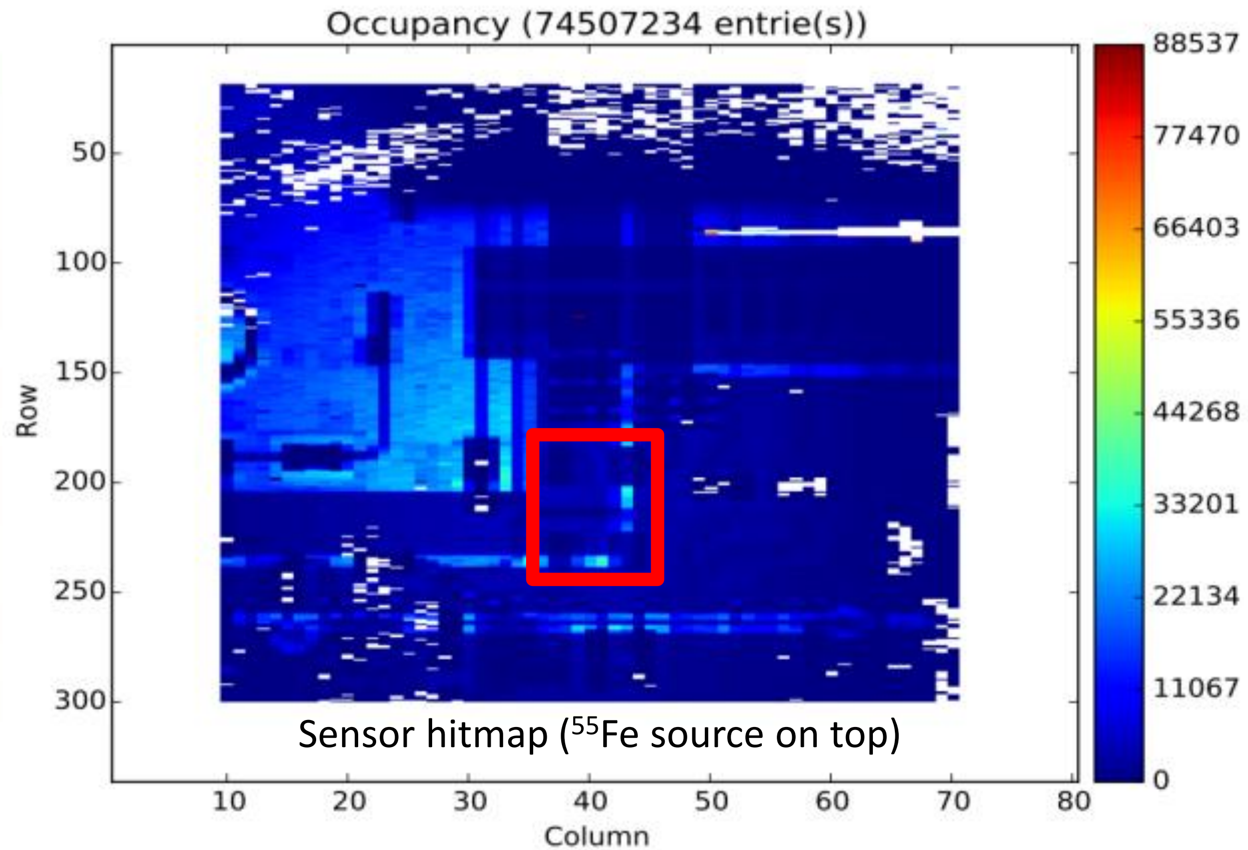


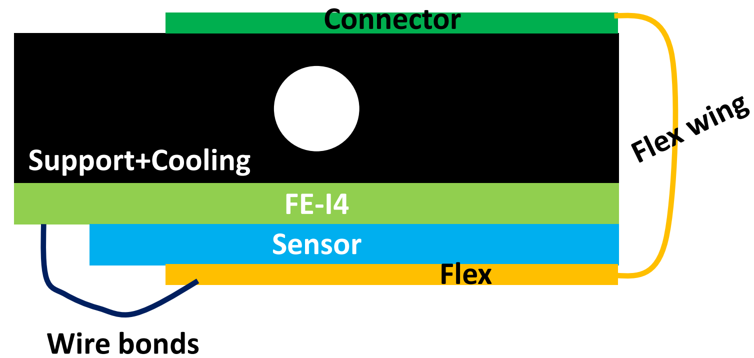


High absorption probability in the low keV range

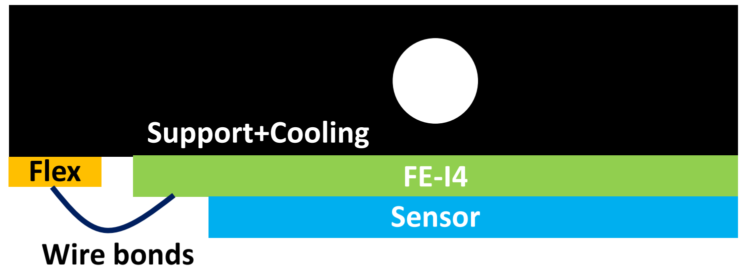
→ Design change with no material in front

FANGS Stave: Design Evolution

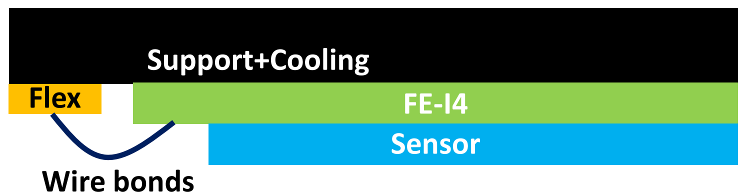
- How to mount few single chips in Phase 2?
  (Reusing existing infrastructure)



- Move the flex to one side. No material in front!



- Thinner support. Make use of PXD cooling



Mechanical Arrangement

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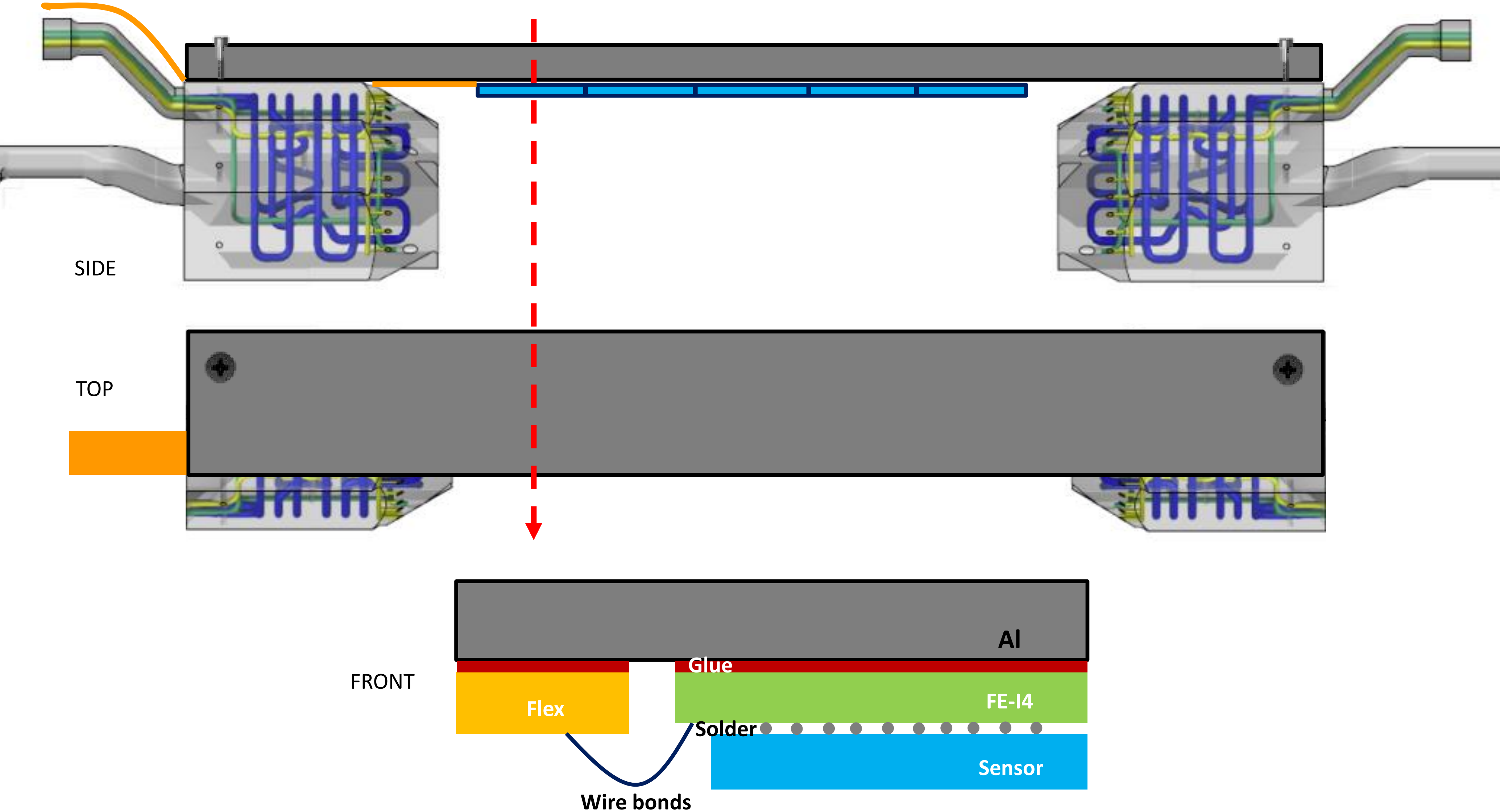
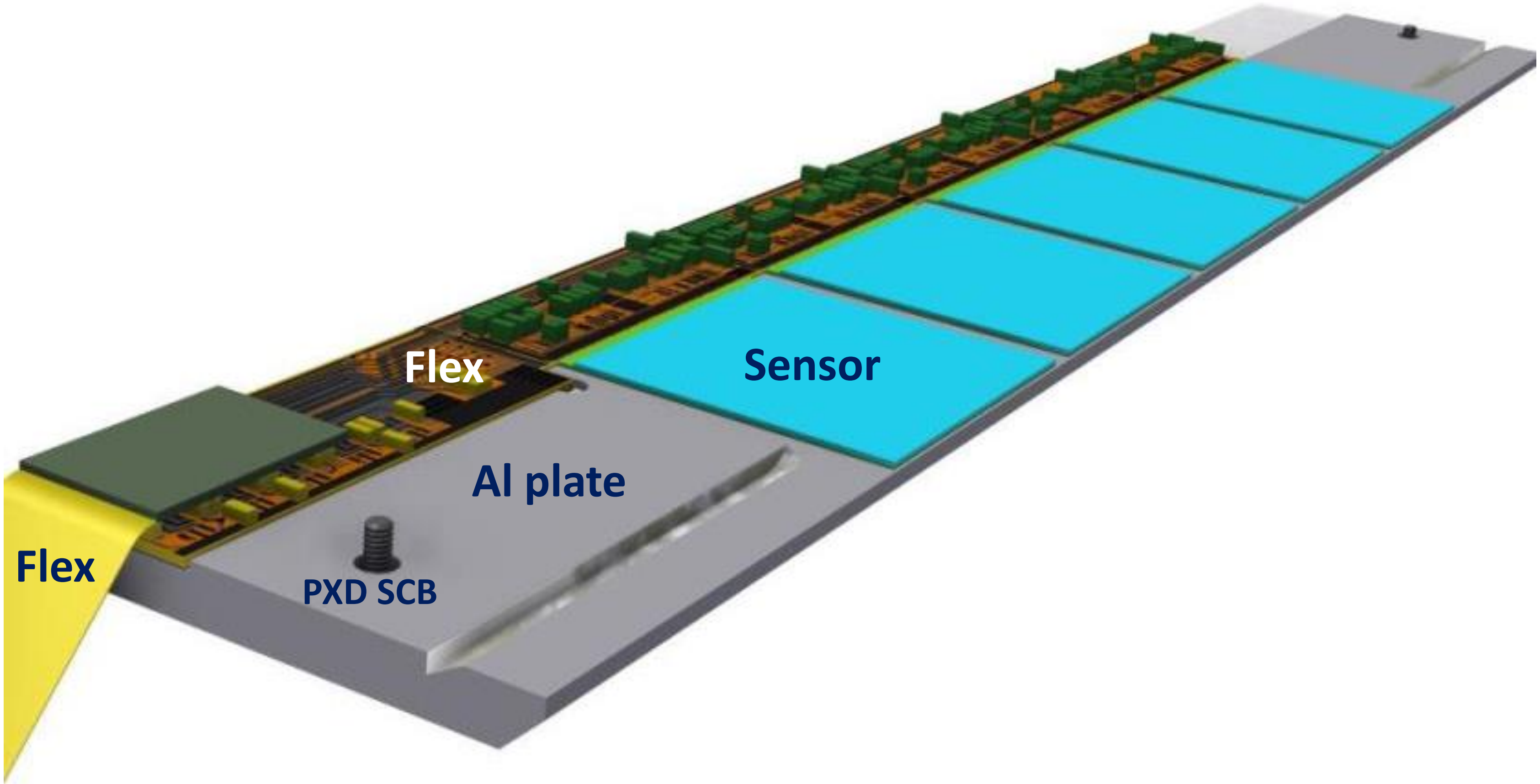
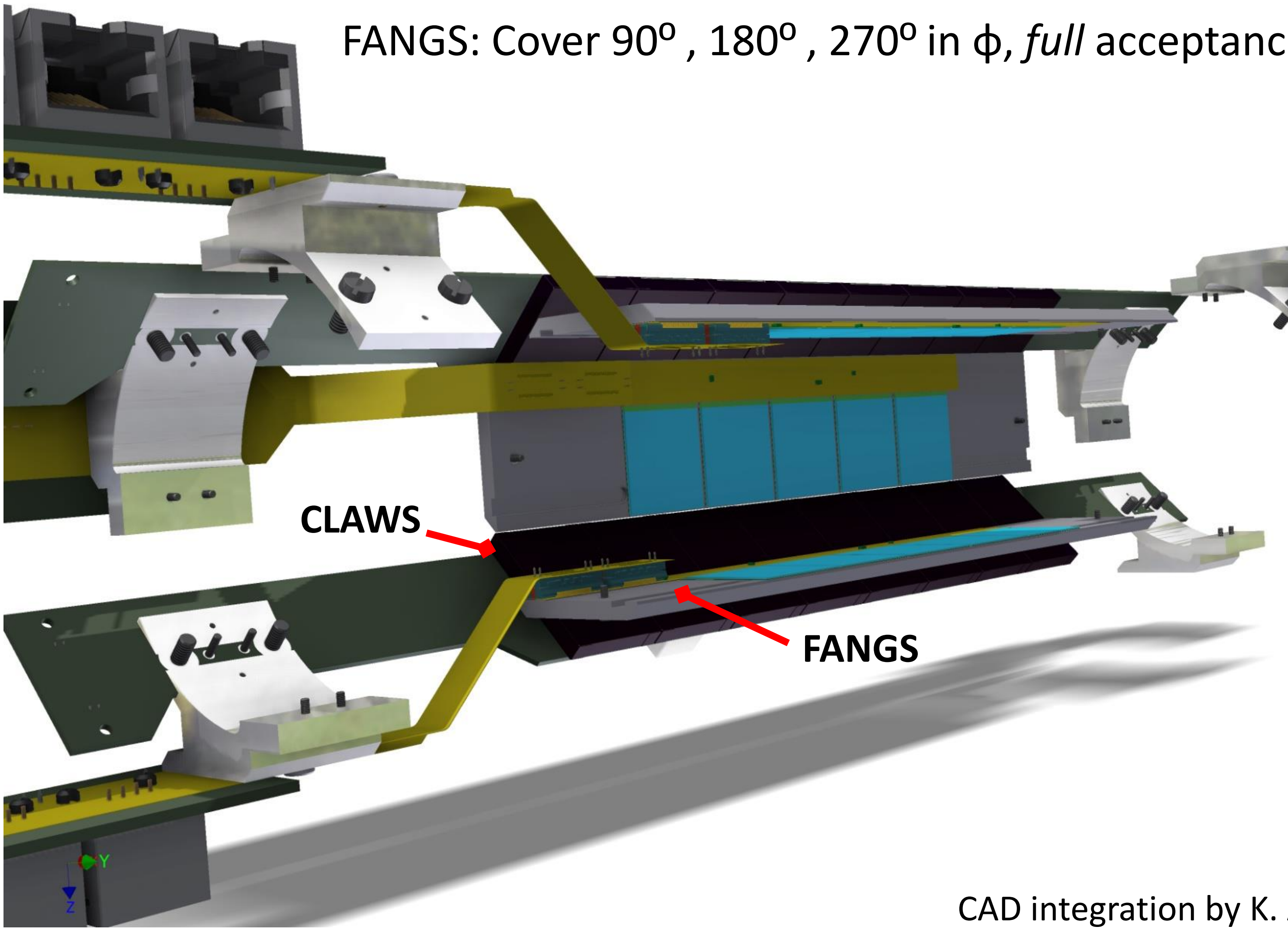


FANGS Stave



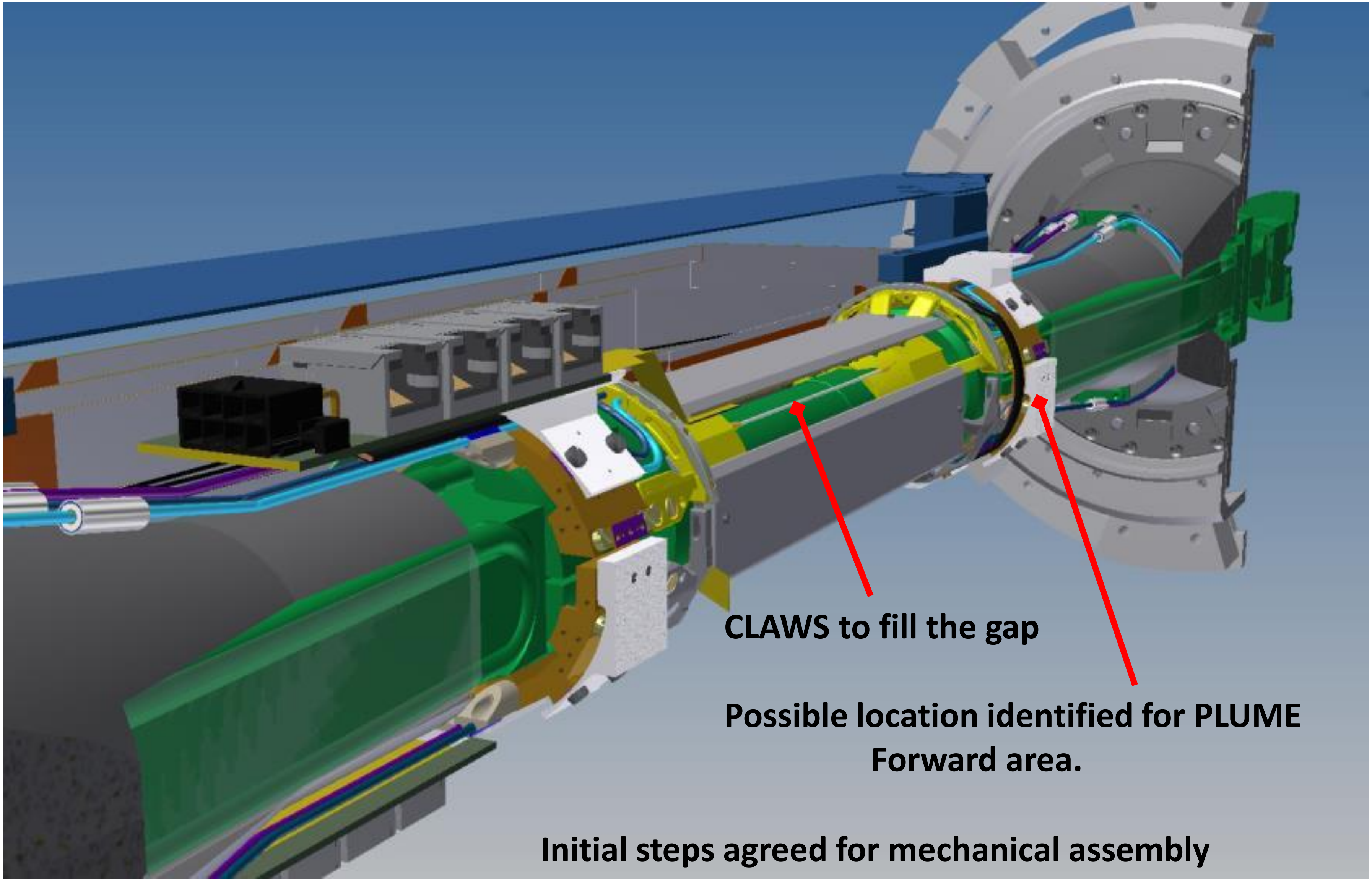
FANGS Integration

FANGS: Cover 90º , 180º , 270º in ϕ, *full* acceptance in θ



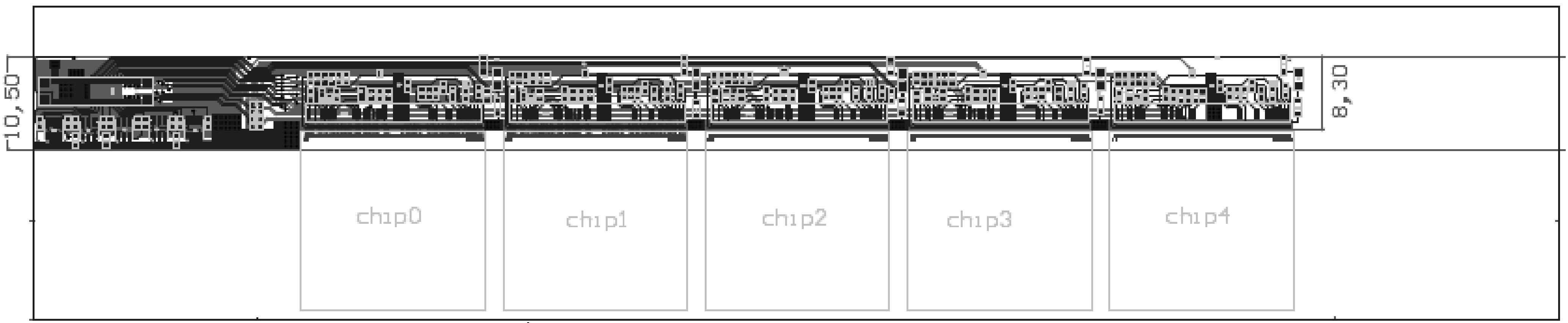
CAD integration by K. Ackermann

System Integration

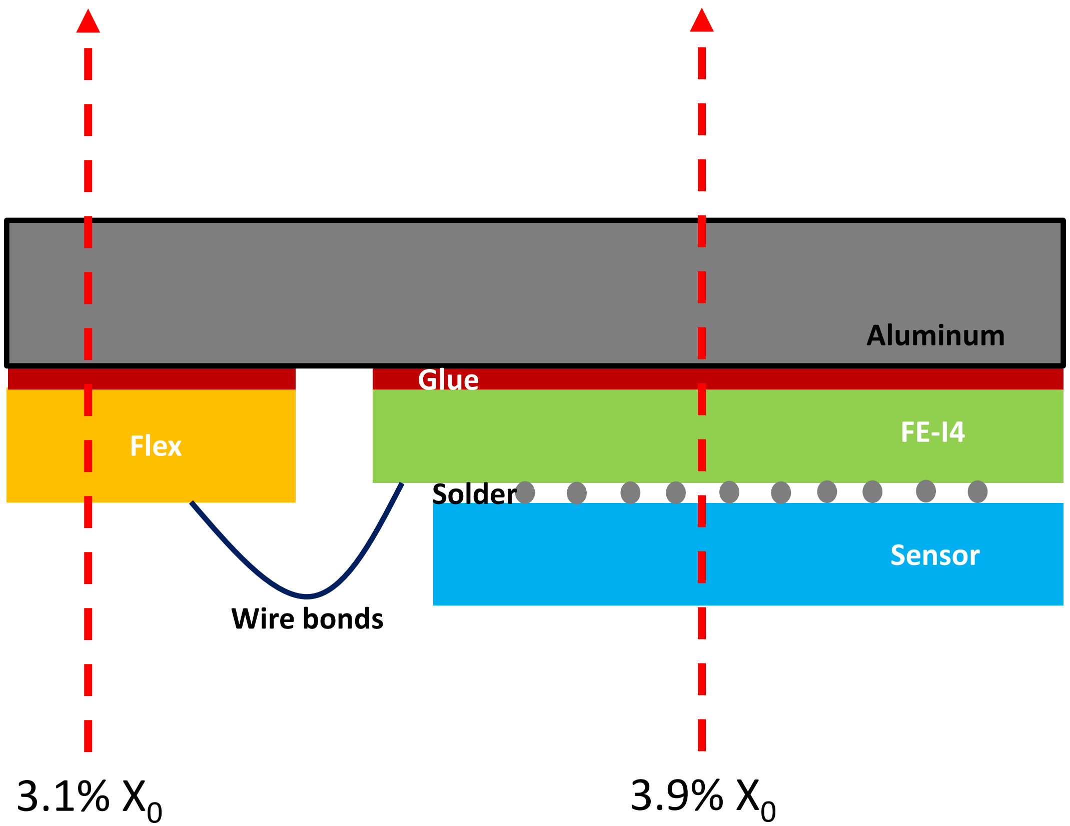


Flex Design

- ❑ Design finalized:
- 8.5 mm wide Kapton
- 50 pin connector on backward side
- Short intermediate Kapton connecting to a PCB attached to SVD ring
- 4 Ethernet and 1 power connectors on PCB (design under discussion)



Aluminum Stave Material Budget



- Support:
3 mm thick Aluminum → 3.4%X_0

- Glue:
50 µm thick Epoxy → 0.014%X_0

- FE-I4
150 µm thick Silicon → 0.16%X_0

- Sensor:
200 µm thick Silicon → 0.21%X_0

- Solder balls
25 µm thick SnAg → 0.17%X_0 (3.3% of the area)

- Flex
66 µm thick polymide → 0.023%X_0
24 µm Cu (2 layers) → 0.17%X_0

- Low and flat material budget distribution
- No impact in outer detectors

$Total_{Max}$: 3.9% X_0

Aluminum Stave Material Budget

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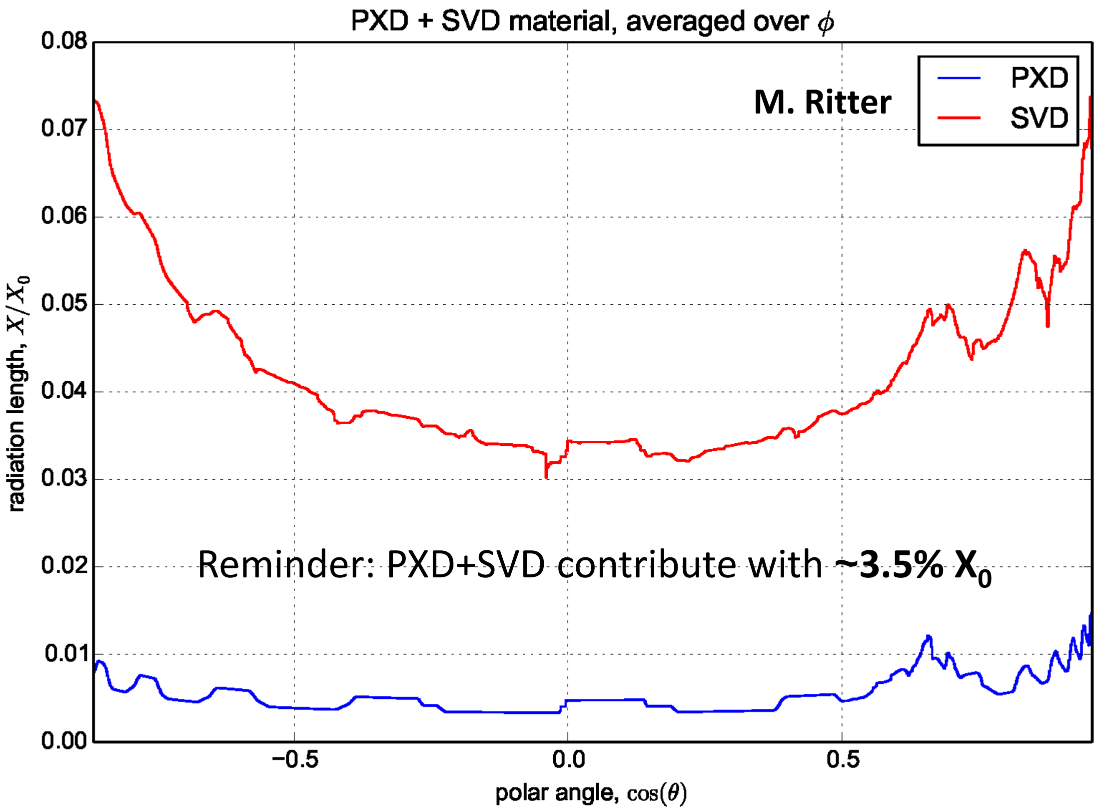

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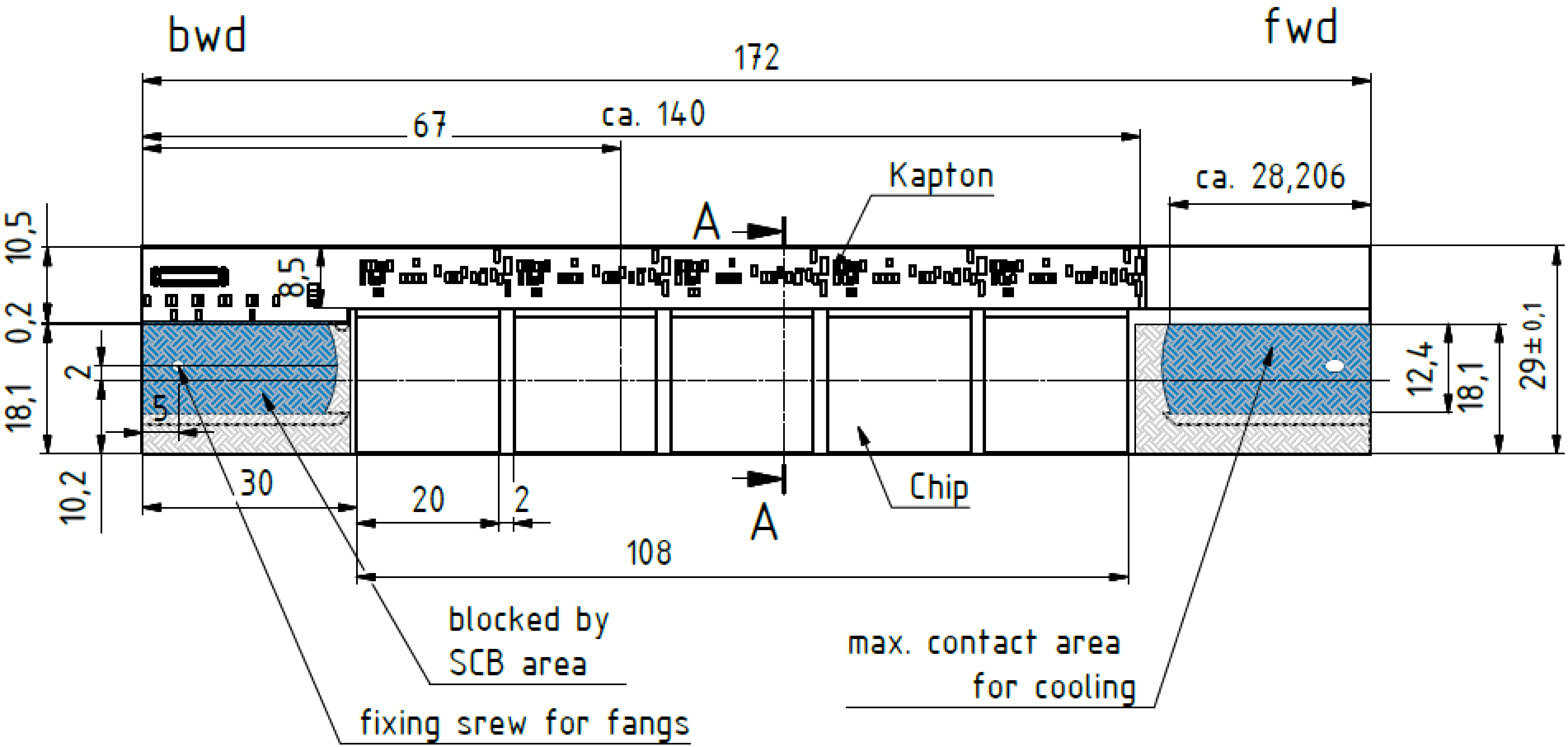
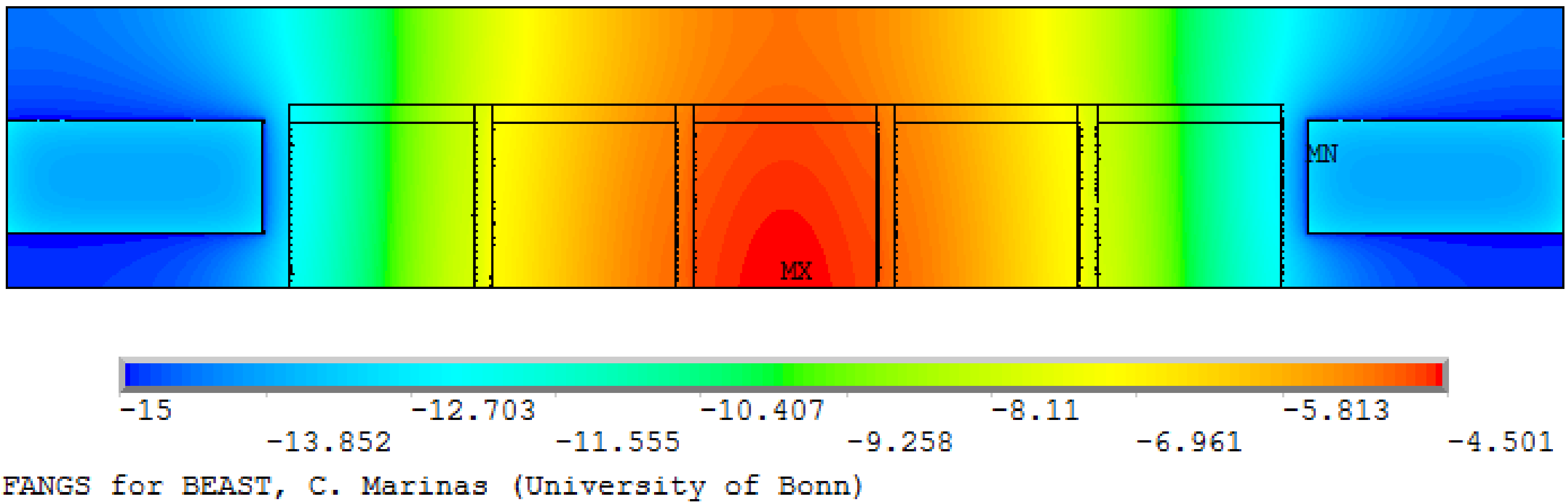
FANGS Stave Dimensions



FEA of the FANGS Stave



- Maximum temperature = -4 ºC
- Maximum ΔT within one sensor = 4 ºC
- Power = 1.2 W each FE
- Cooling block = -15 ºC
- Environment = 20 ºC at 2 m/s

- Proper heat handling
- Low and flat temperature profile

Conclusion

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- FANGS is becoming a final detector system for background (energy and rates) measurements at BEAST Phase 2
- Front end has been **tuned to cover the expected energy range with proper resolution**
- **Multiple-FE DAQ** with long cables is being tested with a new readout system
- Kapton flex and intermediate boards are (being) designed
- Mechanical concept and cooling management are well in progress
- 30 hybrids (FE-I4 and planar sensor) have been prepared (twice what is needed)
- All the aspects related to the design, characterization, integration are in good progress

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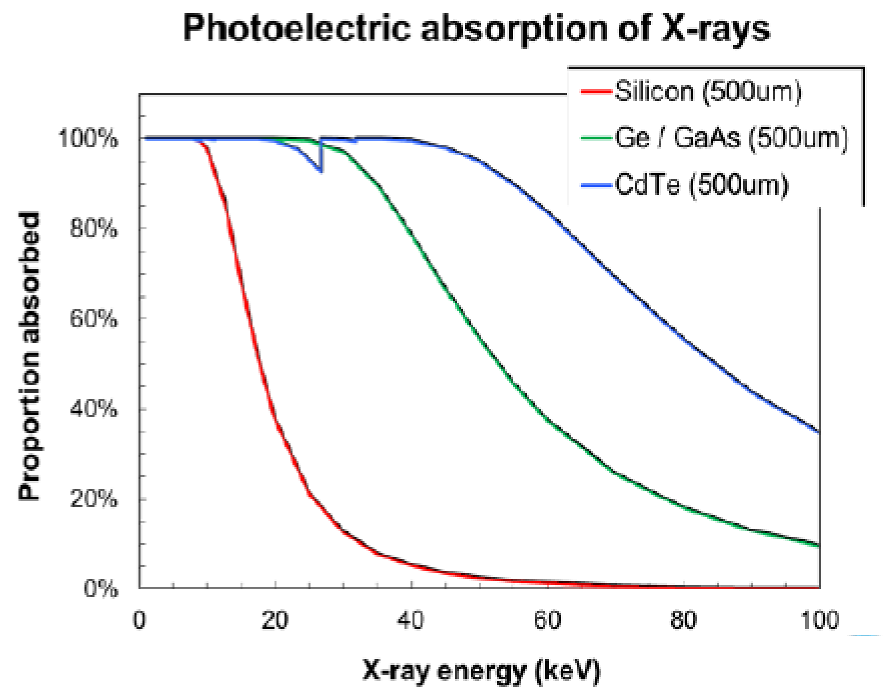
Next Steps

- Spectrum with combined sources and continuum (X-ray machine at different voltages and filters)
- Long cables with new inverters. External trigger. Multiple module readout
- Temperature dependence of calibration, noise and energy resolution
- Absorption coefficient



Thank you

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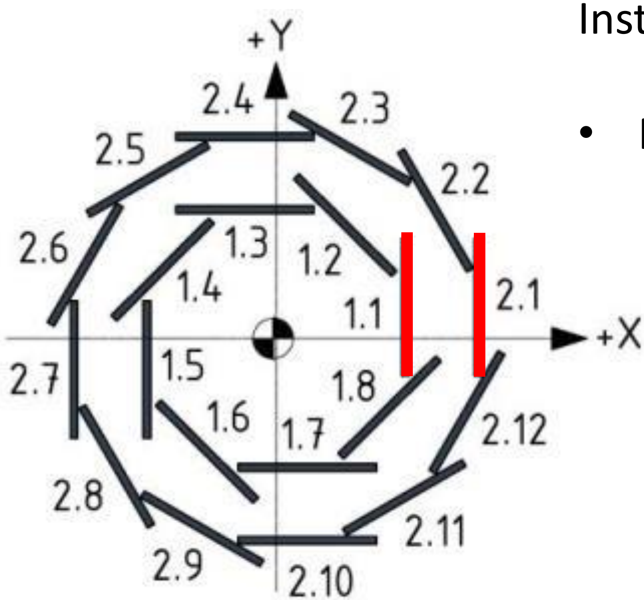
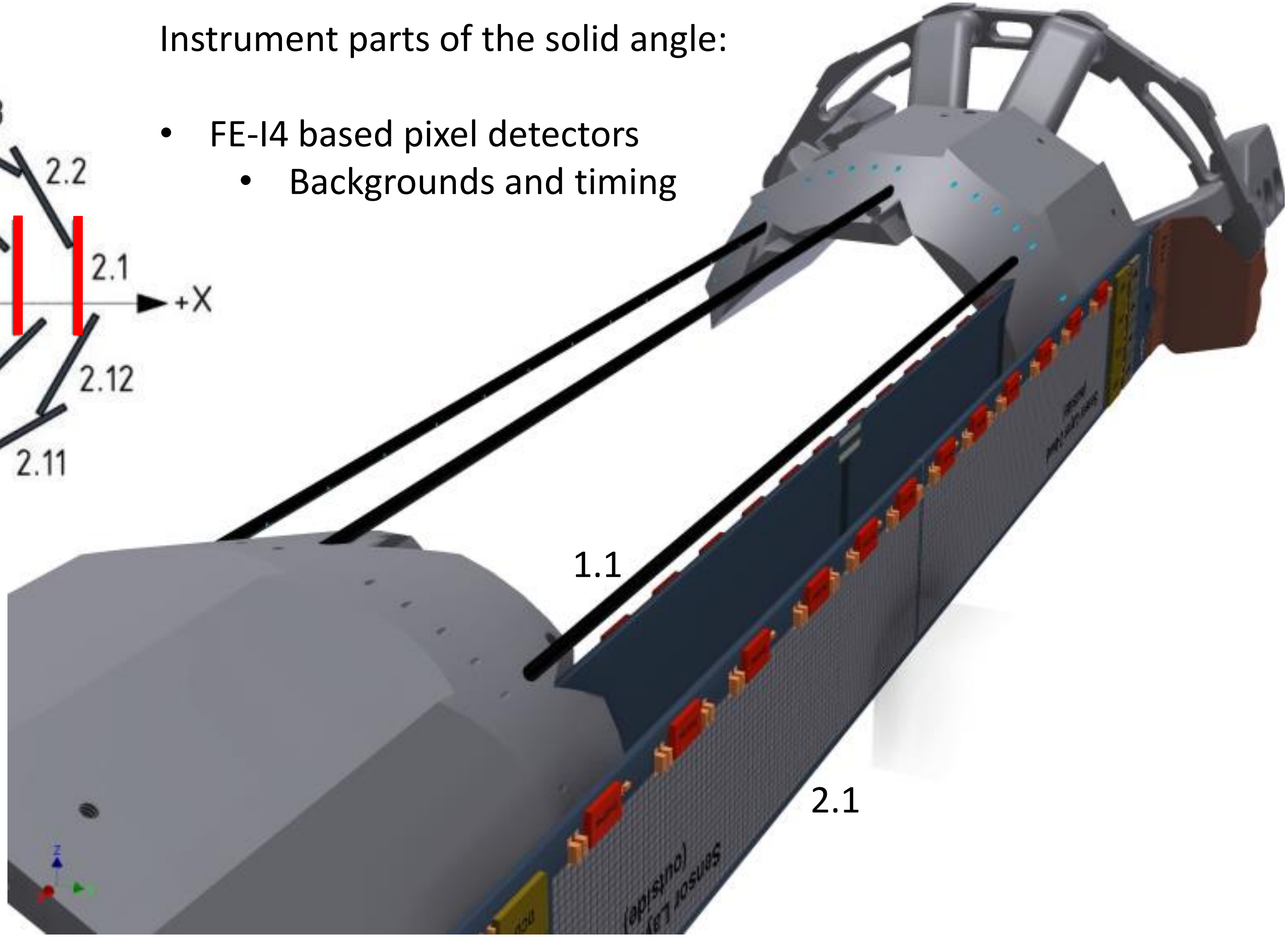
Phase 2 PXD

Instrument parts of the solid angle:

- FE-I4 based pixel detectors
  - Backgrounds and timing





System Integration