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Annual Users' Conference

ADVANCING RADIATION SAFETY. EMPOWERING PROGRESS.

M Resort, Henderson, NV | June 15 – June 18

MIRION TECHNOLOGIES

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Empowering Progress.

Scan QR code to log your attendance for today's (Thursday, June 18th) breakout session

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Understanding PIPS Detectors: A Portfolio Overview

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Mirion Connect | Annual Users' Conference 2026
Henderson, NV

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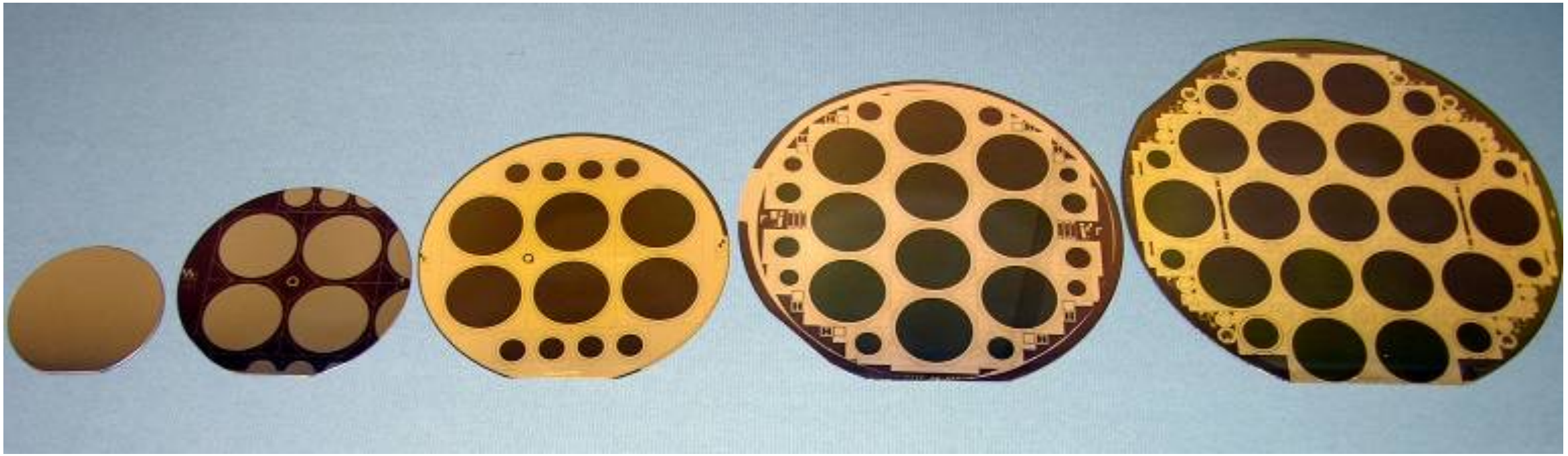
Outlook

- *What are PIPS Detectors?*
- *What are PIPS used for?*
- *Where are PIPS used?*
- *What are the (dis)advantages of PIPS?*
- *Highlighted examples*

What are PIPS?

What are PIPs?

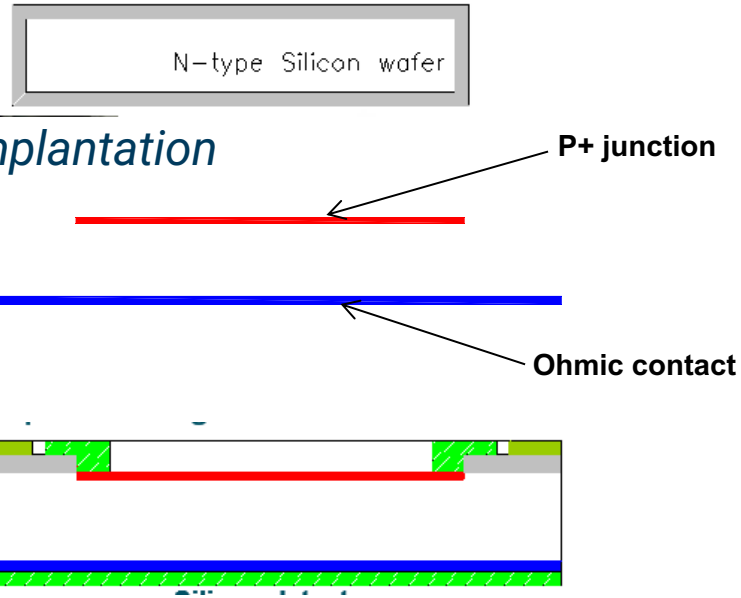
- ***PASSIVATED IMPLANTED PLANAR SILICON (PIPS) DETECTORS***

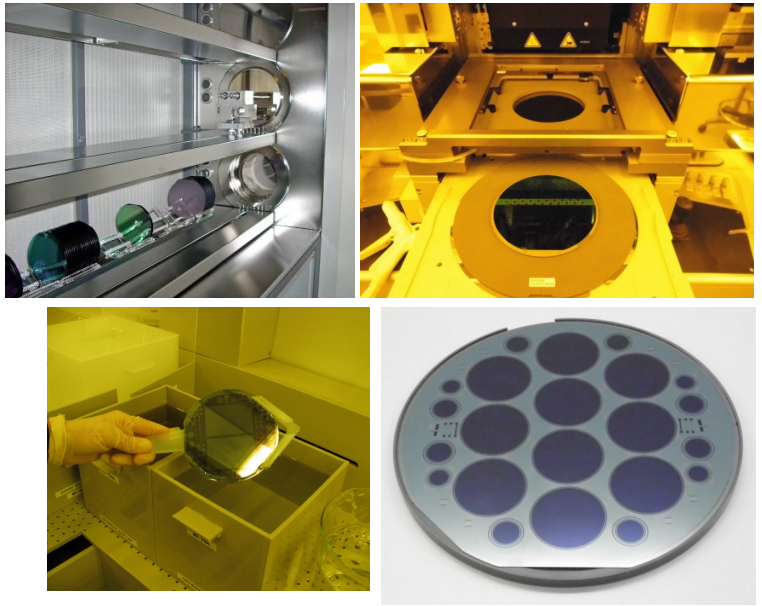


Started 40 years ago on 2” wafers – today we are working on 6”wafers

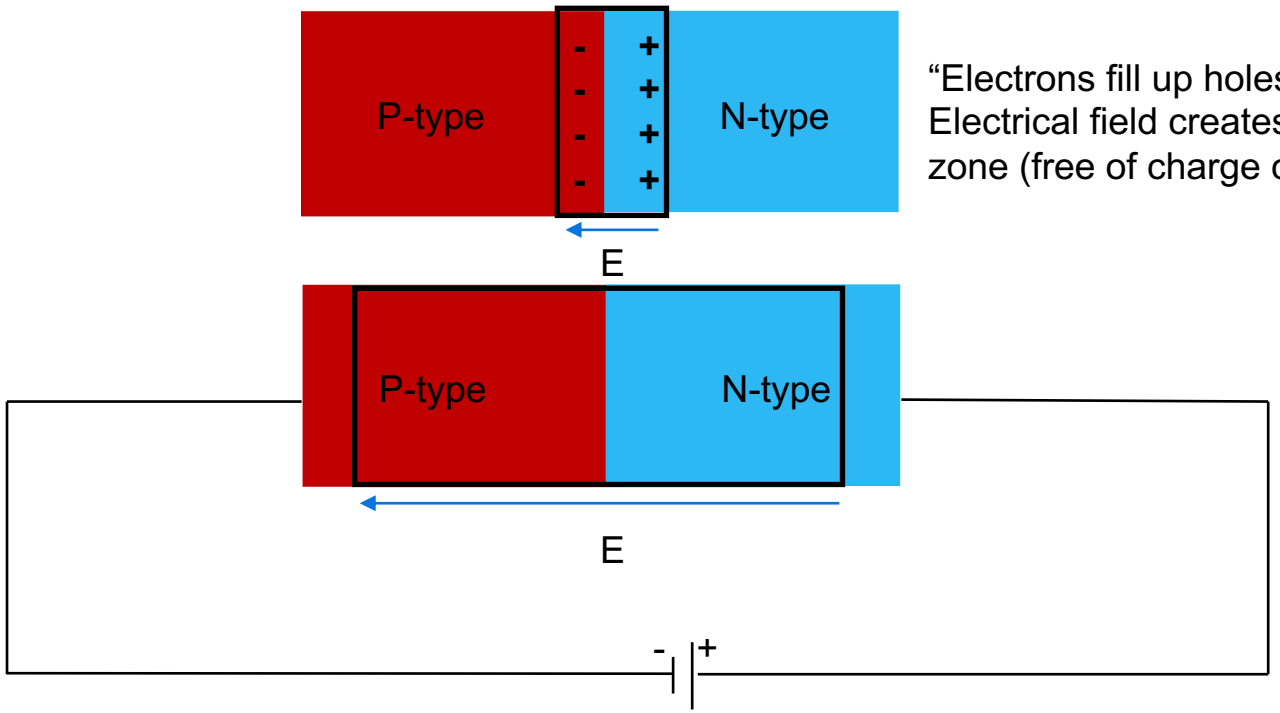
What are PIPS?

- *Thickness silicon wafer: 200 up to 1500µm*
- *Processing done in Olen, Belgium*
- *Processing done in a cleanroom*
  - *Step 1: grow oxide*
  - *Step 2 & 3: lithography & implantation*
  - *Step 4: make contact*





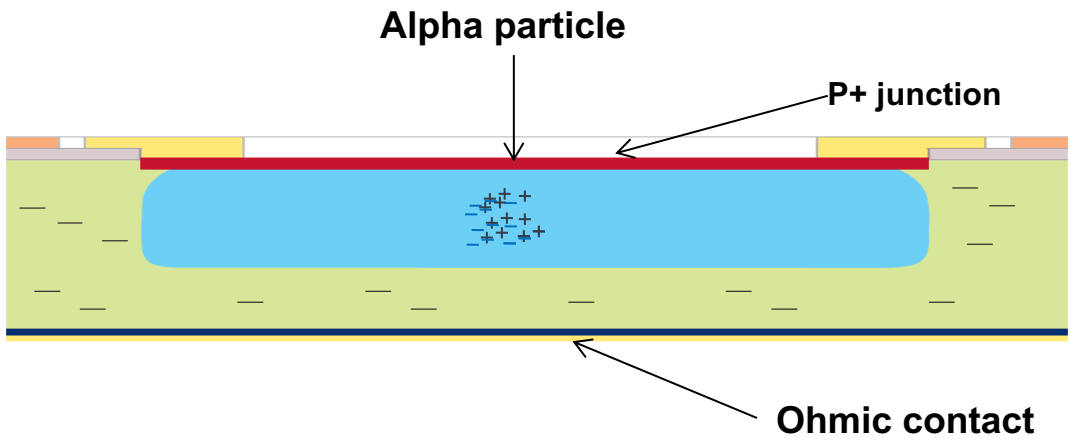
Semiconductor Detector Prinicple



"Electrons fill up holes"
Electrical field creates a depletion zone (free of charge carriers)

Enlarge depletion thickness by applying a reverse bias

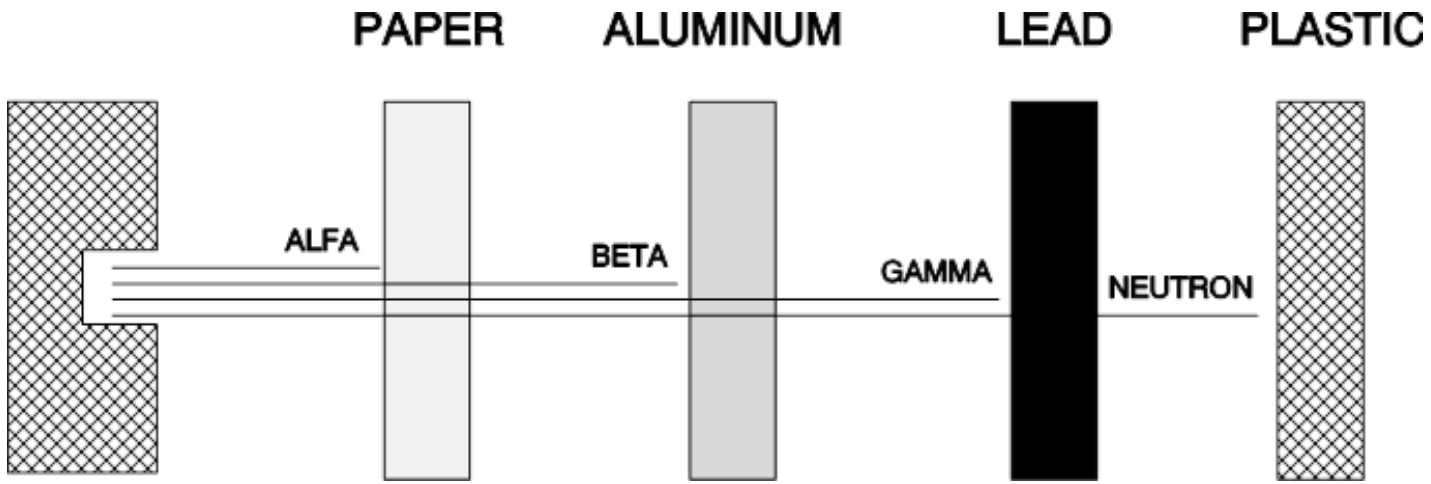
PIPS Detectors



- *Particle ionizes silicon and creates electron-hole pairs*
- *Electric field will create a current*
- *This current/charge will be measured*
  - *Charge quantity linearly dependent on the quantity of energy deposited*

What are PIPS used for

What are PIPS used for?

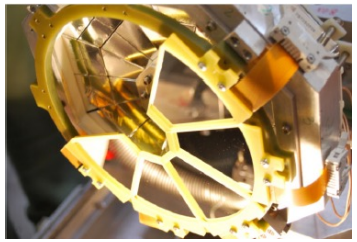


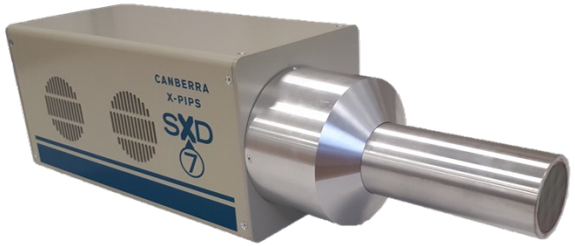
Silicon: Charged particles & X-rays

Where are PIPS used?

Where are PIPS used?

- *Standard series*
  - *ABS – alpha beta standard*
    - *vacuum*
  - *CAM – continuous air monitoring*
    - *air*
- *CD series – custom design*
  - *Space and research*
- *X-PIPS series*
  - *X-ray detection*





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ABS series

- **A-PIPS**
  - *Mainly used in Alpha Analyst*
    - *For environmental monitoring (milk, water, soil…), health phys*
      earth and marine science…
  - *Thin entrance window: excellent energy resolution*
  - *Low background*
  - *Used in vacuum and light-tight environment*

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ABS series

- **PD & FD detectors**
  - *Thin entrance window: best energy resolution*
  - *Used in vacuum and light-tight environment*
  - *Used for charged particle spectroscopy in e.g. nuclear physics research*

  - *FD can be used for particle identification or energy loss measu*
    - *Thin exit window*

CAM series

- **CAM Detectors:**
  - *Optimized for the detection of α and β particles in air*
  - *Excellent rialibility, extremely stable*
  - *Used in a variety of Mirion products*
  - **TCAM** *detectors for harsh environments*
    - *Scratch hard and acid resistant*

ABPM 204M

Easy-Count

i-Solo®

i-Matic™

i-CAM

SPAB-15

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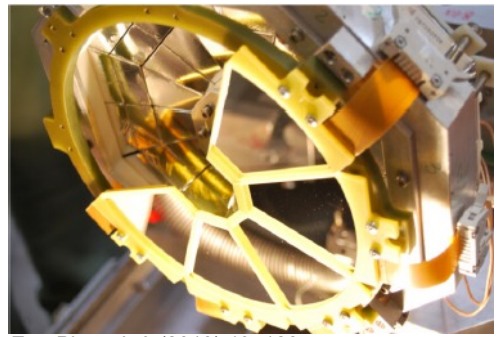
CD series

- **CD Detectors:**
  - *Custom detectors*
    - *Size, shape, pixelization can be chosen by the customer*
  - *Mounted on epoxy or ceramic board*
  - *Used in e.g. physics research or space*



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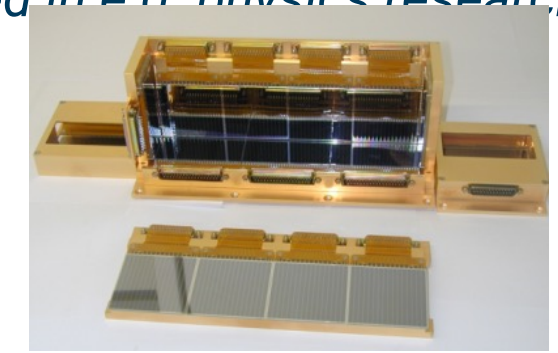
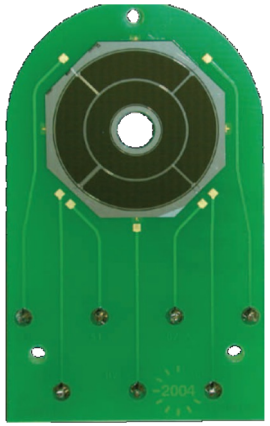


PIPS detectors used to detect new elements 112, 113, 114, 116, 118…



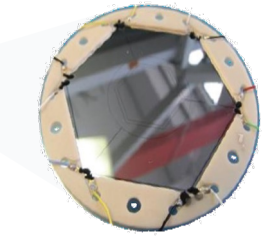
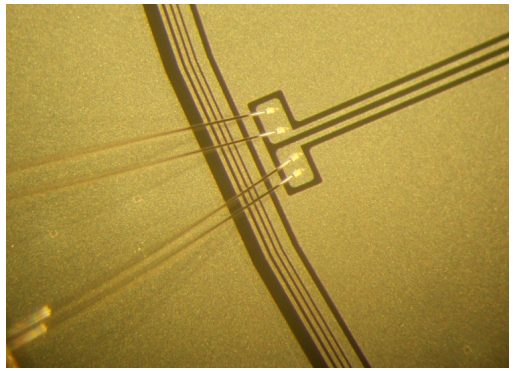
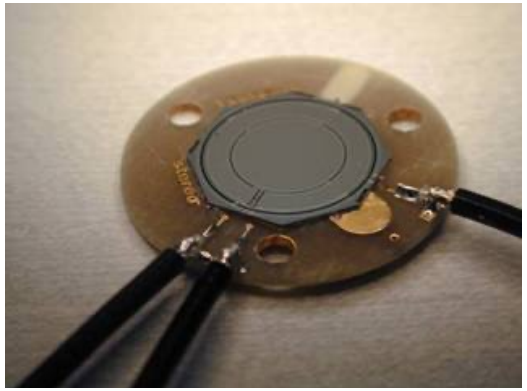


Image credit: NASA /JPL-Caltech/SwRI

CD series

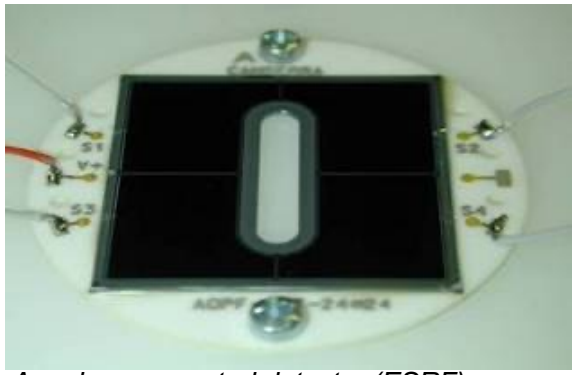


Wire bonding detail (25µm Al wire)



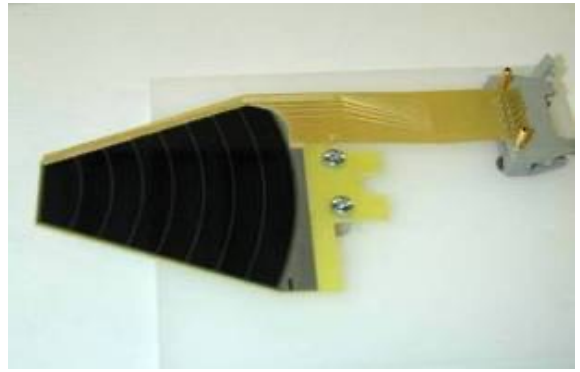
Space Application (STEREO)

(epoxy board)



Annular segmented detector (ESRF)

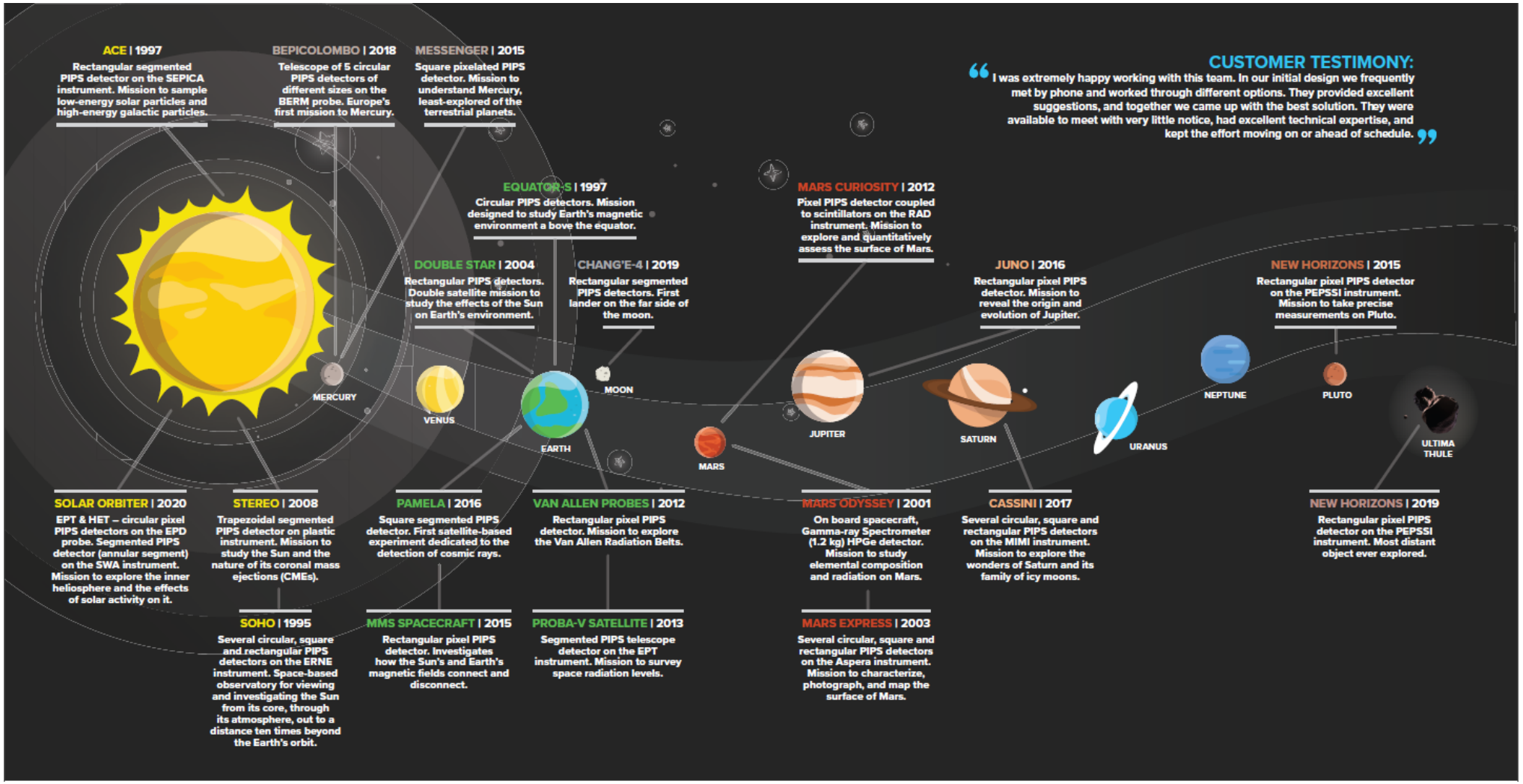
(ceramic board)



Thin window pad detector (INFN)

(Kapton flex)

CD series



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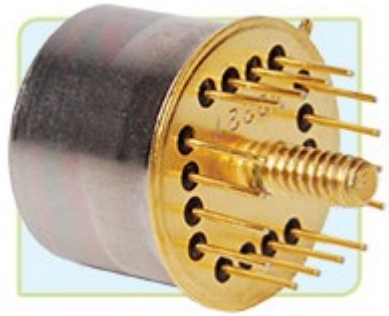
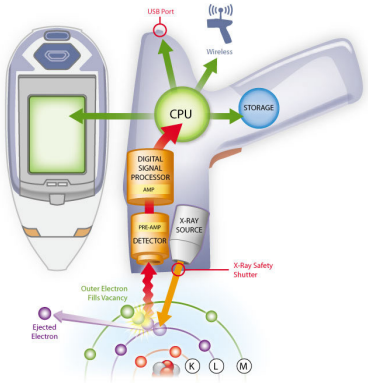
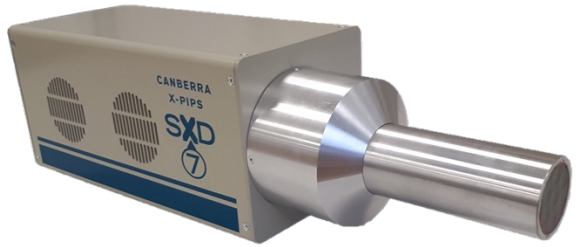
X-PIPS series

- **X-PIPS:**
  - *Detect X-rays*
  - *Silicon Drift Detectors*
  - *OEM customers: single element*
    - *E.g. handheld devices*
  - *Synchrotron users: multi-element arrays*
    - *Standard 7- and 13-element*
    - *Best performance on the market*
    - *Usage of a pulse-tube cryocooler (same as HPGe)*







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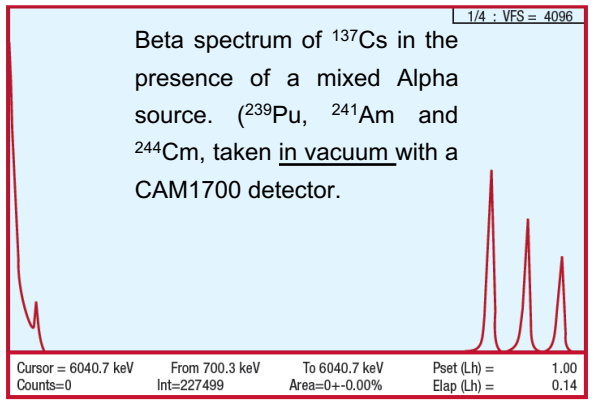
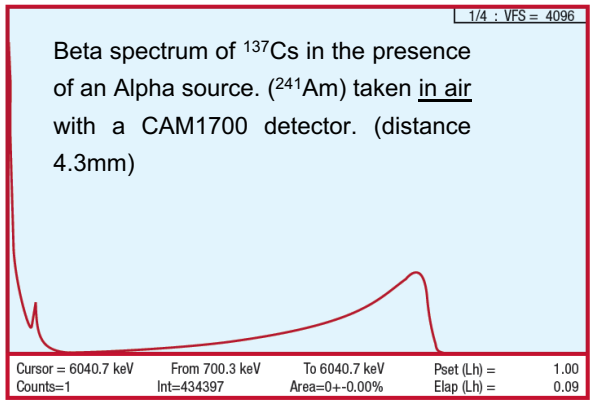
What are the (dis)advantages of PIPS?

Advantage 1: Alpha/beta cross-over

- **No cross-over between alpha/beta**
  - *Alpha region very well separated from beta region*
    - *E.g. SPAB-15 probe: alpha to beta (^{239}Pu) < 3%,*
  - *Very low background in alpha region*
    - *E.g. SPAB-15 probe: beta to alpha (^{90}Sr-^{90}Y) < 0.1%*
    - *False positives in alphas unlikely with a PIPS*
  - *Alpha-beta separation with large CAM PIPS:*





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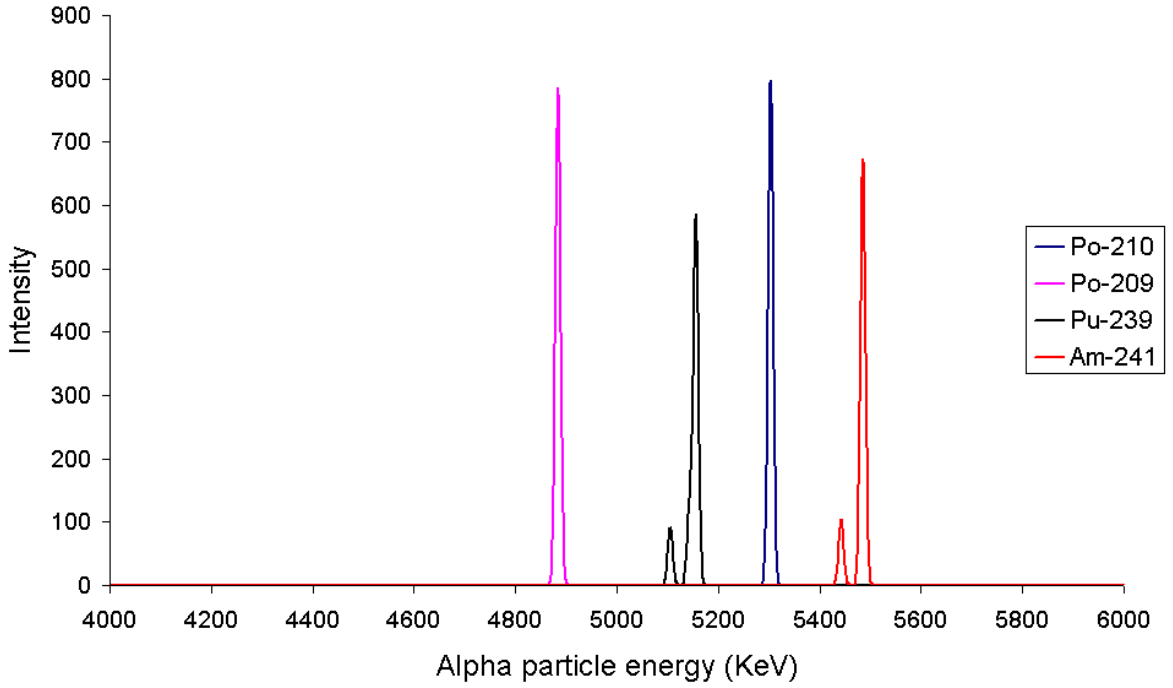
Advantage 2: Resolution

- **Spectroscopy features**
  - *Very good resolution for A, PD and FD detectors:*



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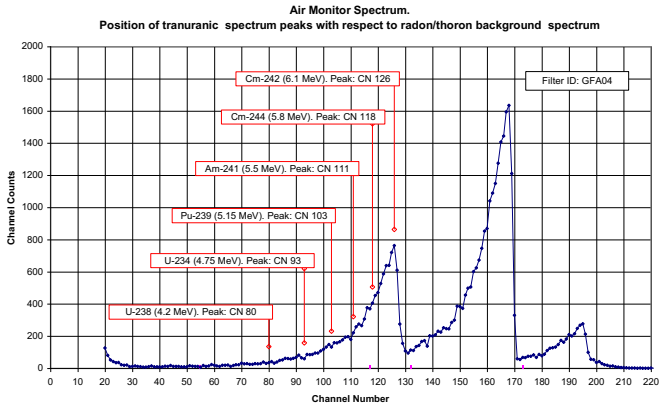
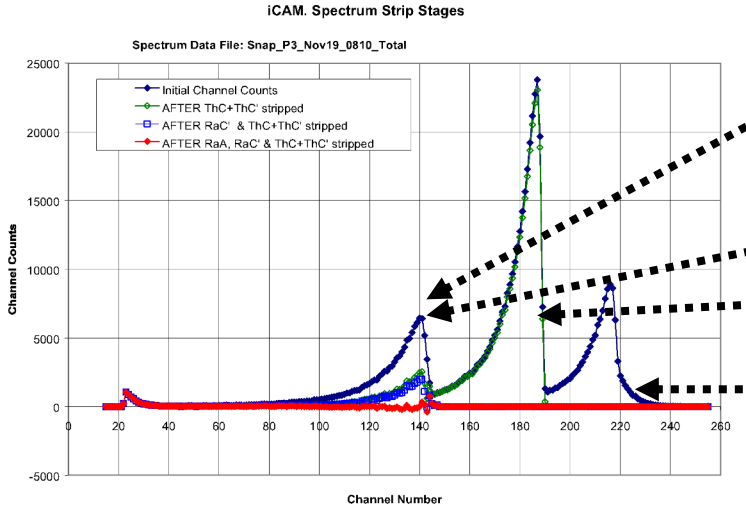
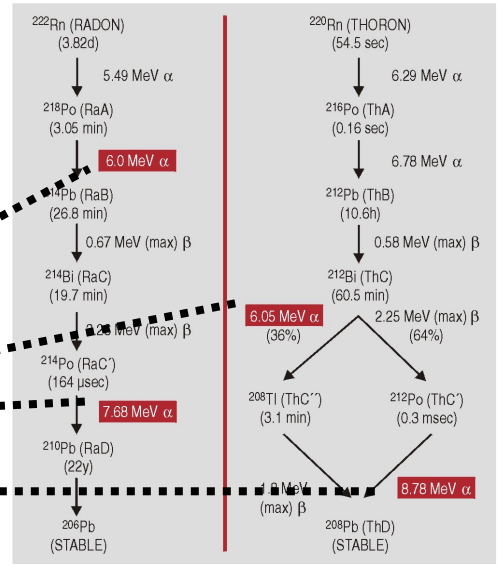
Advantage 2: Resolution

- **Spectroscopy features**
  - *CAM detectors in air: Rn/Th discrimination*
    - *Differentiate NORM based activity in air*
    - *Rn/Th rejection: direct online discrimination of Rn/Th da*







Advantage 3: Beta identification

- **Beta identification possible**
  - *E.g. Measurement with a PD telescope*

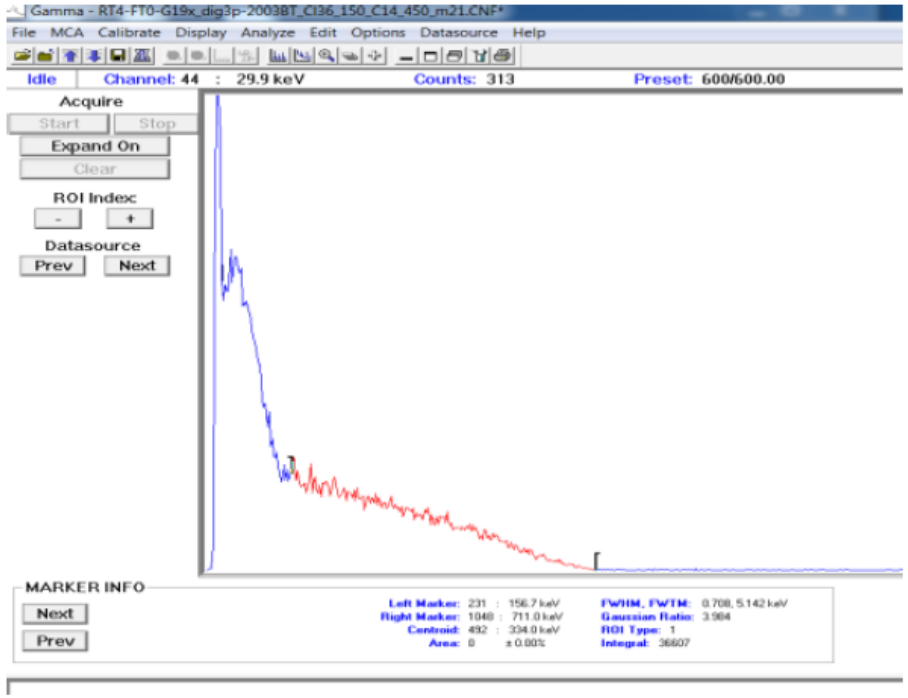


Figure 11 The C-14/3Cl-36 spectrum: the untransformed spectrum.

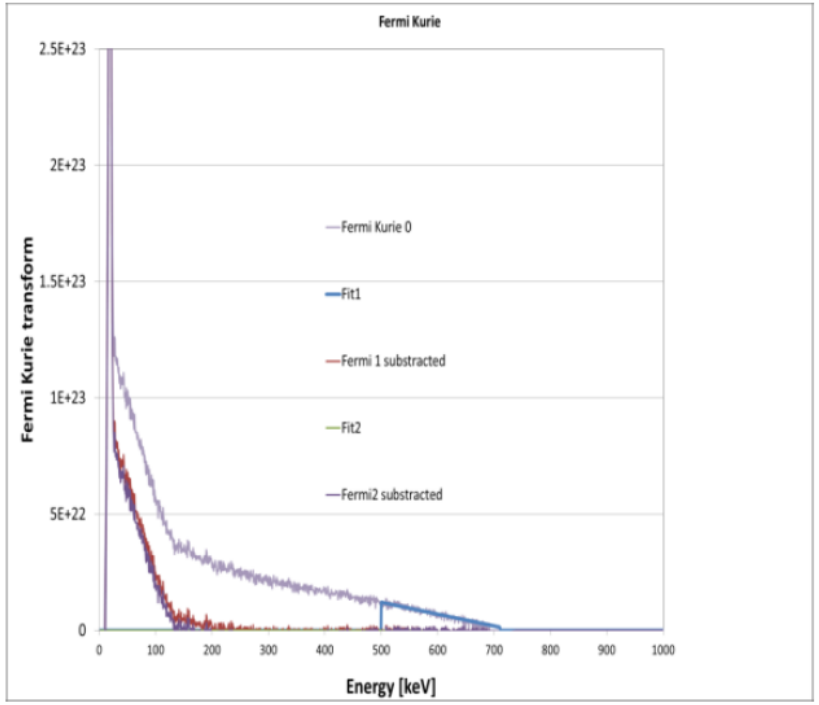


Figure 12 The C-14/3Cl-36 spectrum: the Fermi Kurie transform

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Advantage 4: Low energy threshold

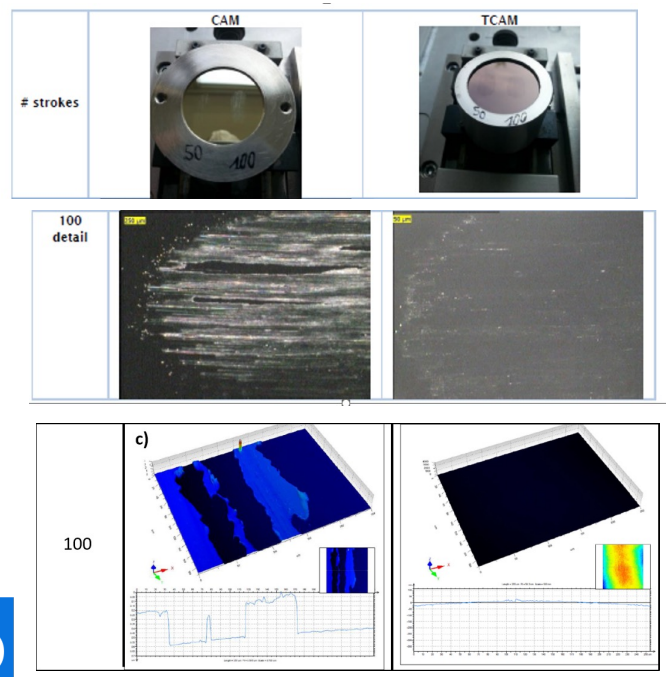
- **Low energy threshold**
  - *Possible through pixelisation*
  - *Low energy threshold <15keV possible*

Advantage 5: TCAM

- **Acid Resistant**
  - *Developed for Sellafield, UK. Standard CAM lasted one week, TCAM at least one year*

- **Scratch hard**

Wipe test



Exposure to sand/dust as defined in MIL-ST-810G
No change in efficiency after test exposure

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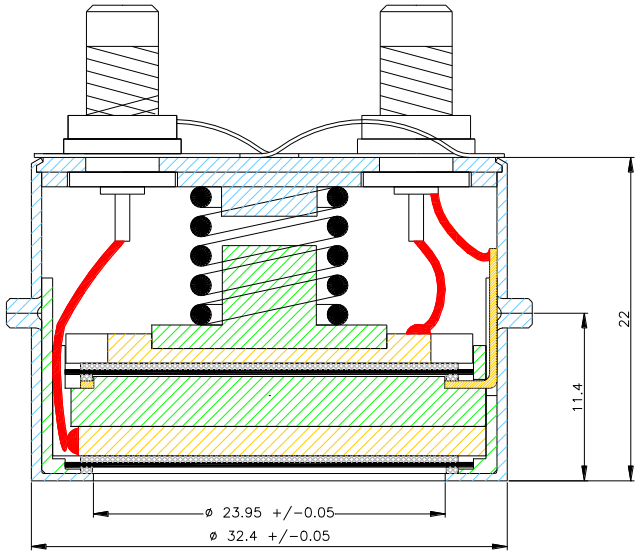
(Dis)advantage 1: No gamma detection

- **No gamma detection**
  - *But telescope configuration can be used to reduce gamma background*
  - *E.g. iCAM telescope*
    - *Alphas and betas counted in det1*
    - *Gammas counted in det1 and det2 (guard detector)*
    - *Dynamic gamma compensation*



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Highlighted examples

PIPS Box

- *Gas box for CTBTO (comprehensive nuclear-test-ben treaty organization)*
  - *The aim of the CTBTO is to prohibit nuclear explosions by everyone, everywhere, always.*
    - *Develops an international monitoring system (IMS)*
  - *Developed in collaboration with CEA (France)*
  - *Uses 2 1200mm² detectors of 500um*

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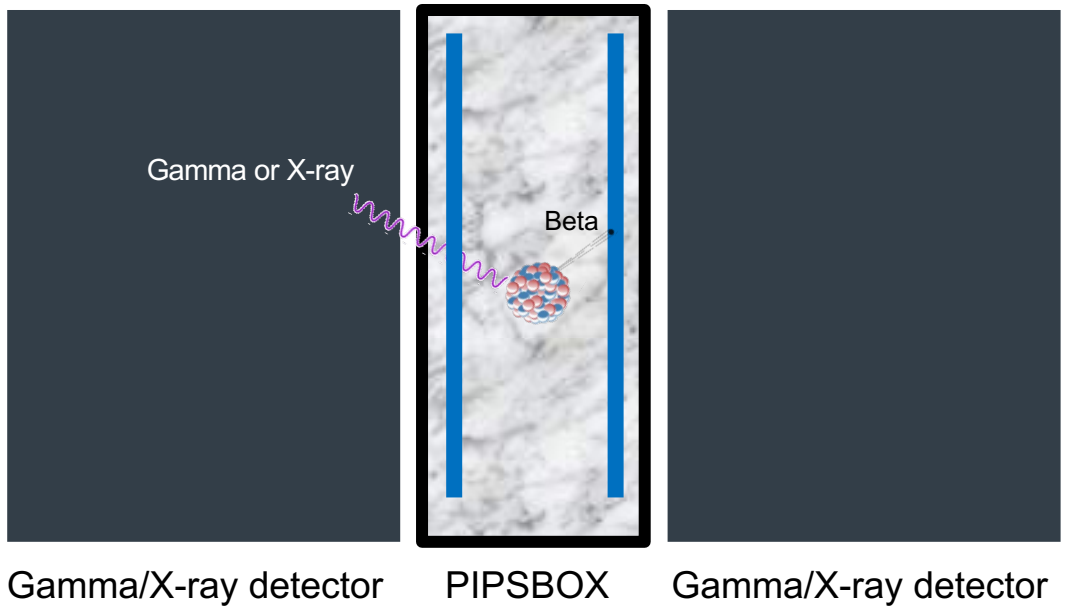
PIPSBOX

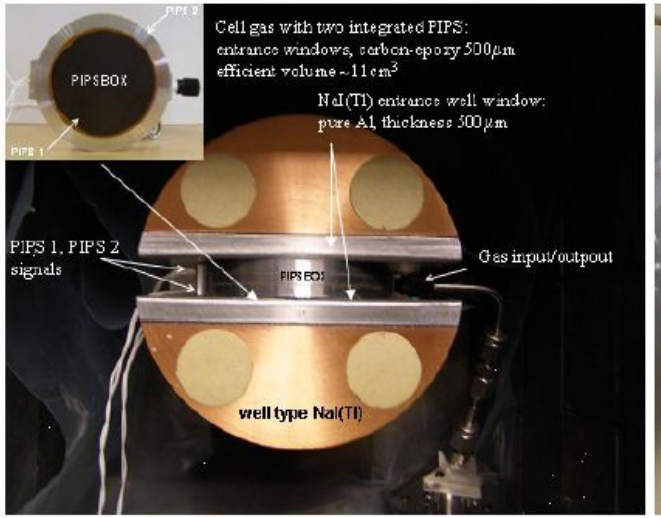
- *Principle*
  - *Measure betas/CE in coincidence with gammas/X-rays coming from the decay of different Xe isomers and isotopes*

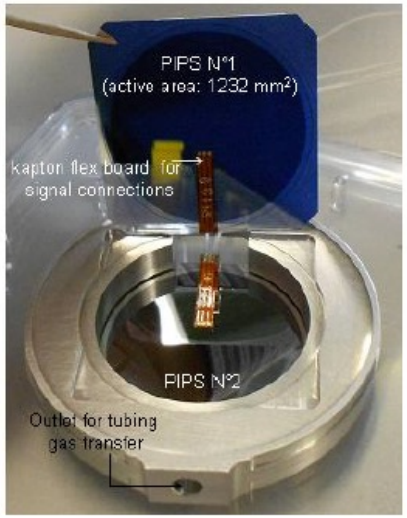


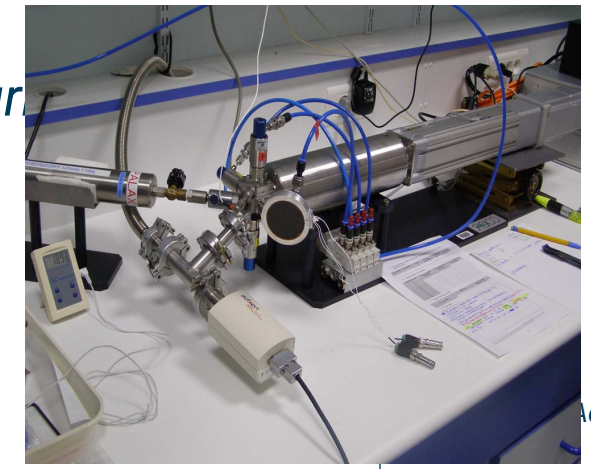
PIPSBOX

- *Principle*
  - *The detection system of a gas cell with two large PI well crystal*
    - *Air is collected*
    - *Xe gas is filtered and injected in the PIPSBOX*
    - *Measured during 24hr*
- *Factor 27 gain in MDC with PIPSBOX/NAI(Tl) compared to cur*

G. Le Petit, J Radioanal Nucl Chem (2013) 298: 1159

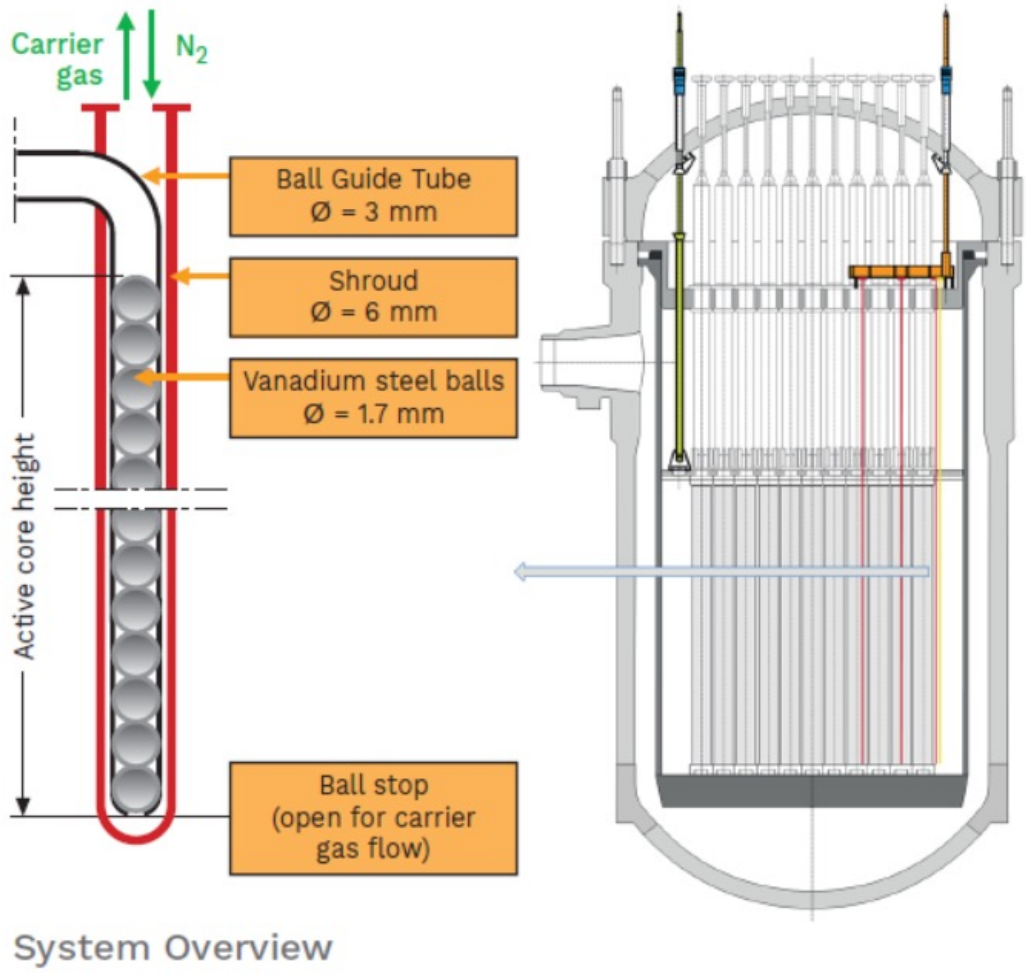






Aeroball Framatome

- *Aeroball Measurement System (AMS)*
  - *Incore neutron flux measurement*
  - *Based on activation analysis with steel balls contai*
  - *When activated they are transported to the measure*
    - *Measurement done with PIPS detectors*



https://www.framatome.com/solutions-portfolio/portfolio/product?product=A0708

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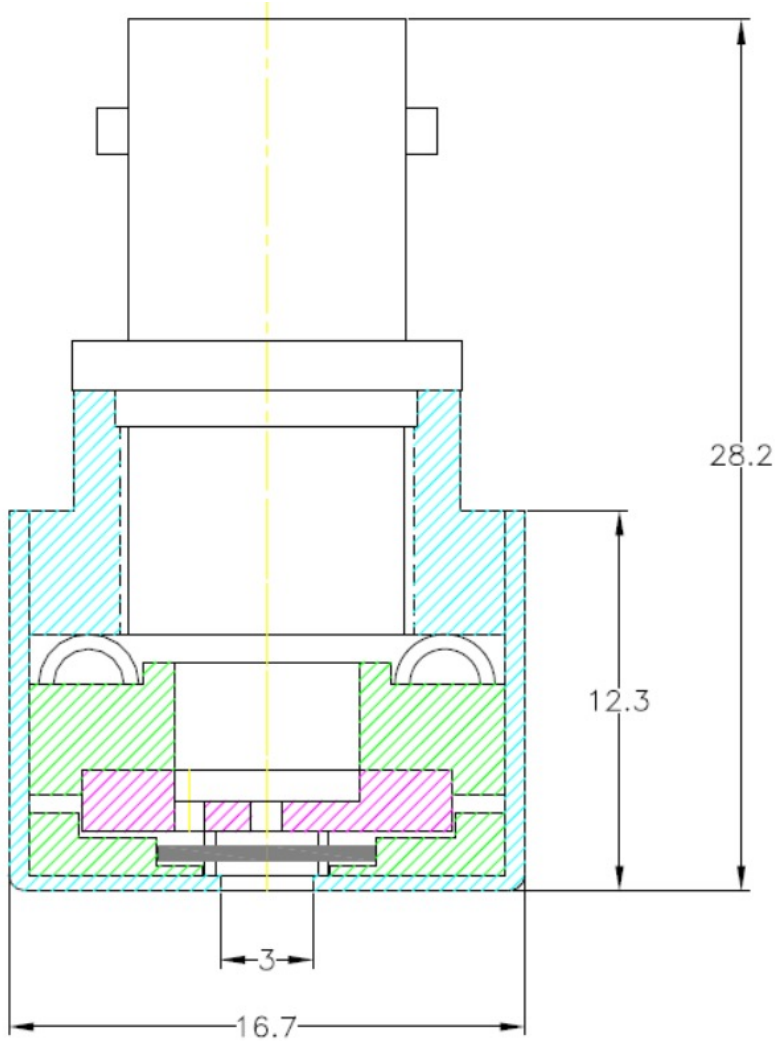
Aeroball Framatome

- *PIPS detector*
  - *CAM detector*
  - *Small active area: 7mm²*
  - *500µm thickness*
  - *several 100 detectors per syst*

PIPS detectors



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Multi-element SDD arrays

- *Typically used by synchrotrons which use extremely intense X-ray beams (several 10 of Mcps)*
  - *Need for segmentation (one element can handle ~5 Mcps OCR)*

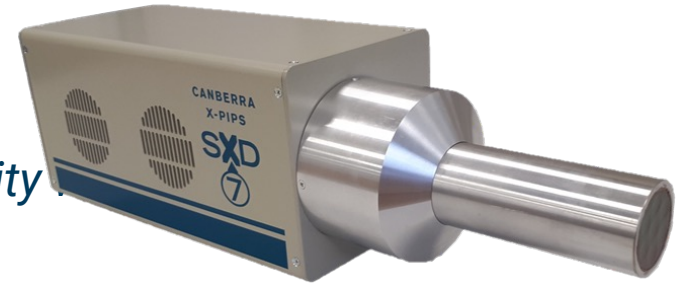
- *Two approaches to build multi-element arrays*

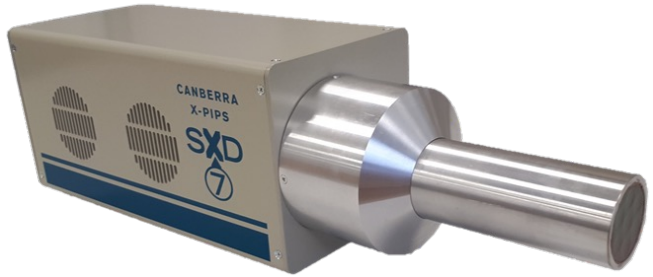
- *Discrete or monolithic arrays*
- *Excellent packing fraction*
- *Less flexibility in configuration*
- *High repair costs in case of failure of the window*

- *Individual elements*
- *Poor packing fraction*
- *High flexibility*

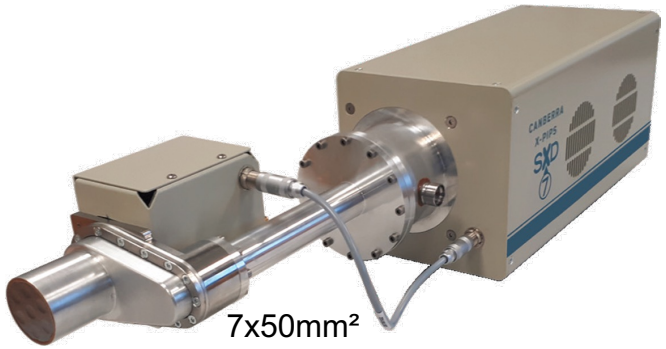
Multi-element SDD arrays

- *Standard multi-element arrays consist of 7 up to 13 (or more) individual Silicon Drift Detector elements in one common vacuum chamber*
  - *Typical energy resolution 125 eV @ 5.9 keV*
  - *Best energy resolution at 2 Mcps output count rate*
  - *Output count rate up to at least 4 Mcps per element possible*
  - *Cryogenic (pulse-tube) cooled*
  - *Low pump down frequency, thermal cycle free and no loss of the vacuum integrity of the detector*
  - *Mechanical design can be optimized to the customer request – easily customized*

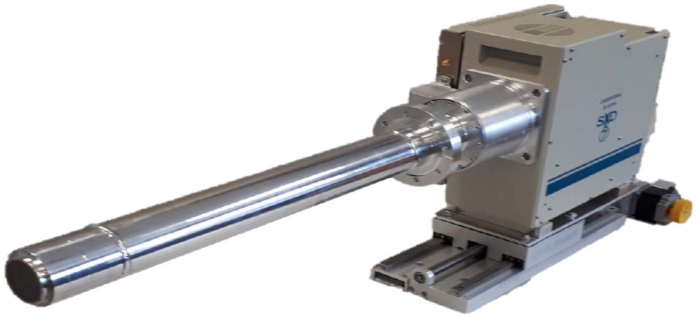




SXD 7-Element SDD Array

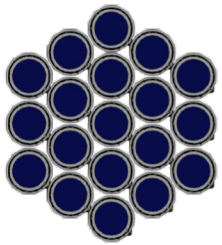


7x50mm²

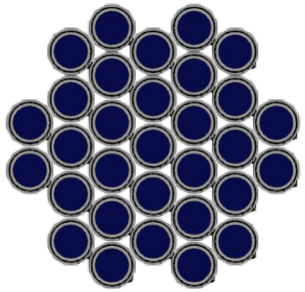


- 7x80mm²
- Focused arrangement
- Nose 500mm
- Closed-cycle water chiller
- Motorized translation system

SXD 13-Element SDD Array
13x80mm²



19x80mm²



31x80mm²

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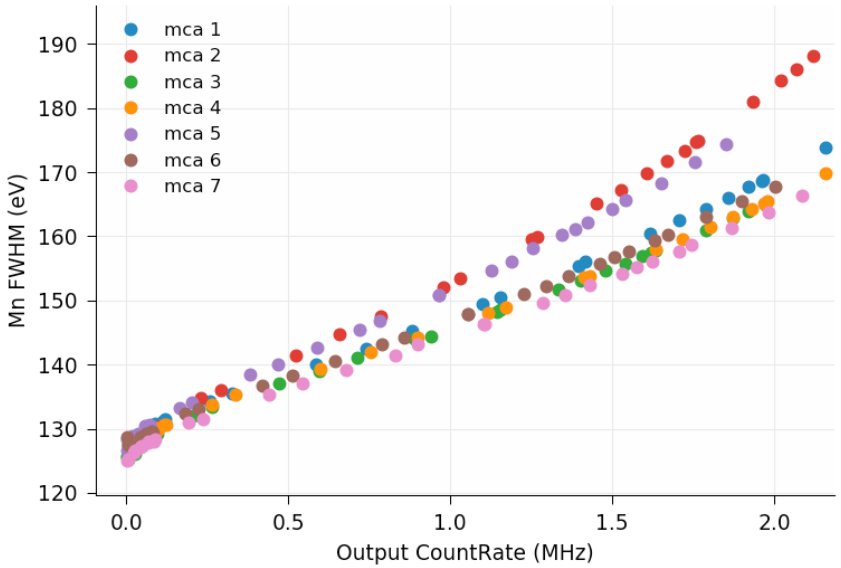
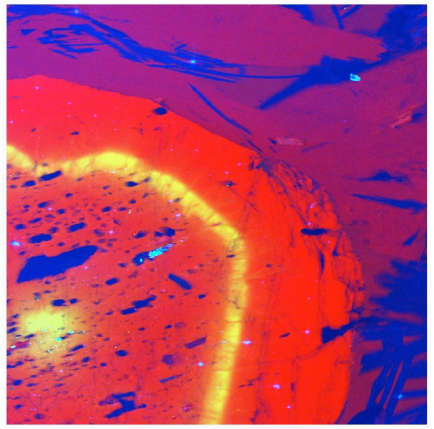
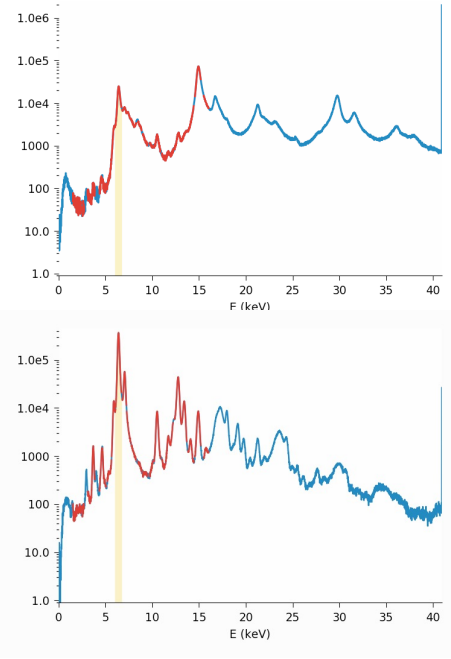
Multi-element SDD arrays

- *Customer results – 7-element for APS, Chicago*



An XRF Map (18keV) of a thin section of a garnet with random zircons (very high scattering) and banding in Y





Data Quality is very good to ~3MHz, no saturation artifacts up to 5.8 MHz

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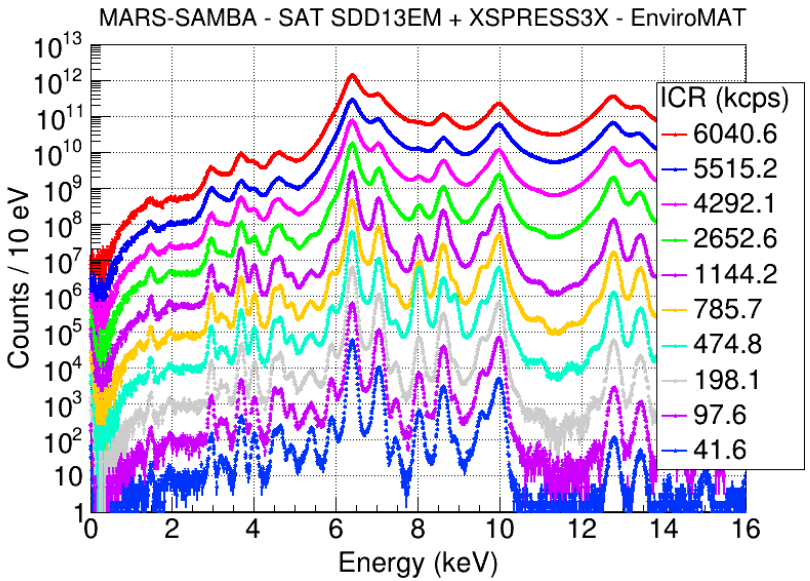
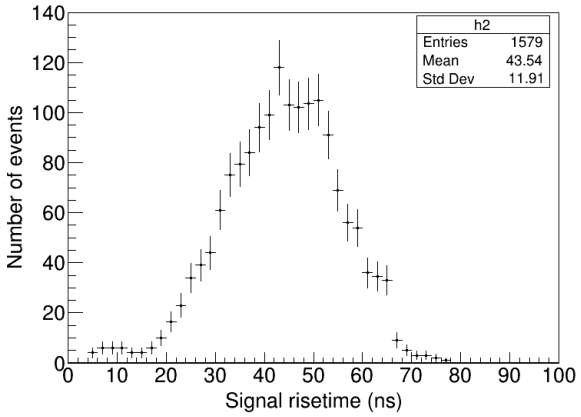
Multi-element SDD arrays

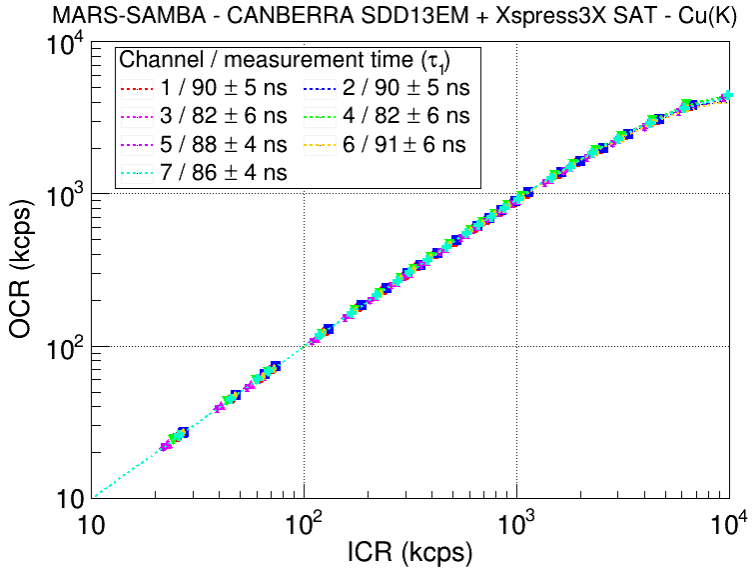
- *Customer results – 13-element SOLEIL, France*



No parasitic lines are present in the energy spectra



Signal rise times below 50ns



OCR up to 4.5 Mcps per element

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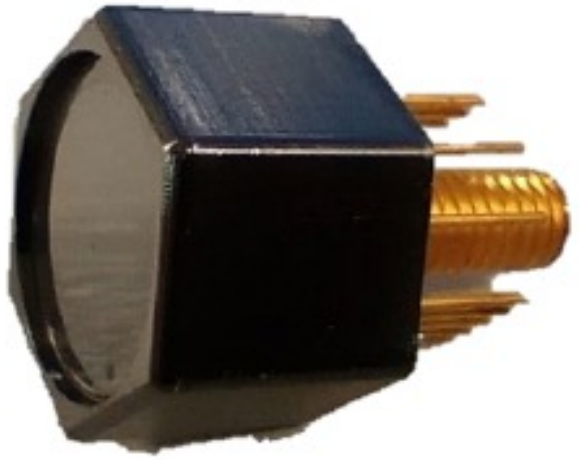
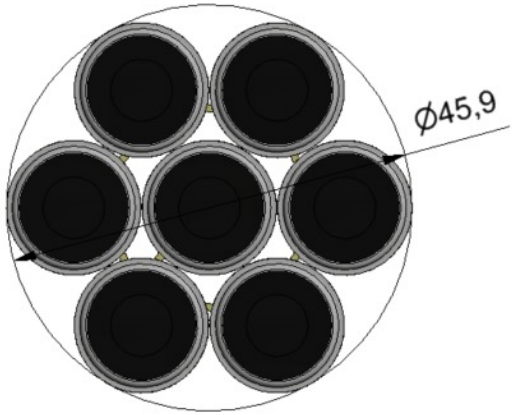
Multi-element SDD arrays

- *New development: hexagonal silicon drift detector in a hexagonal package*
  - *Individually mounted SDDs*
  - *Optimized packing fraction & solid angle coverage*
  - *Reduced dead area between the elements*
  - *Separate entrance windows*
  - *Thermo-electric coolers*
  - *Large flexibility and modularity in configuration*
  - *Simplified maintenance*

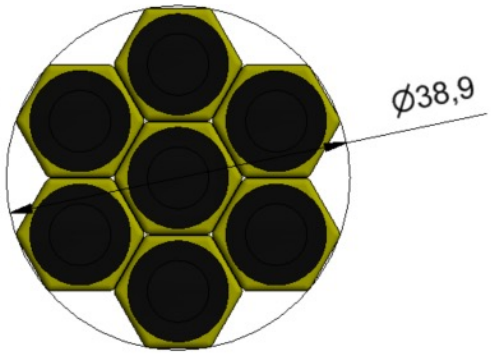


Multi-element SDD arrays

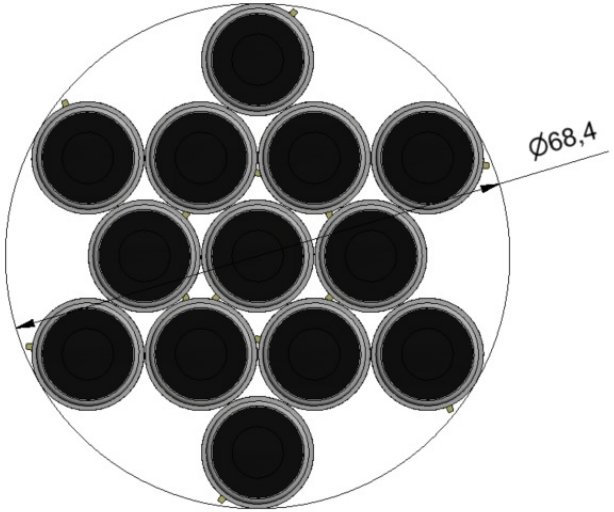
- *Comparison circular vs hexagonal designs*



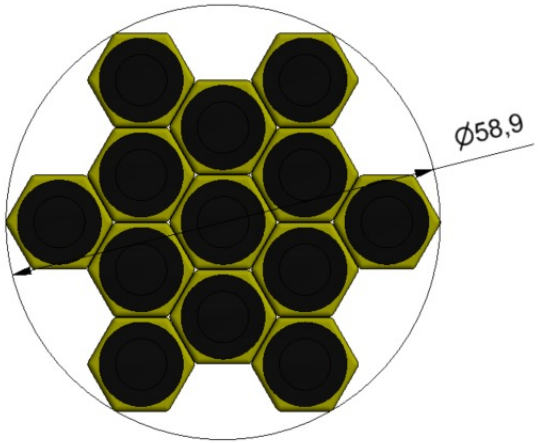
7x50mm²
(70mm² collimated to 50mm²)



7x55mm²
(75mm² collimated to ~55mm²)



13x50mm²
(70mm² collimated to 50mm²)



13x55mm²
(75mm² collimated to ~55mm²)

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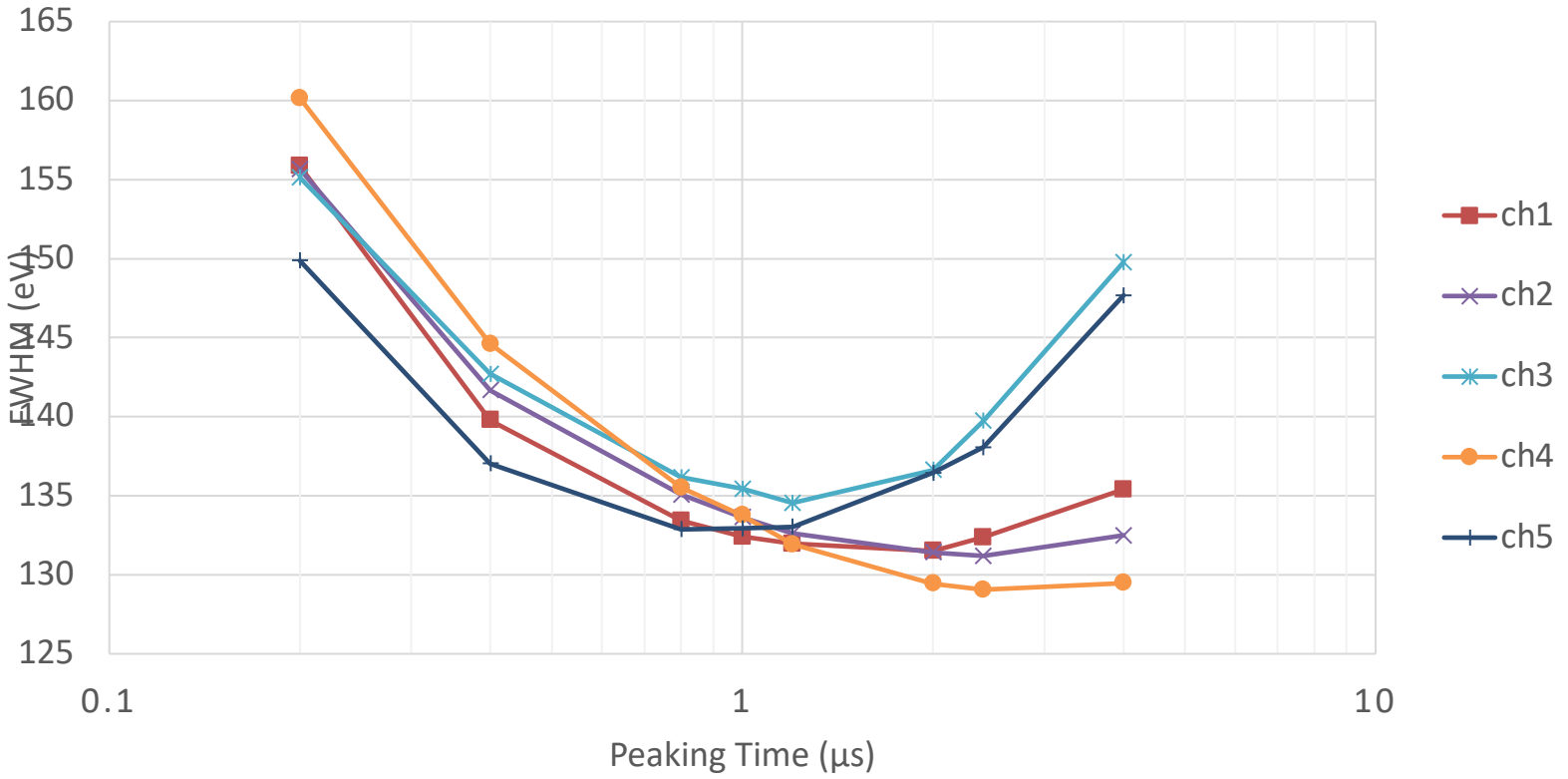
Multi-element SDD arrays

Example of a 5-element hexagonal SDD array



	ch1	ch2	ch3	ch4	ch5
OCR (kCPS)	977	1011	976	975	948
ICR (kCPS)	1083	1110	1067	1066	1035
FWHM (eV)	157.1	162.5	160.5	160.8	156.7

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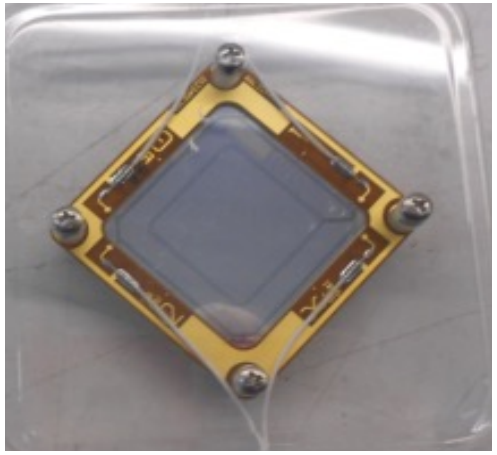
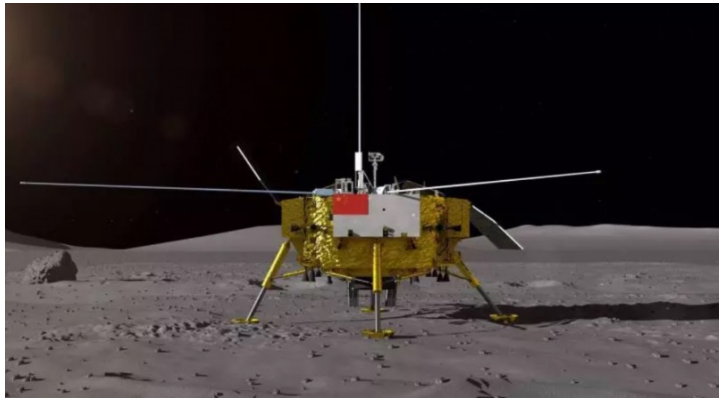
Chang'E4 mission

- *Detectors on board of the Chang'E4 mission to the far side of the moon*
  - *Landed on the 3th of January 2019, first time landing on the far side of the Moon*
  - *10 square segmented detectors are used in the LND instrument*
    - *Lunar Lander Neutron & Dosimetry experiment*
  - *Main objective:*
    - *First active dosimetric measurements on the surface of the Moon for later human exploration.*
    - Determination of particle fluxes and their temporal variations on the far side of the Moon.

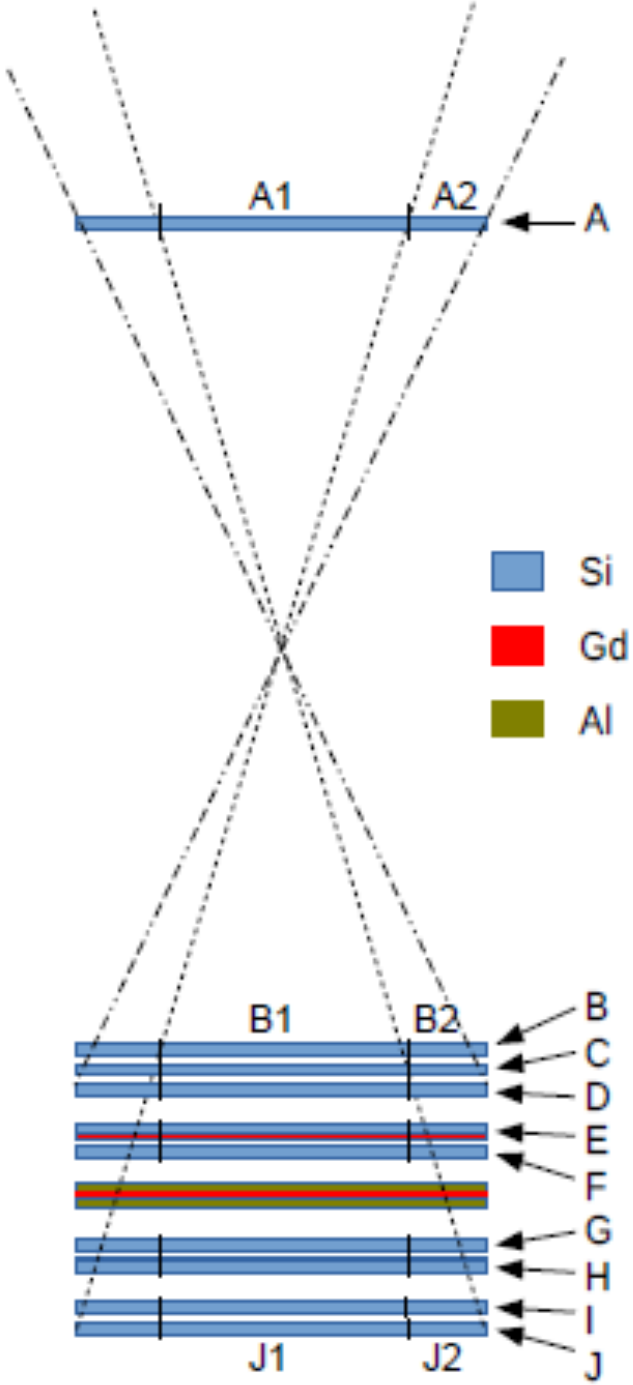




Wimmer-Schweingruber, Space Sci Rev (2020) 216:104

Chang'E4 mission

- *Segmented PIPS detectors configurated to form a particle teles*
  - *Next to charged particles, also measurement of neutral partic*
  - *Neutral particles (gamma rays or fast neutrons) are measure the surrounding segments and detectors.*
  - *Gd foil is used to convert thermal neutrons in electrons, whicl the PIPS detectors*



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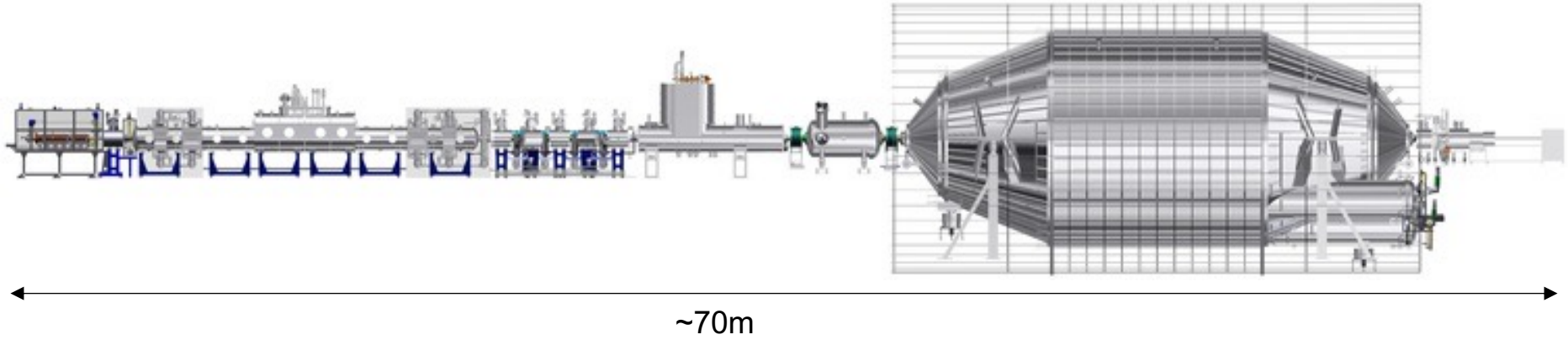
g Progress.

KATRIN

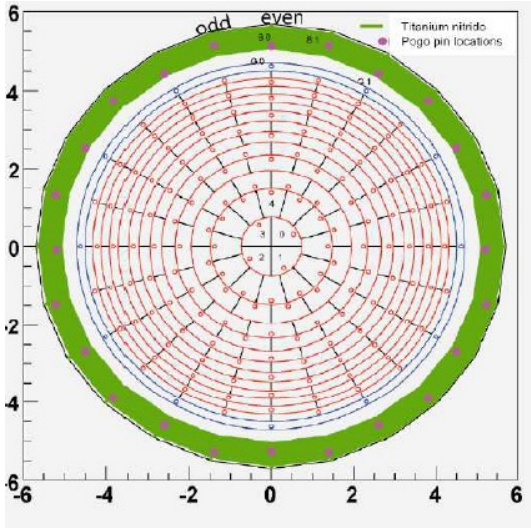
- *Karlsruhe Tritium Neutrino Experiment (KATRIN)*

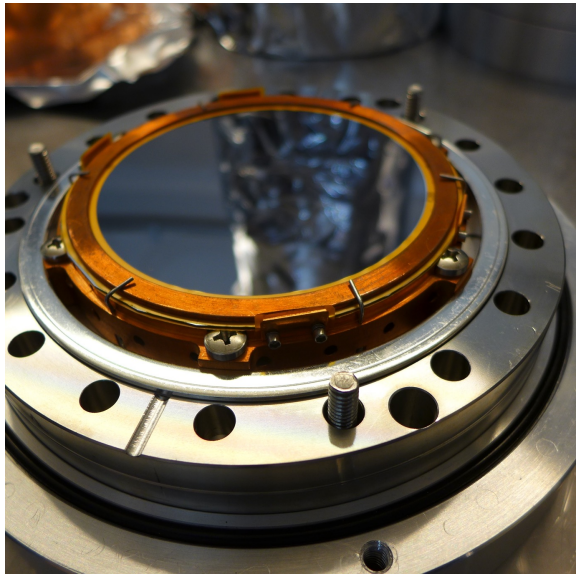


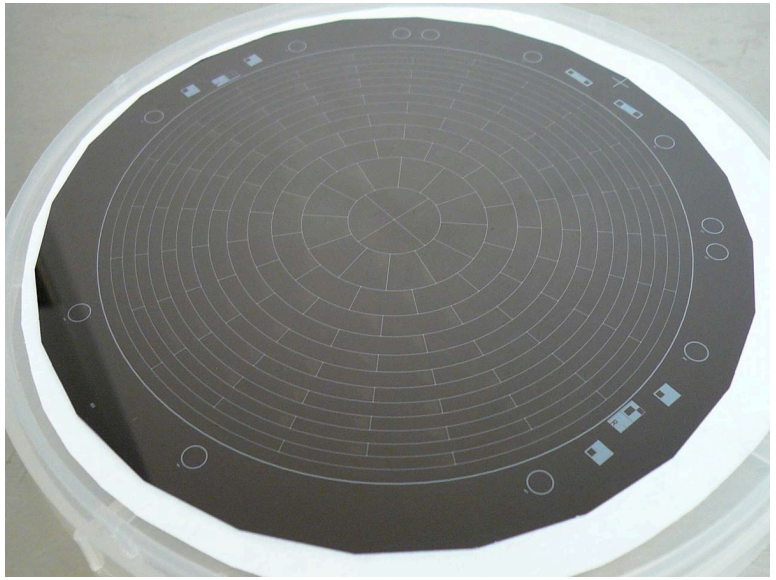
- *Goal: Determine mass of the neutrino*
  - *Model-independant way via ultrahigh precision measurements of the kinematics of electrons from beta-decay or tritium*
- *Needs a high resolution spectrometer to precisely analyze the electron energies*

KATRIN

- *Highly segmented silicon detector*
  - *148 individual pixels (44.1mm²)*
- *500um thickness, 114mm diameter*
- *Electrons from beta decay of tritium (end point energy 18keV)*







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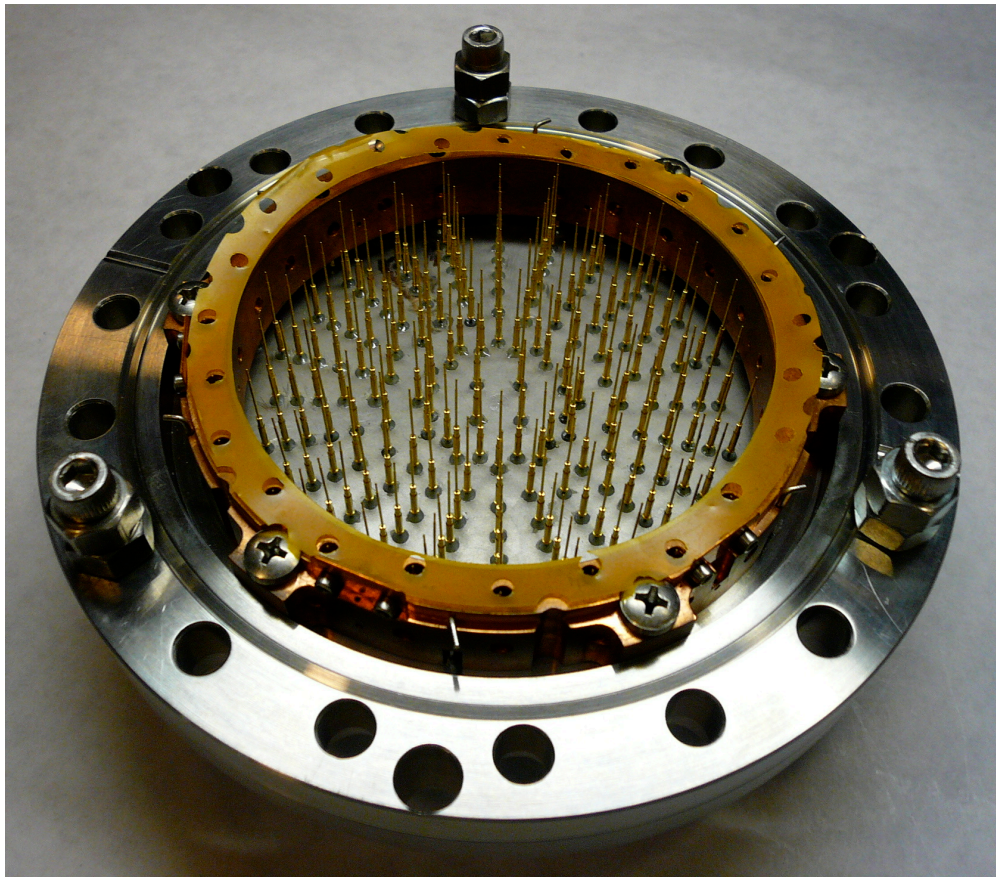
KATRIN

- *Excellent energy resolution:*
  - *Pixelization*
  - *Cooled down to about -10°C*
  - *Typ. FWHM of one pixel ~1.4 keV*
- *Used in ultra-high vacuum (10^{-11}mbar)*
- *Reduce background*
  - *Pixels coated with TiN*
    - *Non-oxidizing*
  - *Contact made with pogo-pins*
    - *No wire bonding because of the radioactivity of ceramics*



Summary

Reliable Performance

PIPS detectors deliver **high resolution and low-noise detection** for charged particles and low-energy radiation

Design Matters

Performance is driven by **active area, thickness, and entrance window optimization**

Custom Portfolio

Mirion offers **standard and customized PIPS solutions** tailored to application needs

User Impact

Optimized detector selection enables **higher sensitivity, stability, and measurement accuracy**

Why Mirion

Proven technology combined with **deep expertise in detector design and integration**

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Survey for:

Understanding PIPS® Detectors: A Portfolio Overview

Please take a moment to fill out a short survey on this session.

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Questions?

Thank you