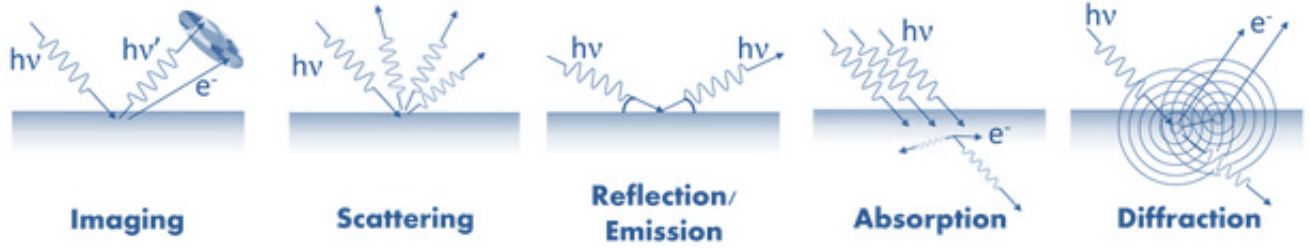
Elettra
Sincrotrone
Trieste

Pixelated detectors for present and future light sources at Elettra

Ralf Hendrik Menk on behalf of many of us
Elettra Sincrotrone Trieste, Italy
INFN, Trieste, Italy
University Trieste, Italy
Midsweden University, Sundsvall, Sweden


Elettra I 150 ps bunch, 2 ns spacing (Elettra II)
CNR IOM
Seeded Fermi FEL 50 Hz, 150 fs pulse

What we need in accelerator based photon science with X-rays



If we can we buy detectors, we will do otherwise we have to develope

- Imaging detectors (Elettra / Fermi)
  - Low energy (30 eV – 2000 eV), frame rate $\geq$ 50 Hz, pixel size $\geq$ 5 µm x 5 µm, D $\geq$ 16 bit
  - mid to high energy (10 keV – 60 keV), frame rate $\geq$ 1 Hz,
    - Pixel size $\leq$ 50 µm x 50 µm (direct conversion), spectroscopic properties
    - Pixel size $\leq$ 5 µm x 5 µm (indirect conversion)
- High Z materials (III – V group elements -> sufficient absorption for high photon energies)
- Ultra fast single photo counters ($\tau \leq 100\ ps$) (requires avalanche processes, high mobility)
- Low time jitter ($\Delta\tau \leq 10\ ps$)
- Scalable multi element Spectroscopic detectors (beamlines want collect more solid angle)

Valuable properties also in other fields (Astrophysics, HEP, medical imaging, etc)

SDD systems for Elettra I /II

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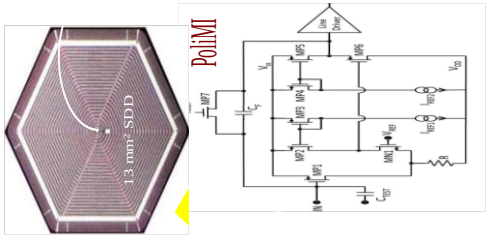
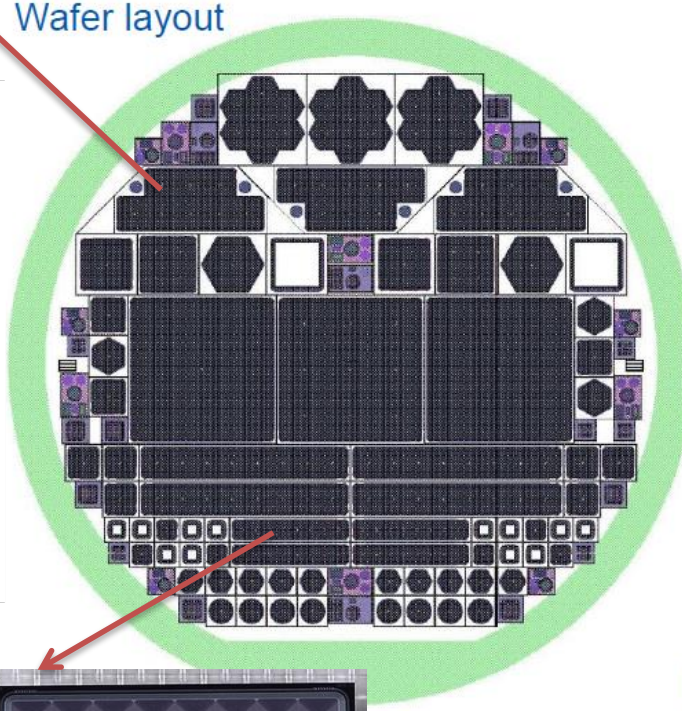
RESEARCH DRIFT FOR SOFT X-RAYS — red SOX

Trapezoidal SDDs for soft X-ray microscopeTwinMic

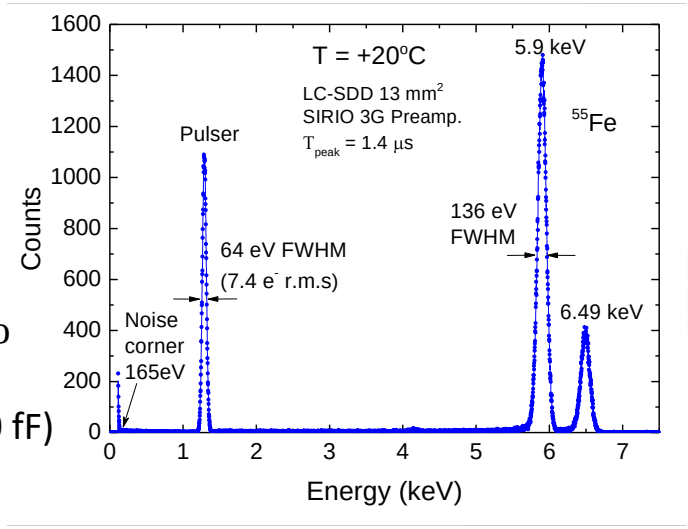


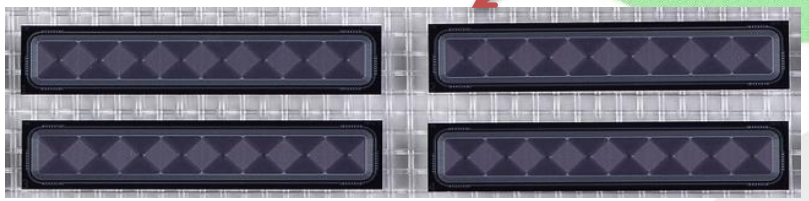
Wafer layout



Main properties:

- 450 µm Si thickness
- Thin entrance window
- Low leakage current (down to 20pA/cm^2 @20ºC)
- Low anode capacitance (~30 fF)
- Implants for temperature measurements





FONDAZIONE BRUNO KESSLER

INFN Istituto Nazionale di Fisica Nucleare

POLITECNICO MILANO

UNIVERSITAS STUDIORUM UTINENSIS

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TIFPA

SDDs for X-ray fluorescence spectroscophy (XAFS) beam line

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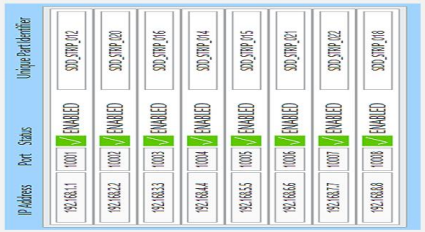
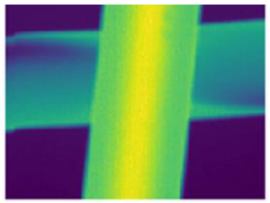
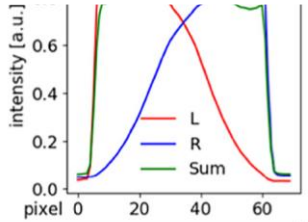
Sincrotrone
Trieste

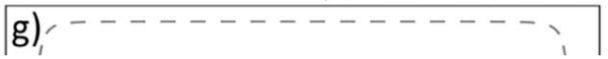
EXAFS SDD

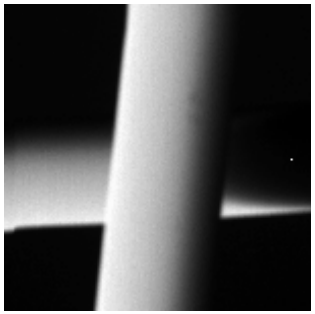


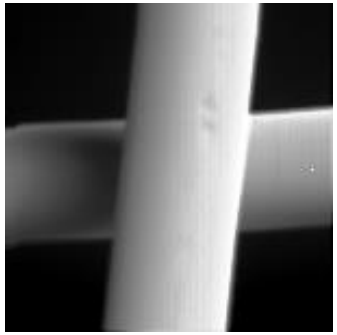
- 8 strips
- 64 channels
- 5.76 mm² active area

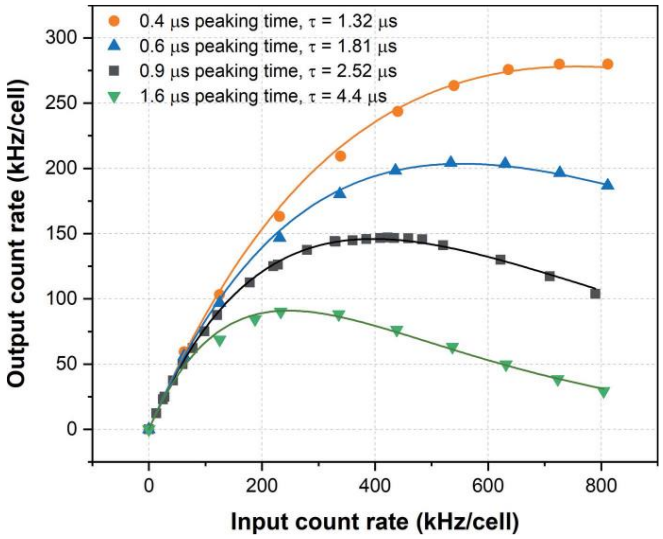


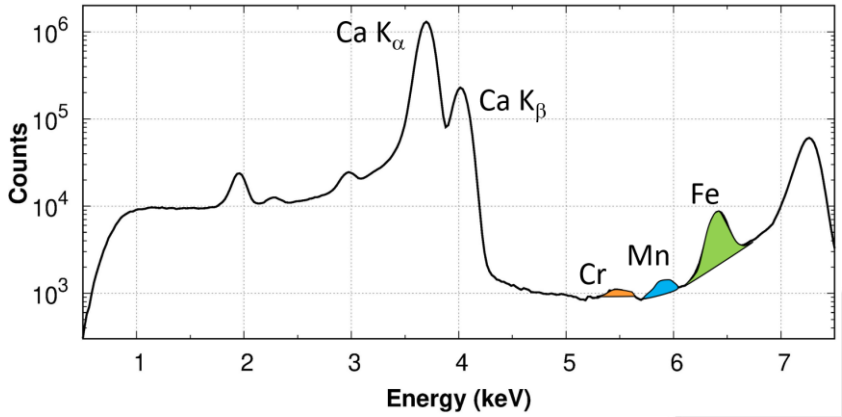












Diluted samples in Ca matrix

Needs for new solutions: increase user throughput

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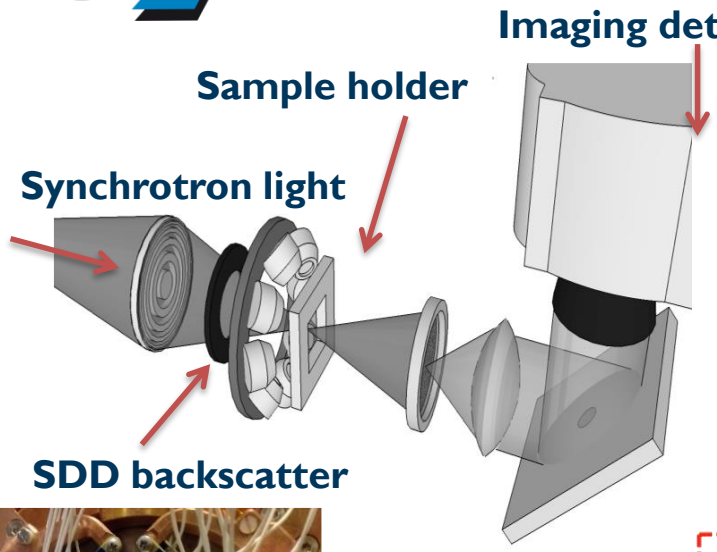
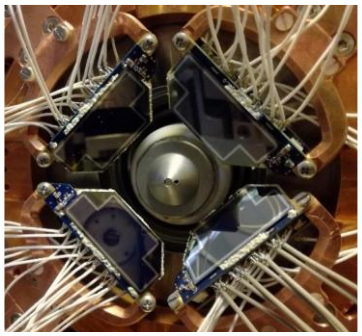
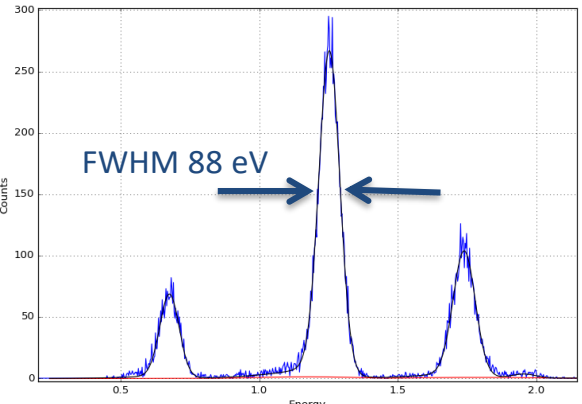
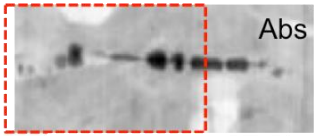
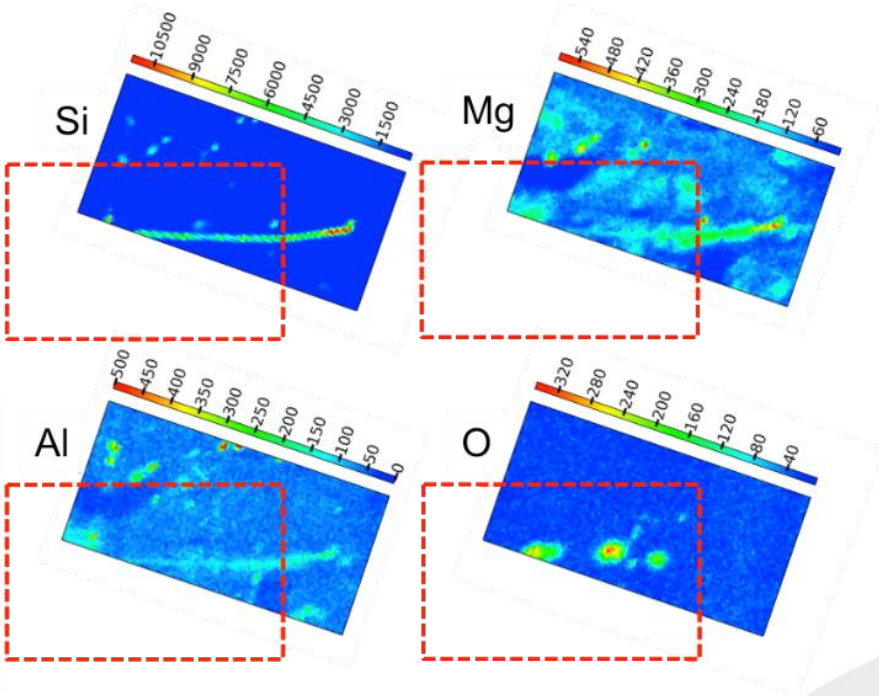




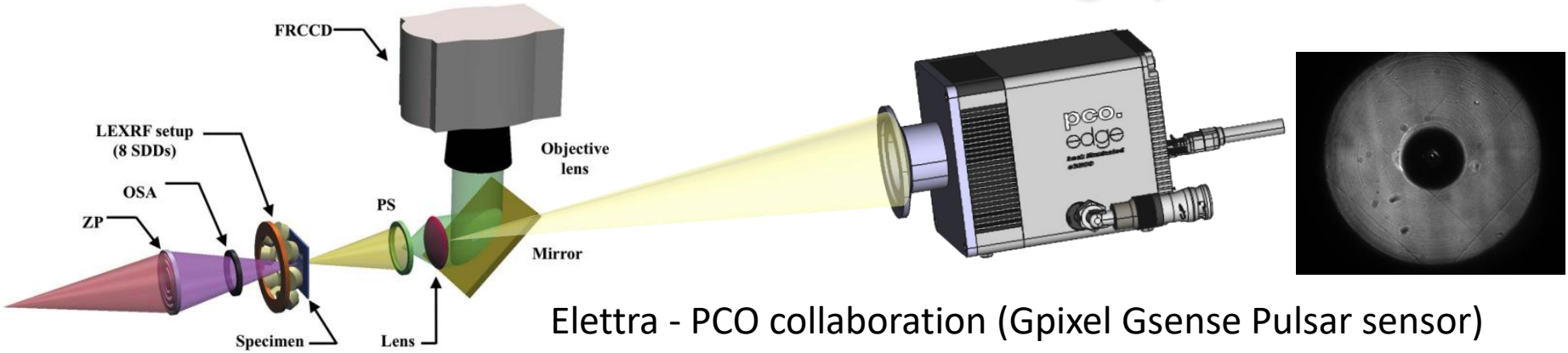


Asbestos fiber in lung tissue

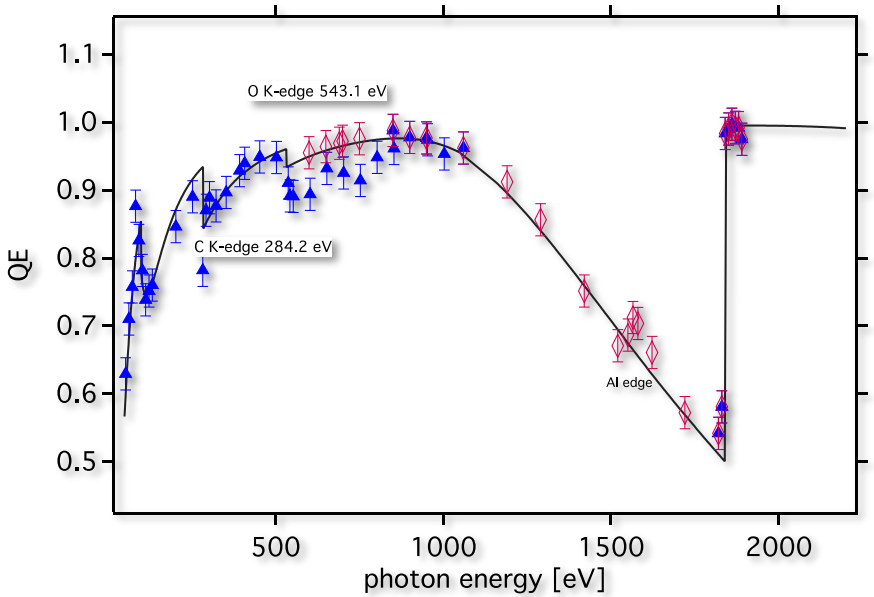




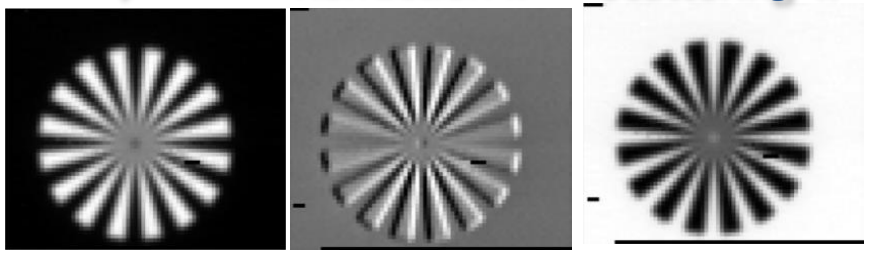
Needs for new solutions: increase user throughput



Elettra - PCO collaboration (Gpixel Gsense Pulsar sensor)
BSI Sensor Towerjazz



Absorption Refraction x Scattering x



Siemens Star pattern Virtual pixel size 300 nm

R.H. Menk et al 2022 JINST 17 C01058
DOI 10.1088/1748-0221/17/01/C01058

50Hz Fermi FEL operation

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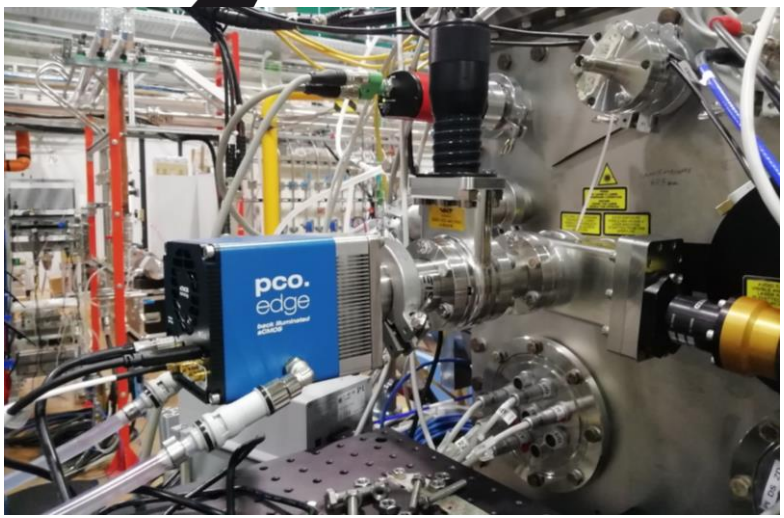
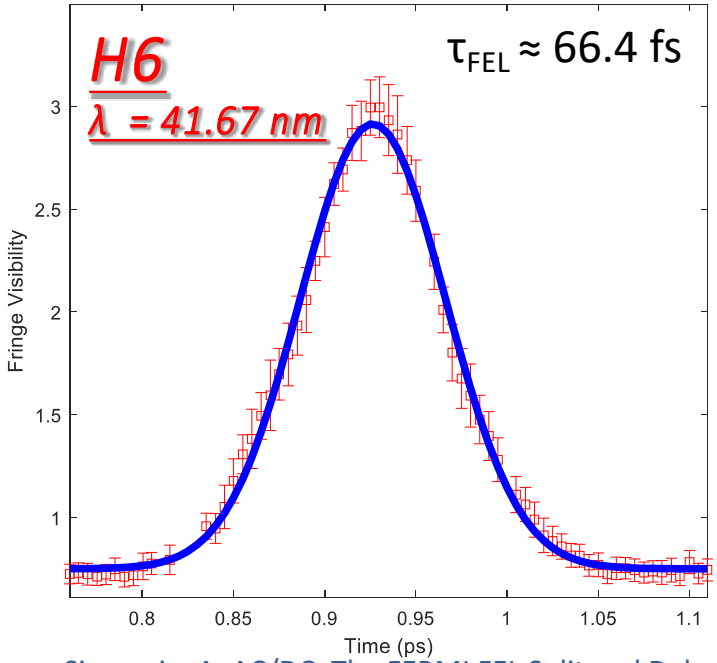
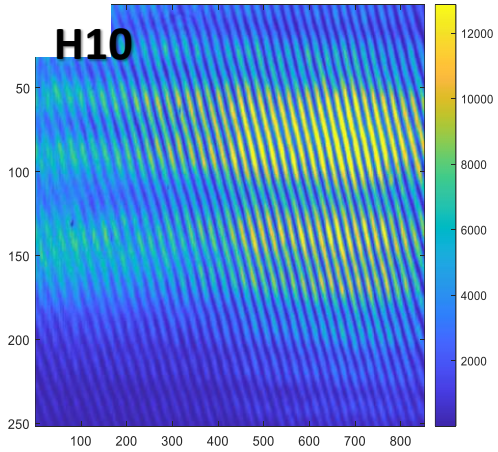
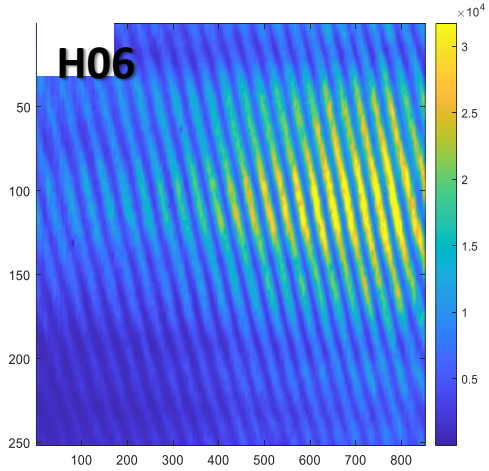
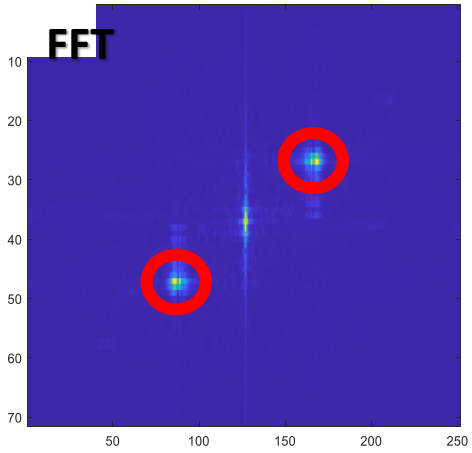


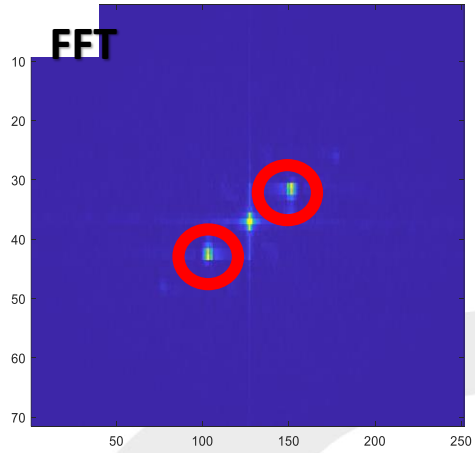
Optical delay line to elucidate the coherent length for each bunch











Simoncig, A. AC/DC: The FERMI FEL Split and Delay Optical Device for Ultrafast X-ray Science, Photonics, vol. 9, issue 5, p. 314, 2022

PERCIVAL CMOS imager

Higher framerate, higher dynamic

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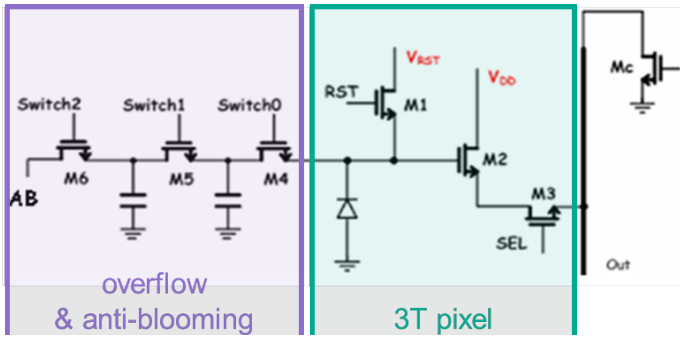
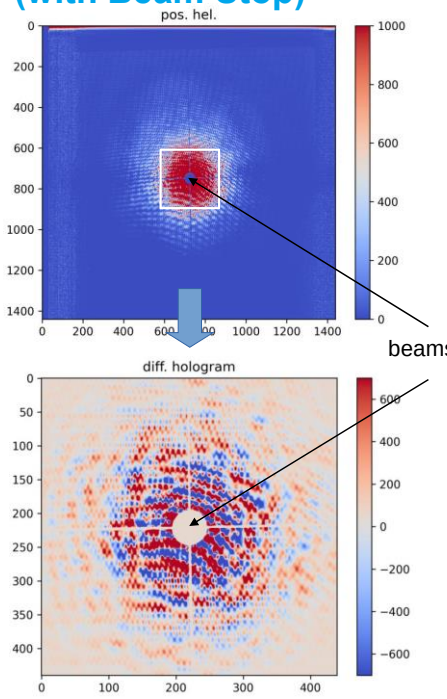
PERCIVAL

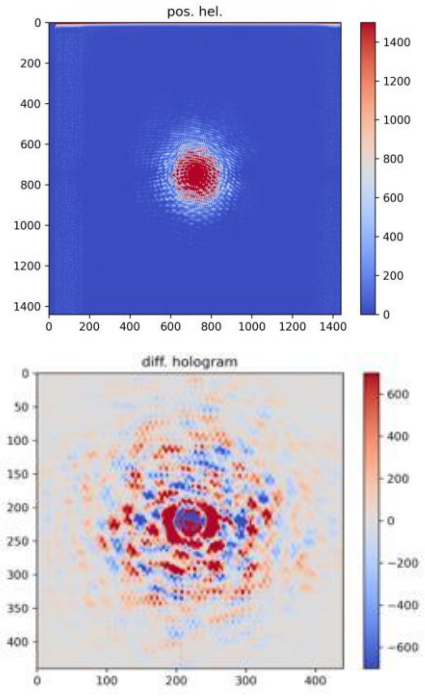
Two flavors

1) BSI (low energy X-rays)
2) FSI (high energy X-rays (scintillators))



Holography (with Beam Stop)





J. Correa et al. The PERCIVAL detector: first user experiments, Journal of synchrotron radiation , Volume 30| Part 1| January 2023| https://doi.org/10.1107/S1600577522010347

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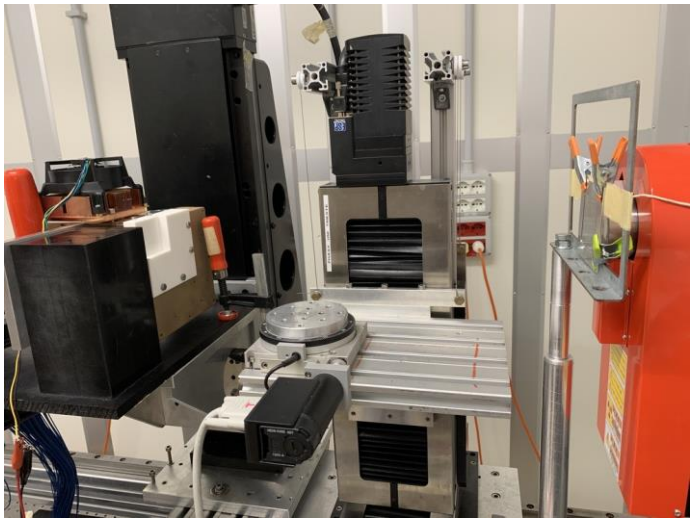
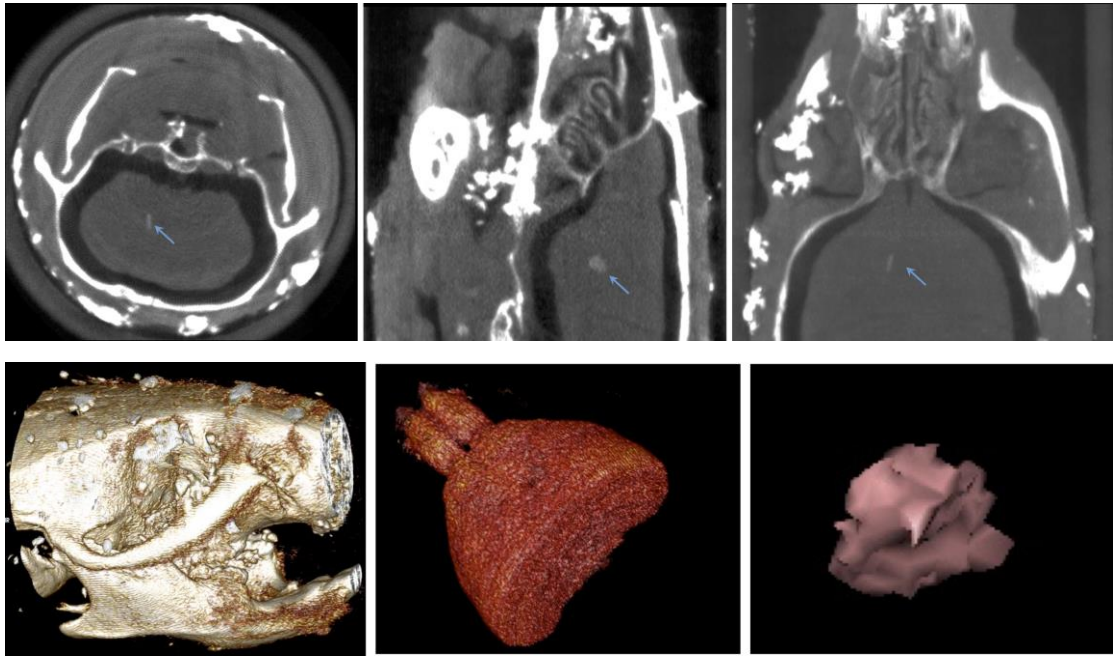
PERCIVAL

PERCIVAL CMOS imager

FSI + CsI scintillator

Gold nano particle loaded tumor cells implanted in a rat brain





G. Pinaroli et al 2020 JINST 15 C02007
DOI 10.1088/1748-0221/15/02/C02007

DESY · Elettra Sincrotrone Trieste · PAL · SOLEIL SYNCHROTRON · CFEL SCIENCE · Mittuniversitetet MID SWEDEN UNIVERSITY

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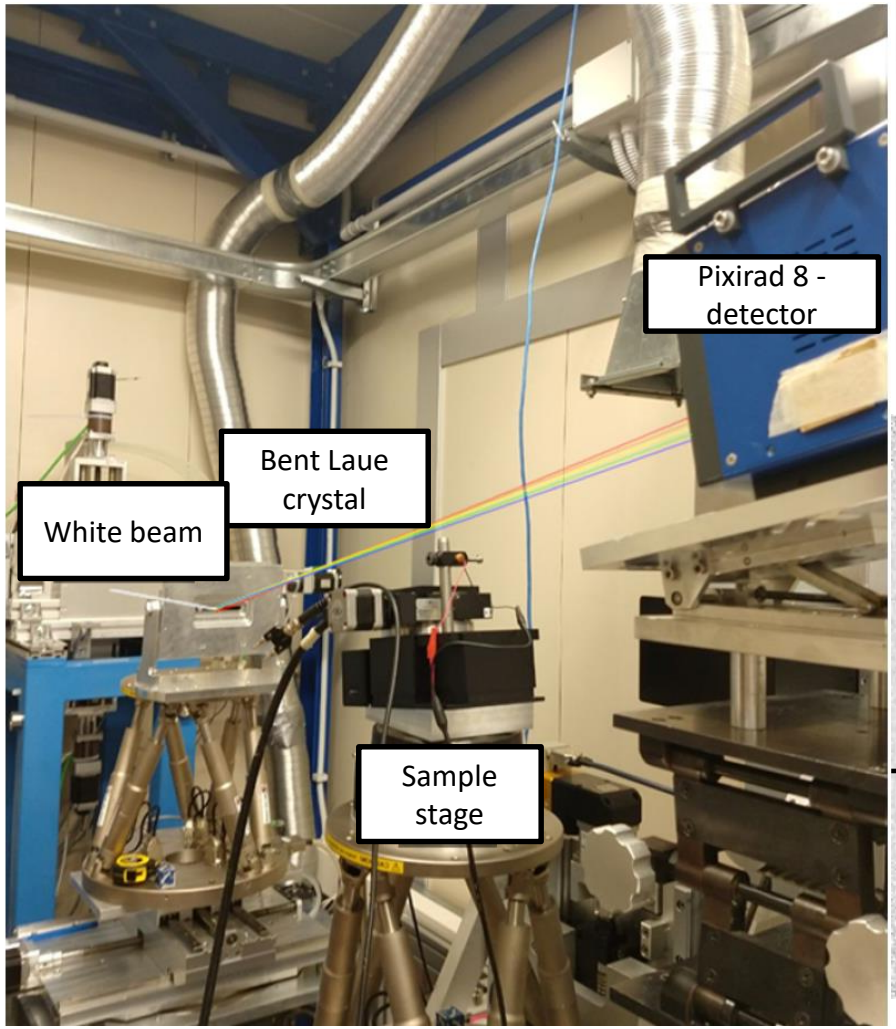
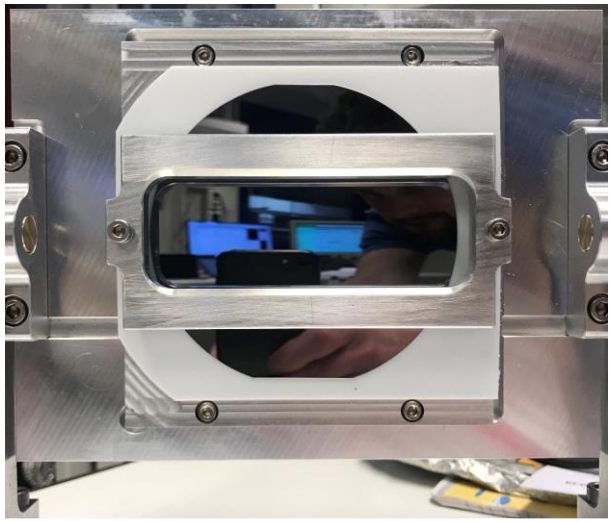
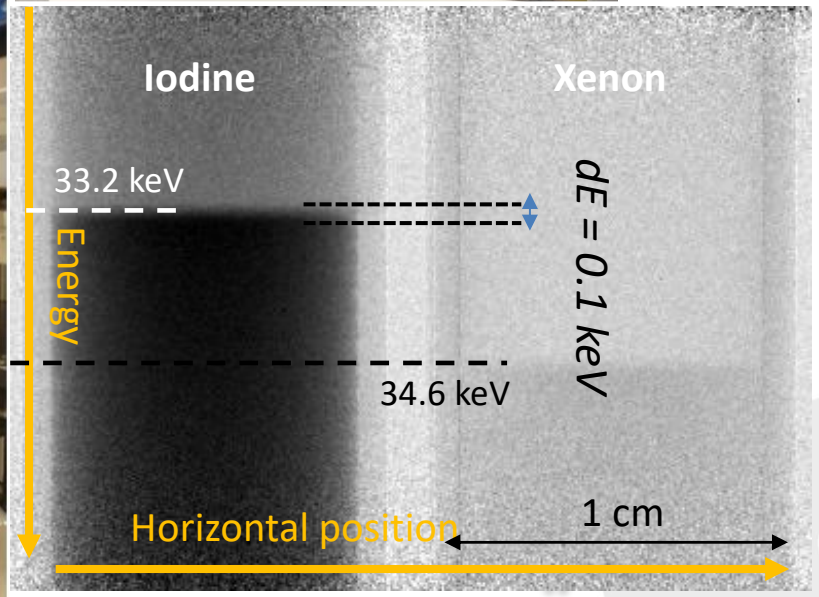
KISS
K-edge Imaging with Spectral Systems

Spectral imaging (PIXIRAD CdTe)



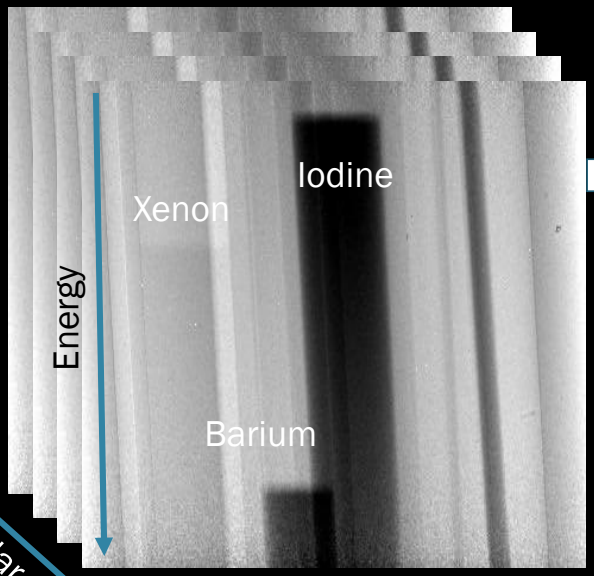


Fixed radius frames
Radius = 0.5 m
Focus ~ 0.25 m



Δ ≈ 50

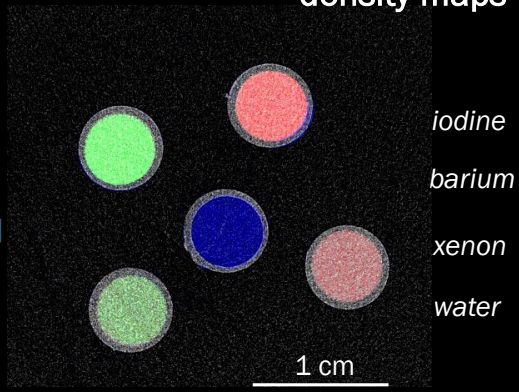
Tomographic multi-material imaging



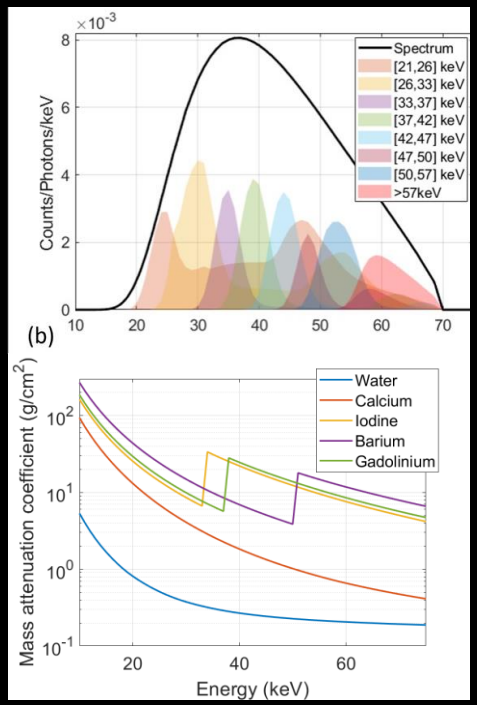
Tomographic reconstruction

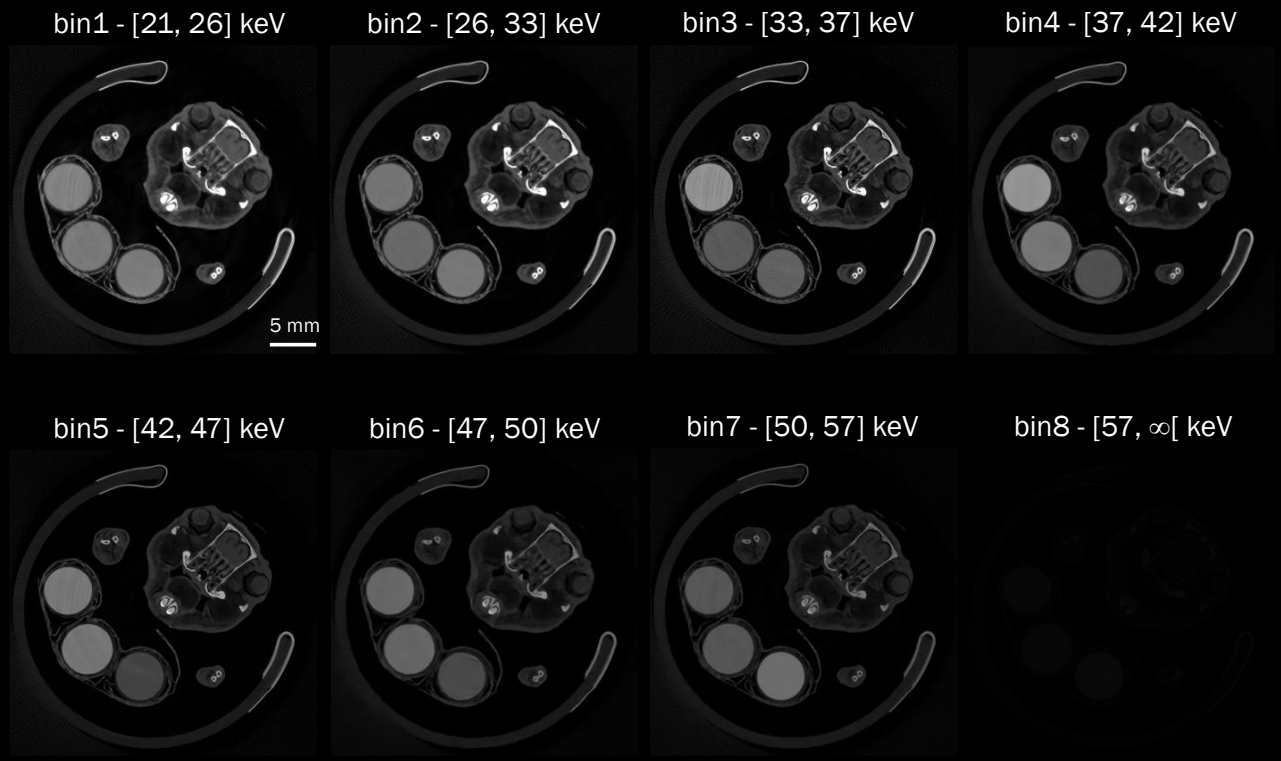
Multi-material decomposition

Multi-material density maps

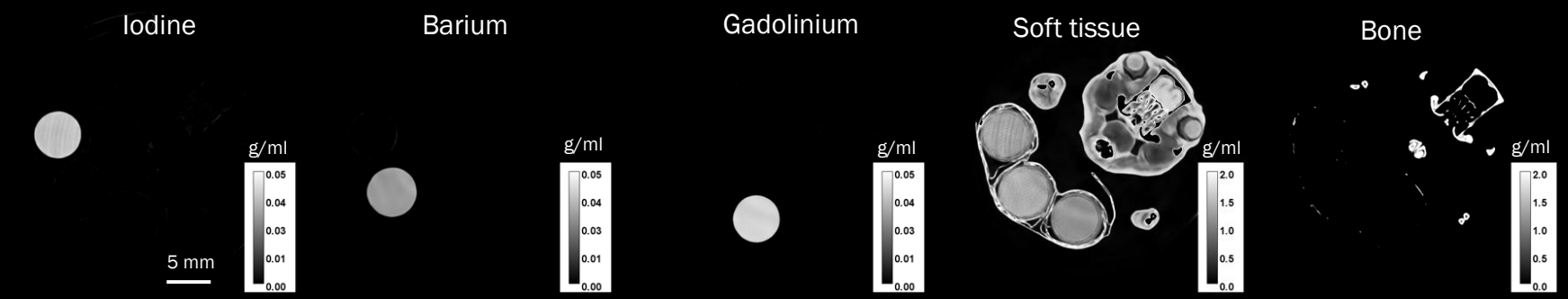


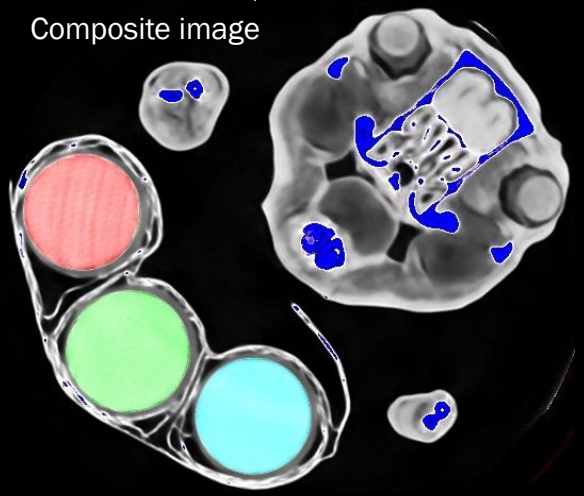
Goal: simultaneous cardiovascular + respiratory + inflammatory imaging!





L.Brombal Unpublished data INFN PEPI Lab.





	Nominal [mg/ml]	Measured [mg/ml]
Iodine	40	37.6 ± 0.8
Barium	35	30.2 ± 0.5
Gadolinium	39	41.2 ± 0.4

L.Brombal Unpublished data INFN PEPI Lab.

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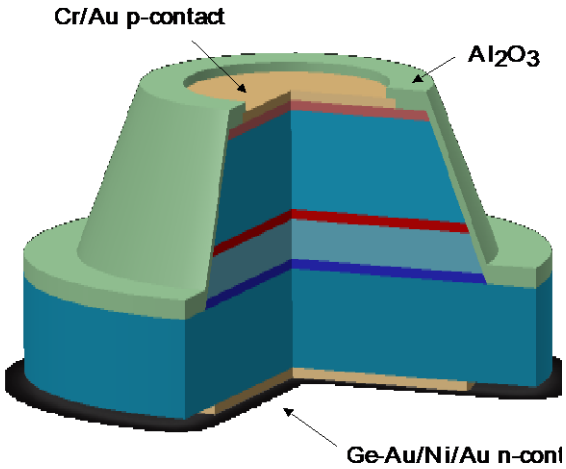
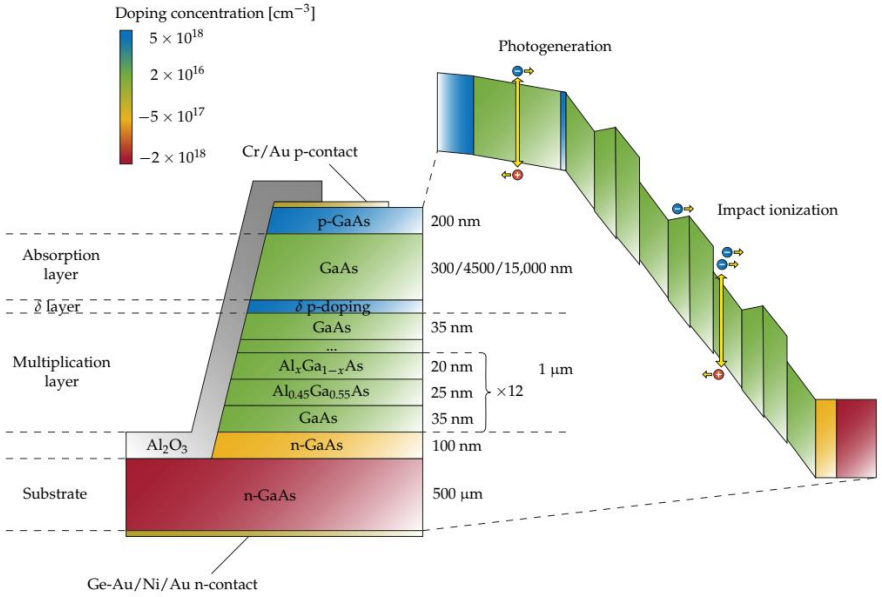
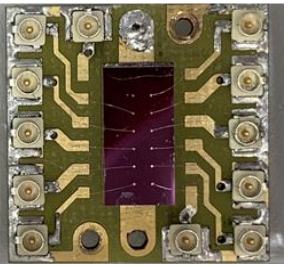
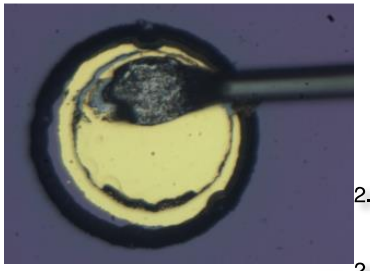
GaAs SAM-APD

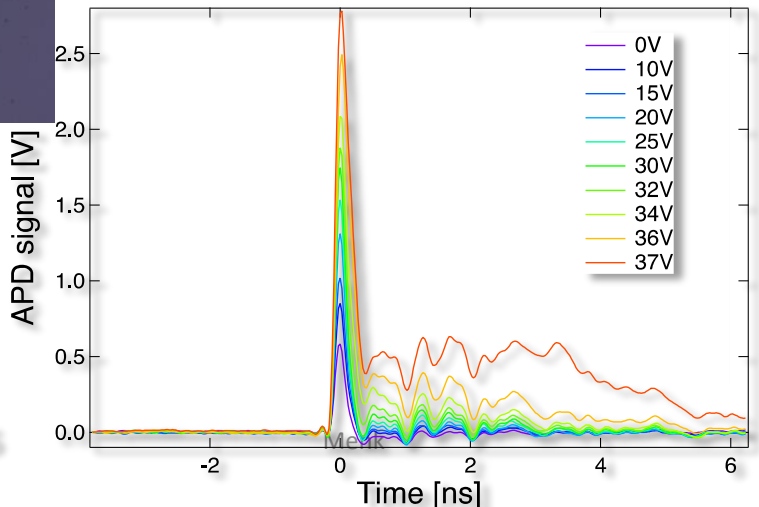
PRIN 2015 number 2015WMZ5C8

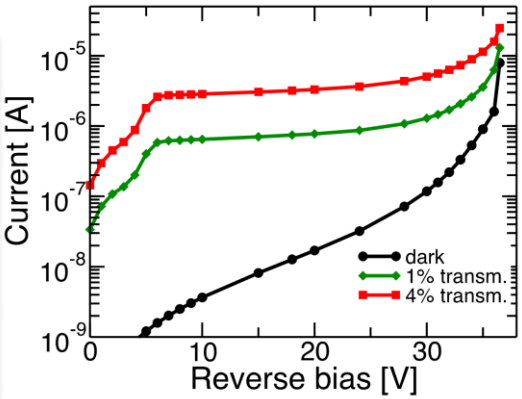










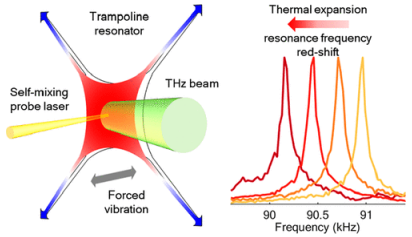


Partners

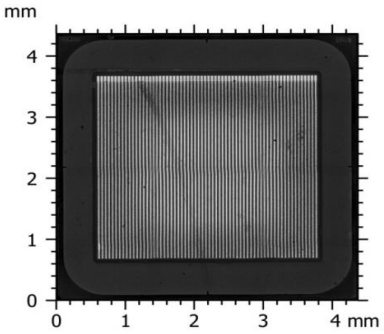
- Uni Udine -> simulations
- Uni Trieste -> experiments
- CNR IOM -> MBE
- EST -> electronics and tests

(Partial) status and future directions

- Spectroscopic XRF system is mature and being commercialized
- Twinmic system has still to be improved (less bulky)
- Spectral X-ray imaging for Elettra II life science beam line
  - Crystal based
  - Detector based
- Respin Percival (mitigating remaining shortcomings) -> choice for high end experiments
- PCO Gsense -> will become workhorses
- GaAs APD pixel arrays
- THz pixel detector (Attract II)



- SiC pixel detector (SAL, Austria)



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