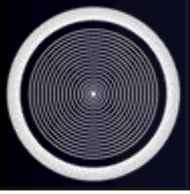


SDDs for Science Applications

Peter Lechner

MPI-HLL Project Review 2007

Schloss Ringberg, 23.04.07

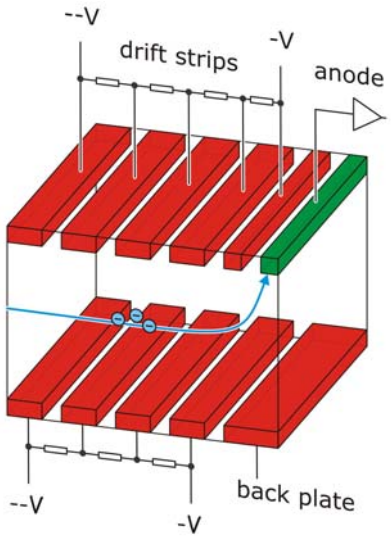
- SDD Introduction
- History of Science Applications
- **HiCam** - Medical Imaging
- **ExoMars** - Planetary Research

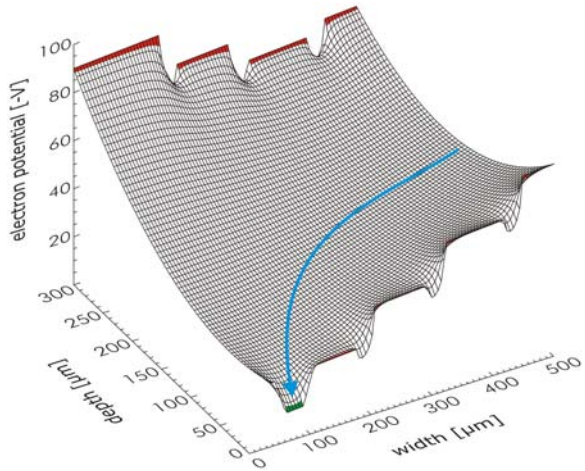
SDD introduction (1 - principle)

- original concept

  by Gatti & Rehak, 1983

  - ▷ depleted volume
  - ▷ transverse electric field
  - ▷ particle tracking

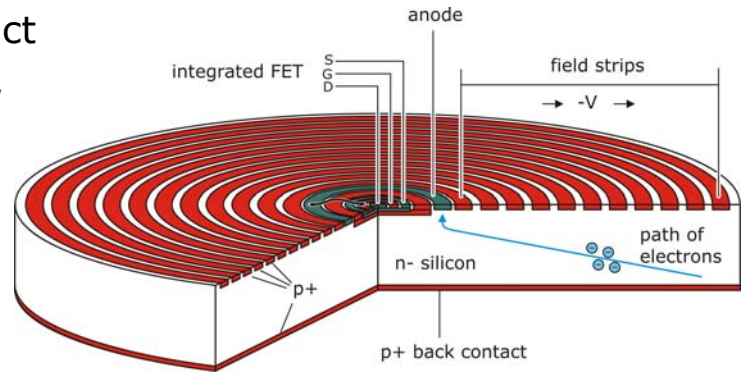


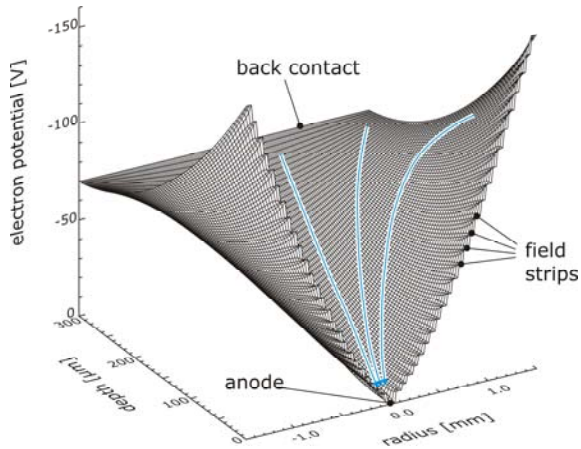


- spectroscopy adaptation

  by Kemmer & Lutz, 1984

  - ▷ uniform back contact
    = entrance window





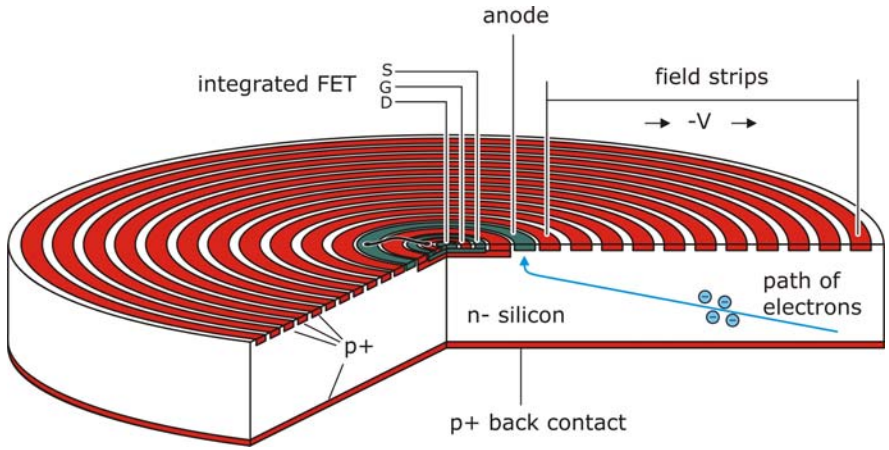
- on-chip transistor

  HLL, 1993

  - ▷ integration of first
    amplification stage

SDD introduction (2 – device properties)

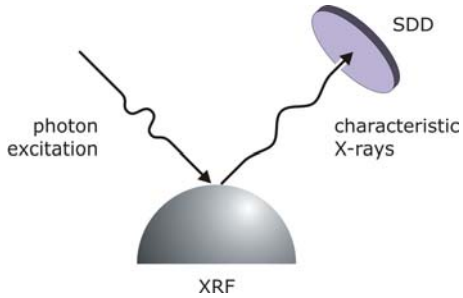
- large area
  - 5 mm² … 1 cm² (… wafer scale)
- small capacitance
  - low noise
  - high count rates
- integration of 1st FET
  - further capacitance reduction
  - no pickup, np microphony
- fully depleted and sensitive
  - efficiency @ high energies
- backside illuminated, thin window
  - efficiency @ low energies
  - peak/background ratio



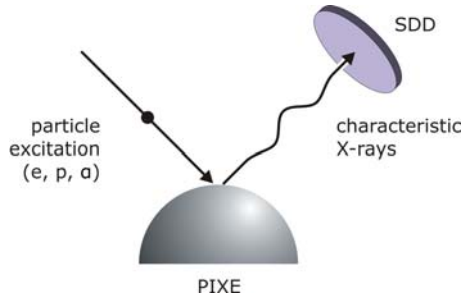
- low leakage current
  - rt operation / moderate cooling
  - thanks to clean room team
- radiation tolerant
- scalable in size, flexible in shape
- multi-channel option
  - monolithic arrays

SDD introduction (3 – application setup)

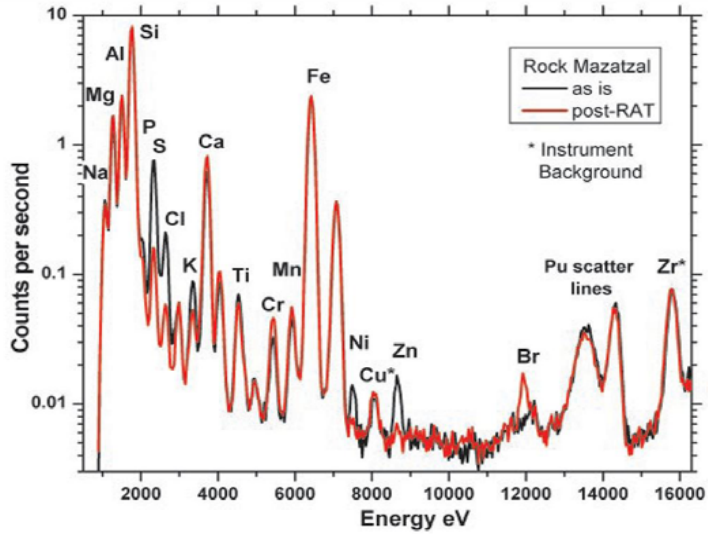
- X-ray spectroscopy
  - ▷ sample irradiation by X-rays (XRF) or by particles (PIXE)
  - ▷ energy and intensity of emitted characteristic X-rays
  - ▷ chemical composition of sample
- fast photon counting
  - ▷ energy discrimination
- γ-ray spectroscopy and imaging
  - ▷ multi-channel SDD & scintillator
  - ▷ optical light intensity
- particle detection



X-Ray Fluorescence analysis

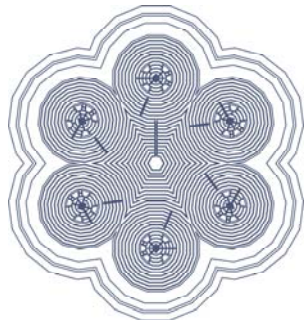


Particle Induced X-Ray Emission



applications – synchrotron experiments

- multi-channel SDDs
  - large area
  - high count rates
- EXAFS (Extended X-ray Absorption Fine Structure)
  - determiation of the bonding in solids by analyzing oscillations in X-ray absorption vs. photon energy caused by interference
  - ESRF/Grenoble, HASYLAB/Hamburg
- X-ray holography
  - 3D holographic imaging of core electron density by referencing scattered to non-scattered X-rays
  - HASYLAB/Hamburg



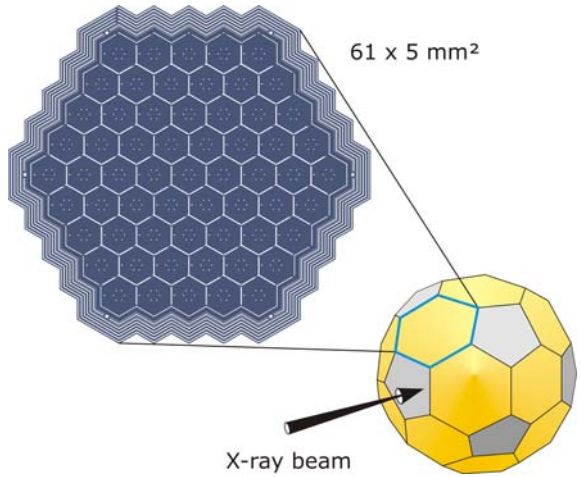
SDD 6 x 3 mm²
"margherita" (1993)

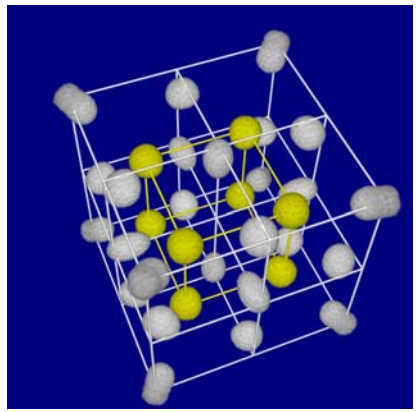
EXAFs @ ESRF/Grenoble

SDD
61 x 5 mm²

20 modules
in football

HASYLAB





holographic image of
Fe crystal

SDD 7 x 5 mm²

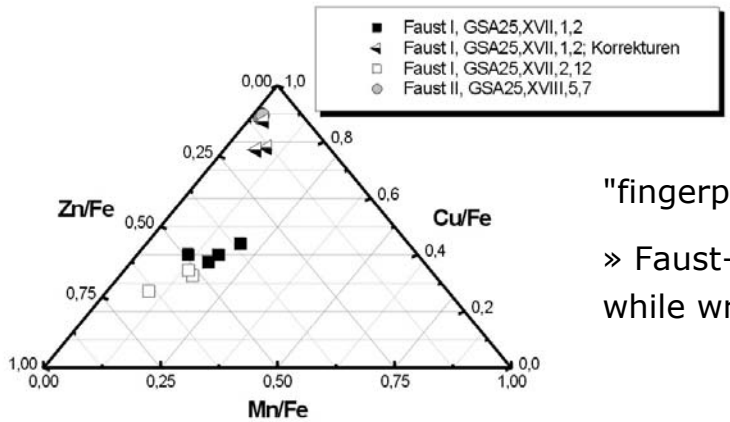
D. Novikov, HASYLAB

applications – analysis of works of art (1)

- material analysis
  - paintings, frescos, monuments, manuscripts, inlays, …
  - non-destructive method
  - no sample preparation
  - portable instrumentation
  - on-site analysis
- compact XRF spectrometer
  - 10 mm² SDD & µ-focus tube
  - e.g. ArtTAX by RÖNTEC

"ArtTAX" analysing the ink of Goethe's Faust-I manuscript

O. Hahn, BAM RÖNTEC

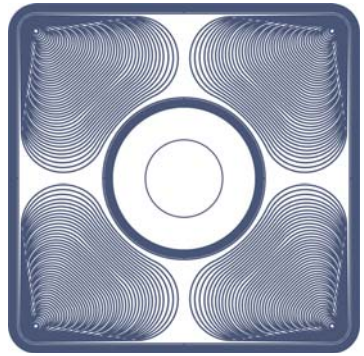


"fingerprint" of ink

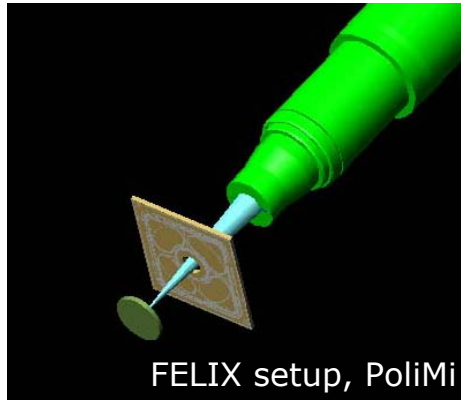
» Faust-I re-edited while writing Faust-II

applications – analysis of works of art (2)

- optimised geometry: SDD ring
  1. SDD 12 x 5 mm²
  2. "FELIX": SD³ 4 x 15 mm²
  - ▷ large area
  - ▷ solid angle coverage
  - ▷ laser cut center hole
  - ▷ polycapillary fibre



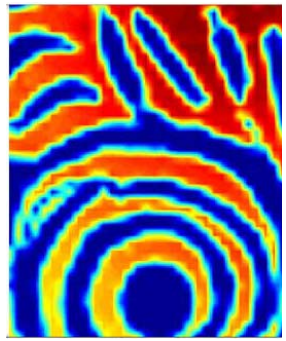
FELIX layout



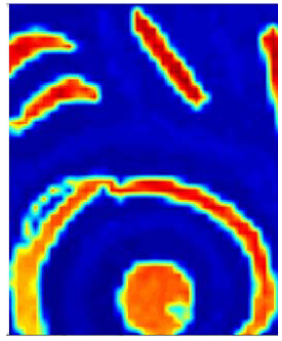
Lombard buckle
inlaid work

VII century a.c.
Trezzo sul` Adda, Italy

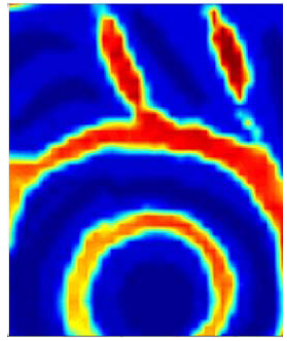
SDD 12 x 5 mm²
module



Fe (matrix)



Au

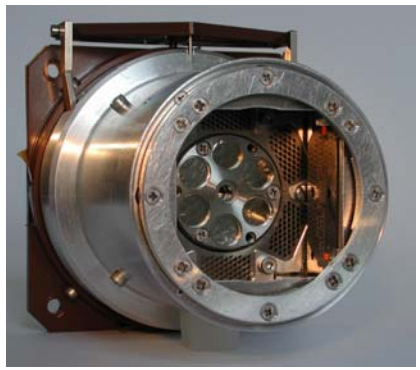


Ag

applications – SDDs in space

- **APXS** (Alpha-Particle X-ray Spectrometer) on NASA's Mars Exploration Rovers **Spirit** and **Opportunity**
  - ▷ landed Jan04, still active
  - ▷ APXS "sniffer" by MPCh, Mainz
  - ▷ SDD 10 mm² & Cu244 α-sources

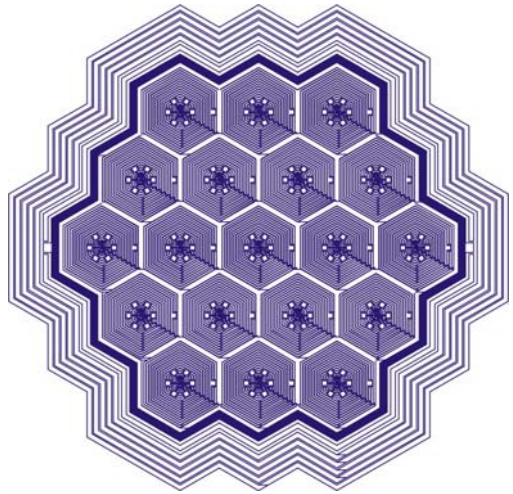
Mars Exploration Rover



APXS system (MPCh)

- **APXS** on ROSETTA Lander
  - ▷ rendezvous with comet 67P/C-G
  - ▷ Mar04, orbit May14, lander Nov14

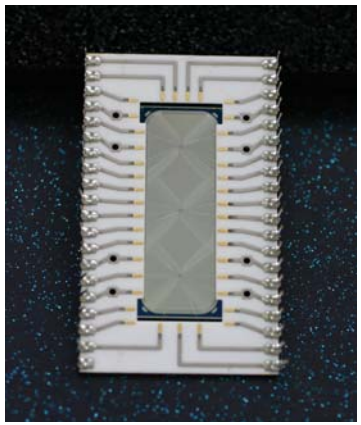
- **XTRA** (X-ray Timing for Relativistic Astronomy) on XEUS (X-ray Evolving Universe Spectroscopy)
  - ▷ observation of X-ray light curves of black holes and neutron stars
  - ▷ photon rate up to 1 Mcps
  - ▷ time resolution 10 µsec
  - ▷ multi-cell SDD 19 x 5 mm²
  - ▷ uniform distribution of photon intensity by out-of-focus operation



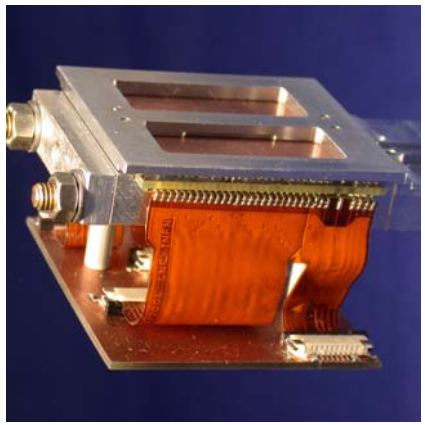
SDD 19 x 5 mm² for XTRA on XEUS

applications – particle physics

- SIDDHARTA (Silicon Drift Detectors for Hadronic Atom Research with Timing Application)
  - DAΦNE sychrotron, Frascati/Italy
  - "hadronic" atoms (H, D, He, N), i.e. an electron is replaced by a Kaon
  - X-ray transitions are a probe to yet unknown terms of QCD
  - 234 SDDs 1cm² on 78 chips
  - mounting in progress, data end 2007

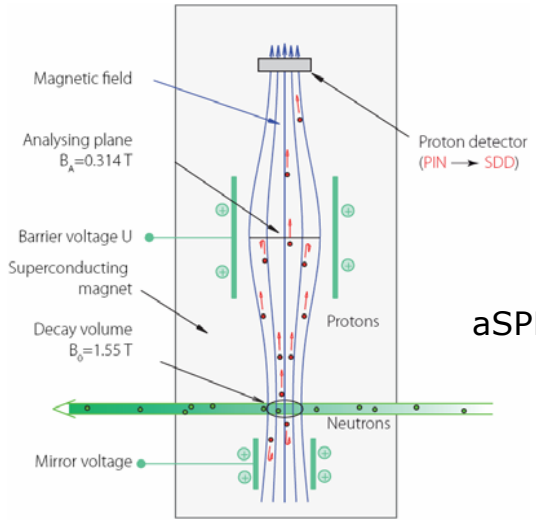


SIDDHARTA SDD chip, 3 x 1 cm²



SDD subunit, 2 chips

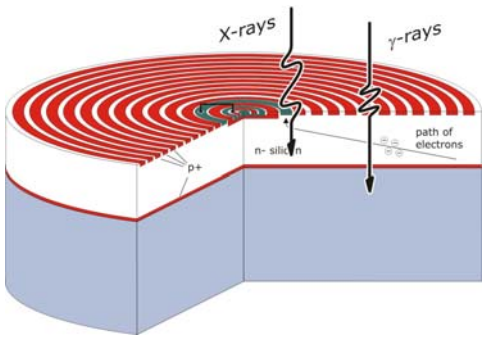
- aSPECT neutron decay experiment
  - TUM E18, FRM-II
  - study of neutron decay parameters
  - spectroscopy of recoil protons by electric field analyser
  - SDD as proton counter
  - 1st test with SDD 30 mm² successful
  - use of SIDDHARTA SDD in preparation



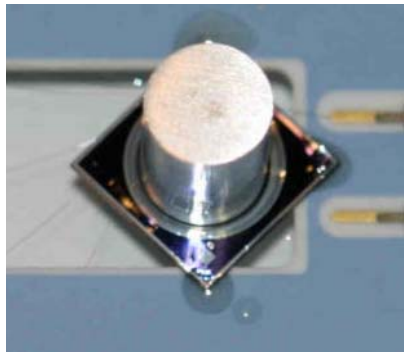
aSPECT setup

applications – scintillator readout

- radiation monitor
  - ESTEC, Politecnico di Milano
  - γ-ray spectroscopy (& imaging) system, e.g. for Solar Orbiter
  - SDD & scintillator (CsI / $LaBr_3$)



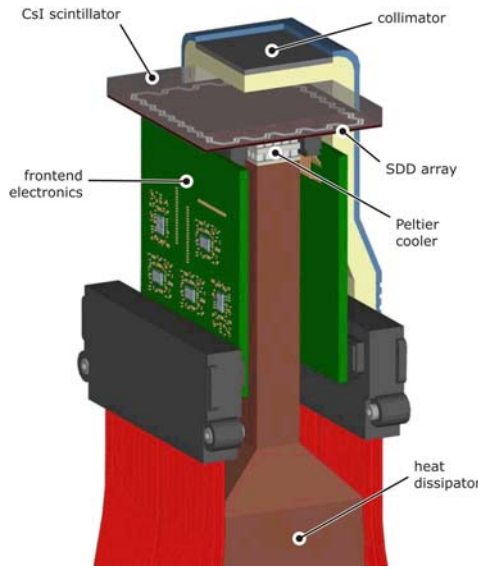
scintillator readout by SDD



SDD 30 mm² & $LaBr_3$ scintillator

- dual X- and γ-ray spectroscopy
  - CNR-IASF, Bologna
  - distinction of X- and γ-events by rise time discrimination

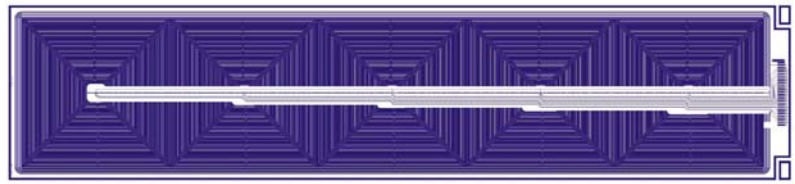
- DRAGO (DRift detector Array Gamma camera for Oncology)
  - Politecnico di Milano
  - SDD array 77 x 8 mm² & monolithic CsI scintillator
  - γ-ray imaging by centroid method
  - position resolution < 1 mm
  - demonstrator for medical applications: nuclear surgery, small animal imaging, …



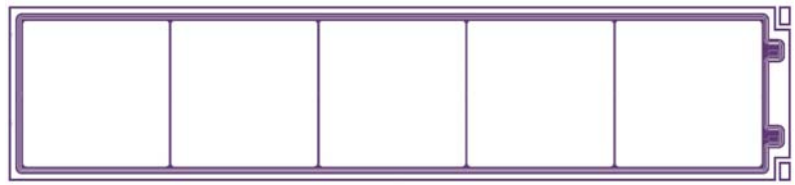
DRAGO setup

HICAM – detector

- HICAM project
  - European 6th Framework Programme
  - lead by C. Fiorini, Politecnico di Milano
  - 2 institutes, 3 companies, 4 hospitals
  - start in Mar07, 3 years
- objectives
  - γ-ray camera (Anger type)
  - spatial resolution ~ 2.5 mm
  - compact detector head
  - magnetic field (NMR) compatible
  - 2 prototypes 5 x 5 cm²
  - 1 application module 10 x 10 cm²
- approach
  - SDD array, cell size 1 cm²
  - CsI scintillator ($LaBr_3$ optional)
  - parallel hole or pinhole collimator
- SDD
  - monolithic subunits 5 x 1 cm²
  - square shaped cells
  - connection pads on narrow edge



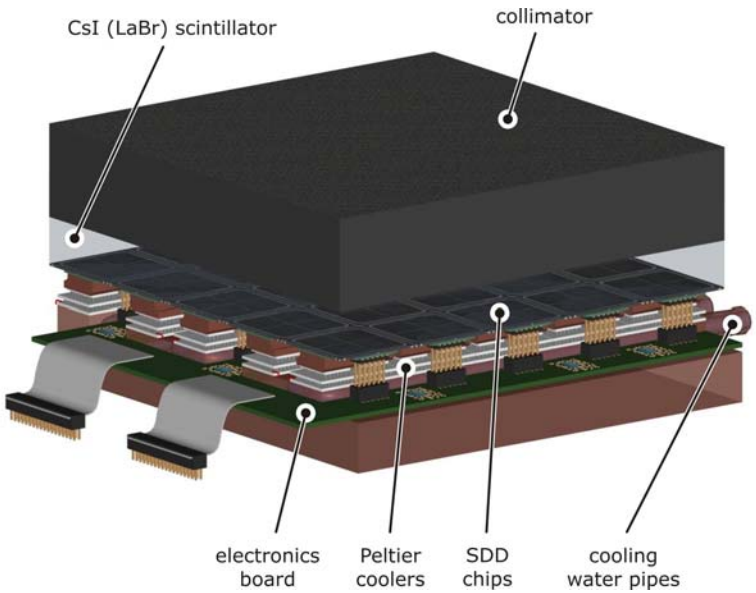
readout electronics side



entrance window side

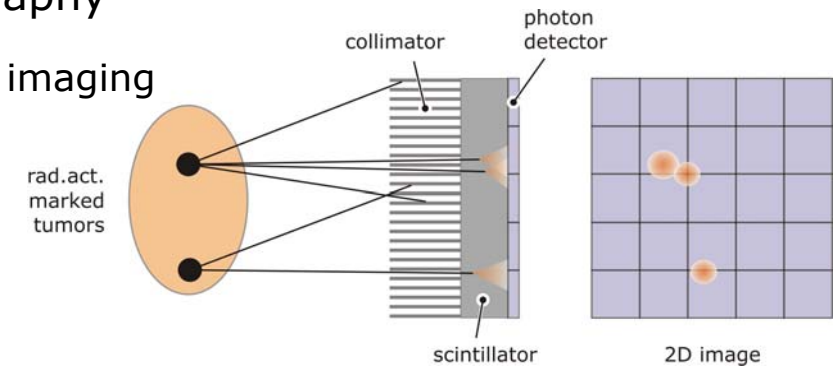
HICAM – system & applications

- HICAM system



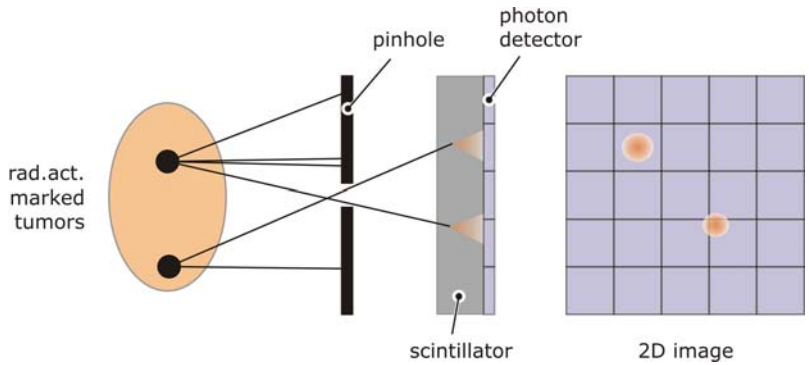
- challenges
  - ▷ cooling to -20 °C is mandatory
  - ▷ dissipation of 300 W (!)
  - ▷ compact housing

- scintigraphy
  - ▷ 2D imaging



- SPECT (Single Photon Emission Computed Tomography)
  - ▷ multiple angles, tomographic 3D reconstruction

- pinhole SPECT
  - ▷ (de-)magnification by geometry
  - ▷ sensitivity ~ 1 % of planar SPECT



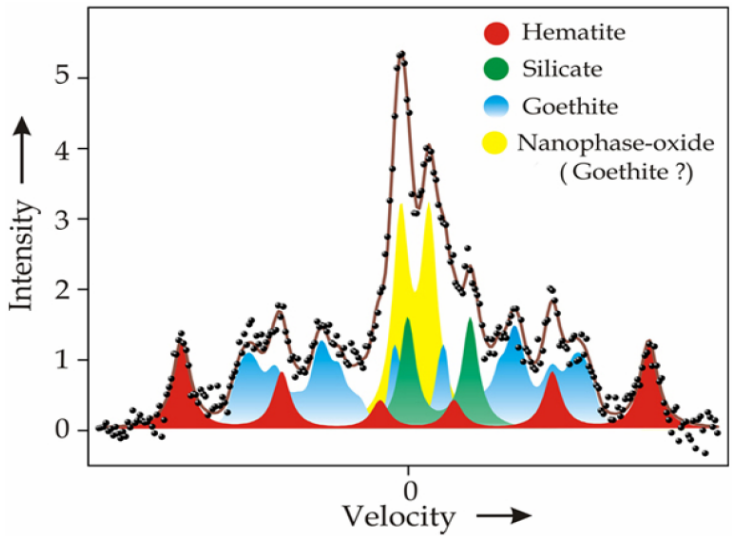
ExoMars – background

- ESA's Aurora programme
  - ▷ explore the solar system
  - ▷ search for life beyond Earth
  - ▷ human Mars mission ~2030
- ExoMars mission
  - ▷ phase B, launch 2013, arrival 2015
  - ▷ orbiter / descent module / rover
  - ▷ rover in autonomous operation
- scientific tasks
  - ▷ geophysics, environment parameters
  - ▷ search for past/present life signatures
  - ▷ identify hazards to humans

- "Pasteur" payload
  - ▷ panoramic instruments
    - optical stereo camera
    - IR spectrometer
    - ground penetration radar
  - ▷ contact instruments
    - microscope camera
    - Mößbauer spectrometer
    - Raman spectrometer
  - ▷ support instruments
    - subsurface drill (2m depth)
    - sample preparation and distribution system
  - ▷ analytical laboratory
    - Raman spectrometer
    - IR microscope
    - gas chromatograph
    - X-ray diffractometer
    - organics and oxidants detector
    - life marker chip

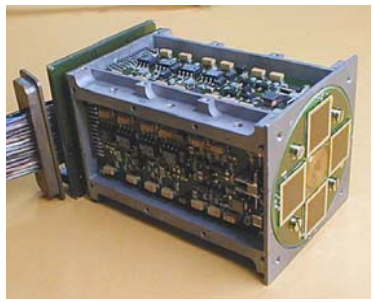
ExoMars – MIMOS2A system

- Mößbauer spectroscopy
  - ▷ resonant recoil-free emission/absorption of γ-rays by nuclei of solid-bound atoms
  - ▷ nuclear levels of emitter/sample shifted and split by chemical environment
  - ▷ probing of levels by red/blue-shift
  - ▷ resolution $\Delta E/E \sim 10^{12}$



Mößbauer spectrum of Martian sample

- MIMOS (MIniature MOeßbauer Spectrometer)
  - ▷ G. Klingelhöfer, Gutenberg-Uni Mainz

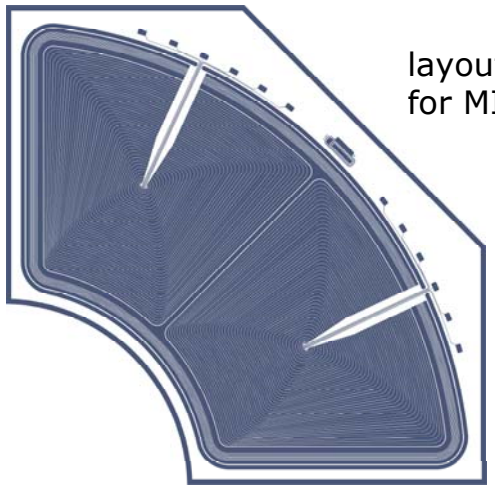


MIMOS on board of MER

PIN diodes

Co57/Fe57 source (14.41 keV)

- SDD for MIMOS2A
  - ▷ 2 x 45 mm², 4 chips around collimator



layout of SDDs for MIMOS2A

Summary

- SDDs are present in many different science disciplines,

  many more to come, no end in sight.

- In addition there is a variety of commercial applications.

  → next talk by Adrian

- Multilinear SDD for ultrafast X-ray imaging @ XFEL.

  → talk by Matteo