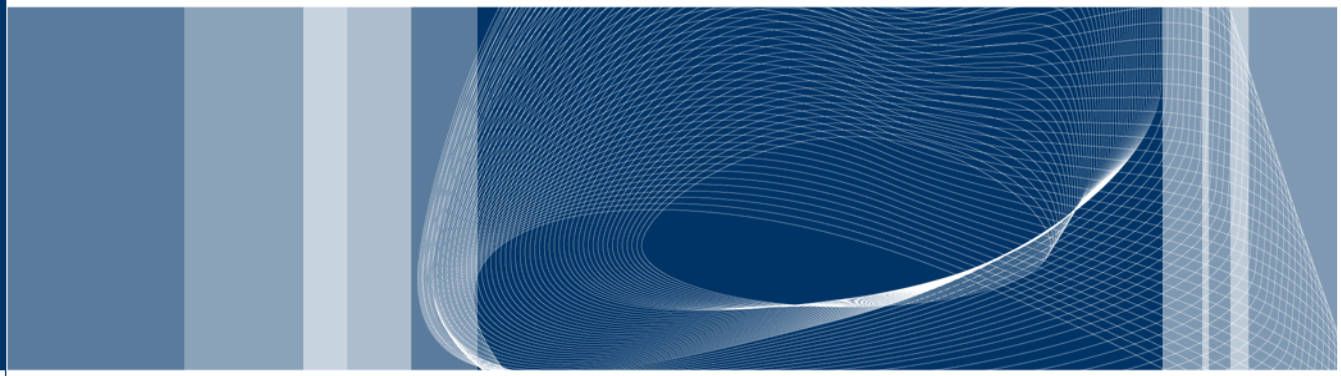
POLITECNICO DI MILANO



ARDESIA: an X-ray Spectroscopy detection system for synchrotron experiments based on arrays of Silicon Drift Detectors

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FONDAZIONE BRUNO KESSLER

ARDESIA

ARRAY of DETECTORS for SYNCHROTRON RADIATION APPLICATIONS

Goal: Development of a **versatile detector** based on **arrays of Silicon Drift Detectors** and **low-noise electronics** for **X-ray detection**

The ARDESIA collaboration:

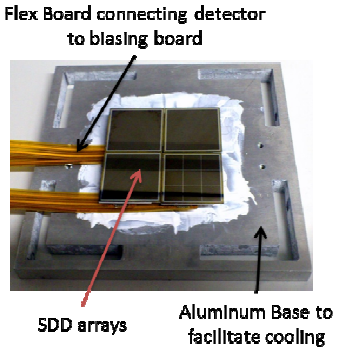
- **Politecnico and INFN-Milano, Italy**
  G.Bellotti, A.D.Butt, C.Fiorini, R.Quaglia, F.Schembari, D.Giove
- **INFN-LNF, Frascati, Italy**
  A.Balerna, E. Bernieri, M.Iliescu, S. Mobilio
- **Fondazione Bruno Kessler – FBK, Trento, Italy**
  C.Piemonte, N.Zorzi

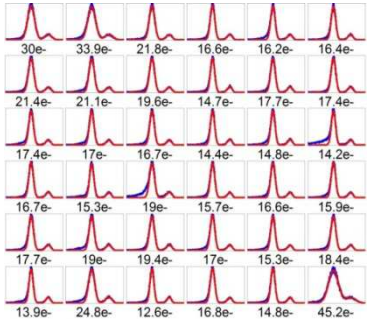
International Endorsers: F.d'Acapito (ESRF), N.Tartoni (Diamond Light Source), ..

Project funded by Italian INFN (start: 1st Jan. 2015)

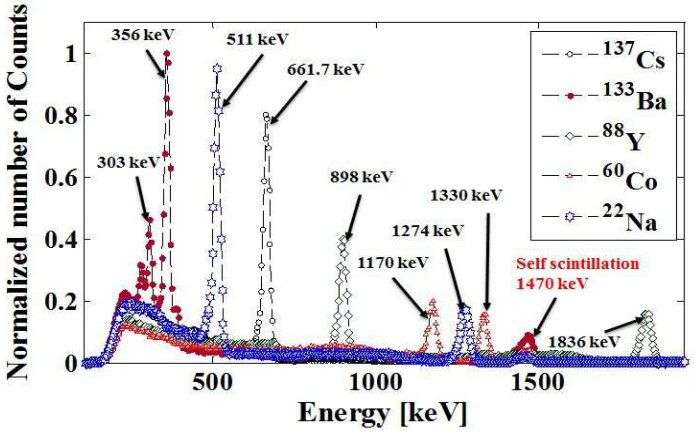
Starting point (1)

SDD technology developed at ***FBK*** laboratories, already proved for ***X-ray Spectroscopy*** *and* ***γ-ray detection*** with scintillators (***C. Fiorini et. al – IEEE TNS, 2013, R.Quaglia et al., IEEE TNS 2015***).



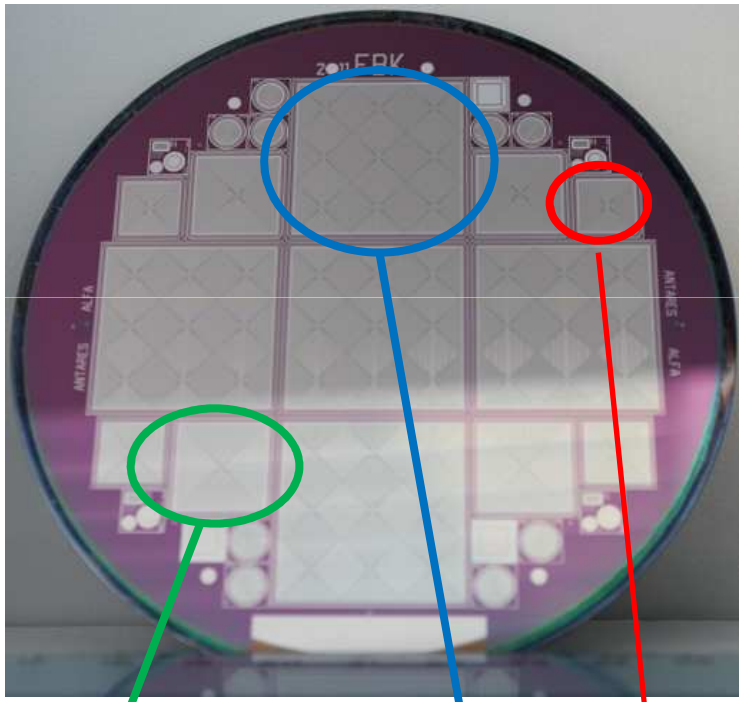


36 channels. Active area: **4.8x4.8 cm²** SDD temperature ≈ -16 °C



γ-ray spectra with 2" $LaBr_3$ coupled to the 4 SDD arrays

Wafer produced in the framework of ***an ESA project***, for the development of γ-ray spectrometers based on **$LaBr_3$** readout by **SDDs**



12 x 12 mm²

Array: 9 SDDs (8 x 8 mm² each)

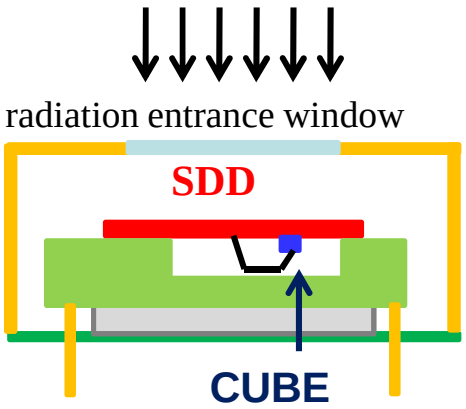
8 x 8 mm²

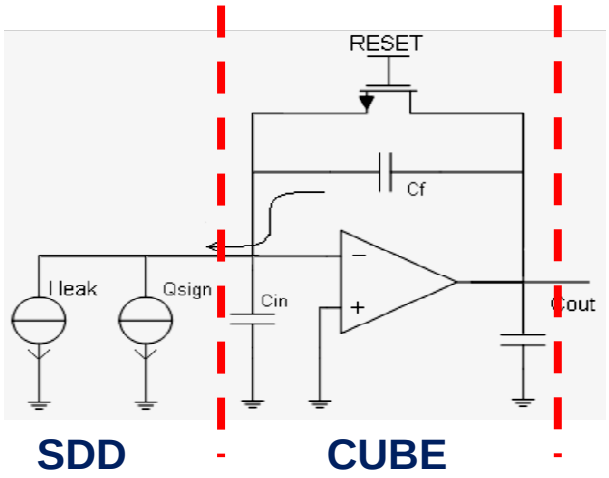
FBK production :
- ***4" wafer (leak. current: 2 nA/cm²)***
- ***now 6" wafer (leak. current: <200pA/cm², Bertuccio et al. 2014)***

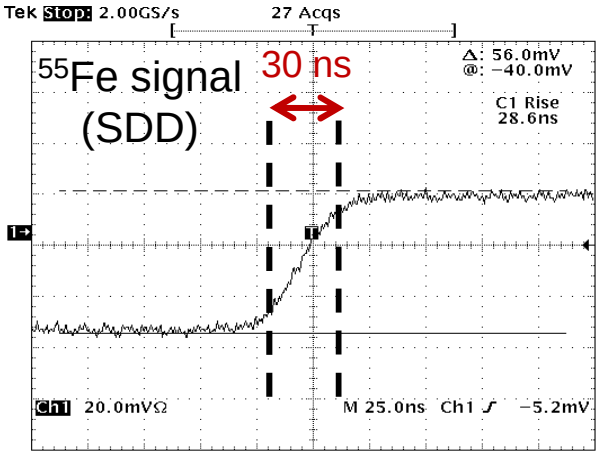
Starting point (2)

CMOS 'CUBE' Preamplifier

- **the whole preamplifier** is connected close to the SDD (and not only the FET)
- **the high transconductance** of the input MOS compensates the larger capacitance introduced in the connection SDD-FET
- the remaining part of the electronics (e.g. the ASIC of analog processing or a DPP) can be placed **relatively far from the detector (even 10-100 cm)**



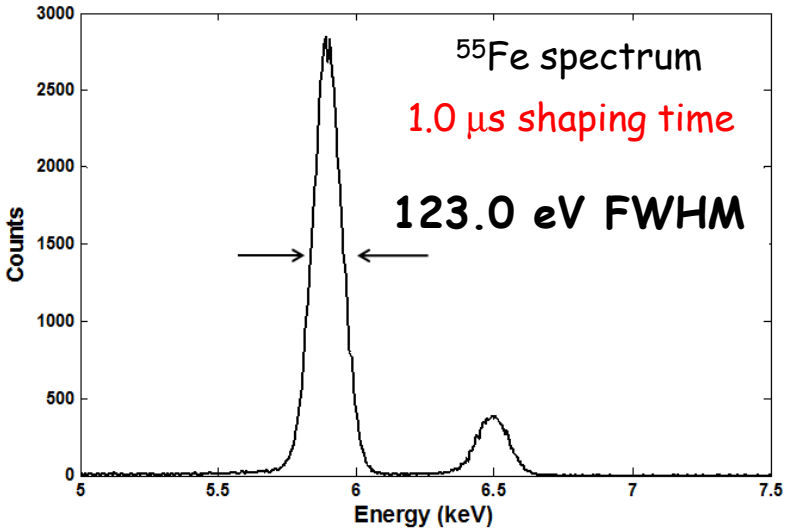




⇒ *High performances, in particular at high counting rates, in X-ray spectroscopy applications with SDDs*

L. Bombelli, et al., " "CUBE", A Low-noise CMOS Preamplifier as Alternative to JFET Front-end for High-count Rate Spectroscopy", Nuclear Science Symposium Conference Record, 2011, N40-5.

X-ray spectroscopy with CUBE preamplifier

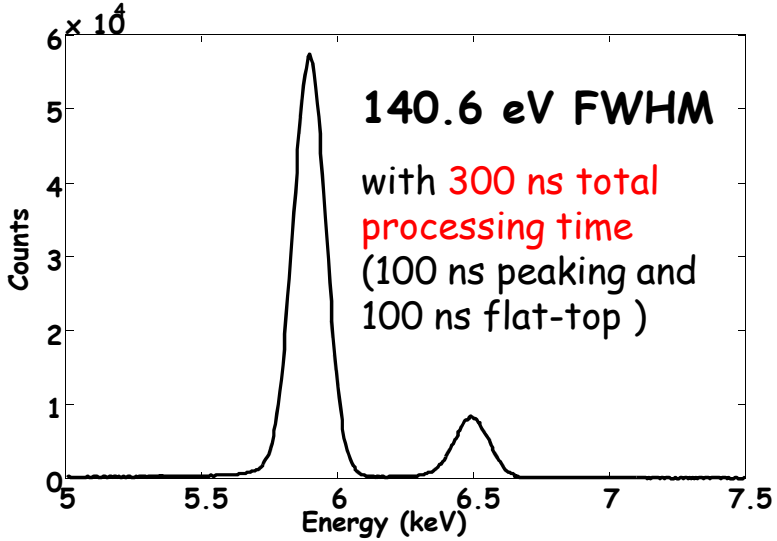


Analog pulse processing

^{55}Fe spectrum

250 ns shaping time
1.2 μs total processing time

126.4 eV FWHM

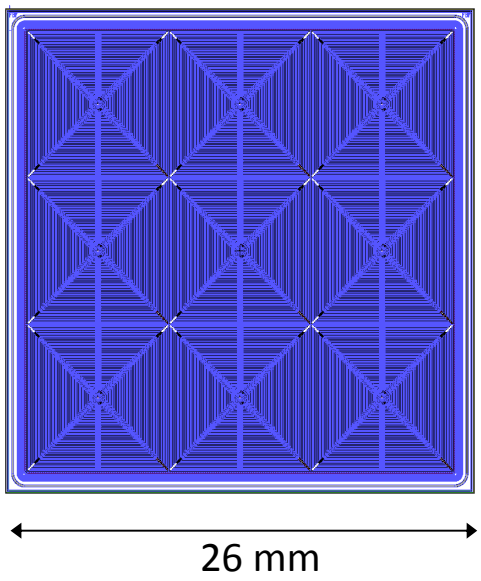


Digital pulse processing

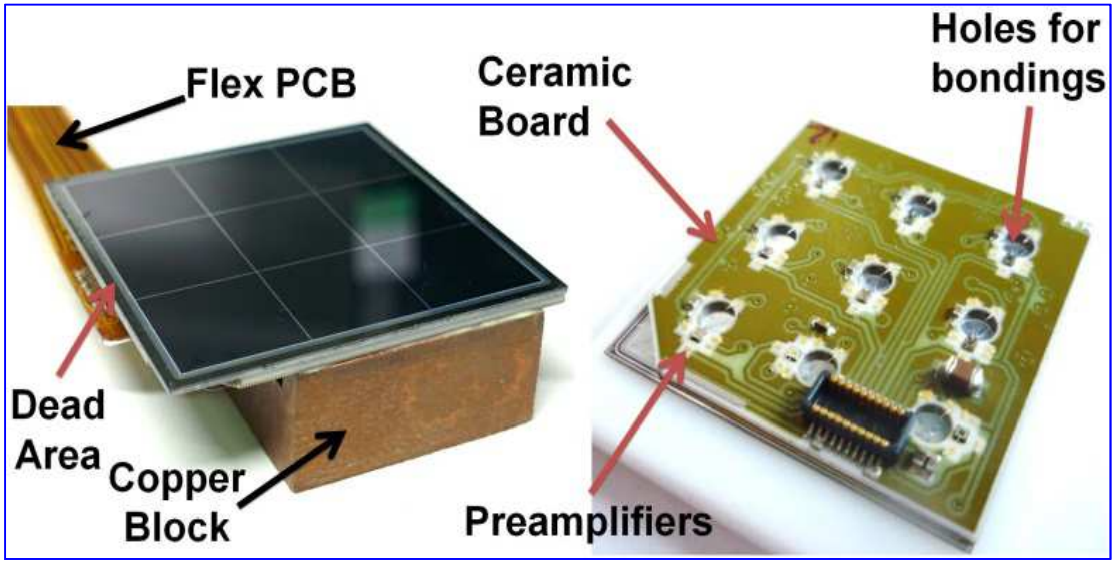
SDD characteristics:

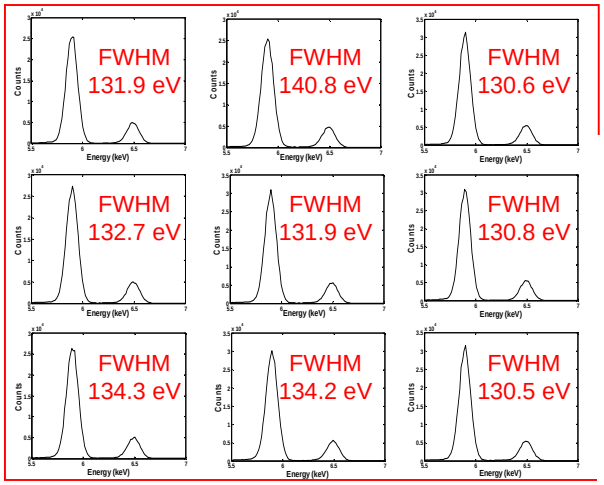
- Area = 10 mm^2 (round shaped)
- T= -40°C (Peltier cooling)
- leakage about 1 nA/cm^2 at RT
- uncollimated source

Monolithic array of 3x3 SDDs and CUBEs

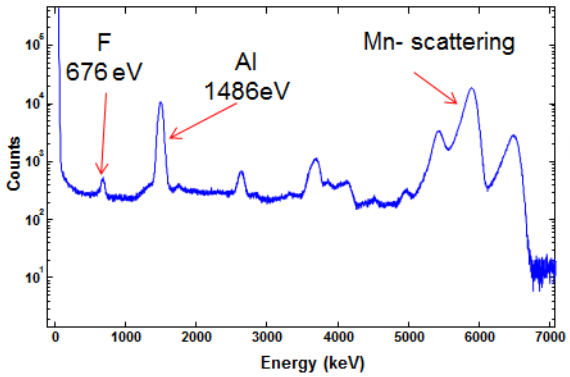


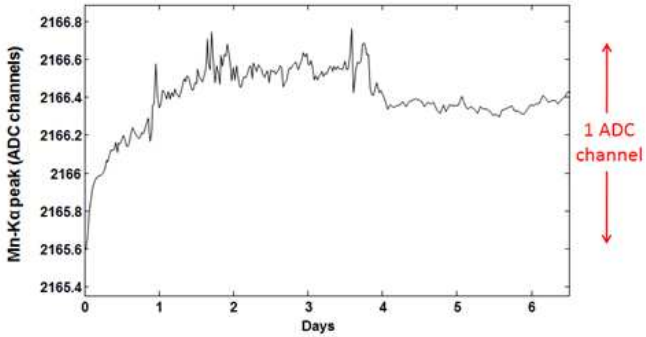
- 5.8cm^2 active area (85% of chip area)
- Bias through the punch-through mechanism





T ≈ 190 K, 6 μs peaking time





Mn-Ka peak stability over 7 days

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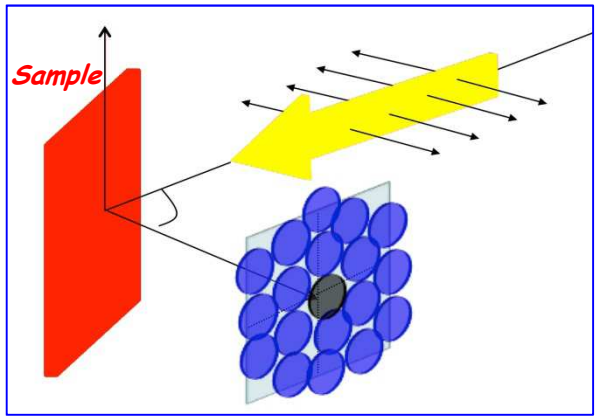
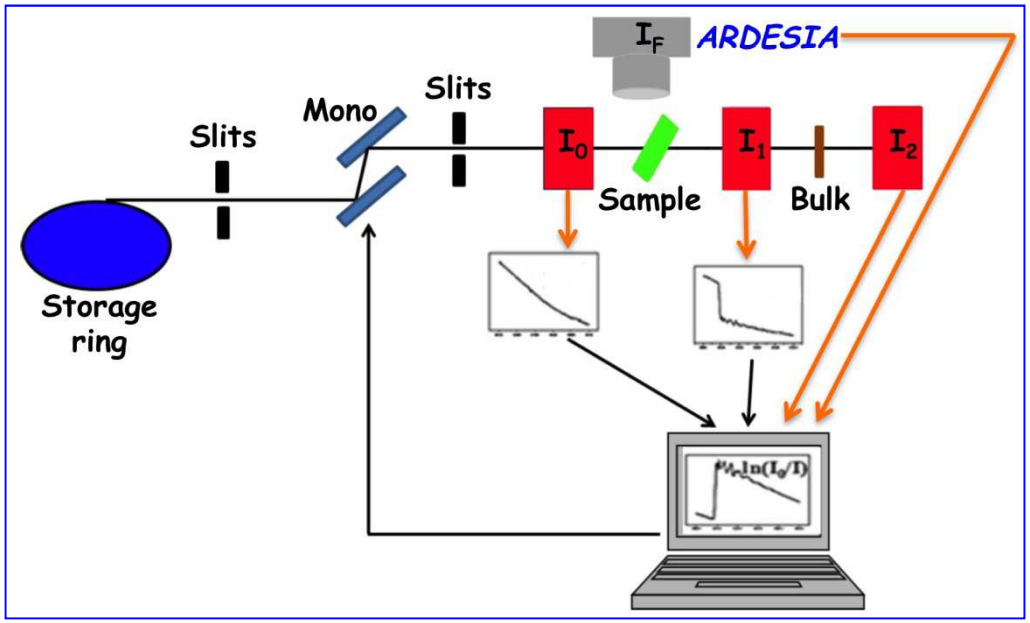
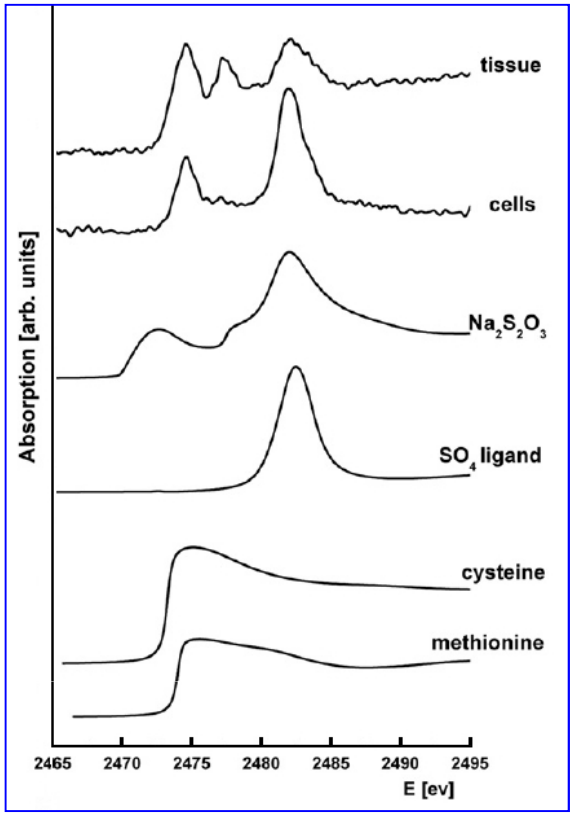
ARDESIA: an X-ray spectroscopy detector for Synchrotron applications



XRF and XAFS





S K edge - DXR1 - DAΦNE-Light

ARDESIA development:

- detector
- processing electronics
- data Acquisition system
- preliminary experiments at beamlines

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Preliminary requirements list
(contributions are welcome!)

- Energy range: **0.2keV – 25keV** (Si detection region)
- Energy resolution vs. counting rate:
  i) **best resolution** (e.g. 123eV@Mn-Kα) at moderate rates
  ii) **maximized throughput** (e.g. ~ 1Mcps/ch.) with <150eV
- Geometrical constraints:
  - fitting synchrotron exp. chamber (e.g. 60 mm max. flange inner diameter)
  - scattering minimization ("90° geometry")
  - maximize count rate (detector close to the sample, e.g. 1cm)
- Peltier cooler, better if operations close to room T
- Operations in vacuum or in air (with window)
- **Modularity, scalability, easy replacement of units**

Approach for ARDESIA design

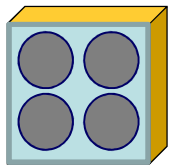
Monolithic array of many units
- compact, low dead area
- high-rate capability
- complex, yield issues
- many readout channels

⇔ trade off

Array of single units
- simple, modular
- large dead area
- few readout channels

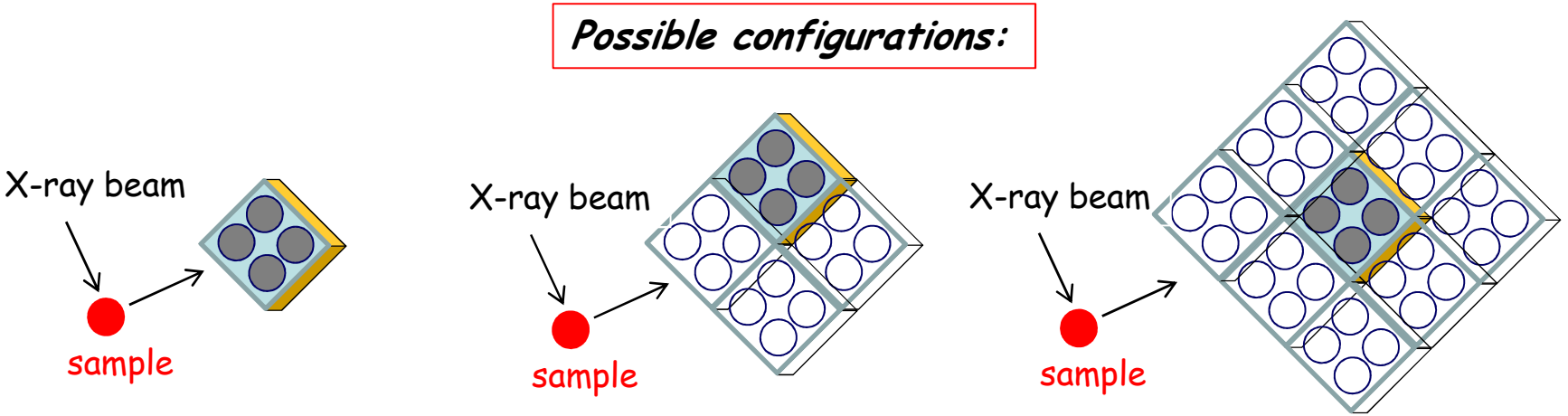
⇒

Assembly of monolithic arrays of few units
- simple, modular
- high-rate capability
- medium/large dead area
- 4-16-36 readout channels



- ***area single SDD***: 10-25mm^2
- ***max. output rate***: ~ 0.5-1Mcps/ch. (analog, ×2 digital)

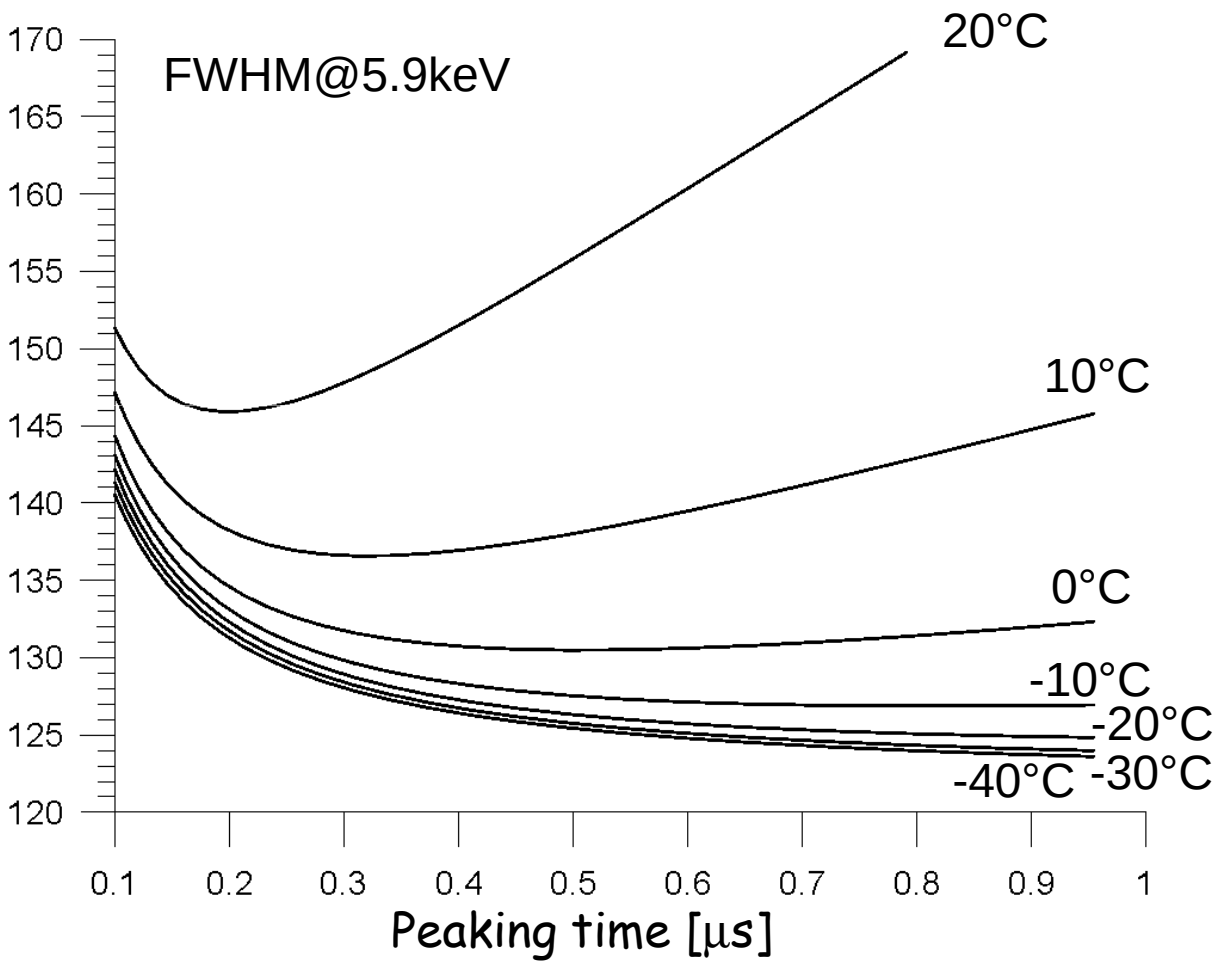
Possible configurations:



Simulated performances (preliminary)

- A=25mm^2
- low leakage FBK technology
- CUBE
- trapezoidal shaping

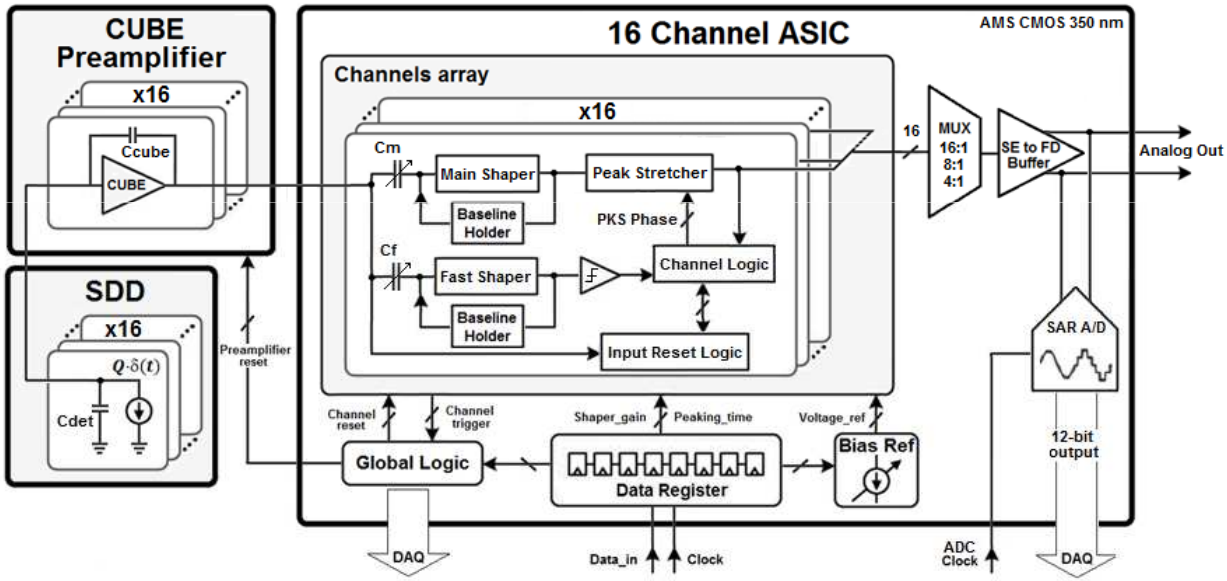
Possible worsening effects due to drift time issues for short processing times to be evaluated!

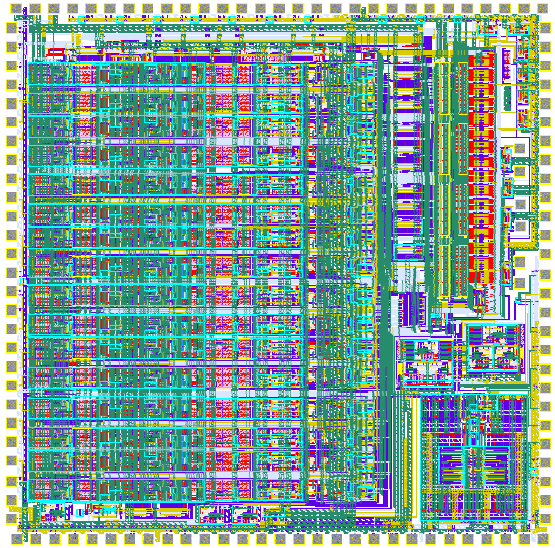


Readout electronics: analog and digital

- ***ARDESIA*** will provide an analog solution as baseline – ***SFERA (ASIC)***
- It will be also fully compatible and tested using ***Digital Pulse Processors***
- DAQ compatible with synchrotron beamlines experimental setup

SFERA (Silicon-Drift-Detectors Front-End Readout ASIC)





- 16 analog channels
- Shaper with selectable gain and peaking times (9^{th} order complex poles)
- Fast shaper (9^{th} order complex poles)

- Pile-up rejector
- Integrated 12-bit ADC
- SPI programming

Conclusions

- ARDESIA is aiming to provide a detection system for high-rates and high-resolution X-ray spectroscopy at Synchrotron facilities
- The project is open to include requirements/suggestions from potentially interested users
- Collaborations with companies during the development are welcome