SOI detector R&D

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on behalf of the SOI workgroup

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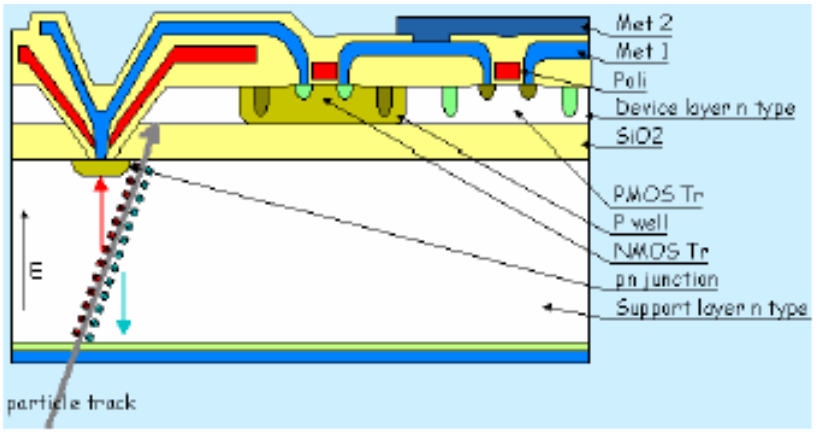
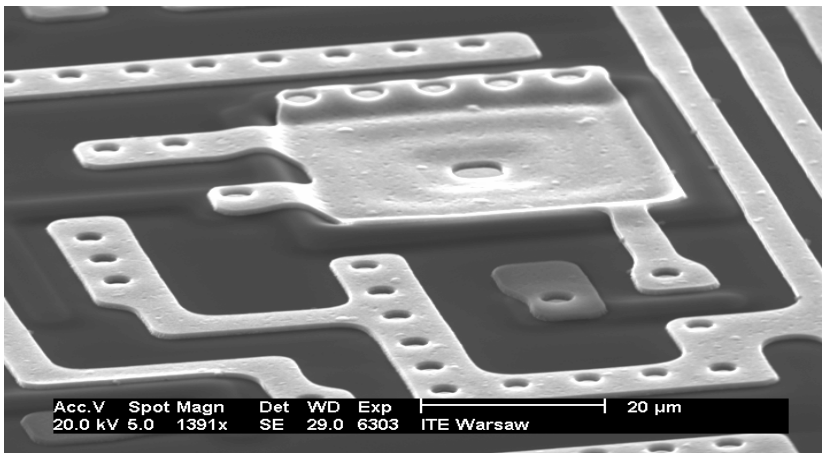
Principle of SOI Monolithic detector





Integration of a fully depleted p^+-n junction matrix and the readout electronics in a wafer bonded SOI substrate

Detector → Handle wafer

- High resistive (> 4 kΩcm, FZ)
- 400 µm thick
- conventional p^+-n matrix

Electronics → Device layer

- Low resistive (9-13 Ωcm, CZ)
- 1.5 µm thick
- Standard CMOS technology

SOI pros and contra

PROS

- Monolithic: no need of any hydridization and consequent thickness reduction
- Fully depleted: high SNR, high sensitivity
- Standard CMOS electronics: both type of transistors
- Custom technology: will never become obsolete

CONTRA

- Non standard technology: requires dedicated process in non standard foundries
- Thermal budget: high temperature processes for the electronics parts clash against the low thermal budget required for high quality p^+-n junctions.
- Low availability of SOI substrate: with detector grade handle wafer

SOI development

Phase 1: Technology definition

Phase 2: Small area prototype

Phase 3: Full area fully functional sensor

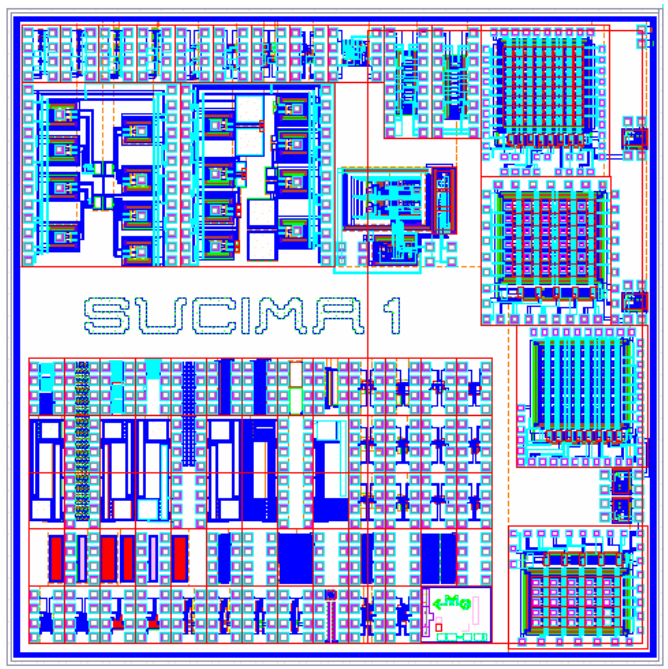
Developed by the SUCIMA collaboration within a EC project for medical applications.
US Patent Application no. PCT/IT2002/000700

- Electronics design by the AGH team
- Technological implementation at IET on a 3µm production line

Phase 1: technology definition

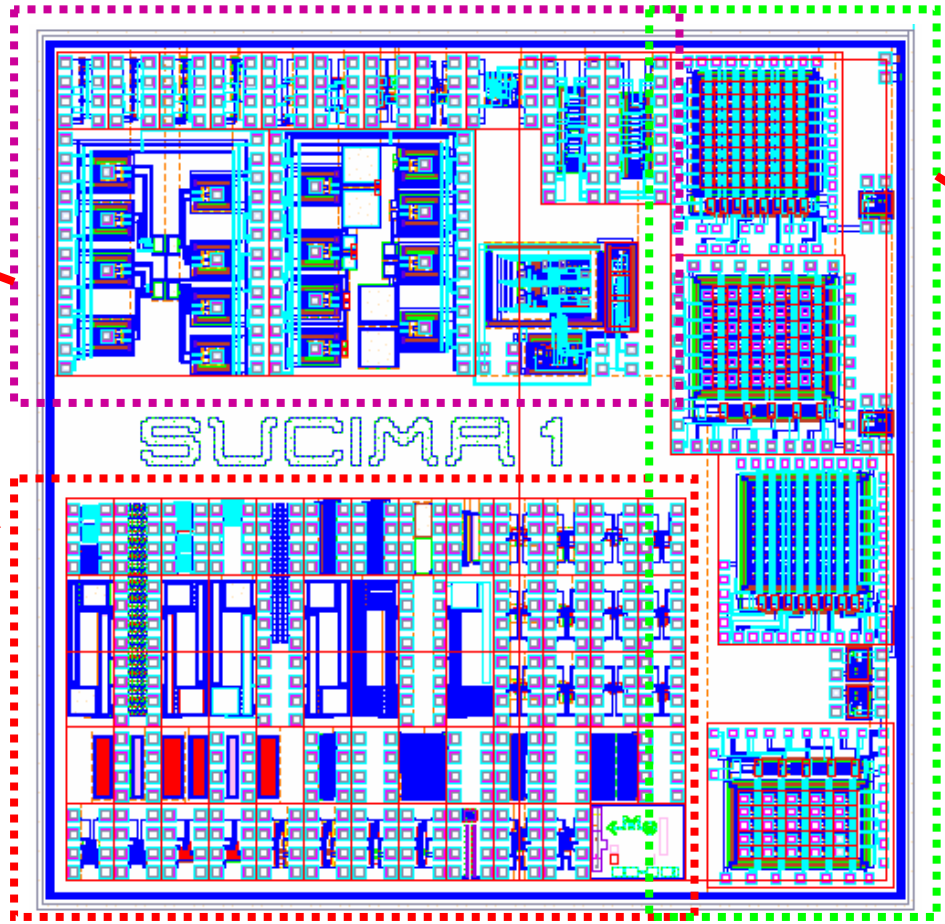
Two steps procedure:

1. Definition of the technology file → test structure
2. Readout electronics functionality → AMS 0.6 multi-project run



SOI test structures / 1

Structure for electronics circuit characterization

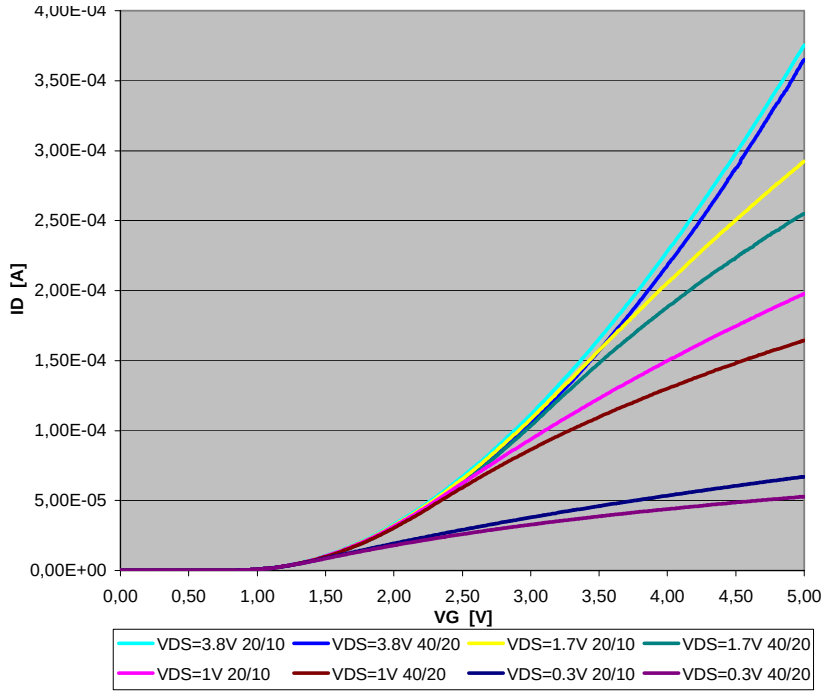


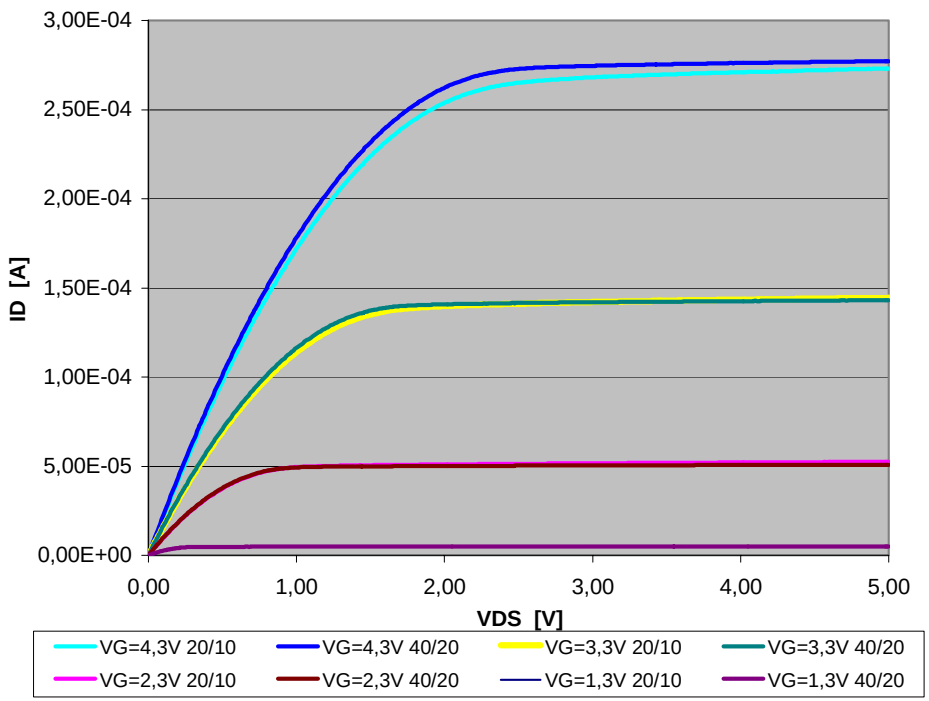
Detector prototypes (8x8 pixels) w/ and w/o charge injection pad.

Structure for technological parameter extraction

SOI test structures / 2

Transfer and output characteristics of NMOS with W/L=20/10 and 40/20





Snowmass 2005

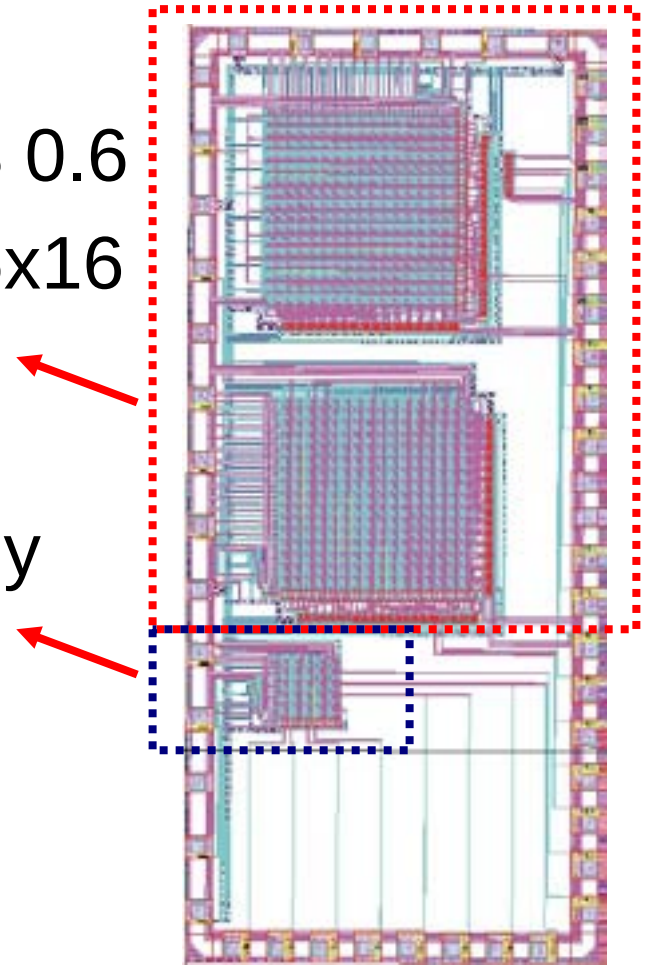
$g_{ds} \approx$ 428 nS @ V_{GS}=2.3 V for W/L = 20/10

$g_{ds} \approx$ 196 nS @ V_{GS}=2.3 V for W/L = 40/20

Electronics functionality assessment / 1

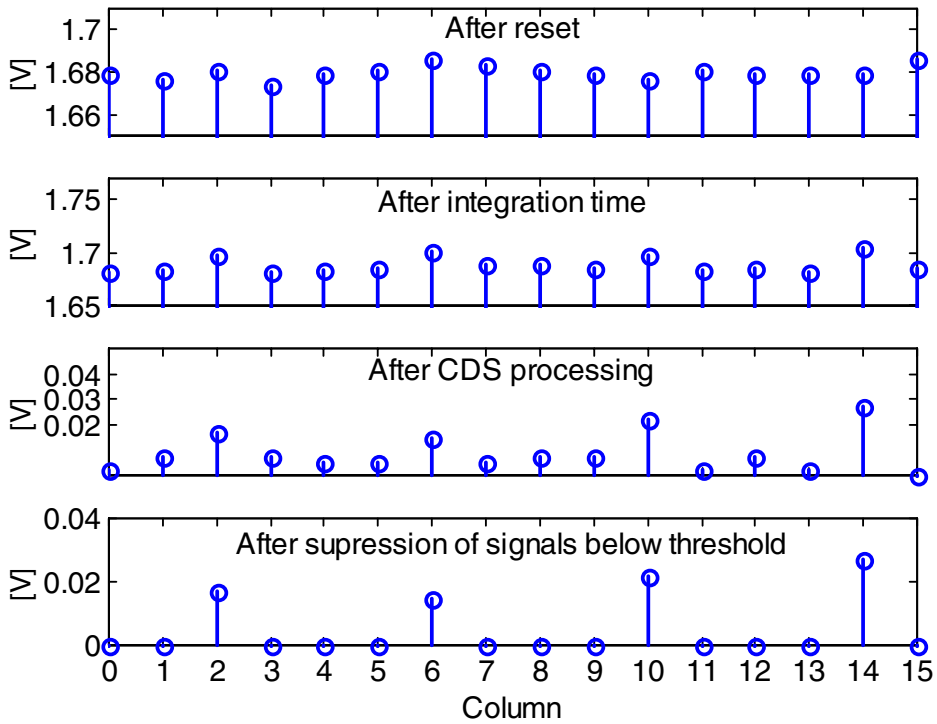
Readout electronics part in AMS 0.6

- 2 fully functional matrices 16x16 pixels with different pixel addressing circuitries
- 1 smaller 5x5 matrix with only the analog part



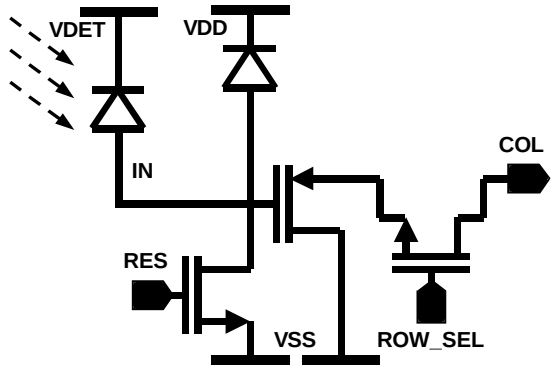
Electronics functionality assessment / 2

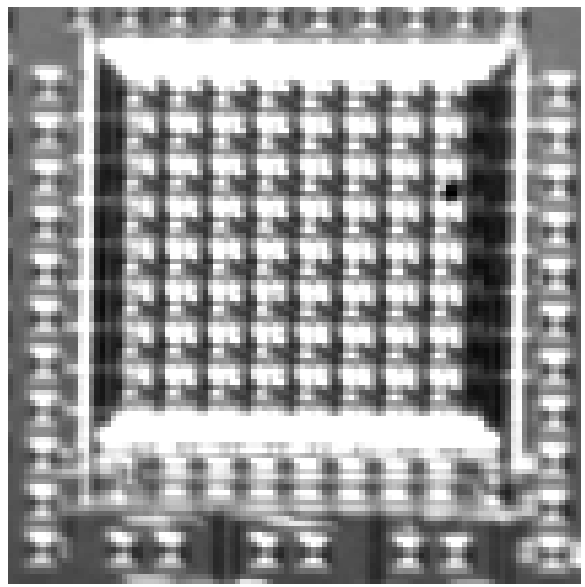
- Measured noise ~ 1.78 mV
- 20 mV signal injected every fourth pixel
- Test of the CDS processing with 5σ threshold.



Phase 2: small area prototype / 1

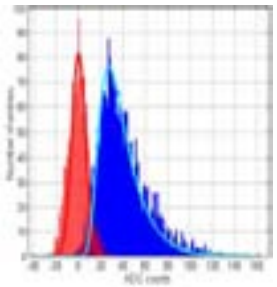
- Basic 3 trans. architecture only slightly modified with PMOS
  - Single cell dimensions are 140 x 122 μm^2.
  - Matrix dimensions: 1120 μm x 976 μm
  - Not surrounded by guardring



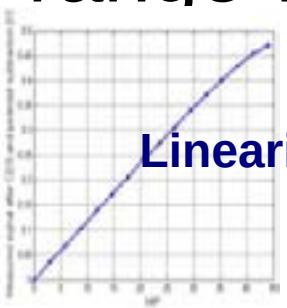


Phase 2: small area prototype / 2

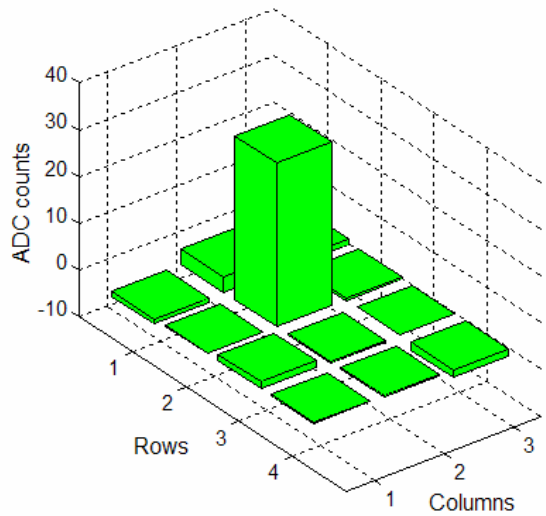
- Charged particle sensitivity with radioactive sources
- Linearity and dynamic range with infrared laser



^{90}Sr

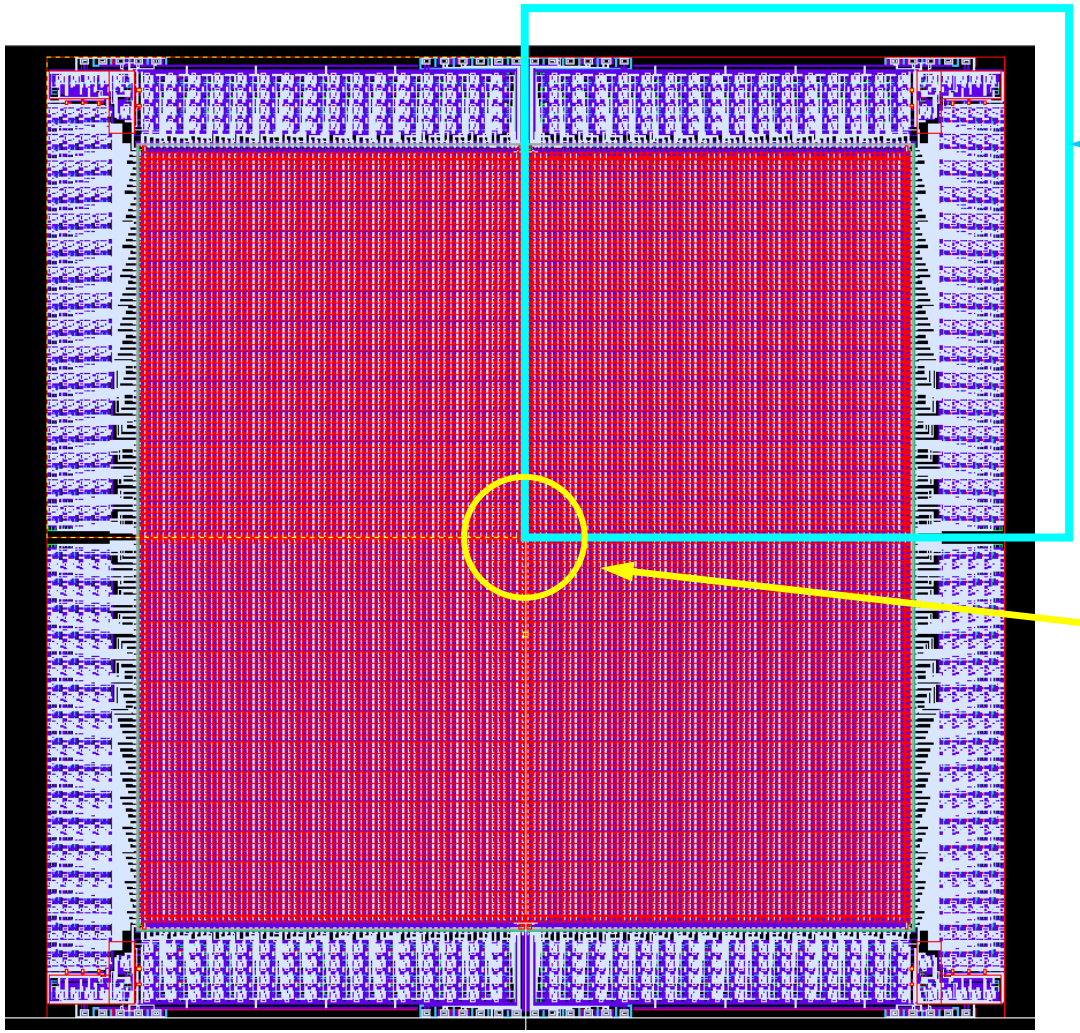


Linearity

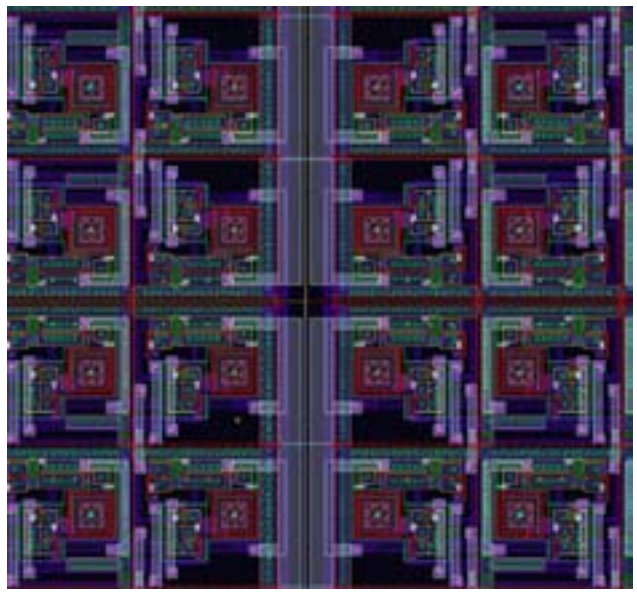


Snowmass 2005

Phase 3: full area sensor design

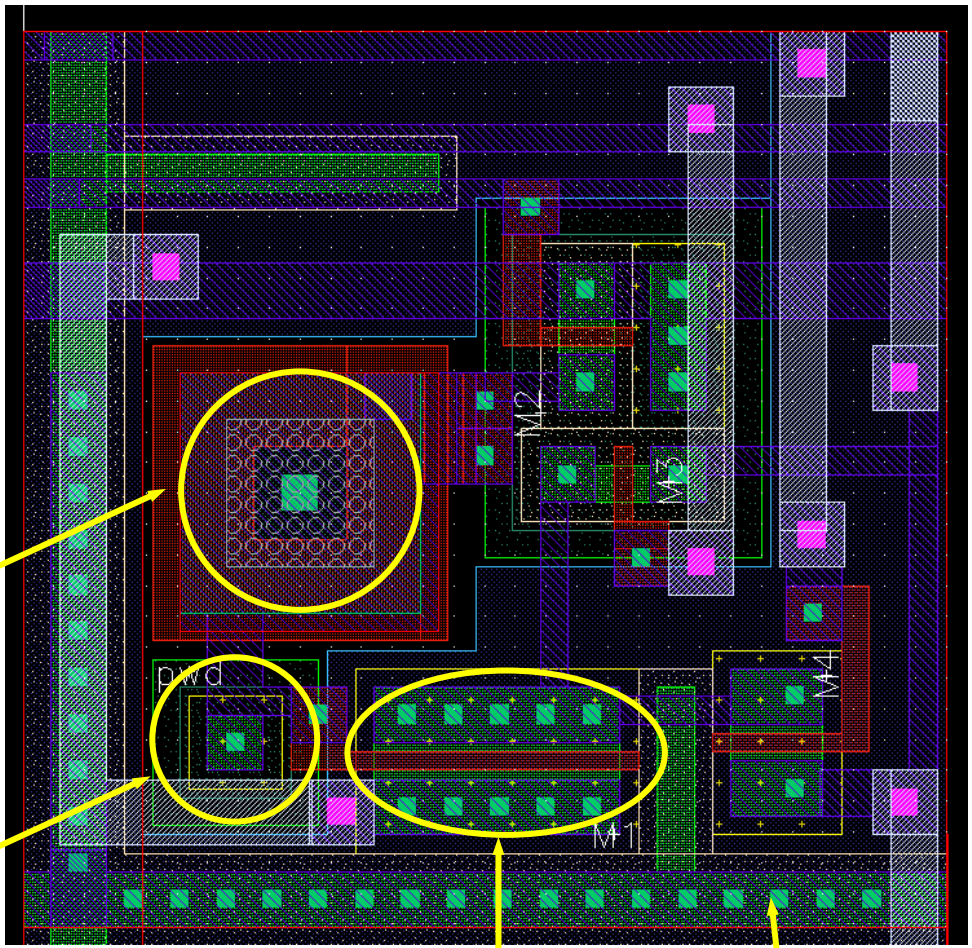


Functionally independent quarter of the detector



No dead area, preserved pitch

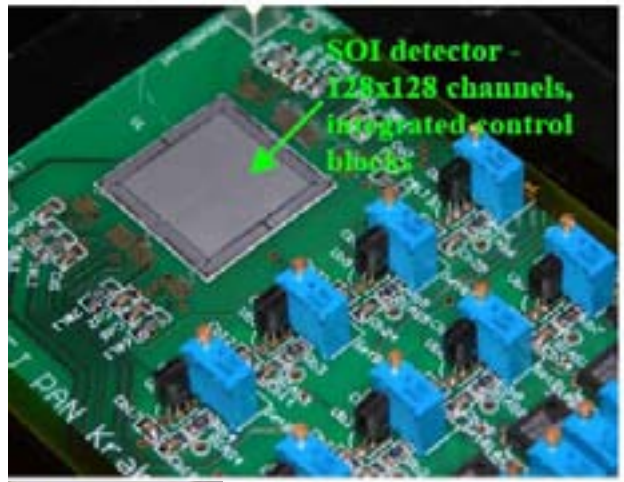
Sensor characteristics

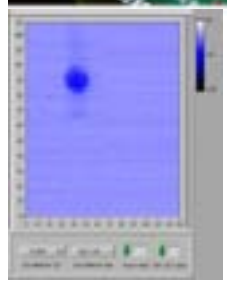


- 128 x 128 pixels on 2.4 x 2.4 cm^2 sensitive area
- Dimensions: 150x150 μm^2
- Input capacitance similar to test structures → similar signals levels
- Larger PMOS in transmission gate → improved linearity

Preliminary results

- Sensor sensitivity observed with laser pointer and α particles.
- Dynamic range up to 100 MIP
- Charge to voltage gain 3.6 mV/fC
- Problems with production yield: only ¾ of the best chip fully functional
- Readout frequency up to 4 MHz





Future plans / 1

- Proof of principle accomplished taking advantage of IET.

Partner foundry with a primitive 3µm production line

Full cost 650 k€ (of which for personnel 200 k€)

Looking for another partner (device company) with a more advanced technology

Contacts positively established with Hamamatsu 1 year ago

Future plans / 2

- Next formal meeting with Hamamatsu during Pixel 2005 conference in September with the definition of a development plan
- Interests from many groups: INFN, AGH, KEK, BONN