
SOCIETÀ ITALIANA DI FISICA
Italian Physical Society



# First results with Hydrogenated Amorphous Silicon devices to detect ionizing radiation fluxes.


L.Servoli

and the HASPIDE collaboration

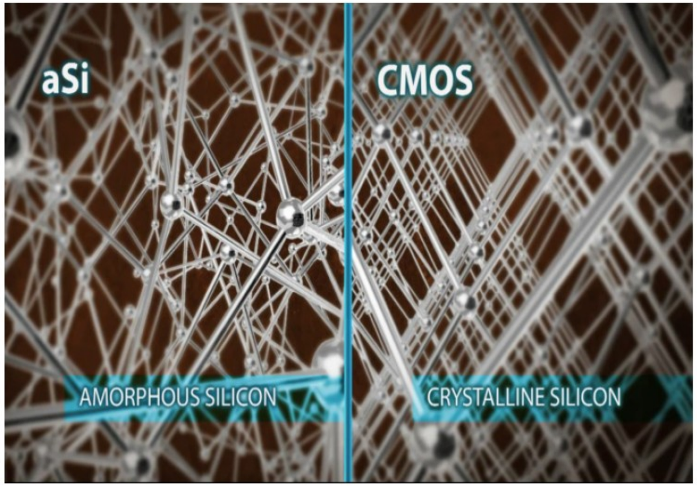
8 institutions


45 rearchers


# Why a-Si:H as material?


- → **1969: a-Si:H synthesized** for the first time by Chittik et al. from growth by plasma-enhanced vapor deposition (PE-CVD) of $SiH_4$ (Silane)
- → **1976:** Spear and Lecomber demonstrated that ***this material could be substitutionally doped both in n and p-types***. → development of ***transistors, solar cells, and memories.***
- → ***from mid '80 on: direct detection of ionizing radiation*** *based on p-i-n or Schottky diode structures (thickness 1 to 50 μm),*
  - → **is not good enough for Minimum Ionizing Particles** (S/N ~ 3-5 at maximum)
  - → ***good for ions or radiation fluxes (proton @ CNAO)***
- → For **synthesized x-rays imaging (energies ~ 100 keV)** detector based on a deposited CsI layer acting as scintillator and the light signal detected by the a-Si:H p-i-n diode with an efficiency better than 70% have been developed (Flat Panel for radiography).

# Why a-Si:H as material?




→ *it is intrinsically radiation resistant;*

→ *it can be deposited in thin layers (~ 1-100 μm);*

→ *it can be deposited on different substrates, even flexible ones like mylar and kapton;*

→ *it has a band gap value just higher than c-Si: 1.7-1.9 eV;*

→ *it has a charge collection efficiency half the c-Si;*

→ *material deposition process can be done on wide areas.*


# The HASPIDE INFN Project


*Creation of thin a-Si:H (1- 10 μm) ionizing radiation detectors deposited over thin plastic supports to be used for:*

→ *beam monitoring of medical LINACs and other types of accelerators*

→ *detection of radiation bursts in space, for example Solar Energetic Particles events;*

→ *neutron detection via $^{10}B$ deposition over an a-Si:H layer to detect α produced by neutron conversion.*


# a-Si:H Device Production


Several standard production techniques:

→ PECVD (plasma enhanced chemical vapor deposition); [EPFL]
In the process is used a mixture of Silane ($SiH_4$) and Hydrogen, with working temperature between 160° and 300°C

→ Radiofrequency PECVD (RF or VHF PECVD), at various Frequencies.

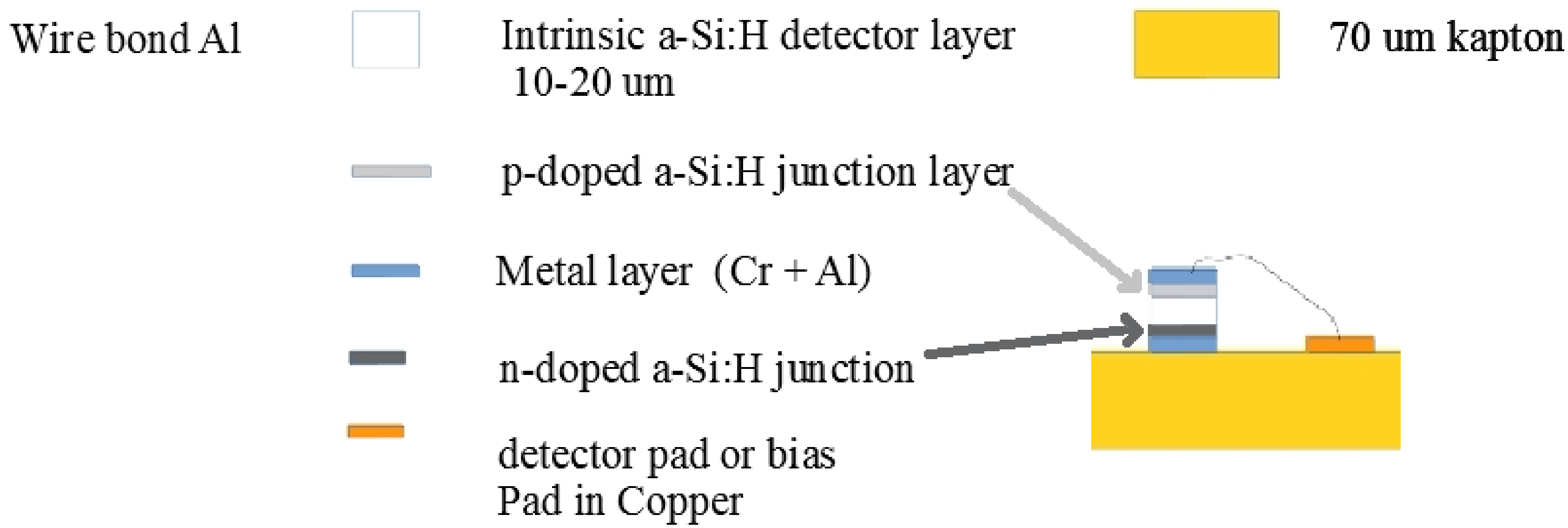
Two new procedures are under development in the HASPIDE project:

→ Pulsed Laser Deposition (PLD) [Lecce]

→ Reactive Sputtering [Lecce]

# a-Si:H Contacts: p-i-n

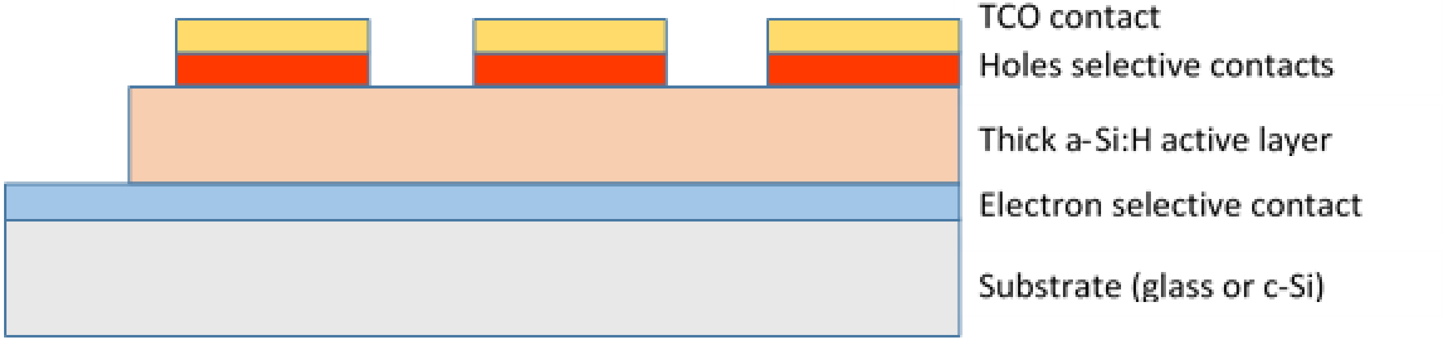
***p-i-n contacts: a-Si:H film between two p or n doped layers***




***Doped layer thickness < 30 nm; intrinsic layer (1-10 μm)***

# a-Si:H Contacts: CSC

*Charge Selective Contacts (CSC): two thin layers of metal oxides sandwiching the sensitive a-Si:H film.*



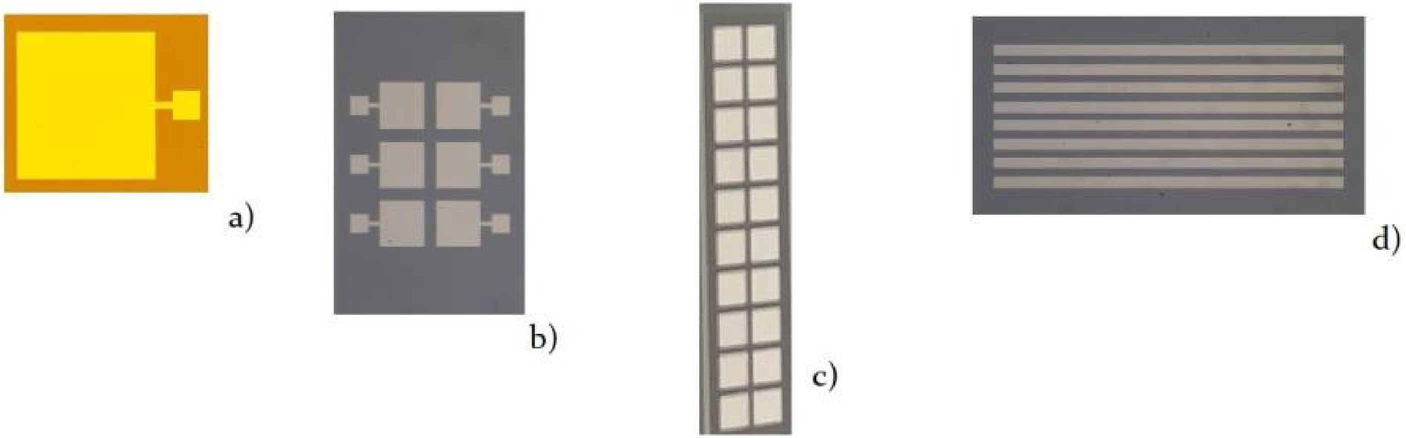

*Our first prototypes:*

→ *electron selective contacts: ZnO:Al or $TiO_2$*

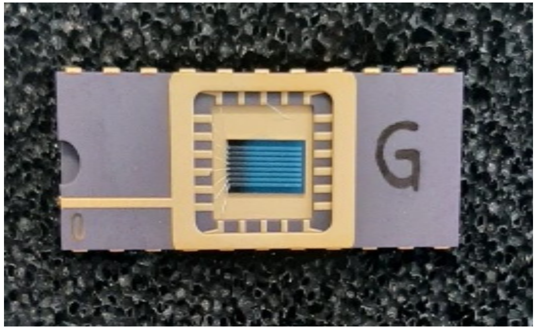
→ *hole selective contacts: MoOx*

*Selective contact layer thickness < 30 nm; intrinsic layer (1-10 μm)*

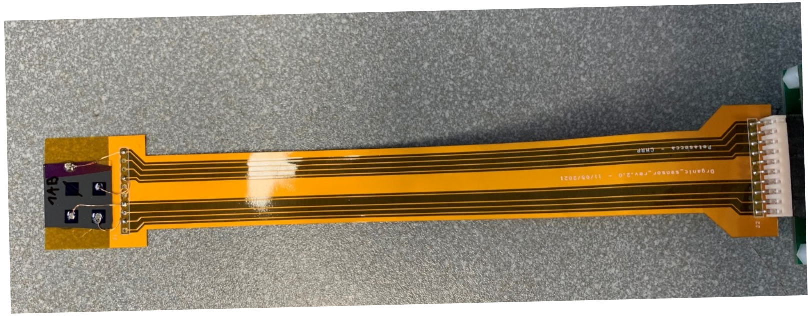
# a-Si:H Devices




## Packaging: socket

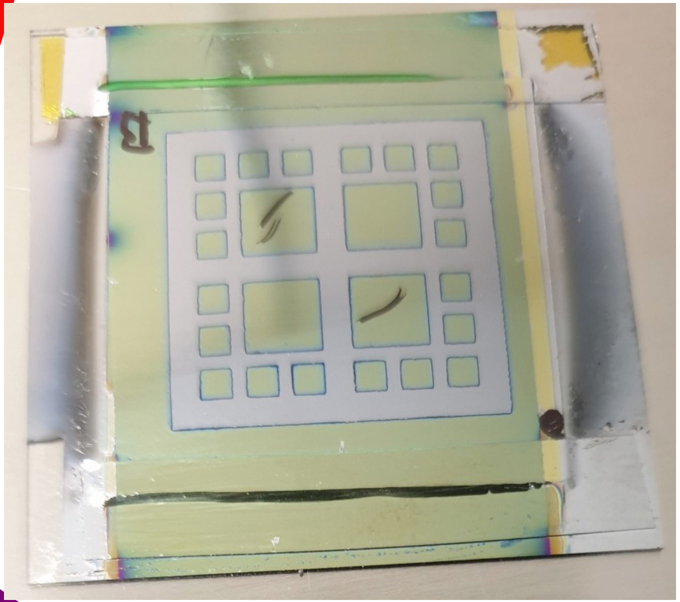



## Packaging: over kapton long tails



# a-Si:H Transmission Devices

The first batch of a-Si:H depositions on polyamide has been produced (PECVD).



2x2 $mm^2$ and 5x5 $mm^2$ devices (p-i-n) are available for cutting and testing.

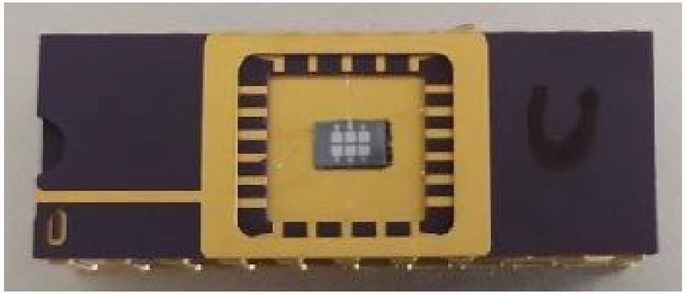
Thickness: 2.5 μm.

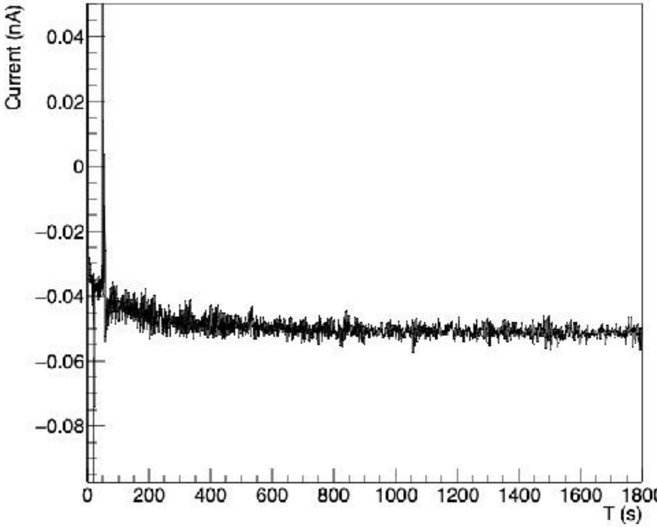
Polyamide thickness: 25 μm

Goal: produce transmission devices to monitor in real time ionizing beams, both in shape and flux

# Device characterization: noise

Noise depends on many cause. Neverthless, given the higher band gap wrt c-Si, we have obtained typical noise values of the order of 10-20 pA for both p-i-n and CSC devices.

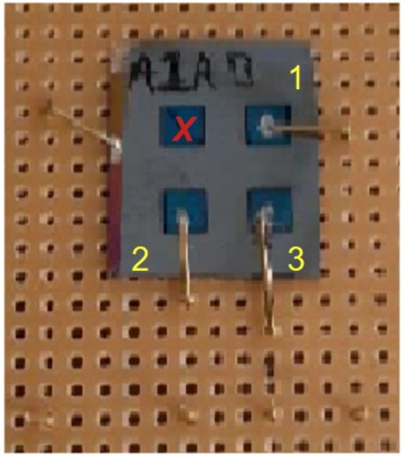


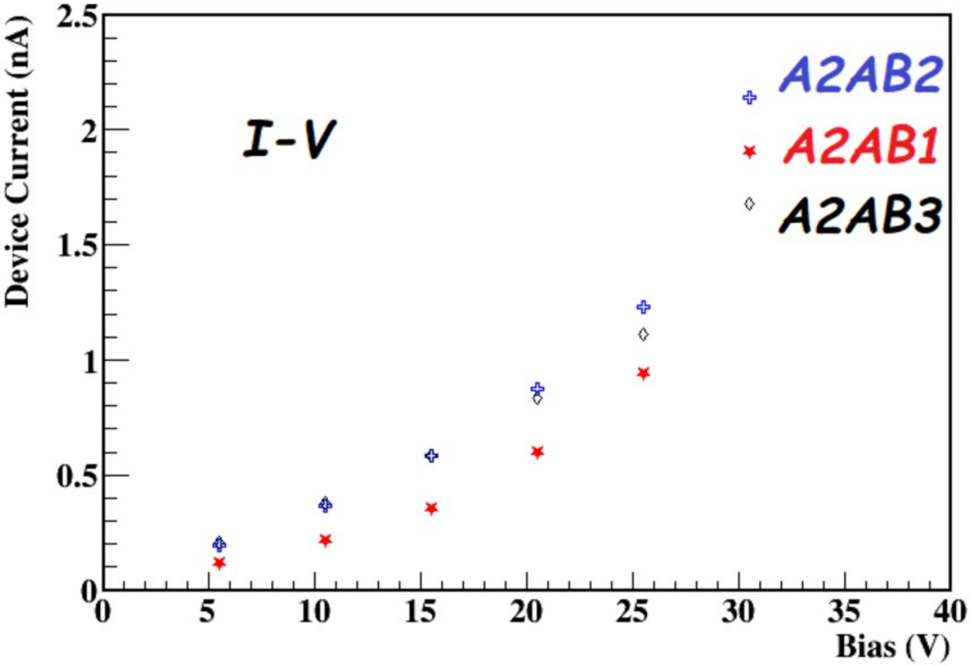



p-i-n pads:
0.5x0.5x0.010 $\mu m^3$
bias 20 V

# Device characterization: I-V

a-Si:H structure: 4x4 mm², 6.2 μm thick, CSC, 20 V bias.



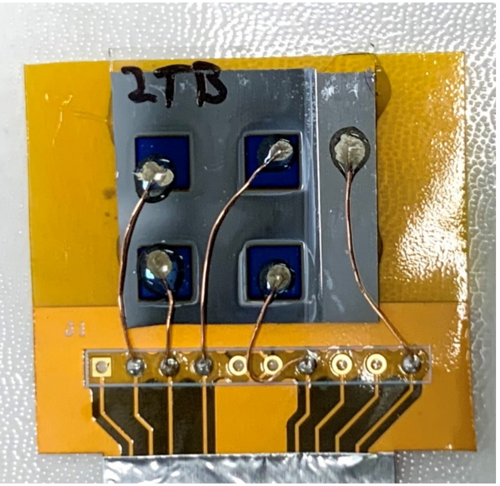

Bias up to 4 V/μm ; reasonable leakage current: 100-200 pA @ 1V/μm.

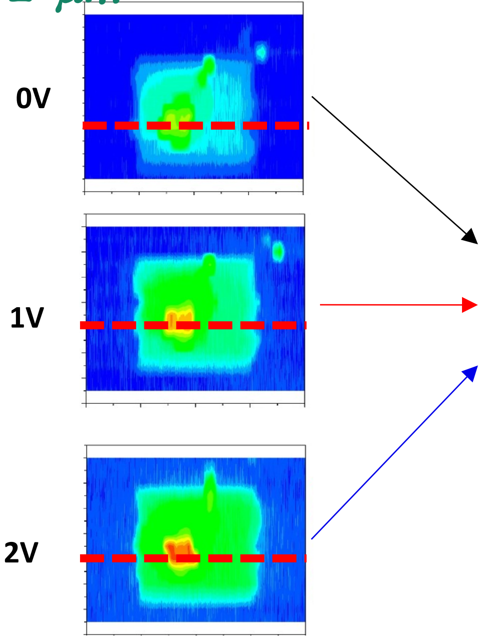
Variation among devices: < 20 % for whole bias range.

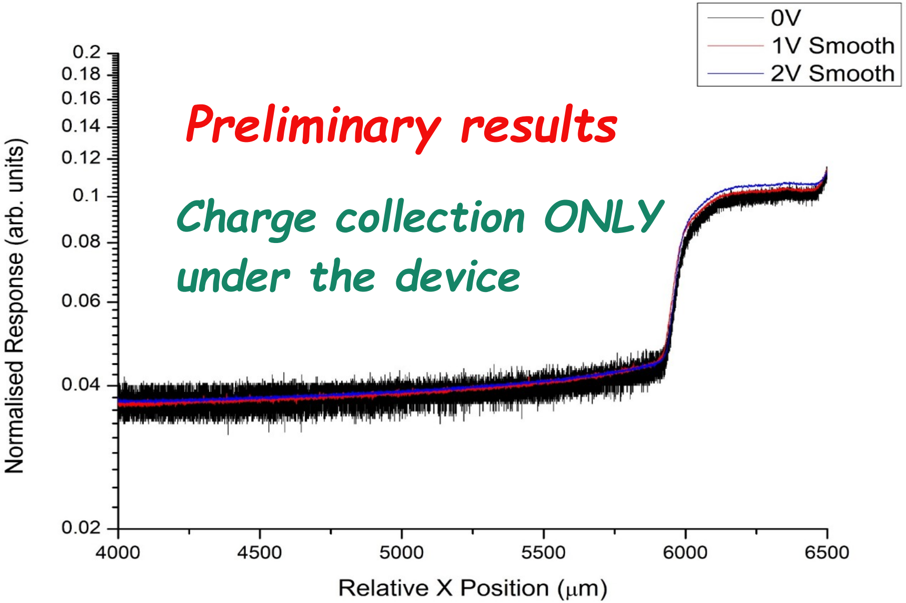
# Device sensitive volume

*Some tests using microfocalized Synchrotron radiation by UOW have been done. Preliminary results show the signal collection as a function of the surface point where the microbeam is pointing:*

*CSC 4x4 mm² x 6.2 μm*



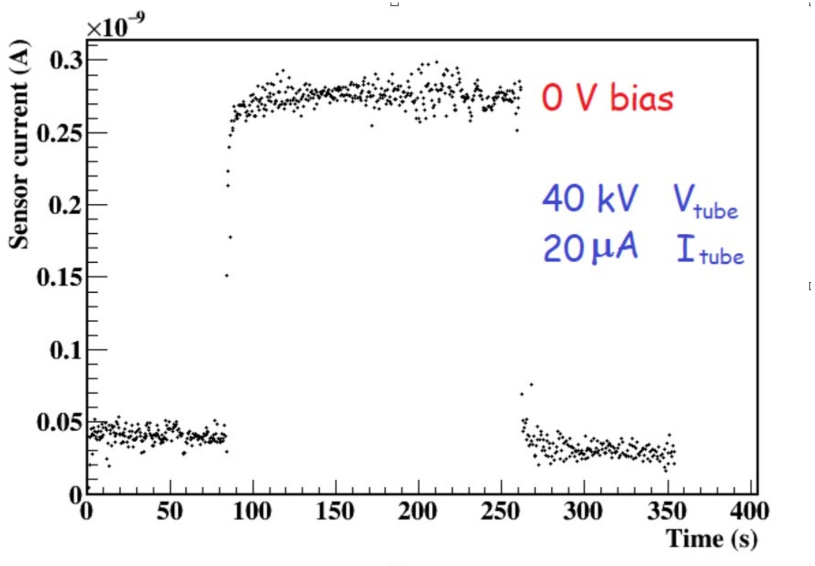


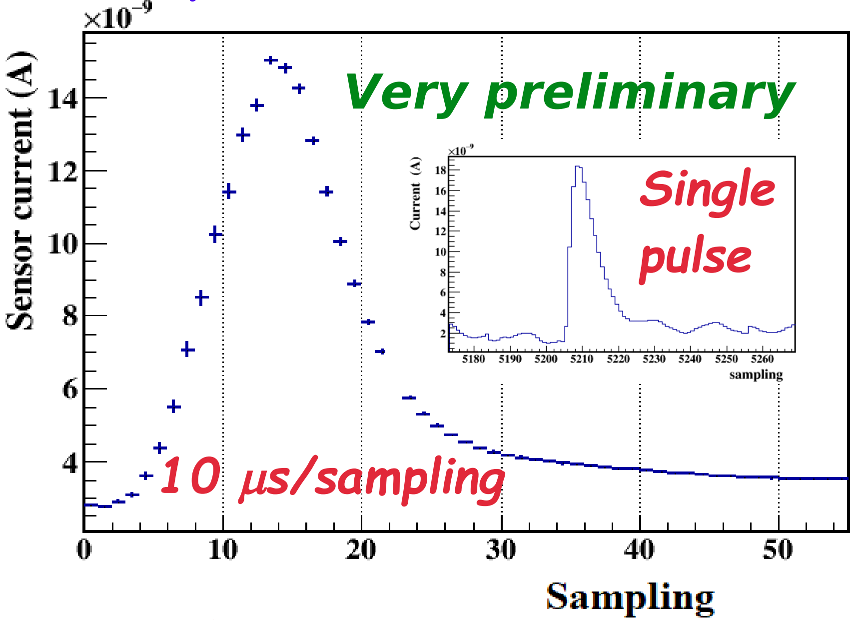



# First results: Response in time

X-ray tube: 40 kV, 20 $\mu A$

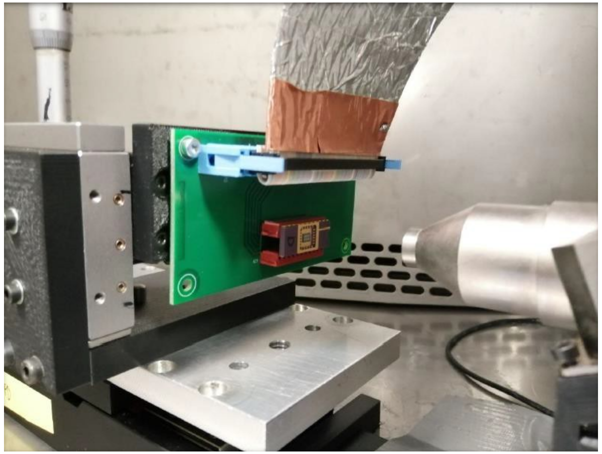
CLINAC pulse width: 6 MV, 3 $\mu s$ pulse width.



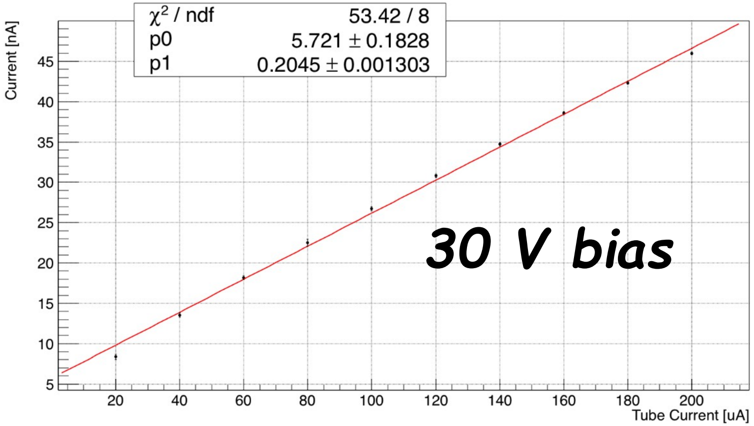

a-Si:H structure: 4x4 $mm^2$, 6.2 $\mu m$ thick, CSC, 20 V bias.

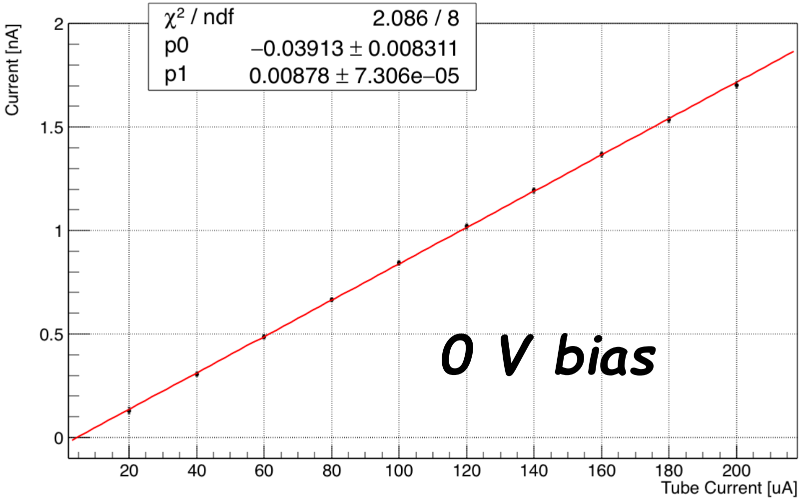
# First results: X-ray beams



CSC 4x4 mm² device, 8.2 μm thick

0 V bias, tube: 30 kV, current scan



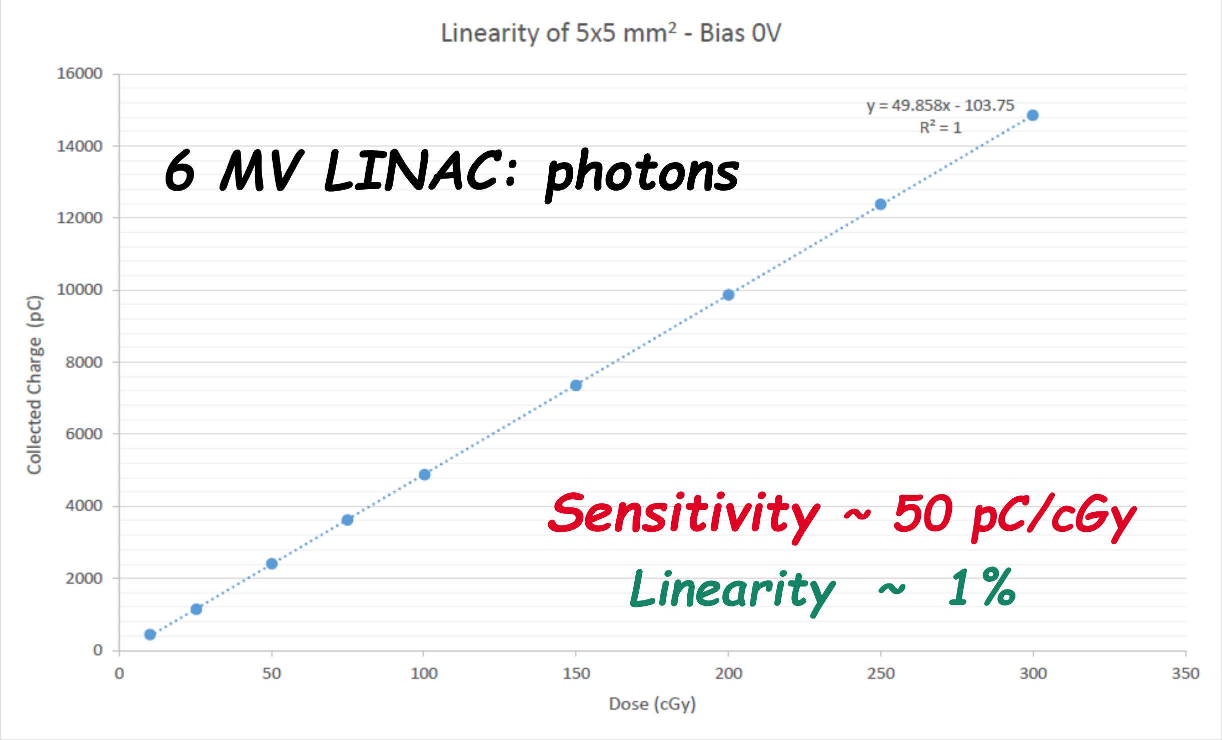




Sensitivity(0 V)/Sensitivity(30 V) ~ 23

Linearity ~ 1-2%

# First results: Clinical LINACS

## CSC 5x5 $mm^2$ device, 10 $\mu m$ thick, 0 V bias




Similar results for 6 MeV electrons from LINAC

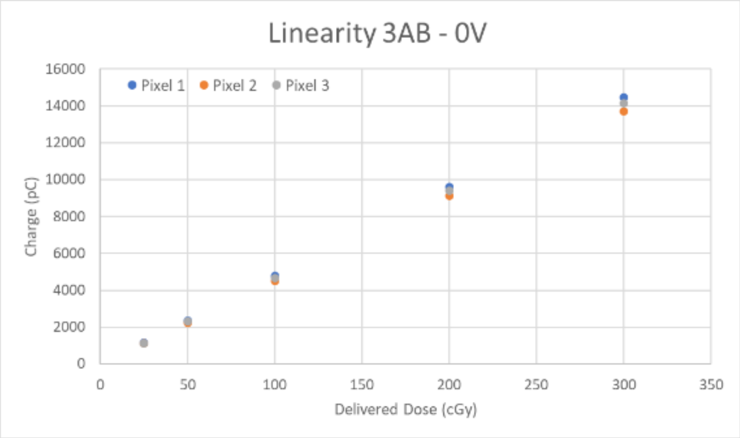
(see talk by C. Talamonti Sez. 5, 13/9/2022)

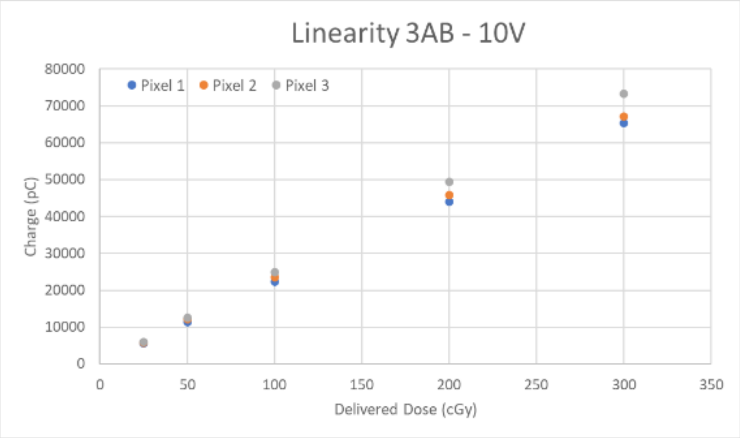
# First results: Clinical LINACS

## Made by UOW at 6 MV Clinical LINAC (Photons) (CSC)

## Linearity – 3AB

- 8.2 μm a-Si:H layer
- Al:ZnO electron selective contact




**Response linearity**
**1-2 %**

| | 0V (pC/cGy) | 10V (pC/cGy) |
|---|---|---|
| Pixel 1 | 48.35 ± 0.03 | 217 ± 1 |
| Pixel 2 | 45.86 ± 0.04 | 222 ± 3 |
| Pixel 3 | 47.37 ± 0.08 | 245 ± 2 |

**Device uniformity:**
**3 % @ 0 V; 7 % @ 10 V**

# Sensitivity vs ionization source

We have tested different p-i-n devices with different type of ionizing radiation beams:

| Ionizing radiation type | 50 kV X-ray Photons | 6 MV Photons (Clinical) | 6 MeV Electrons (Clinical) | Protons (3 MeV) preliminary |
|---|---|---|---|---|
| Sensitivity (nC/cGy) | 1-20 (CSC) | 0.1-1.0 (p-i-n) | ~ 0.1 (p-i-n) | 0.1-0.2 (p-i-n) |

Sensitivity lies in the same range

CSC devices have higher sensitivy
→ investigation is going on


# Conclusions


→ *a-Si:H material looks promising as sensitive substrate to detect ionizing radiation fluxes;*

→ *very thin devices could be built (100 μm total including incapsulation in polyamide foils);*

→ *low noise, radiation hardness, reasonable uniformity among devices;*

→ *response to X-ray, clinical photons and electrons is linear with dose and dose-rate and with uncertainty ~ 1%;*

→ *next test will include more proton and ion beams tests.*


a-Si:H


a-Si:H


Thanks


# Status of WP5: Space


***We have presented the idea of measurement of Solar Energetic Particle (SEP) events at ASI Workshop with a-Si:H. Table is the minimum flux of protons at a given energy to obtain a signal bigger than 5 times the noise. Compatible with SEPs fluxes.***

**Sensor:**
Dimension: 4x4x0.008 mm
Noise: 20 pA;
Sensitivity: 20 nC/cGy

| Proton energy (MeV) | 400 | 200 | 100 | 70 | 50 | 20 | 10 | 5 |
|---|---|---|---|---|---|---|---|---|
| 100 pA Signal ($p/s/cm^2/sr$) | ~$2x10^4$ | ~$1x10^4$ | $7x10^3$ | $6x10^3$ | $3x10^3$ | $2x10^3$ | ~$10^3$ | $8x10^2$ |

*We are writing a paper outlining the idea with some simulated performances of an instrument.*