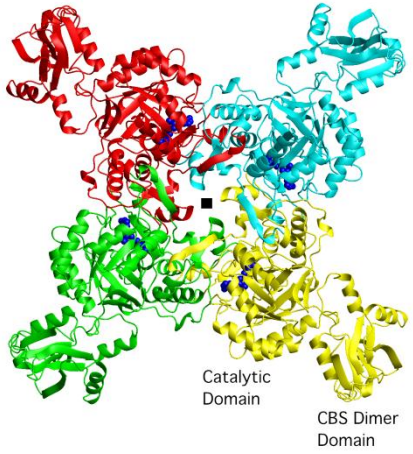
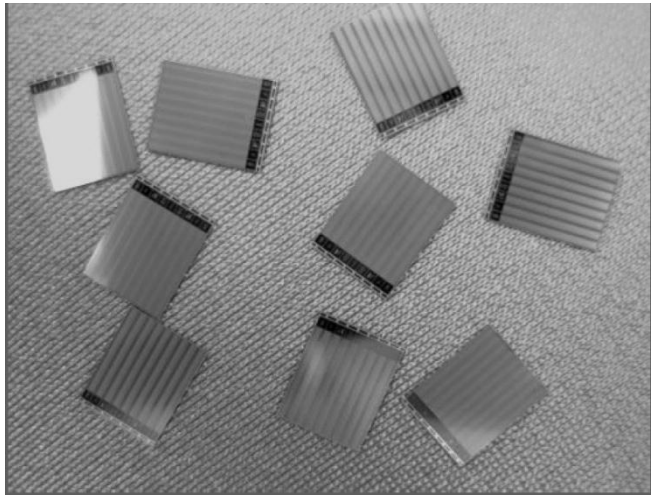
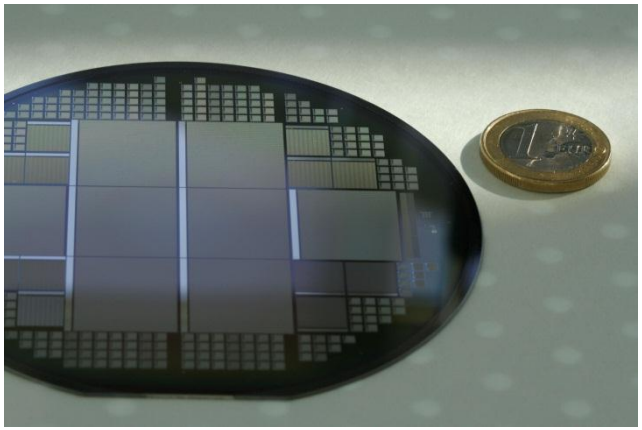
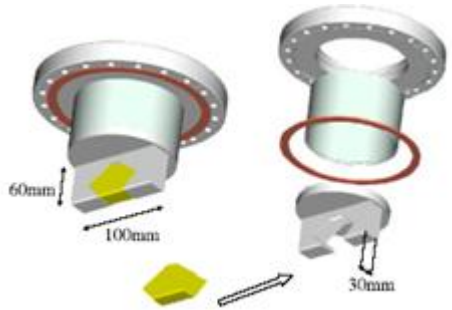
Applications for 3D sensor with active edges



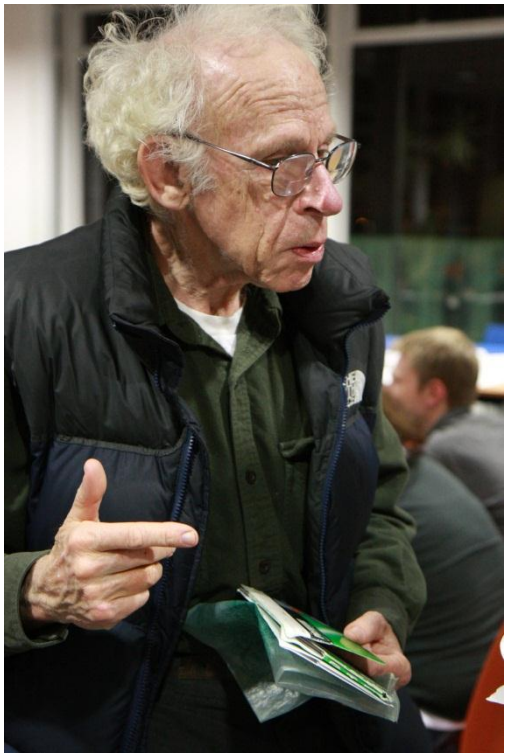


Angela Kok on behalf of
3DC and 3D ATLAS R&D Collaboration

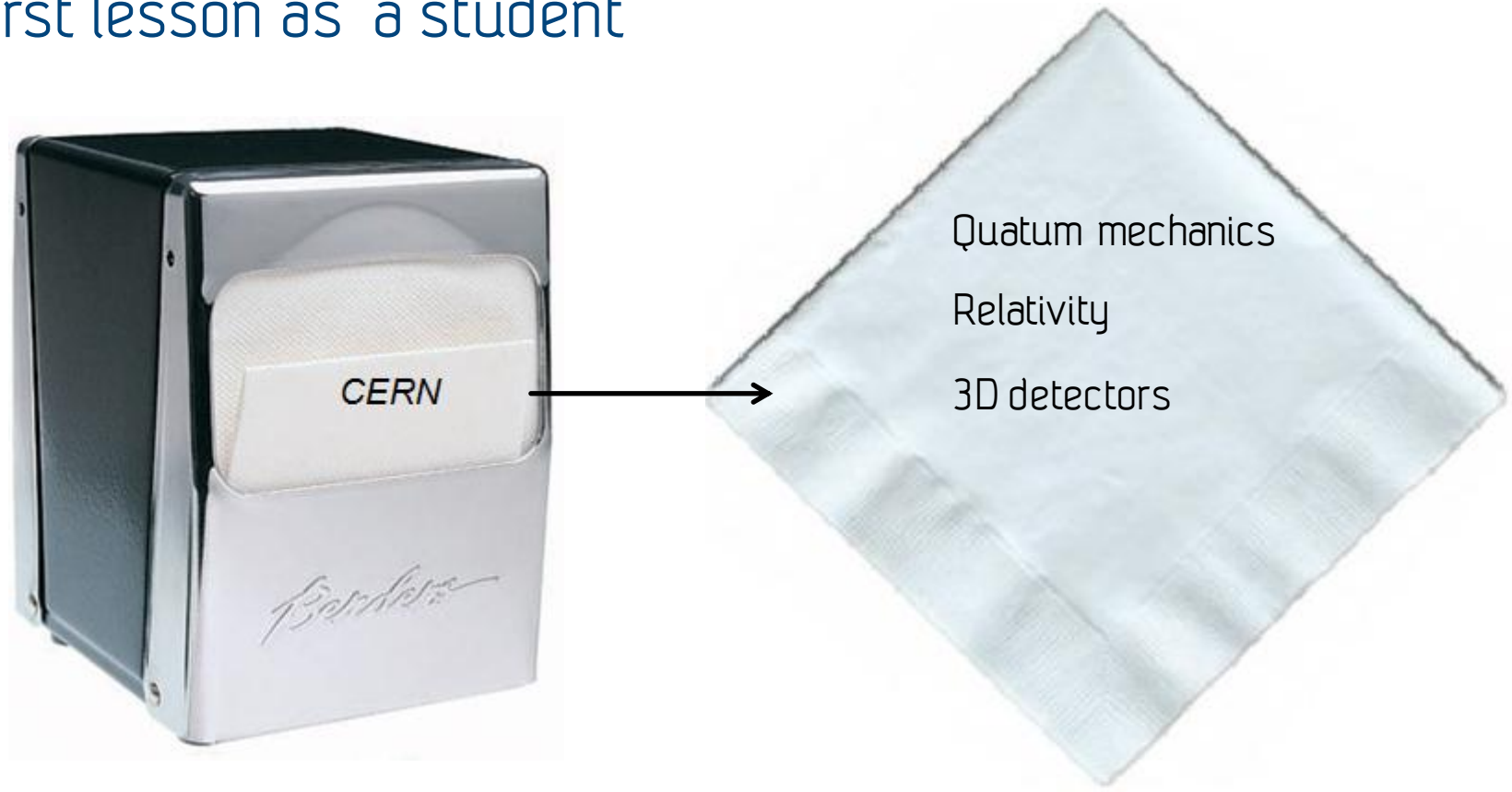




Thank you for your inspiration and generous sharing of knowledge!



First lesson as a student

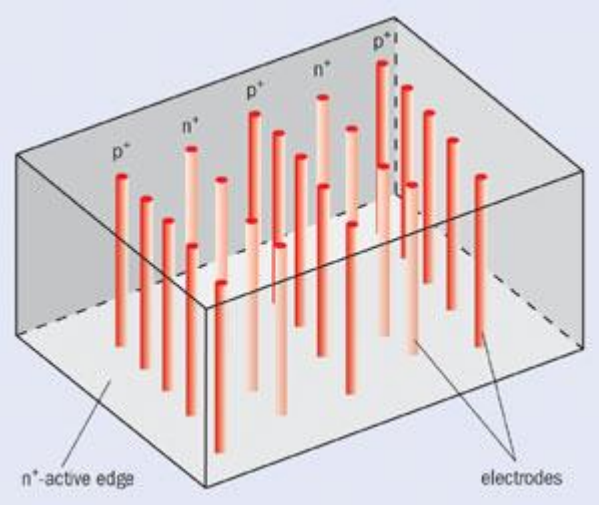


Most important tool for a physicist's success is the use of CERN napkins!

Applications for 3D sensors with active edges

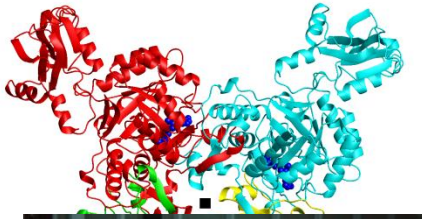
Advantages

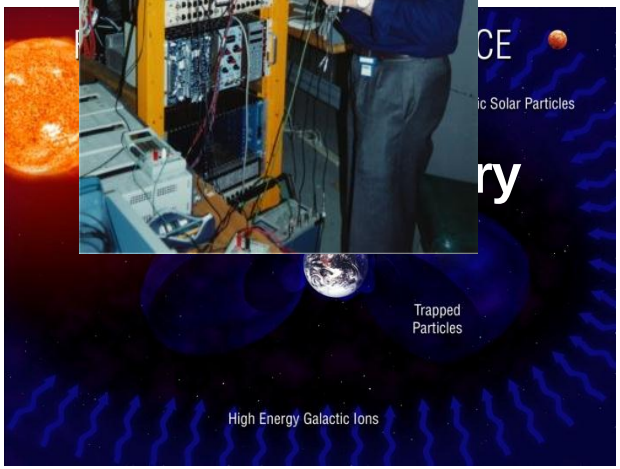
- Active edges
- Low depletion and operation voltage
- Fast charge collection
- Geometry flexibility
- Radiation hardness

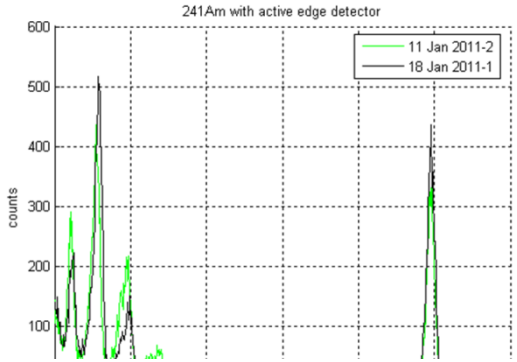


- Low charge sharing
- Improved timing resolution
- Improved spatial resolution
- Well-defined sensitivity volume
- Higher sensitivity for x-ray
- Enlarged surface area for conversion material
- Lower power consumption
- Smaller or zero dead area
- Reduced capacitance in thin material

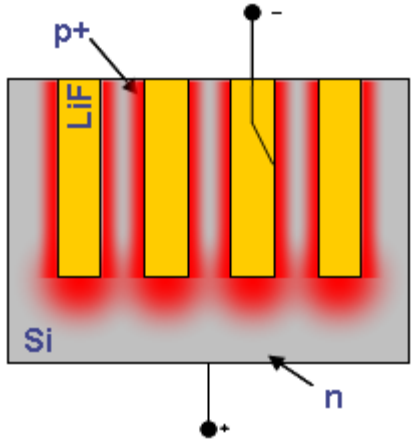
Applications for 3D sensor with active edges







Spectroscopy for material analysis



Neutron imaging

*IEAP

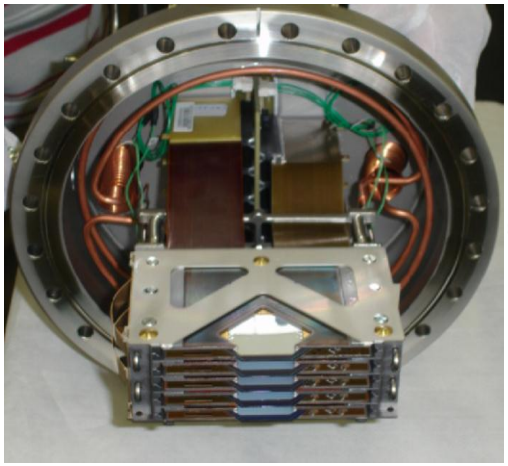
High Energy Physics – Forward Physics

- Radiation hardness
- Fast collection time
- Active edge

To address

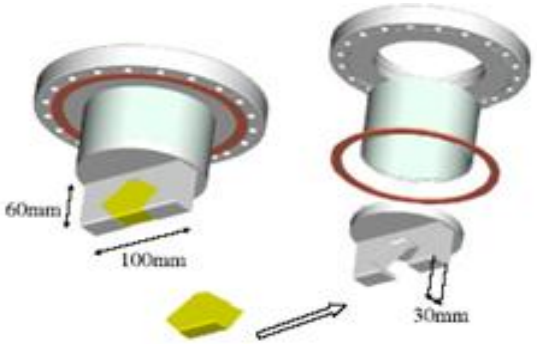
- Increased luminosity
- Forward coverage
  - Diffractive physics
  - Forward protons
- Luminosity measurement

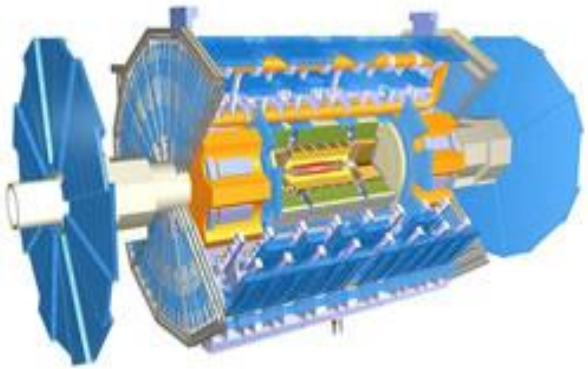
TOTEM detector



G. Antchev, "The TOTEM detector at LHC", Nucl.Instr. Meth Phys. A617 (2010) 62-66

Roman pot detector

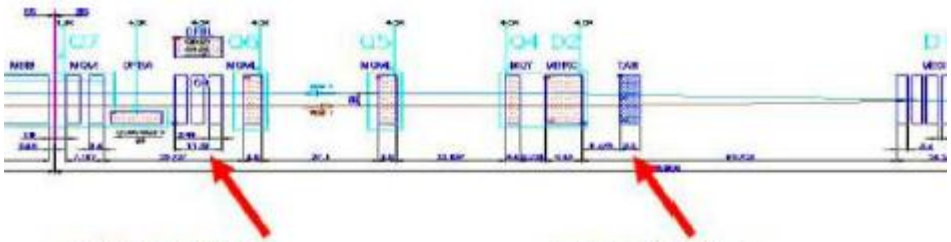




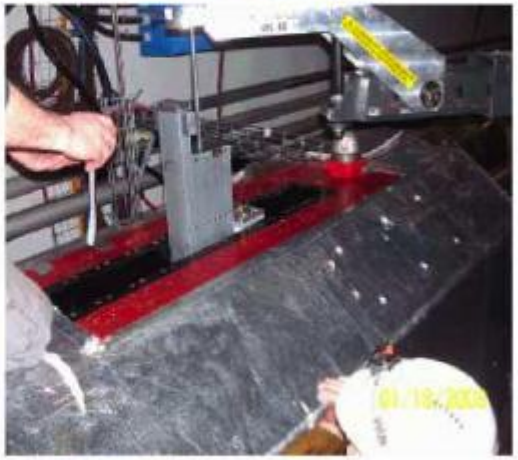
ATLAS Experiment

For IBL upgrade (see G-F. Dalla Betta's talk)

ATLAS Forward Physics Project

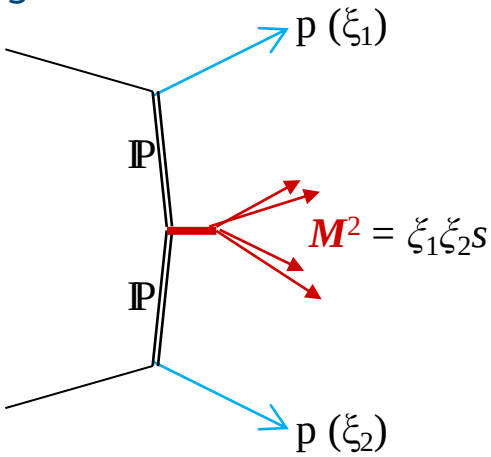


Absolute Luminosity for ATLAS



Zero Degree Calorimeter

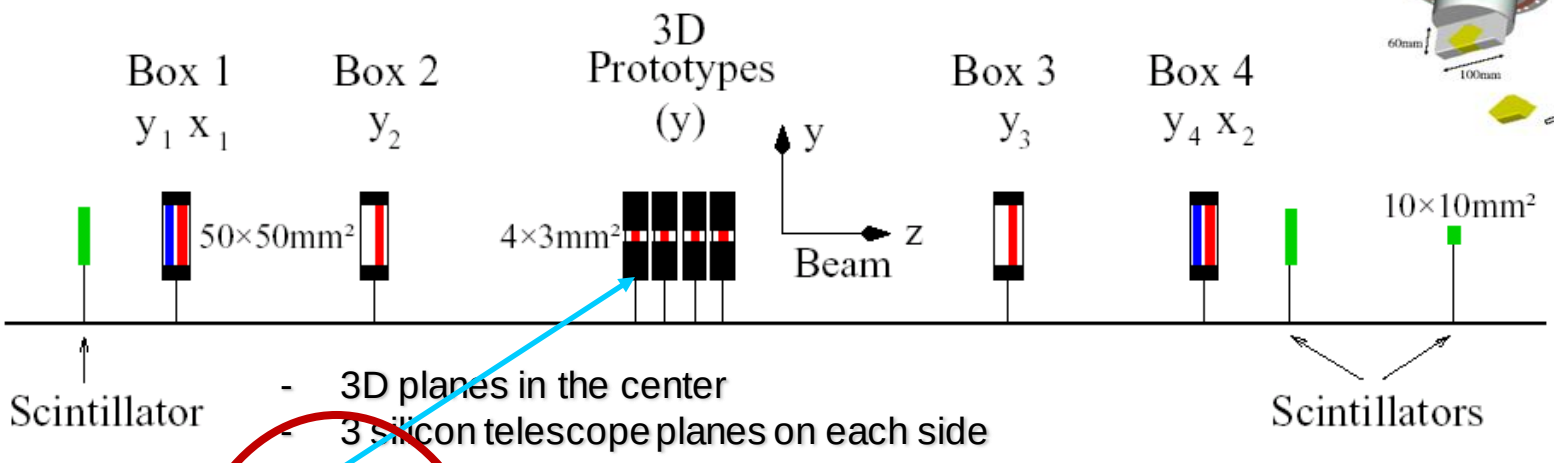
- Spatial resolution of 10(30) µm
- Angular resolution of about 1 µrad
- High efficiency over 20 mm x 20 mm
- Minimal dead space at the edge
- Sufficient radiation hardness
- Installation of detectors at 210 m in 2013

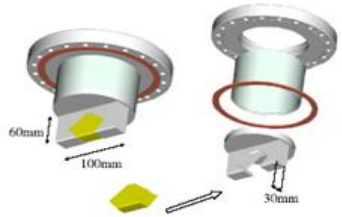


C. Royon, "ATLAS Forward Physics Project", Workshop on exclusive and diffractive processes. ECT, Trento 2012

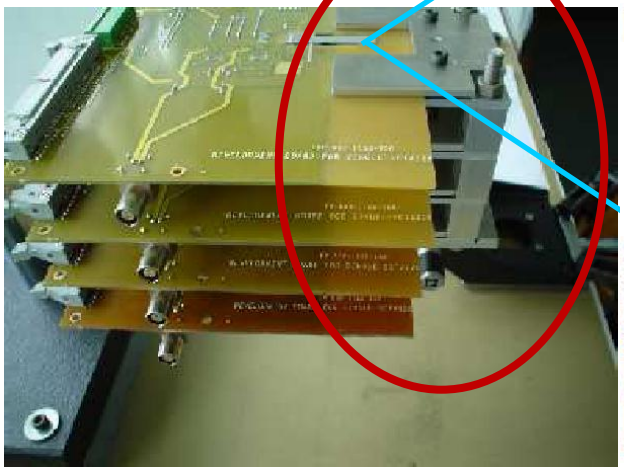
The long summer of 2003

3D – TOTEM X5 Muon Beam 2003



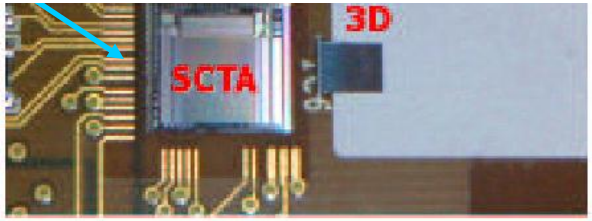


- 3D planes in the center
- 3 Silicon telescope planes on each side

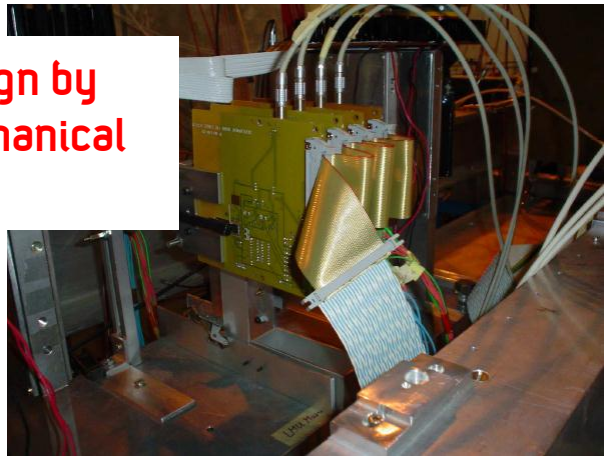


3D Detector Planes

Fantastic mechanical design by Sherwood (what a great mechanical engineer!) and Marco!



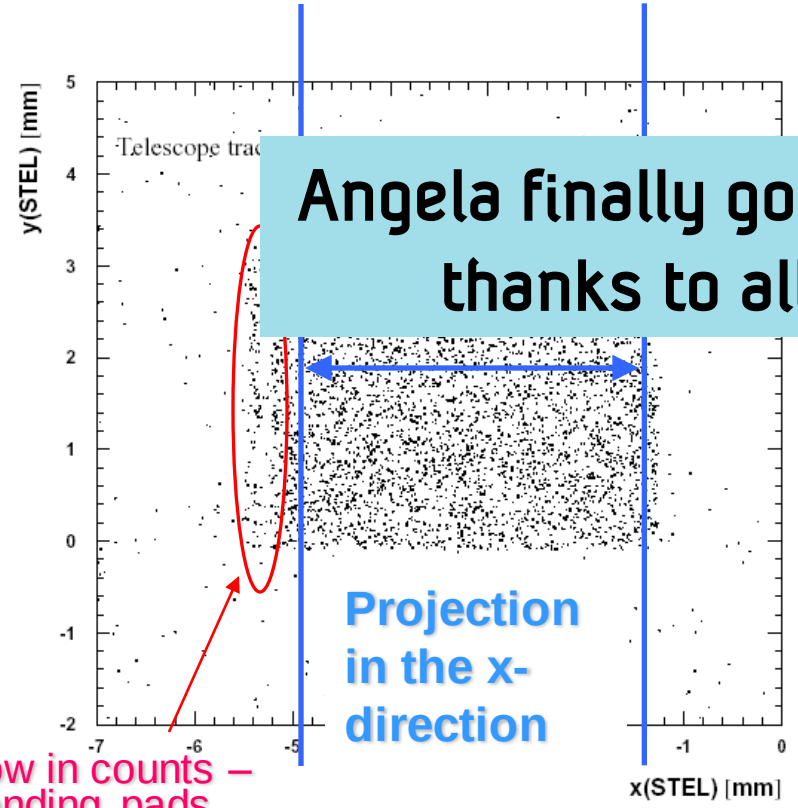
3D & electronics (SCTA)



Full Setup

The long summer of 2003

3D – TOTEM X5 Muon Beam 2003

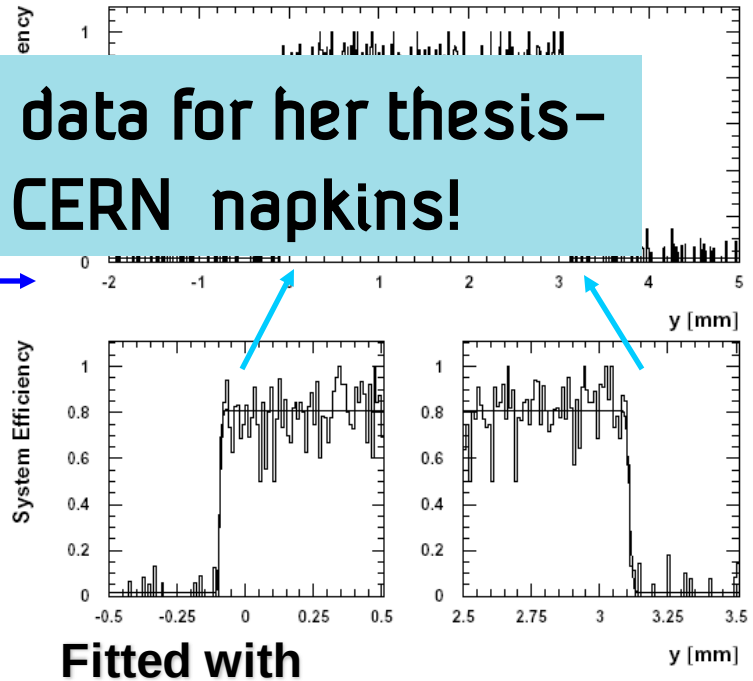


Low in counts – bonding pads

Projection in the x-direction

Image of Detector predicted by telescope

Angela finally got the data for her thesis– thanks to all the CERN napkins!

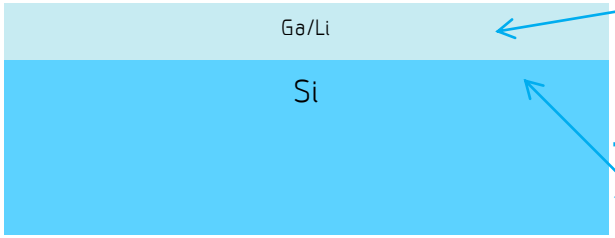


Fitted with

$$\eta(y) = b + \frac{1}{4}\eta_0 \left[1 + \mathrm{erf}\left(\frac{y - y_l}{\sigma_l \sqrt{2}}\right)\right] \left[1 + \mathrm{erf}\left(\frac{y_u - y}{\sigma_u \sqrt{2}}\right)\right]$$

Measured width = 3.203 ± 4 µm
From photolithography = 3.195 µm

Neutron using semiconductor detector



Too thin – low neutron capture

Planar is inefficient!

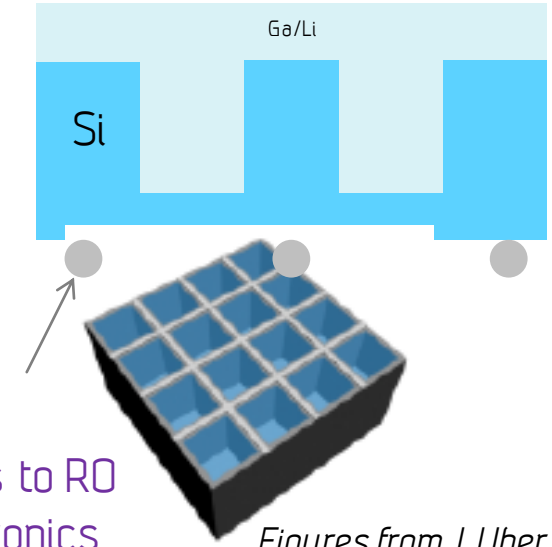
Too thick – by-products do not reach the silicon active volume

Silicon pixel detector can not detect neutrons directly.

a converter layer

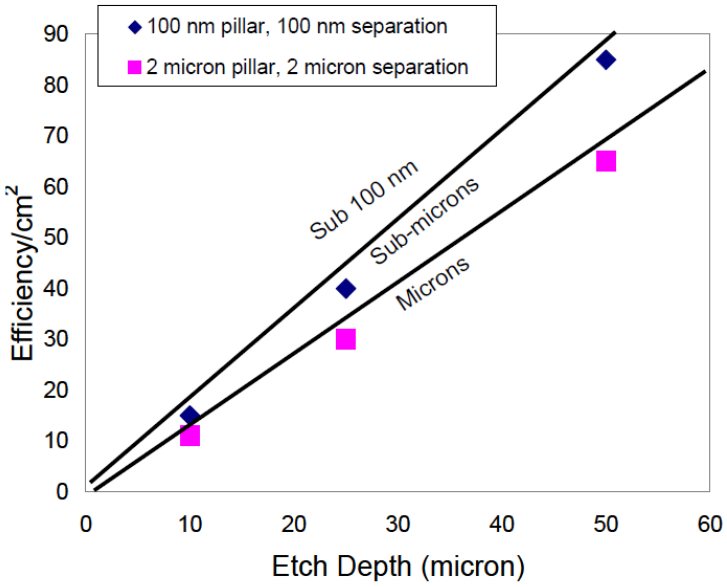
deposited on the detector surface.

3D Stuctures can increase the surface area!



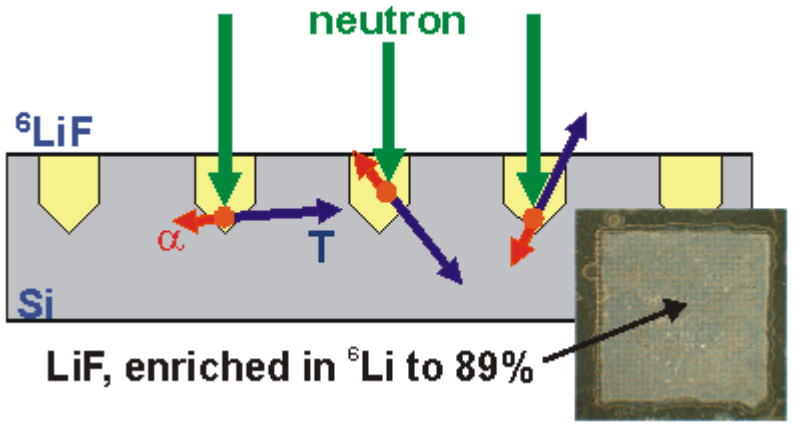
Bumps to RO electronics

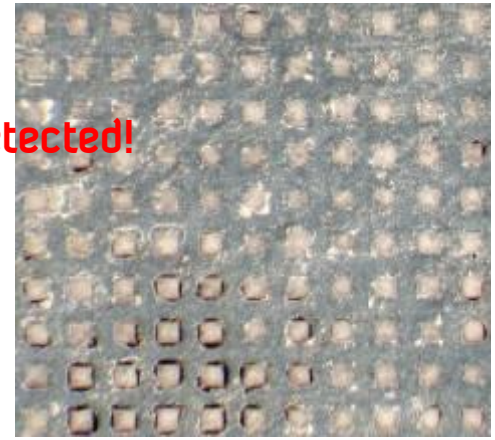
Figures from J. Uher, IEAP 2007



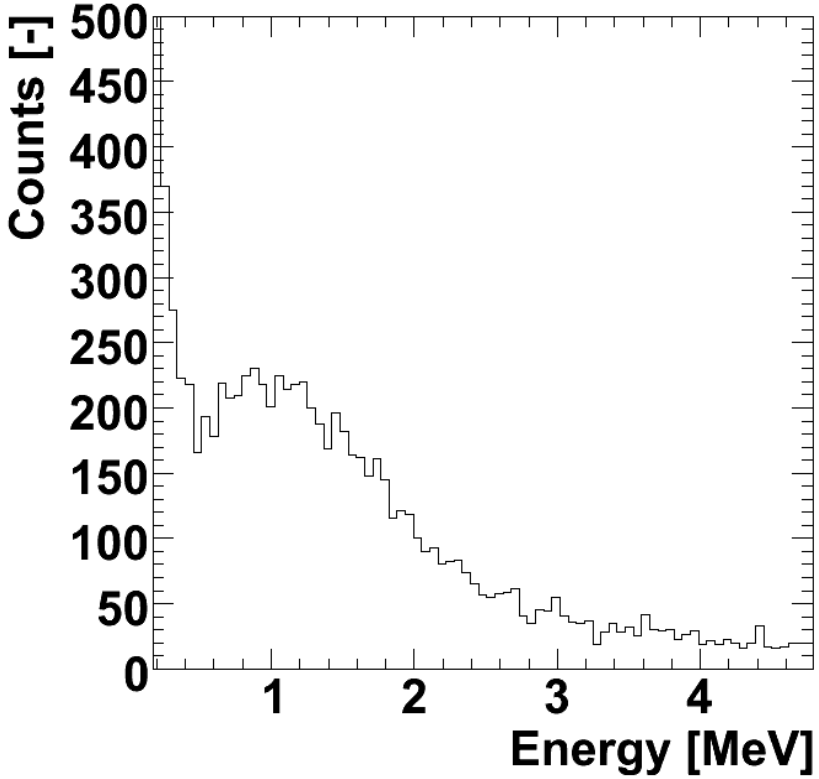
R.J. Nikolic, "Roadmap for High Efficiency Solid-State neutron detectors", Proceedings of SPIE – Volume 6013 Optoelectronice Devices: Phys, Fabrication and appilication II,

Neutron imaging 3D detector





Neutrons were detected!



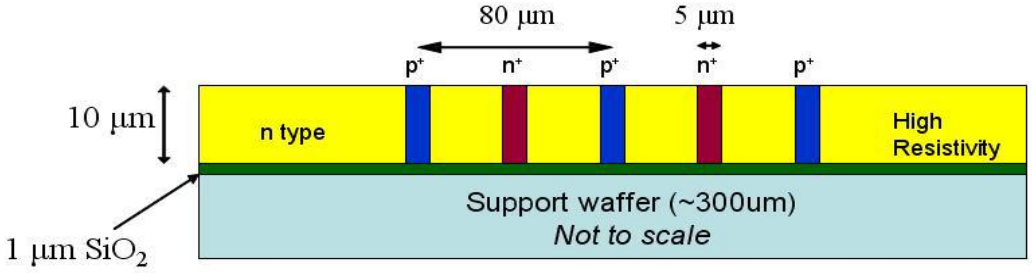
Measured at the horizontal channel of the LVR-15 nuclear research reactor at Nuclear Physics Institute of the Czech Academy of Sciences at Rez near Prague.

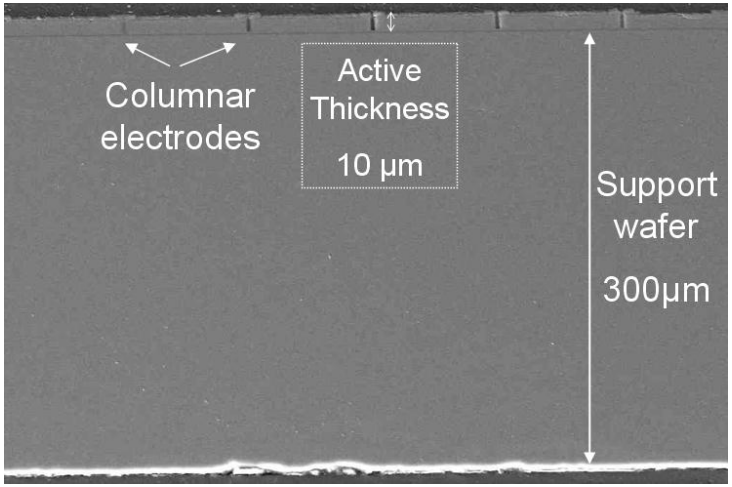
Thermal neutron flux was about 10^7 neutrons/cm^{2}s (at reactor power of 8MW)

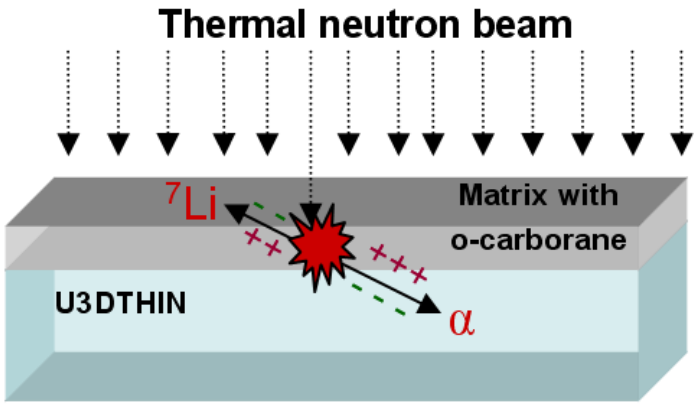
J. Uher, IEAP, 31/01/2007

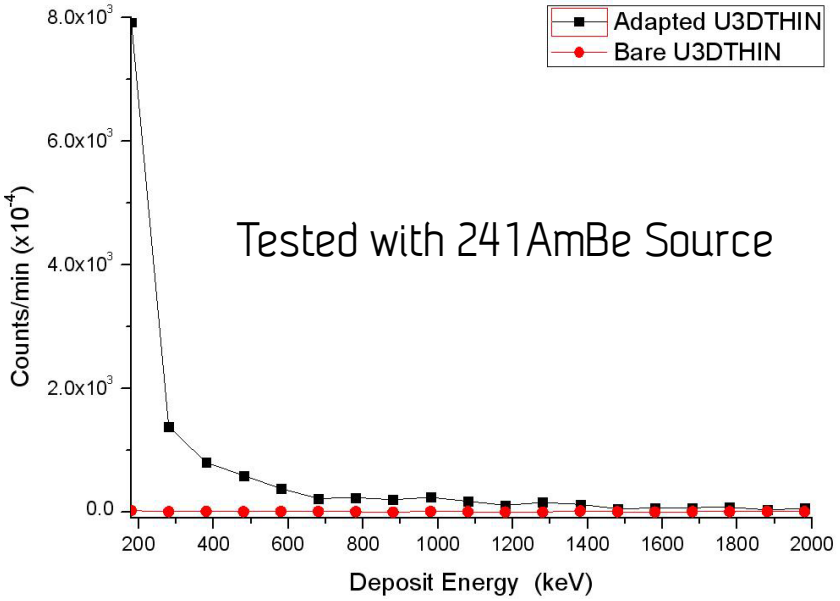
Many efforts are currently undergoing in optimisation of conversion material, geometry to realise 3D neutron imaging

Neutron imaging







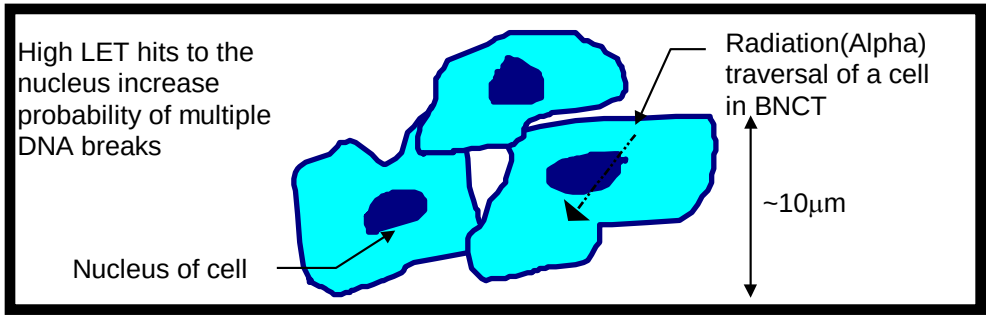


Tested with 241AmBe Source

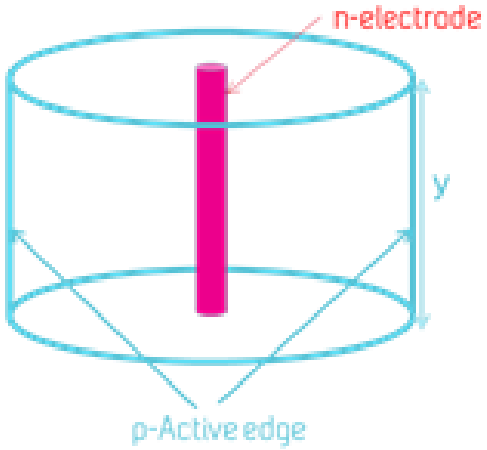
- Ultra thin for gamma rejection
- Lower capacitance
- Neutron detection capability

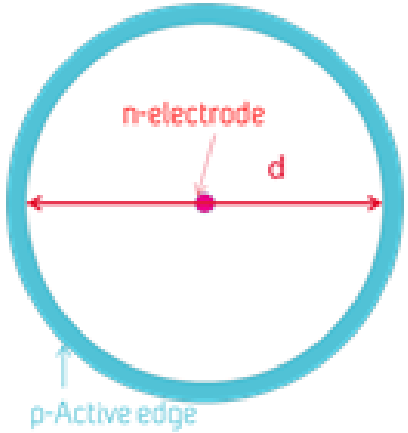
C. Guardiola et al., "Ultra thin 3D silicon sensors for neutron detection", 2012 JINST 7 P03006

Microdosimetry in Space and heavy ion cancer therapy



*A. Rosenfeld, IEEE NSS MIC 2008 microdosimetry Workshop





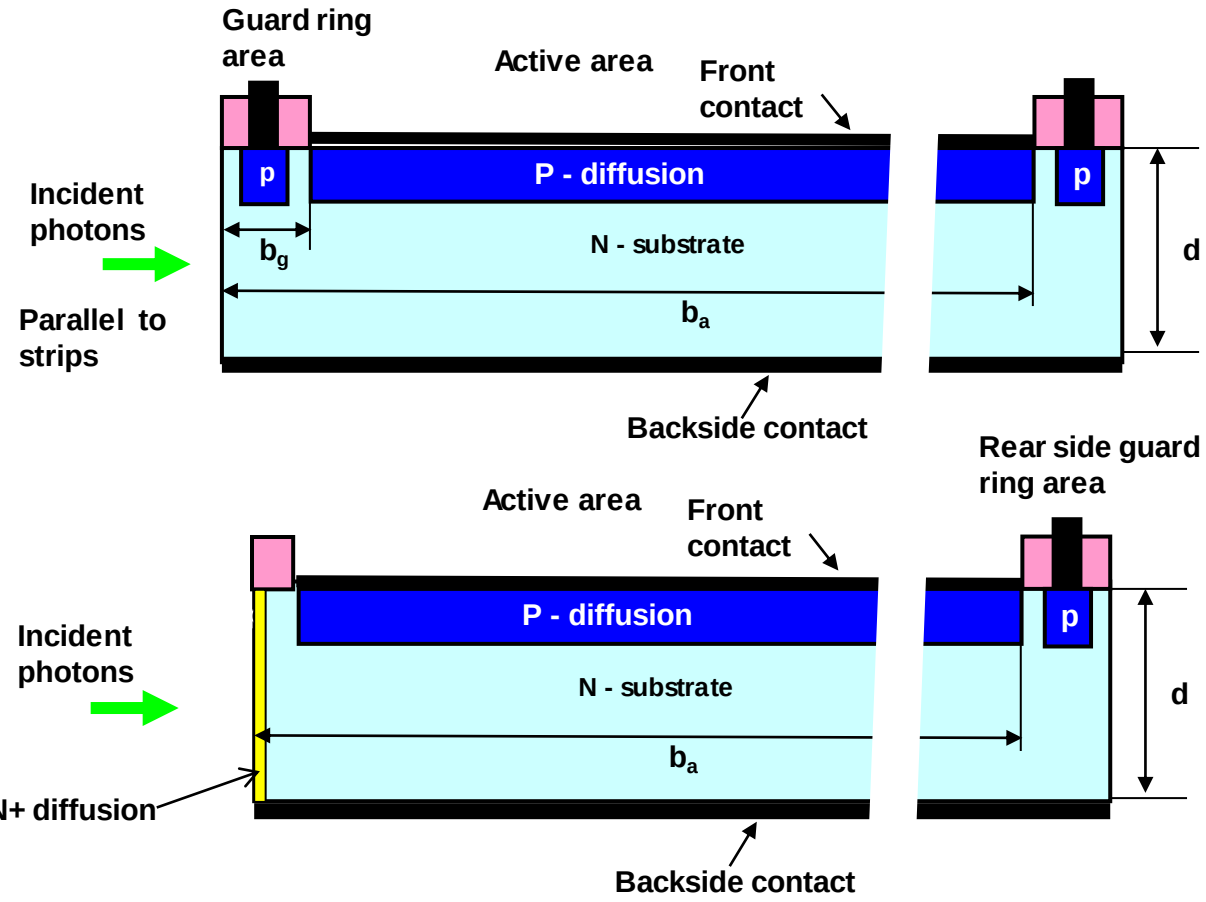
Motivation:

- To measure the radiobiological effect on a cellular level for heavy ion and mixed radiation field
- Measure stochastic radiation event
- Small well defined sensitive volume is required to mimic biological cell!

Accurate microdosimetry can prevent

- Carcinogenesis caused by radiation
- Loss of bone mass or density
- Human Performance: Poor psychosocial adaptation
- Clinical Manifestations: Trauma or acute medical problems

Edge-on detector with active edges



Advantages:

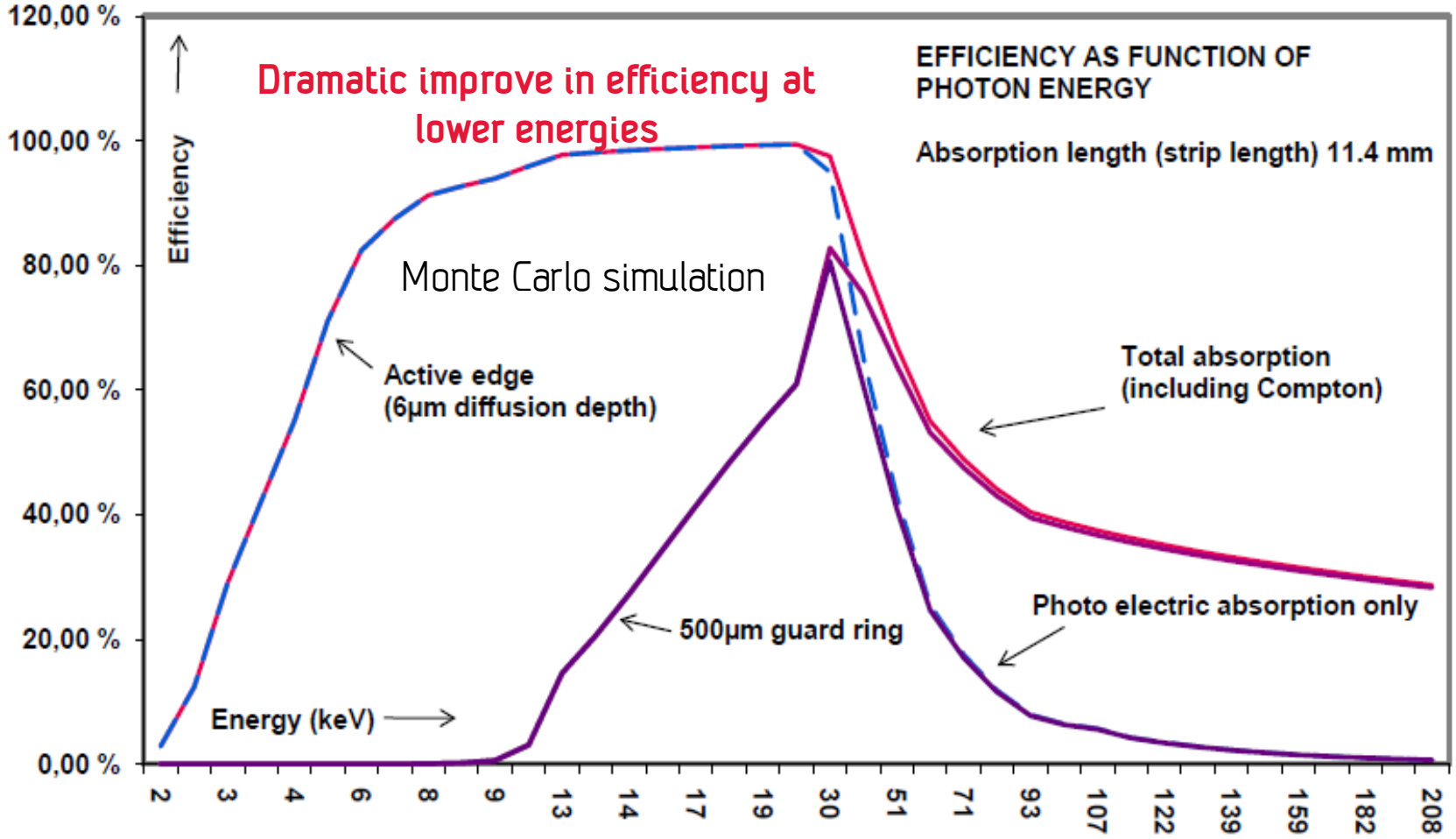
1. Higher efficiency than front illuminated sensors ≥ 10 keV
2. Potential use up to ≥ 100 keV
3. Fast with response times in the10 to 20 ns region

Disadvantages:

1. Applicable to line sensors only

Improved efficiency and performance in waste management, low energy x-ray imaging and material analysis

Edge-on detector with active edges

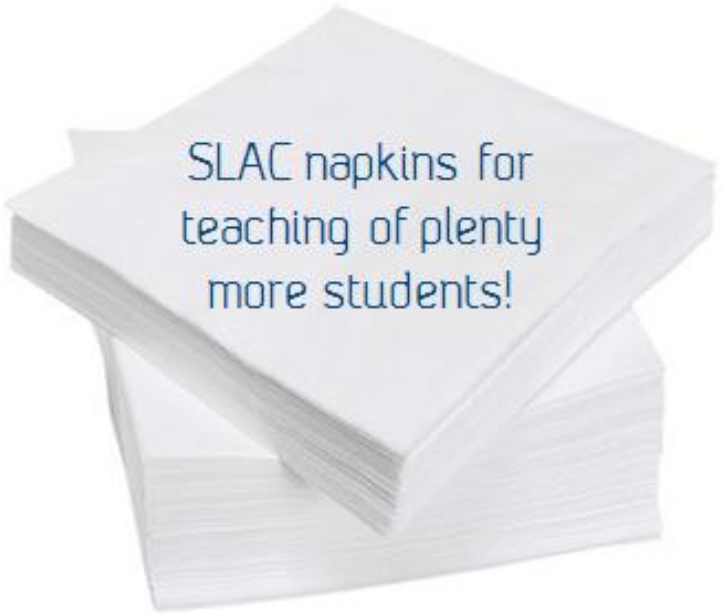


T-E et al., "Edge-on sensor with active edge for X-Ray Photon Counting Imaging", IEEE NSS Proceeding 2011, Valencia

Short summary

Wide range of applications for 3D to improve current technology :

- High energy physics
- Homeland security
- Medical imaging
- Medical therapy
- Radiation protection in space
- Waste management
- Material analysis
- Apologise for not covering all topics!

– Great celebration today!

Please collect your birthday present after the meeting! ☺