Narodowe Centrum Badań i Rozwoju

CBK PAN

Modular GEM detectors and their applications

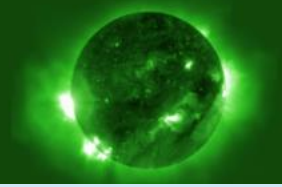
Szymon Gburek

November 21st, 2019

Progress on Spectroscopy and Imaging III, November 19th – 21st, 2019,
Polish Academy of Sciences, Wroclaw Division, Podwale 75 str., 50-449 Wroclaw

Prezentacja promująca Projekt
Modularne Detektory GEM (MGEM)
Nr POIR.04.01.02-00-0080/17

Projekt współfinansowany przez Narodowe Centrum Badań i Rozwoju wybrany w ramach programu Program Operacyjny Inteligentny Rozwój
w Konkursie nr 1 - 4.1.2/2017_RANB.



Progress on spectroscopy and imaging III

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GEM – What is this?

It is specific type of gaseous ionization detector

Can be used for measurement of different kind of ionizing radiation

Almost any kind of radiation - ionizing

GEM foils – the heart of the detectors

Key element of GEM detectors are (typicaly) 50 μm Kapton foils

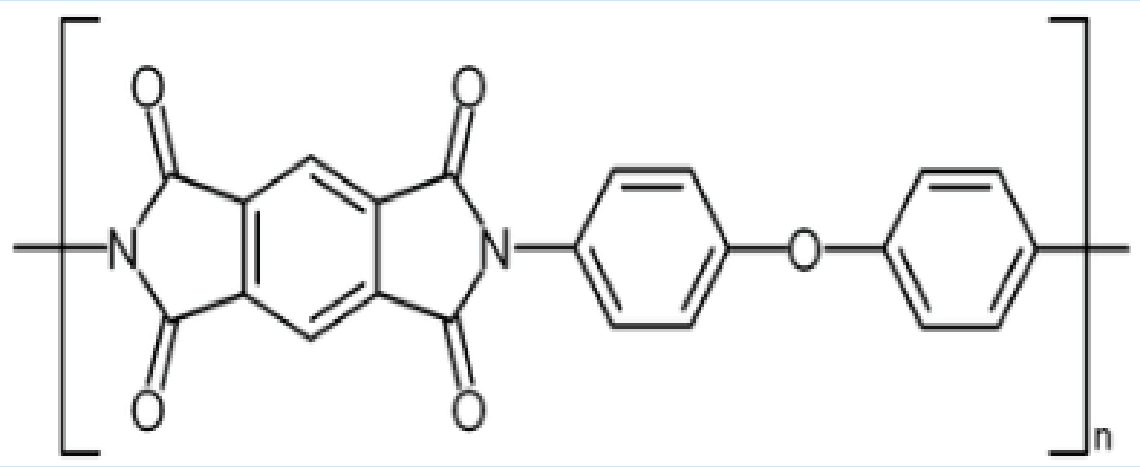
double-sided coated with 5 μm layer of Coper

GEM foils has a system of holes

Usually holes are clepsydre like shaped having diameters 60-80μm on the Coper coatings and 40-60μm at the half of the entire foil thickness

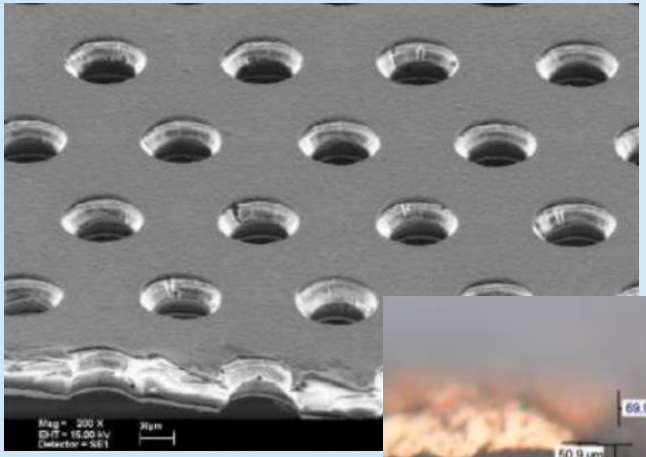
Kapton

4,4'-oxydiphenylene-pyromellitimide



developed by DuPont in the late 1960s

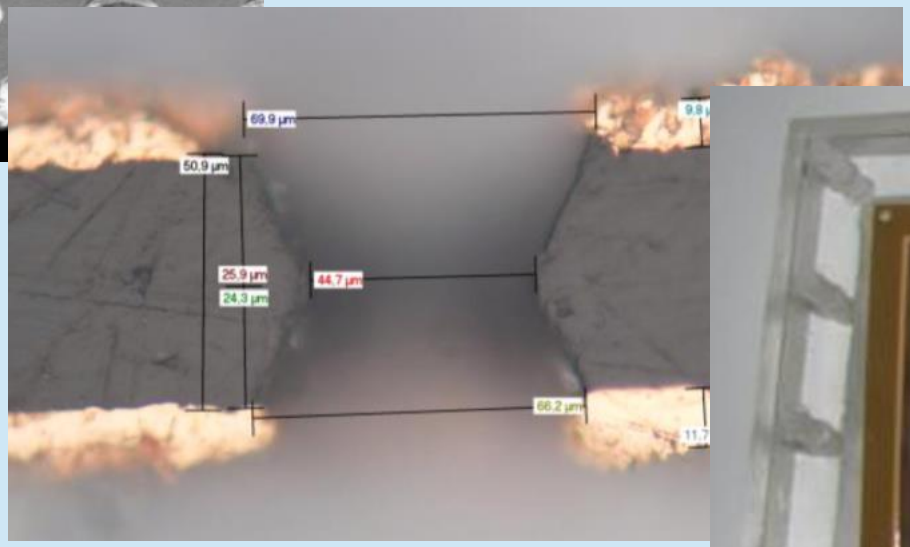
Typical GEM foils



GEM foil.

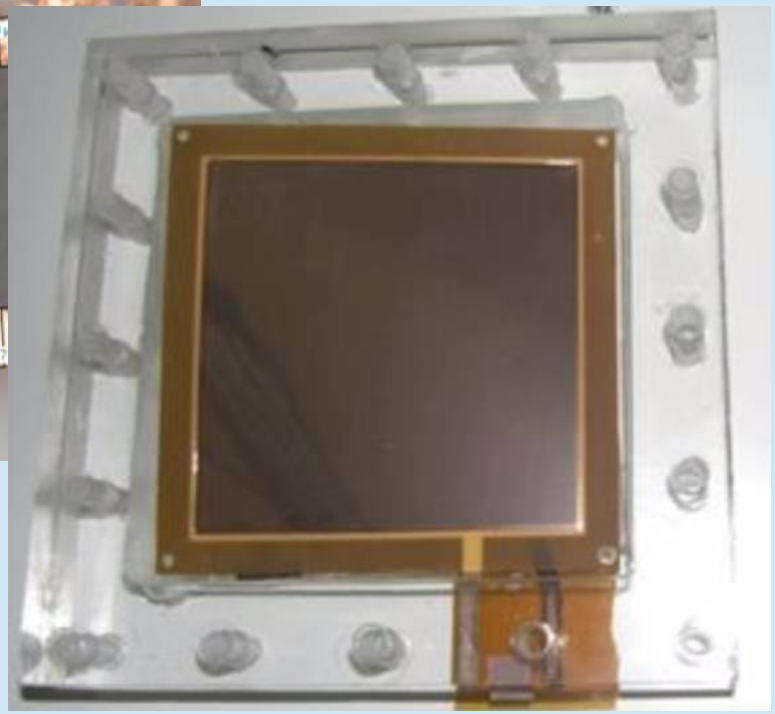
Microscopic

Picture



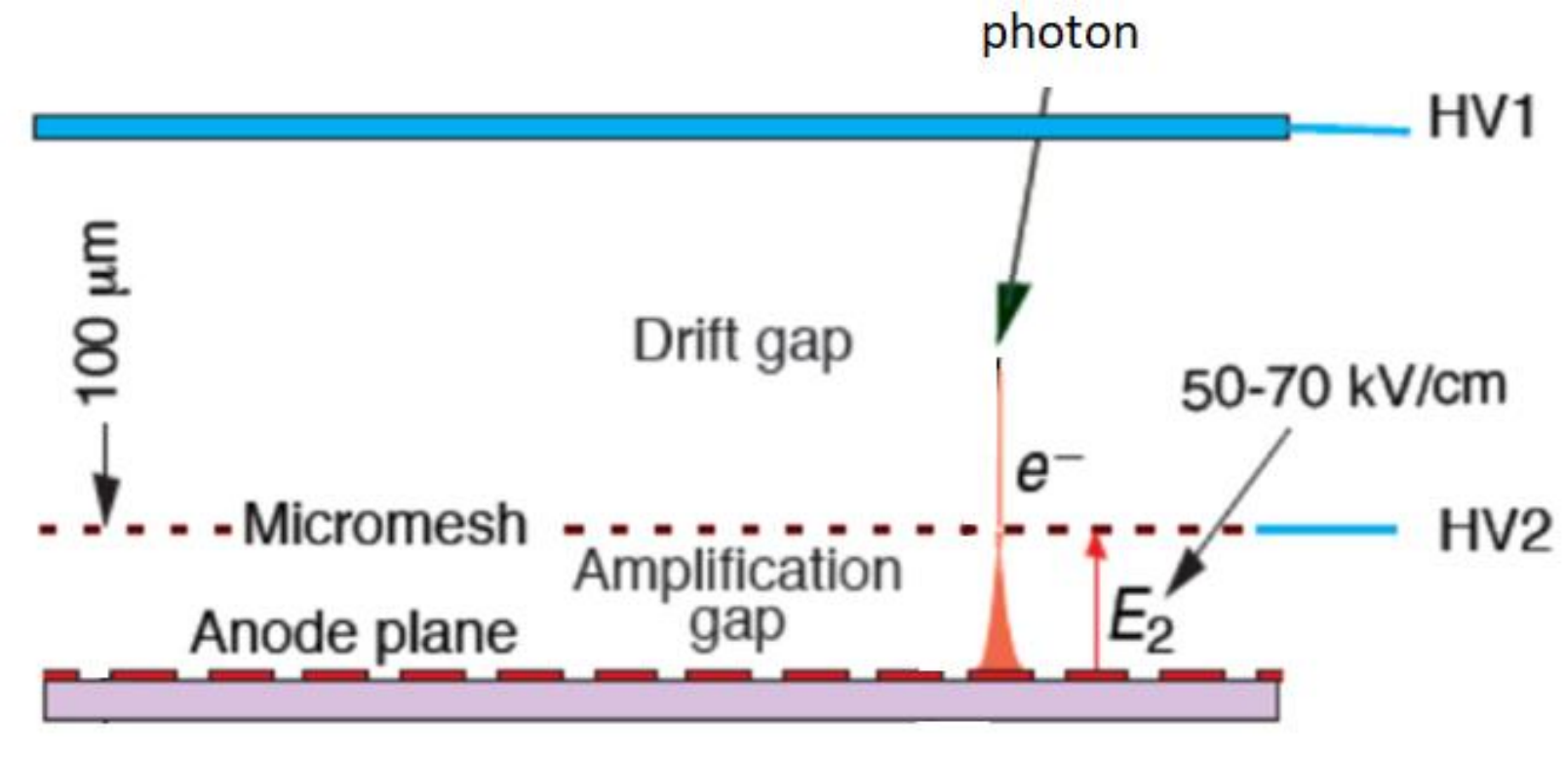
Single GEM hole

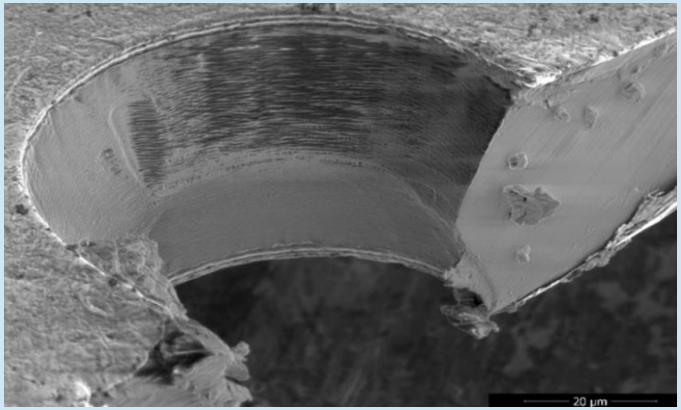
Microscopic Picture CERN

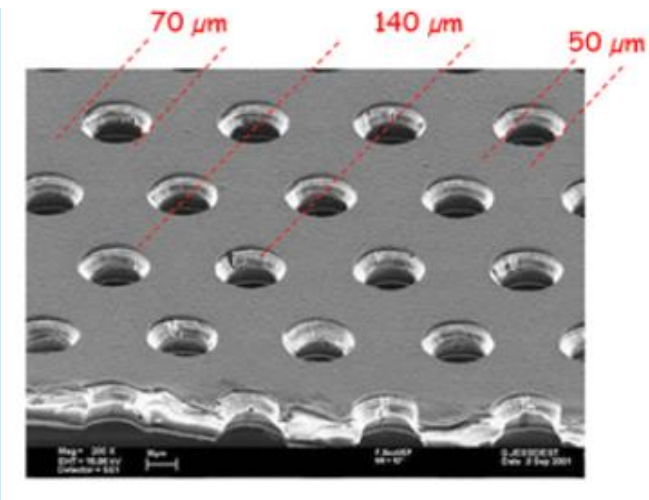


10x10 cm GEM foil. About 500 000 holes

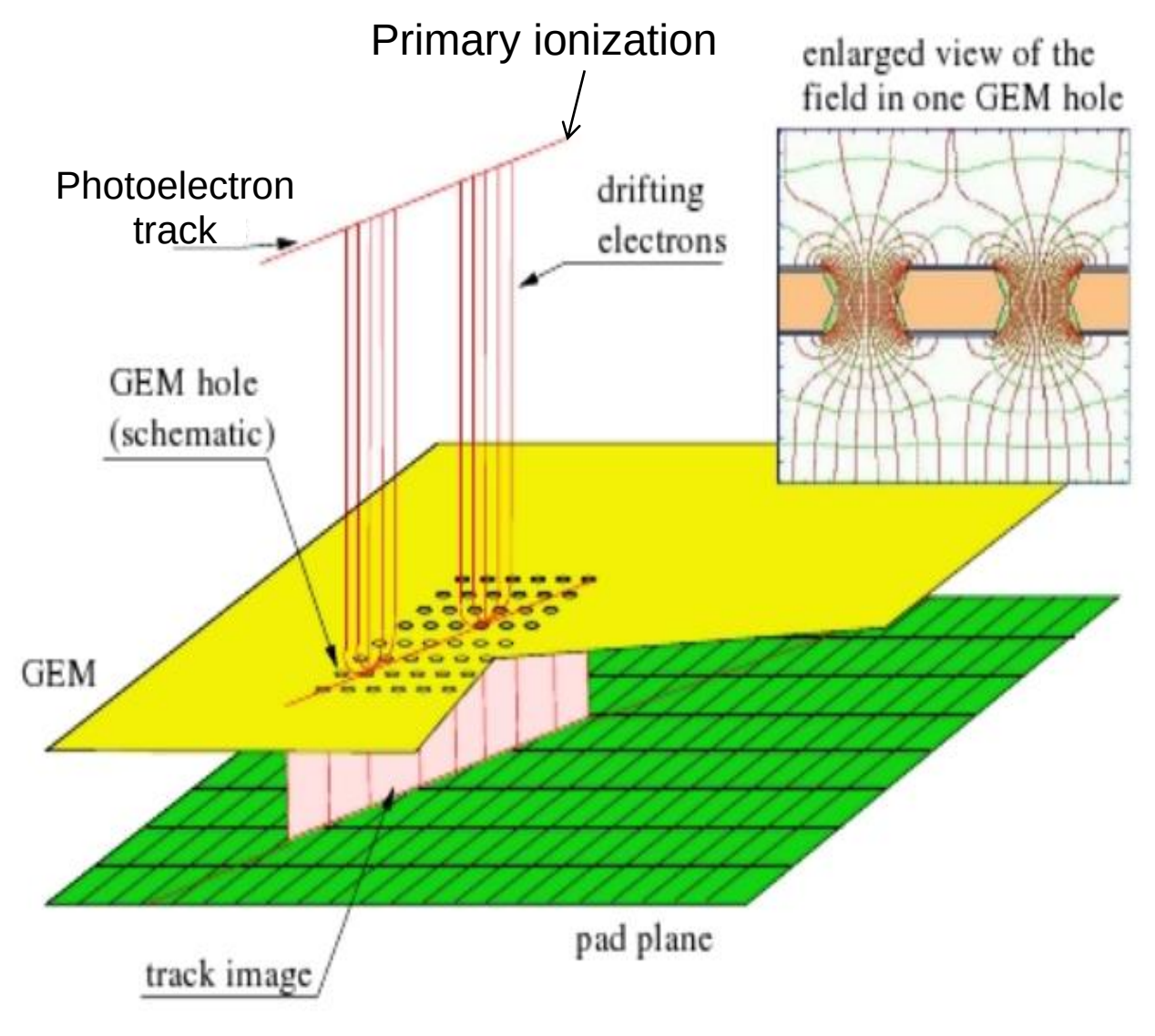
Principle of operation





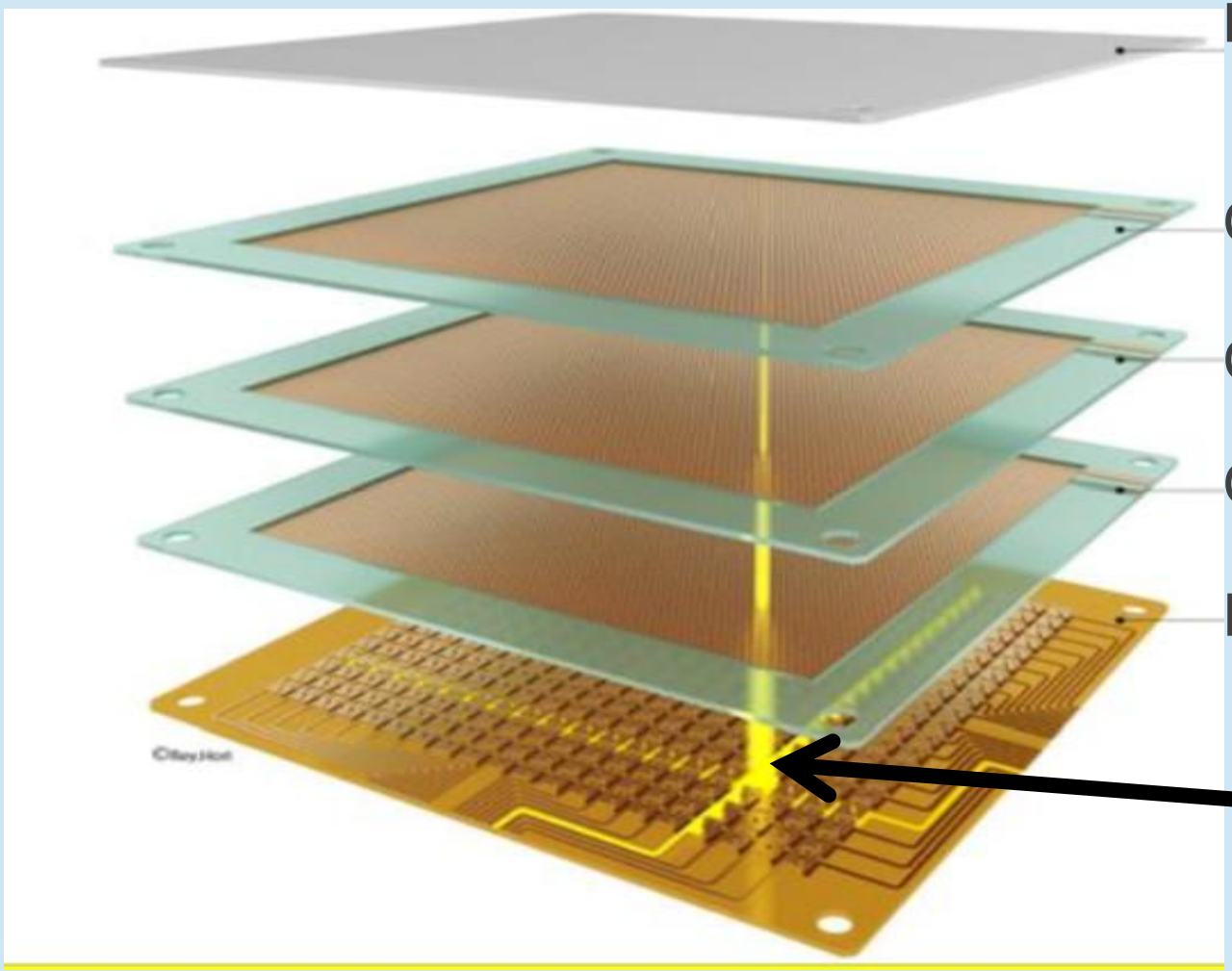


Principle of operation



Primary ionization site

GEM – different configurations possible



GEM – Main features

- count rate capability - high gain thus efficiency
- time resolution
- position resolution,
- stability of operation
- Speed of operation
- easy shaping
- radiation hardness
- relatively low cost

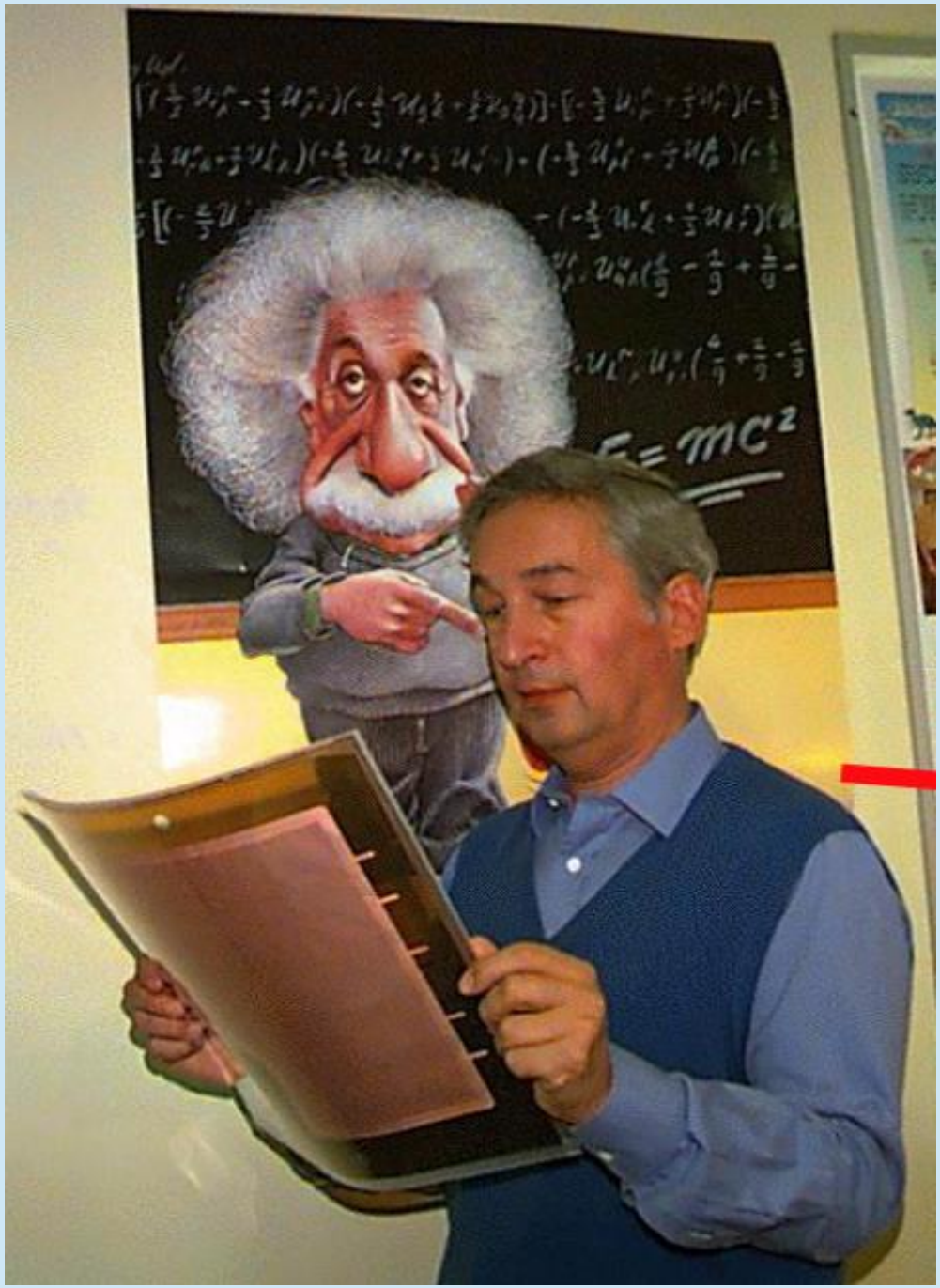
GEMs were invented at CERN

CERN

Conseil Européen pour la Recherche Nucléaire

The European Organization for Nuclear Research

https://home.cern



Who invented GEM

GEMs were invented in 1997 in the CERN Gas Detector Development Group

Physicist Fabio Sauli is considered as the GEM concept author

GEM – application areas

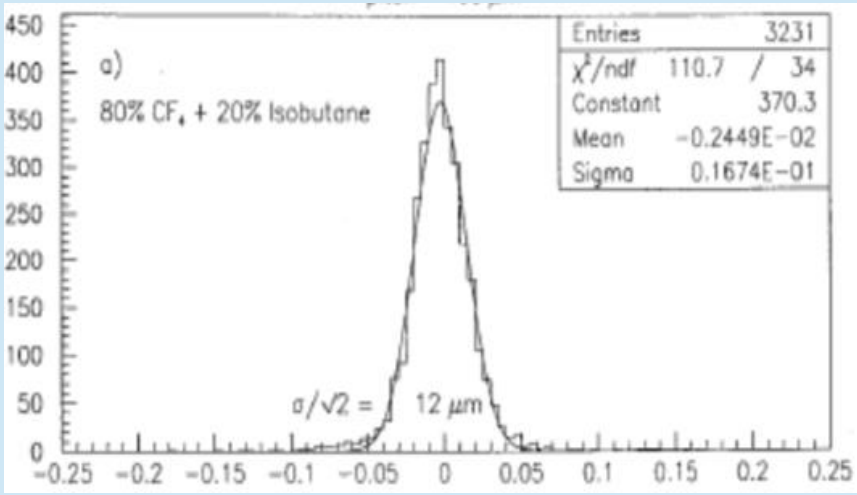
- detection and monitoring of radiation
- spectroscopy, photometry
- non-destructive tests
- quality control
- determining degree of radiation polarization
- imaging

GEM – basic parameters

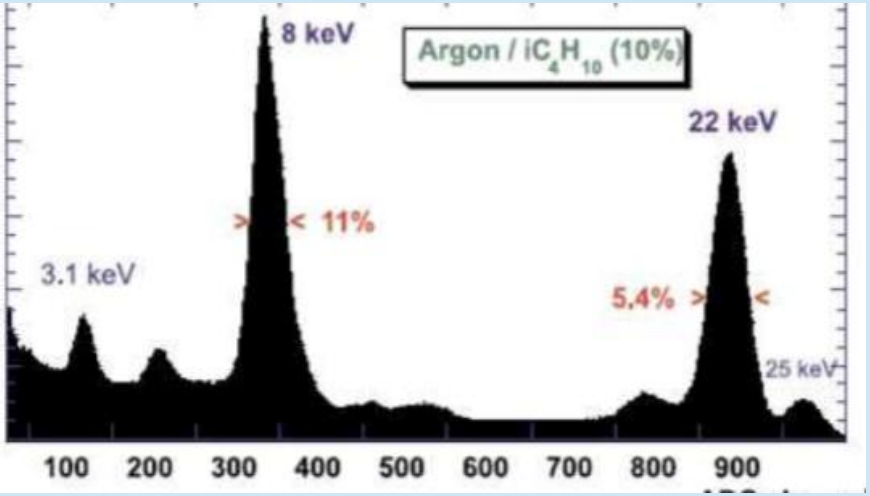
- Good spatial resolution ~30 [μm]
- Photoelectron time resolution - [ns] range
- Cascaded GEMs reach gains above 10^5 (with single ionization event)

A. Bressan et al., Nucl. Instr. Meth., A425(1999), 262., J. Derre et al., Nucl. Instr. Meth., A459(2001), 523.

A. Breskin et al., Nucl. Instr. Meth., A483(2002), 670., Y. Derre et al., Nucl. Instr. Meth., A449(2000), 314.



Spatial resolution



^{109}CD source spectrum obtained with GEM detector – 15% FWHM at 6 keV

GEM – radiographic imaging

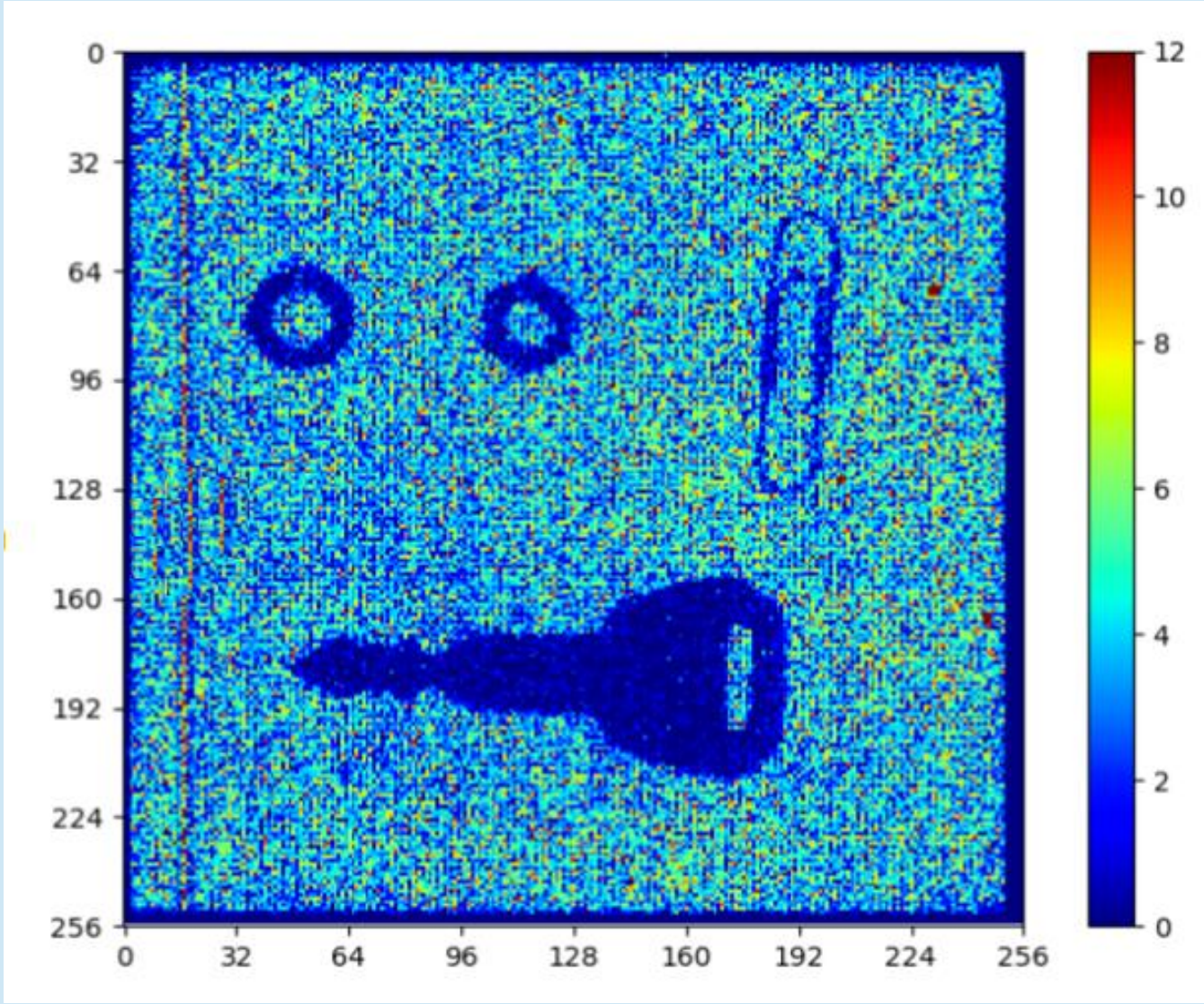


Image of metal objects obtained in gamma rays

GEM – polarization measurements

Even with the best technology,

X-ray polarimetry is facing a big limit

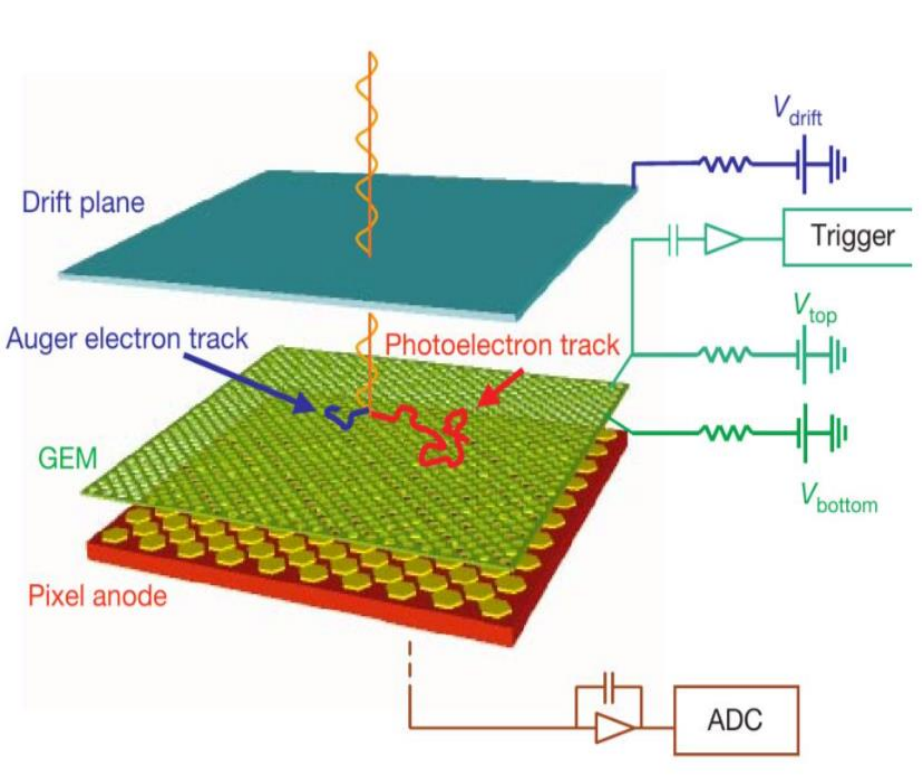
Source detection >10 photons

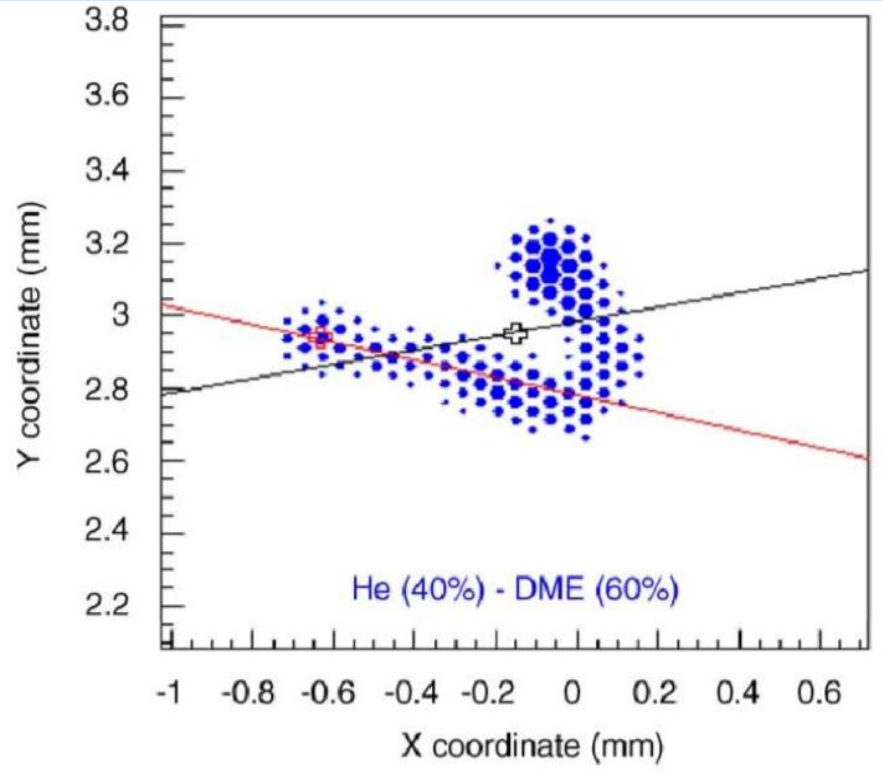
Source spectra >100 photons

Source polarimetry >**100 000** photons

X-ray polarization is photon hungry !

GEM – polarization measurements





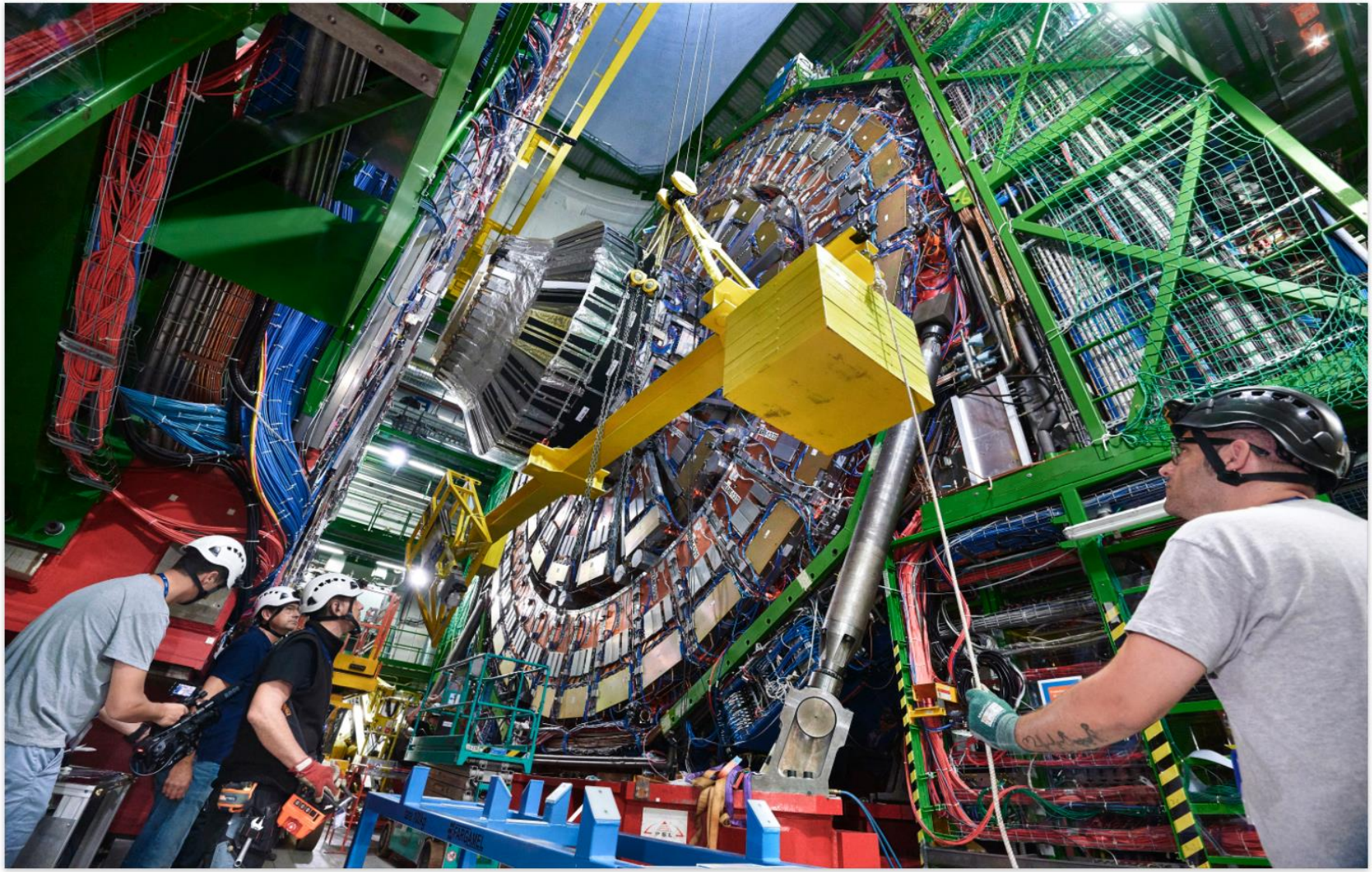
Principle of polarization measurements

Costa, E. et al. (2001) Nature 411,662.
Bellazzini, R., et al. (2006), NIM Phys. Res. A 566, 552.

GEM - Applications

Selected examples

GEM in high-energy physics

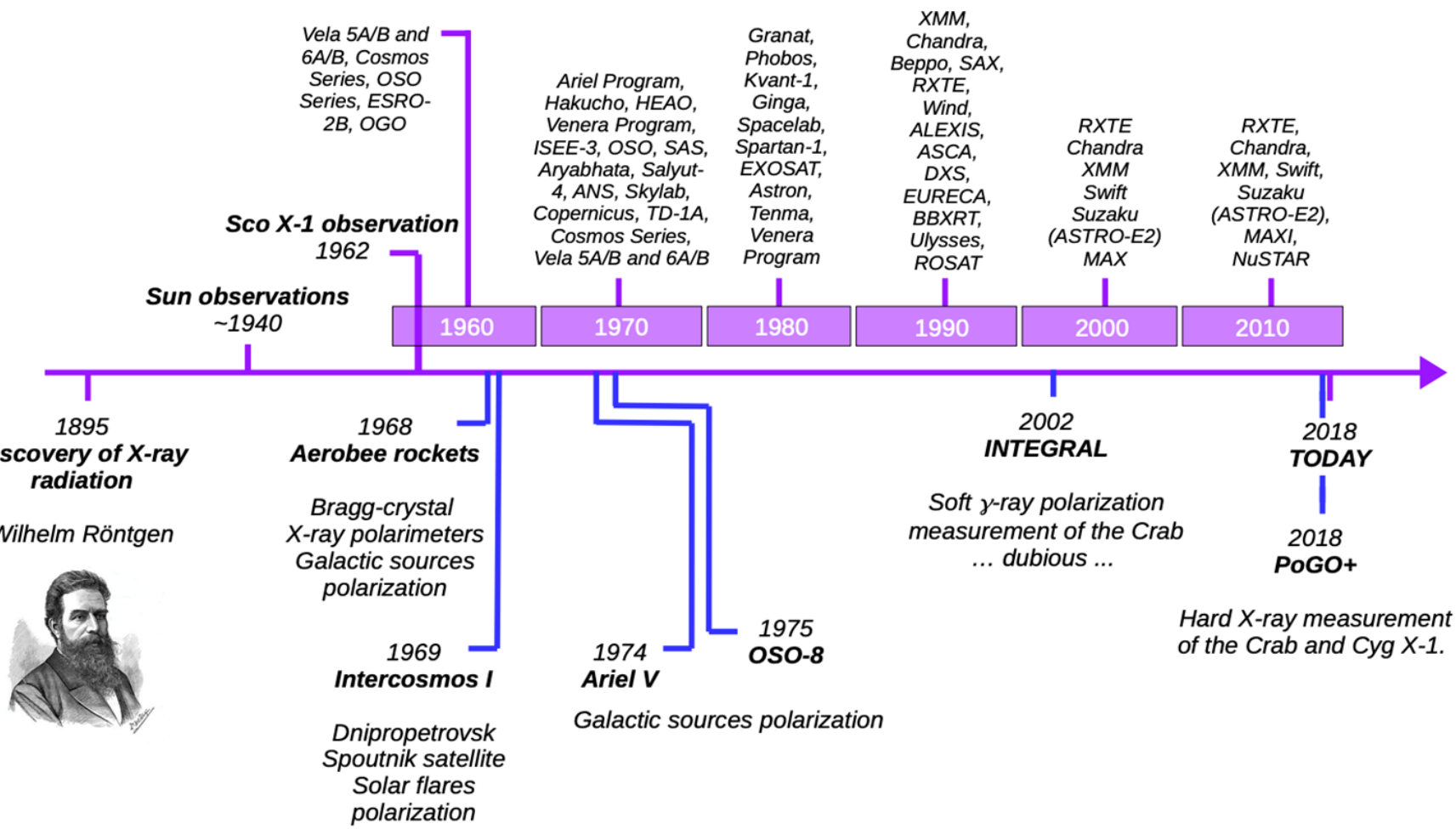


The GEMs being installed in CMS (Image: Maximilien Brice/CERN)

Compact Muon Solenoid, CERN

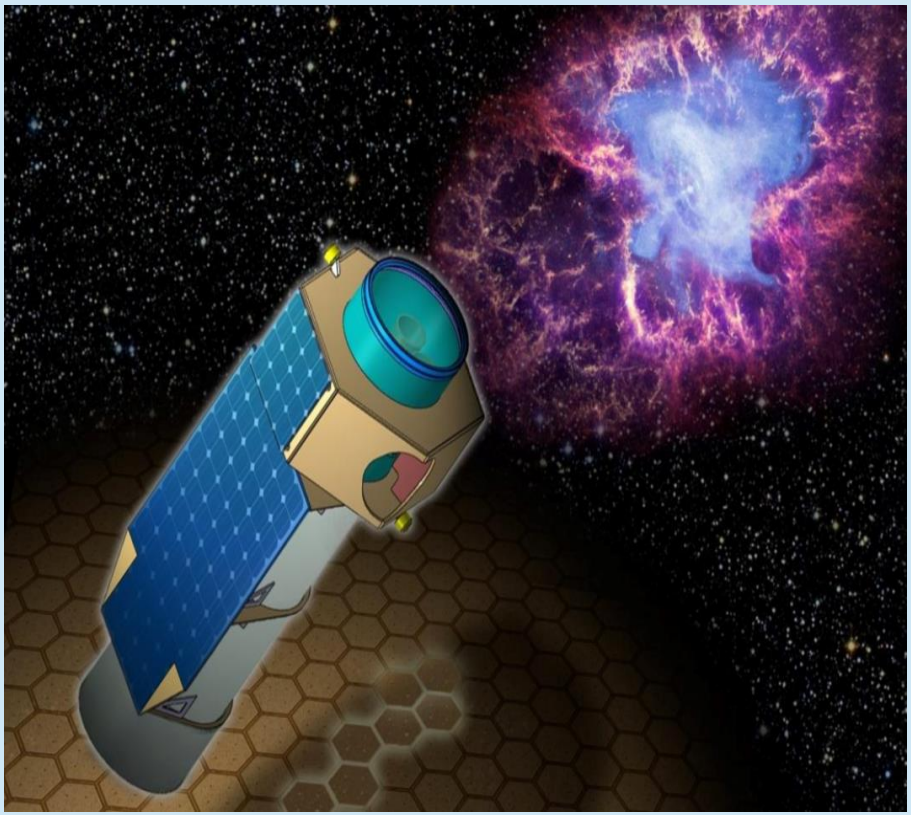
Polarization experiments in astronomy

X-ray polarimetry is the least known/used method in X-ray astronomy

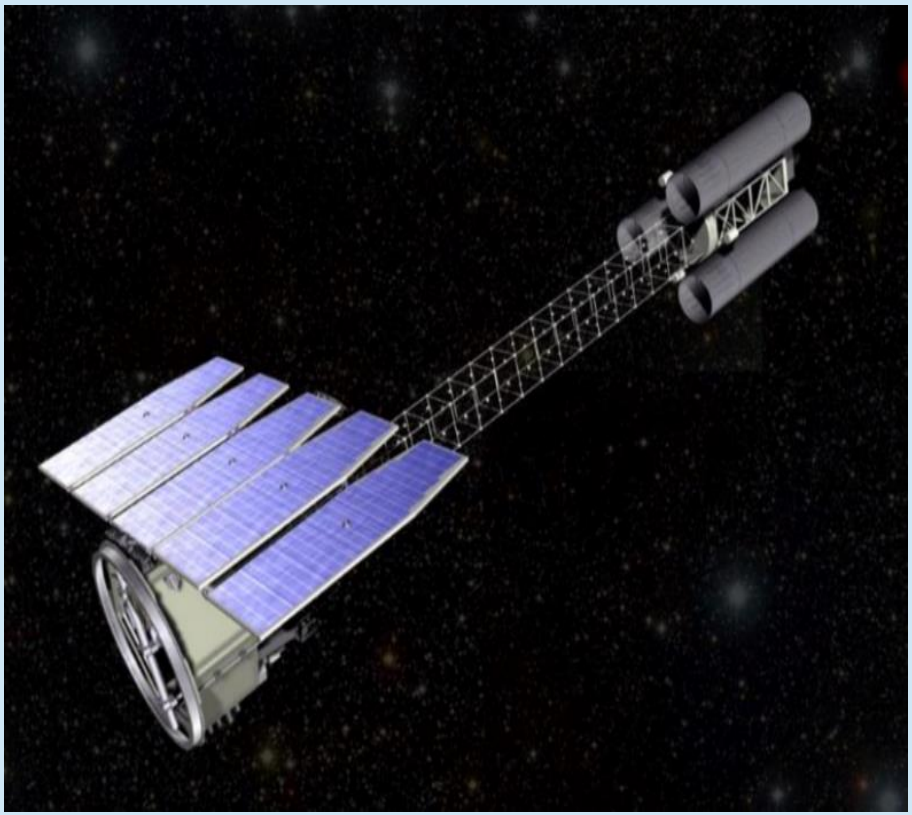


GEM in astrophysics and heliophysics - recent

XIPE - X-ray Imaging Polarimetry Explorer
SIPE - Solar Imaging Polarimetry Explorer
IXPE - Imaging X-ray Polarimetry Explorer

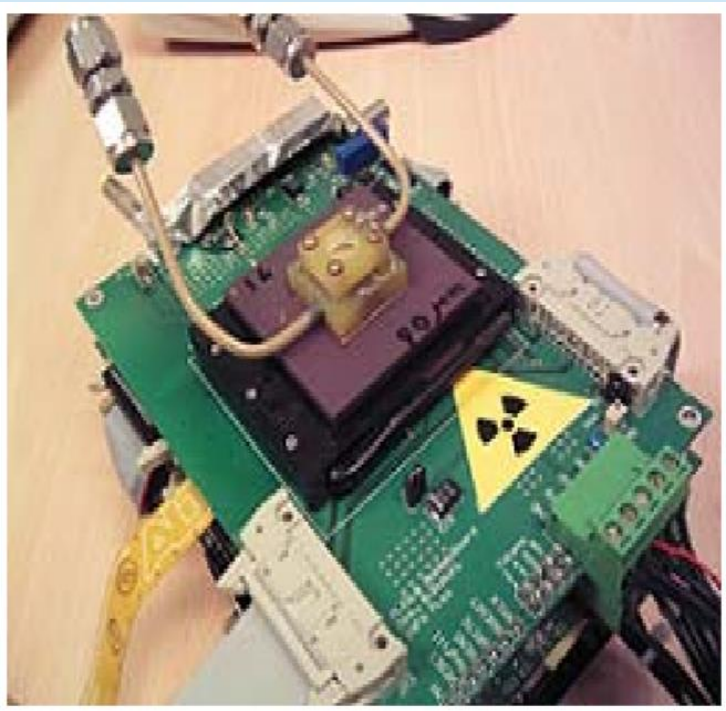


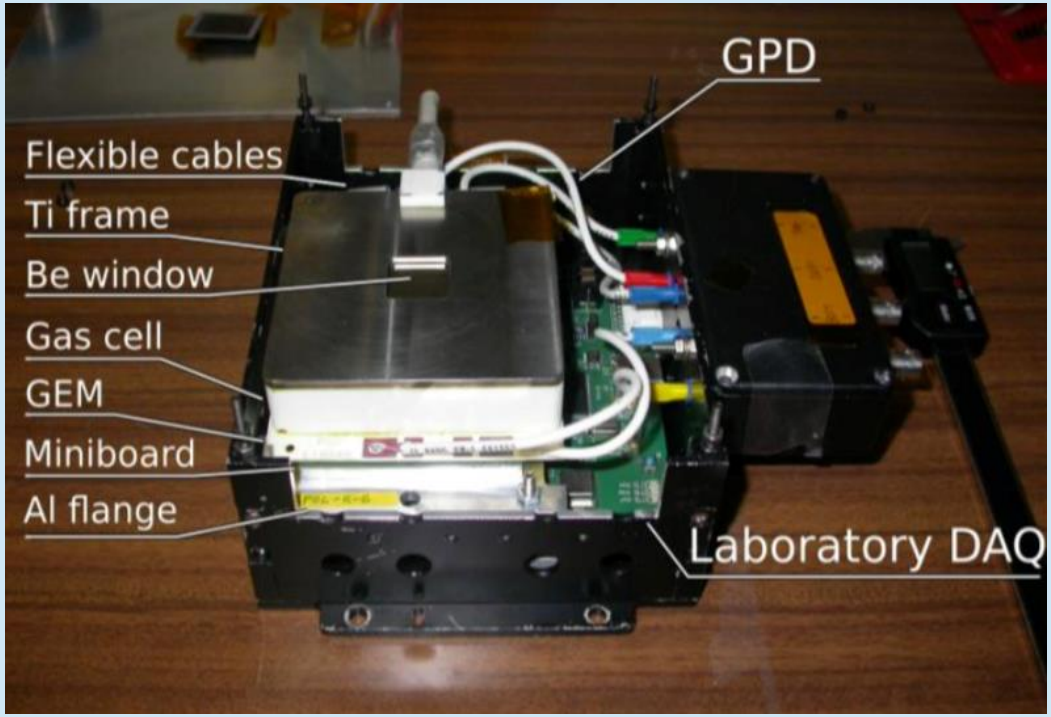
XIPE



IXPE

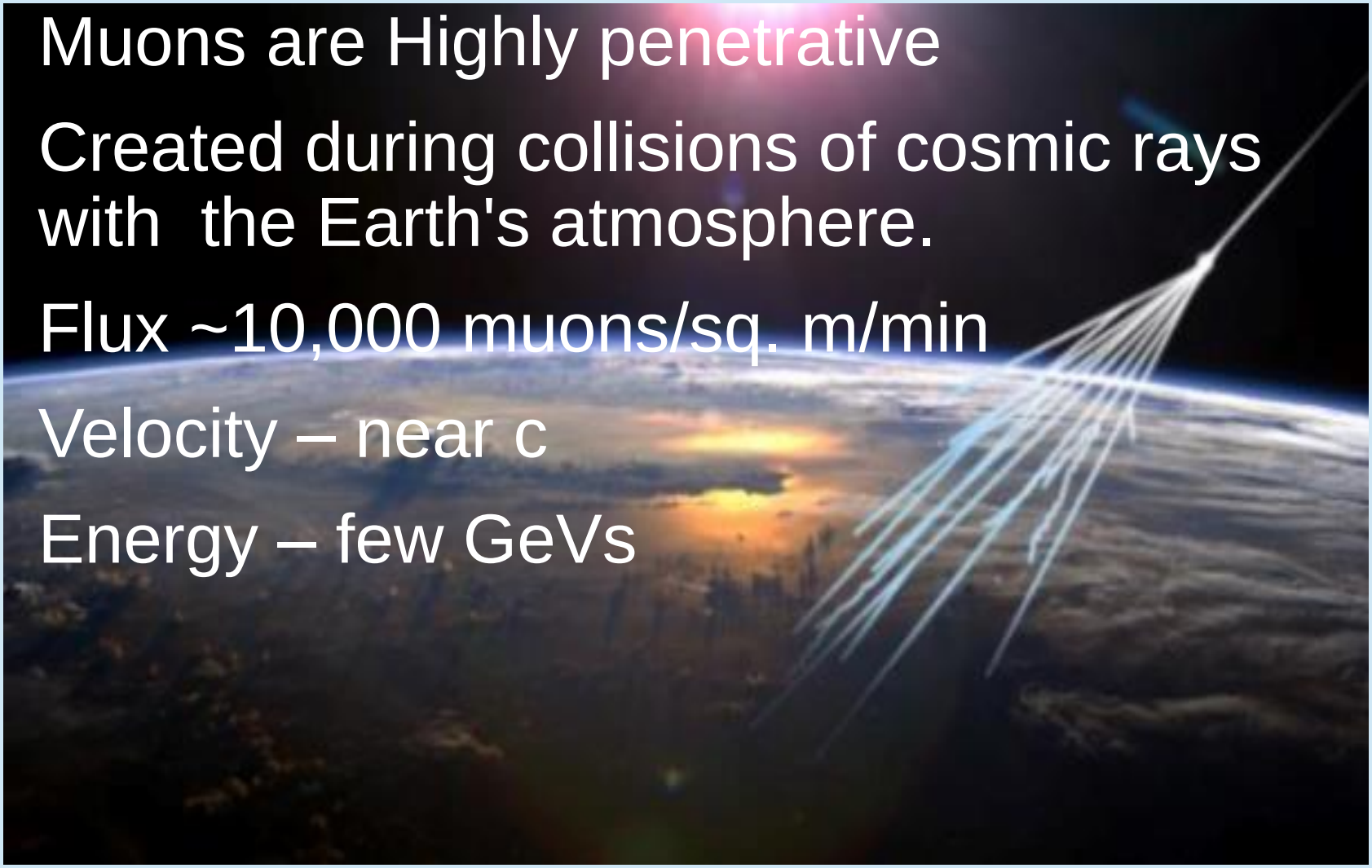
Prototypes of GEM detectors for XIPE spacecraft





Prototypes were tested – lab scale

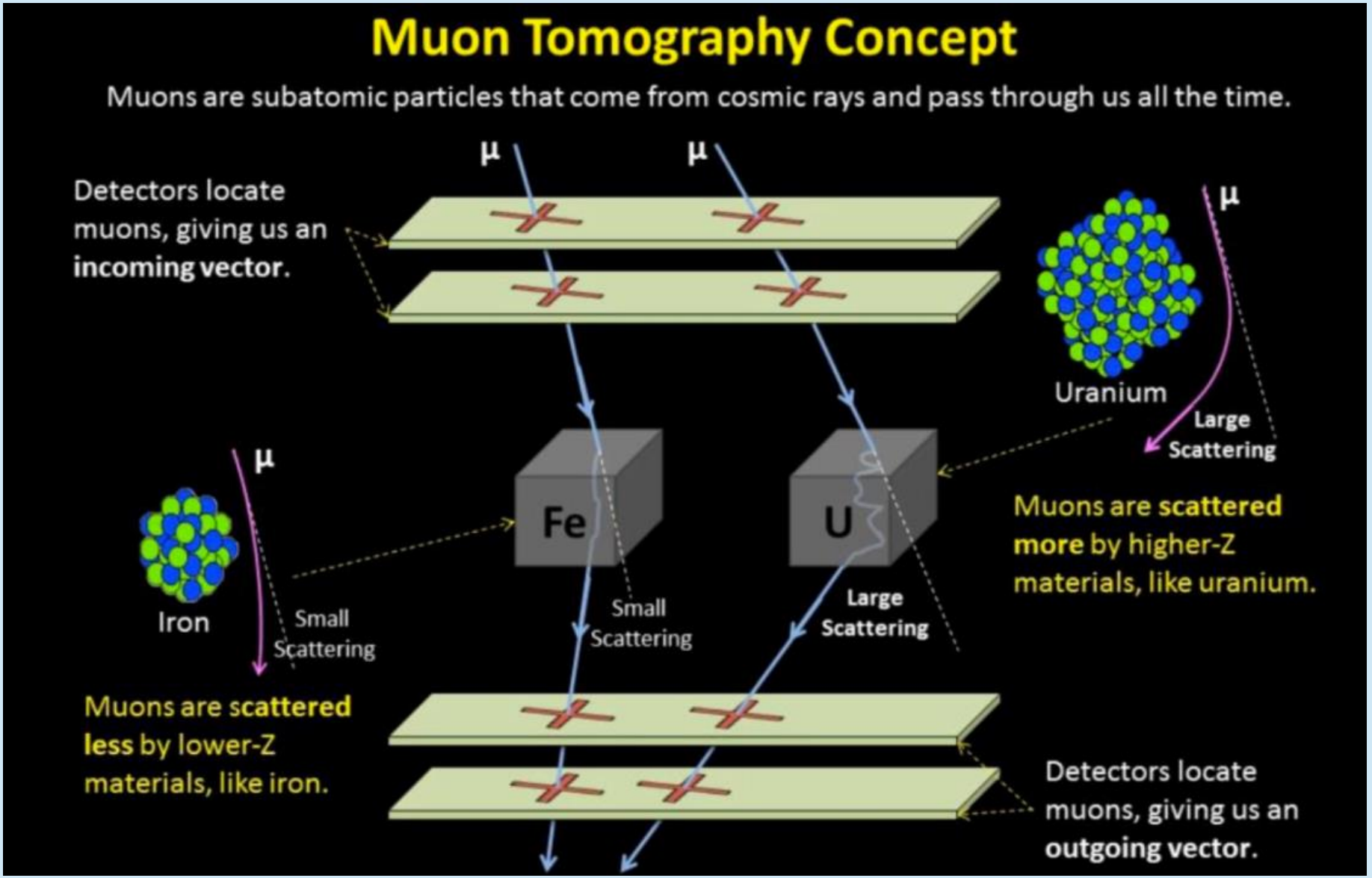
GEM – also can detect muons



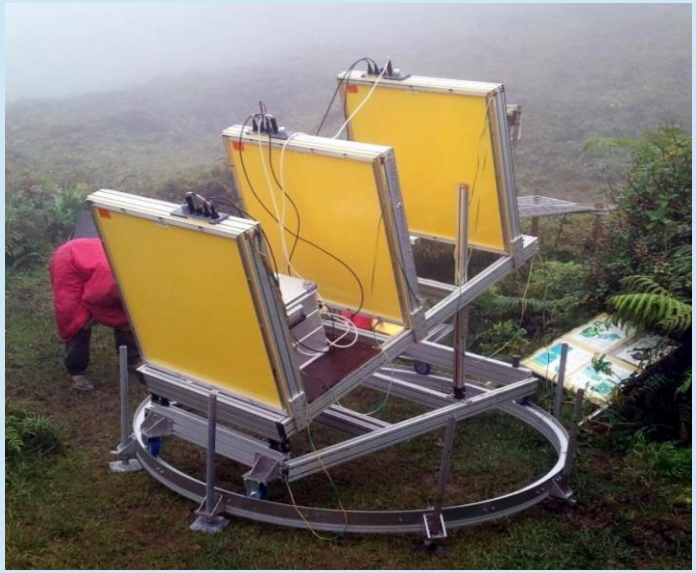
- Muons are Highly penetrative
- Created during collisions of cosmic rays with the Earth's atmosphere.
- Flux ~10,000 muons/sq. m/min
- Velocity – near c
- Energy – few GeVs

And muons are for free!

GEM – detection of muon scattering

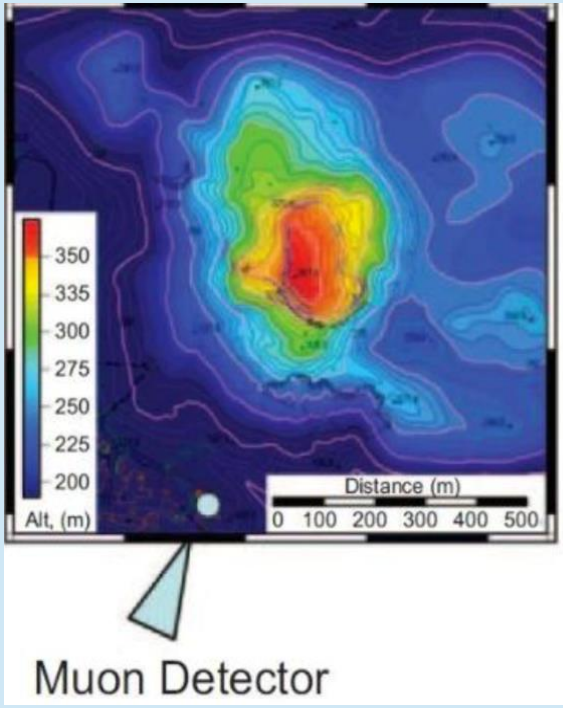


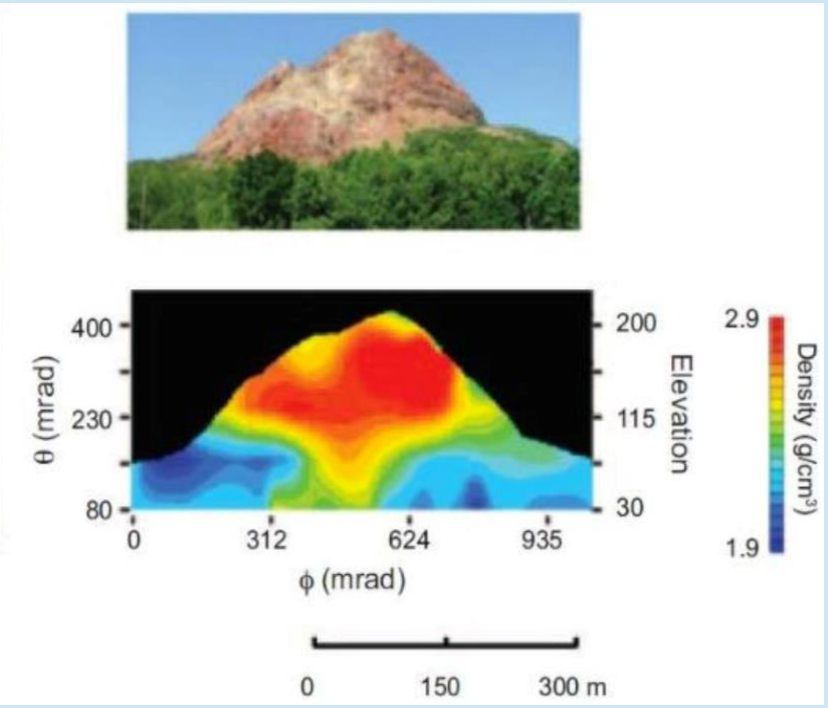
GEM in geology - muon radiography



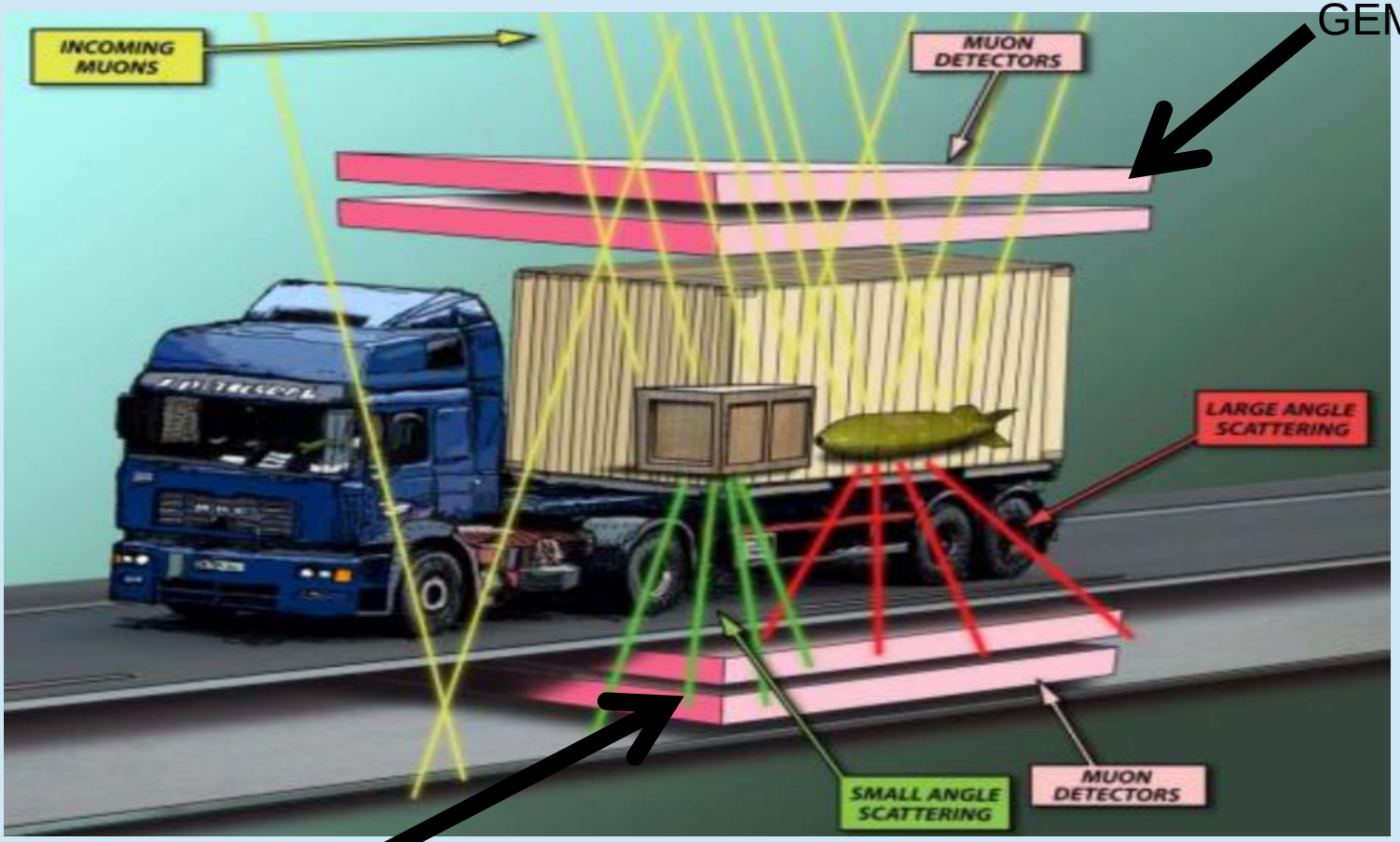
Muon detector prototype

Radiographic Map of the observed structure





GEM – Homeland security applications



Detector size matters

Detection of **nuclear contraband**, fissile materials and other illicit cargo.

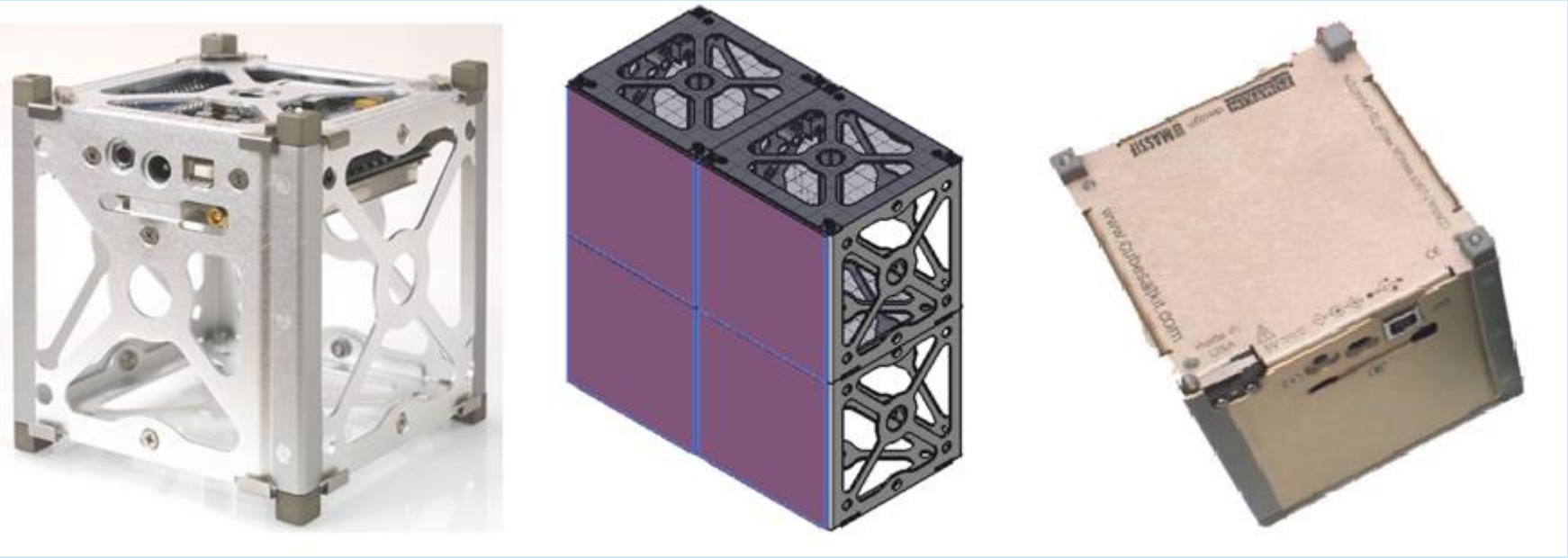
Gnanvo, Kondo & Grasso, Leonard & Hohlmann, Marcus & Locke, Judson & Quintero, Amilkar & Mitra, Debasis. (2011). Imaging of high-Z material for nuclear contraband detection with a minimal prototype of a Muon Tomography station based on GEM detectors. NIMP, 652. 16-20, 10.1016/j.nima.2011.01.163.

Scale also matters

New Project
MGEM – Modular GEMs

Main goals

- Compatibility
- Modularity
- CubeSat ready



Main MGEM detector features

Competitive on detectors market

- **Modularity, scalability**
- High efficiency
- Provides measurement of electromagnetic and corpuscular radiation
- Polarization measurements
- Pixelized readout system
- Work without cooling
- Work in harsh environment – in space and on the Earth
- **Compatible with CubeSat technology**
- **Lightweight**
- **Low power consumption**

Sumary GEM detector features

GEM = 3 in 1

1)Spectrometry
2) Imaging
3) Polarimetry

Modern, flexible, roubust detectors worth to be considered in present and further experiments.

Thank you