



# Cosmic ray tomography: from security applications to medical research

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(Tartu U, UCLouvain, Exeter U, Taltech, CERN)



Tartu, June 2021



# Our story

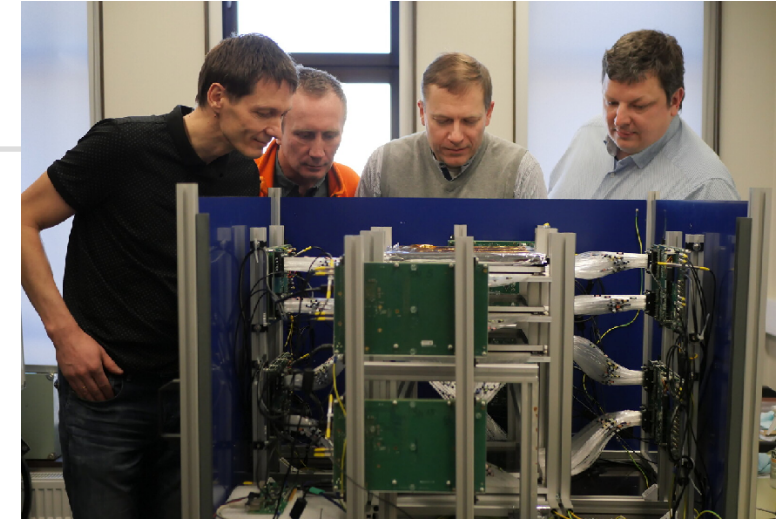
## Cosmic ray tomography



**2016** | Startup company GoSwift:  
Need to count people in cars.  
**The idea: cosmic ray tomography**



**2018** | MC modelling,  
establishing the **startup**  
**company GScan**



**2020** | **Working lab prototype**  
(TRL4). Preparations for  
Minimal Viable Product.

**2017** | **First feasibility study** in  
collaboration with Tartu U.



**2019** | Preparation of the  
**first patent application**.  
Starting to build a **lab**  
**prototype** in collaboration  
with Tartu U.

**2021** | Preparations for  
**production line. SilentBorder**  
project. **Medical tomography**  
in collaboration with KBFI.



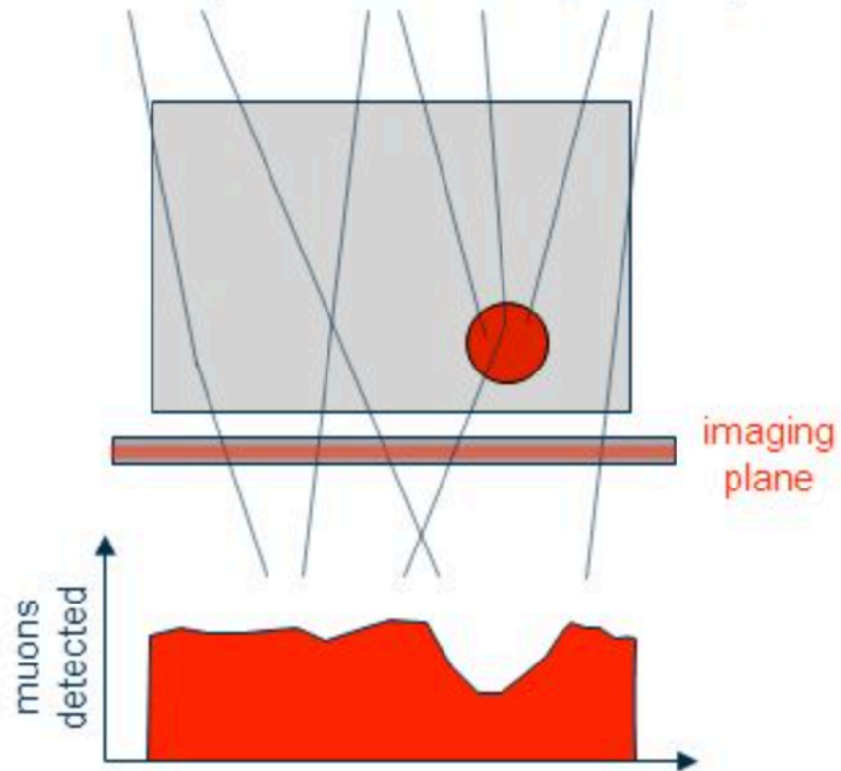




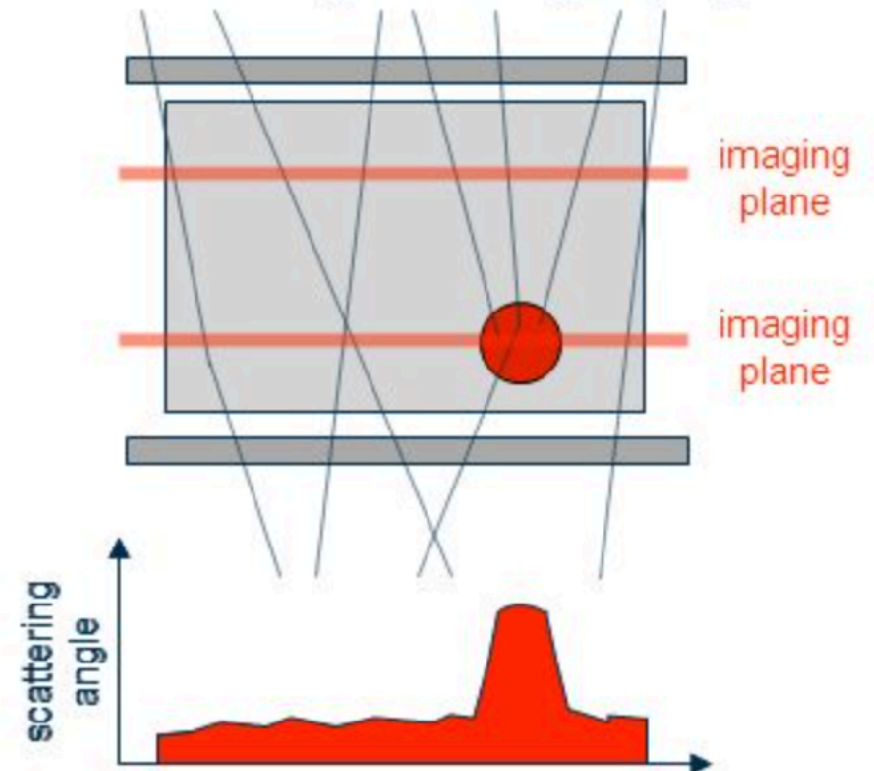
# Cosmic ray tomography (*aka* muon tomography)

| Absorption and/or scattering effect

## Absorption Radiography



## Scattering Tomography

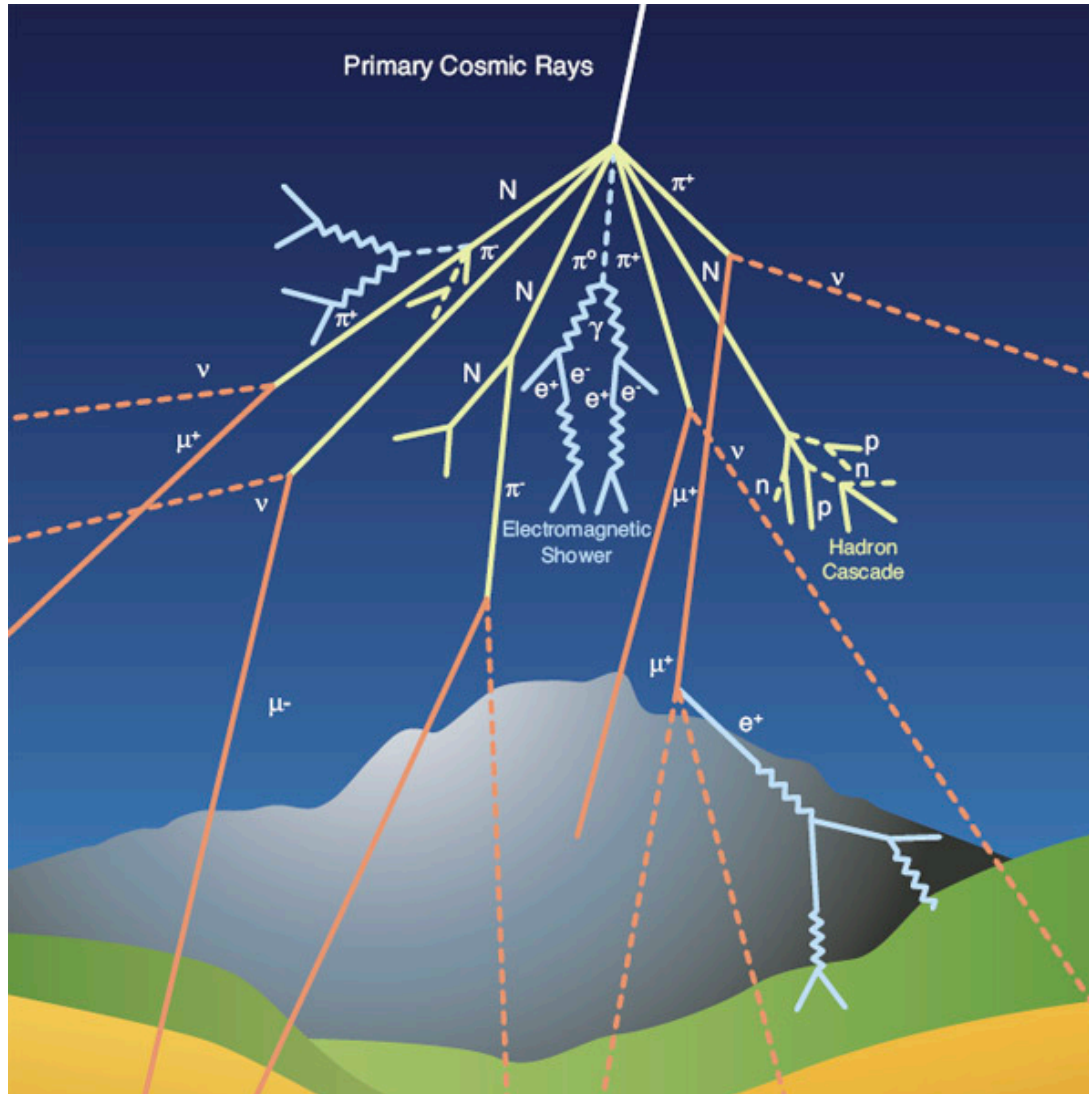


<https://arxiv.org/abs/1410.7192>



# Cosmic ray tomography

| Based on the secondary particles from cosmic rays

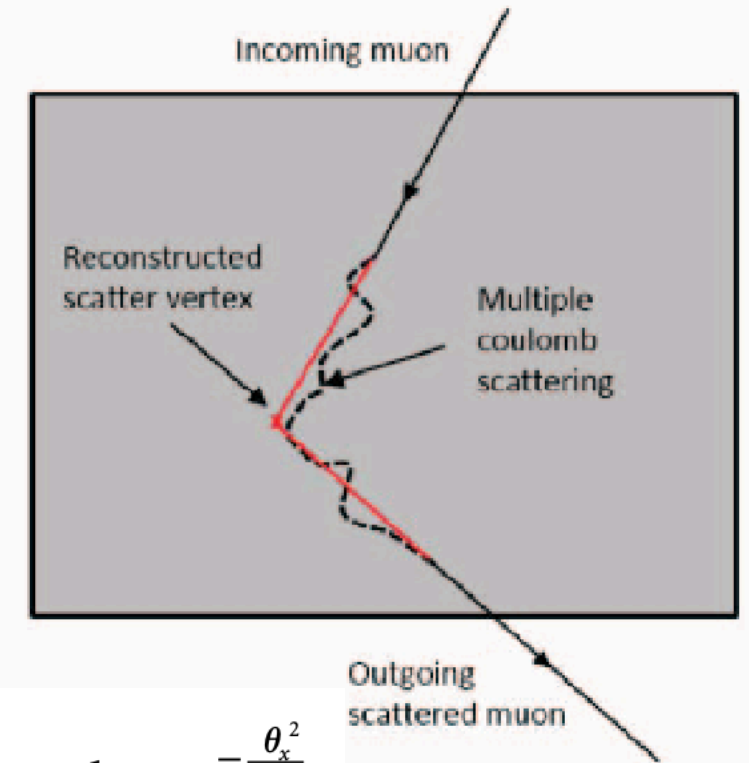
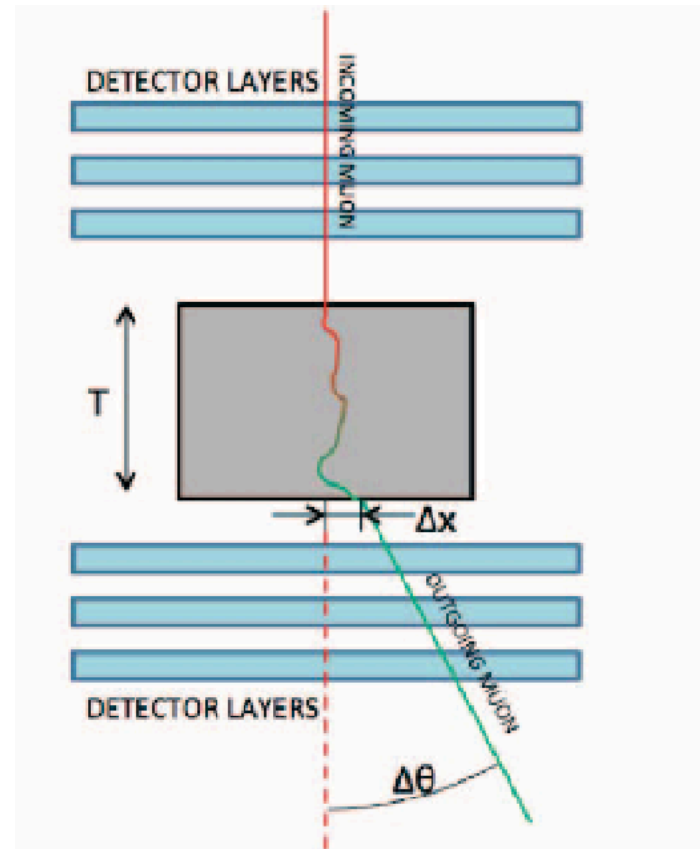


- Primary cosmic rays, mainly protons
- Secondary rays  
$$p + N(\text{Nitrogen/Oxygen}) \rightarrow$$
$$\rightarrow (\text{a lot of pions})$$
- Pions decay to muons
- Tertiary rays  
$$\mu + N \rightarrow \mu + N + e^+ + e^-$$
- For tomography, we use both **muons** and **electrons**



# (Multiple) scattering tomography


## Basic principles



$$\frac{dN}{d\theta_x} = \frac{1}{\sqrt{2\pi}\theta_0} e^{-\frac{\theta_x^2}{2\theta_0^2}}$$

$$\theta_0 = \frac{13.6}{\beta c p} \sqrt{\frac{L}{L_0}} [1 + 0.038 \ln(L/L_0)]$$

### Radiographic imaging with cosmic-ray muons

Konstantin N. Borozdin , Gary E. Hogan, Christopher Morris, William C. Priedhorsky, Alexander Saunders, Larry J. Schultz & Margaret E. Teasdale

*Nature* 422, 277 (2003) | [Cite this article](#)



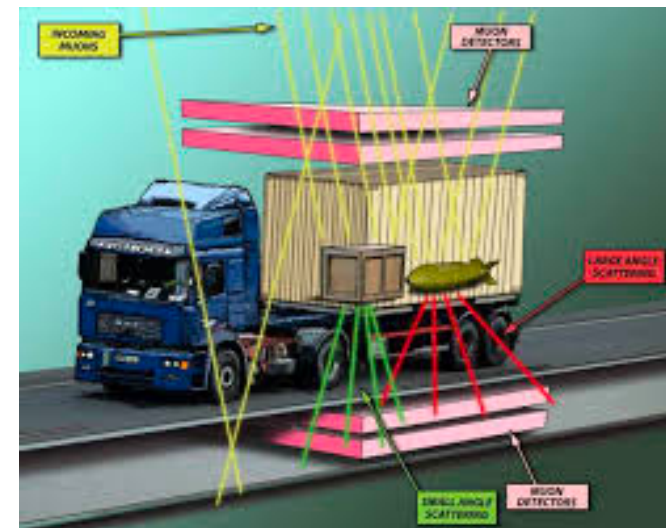
# Applications of CRT

## From geology to security

- Volcanoes, mineral exploration, tunnels
- Pyramids, infrastructure – dams, bridges, buildings etc
- Nuclear reactors, nuclear waste casks, decommissioning
- Security and cargo scanning
- Medicine

- Companies on CRT:

Decision Sciences, Ideon Tech, **GScan**



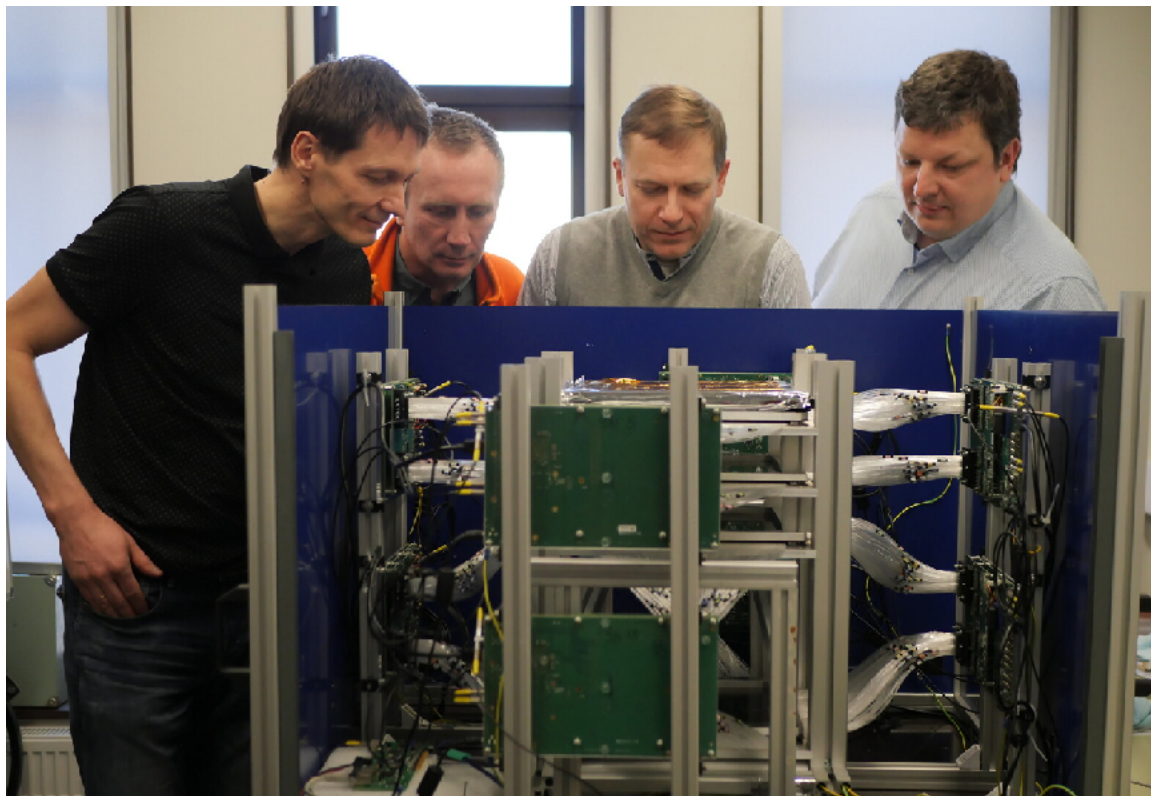
[https://en.wikipedia.org/wiki/Muon\\_tomography](https://en.wikipedia.org/wiki/Muon_tomography)

<http://www.scanpyramids.org/>



# Tomography system by GScan

## Most accurate and compact CRT system



Atmospheric ray tomography for low-Z materials:  
implementing new methods on a proof-of-concept tomograph

Gholamreza Anbarjafari<sup>b,f</sup>, Aivo Anier<sup>a</sup>, Egils Avots<sup>a,b</sup>, Anzori Georgadze<sup>a,c</sup>, Andi Hektor<sup>a,d,e</sup>, Madis Kiisk<sup>a,c</sup>,  
Marius Kutateladze<sup>a</sup>, Tõnu Lepp<sup>a,c</sup>, Märt Mägi<sup>a</sup>, Vitali Pastsuk<sup>a,c</sup>, Hannes Plinte<sup>a</sup>, Sander Suurpere<sup>c</sup>

<https://arxiv.org/abs/2102.12542>

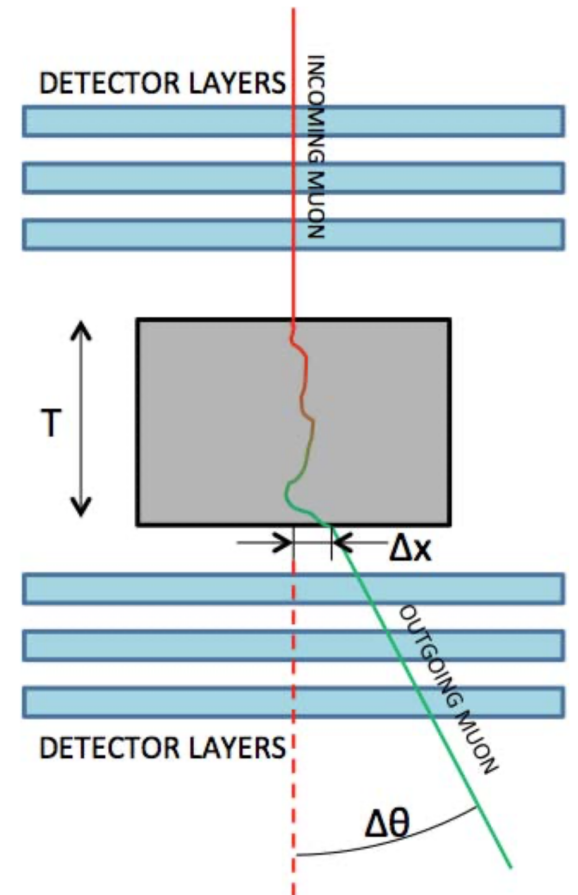
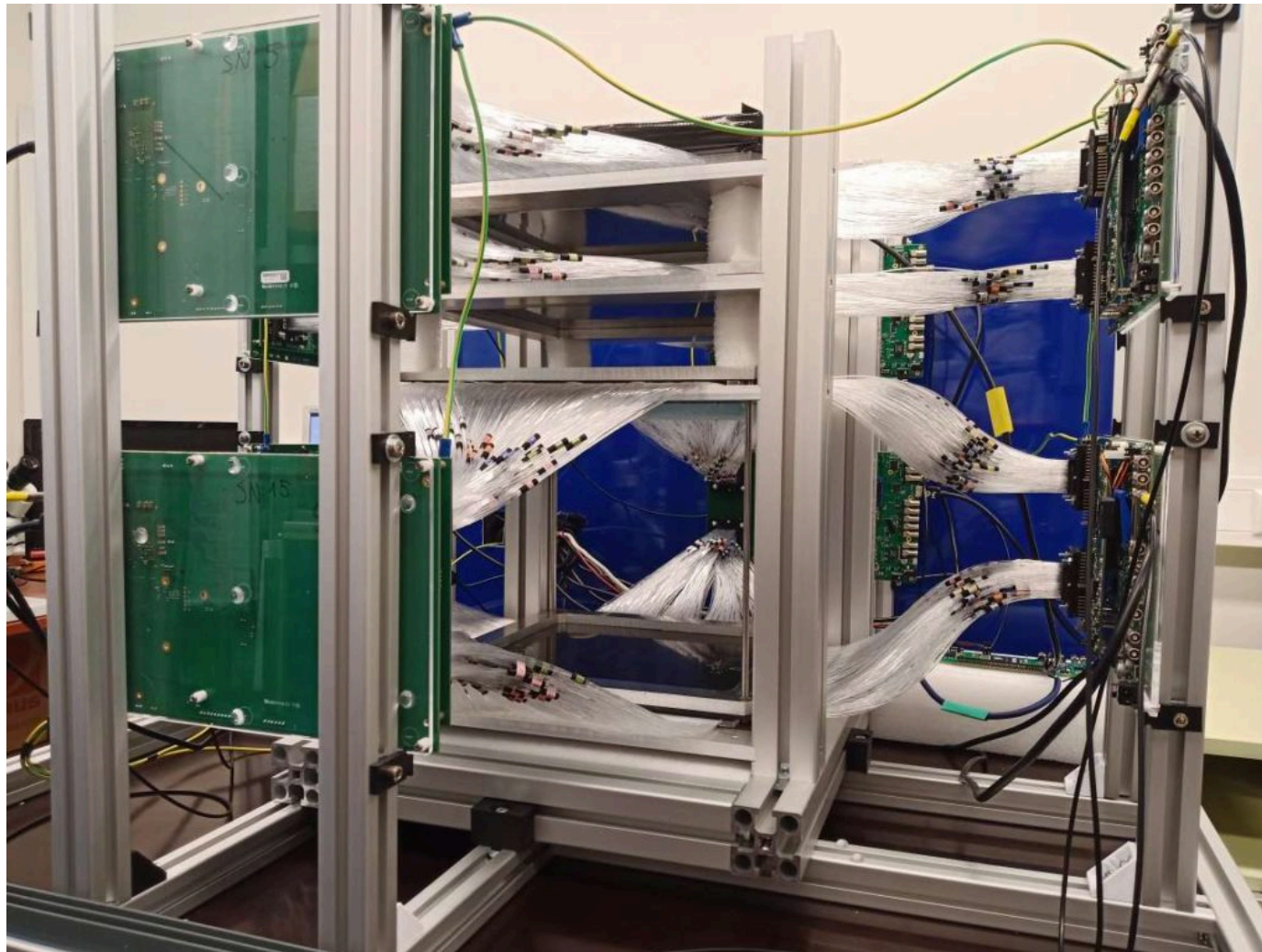
- Compact & very stable
- Superb angular resolution (mrad)
- Possibility to estimate the energy and particle type (muon/electron)
  
- Open up new applications:
  - Recognition of low-Z materials
  - Faster tomographic imaging
  - Security, custom & health apps





# Tomography system by GScan

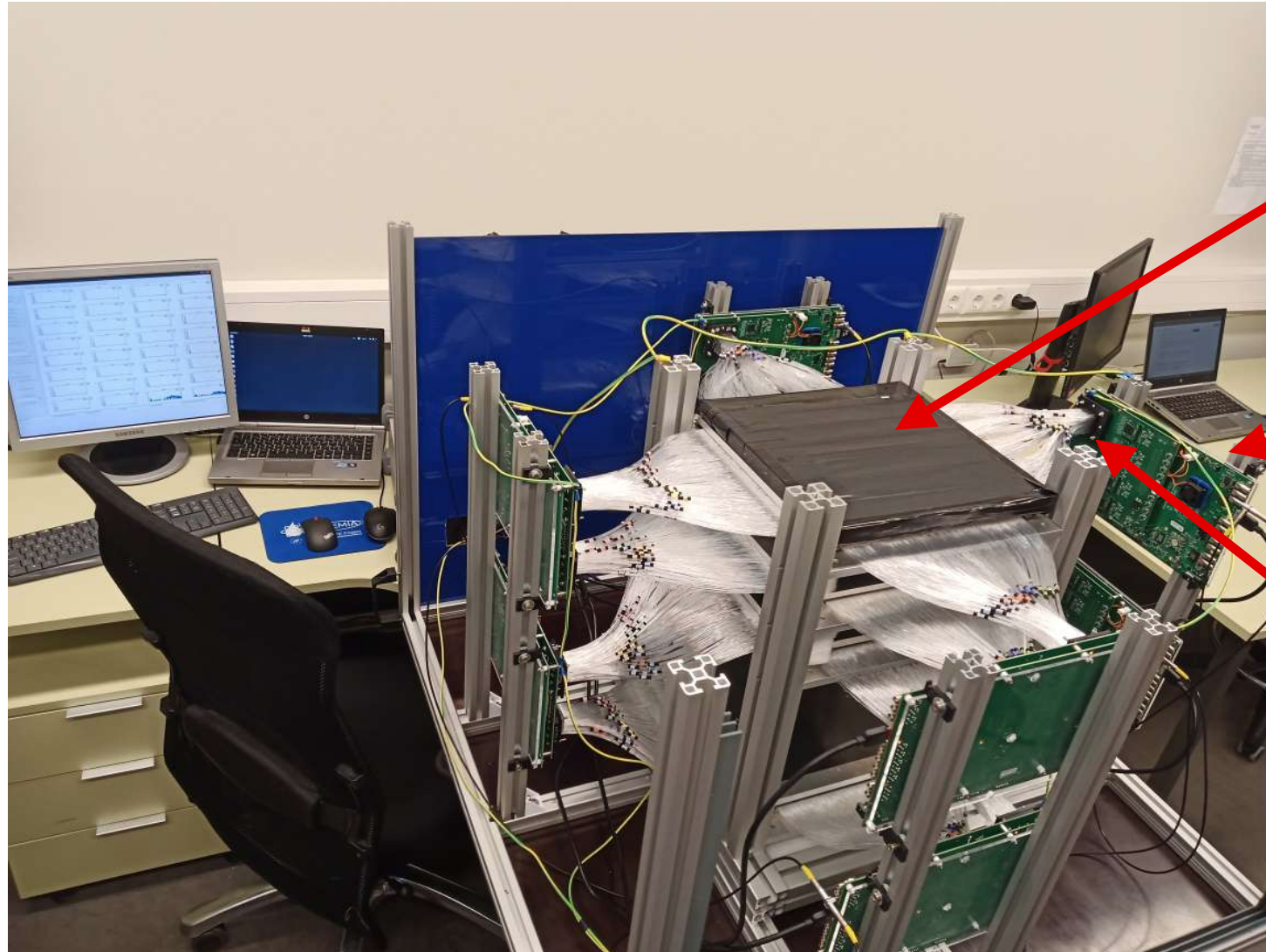
Most accurate and compact CRT system





# Tomography system by GScan

Most accurate and compact CRT system



Multilayer scintillator  
fibre array

Readout electronics

Photo detector (SiPM)

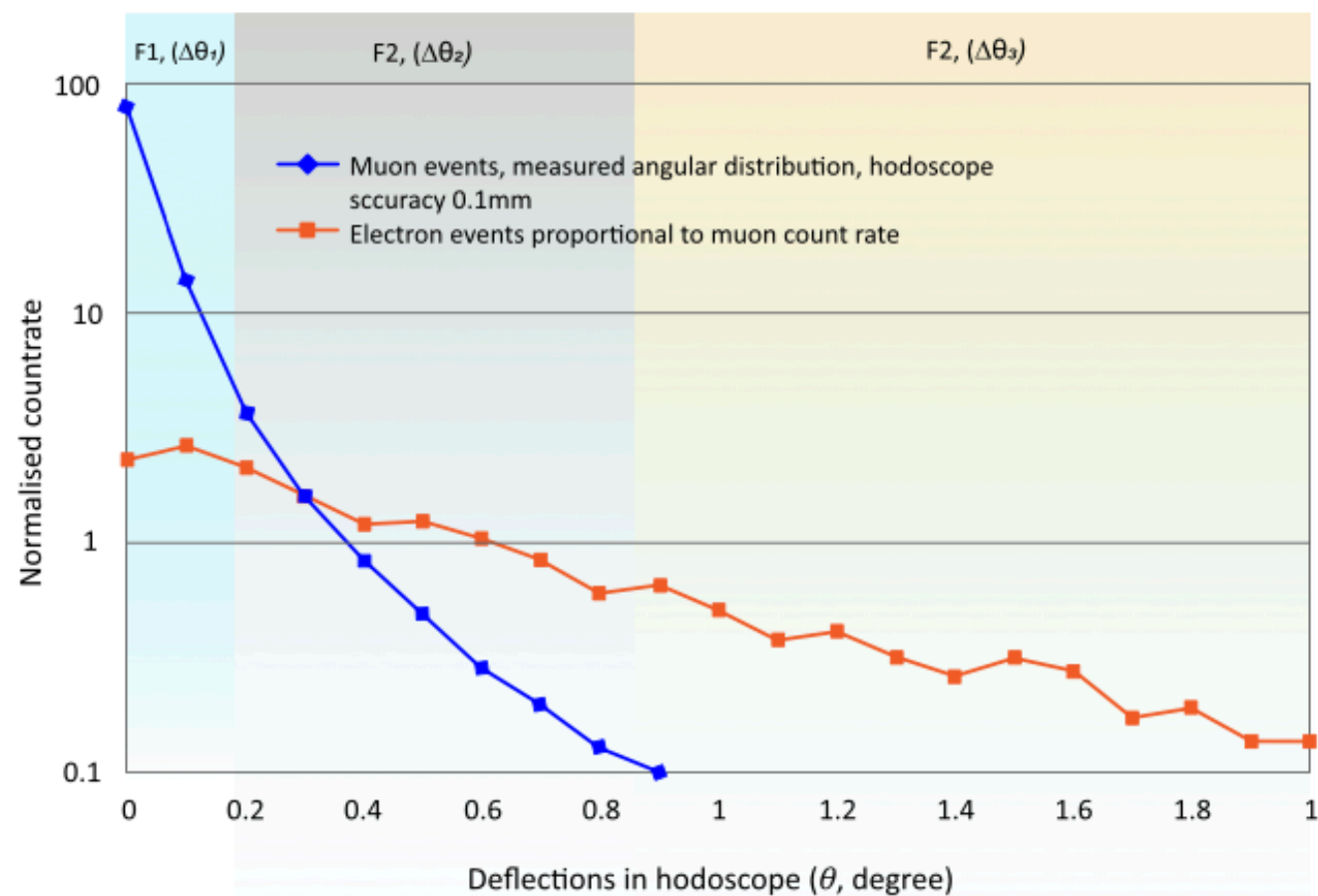
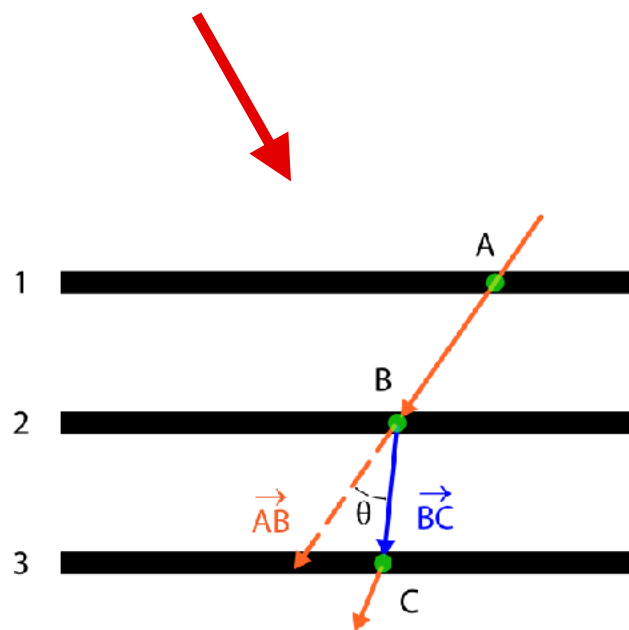




# Tomography system by GScan

## Most accurate and compact CRT system

Multilayer scintillator  
fibre array



We can classify the particle type and energy based on  $\theta$ !



# SilentBorder project by the Horizon programme

## Cosmic ray scanner for cars and containers

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- Budget: 7.5 M€ (May 2021 - May 2025)
- Tech partners: GScan (EE), Tartu U (EE), CAEN (IT), UCLouvain (BE), Sheffield U (UK), DLR (GE), SGS (CH)
- Tests and users: Finnish, Estonian & Turkish customs



# CosmoMed application to the EIC Pathfinder

## Cosmic ray scanner for health applications

- Budget: 2.9 M€
- Partners: GScan (EE), UCLouvain (BE), Exeter U (UK)
- CRT is not just a new health tech, it can open up new exiting research prospects in medicine!

## CosmoMed

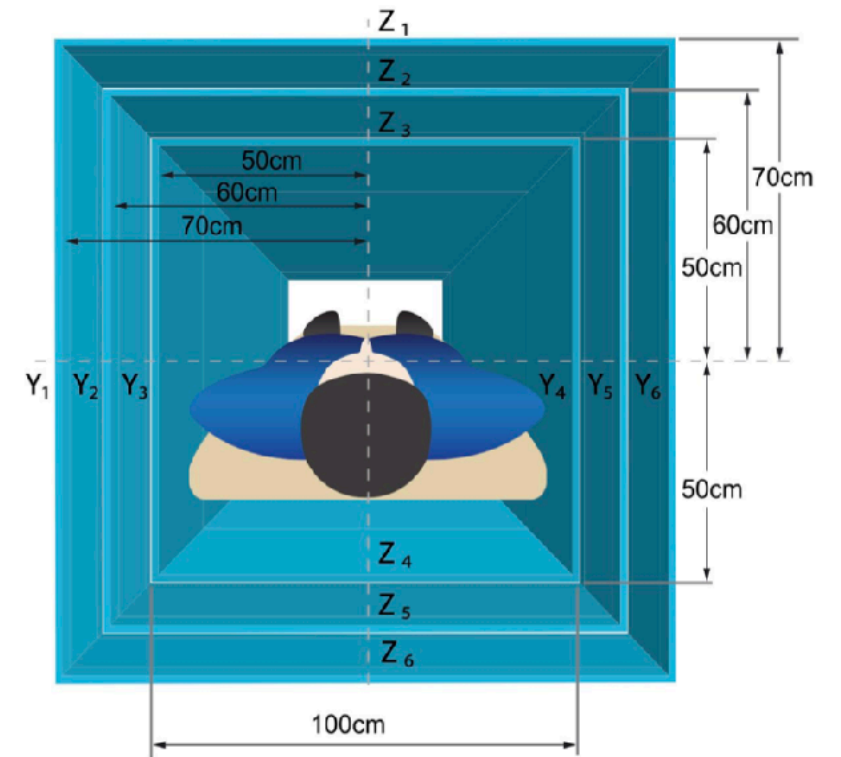
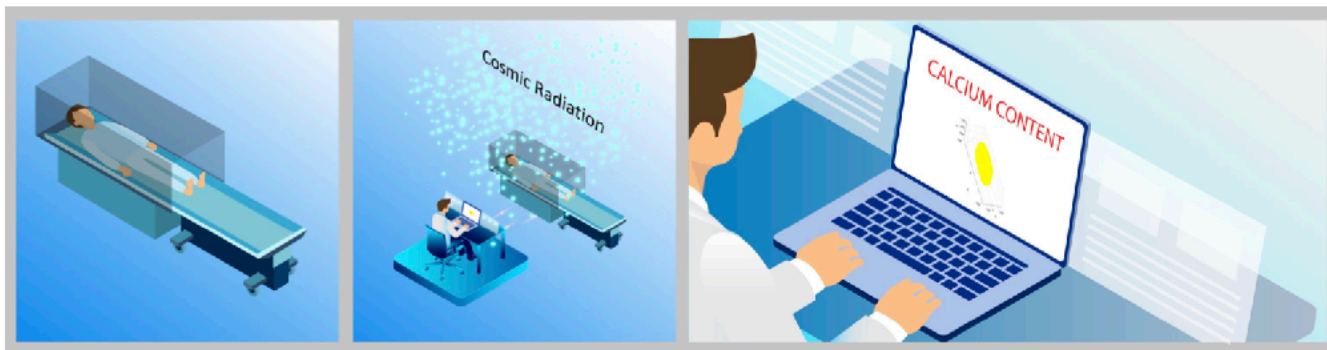


Figure 1: The concept of the planned demonstrator



# Takeaway messages

## From geology to security

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- Cosmic ray tomography is an emerging field of tomography
- Tech challenges: scintillator fibers, SiPMs, electronics
- Theory challenges: special tomographic algorithms
  
- If you are interested in collaboration or to work on detector tech and tomography, please contact: [andi.hektor@cern.ch](mailto:andi.hektor@cern.ch)





Thank you for your attention!

