

High performance Electronics and detectors @ Idea²

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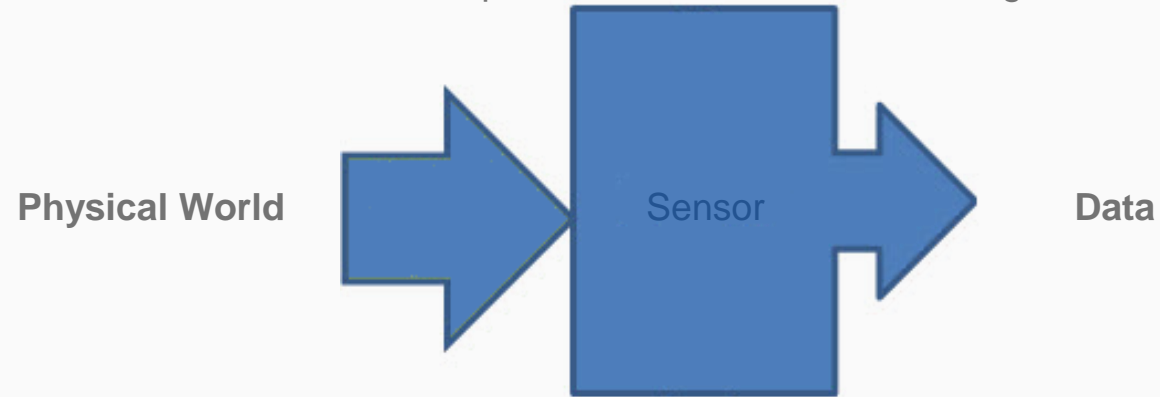
A bit of history

- This activity started in the very early stages of Idea2 with the ITN Marie Curie project EDUSAFE
- Purpose: study a new type of high performance AR system
- Added value: implementing electronic acceleration of artificial vision by using concepts learned to perform a fast trigger in LHC environment
- Based on a new invention (R. Cardarelli) the WRM (Weighting Resistive Matrix)
- A resistive network designed to provide a fit of the input data
- Analog Computing – High Performance Computing – Neural Networks

The problem

Sensors produces BIG DATA

A sensor is whatever is able to produce an observable encoding events in a given format



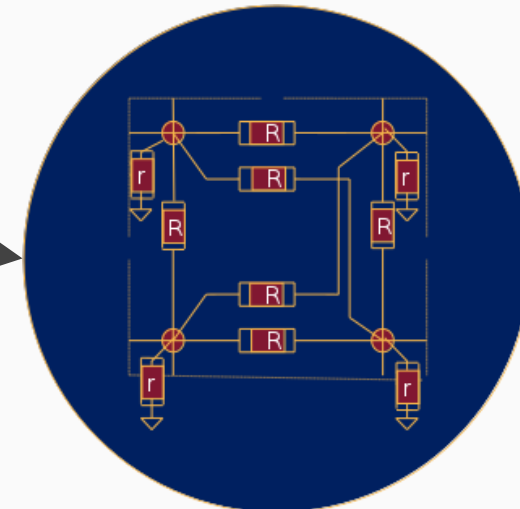
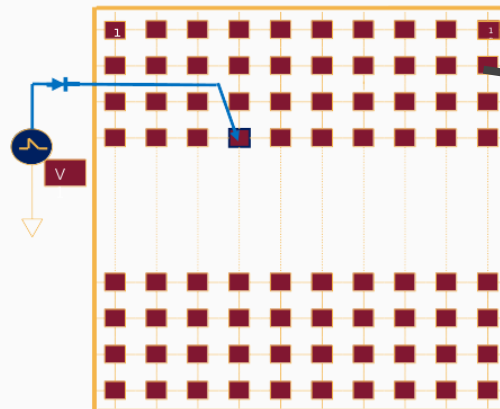
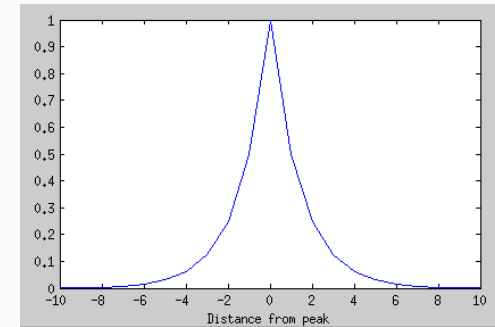
Sensors produce data faster than we can process and store

We need to interact with data to take decisions in real time

We need to operate as close a possible to the sensor

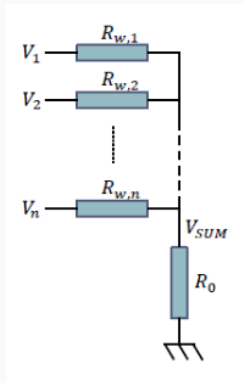
Weighted Resistor Matrix - WRM

- The WRM is an analog computer performing a regression on input data and providing an estimation of the best fit parameters and the associated likelihood
- An interconnected repetitive resistive network subjected to an electrostatic potential provides the necessary elements for a regression-like computation:
 - The diffusion potential as a notion of distance
 - The superposition principle allows to add voltages to build a correlation estimator



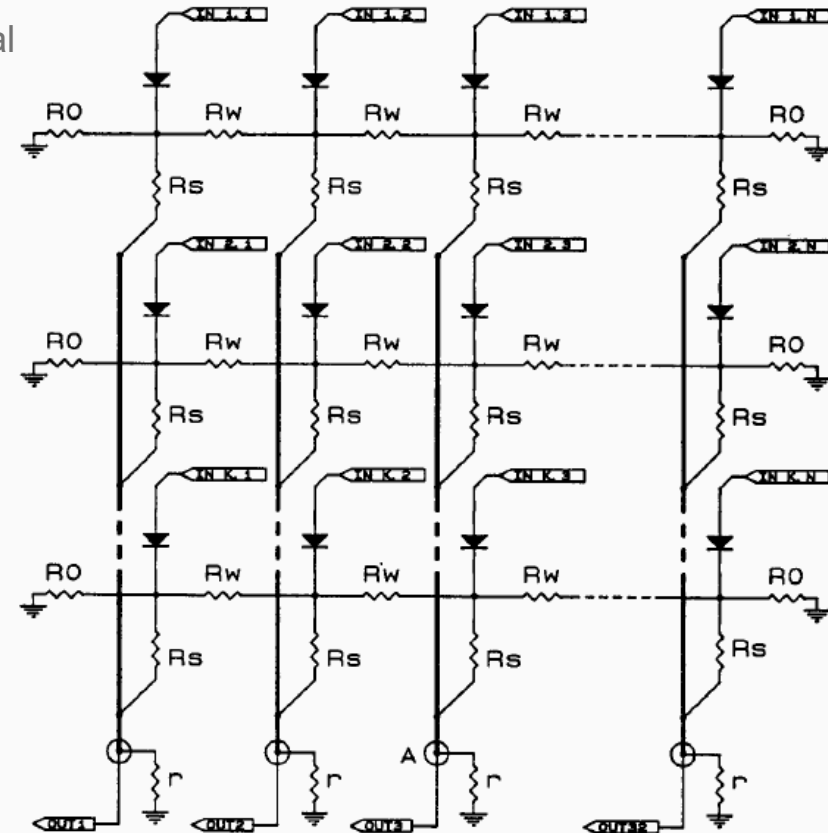
Weighted Resistor Matrix - WRM

- From: R. Cardarelli et al.; “On a very fast topological trigger”; NIM A324(1993)
- A fast tracking trigger for LHC experiments
- The ratio R_W/R_S determines the voltage diffusion rate
- It is coupled to a parallel network Performing the sum to test patterns



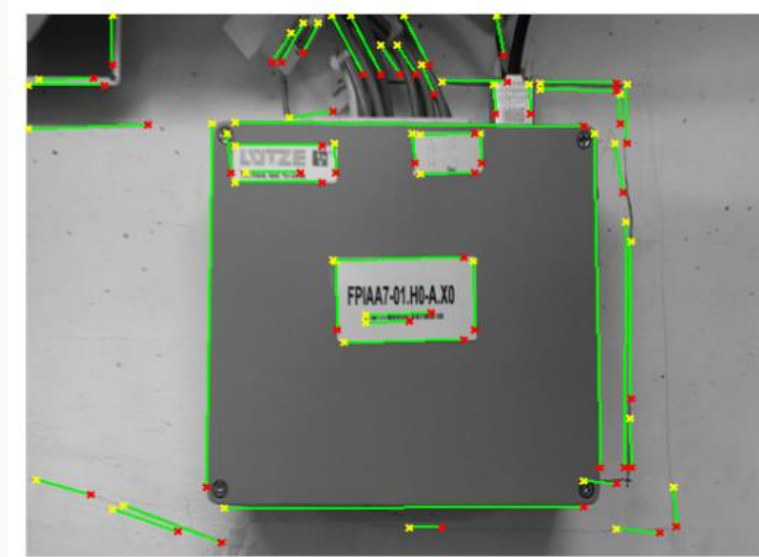
If $R_0 \ll \min(R_{w,1}, \dots, R_{w,n})$

$$\Rightarrow V_{SUM} = w_1 V_1 + w_2 V_2 + \dots + w_n V_n$$



WRM for EDUSAFE

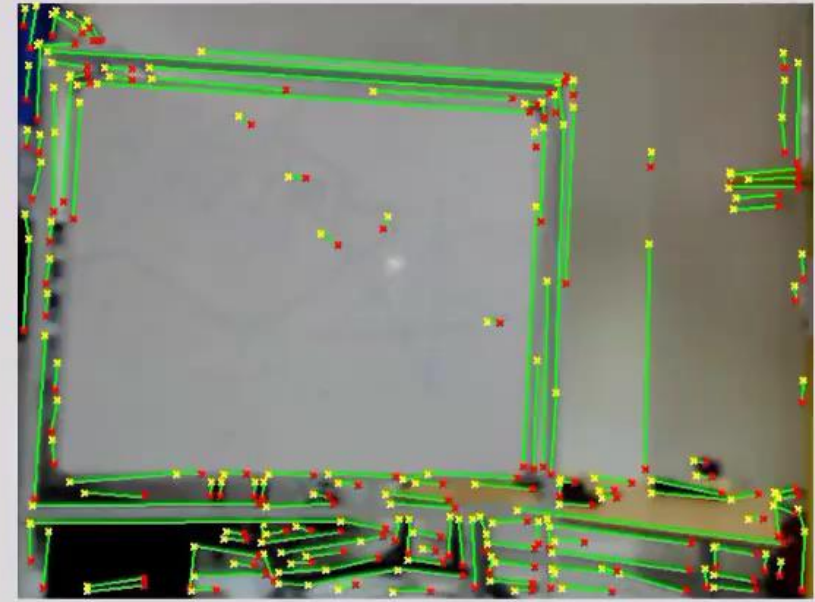
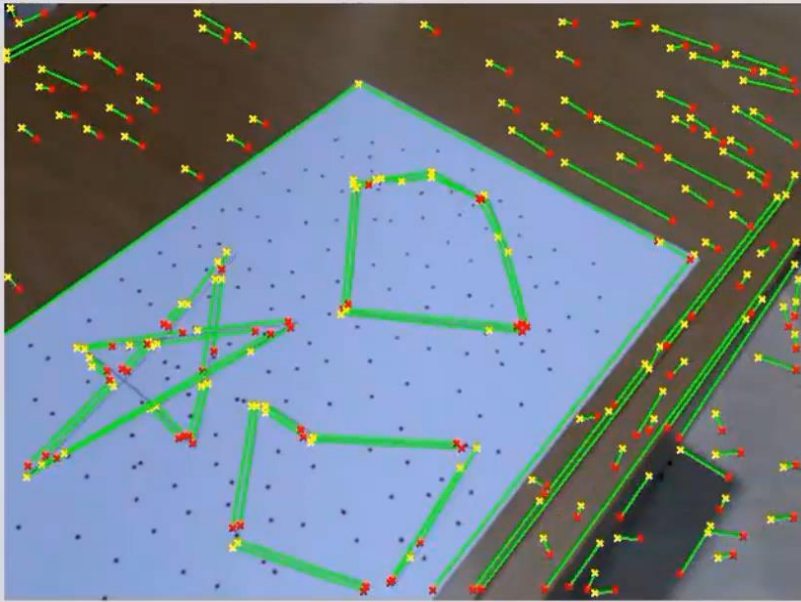
- EDUSAFE [1] is a Marie Curie ITN project focusing on research into the use of Virtual and Augmented Reality (VR/AR) during planned and emergency maintenance in extreme environments.
- Expanding the WRM: from particle physics to computer vision -> It was born to detect linear correlations like particle tracks.
- Original WRM (1995) was able to process 1Mpixel in ~1ms. With new technologies, the speed increases accordingly
- The idea is to use the WRM with a tracking algorithm
- The WRM device can play a hardware acceleration role
- Feeds tracking algorithm with pre-extracted features. Allowing them to save valuable time.



[\[1\] EDUSAFE Website](#)

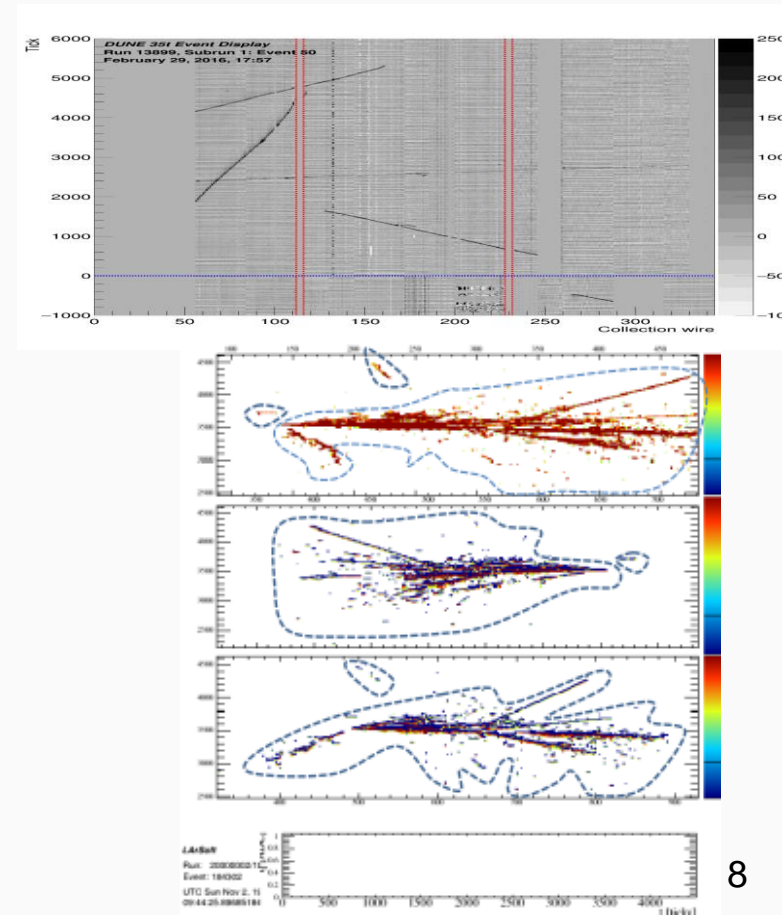
FROM PARTICLE TRACKS TO FAST IMAGE ANALYSIS

- THE IDEA: IN HEP WE CAN RECOGNIZE SIMPLE 1D TRAJECTORIES IN $\sim 10^{-9}$ s
- IN COMPUTER VISION WE NEED TO PROCESS 1 M PIXEL IN $\sim 10^{-2}$ s
- WE CAN USE 10^7 LONGER TIME TO PERFORM MUCH COMPLEX PATTERN RECOGNITION
- REBUILD THE IMAGE STRUCTURES IN TERMS OF A PARAMETRIC REPRESENTATION OF ITS ELEMENTS



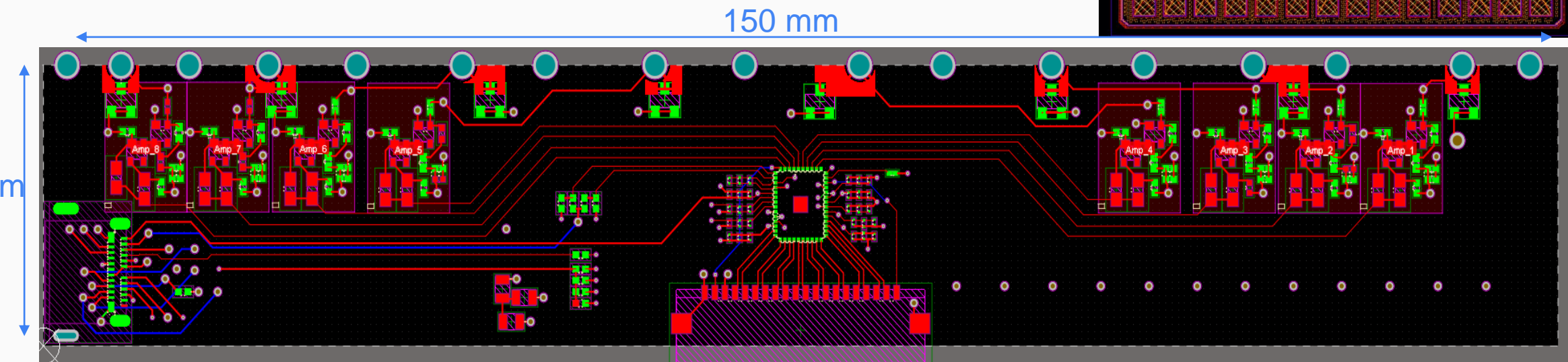
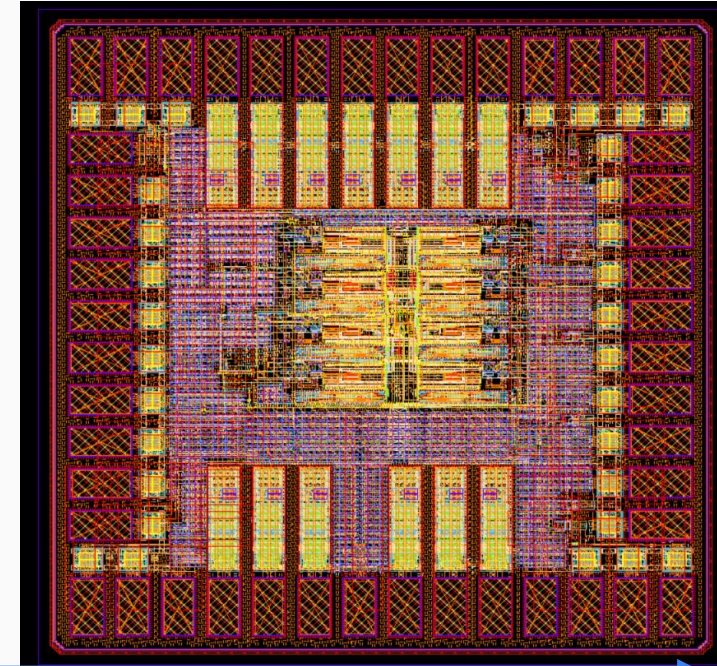
WRM for Neutrinos: Particle Data Analysed as Images

- Collected data is similar to a normal grayscale image
- The idea is to use the WRM to filter out the noise
- Crop then region of interest
- New WRM layout is object of the present proposal, optimized for the neutrino trigger problem
- We want to obtain a fast trigger and optimal zero suppression system!



New detectors and electronics for HL-LHC and beyond

- Requested an increase of performance under any aspect
 - Speed, resolution, noise rejection, radiation tolerance
 - The electronics must be developed to the limit of existing performance
- New technology Si-Ge hetero-junctions
 - Future working frequency toward 1 THz!!!
- Test performed in Idea2

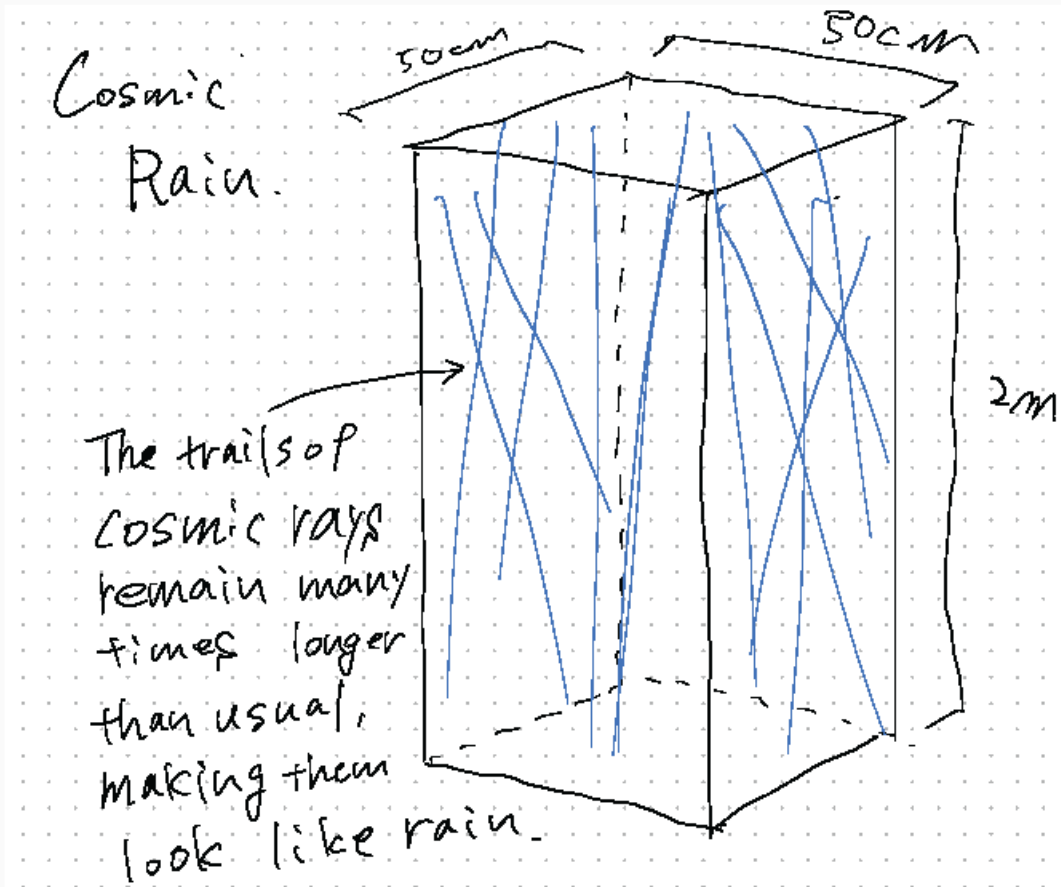


Future applications

Performance: large area fast tracking systems

- ATLAS HL-LHC upgrade
- New dark matter experiment searches, based on enclosing large monitored volumes to search for rare events
- New applications based on the cosmic rays background exploitation:
- Muon tomography for home land security, large infrastructures integrity, geological prospections, cultural heritage searches
- Future colliders....

New proposal to demonstrate advanced concepts to general public



- Several «lightweight» RPC detector planes with XY readout
- Cosmic rays detected and traced
- Using an iper-simplified WRM concept to identify the track pattern
- Using some artistic light effect to visualize it
- Allow some interaction with the user....

The concept is to provide a full analog device with no classic computing intermediation

This must be perceived as a natural process in front of the observer