REAL TIME APPLICATIONS FOR ASTROPARTICLE PHYSICS

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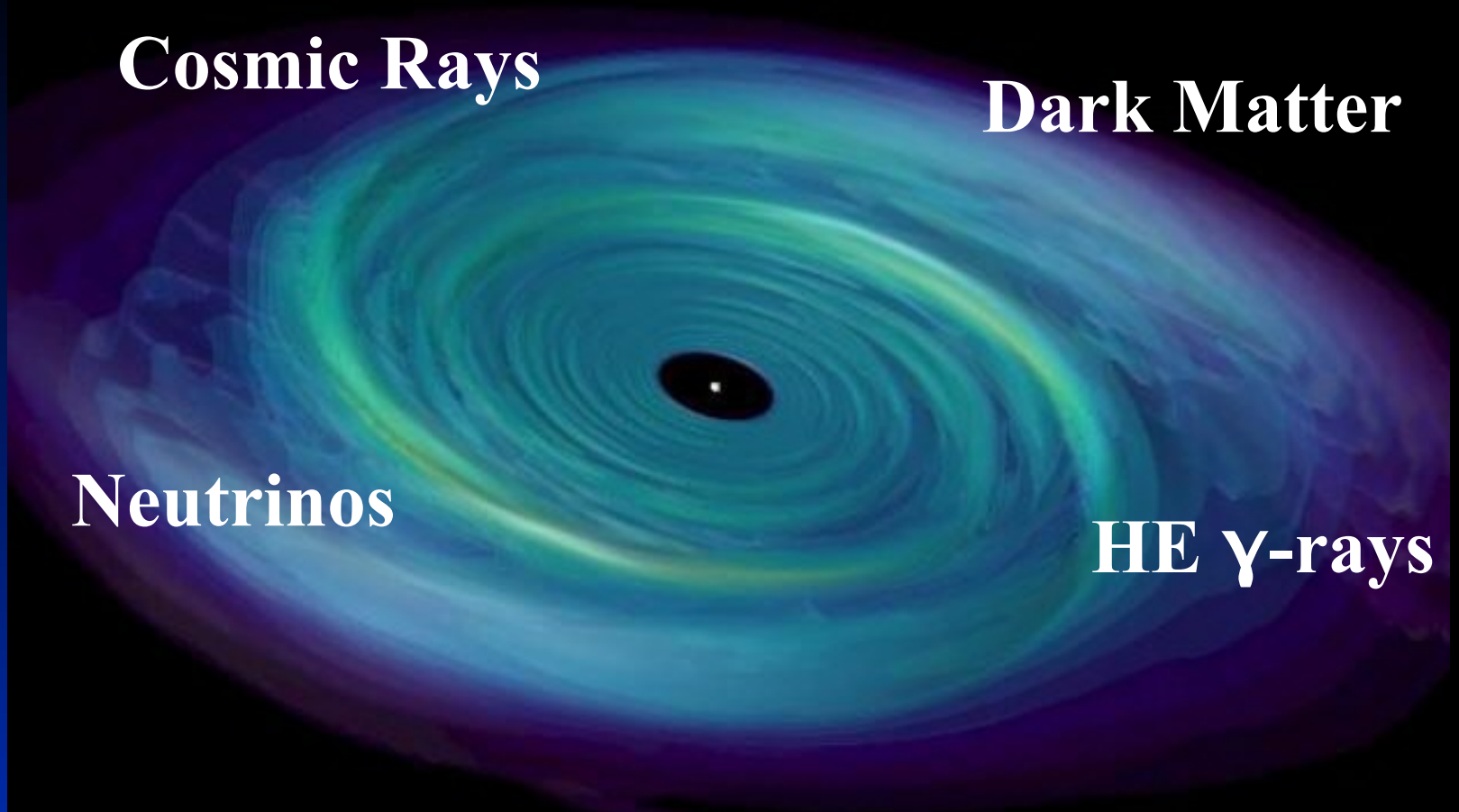
Astroparticle Physics

Branch of physics that studies elementary particles of astronomical origin. It is a relatively new field emerging at the intersection of:

- **Particle Physics**: Study the elementary constituents of matter and radiation, and their interactions.
- **Astrophysics**: Study of the universe, including celestial objects and their interactions
- **Cosmology**: Study of the structure, laws and history of the universe at large scale.

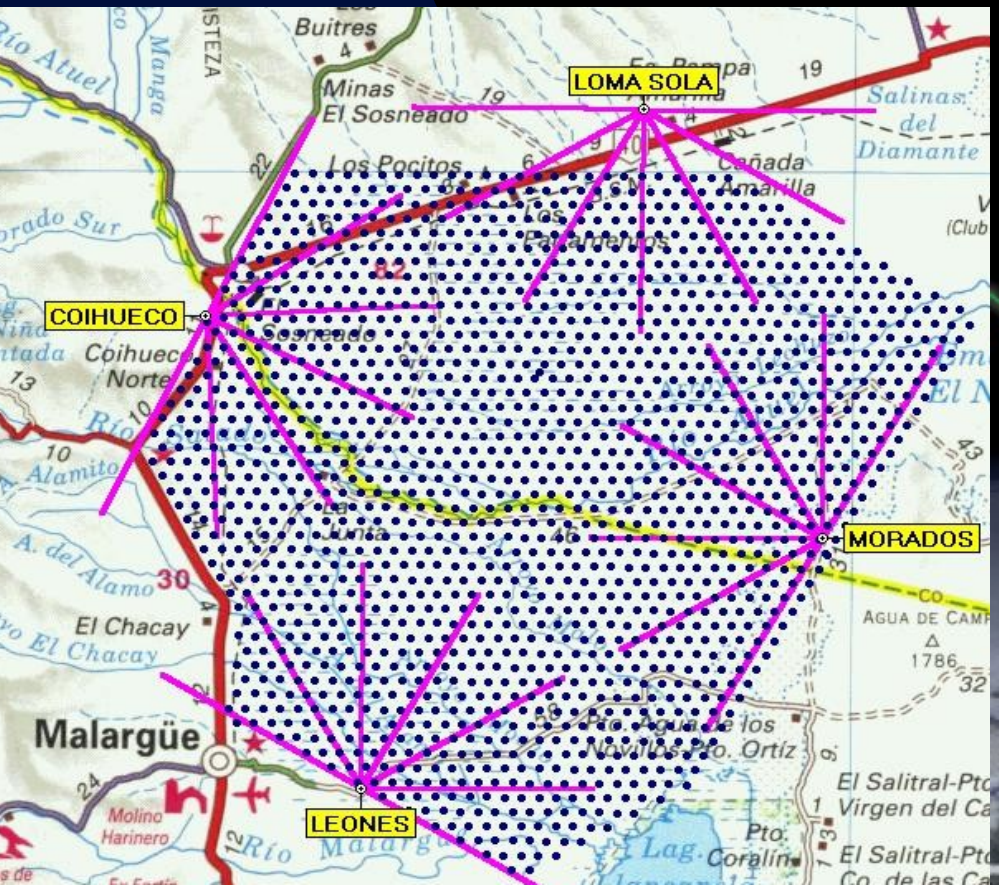
The FIVE messenger for astroparticle physics

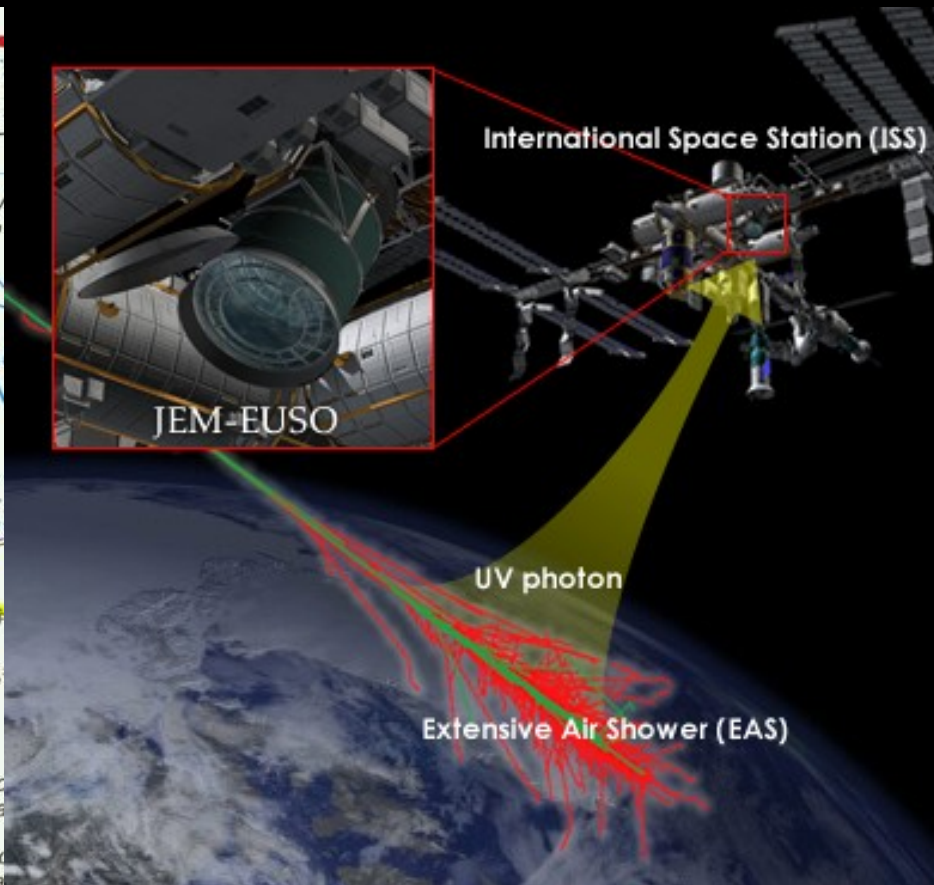


Cosmic Rays

First evidences of the existence of Cosmic Rays are one Century old but their origin still a mystery

They are charged particles originated from outer space and they were the precursors of the astroparticle physics





High energy γ-rays

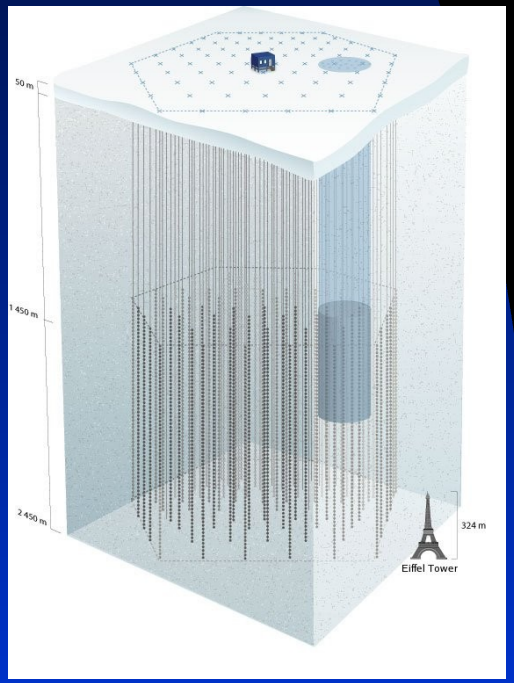
Photons in the high energy extreme of the electromagnetic spectrum

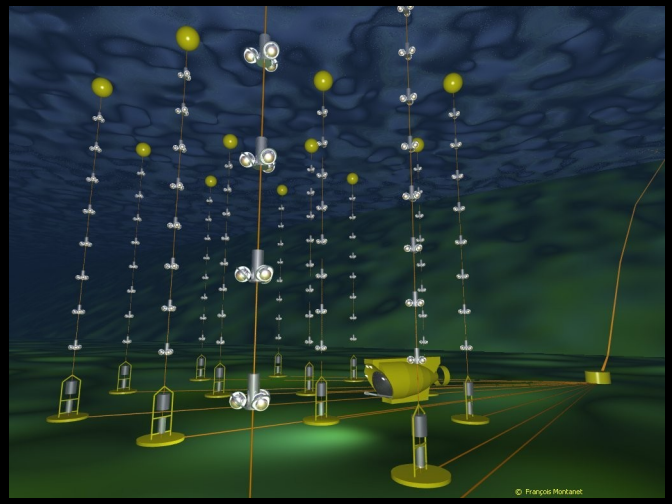
Radio	Microwaves	Infrared		UV	X-rays	γ-rays

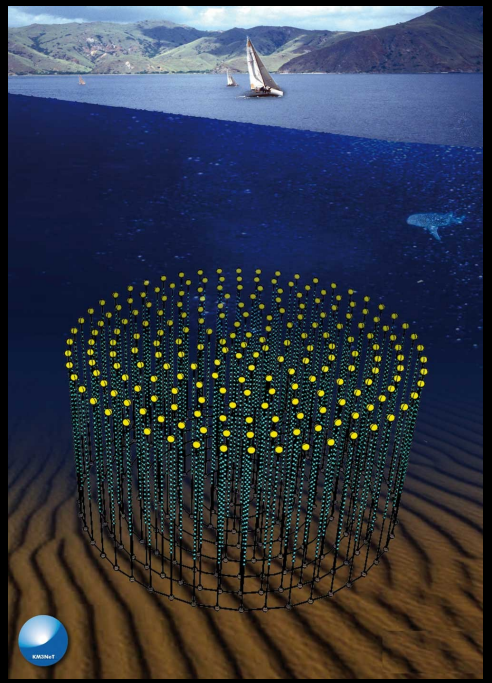
Cherenkov Telescopes:

Neutrinos

- Low interaction probability, which make them difficult to detect but very interesting
- Currently only astrophysical neutrinos detected from Sun and SN 1987A





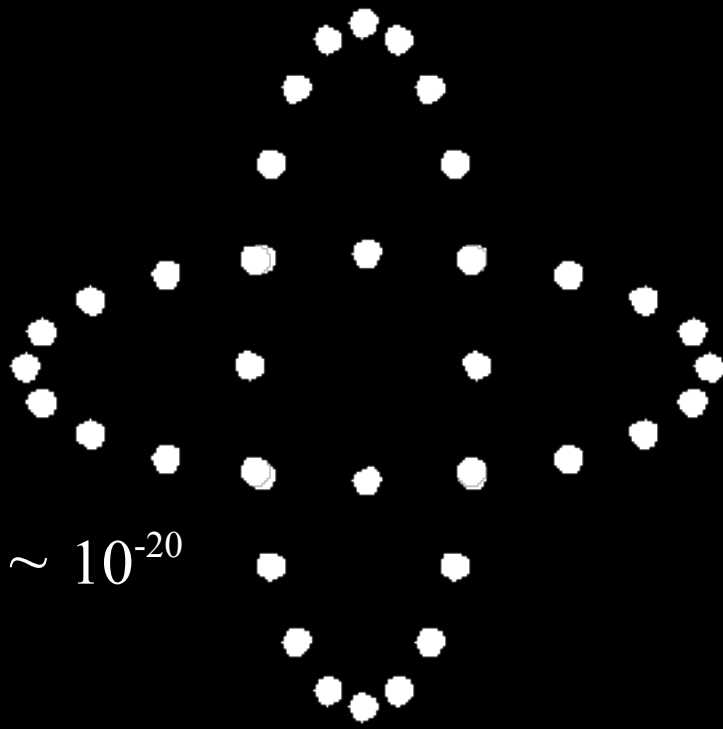


Dark Matter

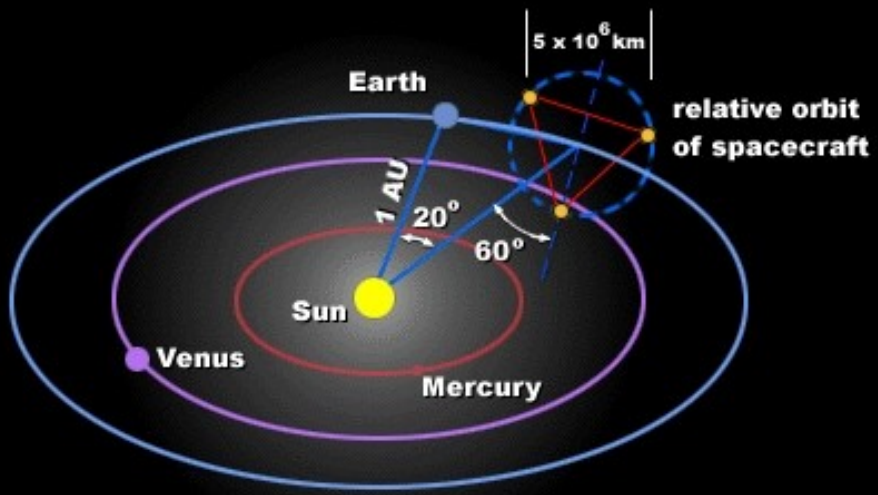
We still do not know what is it …
although it accounts for most of the matter in the universe!

Gravitational waves

Fluctuations of the space-time that propagate as waves



$dh/h \sim 10^{-20}$

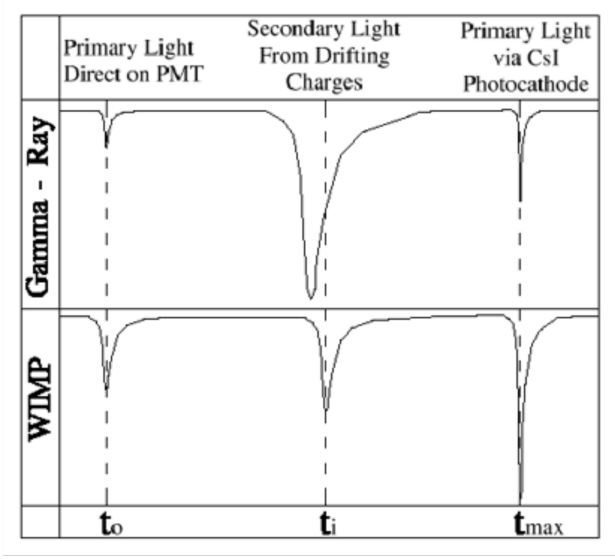


Real Time Applications

- Particle detectors
  - Experiment like Xenon, Dama and Cresst (Dark Matter), Borexino (Neutrinos) or Fermi-LAT (γ-rays)
  - Design to detect (and reconstruct) the particles reaching the detector
- Sampling of Extensive "Air" Showers
  - Detection of secondaries of large shower of particles
- Real time control
  - Global control of experiment or subsytems
  - Control and adjustment of mechanical parts
- And many others, which I may be skipping or forgetting ...

Particle Detectors (I)

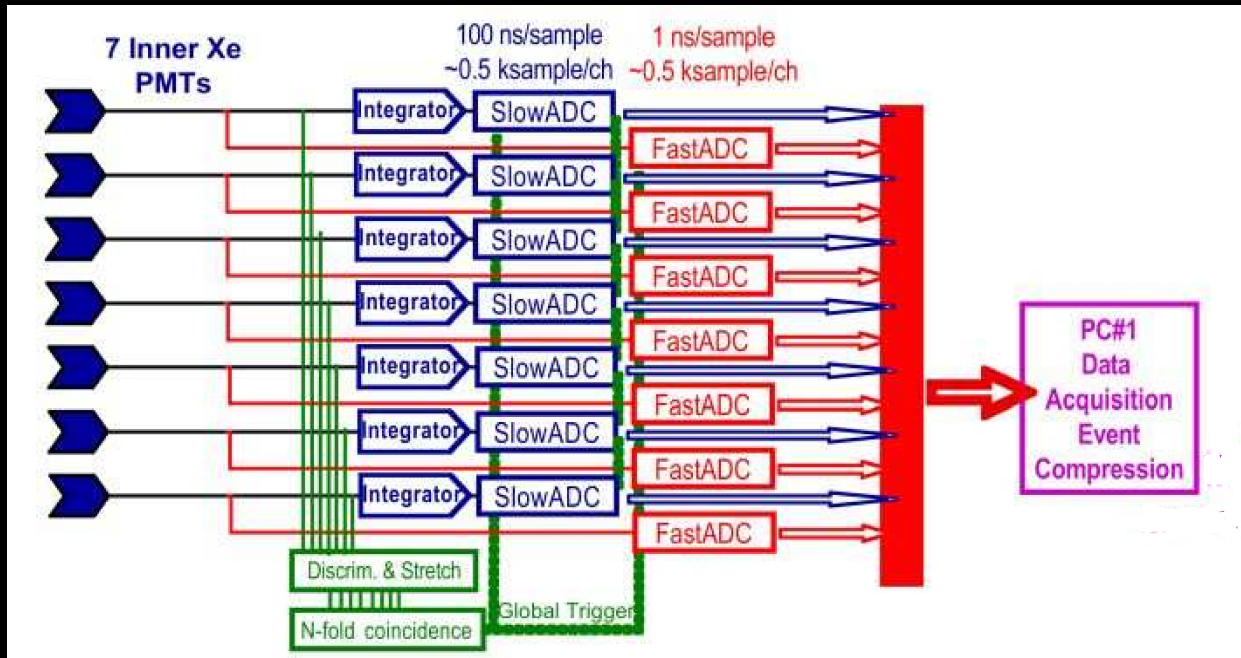
- XENON
  - Dark Matter experiment in Gran Sasso



Two different ADC channels (slow and fast)

Fast allows Xenon to differentiate

Slow allows Xenon to see the three pulses

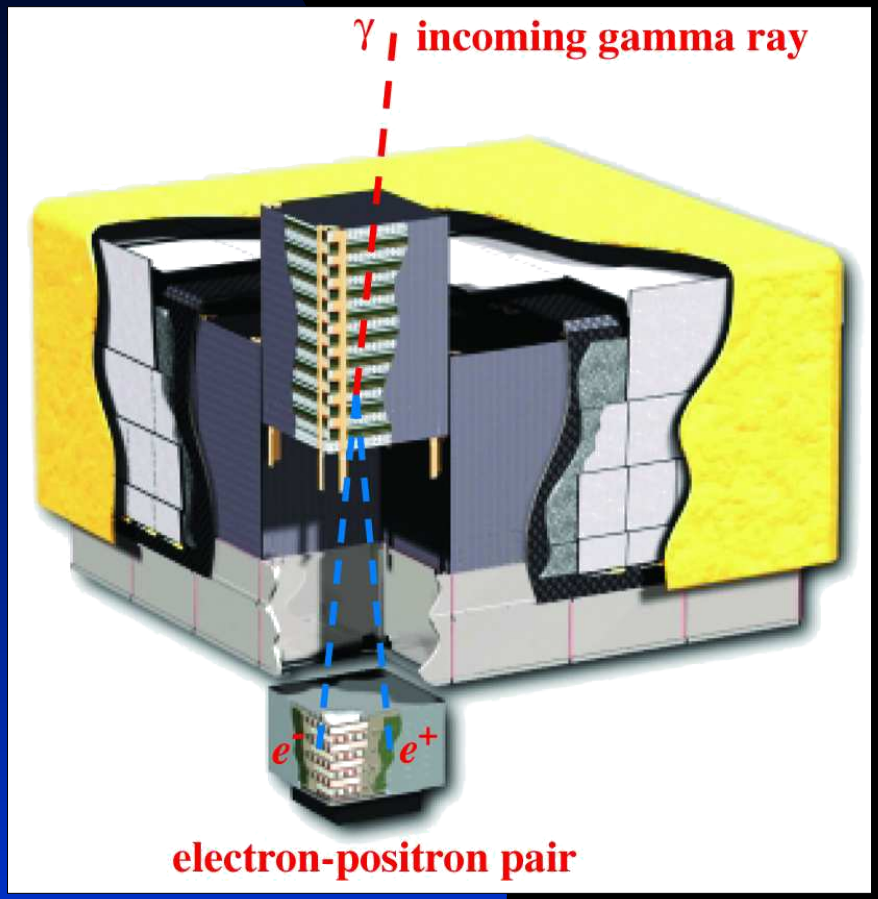


$T_{max} - t_o$ 25 s

Pulses ≈few ns

Particle Detectors (II)

- FERMI-LAT
  - Calorimeter in orbit to detect eletron-positron pairs produced by incoming gamma-rays



On board real time trigger decision

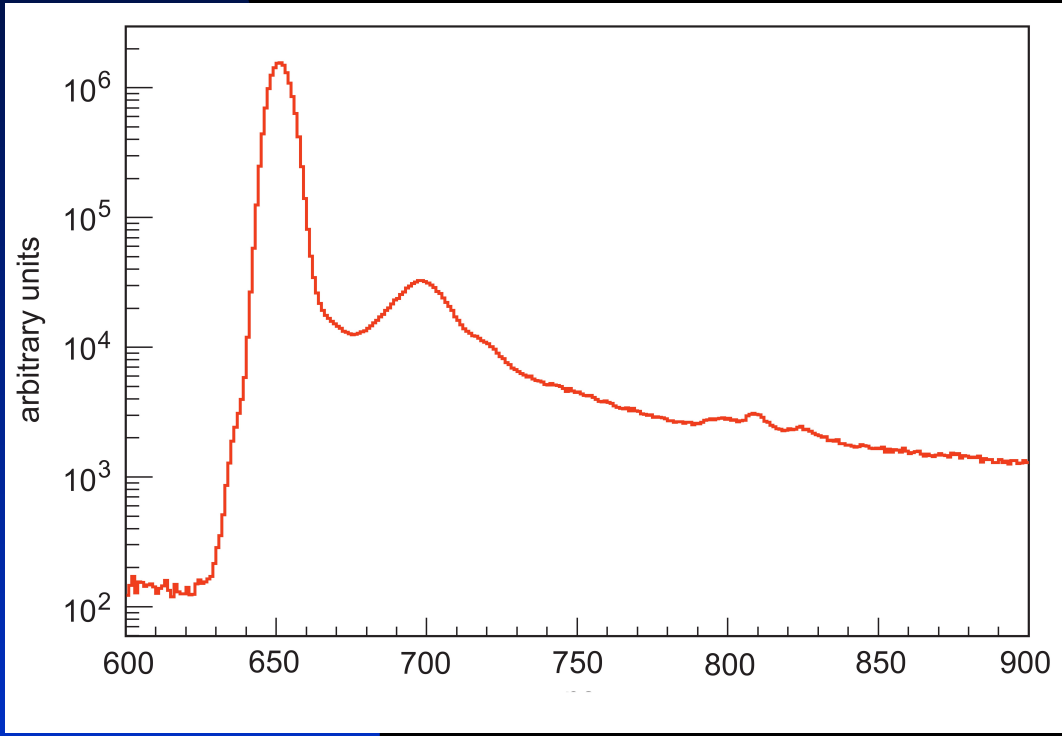
Digitalization of calorimetric signal

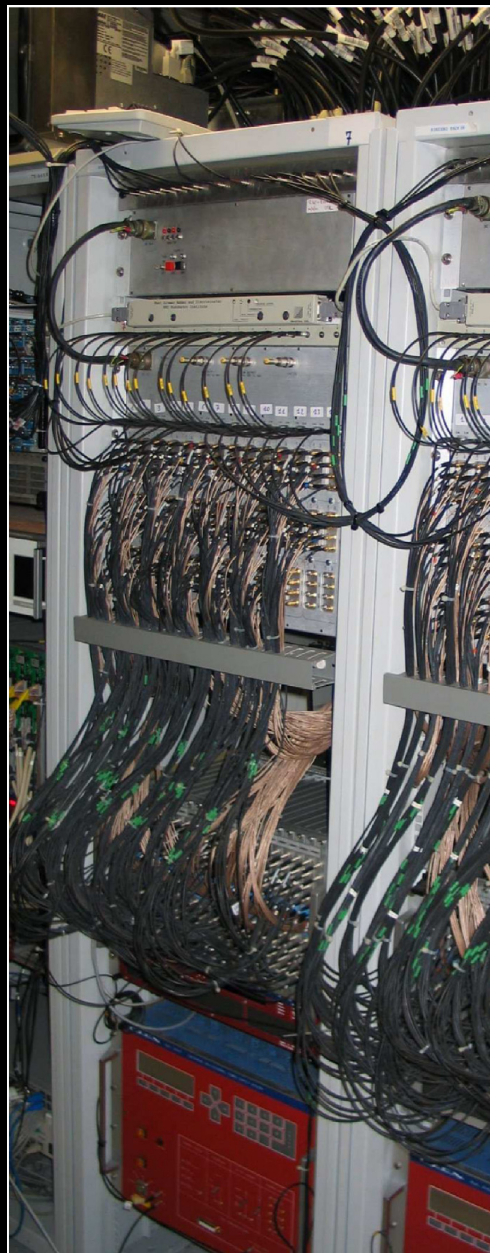
Requirements far from LHC but … in the space

Particle Detectors (III)

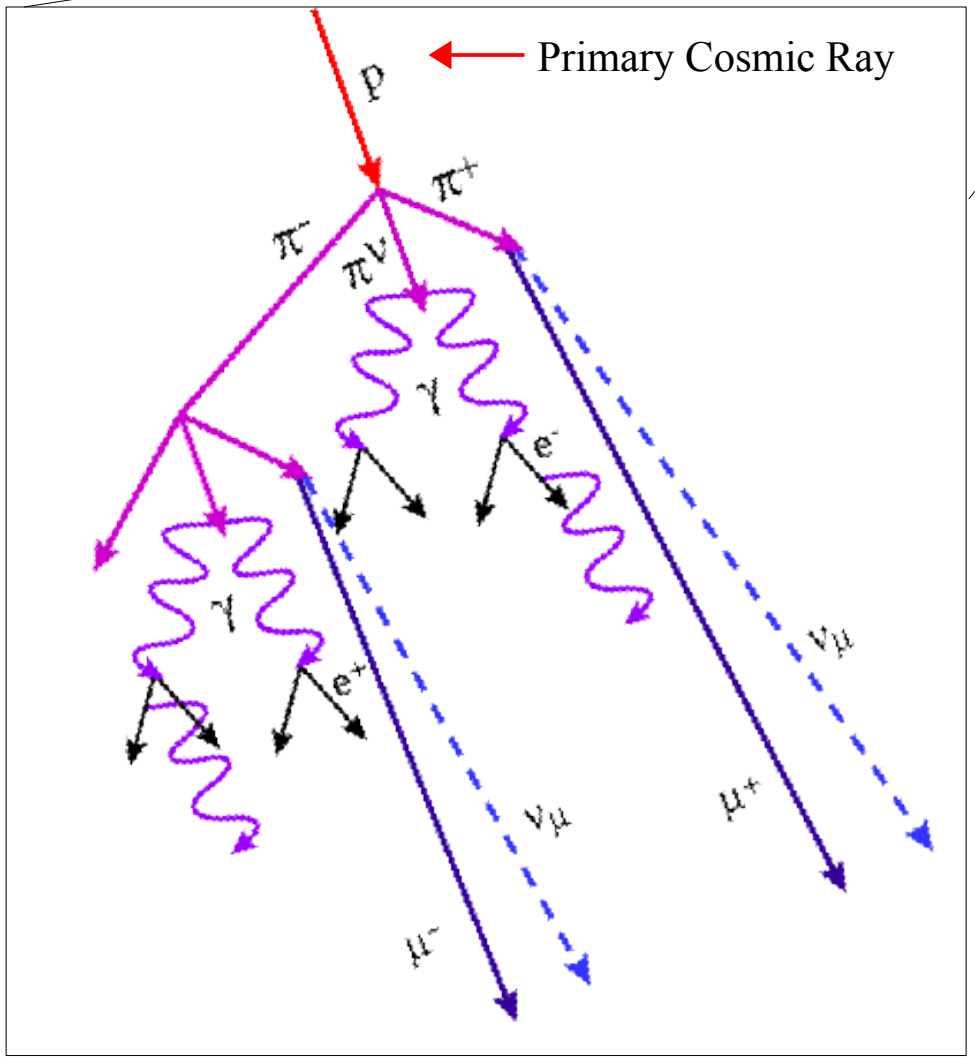
- Borexino: sub-MeV solar neutrinos (Gran Sasso)
  - 8-bit sent to trigger every 25 ns, 4 FPGAs and 1 DSP take the decision
  - Fast waveform digitizer: 4 x 100 MHz, 655 s

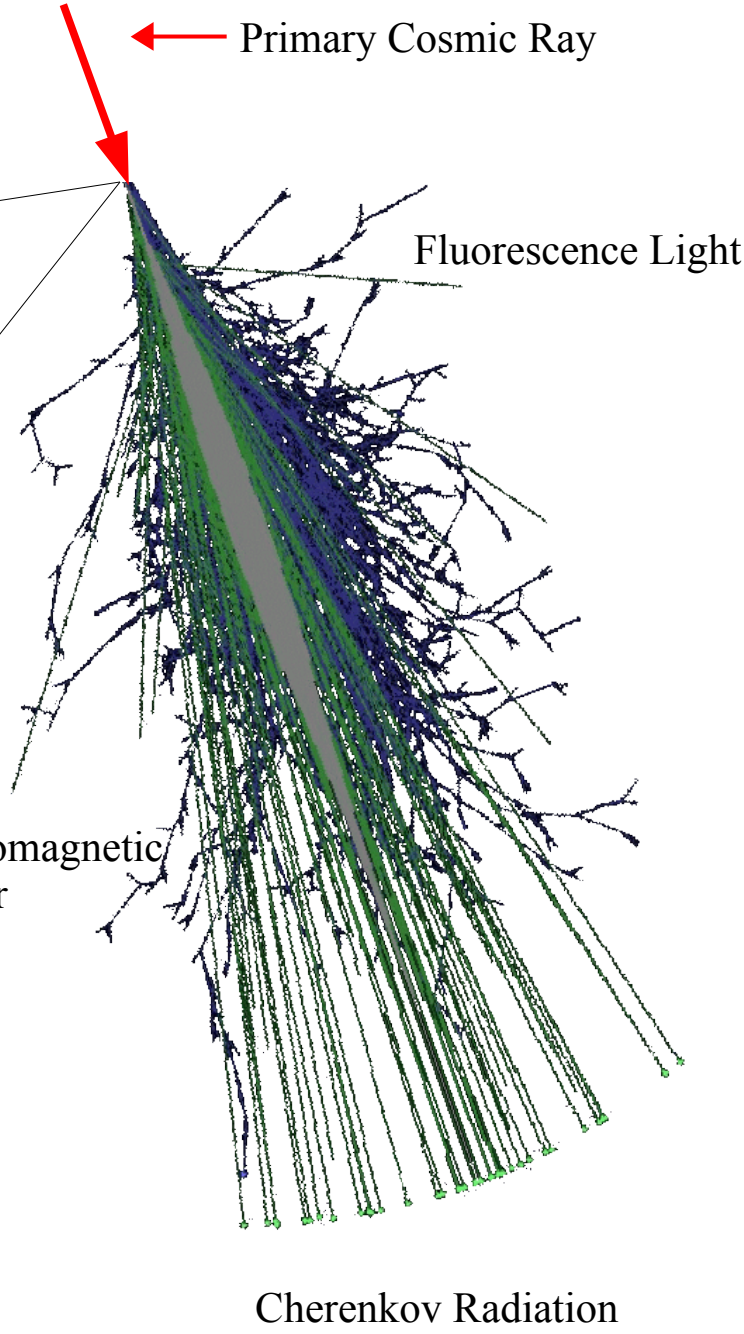
(V896, APC + CAEN)



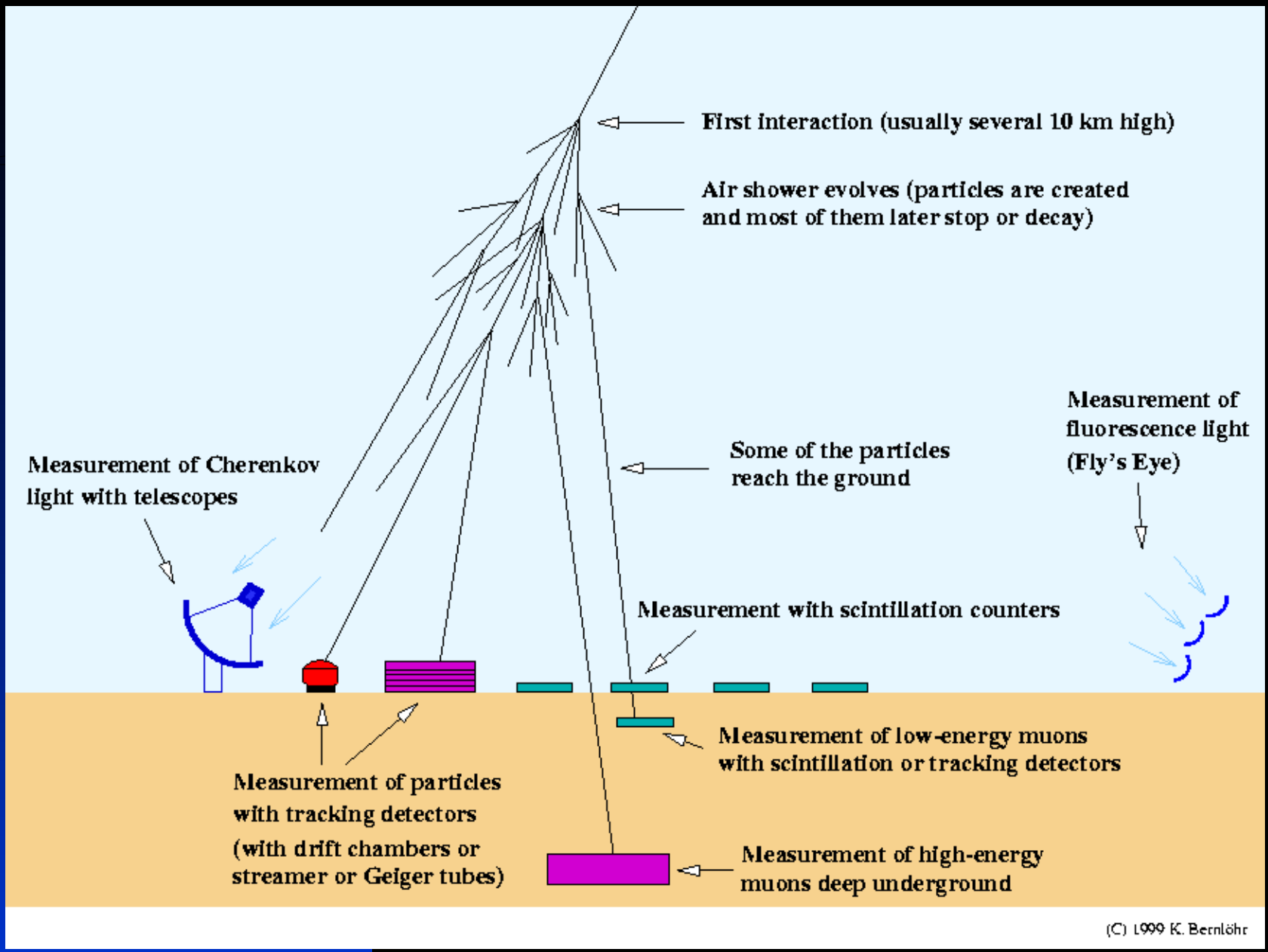


Extensive Air Showers (I)



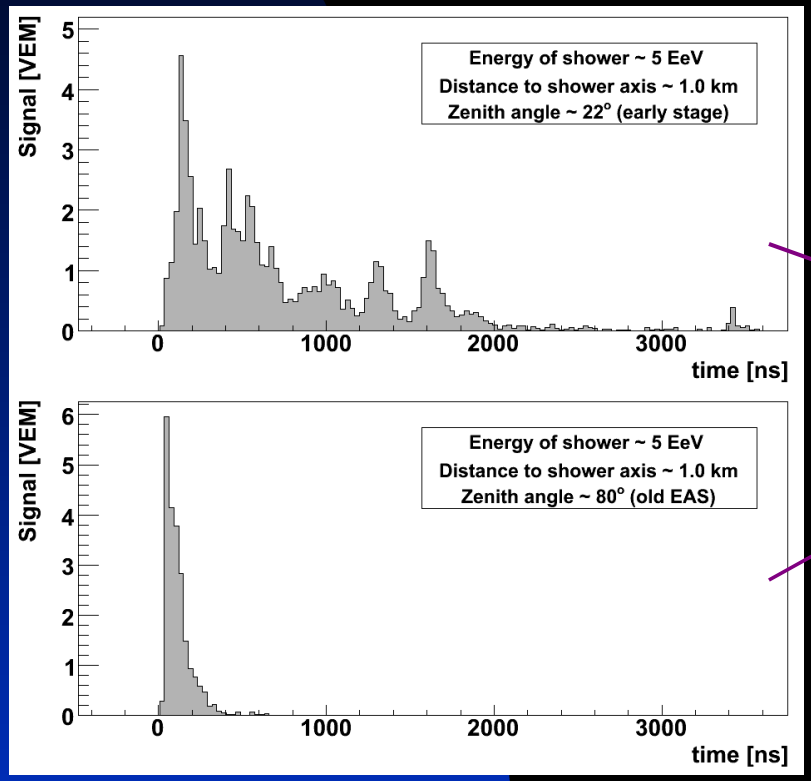


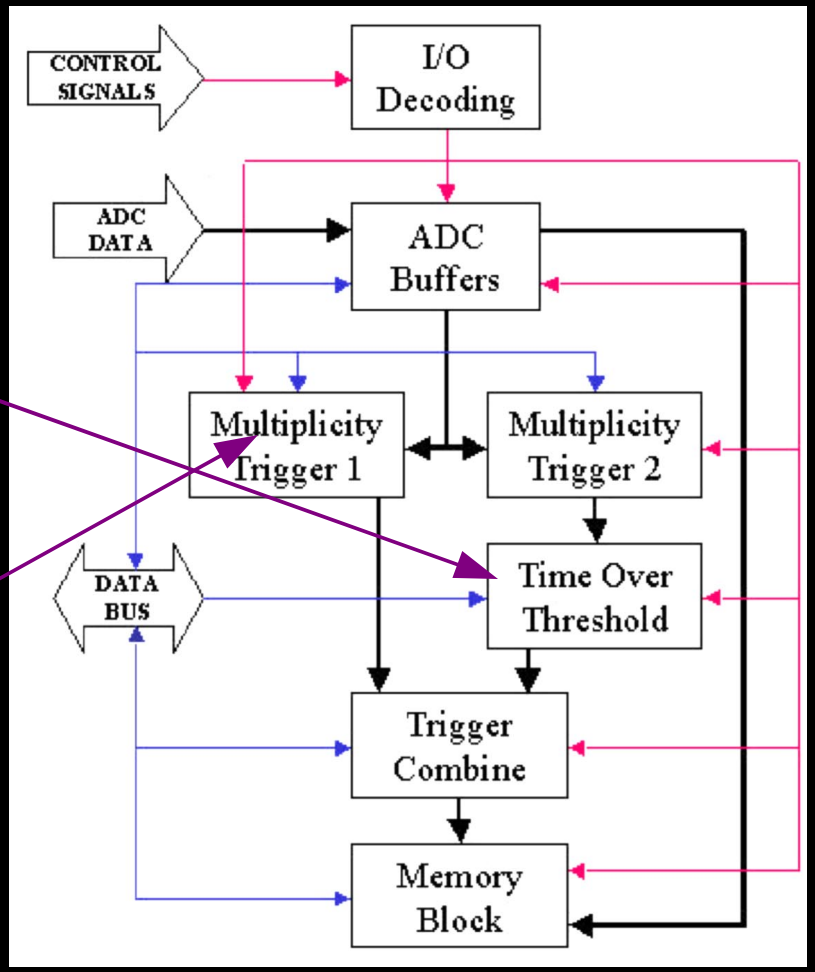
Extensive Air Showers (II)



Trigger Decision for Extensive Air Showers

- Pierre Auger Observatory: Highest Energy Cosmic Rays
  - Local trigger decision every 50 ns





Trigger Decision for Extensive Air Showers

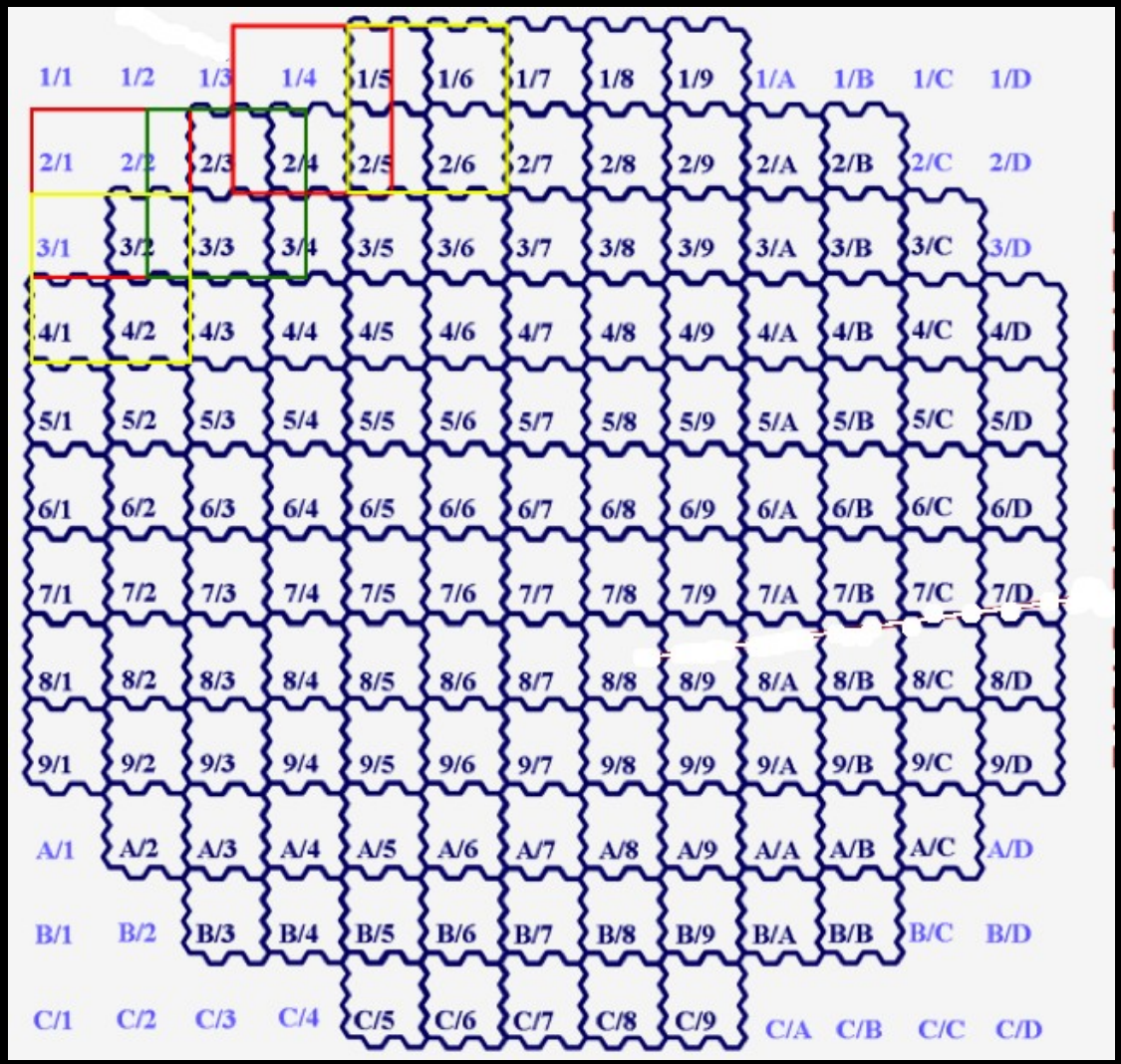
- Cherenkov Telescopes: VHE gamma-rays

- Latency time 100 ns

Comparators, majority, topology

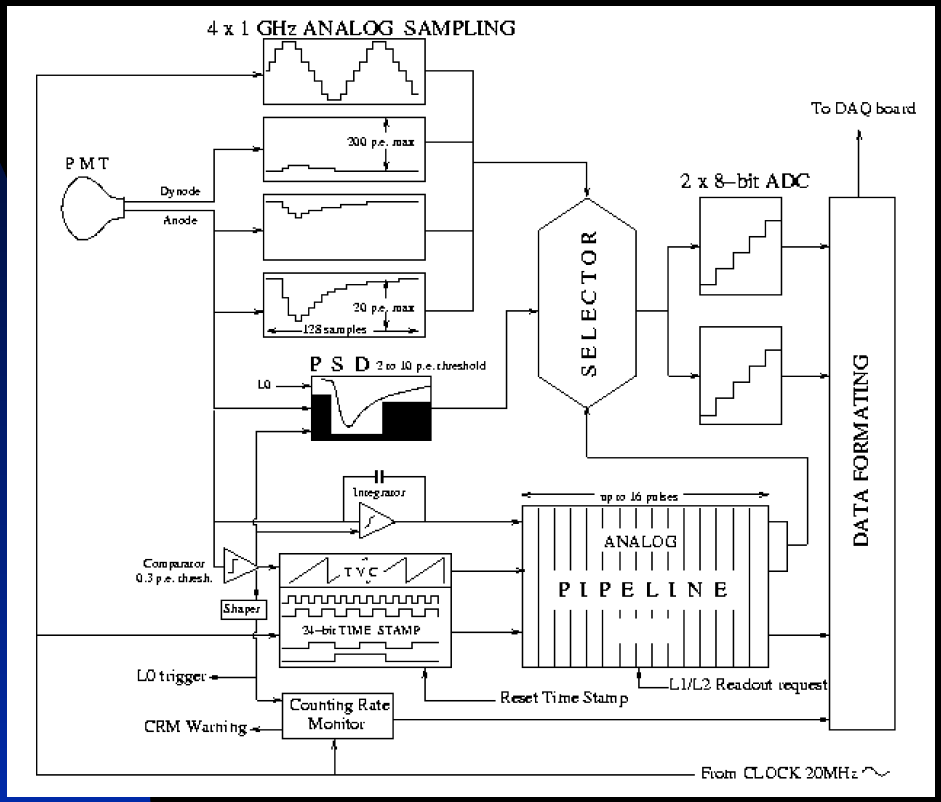
- Fully digital trigger under study

FPGAs, DSP



Sampling of signal from Extensive Air Showers

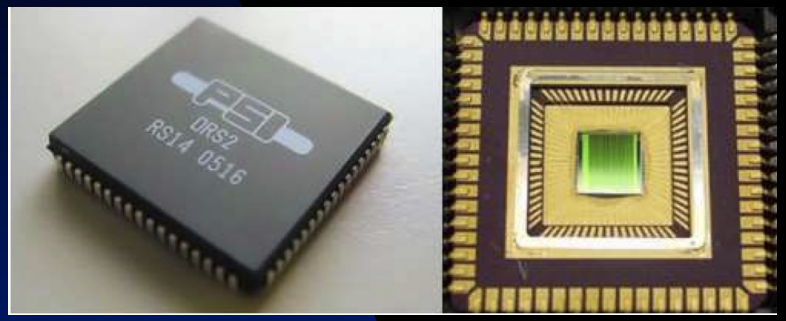
- Neutrino Telescopes: Extensive Water-Ice Showers
  - ARS board from antares: 1 GHz analog sampling + L0 trigger

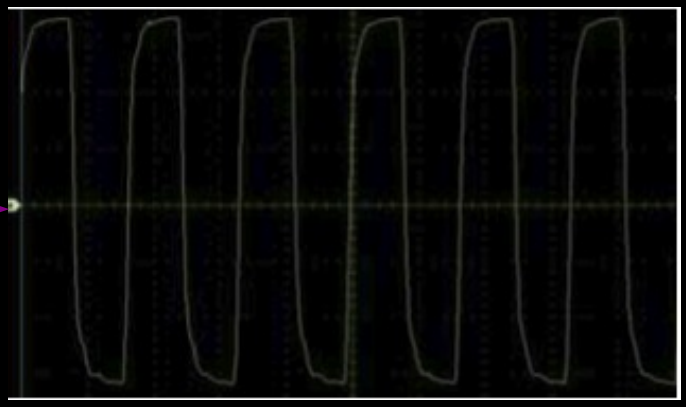


  - Ice Cube: delayed line + decreasing sampling rate

Sampling of signal from Extensive Air Showers

- Cherenkov Telescopes → Analogue memories to sample the signal (up to 2 GHz)



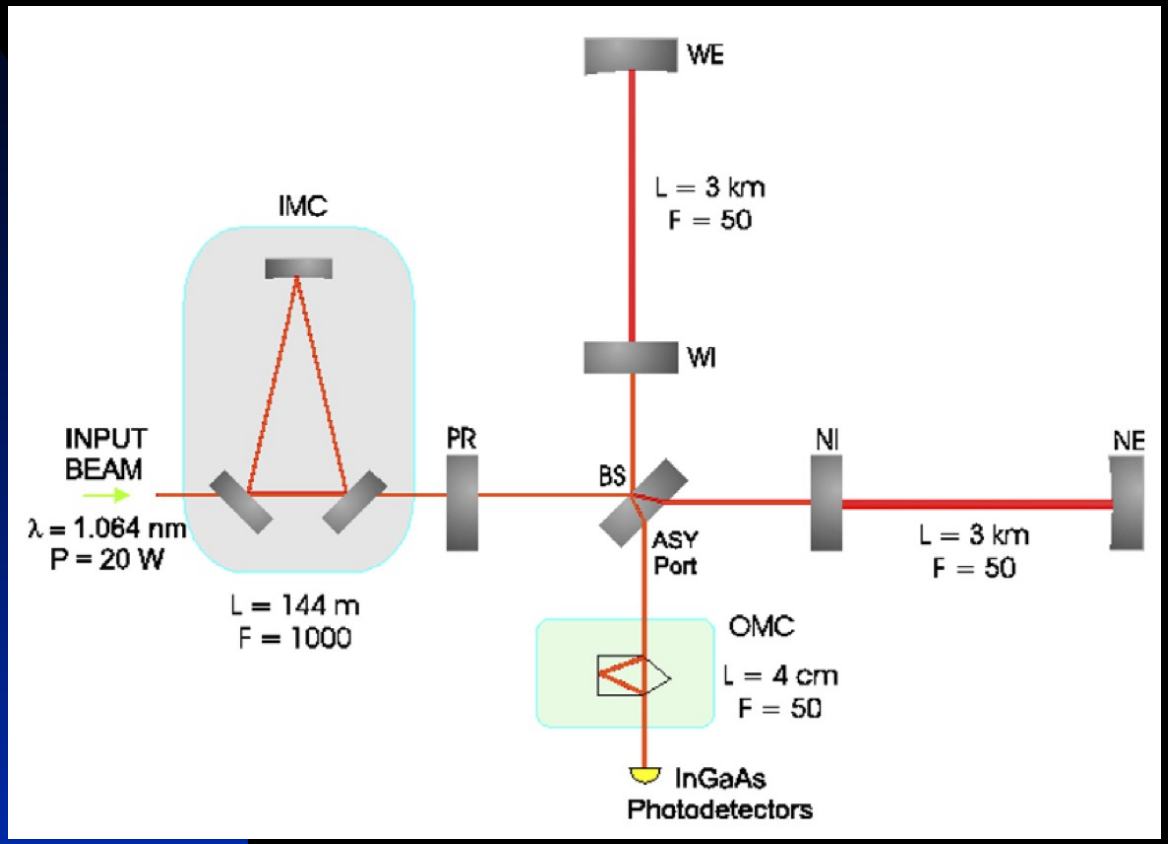


Several ASICs used: DRS, SUM

- CTA (>100 Cherenkov Telescopes, > 1000 pixels/each)
  - Analogue memories are the default option: Dragon vs Nectar
  - Other options under study ...

Real Time Control

- Virgo: interferometer for gravitational wavelength



20 kHz ADC and DSP keep as precise as possible the arm logituds

Real Time Control

- Cherenkov Telescopes : Active Mirror Control
  - Some Telescopes already have AMC but not really a Real Time device

For next generation: real time AMC and even mast deformations

Summary

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