

Gamma ray burst detection over a wide energy range with a ground-based detector

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New perspectives in astroparticle-physics with RPCs

- Most RPC applications dedicated to collider physics with one relevant exception → the ARGO experiment (YBJ-lab Tibet, 4300 m asl) could give an unprecedented approach to the gamma-ray astrophysics and to the cosmic ray physics in general
- I would like to take the Rio Conference opportunity for stressing the potential of a ARGO-like experiment located in the Andes at 5000 m asl. → an opportunity for astroparticle-physics and for the basic research in Latin-America



New perspectives in astroparticle-physics with RPCs (2)

- For several reasons
 - No need of accelerators, usually very expensive devices
 - Most detectors and telescopes located in the North Hemisphere
 - The atmospheric cosmic ray shield at 5000 m asl is almost half than at sea level
 - The center of our galaxy is visible in the South Hemisphere → a great discovery potential for an innovative detector located on the Andes, an ideal environment for this purpose
- A suitable experimental apparatus considered for this purpose could be made of RPCs coupled with water Cherekov detectors

Gamma Ray Bursts (GRB)

- The GRB study represents probably the most important topic of the gamma astrophysics
- The origin of a GRB is associated with a dramatic gravitational collapse of a single massive body, which also emits gravitational waves. The gamma burst is its electromagnetic partner
- This suggests that the correlation between gravitational and e.m. signals could be the key for a deeper understanding of the collapse
- It also stresses that gravitational antennas and GRB detectors have to work in strict connection in their survey of the Universe
- Why a ground-based detector?
 - Duty-cycle near to one; no interruptions of data taking
 - Very large solid angle covered; no need for pointing a single source
 - Crucial features for detecting random events

Which energy range?

- Gamma rays can reach extremely high energies as Lhaso showed.
→ observed PeV energies have changed current models
- Can low energies be of comparable importance? A GRB starts with a very high flux of very low energy photons, order 1 MeV, that can be visible only by satellite experiments
- Later emission, lasting up to a few days, contains photons with increasing energy, which can reach values as high as 1 PeV

Which energy range? (2)

- Lowering the energy threshold as much as possible would extend the GRB observable life-time. A good sensitivity in a very wide energy range would allow following the GRB entire evolution, from the minimum achievable energy up to the extinction
- Search for Gamma Ray Bursts (GRB) seems to require combining very high with very low energies
- This has strong implications in the detector “architecture”

Which kind of detector for covering an energy range from 10 GeV to 1 PeV?

- Such very wide interval requires two different approaches
 - Lower energy → full coverage over a relatively small area, pointing to minimize the energy threshold
 - High energy → sampling array (modest coverage) over a very wide area
- A full coverage RPC detector, some 20000-30000 m², surrounded by a water Cherenkov array covering 1 km², is an excellent solution for covering an energy range of about 5 orders of magnitude
- Two very complementary detectors: large mass thickness of Cherenkov detectors, few meters of water, vs 2mm gaseous target to minimize the energy threshold

How to optimize an RPC for mapping cosmic showers?

Main requirements

- High simplicity, robustness and low maintenance
- Modest rate capability
- Intrinsic time fluctuation of the shower suggests a required **space-time resolution ~ 1 ns x tens of centimeters** → single 2 mm gap is OK

This proposal is based on a large extent on a substantial improvement of the RPC detector, which has the purpose of optimizing the RPCs for experiments located in high mountain laboratories and for mapping the shower particles. This includes

- Signal read out → by squared pads instead of strips
- HV supply by DC-DC converters
- General detector lay-out

How to optimize an RPC for mapping cosmic showers?

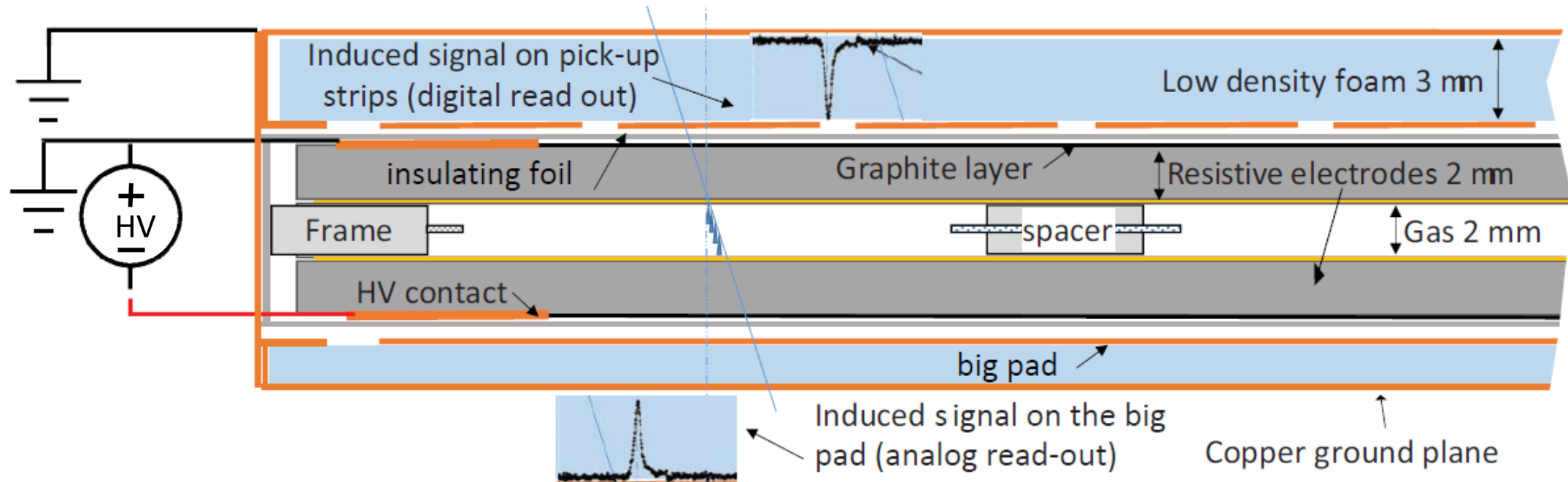
Main requirements

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Which the **optimal read out for mapping cosmic showers**?

- The Argo read-out was made through 8 strips 6.7x60 cm read in parallel by a single TdC channel → is it possible to group 8 strips in a single physical pad?
- This is a drastic change with respect to the strip read-out: a relatively large capacitance is added in parallel to the input → Is this read-out acceptable within the above detector requirements?

Schematic cross section of a Argo RPC



- A RPC is just a gas filled plane capacitor with high resistivity electrodes
- External signal pick up electrodes can be easily tailored with any shape
- Argo gas mixture: $\text{C}_2\text{H}_2\text{F}_4/\text{Ar}/\text{iC}_4\text{H}_{10} = 75/15/10$ Time resolution ~ 1.5 ns

The lay-out of the RPC prototype under test

The new design proposed in this talk , is based on relevant improvements which have the purpose of optimizing the RPCs for experiments located in high mountain laboratories. A new read out developed for mapping the shower particles is the main point.

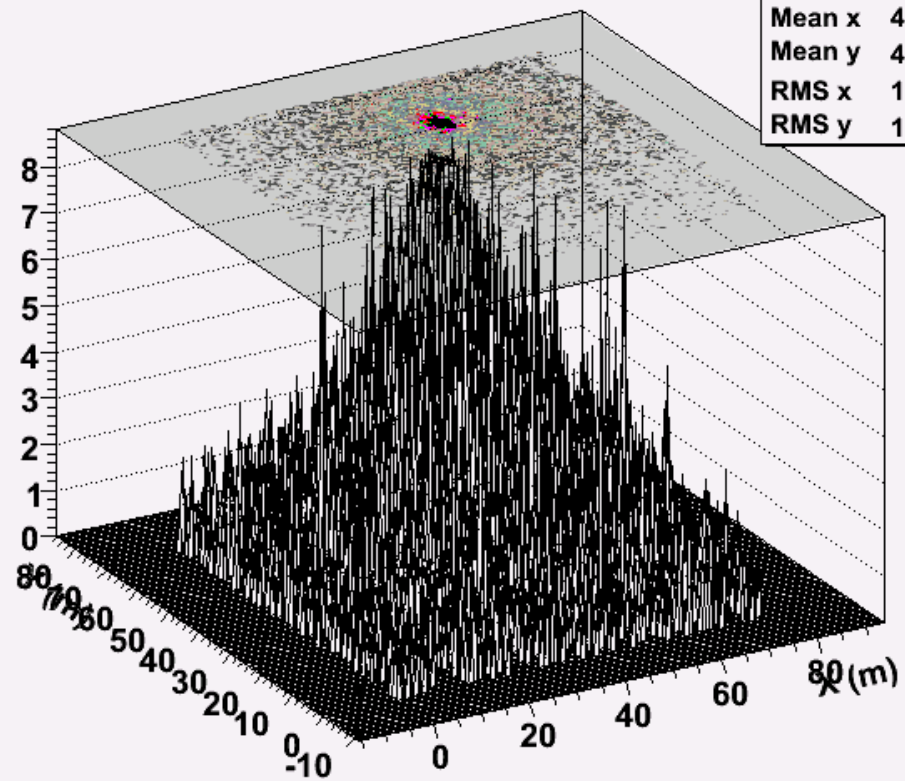
- Chamber size $2.8 \times 0.8 \text{ m}^2$
- Signal read out by 16 pads $35 \times 40 \text{ cm}^2$
- A single “big pad” covering the full chamber area for analog read out
- Front end circuit made with standard industrial components (not full custom) with the input located at the center of the pad
- HV supplied by DC-HVDC converter
- Gas pipes directly glued on the gas gap → no gas inlet connectors = better gas tightness

This will be briefly reported here and described in detail in my talk of Friday

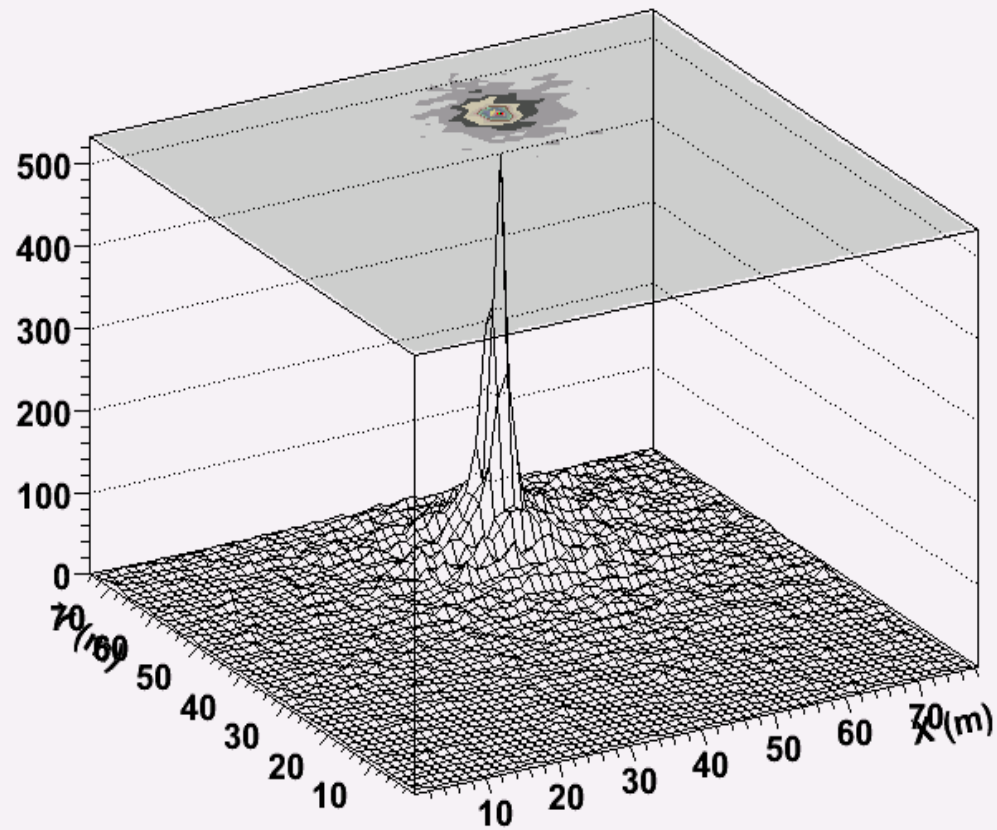
$E \sim 100 \text{ TeV}$

ARGO-130

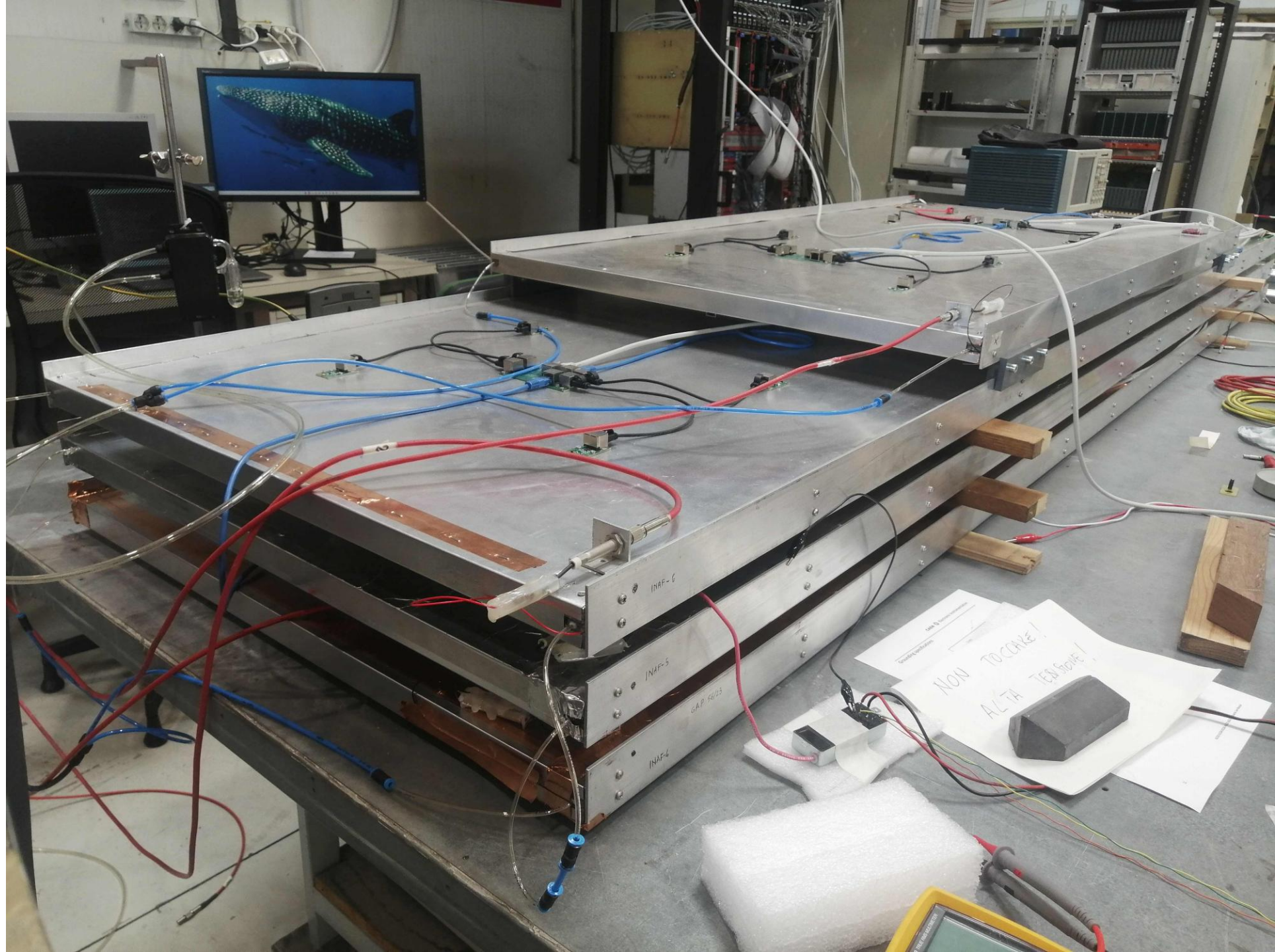
PadXY	
Entries	6404
Mean x	43.63
Mean y	47.82
RMS x	19.09
RMS y	17.52



Strip



Big Pad



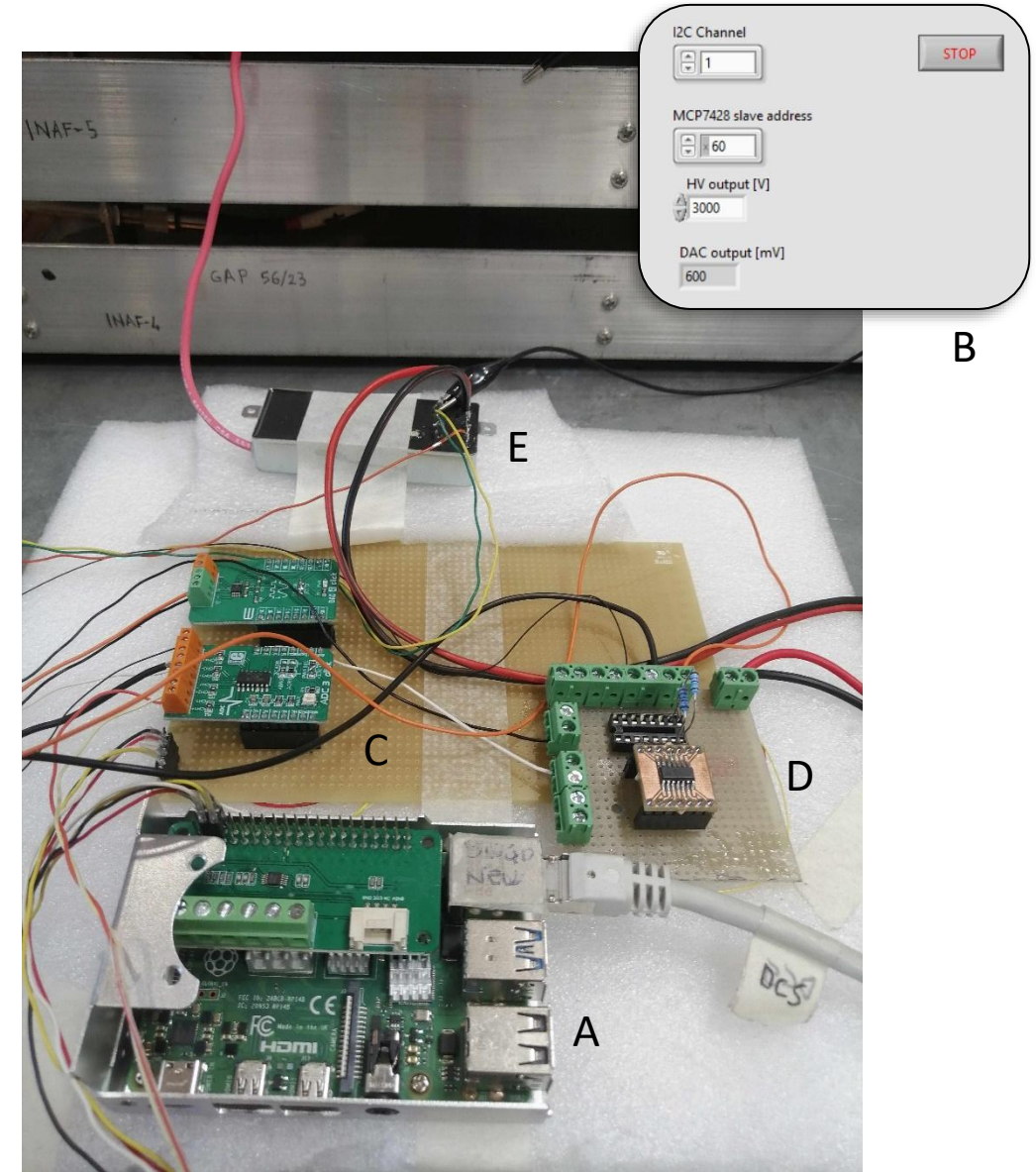
Gas pipes embodied inside the gas gap

- Improved gas tightness
- Minimal leakages in a closed loop



HV supply by DC-DC converters

- Industrial devices to be installed over the chamber
- HV output directly connected to the gap → **no HV connector required**
- Only LV connectors to feed the device at 5 V
- 2 or 4 gaps can be connected to the same converter



Test of 4 prototypes

- The prototypes have been extensively tested with cosmic rays using as trigger signal a triple coincidence excluding the chamber under test
- The test results (to be presented in detail tomorrow) show a detection efficiency $\sim 97\%$ and a time resolution ~ 1.3 ns
- These results are in line with the usual strip read-out in the same conditions, showing that **the new read out do not lose the RPC performance even for pad as large as 1500 cm^2 and possibly more**
- The importance of this conclusion concerns applications, like the detection of cosmic showers, where the number of read-out channels must be kept relatively modest in spite of the very large detector area

Search of new gases to operate RPCs inside National Parks

- High mountains laboratories often localized in national parks where the rules concerning the environment preservation are very strict
- The gas choice is strongly concerned
- Very high gas hermeticity required for single gaps and the detector as a whole → relevant improvement in the gas-to-chamber connection to avoid gas leaks and gas inlets breaking
- Gases with ODP (ozone depleting potential) already eliminated
- Gases with high GWP (global warming potential) like HFC in course of elimination
- HFO components with much lower GWP are now available. New mixture successfully tested OK



Test of new low GWP gases

- Several tests, mainly based on HFO molecules (GWP of a few units), have been carried out and are still in course
- The results show that RPCs can be very well operated with low GWP gas mixtures
- A gas particularly suitable for cosmic ray experiments is reported In:

Proto et al 2022 JINST 17 P05005 “On a new environment-friendly gas mixture for Resistive Plate

Chambers”; → Gas composition $\text{CO}_2/\text{F-HFO}/\text{i-C}_4\text{H}_{10}/\text{Cl-HFO}=76/15/7/2$

- Mostly made of CO_2 , 76%
 - $\text{H}_2\text{C}_2\text{F}_4$ (94.7%) replaced by $\text{H}_2\text{C}_3\text{F}_4$ (15%)
 - **SF_6 removed and replaced with $\text{ClH}_2\text{C}_3\text{F}_3$**
 - GWP of few units and a ODP near to zero
 - Good efficiency and time resolution
- This is an excellent candidate for a high mountain observatory

Search of environment friendly materials → a personal comment

1-The search of new materials starts when somebody discovers hidden dangers in materials so far acceptable

2-The researches start working and find new acceptable materials

3-The same “somebody”, some time later, discovers new hidden dangers that make new materials again unacceptable...so we go back to n 1-

This is a perverse **never-ending cycle** that we have to become familiar with !!!

Gamma/Hadron discrimination. Can timing help?

- It is, up to now, based on muon identification that requires absorbing the shower em component with sufficiently heavy material → a complex and expensive procedure
- Is it conceivable exploiting the RPC timing for ToF measurements identifying “slower” muons?
- Assuming that the shower front propagates at a velocity very close to the light speed, muons should propagate at lower speed thanks to their mass. Is this difference measurable?

Rough estimations

➤ At the moment this is just an idea. A **simulation for realistically checking the difference *shower front velocity – muon velocity*** is needed to accept/reject this idea

➤ Assuming c for the front velocity

$$\Delta t = \frac{L}{c} \left(\frac{1}{\sqrt{1 - \left(\frac{m}{E}\right)^2}} - 1 \right) = 3.3 \frac{ns}{m} \left(\frac{1}{\sqrt{1 - \left(\frac{m}{E}\right)^2}} - 1 \right)$$

➤ A simple example

At sea level the most probable muon energy is about 1 GeV and $\frac{E}{m} = \gamma \sim 10$. Assuming the muon is created 1 km above sea level its delay would be **$\Delta t = 16.6 ns$!!**

Specific features of the GRB detection

- A GRB is a short event where many particles are detected, all coming from the same direction
- Two different detecting modes according to the Argo experience
 - Scale mode requires a very accurate monitor of the detector counting rate to detect the increase due to the GRB
 - Shower mode
 - Specific GRB trigger requiring very low hit multiplicity (=energy) → modest direction resolution on the single photon
 - Very low energy showers give a modest direction resolution BUT strong statistical advantage from the multiplicity of all detected photon

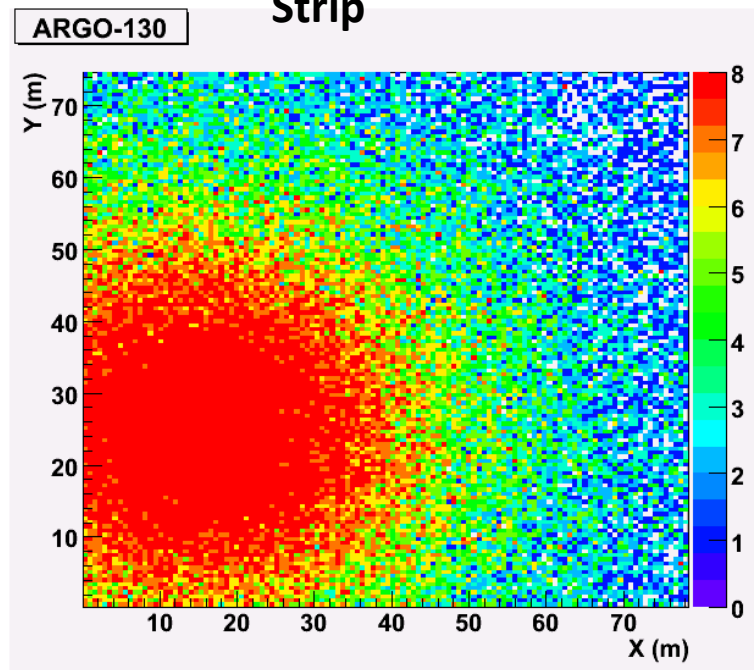
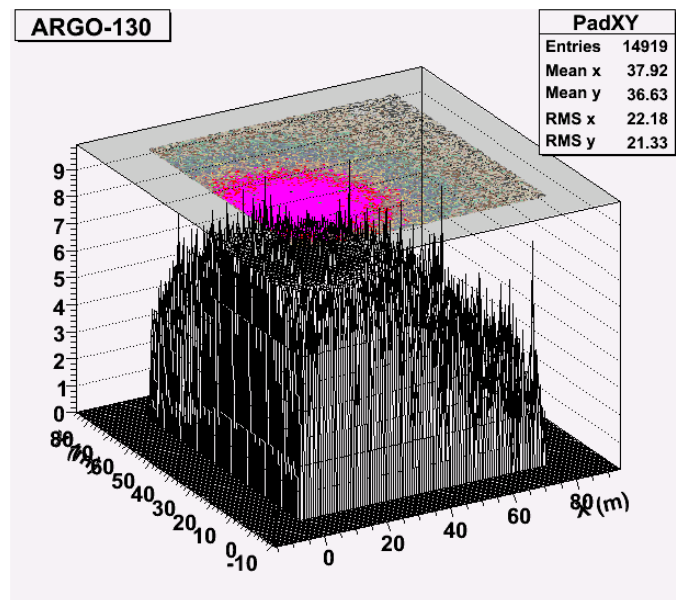
Conclusions

- The gamma ray astrophysics with ground based detectors is a primary task for the Latine-American basic research
- The GRBs are the electromagnetic component of gravitational collapses that generate gravitational waves at the same time
- The combined study of both components will be a key for the understanding of the universe
- A cosmic radiation observatory located in the Andes, made of RPCs and water Cherenkov detectors, would be a crucial instrument to follow a GRB evolution from the minimum detectable energy up to its extinction

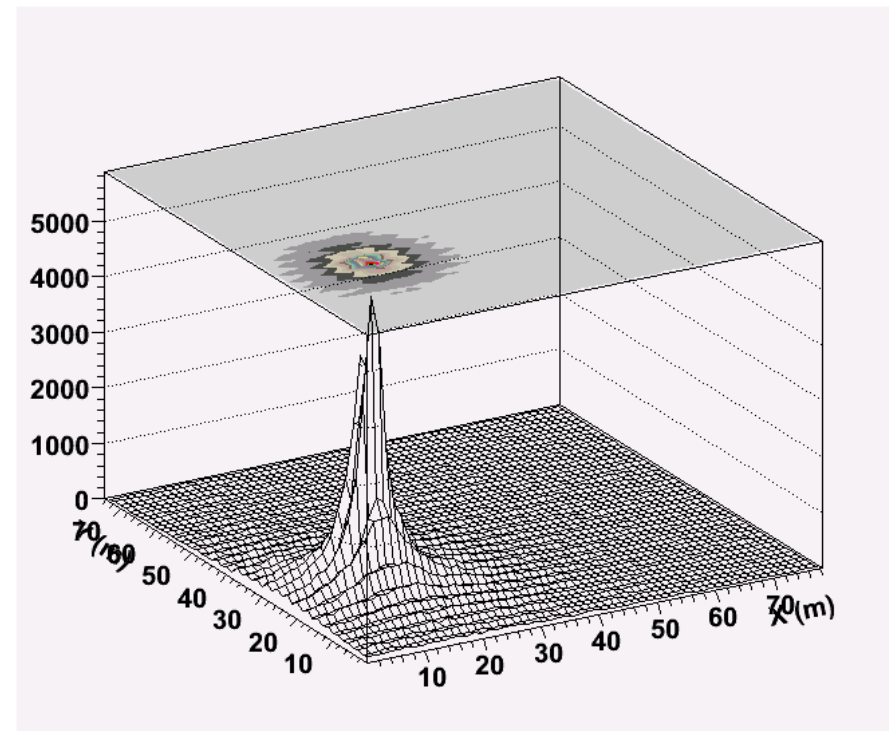
Thanks for your attention

BACK UP

Strip



$E \sim 1000 \text{ TeV}$



Big Pad