Resistive Plate Chambers: the planar geometry impact in the world of gaseous detectors

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The Geyger-Muller counter as the ancestor of a very wide detector family

- Since the invention of the Geyger-Muller counter, gaseous detectors were dominated by the electric field generated by a positively charged wire
- This field configuration has a crucial advantage: it limits the active detector region to a very small volume around the wire, where the field is strong enough to produce the avalanche multiplication of free electrons
- The rest of the gas is just «electron transport region» at very low field
- This gives the detector a very stable operation, which convinced the scientific community that this was the only field configuration suitable for practical applications

Planar detectors

- A planar detector is a plane capacitor connected to a voltage generator, with the gap filled with the operating gas
- The electric field is uniform and must be strong enough to produce the avalanche multiplication of the free electrons released by the primary ionization
- As a consequence the detector sensitive volume is 100% critical: any free electron generated at any point of the detector produces an immediate electrical discharge. A local defect of the electrodes would produce spurious sparking that could destroy the detector in the long term
- This convinced the scientific community that planar detectors would be unsuitable for building stable and reliable apparatuses for particle physics

Pulsed planar detectors

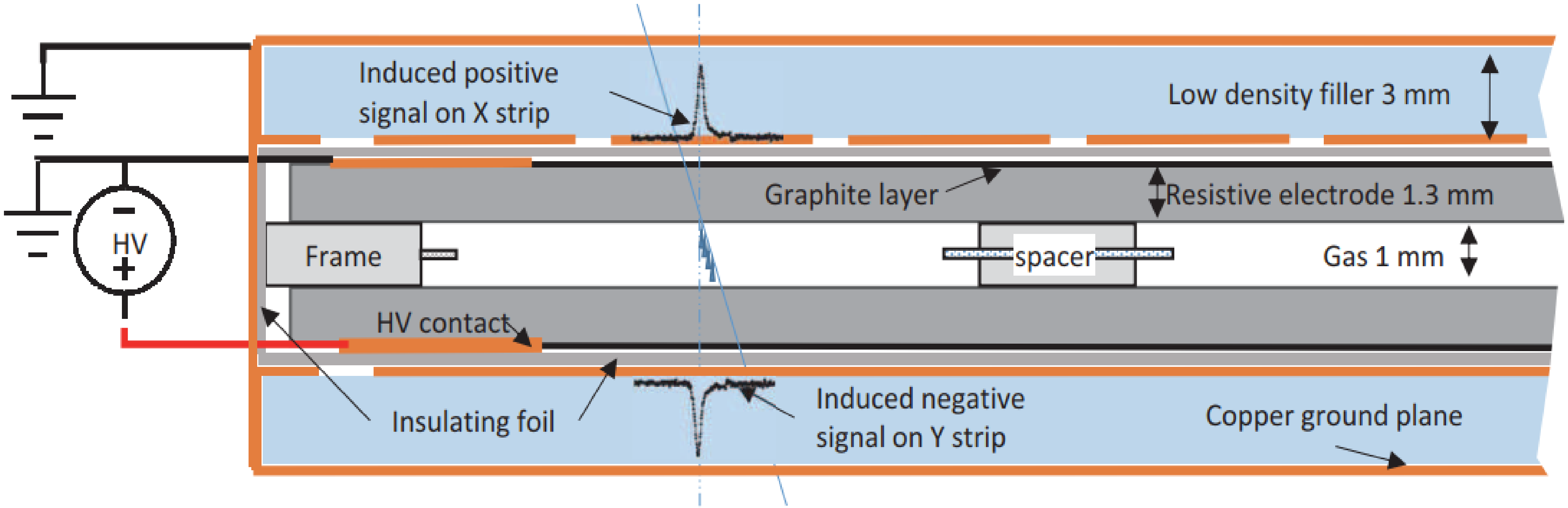
- The above criticism to planar detectors however applies only to continuously sensitive (or DC coupled) detectors
- A planar detector that is activated by a high voltage pulse applied just after the passage of a ionizing particle, would be exempt from the above criticism
- The optical spark chamber is a pulsed planar detector that was extensively used, from the 1950s to the beginning of the 70s, to track particle trajectories
- In this period it was one of the most important detectors in particle physics. The idea of a continuosly sensitive detector with the same planar geometry, however, was considered absolutely remote or impossible

The Resistive Plate Chamber (RPC)

The RPCs could overcome the objections to planar detectors thanks to a few key points:

- The use of high resistivity electrode plates ($10^{10} - 10^{12}$ Ohm cm), suggested by Yuri Pestov, can localize the electrical discharge in a small region around the primary ionization point
- The study of the electrode surface properties: the surfaces of amorphous materials like glass or some polymerizing oils have shown much better properties than others, usually polycrystalline materials
- Proper gas choice: UV-photon absorption is crucial to avoid spurious signals from the gas or the electrode photoionization

An RPC with the gas gap sandwiched between the two read-out strip panels



Gas-gap components

a) High Pressure Laminates electrode plates

b) Grapite electrodes

c) Insulating PET foil

d) Spacers

Which are the advantages of RPCs?

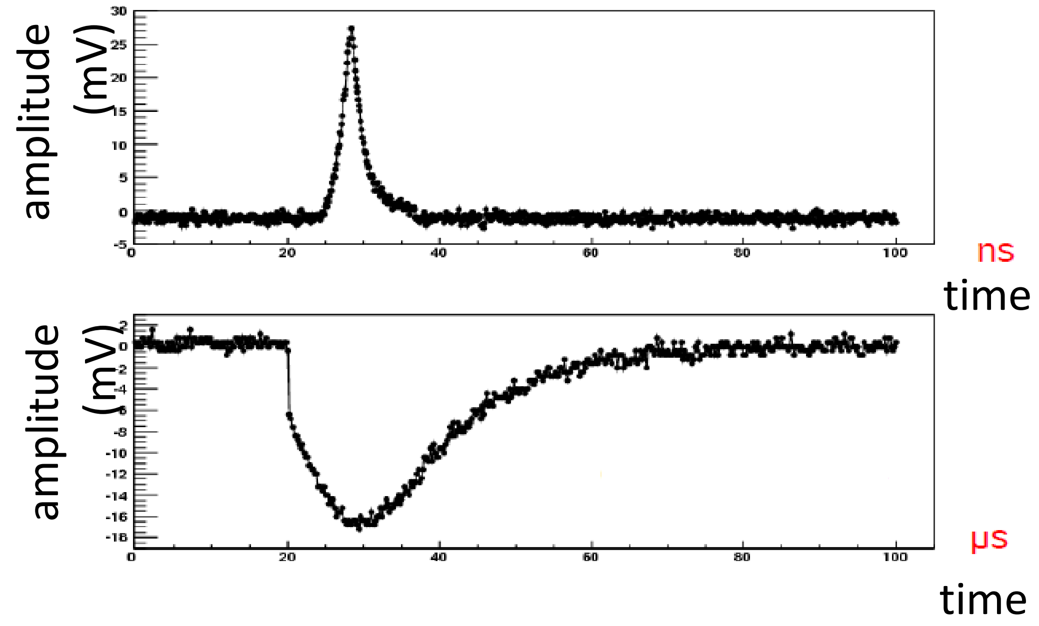
RPCs, compared with the family of the «wire detectors», are more robust and easy to build.

Their main advantage however is a much better time resolution which makes them an ideal instrument for accurate timing and Time-of-Flight measurements

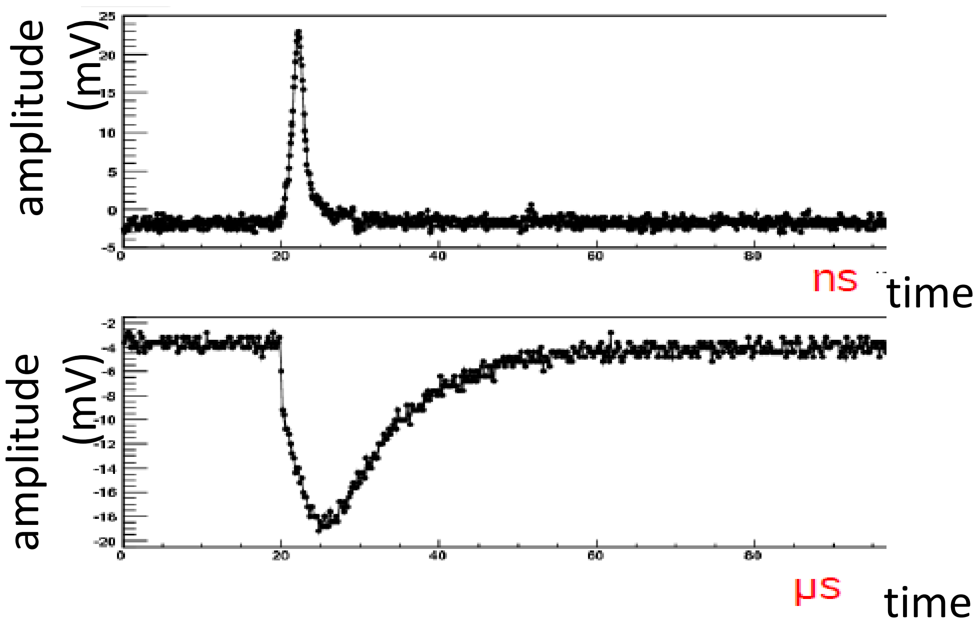
In a wire device indeed the 1/r field requires a significat drift time to allow free electrons to reach the multiplication region, which is very close to the wire, where the avalanche is developed. The fluctuations of this drift time limit the time resolution

The uniform RPC field eliminates any drift-time fluctuation

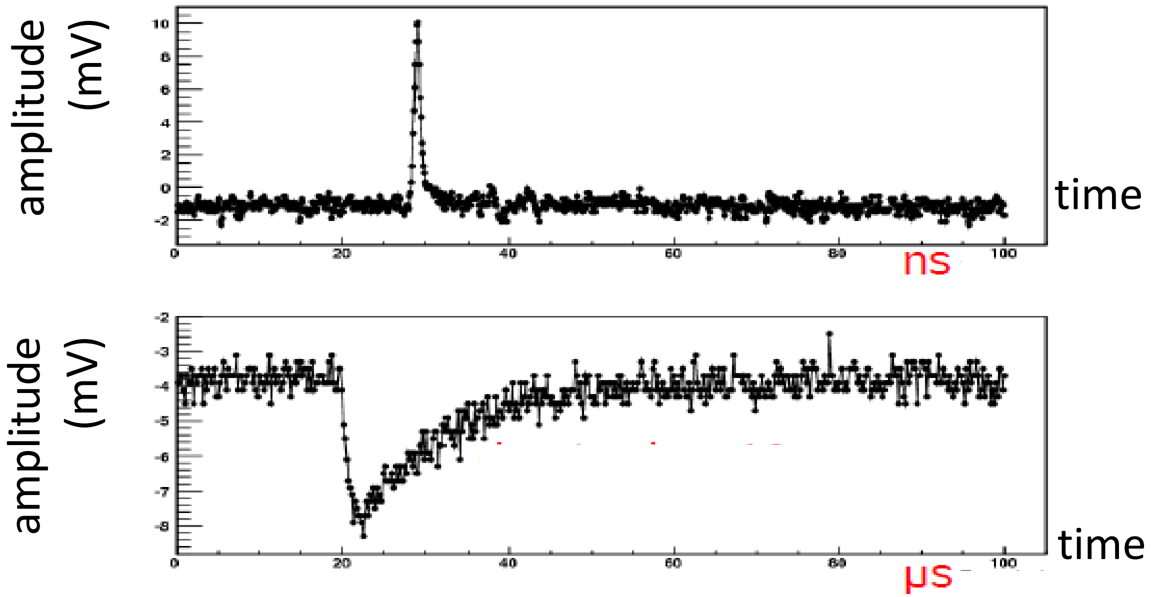
Prompt and ionic signal for 2 mm gap



1 mm gap



0.5 mm gap



The RPC time resolution

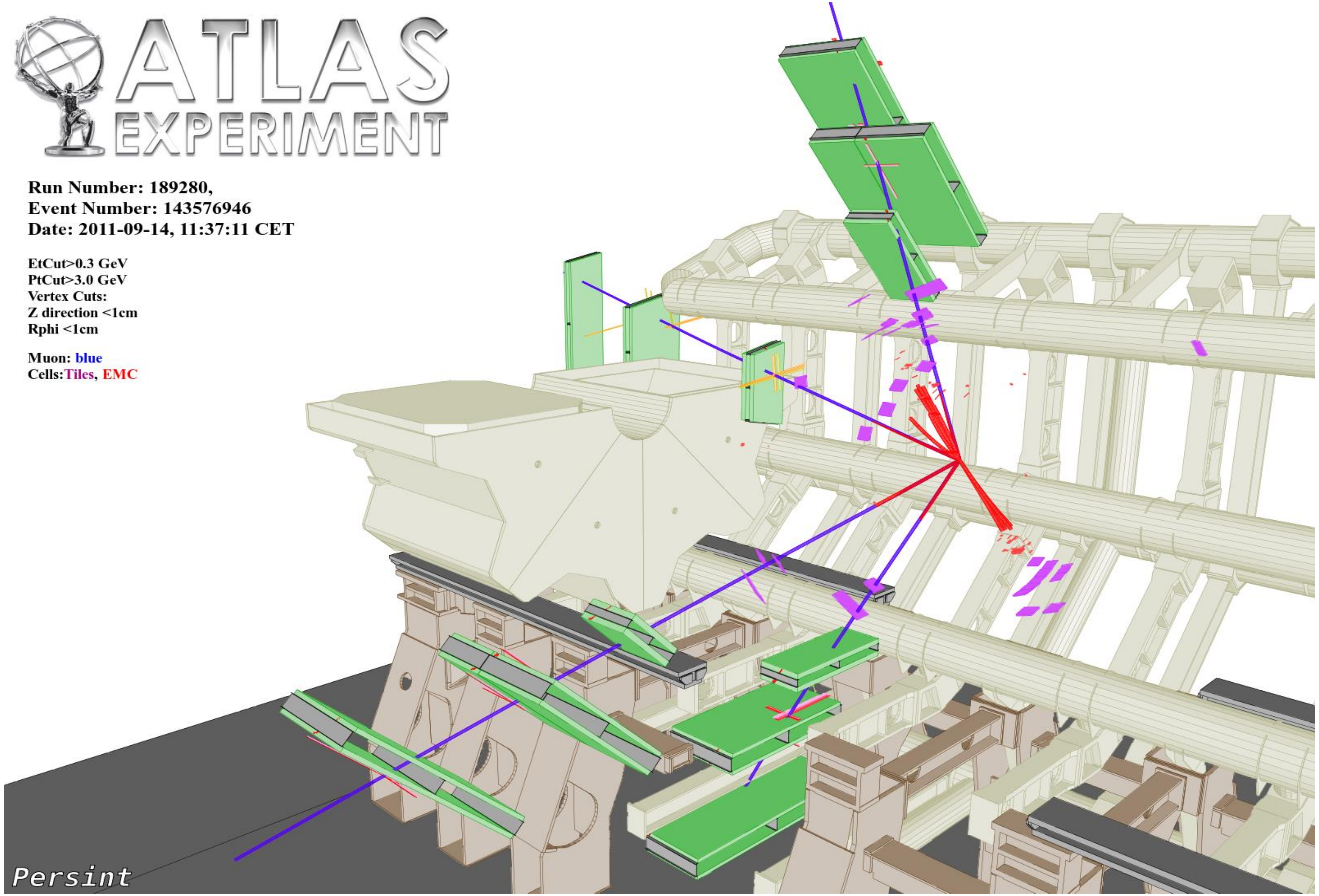
- The RPC signal duration is proportional to the gap size: a narrow gap gives a short signal
- In the uniform field the time uncertainty is proportional to the duration: the shorter is the signal the smaller the timing uncertainty
- Thinner gas gaps give better time resolution BUT less primary ionization and therefore lower detection efficiency
- The problem can be solved with a multiple-gap layout, suggested by Crispin Williams and Paulo Fonte, which can combine good efficiency and excellent timing (down to 30 ps)

RPC applications

- Muon trigger in collider experiments: Atlas , CMS, Alice
- Time of flight for particle identification: Alice Heavy ion physics
- Neutrino physics (Opera)
- Cosmic-ray physics: Argo (Tibet)
- Hadron calorimetry thanks to the RPC capability to detect a very large number of simultaneous hits
- Practical applications: muon tomography...

➢ Finally, RPCs are potentially ideal instruments to study the electrical discharge in gaseous media and the properties of the gas/solid interfaces

Higgs-boson 4-muon decay in Atlas



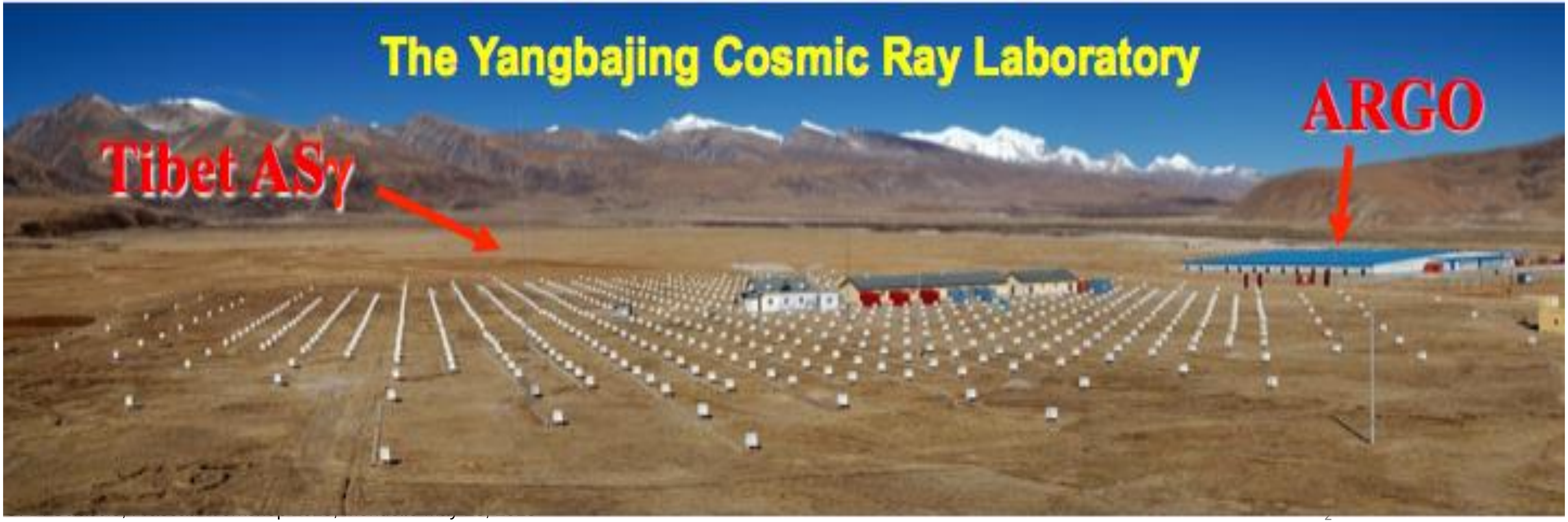
The ARGO-YBJ experiment

Longitude: 90° 31’ 50’’ East
Latitude: 30° 06’ 38’’ North

4300 m above sea level ∞ 600 g/cm^2

INFN IHEP/CAS

90 km North from Lhasa (Tibet)



Two key persons in the RPC history

The RPC realization was possible thanks to the contributions of two key persons:

- ➢ My «big boss» Marcello Conversi who hosted the RPC development in his laboratory and did not want to sign the corresponding paper not to overshadow the younger authors’ names
- ➢ My «young» collaborator Roberto Cardarelli who shared ideas, work and problems with me. His help was crucial for the detector invention

Thanks for your attention!!