An introduction to RPC 2020

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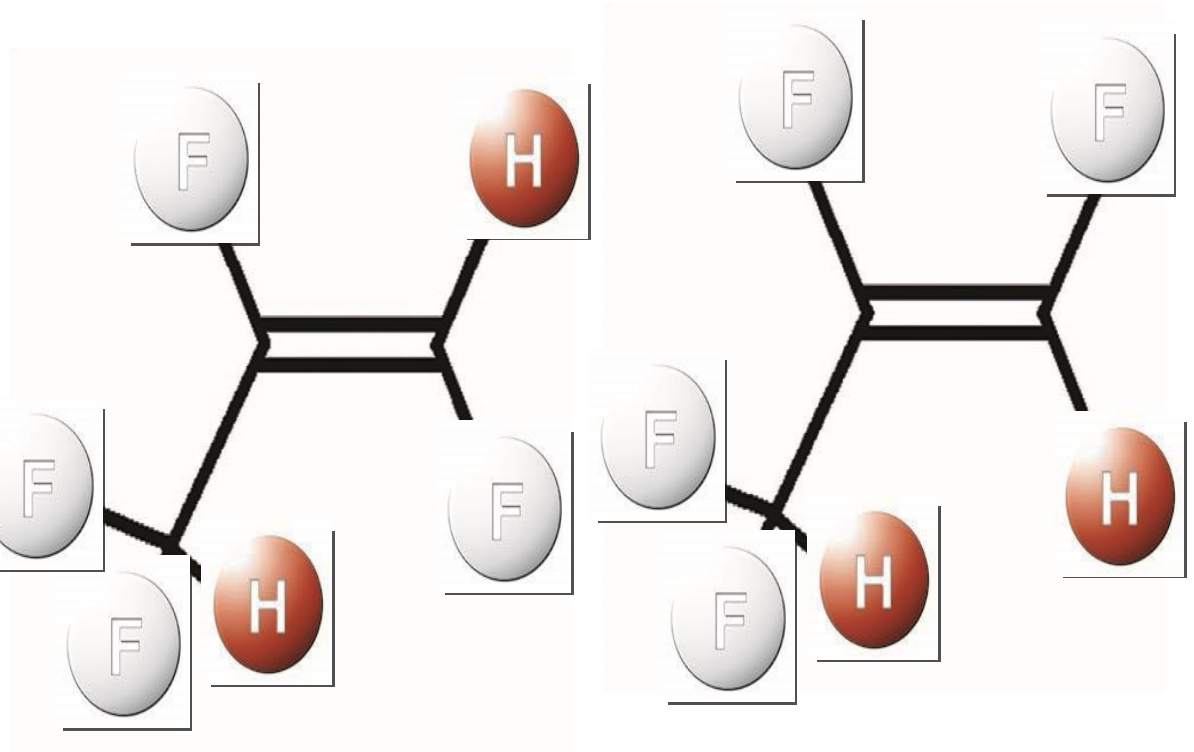
- A warm salutation to all Chinese colleagues who could not come due to the epidemic
- They are one of the most active RPC community
- Hope that the network connection will help to reduce as much as possible this loss for RPC 2020
- Hope to see them again among us asap

Search for new low GWP RPC gases

Present *magic mixture* $C_2H_2F_4$/i-C_4H_{10}/SF_6 = 94.7/5.0/0.3 shows a very large separation, in terms of applied electric field (> 0.5 kV/mm depending on the FE electronics), between avalanche and streamer mode operation

Our efforts to find a new low GWP RPC are mainly directed to reproduce this very confortable feature with the new series of industrial gases HFO (Hydro Fluoro Olefins)



Search for new low GWP RPC gases (2)

- The double carbon-carbon bond C=C has a crucial effect in the gas electrical properties:
  - much larger field required
  - easyer avalanche-to-streamer transition
- Industrial research for a new molecule replacing SF_6 (GWP =24000!) is also very active
- $C_3H_2F_4$ and other molecules replacing SF_6 are presently the most interestring candidates
- For future RPCs, the new gas search is easier thanks to the possibility of optimizing the gas gap and the FE electronics for the new gas
- For the existing very large LHC systems like those of Atlas and CMS where nothing but the gas can be changed, the solution appears less simple

Self triggered space-time tracking (1)

- Collider experiments utilize RPCs for two different functions, triggering and timing, leaving to other detectors the accurate tracking task
- Is it possible to integrate these two tasks in the same detector?
- Tests carried out by different groups show that space resolution in the range of 100-300 μm are achievable with gas gaps around 1 mm depending on the detector size, the strip pitch and the front end electronics features
- The position accuracy with RPCs depends only on the geometrical and mechanical quality of the strip printed board and not on the gas volume geometrical accuracy

Self triggered space-time tracking (2)

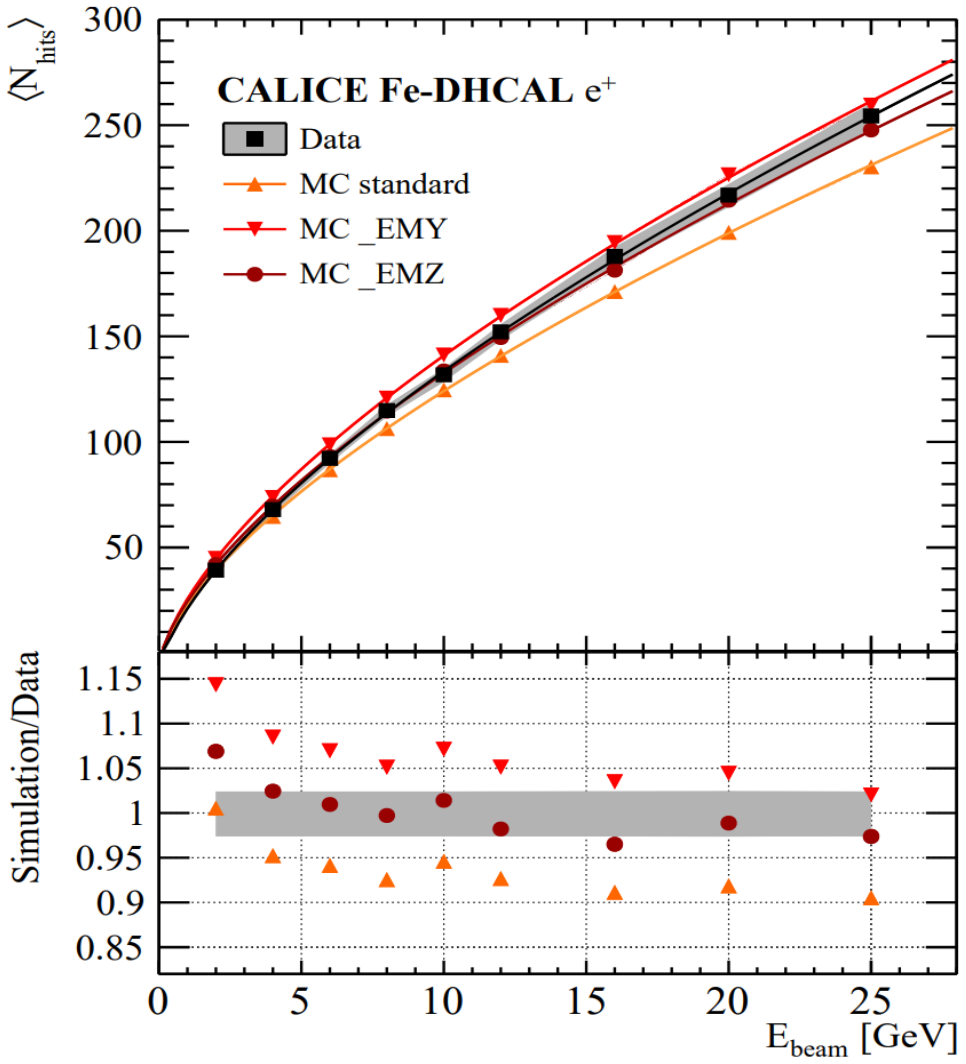
- The time resolution ranges from 400 ps for large size 1 mm gas gap to tens of picoseconds for thinner gaps in a multigap structure
- The FE electronics is crucial for all type of resolution requirements
- In this scenario, the idea of a RPC structure capable of space x time resolutions 100-300 micron x 100-200 ps over a sensitive area of 10^4 m^2 seems to be reasonable challenge
- For these RPCs space-time performance, construction simplicity and cost must be accurately balanced and optimized for each specific application
- Simplicity and reliability are RPC key points

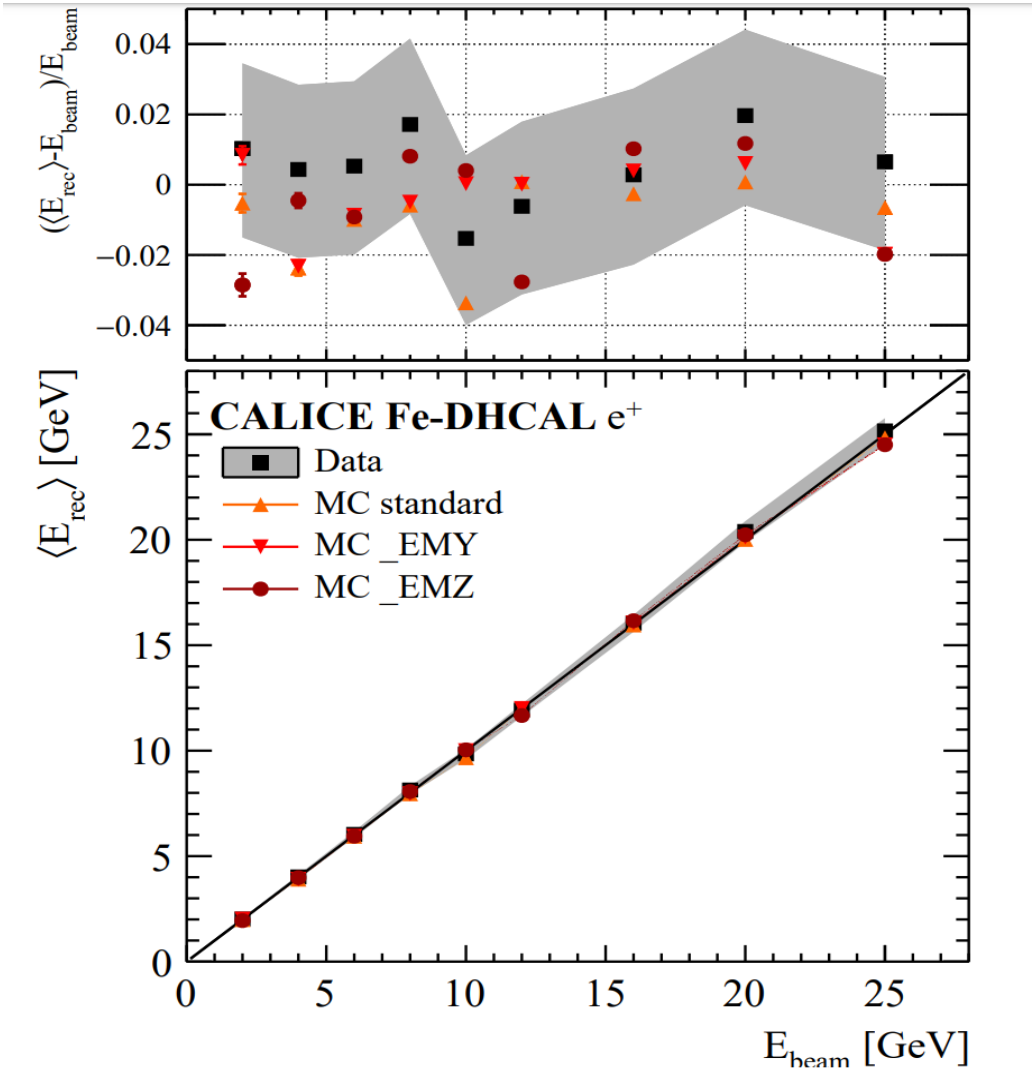
Calorimetry with RPCs

- The first idea of using RPCs for calorimetry was born in connection with neutrino physics
- More recently the tests of the Calice collaboration have shown a relevant progress in the hadron calorimetry with the digital RPC read out

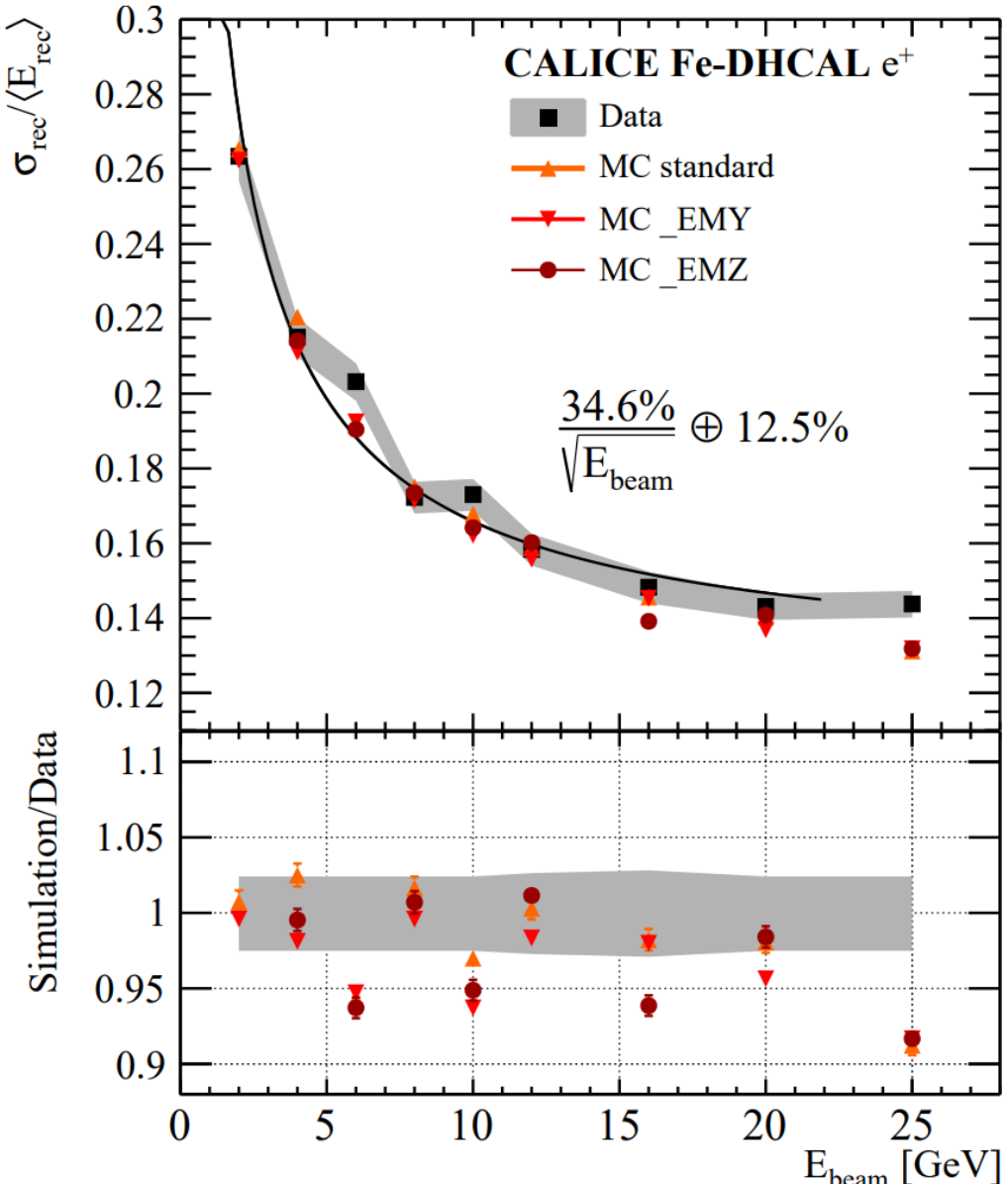
Calorimetry with RPCs e^+ beam

digital read out with $1\ cm^2$ pads

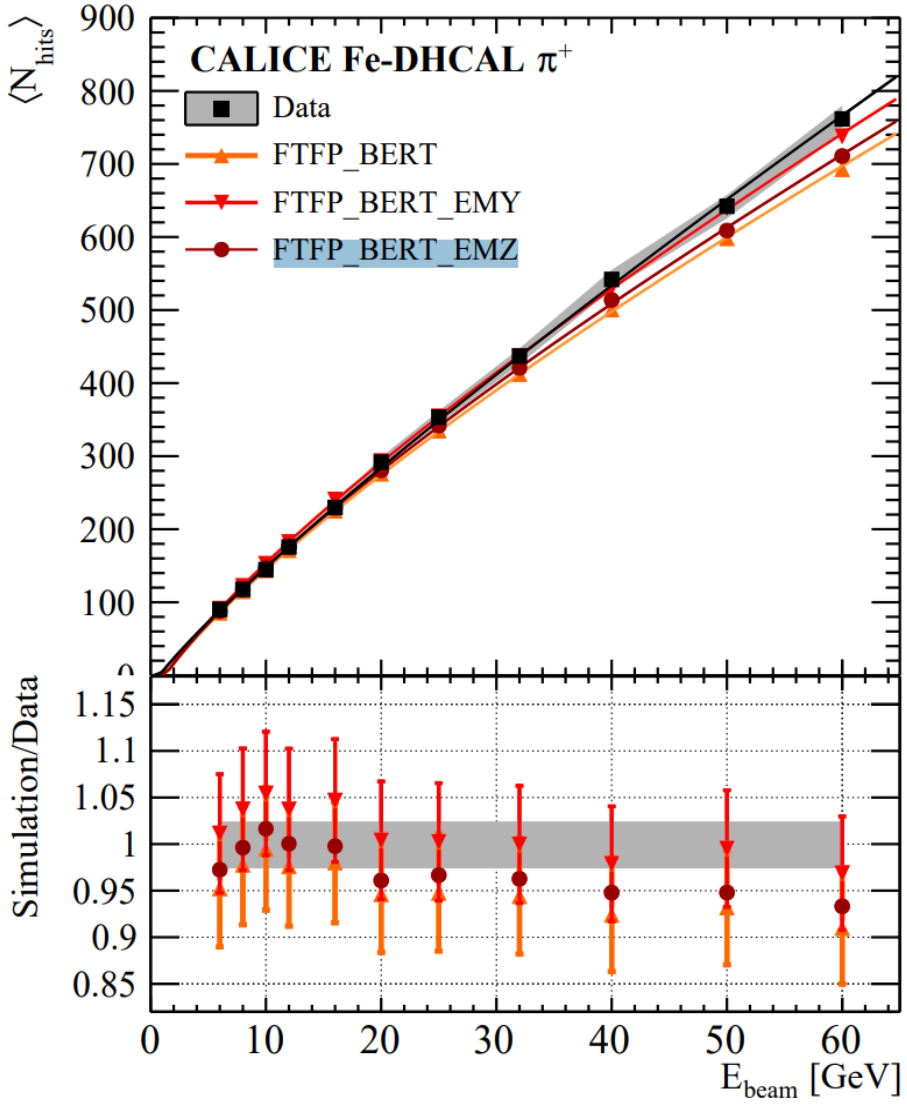


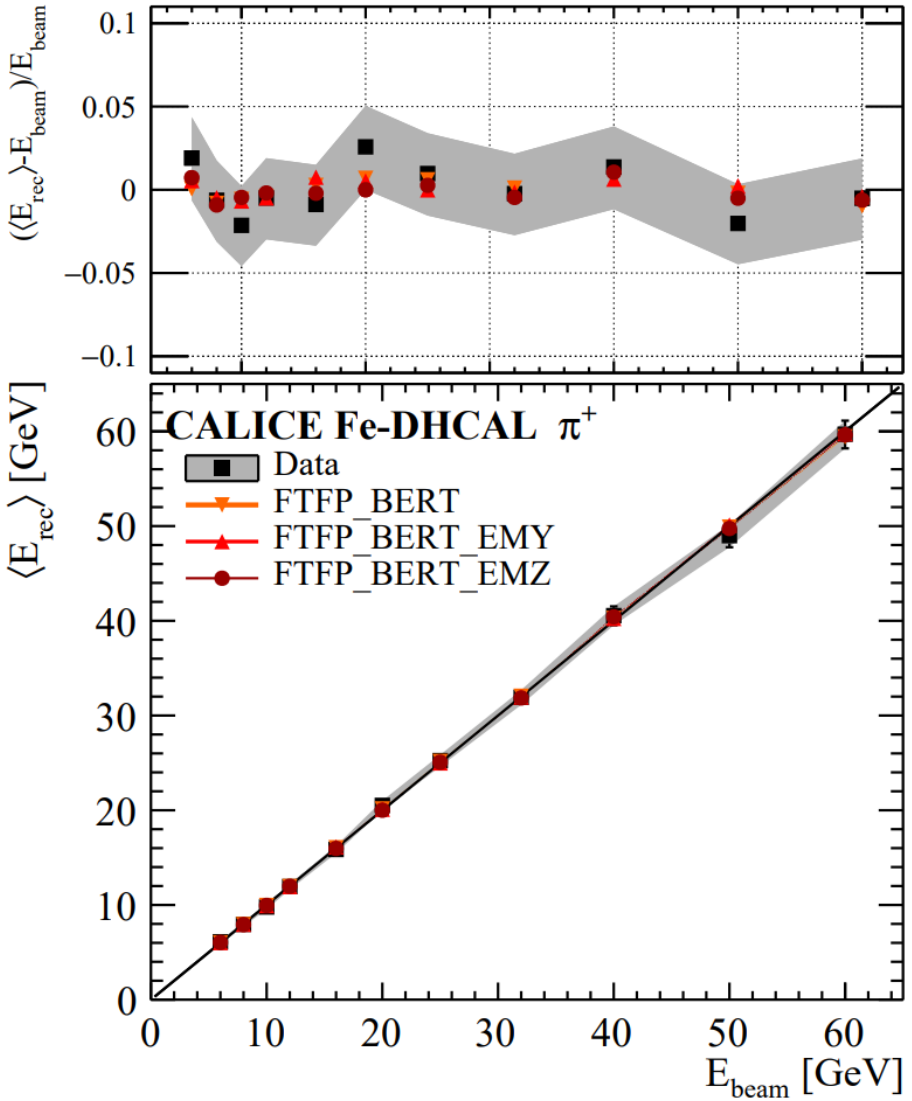


e^+ energy resolution



π^+ beam


CALICE Fe-DHCAL π+
Data
FTFP_BERT
FTFP_BERT_EMY
FTFP_BERT_EMZ
⟨N_hits⟩
Simulation/Data
E_beam [GeV]


(⟨E_rec⟩-E_beam)/E_beam
CALICE Fe-DHCAL π+
Data
FTFP_BERT
FTFP_BERT_EMY
FTFP_BERT_EMZ
⟨E_rec⟩ [GeV]
E_beam [GeV]

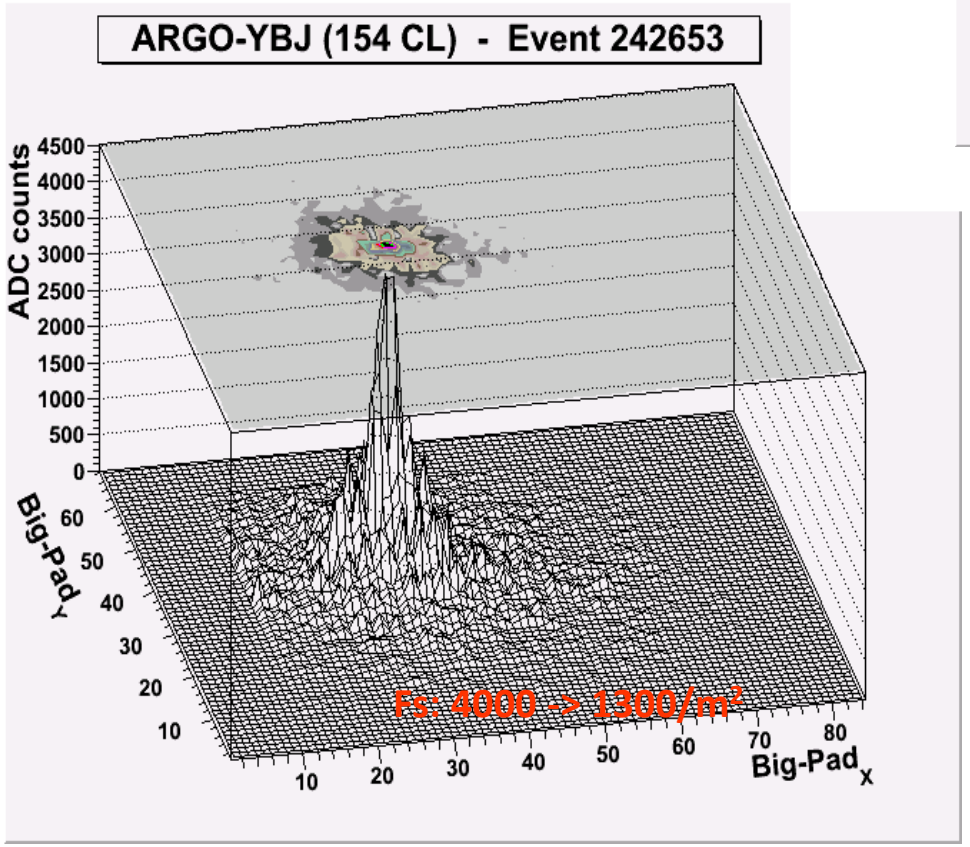
RPCs for cosmic ray showers detection

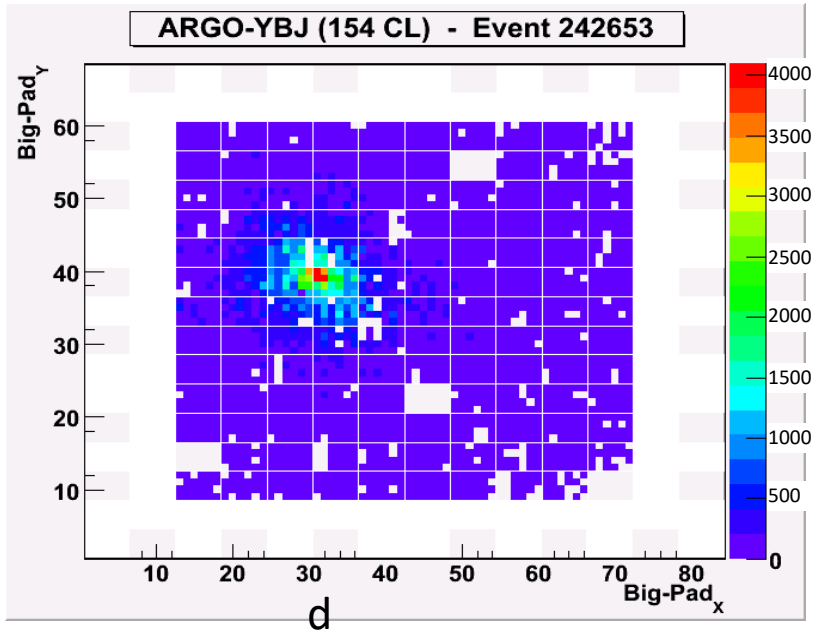
- Extensive air showers generated by the primary cosmic rays can be studied with ground based detectors giving relevant information about cosmic radiation
- The energy of the primary cosmic ray is estimated by the number of detected hits
- Full coverage detectors allow to study the shower core, containing most of the shower particles, with an unprecedented detail
- The usual digital read out can be completely saturated by the core hits density
- The analog read out shows a much wider dynamic range extending up to $2\ 10^4\ hits/\ m^2$

The RPC analog readout

Extending the dynamical range up to PeV

ARGO event





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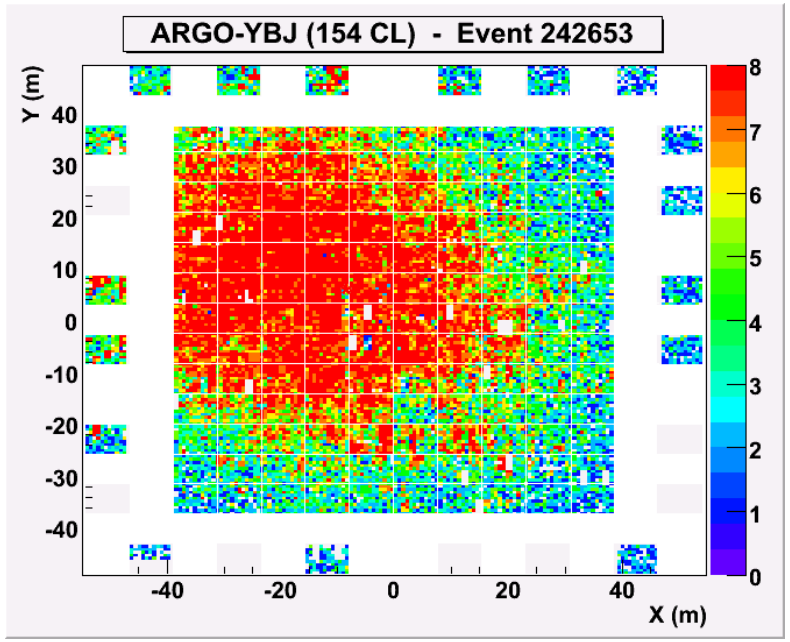
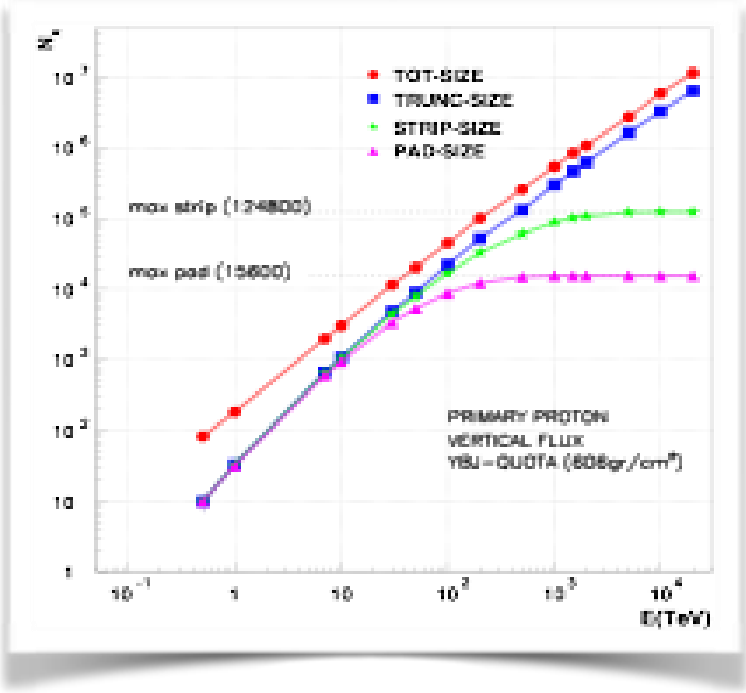


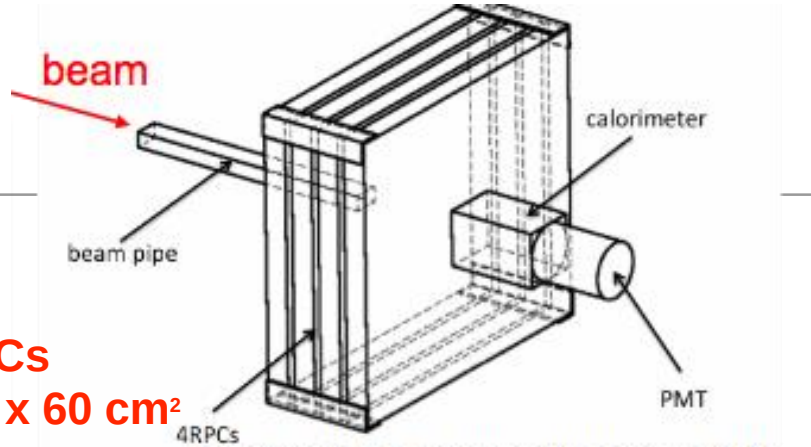
- Is crucial to extend the covered energy range above 100 TeV, where the strip read-out saturates
- Max digital density ~20/m^2
  Max analog dens ~10^4/m^2
- Access the LDF in the shower core
- Sensitivity to primary mass
- Info/checks on Hadronic Interactions



Intrinsic linearity: test at the BTF facility

Linearity of the RPC @ BTF in INFN Frascati Lab:

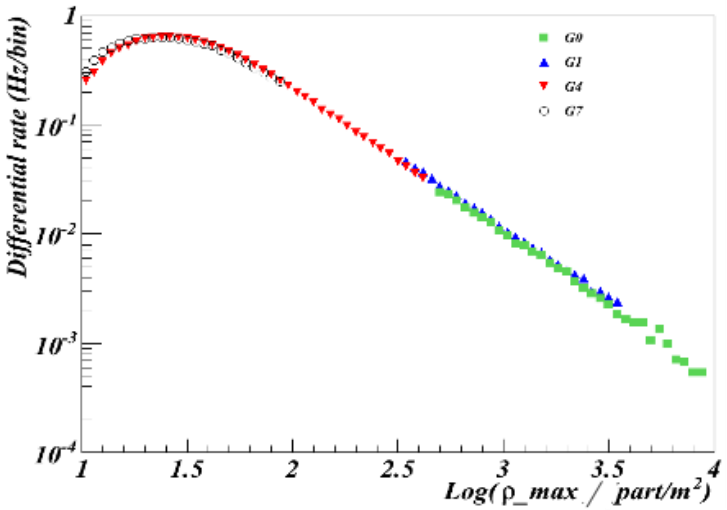
- *electrons (or positrons)*
- *E = 25-750 MeV (0.5% resolution)*
- *<N>=1÷10^{8}particles/pulse*
- *10 ns pulses, 1-49 Hz*
- *beam spot uniform on 3X5 cm*



4 RPCs
60 x 60 cm^2

Calorimeter: lead glass block from OPAL,
PMT a Hamamatsu R2238.

Good overlap between 4 scales with the maximum density of the showers spanning over three decades



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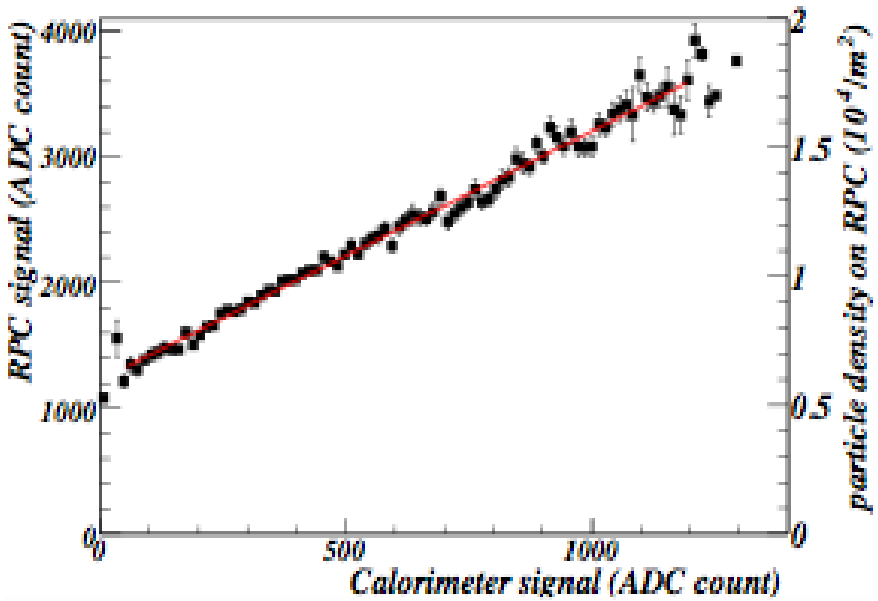
The RPC signal vs the calorimeter signal

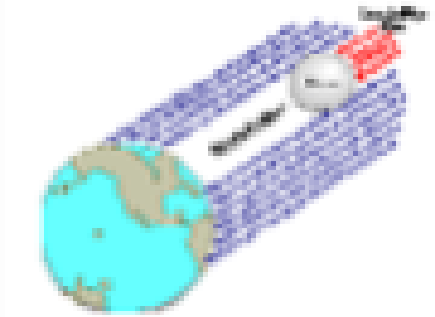


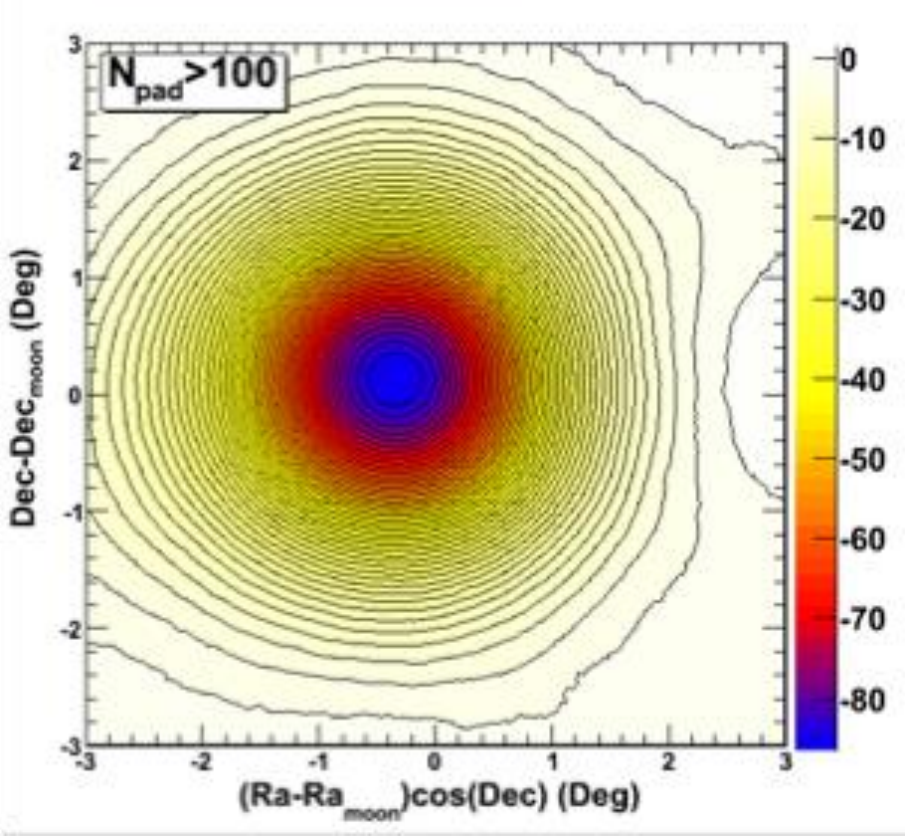
➔ Linearity up to ≈ 2 · 10^4 particle/m^2

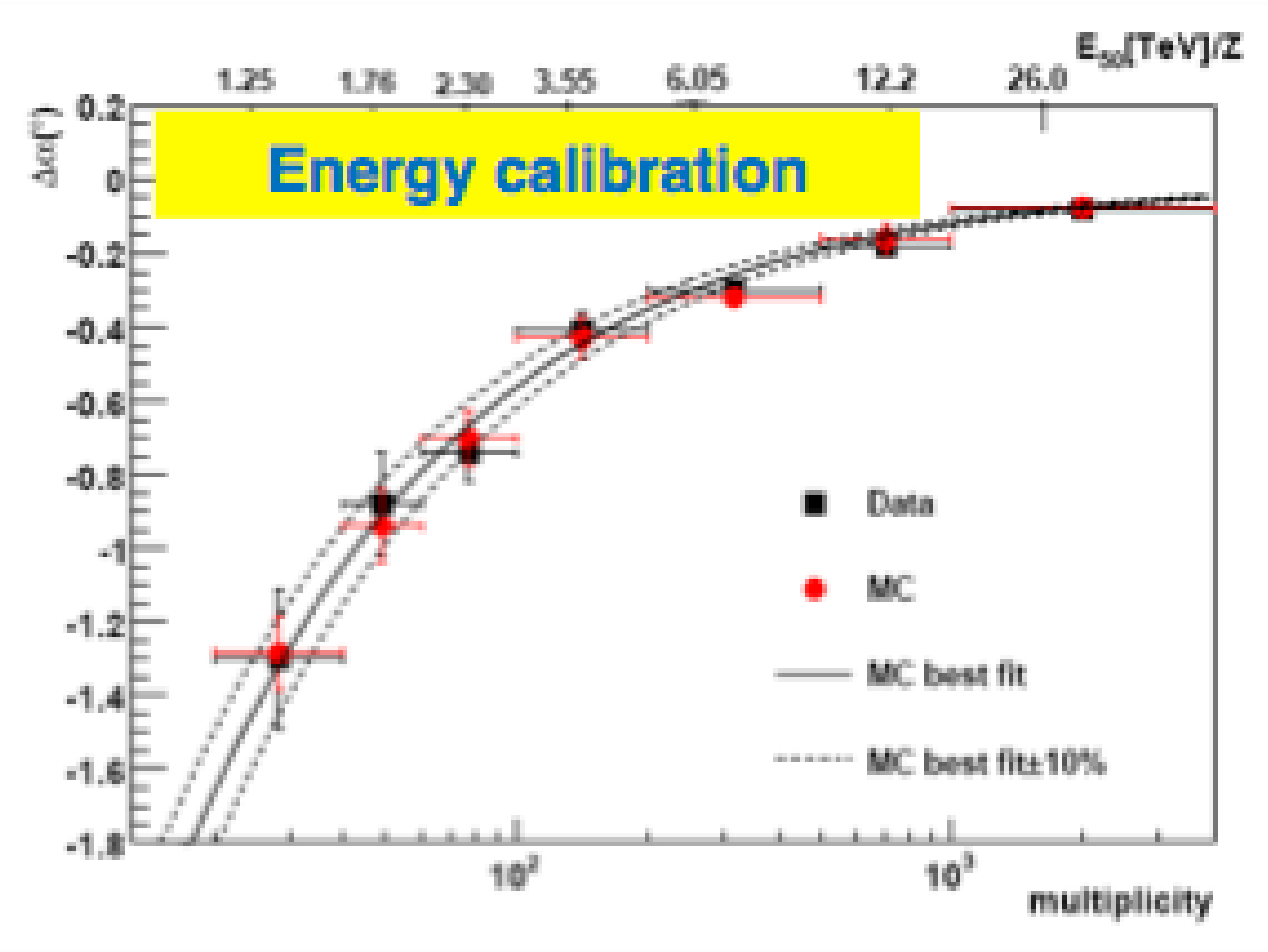
Calorimetric approach to the study of cosmic ray showers

- This suggests that a multilayer RPC detector with interleaved 1 X_0 Lead plates would be a calorimeter much more efficient than usual detectors
- Typical size: 2-3 layers of $2\ 10^4\ m^2$!
- An ideal detector of low energy gamma ray showers
- If located at 5000 m asl it could reduce the gamma ray energy threshold down to 100 GeV or less
- Energy calibration with the moon shadow method

Energy scale calibration







$N \approx 21 \cdot (E_{TeV}/Z)^{1.5}$

10% uncertainty estimated in the energy range
1 – 30 (TeV/Z).

RPCs with semiconducting electrodes

- The idea of using electronic semiconductors as RPC electrodes is mainly motivated by their lower resistivity which allows to increase the RPC rate capability
- Small size RPCs with Silicon and GaAs electrodes have been successfully tested [A. Rocchi et al 2019 JINST **14** C12005]
- Their potential rate capability could be $MHz/\ cm^2$
- RPC with semiconductor electrodes in addition to give an opportunity to extend the RPC range of applications, can offer an unmprecedented opportunity of studying the gas-to-solid interface

RPCs as investigation instruments outside of particle detection outside of particle detection

- Our community of *detector creators* should take this opportunity, not only to get a deeper understanding of the RPC detector physics but also to have some discovery chance in a relatively unknown field like that of the solid-to-gas interface under an extremely high electric field
- This reinforces the idea that RPCs are not only a detector for particle and astroparticle physics. They are themselves an ideal discovery instrument to explore new physics sectors