PERFORMANCE OF MRPC TELESCOPES OF THE EEE PROJECT

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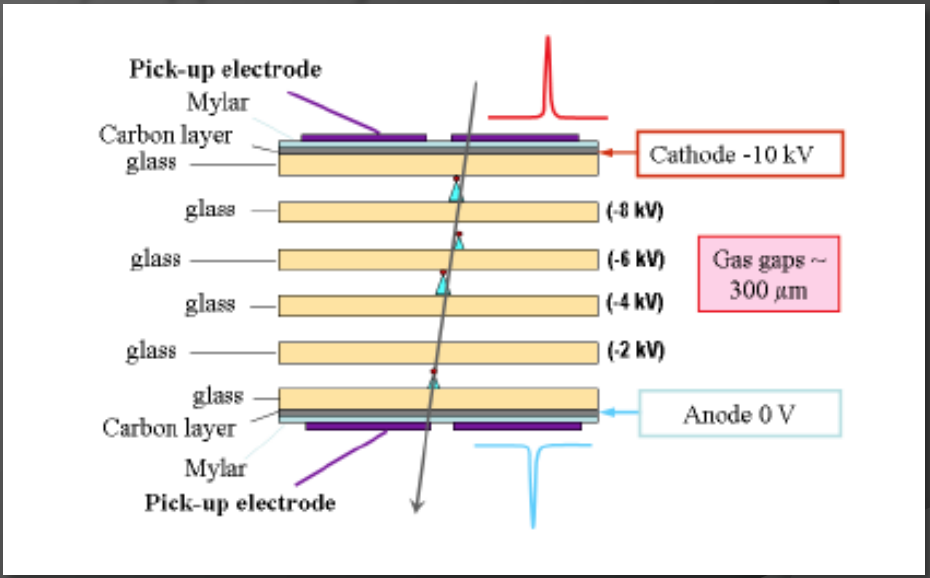
Summary

- ✓ EEE MRPCs
- ✓ time resolution
- ✓ spatial resolution
- ✓ efficiency
- ✓ comparison with 3 indipendent analysis and beam-test

EEE MRPCs

- ✓ 6 gas gaps: 2 glass plates with their external surfaces coated with resistive paint; 5 floating glass plates (spaced by 300 μm)
- ✓ volume resistivity of the glass ~10^{13}Ωcm
- ✓ $C_2H_2F_4$(98%) and SF_6(2%) continuously fluxed by (3 l/h)
- ✓ 24 readout copper strips as electrodes (pitch 3.2 cm)
- ✓ HV up to 20 kV (avalanche mode) supplied by 2 DC/DC converters



- ✓ Townsend avalanche process
- ✓ the glass plates terminate the avalanche development in each gap
- ✓ the induced signals, sum of the signals due to all avalanches in all gaps, are picked up by the copper strips on both vetronite panels

EEE MRPCs

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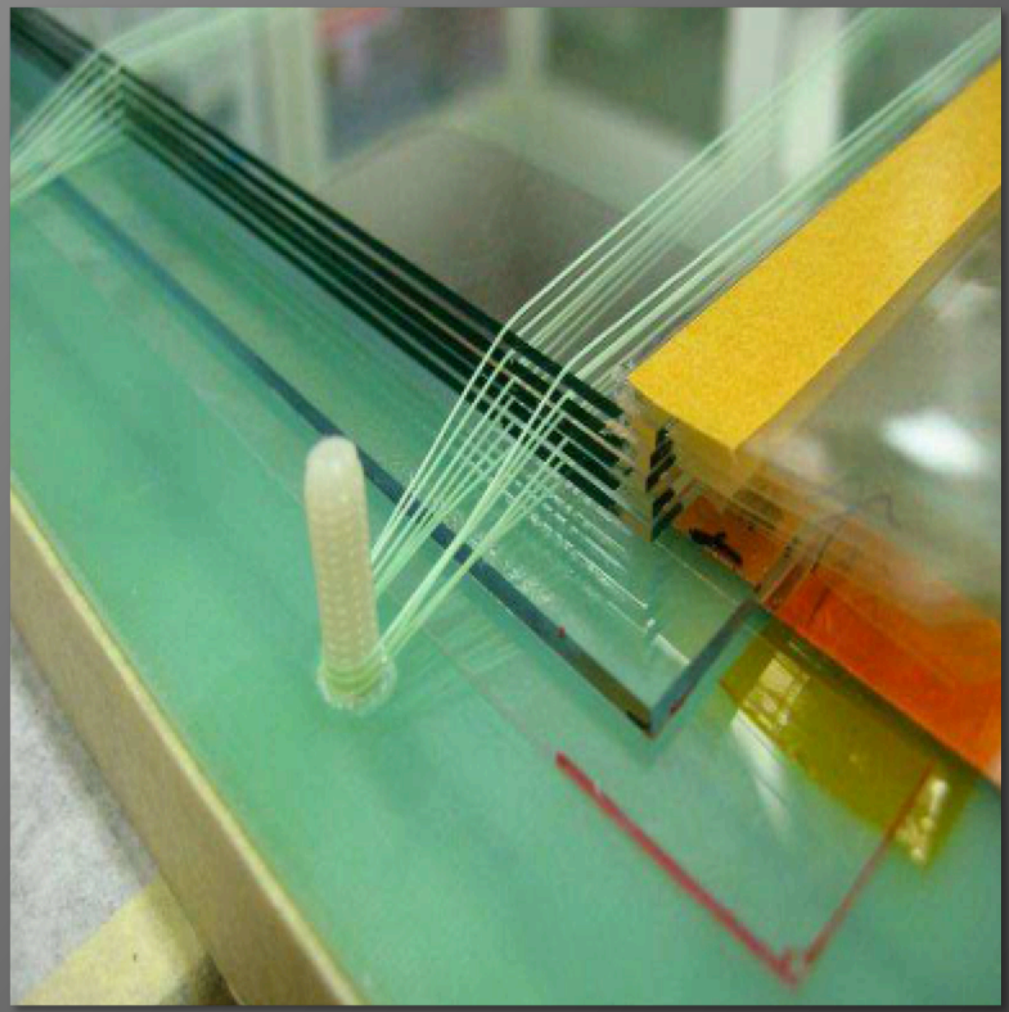

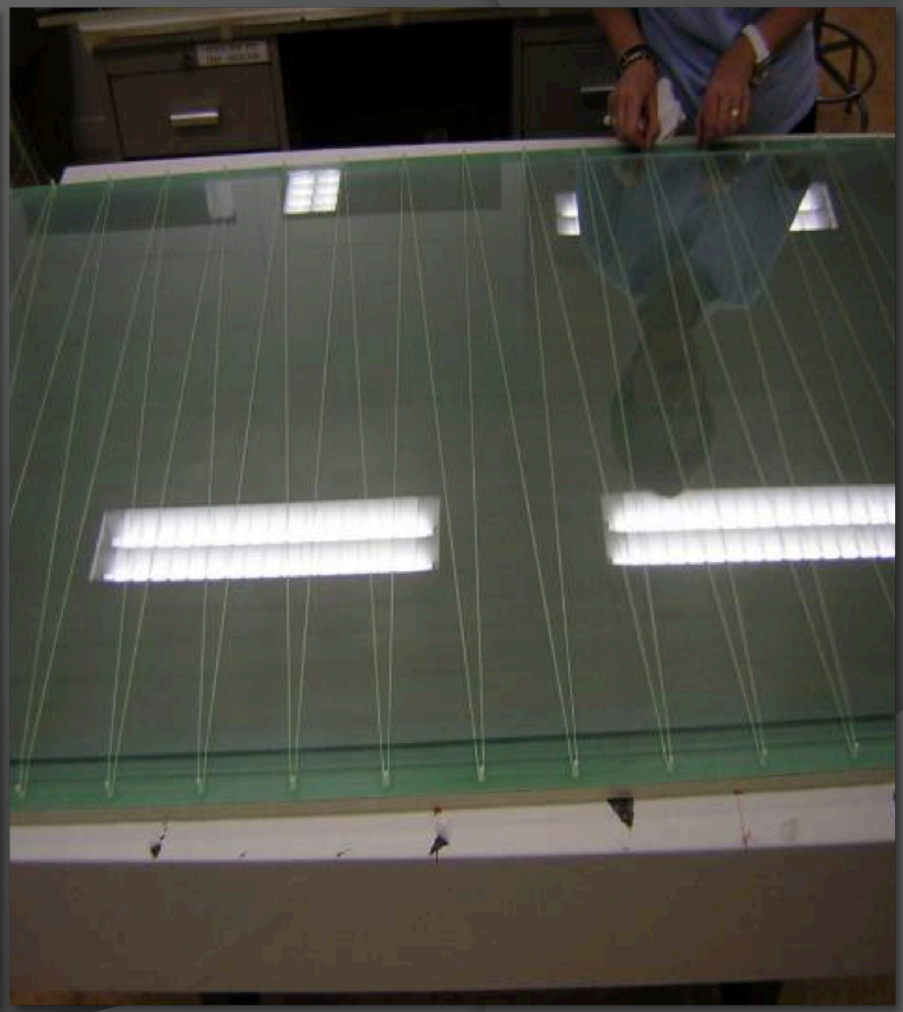

EEE MRPCs

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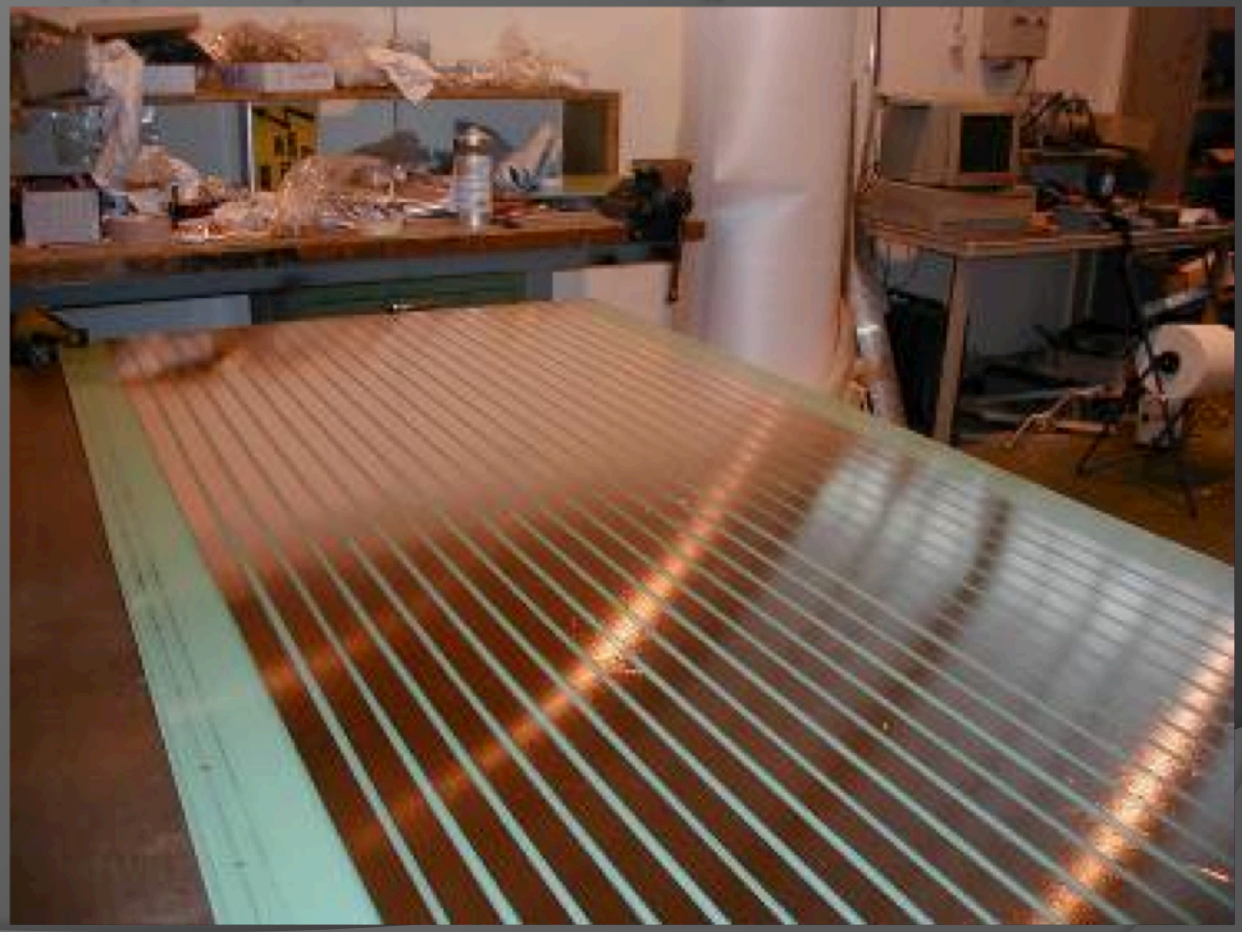
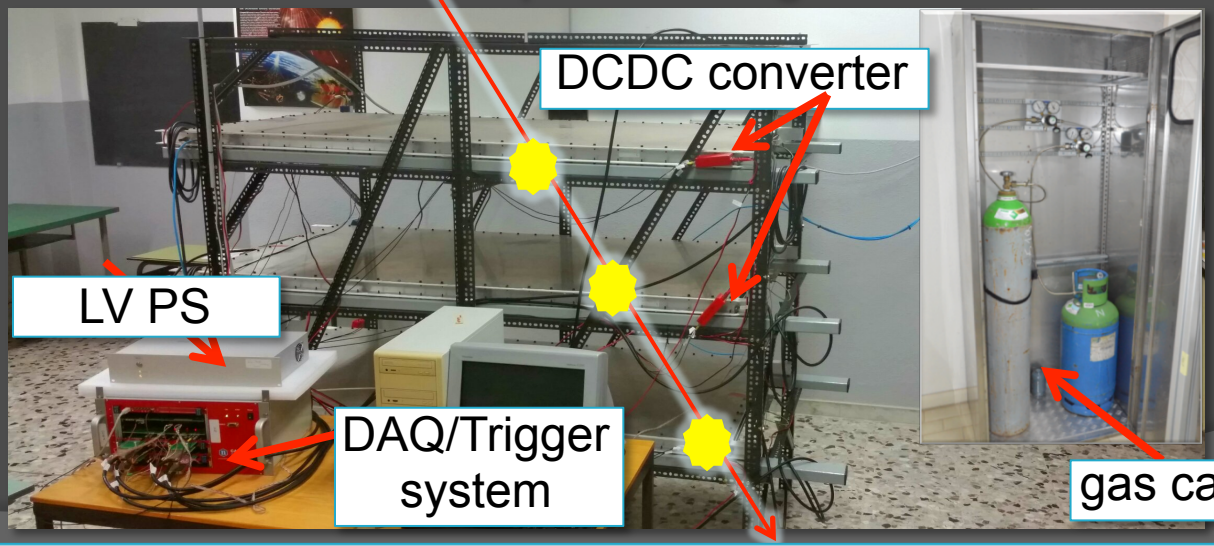


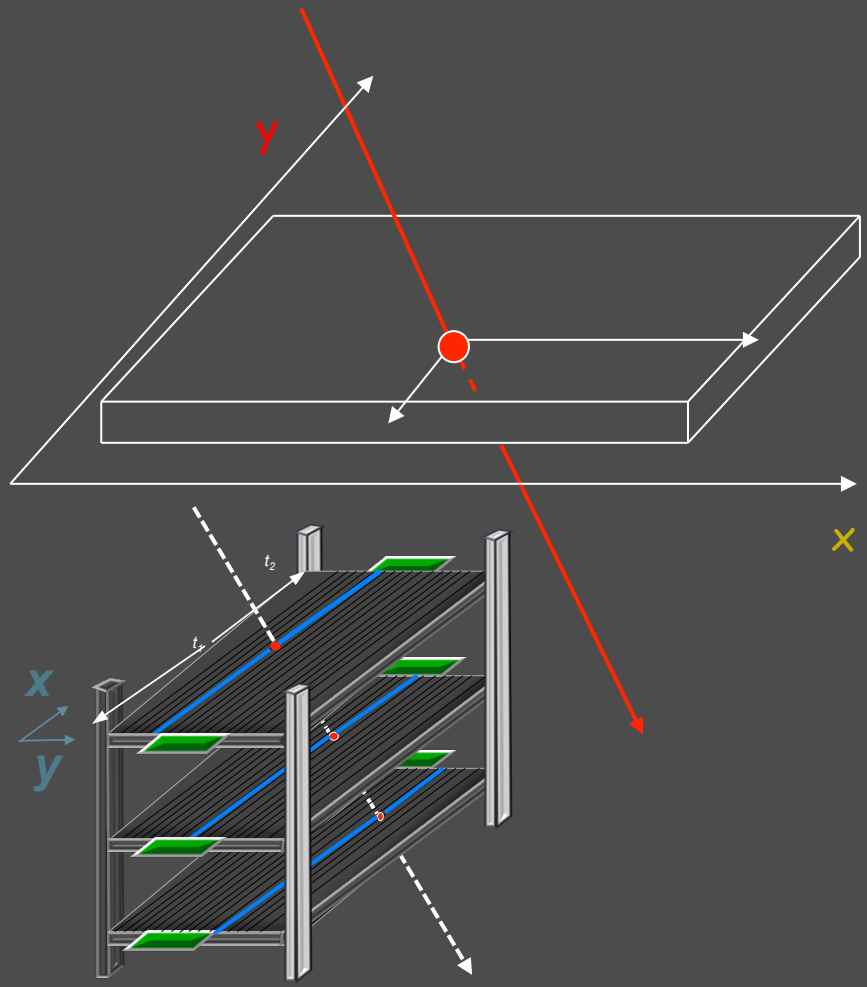
EEE telescope

- ✓ 6 FRONT-END boards (FEAs) with 24 channels to process readout signal (pre-amplification + discrimination)
- ✓ 2 MULTI-HITS TIME TO DIGITAL CONVERTERS (TDCs 128 + 64 channels) to reconstruct the particle impact point
- ✓ 1 MULTI-TRIGGER CARD: a six-fold coincidence of both FEAs of the three MRPCs generates the Data AcQuisition (DAQ) trigger
- ✓ GPS UNIT provides the event time stamp (UTC time) to record and synchronize informations
- ✓ HIGH VOLTAGE provided by DC/DC converters
- ✓ WEATHER STATION to monitor the temperature and the pressure inside and outside the telescopes building



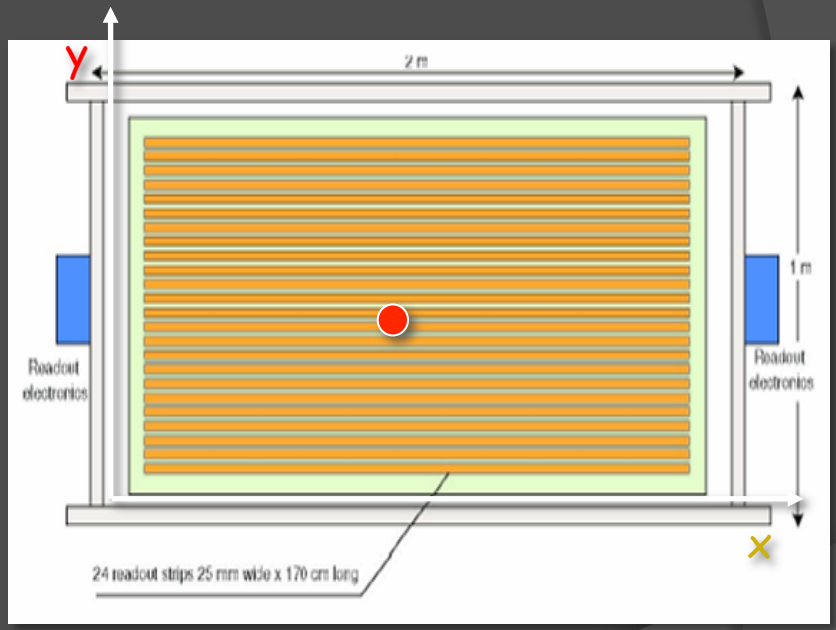
data sent to CNAF to be stored, reconstructed and analysed

Coordinates and performance



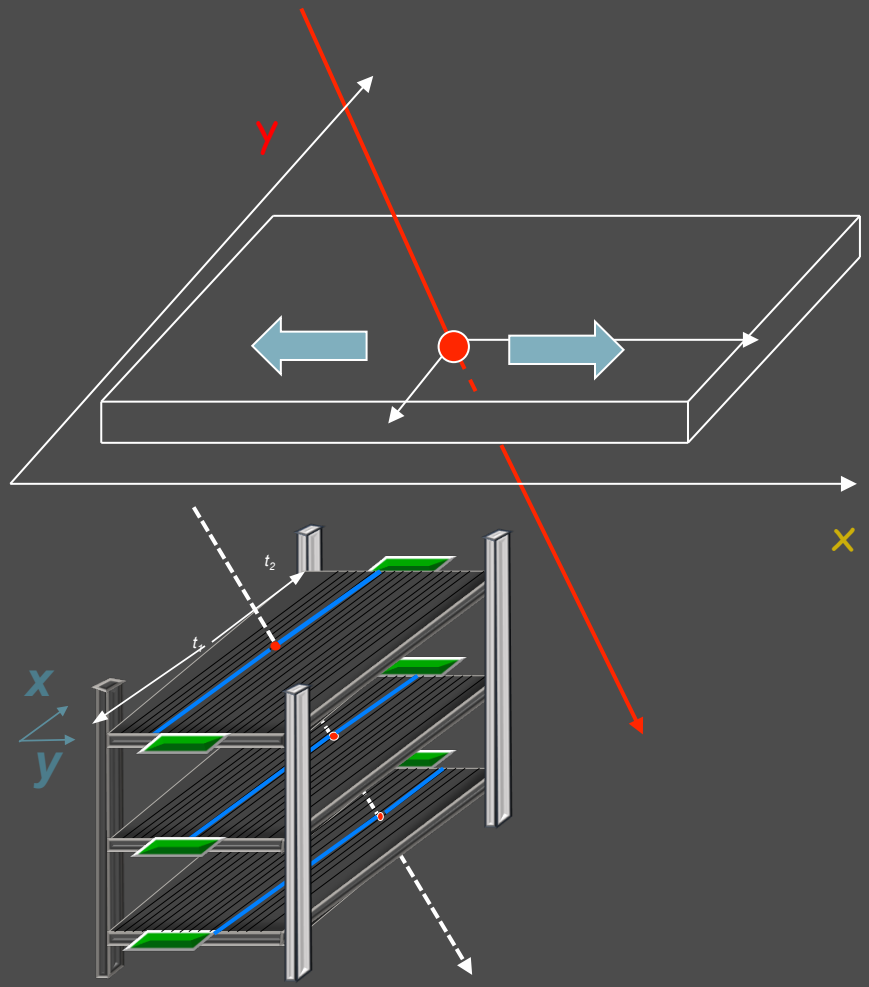
particle impact point reconstructed by:

- ✓ fired strip (y) in one direction
- ✓ difference of signal arrival times at the strip ends (x) measured by TDCs in the other direction



- ✓ 100 ps time resolution of the TDC bin
- ✓ ~1 cm spatial resolution along both coordinate
- ✓ > 95% MRPC efficiency at the operating voltage of 18 kV
- ✓ few tens ns GPS time resolution

Coordinates and performance



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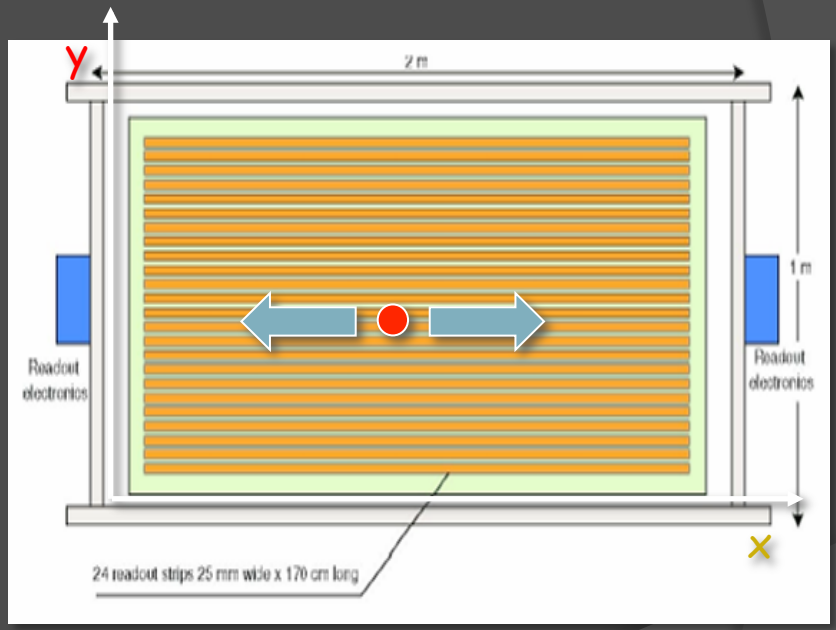

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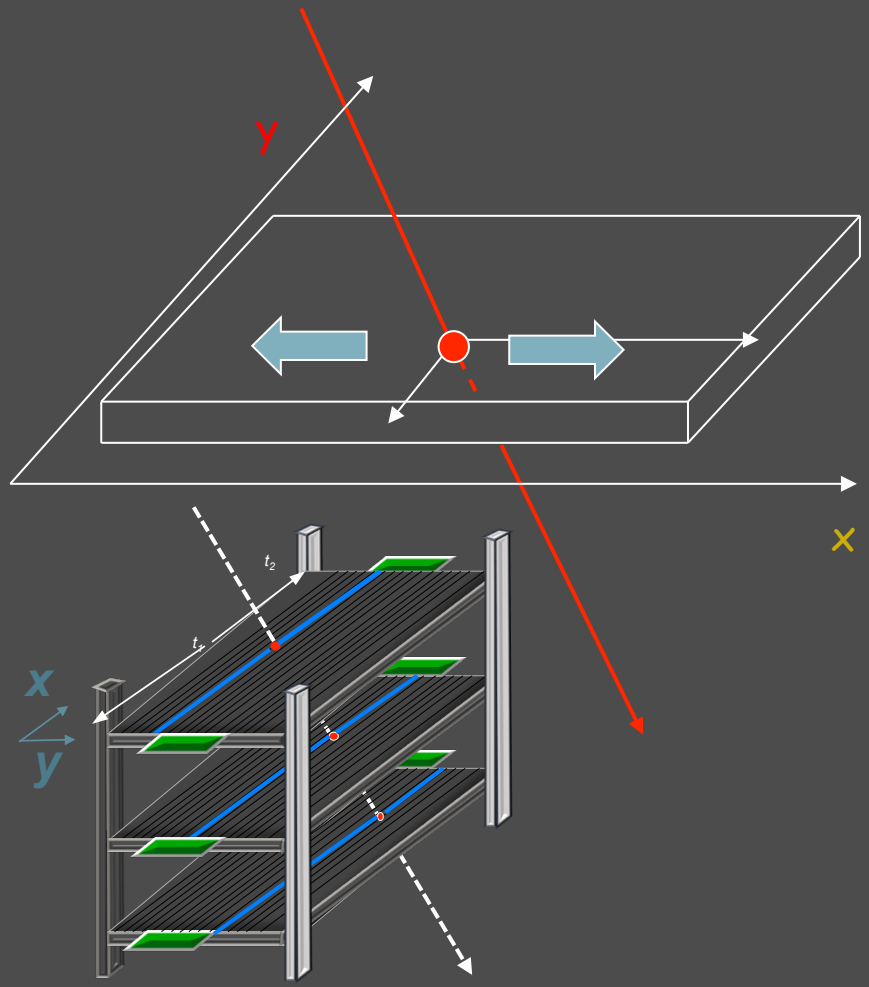

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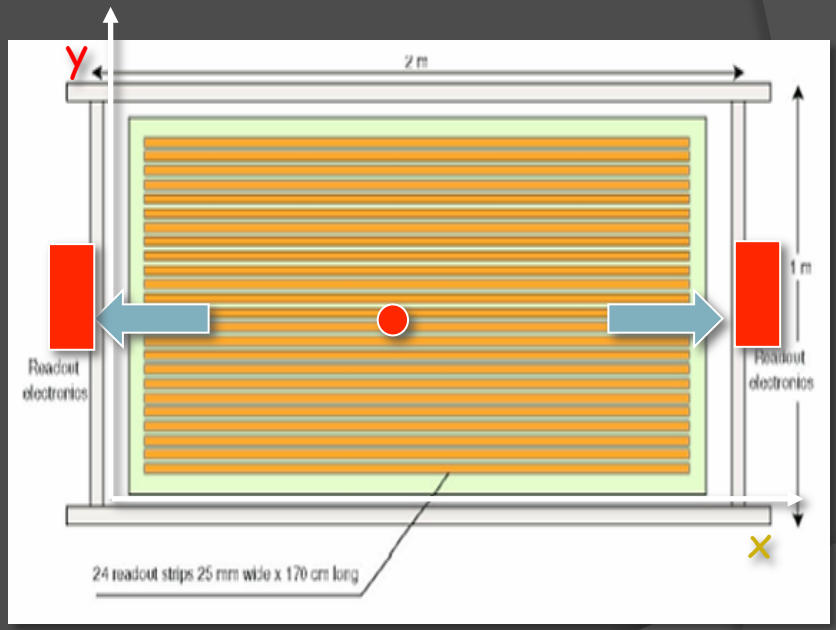

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Students involvement

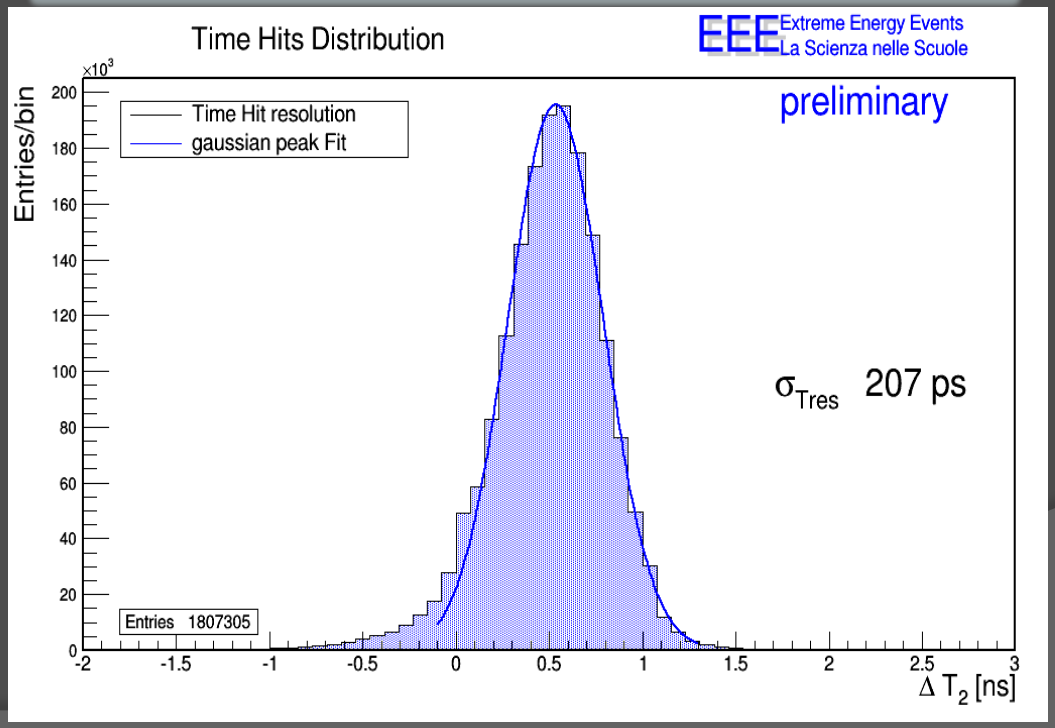
- ✓ one week to build 3 chambers (activity at CERN)
- ✓ secondary school students work under researchers' supervision (activity at CERN)
- ✓ all chambers are correctly working in each single telescope (daily monitor)
- ✓ setup of the telescope (activity at school)
- ✓ chamber efficiency measurements (activity at school)

- ✓ 5-7 students + 2-3 teachers per school
- ✓ ~300 students and ~80 teachers in total

Time resolution

- ✓ cut on reconstructed tracks $\chi^2 < 10$
- ✓ strip by strip calibration applied
- ✓ results recently presented at conferences

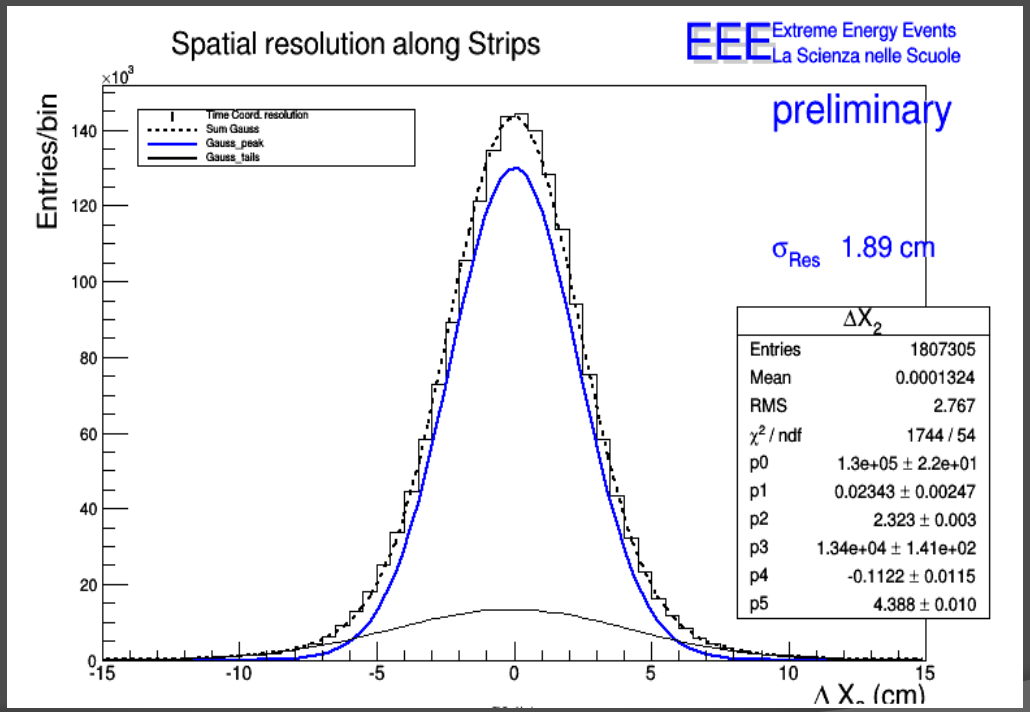
- ✓ $\Delta T_{hit} = (T_{H\_bot} + T_{H\_top})/2 - T_{H\_mid}$
- ✓ $\sigma_T = \sqrt{3}/2\sigma_{\Delta T} \sim 207$ ps
- ✓ time slewing correction to be applied (soon)



Spatial resolution (long side)

- ✓ cut on reconstructed tracks $\chi^2 < 10$
- ✓ strip by strip calibration applied
- ✓ results recently presented at conferences

- ✓ $\Delta X = (X_{bot} + X_{top})/2 - X_{mid}$
- ✓ $\sigma_X = \sqrt{3}/2\sigma_{\Delta X} \sim 1.9$ cm



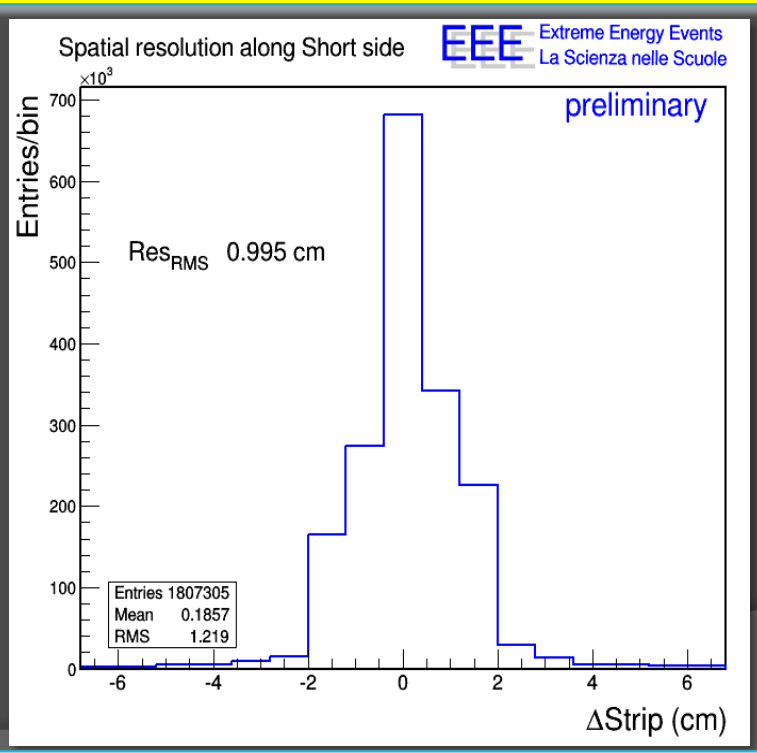
- ✓ two contributions are visible → to be understood
- ✓ two gauss ditributions used for the fit
- ✓ using only one gauss $\sigma_X = 2.05$ cm
- ✓ $\sigma_{Xexp} \sim v_{signal} * (\Delta T_{lef}^2 + \Delta T_{right}^2)^2 \sim 0.68$ cm

(TDC resolution 100 ps → $v_{signal} \sim 15.6$ cm/ns)

Spatial resolution (short side)

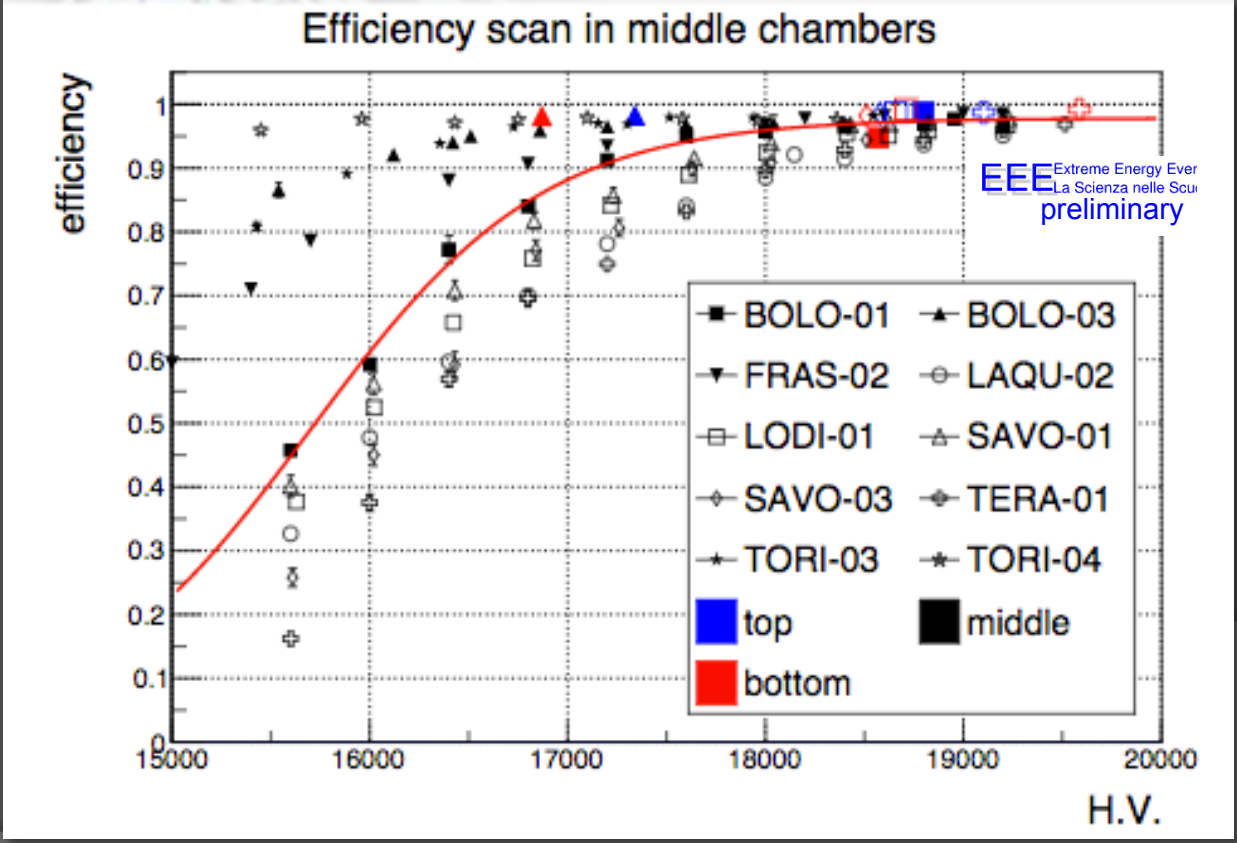
- ✓ cut on reconstructed tracks $\chi^2 < 10$
- ✓ strip by strip calibration applied
- ✓ results recently presented at conferences

- ✓ $\Delta Y = (Y_{bot} + Y_{top})/2 - Y_{mid}$
- ✓ $\sigma_Y = \sqrt{3}/2\sigma_{\Delta Y} \sim 1$ cm
- ✓ $\sigma_{Yexp} \sim pitch/\sqrt{12} \sim 0.92$ cm (pitch 3.2 cm)

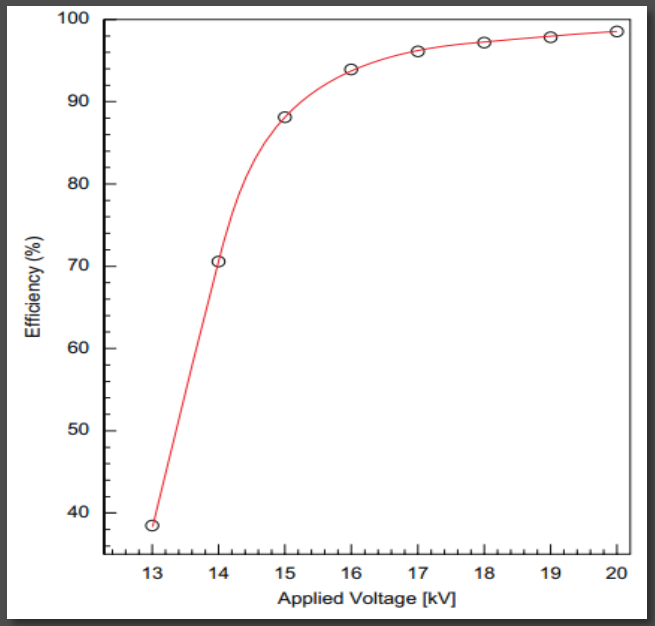


Efficiency

- ✓ external chambers used as trigger
- ✓ efficiency of the middle chamber measured on all telescopes
- ✓ efficiency of external chambers measured on a few telescopes



Results from test beam (2006)

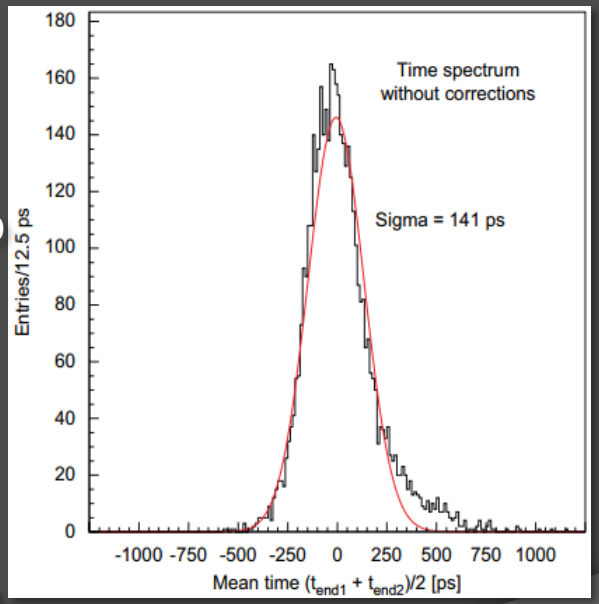


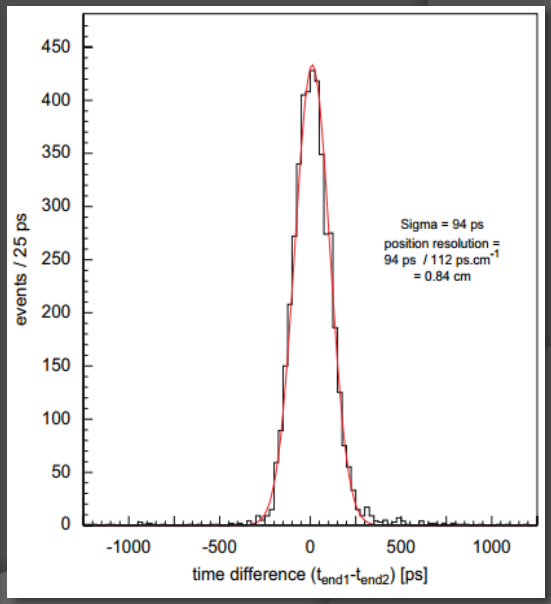
TEST BEAM at CERN

- ✓ efficiency vs HV for a single MRPC chamber
- ✓ triggered by scintillators
- ✓ efficiency plateau ~100%

TDCs 25ps bins , scintillators system time resolution 30 ps

- ✓ σ_T ~ 141 ps in the center of the strip
- ✓ with time slewing correction and scintillators time resolution σ_T ~ 94 ps



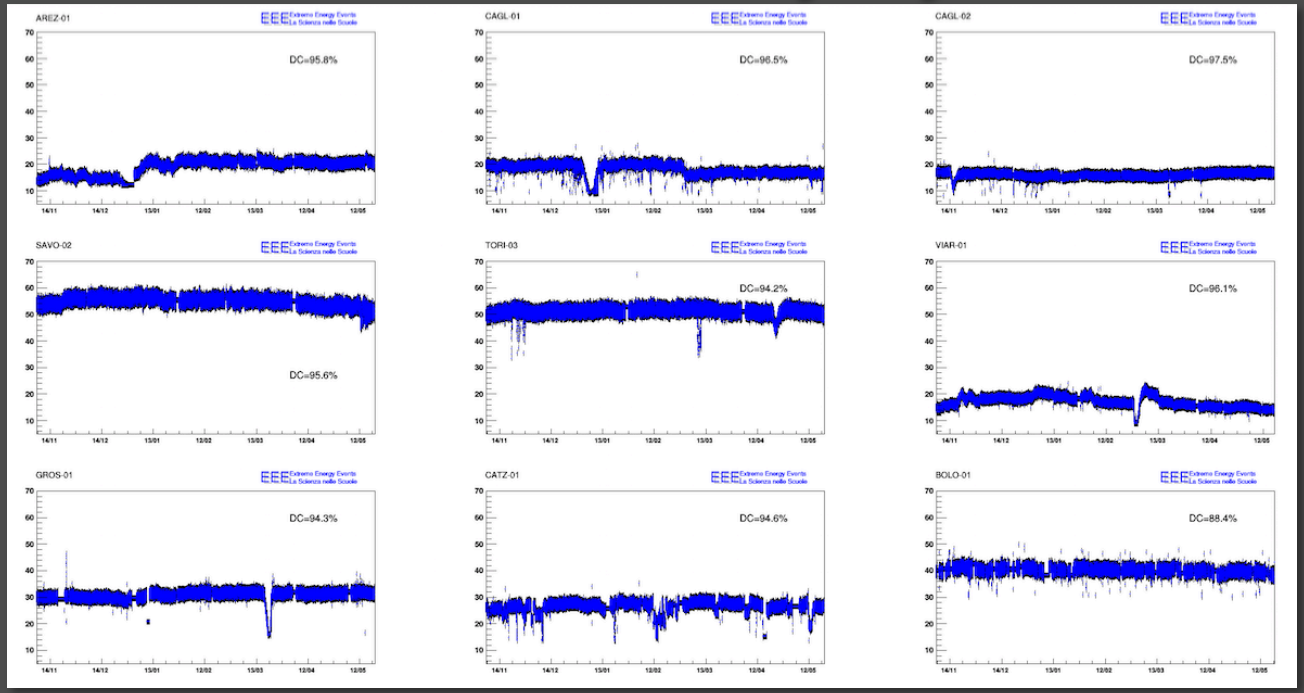


spatial resolution along strips 8 mm

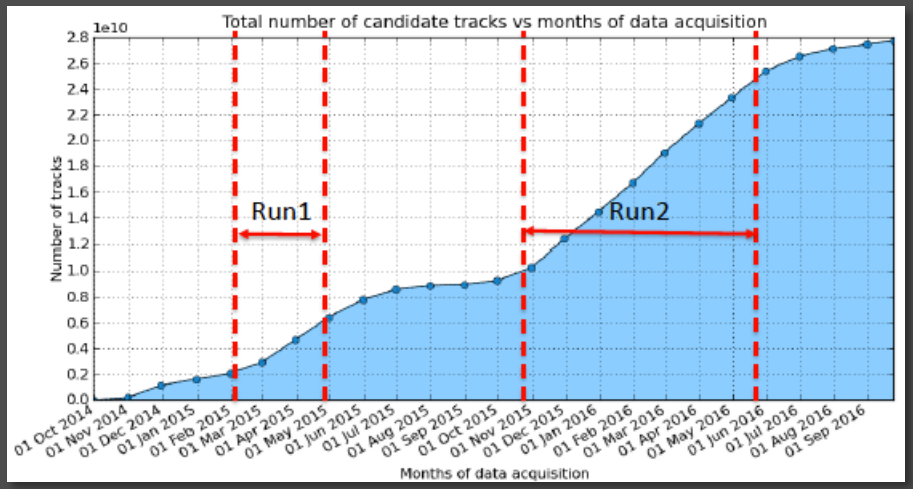
Comparison with indipendent analysis

- ✓ 3 indipendent analysis:
  - ✧recent analysis from degree students in Pisa
  - ✧old analysis for degree in 2008 in Bologna
  - ✧recent analysis on multitrack events
- ✓ results are consistent with analysis from “performance working group” (backup)

Duty cycle

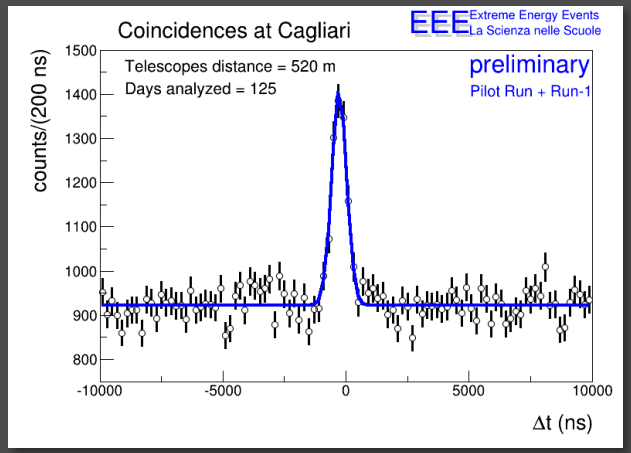


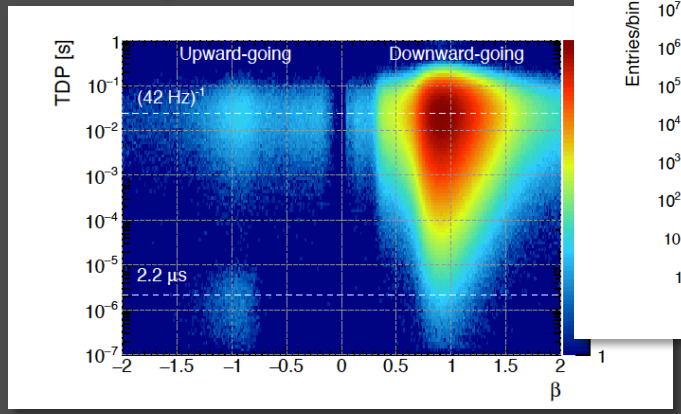
- ✓ stable duty cycle crucial for most of the analysis
- ✓ a few examples here

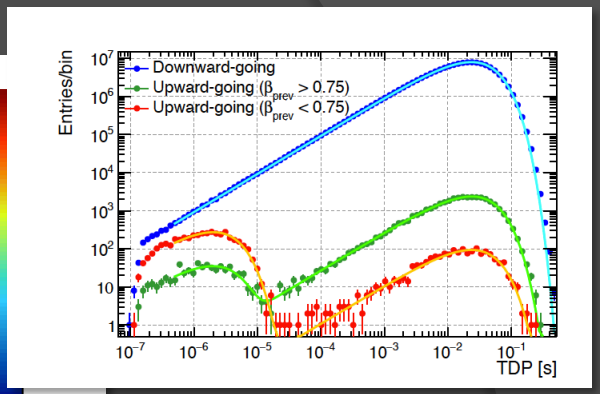


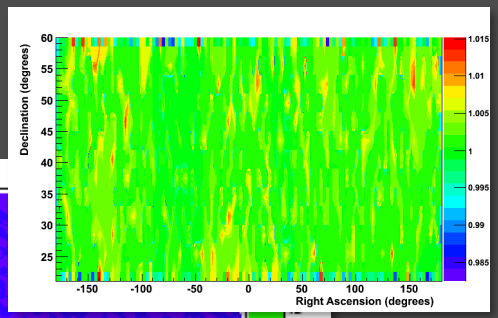
- ✓ ~ 28 billions of tracks collected
- ✓ Run 3 will start on the 14th of October

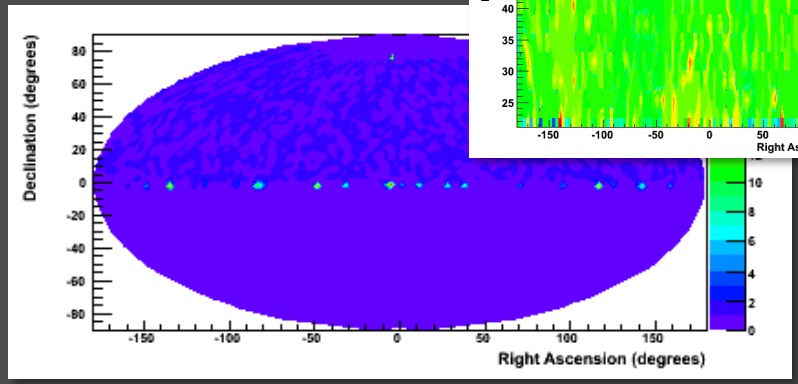
Analysis

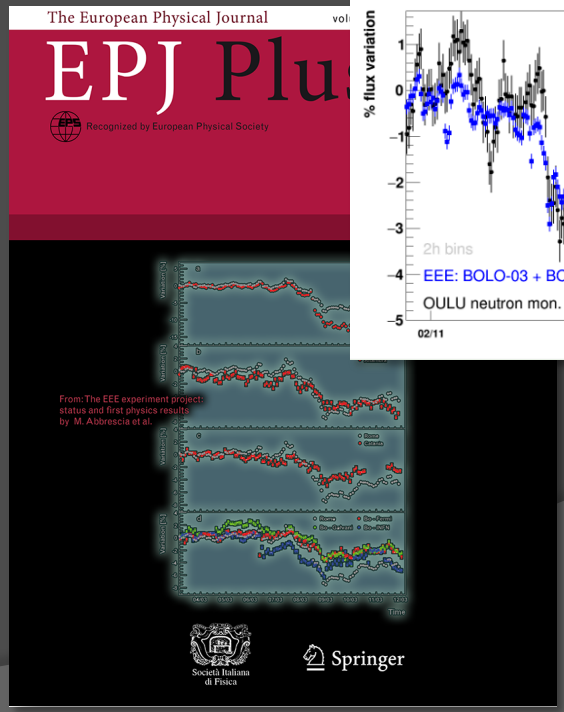


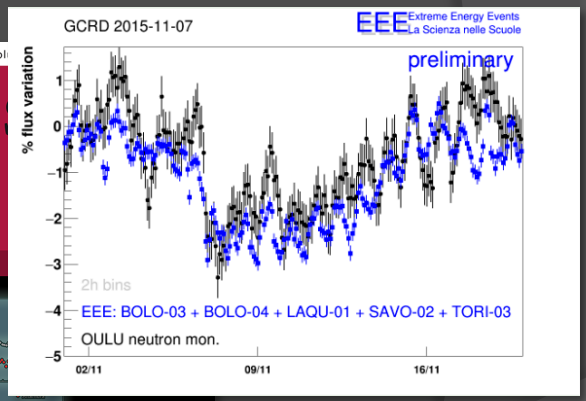






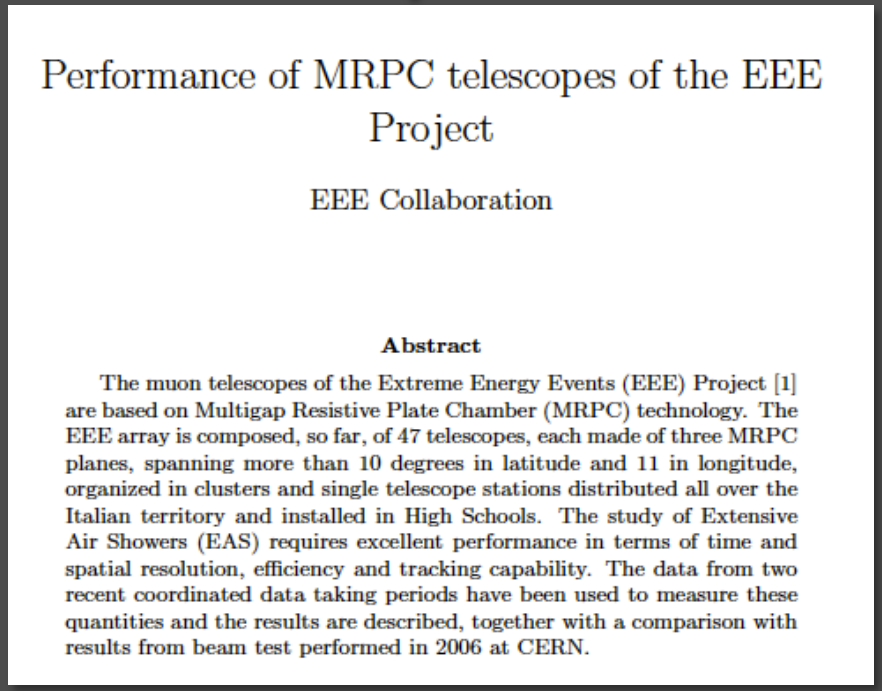






- ✓ telescope coincidences
- ✓ search for anisotropies
- ✓ Forbush decrease
- ✓ muon decay
- ✓ many others…

Papers



Performance of MRPC telescopes of the EEE Project

EEE Collaboration

Abstract

The muon telescopes of the Extreme Energy Events (EEE) Project [1] are based on Multigap Resistive Plate Chamber (MRPC) technology. The EEE array is composed, so far, of 47 telescopes, each made of three MRPC planes, spanning more than 10 degrees in latitude and 11 in longitude, organized in clusters and single telescope stations distributed all over the Italian territory and installed in High Schools. The study of Extensive Air Showers (EAS) requires excellent performance in terms of time and spatial resolution, efficiency and tracking capability. The data from two recent coordinated data taking periods have been used to measure these quantities and the results are described, together with a comparison with results from beam test performed in 2006 at CERN.

2015

EEE coll. *Looking at the sub-TeV sky by cosmic muons detected in the EEE MRPC telescopes* **EPJ-Plus (2015), 130:187**

EEE coll. *A study on upward going particles with the Extreme Energy Events telescopes* **Nucl. Instr. and Meth. A 816 (2016) 142:148**

In preparation

- *Performance of MRPC telescopes of the EEE Project*
- *An extended study of subTeV anisotropies with the EEE array*
- *A study of multistation coincidences at the km scale with the EEE array*
- *A Forbush decrease survey with the EEE telescopes*

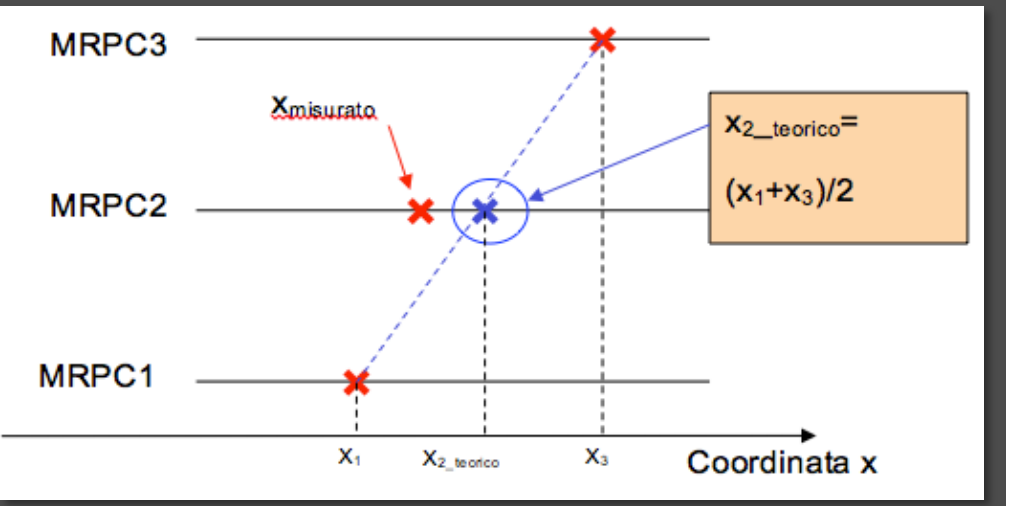
Conclusions

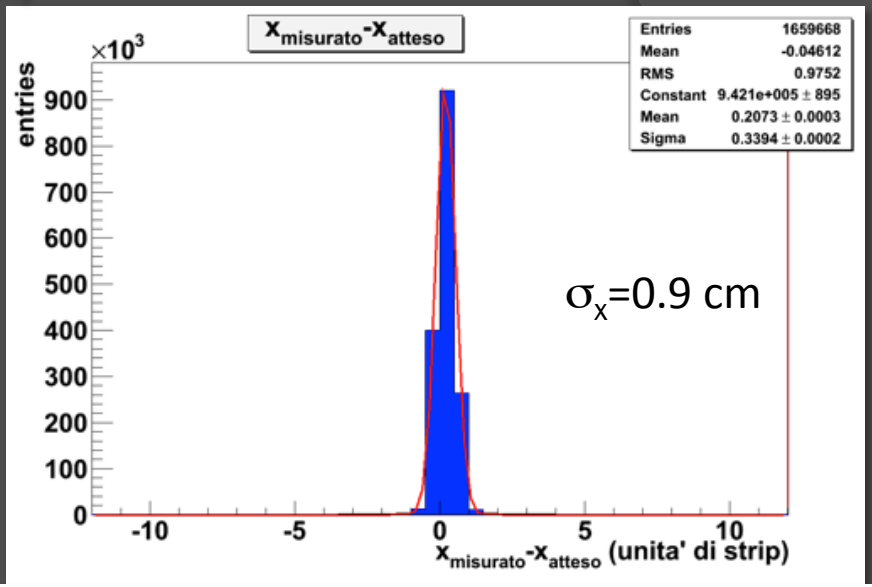
- ✓ Multigap Resistive Plate Chamber (MRPC) technology used to create an array of muon telescopes for an overall area of 3×10^5 km^2
- ✓ very good performance in terms of time resolution and efficiency
- ✓ good amount of results and teaching activity carried out
- ✓ new physics results with Run 3 data (large statistics expected)
- ✓ *young students involved in the project*
- ✓ new schools joining the project

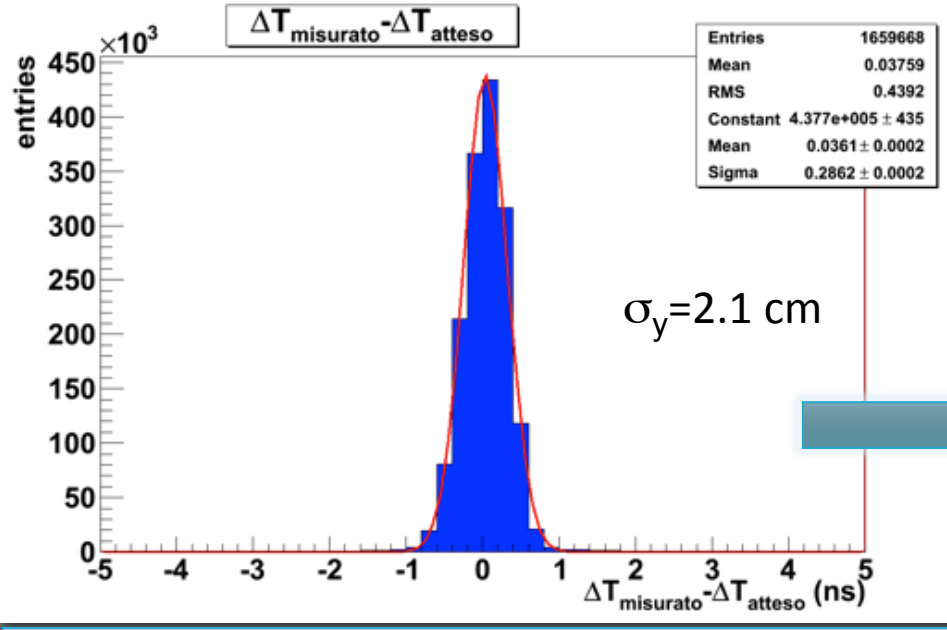
backup

Bologna

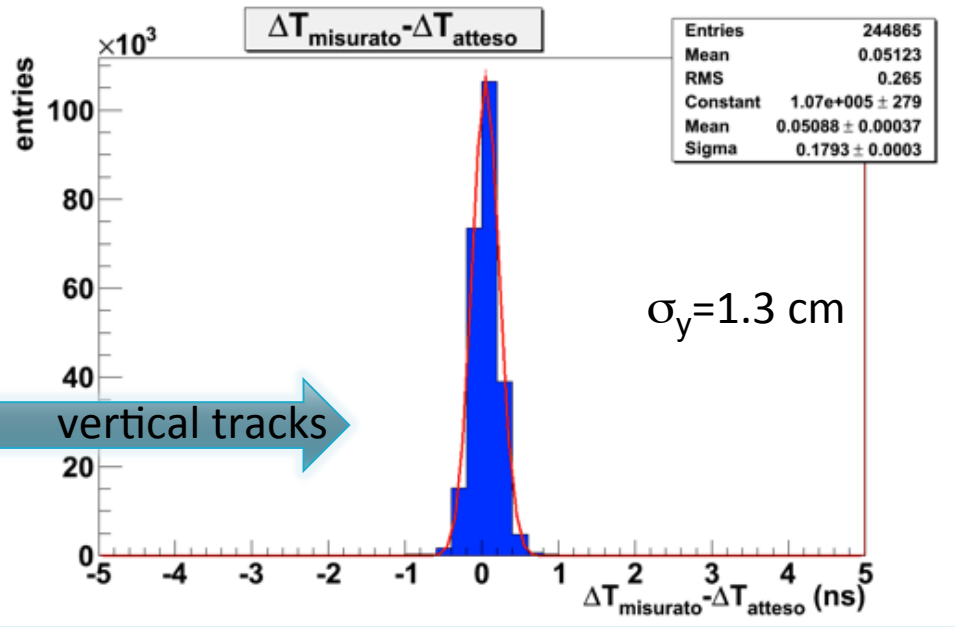
analysis done in Bologna in 2008 (graduate student)







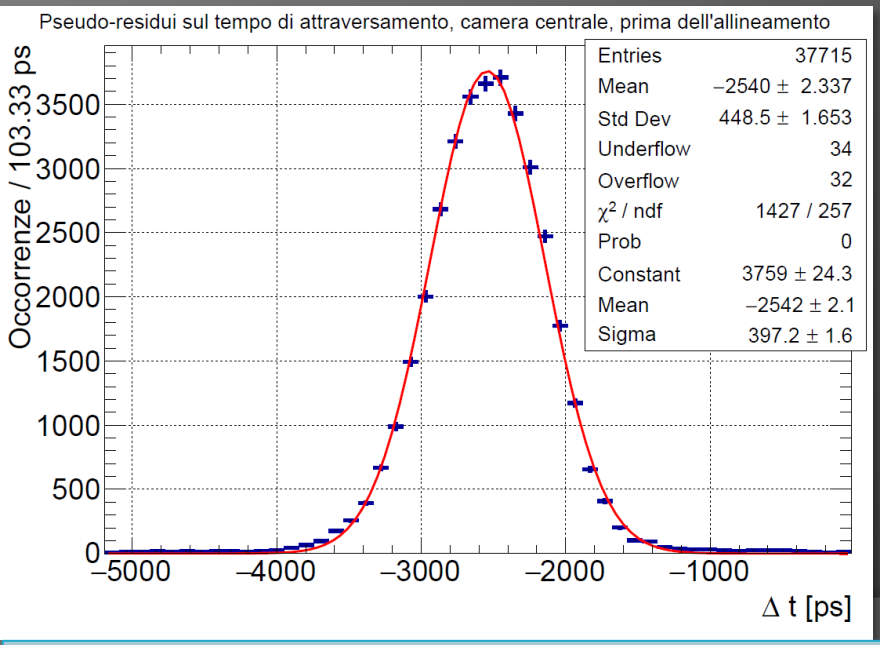
vertical tracks



Pisa

analysis done by graduate students

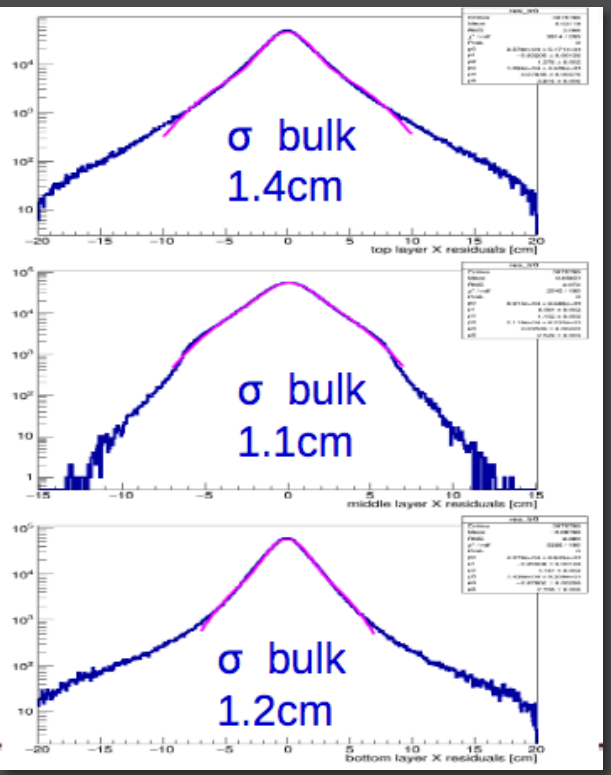
- ✓ raw alignment with the box distribution
  - ✧ hit position obtained by correcting the offset of the box distribution
  - ✧ hit raw time of the middle chamber centered wrt the external chambers
- ✓ track cuts applied after the alignment (1 hit/chamber, χ^2/d.o.f. < 4)
- ✓ align the middle chamber with the residual distribution
- ✓ iterate
- ✓ re-scan all events with the new calibration



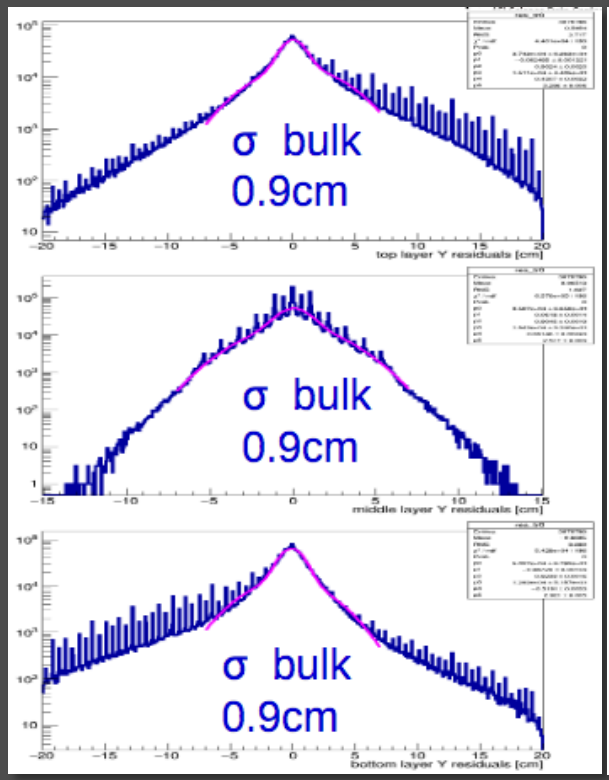
- ✓ similar results for spatial resolution (σ_x~ 1.4 cm, σ_y ~ 1.2 cm)
- ✓ very good time resolution

Multitrack events

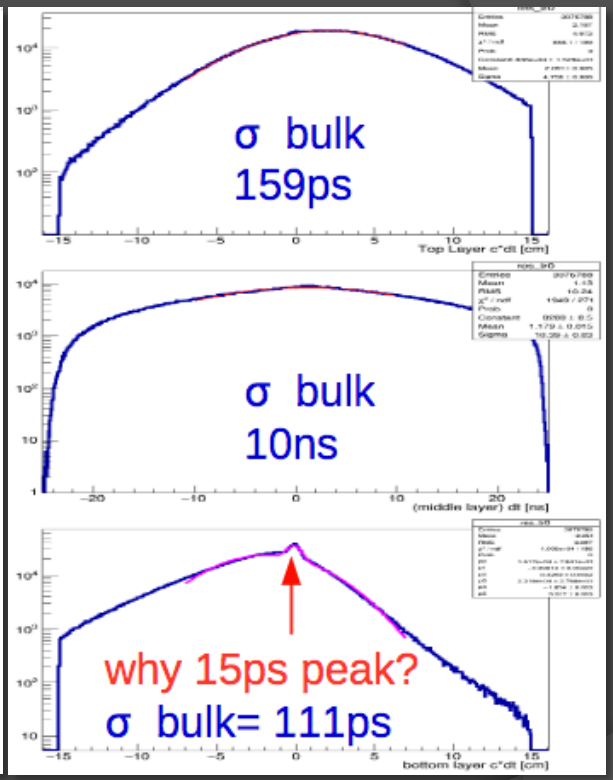
SAVO-01



residual x



residual y



time residual

similar results on SAVO-02 and FRAS-02

EEE array

- ✓ a *pilot phase* with telescopes in 7 High Schools started in 2004
  (Bari, Bologna, Cagliari, Catania, Frascati, L'Aquila, Torino)

- ✓ in *2015*:

an *experiment* with 47 EEE directional telescopes for cosmic ray muons detection (52 in 2016)

  - ✧ 42 in Italian High Schools (+ 5 in preparation)
    + 2 at CERN + 3 at INFN units

- ✓ overall area 3×10^5 km^2

in addition:

- ✓ powerful impact on education
- ✓ introducing high-school students and teachers to particle physics
- ✓ direct involvement in the construction, operation and data analysis
- ✓ >100 teachers, ~500 students directly involved in the last 3 years