XIV Workshop on
Resistive Plate Chambers
and related detectors

RPC2018

Puerto Vallarta, Jalisco, Mexico
Hilton Hotel Feb 19-23, 2018

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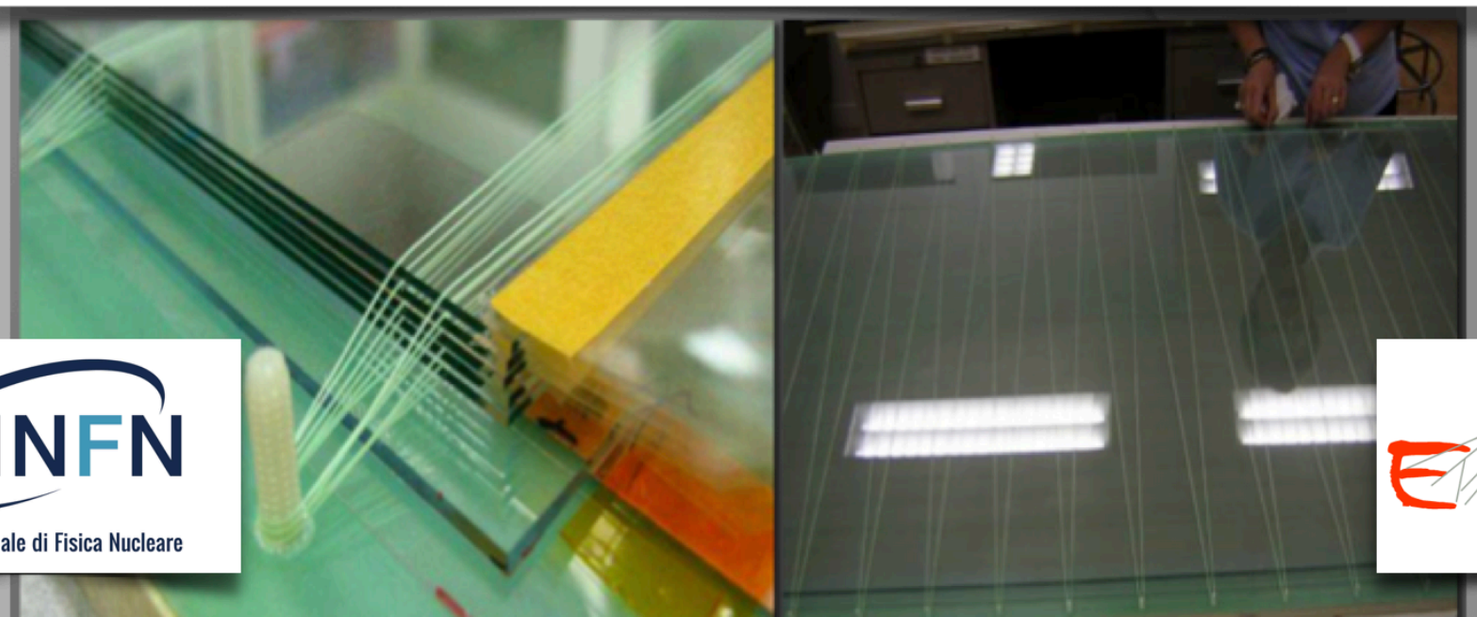
Performance of the Multigap Resistive Plate Chambers of the Extreme Energy Events Project

D. De Gruttola* for the EEE Collaboration

* Centro Fermi, Rome and Salerno INFN - Italy

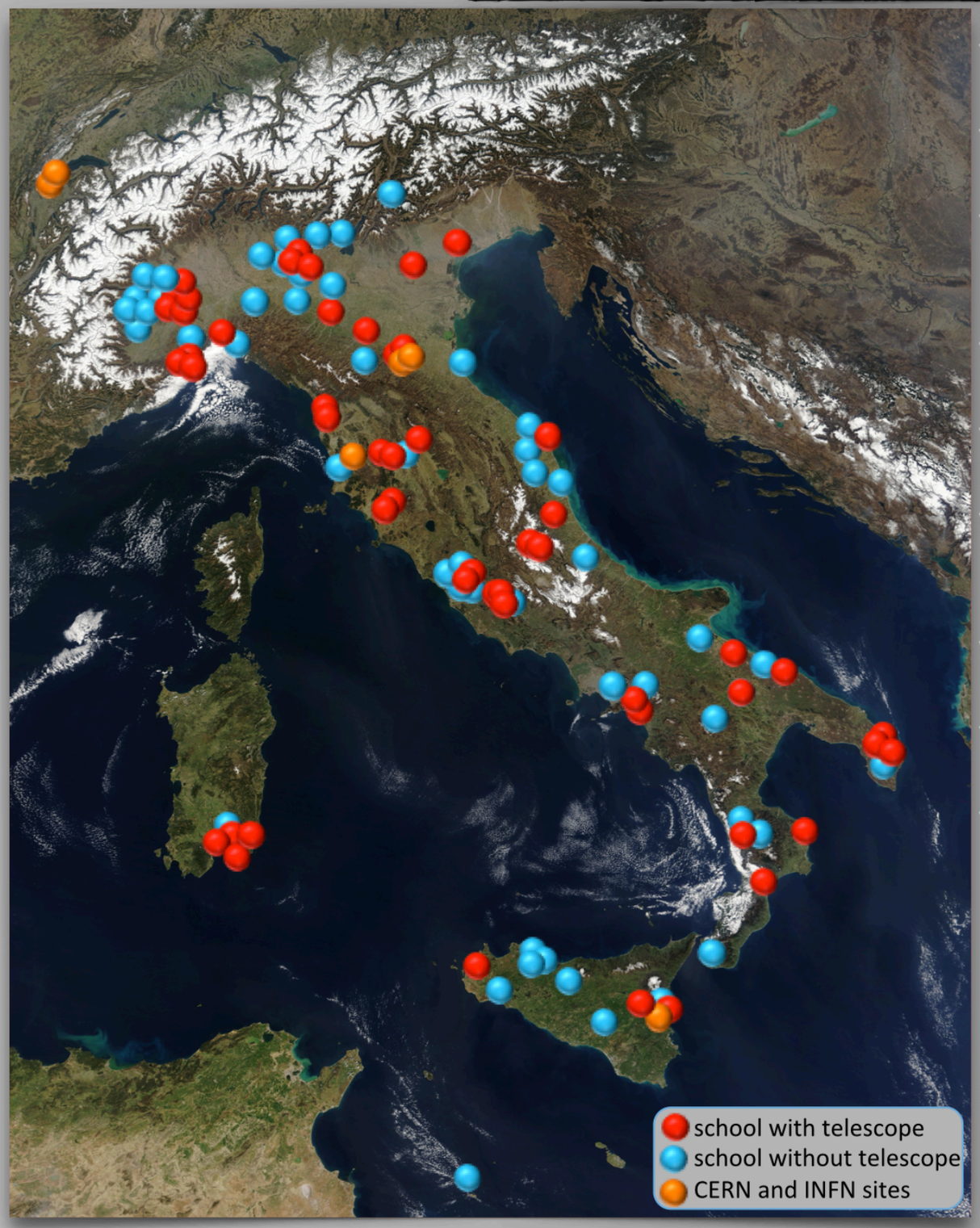


CENTRO FERMI
Enrico Fermi
MUSEO STORICO DELLA FISICA E CENTRO STUDI E RICERCHE ENRICO FERMI

INFN
Istituto Nazionale di Fisica Nucleare

Extreme Energy Events
Science inside Schools

Extreme Energy Events (EEE) Project



- ✓ array of MRPC telescopes covering more than $3 \cdot 10^5 km^2$
- ✓ clusters and standalone stations
- ✓ stations are hosted in Italian Secondary Schools, INFN sections and CERN
- ✓ each station is made of 3 MRPC chambers
- ✓ project started in 2004
- ✓ array composed of 56 telescopes at the moment (continuously growing) (***see M. Abbrescia's talk about the EEE upgrade***)
- ✓ long-living MRPC-based system (14 years)
- ✓ 60 billion tracks currently collected
- ✓ ***unconventional working sites:***
  - mainly school buildings
  - non-professional electrical lines
  - non-controlled environmental parameters
  - heterogeneous maintenance conditions

Extreme Energy Events (EEE) Project

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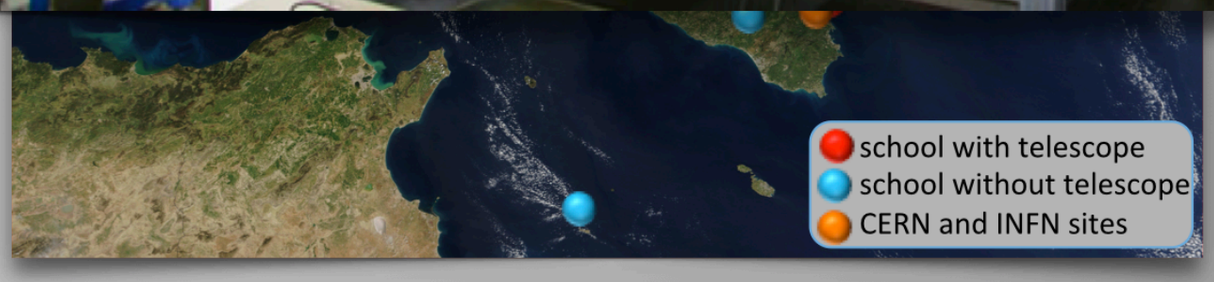

004

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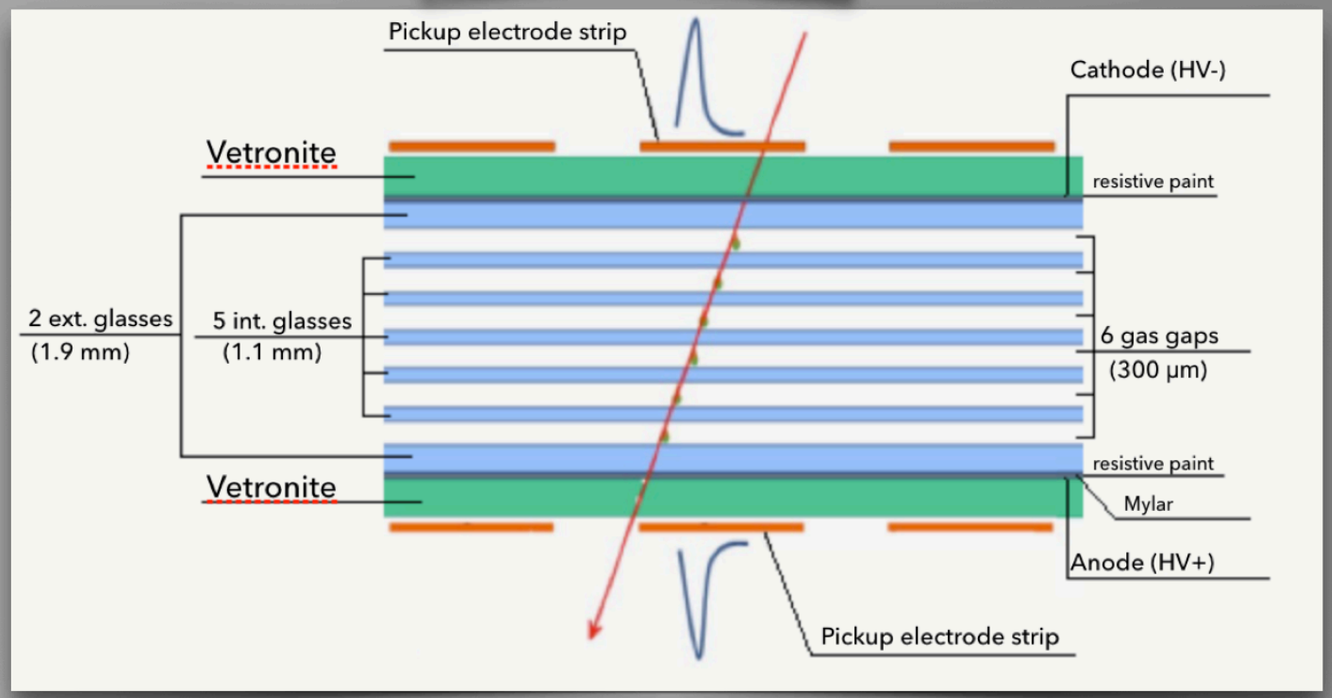
EEE MRPC



✓6 gas gaps (300 μm)

✓two external glass sheets anode and cathode – 160 cm x 85 cm, 1.9 mm thick (resistive paint 5-20 MΩ/□)

✓5 intermediate (electrically floating) glass sheets - 158 cm x 82 cm, 1.1 mm thick

✓24 copper strips (anode and cathode) to pick up the signal – 158 cm x 25 cm, spaced by 7 mm

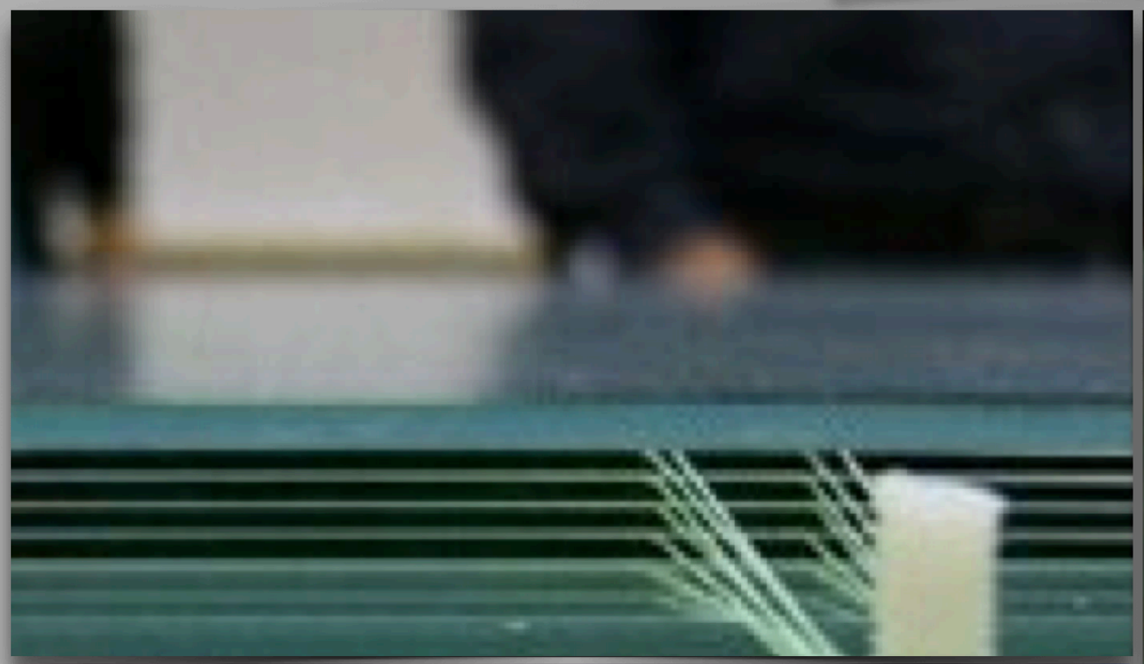
✓honeycomb panels to ensure mechanical stability – 182 cm x 90 cm

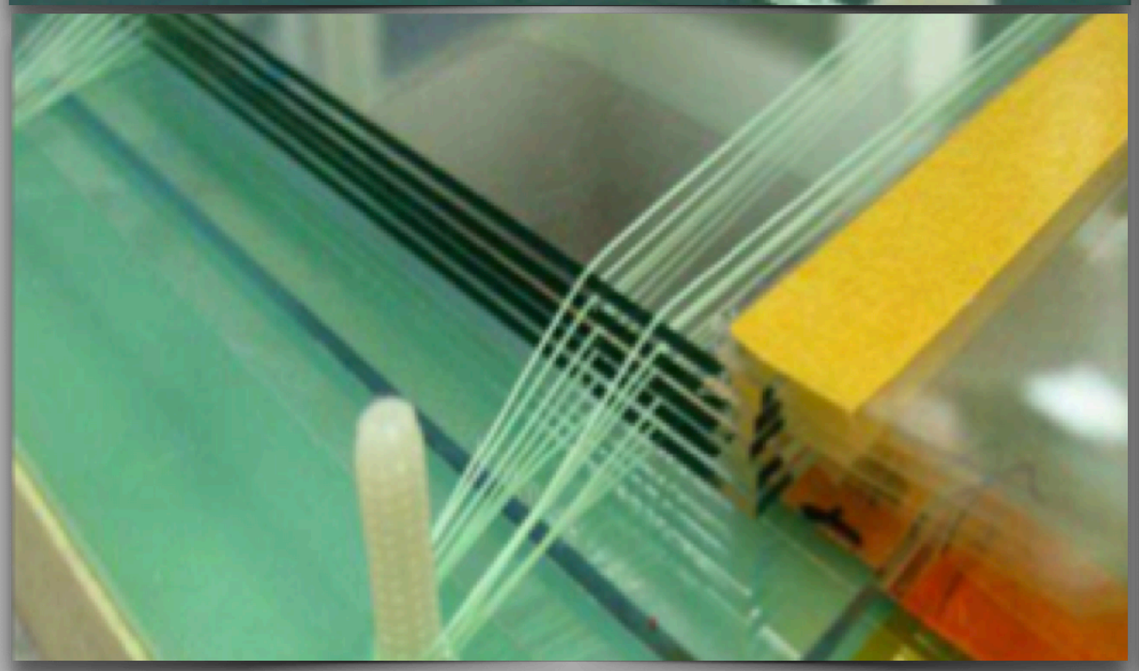
✓gas-tight aluminum box – 200 cm x 100 cm

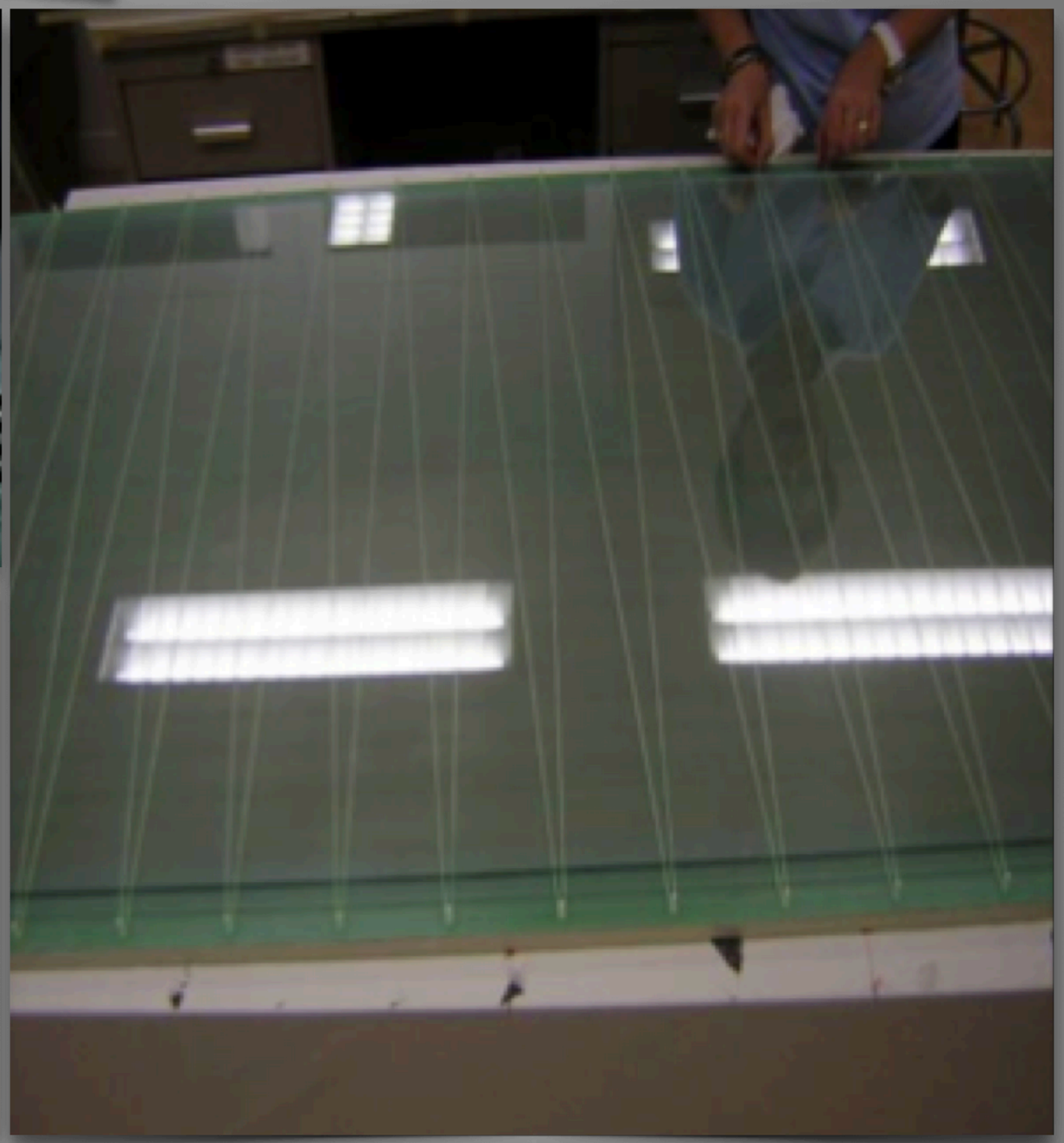
✓gas mixture 98% R134a ($C_2F_4H_2$) - 2% SF_6
(***see S. Pisano's talk about new gas mixtures***)

✓HV up to 20 kV (avalanche mode) supplied by 2 DC/DC converters

EEE MRPC



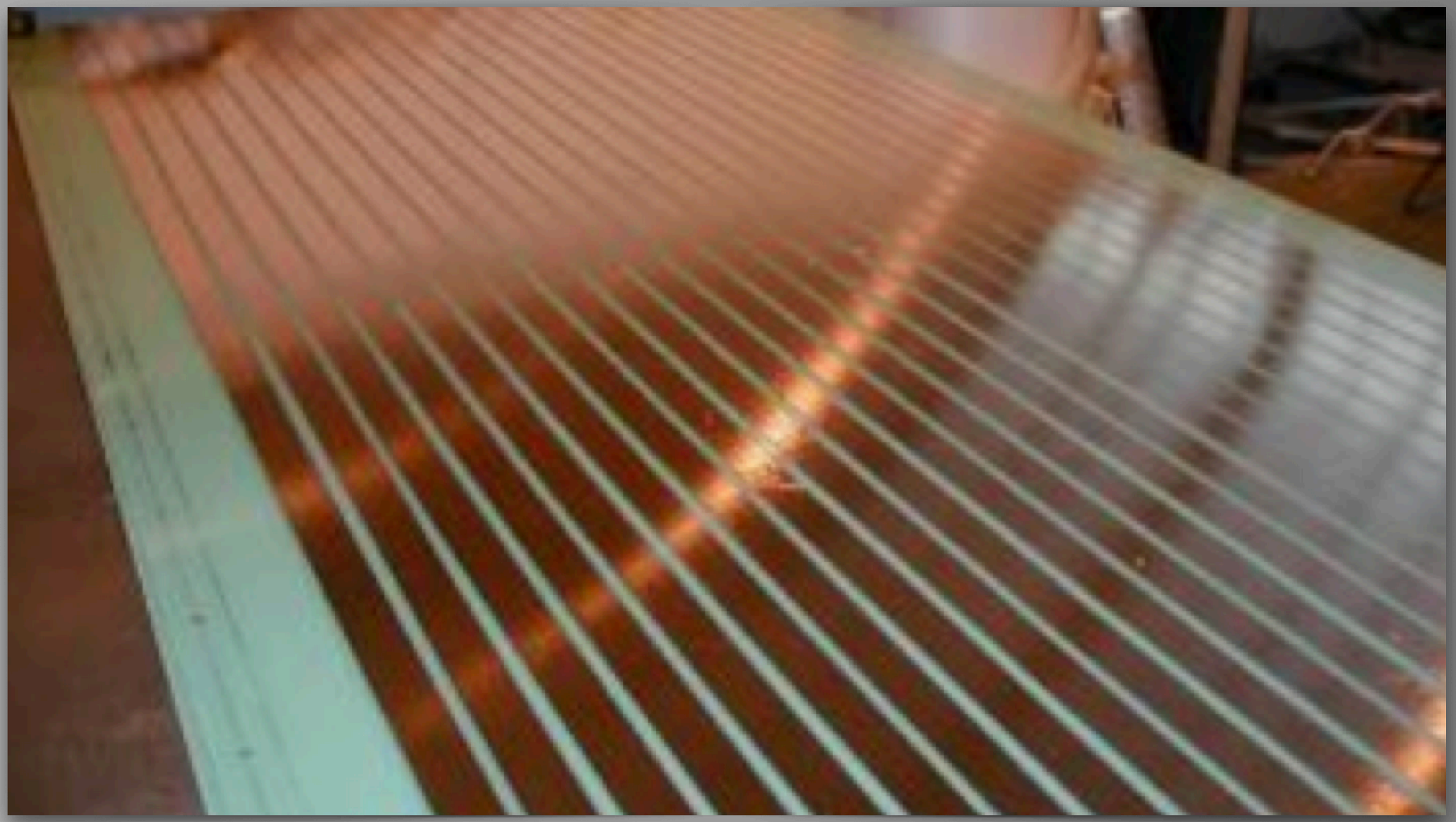




MRPC details:

- ✓ glasses
- ✓ 300 μm fishing line as spacer to create gas gaps
- ✓ vetronite panel

EEE MRPC

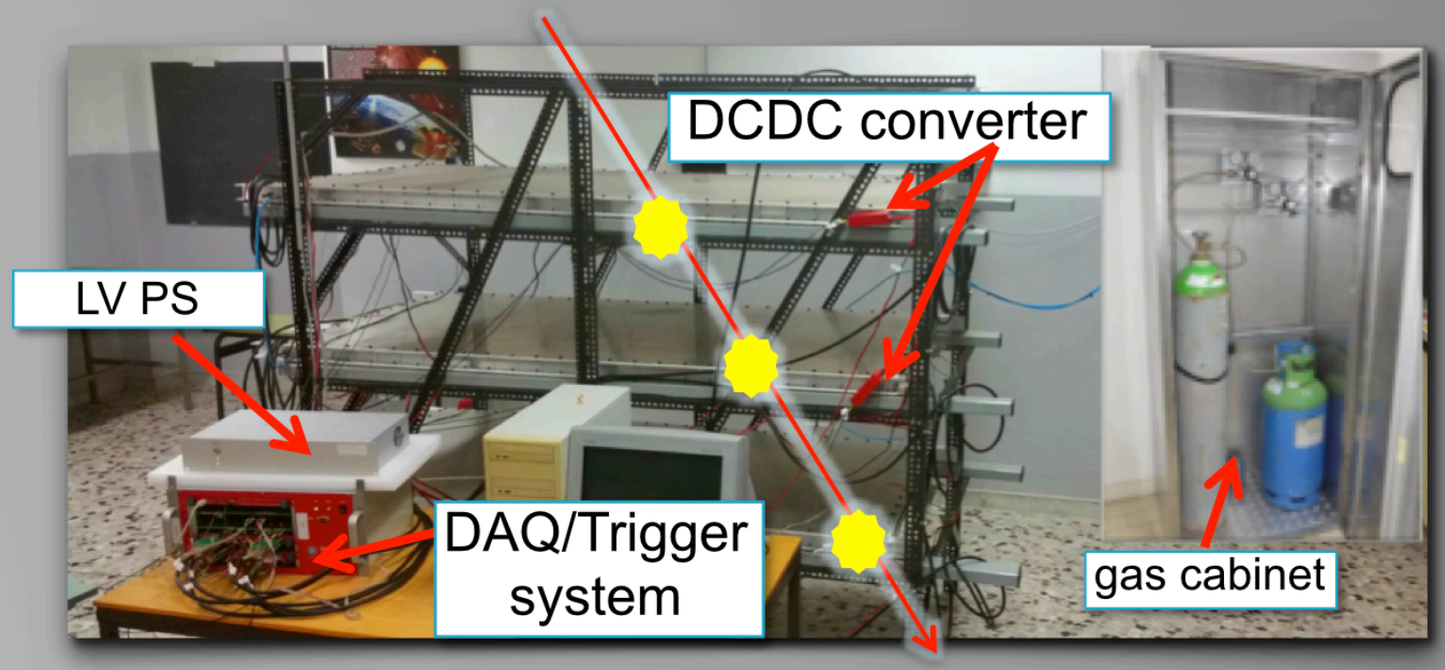


MRPC details:

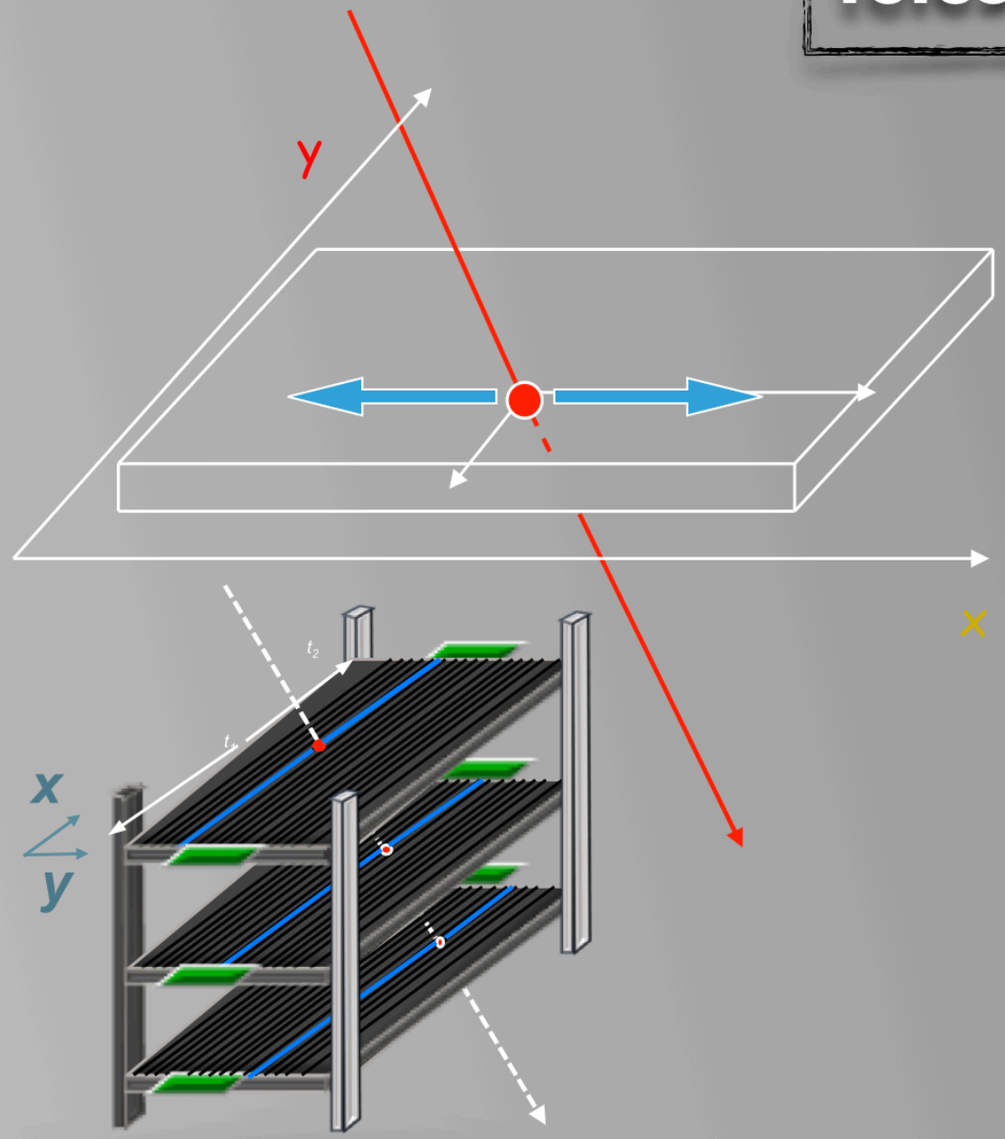
- ✓ 24 copper strips to pickup the signal
- ✓ Pitch 3.2 cm

Telescope and electronics

- ✓ 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)
- ✓ 1 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 information
- ✓ Weather Station to monitor the temperature and the pressure inside and outside the telescopes building

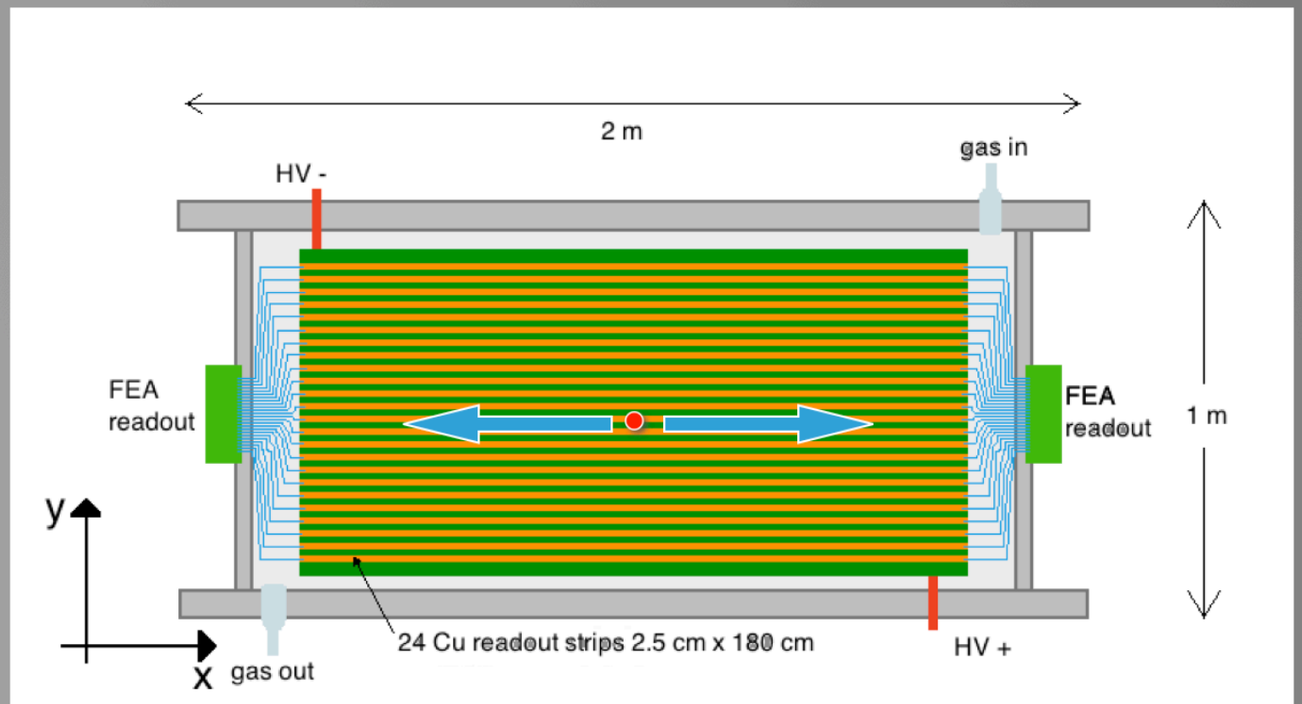


Telescope and electronics



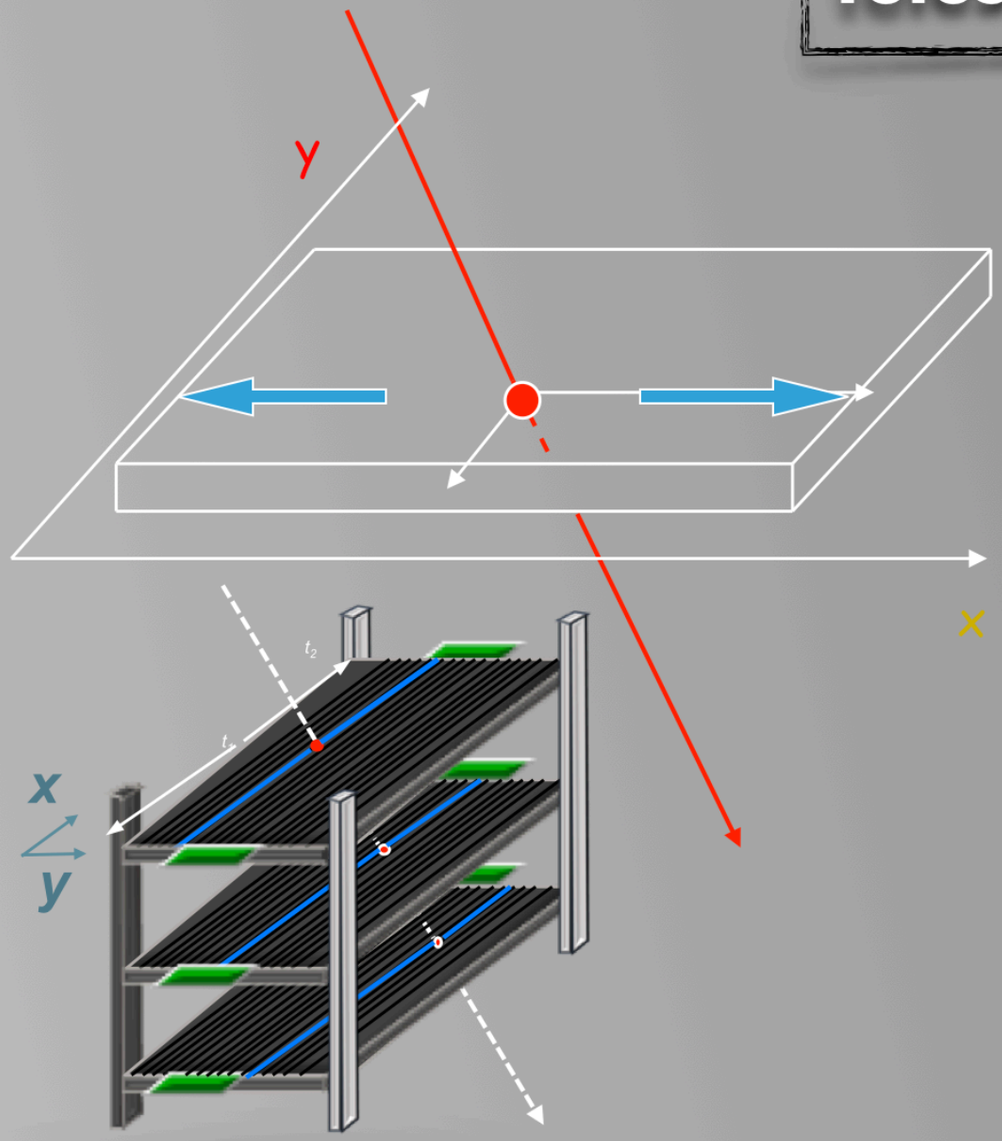
particle impact point reconstructed by:

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



- ✓ 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

Telescope and electronics



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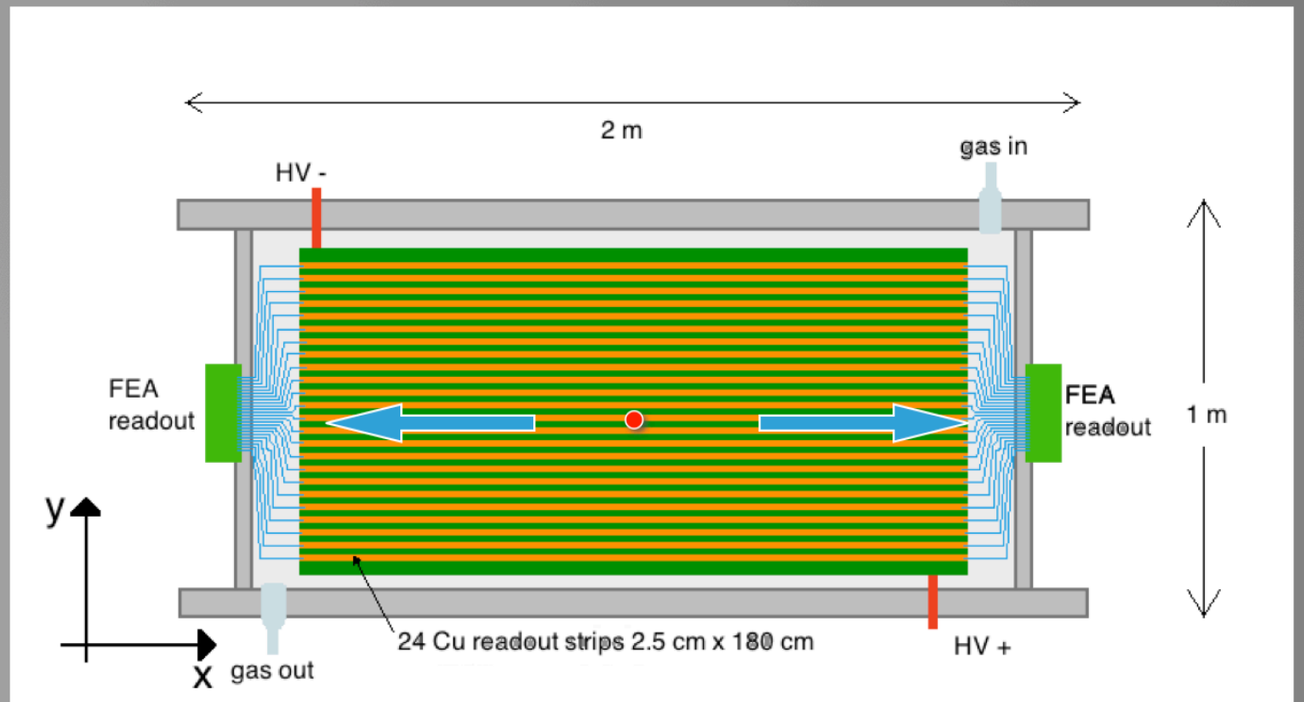

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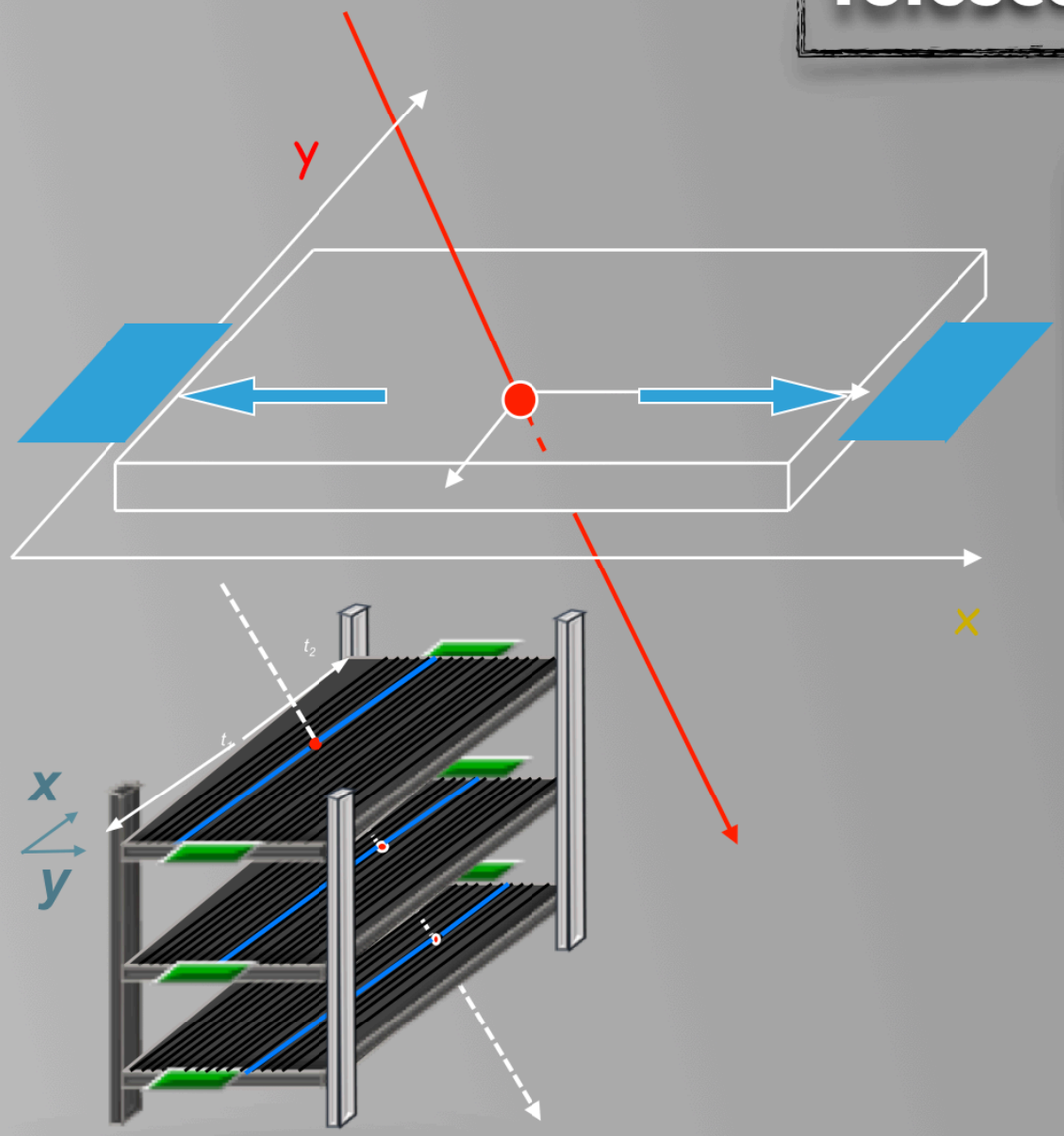

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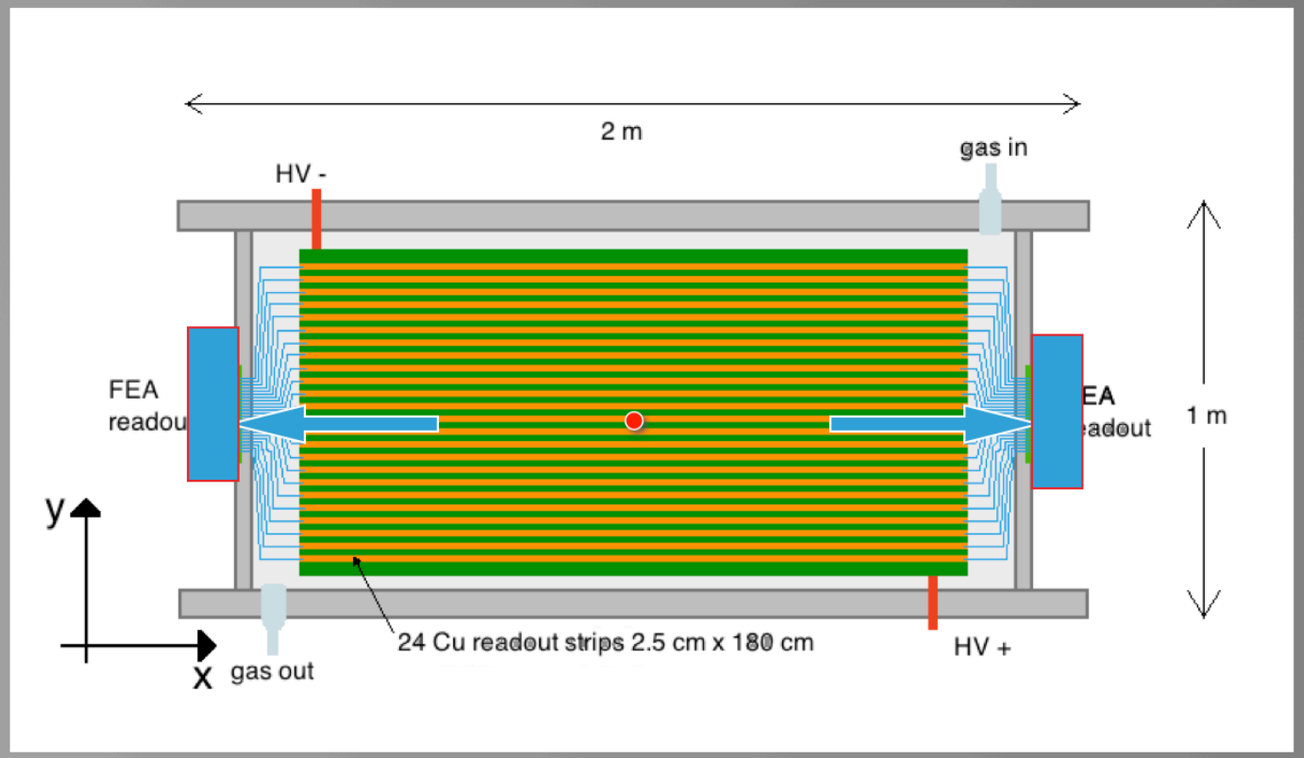

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Students involvement

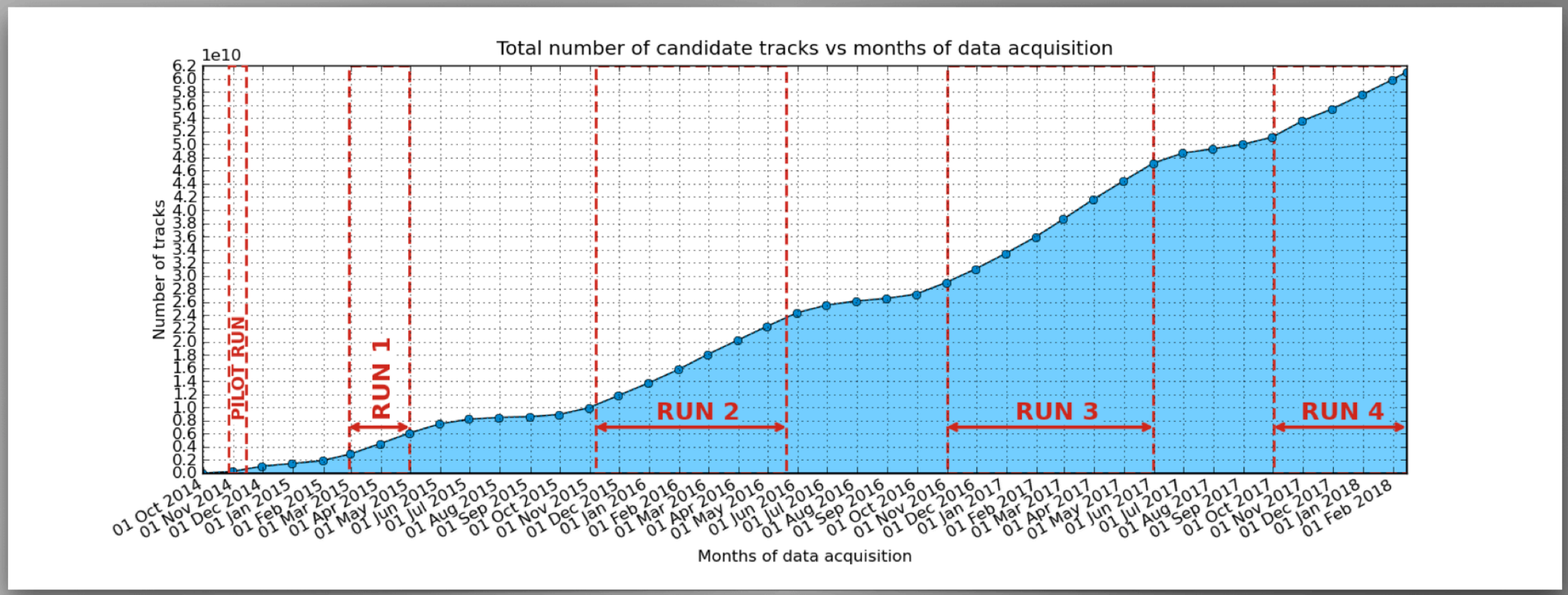
- ✓ one week to build 3 chambers (activity at CERN)
- ✓ secondary school students work under researchers' supervision (activity at CERN)
- ✓ setup of the telescope (activity at school)
- ✓ chamber efficiency measurements (activity at school)
- ✓ all chambers are correctly working in each single telescope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

- <10 students + 2-3 teachers per school involved in the chamber construction at CERN
- thousands of students and hundreds of teachers participating to the project

Performance

Data taking

- ✓ periodic coordinated data taking periods (Runs) are performed
- ✓ all telescopes take data, with a central system of online shift and data quality monitor
- ✓ *Pilot Run, Run 1, Run2, Run 3 have been completed in the last 4 years*
- ✓ *Run 4* ongoing
- ✓ data are sent to CNAF (data storage center in Bologna, Italy) to be stored, reconstructed and analyzed
- ✓ 60 billion tracks collected



Time resolution

✓ cut on reconstructed tracks $\chi^2 < 10$

✓ *results will be published soon*

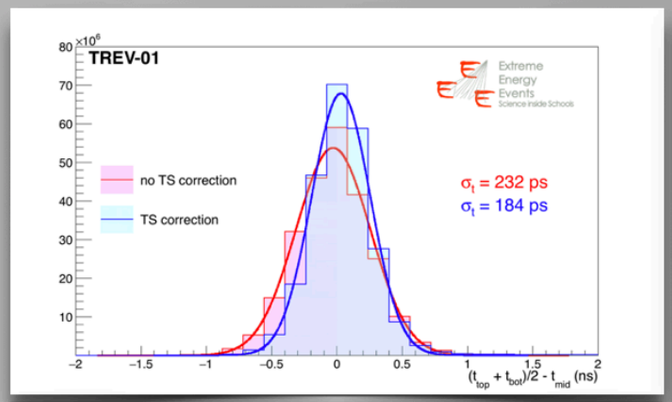
Time Slewing correction:

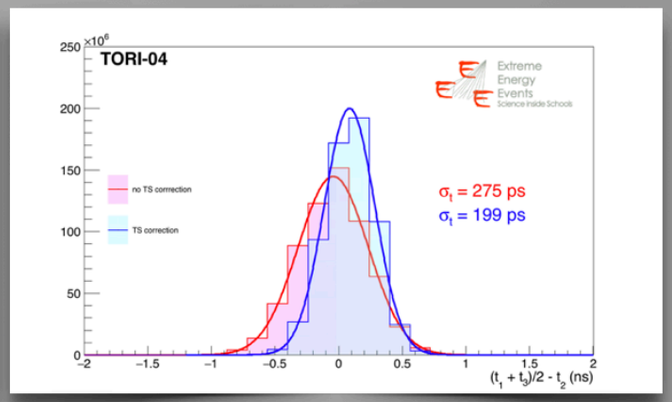
- the hit time depends on the signal amplitude, or equivalently the Time Over Threshold (TOT)
- the effect of its jitter has to be corrected in order to get the real hit time

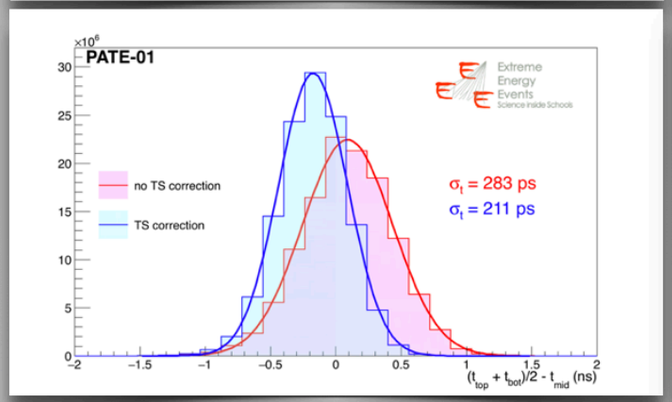
✓ $\Delta t_{hit} = (t_{top} + t_{bot})/2 - t_{mid}$

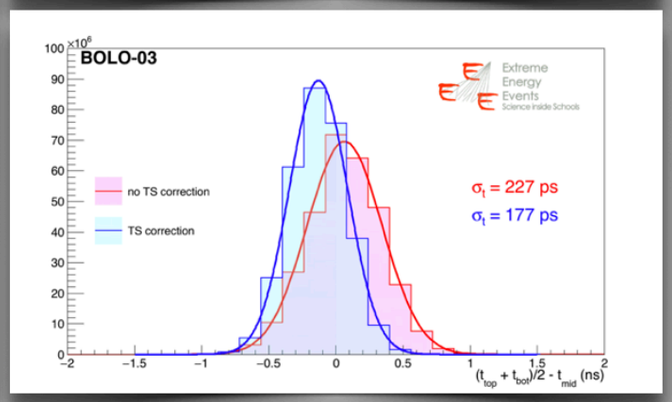
✓ $\sigma_t = \sqrt{3}/2\sigma_{\Delta t} \sim 207$ ps

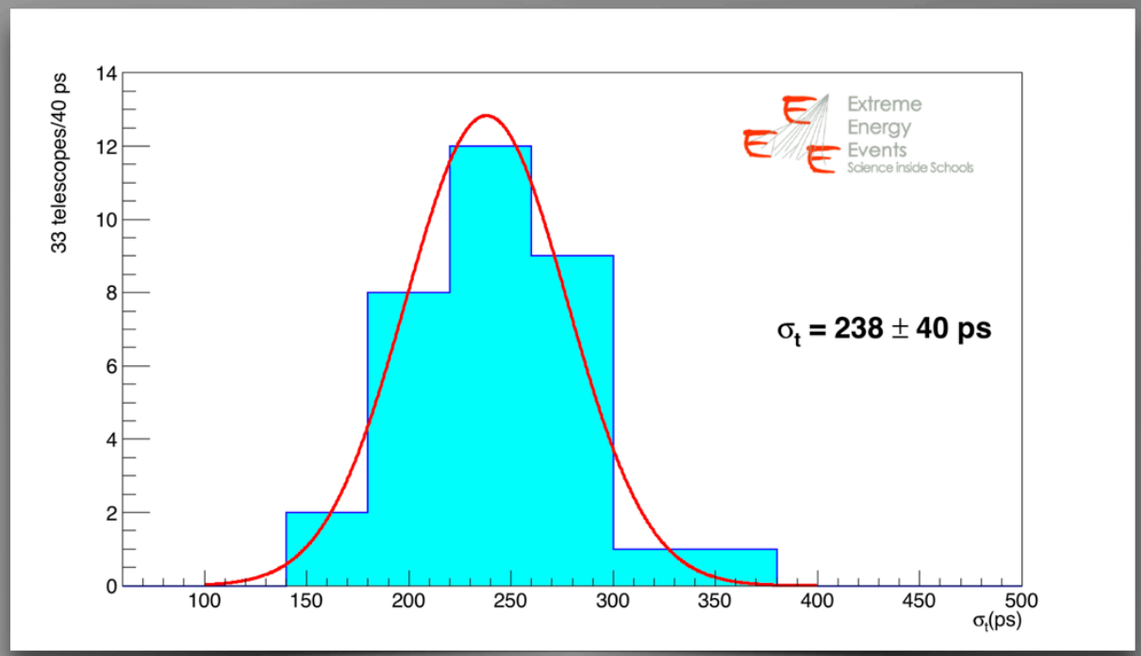
✓ time slewing correction applied











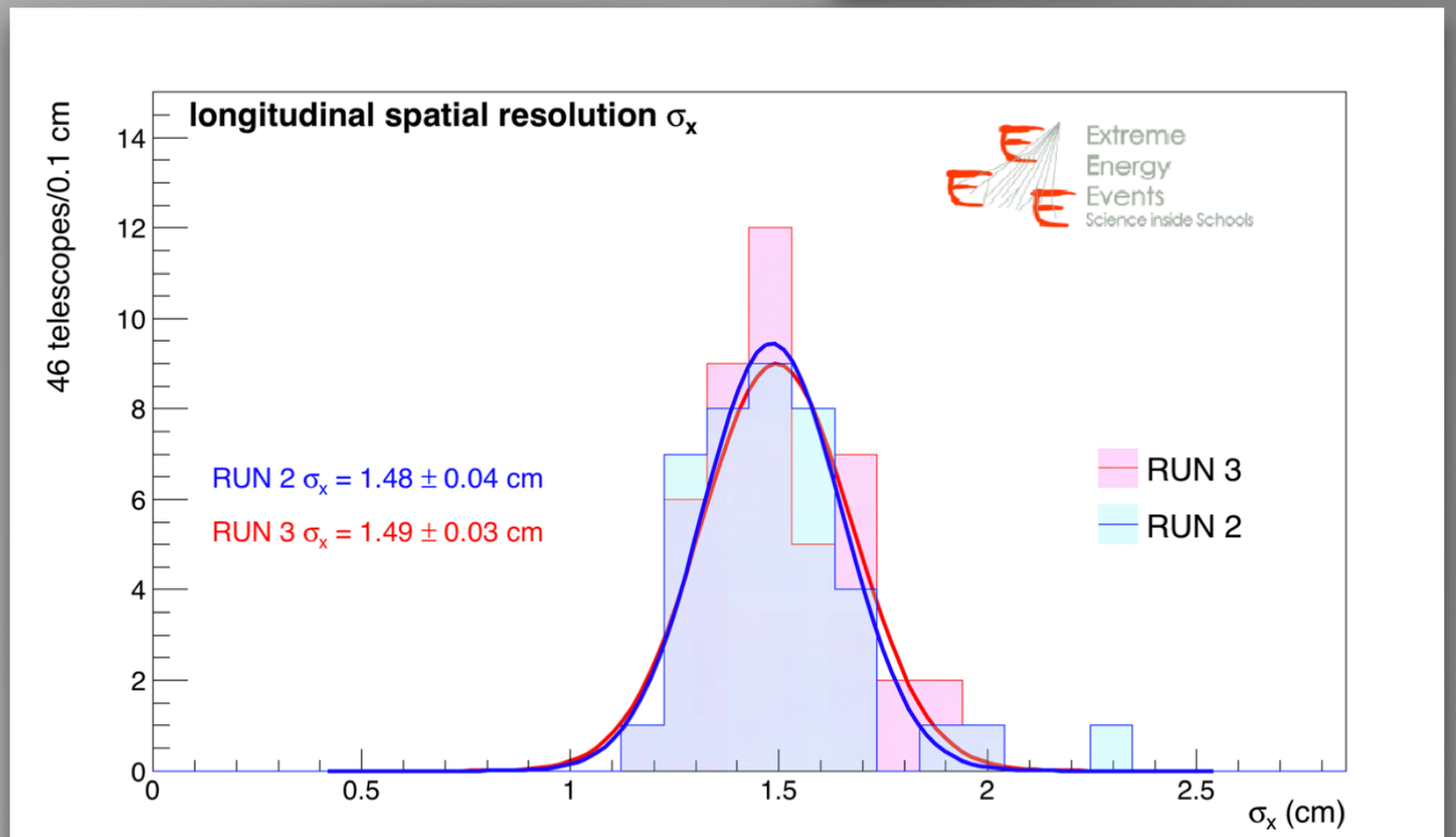
✓ average time resolution ~240 ps

✓ resolution within expectations (order of 10^2 ps) and compatible with requirements

Spatial resolution (long side)

- ✓ cut on reconstructed tracks $\chi^2 < 10$
- ✓ *results will be published soon*

- ✓ $\Delta x = (x_{bot} + x_{top})/2 - x_{mid}$
- ✓ $\sigma_x = \sqrt{3}/2\sigma_{\Delta x} \sim 1.49$ cm
- ✓ $\sigma_{xexp} \sim \sqrt{\sigma_{TDC}^2 + \sigma_{TDC}^2 v_{drift}} / 2 \sim 1.1$ cm

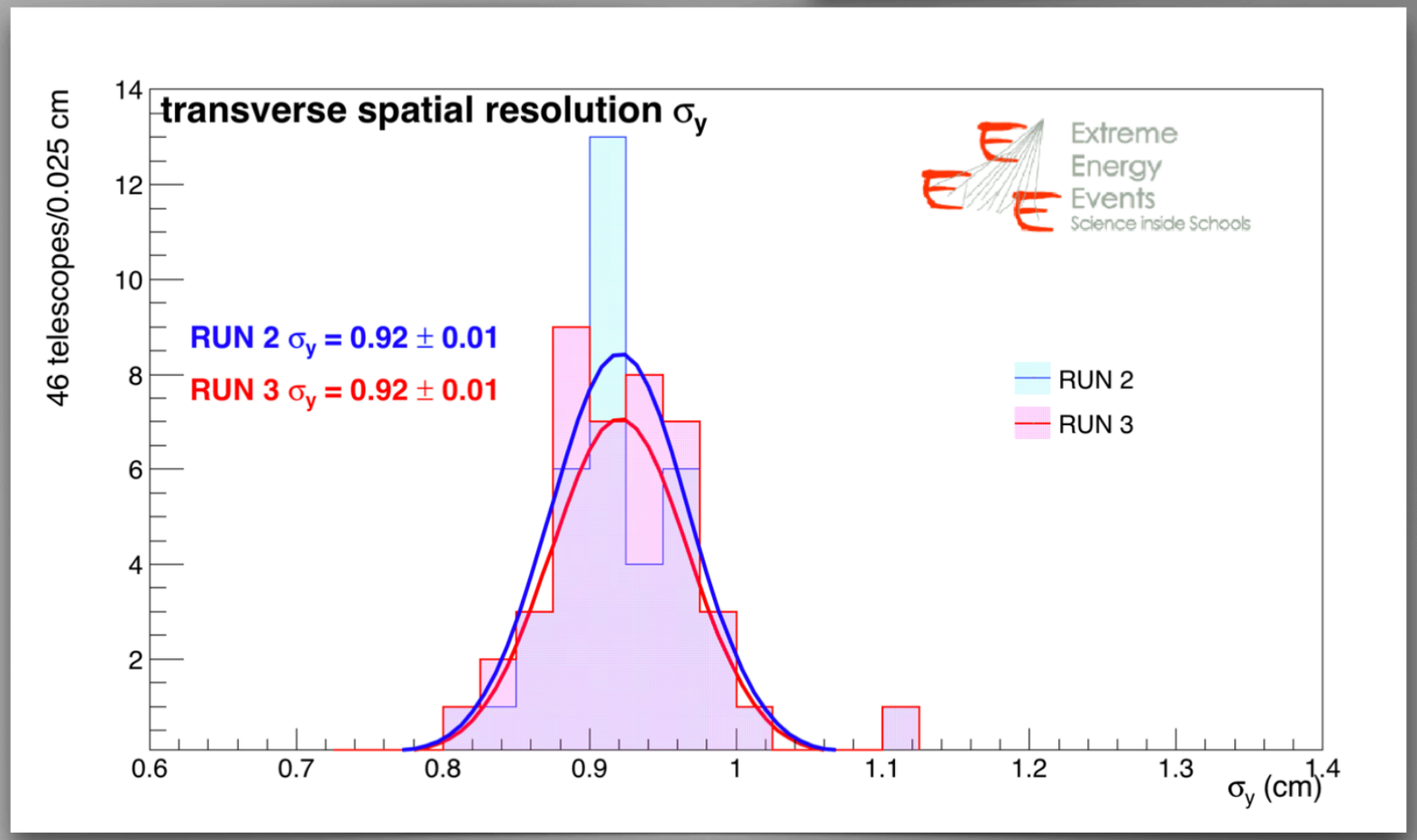


- ✓ average spatial resolution (long side) 1.49 cm
- ✓ resolution compatible with requirements

Spatial resolution (short side)

- ✓ cut on reconstructed tracks $\chi^2 < 10$
- ✓ *results will be published soon*

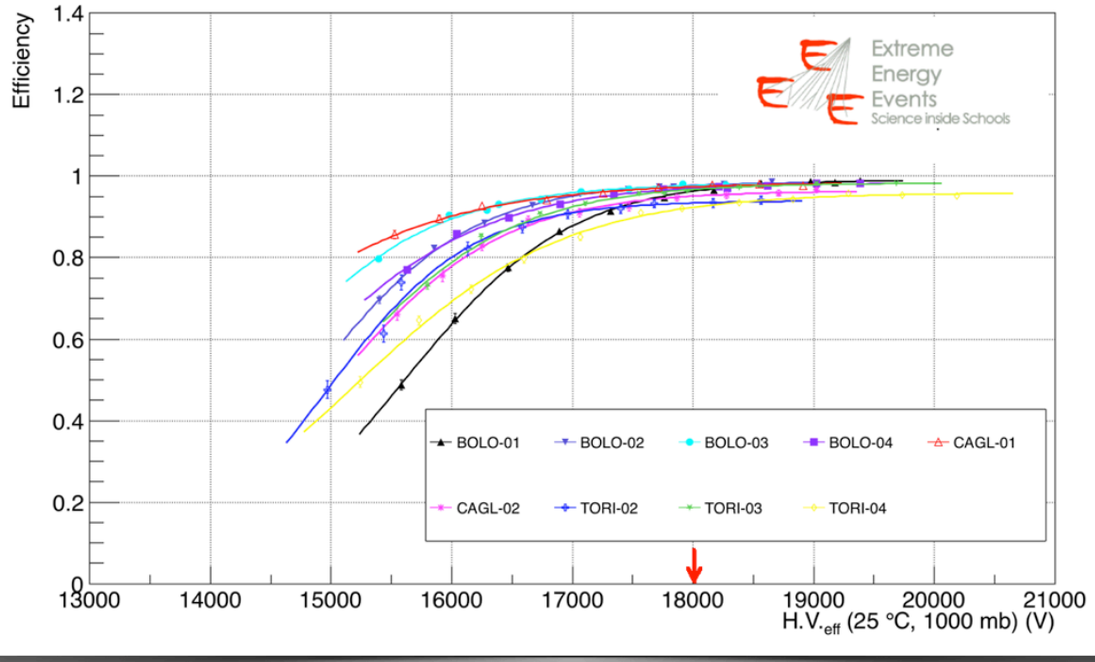
- ✓ $\Delta x = (x_{bot} + x_{top})/2 - x_{mid}$
- ✓ $\sigma_x = \sqrt{3}/2\sigma_{\Delta x} \sim 1.49$ cm
- ✓ $\sigma_{xexp} \sim \sqrt{\sigma_{TDC}^2 + \sigma_{TDC}^2 v_{drift}} / 2 \sim 1.1$ cm

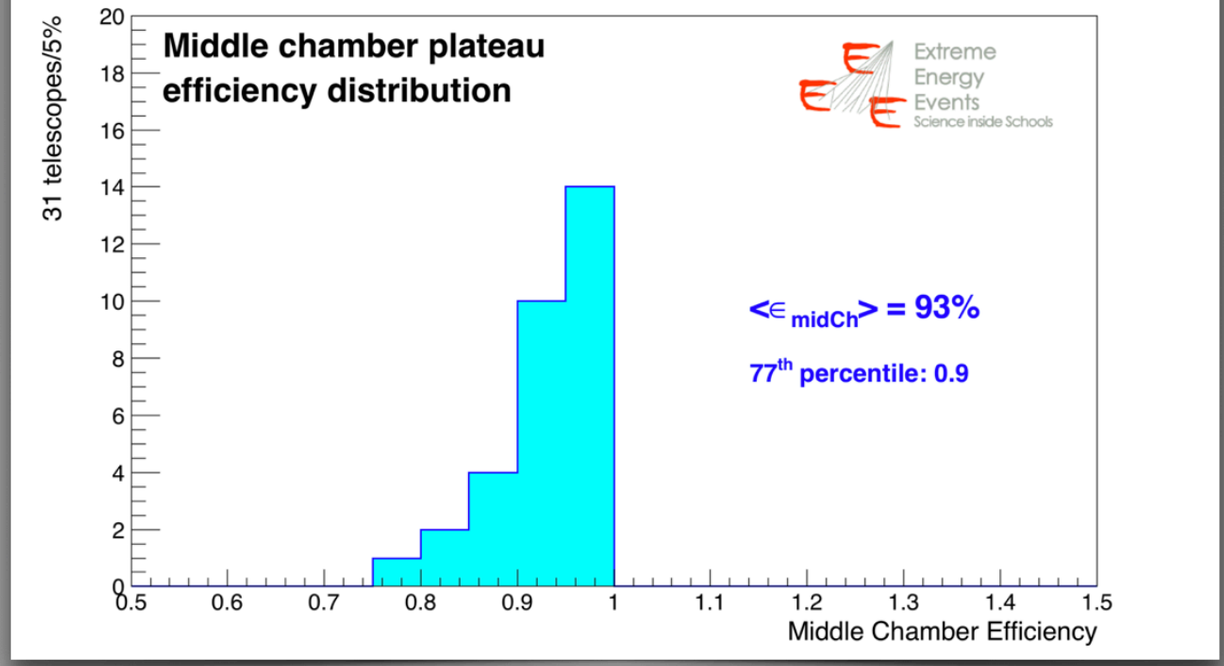


- ✓ average spatial resolution (short side) 0.92 cm
- ✓ resolution compatible with requirements

Efficiency

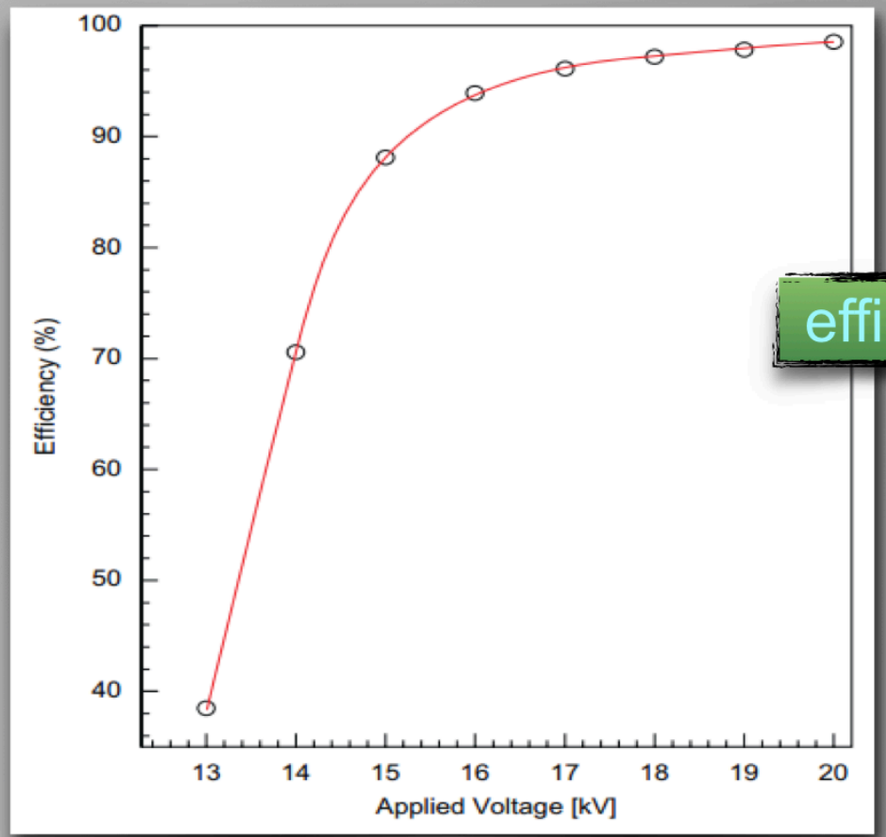
- ✓ external chambers used as trigger
- ✓ efficiency of the middle chamber measured on all telescopes
- ✓ students involved in the measurement (well defined procedure for the HV scan)
- ✓ procedure to measure efficiency of the external chambers ready (and applied in a few cases)





- ✓ average efficiency of the telescope network ~93 %
- ✓ compatible within expectations and with the results from beam-tests performed at CERN
- ✓ efficiency better than 93 % is reached by 77% of the network

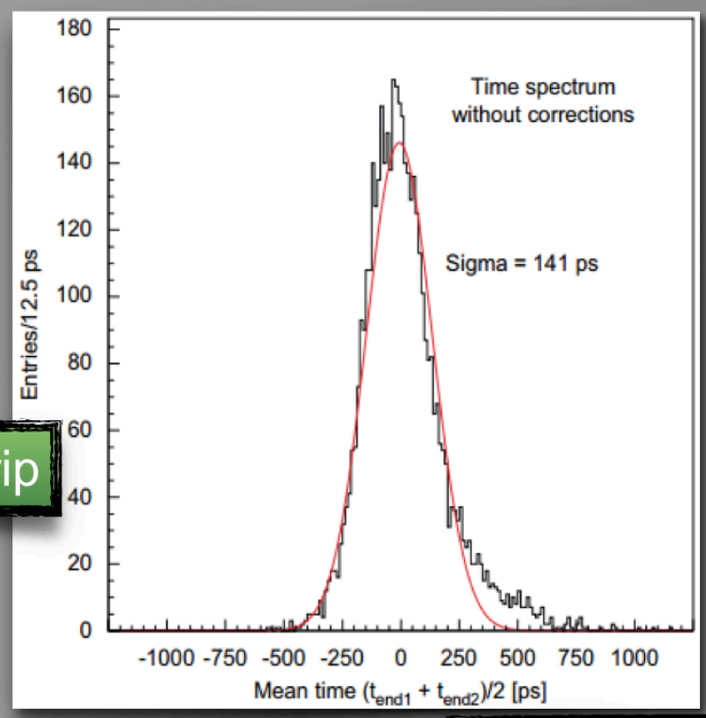
Results from beam-tests at CERN

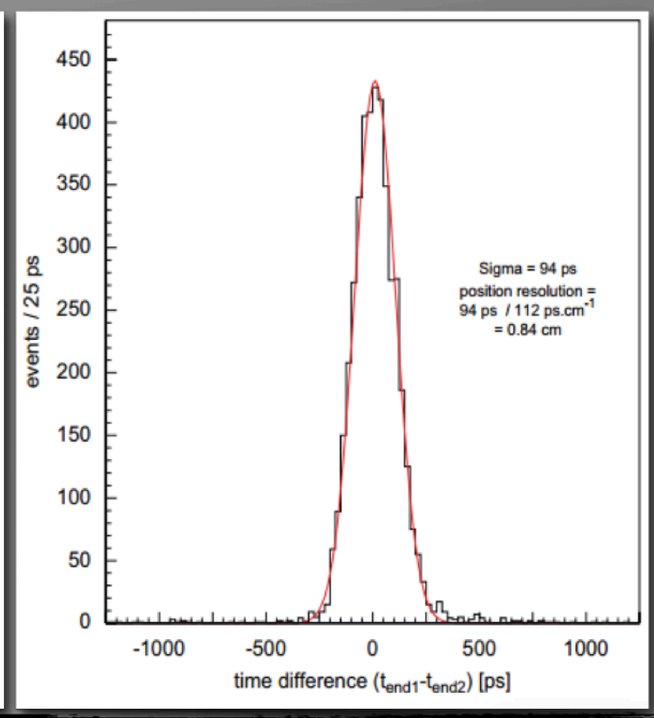


- ✓ efficiency vs HV for a single MRPC chamber
- ✓ events triggered by scintillators

efficiency plateau ~100%

TDCs 25 ps bins, scintillators system time resolution 30 ps



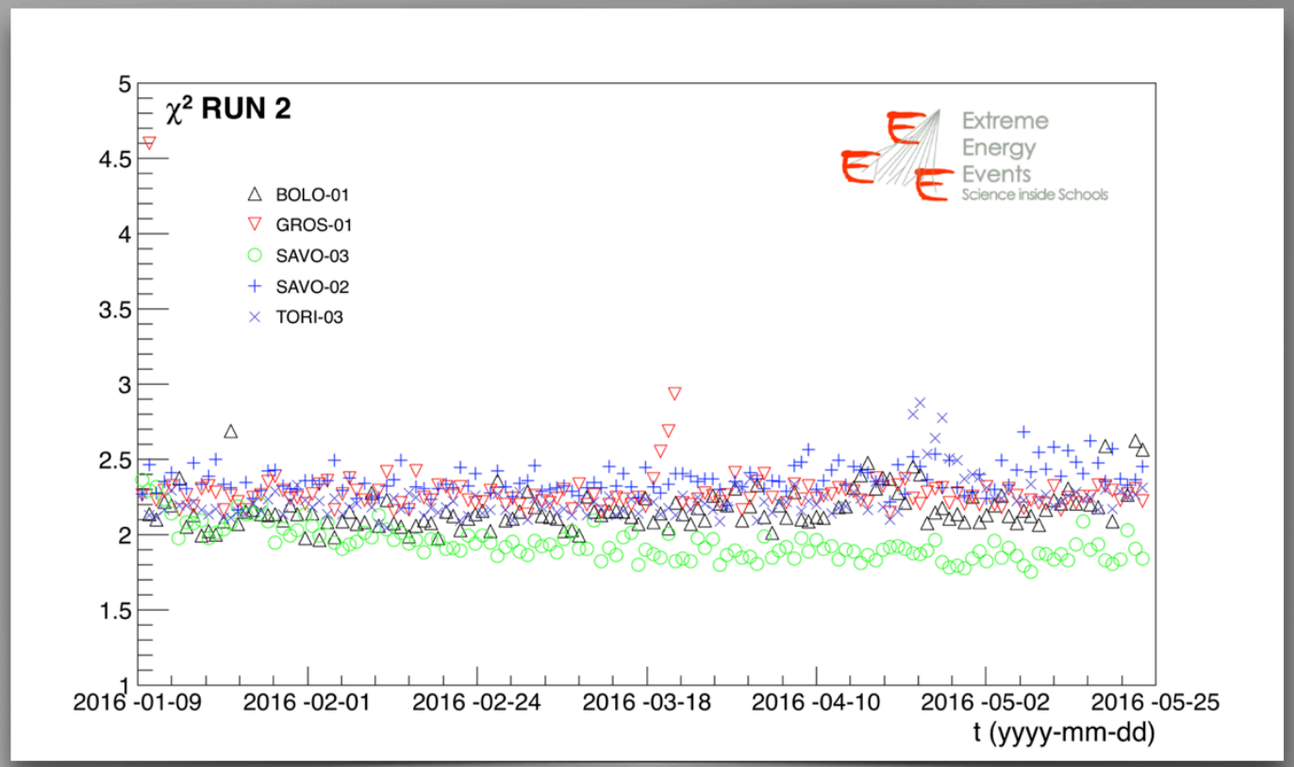


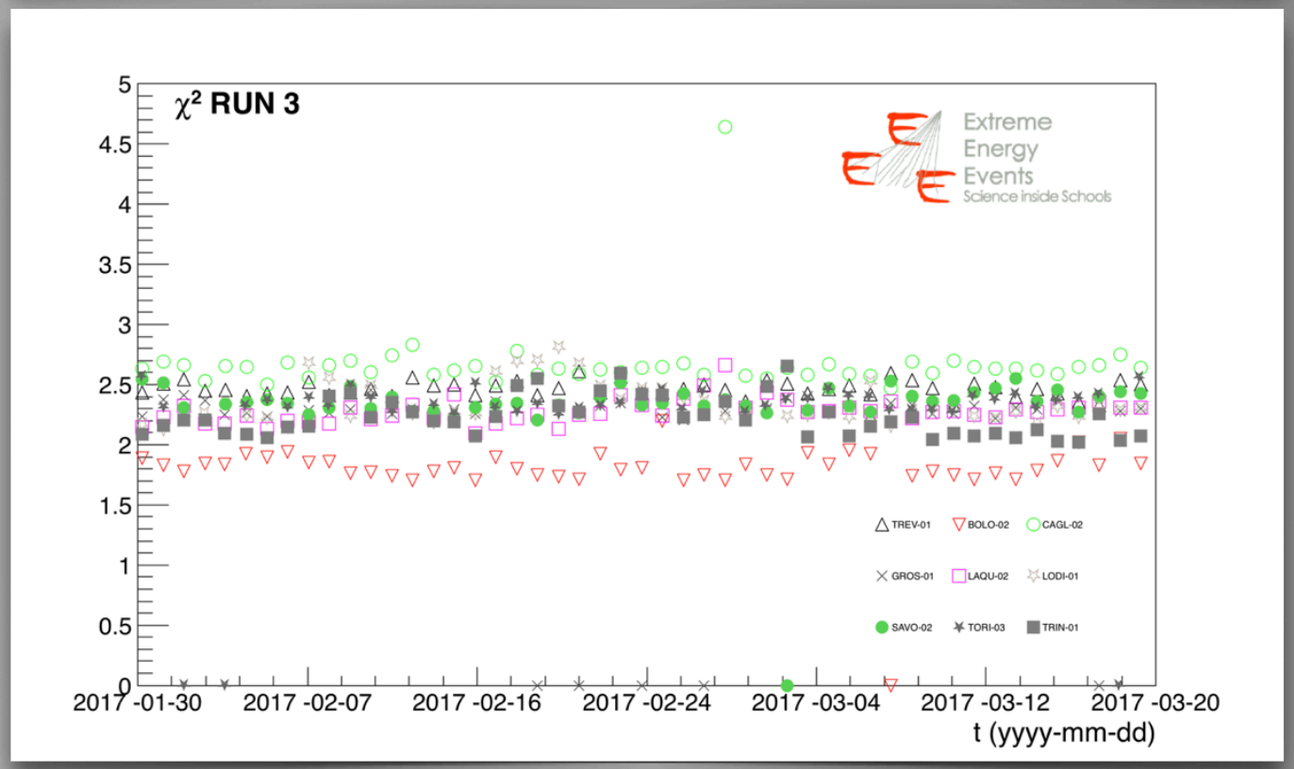
σ_t~100 ps in the center of the strip

spatial resolution along the strip 0.8 cm

Long term stability

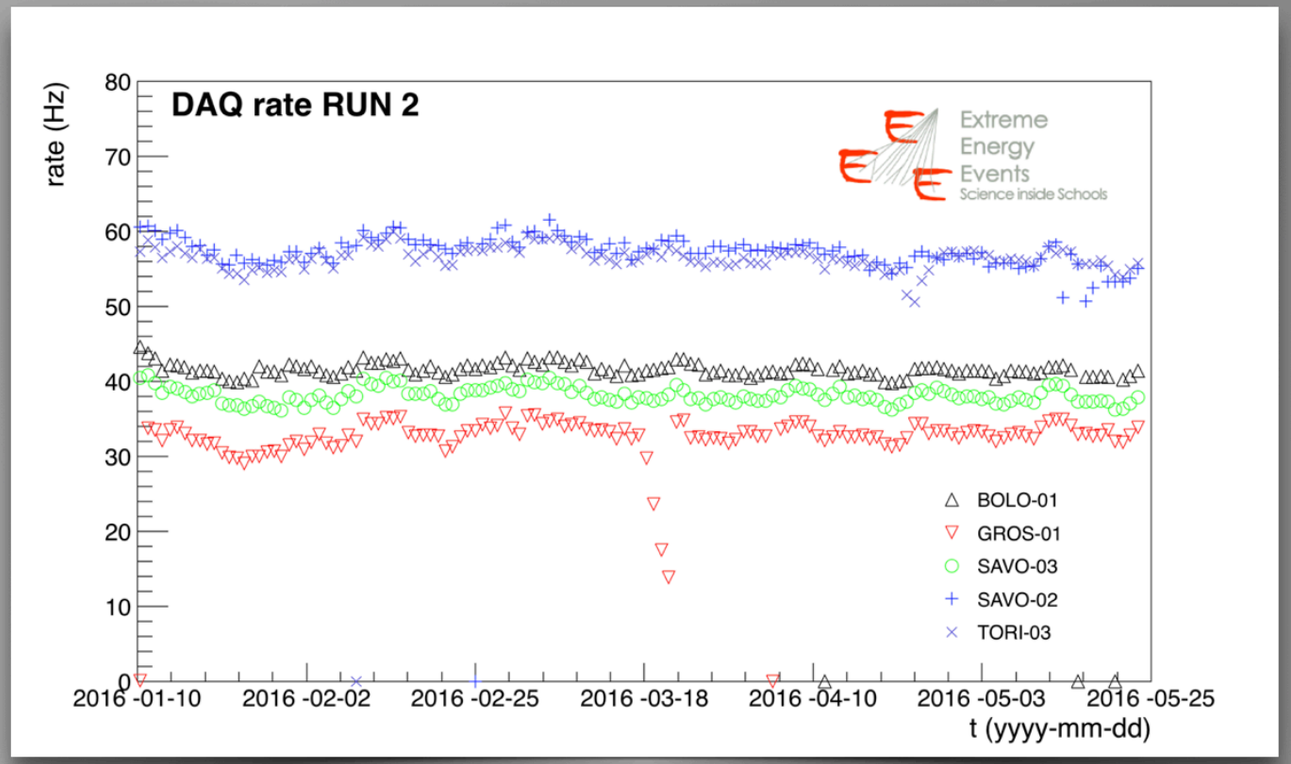
average track χ^2 – computed as the best track in the event if at least on hit on each chamber is recorded

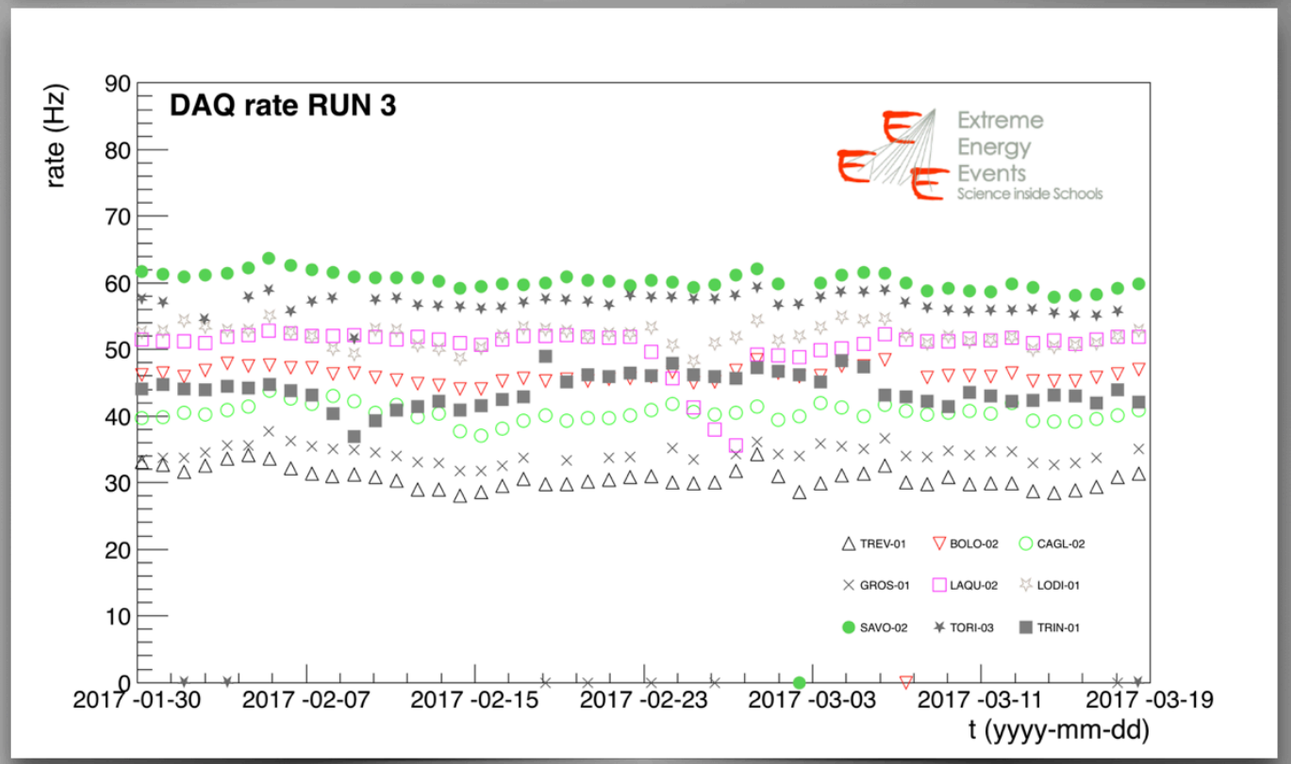




Long term stability

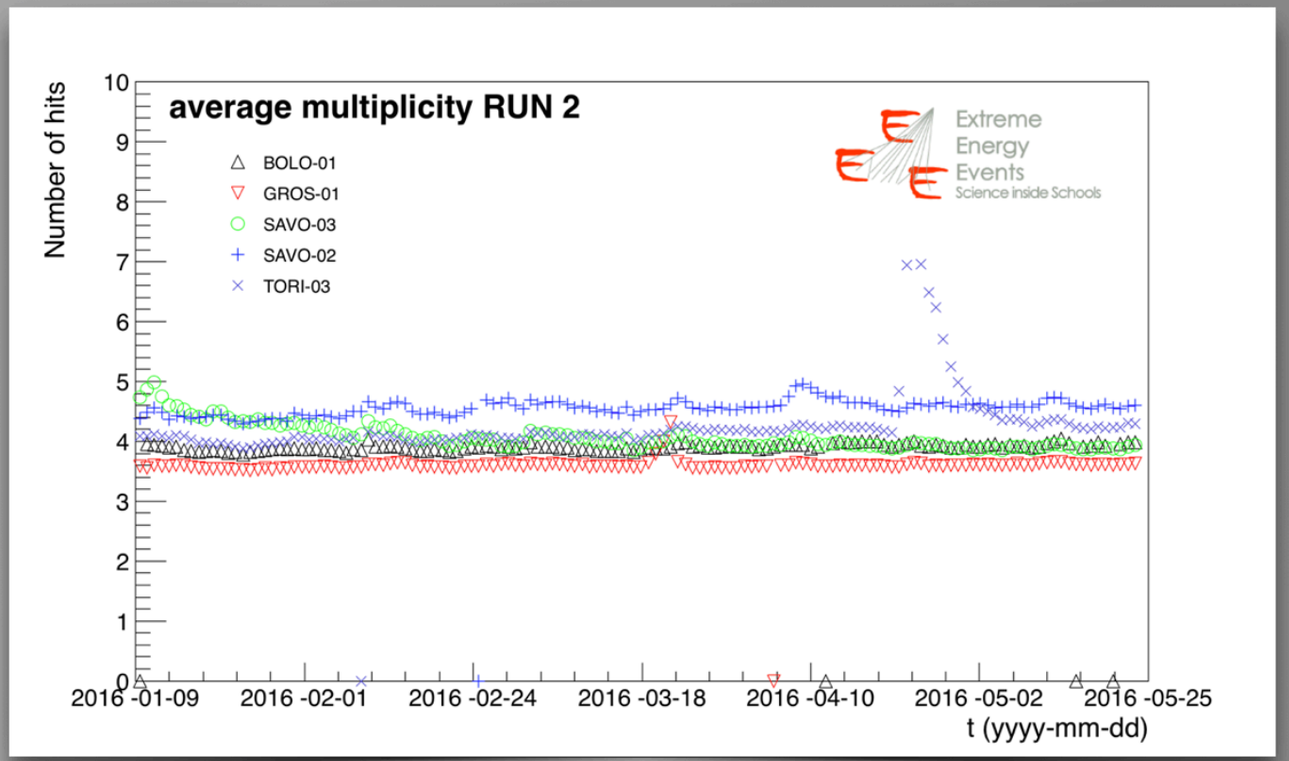
DAQ rate – raw acquisition rate

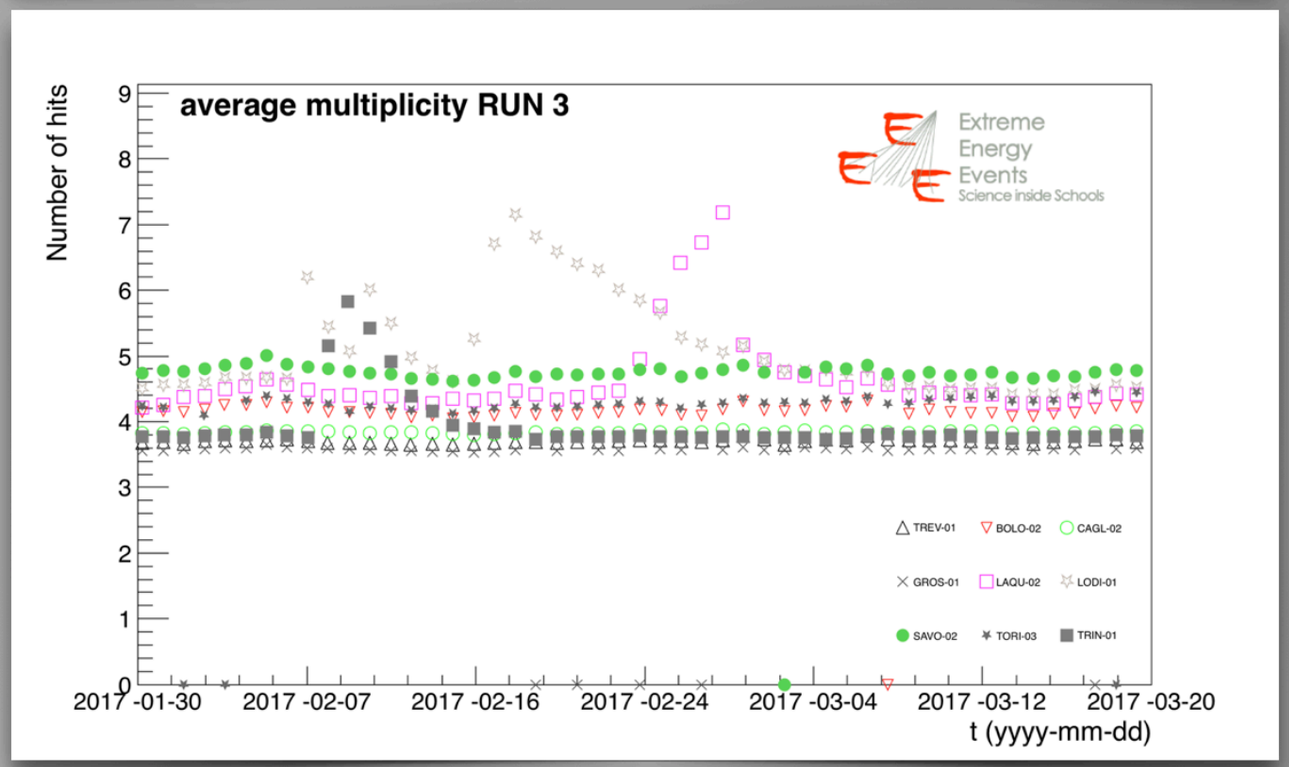




Long term stability

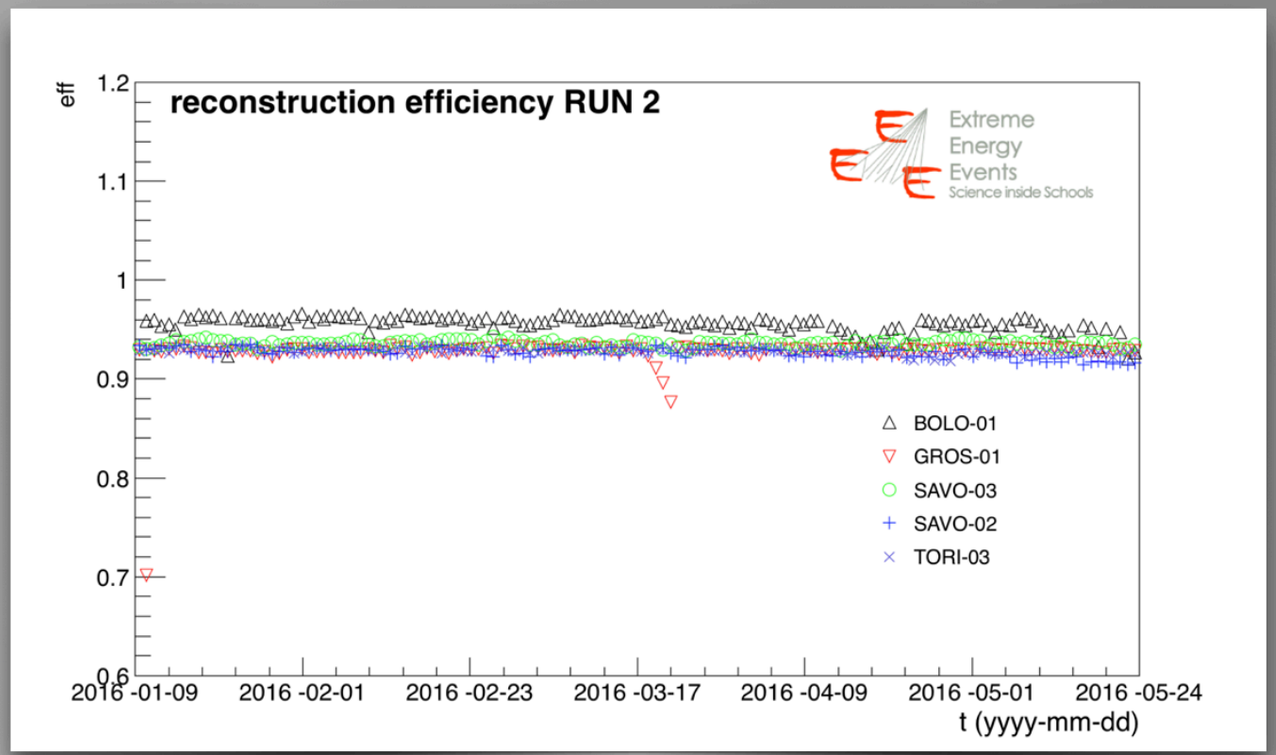
multiplicity – average number of hits on the three chambers for each event

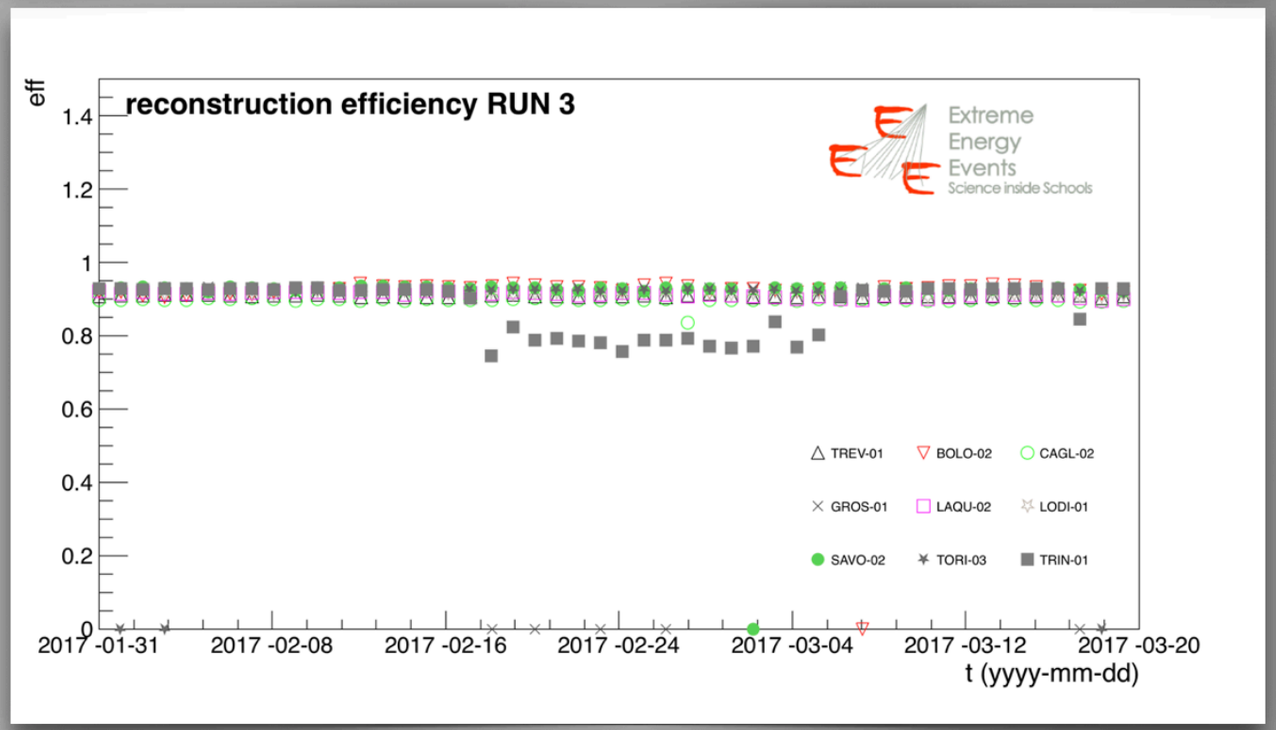




Long term stability

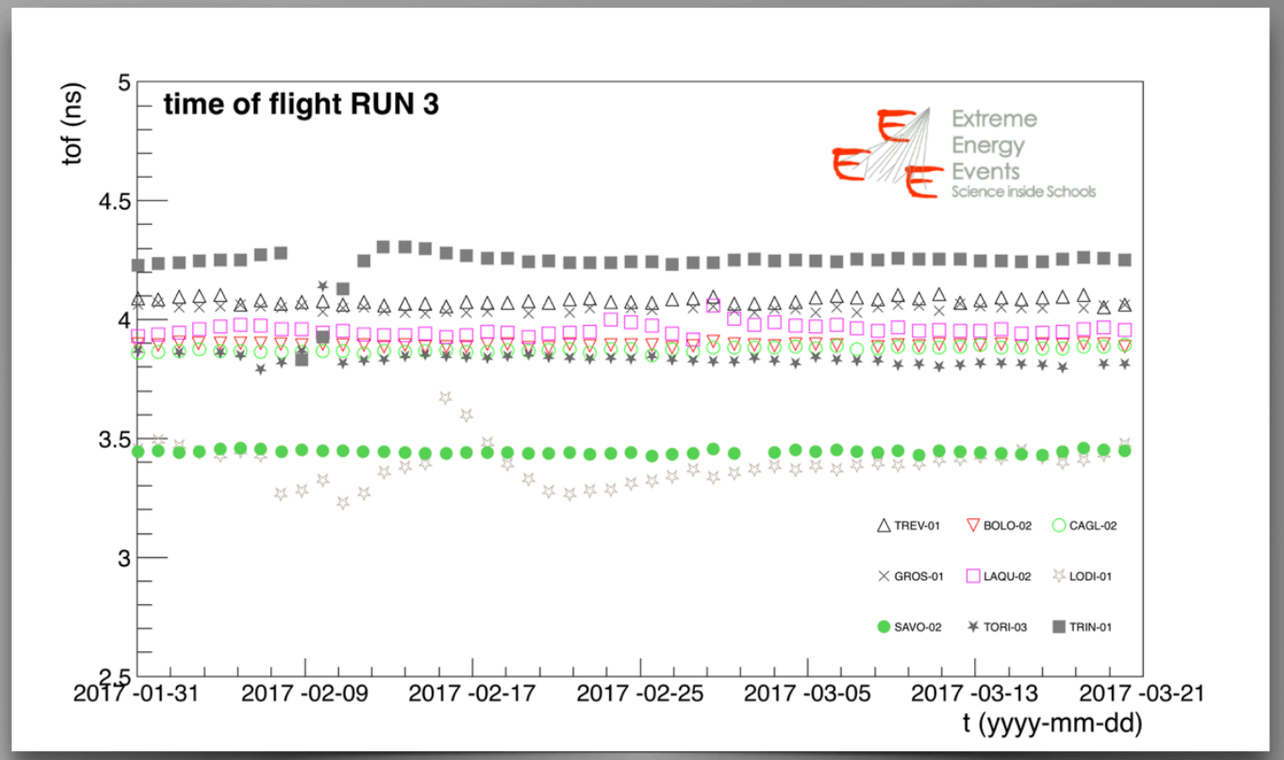
reconstruction efficiency – percentage of raw events where at least one candidate track has been found

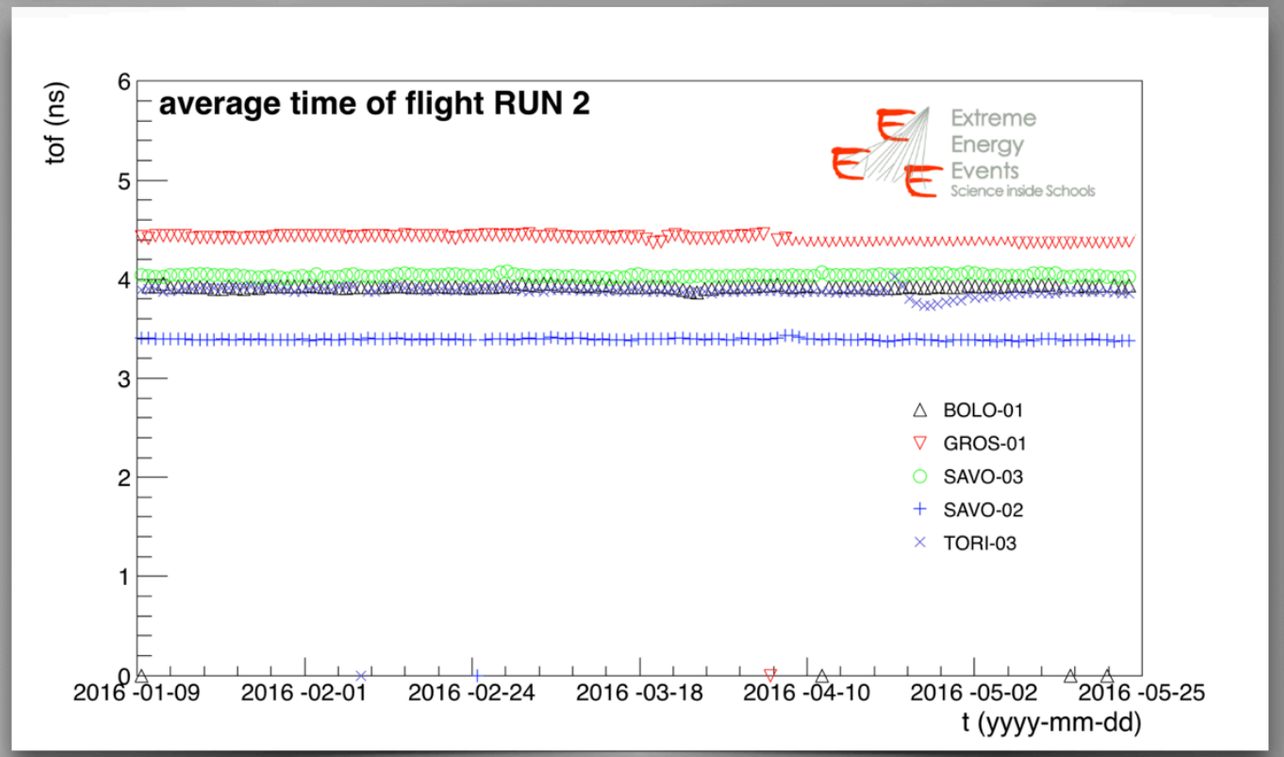




Long term stability

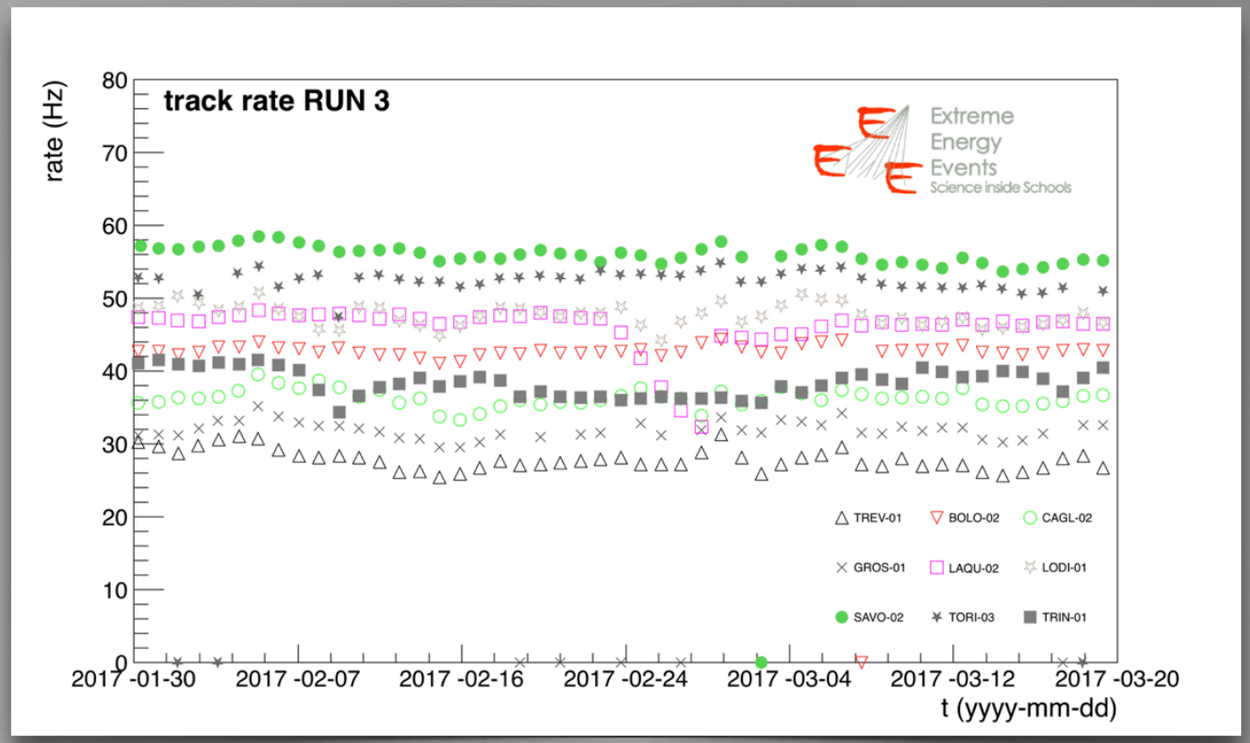
Time Of Flight – average track TOF between top and bottom chambers

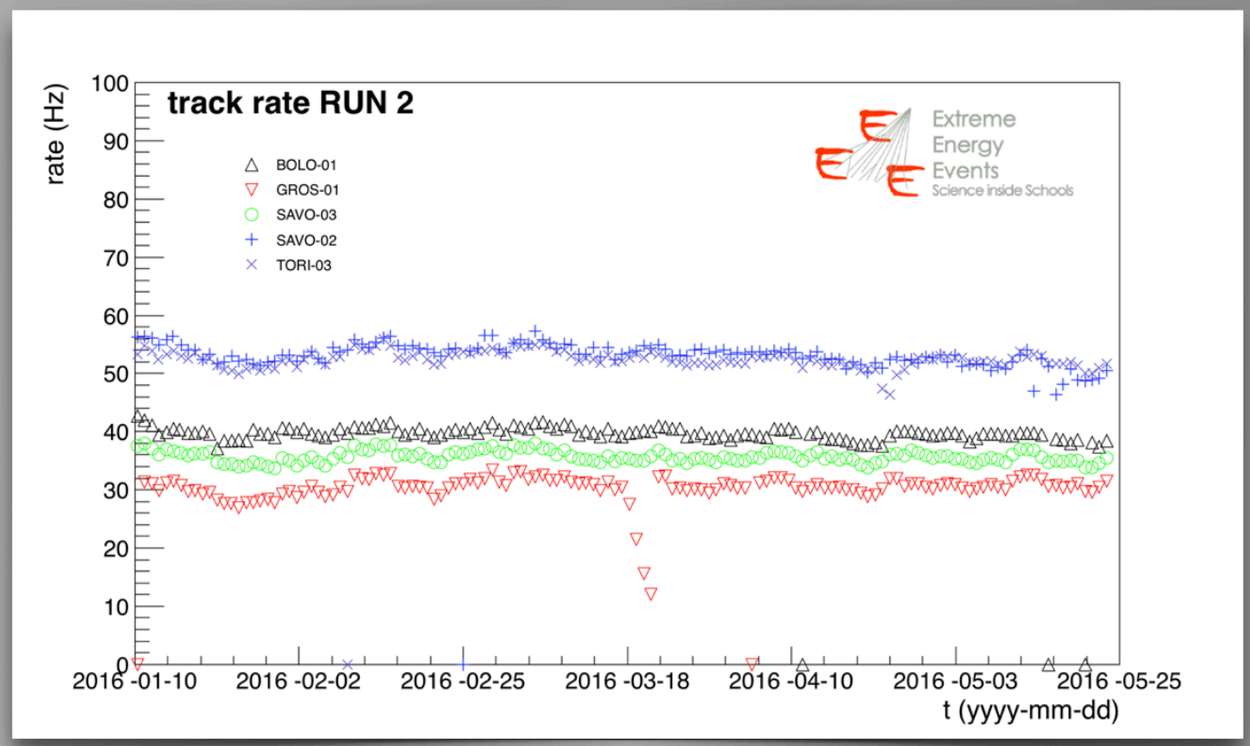




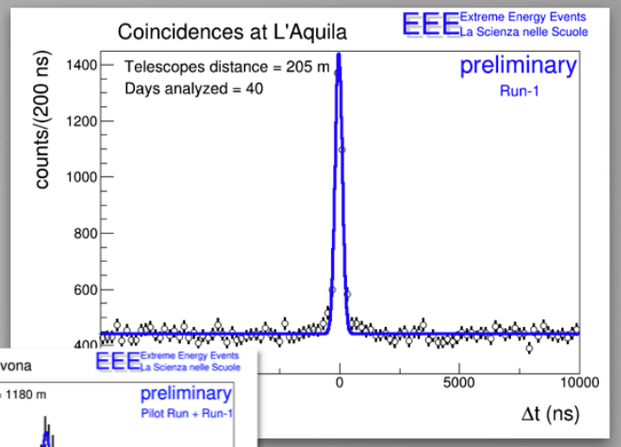
Long term stability

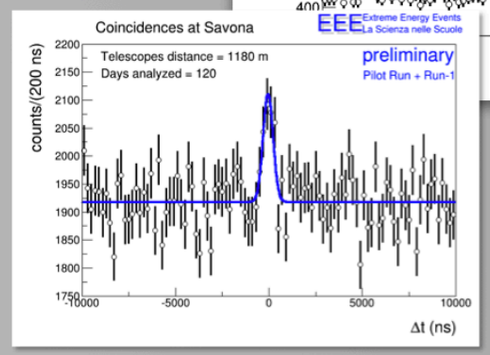
track rate – rate of events with at least one candidate track

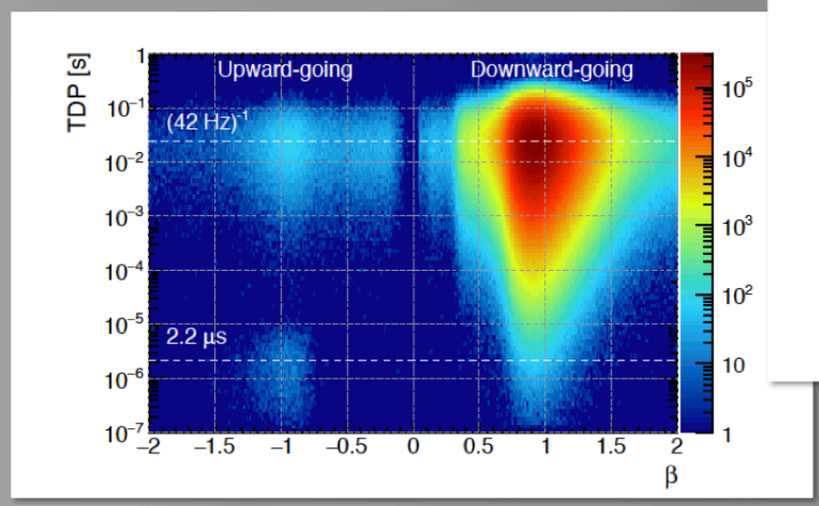


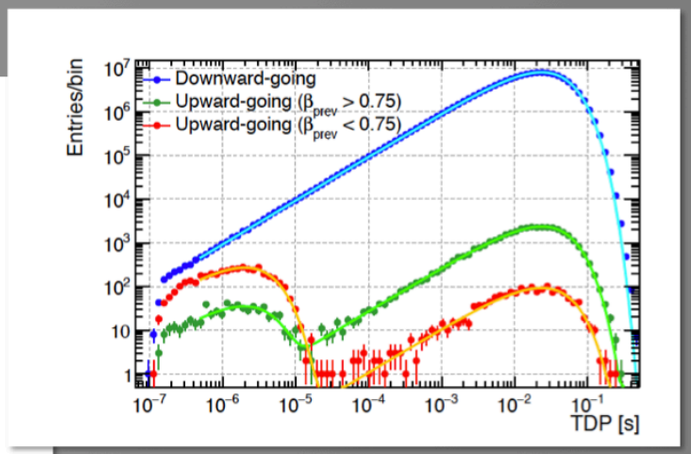


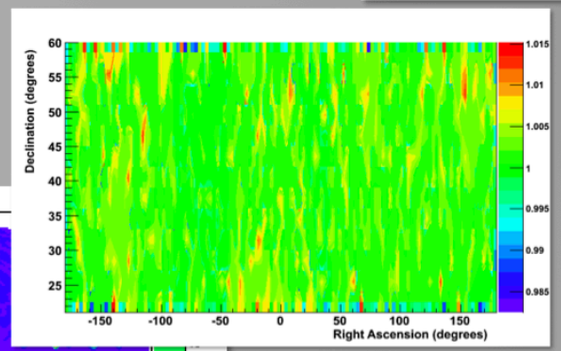
Analysis

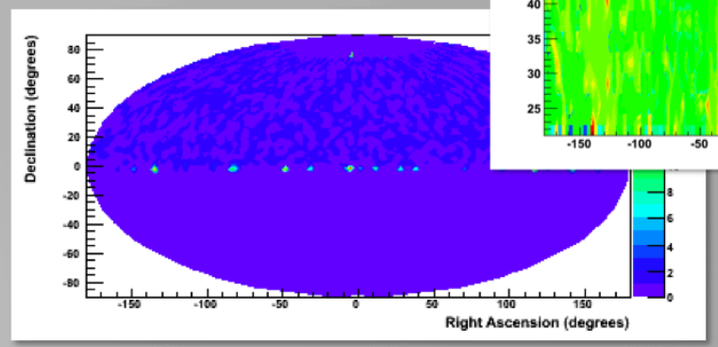


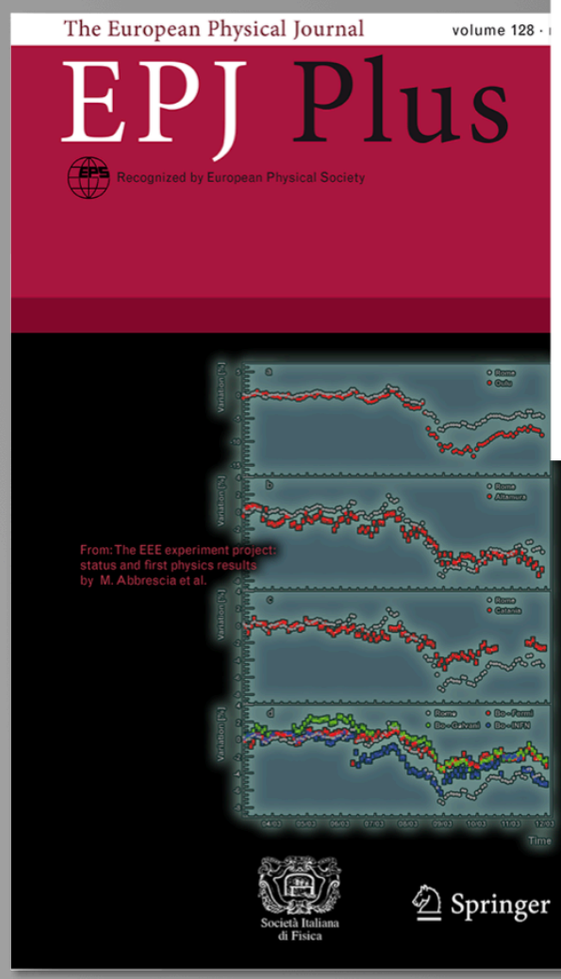


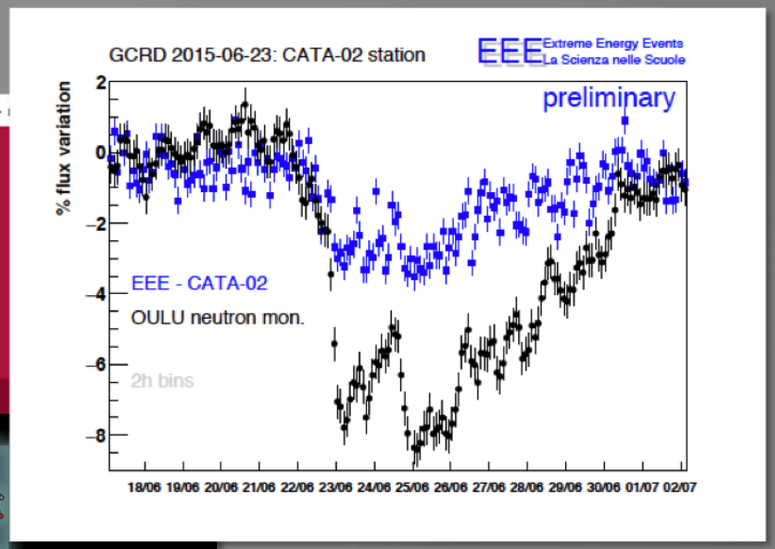












- telescope coincidences
- search for anisotropies
- Forbush decrease
- muon decay
- long distance coincidences
- many others

Conclusions

- ✓ network continuously growing and successfully operating since 14 years
- ✓ excellent performance in terms of time and spatial resolution
- ✓ very high efficiency
- ✓ High School students strongly involved in the Project
- ✓ coordinated data taking periods ongoing (central data storage and reconstruction)
- ✓ more than 60 billion tracks collected

	Pilot Run	Run 1	Run 2	Run 3
starting date	27/10/2014	27/02/2015	07/11/2015	01/11/2016
ending date	14/11/2014	30/04/2015	20/05/2016	31/05/2017
number of days	19	63	196	212
tracks/day (M)	~ 27	~ 53	~ 69	~ 85
purity (%)	75	84	83	80

Table 1: Statistics from the four coordinated runs. The number of active telescopes in Pilot Run, Run 1, Run 2 and Run 3, is respectively 15, 28, 38 and 46. The purity is calculated as candidate tracks/triggers.