

The upgrade of the Extreme Energy Events experiment



M. Abbrescia for the Extreme Energy Events collaboration

The project



The EAS array







✓ Many, low cost, easy to operate stations

Simulation of the shower induced by a 10^{16} eV proton

 \checkmark At ground level 1 million muons arrive, over an area with radius at least 2 km.

High energy showers revealed by detecting muons at different stations at the same time ("coincidences")

Present status

- 50 telescopes at High Schools
- + 2 telescopes at CERN
- + 4 at INFN Units
- Total: 56 telescopes
- $+ \approx 50$ institutes on the waiting list
- ✓ Largest (in terms of total detector area) system using MRPCs
 ✓ Largest cosmic rays experiment in Europe
- Stations in operation at schools
 Stations in operation at research centers
- Institutes in the waiting list



EEE: The largest MRPC system

EEE: 56 telescopes x 3 chambers ≈ 220 m² covered

✓ Synchronized at o(10 ns) across whole Italy

✓ Taking data at the same time

✓ Data transferred to a central repository

EEE is a system of detectors operating in a

coordinate way

Monitoring MRPC performance is intrinsically interesting: See talk by D. De Gruttola

Second largest system using MRPCs : ALICE TOF: 144 m² covered Future largest system using MRPCs: CBM TOF: \approx 110 m² covered Upgrade of the CMS muon system \approx 100 m² covered





EEE Online monitoring

eee.centrofermi.it/monitor



Data taking

✓ About 60 billion events collected since the start of organized data taking



Software architecture





The EEE network upgrade

✓ Plan to build another 20 telescopes

✓Will increase the capability of the EEE network to study the high-energy part of the cosmic rays spectrum

✓ Huge effort for 2017-18!

First bunch already completed ✓ 20-27 February → Lampedusa

✓12-18 March → Genova

✓23-29 April → SIEN-02

✓7-13 May → TORI-05 + Moscow

✓21-27 May \rightarrow LODI-03

✓10-14 July → LODI + Korca

(spare chambers)

✓25-29 September → CAGL-04 ✓21-24 November → BOLO-05



New chambers for new telescopes

250 µm six-gap chambers

✓ Conceived for new eco-friendly gases
✓ Reduce operating voltage
✓ EEE plans to soon operate some telescopes with eco-friendly gases:

See talk by S. Pisano for details

Improved front-end boards

 Amphenol cables and connectors replaced by Nugent ones
 New boards in production

New test protocol at CERN

✓ Tests on electrical (strip) connectivity
 ✓ Tests on gas tightness
 ✓ Tests on current, rate and efficiency
 ✓ Everything stored in a dedicated DB



Costruction details









Chambers tightness tests

Leaks are measured by injecting known volumes of air inside the chambers and measuring the relative overpressure

Overpressure vs. time is then measured in an hour time span and leak rate can be inferred via an exponential fit





Calibration curve

600

500

Est. leak: 0.7 l/h





Corrections are applied to take into account possible temperature variations during the measure

Very precise measure at the chamber operating overpressure

Ê 360

340

320

300

280

260

240

220

Chamber tests: efficiency

 ✓ Efficiency is measured for three chambers placed on top of on CERN-01 (green).

✓ Chambers are fluxed 4 days before measurements.

✓The trigger and tracking is from CERN-01.

✓ Data from CERN-01 "bottom" and "middle" chambers and from the chamber under test are acquired

✓ Efficiency is measured by searching hits on the chamber under in a fiducial zone around the track



Some tests results

Typical curves for a set of 3 new MRPCs. These chambers are now installed as the new EEE telescopi at Cariati (CARI-01)



Some overall statistics



New EEE clock distribution card

✓ Designed at INFN Torino

 ✓ Distributed the same clock to the two TDCs of the EEE readout

✓Essential to exploit time info from the middle chamber

✓ Built and installed in all EEE telescopes



Time Hits Distribution



New trigger/GPS cards

✓ Developed between Bari and Lecce INFN sections

 ✓ Joins the functionalities of the present trigger and GPS boards (+ GPS interface)

✓Additional functionalities:

-clock distribution

-counters accessible via VME

- trigger logic programmable via VME

 ✓ Already installed at LODI-02, FRAS-02, SIEN-01, TORI-02, VICE-01
 ✓ Plan to be deployed in all stations
 ✓ Proposal to be commercialized from CAEN



EEE coincidences searches

Detected coincidences at 1.5 km 60 \checkmark Higher distance \rightarrow higher energy EEE collaboration Time correlation counts/(400 ns) measurements from extensive air showers 1550 detected by the EEE telescopes, Eur. Phys. J. Plus (2013) 128:148, DOI work in progress 10.1140/epjp/i2013-13148-3 1400 Extreme Energy Events Rate vs Distance 1350 Rate coincidences [sr⁻¹ m⁻⁴ day⁻¹] CERN 10³ Acceptance corrected Not corrected for efficiency stations Frascati Torino 10 Savona 200 400 600 800 1000 1200 0 Distance (m)



EEE: long distance correlations

Strategy: correlations between individual showers in telescopes clusters
 Shower rate: 0.001 - 0.04 Hz (depending on cluster and S/N ratio)
 Spurious rate in 1 ms: 10⁻⁸ - 10⁻⁷ Hz (0.001 - 0.01/day)

Number of events $dN/d(\Delta t)$ for decreasing time window

Not the same results for all pairs of clusters: studies ongoing!



Forbush decreases

Solar Flares followed by Coronal Mass Emission, whose eject sometimes envelops the Earth and adds up to the Earth magnetic field, provoking a sudden decrese in Cosmic rays revealed on the ground



EEE Collaboration, *The EEE experiment project: status and first physics results*, Eur. Phys. J. Plus (2013) 128, 62.



The 2016 new year Forbush: at 24.00 of 31/12/2015 our telescopes -in schools- were up and running!

Upward-going events

About 1 event over 2000 observed to go in an upward direction

Some of them identified as electrons coming from muon decays (in the floor or in the bottom chamber),

> Blue track: downward muon Red track: upward electron



ЪР

10-1

10⁻²

 10^{-3}

 10^{-4}

10-5

10-6

(42 Hz)⁻¹

2.2 µs

Downward-going

10⁵

 10^{4}

10³

10²

10

EEE collaboration, A study of upward going particles with the Extreme Energy Events telescopes, NIM-A 816 (2016), 142-148



External collaborations

EGO-VIRGO collaboration interested in having one (or more) EEE telescopes hosted at their lab in Cascina

➢As a veto for cosmic ray showers in coincidence with possible signals coming from gravitational waves

- ➢Similar device already at LIGO
- Some literature already available





University of Santiago de Compostela (Spain) interested in anaylizing EEE data looking for correlations between the cosmic rays flux and temperature and pressure conditions in the throposphere

✓ Memorandum Of Understanding signed up



Polar QuEEEst

3 PolarQuEEEst detectors

✓ onboard on boat Polar Nanuq
 ✓ installed in a Norwegian High School
 ✓ installed in an Italian High School
 Mounted by students, in the EEE tradition
 45° in latitude, span 5000 km





Conclusions

The EEE experiment is the largest system implemented with MRPCs in the world

- ✓ Detector performance similar to LHC experiments
- ✓Will soon run with eco-gas

Its stations –located in high schools- continuosly take data

 ✓ Already > 60 billions muon tracks collected

EEE produces <u>-a lot of- physics</u>!
✓very interesting observations of cosmics phenomena



The End: Thanks for the attention Questions?





The End: ✓ Thanks for the attention ✓ Questions?



The End:

Thanks for the attention Questions?

Hisarletoffdf

EEE smallest (but great) town



EEE: the taskforce

A task force of hardware experts, to intervene where setting up/commissioning/reparation of an EEE telescope is needed
 ✓ Started activity at beginning of 2017

Already interventions at:

TREV-01 (commissioning, now telescope taking part to the data taking)
 VICE-01 (telescope set-up, waiting for trigger card)
 ROMA-01, ROMA-02 (testing and repairs)
 FRAS-02, FRAS-03 (small repairs, now both telescopes taking part to the data taking)

➢Programming interventions at COSE-01, LECCE, etc.





EEE meetings with schools

- Since end of 2016 monthly EEE run coordination meetings open to schools
- ✓ Using dedicated Vidyo virtual rooms
- ✓ Around 50-60 schools connected \rightarrow hundreds of participants!



EEE plenary meetings

- ✓ Bologna, November 6-7North Italy schools
- ✓ Grosseto, April 15-16
 Center Italy schools
 ✓ Bari, October 13-14
 South Italy schools





Erice 2017: ✓May, 29, 30 and 31 ✓December, 6, 7 and 8

Extreme Energy Events

EEE: goal of the project



The future: Run-4



Start: 2 October 2017 – End: 31 May 2018 Commissioning week: 25 September 2017 – 1 October 2017

Schools are called to:

(help) fix all issues in their telescopes (particularly in the Long Shutdown)

- ✓ 50 cm distance between chambers
- \checkmark 2 l/h gas flow
- Complete the measure of the telescope angle wrt. North
- Start measures of the gas consumption
- Telescope startup and shutdown responsibility of the schools

Read emails, diffuse them and react Take part and present to the EEE Run meetings open to schools Keep the telescope in operation Monitor the telescopes (ALL)



The EEE experiment structure

➤Each station consists of a telescope made out of 3 MRPC

✓Exceptional tracking and timing performance

Coincidences among distant telescopes are searched for, to spot high energy showers





Corrections because of the propagation of the wave front of the shower, made possible thanks to the EEE telescopes directionality









Okay, this is all about detector stuff, but... why is EEE so peculiar?





EEE is so peculiar...

>because the experiment does not take place in scientific labs but...

in italian high schools

because main actors of the experiment are not scientists but...

 high schools students and teachers

With the help of experts from the scientific world, students and teachers, they:

✓ Build their detectors at CERN
✓ Build the stations at their schools
✓ Take care of the data taking and relative analysis





...Aaahhh, okay: It is a <u>didactic</u> experiment!





The upgrade







Some physics results



EEE chamber performance

Efficiency measurements...and counting rate

Efficiency HV scan performed
 last year (middle chamber)
 To be repeated for all chambers



Time resolution measurements
 With time slewing corrections,
 improving time resolution about 20%

See talk by D. De Gruttola for details



DAQ&Reconstruction architecture

5-10 TB per year Full statistics from Pilot run to Run-1: ■ ✓~2.4 TB (raw: ~2 TB, reco: ~0.4 TB) (+3 TB from past years)

Run-1: 02/03/2015 - 30/04/2015



