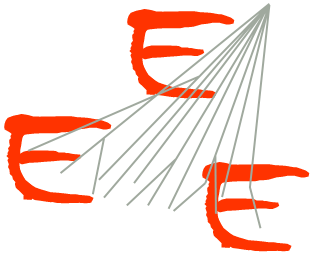


The Extreme Energy Events project

Despina Hatzifotiadou
INFN Sezione di Bologna
Centro Fermi – Roma
EP Department - CERN

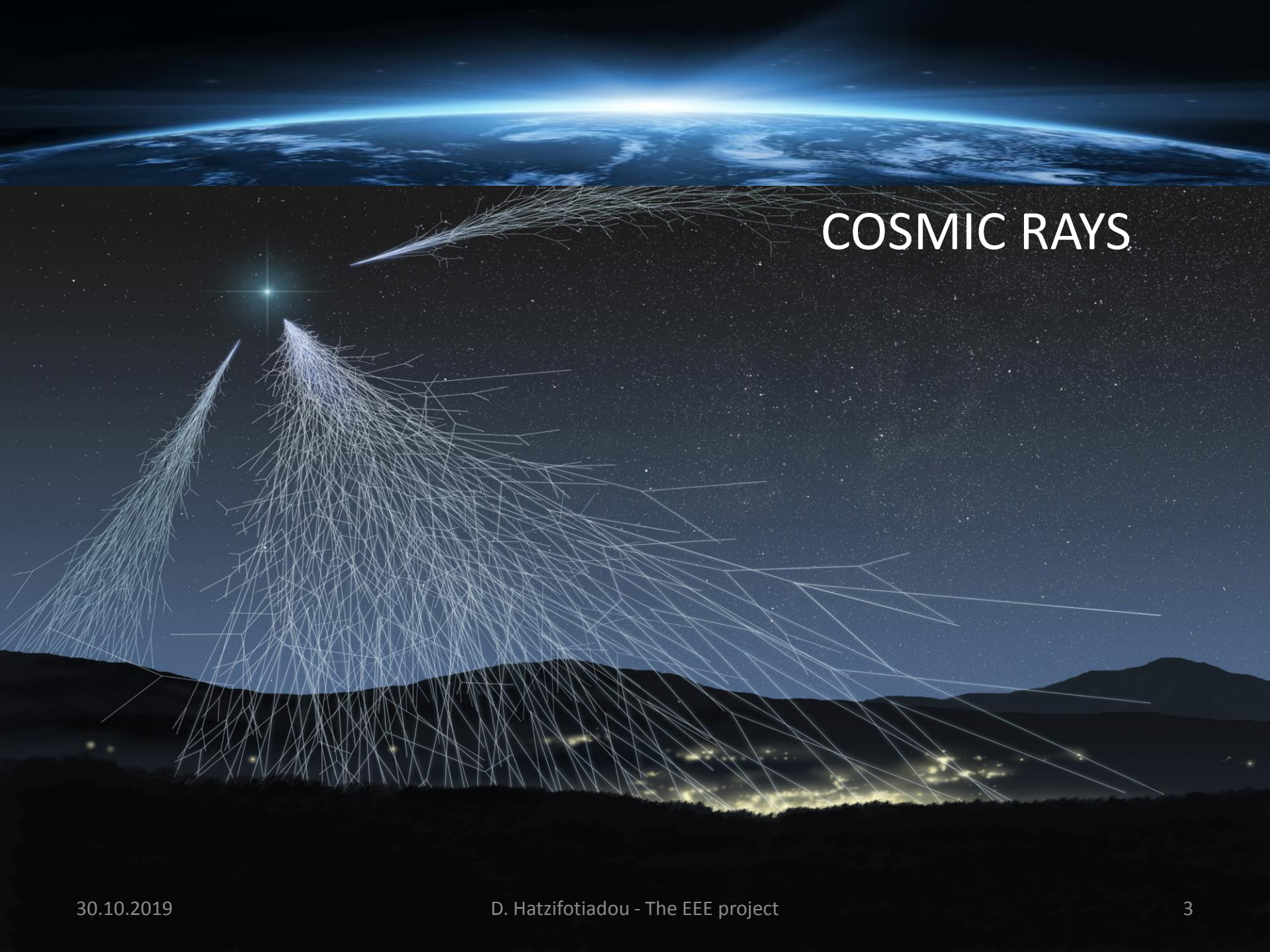
SWEDISH TEACHERS PROGRAMME OCTOBER 2019

Cosmic ray physics experiment with double goal :
Educational / outreach and scientific research

- hands-on activity for high-school students with the aim to stimulate their interest in science through their involvement in all stages of the project (detector construction, installation, comissioning, data-taking, analysis)
- research in cosmic ray physics

A collaboration of

- Centro Fermi – Roma Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi"
- INFN Istituto Nazionale di Fisica Nucleare
- MIUR Ministero dell' Istruzione, dell' Università e della Ricerca
- CERN European Organization for Nuclear Research


COSMIC RAYS

First studies of cosmic rays

In 1909 Theodor Wulf measured, using an electrometer, higher level of radiation at the top of the Eiffel Tower than at its base.

Victor Hess, using balloons, measured in 1912 atmospheric ionisation as a function of altitude. As he ascended to 5300 metres, he measured the rate of ionization in the atmosphere and found that it increased to some three times that at sea level. He concluded that penetrating radiation was entering the atmosphere from above. He had discovered cosmic rays.

What are cosmic rays

Very energetic charged particles coming from outer space that continually bombard the earth

- Protons (hydrogen nuclei) 89%
- Helium nuclei 10%
- Heavier nuclei 1%

When they collide with atoms in the earth's upper atmosphere, they create a shower of lower energy secondary particles, mainly pions.

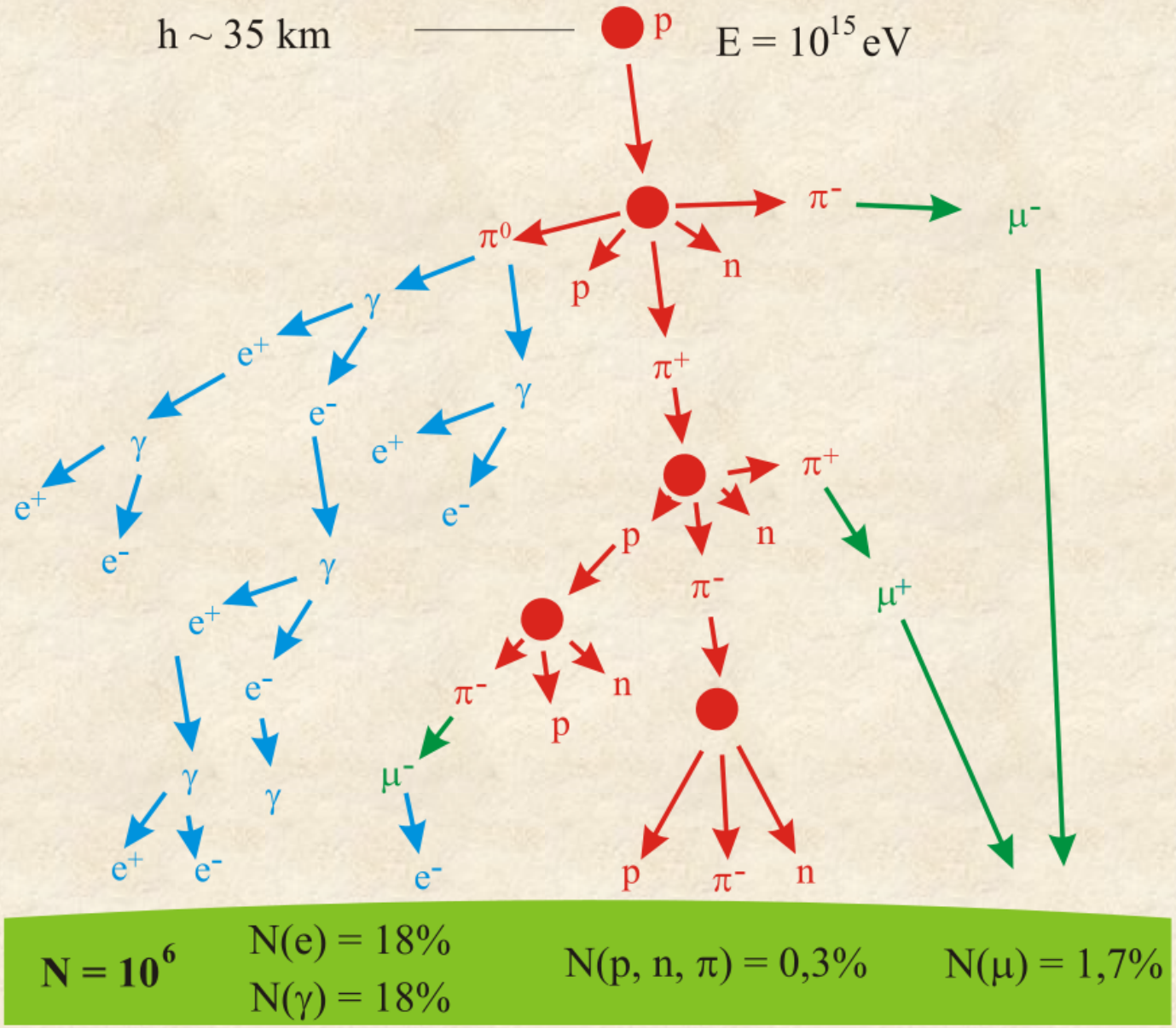
Pions swiftly decay emitting muons, which travel through the atmosphere and penetrate below ground.

A hundred of these secondary particles pass through our bodies every second.

Energies of primary cosmic rays

- from 1 GeV (rate : 10 000 / m^2s)
- up to 10^8 TeV (rate : < 1 /km^2century)

Very high energy cosmic rays generate huge showers of up to 10 billion secondaries spreading over areas of 20 km^2 at the surface of the earth

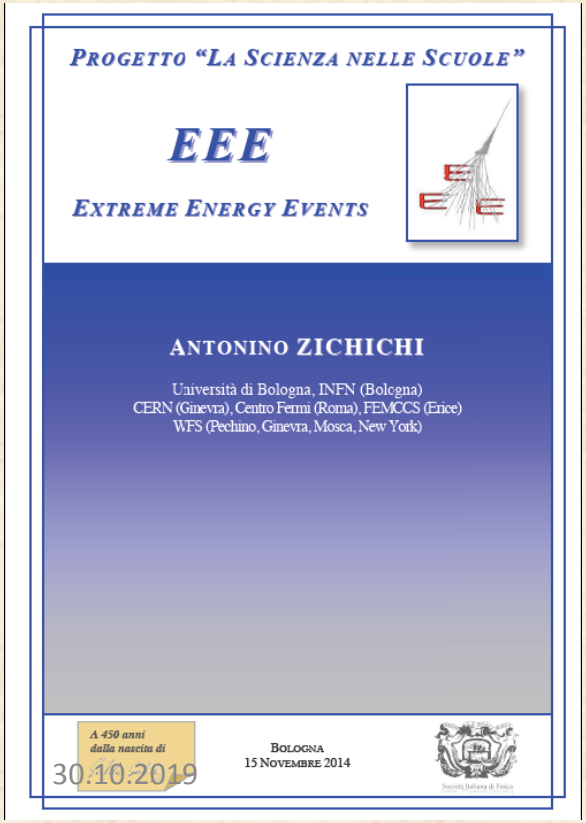


N = 10⁶ N(e) = 18% N(γ) = 18% N(p, n, π) = 0,3% N(μ) = 1,7%

The project

Some history..

Launch event : 3 May 2004
Webcast from CERN
Professor A. Zichichi
Minister L. Moratti
watched by many Italian schools

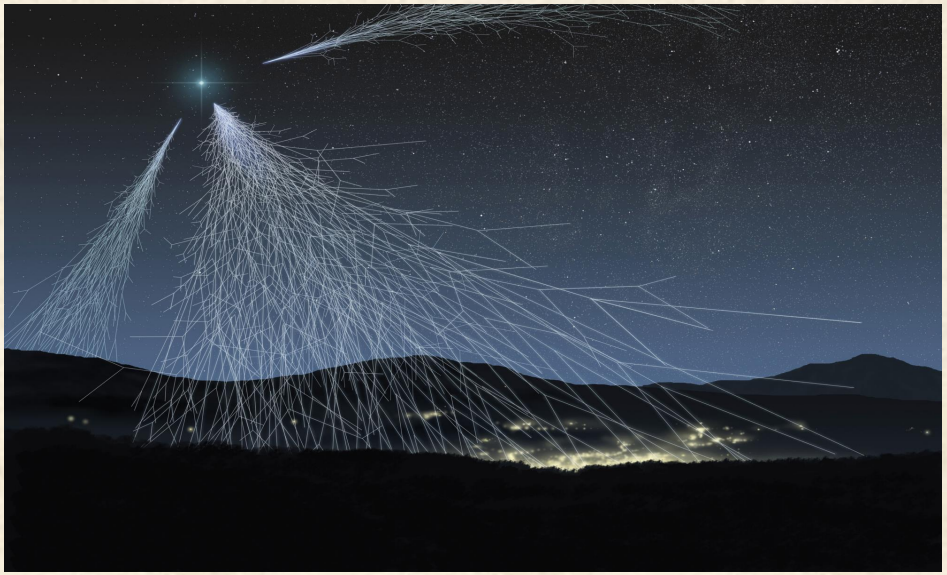


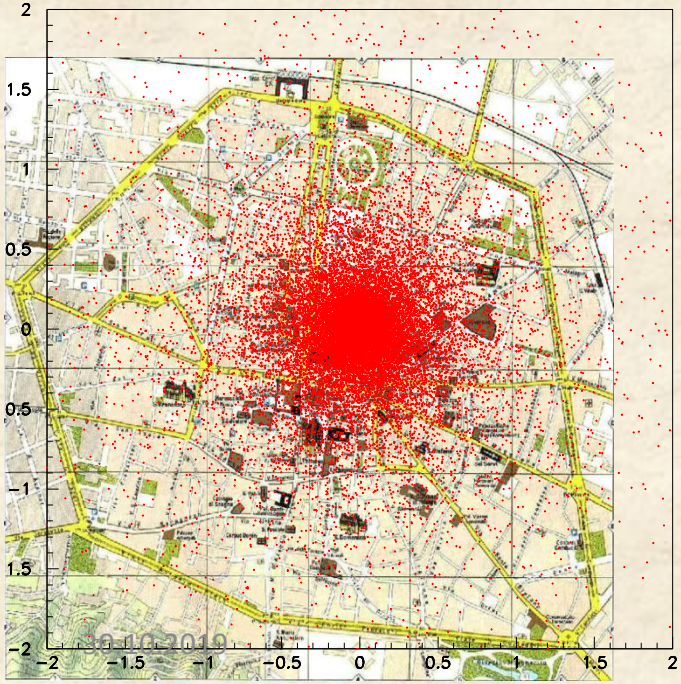
A. ZICHICHI, *Progetto "La Scienza nelle Scuole"*
EEE – Extreme Energy Events
Società Italiana di Fisica (SIF), Bologna
1st Edition 2004; 2nd Edition 2005
3rd Edition 2012, 4th Edition 2014, 5th Ed. 2017

Aim of the EEE project

Look for extended air showers and extreme energy events

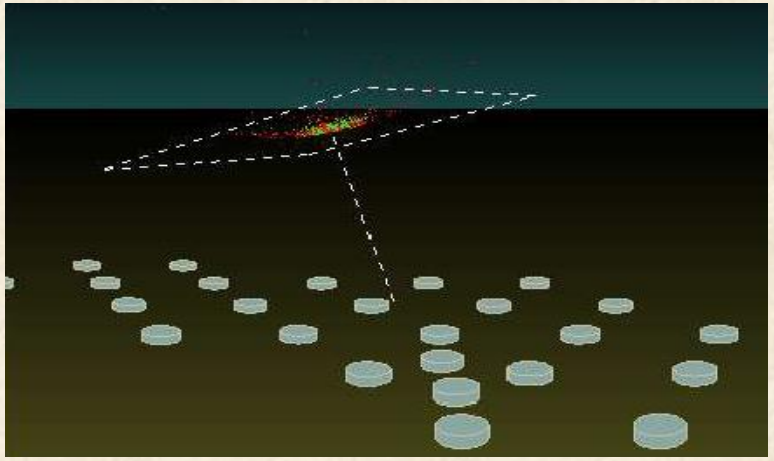
By detecting the muon component of the shower

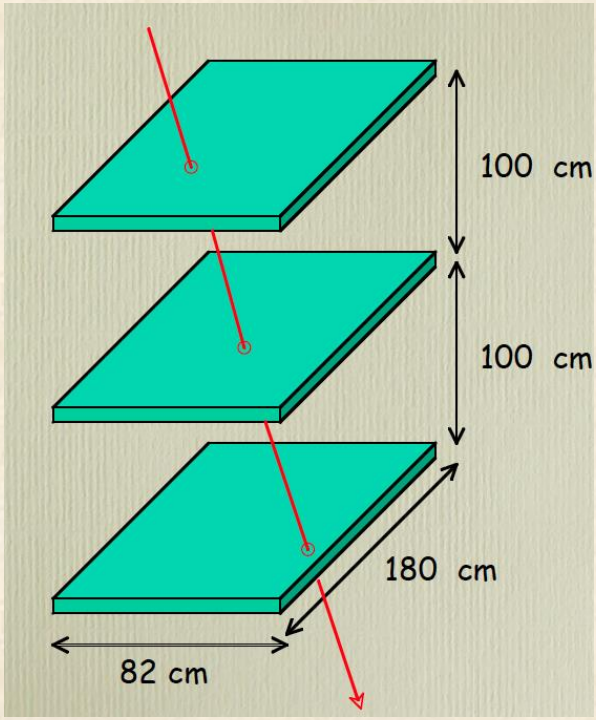




Simulation of a shower induced by a 10^{17}eV proton
At ground level 1 million muons arrive, over an area with radius at least 2 km.

- Place telescopes all over Italy
  in Italian High Schools
- Look for coincidences between telescopes





Key ingredient :
define direction of muon - so that we can point back to interaction point in atmosphere
check that muons belong to same shower and also get direction of incoming particle

An array of muon telescopes

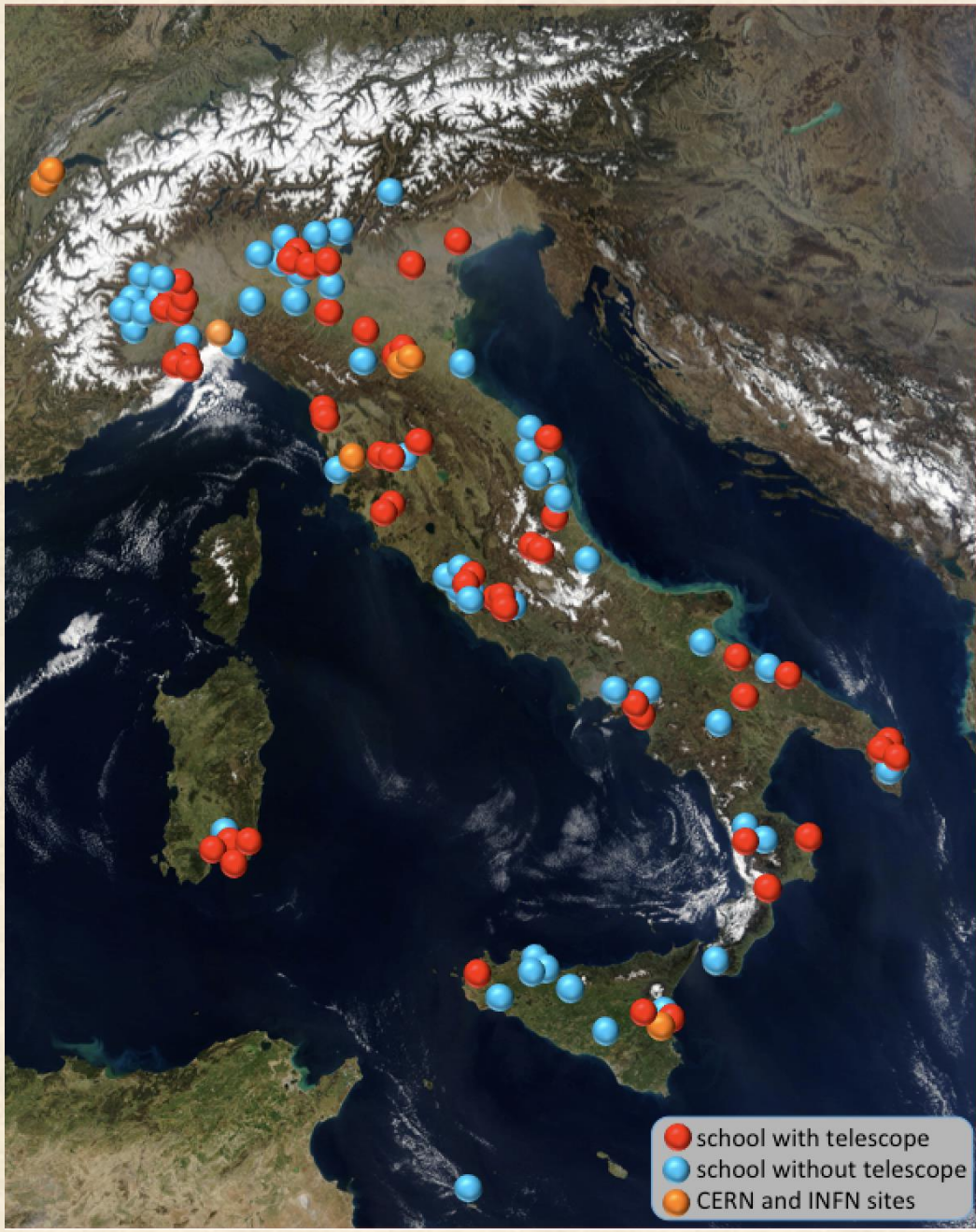
At present

~50 in Italian High Schools

They are mostly distributed in clusters in the whole Italian territory

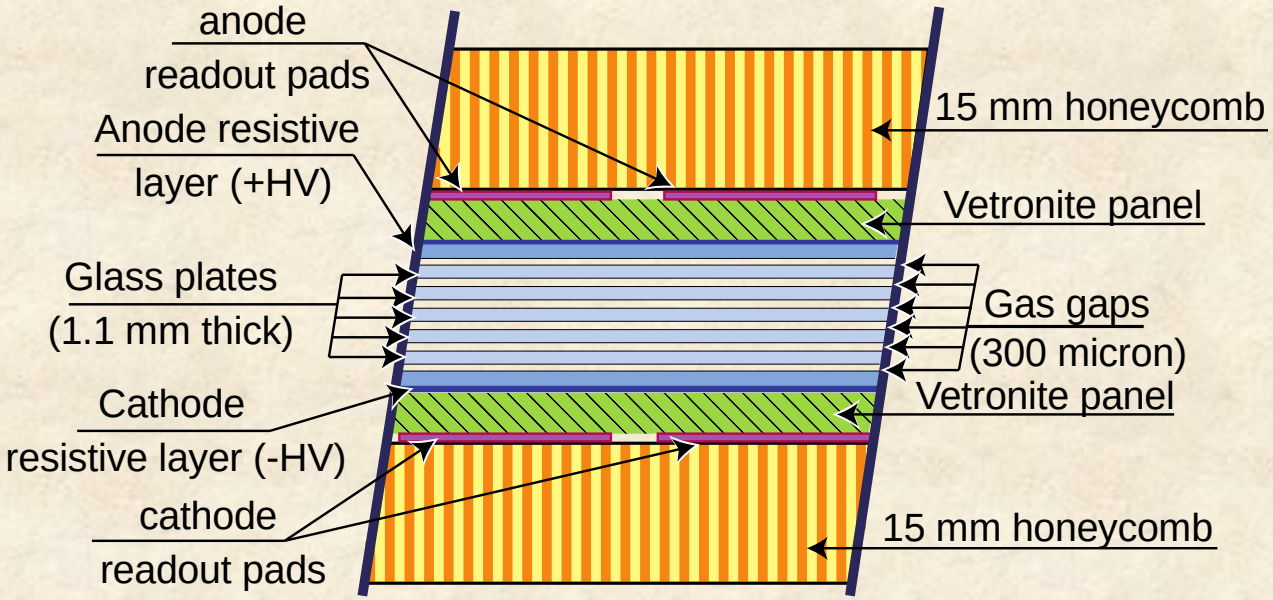
+ 2 telescopes at CERN
+4 in INFN Units or Universities

~45 schools on the waiting list



The experimental aparatus

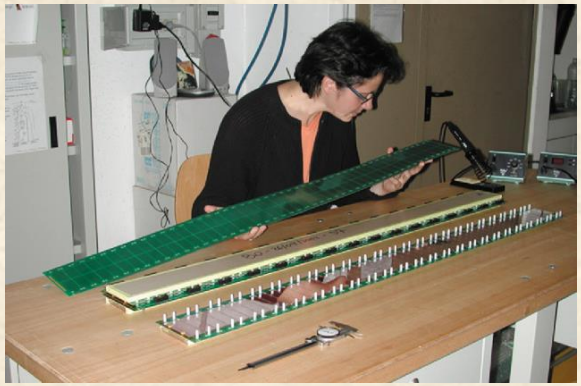
The detector : 3 Multigap Resistive Plate Chambers (MRPC)



- 6 gas gaps of 300 microns each
- dimensions : 82 cm x 180 cm

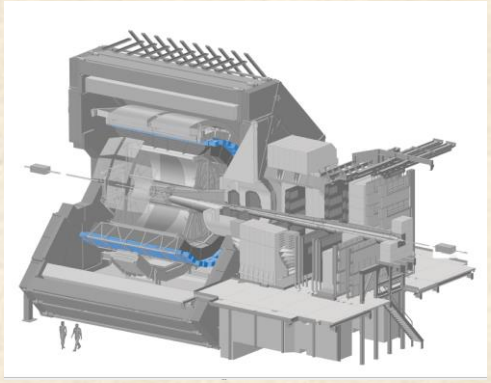
- Requirements : reliable (long-term); easy to use; not expensive
- Design based on the MRPCs of the ALICE Time Of Flight (TOF)

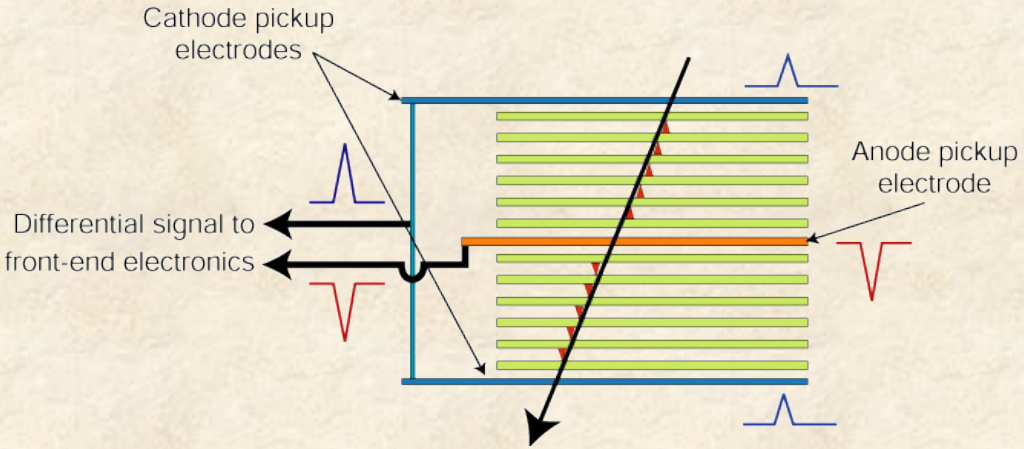
The ALICE Time Of Flight detector

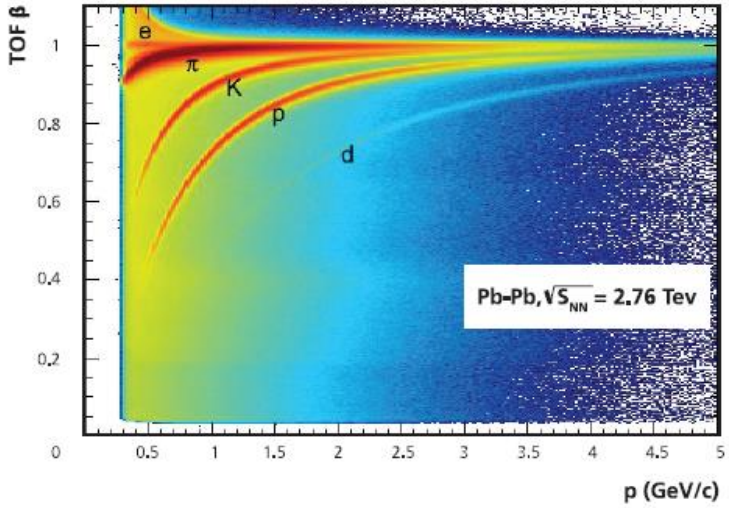


Multigap Resistive Plate Chamber
10 gaps of 250 microns each

Cylindrical array of 150 m^2 r=3.7m
1600 MRPCs in 18 Supermodules



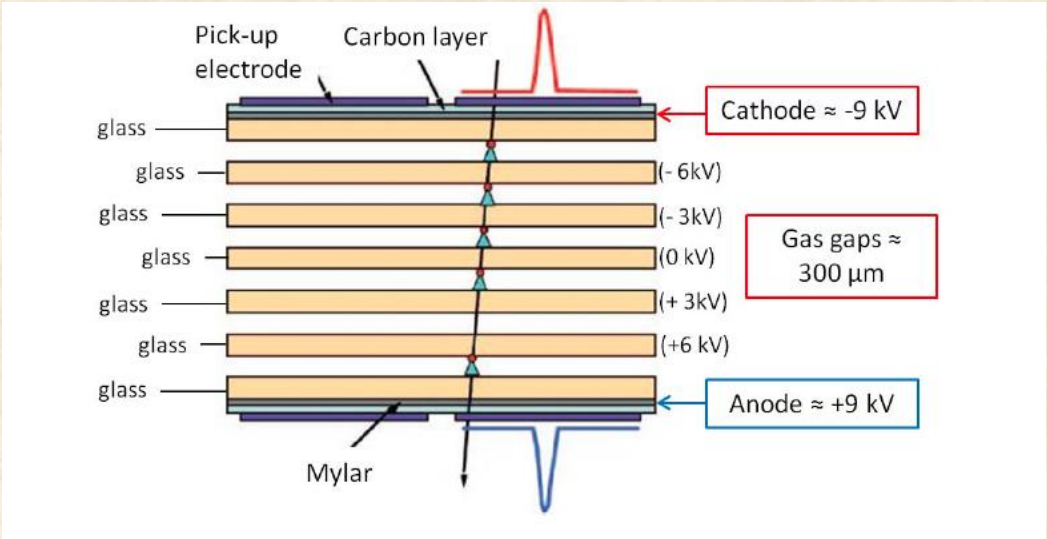


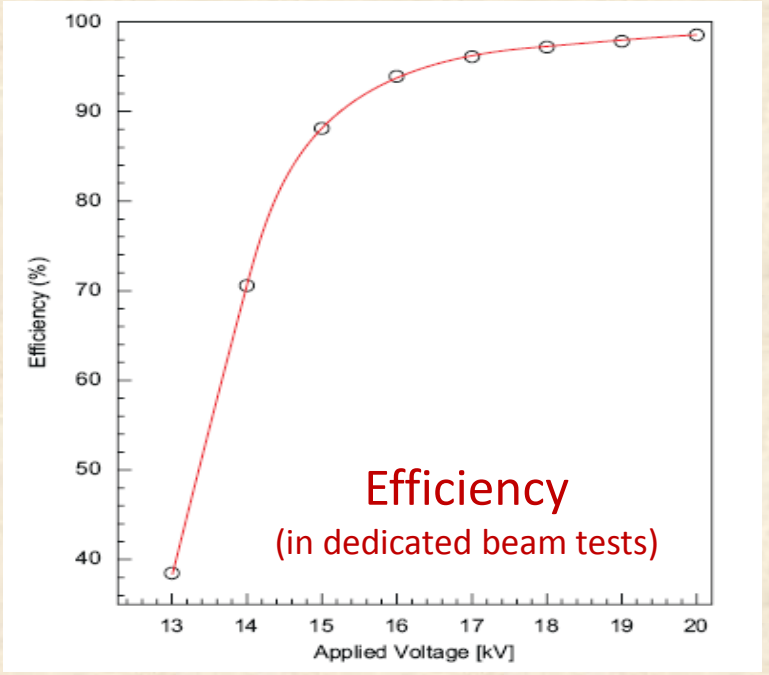


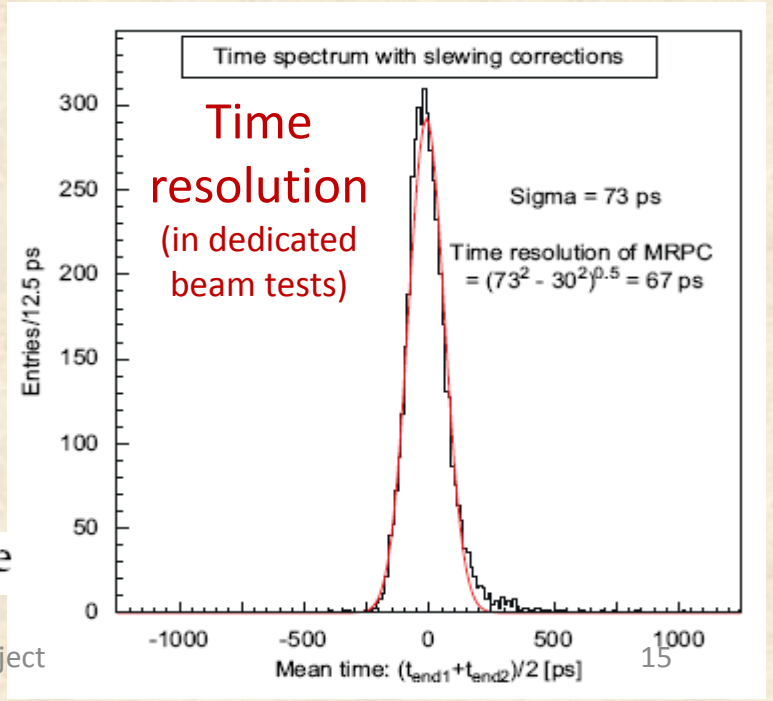
Correlation β = v/c versus momentum as observed by TOF in Pb-Pb collisions. Particle species are clearly separated in the intermediate p_T range

System time resolution σ = 70-80 ps

The EEE MRPC





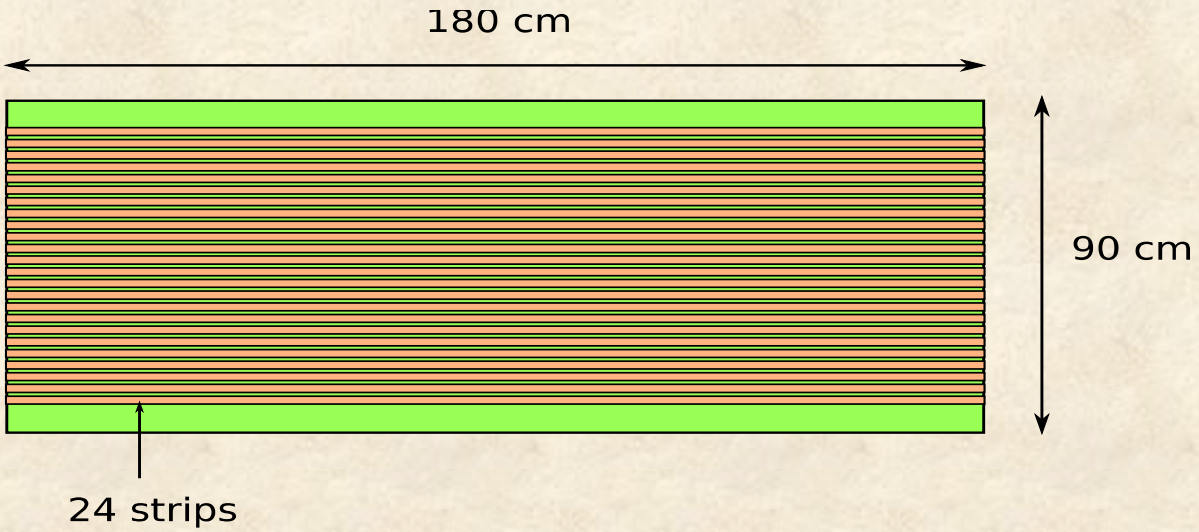


Operated with a mixture of 98 % $C_2H_2F_4$ – 2% SF_6

Performance of a six gap MRPC built for large area coverage

M. Abbrescia et al. / Nuclear Instruments and Methods in Physics Research A 593 (2008) 263–268

Signal readout

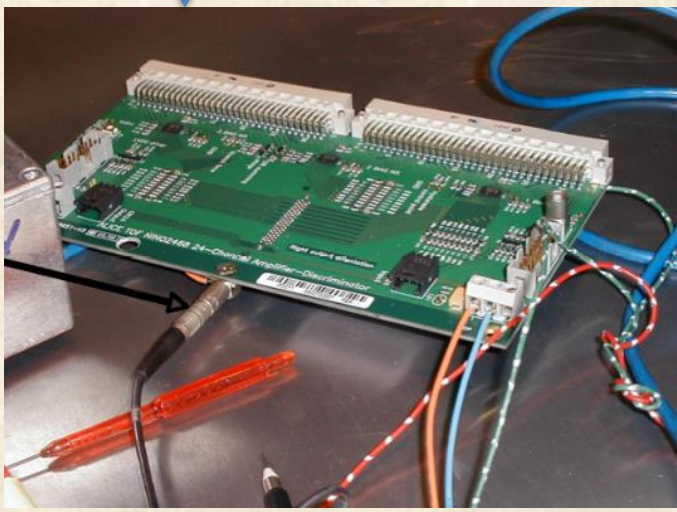


FEA card

3 NINO asics / 24 channels

- Amplification
- Discrimination
- Stretching of pulse
- OR of 24 signals

2 FEAs per MRPC



- 24 strips read out at both ends
- time difference : position of hit along the strip
- Anode & cathode readout plane : differential signal

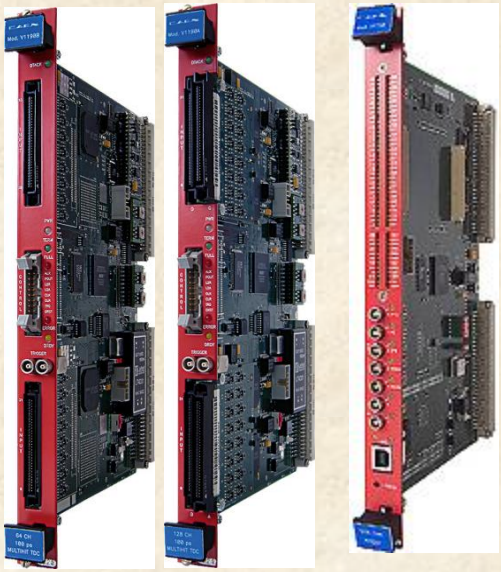
adhesive copper tape on vetronite sheet

strip width : 2.5 cm; distance between strips : 0.7 cm

Space resolution in x and y : ~ 1 cm

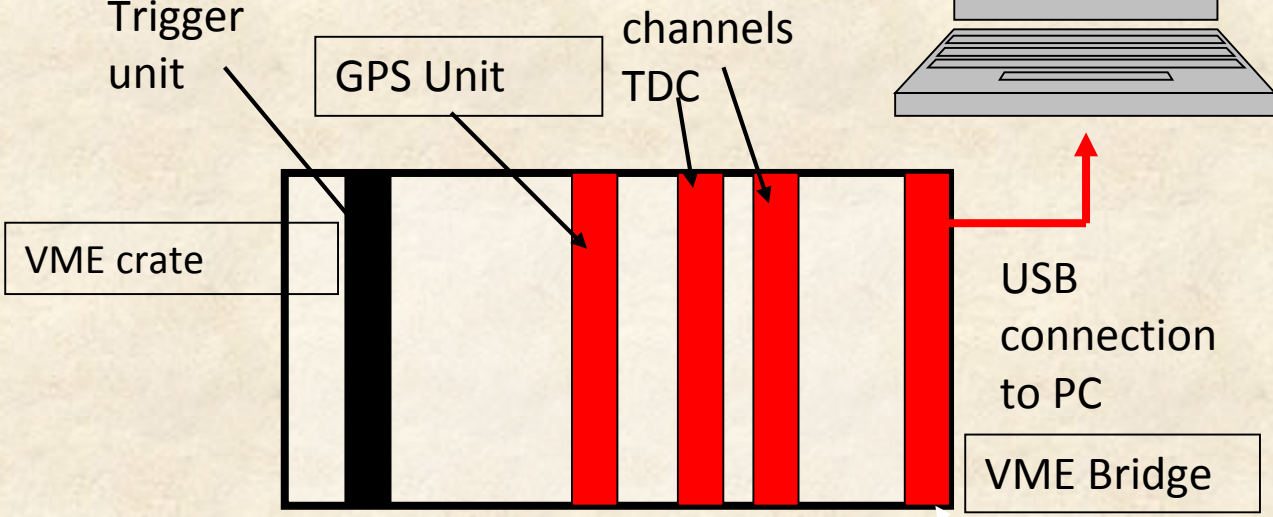
Electronics

TDC TDC VME Bridge



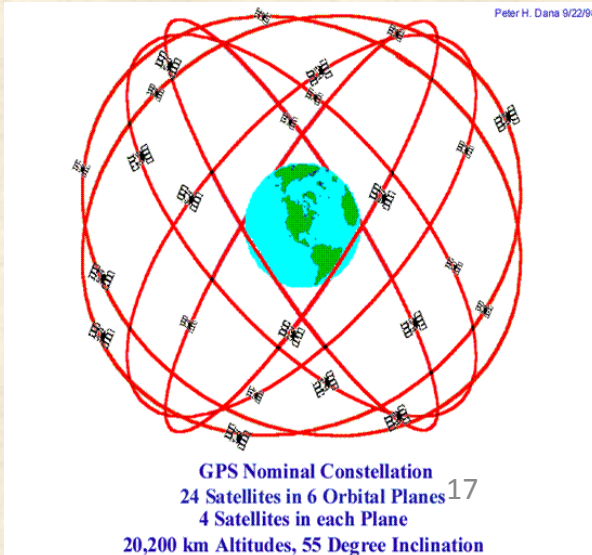
CAEN V1190A CAEN V1190B CAEN V1718

Trigger card
6-fold coincidence



Data Acquisition and monitoring based on Labview

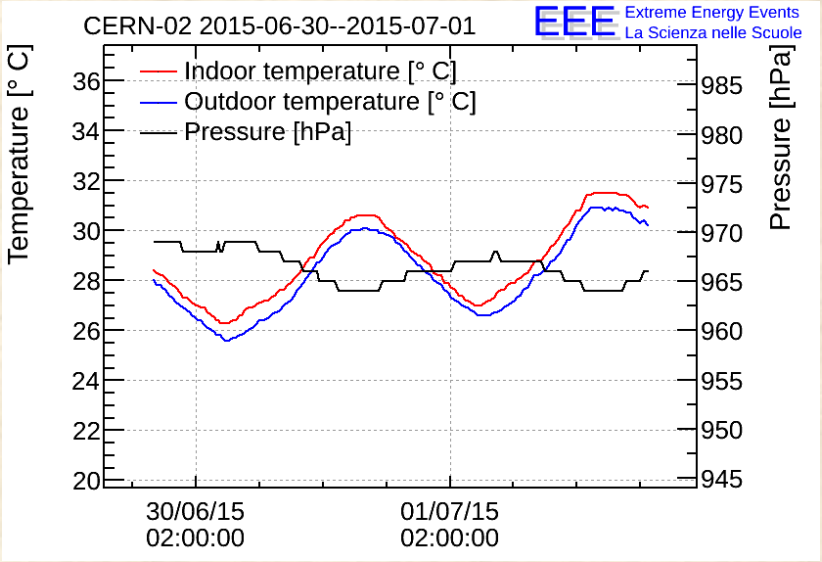
Hytec (or Spectracom) GPS to generate time stamps and synchronize stations at different location

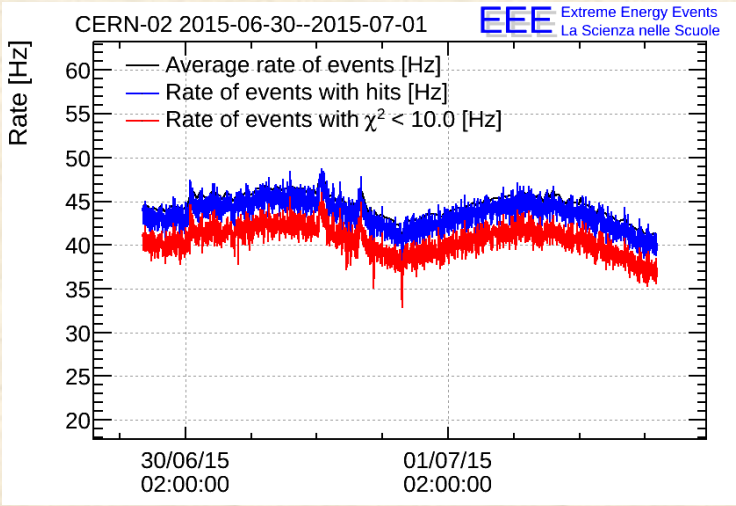


In addition

Weather station to monitor
- temperature
- pressure

read out by the DAQ

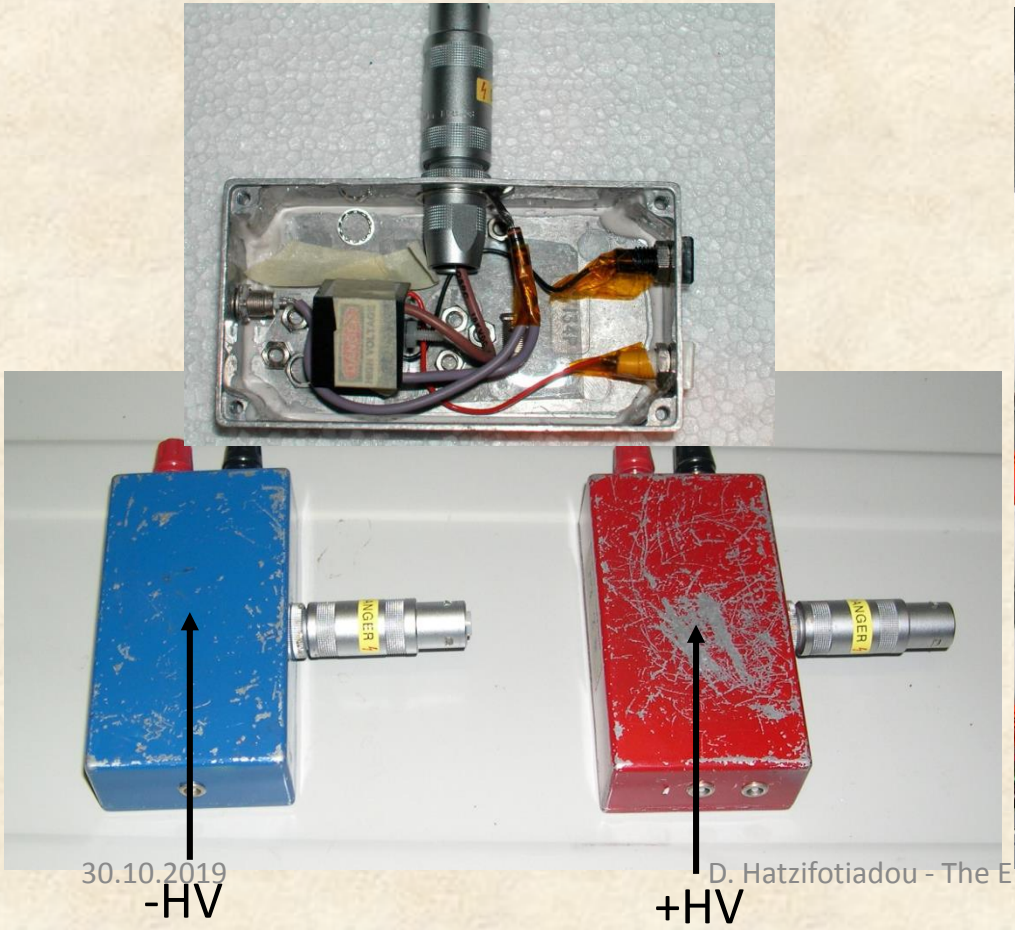


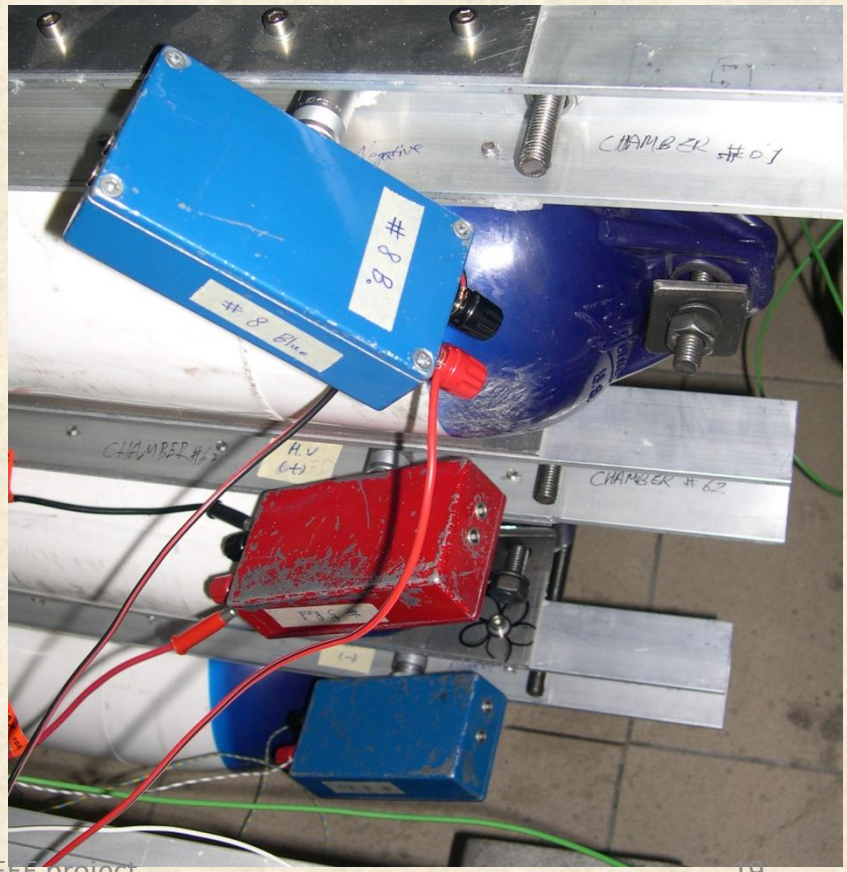


The HV system

Working voltage for MRPCs : 18 - 20 kV

- DC-DC converters inside small boxes
- EMCO Q series converters providing an output voltage up to ±10 kV for 0-5 V input





The students' involvement

Phase I. Construction of muon detectors (MRPCs)

- Done by high-school students and teachers at CERN supervised by researchers*
- Each school sends 5-10 students accompanied by 1-2 teachers
- During their week-long stay at CERN they build 3 chambers

*Special agreement with CERN to allow children <18-years old to work in CERN labs

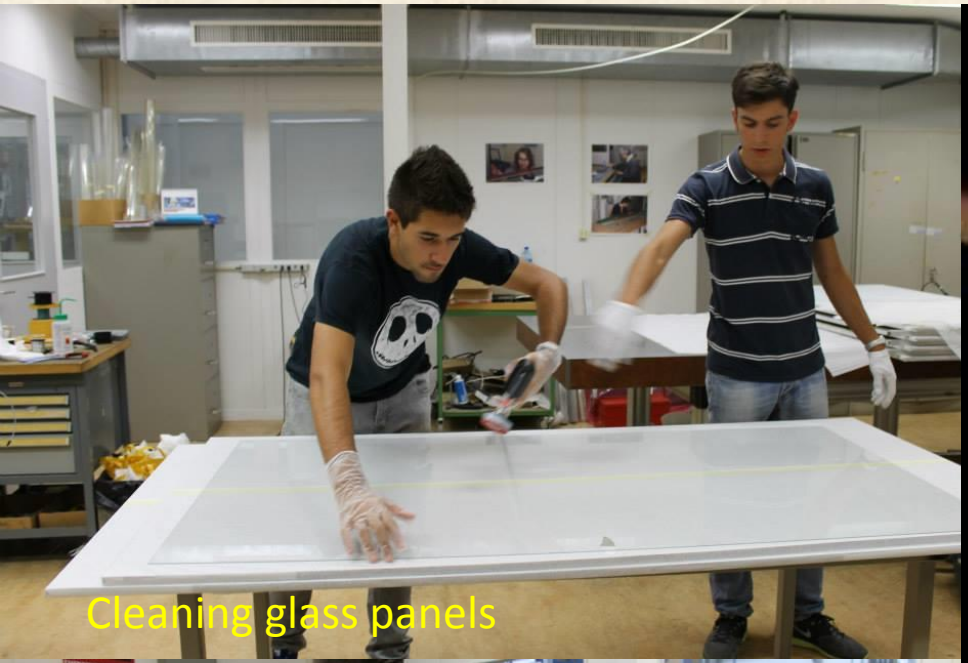
- 2005 7 schools (pilot)
- 2006 14 schools
- 2009 10 schools
- 2012 3 schools
- 2014 6 schools
- 2015 6 schools
- 2017 6 schools
- 2019 4 schools

Total : 56 schools 300-400 students 60-90 teachers

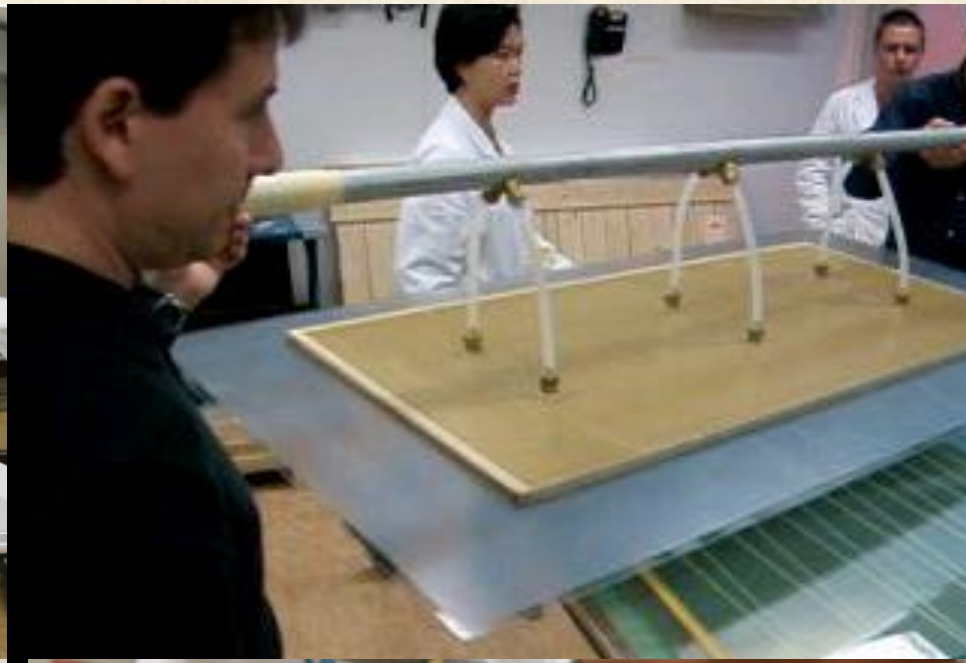
preparation of honeycomb panels

preparation of readout copper strips

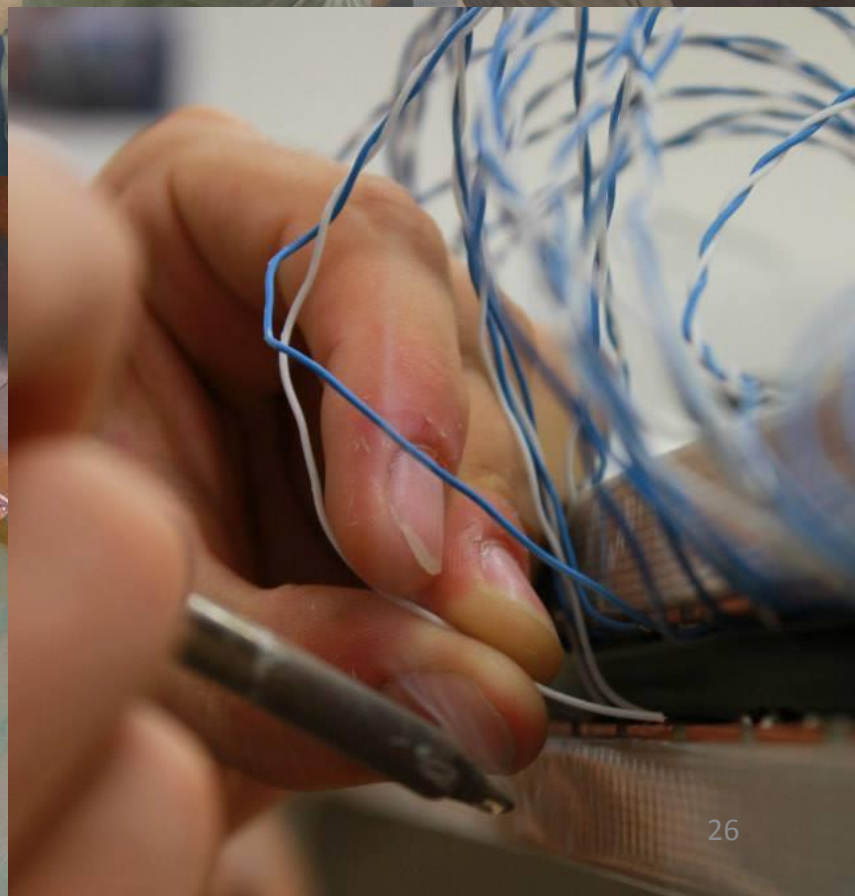
Fishing-line spacers



Cleaning glass panels



preparation of signal cables



Soldering signal cables

Closing the gas box with the MRPC

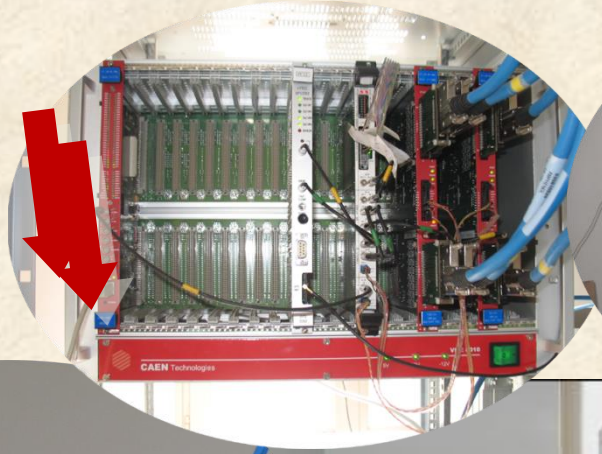
Chambers under gas flow to test for leaks

Chambers are shipped to Italy

Phase II: assembling the muon telescope

The telescope assembled

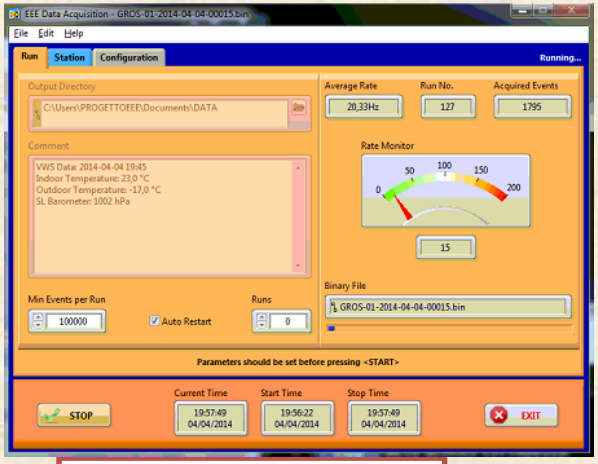
readout and DAQ



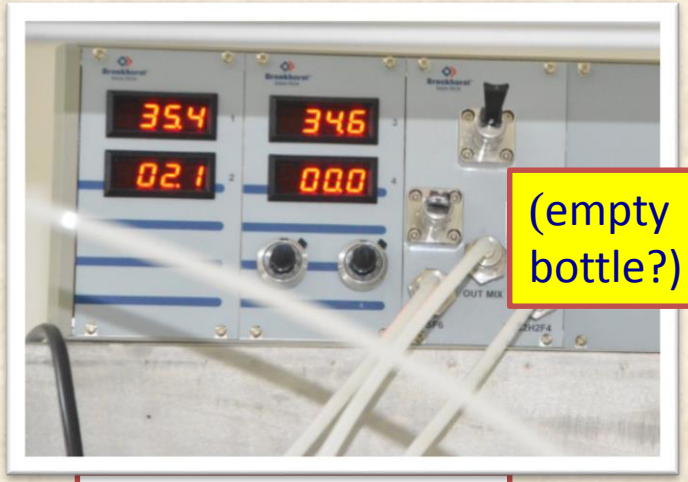
Gas system

Chamber arrival

Phase III. Data-taking and monitoring

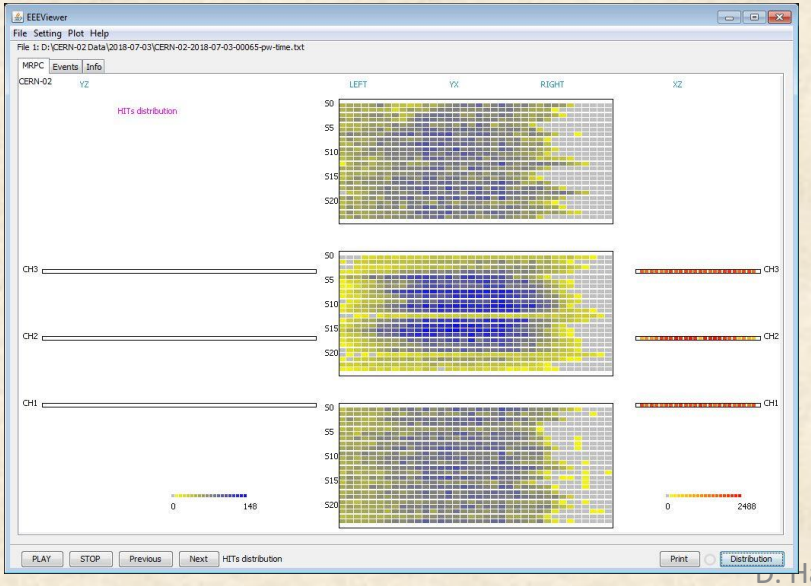


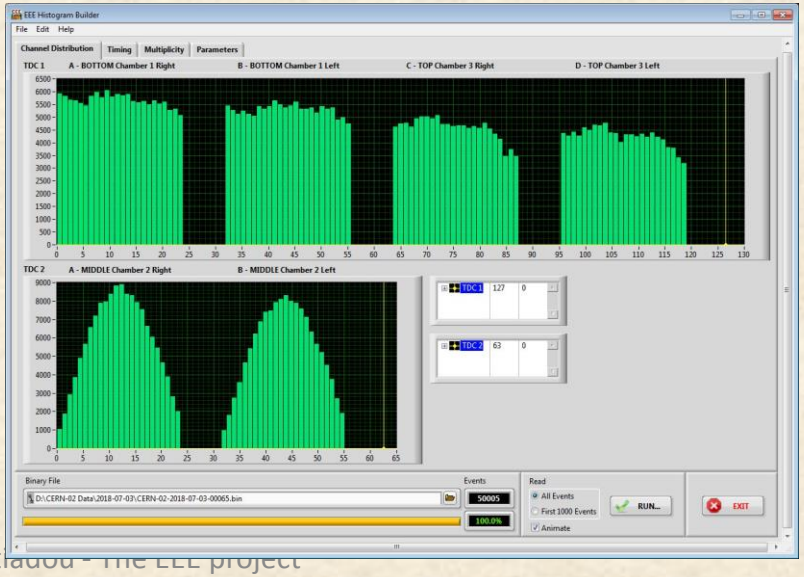
Check DAQ is ON



(empty bottle?)

Check GAS flow



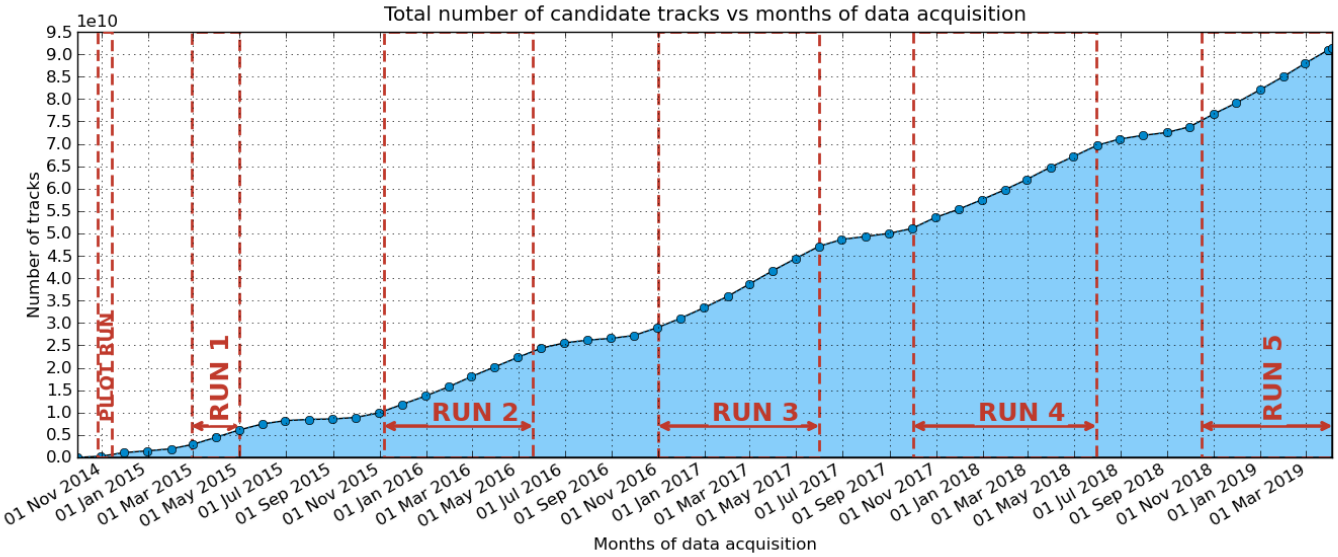


Check chamber hit distributions

Data-taking

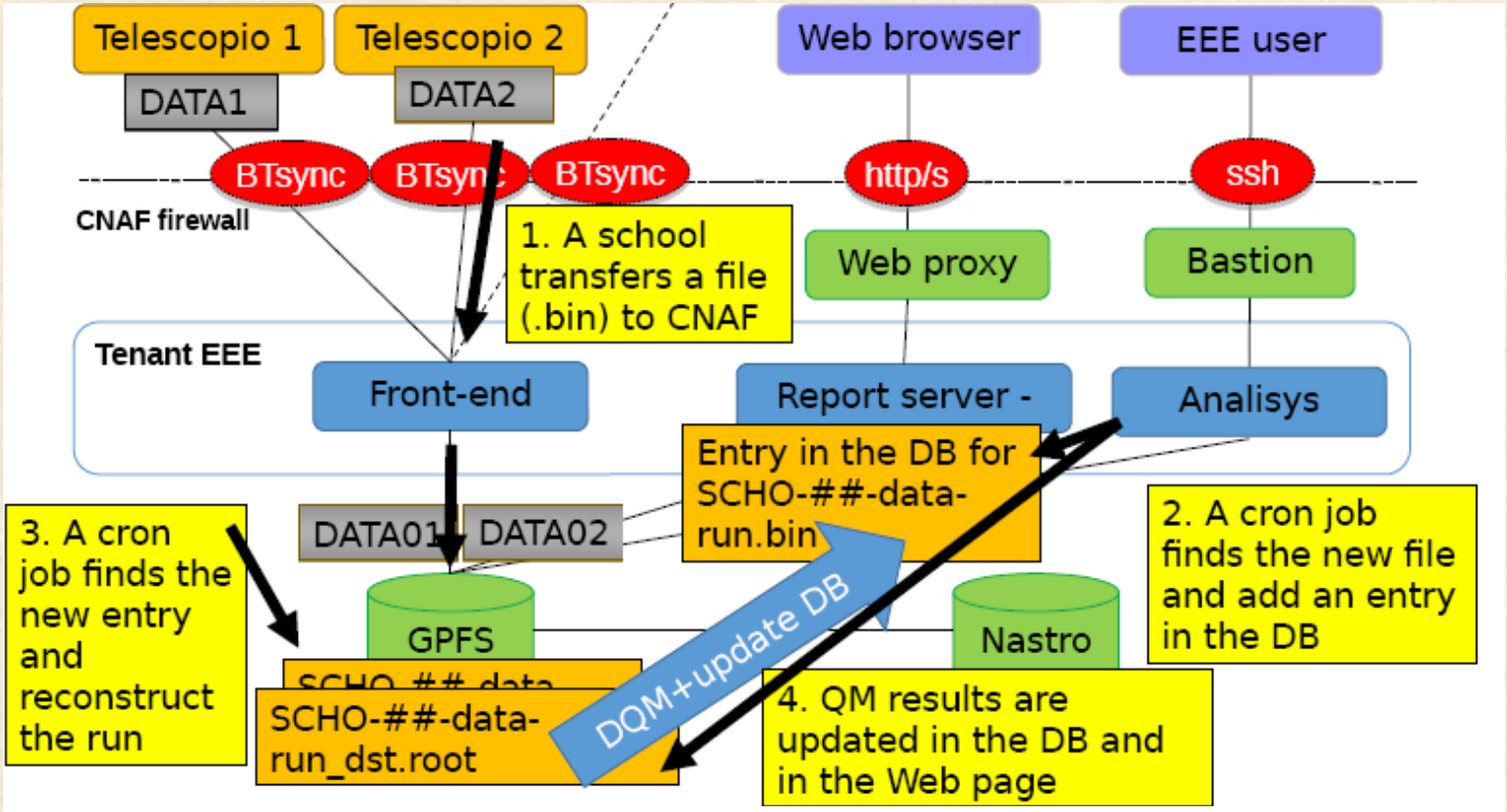
Pilot run : 27 October-14 November 2014 (23 – half of the EEE telescopes)
Run 1 : **February 2015 – April 2015** (two third, 35 of the EEE telescopes)
Run 2 : November 2015 - May 2016 (almost all EEE telescopes)
Run 3 : October 2016 - May 2017 (almost all EEE telescopes)
Run 4 : October 2017 - May 2018 (almost all EEE telescopes)
Run 5 : October 2018 - May 2019 (almost all EEE telescopes)
Run 6 : October 2019 – May 2020 starting now

~95 billion tracks collected up to now



EEE@CNAF

centralised, coordinated data-taking; data transfered and stored at CNAF-Bologna



A complex software architecture has been set-up to reconstruct the data and provide quasi-online (few hours) **histograms on the web for monitoring purposes**

Phase IV: students' participation in coordinated run

Fill the e-logbook

ID	Date	Scuola	Operatore	MRPC1 HV_NEG (V)	MRPC1 HV_POS (V)	MRPC1 I_NEG (microA)	MRPC1 I_POS (microA)	MRPC1 LV (V)	MRPC2 HV_NEG (V)	MRPC2 HV_POS (V)	MRPC2 I_NEG (microA)	MRPC2 I_POS (microA)	MRPC2 LV (V)	MRPC3 HV_NEG (V)	MRPC3 HV_POS (V)	MRPC3 I_NEG (microA)	MRPC3 I_POS (microA)	MRPC3 LV (V)	Front-End LV (V)	SF6 (press)	C2H2F4 (press)	SF6 (flusso)	C2H2F4 (flusso)	Temp (C)	Pres (mba
3487	Sun 07/04/2019 09:43:38	TREV-01	monica nardin	8445	8736	0.48	0.62	4.27	9707	9334	0.49	0.11	4.6	9221	9462	0.22	0.09	4.1	2.7673	24.6	15.4	50.0	50.0	18	1003
3486	Sun 07/04/2019 09:17:51	GENO-01	Chiara Invernizzi	8696.73	8732.15	1.35259	1.19646	4.5205	9883.08	9152.63	1.63239	1.50201	4.5100	8742.33	8483.74	1.52674	1.4674	4.5112	2.8494			26.5	25.0		
3485	Sun 07/04/2019 08:53:01	CARI-01	Domenico Liguori	7705	7805	1.28	1.29	3.7	8094	8588	1.56	1.60	4.2	8860	8049	1.20	1.20	3.9	2.64	23.5	23.0	30.0	30.0	21.5	1003
3484	Sun 07/04/2019 08:35:37	TRIN-01	Giacomo di Staso	9660	9708	0,97	0,93	4,56	9203	10015	1,40	0,63	4,3	9454	9853	0,33	0,27	4,3	2,51					23,4	1006
3483	Sat 06/04/2019 18:54:48	GENO-01	Tommaso Sambuco	8704	8737	1.23	1.05	4.52	8997	9162	1.61	1.49	4.51	8748	8490	1.45	1.39	4.51	2.84			24.9	25.0	22.0	997
3482	Sat 06/04/2019 16:39:13	CARI-01	Fabrizio Bassis	7704	7801	1.28	1.29	3.7	8095	8589	1.58	1.60	4.2	8861	8050	1.2	1.2	3.9	2.64	23.4	23.0	30.0	30.0	21.5	1003
3481	Sat 06/04/2019 12:34:24	SALE-01	Ludovica Ranucci	10342	7836	0.13	1.14	5	9714	10370	0.28	0.21	4.88	9755	9764	0.39	0.33	4.65	2.55	0.48	38.5	61.8	60.1	24.3	1000
3480	Sat 06/04/2019 12:26:46	LAQU-02	Maria Alfonsetti	8758	10565	9504	9847	4.6932	9501	9857	0.386	0.480	4.8916	9793	10067	0.4955	0.3993	4.7959	3.3965	34.3	33.3	39.8	39.9	17.9	919
3479	Sat 06/04/2019 12:10:10	BARI-01	colonna,cassano,caroppo,dimagli,soriano	8613	9723	0.27	0.31	4.3	8878	9475	0.15	0.38	4.4	8528	9077	0.08	0.25	4.5	2.5	23.4	25.0	39.0	39.1	22.4	1009
3478	Sat 06/04/2019 12:03:35	TORI-04	BATTISTI LISA, CURCIO GIULIA, FONTANA FRANCESCA, LEMBO CLELIA	7850	7570	0.120	0.140	4.550	8100	7140	0.020	0.080	4.250	8680	7660	0.020	0.110	4.300	2.69	8.4	6.0	50.9	51.0	19.0	970
3477	Sat 06/04/2019 11:35:59	LODI-03	Attilio Grassotti	6487	7199	2.35	0.43	4.1	6756	7391	2.38	2.44	3.6	6486	8211	2.35	2.37	3.7	2.70						
3476	Sat 06/04/2019 11:21:24	ALTA-01	Stefano Colonna, Pietro Ventura, Monica Ostuni, Domenico Nigro, Nicola Lorusso, Matteo Berloco	8600	8600	0.21	0.21	4.3	8600	8600	0.22	0.22	4.3	8600	8600	0.20	0.20	4.3	3.1	21.8	21.0	25.3	25.3	18.6	949
3475	Sat 06/04/2019 11:20:11	ALTA-01	Stefano Colonna, Pietro Ventura, Monica Ostuni, Ilaria Tafuni, , Nicola Lorusso, Matteo Berloco	8600	8600	0.21	0.21	4.3	8600	8600	0.22	0.22	4.3	8600	8600	0.20	0.20	4.3	3.1	21.8	21.0	25.3	25.3	18.6	949
3474	Sat 06/04/2019 11:11:38	LECC-01	federico bandello	9202	9098	0.49	0.44	4.2	9240	8544	0.55	0.33	4.2	9240	8543	0.55	0.33	4.4	2.76	22.1	22.8	38.1	38.8	19.0	1002
3473	Sat 06/04/2019 10:59:46	TRIN-01	Alyssa De Rosa - Federica Marchiselli	9665	9647	0.96	1.00	4.56	9206	10017	1.38	0.62	4.3	9447	9855	0.32	0.28	4.3	2.51	22.0	19.6	30.2	30.0	23.4	1008
3472	Sat 06/04/2019 10:47:37	REGG-01	Stefania Ceruti	7910	7830	4.34	4.35	4.2	7740	8050	3.83	3.74	4.15	8240	8290	0.08	0.03	4.2	2.65	23.96	21.8	24.9	24.9	20.3	999
3471	Sat 06/04/2019 10:24:42	BOLO-02	Rosolen Lorenzo	9000	9019	10.44	10.44	4.9	9000	9070	9.72	9.72	5.0	9080	8980	9.39	9.39	4.9	2.7	25.2	25.8	25.0	25.1	21.0	999
3470	Sat 06/04/2019 10:08:48	LODI-01	Bozzini Matteo, Nava Riccardo, Bruno Cipolla	9734	9604	0.13	0.05	4.3	9627	9630	0.09	0.04	4.7	9406	9663	0.68	0.35	4.5	2.82	48.8	42.1	30.0	30.0	19.2	995
3469	Sat 06/04/2019 10:01:13	SIEN-01	Lorenzo Schiavone, Jakub Lubelczyk	7670	8450	0.55	0.45	3.8	7692	8516	0.35	0.26	3.8	8287	8503	0.19	0.36	3.6	2.61	0.2	16.9	0.0	30.0	18	967
3468	Sat 06/04/2019 09:49:49	TREV-01	Monica Nardin	8448	8719	0.48	0.66	4.27	9728	9329	0.55	0.04	4.6	9205	9444	0.18	0.33	4.1	2.7670	24,5	15.5	50.1	50.1	19	1005

Progetto Extreme Energy Events - La Scienza nelle Scuole

EEE MONITOR - DQM

[Official address: http://eee.centrofermi.it/monitor]

Ultimo aggiornamento: ore 09:56 - domenica 07 aprile 2019 [by e3monitor]

[EEE Monitor] RUN 5: October 15, 2018 - May 31, 2019
[EEE Monitor] RUN 5 - Data Taking - Day number: 175
Total number of candidate tracks (X^2<10) in the database: 91584932191

SCHOOLs ELOGBOOK for RUN 5 | SHIFTERs ELOGBOOK | EEE Tech Coord
Set Automatic Shift REPORT Messages | Automatic Shift Report ARCHIVE
Home Page EEE | Masterclass | Download the Excel Sheet
Coincidences | Connectivity Report | Data Request

La tabella qui sotto mostra la situazione dei telescopi in acquisizione:
In **verde** sono indicati i telescopi in presa dati e trasferimento nelle ultime 3 ore
e con parametri di acquisizione ragionevoli nell'ultimo run analizzato.
In **giallo** sono indicati i telescopi in cui trasferimento e/o acquisizione sono sospesi da più di 3 ore
o con tracce (X^2<10) minori di 10 Hz nell'ultimo run analizzato.
In **rosso** sono indicati i telescopi in cui trasferimento e/o acquisizione sono sospesi da più di due giorni
o con tracce (X^2<10) minori di 5Hz nell'ultimo run analizzato.

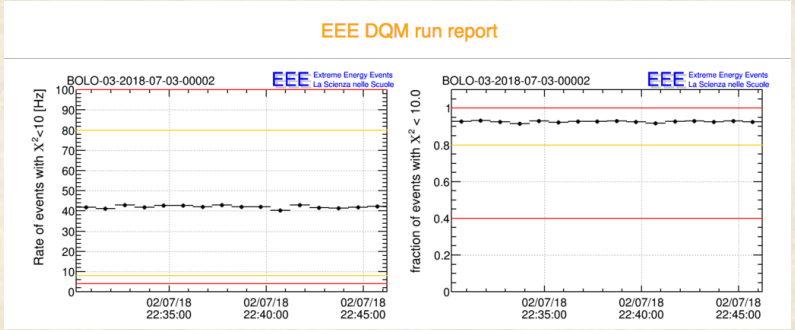
Tweets by @centrofermi

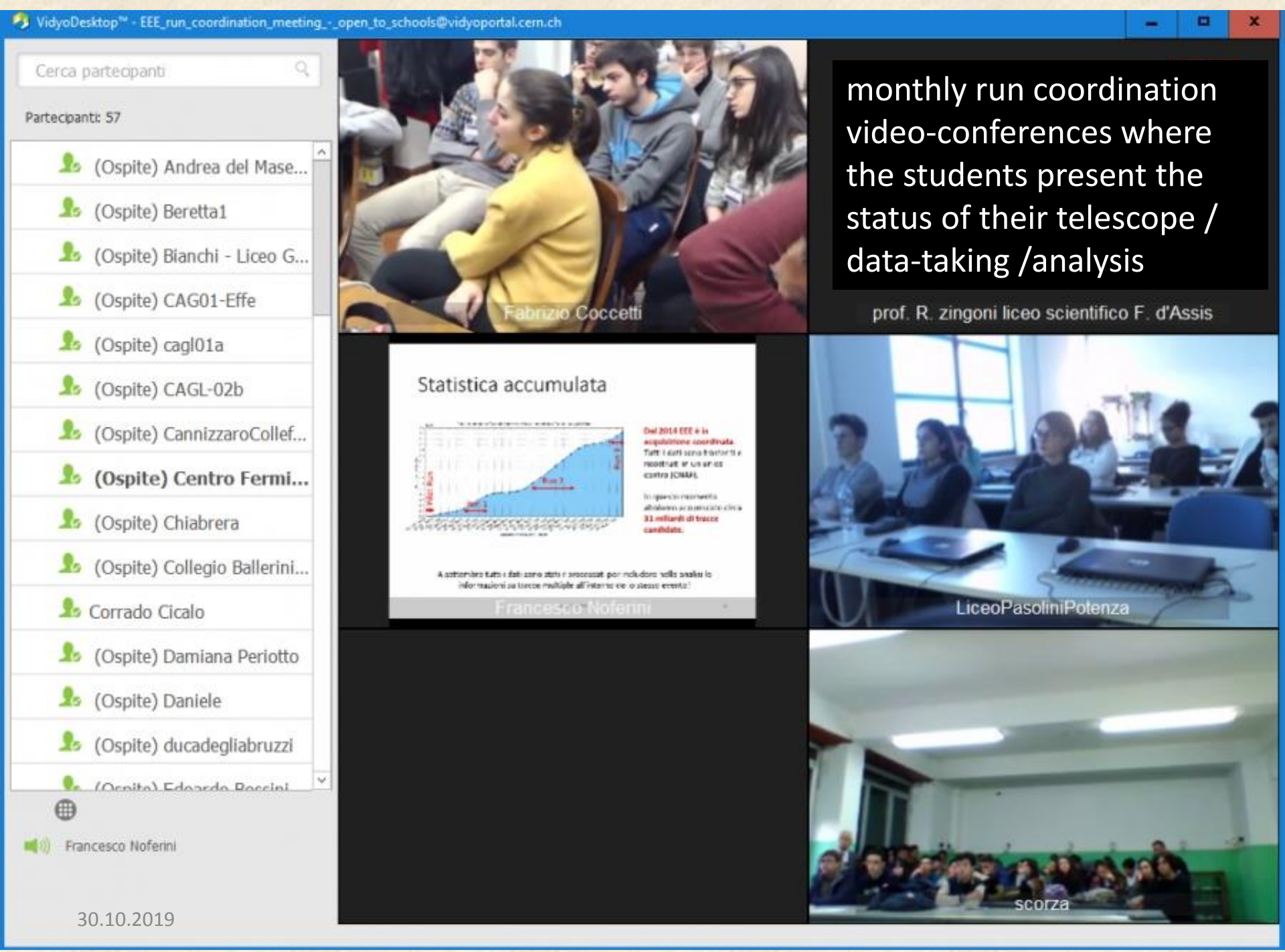
Centro Ferm @centrofermi

Il 28 marzo alla Fondazione "Ettore Majorana" di Erice, prima giornata di studio del Progetto #Lilibeo

School	Day	Time	Name of the last trasferred File	Number of Files trasferred today	Last Entry in the e-logbook of the Schools	Name of the last File analyzed by DQM	DQM daily report	RATE of Triggers for the last Run in DQM	RATE of Tracks for the last Run in DQM	Link DQM
ALTA-01 [Event Display]	dom 07 aprile	09:31	ALTA-01-2019-04-07-00028.bin	30 [History]	11:21 06/04/2019	ALTA-01-2019-04-07-00028.bin	07/04 [History]	43.0	35.0	ALTA-01
ANCO-01 [Event Display]	dom 07 aprile	09:27	ANCO-01-2019-04-07-00019.bin	20 [History]	09:12 06/04/2019	ANCO-01-2019-04-07-00019.bin	07/04 [History]	27.0	21.0	ANCO-01
AREZ-01 [Event Display]	dom 07 aprile	09:29	AREZ-01-2019-04-07-00021.bin	28 [History]	09:37 06/04/2019	AREZ-01-2019-04-07-00021.bin	07/04 [History]	38.0	34.0	AREZ-01
BARI-01 [Event Display]	dom 07 aprile	09:17	BARI-01-2019-04-07-00193.bin	63 [History]	12:10 06/04/2019	BARI-01-2019-04-07-00193.bin	07/04 [History]	24.0	18.0	BARI-01
BOLO-01 [Event Display]	sab 06 aprile	20:28	BOLO-01-2019-04-06-00337.bin	0 [History]	12:59 31/01/2019	BOLO-01-2019-04-06-00337.bin	07/04 [History]	7.0	4.0	BOLO-01
BOLO-02 [Event Display]	dom 07 aprile	09:33	BOLO-02-2019-04-07-00034.bin	35 [History]	10:24 06/04/2019	BOLO-02-2019-04-05-00076.bin	06/04 [History]	48.0	44.0	BOLO-02
BOLO-03 [Event Display]	sab 30 marzo	08:21	BOLO-03-2019-03-30-00019.bin	0 [History]	10:05 01/04/2019	BOLO-03-2019-03-30-00020.bin	31/03 [History]	28.0	24.0	BOLO-03
BOLO-04 [Event Display]	dom 07 aprile	08:57	BOLO-04-2019-04-07-00010.bin	12 [History]	*	BOLO-04-2019-04-07-00010.bin	07/04 [History]	15.0	12.0	BOLO-04
BOLO-05 [Event Display]	dom 07 aprile	09:34	BOLO-05-2019-04-07-00023.bin	25 [History]	*	BOLO-05-2019-04-07-00023.bin	07/04 [History]	27.0	7.0	BOLO-05
CAGL-01 [Event Display]	dom 07 aprile	09:28	CAGL-01-2019-04-07-00045.bin	46 [History]	07:51 06/04/2019	CAGL-01-2019-04-07-00045.bin	07/04 [History]	31.0	26.0	CAGL-01
CAGL-02 [Event Display]	dom 07 aprile	09:37	CAGL-02-2019-04-07-00037.bin	38 [History]	14:43 04/04/2019	CAGL-02-2019-04-07-00037.bin	07/04 [History]	50.0	45.0	CAGL-02
CAGL-03 [Event Display]	mar 19 marzo	11:50	CAGL-03-2019-03-19-00007.bin	0 [History]	12:17 13/03/2019	CAGL-03-2019-03-19-00001.bin	14/03 [History]	46.0	35.0	CAGL-03
CARI-01 [Event Display]	dom 07 aprile	09:12	CARI-01-2019-04-07-00011.bin	12 [History]	08:53 07/04/2019	CARI-01-2019-04-07-00011.bin	07/04 [History]	14.0	12.0	CARI-01
CATA-01 [Event Display]	dom 07 aprile	09:20	CATA-01-2019-04-07-00016.bin	17 [History]	09:06 05/04/2019	CATA-01-2019-04-07-00016.bin	07/04 [History]	23.0	17.0	CATA-01

Check the CNAF on-line monitoring system




VidyoDesktop™ - EEE_run_coordination_meeting_-_open_to_schools@vidyoportal.cern.ch
Cerca partecipanti
Partecipanti: 57
(Ospite) Andrea del Mase...
(Ospite) Beretta1
(Ospite) Bianchi - Liceo G...
(Ospite) CAG01-Effe
(Ospite) cagl01a
(Ospite) CAGL-02b
(Ospite) CannizzaroCollef...
(Ospite) Centro Fermi...
(Ospite) Chiabrera
(Ospite) Collegio Ballerini...
Corrado Cicalo
(Ospite) Damiana Periotto
(Ospite) Daniele
(Ospite) ducadegliabruzzi
Francesco Noferini
Fabrizio Coccetti
monthly run coordination video-conferences where the students present the status of their telescope / data-taking /analysis
prof. R. zingoni liceo scientifico F. d'Assis
Statistica accumulata
Francesco Noferini
LiceoPasoliniPotenza
scorza

National Conference of the EEE project, Erice, May 2017

SCHEDA TECNICA DELL'ESPERIMENTO PER LA RILEVAZIONE DELLA FREQUENZA DEL SUONO EMESSO DALLA BOMBOLA DELE TELESCOPIO EEE

MATERIALE OCCORRENTE:

- Un computer portatile con un microfono interno oppure un computer collegato ad un microfono esterno.
- Il software open source Audacity, scaricabile da questo link http://www.audacityteam.org/
- Un martelletto gommato, come quelli utilizzati per colpire i diapason negli esperimenti di acustica

Audacity®

Il logo del programma Audacity

How to measure the amount of gas in a bottle by means of sound frequency
Liceo F. e M. Campana (Osimo)

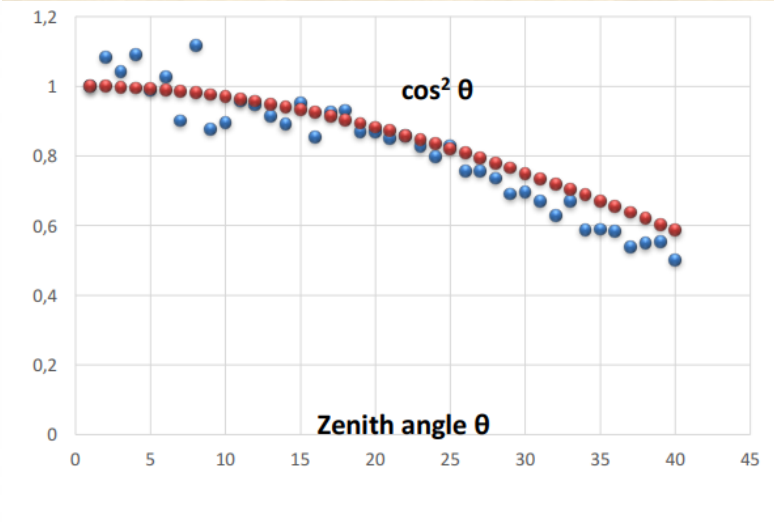
EEE in Erice 2017

Both measurements werepublished in the ***Giornale di Fisica*** with students' signature.

Measurement of the Earth Radius

Measurement of Cosmic rays flux at different altitudes

EEE at International Cosmic Day 2017
47 Schools , 550 students



Liceo Galvani (BO):
data from their telescope

EEE outside Italy

- Moscow Chemical Lyceum

Construction at CERN

Student exchanges between schools: Liceo Staffa Trinitapoli (Bari) and Moscow Chemical Lyceum

French HSSIP 2017, Swedish HSSIP 2018, etc..

- Themistokli Germenji Lyceum (Korce, Albania)
- Istituto de Ciencias Nucleares UNAM (Mexico)
- Oslo University (Oslo)

Some results

- Search for extended air showers
  Coincidences between muon telescopes
- Variation of muon flux in single EEE stations
  Observation of Forbusch decreases
- Study of upward-going particles
  electrons from μ-decay

First detection of extensive air showers with the EEE experiment

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Società Italiana di Fisica
Bologna

30.10.2019

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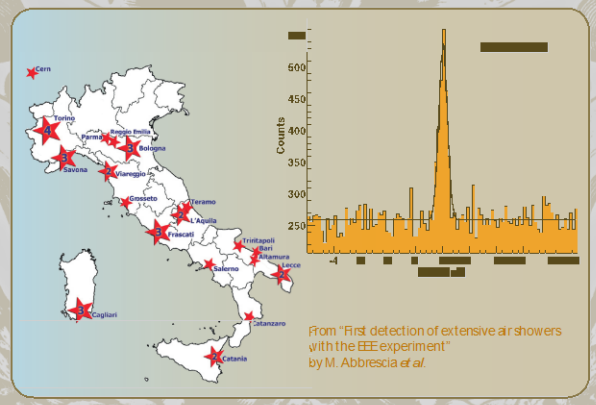
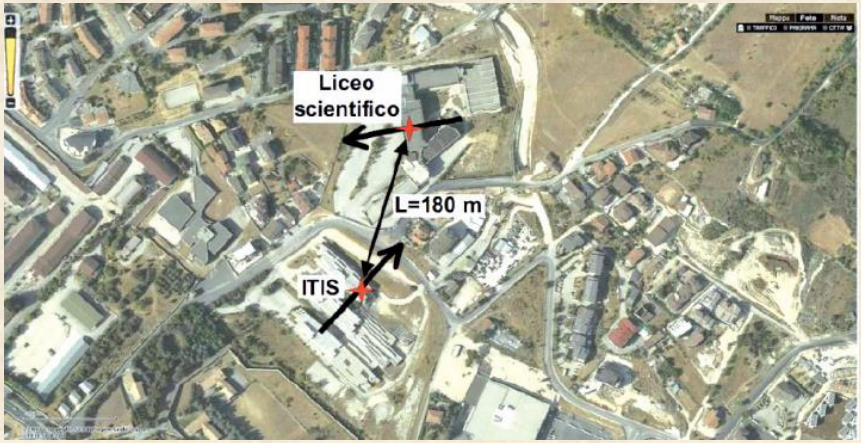
2 125 B
febbraio 2010

IL
NUOVO CIMENTO B
della Società Italiana di Fisica



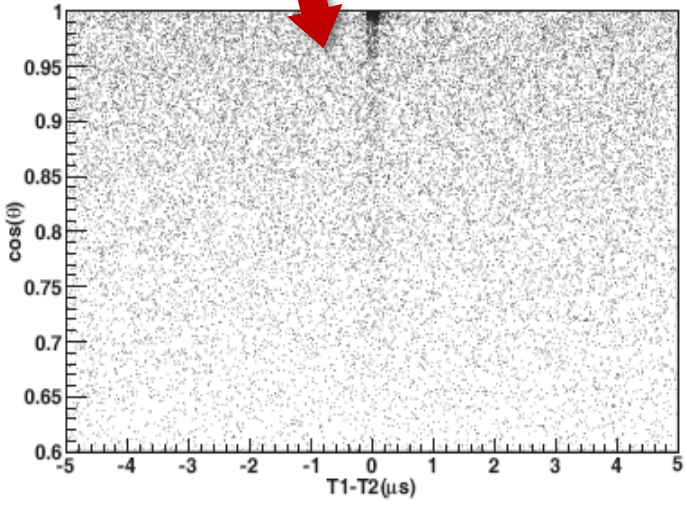
From "First detection of extensive air showers with the EEE experiment" by M. Abbrescia *et al.*

Available on line at www.sif.it



At L'Aquila, closest stations of the experiment

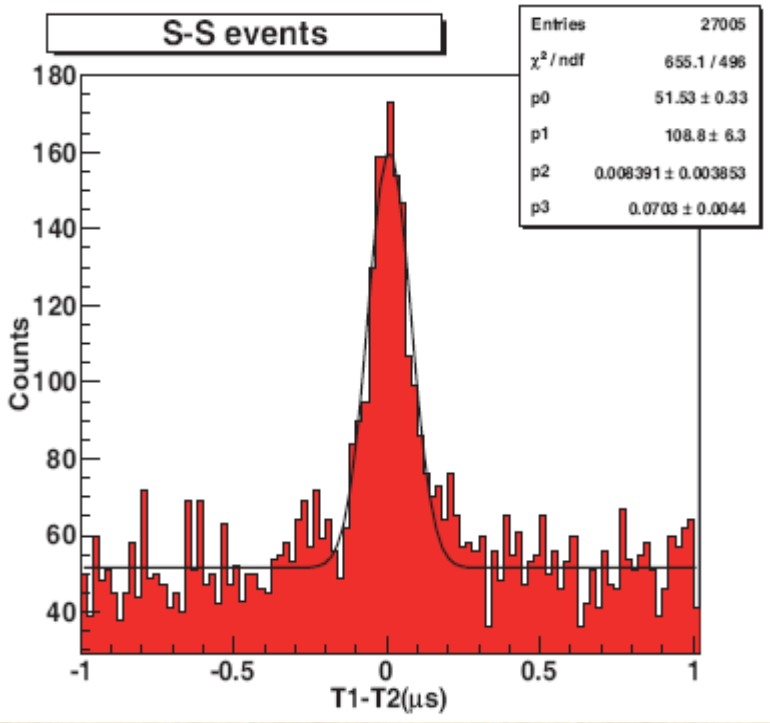
Angular correlations between "coincidences"

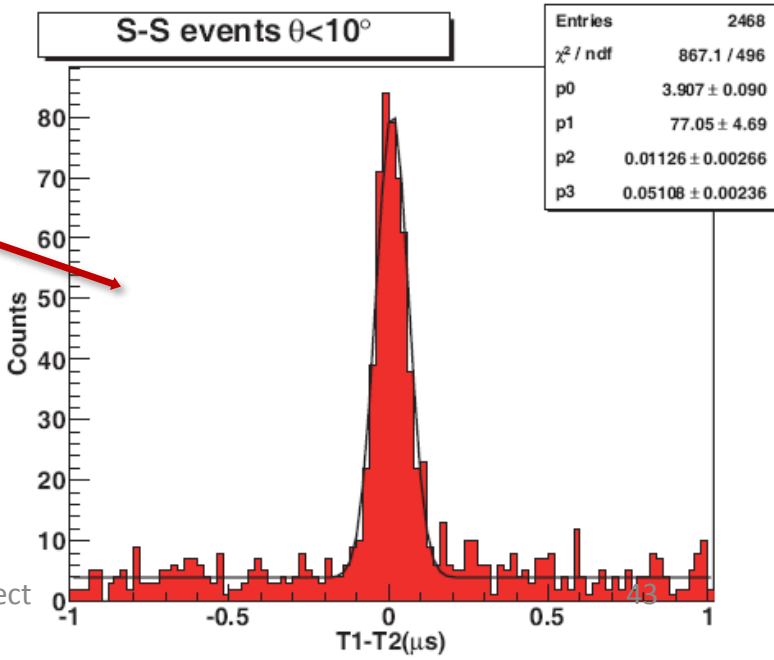


7.6 events/hour
Signal/Noise = 2

Angular cut (requiring quasi parallelism) improves S/N

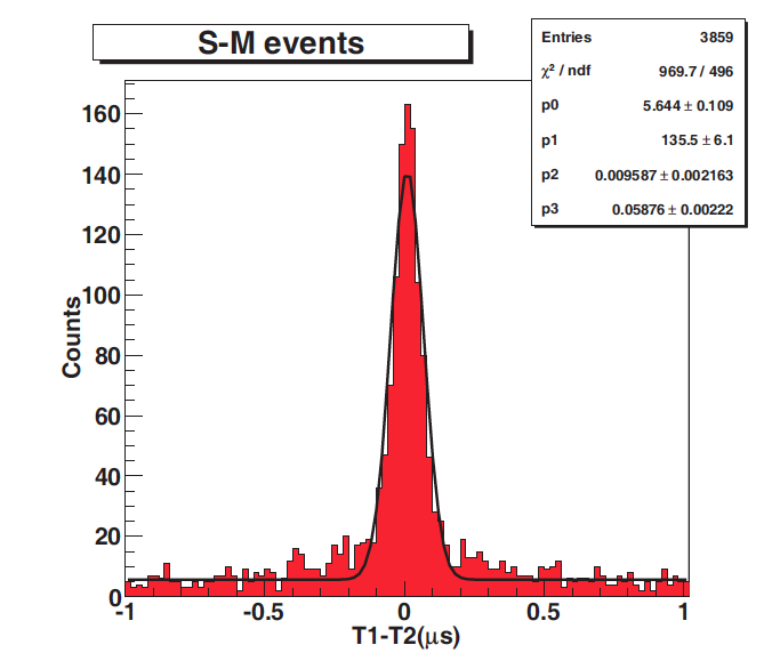
1.6 events/hour
Signal/Noise=18

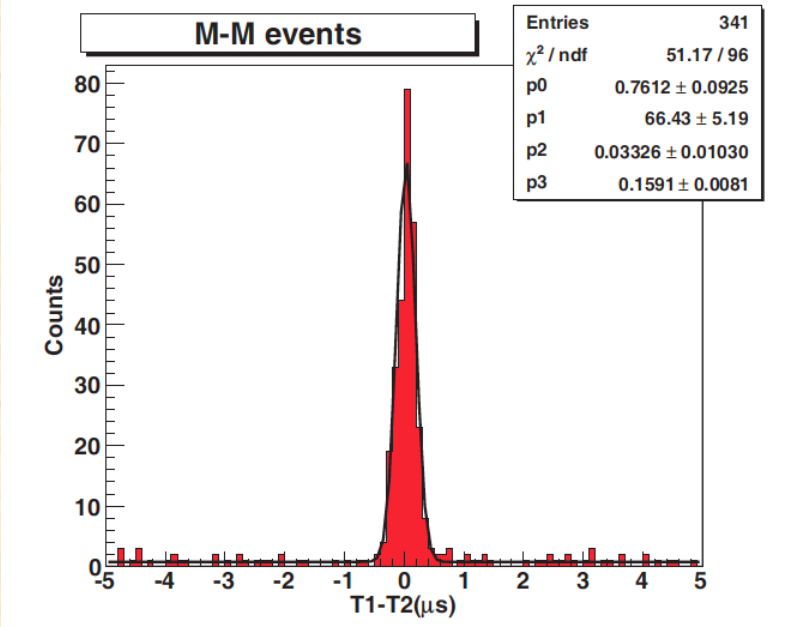




Time difference between events at the two stations

First coincidences detected

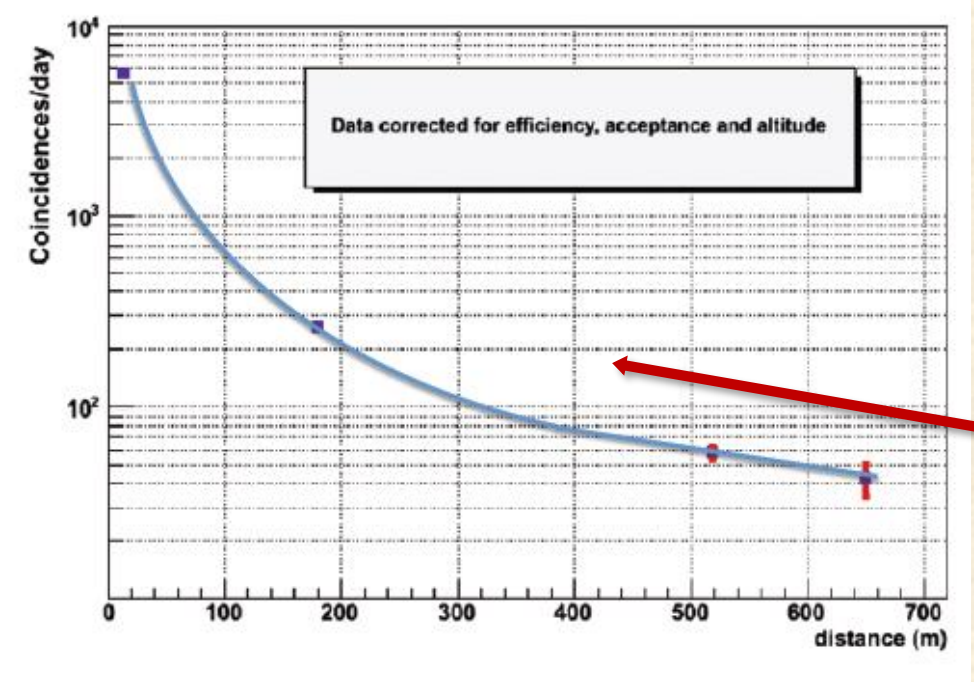




Single track in one school + multiple tracks in the other school
3.6 events / hour
Signal / Noise = 26.4

Multiple tracks in both schools
0.8 events / hour
Signal / Noise = 76

Coincidences up to 2012…



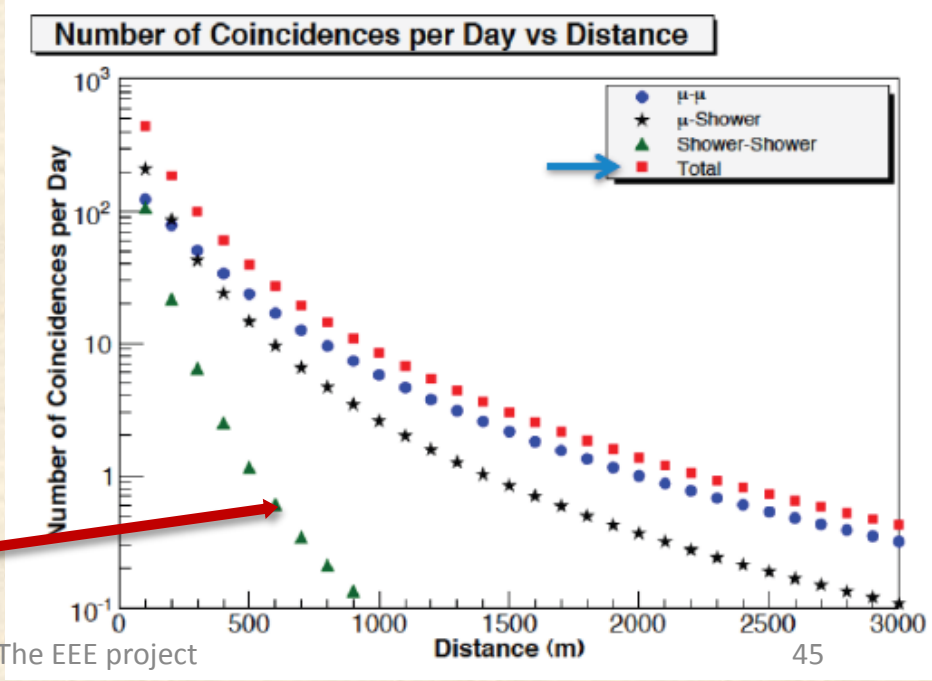
Number of coincidences per day, as measured by different telescope pairs of the EEE network, versus the relative distance between the two telescopes

Included in the plot: CERN-Geneva (15 m), L'Aquila (180 m), Cagliari (520 m) and Frascati (650 m)

Results consistent with Corsika and Cosmos Monte Carlo simulations

Few months to observe coincidences for distances > 1 km

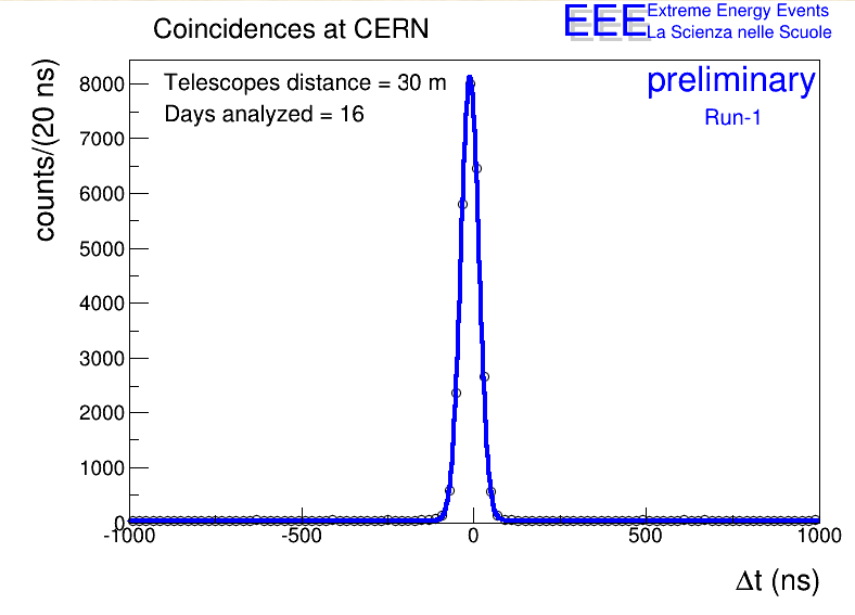
Corsika Monte Carlo simulations

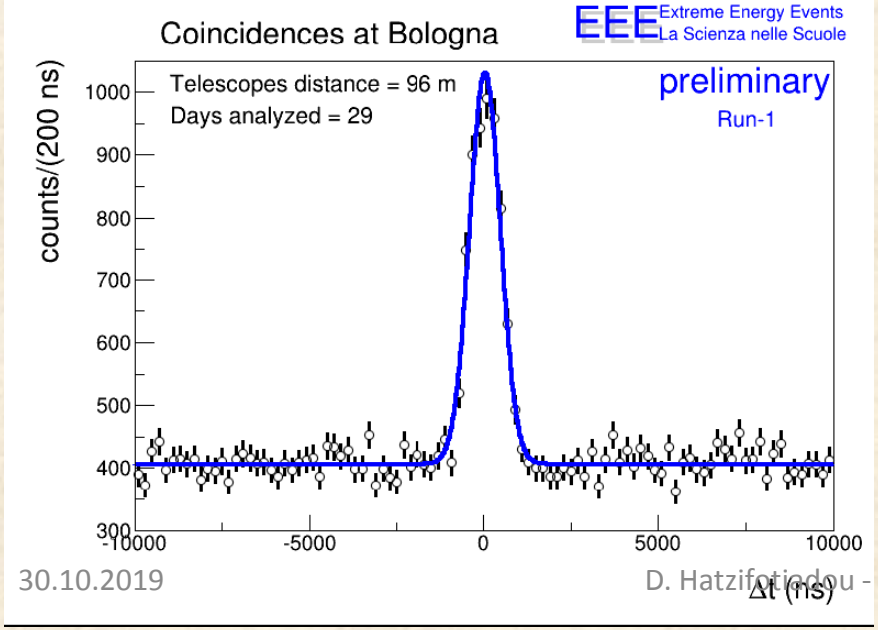


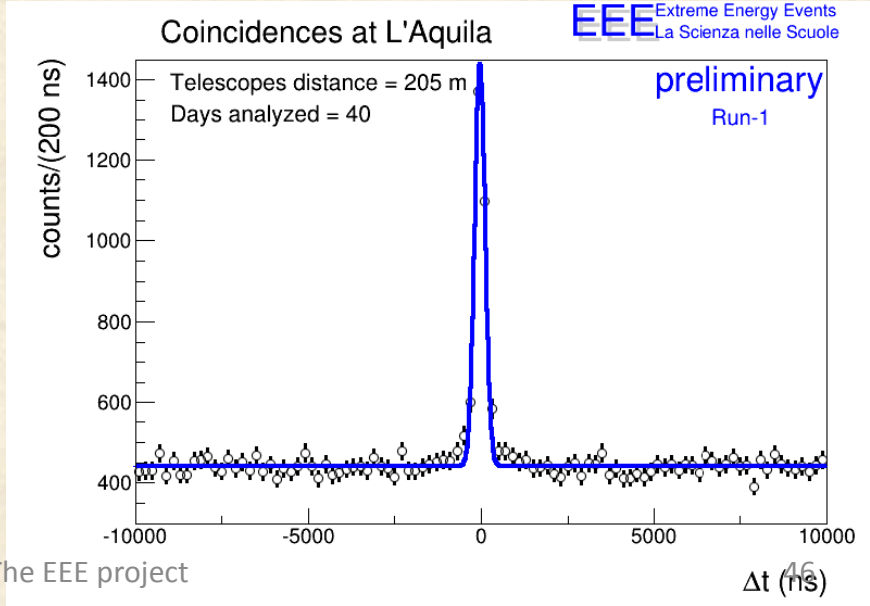
… coincidences during Run-1

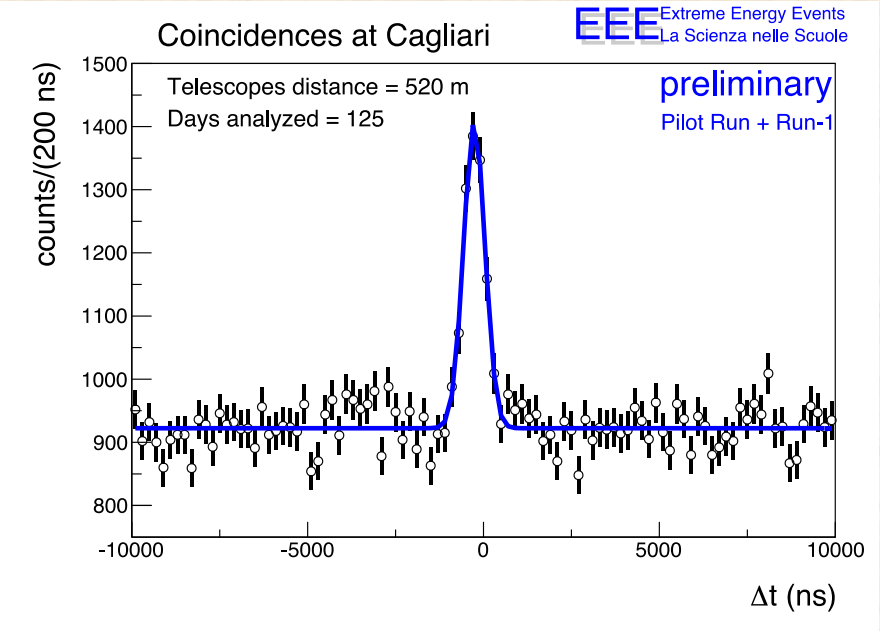
Coincidences were observed for several distances between telescopes : 15 m, 100 m, 200 m, 500 m, 1200 m

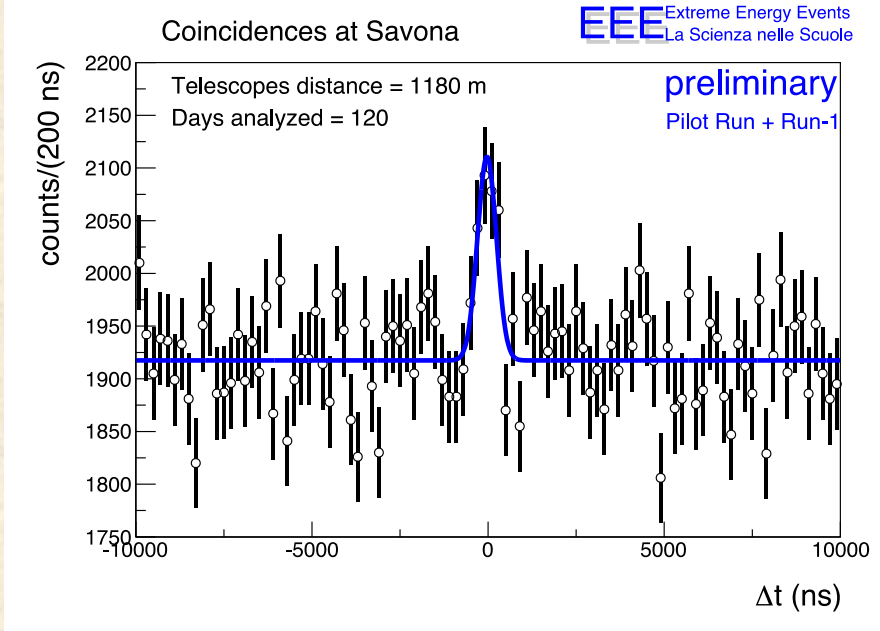
Increasing the distance between telescopes the energy of the primary observed increases as well





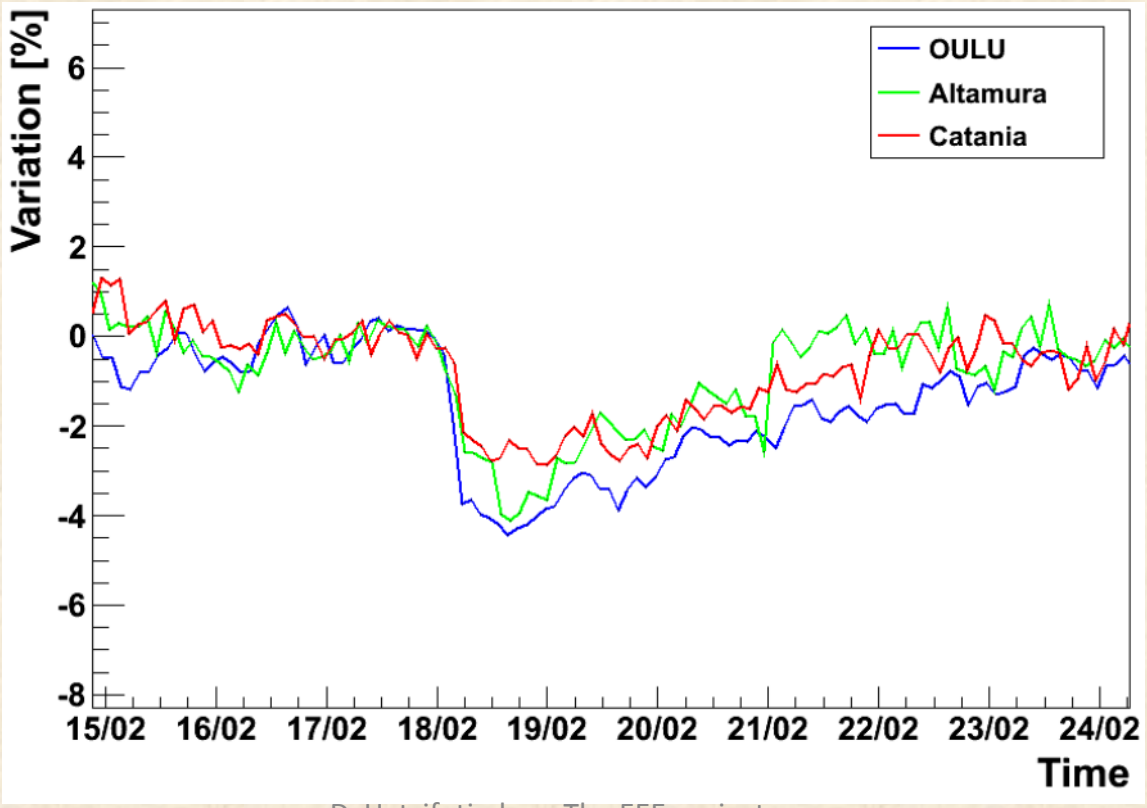



Coincidences at Cagliari
EEE Extreme Energy Events
La Scienza nelle Scuole
Telescopes distance = 520 m
Days analyzed = 125
preliminary
Pilot Run + Run-1
counts/(200 ns)
Δt (ns)


Coincidences at Savona
EEE Extreme Energy Events
La Scienza nelle Scuole
Telescopes distance = 1180 m
Days analyzed = 120
preliminary
Pilot Run + Run-1
counts/(200 ns)
Δt (ns)

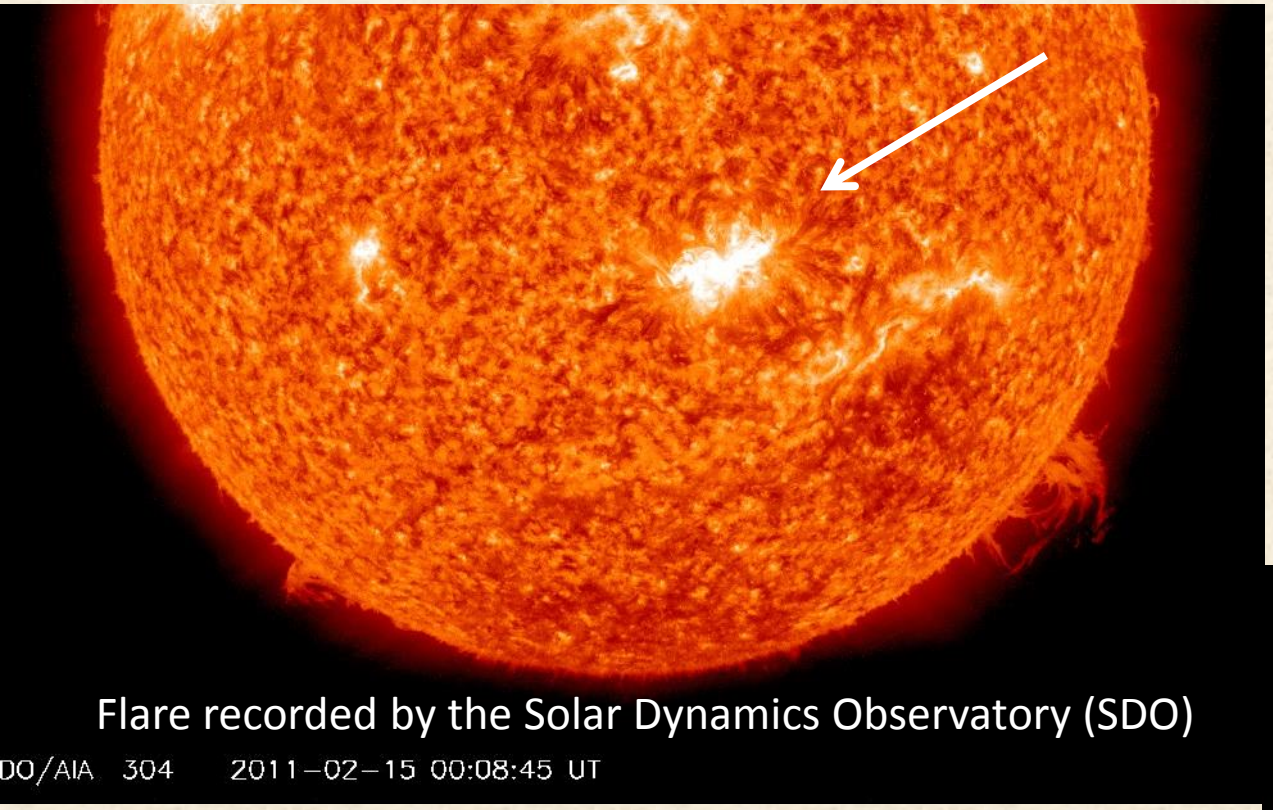
Forbush decrease 2011

- rapid variations of the cosmic rays flux over the course of a few hours associated to solar phenomena as CME (Coronary Mass Emission) and solar flares
- Decrease in muon flux reaching a minimum within hours
- Recovery lasts a few days
- comparison with Oulu neutron monitor station



2011 Valentine's Day Solar Flare

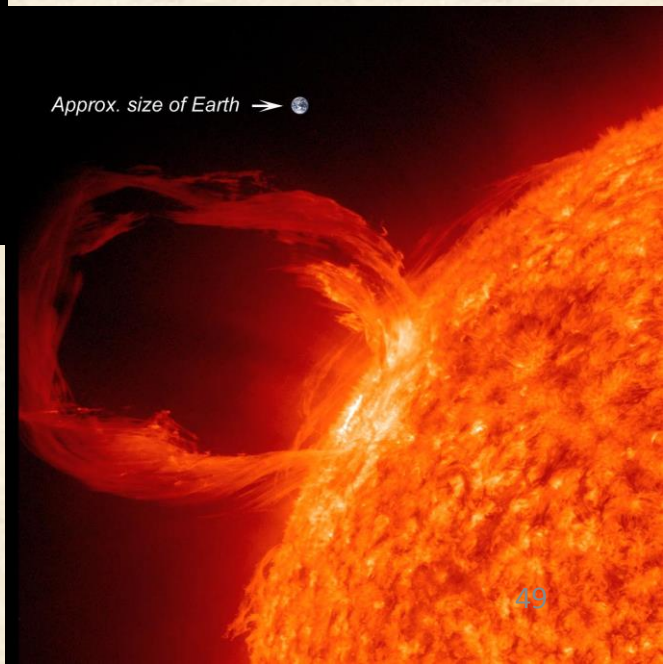
night between 14 and 15 February 2011



Flare recorded by the Solar Dynamics Observatory (SDO)

Solar flares: explosions on the sun, related to storage of energy in twisted magnetic fields -> burst of EM radiation (from radio waves to gamma rays)

Classification: according to intensity in wavelength range 0.1-0.8 nm



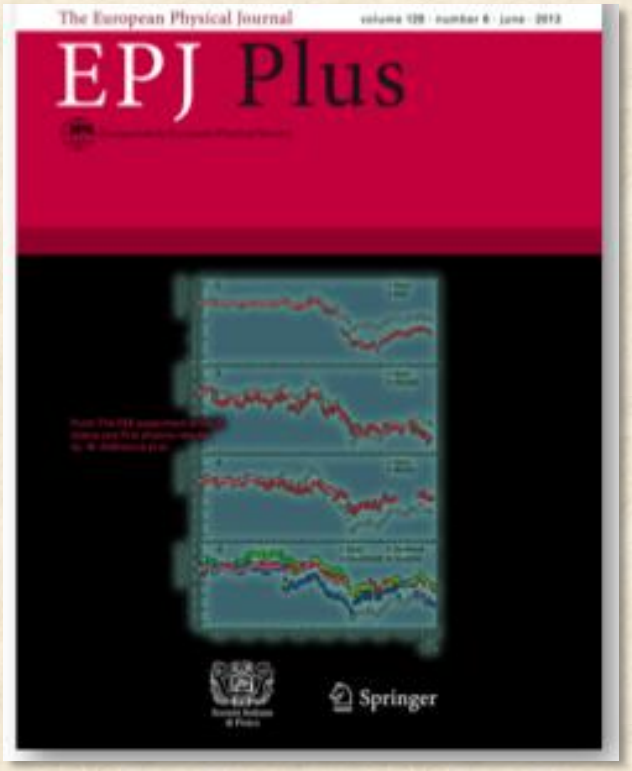
Solar flare, of category X2, followed by an important Coronary Mass Emission (CME)
Observable on earth a few days after the event

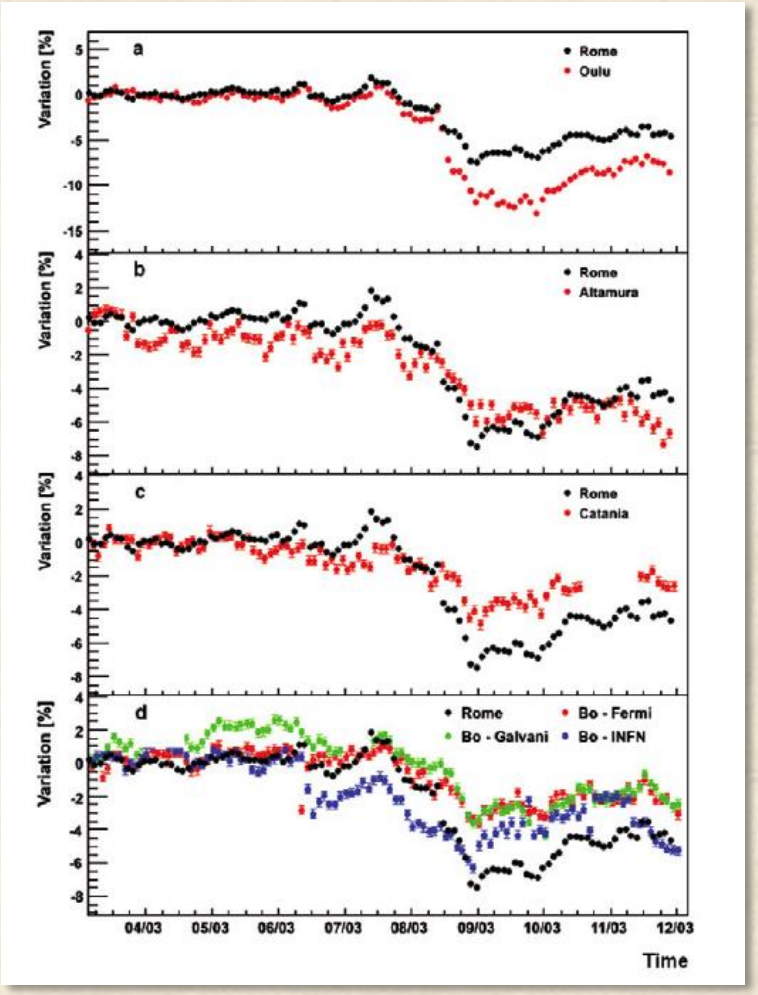
This kind of flares are constantly monitored since they may have relevant consequences on Earth

Forbush decrease 2012

Solar flare on March 6 2012 of category X5.4

- Neutron monitors in Oulu and Rome
- Liceo Gagnazzi – Altamura
- Liceo Galvani, Liceo Fermi – Bologna
- INFN Bologna
- Department of Physics – Catania





March 2012 flux decrease

Upward-going events

Time-Of-Flight (TOF) :
Time Bottom Chamber - Time Top Chamber*

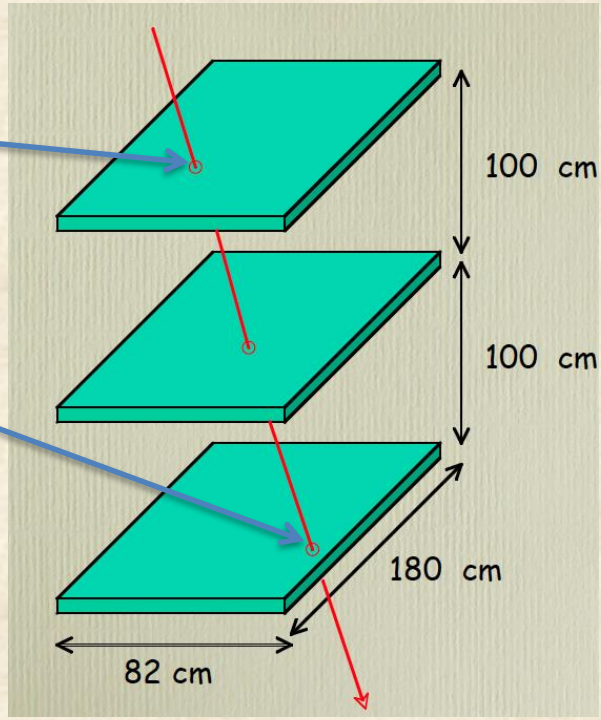
TOF<0 : upward-going particle

Muons from (atmospheric) neutrino interactions with the earth ?

Too many upward-going events observed

intriguing!

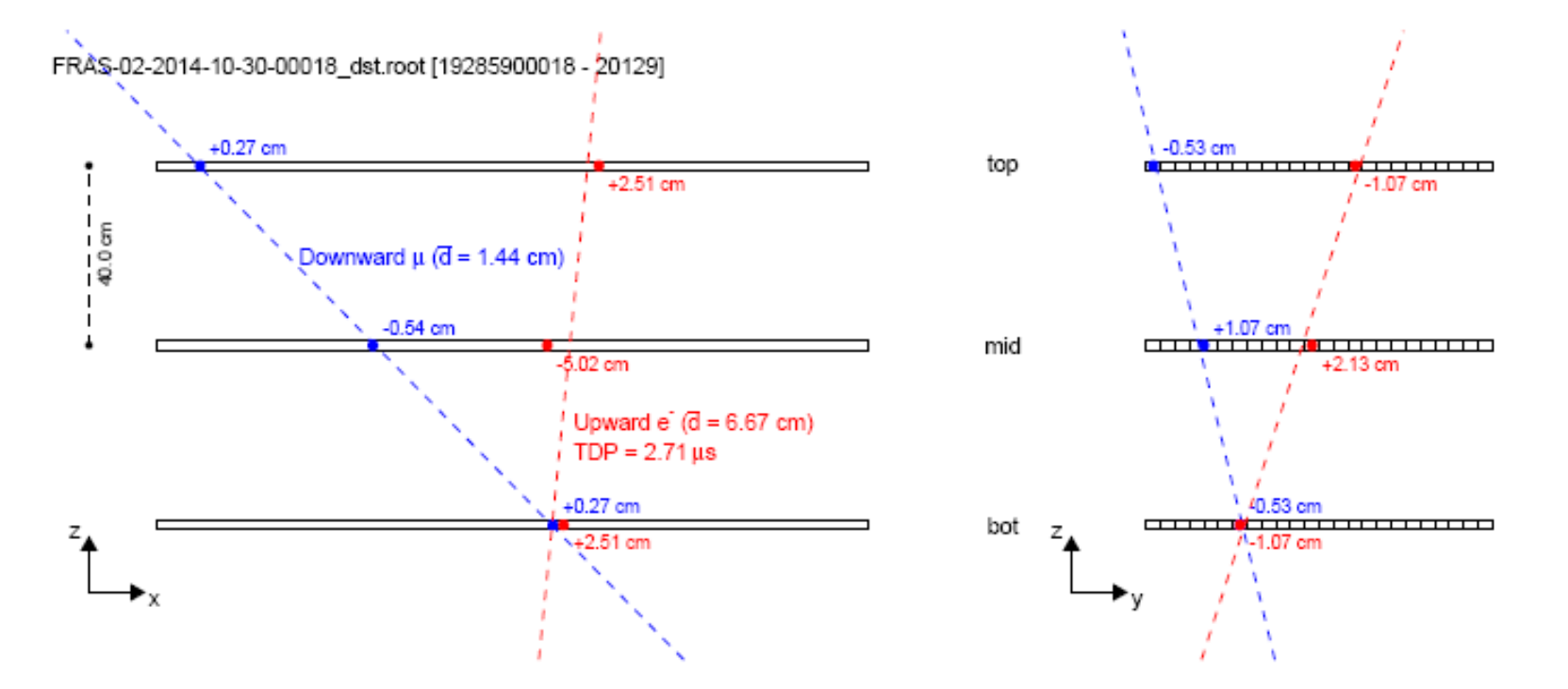
* Top and Bottom chambers are read out with the same TDC : same clock used



Upward-going events

About 1 event every 1000 observed goes in an upward direction

Some of them identified as electrons from muon decays (in the floor or in the bottom chamber), looking at their Time Difference with respect to the Previous (TDP) events



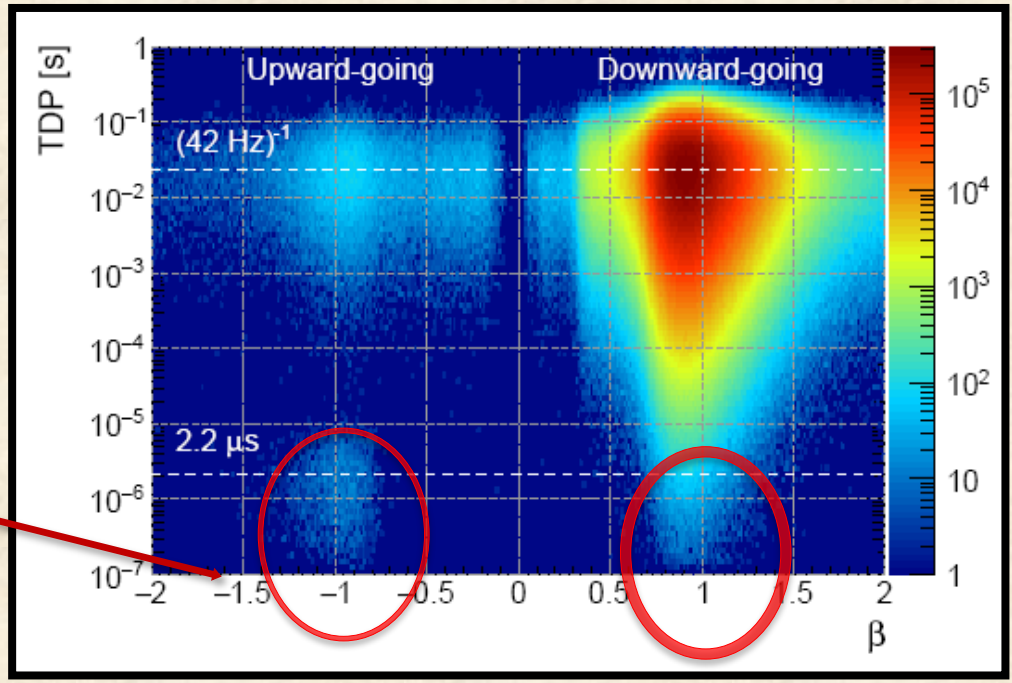
Event display (in the two projections)

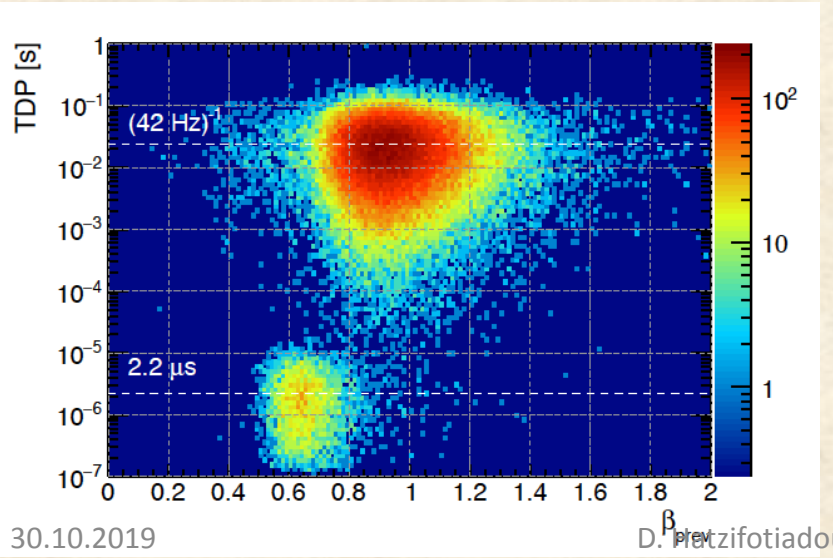
Tagged downward μ + upgoing electron

1.3 x 10^8 good tracks
7 x 10^4 TOF<0

β > 0 downward -going
β < 0 upward-going

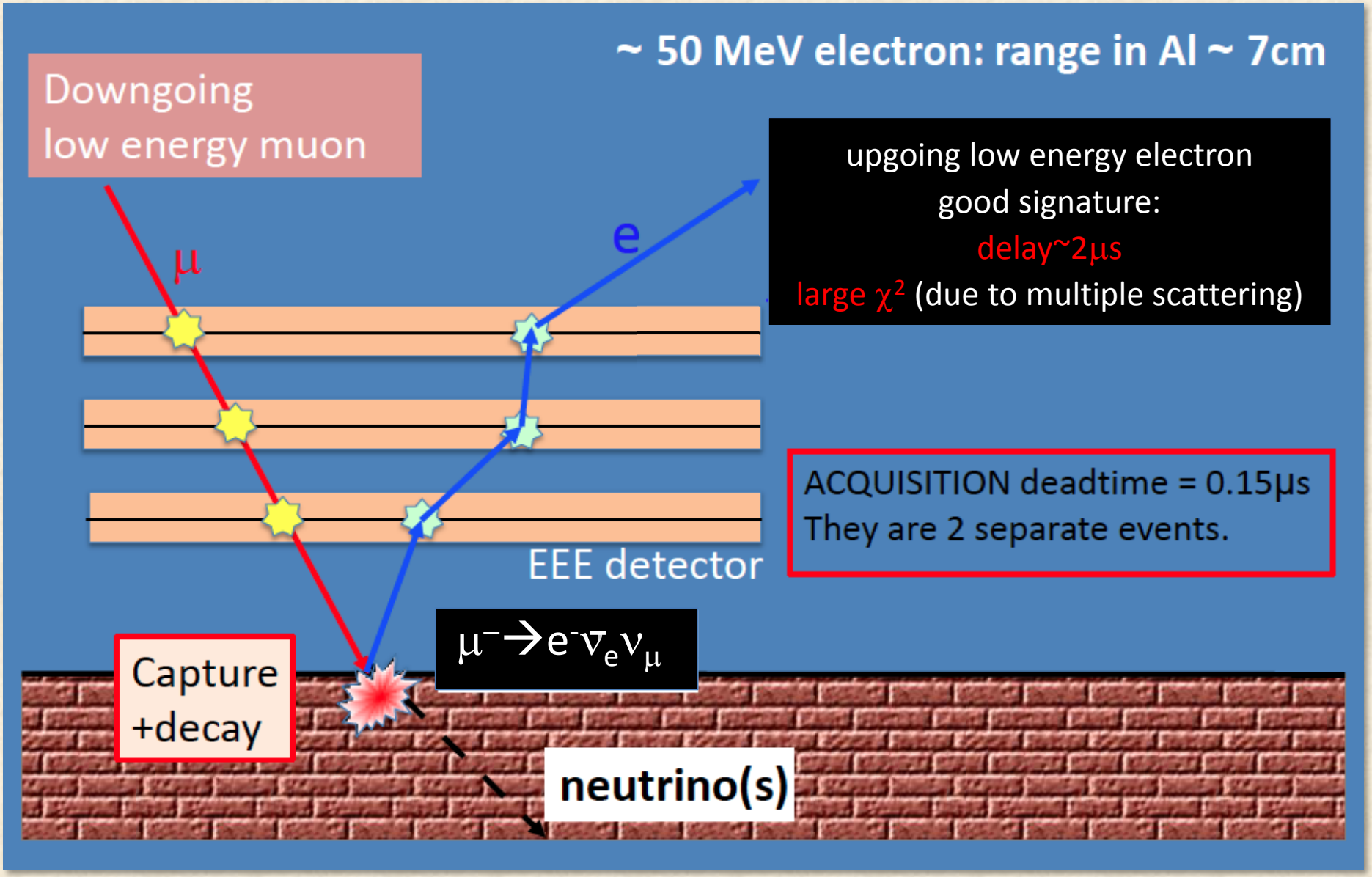
Identify electrons from muon decays (in the floor or in the bottom chamber): look at Time Difference with respect to the Previous (TDP) events versus velocity



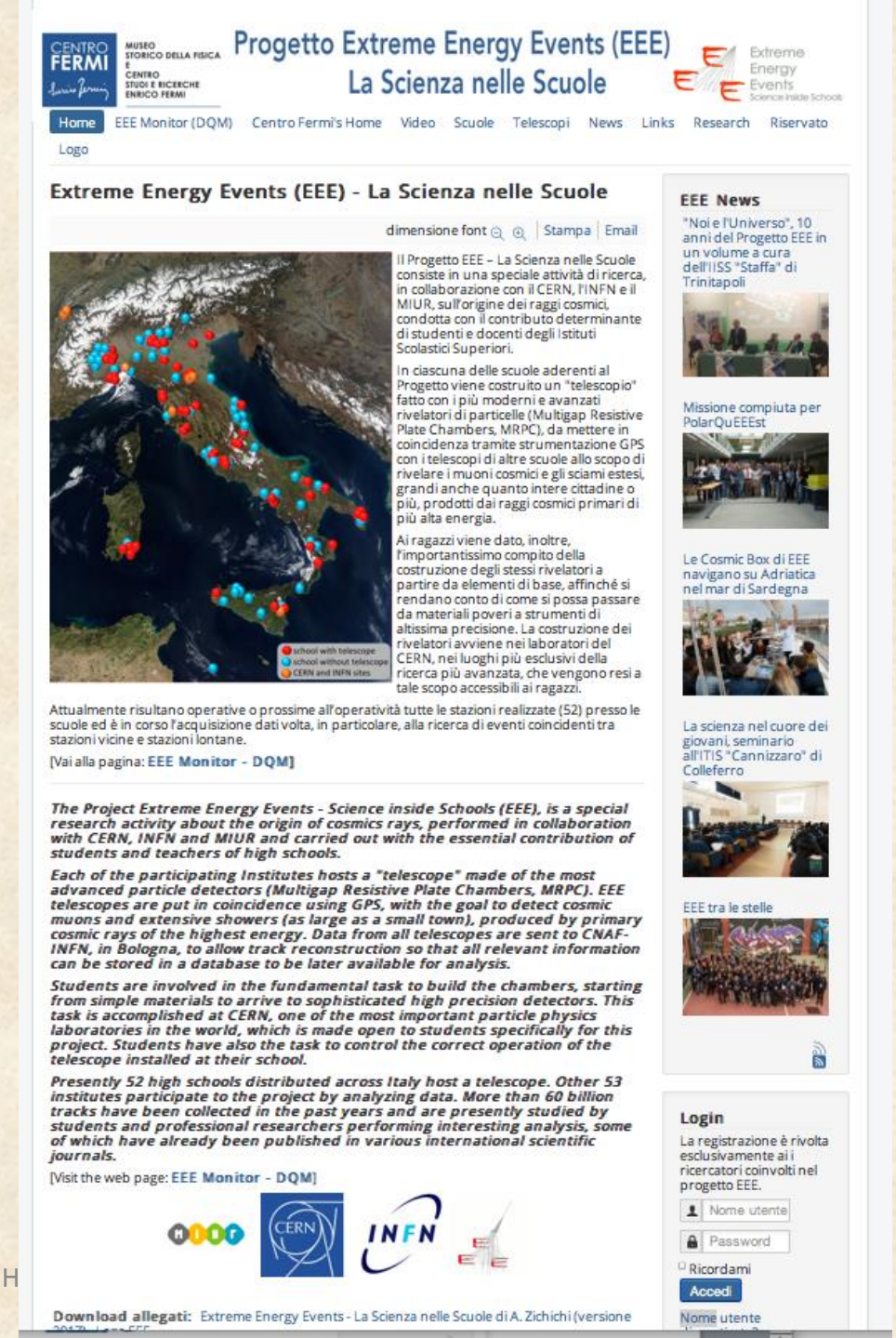


Correlate TDP with velocity of previous particle : electrons come from decays of (slow) muons with 0.5<β<0.8
For β~0.65 range of muons in Al / concrete is 2-3 cm
Electrons from μ-decay, E=50 MeV, range in Al 7 cm

Muon decay



low energy electrons from muon decay are a robust explanation for upward-going particles



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Thanks a lot for your attention