VCI 13TH VIENNA CONFERENCE ON INSTRUMENTATION

The Air Microwave Yield (AMY) experiment to measure the GHz emission from air shower plasmas

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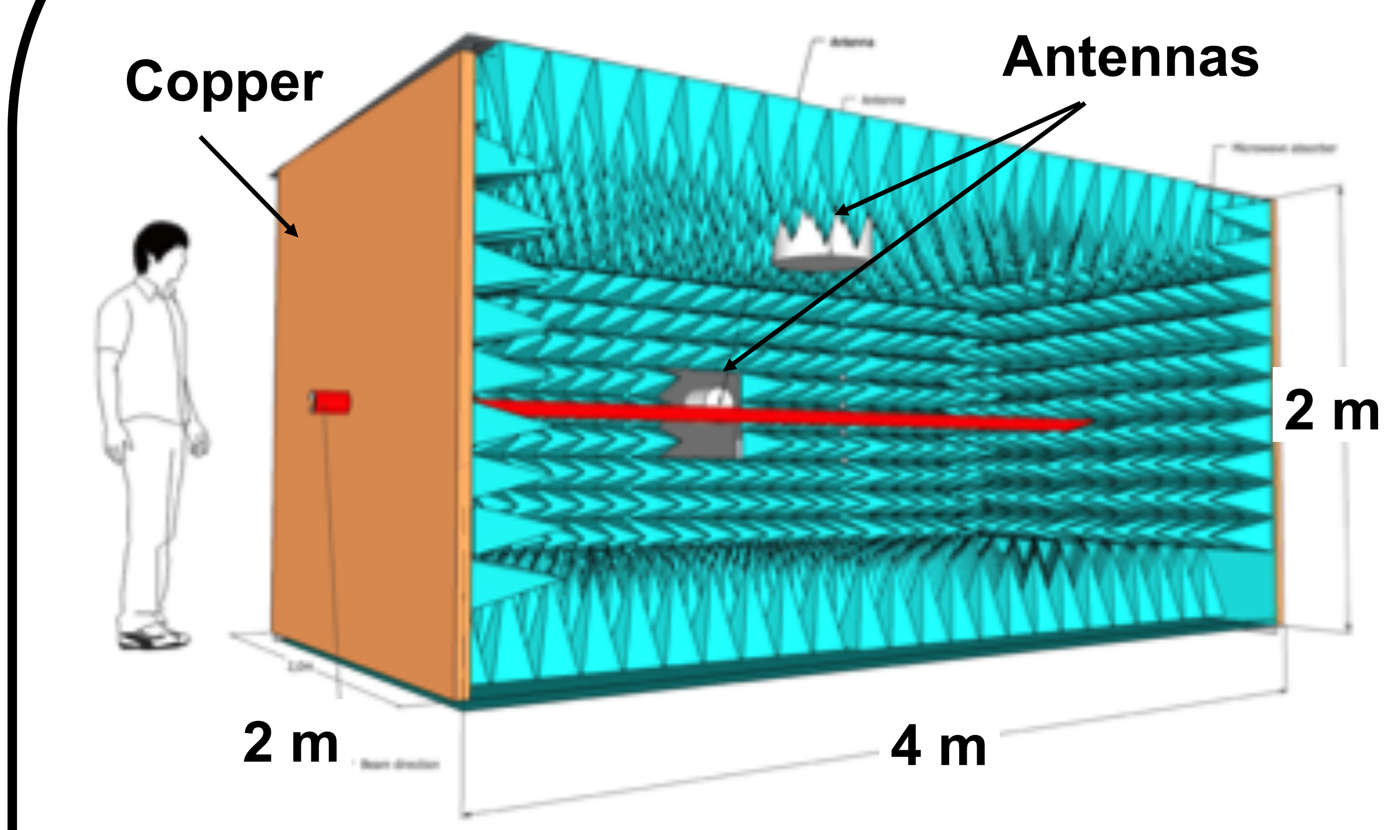
Physics Motivation

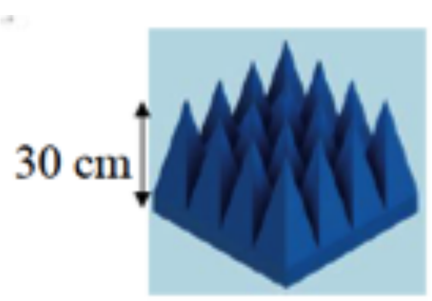
During its development in the atmosphere, an air shower releases its energy through ionization, producing a plasma made by electrons of temperature of about 10^5K. The cooling process of the plasma holds over a time scale of nanoseconds and it comes mainly via the excitation of the medium. However, a small part of the plasma energy can be released through bremsstrahlung emission in the collisions of the electrons with the neutral molecules of the atmosphere. The emitted radiation is in the microwave band and it is expected to be isotropic, un-polarized and proportional to the shower energy deposit[1]. These properties of the microwave molecular bremsstrahlung radiation (MBR) open the possibility to develop a radio telescope which is able to reconstruct the full shower longitudinal development and to provide a calorimetric measurement of the shower energy. In comparison to the fluorescence telescopes, the MBR detection technique would have the fundamental advantage of a 100% duty cycle. Moreover, it does not need a program of atmospheric monitoring. In fact the microwave radiation is not significantly attenuated over distances of several tens of kilometers.

The AMY experiment aims to measure the MBR absoluted yield and its frequency spectrum between 1 and 20 Ghz at the Beam Test Facility (BTF) of Frascati INFN National Laboratories. The experiment will characterize the process to be used in a next generation detectors of ultra-high energy cosmic rays (up to 10^{20} eV). We describe the experimental apparatus and the last test perform the last year.

[1] P.W. Gorham et al. Observations of microwave continuum emission from air shower plasmas. Phys. Rev. D 78, 032007 (2008)

The Anechoic Faraday Chamber

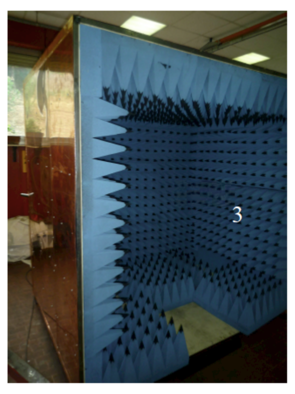


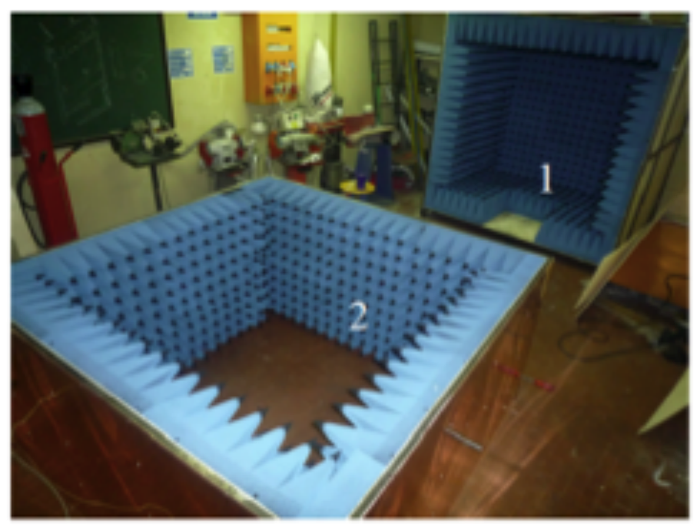


Microwave absorber SATIMO AEP 12

Attenuation:
1 GHz: 30 dB
> 6 GHz: 60 dB

Built by the mechanical shop of the university of Rome Tor Vergata





Three modules:
- 1-3 length 1,5 m
- 2 length 1 m

Measured shielding for outside radiation above 4 GHz better than 85 dB, down to 40 dB at 1 GHz.

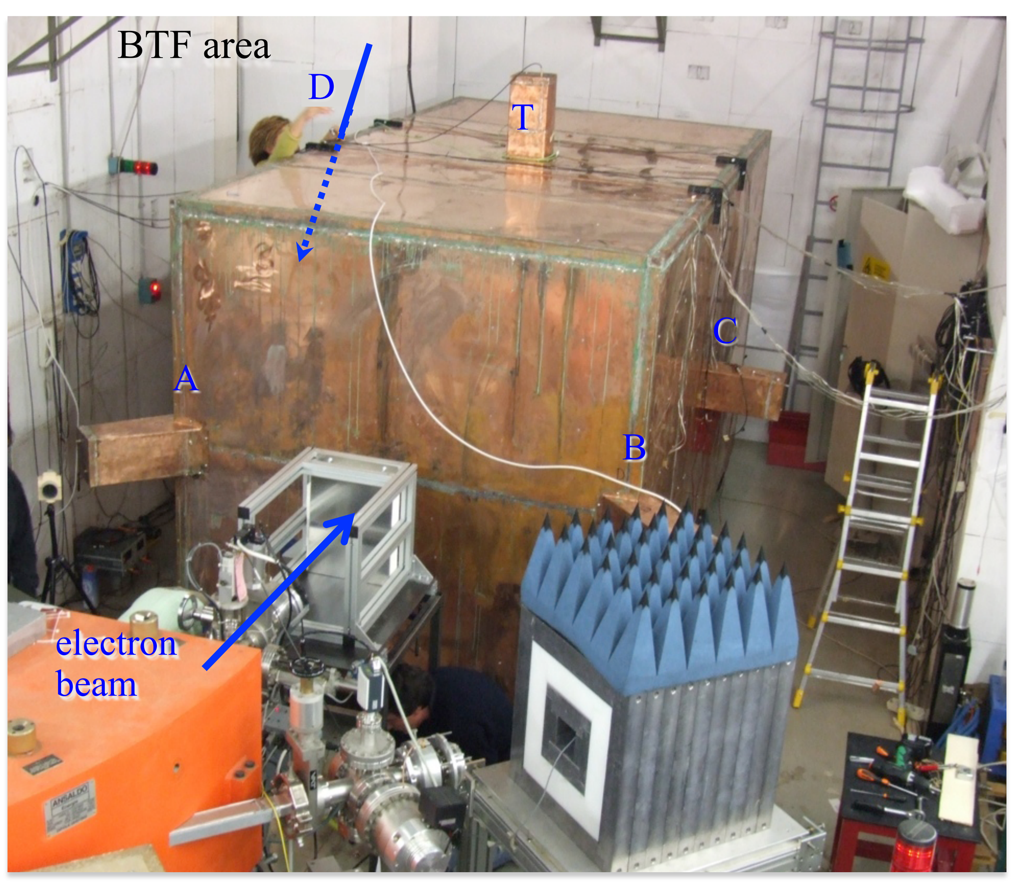
Instrumentation

HORN DRH20 RFSPIN
- **Range: 1.7 – 20 Ghz**
- **Gain: 6-16 dBi**

Log Periodic Rohde&Schwarz HL050
- **Range: 0.25 – 26.5 Ghz**
- **Gain: ~8.5 dBi**

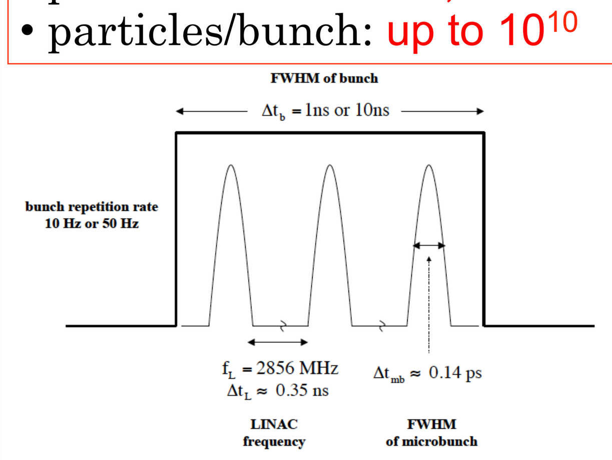
Amplifier Mini-Circuit ZVA-183-S+
- **800 MHz – 21 Ghz**
- **Gain: 26 dBi**

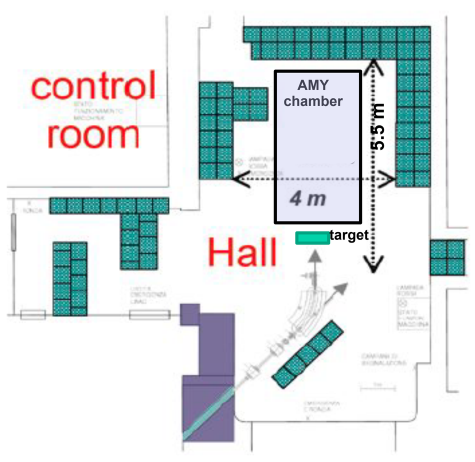
Oscilloscope LECROY SDA 830Zi-A: 4 ch, 20 GHz real time bandwidth, 40 GS/s
Spectrum analyzer ROHDE&SCHWARZ FSV 30: 9-30 kHz, 40 MHz bandwidth
Microwave signal generator ROHDE&SCHWARZ SMF100A: 100 KHz to 22 GHz.



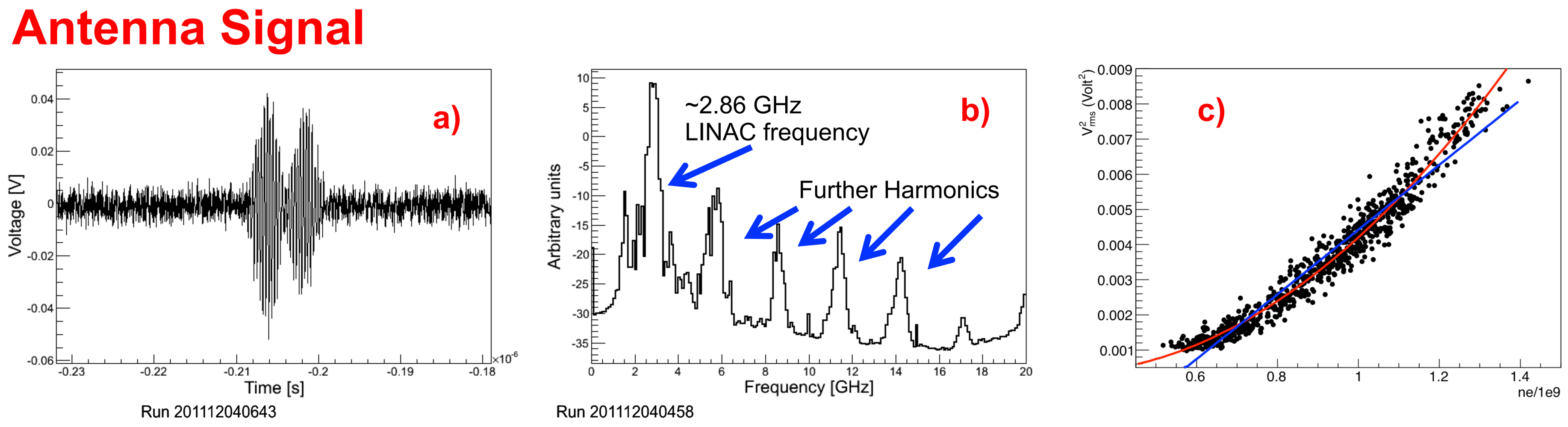
5 antenna positions: 2 at the corners (A, B)
2 on the sides (C, D) + 1 on the top (T)

e-beam delivered @ BTF
- energy range: 510 MeV
- max. rep. rate : 1 or 2 Hz
- pulse duration: 1.5, 3 or 10 ns
- particles/bunch: up to 10^{10}





Antenna Signal



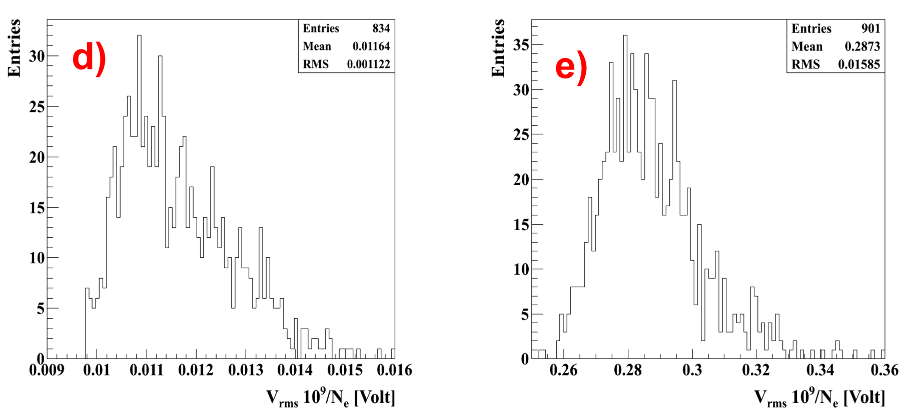
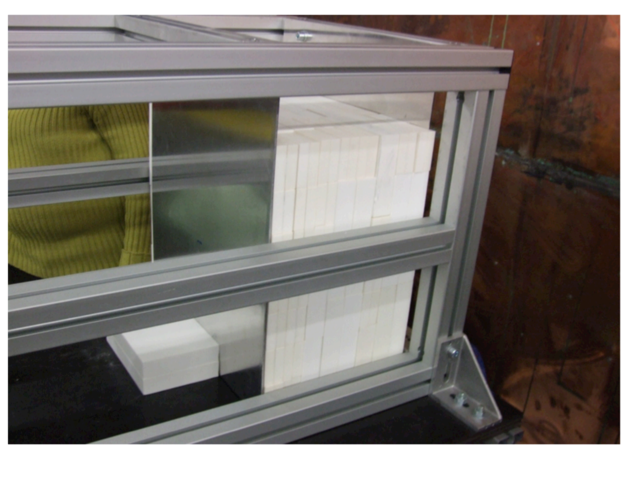
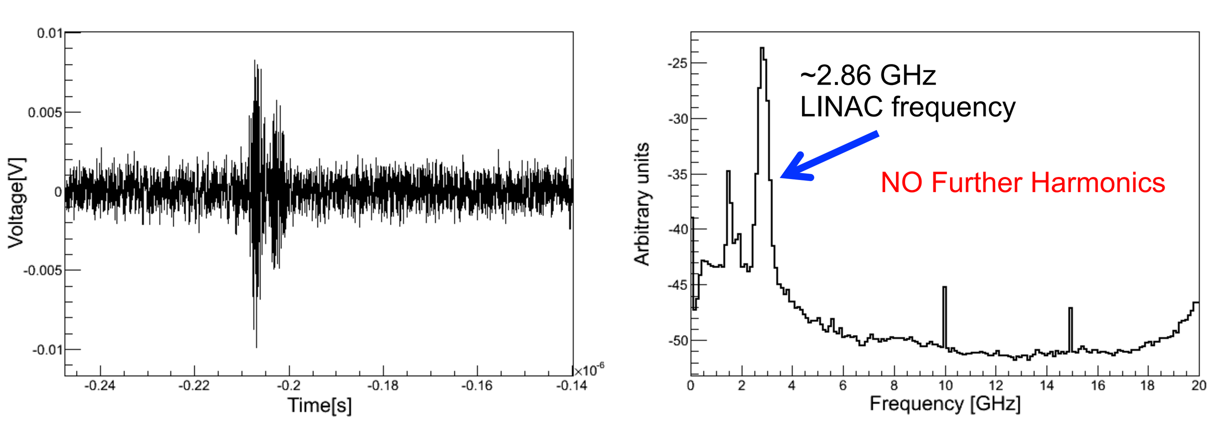


Fig. a: Typical signal recorder with the antenna polarization plane parallel to the beam axis.
Fig. b: Power spectrum as a function of the frequency.
Fig. c: The Power of the signal shows a quadratic dependence with the beam intensity. This trend does not depend on the orientation of the antenna polarization plane.
Fig. d: Voltage r.m.s. distribution normalized to the beam intensity obtained when the antenna polarization plane is orthogonal to the beam axis.
Fig. e: The same as Fig. d but with antenna polarization plane is parallel to the beam axis

Run with alumina Target





- **larger energy deposit (good for MBR)**
- **signals are very small**

Outlook:

A third test beam of the AMY experiment has been performed at the Beam Test Facility (BTF) of the Frascati INFN National Laboratories and the analysis in underway. The data show the presence of a strong and fast radiation produced directly from the relativistic beam and polarized in the plane define by the beam axis and the Poynting vector. This polarized radiation is attenuated using different orientations of the antenna and using an alumina target at the beam. A detail simulation of the prompt radiation is in progress for studying the detector response and its calibration and to understand the background for the MBR measurement.