AMY

AMY: measuring the microwave yield with the high intensity beam of National Laboratory of Frascati (INFN)

Valerio Verzi

Malargue - November 2010

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Observations of microwave continuum emission from air shower plasmas

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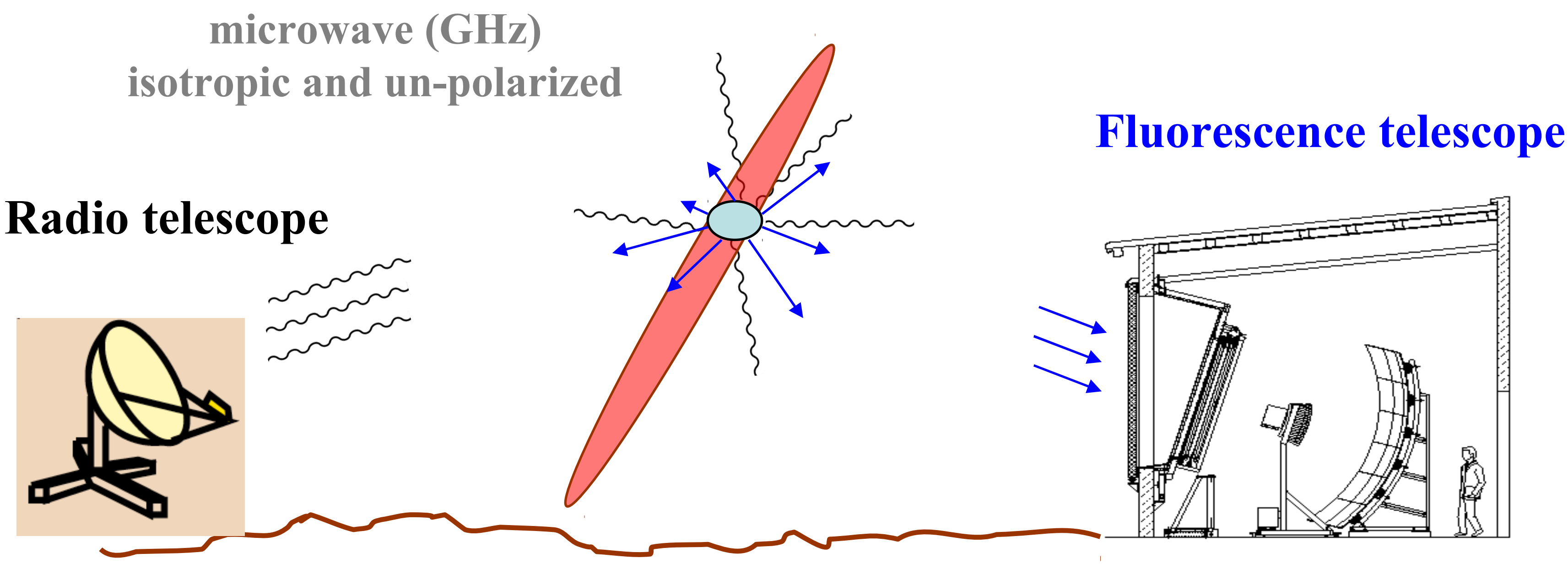


Energy deposit → **plasma $T_e \sim 10^5$ K**

→ **Secondary electrons excite N_2 ⇒ fluorescence radiation**

→ **Secondary electrons themselves produce their own emission like <u>bremsstrahlung in the field of neutral molecules</u>**

THE PHYSICS PROCESS

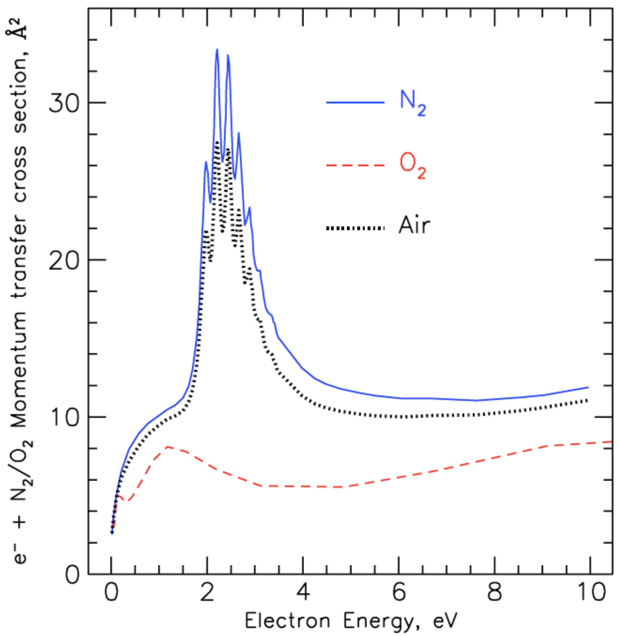
<u>Classical theory of bremsstrahlung from collisions between electrons and neutral molecules</u>

- electron number density and plasma temperature
- Maxwellian distribution of electron velocities
- collision frequency (weak function of electron speed)

but departures from equilibrium conditions make the predictions very uncertain

N_2: rotatinal level excitation
stimulated bremsstrahlung

oxygen attachment



Coherence effects can increase significantly the signal (Debye length)

$$\vec{E} = \sum_{j=1}^{N_e} \vec{\epsilon}_1(\mathbf{v}) \exp(-i\vec{k}\cdot\vec{x}_j)$$ total electric field

$$P/A = |S_{\rm tot}| = |\vec{E}|^2/Z_0$$

Poynting vector

coherence → $P = N_e^2\, \mathrm{P}_1$

incoherence → $P = N_e\, \mathrm{P}_1$

$$P_1 \mu |\vec{e}_1|^2$$

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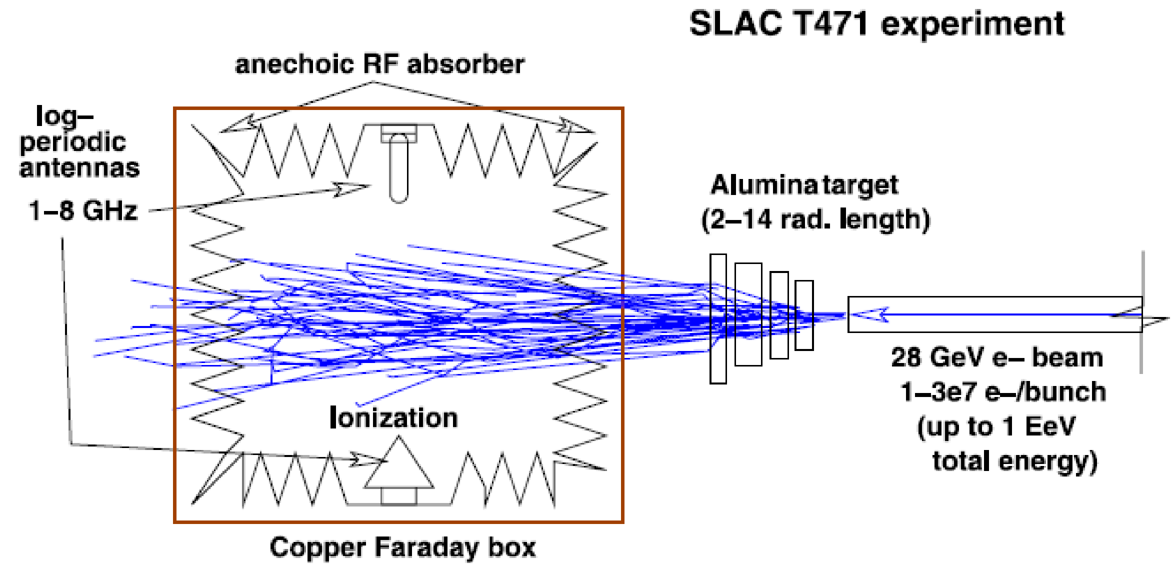
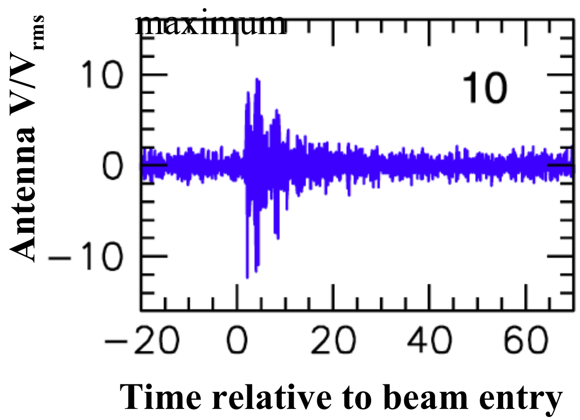
TEST BEAM A SLAC



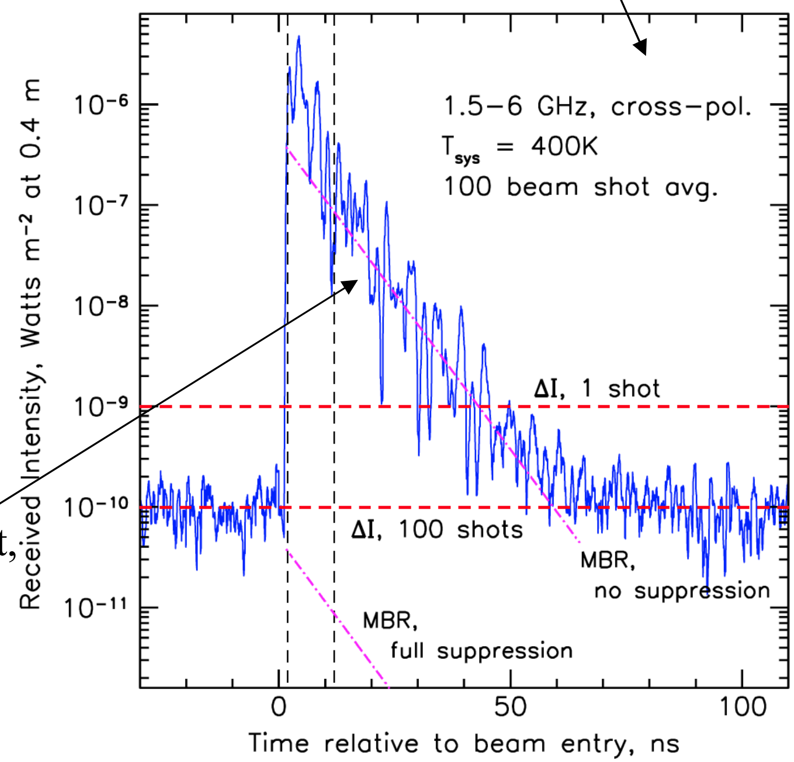
insensitive to cherenkov and transition radiation

6 GHz bandwith oscilloscope

close to shower maximum



7 ns decay constant, compatible with plasma cooling



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THE AMY OBJECTIVE

Limitations of SLAC measurements

It has been proved only the existence of a microwave emission

- the absolute yield is not known precisely
  --> this affect the uncertainty on the threshold in energy of an air shower detector

- the spectrum in frequency has not been measured
  --> it may give important information on the underlying process
  --> if there are bright lines the signal/noise of a telescope can be improved
  --> if not, satellite televisions band are preferable to keep low the costs

With the **AMY** experiment we would like to overcome this limitations **confirming** and **measuring** precisely the **absolute microwave yield** and its **frequency spectrum** in the range **between 1 and 25 GHz**

THE AMY COLLABORATION

- **Roma, Lecce and Aquila**

  INFN committee V ≈100 k€

- **Martina Bohacova (Czech Republic)**

  strong experience with Frascati beam
  already contributing with funds

- **J.Alvarez-Muniz and G.Rodriguez (Santiago)**

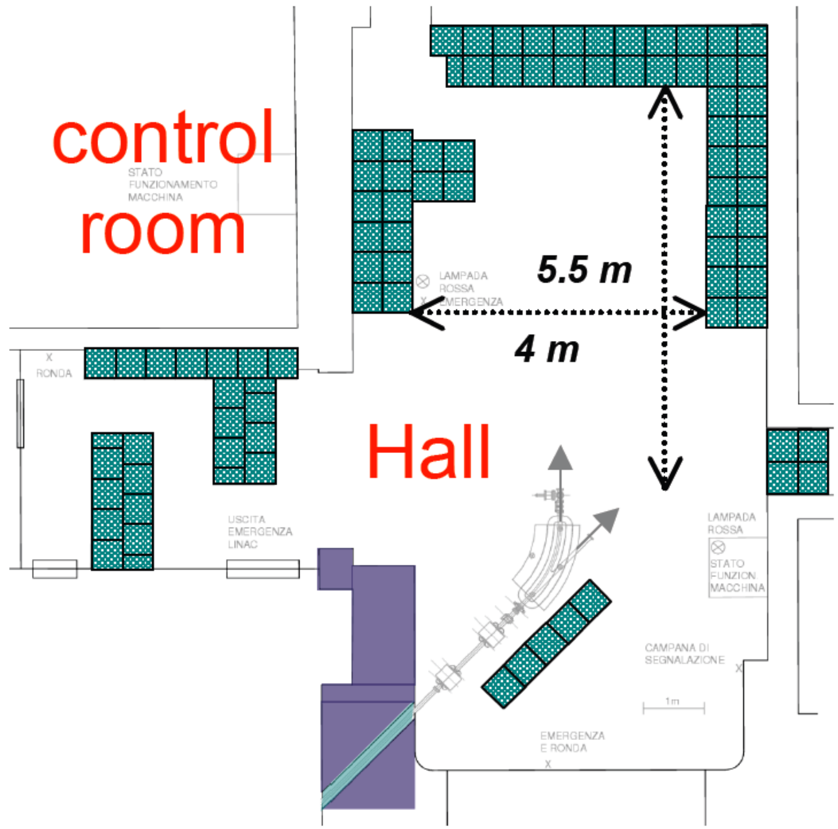
  expertise in radio cherenkov calculation

- **Cooperation with Chicago group**

The DAFNE Beam Test Facility

e-/e+

Energy range	25-750 MeV
Max. repetion rate	50 Hz
Pulse duration	1 - 10 ns
Particles/bunch	Up to 10^{10}



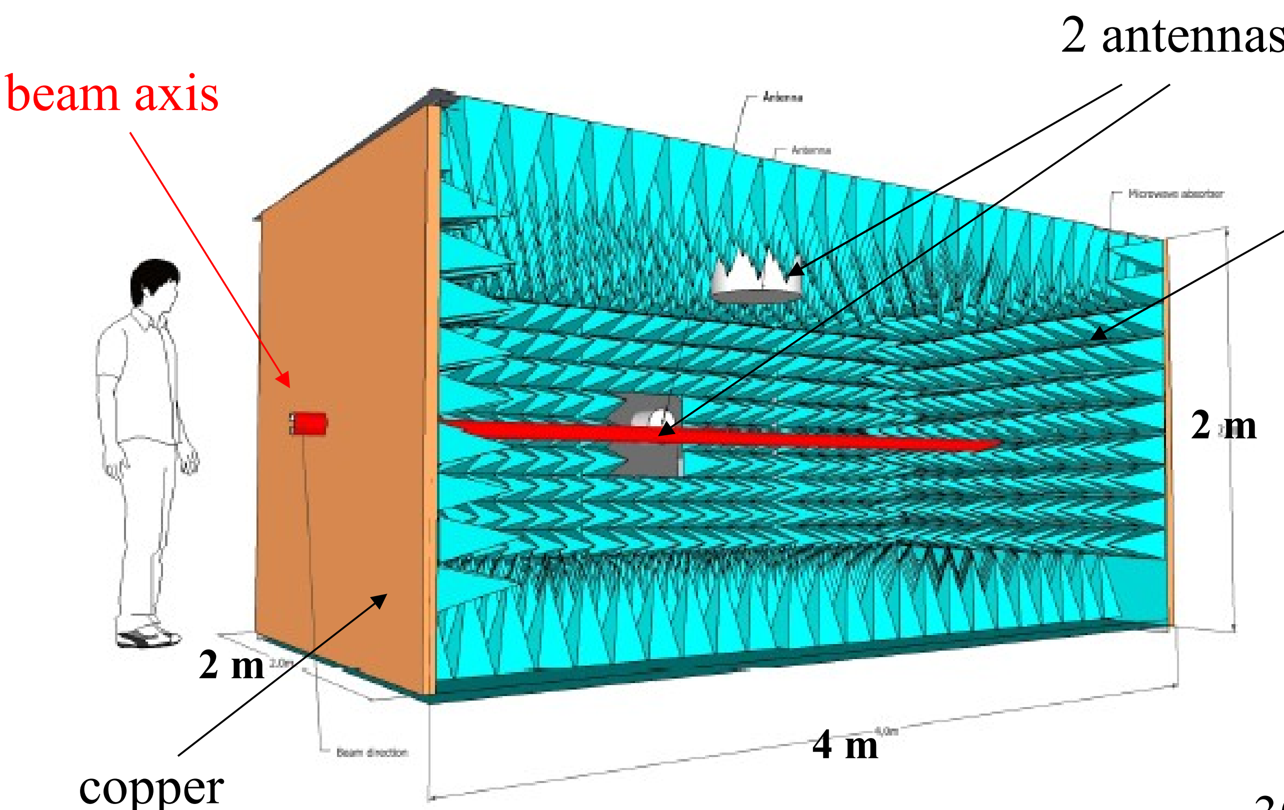
In comparison to SLAC the BTF beam provides a larger shower equivalent energy

$$N_{SLAC} \times E_{SLAC} = 1.2\ 10^7 \mathrm{e}^-/\mathrm{bunch} \times 28\ \mathrm{GeV} \quad = \quad 3.36\ 10^{17}\ \mathrm{eV}$$

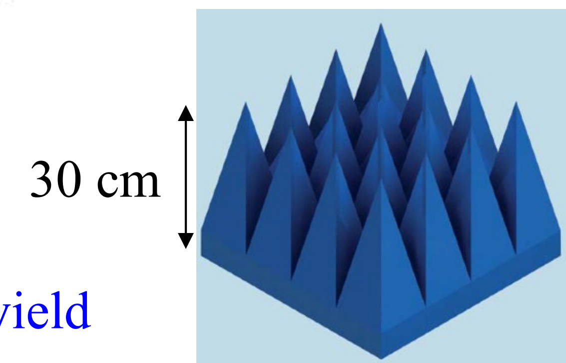
$$N_{BTF} \times E_{BTF} = 10^{10} \mathrm{e}^-/\mathrm{bunch} \times 700\ \mathrm{MeV} \quad = \quad 7\ 10^{18}\ \mathrm{eV}$$

Microwave signal higher by a factor 20 ÷ 400 (linear or quadrating scaling)

ANECHOIC FARADAY CHAMBER



RF adsorber
SATIMO
AEP 12
attenuation
1GHz: 30 dB
> 6 GHz: 50 dB

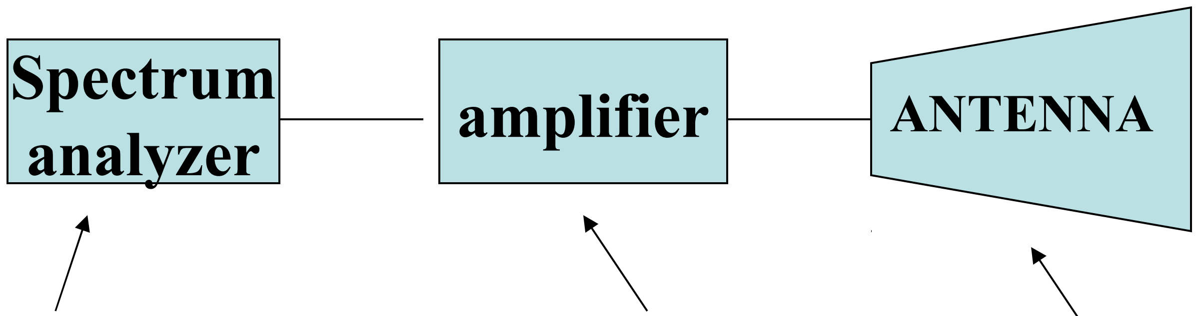


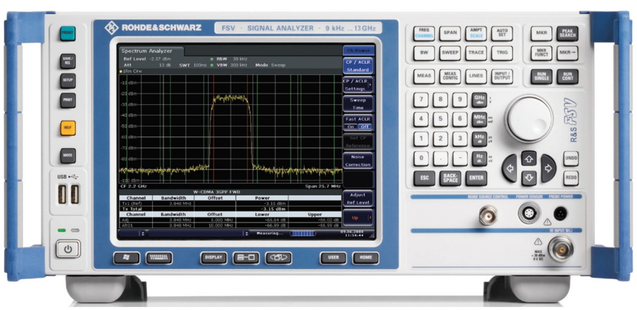
- *spectrum analyzer* -> frequency spectrum and absolute yield

- *power detector & FADC* (*) ->time evolution of the signal

(*) flexibility of a VME system (beam monitoring)

SPECTRUM MEASUREMENT

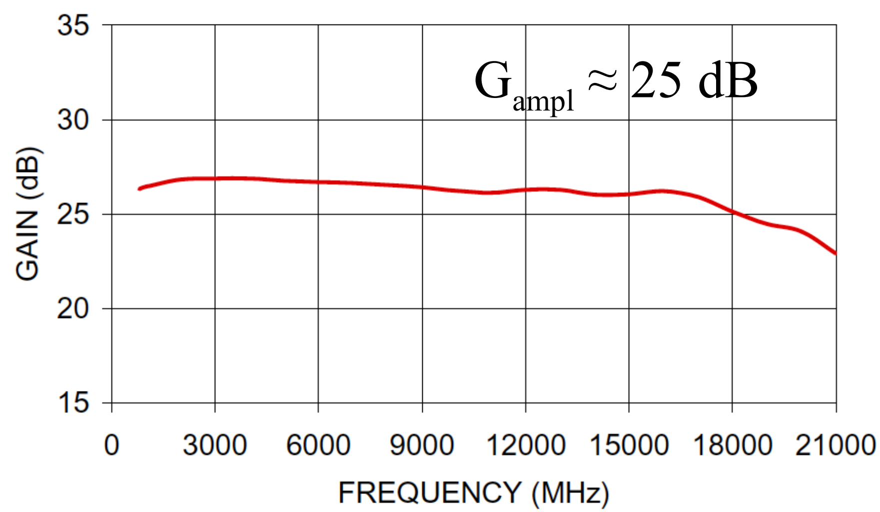




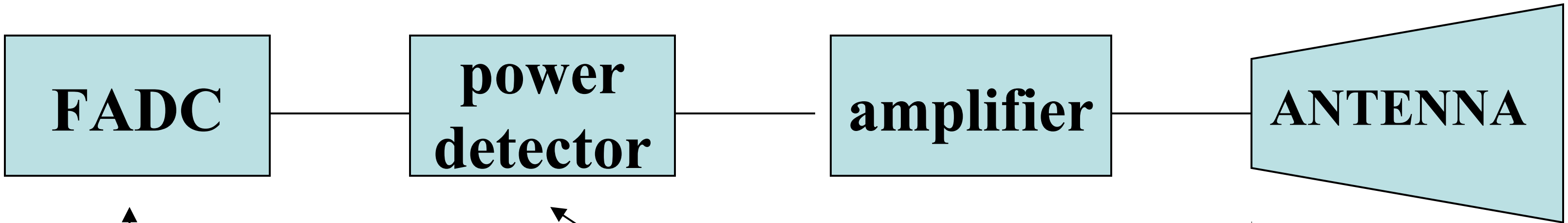
Mini-Circuits®

R&S HL050
Log-periodic
0.85-26.5 GHz

Rohde & Schwarz
FSV30
9 KHz - 30 GHz
40 MHz bandwidth



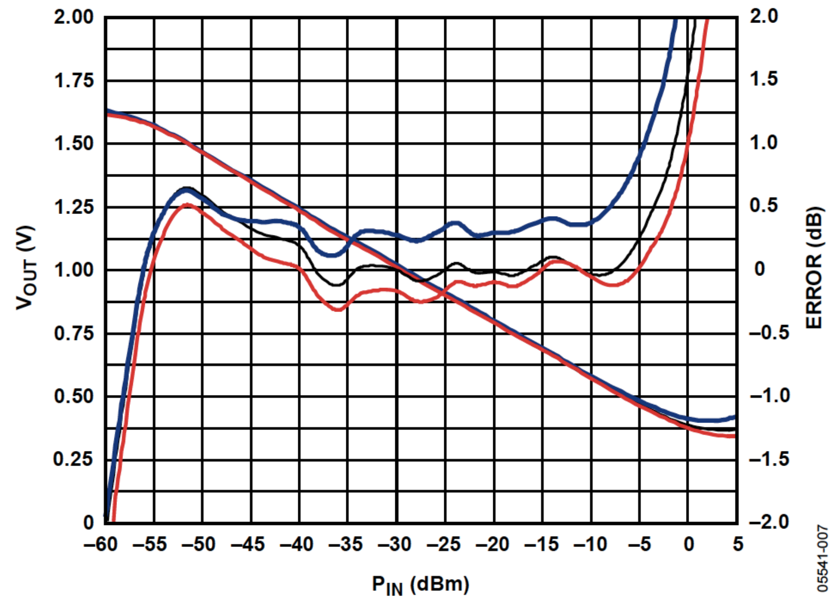
TIME MEASUREMENT



struck innovative systeme

ANALOG DEVICES

AD8317/8318



500 MS/s

12 bit resolution

4 channels

up to 10 GHz

response time < 10 ns

(no signal ⇔ -10 dBm)

FDWAVE

FDWAVE: installing GHz radio receivers in the empty pixels
of LL telescopes

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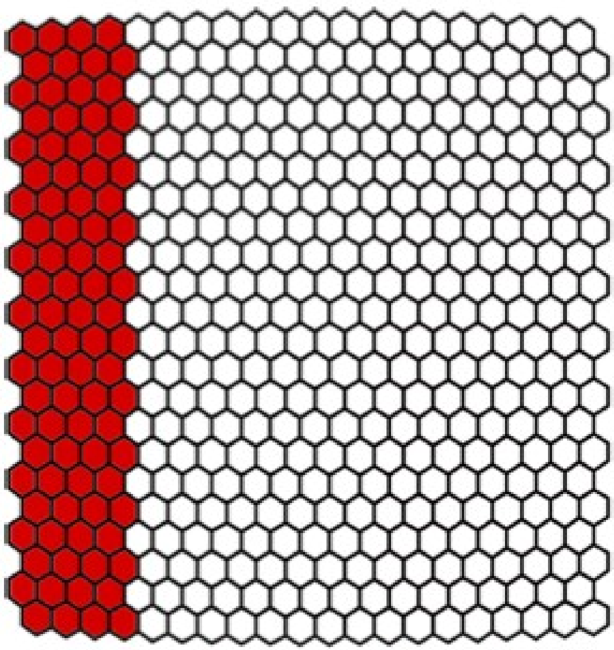
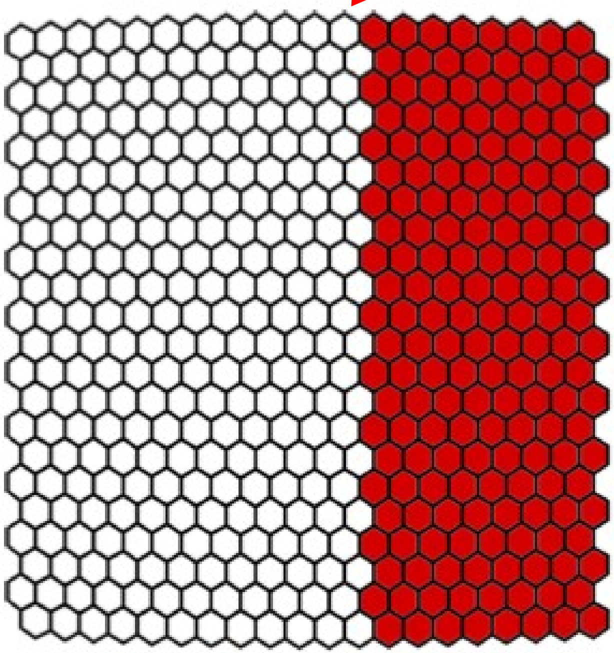
FDWAVE

Pixels without photomultipliers (removed to be installed in HEAT [*])



Los Leones Bay 1



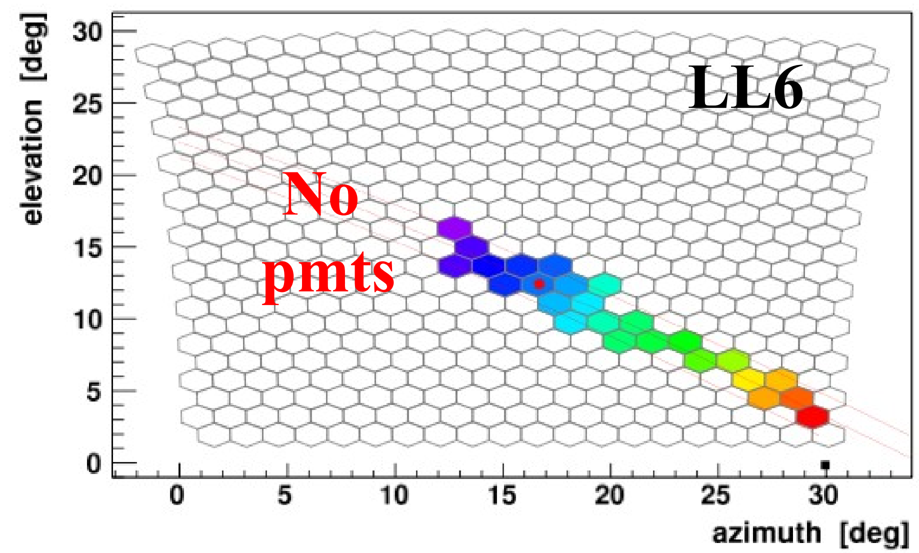
Los Leones Bay 6

220 pixels available (not considering the columns adjacent to pmts)

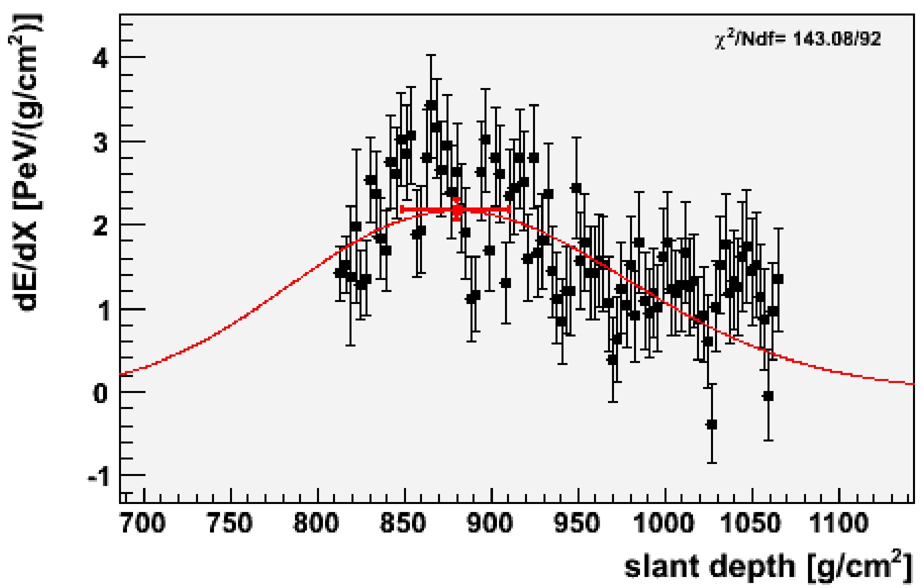
<u>**Use LL1 & LL6 to detect microwave radiation equipping the empty pixels with microwave radio receivers**</u>

FDWAVE

Use the standard FD trigger and readout the radio receivers every FD shower candidate

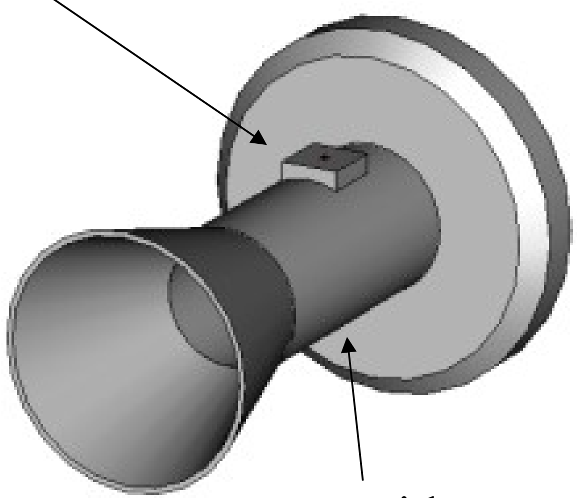


Use the profile reconstructed with pmts to estimate the energy deposit seen by radio receivers



ANTENNA

Conical Horn in the frequency range [9-11] GHz



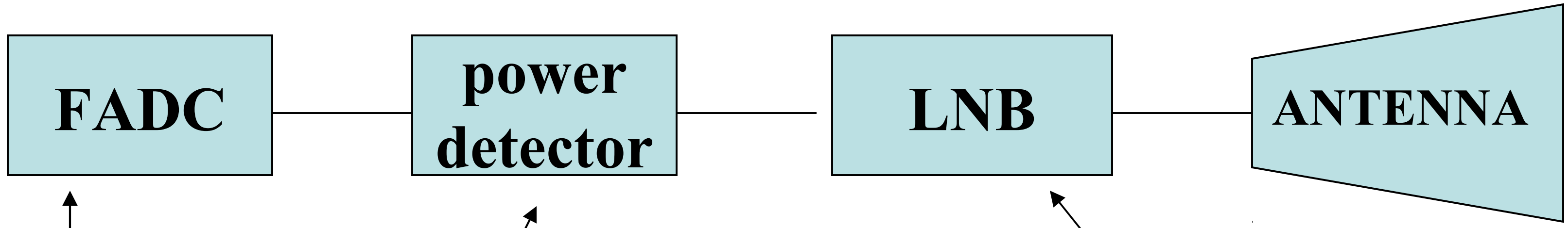
QuickTime and a decompressor are needed to see this picture.

camera holes b=40 mm

maximum aperture a=45.6 mm

- **Half power beam width at 9-11 GHz → $\theta_{HP} = 0.9^0$-0.7^0**
- **Camera geometry does not allow to lower significantly the frequency (higher θ_{HP})**
- **Optimal frequency → 11 GHz**
  in Ku band costs of electronics significantly reduced

FE ELECTRONIC & DAQ



Log-power detector AD8317
up to 10 GHz 55 dB dyn. range

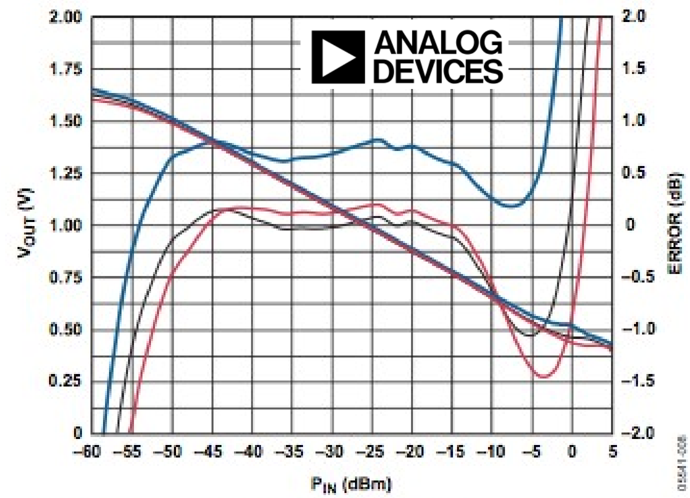


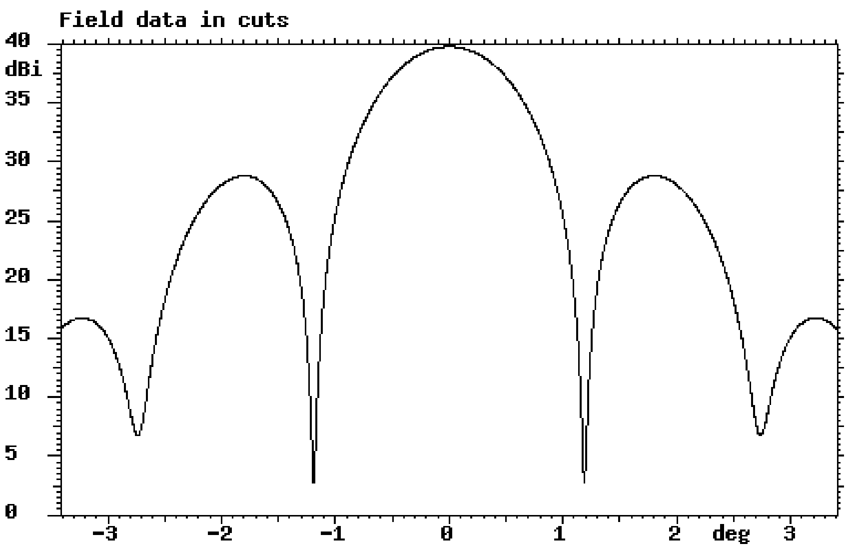
Figure 8. V_{OUT} and Log Conformance vs. Input Amplitude at 8.0 GHz, R_{TADJ} = Open, Error Calculated from P_{IN} = −34 dBm to P_{IN} = −16 dBm

Low Noise Block
NRJ 2837 Ku-Band PLL

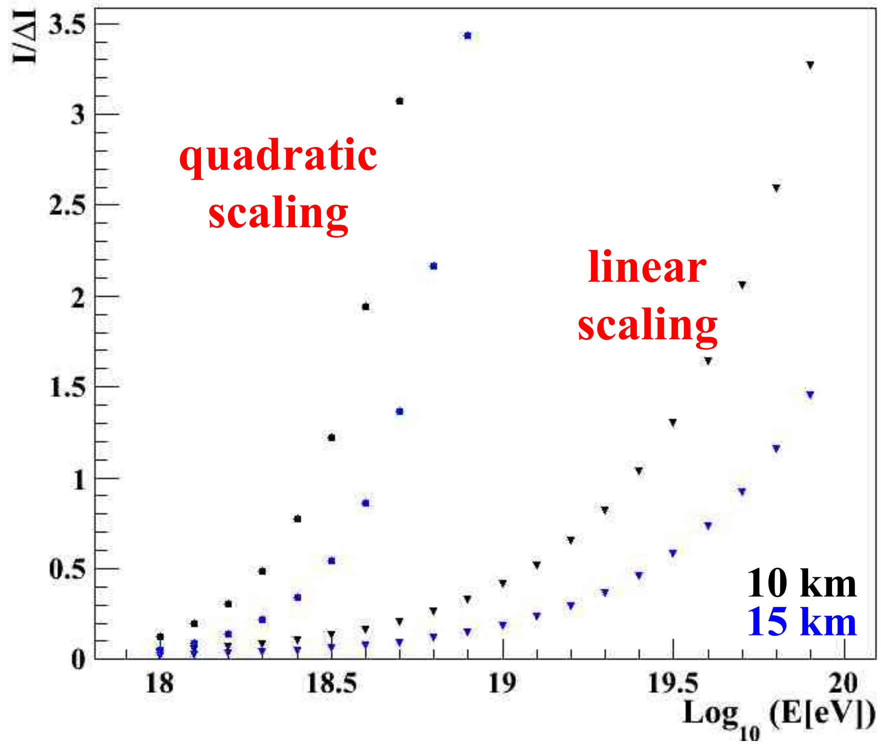
Input freq.	**10.95÷11.7 GHz**
Output freq.	**950÷1700 MHz**
Gain	**60 dB**
Noise figure	**0.8 dB**

use the FD FADCs → **a trigger signal is needed**
→ **radio signals will be available in a friendly format and this makes easier the access for all Auger people**

Gain simulated with GRASP



Signal to noise (300 K) ratio



$A_{eff} = 1.36\ m^2$ $(\eta \approx 50\%)$

Few tens of events per year above $10^{18.5}$eV

Possibility to increase I/ΔI: Δt > 100 ns

averaging over more showers and FADC traces

OUTLOOK

- **AMY has been fully funded by INFN and the activities will start at the beginning of the next year**

- **we are applying to ASPERA to fund FDWAVE**

- **further money hopefully will be provided by HEAPNET**

- **the GHz business can be a good opportunity for next generation experiments. We hope that the common effort of the Auger people will assess the feasibility of the experimental technique in a couple of years.**