THE AMY (AIR MICROWAVE YIELD) EXPERIMENT TO MEASURE THE GHZ EMISSION FROM AIR SHOWER PLASMA

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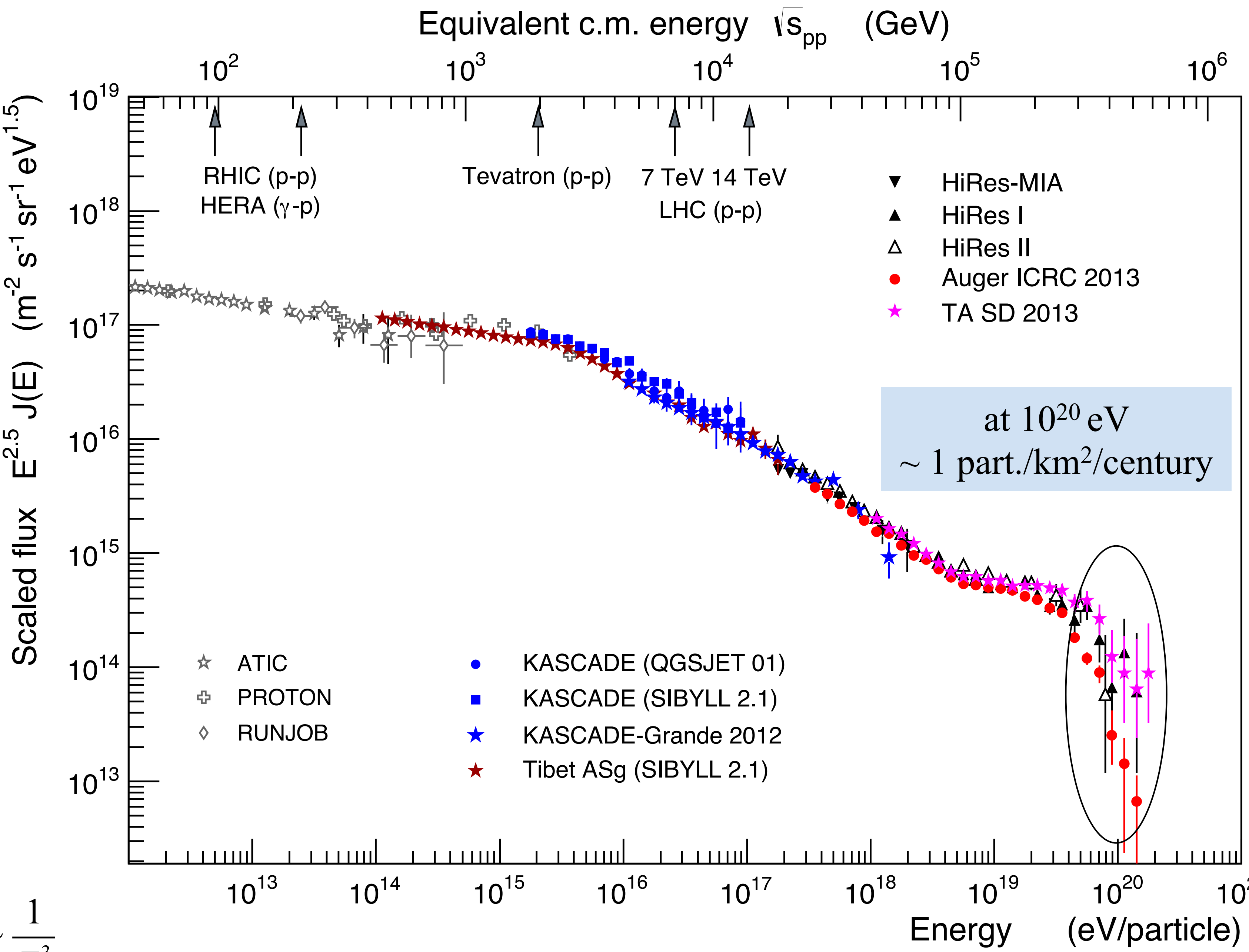
INFN ROMA Tor Vergata

** for the AMY Collaboration*

Annapolis (USA), 9-12 June

ARENA 2014

ENERGY SPECTRUM x $E^{2.5}$



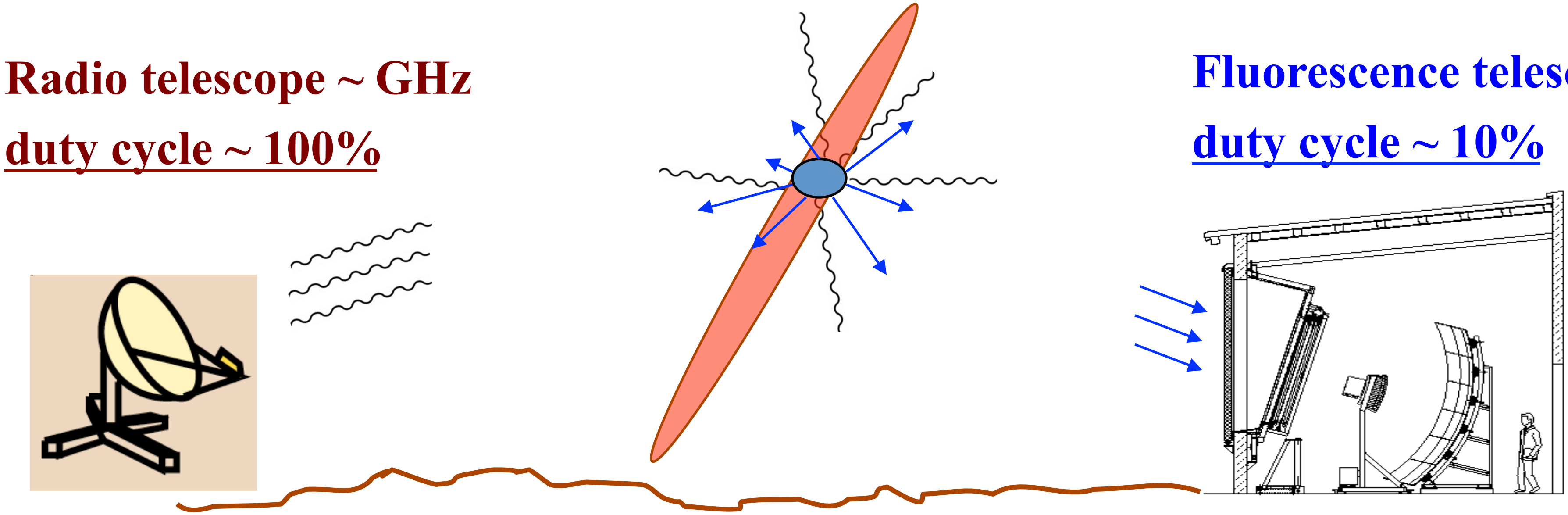
$$\frac{dN}{dE} \sim \frac{1}{E^3}$$

Observations of microwave continuum emission from air shower plasma (SLAC)

P.W. Gorham et al.
Physical Review D 78, 032007 (2008)

Microwave Bremsstrahlung Radiation (MBR)

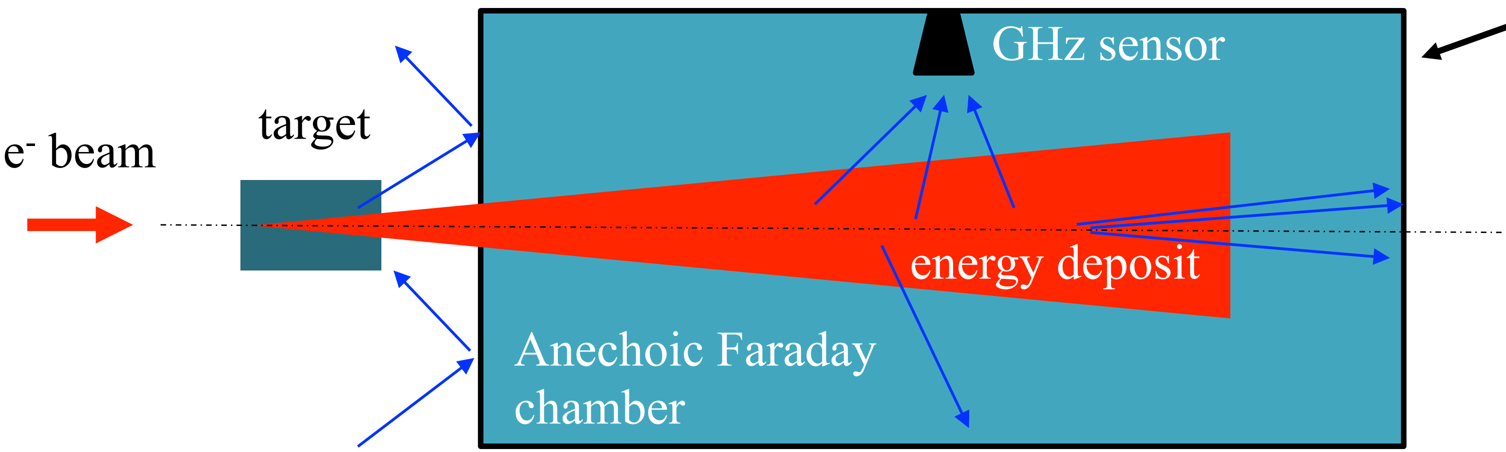
isotropic and not polarized (like fluorescence radiation)



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

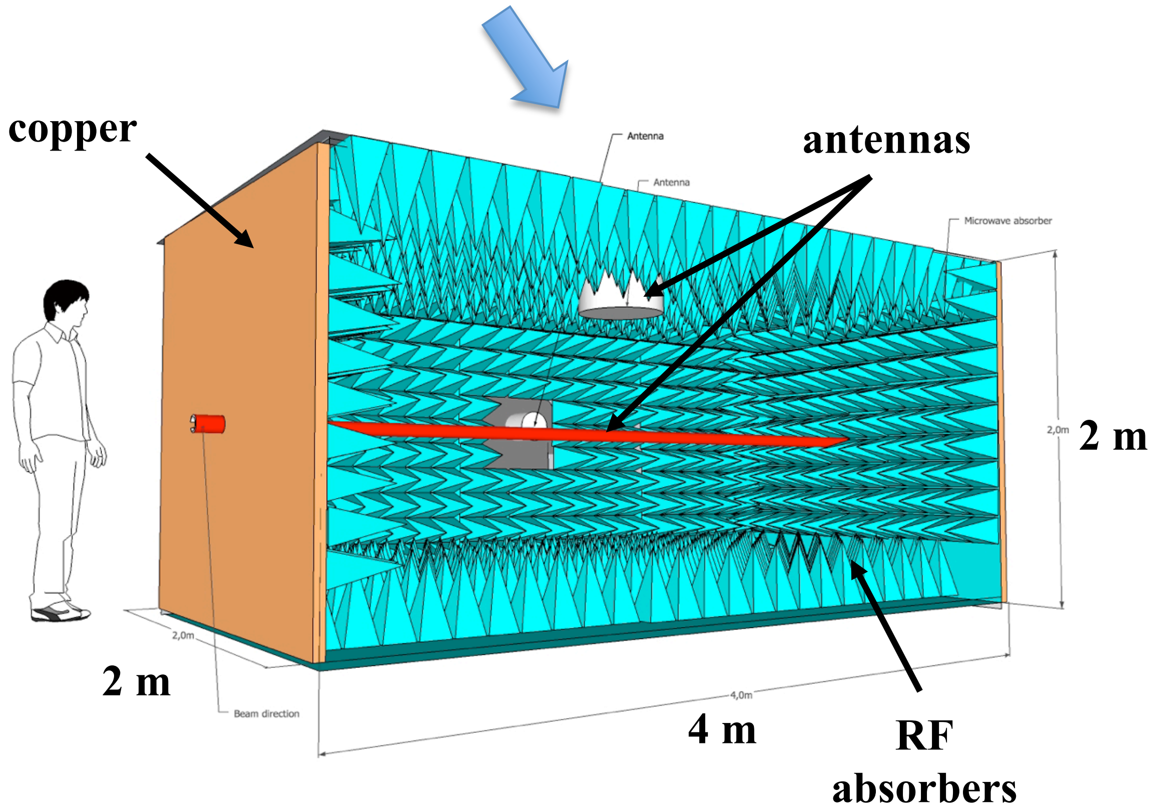
- **Secondary electrons excite N_2 ⇒ fluorescence radiation**
- **Secondary electrons produce bremsstrahlung radiation in the field of the neutral molecules**

AMY EXPERIMENT



$16\ m^3$

$1\ m^3$ at SLAC

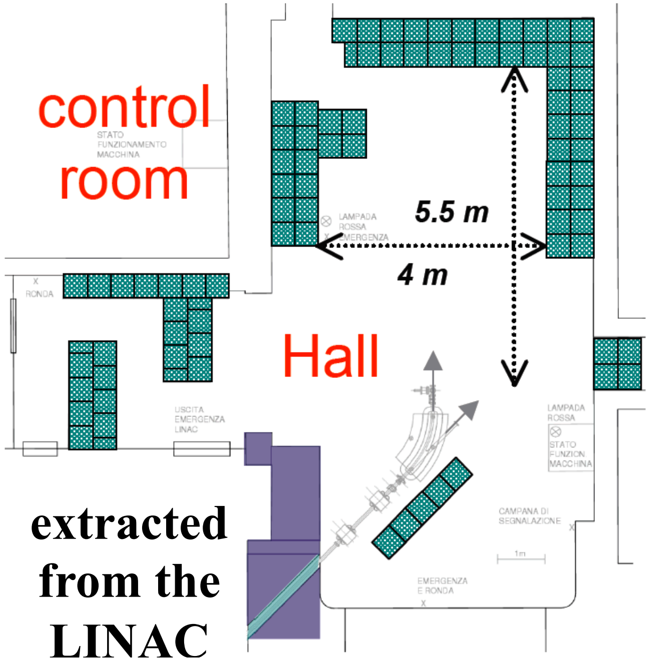


- MBR ~ energy deposit
- shield from outside radiation
- avoid reflections within the chamber

Beam Test Facility (BTF) AT DAΦNE

INFN Frascati National Laboratories

beam	e^-
energy range	**510 MeV**
repetition rate	**few Hz**
pulse duration	**1.5 3 and 10 ns**
max particle/bunch	**10^{10}**

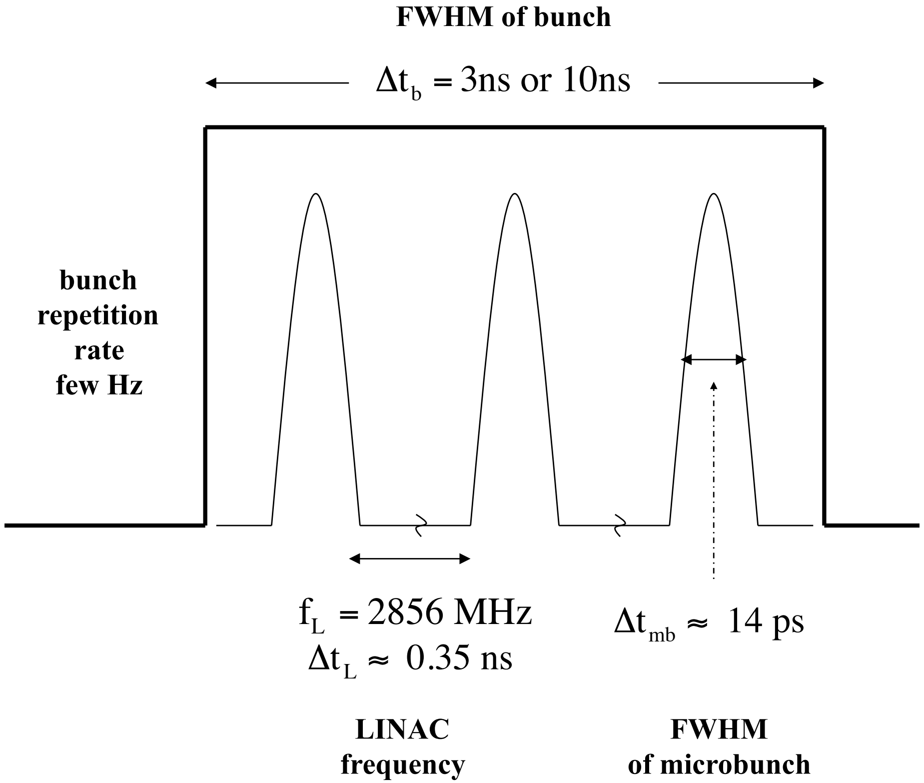


factor 10 higher intensity:

$$\text{BTF} \quad 10^{10}\,\frac{e^-}{\text{bunch}} \times 510\ \text{MeV} \approx 5\times10^{18}\,\text{eV}$$

$$\text{SLAC} \quad 2\times10^{7}\,\frac{e^-}{\text{bunch}} \times 28\ \text{GeV} \approx 3\times10^{17}\,\text{eV}$$

Observations of microwave continuum emission from air shower plasma
Physical Review D **78**, 032007 (2008)



AMY COLLABORATION

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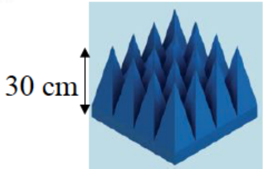
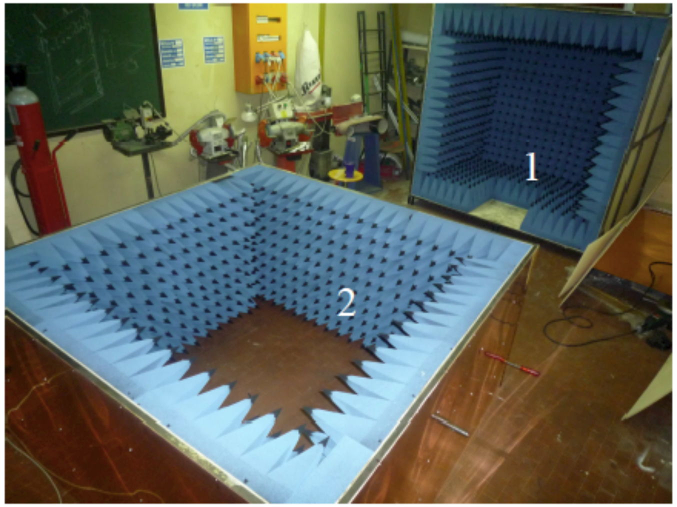
ANECHOIC FARADAY CHAMBER

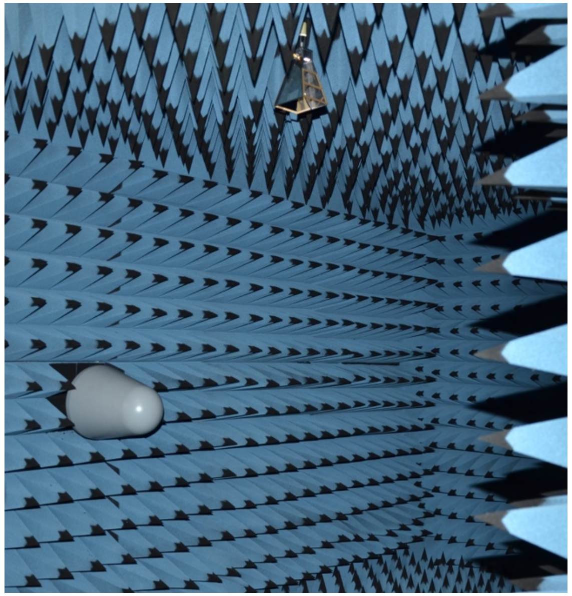
Three modules
(Tor Vergata university)

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



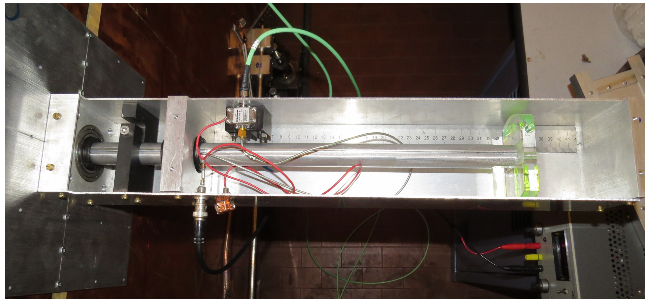


ANTENNA

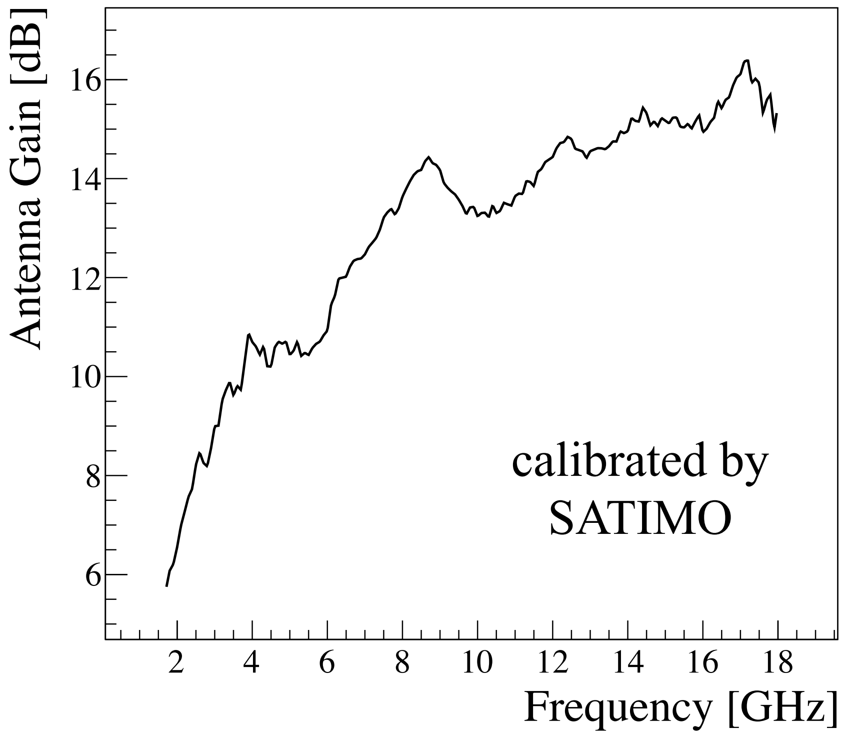


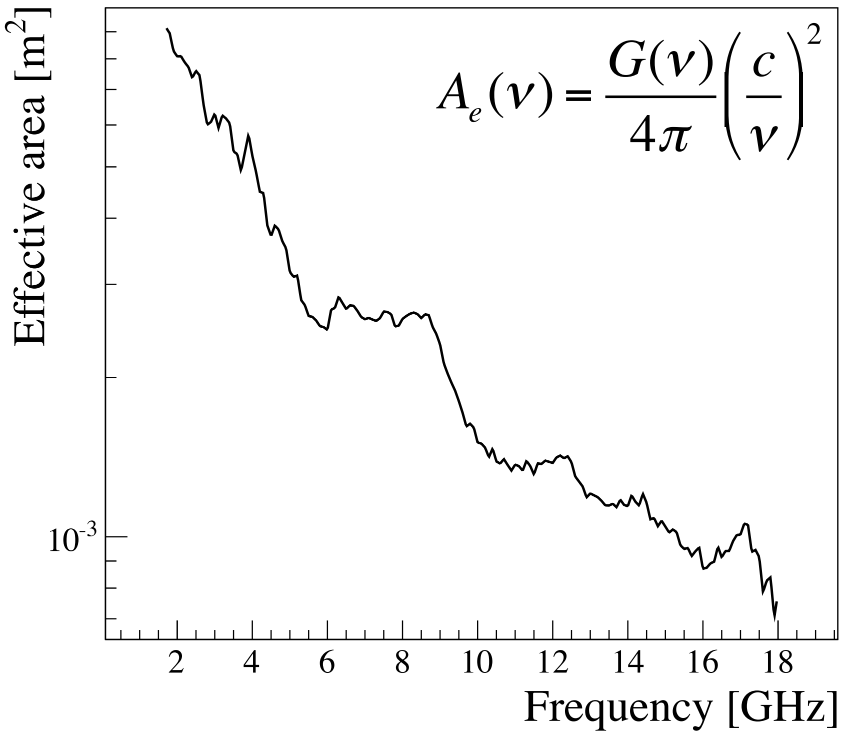
Horn RF Spin DRH20
1.7 - 20 GHz
Gain: from 6 to 16 dBi

Log Periodic
Rohde&Schwarz
HL050
0.25 - 26.5 GHz
Gain: ~ 8.5 dBi



- support external to chamber
- rotation of polarization plane



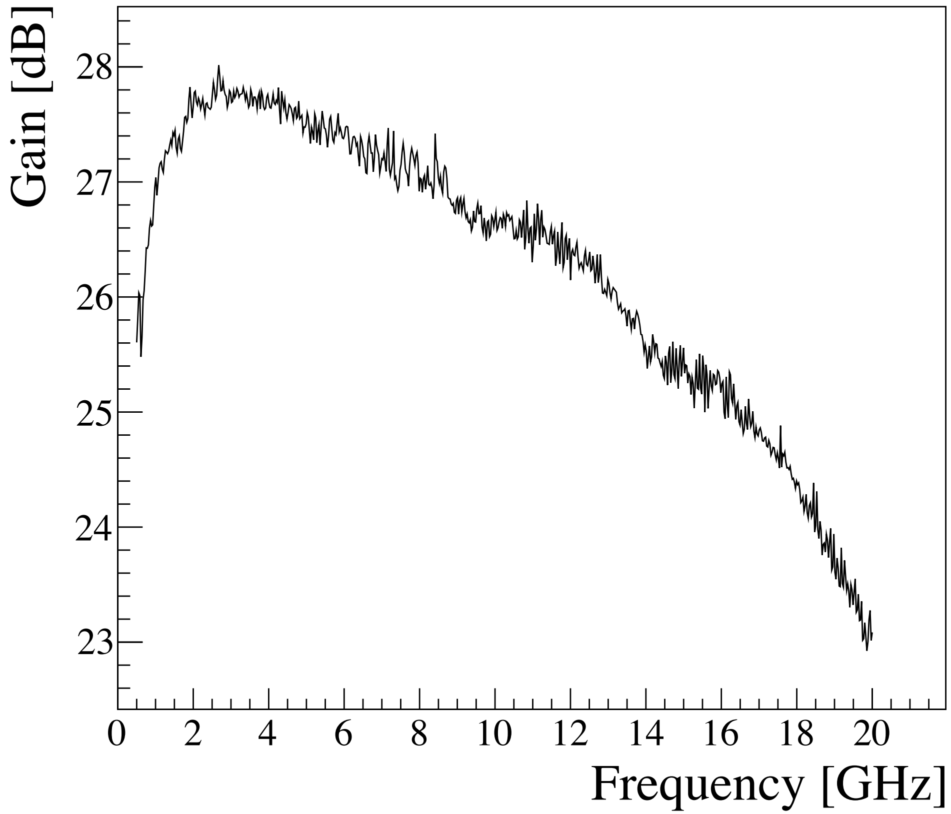


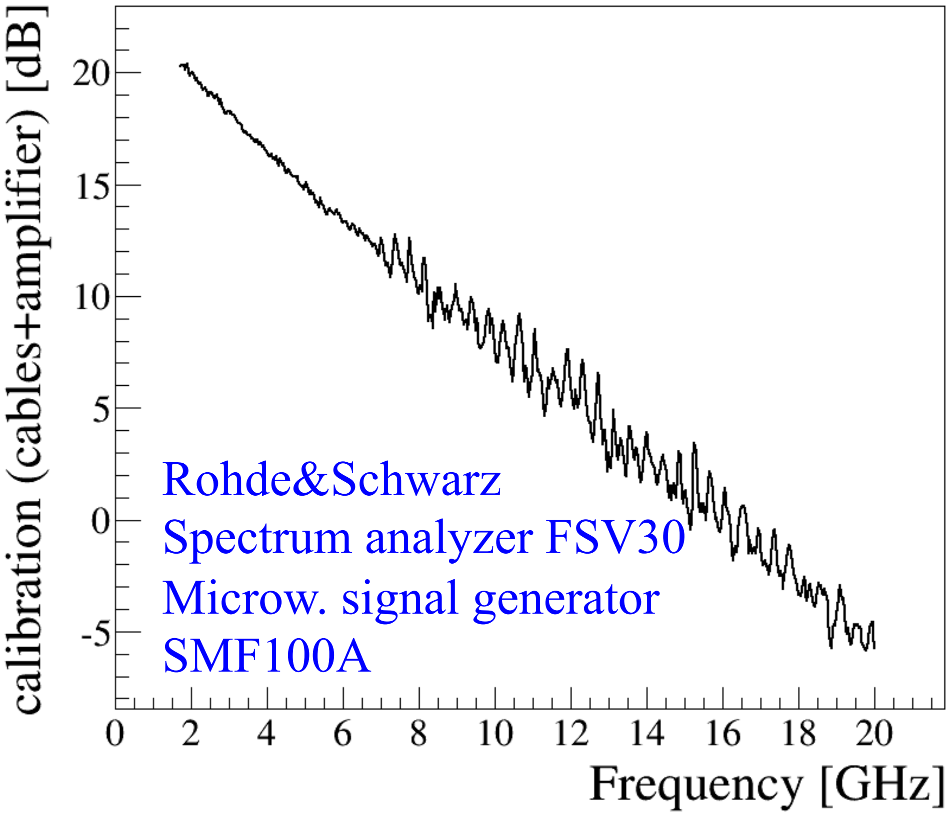
SETUP AT THE TEST BEAM

1m cable SMA MM — **amplifier SMA FF** — **18 m cable SMA MM** — **Oscilloscope (control room)**

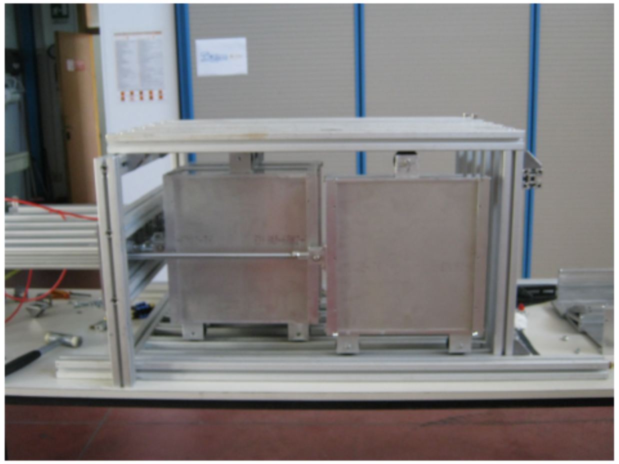
Mini-Circuits
ZVA-213-S+
Gain: ~ 26 dB

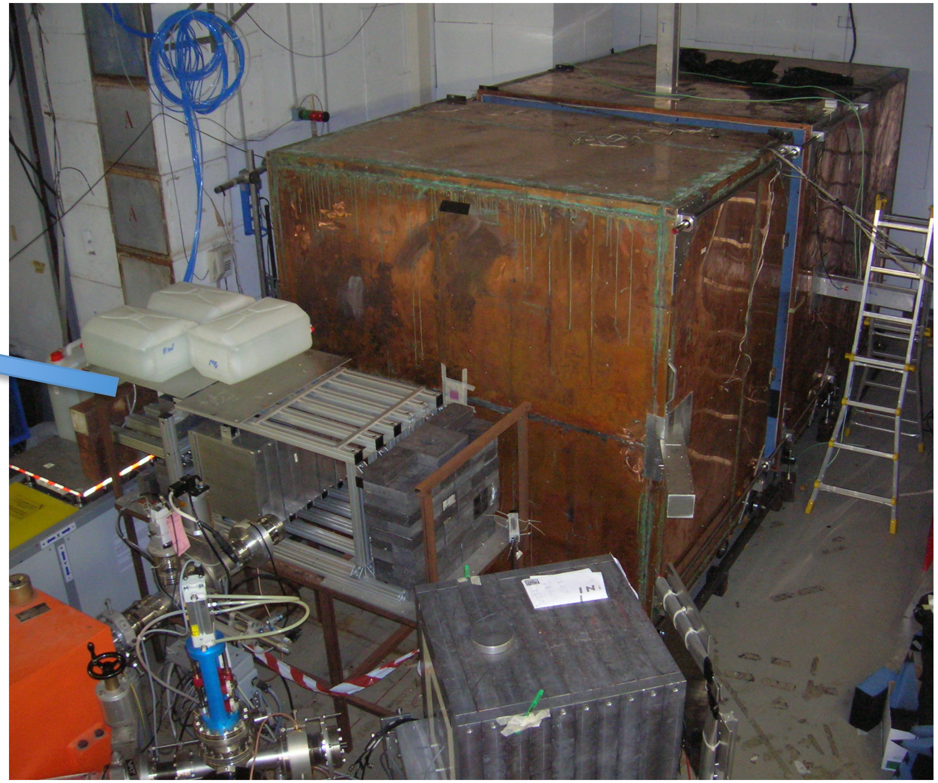
Lecroy SDA 830Zi-A
20 GHz real time bandwidth
4 ch. , 40 GS/s

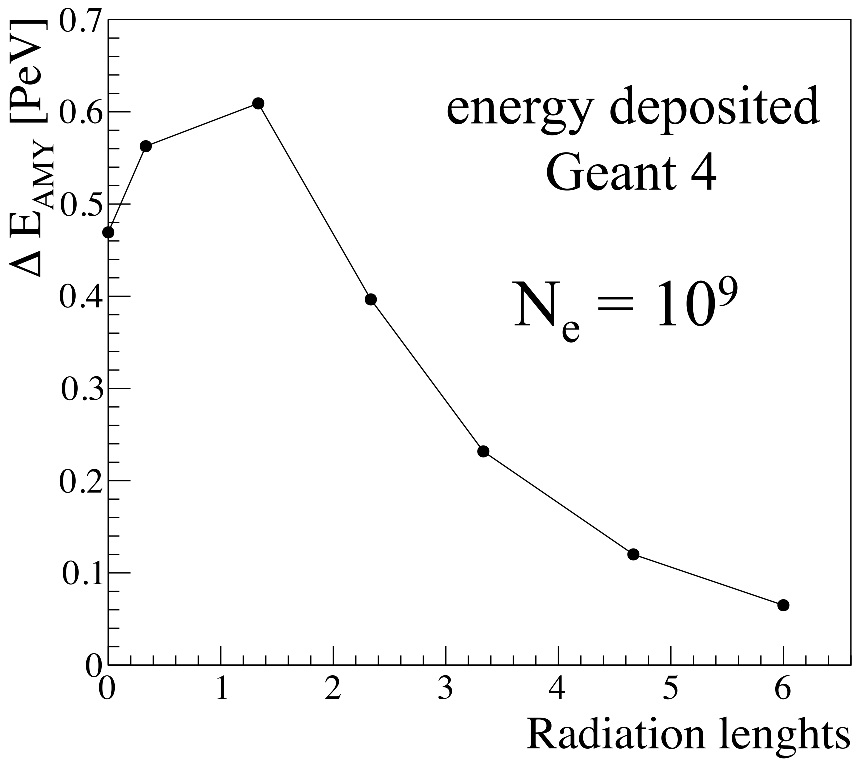




SETUP AT THE TEST BEAM







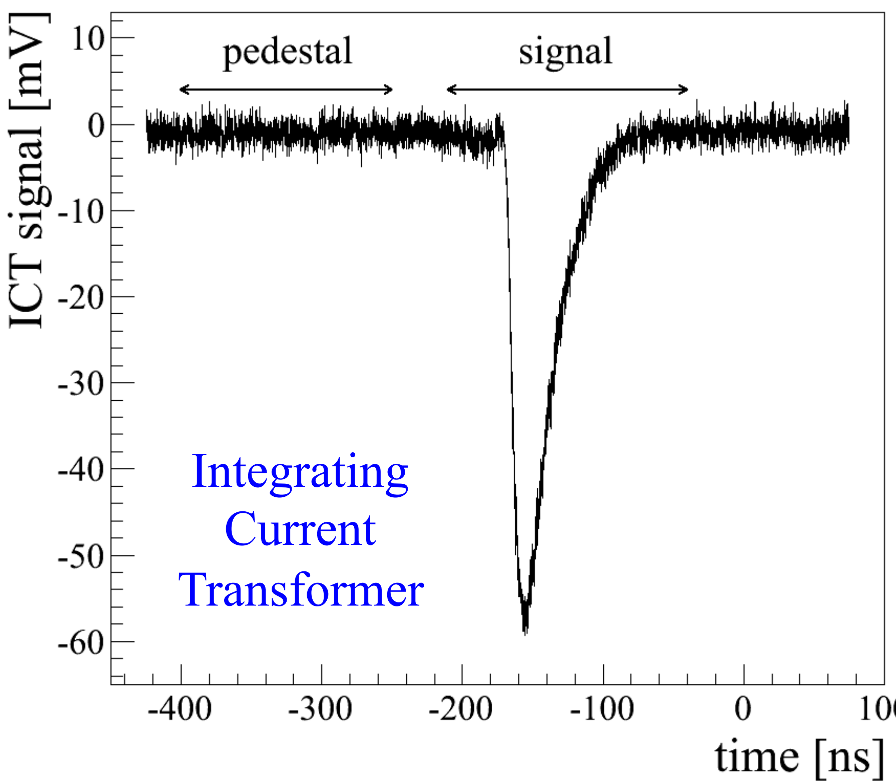
Al_2O_3 $X_0 \approx 7.5$ cm

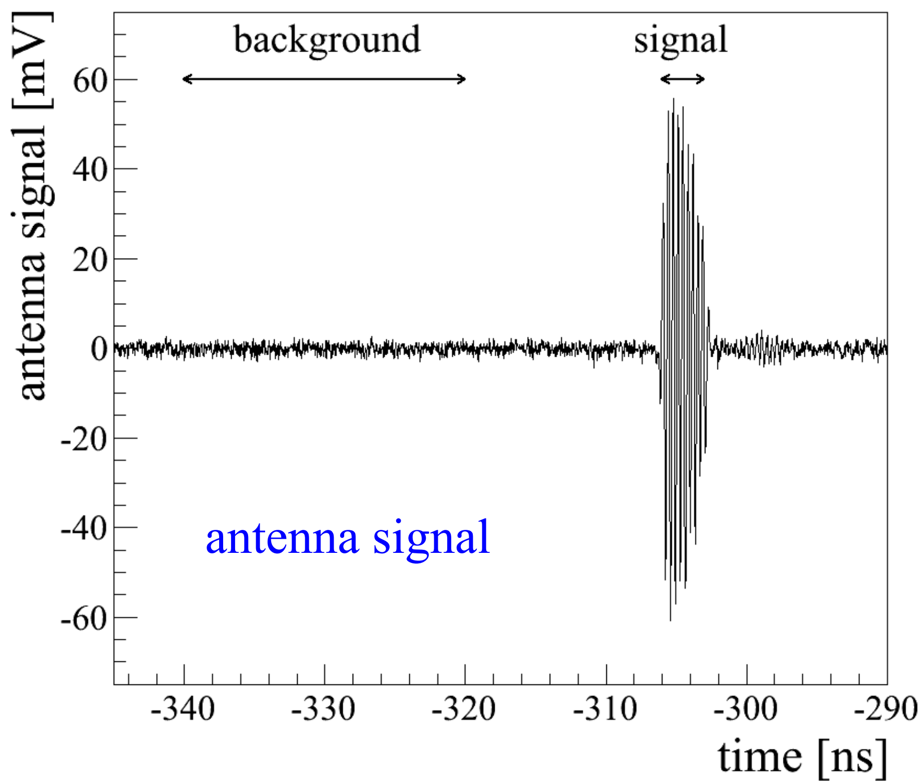
6 modules remotely controlled with compressed air system

SIGNAL DEFINITION

For each bunch

- trigger from LINAC
- acquire beam and antenna signals with the oscilloscope ($\Delta t = 25$ ps)





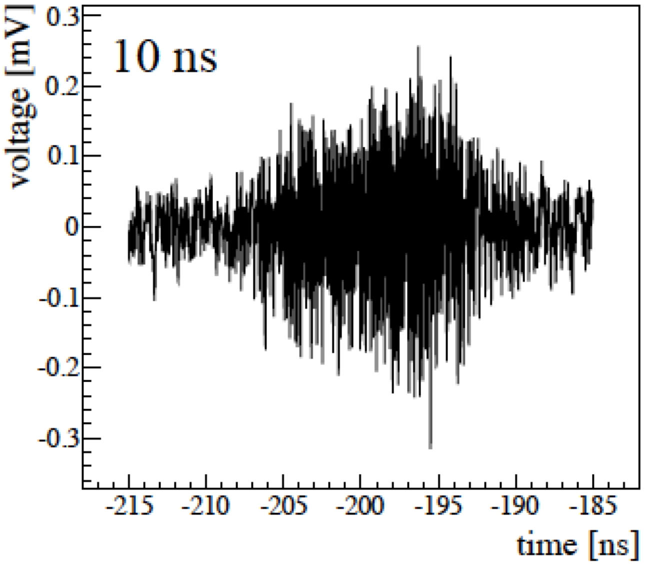
$$N_e \propto \int dt\, V(t)$$

$$\text{Power} = \frac{(V_{RMS}^{sgn})^2 - (V_{RMS}^{bkg})^2}{R}$$

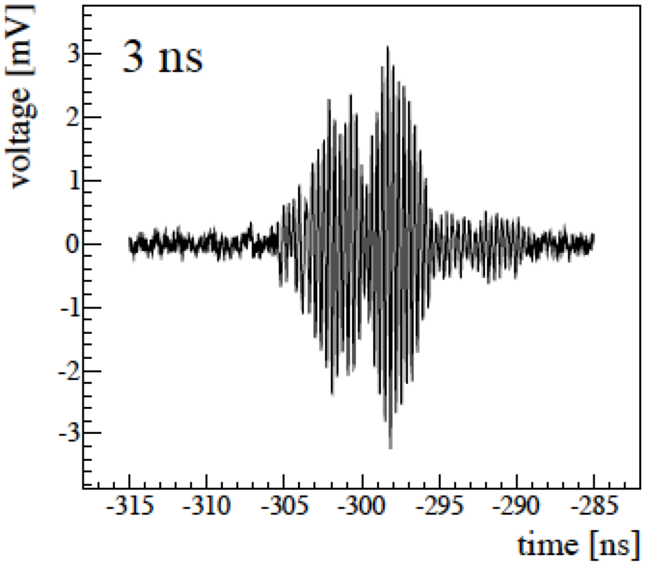
BUNCH LENGTH

three test beams

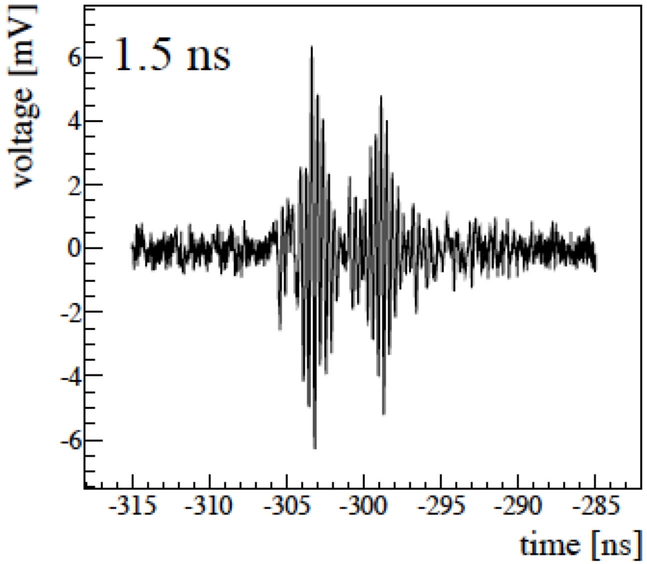
December 2011



May 2012

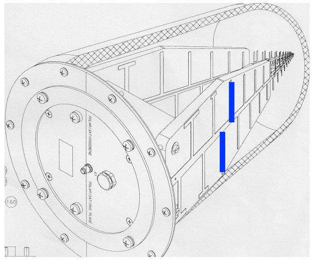


December 2012

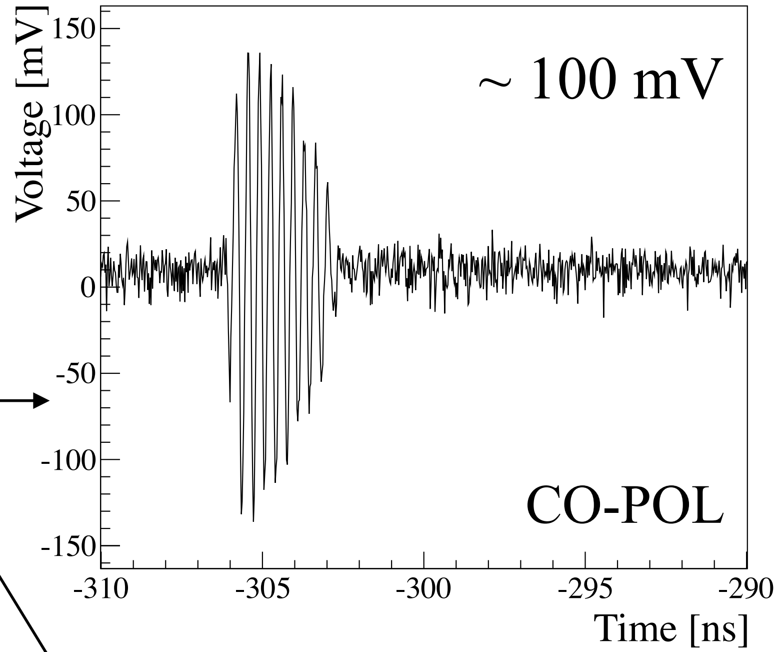


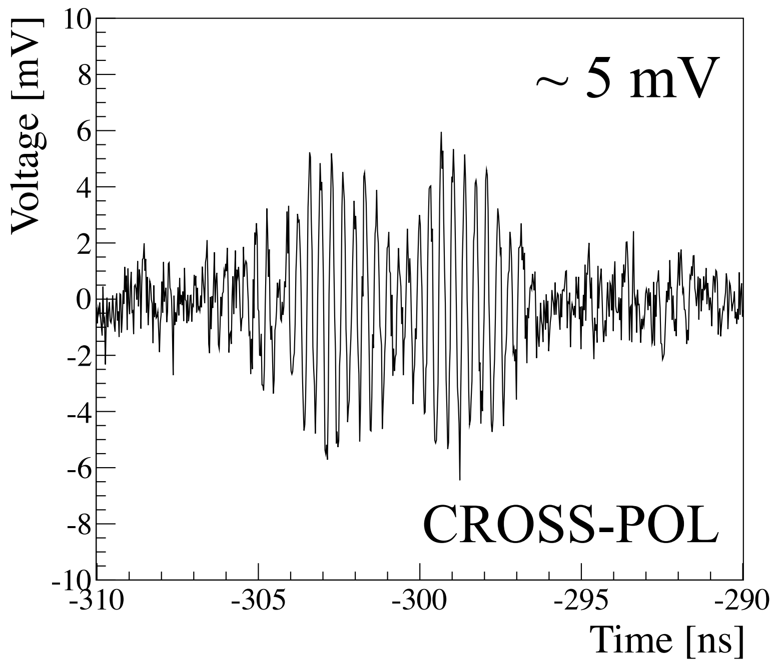
short bunch length reveals a particular signal time structure

CROSS/CO POLARIZATION



Cherenkov background reduced with dipoles perpendicular to beam axis





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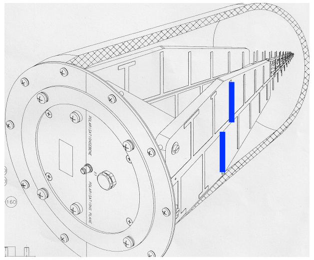

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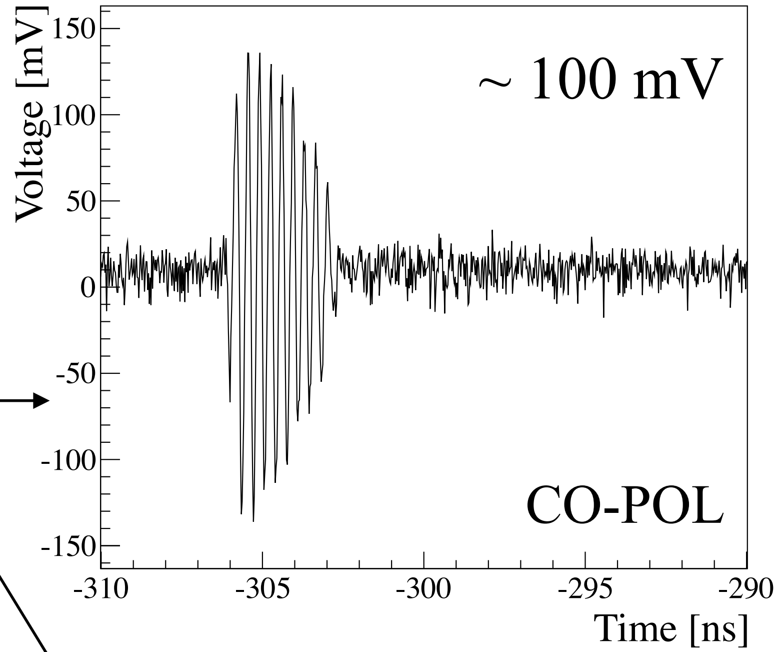
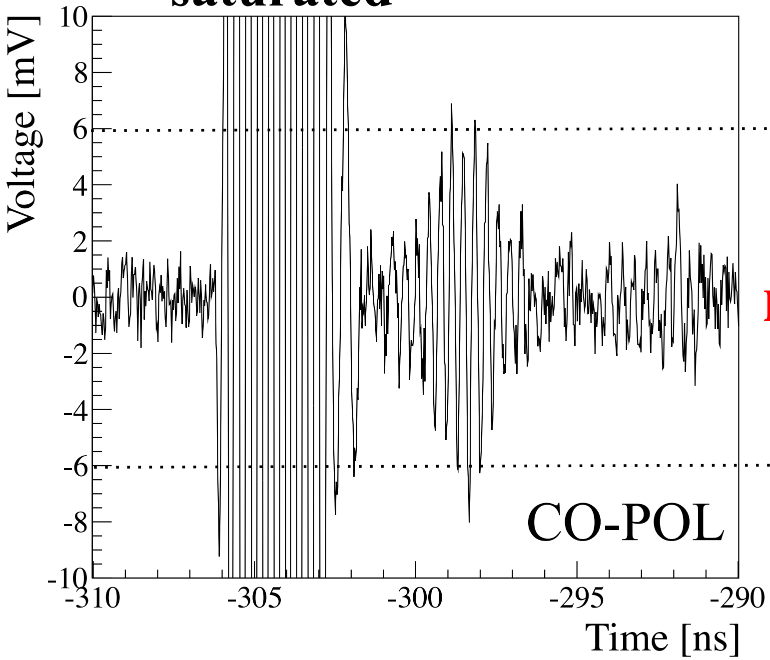
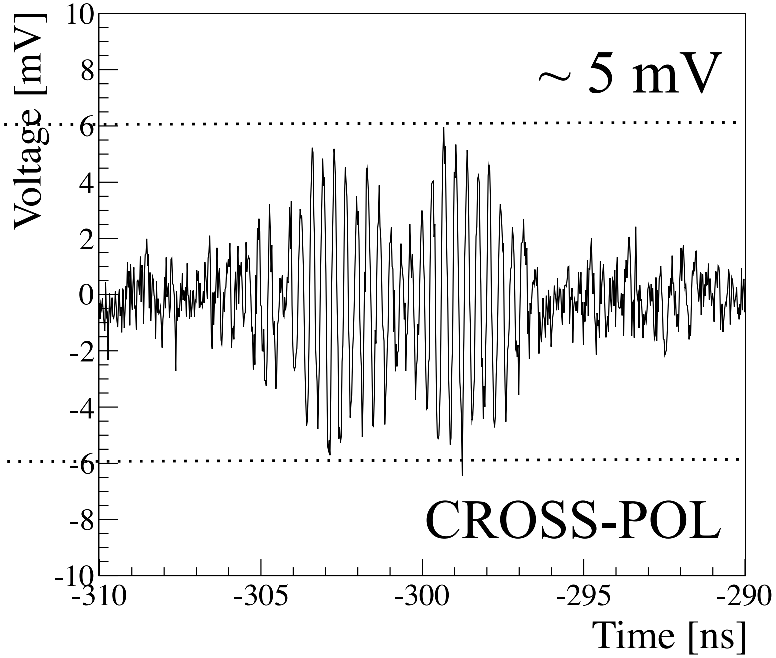


saturated



second peak non-polarized (MBR?)

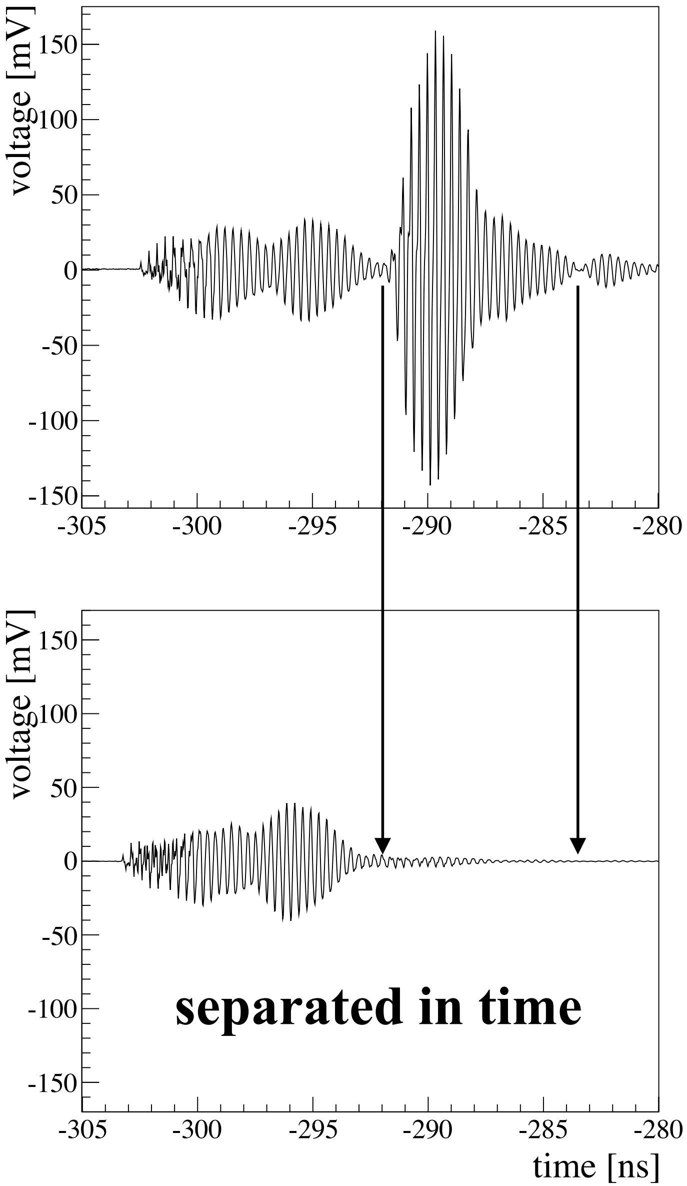


INTERPRETATION ?

Second peak seems not generated by reflections

- **in the chamber**
- **cables**
- **amplifier**
- **….**

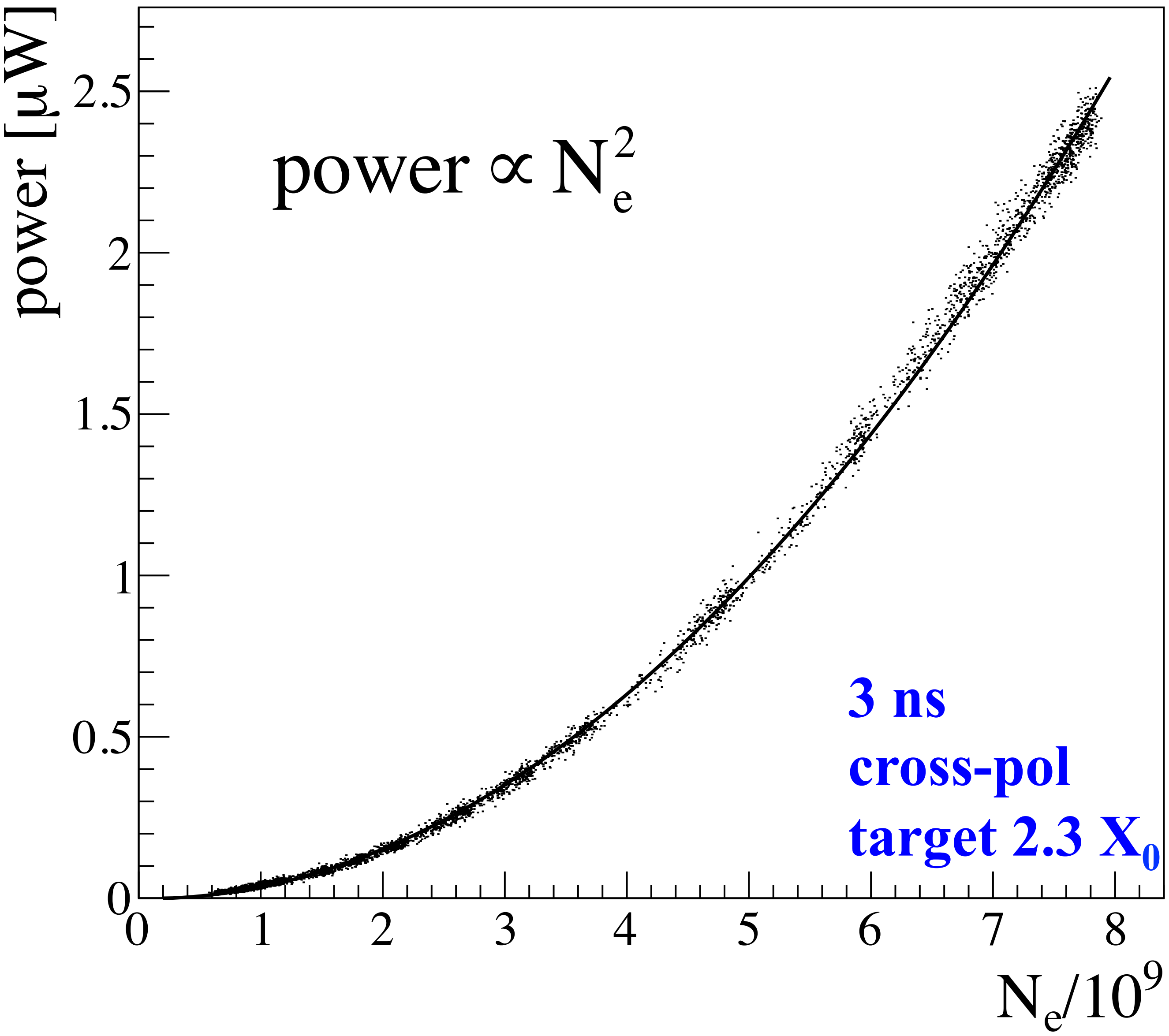
<u>**very difficult …**</u>



big reflections ***only*** with a metal plate centred at the end of the chamber

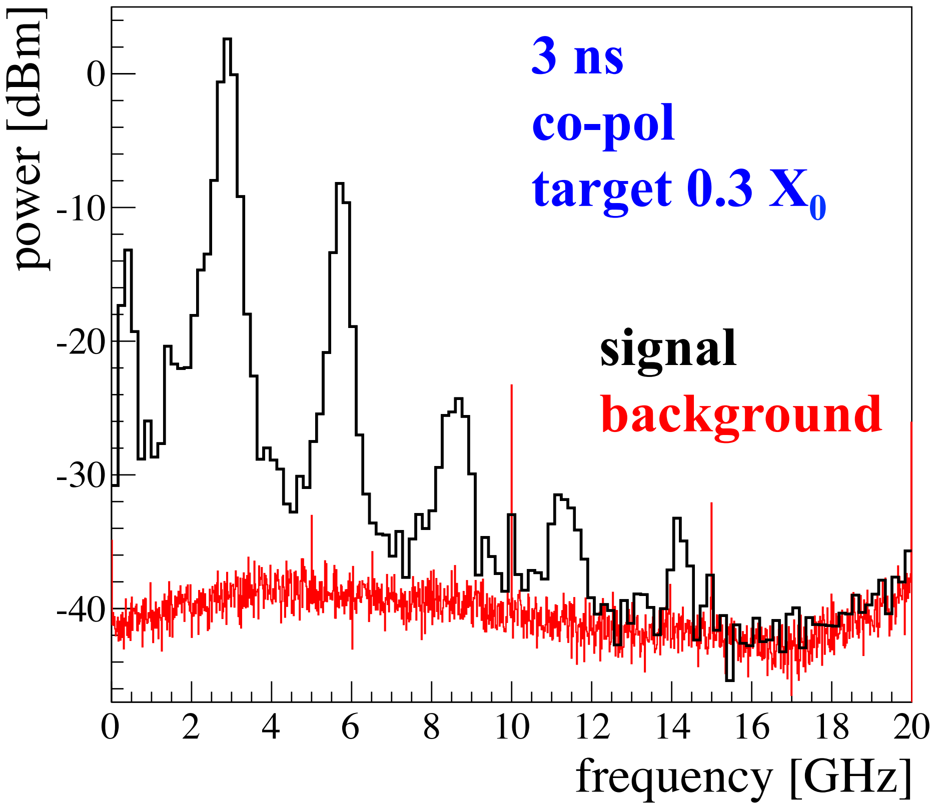
without reflector

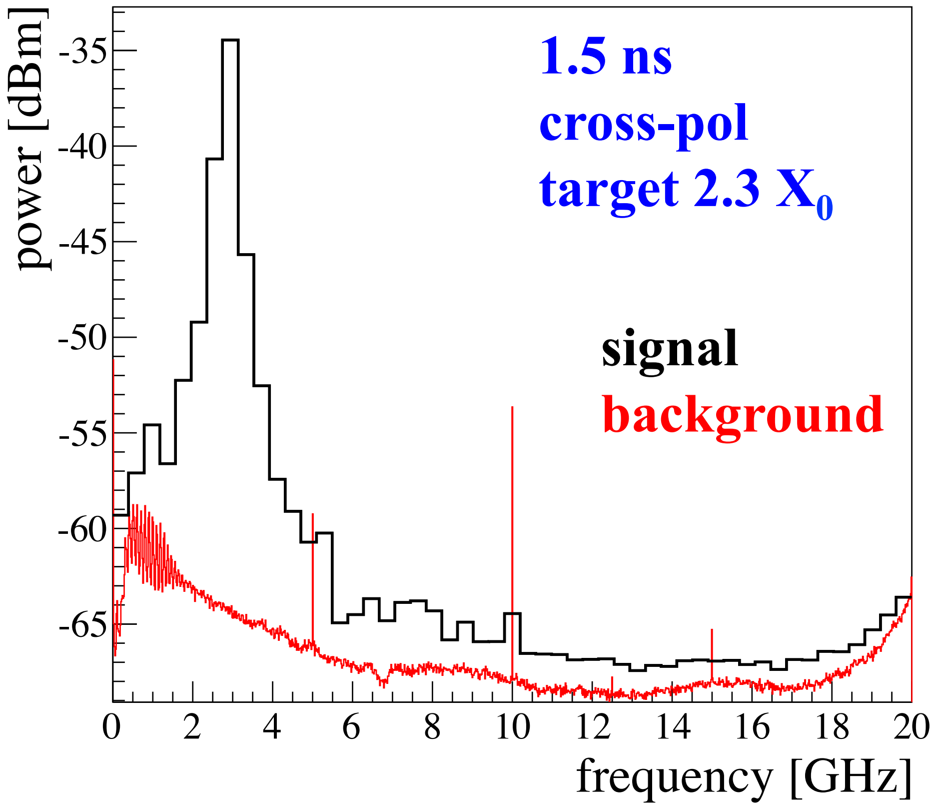
POWER vs BEAM INTENSITY



FREQUENCY SPECTRUM

FFT of oscilloscope traces (average over many triggers)

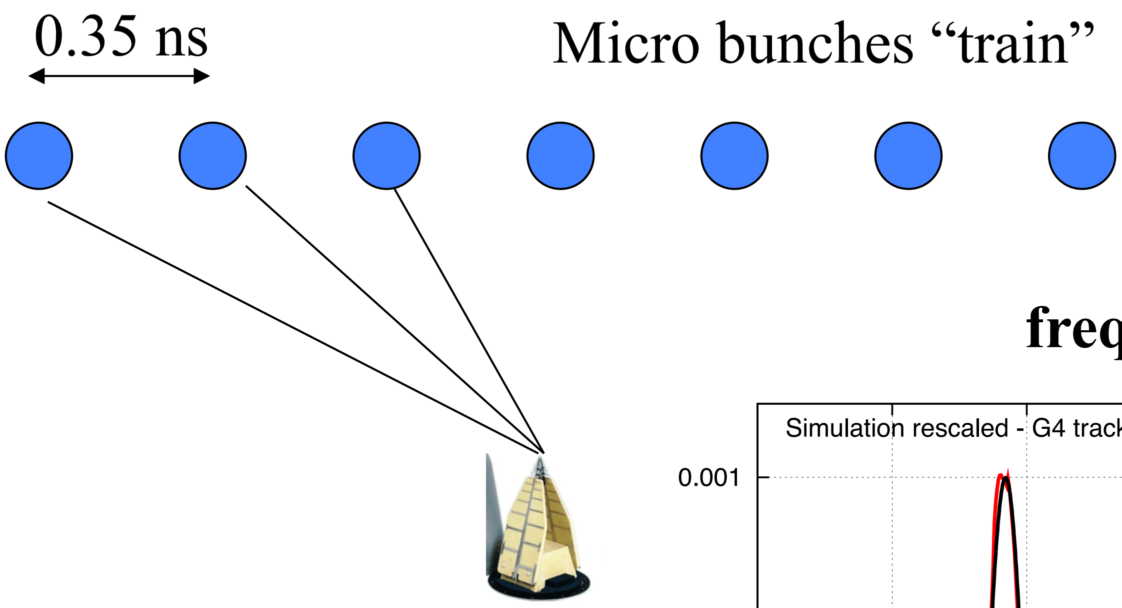




main line at f_{LINAC} = 2.85 GHz

for small thickness of the target (higher signals) harmonics at multiples of f_{LINAC}

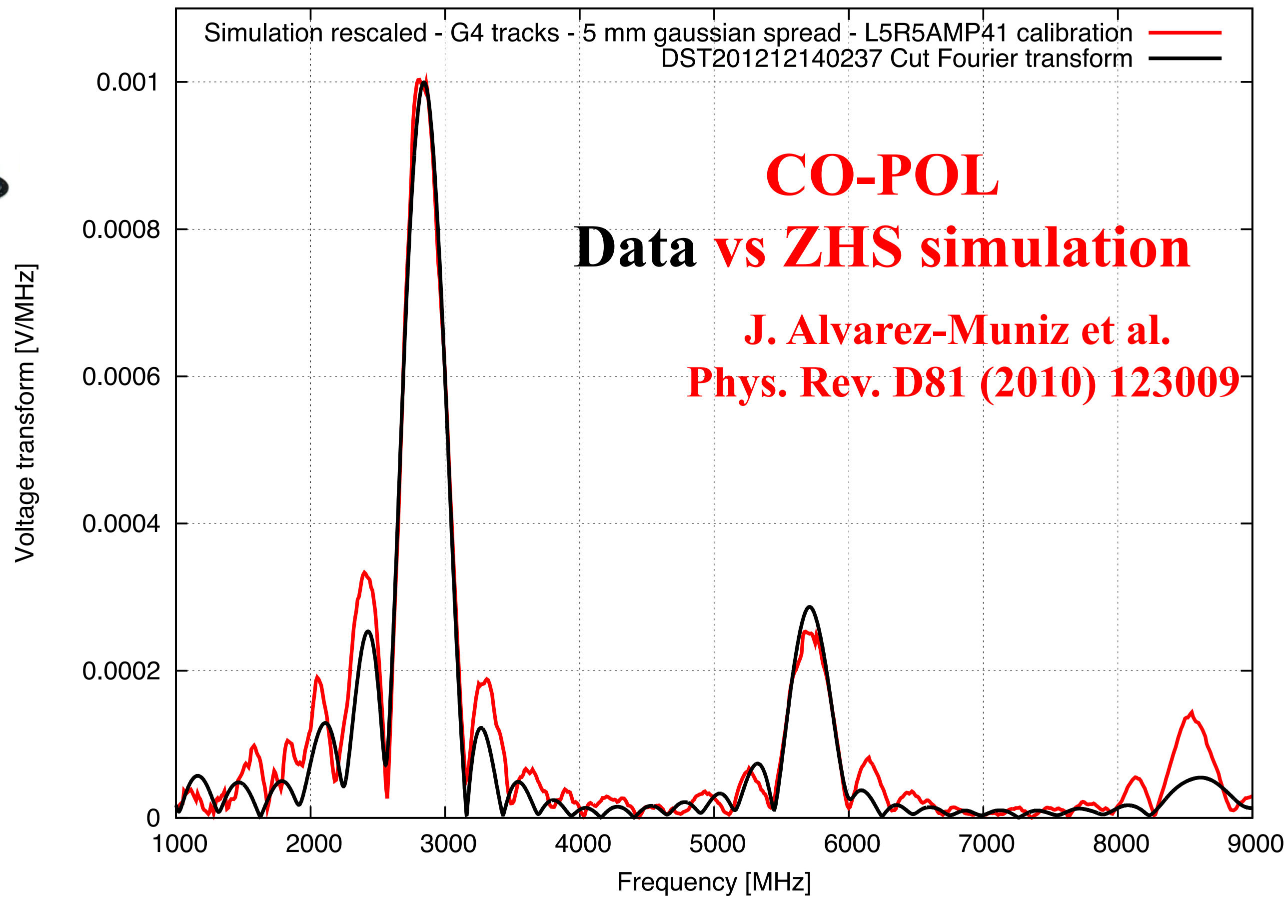
FREQUENCY SPECTRUM



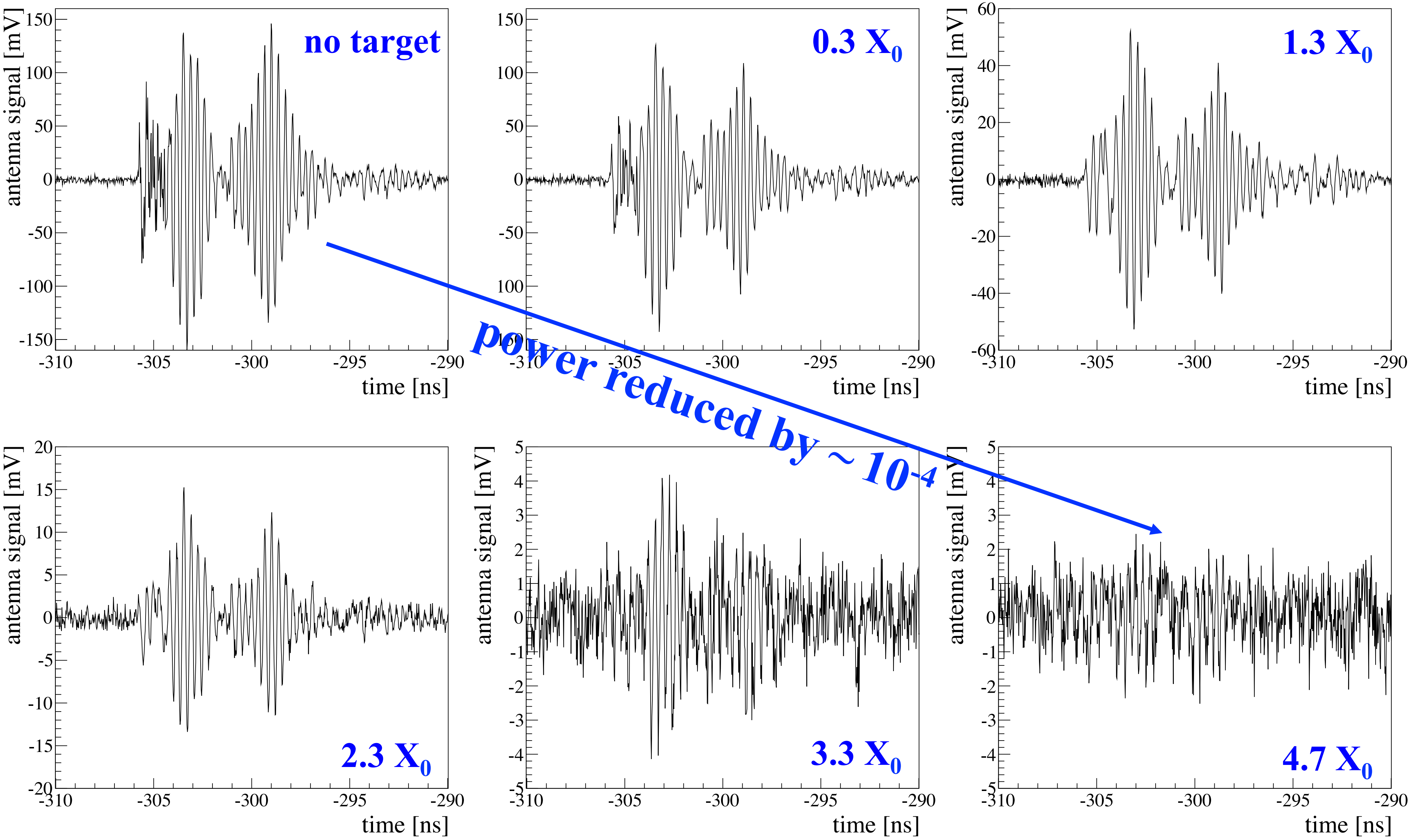
simulation of Cherenkov radiation

interference peaks at the LINAC harmonics

frequency spectrum



SIGNAL vs TARGET TICKNESS

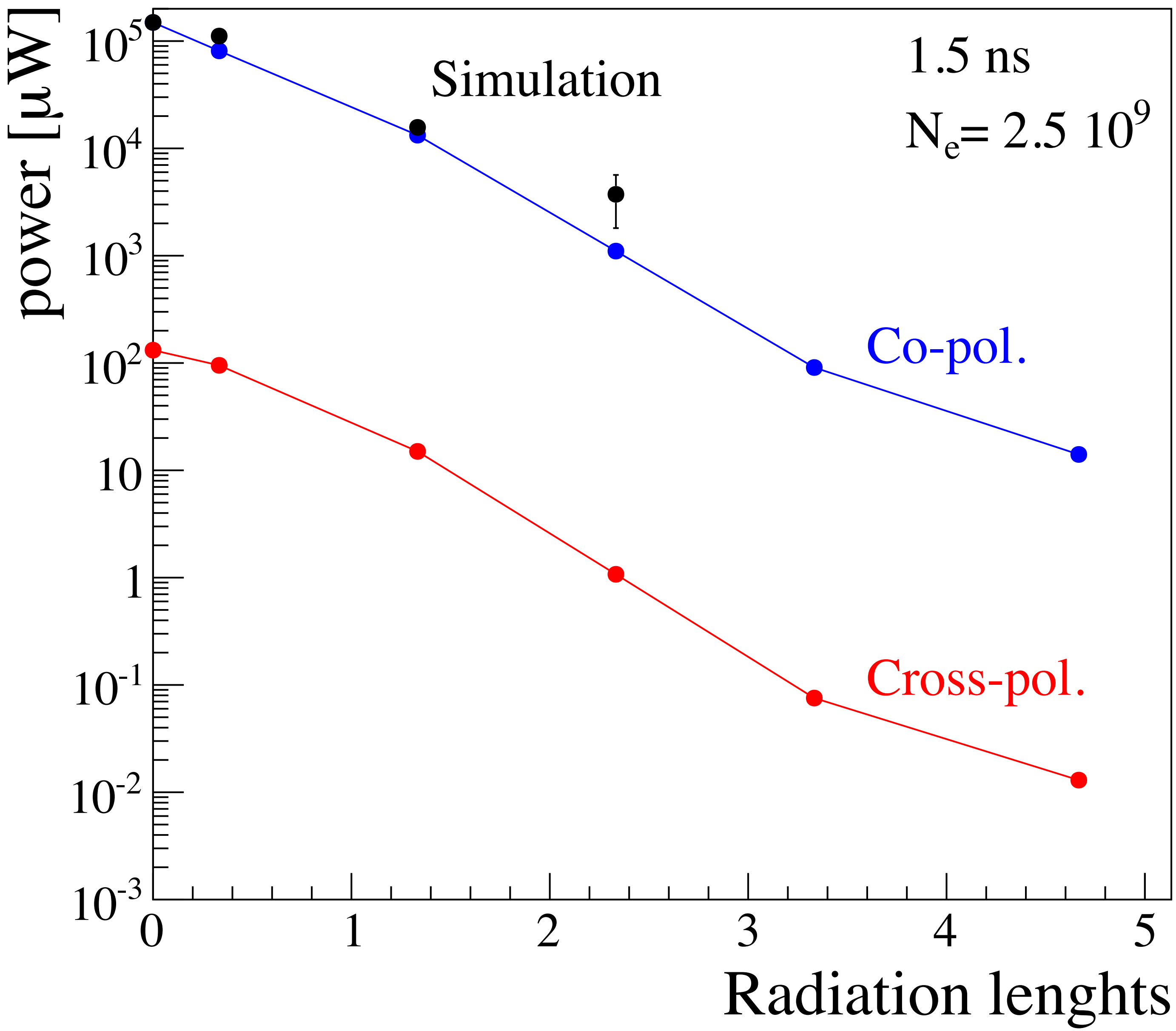


SIGNAL vs TARGET TICKNESS

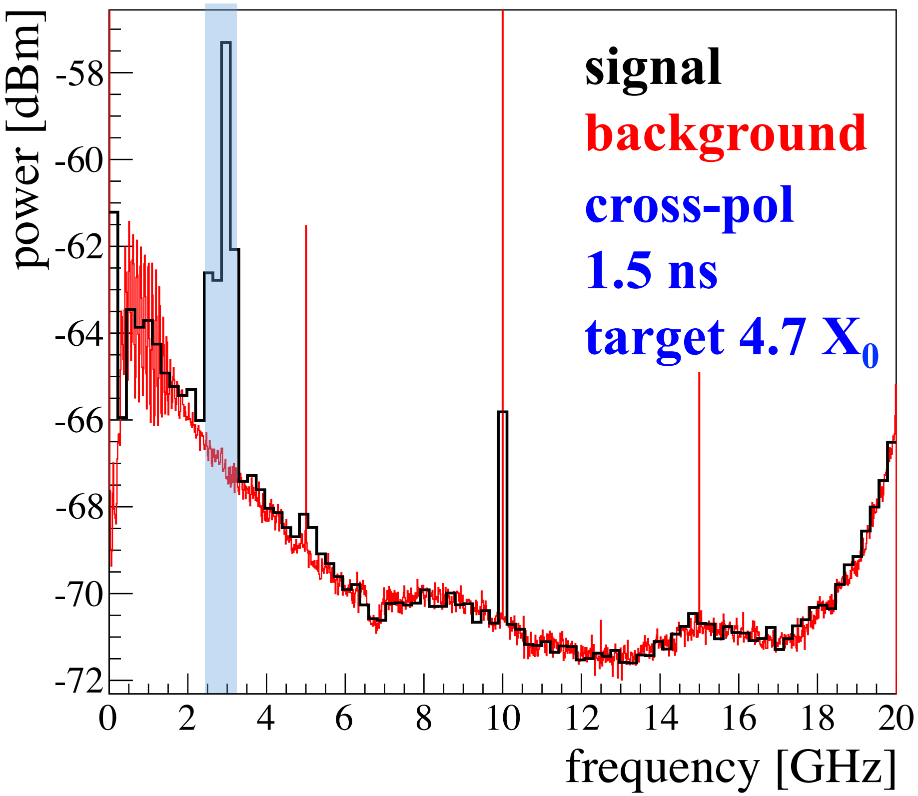
Cross-pol
very similar
to Co-pol

coherence partially destroyed by the target

confirmed by Cherenkov simulation
(preliminary)



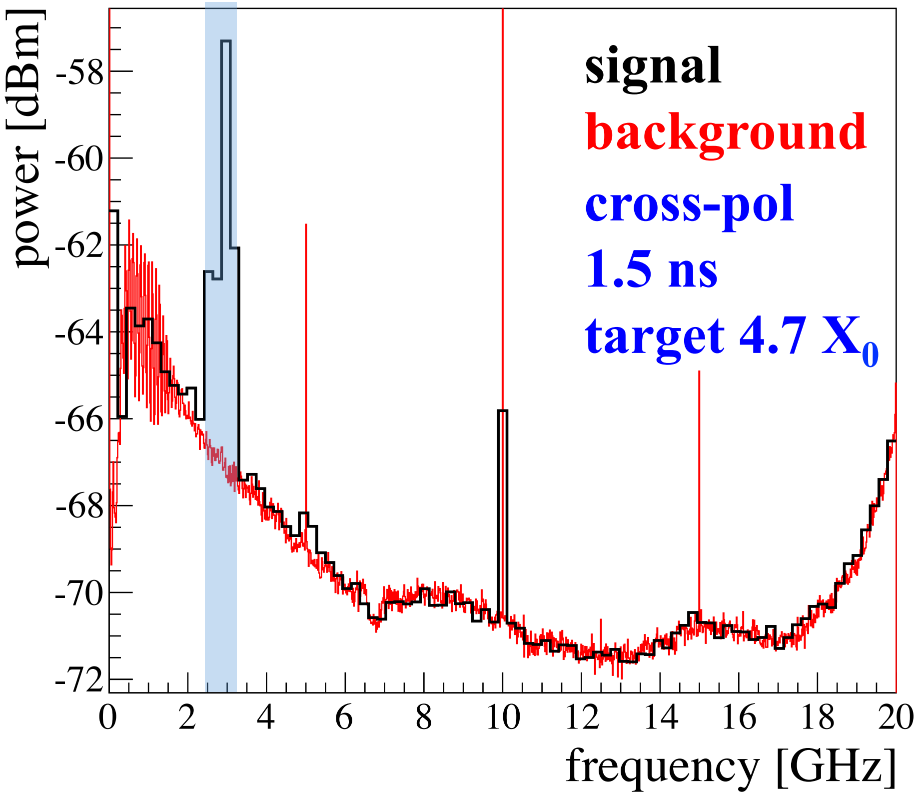
CROSS-POL SIGNAL WITH 4.7 X_0

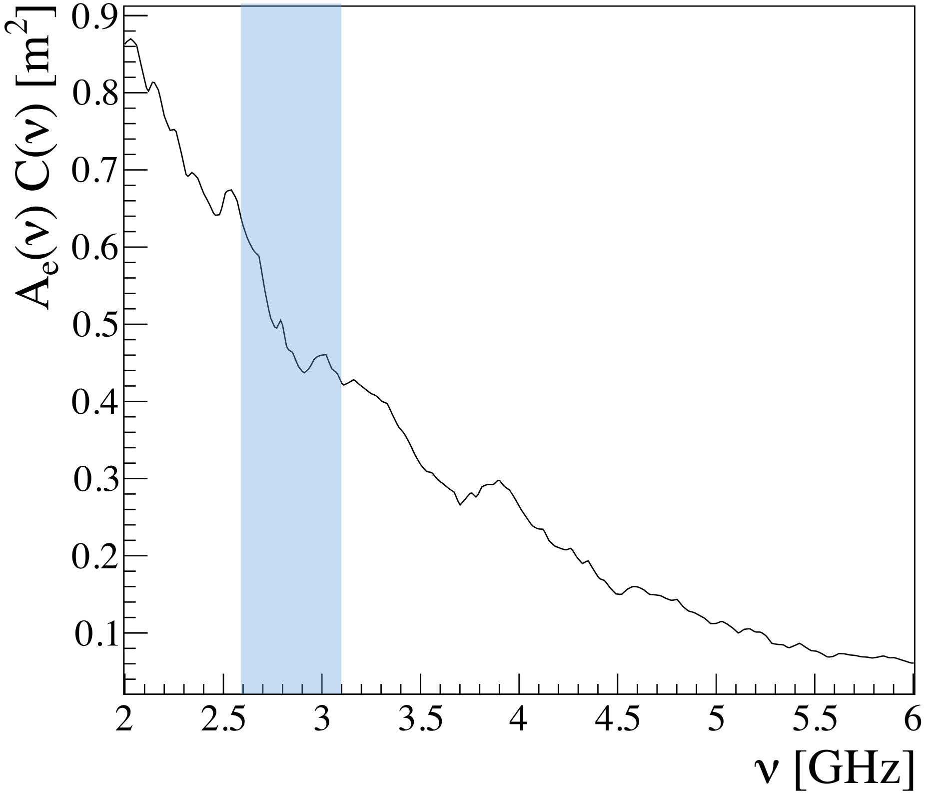


strong coherence induced by the LINAC even with maximum target thickness

- **If MBR, in atmospheric showers the yield should be lower**
- **Density flux ($W/m^2/Hz$) ?**

CROSS-POL SIGNAL WITH 4.7 X_0





$$P(\nu_1,\nu_2) = \int_{\nu_1}^{\nu_2} d\nu\, I(\nu)\, A_e(\nu)\, C(\nu)$$

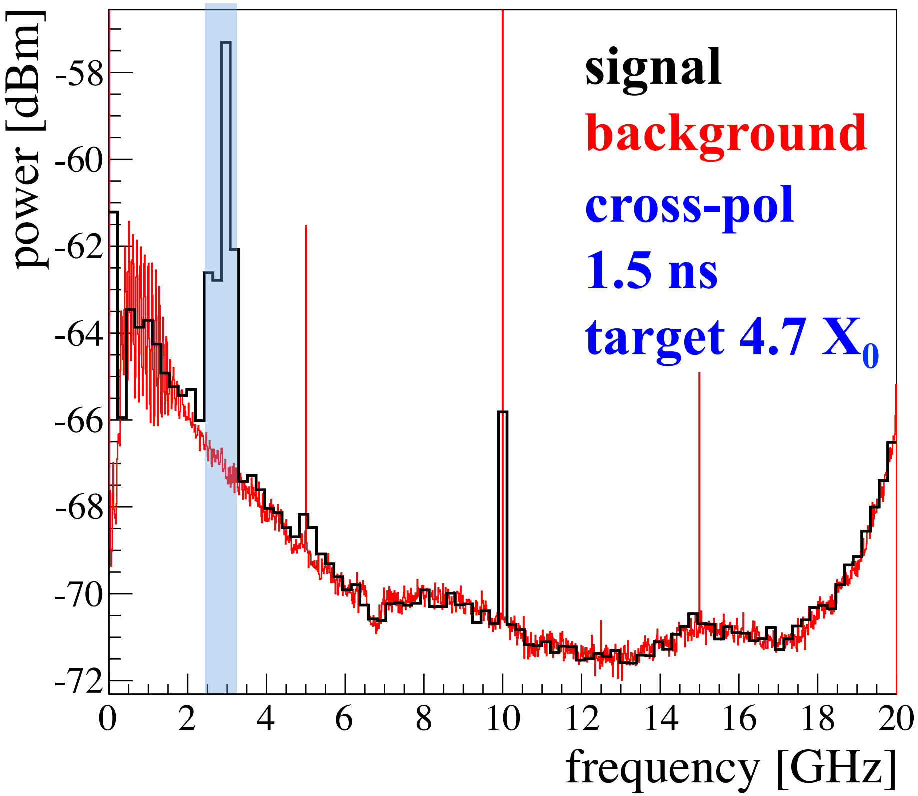
density flux — antenna effective area — calibration cables+amplifier

$$I_{meas} \approx \frac{P_{meas}}{\Delta\nu\, A_e(\nu_L)\, C(\nu_l)}$$

$$\nu_L = 2.86\ GHz$$

$$\Delta\nu \sim 0.5\ \mathrm{GHz}$$

CROSS-POL SIGNAL WITH 4.7 X_0



$$P_{meas} \approx 10 \text{ nW}$$

$$I_{meas} \sim 5 \cdot 10^{-17} \frac{\text{W}}{\text{m}^2\text{Hz}}$$

$I_{meas} < 4\ 10^{-16}$ W/m²/Hz
Physical Review D **78**, 032007 (2008)

$$P(\nu_1, \nu_2) = \int_{\nu_1}^{\nu_2} d\nu\ I(\nu)\ A_e(\nu)\ C(\nu)$$

density flux — antenna effective area — calibration cables+amplifier

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$$\nu_L = 2.86\ GHz$$

$$\Delta\nu \sim 0.5 \text{ GHz}$$

OUTLOOK

- **AMY: three successful tests at the BTF**
- **not clear interpretation of the cross-pol signal**
  Cherenkov, MBR, ..?
- **strong coherence induced by the LINAC**
  → if MBR, in atmospheric showers the yield should be lower
- **density flux (at 4.7 X_0) ~ 5 x 10^{-17} $W/m^2/Hz$**
- **other test beam in Dec 2014: increase the sensitivity between LINAC peaks**
  (hardware in narrower bands → 60 db amplifiers)

END

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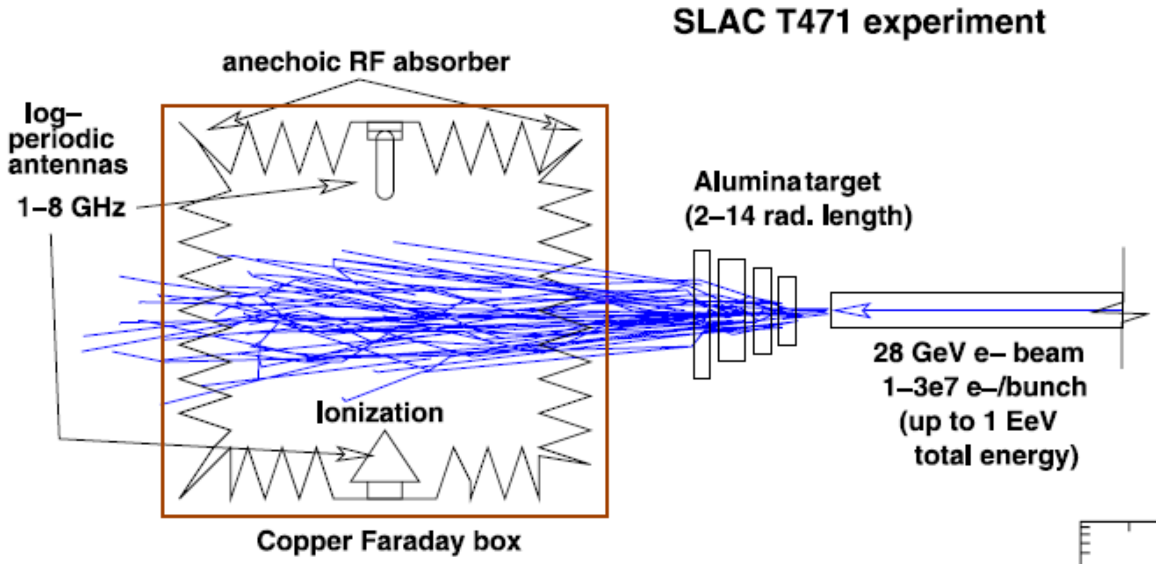
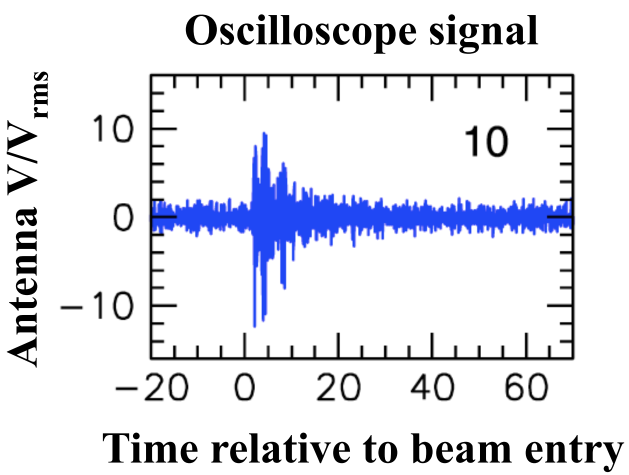
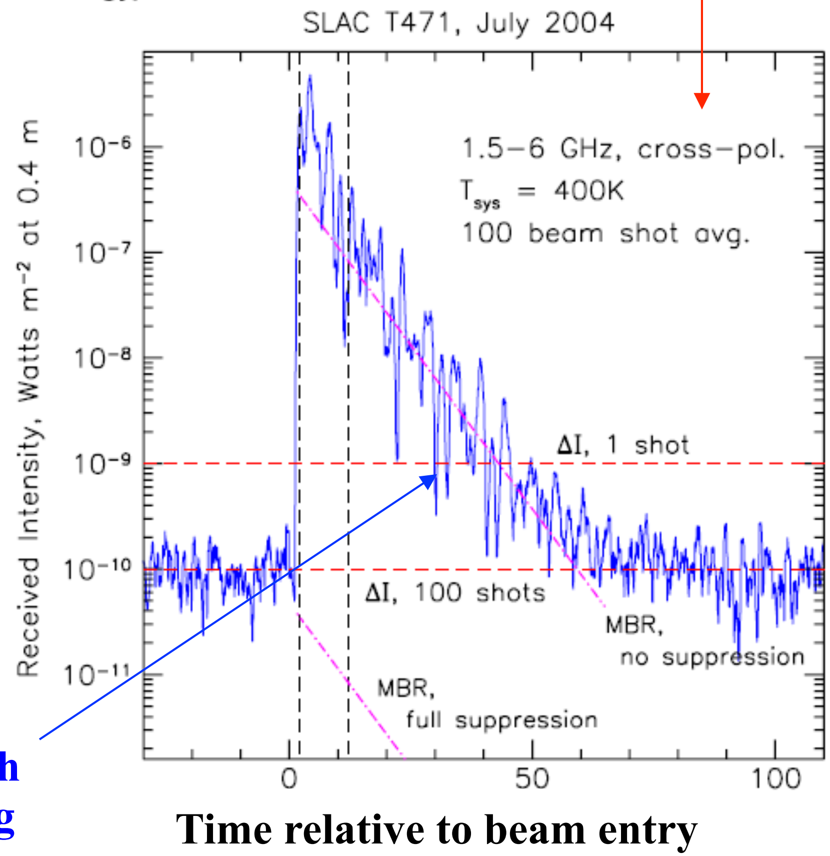


Insensitive to cherenkov radiation



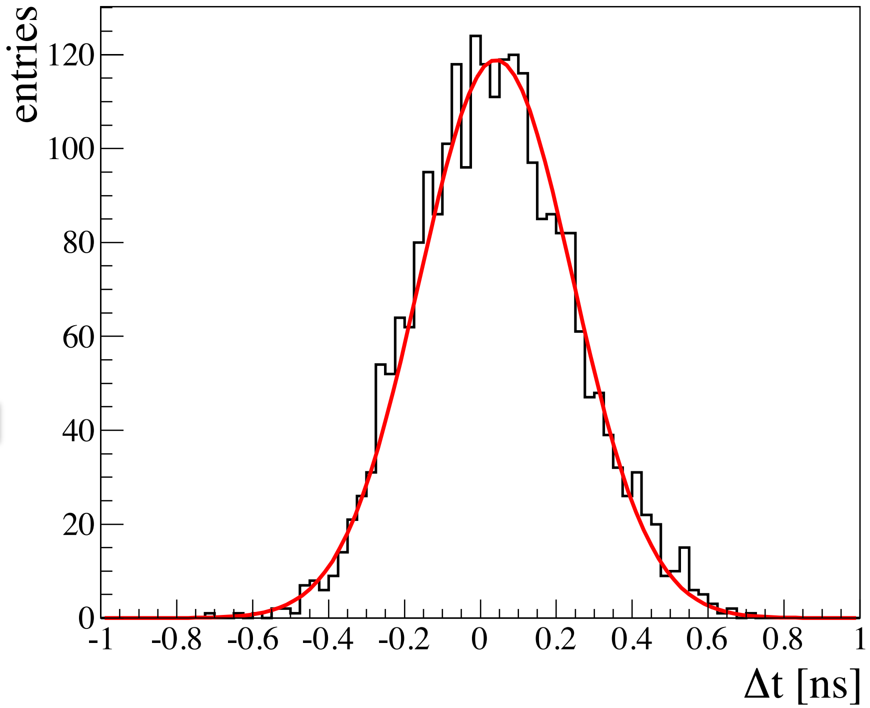


7 ns decay constant, compatible with plasma cooling

TRIGGER JITTER

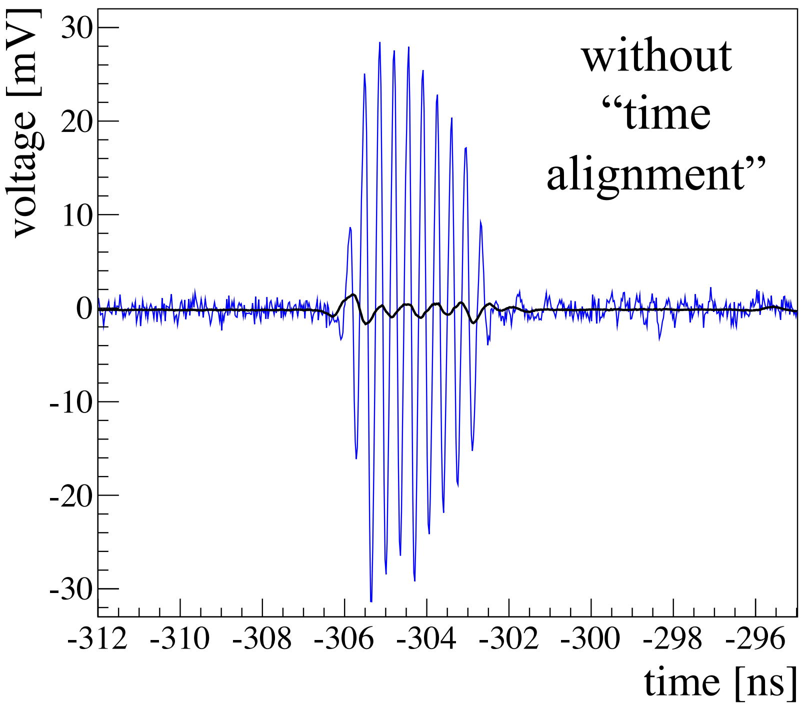
Evaluate the time shift between different triggers comparing the shape of the signals

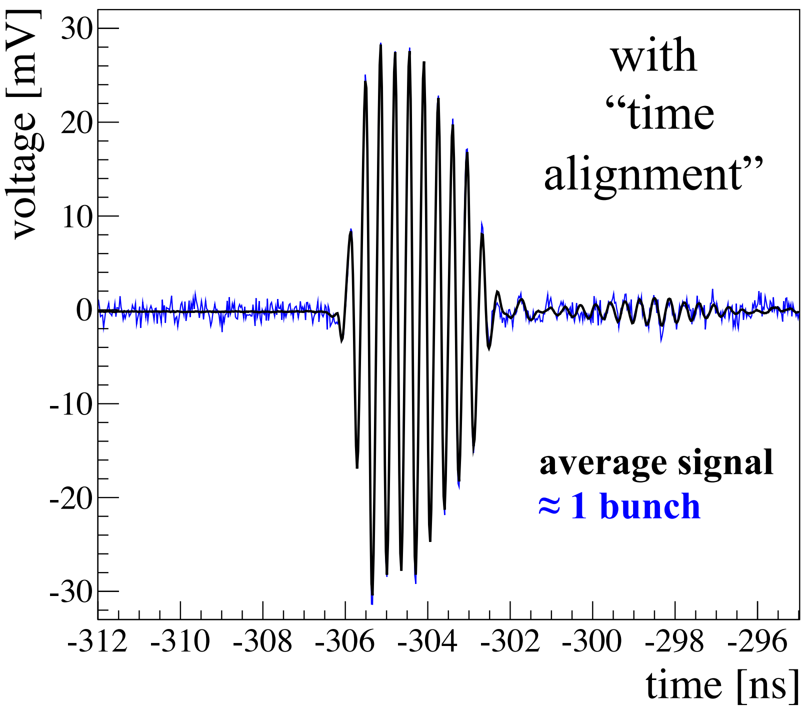
$\sigma_{\Delta t} \sim 0.2$ ns



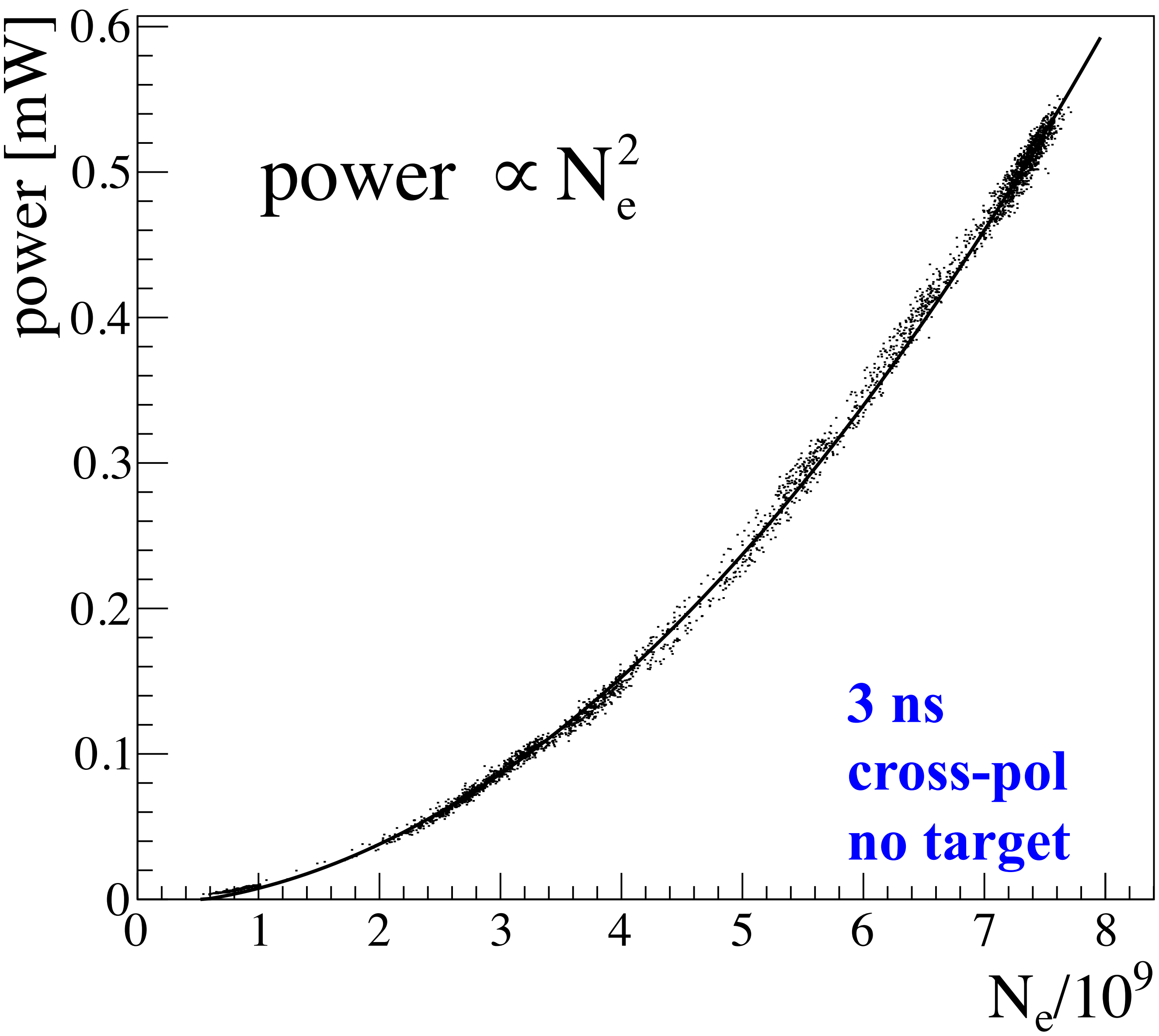
signal for 1 bunch

signal averaged over many triggers





POWER vs BEAM INTENSITY



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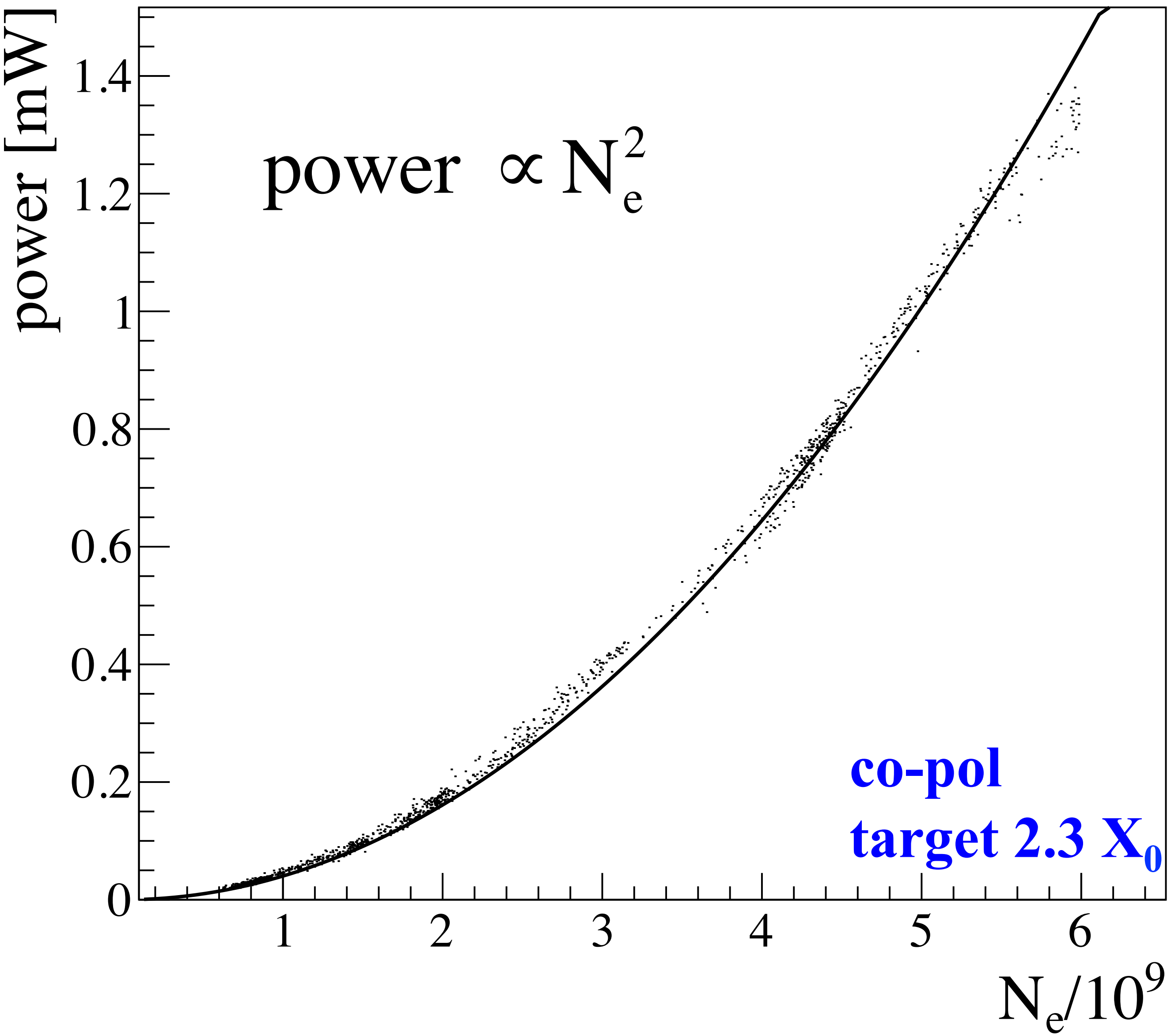
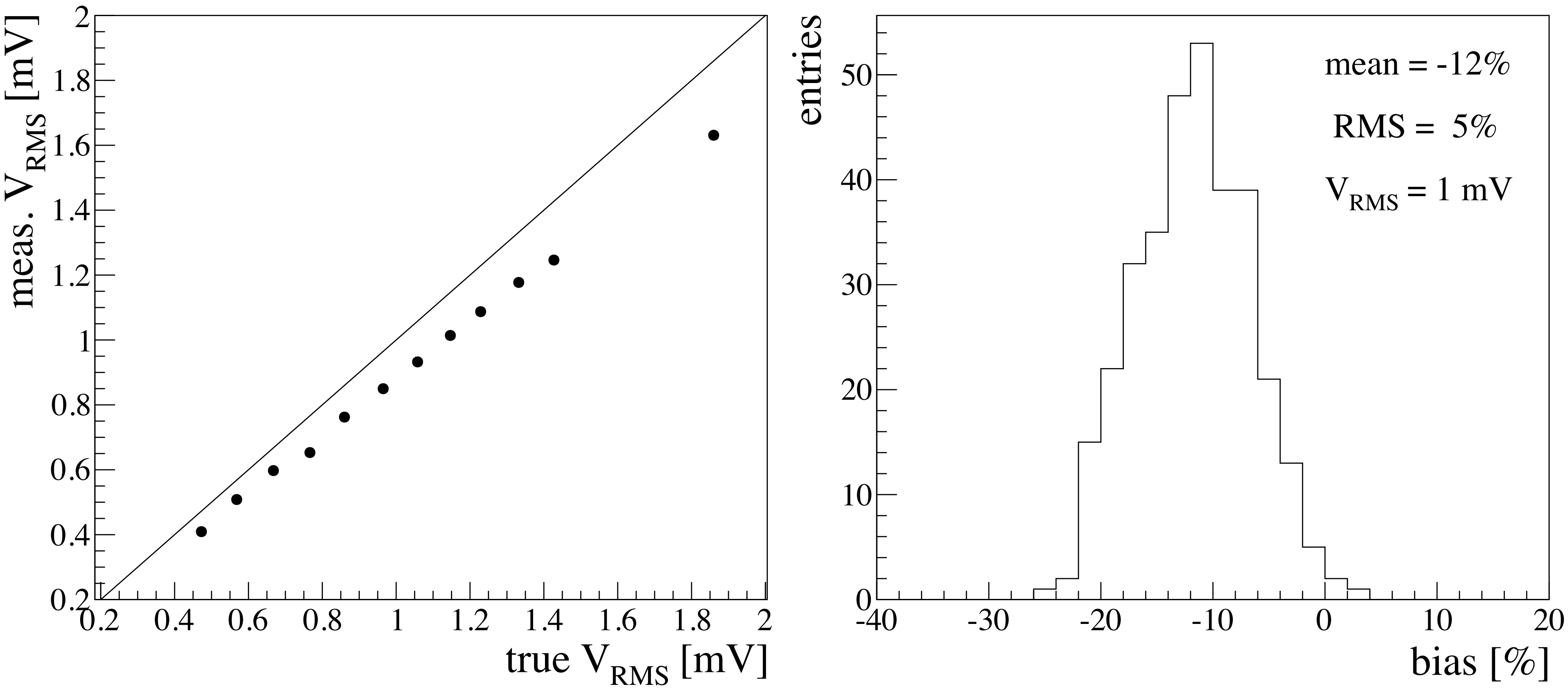


OSCILLOSCOPE SENSITIVITY



oscilloscope sensitivity guaranteed above 10 mV

at 1 mV: V_{RMS} bias ~ -12% (-24% in power)