EM signals generated by high-energy showers

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Contents

Initial Motivation:

If Askaryan radiation could be used at accelerators

- **Askaryan effect**
- **Observation / Properties**
- **Astro-particle applications**
- **Possible use in diagnostics**

More intense source of radiation in the shower

- **Shower charge variation**
- **Transverse Field**
- **Axial Radiation**

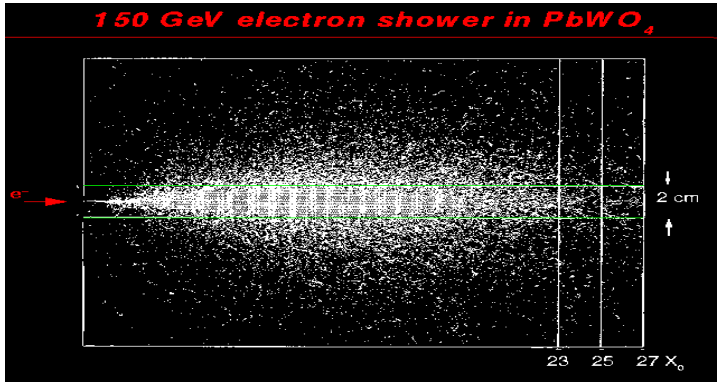
Is there radiation at all?

- **Monopole in a Medium**
- **Reactive Fields**

Explore Near Field of Shower !

- **A New Class of Detectors**

Askaryan effect



Electromagnetic Showers have about 20-30% negative charge excess.

When moving in a proper medium this macro-charge radiates RF waves.

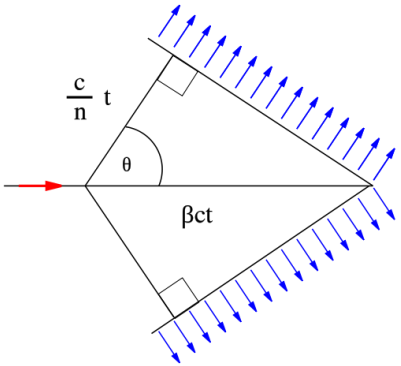
Superposition of N single charge Cherenkov radiators:

For dense materials $R_{Moliere}$ ~ few cm

$\lambda << R_{Moliere}$ (optical waves) random phases $\Rightarrow P \propto N$

$\lambda >> R_{Moliere}$ (microwaves) coherent $\Rightarrow P \propto N^2$

Properties

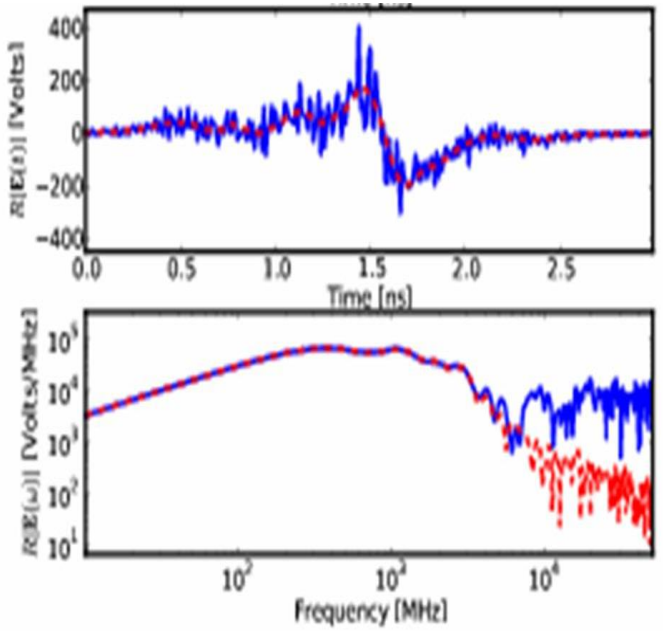


Possess main features of the Cherenkov radiation:

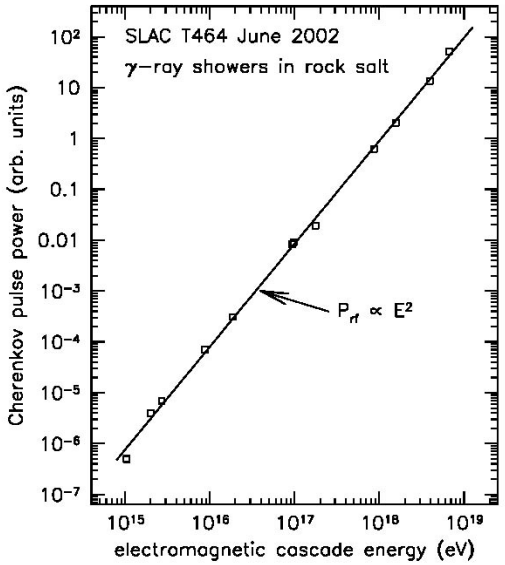
- Angular dependence/Linear Polarisation
- Fast timing / Low intensity

and

Coherence

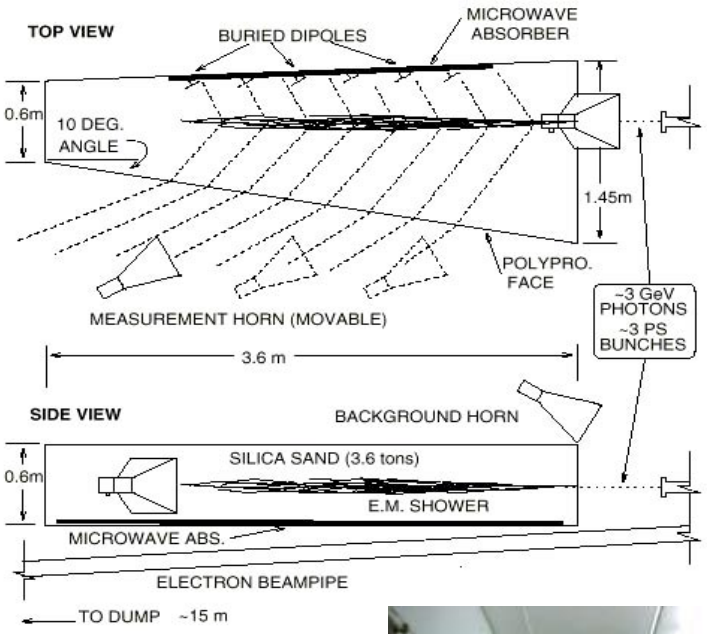


Wide bandwidth.



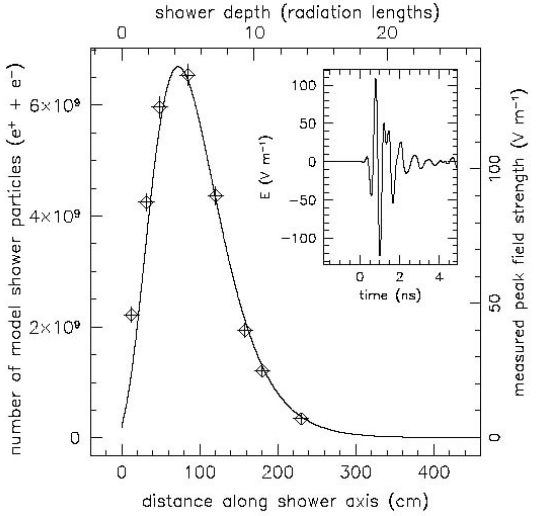
Observation

SLAC 2000, PRL 86, 2802 (2001)



Big Radiator

Results:
Shower Profile,
Huge Signals(200Vpp, w/o amplification)

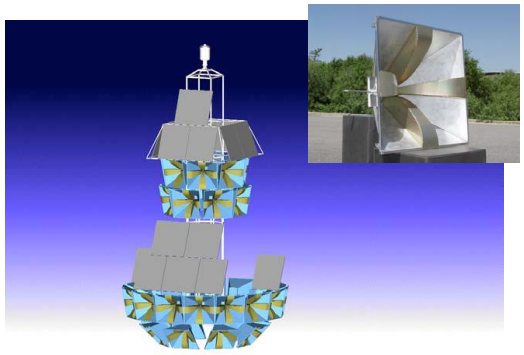


Astro-particle applications

Hunt for UHE cosmic rays

Antarctic mission ANITA

Plans

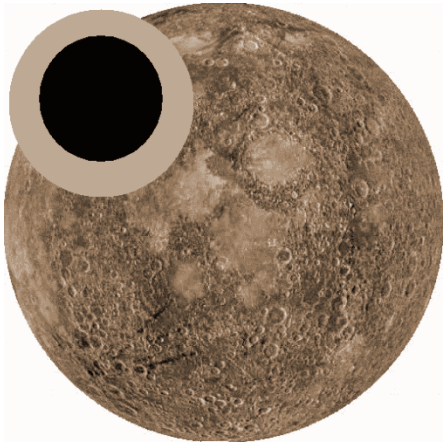


Test @ SLAC

@ Antarctic

Astro-particle applications

Moon as UHE cosmic rays RF converter

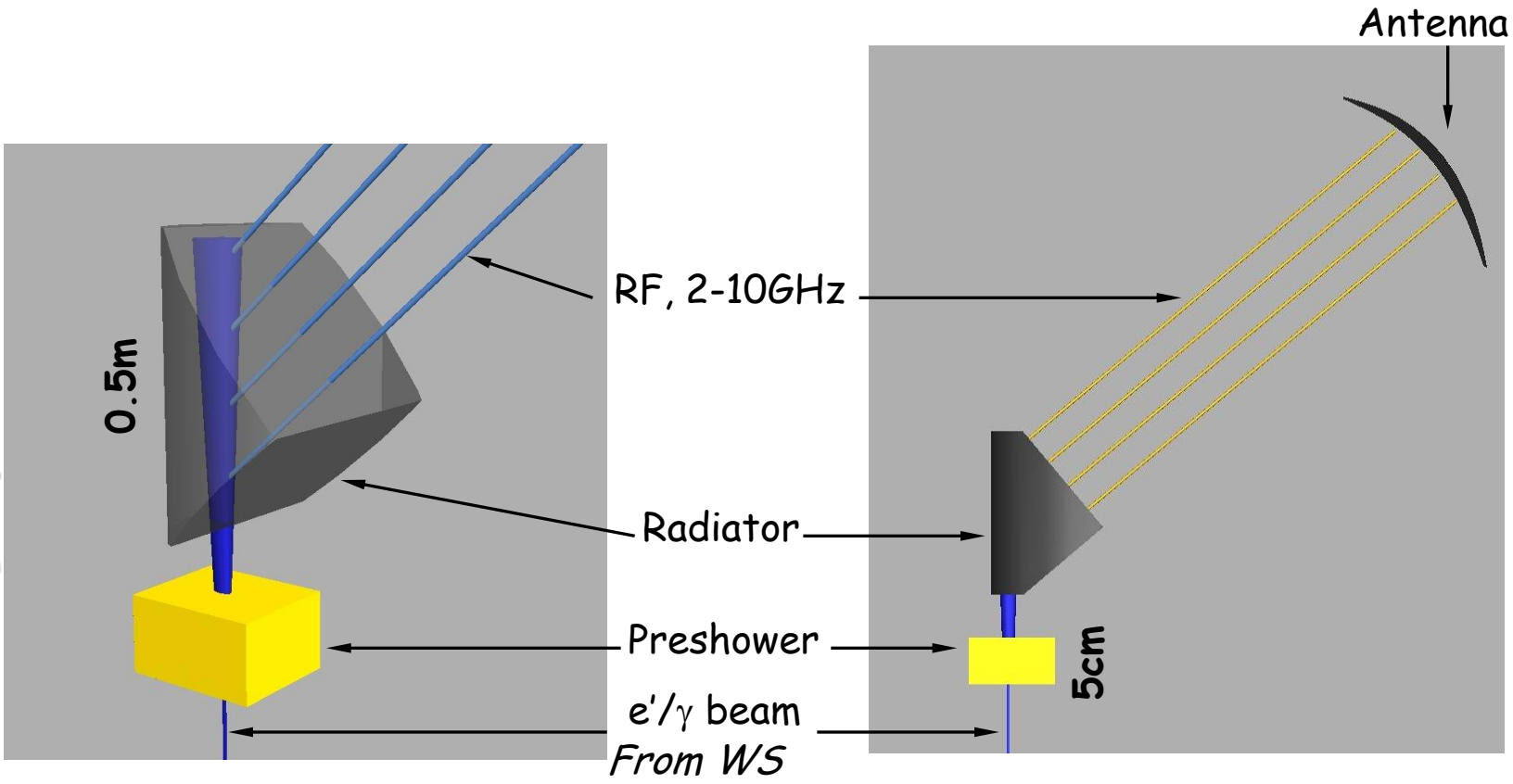


Moon's 10-100m deep surface (Lunar Regolith) is transparent for RF.

Possible use in diagnostics

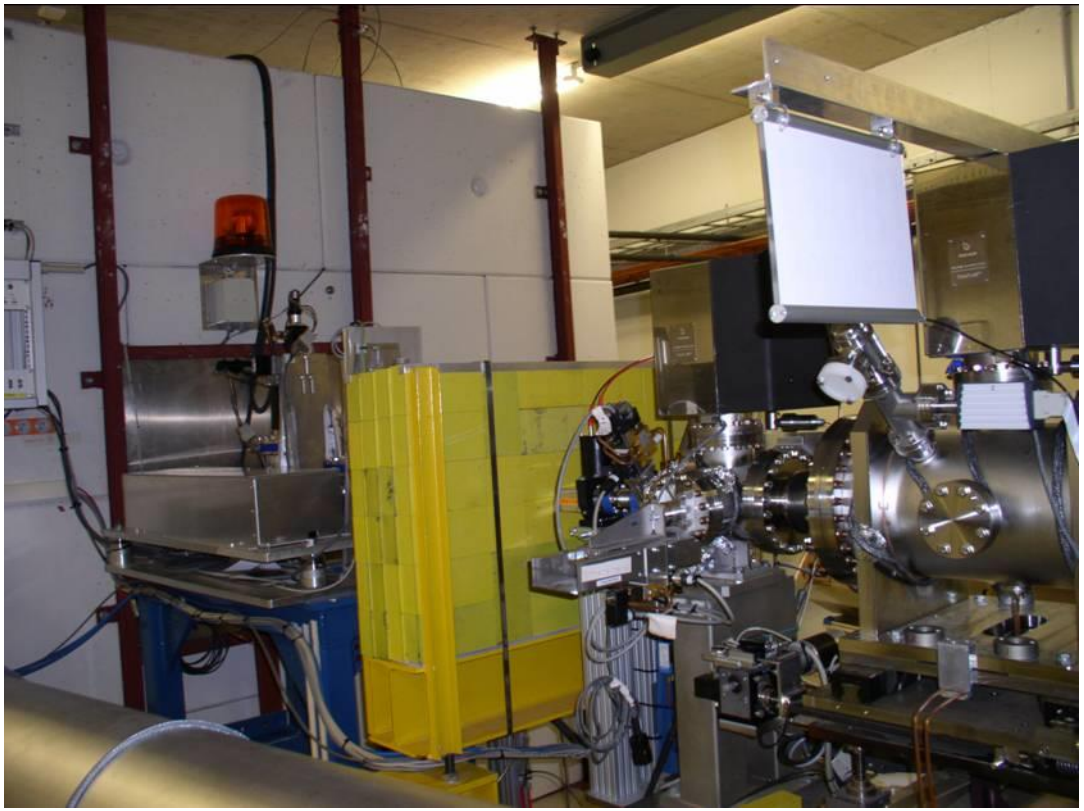
1. Reduce the radiator sizes by inserting a preshower.

2. Apply amplification in the RF detector.



Possible use in diagnostics
FLASH (FLASH2/TB2*) case

Photon Dump



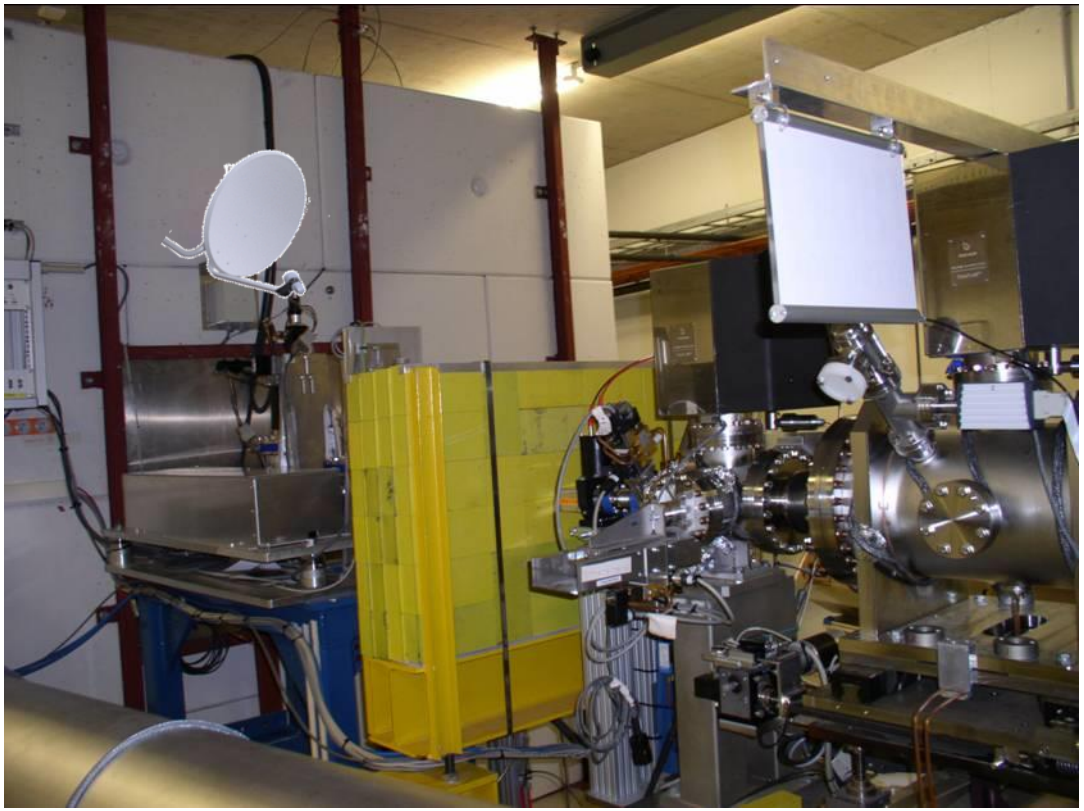
Remove 1 cell of central bricks, retain one as preshower.

Put the radiator behind, with RF exit window looking UP.

Mount receiver dish/horn at top.

Possible use in diagnostics
FLASH (FLASH2/TB2*) case

Photon Dump



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New radiation

Transverse EM field of the shower variable macro-charge propagates in a dielectric medium.

Calculations:
Parameterize shower profile by

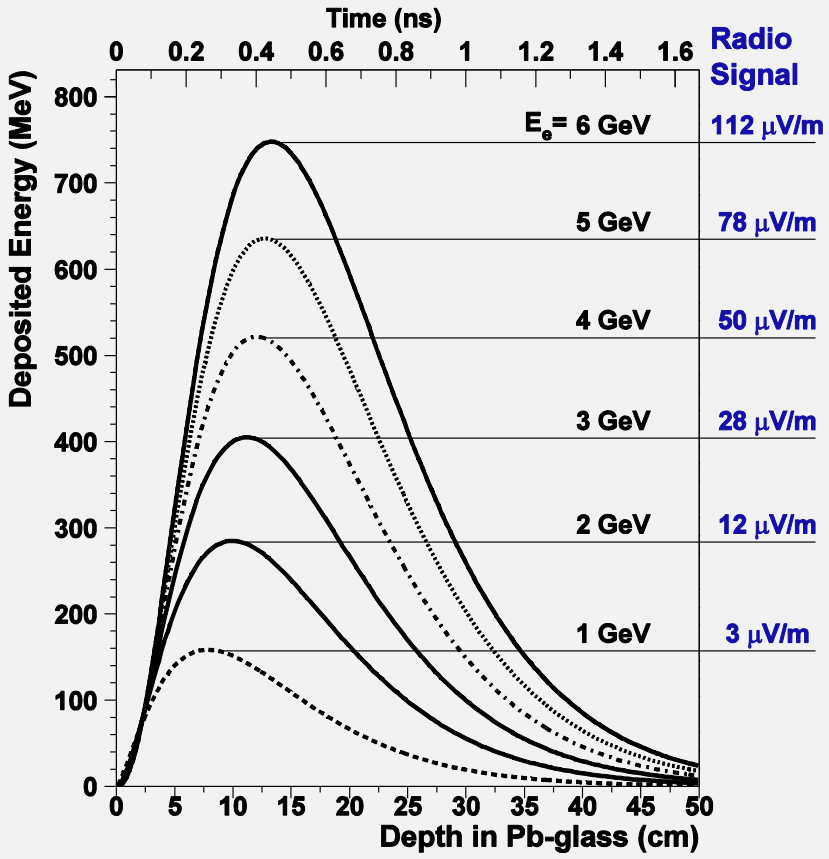
$$\frac{1}{E}\frac{dE(t)}{dt} = \frac{(\beta t)^{\alpha-1}\beta \exp(-\beta t)}{\Gamma(\alpha)}$$

E – energy deposition
t -- shower depth [X0]
α,β - parameters (material dependent)

Evaluate E field in the macro-charge's rest frame and boost to LAB frame.

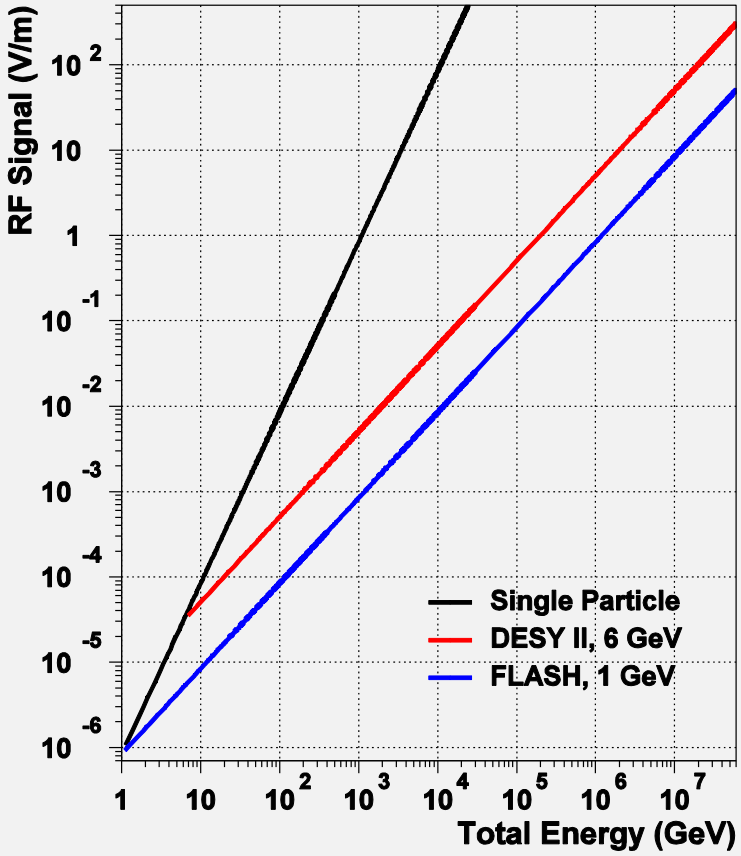
Magnitude

Showers in Lead-glass 1X0=2.8cm



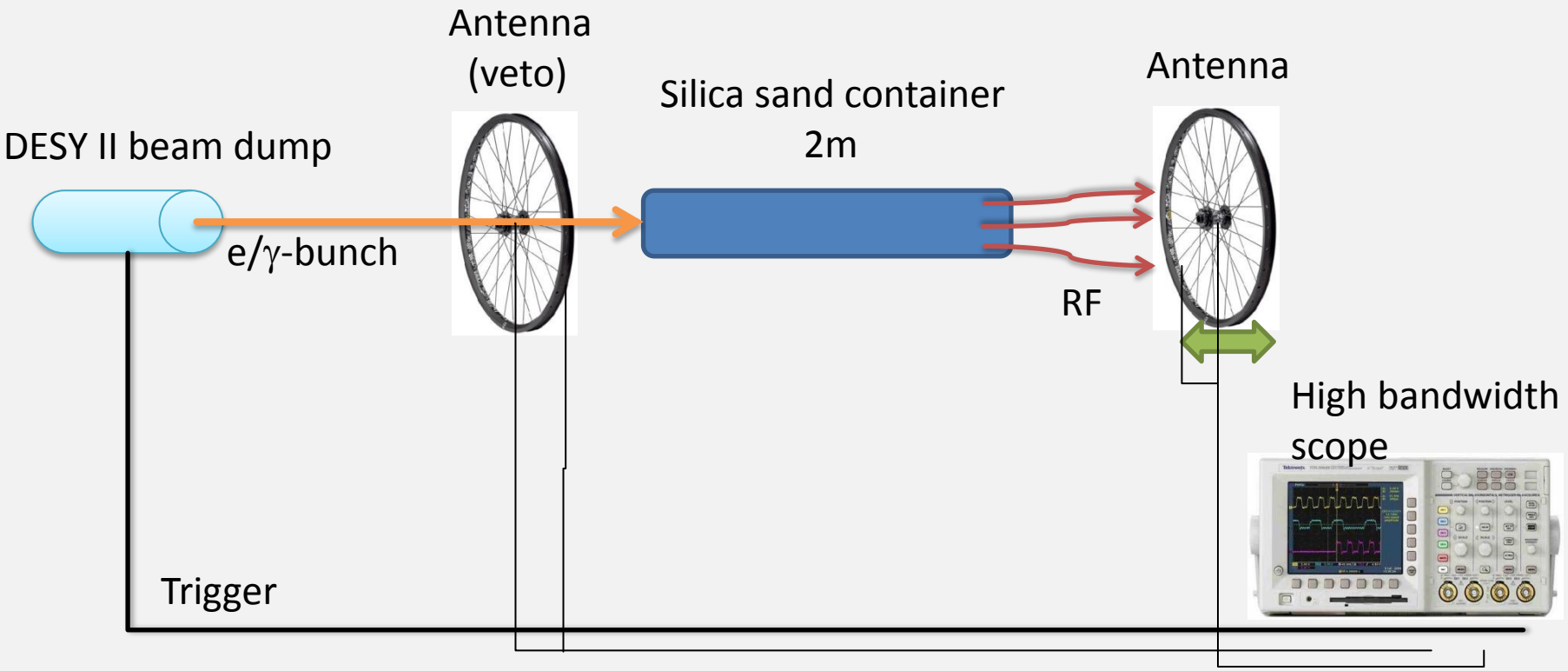
Detection Prospects

Showers in Silica sand 1X0=10.9cm



Detection Scheme

Expected signal from SiO_2: axial / unpolarized,
100V/m per 10^7 6GeV particles, 3ns duration



Expectations

- A new type of RF radiation is possible from particles' cascades
- The radiation is axial (intense) and exceeds Askaryan RF radiation by a factor of 2000 (28 GeV in sand)
- Detection could be done at DESY II or FLASH beam dump

- Applications:
  - Accelerators
  - Cosmic ray showers (times μsec, bandwidth 100s of kHz)
  - Astrophysics

Bad News

Photon is a vector particle with spin =>
Monopole EM radiation is forbidden in vacuum =>

Shower's variable charge radiation is suppressed by this basic principle, the large EM field is mostly reactive.

A possible solution – Magnetic field will modify monopole to dipole.
Since many decades the geomagnetic field is explored for cosmic ray's EAS modeling.

Could be tested at accelerators – RF from calorimeter in magnetic field.

Good News

It is possible to explore variable charge reactive field for shower detection. EM pickups could deliver showers energy, position-angle information.

Single particle detection below to GeV energies is feasible -
amplifiers thermal noise 1.4nV/$Hz^{-1/2}$ is sufficiently low for tens of μV, MHz bandwidth signal handling.

Detectors should be properly shielded – put inside the Faraday cages.

Proof of effect experiments are foreseen at DESY.