Reflection of Microwave from Energy Deposit by X ray Irradiation in Rock Salt: Implying Salt Ultra High Energy Neutrino Detector to act like a Radio Bubble Chamber

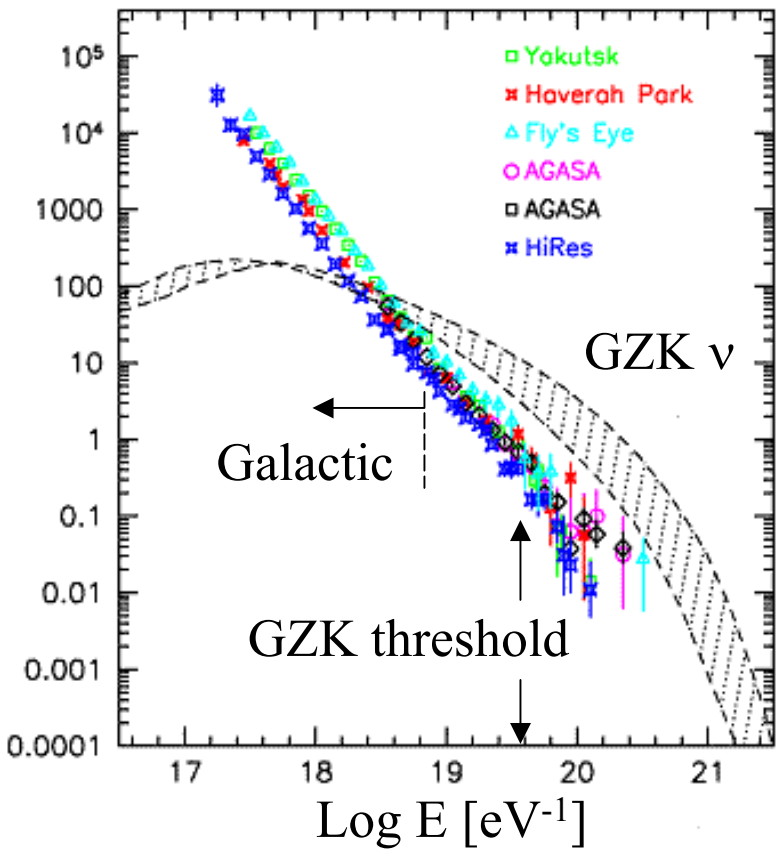
Masami Chiba, Yoko Arakawa, Toshio. Kamijo, Shunsuke Nakamura, Fumiaki Yabuki, Osamu Yasuda, Yuichi Chikashige*, Keisuke Ibe*, Tadashi Kon*, Sosuke Ninomiya*, Yutaka Shimizu*, Michiaki Utsumi**, Yasuyuki Taniuchi**, Akio Amano*, Yuji Shibasaki, Yasuhiro Takayama, Yoshito Takeoka*, Yusuke Watanabe and Masatoshi Fujii***

Tokyo Metropolitan University,
Seikei University*, Tokai University**, Shimane University***

Talk at SUSY2007 – July 26, 2007

UHE Neutrinos Originate in UHE Cosmic Rays & CMB

Cosmic ray energy spectrum
Log E(dN/dE) [km^{-2} yr^{-1} (2π sr)$^{-1}$]



- Observed highest energy exceeds 10^{20}eV
- Cosmic microwave background exists.
- Greisen-Zatsepin-Kuzmin(GZK) effect.
  - The energy exceeds Δ production threshold.

$$p + \gamma_{2.7\,k} \rightarrow \Delta \rightarrow n + \pi^+$$

(CMB)

$$\pi^+ \rightarrow \mu^+ \nu_\mu$$
$$\mu^+ \rightarrow e^+ \nu_\mu \nu_e$$

  - GZK neutrino flux is as low as 1 [/km^2/day] .

→Need a huge mass of detection medium

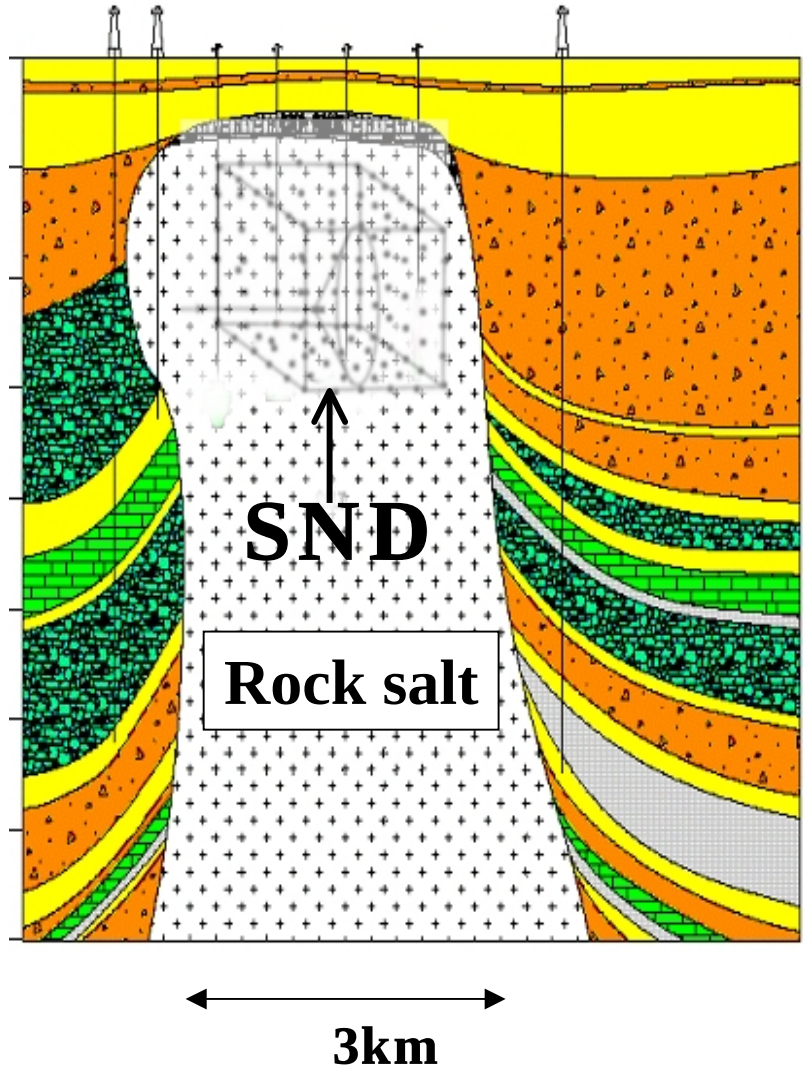
Salt Neutrino Detector installed in a salt dome

Radio detection method for UHE neutrinos: Coherent Cherenkov radiation from excess electrons in EM shower: (Askaryan effect): Hankins, et al., RICE, GLUE, FORTE, ANITA, etc.

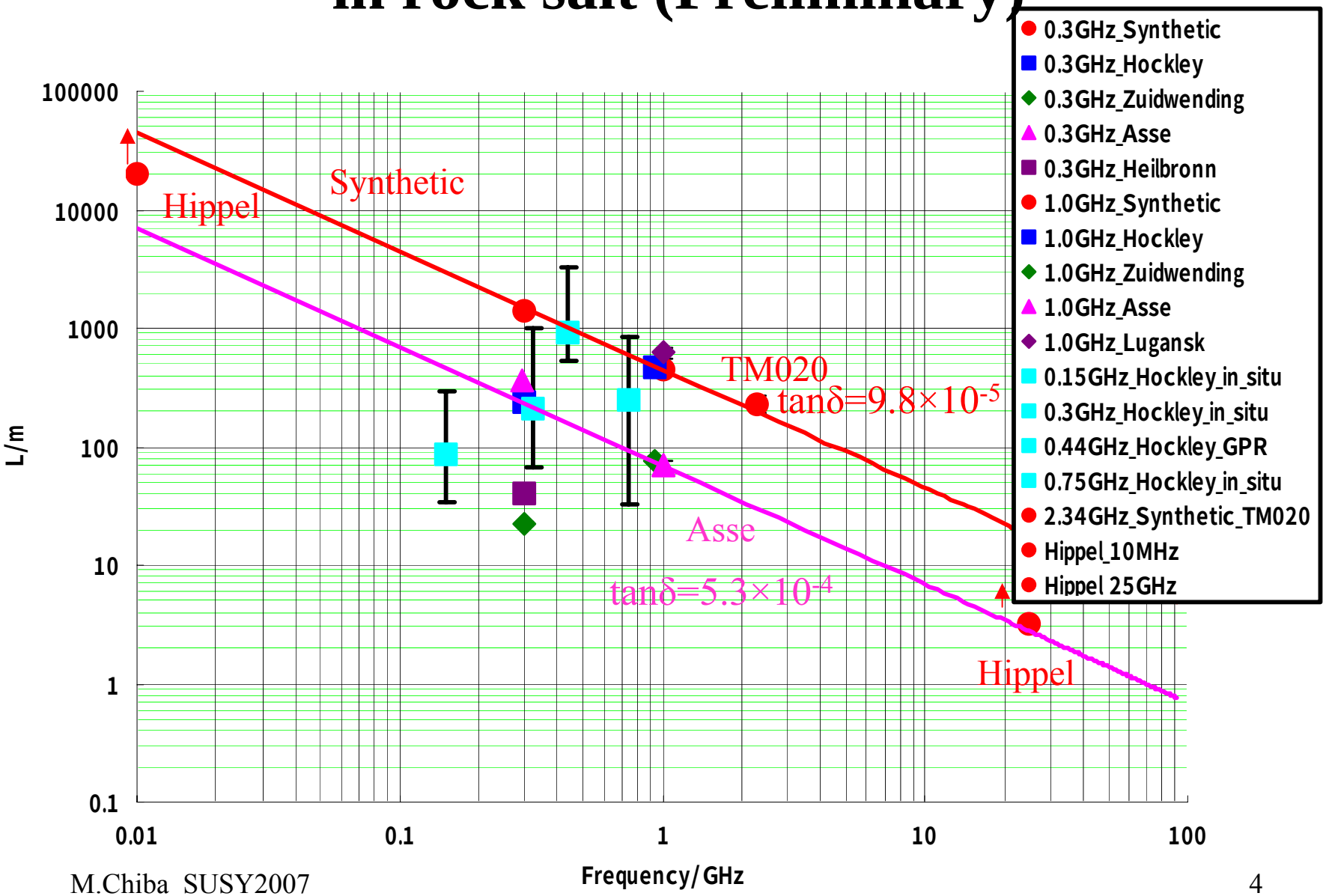
SND/SalSA

1. Rock salt is free from liquid and gas permeation
2. Free from water permeation leads good radio wave transparency in a salt dome.
3. Covered soil prevents surface radio wave to penetrate. Conceivable background is black body radiation in salt dome.
4. 8-62 GZK neutrinos/year would be detected by 50Gt detector.
5. Needs, 100 of boreholes with anntenas

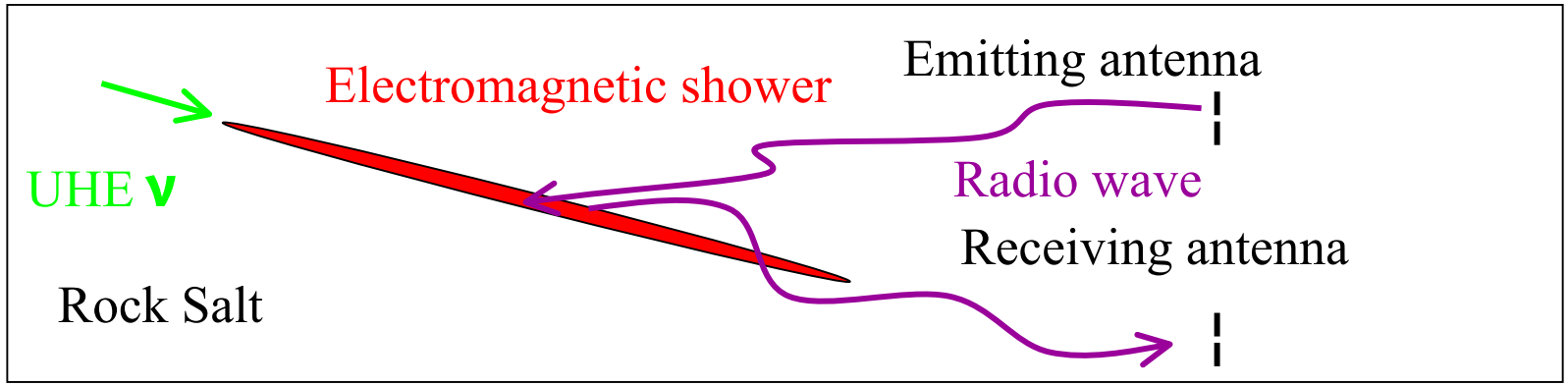
Dow Earth Sciences, Geol: J.Hertzing



Attenuation length of radio wave for electric field in rock salt (Preliminary)



Radar method: radio wave reflection



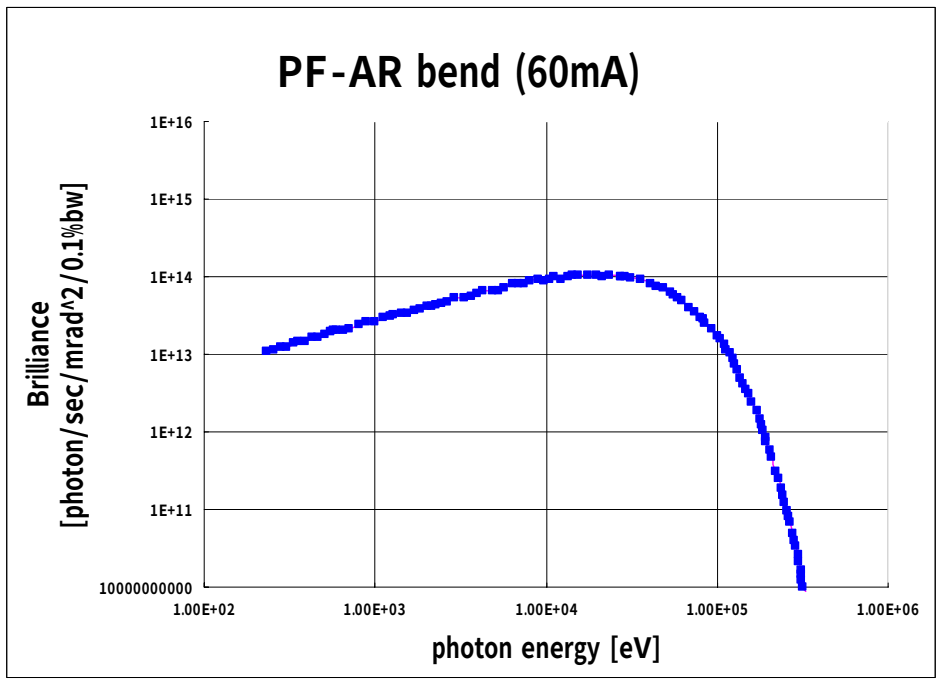
Electromagnetic ionization in rock salt

- X ray Spectrum: white
- Energy: 8-100 keV
- Repetition: 800 kHz
- Pulse width: 30ps

Synchrotron radiation from KEK AR electron accumulation ring

- Electron energy: 6.5GeV
- Current: 60mA
- Lifetime 10 hours

Brilliance of X ray source

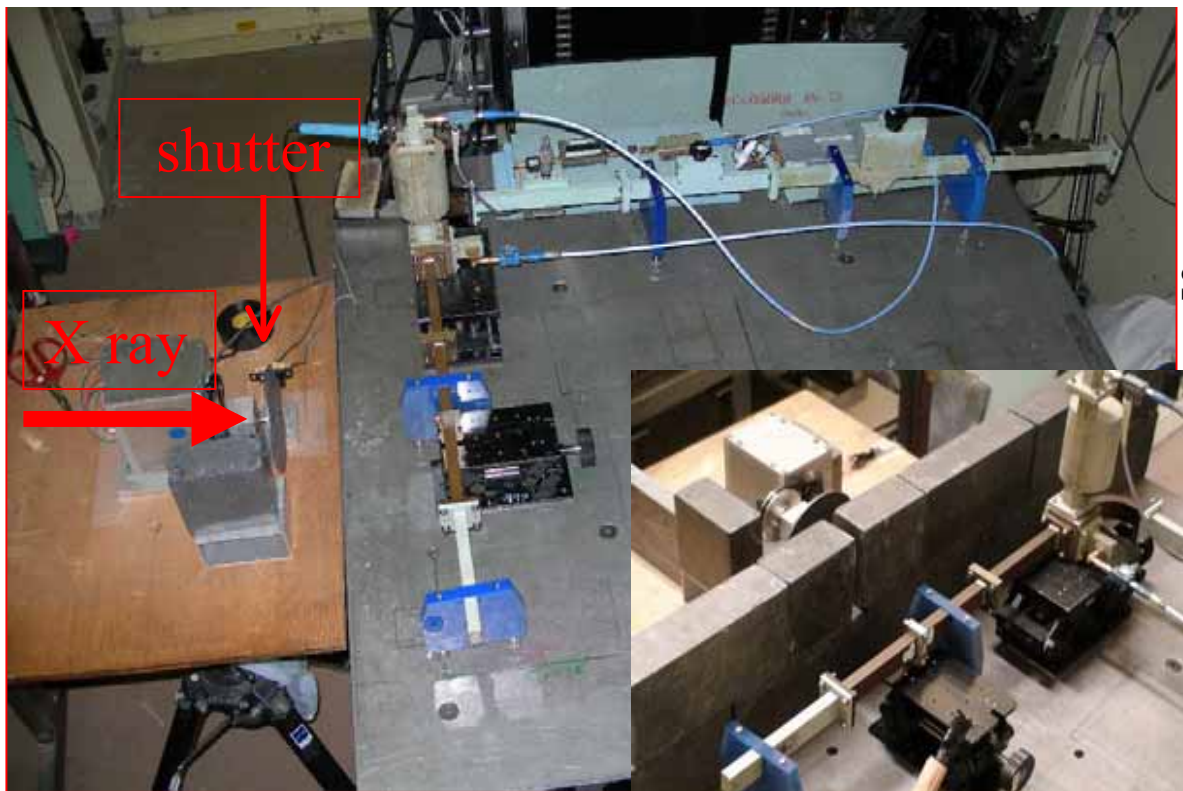


Experimental setup with X ray disc shutter

- X ray and microwave (9.4 GHz, 10^{-4} W) are irradiated to a rock salt sample, simultaneously.
- Null detection method is employed for detecting minimal signal.
- Measure microwave reflection change due to X ray irradiation.

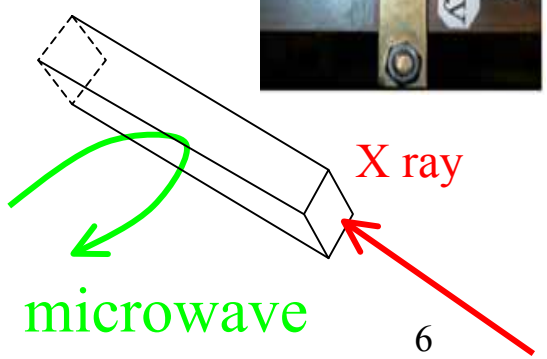
Rotary X ray disc shutter

- Lead: 4mm^t
- Φ:100mm,
- Orifice: 4x4mm^2

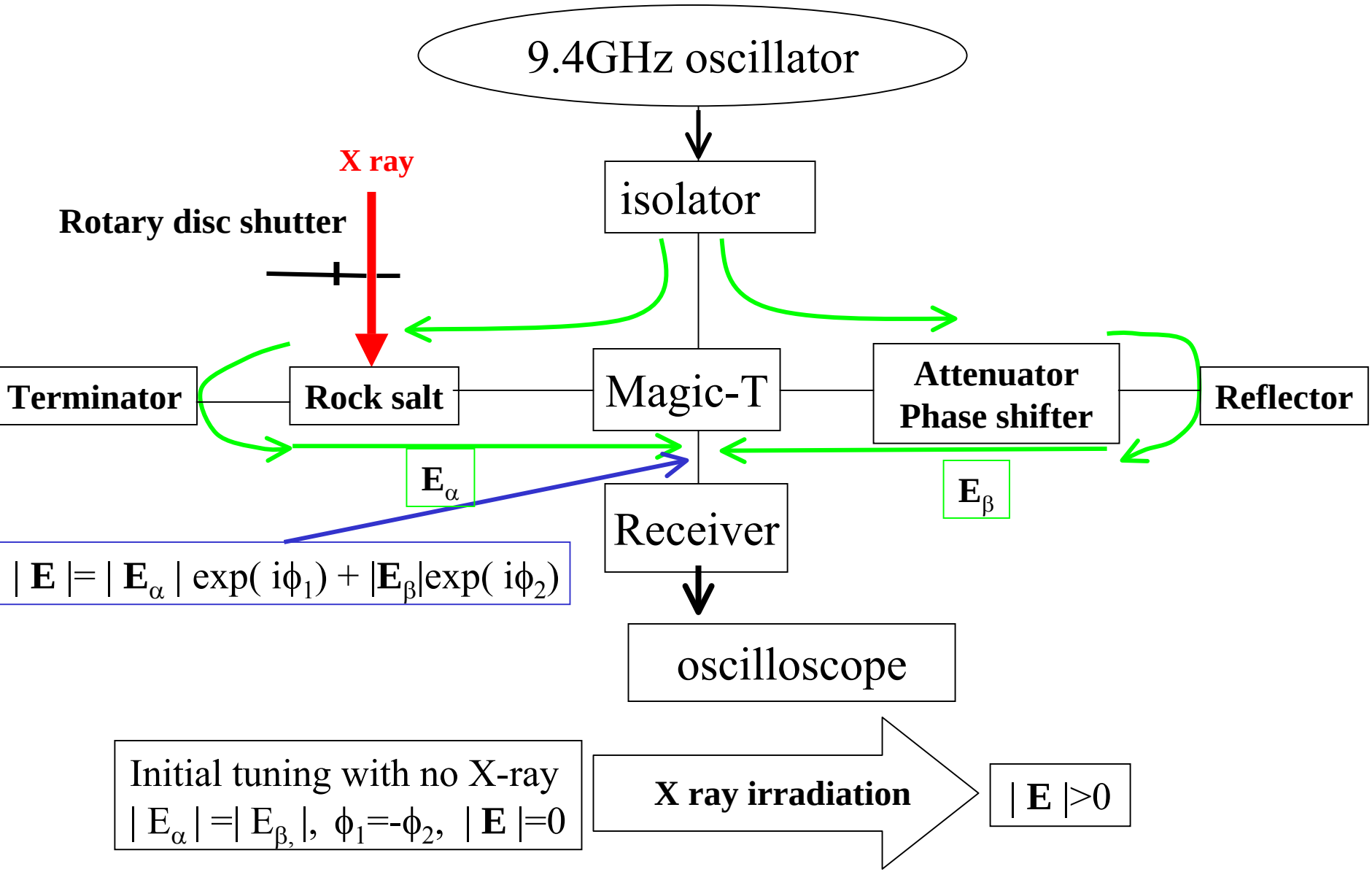


Synthesized rock salt

2×2×10 mm^3

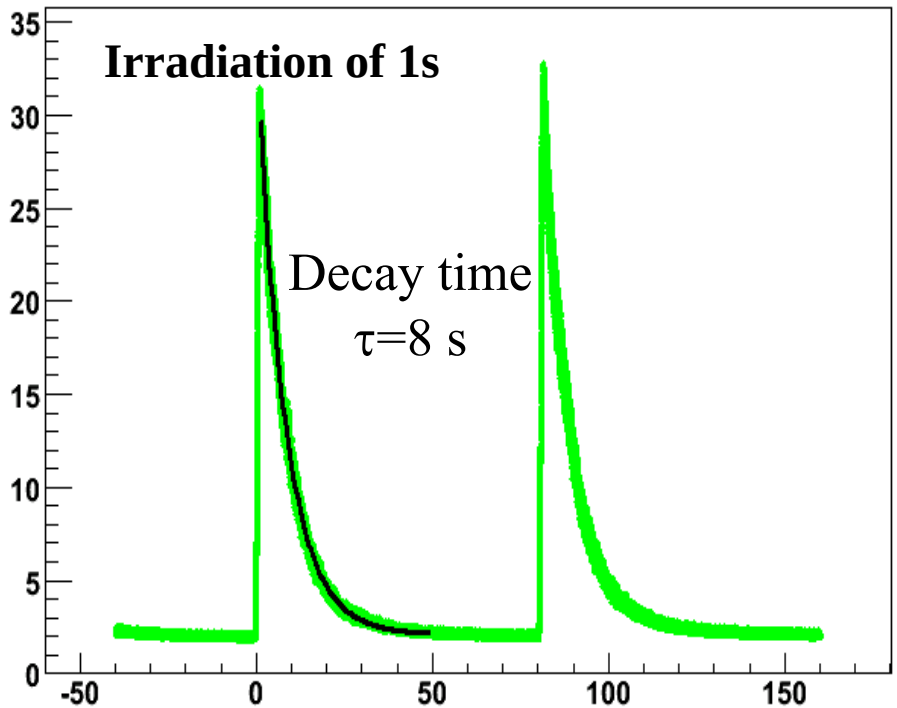


Metal wave-guide system （Null Method）



Reflected power vs. elapse of time

10^{-13} /W



Elapse of time/s

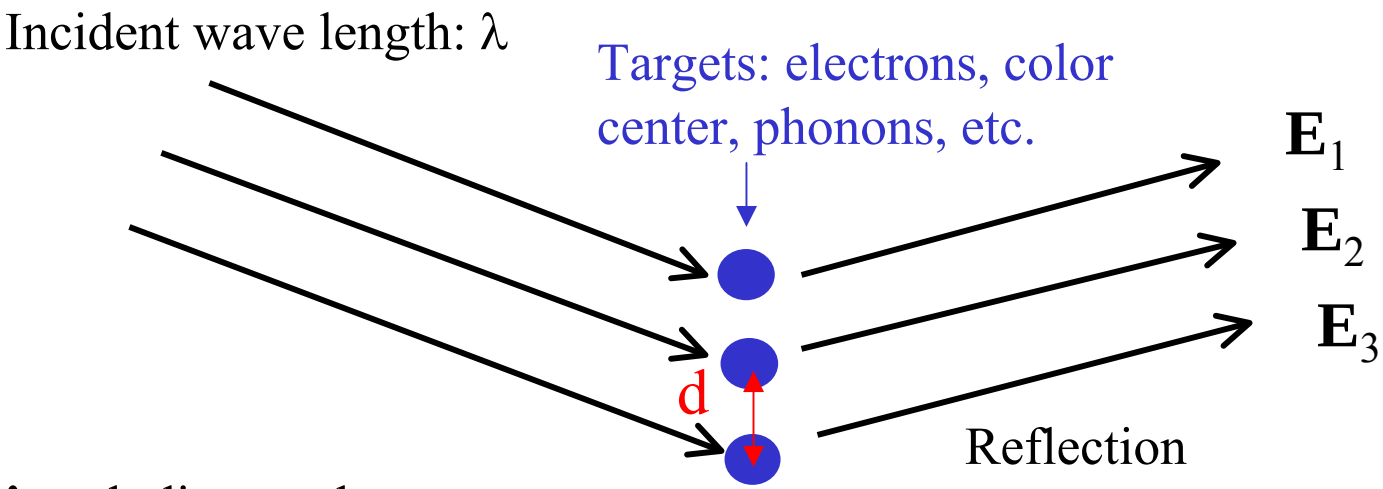
Receiver:

Ueda-NEC Co. Ltd.: NRG-98

- Logarithmic amplification: 10^{12}
- Receiving power range；10^{-14}-10^{-4} W
- 9.4GHz, Band width: 3MHz

- Microwave reflection rate of 10^{-7} at the X ray energy deposit of 7×10^{19} eV/s.
- Microwave targets: free electrons, color centers, phonons, polarons, polaritons?
- Number of targets?

Coherent scattering



λ>>d: distance between targets

$$P = |\mathbf{E}_1 + \mathbf{E}_2 + \cdots + \mathbf{E}_n|^2 = |\mathbf{E}_1|^2 + |\mathbf{E}_2|^2 + \cdots + |\mathbf{E}_n|^2 + \cdots + 2\mathbf{E}_i \cdot \mathbf{E}_k + \cdots = n^x |\mathbf{E}_i|^2$$

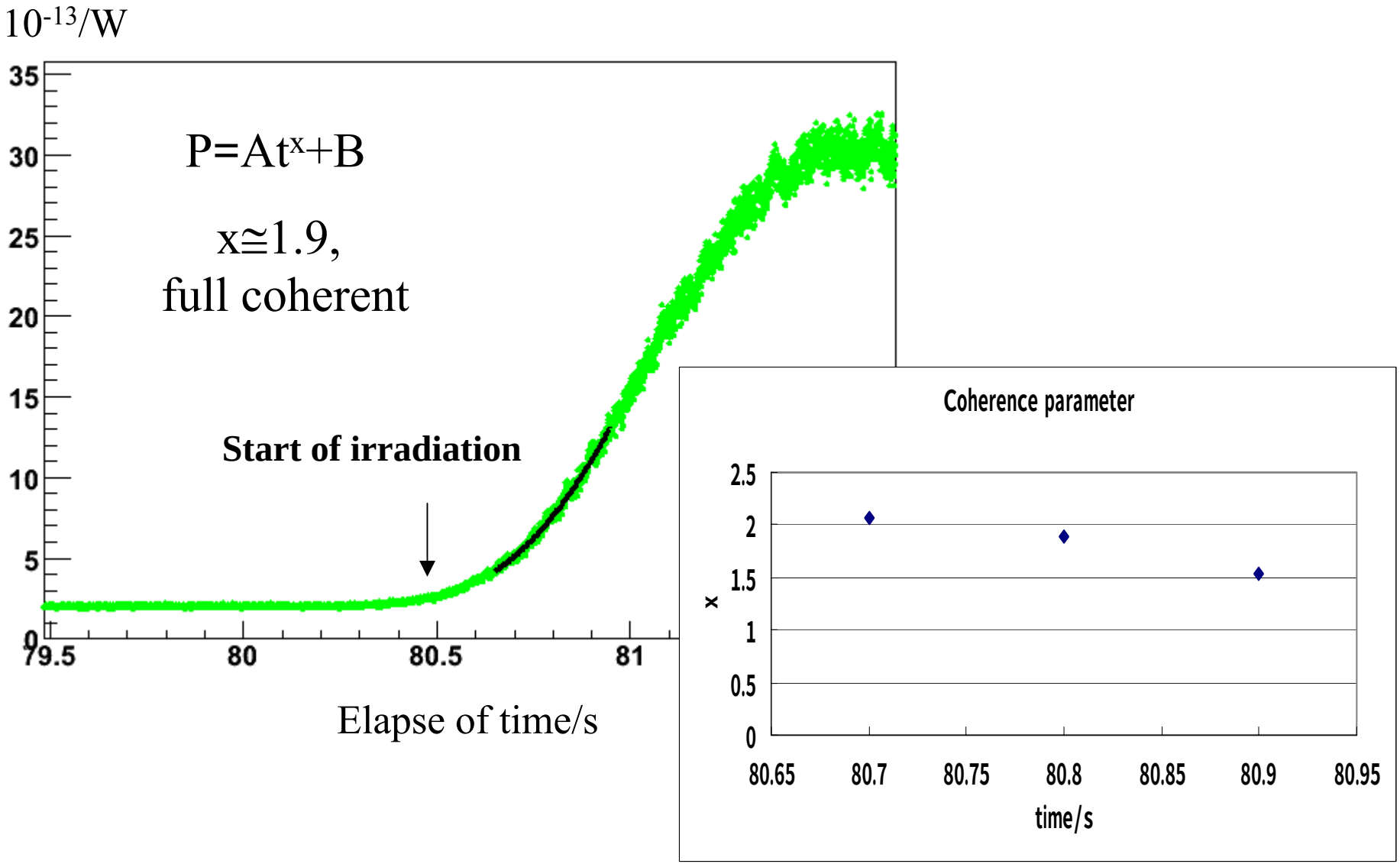
- P: reflected power
- n: number of targets
- t: X ray integration time

If lifetime of targets is long:
$n \propto t$

$P = At^x + B$

- A, B, x: fitting parameter
- x: coherence parameter
- x=2: full coherent
- x=1: random phase

Coherence parameter with time



Number of targets assuming Thomson scattering cross section with coherent scattering

Number of targets:

- $R=10^{-7}$: reflection rate in power at X ray after integration of 1s
- $\sigma_t = 6.653 \times 10^{-25}$ cm^2 : Thomson scattering cross section
- N_t: number of targets
- $R= N_t^2 \sigma_t$

$N_t =(R/ \sigma_t)^{1/2}=10^8$ at 1s after start of X ray irradiation.

Production cross section of targets:

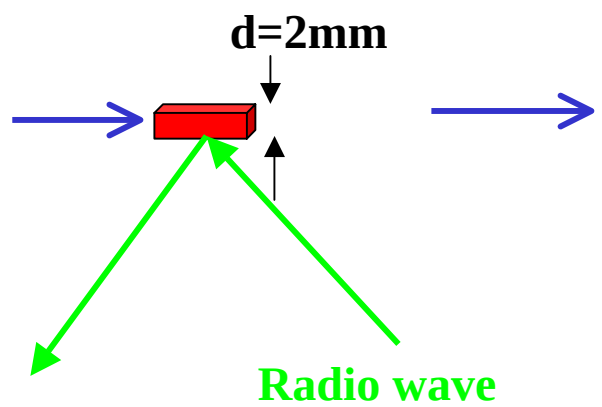
- $N_\gamma=10^{12}$/s: number of X ray photons
- $N_e=3 \times 10^{22}$: number of electrons in the rock salt sample

$\sigma = N_t / (N_\gamma N_e) = 3 \times 10^{-27}$ cm^2 : production cross section of the microwave target

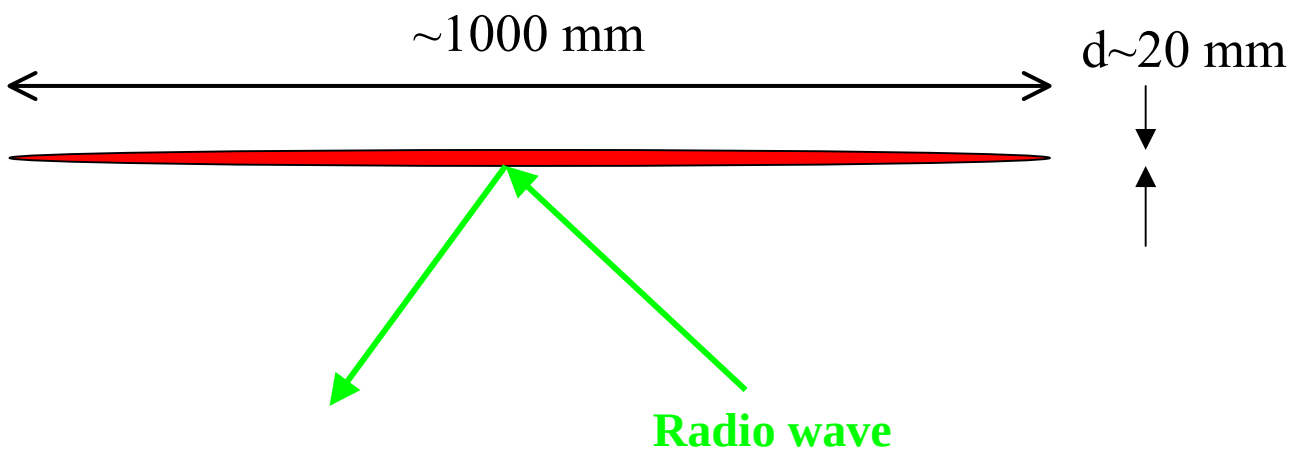
$\sigma <$ Compton scattering cross section with the order of 10^{-25} cm^2.

Scaling of transverse size and radio wavelength to real UHE shower

Synthetic rock salt sample
2×2×10 mm^3



UHE electromagnetic shower



λ>d/10: strong coherency, n=2.4: refractive index

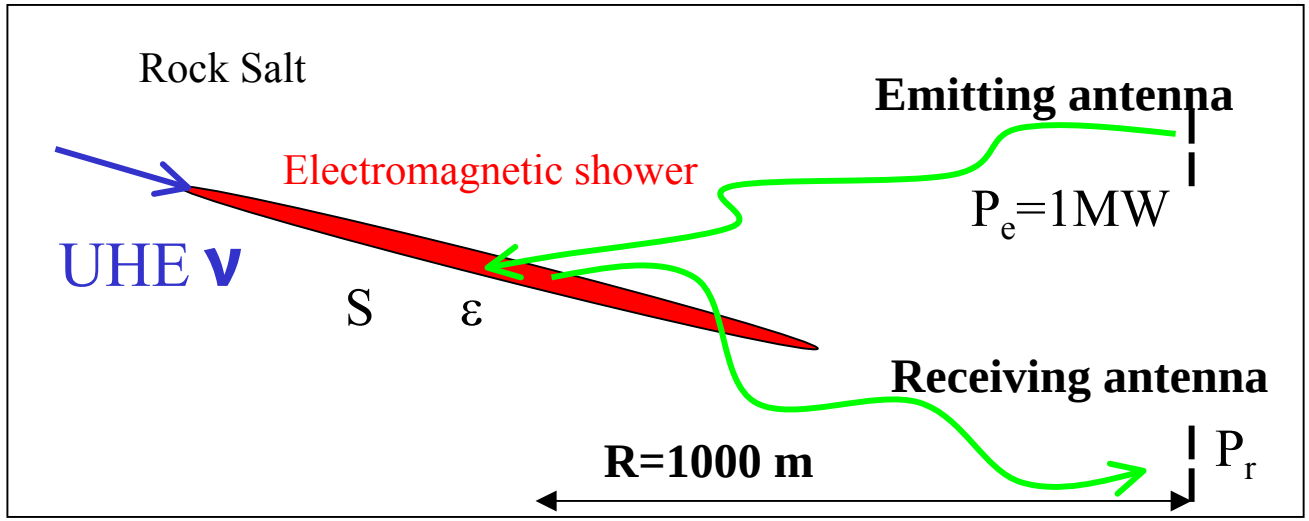
9.4GHz:

λ=30mm/n=13mm>2mm

0.1GHz:

λ=3000mm/n=166mm>20mm

Range of Radar



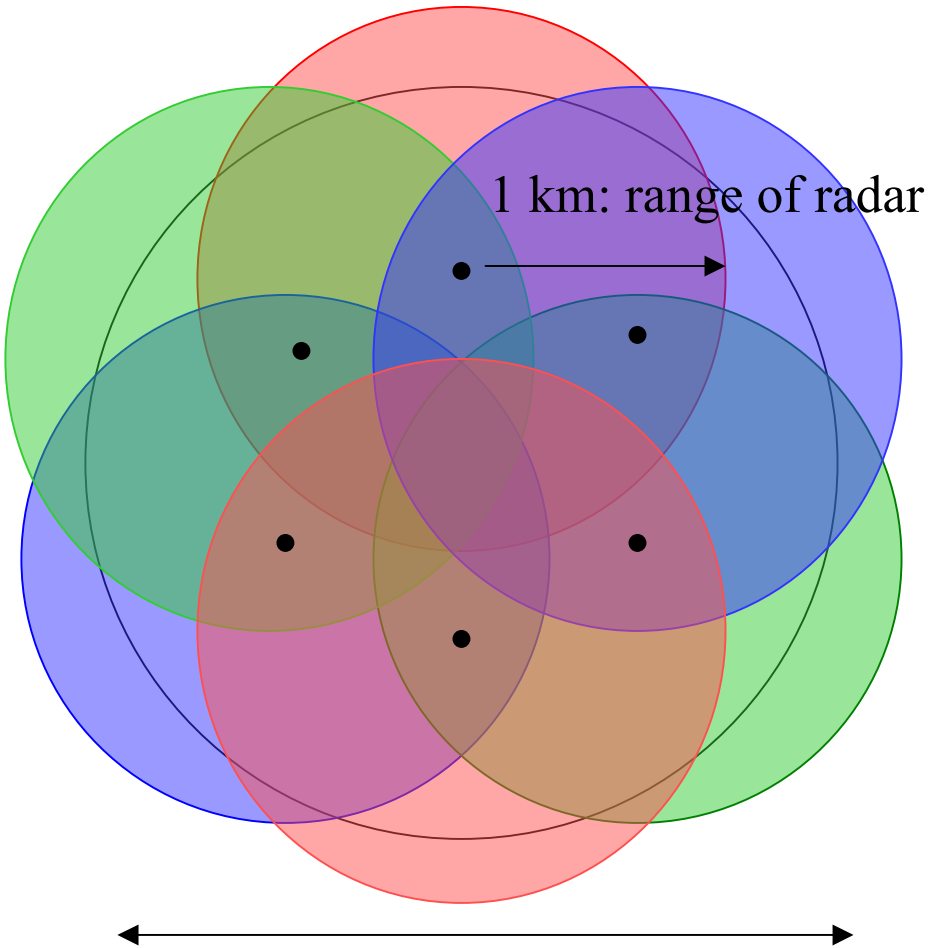
Receiving power at range of 1000 m

- ε=10^{-7}: reflection efficiency
- R=1000 m: range
- S=1 m^2: cross section of UHE electromagnetic shower
- L=200 m: attenuation length of radio wave in rock salt
- α=exp(-2R/L)=exp(-10)=5 × 10^{-5}: attenuation in the rock salt
- P_e=1MW: peak power of emitting radio wave

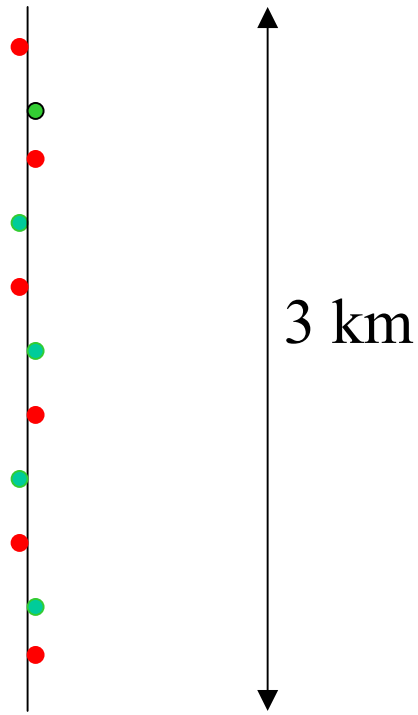
P_r= $P_e(4\pi R^2)^{-2}$ εα=3 × 10^{-14} W: at receiving antenna → detectable

6 boreholes for 3D reconstruction

- boreholes



- Emission antenna
- Receiving 16 antennas, detect time and amplitude



A string in a borehole

Summary

1. Microwave is reflected from X ray irradiated rock salt at a rate of 10^{-7} at the energy deposit of 7×10^{19} eV.
2. Life time of microwave target was several seconds. It is long enough to employ periodic pulsing of radar without triggering by Askaryan radio wave.
3. The microwave scattering was coherent.
4. Target species is not known yet.
5. Radar method would allow to detect UHE neutrinos in a huge rock salt dome with several bore holes.
6. Radar method would have a potential to realize Salt Neutrino Detector to act like a Radio Bubble Chamber.