

# **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**

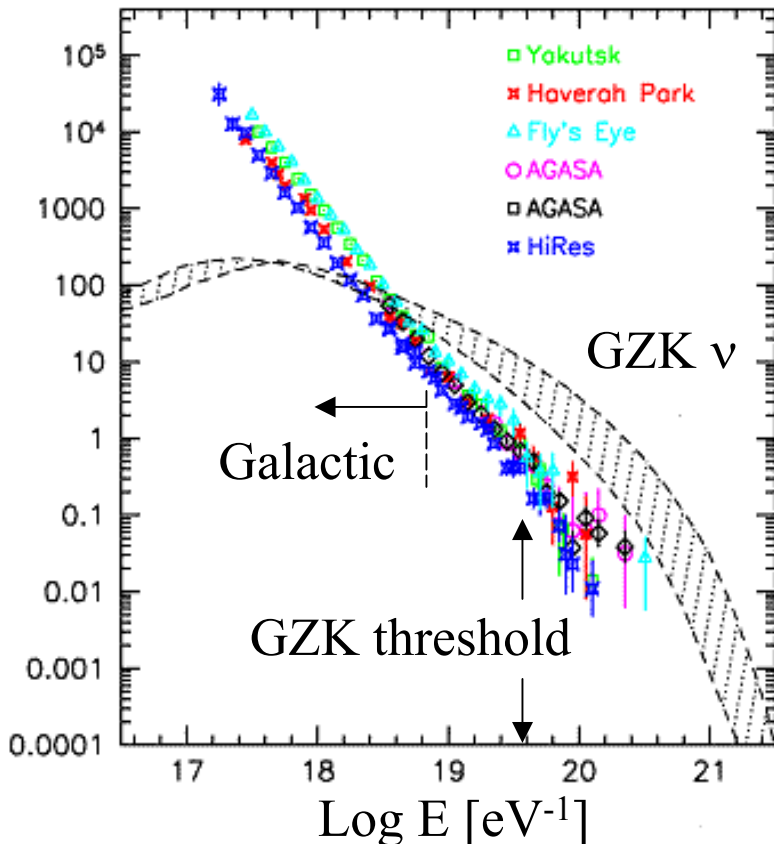
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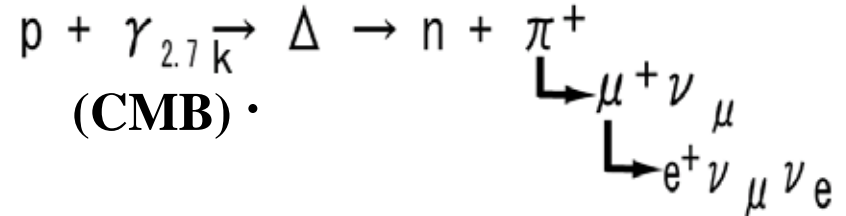
Talk at SUSY2007 – July 26, 2007

# UHE Neutrinos Originate in UHE Cosmic Rays & CMB

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



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



- GZK neutrino flux is as low as 1  $[\text{km}^2/\text{day}]$ .

Need a huge mass of detection medium

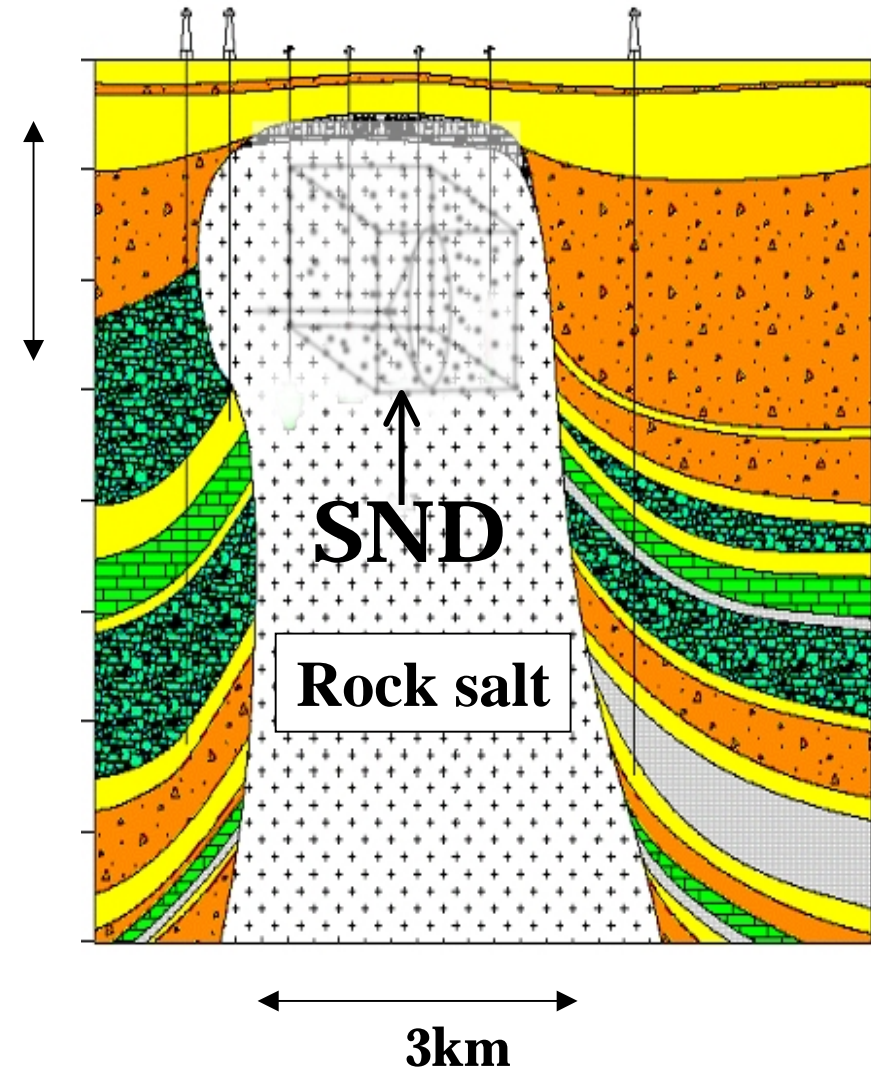
# Salt Neutrino Detector installed in a salt dome

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.

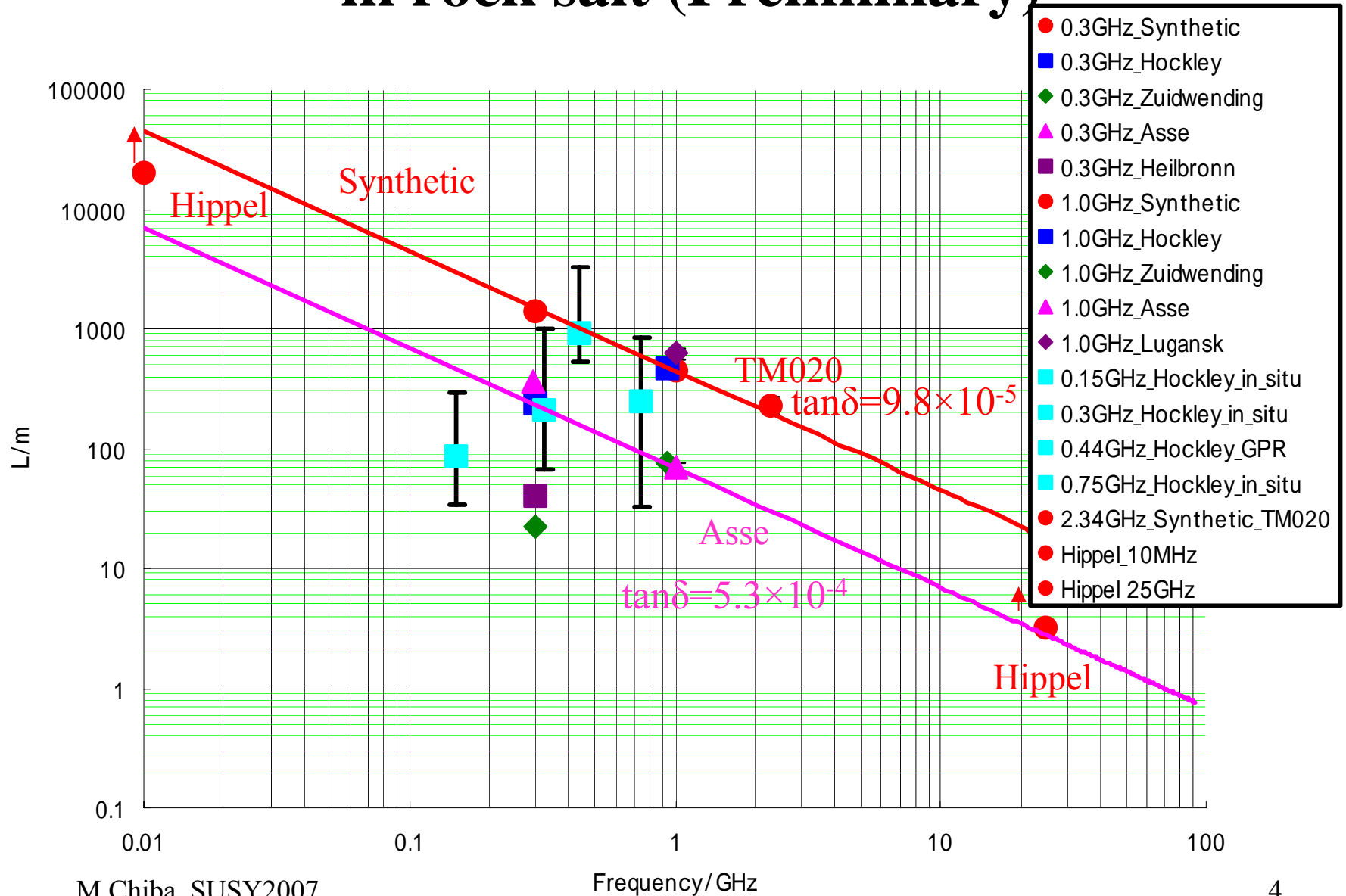
## SND/SaISA

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 antennas

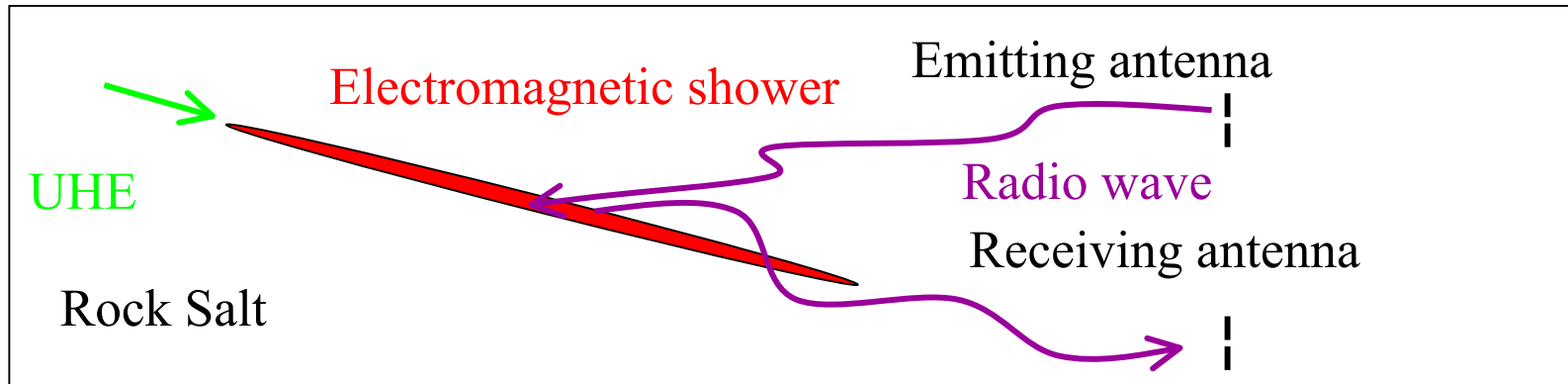
Dow Earth Sciences, Geol: J.Hertzing



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



# Radar method: radio wave reflection



Electromagnetic ionization  
in rock salt

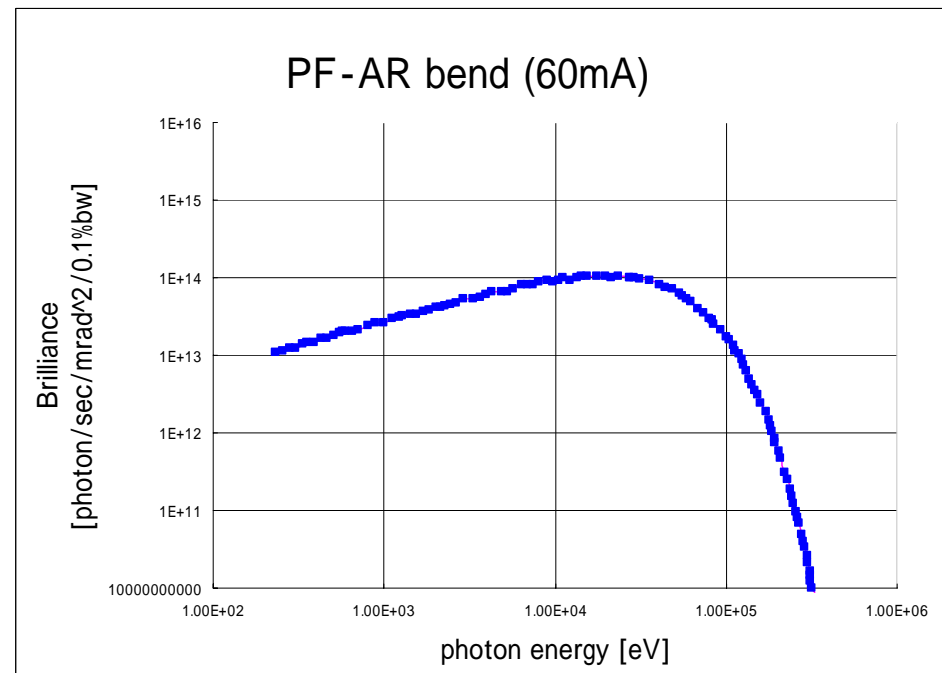
- X ray Spectrum: white
- Energy: 8-100 keV
- Repetition: 800 kHz
- Pulse width: 30ps

Synchrotron radiation from KEK  
AR electron accumulation ring

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

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## Brilliance of X ray source

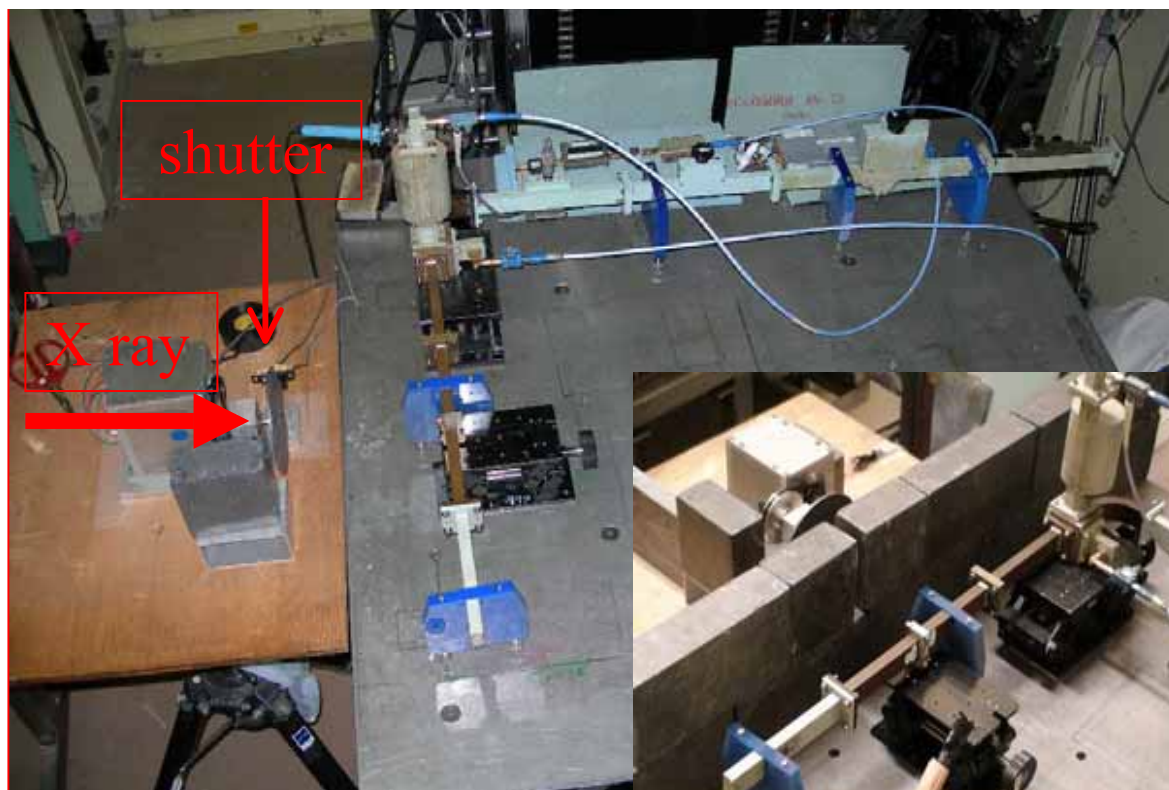


# Experimental setup with X ray disc shutter

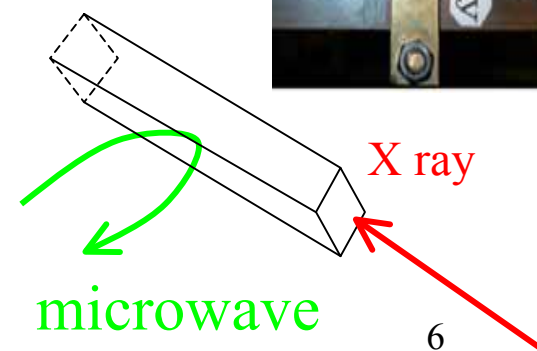
- X ray and microwave (9.4 GHz,  $10^{-4}$  W) are irradiated to a rock salt sample, simultaneously.
- Null detection method is employed for detecting minimal signal.
- Measure microwave reflection change due to X ray irradiation.

Rotary X ray disc shutter

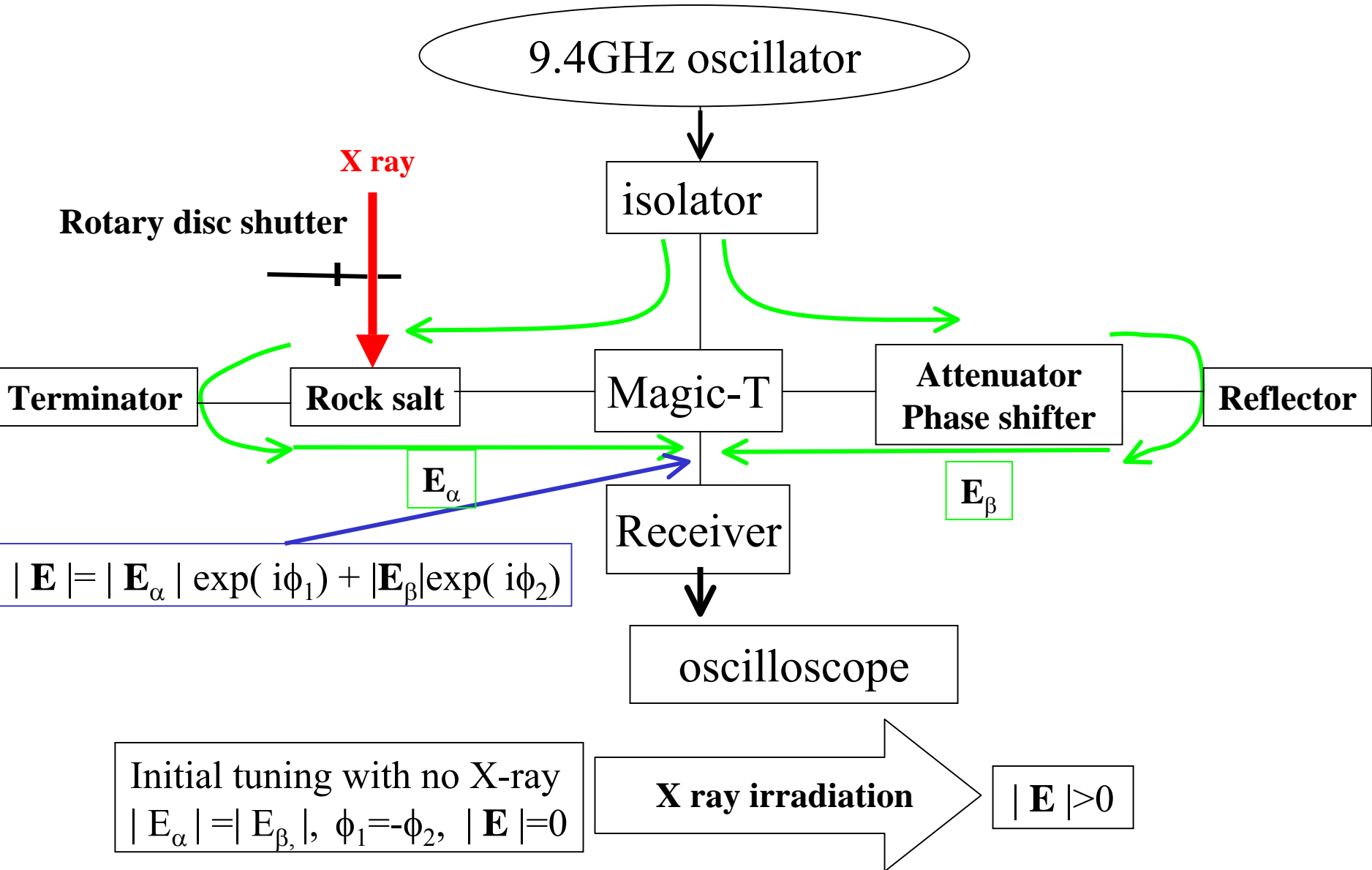
- Lead: 4mm<sup>t</sup>
- $\Phi$ : 100mm,
- Orifice: 4x4mm<sup>2</sup>



Synthesized rock salt  
 $2 \times 2 \times 10 \text{ mm}^3$

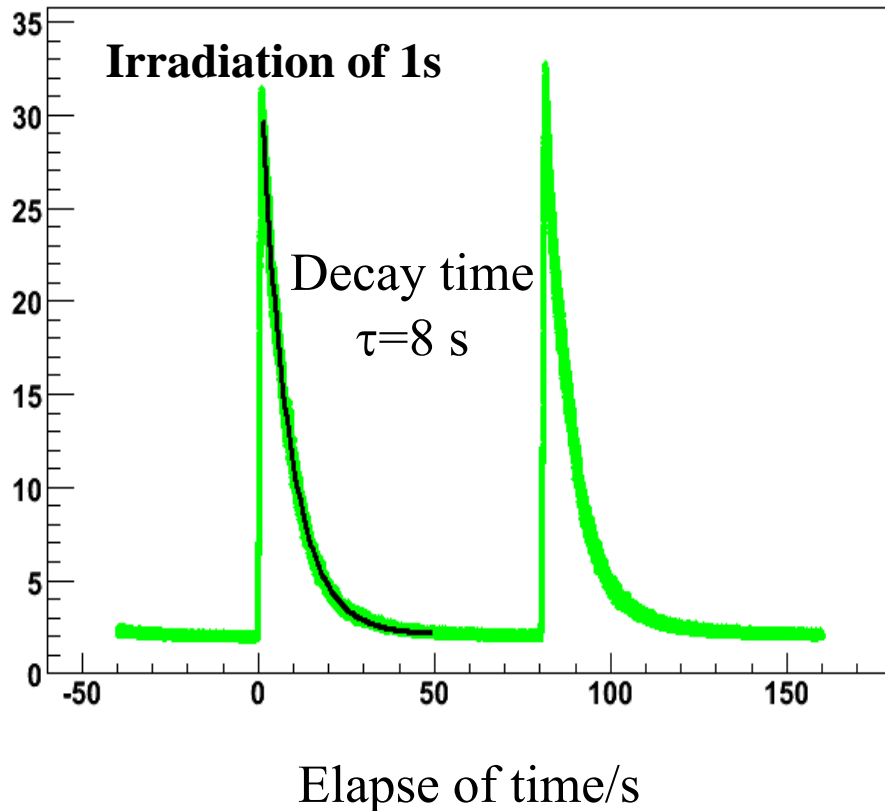


# Metal wave-guide system ( Null Method )



# Reflected power vs. elapse of time

$10^{-13} / \text{W}$



Receiver:

Ueda-NEC Co. Ltd.: NRG-98

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

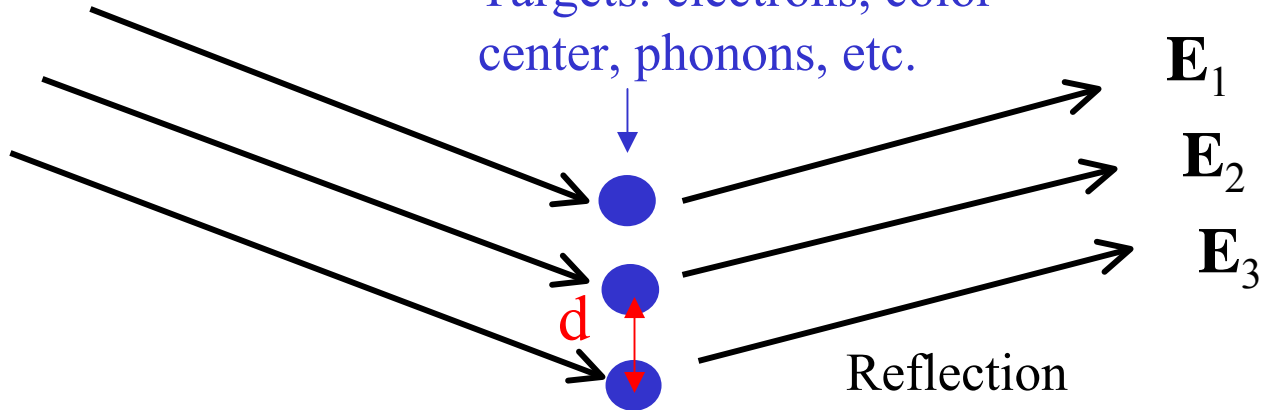
- Microwave reflection rate of  $10^{-7}$  at the X ray energy deposit of  $7 \times 10^{19}$  eV/s.
- Microwave targets: free electrons, color centers, phonons, polarons, polaritons?
- Number of targets?



# Coherent scattering

Incident wave length:  $\lambda$

Targets: electrons, color center, phonons, etc.



$\lambda \gg d$ : distance between targets

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

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

$$P = At^x + B$$

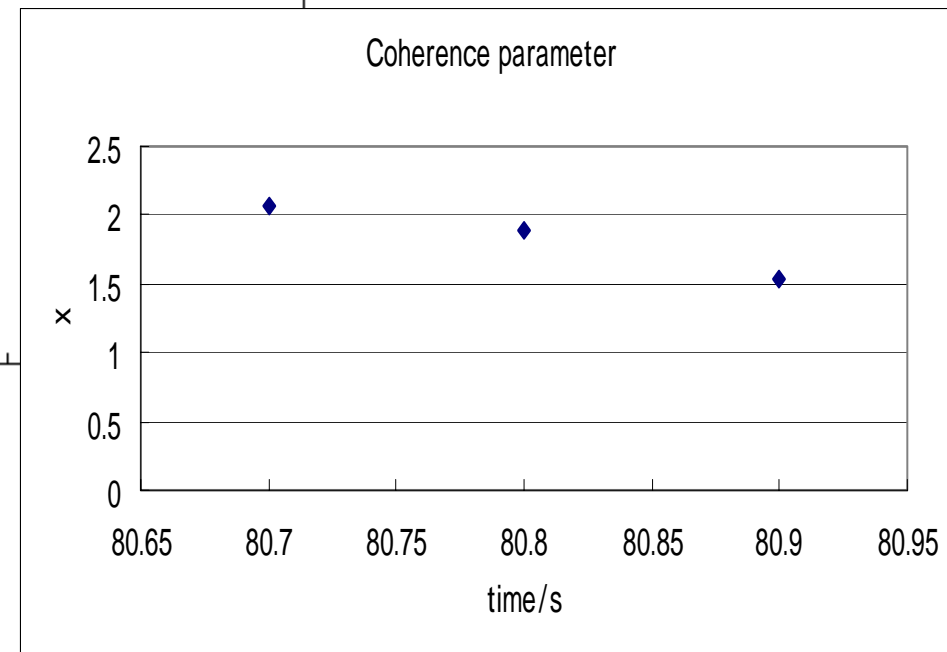
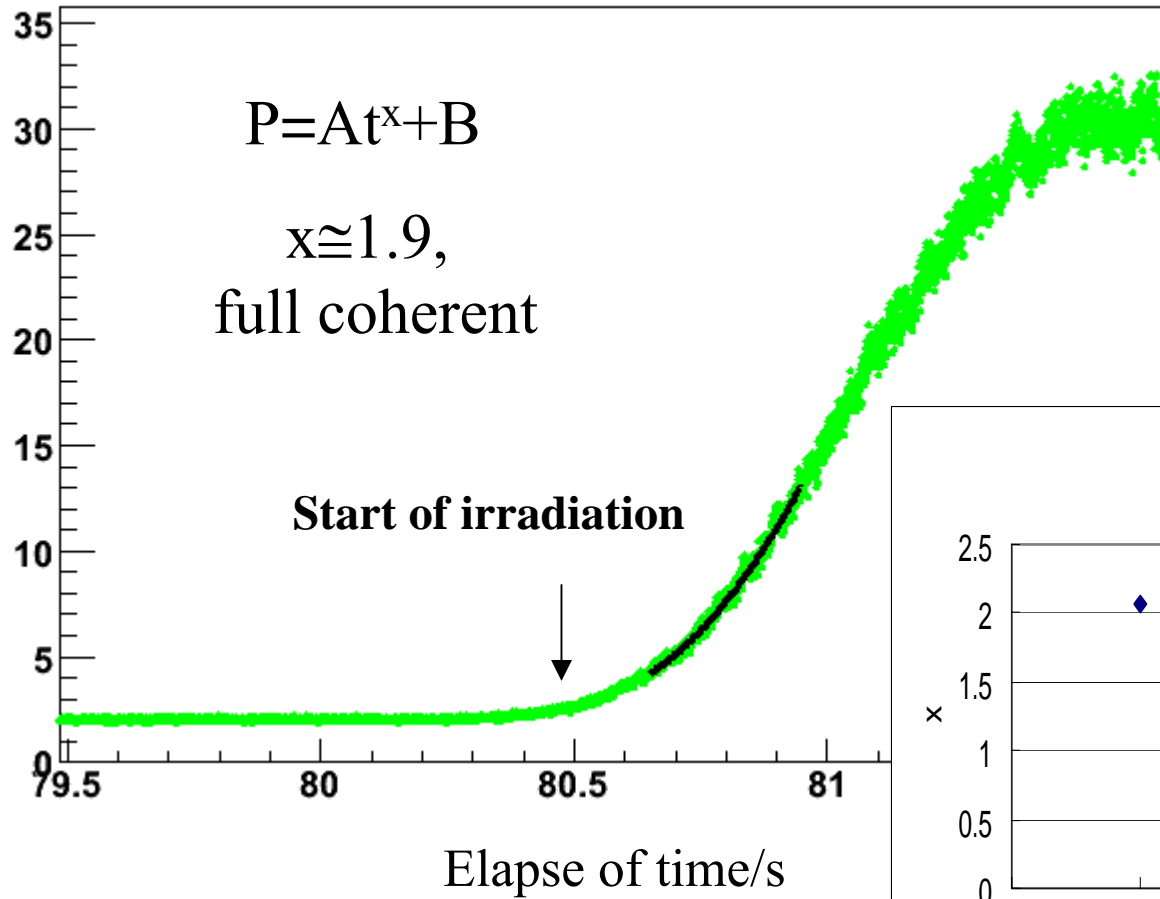
- A, B, x: fitting parameter
- x: coherence parameter
- x=2: full coherent
- x=1: random phase

If lifetime of targets is long:

n t

# Coherence parameter with time

$10^{-13}/W$



# 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

●  $\sigma_t = 6.653 \times 10^{-25} \text{ cm}^2$  : 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:

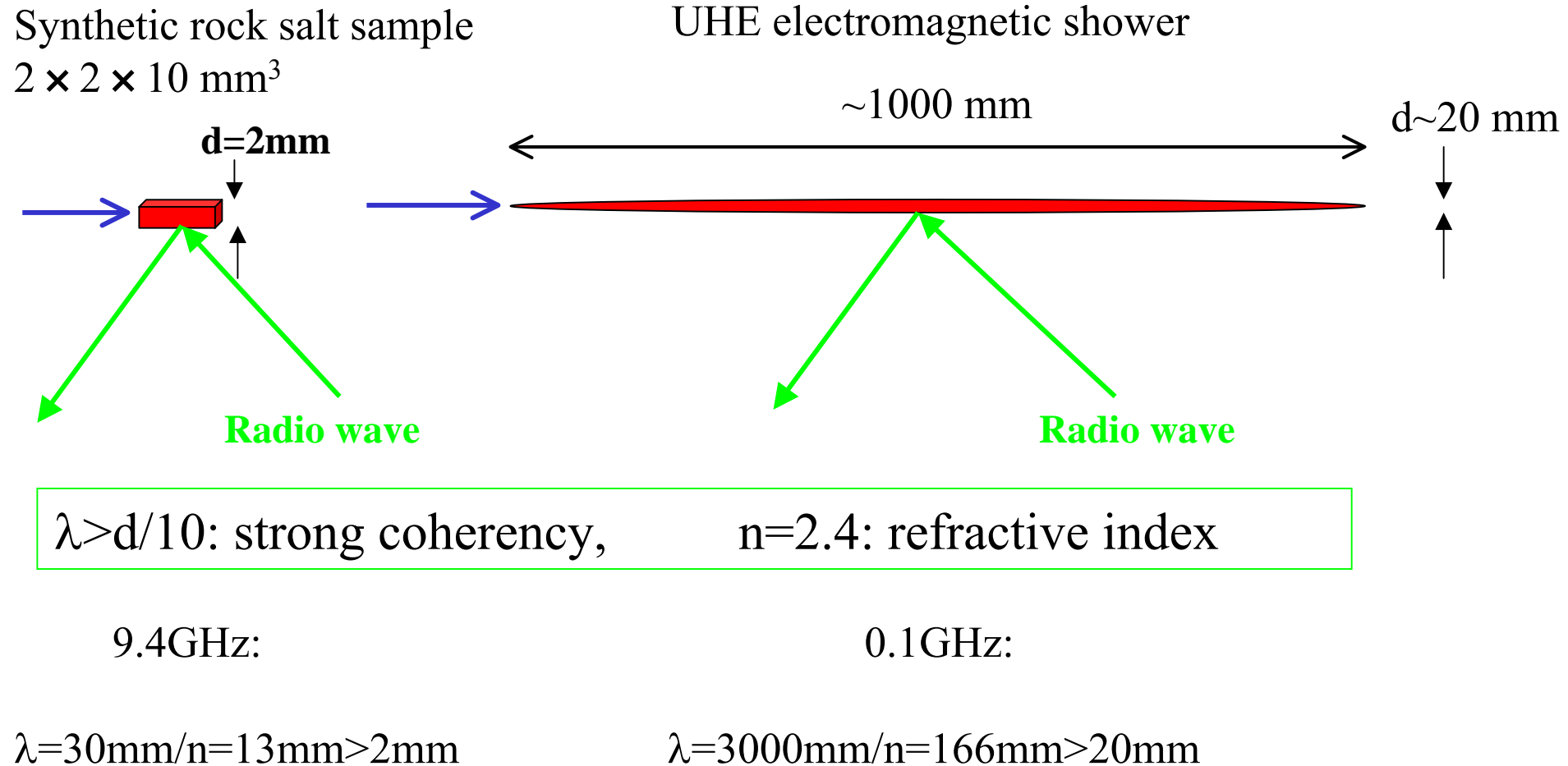
●  $N_\gamma = 10^{15}/\text{s}$ : number of X ray photons

●  $N_e = 3 \times 10^{22}$  : number of electrons in the rock salt sample

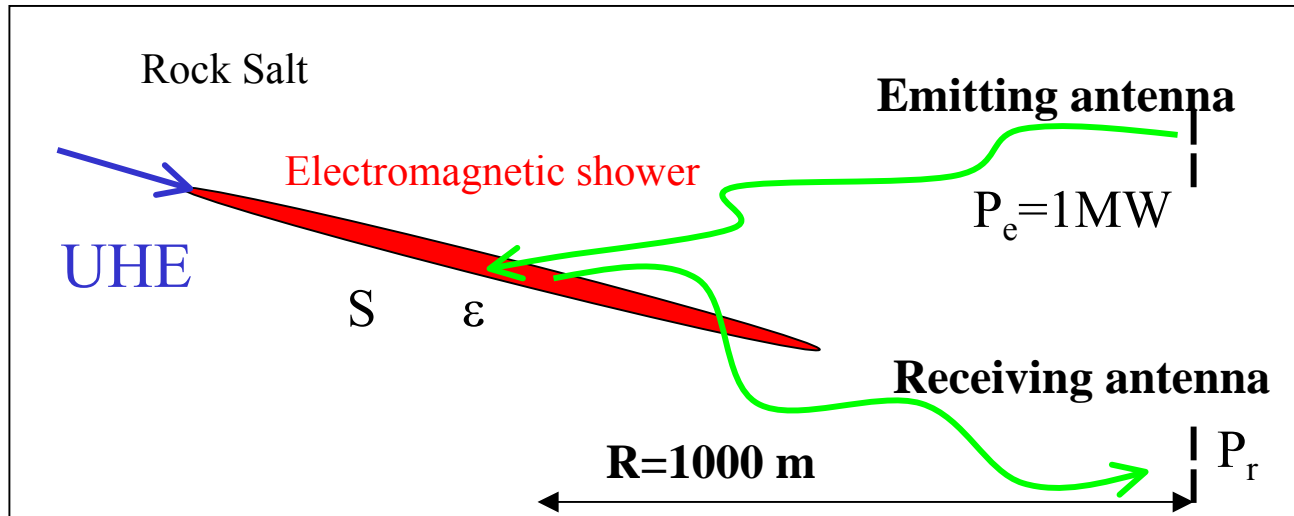
$\sigma = N_t / (N_\gamma N_e) = 3 \times 10^{-30} \text{ cm}^2$  : production cross section of the microwave target

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

# Scaling of transverse size and radio wavelength to real UHE shower



# Range of Radar



Receiving power at range of 1000 m

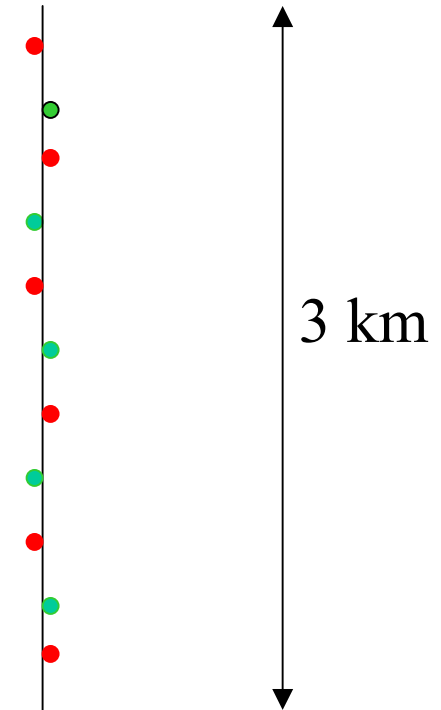
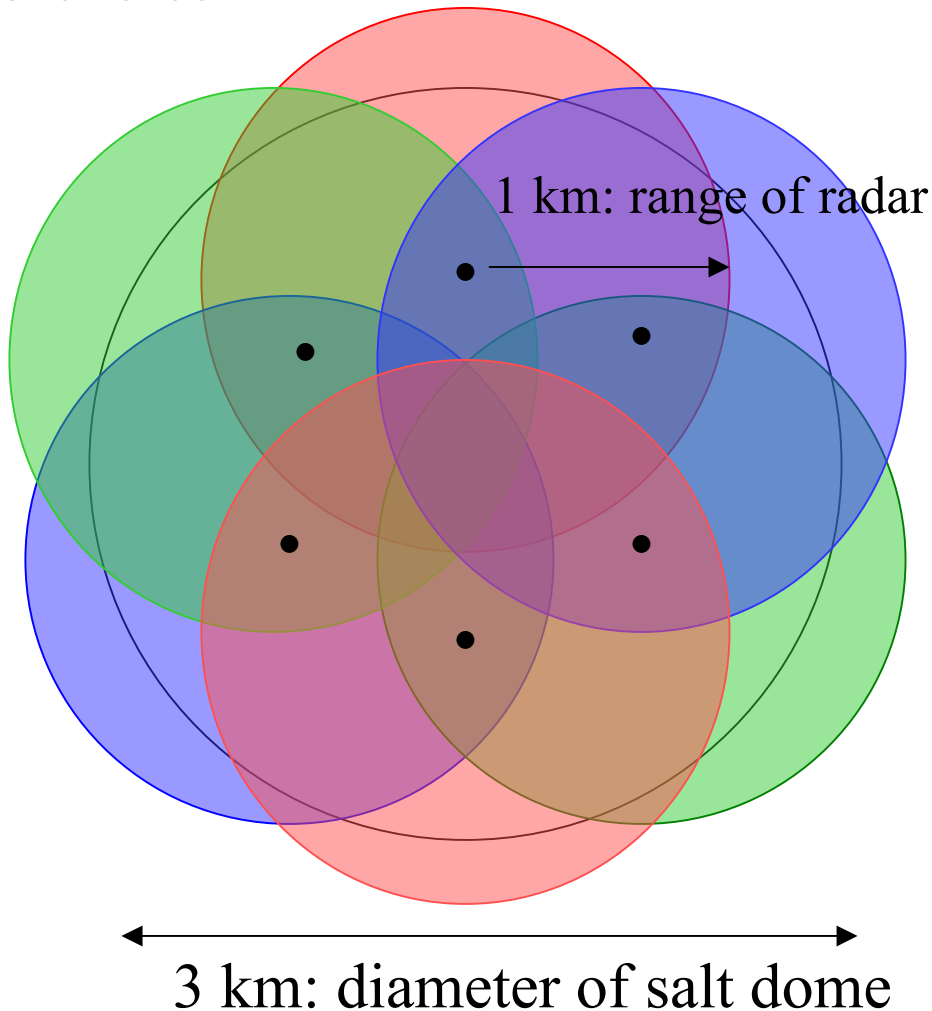
- $\epsilon = 10^{-7}$ : reflection efficiency
- $R = 1000 \text{ m}$ : range
- $S = 1 \text{ m}^2$ : cross section of UHE electromagnetic shower
- $L = 200 \text{ m}$ : attenuation length of radio wave in rock salt
- $\alpha = \exp(-2R/L) = \exp(-10) = 5 \times 10^{-5}$ : attenuation in the rock salt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

$P_r = P_e (4\pi R^2)^{-2} \epsilon \alpha = 3 \times 10^{-14} \text{ W}$ : at receiving antenna  $\rightarrow$  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  $7 \times 10^{19}$  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.