

# **Neutrino Detection in Salt Domes under LOFAR**

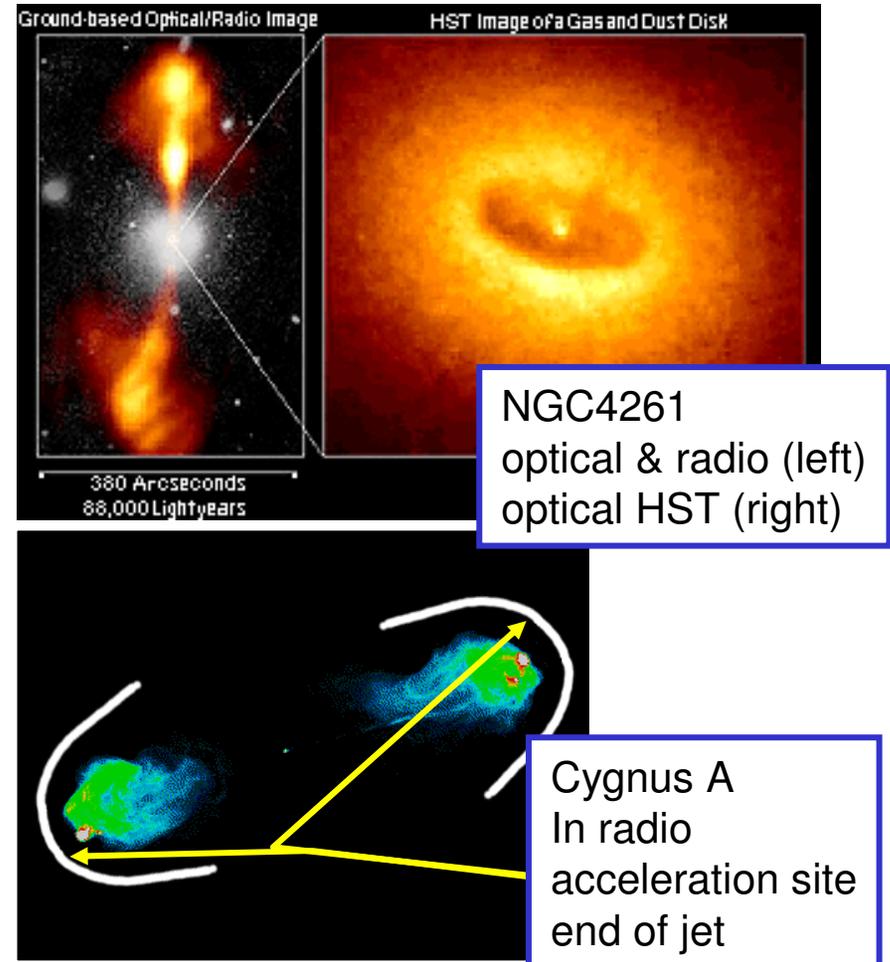
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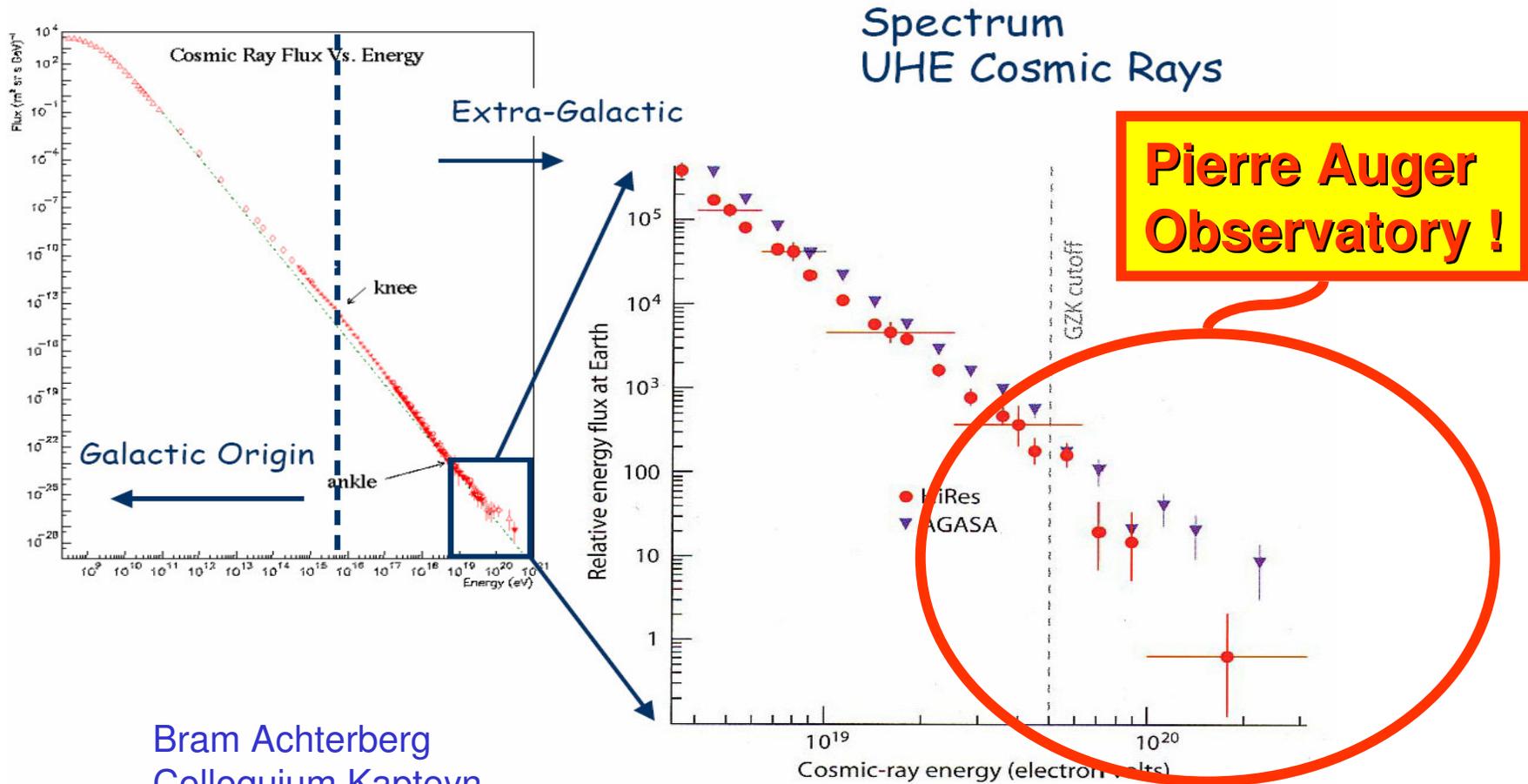
**International ARENA Workshop**

# Questions in CR physics

- **Origin and sources**
  - Bottom-up: role of Active Galactic Nuclei, Gamma-ray bursters, Quasars
  - Top-down: Topological Defects, unknown physics
- **Energy spectrum; composition**
- **UHE CR's  $\Leftrightarrow$   $\nu$ 's; GZK?**

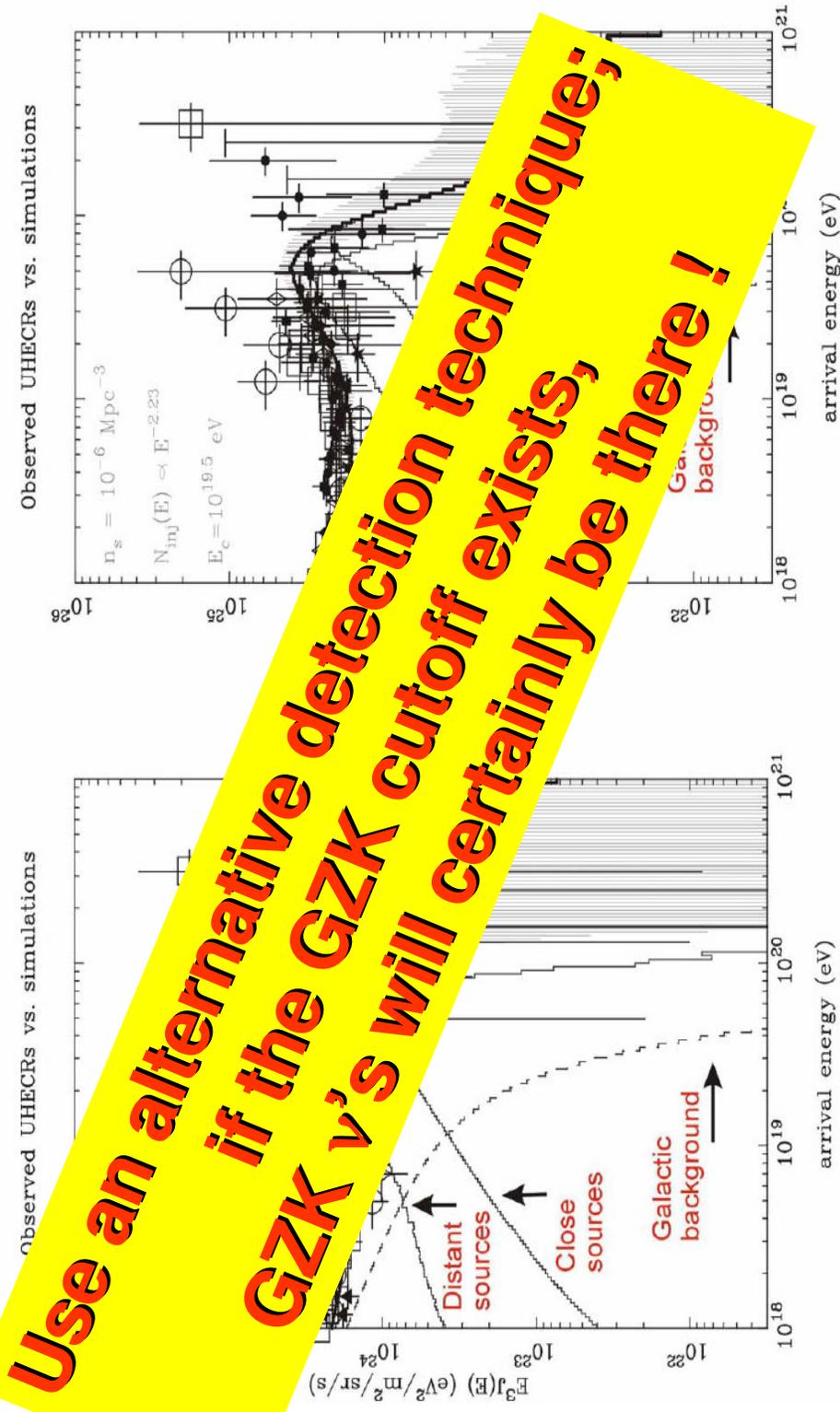


# High-Energy CR spectrum



Bram Achterberg  
Colloquium Kapteyn  
15 November 2004

# Marginal explanation by conventional models



**Use an alternative detection technique; if the GZK cutoff exists, GZK v's will certainly be there !**

Bram Achterberg  
Colloquium Kapteyn  
15 November 2004

# Advantage of UHE $\nu$ detector

## UHE $\nu$ 's provide complementary information

- sources are transparent
- Universe is transparent
- no charge; no influence from EM fields
- velocity is known
- direct link between  $\gamma$  and  $\nu$  spectrum

## But

- A huge target volume is needed (several km<sup>3</sup>)
- Signal to noise should be optimized

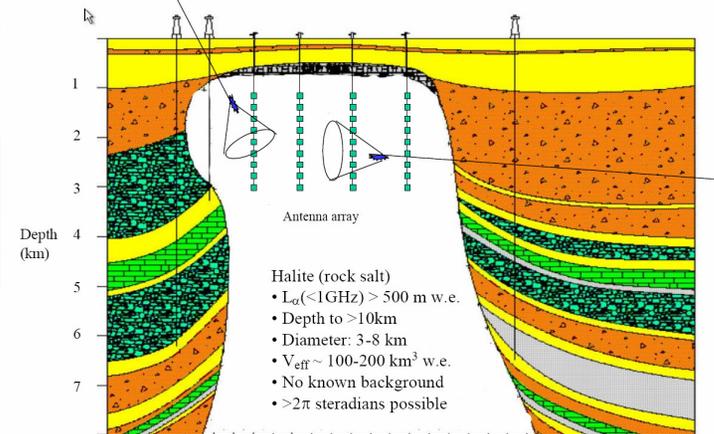
# How (one option ...)

- Detect UHE  $\nu$ 's using rock salt in Northern Europe (Groningen)
- Coherent emission in radio band (Askar'yan)
- Cooperate with gas & salt industry to get access to salt domes
- Long lead time
  
- At the same time get involved in other experiments (Auger, WSRT), jump start !

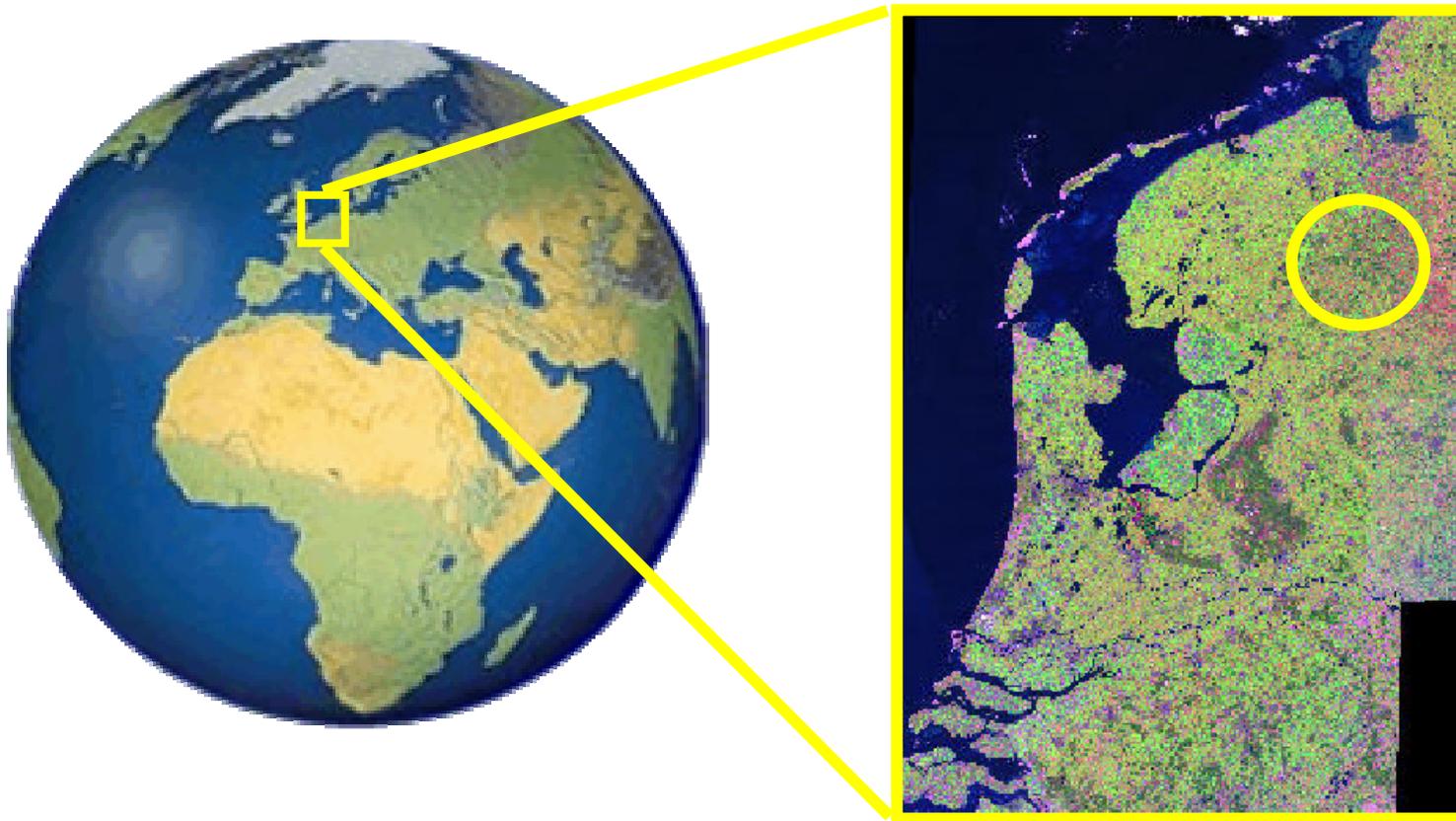
# Foreseen UHE CR Program

Radio detection for cosmic rays hitting

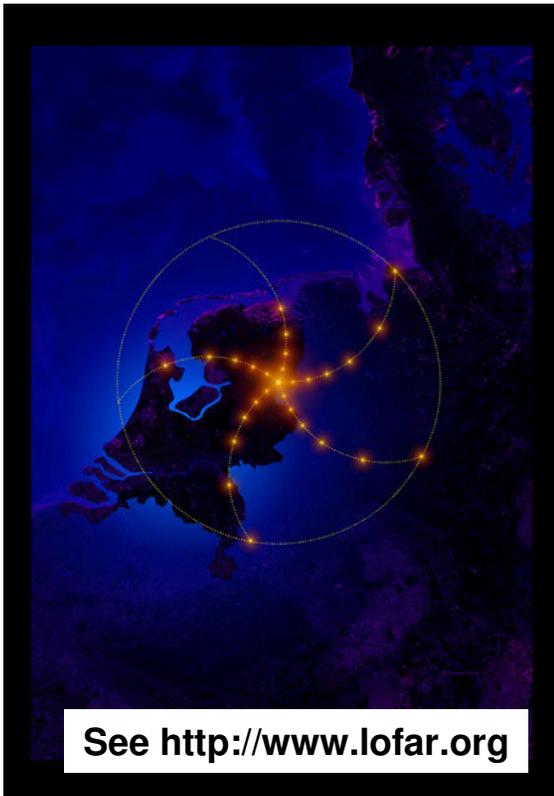
- ✓ the Earth's atmosphere (Falcke, University of Nijmegen and ASTRON, Dwingeloo)
- ✓ the surface of the Moon (Bacelar, KVI, Groningen)
- ✓ salt domes in the Netherlands (this talk)



# New site in the Netherlands

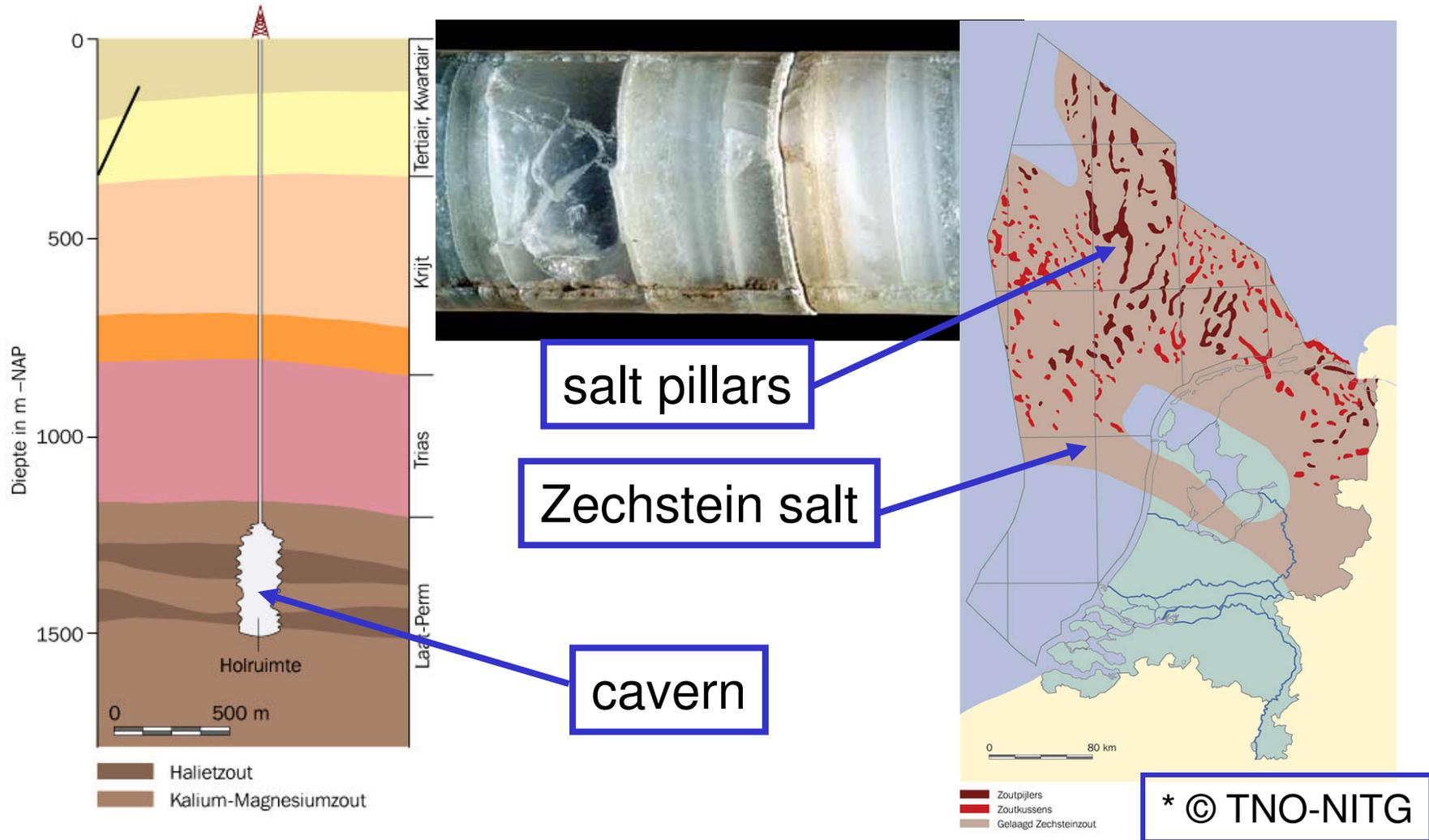


# LOFAR: Low Frequency Array



- Interferometer in frequency range of 10 - 200 MHz
- Array of 100 stations of 100 dipole antennas
- Baselines of 10 m to 400 km
- Fully digital: received waves are digitized and sent to a central super computer (IBM Blue Gene @ university of Groningen)
- Science:
  - Cosmology: HI at  $z > 10$  (époque of re-ionization)
  - Surveys:  $> 10^8$  new sources
  - All-Sky monitor: transient events
- And more .....

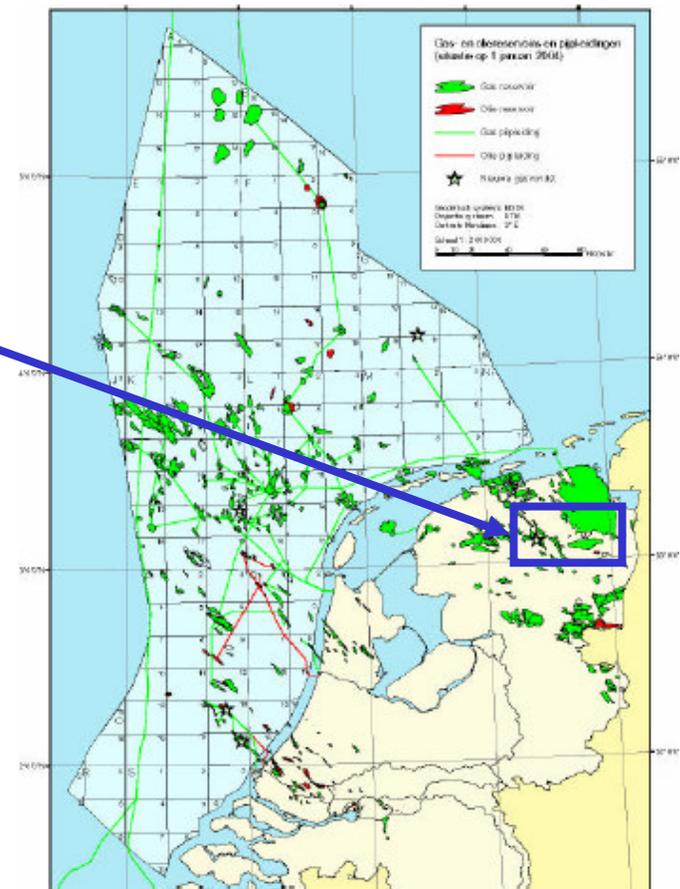
# Underground Salt Layers\*



# LOFAR and oil & gas



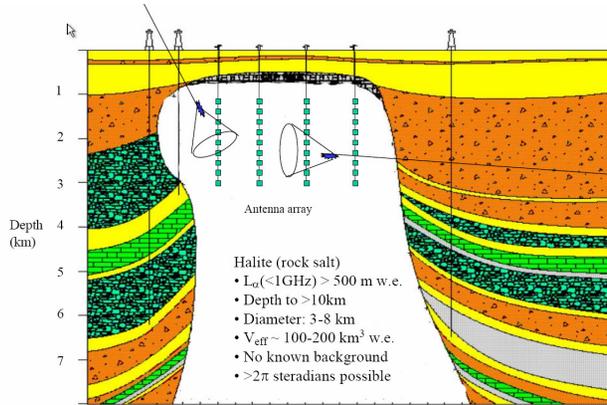
salt domes



Source: Ministry of Economical Affairs, Annual Report 2003

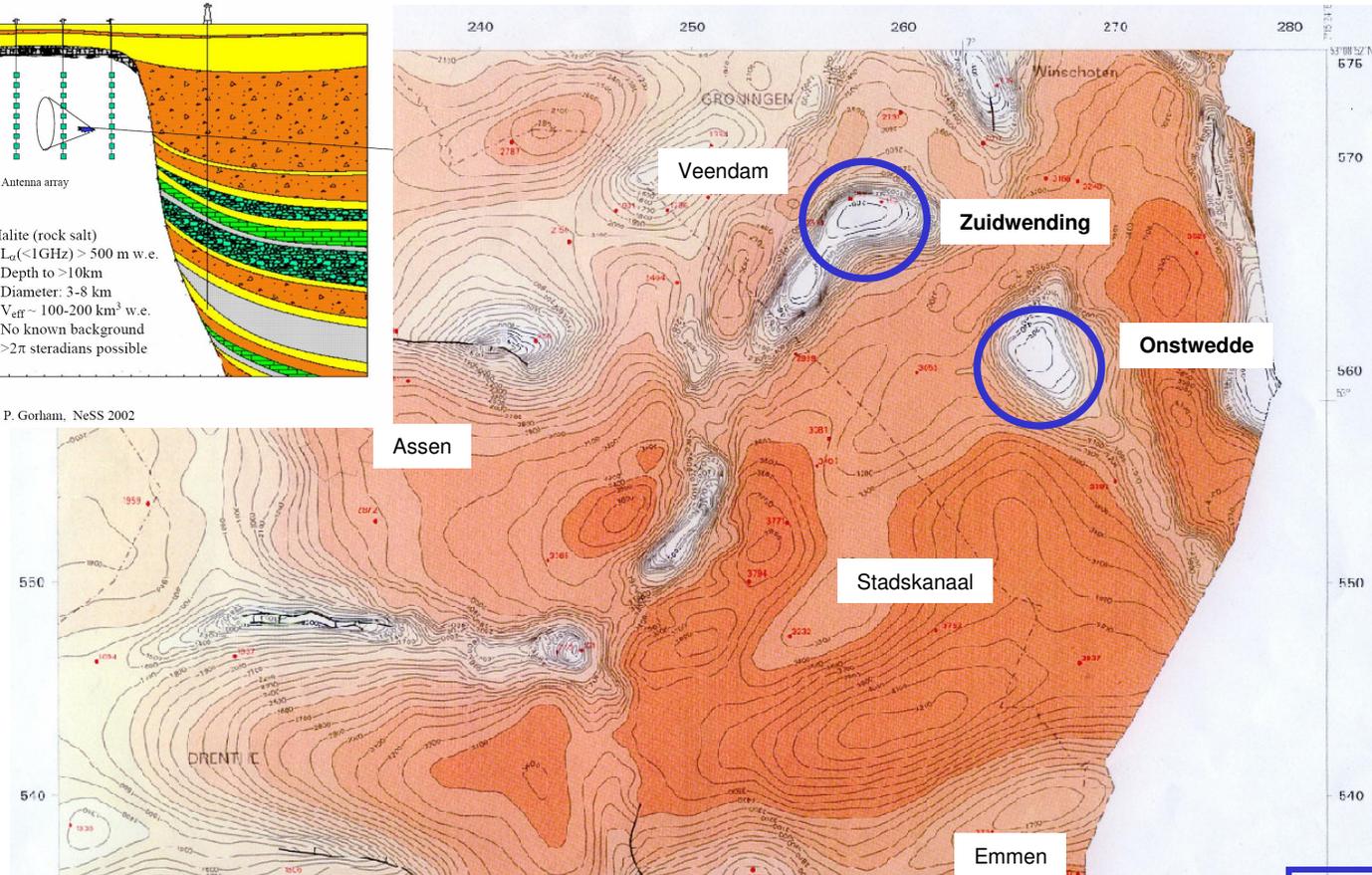
# Salt in Groningen

## ZESANA: ZEchstein SALT Neutrino Array



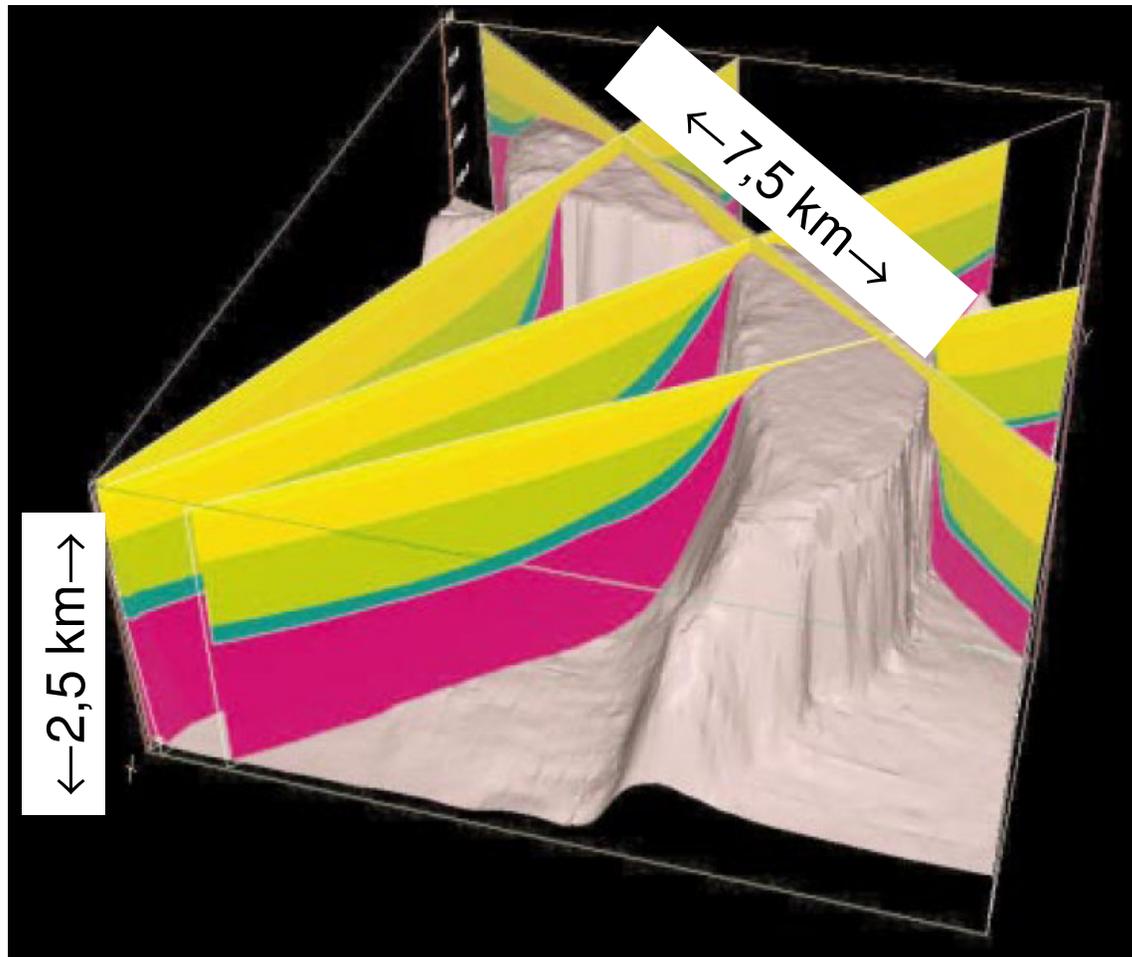
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P. Gorham, NeSS 2002



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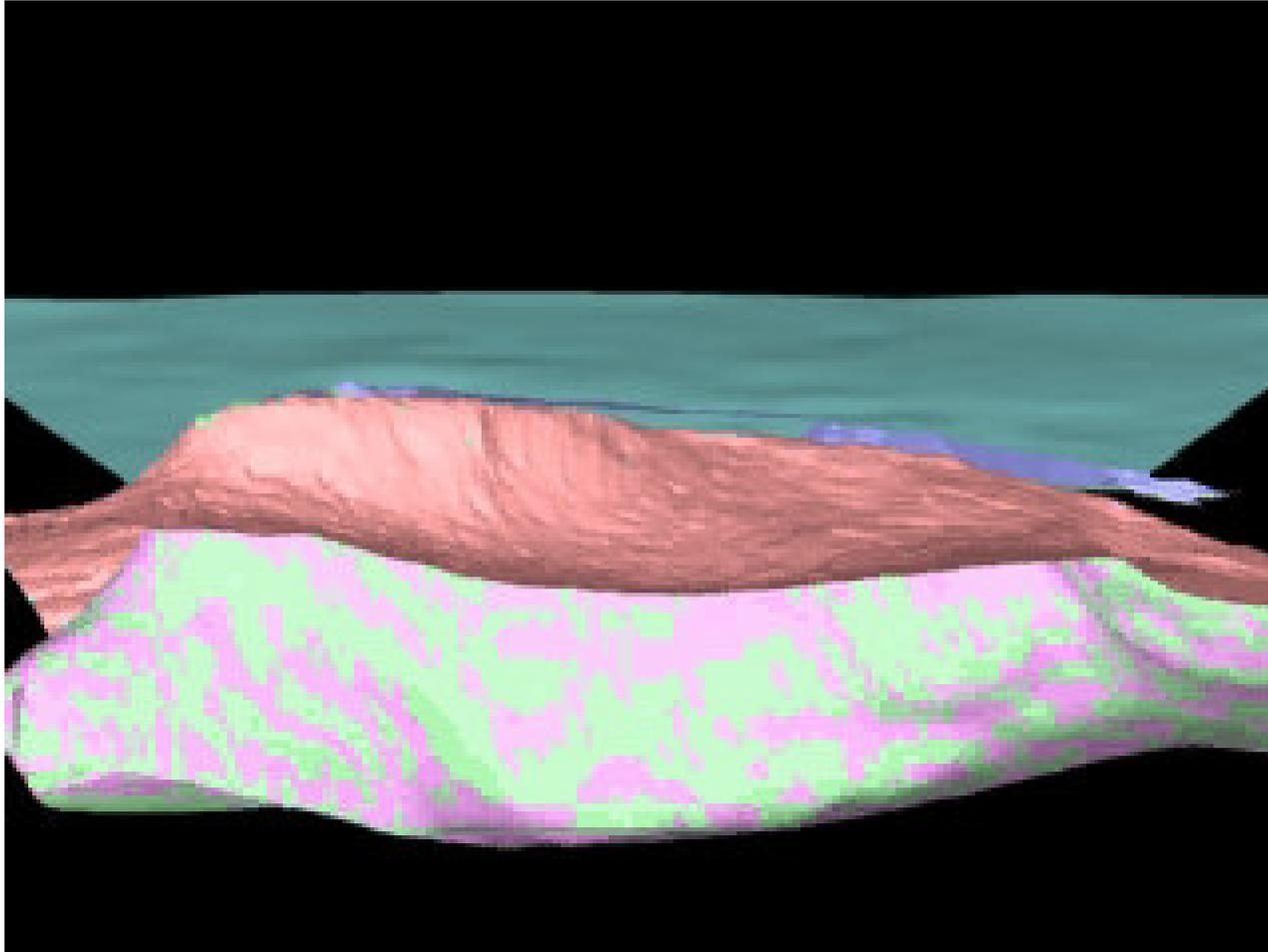
# Zuidwending salt dome



3D model of the Zuidwending salt dome: view from the East. The active horizon is the top of the salt.

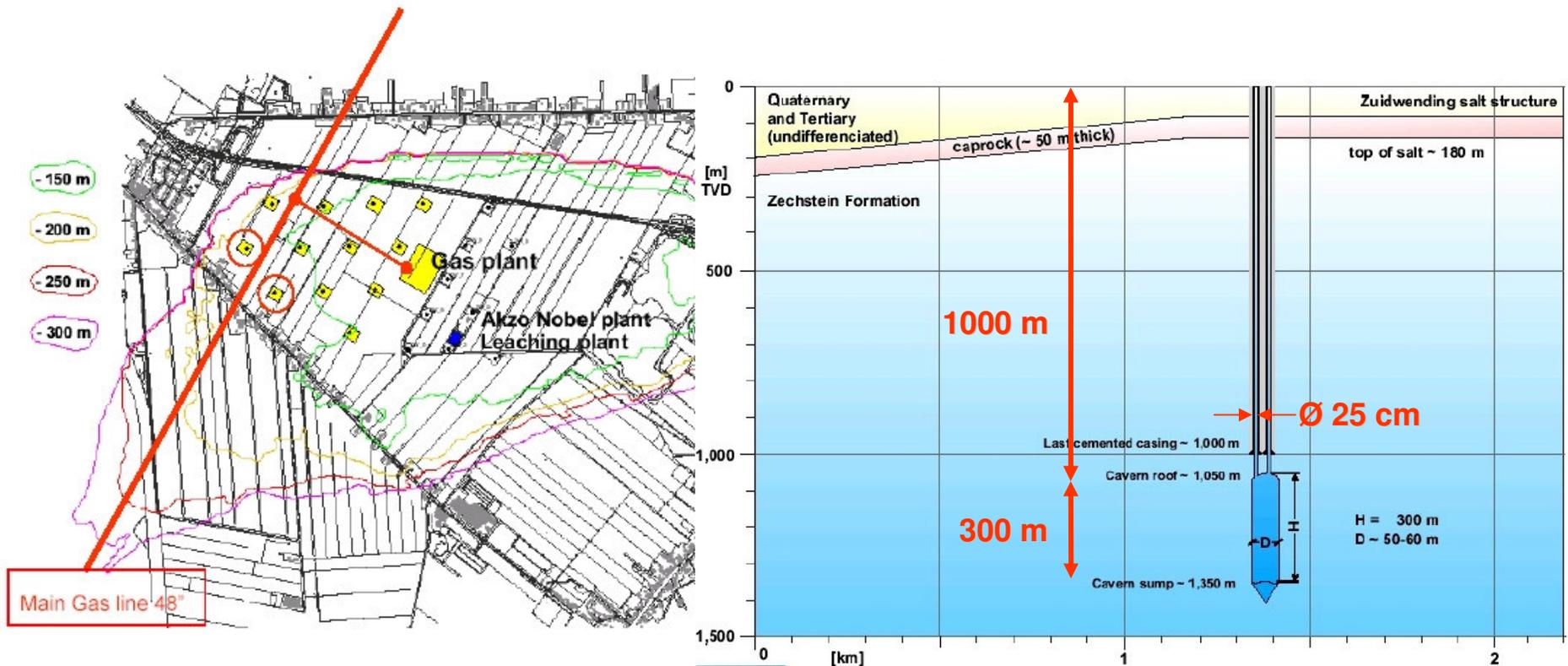
Purple: Triassic;  
Dark green: Lower Cretaceous;  
Light green: Upper Cretaceous  
Orange: Lower Tertiary;  
Yellow: Miocene-Quaternary.

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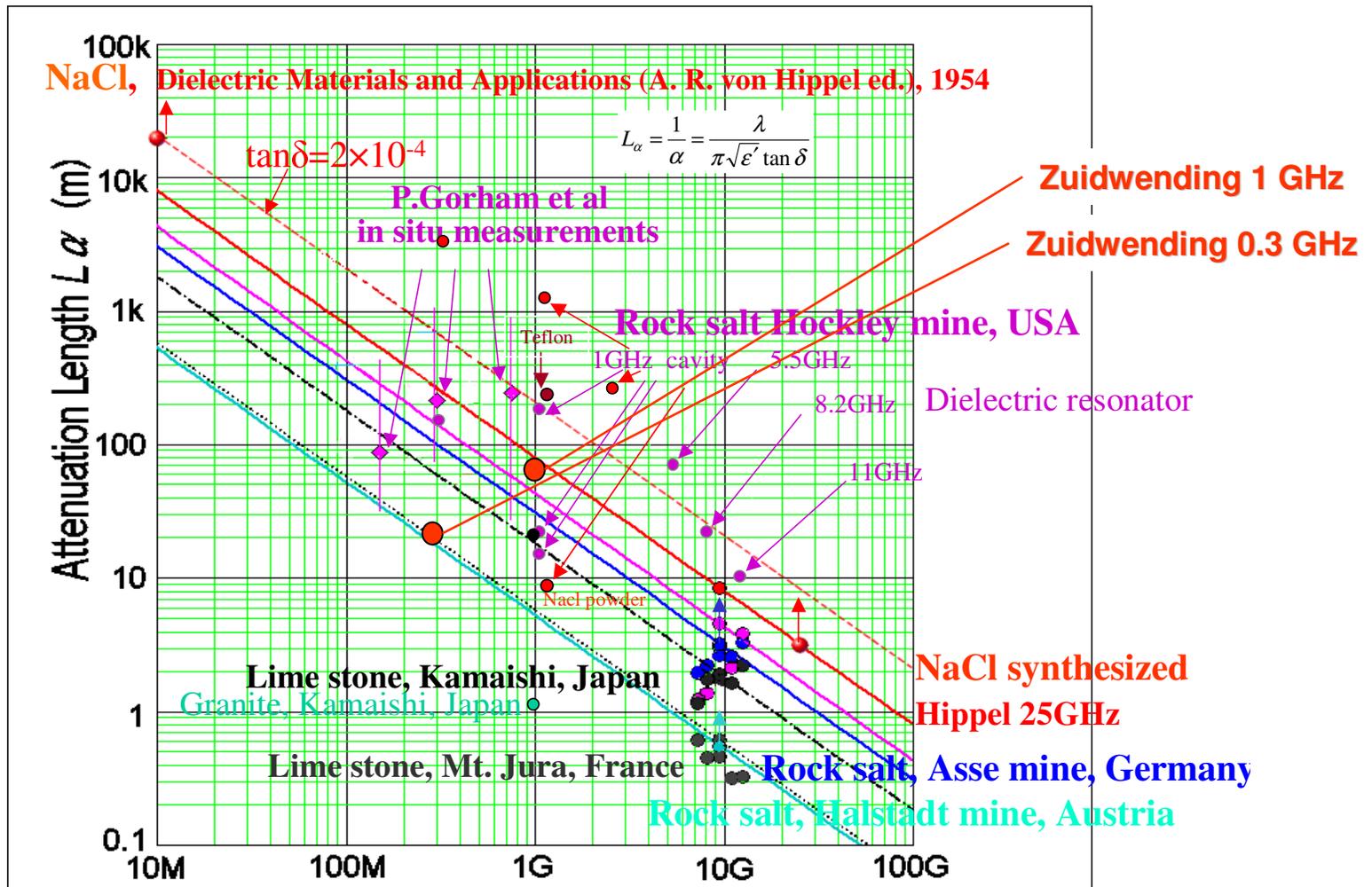
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# Zuidwending Dome ?



Aardgasbuffer Zuidwending: a fast Compressed Natural Gas storage  
 Gastransport Services, Akzo Nobel Salt, NUON (Energy Valley)

# Results (Chiba san)



# R & D Needed

- Further attenuation length measurements
- Ultra-sensitive underground radar techniques
- Theory on showers and radio emission
- Cross calibration with other experiments (Auger, acoustic, WSRT, ...?)



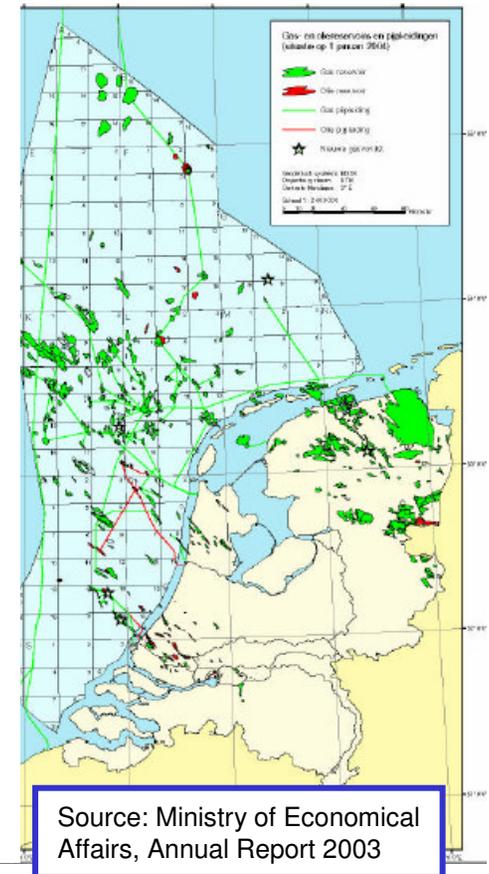
# A Pilot

In the coming years exploration of salt domes will rapidly increase

- Natural gas (additional capacity for nearby liquid gas terminal)
- Storage of other ‘stuff’
- Interest from geophysical department to make a joint proposal

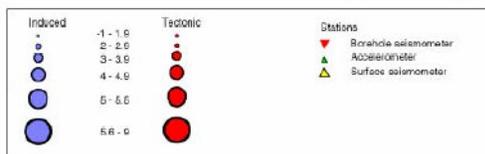
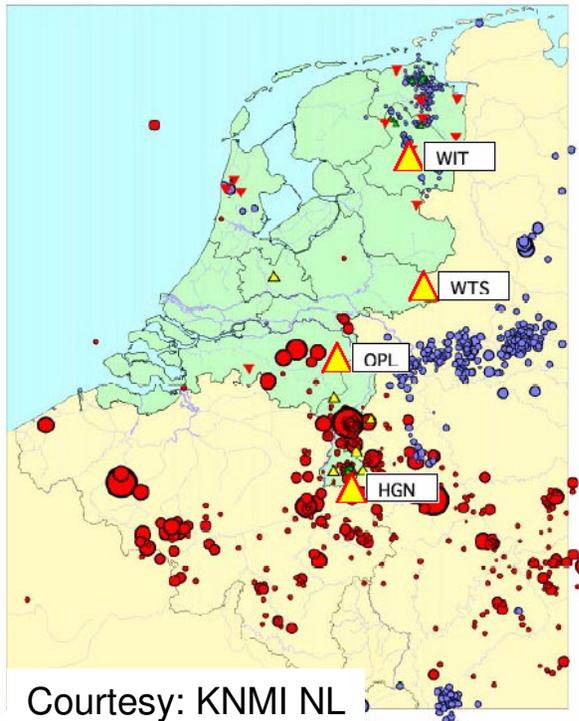
Window of opportunity in 2006 – 2007

Drill fase 1 of natural gas buffer (4 cavernes)



# LOFAR: a Sensor Network

As part of the LOFAR project, deployment of geophones has started already.



# Conclusion

- Radio techniques for detection of UHE  $\nu$  are very promising and provide an important step for the next generation of  $\nu$  telescopes
- LOFAR, the largest radio telescope in the world, can be used for UHE CR and  $\nu$  detection (Falcke, Bacelar)
- Jump start in physics (Auger, WSRT)
- Window of opportunity for pilot salt dome project (radio, acoustic, ...)