~~Induction~~ FFAG for Accelerator Driven Reactor and Deep Underground Facility

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ATW

- High power accelerator (Linac,
- Beam splitting by Laser or foil
- 40 MW b to 500 MW t k=0.95
- Reliability
- Power peaking
- Expensive 40 % increase than one through
- Not so economical

5
A

Cyclotron

- Small device not expensive for shielding
- Not expensive than linac (Economic)
- but limited beam current
- CW operation
- Proposed at Euratom with Mandrillon
- Prof. Rubbia promoted
- Not shock wave in sub-critical reactor
- Difficult extract high momentum beam

High conversion LWR

- NERI program
- No R and D like Pb cooled reactor.
- Thorium fuel; high gamma non proliferation
- Tight lattice hard neutron spectrum
- Heat removal (accidenent case)
- Passive heat removal (Natural Ciculation)
- High pressure due to earth gravity

B

Accelerator

- LINAC
- Cyclotron
- Fixed Field Alternating Gradient Synchrotron (FFAG Ohkawa, Mori)
- Circular Induction Accelerator (Takayama)
- Circular Induction (CI) FFAG,(CIFFAG)

Accelerator Driven Reactor

- Slightly sub-critical reactor k=0.99
- Author proposed to run the reactor with subcritical condition to get safe operation
- Cyclotron instead of linear accelerator
- limit of current
- 10 mA (1GeV :10 MW) possible by cyclotron for 1GWe Power plant
- Further increase by FFAG

FFAG

- Fixed field
- not cw beam but high repetition
- widening beam to reduces the space charge
- Acceleration by RF; iso chronous
- Compact accelerator
- Not only medium energy (1-3 GeV for ADR)
- Hadron physics (Y.Mori. S.Machida and D. Trojevic)

Slightly or deep sub-criticality

- We have accumulated critical reactor and one with slightly critical is close to critical reactor, but prevent accidental insersion of small reactivity.
- Cold coolant sudden insersion or fuel bowling
- Dopper coefficients should be negative

Long lived fission products (LLFP)

- Not considered seriously
- Neutron capture Loss
- High neutron economy
- Disposal of LLFP to outer space by propulsion from space shuttle or moon
- New initiative of space reactor
- Hybrid fusion not pure fusion

B 7 ~

Thermal vs Fast

- Thermal Furukawa and Boaman
- Smaller MA fast transmutation
- Dedicated one is also fast transmutation
- Fast spectrum for large burn up high neutron economy
- Molten Salt technology, Dri process
- Not high cost of the fuel manufacturing

A Proliferation Resistant Hexagonal Tight Lattice BWR Fuel Core Design for Increased Burn-up and Reduced Fuel Storage Requirements

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NERI project assessments
DOE HQ. Sept, 2001

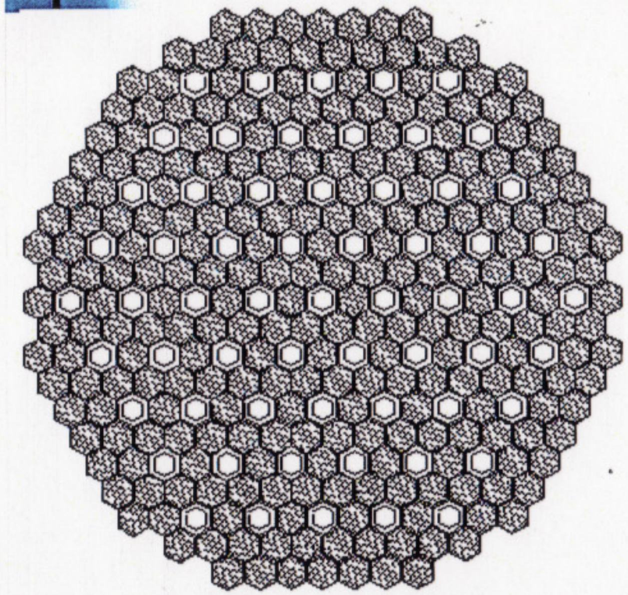
HCR Research Objectives

- Minimize the potential for proliferation of weapons grade fissionable materials
- Maximize the inherent safety features of the reactor
- Maximize the achievable fuel burnup and plant capacity factor

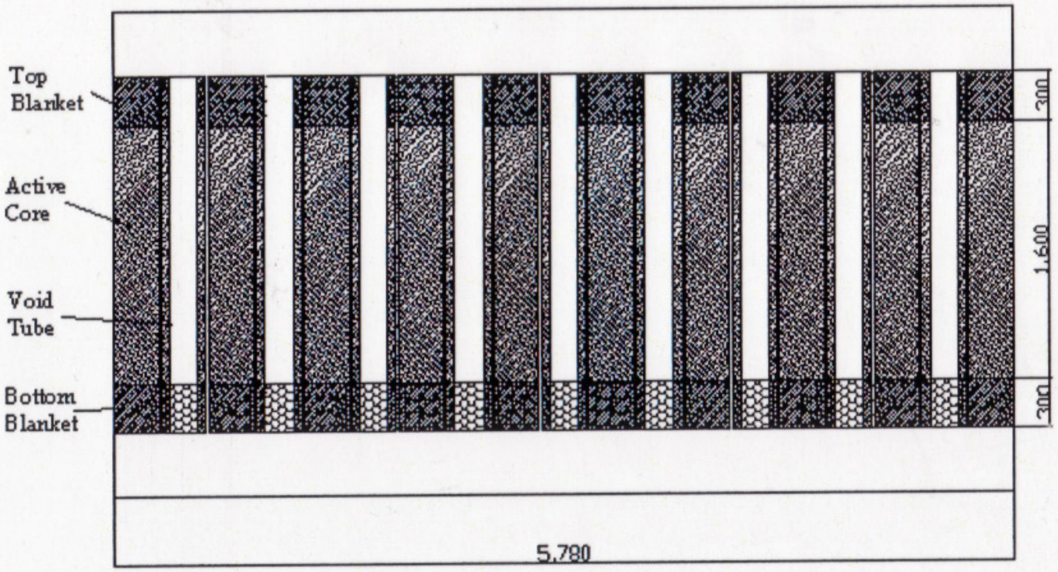
Reference Design

- RMWR proposed by JEARI and JAPC
- Features:
  - Tight lattice
  - Hexagonal assembly
  - Flat core
  - Blanket
  - Void tube

RMWR Core Geometry

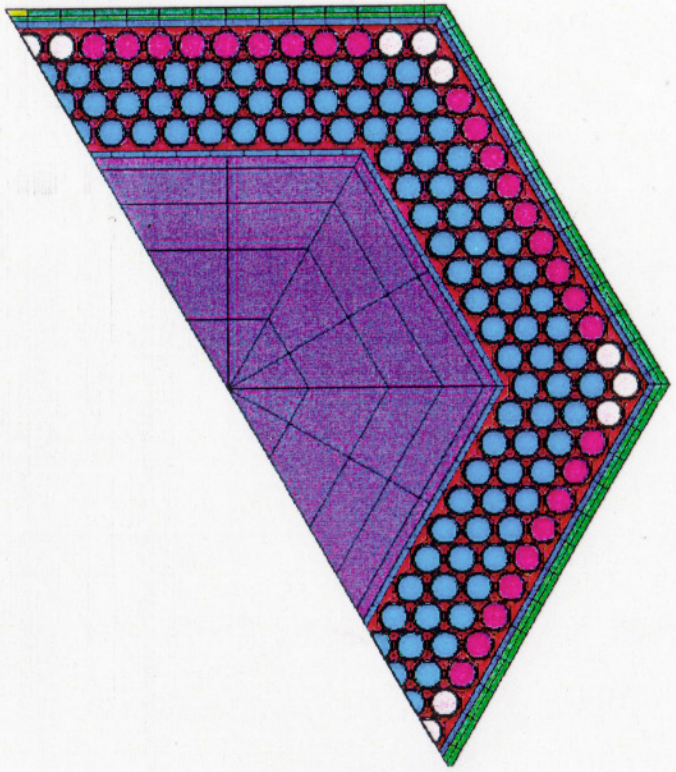


Horizontal view



Vertical view

Assembly with Void Tube



- fuel pins 252
- Void tube
  - Wall

    Material: Zr

    inner distance/mm: 185.67

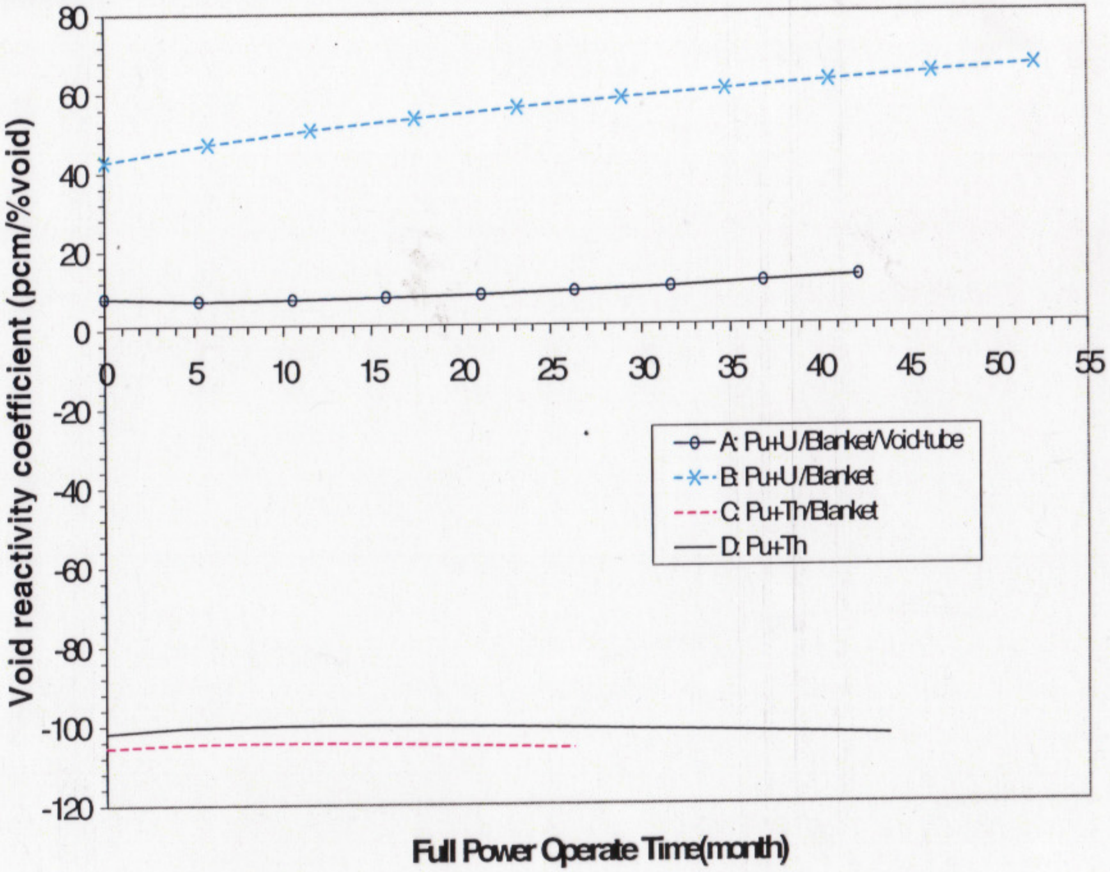
    Thickness/mm: 0.25
  - inside

    Material H_2O

    Density $0.03753 g/cm^3$

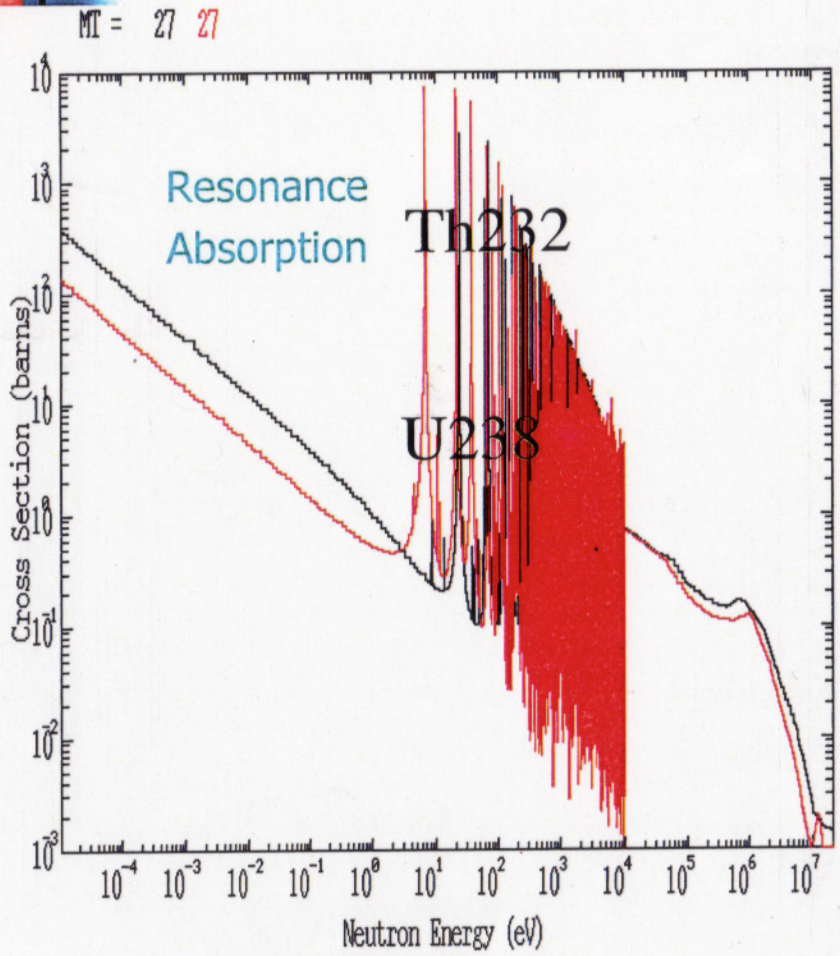
13'

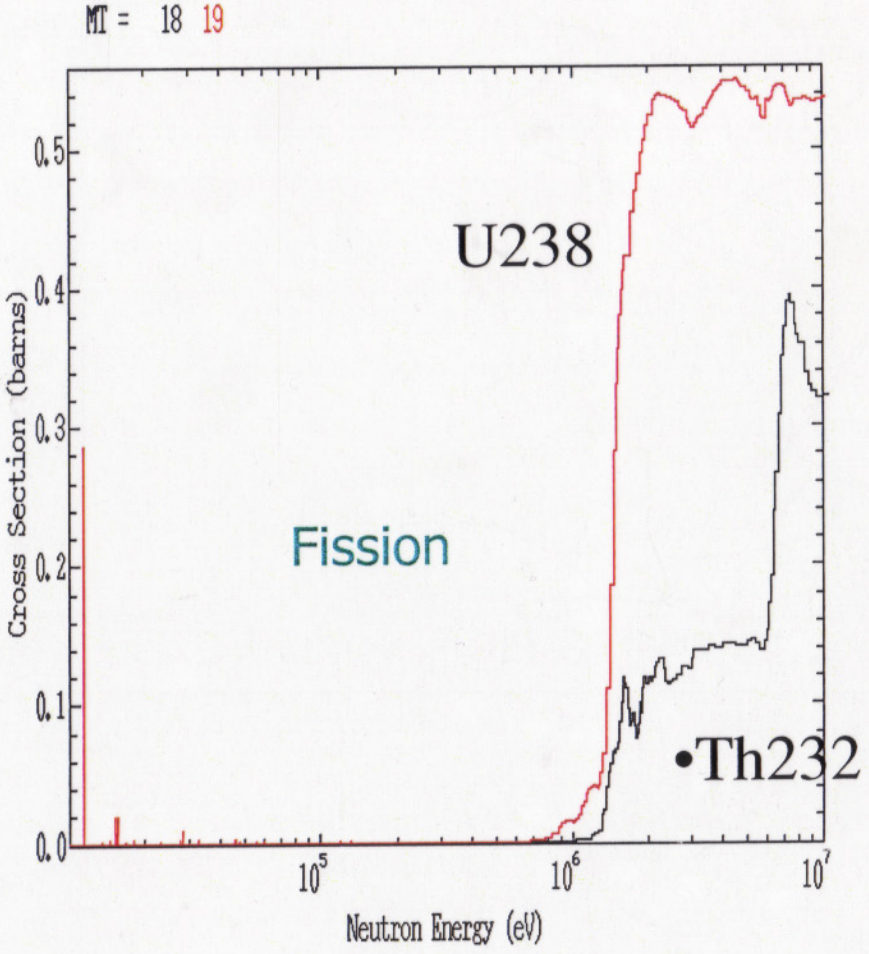
Void Reactivity Coefficient



- The VRC for case A, B (with Pu-U fuel) are positive.
- With void tube, case A has less positive VRC.
- But it is not negative as RMWR is, maybe caused by Case A has much deep burnup than RMWR
- Pu-Th fuel insure The VRC are negative throughout the core life

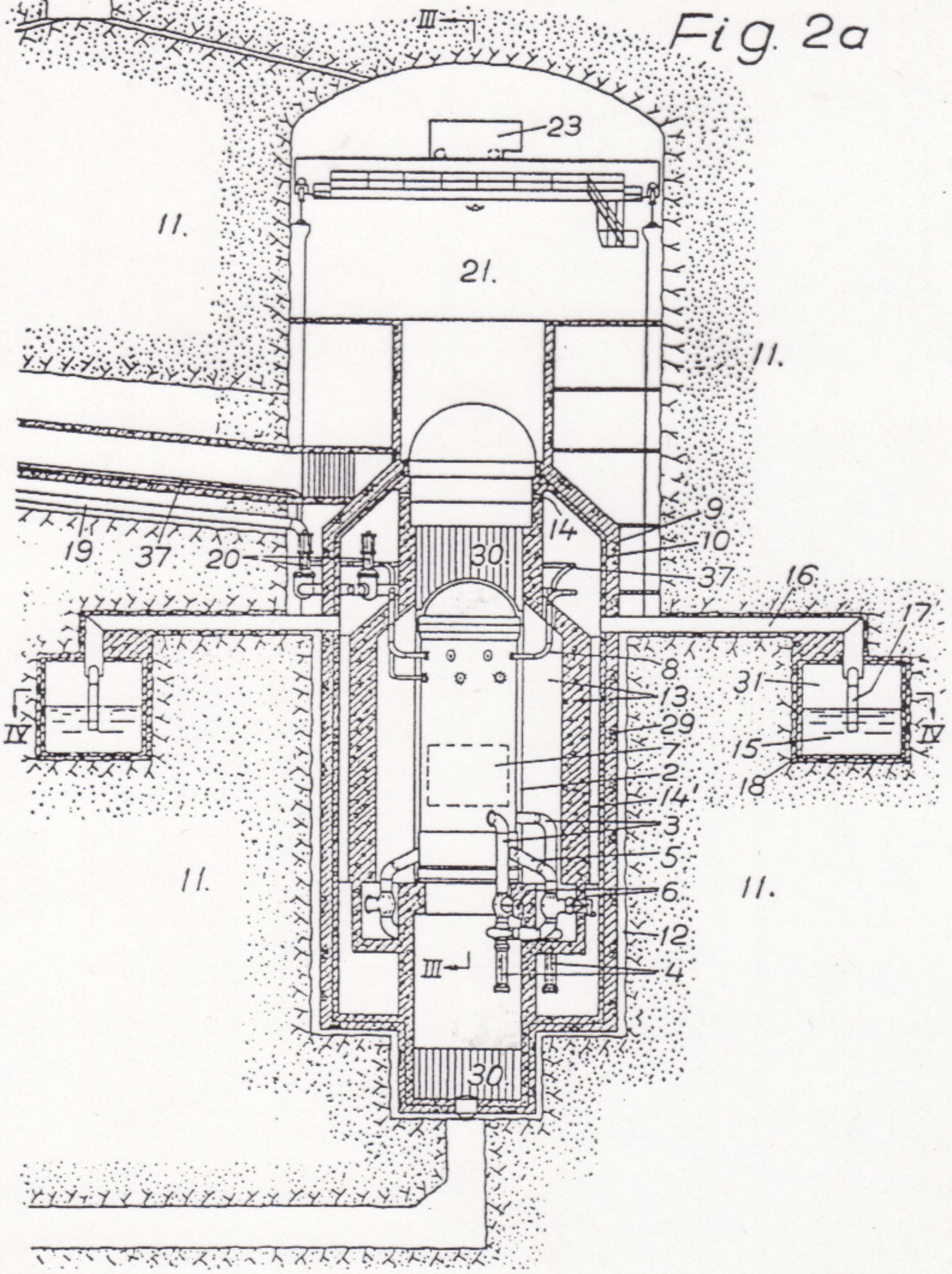
Comparison of Th-232 and U-238





14'

Fig. 2a



INVENTORS
PER GUSTAF ISBERG
CHRISTEN WILLEMOES PIND
BY CNUT HERBERT SUNDQVIST

Conferences on Underground Science

NUSL Documents

NUSL Affiliates

NUSL Talks

History

Neutrino Physics Links

Collaborator's section

nterested in joining us? Go to our

Homestake Mining

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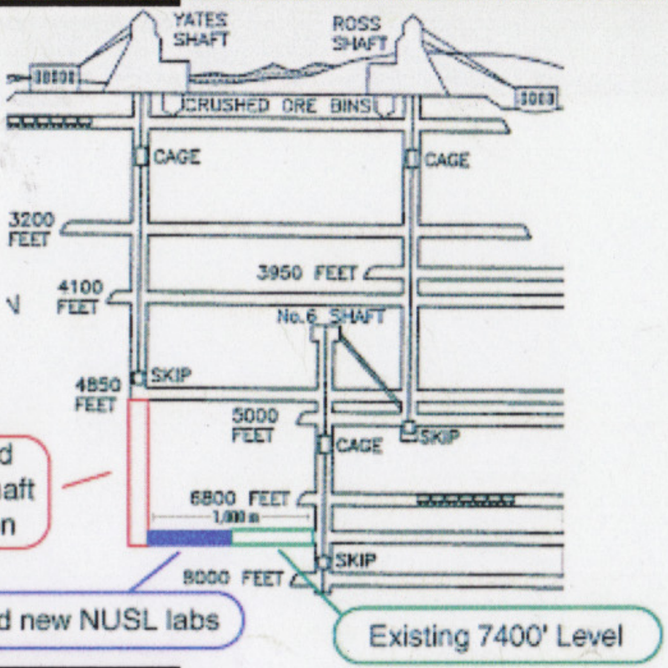
Learn about Lead, South Dakota

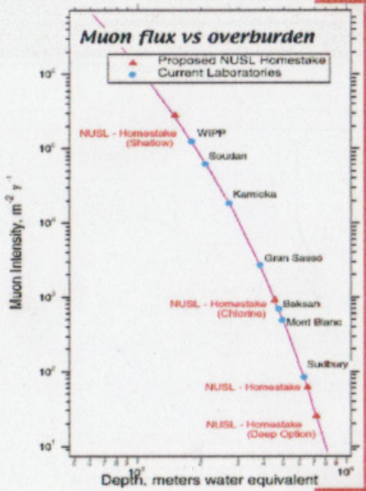
Wednesday, January 2, 20

Find out more about the Black Hil Dakota at these links:

U.S. Forest Service

Great Outdoor Recreation P





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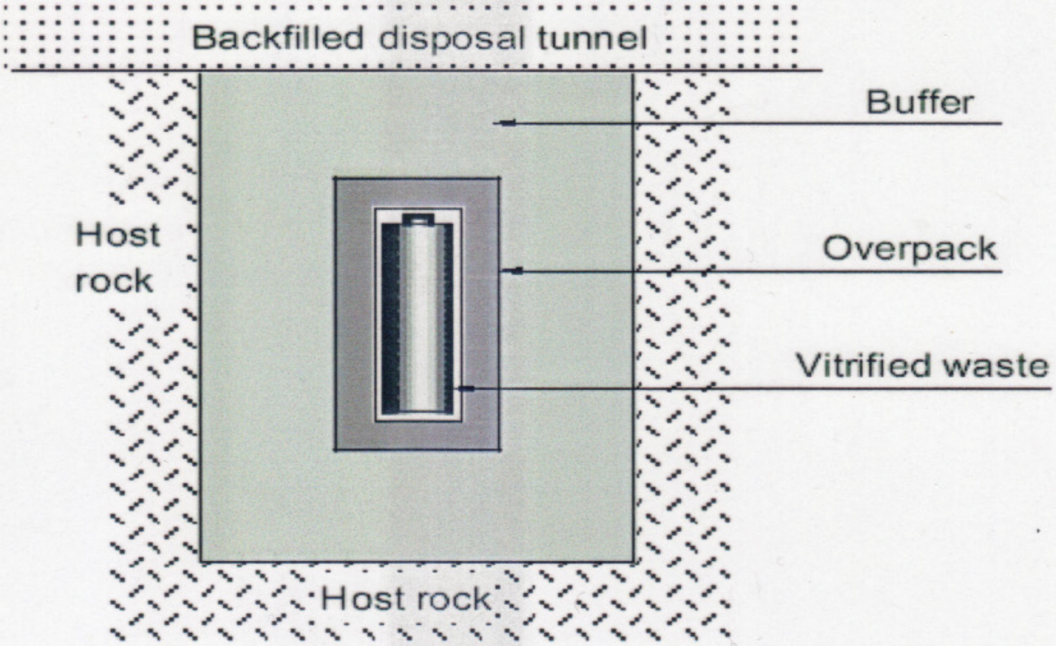
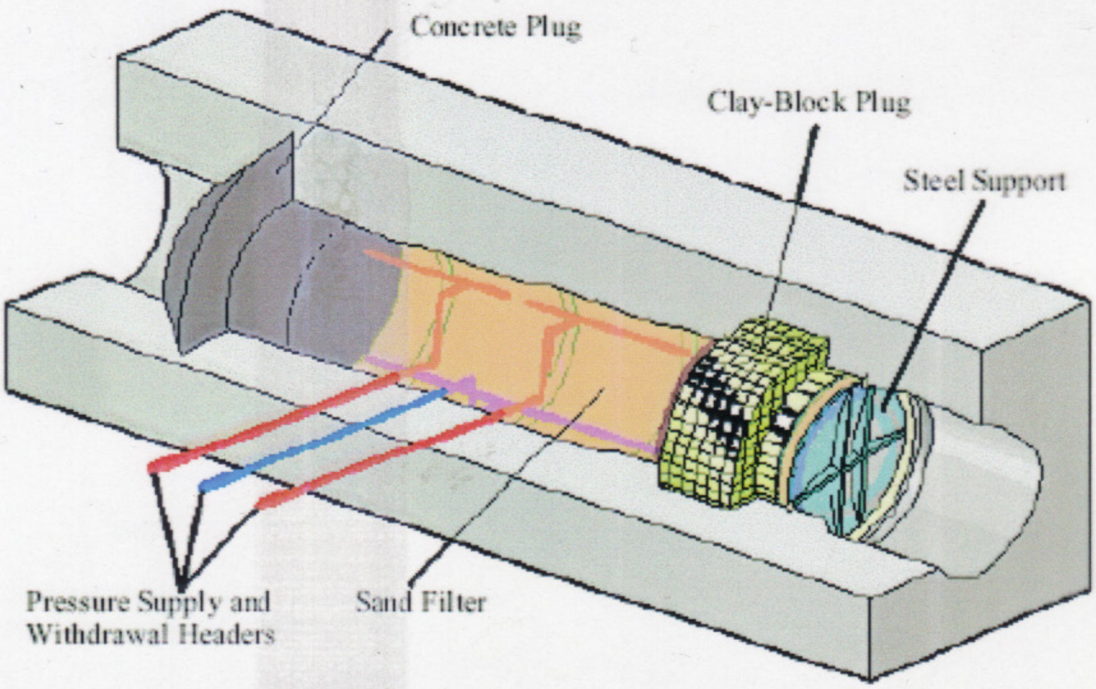


Vertical emplacement concept



Schematic view of Tunnel Sealing Experiment (TSX)

Fig.5

Embedding Materials

- Direct earth pressure
- Between container and reactor vessel or cooling pipe
- Easily drained for reparing of maintenance
- He gas
- Water Solid Ice
- Salt, less expensive to make space 1/5 of rock

Embedding Materials(2)

- Fine sand (not solidify by high pressure)
- Bentnite
- Concrete

Small reactor in underground

- China, Japan,
- Transportation of fuel, and Spent fuel?
- Protection of public?
- Non proliferation ?
- Many inspection

- South Dakoda Gold mine Homestake
- Physics laboraory Neutrino experiemts
- R. Davis Solar neutrino Osciallation mass of neurino.
- Double beta decay low back ground the basis of elementary particle theory
- Biology labo for deep

Large reactor in deep underground

- More than 1GW e power plants, Nuclear Parks
- Modular type for low capital cost
- Small numbers of access port
- 2 shafts and holizontal tunnel
- Limited access but emergency shafts 2.
- Non proliferation
- Every Nuclear facility in DUG.

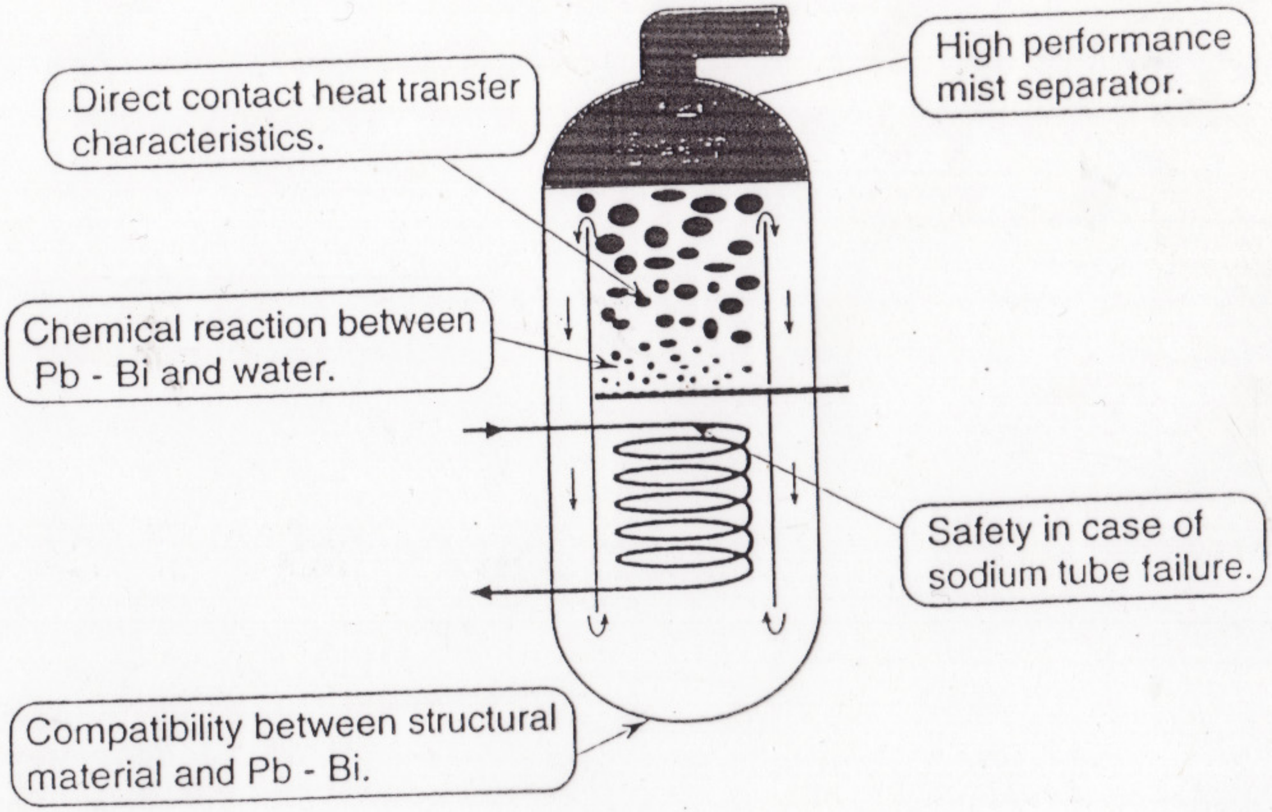
Deep Underground Reactor

- Fission gas circulate but well shielded by earth
- Circulation can be done by compressor.
- Large storage space in underground well shielded.
- Natural circulation ?

Deep underground ATW, ADS

- Embedding the reactor in earth
- High pressure utilize for high efficeincy
- 500-1000 meters deep 13- 25 ATM
- Thin pressure vessel.
- Modular type smaller intitial investements
- Cost of deduction
- No tall container building

Main R & D Items

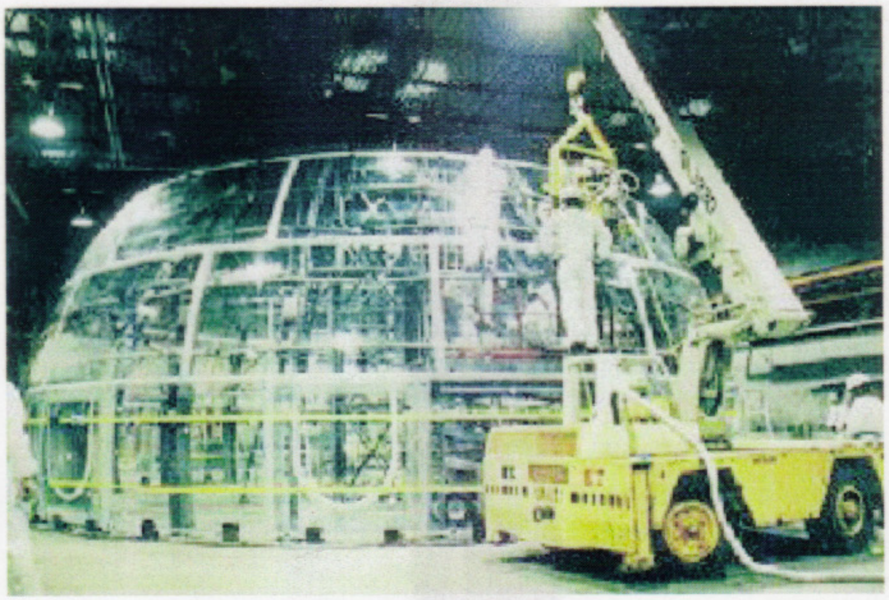


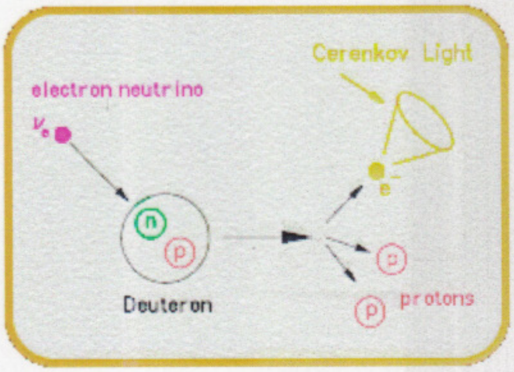
CRIEP

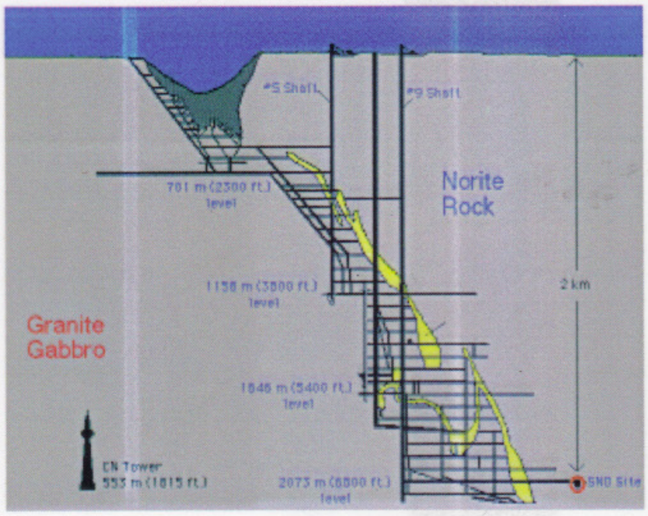
Super kamiokande

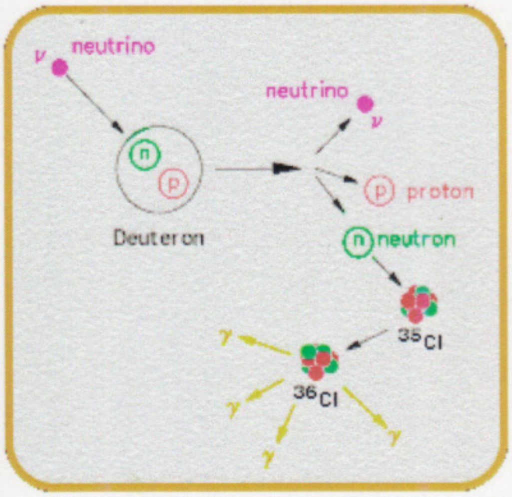
- Neutrino osciallation
- Detector for KEK neutrino
- Japnese Tunnel
- Kashima Co. Dream 1Km dia and height under Tokyo Article Space not filled by earth in DUGR concept

D34




Cerenkov Light
electron neutrino
ν_e
e^-
n
p
Deuteron
p
p
protons


#5 Shaft
#9 Shaft
701 m (2300 ft.) level
Norite Rock
1158 m (3800 ft.) level
2 km
Granite Gabbro
1646 m (5400 ft.) level
CN Tower 553 m (1815 ft.)
2073 m (6800 ft.) level
SNO Site


ν neutrino
neutrino ν
n
p
Deuteron
p proton
n neutron
^{35}Cl
^{36}Cl
γ
γ
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Circular Induction Accelerator (CIA)

- K. Takayama, Kishiro (KEK)
- make small real estate for circular
- Longitudinal spread of beam
- using the potential barrier by induction
- Not isochronous due to induction acceleration
- but consumption of magnetization energy

Circular Induction FFAG (CIFFA)

- Combine CIA + FFAG
- Widen beam transverse and longitudinal
- Transverse by FFAG: Longitudinal by Induction
- Focusing the beam at acceleration region to get high acceleration
- With small induction accelerator

RF vs Induction

- **Not isochronous for Ind.**
- **RF is well developed than Induction?**
- **Cavity with Ferrite**
- **increase the field**
- **magnetization is not so fast than RF**
- **Recoverability of energy**
- **Technology development of magnet is improved.**

FFAG + Induction Linac

- Ruggiero suggest to FFAG + Induction Linac
- H- strip for beam injection
- Induction linac for injection of high current beam
- Fixed Field Gradient Synchrotron FFAG by Mori and Machida

Beam Control

- Simple in LINAC high power
- Phase matching in RF Acceleration
- Space charge problem High intenstiy
- Dephasing
- Induction acceleration DB/DT
- No phase matching
- Hysteresis loss.