

Super-bunch acceleration scheme in FFAG

(Induction FFAG for Accelerator Driven Reactor & deep
underground laboratory)

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Accelerator Driven Reactor

- INFCE
- Accelerator breeder
- 300-400 MW proton linac for production of pu
- Deutche (nuclear energy director CIA)
- Accelerator prouction of tritium (APT)

Accelerator Driven Reactor

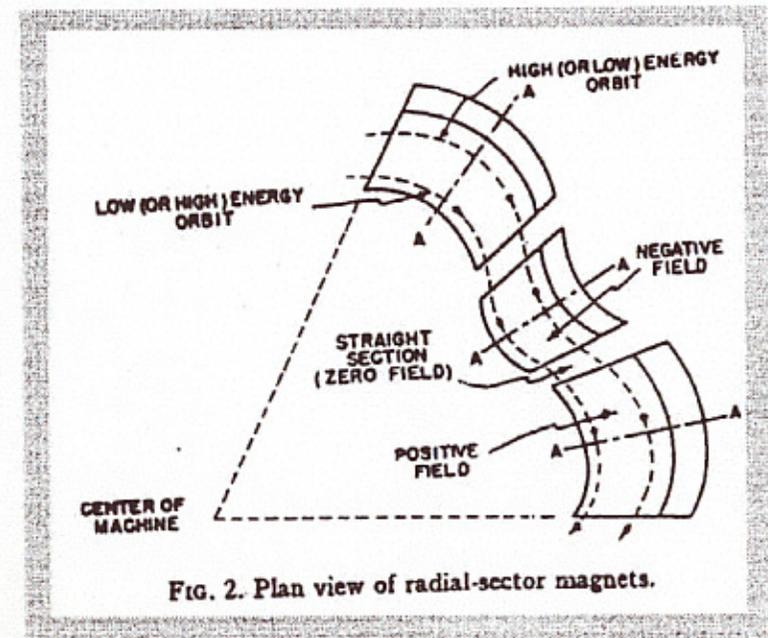
- Slightly sub-critical reactor $k=0.99$
- Author proposed to run the reactor with subcritical condition to get safe operation
- Cyclotron instead of linear accelerator
- limit of current
- 10 mA (1GeV :10 MW) possible by cyclotron for 1GWe Power plant
- Further increase by FFAG

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**

FFAG (Fixed Field Alternating Gradient) Synchrotron

- Fixed Field (like cyclotron)
 - High repetition rate
 - Various acceleration patterns are possible
 - high average beam current, flexibility, low power consumption*
- Alternating Gradient Accelerator
(like synchrotron)
 - high peak beam current*
- Large Horizontal acceptance
 - variable extraction energy*



FFAG

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

FFAG + Induction Linac

- Ruggiero suggest to FFAG + Induction Linac
- H- strip for beam injection
- Induction linac for injection of high current beam

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 (CIFFAG)

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

RF vs Induction

- **Not isochronous for Ind.**
- **RF creates well developed acceleration field than Induction, ?**
- **Cavity with Ferrite enhances the field.**
- **magnetization is not so fast than RF**
- **Recoverability of energy**
- **Technology development of magnet is improved (Profs. Nishizawa, Takayama).**

+&- charge acceleration.

- dB/dt
- Use of the reverse field for negative charge in similar to RF
- Electrons & positrons,
- negative & positive muons

Acceleration ratio

- $E_{out} / E_{in} = 5, 0r 4$
- wider magnet for large M
- but large radius
- frequency of accelerator shock wave
- mini bunch
- RFQ ?
- Plasma Acceleration?

Generation of short pulse using many capacity bank

- high frequency of induction acceleration
- Zhao 's method (use of shortning of capacity bank)
- fast switching device

Reliability

- Important for power supply to public
- Shortening of high voltage
- Induction not require the high voltage

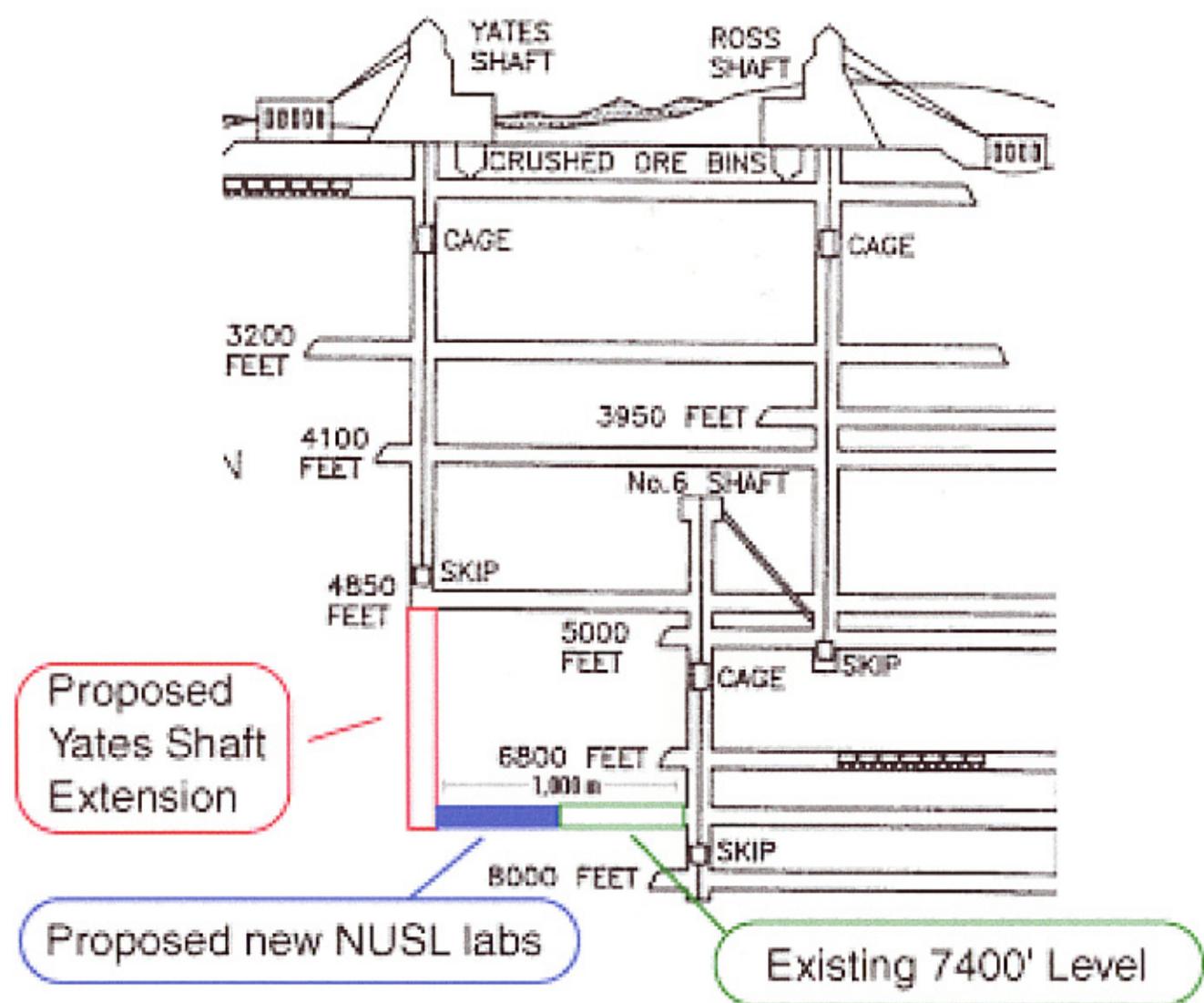
Deep underground reactor

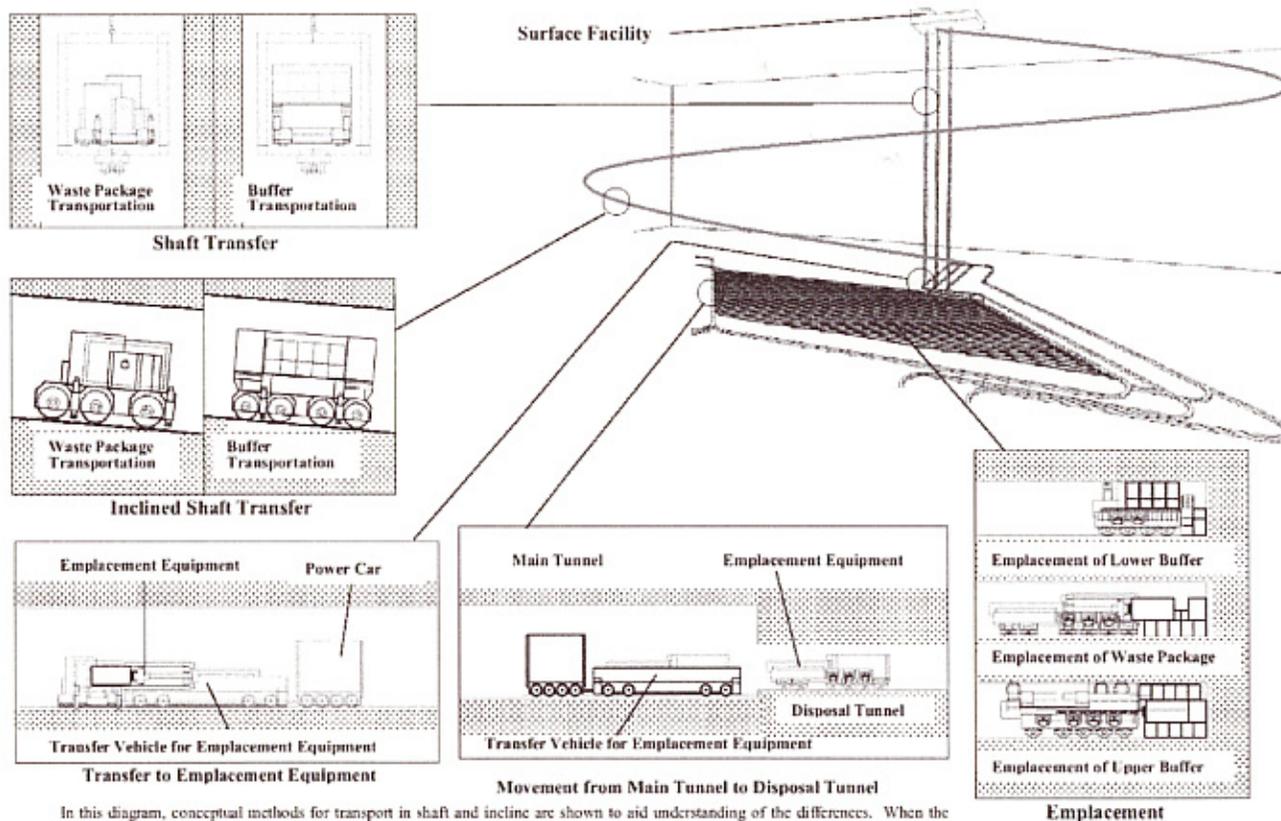
- Promoted for nuclear industry
- Savarov, and Teller promoted underground reactors
- Sweden's first reactor,
- Deep 500-1000 meters
- LILCO, \$ 5B BWR difficulty of evacuation
- No reactor in BNL. (Marburger)

Deep underground laboratory

- Davis solar neutrino experiments
- Kamiokande (Koshiba) super-
- Home-stake gold mine in South Dakota
- Neutrino experiments
- Double beta decay beyond standard model
- Biology study in DUGL
- Yacca Mt. JNC.
- Beta decay and Supernova astronomy
- Delayed neutrons and high level waste







In this diagram, conceptual methods for transport in shaft and incline are shown to aid understanding of the differences. When the repository site is decided, the optimum method will be selected in accordance with the geological and environmental conditions.

Cosmology

- Dark matter more than 99 %
- Extra dimension

Deep Underground CIAFFAG

- Near neutrino or other exotic particle source
- Well shielded.
- Installed in deep underground small background
- Linear Accel. can be accepted by making long tunnels
- Not expensive, 500 miles tunnel in home stake mine