Direct Production of ^{233}U in Auto-Colliding Beams of ^{232}Th*

by
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* US Patent #4,788,024
Patent Pending #62/139,034

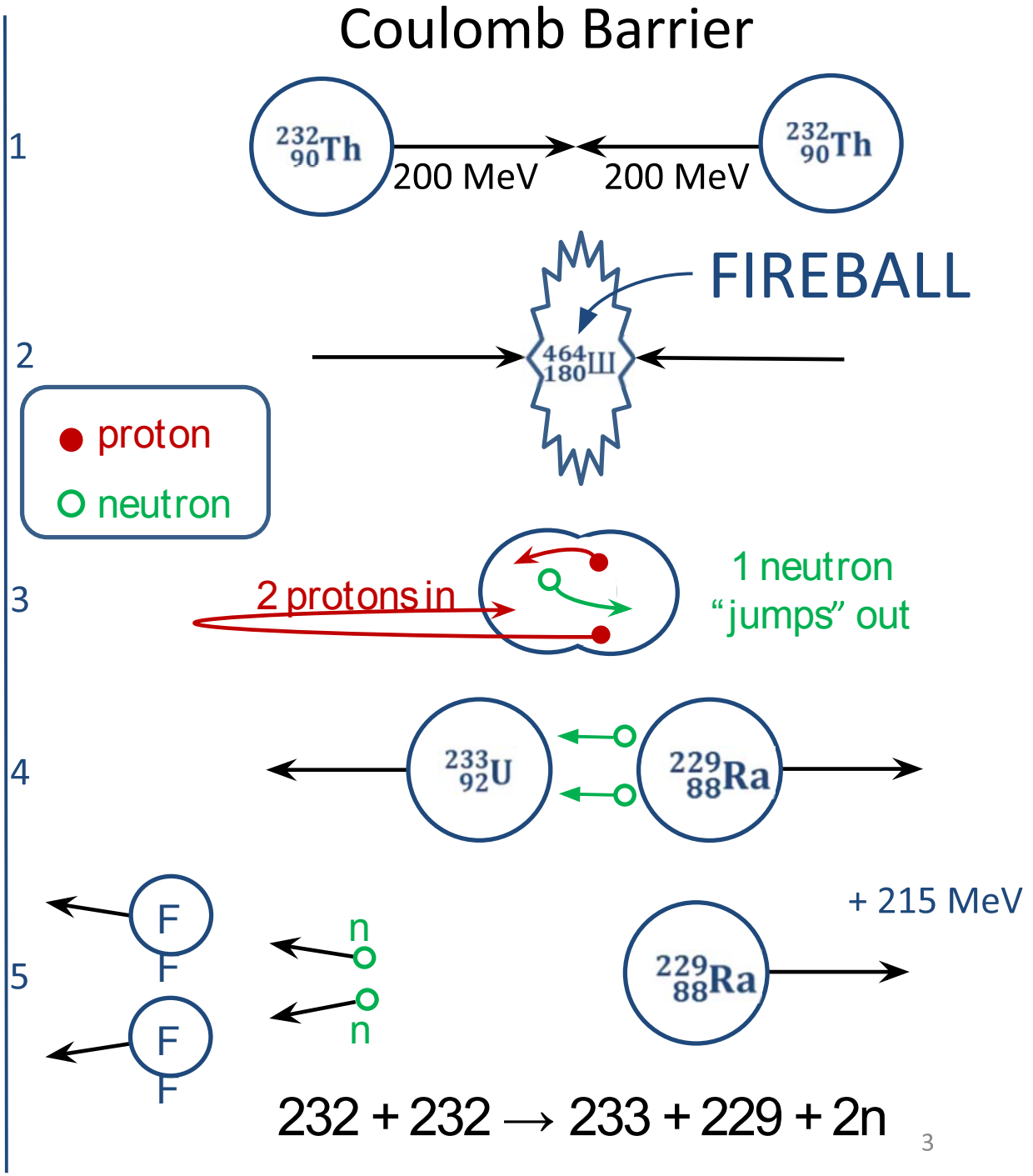
$$^{232}_{90}\mathrm{Th} \rightarrow {}^{233}_{91}\mathrm{Pa} \rightarrow {}^{233}_{92}\mathrm{U}$$

Can we go directly?:

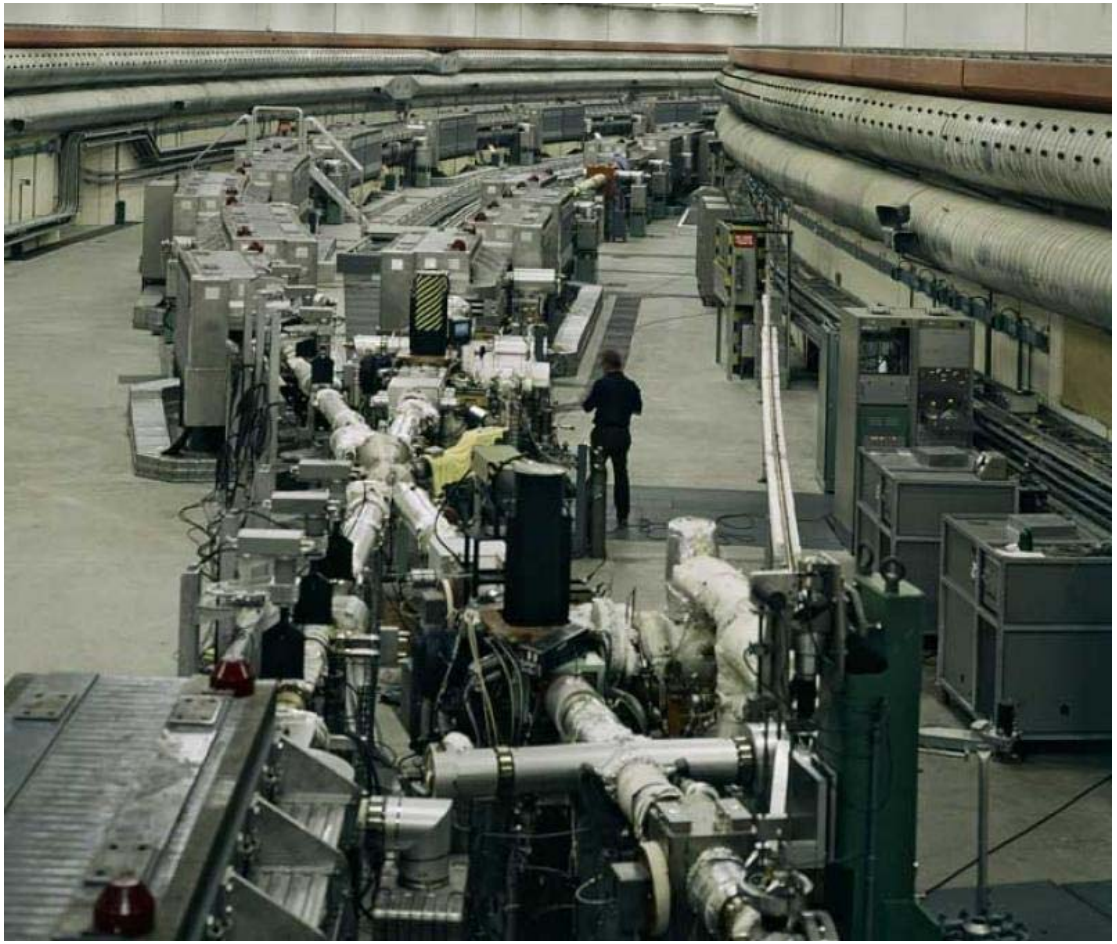
$$^{232}_{90}\mathrm{Th} \rightarrow {}^{233}_{92}\mathrm{U}$$

Making Thorium FIREBALL

- Colliding natural ^{232}Th with itself (1)
- Resulting in FIREBALL (2) with 464 A (180 Z) in which neutrons and protons exchange positions (3)
- Fissionable ^{233}U, ^{229}Ra and 2 neutrons are produced in the reaction (4)
- ^{233}U decays into fission fragments and 215 MeV is released (5)
- If Th^{68+} ionized, 3 MeV accelerator will produce 200 MeV Th beam



ISR: Intersecting Storage Rings at CERN, 1971



p + p (20 GeV + 20 GeV)

Energy Confinement Time:

$$\tau = 5 \times 10^5 \text{ sec}$$
$$= 2 \text{ months}$$

Note: Brookhaven's Relativistic Heavy Ion Collider (RHIC) collided $^{238}U + ^{238}U$
At 200 GeV with a cross section σ_{total} = 487 barn

This is the only data on σ(U + U)

PERFORMANCE OF THE NEW EBIS PREINJECTOR*

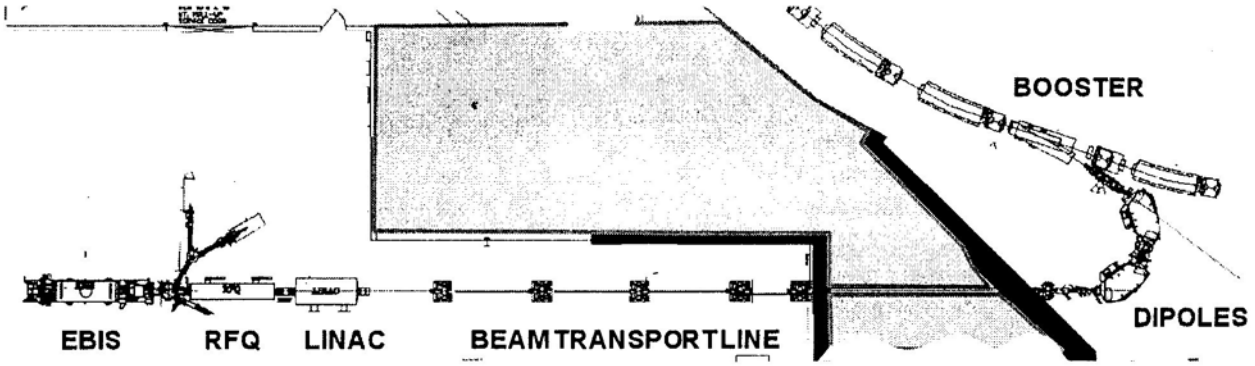


Figure 1: Schematic of the EBIS-based heavy ion preinjector

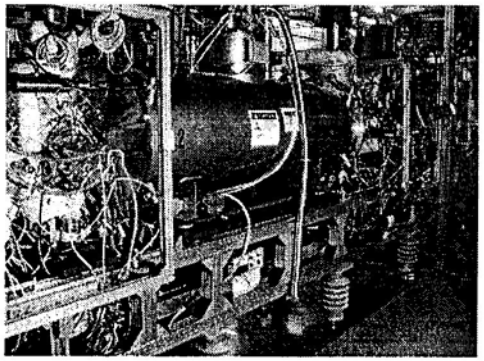


Figure 2: The EBIS source, with the 2m long superconducting solenoid producing a 1.5 m trap region.

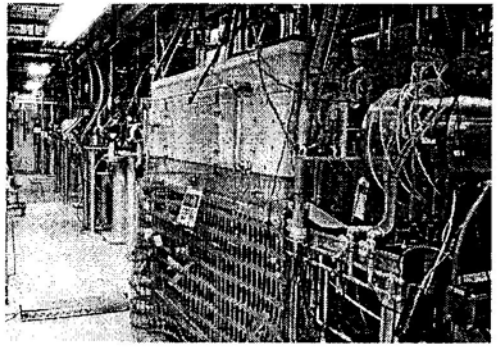
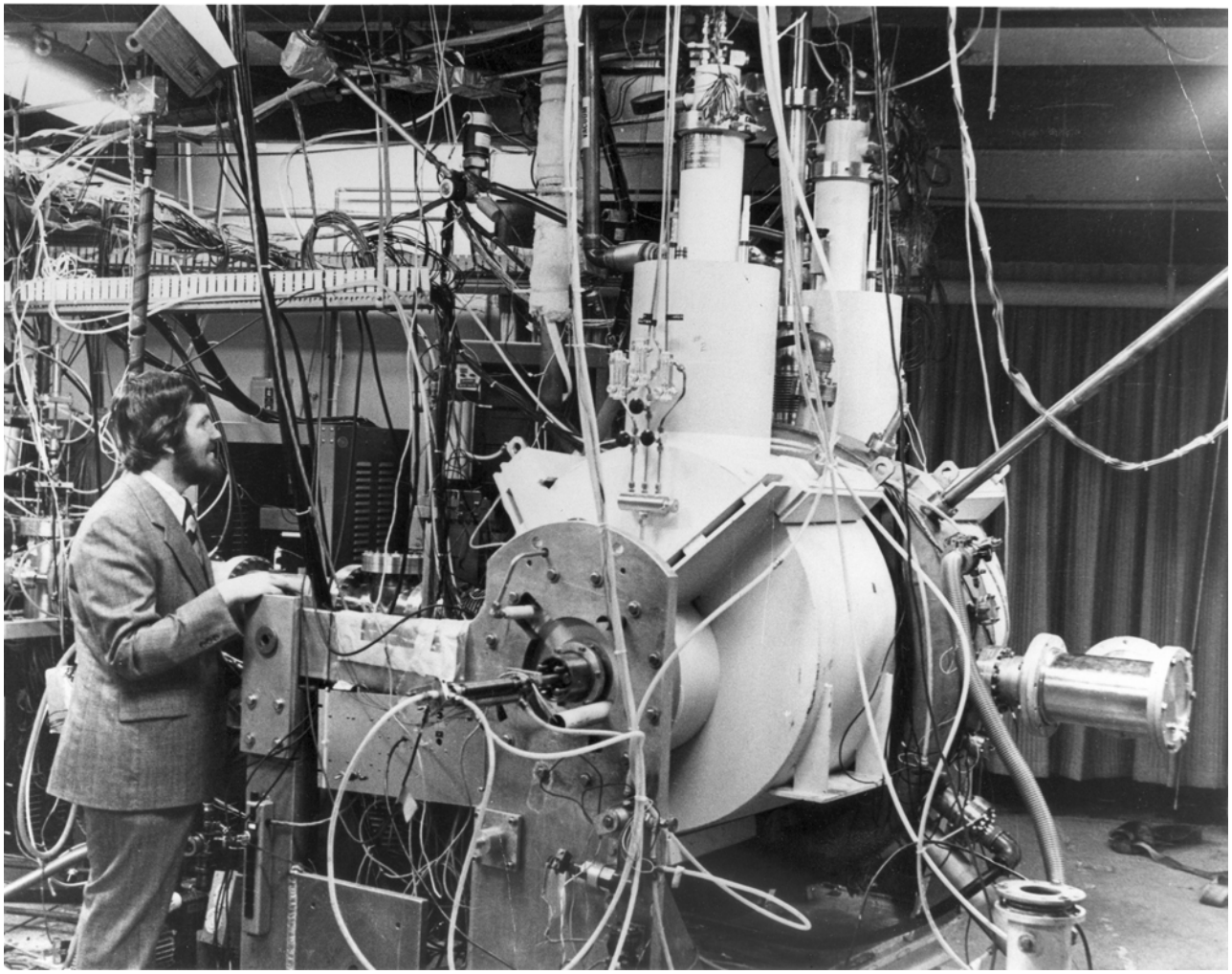


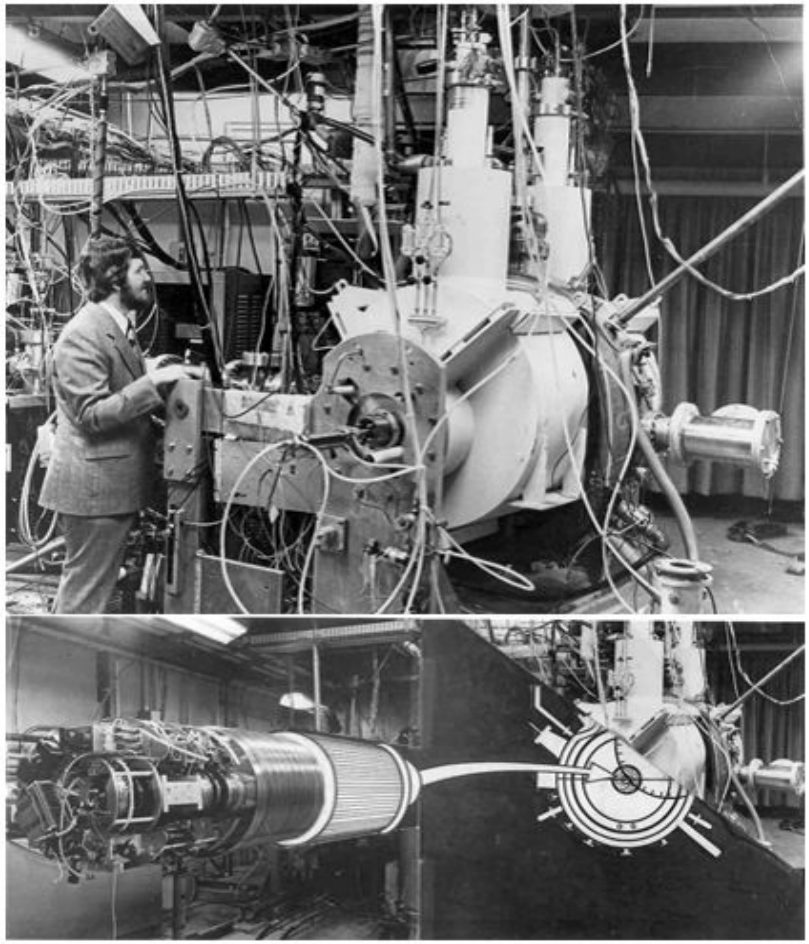
Figure 3: High energy end of the RFQ is seen on the right, linac (yellow) in the center, and the high energy transport on the left.

Auto Collider MIGMA IV



One beam collides head-on with itself.

AUTO-COLLIDER MIGMA IV



ACCELERATOR INJECTION ENERGY:

D_2^+ ions of 1.45 MeV

SUPERCONDUCTING NiTi MAGNET

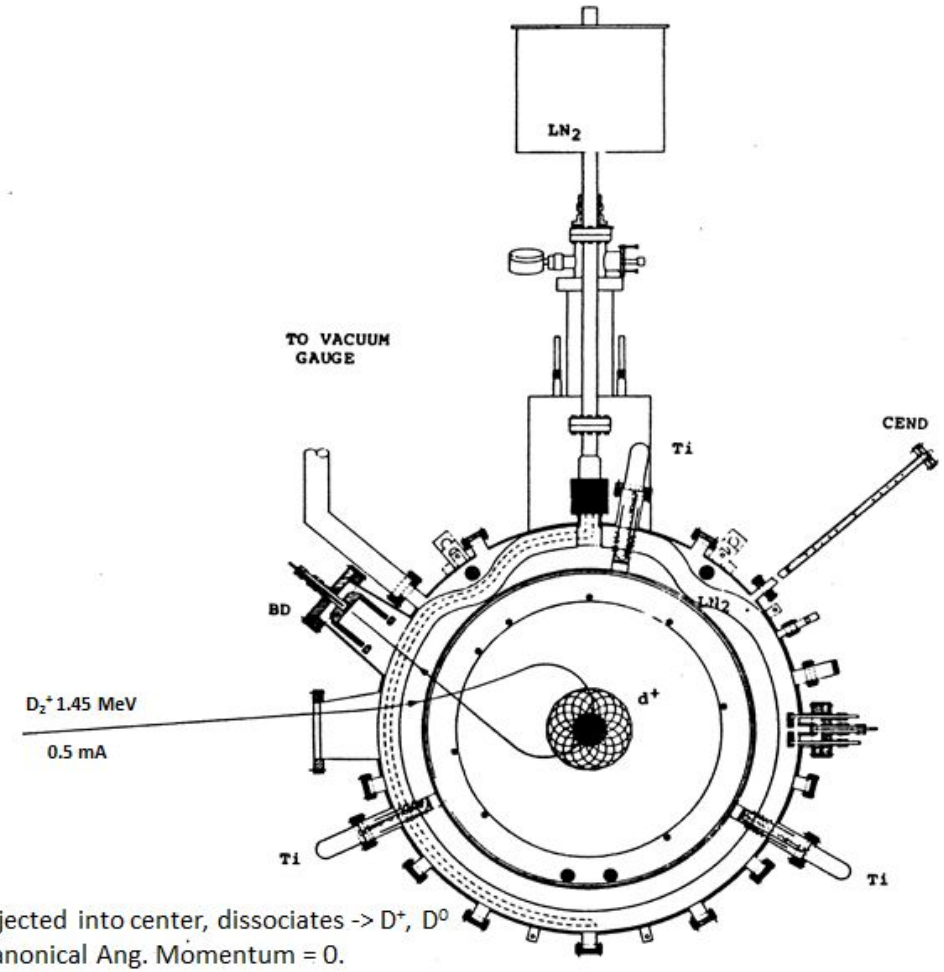
6 Tesla on coil, **3.2 Tesla** midplane

VACUUM 10^{-11} Torr (static); 10^{-9} (beam in) **V = 5 liter**

Baked 450°C 24 hours

Migma Institute of High Energy Fusion, Princeton 1986.

AUTO COLLIDER



Injected into center, dissociates -> D^+, D^0
Canonical Ang. Momentum = 0.

Cross –section through z = 0 plane. CEND = charge-exchange neutral detector; Ti, titanium sublimator pumps; LN2, liquid N2; d+, orbits of trapped ions; C, center of

SYMMETRY X=Y-Z=0; BD (Beam Dump)

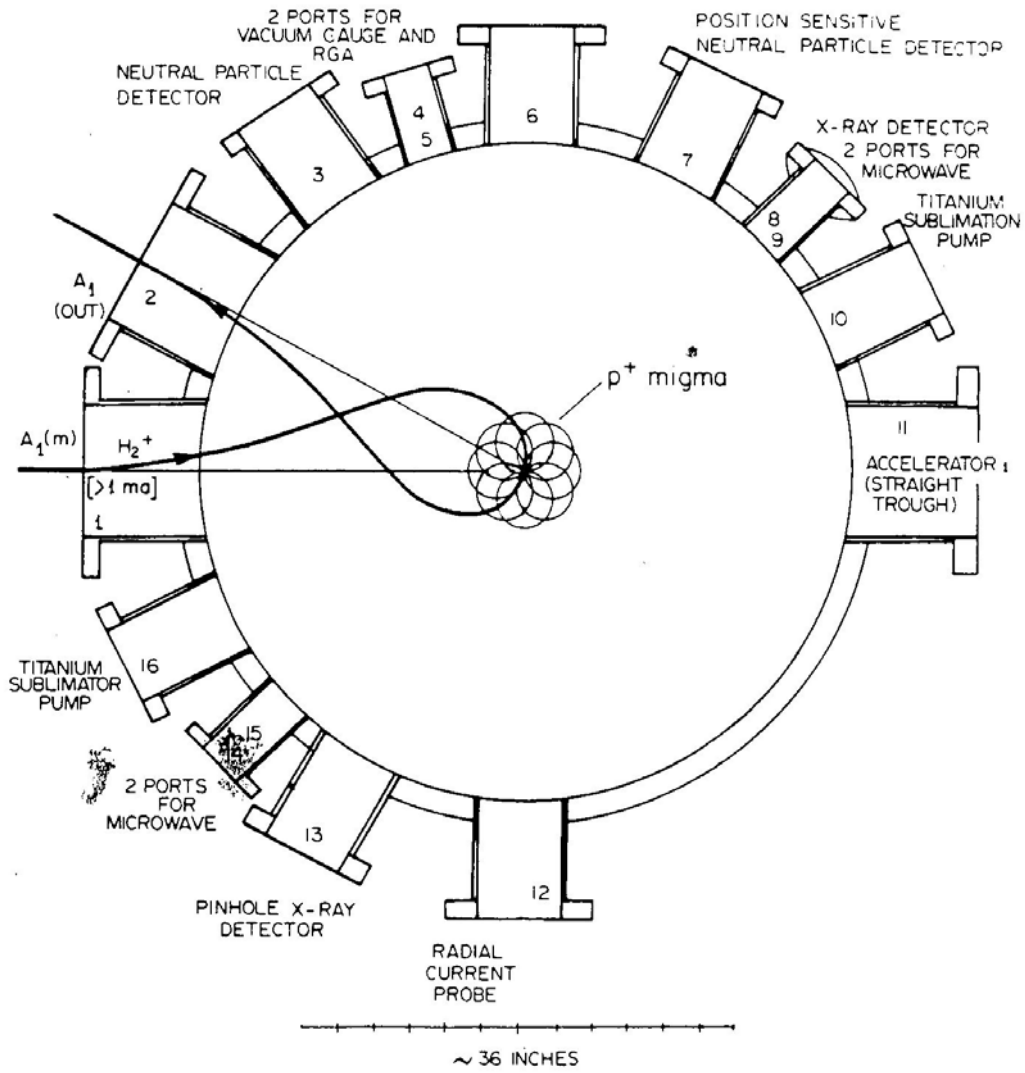


Fig. 5. Top view of the conceptual design of the migma chamber for the IVb experiment. The 1.4 MeV H_2^+ beam enters the chamber from the left through port #1; the undissociated beam goes to the beam dump through port #2.

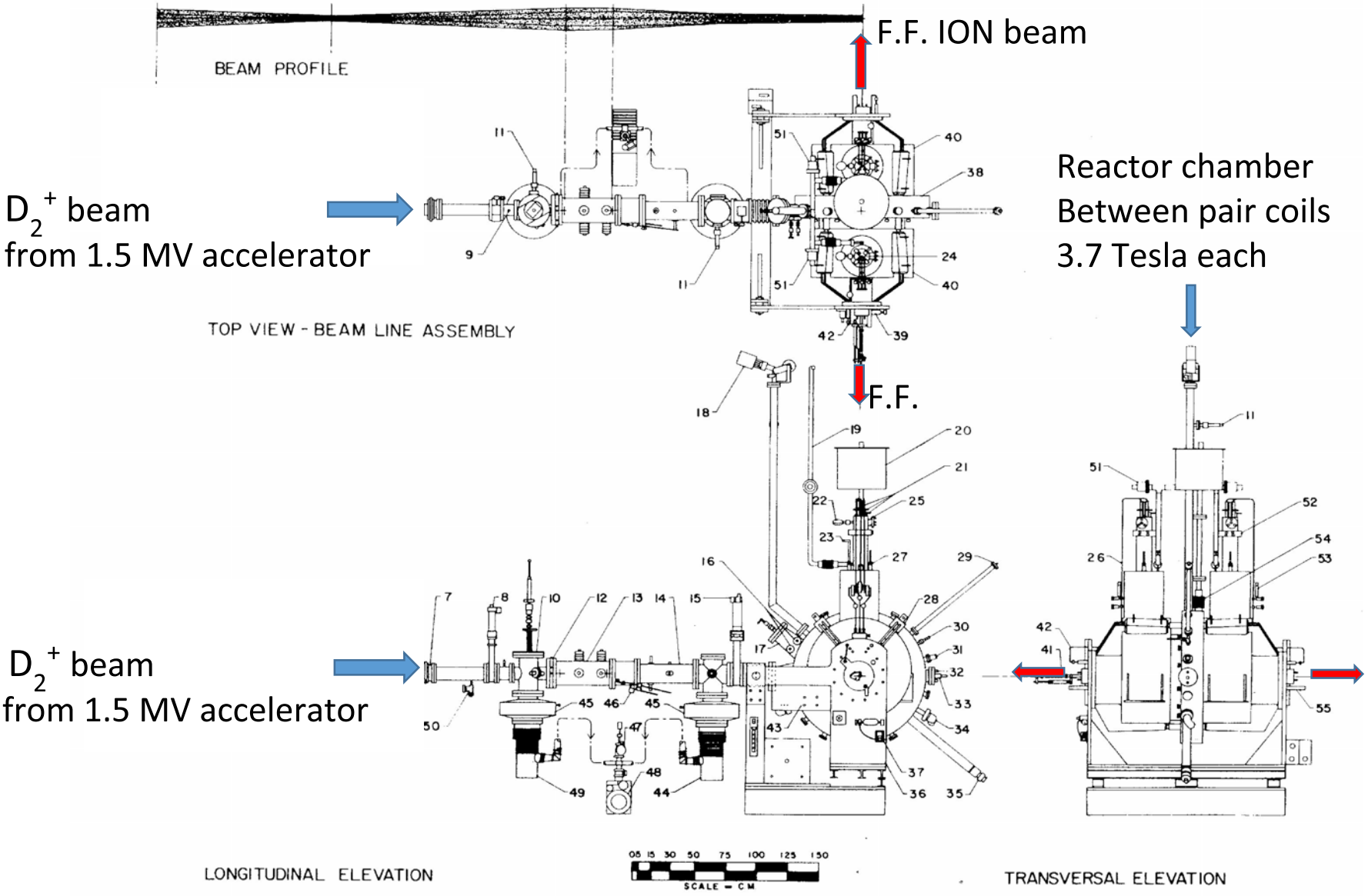
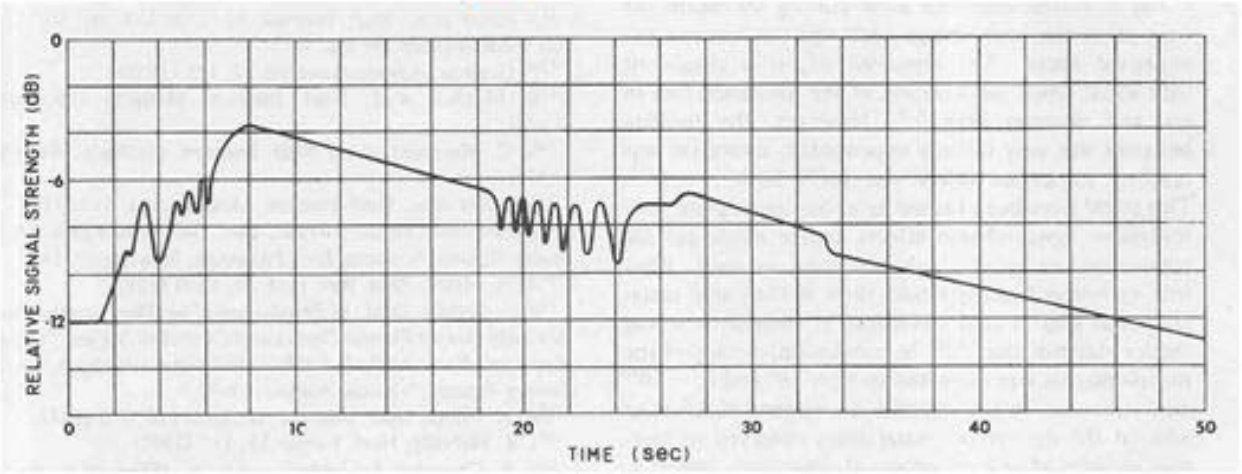


Fig. 3. Layout of the beam transport system, chamber, and superceding magnet.

LONGEST ION ENERGY CONFINEMENT TIME IN FUSION

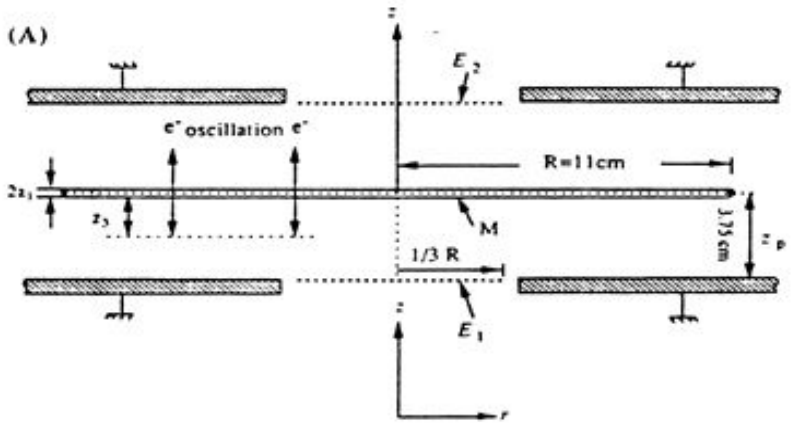
$\tau_{1/e} = 24 \pm 4$ sec



Non-linear stabilization: "Electron cloud oscillations through stored ions 40 times in excess of space-charge limit" Phys. Rev. Lett. 70,299 (1993)

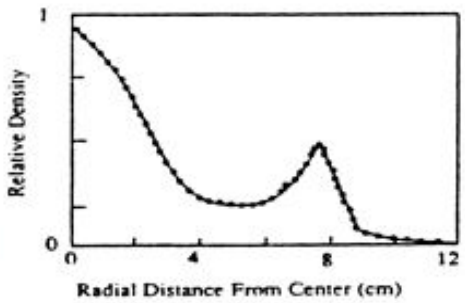
US Patent 4,788,024 B.Maglich and S.Menasian

Barkhausen Oscillator with virtual anode and cathode



(B)

Nonliner Van der Pol equation:
$\ddot{x} + \eta\rho(x) + \nu_0 + \dot{x} + \nu_0^2 = 0$
η weak nonlinearity, ρ nonlinear *resistance*. Negative resistance, $\rho < 0$ instability; $\rho > 0$ stability. Lashinsky and Dewan IEEE Trans. Autom. Contr. **12**, 244 (1967); **14** 212 (1969).



(A) Migma end plate geometry: *M* = migma; E_1, E_2, = end plates at *z* = +3.75 cm; z_1 = half thickness of migma. (B) Migma density vs. r, measured by amplitude of Schotky Noise rf signal.

Landau Damping (linear) by increase in Amplitude.
Nonlinear damping by increase in Frequency.
Critical test: Negative resistance changes sign!

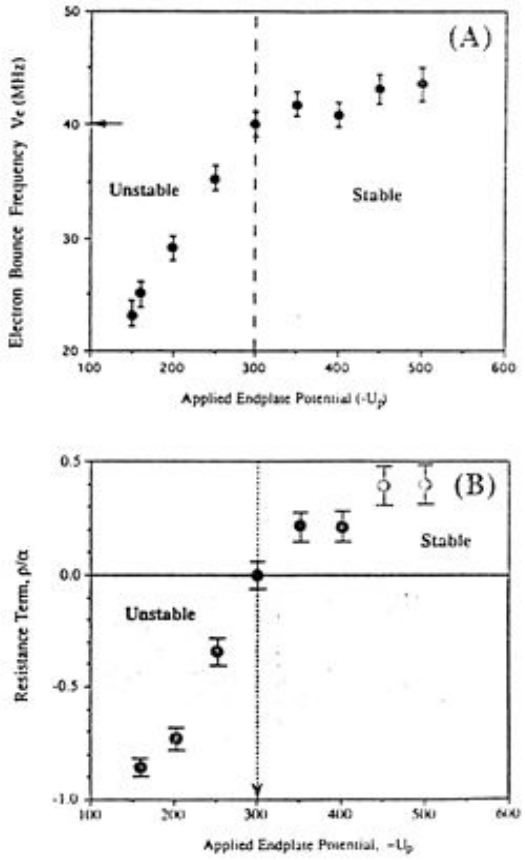
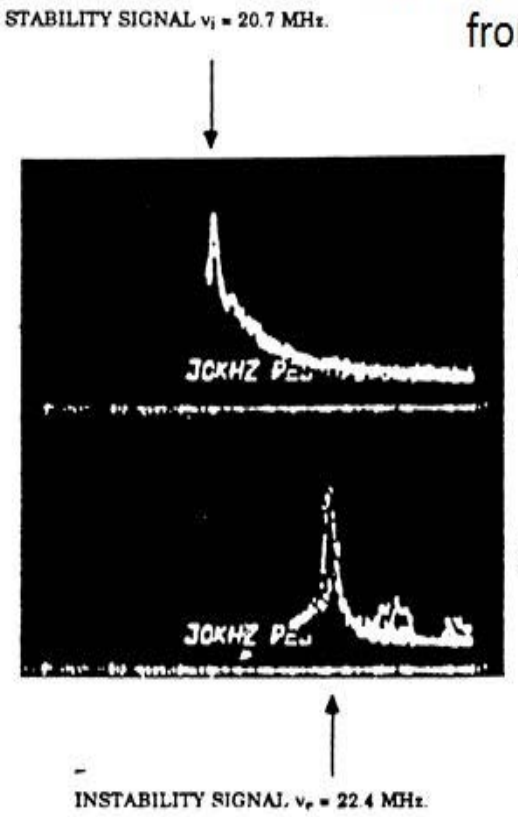


FIG. 5. (a) Axial bounce frequency of electrons, ν_e, vs negative voltage at plates, $-U_p$, with low D_2^+ beam injection, $I = 0.035$ mA. (b) The resistance term ρ/α as a function of the applied electric potential to end plates E_1 and E_2 [Fig. 3(a)].

Imposed v extracts energy
from instability

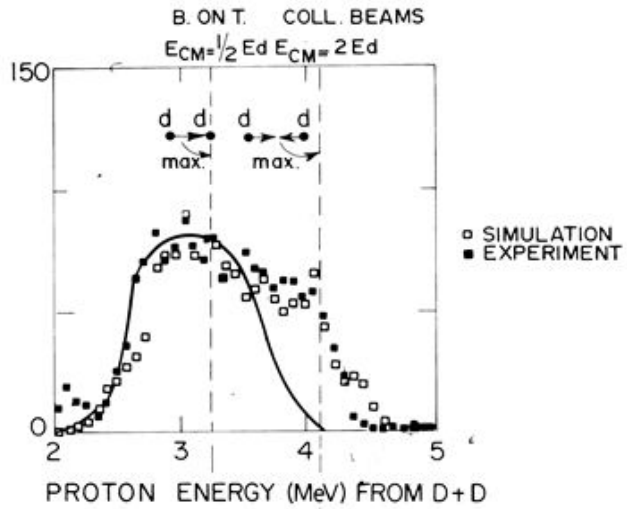


Radial frequency *vs.* (A) d^+ ion peak at 20.7 MHz when only d^+'s with a small impact parameter ≤ 0.1 cm are kept. Others removed by a mechanical scraper at $R > 11$ cm. (B) Instability peak at $\nu_{e,INS}$ at 22.4 MHz *axial* oscillations.

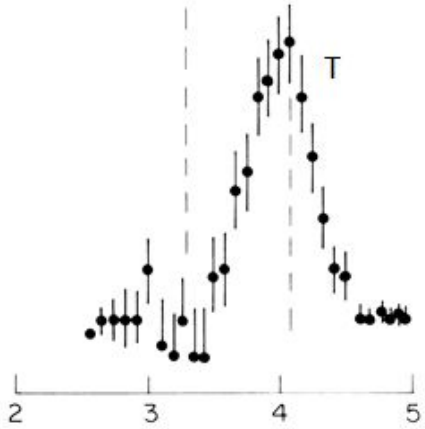
Copious T and ^{3}He Production

Luminosity L = 3×10^{43} V [m^3] I^2 amp

PROOF OF
BEAM→←BEAM
FUSION T AND ^{3}He
PRODUCTION



CR = 5×10^7 s-1
V =10^{-4} m^3, I = 5×10^{-4} amp

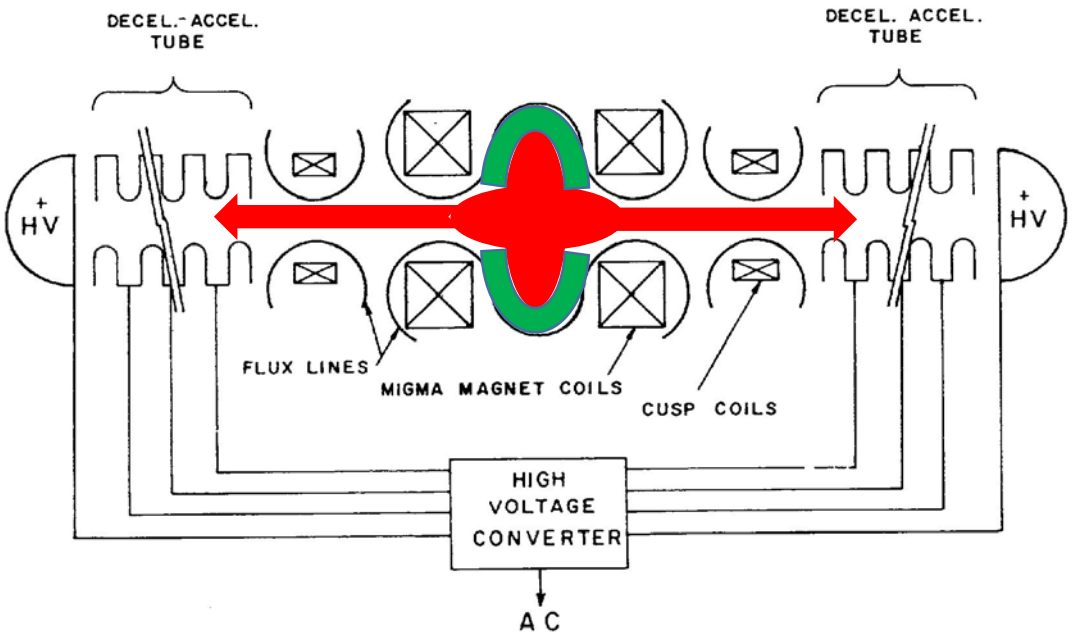


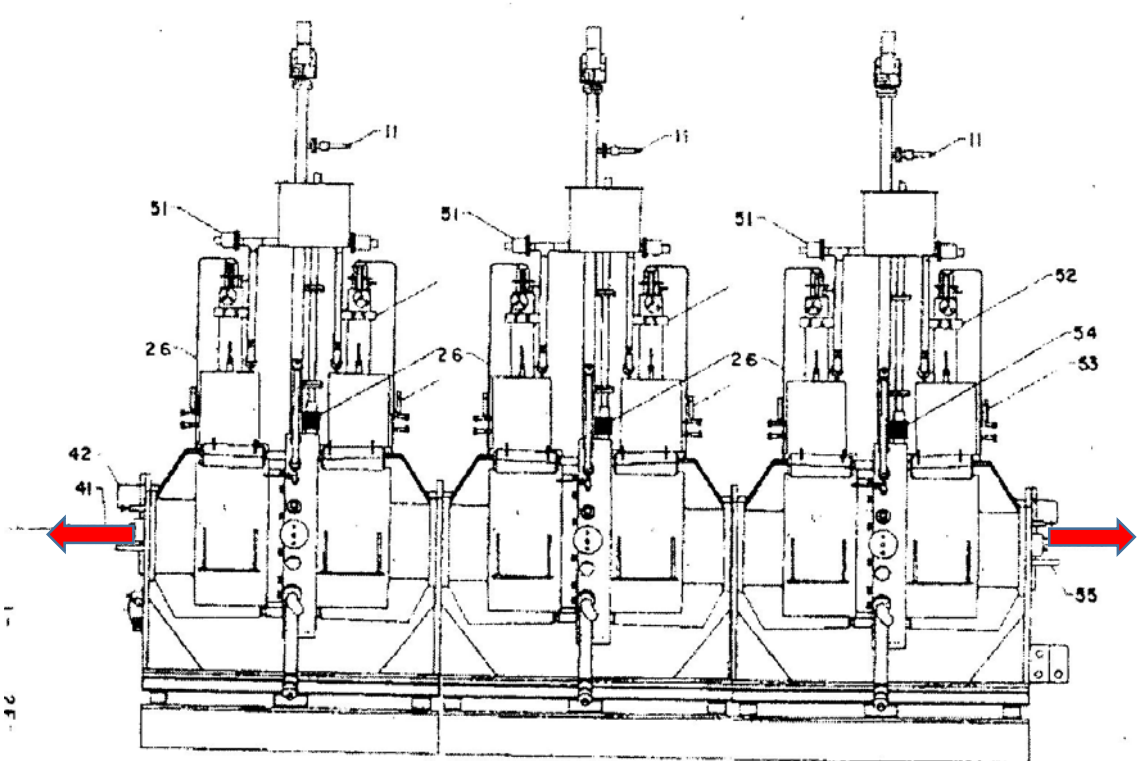
Landau Damping (linear) by increase in Amplitude.
Nonlinear damping by increase in Frequency.
Critical test: Negative resistance changes sign!

Projected production grams/day from 10 m^3 EXYDER 30 units 0.33 m^3 ea. (scaled from Migma IV);
1.58 g neutrons + 4.75 g ^{3}He + 4.75 g T.
Energy cost per n: 11 MeV. Energy output ^{233}U fission: 120 MeV/ n breeding Thorium. Q_{eng}=11

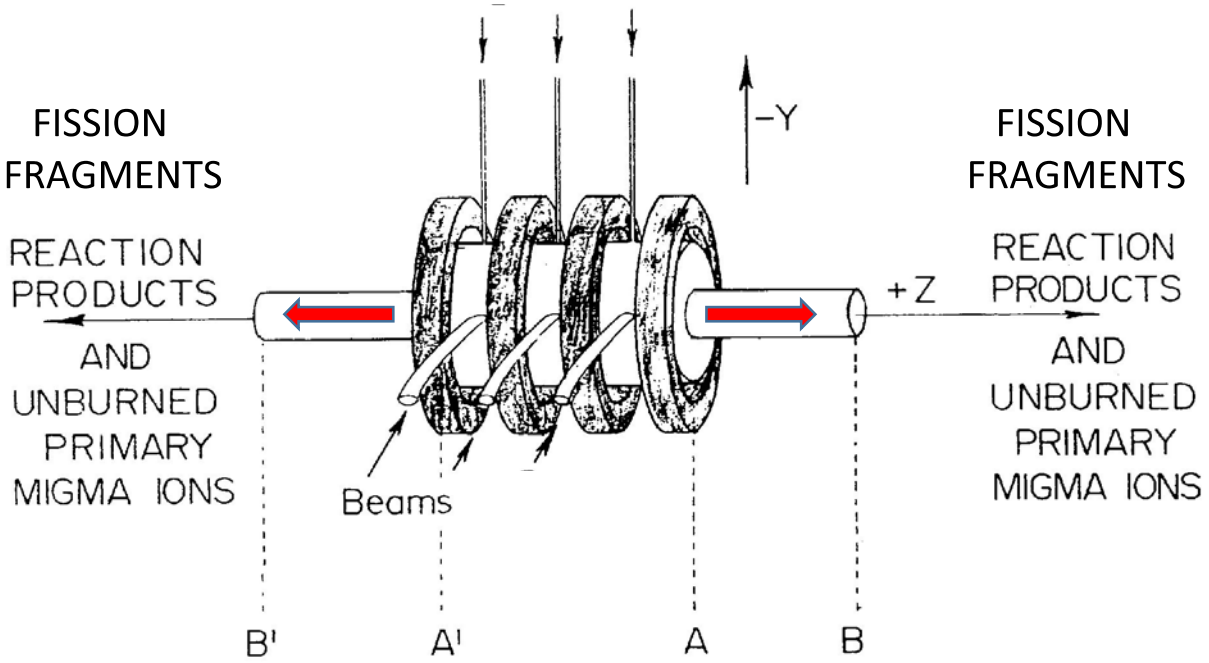
Market price of ^{3}He : \$7.4 x 10^4 \$/g = 120 MeV/ atom
Market price of T : \$3.5 x 10^4 \$/g = 64 MeV/ atom
Total.....= 184 MeV/atom
D energy + fuel cost .....= 11 MeV for n, T, ^{3}He
Net energy surplus.....= 173 MeV → \$508,000/day to use for Auto-Collider improvement R&I
Energy gain Q_{eng}.....= 23

NOT "scientific Q": All numbers include conversion efficiencies and market prices
Currency: MeV/atom. Conversion: 1 MeV= 4.44x10^{-23} MWh=2.66x10^{-21}\$.

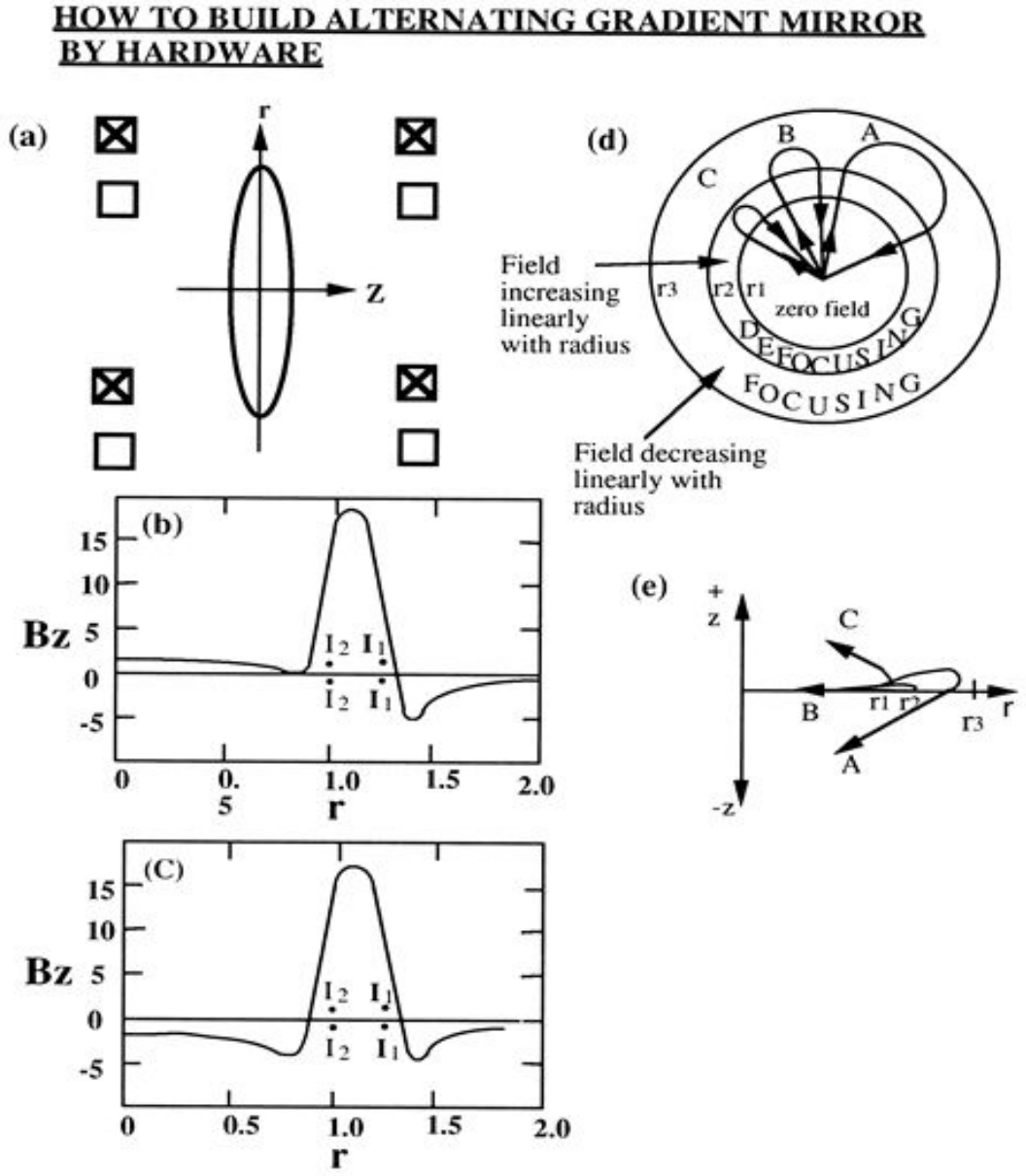

DECEL.-ACCEL.
TUBE
DECEL. ACCEL.
TUBE
+
HV
+
HV
FLUX LINES
MIGMA MAGNET COILS
CUSP COILS
HIGH
VOLTAGE
CONVERTER
A C



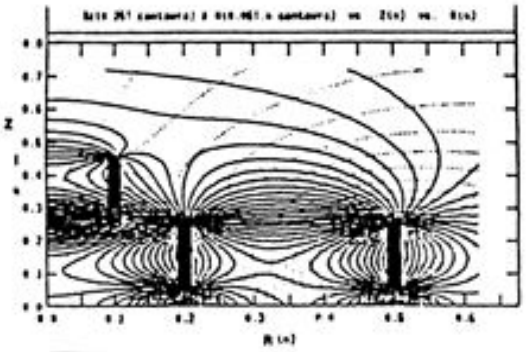
TRANSVERSAL ELEVATION


FISSION
FRAGMENTS
REACTION
PRODUCTS
AND
UNBURNED
PRIMARY
MIGMA IONS
-Y
+Z
FISSION
FRAGMENTS
REACTION
PRODUCTS
AND
UNBURNED
PRIMARY
MIGMA IONS
Beams
B'
A'
A
B

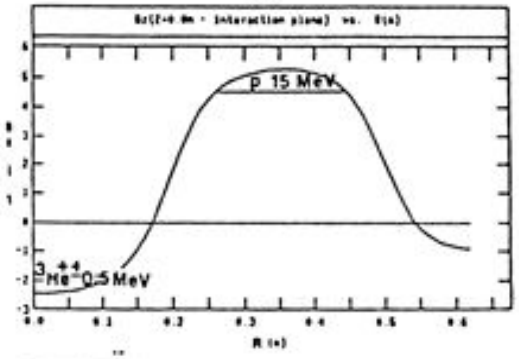
Ion Density Increase 100 - Fold



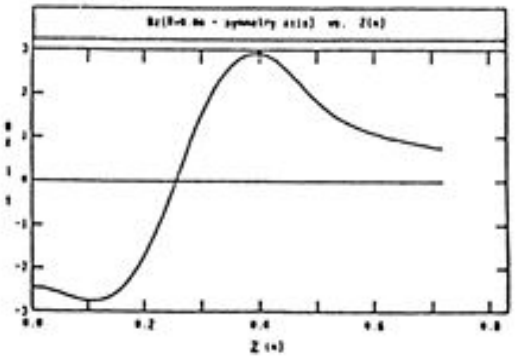
(A)



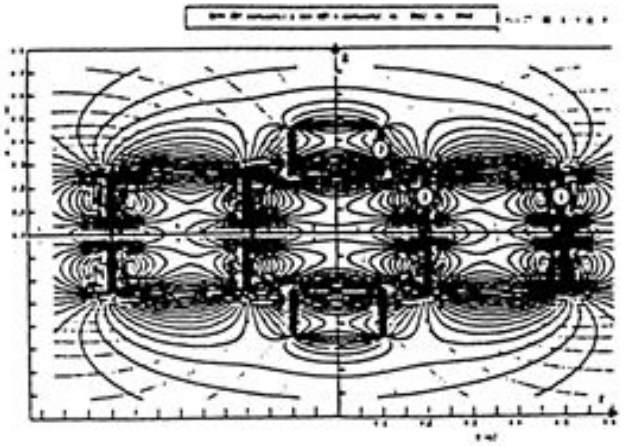
(B)



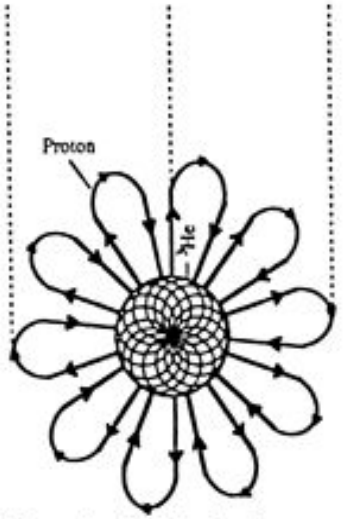
(C)



(D)

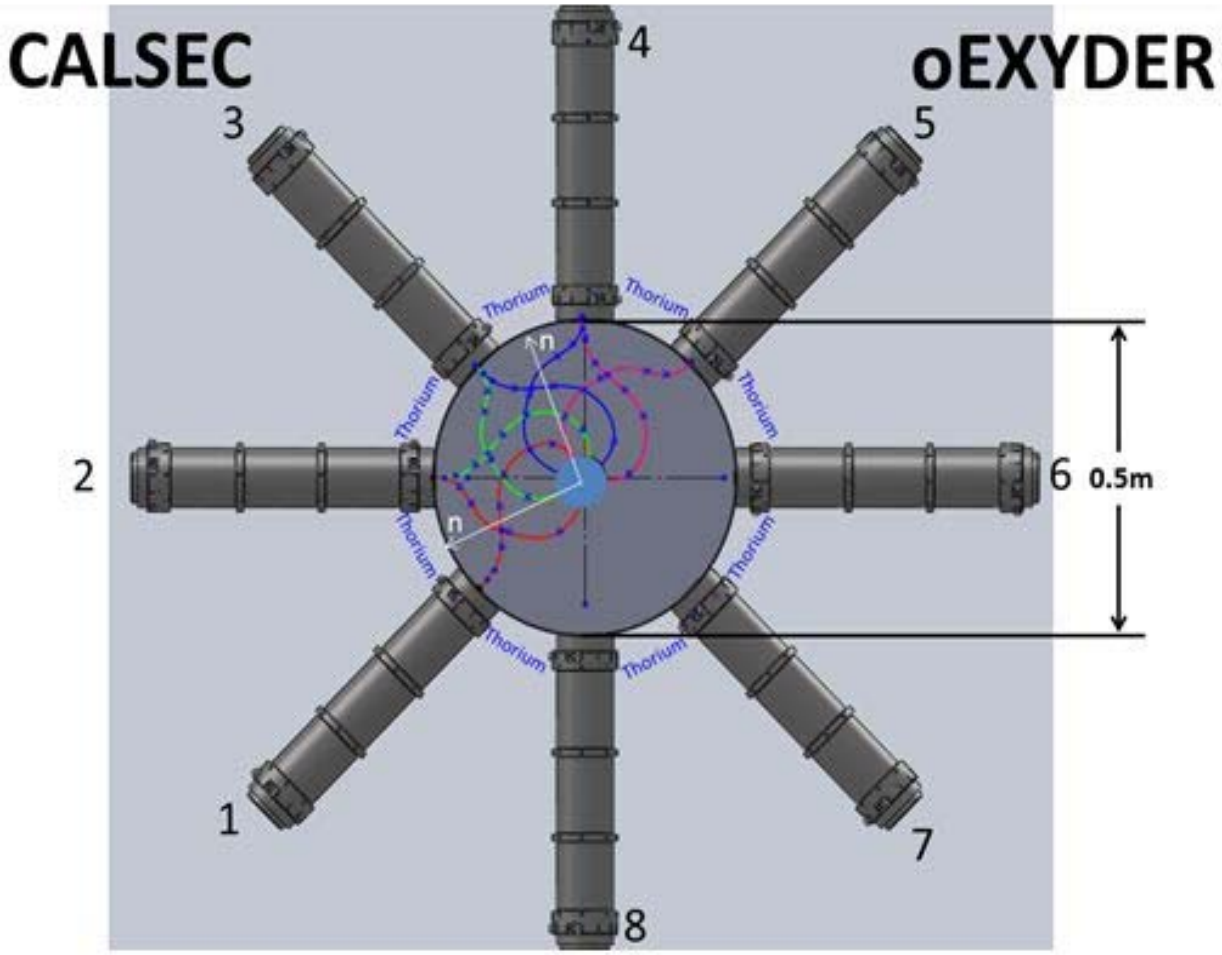


(E)



3-coil AGM design

Proton - Lithium Fusion



Ion sources not shown US & International Patent pending 2011

Luminosity Definition: Collision Rate for σP = 1

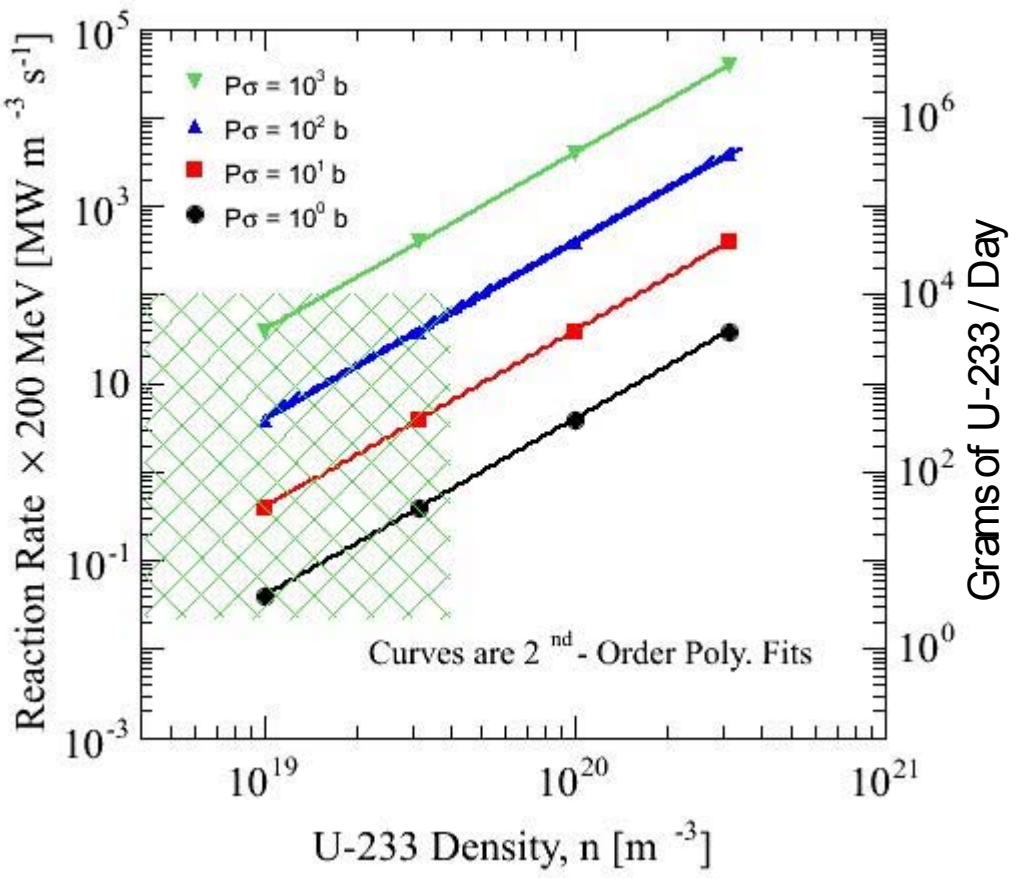
$$L = \frac{2N_1 N_2 v_{12}}{V}$$

$$N_1 = N_2$$
$$\sigma P \sim 10^2 b$$

$$\text{Rate} = \sigma L = \frac{2N^2 P \sigma v}{V} \sim \underbrace{10^{18} - 10^{19}}$$

U-233 / second

P = pulsed beam factor
(P = 1 for DC beam)

~ 10 - 1000 gram / day

U-233 Production / Day (RH Scale) and Fission Power Density in Strong-Focusing Auto-Colliding Beam Reactor (EXYDER)