Plasma Centrifuge Heat Engine – a Route to Non-thermal p-^{11}B Fusion

D. C. Barnes
coronadocon@msn.com

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Plasma Centrifuge Heat Engine for Colliding Beam Fusion Reactor*

Plasma Centrifuge Heat Engine for Continuous Beam Fusion Reactor†

*Patent Pending, App. No. 60/596567, USPTO (2005).

† Patent Pending, App. No. 60/766791, USPTO (2006).

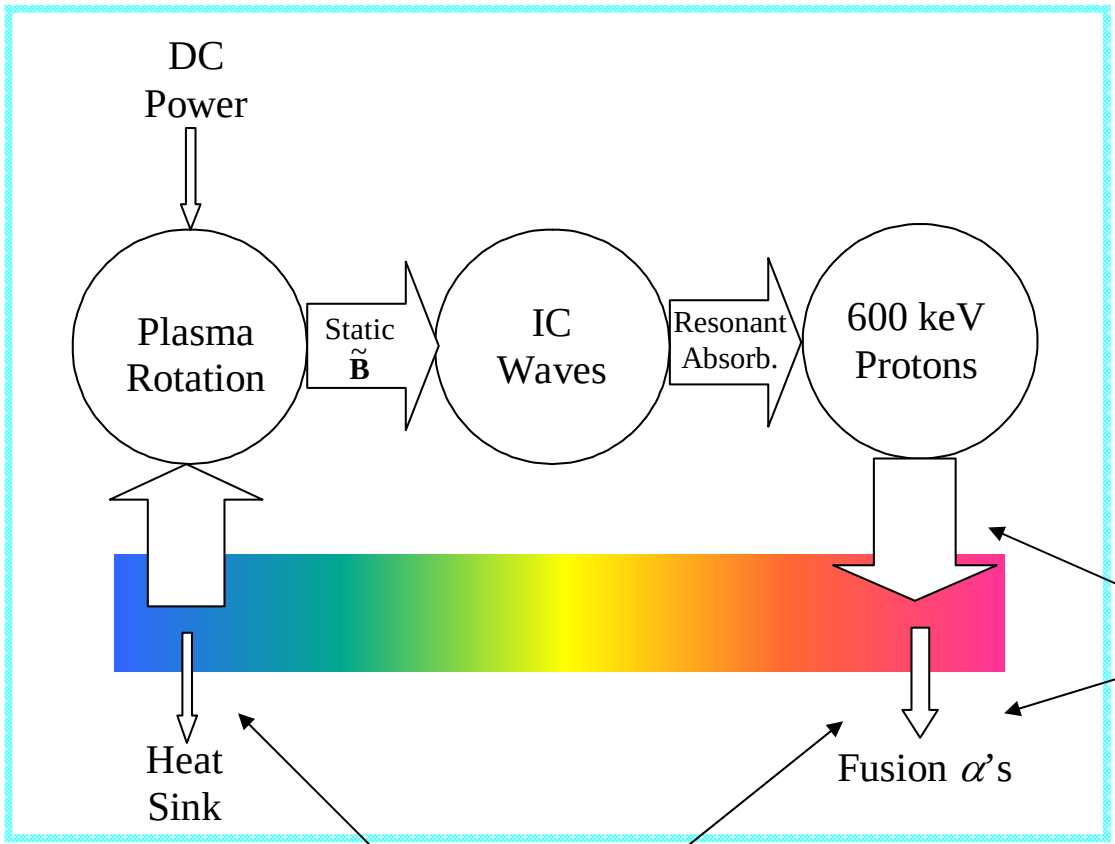
Objective

- Develop aneutronic fusion system using beam-target approach
  - Requires physics invention(s)
  - Short development time and large market if avoid materials, shielding, proliferation, and waste problems of D-T
  - Economics shifted toward small unit size and lower mass power density (think about the core size of 50 MW coal plant)

In a Nutshell

- Magnetically confined, quasi-neutral plasma
- Dipole-like diverted field w. centrifugal confinement
  - Plasma compressed/expanded by interchanges across **B**
  - Heat delivered to hot plasma, removed from cooler plasma
- Fusion from p beam on ^{11}B plasma target
- Resulting thermal cycle converts heat to rotation
- Rotation produces waves
  - Zero Doppler frequency in lab frame
  - Rotation converted to wave energy
- Waves heat p's
- Some details given here, much physics and engineering remains

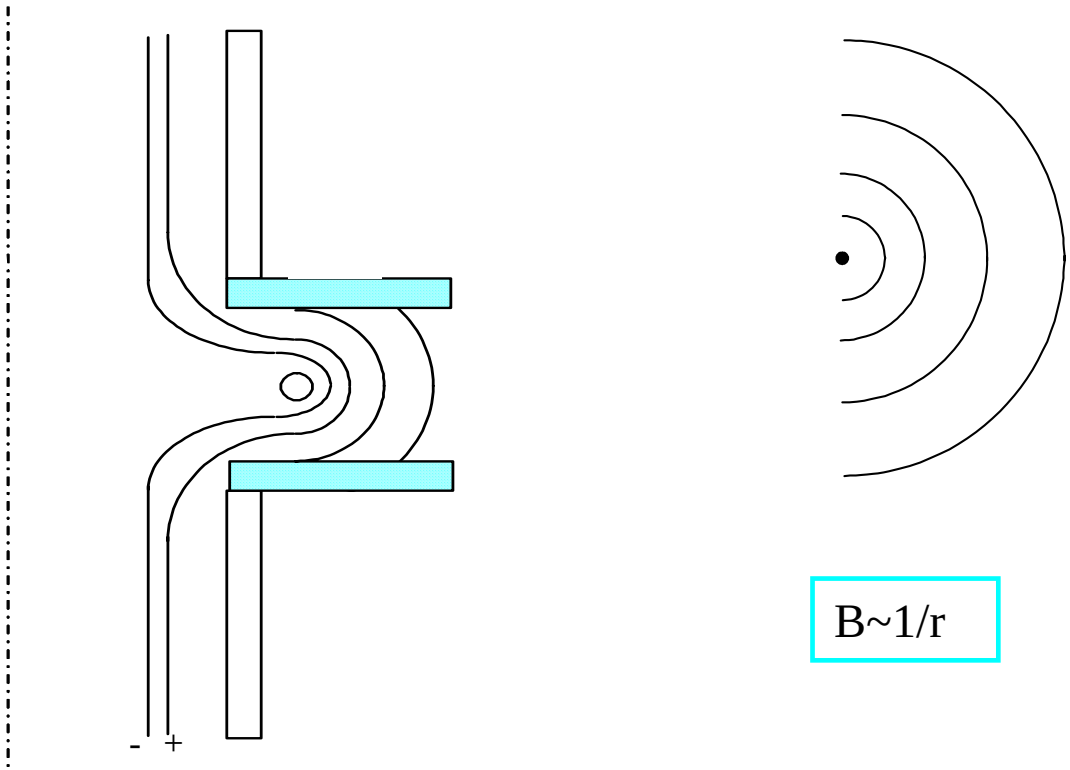
Power Flow


DC
Power
Plasma
Rotation
Static
$\tilde{\mathbf{B}}$
IC
Waves
Resonant
Absorb.
600 keV
Protons
Heat
Sink
Fusion α's
Beam-target
fusion gives
this Q ~ 5%
Plant engineers see this Q ~ 3

Complication: Lack of Collisions

- 1000 atmosphere proton plasma at 20 keV has mean free path of nearly 400 m
- Expander would be several km long
- Physics iinnovations can reduce this to a few meters
  - (POPS) A plasma in harmonic well will behave isentropically, independent of collisions
  - (Bounce average) A plasma expanded slower than bounce time will behave isentropically …
- Need to match parallel and perpendicular compression (μ conservation *vs.* parallel ω)

Magnetic Configuration



Idealized Equilibrium

$$T_{\perp} \sim B \sim 1/r$$

$$T_{\parallel} \sim 1/r \sim \omega \sim \Omega\sqrt{R''} \sim \Omega/\sqrt{r}$$

$$\Rightarrow \Omega \sim 1/\sqrt{r}$$

$$\ell_{\parallel} \sim \sqrt{T_{\parallel}}/\omega \sim \sqrt{r}$$

Rotation Profile "Automatic"

$$\tau_{ii} \sim n / T^{3/2} \sim 1$$

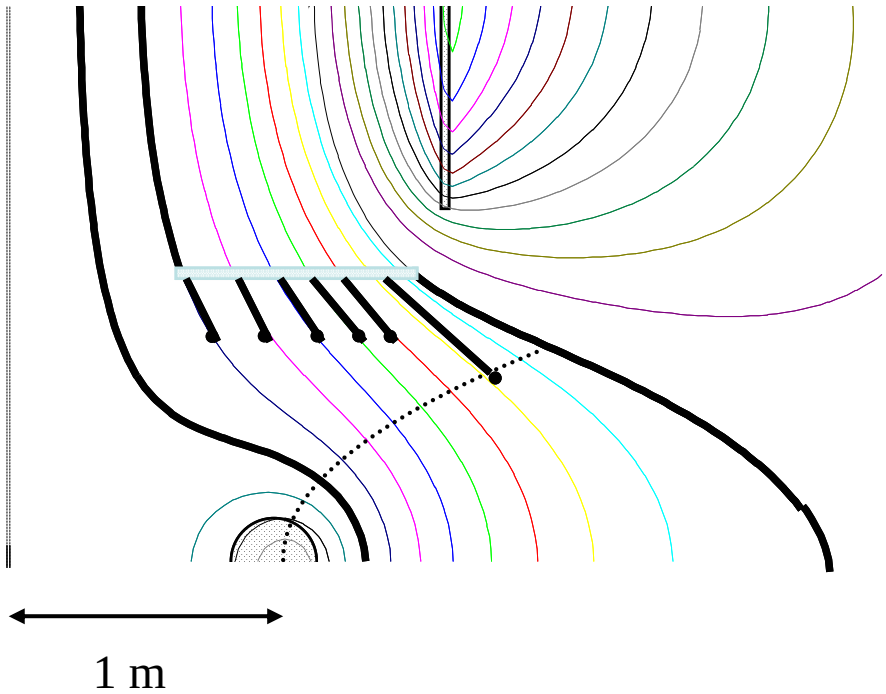
$$\rho_i \sim \sqrt{T} / B \sim \sqrt{r}$$

$$D_{vii} \sim \rho_i^2 / \tau_{ii} \sim r$$

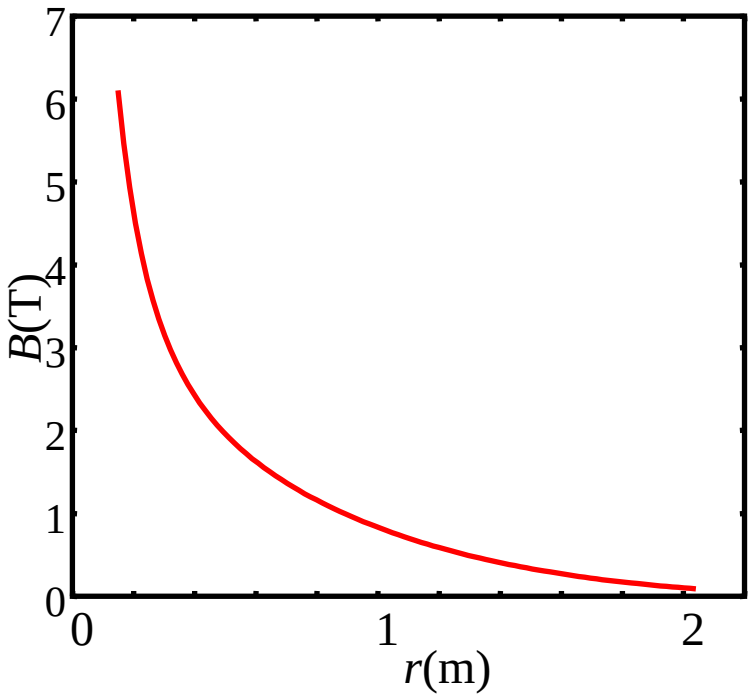
$$\left\langle \Pi_{ii} \right\rangle \sim \ell_{\|} D_{vii} \Omega' \sim \sqrt{r} r / r^{3/2} \sim 1$$

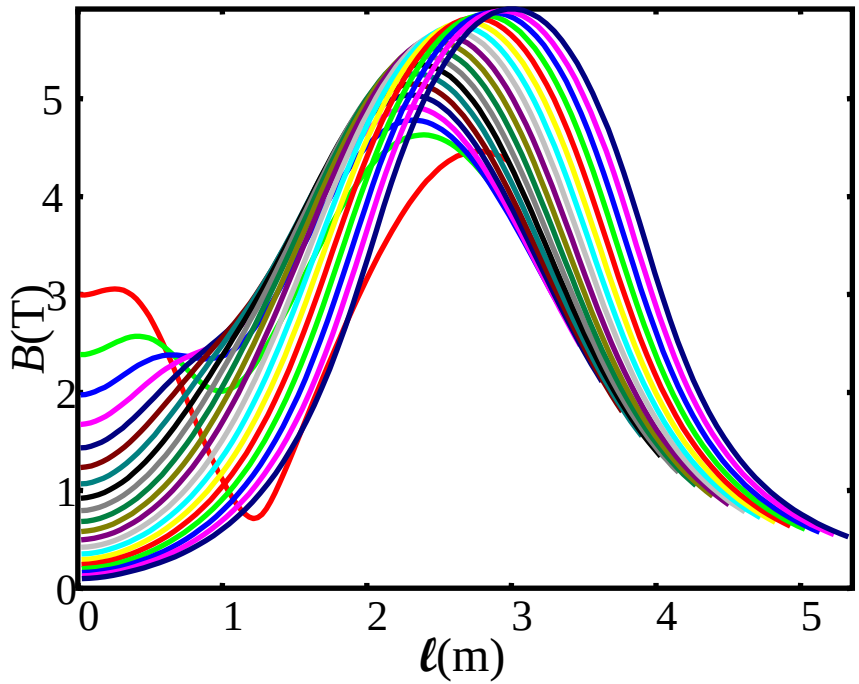
Desired rotation profile produced by driving inner surface and dragging outer surface

Biot-Savart Gives Desired Field



Magnetic Field Approximates Ideal





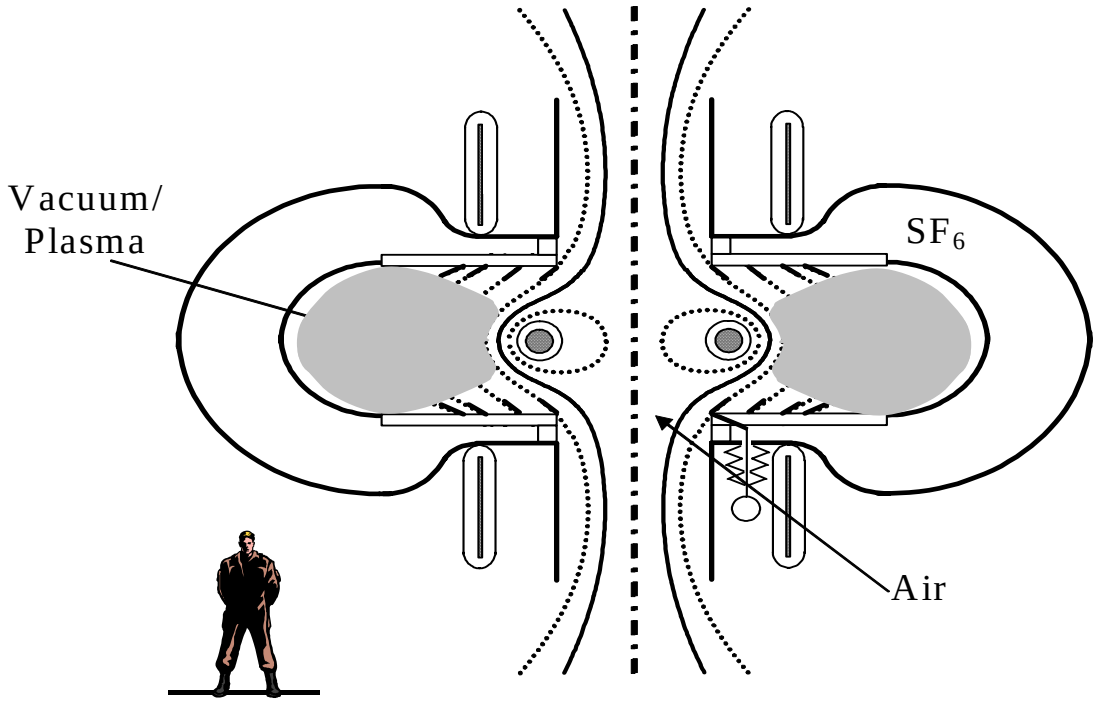
Reactor Sketch

B_M = 5 T (W_B ~ 100 MJ)

V = 2 MV

P_F = 5 MW

α's are prompt lost to ends – could be direct converted or use high T gas cycle



Not Sci Fi, ½ MV Already Done*

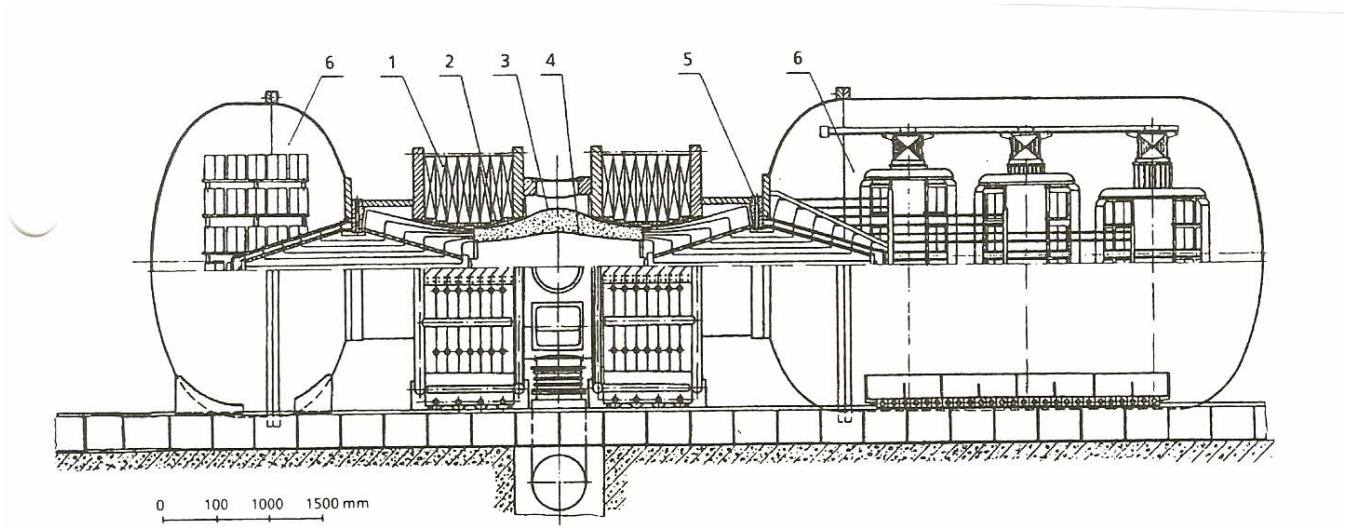


FIG. 1. PSP-2 cross-section; 1 — magnetic field coils; 2 — plasma region; 3 — outer liner; 4 — inner liner; 5 — electrode system; 6 — HV unit.

PSP-2 Experiment at Novosibirsk

*G. F. Abdrashitov, *et al.*, *Nucl. Fusion* **31**, 1275 (1991)

A Few Details Were Omitted

- IC waves generated by stationary $\tilde{\mathbf{B}}$
- Energetic p confinement near midplane
  - Waves give large perpendicular energy
  - Slowing down faster than pitch angle scattering by choice of T_e
- Interchange physics
  - Marginal profile since isentropic
- Other power loss channels
  - Parallel conduction
  - Viscous losses

Plans and Outlook

- Advantages
  - New and patentable
  - Relatively low development cost ($10M's)
  - Aneutronic
  - Formation and heating straightforward
- Seek private funding
  - Need technical partners
  - Need business partners
- Build scale experiment
  - Show principle of rotating Boron plasma
  - Inject proton beam to make some fusion α's
  - Complete Patents