Interplay between Concept Exploration (CE) Experiments and a Burning Plasma Experiment (BPX)

By

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Outline

- Mission of ICC program
- CE experiments can help a BPX
- BPX can help CE experiments
- BPX must be done right
- Summary

Mission of ICC program

- Search for large improvements to our product by exploring different parts of parameter space for a better local optimum to dramatically advance fusion in the areas of physics, engineering, and economics

- Test the general validity of plasma physics and technology in wider parameter regimes

- Develop new fusion plasma physics outside the mainline

- Cross fertilize with other fields of plasma physics

Experiment	Institution
Rotomak FRC / Drive support	LANL
FRC Stability by Internal Toroidal Field	Swarthmore
FRC TCS: Current Drive by RMF	Washington
FRC Theory	PPPL
FRC Rotating Magnetic Field	PPPL
Ion Rings for Fusion	Cornell
Edge Physics Studies	Washington
MTF Studies	LANL
MTF Collaboration	LLNL
MTF Exp. Eval. Of Fuel- Cont.	AirForce Lab
MTF Theory	GA
SSPX Collaboration	LANL
Spheromak Research	LLNL
Determination of Helicity Injection	CIT
Invest Spheromak formation	UCDavis
Stabilization of RWM	Wisconsin
Helicity Injected Current Drive	Washington
Levitated Dipole	MIT
Levitated Dipole	Columbia
Maryland Centrifugal Torus	Maryland
ZAP: Z- Pinch Experiment	Washington
Ultra-low Aspect Ratio Toroidal Plasma	Wisconsin
Oscillating Inertial Electrostatic Confinement	LANL
Off- Site University Support	PPPL
Penning Fusion Exp (Ion Trap)	LANL
Electric Tokamak	UCLA
HBT- EP	Columbia
Tokamak Transport and Feedback control	Columbia
HSX	Wisconsin
CTH	Auburn

- About 30 experiments with total budget of about $20M
- Not PoP ICC, not non-ICC CEs like CDX-U, IFE

While it is not the main purpose of CE experiments they might help a BPX, provided the machine has the flexibility to incorporate new understanding.

- Achieving AT behavior with less auxiliary power for control, in this more self-organized plasma, may be difficult. CE experiments may be valuable

  - The application of electric fields for plasma rotation (needed for transport barrier maintenance) is being studied in ET, MCE and CHI

  - The use of MHD activity for current drive and for driving differential rotation has possible application to BPX and is being studied in CE experiments

- Dipole experiment may help in understanding beta-limited transport

- RMF current drive being studied for FRCs and CHI current drive in spheromaks may lead to efficient current drive for BPX.

- At very high-Q, plasma fueling will be the dominant control method. CT injection of both FRCs and spheromaks is being developed at the CE level.

CE experiments are a necessary part of a healthy fusion program needed to support a BPX

- Testbed for new diagnostic
- Attract and train new scientific talent
- Retain active scientists during the long construction and regimented running of BPX
- Maintain public interest in fusion during BPX construction and before and after high-Q operation starts

BPX may help progress with the plasma physics of new concepts

- A healthy fusion program is necessary to stimulate and support ICC research.

- For helping with present frontiers of CE plasma physics present tokamaks are probably almost as good as a BPX.

- However, CE physics progress toward fusion power may benefit from BPX

  - There is a possibility of transitions at very large S for MHD and very high $\omega\tau$ for Hall physics in a reactor like plasma.

  - Alpha heating, very collisionless electrons, and extremely low resistivity will explore kinetic effects on profile relaxation and current drive beyond bootstrap in a reactor like environment. Lack of auxiliary power may make effects more detectable (compared to present day tokamaks) in the alpha-particles-only environment.

  - Many CE magnetic confinement reactor concepts have lower ρ^*_{NE} than a tokamak. BPX will begin to explore this higher I_p regime.

  - The discovery of any new effect may lead to a new concept and CE experiment.

A successful BPX will allow the faster development of other potentially more attractive concepts.

- Sets a standard for comparison

- One success will allow larger quicker steps in already cheaper development paths
  - Success will allow higher risk
  - BPX knowledge will lead to larger steps in the correct direction
  - BPX will remove fear of unknown
    - Non-linear coupling of self-generated heating
    - Alpha particle instabilities

- BPX diagnostics will be ready

- Burning plasma technology and techniques will be available

- BPX facility will be built and may be available

Thus, BPX should be built because the development time of magnetic fusion power will be shortened by several years (even for non-tokamak magnetic fusion).

- Electrostatic confinement has fewer benefits since reactor problems might be more like fission.

- Success with BPX will give all of fusion more credibility including IFE and MTF.

Realizing a positive impact on the development of fusion power requires BPX to be successful

- Achieve Q>5

- Acquire funding without claiming to be the first step of an engineering program to attractive fusion power

- Strengthen and broaden the other parts of the fusion program so rapid progress can be made on all fronts. For example, the domestic program must be able to move ICC's up through PoP to PE, in order to get to DEMO.

- Maintain our clean image (extremely important)
  - Practice high level of containment and mechanical safety
  - Must have a small amount of radioactive waste when the experiment is over
    - Should not build ITER out of stainless steel
    - Must do nuclear homework and testing

Summary

- Although it is not their purpose CE experiments will support a BPX

- Only if an unlikely plasma physics transition occurs when going to the extreme BPX parameters will it impact CE physics significantly more than present tokamaks

- Provided the BPX is done properly it can augment the progress and increases the depth of the rest of the program and cut years off the time required for achieving practical fusion.