The Fusion Program at PPPL
(in the context of the US program)

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FPA symposium

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ReNeW opportunities and the U.S. program

- Burning plasmas
- Steady-state, high performance
- Optimizing the magnetic configuration
- Taming the plasma-material interface
- Harnessing fusion power

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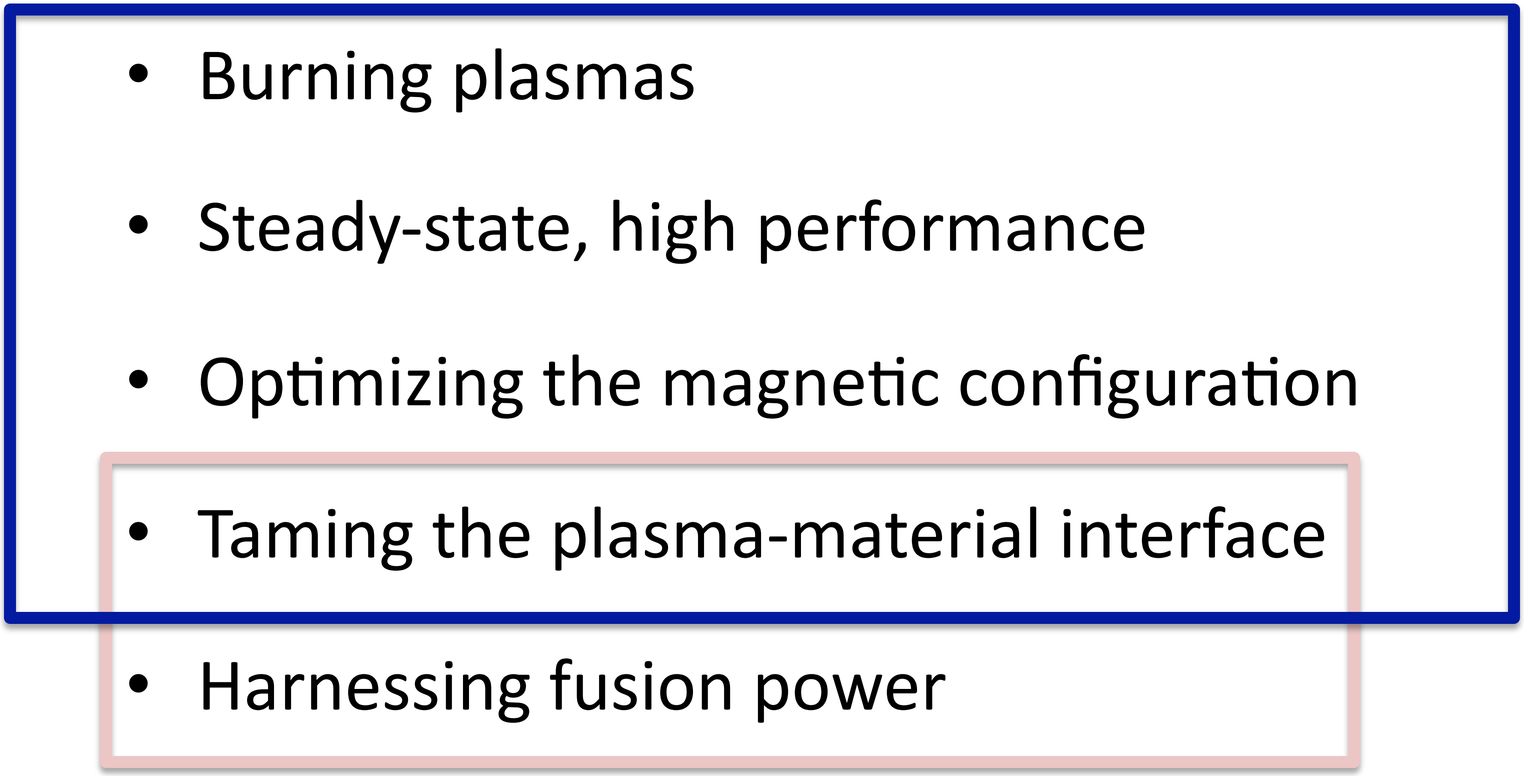
Materials and fusion nuclear science,
It is now time for the U.S. to move into fusion materials research,
Re-establish core competencies

ReNeW opportunities and the U.S. program

Plasma confinement science,
Opportunities to resolve remaining crucial issues,
Benefit from U.S. cutting edge expertise (and maintain that expertise)



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Pathways towards integrated DT experiments

mission elements

plasma-materials interaction

neutron effects on materials

fusion nuclear science (component testing)

net electricity production (pilot plant)

Consider aiming toward a pilot plant

- $Q_{eng} > 1$, integrates missions in one facility
- Can start with demonstration of electricity production at low availability, then proceed with neutron fluence tests
- Pilot plant can be a driver for the fusion program and convey fusion's potential to the public

Spreadsheet Pilot Plants parameters

($Q_{eng} > 1$)

- **Tokamak**
  - $R/a = 4m/1m$, $B_0 = 6T$, $I_p = 8MA$
  - $H_H = 1.5$, $P_{fus} = 500MW$

- **Stellarator**
  - $R/\langle a \rangle = 4.6m/1m$, $B_0 = 5T$
  - $H_{ISS04} = 2$, $P_{fus} = 200MW$

- **ST**
  - $R/a = 1.5m/0.9m$, $B_0 = 2.2T$, $I_p = 15$ MA
  - $H_H = 1.7$, $P_{fus} = 500MW$

Can combine missions into facilities in various ways

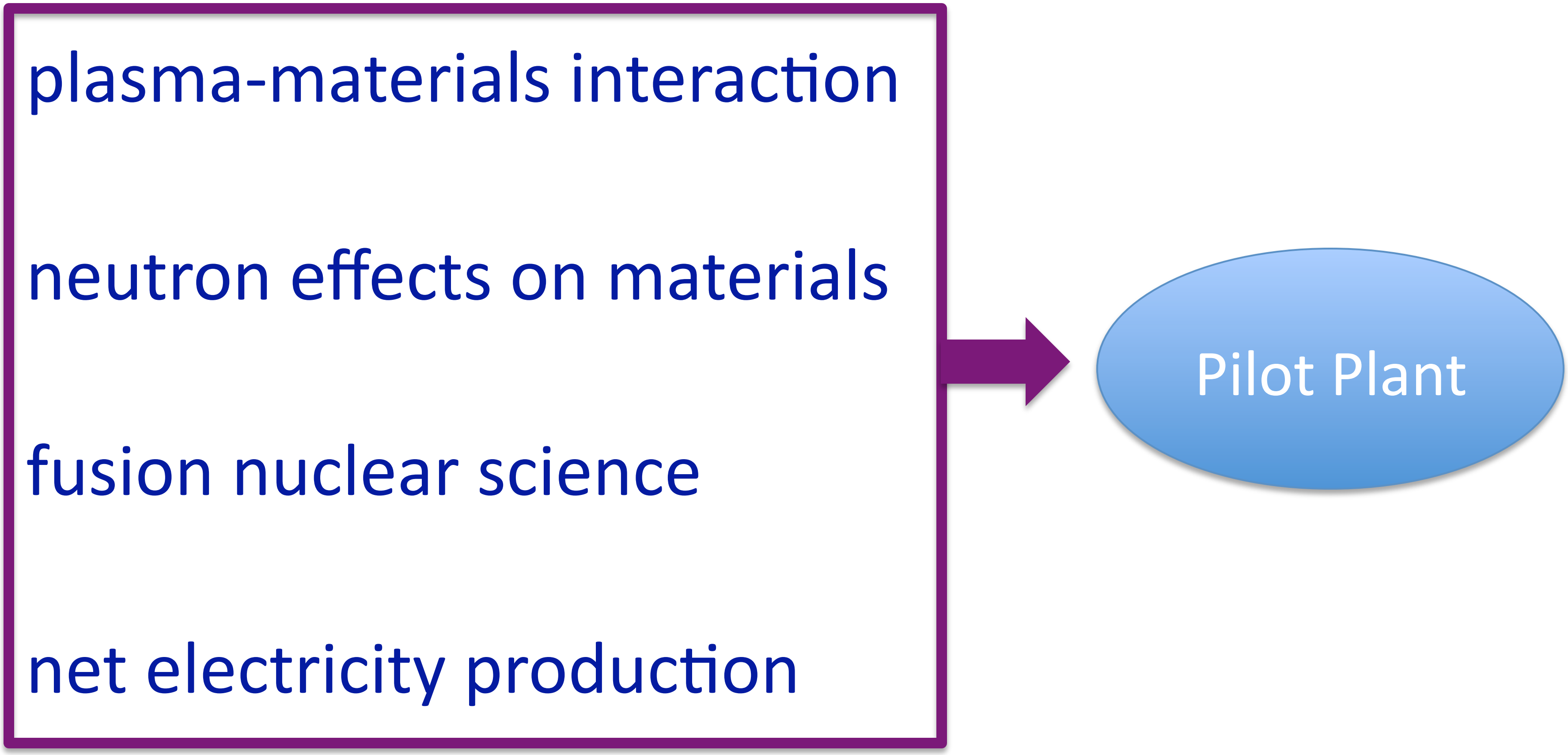
plasma-materials interaction

neutron effects on materials

fusion nuclear science

net electricity production

very aggressive, possibly high risk



plasma-materials interaction

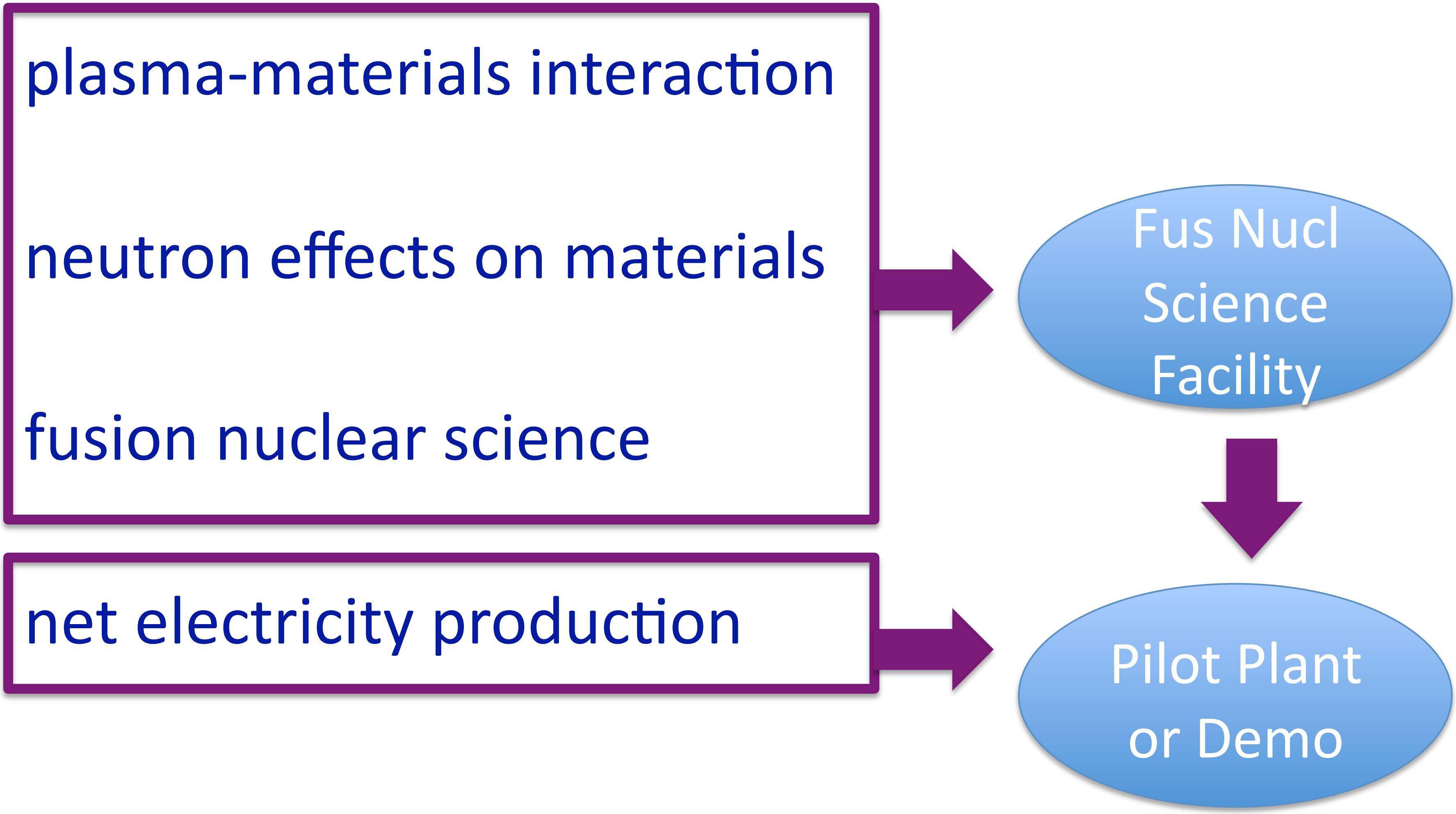
neutron effects on materials

fusion nuclear science

net electricity production

Pilot Plant

slightly less aggressive,



plasma-materials interaction

neutron effects on materials

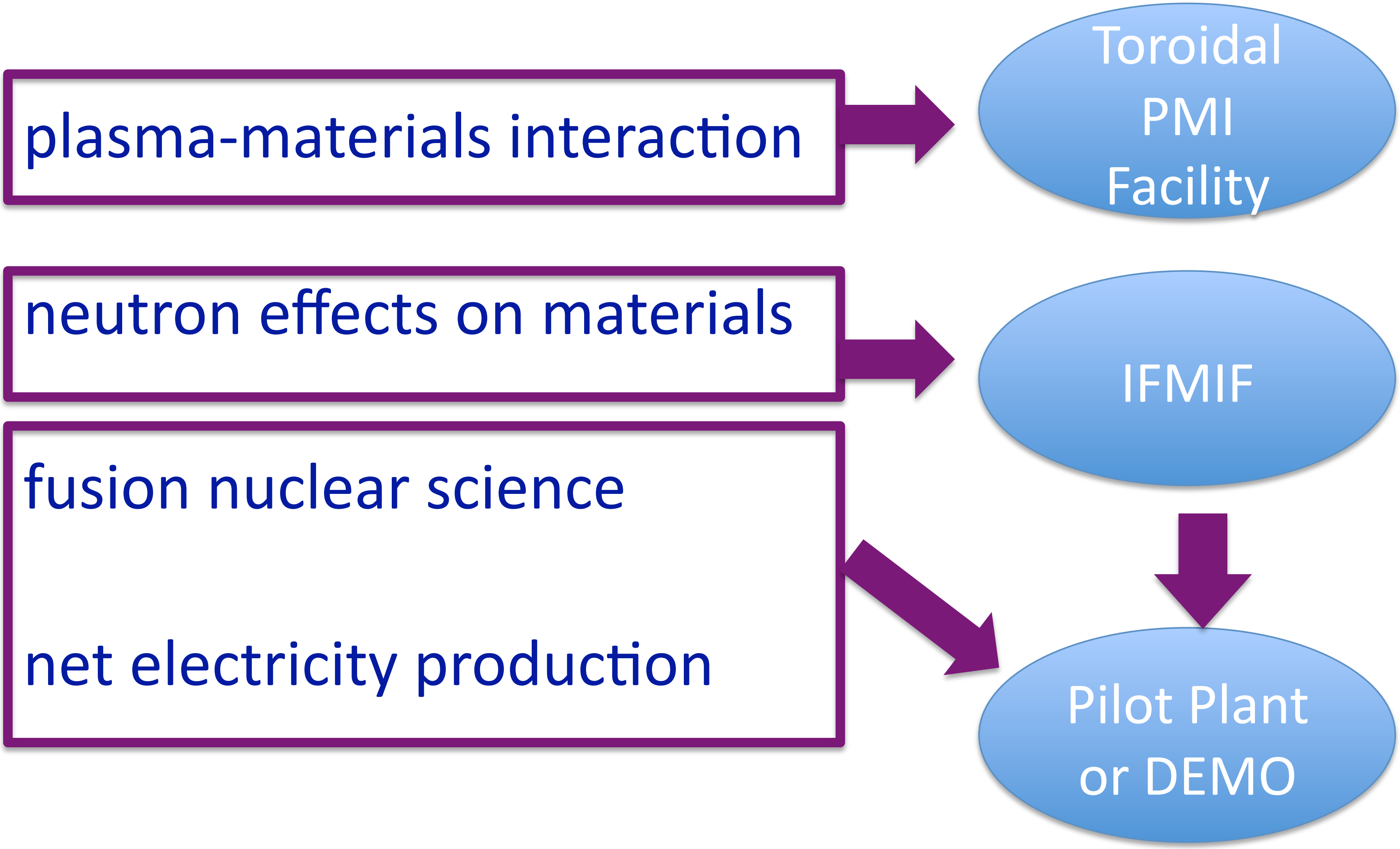
fusion nuclear science

net electricity production

Fus Nucl Science Facility

Pilot Plant or Demo

less aggressive



plasma-materials interaction

Toroidal
PMI
Facility

neutron effects on materials

IFMIF

fusion nuclear science

net electricity production

Pilot Plant
or DEMO

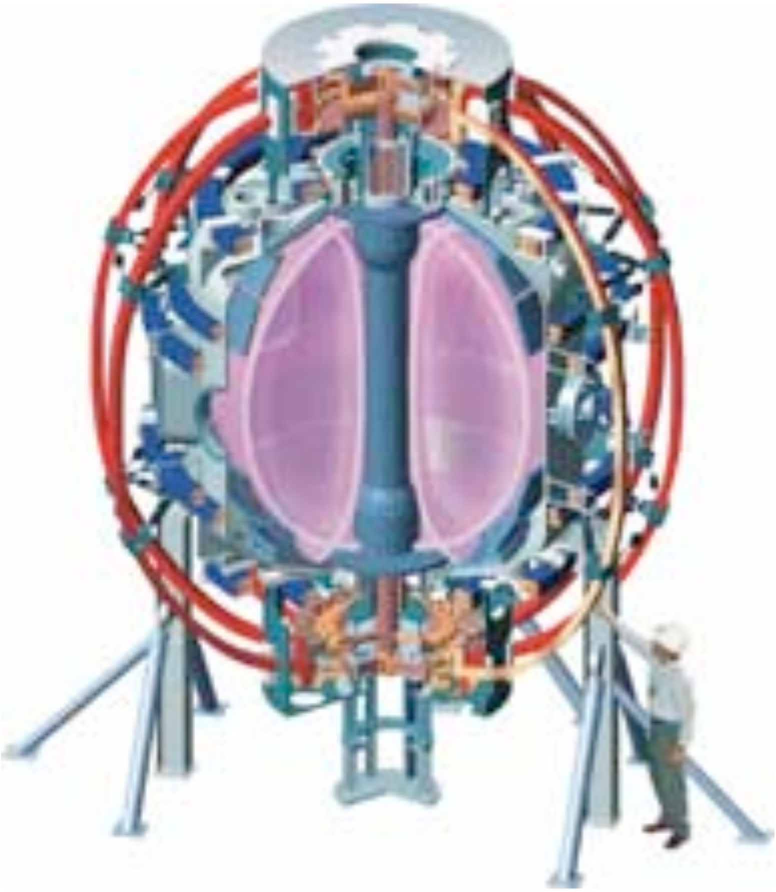
See Goldston talk

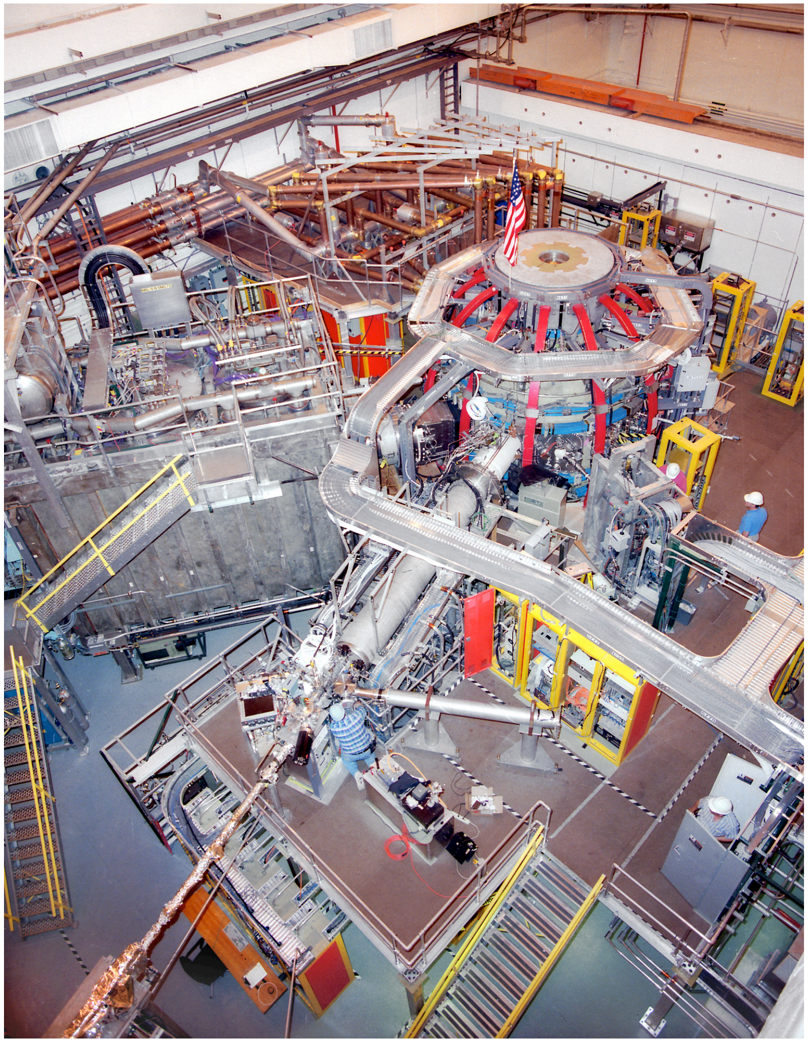
A design/strategic study is required to assess risks, readiness, required R&D, costs, timeline of various paths

PPPL activities and plans span many ReNeW themes

NSTX

Spherical tokamak = relatively compact, high beta configuration

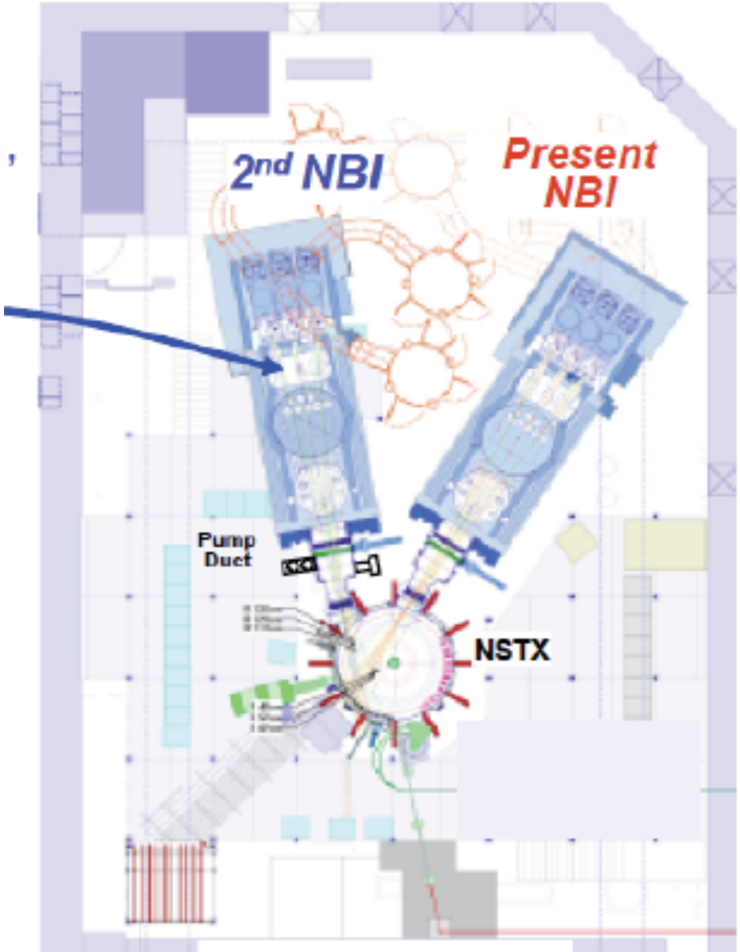




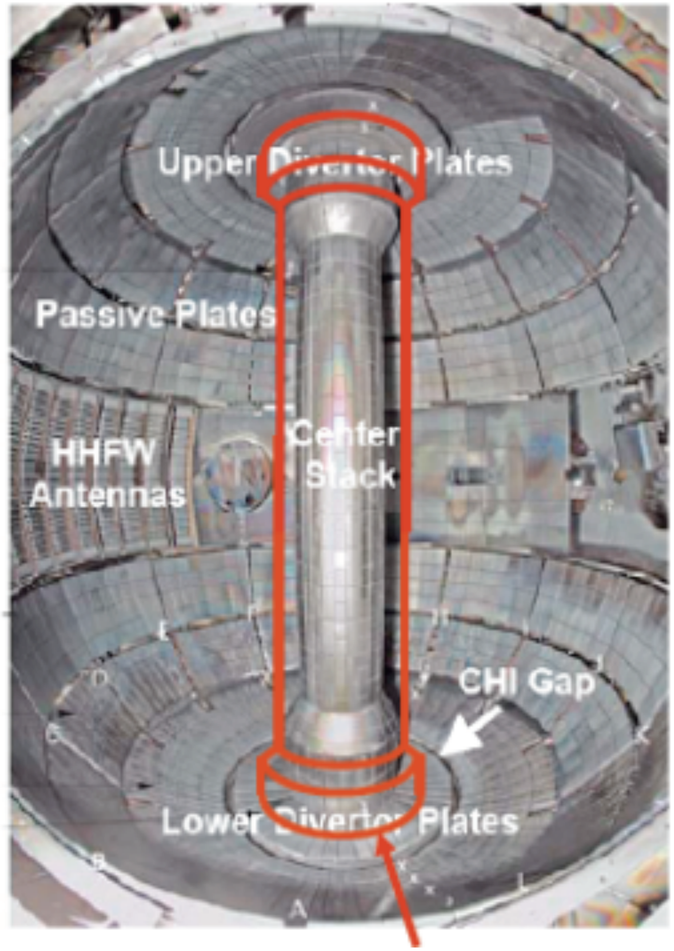
NSTX upgrade

Increase current 2x, increase pulse length 5x (2 MA for 5 sec)

second neutral beam



new center stack



Reasons for Upgrade

- PMI/first wall materials research
  - high exhaust heat flux (≥ ITER)
  - novel first wall boundary (liquid Lithium)
  - scoping hot walls, advanced magnetic divertor

- Develop ST for fusion next steps
  - Fusion nuclear science facility, toroidal PMI facility

- Explore new fusion parameter regimes
  - confinement at low collisionality and low R/a

Cost effective: majority of funds provided by reduced NSTX operations

Evolving a program in PMI/first wall materials

Experimental elements

- Developing liquid metal boundaries
  - NSTX-U, LTX (Lithium Tokamak experiment)
  - test stands
- Testing materials and PMI at high heat flux
  - NSTX-U (heat flux ≥ that of ITER)
  - test stand
- Investigating hot walls and advanced magnetic divertors
  - NSTX-U

Stellarator research

- Stellarators are increasingly critical to fusion

  steady-state, disruption-free, reduced control requirements,
  confinement physics of quasi-symmetry

- U.S. can play leadership role in world program

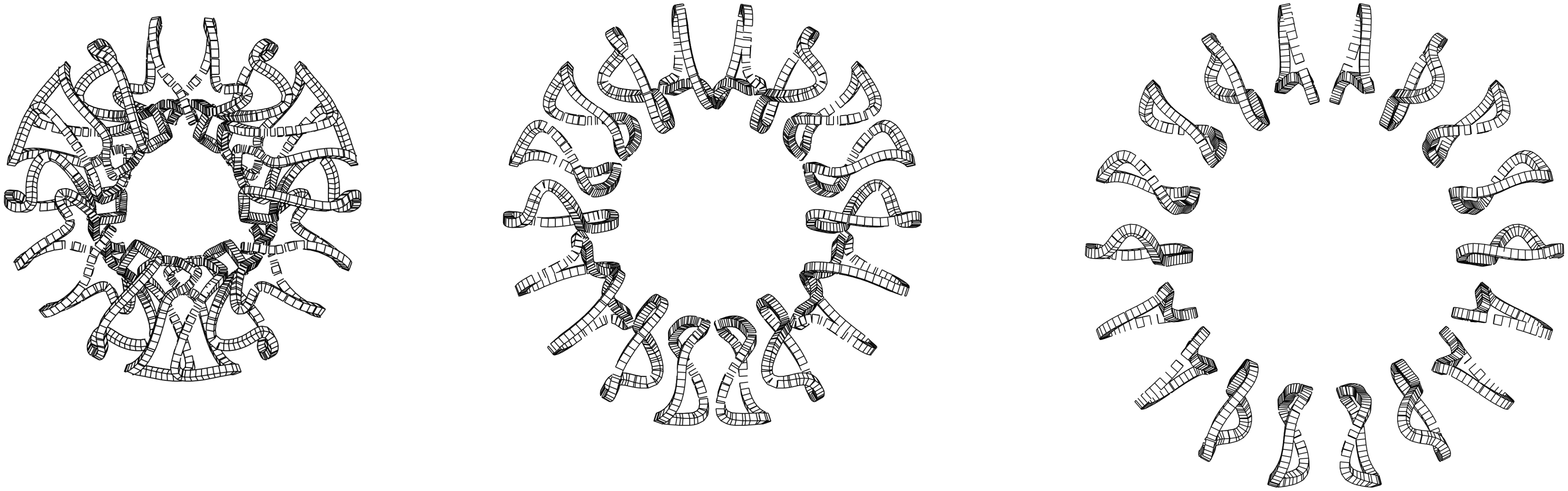
  through quasi-symmetry, building on tokamak understanding

- Collaborations with W7-X and LHD are expanding

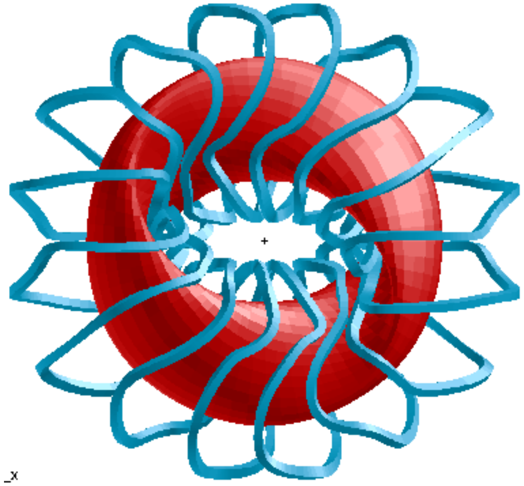
- The National Stellarator Coordinating Committee is assessing opportunities for U.S. experiments

  scoping optimized designs for best step for US

Optimizing aspect ratio/coil complexity



Relaxing theoretical MHD stability constraints (based on experiments)



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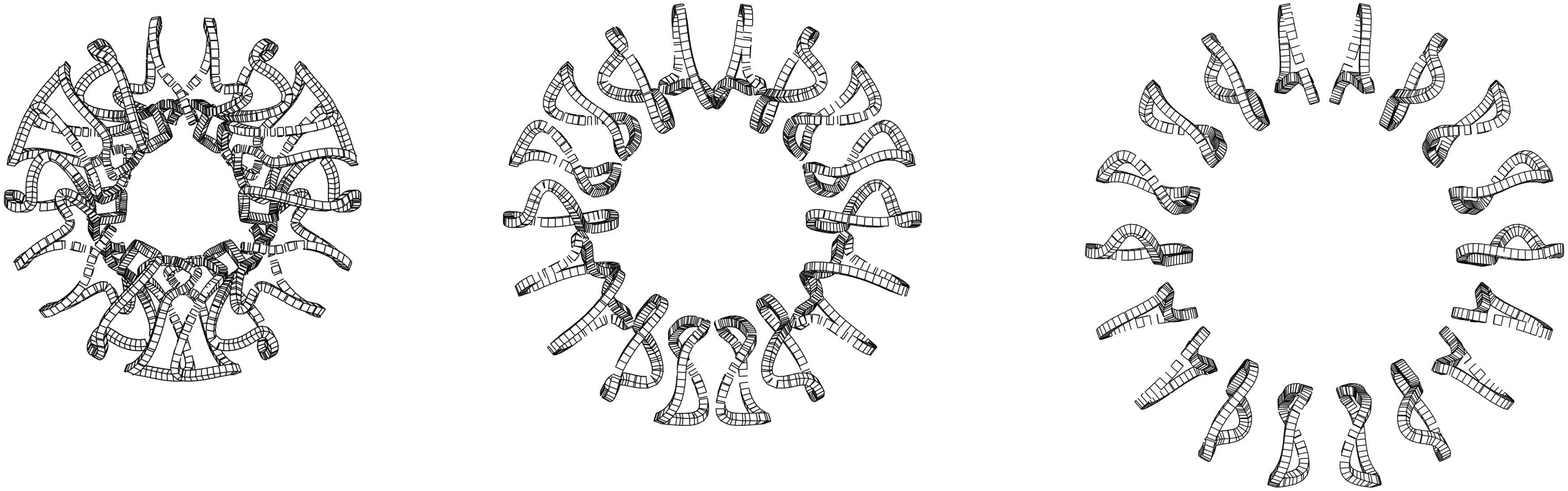

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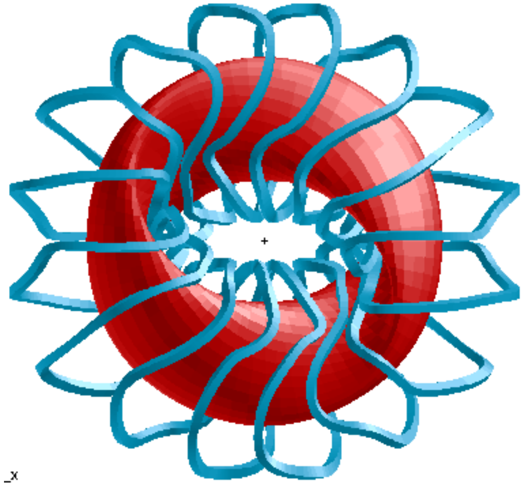


Wisest experimental path will emerge from scoping studies

PPPL Tokamak program

- Collaboration program on off-site experiments

  (DIII-D, C-Mod, EAST, KSTAR, JET)

- Builds on other PPPL elements

  (NSTX, engineering, theory)

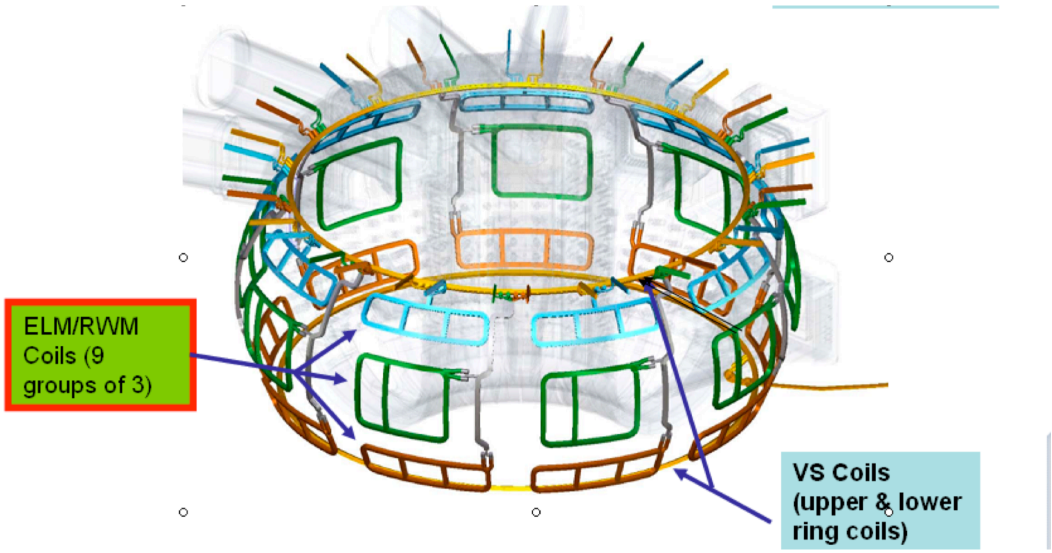
- Prepares for ITER (and other future tokamaks)

ITER design and fabrication

- Ongoing responsibility for diagnostics, steady-state electric power

- Leading the conceptual design of ITER in-vessel coils

(construction decisions pending at international and national level)



Fusion Simulation Program

- Program definition phase launched in August

  (national effort, two years, PPPL has oversight responsibility)

- FSP Goal:

  enable discovery and understanding of new plasma phenomena that emerge only upon integration.

The role of PPPL in FSP

- Responsible for facilitating success of FSP,
- Will oversee issues such as management, community outreach…..
- PPPL responsibility for national FSP is distinct from its scientific participation in FSP

Summary

- U.S. should move toward DT physics and engineering (encompassing ReNeW themes 1,4)

  A national design/strategic study could assess DT pathways aiming toward a pilot plant

- U.S. should seize opportunities in first wall materials and plasma control (themes 1, 2, 3, 5)

- Opportunities and need for U.S. leadership across all themes, and to accelerate the availability of fusion energy

  PPPL is collaboratively developing plans across several themes