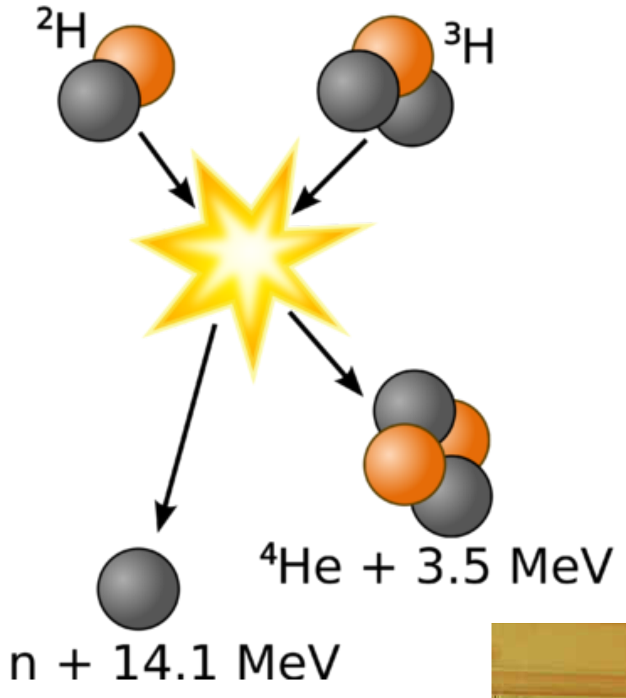
Modelling PFRC Reactor Scrape-off Layer using UEDGE

PEI Summer 2018

Professor Sam Cohen

Ben Taylor

Nuclear Fusion at the PPPL

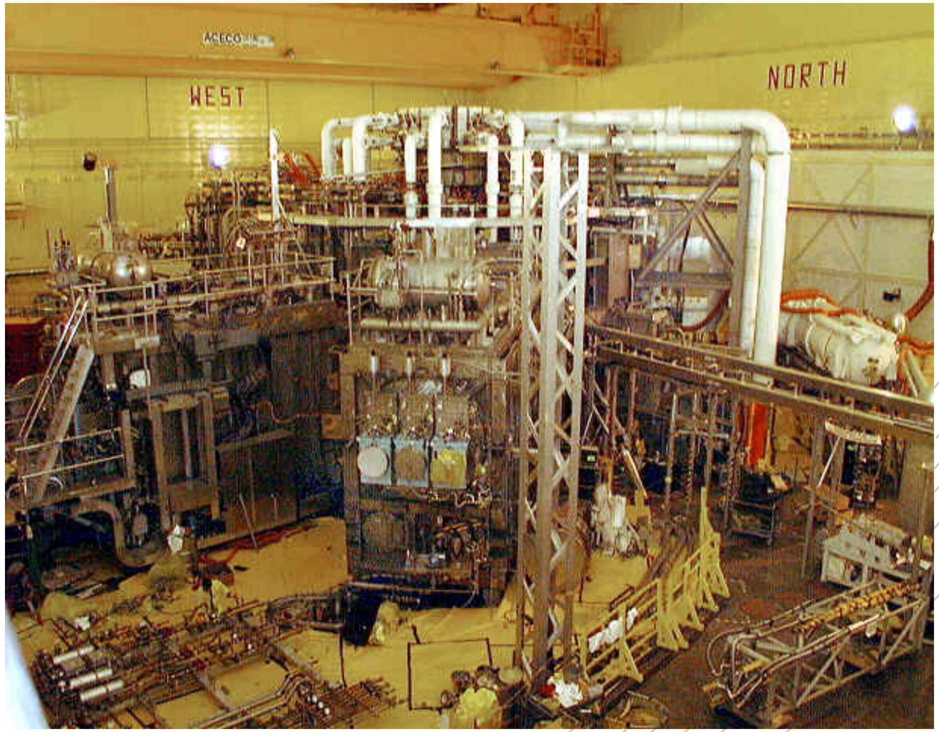


Temperature ~ 100 million C

Power multiplication ~ 450:1

PPPL: National Lab devoted to Studying plasma

TFTR:
10 MW of fusion power



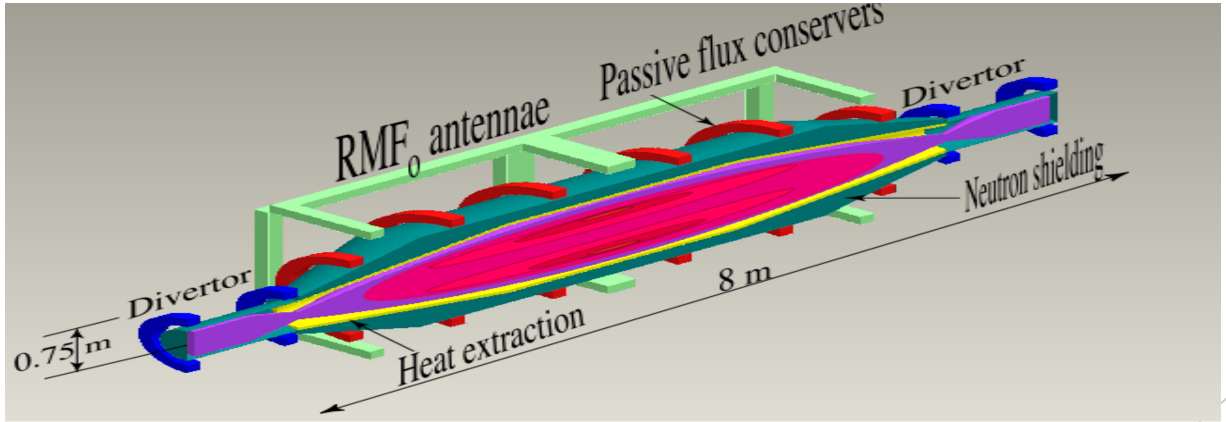
Fusion Power

- Enormous Potential
- Relatively Clean
- Unlimited power source

- But … it’s hard to do.
- Plasmas (ionized gases) are hard to confine
- Challenges in heating, maintaining pure plasma, etc
- Prof Cohen’s interest: neutrons are nasty

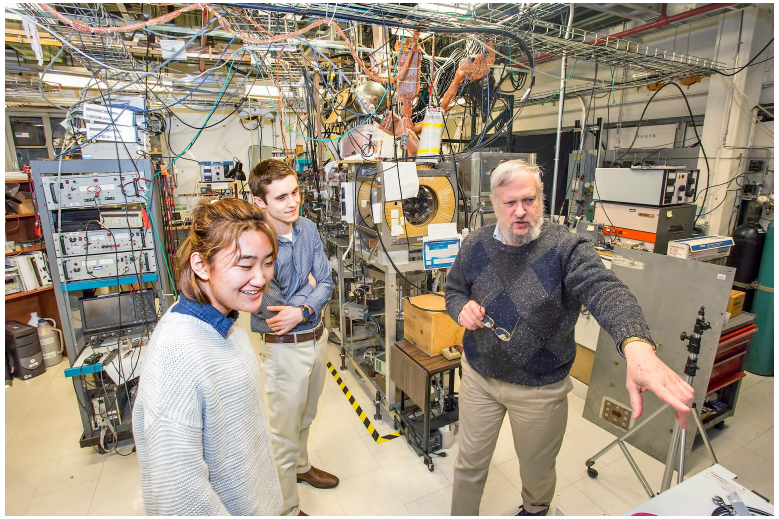
The Princeton Field-Reversed Configuration

- Addresses many big-picture problems with the mainstream fusion reactors.
- Helium 3 has lower neutron content
- Smaller reactor easier to build, operate and integrate
- Logical shape, easy ash separation, etc…
- But …the physics (Heating, energy confinement, stability, etc.) is difficult!

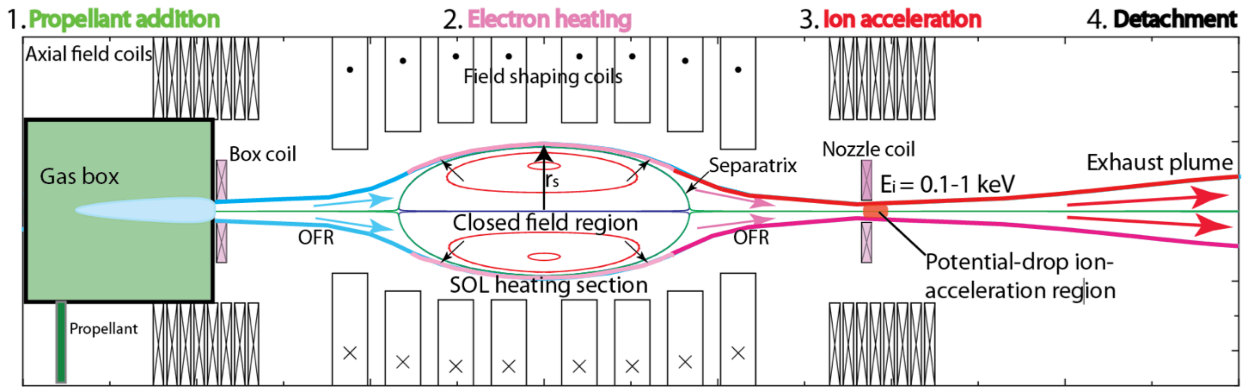


Enter the Team!

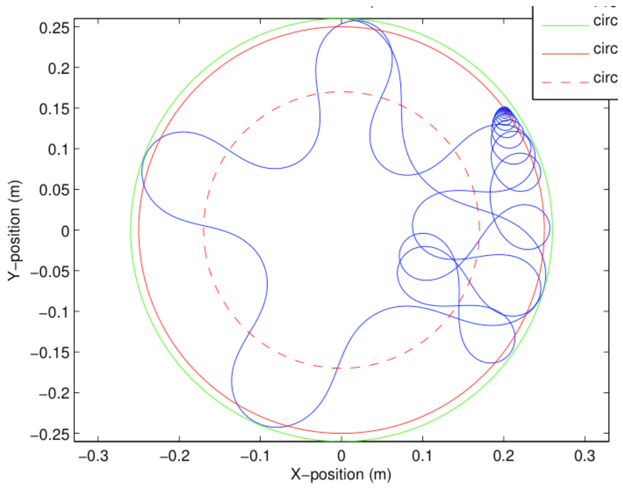
- Professor Sam Cohen
- Grad Students Eugene Evans, Dr. Charles Swanson
- Princeton Satellite Systems, Inc.
- Many undergraduates from across the years!



The Scrape-Off Layer

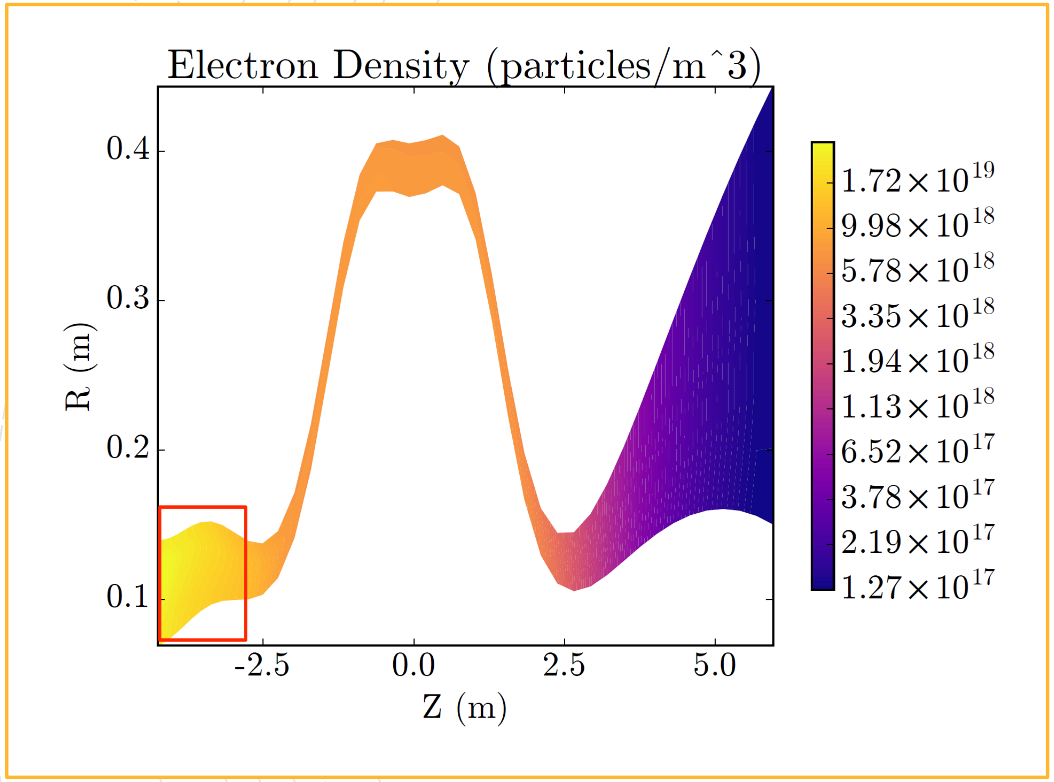


- First layer of unconfined plasma
- In PFRC, SOL particles travel from one end to another
- "Scrapes off" power and ash from fusion core



Figures from Prof Cohen's Internal presentations

What is UEDGE?

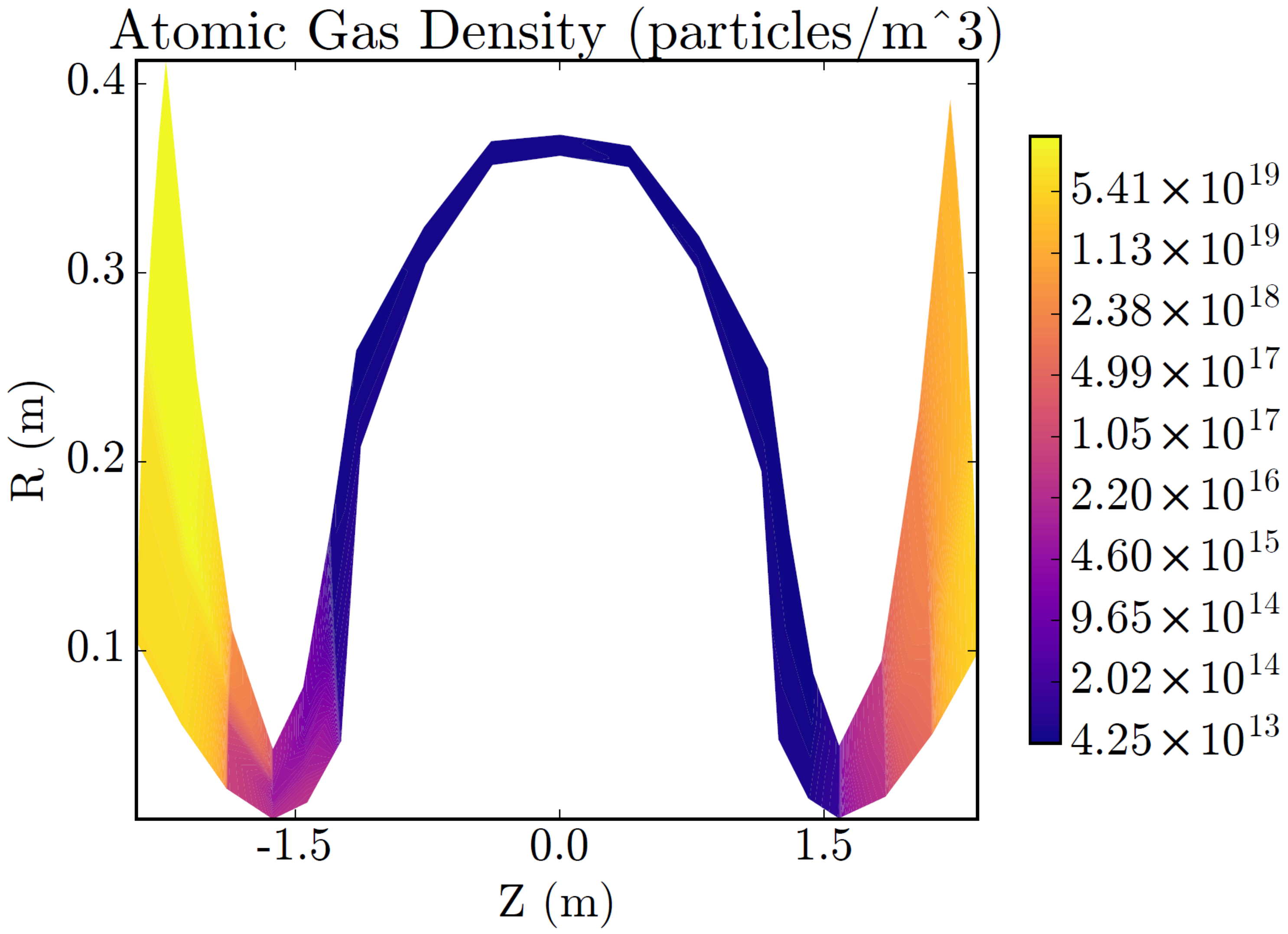


- 2D MHD modelling code widely used for tokamaks
- Takes magnetic geometry ("grid")
- Modified by boundary conditions
  - Temperature and density at walls
  - Particle-surface interaction (recycling, etc)
  - Particle sources and sinks
- Generates time-independent solutions
  - Particle densities, temperatures, and velocities
  - Electric potential

My Goals

- To produce a useful simulations
  - New, accurate geometry ("grid") – accomplished thanks to Gingred*
  - Self-consistent power balance (not accomplished)
- To qualitatively understand behavior over a small parameter range
- Thesis: quantitatively understand behavior across relevant parameter spaces for rocket operation.

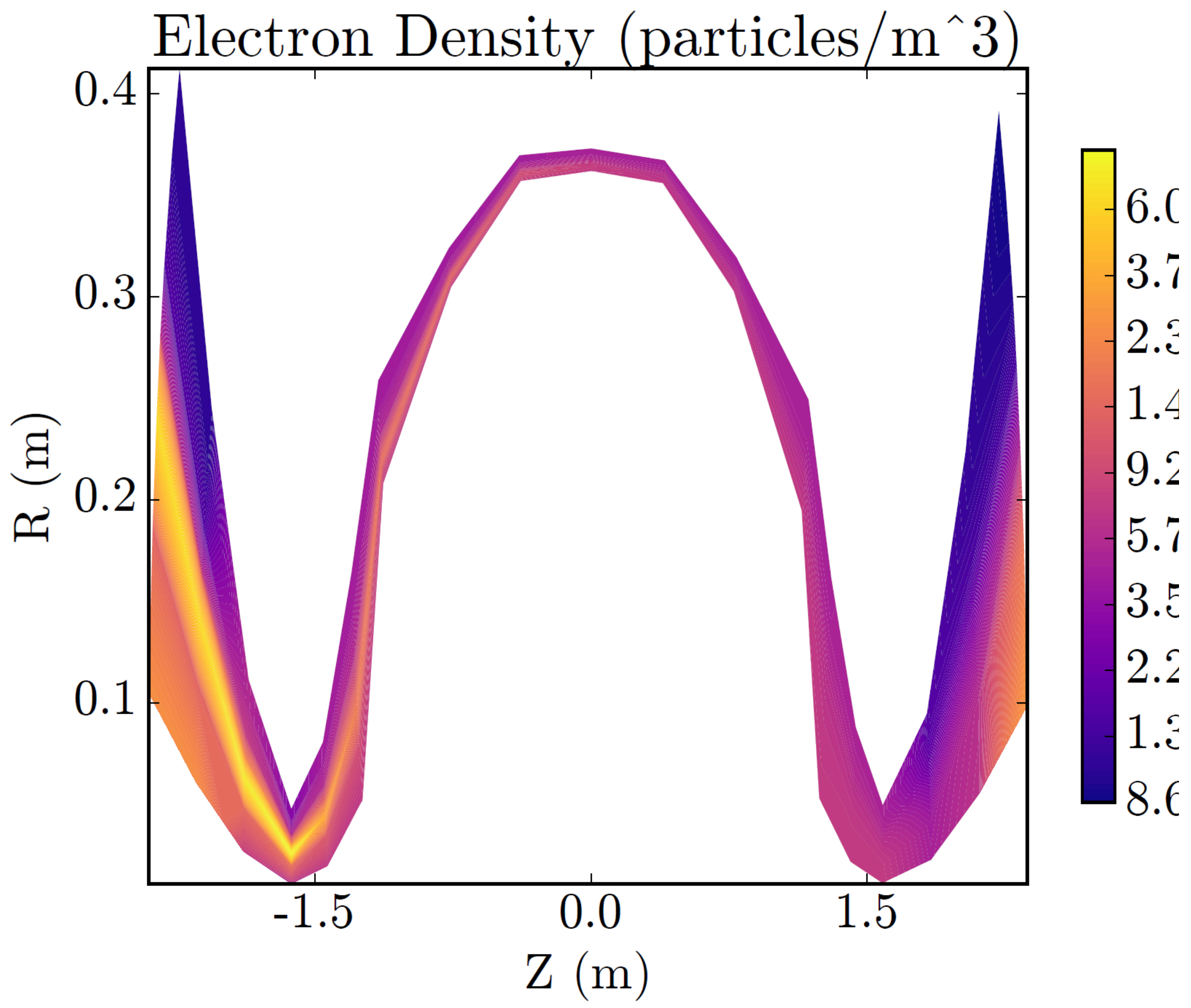
* O. Izacard, 2017



A realistic geometry!

- Zones of puffing and pumping
- Ionization near core

A realistic geometry



Note the ionization front, and low density near puffing and pumping.

Thank you!

- Huge thank you to Professor Cohen for his generosity, encouragement, and at times, tough love
- To Olivier Izacard for his assistance with the technical details and his very useful software Gingred.
- To Eugene Evans for guiding my project and chatting extensively about the PFRC
- To Nick McGreivy, Charles, Nathaniel, and all of Prof Cohen's lab group for their advice and fellowship
- To the PPPL staff for accommodating me
- To PEI, and especially to Ms. Ahmetaj, for all the support and for making this internship possible!!
- To my Lord, for sustaining me with your abundant life!

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Rocket or Reactor

What happens to the particles at the end?

a) Rocket: particles accelerated into space: OPEN

b) Reactor: particles transmit energy into an end plate, recombine to neutral atoms and are pumped away to be used again: CLOSED

I am trying to produce initial results on b)'s feasibility

Why do we care?

- Useful for rocket design
  - Electricity production without propulsion once payload is at destination
  - Simple transition from open to closed
- Critical for electricity production on earth
  - Need an efficient energy extraction and ash separation system
  - Will particle power be efficiently transmitted to the end plate?

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