The Rutgers cyclotron: putting student's careers on target

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G. Hine, T. Koeth (Univ. of Maryland),
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RUTGERS

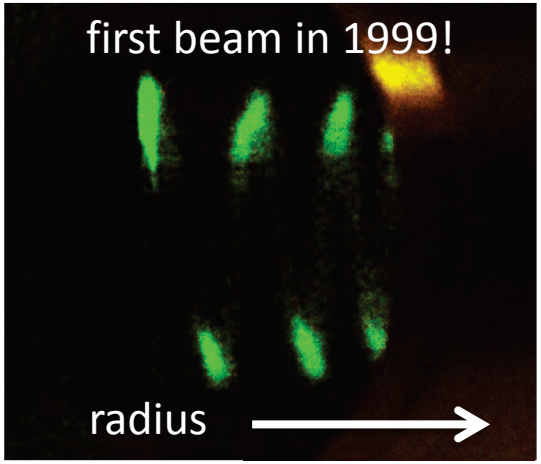
Outline

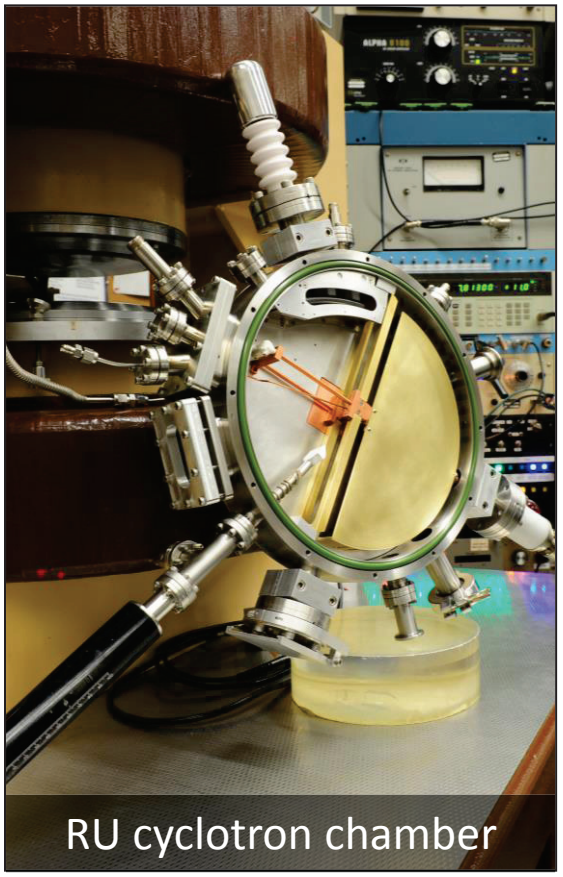
- Introduction to RU cyclotron
- Focusing fields
- Spring 2011 student project:
  - Design of AVF pole tips
- Guiding beam in AVF field
- Future Plans
- Community Impact
  - accelerator careers

RU cyclotron chamber, coils, frame

Rutgers Cyclotron: Introduction

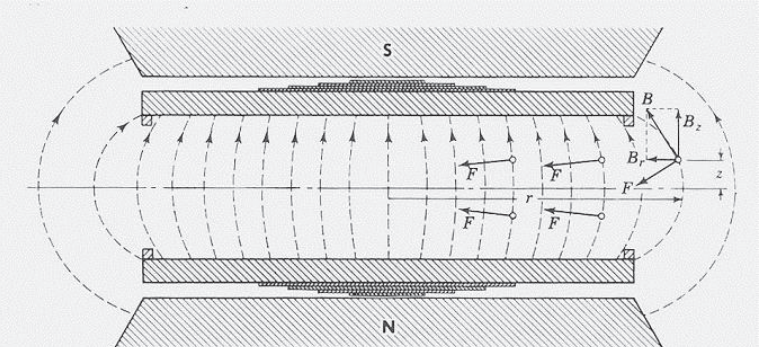
- Motivation: replicate Lawrence & Livingston 1.2 MeV Cyclotron
- Started in 1995 by Tim Koeth, Stuart Hanebuth
- Supported by growing team of Rutgers "cyclotroneers"
- Dedicated to accelerator education
- Incorporated into junior/senior Modern Physics lab course




RU cyclotron chamber

- www.physics.rutgers.edu/cyclotron

Weak Focusing Pole Tips

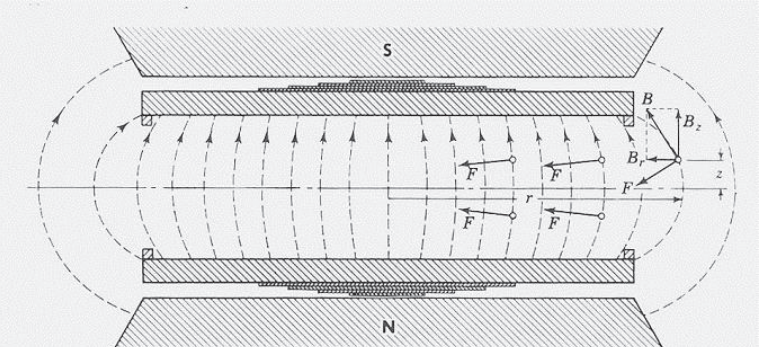


Weak focusing field diagram

$$n = \frac{r}{B}\frac{dB}{dr}$$ Field index

$$\nu_z = \sqrt{n}$$ Vertical tune

Weak Focusing Pole Tips



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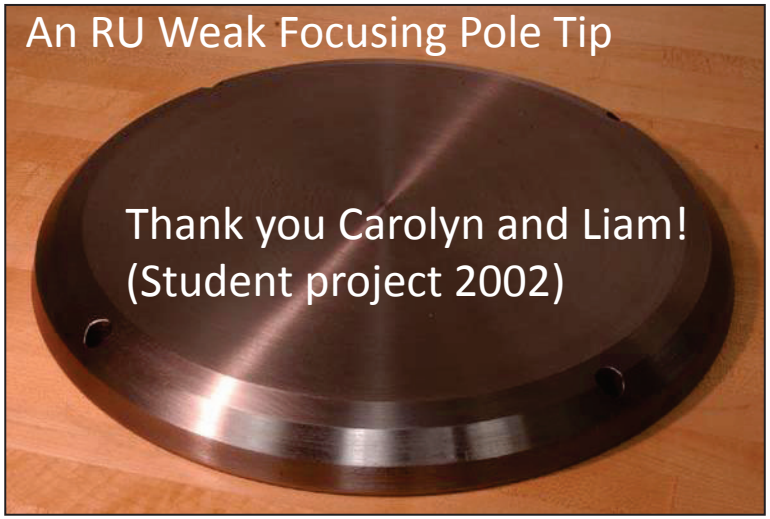
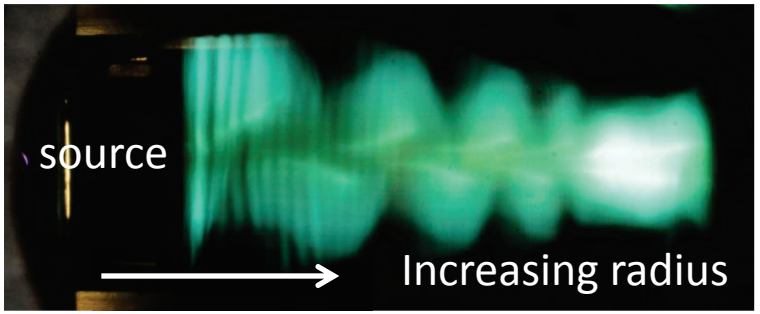
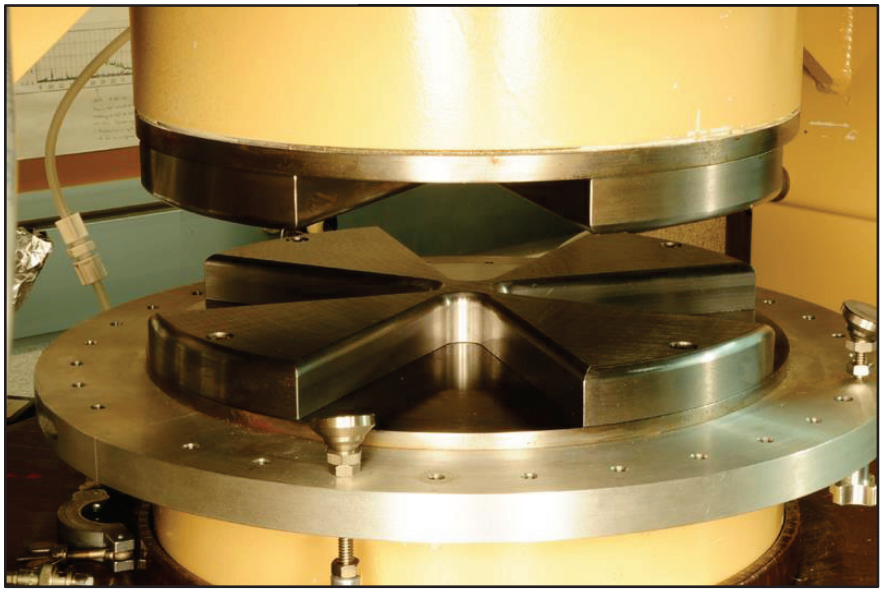


See poster WEPPT025 for demonstration of WF resonances.



Sector AVF Pole Tips



Sector Focusing

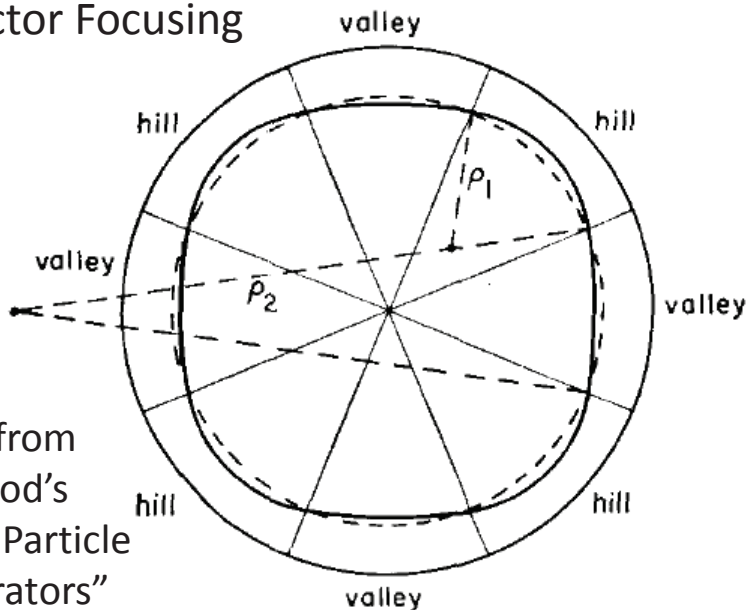
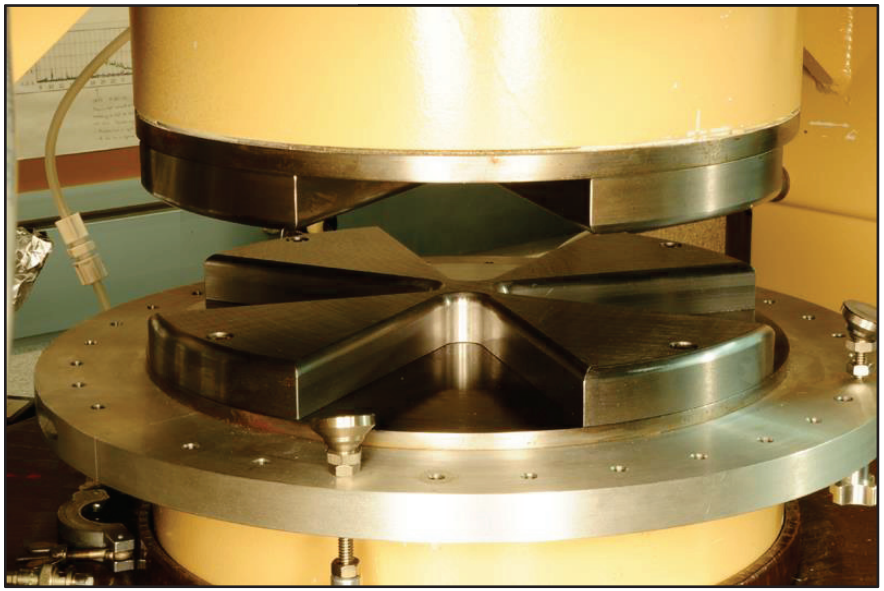


Image from Livingood's "Cyclic Particle Accelerators"

$$\square_z^2 = \square k + F$$ (k is average field index, F is flutter)

Could not transport ions to deflector!

Sector AVF Pole Tips



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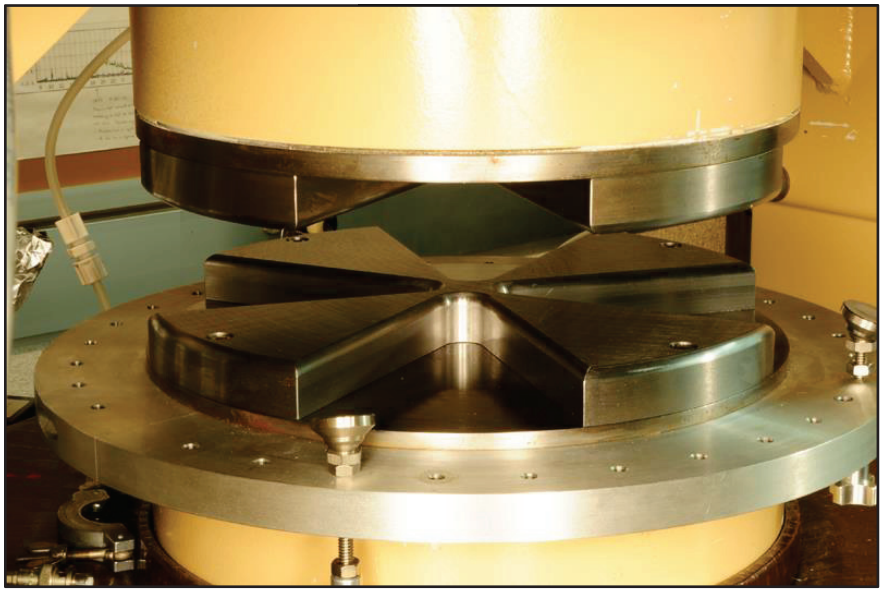

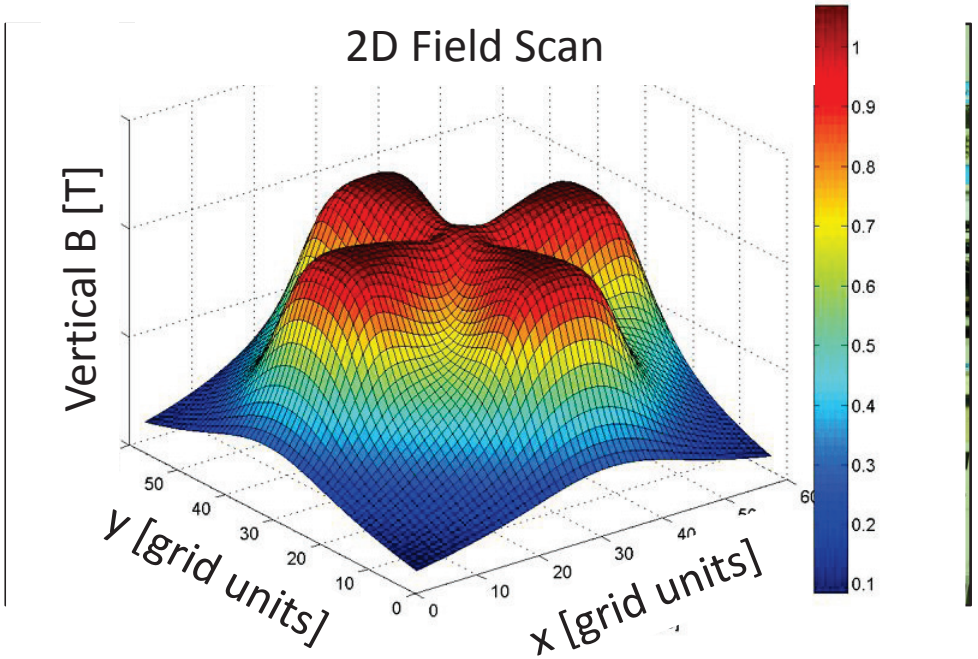

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Could not transport ions to deflector!

2011 Spring Project: AVF pole tip design

- **Goal:** Design and commission AVF focusing pole tips to bring beam to chamber periphery.
- **Motivation:** Achieve stronger focusing than in WF field ($\nu_{z,AVF} > \nu_{z,WF}$) by incorporating edge focusing:

$$\nu_z^2 = -k + F(1 + 2\tan^2\xi)$$

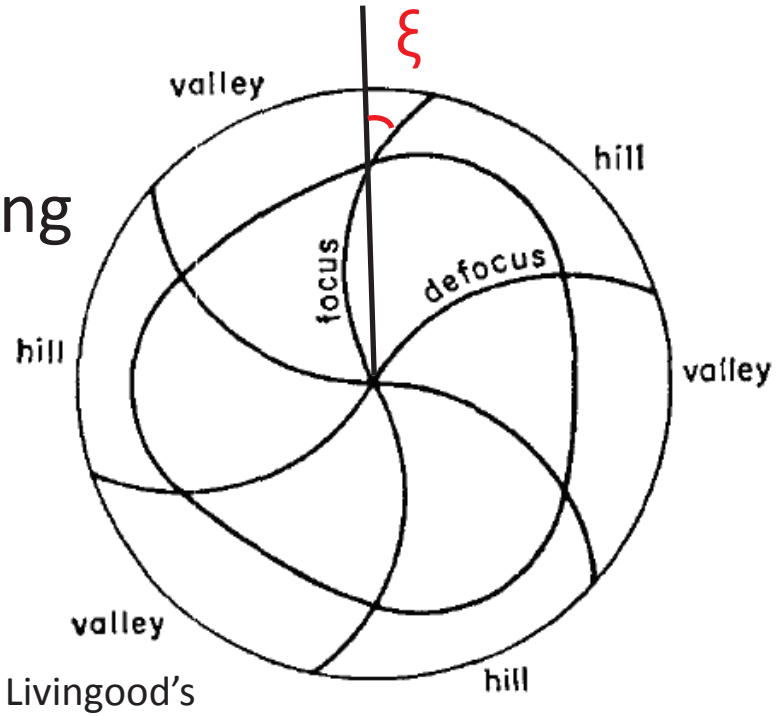
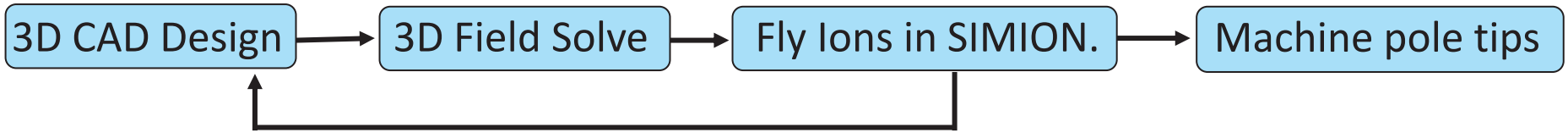
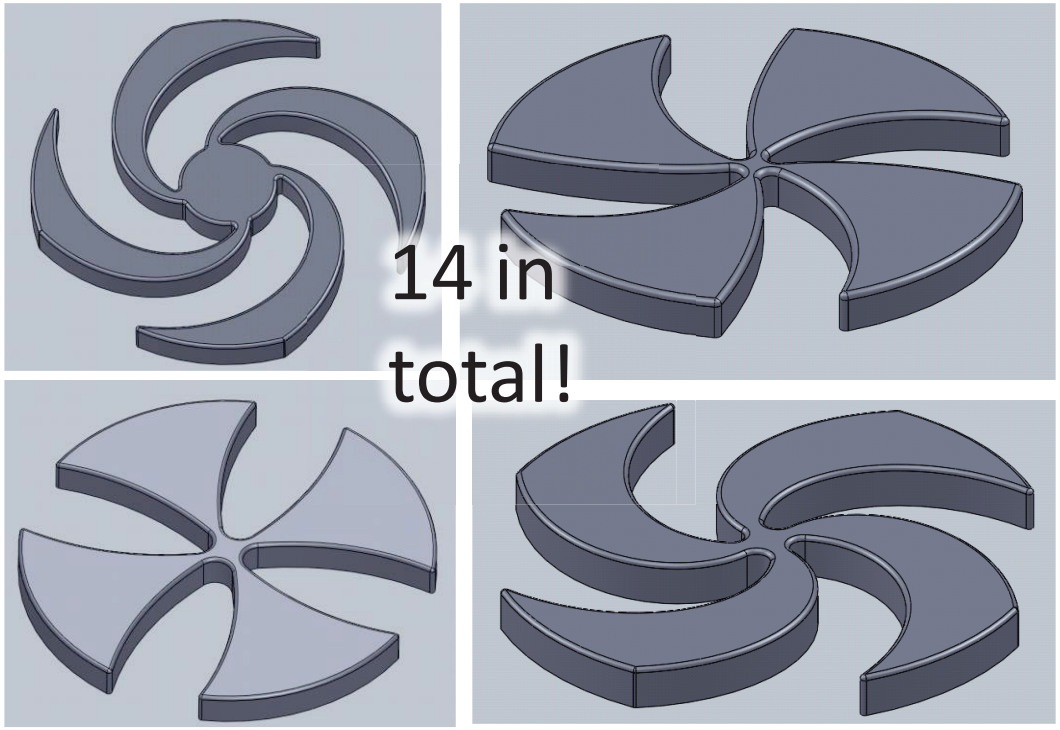


Image from Livingood's "Cyclic Particle Accelerators"

Poletip Design



Many different pole tips were modeled…

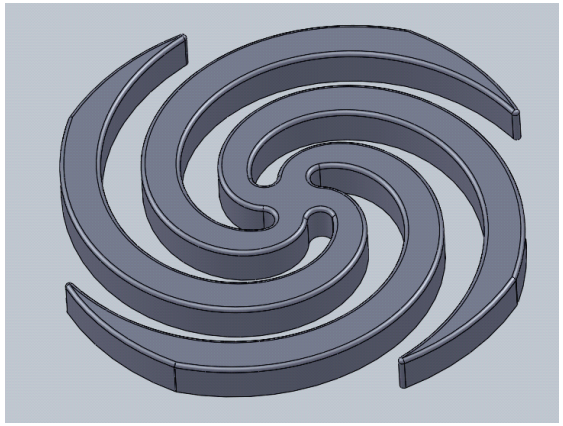


Metrics:

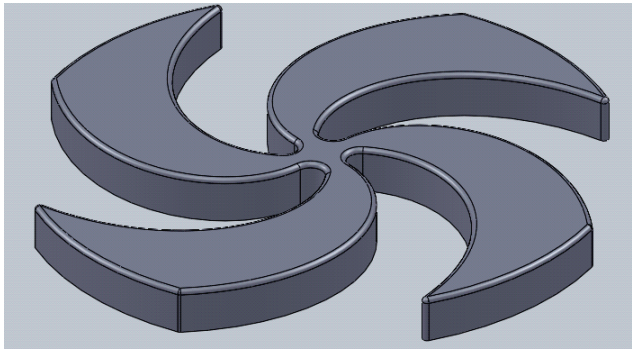
- Radial Profile
- Flutter
- SIMION simulations:
  - Stable region
  - Transport with RF

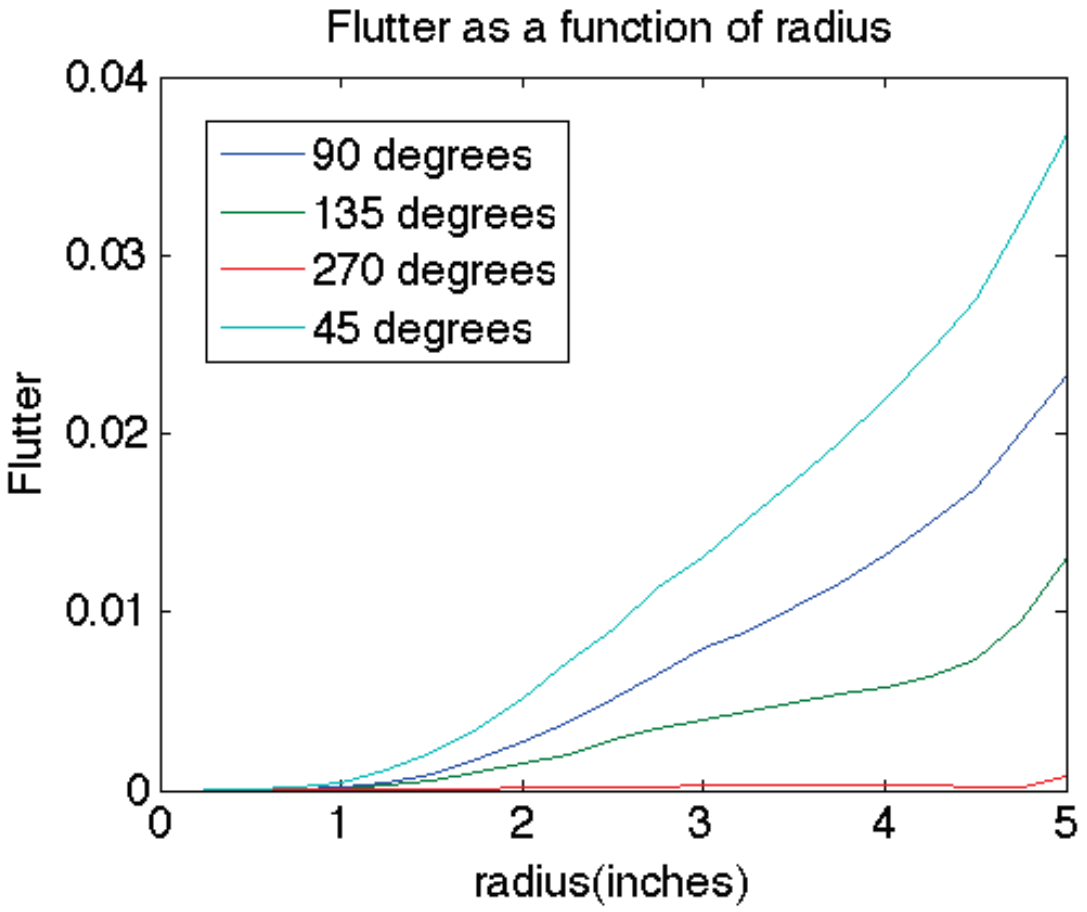
Archimedean Spiral AVF

270° spiral



90° spiral





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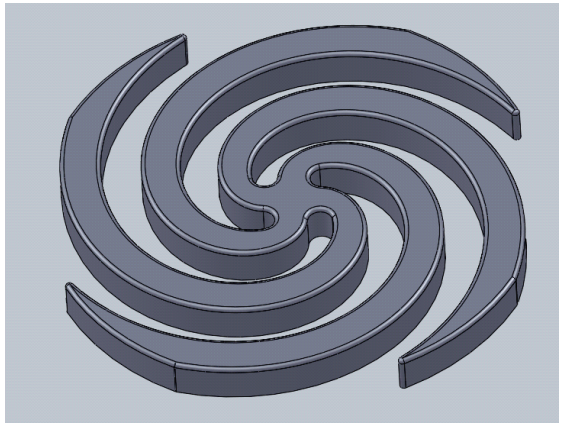

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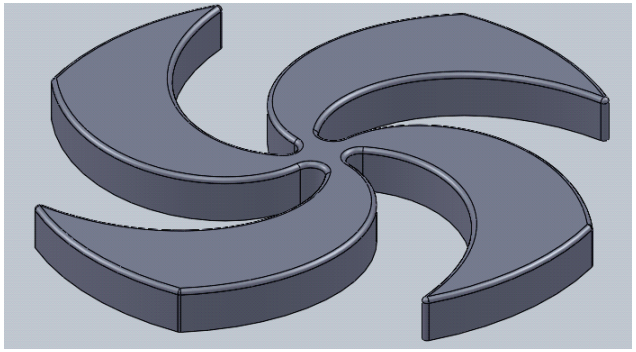
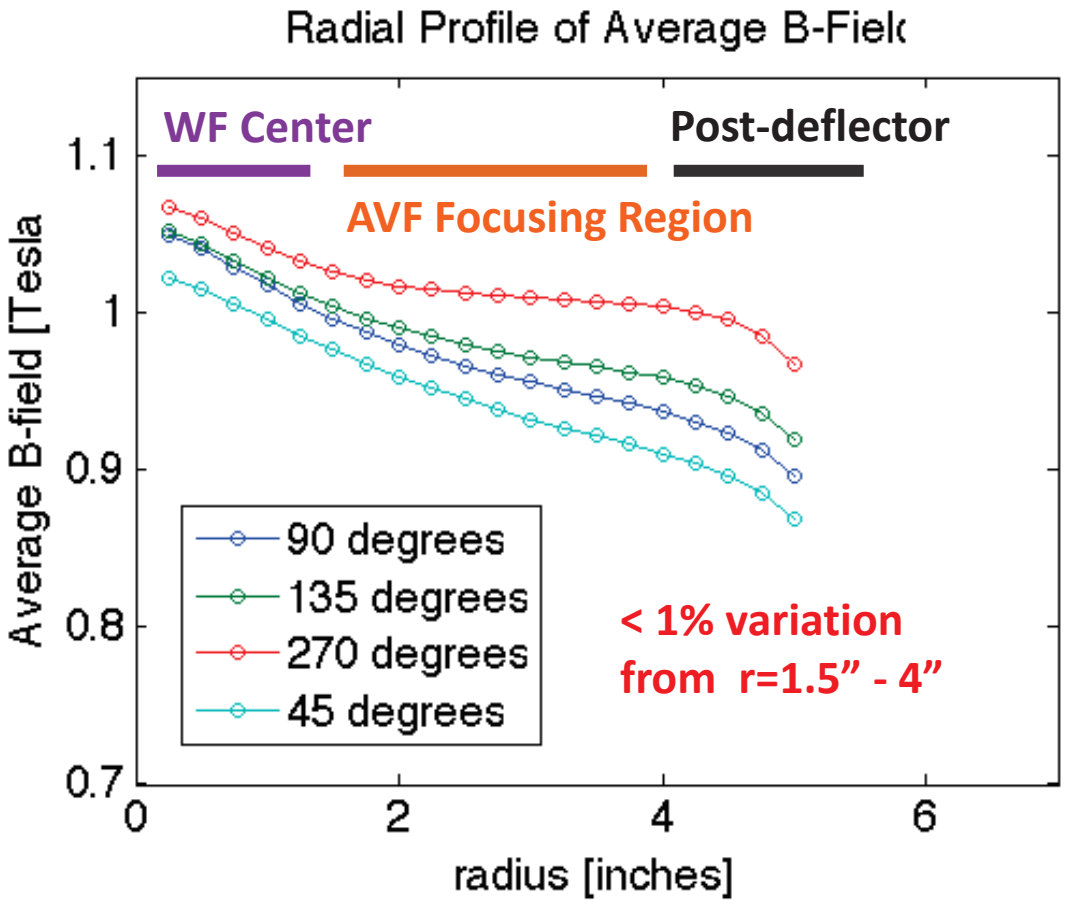
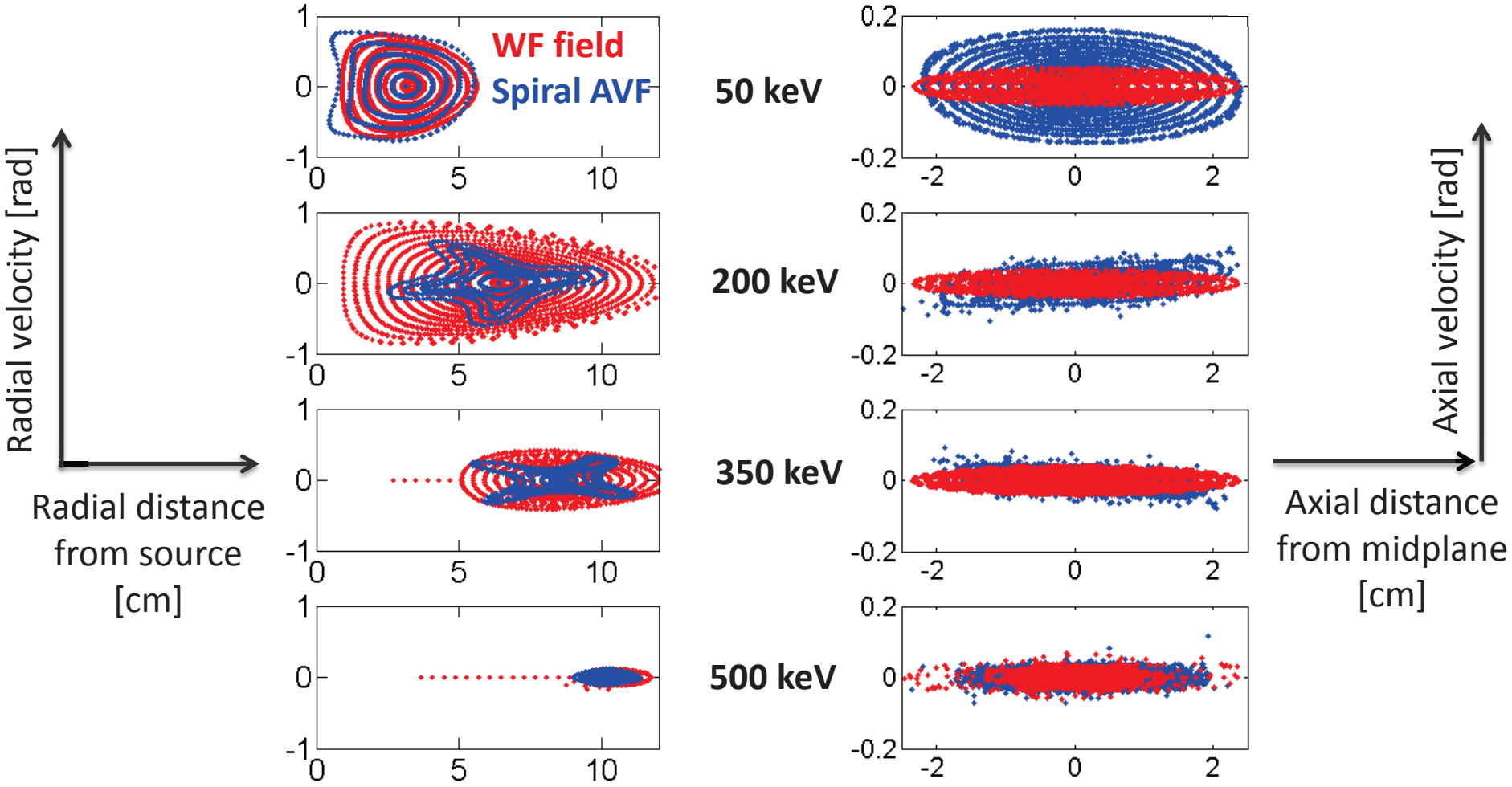




Spiral AVF: Particle Stability



Machining and Installation

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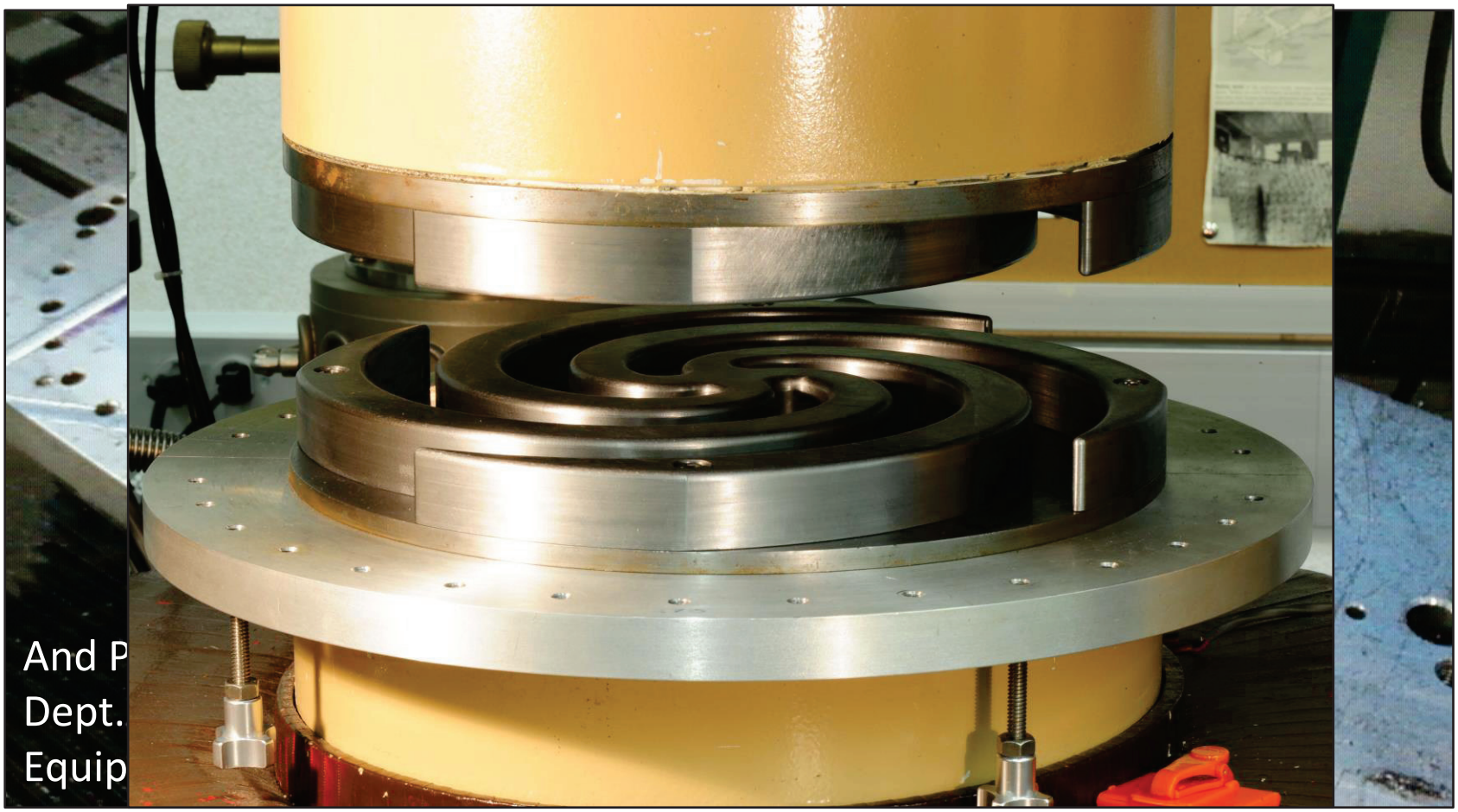

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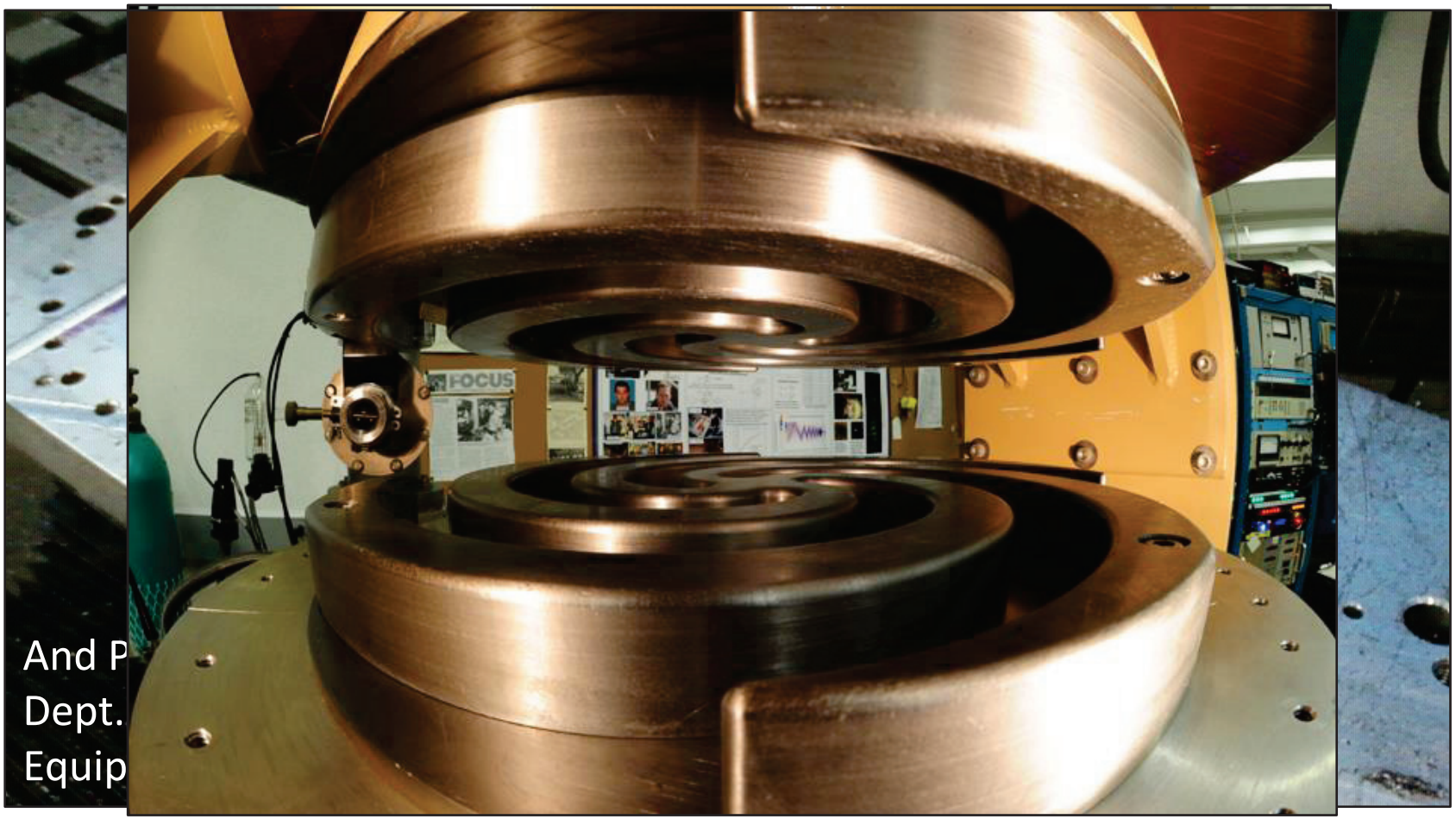
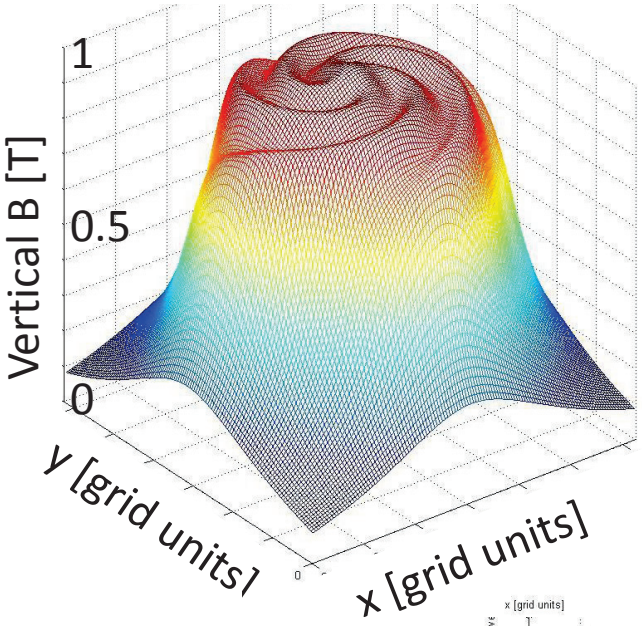


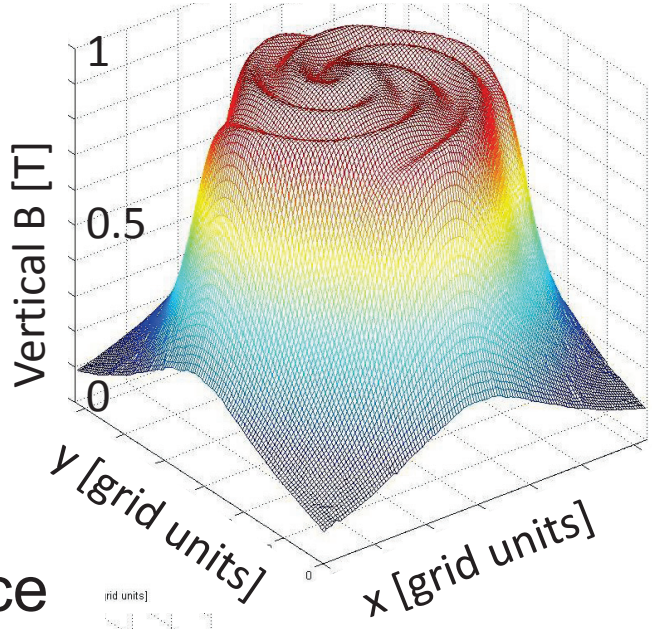
And P
Dept.
Equip

Field Comparison

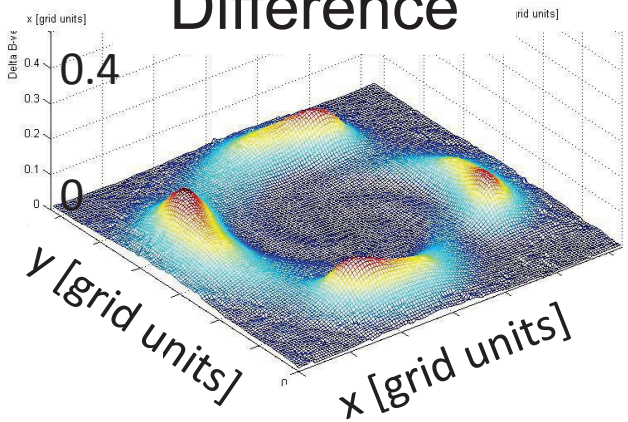
Hall Probe Measurement



Simulation

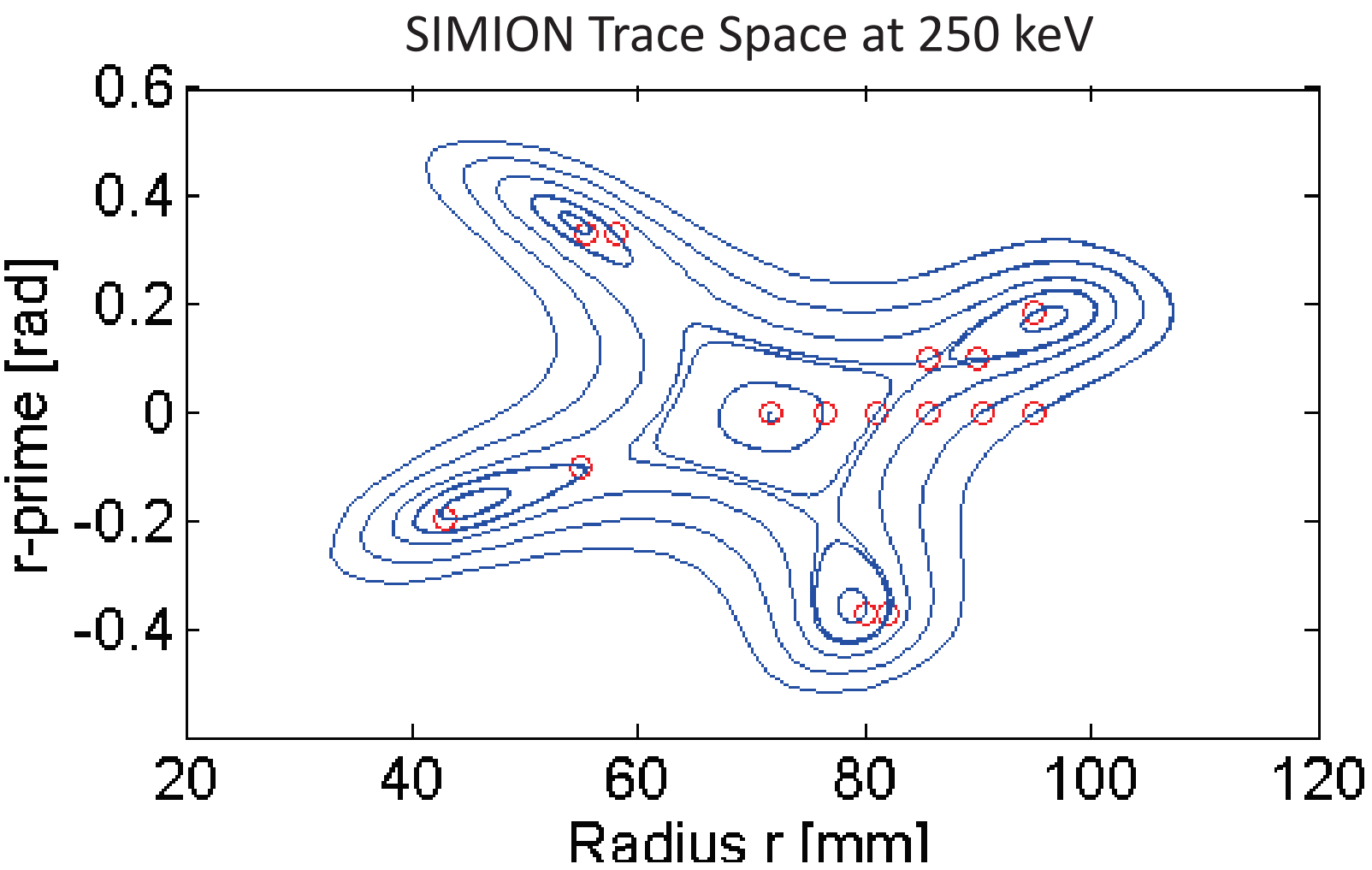


Difference

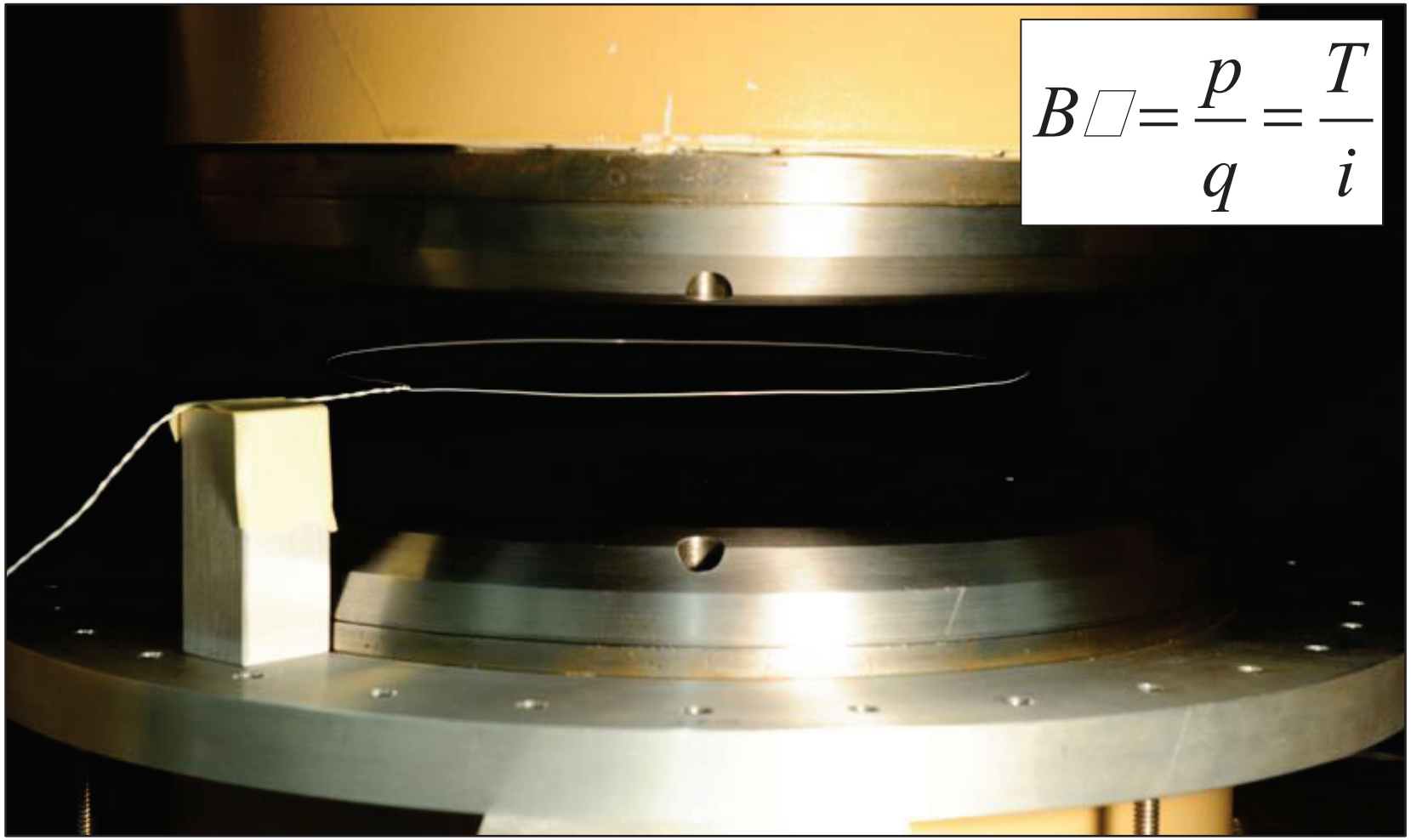


Max. 14% variation
<1% variation in r<5”

SIMION Predicts Many Stable Orbits!



Wire Loop Experiment



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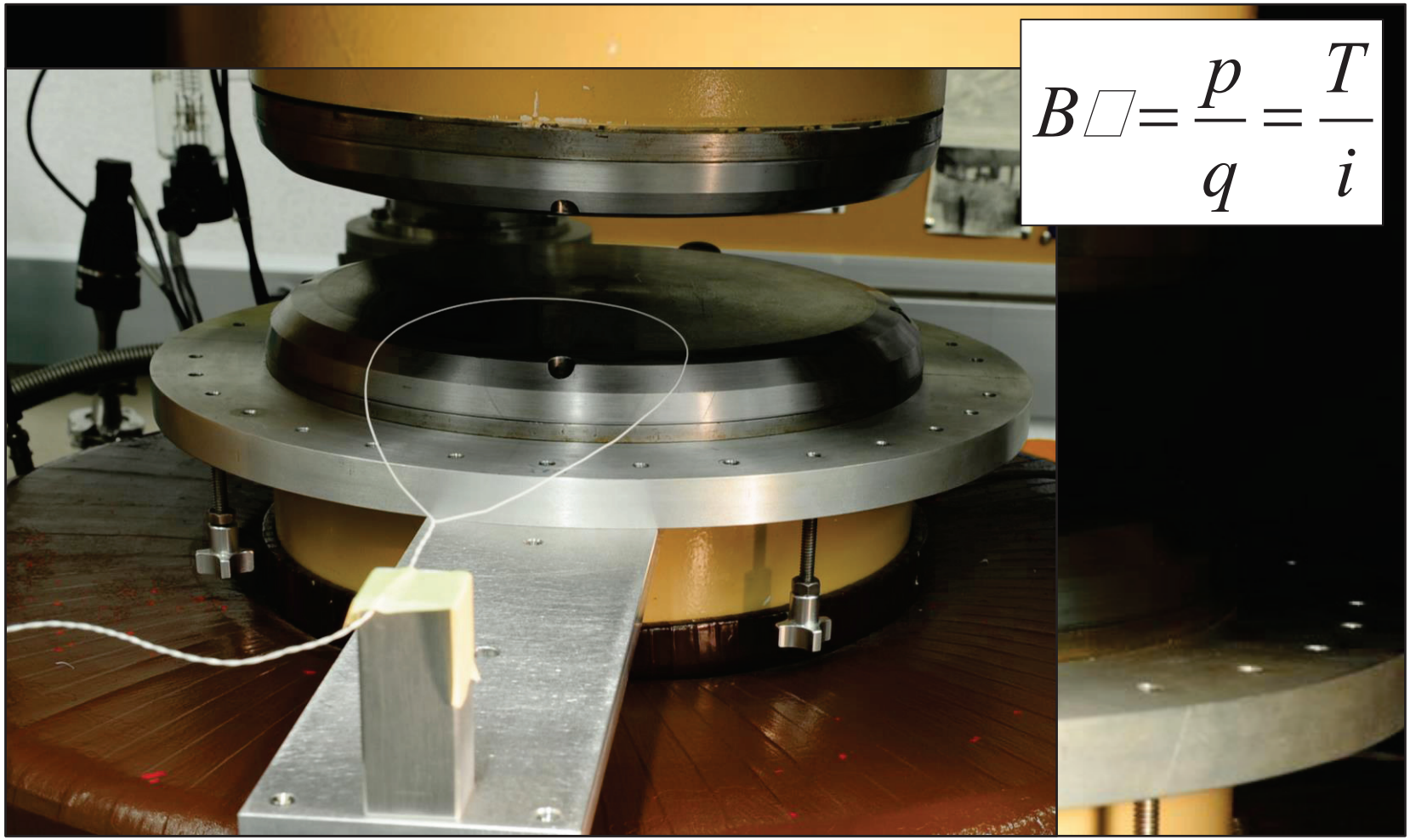

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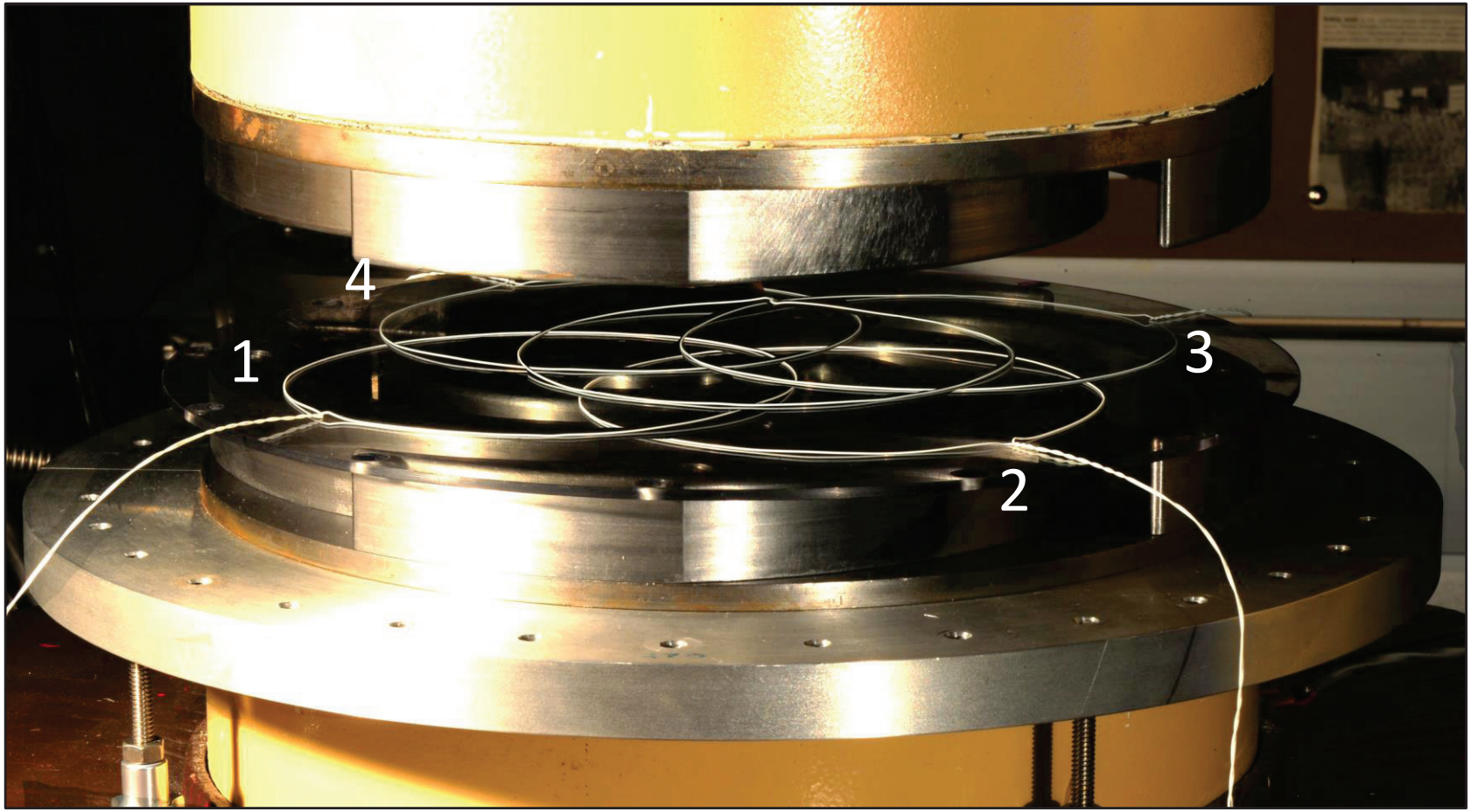
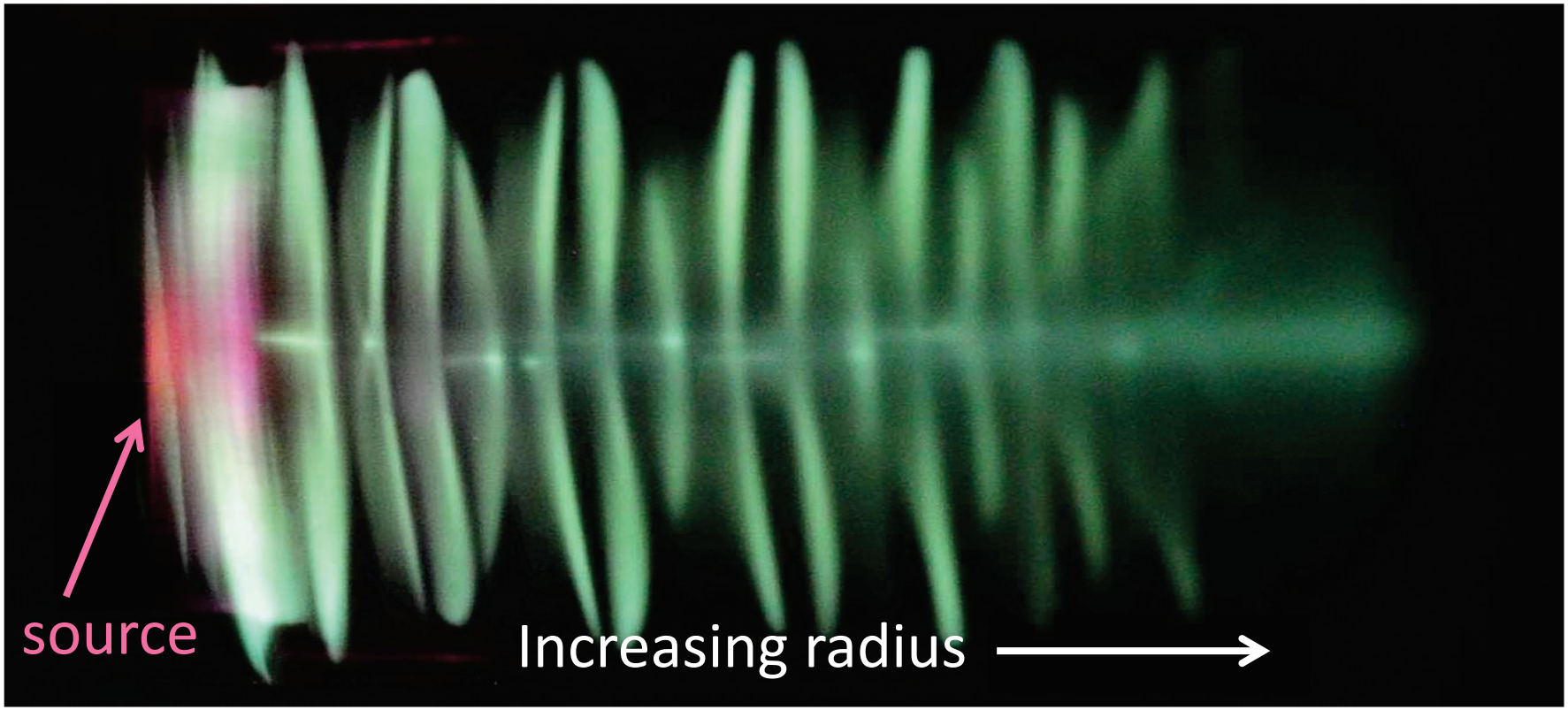
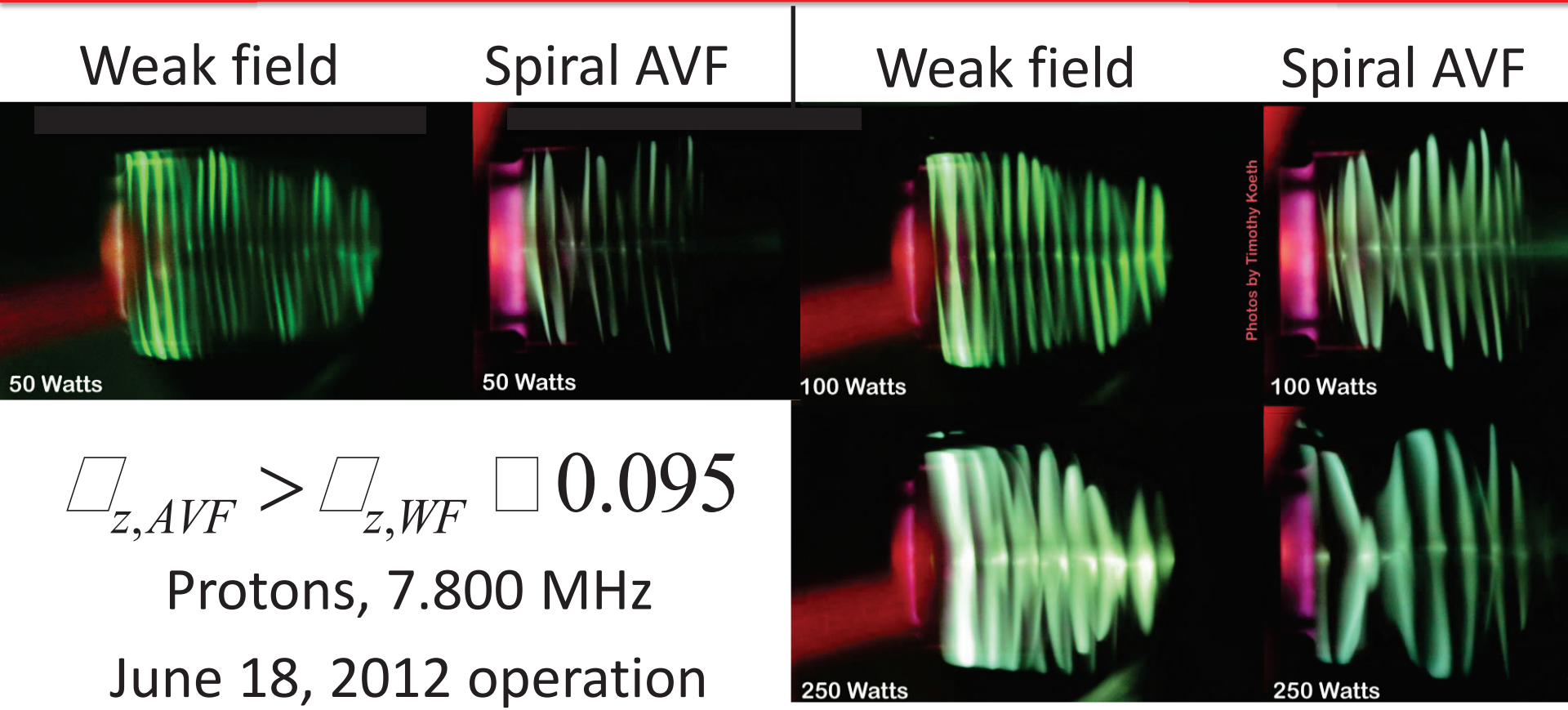


Spiral AVF Performance



$$\square_{z,AVF} \square 0.33$$

Spiral AVF Performance

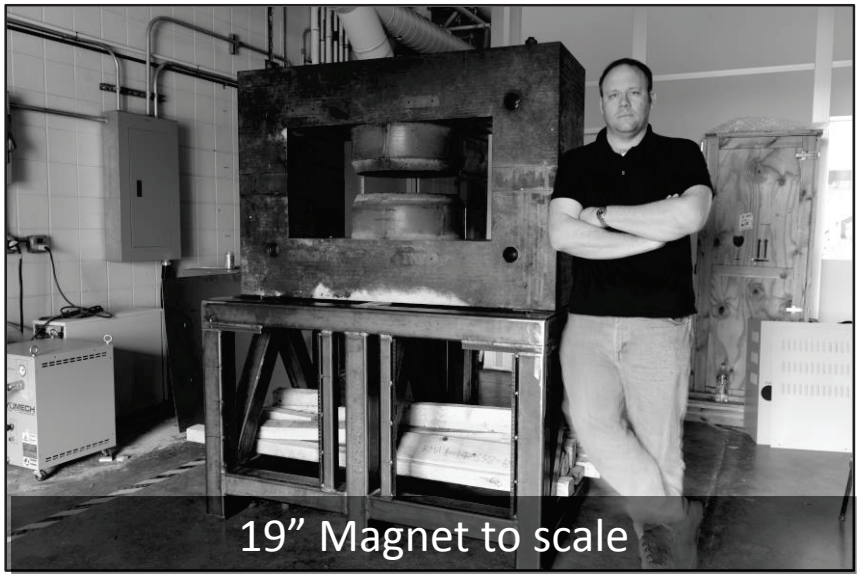


$$\square_{z,AVF} > \square_{z,WF} \square 0.095$$

Protons, 7.800 MHz

June 18, 2012 operation

Future Plans: 19-inch Magnet


19” Magnet to scale


New copper for 19” coils

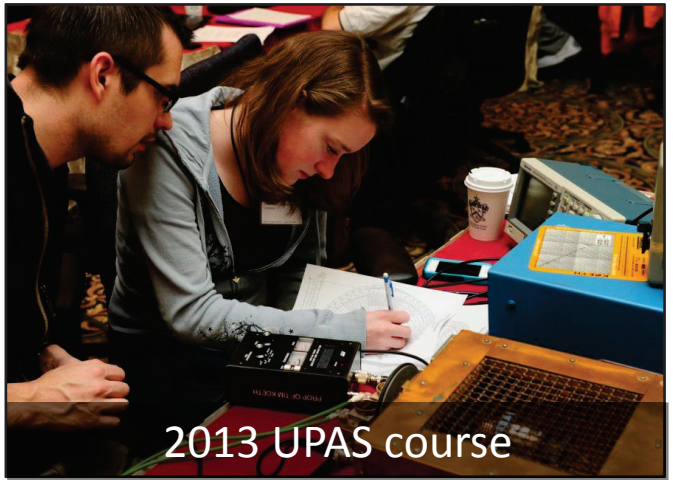
- Retired NMR exp.
- 19.5” diameter
- 1.5 Tesla
- 12,000 lbs
- We have copper!
- 160,000 Amp-turns

What we need:

- Poletips
- Chamber
- Pumping system
- RF system
- Control System

Beyond Rutgers

- 12 white papers (4 published in these proceedings)
  - www.physics.rutgers.edu/cyclotron
- Hosted QuarkNet & NJ AAPT
- USPAS courses (Jan. 2013, 2015)
  - interest in mobile cyclotron
- Guidance for “Cyclotron Kids”
- Inspired projects
  - Clemson Univ. machine
  - Visited by IIT’s Physics Chairman
  - Interest from UMD Physics in 19” magnet
- cyclotrons.net forum


2013 UPAS course

QuarkNet students and teachers

Launching Accelerator Careers

6.5 out of 18 students are pursing accelerator physics!

2011: George, Kiersten, Aaron & the Tims

- **Heidi Baumgartner (WE1PB05)**
  - MIT physics, class of 2014
  - DESY Summer internship (2012)
- **Timothy Ponter**
  - Summer internships at UMER (2009,10)
  - IBA cyclotron engineer (2011- present)
- **George Hine**
  - UMD PhD in Laser/Plasma Accelerator (2011- present)
- **Kiersten Ruisard (this talk)**
  - Summer IREAP fellowship (2011)
  - UMD PhD in Accelerator Physics @ UMER (2012-present)
- **Jason Osheroff**
  - Post-grad work at UMER (2012-13)
  - UMD PhD in Chemical Physics (2013-present)
- **Mehpare Atay**
  - DESY Summer internship (2013)

Conclusions

- The RU cyclotron is a unique machine that introduces many students to accelerator physics
- Spring 2011 AVF poletip project was successful
  - Delivered AVF tips that transport beam to deflector
  - AVF tips are “stronger” than WF in central region
  - We could understand it better. Needs more work!
- 19” machine coming soon…
- RU cyclotron influence stretches far beyond home university

Thank you!

- The Rutgers Cyclotroneers for their time and expertise!
- Bill Schneider and RU machine shop for taking on the AVF tips
- RU physics dept. donor-funded Instructional Equipment Fund