The Rutgers cyclotron: putting student’s careers on target

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• 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
• 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

• [Link: www.physics.rutgers.edu/cyclotron]
$n = \frac{r \ dB}{B \ dr}$  
Field index

$\frac{a}{z} = \sqrt{n}$  
Vertical tune

Weak focusing field diagram
Weak Focusing Pole Tips

Weak focusing field diagram

An RU Weak Focusing Pole Tip

Thank you Carolyn and Liam! (Student project 2002)

Field index

Vertical tune

See poster WEPPT025 for demonstration of WF resonances.
Could not transport ions to deflector!

\[ \frac{2}{z} = k + F \]  
(k is average field index,  
F is flutter)
Could not transport ions to deflector!

\[ \frac{2}{z} = k + F \]  
(k is average field index,  
F is flutter)
\( \frac{2}{z} = k + F \) (k is average field index, F is flutter)

Could not transport ions to deflector!
• **Goal:** Design and commission AVF focusing pole tips to bring beam to chamber periphery.

• **Motivation:** Achieve stronger focusing than in WF field \( z_{AVF} > z_{WF} \) by incorporating edge focusing:

\[
\frac{z^2}{k} = k + F(1 + 2 \tan^2 \theta)
\]

Image from Livingood’s “Cyclic Particle Accelerators”
Many different pole tips were modeled...

14 in total!

**Metrics:**
- Radial Profile
- Flutter
- SIMION simulations:
  - Stable region
  - Transport with RF
Archimedean Spiral AVF

270° spiral

90° spiral

Flutter as a function of radius

- 90 degrees
- 135 degrees
- 270 degrees
- 45 degrees

Flutter

radius (inches)
Archimedean Spiral AVF

270° spiral

90° spiral

Radial Profile of Average B-Field

- WF Center
- Post-deflector
- AVF Focusing Region

< 1% variation from r=1.5” - 4”

Average B-field [Tesla]

radius [inches]
Spiral AVF: Particle Stability

Radial distance from source [cm]

Radial velocity [rad]

Axial distance from midplane [cm]

Axial velocity [rad]
Thank you, Rutgers Machine Shop!

And Physics Dept. Instructional Equipment Fund!
Machining and Installation

And P
Dept. Equip

Rutgers
Machining and Installation

And Physics Dept. Instructional Equipment
Field Comparison

Hall Probe Measurement

Simulation

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

11/21
SIMION Predicts Many Stable Orbits!
Wire Loop Experiment

\[ B = \frac{p}{q} = \frac{T}{i} \]
Wire Loop Experiment

\[ B = \frac{p}{q} = \frac{T}{i} \]
Many Stable Orbits!
Spiral AVF Performance

Increasing radius

\[
\begin{align*}
\mathcal{F}_{z, AVF} & = 0.33
\end{align*}
\]
\[ z_{AVF} > z_{WF} \geq 0.095 \]

Protons, 7.800 MHz

June 18, 2012 operation
What we need:

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

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
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
6.5 out of 18 students are pursuing accelerator physics!

• **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)
• 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