UMER : The University of Maryland Electron Storage Ring

Rami A. Kishek
on behalf of UMER collaboration

Institute for Research in
Electronics & Applied Physics
University of Maryland, College Park, MD

Research sponsored by US Department of Energy

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We Thank:

University of Maryland Electron Ring (UMER) **Team:**

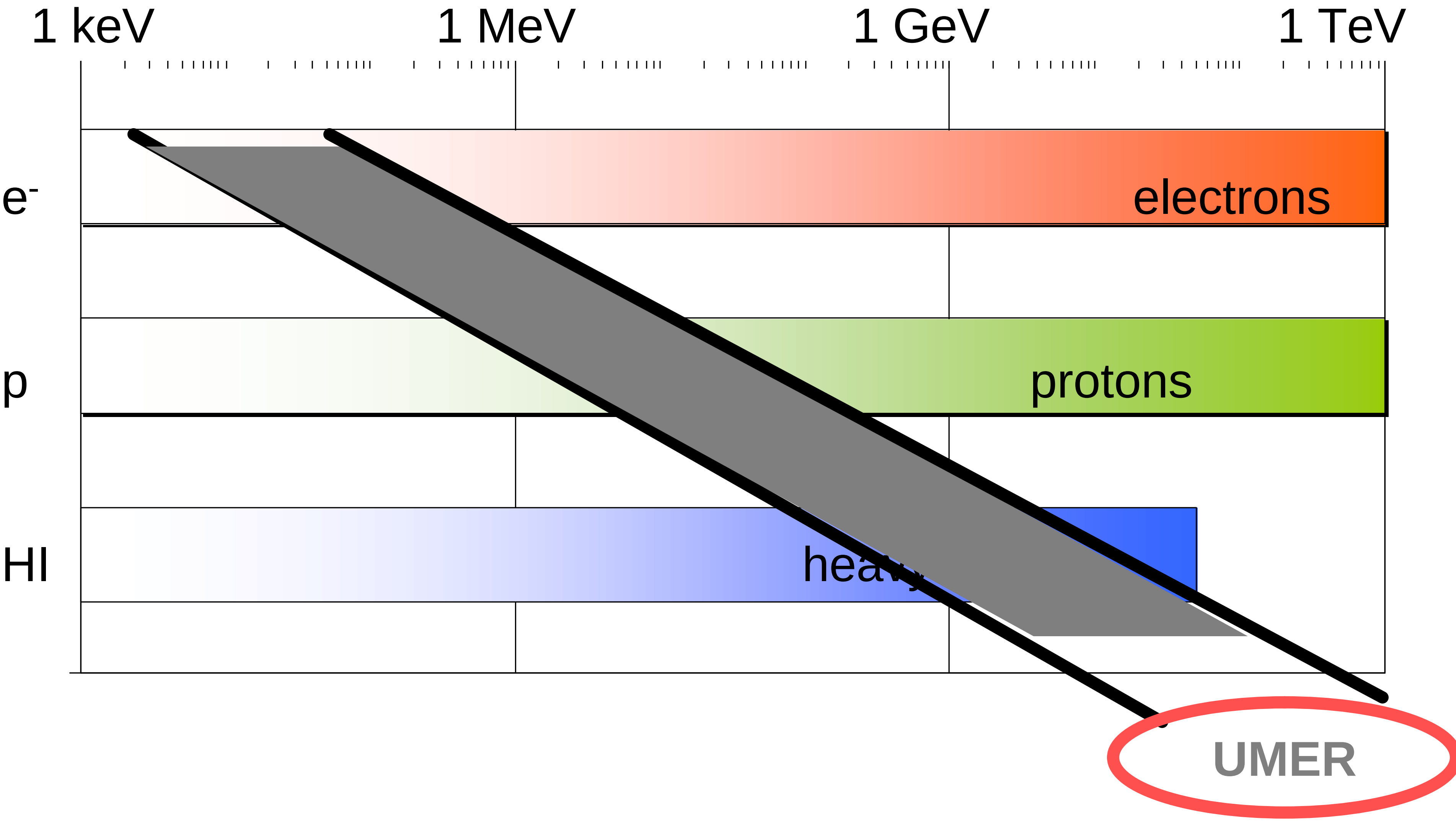
	Junior Scientists:	Graduate:	Former:
Patrick O'Shea Martin Reiser Irving Haber Rami Kishek	Santiago Bernal Mark Walter Bryan Quinn	John Harris Gang Bai Kai Tian Mike Holloway C Papadopoulos Diktys Stratakis	*Yun Zou* *Yupeng Cui* *Hui Li* *Yijie Huo*
Terry F. Godlove Don Feldman Renee Feldman			Charles Tobin

Virtual National Lab for Heavy Ion Fusion (also provided WARP)	Alex Friedman Dave Grote Jean-Luc Vay John Barnard	Peter Seidel Christine Celata Steve Lund Simon Yu	**PPPL** Ron Davidson Hong Qin Eric Gilson
NIU	Court Bohn	Ioannis Sideris	
Others **IREAP**	Ingo Hoffman Tom Wangler		

Outline

1. The University of Maryland Electron Ring: Why and What?
2. UMER Design
3. Transverse Physics and Control
4. Longitudinal Physics
5. Summary

Why electrons? Scaling Laws



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Common Beam Dynamics Challenges

Transverse:

- Errors & Control
- Halo Formation & Beam Losses
- Emittance Growth
- Instabilities
- Resonances

Longitudinal:

- Energy Spread
- Transverse-Longitudinal Coupling
- Compression
- Instabilities

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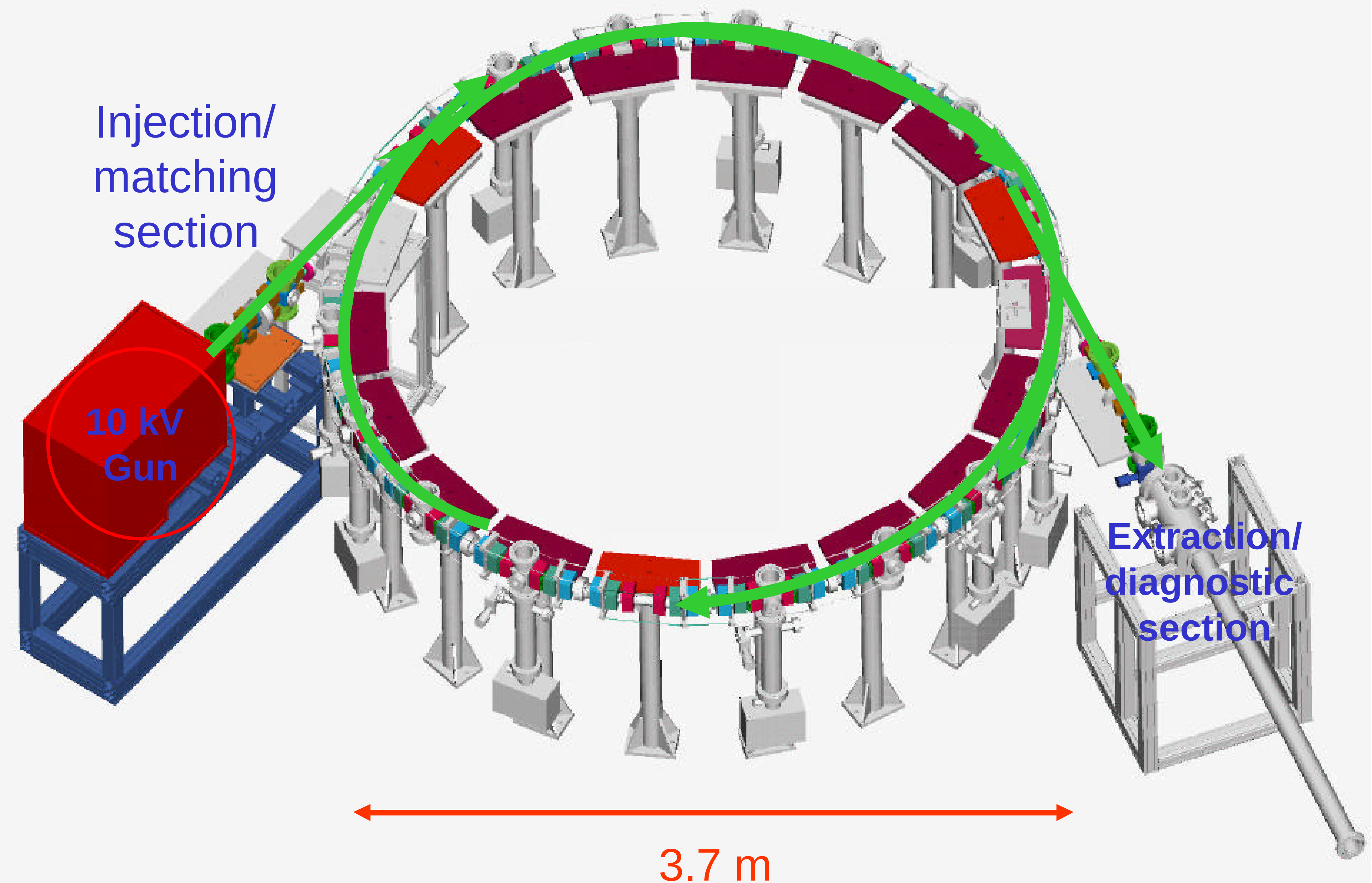
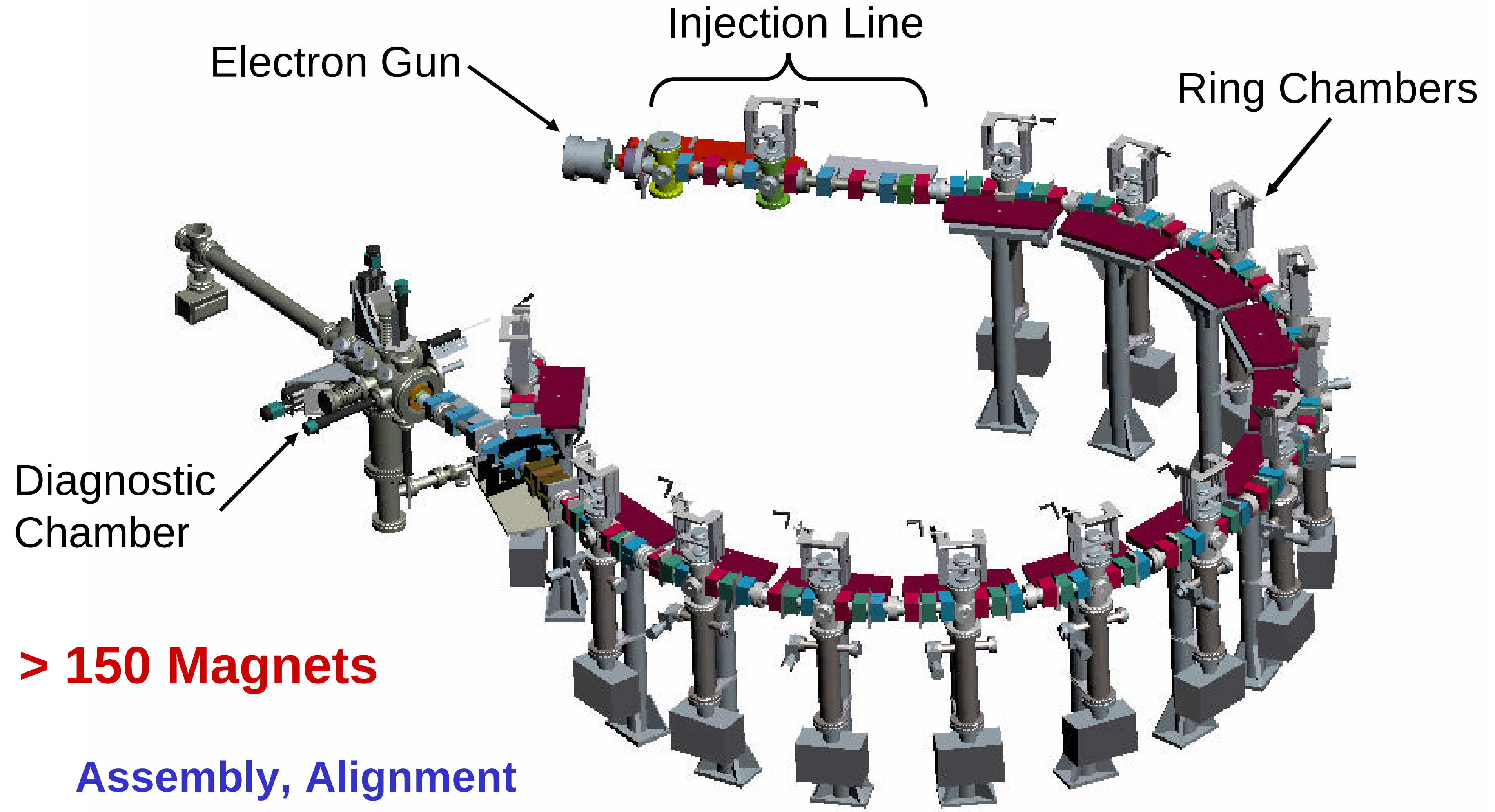
UMER Schematic



UMER is a Complex Machine



> 150 Magnets

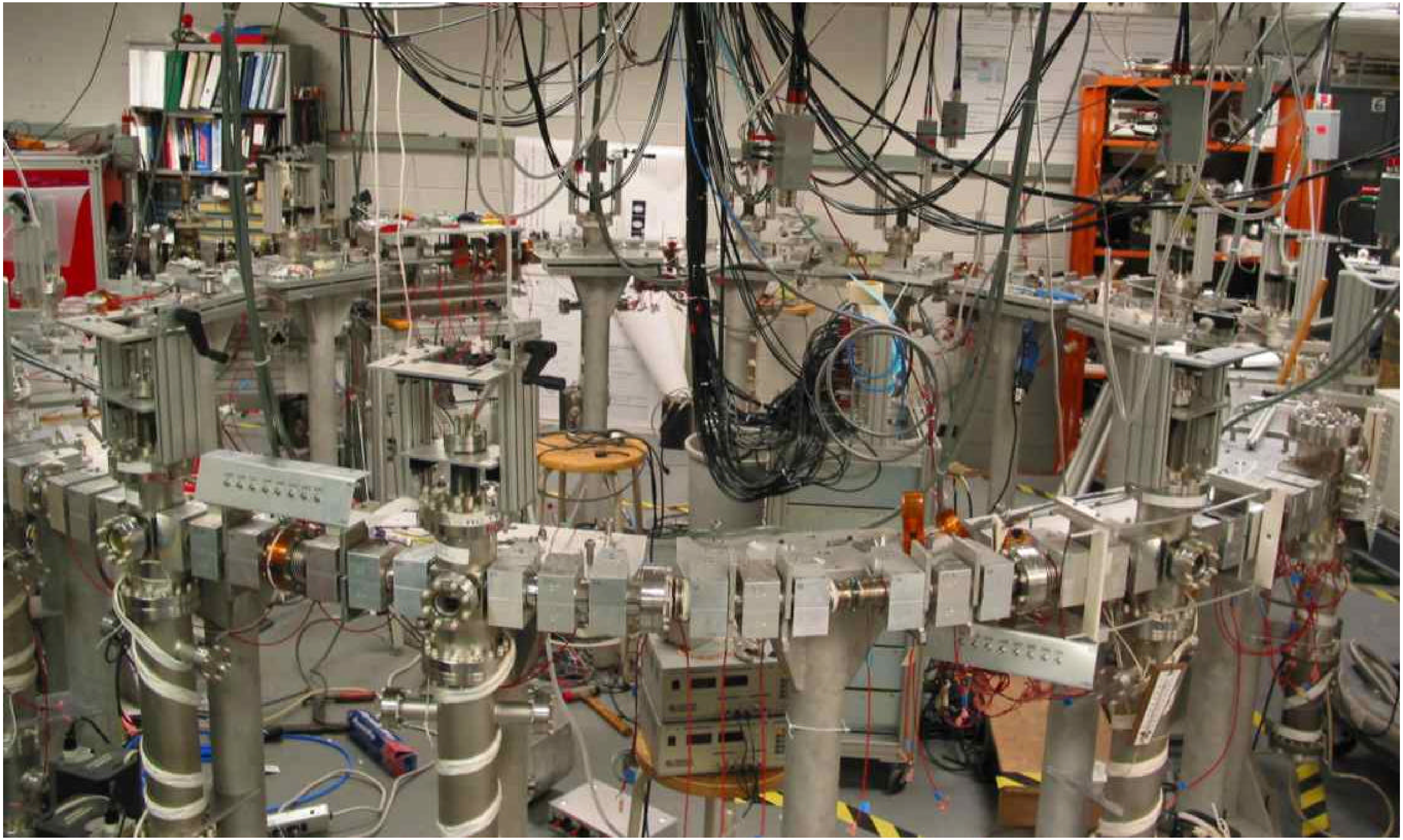
Assembly, Alignment

Power Supplies, Wiring

Diagnostics

Beam Control

UMER as of Aug. 2004



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Review of UMER Design

UMER Beams

Energy	10 keV
Energy Spread	20 eV
Current Range	0.6-100 mA
rms Emittance $_n$ Range	0.2-3 µm

Non-Relativistic:

- Negligible radiation, below transition, etc.
- Earth field important!

Low Energy Spread

Current and Emittance Adjustable:

- using apertures in the gun (large jumps)
- by varying the gun grid voltage (fine-tuning)

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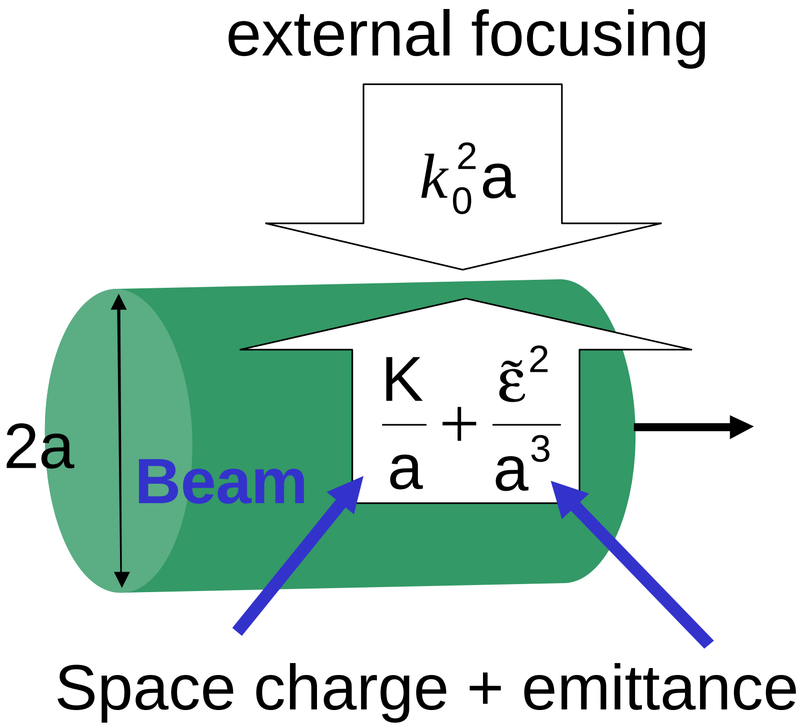
Dimensionless Space Charge Intensity

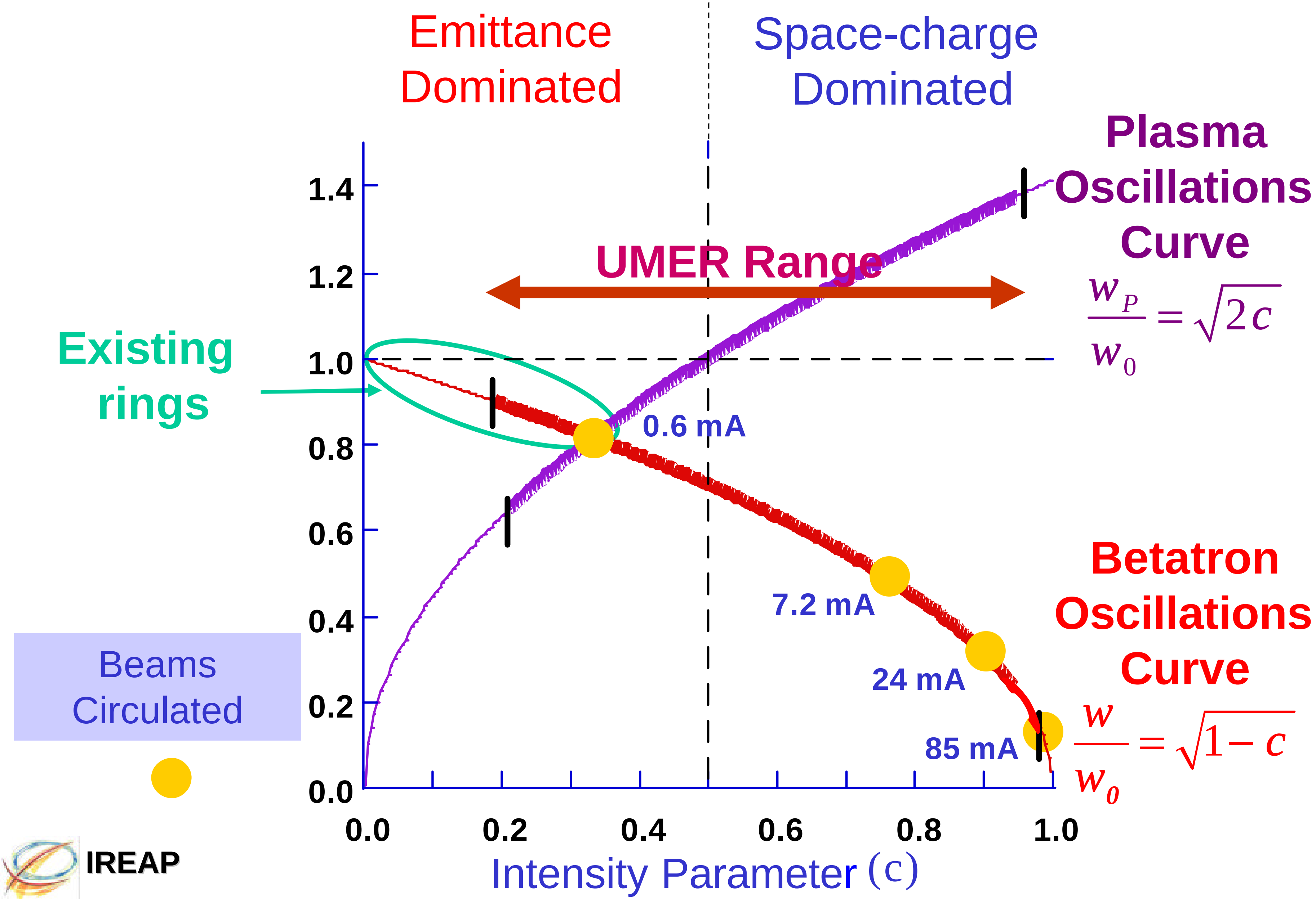
Intensity Parameter:

$$\boxed{c \equiv \frac{K}{k_o^2 a^2} = \frac{\text{space charge force}}{\text{external focusing force}}}$$

0 £ c £ **1**



Present UMER Operating Points



$$\frac{w_P}{w_0} = \sqrt{2c}$$

$$\frac{w}{w_0} = \sqrt{1-c}$$

Beams Circulated ●

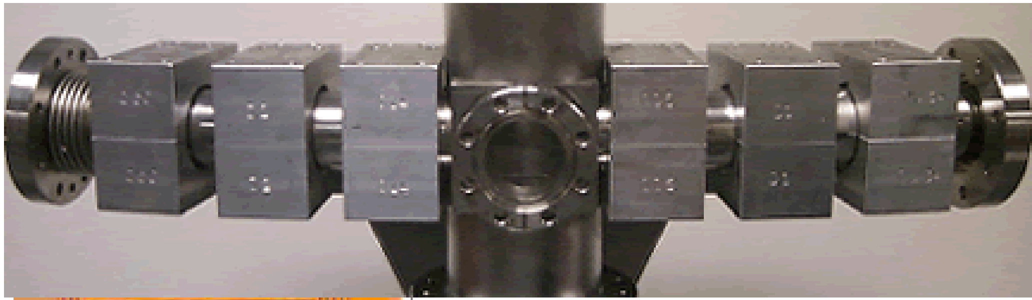
UMER Lattice Parameters

Ring Circumference	11.52 m
Ring Radius	1.83 m
Lattice Period	32 cm
Number Lattice Periods	36/turn
Zero-Current Tune	7.6
Zero-Current Tune Range	7.2-8.5
Average Beam Radius	1.4-10 mm

Tune adjustable, currently 3 operating points

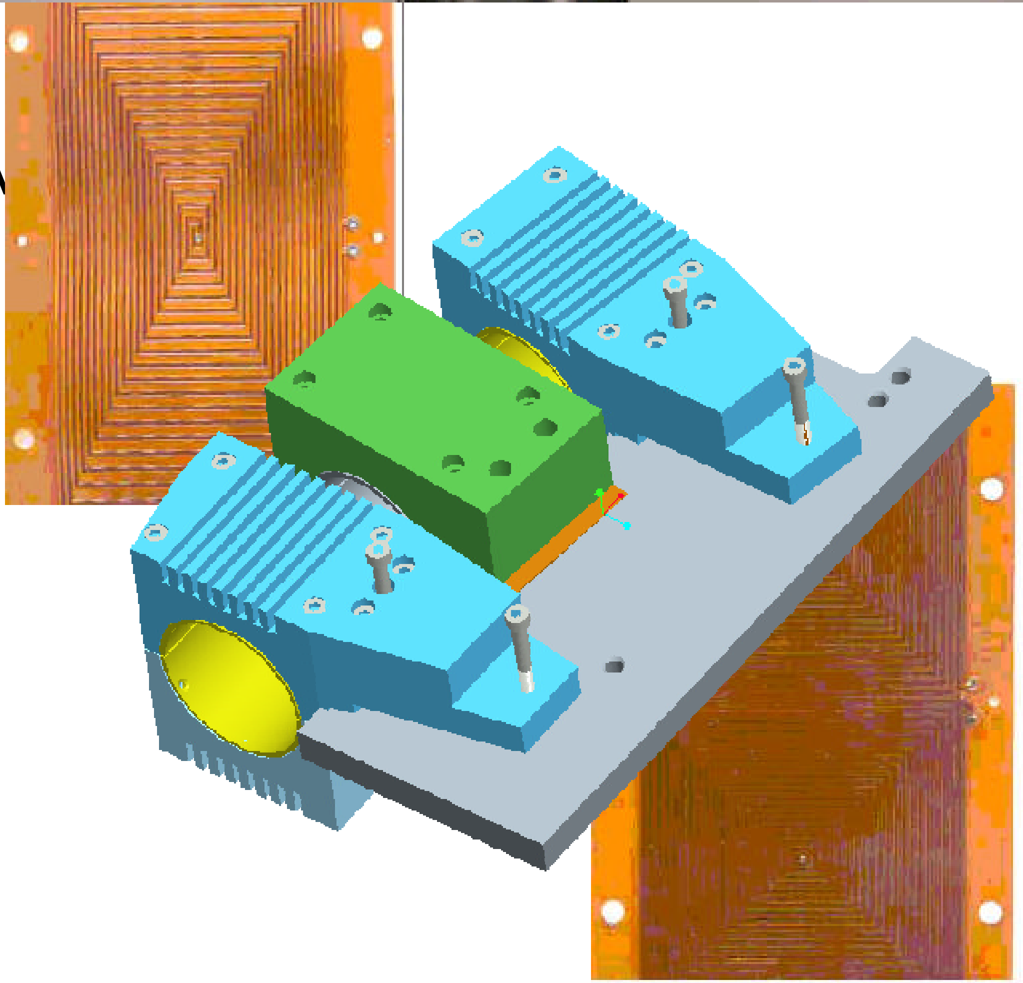
Interested also in anisotropic focusing (different tunes in x and y)

UMER Magnets & Lattice



PC Dipoles (34 X)

Dipole field	15.4 G
Current	3 A
Physical length	4.4 cm
Effective length	3.8 cm
Radius	2.8 cm
Field integral	20 G-cm/A
Resistance	3Ω



PC Quadrupoles (68x)

Field gradient	~ 8 G/cm
Current	2 A
Physical length	4.4 cm
Effective length	3.6 cm
Radius	2.8 cm
Field integral	15 G/A
Resistance	3Ω

UMER Goals

1. Maintain emittance growth $\Delta\varepsilon/\varepsilon < 4$, while:
   - At full current, without acceleration, 10 turns
   - At lower current or with acceleration, 100 turns
2. Conduct a wide range of beam dynamics experiments on UMER!

Diagnostics Presently Installed

Invasive (can only be used over first turn):

- Phosphor screen imagers:
  - Beam-intensity image, size, position, and skew angle
  - Beam emittance and transverse phase space (in combination with a quad scan and Tomographic techniques)
  - Beam emittance (in combination with quincunx mask at gun)

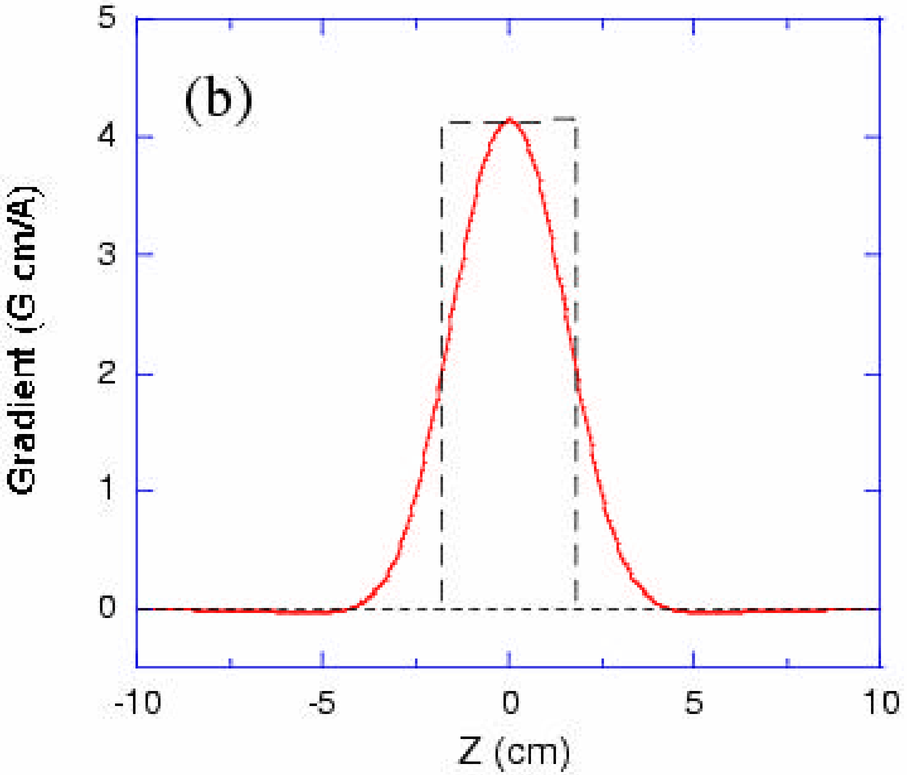
Non-Invasive (multi-turn diagnostics):

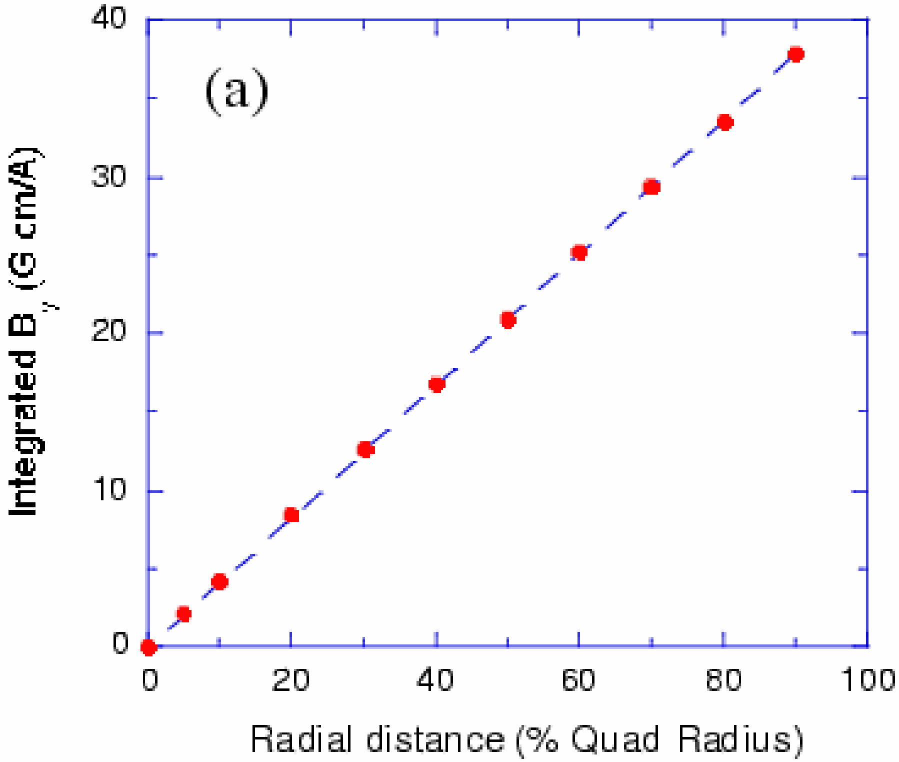
- Beam Position Monitors:
  - Beam position
  - Beam current
- Bergoz Coils (Beam Current)
- Perturbation Techniques (Line Charge)

Diagnostics to be Added

1. Energy Analyzers (invasive, can be placed in any chamber)
2. End Diagnostic Chamber (non-invasive):
   - Time resolved high-resolution Energy Analyzer
   - Slit-slit time-resolved transverse phase space mapper
   - Pepper-pot transverse-phase-space mapper
   - Current measurement devices
   - Phosphor Screen Imager

Quadrupole Linearity & Field Profile





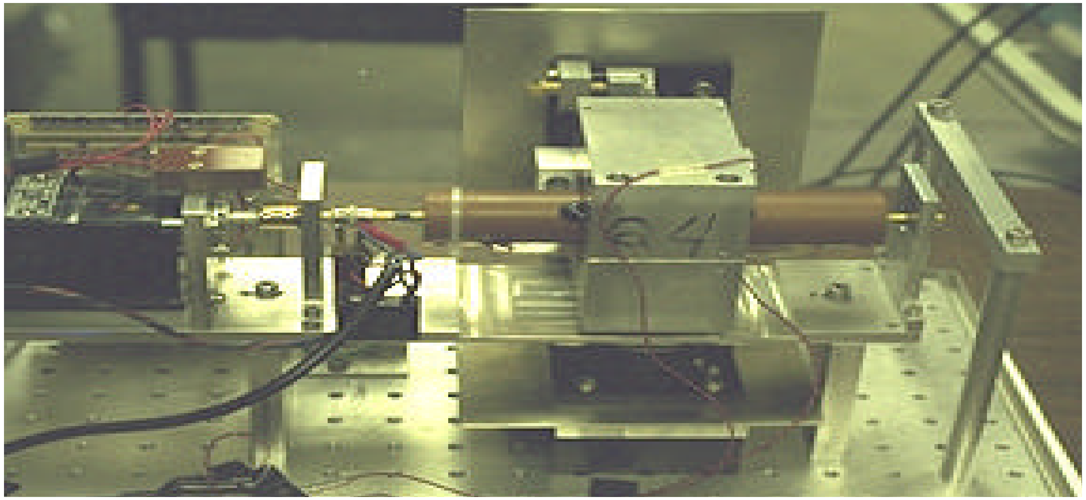
3-D field calculations:

Z-integrals used for field quality.

Constant k adjusted for best uniformity (dipole) or linearity (quad); e.g., k = 0.976 for ring dipole; deviations <0.1%

Magnet Harmonic Measurements

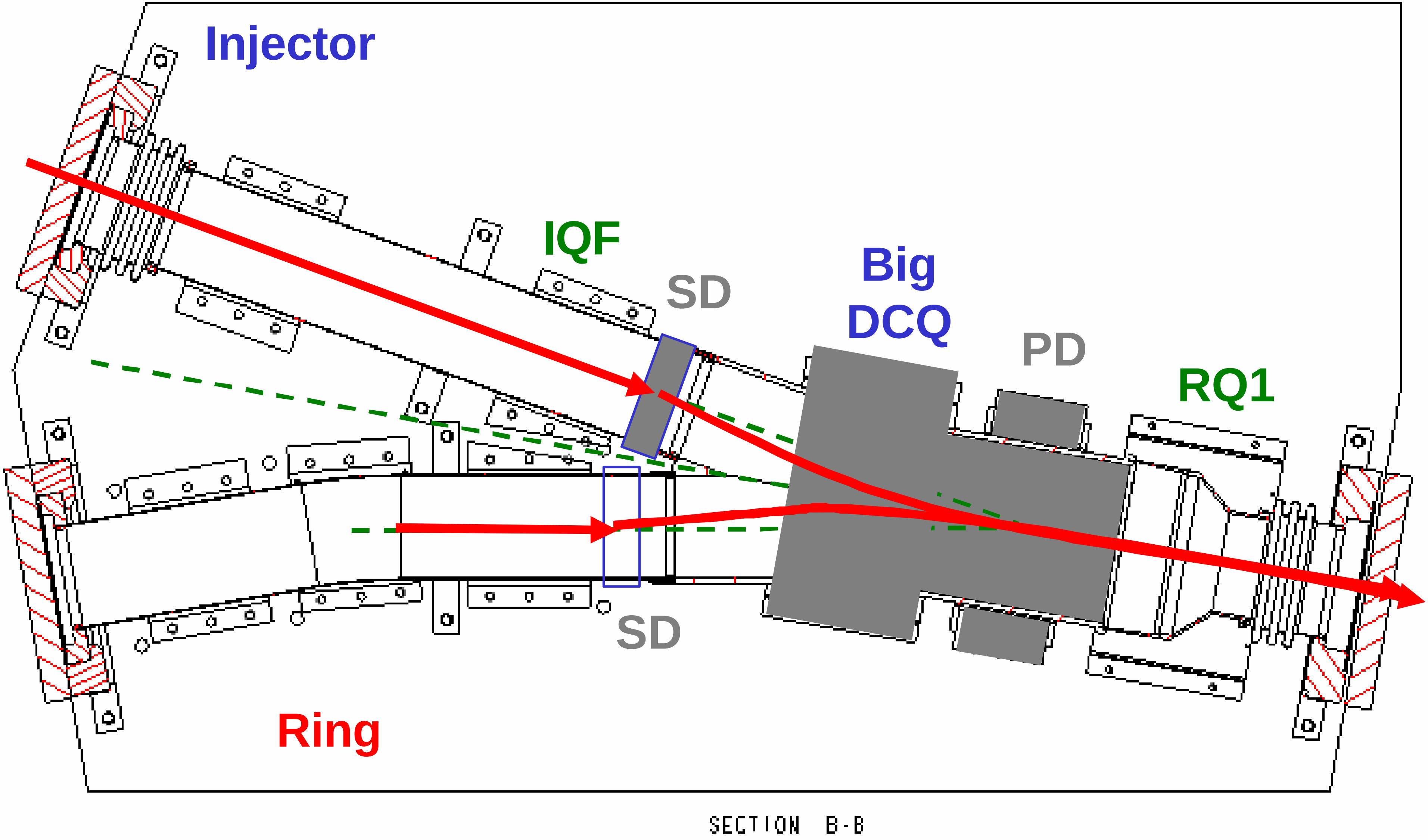
Rotating coil and pulsed wire systems



Normal Multipole Harmonics	Expected (w/ errors)	Allowed Max	Measured
Quadrupole	10^4	10^4	10^4
Sextupole	20	150	32
Octupole	68	90	53
Decapole	13	45	4.8
Duodecapole	130	22	3.2

Zhang, et al., PRST-AB, **3**, 122401 (2000).

New Injection Y in place



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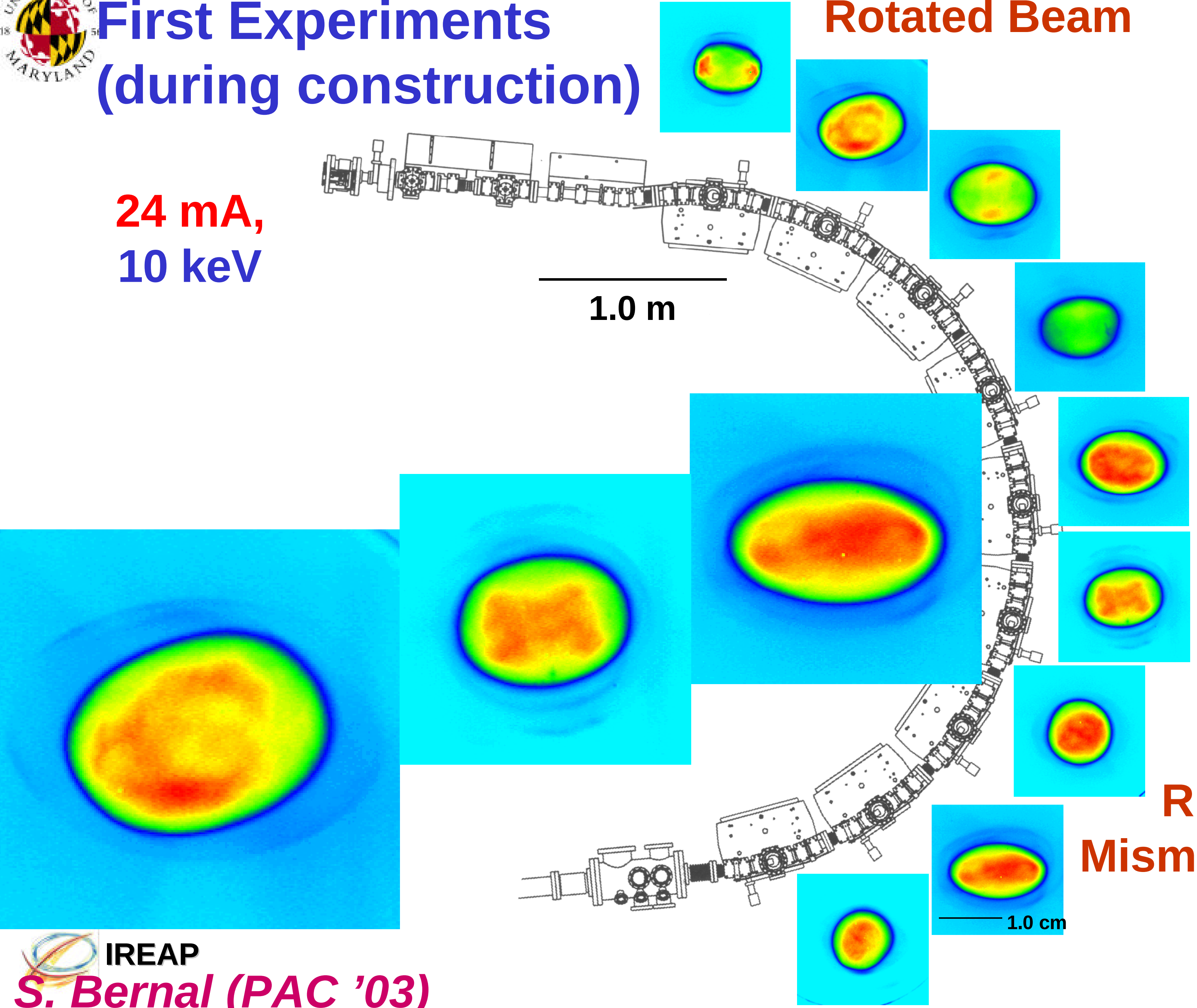
Beam Control

First Experiments (during construction)

24 mA,
10 keV



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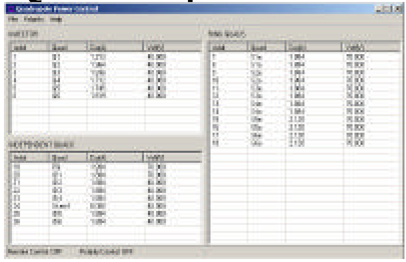
S. Bernal (PAC ’03)

Beam Control System Software

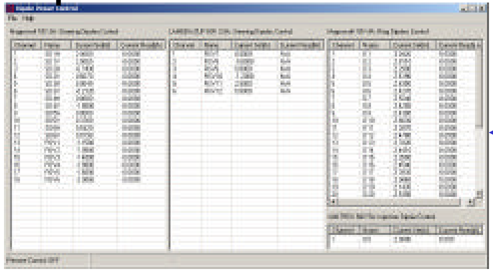
Hui Li

Quadrupoles Control



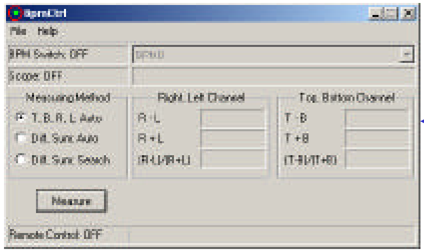
network

Dipoles Control



network

BPMs Control



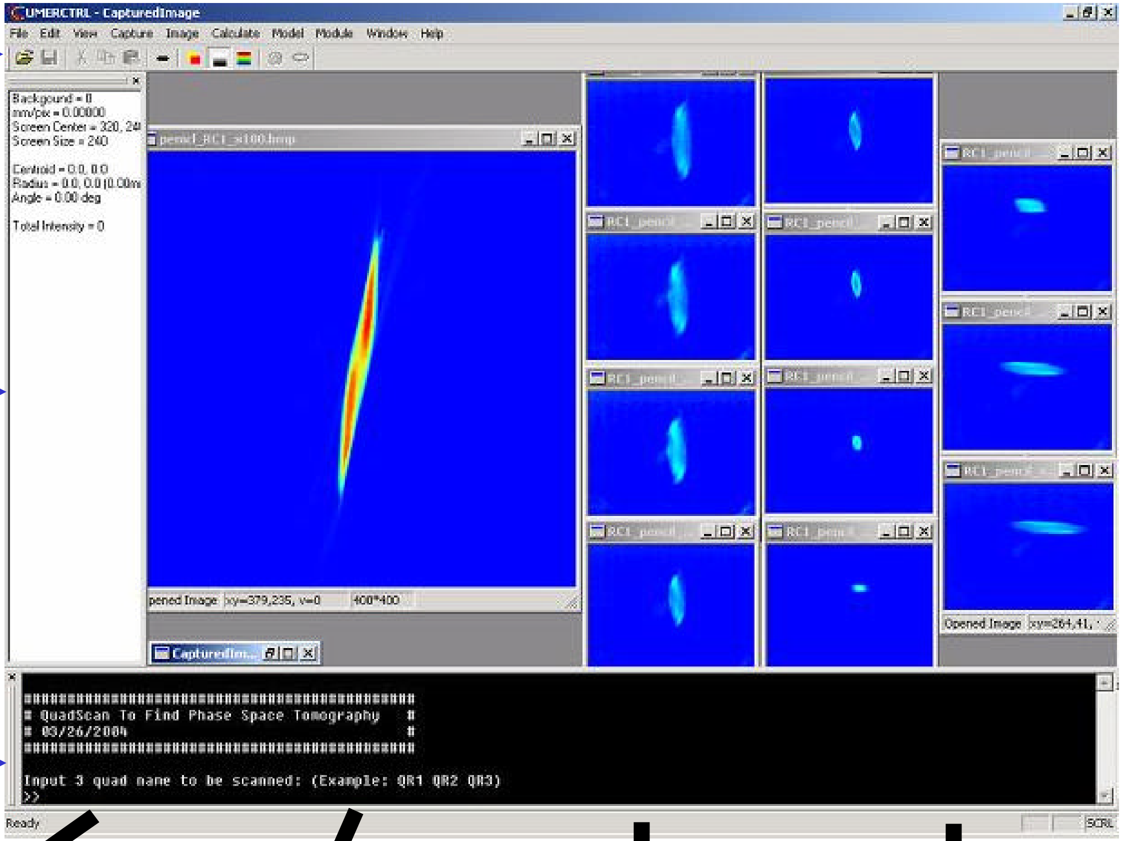
BPM Switch: OFF

Scope: OFF

Remote Control: OFF

network

Central Control Platform



Backgound = 0
mm/pix = 0.00000
Screen Center = 320, 24
Screen Size = 240

Centroid = 0.0, 0.0
Radius = 0.0, 0.0 (0.00m
Angle = 0.00 deg

Total Intensity = 0

pened Image xy=379,235, v=0 400*400

Opened Image xy=264,41,

```
##############################################
# QuadScan To Find Phase Space Tomography    #
# 03/26/2004                                 #
##############################################

Input 3 quad name to be scanned: (Example: QR1 QR2 QR3)
>>
```

Steering Module

Skew Correction Module

Matching Module

Tomography Module

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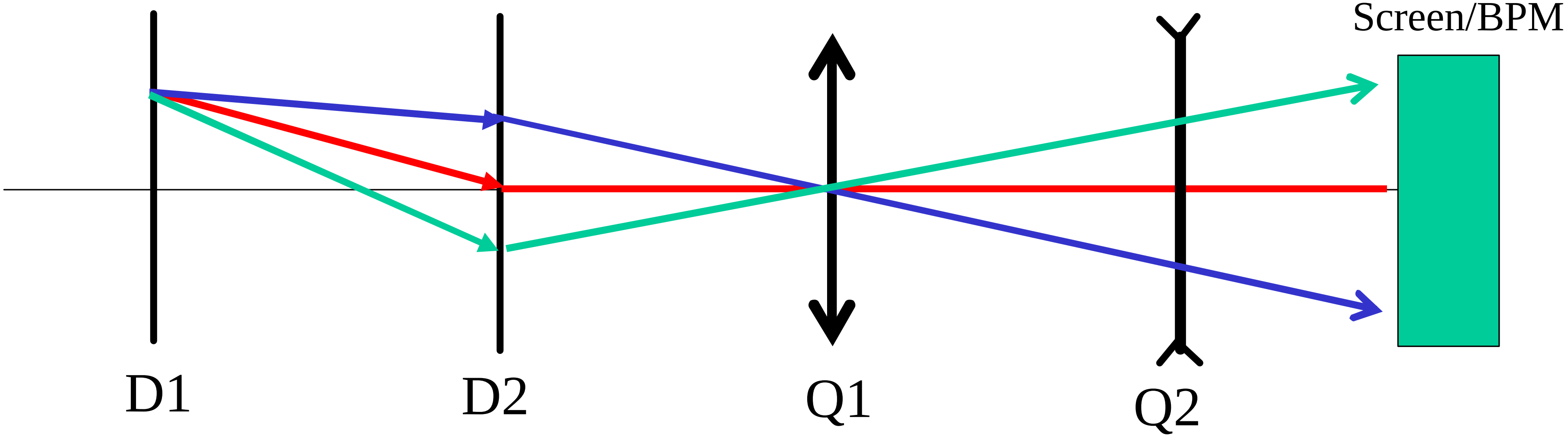
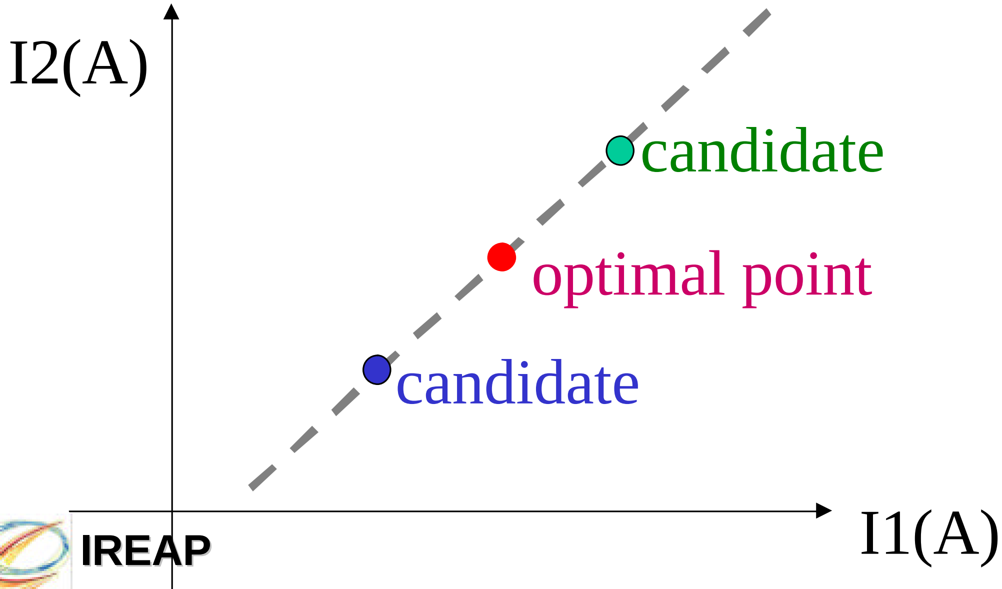
Beam Steering

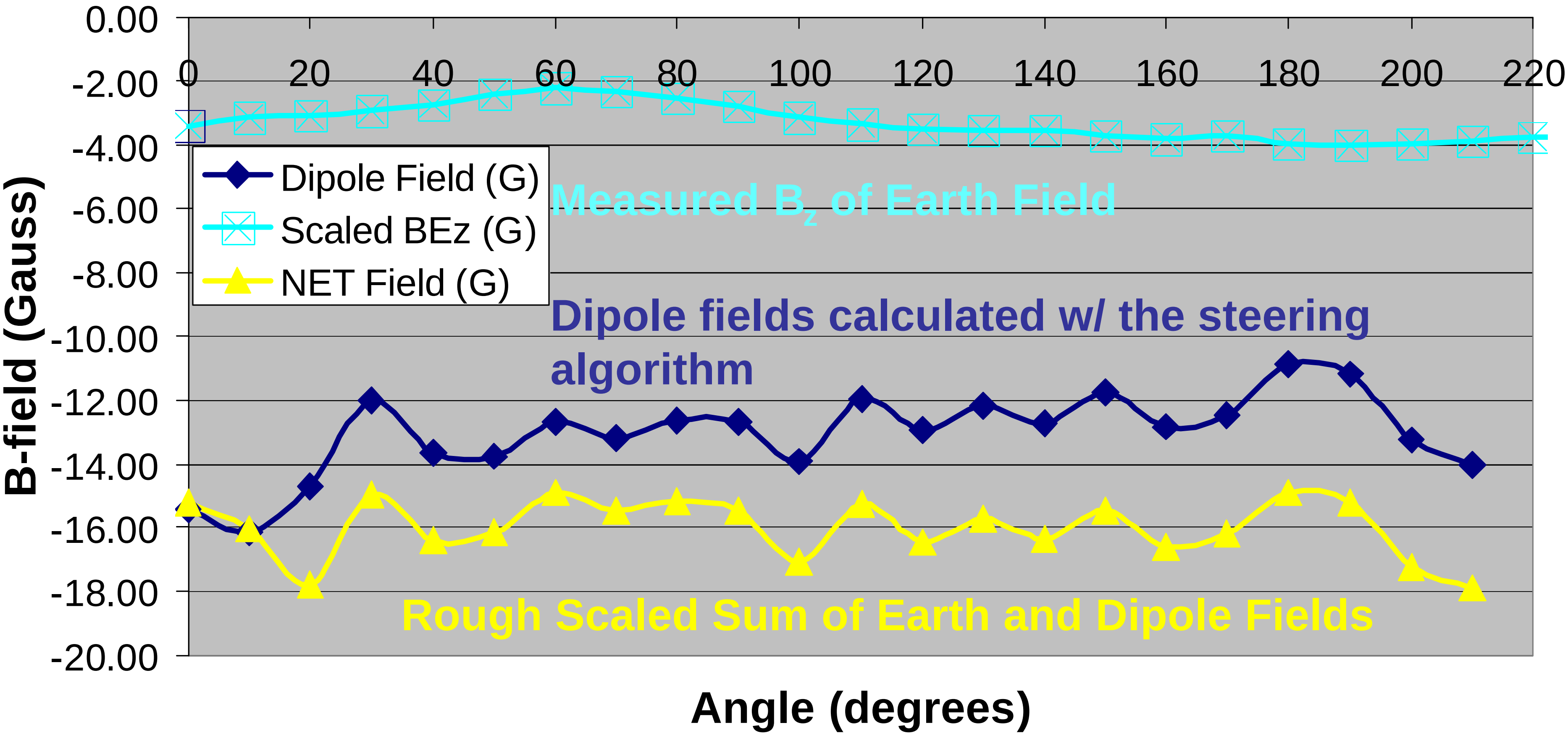




Steps:

- Scan Q1, find all rays through Q1's center
- Scan Q2, find the optimal ray

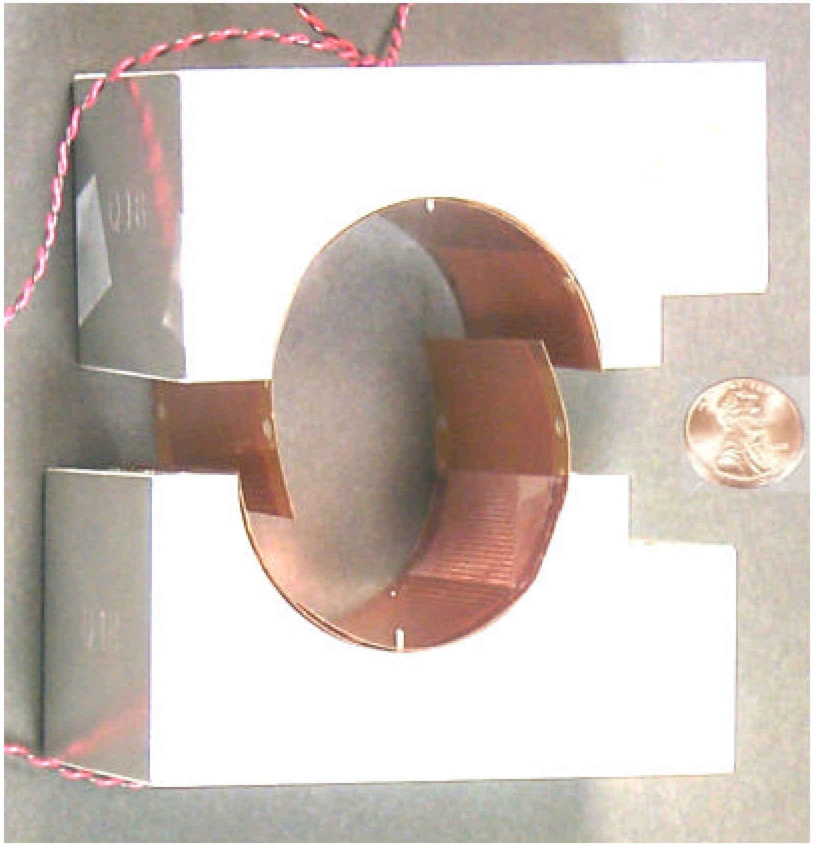
Beam Steering Results

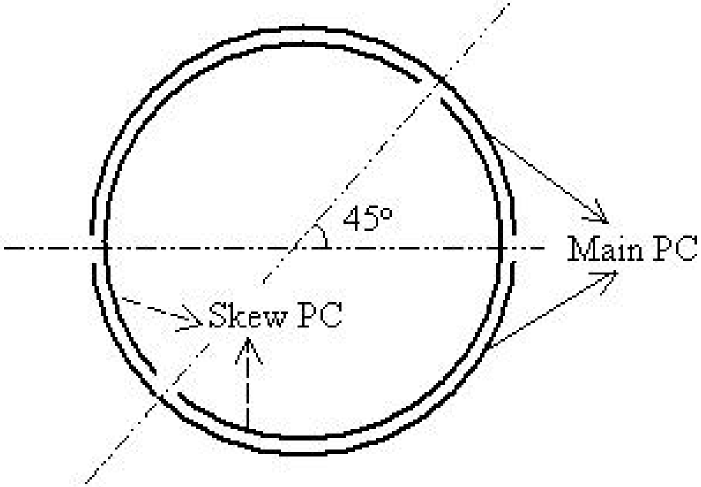


Two pilot beams (7mA, 0.6mA) have given similar results.

Beam Rotation Correction

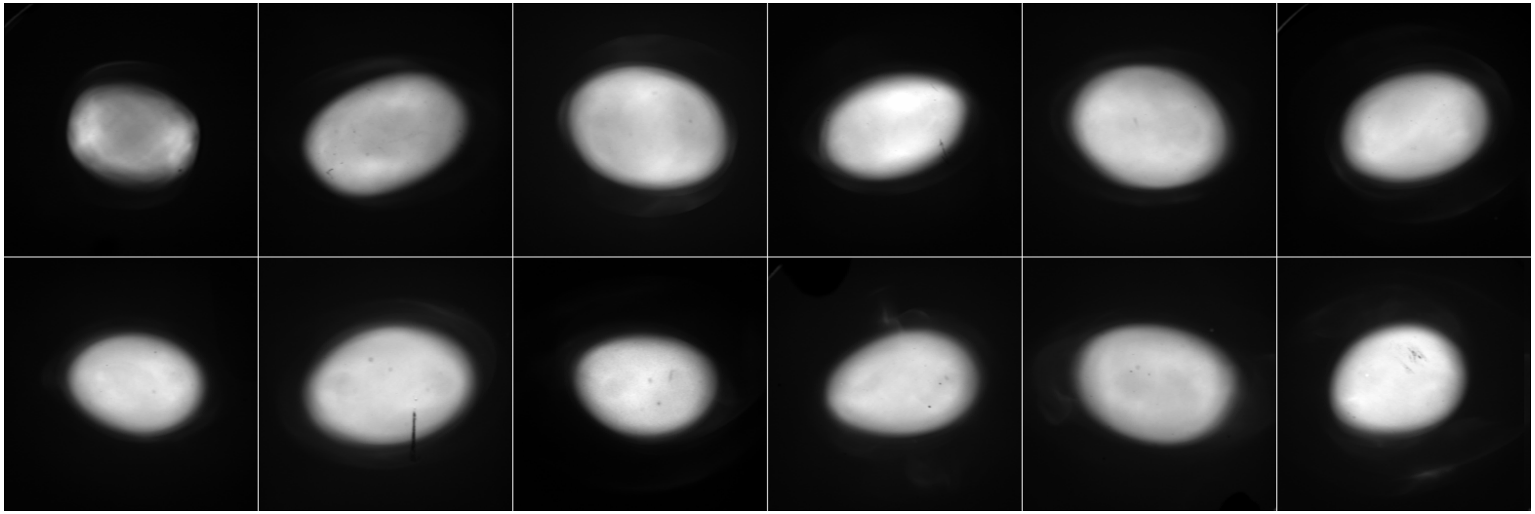
Electronic Skew Corrector



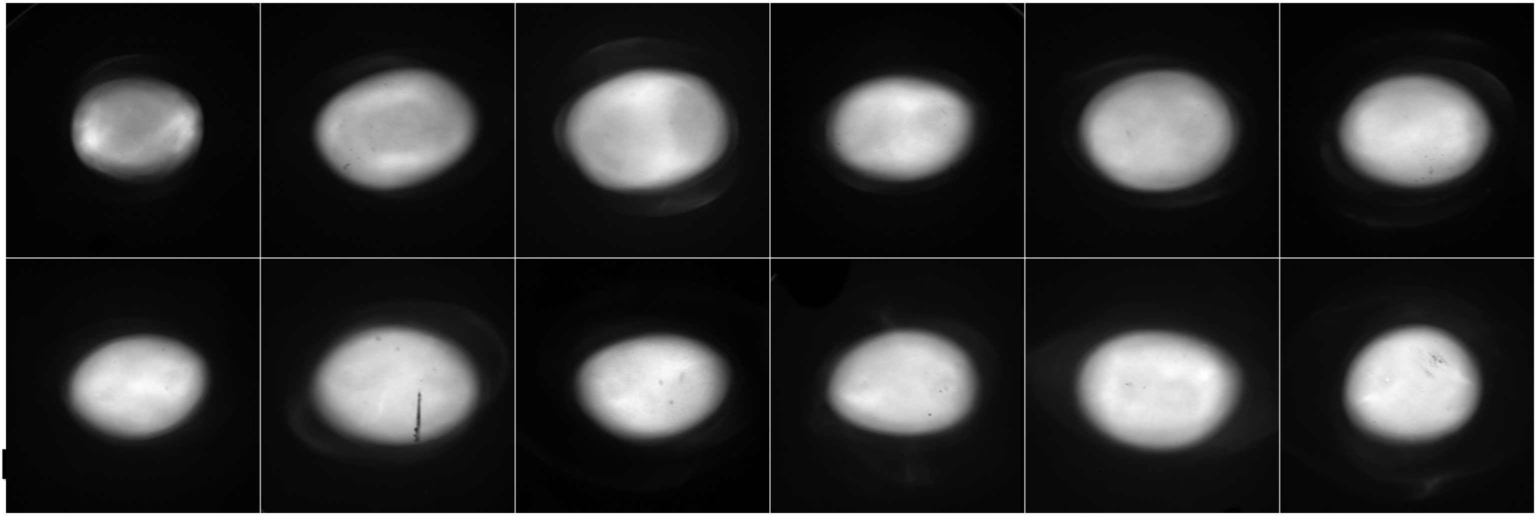


Beam Rotation Correction

24mA Beam (RC1-12) Before Skew Correction

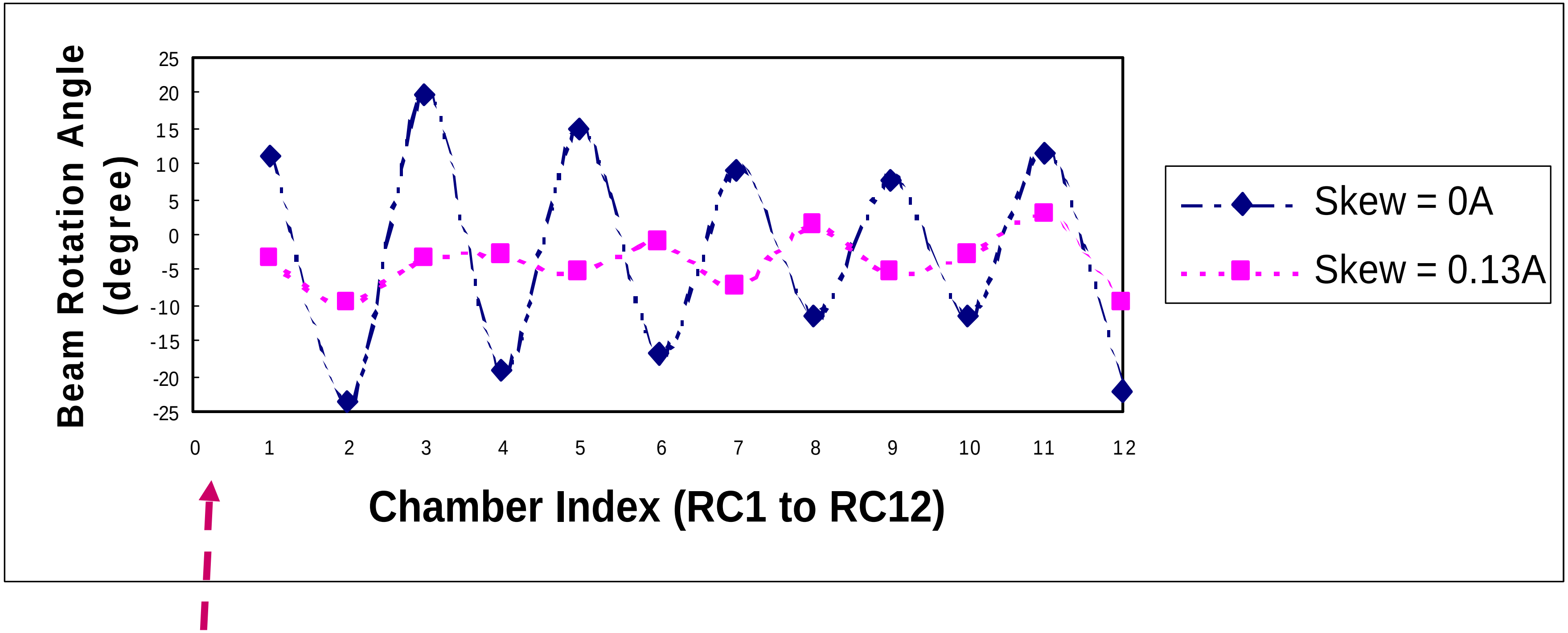


24mA Beam (RC1-12) After Skew Correction



Beam Rotation Correction

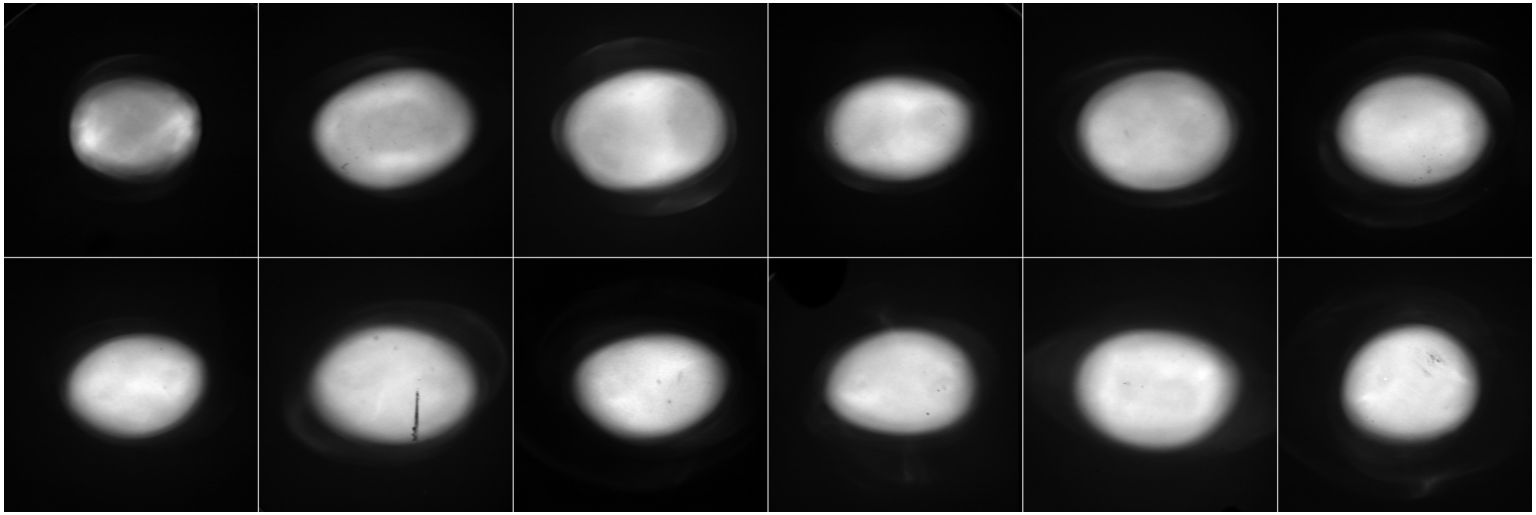
24mA Beam (RC1-12) Rotation Angle Before Correction v.s After Correction



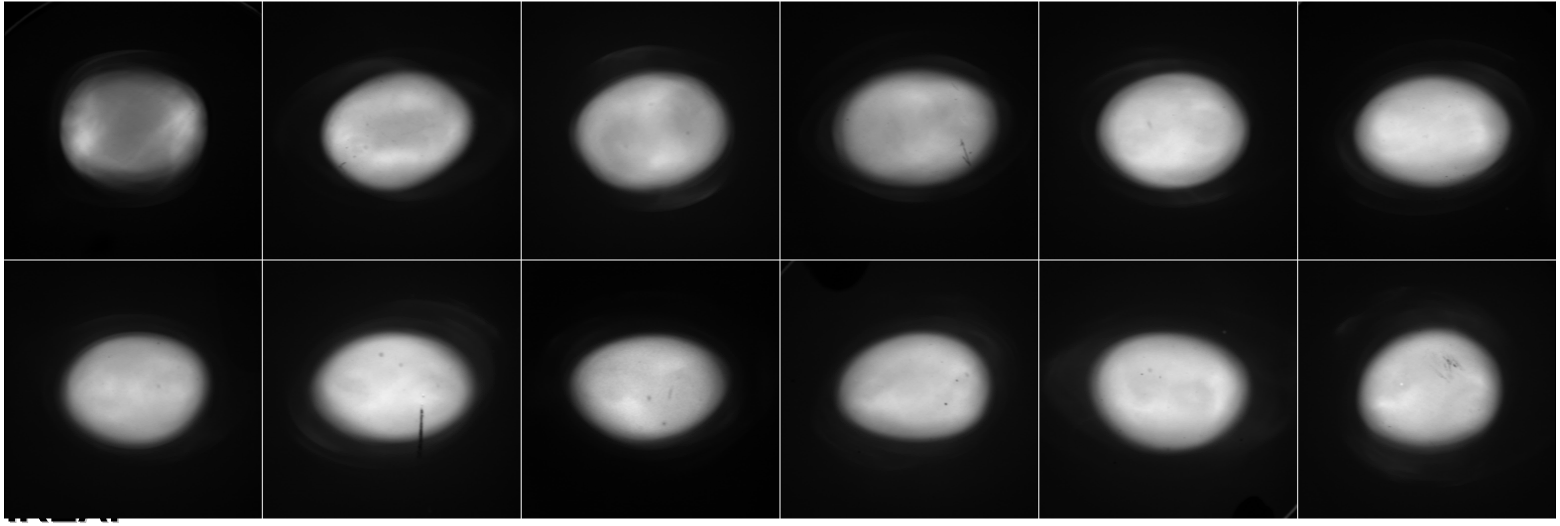
Skew corrector at here

Beam Matching

24mA Beam (RC1-12) after Skew Correction



24mA beam pictures (RC 1-12) after beam-based matching



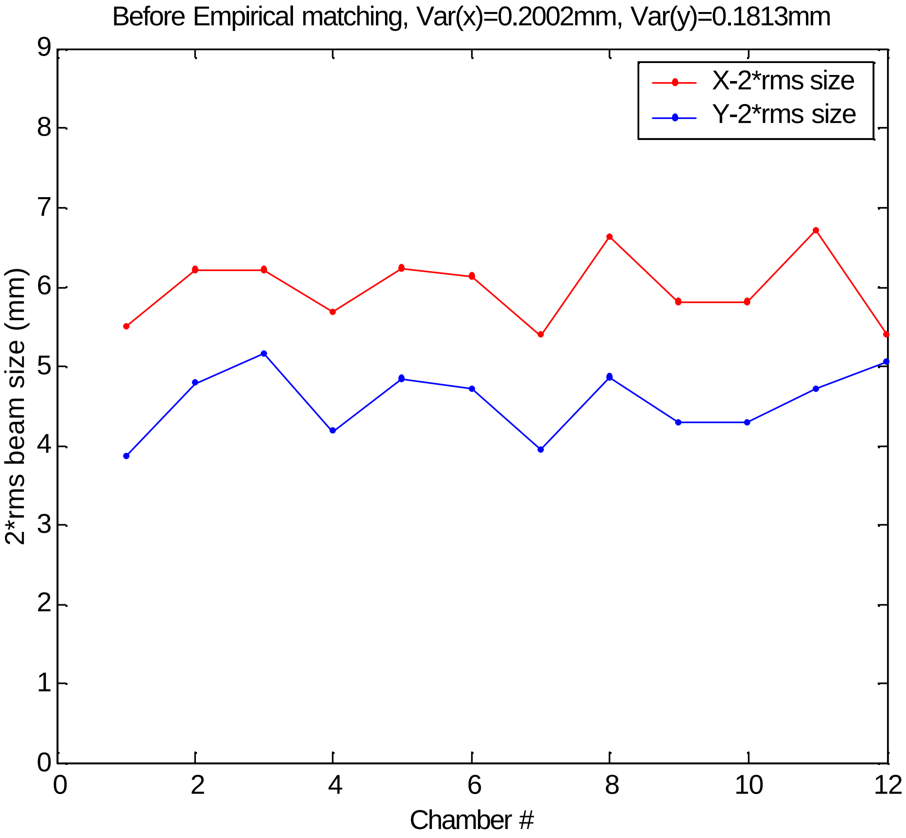
Beam Matching

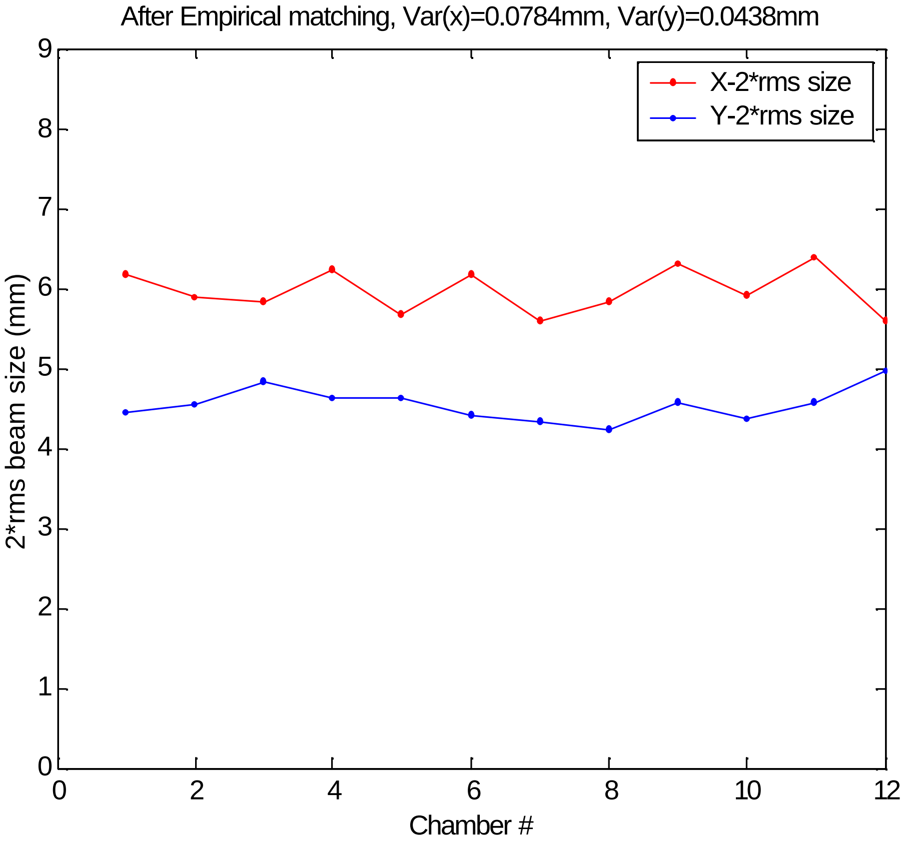
Before empirical matching:

σ_x=0.20mm σ_y =0.18mm

After empirical matching:

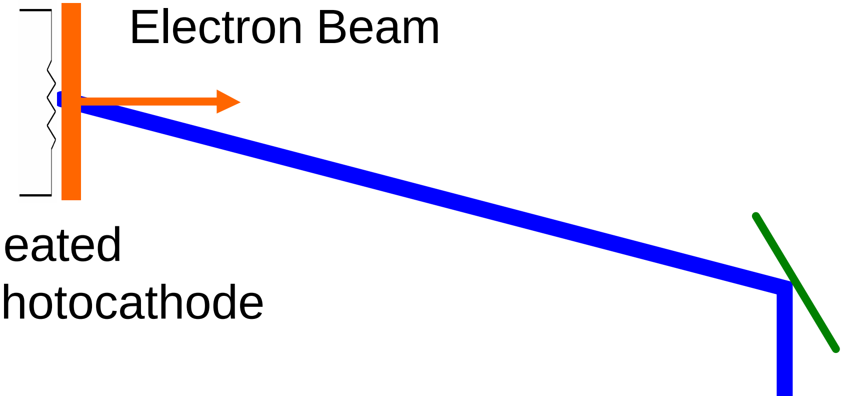
σ_x=0.08mm σ_y=0.04mm


Before Empirical matching, Var(x)=0.2002mm, Var(y)=0.1813mm


After Empirical matching, Var(x)=0.0784mm, Var(y)=0.0438mm

Longitudinal Dynamics: Inducing Perturbations

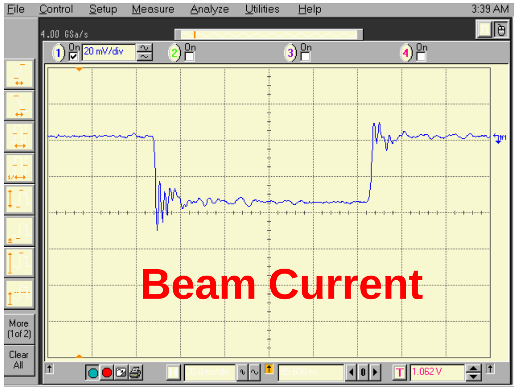
Photo & Thermionic Emission Electron Beams



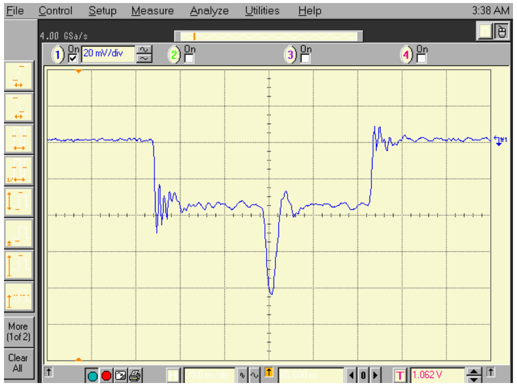
Electron Beam

Heated
Photocathode

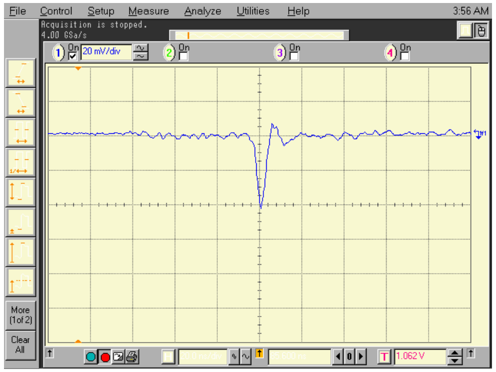
Drive
Laser



Thermionic only, 100ns pulse



Photoemission +
Thermionic 5ns pulse



Acquisition is stopped.

Photoemission only
(Cool cathode)

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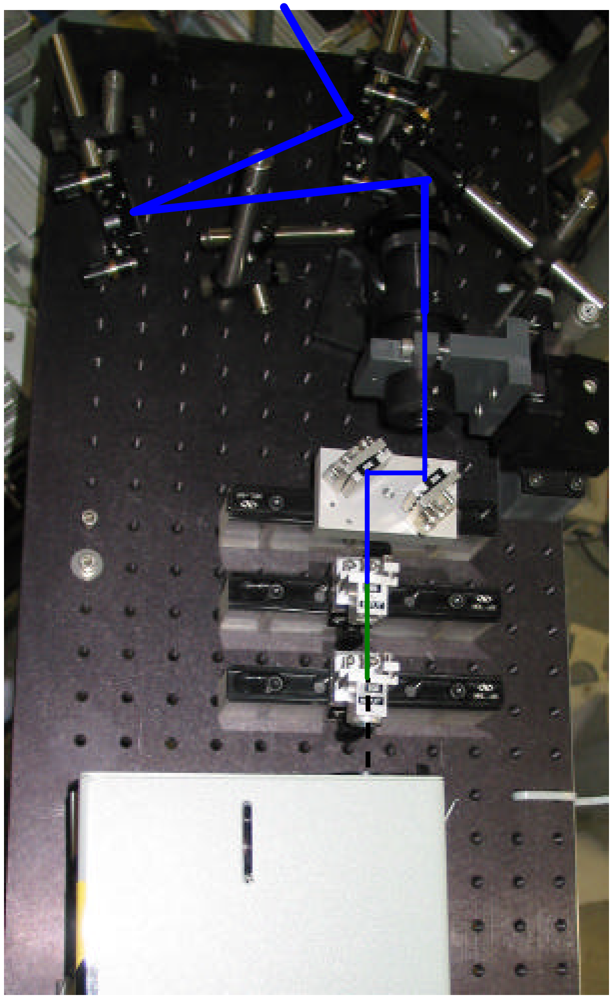
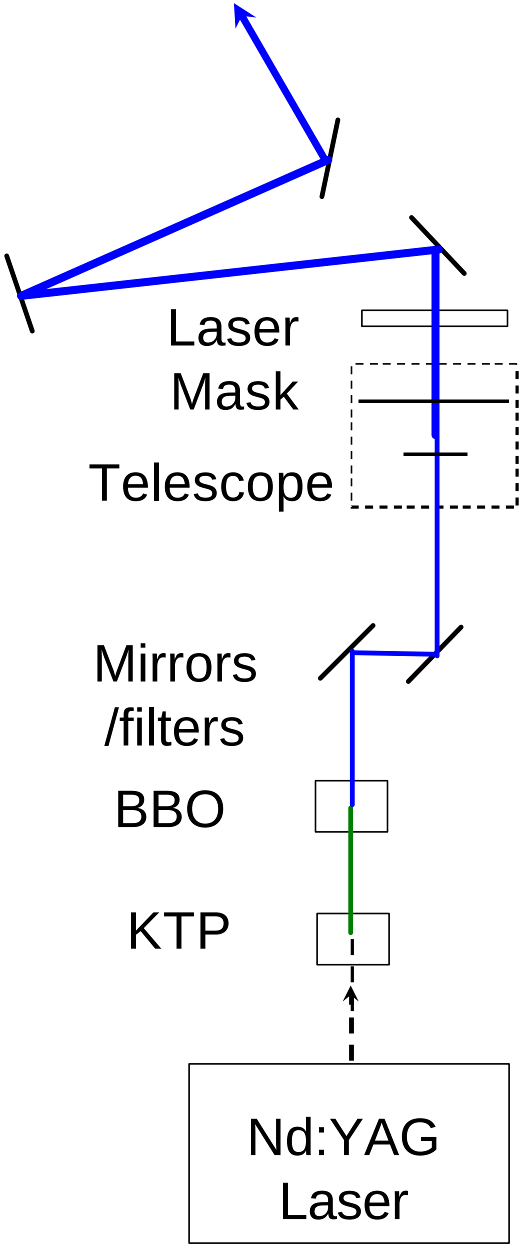
Yijie Huo

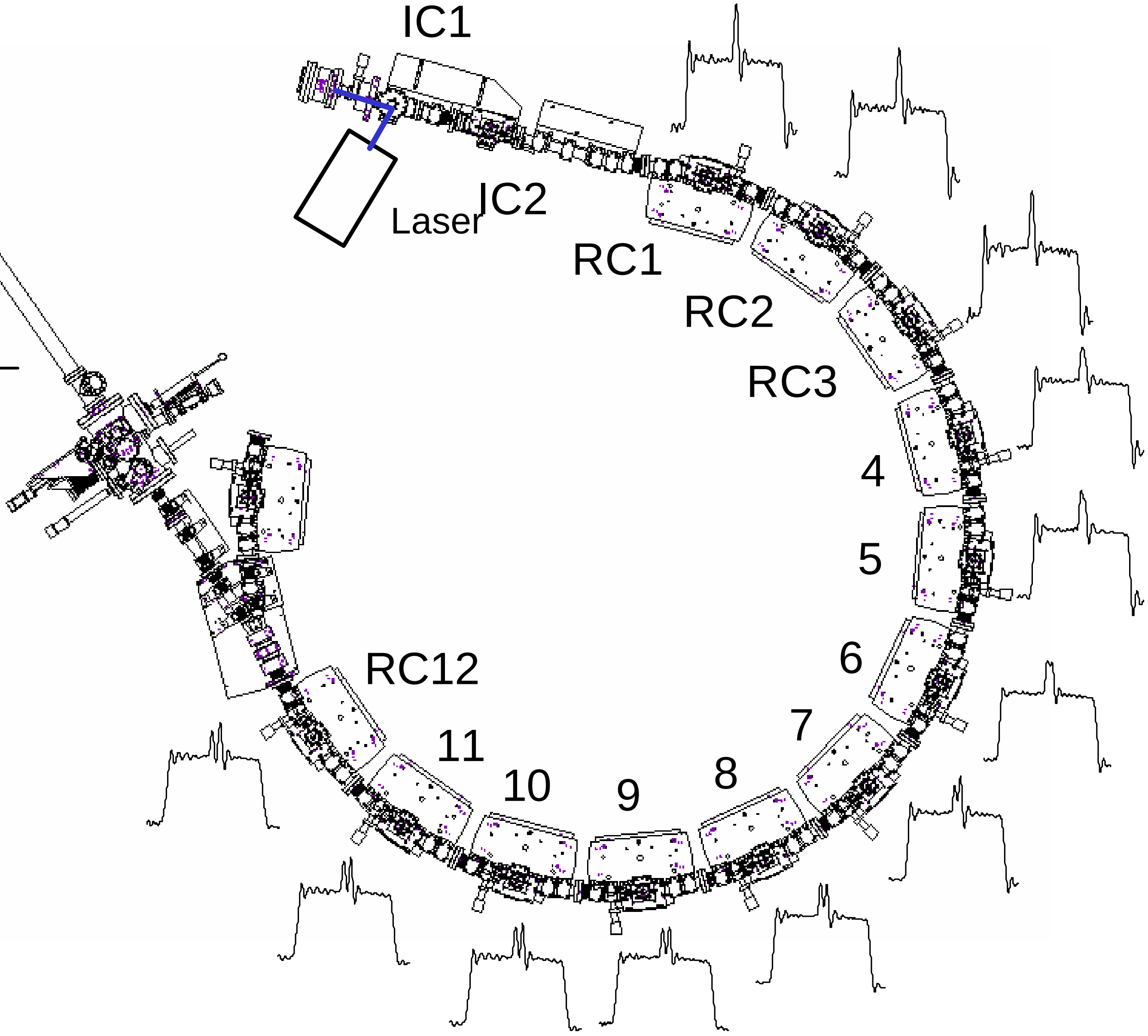
Drive Laser Setup





UV (355nm) Laser
Photon energy: 3.5 eV
Work function: 2.7 eV

Experiment Data Positions



Window : IC1	0.36 m
Bergoz Coil	0.62 m
BPM : IC2	0.80 m
BPM : RC1	1.91 m
BPM : RC2	2.55 m
BPM : RC3	3.19 m
BPM : RC4	3.83 m
BPM : RC5	4.47 m
BPM : RC6	5.11 m
BPM : RC7	5.75 m
BPM : RC8	6.39 m
BPM : RC9	7.03 m
BPM : RC10	7.67 m
BPM : RC11	8.31 m
BPM : RC12	8.95 m

Conclusion

- UMER Mechanically Closed
- Beam Control algorithms and systems developed.
- Poised for Multi-Turn Operation
- Can use laser to produce localized density perturbations – good agreement with WARP simulations.
- Rich physics content promises exciting results

Website: **http://www.ireap.umd.edu/umer**

Publications: **http://www.umer.umd.edu/**

Extras

Design of Printed Circuit Magnets

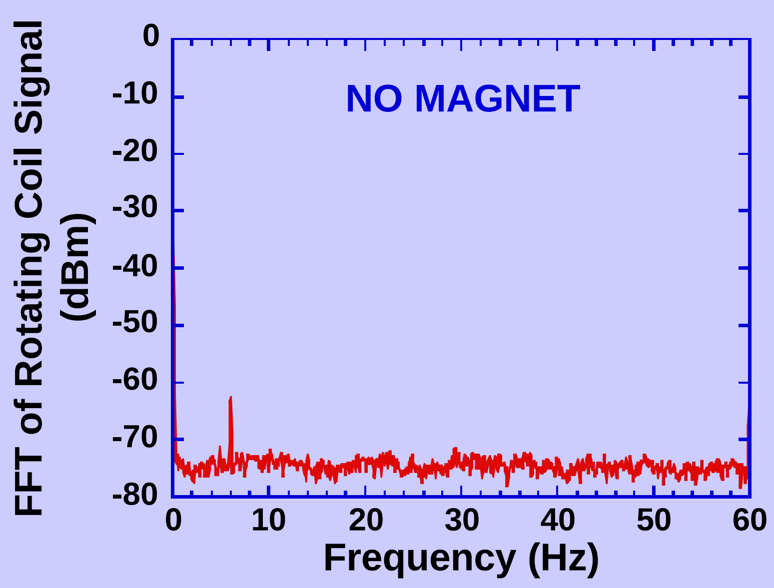
- 10 keV ⇒ use ironless printed-circuit magnets
- Quadrupole, Dipoles, and additional Short Dipoles for small steering corrections
- Can handle up to 3 Amps DC/conductor.
- Double-sided: minimizes effect of external leads & doubles the field.
- Algorithm:

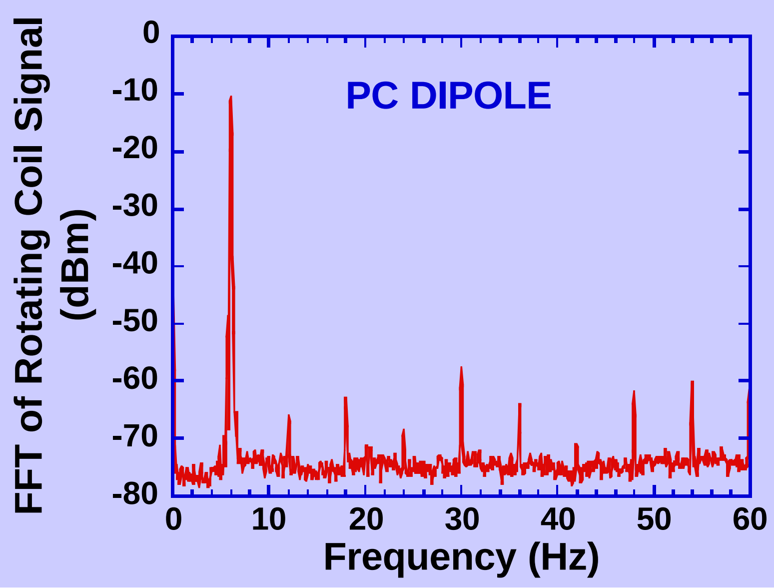
$\mathbf{\sin(m\Phi_n) = 1 - (2z_n/kL)^2}$, n = 20 loops for ring

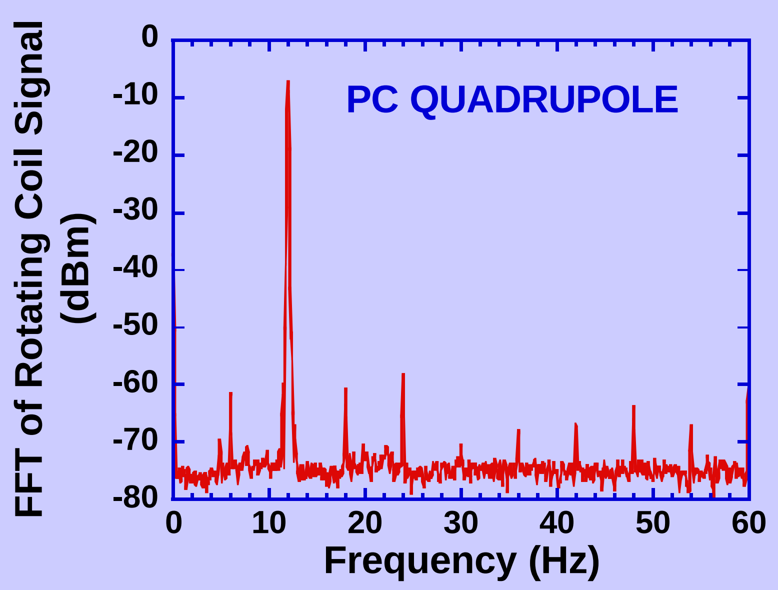
dipoles (m=1) and quad's (m=2)

Courtesy of T.F. Godlove

FFT of Rotating Coil Signal







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Sources of Quad Multipole Spectrum

Multipole	Source
Normal dipole	Residual Earth's field and ***R***
Skew dipole	Residual Earth's field and ***R***
Normal quadrupole	Design
Skew quadrupole	H and R
Normal sextupole, decapole	R
Skew sextupole, decapole	Conductor finite width
Normal octupole	V
Skew octupole	H
Normal duodecapole	Design and V
Skew duodecapole	H