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THE SMALL ISOCHRONOUS RING PROJECT AT MICHIGAN STATE UNIVERSITY

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OUTLINE:

- Introduction
- Injection and Extraction Lines of SIR
- Simulations & Experimental Results
- Conclusions

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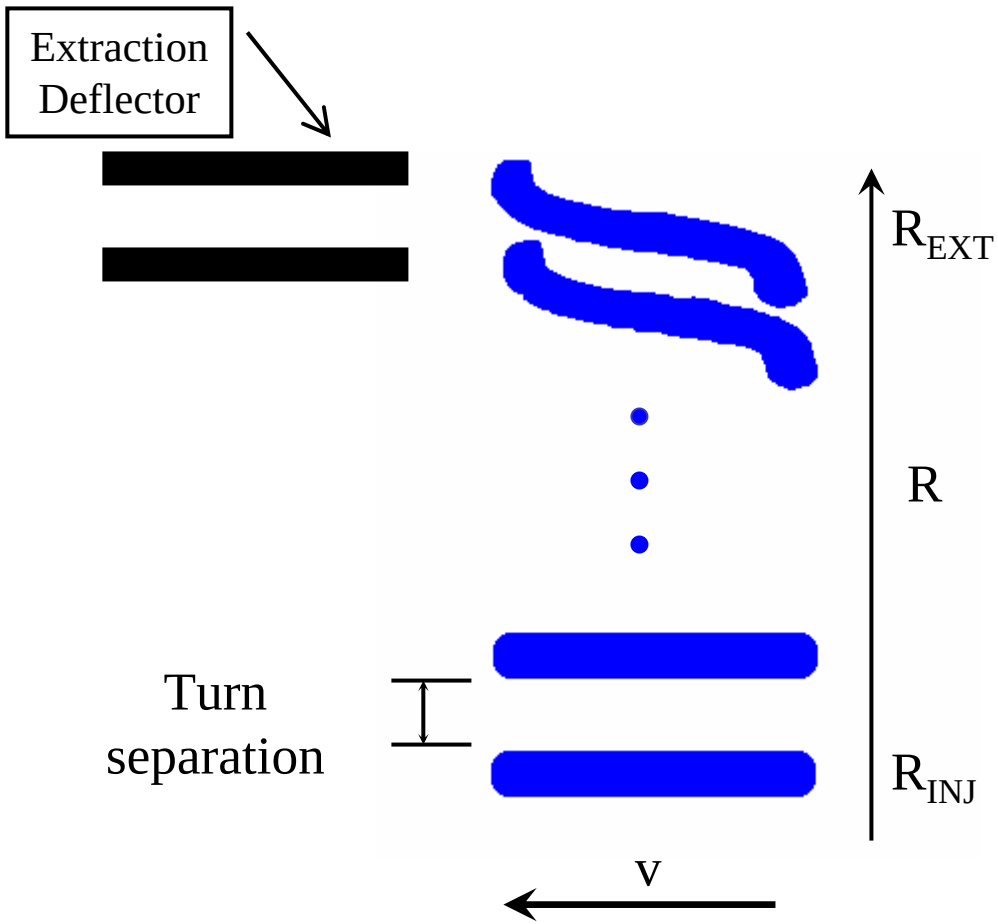
INTRODUCTION

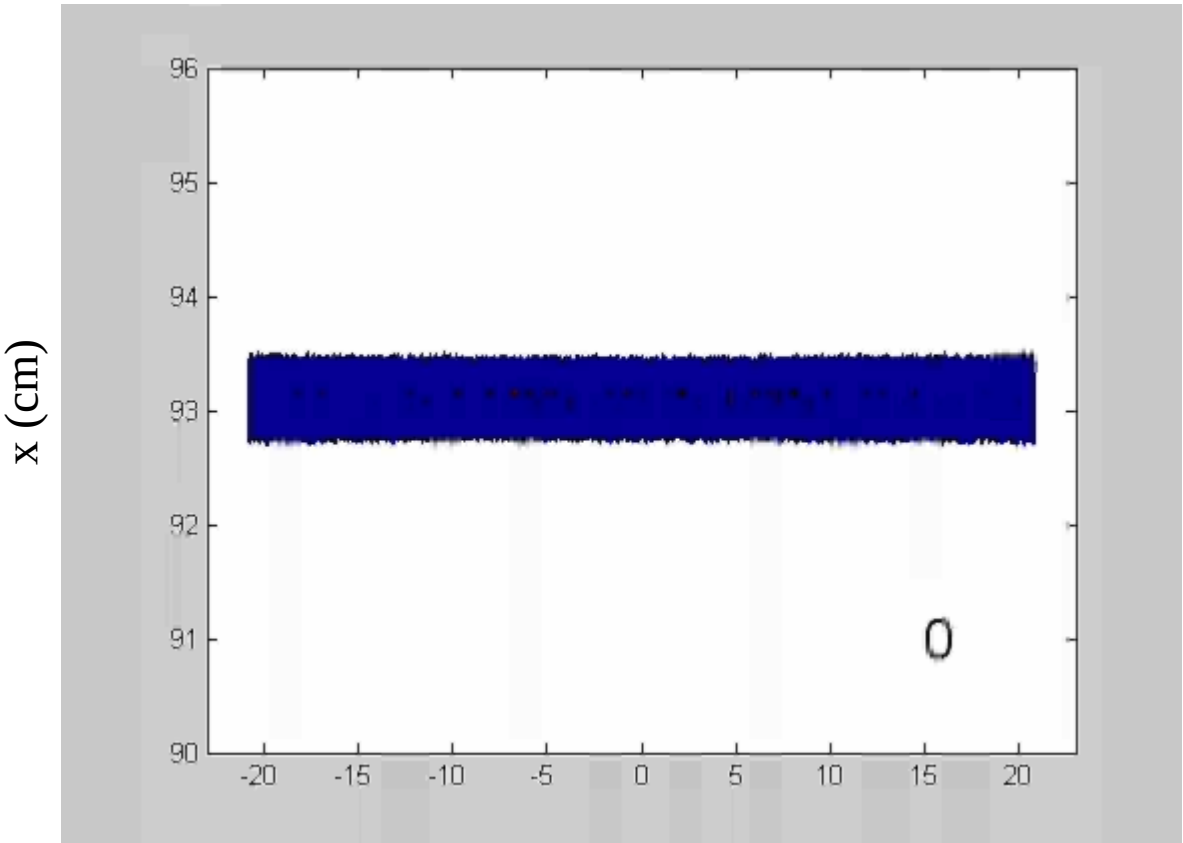
- Several authors have proposed using high power cyclotrons for different applications.
- The space charge forces at these current levels (~ 10 mA) become very important and must be considered when such a machine is designed.
- Some understanding about space charge effects in the isochronous regime exists, although this knowledge is not yet complete.



Effects of the longitudinal space charge electric field:

- Energy spread within the bunch.
- Increase effective radial size.
- Destroys turn separation.
- Losses in extraction deflector.

- Preliminary simulations showed a break up of the bunch.



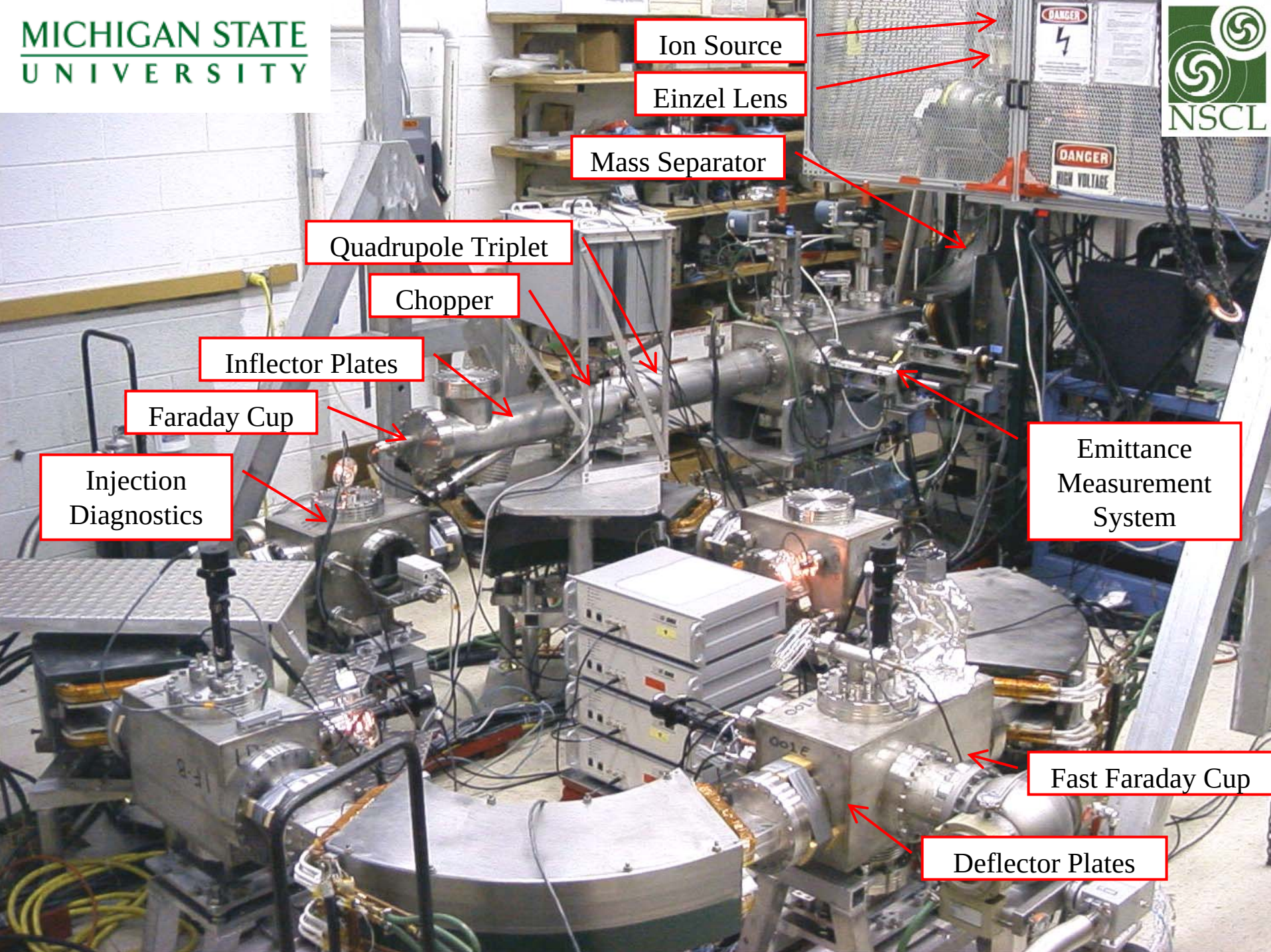
Space charge forces scale with:

$$k \equiv \frac{q \cdot I_{AV}}{\gamma^5 \cdot m \cdot h \cdot \omega^3} \qquad I_{AV} = \frac{I_{PEAK} \cdot h \cdot L_{BUNCH}}{2\pi \cdot R_{AV}}$$

	PSI Injector II (first turn)	SIR	PSI Main Cyclotron (first turn)	SIR
Ion	H^+	H_2^+	H^+	H_2^+
E	870 keV	20 keV	72 MeV	20 keV
I_{PEAK}	34 mA	13 µA	290 mA	9 µA
	Same *k*		Same *k*	

Advantages of SIR:

- Time resolution of the diagnostics is much less demanding.
- Beam power is much lower.
- Availability is not an issue.
- Larger space charge forces than in PSI Injector II.
- Possibility of studying turn by turn evolution.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Ion Source
Einzel Lens
Mass Separator
Quadrupole Triplet
Chopper
Inflector Plates
Faraday Cup
Injection Diagnostics
Emittance Measurement System
Fast Faraday Cup
Deflector Plates
DANGER
DANGER

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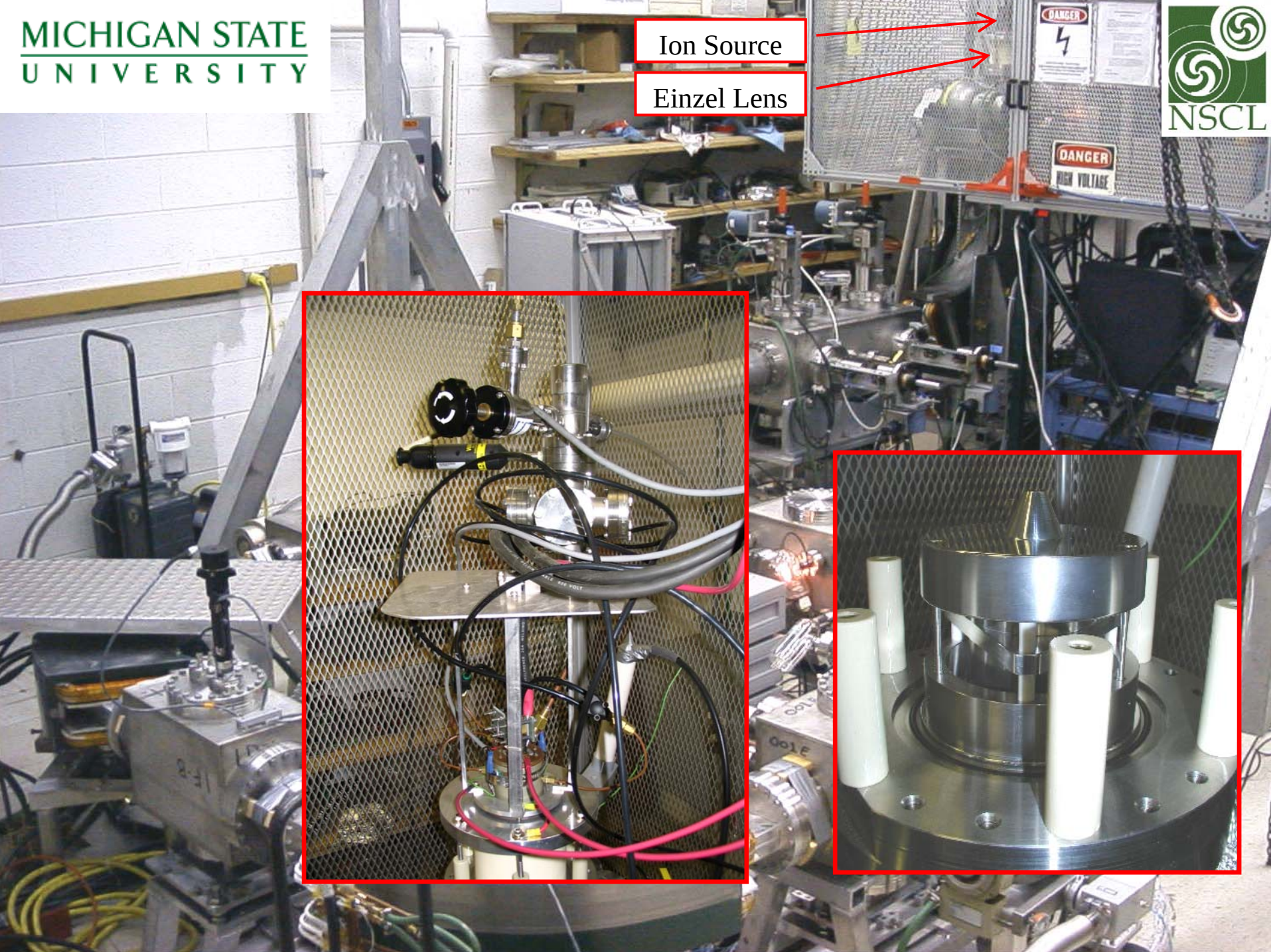

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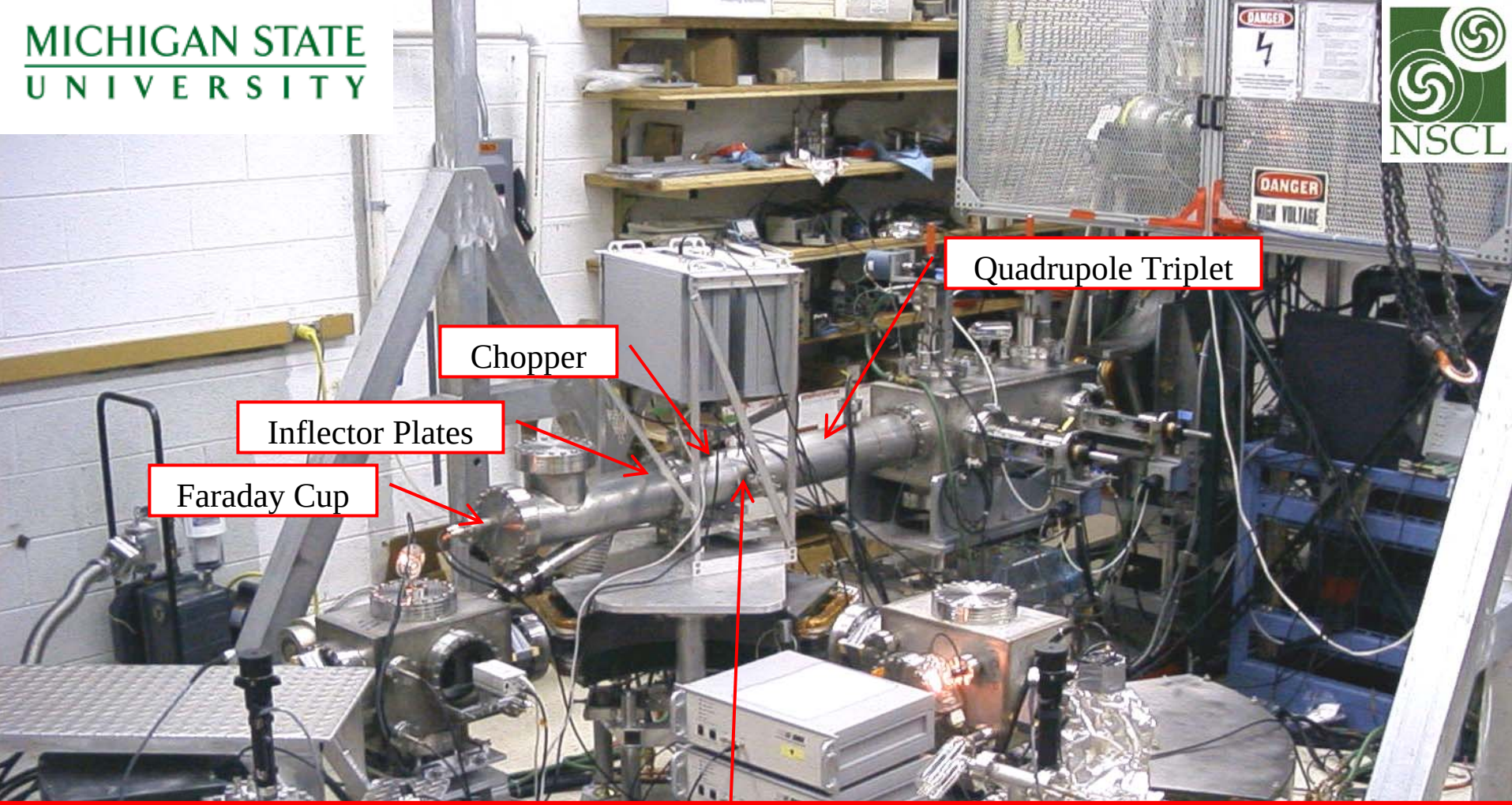

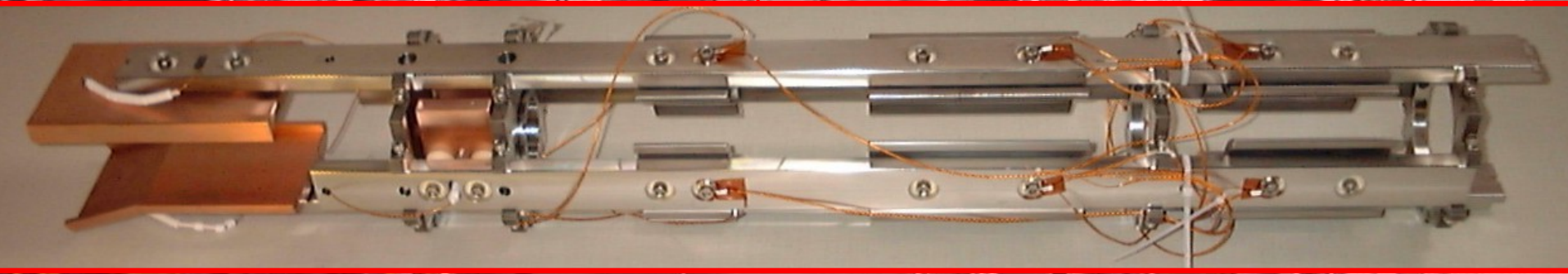

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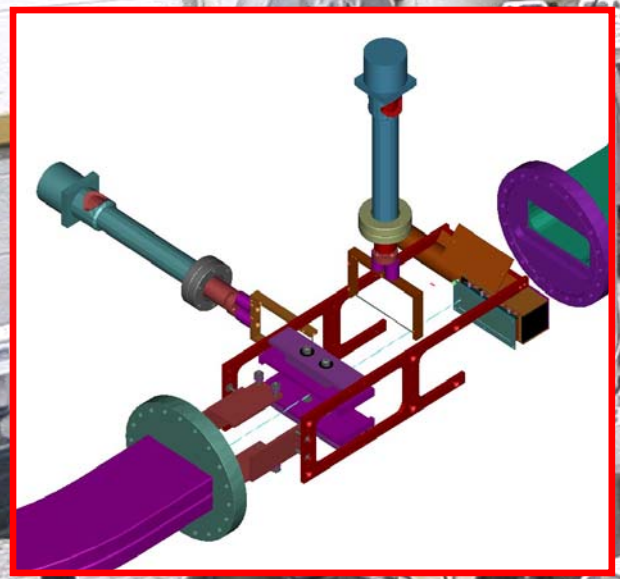

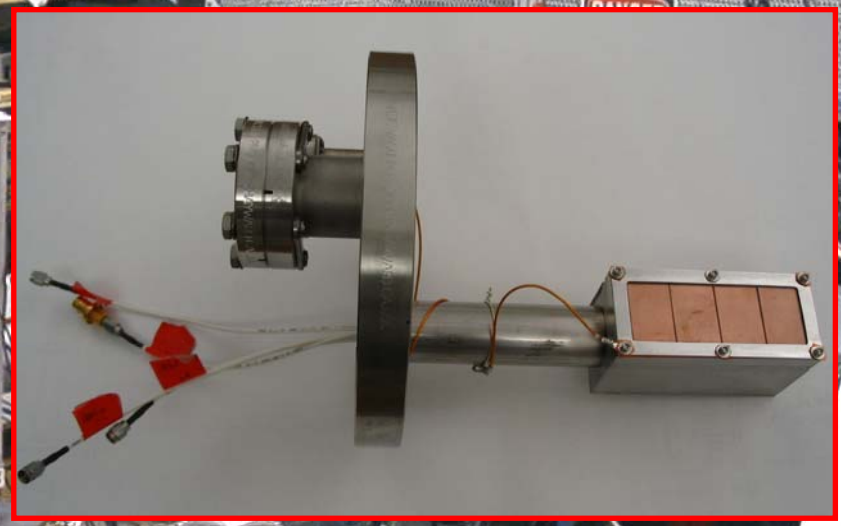

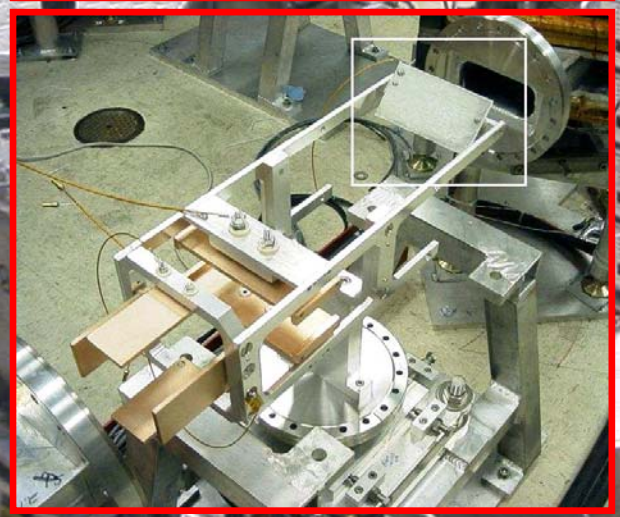

Fast Faraday Cup

Deflector Plates

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SIMULATIONS & EXPERIMENTAL RESULTS

- Methodology used in the analysis
- Scaling with bunch length, peak current and energy
- Impact of the beam emittance
- Energy spread within a bunch
- Repeatability of experimental measurements
- Experiments vs. Simulations

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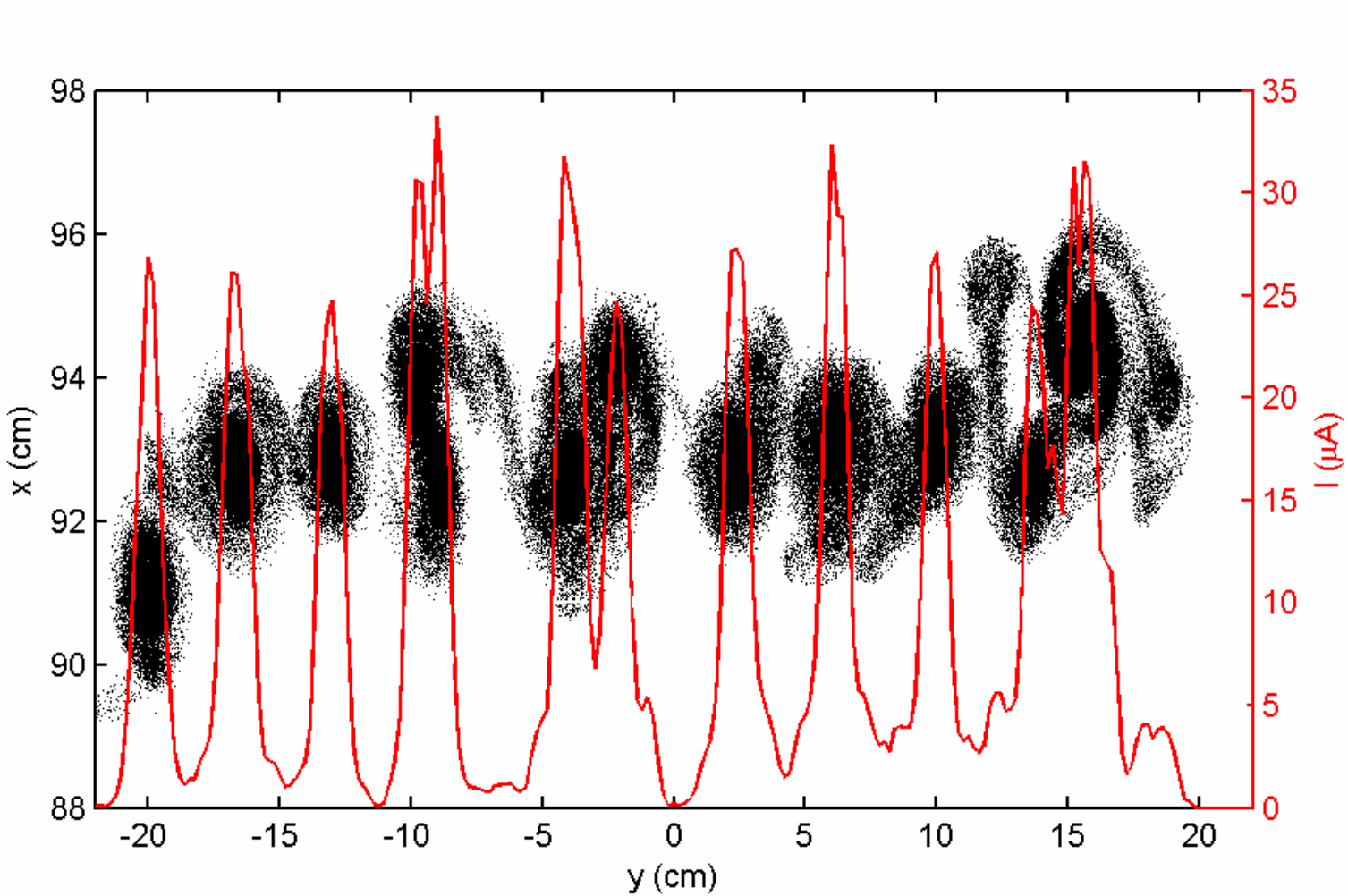
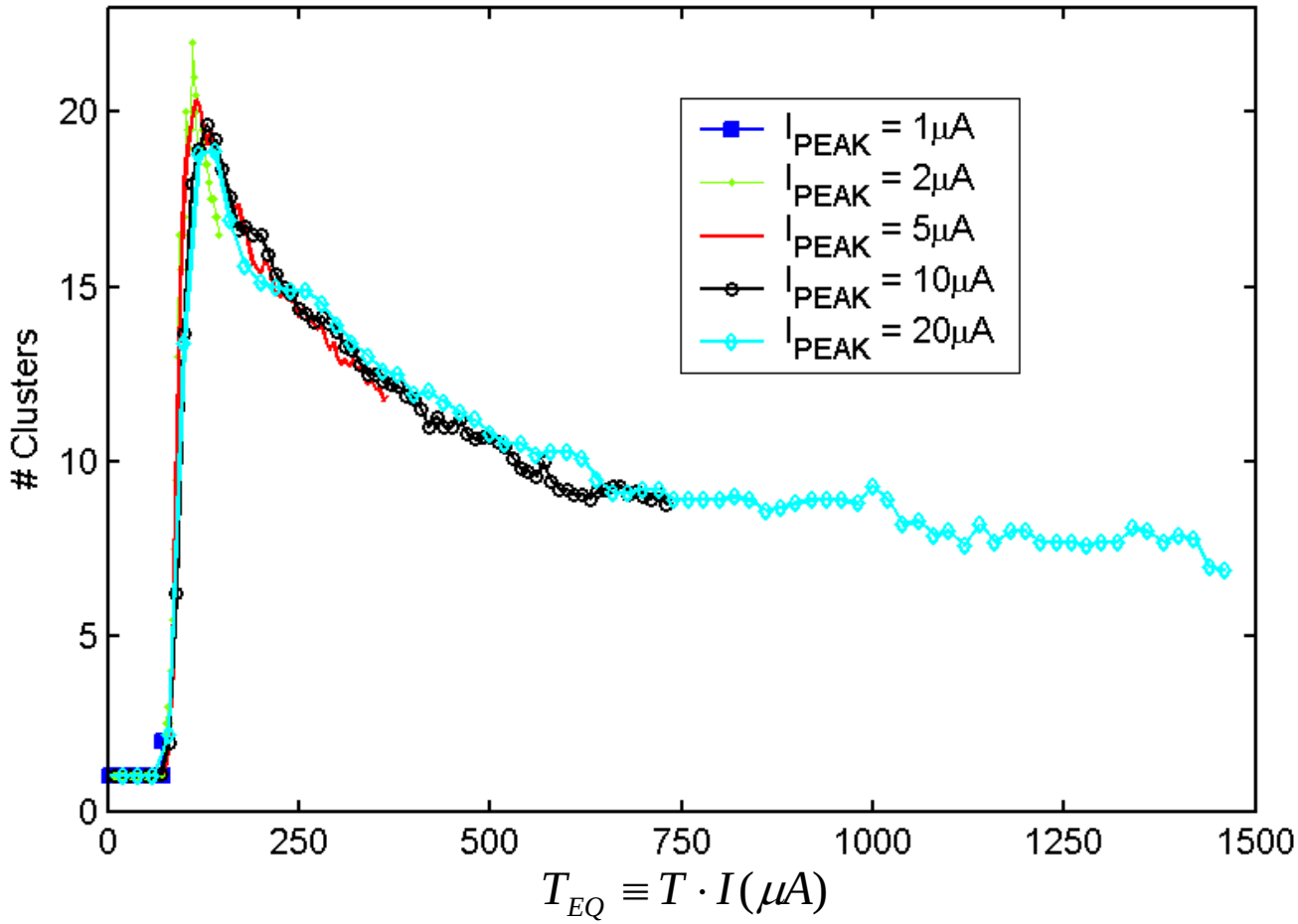
Methodology used in the analysis



Scaling with bunch peak current



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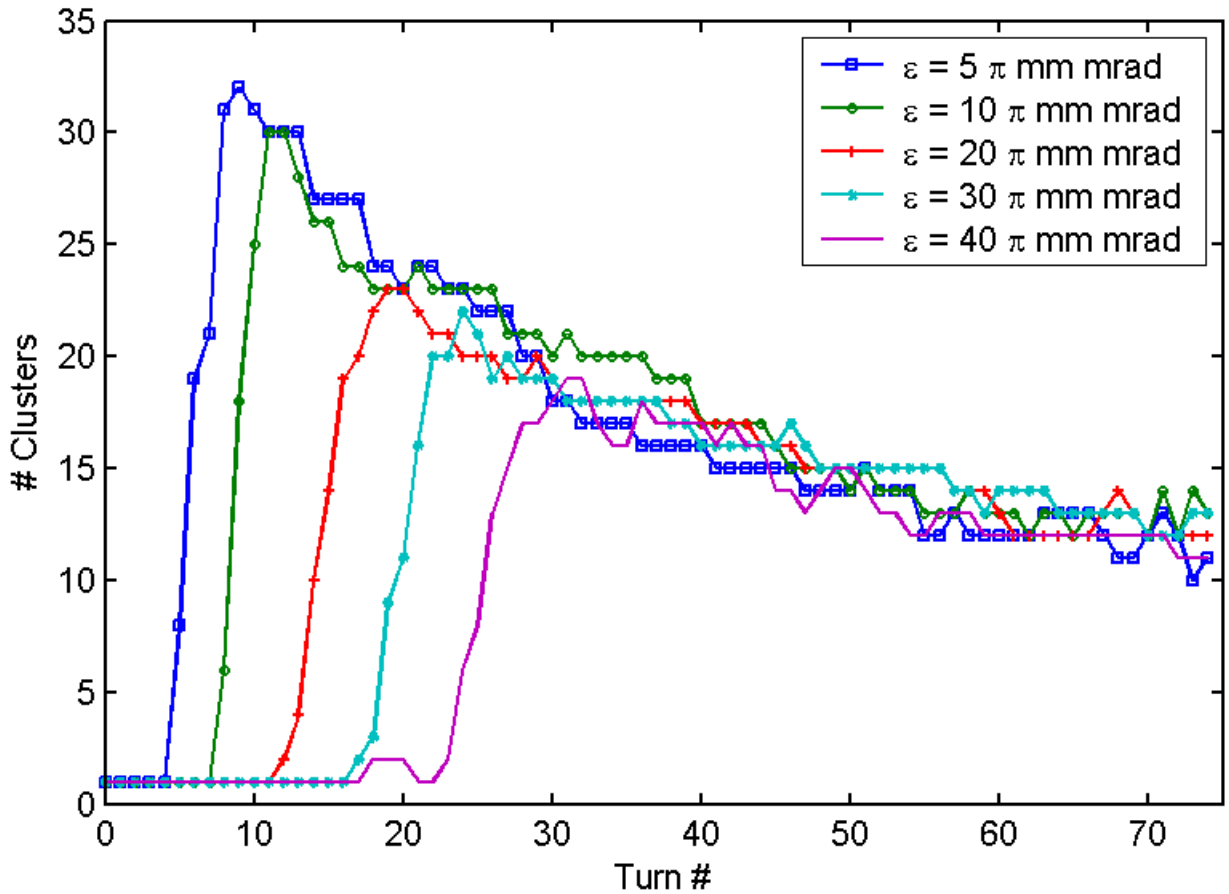
Impact of the beam emittance



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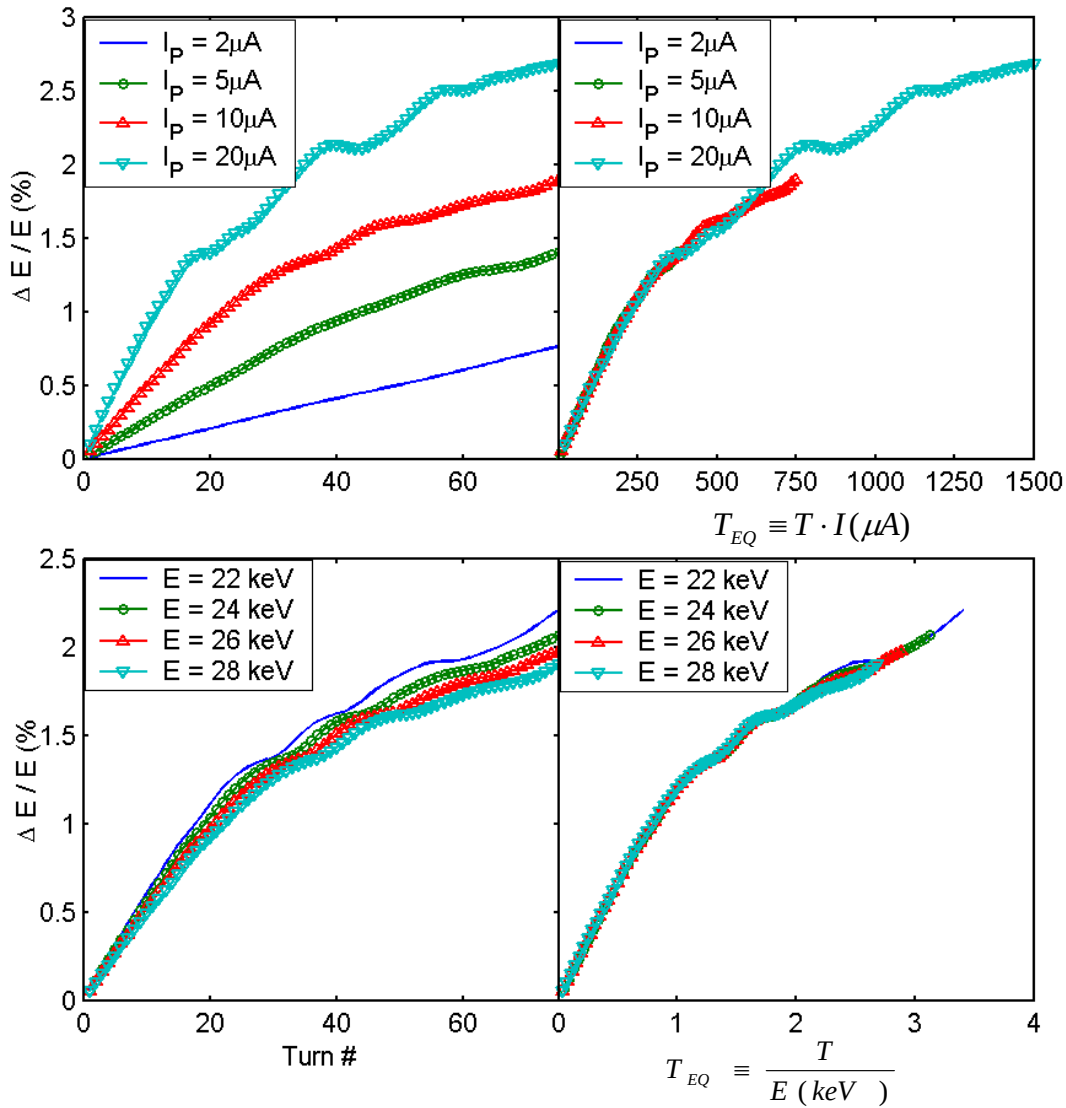
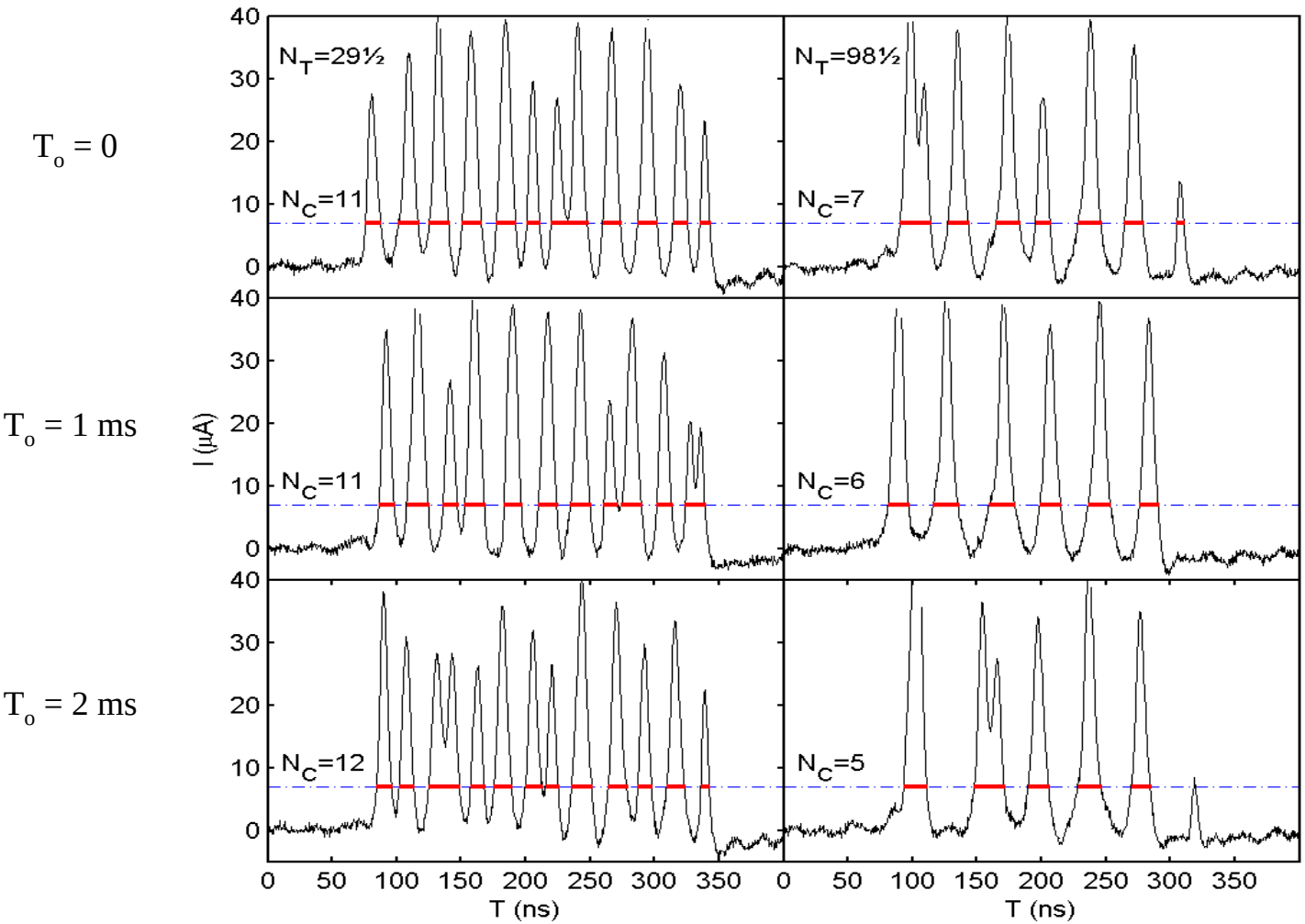
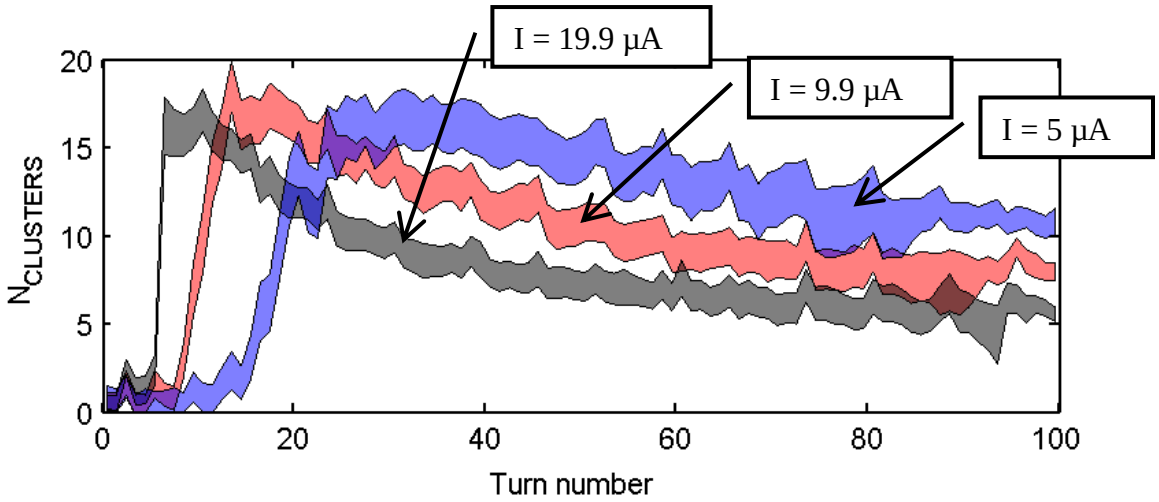
Energy spread within a bunch

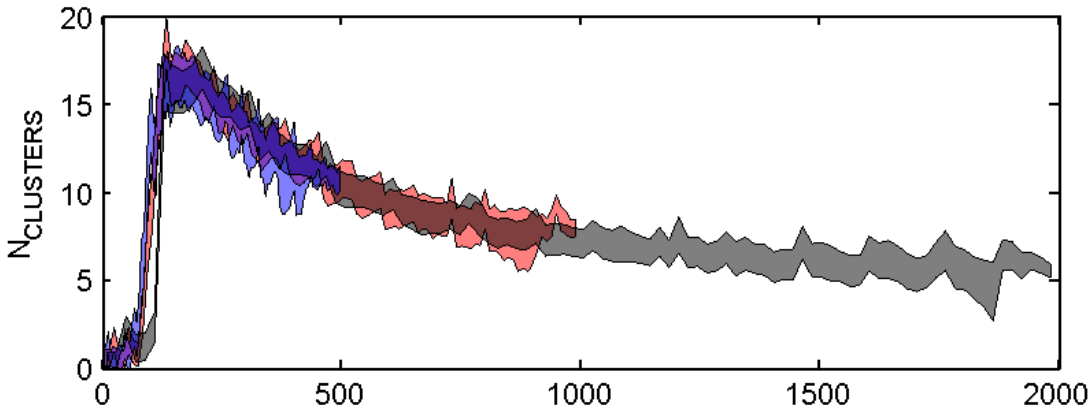


Repeatability of experimental measurements



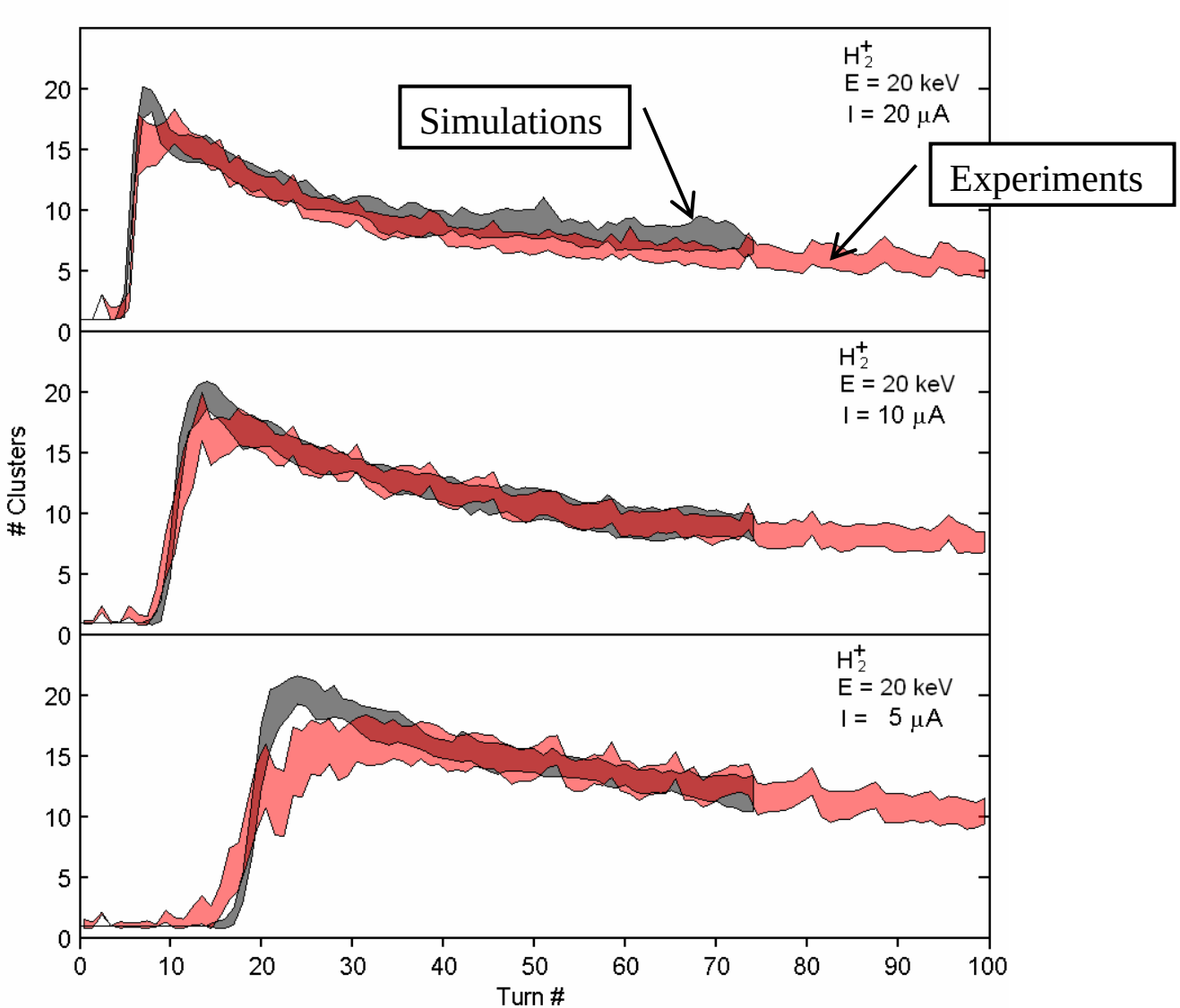
Scaling with bunch peak current





$$T_{EQ} \equiv T \cdot I(\mu A)$$

Experiments vs. Simulations



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CONCLUSIONS

- The Small Isochronous Ring (SIR) has been completed.
- The control and data acquisition system of SIR has been finalized.
- Extensive simulations have been performed to characterize the impact of bunch length, current, energy and emittance on the bunch dynamics.
- The scaling laws of space charge effects with energy and current have been validated numerically and experimentally.
- Good agreement between experiments and simulations performed with CYCO has been shown.