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Thermionic Sources for Electron Cooling at IOTA

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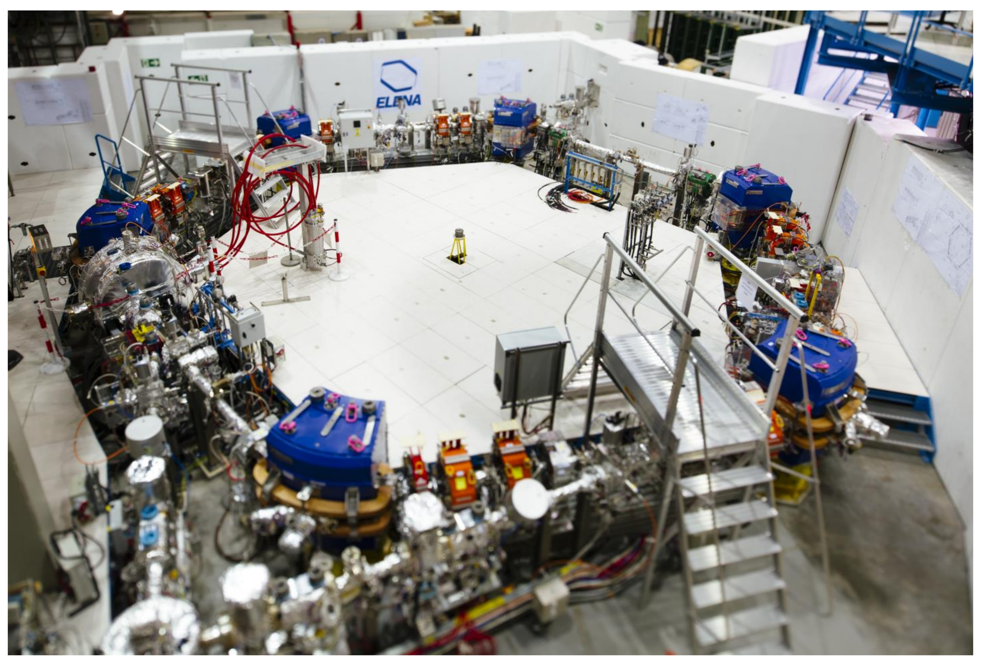
We are designing two new thermionic sources for IOTA at Fermilab, which will be useful for both cooling research and hadron beams.

Introduction



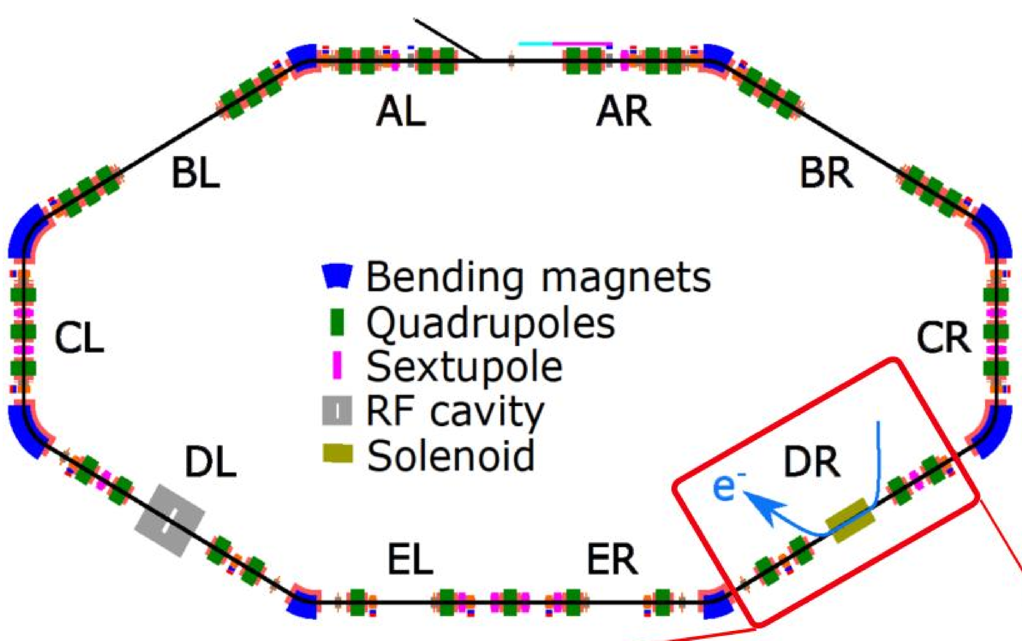
- Beam cooling causes an increase in particle density, leading to an increased intensity:

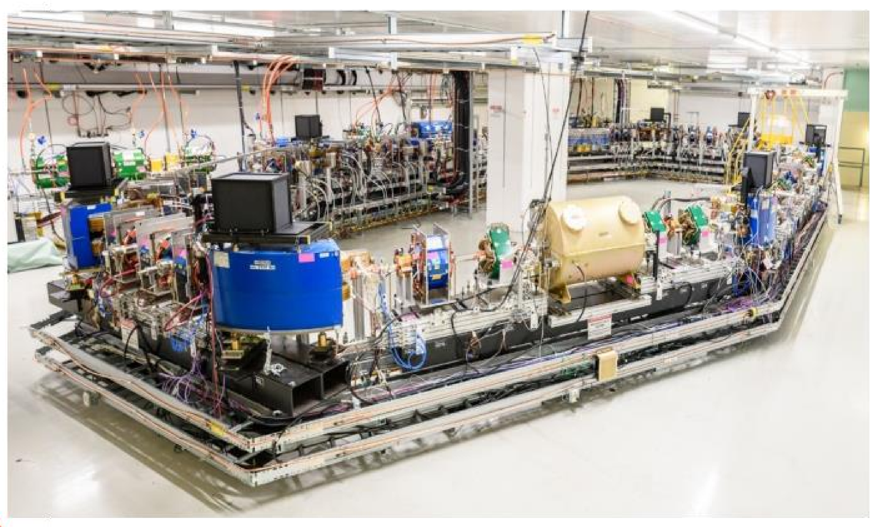
$$L, B = \frac{N^2}{\sqrt{\epsilon_x \epsilon_y}}$$

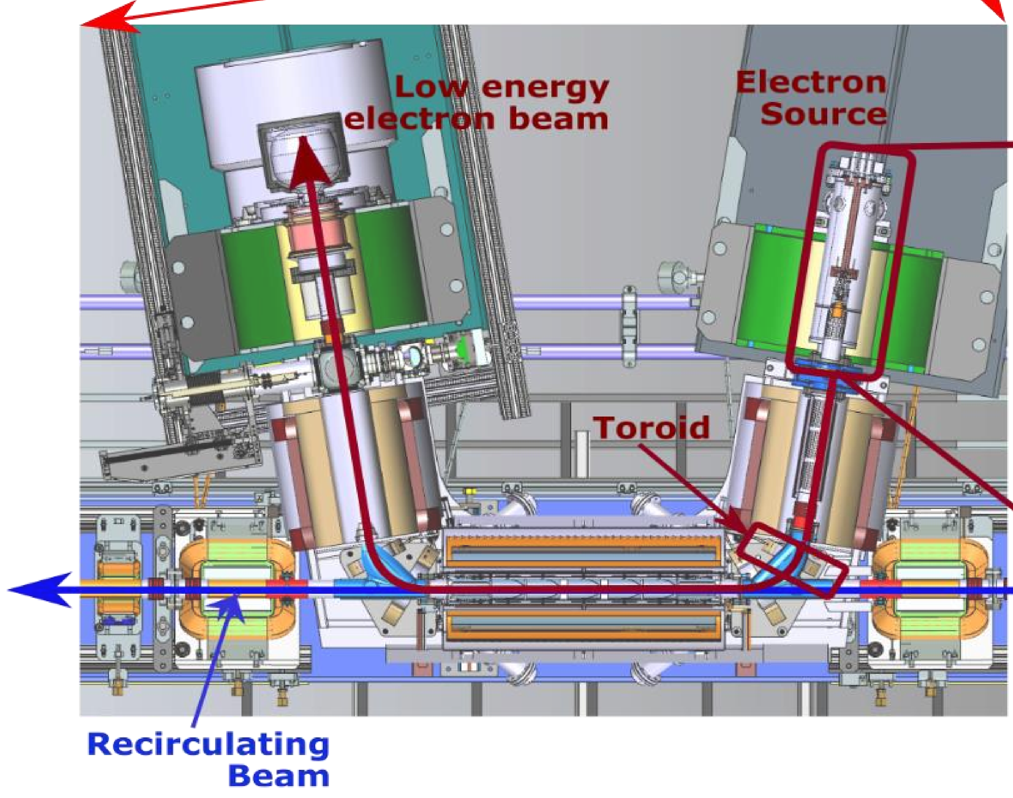
- There exist multiple methods of beam cooling: ionization, stochastic, laser, and **thermionic electron cooling**.

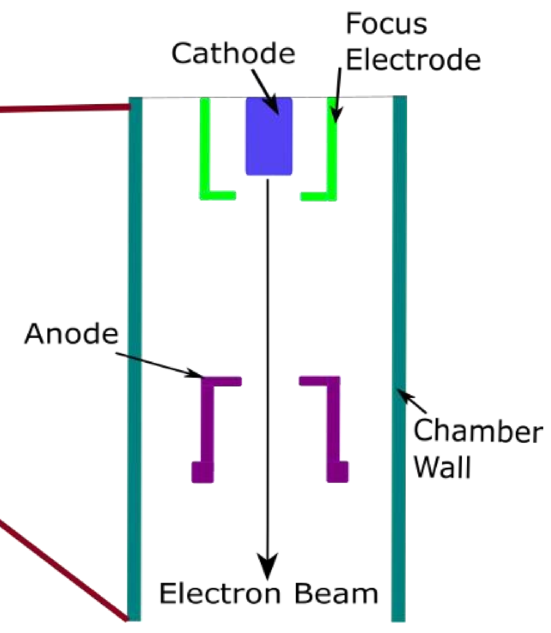
- We aim to design and build two thermionic electron sources for cooling of a 2.5 MeV proton beam at the Integrable Optics Test Accelerator (IOTA) at Fermilab.

IOTA Schematic:





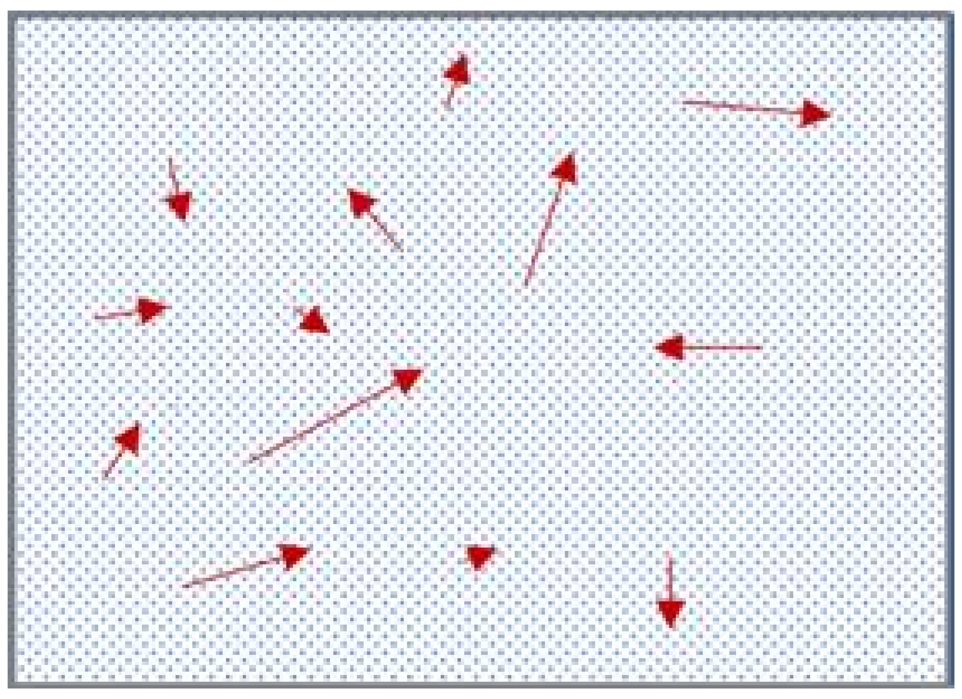




Objectives

- **Electron cooling**: beam of hadrons exchanges thermal energy with co-propagating beam of electrons and reduces transverse velocity distribution of hadron beam, decreasing the beam divergence.

- **Goals**:
  1. Simple source to use for other IOTA experiments.
  2. Strong source to research interplay between electron cooling and space charge.
- Design, manufacture, and test the sources for cooling at IOTA.
- Use simulations to design the cooling beams.
- Build test stand for the sources.
- Manufacture and test the sources with the test stand.



Transverse profile view of electron cooling. Red arrows represent protons, Blue dots represent electrons.

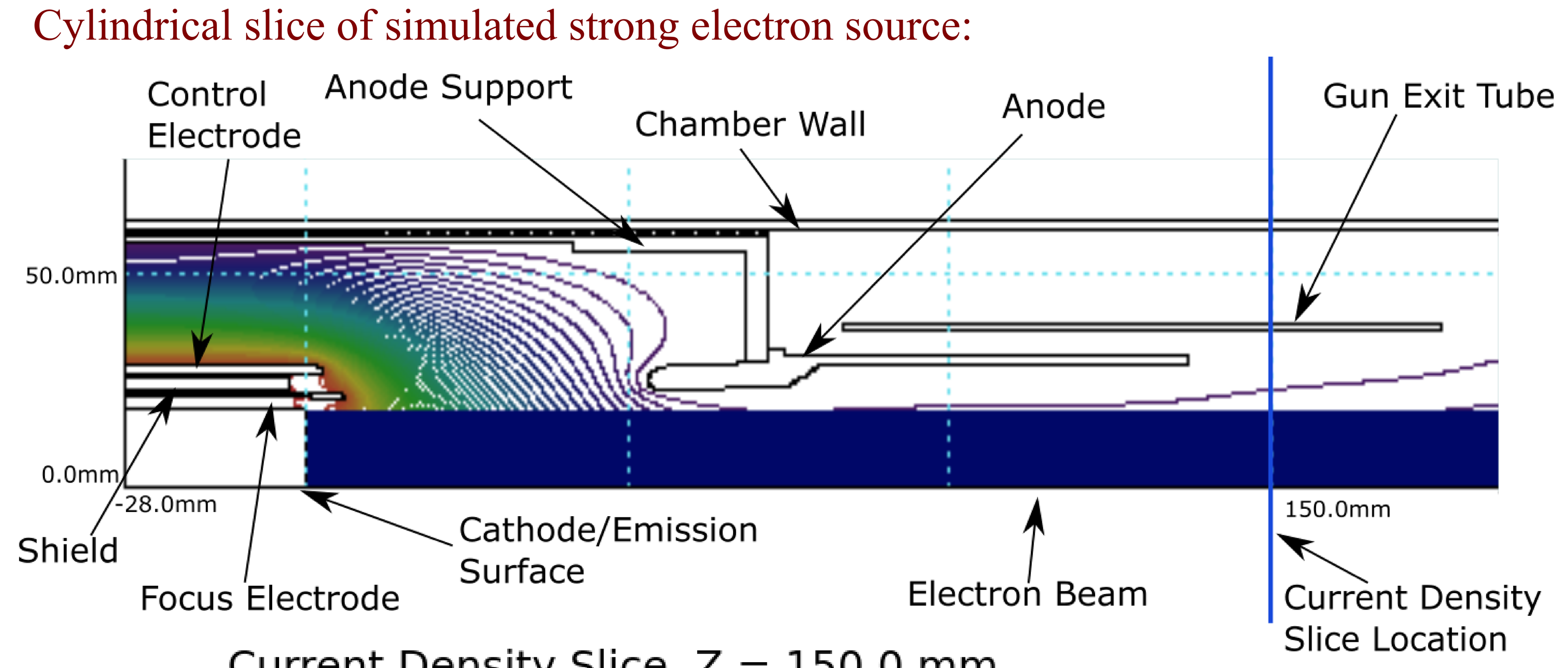
	Simple Source	Strong Source
Current	1.2 mA	80.3 mA
Radius	14.1 mm	18 mm
$\tau_{x,y,z}$	7.6, 6.5, 5.3 s	2.5, 2.4, 5.3 s

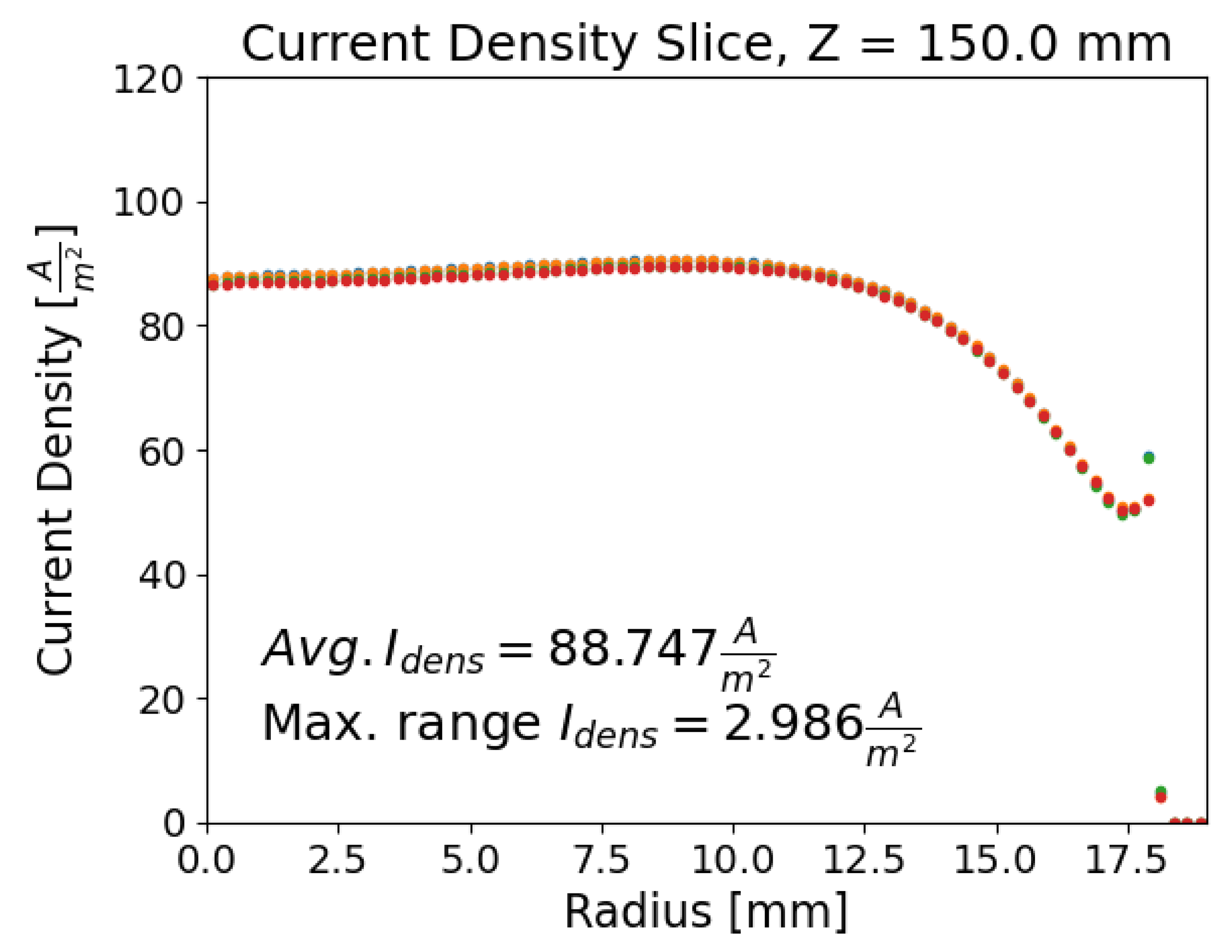
Electron Source Parameters	
Kinetic Energy	1.36 keV
Transverse Profile	Flat
Temporal Profile	DC
Source Cathode Temp.	1400 K

Simulations in TRAK

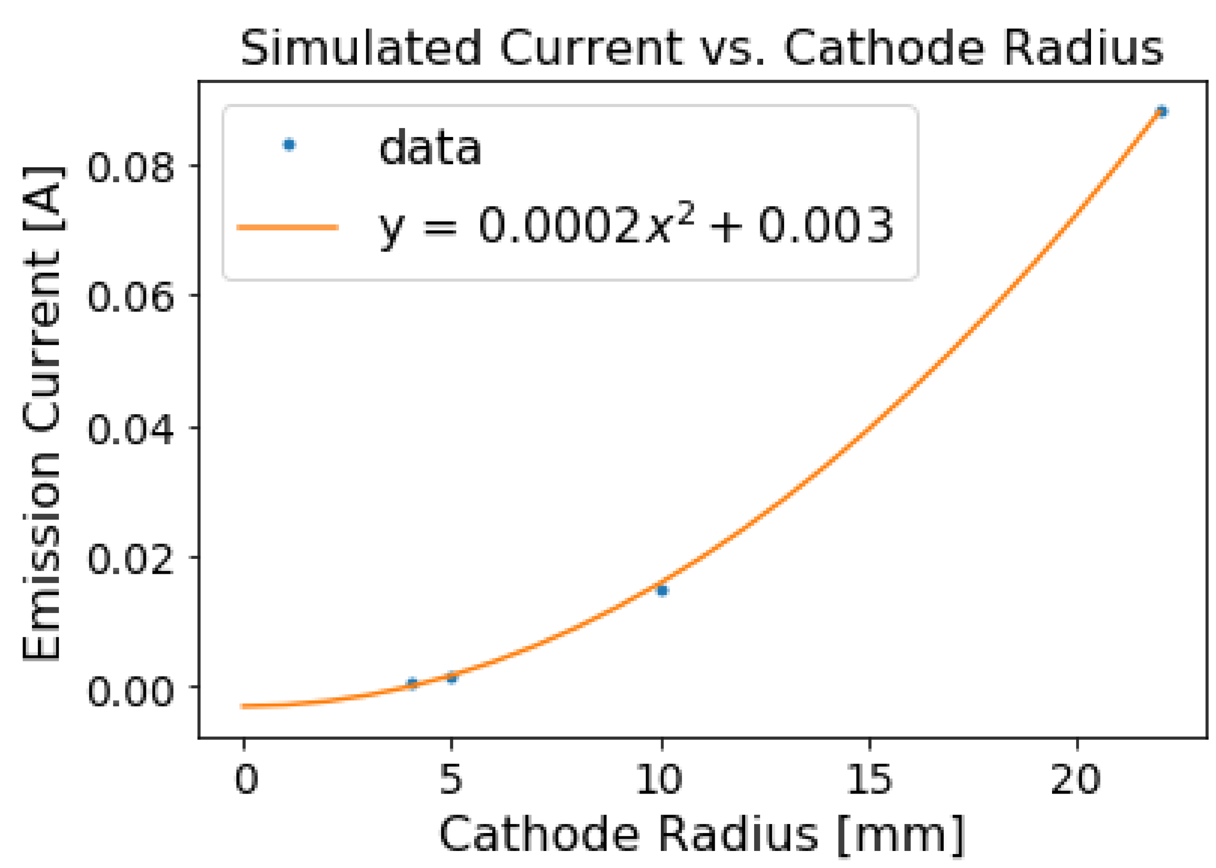
- Electron beam simulations will be used to design an electron source.
- Simulation package **TRAK**: advanced 2D code for charged-particle optics and particle source design.

Cylindrical slice of simulated strong electron source:





- Relevant beam features:
  - Radial profile
  - Total current emitted
- Design procedure:
  1. Develop electrode geometries in TRAK.
  2. Use Xopt's CNSGA optimizer for beam solutions on pareto front.



- Strong source solutions completed through TRAK.
- To test these and other sources, a test stand at the University of Chicago has been developed (Poster by S. Kladov: THPL050).

Conclusions

- Electron cooling increases beam intensity, valuable for future of hadron beams.
- IOTA at Fermilab is working to create two thermionic electron sources. One to cool proton beams, and one to investigate electron cooling and space charge.
- To generate appropriate electron beams, we are designing two electron sources.
- We are also building a test stand at the University of Chicago to test the sources.
- Next, we will build, test, and commission these thermionic sources.

Acknowledgments

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References

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