RADiCAL

a Radiation Hard Innovative EM Calorimeter

JAMES WETZEL

Caltech
University of Notre Dame
Iowa
University of Virginia

Beam Test Results of the RADiCAL

a Radiation Hard Innovative EM Calorimeter

RADiCAL Collaboration

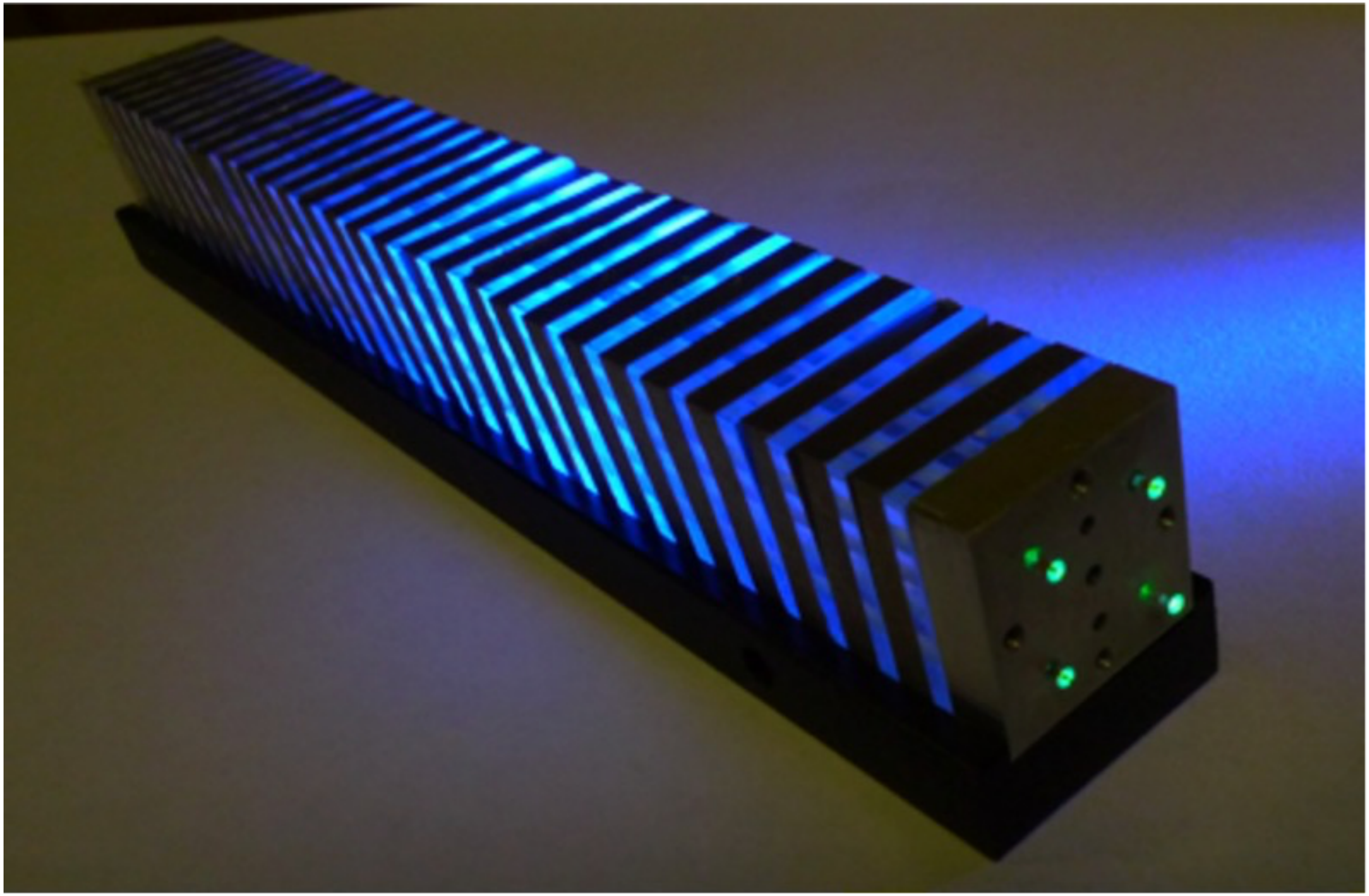
IOWA — U. Akgun, P. Debbins, D. Blend, M. Herrmann, G. Karaman, O. Koseyan, M. Mohammed, Y. Onel, and J. Wetzel

Caltech — C. Hu, L. Zhang and R-Y. Zhu

University of Virginia — T. Anderson, N. Chigapurupati, B. Cox, M. Dubnowski, R. Hirosky, A. Ledovskoy and C. Perez Lara

University of Notre Dame — T. Barbera, K. Ford, A. Heering, C. Jessop, Yu. Musienko, R. Ruchti, D. Ruggiero, D. Smith, M. Vigneault, Y. Wan and M. Wayne

A RADiCAL Module



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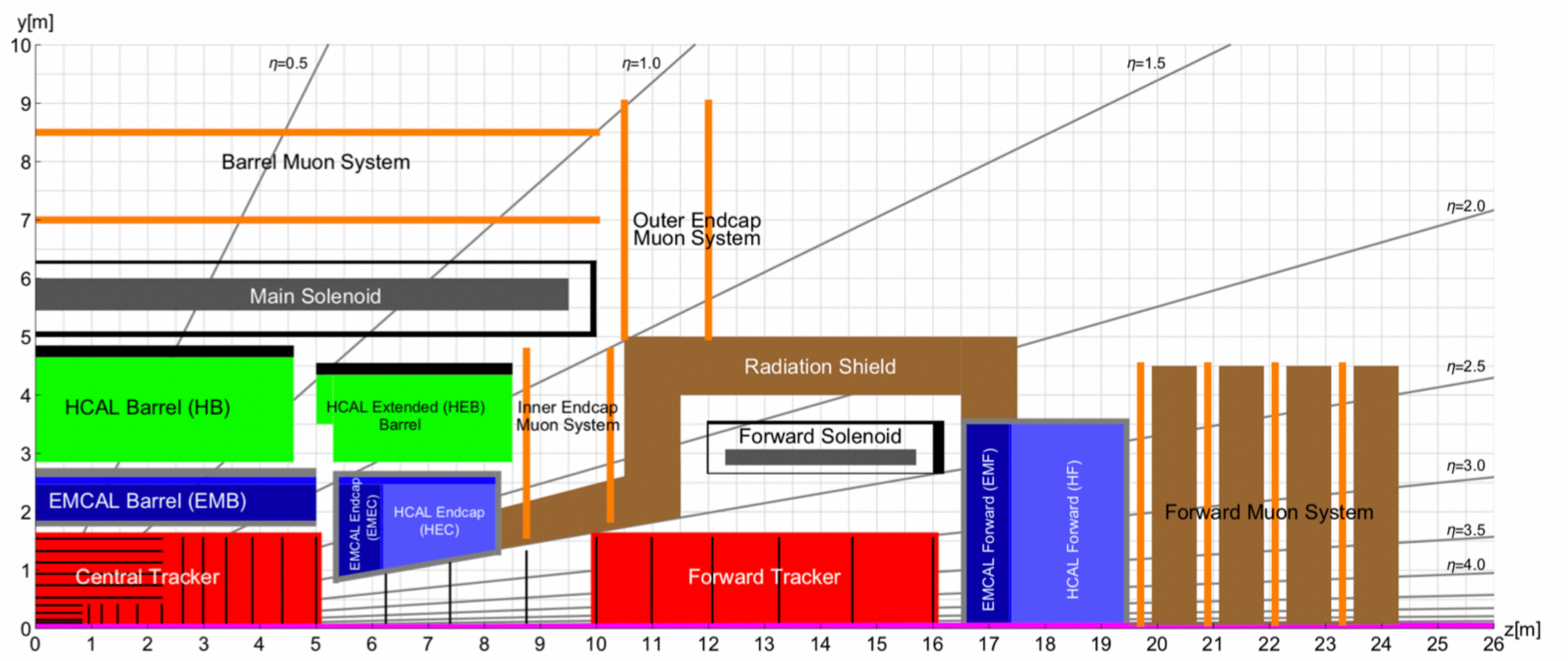
    - precise timing resolution.
    - precise energy measurement resolution.

An example FCC-hh Detector



	R_{min}	R_{max}	z coverage	η coverage	Dose	1 MeV n_{eq} fluence
Unit	m	m	m		MGy	$\times 10^{15}$ cm^{-2}
EMB	1.75	2.75	$\|z\| < 5$	$\|\eta\| < 1.67$	0.1	5
EMEC	0.82–0.96	2.7	$5.3 < \|z\| < 6.05$	$1.48 < \|\eta\| < 2.50$	1	30
EMF	0.062–0.065	3.6	$16.5 < \|z\| < 17.15$	$2.26 < \|\eta\| < 6.0$	5000	5000
HB	2.85	4.89	$\|z\| < 4.6$	$\|\eta\| < 1.26$	0.006	0.3
HEB	2.85	4.59	$4.5 < \|z\| < 8.3$	$0.94 < \|\eta\| < 1.81$	0.008	0.3
HEC	0.96-1.32	2.7	$6.05 < \|z\| < 8.3$	$1.59 < \|\eta\| < 2.50$	1	20
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Calorimeters for the FCC-hh, M. Aleksa et al. CERN-FCC-PHYS- 2019-0003, 23 December 2019

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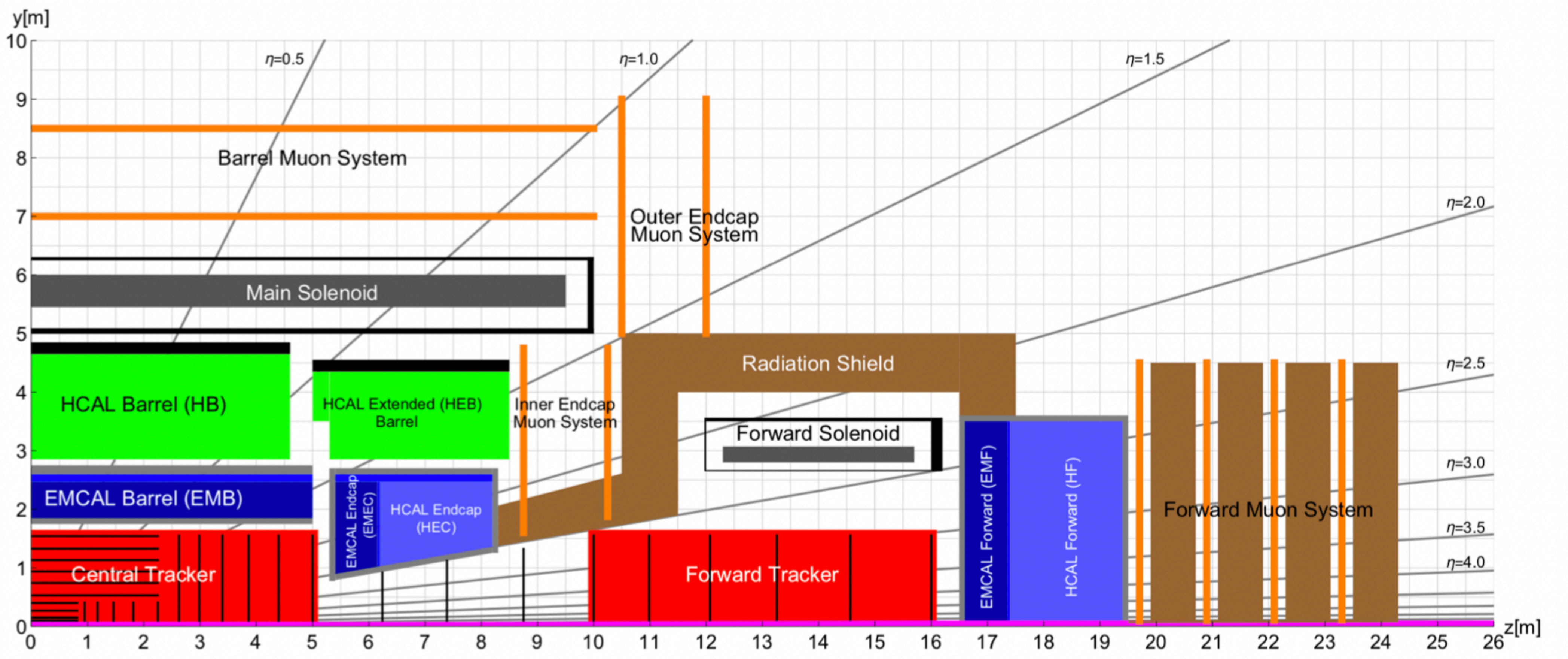

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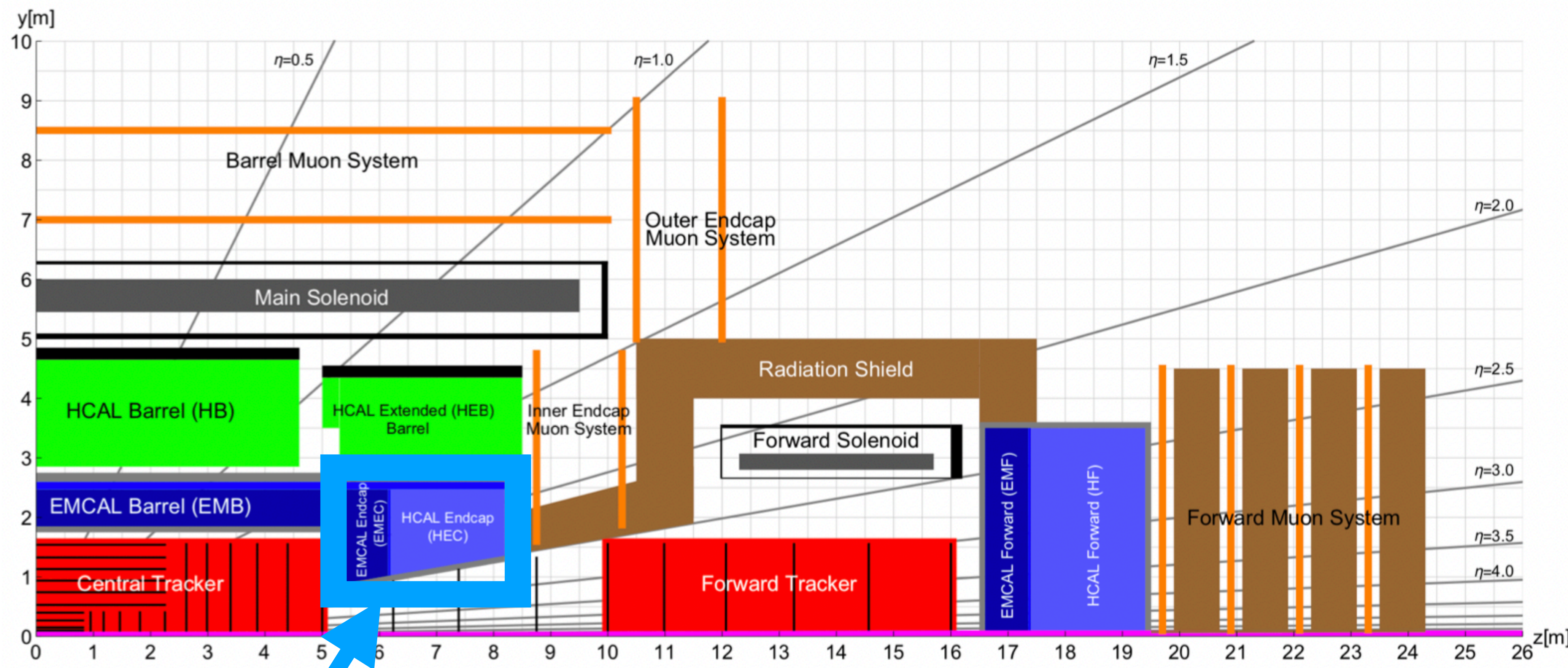

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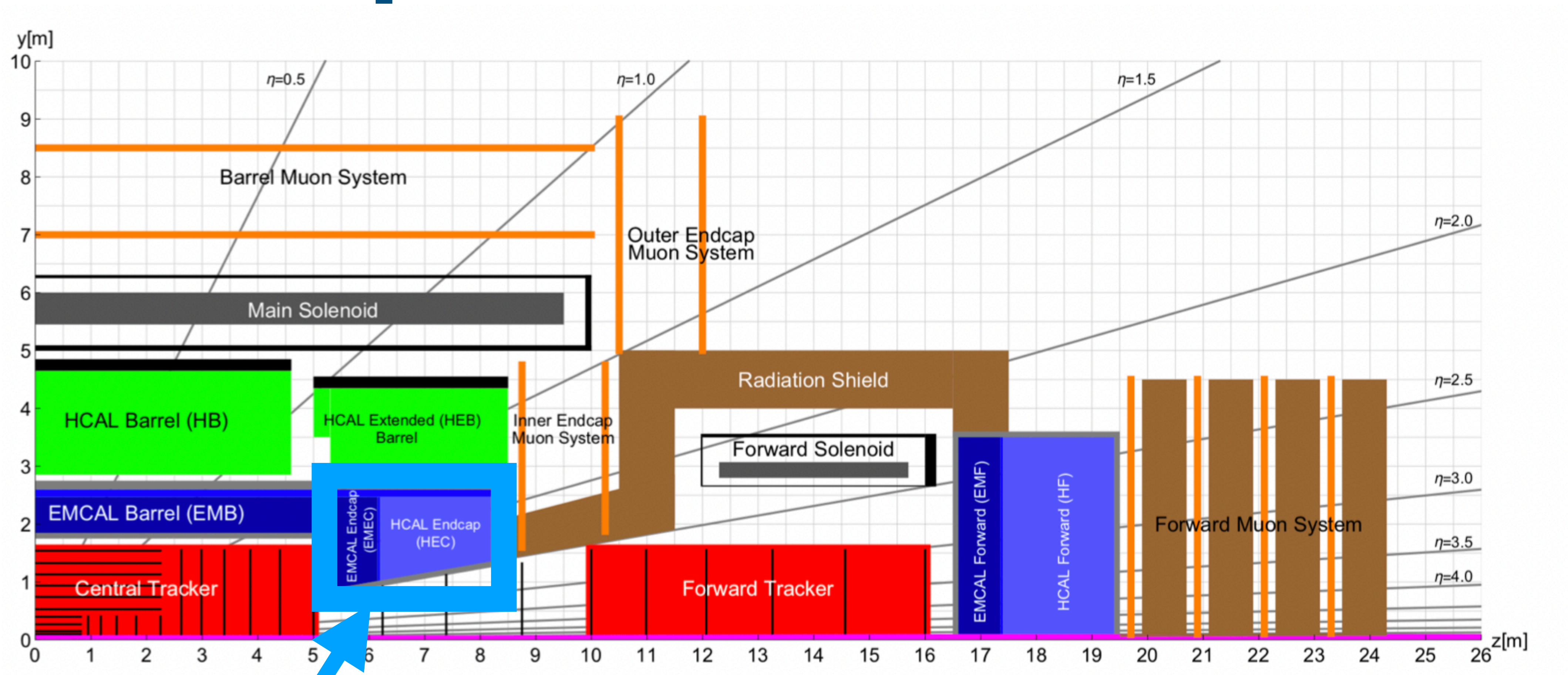

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  - Hence: the sampling calorimeter or Shashlik.

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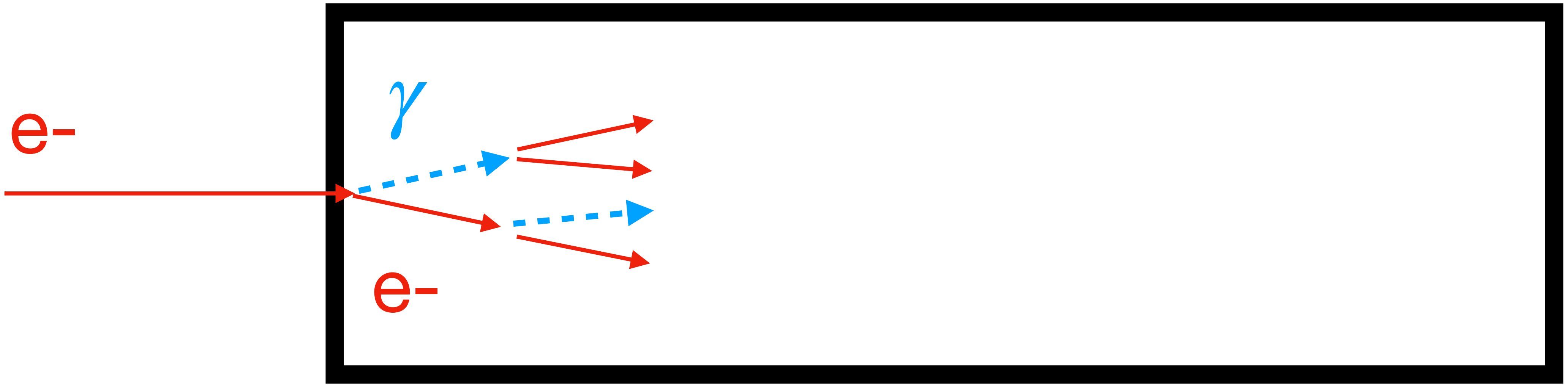

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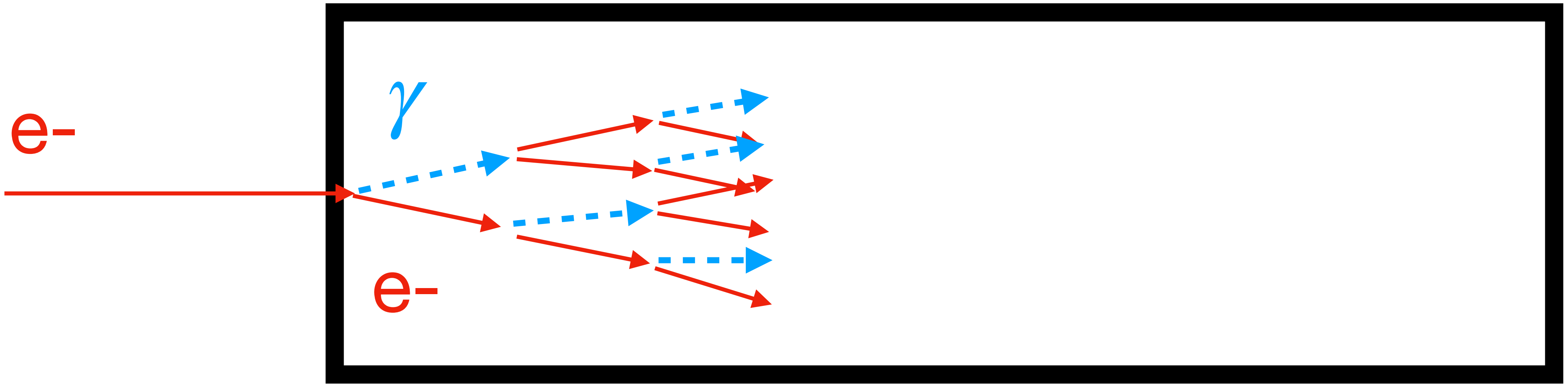

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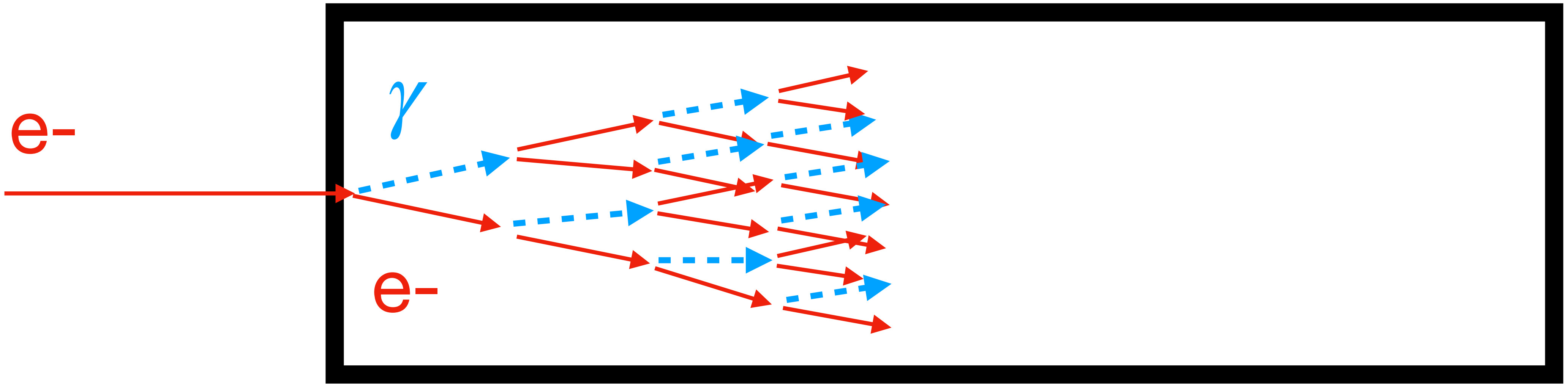

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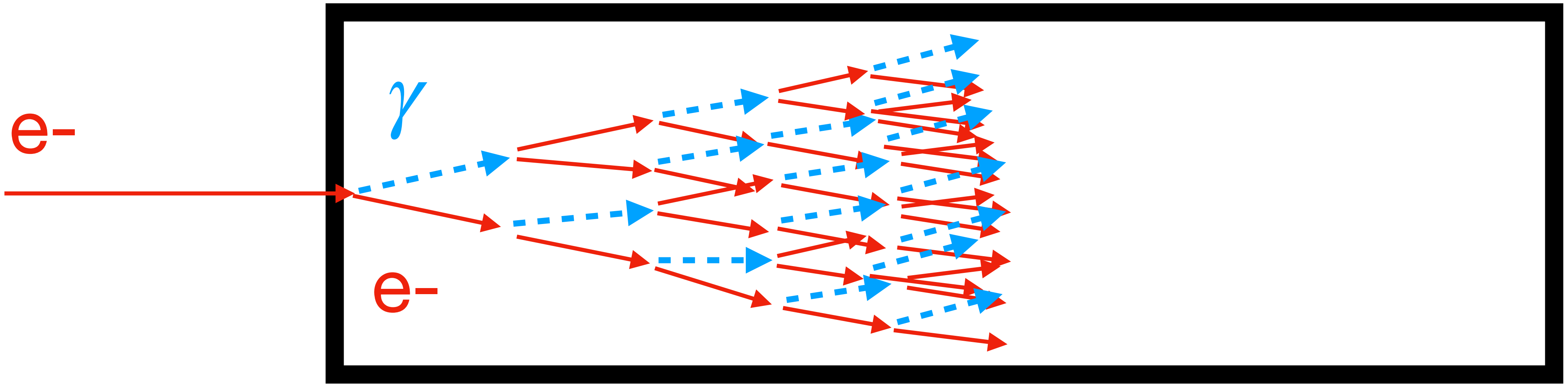

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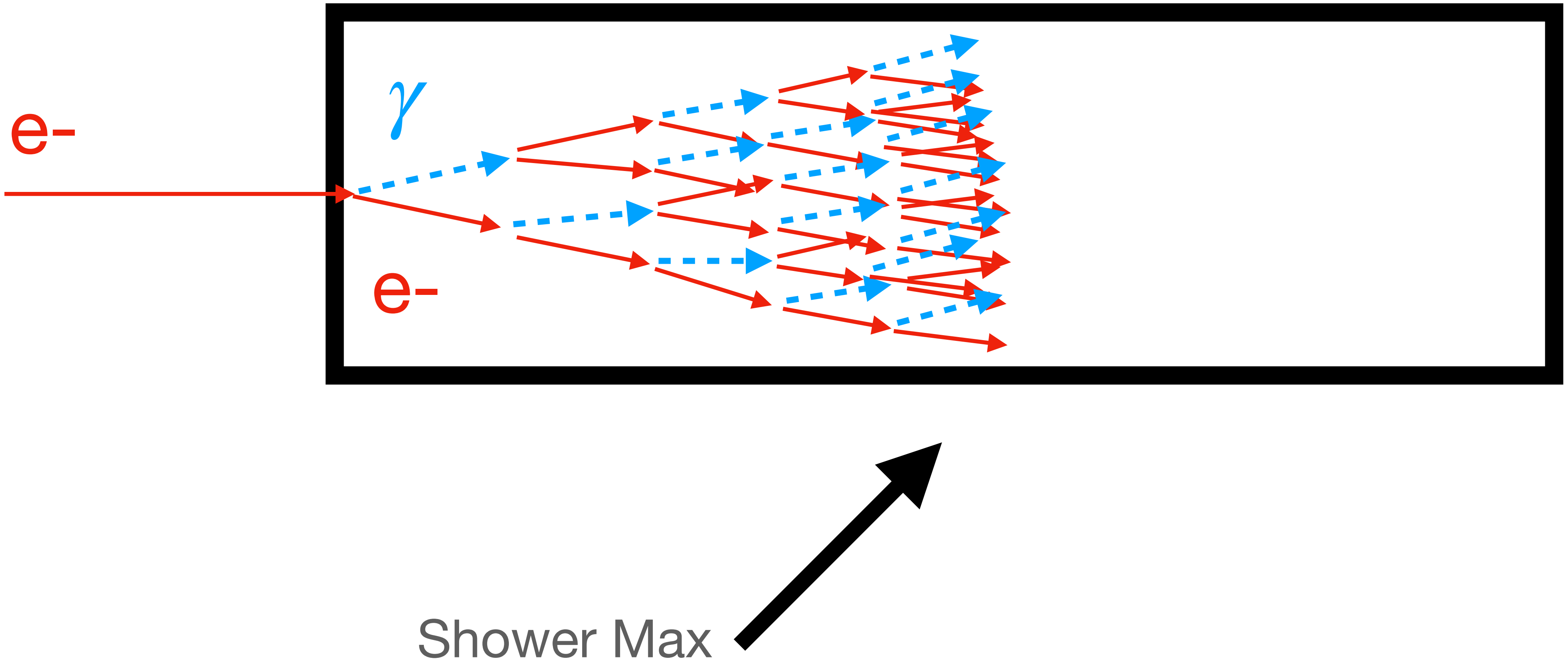

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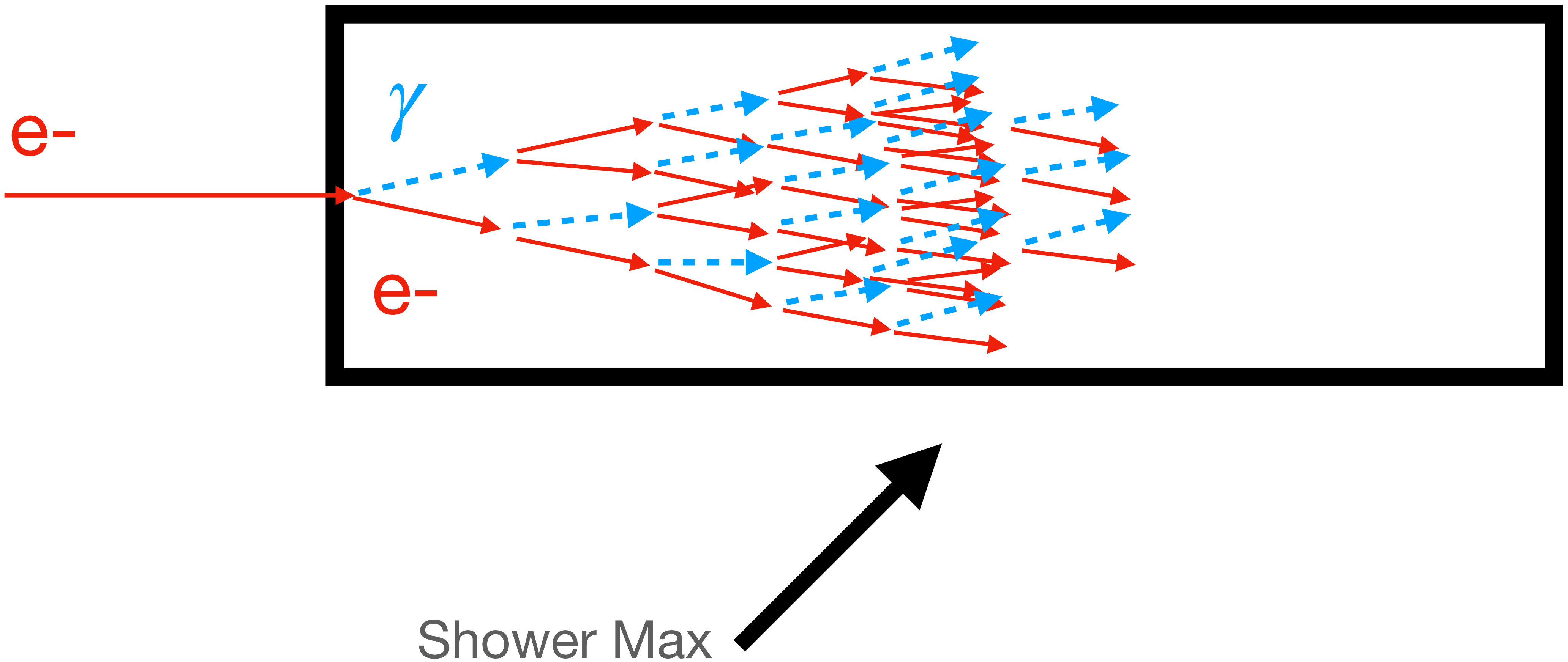

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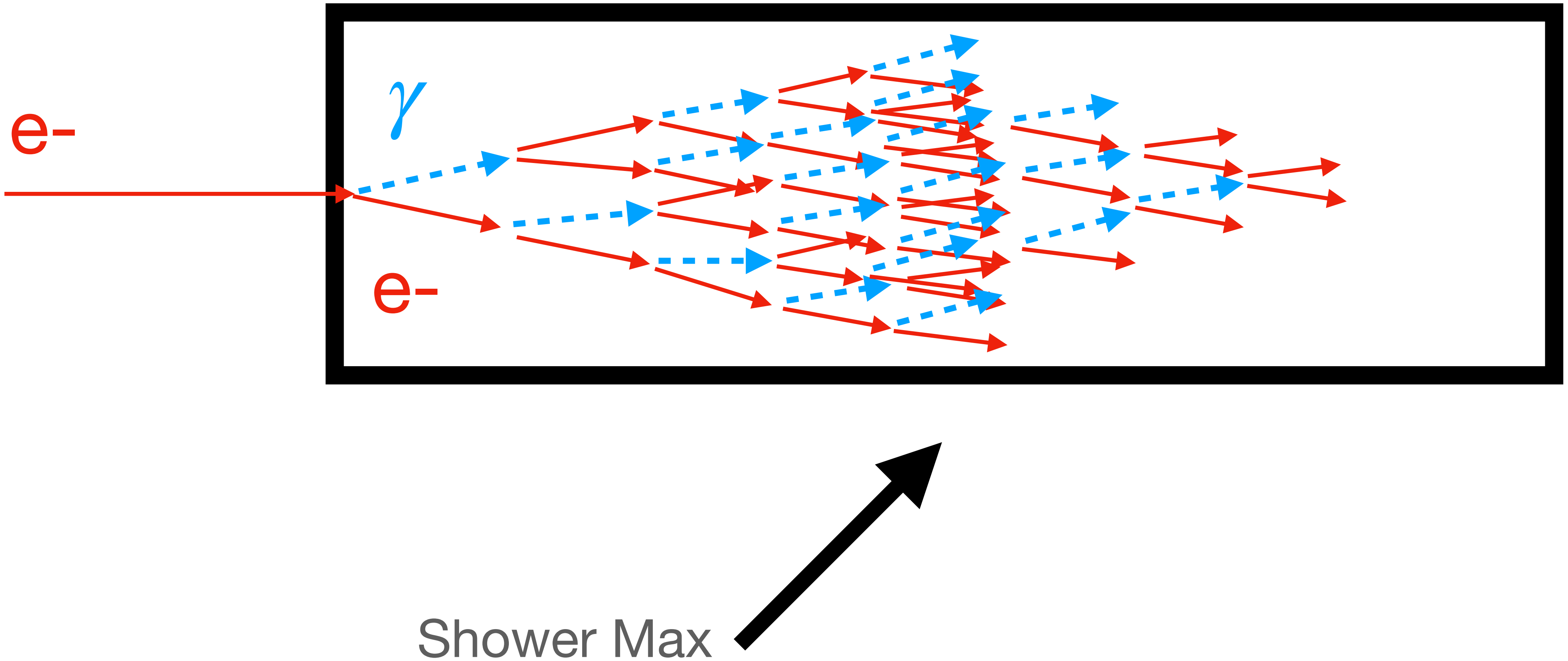

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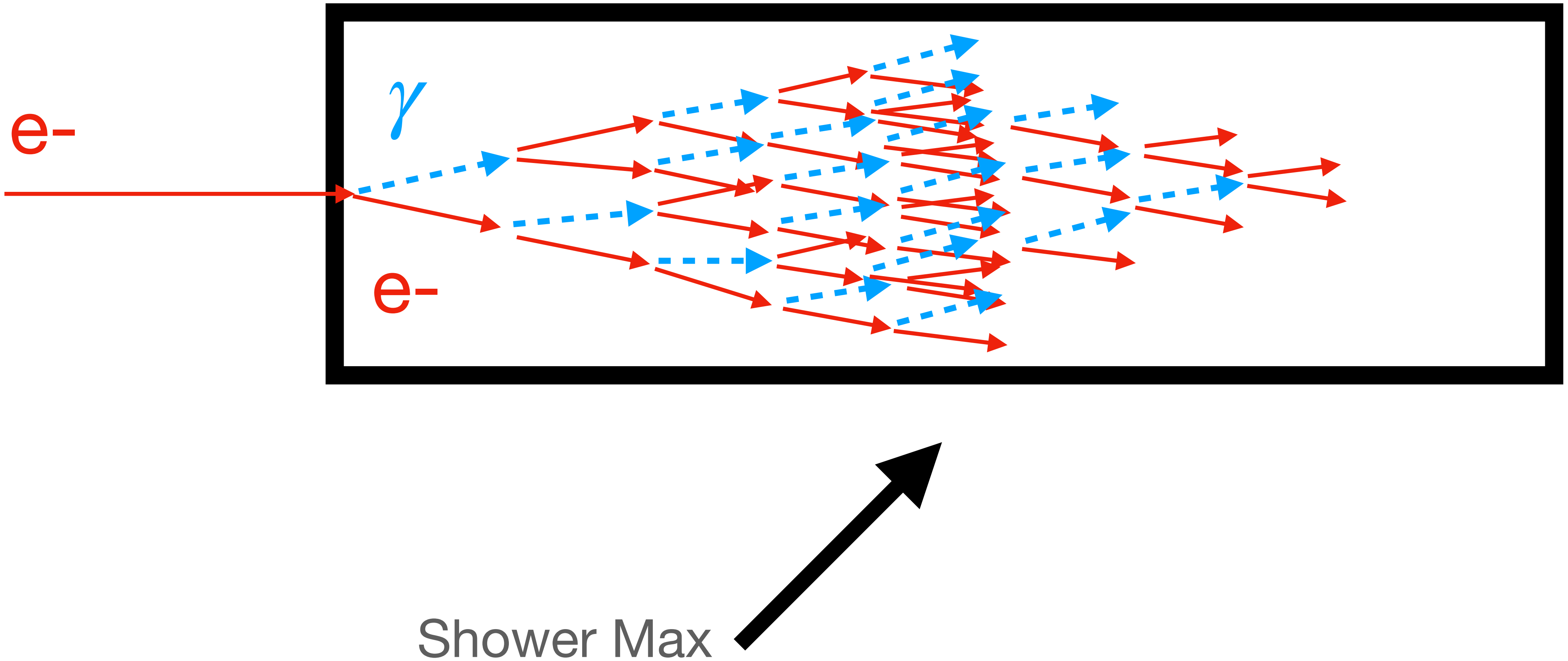

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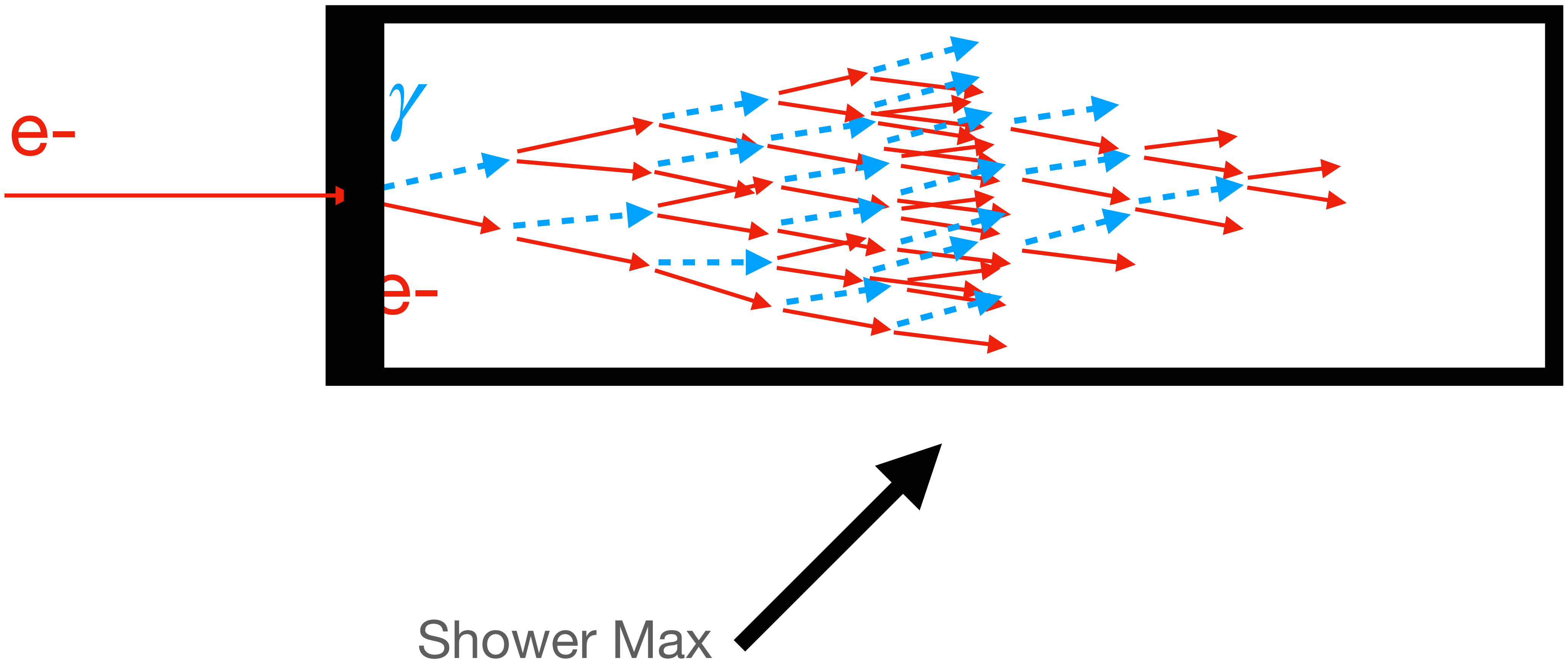

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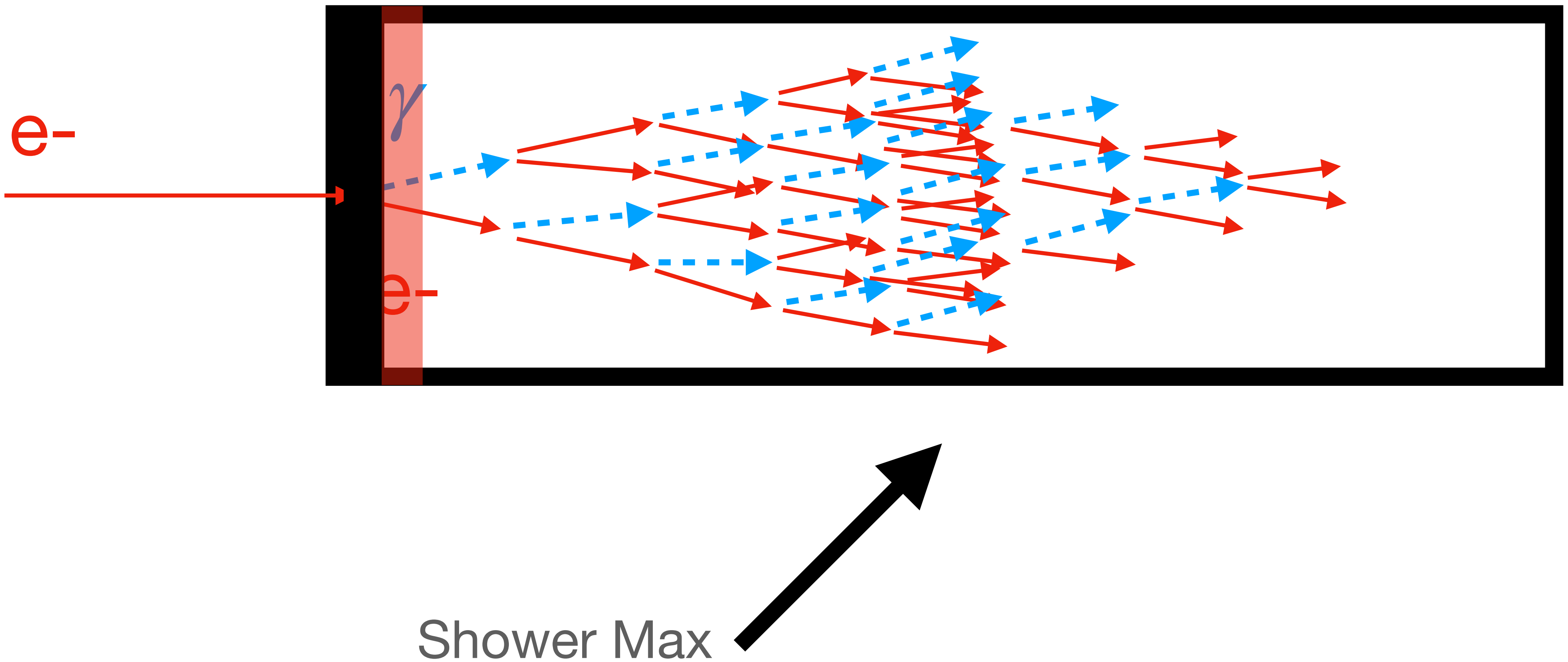

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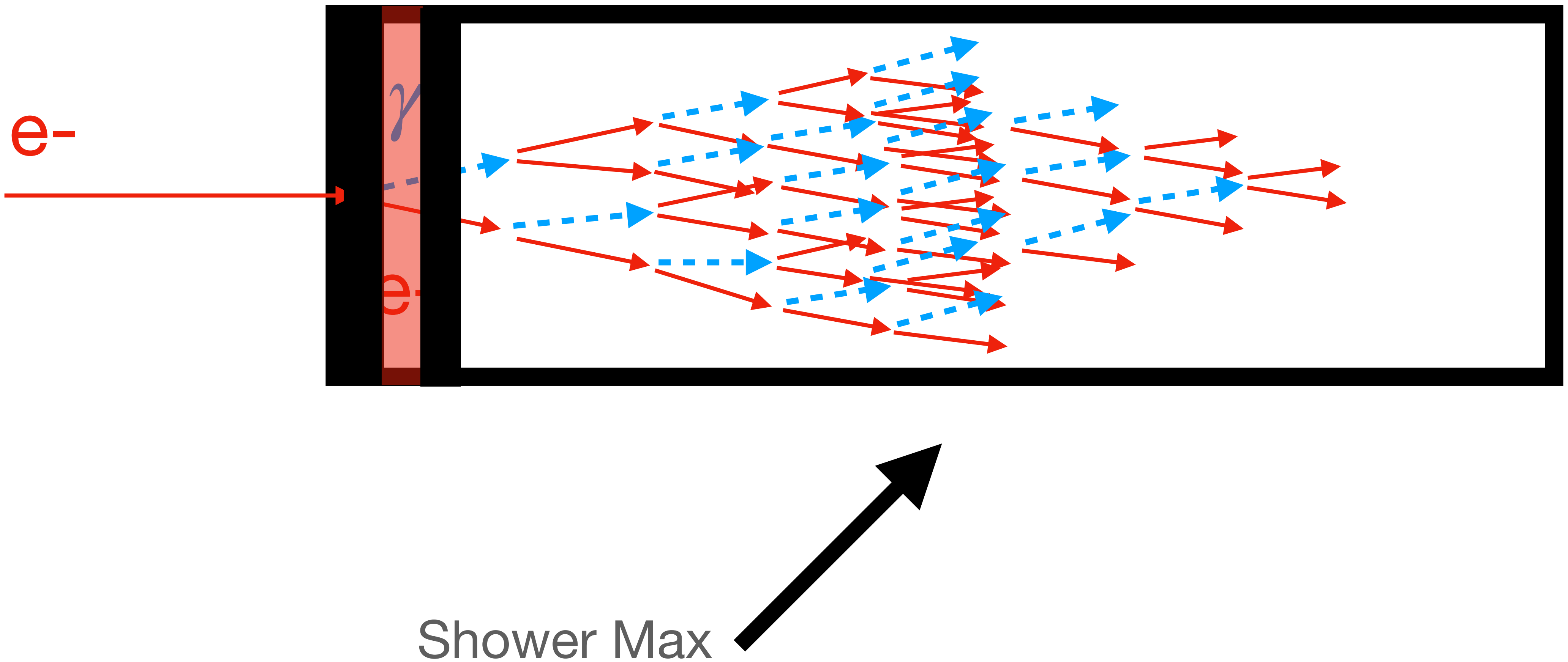

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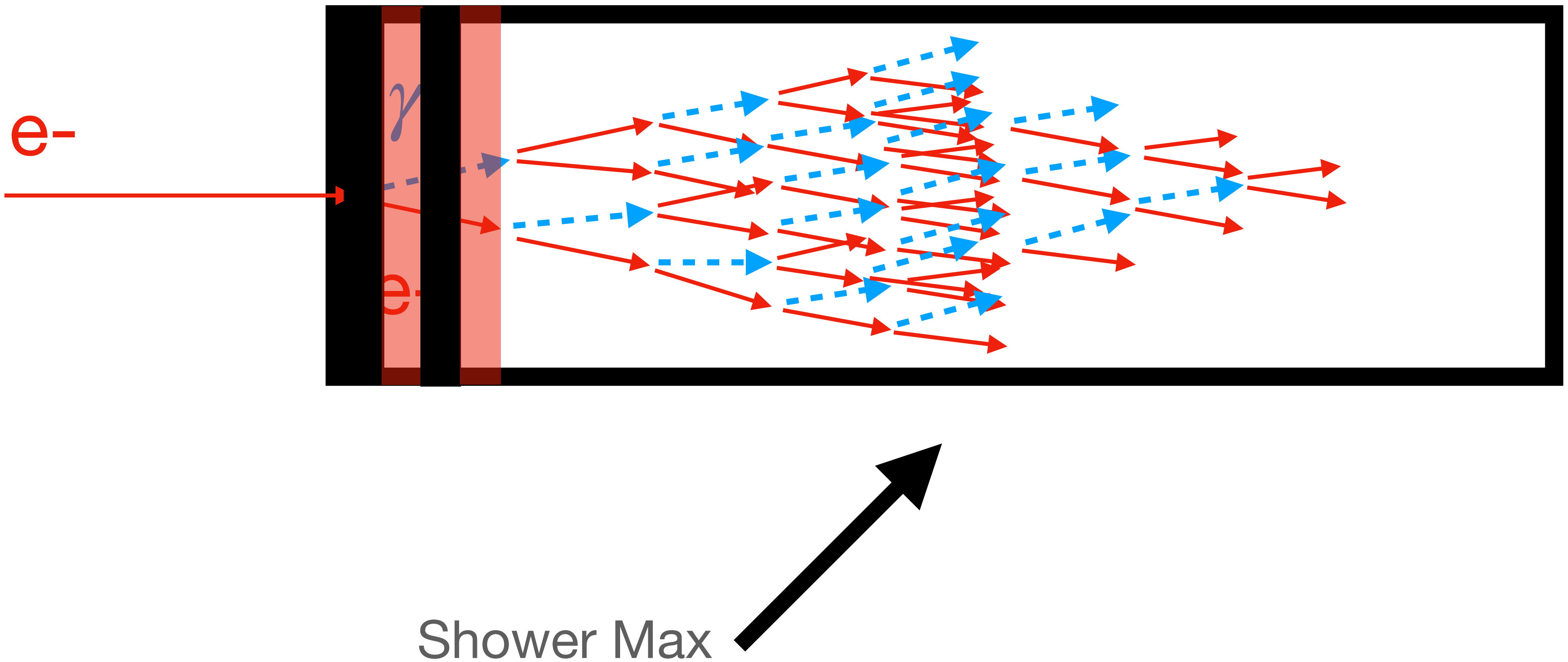

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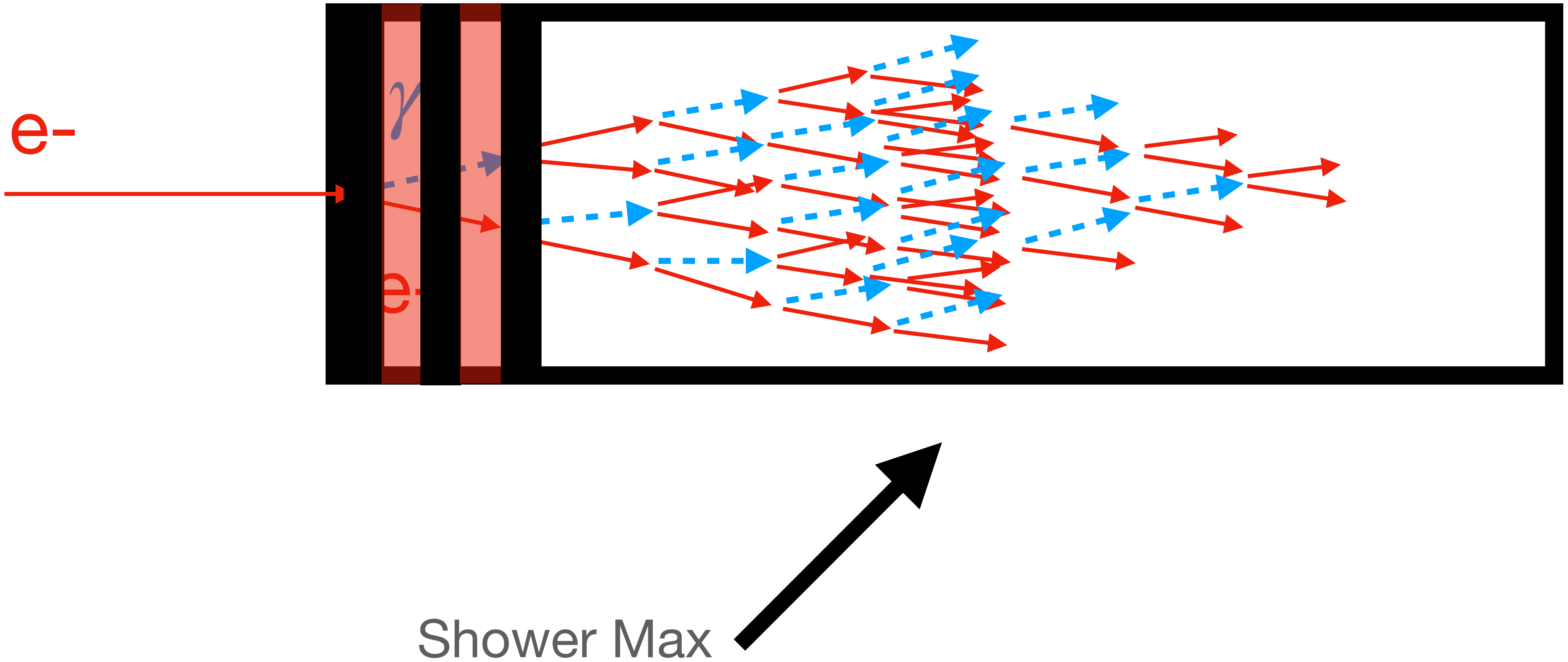

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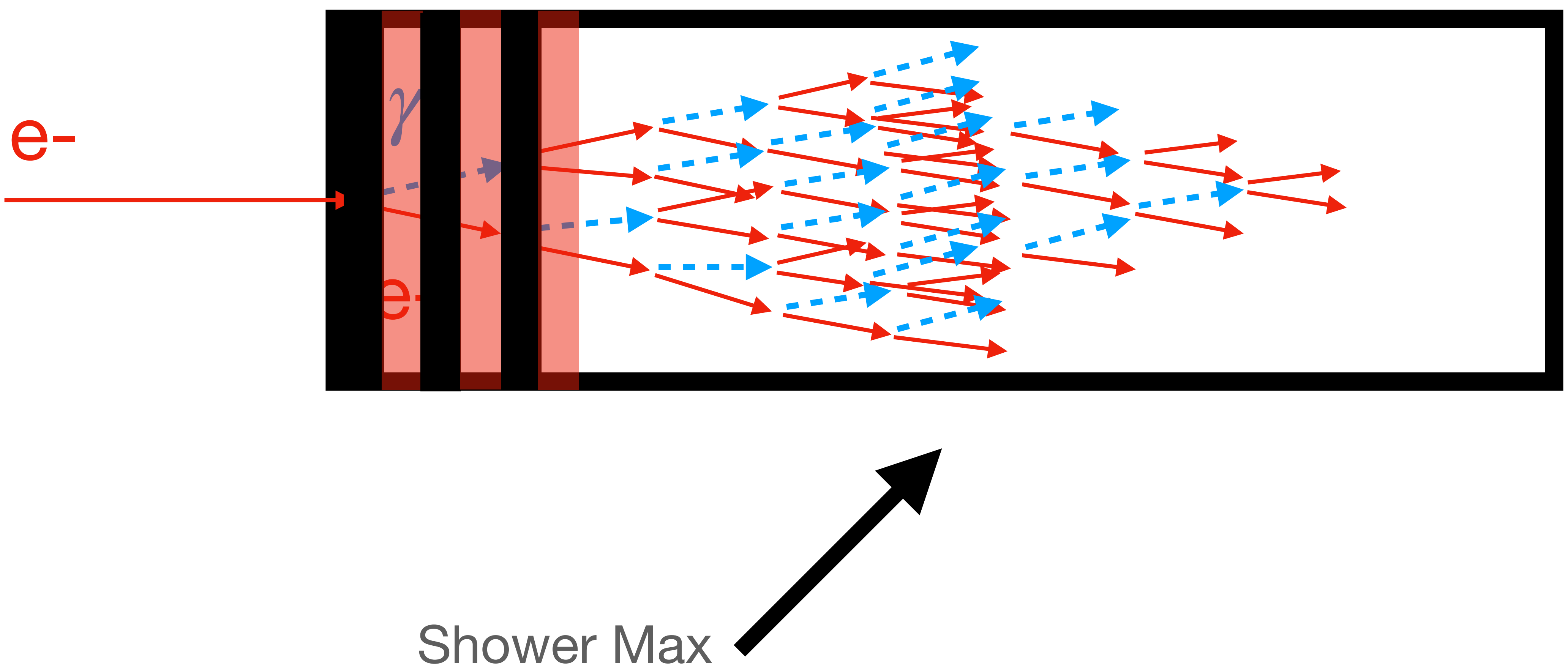

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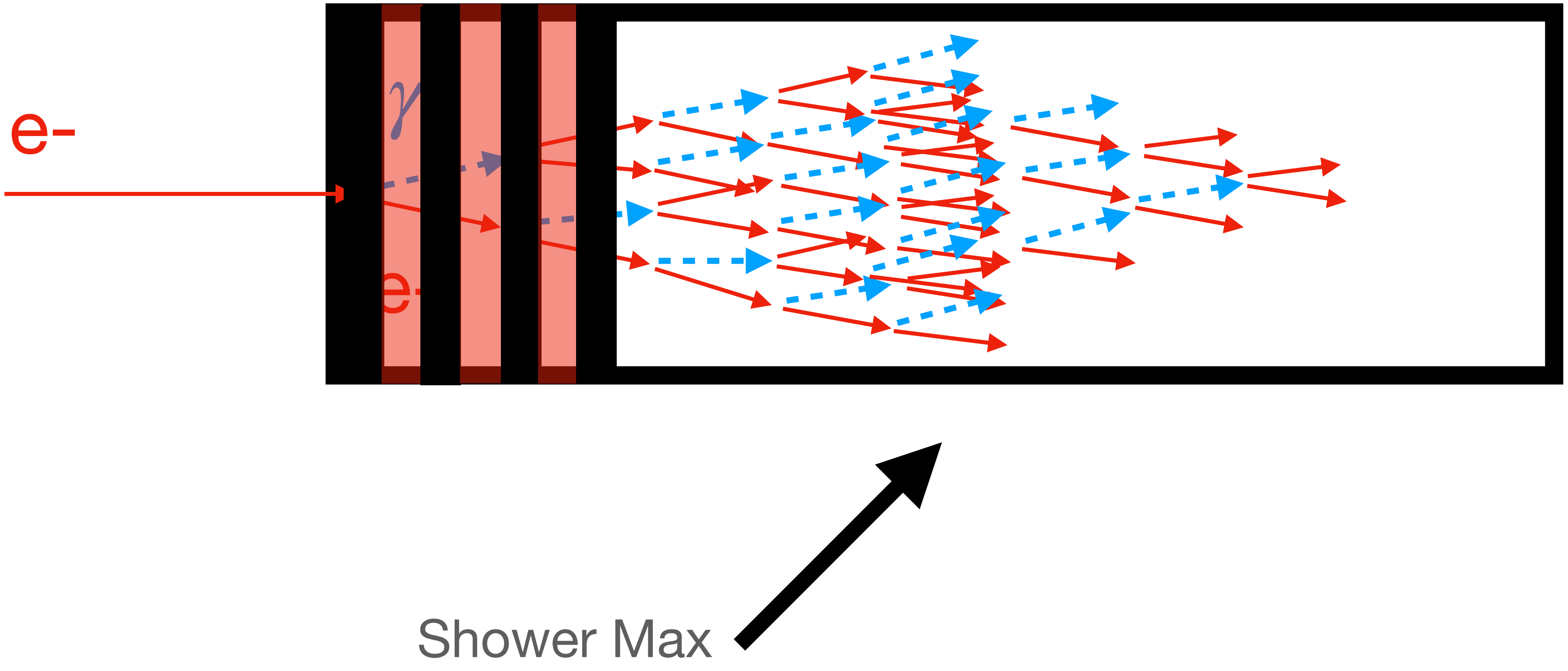

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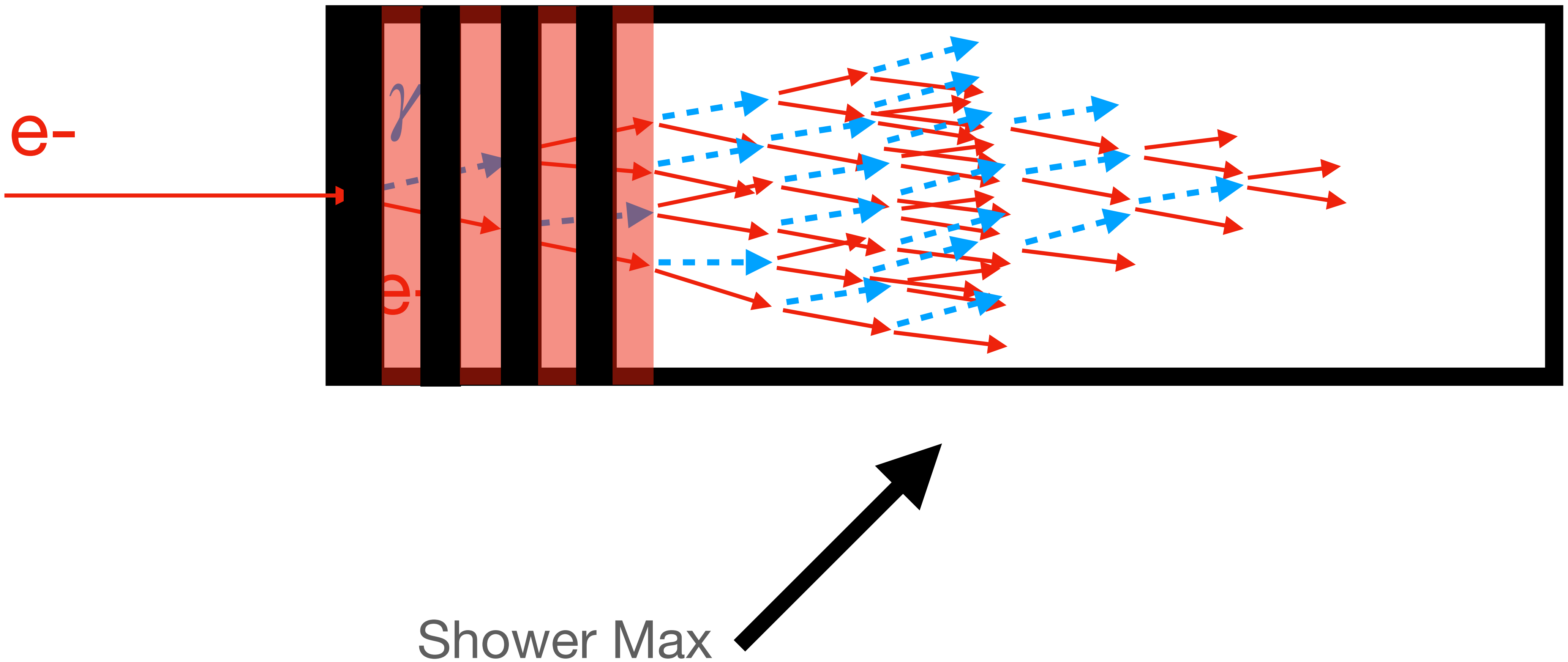

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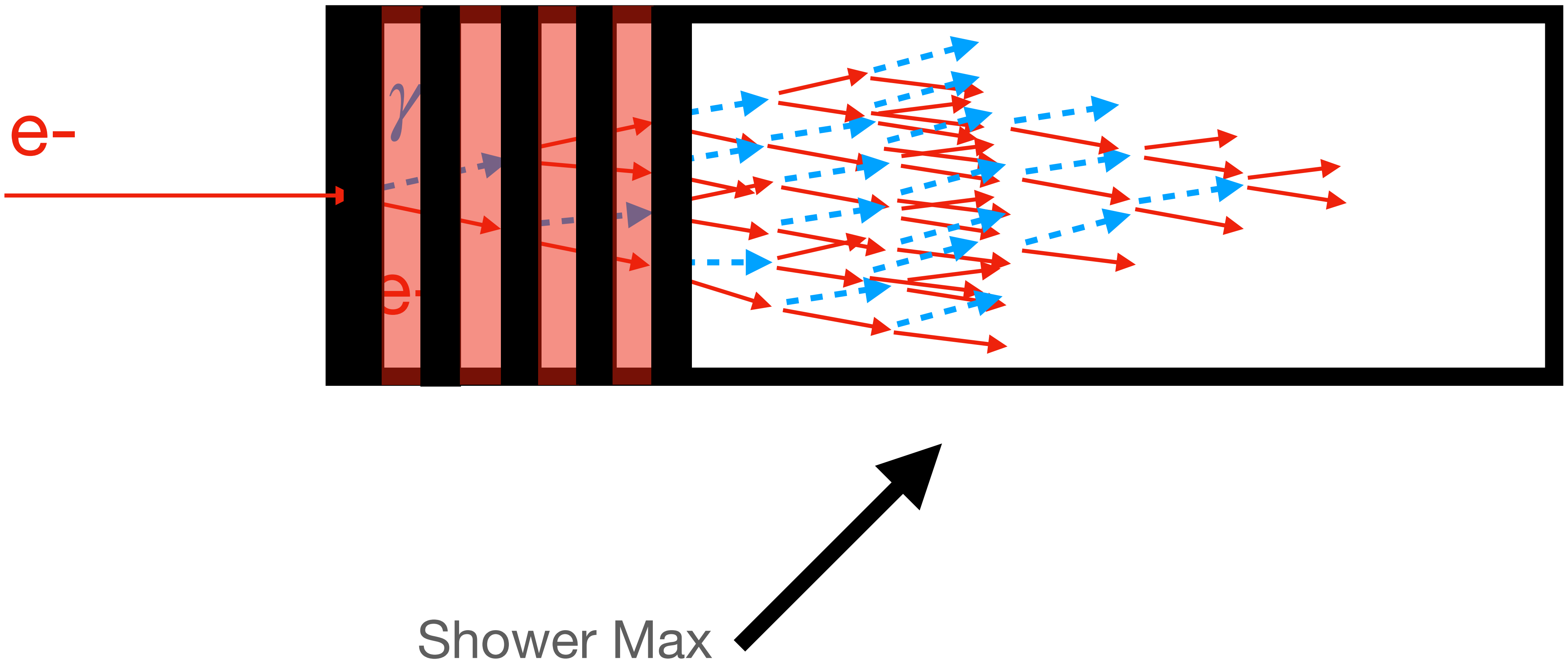

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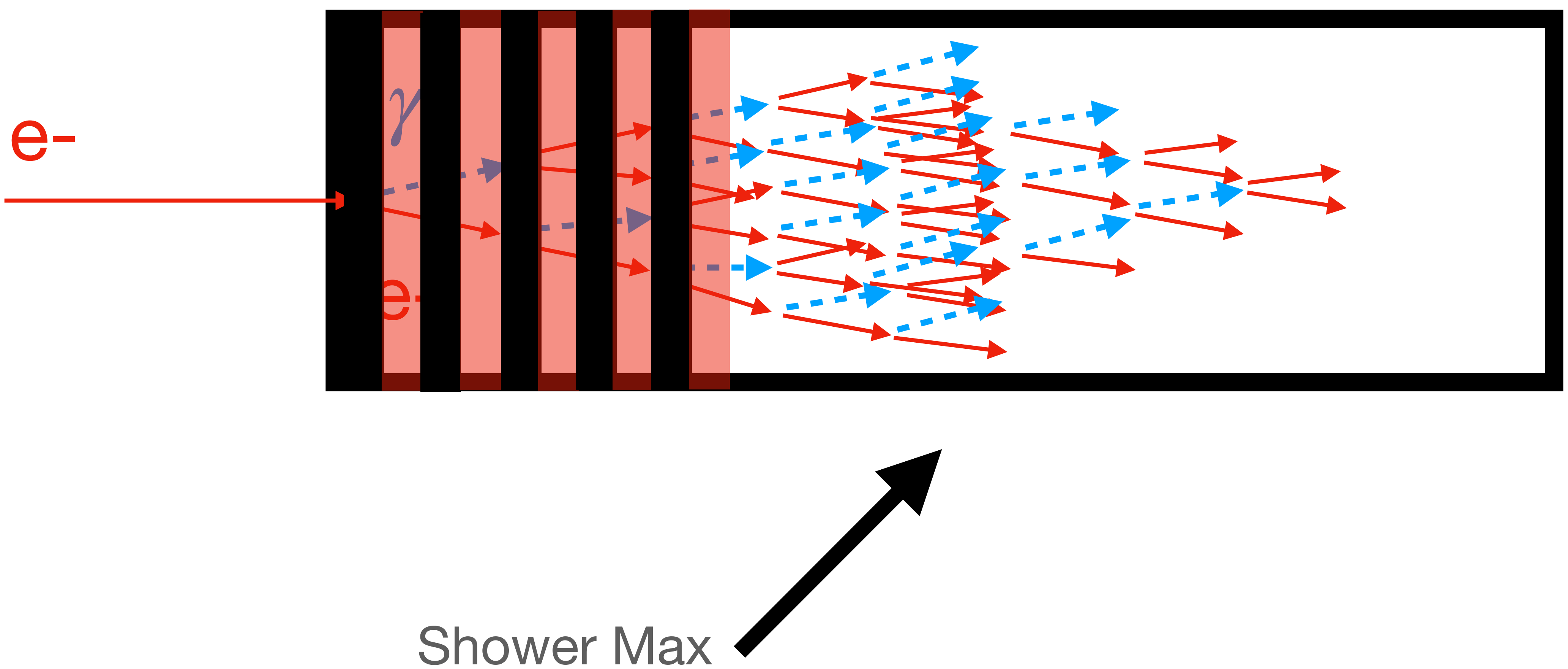

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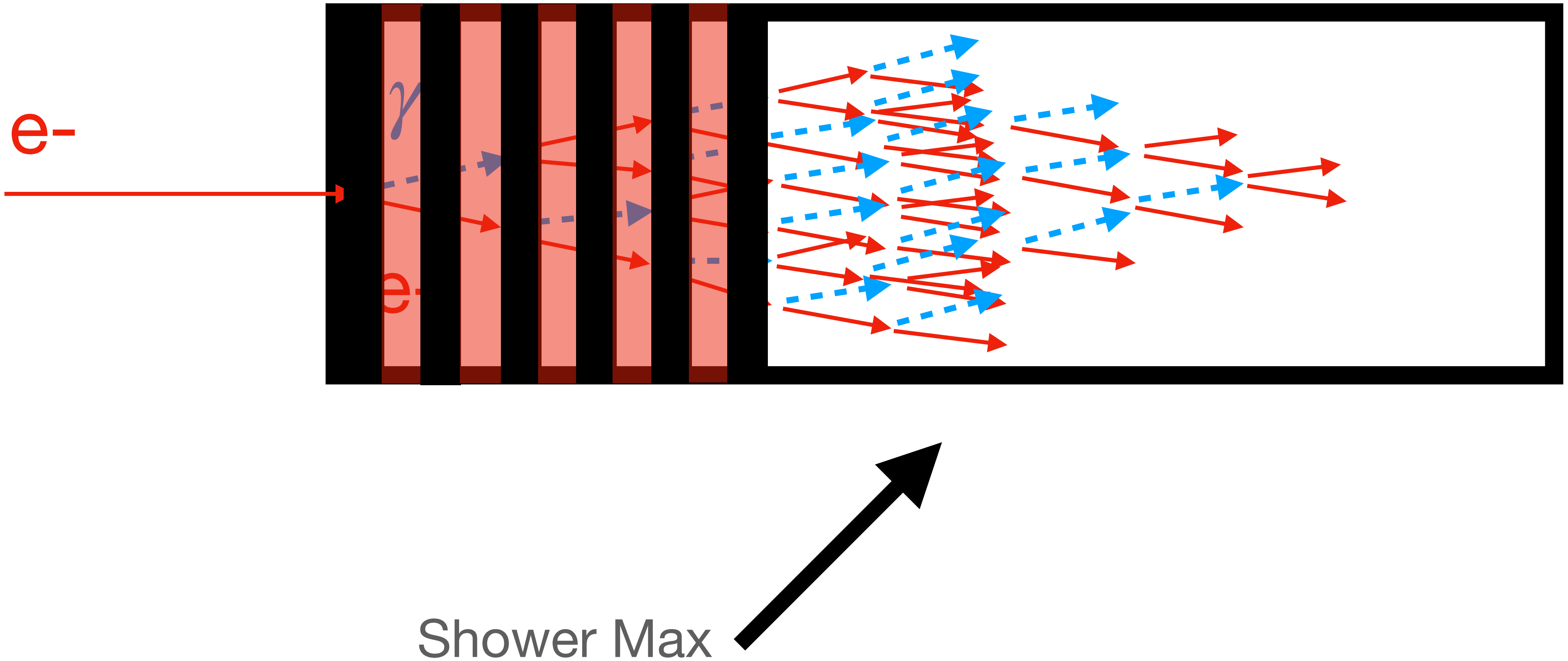

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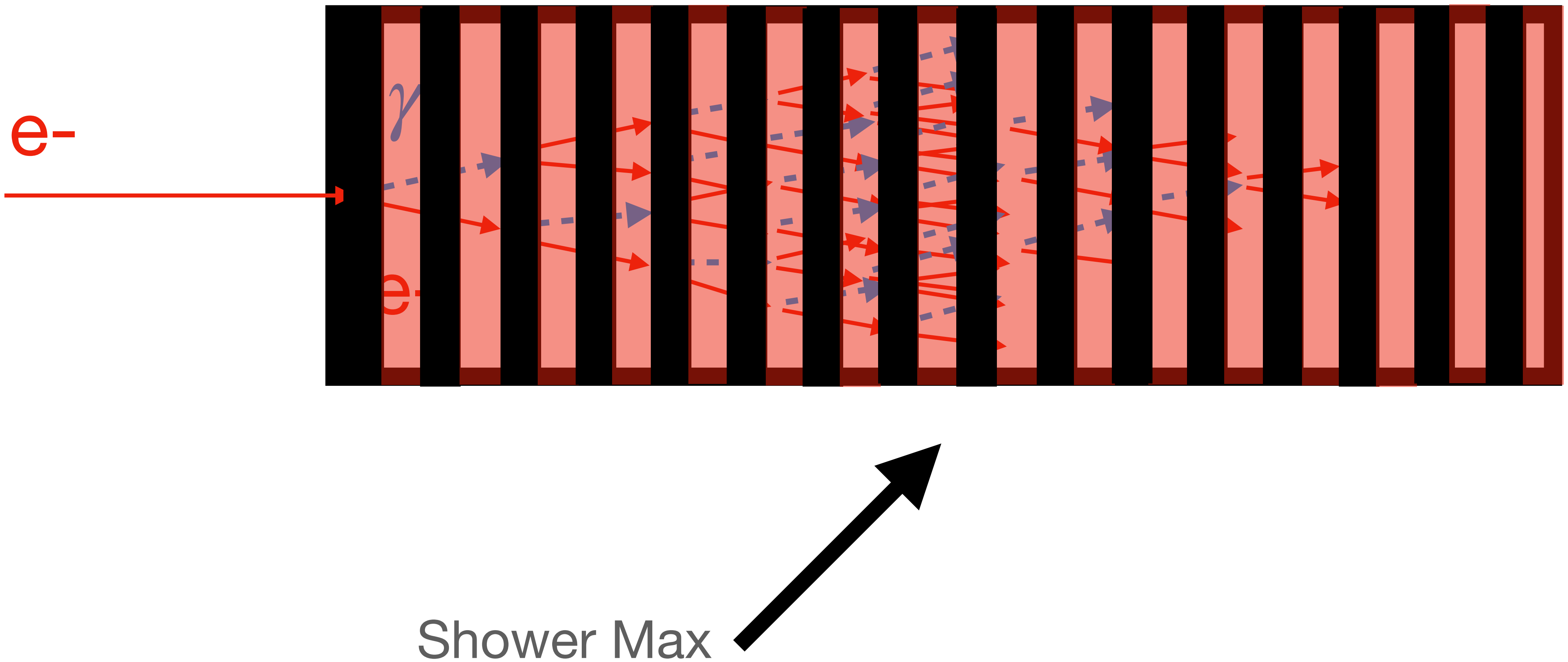

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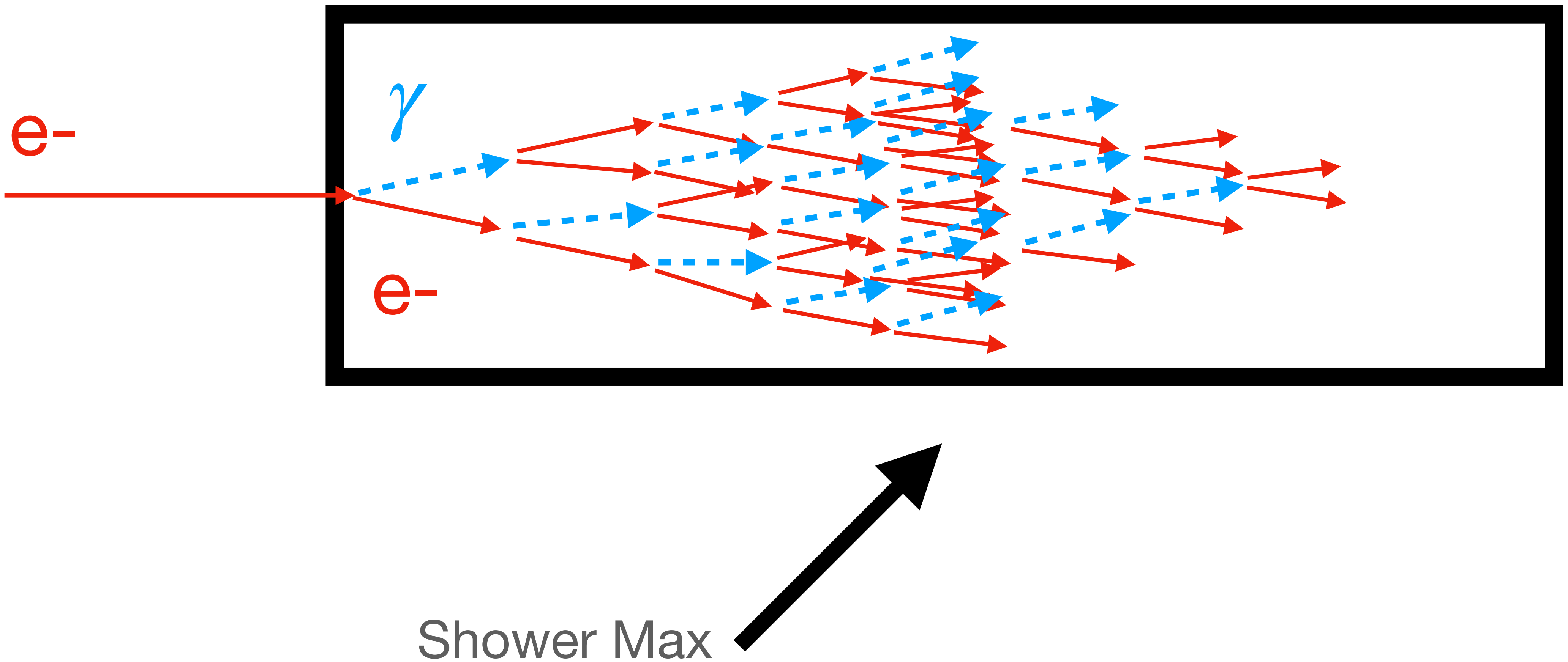
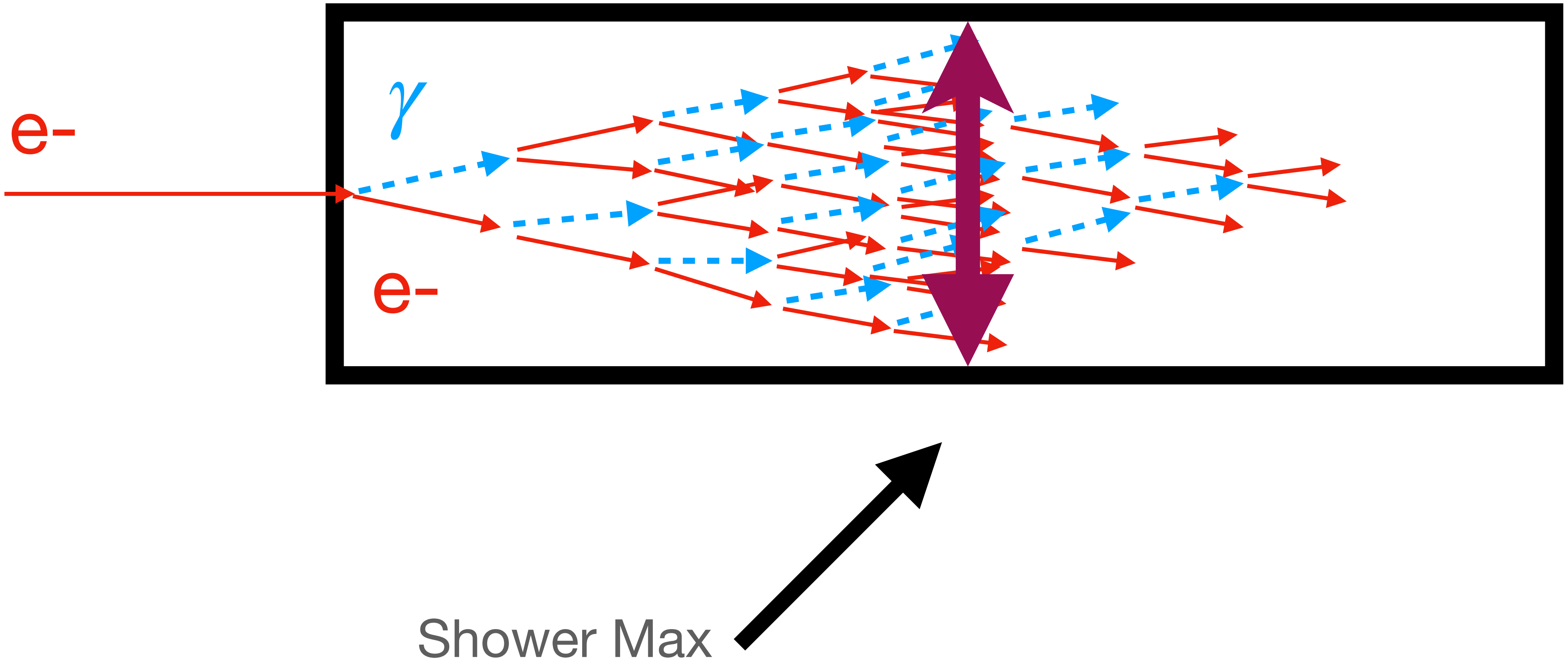


Calorimetry in a Nutshell

- Radial size at shower max is called the <u>Molière Radius</u>



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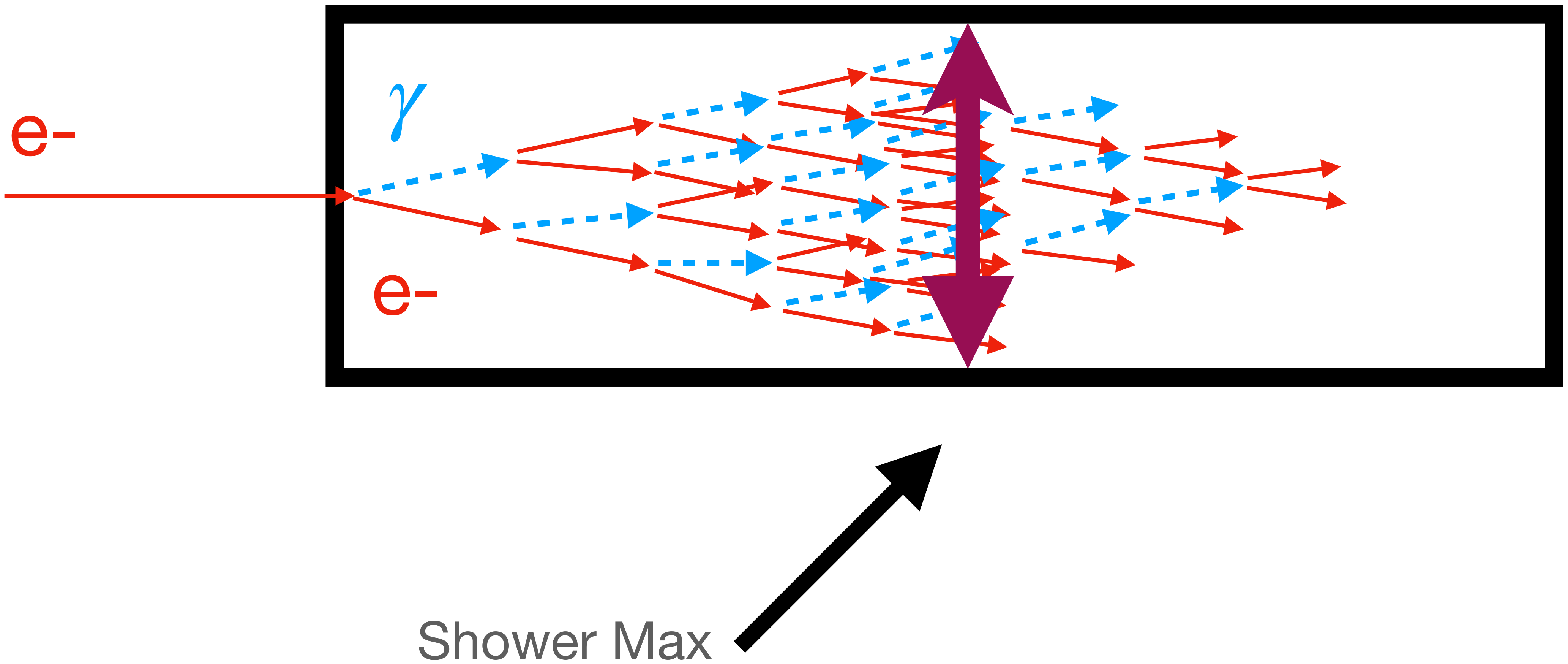
- Molière radius is material dependent



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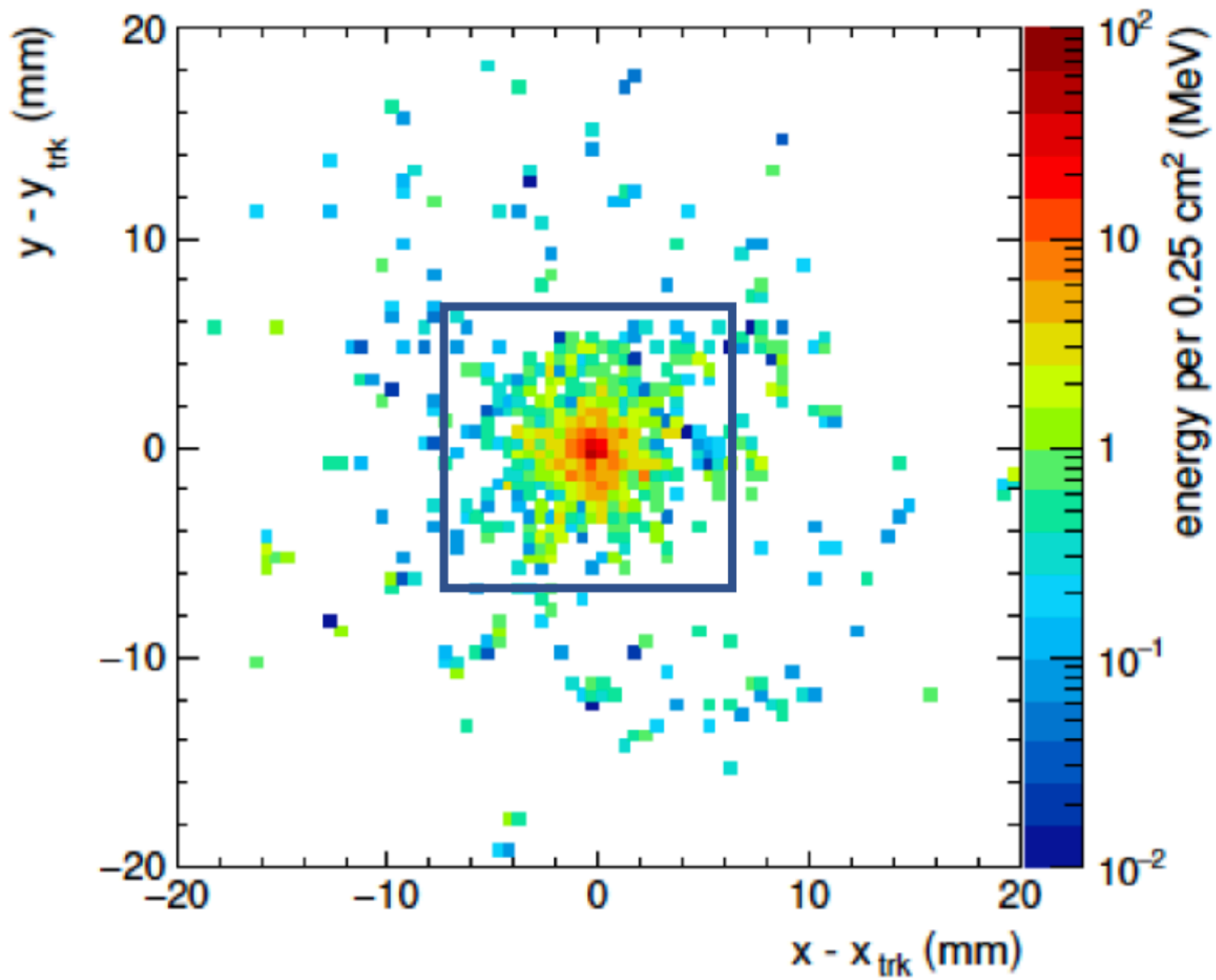

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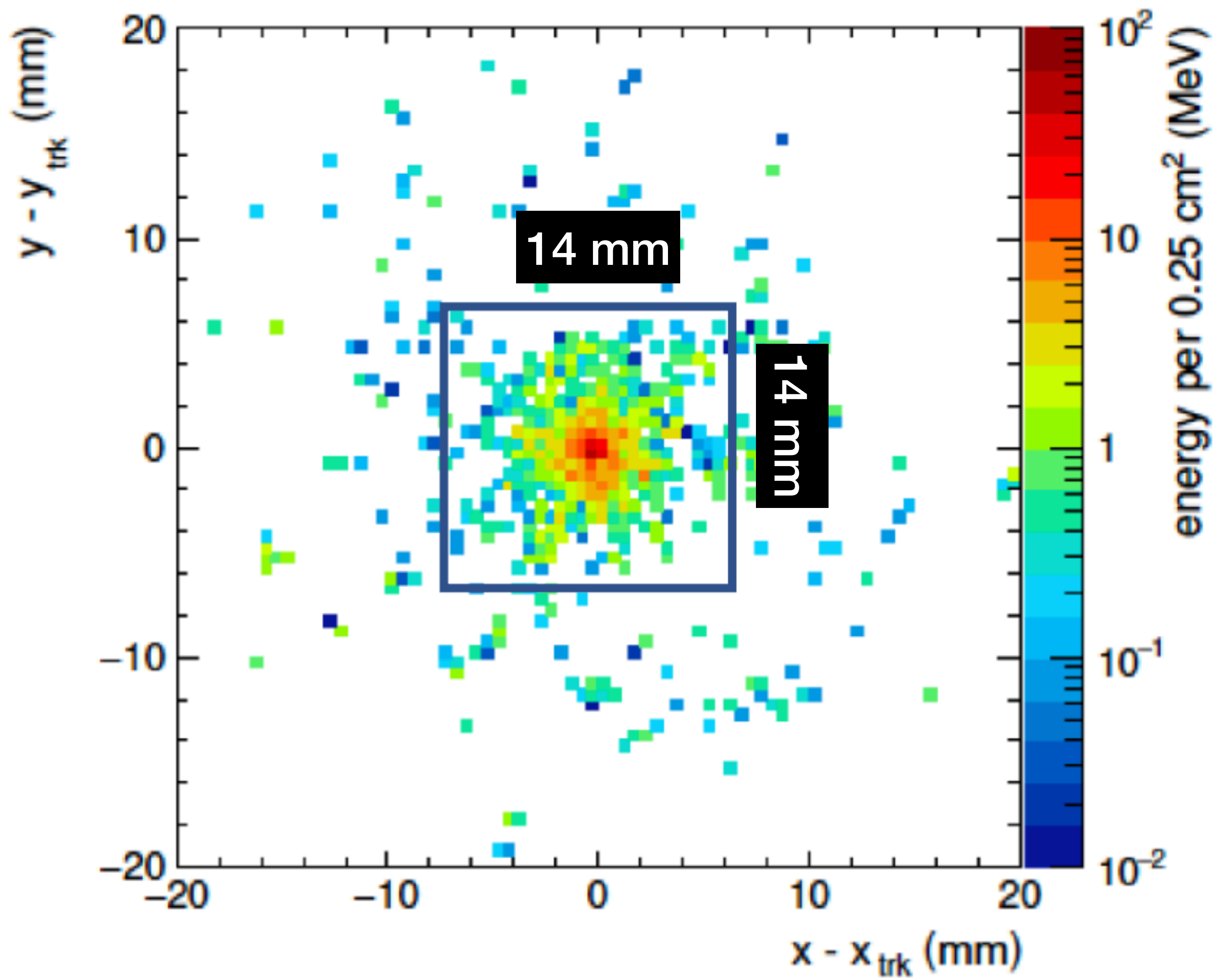

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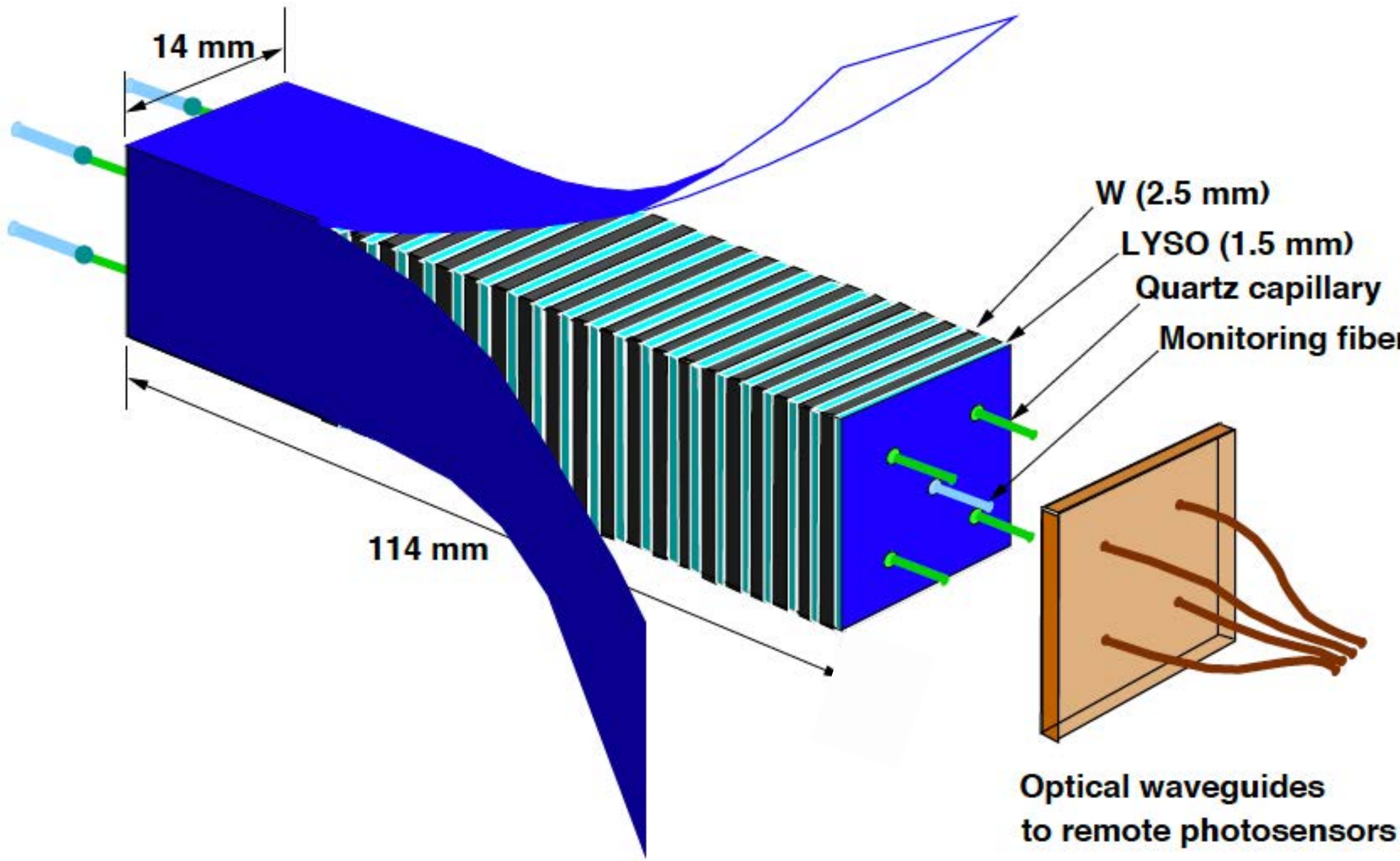

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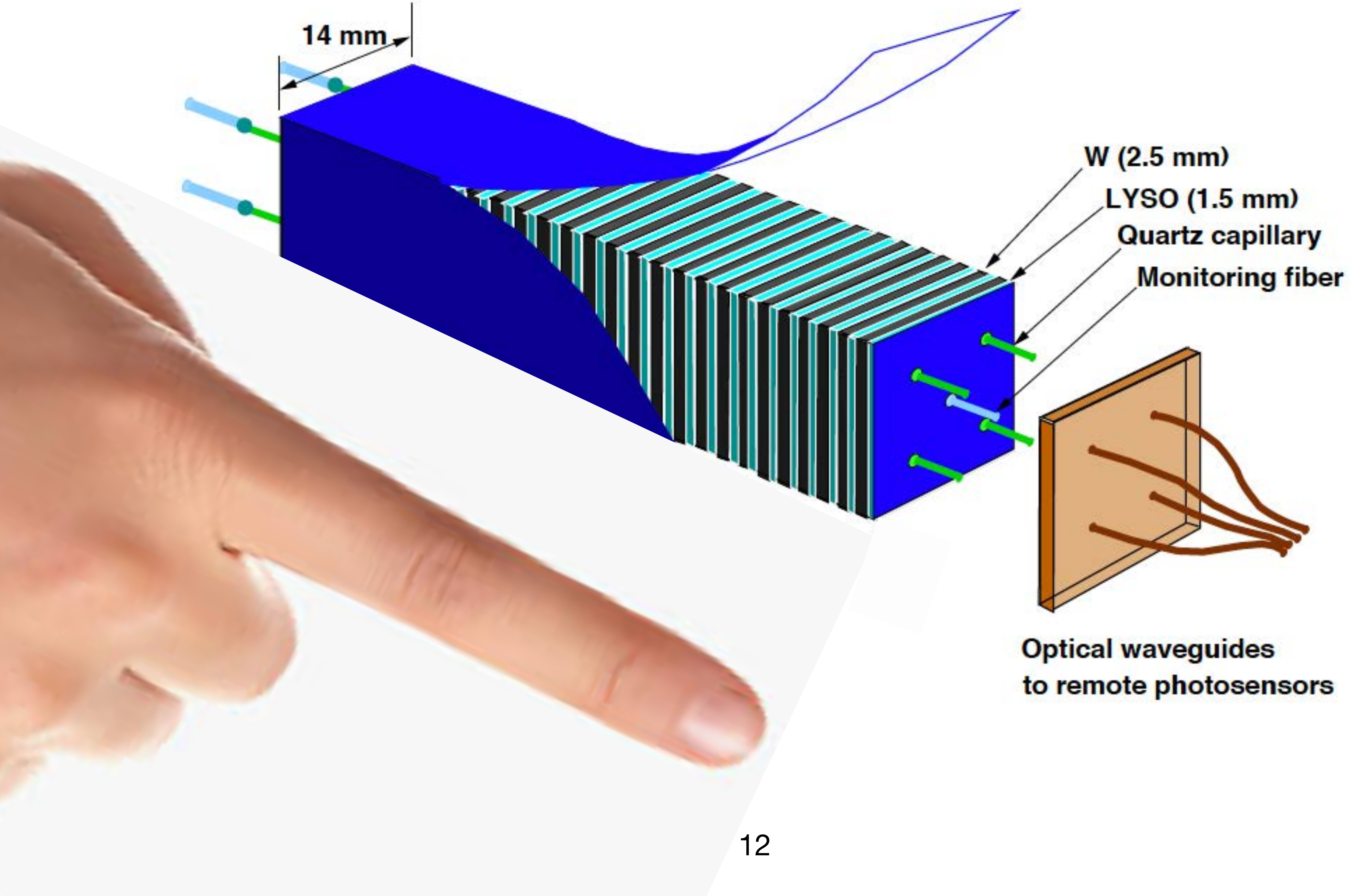

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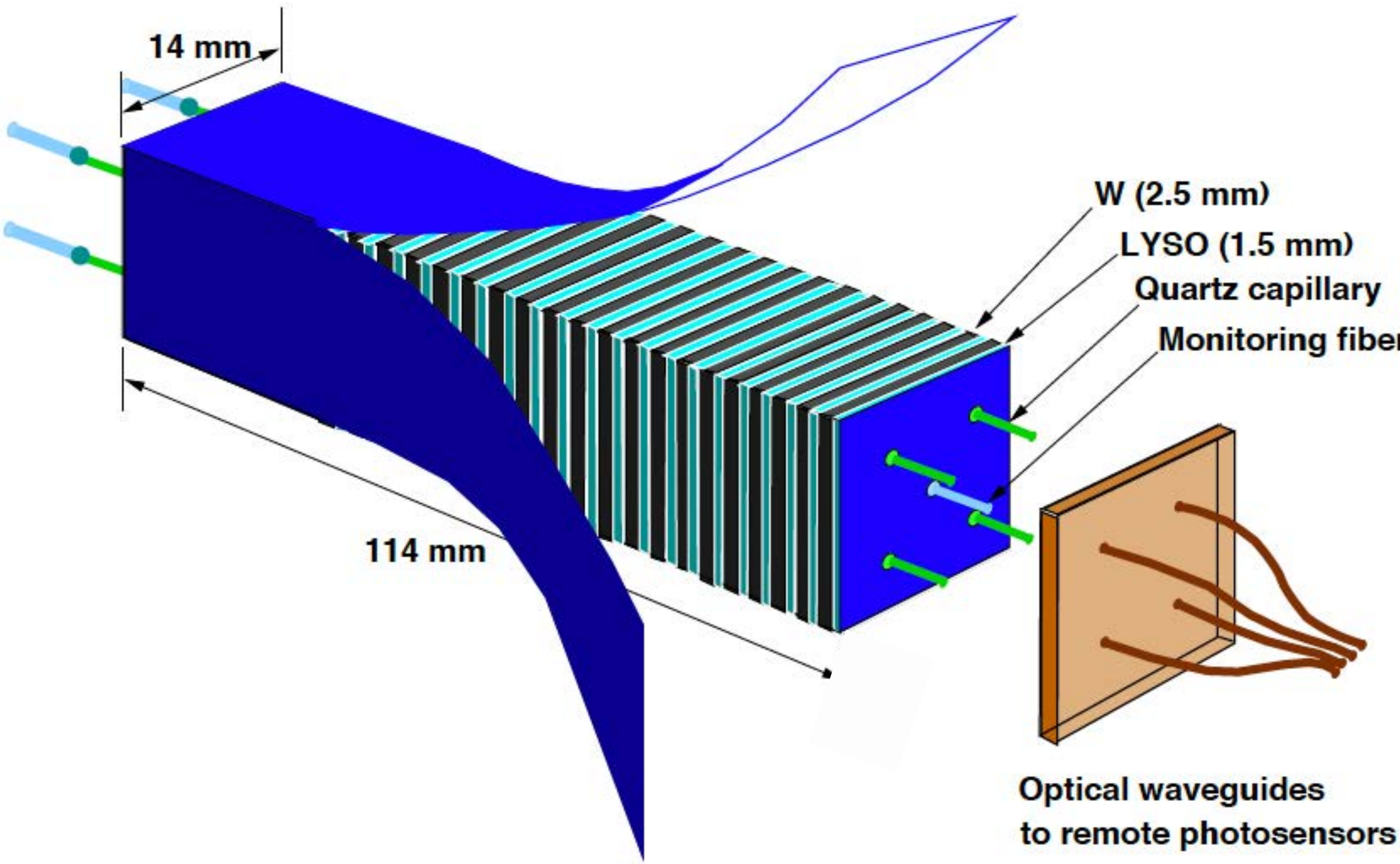

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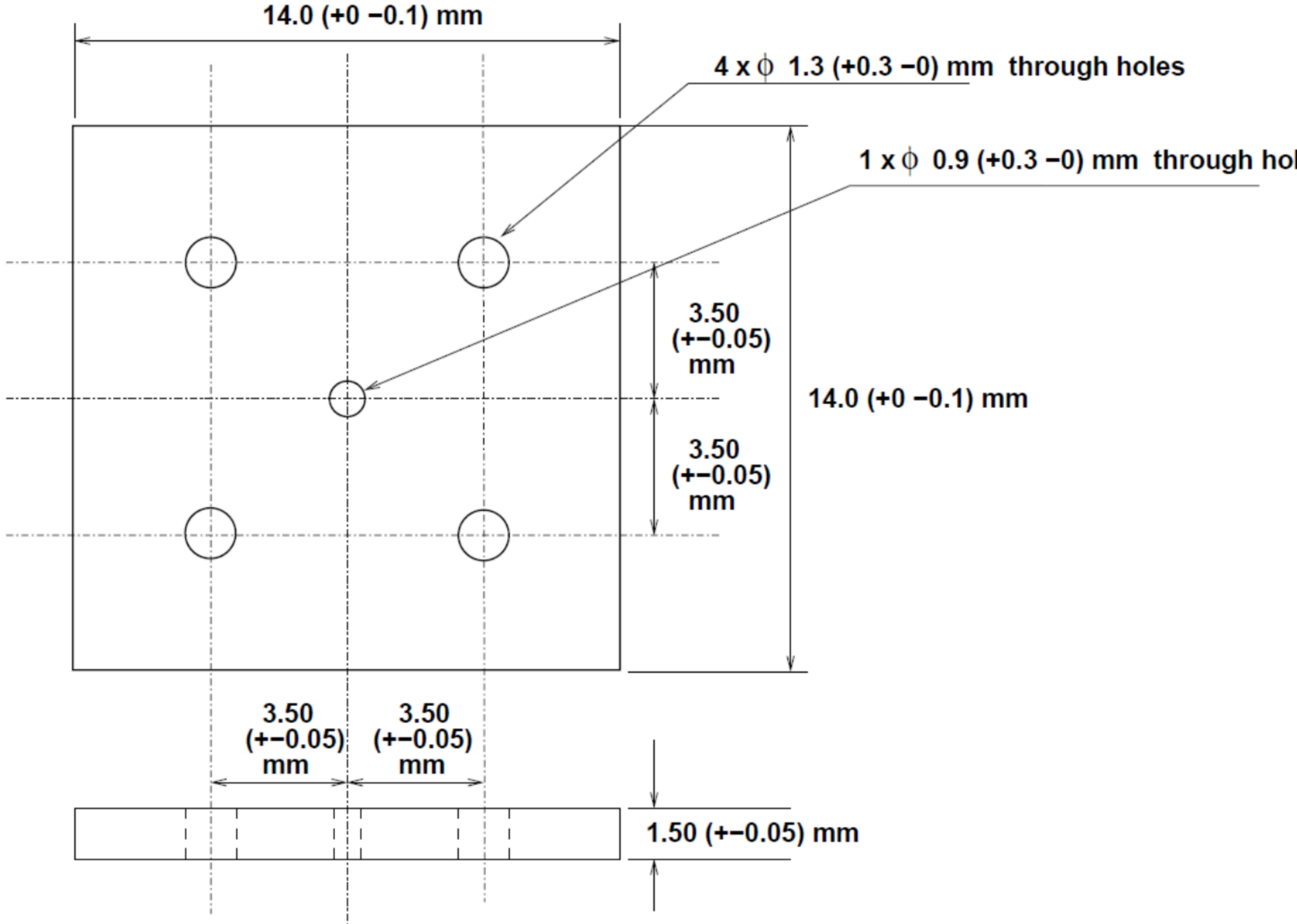

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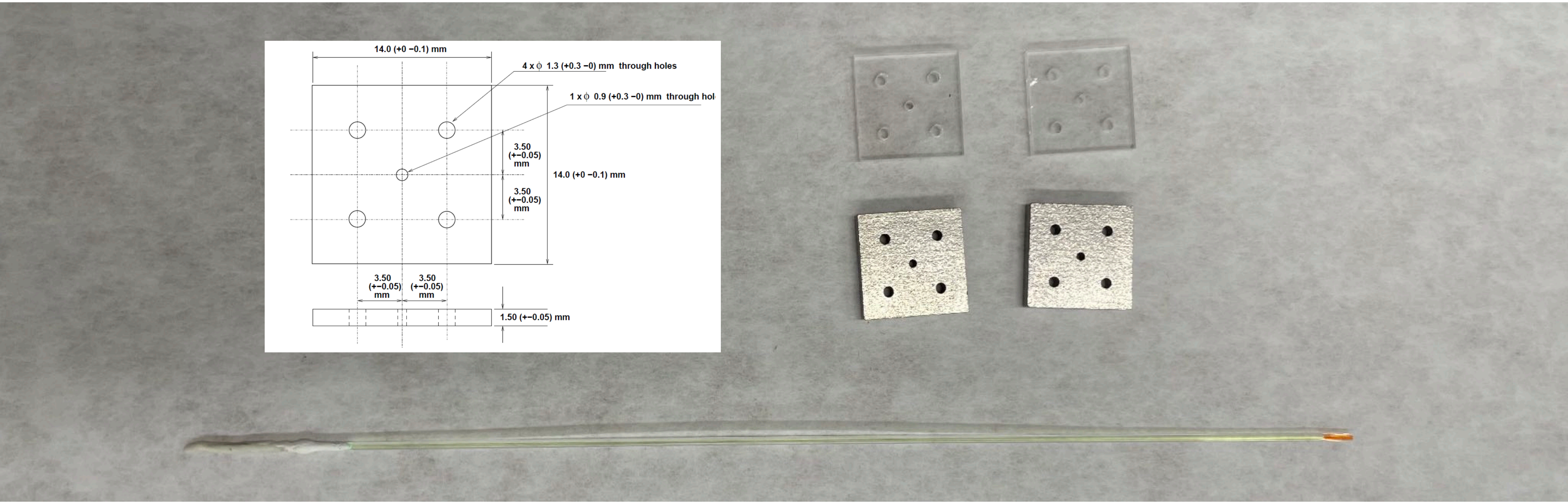

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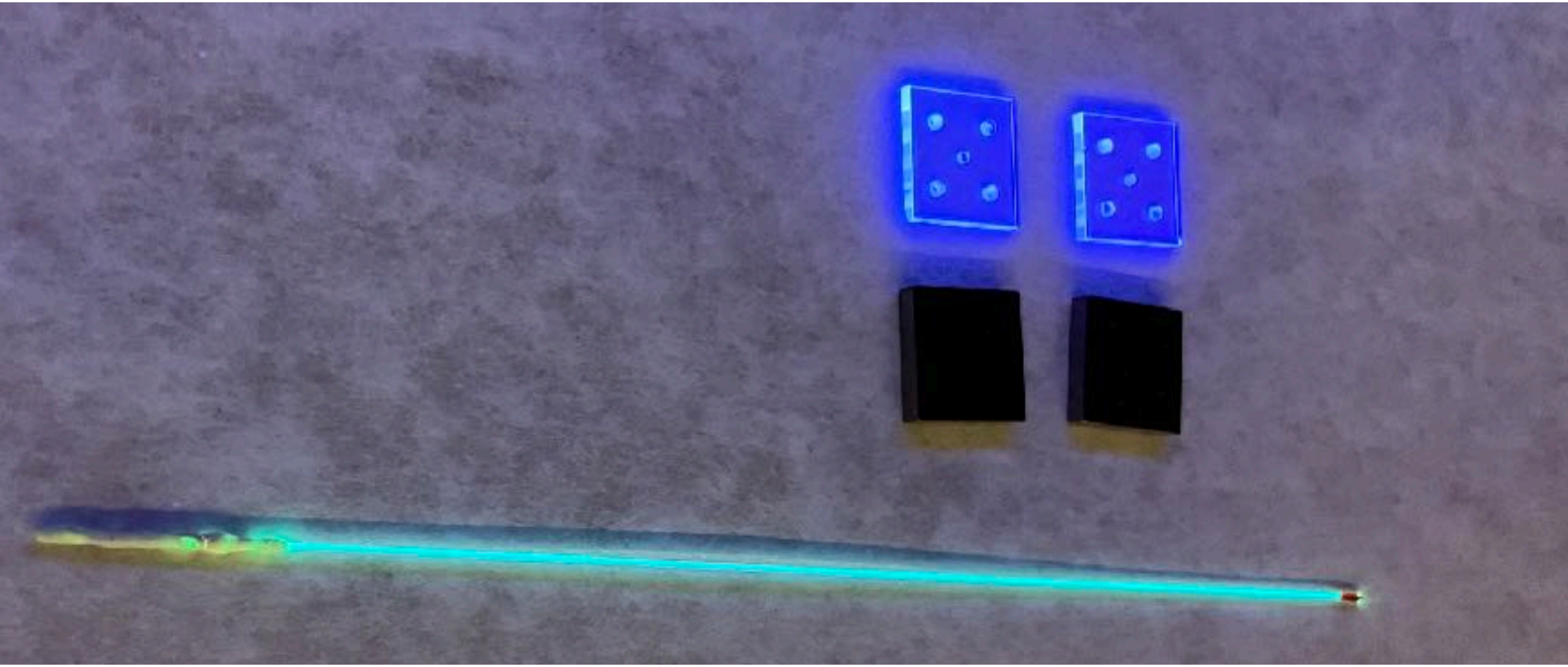

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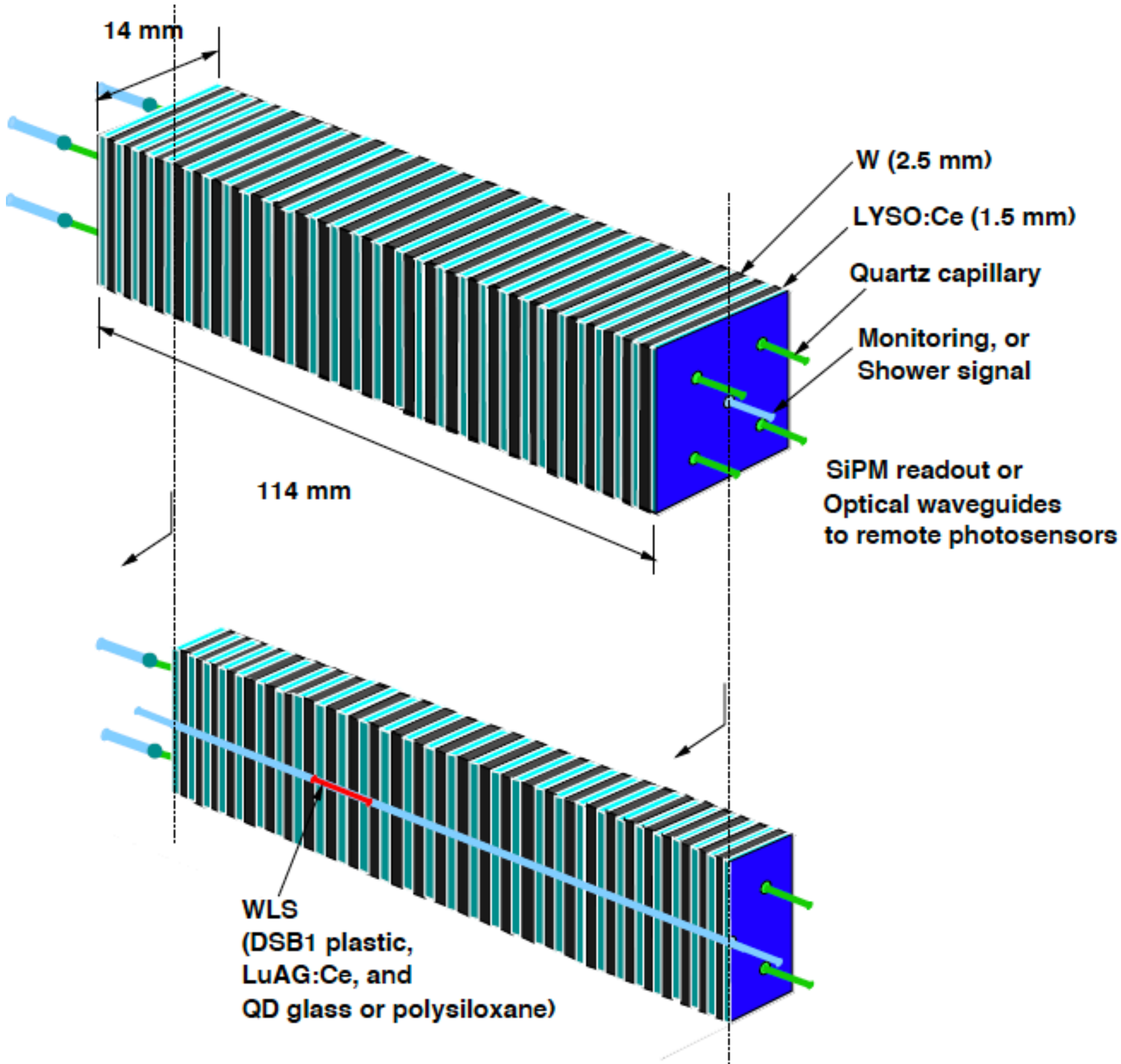

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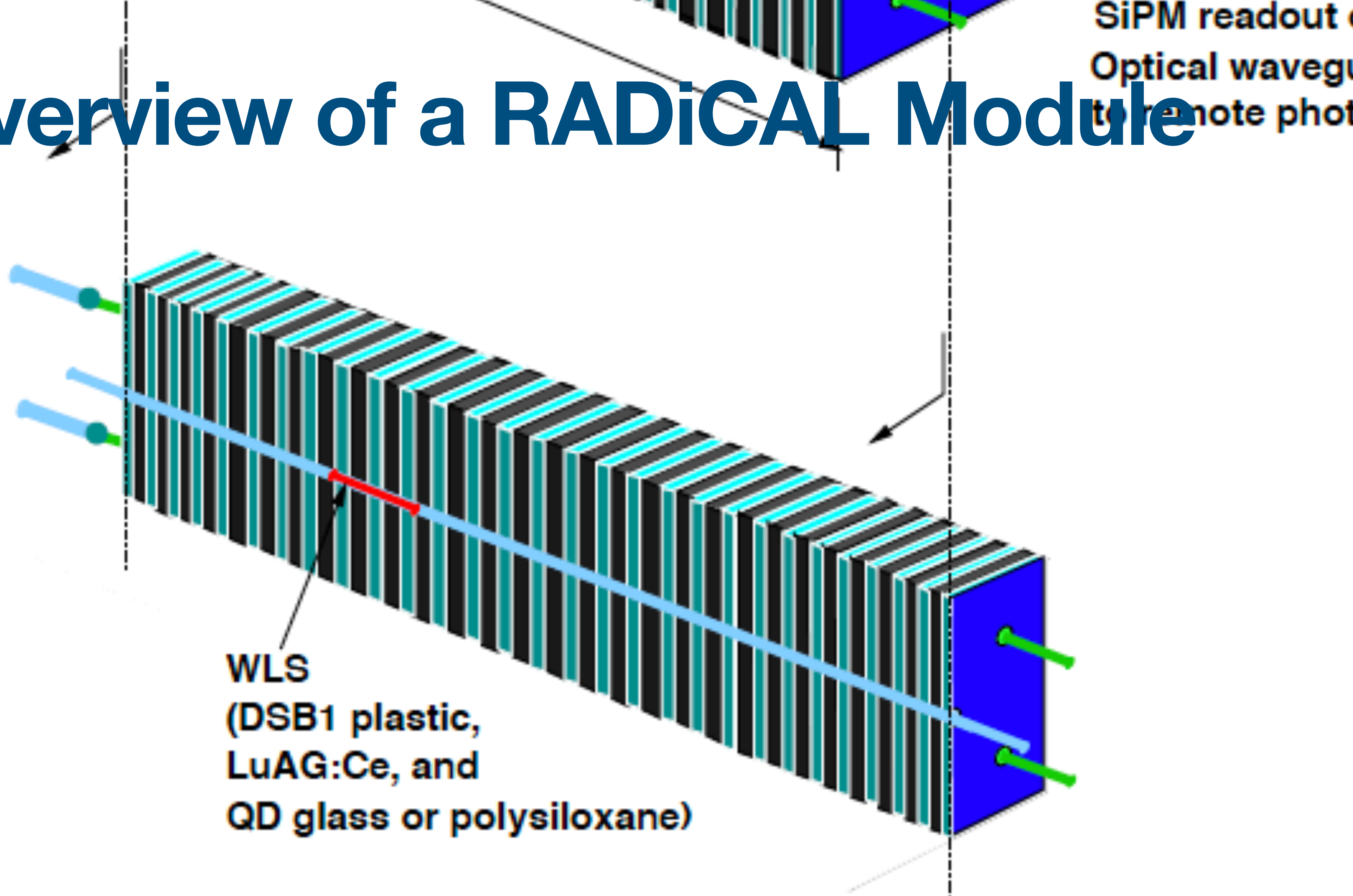
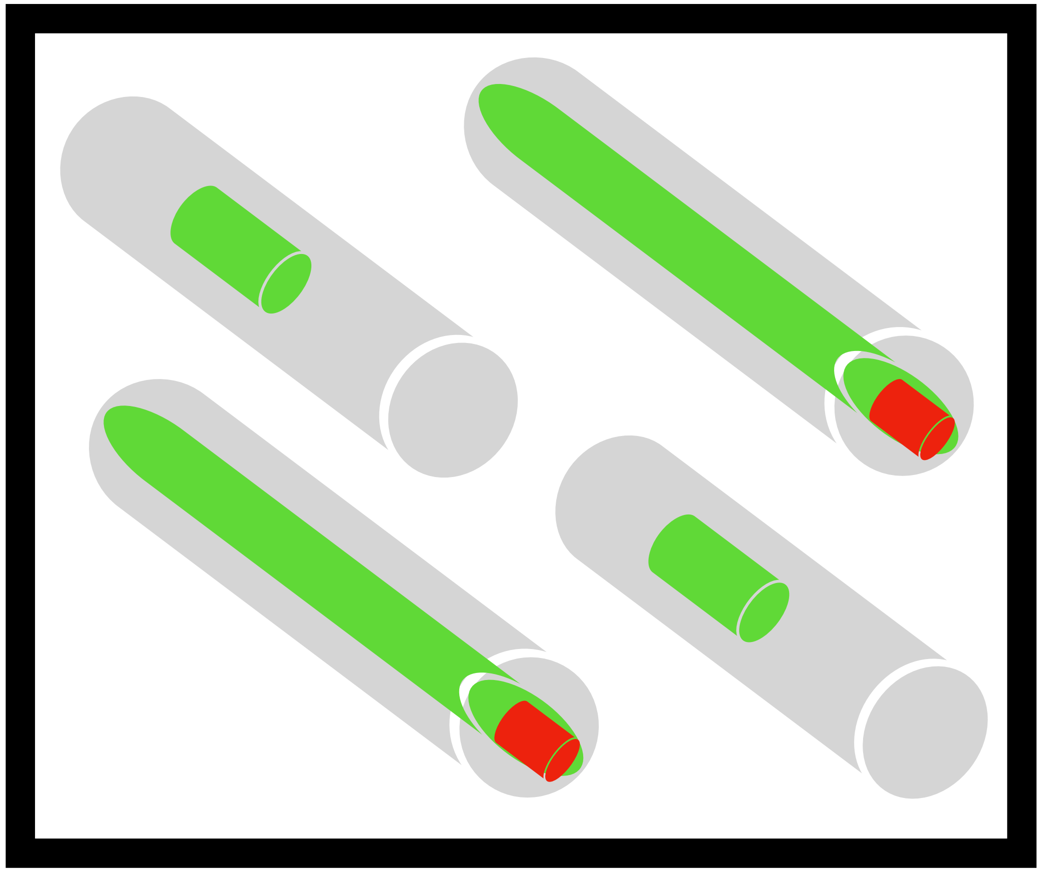


The RADiCAL at Fermilab



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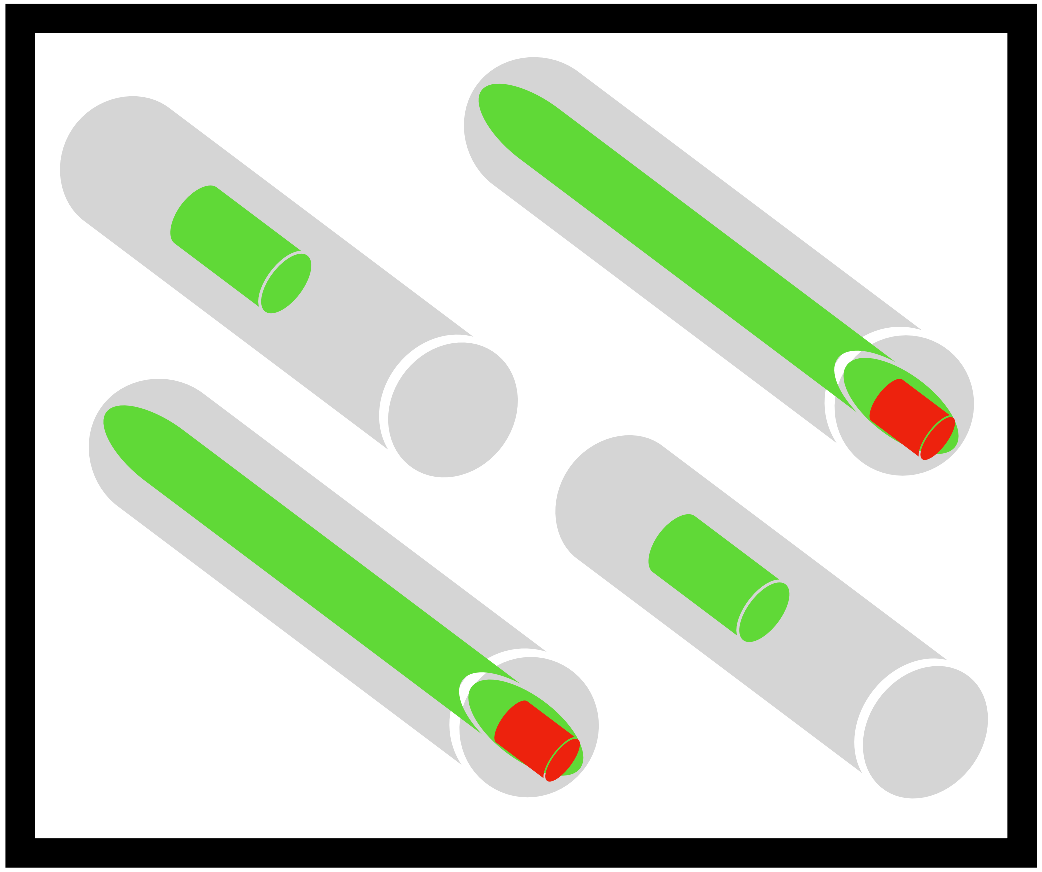
- Energy Capillaries:



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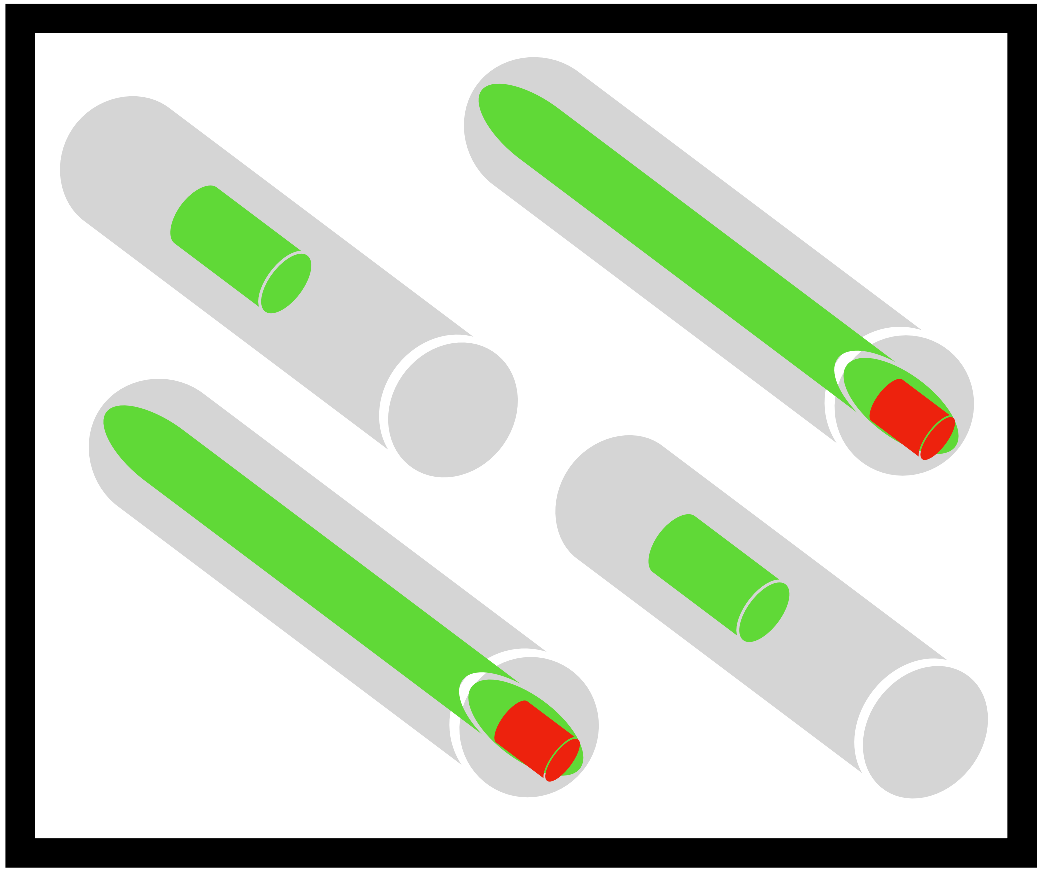

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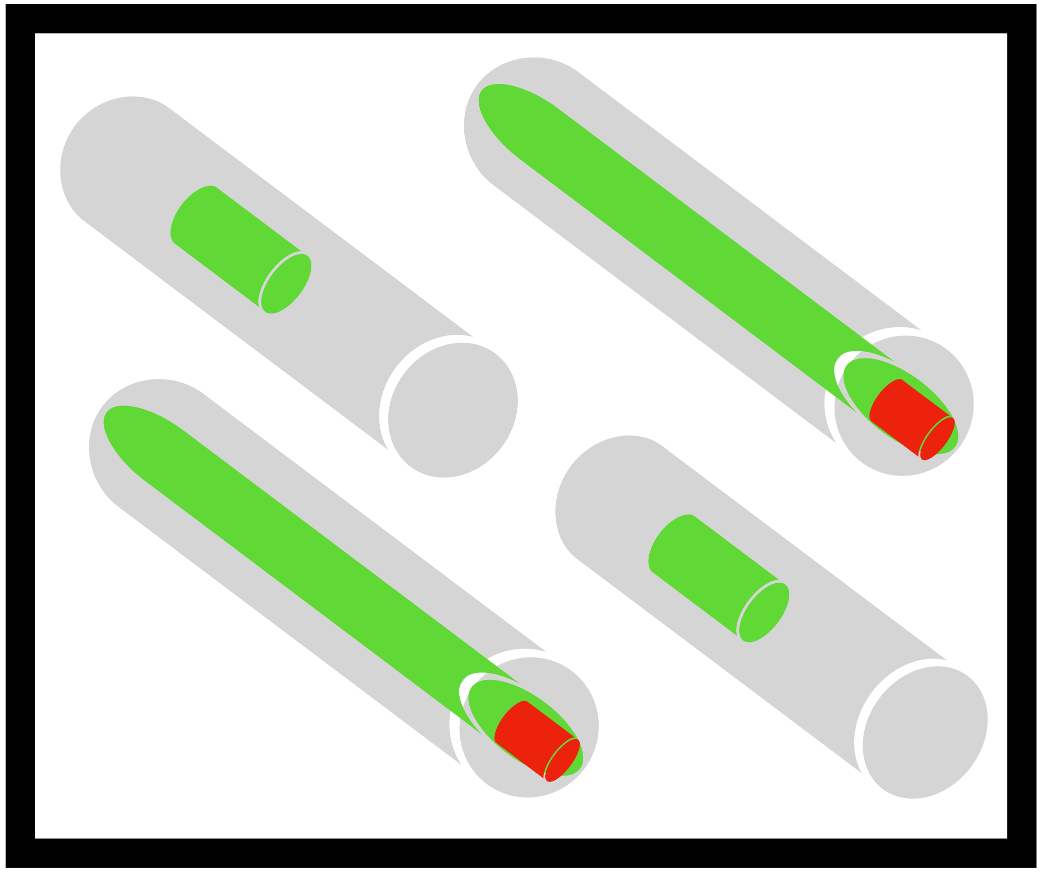

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- Energy Capillaries:
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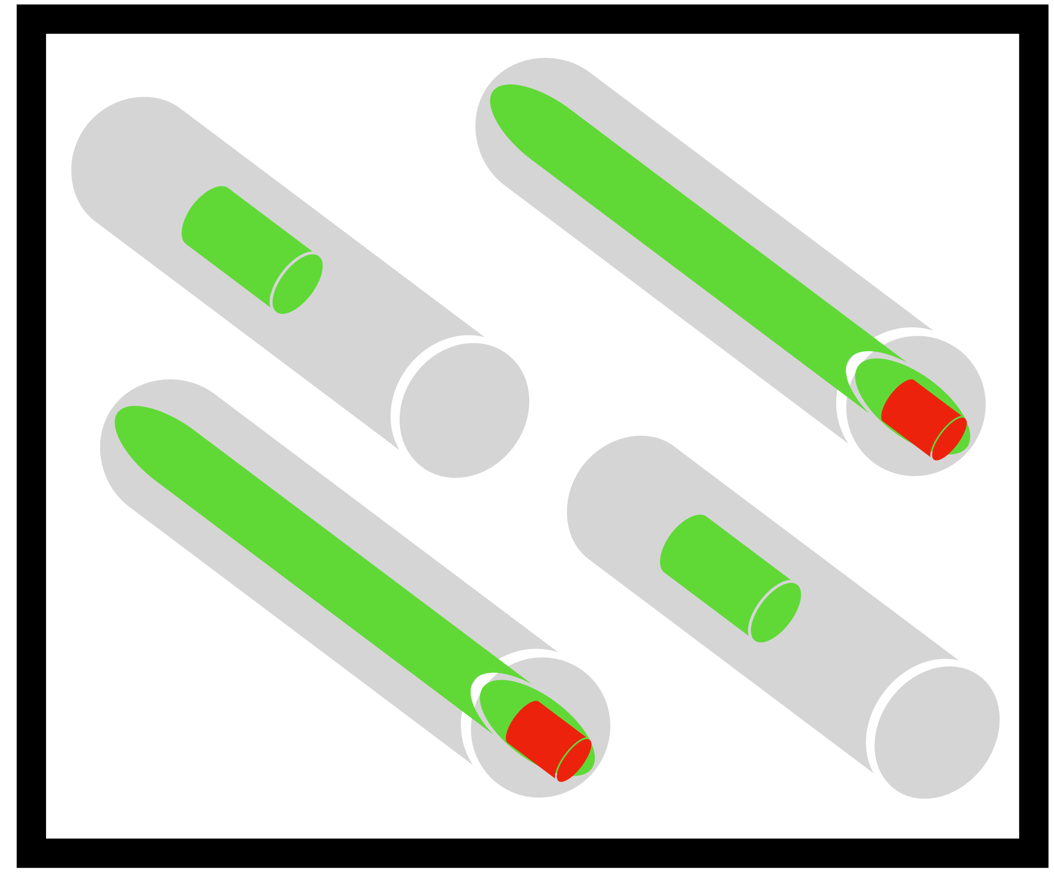
  - Core blocking Ruby Filter



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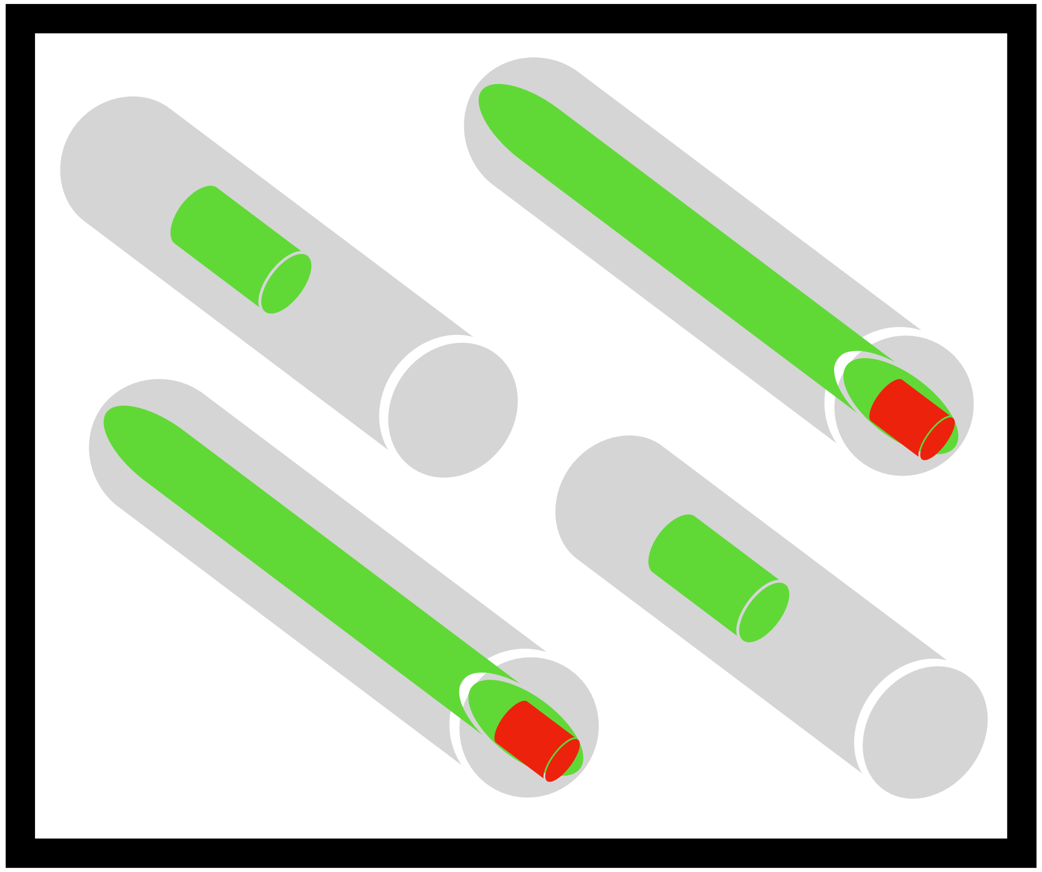
- Timing Capillaries:



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- Timing Capillaries:
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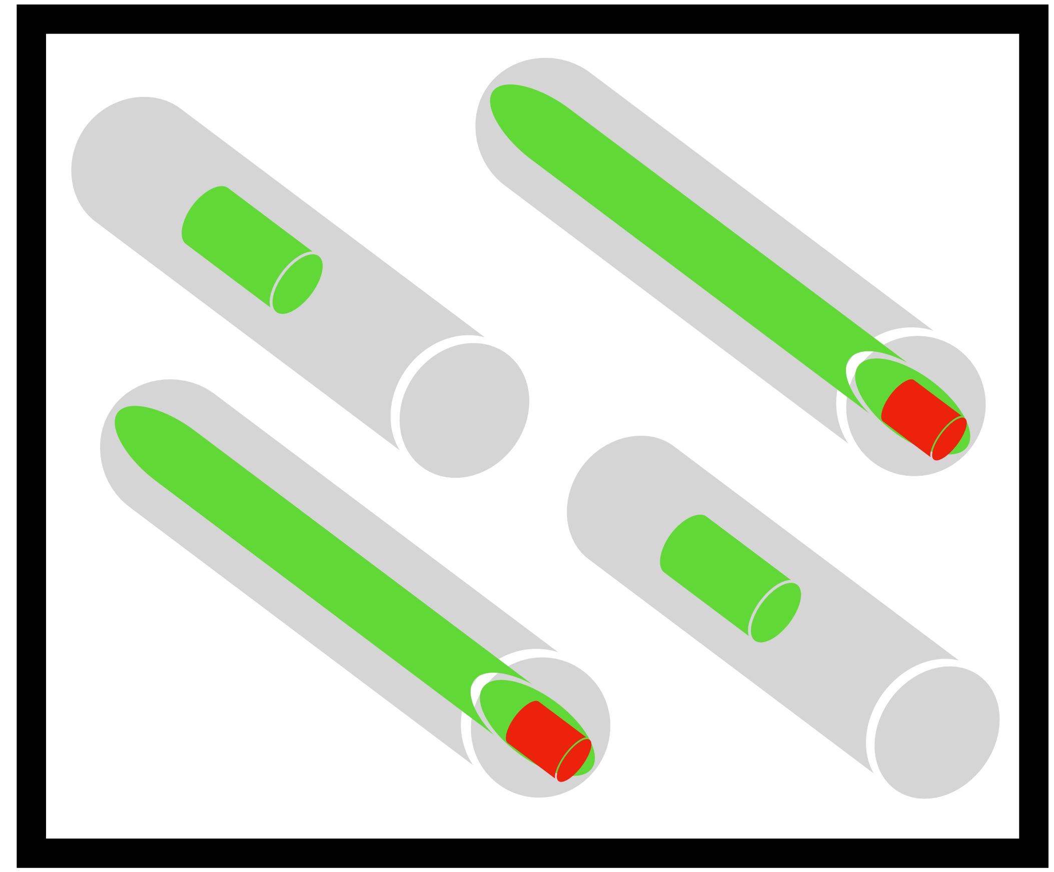

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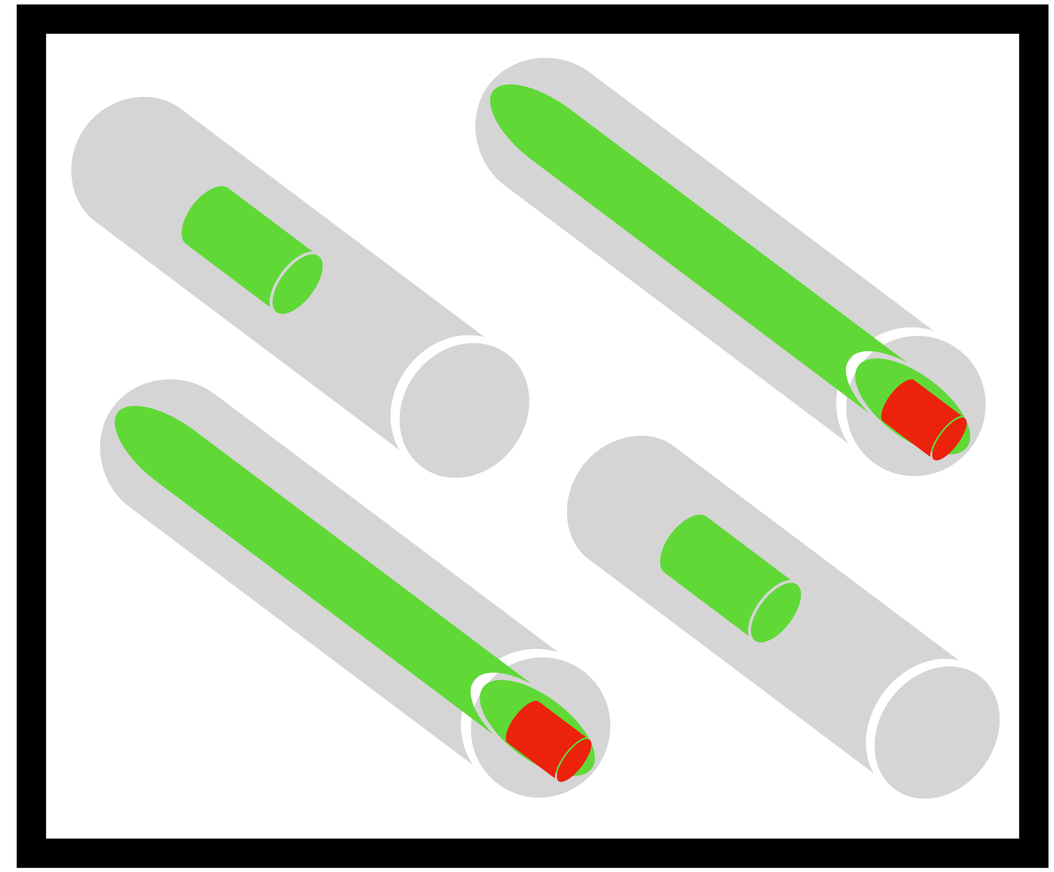

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  - Eljen EJ309 liquid doped with DSB1
  - Core blocking Ruby Filter
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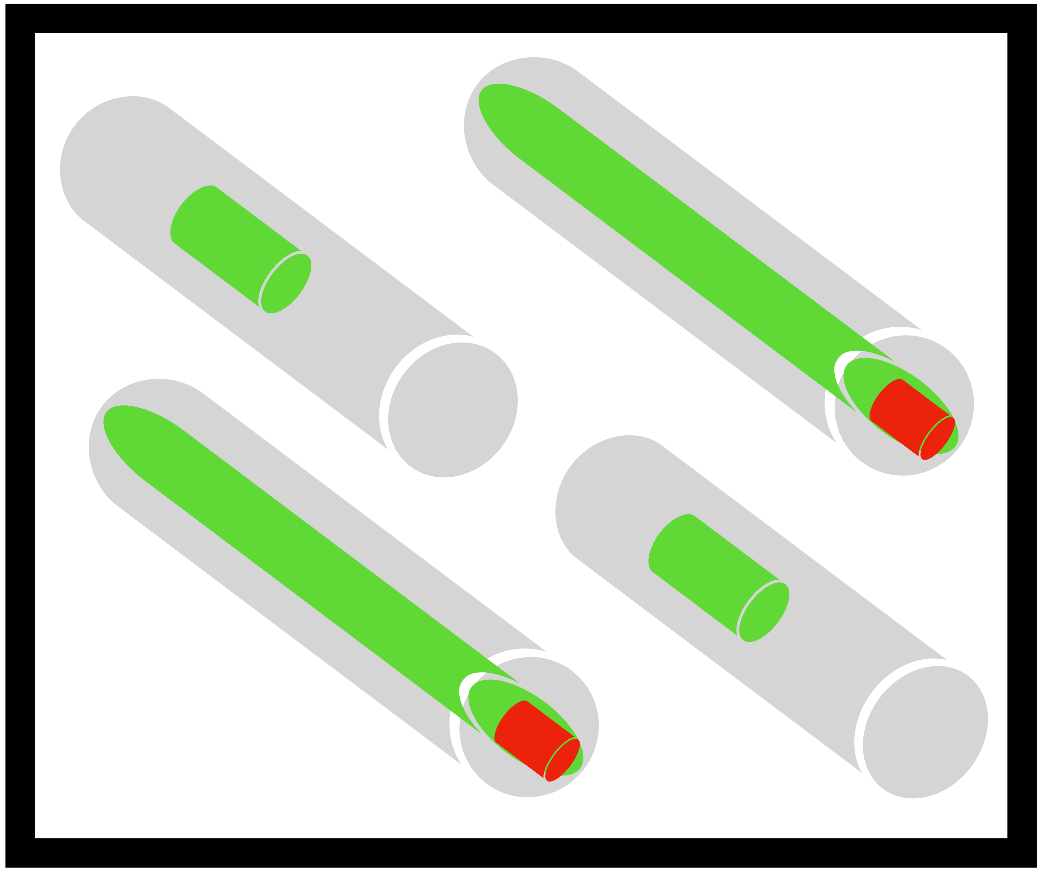
  - WLS DSB1
  - Quartz rod fused in either end



Motivation for RADiCAL

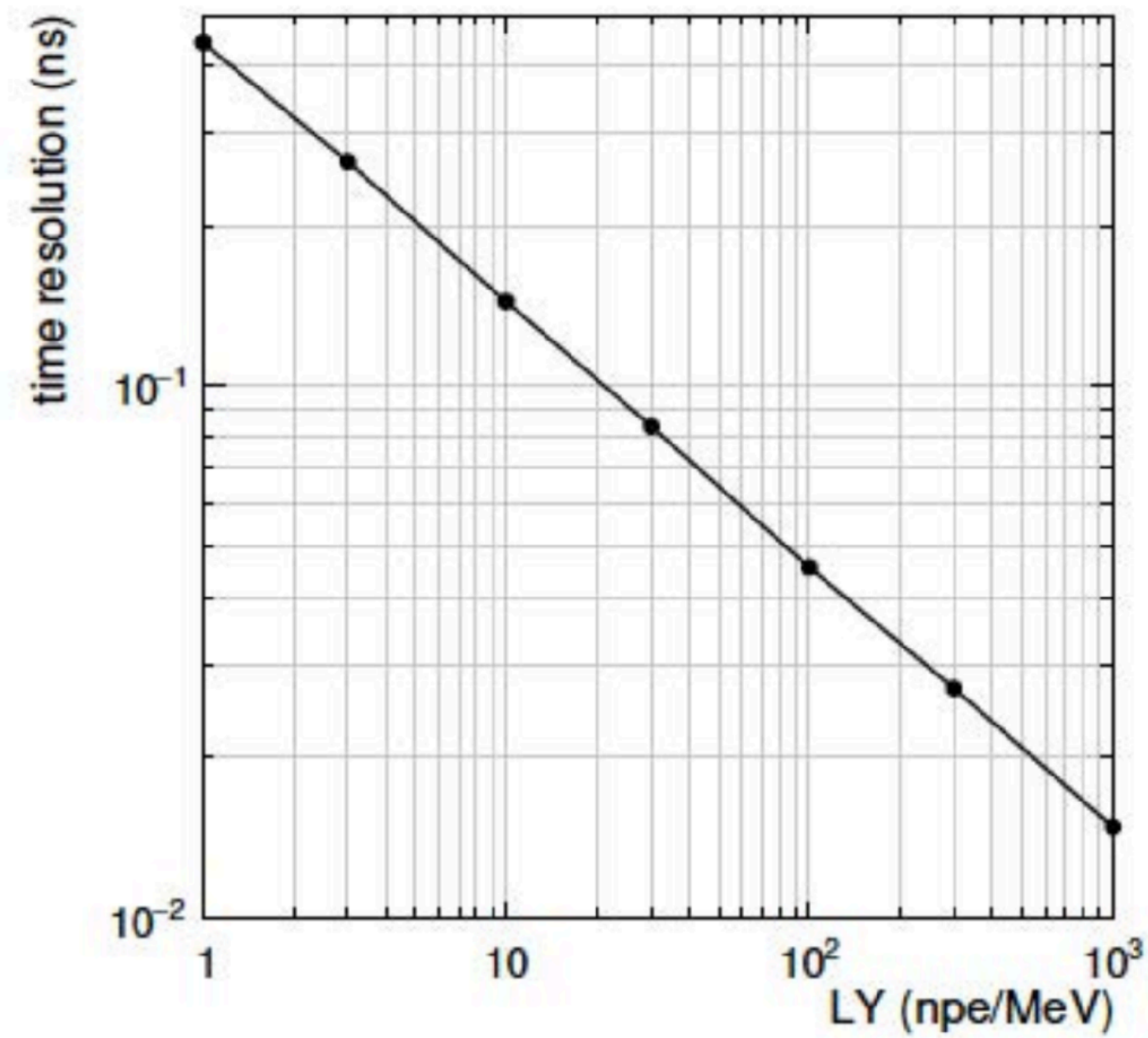
Motivation for RADiCAL

GEANT4 Simulations predict time resolution of 10s of ps

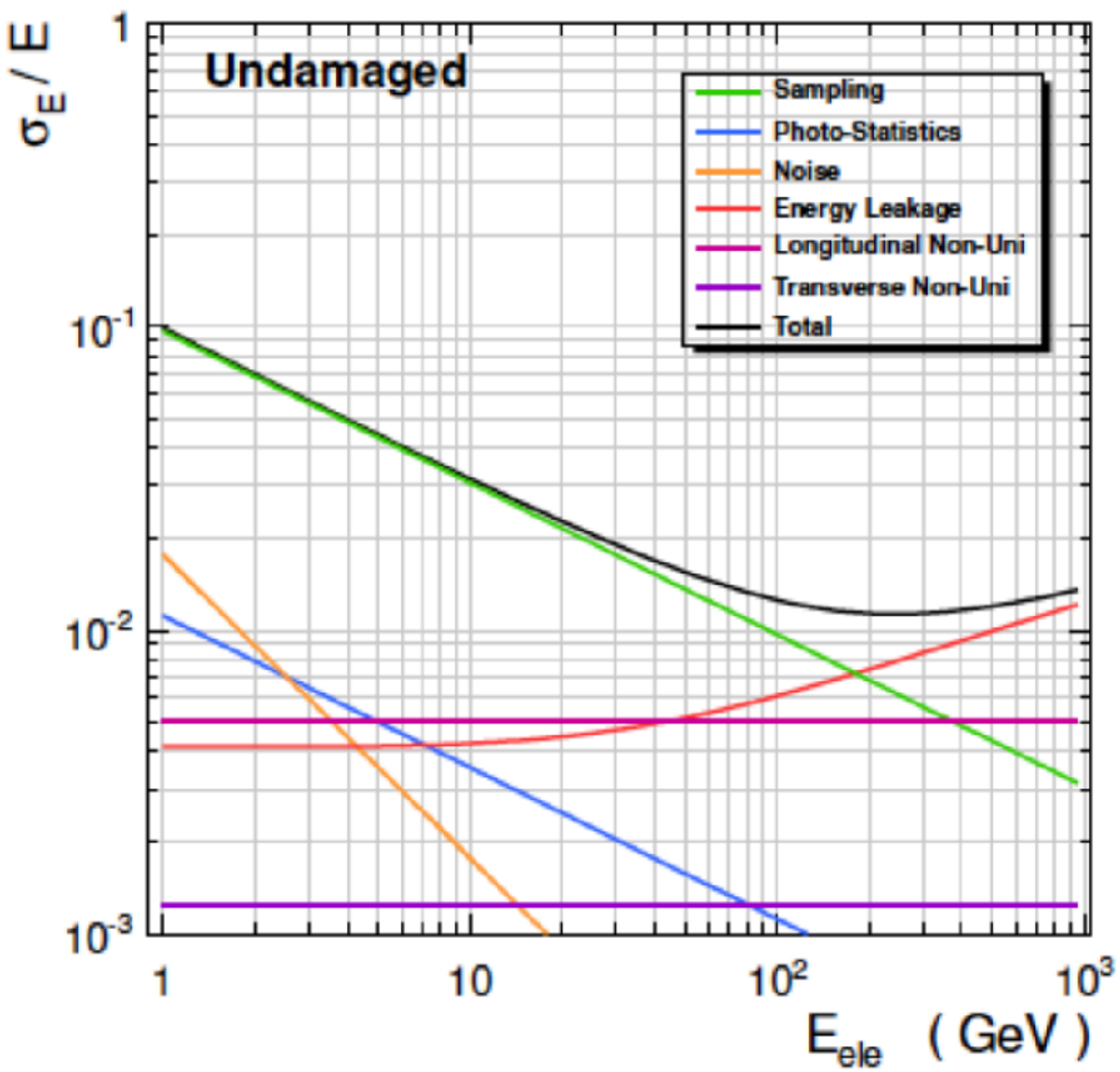
Motivation for RADiCAL

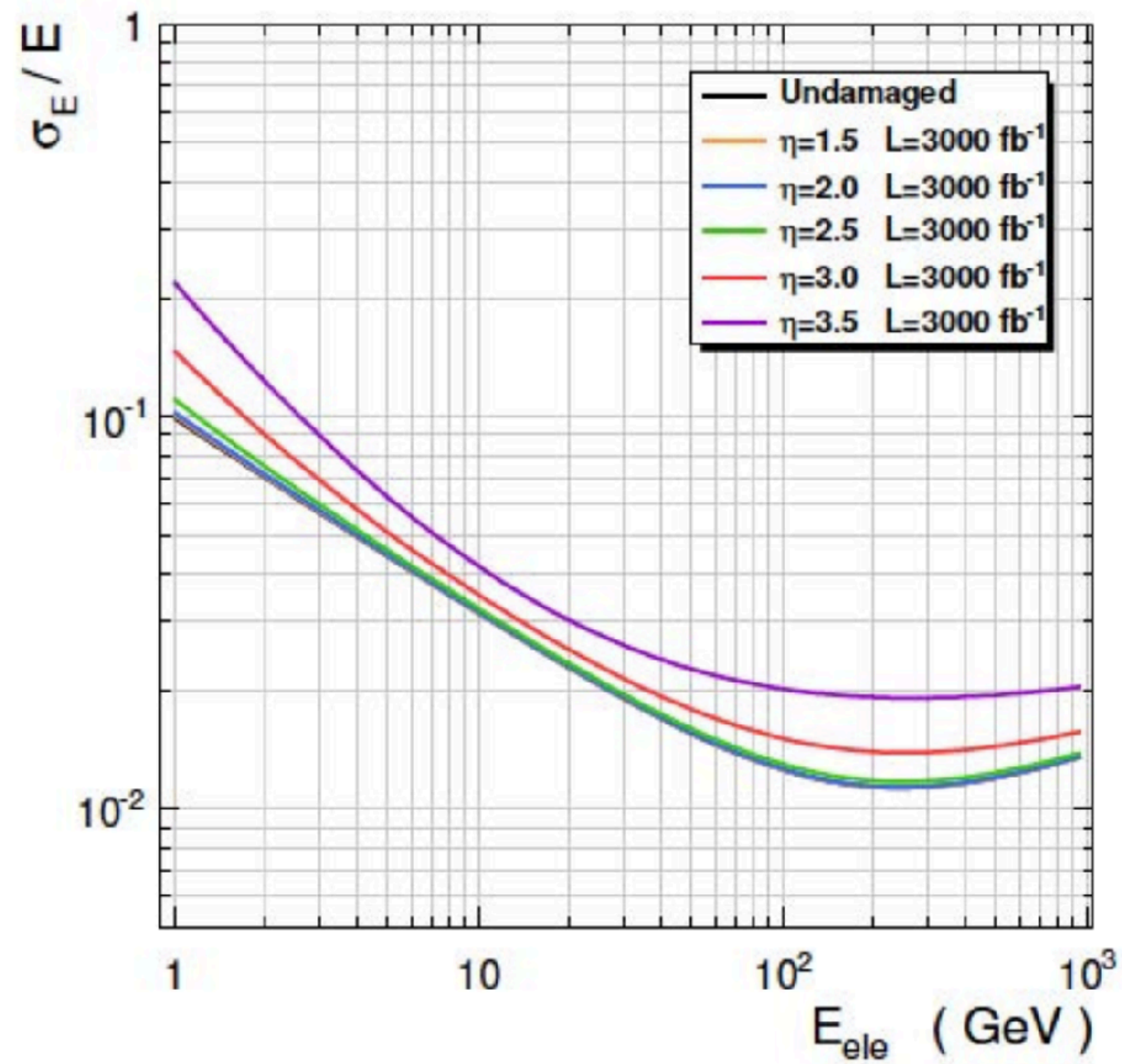
GEANT4 Simulations predict time resolution of 10s of ps

A. Ledovskoy



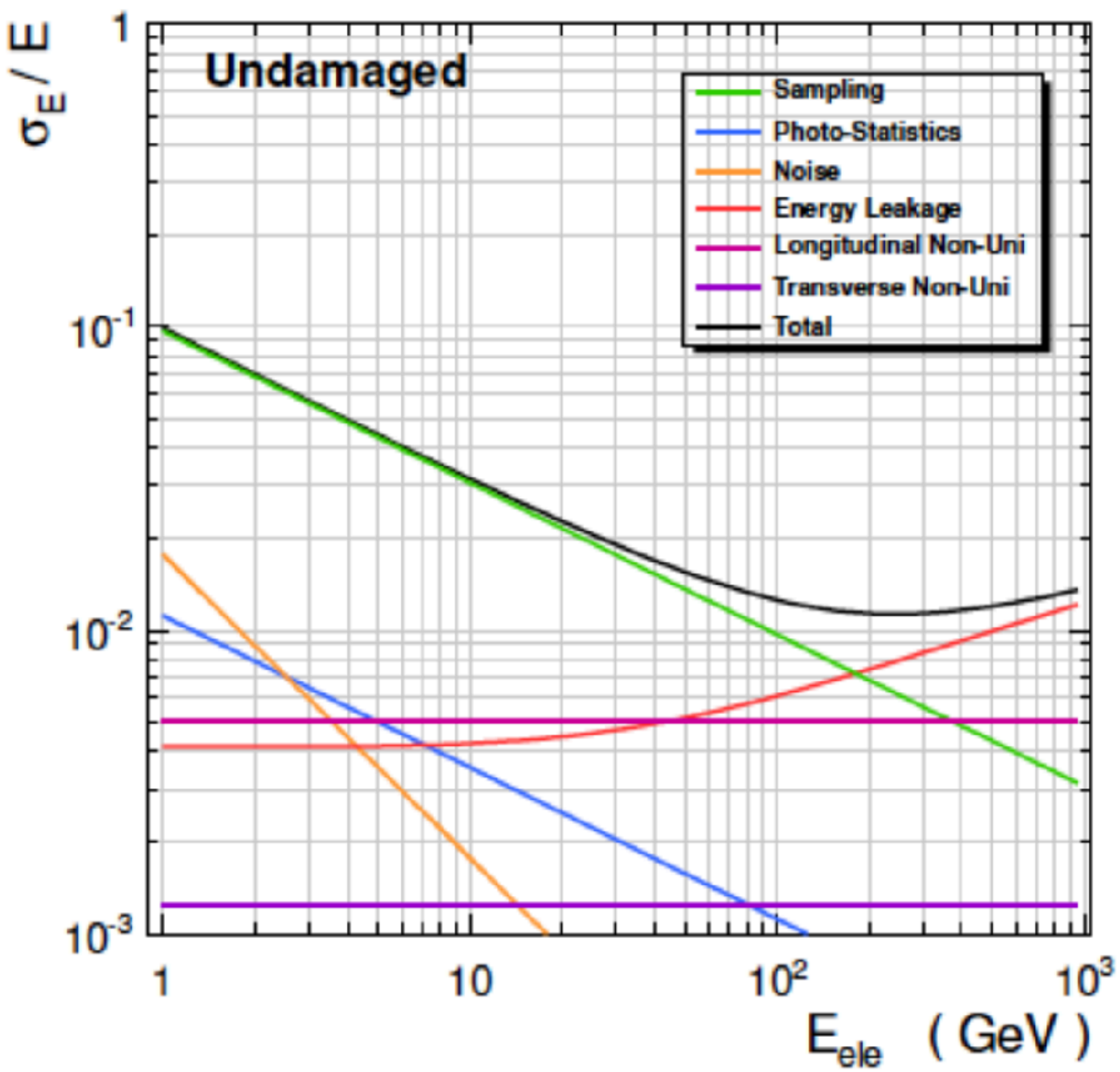
Motivation for RADiCAL

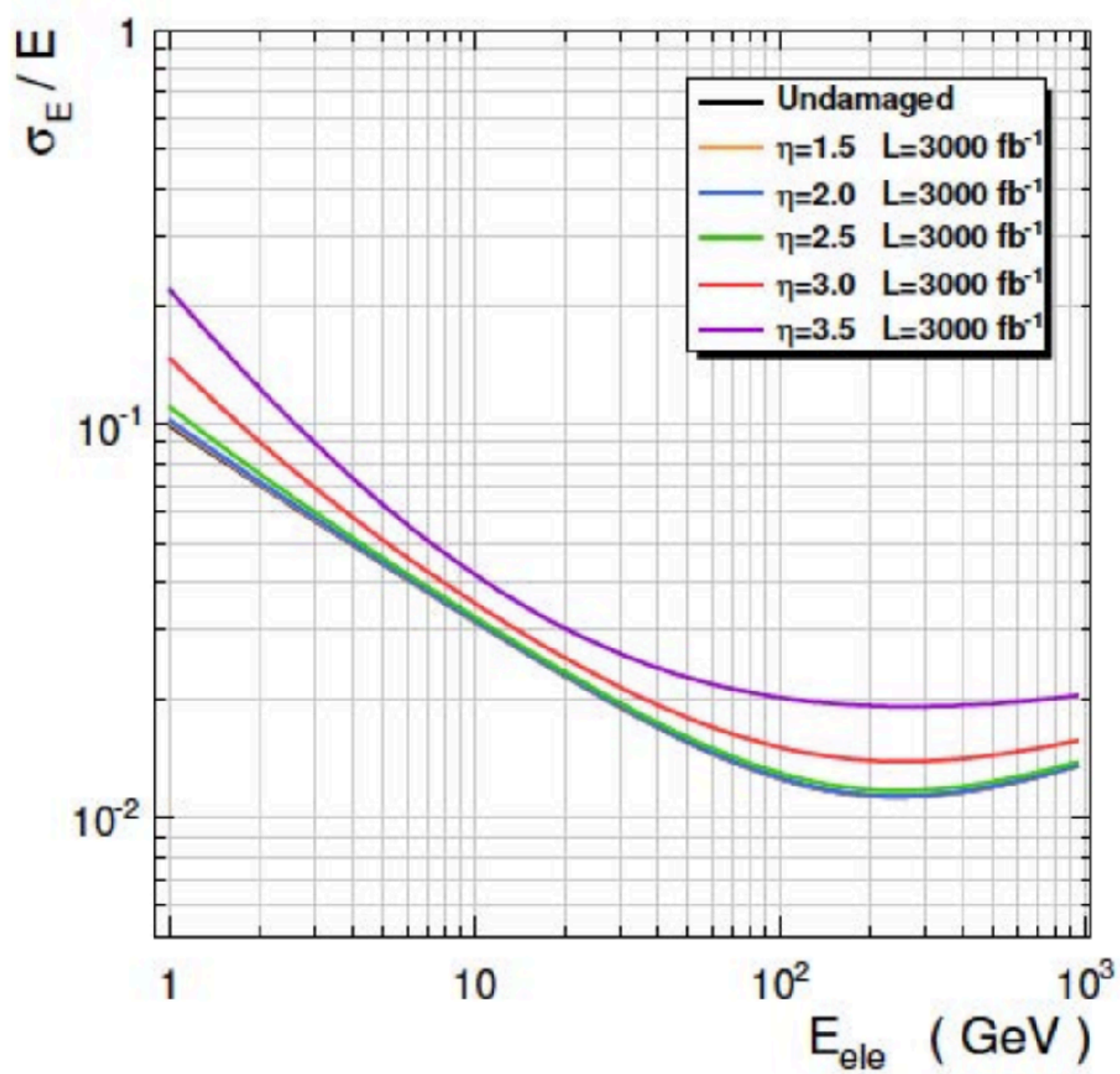




Motivation for RADiCAL

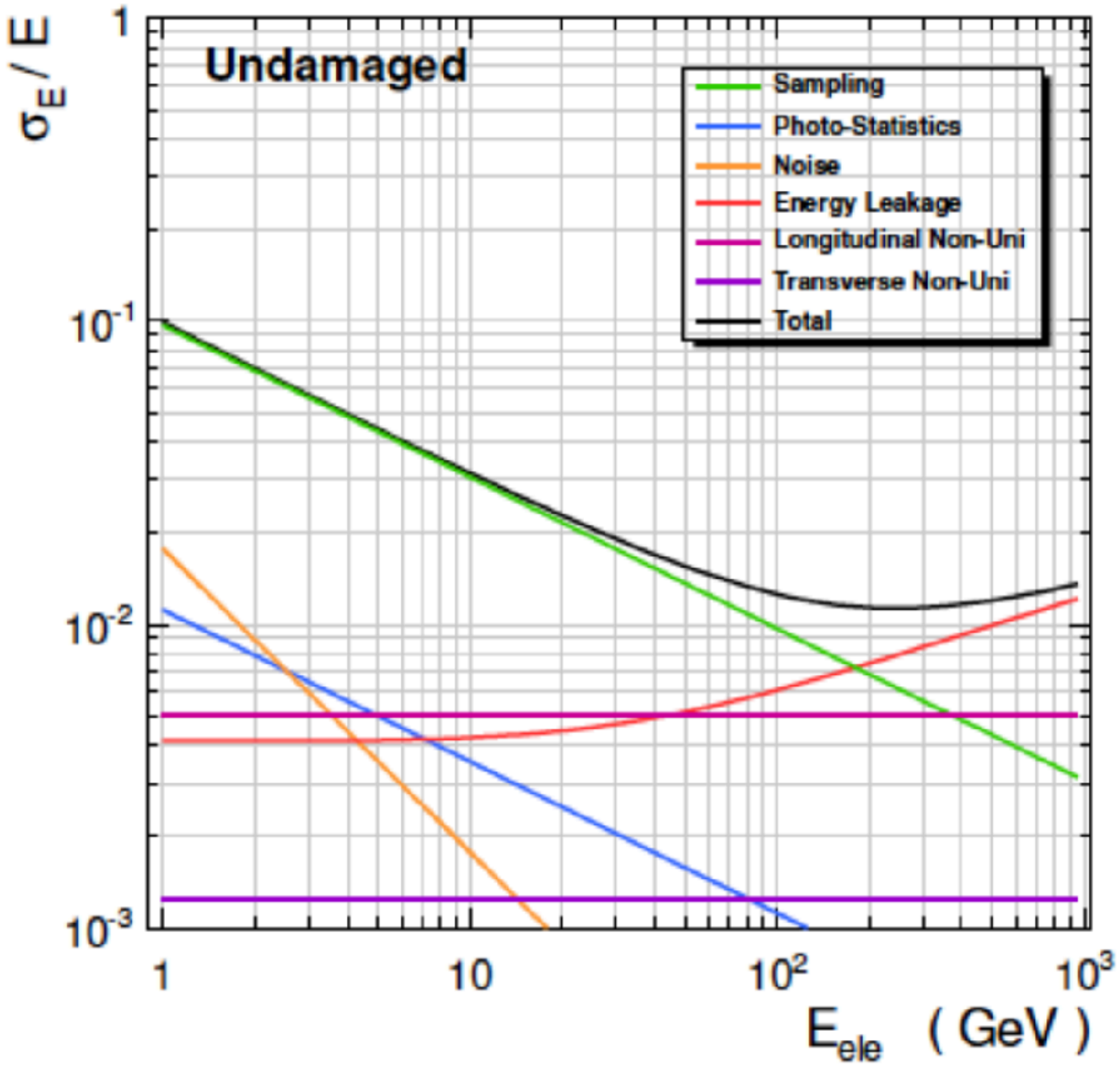
GEANT4 Simulations predict energy resolution

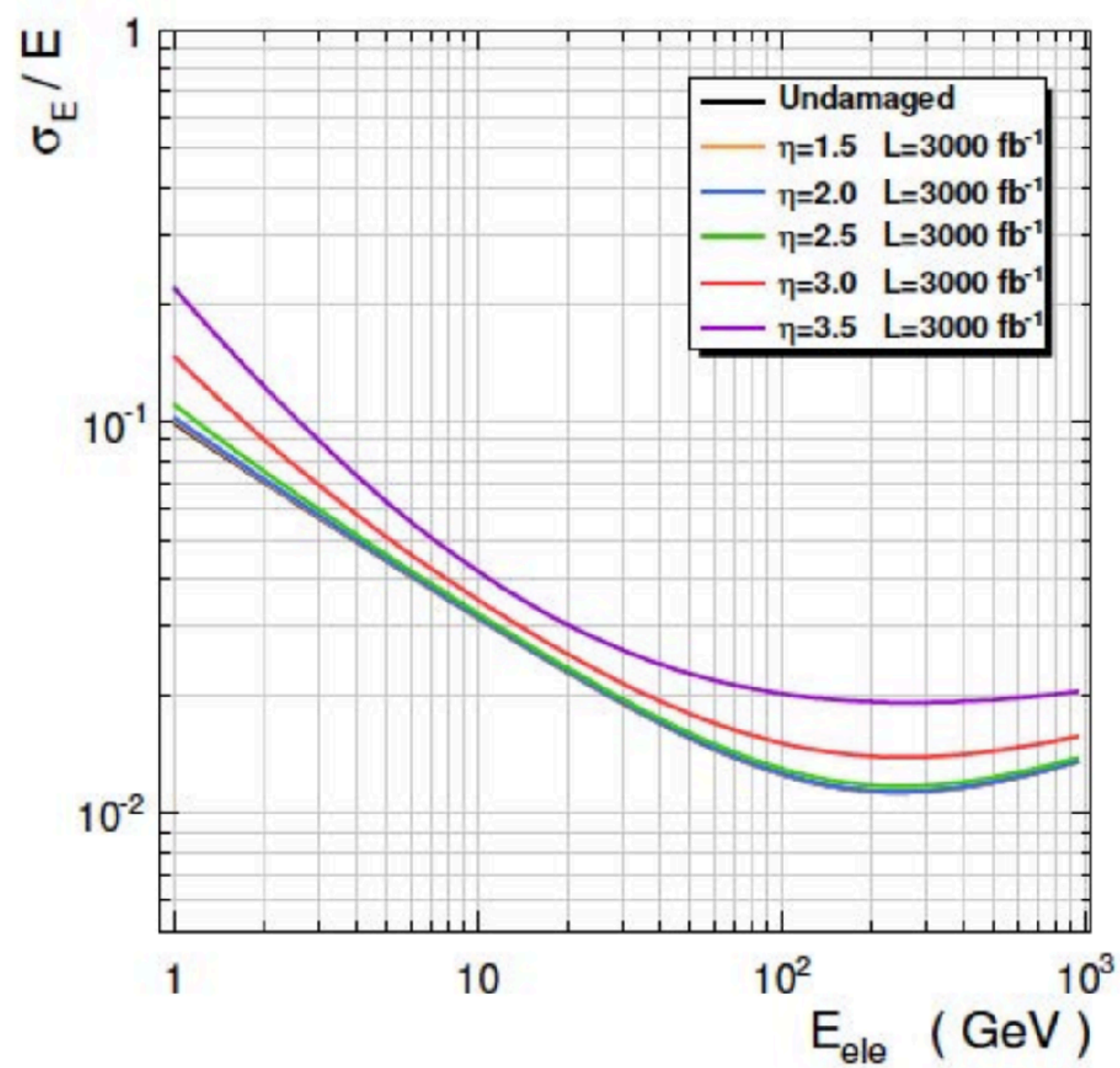




Motivation for RADiCAL

GEANT4 Simulations predict energy resolution
CERN H4 Beam Test measured resolution.

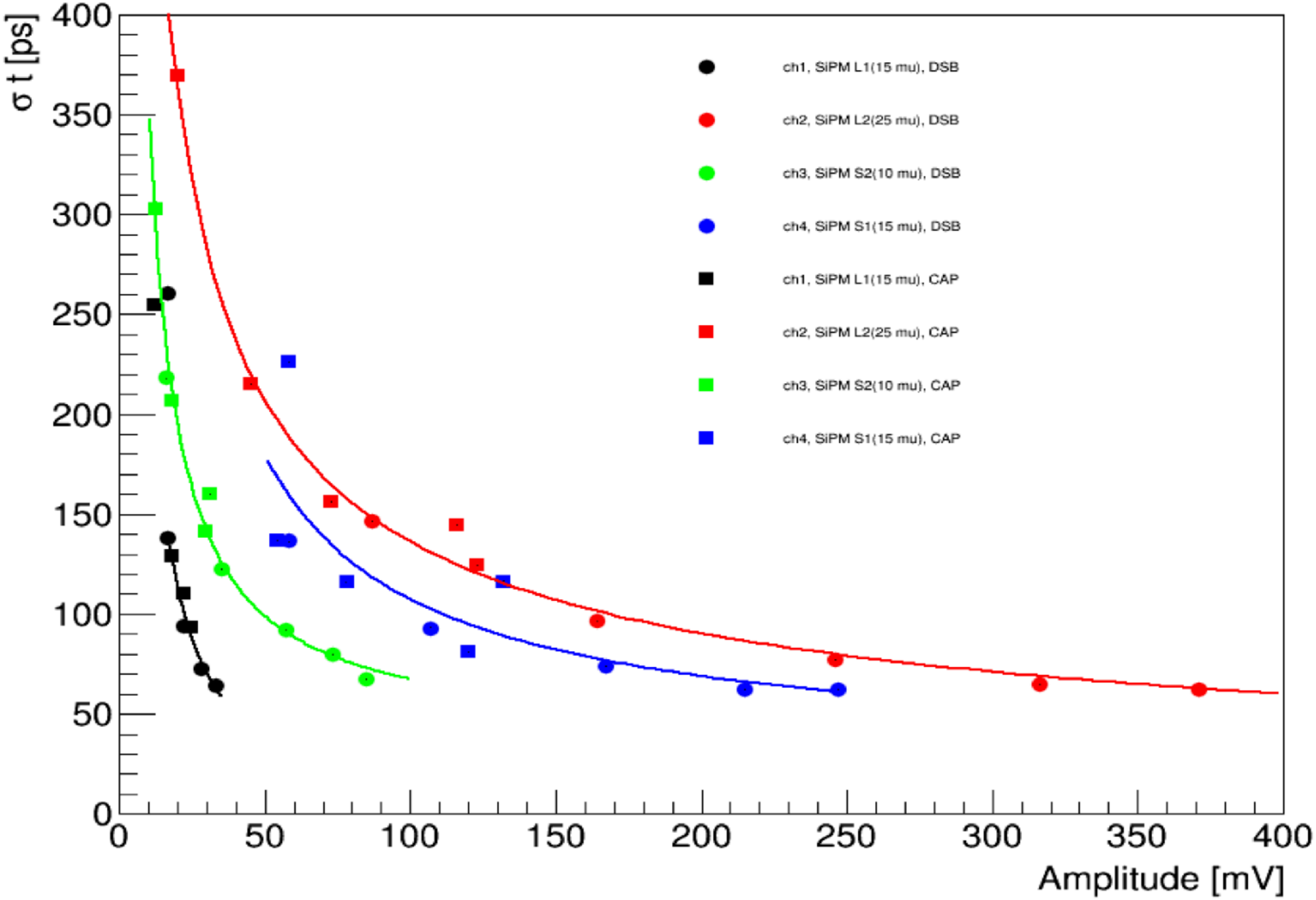




Motivation for RADiCAL

Beam Tests

FTBF / A. Bornheim et al.



Motivation for RADiCAL

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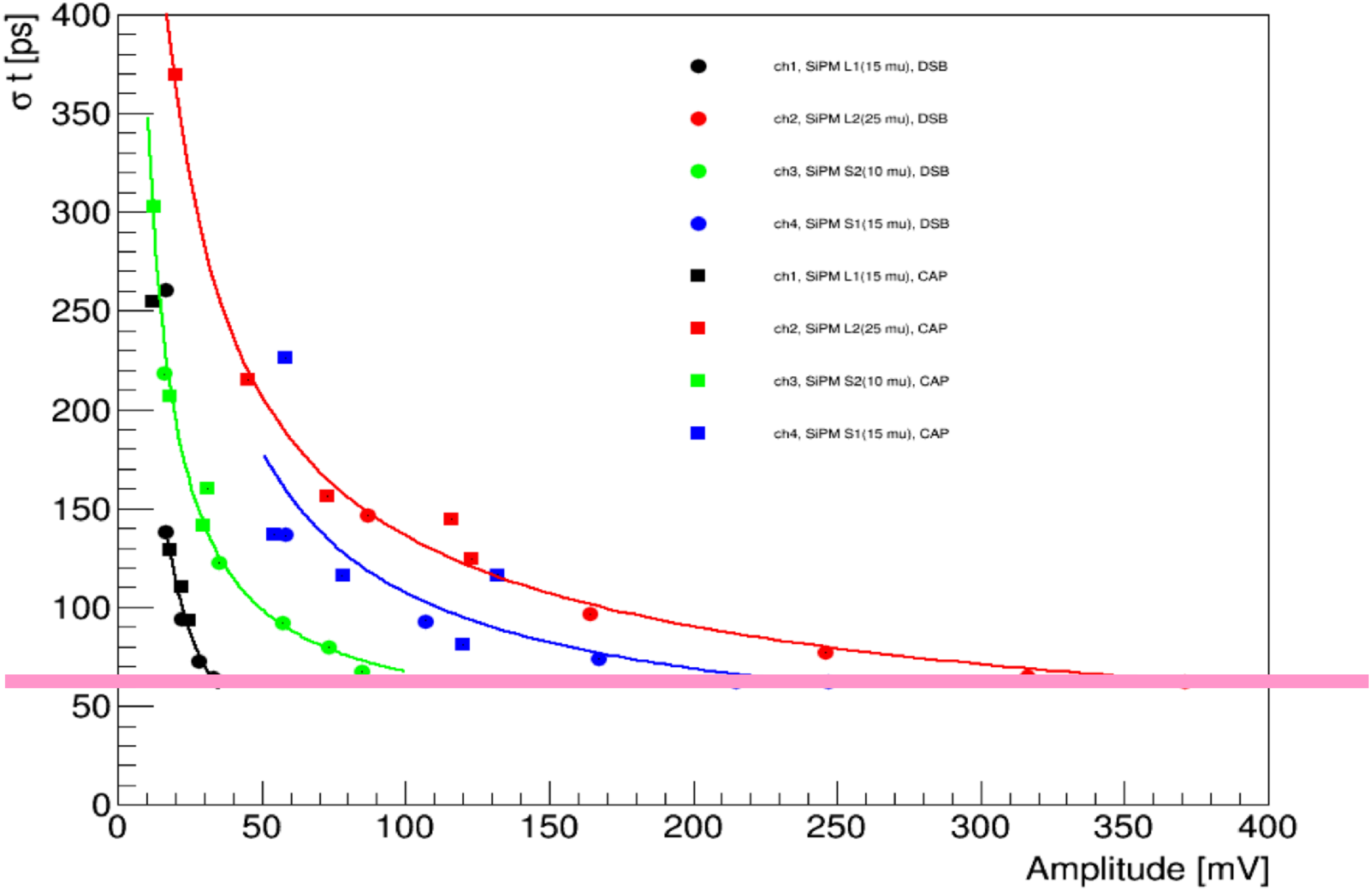
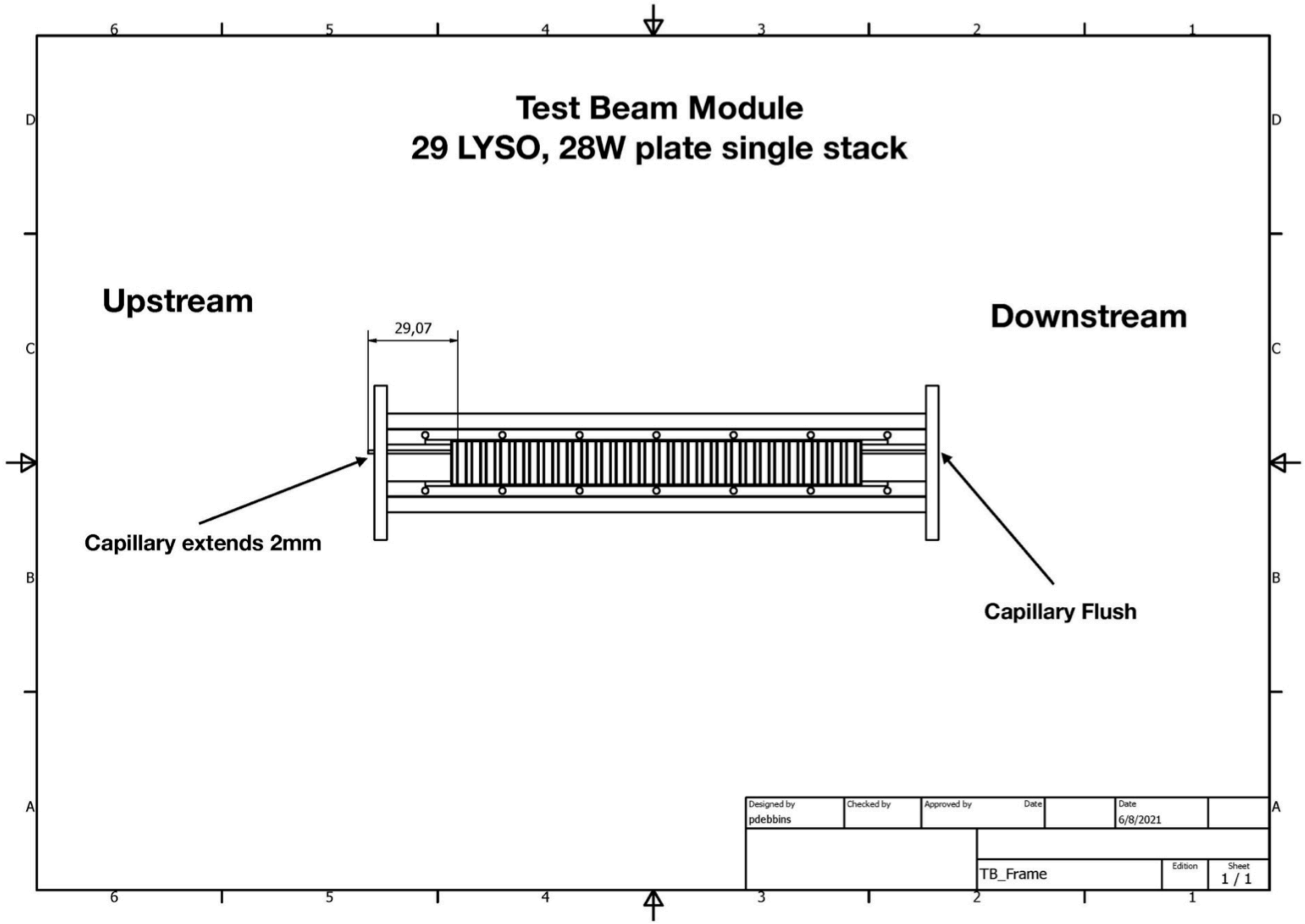


Overview of a RADiCAL Module



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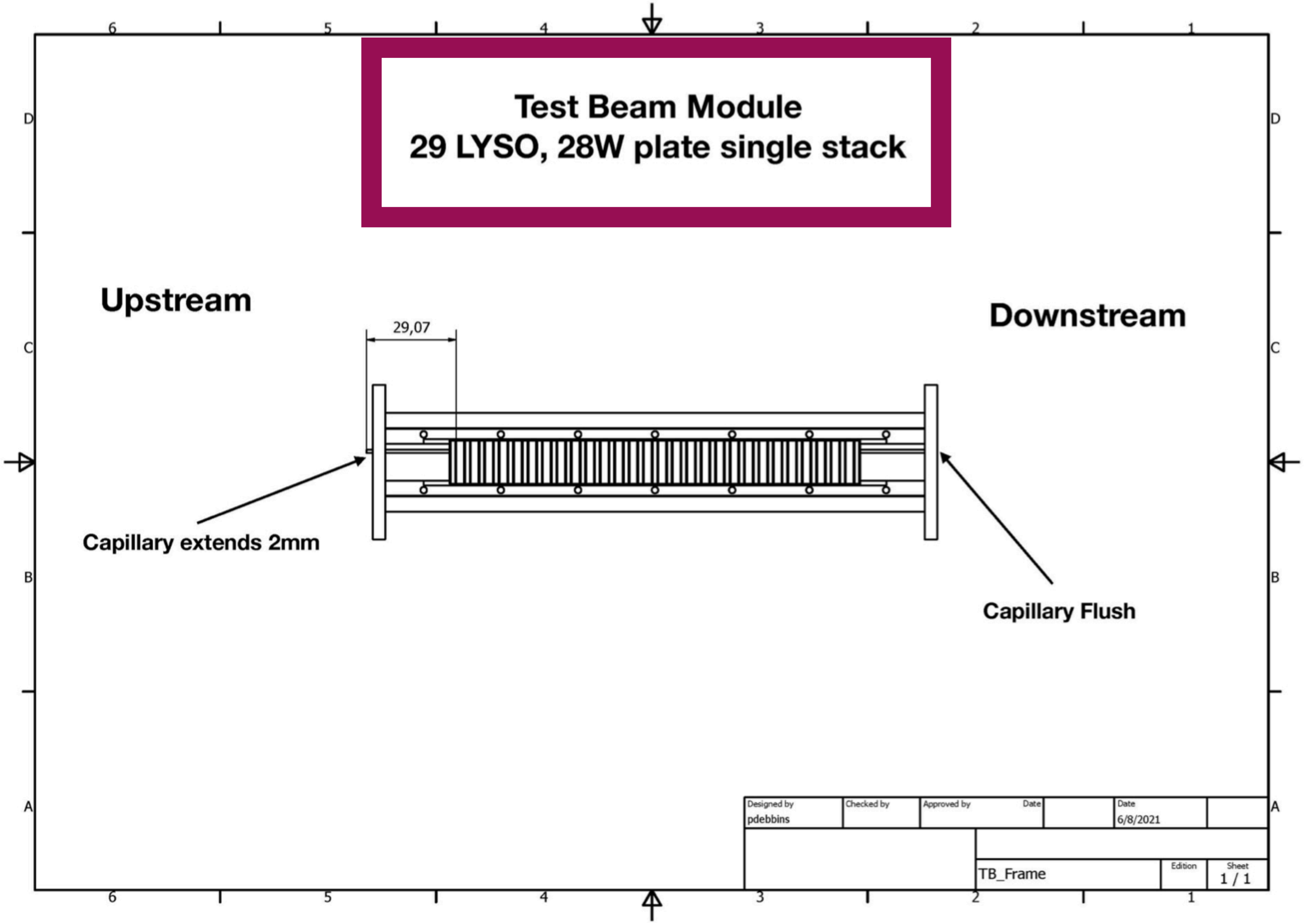
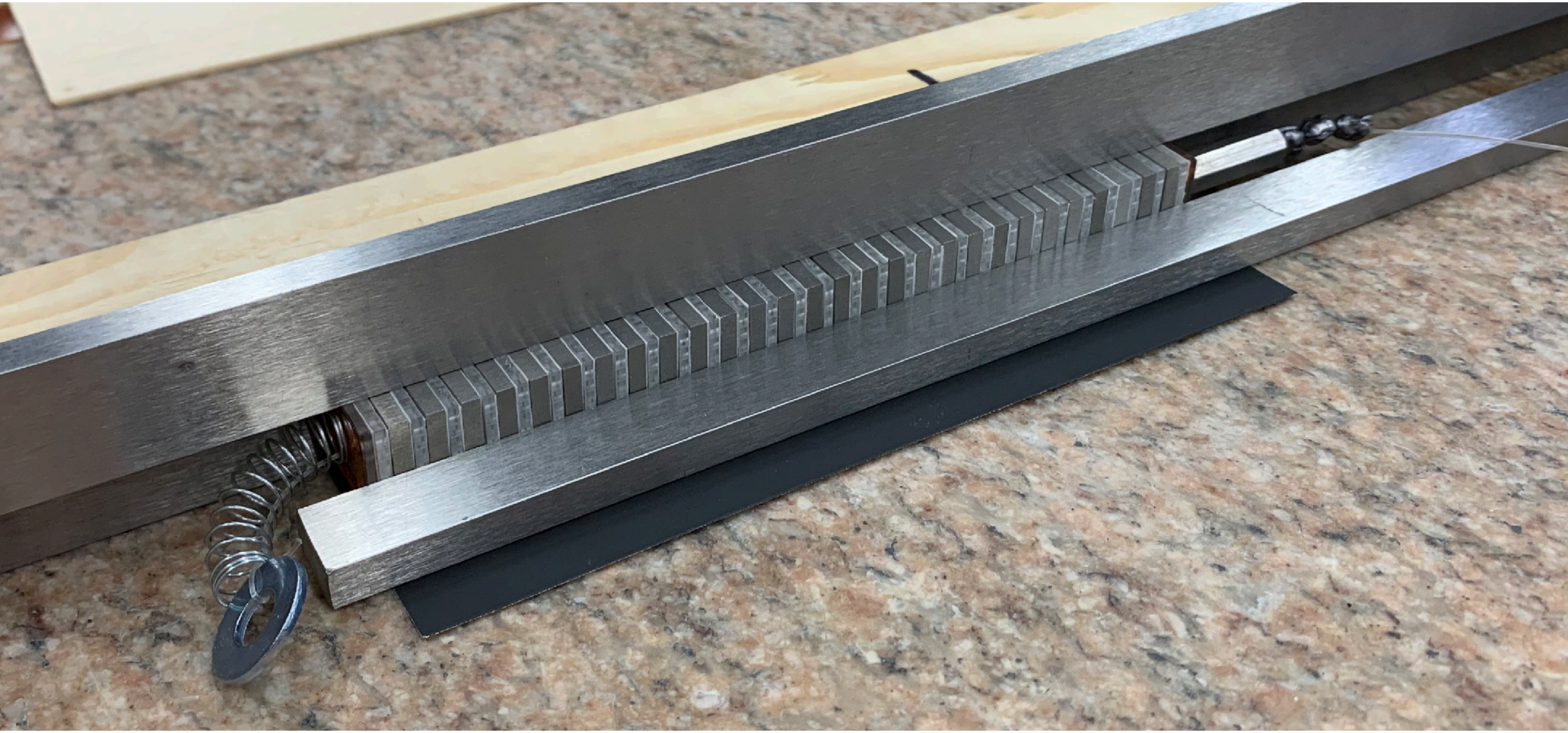


Preparing the Module

P. Debbins at IOWA



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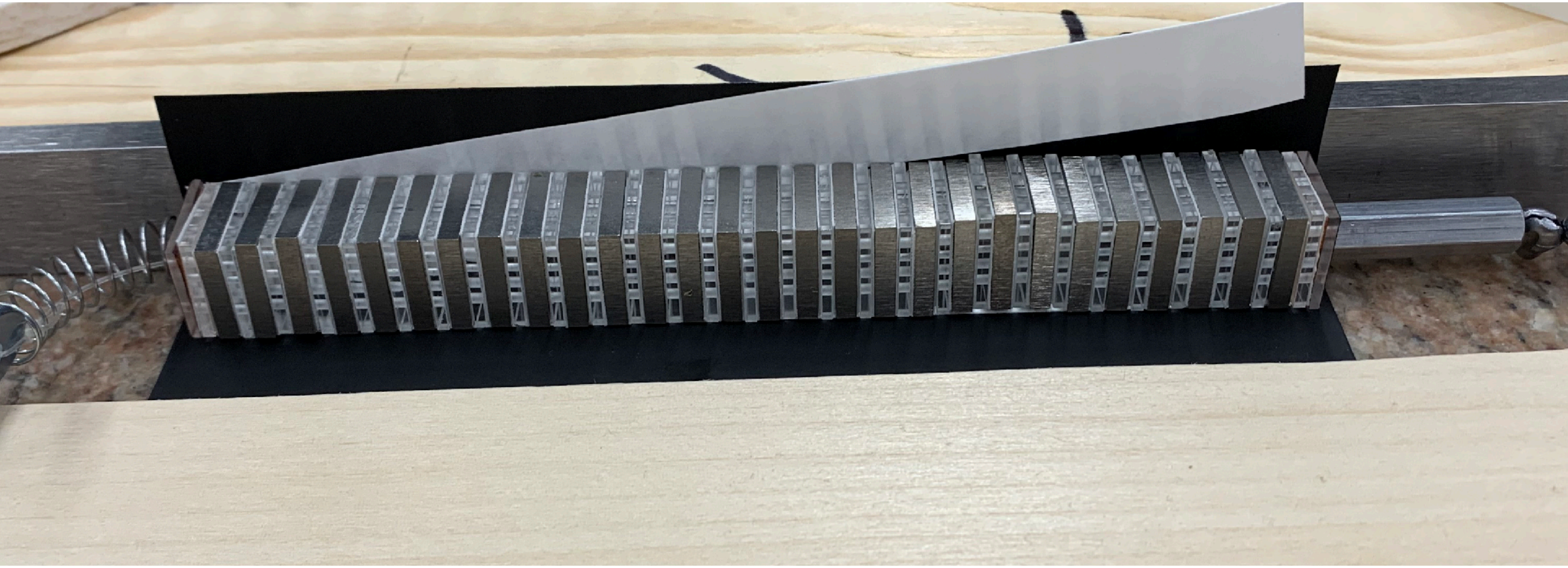

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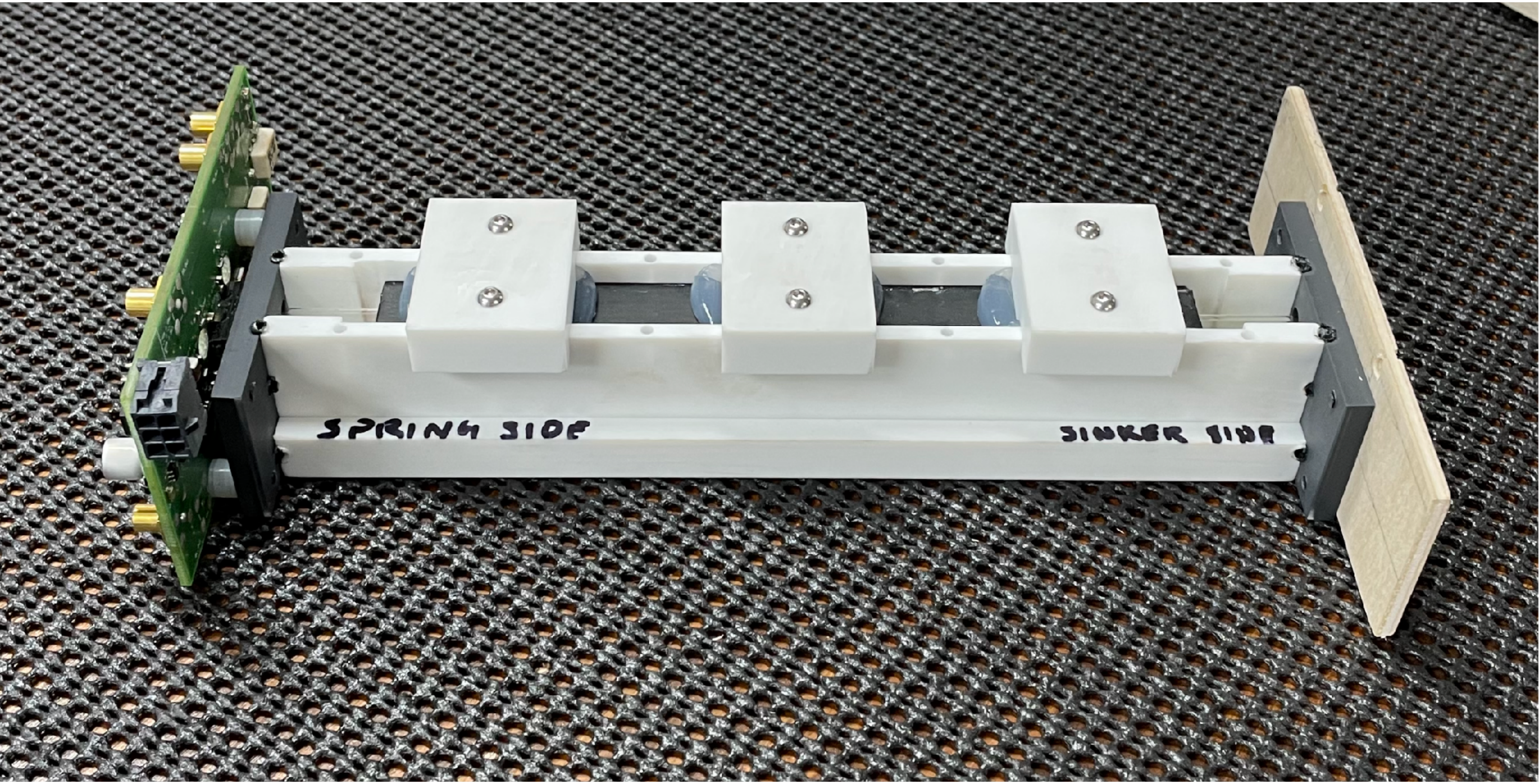
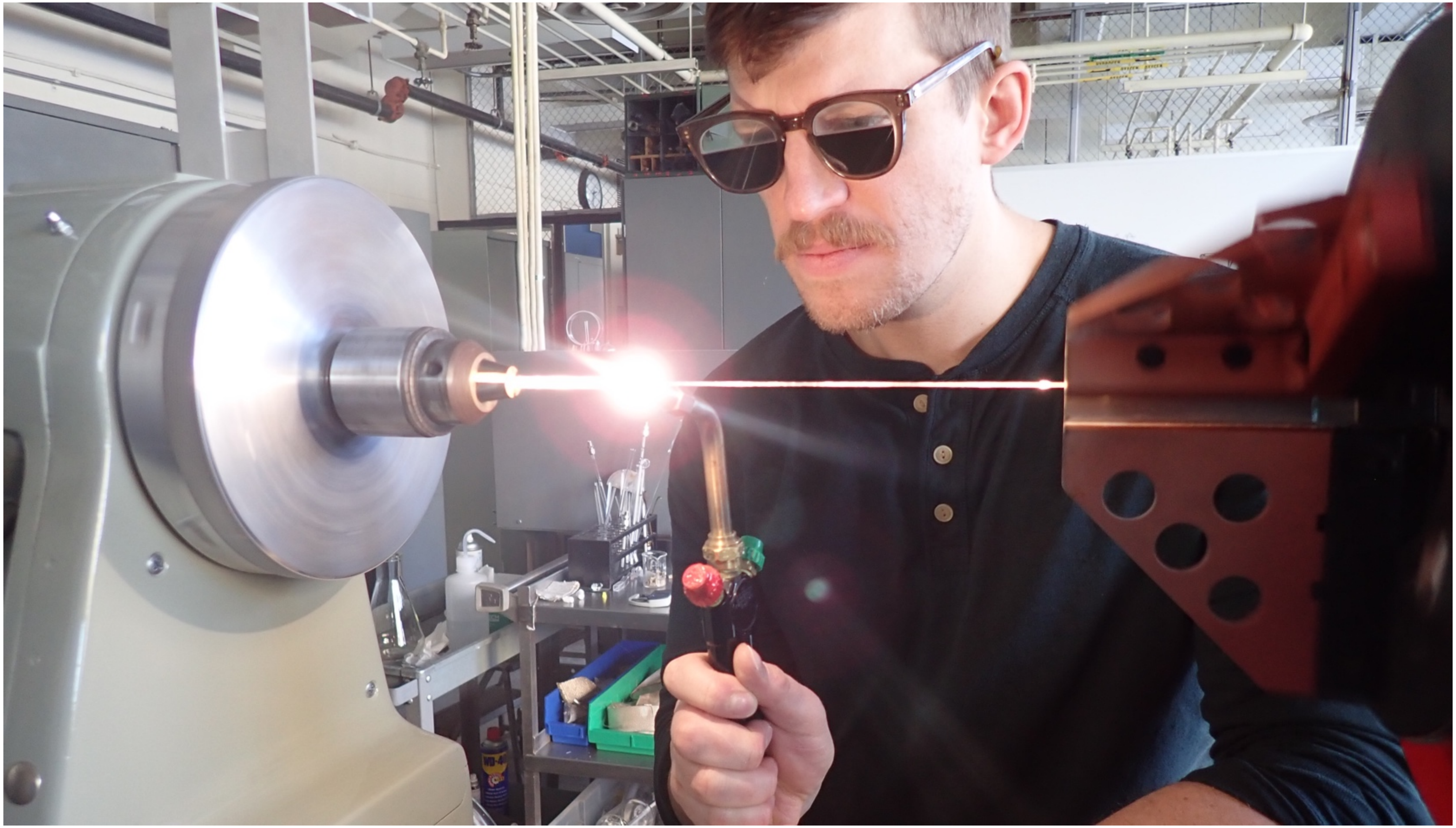


Preparing the Capillaries

K. Ford
Radiation Laboratory Glassblowing Shop
University of Notre Dame Core Facility, Radiation Laboratory, Notre Dame IN 46556



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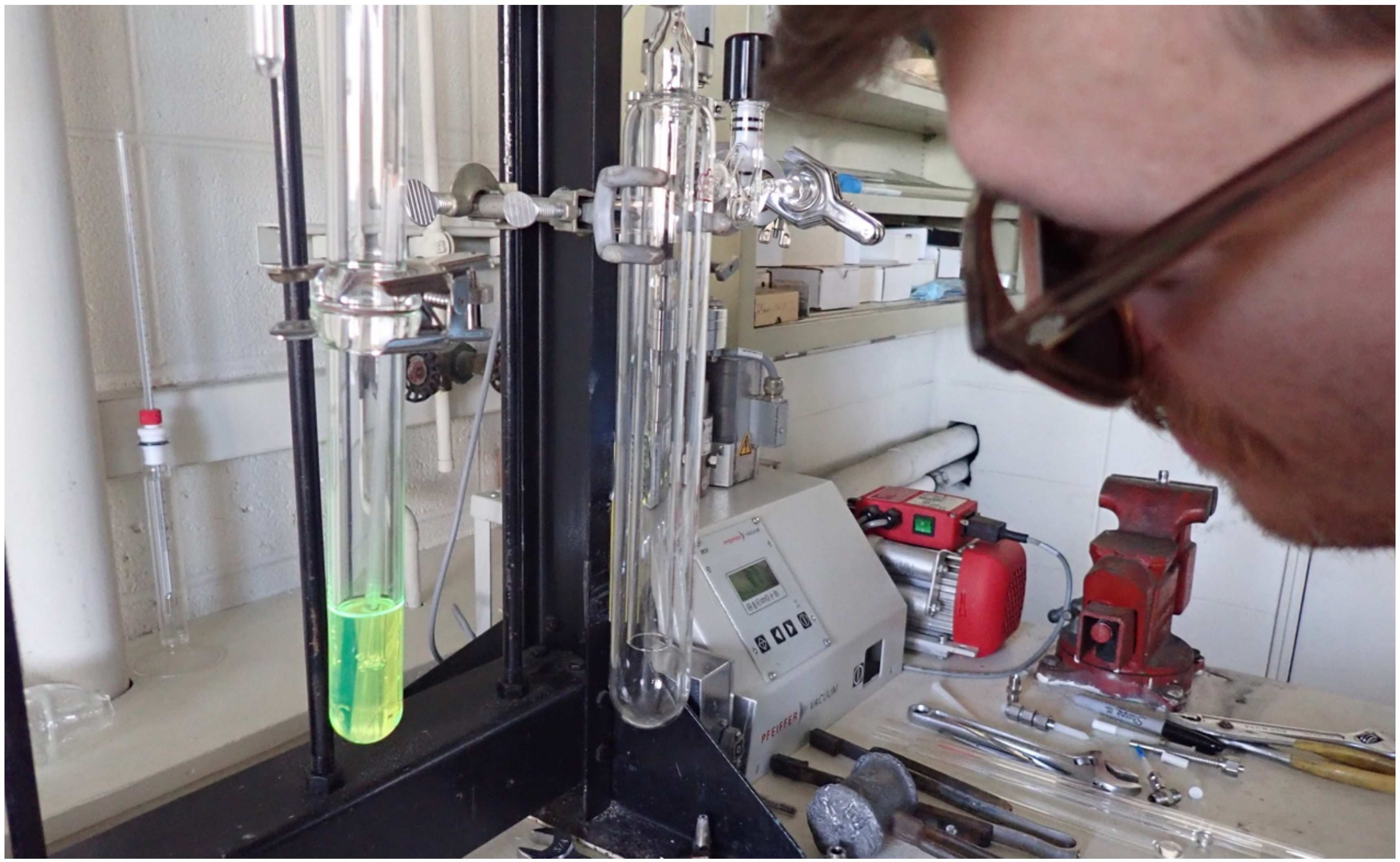

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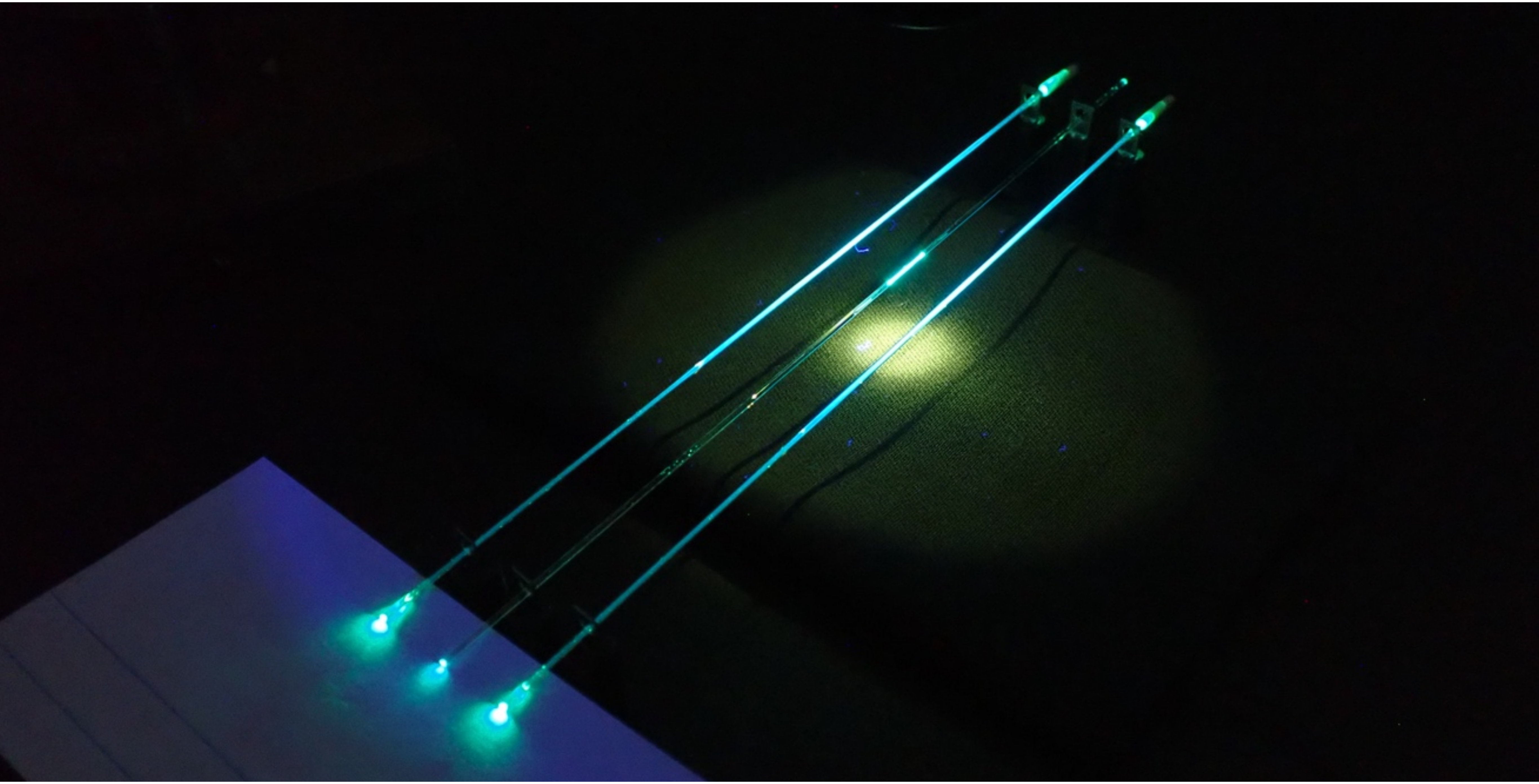

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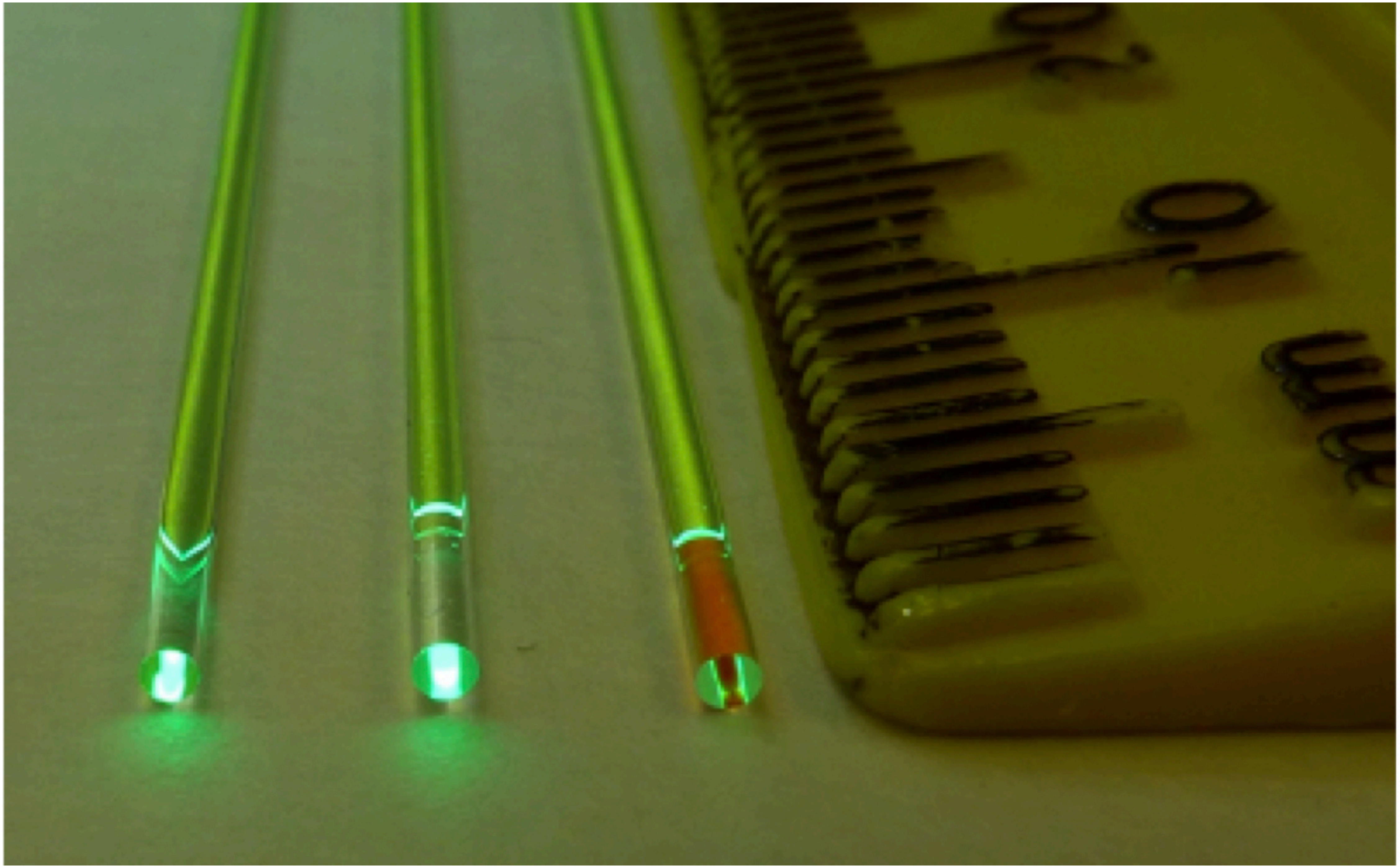

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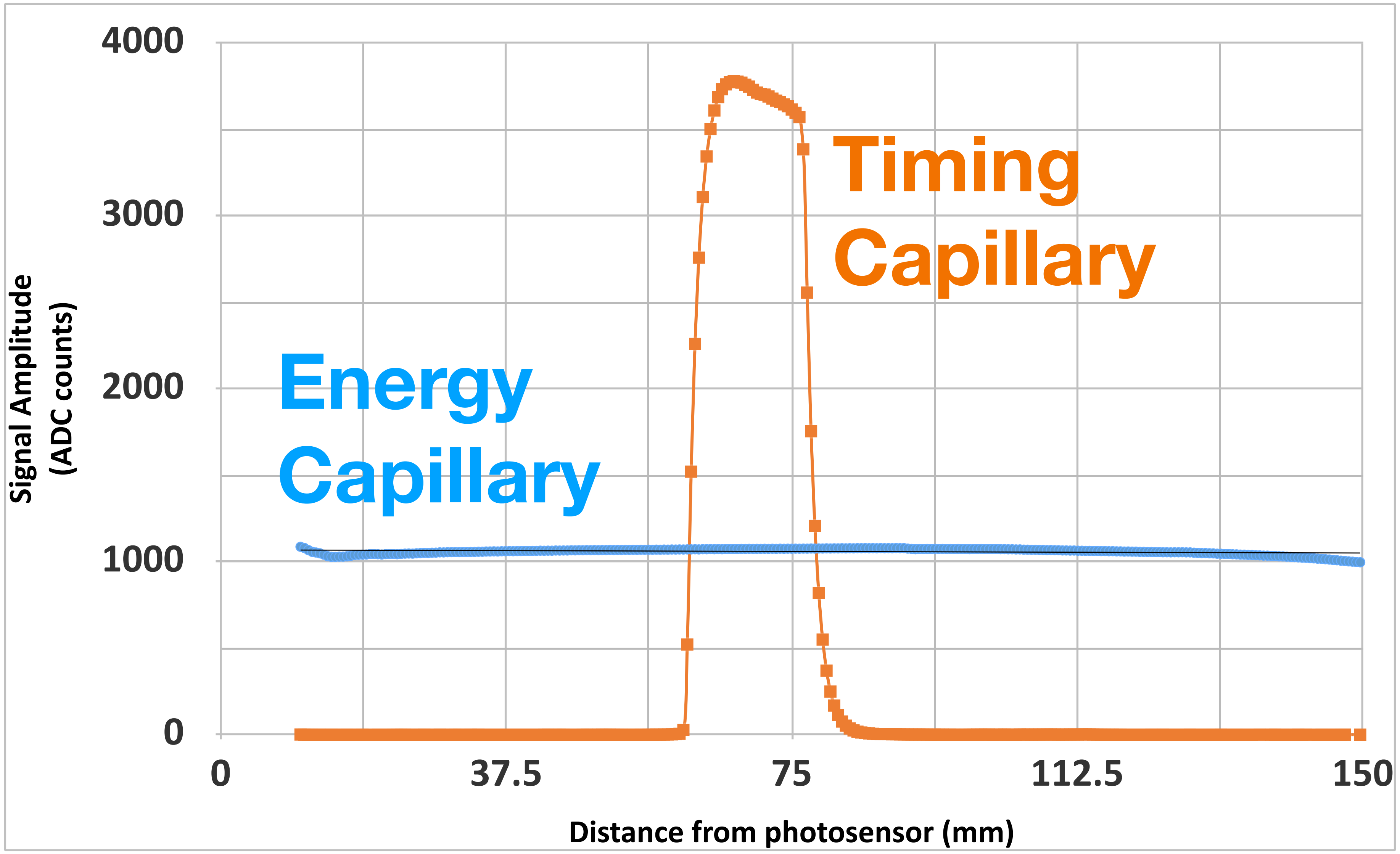

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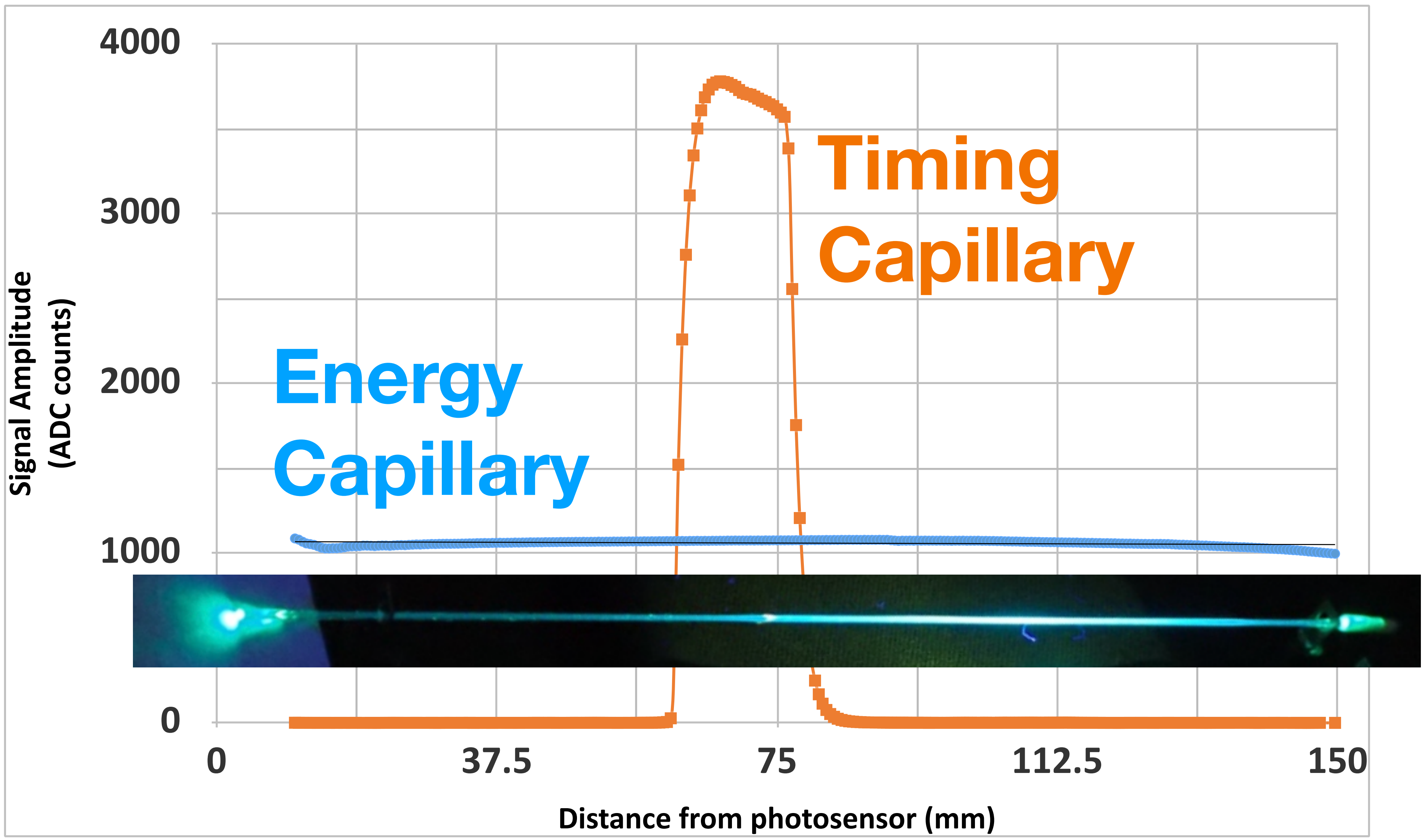

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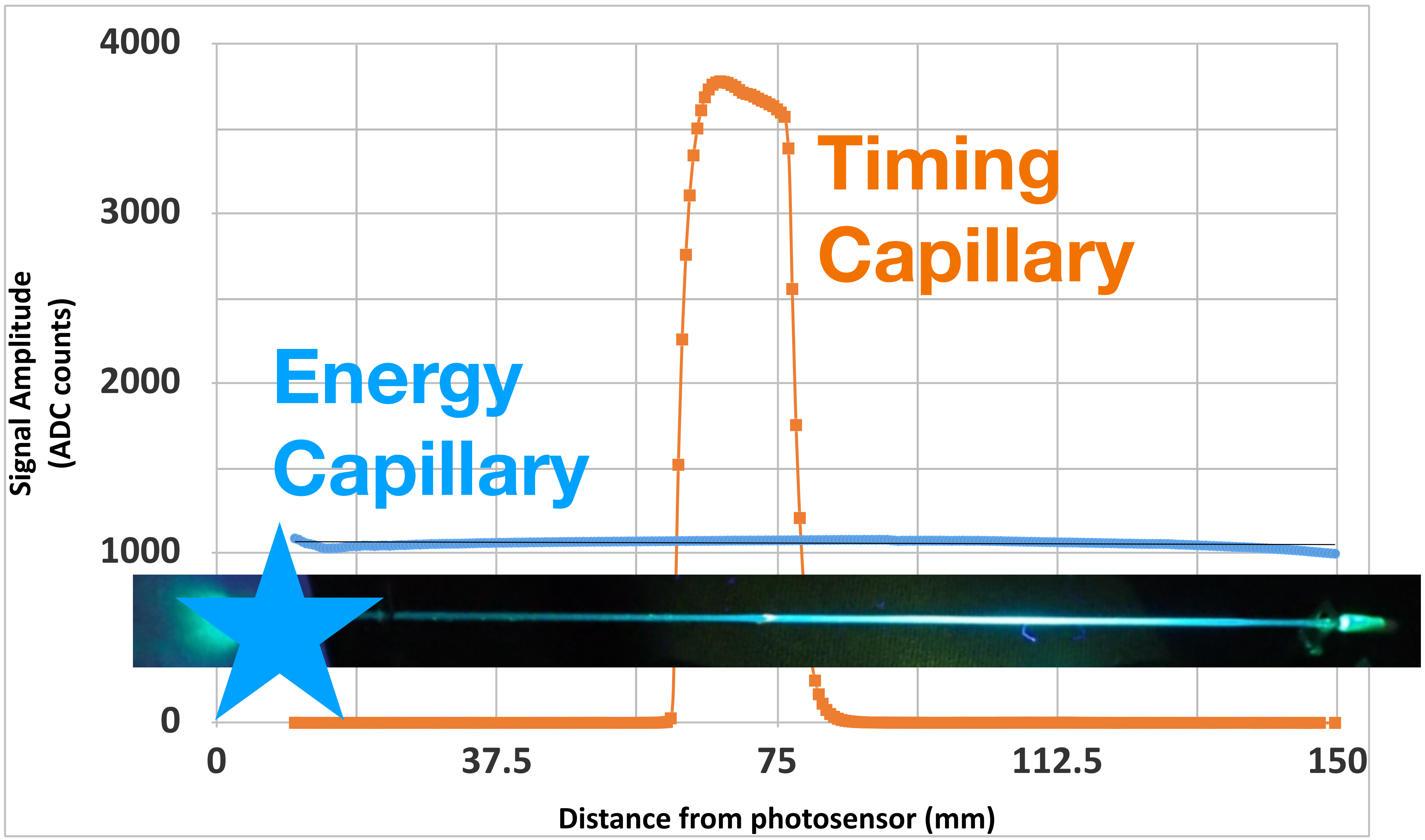

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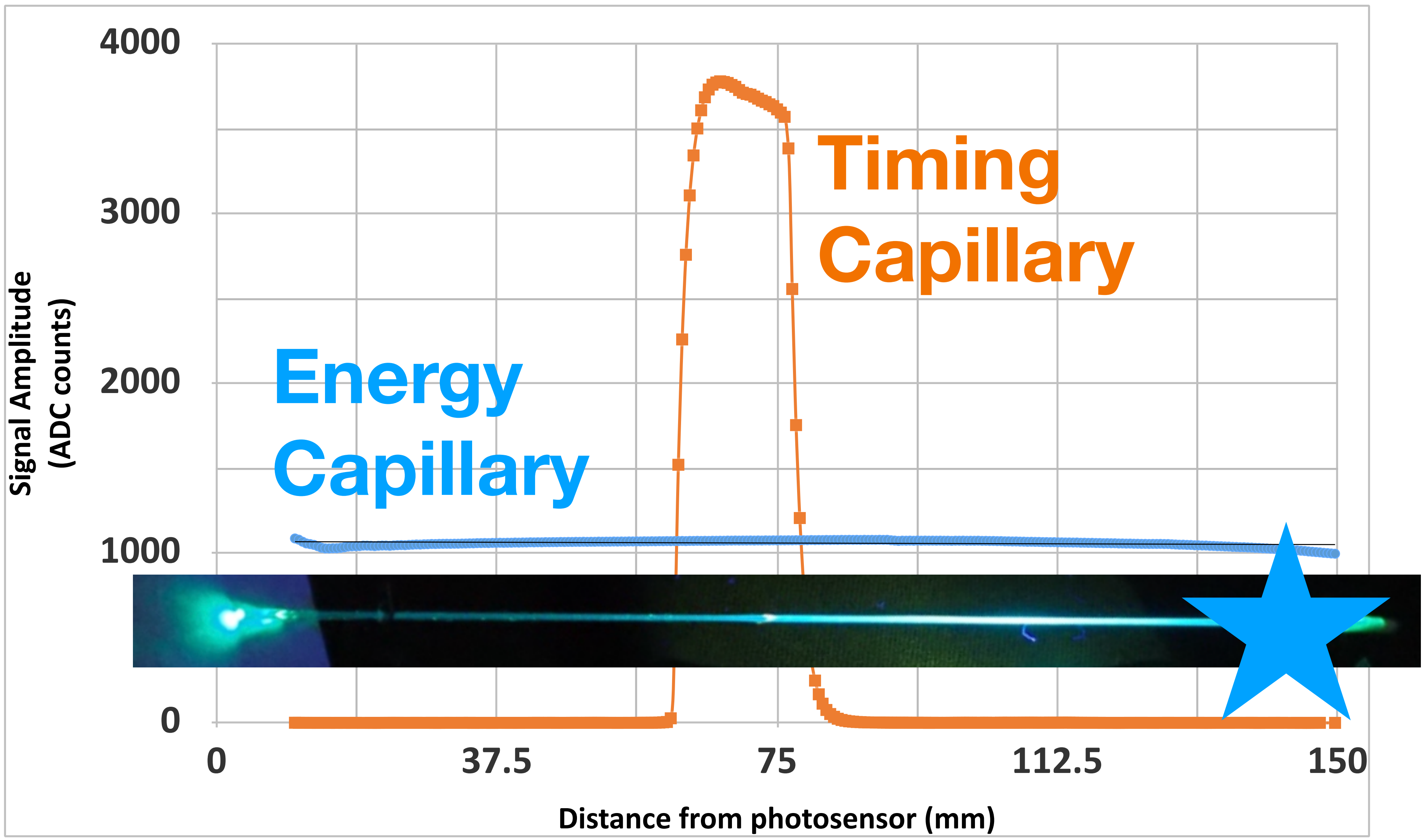

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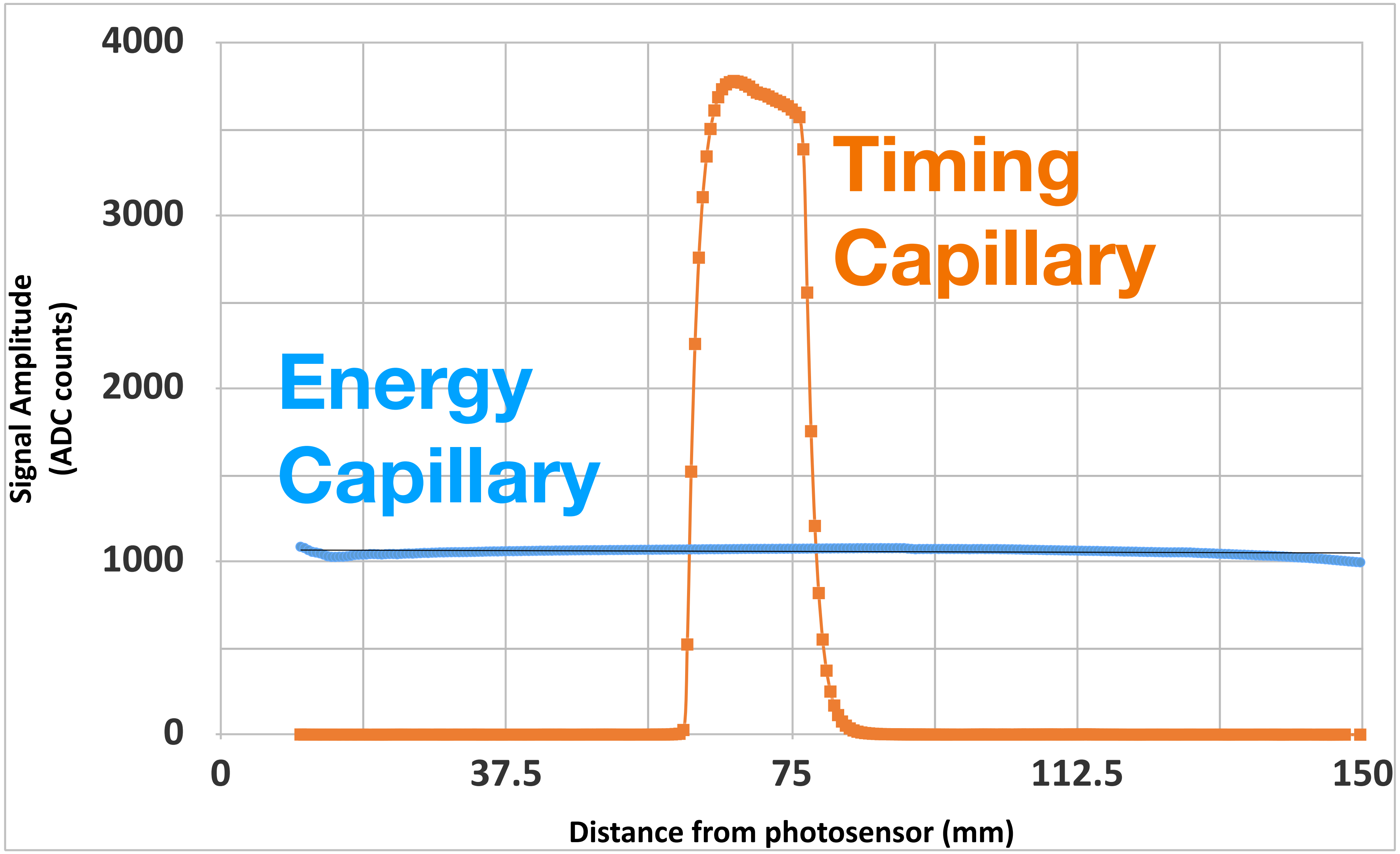

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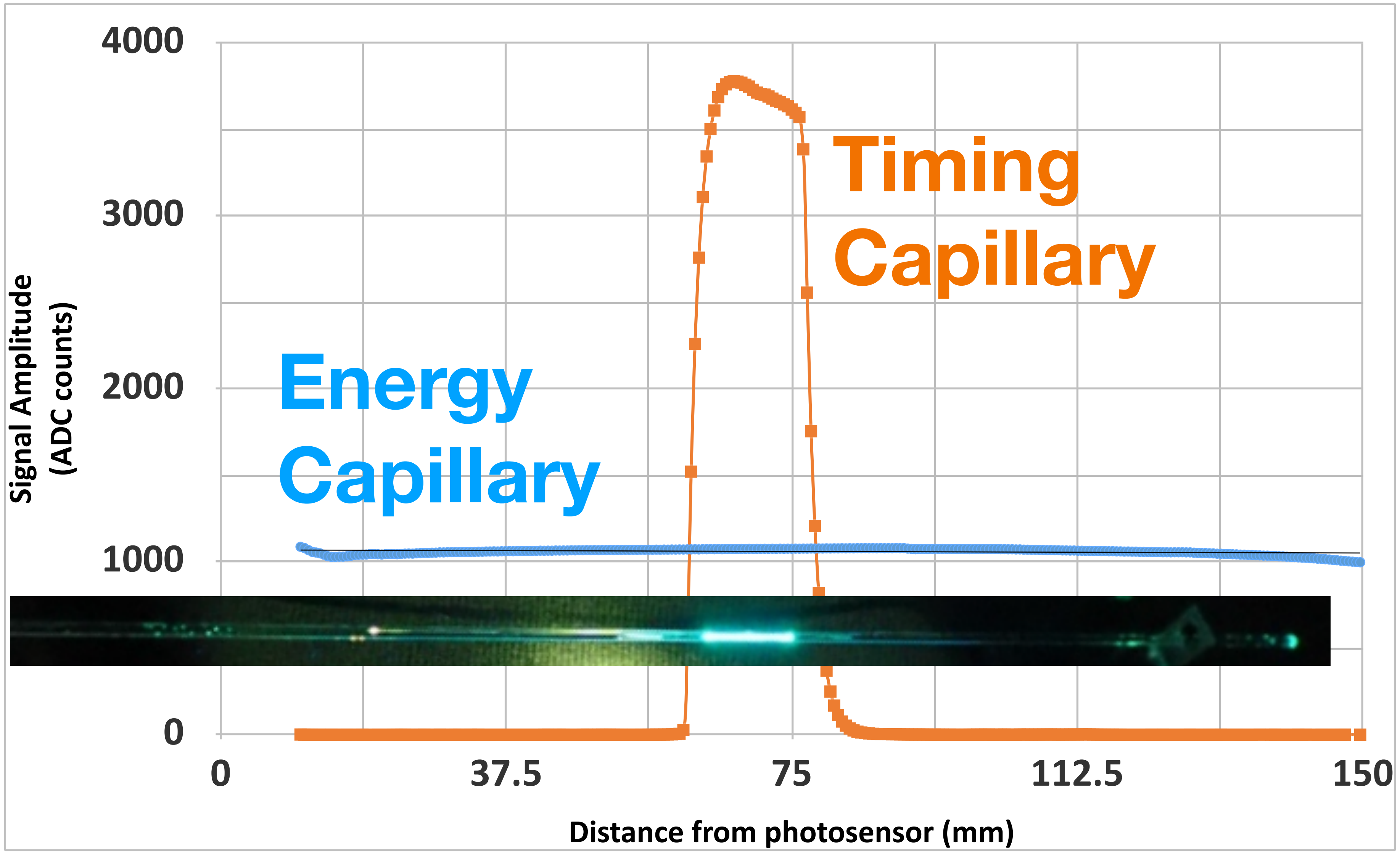

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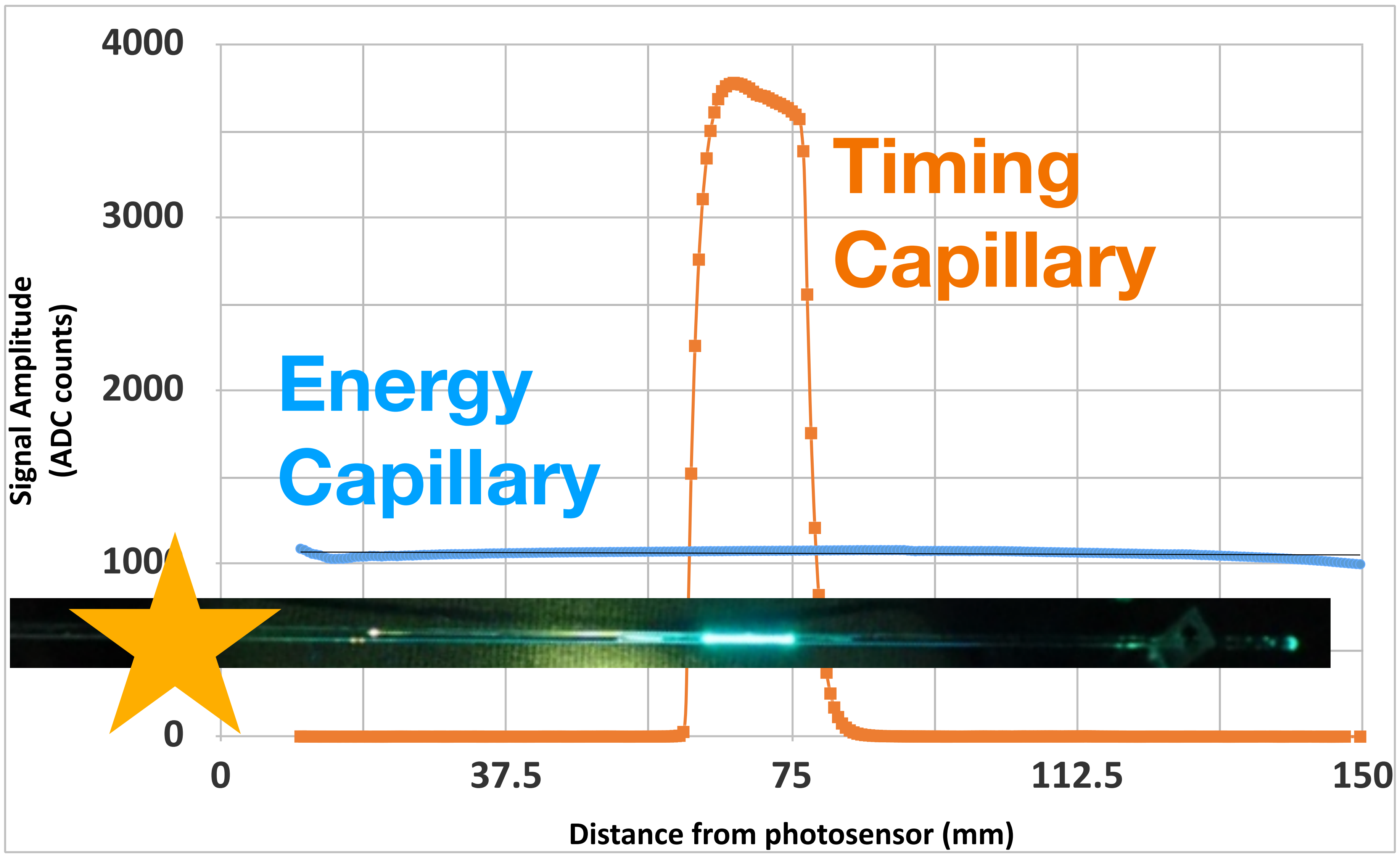

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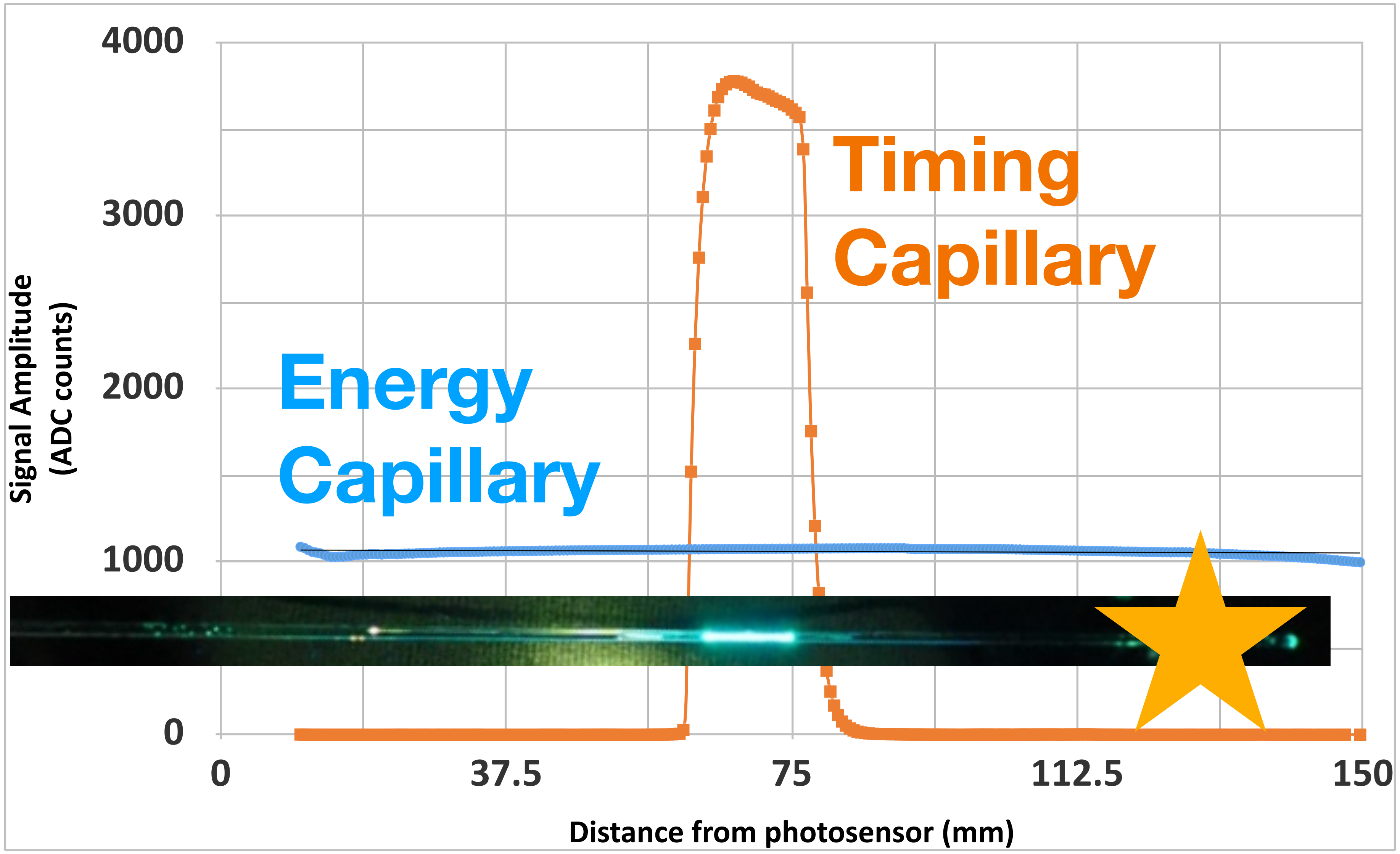
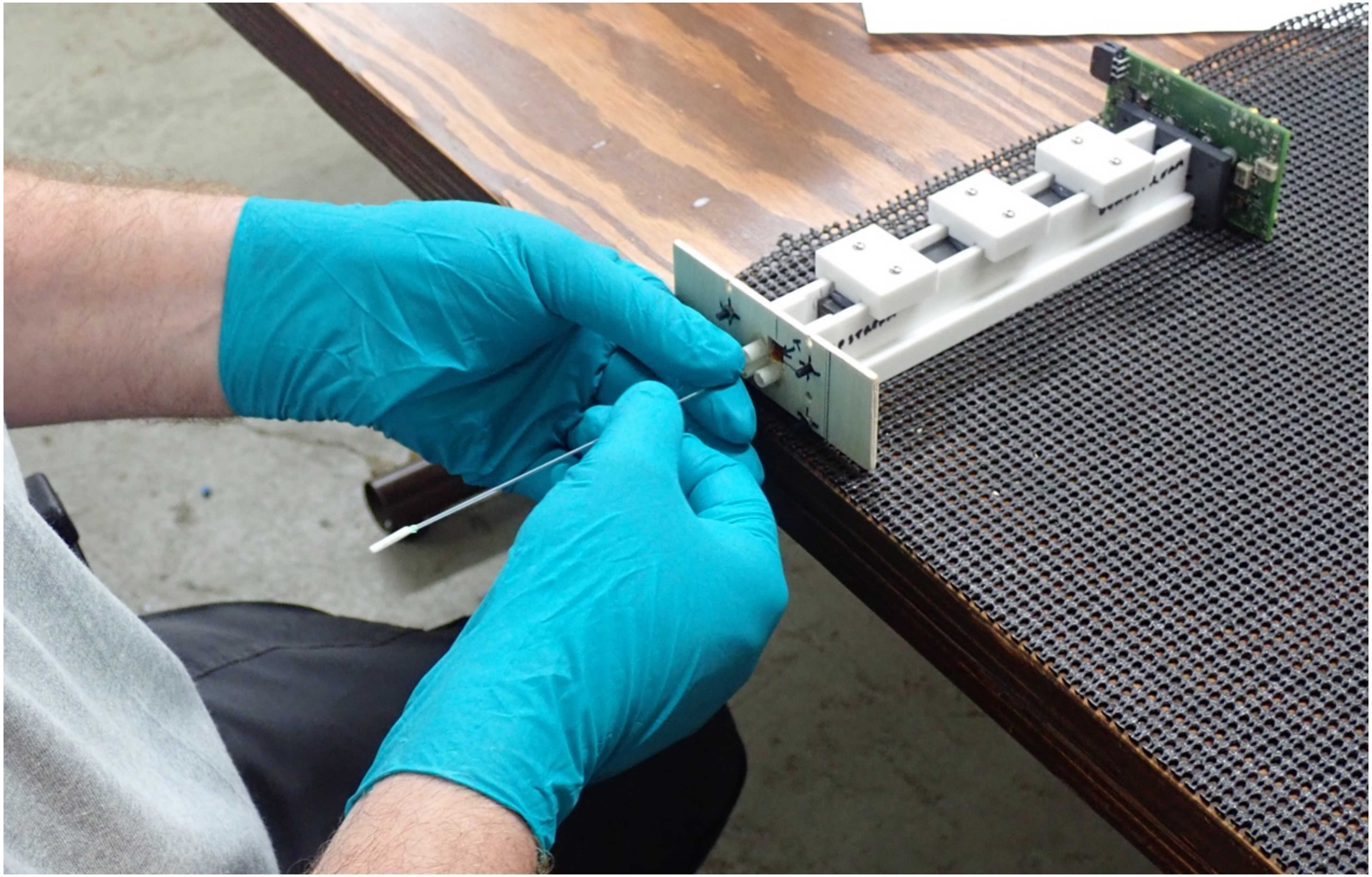


Preparing the Capillaries

P. Debbins at FNAL



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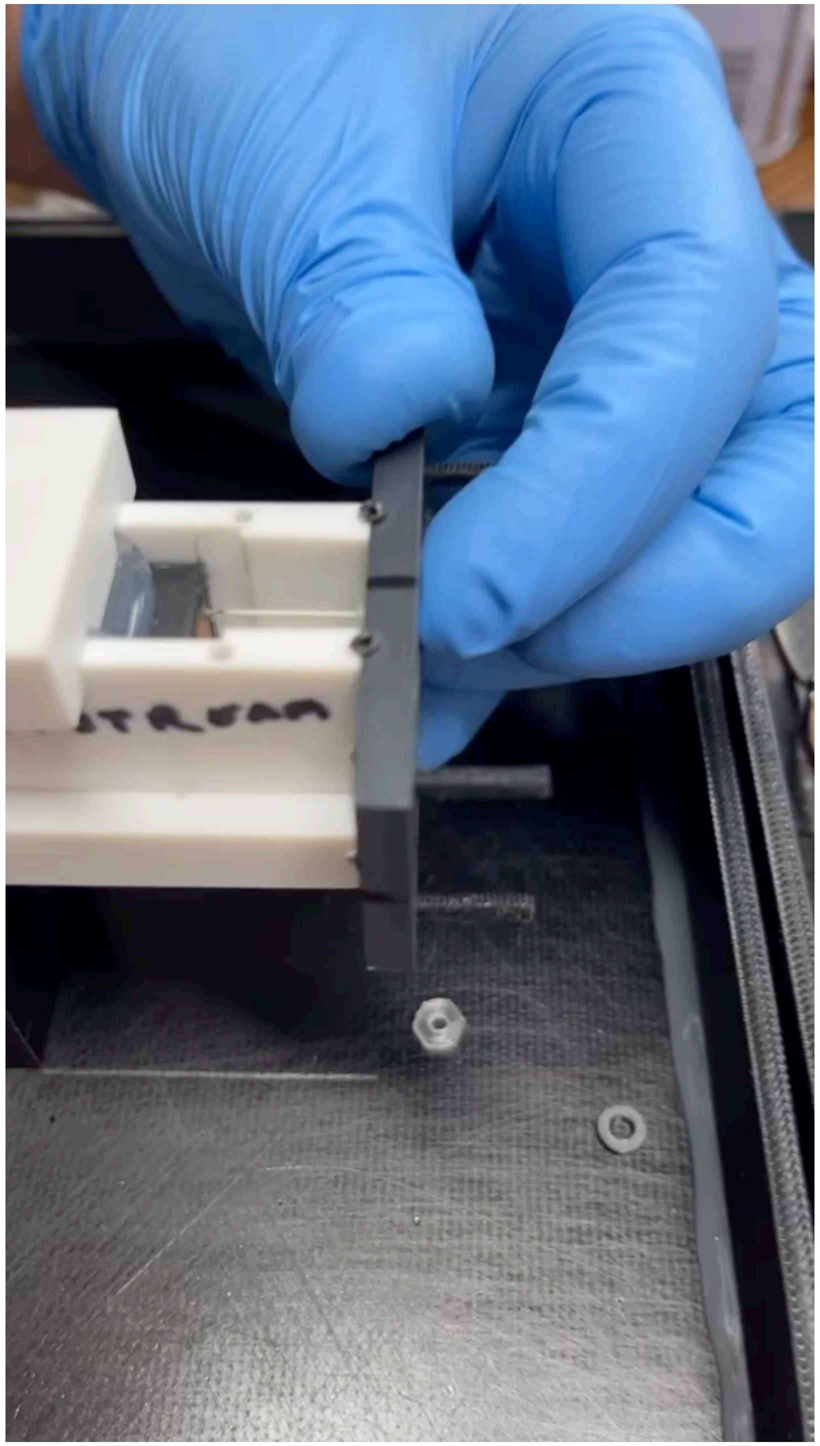
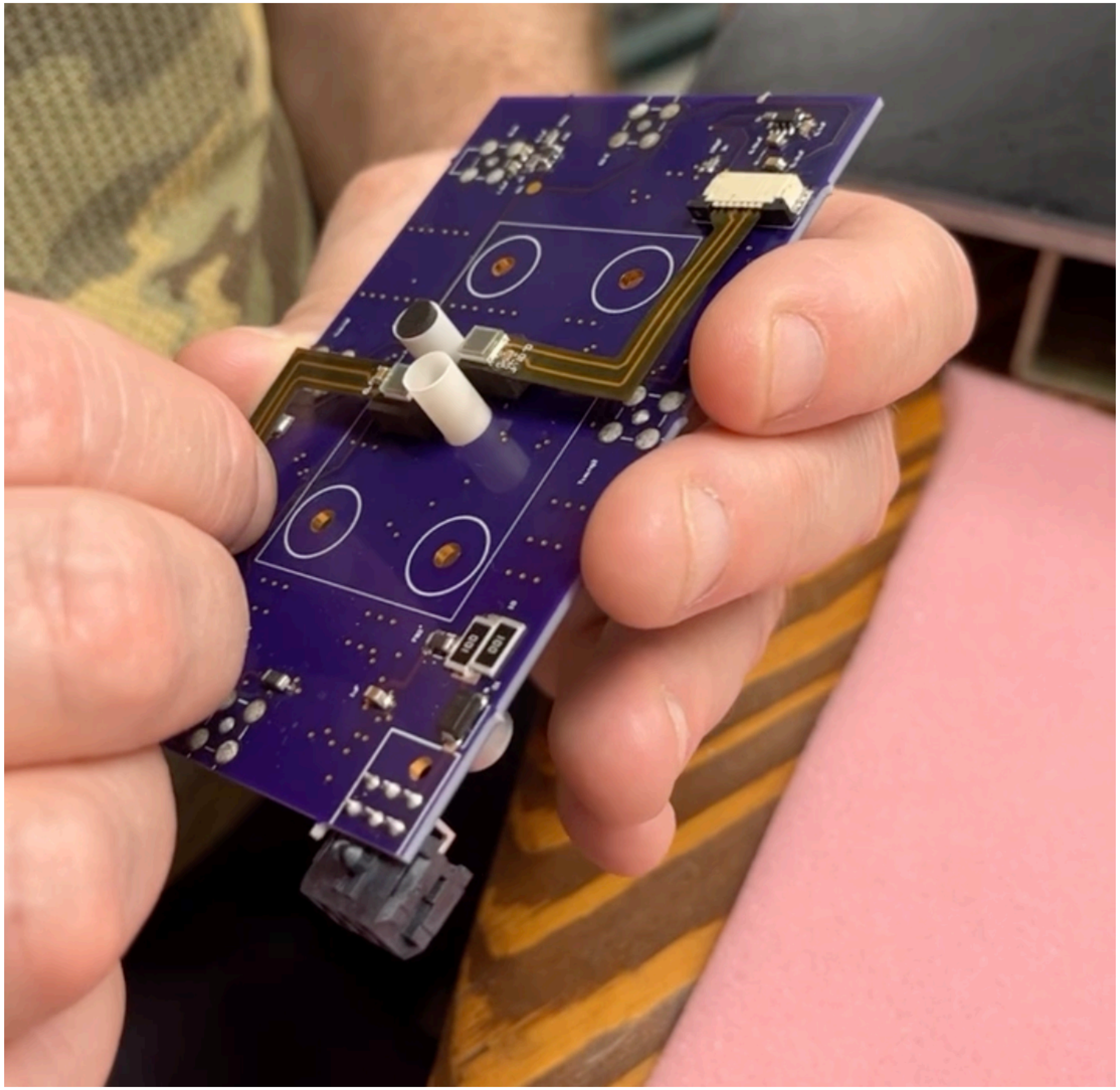
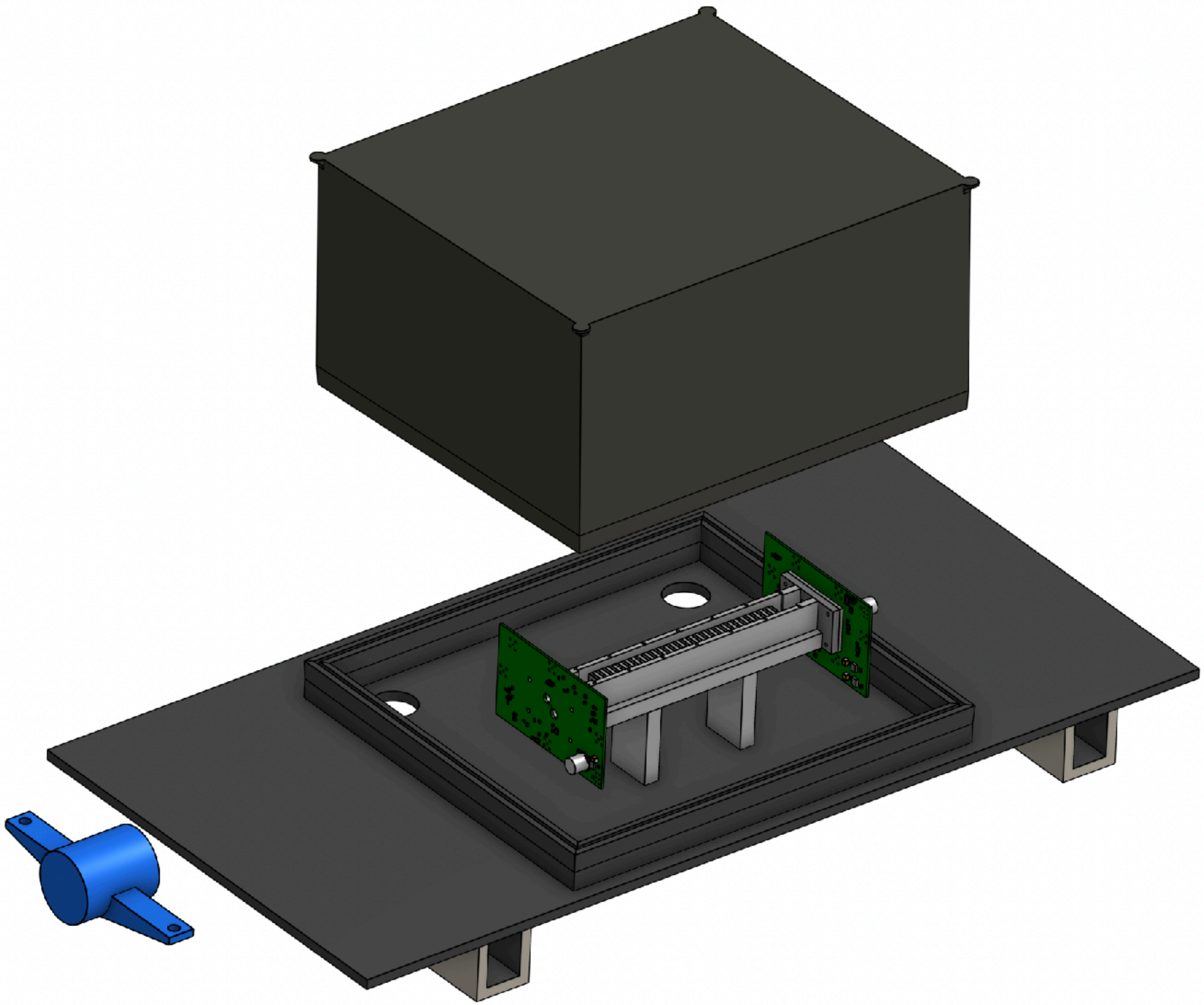




RADiCAL at Fermilab



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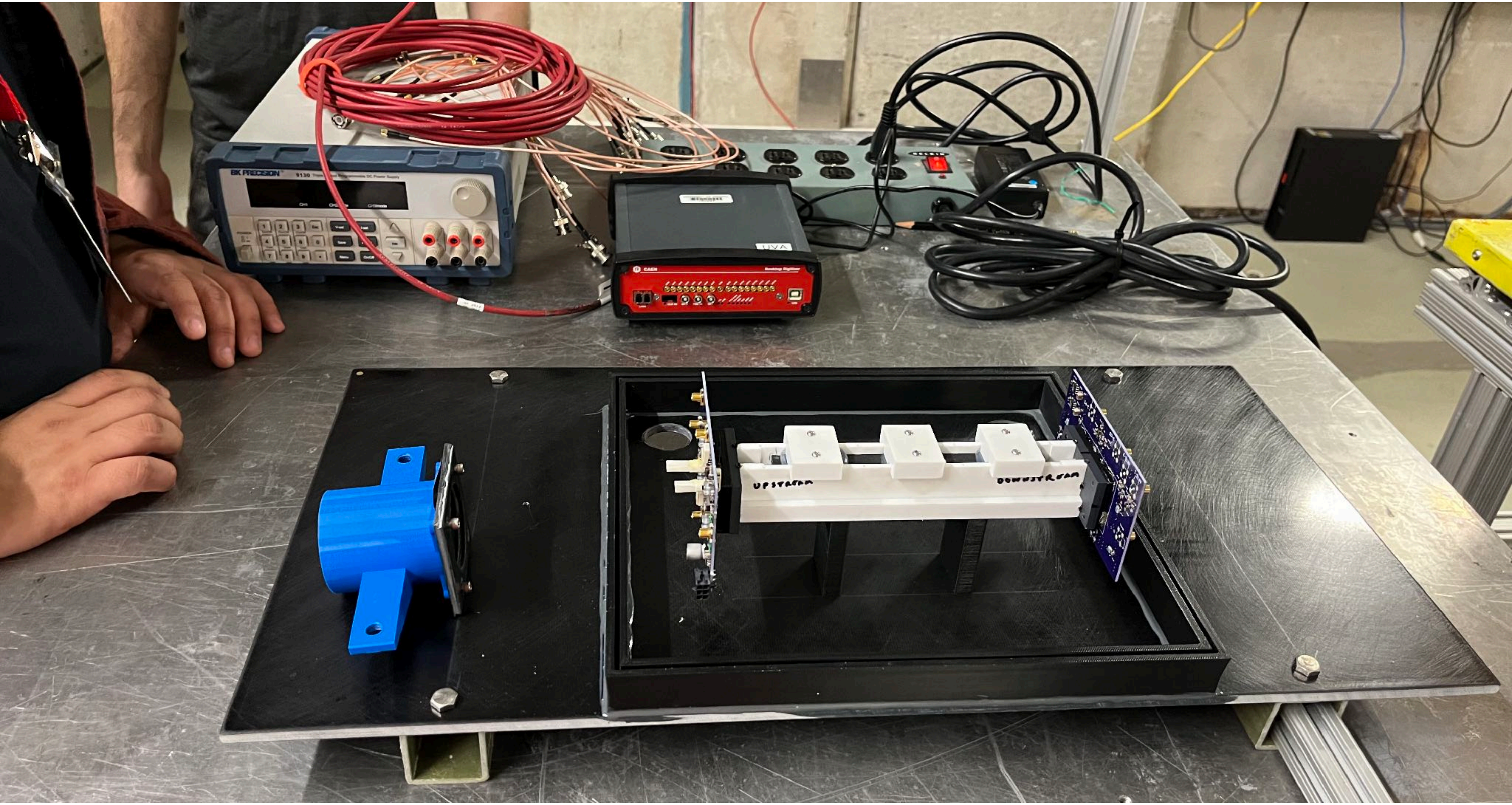

RADiCAL at Fermilab

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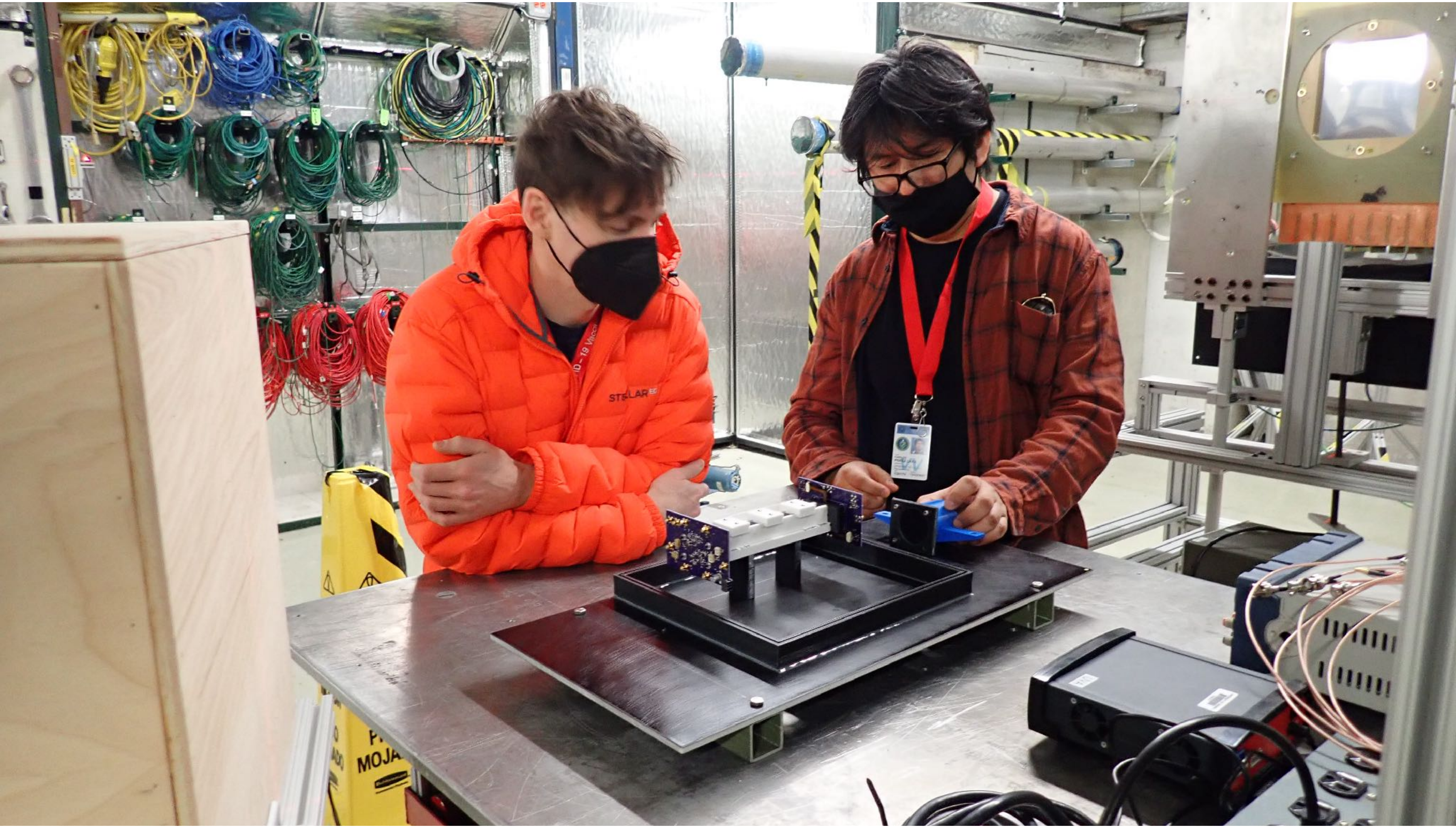
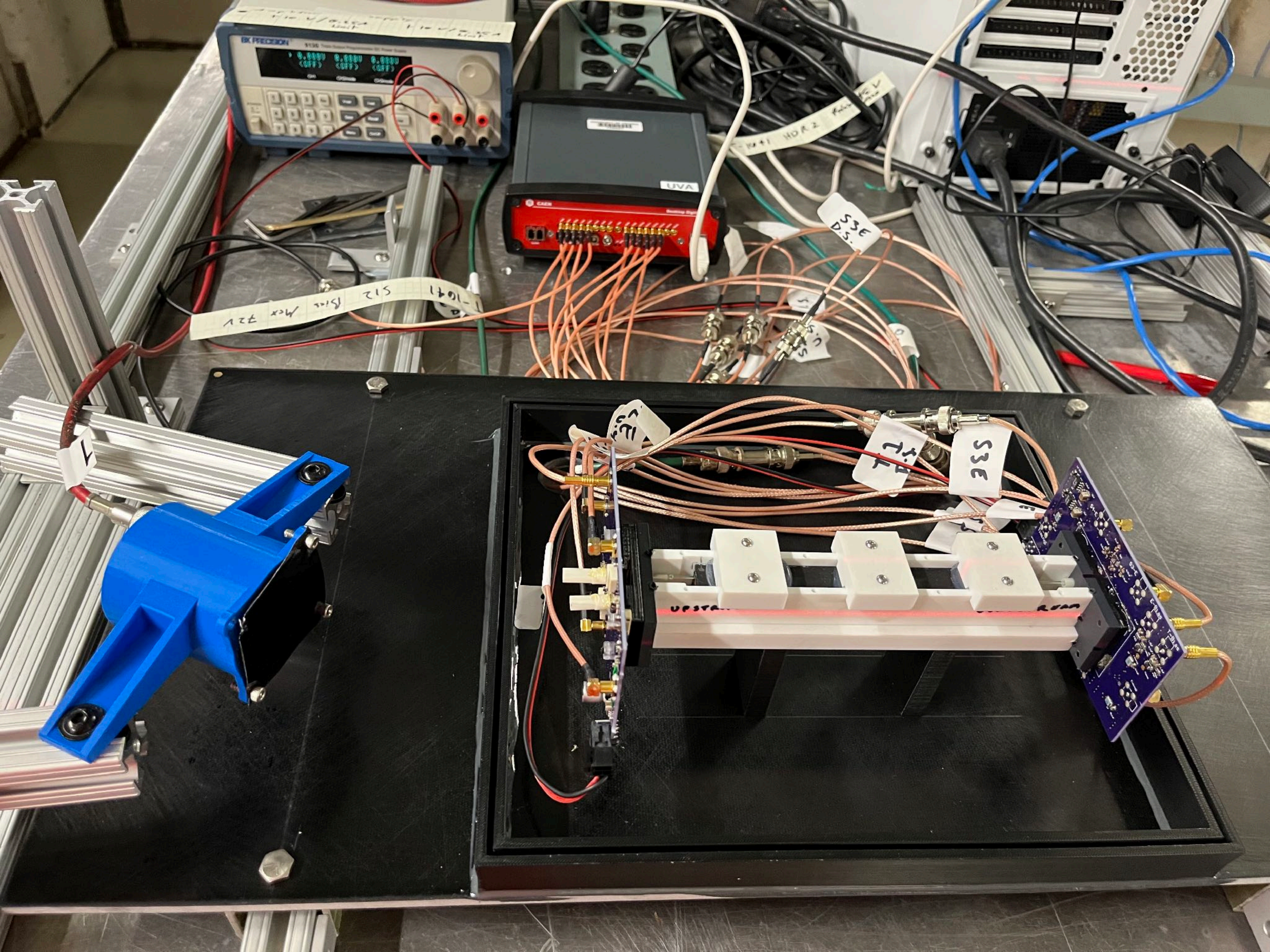
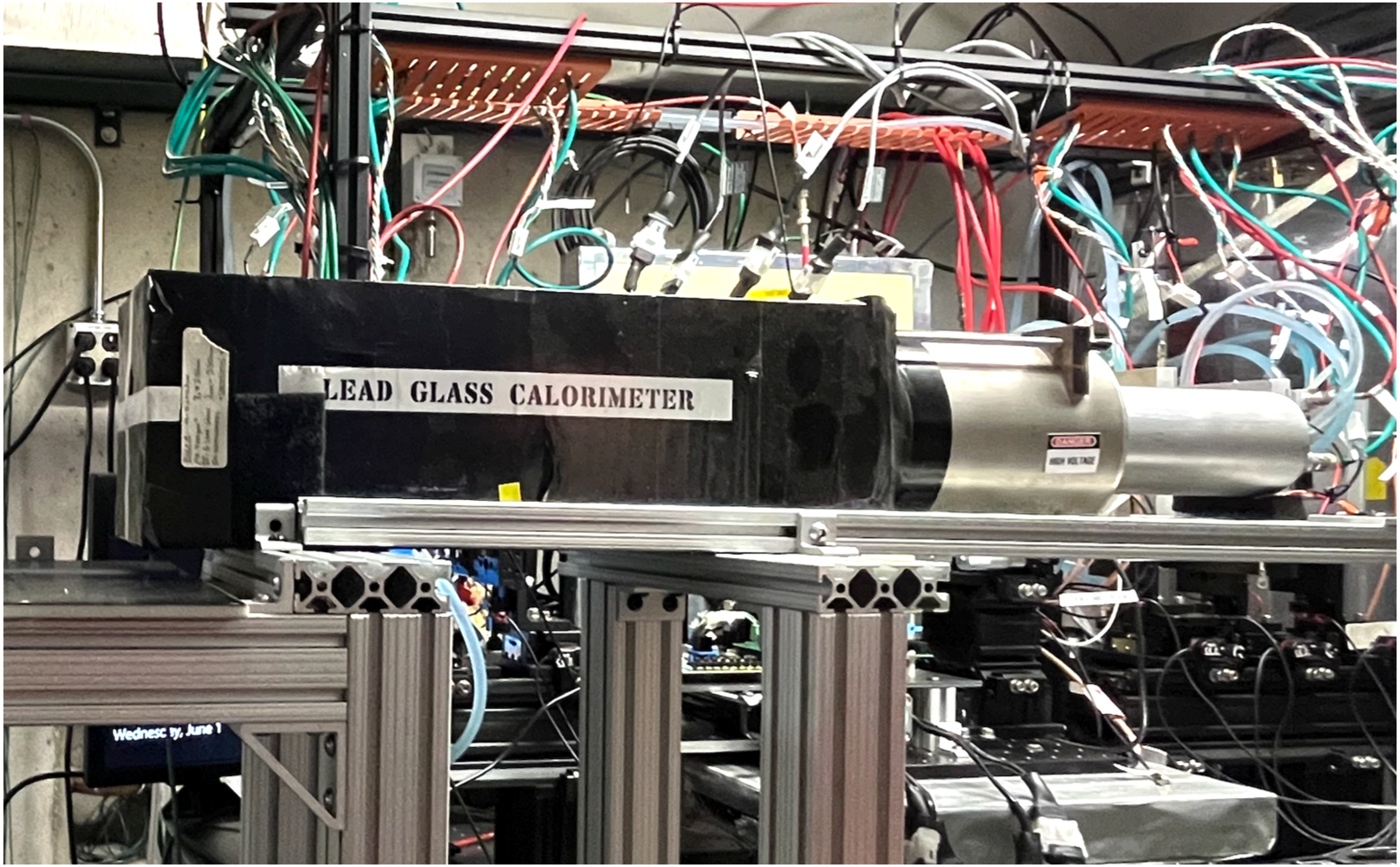



BK PRECISION
CAEN
UVA
S3E D.S.
S3E

RADiCAL at Fermilab



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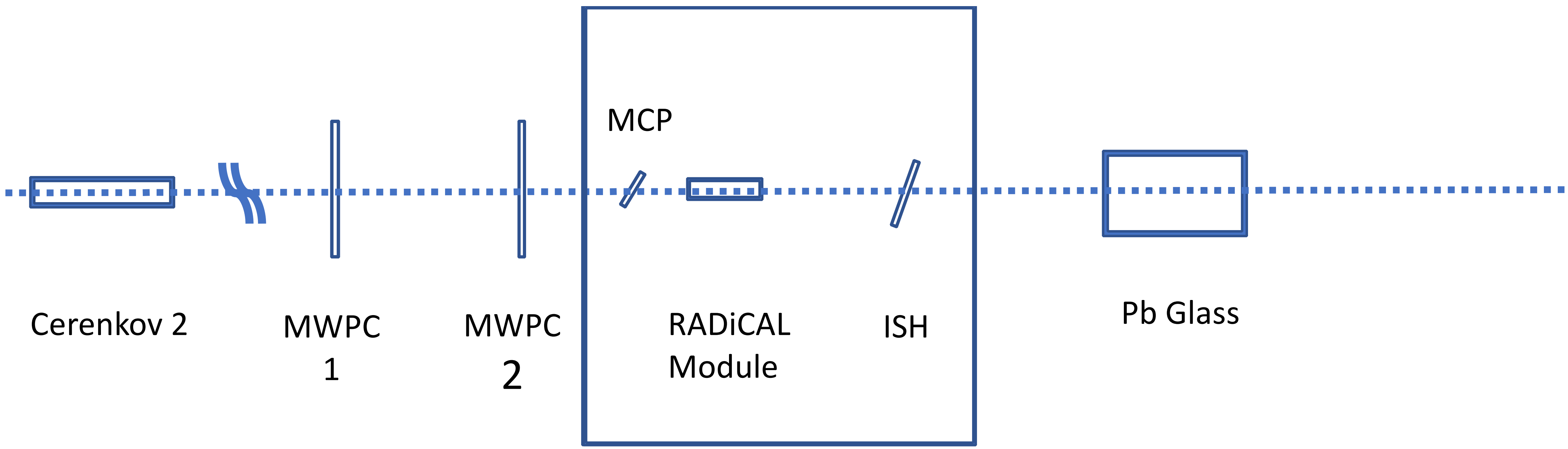

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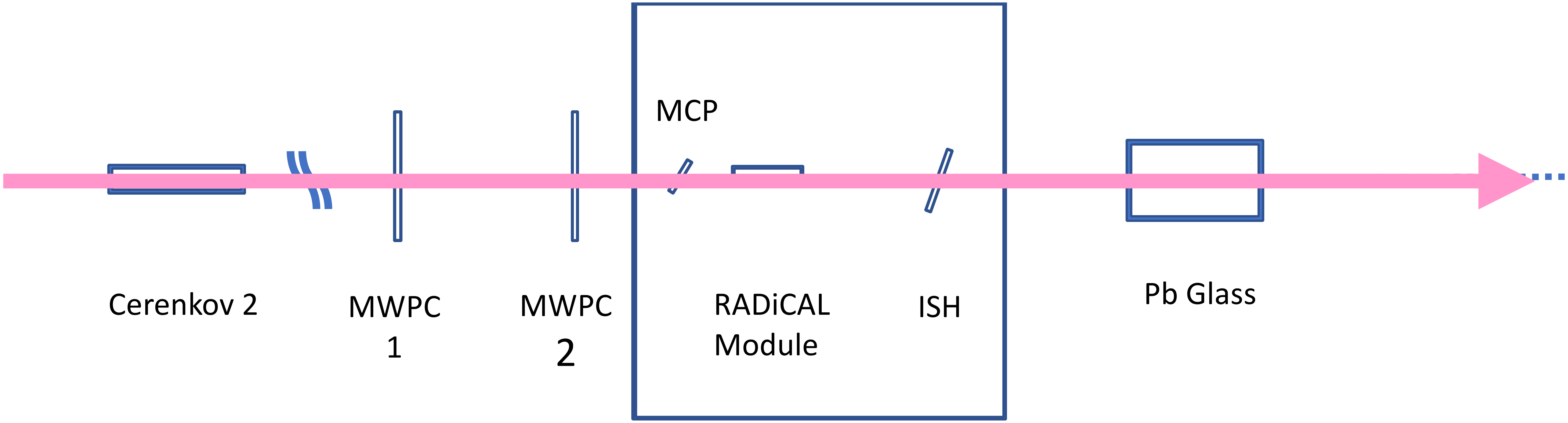

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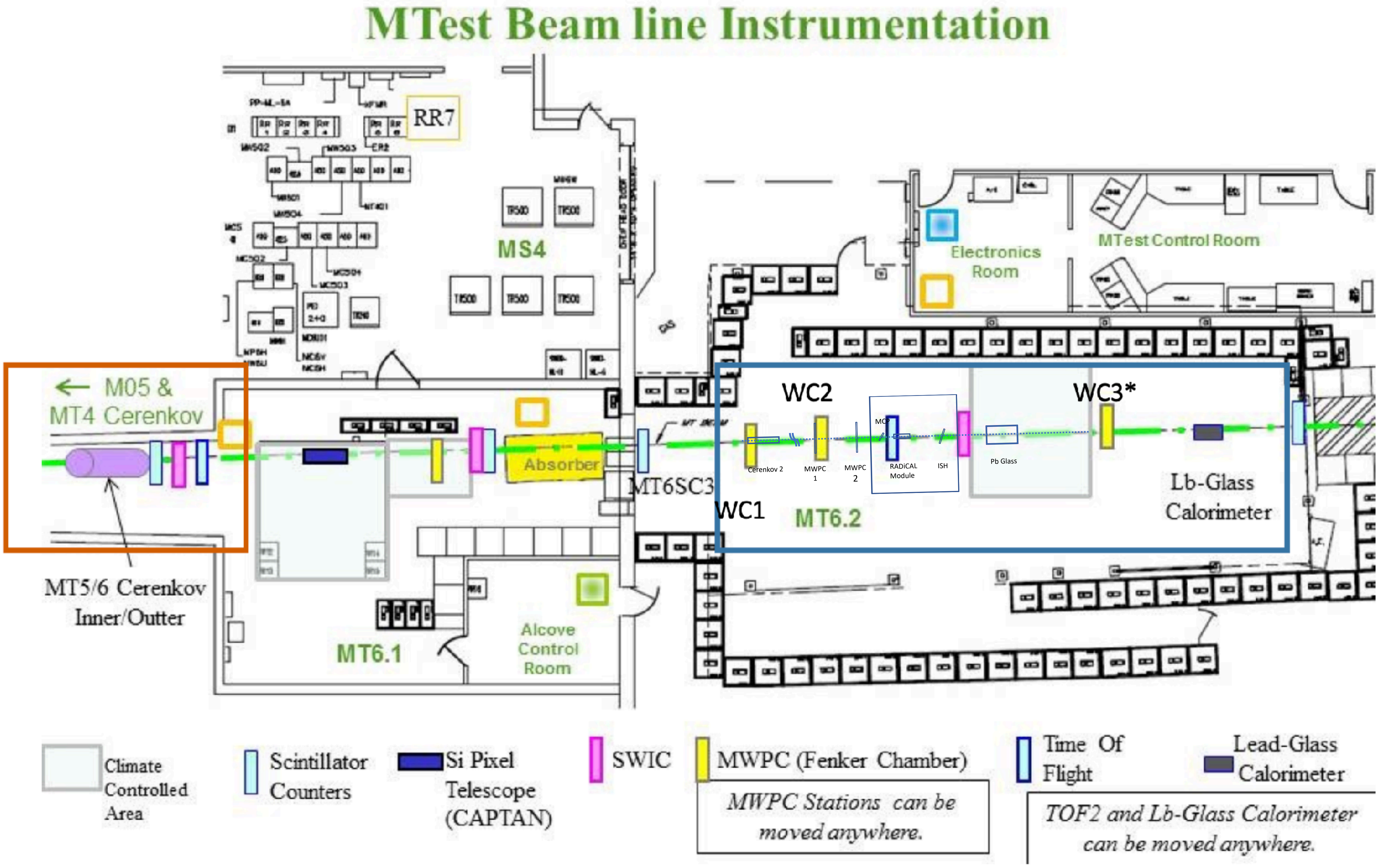

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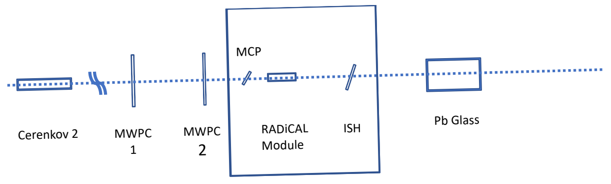

RADiCAL at Fermilab

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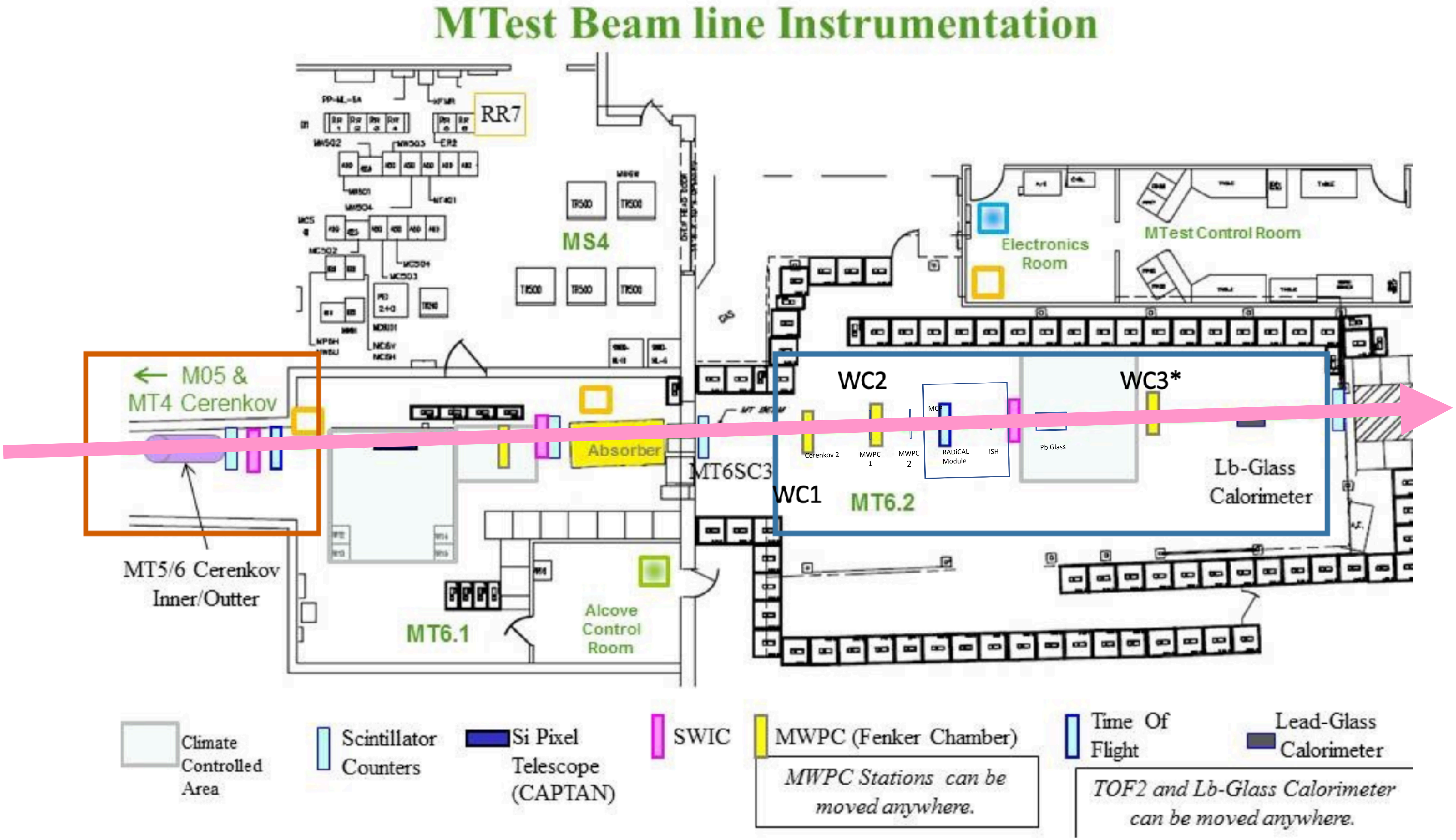

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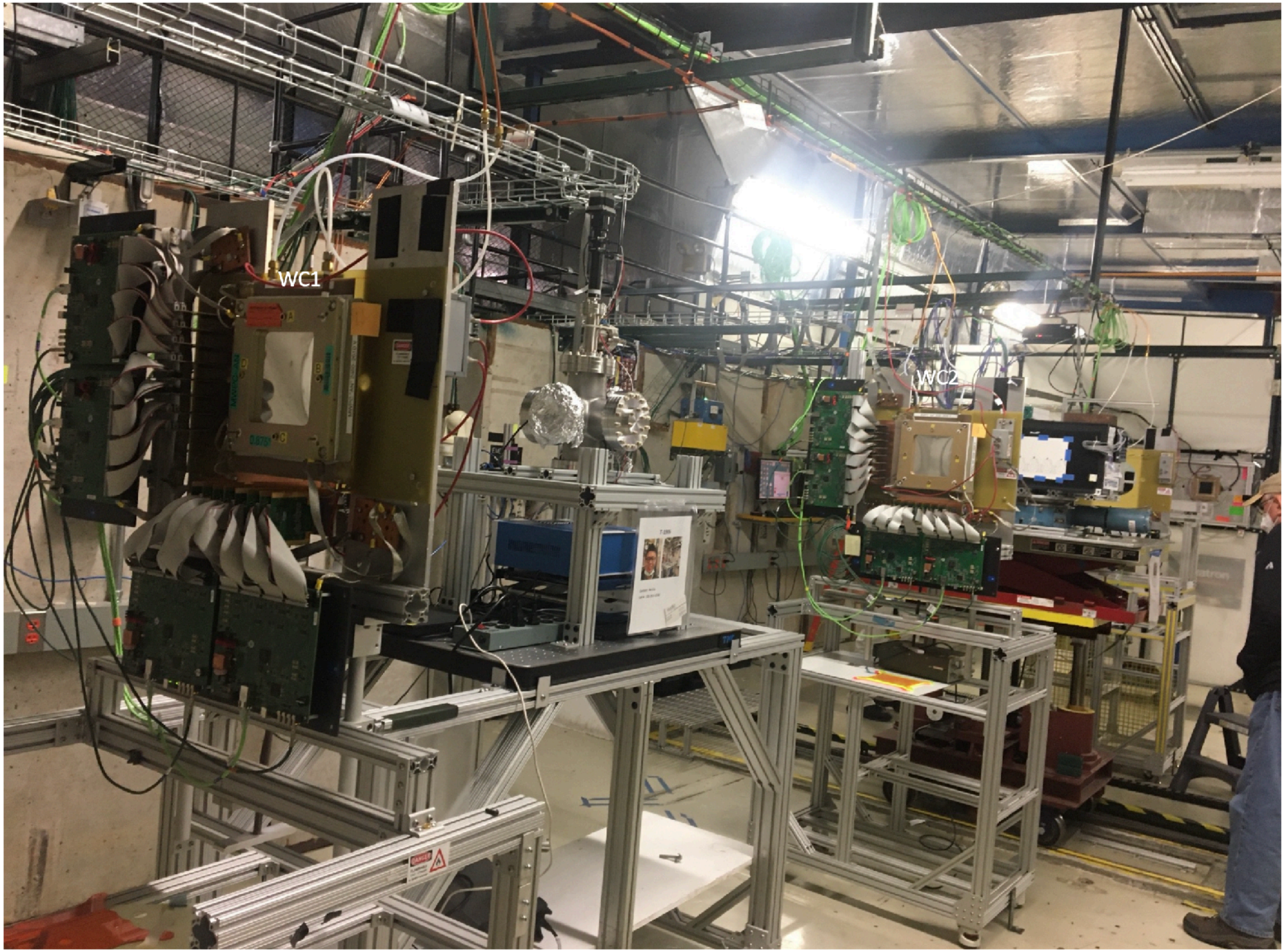

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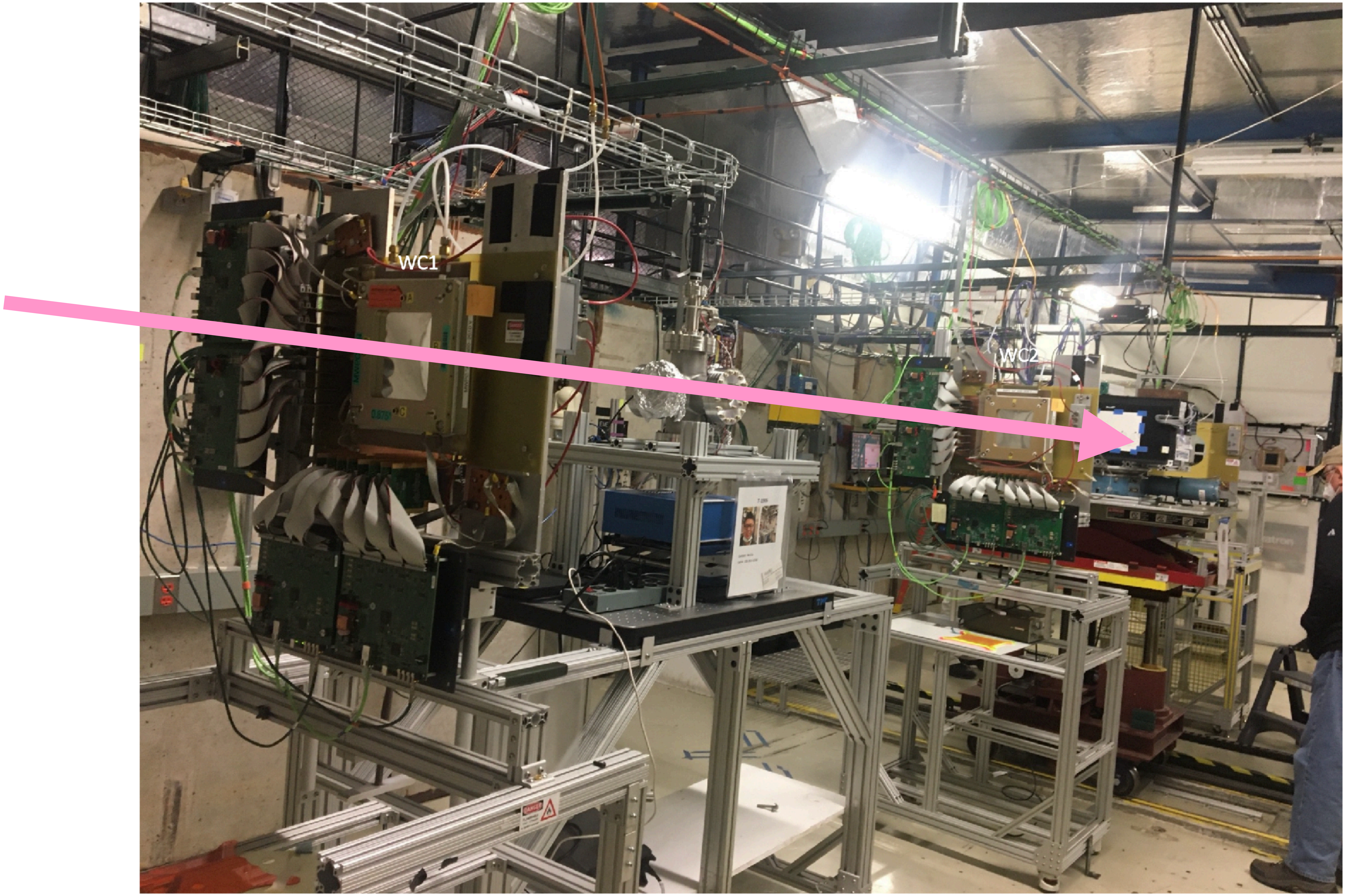

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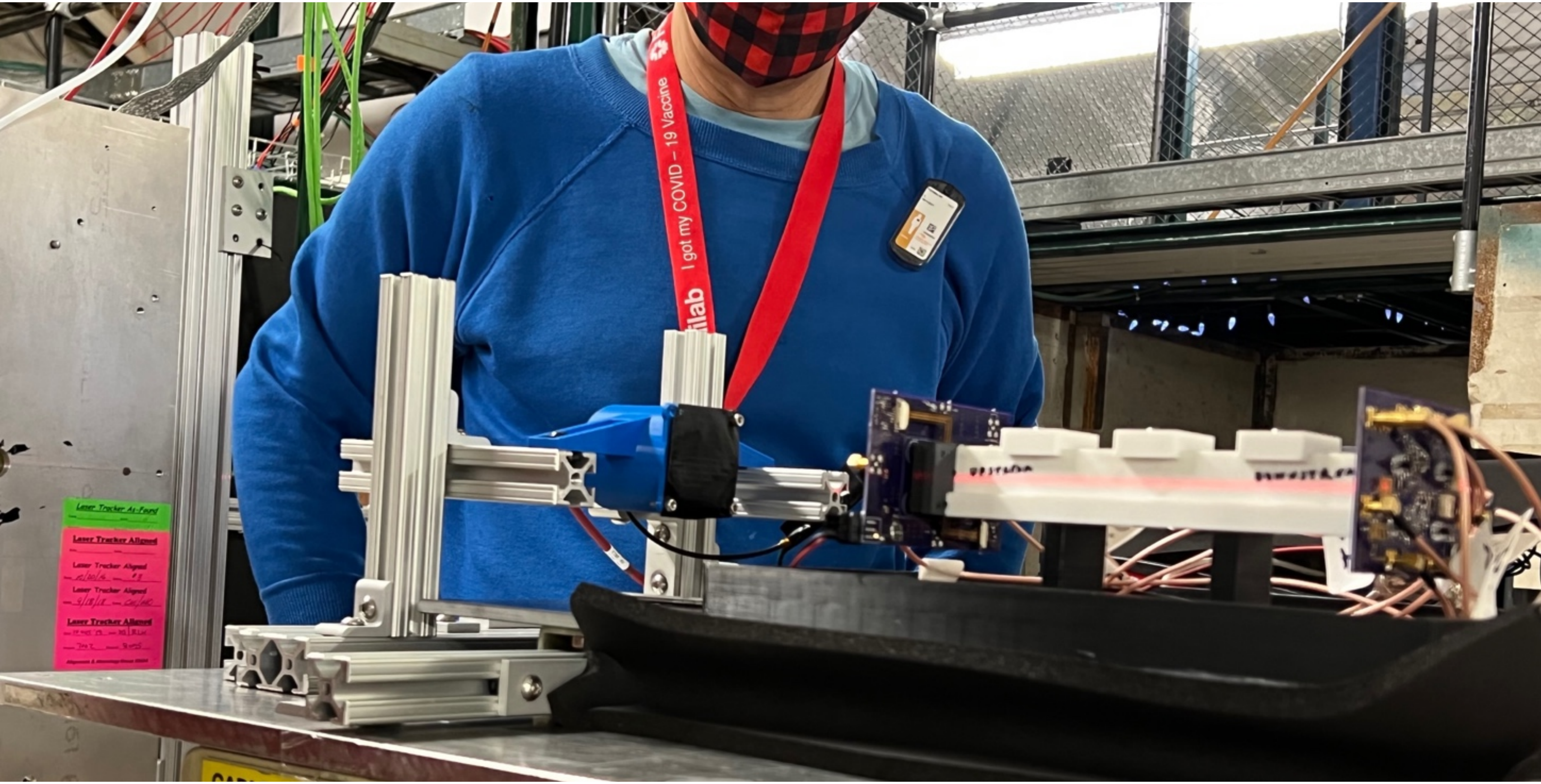

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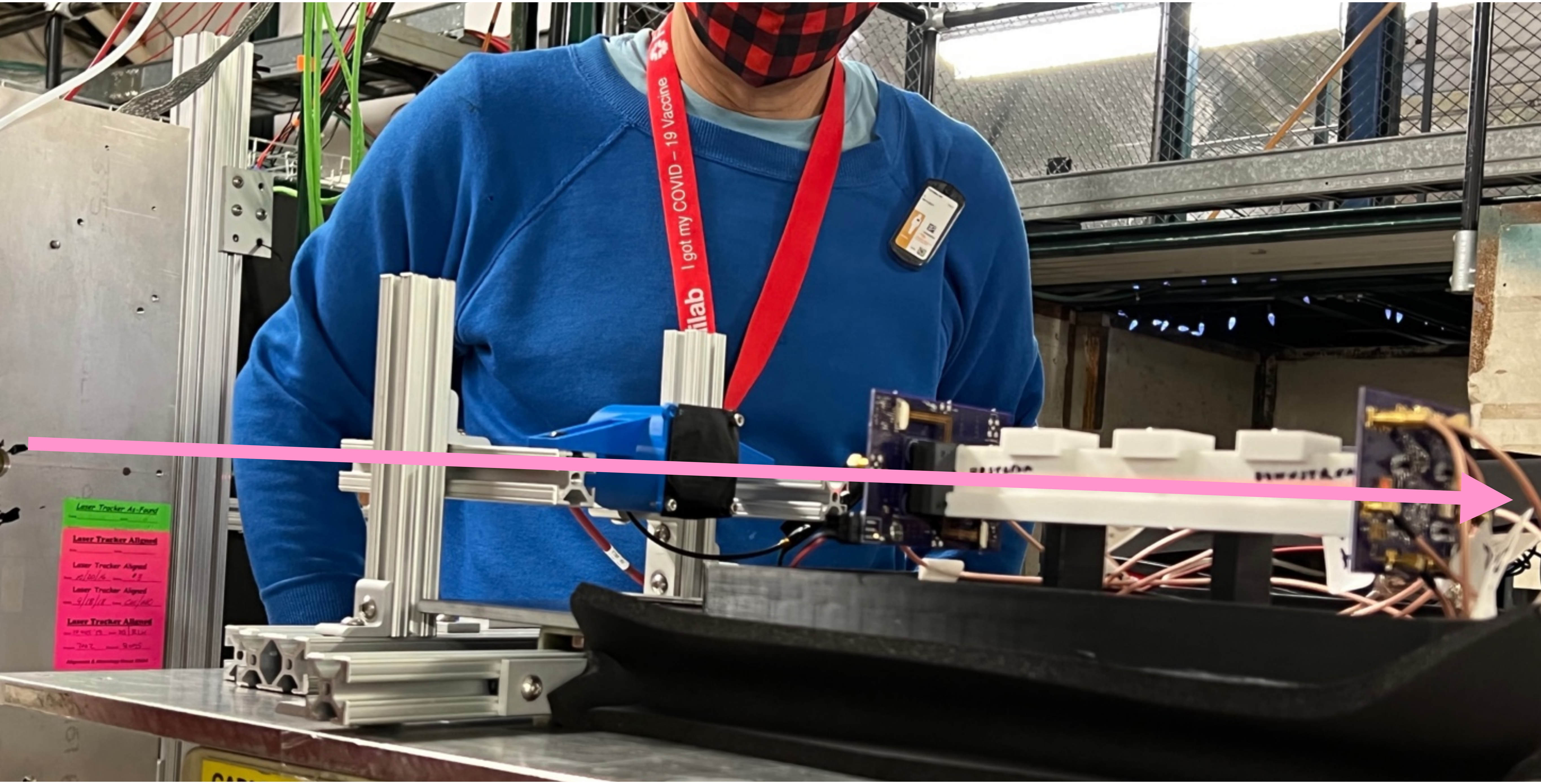
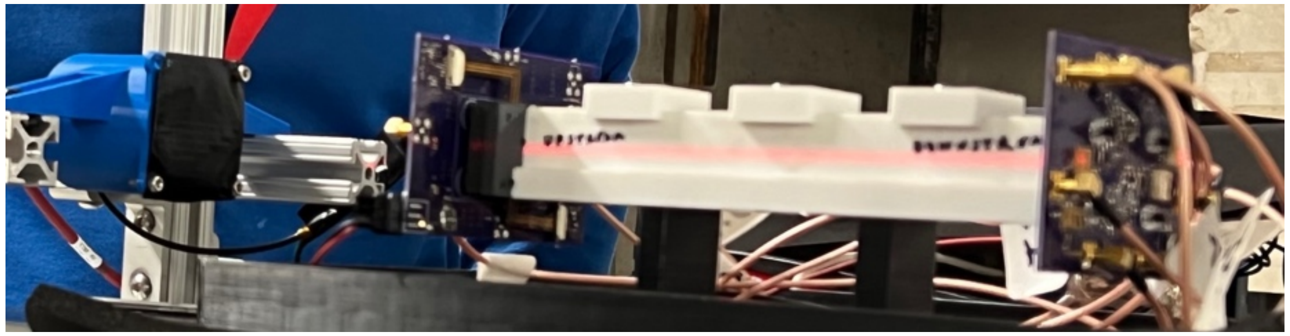
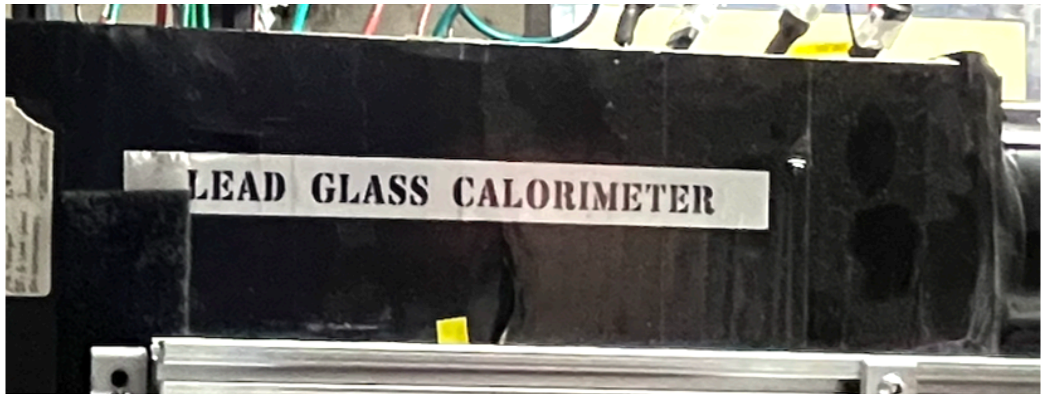


RADiCAL at Fermilab

MCP RADiCAL



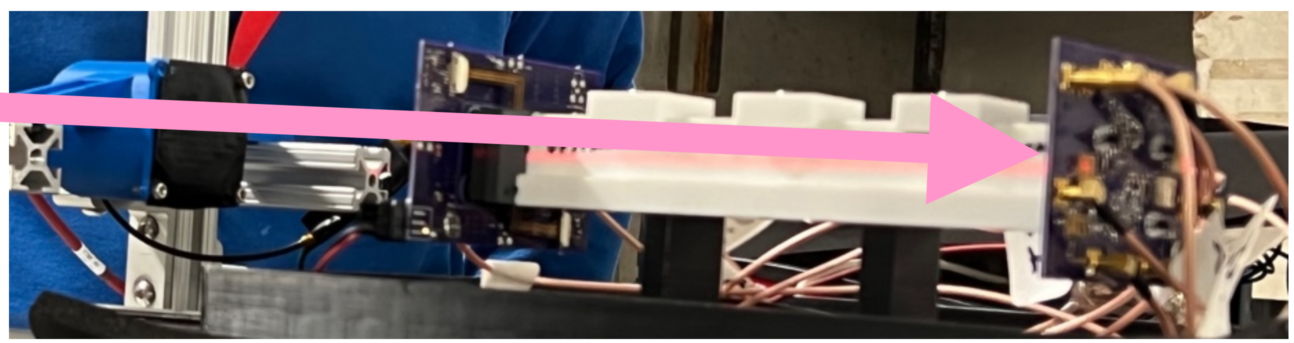
Pb Glass



28 GeV e-

RADiCAL at Fermilab

MCP RADiCAL



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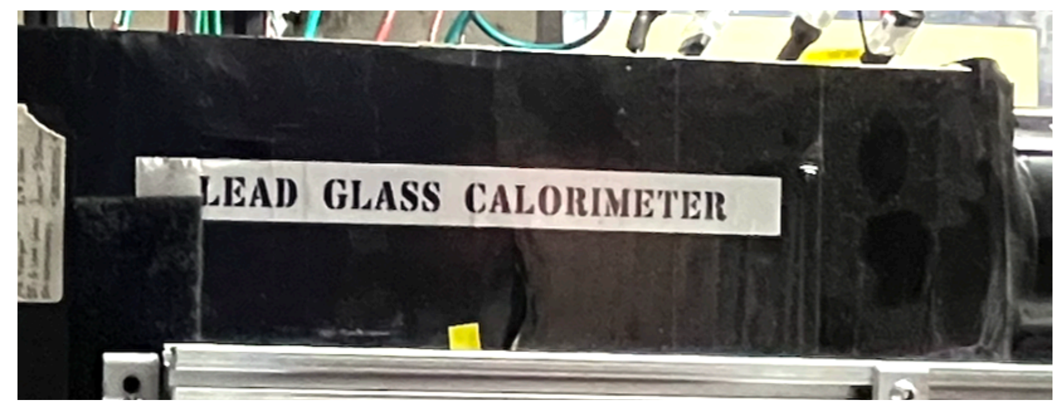

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RADiCAL at Fermilab

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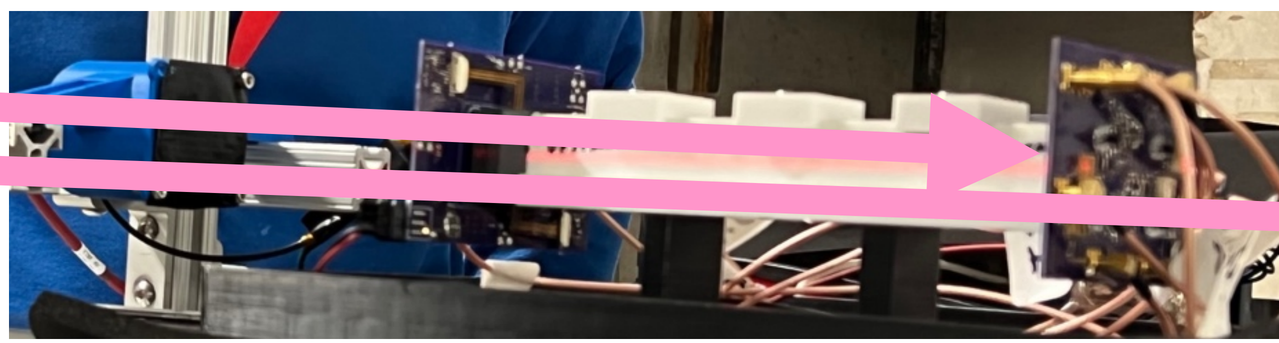

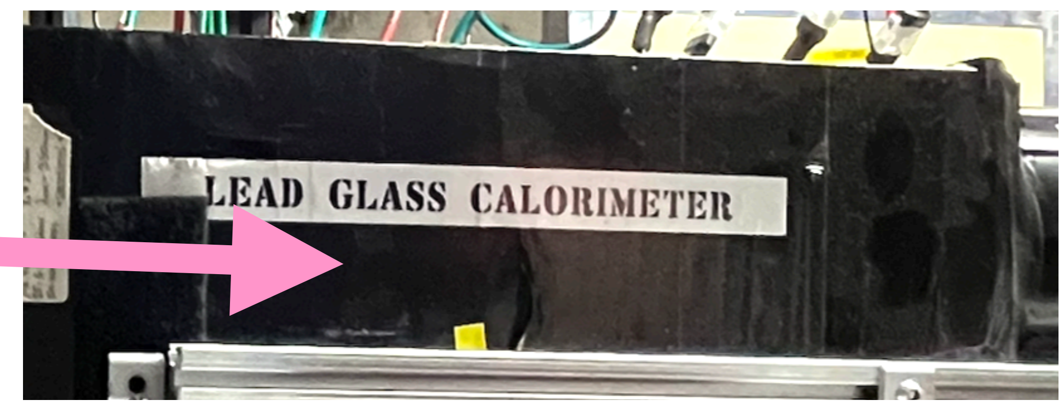

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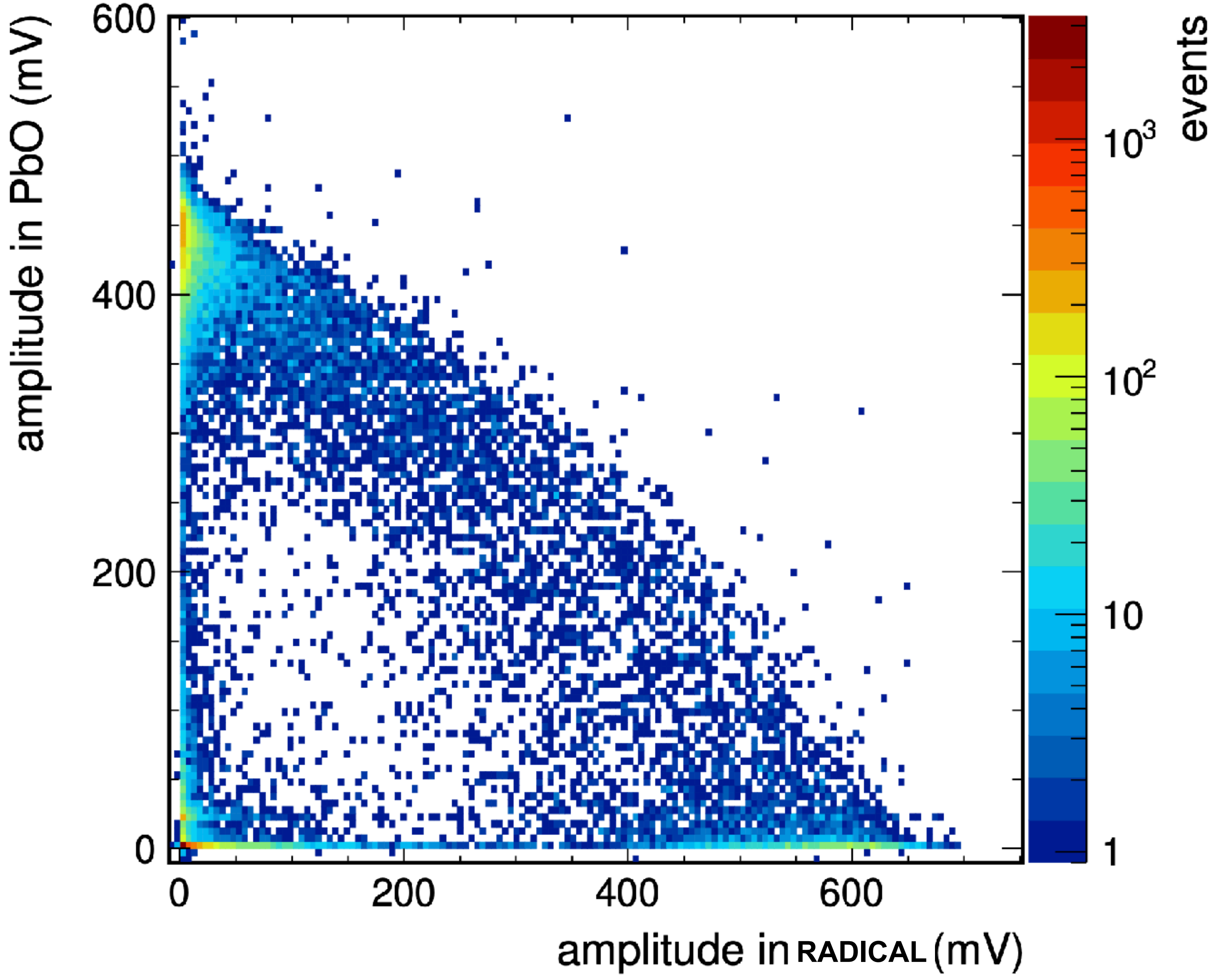
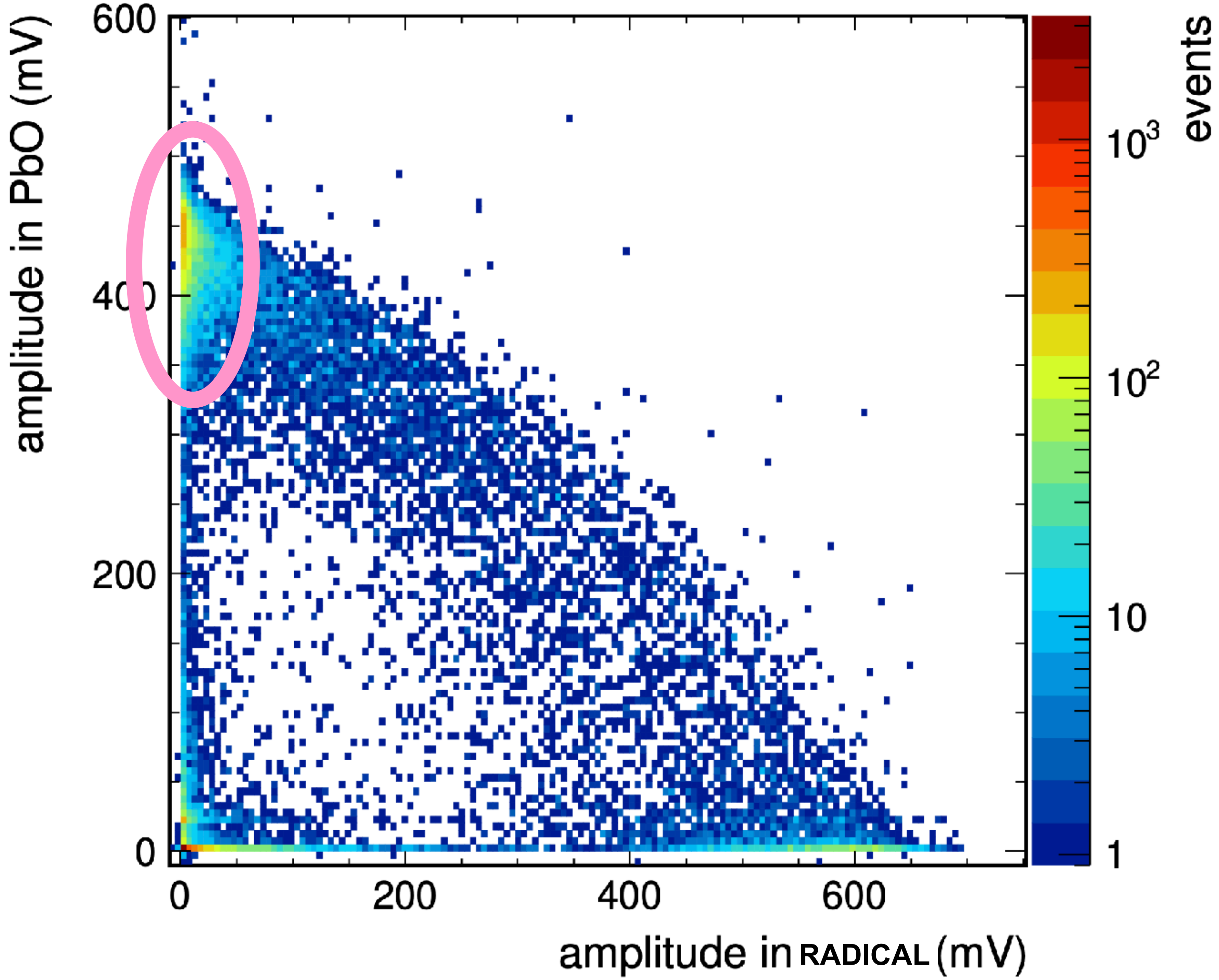
RADiCAL at Fermilab 28 GeV



RADiCAL at Fermilab 28 GeV



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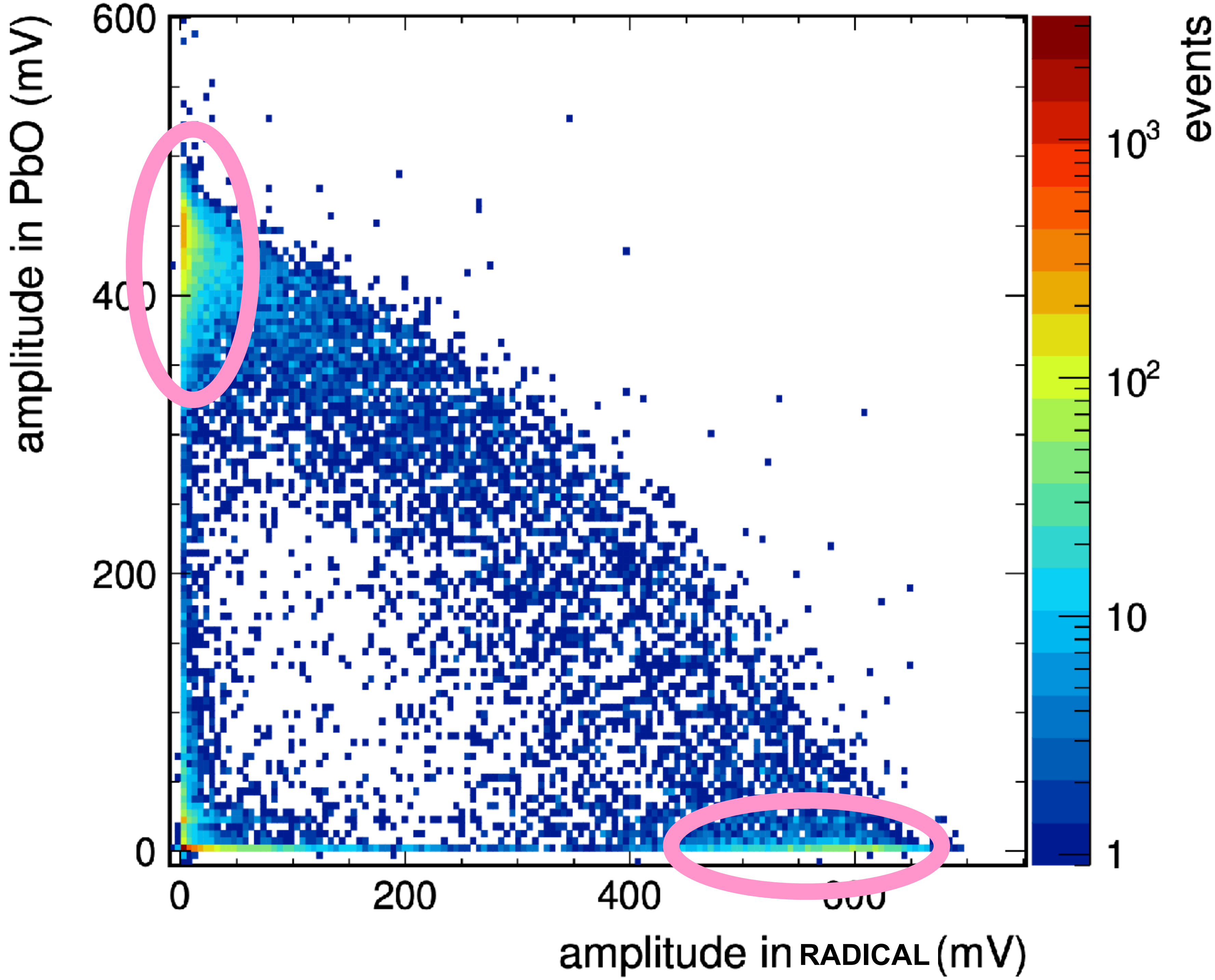
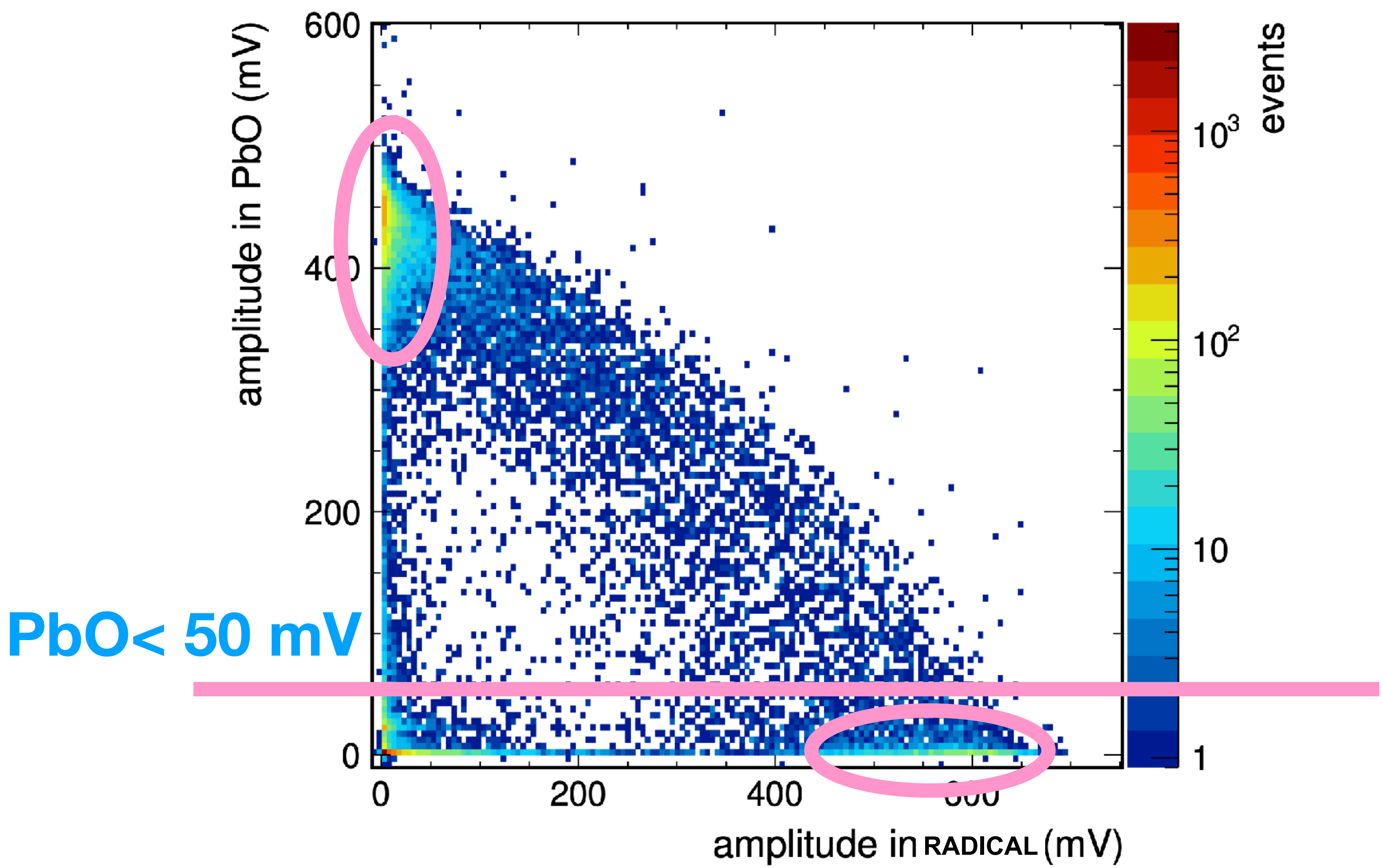


RADiCAL at Fermilab 28 GeV



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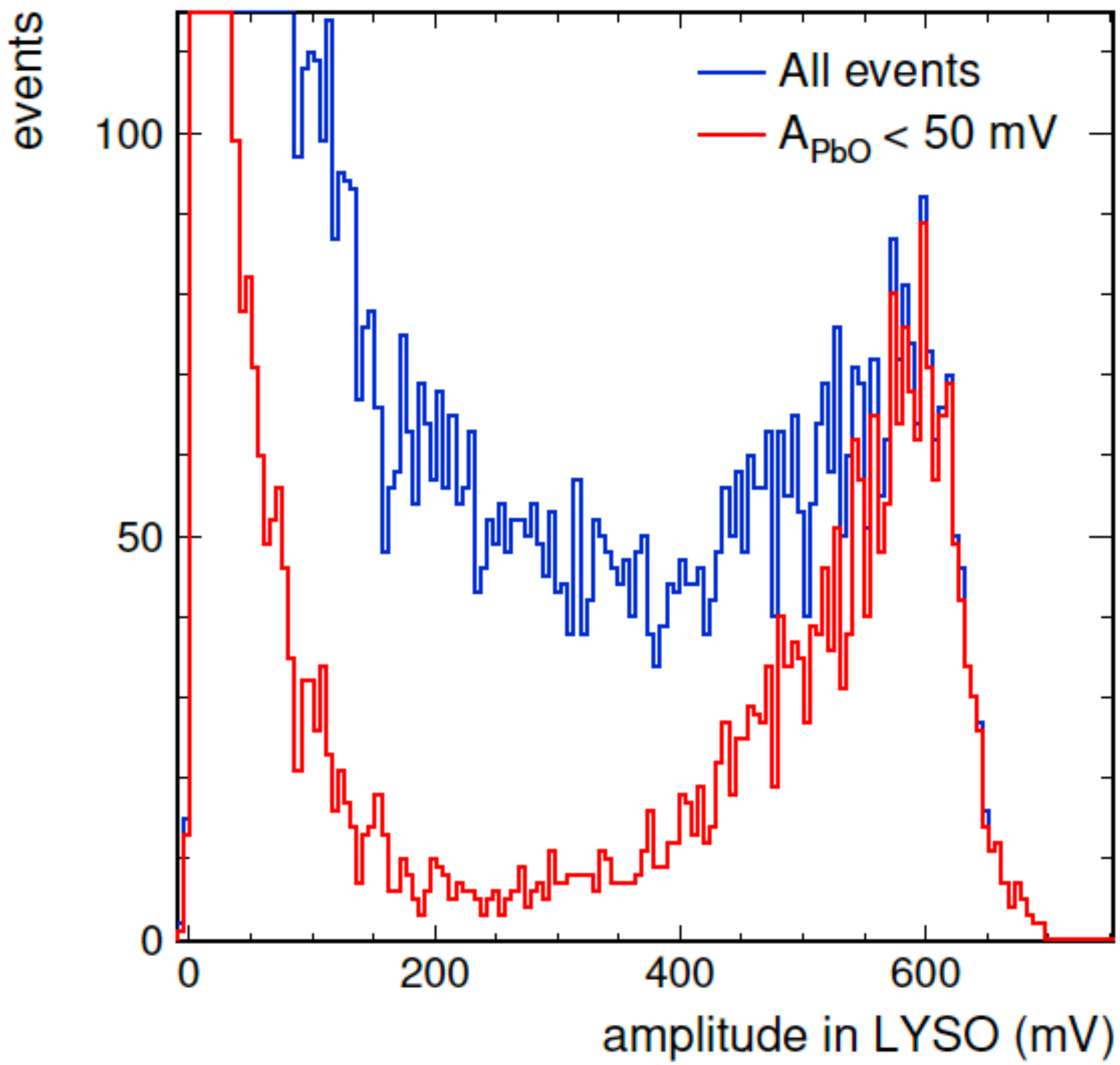
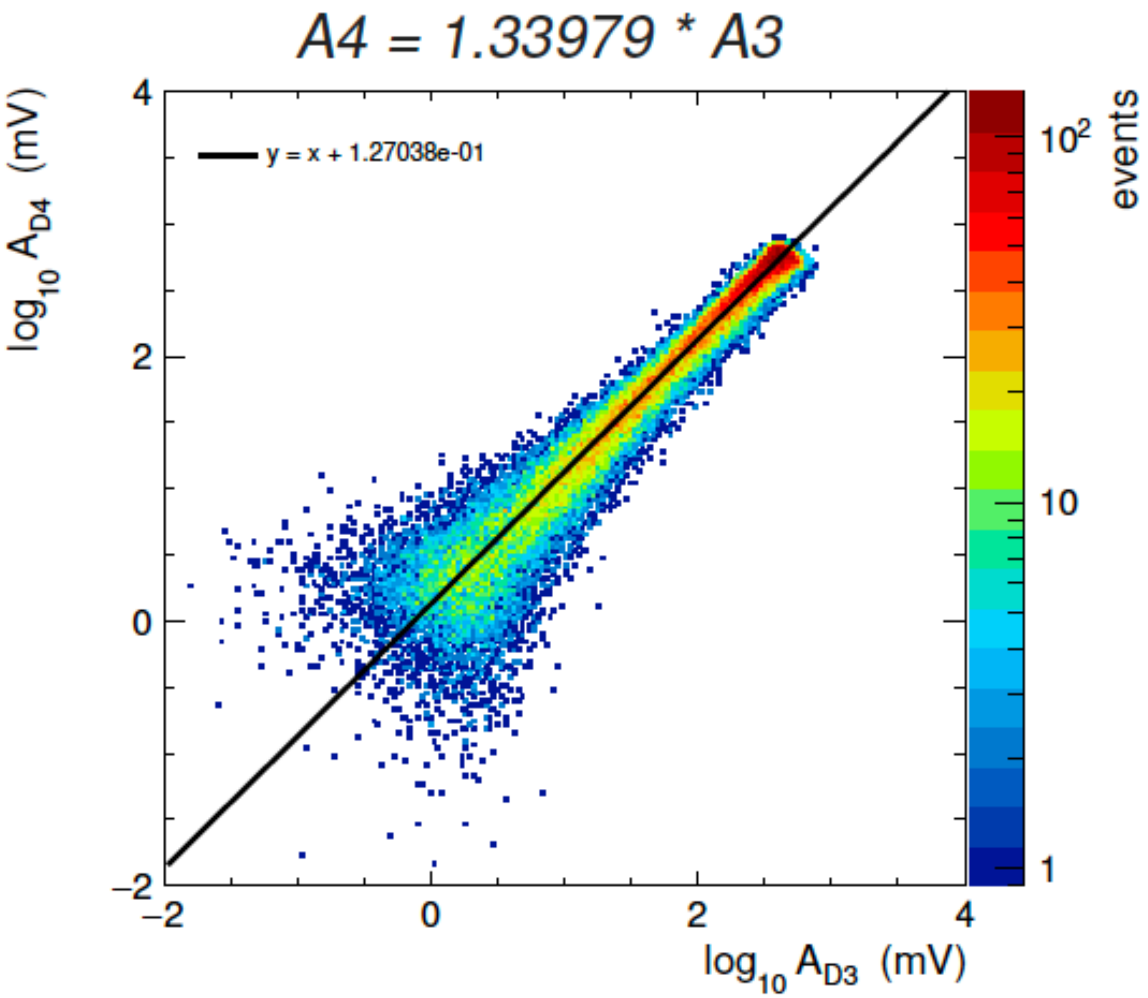
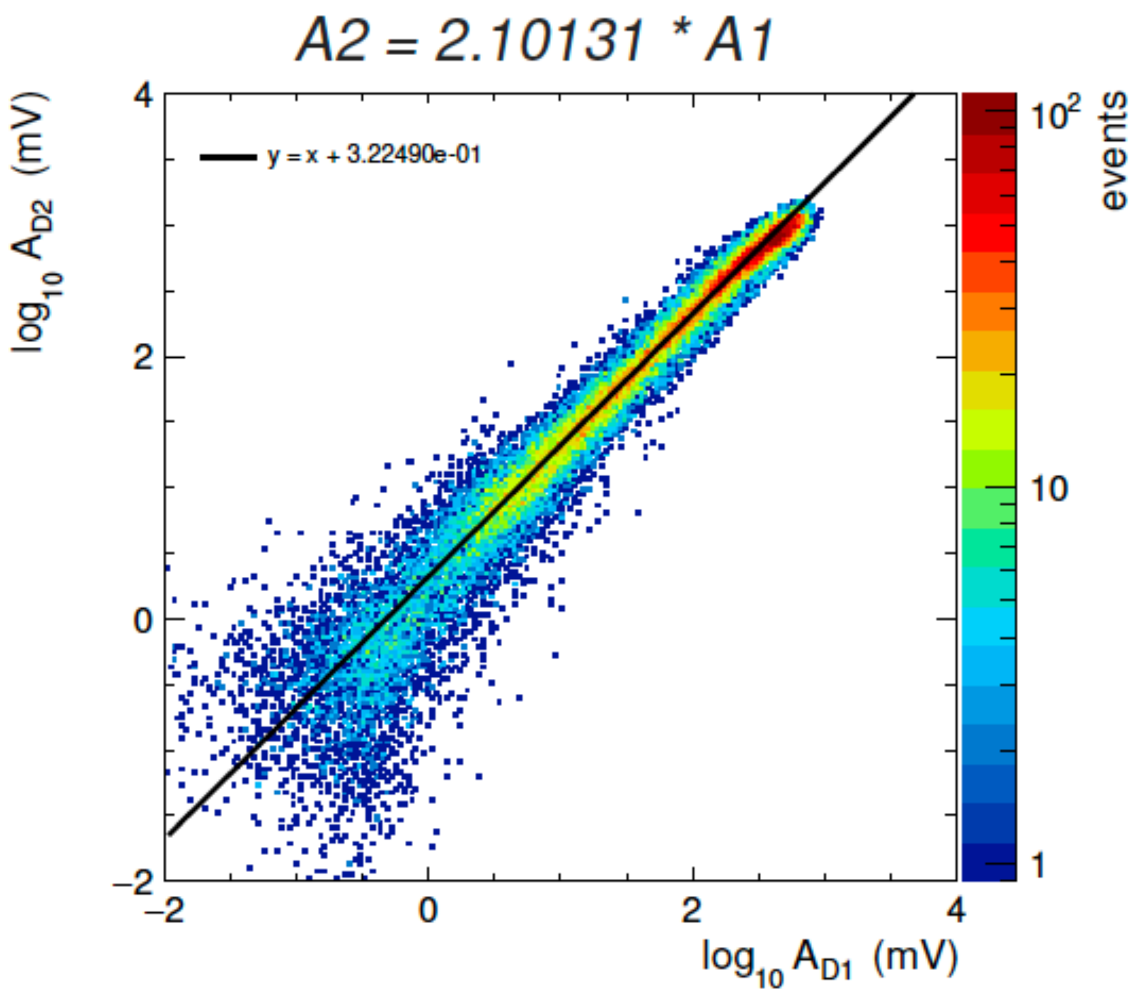


RADiCAL at Fermilab 28 GeV

Signal equalization between diagonal fibers





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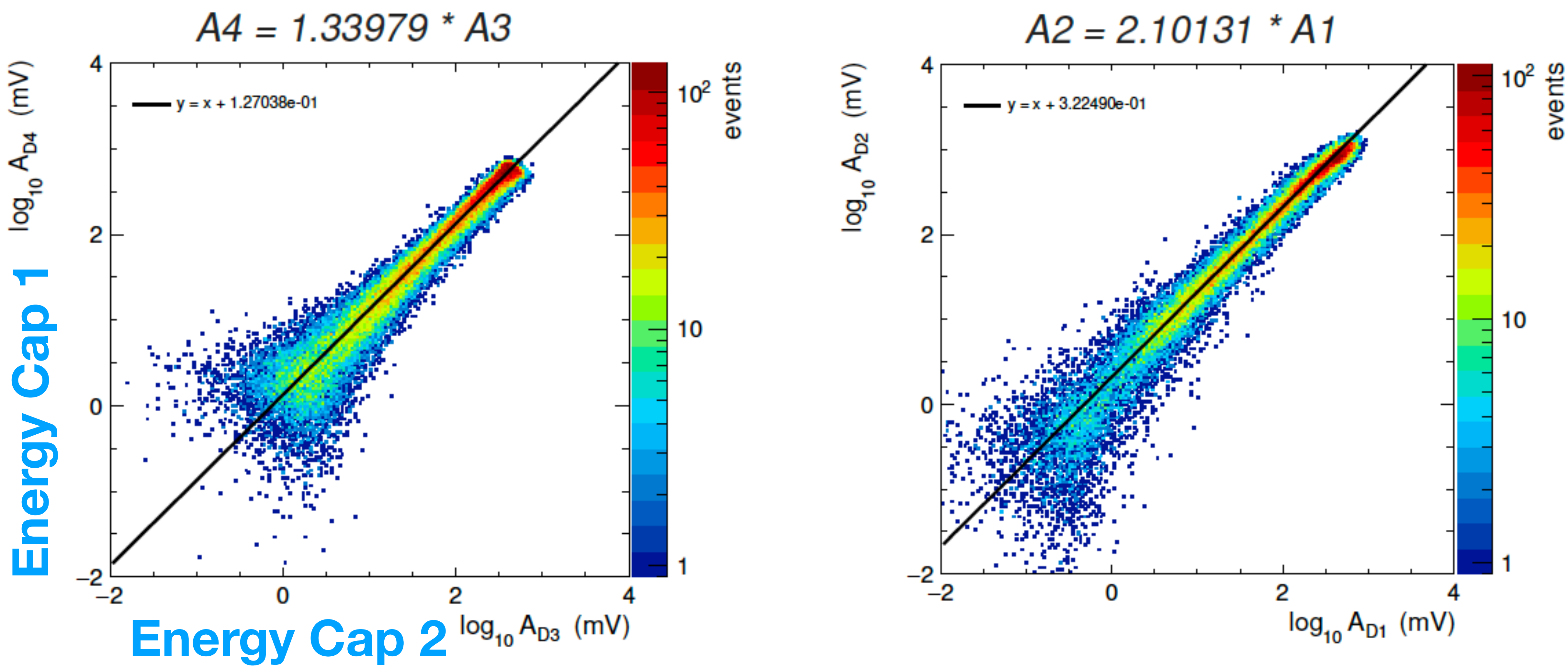

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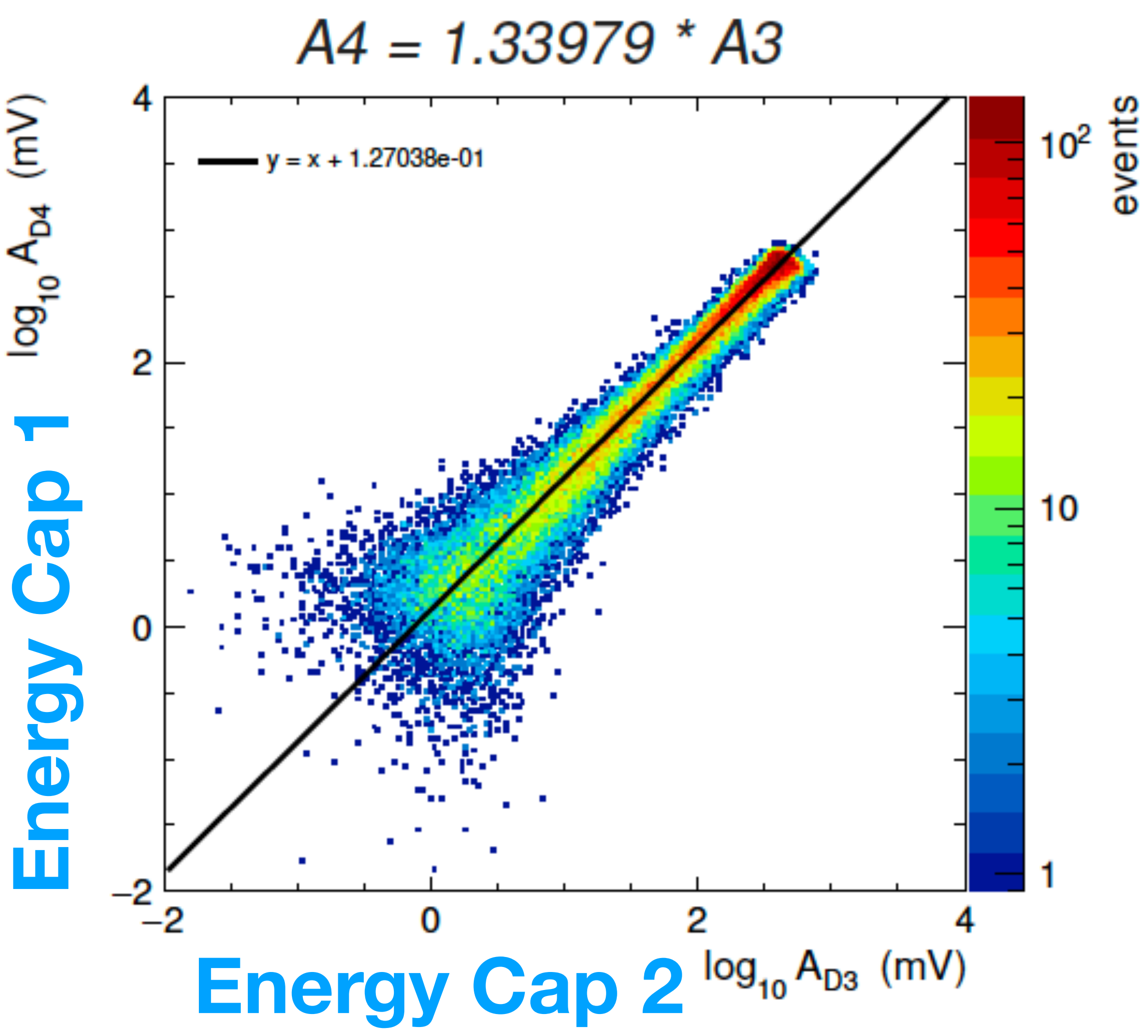
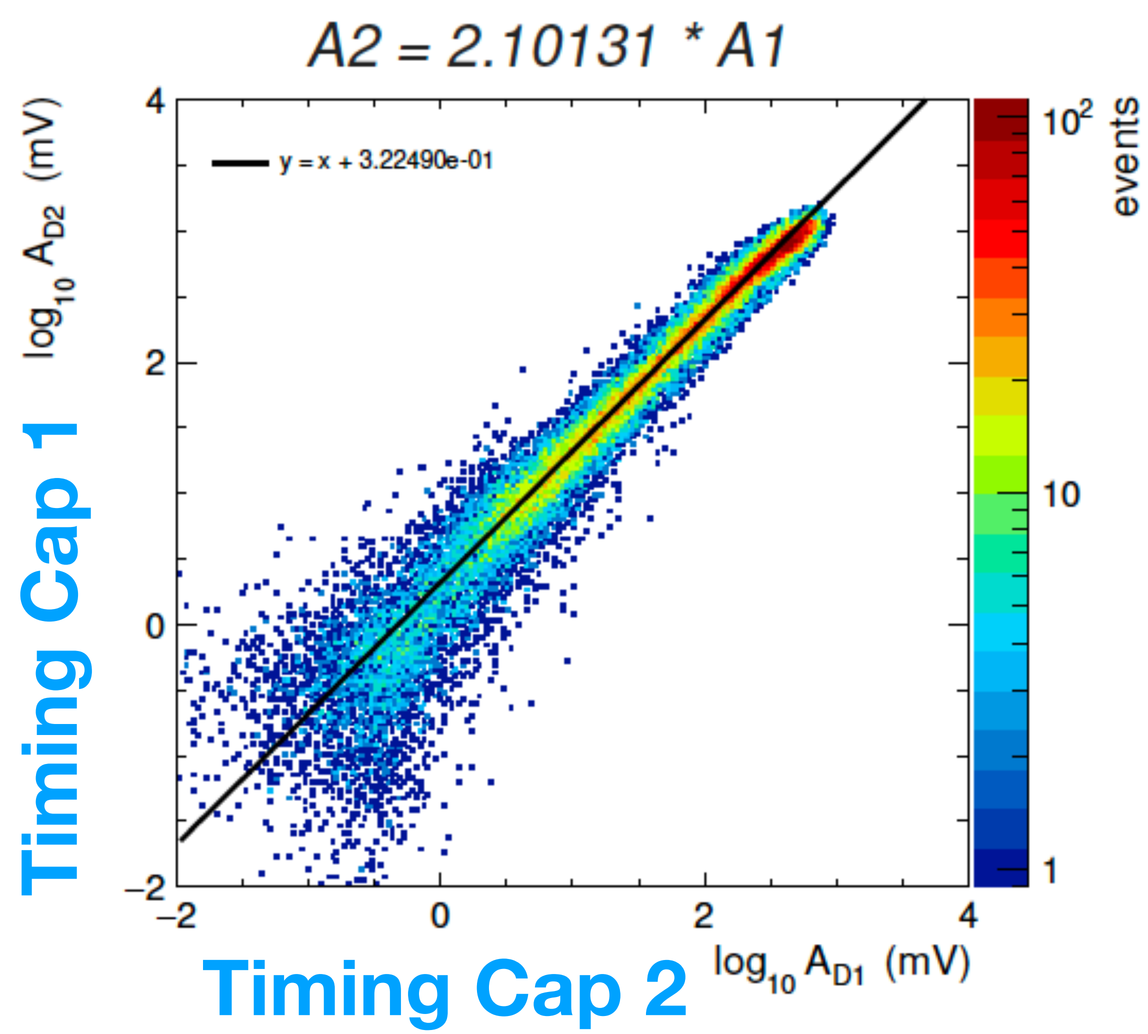
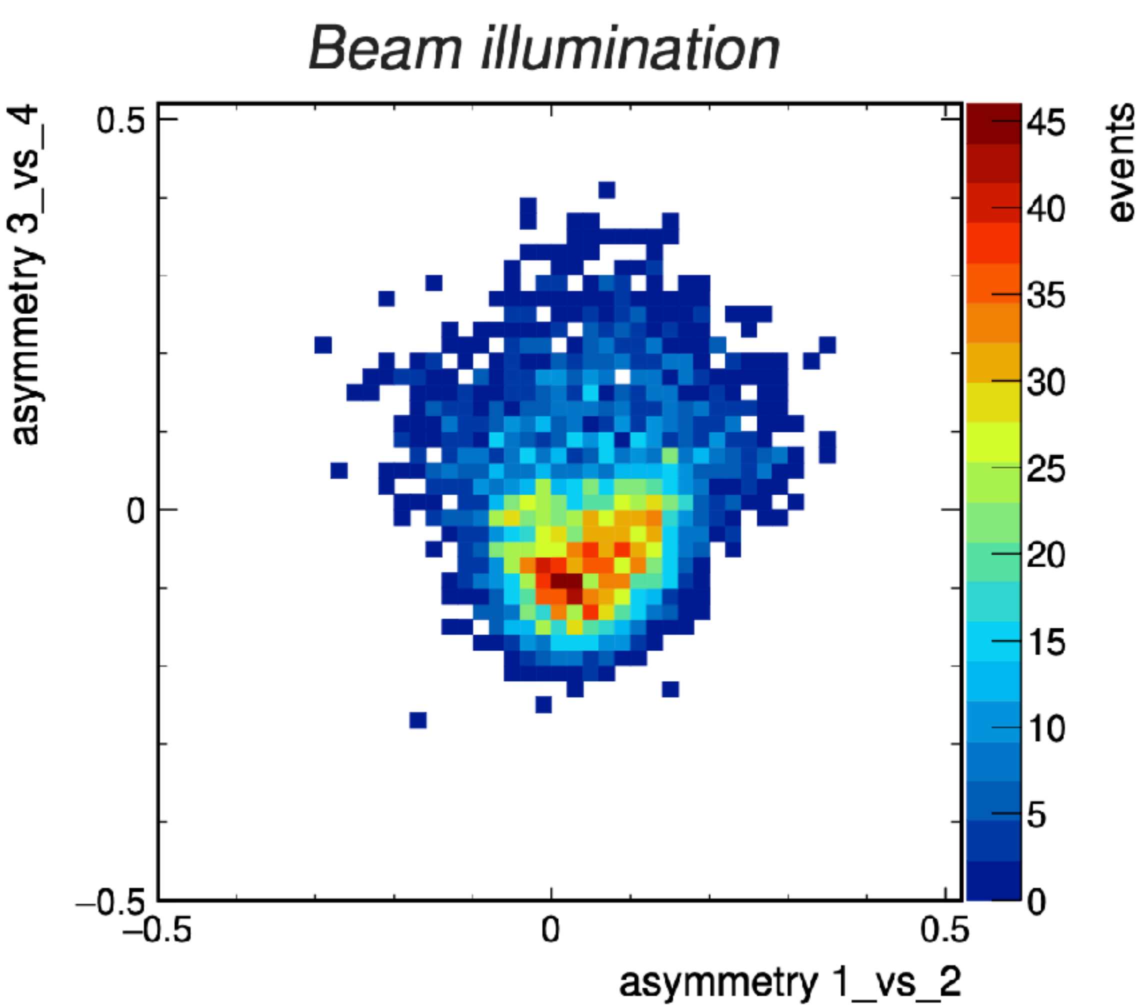
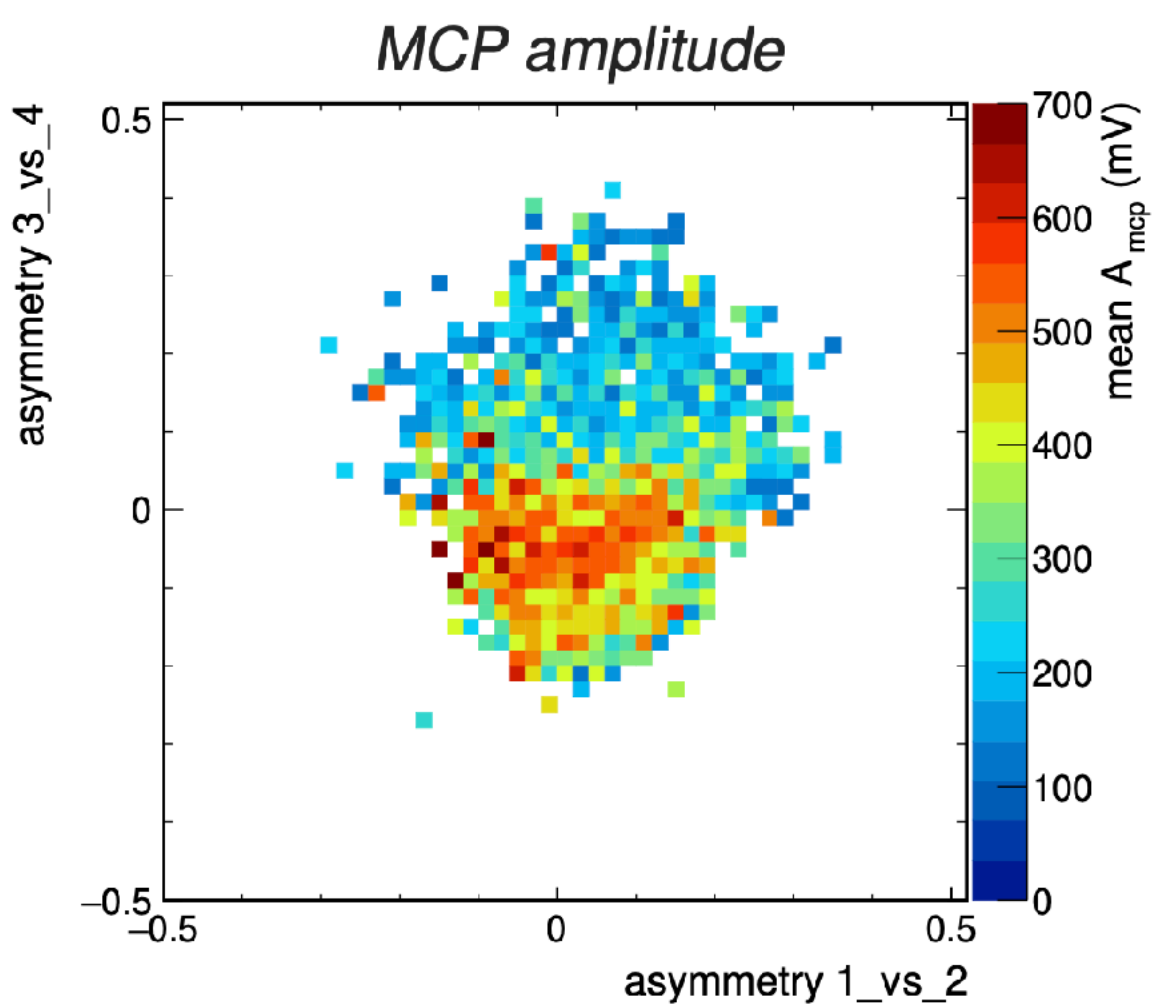




RADiCAL at Fermilab 28 GeV

Beam Localization by Relative Signal Amplitude





Results thus far

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  - The RADiCAL module is radiation hard.

Future Work

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- January 2023 Test Beam at Fermilab:

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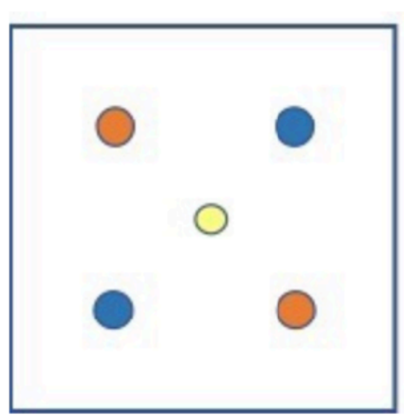
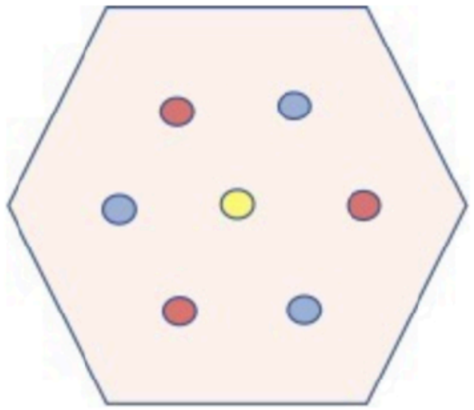
- Simulate different geometries:





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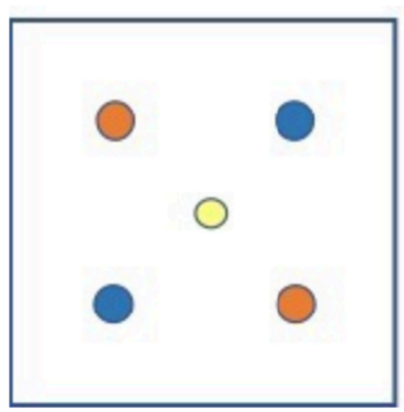
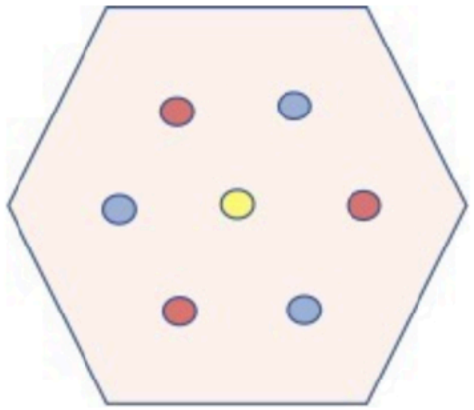
  - Optimized electronics to reach sub-60 ps timing resolution.
  - Study spatial resolution of EM shower position reconstructed in the RADiCAL module vs incoming beam position with precise tracking.
- Simulate different geometries:





- Conduct Advanced Rad-hard Photosensor R&D

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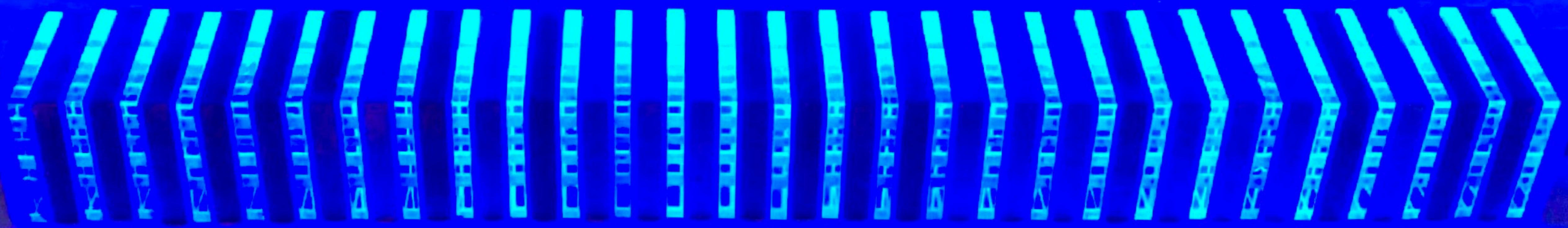

In Conclusion

Work Supported by in part by:
U. S. Department of Energy: DE-SC0017810.006
U. S. National Science Foundation: NSF-PHY-1914059
University of Notre Dame: Resilience and Recovery Grant Program

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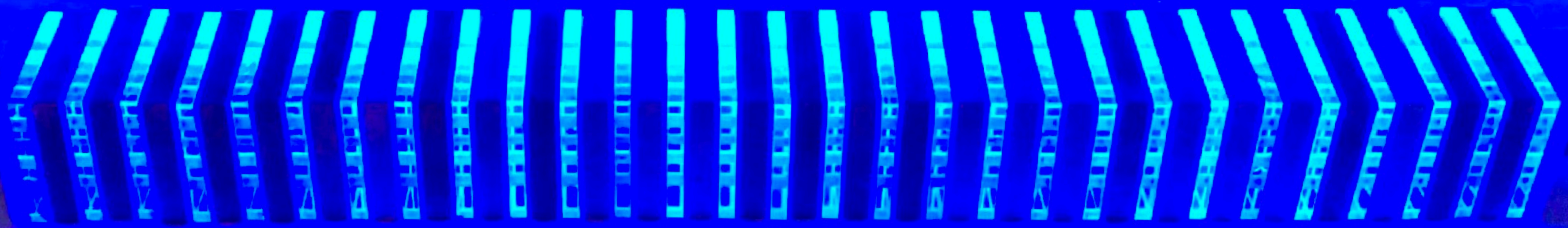

In Conclusion

- RADiCAL concept has been tested at the Fermilab Test Beam Facility and demonstrates its potential as an effective rad hard EM calorimeter.

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Thank You!