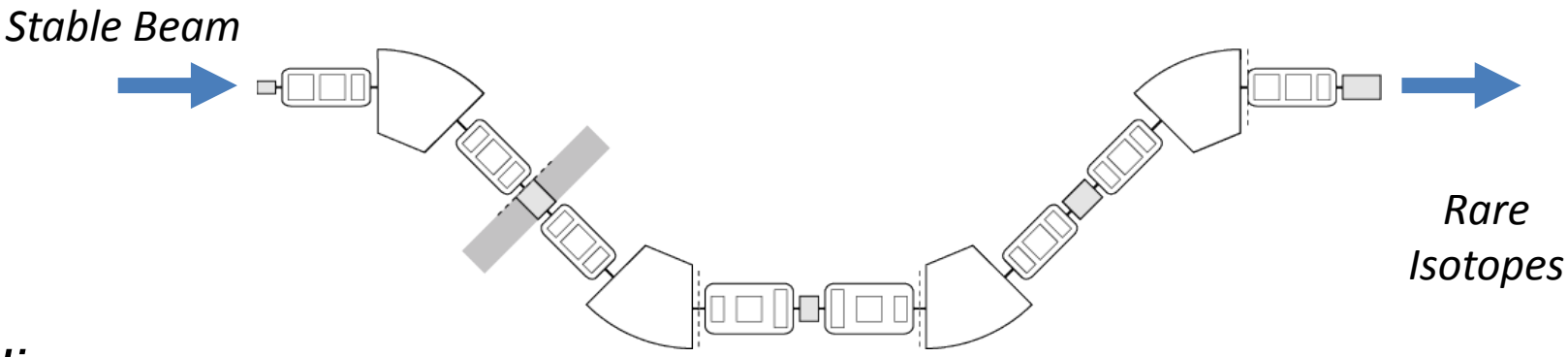
Momentum Calibration of the A1900



Outline:

- Why it had to be done with beam
- How we did it
- Applications

Tom Ginter

Michigan State University

RESULTS

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Better knowledge of momentum distributions

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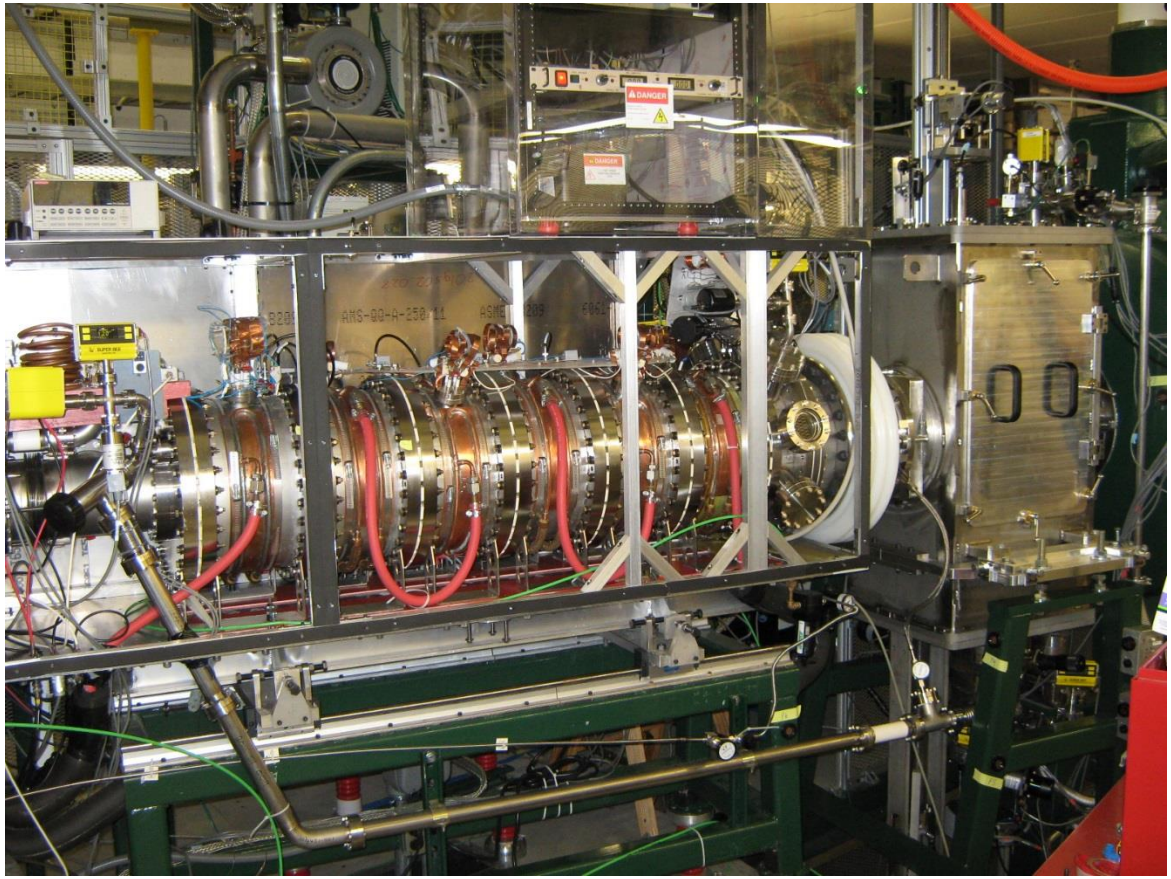

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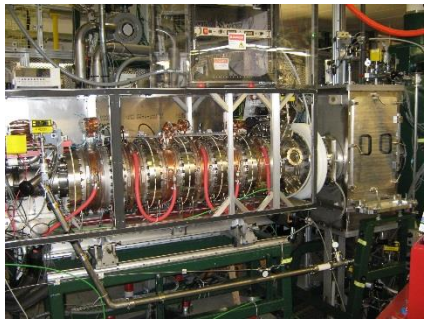

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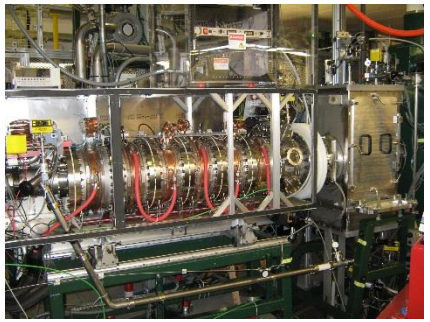

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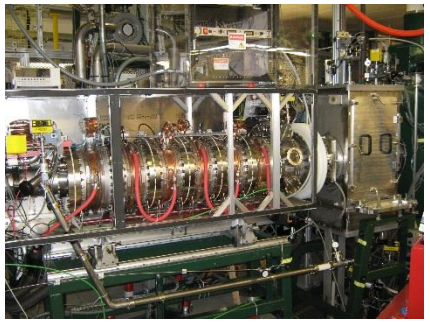

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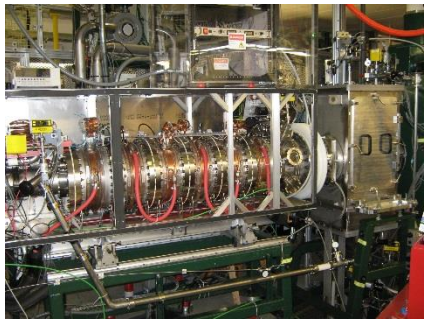

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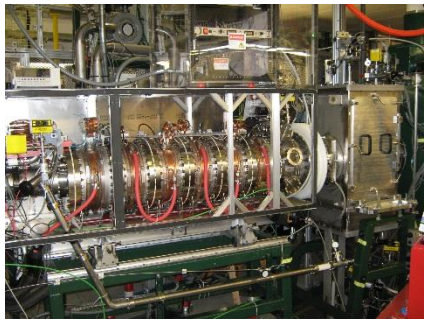

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The question about beam energy is now no longer a dynamic in gas cell operation

WHY USE BEAM?

T.N. Ginter et al., Nucl. Instr. Meth. B 376 (2016) 131

WHY BEAM? Dipole effective length varies

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Dipole bending radius: ρ

$$\text{momentum} = q \bullet \text{rigidity} = q\, B\rho$$

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Dipole bending radius: $\rho(B)$

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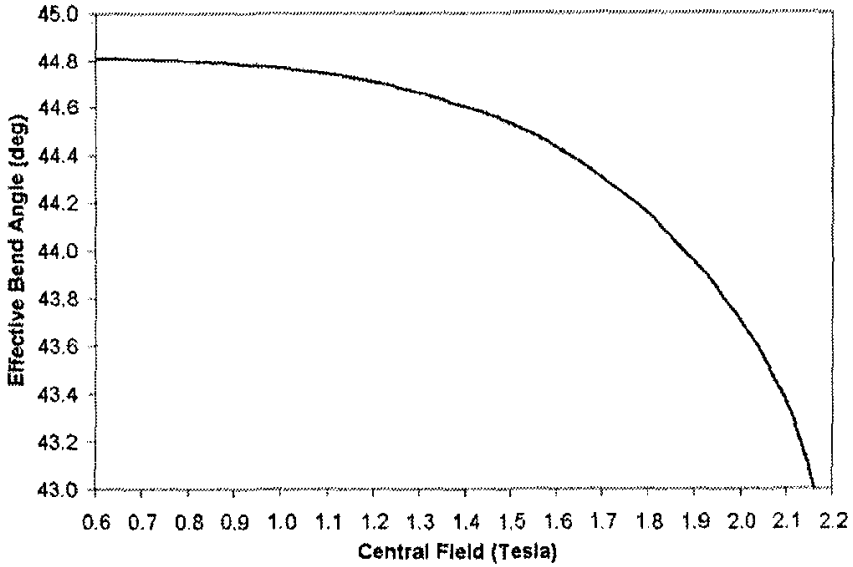

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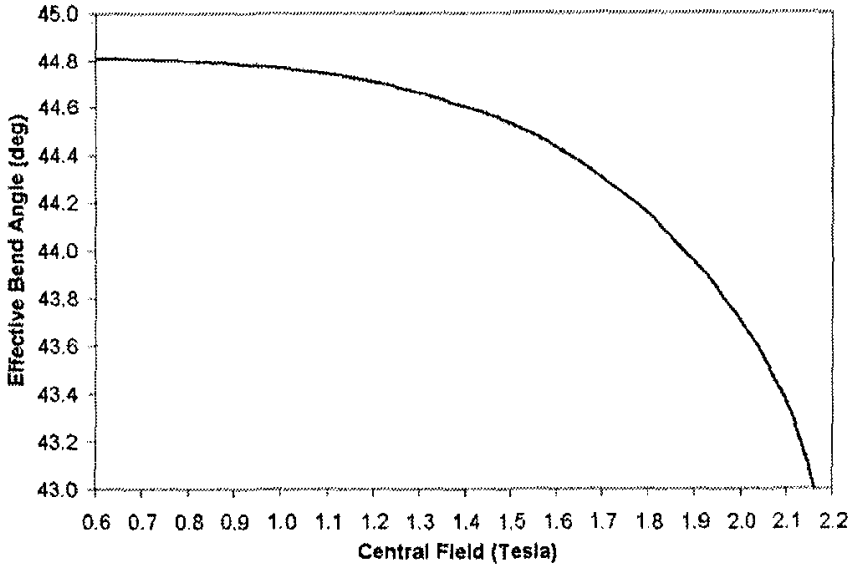

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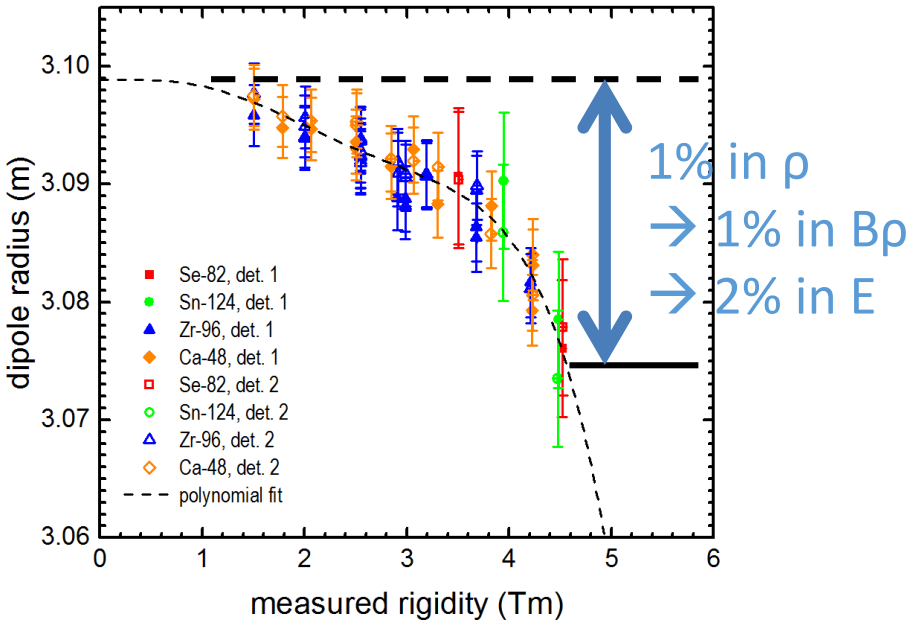

Present work

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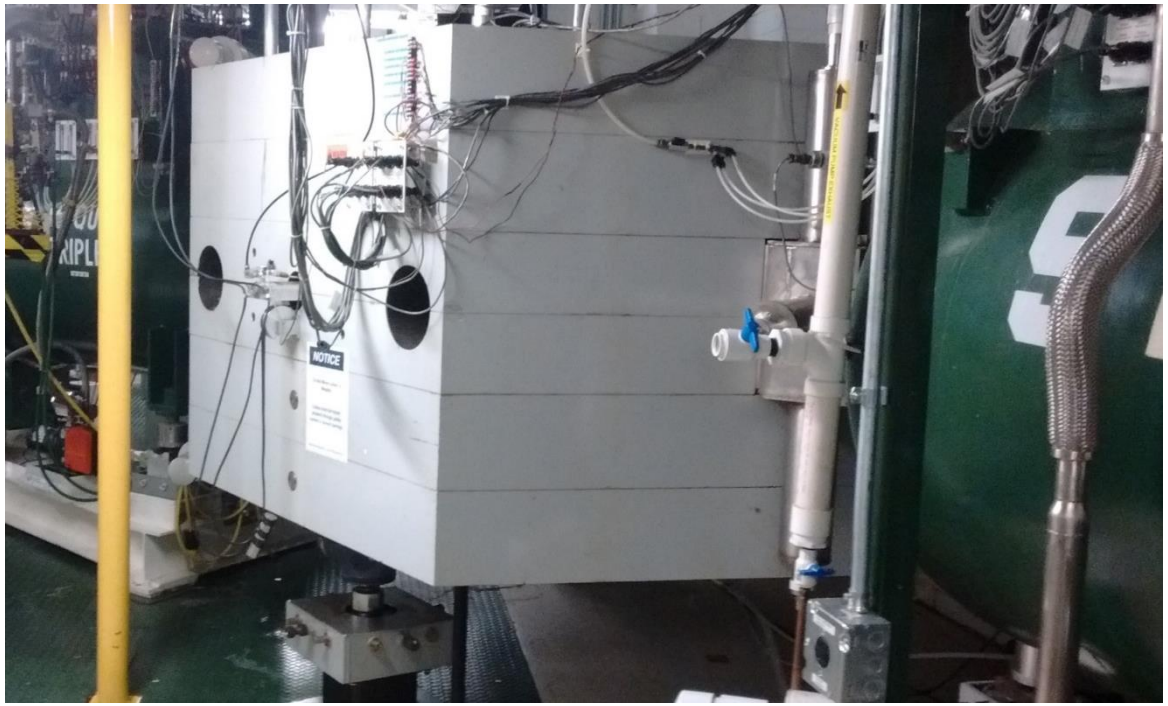

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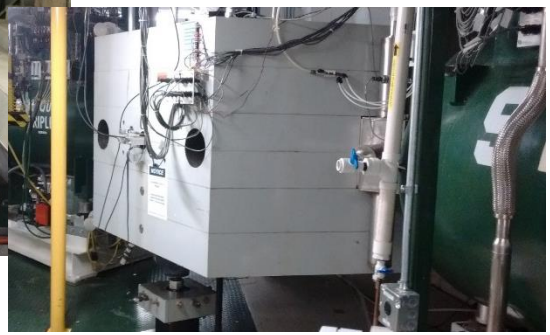

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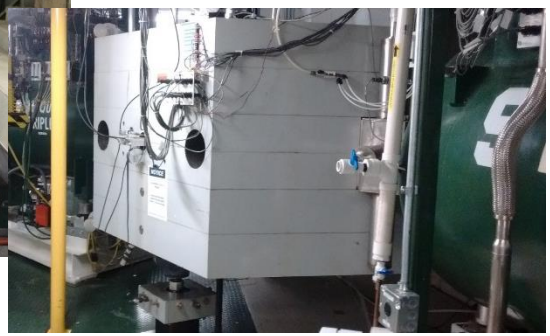

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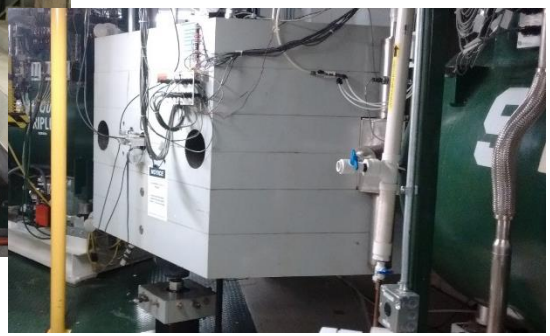

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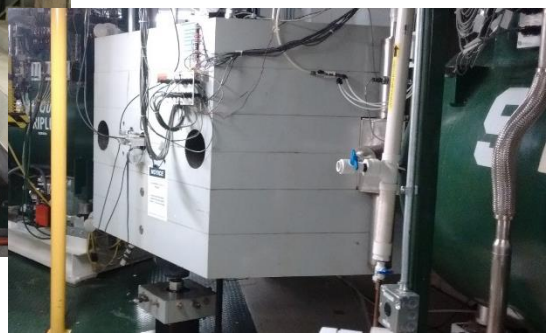

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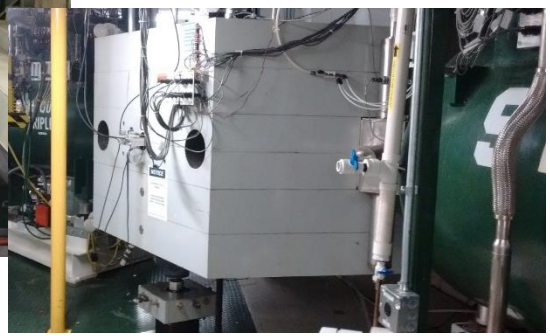

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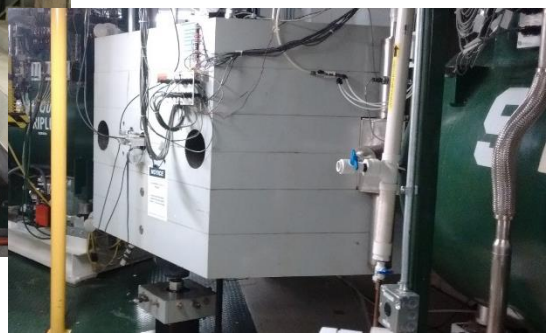

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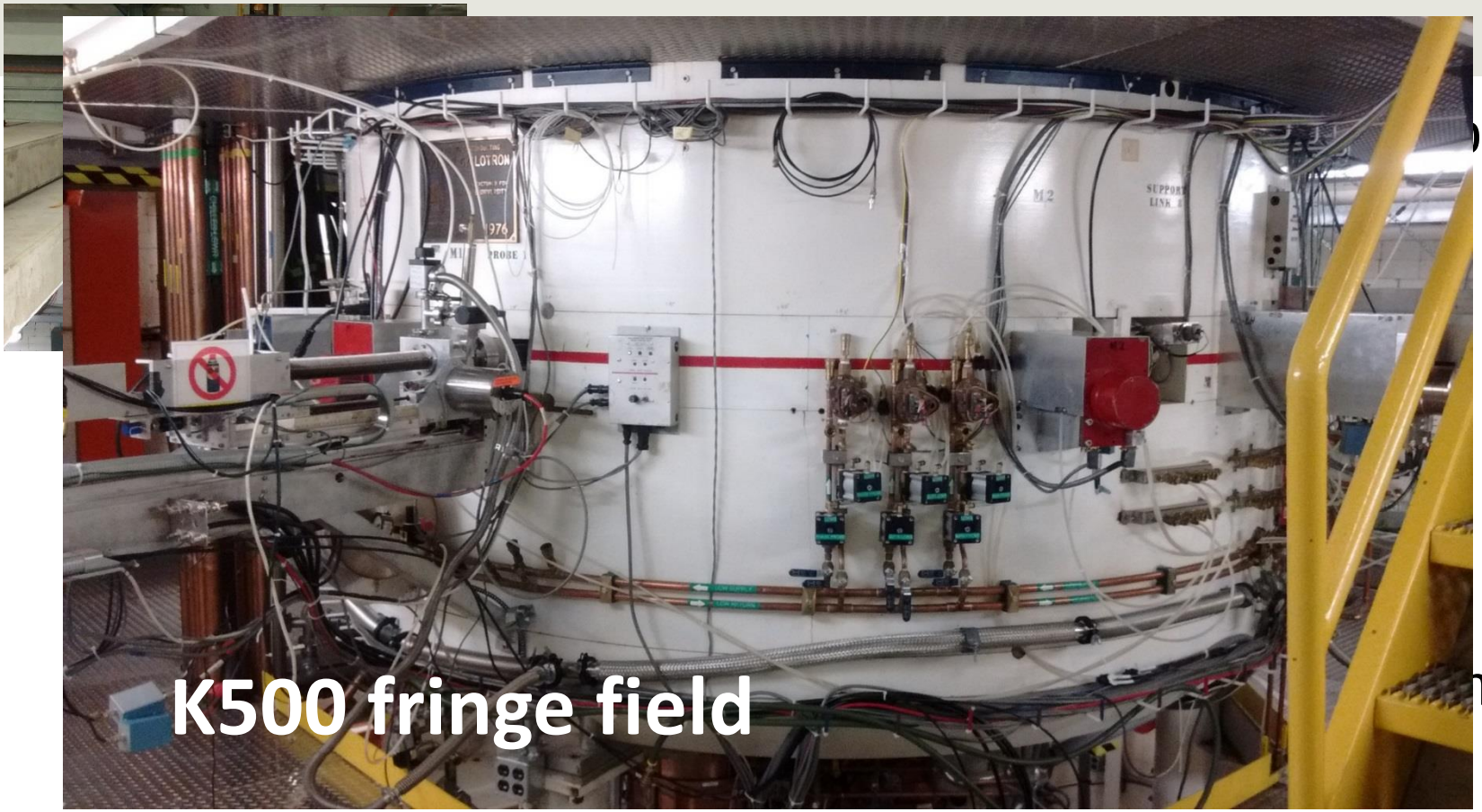

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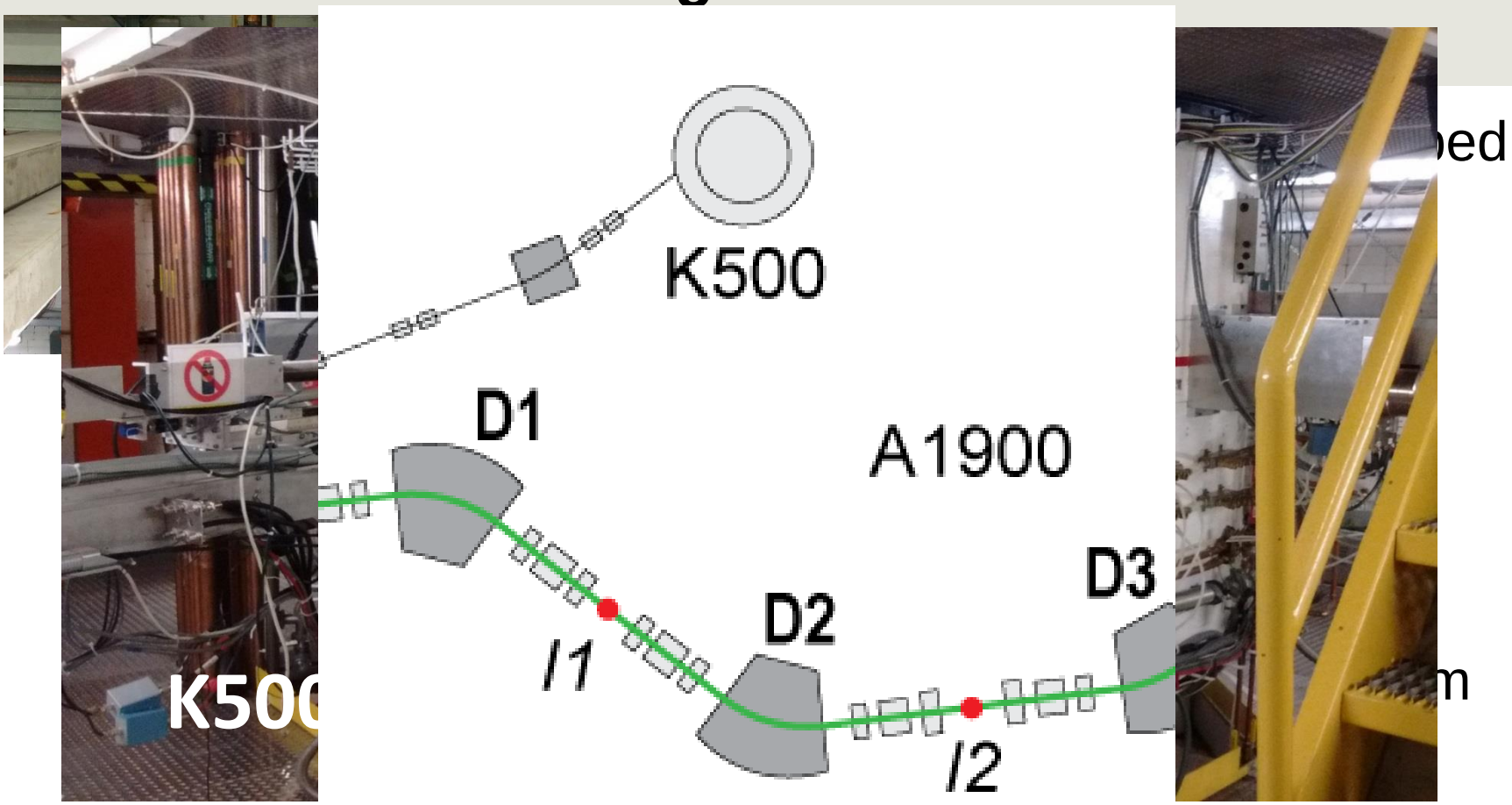

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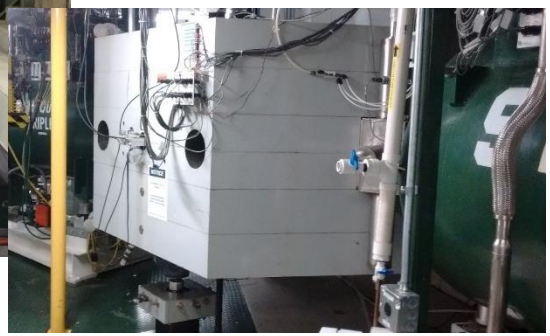

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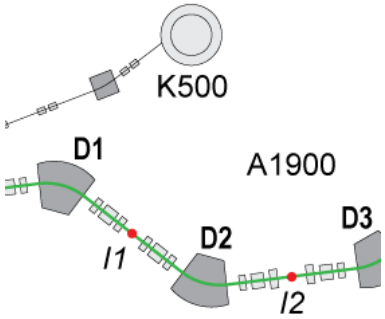

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HOW WE DID IT

T.N. Ginter et al., Nucl. Instr. Meth. B 376 (2016) 131

T.N. Ginter et al., submitted to Nucl. Instr. Meth. A

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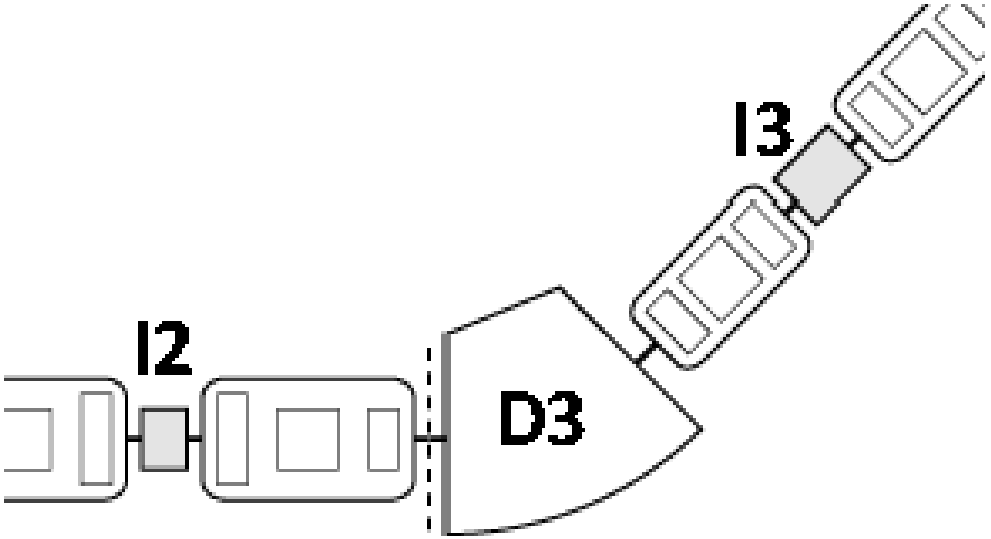

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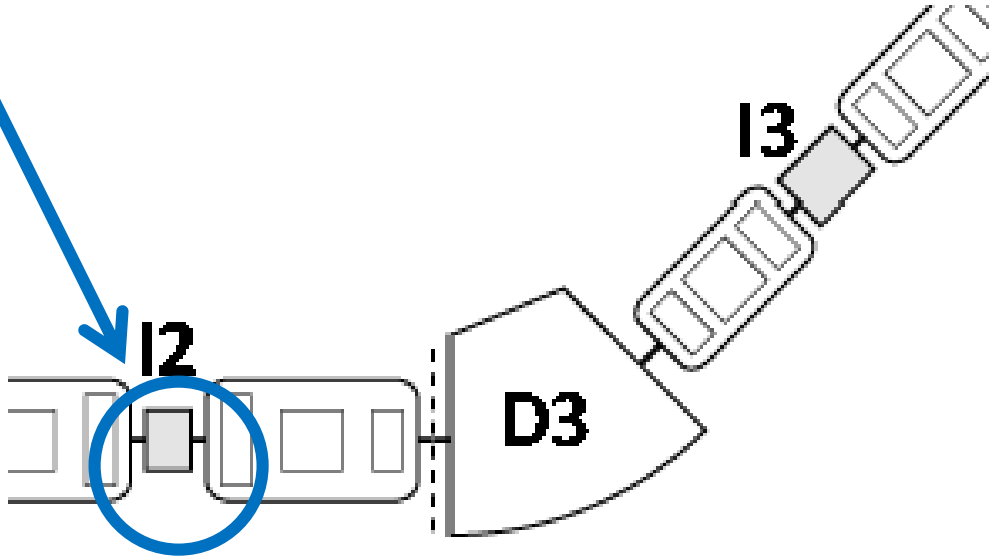

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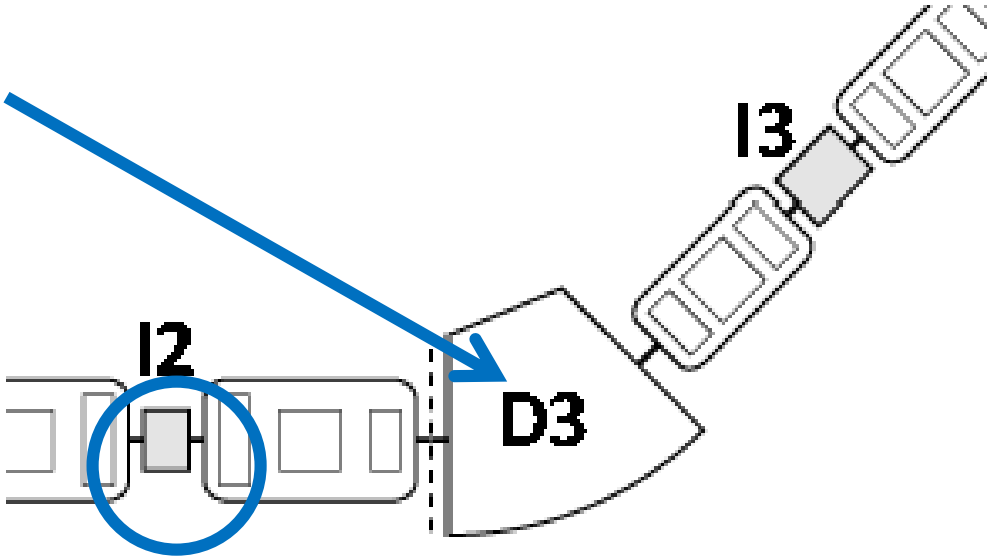

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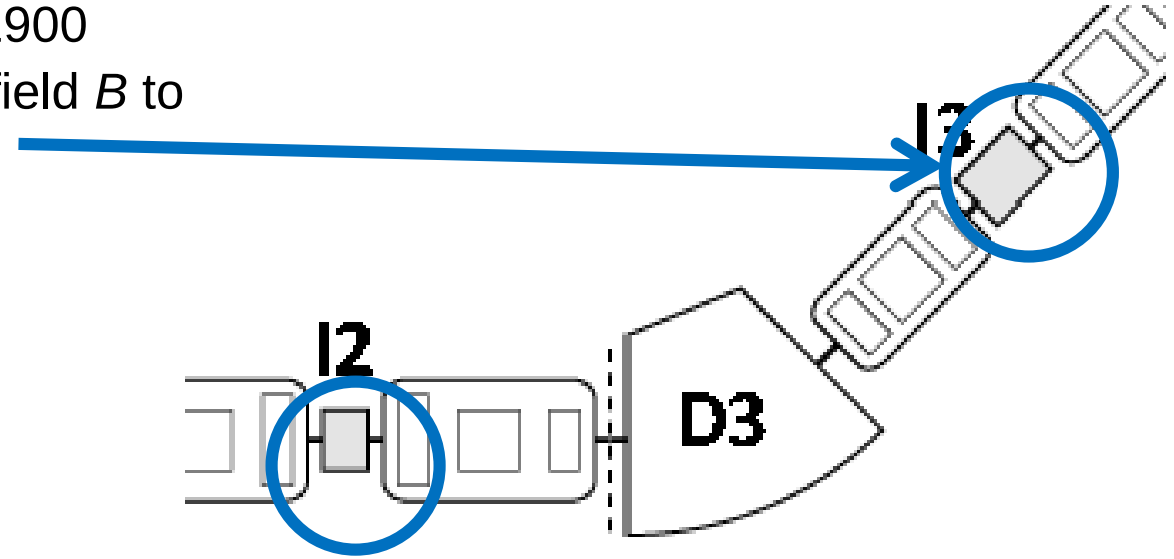

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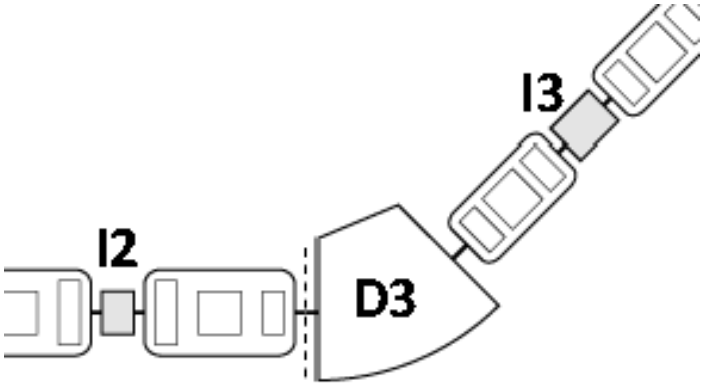

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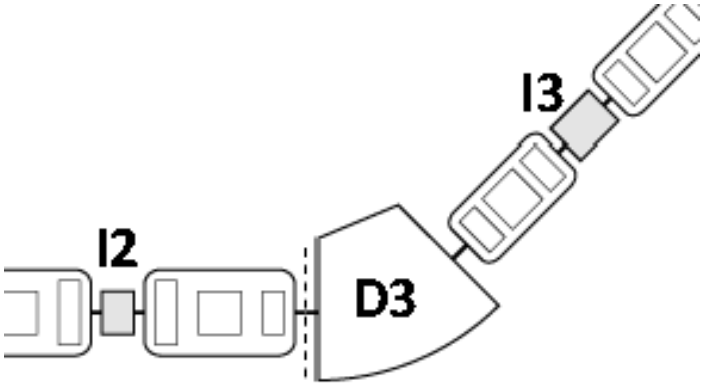

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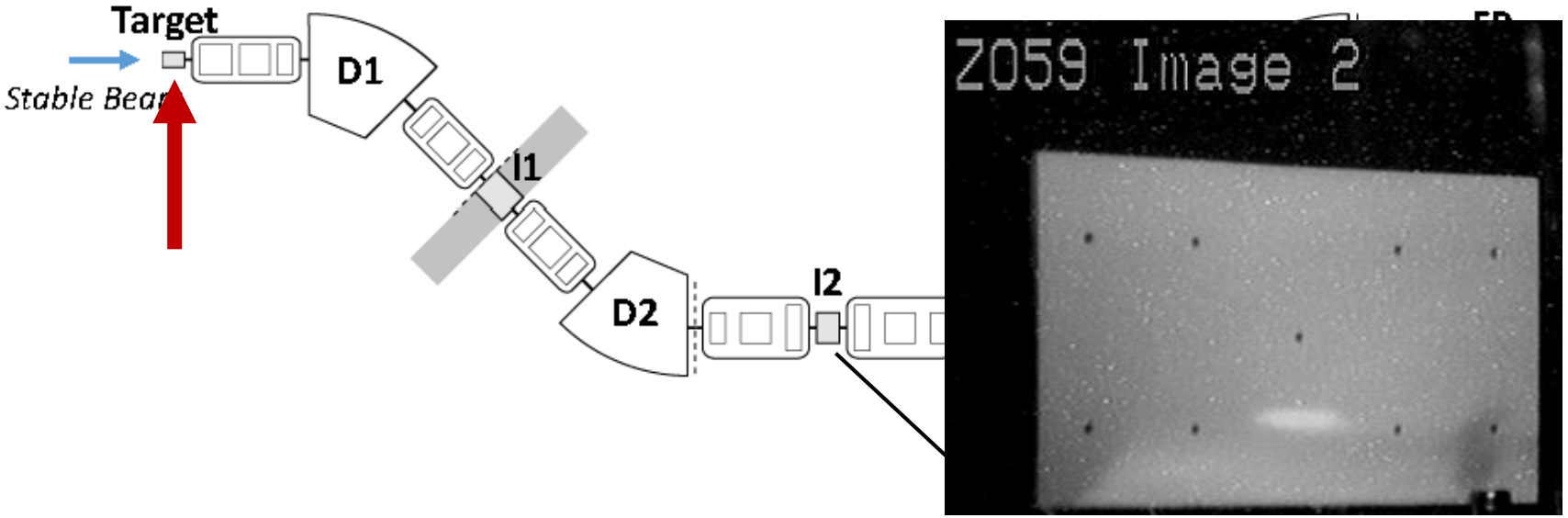

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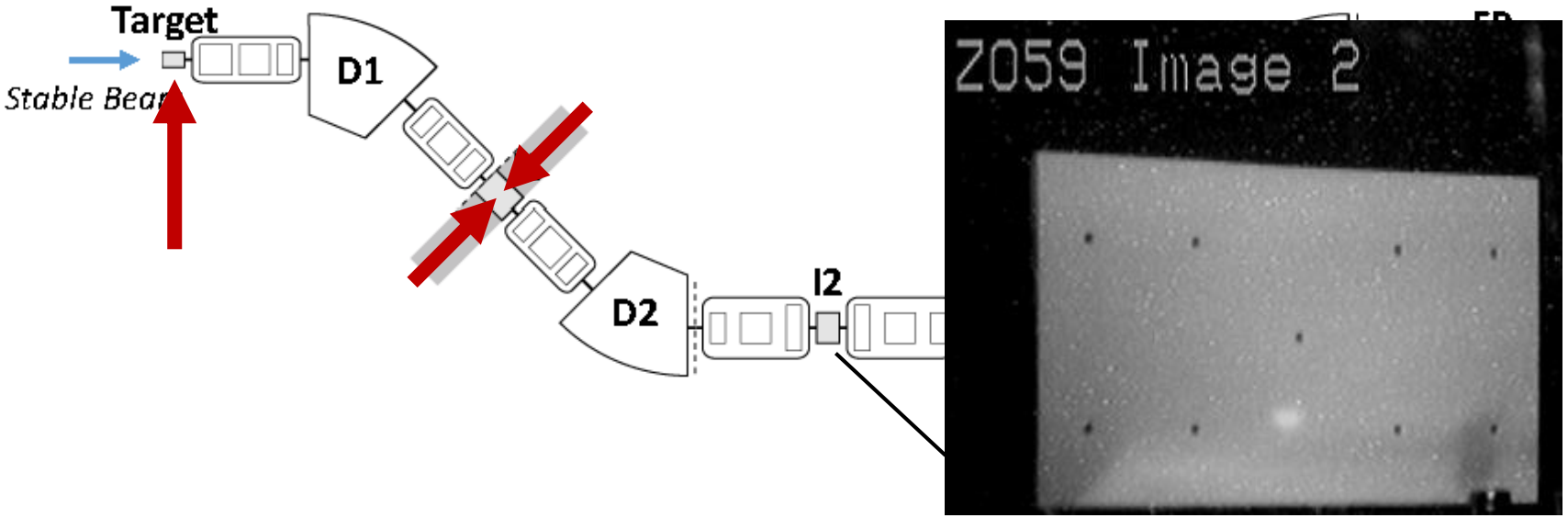

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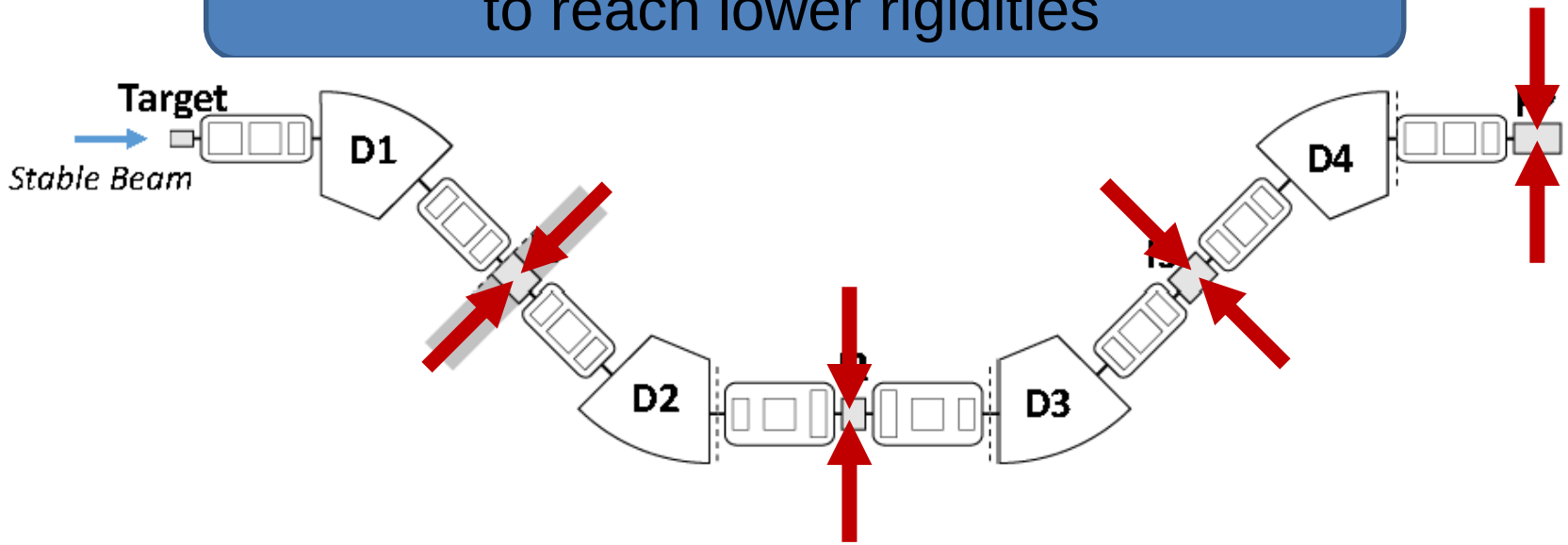

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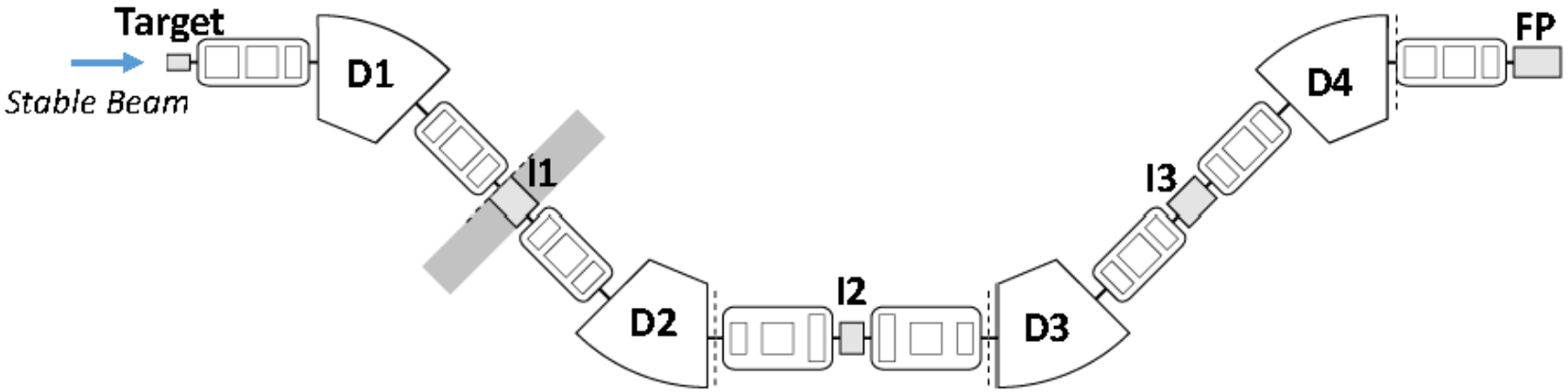

Beam setup details: Nucl. Instr. Meth. B 376 (2016) 131

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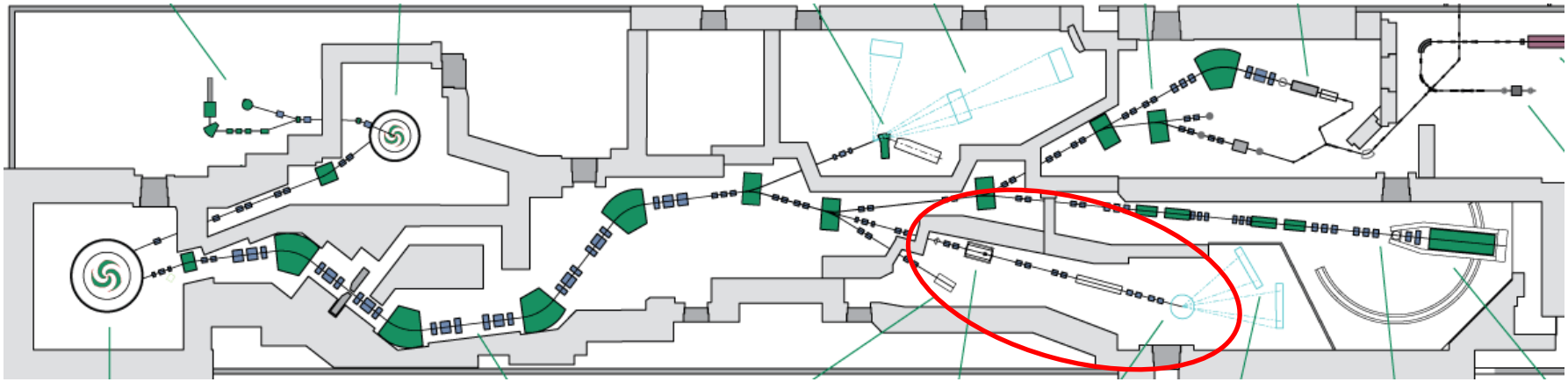

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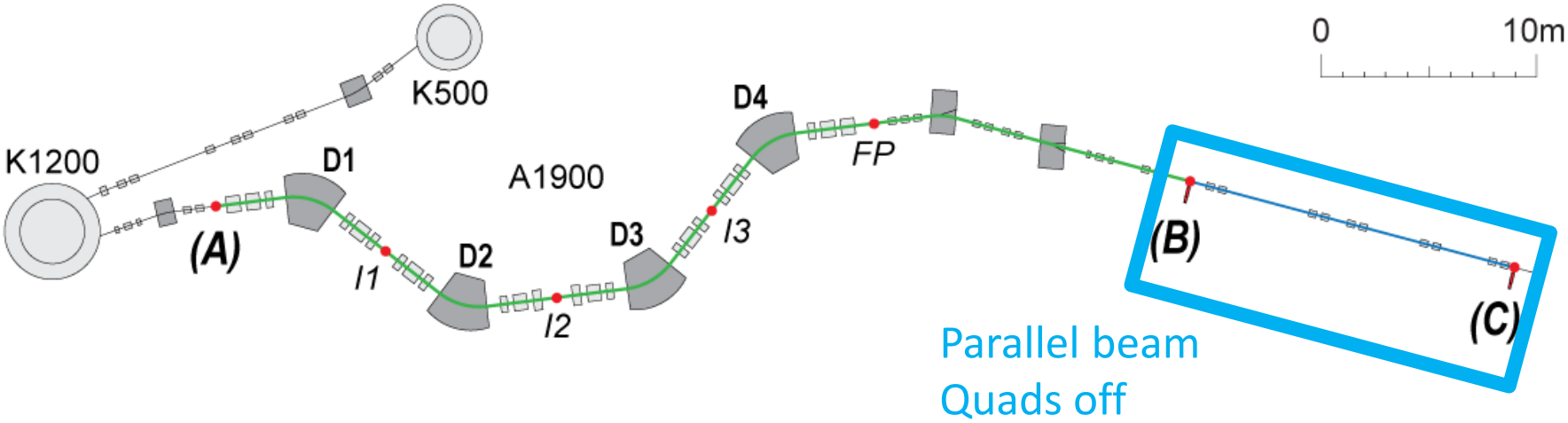

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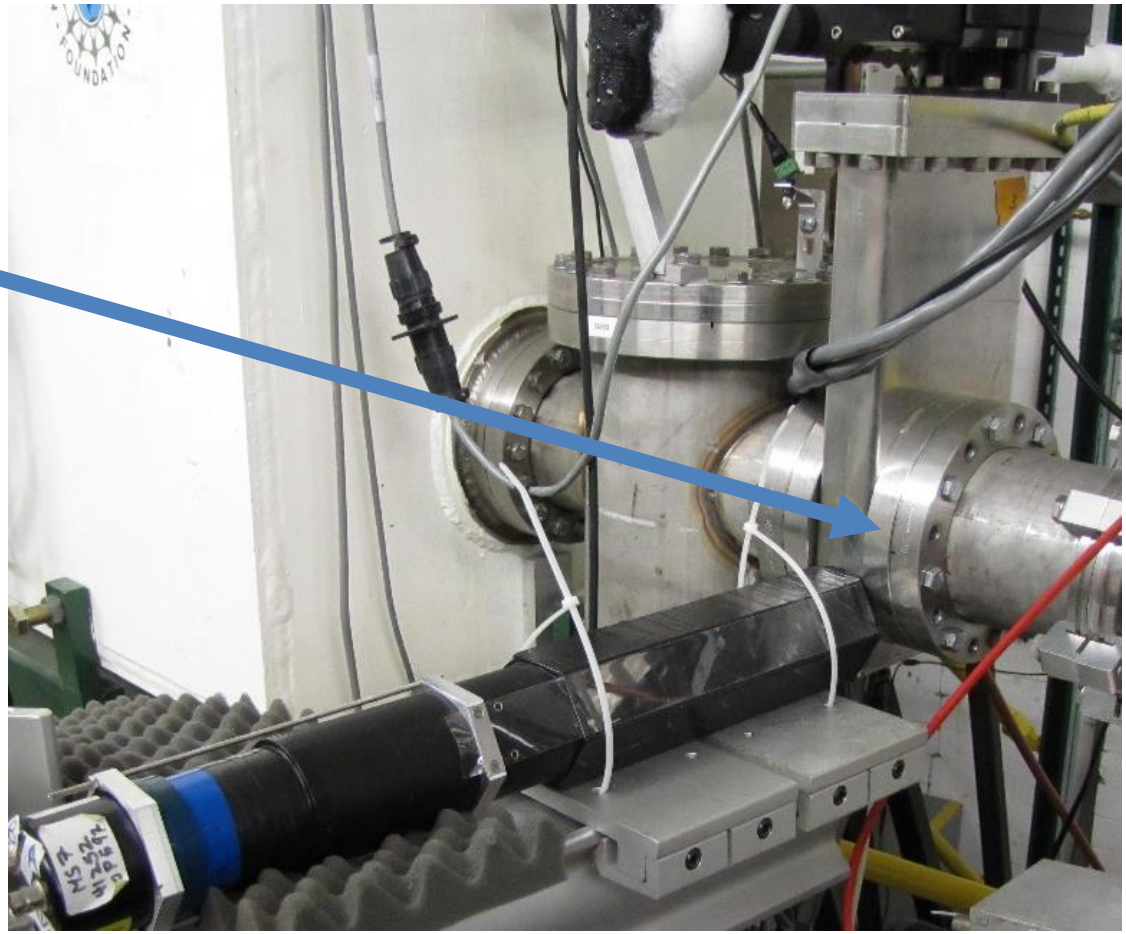

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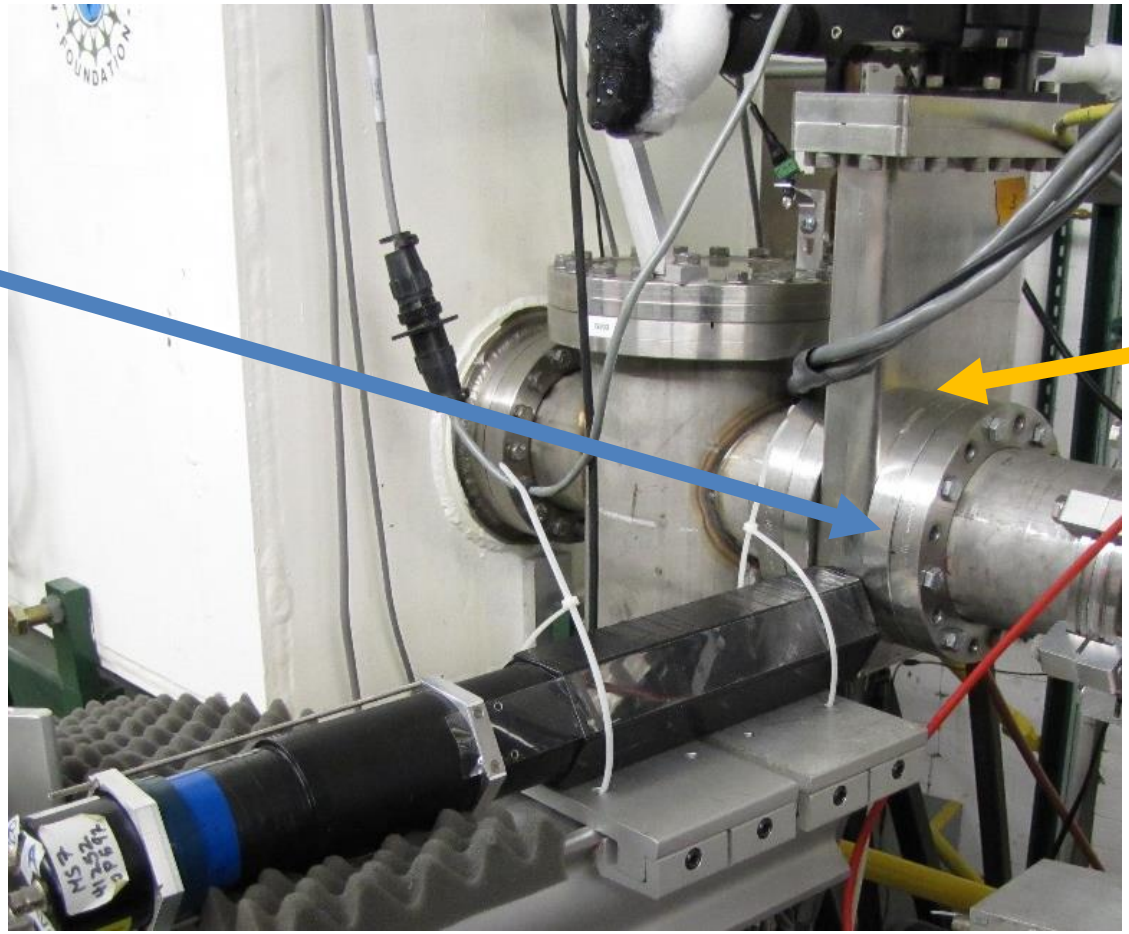

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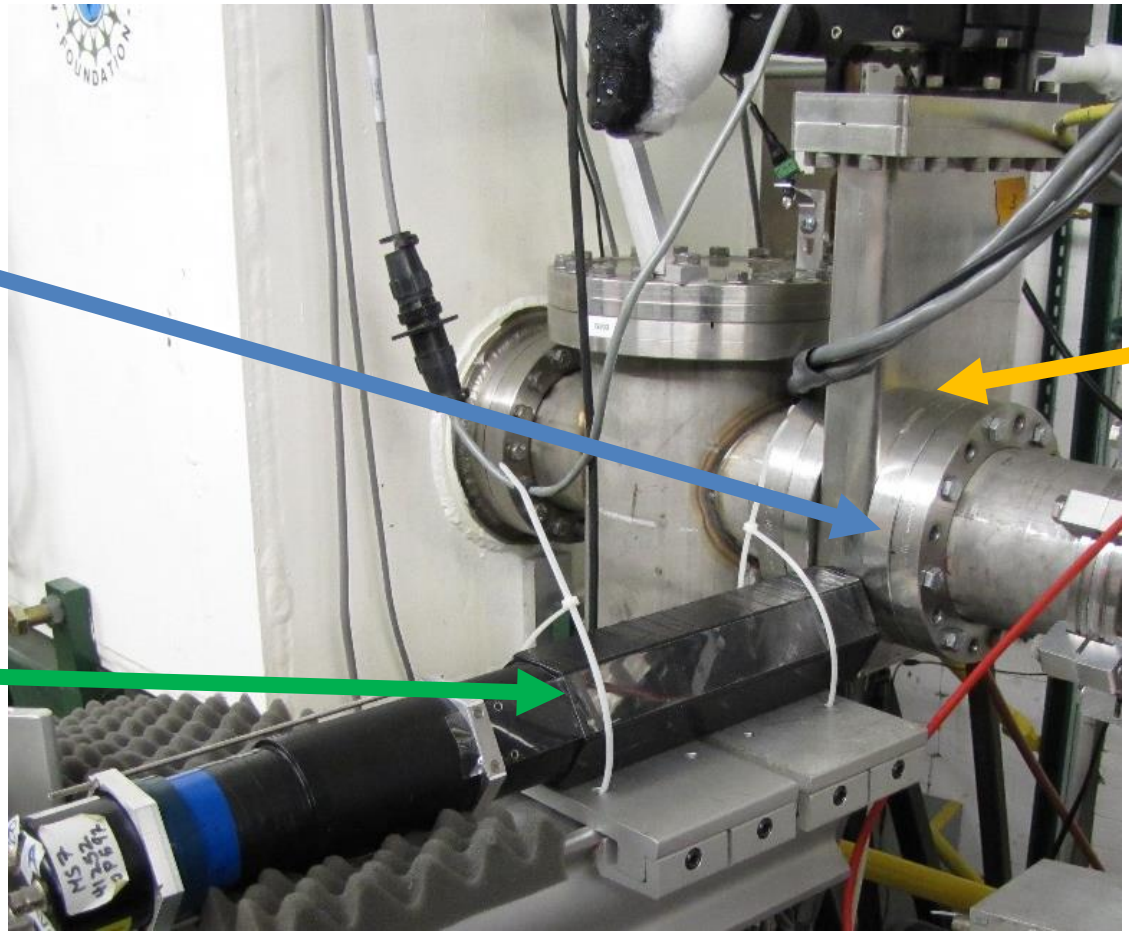

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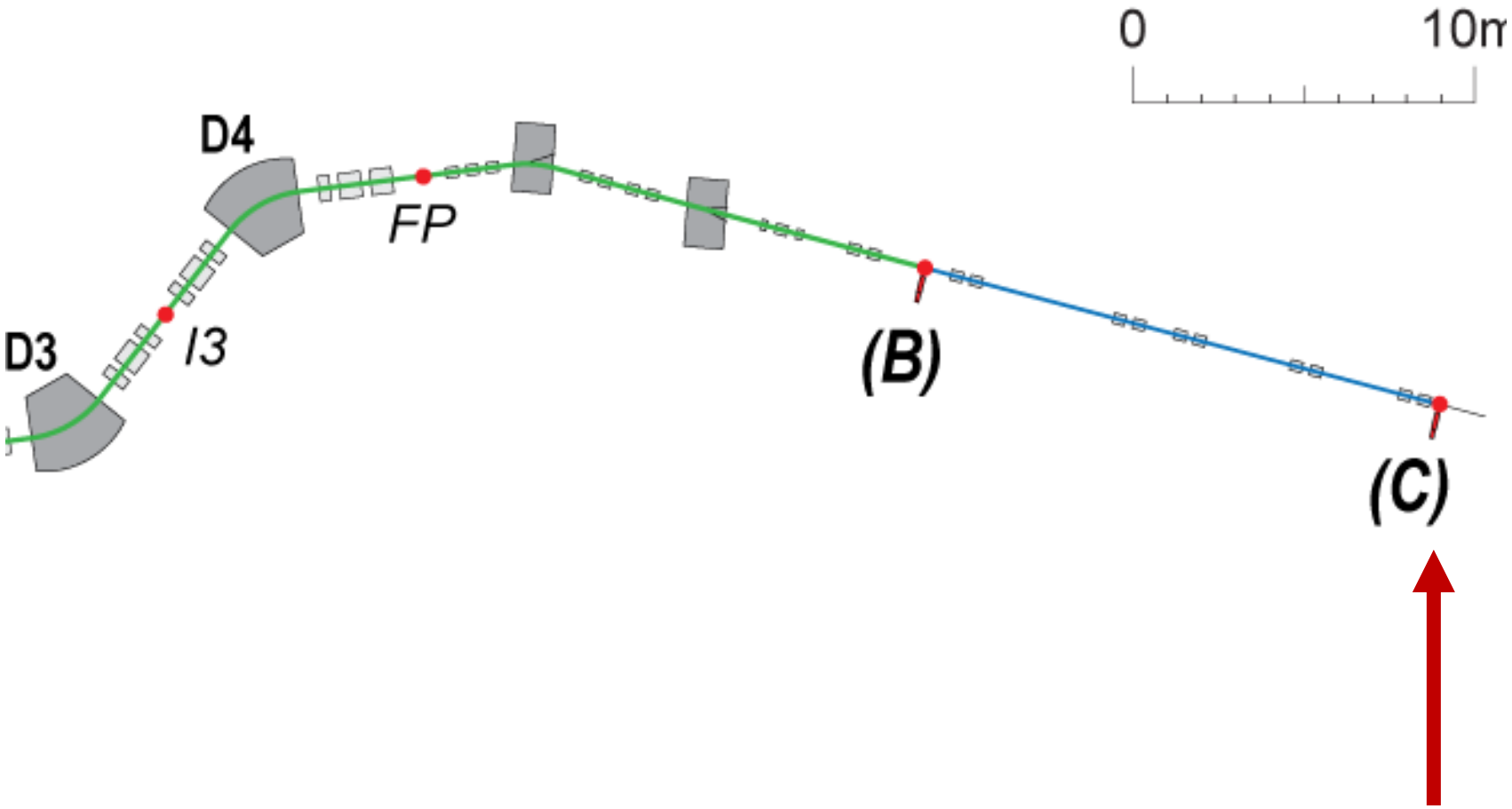

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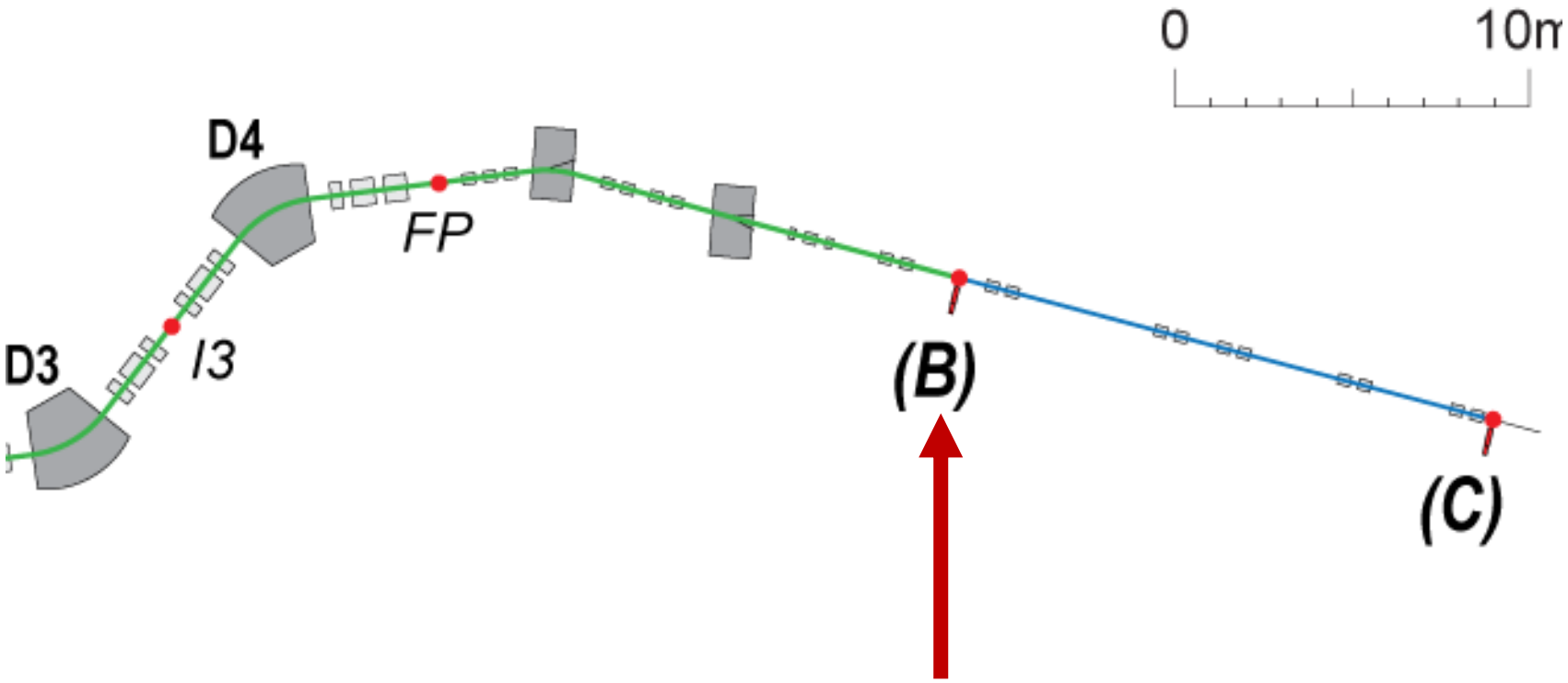

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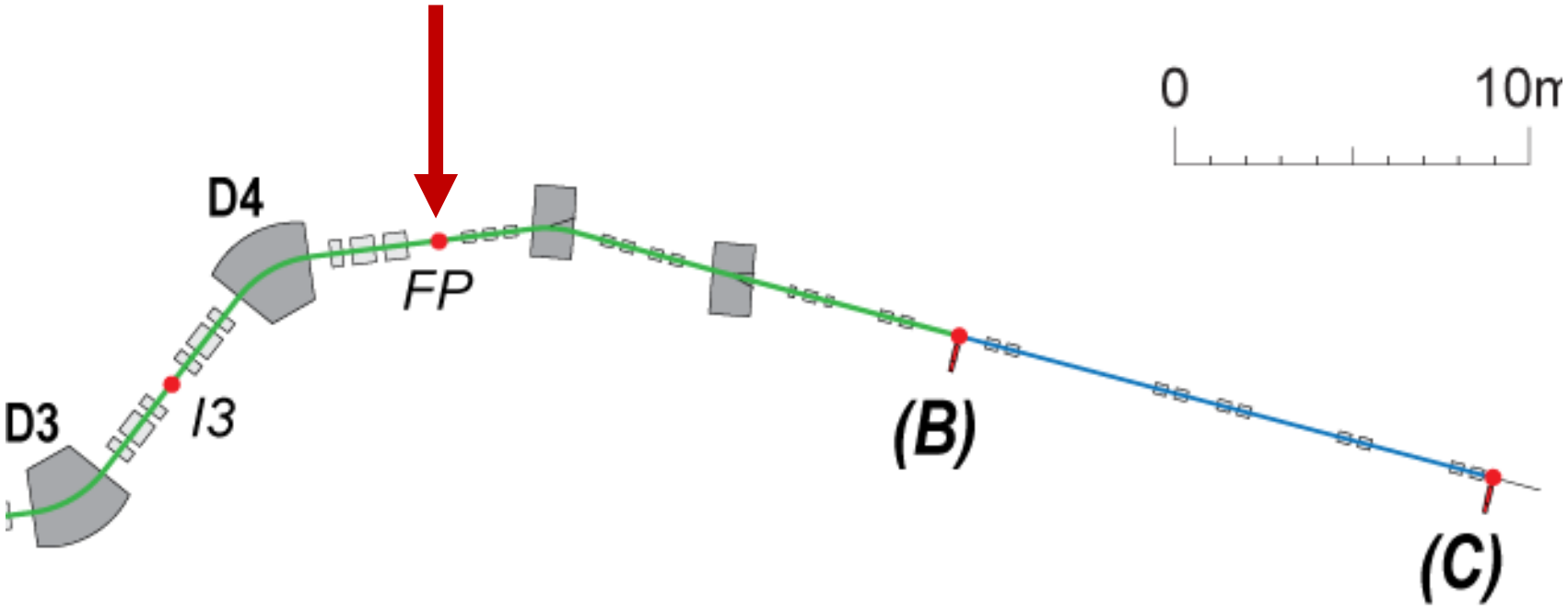

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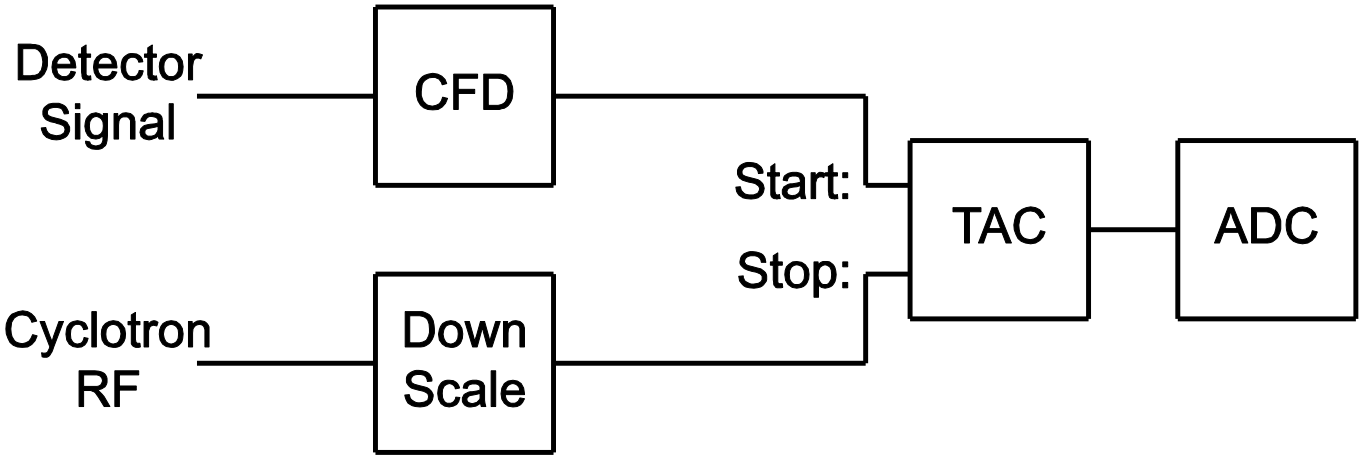

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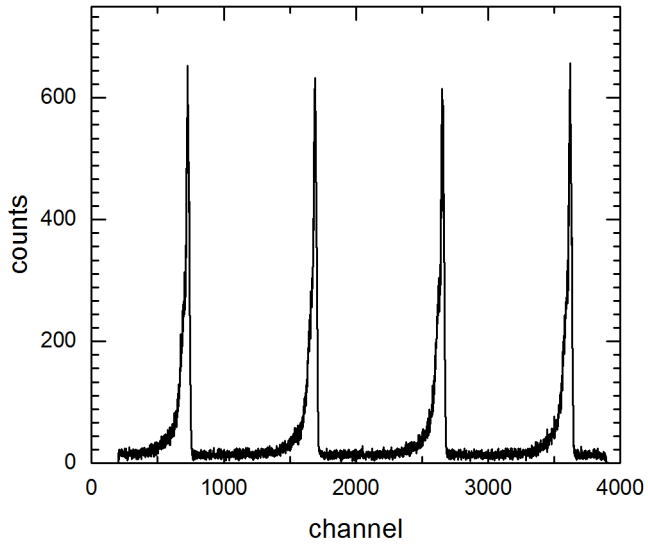

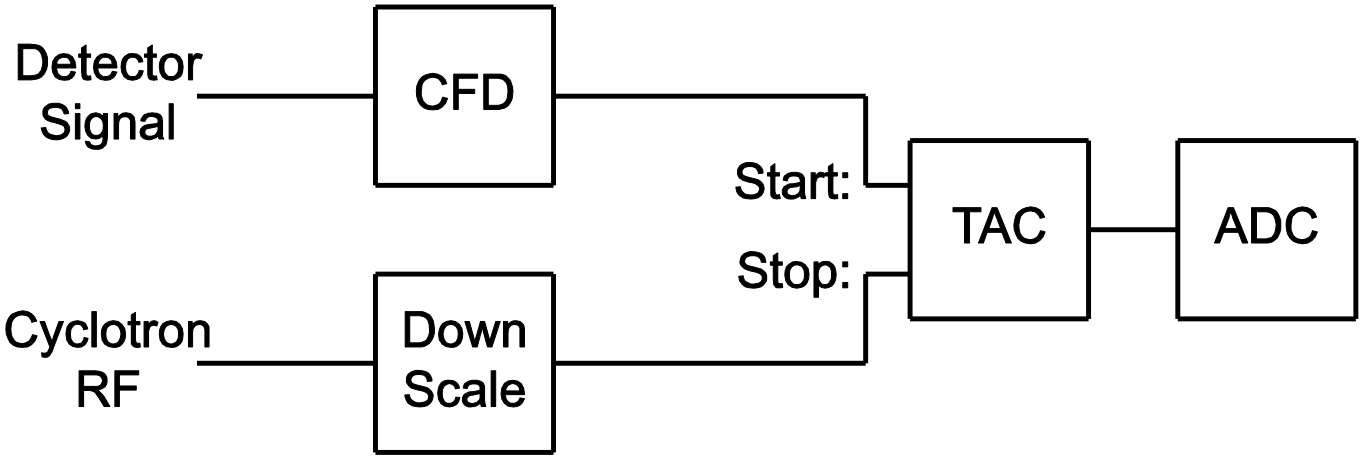

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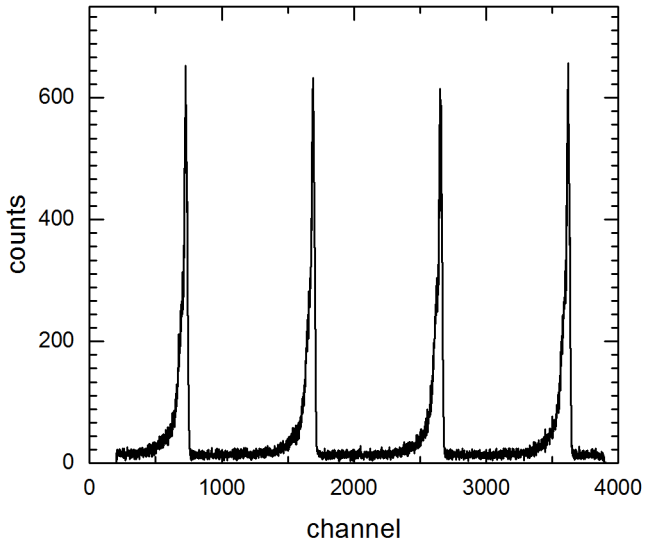

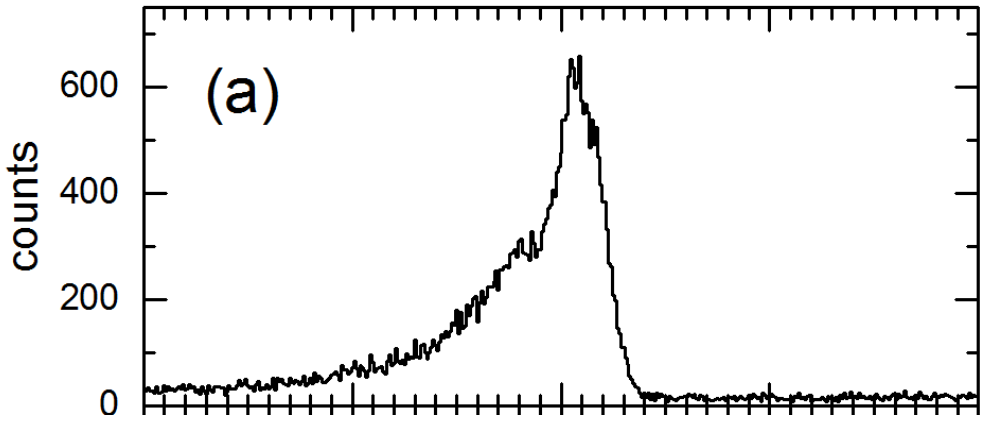

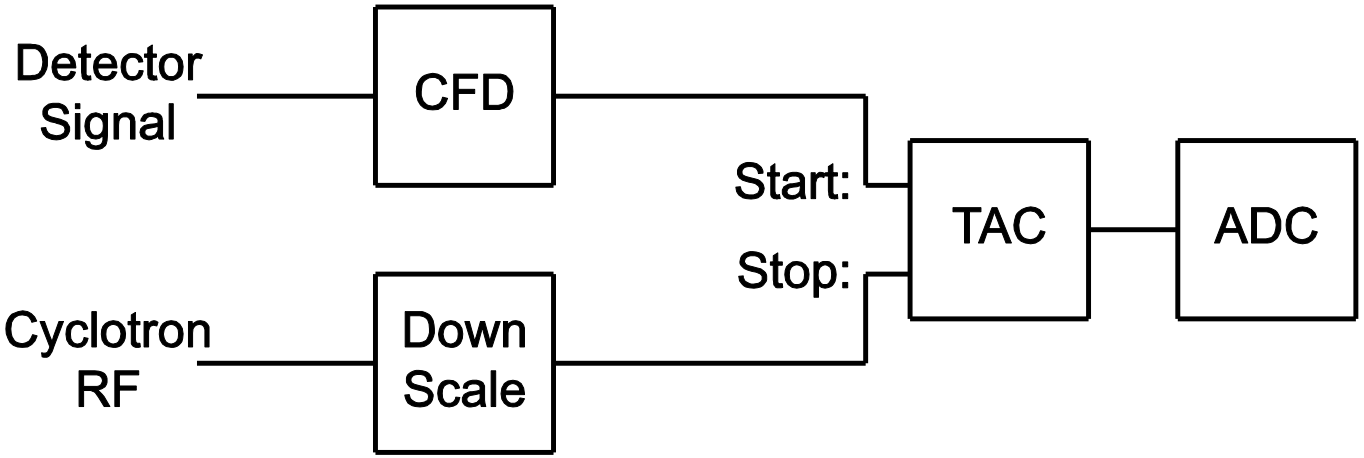

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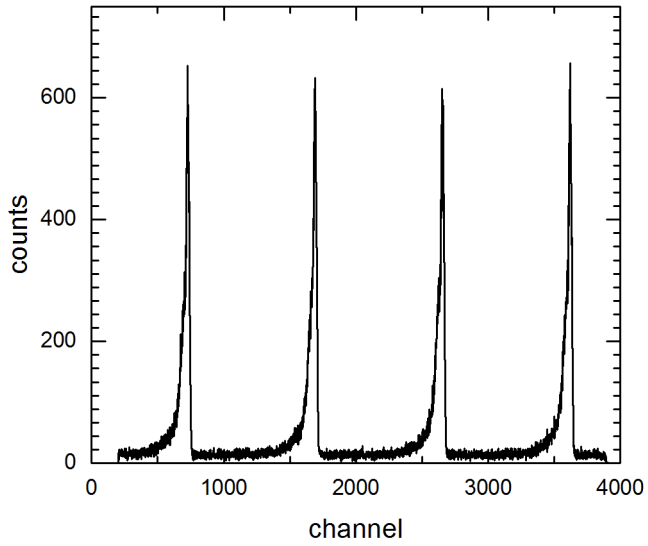
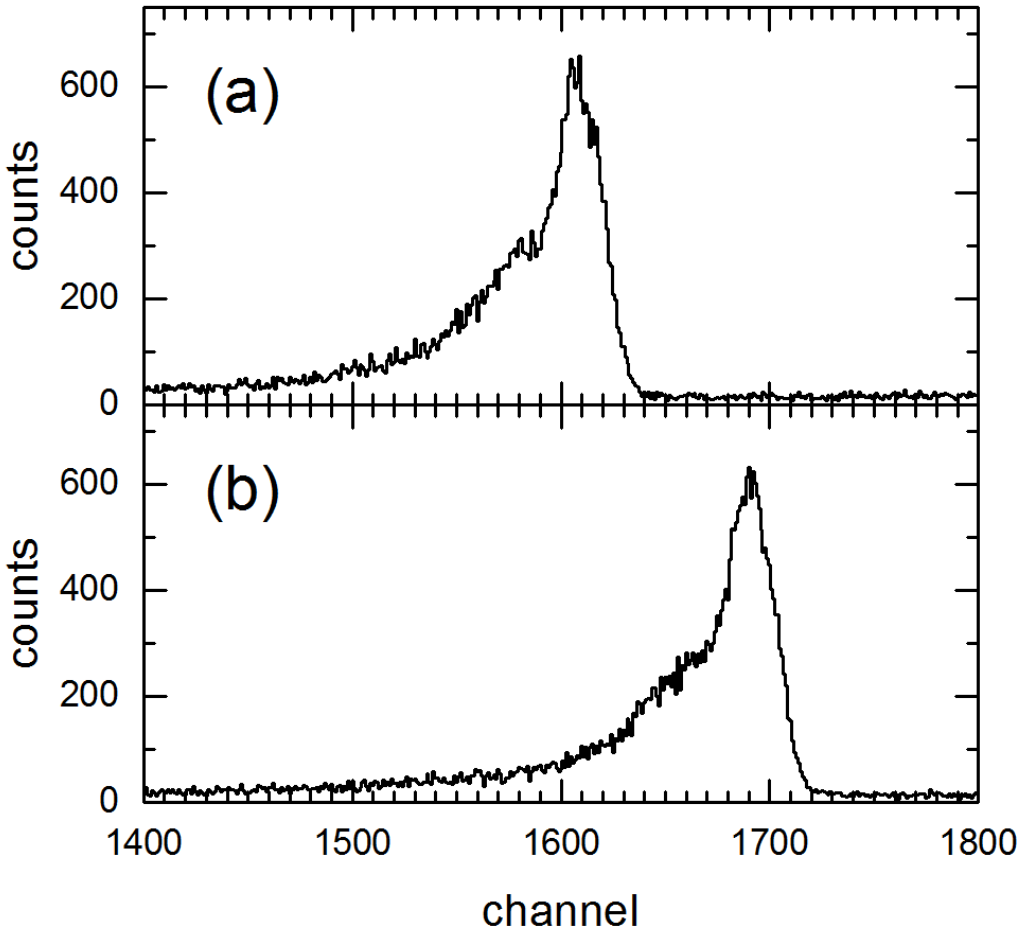
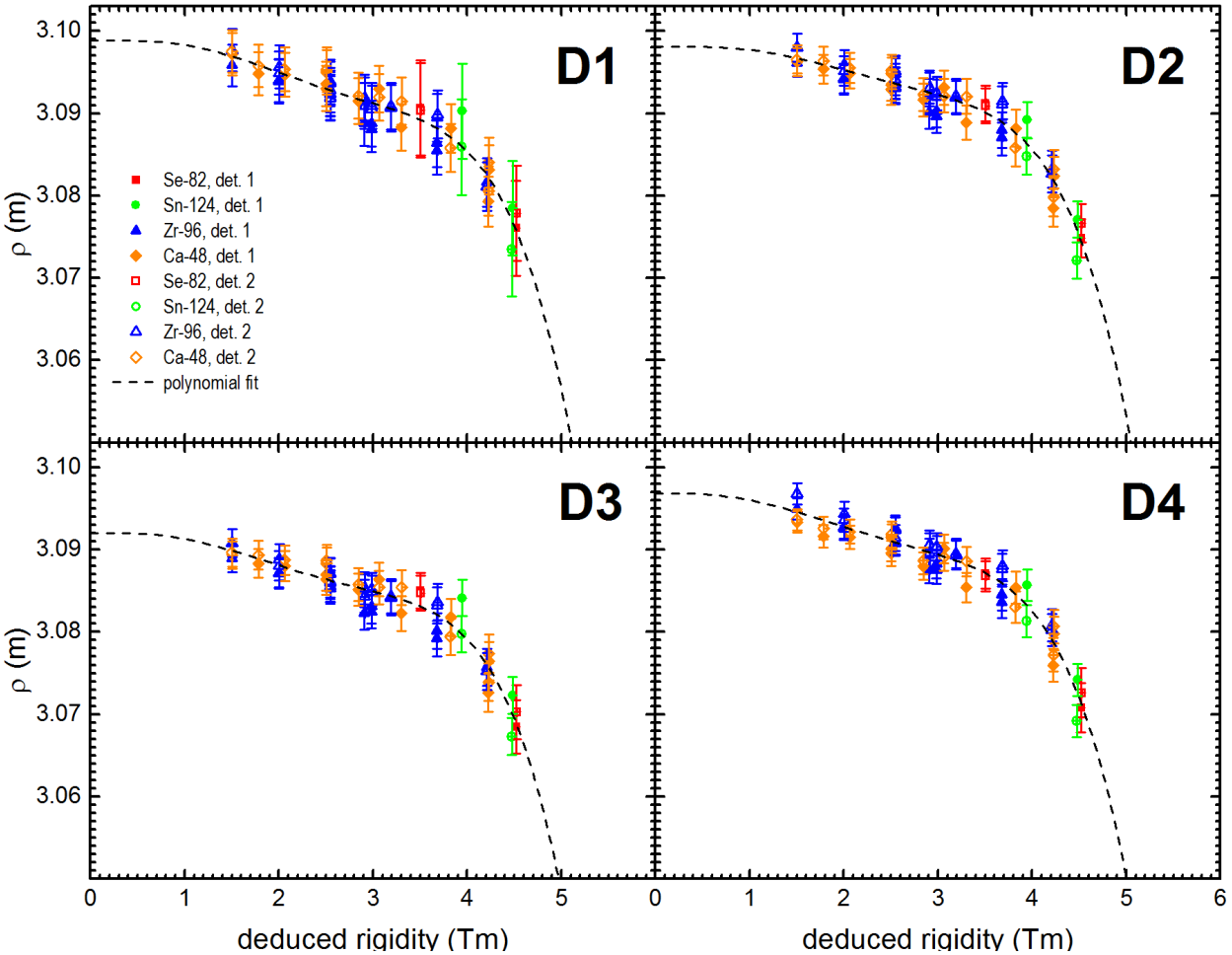




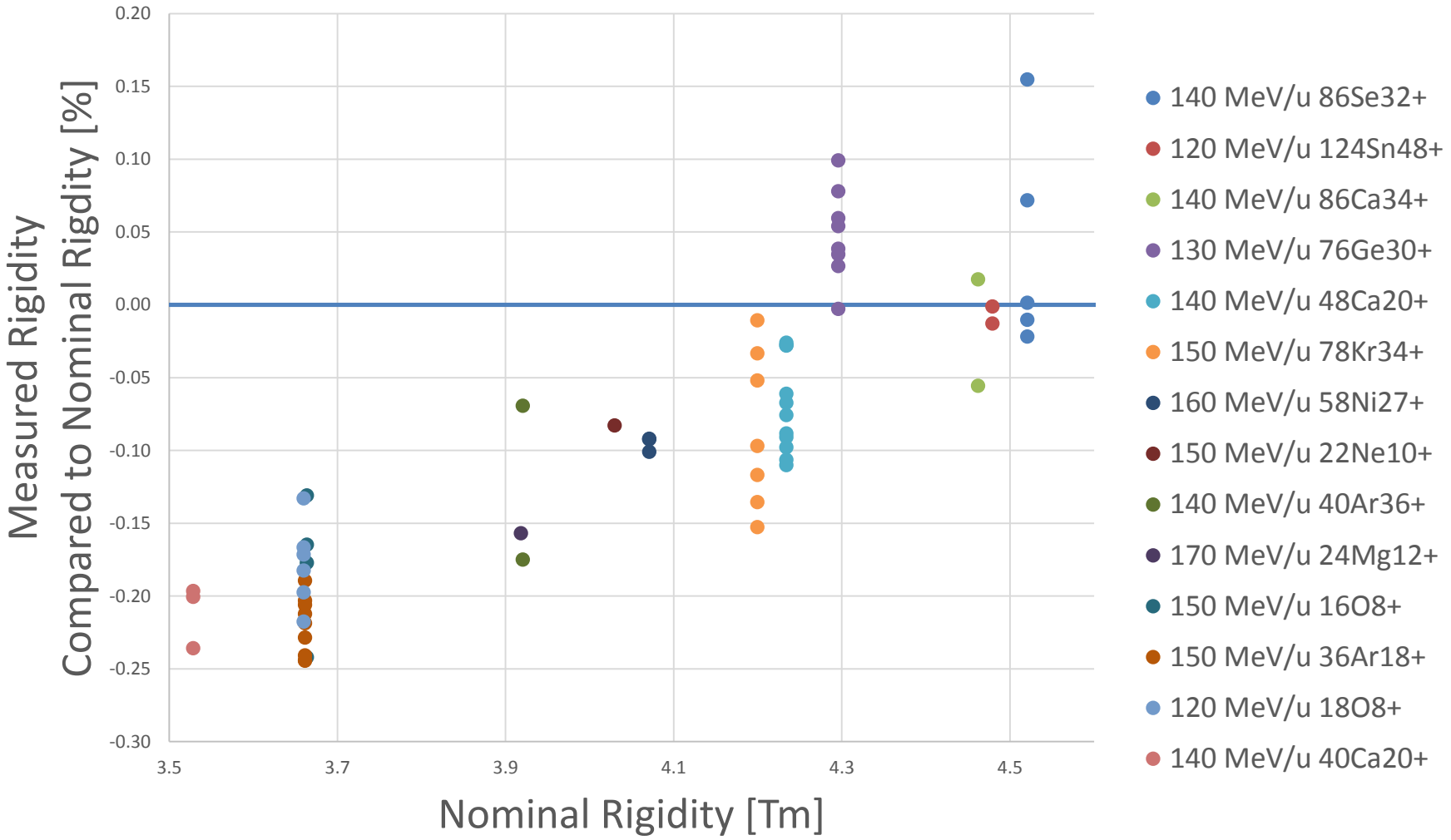
HOW? Results



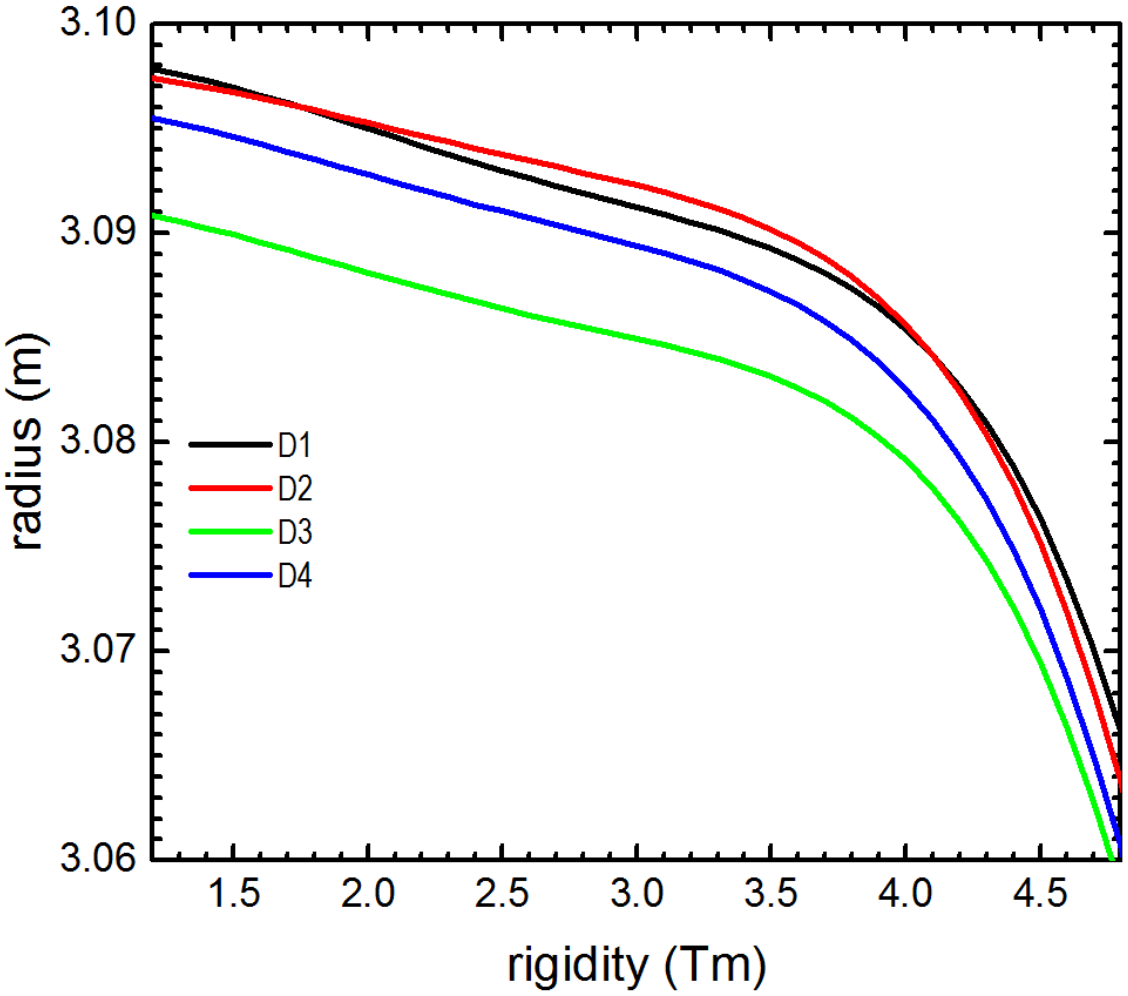
T.N. Ginter et al., submitted to Nucl. Instr. Meth. A

APPLICATIONS

APPLICATION I: Measure cyclotron beam energy



APPLICATION II: Calibrate replacement D3



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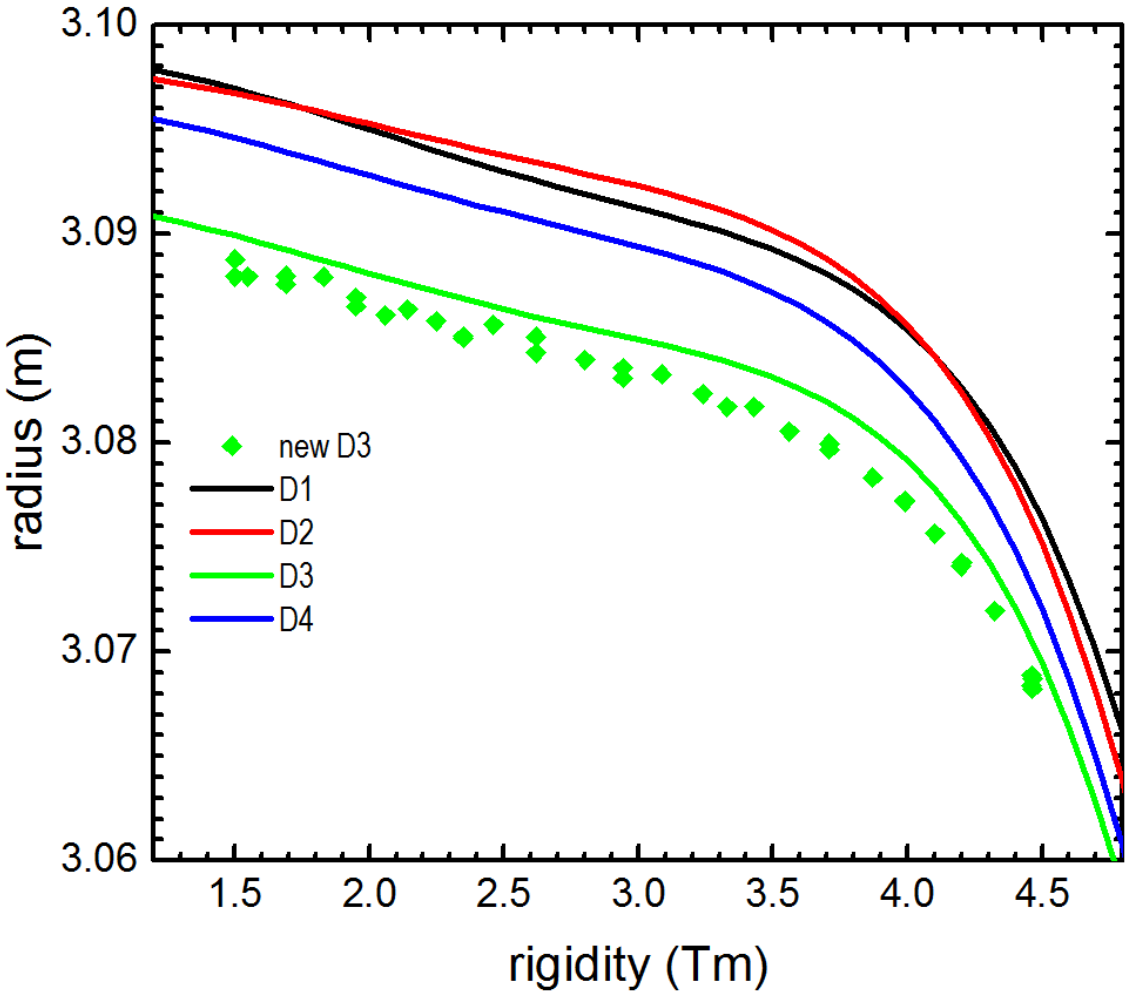

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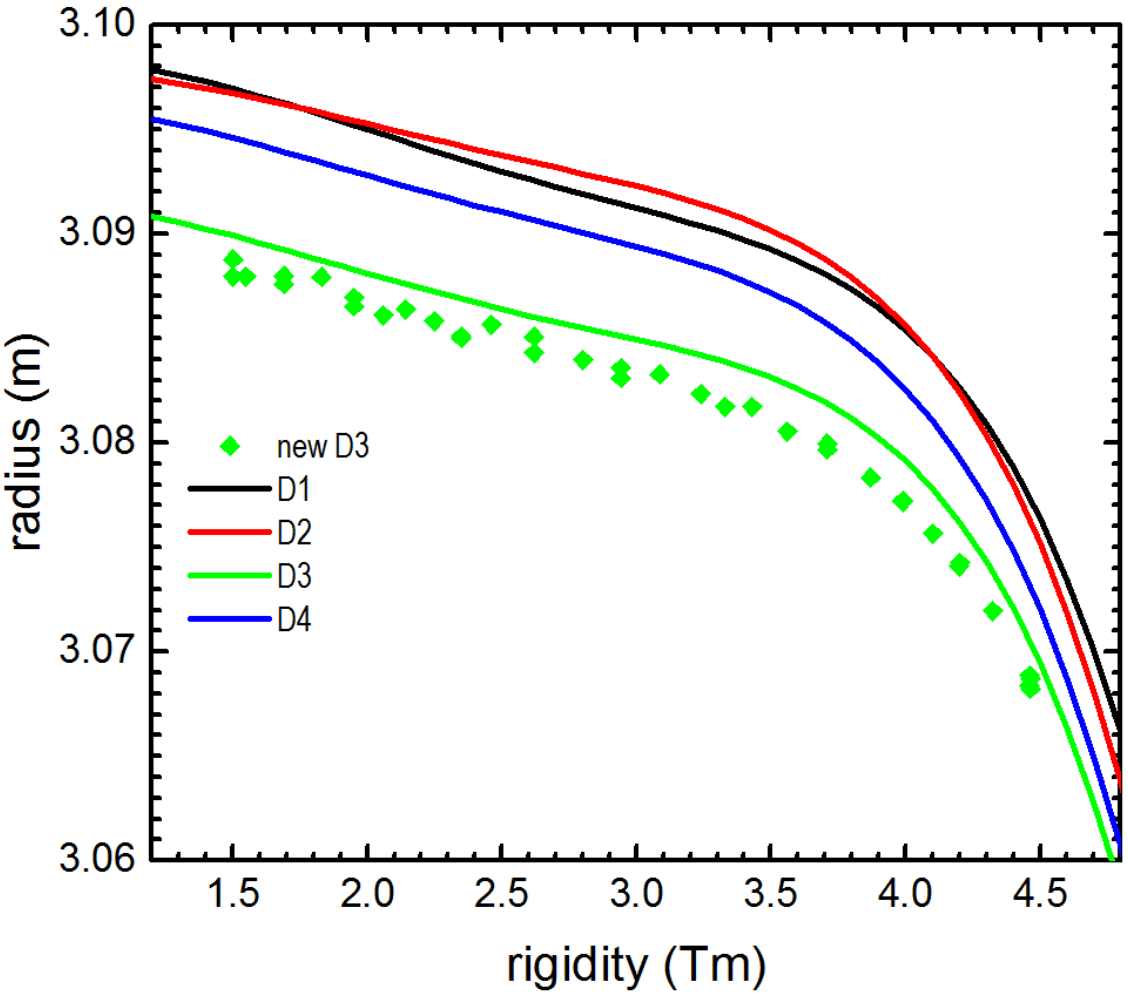

APPLICATION III: Determining q-states from a target by rigidity spacing

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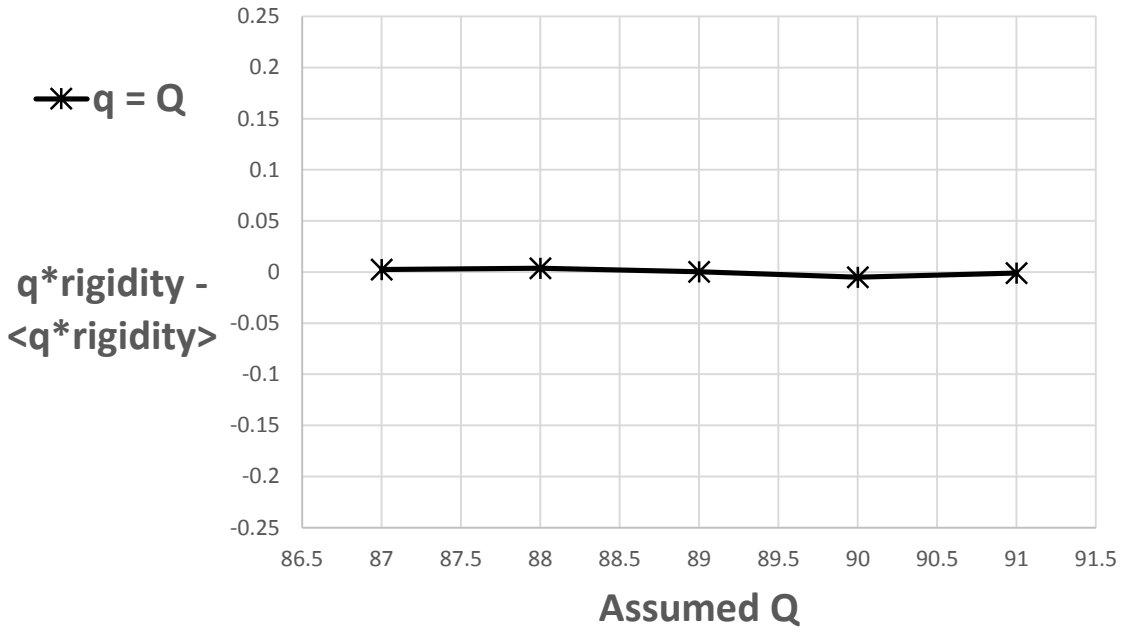
Rigidity [Tm]	Assumed Q
3.3274	87
3.2896	88
3.2526	89
3.2164	90
3.1811	91

Ideal:

Beam: U-238(69+) 80 MeV/u

Target: Be 47 mg/cm^2



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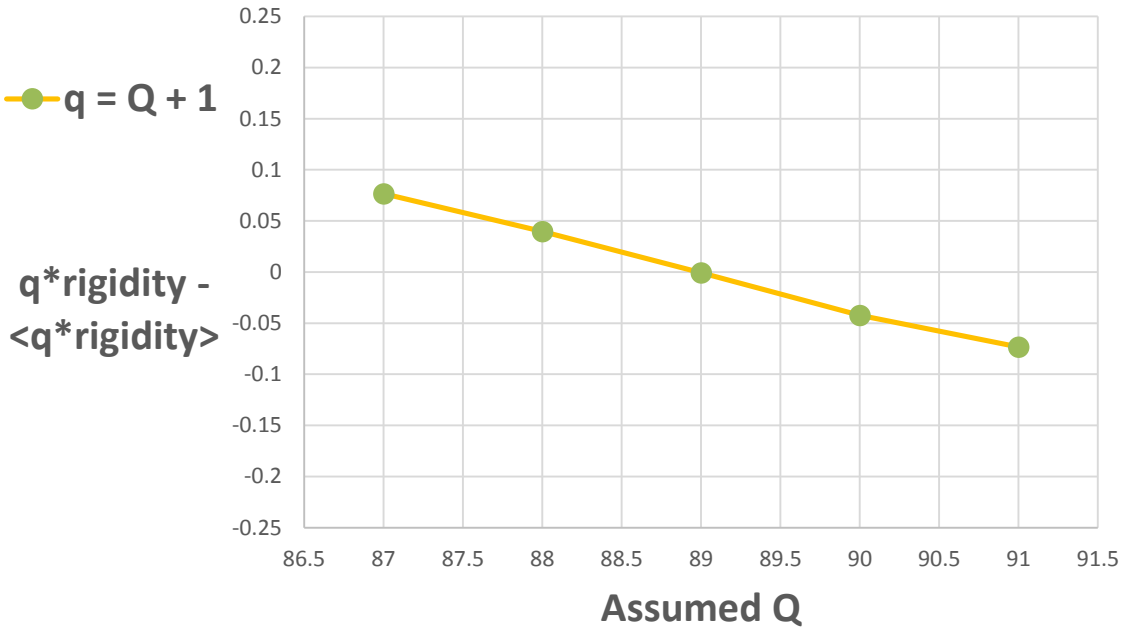

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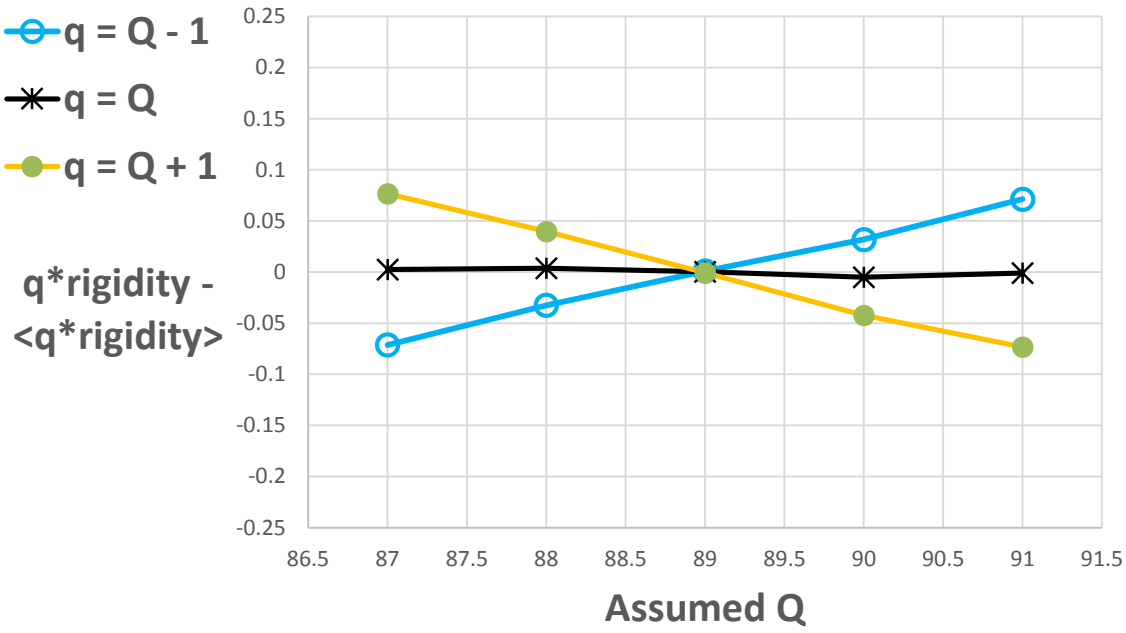

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3.2732	85
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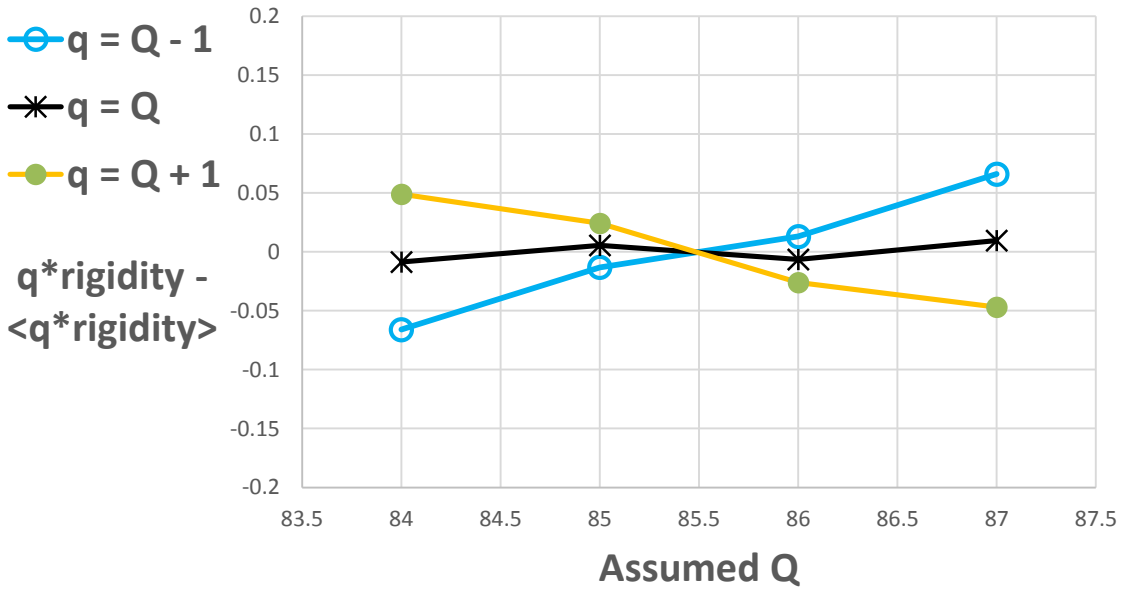

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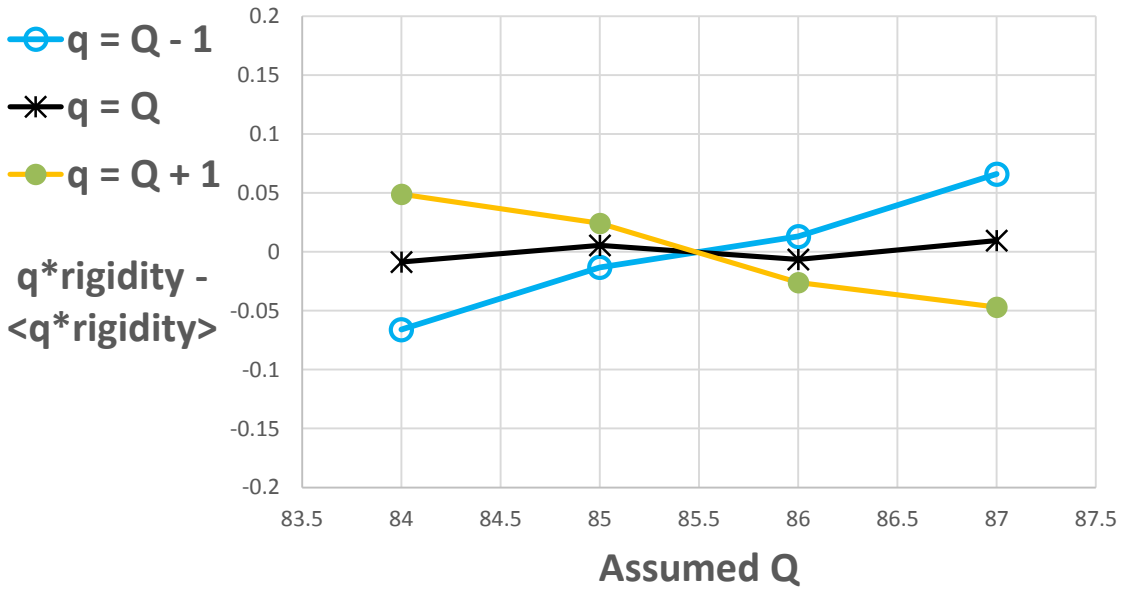

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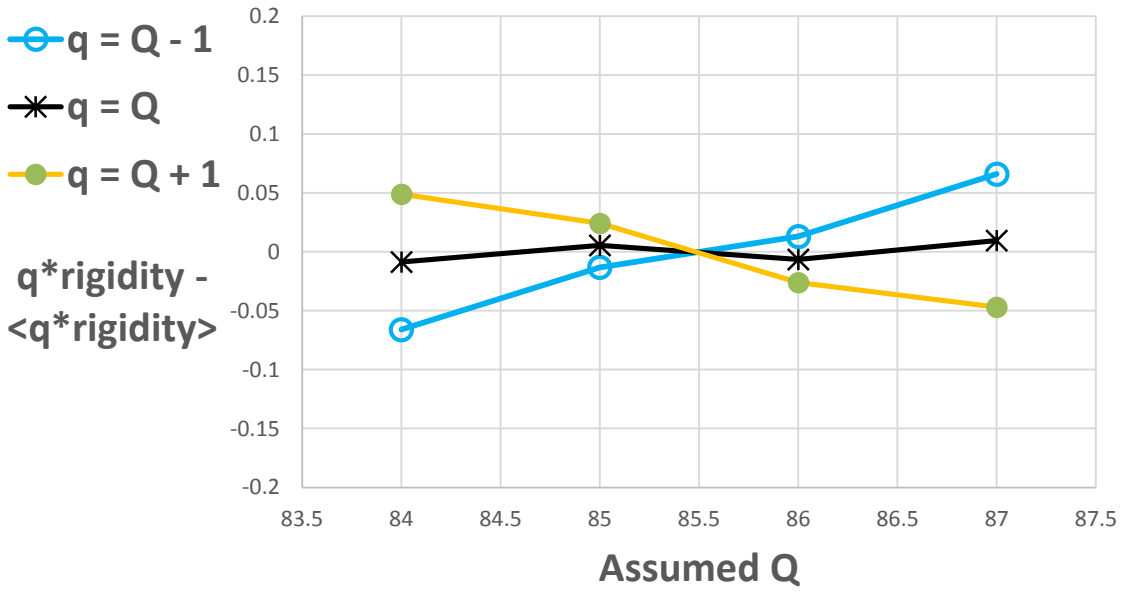
Target: Be 47 mg/cm^2

Calculated target thickness:

70.5 mg/cm^2



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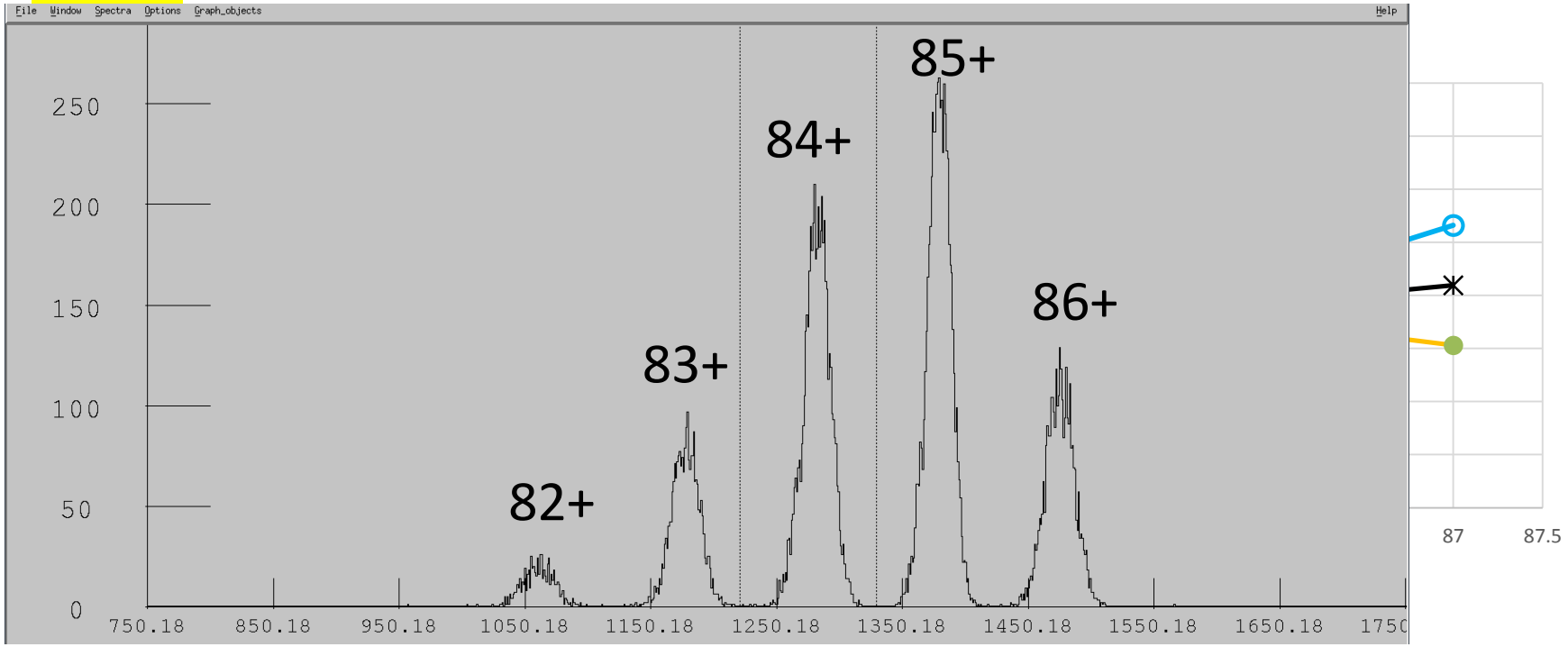

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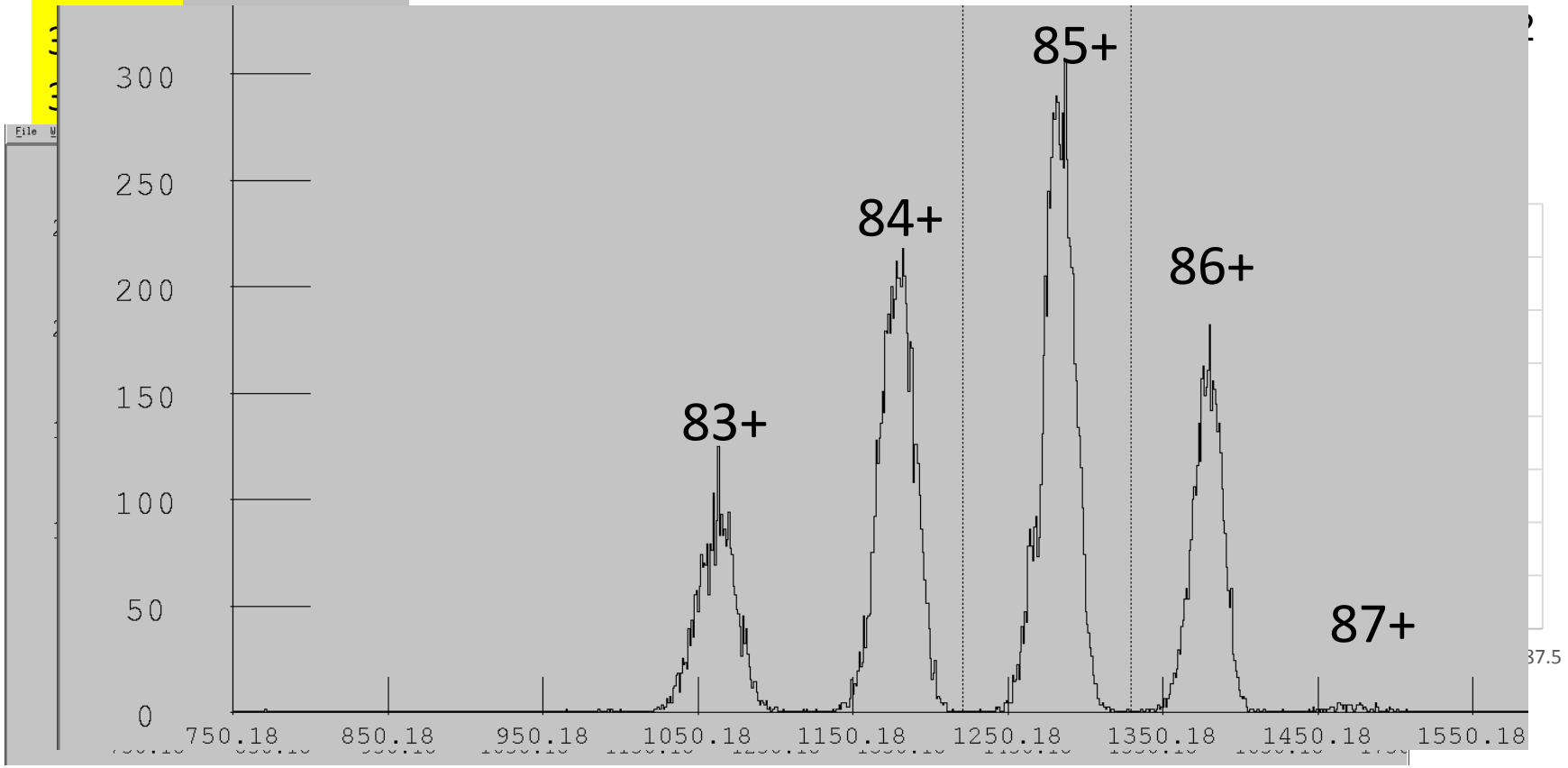
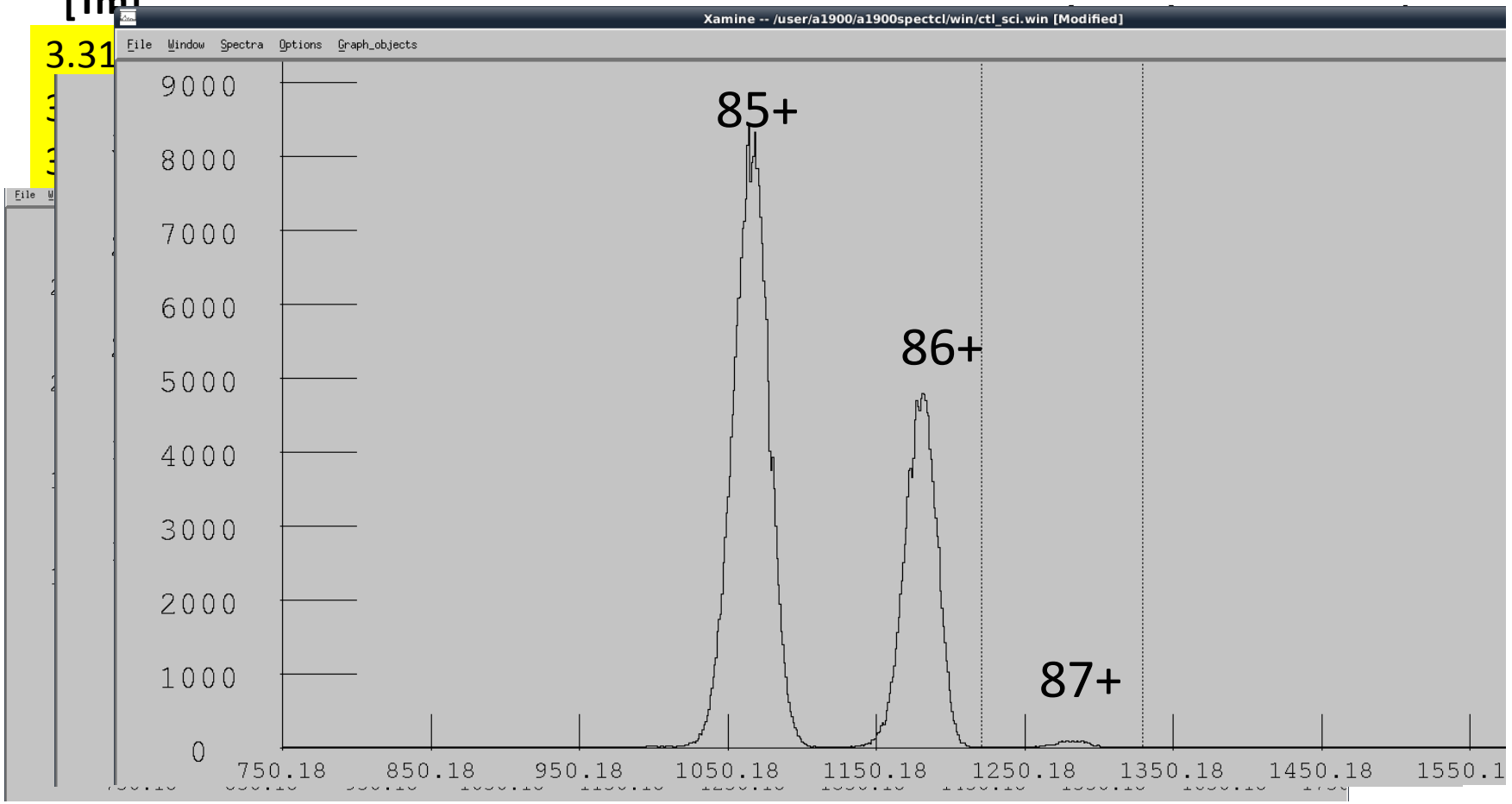


APPLICATION III: Determining q-states from a target by rigidity spacing

Rigidity [Tm] **Assumed Q**

3.31

Real:



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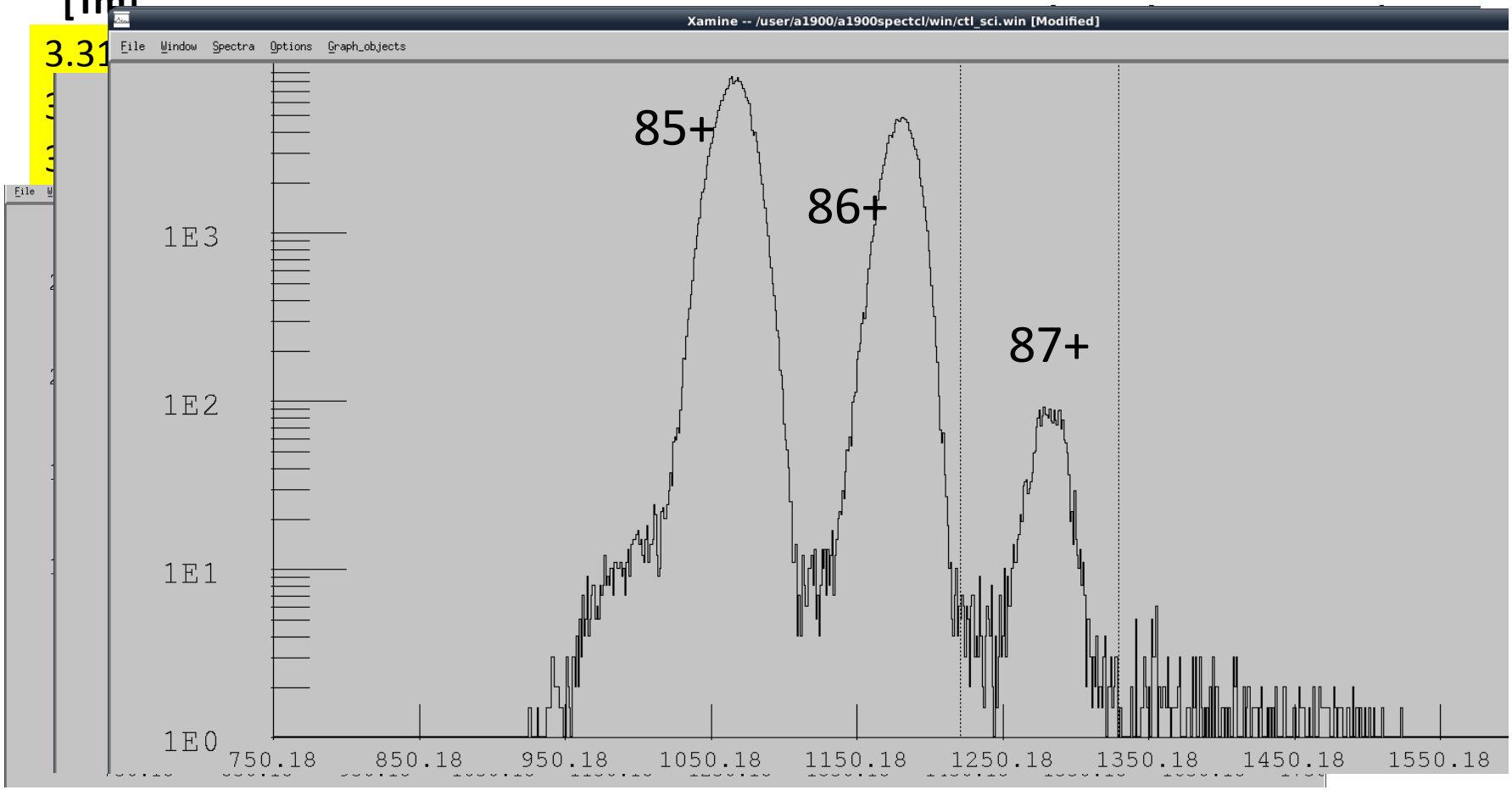

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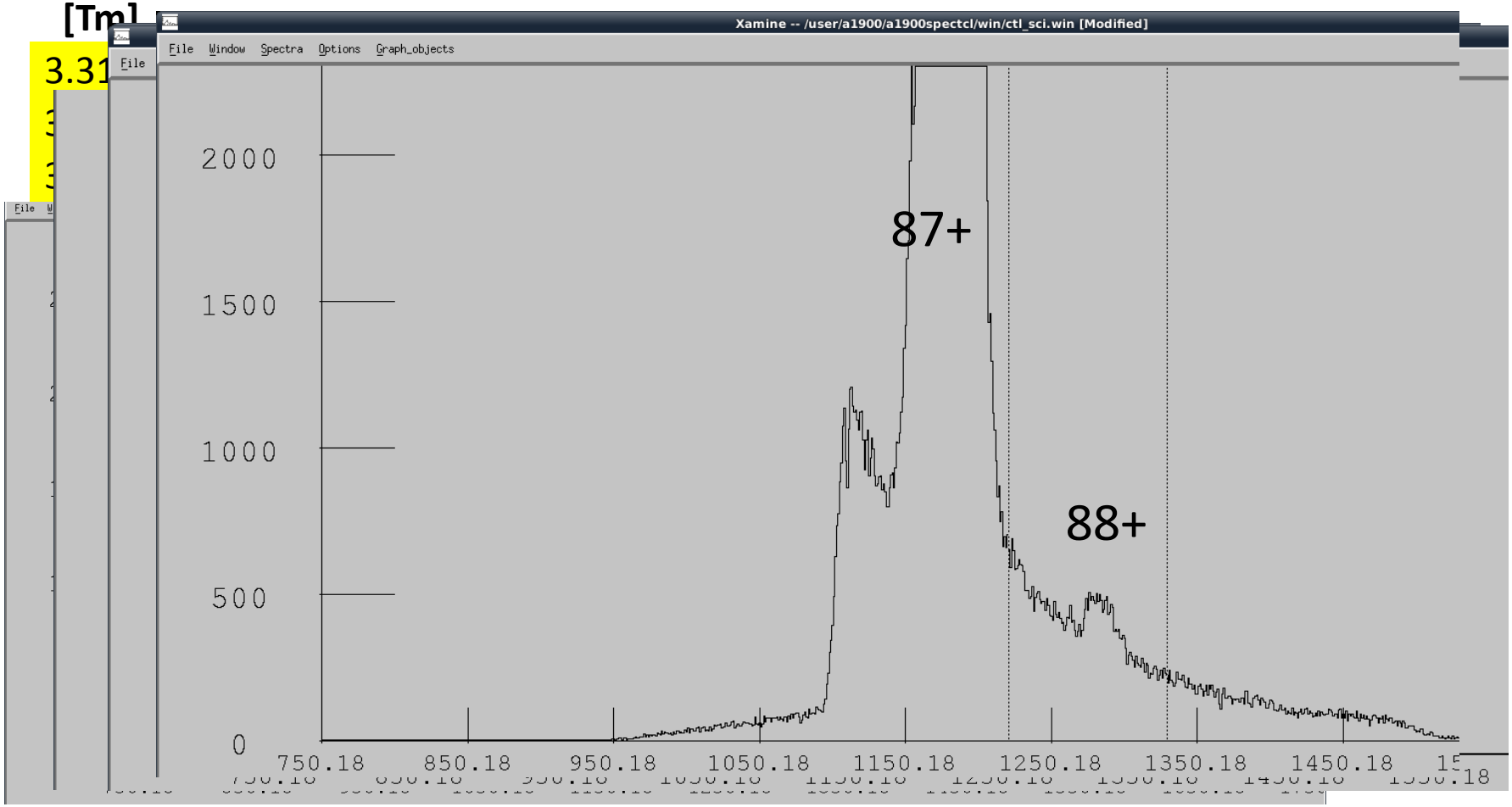

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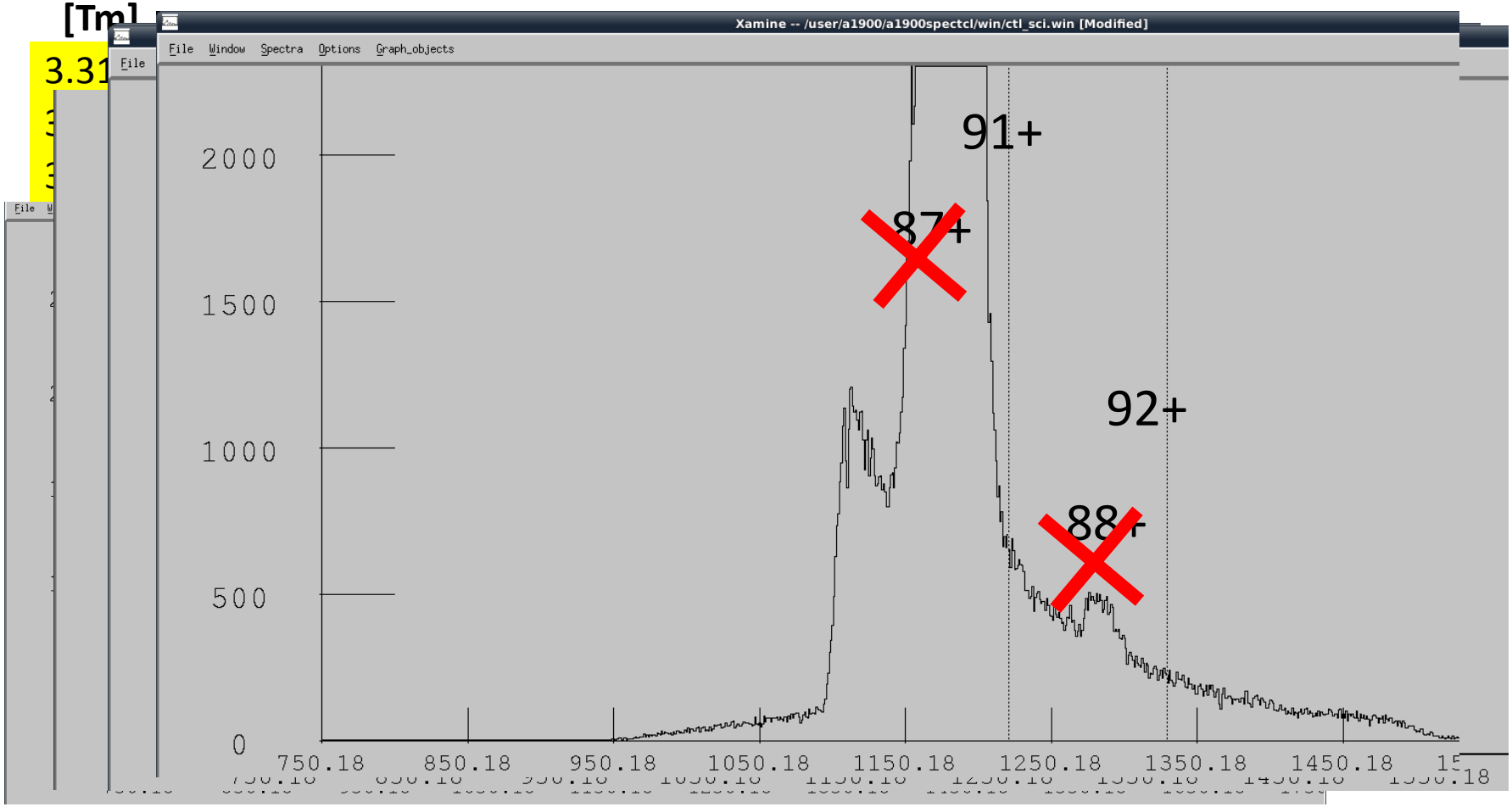

APPLICATION III: Determining q-states from a target by rigidity spacing

Real:

Beam: U-238(69+) 80 MeV/u

Target: Be 47 mg/cm^2

Q = 88+ → Thickness = 45.8 mg/cm^2

APPLICATION III: Determining q-states from a target by rigidity spacing

What went wrong?

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Discrepancy Estimate: 0.15% per q-state step
(if Z=92 stops like Z=91)

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What went wrong?

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Discrepancy Estimate: 0.15% per q-state step
(if Z=92 stops like Z=91)

Have we managed to measure the effective nuclear screening of the added electrons?

OUTLOOK

- Same technique planned for energy calibration of ReA3

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- We can now review 15 years of fragment settings within a consistent basis
- We are in a strong position to do routine stuff better, faster (e.g., avoid beam charge states, find where we are on beam charge state distributions)
- This experience helps us get up to speed quickly for FRIB

Collaborators

NSCL Beam Physicists Group

T. Baumann, E. Kwan, A. M. Rogers,
C. Sumithrarachchi

FRIB Separator Group

F. Farinon, M. Hausmann, M. Portillo

Others

O. Naviliat Cuncic, J. Stetson,
A. C. C. Villari, S. J. Williams

Momentum Calibration of the A1900

Tom Ginter
Beam Staff Physicist

MICHIGAN STATE UNIVERSITY

U.S. DEPARTMENT OF ENERGY | Office of Science

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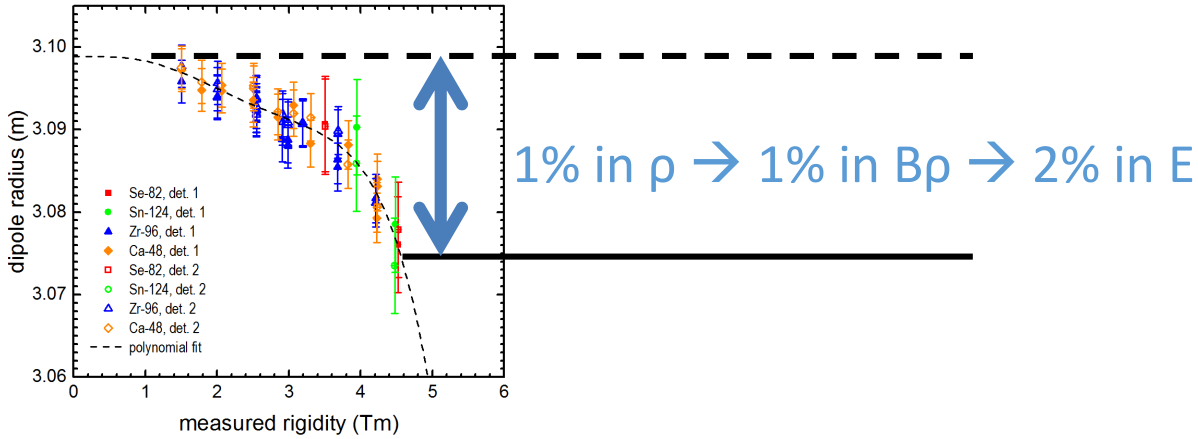
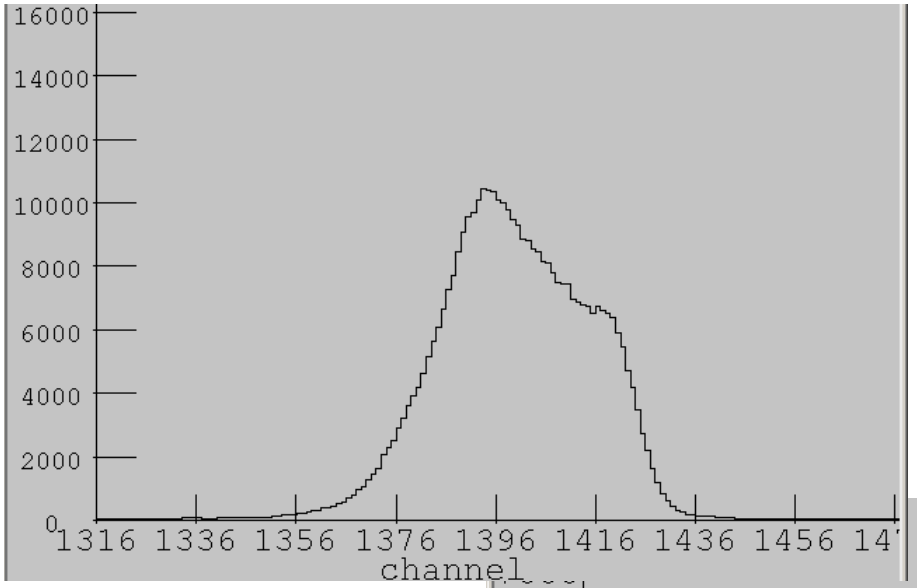
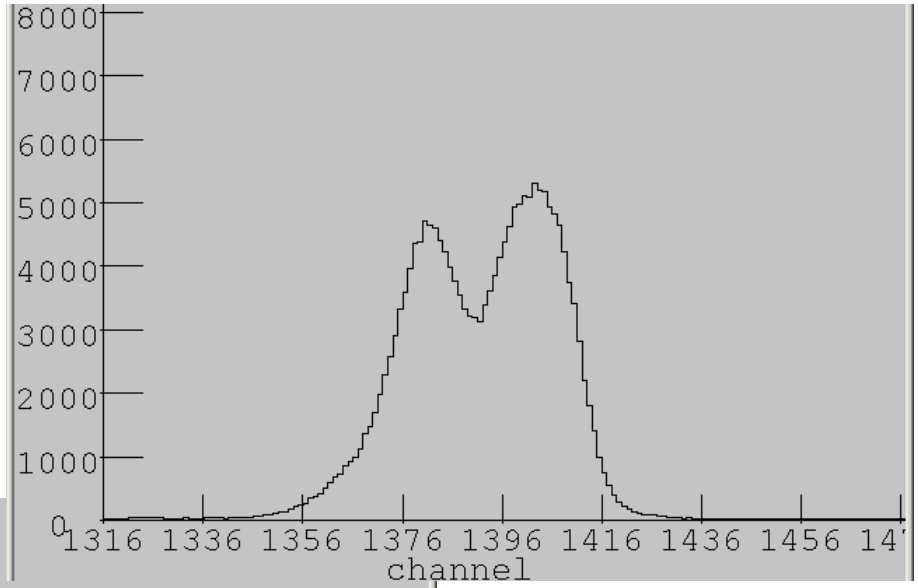
the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661, the State of Michigan, and Michigan State University.
Michigan State University designs and establishes FRIB as a DOE Office of Science National User Facility in support of the mission of the Office of Nuclear Physics.

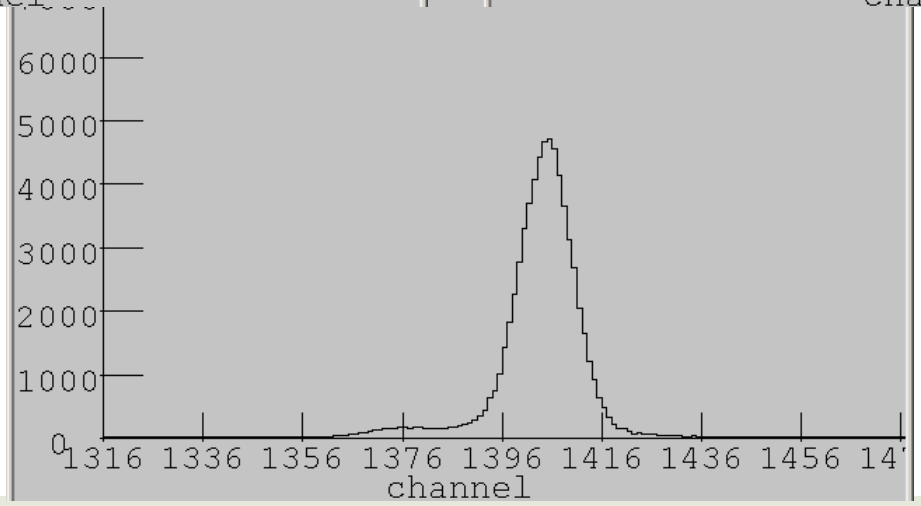
Understanding old Calibration

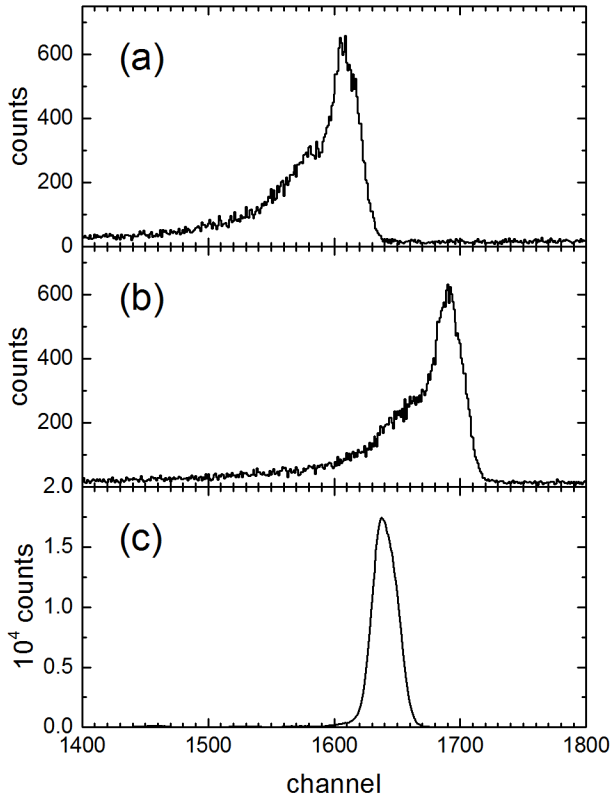


RF Peak structure – potential variability







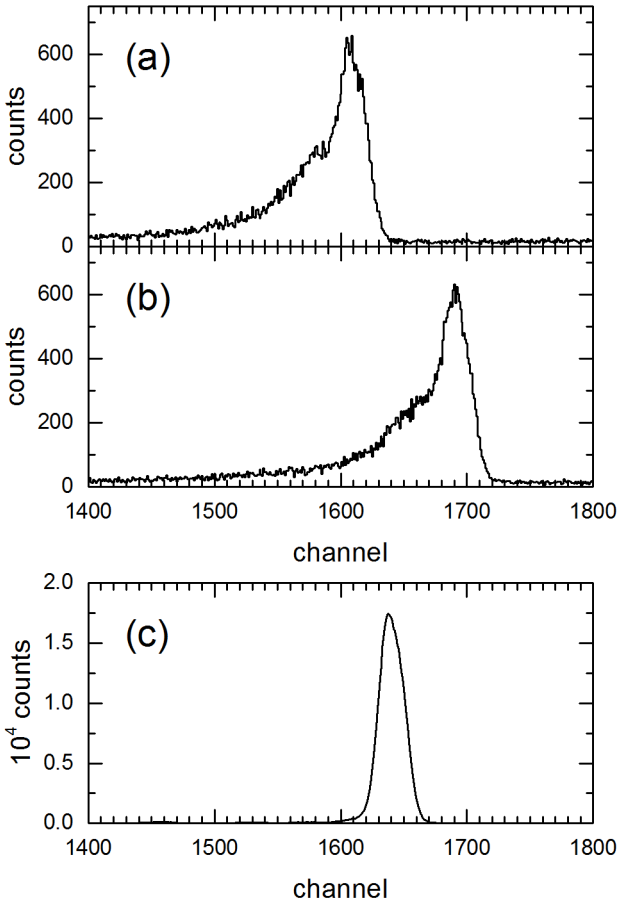

(a)
(b)
(c)
counts
counts
10^4 counts
600
400
200
0
600
400
200
2.0
1.5
1.0
0.5
0.0
1400
1500
1600
1700
1800
channel

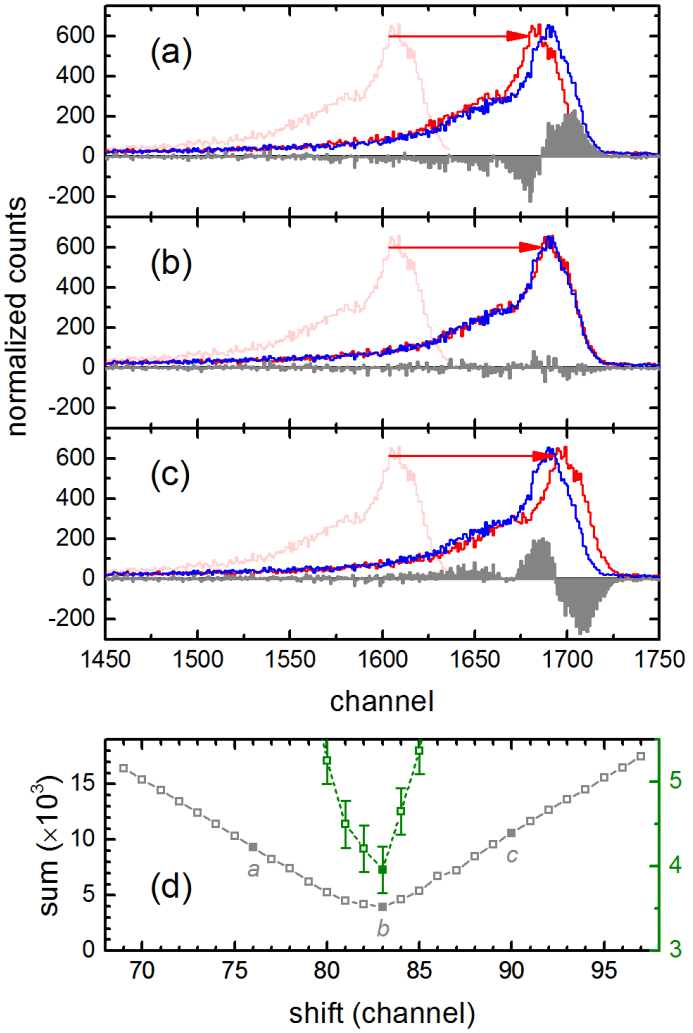
$$\chi = \frac{(d/t)\, N_A (m - q m_e)}{qe\sqrt{1 - \frac{(d/t)^2}{c^2}}}$$

χ ion rigidity [Tm]

d	flight path length [m]
t	TOF [s]
N_A	Avogadro constant [mol^{-1}]
m	beam particle atomic mass [u]
q	beam particle charge state
m_e	electron mass [u]
e	proton charge [C]
c	speed of light [m/s]

Peak shift determination





Isotope	Energy from Cyclotron [MeV/u]	Charge state From Cyclotron	Maximum Rigidity [Tm]	Charge States From Target Used
^{82}Se	140	32+	4.52	34+
^{124}Sn	120	45+	4.48	50+
^{96}Zr	120	37+	4.22	40+, 39+, 38+
^{48}Ca	140	20+	4.24	20+

Protocol

Step	Time Needed
Beam setup at new rigidity	1 hr
Timing measurement at C with 1st BaF_2 detector	5 min
(Repeated for alternate beam charge state)	(5 min)
Beam timing check at FP	5 min
Timing measurement at B with 2nd BaF_2 detector	5 min
(Repeated for alternate beam charge state)	(5 min)
Beam timing check at FP while swapping BaF_2 detectors	20 min
Timing measurement at C with 2nd BaF_2 detector	5 min
(Repeated for alternate beam charge state)	(5 min)
Beam timing check at FP	5 min
Timing measurement at B with 1st BaF_2 detector	5 min
(Repeated for alternate beam charge state)	(5 min)
Total:	**~2 hrs**

HOW? TOF: particle-by-particle

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Using 2 detectors to measure particle by particle

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Using 2 detectors to measure particle by particle

Challenges

HOW? TOF: particle-by-particle

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- Upstream detector disturbs the measurement

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Using 2 detectors to measure particle by particle

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- Upstream detector disturbs the measurement
- Controlling time response differences between detectors

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