SuperCREX at Jefferson Lab

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Office of Nuclear Physics
Exploring Nuclear Matter - Quarks to Stars

JSA

Thomas Jefferson National Accelerator Facility

Office of Science
U.S. DEPARTMENT OF ENERGY

Extending C-REX to other kinematic points

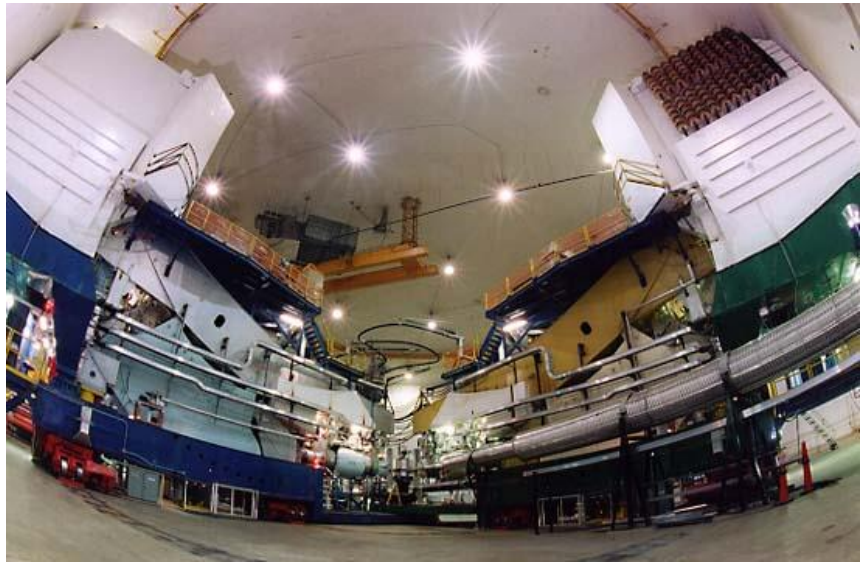
- Using the HRS in Hall A
- Using a large-acceptance device

For inputs, I thank

Roger Carlini, Charles Horowitz, Krishna Kumar, Zidu Lin, Nicholas Saylor, Paul Souder , Bogdan Wojtsekhowski

Part I -- Considering the HRS in Hall A

The high-resolution spectrometers are well suited to suppress background and discriminate inelastic states.



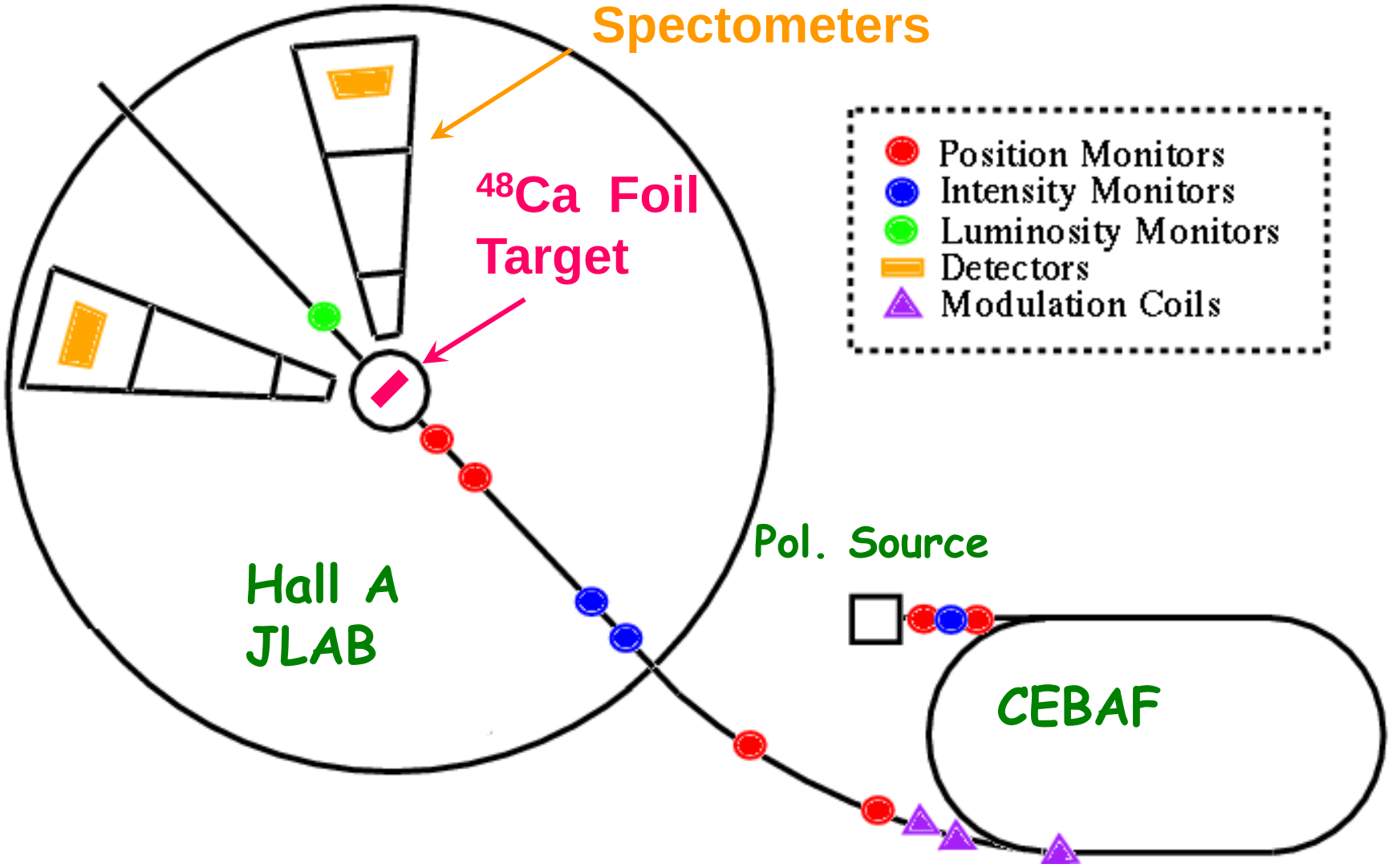
- Septum Magnet

- "Trombone" target, variable Z position to reach

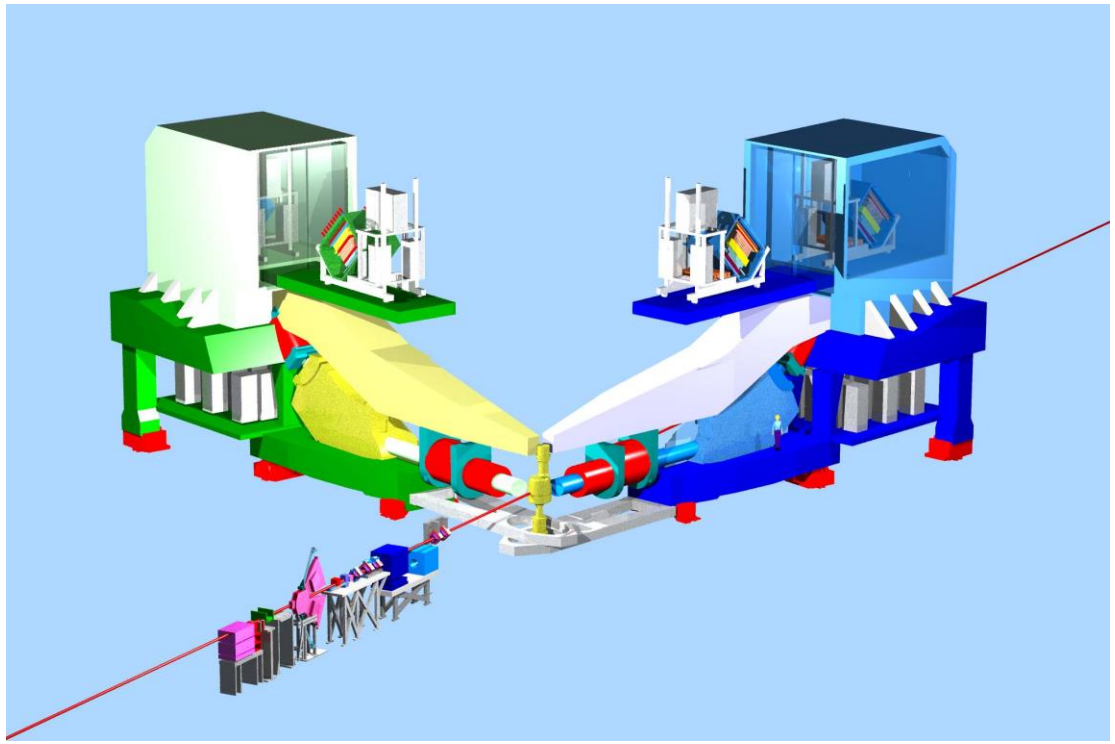
$$4^0 < \theta < 7^0$$

C-REX Setup

"The entire lab is the experiment"



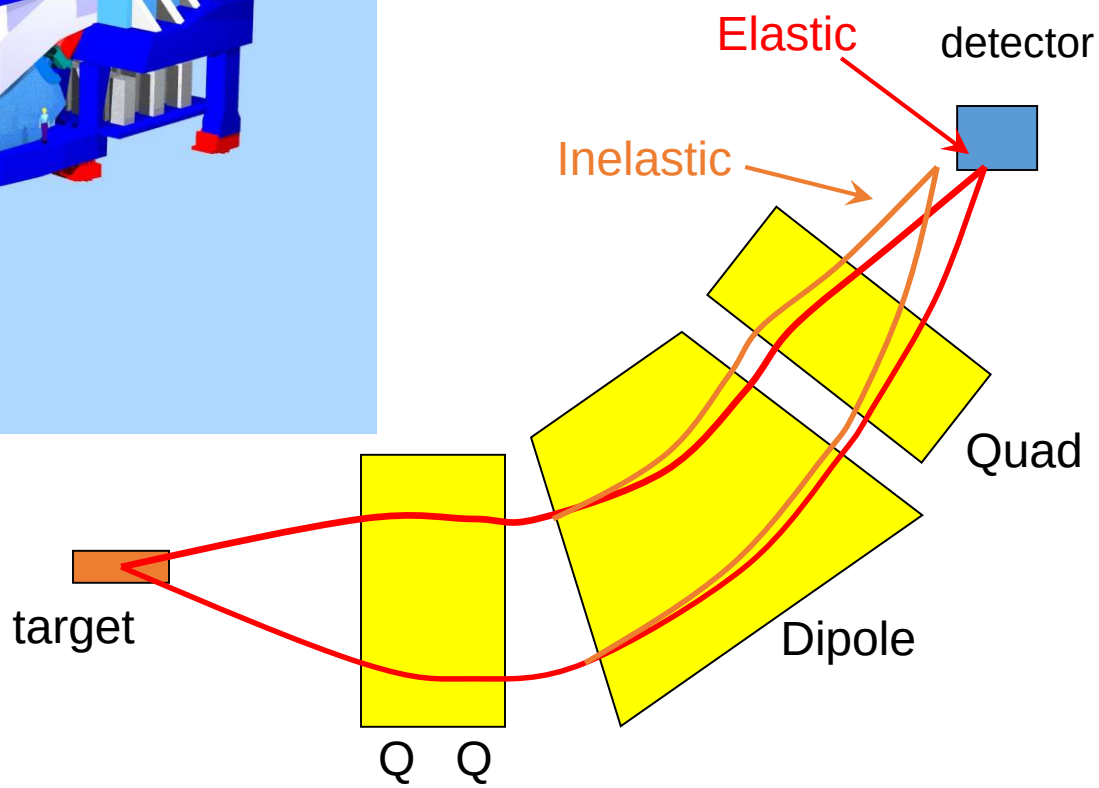
High Resolution Spectrometers -- HRS



Left-Right symmetry to control transverse polarization systematic

Spectrometer Concept: Resolve Elastic

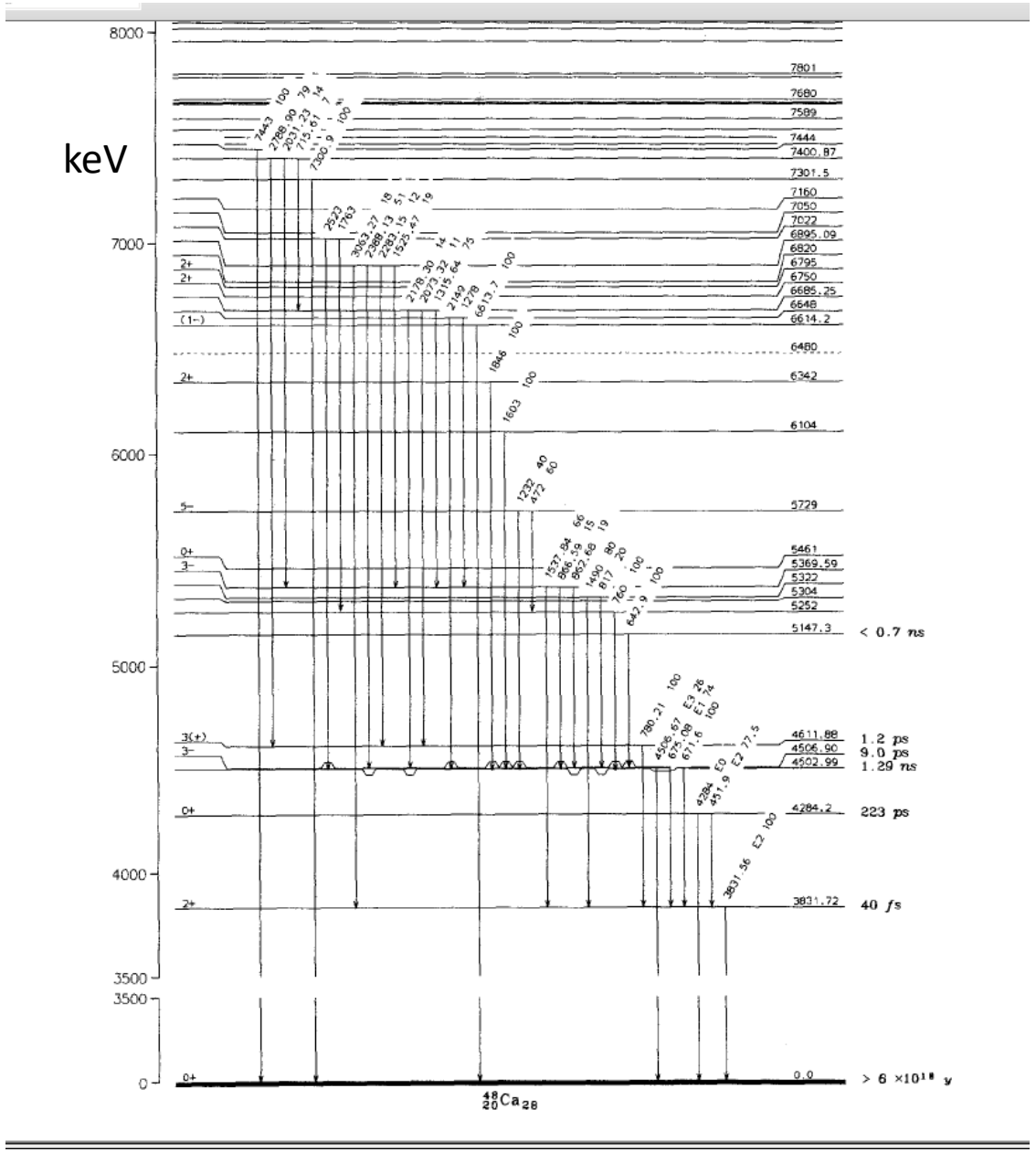
1st excited state ^{48}Ca 3.8 MeV



Nuclear Levels

^{48}Ca

E (MeV)	J ^{P}
Gnd	0^+
3.83	2^+
4.28	0^+
4.51	
4.61	



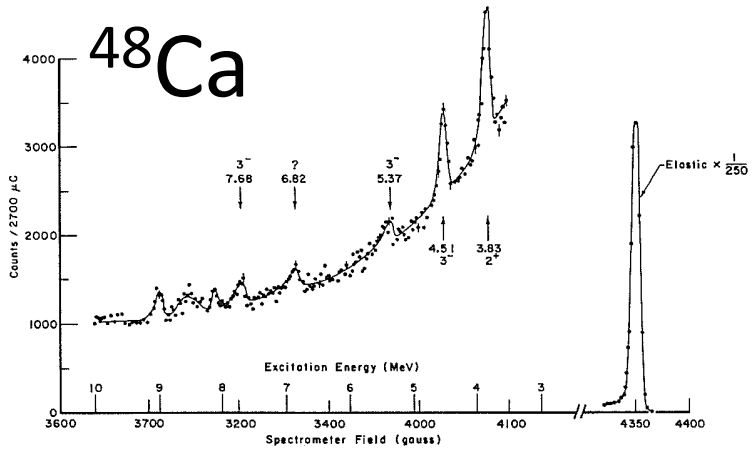


FIG. 7. Spectrum of electrons scattered from Ca^{48}. The incident energy is 60.1 MeV and $\theta = 130°$. The spectrum has been corrected for background.

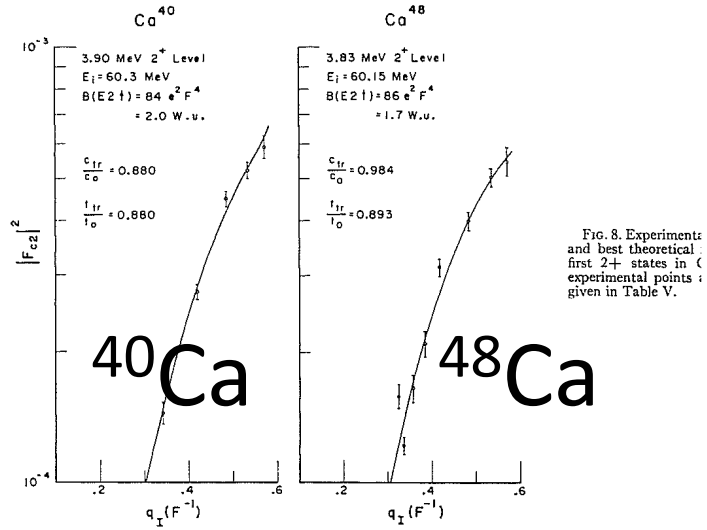


FIG. 8. Experimenta and best theoretical first 2+ states in (experimental points a given in Table V.

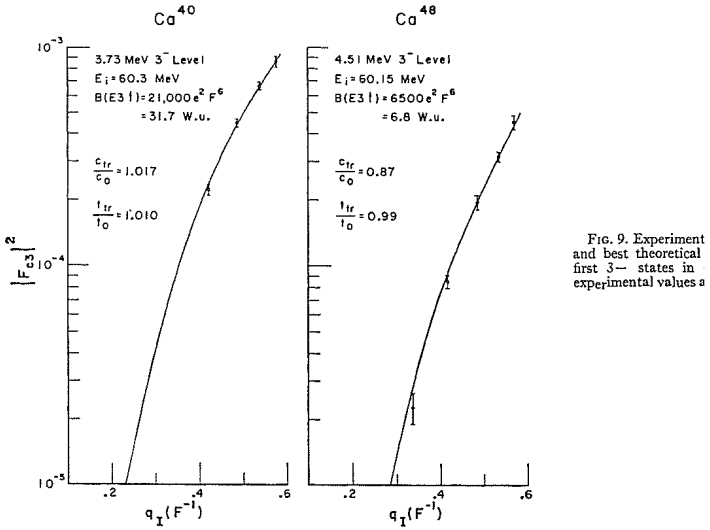


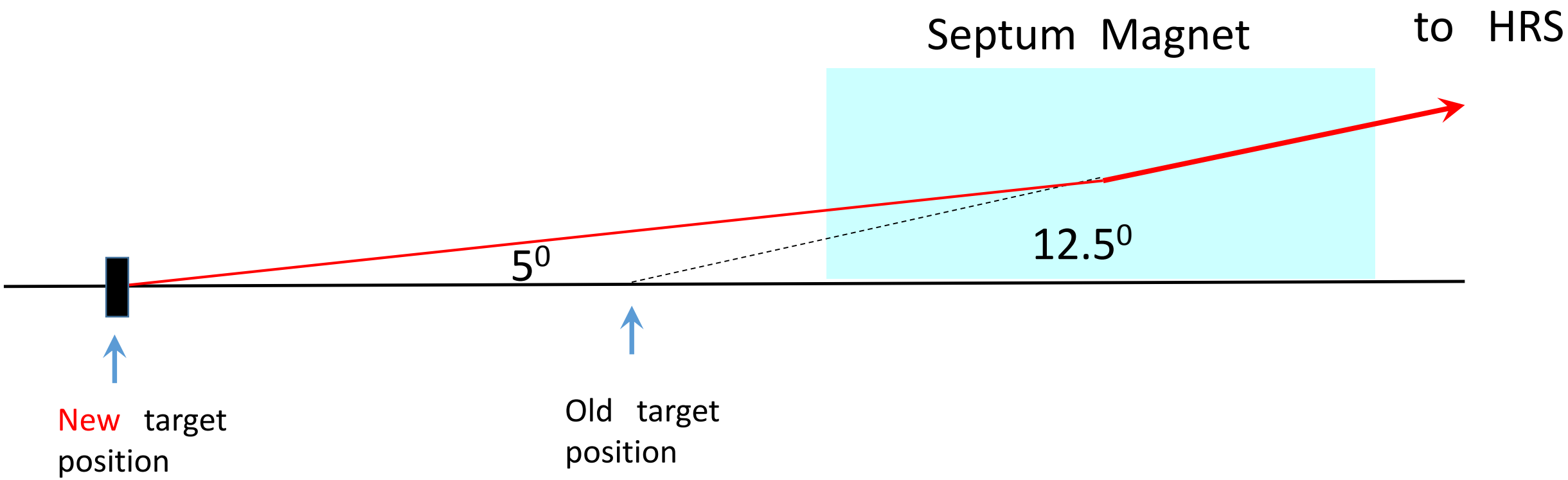
FIG. 9. Experiment and best theoretical first 3− states in experimental values a

Electron scattering data and **form factors** for low-lying states of ^{48}Ca

Concept of a Septum Magnet

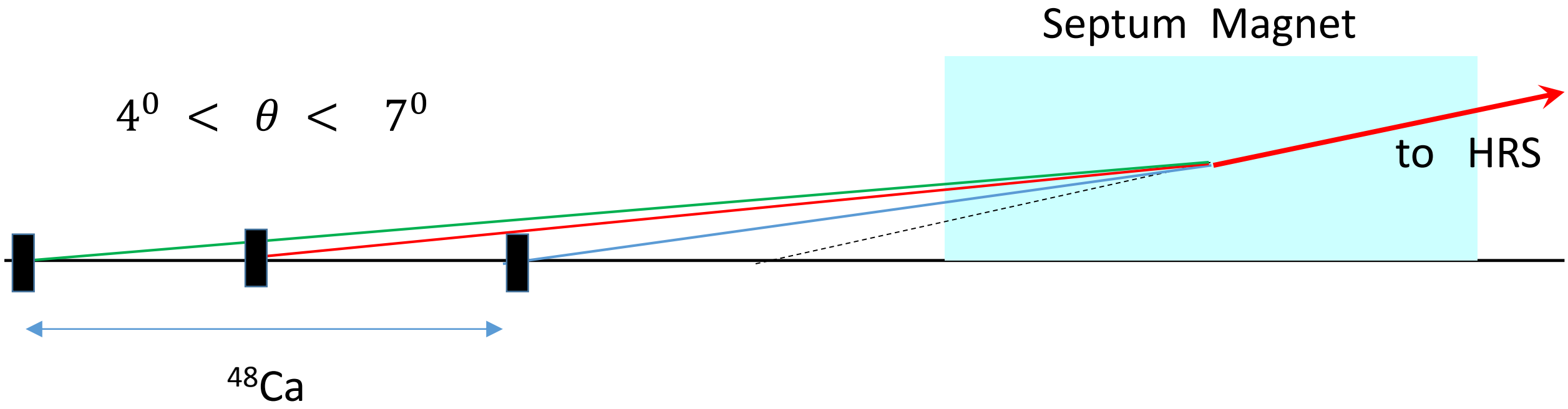
The HRS is limited to $> 12.5^0$

To reach smaller scattering angle, which improves the FOM, we add a **septum magnet** (dipole) and move the target upstream by ~1.5m.



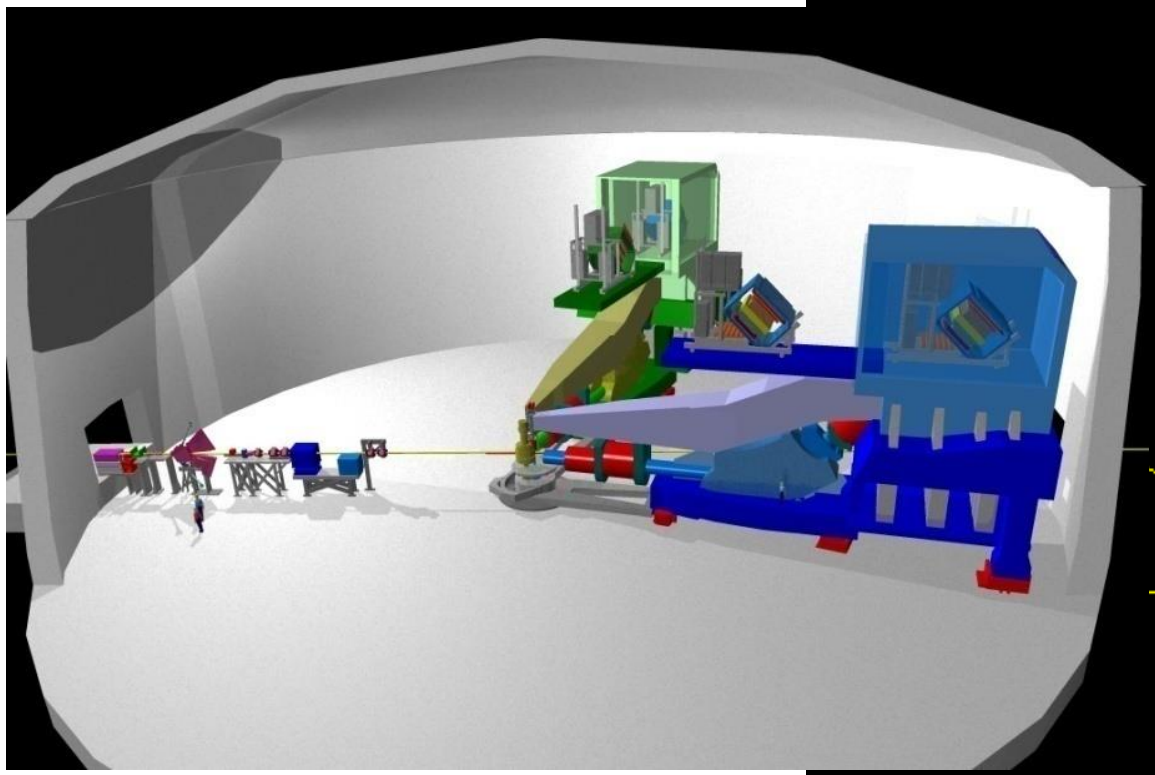
Trombone target for SuperCREX

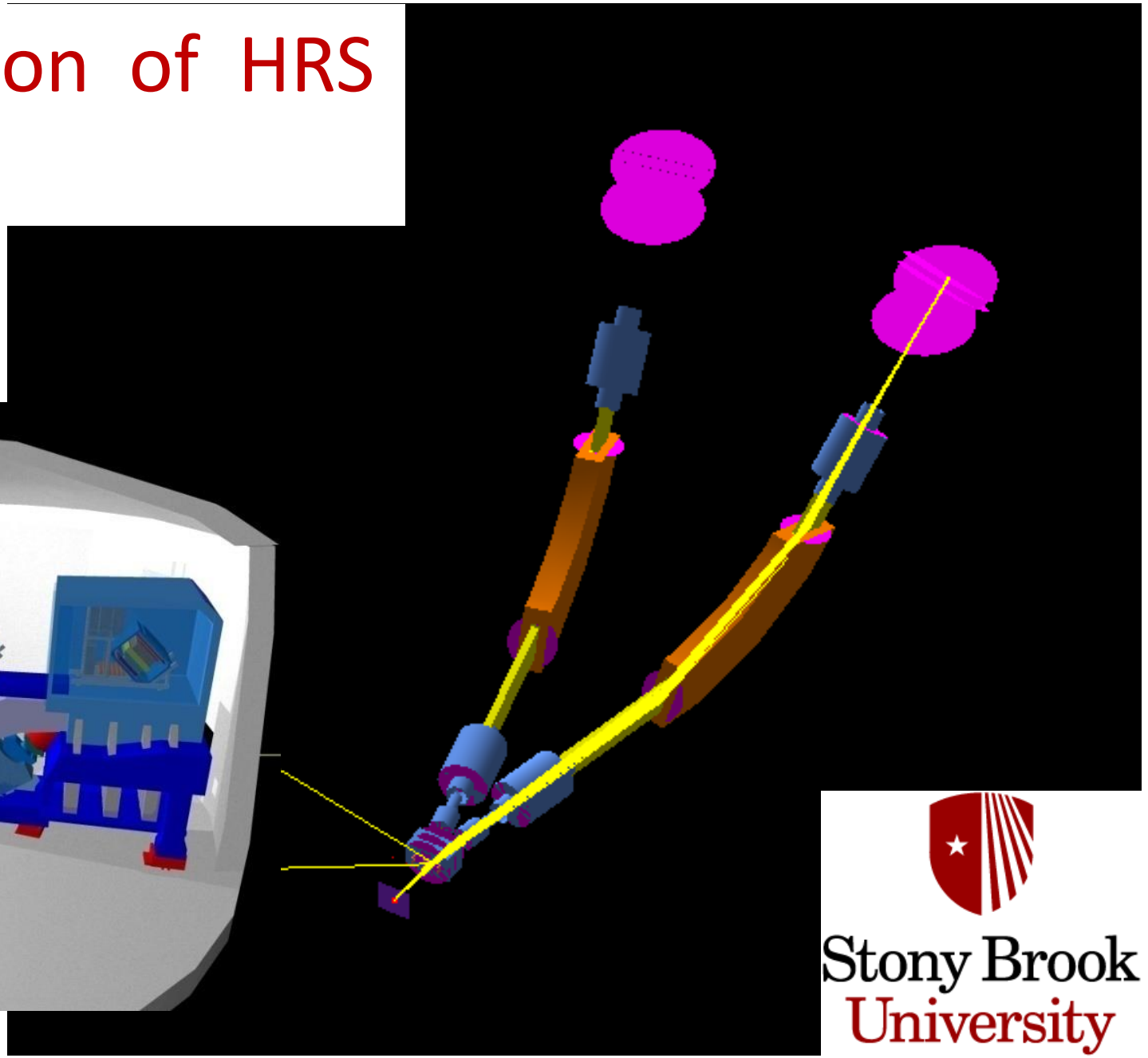
Put ^{48}Ca target on a rail in a vacuum chamber.



Geant4 Simulation of HRS
G4HRS

Nicholas Saylor
Stonybrook University

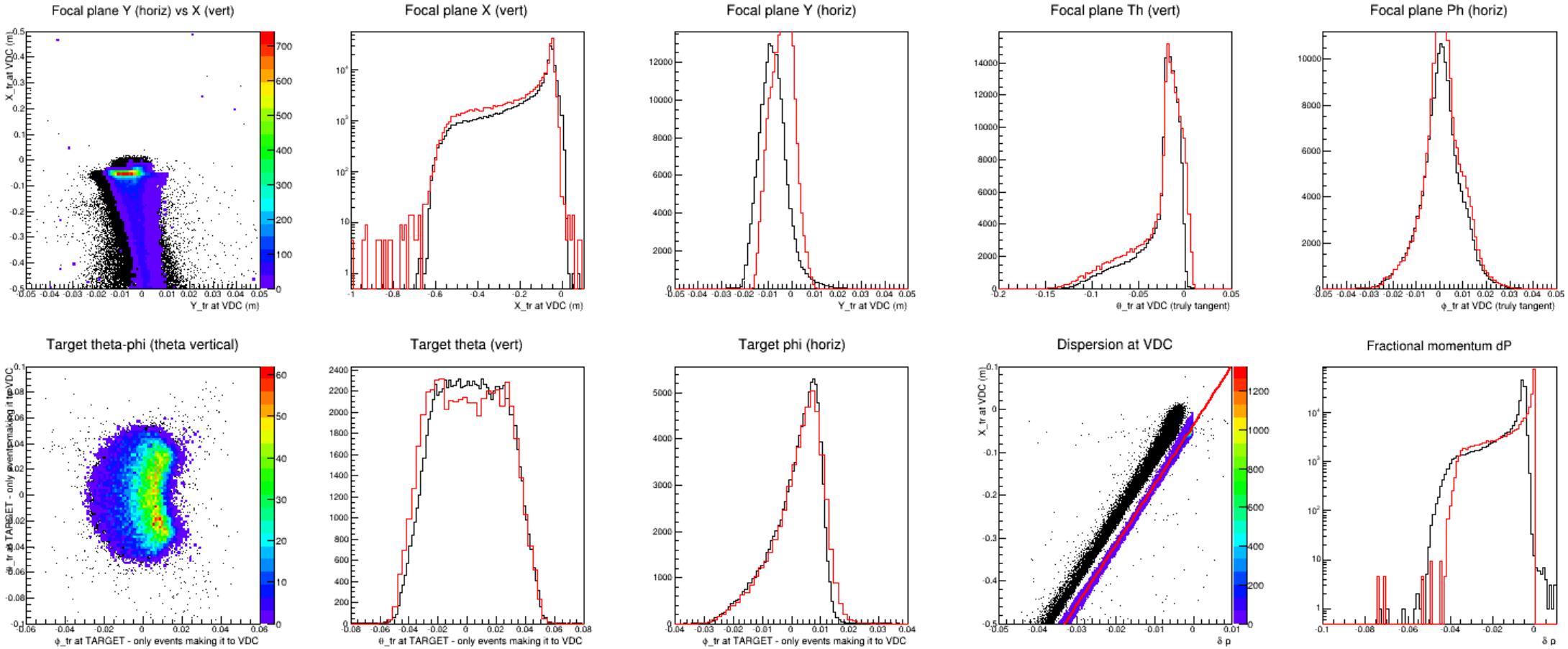




Stony Brook University

Certification of G4HRS Monte Carlo

Comparing PREX data (black) to Simulation (red) for various observed quantities.

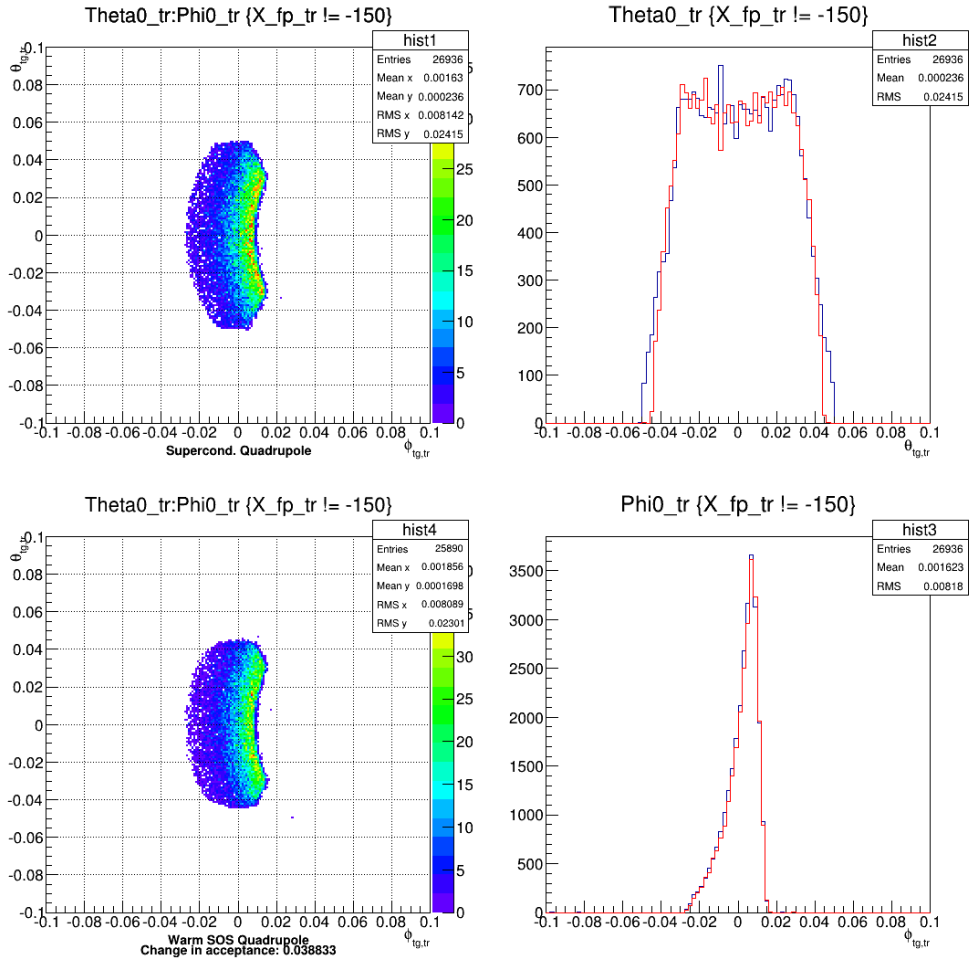


Nicholas Saylor

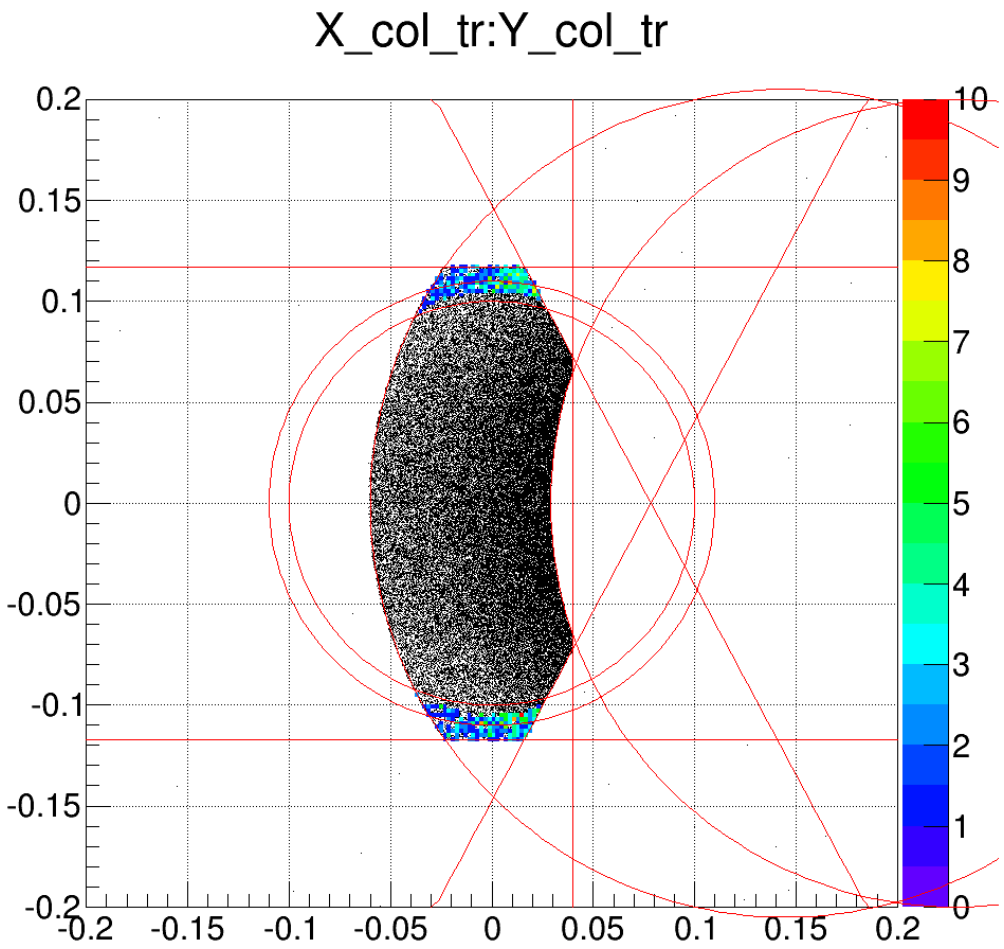
Stony Brook University

Applications of G4HRS Monte Carlo

Acceptance study for new Q1



Design of acceptance-defining collimator



Other apps: Tolerance to E_{beam}, design of detector, **FOM for superCREX**

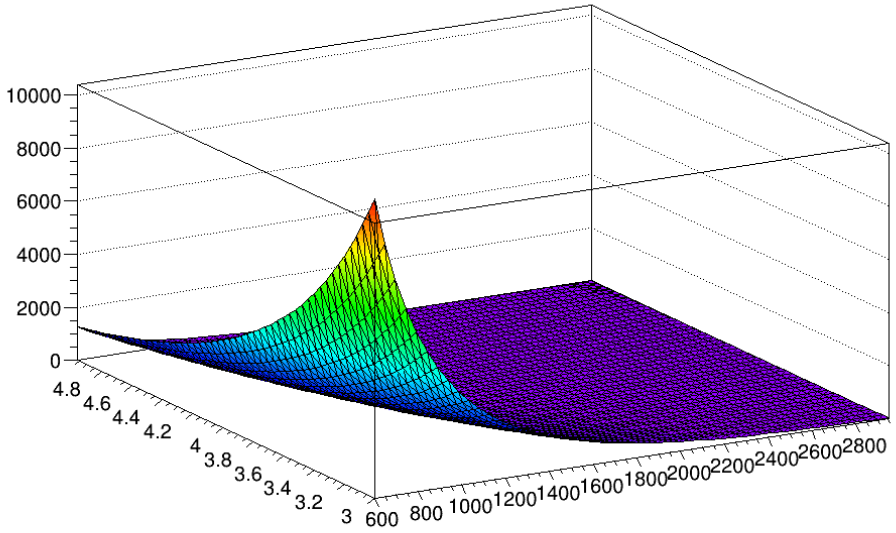
Nicholas Saylor

Stony Brook University

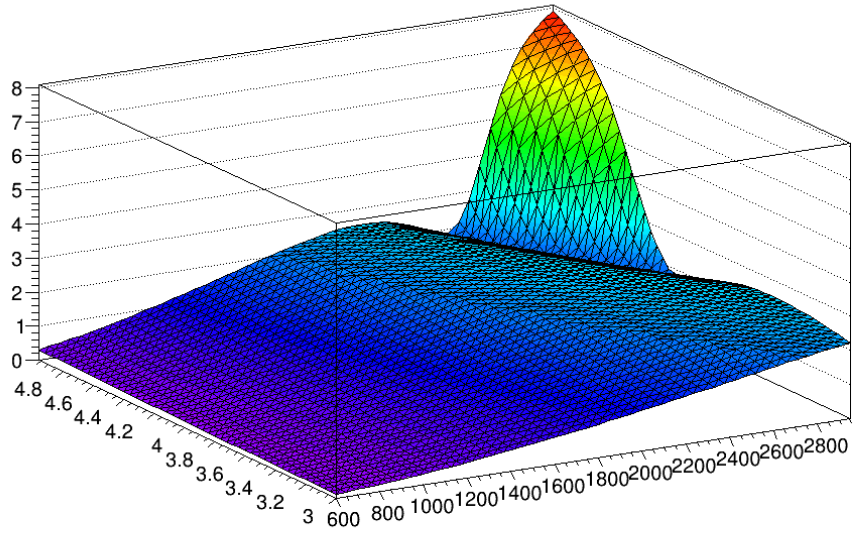
Inputs for optimizing figure-of-merit

Thanks C.J. Horowitz and Z. Lin
… but we'll need to extend the tables

Cross Section (E (MeV), θ (degrees)) in mb/sr



Asymmetry (E (MeV), θ (degrees)) in ppm



ε (E (MeV), θ (degrees)) : (error in neutron radius)

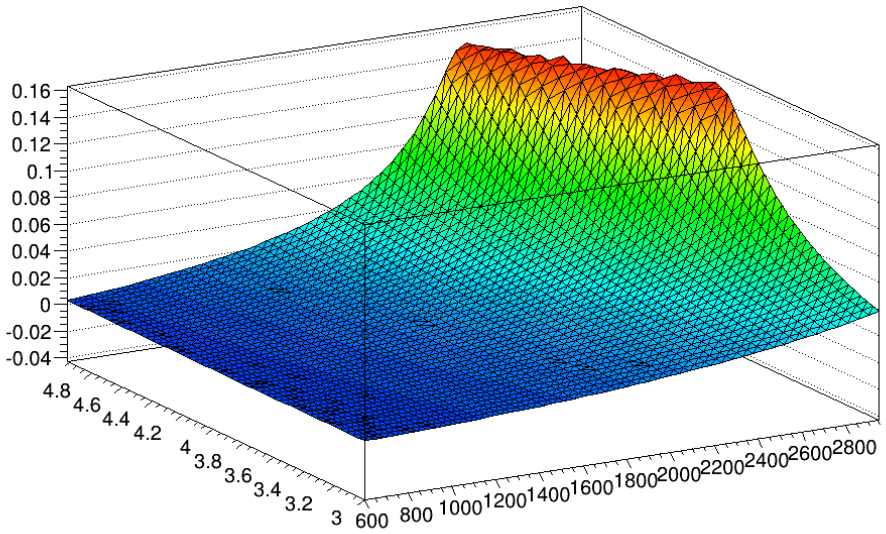
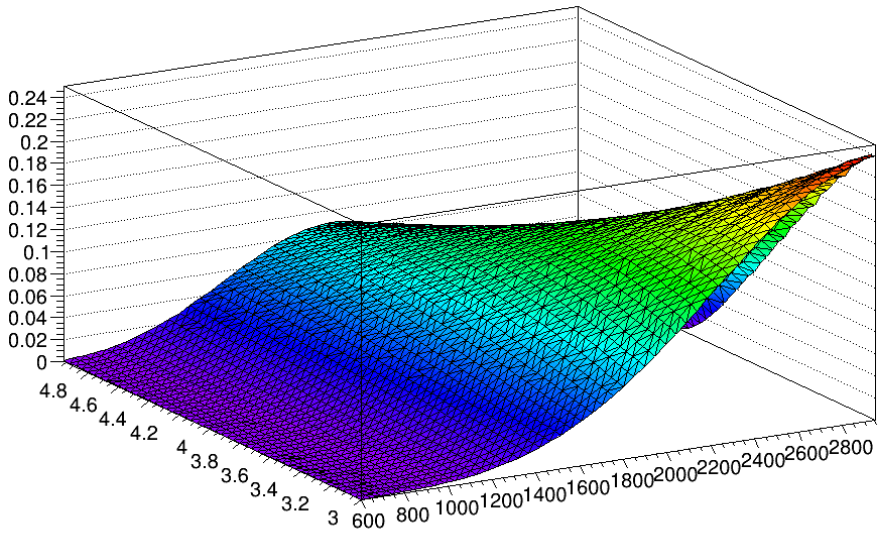
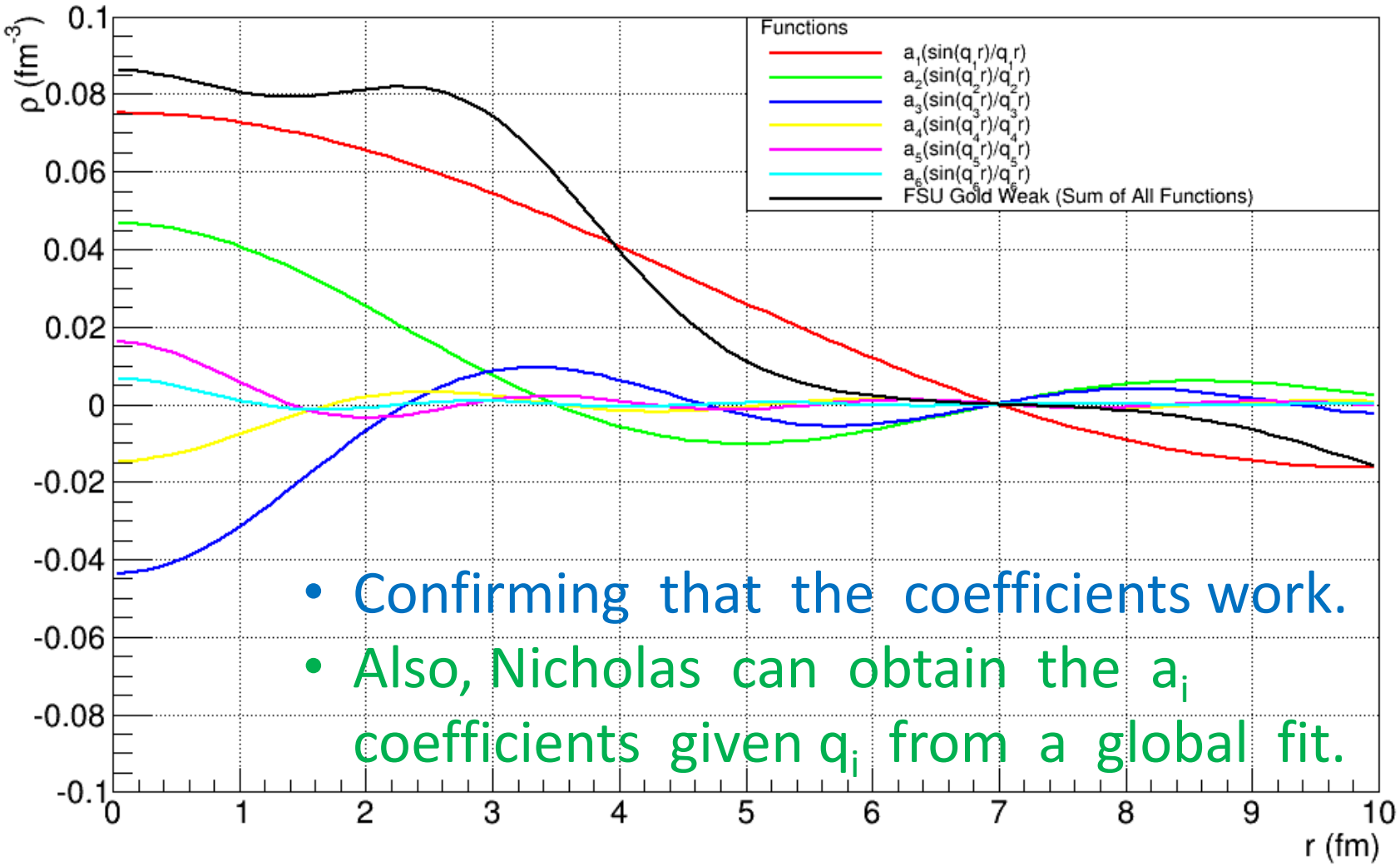


Figure of Merit (E (MeV), θ (degrees)) = XS * A^2 * ε^2



FSU-Gold* Weak Density



- Confirming that the coefficients work.
- Also, Nicholas can obtain the a_i coefficients given q_i from a global fit.

$$\rho_W(r) = \sum a_i \; j_0(q_i r)$$

$$q_i = i\pi / R_{max}$$

$$R_{max} = 7 \; fm$$

Following

Z. Lin and C.J. Horowitz
Phys. Rev. C92 014313 (2015)

* B.G.Todd-Rutel and J. Piekarewicz, Phys. Rev. Lett. 95, 122501 (2005).

Nicholas Saylor

Stony Brook University

^{48}Ca
Suggested Kinematics in Z. Lin and C.J. Horowitz Phys. Rev. C92 014313 (2015)

E (GeV)	θ	q fm^{-1}	A (ppm)	T (days)	a_i	$\Delta a_i/a_i$
2.06	5	0.90	2.54	5	0.0468	5.9 %
3.09	5	1.35	8.31	7	-0.0438	7.6 %
4.0	5	1.80	9.92	10	-0.0147	27 %
4.0	6.3	2.24	22.5	15	0.0161	29 %
4.0	7.6	2.69	36.5	23	0.0066	90 %
		0.45			0.0752	1.1 %

Results confirmed by Nicholas Saylor and R.M.

^{48}Ca
Nicholas's Kinematics

uses already-approved CREX-1 kinematics as one point.

E (GeV)	θ	q fm^{-1}	A (ppm)	T (days)	a_i	$\Delta a_i / a_i$
1.1	4	0.39	0.67	5 ?	0.0551	1.3 %
2.2 CREX-1	4 approved.	0.78	2.22	45	0.0646	0.77 %
2.2	6	1.17	4.82	7 ?	-0.0194	17 %
3.9	4.5	1.56		10 ?	-0.0328	
4.0	5.5	1.95		15 ?	-0.0018	
4.0	6.5	2.34		23 ?	0.0200	

Work in progress ...

Question: What criteria do we use to optimize the experiment run time ?

Part II -- Considering a Future Large Solid Angle Spectrometer

SuperBigBite --- a large dipole

Custom Crescent-Shaped Dipole

Toroid

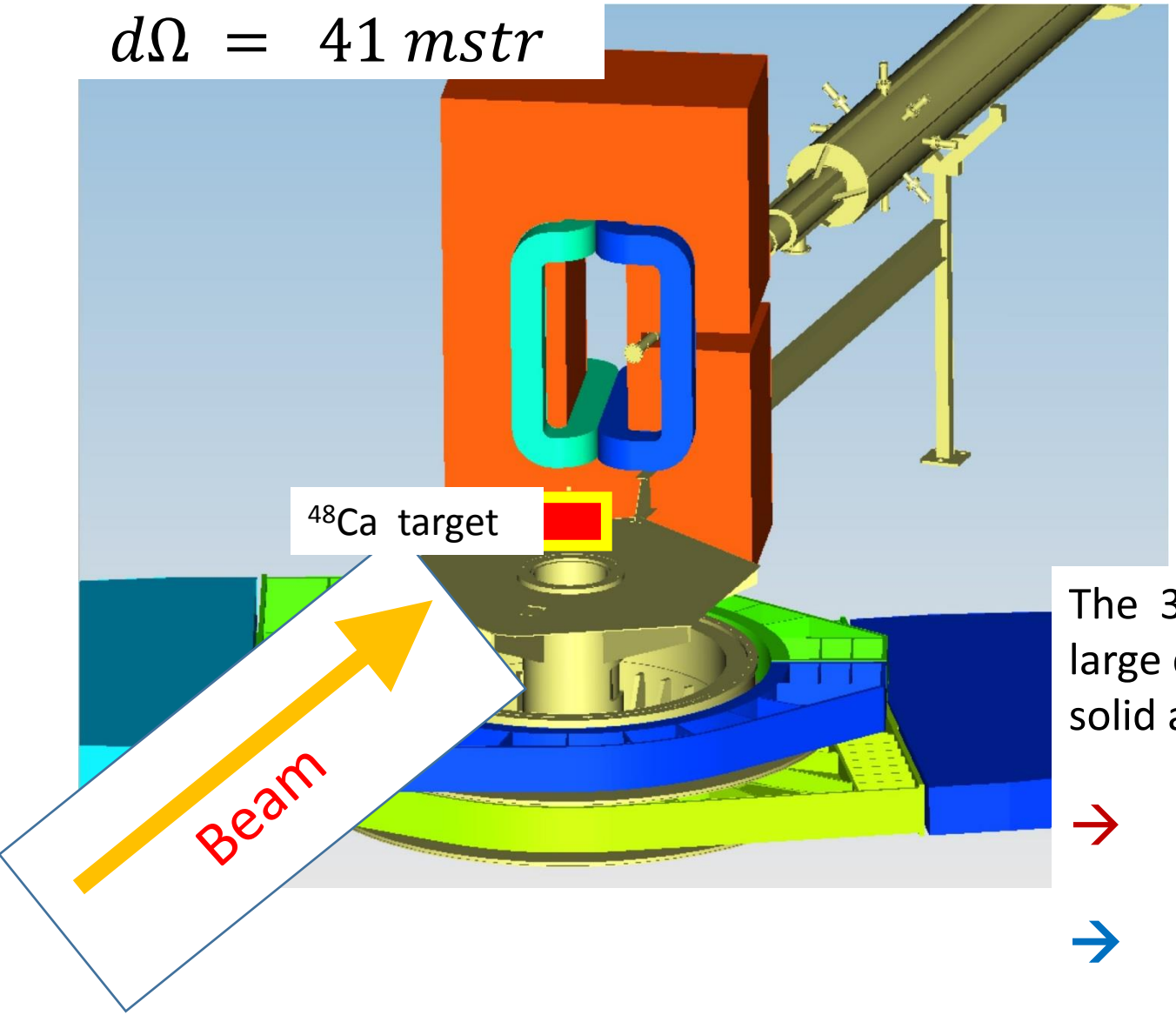
} Lacking in momentum resolution without sacrificing solid angle

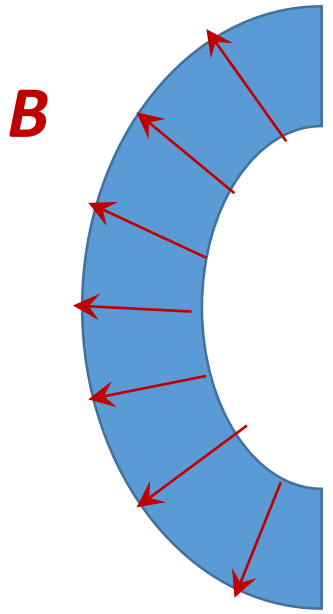
Solenoid → Promising, but so far limited to $q < 1.8$ fm^{-1}

With Bogdan Wojtsekhowski

Using the SuperBigBite Spectrometer or a Crescent Spectrometer

$d\Omega = 41\, mstr$

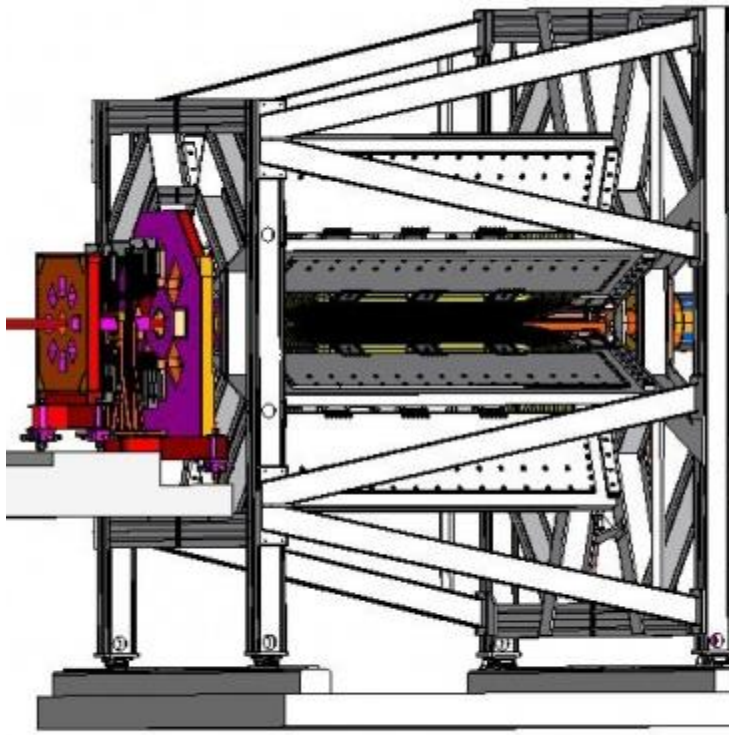




The 3 MeV resolution could be achieved over a large distance (radius of Hall A) but only for a reduced solid angle, and requiring a big vacuum chamber.

→ Not really feasible.

→ **HRS is better.**

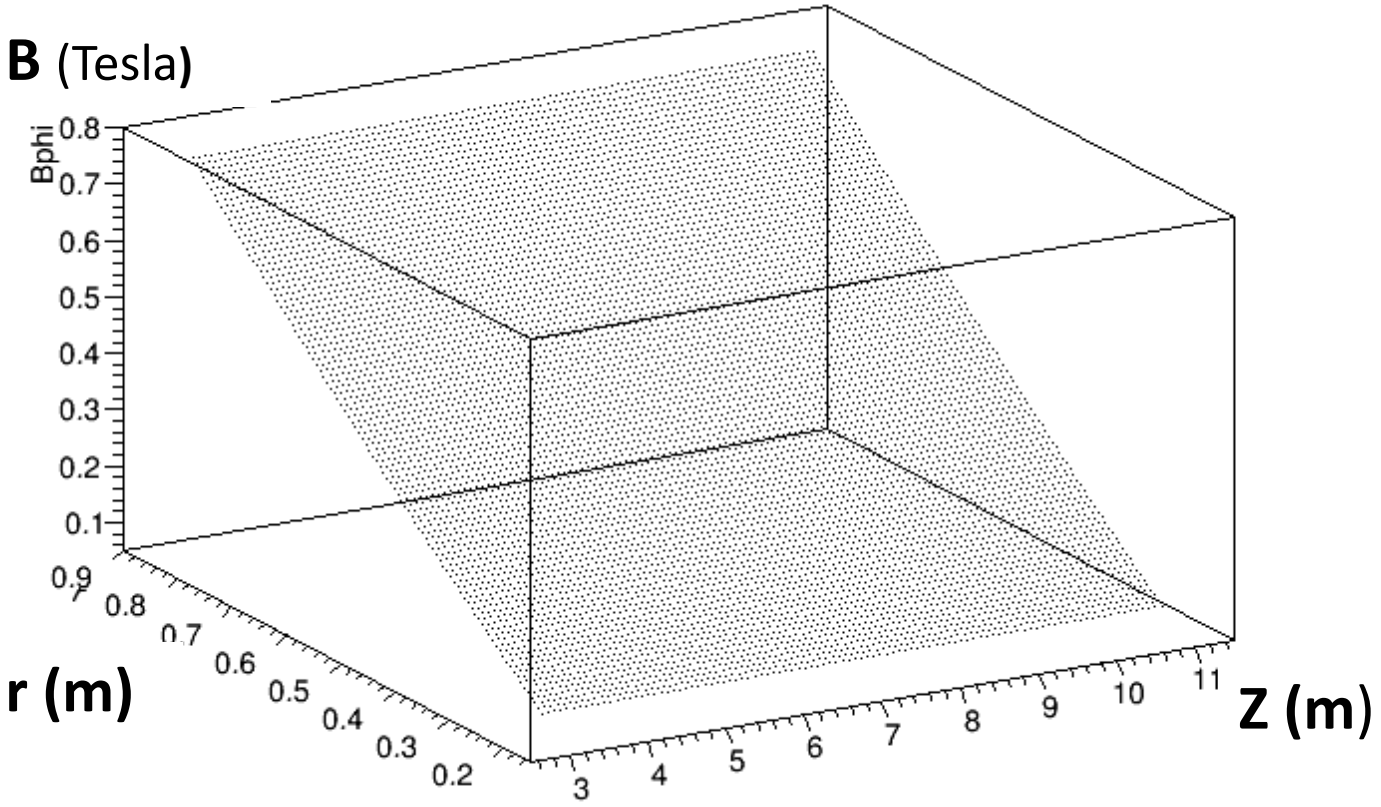


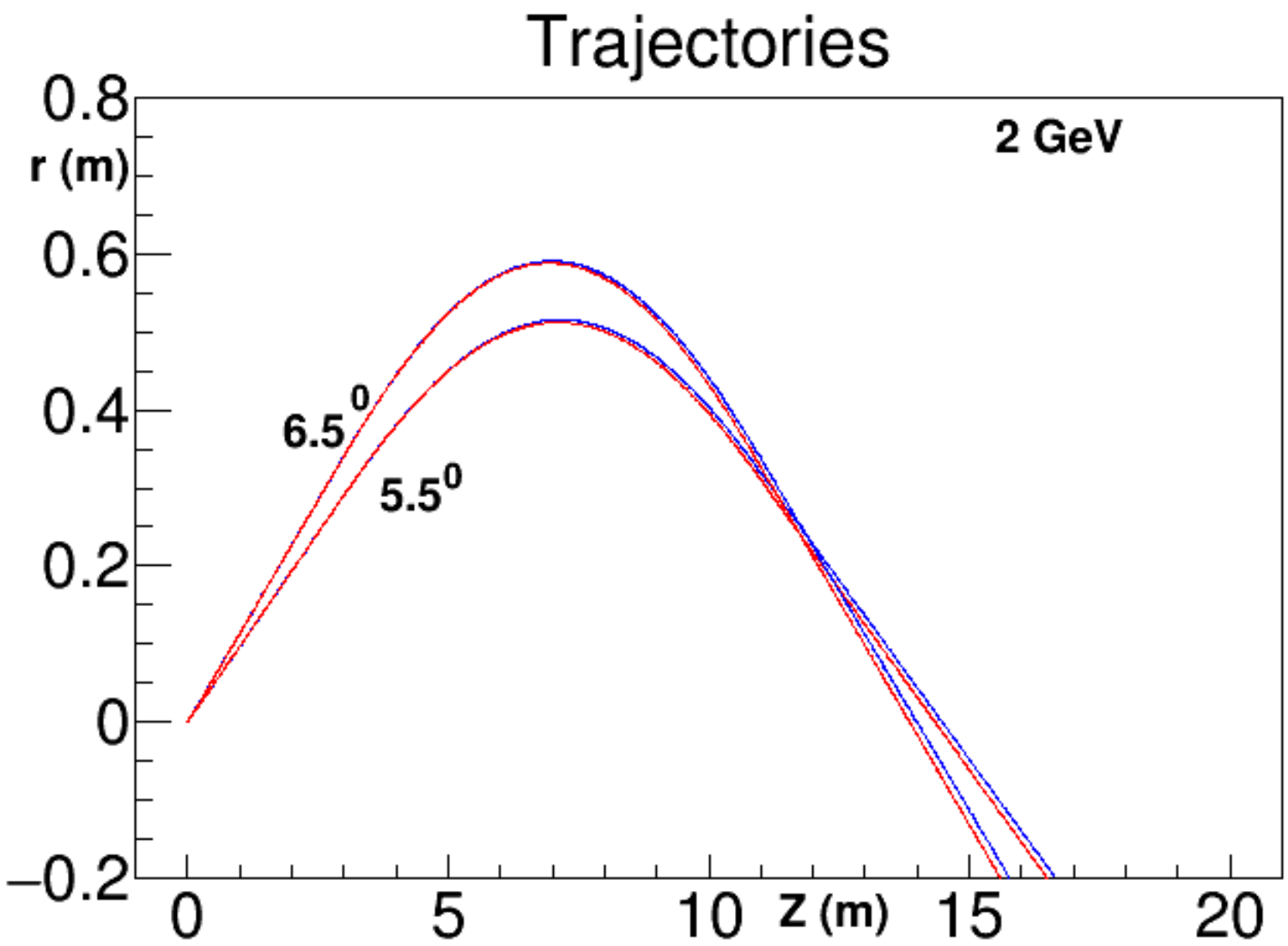
Similar to Qweak

try a

TOROID SPECTROMETER

B_φ **magnetic field in one Sector**



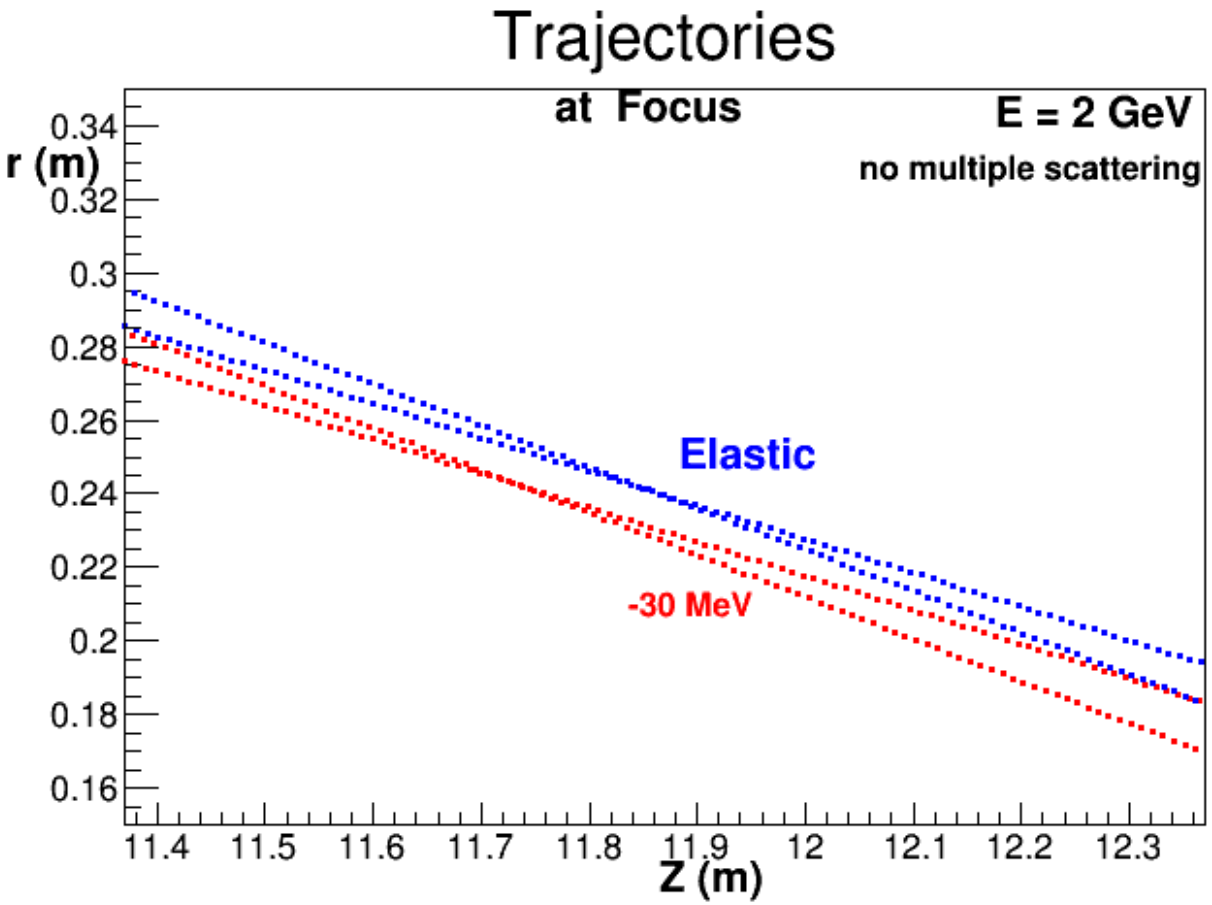


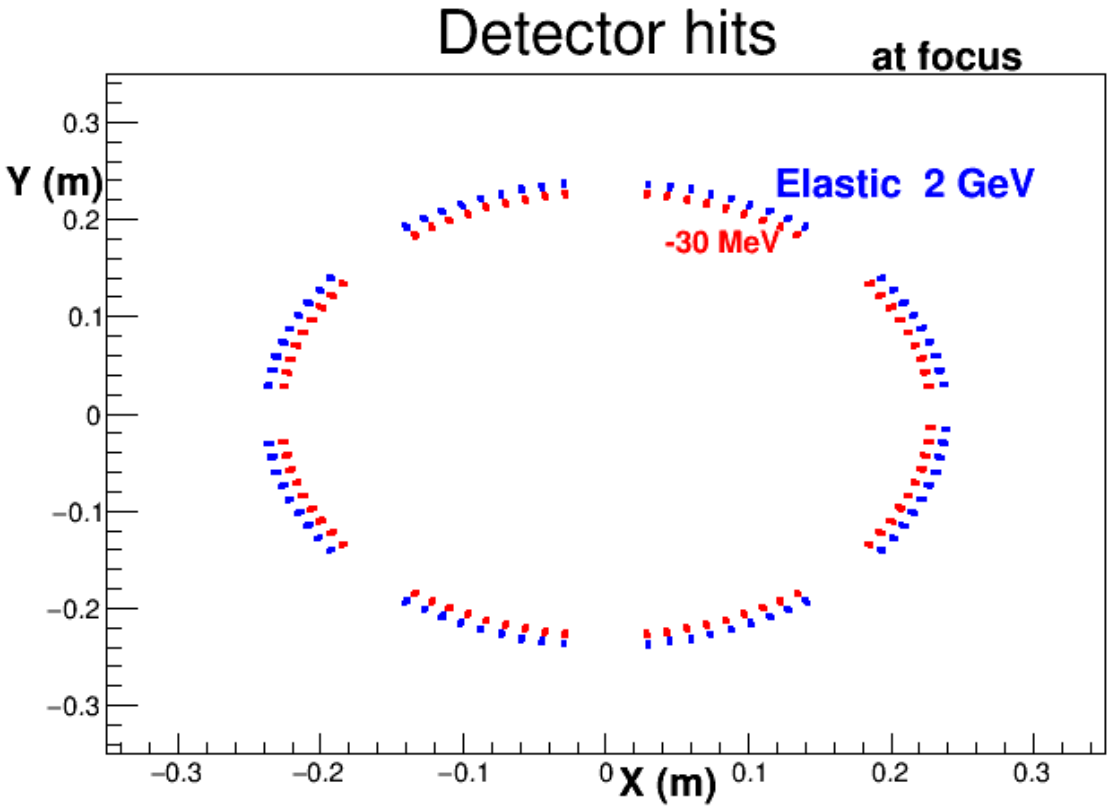
Elastic

-30 MeV

But 3 MeV is not well resolved

TOROID SPECTROMETER



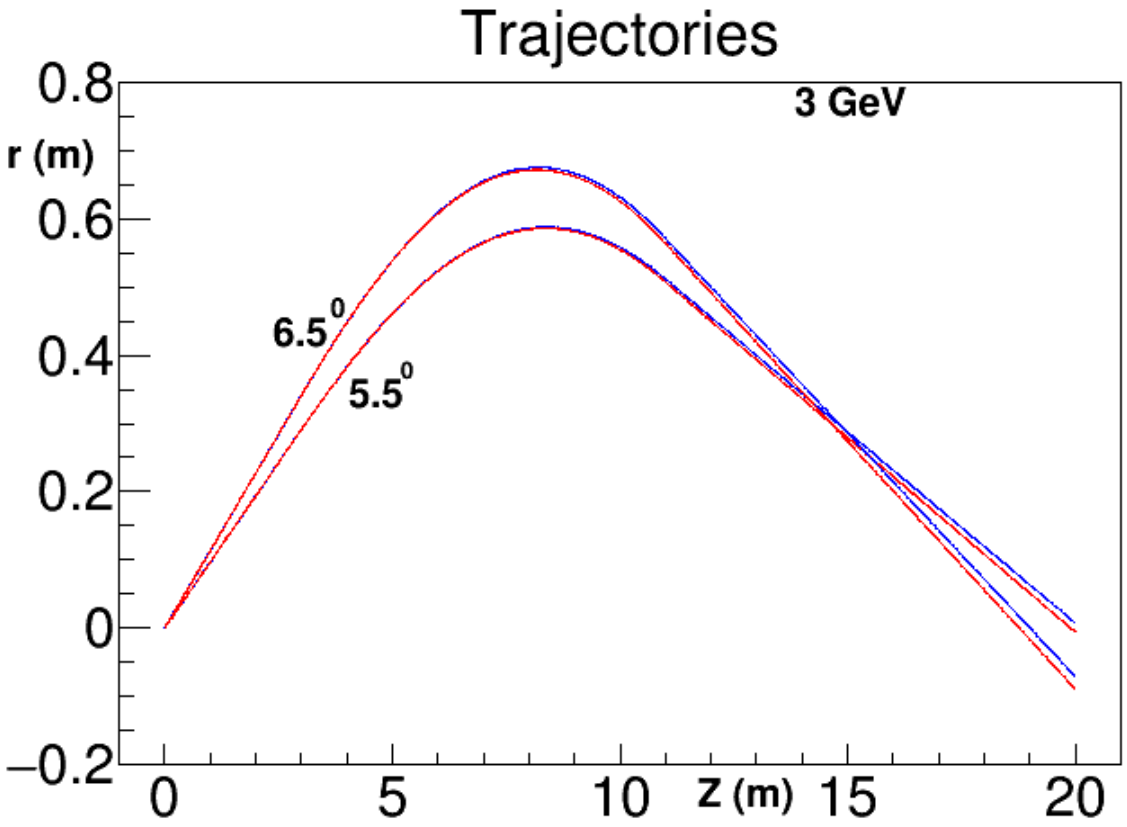


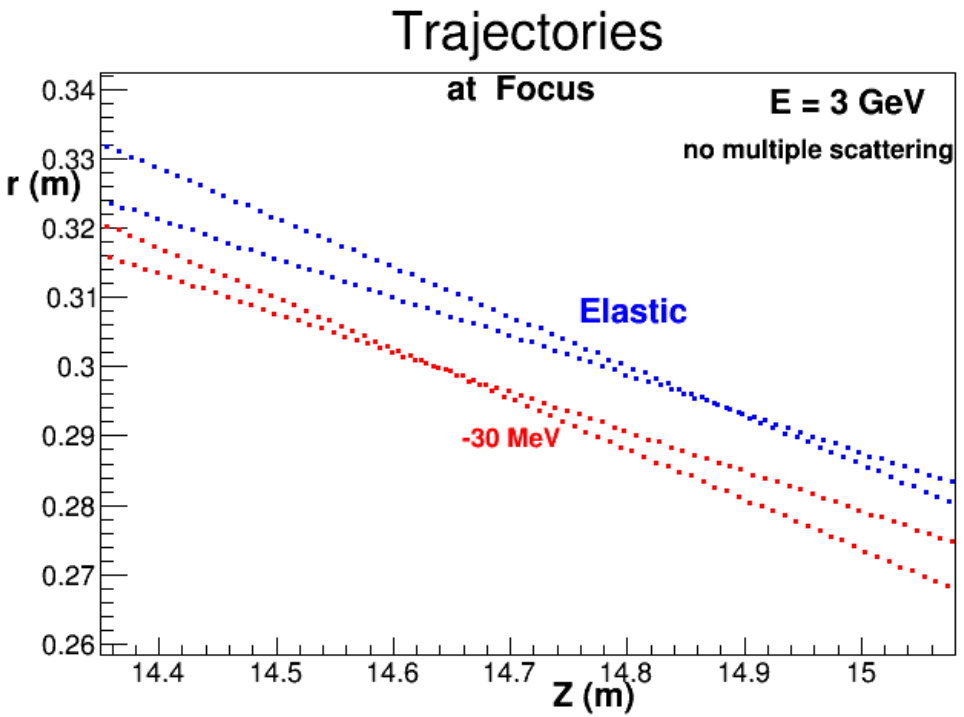
Conclusion: not enough resolution for 3 MeV separation.

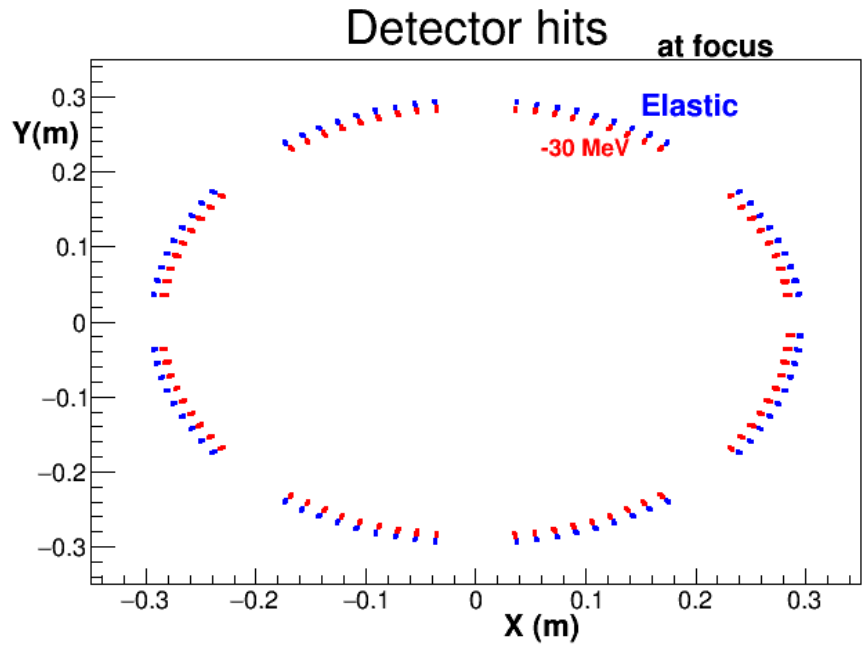
(Note, shown is 30 MeV)

TOROID SPECTROMETER

At 3 GeV

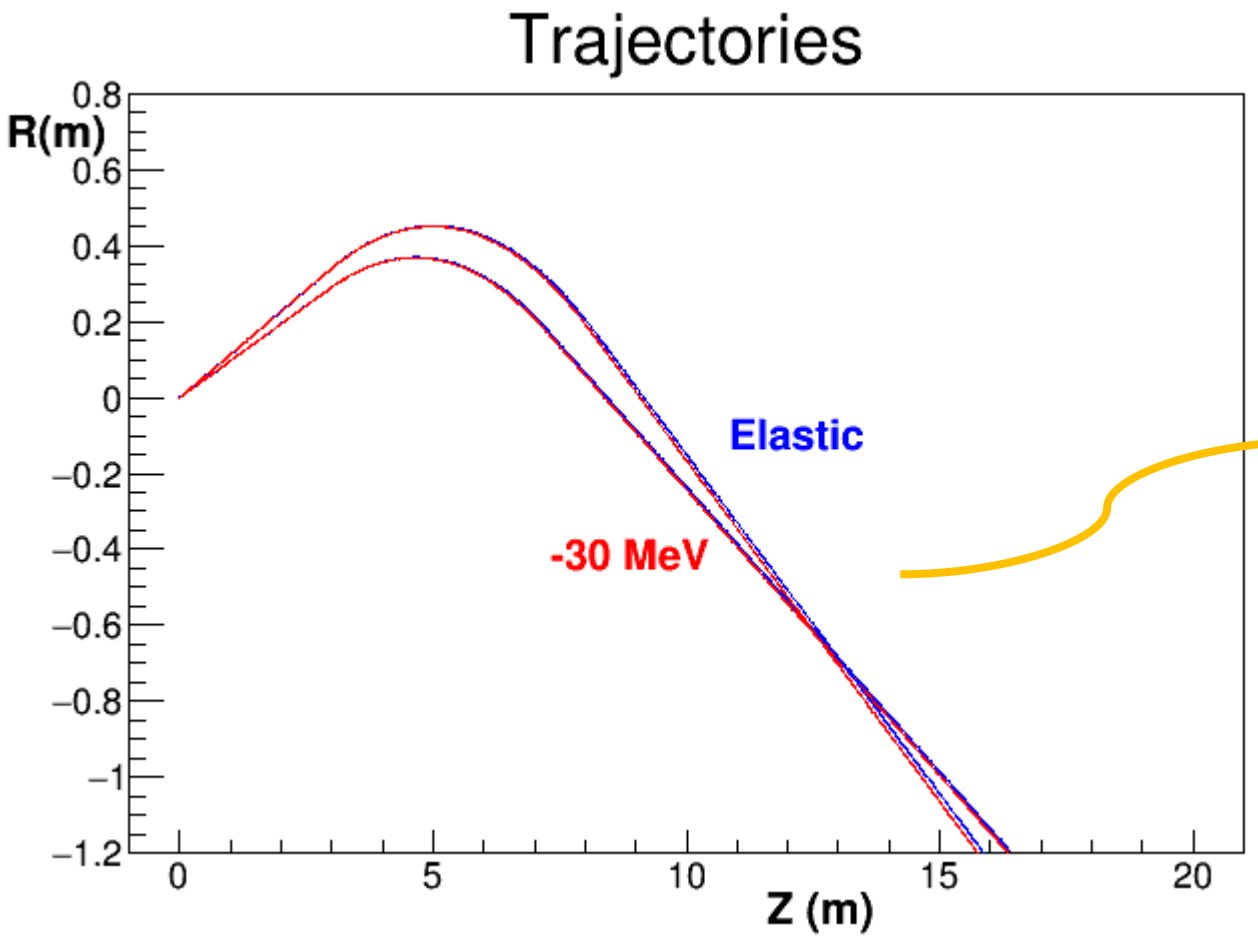




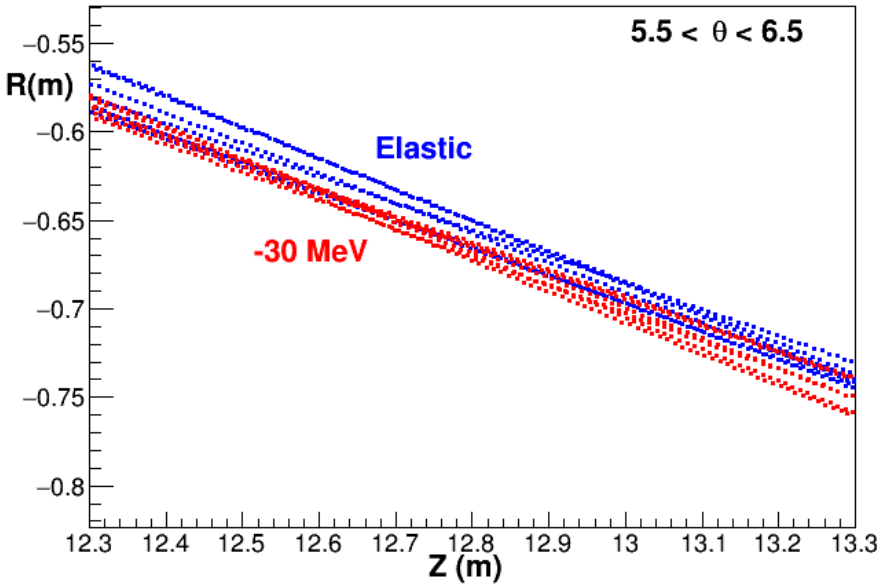


Focusing to other side of the beam. (2 GeV)

$$B = 0.8\left(1 - \frac{1}{2}r + \frac{3}{8}r^2\right) \text{ (Tesla)}$$

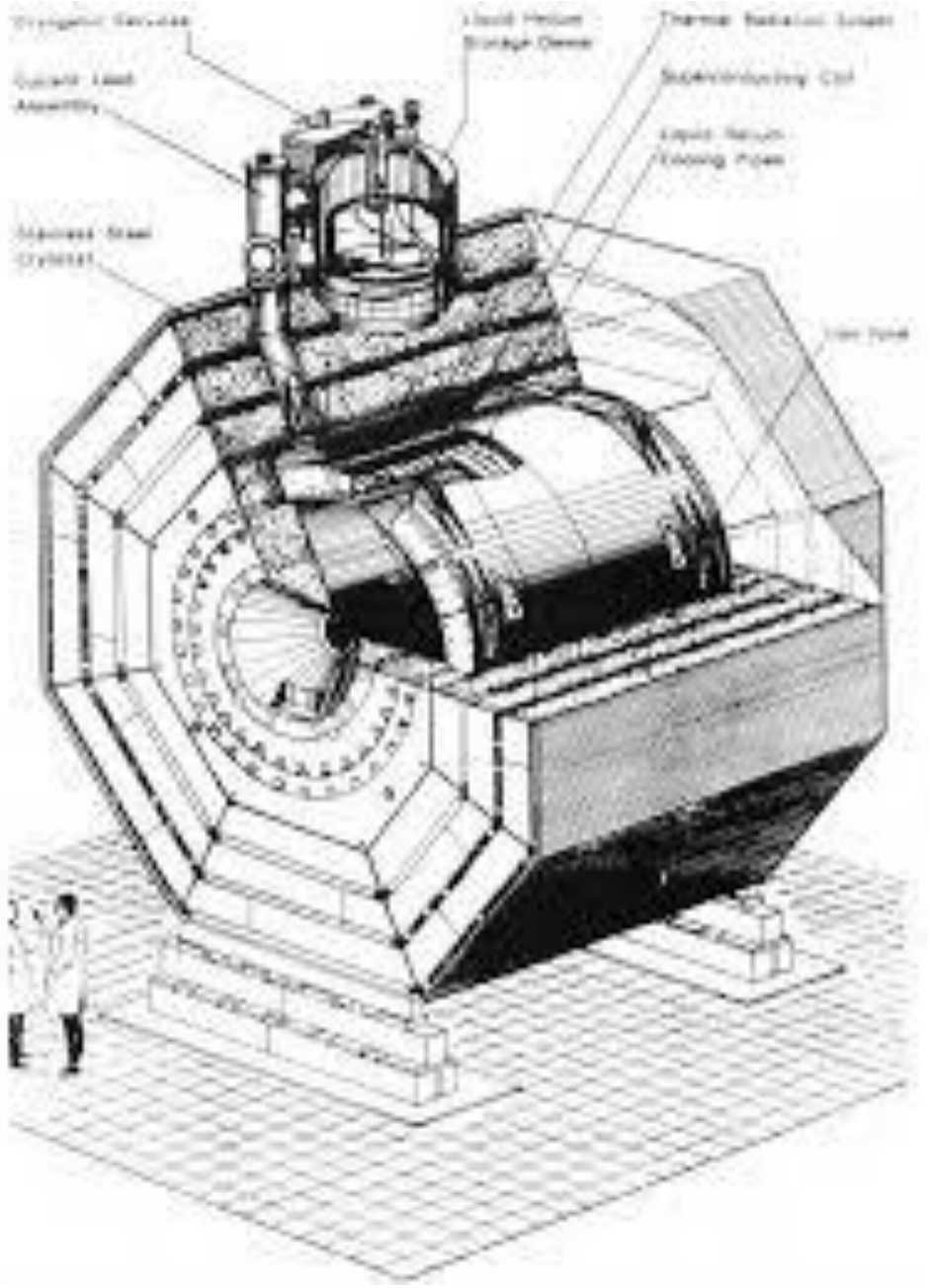


At focus



SOLENOID SPECTROMETER

The CLEO-II magnet is being moved to Hall A for the SOLID spectrometer. Here, we try using it for superCREX.

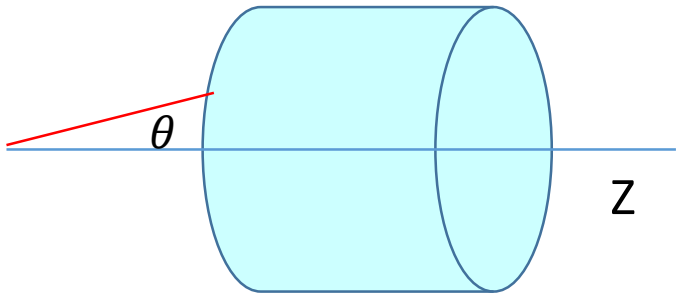


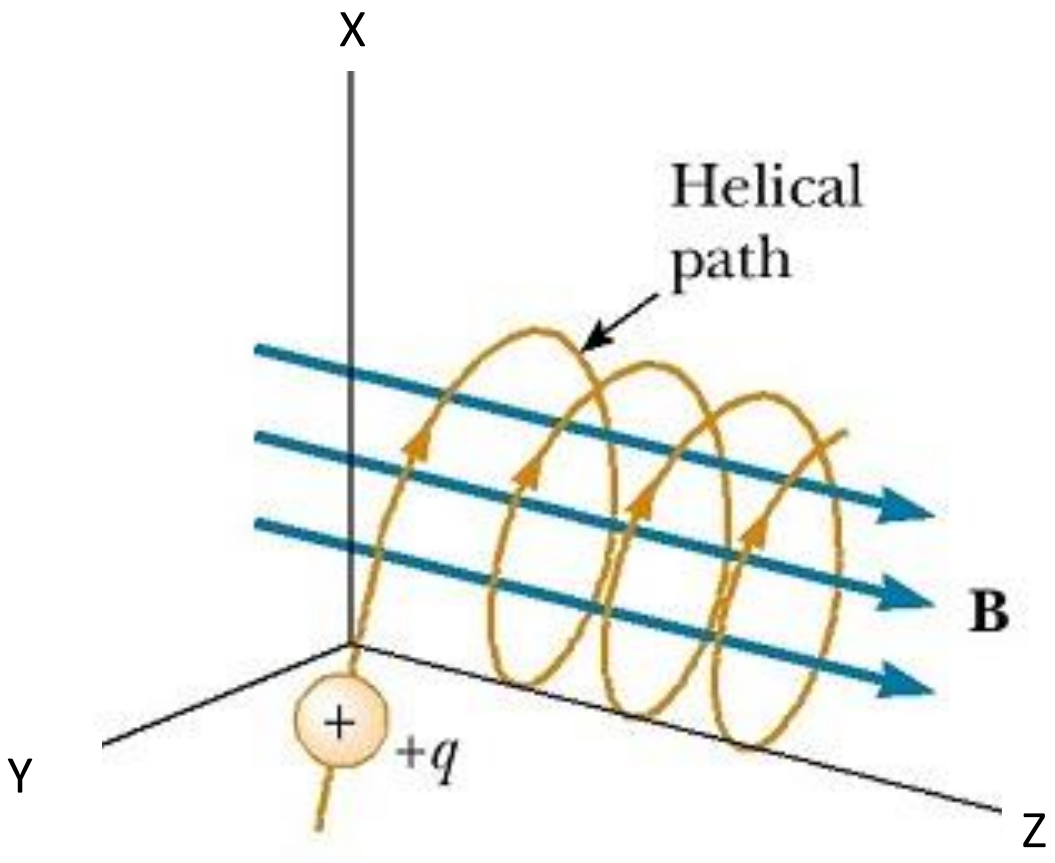
Credit: Paul Souder

Using a Solenoid (like CLEO)

- larger solid angle
- 3 MeV discrimnation

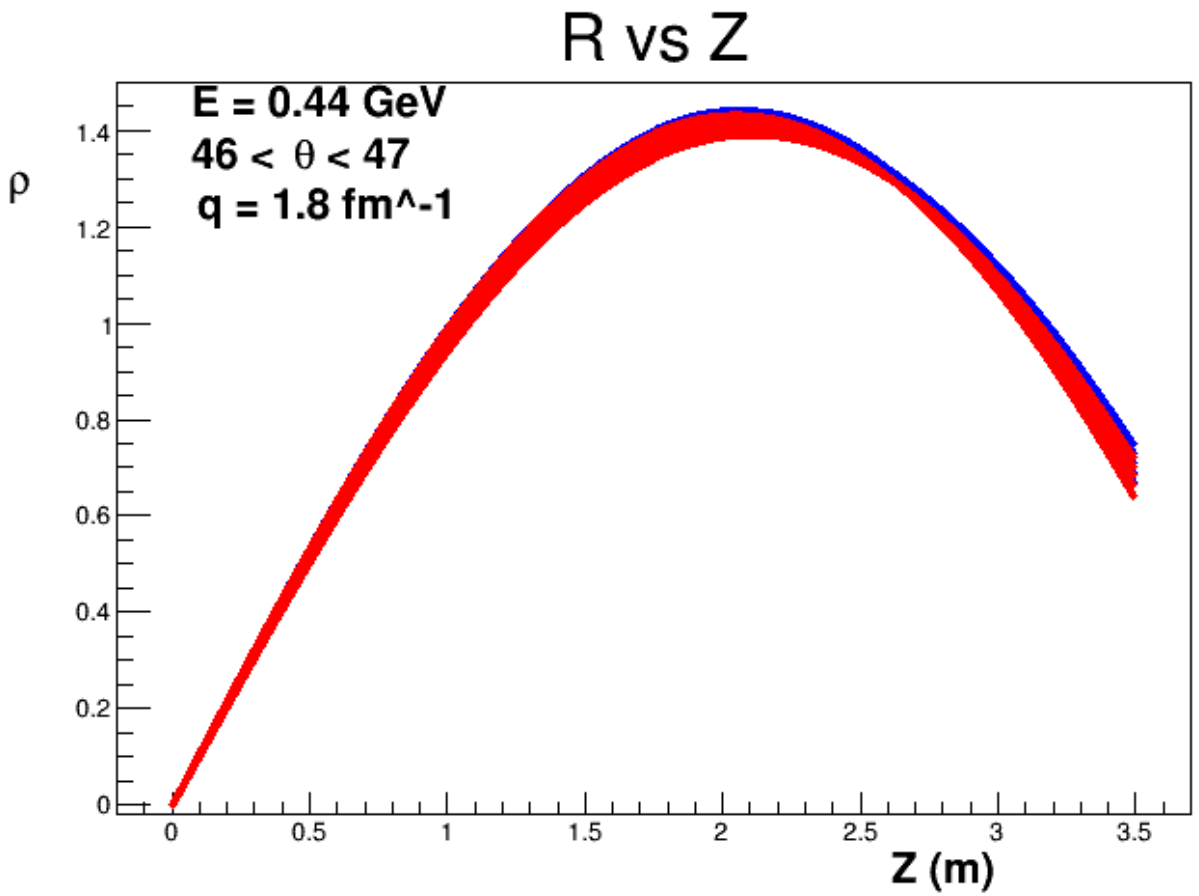
Credit: Paul Souder



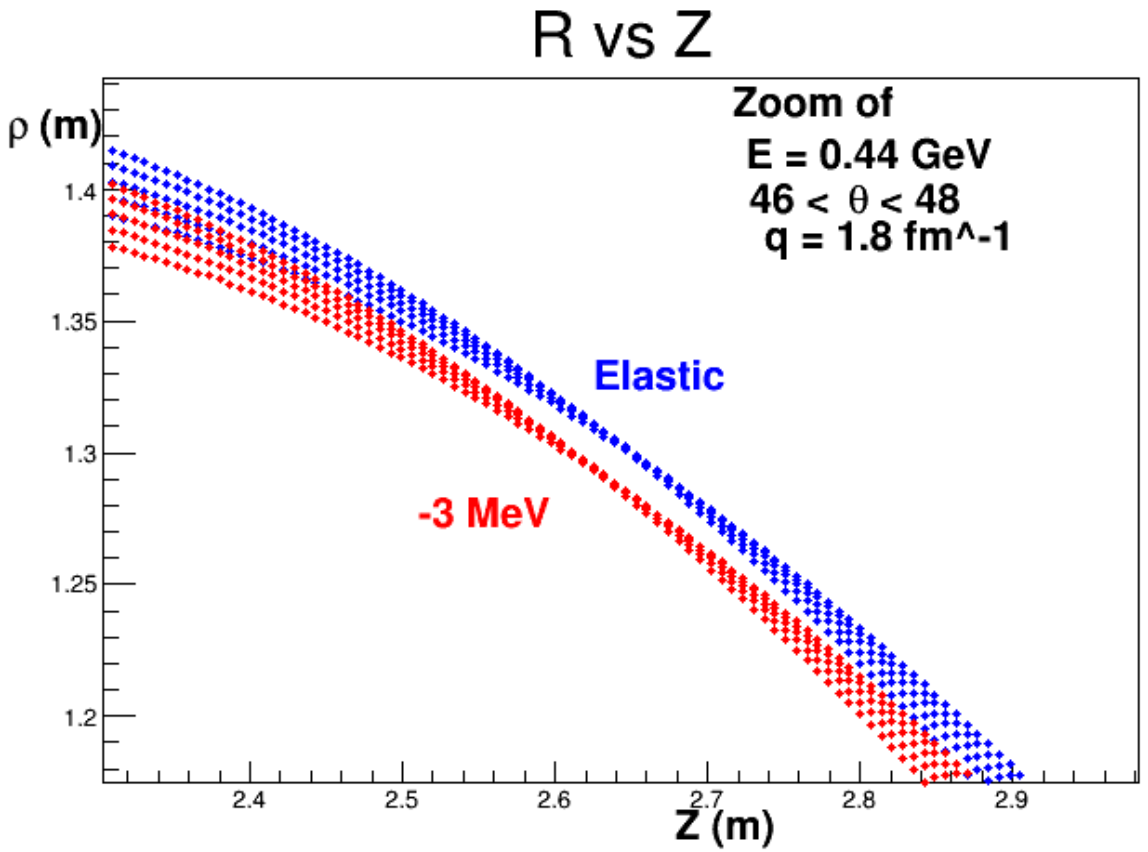


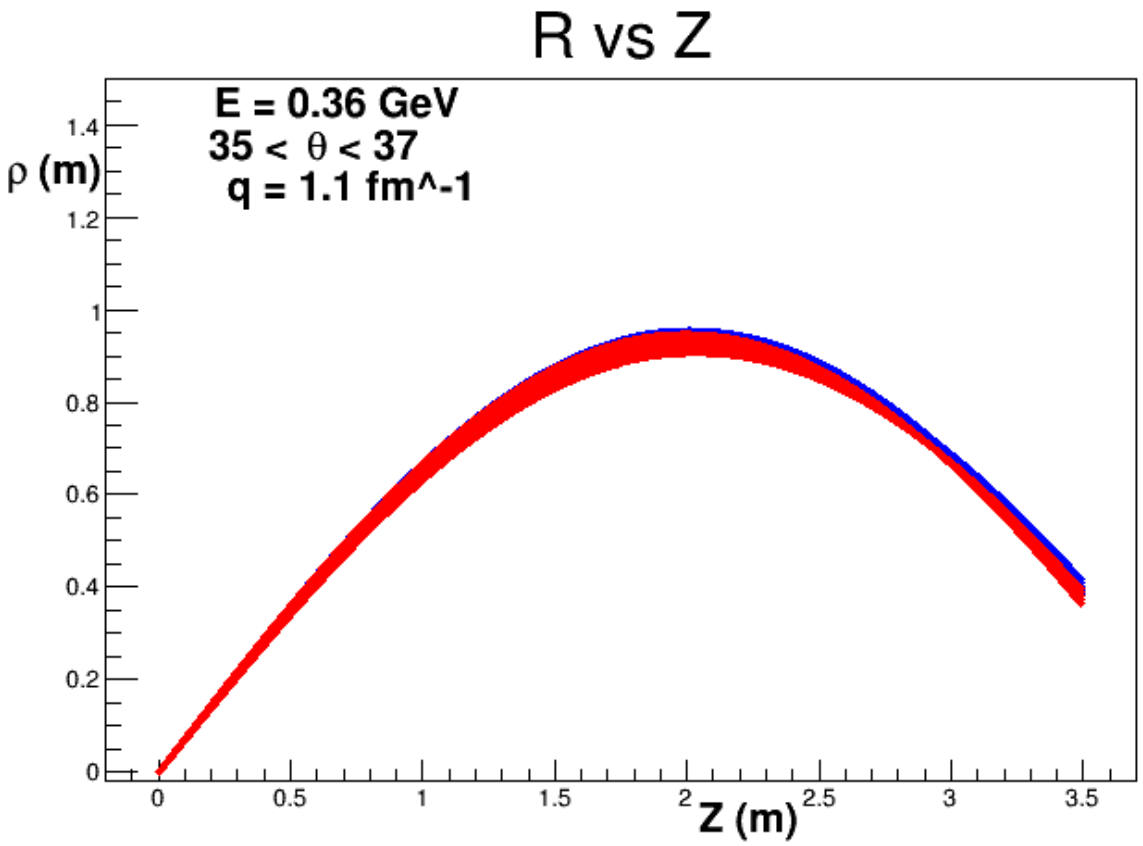
$$R = \frac{p \ \sin\theta}{0.3 \ B}$$

$$\rho(z) = 2\,R \left| \sin\left(\frac{z}{2R} \tan\theta\right) \right|$$

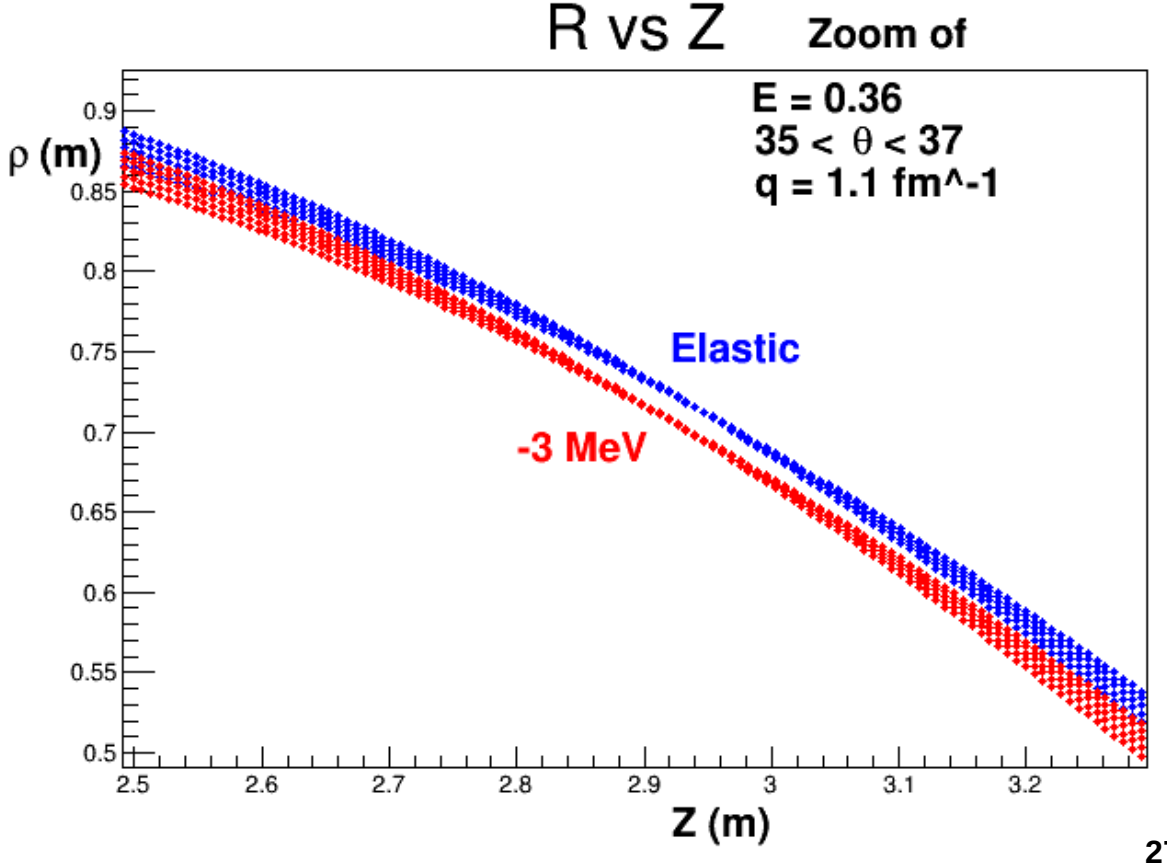


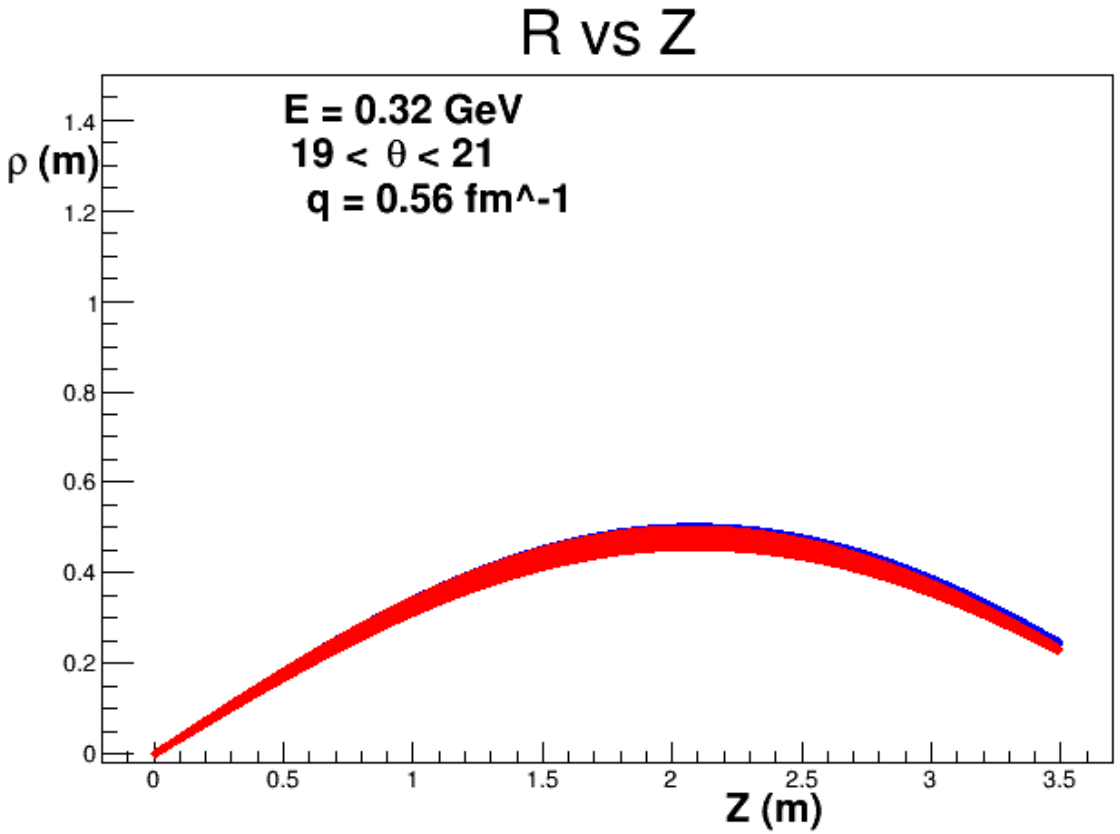
Example 1 of Trajectories in CLEO Solenoid



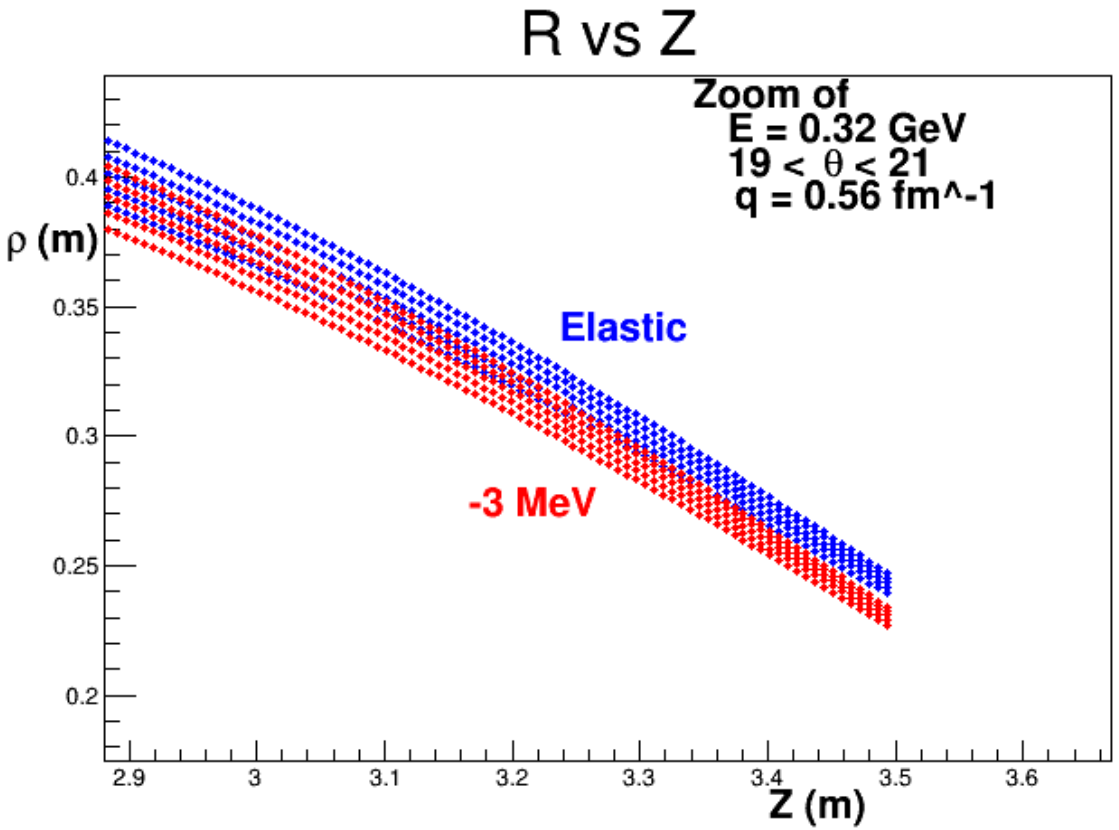


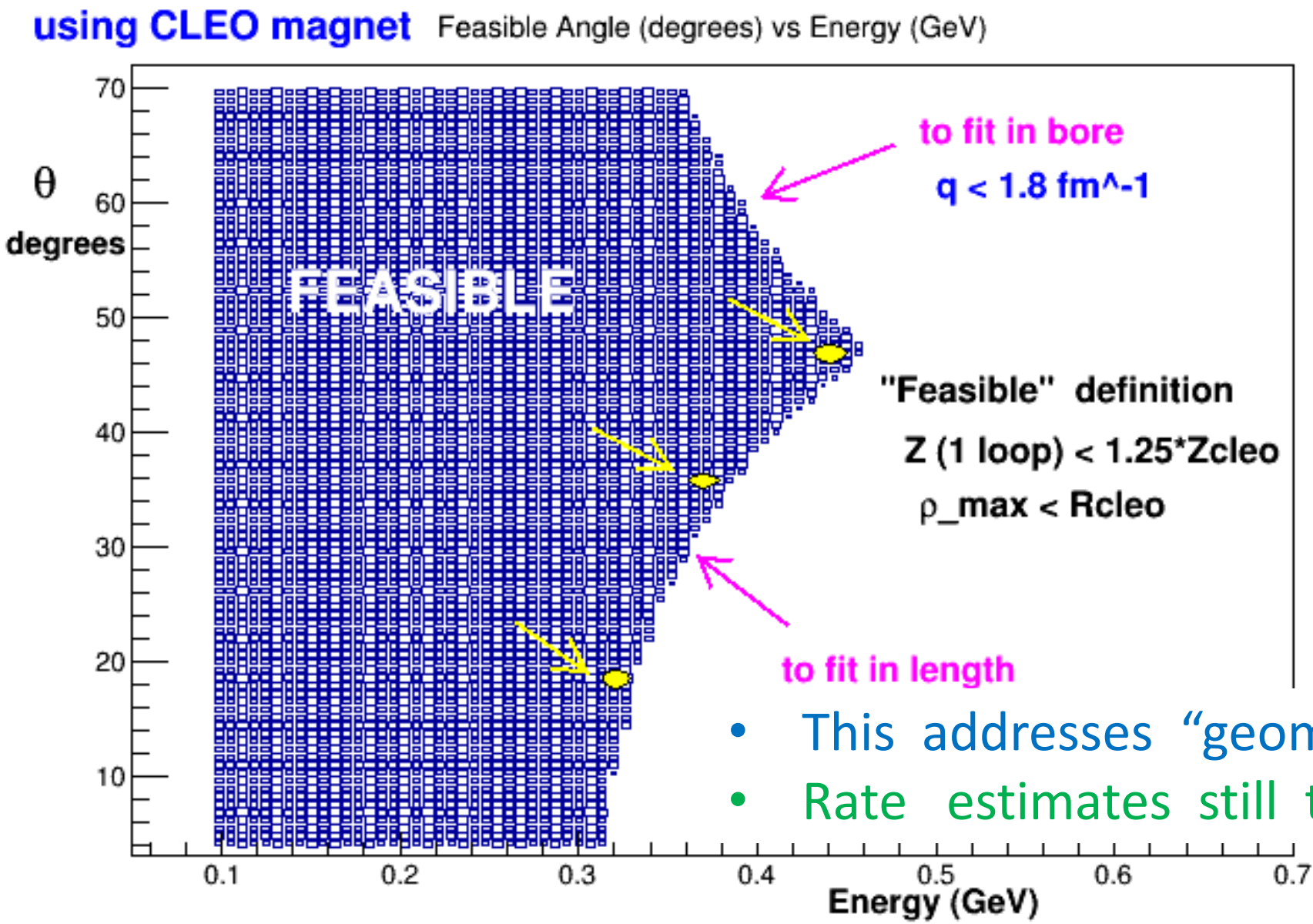
Example 2 of Trajectories in CLEO Solenoid





Example 3 of Trajectories in CLEO Solenoid





- This addresses "geometric" feasibility.
- Rate estimates still to come.

Conclusion : Extending C-REX to other kinematic points

- Using the HRS in Hall A

  an experiment can probably be designed
  which uses 60 days of beam for ~5 new Q^2 points

- Using a large-acceptance device

  a solenoid seems to be the only option,
  and mostly suitable for low energy (< 1 GeV).