Shameless Advertising:

Particle Physics Week at UWinnipeg

- Today
  - Jeff Martin (UWinnipeg) — Precision Electroweak
- Friday (2M77 @ 12:30 pm)
  - Eric Poisson (Guelph) — Black Holes
- Monday (1L13 @ 12:30 pm)
  - Cliff Burgess (Perimeter Inst.) — Physics at the Large Hadron Collider

Bring your interest in Physics

The Electroweak Force

Jeff Martin
Physics

Outline:

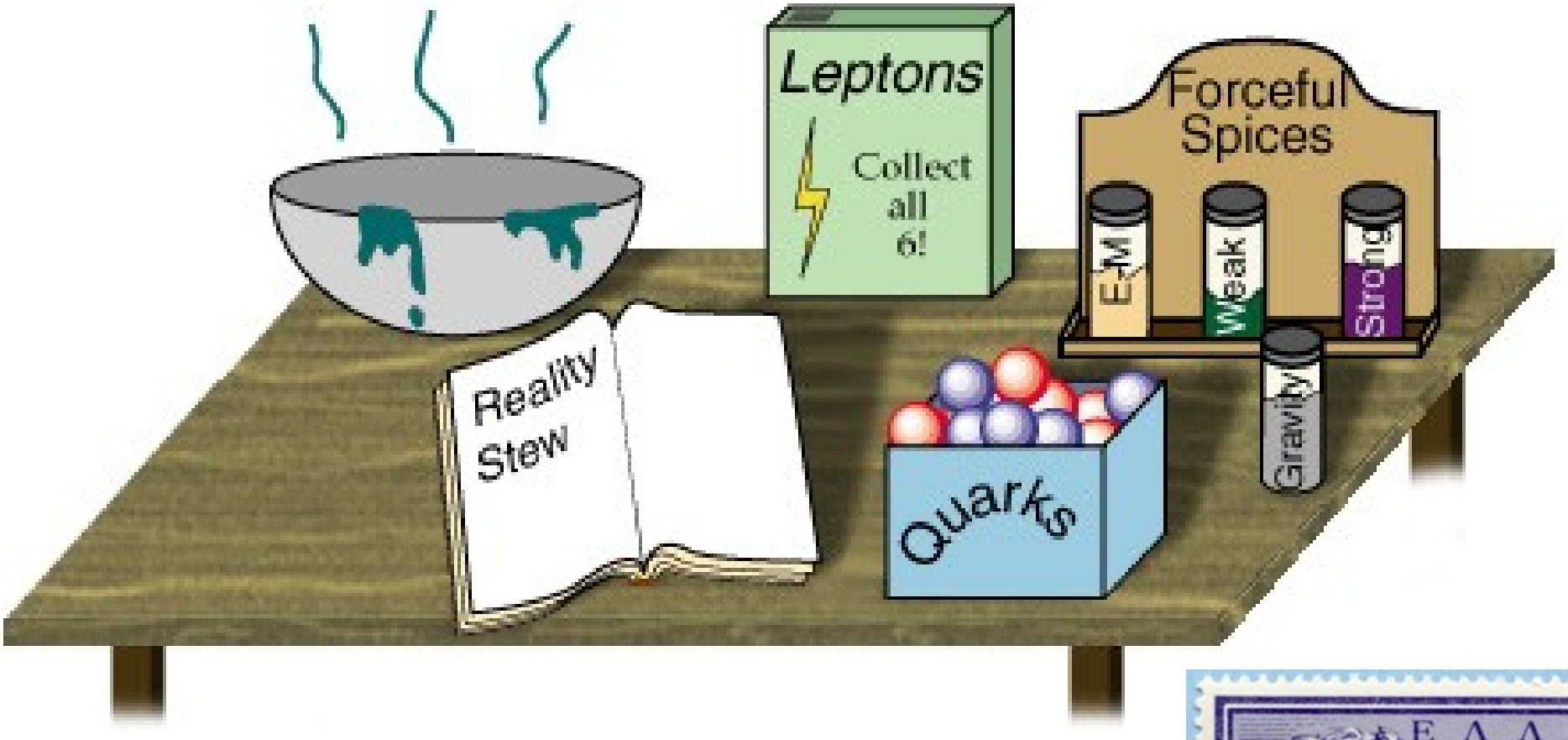
- Theory
- Experiment
- UWinnipeg

NSERC
CRSNG

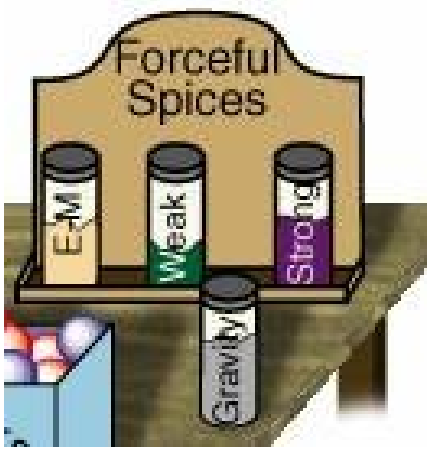
Canada Foundation
for Innovation

Fondation canadienne
pour l'innovation

What Little Boys and Girls are Made Of



What Holds It All Together



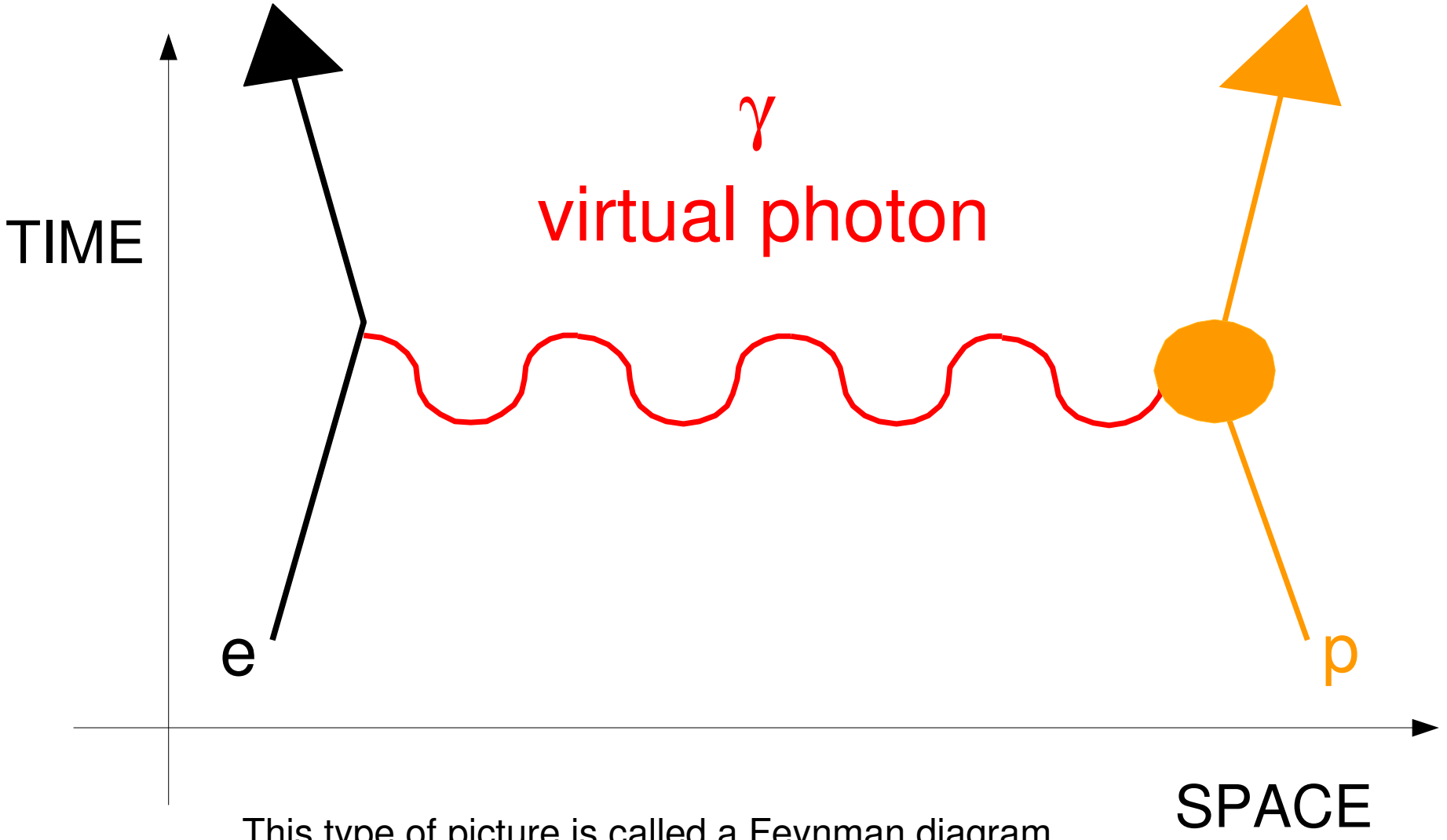
- Gravity:
  - Holds the cosmos together
- EM:
  - Holds most other macroscopic objects together
- Strong:
  - Holds atomic nuclei together
- Weak:
  - Responsible for some nuclear decays

The Weak Force:
It's weak. It's a force. Get used to it.

- Nuclear Decays.
  - Sunshine.
  - Medical diagnostics, applications in materials sci.
- Other weird facts about the weak force.
  - It's so darn weak.
  - It violates parity (mirror symmetry).
  - It is perhaps the most well-understood and theoretically interesting force. Physicists would love to cast their theories into a theory as beautiful as the weak force.

Telling Stories About Particles

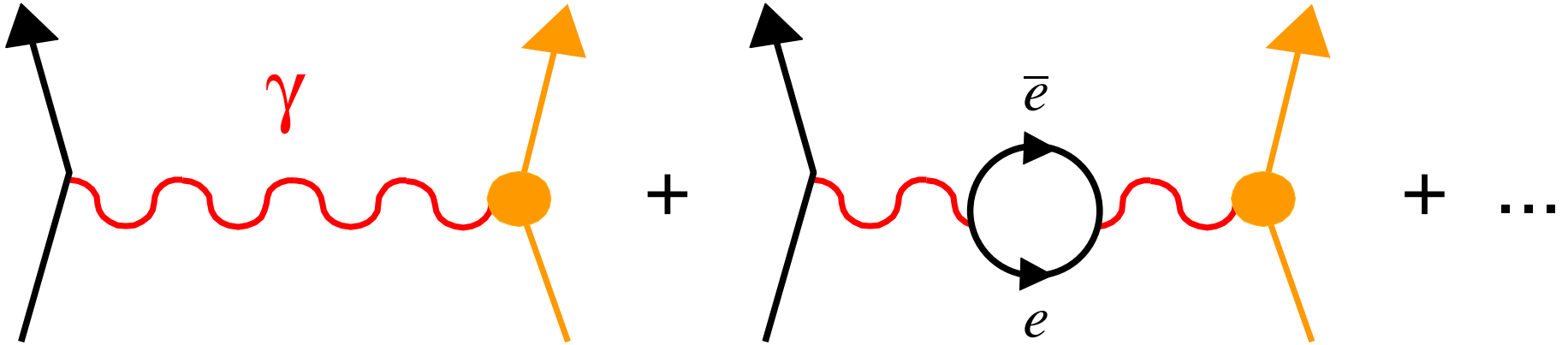
- E.g. a story about an electron and a proton.



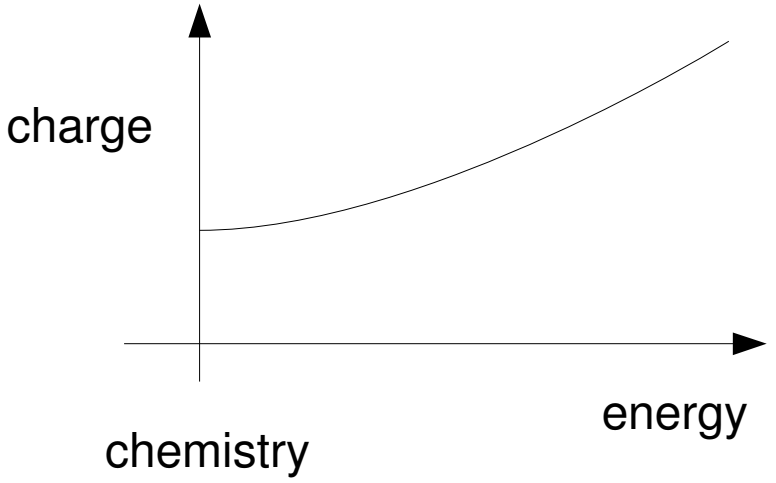
This type of picture is called a Feynman diagram.

Quantum Field Theory in a Nutshell

- Sum contributions from all possible diagrams

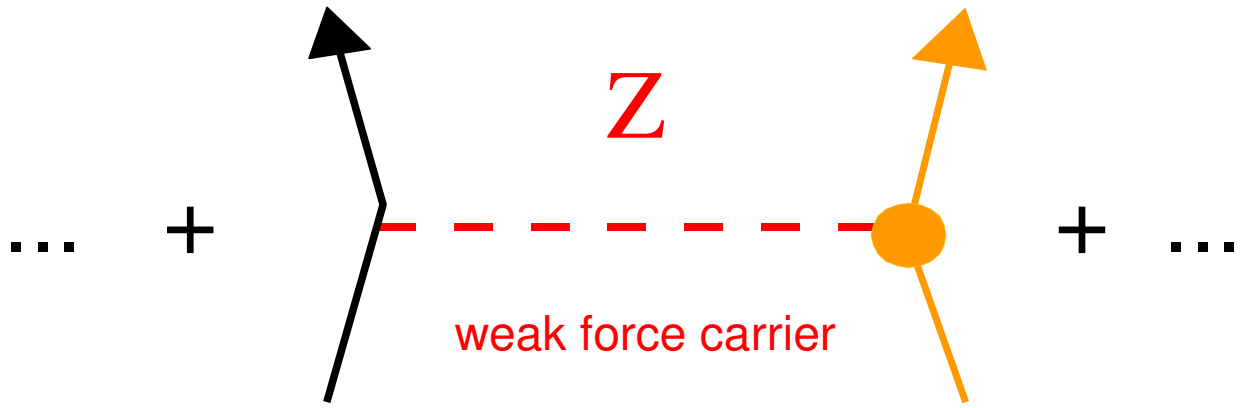


- A consequence: the "charge" of the electron (or proton) is not a constant!
- The closer you "look", the larger the charge appears to be.



Why the weak force is weak.

- Equation continued...

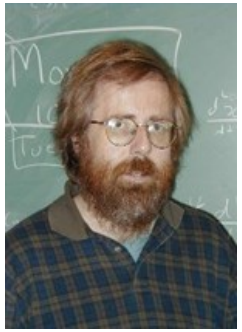


- The Z-particle is very heavy.
- $E=mc^2$.
- And if you borrow energy from the vacuum, you must give it back fast. (The Z is “virtual”.)

“Electroweak” Theory

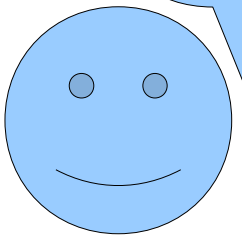
- As it happens, γ and Z are manifestations of the same particle (and so are W^+ and W^-).
- The Z, W^+, and W^- get their mass, and the photon remains massless, by interactions with the Higgs field.
- The gamma and Z are related by a parameter called: $\sin^2\theta_W$ “the weak mixing angle”.

The Beautiful (Standard) Model



Just write down the most general possible Lagrangian respecting $SU(3)_c x SU(2)_L x U(1)_Y$ and local gauge invariance.

Yeah, then throw in a Higgs field and boom you have mass.



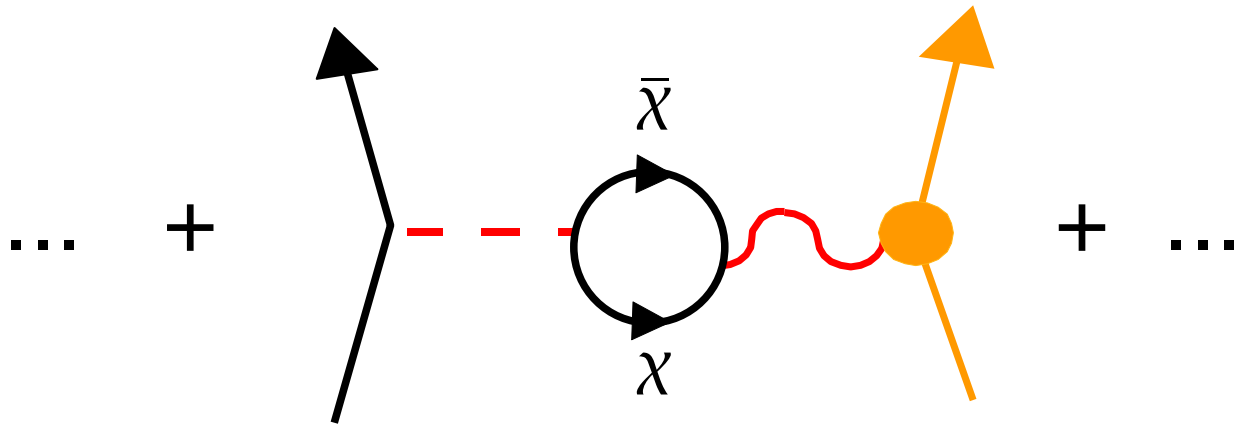
By the way, my name is Dwight Vincent

Why can't gravity be so trivial?

Keep smiling

The Footprints of Giants

- Equation continued...



- Maybe there is a “GIANT” particle hidden in that bunch of virtual particles somewhere.
- And it's very heavy, so its effects are very small.
- Possible giant particles: Gravitinos, Leptoquarks, ...

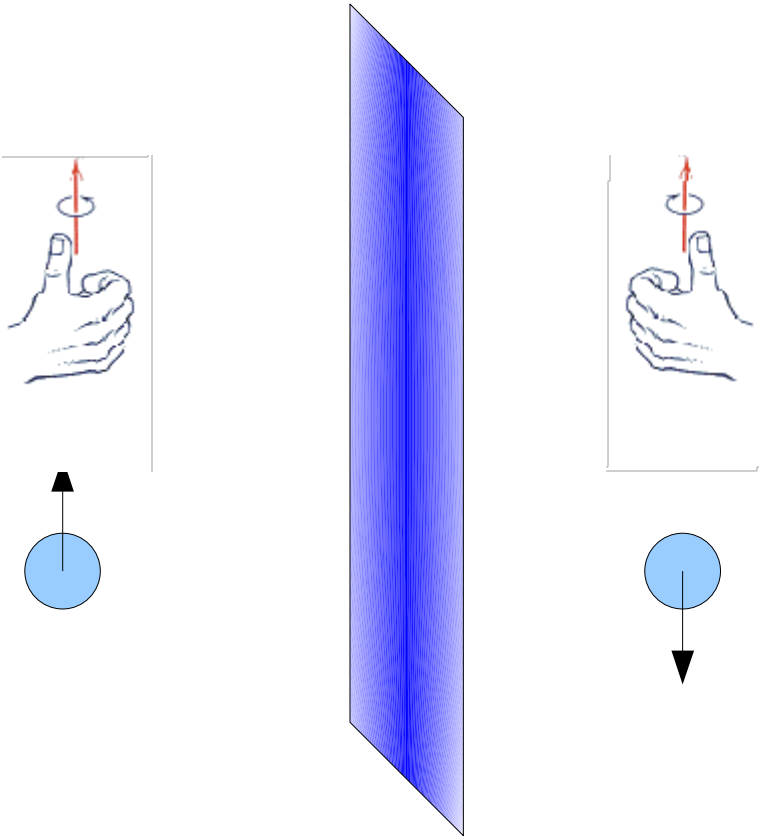
The game: find the effects of that virtual particle by doing very precise measurments of the weak force ($\sin^2\theta_W$).

Through the Looking Glass

- The weak force is the only force that doesn't look the same when viewed in the mirror.
- This is called

  “parity violation”

- In fact, that's how we isolate the weak force.

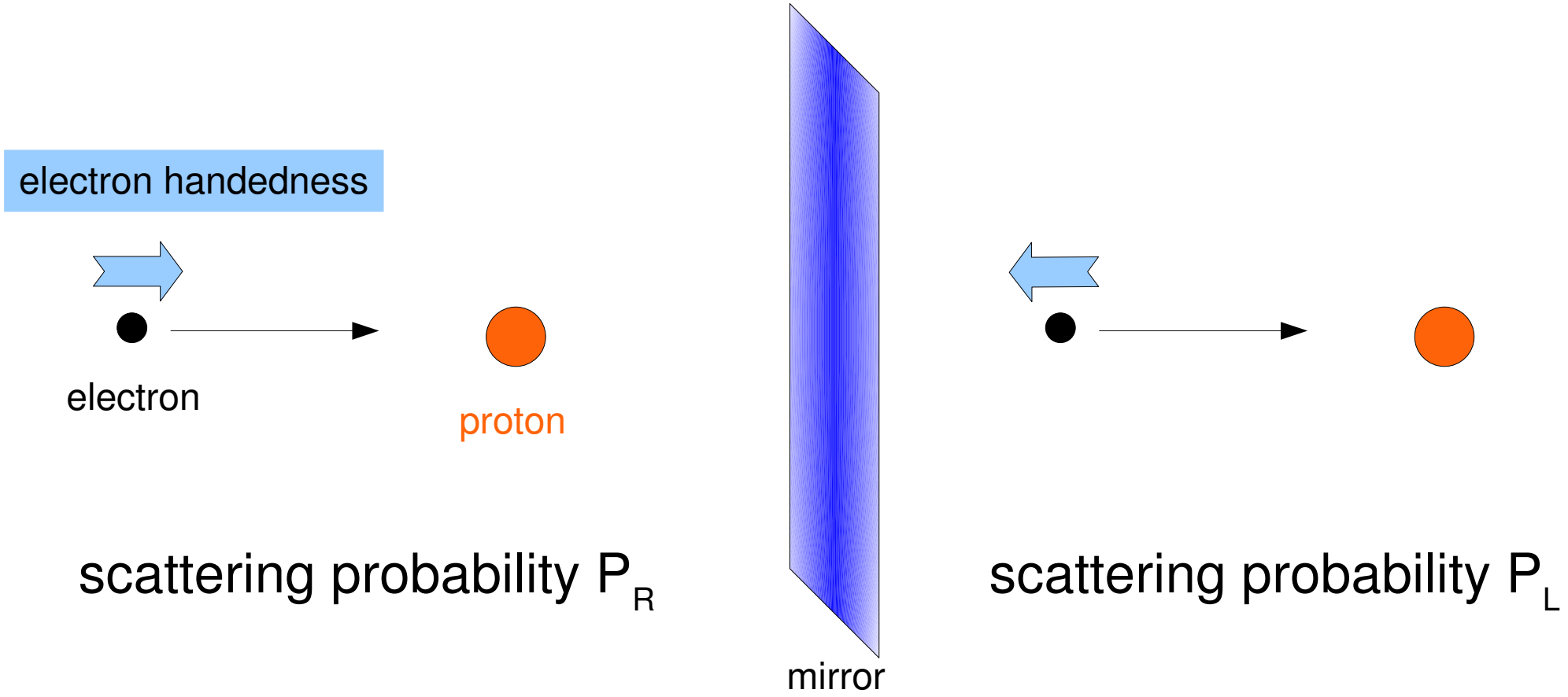


Half-time: Mini-Review

Precise Parity Violation Experiment
-> Precision Measurement of Weak Force
-> Test of Electroweak Theory
-> Discovery of New Particle
-> Pick up Nobel Prize

(Consolation: if you don't discover a new particle, well at least you found that one does NOT exist, which is also valuable for keeping those theorists in check.)

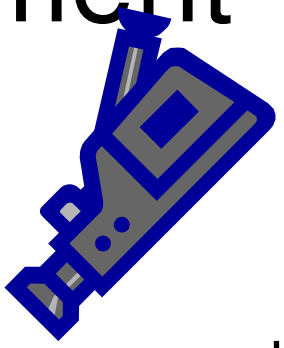
The Weak Force is WEAK!



$$\text{The "asymmetry"} = \frac{P_R - P_L}{P_R + P_L} \approx 100\,\text{ppb, and we want to measure it to } 1\%$$

Like trying to measure the diameter of the Earth to a precision of 1 cm.

Generic Parity Violation Scattering Experiment

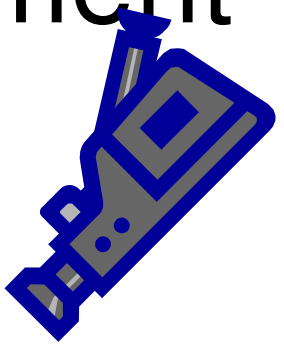


detector

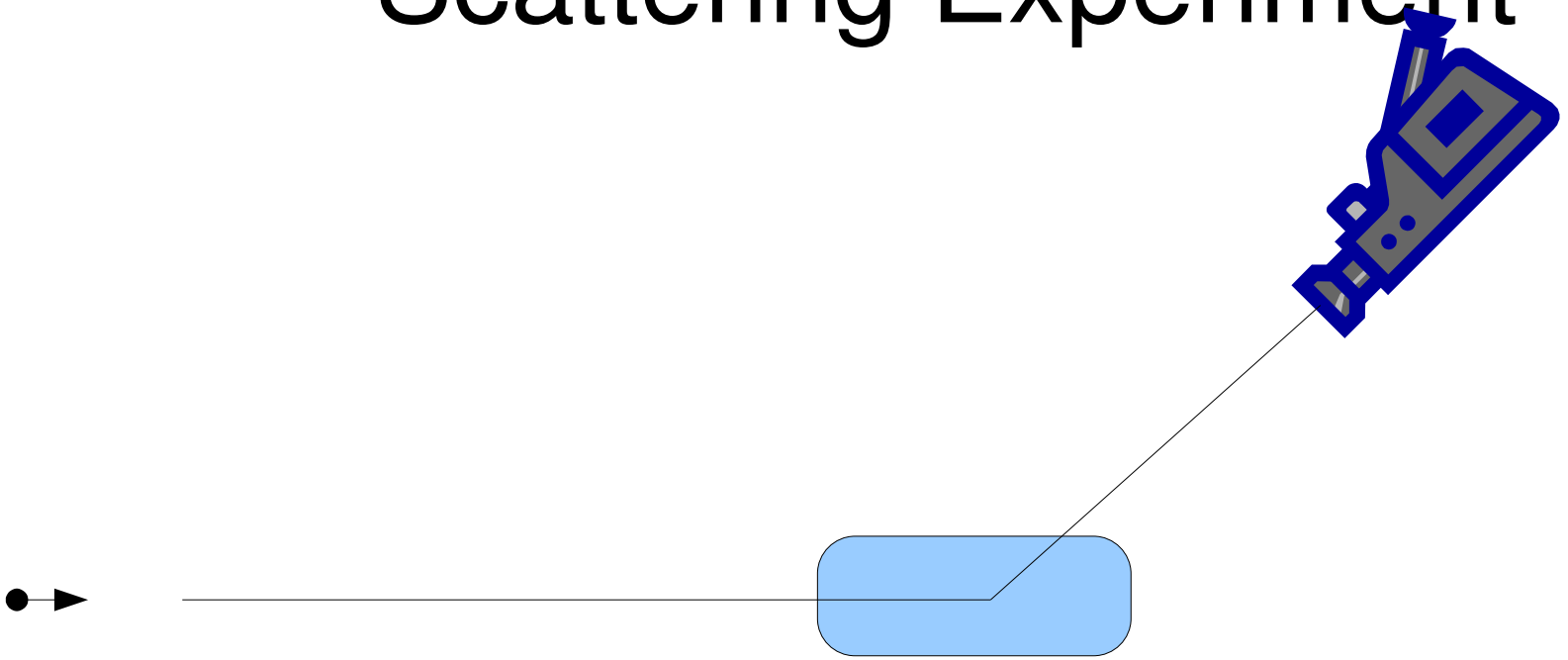
electron

target (LH2)

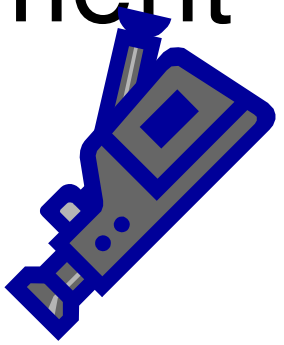
Generic Parity Violation Scattering Experiment



Generic Parity Violation Scattering Experiment

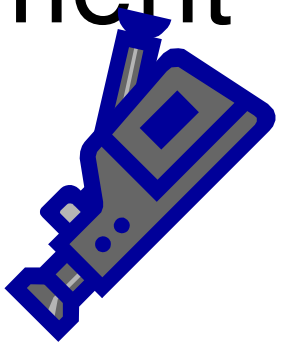


Generic Parity Violation Scattering Experiment

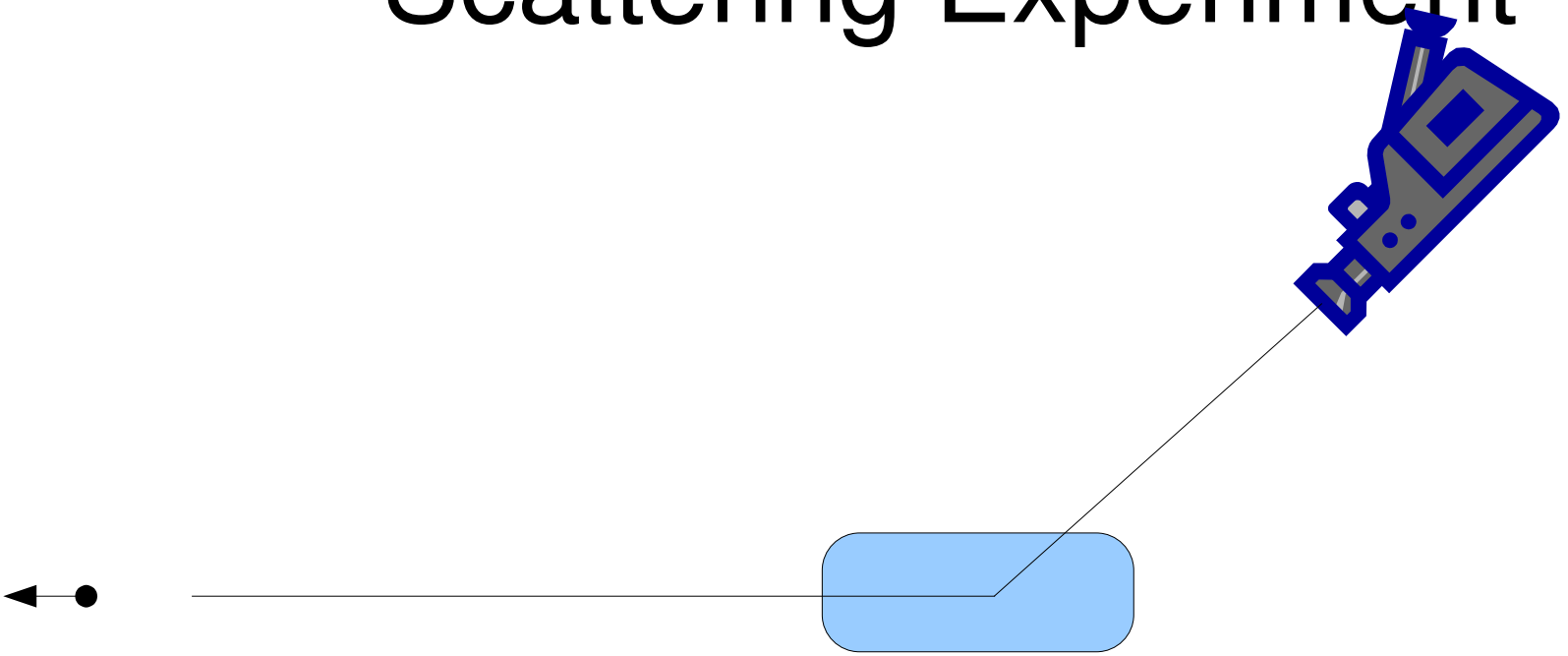


parity-reversed experiment

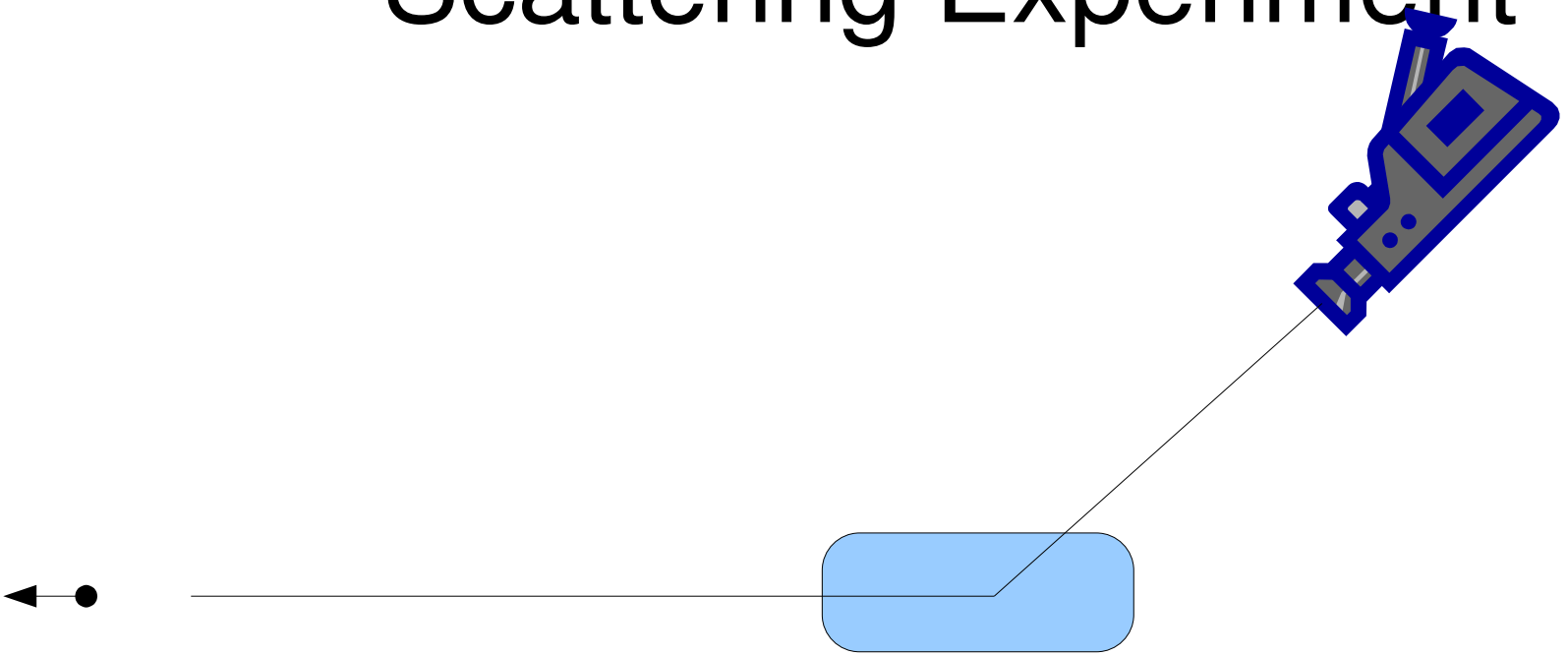
Generic Parity Violation Scattering Experiment



Generic Parity Violation Scattering Experiment

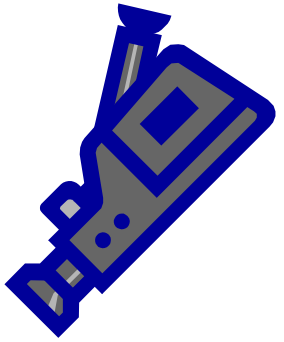


Generic Parity Violation Scattering Experiment

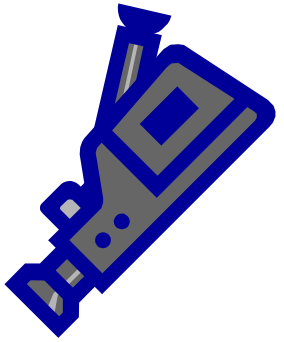


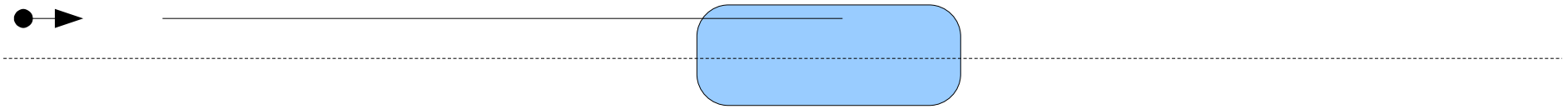
These experiments are the same to 10^{-7}

Helicity-Correlated Systematics



Helicity-Correlated Systematics





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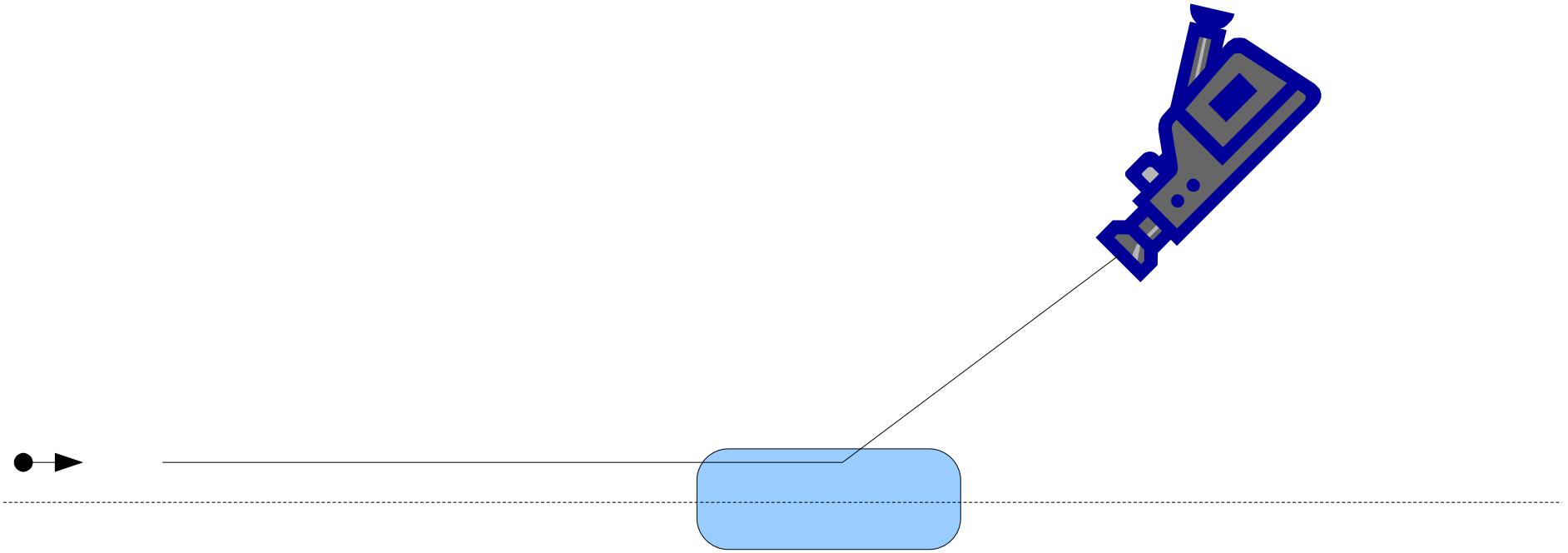

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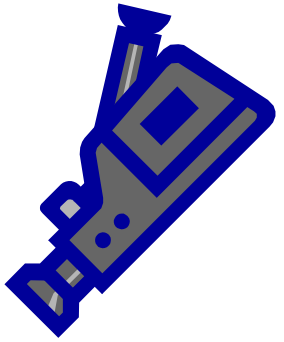

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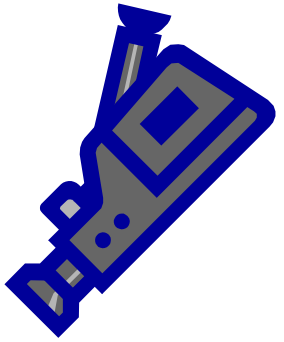

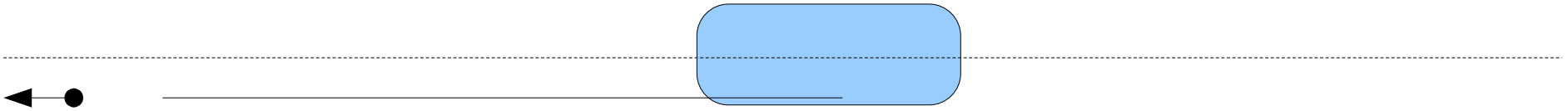

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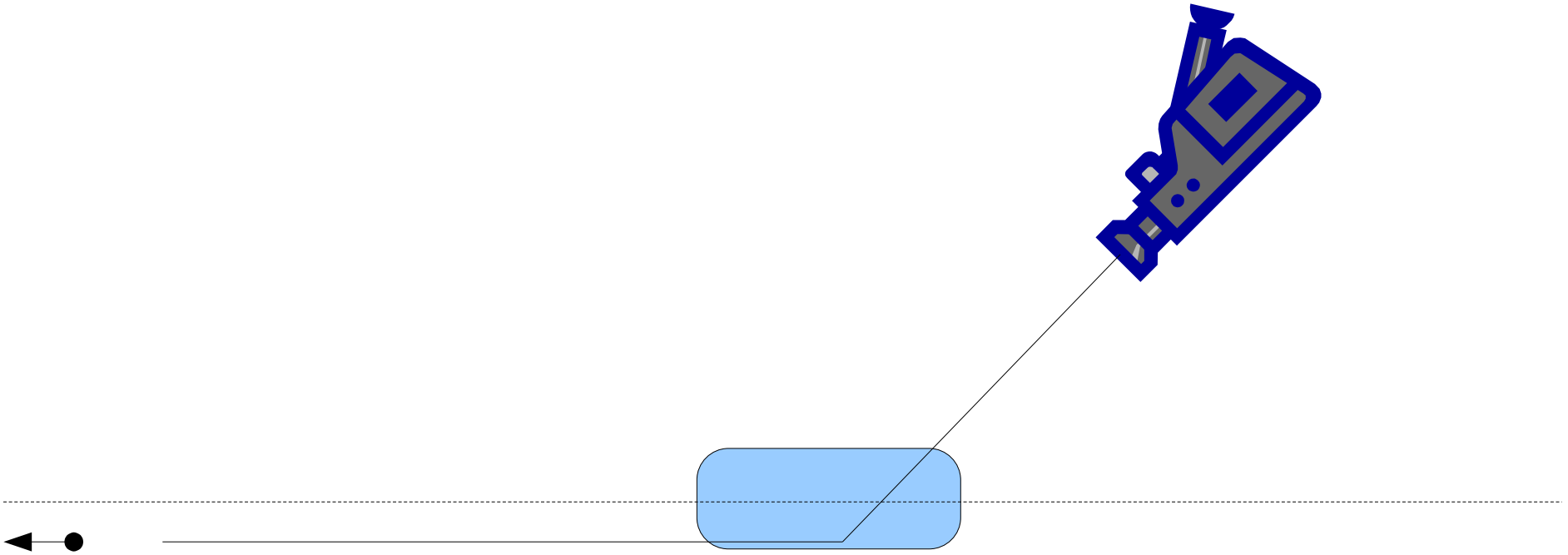

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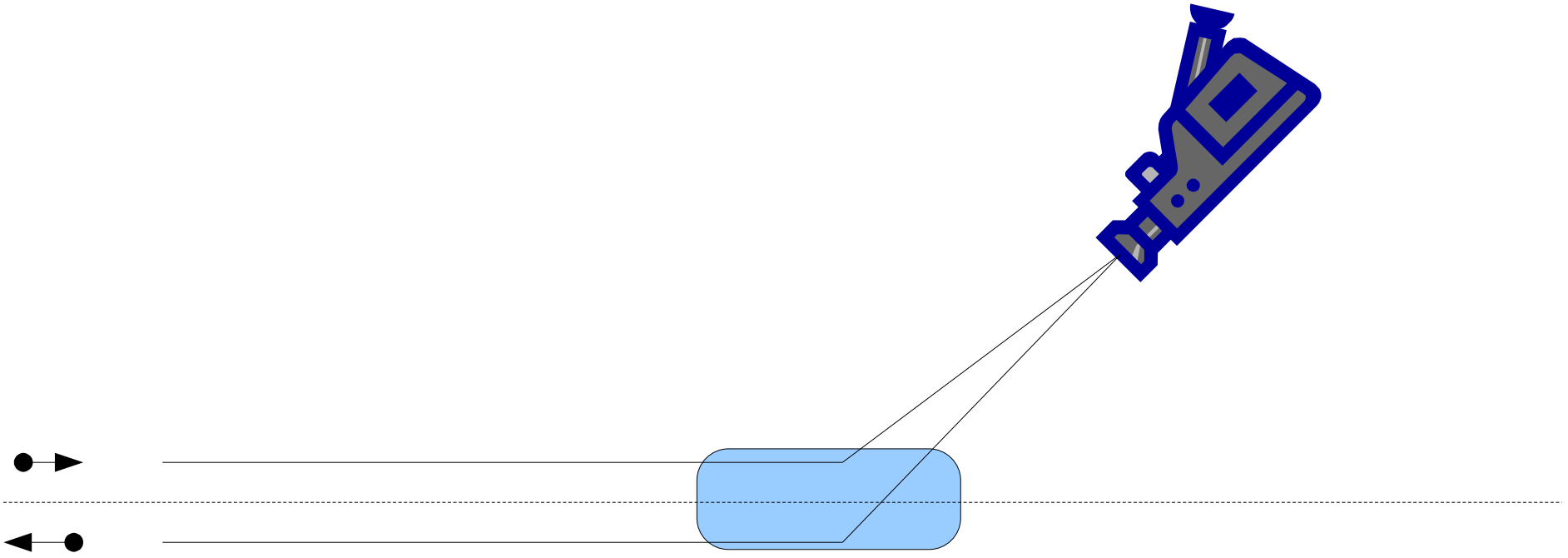

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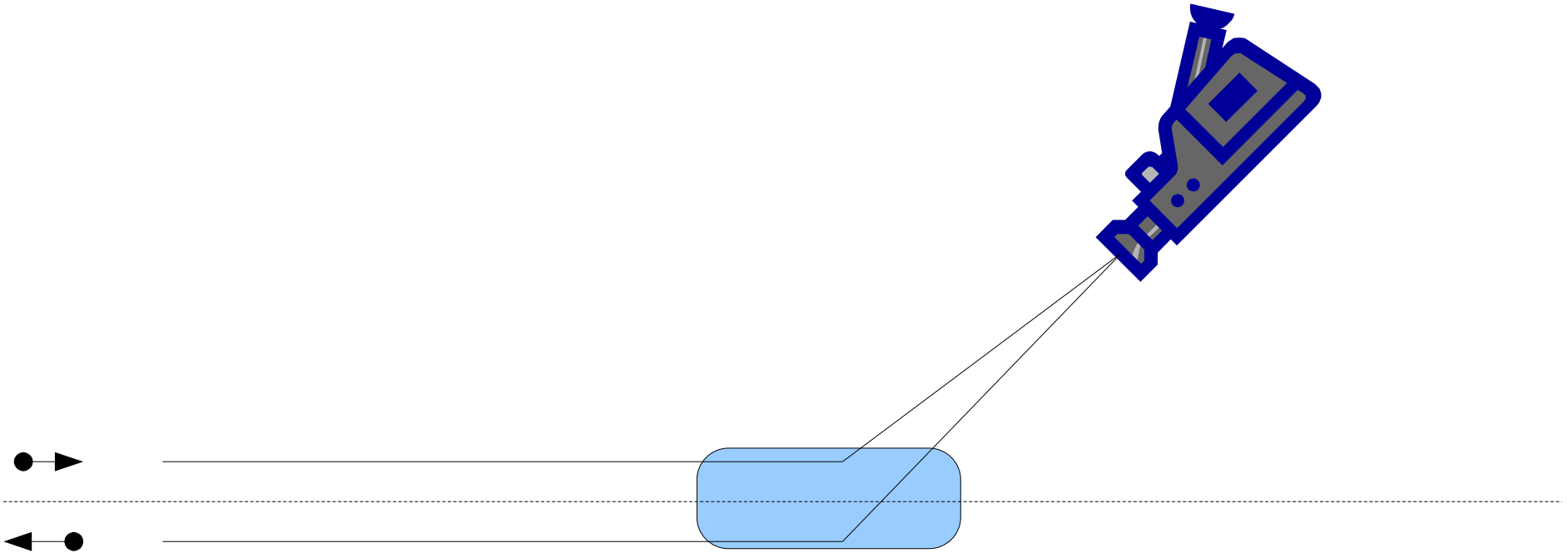
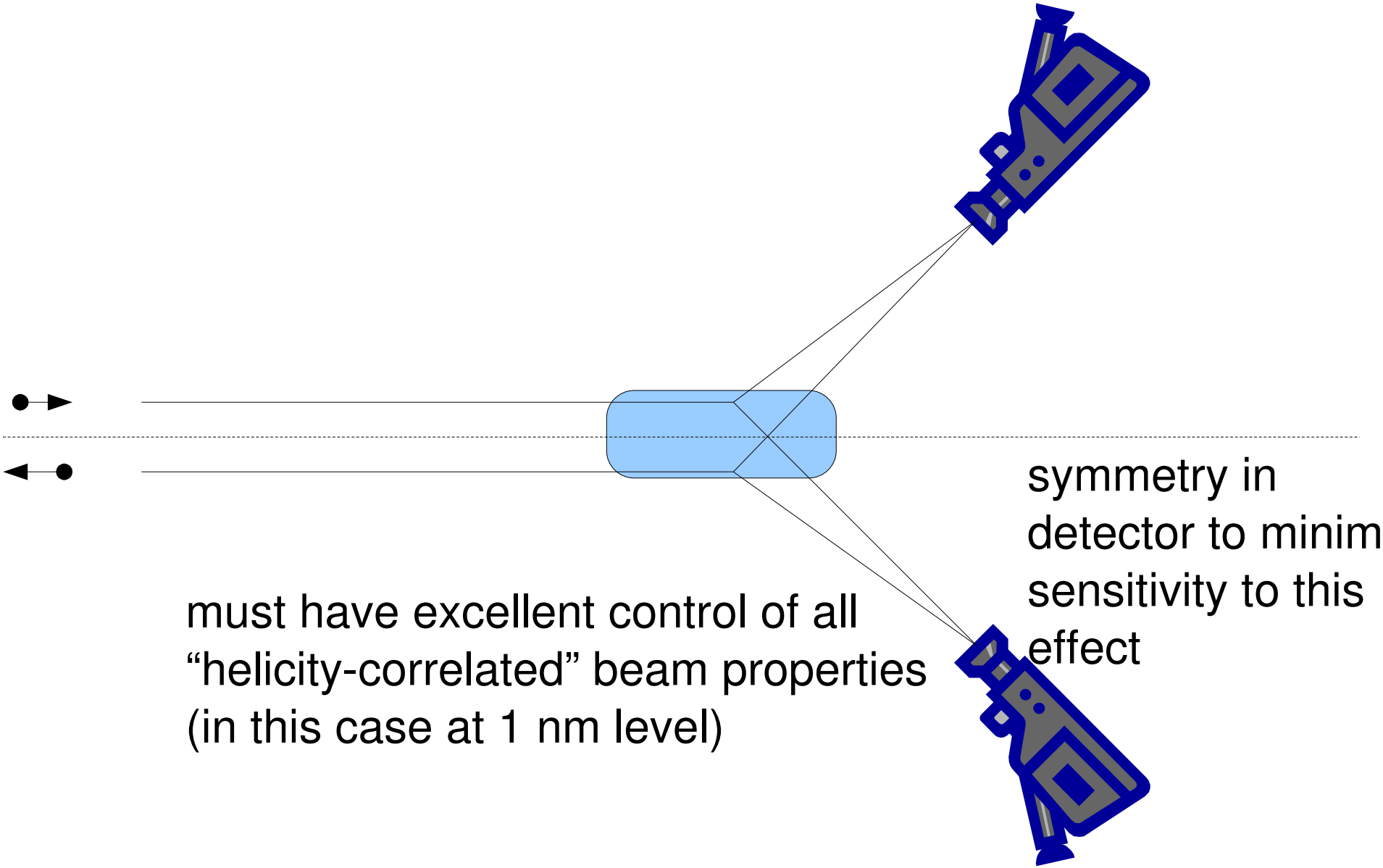


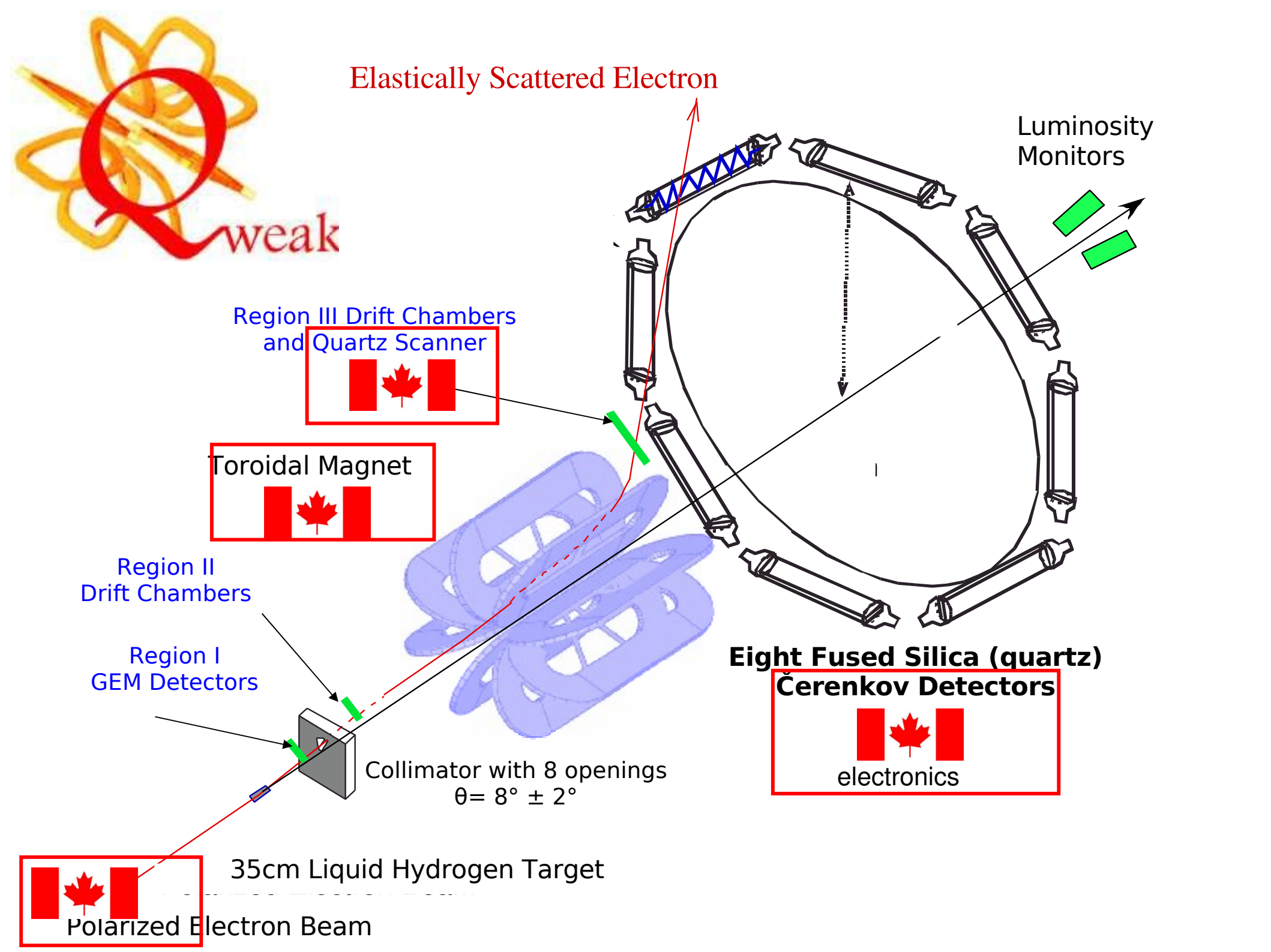
must have excellent control of all
“helicity-correlated” beam properties
(in this case at 1 nm level)

Helicity-Correlated Systematics

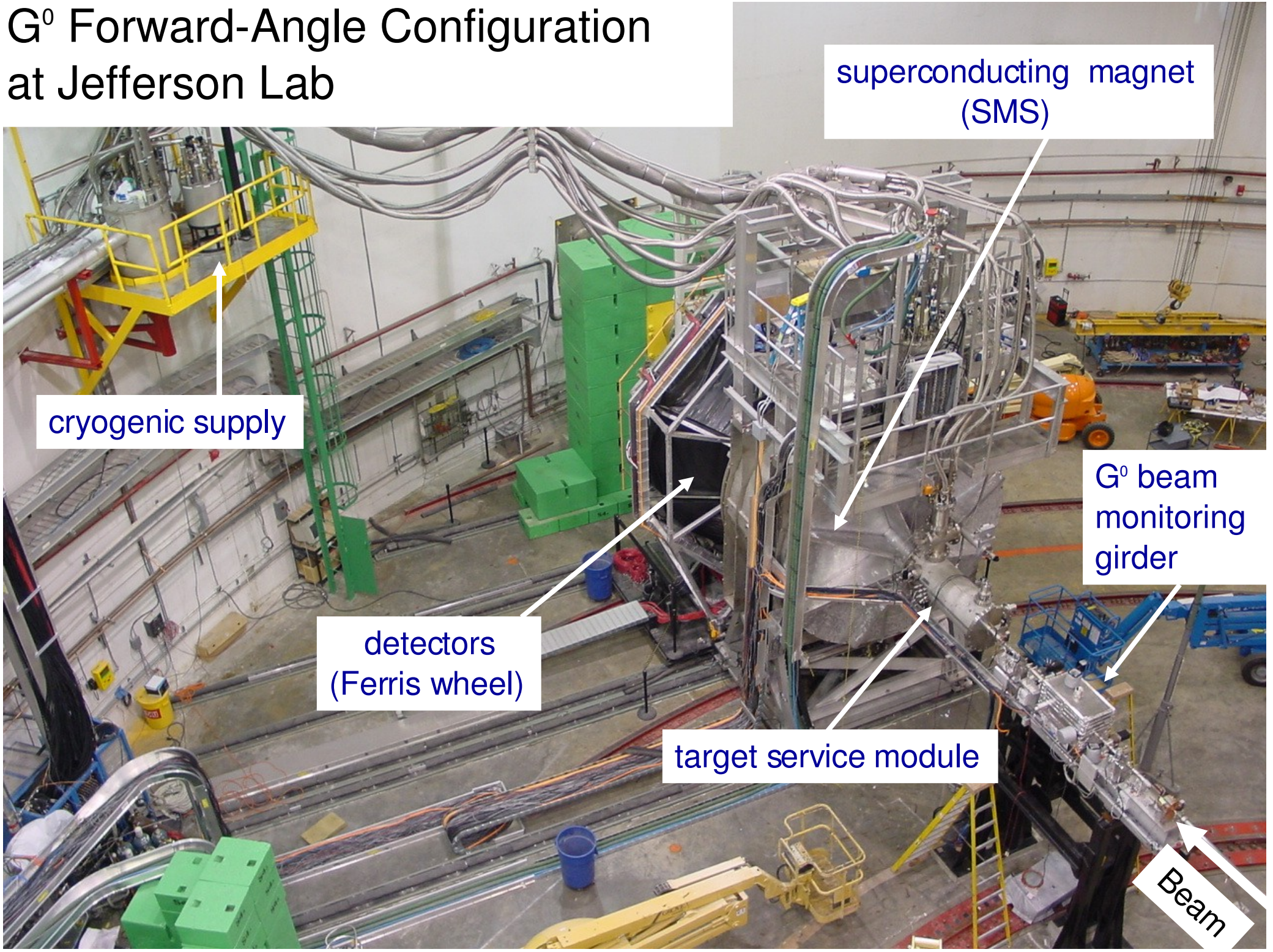


symmetry in detector to minimize sensitivity to this effect

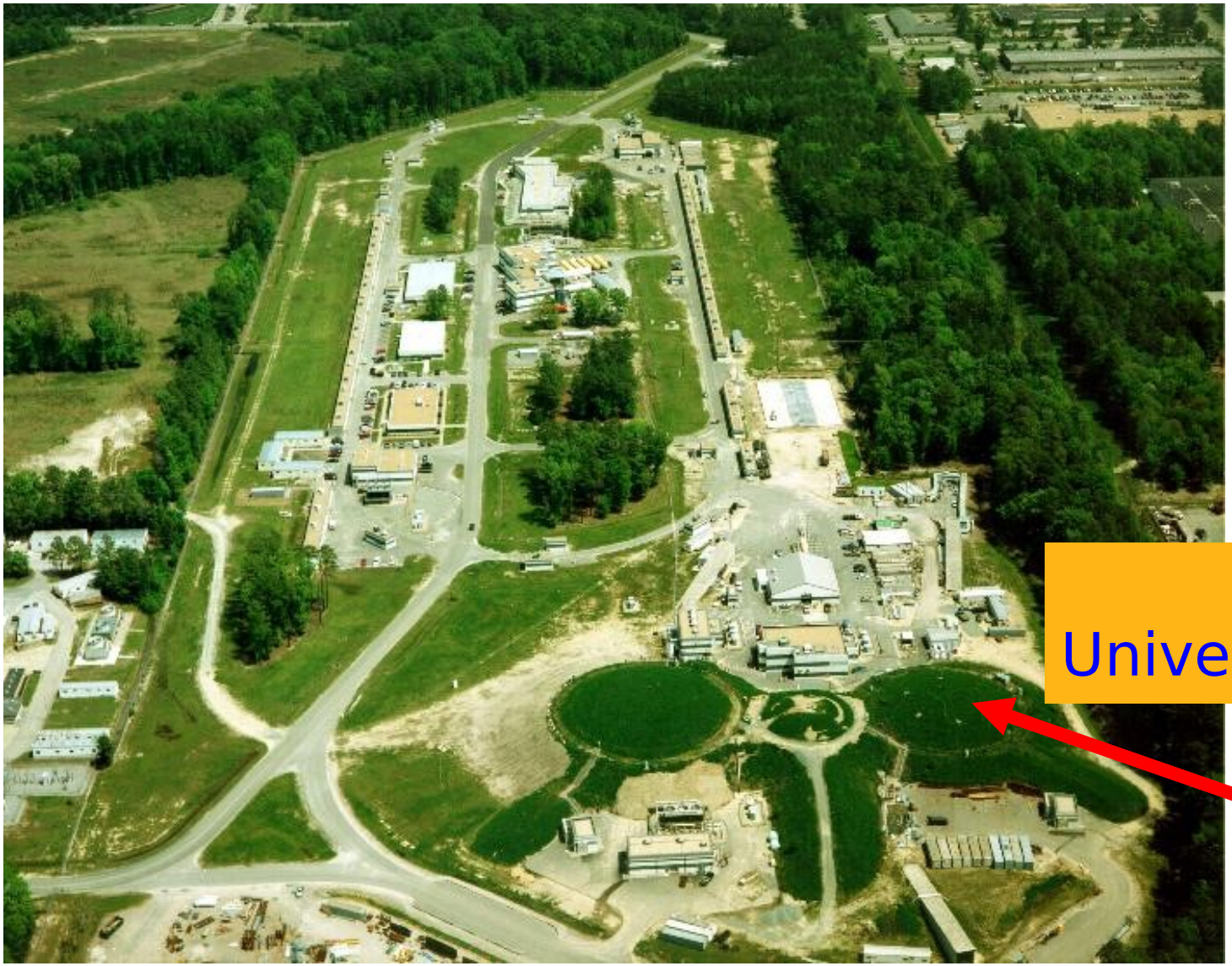
must have excellent control of all “helicity-correlated” beam properties (in this case at 1 nm level)


Elastically Scattered Electron
Luminosity Monitors
Region III Drift Chambers and Quartz Scanner
Toroidal Magnet
Region II Drift Chambers
Region I GEM Detectors
Eight Fused Silica (quartz) Čerenkov Detectors
electronics
Collimator with 8 openings
θ= 8° ± 2°
35cm Liquid Hydrogen Target
Polarized Electron Beam

G^0 Forward-Angle Configuration at Jefferson Lab



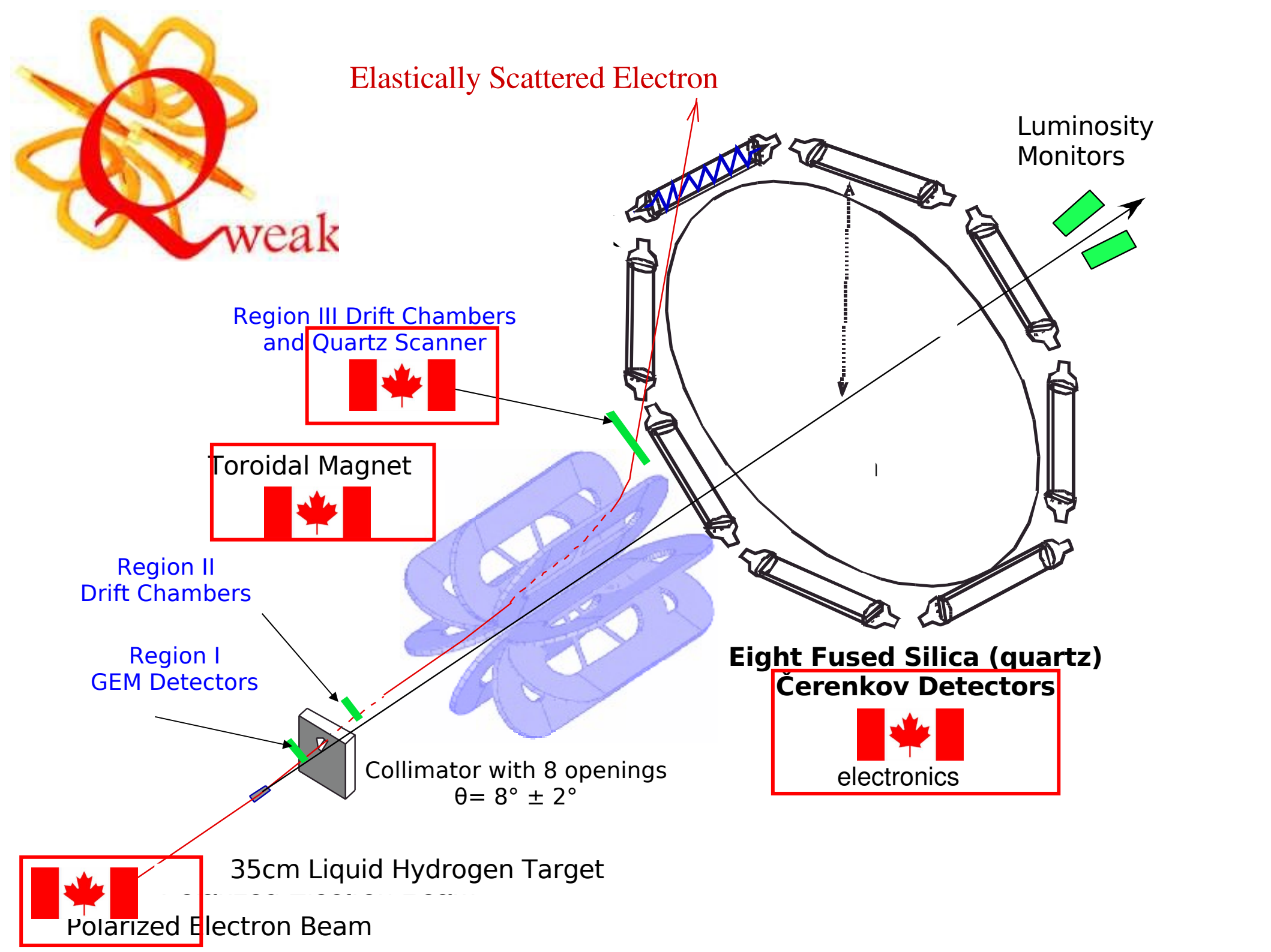
Jefferson Lab



Caltech
Coll. of William and Mary
Dartmouth Coll.
George Washington U
Hampton U
UNAM (Mexico)
Idaho State U
Louisiana Tech U
MIT
Mississippi State U
Ohio U
Syracuse U
TRIUMF
Jefferson Lab (TJNAF)
U Conn
U Manitoba
U New Hampshire
U Northern British Columbia
U Virginia
Virginia Tech
Yerevan Physics Institute

and The
University of Winnipeg

Qweak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Collimator with 8 openings
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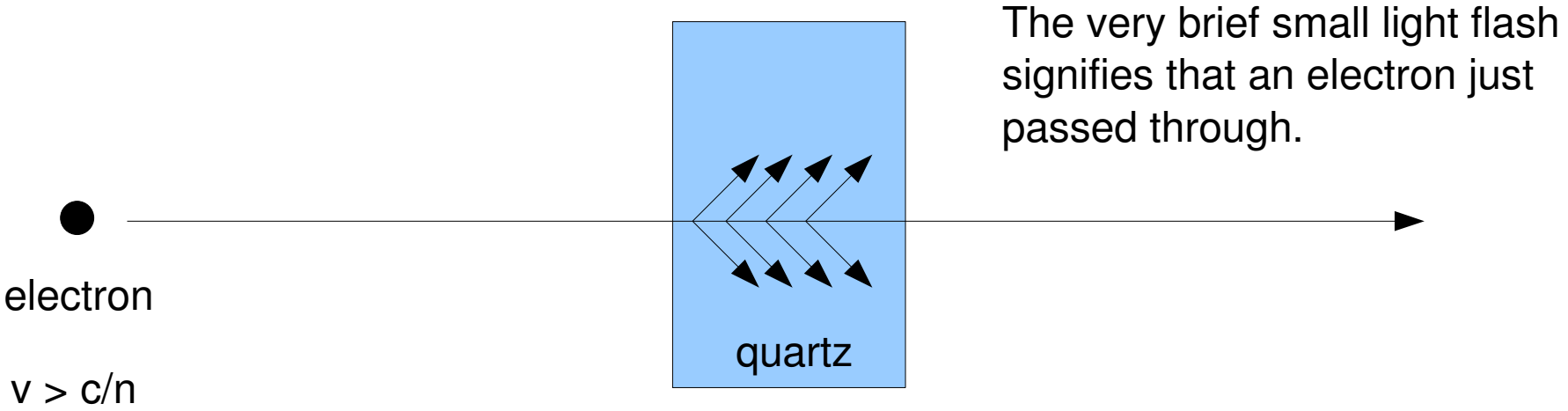
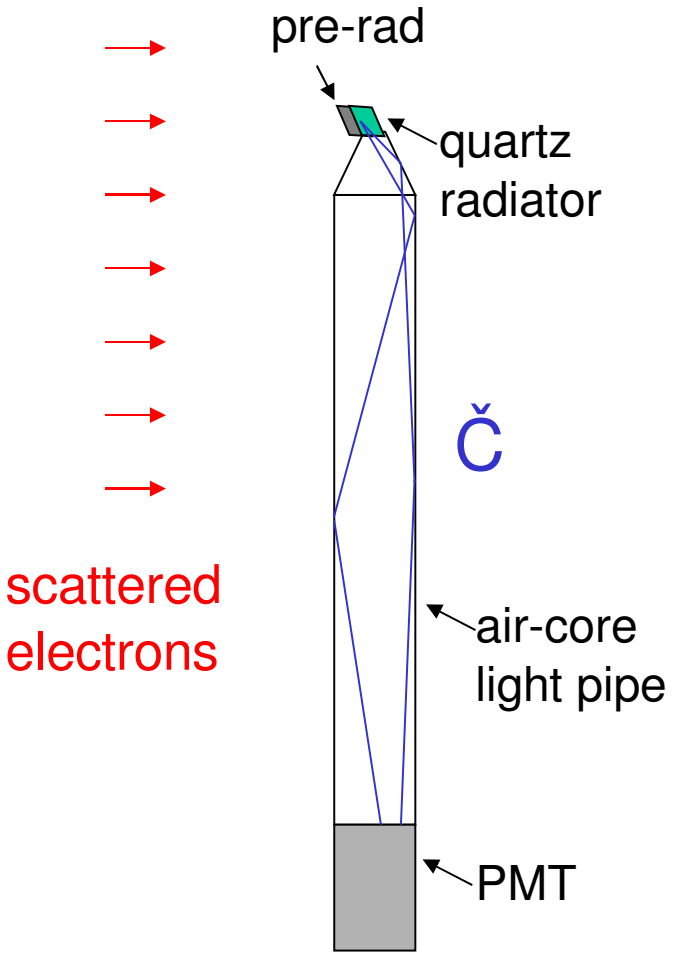
35cm Liquid Hydrogen Target
Polarized Electron Beam

Light Boom

- A sonic boom happens when a plane exceeds the speed of sound in air.
- A light boom happens when a particle moves faster than the speed of light in the medium.
- Physicists call this the Čerenkov effect.



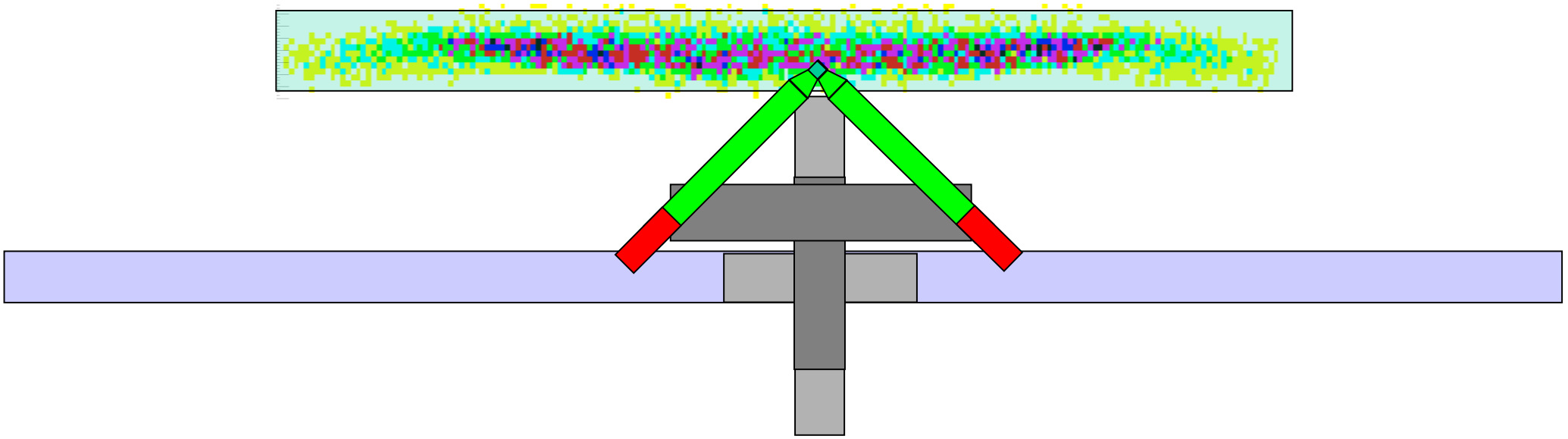
A Quartz Scanner for Qweak



Concept:

- Scan a small piece of quartz over the surface of the main quartz bars to characterize their performance during the experiment.

Implementation in Qweak



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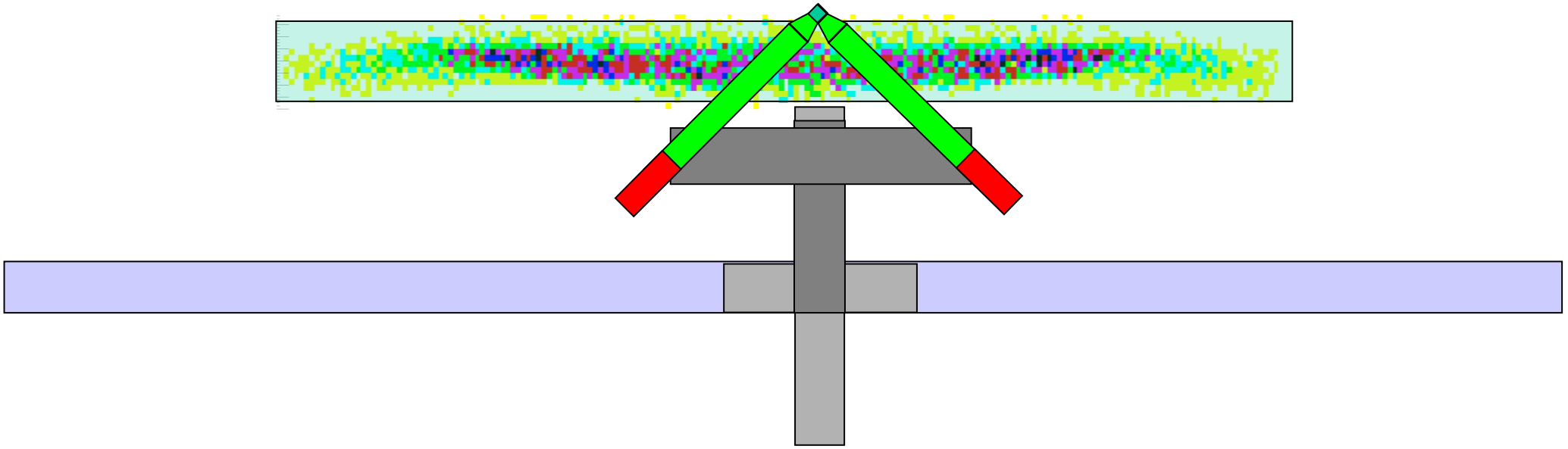

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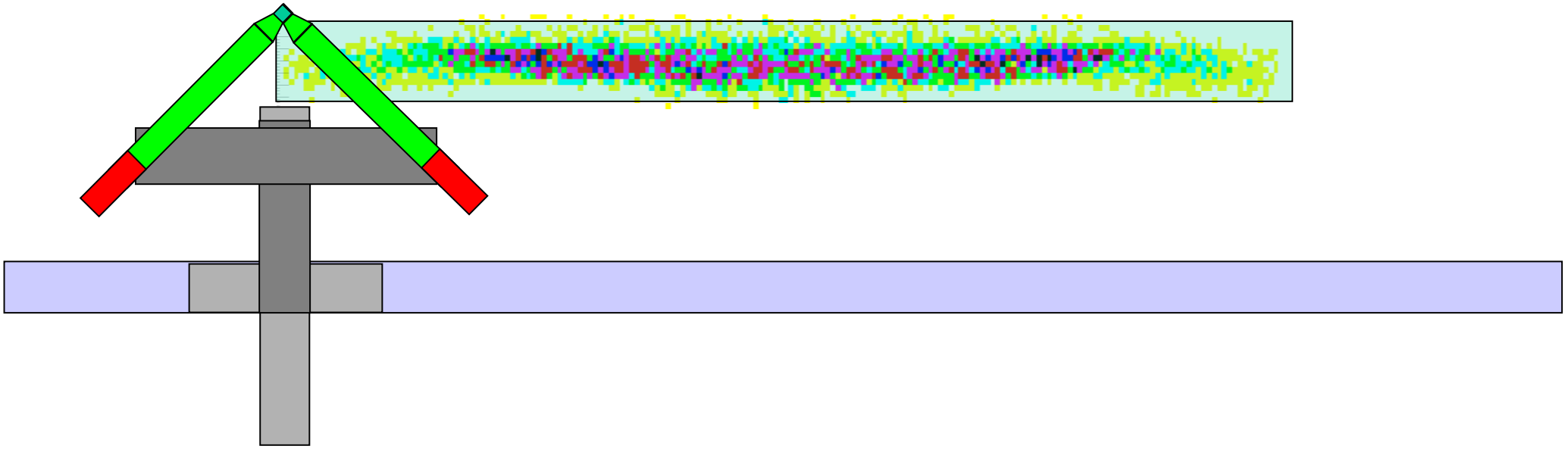

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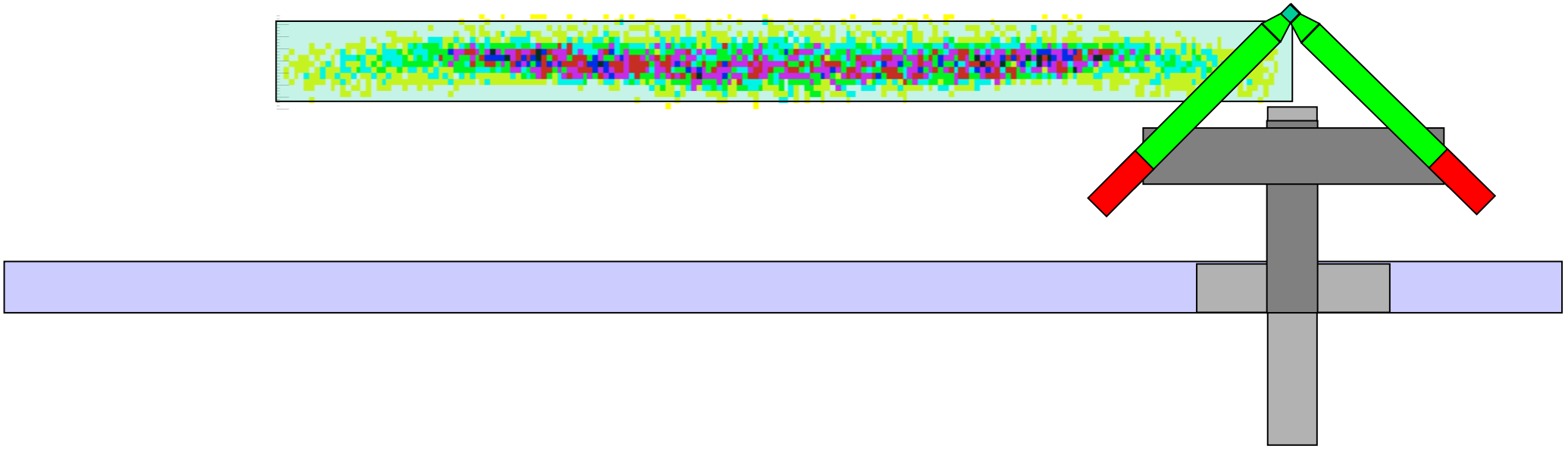

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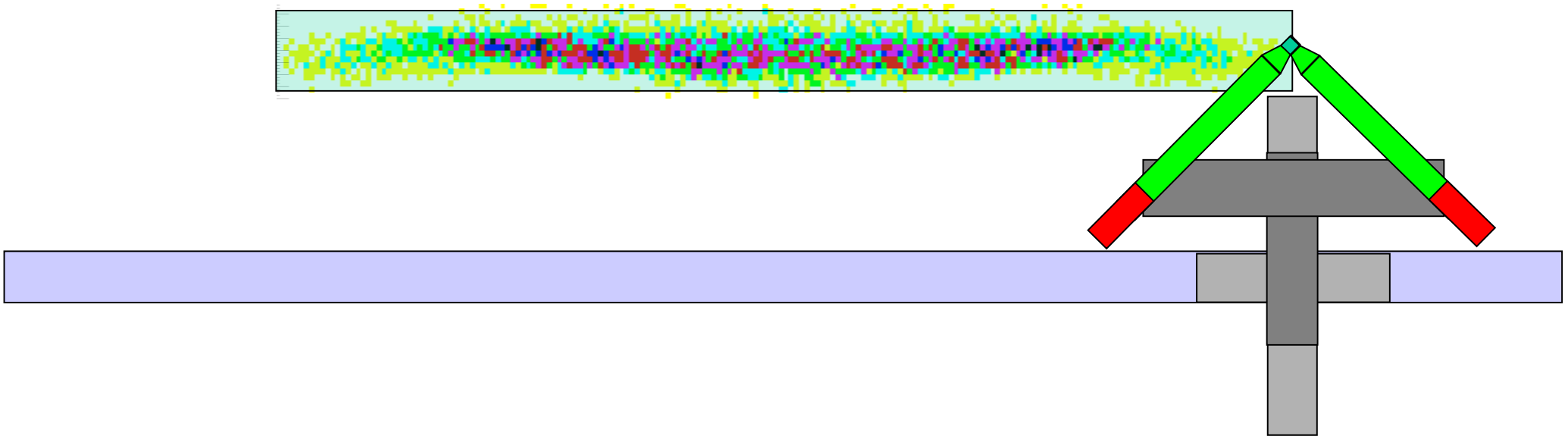
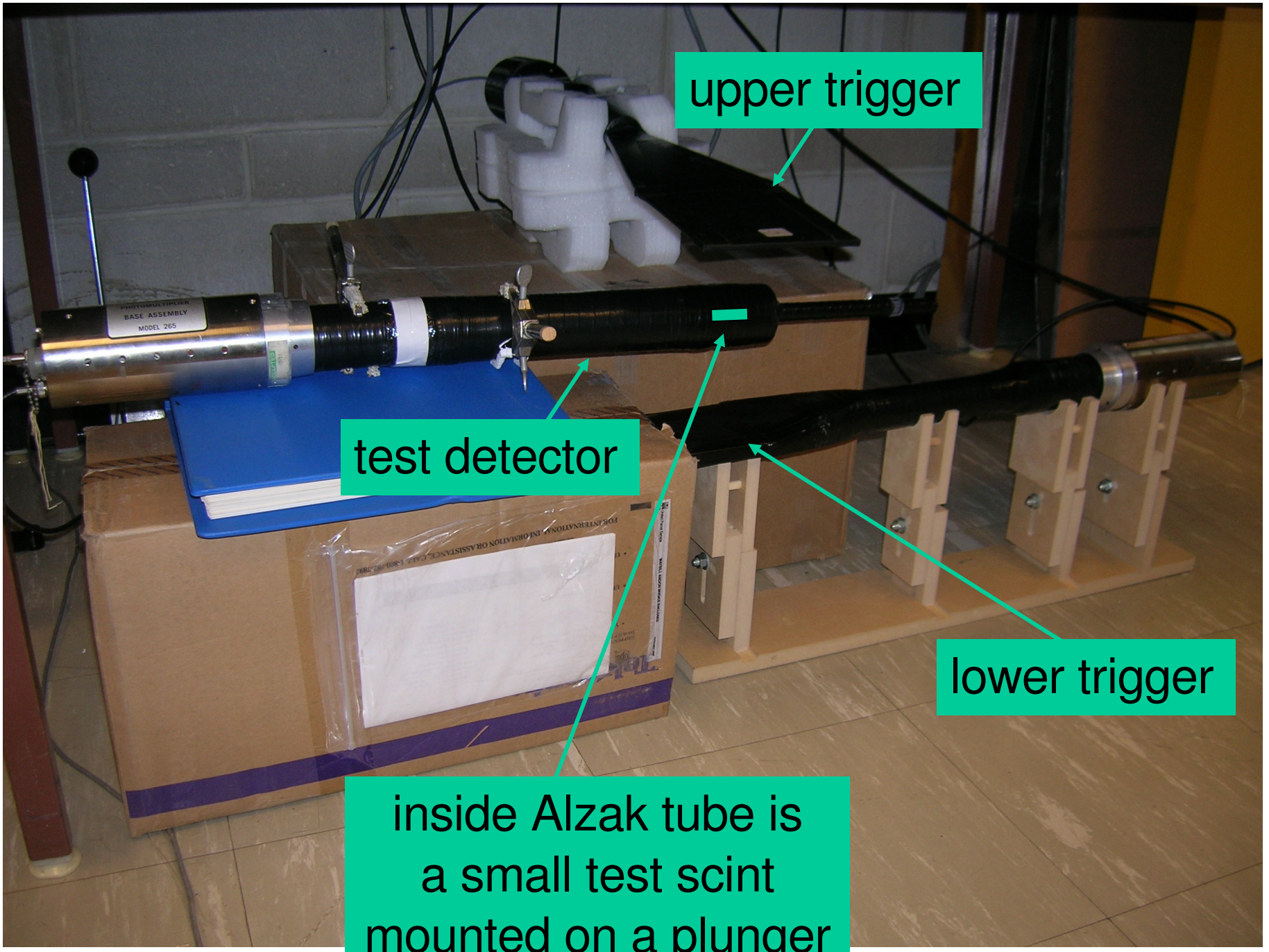


Prototyping Tests – Cosmics Testing



New CFI Test Electronics

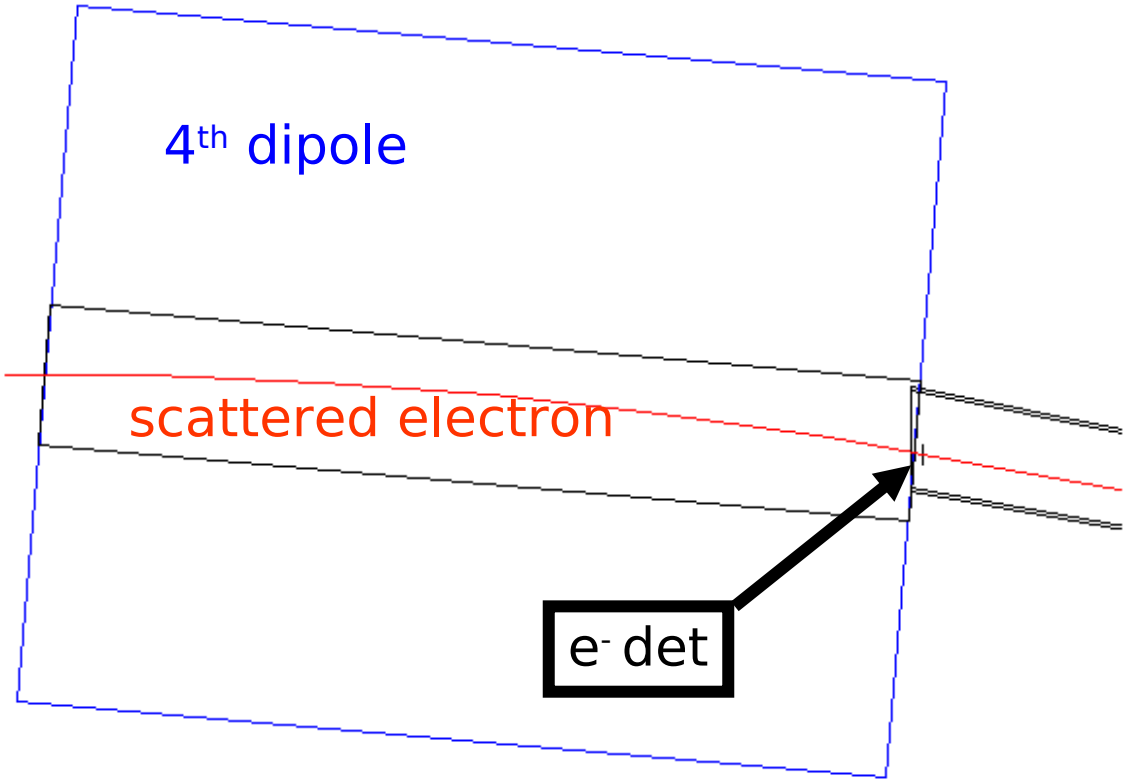
- Multichannel HV system.
- Multichannel VME ADC/TDC/Scaler
- NIM bin with modules with lemo connectors on them!
- Lemo cables purchased from TRIUMF
- 500 MHz DPO oscilloscope.
- A few more items to be purchased.

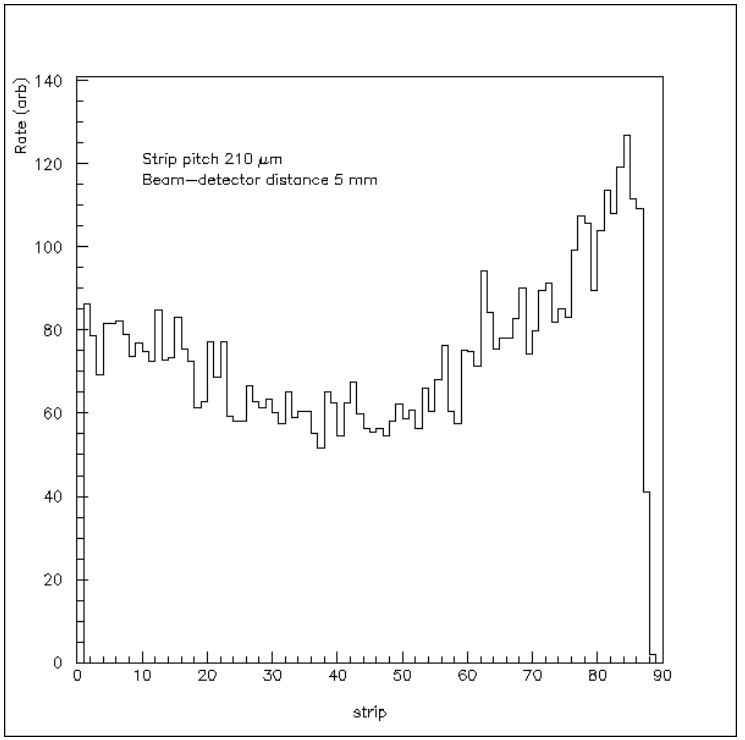
Detector Projects at UWinnipeg

Project	Timeframe	People
G-Zero Cherenkov electronics	2005	Alana Lajoie-O'Malley Blair Cardigan Smith
UCNA LED pulsers	2006	David Harrison
UCNA muon veto (at LANL)	2006	Vince Bagnulo
Qweak Quartz Scanner	2005 – 2009	David Harrison Jie Pan (G) Peiqing Wang (G)
Qweak Compton Diamond Det.	2006 – 2009	Doug Storey Peiqing Wang (G) Anna Micherdzinska (PD)

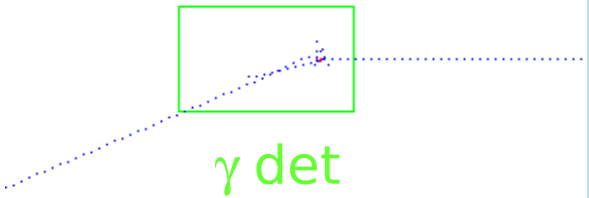
Also we have to analyze the data once it comes in! Alex Coppens (G), and G-Zero UG's.

Diamonds are Forever
(D. Storey, UWinnipeg undergrad thesis)





Strip map for Compton events 210 μm strips



- Detector to measure the handedness of the electrons.
- New collaboration with Steen (“Mr. Diamond”) Dannefaer, UM Engineering, Mississippi State University.
- Crossing my fingers until April 1 (not funded yet).

Summary

- Precision tests of Electroweak Standard Model may lead to interesting discoveries!
- But challenging experiments must be conducted.
- The University of Winnipeg is having an impact on several key experiments in this field.