Qweak: a parity-violation experiment

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<u>Outline:</u>

- Principle
- Experiment
- U. Winnipeg

Mini-Review from Last Class

Precise Parity Violation Experiment

-> Precision Measurement of Weak Force

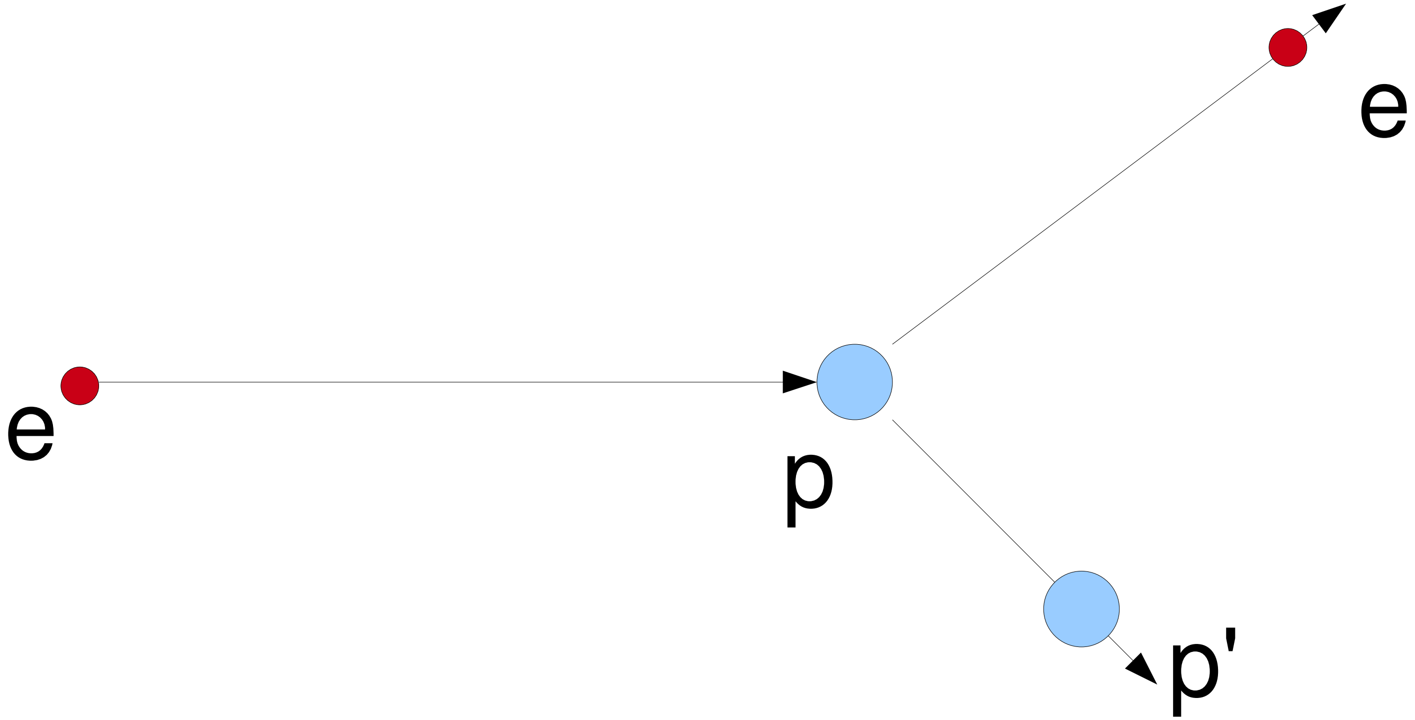
-> Test of Electroweak Theory

-> Discovery of New Physics

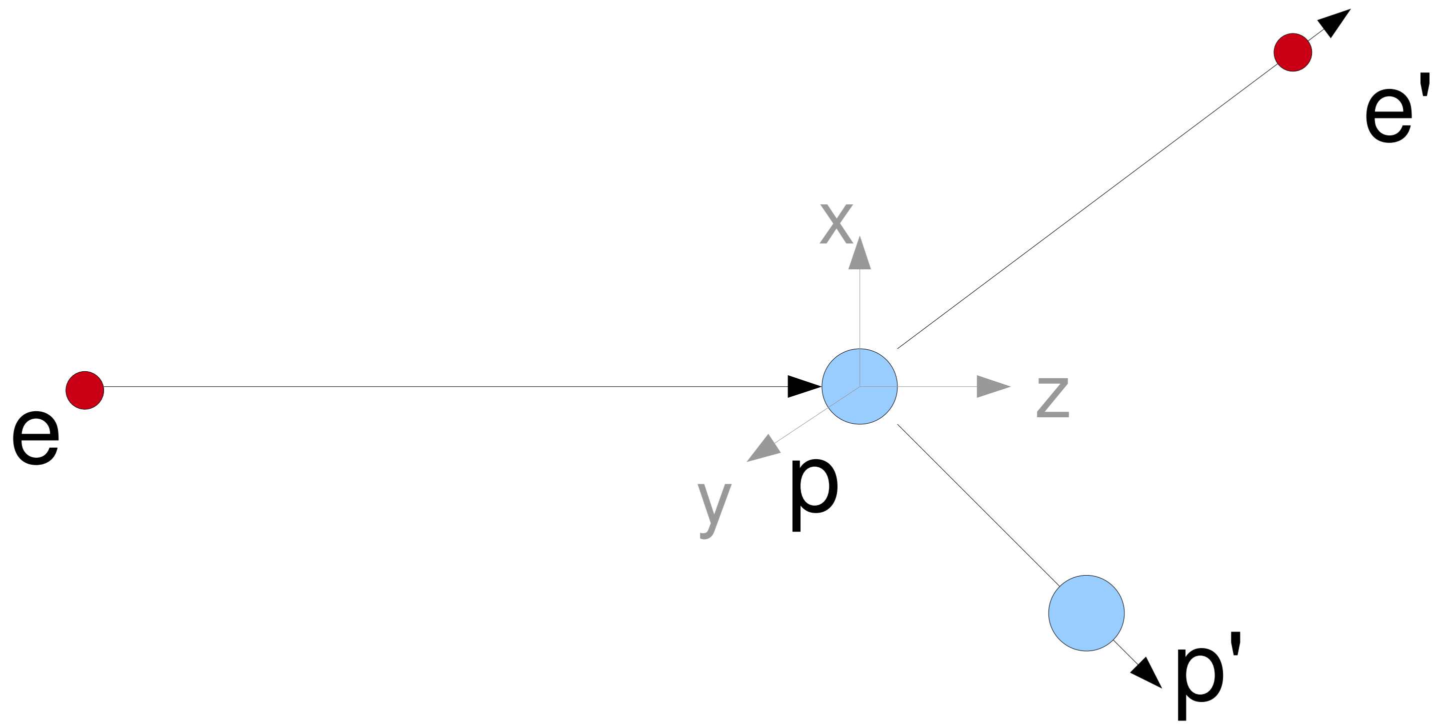
-> Pick up Nobel Prize

(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.)

e-p scattering

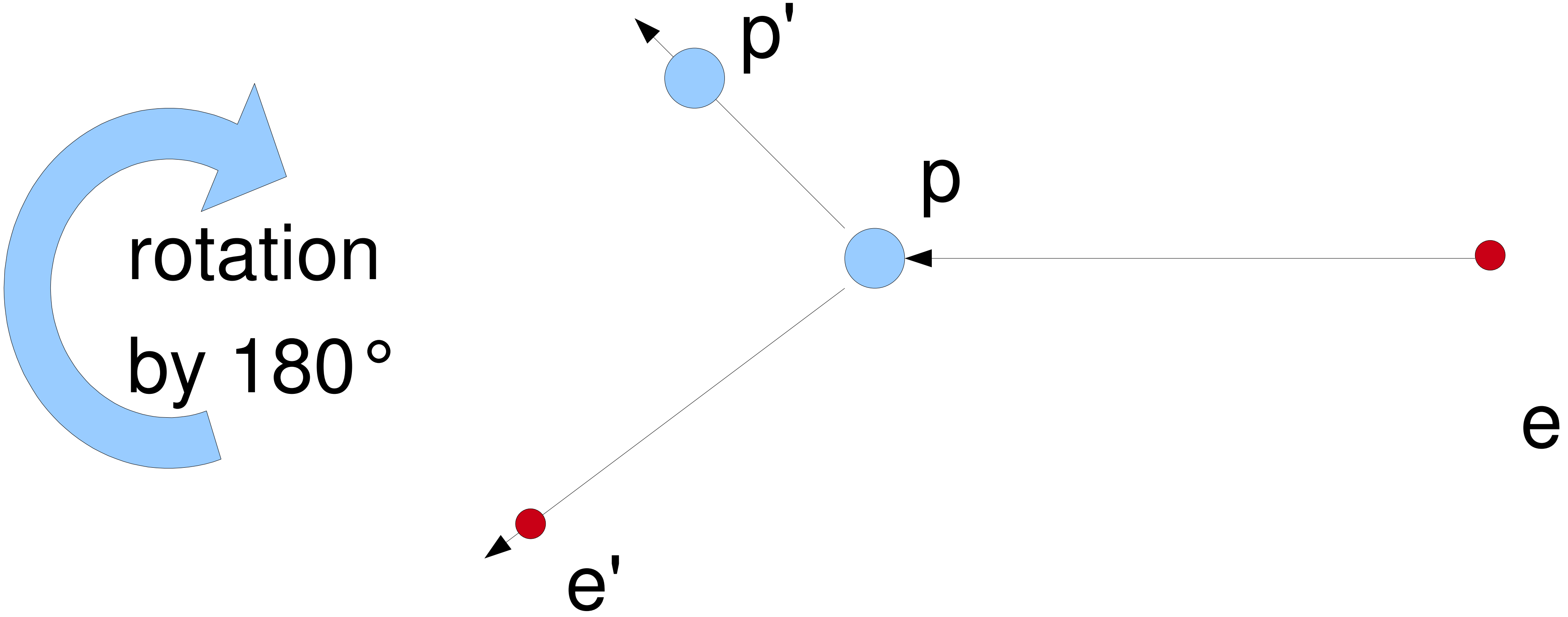


e-p scattering

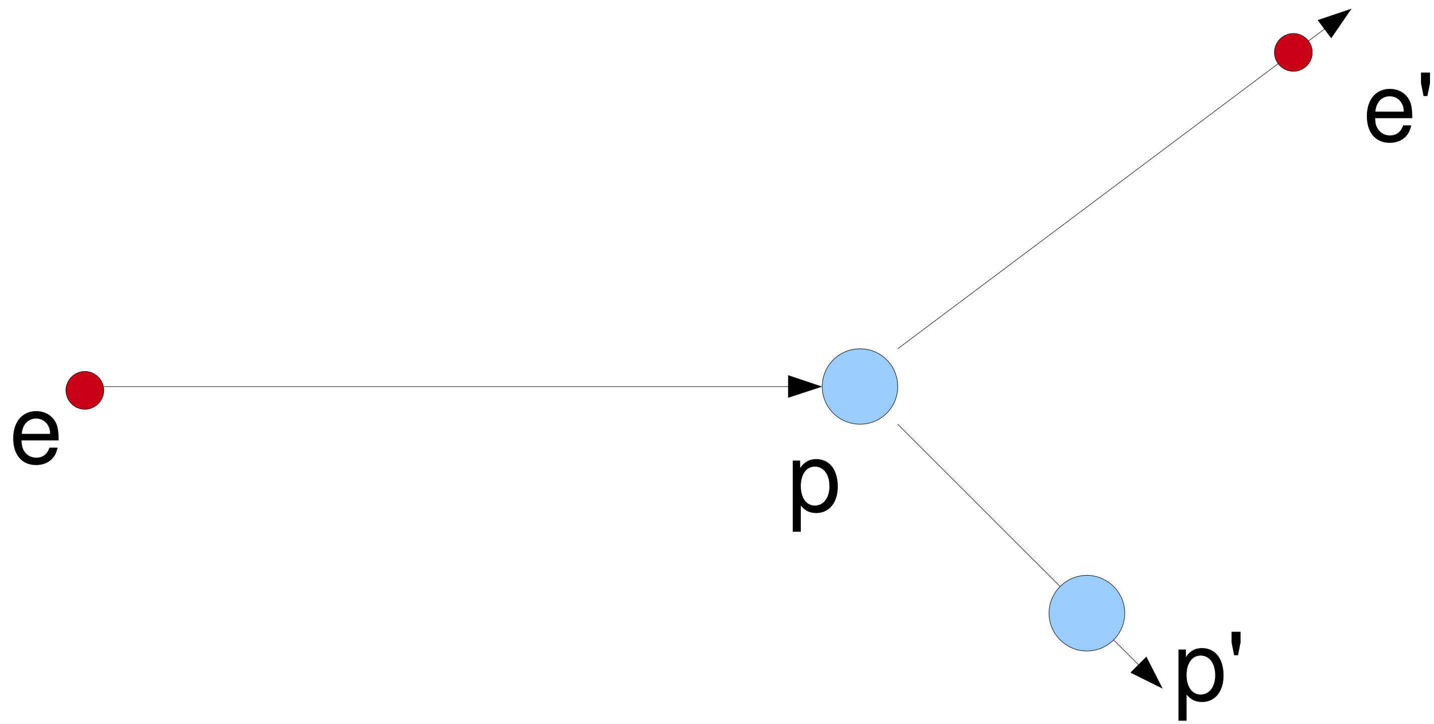


Parity: reflect all vectors through origin.

e-p scattering

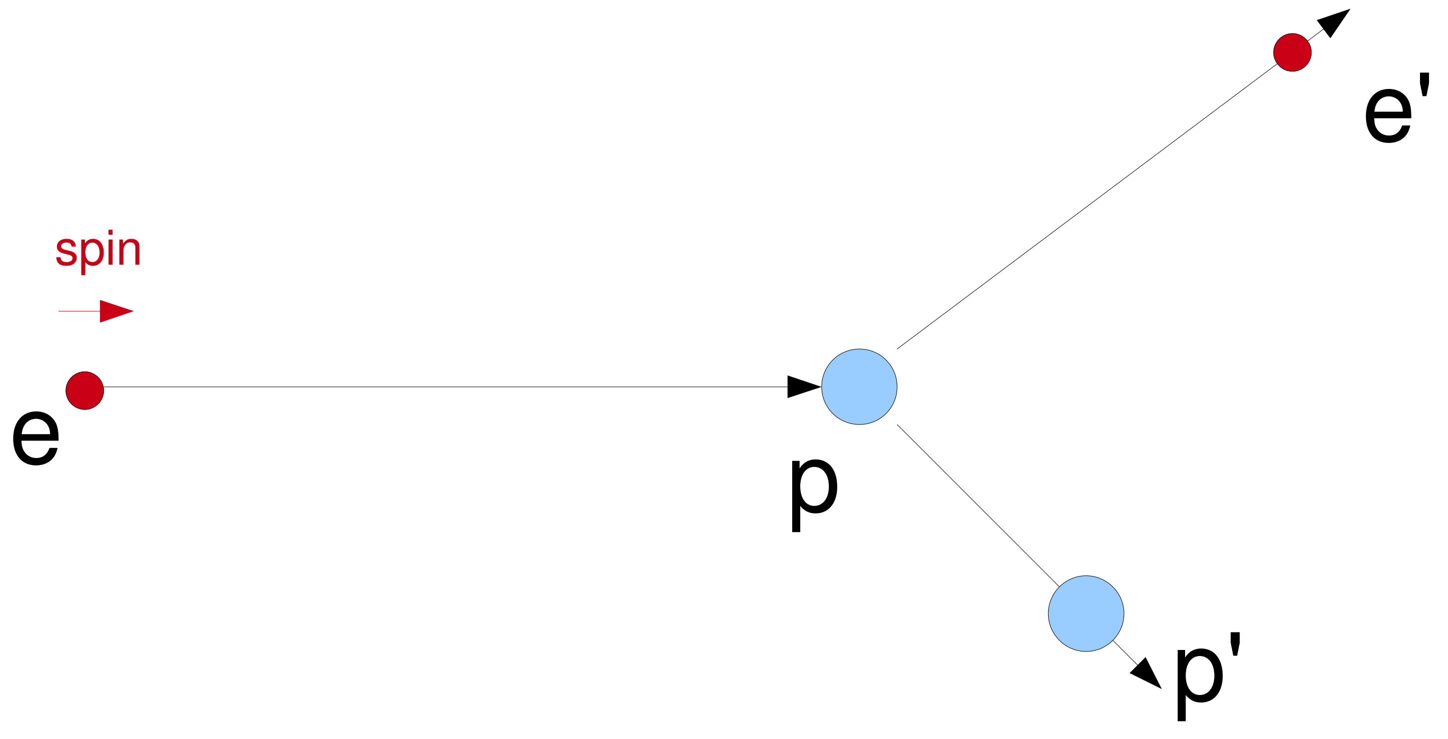


e-p scattering

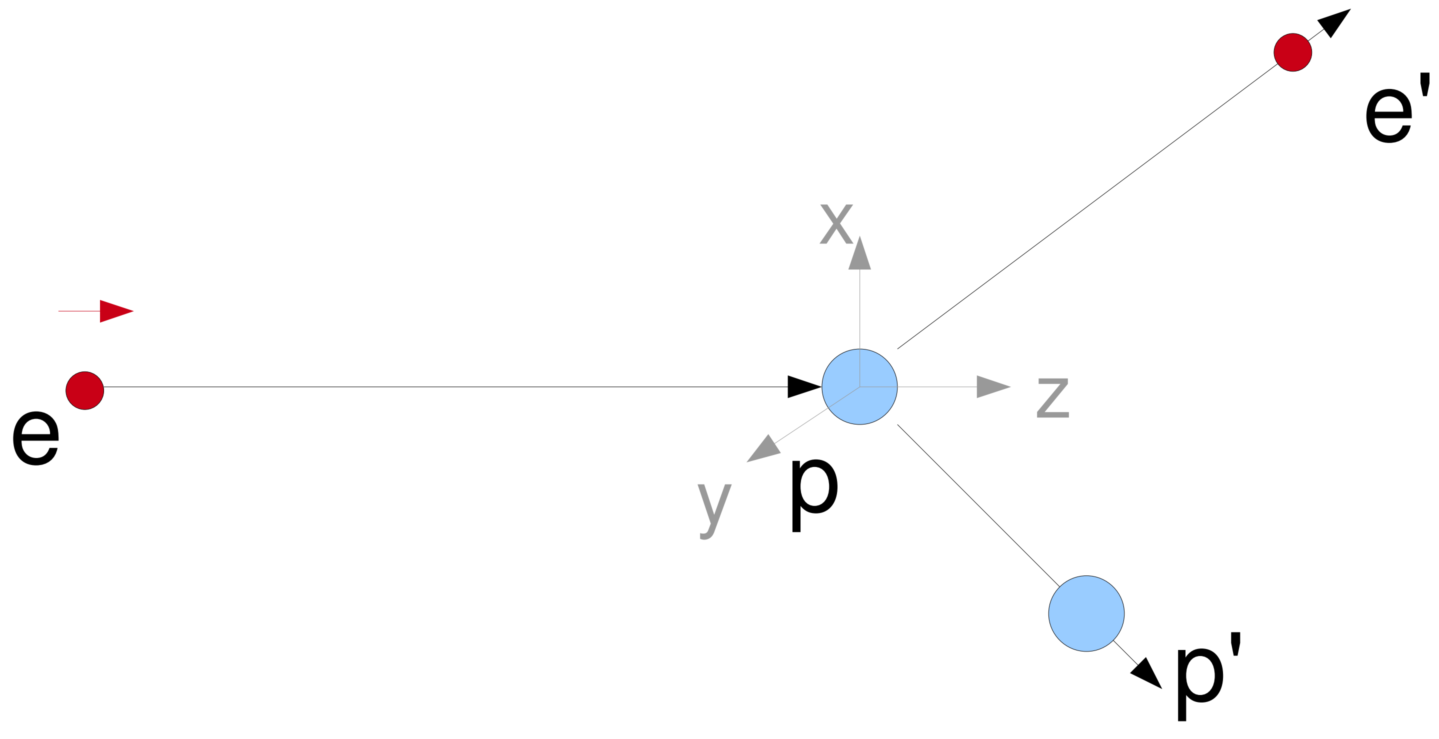


Conclusion: regular old e-p scattering is the parity-reversed image of itself.

$\vec{e}$-p scattering

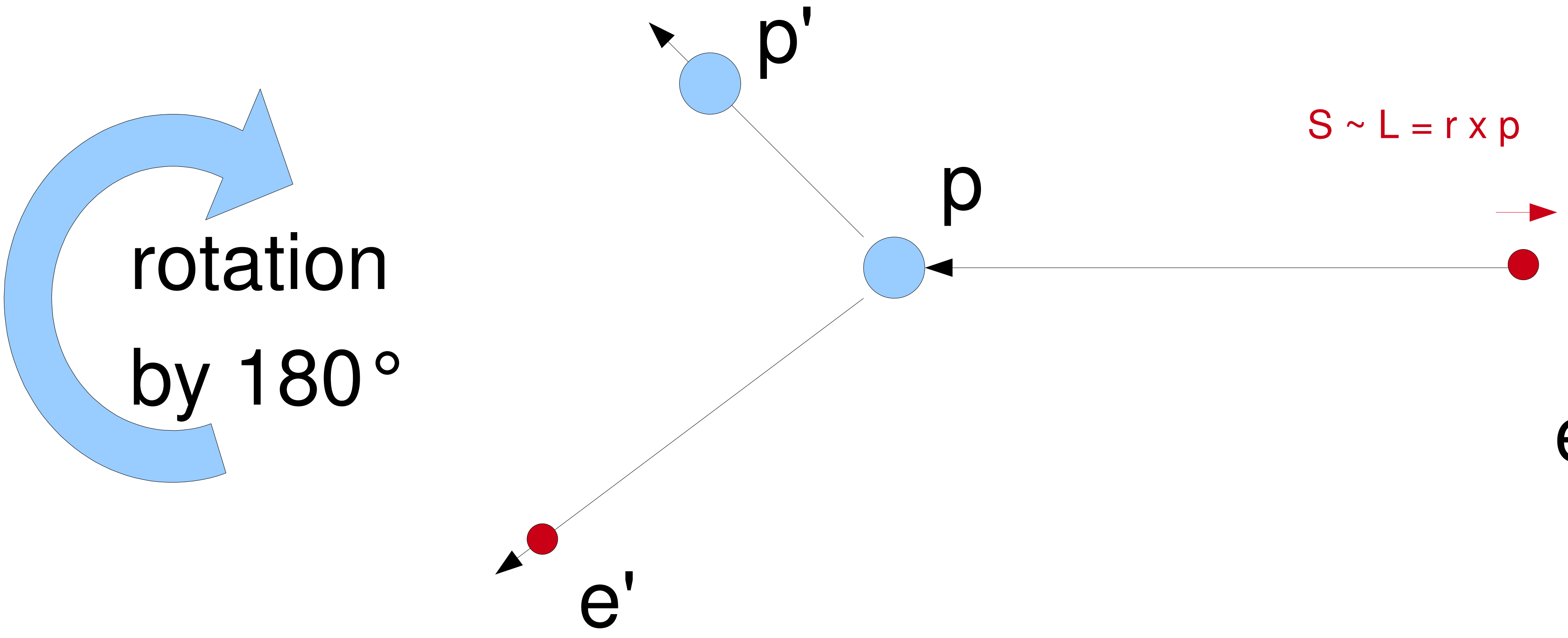


e-p scattering

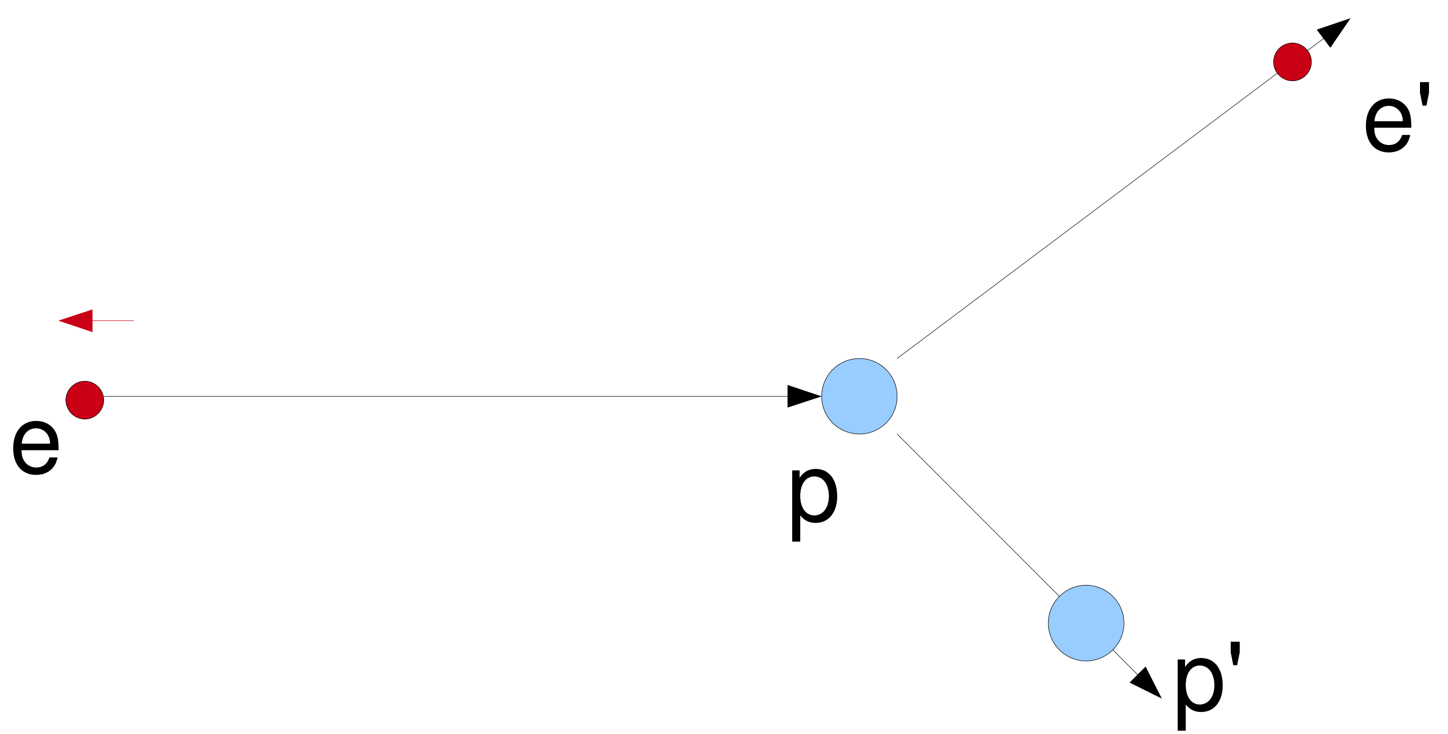


Parity: reflect all vectors through origin.

$\vec{e}$-p scattering



$\vec{e}$-p scattering



Conclusion: helicity reversal is like doing the opposite parity experiment.

$$h = \frac{\vec{S} \cdot \vec{p}}{\sqrt{S^2 p^2}}$$

“Asymmetry”

- We compare the two experiments using:

$$A = \frac{N^+ - N^-}{N^+ + N^-}$$

- Here, N± is the number of counts we got, in a detector, for the ± helicity experiment.
- In fact,
  - we reverse the beam helicity all the time (1/150) s.
  - we usually measure currents instead of counts

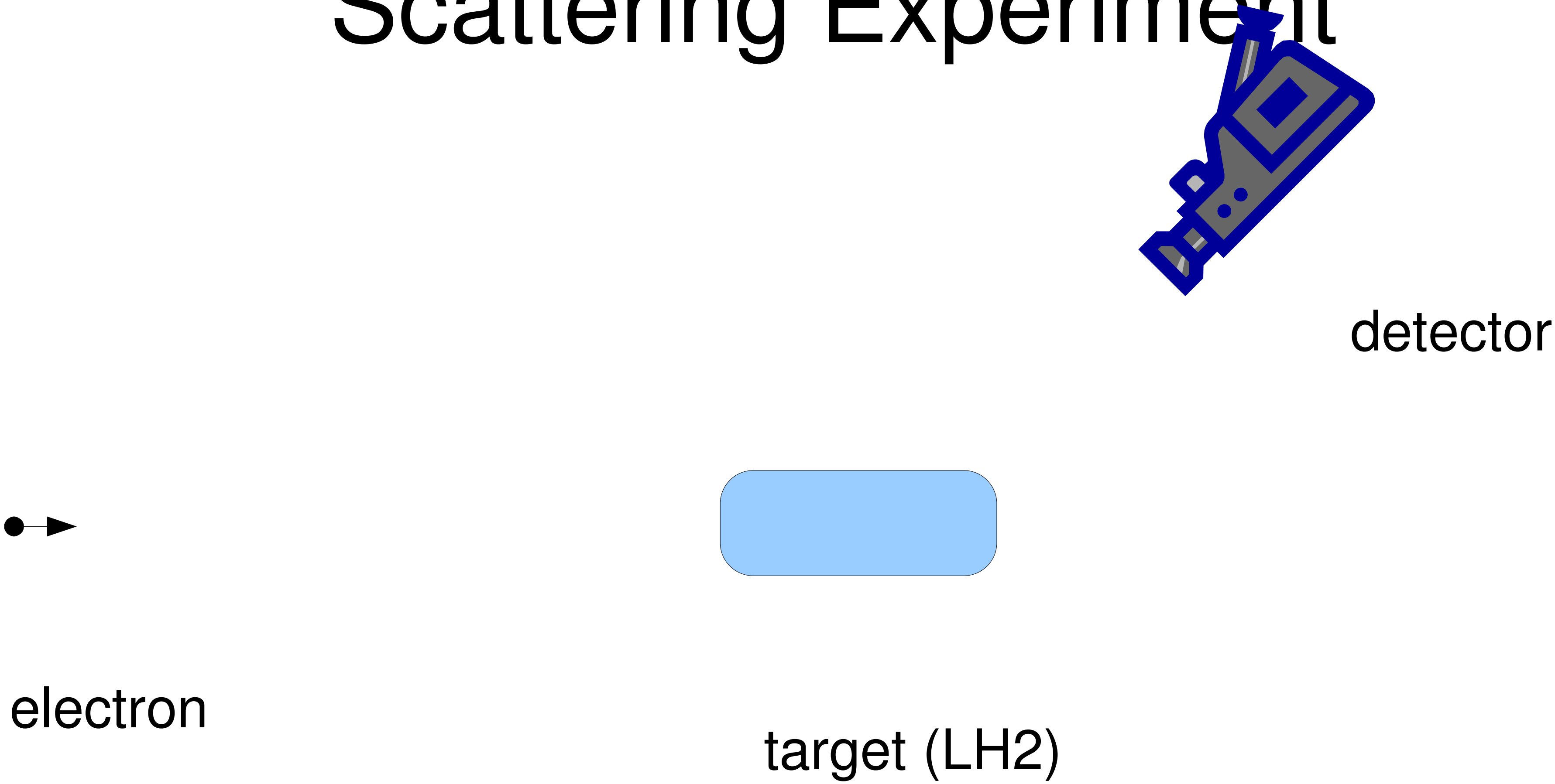
Statistical Uncertainty

- Taking the N+ and N- as two different experiments:

$$\delta A = \frac{1}{\sqrt{N^+ + N^-}} = \frac{1}{\sqrt{N}}$$

- Now A = -1e-8   (very small)
- and we want dA = 0.01 |A| = 1e-10
  - We need N = 1e20. I.e. large $\mathscr{L} = (\mathrm{I/e})*(\rho \mathrm{t/m})$
    - (Luminosity = #electrons/s x #protons/cm^2)
    - Rate into $\mathrm{d}\Omega = \mathscr{L} \times \mathrm{d}\sigma/\mathrm{d}\Omega$, to get high rate.
  - Any small effect can potentially screw up this experiment (systematic errors)

Generic Parity Violation Scattering Experiment



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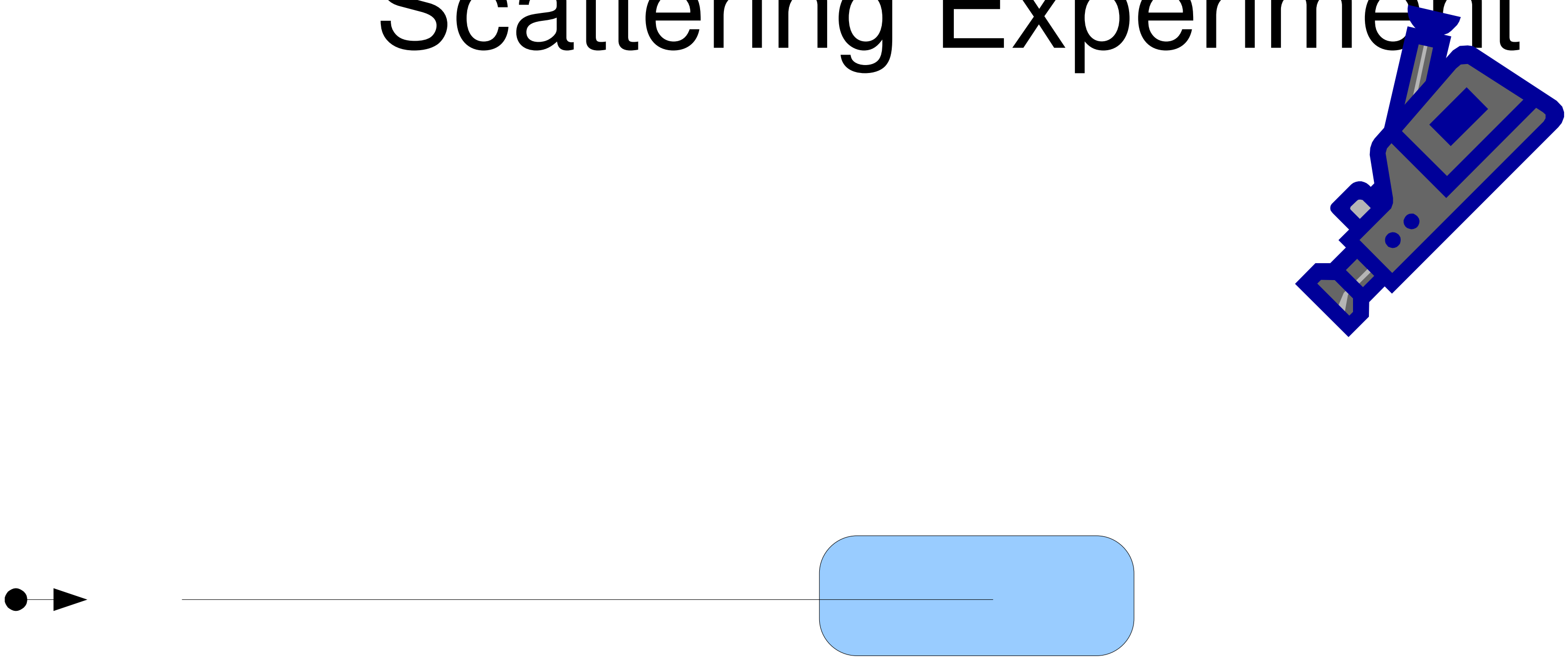
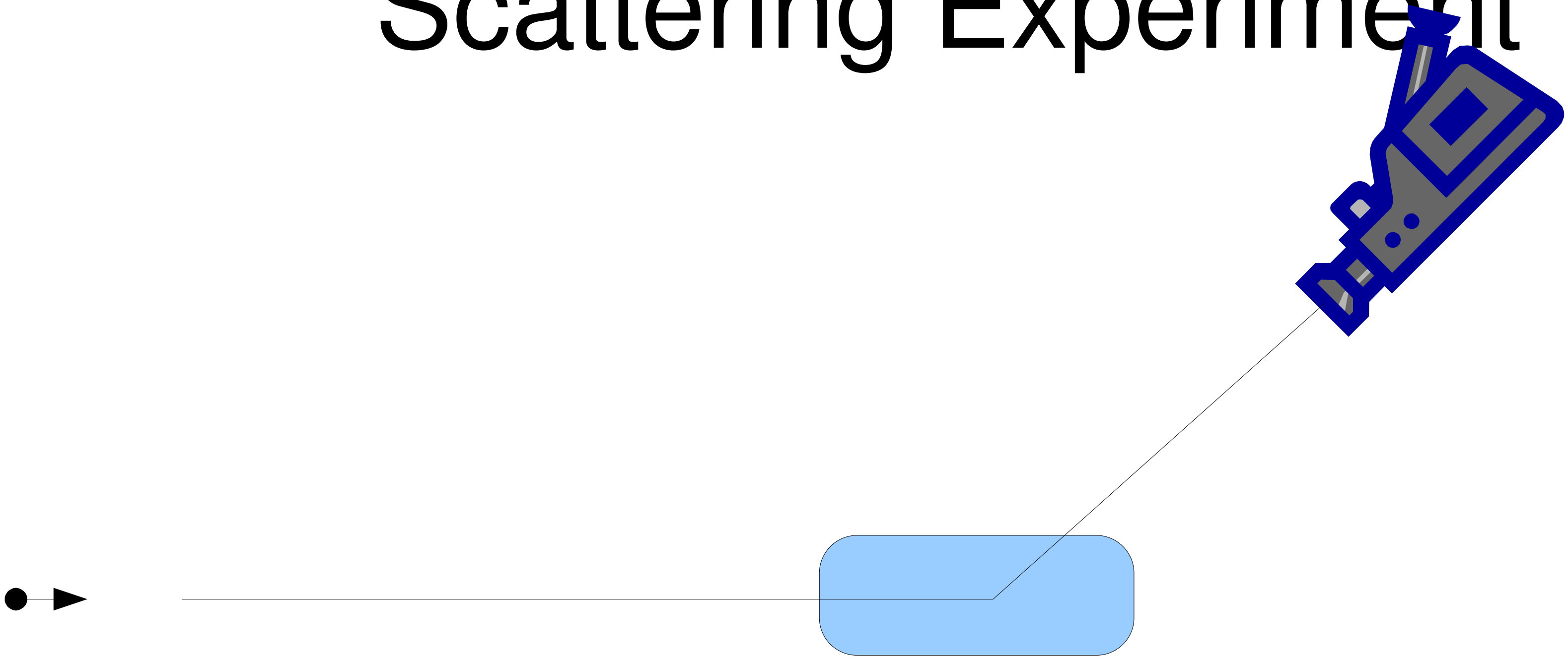
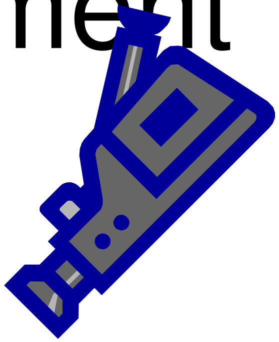


Generic Parity Violation Scattering Experiment

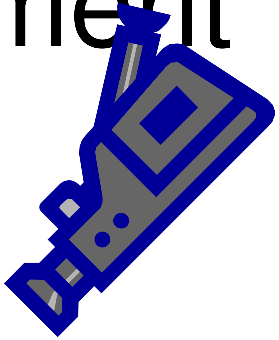


Generic Parity Violation Scattering Experiment

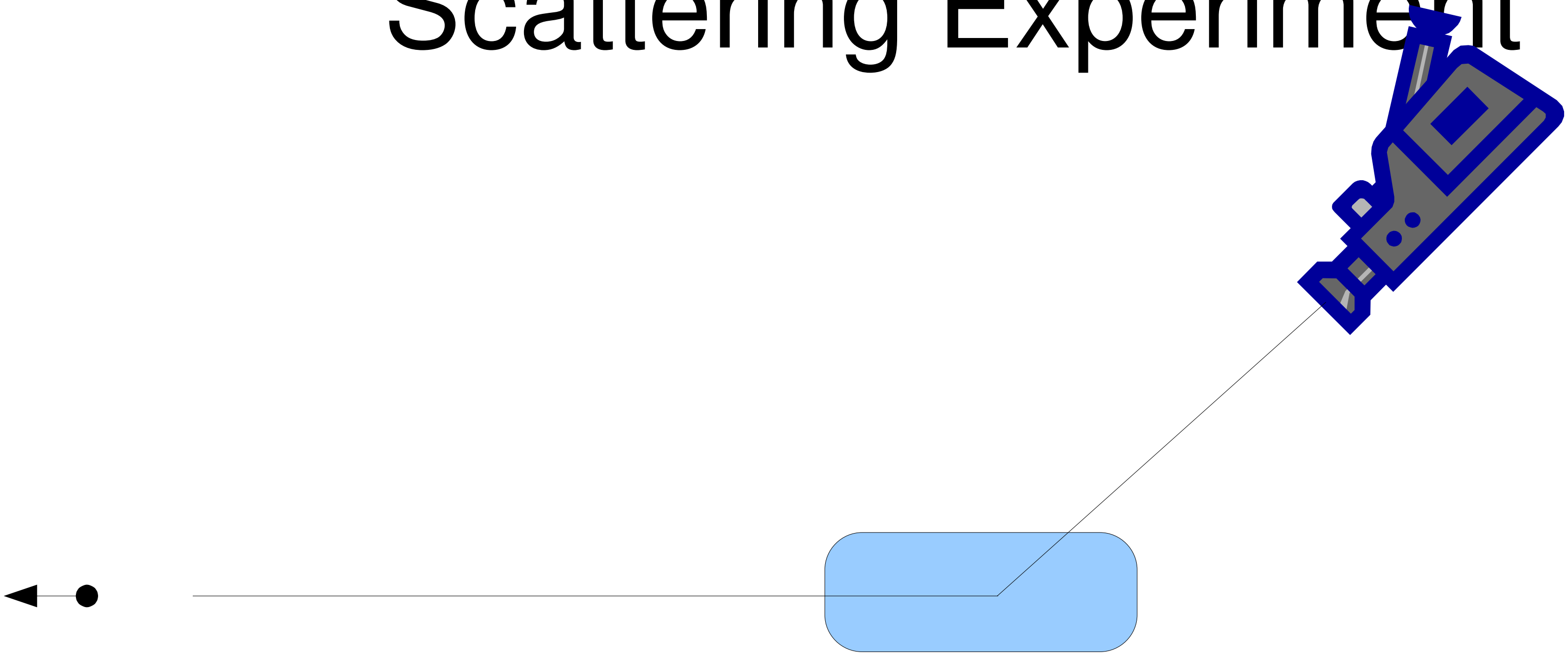


parity-reversed experiment

Generic Parity Violation Scattering Experiment



Generic Parity Violation Scattering Experiment



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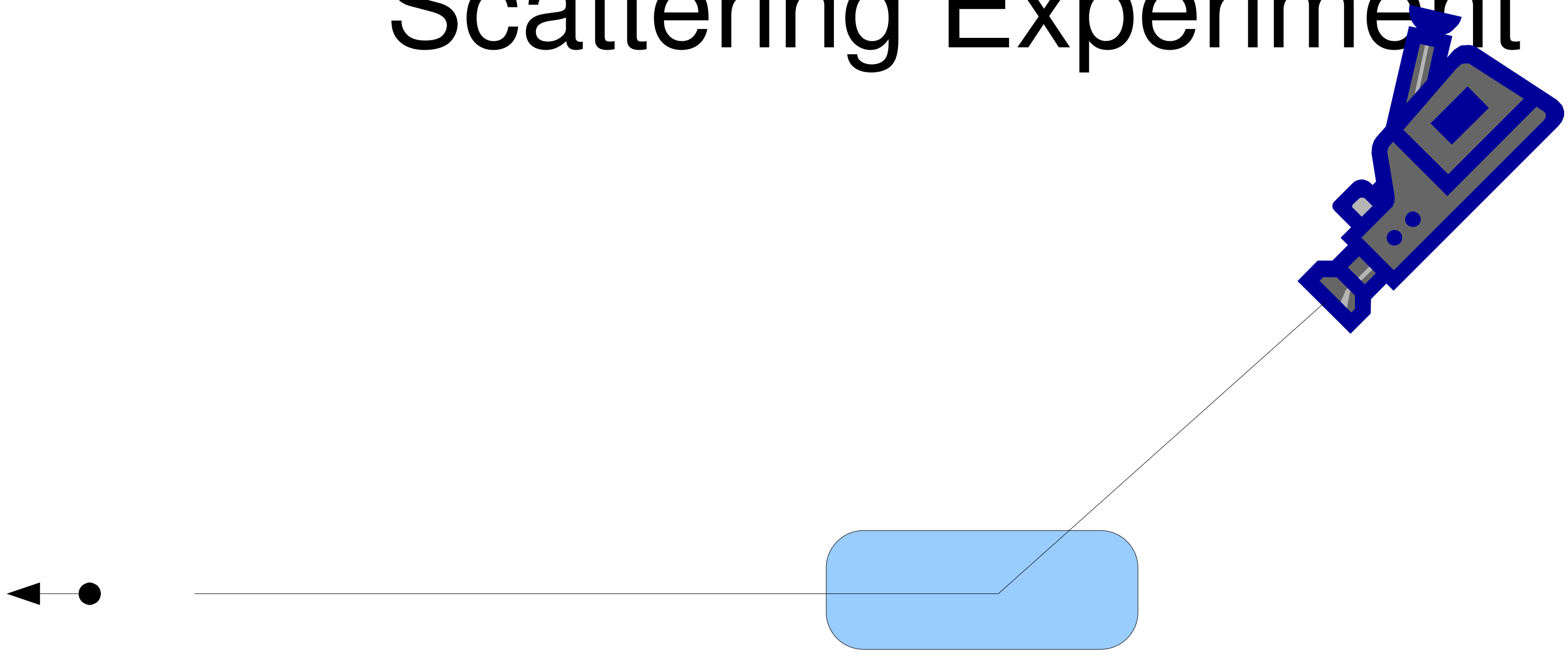
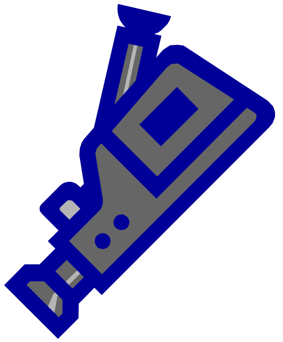
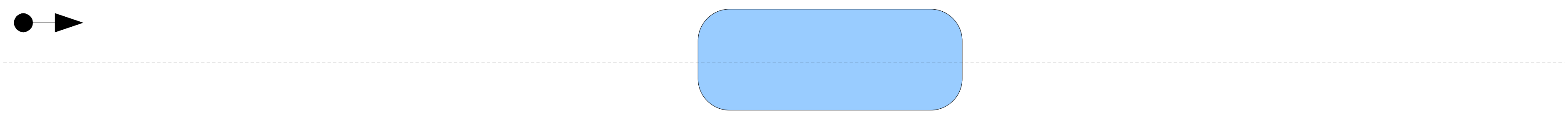


These experiments are the same to 10^{-7}

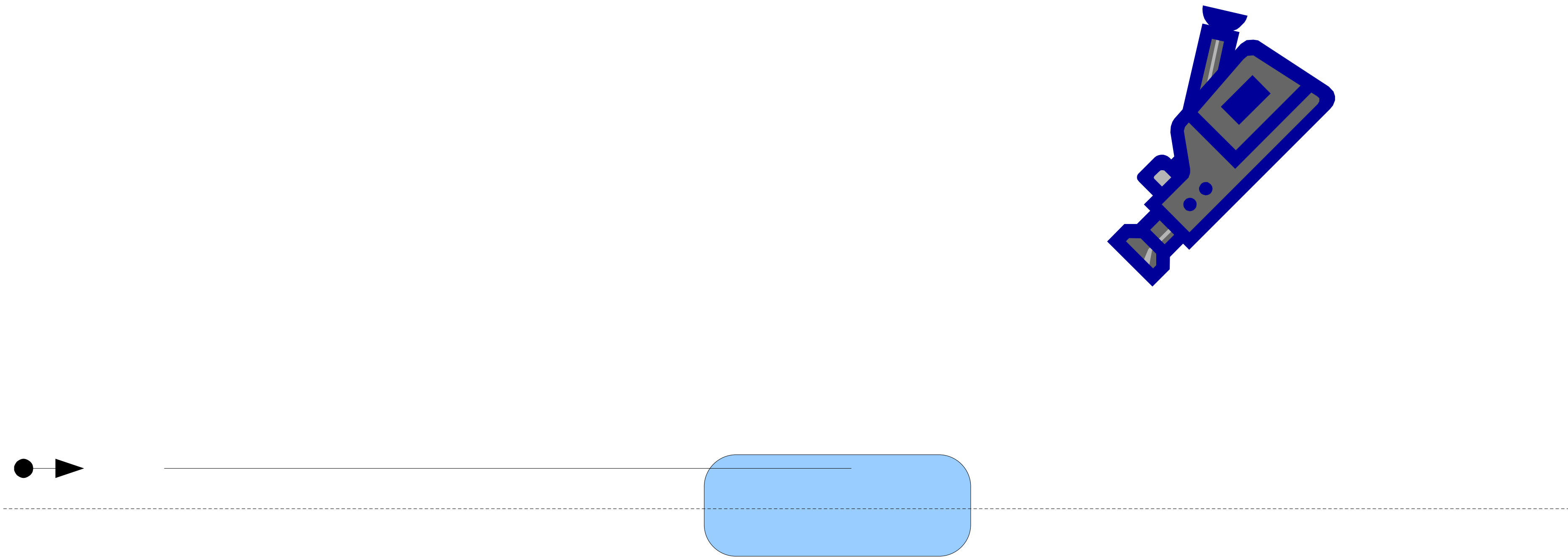
Helicity-Correlated Systematics

or: how to get screwed in a parity-violation experiment





Helicity-Correlated Systematics



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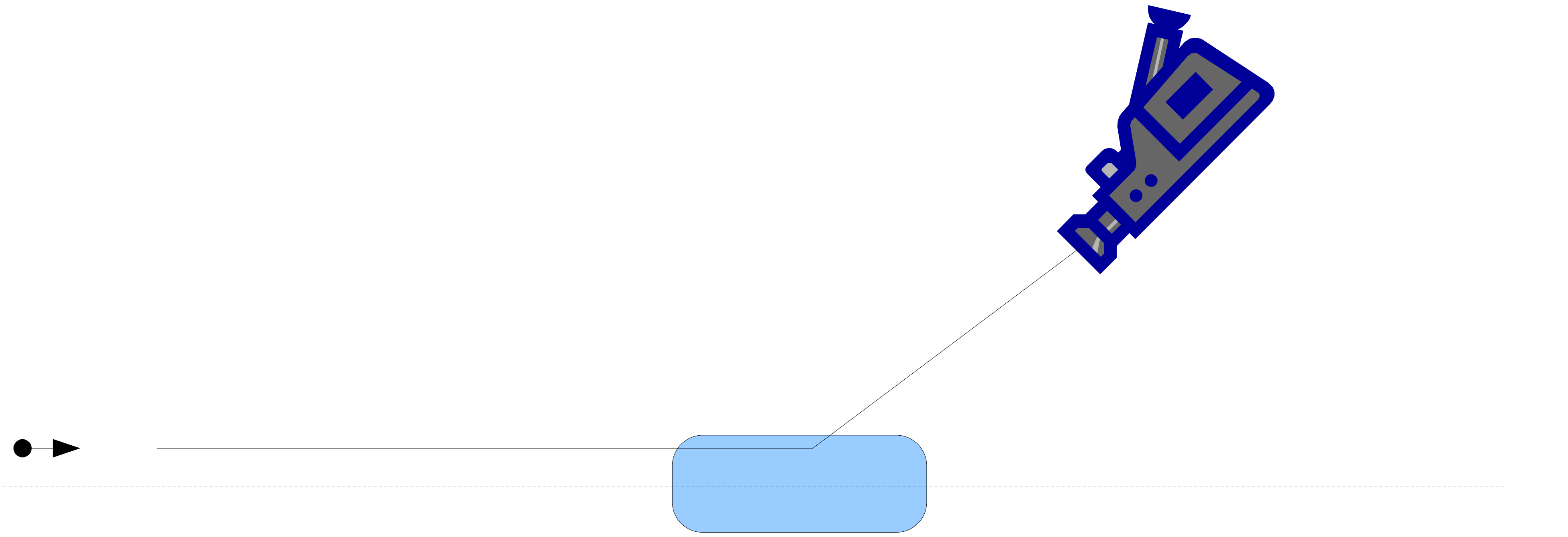

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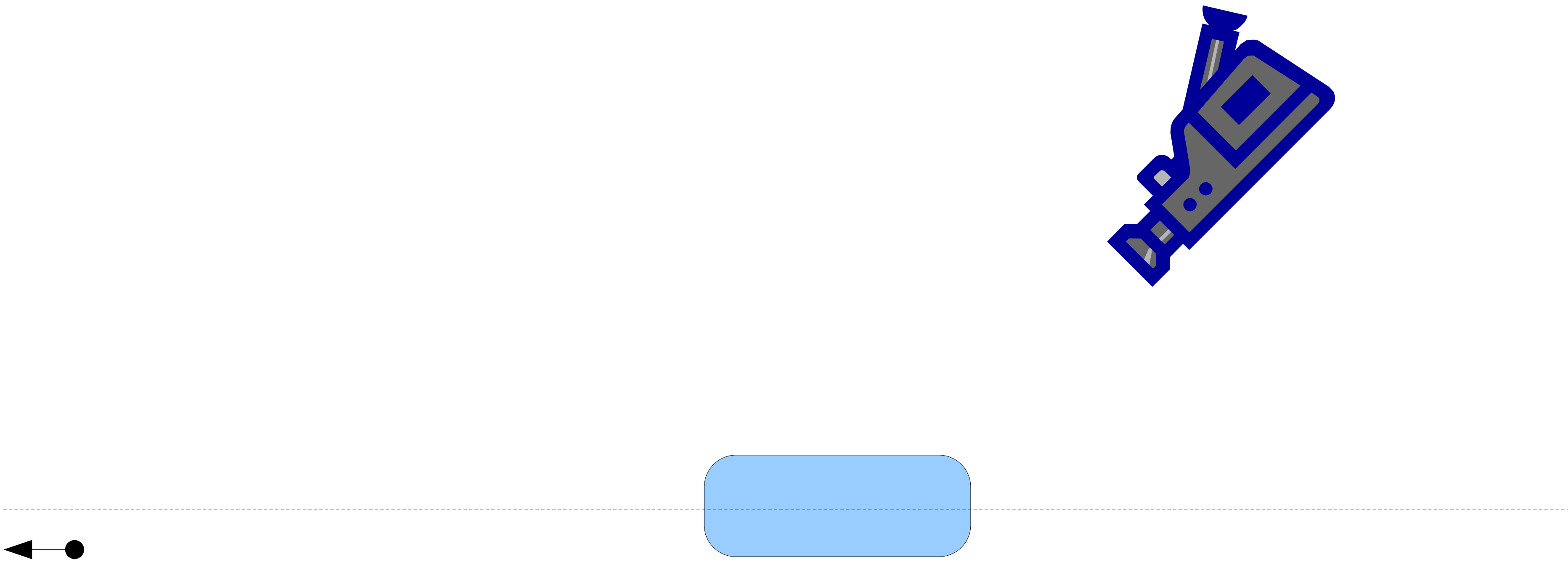

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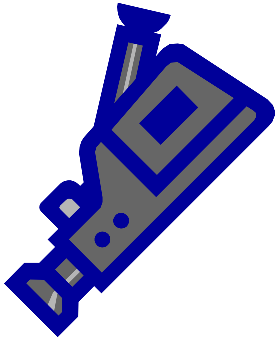

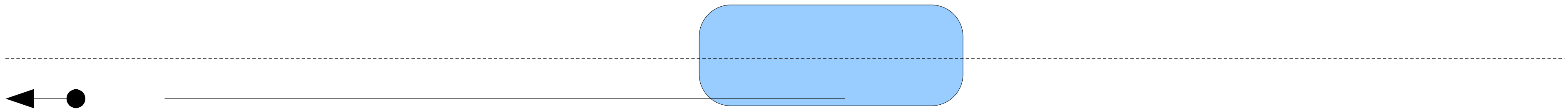

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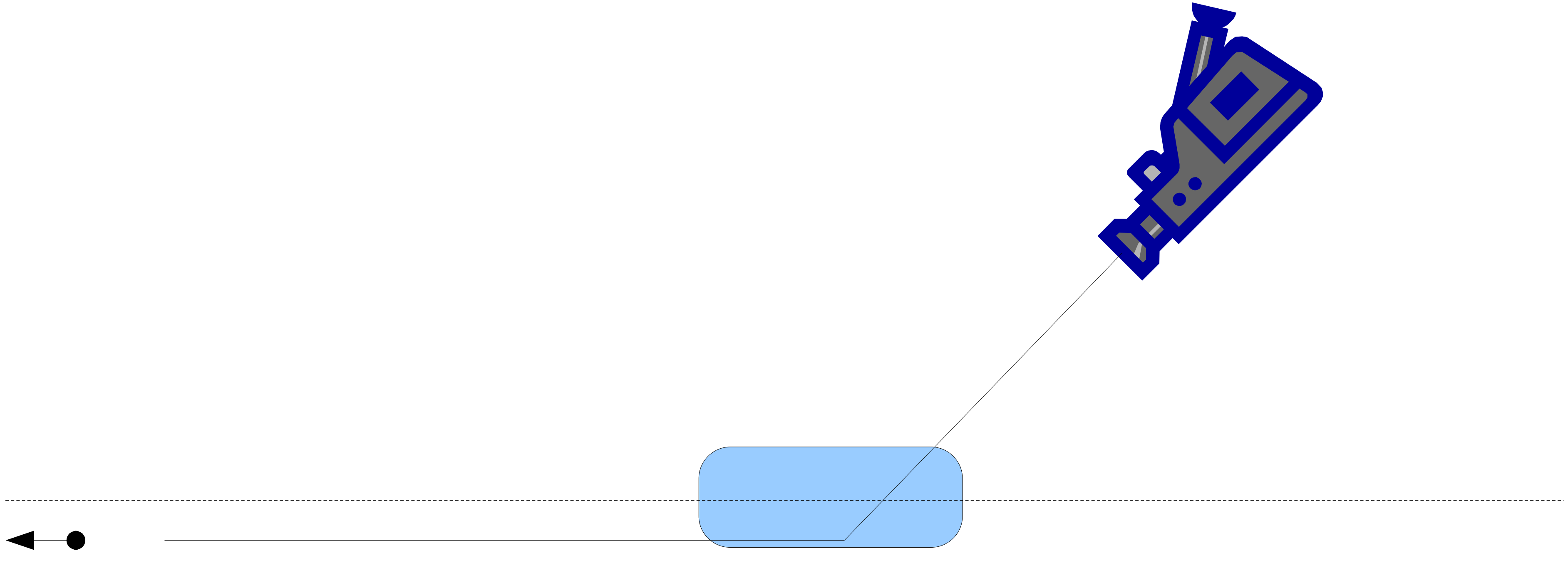

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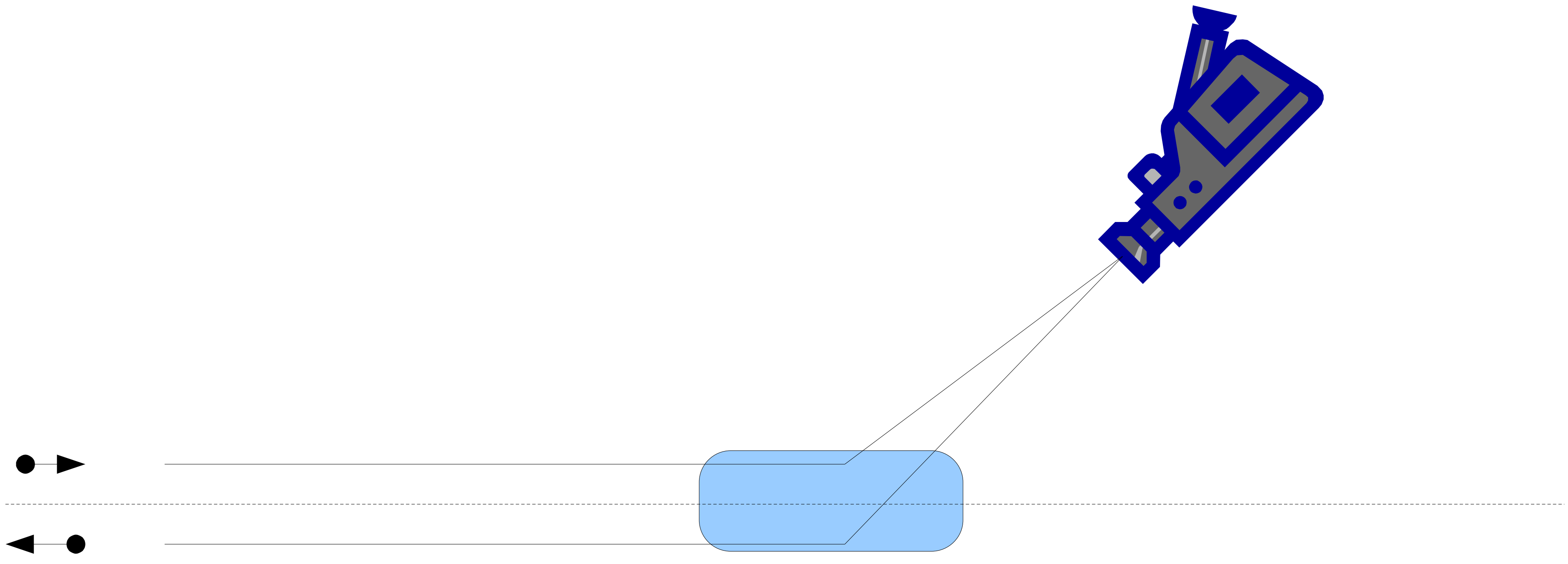

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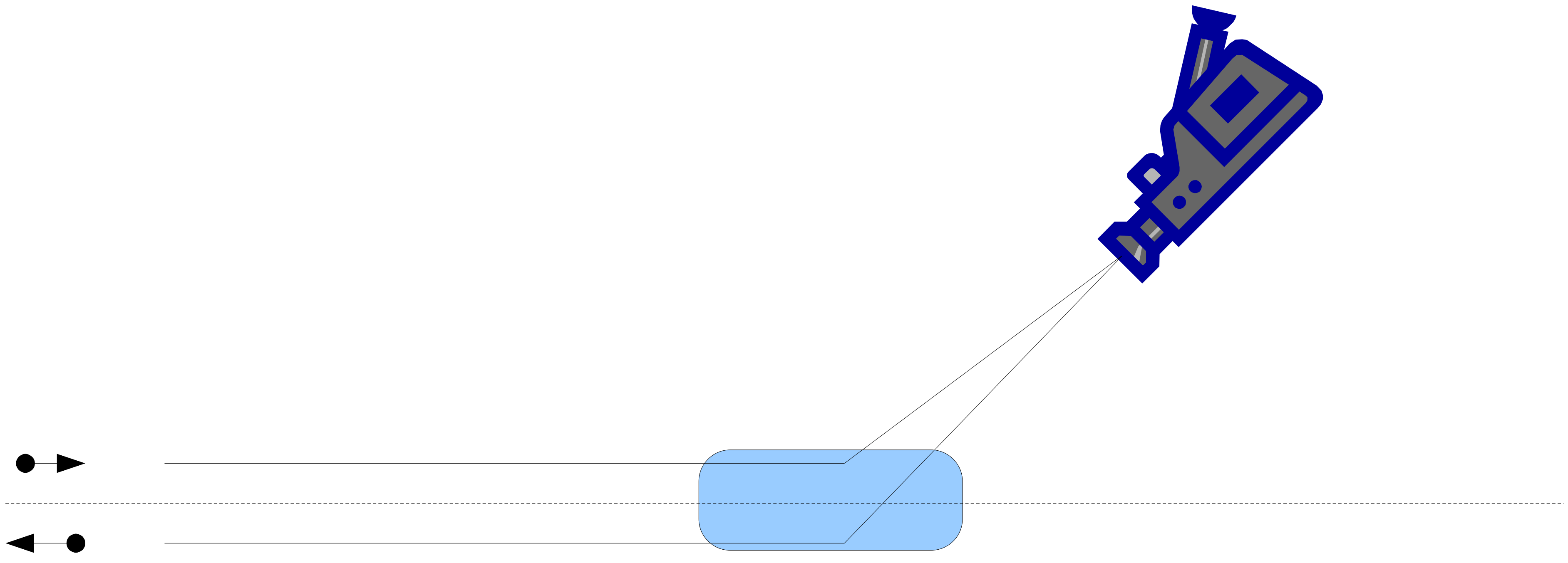
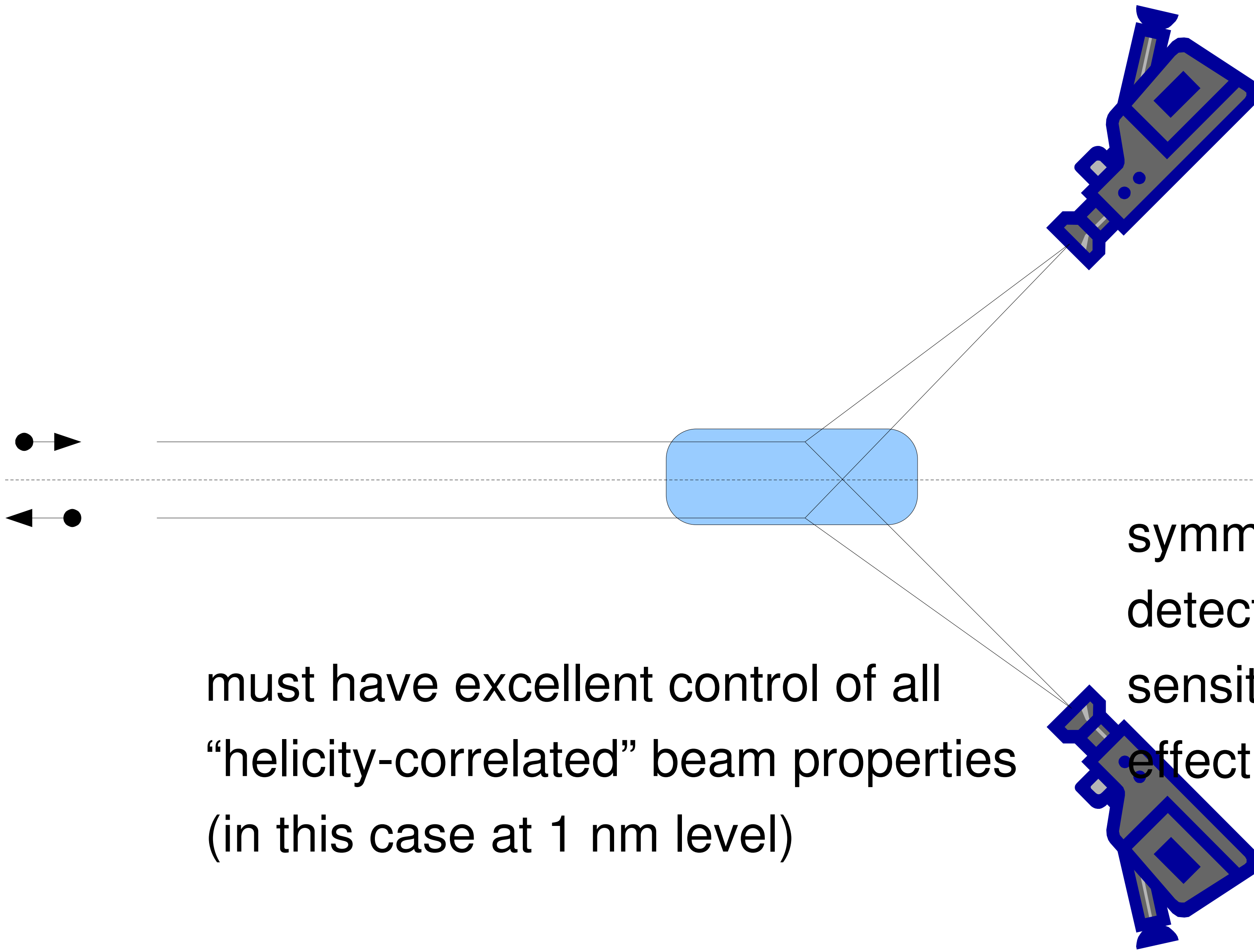


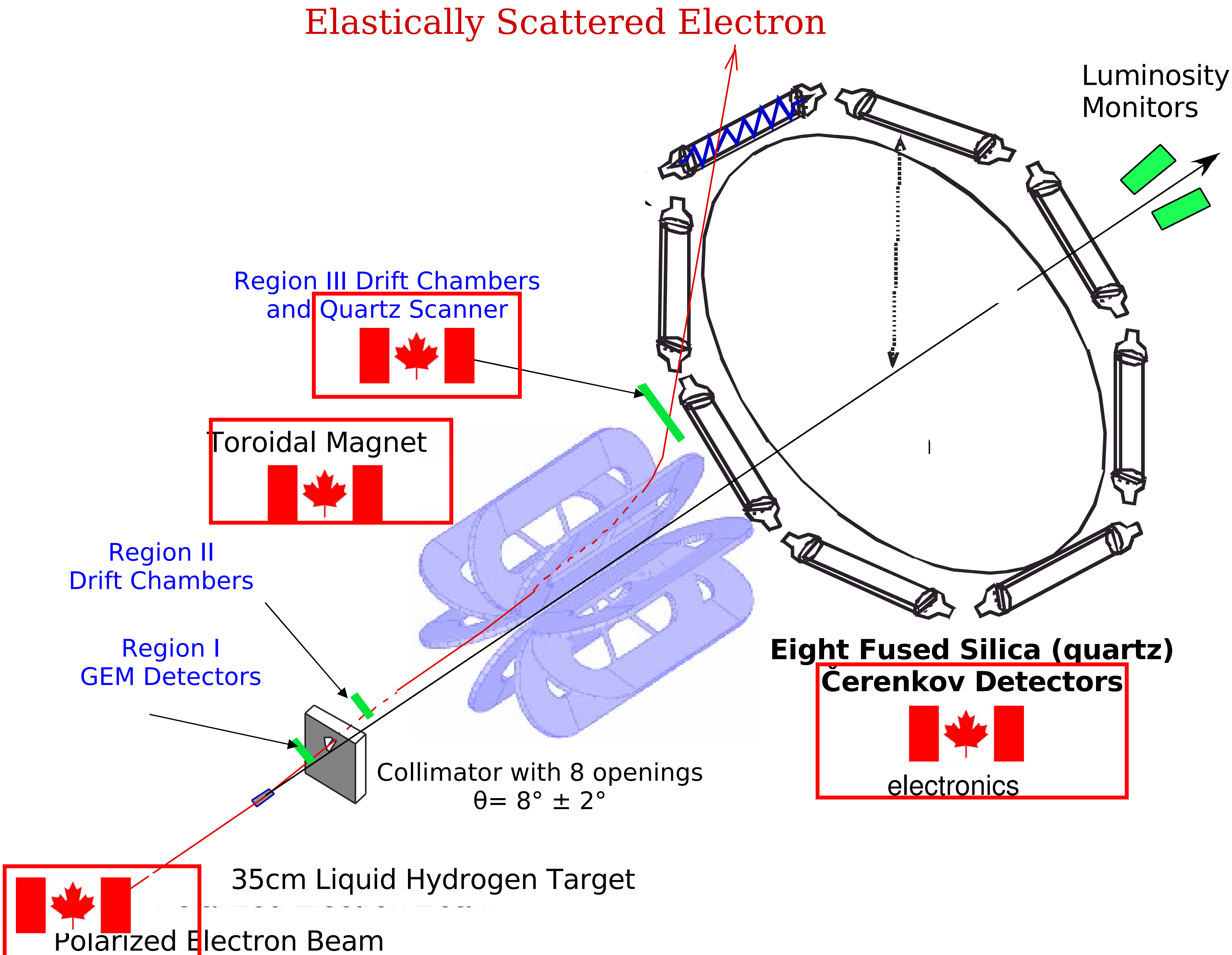
must have excellent control of all
“helicity-correlated” beam properties
(in this case at 1 nm level)

Helicity-Correlated Systematics

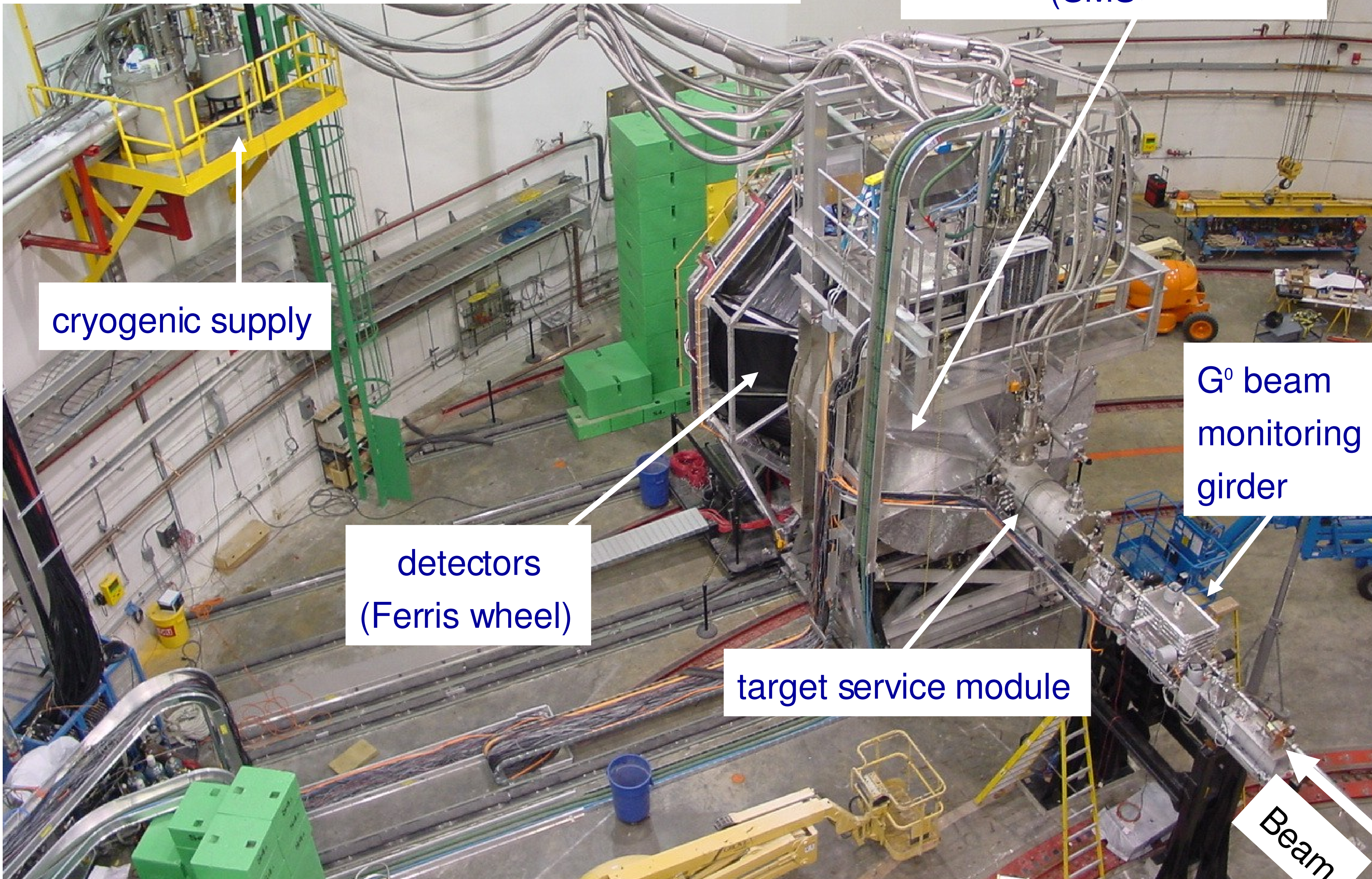


symmetry in detector to minimize sensitivity to this effect

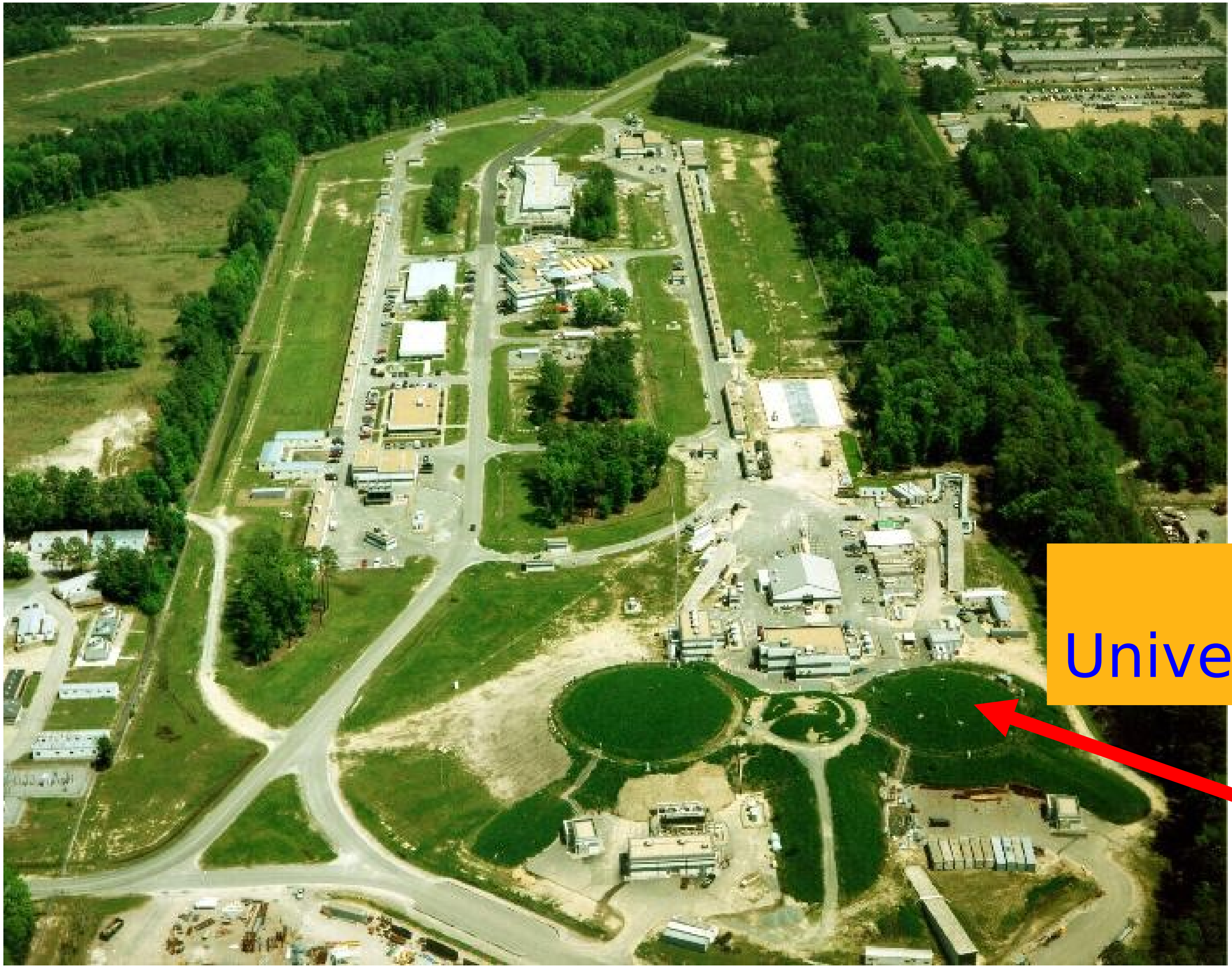
must have excellent control of all "helicity-correlated" beam properties (in this case at 1 nm level)


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

G^0 Forward-Angle Configuration at Jefferson Lab



Jefferson Lab

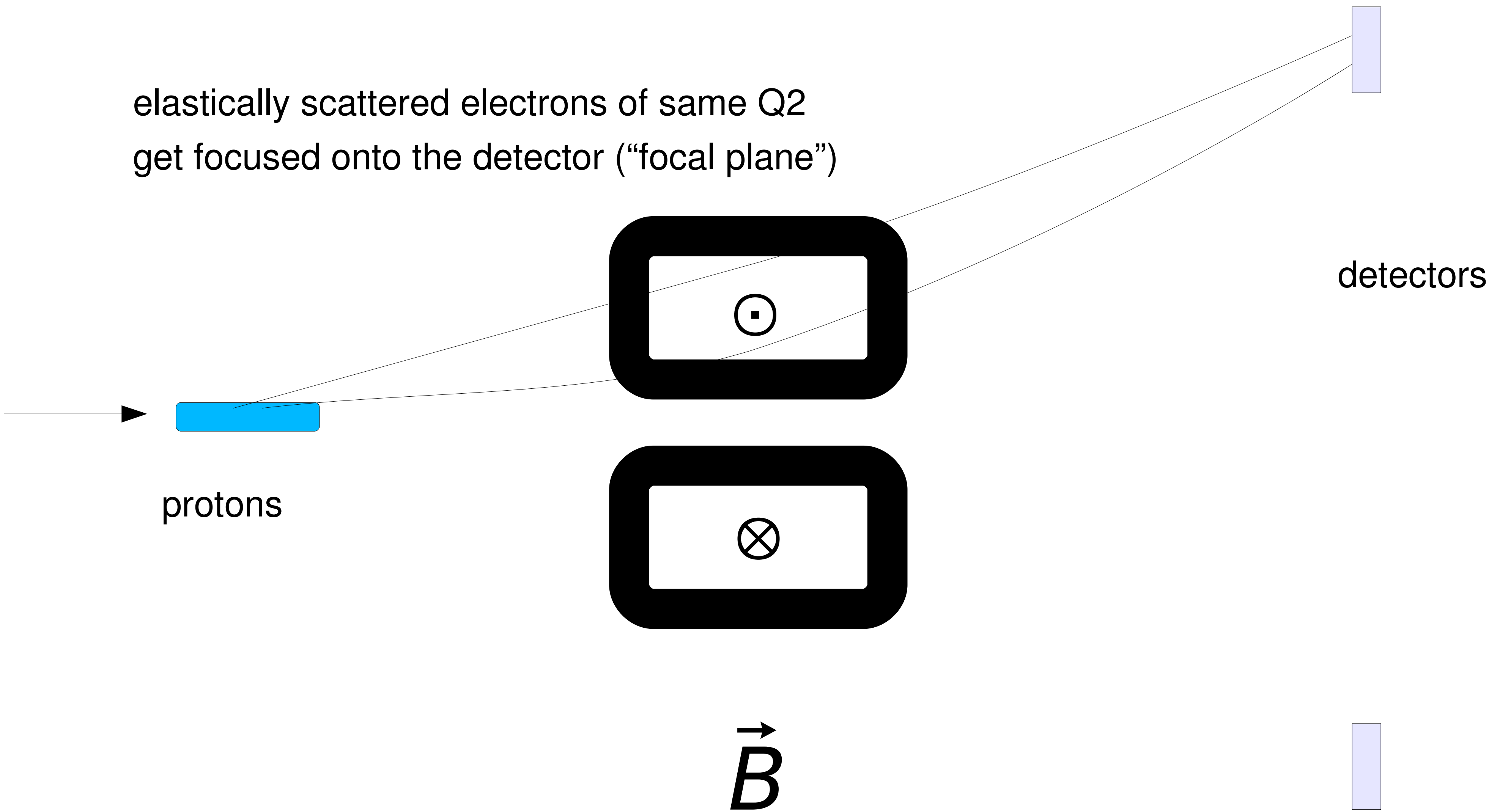


Caltech
Coll. of William and Mary
Dartmouth Coll.
George Washington U
Hampton U
UNAM (Mexico)
Idaho State U
Louisiana Tech U
MIT
Mississippi State U
Ohio U
Syracuse U
TRIUMF
Jefferson Lab (TJNAF)
U Conn
U Manitoba
U New Hampshire
U Northern British Columbia
U Virginia
Virginia Tech
Yerevan Physics Institute

and The
University of Winnipeg

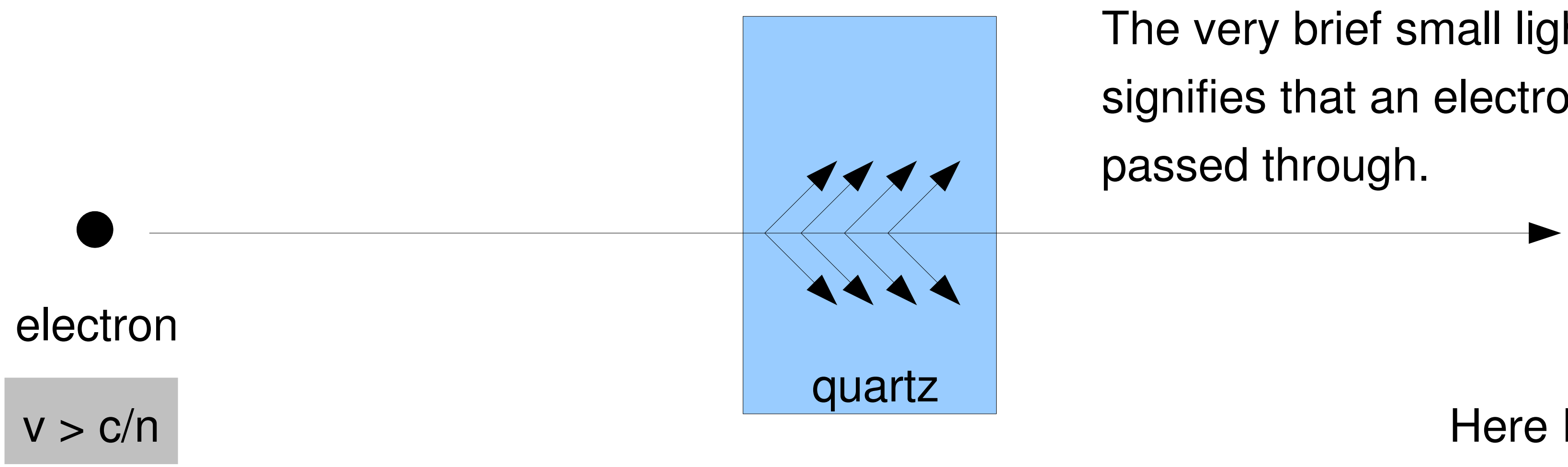
Qweak

Qweak Experiment Schematic



How the quartz bars work: the Cherenkov Effect + PMT's

- 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.



The very brief small light flash signifies that an electron just passed through.

Here I assume you know what a PMT is.

Some (Detector-Related) Systematic Uncertainties

- We need to know Q2 because:

$$A_{theory}=\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left(Q_W^p+Q^2\times s\bar{s}\right)$$

- We need to know backgrounds because:

$$\begin{aligned}
A_{\exp} &= \frac{N^+-N^-}{N^++N^-}\\
&= \frac{(N_s+N_b)^+-(N_s+N_b)^-}{(N_s+N_b)^++(N_s+N_b)^-}\\
&= \frac{N_s^+-N_s^-}{N_s^++N_s^-}\cdot\frac{N_s}{N_s+N_b}+\frac{N_b^+-N_b^-}{N_b^++N_b^-}\cdot\frac{N_b}{N_s+N_b}\\
&= A_s\cdot f_s+A_b\cdot f_b
\end{aligned}$$

Here's how well we think we can do on them:

Estimated Uncertainties

	$\Delta A_z/A_z$	$\Delta Q_w/Q_w$
Statistical (2200 hours)	1.8%	2.9%
Systematic:		
Hadronic structure uncertainties	--	1.9%
Beam polarimetry	1.0%	1.6%
Absolute Q2 determination	0.5%	1.1%
Backgrounds	0.5%	0.8%
Helicity correlated beam properties	0.5%	0.8%
Total:	2.2%	4.1%

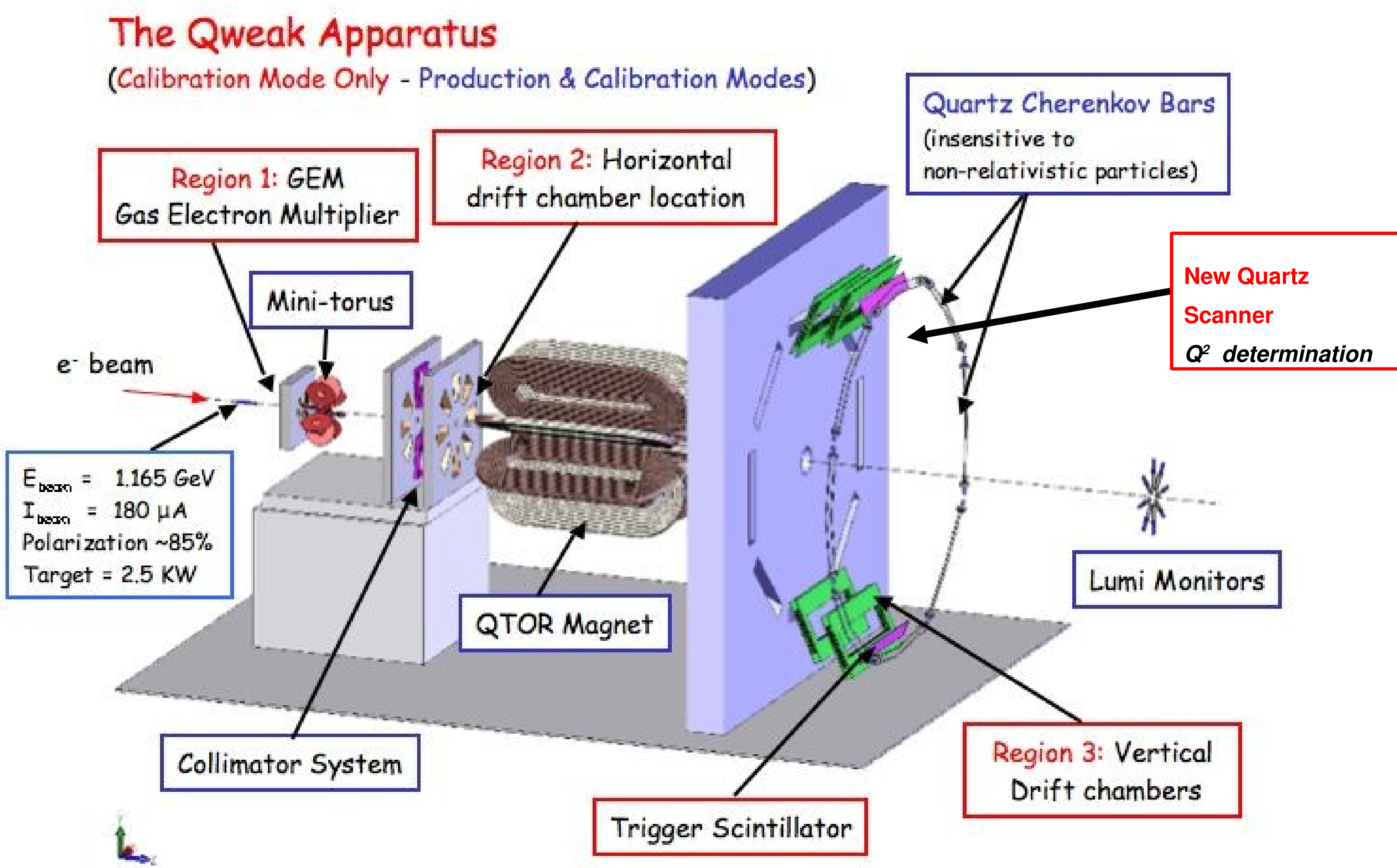
- Because of the linear relationships before, column #1 is basically how well we're doing on Q2 and backgrounds.

Production Mode: Actual asymmetry measurement

180 μA electron beam, high detector rate, current mode readout

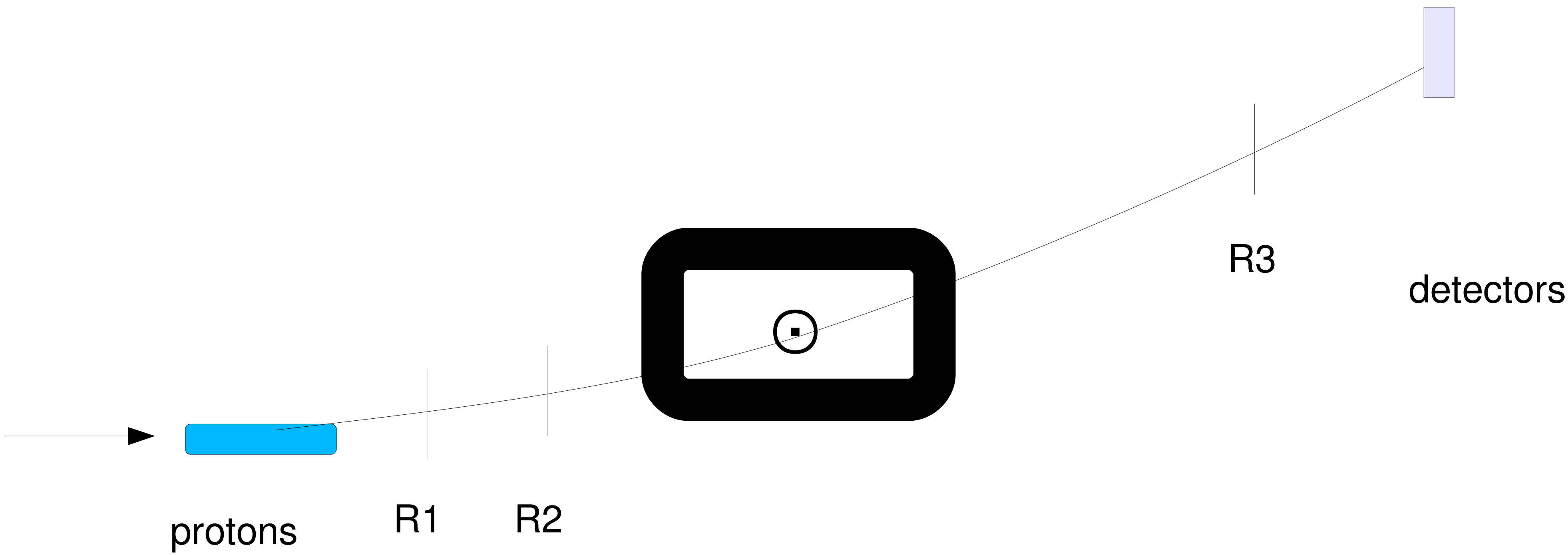
Calibration Mode: Background and Q^2 determintation

Low current (~ 10 nA), low detector rate, pulsed mode readout



4 m

Determining Q2



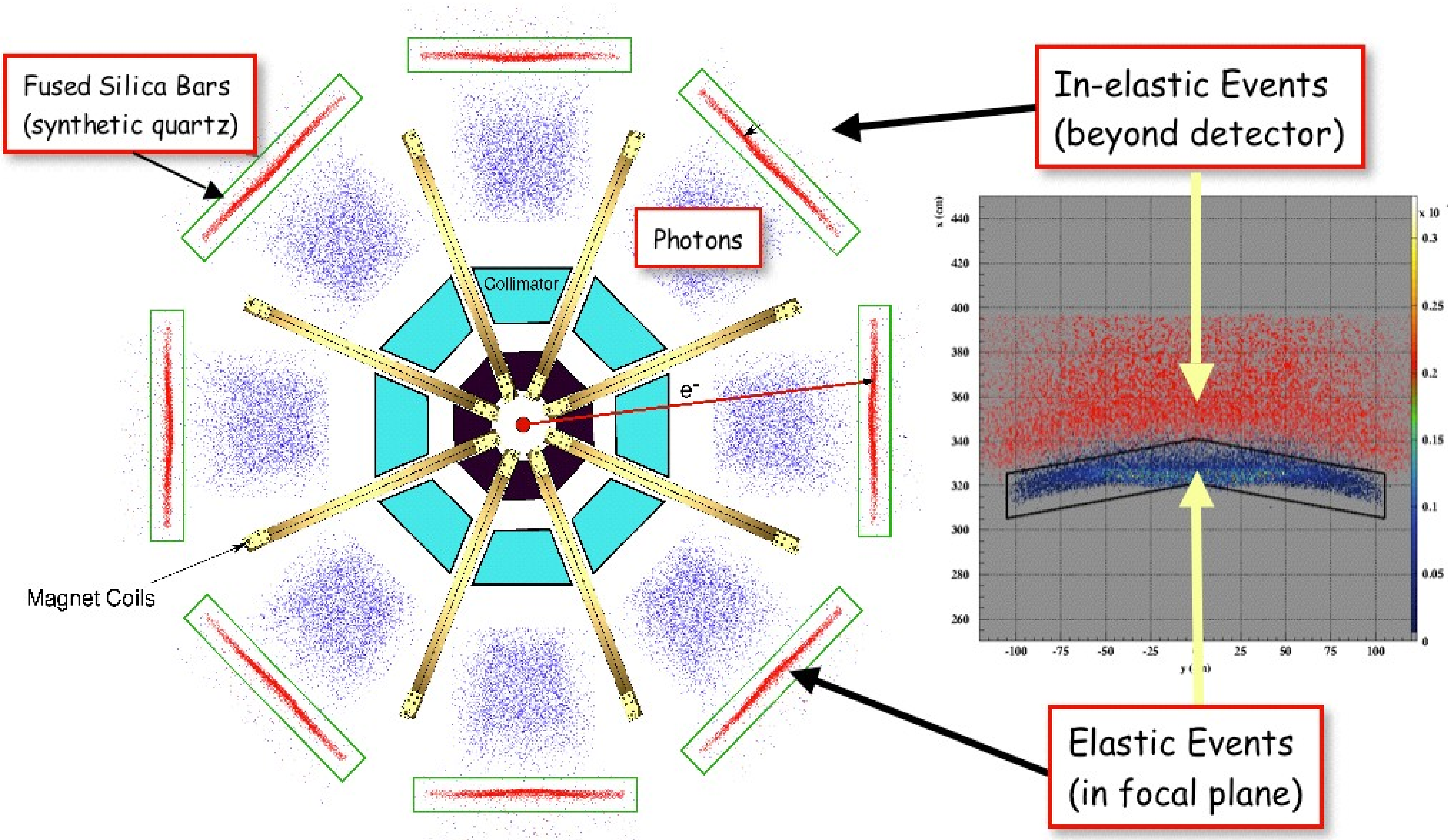
R1 and R2 GIVES scattering angle θ

R2 and R3 GIVES momentum pf (approx. Ef)

$$Q^2 = 4 E_i E_f \sin^2(\theta/2)$$

Ei known because the accelerator has magnets!

Some examples of backgrounds



Black region in center
is Pb shielding

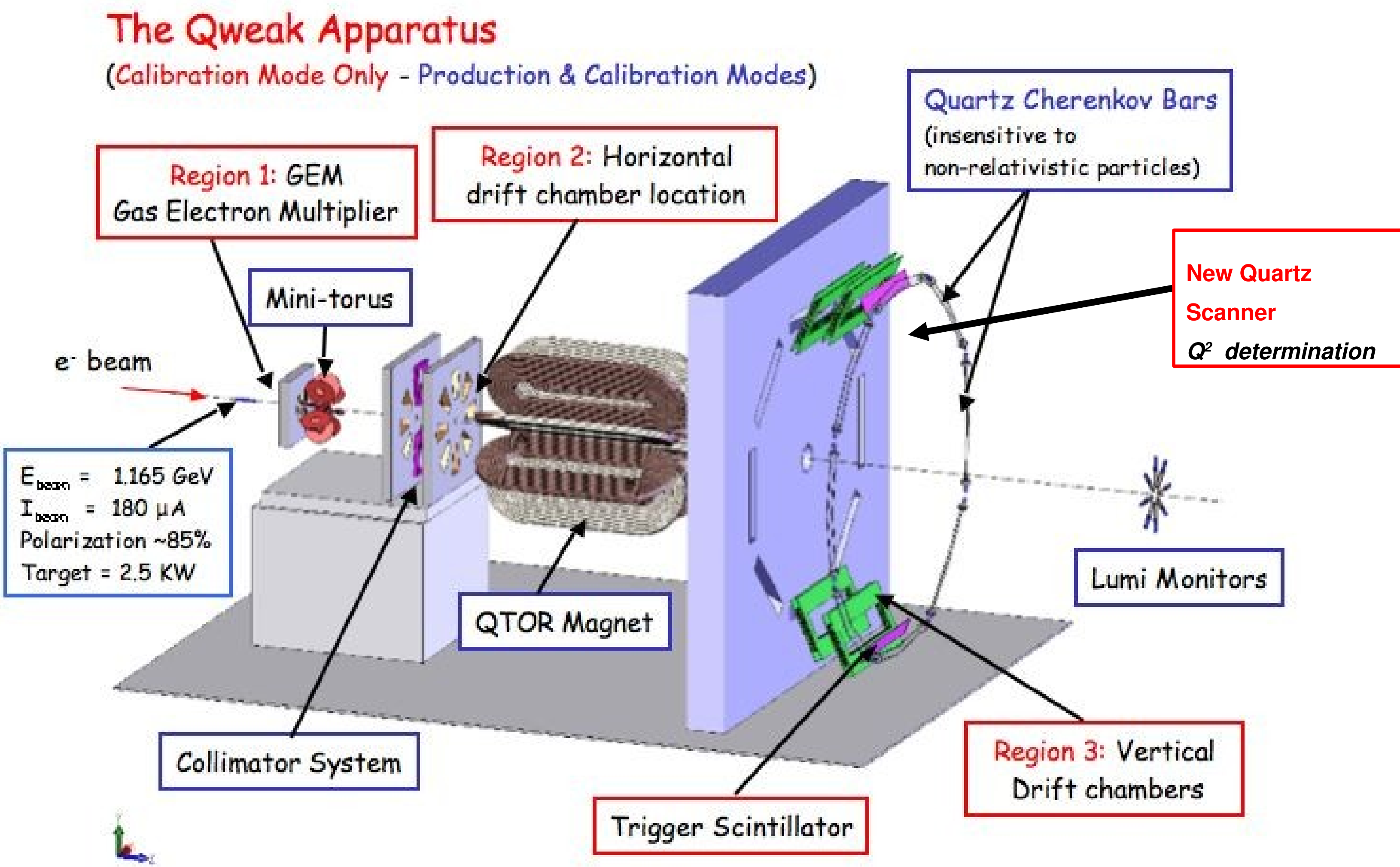
Production Mode: Actual asymmetry measurement
180 μA electron beam, high detector rate, current mode readout

Calibration Mode: Background and Q^2 determintation

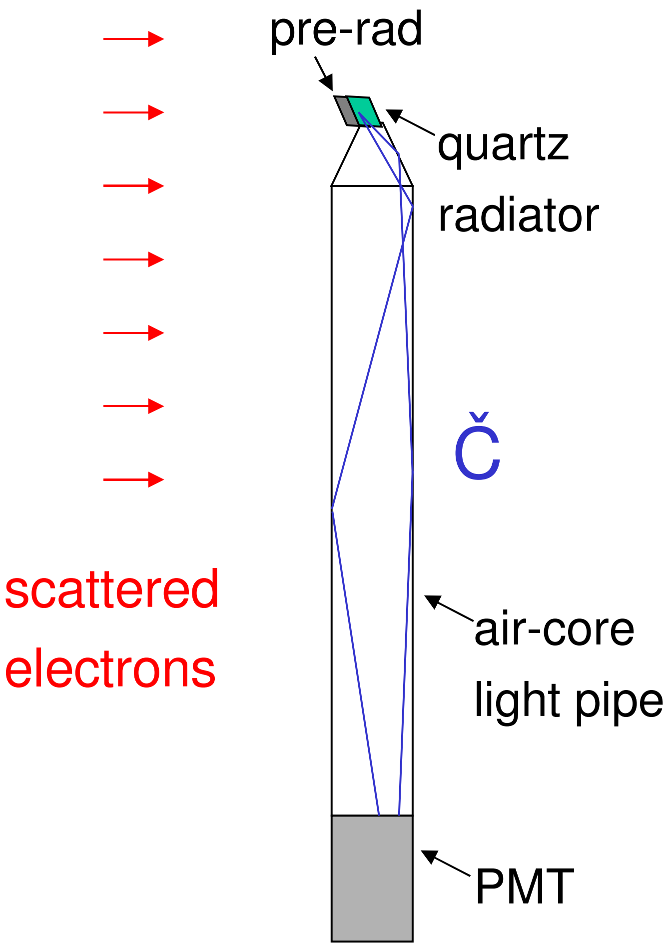
Low current (~ 10 nA), low detector rate, pulsed mode readout

These are big, slow detectors that only work at low rate (a few kHz of electrons striking the whole detector) (caveat: GEM)

4 m



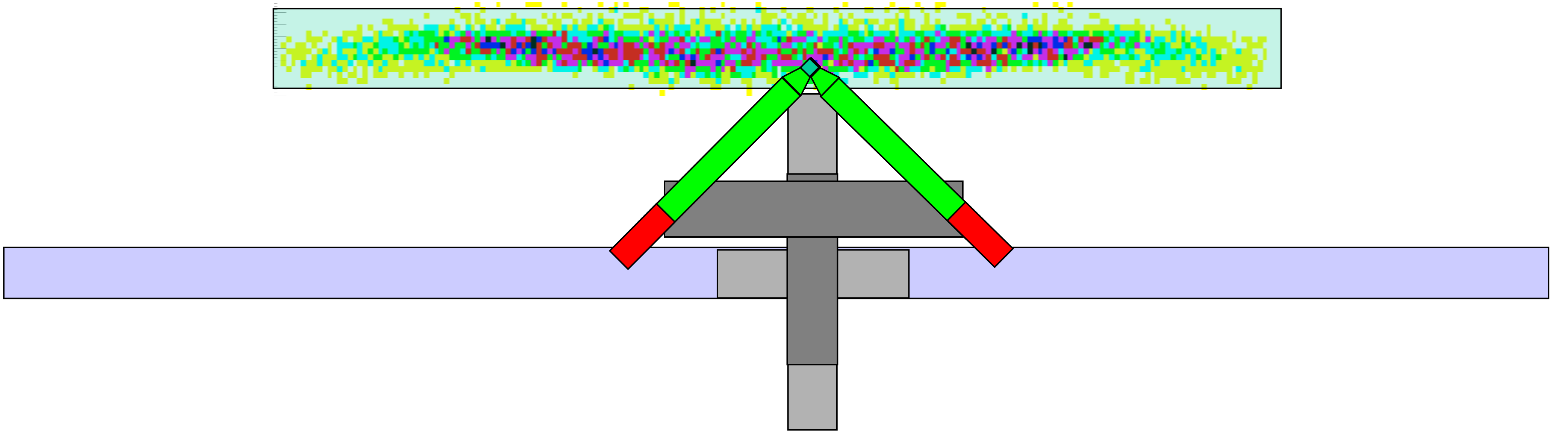
A Quartz Scanner for Qweak



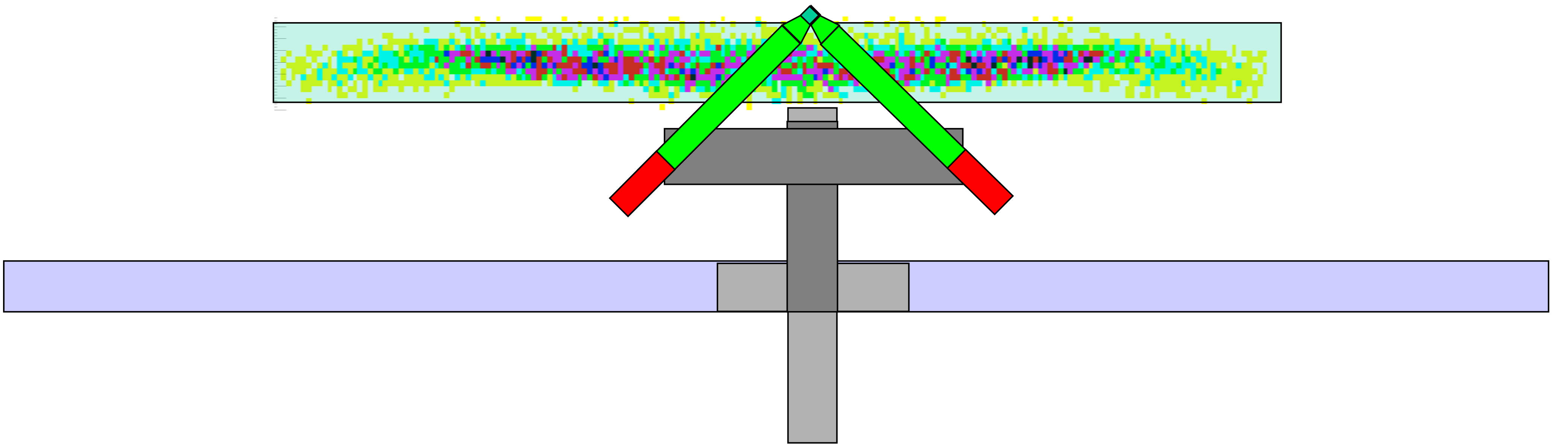
Concept:

- Scan a small piece of quartz over the surface of the main quartz bars to characterize Q2 and backgrounds at both low and high beam current.
- <u>This</u> detector will be able to run at ALL currents, because it is a tiny, fast detector.
- tiny ~ cm^2
- fast ~ speed of light

Implementation in Qweak



Implementation in Qweak



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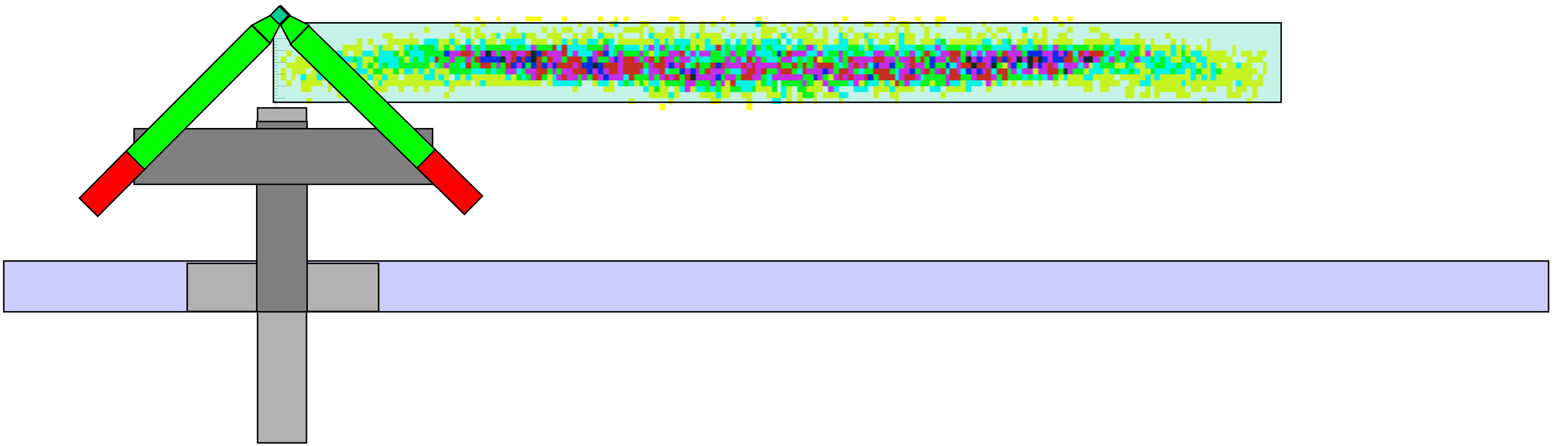

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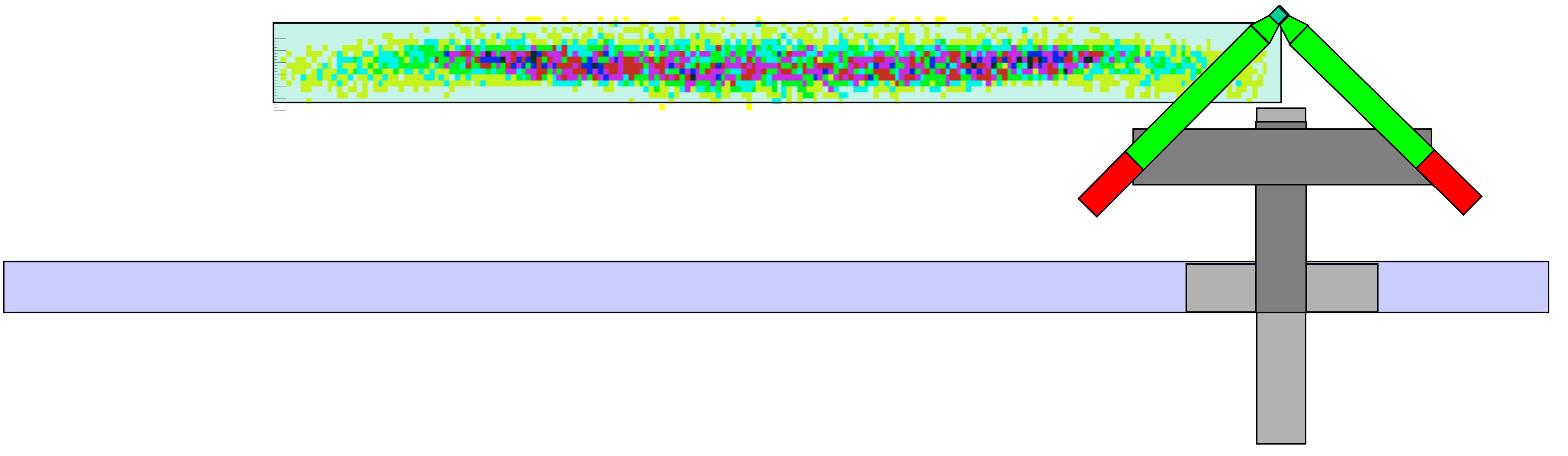

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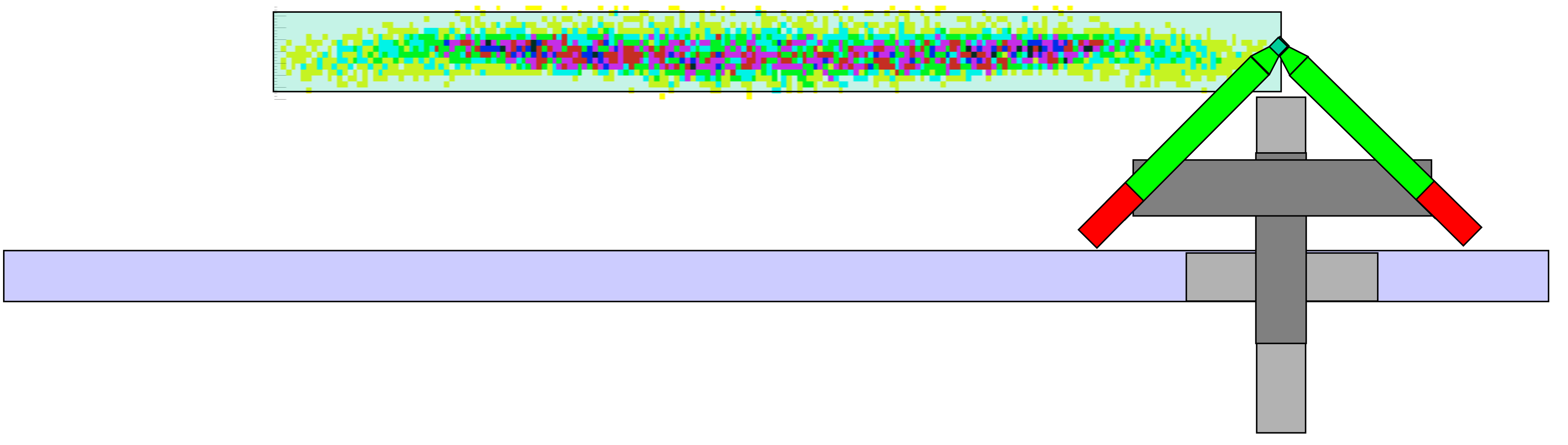
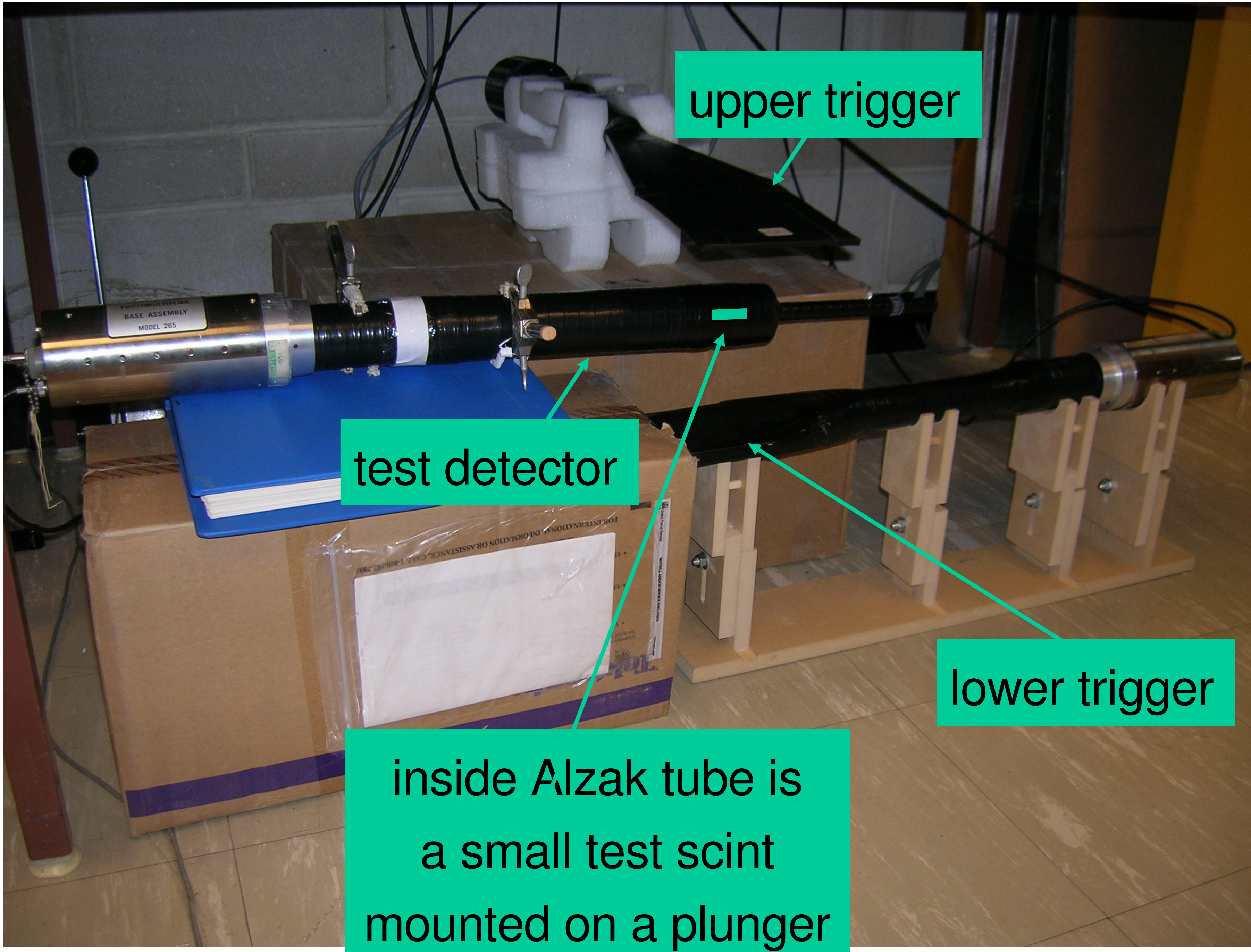


Prototyping Tests – Cosmics Testing



Scanner: open questions

- Well, it's not done, yet. Guess that's a question.
- i.e. we need a light-tube assy and a big robot.
- We need to know where the robot is (laser+photodiode, Laura).
- Supposing we have a scanner, how do we use it most effectively?
  - scan rate? scan pattern?
  - How do we adjust these to minimize the systematic uncertainties?
  - And what is the systematic uncertainty and how do we quantify it?

Summary

- Parity-violation experiments are hard (helicity-correlated systematics).
- Qweak is made harder because of several non-parity violating systematics (Q2, backgrounds, polarization).
- Scanner to address Q2 and backgrounds, particularly at high beam current.
- Polarimeter to address polarization.