Suppression of false asymmetries for the Q^p_{weak} experiment

A SEARCH FOR NEW PHYSICS

Qweak

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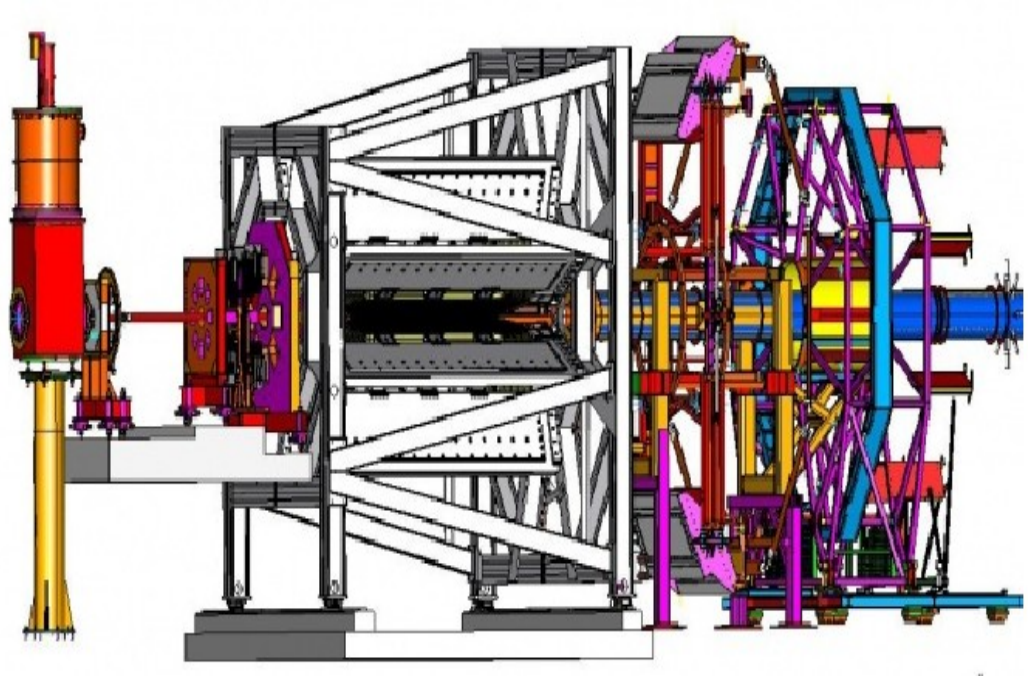
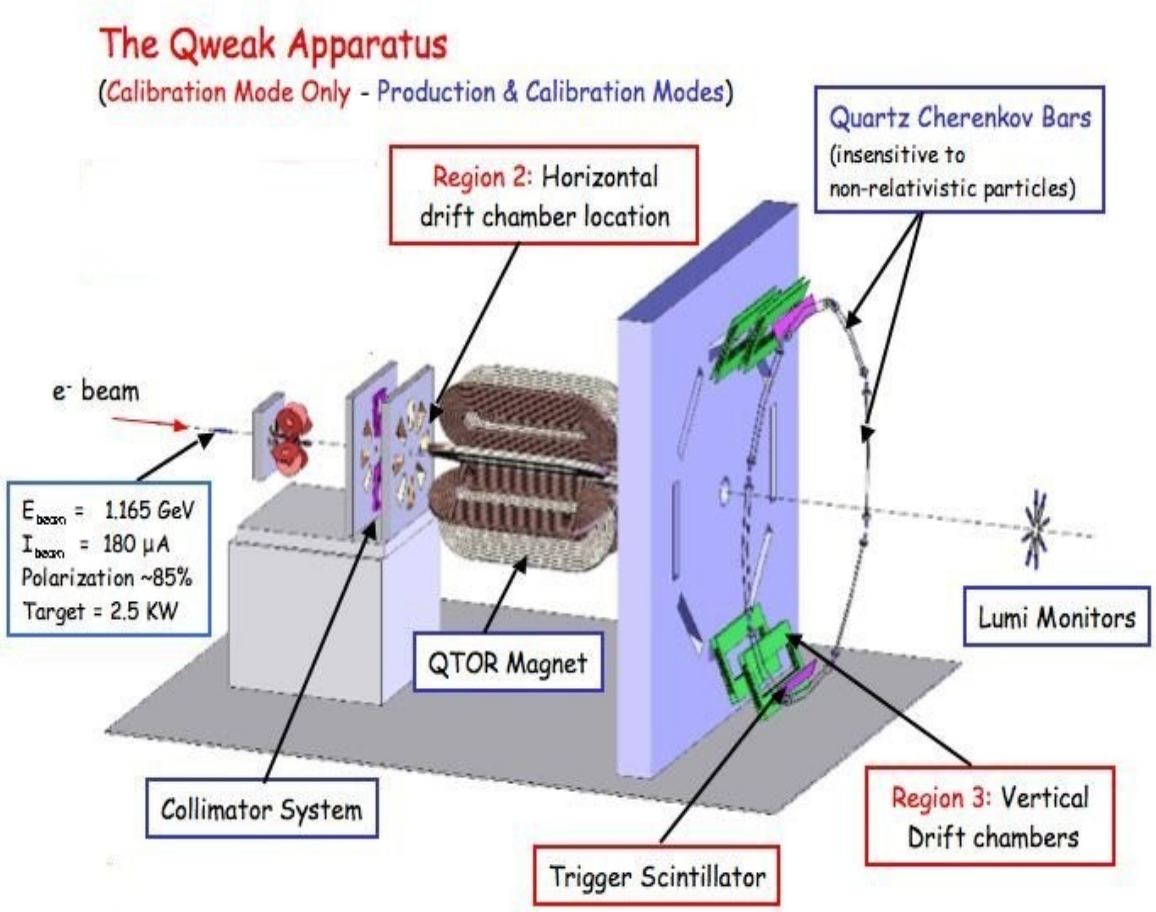
The Q^p_{weak} experiment

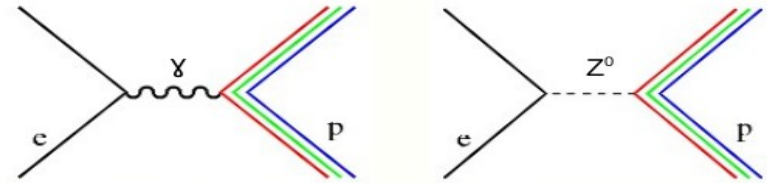
"A Search for New Physics at the TeV Scale
Via a Measurement of the Proton's Weak Charge"



- First measurement of Q^p_w
- 4% proposed precision
- Parity-violating elastic e-p scattering.

Experiment ran in Jefferson Lab Hall C from September 2010 to May 2012; it was a long ride!





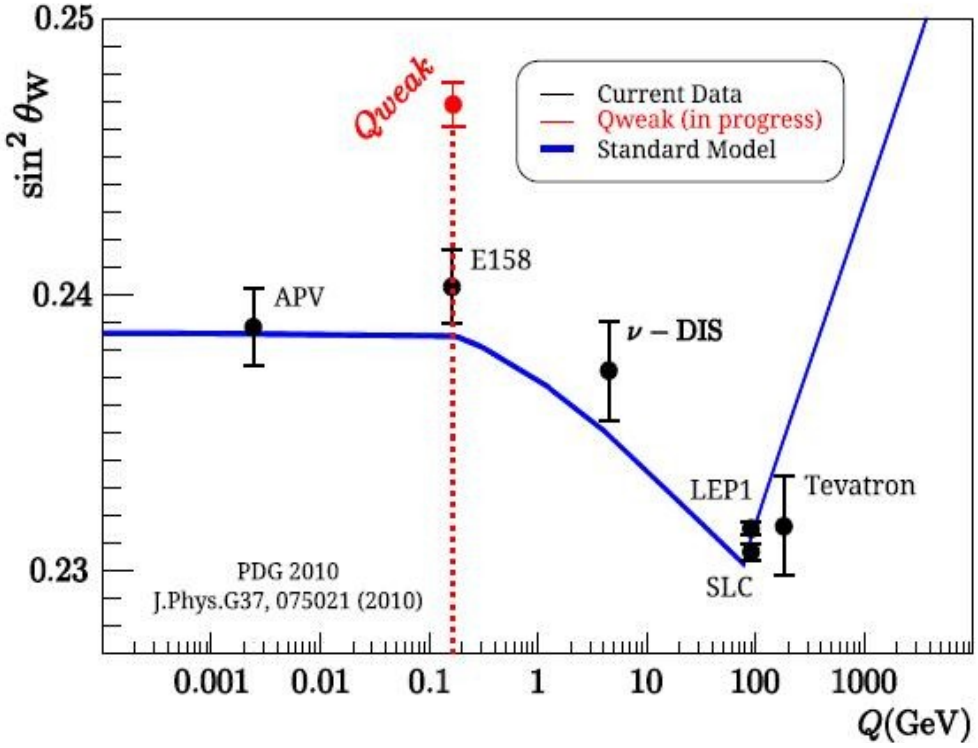
Access the weak amplitude through the PV asymmetry:

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

- Estimated SM asymmetry: -0.27 parts-per-million
- Proposed error bar: 5 parts-per-billion

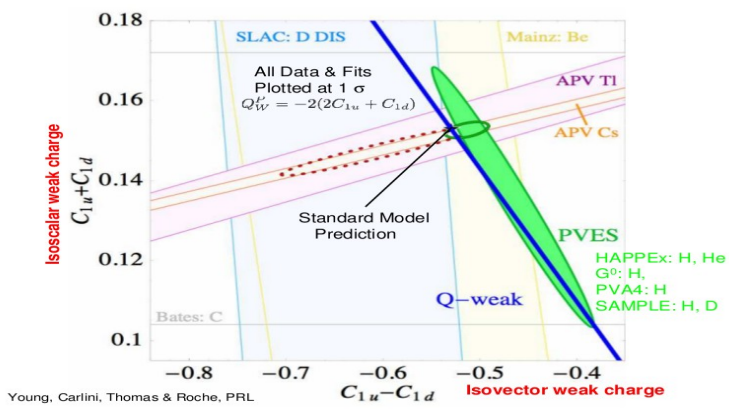
Then, extract Q^p_w :

$$A_{PV} = \frac{-G_F}{4\sqrt{2}\pi\alpha}\left[Q^p_w Q^2 + B(Q^2) Q^4 \right]$$



$$Q_w^p = 1 - 4\sin^2\theta_w \approx 0.071$$

(SM prediction)



Young, Carlini, Thomas & Roche, PRL

- *Most precise measurement of the weak mixing angle off the Z-resonance.*
- *A very stringent test of the SM, with sensitivity to certain classes of new physics up to a few TeV.*
- *Complementarity to LHC, as well as other PV measurements.*

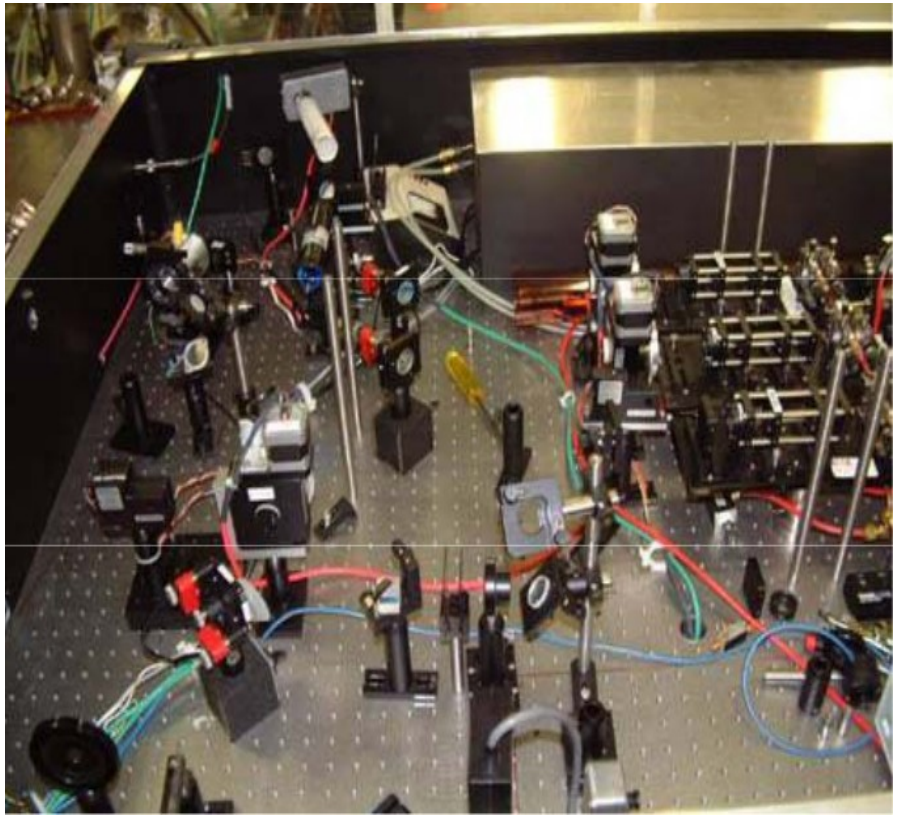
False asymmetries

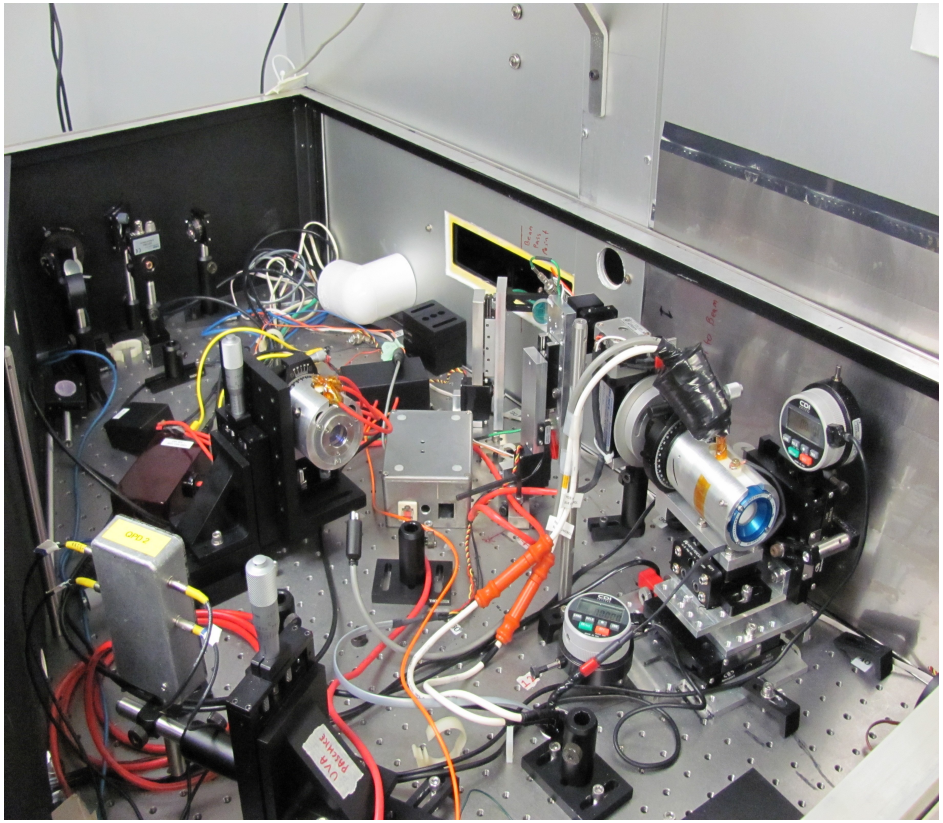
At the required level of precision it is very important to suppress and account for *false asymmetries*

$$A_{meas} = A_{phys} + \sum_i \frac{\partial A}{\partial P_i} \delta P_i$$

Because the detector rate depends on beam parameters, such as intensity, position, angle, energy, *helicity correlated differences* in these parameters can produce false asymmetries

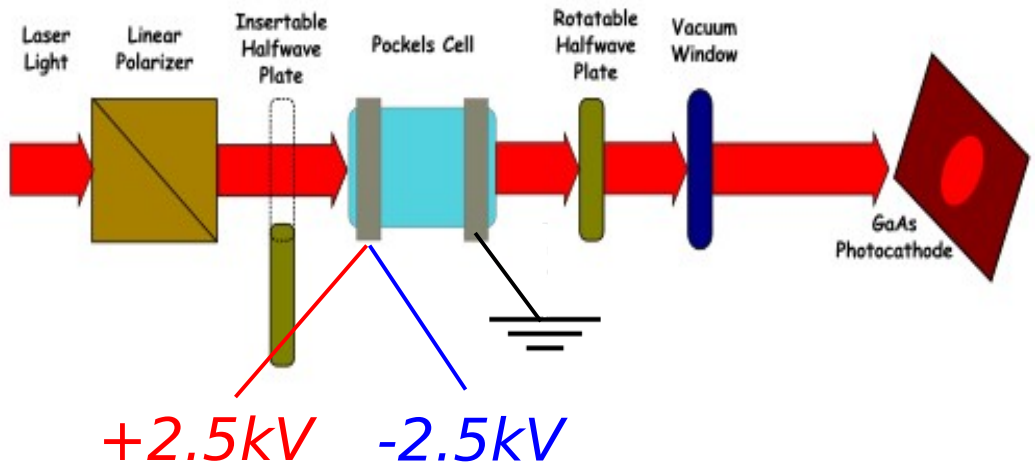
JLab Polarized Source





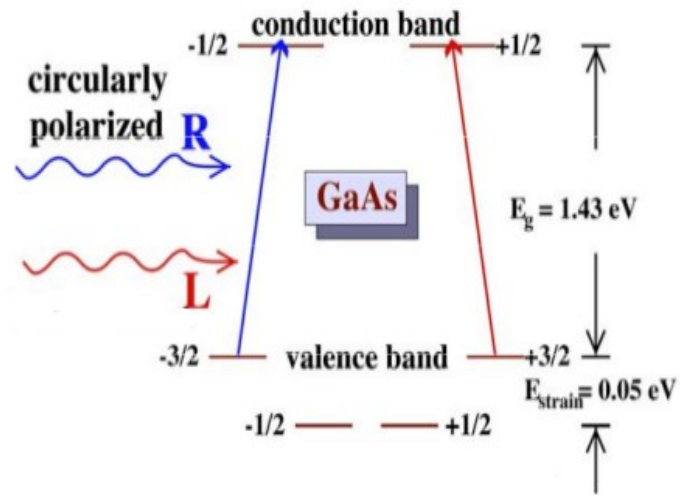
JLab Polarized Source

Differences arise at the polarized source, where circular light is created from a Pockels Cell acting as a λ/4 plate (electro-optic effect).

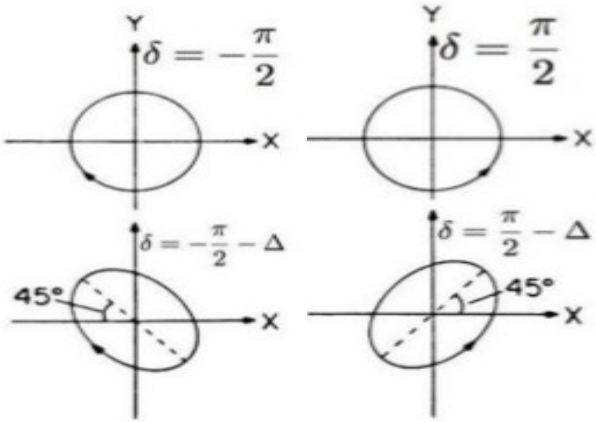


Fast, 960Hz helicity flip rate

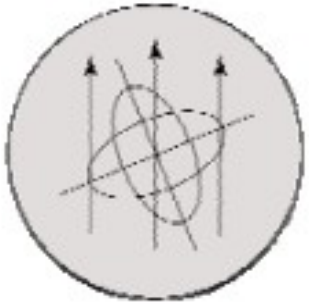
GaAs photocathode emits polarized e^-



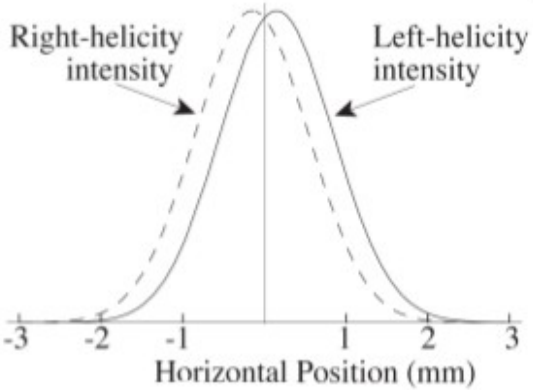
False asymmetries



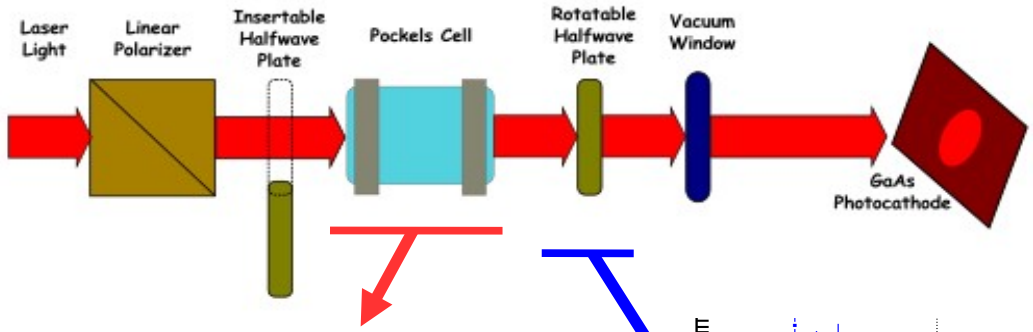
Main source of HC differences:
Relative residual linear light
on the cathode.
Coupled with an
asymmetric transport
(Quantum Efficiency anisotropy)
this will create an intensity
asymmetry.

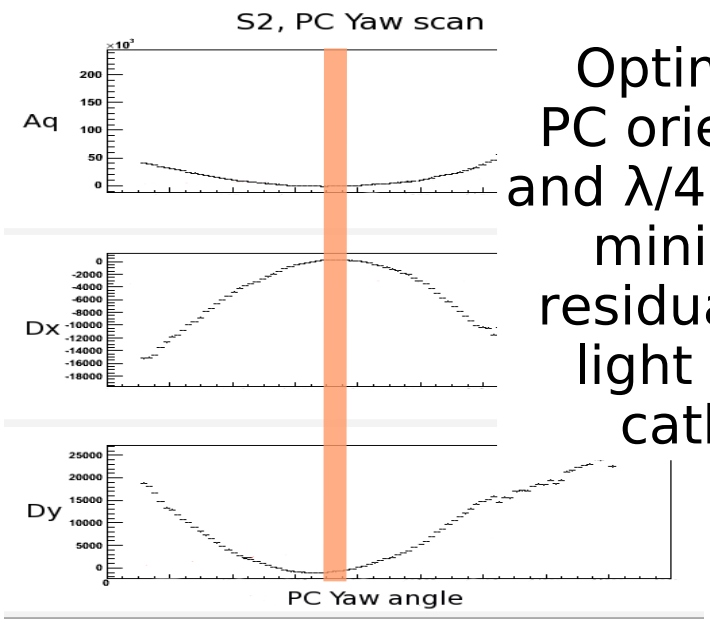


Higher moments:
Position differences arising from
polarization gradients
across the beam spot

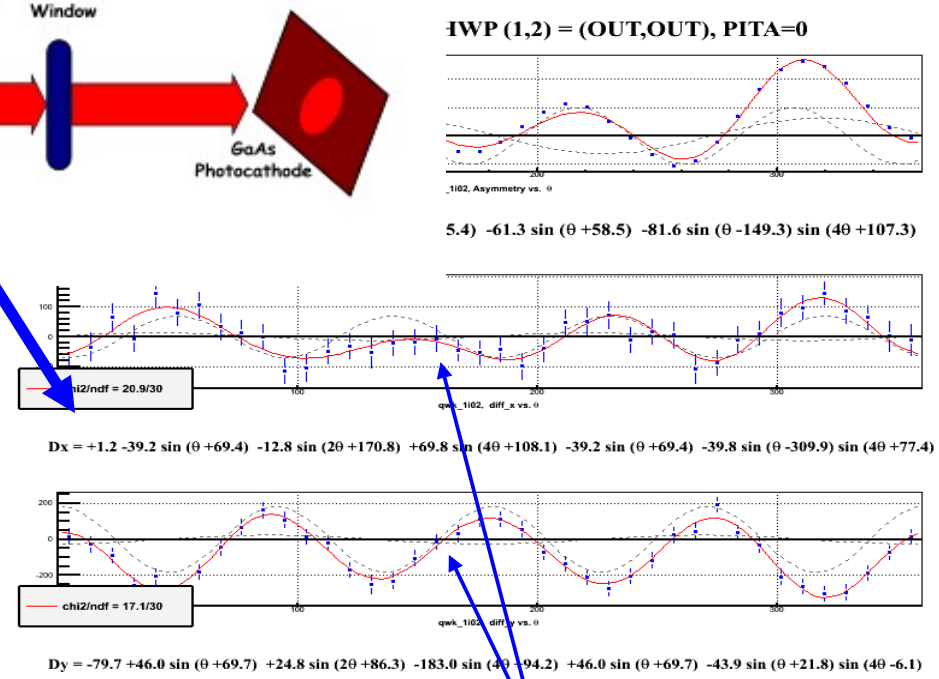


Optimizing the source





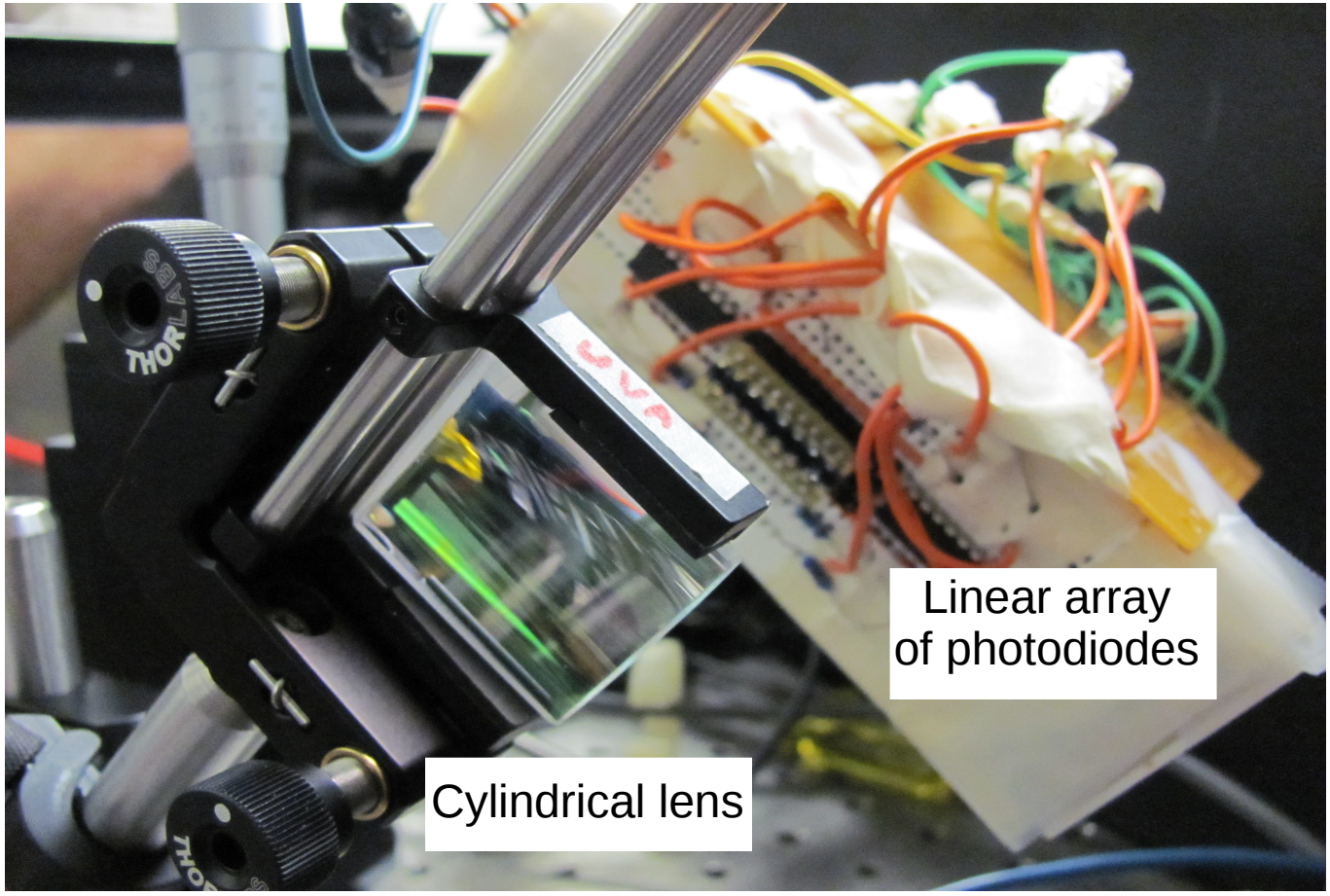
Optimizing PC orientation and λ/4 voltages minimizes residual linear light on the cathode



Rotatable HWP rotates the linear light to minimize its effect.

Spot size asymmetry

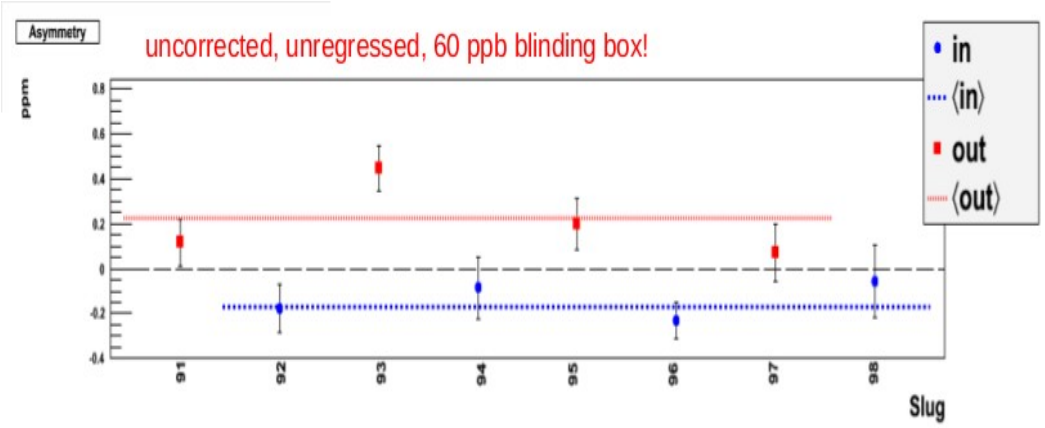
Dominant 2nd moment, effect needs to be bounded to $<10^{-4}$.
A novel measurement to bound with high precision.

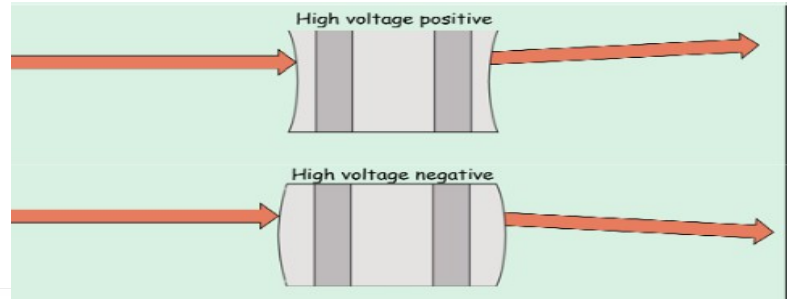


Slow reversals

Insertable HWP
(~8hr)

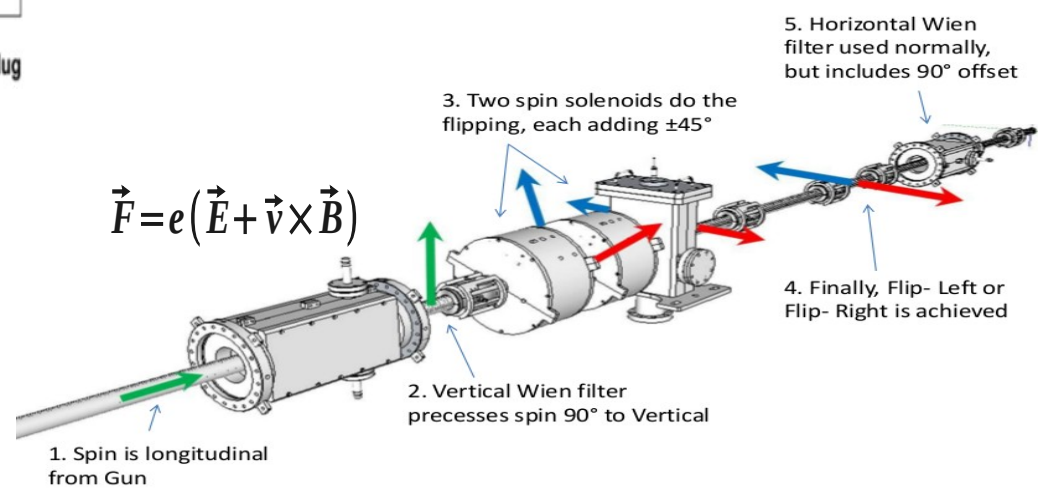
Cancels some sources of systematics,
eg: PC steering (piezo-electric effect)



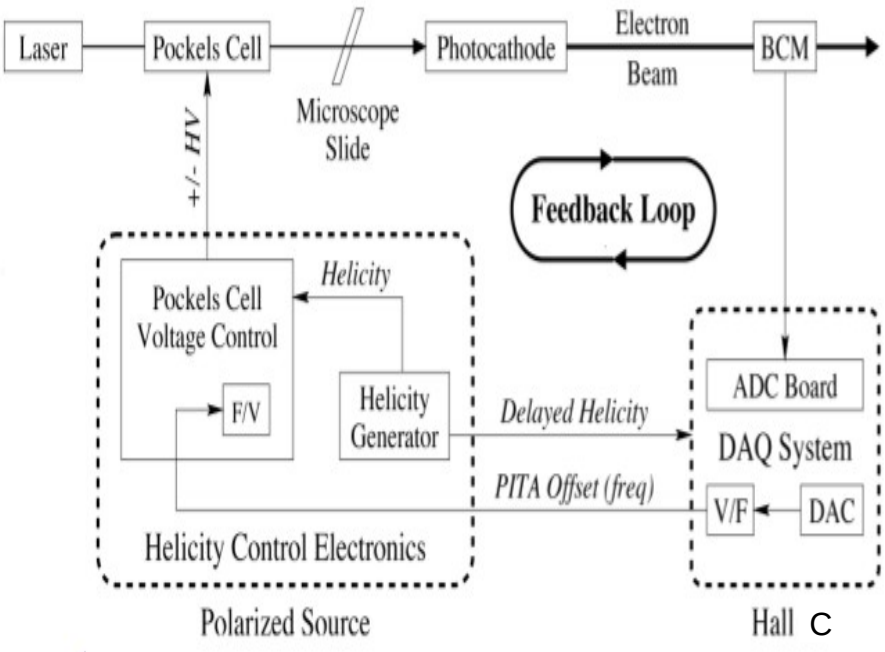


Injector spin manipulator
(~month)
Should cancel most differences
from the source

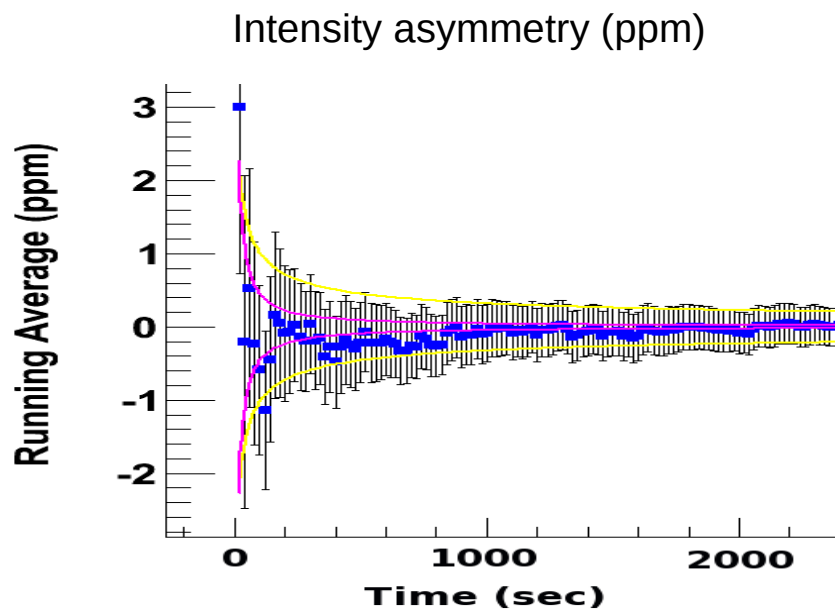
$$\vec{F}=e\left(\vec{E}+\vec{v}\times\vec{B}\right)$$



Feedback

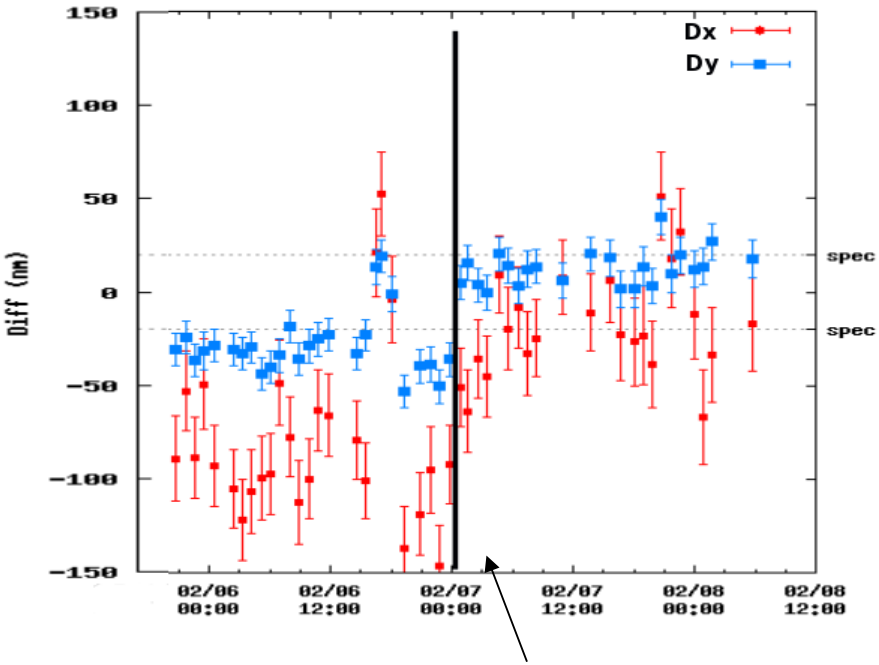


Intensity asymmetry brought within the ppm level by adjusting PC voltages



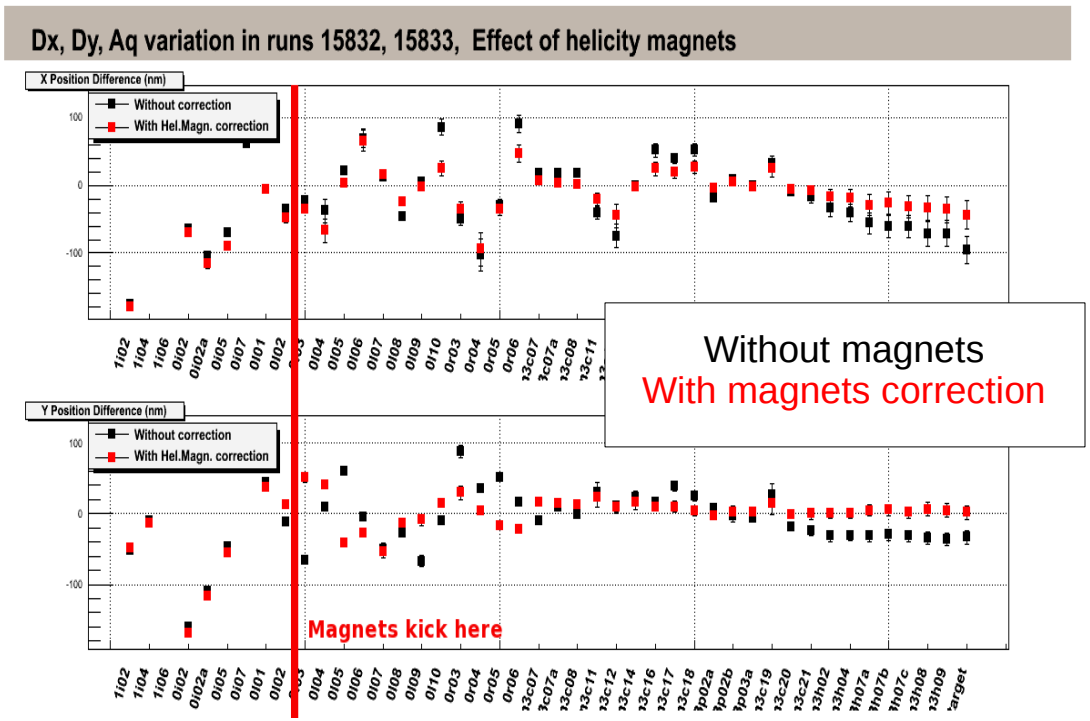
Feedback

Position differences (nm)



Magnets correction starts here

Position and angle differences corrected using a system of 4 fast air-core magnets at the 5MeV region



Without magnets
With magnets correction

Corrections

Remaining HC differences
will have an effect
(*false asymmetry*)
that must be corrected.

$$A_{meas} = A_{phys} + \sum_i \frac{\partial A}{\partial P_i} \delta P_i$$

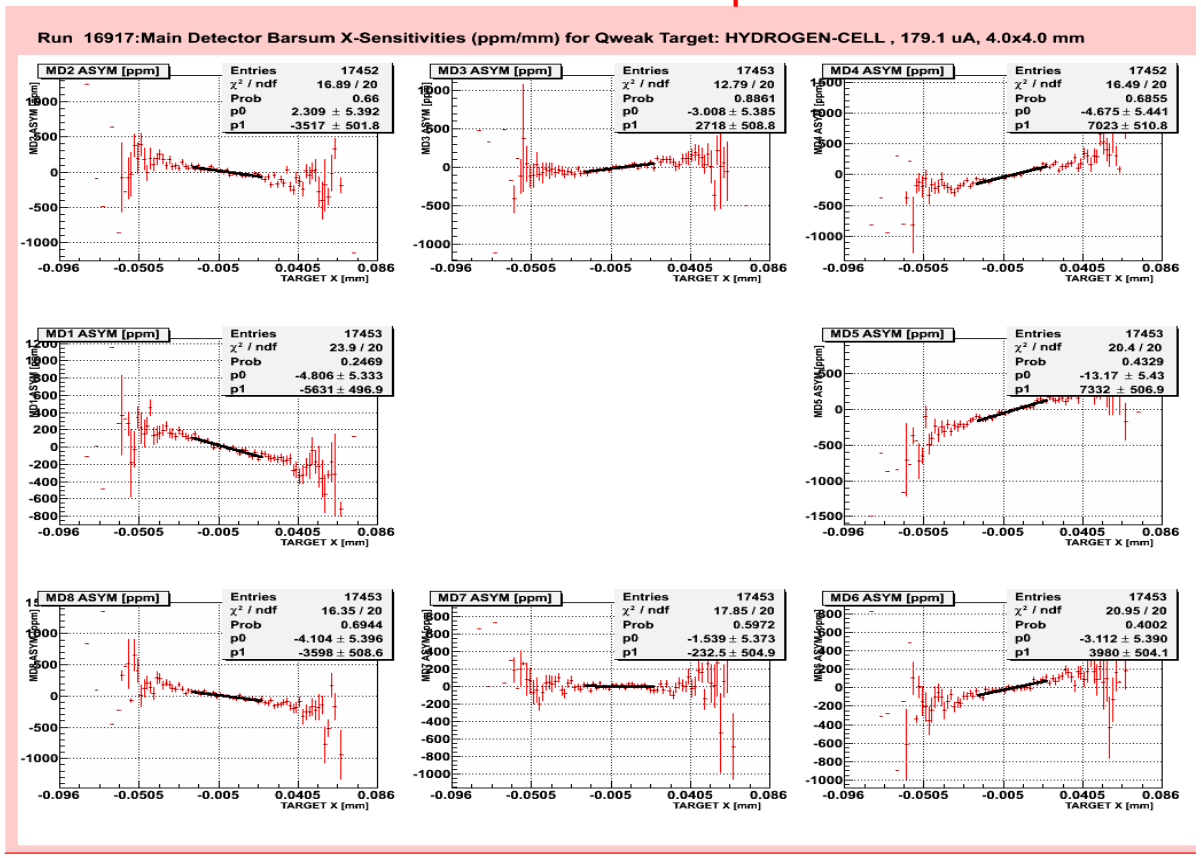
Differences measured
from monitors

To correct we need to extract
the *sensitivity* of the measured asymmetry
to each of the parameters

Extracting sensitivities (a)

Sensitivities extracted from natural beam motion.
Then, perform multilinear regression to correct the false asymmetries.

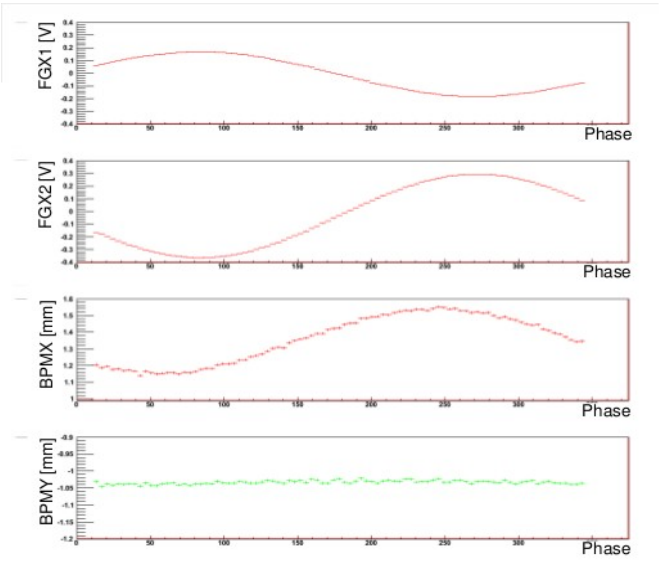
Detector bars sensitivities to Y-position differences



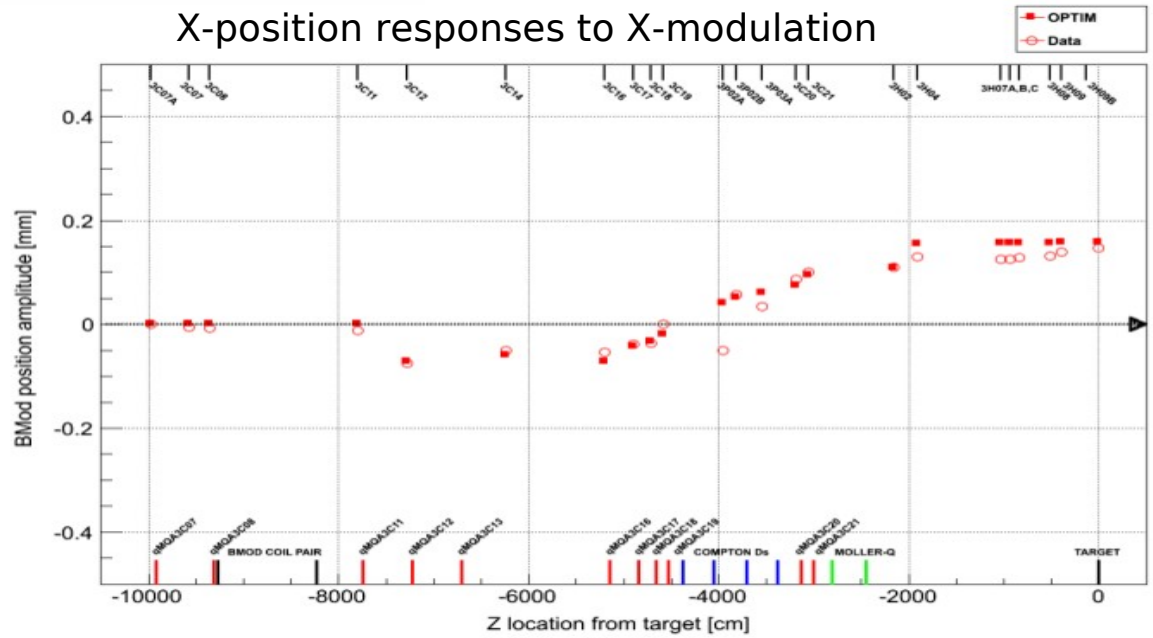
Extracting sensitivities (b)

Extract sensitivities independently
from driven modulation in 5 beam parameters:
X and Y positions and angles (pairs of dipole magnets)
and energy (SRF cavity).

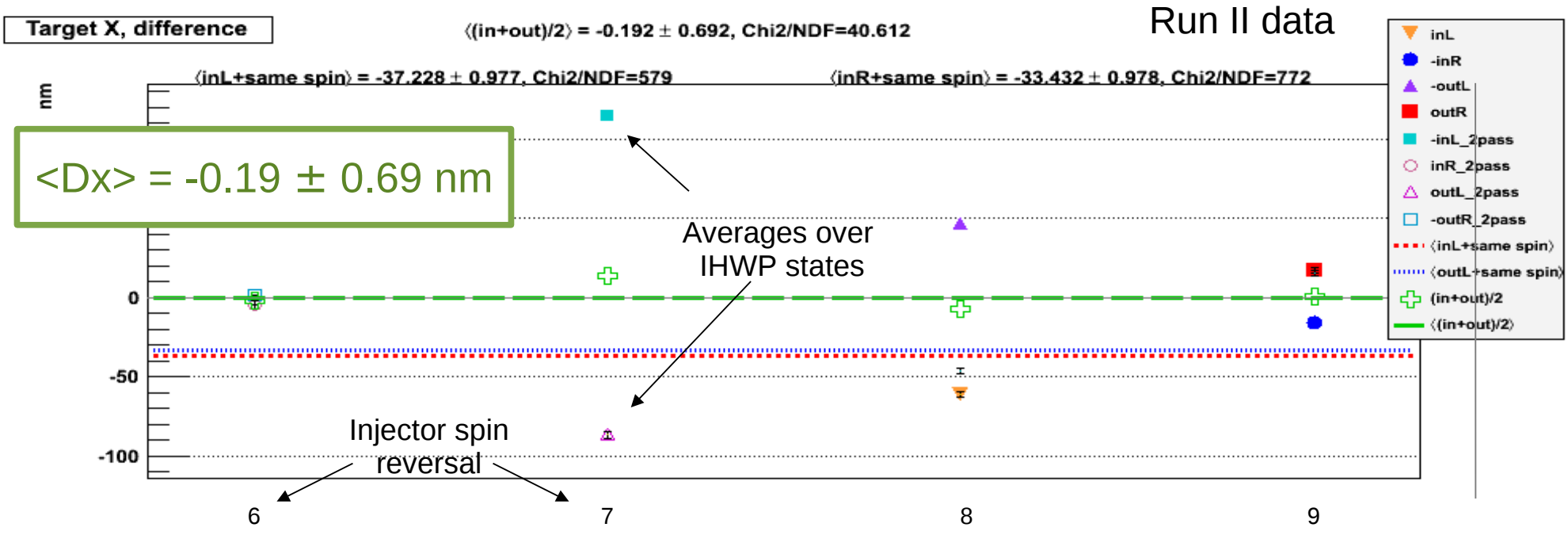
Modulation driving signals



X-position responses to X-modulation



Suppressions and cancellations are working!



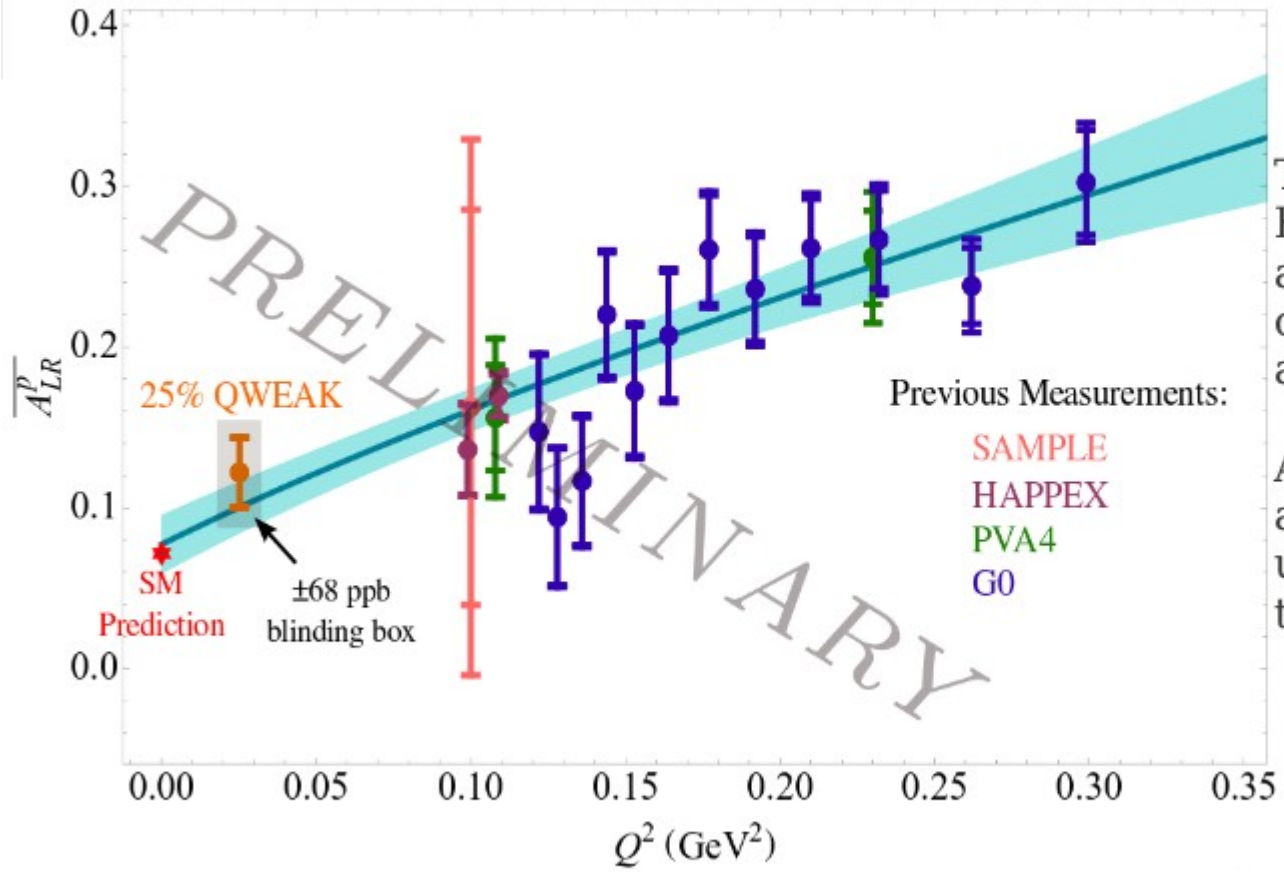
Corrections will take care of the rest.

Property	Design goal	Achieved (Run II)
Charge asymmetry (ppm)	<1	0.02 ± 0.02
X position difference (nm)	<2	-0.2 ± 0.7
Y position difference (nm)	<2	1.0 ± 0.3
X angle difference (nrad)	<0.6	-0.06 ± 0.02
Y angle difference (nrad)	<0.6	-0.05 ± 0.01

Qweak achieved its design goals for the average HC differences and their contribution to uncertainty

Preliminary 25% Results

Calculation by Katherine Myers



This fit uses the Kelly form factors and OLD γZ box corrections (old axial only)

Account for this and add a 3% uncertainty for the γZ box

$$Q^p_W = 0.0805 \pm 0.0189 \pm 0.026 \text{ (blinding)}$$

Standard Model:

$$Q^p_W = 0.0705(8)$$