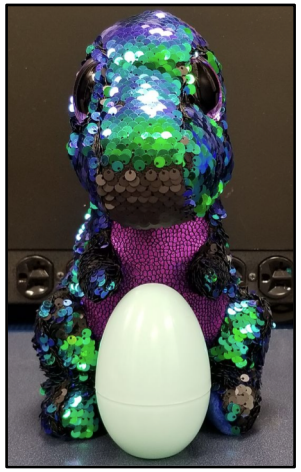
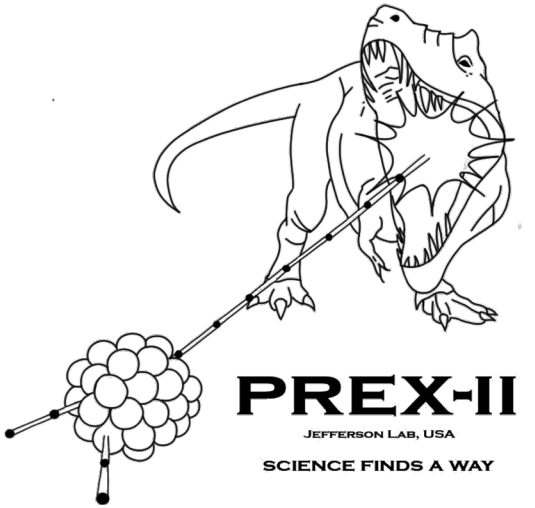
Parity Quality Beam Preparations

Caryn Palatchi, IU

MOLLER Collaboration Meeting 5/6/2023





*Artwork by Marisa Petrusky

Beam Asymmetries Previously Achieved and Future Goals

Any change in the polarized beam, correlated to helicity reversal, can be a potential source for a false asymmetry

$$A_{raw} = A_{det} - A_Q + \alpha\Delta_E + \Sigma\beta_i\Delta x_i$$

HCBA's are expected to contribute ~0.14 ppb uncertainty for Moller *(~10ppb for PREXII)*

(Helicity Correlated Beam Asymmetries)

HCBA Contributors	HAPPEX-II [29] (achieved)	Q_{weak} [12] (achieved)	PREX-2 (achieved)	CREX (achieved)	MOLLER (required)
Intensity asymmetry	400 ppb	30 ppb	25 ppb	−88 ppb	10 ppb
Energy asymmetry	0.1 ppb	0.4 ppb	0.8 ± 1 ppb	0.1 ± 1.0ppb	< 1.4 ppb
position differences	1.7 nm	4.4 nm	2.2 ± 4 nm	-5.2 ± 3.6nm	0.6 nm
angle differences	0.2 nrad	0.1 nrad	$< 0.6 \pm 0.6$ nrad	-0.26 ± 0.16nrad	0.12 nrad
size asymmetry (quoted)	–	$< 10^{-4}$	$< 3 \times 10^{-5}$	$< 3 \times 10^{-5}$	$< 10^{-5}$
			19 days	~40 days	344 days

Constrained at nm, nrad, ppb level

How were these small beam asymmetries achieved and how can we meet our future goals?

Recipe to suppress HCBA and achieve Parity Quality Beam for PVES Experiments

Beam Setup Pre-Experiment:

- *Laser Table Alignment : minimize HCBA*
- *Injector setup: minimize HCBA*
- *Slow Reversals Symmetry*

Beam Corrections During Experiment:

- *Aq Feedback*
- *RTP Position Difference Corrections*
- *Beam Modulation*
- *Fast feedback*

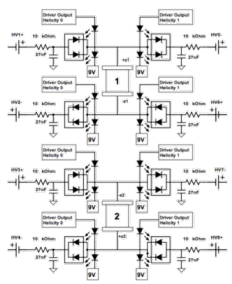
Beam Transport Considerations:

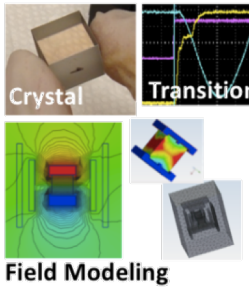
- *High Transmission*
- *Adiabatic Damping/Optics Match*

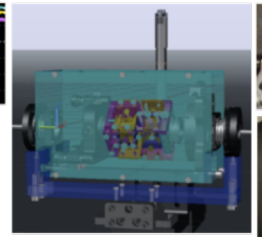
Parity Quality Beam Preparations Status

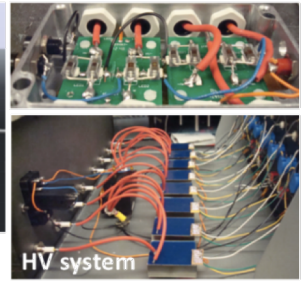
- PQB Group (Caryn, Kent, Paul, Riad, etc…) meeting weekly
- Requirements documents on hardware components (Helicity magnets, helicity generator board, IA cells, etc.) being generated and communicated
- Injector Upgrade is proceeding as planned
- Dedicated Beam Studies are planned to assess PQB readiness of new machine

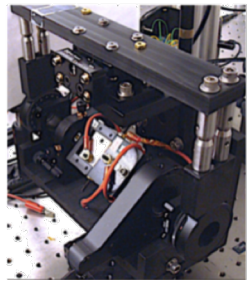
PQB hardware on Accelerator Tasks List formed by PQB group









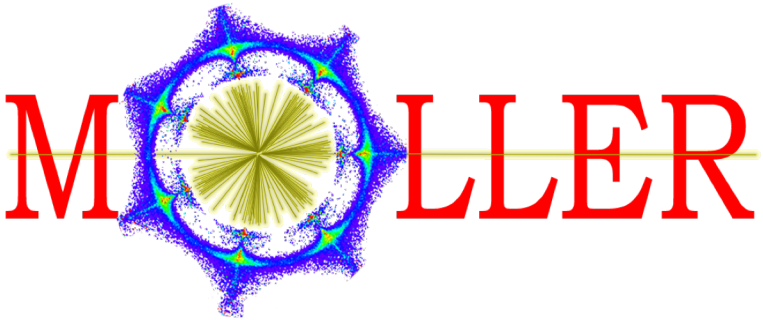


We can flip fast with the Pockels cell now, everything else need to flip fast too.

- Helicity Generator Board – currently debugging, will be able to produce mega-multiplets and have delay option of 10-20us. 8 boards (out of 13 total) will be available for MOLLER for detector and data acquisition development
- Helicity Magnets – needed to be required to transition in <10us and field maps examined to verify position/lensing coupling is negligibly small.
- IA cells – needed to be tested to ensure transition time is <10us and plan to update the IA cells driver circuit to ensure fast transition and ….. (so Helicity signal isn't carried by a BNC cable!)
- Pockels cell driver circuit - IU reverse engineering circuit so John H's circuit is properly documented, Electronics group to make a spare, exploring solid-state switch development (UVA)
- Helicity Decoder Boards: Newly designed board to prevent mis-identification of real helicity events in counting mode for the 2 kHz MOLLER helicity reversal. 20 boards needs to be fabricated and installed in data acquisition systems of four Halls and for all helicity or polarimeter data acquisition systems

Injector Upgrade – phase II

March 20 – July 21, 2023



Accelerator Division

May 1, 2023

Jefferson Lab

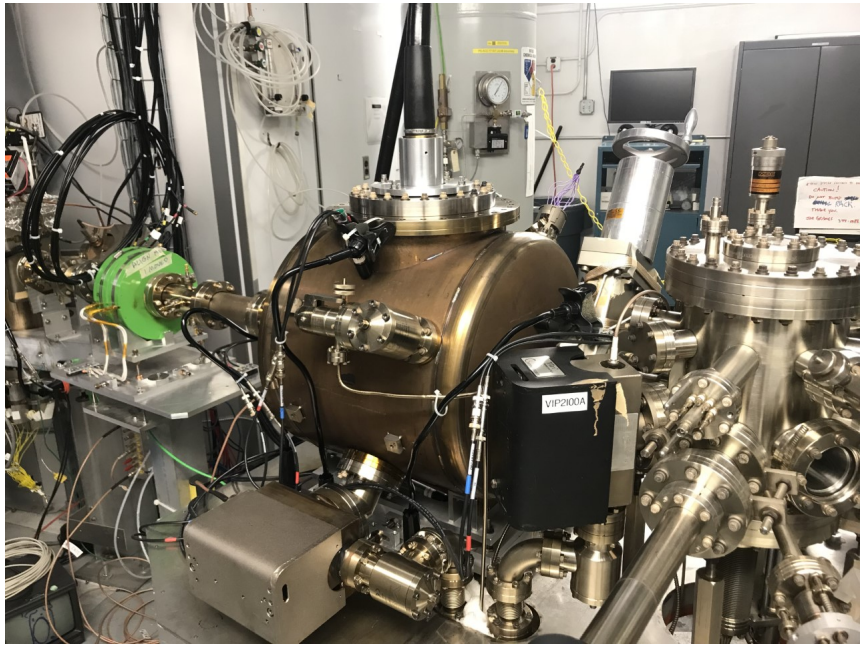
Thanks, Riad, for slides

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

New Gun

- New larger (18" diameter compared to old 14" diameter) HV Chamber
- Spherical cathode electrode instead of T-shaped
- 200 kV (instead of 130 kV)
- Tilted anode (2.43°) to cancel vertical kick from ceramic insulator and triple-point HV shield

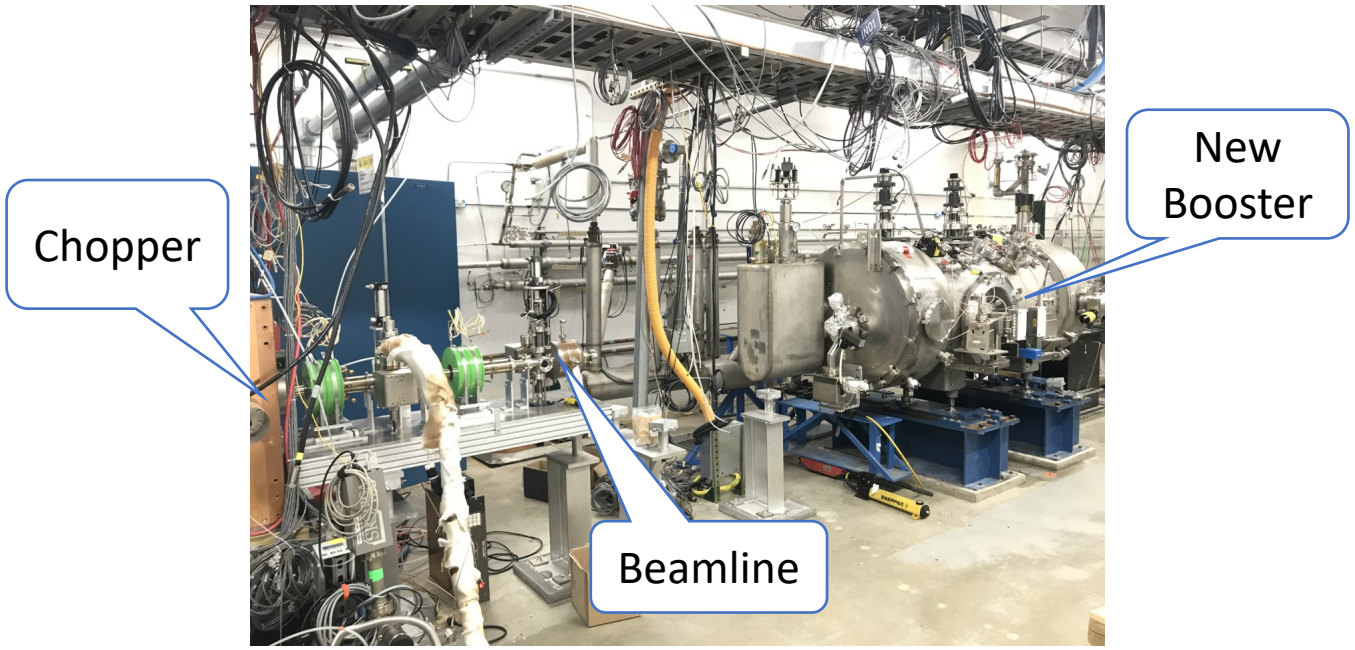


- Status:
  - HV conditioned – ready to run at 200 kV

Thanks, Riad, for slides

New Booster

- Booster installed. Now working on beamline between Chopper and Booster
- Added three new BPMs between Chopper and Booster (S/H outputs are available at parity DAQ) – now a total of five BPMs are in this region



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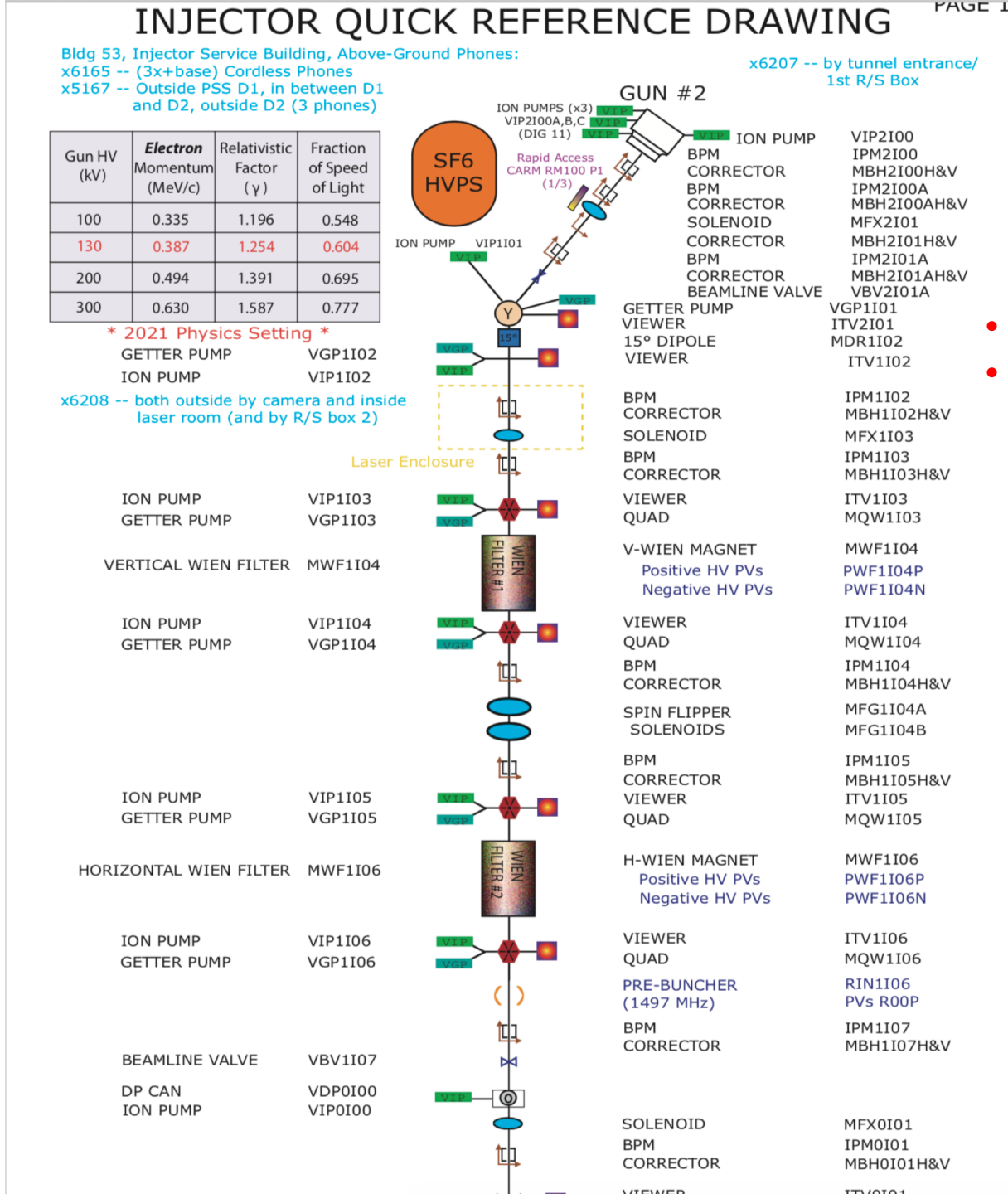


- Some New BPMs near the gun
- Will have to select which BPMs are useful to use

Accelerator Beam Tests (June – July 2023)

- **200 kV gun optics and gun-exit steering:** measure beam angle and displacement from new gun as a function of laser spot position Could help PQB because the RTP cell can control 2 degrees of freedom, not 4 (X,Y,X',Y'), so less coupling off the gun may help minimize position differences further

- **Beam studies of New Booster:** measure beam emittance upstream and downstream of Booster, beam kicks, energy spread, and x/y coupling caused by Booster

- **200 keV Wien filter optics:** optimize Wien filter operation at any angle with no significant impact on transmission or downstream optics

- **200 keV E/B Calibrations of V-Wien and H-Wien:** determine E and B field settings which do not deflect electron beam at 200 keV energy

- **200 keV Spin Dance Calibrations of V-Wien, H-Wien, and Spin Solenoids:** Calibrate spin rotators using Mott polarimeter

- **PQB studies in Injector:** first look at beam from new gun and Booster

PQB tests (hopefully July)

- Wein flip symmetry test (VWien flip was soooo good. Is it still good?)
- Beam noise tests in injector at 960Hz / 1920Hz (if ADCs/timing board in injector can handle it) with new helicity board
- New vacuum window put in with less birefringence, do RHWP scan to see how Aq offset improved (window helps to minimize introduction of gradients we can't control)
- Injector transmission assessment (Apertures have been changed, so hopefully at high currents, there will be less clipping. Also with new gun, less space charge expansion, so that may help)
- Chopper Scan (new temporals structure of beam, new high E gun, new booster, look at beam tails and compare with previous chopper scans)
- Do feedback on Pos Diffs with RTP and see how good we can get (best we saw before was 30nm)

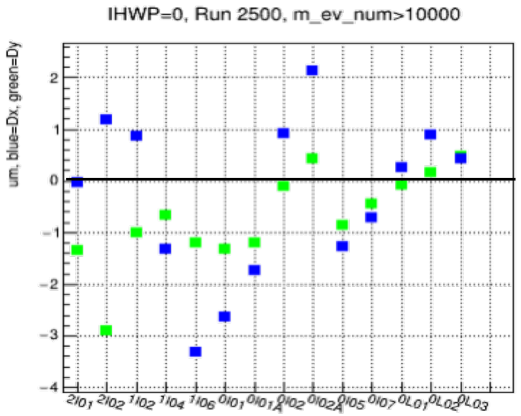
Wein Flip

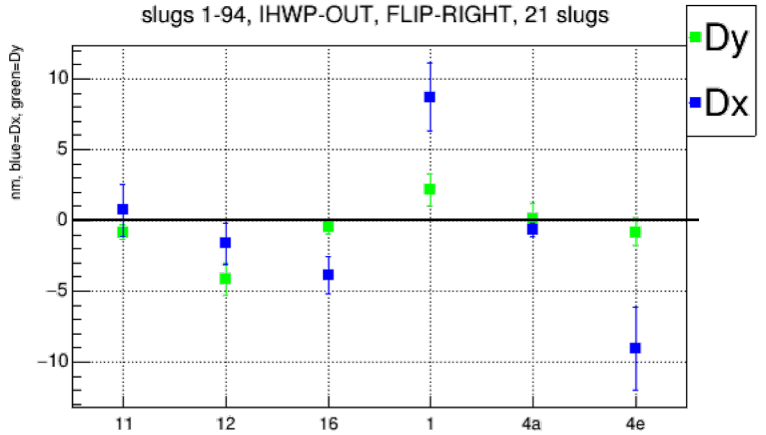
Pre Experiment: low energy injector

After experiment: experimental hall

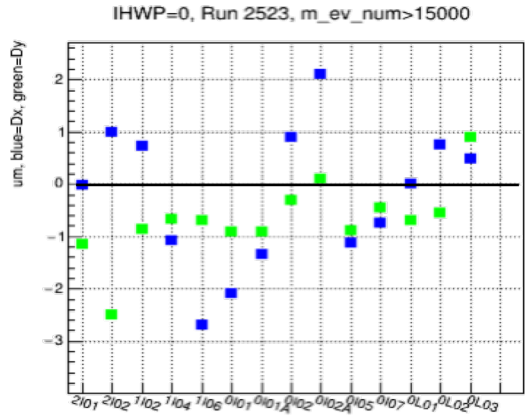
Is it still this good?

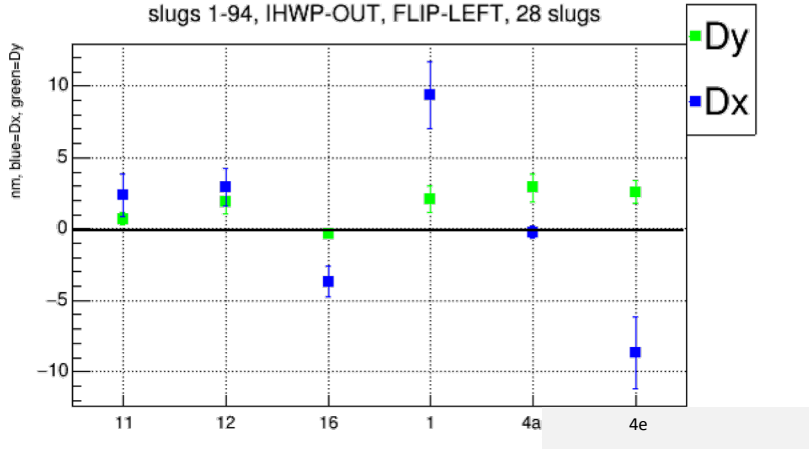
Flip Right:





Flip Left:





BPM name

BPM name

Electron Spin Reversal:

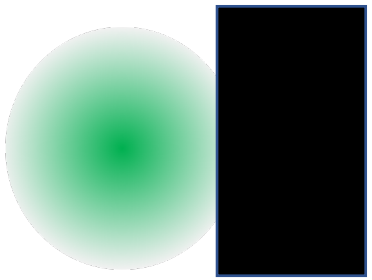
- ExB for 1π precession
- Symmetry – good for position difference cancellation, also good for spot size asymmetry cancellation
- Spin Flip (pre-upgrade) done back-to-back is quite symmetric.
- In practice, over weeks, settings can change.
- Goal: Flip often, flip efficiently AND quantify flip symmetry each time (RTP cell let's you do this)

Run2523_VWeinMinus89p9deg_FlipLeft_IHWPout_AposUm3000_AposVm3000.png

https://logbooks.jlab.org/entry/3685216

Jefferson Lab

Transmission and Beam noise



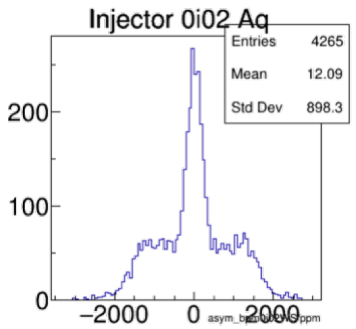
= noise + HCBA intercoupling

$$D_x \Rightarrow A_q$$

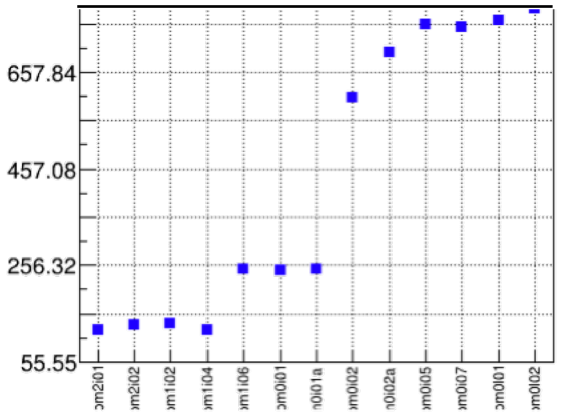
Beam Property	Required 1 kHz random fluctuations	Required cumulative helicity-correlation
Intensity	< 1000 ppm	< 10 ppb
Energy	< 110 ppm	< 1.4 ppb
Position	< 50 μm	< 0.6 nm
Angle	< 10 μrad	< 0.12 nrad

noise

Aq distribution



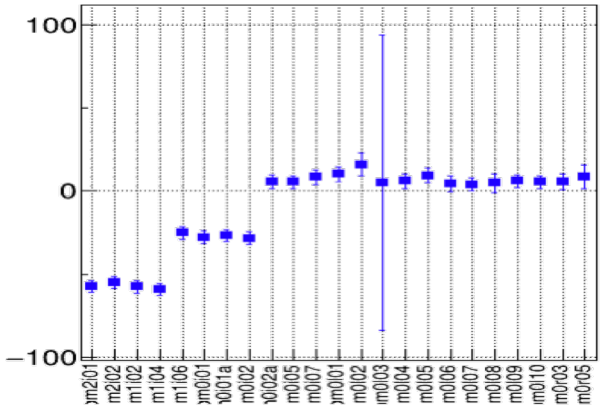
Aq RMS



BPM name

HCBA intercoupling

<Aq>

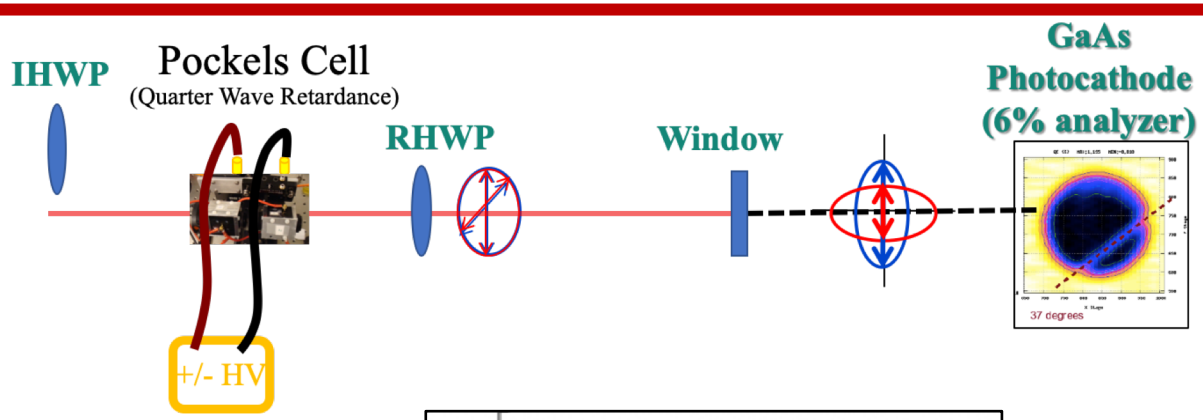


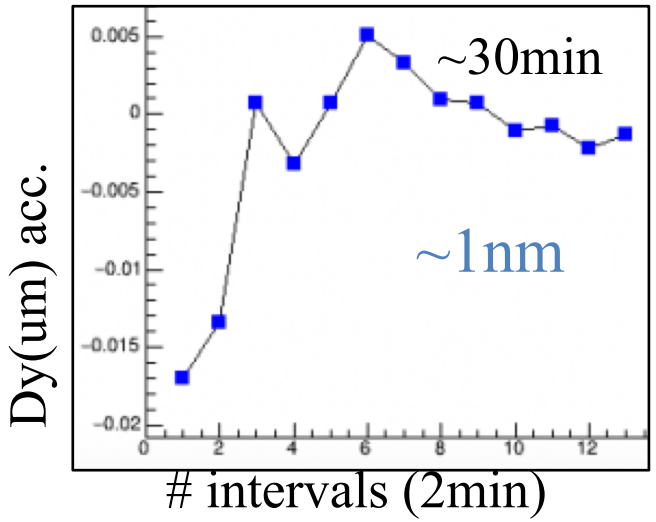
BPM name

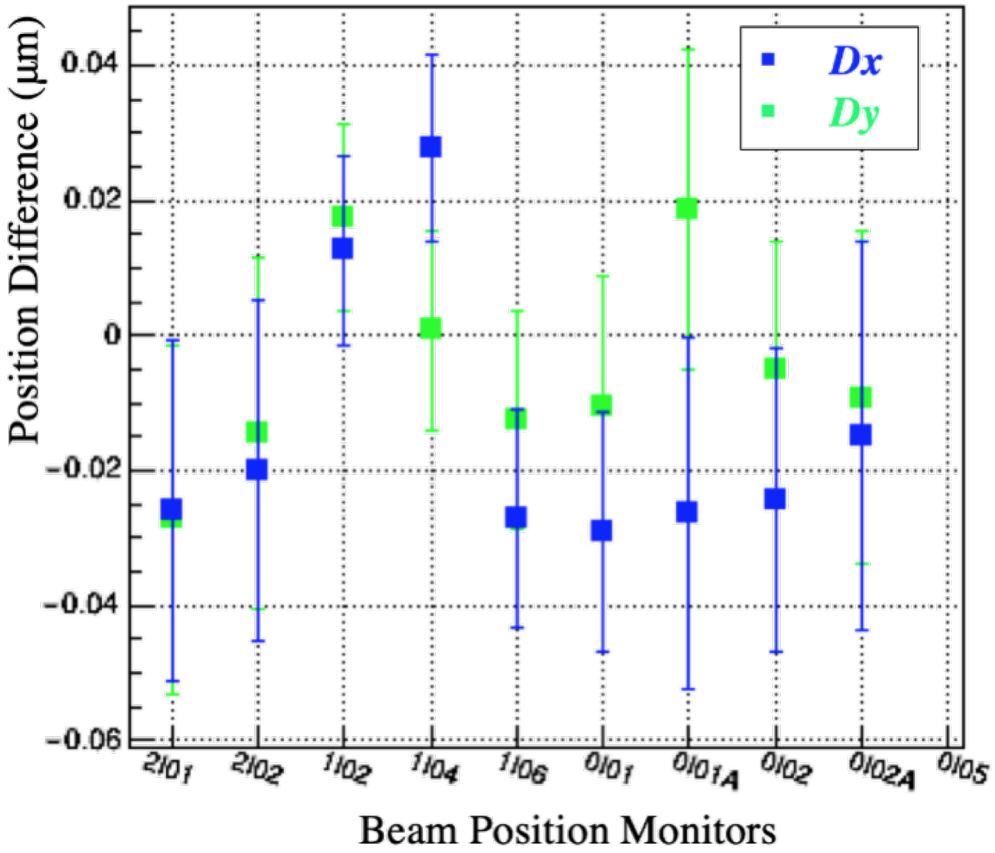
Poor Beam Transport Can Mess things up BADLY

Jefferson Lab

How well can we do with RTP feedback?



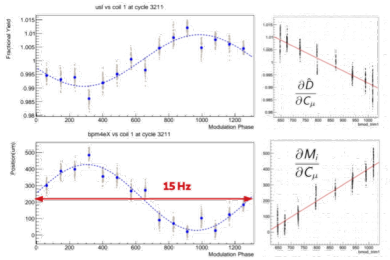




Can we do better than 30nm now?

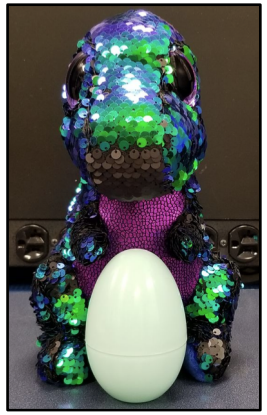
On the horizon

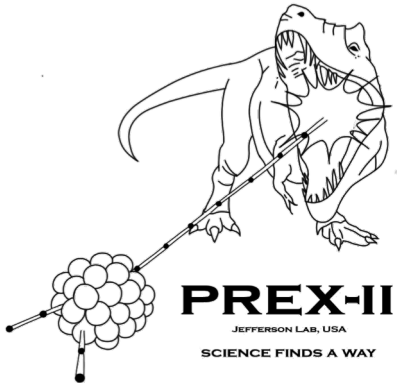
- **Fast Feedback (FFB) System resurrection (December 2024)**
- **Injector transmission and parity-quality beam (December 2024)**
- **Wien filters slow reversal – Wien Flip (December 2024) -** The preservation of beam properties under polarization reversal is key to the utility of this flip. The planned high frequency of the flip will require the ability to perform a rapid configuration change. Explore ideal frequency of Wein flips 1/week 1/3days? How long for things to drift?
- **Feedback on polarization orientation (December 2024)** - corrections for drifts envisioned to occur daily during regular running, or in a shorter time scale after any significant linac energy rebalancing. The changes are expected to be about 1-2° and applied to the nominal Injector Wiens angles.- *Ops-Inj and CIS should provide the optimal protocol to apply the required changes, find out if the feedback can be done by the beam energy instead*
- *We also need to resurrect the Beam Mod System and check it can handle 11GeV*



Summary

- Weekly Organizational Meeting taking place between MOLLER collaboration and JLab staff
- Parity Hardware being updated with our input
- Injector Upgrade Phase II gone as planned
- Injector Beam tests as soon as July
- Lots of work to be done, we just have to continue and remain on track





Also…. For MOLLER we need :

A Mascot, a Logo, and a Blinding String

- Seed string: [Using CREX Positions!] It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts.---A Scandal in Bohemia, Arthur Conan Doyle.

Road kill stew sounds mighty good right now