PREX: Beamline and Parasitic Test Ideas

Mark Pitt, Virginia Tech April 11, 2014

- Comparison of PREX and MOLLER goals
- Some relevant experience from Qweak
- Ideas for parasitic tests

MOLLER and PREXII Resolution/Jitter Specs.

Monitor resolutions at 1 kHz pair rate

Monitor type	MOLLER spec.	Qweak observed
BCM	10 ppm	65 ppm
BPM	3 μm	6 μm

Random beam fluctuations at 1 kHz pair rate

Beam property	MOLLER spec.	PREXII spec.
Intensity	< 1000 ppm	< 8000 ppm
Energy	< 286 ppm	< 41 ppm
Position	< 47 μm	< 82 μm
Angle	< 4.7 μrad	< 12 μrad

PREXI ran at 120 Hz (240 Hz pair rate for comparison here)

PREXII will run at?

Qweak resolution observations:

BCM: based on Musson digital receivers being tested now in Hall A

BPM: quoted number for striplines, cavity monitors expected to be better

PREX specs. from http://hallaweb.jlab.org/parity/prex/PREX_Beam_Requirements.pdf

"Wish List" for MOLLER Beamline Monitoring R&D

In January 2013, memo outlining "Near-term Hall A Beamline Instrumentation for MOLLER Development" was prepared at Thia's request
(authors: Krishna Kumar, Bob Michaels, Kent Paschke, Mark Pitt, Paul Souder)
(see MOLLER docdb: https://hallaweb.jlab.org/doc-private/ShowDocument?docid=77)

To achieve MOLLER's goals for beamline monitoring precision/redundancy, it would be very useful to have this hardware available for parasitic testing during early Hall A 12 GeV era running

1. Three XYQ cavity monitor assemblies in non-dispersive region ➔ in progress
   - All exist in the Hall (2 near target, 1 – from G0/Qweak girder – ready to be installed)
   - Motivation: Allow definitive measurement of beam position resolution of the cavity monitor hardware/receivers (recall: MOLLER goal is 3 μm position resolution for 1 kHz "window pairs") ➔ Also useful for PREX to have redundant position measurement with well determined resolution

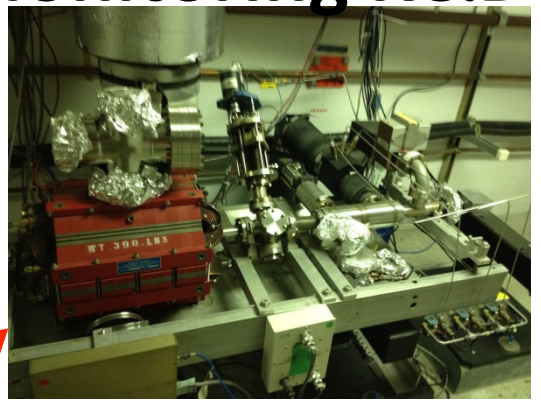
2. A "triplet" of cavity charge monitors (BCMs) wherever convenient
   - Motivation 1: would provide large redundancy in the critical charge measurement (recall: MOLLER goal is 10 ppm charge resolution for 1 kHz "window pairs")
   - Motivation 2: would provide self-contained set of nearby BCMs to study the position dependence of the charge measurement

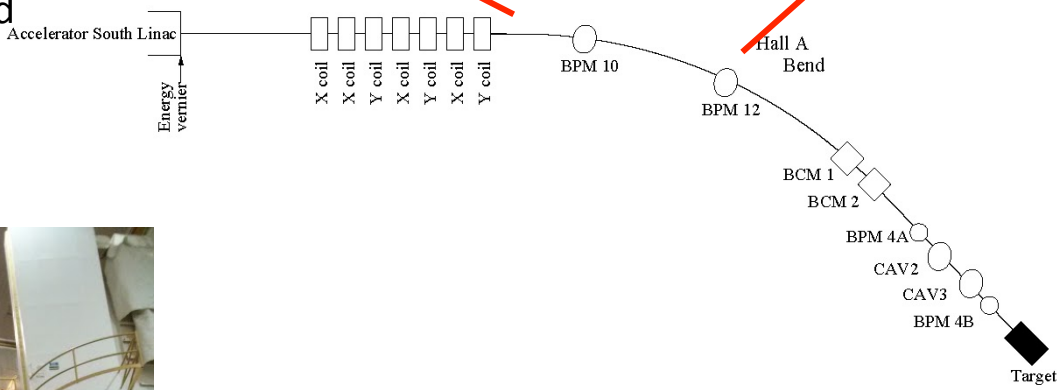
3. An XYQ cavity monitor assembly in the dispersive region
   - Possible candidate is the unconnected XYQ cavity assembly that is further upstream in the arc
   - Motivation: to have redundant measurement of helicity-correlated beam energy fluctuations (in addition to the usual "stripline" BPM12)

“Wish List” for MOLLER Beamline Monitoring R&D

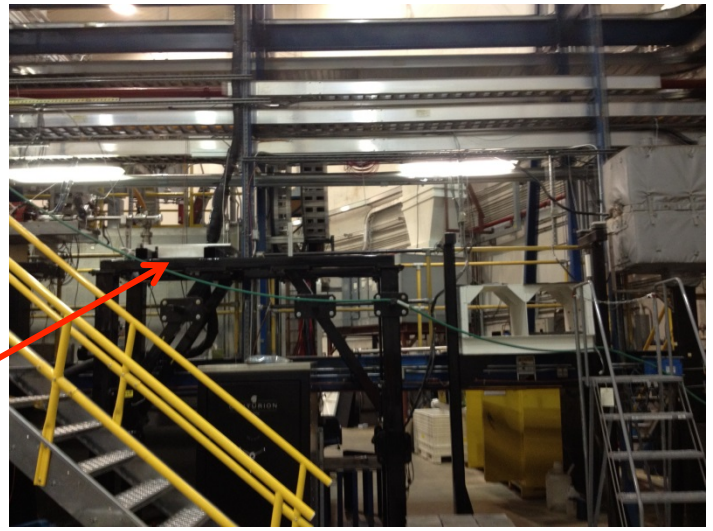
BCM cavity triplet could go here?

“12” girder; XYQ monitor (from upstream in arc) could go here? – energy measurement





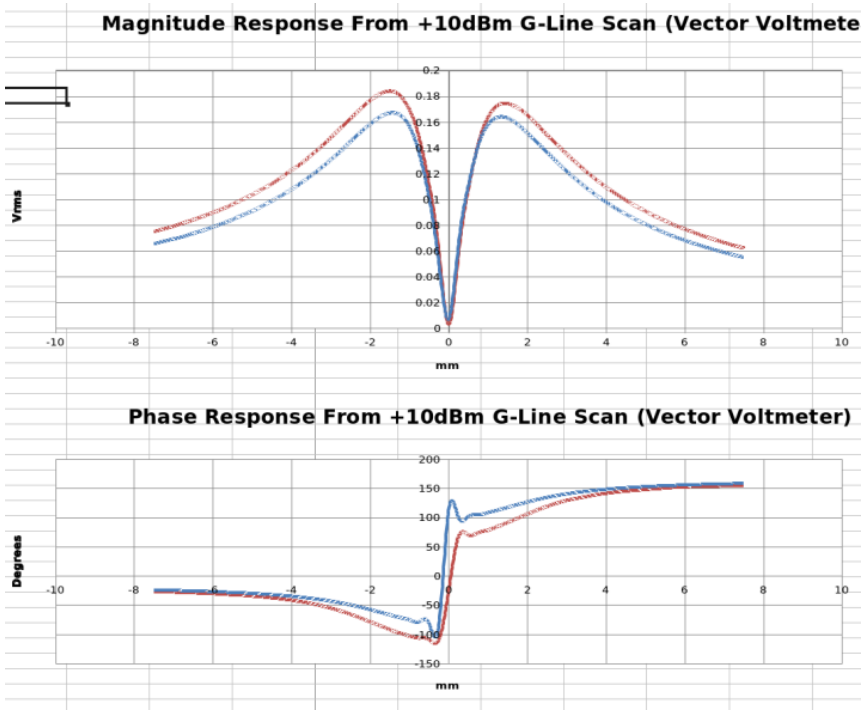
XYQ from old G0/Qweak girder, on floor in Hall A, can go in here – room exists according to Ed Folts

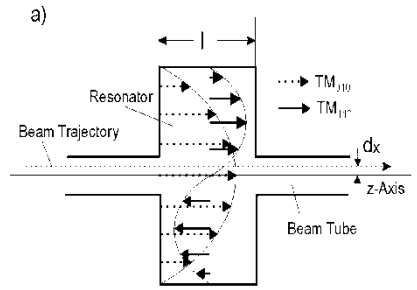


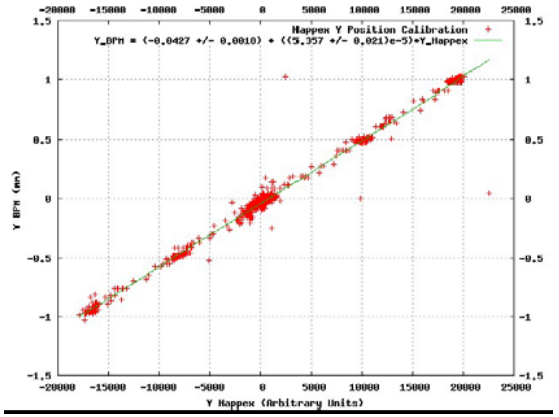
What is real cavity BPM/BCM aperture?

John Musson “G-line” tests indicate only +/- 1 mm active aperture instead of the designed +/- 1 cm aperture indicated by MAFIA simulations

➔ This issue is best resolved directly with a beam test.







Best existing data (Dong et al. PAC2005) only looked at range ±1 mm

Direct beam test with unrastered beam and comparison to nearby stripline would be best

According to Doug H. a +/- 2 mm aperture looks to be achievable (based on previous bullseye scans)

Some Relevant Experience from Qweak

- Best BCM resolution with digital receivers
- Helicity-correlated beam properties – need for injector/ accelerator matching
- Experience with double Wien spin reversal system

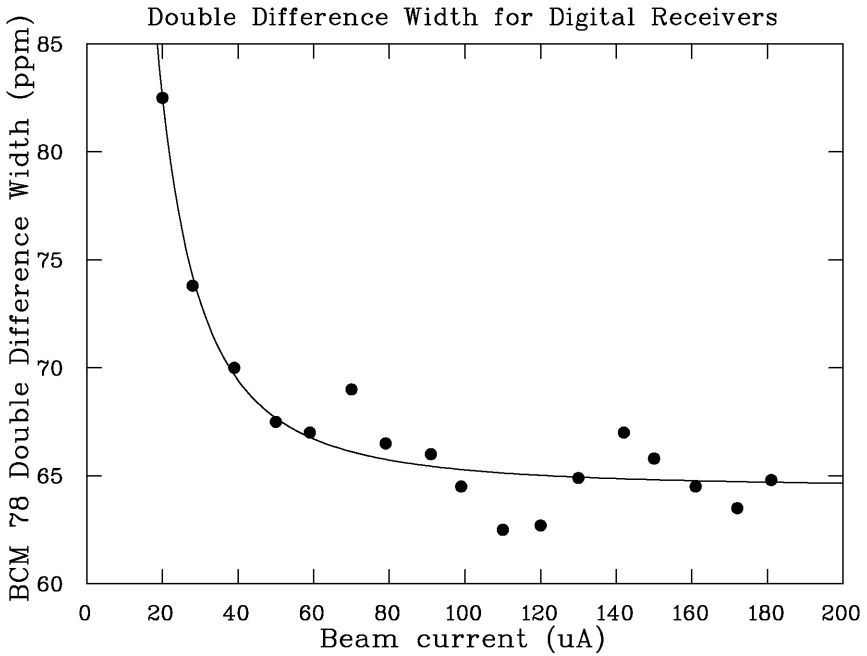
Best BCM Resolution with Digital Receivers

- MOLLER goal for charge monitor resolution is ~ 10 ppm for 1 kHz pairs
- Qweak best values ~ 46 ppm for effective 480 kHz pairs

Qweak got these results with:

- Standard BCM hardware (TM_{010} cavities)
- Most recent version of the "Musson/Allison" digital receiver chain (currently being tested in Hall A?)

Double difference
measures uncorrelated noise between two monitors



Fit by simple functional form:

$$\Gamma = \sqrt{\left(\frac{1032\,\text{ppm}\,\mu\text{A}}{I}\right)^2 + (64.5\,\text{ppm})^2}$$

→ apparent noise floor at ~ 65 ppm

Assuming white noise scaling ➔ ~ 16 ppm for PREXII

< 1% increase in statistical width of 170 ppm@ 70 μA ➔ good enough!

Helicity-Correlated Beam Properties

Strategy:

- Properly set up laser table devices (Pockels cell, RHWP, …) prior to run to give minimum helicity-correlated beam properties – check with measurements in injector
  - good setups typically give < 200 nm position differences in early part of injector

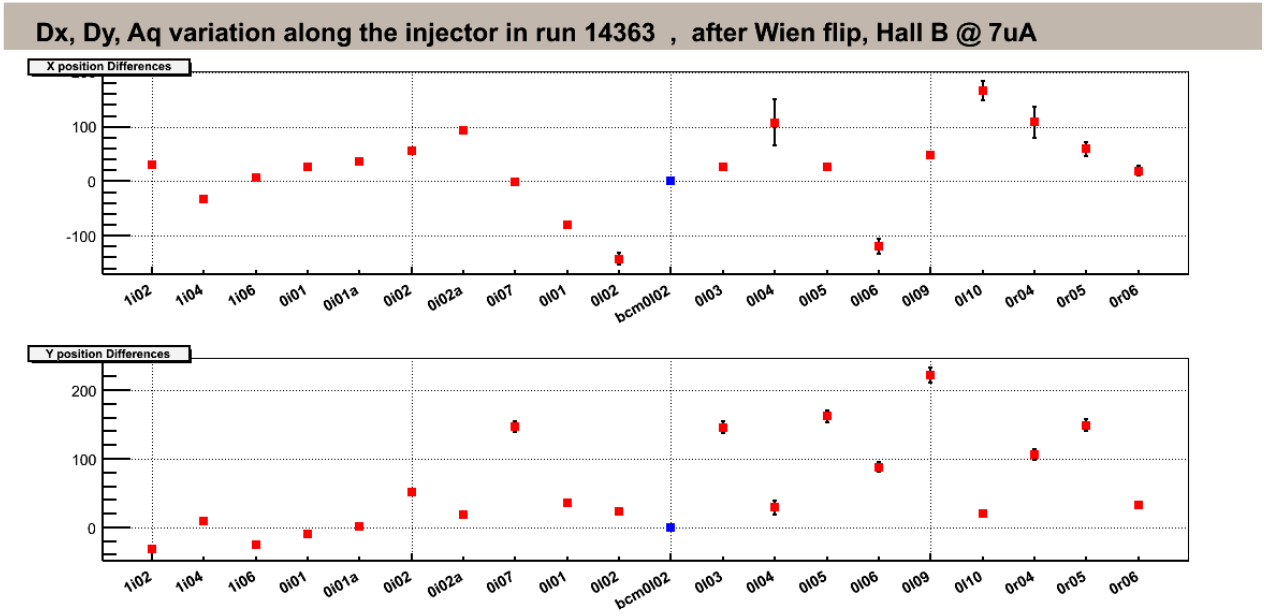
- Obtain additional suppression ("adiabatic damping") with optimized injector/ accelerator optics match
    - Actively pursued during HAPPEX-II; clearly helped and was implemented with a specific procedure

➔ Qweak did not devote time to matching; we suffered from some periods with large position differences despite optimized laser table setup

Qweak: Injector and Hall Position Differences

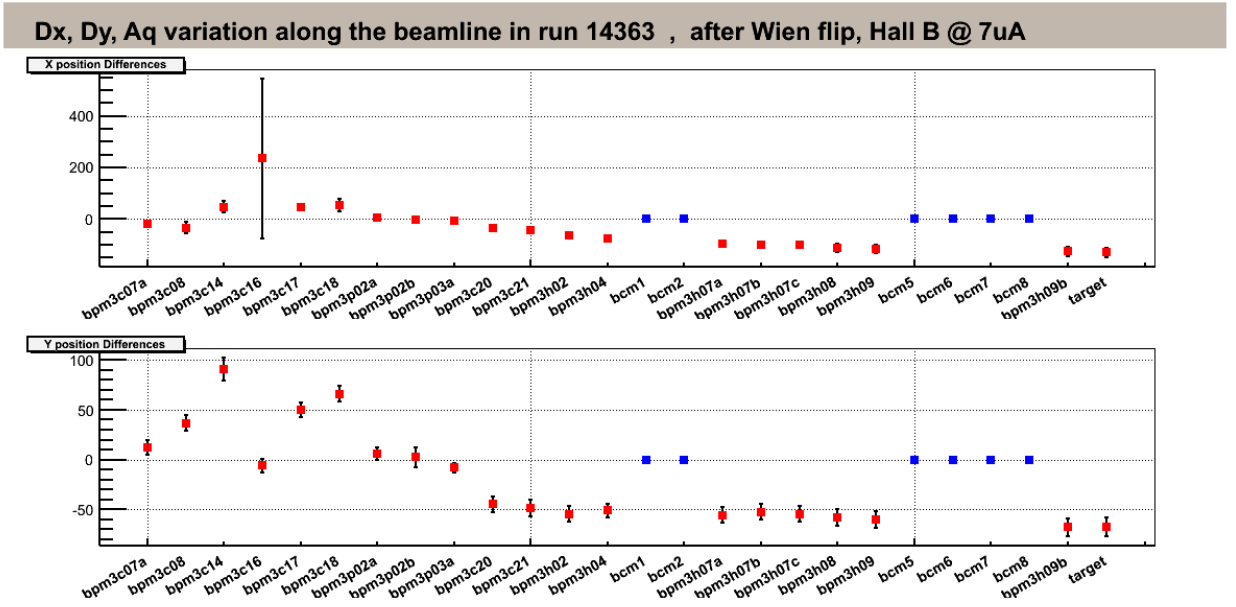
Injector and Hall C position differences measured at same time.

X, Y position difference early in injector < 50 nm (better than typically seen in HAPPEX-II

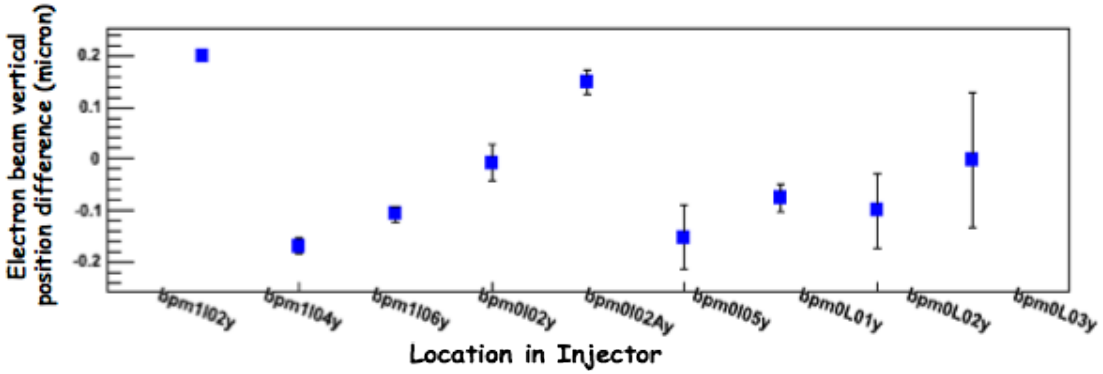


Position differences at Qweak target in Hall C:
X ~ - 100 nm
Y ~ -70 nm

HAPPEX-II saw much smaller position differences in hall with comparable injector differences – seems to argue that injector/accelerator optics matching is important

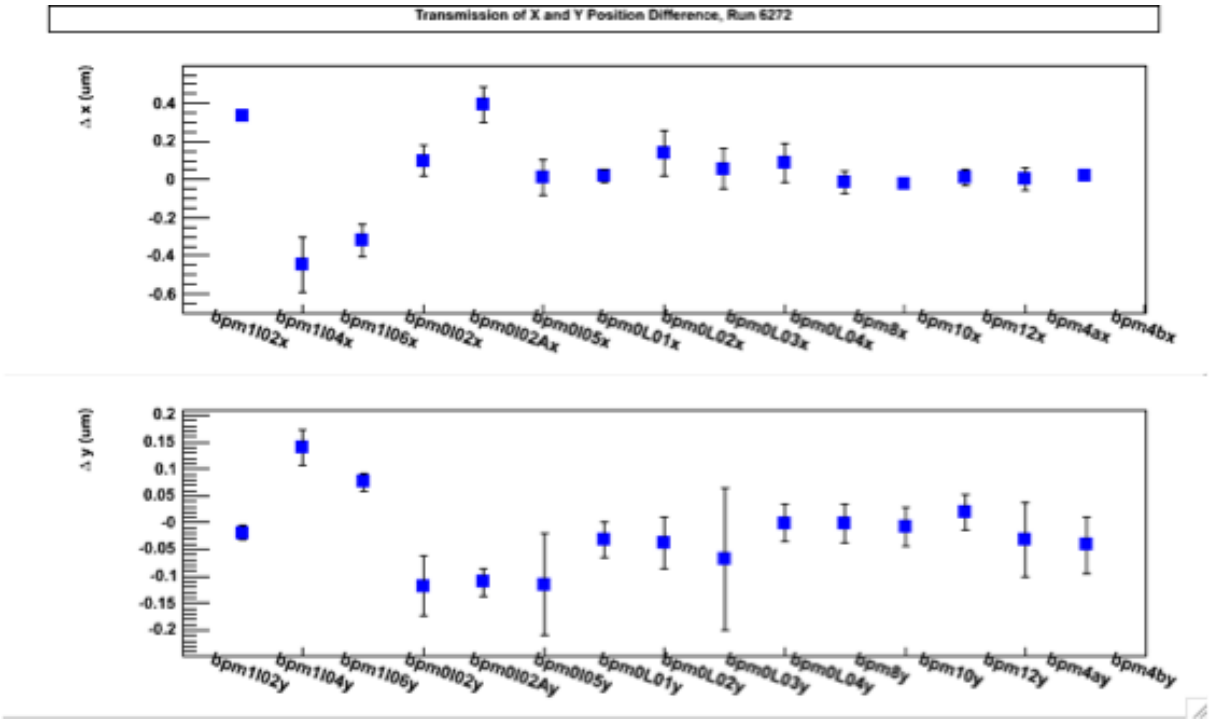


Injector Position Differences for 2005 HAPPEX-II-H



After injector configuration: position differences in injector had maximum around 200 nanometers - this produced the previously shown pretty results for H

At end of run: injector position differences had doubled, but increase was not evident in hall (damping!)



Helicity-Correlated Beam Properties – Some Conclusions

Conclusions of HAPPEX-II collaboration after their experience with matching (from Kent Paschke):

- Transport matching design (linacs & arcs) now routine.
- Improvements in the 5 MeV injector major step forward
- Configuration very stable over 2+ months

For PREX, it will likely be very important to establish a routine "matching" procedure to insure we meet our first order beam property goals and to suppress potential higher order effects.

- Much progress could be made with beam studies early in the 12 GeV running in Hall A (assuming the Hall A beam instrumentation has its parity electronics attached)

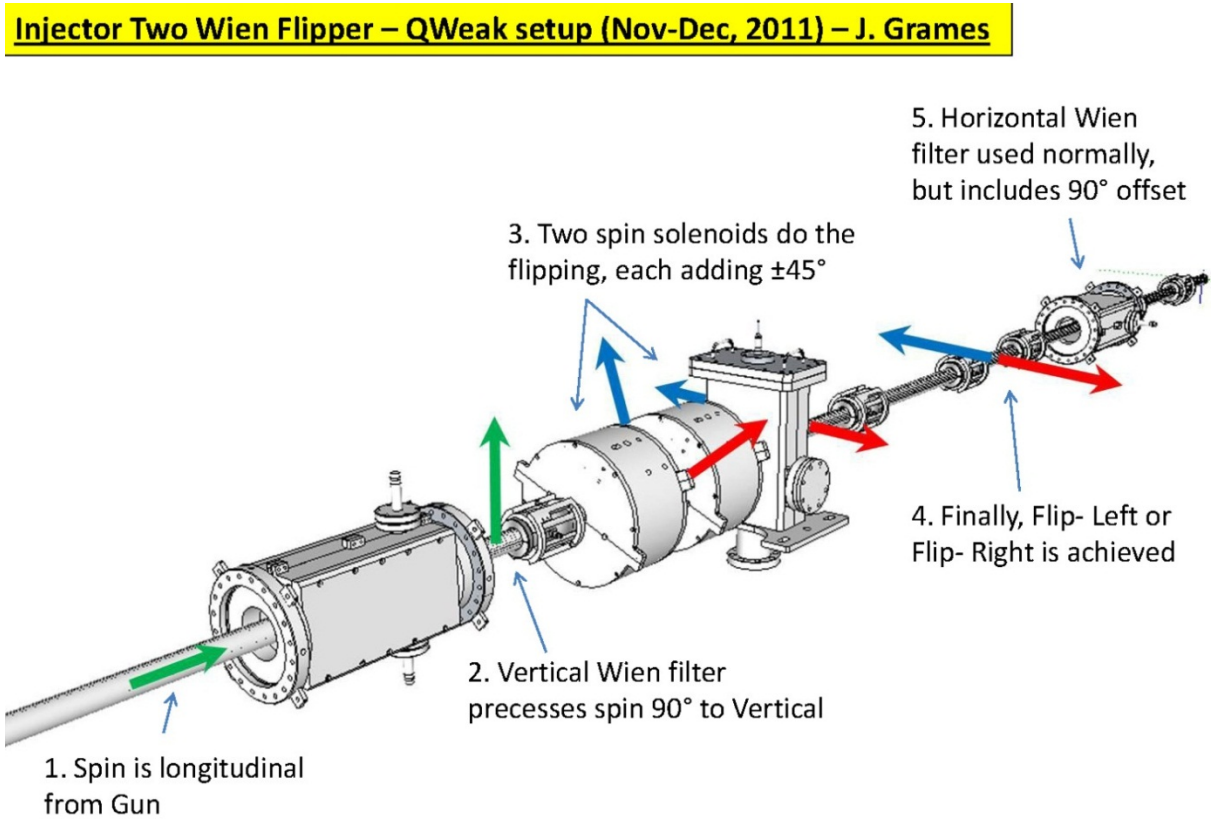
- Ideally, we would like to re-establish the physics/accelerator collaboration (ala HAPPEX-II) to work on this issue

Some Qweak Experience with Double Wien Spin Flipper

- During Qweak Joe Grames evaluated how much deviations in Vertical Wien from "90^{o}" would cause non-zero residual transverse polarization after flip

- Time was requested to do spin dance for both "Flip left" and "Flip right", but (I don't think) it happened

➔ It might be useful to do this and any other double Wien commissioning items that were never fully explored



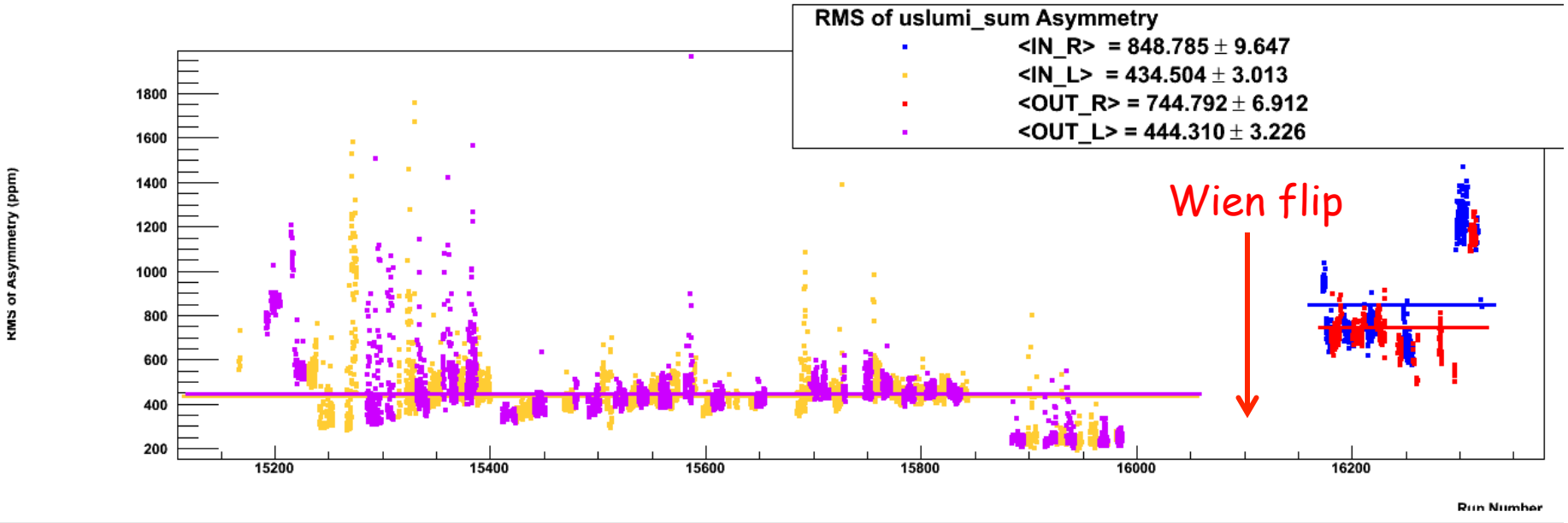
Some Qweak Experience with Double Wien Spin Flipper

Qweak analysis is still in progress, so the relative benefits/problems with Double-Wien is still under evaluation

This is just an example of things we can look at

"Upstream luminosity monitor width" – found empirically to be very sensitive to beam transverse properties like halo and tails

Often does appear to change at Wien flip (from ~ 220 ppm to 700 ppm in this case) – BUT it changes at other times as well



Ideas for Parasitic and Dedicated Tests

- Measure random beam fluctuation properties ("jitter") with parity DAQ (*)
- Work on injector/accelerator "matching" to achieve as much "adiabatic damping" as possible
- Check the "aperture" of the existing microwave cavity monitors with dedicated test
- Check the beam modulation coil system (what energy does it work usefully up to at the moment for test purposes?)
- Carry out any remaining double Wien flipper "commissioning tasks"
- When third XYQ cavity is installed in Hall A, do direct measurement of cavity monitor resolution with parity DAQ (*)
- Measure and monitor BCM charge resolution with parity DAQ (*)

(*) can be done parasitically if flip rate is near what we want