Electron Beam Setup for Bubble Chamber

A. **Hofler**, Accelerator-Physics Experiment Liaison (APEL)

J. Benesch, B. Cade, A. Freyberger, J. Grames, R. Kazimi, M. McCaughn, D. Moser, M. Poelker, & R. Suleiman

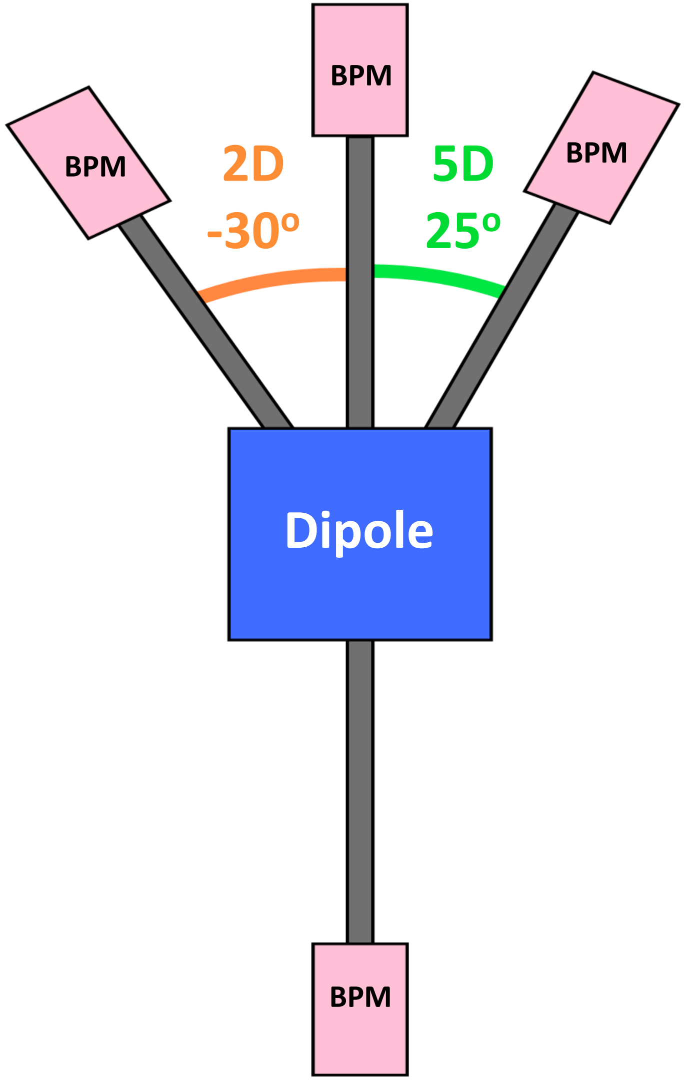
August 22, 2018

Improvements since 2015 Engineering Run

- Dipole
  - More accurate dipole field map [1,2]
  - Dipole current readback resolution
    - Readback with Digital Multimeter (Keithley 2000)
    - Higher resolution (1 mA) than trim card readback (5 mA)
  - Hall probe in dipole
    - Measure field in dipole
    - Digital Teslameter (Group3 Technology DTM-151)
    - MPT-231 Hall probe (Group3 Technology MPT-231)
  - Stray magnetic field shielding in 5D line [3]
- Beam diagnostics
  - Wire scanner beam profile monitor (harp) in 5D line
    - Measure beam size upstream of radiator
- Procedures for Operations [4]
  - Set energy
    - Use dipole Hall probe readback to set momentum delta and reproduce setting
  - Measure energy
  - Measure energy spread with harp in 2D line
  - Set optics to produce requested spot size on radiator
    - Quadrupole scan technique
    - Wire scanner beam profile monitors (harps) in straight ahead and 2D lines

[1] R. Sulieman, BTeam presentation, 2016
[2] J. Benesch, JLAB-TN-017, 2015
[3] R. Sulieman, e-log 3392568, 2016
[4] Bubble Chamber wiki (http://wiki.jlab.org/ciswiki/index.php/Bubble_Chamber)

Energy Measurement



BPM=Beam Position Monitor

Procedure:

1. **A priori, center beam in quadrupole closest to BPM and note positions (except 2D—no quads).**
2. **Turn OFF and cycle all unnecessary magnets around hysteresis loop.**
3. **Degauss dipole.**
4. **Establish straight ahead orbit with restricted corrector magnet set.**
5. **Adjust dipole setting (and cycle) for zero orbit in each dump BPM.**

For fixed incoming momentum, $p = p_{2D} = p_{5D}$,

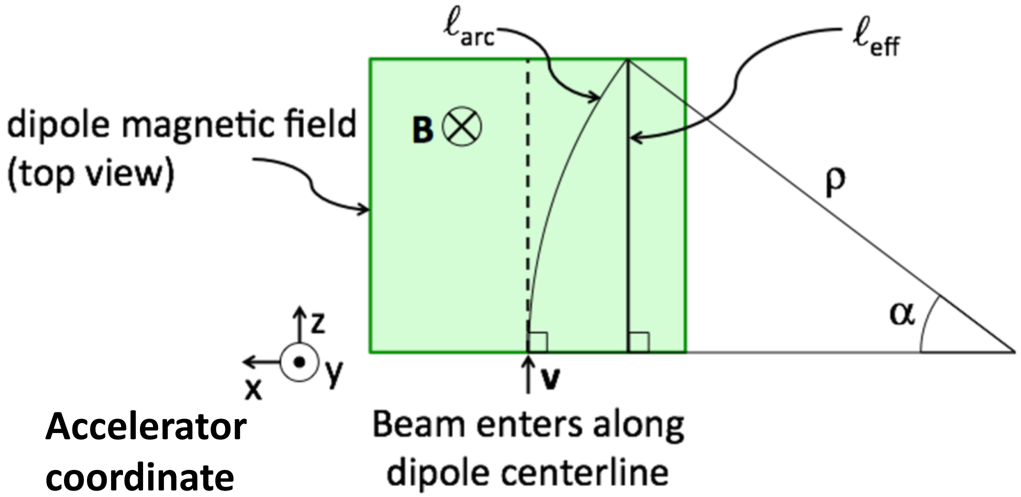
$$\frac{\alpha_{2D}}{\alpha_{5D}} = \frac{-30^\circ}{25^\circ} = \frac{B_{2D}\ell_{arc2D}}{B_{5D}\ell_{arc5D}}$$

Fits of dipole settings give p and errors in angle and field.

Note dipole setpoint

< 0 for beam in 2D line

> 0 for beam in 5D line



Accelerator coordinate system is LH

Jefferson Lab

Measured Energies

Design p (MeV/c)	Design K.E. (MeV)	2D line dipole setting (G cm)	5D (Bubble) line dipole setting (G cm)	Measured p (MeV/c)	Measured K.E. (MeV)
5.84	5.35	-9937.637	8168.800	5.885	5.395
5.74	5.25	-9865.500	8099.000	5.840	5.355
5.64	5.15	-9632.300	7909.200	5.705	5.215
5.54	5.05	-9468.500	7771.400	5.605	5.115
5.44	4.95	-9320.700	7646.800	5.515	5.030
5.34	4.85	-9135.993	7490.000	5.405	4.920
5.24	4.75	-8957.675	7338.900	5.300	4.815

Beam Energy Errors

- Dipole current uncertainty is 1 mA
  - Average dipole current for beam in 5D line 3.177 A
  - Average dipole current for beam in 2D line -3.817 A
  - ➢ 0.03% uncertainty

- Field map uncertainty is 7 G cm [1,3]

- Magnet Model (to find momentum from field map) uncertainty is about 0.1% [2,3]

- Errors in bend angle and stray fields are still under study

Errors Summary (so far):

Error	Uncertainty
Dipole Current	0.03%
Field Map [1,3]	0.1%
Magnet Model [2,3]	0.1%
Total	**0.14**

[1] R. Sulieman, BTeam presentation, 2016
[2] J. Benesch, JLAB-TN-017, 2015
[3] J. Grames, JLAB-TN-17-001, 2017

Summary and Future Plans

Efforts since 2015 Engineering Run to improve

- dipole field characterization
- monitoring of dipole current and field

⇒ **Successful set and measurement of energies during the 2018 Engineering Run**

Minor Suggested Changes for Future Engineering Runs

- To set and verify beam spot position on the radiator
  Install retractible X-ray screen in front of the radiator
- To reliably set the beam size at the radiator
  Improve optics model to more accurately reflect beam dynamics affecting beam size

- To reduce variability in setting and measuring the energy
  - Put controller for Hall probe in a shielded box and move to floor (eliminate controller resets)
  - Reduce number of magnets used in straight ahead orbit (reduce fields)
  - Improve ability to measure and reproduce beam orbit angles through dipole
    - fiducialize 2D and 5D harps
    - add quads to 2D line for quad centering to establish orbit reference

Summary and Future Plans

- Efforts since 2015 Engineering Run to improve
  - dipole field characterization
  - monitoring of dipole current and field

    ⇒ **Successful set and measurement of momenta/energies during the 2018 Engineering Run**

- Minor suggested changes for future Engineering Runs

- To better measure blat
  - Will do this
  - To test in next run

- Dipole Hall probe resets
  - Put controller in lead box
  - Move to floor

- Disagreement between calculated and measured beam sizes at IHA5D01

Minor Issues and possible mitigations:

- straight ahead orbit
  - improve set up procedure (to eliminate/reduce unnecessary magnetic fields)
- stray fields
  - more shielding
- how well know beam orbit angles
  - fiducialize 2D and 5D harps
  - add quads to 2D line for quad centering/establish orbit reference
- beam position on copper radiator
  - X-ray screen at radiator for steering