Hall A Beam Energy Measurements for GMP

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01-13-2016

Available Methods

- To keep the relative error on our cross-section at ~1% - 2%, we need to have an absolute energy measurement at the level of 10^{-4}
- Following methods are available to determine the beam energy:
  - Arc Measurement
  - Spin Dance
  - OPTIM model (Tifenbach)

    (NOTE – eP method is not in use anymore.)

- We can use above 3 methods to improve the final error on the absolute energy. But Doug thinks it is highly unlikely we will reach a precision of 10^{-4} with the 11 GeV beam.
  - The best we may get is 10^{-3}
- Doug also pointed out that when Hall C starts up, we can use the Hall C moller and Hall A moller intercomparision of the spin precession (more on this later) to check for hidden systematics. This method, according to Doug, is the most clean (independent of accelerator systematics) way to measure the absolute beam energy. So we have a way of checking our energy measurement numbers after the experiment.

Arc Measurement

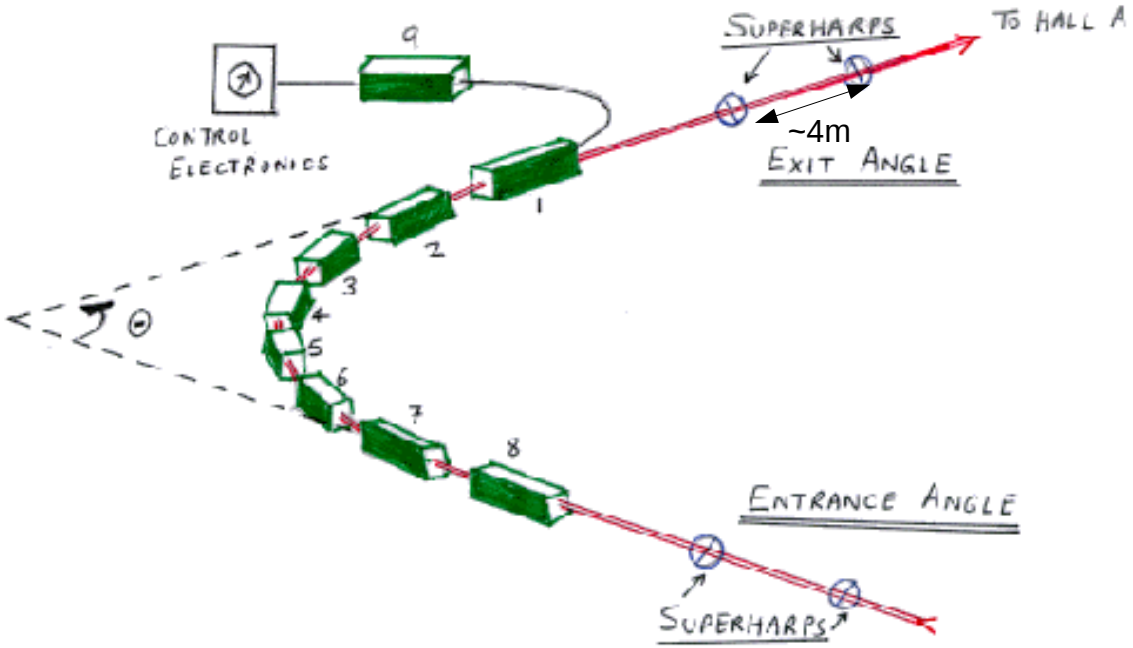
- Measures the energy, E, as a function of the field integral of the eight dipole magnets and the bend angle of the arc.

$$E = k \frac{\int \vec{B} . \vec{dl}}{\theta}$$

For the E range = 0.5 to 6 GeV

Accuracy:

p/p <= 2 x 10-4 (FWHM)



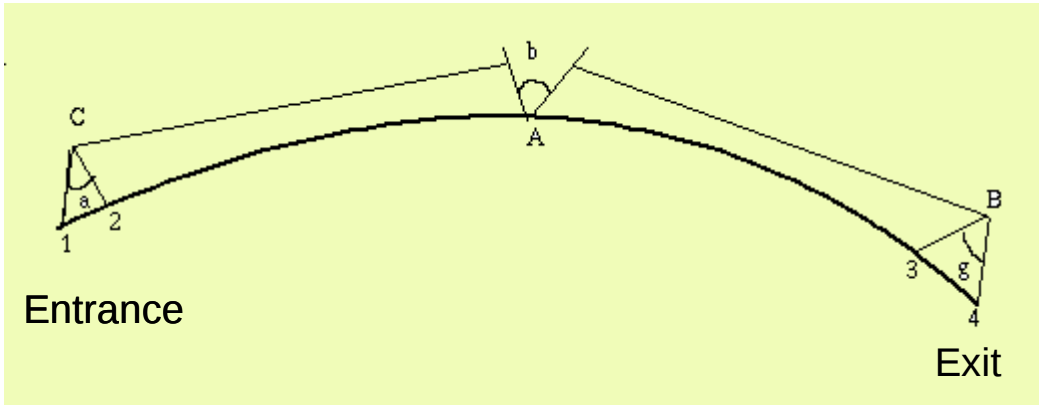
Instrumentation used:
1. 4 Superharps
2. absolute angle measurement device
3. absolute field integral measurement device

http://hallaweb.jlab.org/equipment/beam/energy/arc_web.html

Arc Measurement - The bend angle

- The bend angle θ is measured by using 4 wire scanners (superharps) at the entrance and exit of the Hall A arc.
- Each scan the beam giving a horizontal profile of the beam readout via PMTs. The profiles from each scanner are compared with the other in the respective pair to come up with a horizontal beam angle both upstream and downstream
- A pair of mirrors is placed over the middle point of the arc tunnel ("A"), one mirror facing a marker at the axis of scanners 1 and 2 while the other mirror faces a marker at the axis of scanners 3 and 4. The mirrors can be made so that the angle, b, between them will remain constant forever.
- The sum of all the angles can then be used to find the the total bend angle, θ

$$a+g+b=\theta.$$



Arc Measurement- The field integral

- The field integral of the 8 magnets is measured using an *almost* identical magnet placed in an outside building. It is powered in series with the other 8.
  - If we want to reach a precision of 10^-3 we need to consider the higher order corrections coming in from the differences between the reference magnet and the arc magnets.
- Uses 'translating coil' technique to measure the field.

$$\int \vec{B}.\vec{dl} = B_0.L + (s/a)\iint V.dt^2$$

Spin Based Energy Measurements

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS, VOLUME 7, 042802 (2004)

- The total spin precession between the injector and any experimental hall, as measured by the Mott polarimeter and the corresponding experimental hall polarimeter, can be exactly calculated. Comparing injector and Hall A polarimeter (>10,000 degrees of precession)
  - Final beam energy resolution better than 0.01%.
  - Sensitive to the equality of linac gradient ($E_{12} = E_{linac\#1} - E_{linac\#2}$).

$$E = \frac{\frac{4m_e\Psi_n}{g-2} - E_0(\theta_t - \theta_h) - \frac{nE_{12}[\theta_t - \theta_h + (n-1)\theta_{12}]}{(2n-1)}}{\theta_t + \theta_h}.$$

TABLE X. Final beam energies measured by total precession evaluated at $E_{12} = 5.2 \pm 1.0$ MeV.

Polarimeters	Ψ (deg)	E (MeV)
Mott-Compton	10 985.94 ± 1.37	5649.21 ± 0.89
Mott-Møller A	10 984.96 ± 0.71	5648.70 ± 0.65
Mott-Møller B	10 501.60 ± 0.64	5647.20 ± 0.66
Mott-Møller C	10 024.51 ± 0.69	5649.03 ± 0.71

~10^{-4}

Spin Based Energy Measurements

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- Comparing only end-station polarimeters (<1000 degrees of precession)
  - Final beam energy resolution ~0.1%.
  - Insensitive to accelerator uncertainties, e.g., (linac equality, injector energy).
  - Requires knowladge of injector energy, linac gradients, and all bend angles.

$$\Delta\Psi = \frac{g-2}{2}\frac{E}{m_e c^2}\cdot\Delta\Theta,$$

TABLE XI. Summary of energy measurement results comparing only end-station polarimeters by the relative spin precession method.

Polarimeters	$\Delta\Psi$ (deg)	$\Delta\Theta$ (deg)	E (MeV)	$\frac{\sigma_E}{E}$ (%)
Møller A-Møller B	483.36 ± 0.84	37.4913 ± 0.0102	5681.10 ± 10.03	0.176
Møller A-Møller C	960.45 ± 0.88	74.9687 ± 0.0060	5645.30 ± 5.17	0.092
Compton A-Møller B	484.34 ± 1.44	37.4913 ± 0.0102	5692.62 ± 17.03	0.299
Compton A-Møller C	961.43 ± 1.46	74.9687 ± 0.0060	5651.07 ± 8.61	0.152
Møller B-Møller C	477.09 ± 0.83	37.4774 ± 0.0115	5609.49 ± 9.89	0.176

~10^{-3}

What went wrong during the last Arc Measurements and what has been done to fix those

- The PMT reading out the wire scaners at the end of the ARC was saturated. Most probably due to large sync. Radiation.
  - The wire scanners are being converted to secondary emission like the rest of the harps in the machine. They are working.
- 9th dipole current and central field
  - NMR meter was not working (unplugged cables, unstable lock). It is working now at 11 GeV field setting.
  - Magnets current monitor was not working. Was replaced with a high precision current monitoring unit. Good agreement with the accelerator.
  - Problems with ARC mapper
    - Mapper software is still not working. The mapping was done by hand on 12-09-2015 to get Bdl. Techs are still working to find the problem.
    - Encoder problem was fixed.
- Standard analysis code was not working
  - Status not known. Probably have to fix this my self.

Update from Doug (01-14-2016) on the Arc measurement

The Good

1) 9th Dipole NMR working great even at 11 GeV field setting

2) 9th Dipole magnet still very homogeneous as determined by NMR at various point (check during Dec. run period)

3) Independent, high precision current monitoring unit agreeing with accelerator (using Ultra-stab zero flux current transducer system borrowed from Jack)

4) New accelerator based Harp system works great and much easier to maintain.

5) Agreement with Yves mode currently at the ~1E-3 level, all work is to push that number down further.

NOTE: When we first started the 11GeV program there was ~1% disagreement which turned out to be simply a software issue; but due to our independent ultra-stab measurement was caught very quickly.

Update from Doug (01-14-2016)

The Bad

1) During the Dec. run, I had to "run" the NMR mapper table by hand. Not ideal at all for getting best possible Bdl. Techs are working on finding the problem.

The Ugly

1) Sync. Radiation. In process of switching from PMT system to Accelerator standard as at 11GeV PMT used to detect harp wire cross the beam was saturated. (PMT at start of ARC ok, so Yves & I both suspect sync. radiation which

SIDENOTE: Accelerator based harp near my PMT harp system (1C17 vs 1C18) was working fine.

How to lists

Need to check how updated these are

- How to make a harp scan
  http://hallaweb.jlab.org/equipment/beam/harp_halla/harp.html
- How to make an Arc measurement
  http://hallaweb.jlab.org/document/OPMAN/node29.html