Hello,
Here are my thoughts about RF-resonance Polarimeter at CEBAF:

A. Cavity:

 1. We should start with a warm cavity. If simulations show a too small signal, then we can use an SRF cavity - signal is proportional to Q.

2. We should start with 500 MHz beam. Again, if signal is too small, then we can try 1500 MHz - signal is proportional to f^4.

3. The cavity must have a TM110 mode: B field on axis (zero on entrance and exit and maximum at centre). No E field on axis (longitudinal or transverse). Cavity length is lambda/4.

4. This cavity will not be sensitive to charge but there will be some signal since the beam can be slightly off-axis.

5. The cavity will be sensitive to longitudinal polarization p and the signal is proportional to (q p)^2, where q is the bunch charge.

B. Data Collection:

1. Both helicities will give the same signal. So instead of flipping between ±p, we will flip the Pockels Cell between 0 and p (i.e, instead of ± 2.5 kV, it will be 0 and 2.5 kV).

2. We will use the parity DAQ to read BCM, BPMs, and the RF cavity.

3. The BCM and BPMs will be used to make sure the beam is the same between 0 and +h (as in parity experiments).

4. For the RF cavity: when p=0, the signal will consist of thermal noise and "background" from beam being off-axis. For p, the polarization will contribute to signal. We will measure the difference: (p signal + thermal + background) - (thermal + background) = p signal.

5. It is very important to have a parity DAQ and BCM and BPMs to measure beam properties since p signal is very small (similar to position differences in a parity experiment).

C. Location: There is two ideal places at CEBAF for such measurement with DAQ, BPMs and BCM: Injector 5 MeV region and Hall A beamline.

D. Measurements:
1. With 50 uA, we can use the Wien flipper to scan the polarization in 3D (i.e, horizontal and vertical). Measure p signal vs p.
2. One open question in theory is the scaling of signal with energy: we can study this by changing energy in injector between 3 and 9 MeV, or in Hall A between 2.2 and 11 GeV.

E. Deciding on cavity type: we can start the simulations with a warm cavity, if signal is too small, we switch to SRF cavity. John Musson/SRF can help with design and readout (receiver + amplifiers).

F. Deciding on location: We can start with injector since it is easier to get beam time, then try Hall A if it turns out the higher energy gives larger signal.

Thanks, Riad

Dear Matt and all,

thanks a lot for the information. I've started going through all this in more detail and to first analytically (in "conventional" way without using Hamilton formalism which is too hard for a poor experimentalist) derive correct formulas, which will be presented soon in a detailed report/paper.  I've filled already 5 pages, but I will need at least some more days to work out the integrals for different cavity modes. But I would like to make some comments already now, see below.

Best,
Wolfgang

A. Cavity:

1. We should start with a warm cavity. If simulations show a too small signal, then we can use an SRF cavity - signal is proportional to Q.

2. We should start with 500 MHz beam. Again, if signal is too small, then we can try 1500 MHz - signal is proportional to f^4. Why should the frequency scale with the 4th power of frequency? Important: I expect a very weak signal which is additionally suppressed by the factor G (transverse) or 1/gamma (longitudinal). See less chance with normal conducting cavities ....

3. The cavity must have a TM110 mode: B field on axis (zero on entrance and exit and maximum at center). No E field on axis (longitudinal or transverse). Cavity length is lambda/4.

4. This cavity will not be sensitive to charge but there will be some signal since the beam can be slightly off-axis.

5. The cavity will be sensitive to longitudinal polarization p and the signal is proportional to (q p)^2, where q is the bunch charge. First: TM110 will have no longitudinal change of fields!!! Second, concerning longitudinal polarisation: Definitely no! TM110 is only sensitive to transverse polarisation, because there is (by definition!) no longitudinal B-field! But it could be used for transverse

polarisation. Length of lambda/4 will only waste signal, I would strongly

recommend lambda/2. Hope that this will be clearly verified by formulas soon...

B. Data Collection:

1. Both helicities will give the same signal.

Not in case for longitudinal polarisation and TE011. This in my opinion is the favorite one for CEBAF! The cavity should be operated at low gamma because the longitudinal signal is suppressed by factor 1/gamma. It should be tuned to the bunch frequency (no direct coupling to charge due to missing longitudinal E-fields). Data taking should be phase-locked to RF. In this case the signal should flip phase when flipping helicity.

So instead of flipping between ±p, we will flip the Pockels Cell between 0 and p (i.e, instead of ± 2.5 kV, it will be 0 and 2.5 kV).

2. We will use the parity DAQ to read BCM, BPMs, and the RF cavity.

3. The BCM and BPMs will be used to make sure the beam is the same between 0 and +h (as in parity experiments).

4. For the RF cavity: when p=0, the signal will consist of thermal noise and "background" from beam being off-axis. For p, the polarization will contribute to signal. We will measure the difference: (p signal + thermal + background) -(thermal + background) = p signal.

5. It is very important to have a parity DAQ and BCM and BPMs to measure beam properties since p signal is very small (similar to position differences in a parity experiment). This is fine for transverse polarisation. But I would favor a longitudinal setup. In addition, I doubt that the resolution of the BPMs will be sufficient to detect harmful changes in beam position and pointing ...

C. Location: There is two ideal places at CEBAF for such measurement with DAQ, BPMs and BCM: Injector 5 MeV region and Hall A beamline. Do it at low gamma!!!

D. Measurements:

1. With 50 uA, we can use the Wien flipper to scan the polarization in 3D (i.e, horizontal and vertical). Measure p signal vs p.

2. One open question in theory is the scaling of signal with energy: we can study this by changing energy in injector between 3 and 9 MeV, or in Hall A between 2.2 and 11 GeV. This is trivial! For sufficiently high gamma, the transverse signal is independant of beam energy, whereas the longitudinal scales with 1/gamma. Wait a few days for the formulas ...

E. Deciding on cavity type: we can start the simulations with a warm cavity, if signal is too small, we switch to SRF cavity. John Musson/SRF can help with design and readout (receiver + amplifiers). I would propose a phase-sensitive signal detection using a lockin amplifier locked to the rf. Zurich instruments can go up directly to 500MHz. If not available or use of higher frequencies, the signal has to be down-converted by a dedicated LO. There is a paper of Pusch et al. in PR-STAB concerning this, where we have demonstrated detection of P < 10^-18W.

F. Deciding on location: We can start with injector since it is easier to get beam time, then try Hall A if it turns out the higher energy gives larger signal.

Again: I would propose to start with low gamma!

Thanks,

Wolfgang Hillert

Riadd and Matt,
You might missed following e-mail I sent on Feb. 5th. When I said that the second day's idea is better than the first day.

The best cavity type is the TE011 (cylindrical) type. So when the beam is running through the cavity axis, there is no beam impedance to the bunch charge. That will significantly reduce the noise due to the q but maximize to the p.

Using TM110 type, 1/4 lambda long would reduce the beam transient time factor. So my idea was to use it in side way, so magnetic field would not kick the beam (due to charge effect). Then you can use longer cavity length (but <= 1/2 lambda) in the beam path direction. Since the electric kick is 90 degree away near cavity entrance and exit, by a EM design such an effect can be minimized.

The cavity has to be superconducting in high Q in order to get high impedance to the polarization and filter out the rep rate frequency signal induced from the charge (side band discussion in our meeting), if any. It can be run in the passive mode as long as the design has a very high longitudinal polarization impedance.

We have developed such TE011 cavity by Gigi Ciovati in 2010. After overcame of a multipactor problem, we got ~90mT on the cavity wall with a high Q of ~10^10.

I hope this information will help you on the cavity part of this experiment.
Regards
Haipeng

Haipeng wrote following e-mail on Feb. 5, 2016

Mei,
We had a few conversations about the SRF cavity design for your polarimeter between Matt and Bob yesterday and this morning. Based on our understanding, the best cavity type is to let polarization vector mu parallel to the RF magnetic field but to avoid the charge inducted voltage and beam abbreviation effect. That means longitudinal polarized beam is the best choice.

Bob has suggested that using a TE011 type cavity with the beam running though the magnetic field lines but all electric field lines are in the circular direction which I think is the best. The Q of such cavity can be much higher than regular TM type due to the low joint loss on the circular contacts of the cavity.

I thought also about using TM110 type cavity but running beam in side way unlike we using the magnetic field for kicking the beam. So magnetic field is also parallel to the beam running direction. But beam abbreviation can cause the bunch kicked by the electric filed in side way (like in vertical direction, but in 90 deg phase, so for a short bunch there is possible no problem). The magnetic field cause no kick and also would not inducing voltage in the cavity.

The best place to do this experiment is at CEBAF where beam is relativistic, bunch length can be very short compare to the cavity wavelength. The cavity frequency could be reasonable high to the multiple harmonics of 499MHz. The cavity can be passive to the beam, without LOM HOM damping? In fine tunable design for the sideband detection and rigid enough to minimize the microphonics or with a fancy LLRF control to reject unwanted signals.

We might be able to give you signal to noise ratio estimate for such idea and the a practicable design.
Best Regards, Haipeng

Dear Wolfgang, Raid, Matt, Haipeng et al.

I had come to the opinion that TE modes were strongly favored (for the reason expressed by Haipeng that it eliminates direct coupling to beam charge, and for best separation from other modes). I worked out only rectangular TE101, but I hope that cylindrical TE011 is comparably good.

Just to be sure we are talking about the same cavity, I have copied a nice representation of cylindrical TE011 field patterns from a paper on the web. (page 7, 2009 Master's thesis, Jason Walter Sidabras, Marquette University). It looks to me from the figure that this mode couples only to longitudinal beam magnetization. We think (I think) that this is disadvantageous for high energy electrons because of the signal reduction by one power of gamma in transforming the MDM from rest frame to lab.

I also agree with Haipeng that "The cavity has to be superconducting with high Q in order to get high impedance to the polarization and filter out the rep rate frequency signal induced from the charge (side band discussion in our meeting).

With Wolfgang, I am elated about Haipeng's statement that "We have developed such a TE011 cavity by Gigi Ciovati in 2010. After it overcame of a multipactor problem, we got ~90mT on the cavity wall with a high Q of ~10^10.

It seems too good to be true that such a cavity may already exist. But, before becoming too confident, there are a lot of details to be worked out.

Best wishes

Richard

Hi all,

I think the cavity Haipeng was referring to was a sample test cavity, not suitable for putting in the beam, but it would not be hard to make one operating in the TE011 mode at CEBAF frequency. In fact, people have proposed using this mode inside SRF photocathode guns to provide a kind of local compensating solenoid to counter emittance growth due to space charge (since the SRF gun would not like being inside a real solenoid).

More challenging will be finding a place in CEBAF where we can make the cavity cold and put it in the beam. Perhaps the UITF (Matt's cave)? If there is any chance a warm cavity might work that would be a lot easier to install. Perhaps a proof of principle test to develop the detection scheme? Could it set an upper bound on the measurement?

The TE011 mode should have the highest Qo of any normal cavity mode because of the low wall currents (TE0 modes were proposed for long distance transmission lines before fiber optics came along and killed that idea stone dead).

The picture you show is indeed the mode we are considering and illustrates the field distributions nicely.

Bob.

