

FFA@CEBAF Working Group | MINUTES

Meeting date | time 05/30/2025 | 11 AM EST | Meeting location <https://jlab-org.zoomgov.com/j/1614898082?pwd=TnUzMS81M2sxbDZlbERJU01tYkJCQT09>

Meeting called by Alex B

Type of meeting Weekly Meeting

Facilitator Alex B

Note taker Donish

Timekeeper Alex B

Attendees

Alex B, Volker, Dejan, Stephen, Donish, Salim, Kirsten, Sadiq, Edy, Nick, Scott

AGENDA TOPICS

Time allotted | 25 mins | Agenda topic (S)RF History | Presenter Salim

FFA Beam Transport Test
LDRD Proposal Discussion v2

05/30/2025

Proposal Title: FFA Beam Transport Test at CEBAF – Measurements Scoping and Beamline Modifications
Principal Investigator, Division: Salim Ogar (CASA)
Co-Investigator, Division: Donish Khan (CASA), Alex Bogacz (CASA), Edith Nissen (CASA)
Contributors, Division:
Advisor(s), Division: Stephen Brooks (BNL), Dejan Trbojevic (BNL)

Jefferson Lab US Department of ENERGY

Credit: Stephen Brooks

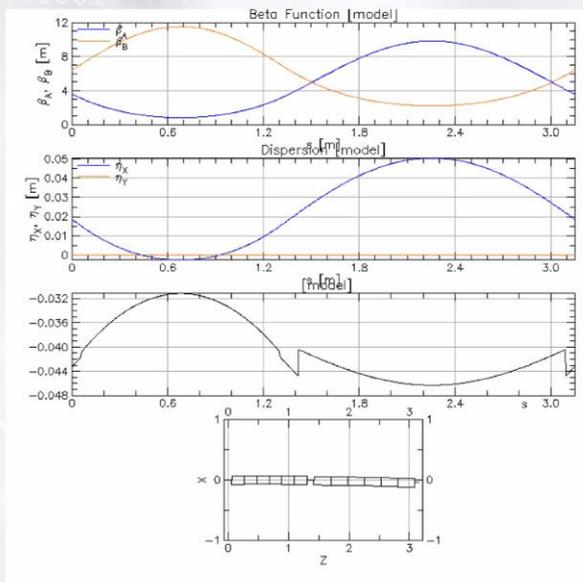
-
- No green light yet on the LDRD proposal.
- Regardless of green light, underlying studies in proposal are still good to have for overall knowledge of FFA cell (and paper for NAPAC).

Today in this presentation

- The FODO magnet of S. Brooks already serves for 11 GeV beam. **Half or full cell, periodic or open.**
- The flexibility of the existing magnetic hardware (quadrupoles, corrector magnets, etc.) in the BSY beamlines for matching to the FFA magnet. **Matching to 11 GeV periodic solution of the FFA Cell.**
- Whether additional magnets (quadrupoles, skew quadrupoles, horizontal/vertical correctors, etc.) and beam diagnostics elements are needed. **A discussion.**
- Whether the exact location of the FFA magnet array in the BSY beamline, so that the proposed goals are achieved. **The first of the 3 dipoles for now.**
- The closed orbit (beam position and divergence) and matched (horizontal) dispersion functions using bends and correctors. **An example at 11 GeV, except the centroid position and angle.**
- The beam polarization stability through the FFA magnet. **The SLAC polarization example.**
- The 6D acceptance of the FFA magnets. **Later.**

1.1- FFA Lattice for 11023 MeV

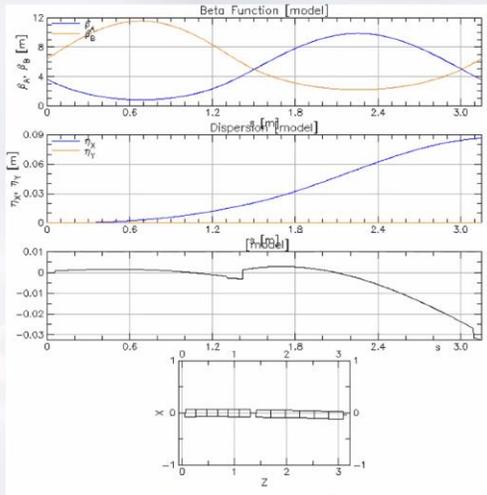
- Periodic solution for a full FODO lattice at 11023 MeV.



```
1 parameter[geometry] = Closed
2
3 parameter[p0c] = 2.0099999935045E10
4 parameter[particle] = Electron
5 bmad_com[rel_tol_tracking] = 1E-7
6 bmad_com[abs_tol_tracking] = 1E-7
7 bmad_com[radiation_damping_on] = T
8 bmad_com[radiation_fluctuations_on] = T
9
10 beginning[beta a] = 3.58734689238656
11 beginning[alpha a] = 2.5008144571055
12 beginning[eta x] = 0.0193338045330629
13 beginning[eta p_x] = -5.00036821364292E-3
14 beginning[beta b] = 6.43552833965767
15 beginning[alpha b] = -3.11319931351031
16 particle_start[x] = -0.0440176197654463
17 particle_start[p_x] = 0.0157336548807662
18 particle_start[p_z] = -0.45159
19
```

1.2-FFA Lattice for 11023 MeV

- Only Twiss(α, β) matched to its periodic solution, zero-dispersion and on-axis entrance for a full FODO lattice at 11023 MeV.
- **Almost periodic Twiss(α, β) returned**, is this what we seek?

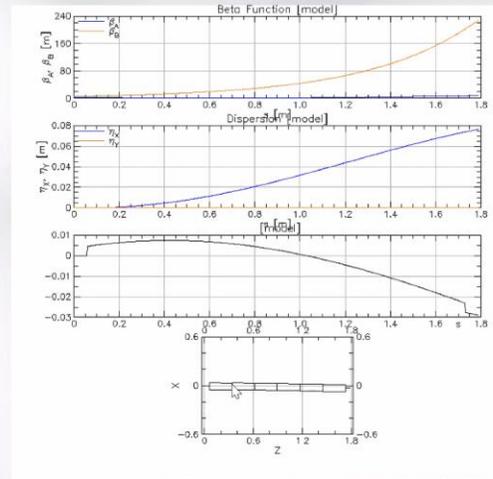
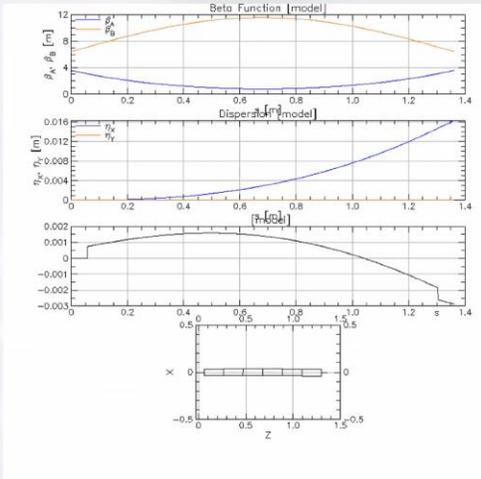


```
Tao> show Lat
# Values shown are for the Downstream End of each Element (Cindor at ref point):
# Index name key s l beta phi_a eta orbit beta phi_b eta orbit Track
# x [mm] x [mm] [psi] y [mm] State
0 BEGINNING Beginning_Ele 0.000 0.000 3.59 0.000 0.00 0.000 6.44 0.000 0.00 0.000 Alive
1 OBO Drift 0.058 0.058 3.08 0.005 0.00 0.000 7.11 0.002 0.00 0.000 Alive
2 MK_BPM Marker 0.058 0.000 3.08 0.005 0.00 0.000 7.11 0.002 0.00 0.000 Alive
3 PR_BD_IN Patch 0.058 0.000 3.08 0.005 0.00 0.737 7.11 0.002 0.00 0.000 Alive
4 BDA S Bend 0.206 0.207 1.70 0.031 0.00 1.320 9.40 0.010 0.00 0.000 Alive
5 DOB S Bend 0.473 0.297 1.04 0.977 0.00 1.573 10.98 0.016 0.00 0.000 Alive
6 BDC S Bend 0.681 0.297 0.82 0.145 0.00 1.399 11.55 0.021 0.00 0.000 Alive
7 BDC S Bend 0.888 0.297 1.00 0.213 0.01 0.765 10.98 0.026 0.00 0.000 Alive
8 BDC S Bend 1.095 0.297 1.70 0.258 0.01 -0.331 9.40 0.032 0.00 0.000 Alive
9 BDC S Bend 1.303 0.297 3.08 0.285 0.01 -1.854 7.12 0.039 0.00 0.000 Alive
10 PR_BD_OUT Patch 1.303 -0.000 3.08 0.285 0.01 -2.591 7.12 0.039 0.00 0.000 Alive
11 OBO Drift 1.361 0.058 3.59 0.290 0.02 -2.863 6.44 0.042 0.00 0.000 Alive
12 OBF Drift 1.419 0.058 4.14 0.294 0.02 -3.146 5.80 0.045 0.00 0.000 Alive
13 MK_BPM Marker 1.419 0.000 4.14 0.294 0.02 -3.146 5.80 0.045 0.00 0.000 Alive
14 PR_BF_IN Patch 1.419 0.000 4.14 0.294 0.02 1.313 5.80 0.045 0.00 0.000 Alive
15 BFA S Bend 1.698 0.279 6.91 0.309 0.03 2.884 3.59 0.063 0.00 0.000 Alive
16 BFB S Bend 1.977 0.279 9.05 0.319 0.04 1.429 2.52 0.090 0.00 0.000 Alive
17 BFC S Bend 2.256 0.279 9.80 0.328 0.05 -2.732 2.21 0.125 0.00 0.000 Alive
18 BFC S Bend 2.535 0.279 9.04 0.336 0.07 -9.376 2.52 0.160 0.00 0.000 Alive
19 BFC S Bend 2.813 0.279 6.89 0.346 0.08 -17.408 3.59 0.188 0.00 0.000 Alive
20 BFAC S Bend 3.092 0.279 4.13 0.361 0.09 -26.916 5.79 0.206 0.00 0.000 Alive
21 PR_BF_OUT Patch 3.092 -0.000 4.13 0.361 0.09 -21.363 5.79 0.206 0.00 0.000 Alive
22 OBF Drift 3.150 0.058 3.58 0.365 0.09 -32.503 6.42 0.209 0.00 0.000 Alive
23 END Marker 3.150 0.000 3.58 0.365 0.09 -32.503 6.42 0.209 0.00 0.000 Alive
```

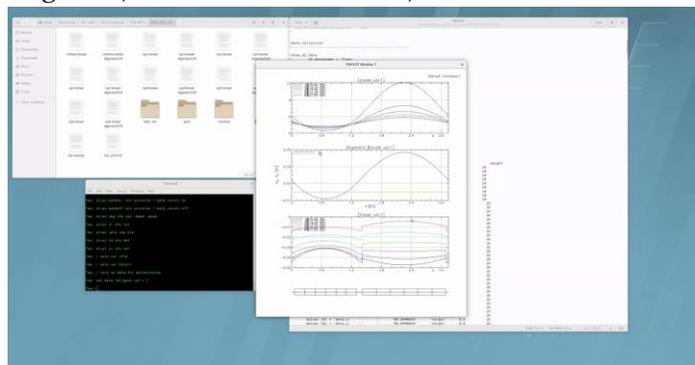
- Stephen: The closed orbits do not make sense; they are too large and will fall out of the magnet. You need a new angle/position otherwise experiment fails.
 - Dejan: Use triplet with right angle of entrance and “slide” for different energies
 - Stephen: All that matter is that the closed orbit doesn’t fall out of the magnet.
 - Alex B: We can use correctors to keep the orbit within the FFA magnet.
- Donish: Why is there a discontinuous jump in the orbit after the magnet?
 - Kirsten: The jumps are an artifact of using patches in Bmad.

1.3- FFA Half-Lattice for 11023 MeV

- No closed orbit found for neither of BD or BF magnets at 11023 MeV!
- Full-cell's periodic Twiss functions with zero-dispersion and centered orbit returns followings for BD and BF respectively:

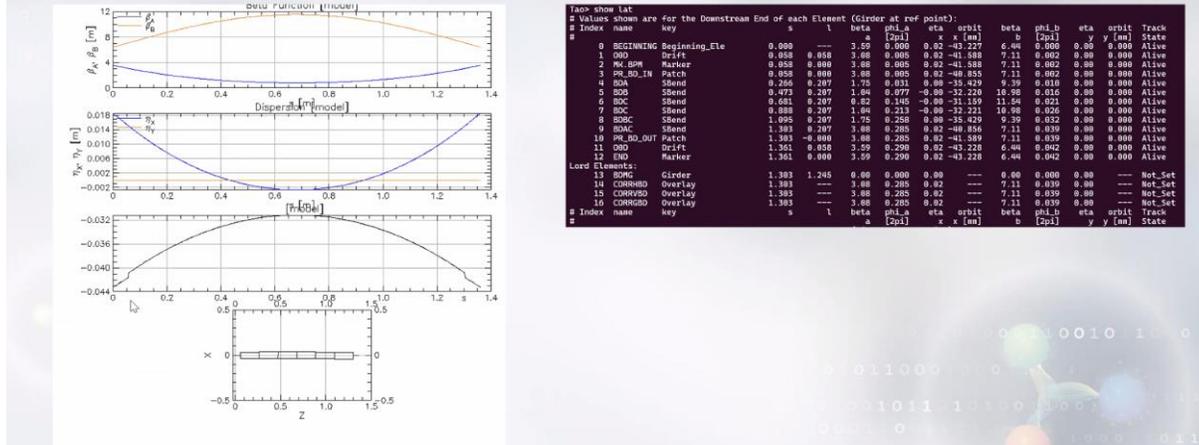


- Salim: No closed orbit could be found, but I am attempting to explore what we can study here.
- Stephen: You will not have a stable orbit, you only have one component of the FODO. You need match into the cell.
- Dejan: Inject the beam into your magnet with the proper injection conditions (Twiss parameters, orbit spatial and angular offsets).
 - Donish: You can use an "Open" lattice with proper injection conditions instead of "Closed" lattice setting.
 - Salim: In the next slide (slide labeled 1.4 FFA) I used the closed orbit solution and injected into the FFA.
 - Kirsten: The coordinate system used by Alex C. shows that the orbit is not aligned (see screenshot below).



1.4- FFA Half-Lattice for 11023 MeV

- No closed orbit for neither BD or BF magnets at 11023 MeV!
- Full-cell's periodic Twiss function, orbit and dispersion are injected to BF magnet returns nearly-closed orbit



```

[Tab Show List]
# Values shown are for the Downstream End of each Element (Girder at ref point):
# Index name key s l beta phi_a eta orbit beta phi_b eta orbit Track
#
0 BEGINNING Beginning_Ele 0.000 --- 3.69 0.000 0.02 -43.227 6.44 0.000 0.00 0.000 Alive
1 DSD Drift 0.958 0.888 3.08 0.000 0.02 -41.388 7.21 0.002 0.00 0.000 Alive
2 MK_BPM Marker 0.958 0.880 3.08 0.000 0.02 -41.588 7.11 0.002 0.00 0.000 Alive
3 PR_BO_IN Patch 0.958 0.880 3.08 0.000 0.02 -40.855 7.11 0.002 0.00 0.000 Alive
4 SOB SBend 0.266 0.207 1.75 0.031 0.00 -35.829 6.29 0.010 0.00 0.000 Alive
5 SOB SBend 0.473 0.207 1.04 0.077 -0.00 -32.220 10.50 0.016 0.00 0.000 Alive
6 SOC SBend 0.681 0.207 0.82 0.145 -0.00 -31.159 11.58 0.021 0.00 0.000 Alive
7 SOC SBend 0.888 0.207 1.04 0.213 -0.00 -32.221 10.98 0.026 0.00 0.000 Alive
8 SOC SBend 1.095 0.207 1.75 0.250 0.00 -35.829 9.29 0.032 0.00 0.000 Alive
9 SOAC SBend 1.303 0.207 1.04 0.285 0.02 -40.856 7.11 0.030 0.00 0.000 Alive
10 PR_BO_OUT Patch 1.303 -0.000 3.08 0.285 0.02 -41.389 7.11 0.030 0.00 0.000 Alive
11 DSD Drift 1.361 0.888 3.09 0.290 0.02 -43.228 6.44 0.002 0.00 0.000 Alive
12 END Marker 1.361 0.000 3.09 0.290 0.02 -43.228 6.44 0.002 0.00 0.000 Alive

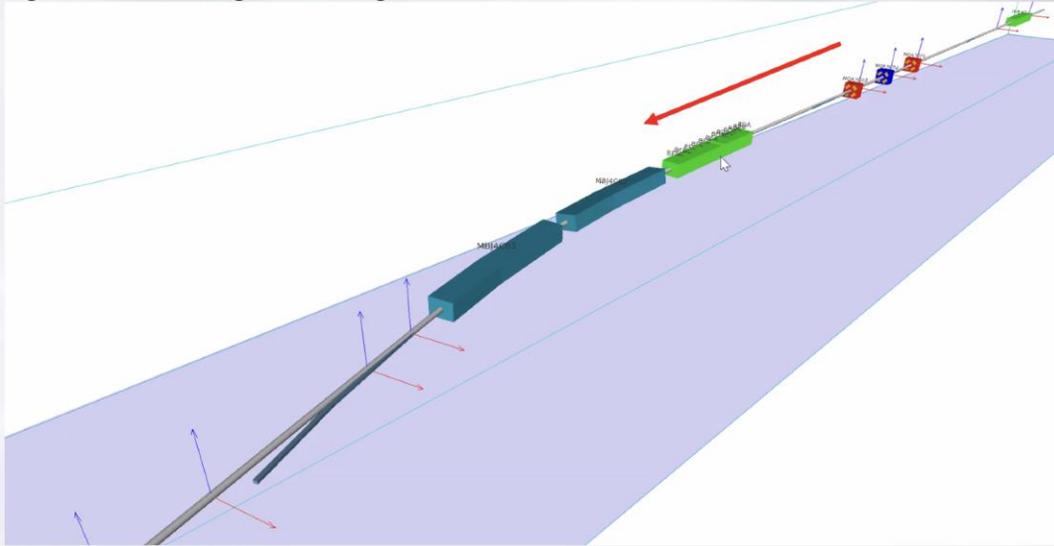
Lord Elements:
13 SOAC Girder 1.303 1.245 0.00 0.000 0.00 --- 0.00 0.000 0.00 --- Not_Set
14 CORRBD Overlay 1.303 --- 3.08 0.285 0.02 --- 7.11 0.030 0.00 --- Not_Set
15 CORRBD Overlay 1.303 --- 3.08 0.285 0.02 --- 7.11 0.030 0.00 --- Not_Set
16 CORRBD Overlay 1.303 --- 3.08 0.285 0.02 --- 7.11 0.030 0.00 --- Not_Set
# Index name key s l beta phi_a eta orbit beta phi_b eta orbit Track

```

- Stephen: I'm confused about the orbit coordinates. It still shows a 4 cm offset which would result in a failure.
 - Kirsten: One thing to keep in mind, the zero orbit is not where you think it is.
 - Scott: Would be better to align with coordinate system that Stephen is using.
 - Kirsten: It just a transverse translation between coordinate systems.
 - Scott: We have an understanding of what is happening here, we know what to do and can move onward.
 - Dejan: I'm surprised that we took this as the nominal orbit.
 - Salim: Is this something we (someone) should fix?
 - Everyone: Yes.
 - Kirsten: I will take a look at it, I'll emphasize that this lattice has been presented many times before.
 - Alex: If we can fix and put it in the Github that would be great.
 - Kirsten: Alex C used offsets of magnets (DX) and patches at the end.
 - Scott: Make the zero the same as Stephen's coordinate system.
 - Dejan: When I recreated this magnet I used sector instead of rectangular magnets with no disagreement. Why is all this patches being used here complicating everything?
 - Stephen: This is a engineering decision; I'm using rectangular magnets to construct the FFA.

2- Full Magnet at BSY Dumpline

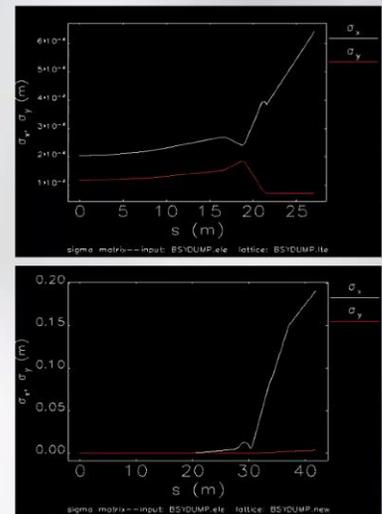
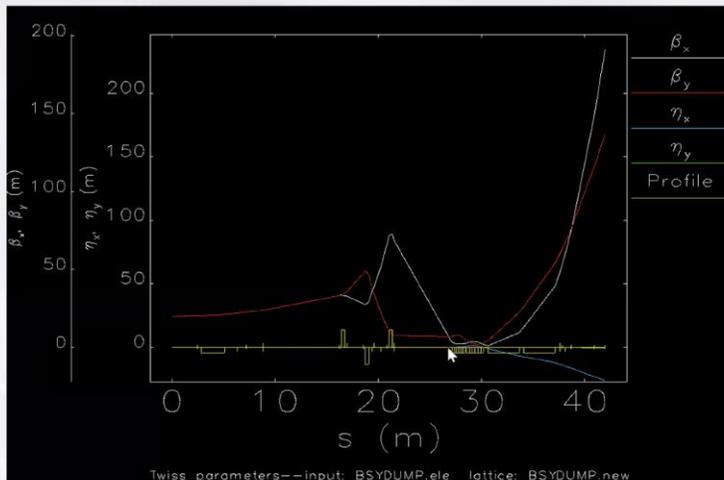
- The initial thought was to put the FFA cell just before the dump as the 3rd dipole magnet, and think of the skew-quadrupoles for measurements.
- However, it makes much more sense to be the 1st dipole, in other words, just after the triplet magnet, i.e. easier matching. Below a full cell green rectangles



- Alex: We will use a wire scanner after the FFA magnets to do measurements (after green magnets in above)

2.1- Full Magnet at BSY Dumpline

- Let's match to the periodic solution we found for the Full Magnet, using the available triplets and steerers.
- By putting the FFA as the first of the three dipoles, the beam blows-up afterwards, needs to be suppressed before the beam dump, might be useful for emittance.



```
salim_ubuntu@CASASTUDENTLAP:~/BSY_Dumpline$ sdds2stream *twi -col=s,betax,alpha,betay,alphax,etax,etaxp,etay,etayp | sed -n '$p'
```

- Salim: I imported the FFA magnet array into Elegant; not sure if I trust it completely. This was done purely for demonstration purposes.

- Salim: How about if we use the upstream triplet to scan the beam parameters for measurement.
- Scott: Why not build an FFA magnet so that the alpha's and dispersion prime are zero at the exit.

3. Polarization at SLAC

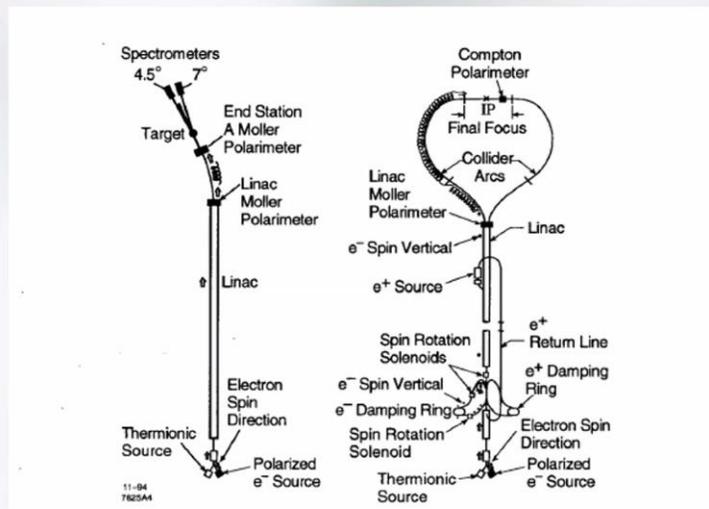
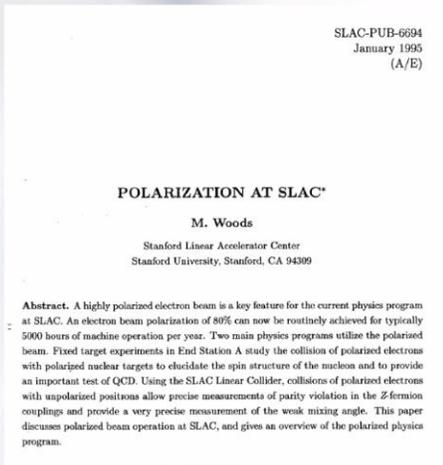


Figure 4. Polarized ESA operation.

Figure 5. Polarized SLC operation.

- Salim: Are we going to measure polarization? I am looking at examples conducted at SLAC.

3. Polarization at SLAC

3. Polarimetry

Three different polarimeter techniques are used at SLAC; these techniques are based on Mott scattering, Moller scattering, and Compton scattering. The ESA experiments rely on Moller polarimeters, while the SLD experiment relies on a Compton polarimeter. Mott polarimeters are used in test_labs for polarized gun development work and for photocathode R&D. A considerable amount of work has been done and is continuing to be done at

Mott Polarimeters. Mott polarimeters utilize the spin-dependent cross-section asymmetry in the elastic scattering of polarized electrons from an unpolarized high Z nucleus.^[26] SLAC has three Mott polarimeters; all are in test labs. polarimeter to give $P_e = (64 \pm 2)\%$

Moller Polarimeters. SLAC's Moller polarimeters^[29] measure the elastic scattering cross-section asymmetry in the collision of polarized beam electrons with polarized electrons in a magnetized permendur foil (49% iron, 49% cobalt, 2% vanadium). The linac Moller polarimeter is a A proper analysis of the linac Moller data then gave $P^L = (69 \pm 3)\%$,

Compton Polarimeters. The longitudinal electron beam polarization (\mathcal{P}_e) at the SLC IP is measured by the Compton polarimeter^[32] shown in Figure 7. This polarimeter detects Compton-scattered electrons from the collision of the longitudinally polarized electron beam with a circularly polarized photon beam. The photon beam is produced from a pulsed

- Salim: SLAC outlines how to do this in three ways.
- Dejan: In prior studies (Francois et al), polarization was found to be preserved in FFA. Very comprehensive studies.

Conclusions

- A Full magnet can be placed at BSY Dump line.
- Existing triplet would suffice the matching and beam waist scan before the FFA magnet.
- Beam size just before the beam dump requiring some optimization including the introduction of (skew) quads which might be useful for emittance measurement after the FFA magnet (and the other two long dipoles).
- Studying the closed orbit, periodic case might be useful.
- The SLAC polarization paper asserts the polarization measurement, at least at BSY dump line, is difficult and might not result in an accurate measurement. Having the FFA testbed at the Hall C case might be different.

- Alex: Need to determine if the polarization can be meaningful to measure before we put it in proposal.
- Alex: Need to reconcile the coordinate system of the FFA magnet in Bmad.
- Dejan: Stephen has done studies

Special notes

Pathway to Repository: https://jeffersonlab-my.sharepoint.com/:f/g/personal/tristan_jlab_org/EqZ5MeS-nipCgPfZB5p0oS4B9Is67d3nQb9sLJI3Zyev9g