FFA@CEBAF Working Group | MINUTES

Meeting date | time *07/07/2023 | 11 AM EST* | Meeting location https://jlab-org.zoomgov.com/j/1614898082?pwd=TnUzMS81M2sxbDZIbERJU01tYkJCQT09

Meeting called by Alex B

Type of meeting Weekly Meeting

Facilitator Alex B

Note taker Donish

Timekeeper Alex B

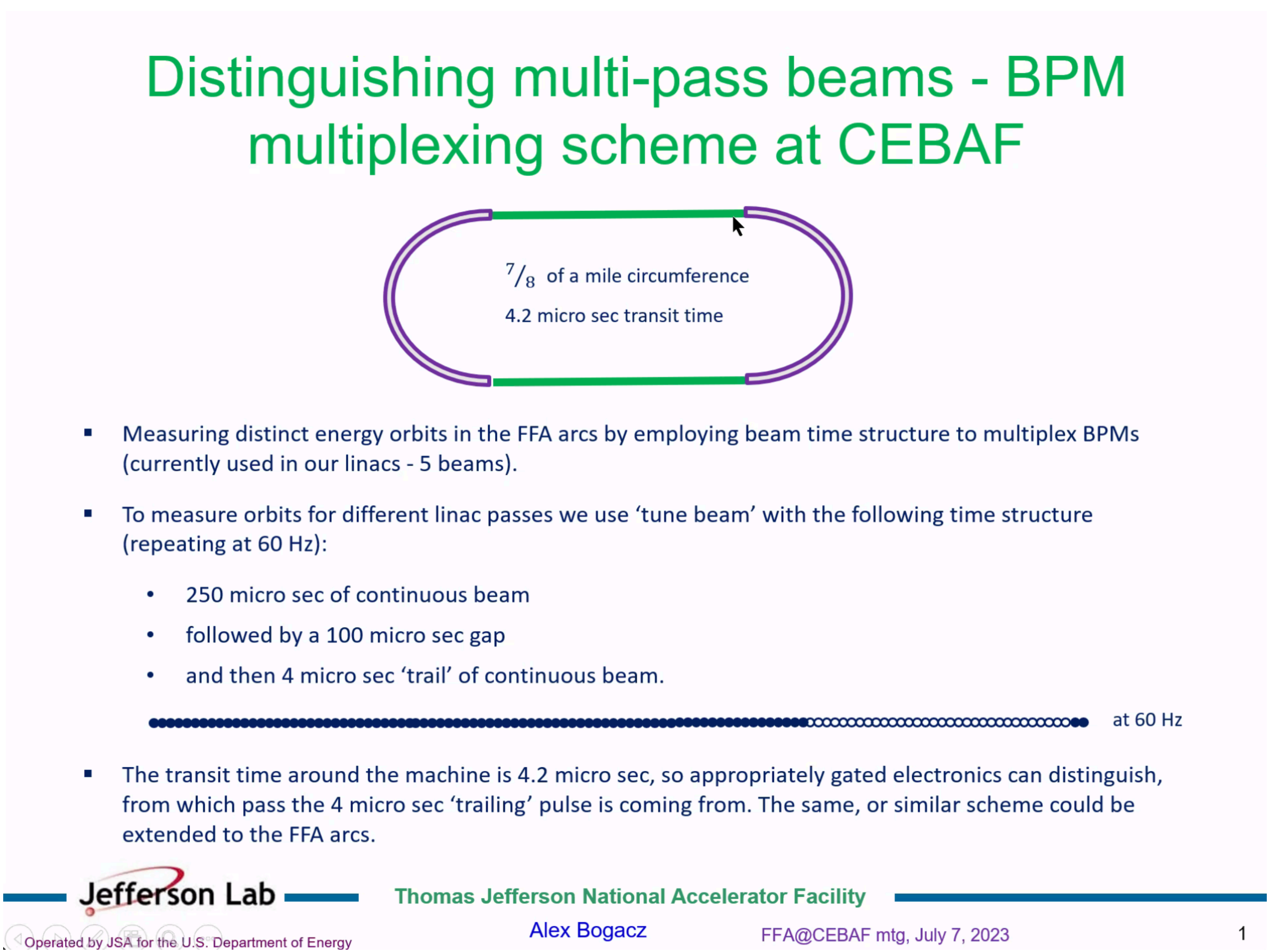
Attendees

Alex B, Alex C, Donish, Kirsten, Todd, Stephen, Randika, Scott, Andrei, Vasiliy, Annika, Reza, Dejan

INTRO DISCUSSION

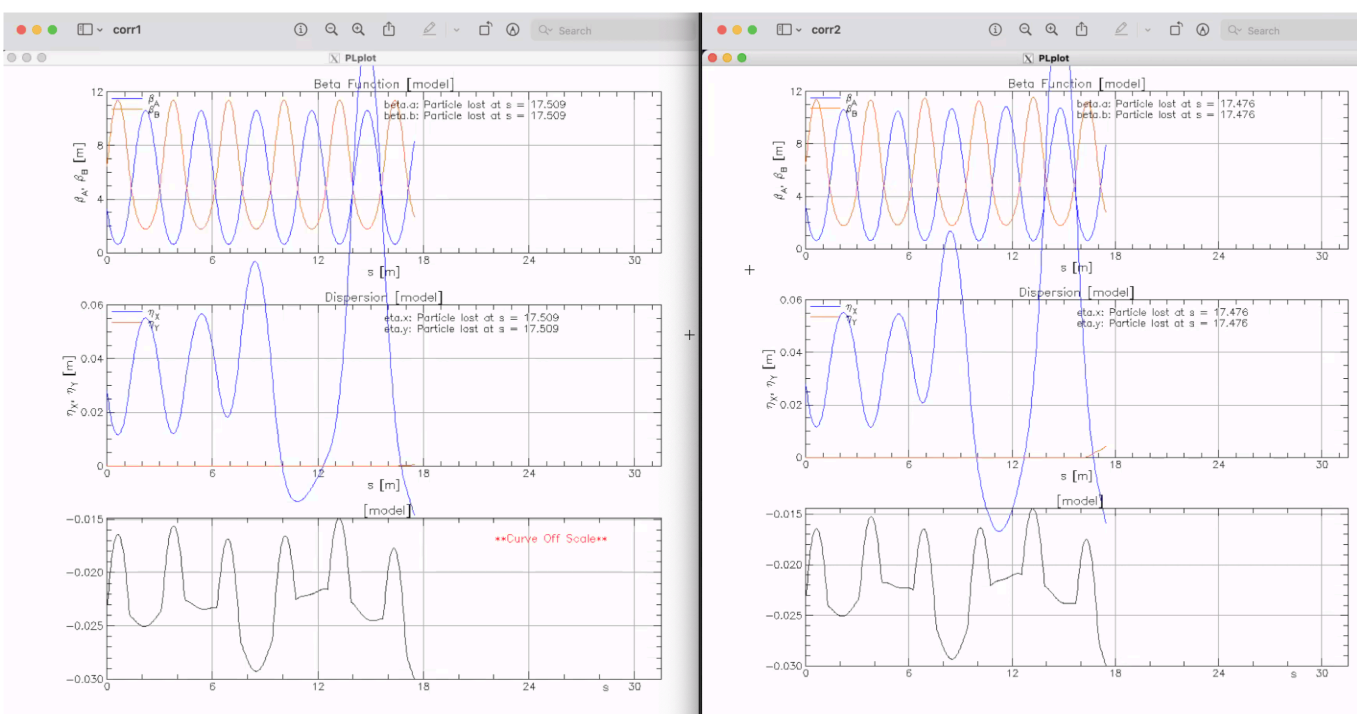
AGENDA TOPICS

Time allotted | *20 mins* | Agenda topic *Distinguishing Multi-Pass Beams - BPM Multiplexing Scheme At CEBAF* | Presenter *Alex B.*



- We want to be able to diagnose/measure orbits for 6 different energies in the FFA arcs
- We currently have multiplexed BPMs to achieve this in the linacs (5 distinct beam energies)
- CEBAF's circumference = 7/8 of a mile (4.2 microseconds transit time)
- Don't use a continuous beam, we use a "Tune Beam"
  - (250 microsecond continuous beam + 100 microsecond gap + 4 microsecond trail) @ 60 Hz
  - Typical diagnostic tool for measuring different energy orbits in the linac
  - Can extend the idea to our FFA arcs
- Reza: A brief history on the choices of Tune Beam timing structure:
  - Observed beam was being lost and "moving around everywhere"; spent all night to figure out what was wrong
  - Figured out that when you send beam through the linac, it takes time for the SRF to feedback and account for beam loading; low-current is fine but high-current is problematic
  - Lead to decision to make pulse 250 microsecond
  - Make 4 microsecond to see different passes
  - Optimizing output of cavity will give most in synch results
- Dejan: Could reach out to Bob Mitchell for guidance on how it was done in CBETA
  - Alex B: Yes, plus similar work is being done for PERLE that we could look into
- Dejan: This is going to be a challenge. Stephen worked on schematic on how to avoid beam loading in the best possible way
  - Stephen: Various ways to do this: Changing pulse lengths, ramping up slowing…

Time allotted | *40 mins* | Agenda topic *Distinguishing Multi-Pass Beams - BPM Multiplexing Scheme At CEBAF* | Presenter *Alex C. And Annika T.*



- Jay designed Panofsky-Quad correctors that are used in the simulation
- Looks like having 1 corrector magnet per cell is just as good as having 2
- corr1 image is simulation results with "larger than expected" errors (to force beam loss)
    - Non-random errors, will run Monte Carlo sample next
    - Impose on every few cells a 300 um shift in the +/- x direction of a whole magnet
    - For a set of errors, 1 corrector/cell lose beam @ ~17.5 m
    - For same set of errors, 2 corrector/cell lose beam @ ~17.45 m
- Vasiliy: How do you choose the corrector settings?
    - Jay designed the corrector magnets; gave limits on field/gradient strengths
    - Not easy to superimpose these correctors over magnets in Bmad
    - Tried to separate the correctors from BPMs by pi/2 in phase advance
    - Looking at 1st pass only because it is the most error sensitive
- Vasiliy: How do you set the strengths of the correctors?
    - Alex C: I'm using the "LM optimizer" in Bmad
- Project with Annika
    - Generate orbit data from 10 cell lattices optimized using "LM" in Bmad
    - Inject data into a neural network (NN) which has been shown to do a good/better job in linear corrections than deterministic algorithms
- Vasiliy: What are you optimizing?
    - Alex C: The (x, y, x', y') at each BPM because this is what is important for merging back into the linacs according to Kirsten
    - Kirsten: If you don't isolate the passes from one another it's a lot of pain and suffering
- Dejan: In the end, every pass can have a perfect orbit. Stephen is someone to talk to about this; worked on it for CBETA.
- NN for chaotic systems can correct more narrowly than a linear correction
- Have been discussing control theory with Annika and optimizing a NN for orbit correction
- Alex B: Can you expand a bit on NN? Is it the same as Machine Learning (ML)?
    - Yes, NN are a variety of ML. They contain a layer/structure neurons that you "train" via "weights" by giving them data
    - Advantage of NN are that they are very-very fast
- Alex B: How many simulations will you be using?
    - Alex C: Goal is 100k and will be using the farm to conduct studies
- Reza: How different is this from a genetic algorithm (GA)?
    - Alex C: I have been discussing this with colleagues. They are both types of ML where GA is more "heavier weight" via resource intensive and does not require "priors" (i.e. the 100k simulation data)
    - Alex C: Thinking about doing initial correctors with an GA and then feeding into a NN
- Dejan: Stephen is working on a magnet design and will be able to provide magnet errors
- Kirsten: If we use ML instead of Singular Value Decomposition (SVD), do we train the initial model on simulation data and then train on actual data from the real CEBAF machine?

- Alex C: Yes!

- Vasily: Instead can we use a simple orbit aligning algorithm that corrects the orbit at each bpm piece-wise?
  - Alex C: Saw that 1 corrector per cell was better than our originally planned 2 correctors per cell so it made me think where/how else can we optimize?
  - Stephen: 2 correctors should be just as good as 1. Typically, for more simultaneous beam energies the more correctors you will need.
  - Kirsten: Double-check that the 1 corrector per cell solution works well with multiple-simultaneous beam propagation.
- Scott: Seems like you were running into limitations with Tao's optimizer/algorithm, so it may be a good idea to switch to PyTao.
  - Alex C: I can't install PyTao on my ARM64 architecture.
  - Scott: Should work on ARM64. You should start optimization in PyTao now.
- Vasily: What does PyTao give us?
  - Scott: Its a wrapper for Tao and Bmad. You can script in it.
- Dejan: You should into the past error correction work done by Lebedev et. al. as a primer.
  - Alex B: Yes, the initial correction algorithm was called "Auto Steer".
- Vasily: Does Bmad have orbit correction built in?
  - Scott: Yes, it should have it.
  - Dejan: Yes, had the same issue at CESR and they used Bmad.

Action Items	Person responsible	Deadline

Special notes

- Alex B: Kudos to Stephen for his paper on "Integrating Polynomials On Spheres And Balls"!

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