FFA@CEBAF Working Group | MINUTES

Meeting date | time *09/26/2025 | 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

Salim, Donish, Ryan, Stephen, Scott, Kirsten, Vasiliy, Patrick, Nick, Edy, Reza, Volker, Sadiq, Randy

INTRO DISCUSSION

Time allotted | *25 mins* | Highlights/Impressions of the FFA'25 Workshop | Presenter *Stephen Brooks*

Stephen's impression on various talks at FFA25:

ERIT for Heavy-Ion Beams with Stochastic Charge State Conversion, Dr Yoshihiro Ishi (online) *Yoshihiro Ishi*
Dept. of Electrical Engineering building, LT408, Other Institutes 09:35 - 10:05

Possibility of nuclear transmutation of heavy elements using FFAG-ERIT at Kyushu University, Prof. Satoshi Sakaguchi (online)
Satoshi Sakaguchi

Simulation study of RI-beam circulation in FFAG-ERIT toward synthesis of long-lived superheavy nuclei, Naoyuki Kitagawa (online)
Naoyuki Kitagawa

Coffee Break
Dept. of Electrical Engineering building, LT408, Other Institutes 11:05 - 11:25

Analytical Approach to Neutron Yield Estimation in FFA-ERIT-Based Systems, Yasutomo Tominaga
Dept. of Electrical Engineering building, LT408, Other Institutes 11:25 - 11:55

Status of development of FFAs at Kyushu University, Dr Yujiro Yonemura (online) *Yujiro Yonemura*
Dept. of Electrical Engineering building, LT408, Other Institutes 11:55 - 12:25

Various talks on FFA for nuclear transmutation (run a beam through a target and recirculate particles that did not interact). FFA is useful here because there is a wide range of energies that come out of the target (foil collision). Kyushu University is a hotspot for this FFA application (ERIT).

A Diagnostic Suite for the FETS-FFA, David Posthuma de Boer (in person) *David Posthuma de Boer*
Dept. of Electrical Engineering building, LT408, Other Institutes 15:50 - 16:20

FETs FFA project in England which Stephen has been advising. It is a proton ring with energy span of 3-12 MeV (prototype) or 100MeV-1.2 GeV (actual). FFA will allow them to ramp the beam faster and stack beams as well as a novel scheme for accumulation.

muTRISTAN, Dr Hiromasa Takaura (online) — *Dr Hiromasa Takaura*
Dept. of Electrical Engineering building, LT408, Other Institutes — 09:00 - 09:50

Negative muonium ion source for muon accelerators, Dr Yoshihiro Ishi (online) — *Yoshihiro Ishi*
Dept. of Electrical Engineering building, LT408, Other Institutes — 09:50 - 10:20

FFA application to the muon collider complex, Dr Max Topp-Mugglestone (online) — *Dr Max Topp-Mugglestone*
Dept. of Electrical Engineering building, LT408, Other Institutes — 10:20 - 10:50

Discussion on development of muon accelerators
Dept. of Electrical Engineering building, LT408, Other Institutes — 10:50 - 11:00

FFA application for Muon colliders which closely resembles what we [CEBAF] are doing for FFA@CEBAF.

2FFA Transport Line for Laser-Plasma Accelerated Electrons, Dr Samira Fatehi (online) — *Dr Samira Fatehi*
Dept. of Electrical Engineering building, LT408, Other Institutes — 11:20 - 11:50

With a laser plasma accelerator, electrons are emitted with a high energy/momentum range where an FFA-based electron transport line would be advantageous. These applications would use high-field but within small dimensions in their applications.

Characterisation and mitigation of RF knockout, Carl Jolly (in person) — *Carl Jolly*
Dept. of Electrical Engineering building, LT408, Other Institutes — 10:00 - 10:30

RF knockout can be used a diagnostic tool if you have two stacked beams of different in the same FFA-based storage ring. The RF frequency for the accelerating beam can go through resonant frequency/beating of the stored electron beam. This makes the stored beam unstable which can be mitigated by phasing the cavities properly or via a tune diagnostic.

An FFA with a negative k-value and related subjects, Dr Shinji Machida (in person) — *Shinji Machida*
Dept. of Electrical Engineering building, LT408, Other Institutes — 11:20 - 11:50

Negative k-value FFA are characterized by having the higher energy beams/particles on the inside of the arc rather than the outside. This could have applications for CEBAF in the sense that path length variations can be canceled out to first-order.

FFA-based beam delivery: progress toward realisation of TURBO (Technology for Ultra Rapid Beam Operation), Dr Suzi Sheehy (in person)
Dr Suzie Sheehy

Status of FFA development for LhARA project, Dr J. Pasternak (in person) — *Jaroslaw Pasternak*
Dept. of Electrical Engineering building, LT408, Other Institutes — 15:00 - 15:30

There were several particle therapy talks on their application to FFAs. In the University in Melbourne, they are developing 3MeV proton therapy gantry that will ultimately be scaled up (in energy). In LhARA, protons are initially laser-accelerated to 10 MeV and then a FFA-based transport line completes the acceleration to 20 MeV. This is an interesting hybrid between laser and FFA based acceleration techniques.

Status of the LBNL R&D program developing elliptic-aperture combined-function superconducting magnets, Lucas Brouwer
Lucas Brouwer

This talk discussed the development of superconducting magnets that can be used for FFAs. The magnet designs are based on canted cosine-theta that have two layers of coils with different shapes. This allows one to produce any harmonics in the b-field and generate large field intensity (5-7 Tesla). This could have a great application if your FFA required a compact but high field.

Final remarks: The next FFA workshop will be held in Melbourne, Australia. Final date is still being decided.

Time allotted | 25 *mins* | Arc-to-linac Transition update | Presenter ***Vasiliy & Randy***

Matching Schemes Under Consideration

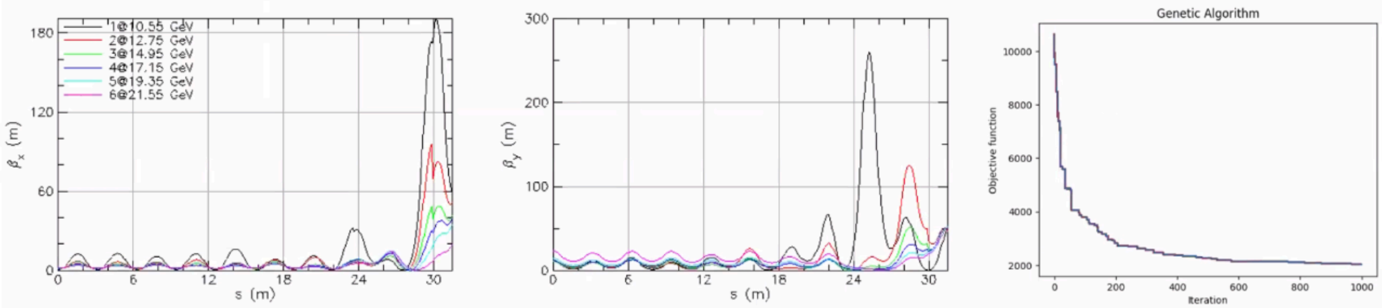
1. Arc FODO with bends turned off
   a. Two parametric resonance (PR) quadrupole families
   b. One PR quad family in X and one $(\nu_x - \nu_y)$ coupling resonance quad family
2. Similar to arc FODO with bends turned off but with equal betatron phase advance in x and y
3. Doublet
4. Triplet
   a. -DFD-FDF-
   b. -DFD-

1 OAK RIDGE National Laboratory | HIGH FLUX ISOTOPE REACTOR | SPALLATION NEUTRON SOURCE   V.S. Morozov, September 26, 2025

Vasiliy: Considering variation options but this is work in progress. Start with the simple example of an arc FODO (with the bends turned off); the main goal is to increase the beta functions at the entrance of the linac. The matching can be achieved using two parametric resonance (PR) quadrupole families or by using a single PR quadrupole family and a coupling resonance (nux-nuy, but will try nux+nuy next time).

Applying GA Optimization in Two Planes (1.a)

- 12 resonance amplitudes and 12 resonance phases are the optimization parameters
- GA optimization results after 1000 iterations with a population of 10,000

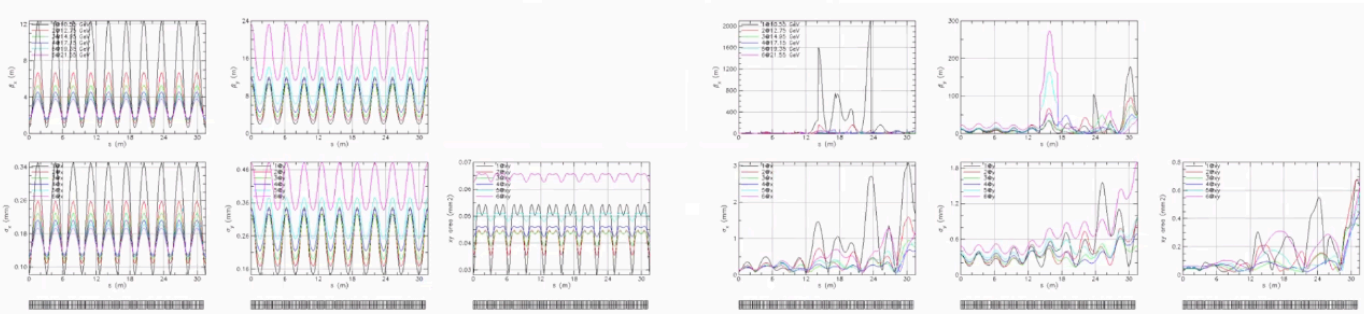


V.S. Morozov, September 26, 2025

Vasiliy: Results shown from the last meeting/presentation. Matching to the linac (alpha = 0, for both planes) shows good results for the vertical plane but not the horizontal. These results were obtained by utilizing 1 PR quadrupole family and a difference tune (nux-nuy) coupling resonance.

Applying X/Y Coupling (1.b)

- Optimization parameters: 6 amplitudes and 6 phases of the PR in x plane and 6 amplitudes and 6 phases of the $(\nu_x^i - \nu_y^i)$ coupling resonance
- GA optimization results after 100 iterations with a population of 100,000

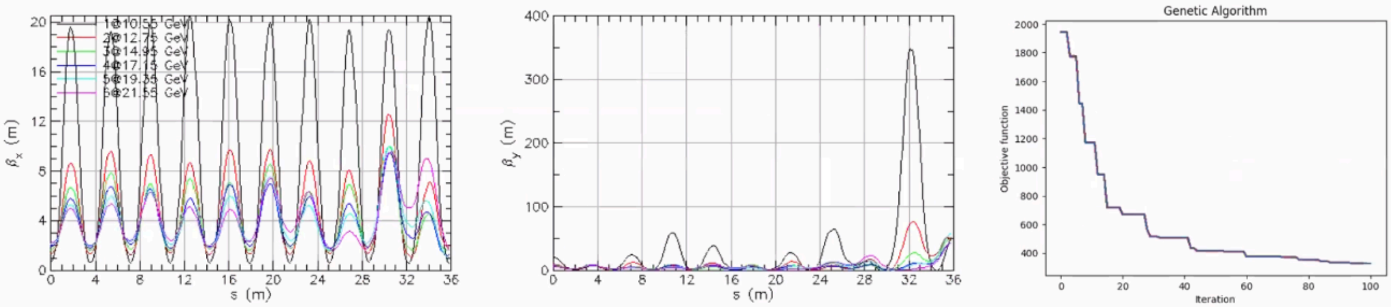


V.S. Morozov, September 26, 2025

Vasiliy: I keep an eye on the RMS beam sizes in each plane to ensure the beam is not being too heavily skewed. Again, for the vertical plane the results were sufficient but the horizontal requires more work. The beam size area was also sufficient.

Equal Betatron Phase Advances in X and Y (2)

- 6 resonance amplitudes and 6 resonance phases are the optimization parameters
- GA optimization results after 100 iterations with a population of 10,000



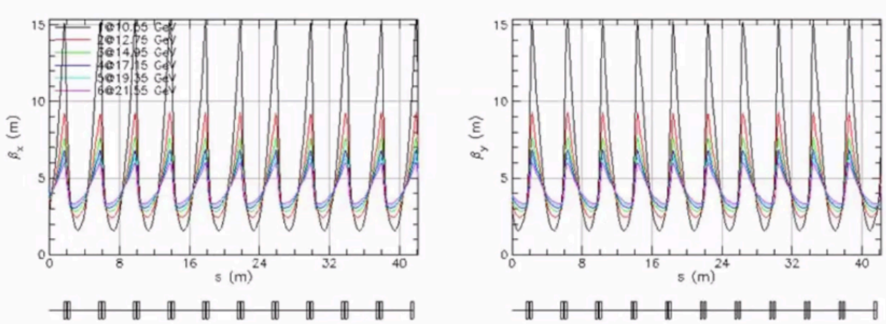
4 OAK RIDGE National Laboratory | HIGH FLUX ISOTOPE REACTOR | SPALLATION NEUTRON SOURCE

V.S. Morozov, September 26, 2025

Vasiliy: The PR quadrupoles are placed at vertical beta function peaks; the horizontal optics are relatively unaffected.

Doublet-Based Lattice (3)

- Did not look promising
- No convenient location at which to expand both βs
- Pursued triplet optics more thoroughly but shown here for completeness



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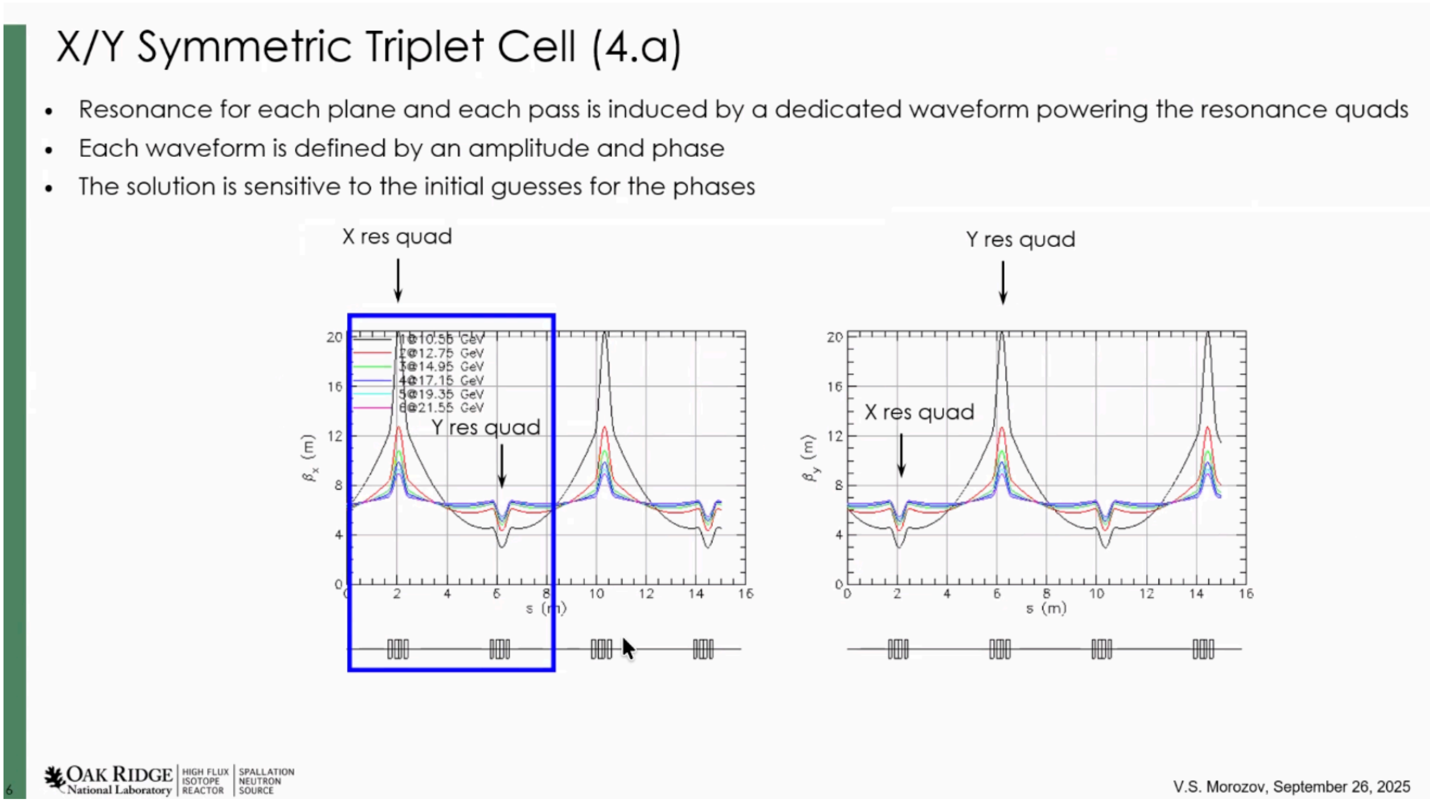
V.S. Morozov, September 26, 2025

Vasiliy: Results for this test were not that promising. There is no convenient place where both (horizontal and vertical) beta functions are large in size but small in slope.

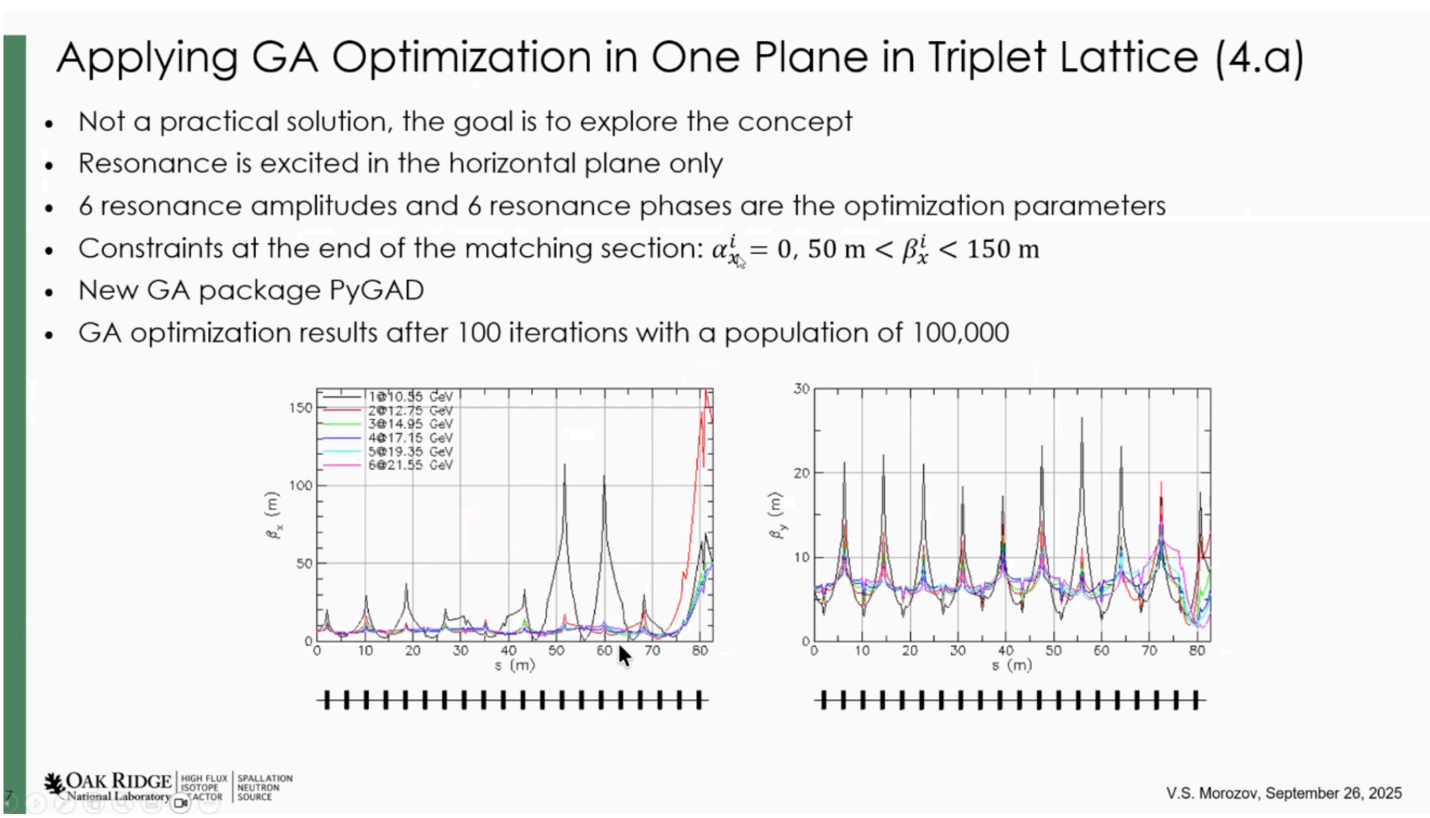
Ryan: There seems to be some saw-tooth behavior.

Vasiliy: That’s just the doublet optics.

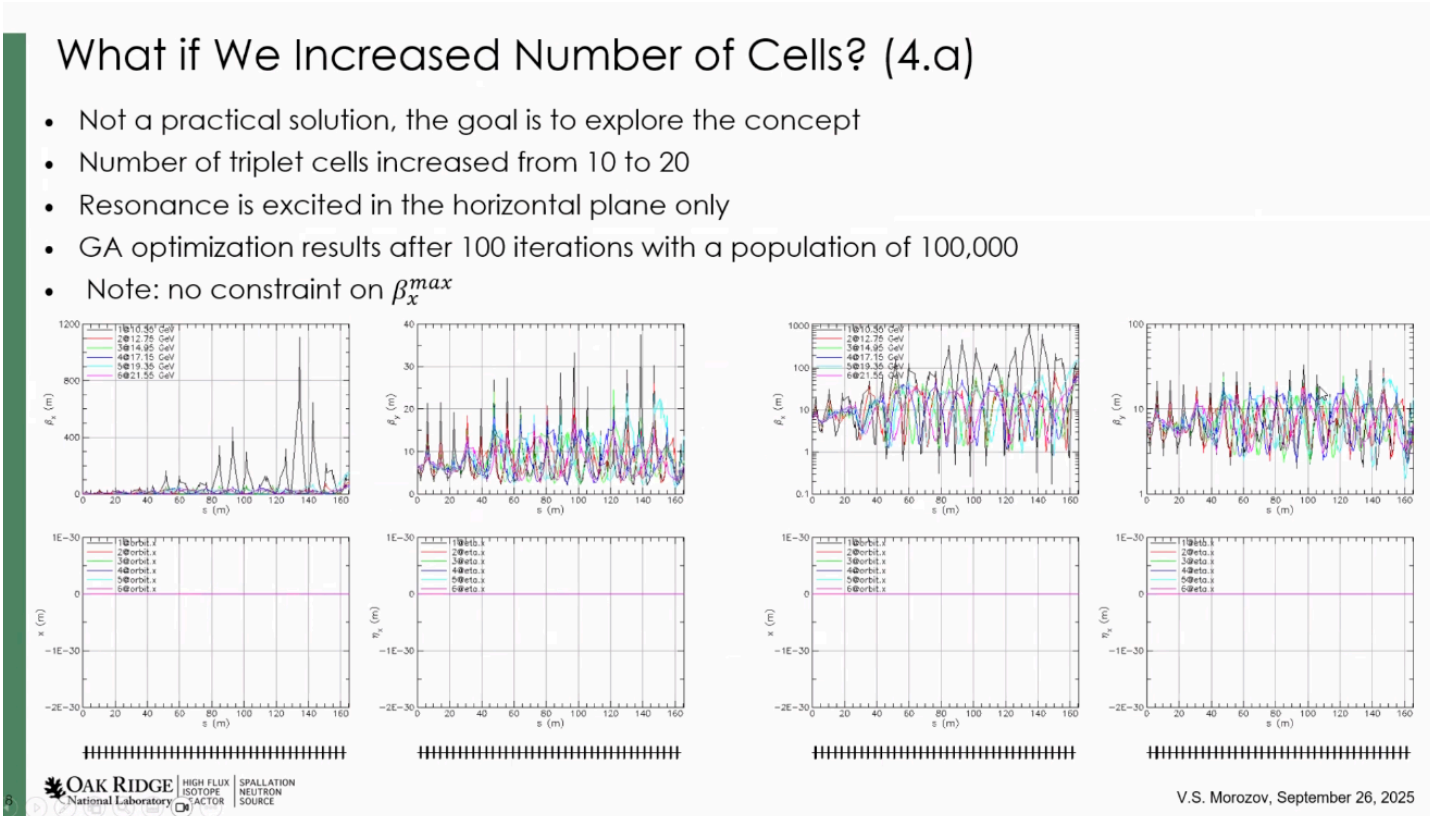


Vasiliy: Each cell consists of 2 triplet cell with focusing and defocusing quads flipped. This seems to create ideal locations for PR quads.

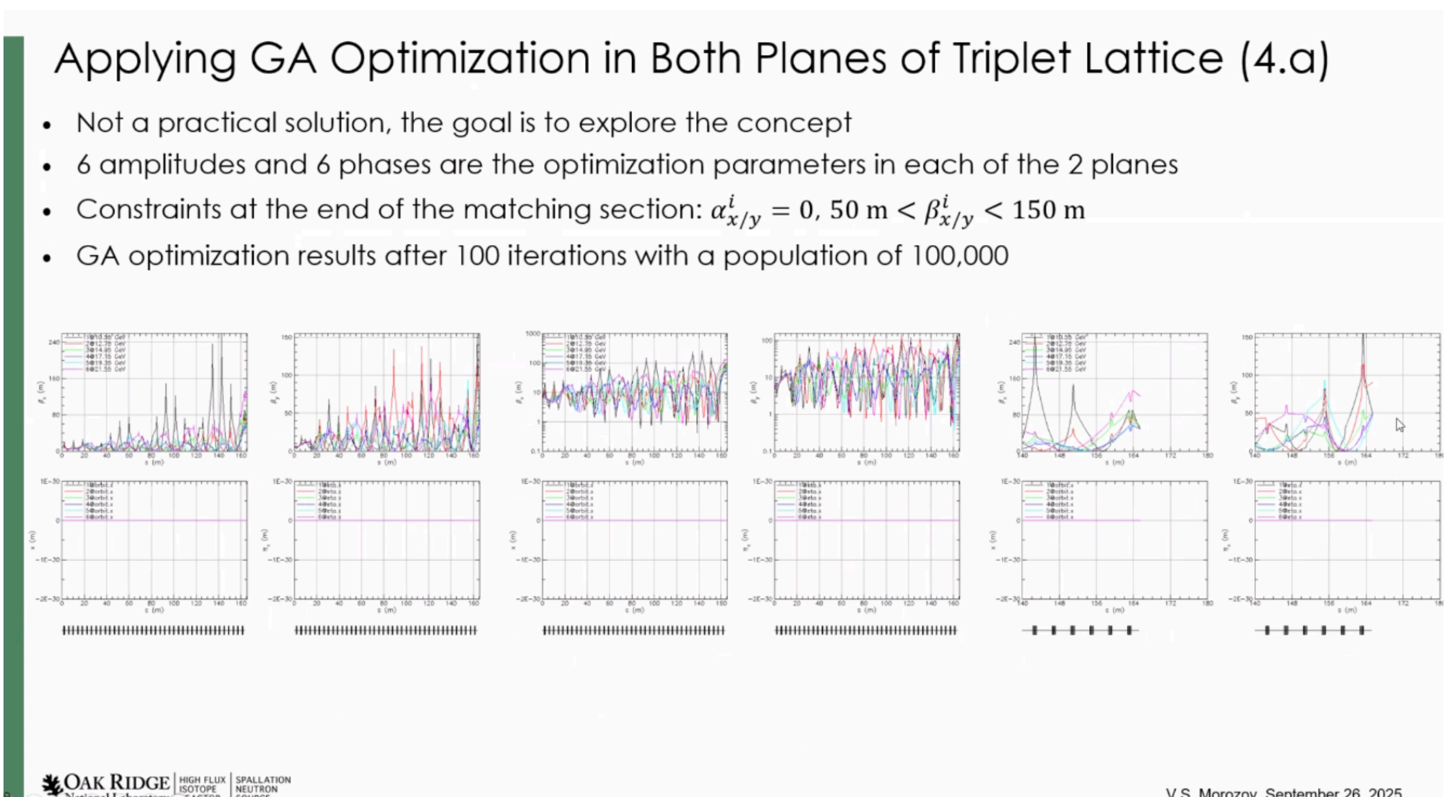
Alex B: This is the same trick that we did for the linac.



Vasiliy: Ran into a a technical issue where I was not able to run the optimization algorithm in both planes with high/ large statistics. I had to switch to another genetic algorithm (GA) package called PyGAD. This seemed to produce more stable results with a larger suite of optimization options. Optics matching results were not great.



Vasiliy: As a knob for optimization, we decided in increase the number of cells. This improved the matching in only one plane. The beta function in the horizontal plane did increase to large numbers.



Vasiliy: Results were recently acquired; not an ideal solution. Pursuing the triplet scheme seems like the most promising path forward.

Stephen: Depending on the allowable error, I could imagine that we mismatch the beam when in goes into the arc so that it could assist the matching in the transition section.

Vasiliy: Correct there is another knob to use.

Stephen: But you need to be cautious because you can’t mismatch the beam in the FFA too much. This would need to be studied.

Salim: Do the triplets have all the same field?

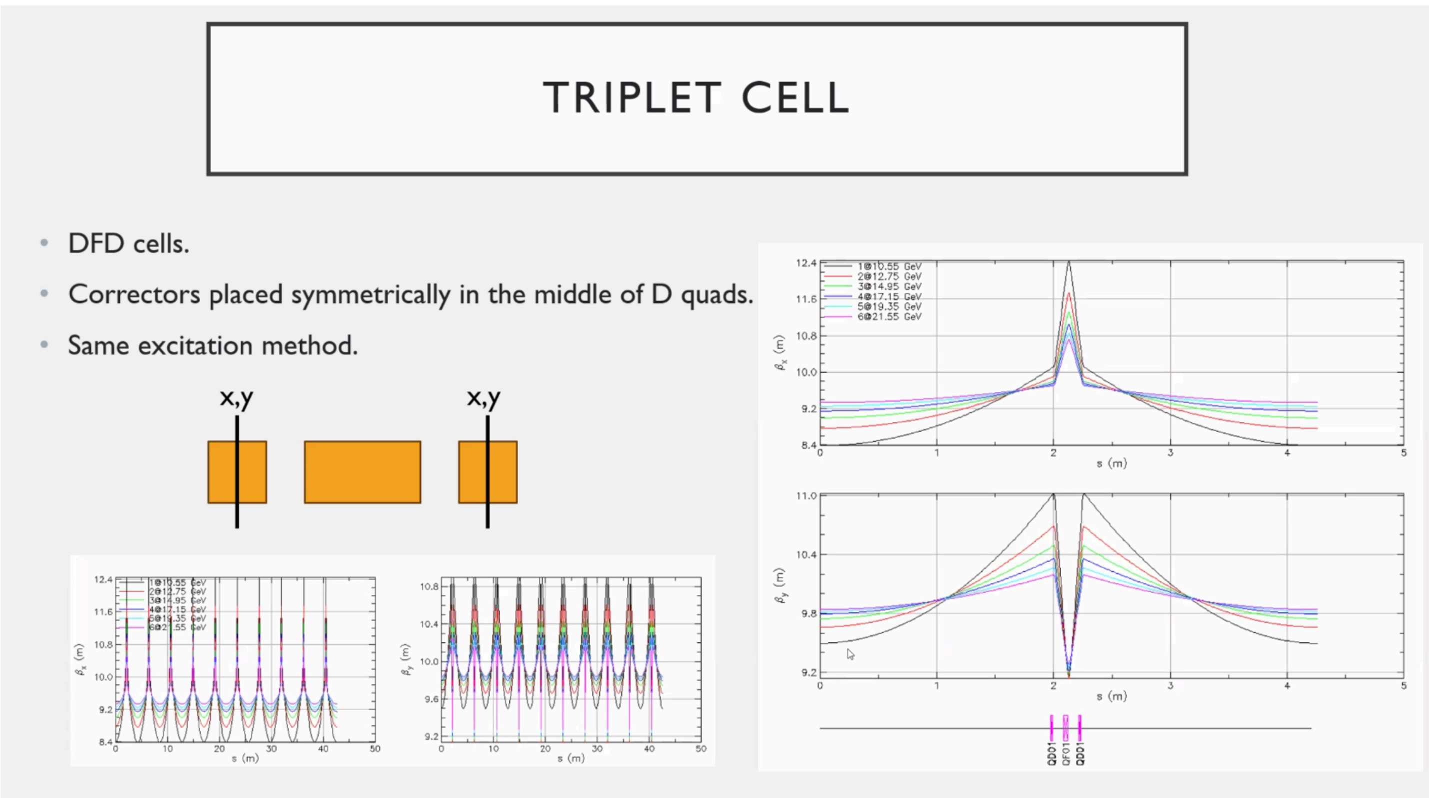
Vasiliy: They are all the same.

Salim: Can you use the last set(s) of triplets to achieve the matching?

Vasiliy: There are two reasons why we dont want to do that: 1. Engineering is more expensive 2. The phase advance needs to be constant throughout each cell which means that the strengths need to be the same. We tried to relax some of these strength-constraints but not successful.

Salim: You say coupling, does that mean you include a skew quadrupole?

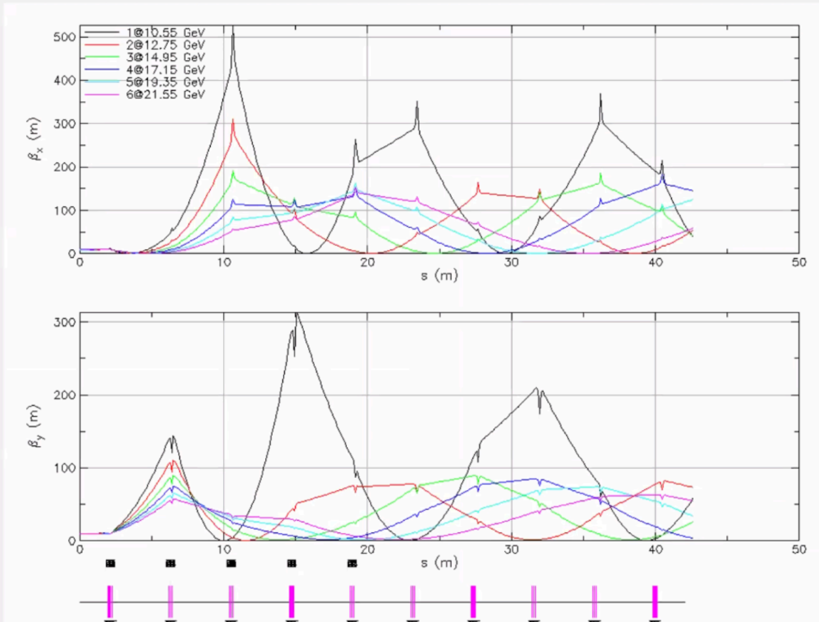
Vasiliy: Yes.

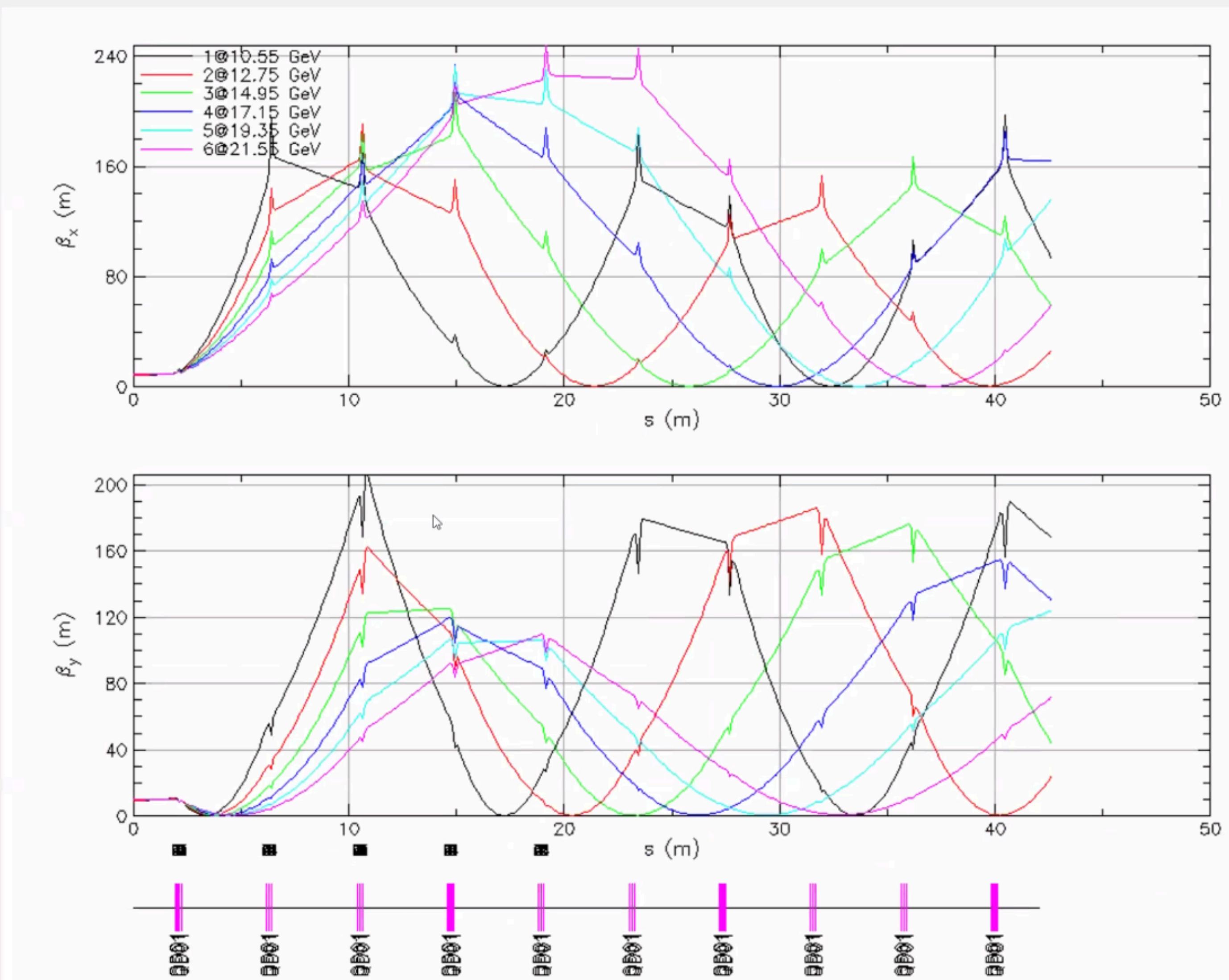


Randy: The correctors are placed on the defocussing quads; I am not using coupling yet. Results did not converge. My computing power is limiting the optimization, at the moment I am trying to run these optimization using parallel computing.

TRIPLET CELL

- 100 iterations with 10000 populations
- Both planes excited
- No coupling (yet?)





Alex: Why do you need so much compute time to run these simulations?

Randy: Genetic algorithm require large compute resources. I can't use the JLAB laptop to run these without the computer crashing so I'm running it on my desktop.

Alex: Speak with Isurumali for advice, she used GA for prior simulation/matching studies.

Vasiliy: Setting up the algorithm with the computing environment takes effort/time.

Time allotted | 5 *mins* | White paper| Presenter *Alex B*

Alex: We have extra time any other items we would like to bring up?

Salim: White paper?

Alex: Yes, lots of papers and documentation have been written already about this project that could be modified into the white paper. Please take a look at the overleaf and add your contributions to it as best you can.

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