FFA@CEBAF Working Group|Minutes

## Meeting date | time 03/07/2025 | 11 AM EST | Meeting location <https://jlab-org.zoomgov.com/j/1614898082?pwd=TnUzMS81M2sxbDZIbERJU01tYkJCQT09>

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| |  |  | | --- | --- | | Meeting called by | Alex B | | Type of meeting | Weekly Meeting | | Facilitator | Alex B | | Note taker | Ryan | | Timekeeper | Alex B | | Attendees  Alex B, Ryan, Donish, Dejan, Scott, Edith, Salim, Volker, Kirsten, Stephen, Donish, Reza, Vasiliy, Tim |

# Intro Discussion

* Stephen can reproduce Dejan’s work. Lowest E was 12.5, couldn’t get to 9.5 GeV.
  + Tuning by hand – never finished. Hopes Stephen can optimize.
  + More or less the FMC lattice – Salim is awaiting these files.
* Volker has a tech note – will present next week

# Agenda topics

## Time allotted | 50 mins | Agenda topic Sym. Splitter| Presenter Donish

* Table

  AI-generated content may be incorrect.
  + Still using the Twiss from the SFL, matching conditions from Ryan
  + Should be some changes to be applied. Need FFA optics, linac optics need changing, and R56 requirements will change
    - Not considered yet.
* Diagram

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  + From last time – breaking the Splitter into sections.
  + Gave it an honest go, but no success
  + Biggest issue: matching sections too long, required too many quads.
    - Too little space for periodic FMC cells
    - Initially, thought could make small enough matching section then insert FMC cell
    - Really no way to correct R56 this way
* A picture containing graphical user interface

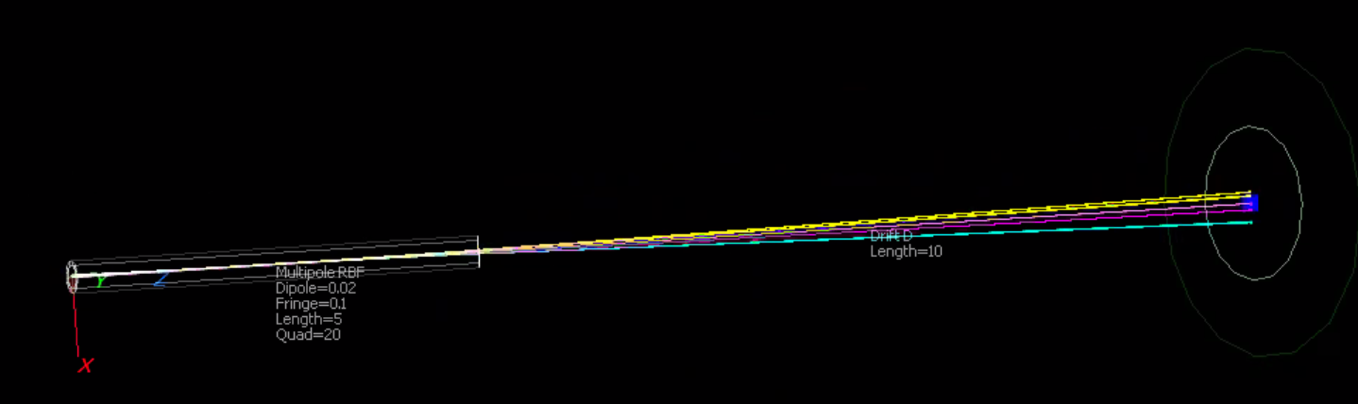
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  + Wanted to make an arc-like beamline instead of a chicane, make bending less aggressive, but didn’t work out.
  + Plot shows Pass 1 – increased number of bends –
    - B1 and B7 are common dipoles for splitting/recombining
    - B2-6 are smaller dipoles, trying to make softer arc. Got solutions and matching
    - Couldn’t get betas down – Beta\_X over 1.5 km
  + Stephen – why are there no elements between B1 and B2?
    - Ryan – I’m guessing just no space due to adjacent beamlines – beam pipes are too close
    - Donish – what Ryan said
  + Donish – finding smaller bend strengths in first bend give improved parameters.
  + Stephen – need some quads between B6 and B7
    - Ryan – he’ll have the same problem unless he recombines without a common dipole.
    - Stephen – or add some halbachs in there
    - Donish – you’ll also get off-axis beams in the quads
* Scott – always have this basic problem. You have to start at the FFA – separate the beams with a dipole. Take a while for them to separate before you can stick things in.
  + What if we take advantage of the large orbit divergences in the FFA and end the FFA such that the orbit separation is accomplished in the FFA
  + Let’s let the beam separate itself
  + Stephen – doesn’t work as well for CEBAF as CBETA b/c the cell is longer
  + Scott – energy separation in CBETA was enormous, not here
    - Lots of issues with this idea, but maybe
    - Maybe combine this idea with what is being said today – take beam out of FFA at max divergence, then increase rate of separation
    - Problem also – focusing in vertical plane
    - Instead of one diverging and one converging, you split them
    - Now manage two diverging beams
    - Ryan – are you putting this backwards?
    - Scott – yes, I’m switching it backwards
  + Donish: are you talking about this?
    - **Table

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  + Scott – I’m talking about Px
    - Smart thing is to get the beams coming out parallel so that it fits in common dipole aperture, and so they don’t grow and converge in different places
  + We might need a place with high divergence
  + Small energy differences between passes makes this problem even harder. The dipoles helped more in CBETA
* Stephen – could make odd magnet to address this.
* Stephen draws:
  + **Diagram

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    - Maybe some tricks to get more gradient in, or put more on initial dipole
    - Dots are beams at different energies, experiencing different gradients
  + Donish – I thought these were basically sextupoles
  + Stephen – a bit different, but similar.
  + Volker – you’re describing an undulator
    - Stephen – basically a sideways one.
* Volker – wondering, if you have the splitter dipole and make it weaker and put a defocusing quad closer to it, you can also get a dipole term from the offset passes
  + Some distance after it, get a focusing quad, offset and weaker, make the beams parallel again
  + Donish – so make a series of off-axis quads to do the bending. We’ve studied the quads to help with separation. Found that the apertures are too limiting
    - Would complicate the design
  + Try dipole, defocus, space, focusing, adjust quad strengths to see if get parallel and controlled betas.
* Donish – do any doglegs do this for multiple passes?
  + Volker – should be all doglegs.
  + Donish – need dispersion to close (achromatic)
    - Volker – need phase advance of 180 or 360 depending on dipole placement
      * Put 1-2 quads in between
    - So basically a DBA
      * But not quite, b/c DBA all dipoles have the same polarity and doglegs have opposite
  + Problem running into is that the central quad that flips the dispersion so it closes at the opposite bend, won’t work for off-axis beams.
    - Thought about sextupoles, but can’t find anything
* Edy – looked at a system where you can hold two energies in the same dogleg. Use sextupoles. But you add so much nonlinearity that controls become incredibly difficult.
  + Donish – creates more problems than solves?
  + Was trying to go from 6 to 3 pipes in the splitter. So if you can separate them slightly then it might not be too bad.
* Donish – cental axis of accelerator is not centered. You lose a lot of space because only bending in 1 direction. Only have 1.6 m max of space in one direction.
* Salim – the bending is horizontal?
  + Ryan – there’s no space. If you kick down, there’s no space to extract. There are 4 passes above, so only linac height and down.
* Alex – but extraction takes place outside of the splitters with RF. Puts 750 MHz RF separators on the outside of each side of the splitter.
  + Ryan – no, the kicks are given outside, but you still need the magnets in the splitters to fully extract. The downstream separator cleans up the rest of the beams. Still need the magnets in the splitters to finish separation.
  + Reza – Ryan is right. You kick a little outside, then use a magnets (quads/YA/etc) in the splitter to kick it out the rest, then if needed, you add another RF kicker to clean up the others.
  + One remaining question: do I need the second one to put it back, or is the kick small enough to be able to ignore it for the other beams? There will be small y offsets without it. Needs to be simulated.
  + So basically one group of RF separators to develop initial kick, develop it, extract with magnets, and hopefully done, or fix with downstream RF.
* Alex – but we have space above?
  + Ryan – height of the current magnets is about 30 cm. I think it’s about half a meter between different lines.
  + Alex – so less than half a meter
  + Ryan – yes, then the magnet thicknesses – you’d have to interleave with different passes again.
* Donish – it was a good idea, Salim. Since these are the symmetric splitters, I looked into symmetries. And vertical is a degree of freedom.
  + Some storage rings do something like this. SLAC SSRL does this.
  + To be honest, never pursued b/c it would really complicate things.
* Alex – going vertical gives you more flexibility for R56
* Salim – was thinking there’s 2m. Thought could put 2-3 beamlines. If 6 passes, do 2, 4, 6. But if there’s not space, it won’t work.
* Donish – first drift length is a function of magnet strength and the width of the first quad
  + Minimum distance between B1 and first quad
* **Text

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  + Never struggled matching Twiss this badly, never had so many constraints. Why so hard?
  + Plotted log of optimization function and step sizes.
  + As the matching starts working more, function oscillates like crazy
  + B/c small betas at FFA, system is extremely sensitive to any changes of the parameters.
  + For stiff numerical systems, combat with reducing step size
* In the chat, Stephen:
  + It splits in both directions! Adding gradient to the splitting magnet and choosing the FFA end point like Scott said can get beams that diverge both ways (although a little randomlyChart

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  + Graphical user interface, text

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  + **Text, letter

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  + This isn’t unreasonable. And then the splitting is in two directions.
  + The beams don’t come out in order.
  + This is the recombining end (starting at FFA)
* Donish – this initial separation from the LINAC end – how would we do it?
* Dejan – Kirsten found that there’s emittance growth – need to reduce values of ToF an R56 so we don’t need as much separation.
  + If we do that, can find a solution like CEBAF doglegs
  + Ryan – I agree, but the issue is that even at smaller energies, the dogleg magnets are huge. At higher energies, we’ll need larger magnets.
* For emittance growth – the dispersion in the FFAs is so small (~100X smaller), you get the splitters contributing more than the entire arc.
  + Need to add more focusing in splitters, and keep the dispersion down
* Dejan – instead of 1-step chicane, doing it in 2 steps, dispersion drops to half
* Kirsten – one thing to keep in mind (Emittance blowup in splitters) – it’s not just a matter of the dispersion, it’s also the transverse optics.
  + For a given physical layout of the dipoles, you get an I2 geometric integral (Alex says I5/I2).
  + Volker: I5 is dipole dispersion, I2 is total energy emitted.
    - Basically dispersion squared over bend
  + Point: for given layout of dipoles, there is some “magic number” to keep dispersion under control, and it’s not clear that this is an achievable number.
  + Alex – Curly-H average for FFA cells is of the order mm – very small. In the splitters, can’t have that range b/c the dispersion and D’ are much higher.
  + Kirsten – you can try to drive the dispersion where you want, but to some extent, the most straightforward way to deal with this problem is to have less bending
    - Do that by dropping down to 5 passes instead of 6 passes.
    - Rapidly running into evidence that suggests 6 passes is too hard to handle.
* Alex – dominant factor is bending, not optics?
  + Kirsten – in the integral, there’s a term (G3 integral in the I integral) L integral is bending that limits feasibility
    - Curly-H so tiny, it is a bit unrealistic on what you can tolerate
    - FFA: I3 of the lowest pass – E-2, I5 = E-7
    - Go to splitters, I3 is order of magnitude smaller in I3 and 6 times larger just because no longer have tiny betas
    - So what’s realistic Curly-H to expect in Splitters??
    - End of day, need far less bending
* Alex – sidewise undulator – intricate idea. Hasn’t been designed yet, but the alternating slopes is not in violation of any Maxwell equations – maybe that can be designed!
  + For the time being, perhaps we can start thinking that somewhere in the splitters
* Stephen – instead of less bending, maybe need more focusing. Can put some gradients on the beams.
* Volker – that’s a Halbach undulator – fields calculated in analytic form.
  + As you go away from the axis, you have to go numerical.
  + Stephen – in the 3rd dimension, it fans out
* Diagram

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  + Create a symmetric system
  + More involved – running out of time
  + Matching from FFA into FFA
  + Working backwards, changing quads from FFA end to match into LINACs
* **Chart

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* Graphical user interface

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* **A picture containing chart

  AI-generated content may be incorrect.**
* Graphical user interface

  AI-generated content may be incorrect.
* Chart

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* Ryan – did you check these all fit next to each other?
  + Yes
* Scott – FFA on the left side? Yes
* **Chart

  AI-generated content may be incorrect.**
* Graphical user interface

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* Donish – no way to address Curly-H. You’re sort of just stuck with it.
* Kirsten – can I pull numbers from this?
* Scott – These are not small Curly-H numbers. If you look at what’s coming out, it’s much less than a cm. Used to numbers like 3-4 cm. 10 cm is “not going well” in Scott’s experience
  + Not thinking in terms of radiation
  + Flag of how hard matching is.
* Pass 5 and 2 not finished. These are really not promising.

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| Action Items | Person responsible | Deadline |
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## Time allotted | 10 mins | Agenda topic AOB | Presenter All

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| Action Items | Person responsible | Deadline |
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## Special notes

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