TJNAF – IR FFQ Prototype Definition

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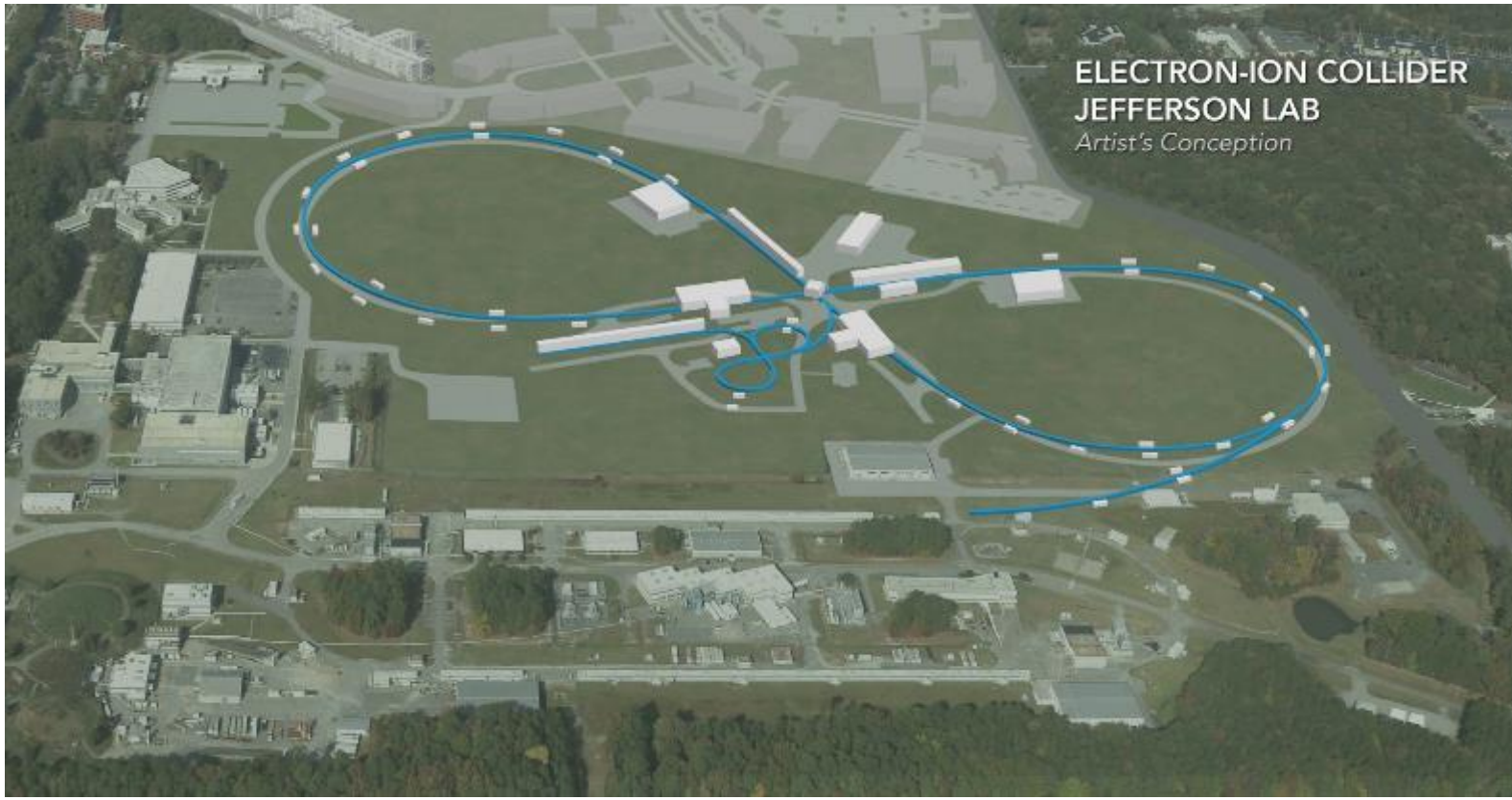


2018 Accelerator R&D PI Exchange Meeting

November 14, 2018

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

JSA

TJNAF – IR FFQ Prototype Definition

- **Description**
  - This activity will serve to identify candidate IR FFQ magnets, with performance parameters which will satisfy both JLEIC and eRHIC requirements.
  - A prototype will be developed and tested to demonstrate functional capability.
- **Status**
  - Awaiting short mechanical model testing at BNL.
- **Main Goal**
  - Develop and test a prototype IR FFQ magnet. The prototype contains a shielding coil to mitigate interaction with the adjacent beamline.
- **Funding**
  - Not base funding for FY'17
  - FY 2018 NP Accelerator R&D FOA – Approved for FY'18/FY'19 – Base redirect
- **Budget**

	FY 2017	FY 20XX	FY 20XX
a) Funds allocated	$XXXk		
b) Actual costs to date	$XXXk		

TJNAF – IR FFQ Prototype Definition

- **Milestones**

Milestone	Schedule	Status
Magnet requirement review with BNL	October, 2017	COMPLETE
Magnet short mechanical model Test Readiness Review	TBD	Open
Thermal Cycle Test at BNL of short mechanical model	TBD	Open
JLEIC ion FFQ magnet analysis of shield coil	N/A	Preliminary Analysis COMPLETE

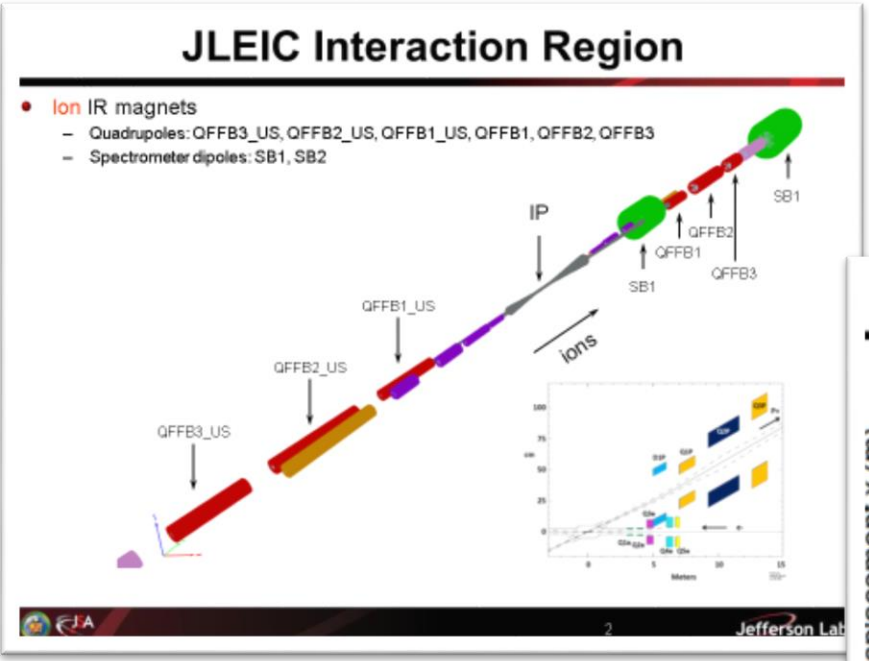
- **Jones Report Ranking**

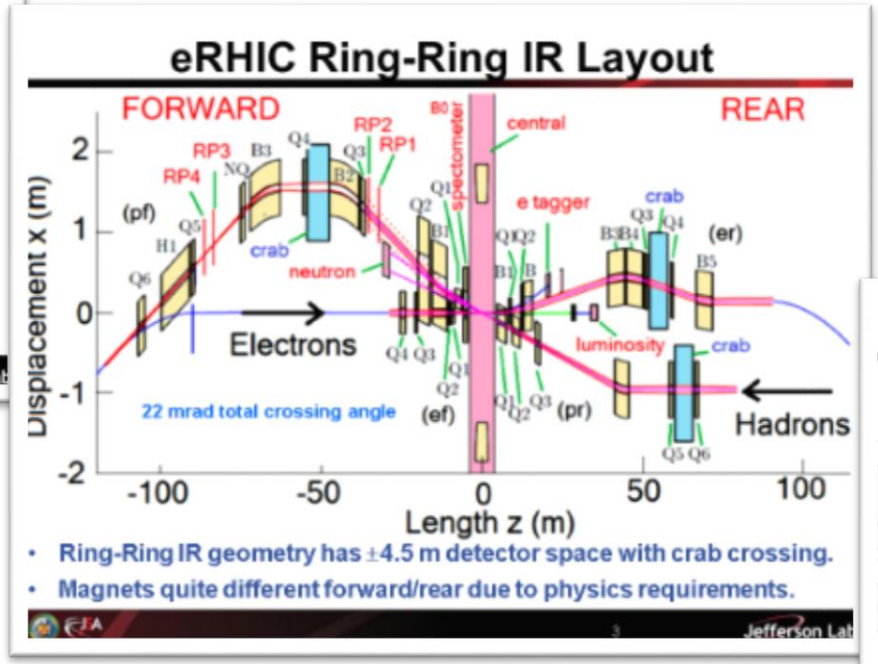
Row No.	Proponent	Concept / Proponent Identifier	Title of R&D Element	Panel Priority	Panel Sub-Priority
1	PANEL	ALL	Crab cavity operation in a hadron ring	High	A
2	PANEL	ALL	High current single-pass ERL for hadron cooling	High	A
3	PANEL	ALL	Strong hadron cooling	High	A
4	PANEL	ALL	Benchmarking of realist EIC simulation tools against available data	High	A
5	PANEL	ALL	Validation of magnet designs associated with high-acceptance interaction points by prototyping	High	A
6	PANEL	ALL	Polarized ^{3}He Source	High	A
7	PANEL	LR	High current polarized and unpolarized electron	High	B

Outline

- Parameter Assessment
- BNL's Fast Track R&D Magnet
- Fast Track R&D Magnet Verification
- JLEIC Actively Shielded FFQ Parameters
- QFFB2-Electron Beamline Interaction
- Summary and Outlook

Assessing Similarities – eRHIC & JLEIC IR Magnets





- Designs at time of assessment
- eRHIC information courtesy Brett Parker, BNL

- Assessed magnet parameters of IR designs
- Identified spectrometer dipole and high field FFQ as candidates
- Selected ion FFQ as magnet to prototype and test
  - Field in the quadrupole coil requires Nb3Sn
  - Opportunity for BNL to validate active shield coil design

Where might we be close enough?

Name	Type	Start Distance from IP [m]	Length [m]	Good-field radius [cm]	Inner radius [cm]	Outer radius [cm]	Min. beam separation [cm]	Strength [T or T/m]	Pole-tip field [T]
eRHIC Ion/Hadron IR Magnets									
B0pf (spectrometer)	Dipole	4.5	1.3				25	1.7	
Q1pf	Quad	6.5	1.8		4.3	12	~14	90.37	4.5
JLEIC Ion IR Magnets									
SB1	Dipole [T]	6	1.5	4	17	24	25.0	-1.3	-1.3
QFFB1	Quad [T/m]	7	1.2	4	6.8	17.1	35.9	-88	-6

- The JLEIC SB1 equates to the eRHIC B0pf spectrometer magnet.
- The first ion quad downstream of the IP are of consideration too.
  - It appears BNL has traded off pole tip field for a bit more length on the quads. They mentioned trying to keep all peak fields to less than 5T.
- Both magnets (1st spectrometer and 1st quad) have the issue of electron beam passing in close vicinity.

BNL Proposed Fast Track R&D Concept Quadrupole Magnet Design

A Fast Track R&D Quadrupole Magnet Concept

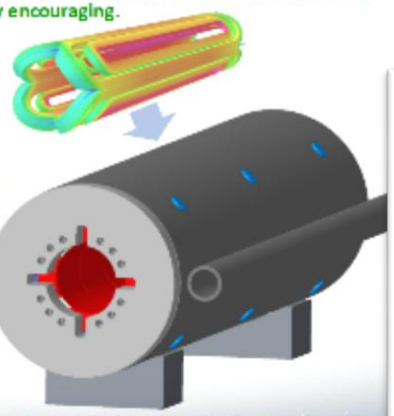
- Repurposing the existing LARP HQ magnet R&D prototype leverages existing equipment, infrastructure and experience to a maximum extent possible.
- This R&D program requires the least investment possible and should give feedback on a useful (rapid) time frame.
- **Demonstrating 8 T performance with an actively shielded quadrupole concept benefits both BNL and JLAB.**
- **But the 120 mm aperture is not specific to either the BNL or the JLAB IR designs (i.e. R&D neutral test parameters).**
- Note there are also 90 mm and 150 mm LARP prototypes, but the 90 mm seems a bit to specific for BNL while the tooling for the 150 mm R&D program is now in active demand.
- Worst case scenario is that we have to use the existing (but not in active use) tooling to make new HQ coils; **best case is that we can take apart an existing HQ prototype and reuse its coils.**

12 Electron Ion Collider, – eRHIC

A Fast Track R&D Quadrupole Magnet Concept

R&D Proposal for a "Fast Track" High Field Nb_3Sn Actively Shielded Quadrupole

A compact structure is needed to provide Nb_3Sn coil prestress. Our preliminary modeling results are very encouraging.



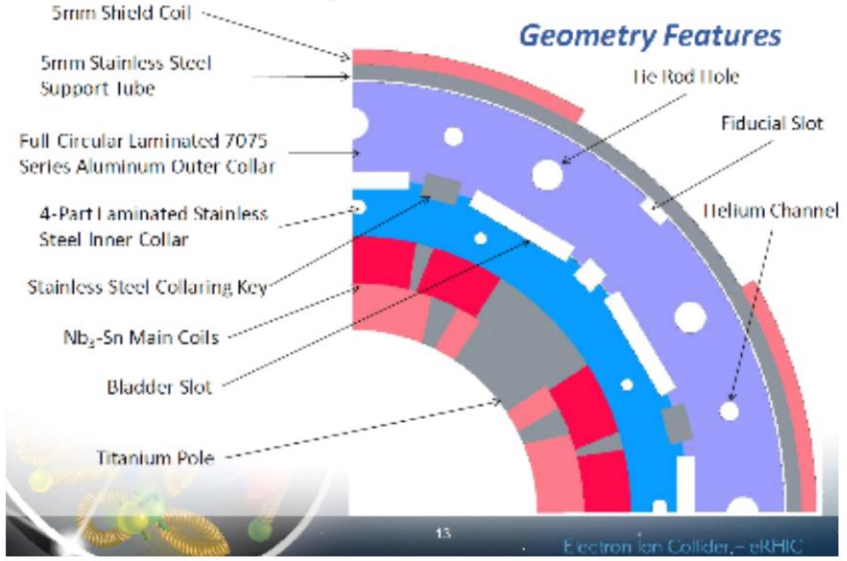
Idea is to add active shield around existing Nb_3Sn coil.

*Received funding so far to design, build and test a 15 cm long mechanical model.

3D Model of Fast Track R&D Quadrupole

11 Electron Ion Collider, eRHIC

Fast Track R&D Magnet: Finite Element Simulations



13 Electron Ion Collider, – eRHIC

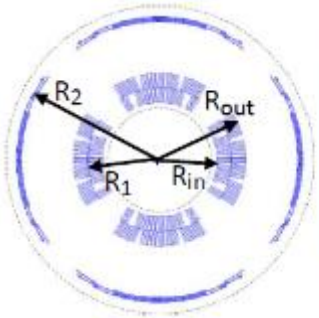
**Courtesy Brett Parker, BNL

BNL Fast Track R&D Magnet: Verification Testing

- BNL to test a short mechanical model
- Uses short sections of HL-LHC HQ coils
- JLab plans to:
  - Participate in Readiness Review
  - Witness Testing at BNL

JLEIC Actively Shielded Quadrupole Parameters

- Per Brett Parker's Fast Track R&D analysis:
  - Main Coil Scaled as $ln(R_{out}/R_{in})$
  - Shield Coil Scaled as $[1-(R_1/R_2)^4]$

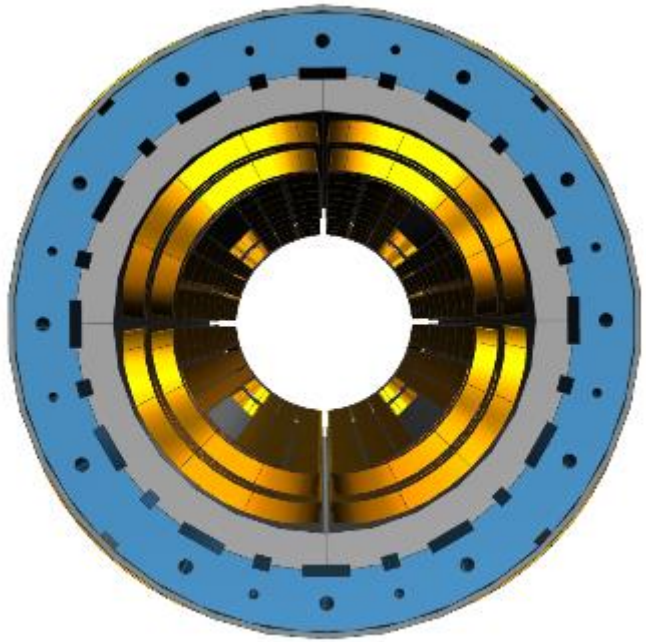


Fast Track R&D
G = 133 T/m
R_{apt} = 54 mm
R_{outer} = 160 mm

- Applying to JLEIC QFFB2 magnet:

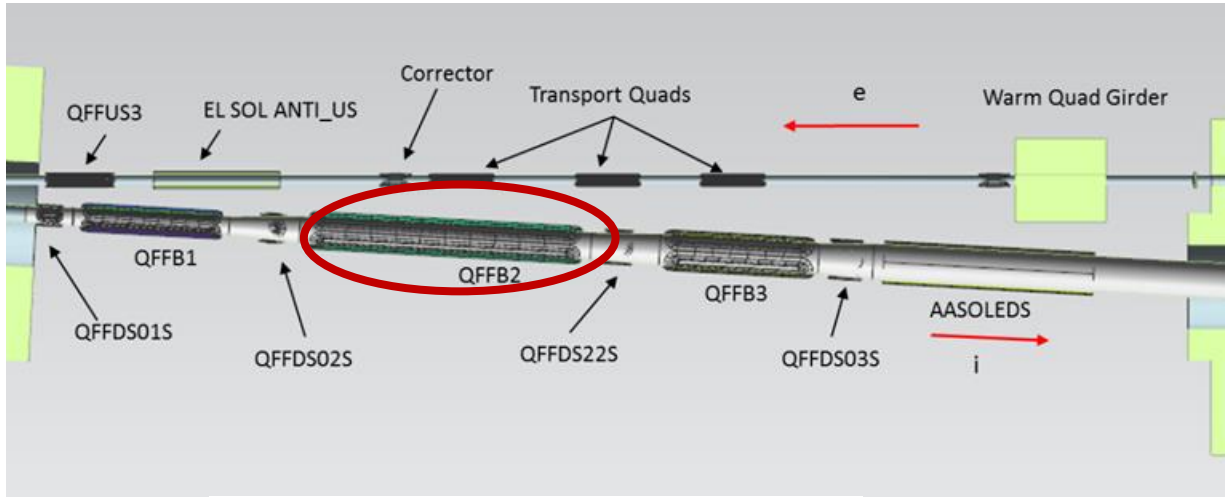
	QFFB2 Parameters	Units
Gradient T/m	51	T/m
Magnetic Length	2.4	m
Peak Coil Field	10.3	T
Peak Shield Coil Field	~4	T
Beam Pipe Aperture Radius	126	mm
Rin - Coil Aperture Radius	133.4	mm
Rout - Coil Outer Radius	178.4	mm
R1 - Coil Mean Radius	145.9	mm
R2 - Shield Coil Mean Radius	268.7	mm
Main Coil Radial Width	45	mm
Shield Coil Radial Width	2	mm

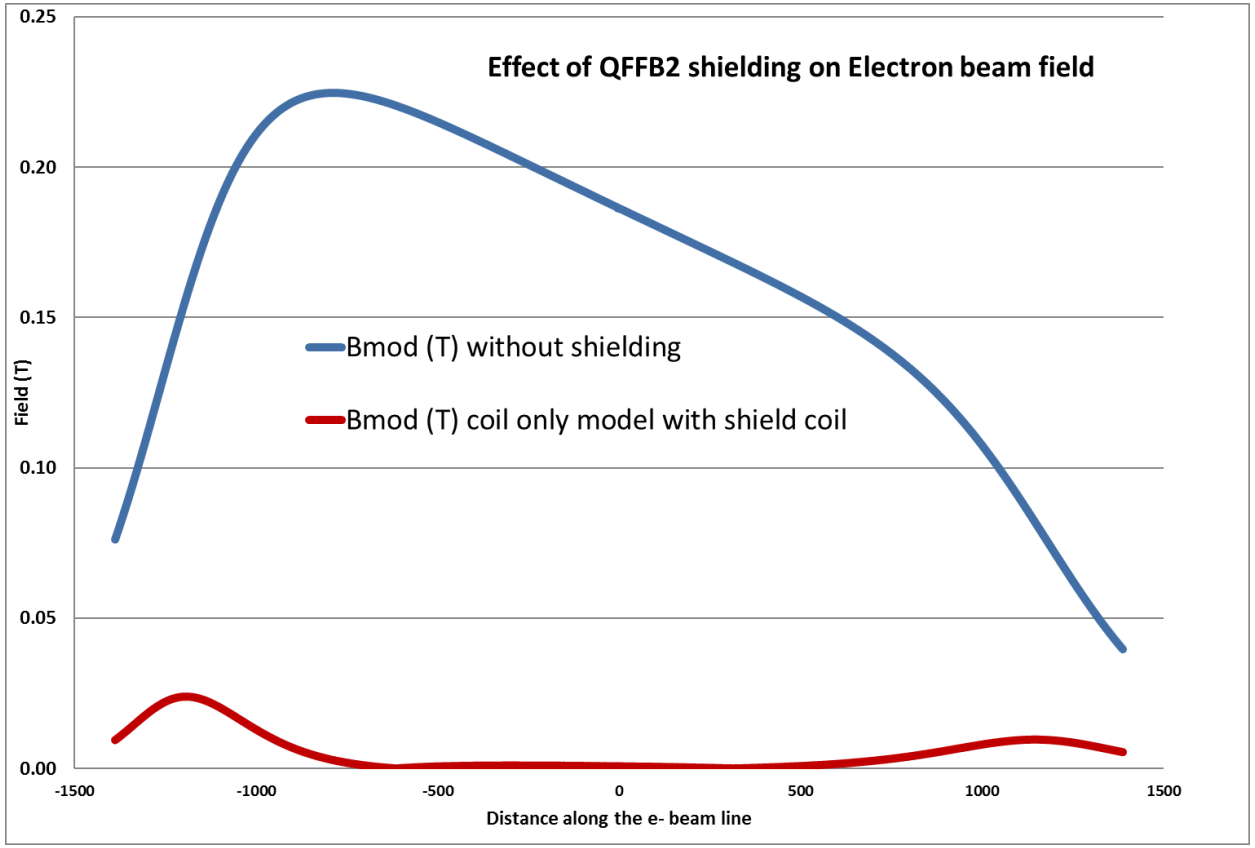
QFFB2 Ion FFQ Design

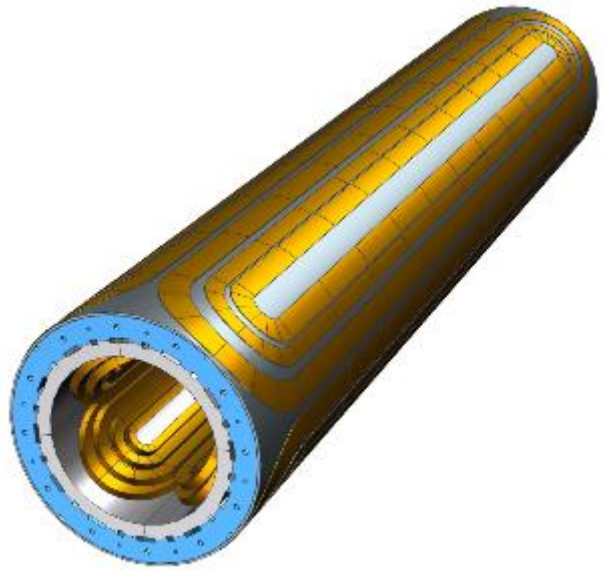


Magnet – Electron Beamline Interaction

- Study of QFFB2 with electron beamline due to high field and close proximity. Determined to be the worst case.
- **Associated transport quads and corrector not considered.**







Summary and Outlook

- A final focus quadrupole magnet with shield coil has been selected as the magnet design to prototype.
- BNL has developed a design to support Nb3Sn coils.
- The coils to be used are from HL-LHC HQ magnets.
- Awaiting construction of the short mechanical model.
- Thermal cycle testing to follow.

- Mechanical and TOSCA models of the QFFB2 ion FFQ have been made.
- A preliminary analysis on the impact of the QFFB2 to the adjacent electron beamline has been performed.
- Further optimization of the shield coil is required.

- We await the testing at BNL to validate the structural design and pre-stress on the coils.
- A fully functional prototype is the objective of follow-on FY'18/FY'19 FOA R&D.

Thank you for your attention.

Are there any questions?