FLArE: Design, Engineering, and Costing

Steven Linden on behalf of the FLArE Technical Group
FPF6, CERN, 8 June 2023

Outline & Overview

Brief review of current FLArE design (liquid argon TPC)

Update on engineering status

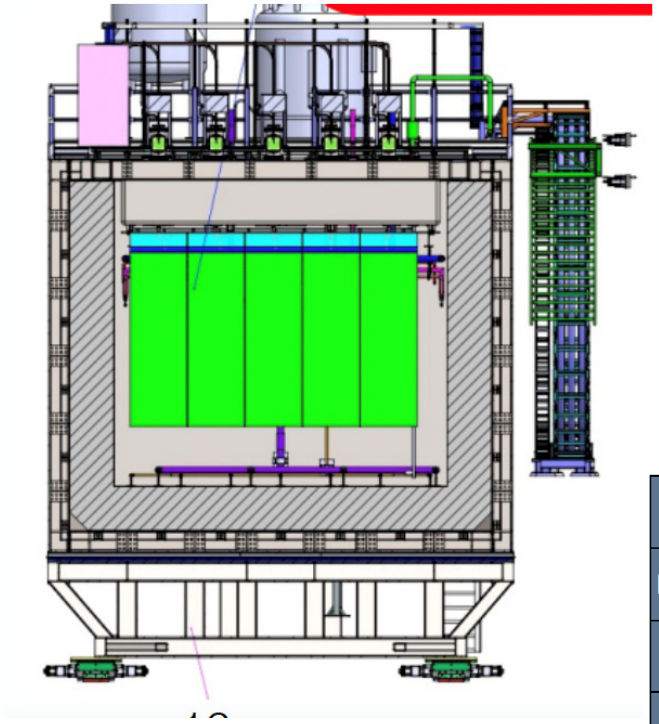
Notes on costing exercise performed for P5

Wenjie will then talk about current status of simulation & physics reach

Reminder: We have a FLArE working group with regular meetings. Please feel free to attend these if you are interested!

Meetings are biweekly, Mondays at 9:30 a.m. eastern time. The next meeting is next Monday, June 12th.

Cryostat



• Space in FPF hall currently is limited to 3.5 m x 3.5 m x 9.6 m for FLArE.

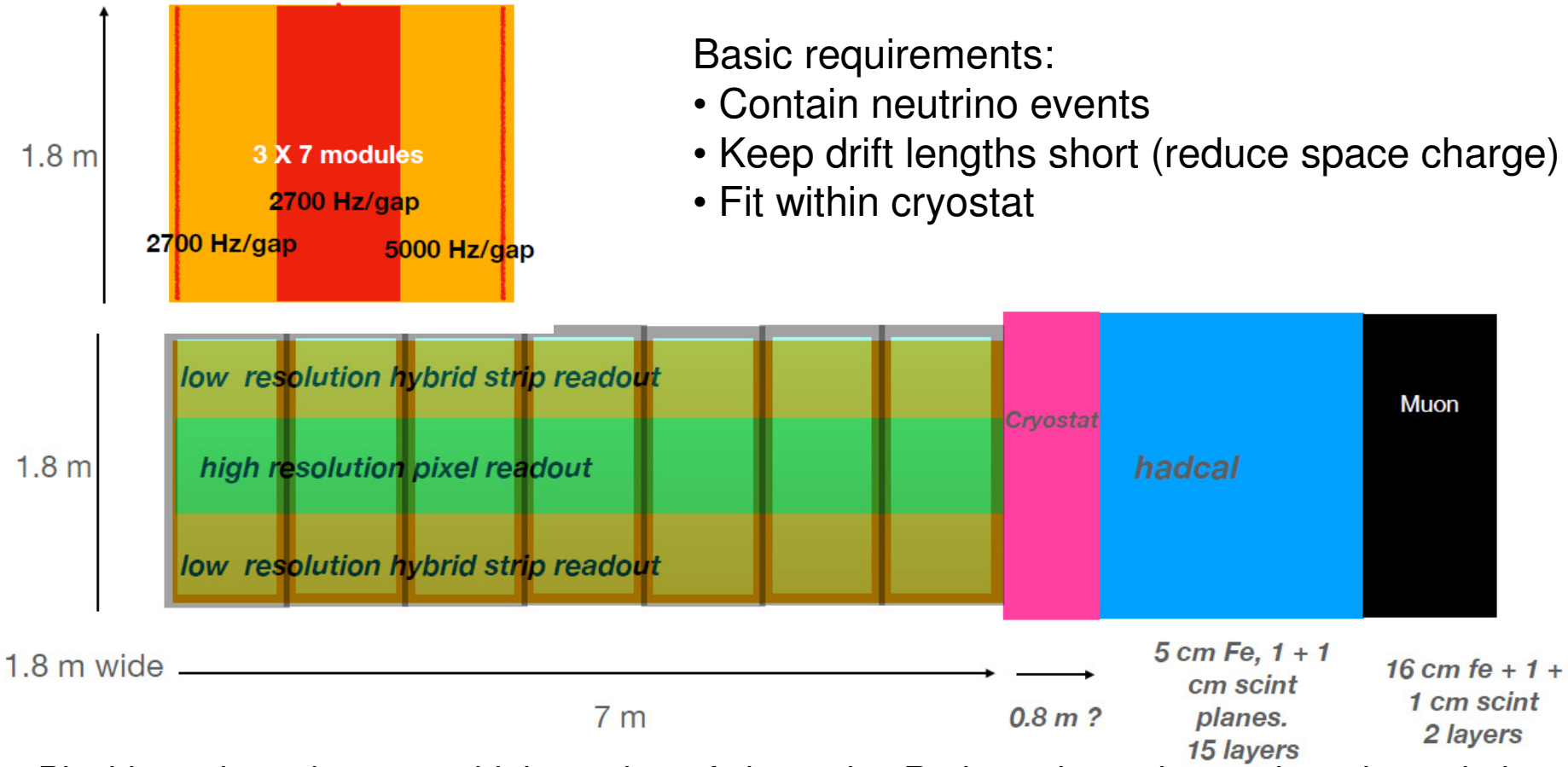
• 80 cm GTT membrane occupies 1.6 m out of 3.5 m.

→ About 1.9 m x 1.9 m cross section allowed for detector.

	Cryostat Inner Dimensions	Insulation Type	Insulation Thickness	Insulation density	Heat leak	Cold shield
MicroBooNE	3.8m dia x 12 m	Polyurethane Foam	**400mm**	32 kg/m^3	**~13 W/m^2**	No
ICARUS-GS	3.9m x 3.6m x 19.6m	Nomex honeycomb+perforated Al	**665 mm+ (combined)**	25-35 kg/m^3	**7-22 W/m^2**	Yes
ICARUS-SBN	3.9m x 3.6m x 19.6m	Al extrusion+GTT foam	**665 mm+ (combined)**	25-35 kg/m^3	**10-15 W/m^2**	Yes
ProtoDUNE	7.9m x 8.55m x 8.55 m	GTT membranc	**800mm**	90 kg/m^3	**~8 W/m^2**	No
ND-LAr	3m x 5m x7m	GTT membrance	800mm	90 kg/m^3	**~8 W/m^2**	No
FLArE	~(1m x 1m x 7m)					No?

Yichen Li

Detector Dimensions: 3x7 option



Basic requirements:

- Contain neutrino events
- Keep drift lengths short (reduce space charge)
- Fit within cryostat

Pixel-based anode → very high number of channels. Reduce channel count by using strip-based anodes in non-fiducial region

Photodetectors needed for triggering – e.g. ARAPUCA (Photon is trapped through wavelength-shifting and dichroic short-pass filters; readout by one or more internal SiPMs.)

Drift length of 30 cm.

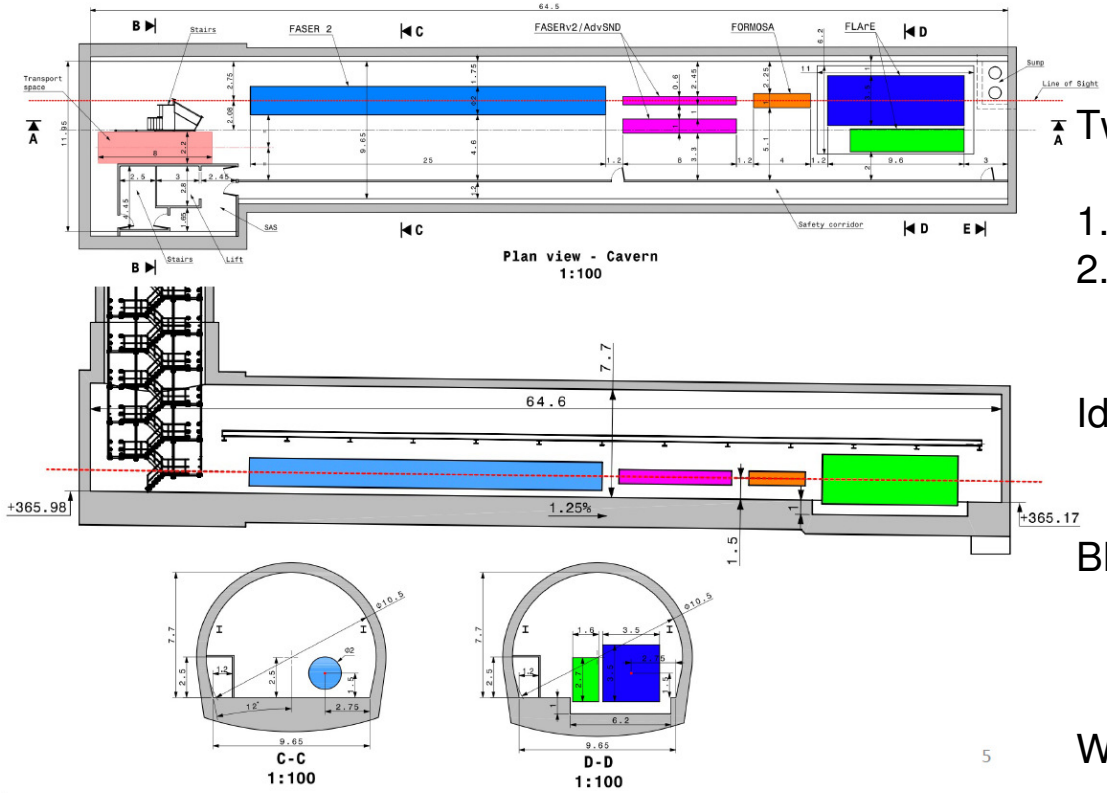
Detector Parameters: 3x7 option

	Most Aggressive	Least Aggressive
# of modules	21	21
Module height	180 cm	180 cm
Module width	60 cm	60 cm
Module depth	100 cm	100 cm
Total TPC height	180 cm	180 cm
Total TPC width	180 cm	180 cm
Total TPC depth	700 cm	700 cm
# of cathodes	21	21
# of anodes (pixel)	42	14
# of anodes (strip, two planes)	0	28
Pixel/pitch size	2	5
Channels per anode (pixel)	450,000	72,000
Channels per anode (strip)	-	1,120
Total channels	18,900,000	132,160

We may be looking at a very high number of channels!

Important to consider heat load per channel and optimize

Design & Installation - Engineering



Working toward preliminary design of the cryostat and detector for pre-CDR

Two major issues for FLArE:

1. Want to install TPC from above
2. Will the large magnet prevent installation access to FLArE?

Ideally, want to be able to remove and replace modules after installation.

BNL is contracting an engineering firm (Bartoszek Engineering) for initial design of FLArE cryostat and detector installation

We also have some time from a BNL engineer (Connor Miraval) to oversee and provide QC.

To make the best use of this contractor, we need to figure out how BNL, CERN, and Bartoszek will communicate and collaborate.

FPF/FLArE Cost Exercise

- Year by year cost estimates were presented at the P5 Energy Frontier Committee Meeting in April.

- These estimates were at a more sophisticated level than most of the other projects discussed at P5.

- Milind will show something on the overall budget tomorrow.

- I want to briefly explain how I arrived at the FLArE estimate.

- Wherever possible, FLArE estimates were based on ND-LAr BOE.

- Maybe the strategy of extracting numbers from comparable experiments with existing BOE can be implemented for other FPF projects.

FLArE Cryostat Estimate

Item	ND Quantity	ND Unit Cost	Required for FLArE?	Extended Cost	
Warm Structure Production					
DU-1003-4961 Side Panel	16	$44,105		$ 705,680	
DU-1003-5179 Corner Element	8	$67,187		$ 537,496	
DU-1003-5348 Support Element	10	$33,357		$ 333,570	
Bolts and Misc Hardware	12000	$31		$ 373,440	
Subtotal: Warm Structure Fabrication				$ 1,950,186	
Tooling: Warm Structure Weldment Sawhorses	16	$4,000		$ 64,000	
Tooling: Warm Structure Wall Feet	4	$7,500		$ 30,000	
Tooling: Warm Structure Wall Supports	4	$10,000		$ 40,000	
Tooling: Welders, Leak Checker, Hand Tools	1	$50,000		$ 50,000	
Subtotal: Warm Structure Tooling				$ 184,000	
Total: Warm Structure Vendor Costs				$ 2,134,186	$ 2,134,186
Warm Structure Shipping	1	$58,000		$ 58,000	
Warm Structure Storage	26	$500		$ 13,000	
Lid Section and Mezzanine Production					
DU-1003-7118 Lid Section	9	$67,187		$ 604,683	
DU-1003-7143 Cryogenics Mezzanine	1	$276,250		$ 276,250	
DU-1002-3511 TPC Mezzanine	1	$198,750		$ 198,750	
Total: Lid and Mezzanine Production				$ 1,079,683	$ 1,079,683
Lid Section Prototypes					
DU-1003-5179 Corner Element for TPC Integratio	2	$67,187		$ 134,374	
DU-1003-7118 Lid Section for TPC Integration Te	2	$67,187		$ 134,374	
TPC Installation Test: Misc Hardware	1	$20,000		$ 20,000	
Total: Lid Section Full Scale Prototype				$ 288,748	$ 288,748
Simplified Lid Section Serviceability Prototype	1	$75,000		$ 75,000	$ 75,000
Muon Window Prototypes			Not required		
Muon Window Early Prototypes	1	$6,977		~~$ 6,977~~	
Muon Window Benchtop Prototype	15	$1,000		~~$ 15,000~~	
Muon Window Manufacturing Model	1	$75,000		~~$ 75,000~~	
ND-LAr Cryostat Cold Membrane Estimate					
Total Cold Membrane Engineering		$ 1,200,000		$ 1,200,000	$ 1,200,000
Cold Membrane Vendor Preliminary Engineering Study		$ 500,000		$ 500,000	
Cold Membrane Vendor Final Engineering Study		$ 700,000		$ 700,000	
Cold Membrane Materials		$ 2,892,000		$ 2,892,000	$ 2,892,000
Cold Membrane Installation		$ 972,000		$ 972,000	$ 972,000
Cryostat and structure total					8641617

Costs directly extracted from DUNE ND-LAr budget (July 2022)

Warm structure and lid/mezzanine are more complex than what is required for FLArE → this is a conservative estimate pending engineering studies

Should compare to actual ND-Lar expenditure

Also performed this exercise for cryostat engineering/design labor

Similar exercise done for engineering/design: $575,000

FLArE Detector Estimate

Item	Detector	Detector labor	Detector labor hours	
Field structures - mechanical engineer			1130	Based on DUNE ND
Field structures - mechanical designer			538	""
Field structures - technician			128	""
Field structures - grad student			512	""
Field structures - materials & supplie	1102			""
Electronics - design engineer			4900	""
Electronics - electrical designer			61	""
Electronics - technician			826	""
Electronics - postdoc			3122	""
Electronics - grad student			1972	""
Electronics - physicist			581	""
Electronics - materials & supplies	1638			Estimate = 150% DUNE ND
Photodetection design		2000		Guess for R&D
Photodetection materials & supplies	630			Guess for how many sensors and dichroic filers for each mod
Assembly and testing - mechanical designer			770	Based on DUNE ND
Assembly and testing - technician			1970	""
Assembly and testing - grad student			10336	""
Assembly and testing - physicist			520	""
Assembly and testing - materials & s	131			
DAQ	2000	2000		Just a guess
Management - lead engineer			1768	Based on DUNE ND
Management - physicist			884	""
Prototypes	2000			
FLARE magnetized hadron and muon range HADMU		1500		very rough estimate (MVD)

Most of this comes from ND-LAr BOE spreadsheets (March 2022)
Scaled quantities as appropriate based on FLArE vs. ND-LAr size, number of channels
“Detector labor”: $ (not hours) guesses (including overhead) for labor items not included in ND-LAr BOE

FLArE Detector Estimate – budget from BNL Business Operations

	DETECTOR					DETECTOR Total
Group Break Descr	2027	2028	2029	2030	2031	
BNL Direct Labor	$ 1,011,648	$ 1,346,919	$ 2,068,687	$ 2,193,584	$ 2,262,101	$ 8,882,939
Capital Equipment		$ 2,000,000	$ 3,500,000	$ 2,001,000		$ 7,501,000
Misc Other Direct Costs						
Contingency	$ 843,716	$ 2,092,372	$ 3,421,108	$ 2,859,689	$ 1,922,305	$ 11,139,190
Procurement Burden		$ 280,000	$ 490,000	$ 280,140		$ 1,050,140
Departmental Charges	$ 318,770	$ 424,414	$ 651,843	$ 691,198	$ 712,788	$ 2,799,014
	$ 2,174,135	$ 6,143,705	$ 10,131,638	$ 8,025,611	$ 4,897,194	$ 31,372,283
Indirect Overheads-Project G&A	$ 717,437	$ 1,031,318	$ 1,600,265	$ 1,631,791	$ 1,604,228	$ 6,585,039
Indirect Overheads - LDRD	$ 61,436	$ 148,280	$ 241,974	$ 351,509	$ 226,644	$ 1,029,842
	$ 778,872	$ 1,179,597	$ 1,842,239	$ 1,983,299	$ 1,830,872	$ 7,614,881
	$ 2,953,007	**$ 7,323,302**	**$ 11,973,877**	**$ 10,008,911**	**$ 6,728,066**	**$ 38,987,164**

Budget produced by Ken Koebel based on our estimates, Milind's year by year profile.

Includes 40% contingency

Schedule constrained by HL-LHC run

Bottom line numbers: ~$40M for detector, ~$65M with cryostat, infrastructure