Forward Liquid Argon Experiment.

FLArE - Status of
1. Physics Simulations
2. Infrastructure design and feasibility
3. Detector design
4. Organization.

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Briefing for the NSF E/P

References for FLArE design and organization.

- **Science and Project Planning for the Forward Physics Facility in Preparation for the 2024-2026 European Particle Physics Strategy Update: https://arxiv.org/abs/2411.04175**

- Dedicated, interdisciplinary meetings to develop the FPF's potential. 5 physics themes: BSM, neutrinos, QCD, DM, and astroparticle physics.

- Nov 2020 (FPF1), May 2021 (FPF2), Oct 2021 (FPF3), Jan 2022 (FPF4): Nov 2022 (FPF5), June 2023 (FPF6) coordination of experimental program, FPF7 (Feb 29-March 1, 2024).

- FPF8 will be Jan 21-22, 2025
  - US working FLArE Technical design (Steve Linden, Jianming Bian, MVD) group.
  - Many many seminar and talks: Wine and Cheese at FNAL by MVD

- A simulation note and a technical report are in progress. Completion Jan 20, 2025.

FLArE Organization (under (PBC) and FPF)

FLArE Technical group:

Bringing together experts from CERN, BNL, and an external engineering contractor Bartoszek engineering:
BNL: M. Diwan, S. Linden, Y. Li, C. Miraval + L. Bartoszek, S. Trabocchi

CERN: J. Boyd, J.P Corso (integration), A. Magazinik (integration), Julien Andre Prosic, F. Resnati (neutrino platform), J. Bremmer.

Focus:

- detector and infrastructure footprint in cavern
- Installation of large / most-complicated pieces:
  - FASER2 magnet,
  - FLArE cryostat and
  - cryogenic infrastucture.

FLARE Physics working group meets every two weeks. Focus is to complete simulation and design documentation.

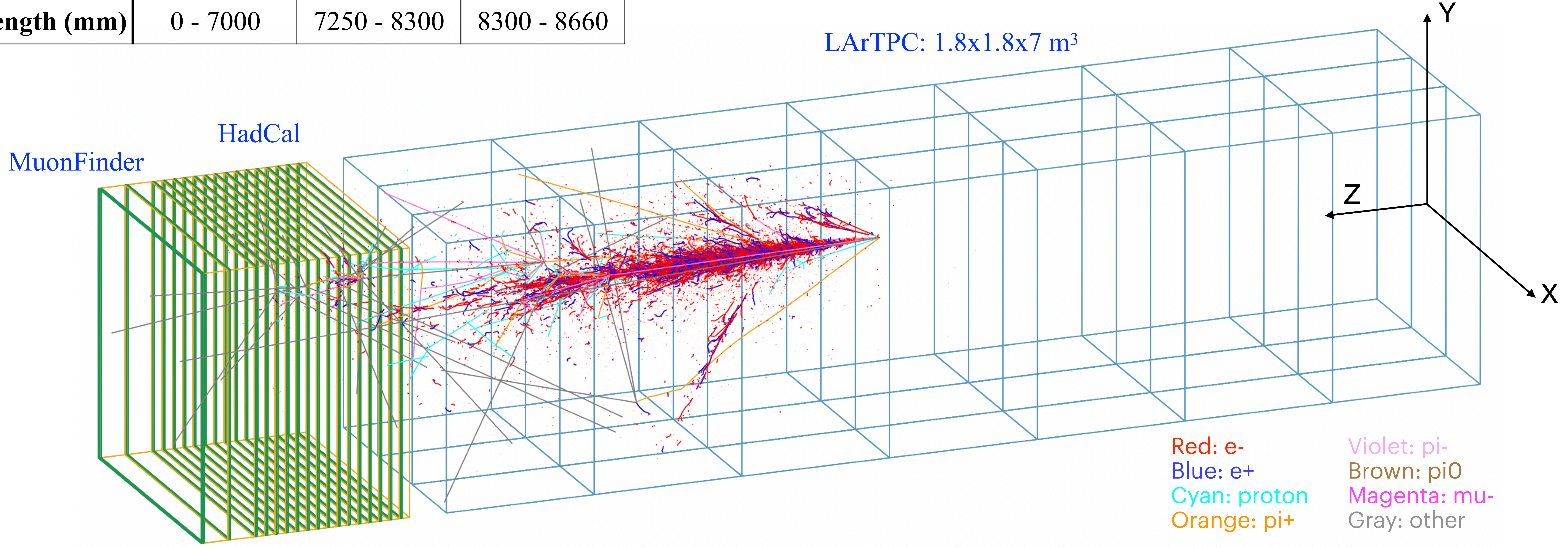
lhc-far-fwrd-flare-l AT lists.bnl.gov has 72 members across US, UK, Japan, Germany, Poland, CERN.

Collaboration could be assembled rapidly once sponsors are ready.

FLArE Detector configuration in simulation

- **Fiducial mass of 10 tons (1x1x7 m^3) is needed for good statistics and sensitivity to dark matter.**
- **Detector needs to have good energy containment and resolution for neutrino physics. (1 m2 around LOS is Fiducial)**
- **Muon and electron ID. Very good spatial resolution (~1 mm).**
- **Working on Statistical techniques for Tau neutrino identification.**

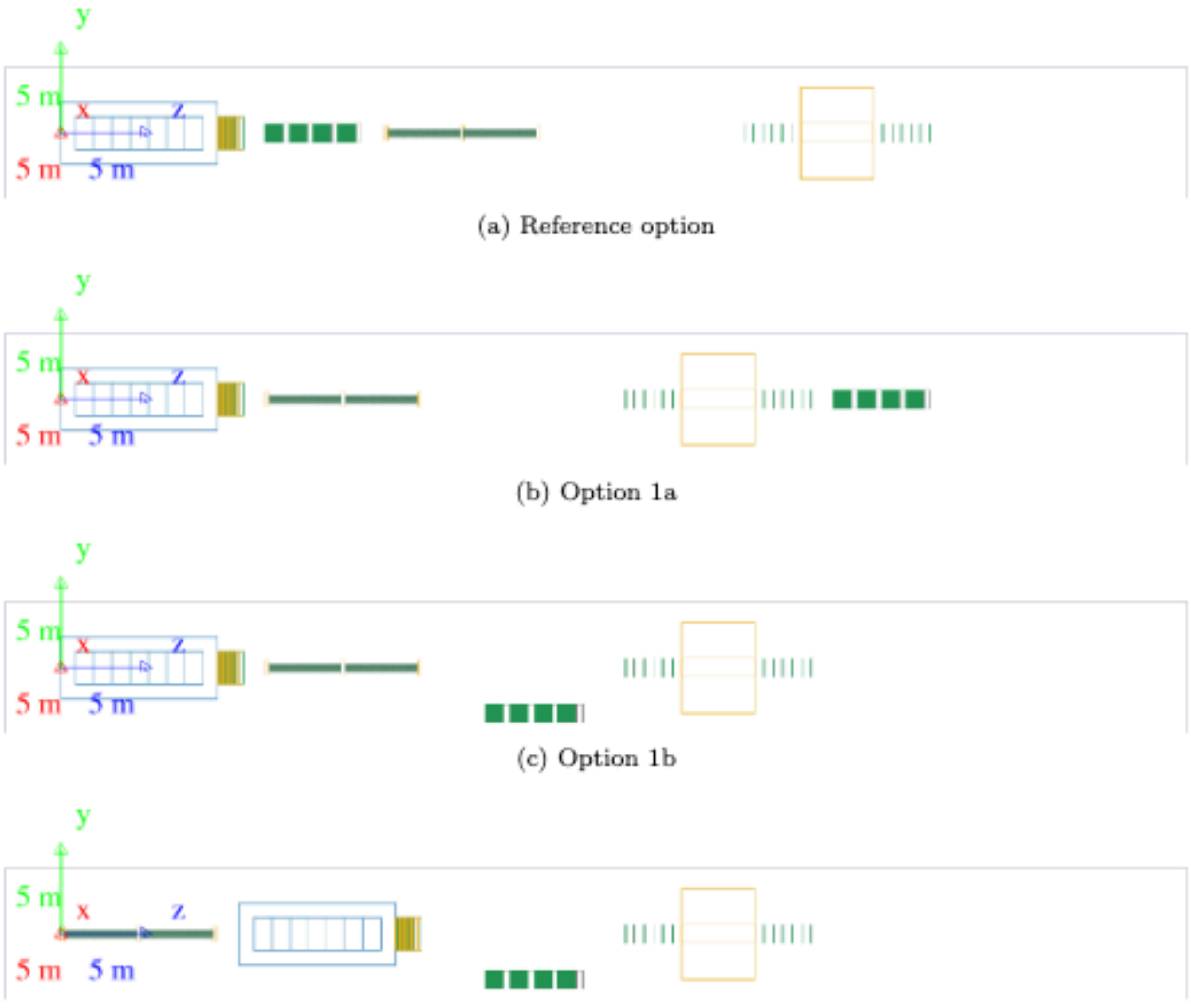
	LArTPC	HadCal	MuonFinder
Length (mm)	0 - 7000	7250 - 8300	8300 - 8660



Status of Simulations for FPF and FLArE.

Matteo Vicenzi (BNL), Wenjie Wu (UCI), Kin Yip (BNL)

- Flexible full GEANT based simulation of all detectors, and FPF facility is ready and installed on lxplus.cern.ch
- The simulation allows configuration alternatives.
- Neutrino event rates are from PRD 104(11).
- Muon flux from LHC is from the FLUKA working group at CERN.



(a) Reference option

(b) Option 1a

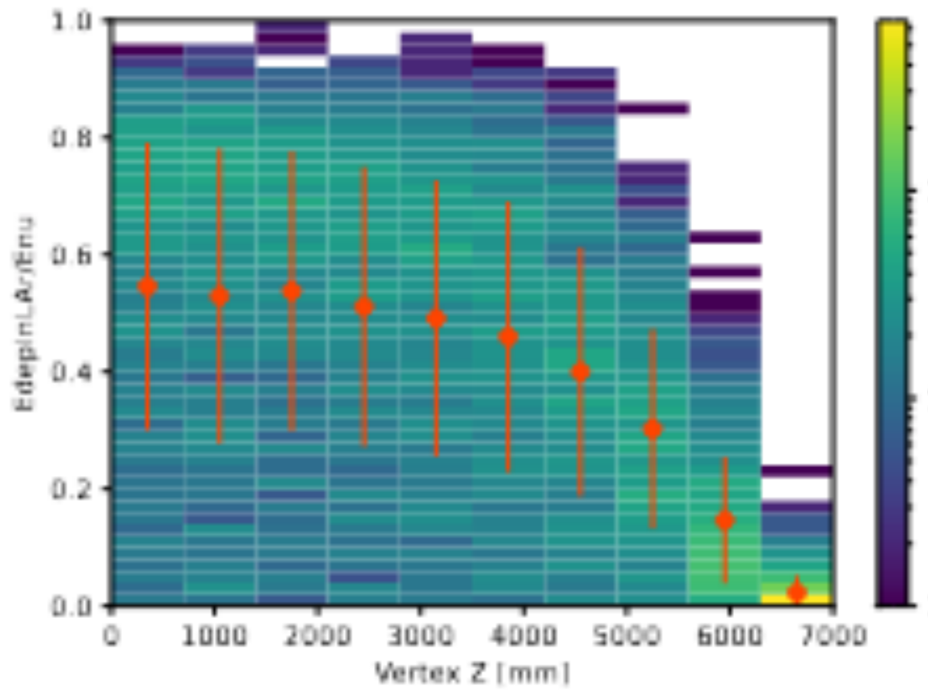
(c) Option 1b

(d) Option 2

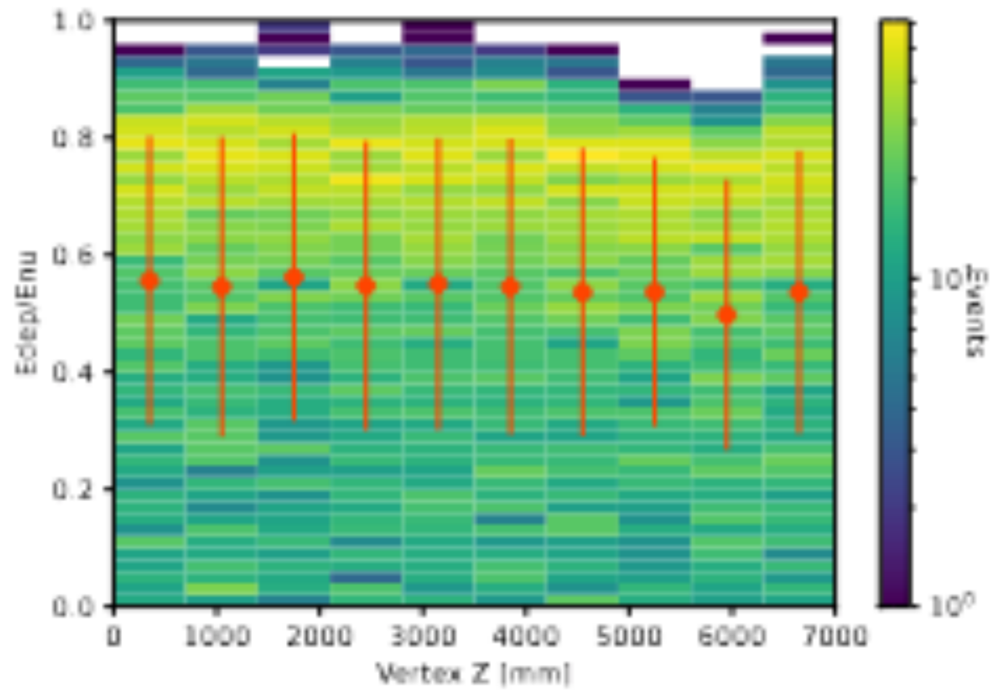
FLARE detector optimization studies

Note is in preparation.

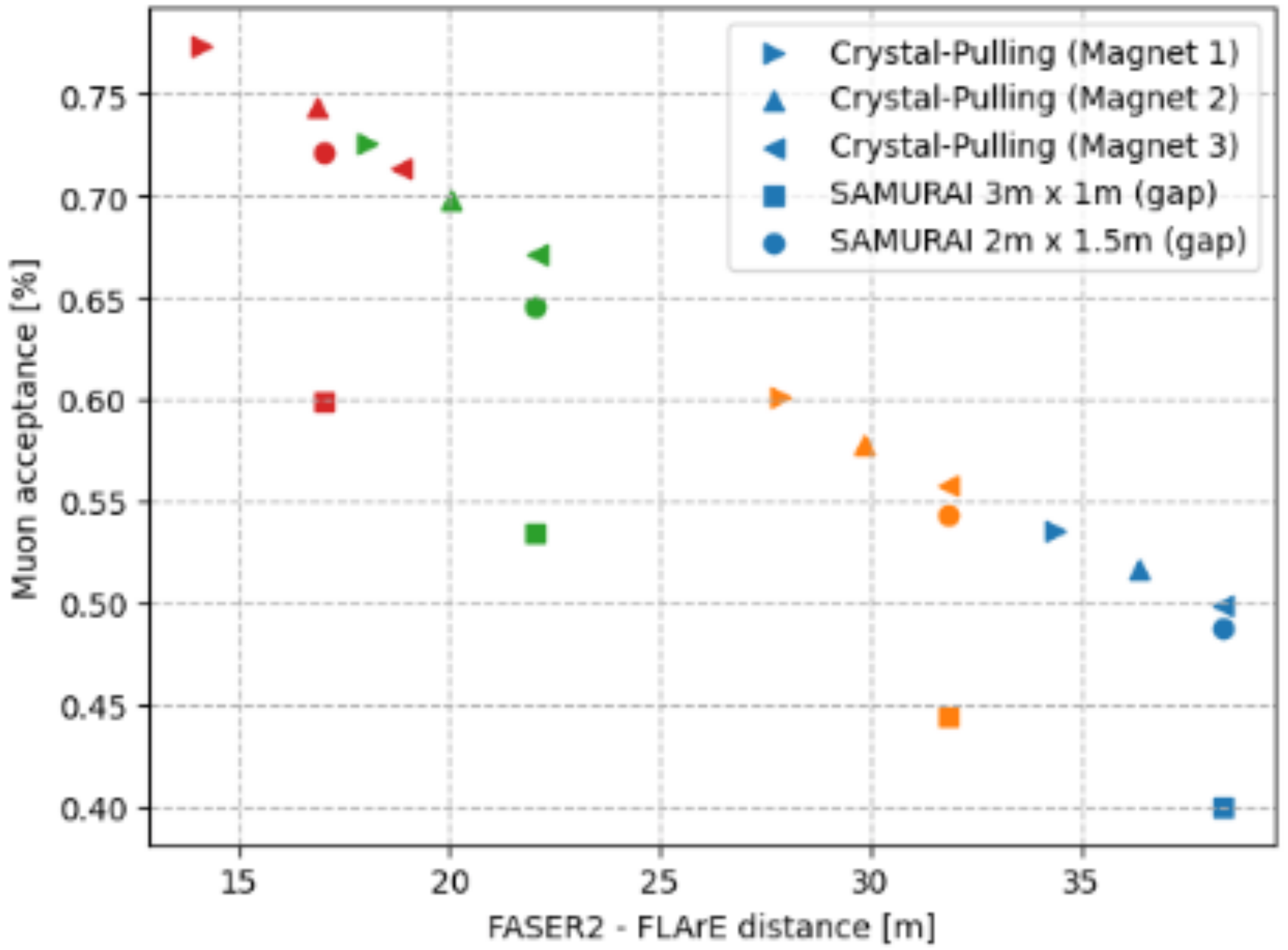
- Energy containment.
  - The chosen size 1.8x1.8x 7 m3 with hadcal has excellent energy containment for fiducial events.
- Muon measurement.
  - FASER2 magnetic spectrometer provides excellent acceptance for >100 GeV/c
- Particle ID and kinematics
  - muon, electron ID is not difficult.
  - Tau ID will require much more work
  - A lot of possibilities for AI/ML
- Trigger studies are needed to isolate neutrinos from beam muons.
- Work is needed to optimize hadronic Fe/Sci calorimeter.



(a) Energy containment without HadCal for the size $1.8 \times 1.8 \times 7$ m^3.



(b) Energy containment with HadCal for the size $1.8 \times 1.8 \times 7$ m^3.

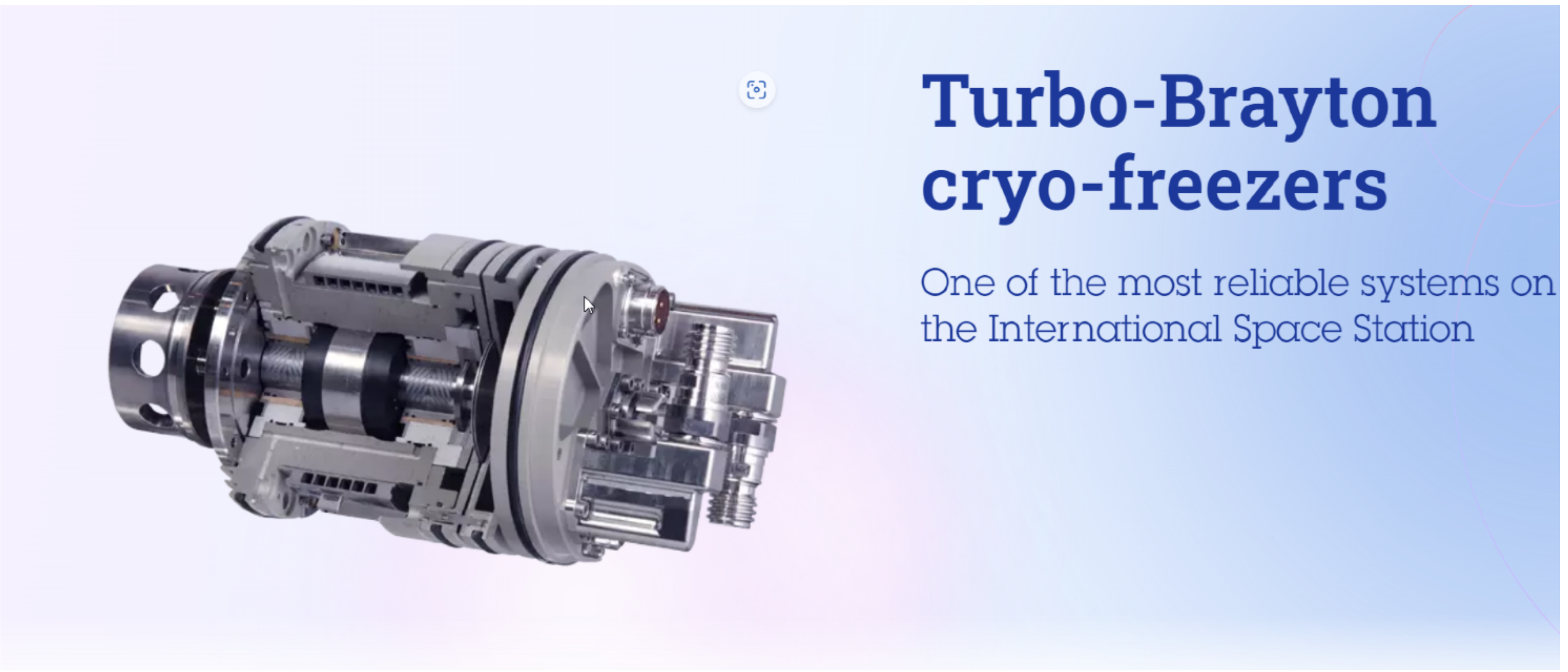


Basic detector requirements for FLARE from studies

Item	Technical Issue	Choice
Liquid fill	LAr or LKr or LAr/LXe mix	LAr rad length 14 cm. LKr is radioactive and has space charge problem.
Cryostat and TPC dimensions	Keep the total to active volume ratio small. Need to fit into FPF space and ease of installation	Foam insulated flat walled cryostat with side installation. Easy to procure. (cylinder also possible)
Cryogenics	Cryostat must be kept cold underground. Difficult to bring LN2 down.	Use Turbo-Brayton TBF-175 local LN2 cooling unit. Installation studied.
TPC gap size	Muon rate from the ATLAS IP is ~1 Hz/cm2. Space charge needs to be kept limited or corrected.	Keep gap ~0.3 m. Space charge ~(gap/field)^2
Cathode/anode	Channel count for spatial resolution and scintillation light for trigger needs to be considered	Keep cathode transparent to light, Use pixellation for high spatial resolution.
Photon readout	Need to trigger on contained neutrino events. Cannot use PMTs due to space limitations	Use VUV SiPMs and optically separate modules.
SiPM density, timing resolution and trigger	This requires detailed simulations and R&D. **A minimum density is needed for recognizing contained events versus muons for trigger.** Timing resolution is needed to associate with LHC bunch.	
Electronics	Cold electronics for low noise. optimize for spatial resolution.	Need < 1 mm resolution in drift dimension

FLARE

- [Turbo-Brayton cryo-freezers | Air Liquide Advanced Technologies]
- [Air Liquide presents the latest developments to its Turbo-Brayton cryogenic technology to the Go LNG project | Air Liquide Advanced Technologies]



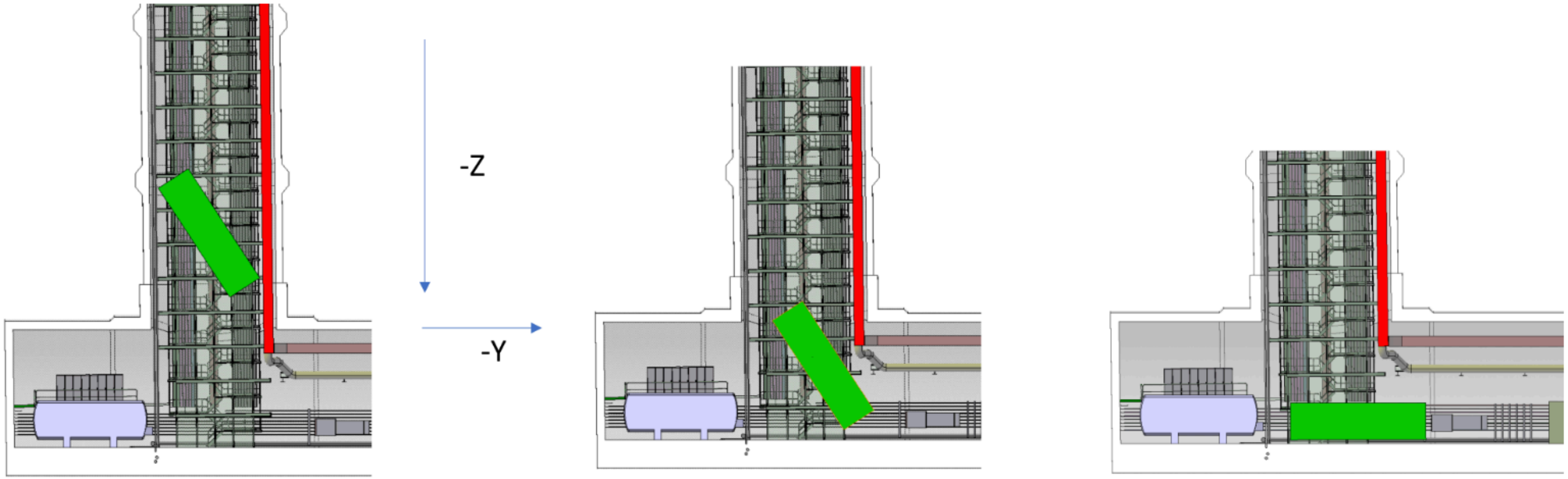
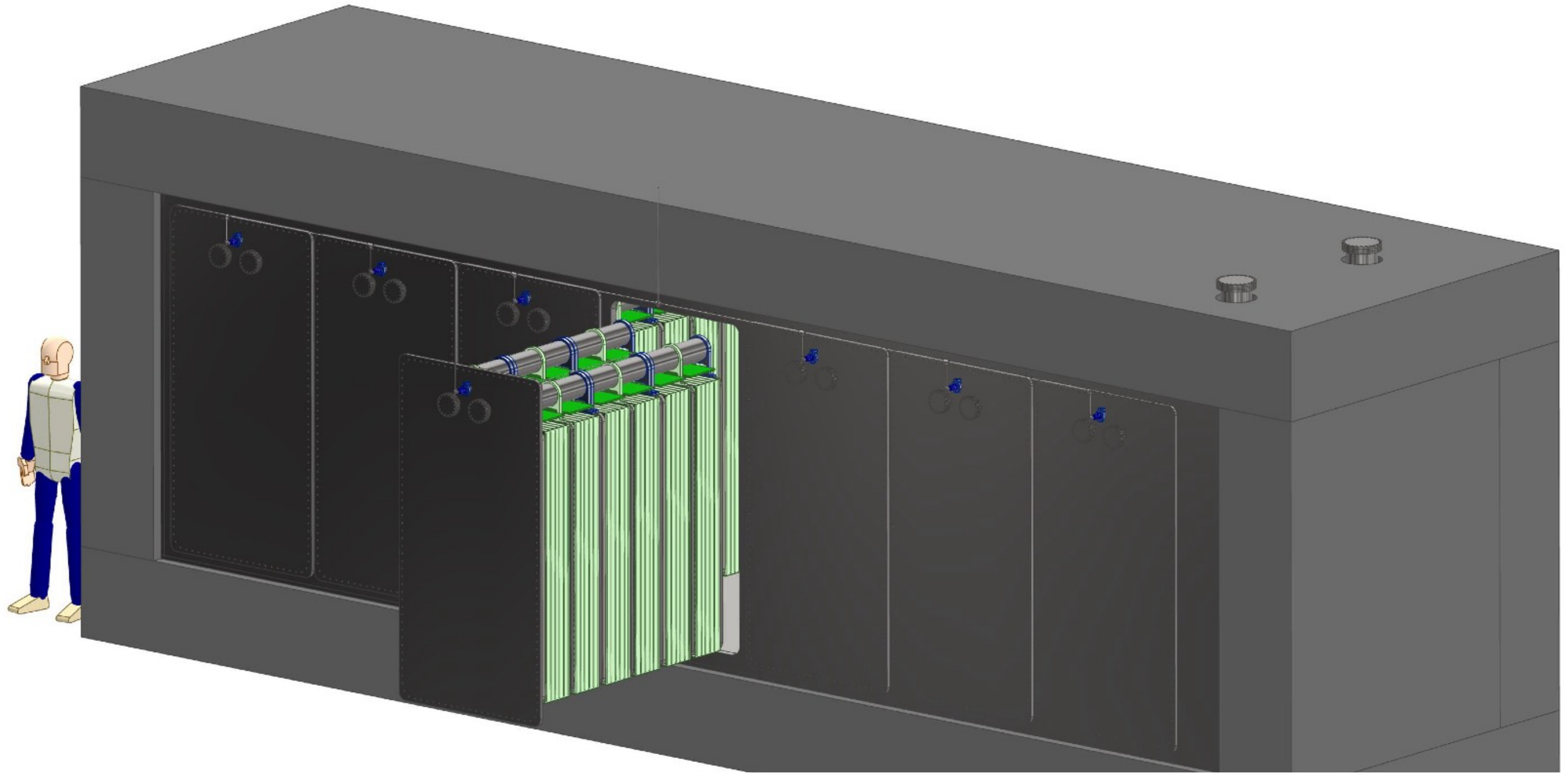
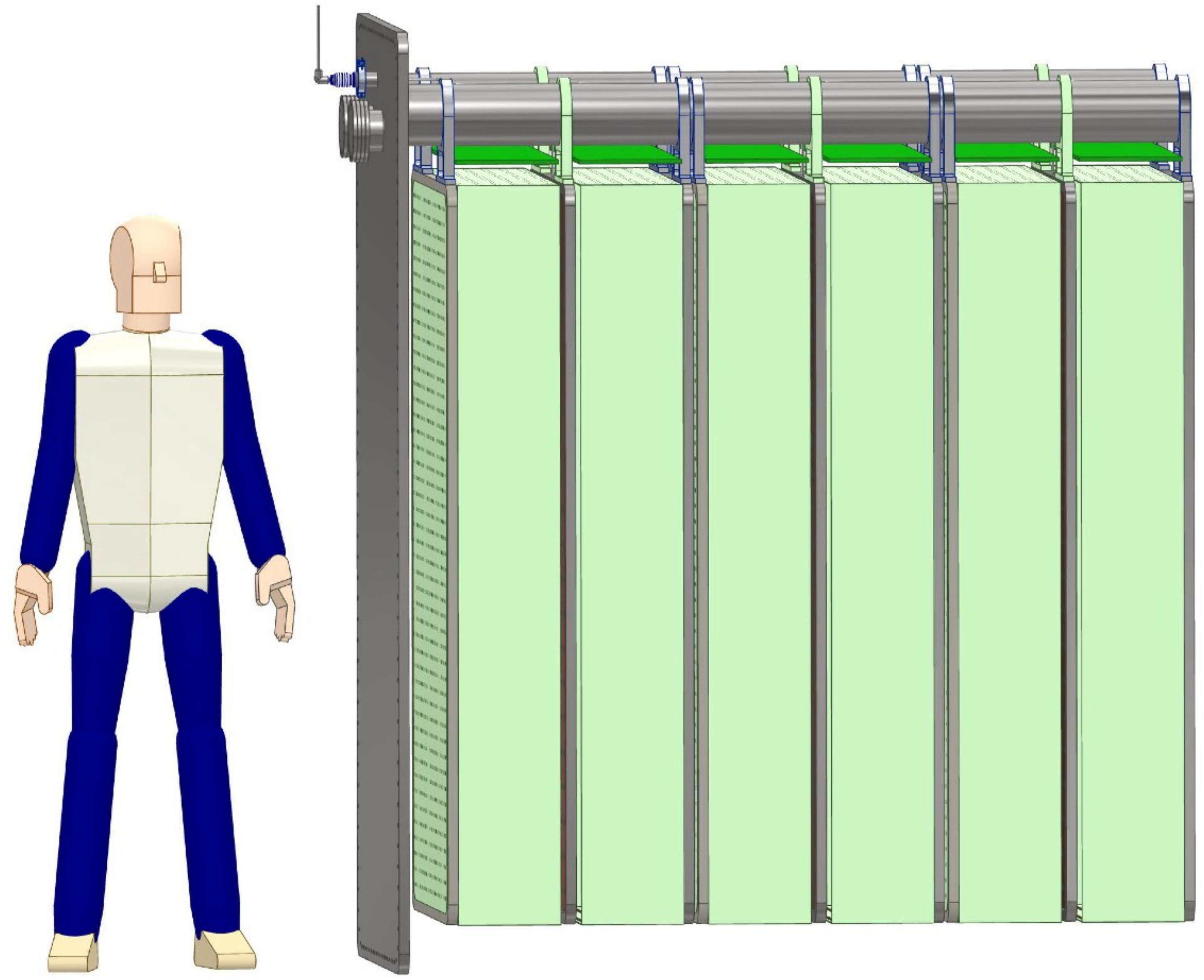


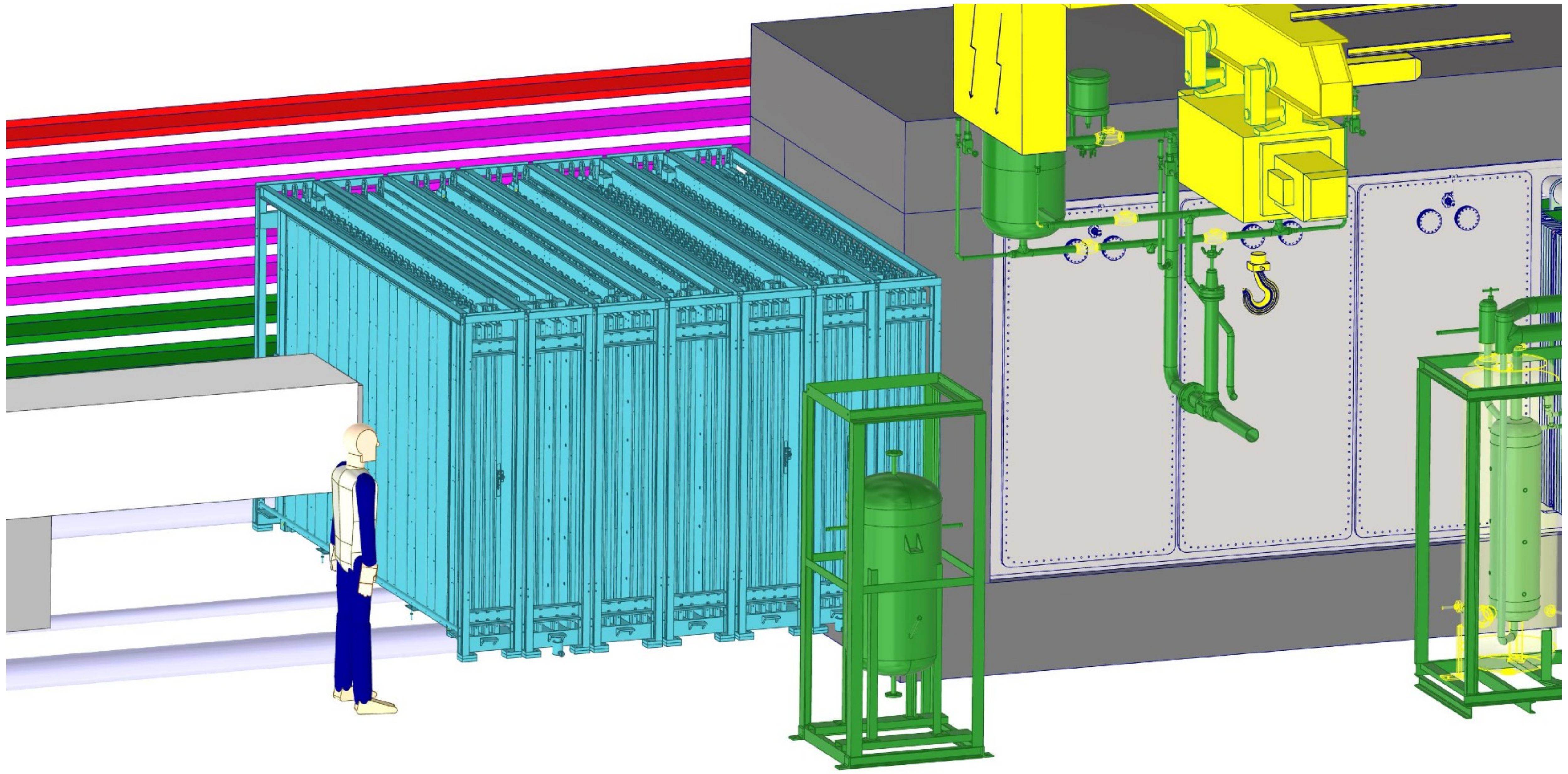
Figure 21: Transport study for the installation of Turbo-Brayton unit.

Modularized TPC with side installation.

Small gap to allow for minimum space charge effect due to muons.





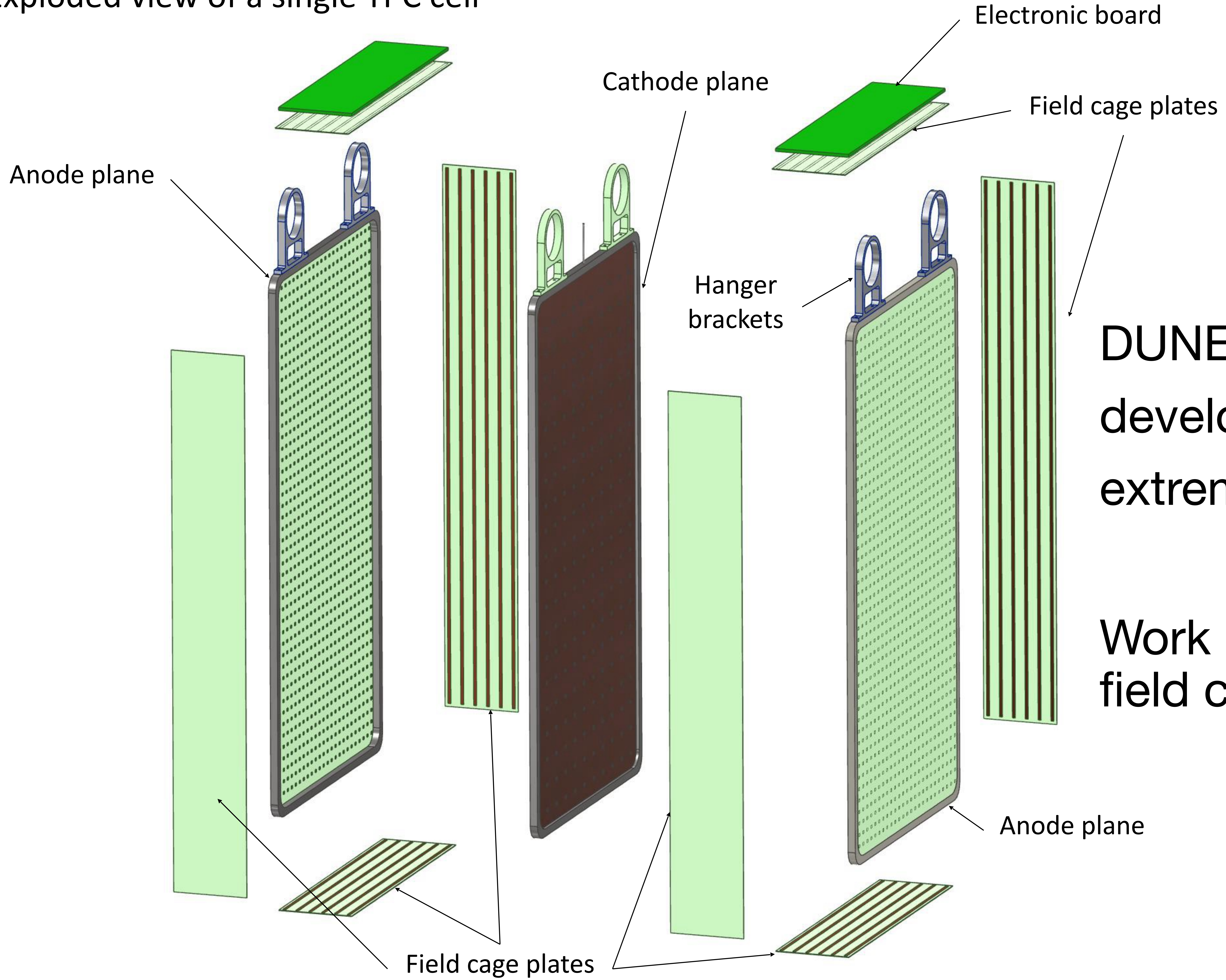


FLARE will have a Fe/Scint calorimeter in the back. Based on Baby-MIND concept.

Side installation requires special seals. Discussion with CERN Cryo/safety experts.

Full understanding of the electric field cage needed through COMSOL calculations.

Exploded view of a single TPC cell



Gap: 30 cm

Voltage: 15k

Total #channels ~160k/module

21 modules

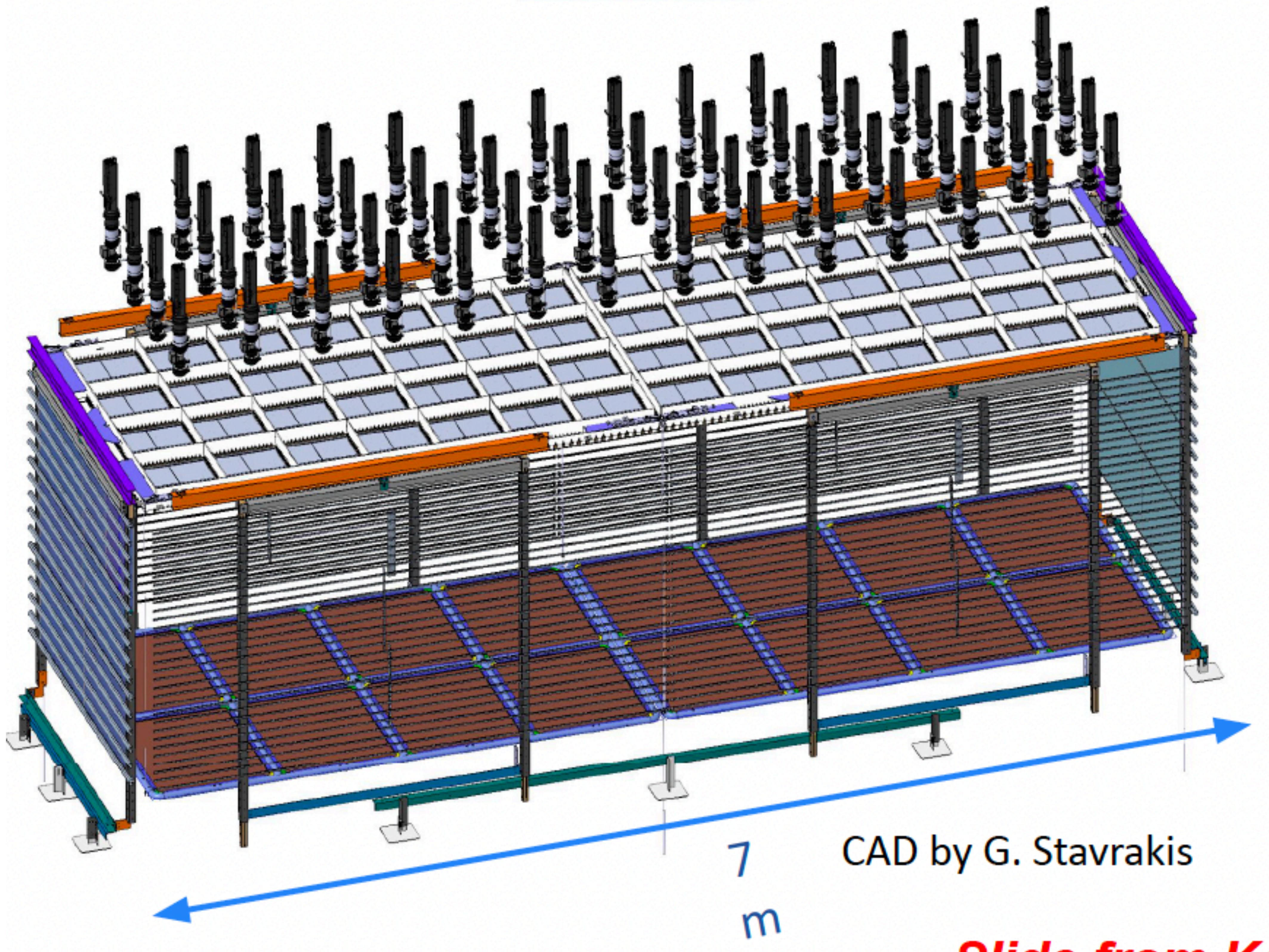
SiPM channels TBD

DUNE ND development is extremely helpful.

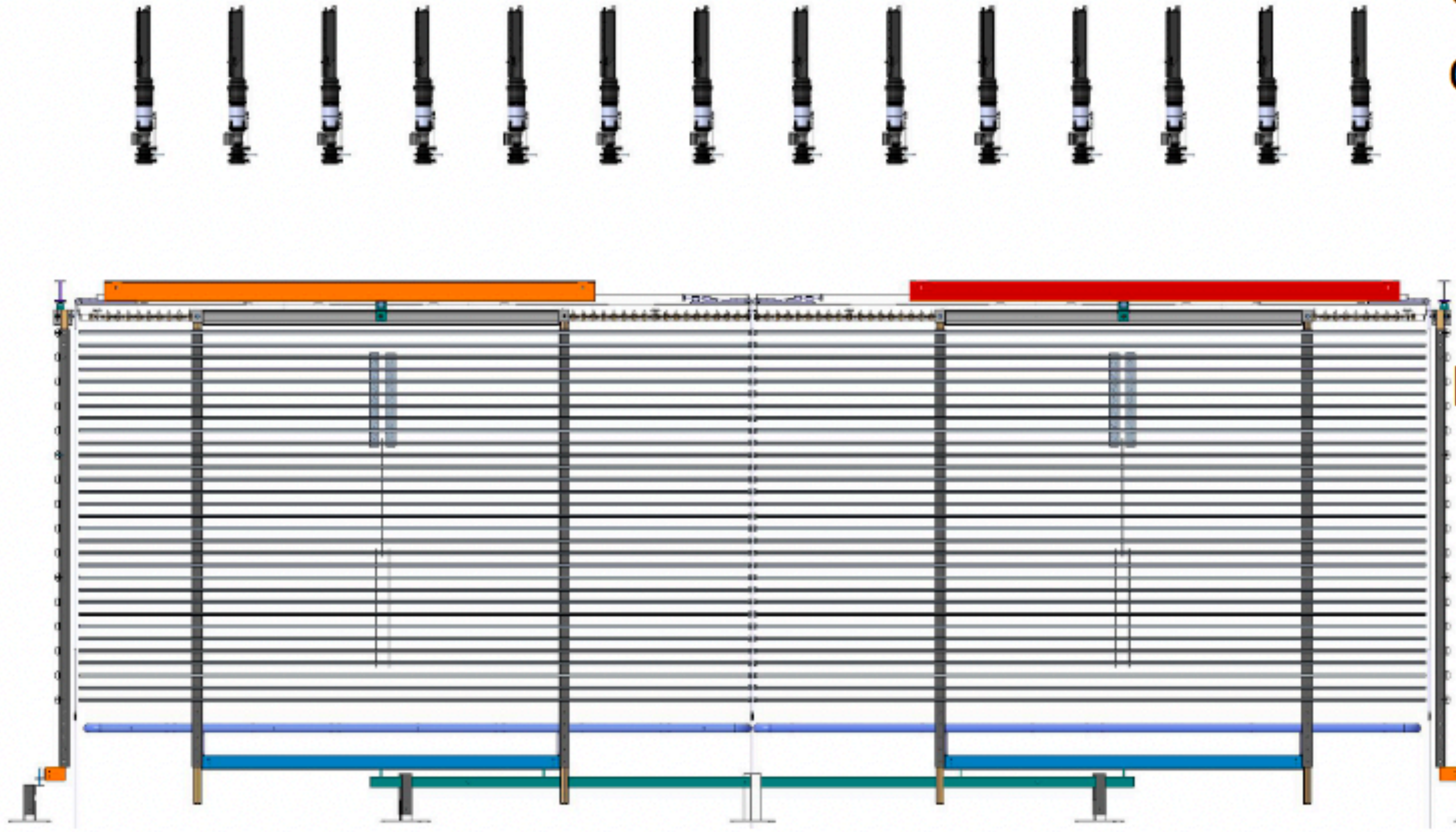
Work needed on field cage

Option2: ARIADNE technology

A conceptual FLArE LAr TPC using 56 TPX3cams providing 1.8mm/pixel resolution and 1.6ns time resolution for the electron drift



CAD by G. Stavrakis



An opportunity to bring a cost effect innovate fast 3D optical readout to the FPF.
Technology already well developed and demonstrated.
Liverpool is interested in delivering the light readout plane and the optical system for FLArE

Slide from Kostas Mavrokoridis

Estimates for FLArE

Very preliminary with many assumptions.

Item	M&S and contract	Labor (100 Hrs)	Comment
Cryogenic Infrastructure	3782	TBD	Must be confirmed with CERN.
Cryostat	2626	TBD	Must be confirmed with CERN.
LAr	40	TBD	Must be confirmed with CERN.
Field structures	1102	23	eng/technical
Electronics	1638	115	eng/tech/students
TPC HV	200	5	
HV feedtrus/cables	21	5	
LV power	200	5	
Photon system	639	25	
Trigger system	200	35	
Baby-MIND	4120	50	Could be separated.
Assembly	131	135	
DAQ	200	35	
Computer and online	200	50	
Management/lead eng.		25	
Prototypes	2000	TBD	

Young People

- Karan Kumar was an undergraduate at Stony Brook and won the NSF graduate fellowship.

  Simulation and analysis of neutrino fluxes from the Large Hadron Collider

- Students from Embry-Riddle University (Rylee Grover, Emily Grunger) have been reaching out to me and want to participate in this development.

- At my recent talk at CPAD in Knoxville, the meeting was quite young and there was much curiosity about how one proposes an experiment !

Conclusion

- The headline physics interest is
  - Neutrinos in the 1 TeV range: ~20-50 events/ton/day
  - Tau neutrino flux and associated heavy flavor physics: ~0.1-0.2 events/ton/day
  - Light dark matter search with decays and interactions.
- Noble liquid detector for FPF is being considered along with other technologies.
- Preliminary examination of event rates and backgrounds suggests that a LAr detector is feasible and ground-breaking.
- Muon backgrounds, and engineering considerations necessitates a modular TPC detector.
- A LArTPC requires much more advanced readout for ultimate spatial resolution, and a trigger system that can find contained events in the presence of muons. Timing could associate events with the ATLAS bunch crossing (studies are needed).
- Cost. A very preliminary estimate for FLArE based on DUNE ND is ~11 MCHF (core cost).
- We expect the project to be very international with substantial US involvement.
  - An international collaboration could be assembled rapidly — will need discussion what is needed.
- The work in these slides was supported by HSF, UCI, and BNL (LDRD and PD funding).

backups

Muon fluence at the FPF.

Muon flux: 0.6 Hz/cm^2 at 5*10^34/cm2/sec, 0.15mu+, 0.45mu-

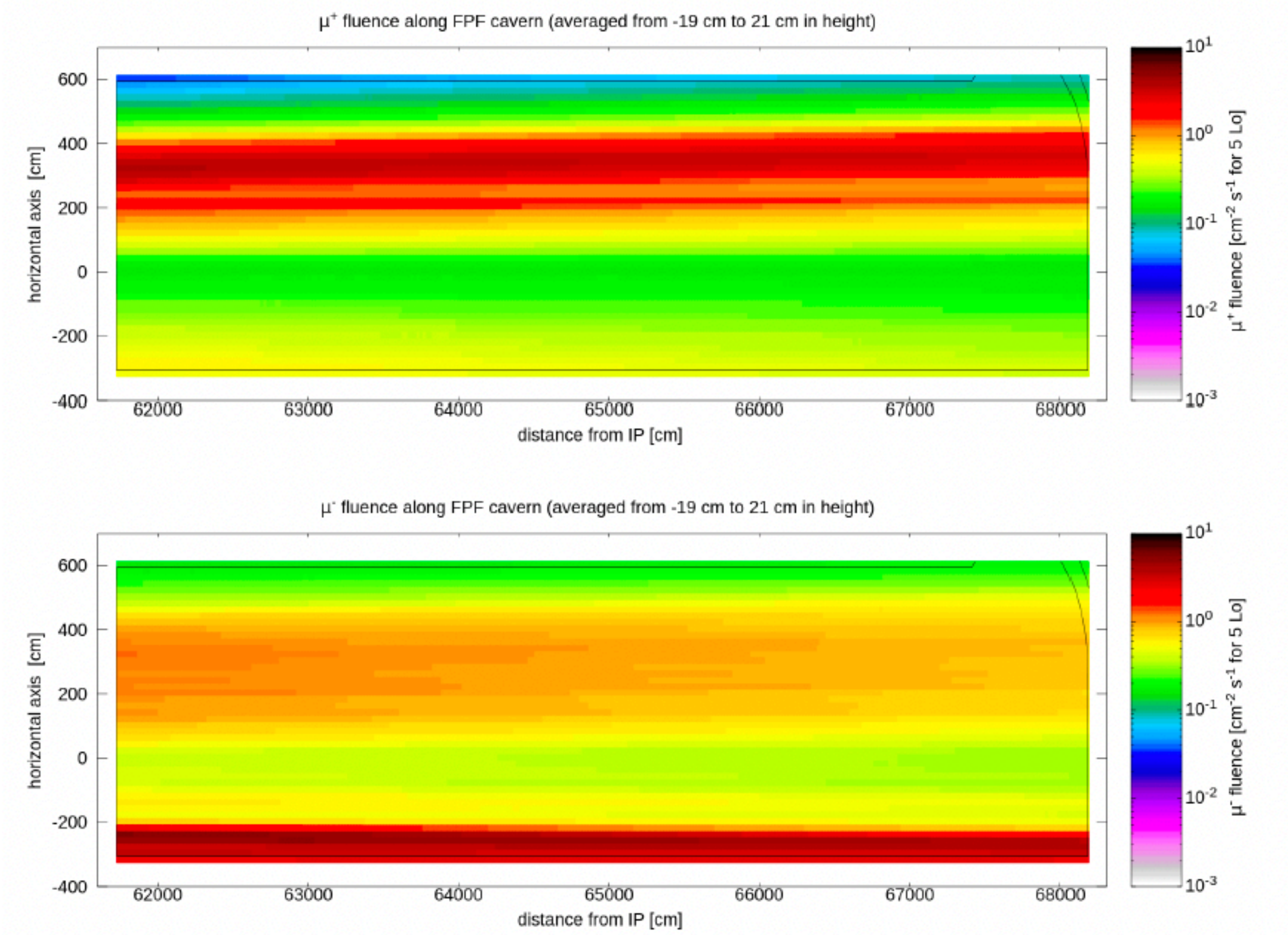


Figure 8: Spatial distribution of positive (top) and negative (bottom) muon fluence rate along the FPF cavern for 5 L0 instantaneous luminosity. The 2D view is on the horizontal xz plane, with values averaged from -19 cm to 21 cm in the missing vertical dimension, being y=0 the beam height.

0 is the ATLAS axis. Crossing angle in the horizontal plane is included.

Neutron flux ~0.1 Hz/cm2 is mostly at low energies.

FPF Neutrino Statistics

Numbers from: https://arxiv.org/pdf/2203.05090.pdf
Numbers from 2 generators shown (SIBYLL / DPMJET), typically span the range of other generators.

Detector				Number of CC Interactions		
Name	Mass	Coverage	Luminosity	$\nu_e + \bar{\nu}_e$	$\nu_\mu + \bar{\nu}_\mu$	$\nu_\tau + \bar{\nu}_\tau$
FASERν	1 ton	$\eta \gtrsim 8.5$	150 fb^{-1}	901 / 3.4k	4.7k / 7.1k	15 / 97
SND@LHC	800kg	$7 < \eta < 8.5$	150 fb^{-1}	137 / 395	790 / 1.0k	7.6 / 18.6
FASERν2	20 tons	$\eta \gtrsim 8.5$	3 ab^{-1}	178k / 668k	943k / 1.4M	2.3k / 20k
FLArE	10 tons	$\eta \gtrsim 7.5$	3 ab^{-1}	36k / 113k	203k / 268k	1.5k / 4k
AdvSND	2 tons	$7.2 \lesssim \eta \lesssim 9.2$	3 ab^{-1}	6.5k / 20k	41k / 53k	190 / 754

Huge increase in number of neutrinos detected with FPF.
Enables broad physics programme.