Forward Physics Facility at the LHC and Experiments

Physics
Facility
Experiments
What are we doing ?

Many thanks to numerous people who are now contributing to this effort: Jonathan Feng (UCI), Jianming Bian (UCI), Wenjie Wu (UCI), Mary Hall Reno (Iowa), Maria Garzelli (Hamburg), Jamie Boyd (CERN), Albert De Roeck (CERN), Karan Kumar (StonyBrook), Yu Seon Jeong (Chung-An Univ), Weidong Bai (Sun Yat Sen U.), Sebastian Trojanowski (Astrocent), Felix Kling (SLAC), … about 40 participants in meetings every other week.

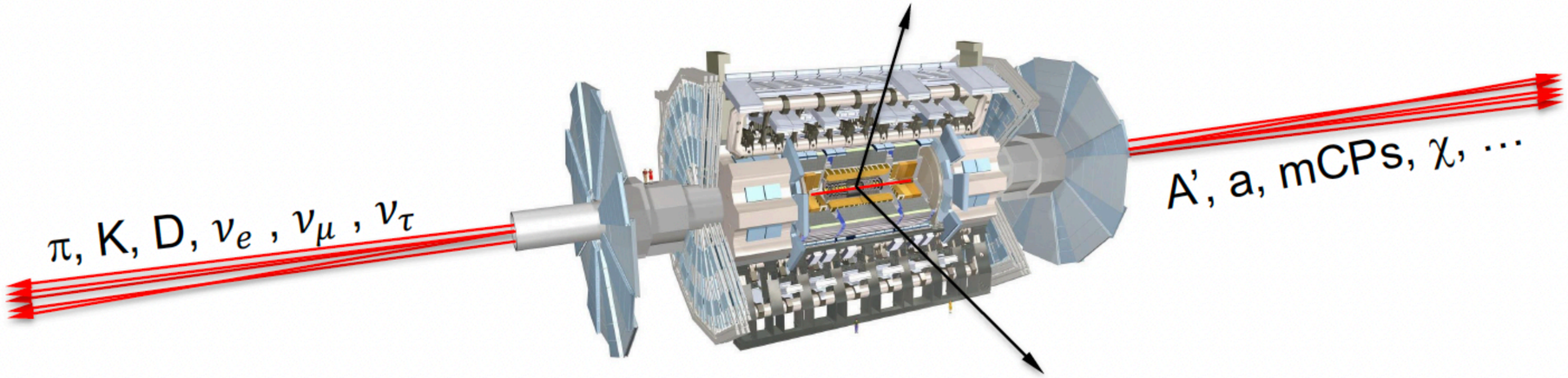
This young community is having a lot of fun writing papers and ideas.

A major paper should be coming out on the LHC neutrino flux in a couple of weeks

Milind Diwan Dec. 16, 2021

Physics

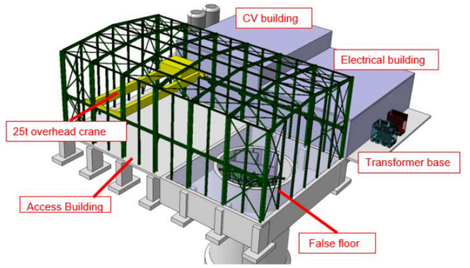
What is the physics in the forward direction of the LHC ?

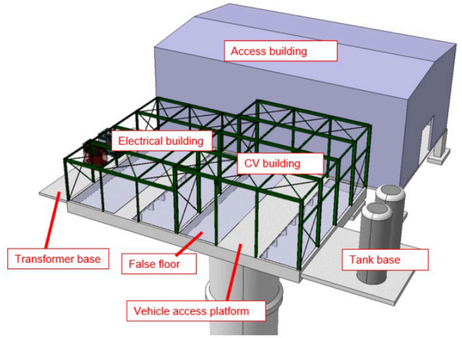


- Incredible progress in particle physics examining physics at high Pt. Are we missing opportunities in the forward direction ?
- The largest flux of light high energy particles (mesons and neutrinos) is far forward.
- Could there be discoveries such as: dark photons, axion-like particles, millicharged particles, light dark matter scattering, etc? What can be measured with TeV neutrinos, especially tau neutrinos ?
- Unique characteristics may make such discoveries possible: the intense flux, and extremely high energies (~TeV).

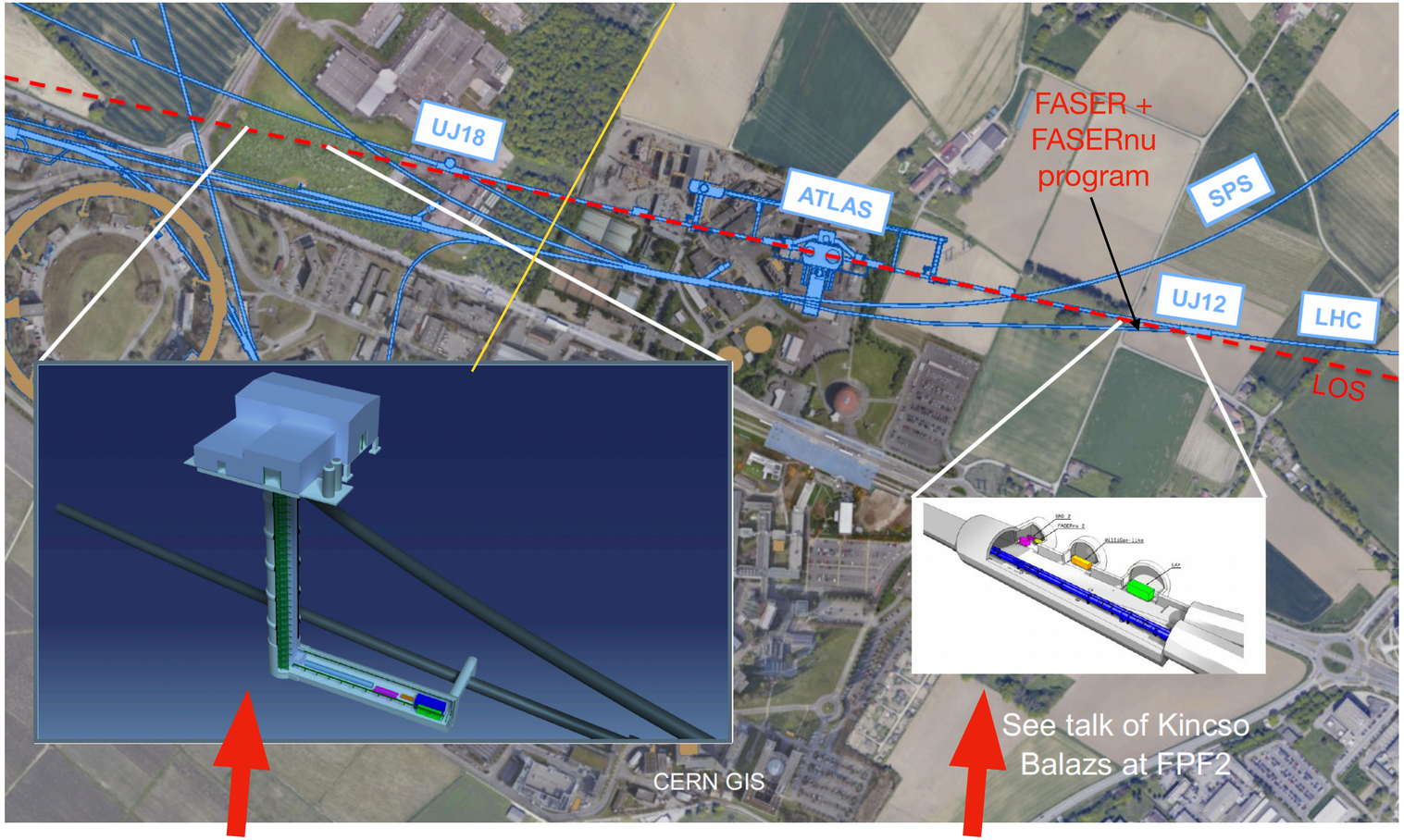
Current program

Recent progress on forward physics



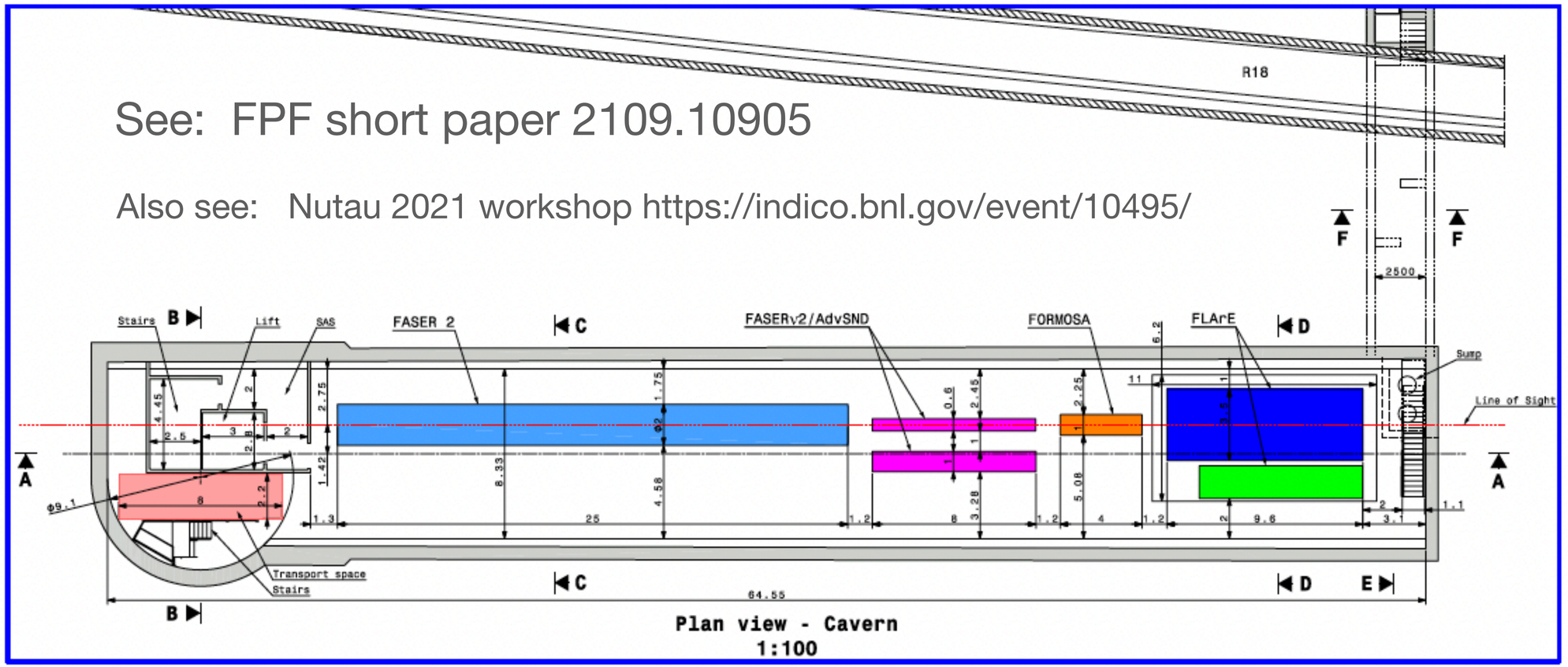


- 3 experiments in progress for LHC-run3 for 150fb^{-1} 2022-24.
- FASER (March 2019), FASERnu (Dec 2019), SND@LHC (Mar. 2021)
- Expanded program for HL-LHC under consideration - 3 FPF workshops held.
- New purpose built facility 620 m east in France.
- 65m long hall line of sight.
- Class 4 estimate: 40MCHF



Future FPF concepts

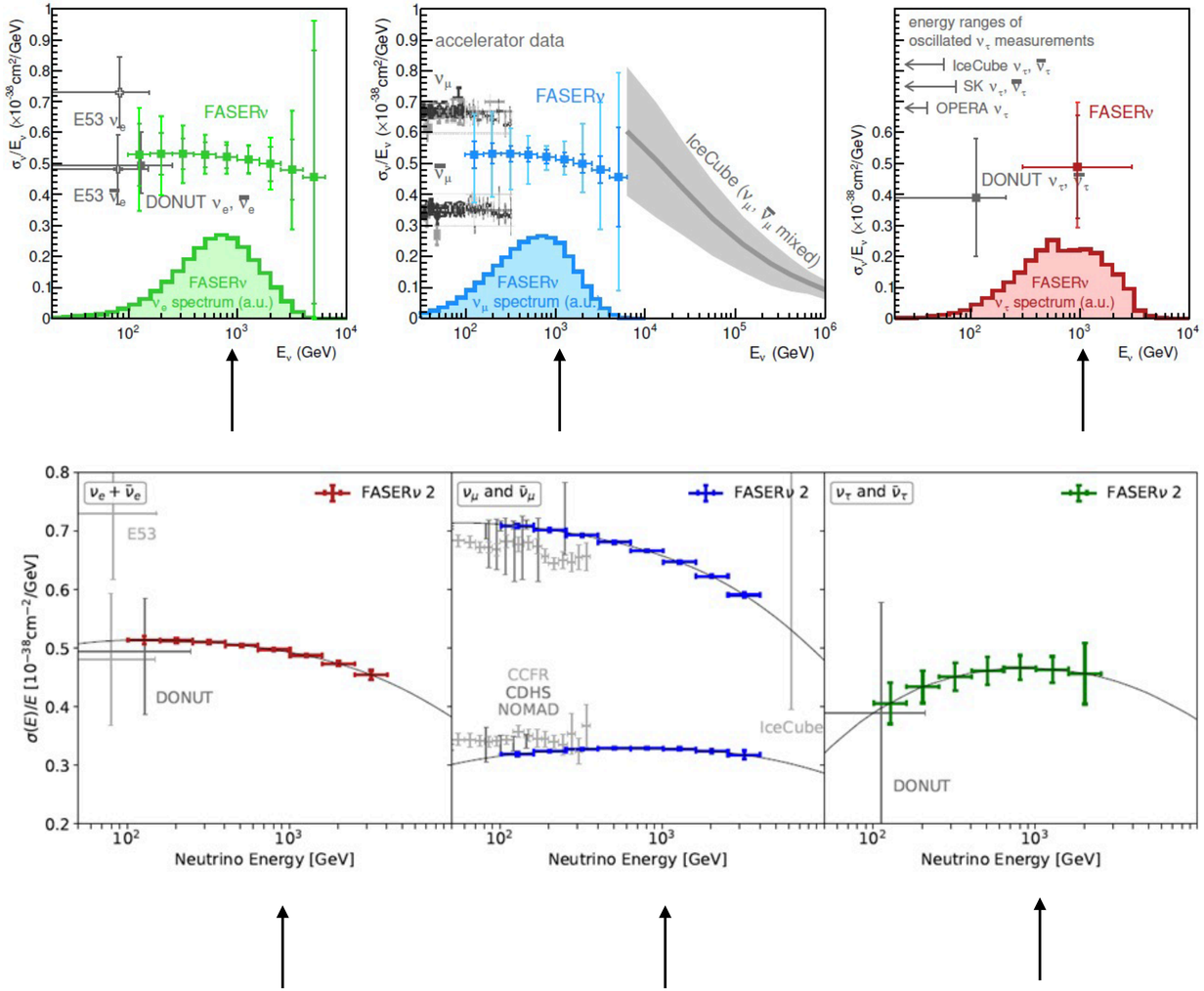
Experiment	Science Priority	Technology
Faser 2	Long-live neutral particles decay	Large decay volume (super-conducting) magnetic spectrometer
FASERnu2	Neutrino Interactions	Tungsten/Emulsion 20 tons. Veto and interface tracker for muons
AdvSND	Neutrino Interactions on/off axis	Hybrid electronic and tungsten/emulsion detector with had. cal.
FORMOSA	Milicharged particles	Scintillation bars with photomultiplier readout.
FLArE	DM scattering and neutrino interactions	Noble liquid TPC (liquid argon or krypton) 10-20 tons



Far forward Neutrino and Dark matter physics

- Run #3: 150 fb^{-1}
- FASERnu (on-axis) and SND (off-axis) ~1 ton tungsten/emulsion
- ~6000 $\nu_\mu cc$, ~1500 $\nu_e cc$, and ~15 $\nu_\tau cc$

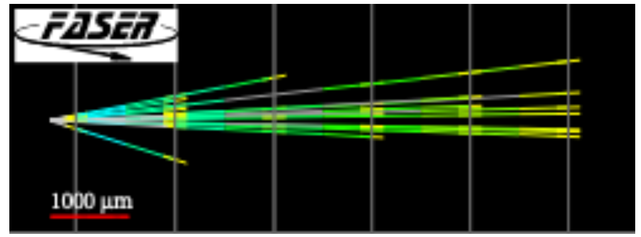
- HL-LHC: 3000 fb^{-1}
- Detector on the scale of ~10 ton need design.
- ~1.2M $\nu_\mu cc$, ~300k $\nu_e cc$, and ~ 3k $\nu_\tau cc$
- Very high energy neutrino physics.
- Precision ν_τ physics
- sterile neutrinos at high mass $\Delta m^2 \sim 1000 eV^2$
- QCD in the far forward region
- Neutrino tagging of far forward hadrons production.
- Light dark matter scattering.



Arrows are at 1 TeV

Studies and progress towards the FPF

- FASERnu pilot run analyzed with 6 neutrino candidates. https://arxiv.org/abs/2105.06197
- Active planning for a larger forward physics facility
- 3 FPF workshops: https://indico.cern.ch/category/14436/
- Snowmass discussions: https://snowmass21.org
- Nutau 2021 workshop: https://indico.bnl.gov/event/10495/
  - Several documents are in preparation. Nutau document editor: Peter Denton.
- Physics beyond colliders: https://pbc.web.cern.ch
- FPF short white paper: “The Forward Physics Facility: Sites, Experiments, and Physics Potential” (2109.10905), FPF long paper (200 pages) is in preparation for Feb-Mar 2022.



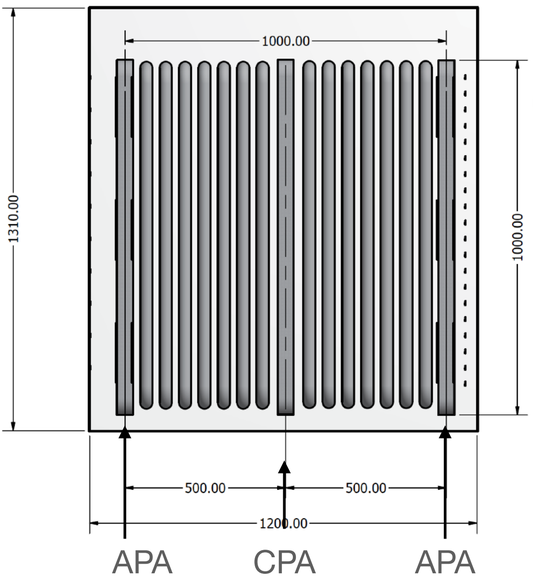
BNL Working group was launched April 15, 2021 to examine the potential for a new detector for the FPF: https://indico.cern.ch/category/14011/
Please ask me if you want to join. Meetings are every other week

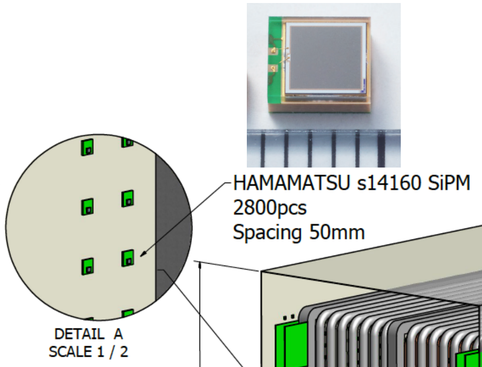
Progress on FLArE Detector Design

- **All dimensions are in milimeter (this is not a design, just a sketch)**
- **In particular, the GTT cryostat has corrugations which need to be considered (Bo Yu)**
- **The gap needed for safety is inspired by NeXO design with similar HV needs**

Volume	11.5 m^3
LAr	16 ton
LKr	27.5 ton
menbran	0.5 m
heat loss	290 W

TPC-side view 2

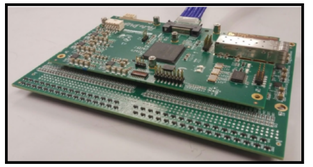




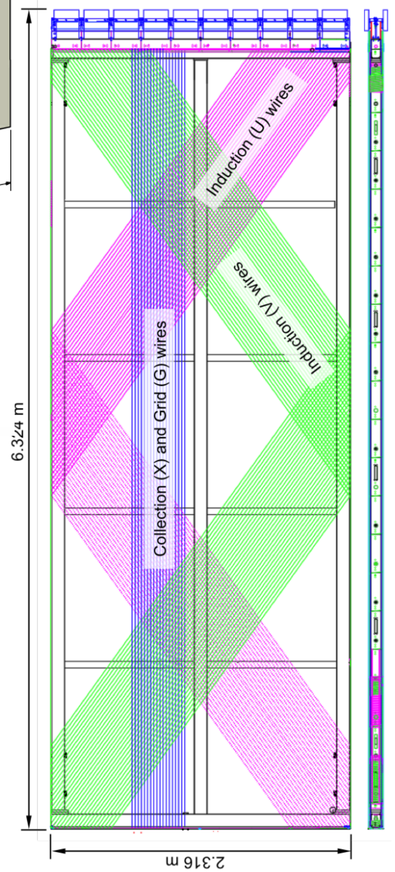
HAMAMATSU s14160 SiPM
2800pcs
Spacing 50mm

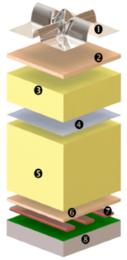
Conceptual FLARE Detector

DUNE Front End Motherboard

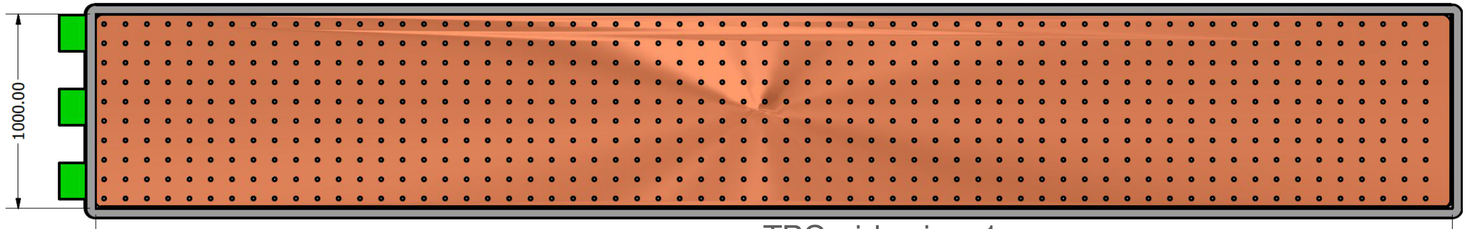


DUNE APA for scale only





Membrane Cryostat
Insulation



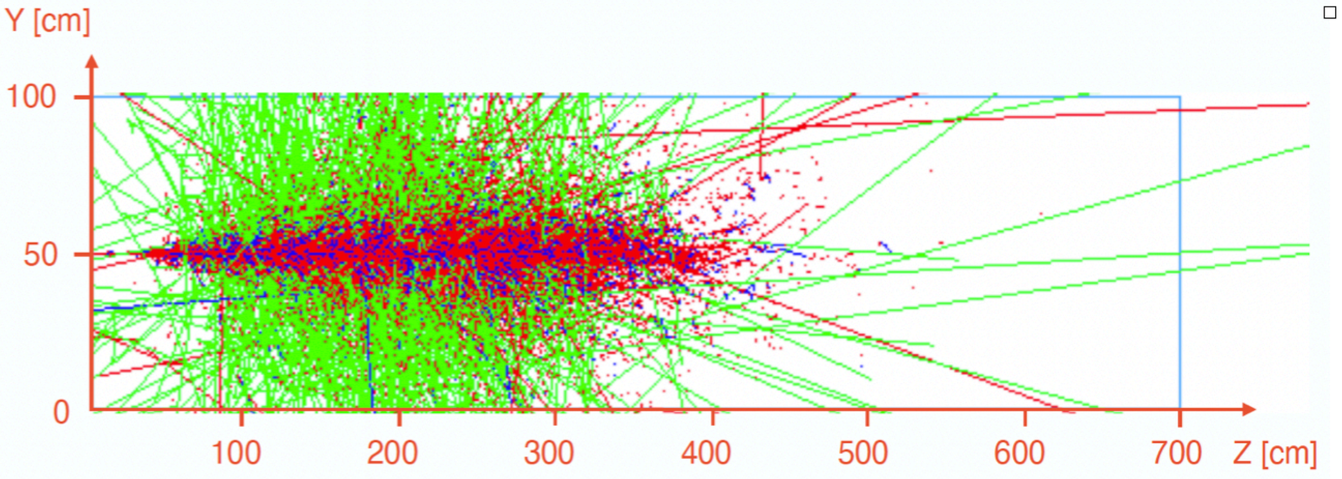
TPC-side view 1

Yichen Li

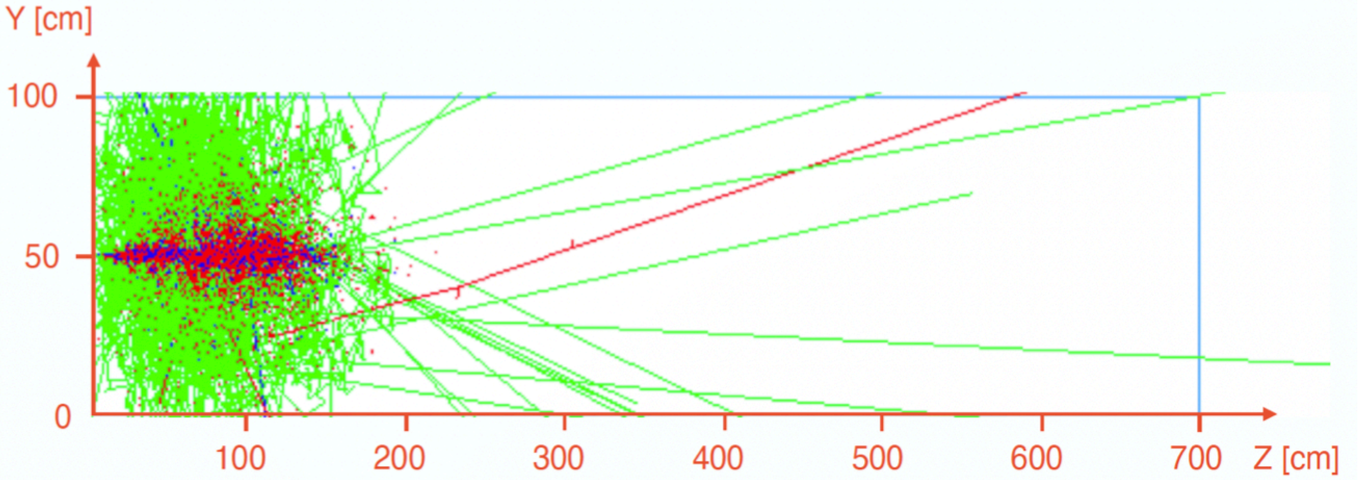
Issues to be resolved in design process —

Item	Choice	Comments
Liquid fill	LAr or LKr or keep both options open	If we made the choice for LKr only then detector could be much smaller for same mass.
Cryostat and TPC dimensions	Keep the total to active volume ratio small (for LKr)	Cryostat, field cage, HV design must be integrated.
Cathode/anode	Central cathode with two anode planes. (makes two drift volumes)	Doubles channels, but better for HV safety. cathode must be transparent to light
Photon readout	SiPM's. Cannot use PMTs to keep the unused volume small.	Will need large number of channels.
Wavelength shifter for scintillation light	LAr: 128 nm, LKr: 150 nm	Will require R&D to understand this issue.
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.	
Anode electrode design	Pixels versus wires	Simple wire geometry may not be possible because of straight thru muons. Need Simulation input.
Anode readout pitch	2 or 5 mm (LKr has higher signal)	Depends on kinematic resolution needed and also signal to noise.

1 TeV e- LAr



1 TeV e- LKr



Wenjie Wu from UC/Irvine

Conclusion

- **A forward physics facility FPF is being considered at CERN for neutrino and dark matter physics.**
- **Noble liquid detector for FPF is being considered along with other technologies.**
- **Preliminary examination of event rates and backgrounds suggests that a LAr and/or Krypton detector is feasible and ground-breaking.**
- **Big improvement in performance for EM showers may be possible if we can use LKr. (Radeka)**
- **A strong US collaboration for FLArE is obviously welcome. And BNL will be the national laboratory for this collaboration.**