ND-GAr-Lite Overview

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DUNE BSM Meeting
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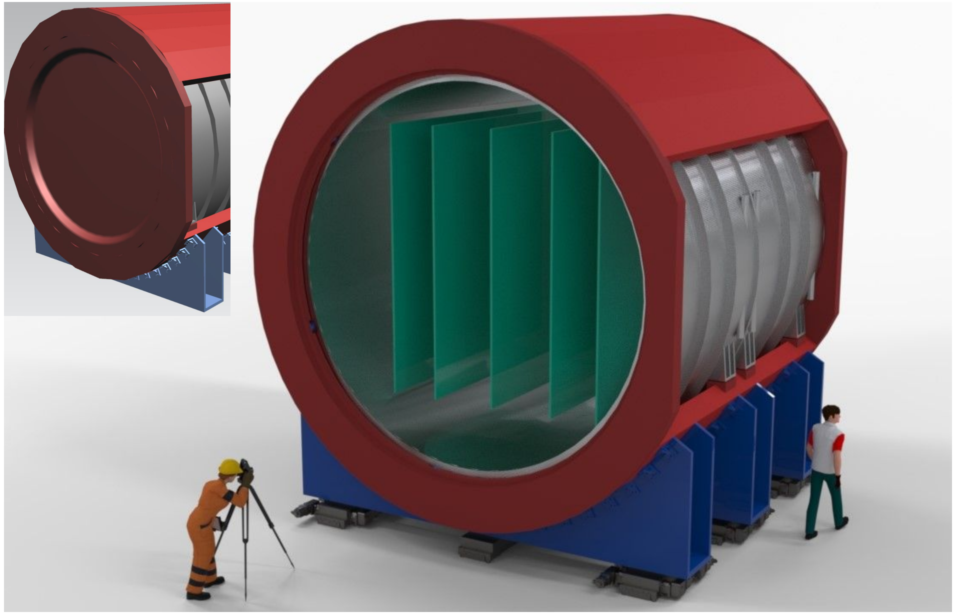
University of Colorado Boulder

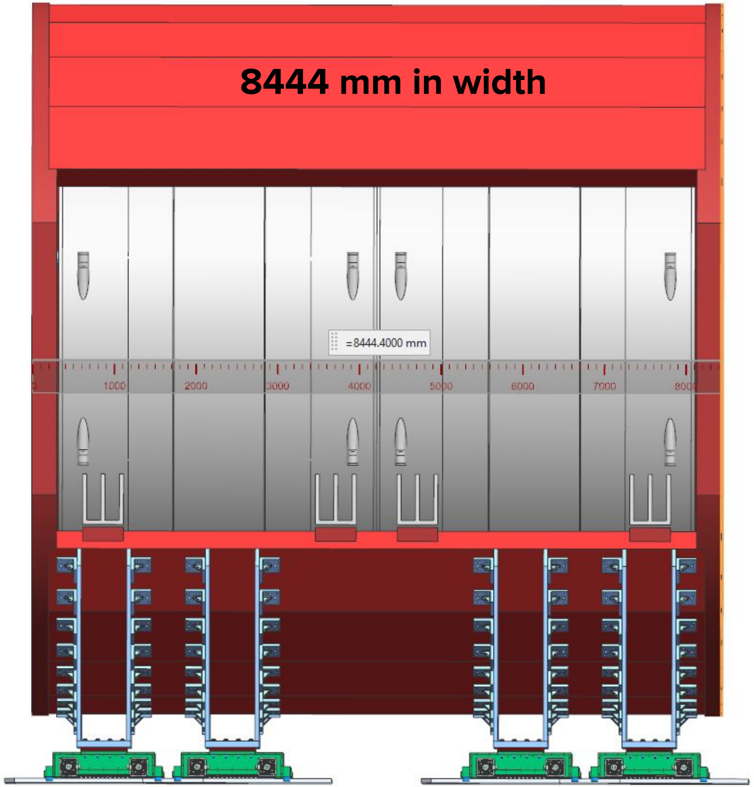
Alternative TMS: ND-GAr-Lite

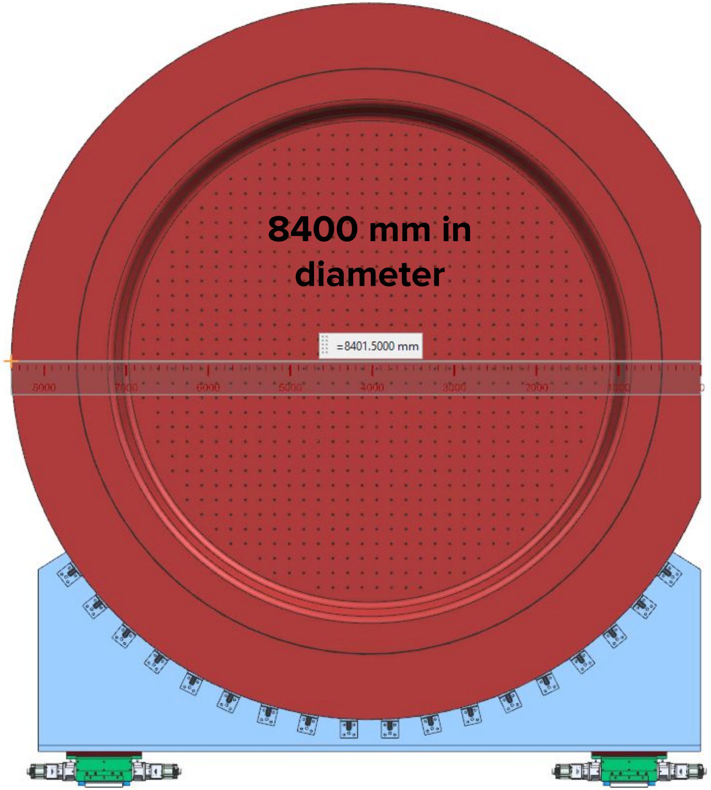


ND-GAr-Lite Design:

- Superconducting magnet including partial return-yoke (SPY design)
- Scintillator tracking planes
  - Nominal design of 5 tracking planes (6m W x 5m H)
  - Update of MINERvA bars
  - Similar electronics as baseline TMS
- ECAL modules could be added (but may degrade performance)
- “Window” in return-yoke to minimize energy loss for muons from ND-LAr

Overall Detector Dimensions





Beam Direction

Magnet System

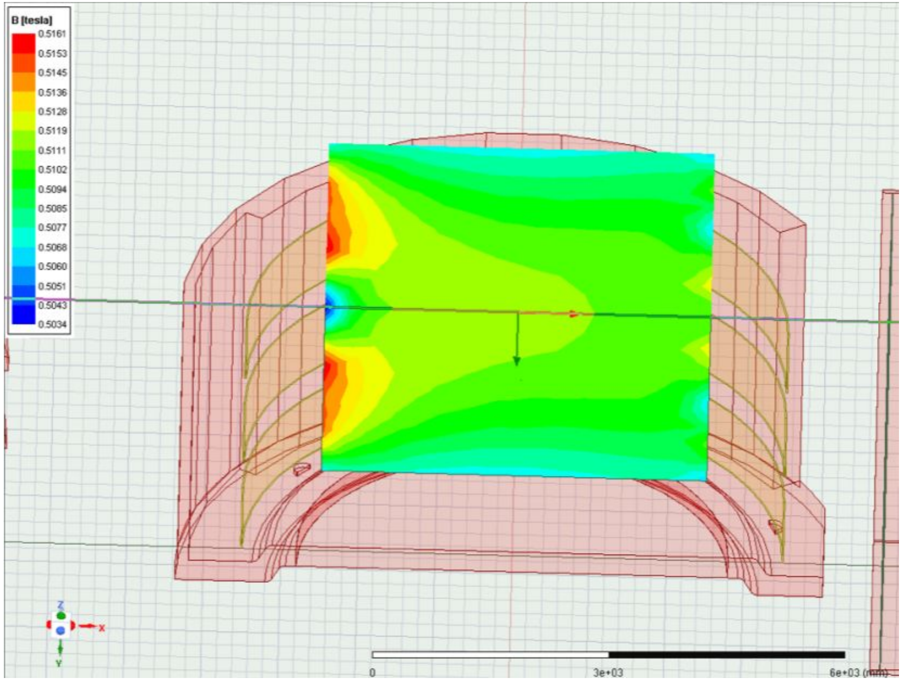
Superconducting magnet to provide a nominal 0.51 T magnetic field.

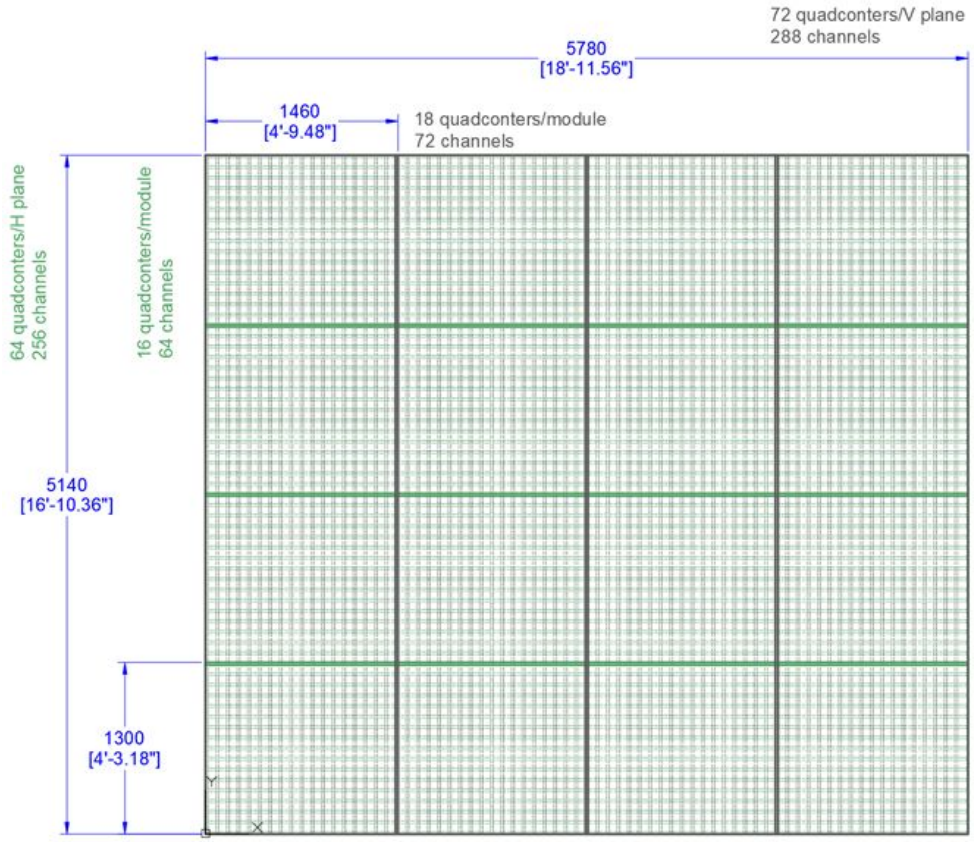
- Operating current 4665 A
- Min B field in TPC area: 0.5034 T
- Max B field in TPC area: 0.5161 T

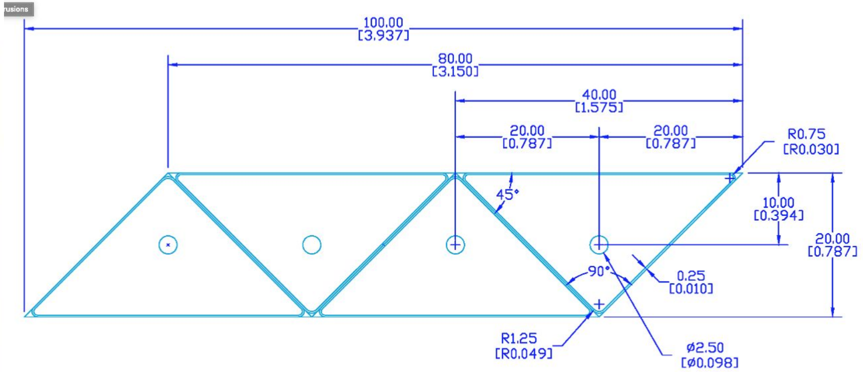
Magnetic field non-uniformities within TPC area on the order of 1% or less.

Small amount of stray field toward the LAr that may be used for reconstruction.

Design very mature and near final.







Approximately 6m x 5m (W x H).

Triangular scintillator bars.

An X view and Y view combine as a single tracking plane.

Preliminary studies show position resolution of about 1 mm and timing resolution of about 1 ns.

Tracker XY Plane Concept

ND-GAr-Lite Advantages & Disadvantages

Advantages:

- First step towards essential ND component
- Performance might be better than the baseline TMS design
- Allows easier (faster) upgrade to full ND-GAr
- Cheaper than ND-GAr
- Minimizes additional resources for temporary solution
- Allows gradual increase of international contributions

Disadvantages:

- Initially more expensive than baseline TMS design (overall less expensive)
- Needs substantial international contributions
- Not yet fully optimised

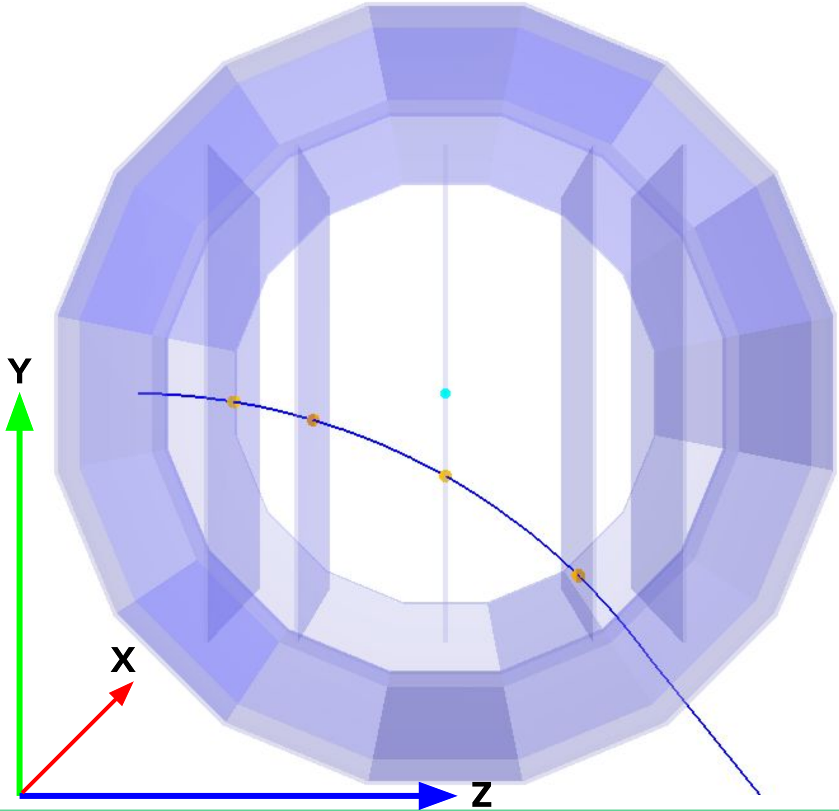
ND-GAr-Lite Nominal Design

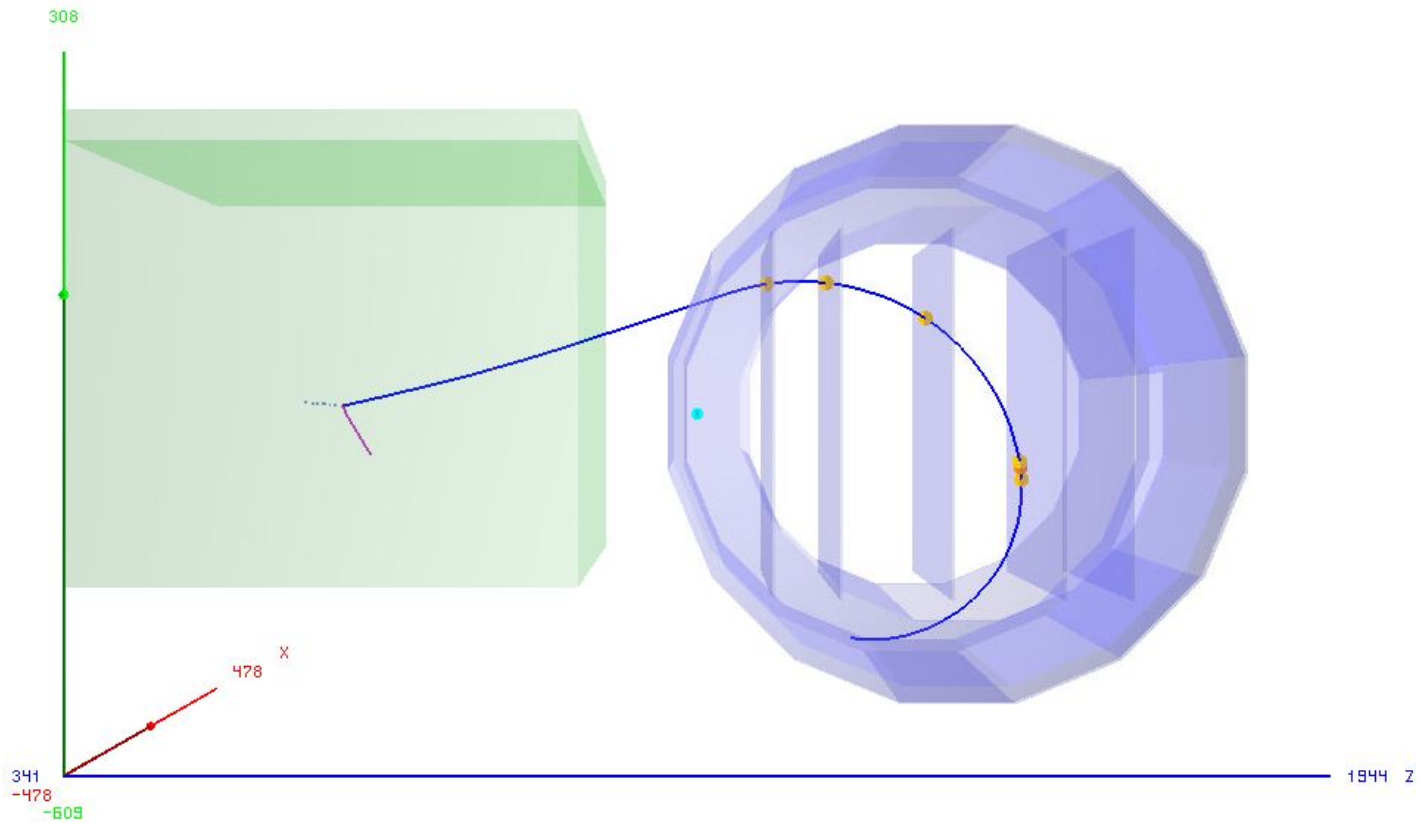
Five planes placed at z = {-240, -150, 0, 150, 240} cm where 0 is the center of the cylinder (not final positions).

Larger area for muon acceptance than ND-GAr

Optimization needed for both geometry and track reconstruction.

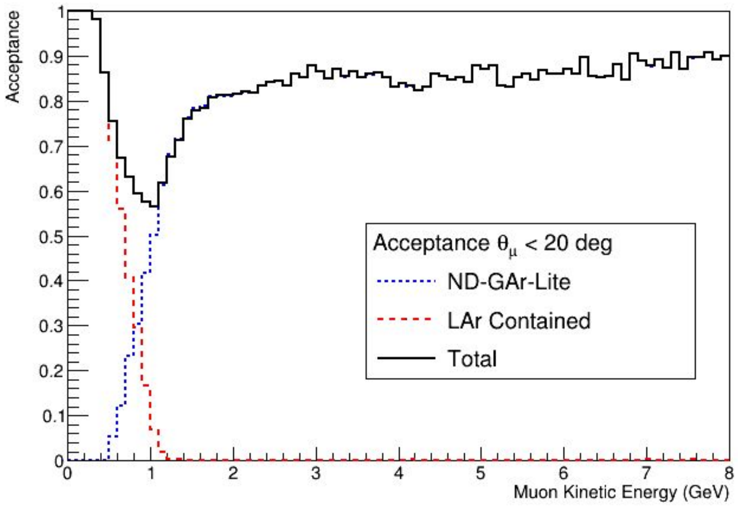
Design and optimization of the design is driven by the oscillation analysis.





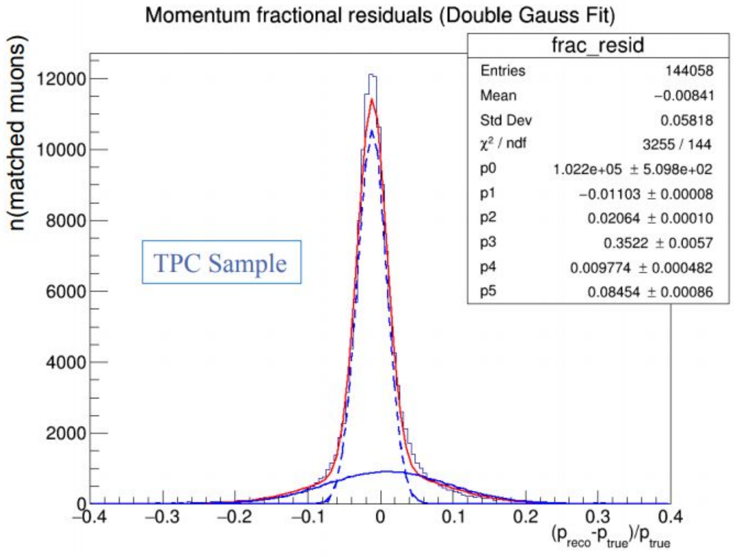
Event Display of a Simple Interaction (Original Design)

Performance: Acceptance & Momentum Resolution



Muons from neutrino interactions in ND-LAr

- Includes ND-LAr-contained muons
- ND-GAr-Lite muons crossing first plane
- Muon kinetic energy at production



Core width for resolution of about 2% for muon tracks.

- Better fit and hit selection quality cuts will improve tails
- GEANT4 simulation plus simplified realistic reconstruction

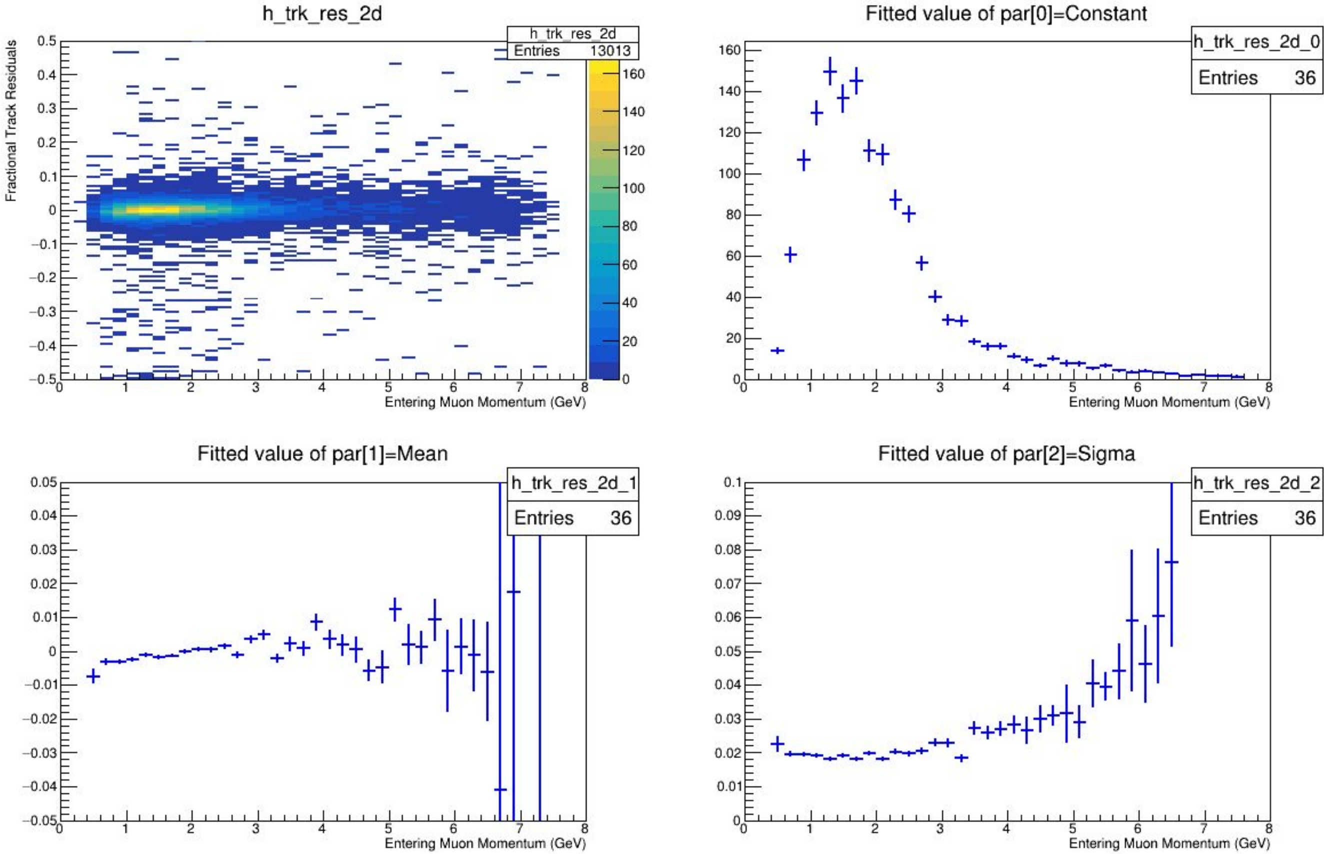
Performance of track reconstruction for nominal spacing.

Track residuals are calculated as: (p_reco - p_true) / p_true

Each momentum bin (200 MeV width) is fit with a single Gaussian function.

Correcting (partially) for energy loss.

Using 3 mm point resolution for scintillator.



Nominal Spacing & Reconstruction

$$f(x;\vec{p}) = p_0 \exp\left[-\frac{1}{2}\left(\frac{x-p_1}{p_2}\right)^2\right]$$

Latest Optimization Studies

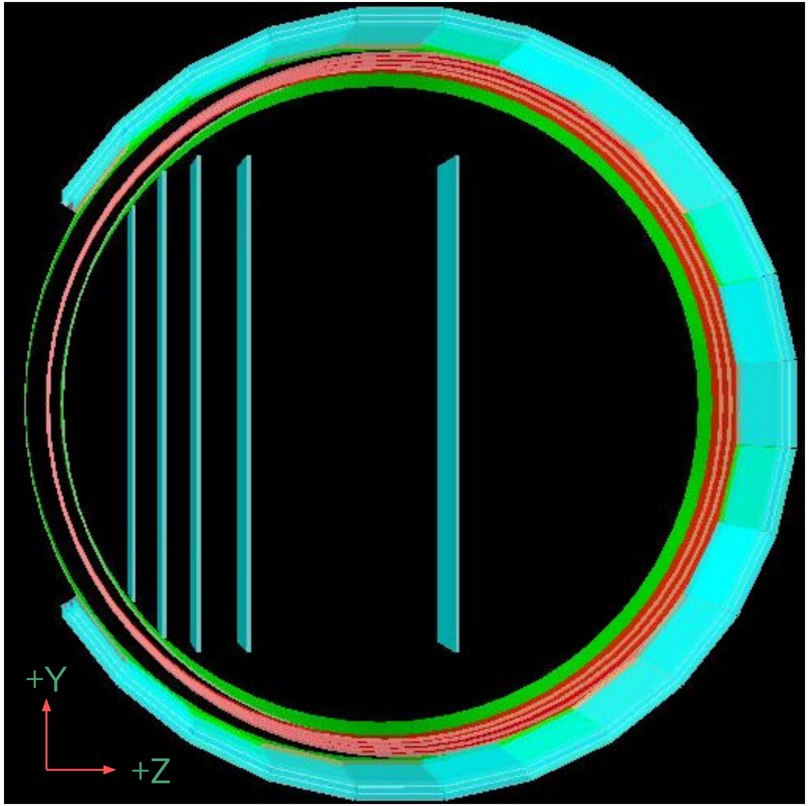
Note that the display is at an angle and does not accurately depict all the dimensions of each object.

Next idea for plane spacings defined by the first plane being roughly the same height as the window in the yoke.

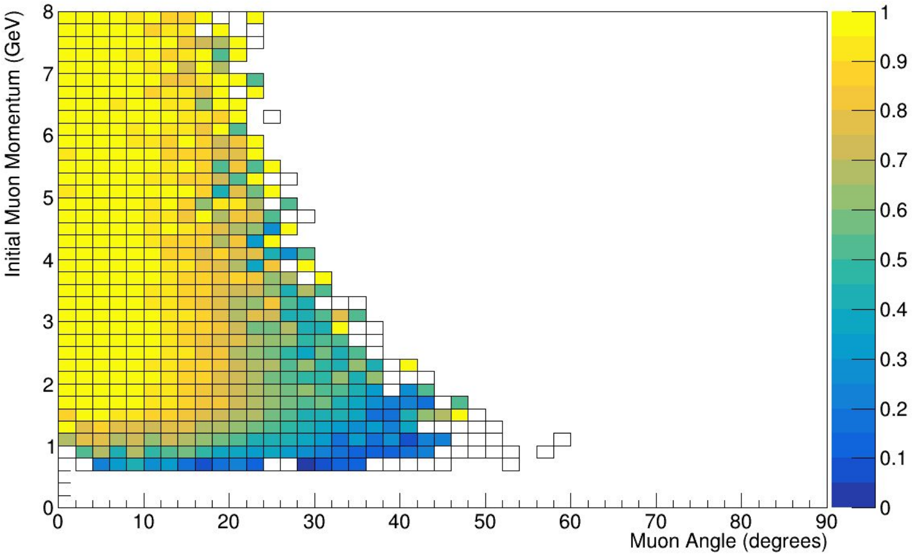
Plane arrangement: 1221, 1251, 1286, 1346, 1546 cm in Z.

The first plane has height of 400 cm, the second 470 cm, and the rest are at 500 cm.

NB: Not the latest geometry regarding the SPY magnet and cryostat.



Efficiency Map

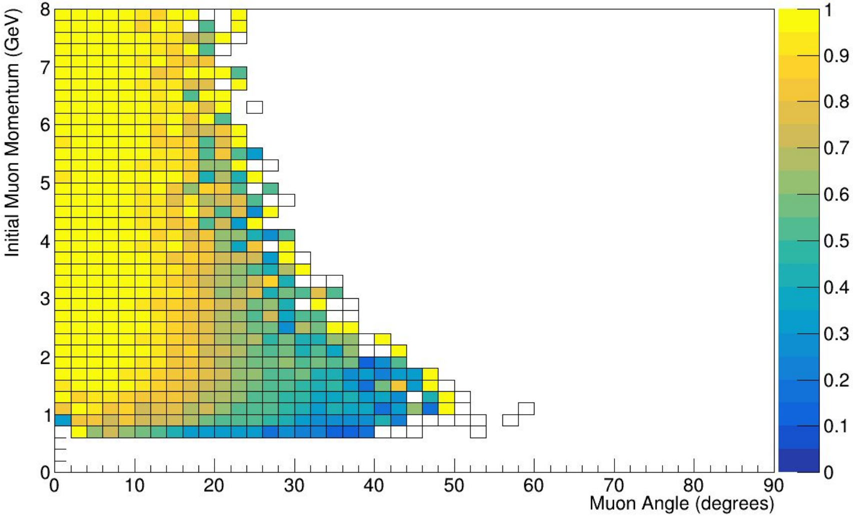


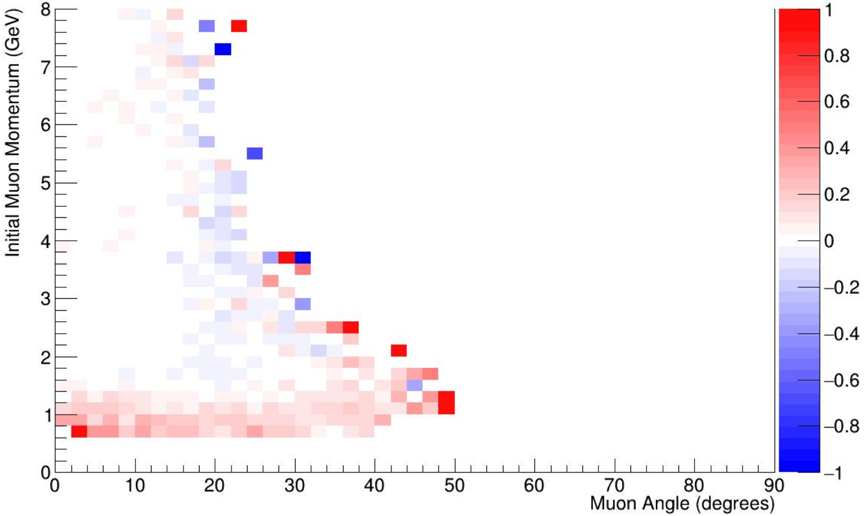
Efficiency map as a function of initial muon momentum and angle w.r.t to the neutrino.

The color map is the efficiency while the boxed outline show the kinematic region where events were created.

Restricted to events which “reached” ND-GAr-Lite and the vertex was within the LAr FV.

Further Improved Efficiency





Six planes: 1181, 1201, 1221, 1241, 1341, 1541 cm in Z with heights of approx. 267, 345, 400, 450, 500, and 500 cm.

Similar gain in efficiency to previous upstream configurations, but less momentum loss at higher momentum. The difference is with respect to the first benchmark arrangement.

Ongoing Design Work

The main ongoing design changes are related to the scintillator tracker.

The position and overall sizes of the scintillator planes are currently being optimized for maximum efficiency while keeping good-enough momentum resolution (5% or better).

Inputs from BSM physics that could be considered:

- Regions of kinematics that are important for either momentum resolution or efficiency, particularly at medium to high momentum (e.g. greater than 3 GeV).
- Usefulness of ECAL modules in ND-GAr-Lite
- Properties/specifications of the scintillator bars

ND-GAr-Lite and BSM Physics

ND-GAr-Lite is designed for high precision momentum measurements and sign-selection for charged particles, particularly muons, originating in the LAr.

BSM channels that primarily rely on measurements of charged particles, e.g. neutrino tridents, are very well suited to ND-GAr-Lite.

ND-GAr-Lite will have a larger tracking volume than the HPTPC and possibly better momentum resolution.

Main disadvantages to ND-GAr-Lite (compared to ND-GAr) are the lack of an interaction target, TPC PID, and vertex measurements.

ND-GAr-Lite Run Plan

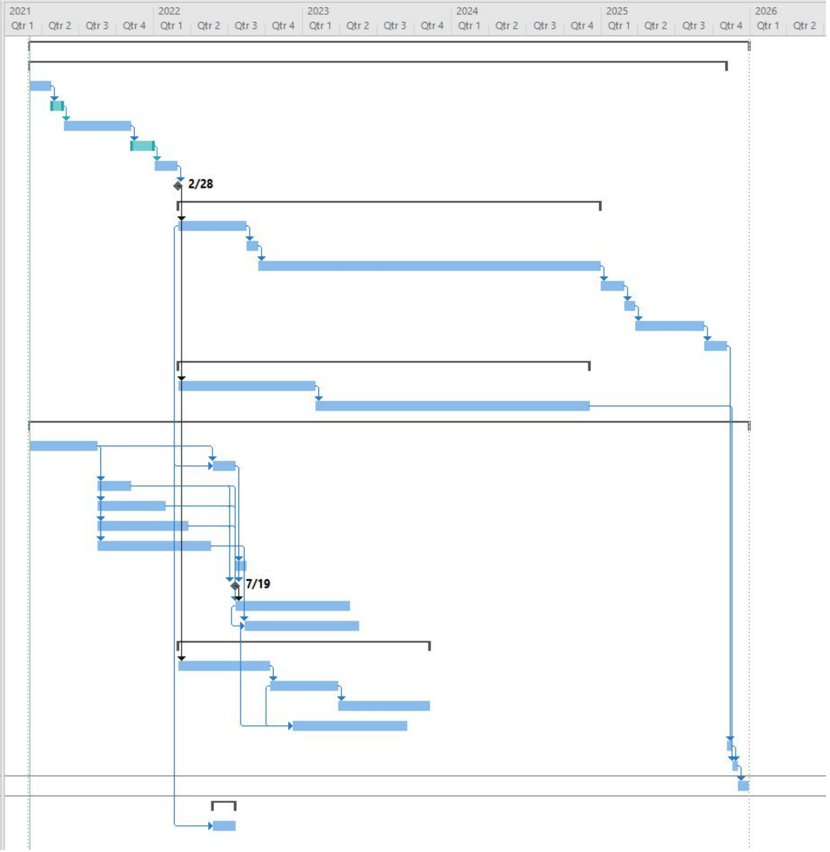
Rough idea of an upgrade plan to full ND-GAr with ND-GAr-Lite installed as the Day-1 detector.

1. Get a new R&D proposal approved in 2 years for ND-GAr
2. About 3 years to put together a proposal to NSF
3. An additional 2 years and NSF approval
4. Approximately 4 years construction for the rest of ND-GAr (primarily the HPTPC)
5. Then 1 year installation and commissioning

This would put full ND-GAr running in about 2033, giving about three years of ND-GAr-Lite running.

ND-GAr-Lite Preliminary Schedule

	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		**ND-GAr lite**	**1261 days**	**Mon 3/1/21**	**Mon 12/29/25**	
2		**Magnet System**	**1221 days**	**Mon 3/1/21**	**Mon 11/3/25**	
3		Conceptual Design Study	2 mons	Mon 3/1/21	Fri 4/23/21	
4		Conceptual Design Report	1 mon	Mon 4/26/21	Fri 5/21/21	3
5		Preliminary Design Study	6 mons	Mon 5/24/21	Fri 11/5/21	4
6		Preliminary Design Report	2 mons	Mon 11/8/21	Fri 12/31/21	5
7		Tender preparation	2 mons	Mon 1/3/22	Fri 2/25/22	6
8		PO tendered	1 day	Mon 2/28/22	Mon 2/28/22	7
9		**Magnet production & test at vendor**	**740 days**	**Tue 3/1/22**	**Mon 12/30/24**	
10		Technical deisign report	6 mons	Tue 3/1/22	Mon 8/15/22	8
11		Pre-production design review	1 mon	Tue 8/16/22	Mon 9/12/22	10
12		Production and test at vendor	30 mons	Tue 9/13/22	Mon 12/30/24	11
13		Preparation for shipping	2 mons	Tue 12/31/24	Mon 2/24/25	12
14		Shipping	1 mon	Tue 2/25/25	Mon 3/24/25	13
15		Re-assembly and test	6 mons	Tue 3/25/25	Mon 9/8/25	14
16		Commissioning	2 mons	Tue 9/9/25	Mon 11/3/25	15
17		**Cryo Infrastructure**	**720 days**	**Tue 3/1/22**	**Mon 12/2/24**	
18		Valve box design	12 mons	Tue 3/1/22	Mon 1/30/23	8
19		Procurment and installation	24 mons	Tue 1/31/23	Mon 12/2/24	18
20		**Tracker System**	**1261 days**	**Mon 3/1/21**	**Mon 12/29/25**	
21		System design optimization	6 mons	Mon 3/1/21	Fri 8/13/21	
22		Support system engineering	2 mons	Tue 5/24/22	Mon 7/18/22	21,10SS+3 mons
23		Scintillator procurement	3 mons	Mon 8/16/21	Fri 11/5/21	21
24		WLS fiber procurement	6 mons	Mon 8/16/21	Fri 1/28/22	21
25		SiPM procurement	8 mons	Mon 8/16/21	Fri 3/25/22	21
26		Strong back procurement	10 mons	Mon 8/16/21	Fri 5/20/22	21
27		Factory setup	1 mon	Tue 7/19/22	Mon 8/15/22	22
28		Ready for assembly	1 day	Tue 7/19/22	Tue 7/19/22	22,23,24,25
29		Quad counter assembly	10 mons	Wed 7/20/22	Tue 4/25/23	28,23,24,25
30		Modual assembly	10 mons	Wed 8/10/22	Tue 5/16/23	29SS+3 wks,26
31		**Electronics Design**	**440 days**	**Tue 3/1/22**	**Mon 11/6/23**	
32		Design	8 mons	Tue 3/1/22	Mon 10/10/22	8
33		Prototyping	6 mons	Tue 10/11/22	Mon 3/27/23	32
34		Production and test at vendor	8 mons	Tue 3/28/23	Mon 11/6/23	33
35		Modual testing	10 mons	Tue 12/6/22	Mon 9/11/23	30SS+1 mon,33S
36		Installation into magnet	2 wks	Tue 11/4/25	Mon 11/17/25	16
37		Final testing	2 wks	Tue 11/18/25	Mon 12/1/25	36,19
38		Commissioning	1 mon	Tue 12/2/2	Mon 12/29/25	37
39		**ECAL support integration**	**40 days**	**Tue 5/24/22**	**Mon 7/18/22**	
40		ECAL module suport design	2 mons	Tue 5/24/22	Mon 7/18/22	10SS+3 mons



Summary

ND-GAr-Lite has been developed as an alternative design for the TMS.

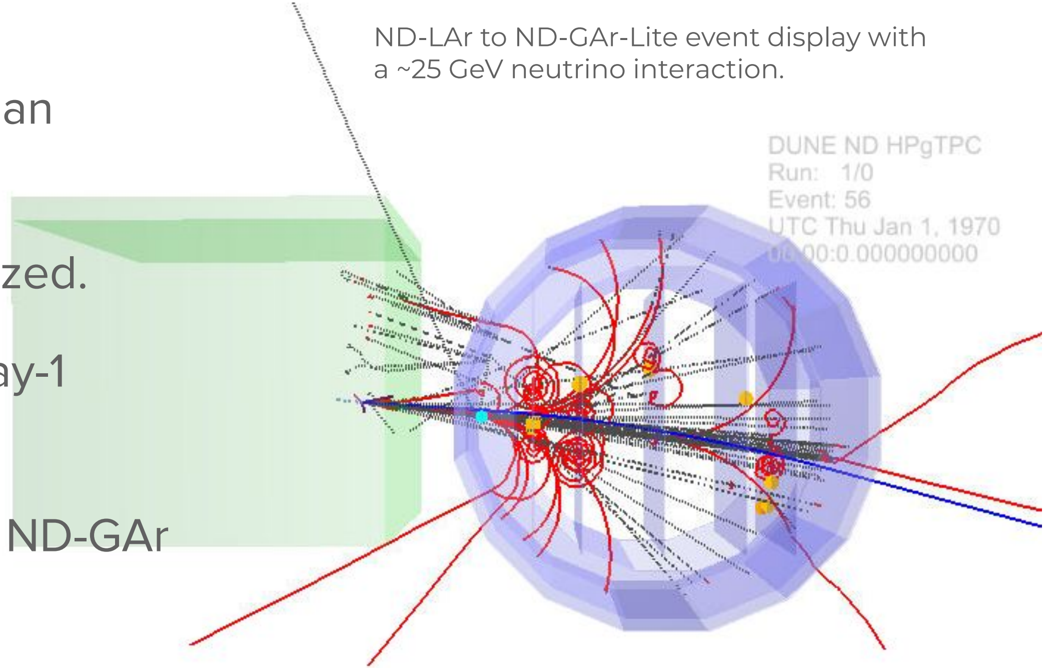
Design is being improved and optimized.

Current performance sufficient for Day-1 Physics goals.

Provides natural upgrade path to full ND-GAr detector.

Will be useful for BSM physics searches.

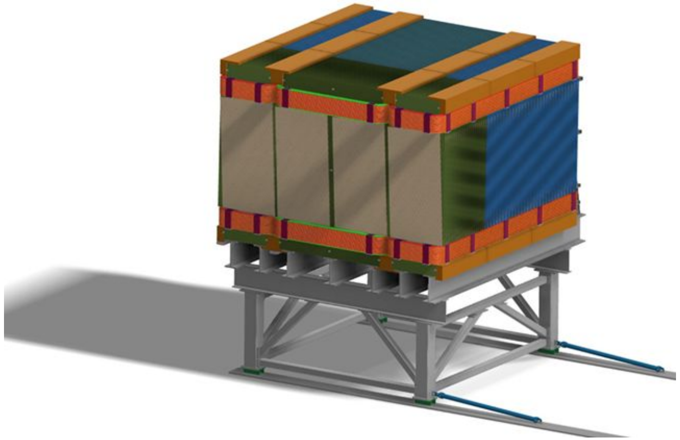
ND-LAr to ND-GAr-Lite event display with a ~25 GeV neutrino interaction.



Backup Slides

The Day-1 Detector: Enter the TMS

- The resources for ND-GAr are not available yet
- Need alternative Day-1 Detector to measure ND-LAr muons
  - Temporary Muon Spectrometer (TMS)
  - Baseline design is a magnetized range stack comprised of steel/scintillator layers
- DOE DUNE Project
  - TMS as an affordable alternative within US project
  - Implement as late as possible to allow ND-GAr, if funding is found

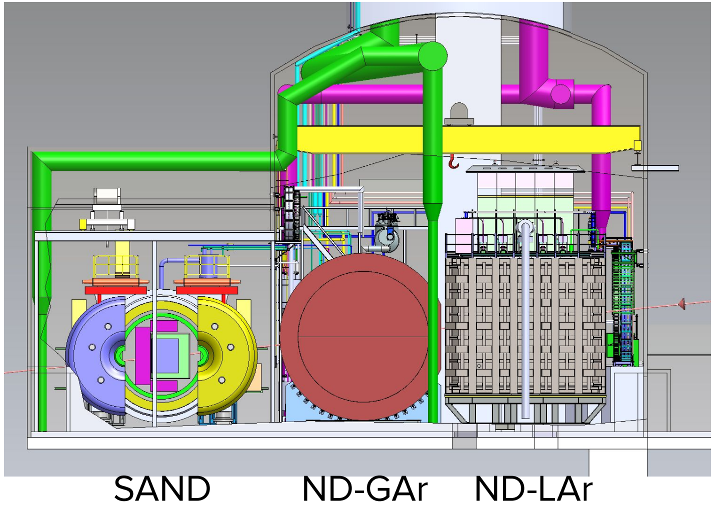


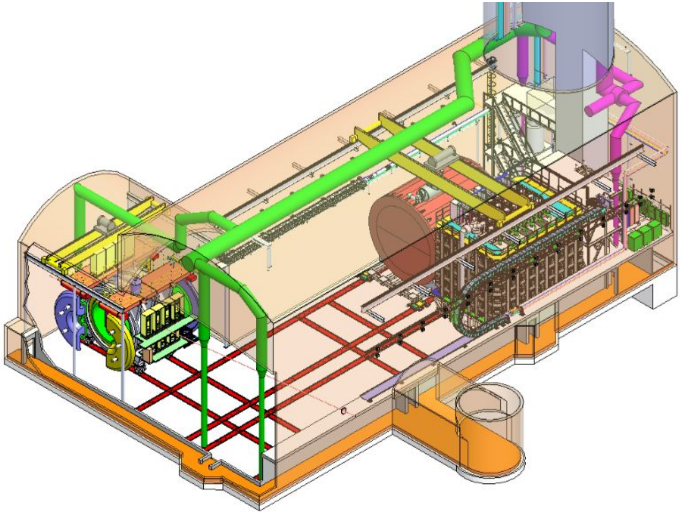
Near Detector Complex

Four main components

1. Liquid argon detector (**ND-LAr**)
2. Downstream tracker with gaseous argon target (**ND-GAr**)
3. ND-LAr and ND-GAr systems can move to off-axis fluxes (**PRISM** concept)
4. **S**ystem for on-**A**xis **N**eutrino **D**etection (**SAND**)

High statistics constrains cross section and neutrino flux.





Full ND-GAr Design

Return yoke, magnet, cryostat act as the pressure vessel.