Overview

FNAL Review
R&D plans for a 100 k-Ton LAr Detector.

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- Comments on Agenda and charge for review
- Endgame: Design ideas and R&D issues for 100kton scale detector
- Path to massive detectors

Review Charge & Agenda:

Review Charge: Liquid Argon TPCs show promise as scalable devices for the large detectors needed for long baseline neutrino oscillation physics. Over the last several years a staged approach to developing the technology for large detectors has been developed. A specific plan with the ~200 ton μ–BooNE detector and the ~5000 ton LAr5 detector as key elements emerged with the presentations of these detectors to the Fermilab Physics Advisory Committee.

Please evaluate this specific approach as a path to a ~100kton LArTPC detector mass. In particular, are the proposed R&D programs, in the context of other initiatives worldwide, effective steps towards large detectors?

Agenda:

• Overview:	D. Lissauer	(30+10)
• LAr 5:	G. Rameika	(25+10)
• μ–BooNE:	F. Lanni	(35+10)
• Test stands and Purification:	S. Pordes	(30+10)
• ArgoNeuT:	M. Soderberg	(15+5)
• Summary:	B. Fleming	(20+10)

R&D plans for 100 K-ton LAr Detector

1. Physics Motivation & needed performance
2. Design considerations for 100 K-ton detector.
3. Detector Technology - TPC
4. Readout Architecture
5. Time-zero (t^0) measurement by scintillation light detection
6. HV distribution
7. 100 K-ton detector – Layout considerations
8. Cavern & Experimental Layout
9. Cryostat
10. Cryogenics – LN_2 supply
11. LAr Supply
12. LAr Purification system
13. Assembly & installation
14. Software & Performance
15. Evolution of the R&D program
16. Summary R&D Program

Physics Motivation & needed Performance

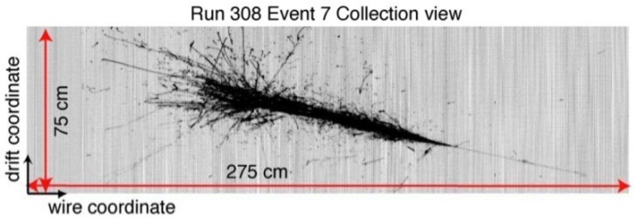
Neutrino Oscillations (FNAL-Homestake 1300km)

Need Large Detector (300-500k-ton H_2O, or/& 100 k-ton LAr)

Leptonic CP Violation, θ_{13}, Mass Hierarchy,…Precision

Proton Decay,

Supernova ν, Atmospheric ν,…

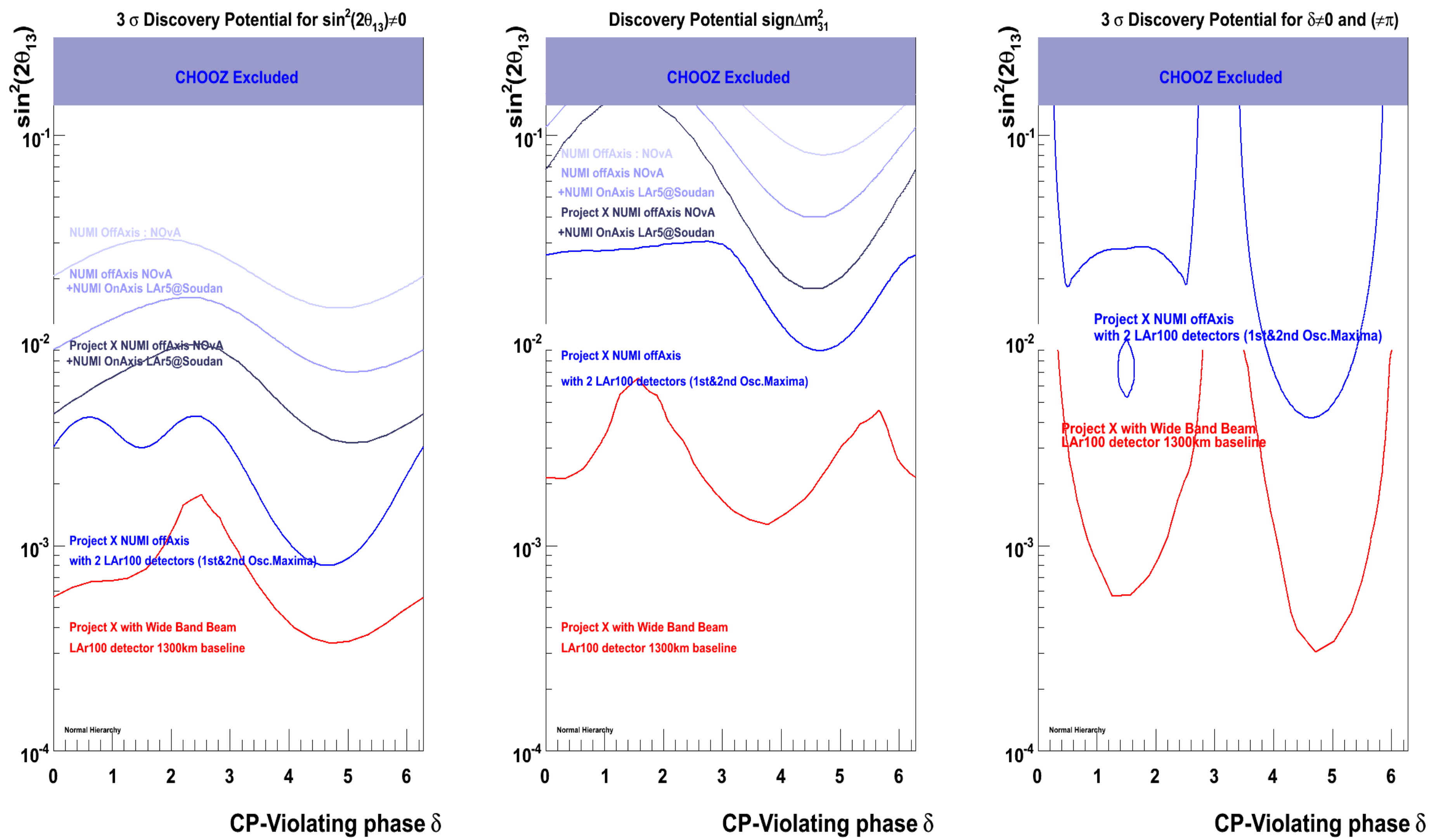


LAr TPC's Unique Detectors appear scalable to large volumes

ν oscillation physics: LAr 3-4 times more sensitive than WC.

ν_e appearance is difficult. Need powerful detectors.....
Differentiate γ /e's using topology and dE/dx
Proton decay searches: sensitive to p → $K^+\nu$
Supernova

Discovery Potential for LAr detectors LBL



Design Consideration for 100 k-ton LAr Detector

1. LAr TPC's aimed at studying ν interactions have been developed over the last ~20 years. (ICARUS > 20 years , 1st paper: Gatti, Radeka IEEE Tran. In Nuclear Science NS-26, 2, April 1979)
2. ICARUS optimization is for a number 600T detectors with warm electronics and evaluable vessel.
3. One of the key considerations for the design is the type of readout electronics to be used.
   i. warm electronics – limits size of detector:
      a) Active wire + connection length → Large Capacitance → S/N
      b) Large number of Cables and Feedthroughs → more complex integration and Cryogenics, Purification loads.

Design Consideration for 100 k-ton LAr Detector

ii. Cold Electronics – allows for more flexibility in the design:

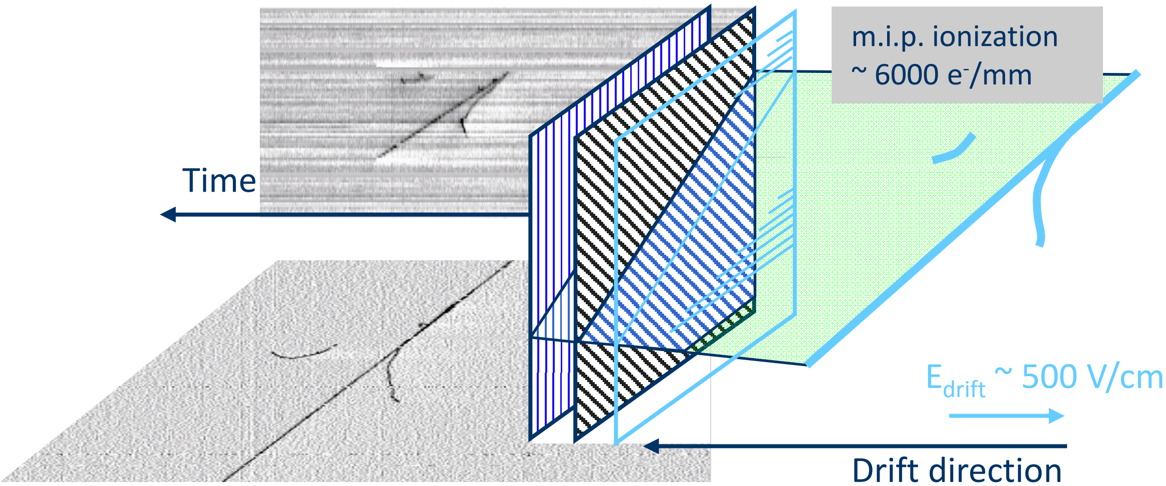
   a) S/N improvement for a given active wire length.
   b) Multiplexing → Reduction in the cable
      a) Reduction of Cables → Purification
      b) Fewer feedthroughs → Heat Loss, Purification

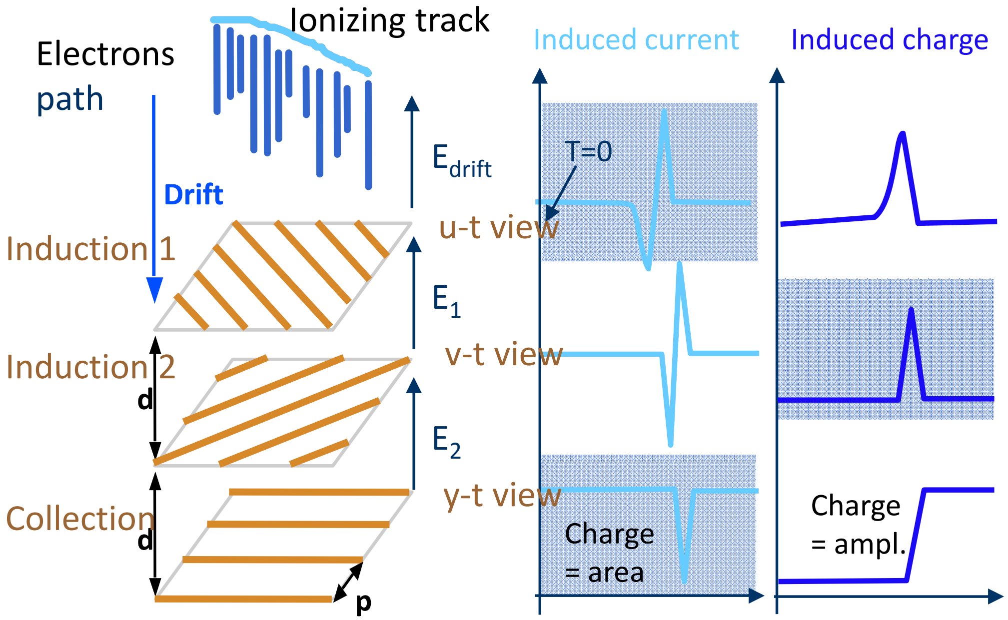
iii. Purification system needs to cope with non –evaluable vessels.

4. The advances in electronics allows better optimization of large detectors. Critical issues needs additional R&D and engineering studies that have to be addressed before a design is complete.
5. Key consideration that is the ability to construct and operate large LAr detector underground.

This presentation will highlight some of the issues one faces in the design of 100 k-ton detector.

Detector Technology - LAr TPC





The TPC field cage and wire plane need to ensure:

i. uniform drift field.

ii. U,V readout by induction.

iii. Y collecting plan

3D Reconstruction

DE/DX Information

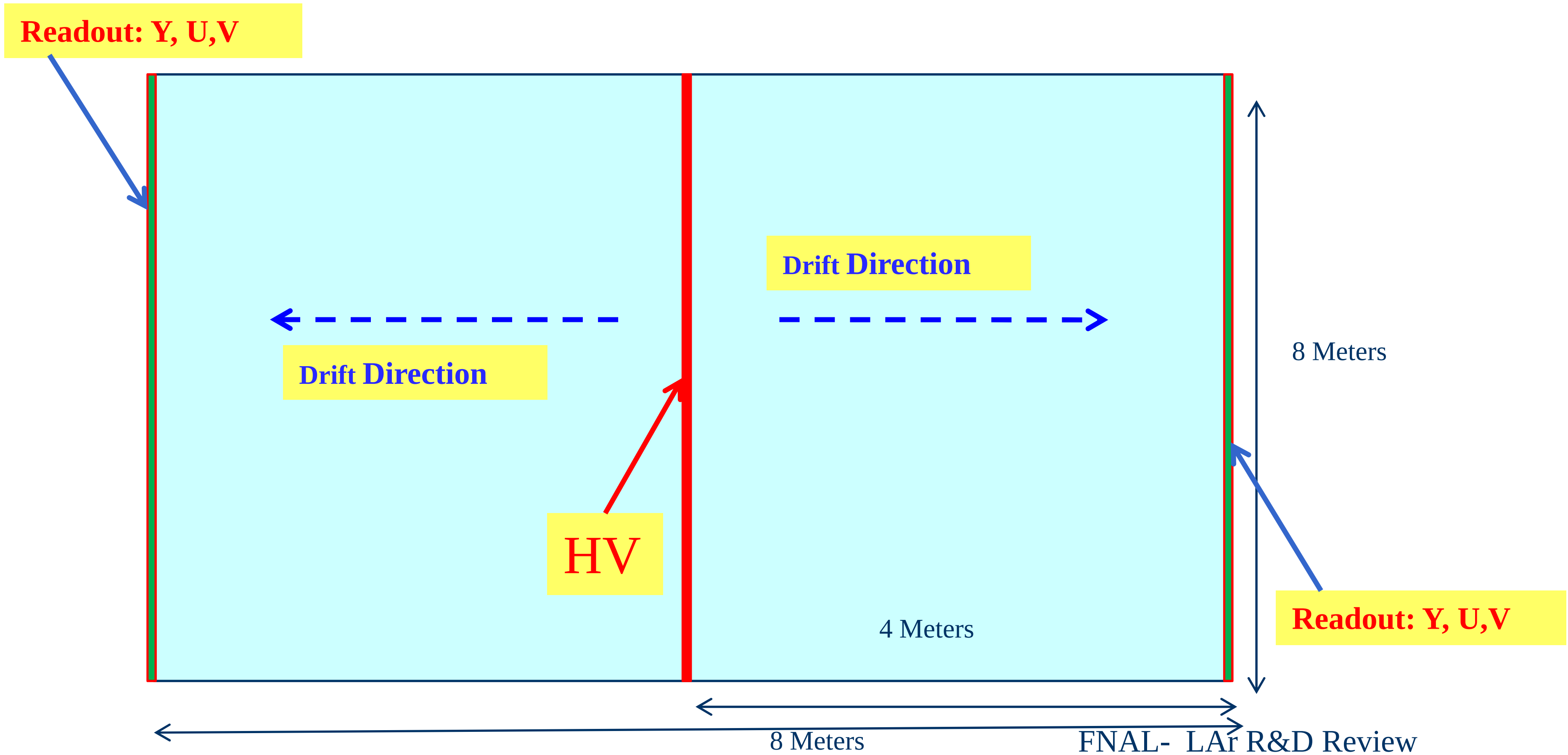
Calorimetric Energy (e, hadronic shower)

e/γ discrimination

TPC - Module

An possible "evolution" of μ–BooNE Geometry.

Basic building block.

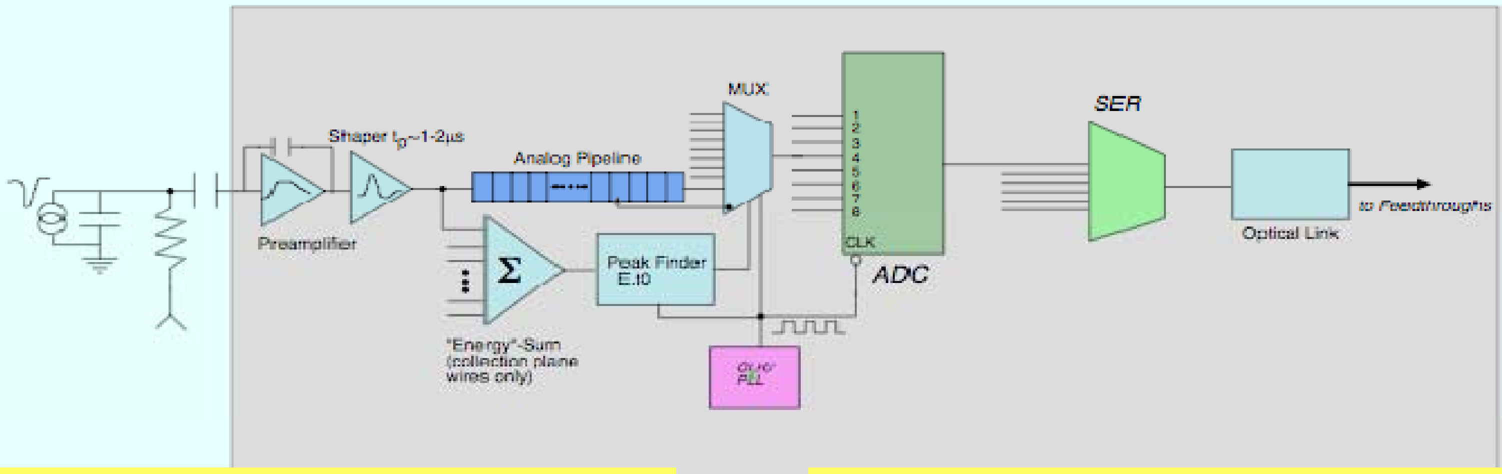


TPC - Issues

1. HV position – Center or sides? (drift direction)
2. Wire Length (8-10 Y, 16-20 U,V)
    1. S/N
    2. Mechanical Issues
3. Wire Spacing (3-5 mm)
4. Drift length (3-5 m)
    1. Purifications
    2. Signal uniformity
5. “transparent” to light t^0 considerations (PM)
6. Alternative Electrode configuration
    1. Cryostat layout
    2. Space optimization
7. Mechanical Construction

Expect significant information from μ–booNE (F. Lanni)

Readout - Architecture



Multiplexed Cold electronics.

Pipeline:

Analog (SCA)

Digital (Post ADC)

Power

Reliability

Operation in the cold

Shaping time (1-2 μ–sec)

Sampling frequency (200-400 n-sec)

Dynamic Range (~ 10 -12 bits)

Data Volume and transmition (0 suppression)

- **Steps:**
  - **Analog Front-End (PA+Shaper, Peak Finder)**
  - **Analog Pipeline/ MUX**
  - **Digitization and transmission**

Readout R&D Plan

1. μ-BooNE: 1st stage, cold PA , information and data to finalize design issues.

2. Technology selection: Test structures, cold performance (On going) P-MOS technology seems to be most promising.

3. Fully integrated Analog Front end – in P-MOS.
   Need to define: Wire length, Optimal Shaping time,

4. Multiplexing: Finalize Architecture (SCA? , ADC?), Specify: Data transfer, sampling frequency, zero supression.

5. Optical Links

6. Full System

t^0 Determination

For beam induced ν interactions beam spill timing can be used for t^0.

For Proton Life time and for SN ν t^0 needs to be determined using a different system.

A possible solution is to use PM that are placed at the edge of the detector.

Issues:

- "Transparent" detector – light acceptance.
- PM operation in LAr
- Readout – Multiplex in the cold?
- HV supply – Min number of cables.

HV - Distribution

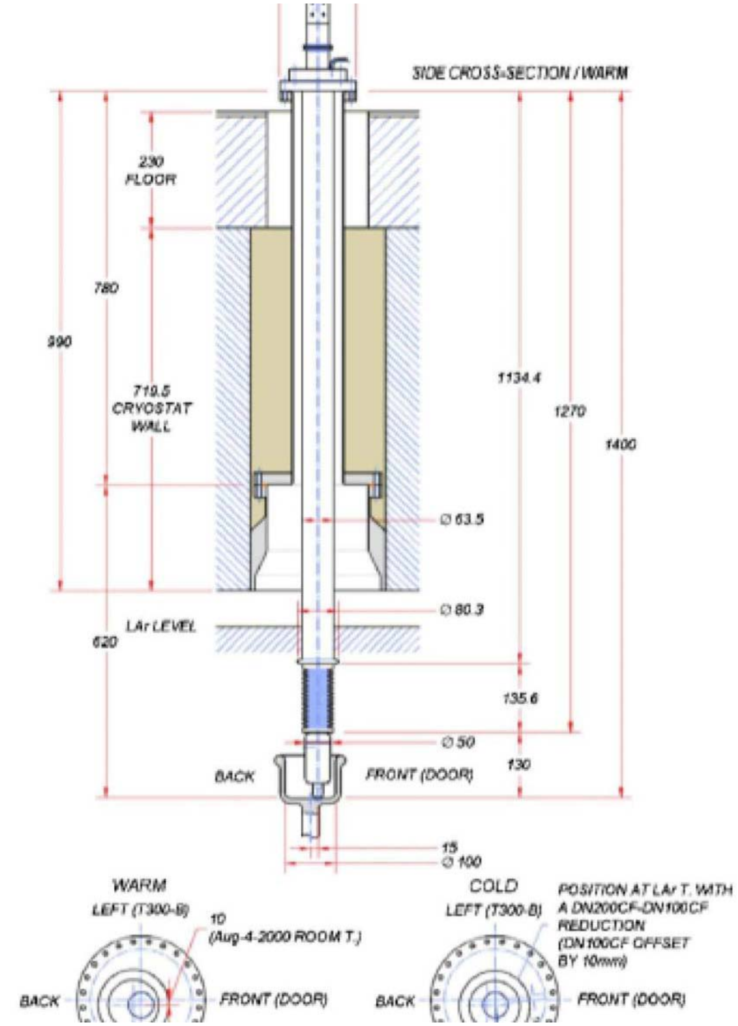
For a 5 meter drift and assuming 500 V/mm need to supply up to 250 K-volts.

Issues :

i) External Generation of the HV –FT cable of handling 250 K-Volts.

i) Internal Generation of HV – step up from few hundred Volts.

ii) High quality resistors to establish the needed HV gradient on the Cage.



ICARUS design of a “Warm” HV FT

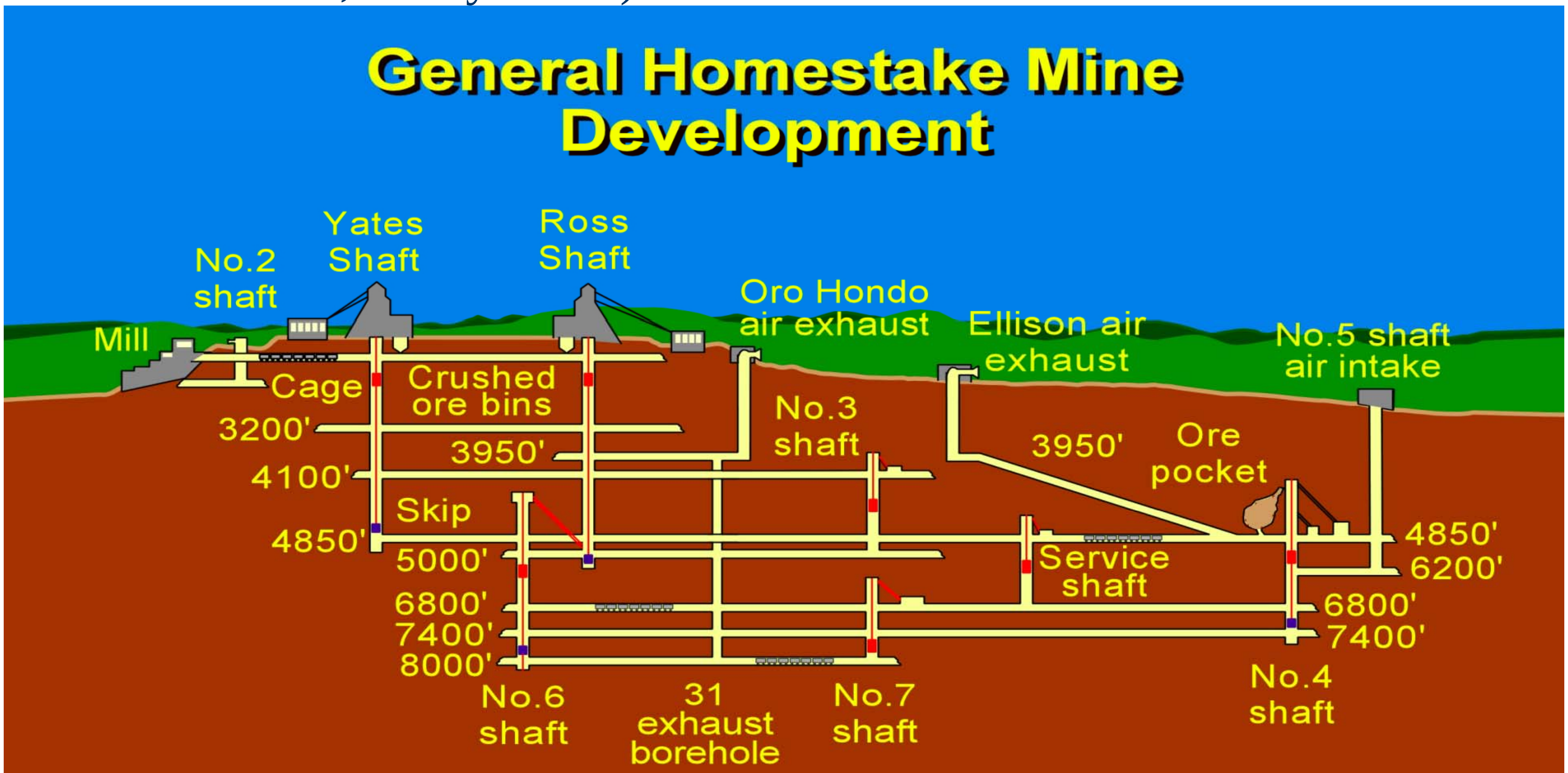
100 k-t Detector Layout Considerations

Some of the considerations and studies that are needed are:

Location: Depth? : 300 , 4850 or in between?

Proton Life time & SN ν can they be done at 300 feet. (Background)

Cost differential for different depth. (Excavation cost, assembly cost differential , Safety issues)



Layout of Mine in south Dakota

Possible Location at 4850

Existing Shafts and Access tunnels at the 4850 Level.

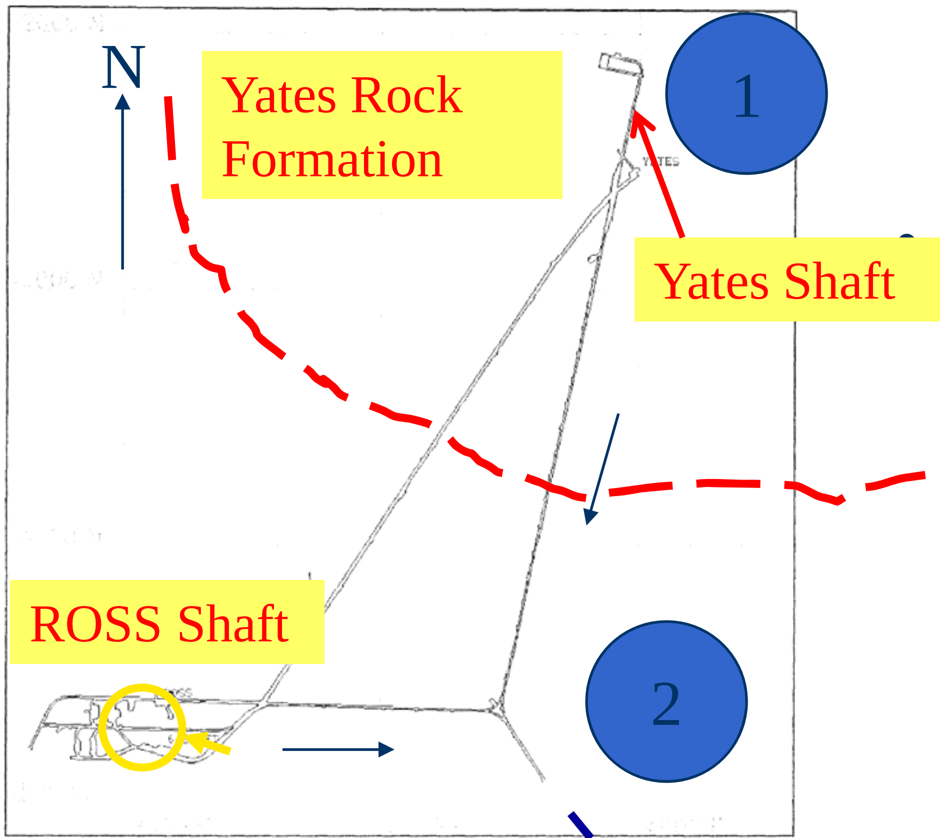


Fig.5 4850 level - area of interest (DUSEL mid level)

Note: Local coordinate system in feet with false orirgin.

To Exhaust Shaft

Fermilab (287.7 degrees)

- Discussions started.

  Two different Rock formations.

  Yates formation is considered to be better.

- Location:

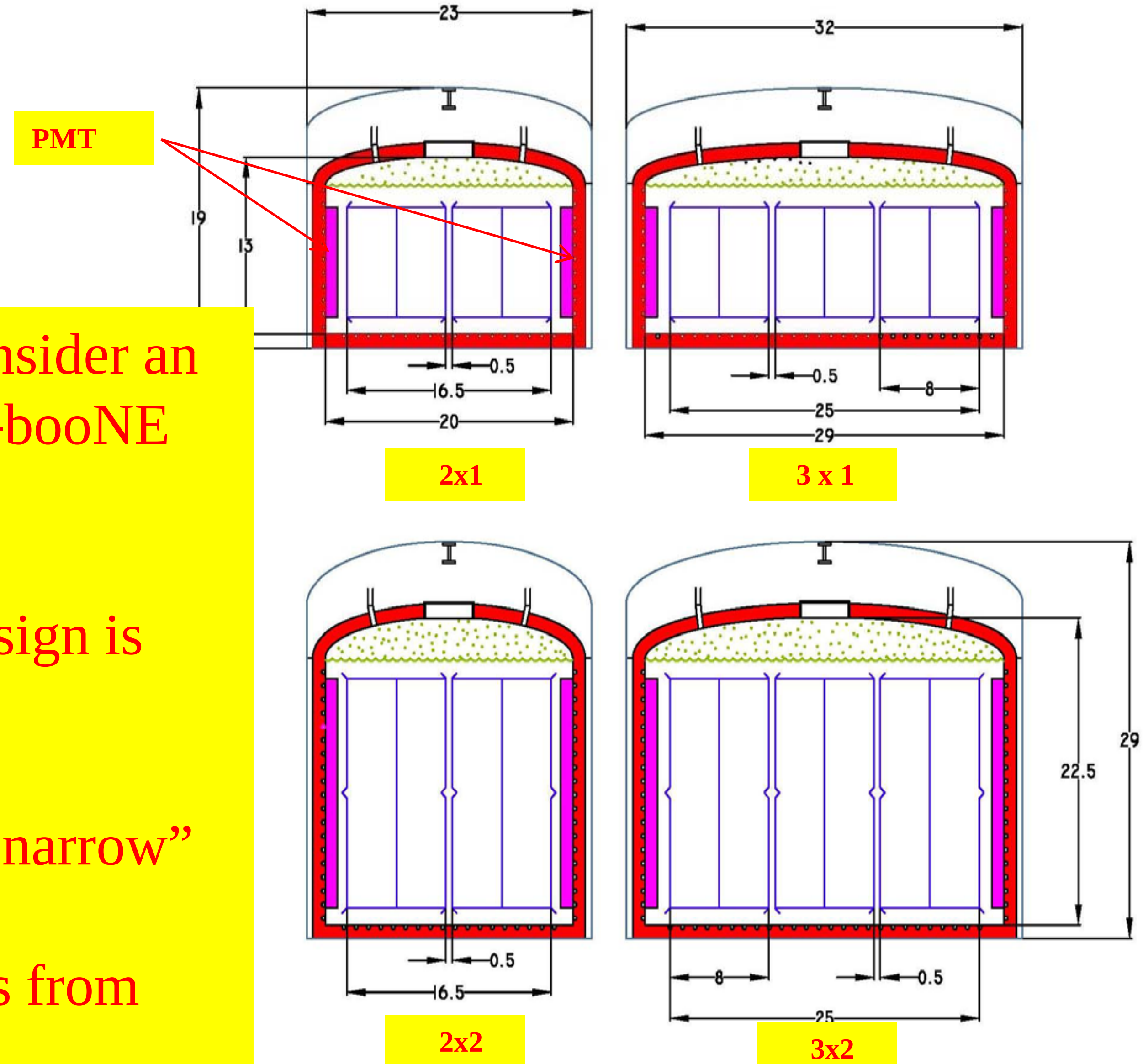
  Two locations are being considered at present.

  - Close to the Yates shaft

    Primary shaft for access, material , personnel, etc.

  - "exhaust shaft" - ventilation

Cavern & Experiment Layout



As an example: Consider an evolution of the μ–booNE concept.

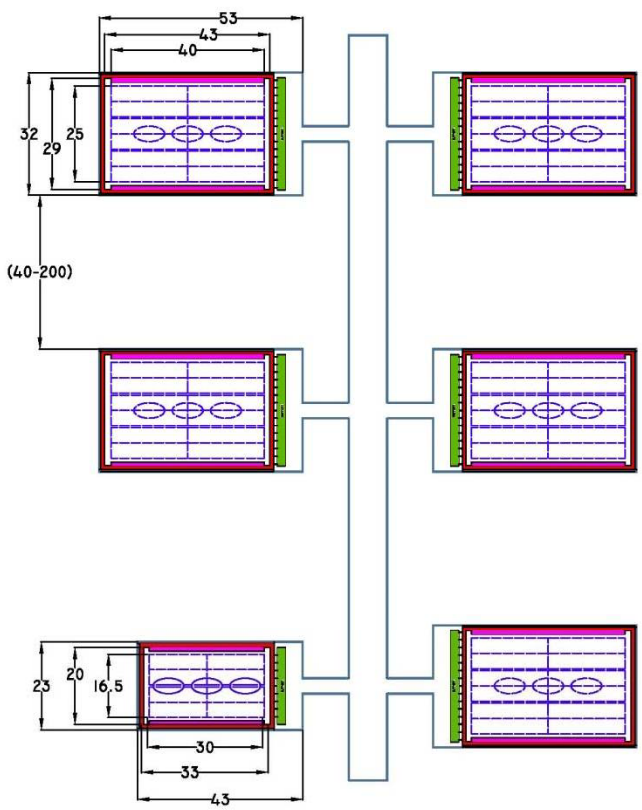
Cavern/Cryostat design is Coupled.

Cavern: Long and "narrow"
Cryostat: "Square"
Detector: deviations from square → Long

Cavern & Experiment Layout

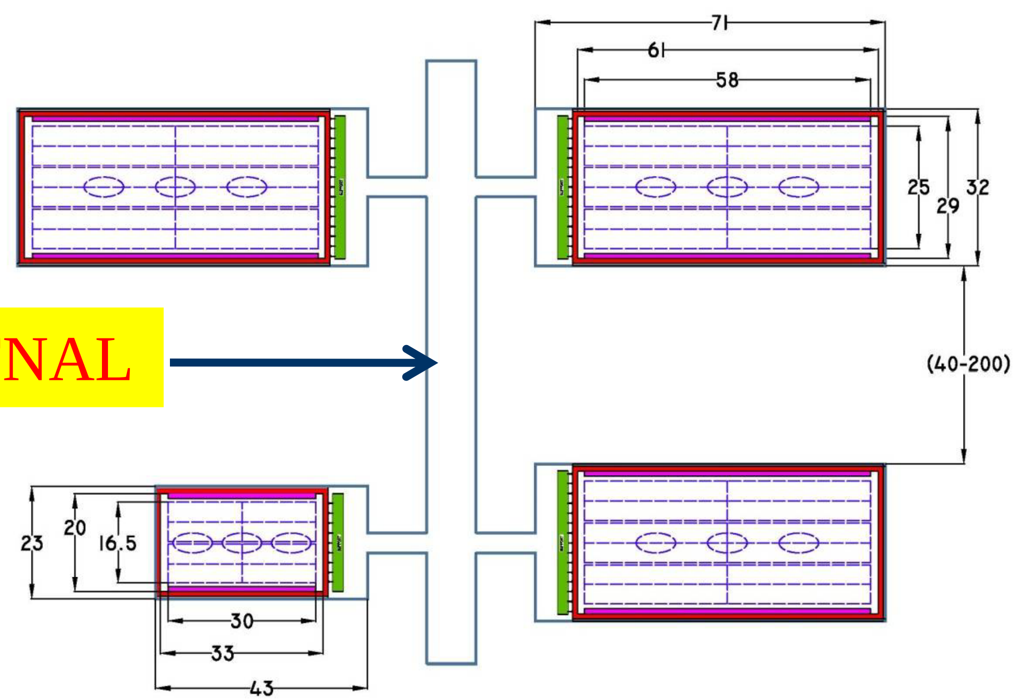
Staged Installation: Minimum distance between caverns 40-200 m
40 m Wall integrity, 200 m being able to excavate and run in parallel

Top View : 20 k-ton for 3x2 configuration



Top View : 30 k-ton for 3x2 configuration

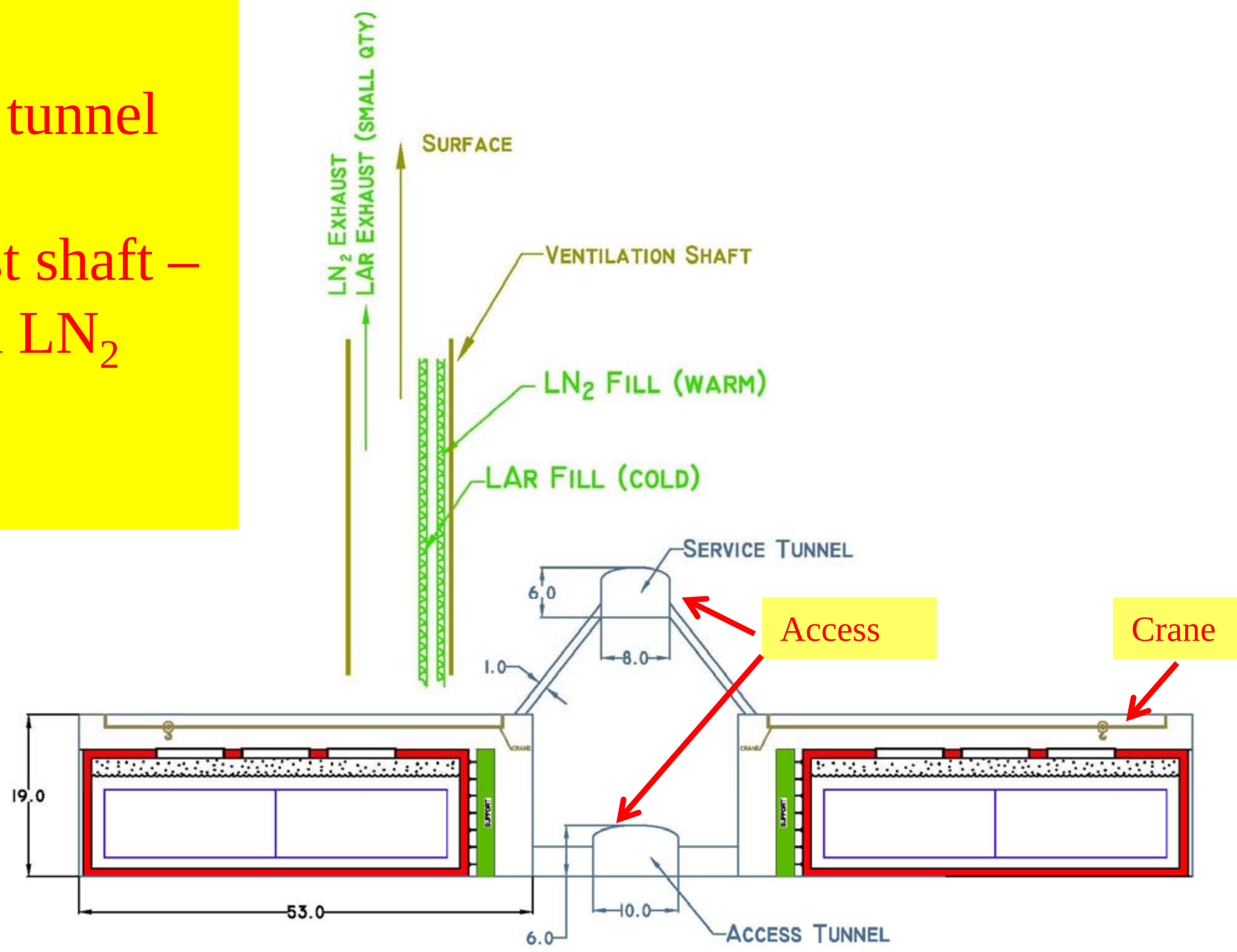
FNAL



Cavern & Experiment Layout

Transverse View:
Service Cavern
Access and excavation tunnel

Location of the Exhaust shaft –
Utilization for LAr and LN_2
lines .



Cryostat Issues

1. Size / Cost consideration
   i. Vessel is “non evcuable”
   ii. Foam insulation (Glass Foam?, Perlite?)

2. Minimize the Cavern Size (Cost)
   i. Possible use of the Cavern walls as “support”
   ii. Cryostat shape (Rectangle? , Ellipsoid? , others)

3. Vessel material
   i. SS Vessel + Foam insulation
   ii. “Perlite + cement” wall insulation with thin liner (Metal?)

4. Access during assembly

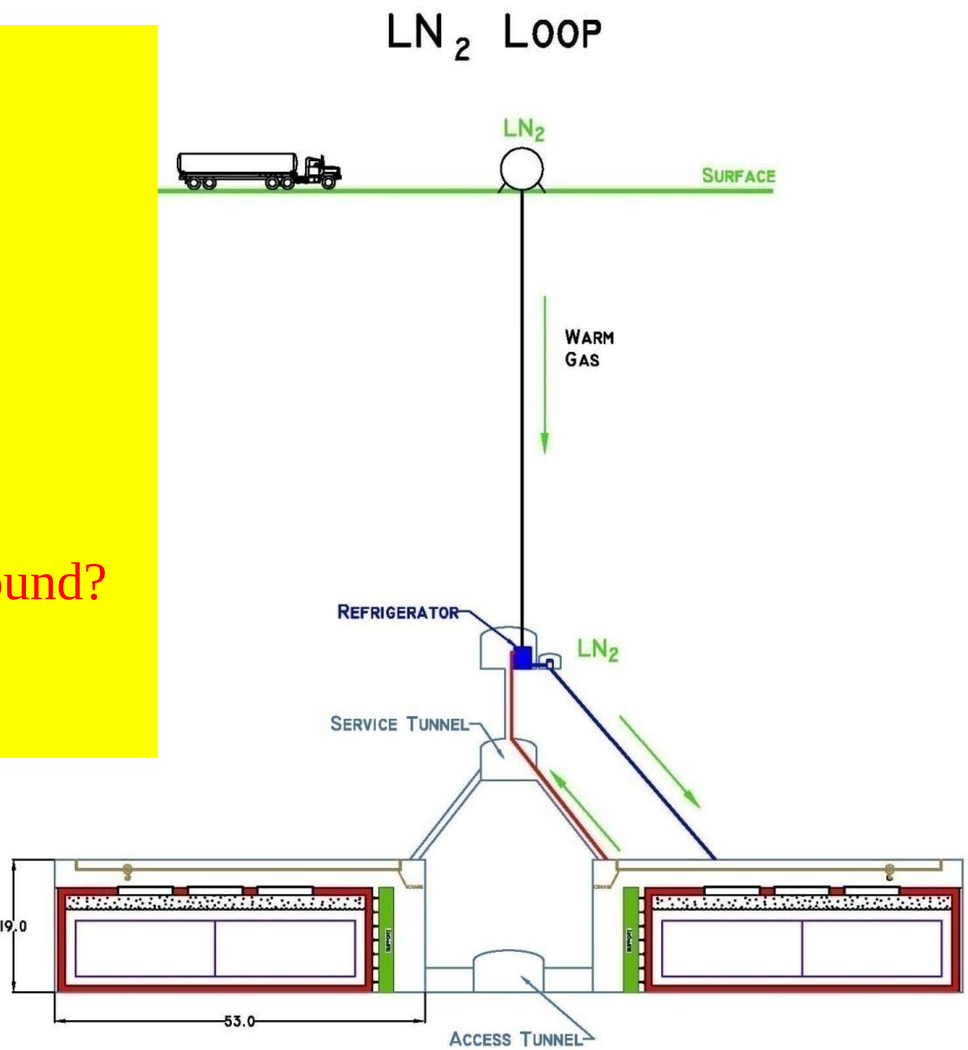
5. Feedthroughs
   i. Hermetic FT (better isolation)
   ii. HV

Cryogenics – LN_2 System

Heat Load: (Conservative?)
5 k-watt/m^2 surface area
Power / Channel: 40 m-watt
~50 K-Watt / large det.

Issues:

i. Refrigerators :
    i. size -Redundancy
    ii. location -surface/underground?
ii. Supply Pipe – Cold? Warm?
iii. Buffer tanks? Size, Location.

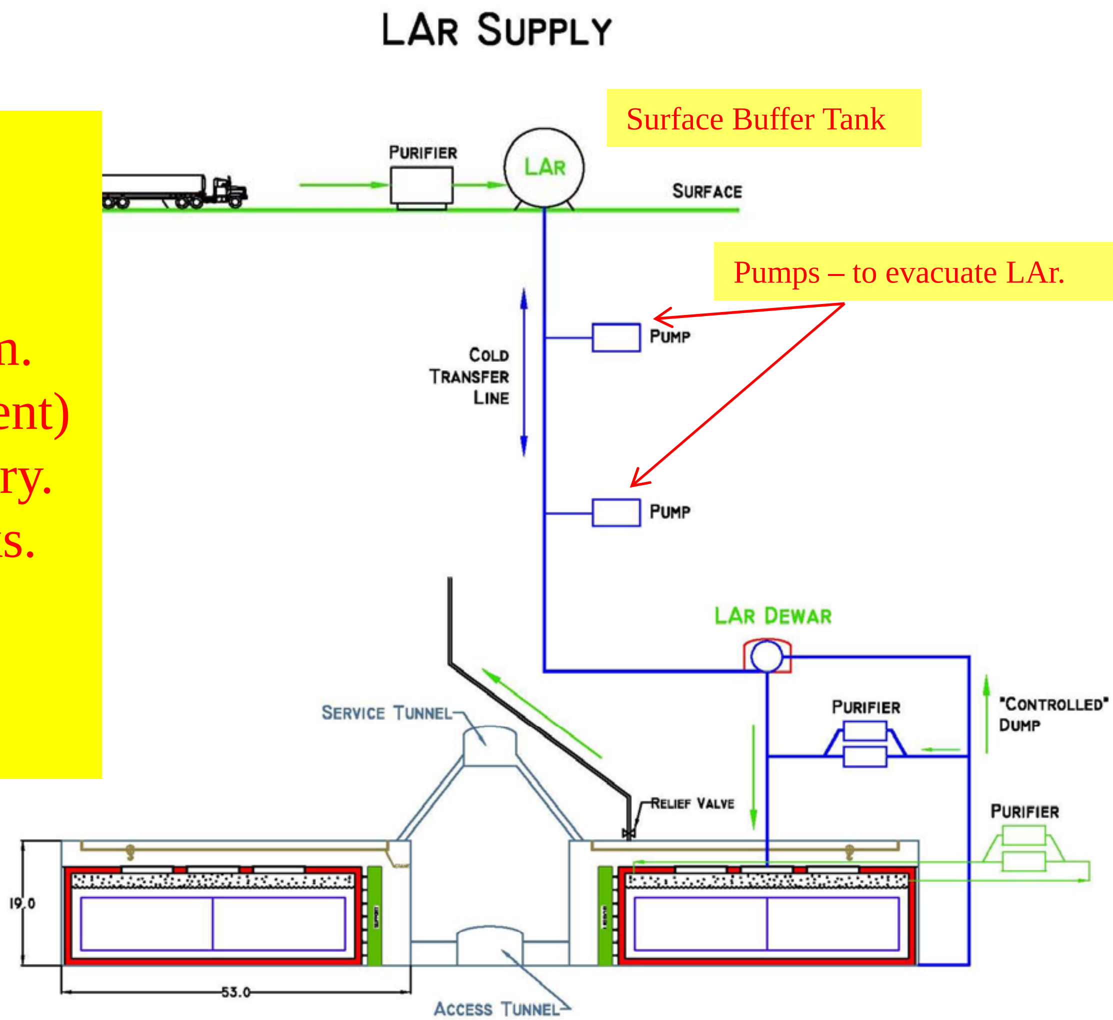


LAr Supply system

Procedure to supply the LAr.

Issues:

i. Cleanliness of the supply system.
ii. Ability to evacuate LAr (Accident)
iii. Acceptance tests for LAr delivery.
iv. Size and location of Buffer tanks.
v. # of buffer tanks underground.
vi. Location and size the purifiers.
vii. Cold pipe from the surface.



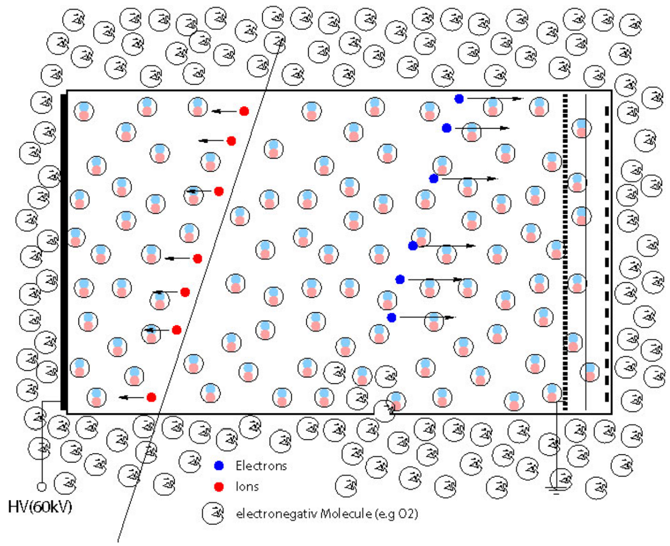
LAr Purification system

Purification → drift-distance , uniformity

Voltage: 0.5kV/cm 3-5 m → 150-250 kV

V_{drift}: 1.55 mm/μ–sec

t_{drift} = 2 - 3.3 m-sec for 3-5 m



Number of collisions/sec ~10^{12}

$2x10^9$ collisions along the path

'none' of them must 'eat' an electron

Concentration of electronegative (O_2) impurities < **10^{-10}**

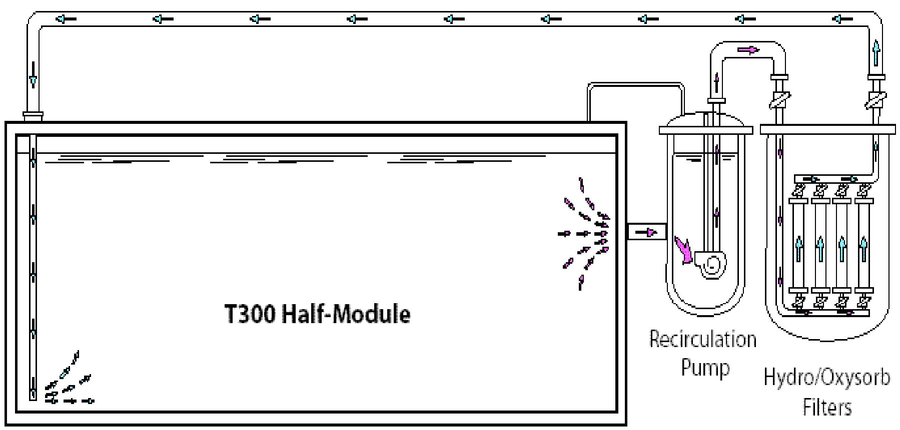
Total absorption calorimeter: 2mm drift so we need to be ~ 10^3 – 10^4 better purity.

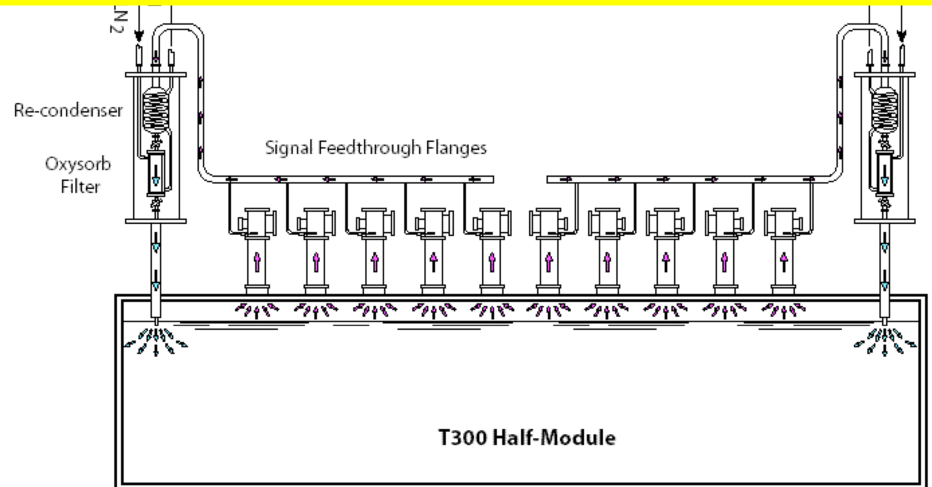
μ–BooNE will (inevitably) make significant contributions to purification issues.

LAr Purification Liquid/Gas

- Re-circulate liquid/gaseous argon through Purification system
- ICARUS T600 module:
  - 25 Gar m^3/hour/unit
  - 2.5 Lar m^3/hour

GAS – less pure than the Liquid.
FT effect? Hermetic FT (ATLAS style)
More effective in removing impurities from surfaces.





R&D Issues: (removal of) surface contaminants
Material certifications (Cables, MB)
filter materials
Purification Speed gas, Liquid
Cleanliness during assembly

S. Pordes : More details on LAr Purification & FNAL Test program.

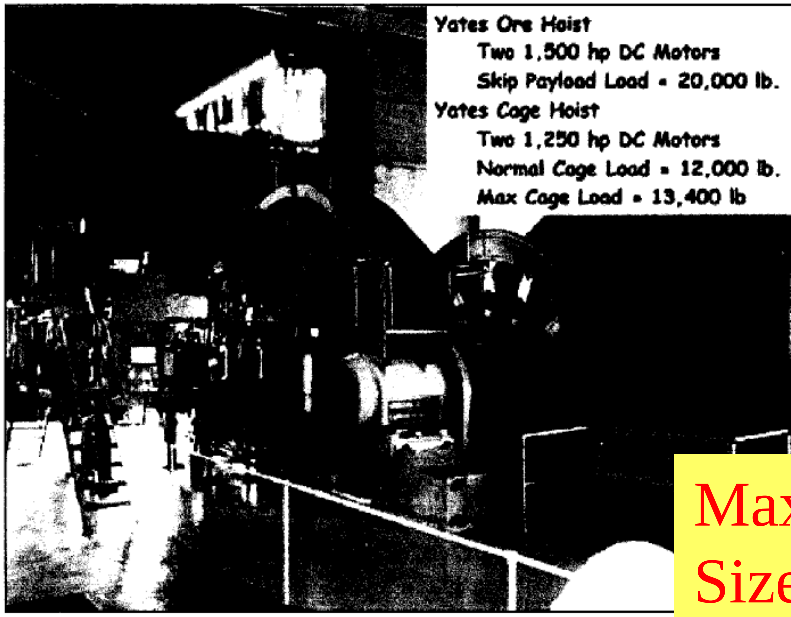
Assembly and Installation

Assembly underground poses serious challenges:

1. Access Limitation shaft and tunnels:
   i. elevator capacity (~ 6 tons)
   ii. Limited Volume (1.4x3.7x2.2 m)
   iii. Sever limitation on design and assembly
2. Space limitation
   i. Excavation cost will limit cavern size.
3. Limited Infrastructure
   i. Proximity of shops etc.
4. Safety consideration
   i. ODH – LAr has very specific safety issues.
   ii. Work underground – we need to understand better the limitation.
   iii. Access and Egress considerations.

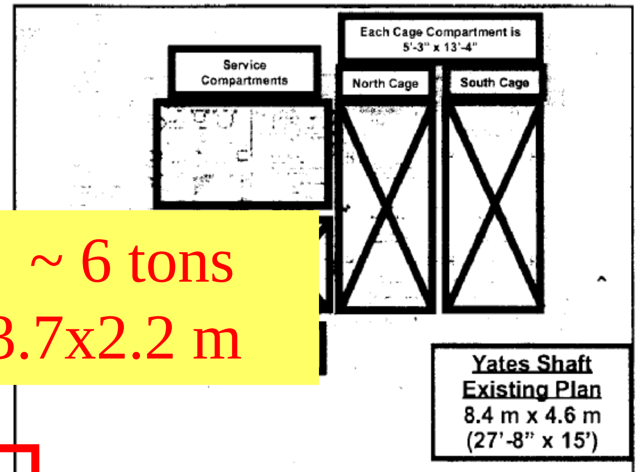
Need for a strong engineering team to fold these constrains in to the detector design from the start as well as the cavern.

DUSEL Shaft Capacity



Yates Shaft Upgrade Plan

Improved access to the 4850 Level for personnel, equipment, and utilities



Max Weight: ~ 6 tons
Size: 1.4x3.7x2.2 m

Existing Cage Dimensions and Capacities

Yates Cage Hoist

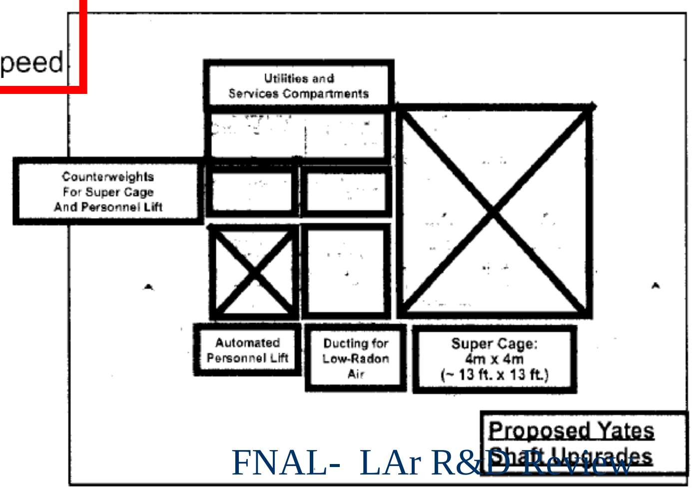
Maximum cage dimensions: 1.4 x 3.7 x 2.2m high (side-by-side)
(4' 8" x 12' 1.5" x 7' 2" high)
Maximum cage payload: 5,450 kg (12,000 lb), nominal
5,900 kg (13,000 lb), allowable at 1/2-speed

Ross Cage Hoist

Maximum cage dimensions: 1.3 x 3.8 x 2.2m high (double deck)
(4' 4-5/8" x 12' 5" x 7' 2" high)
Maximum cage payload: 5,450 kg (12,000 lb, nominal
6,100 kg (13,400 lb), allowable at 1/2-speed.

#6 Winze Cage Hoist

Maximum cage dimensions: 1.3 x 3.7 x 2.2m high (double deck)
(4' 4" x 12' 1-1/2" x 2.2m high)
Maximum cage payload: 5,450 kg (12,000 lb), nominal
6,400 kg (14,000 lb), allowable at 1/2-speed.

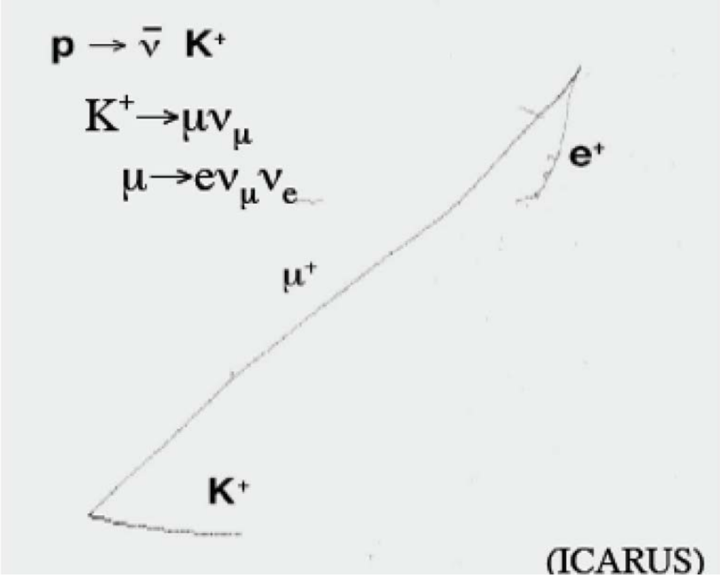


Software & Performance

Development of a complete analysis chain has to go hand in hand with finalizing the specifications and the optimization of the detector parameters.

Optimal TPC parameters – wire spacing, U,V angles, Sampling frequency, calibration need significant and early feedback from simulation and real data.

Building up a team capable of executing these detail studies and getting feedback from real data needs to be given a high priority.

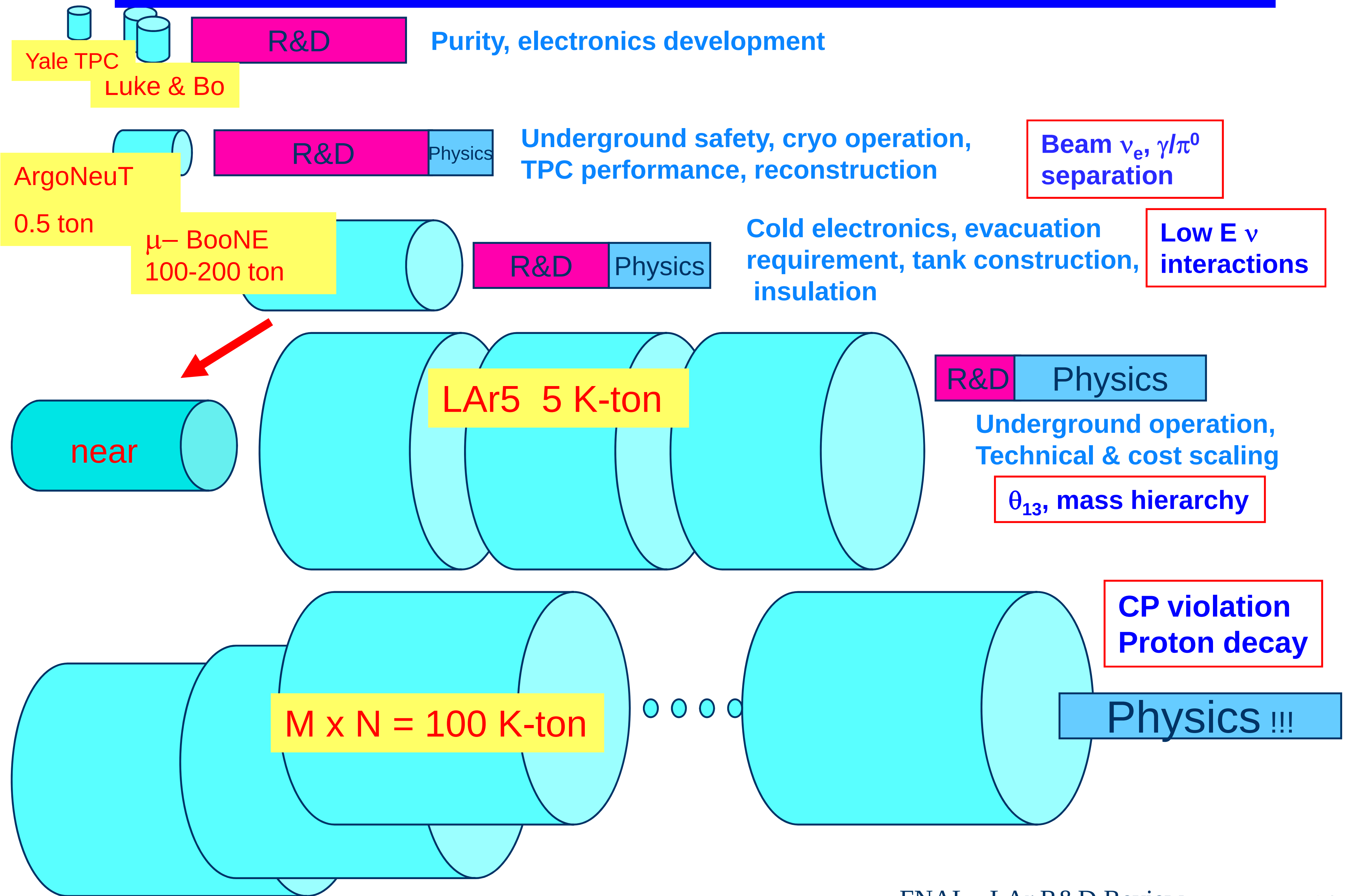


Simulation of Proton Decay:

Issues to be addressed:

DE/DX – # Samples , Wire spacing.
Energy resolution –corrections as a function of position.
Pattern recognition – e/γ discrimination.

Evolution of the LAr R&D & Physics Program



Experimental Roadmap

μ–BooNE - Construction		2009-2011
*****		
Agree on a Strawman Layout		2008-2010
Caverns design & excavation plan		2009-2011
Start excavation of the caverns		2012-2015
Finalize the design of 5 k-ton		2012
5 k-ton Construction		2012 -2017
20-30 k-ton:	1st det. Construction	2015-2020
	2nd det. Construction	2017-2022
	3rd det. Construction	2019-2023
	4th det. Construction	2020-2024

Additional discussion needed to define exact milestone.

Conclusions

1. Significant R&D and Engineering studies are needed before finalizing the design of large underground detector.
2. Issues are inter-related and R&D needs to proceed in parallel.
3. μ -booNE will be critical to give the team a focus and answer critical questions.
4. The R&D topics are well defined .
   i. Key personal are identified for both the R&D and Engineering effort.
   ii. DUSEL Lab has local engineering that can help in excavation , safety and infrastructure issues.
5. Stepped program needed to test "table top R&D" can be translated to an experiment.

Schedule presented is ambitious assuming a fast start on the μ- booNE program.

The following presentations will show the stepped approach being taken for the R&D. (Test Stands, ArgNeut, μ- booNE)