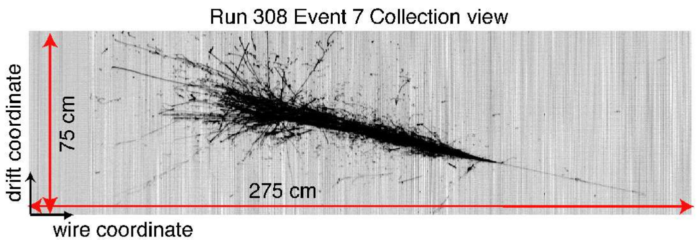
B.T.Fleming
HEPAP meeting
Feb. 24, 2008

R&D program and plan towards LArTPC program at DUSEL

- Baseline plan for LAr detectors at DUSEL
- Challenges for large detectors
- US R&D program to address these
- MicroBooNE, LAr5 as first steps towards big detectors

Why consider Liquid Argon TPCs.....

Liquid Argon TPC detectors for neutrino physics and nucleon decay

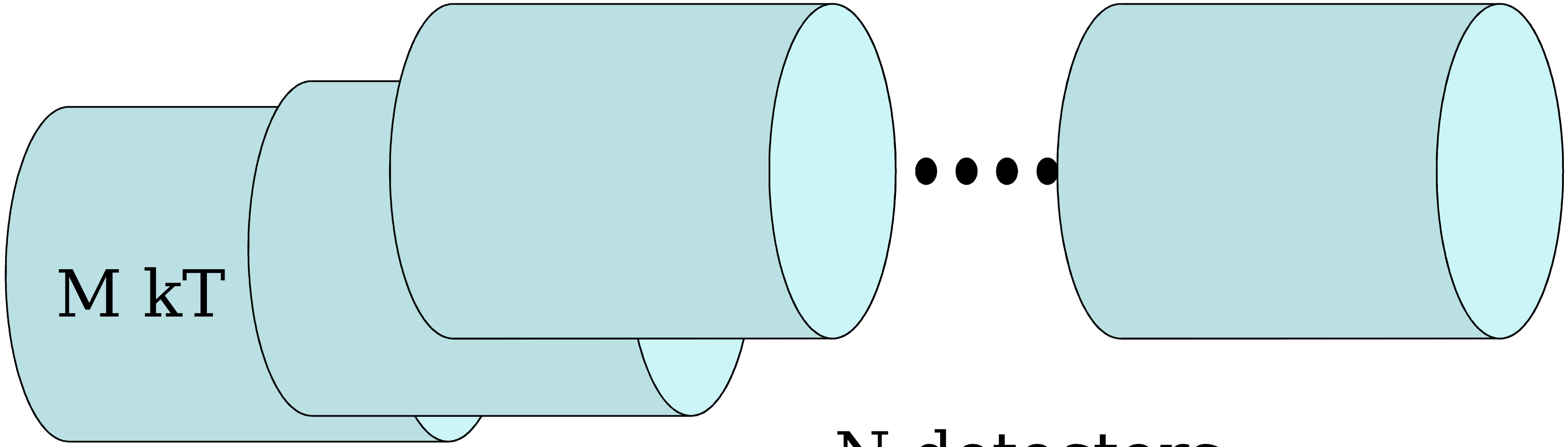


Unique Detectors
$\Rightarrow$ precision measurements in neutrino physics
$\Rightarrow$ appear scalable to large volumes

- Neutrino oscillation physics: significantly more sensitive than WC detectors.
  (~6 times more sensitive than WC technology
  translates into smaller volumes for same physics reach)
  background reduction in ν_e is difficult. Need powerful LAr detectors.....
- Proton decay searches
  - sensitive to $p \rightarrow \nu$ k
  - Extend sensitivity beyond SK limits with detectors 5kton and larger
- Supernova and solar neutrinos

Very large detectors have not yet been realized
-> need a program to get there....

Modularized Option



N detectors

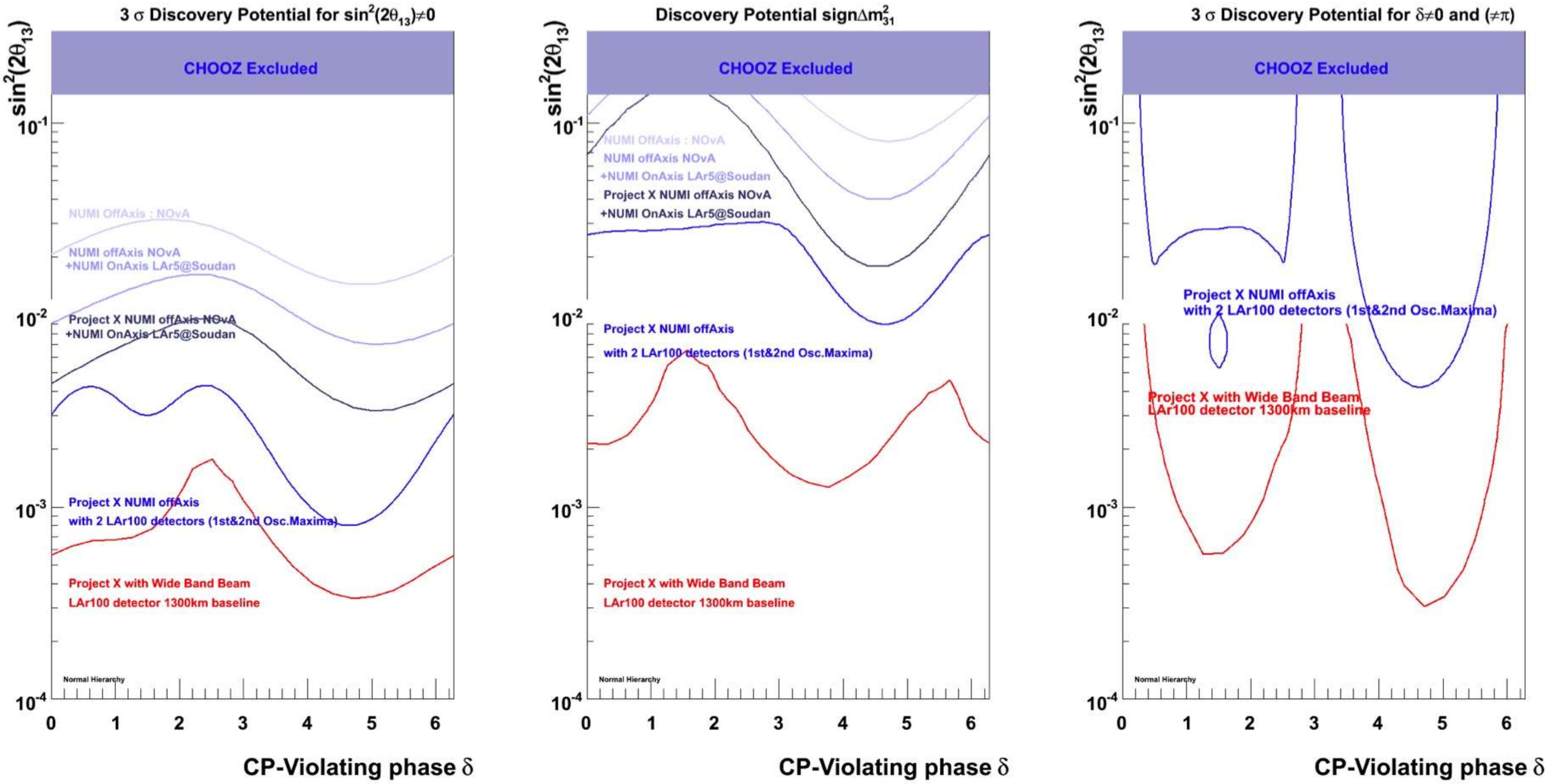
M x N = 100

100 > M > 5

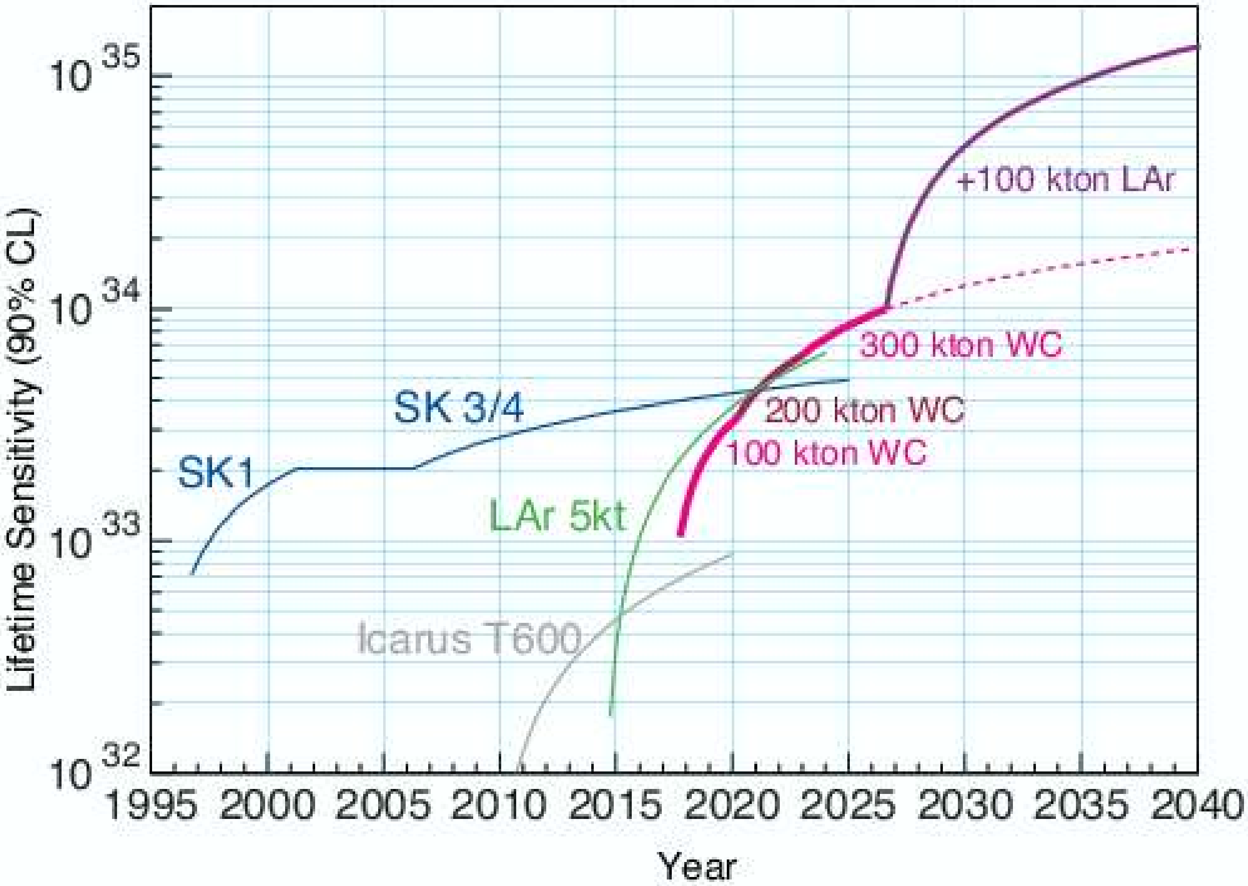
1 < N < 20

Optimize M & N against cost, schedule, technical feasibility, and safety

100 kton fiducial volume gives impressive physics reach for CP Violation search and proton decay



$p \rightarrow K^+\nu$



WC efficiency = 0.14
BG = 1.2 evts/100 kty
Nobs = Nbg

LAr efficiency = 0.98
BG = 0.1 evts/100 kty
Nobs = Nbg

Main challenges for massive LArTPCs

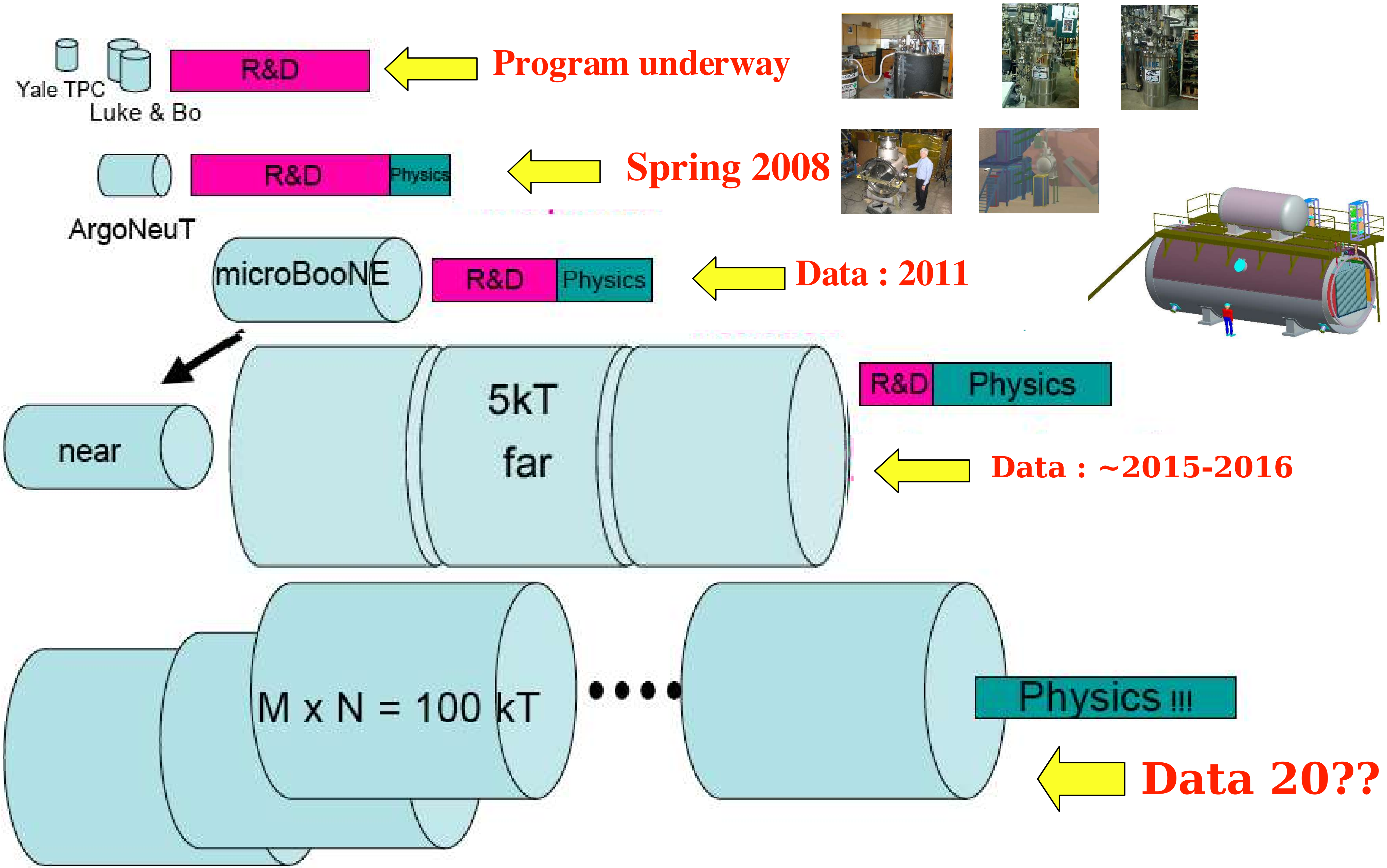
- **Purification Issues: large, industrial vessels**
  - Test stand measurements
  - Purification techniques for non-evacuatable vessels
  - Purity in full scale experiment
- **Cold, Low Noise Electronics and signal multiplexing**
  - Test stand measurements
  - Plan for R&D towards cold electronics
- **Vessels: design, materials, insulation**
  - Learn as we go in designing MicroBooNE
- **Vessel siting underground: safety, installation …**
- **Understanding costs of these detectors**

Working to address these within DUSEL WGs

US program to address these is moving along rapidly!
Ongoing R&D and plans for what more needs to be done….

Collaborations are growing and getting organized
→ building teams to do this work….

Liquid Argon TPC R&D program in the US

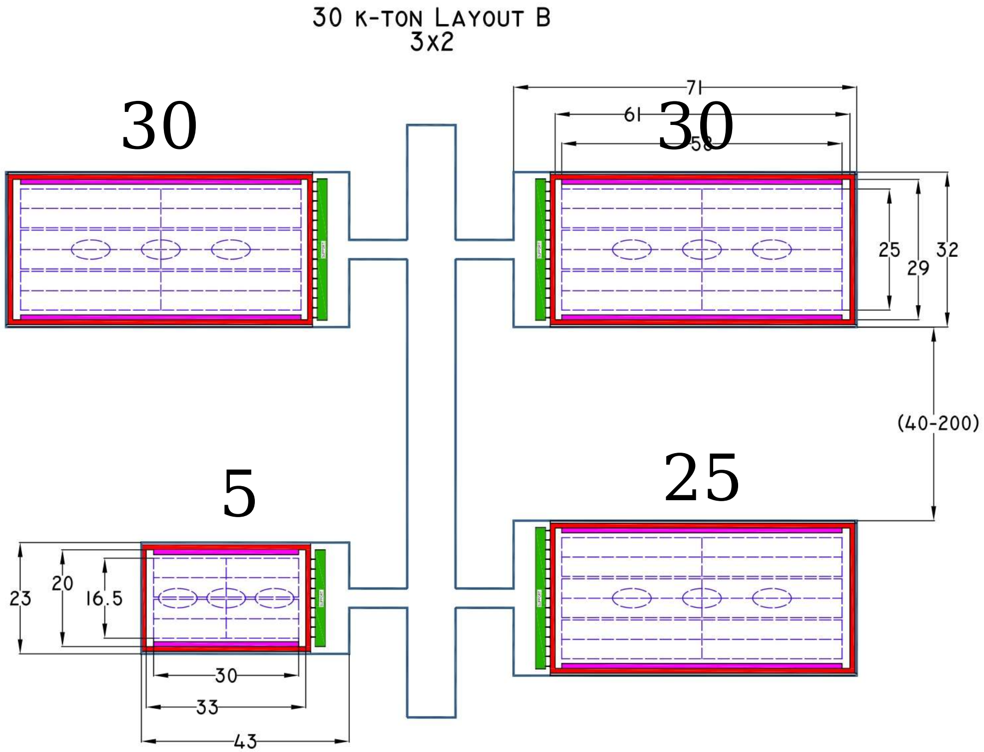


Over the last year, a plan has emerged from within the LAr community:

DUSEL LAr baseline plan for total detector mass of 90ktons comprised of smaller detector modules

5+25ktons
+ 30kton
+ 30kton

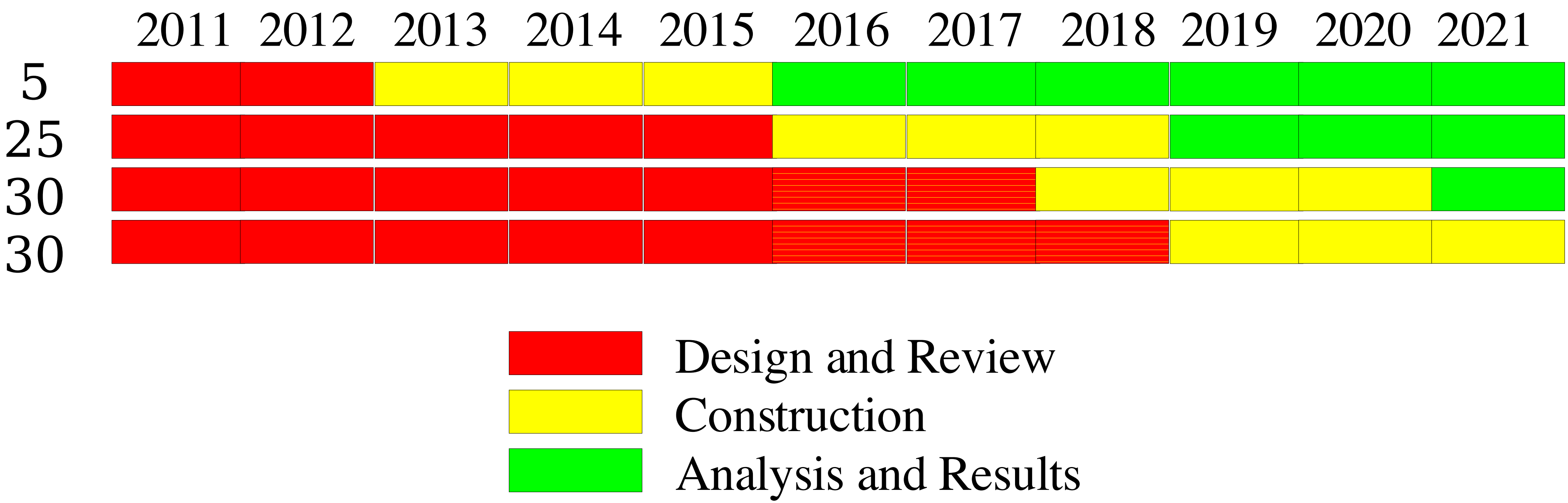
90ktons total



sited at 4850 ft level (see depth document)

Why modularized detector?

- Allows for first physics results early on
- Flexibility in construction and costs over time

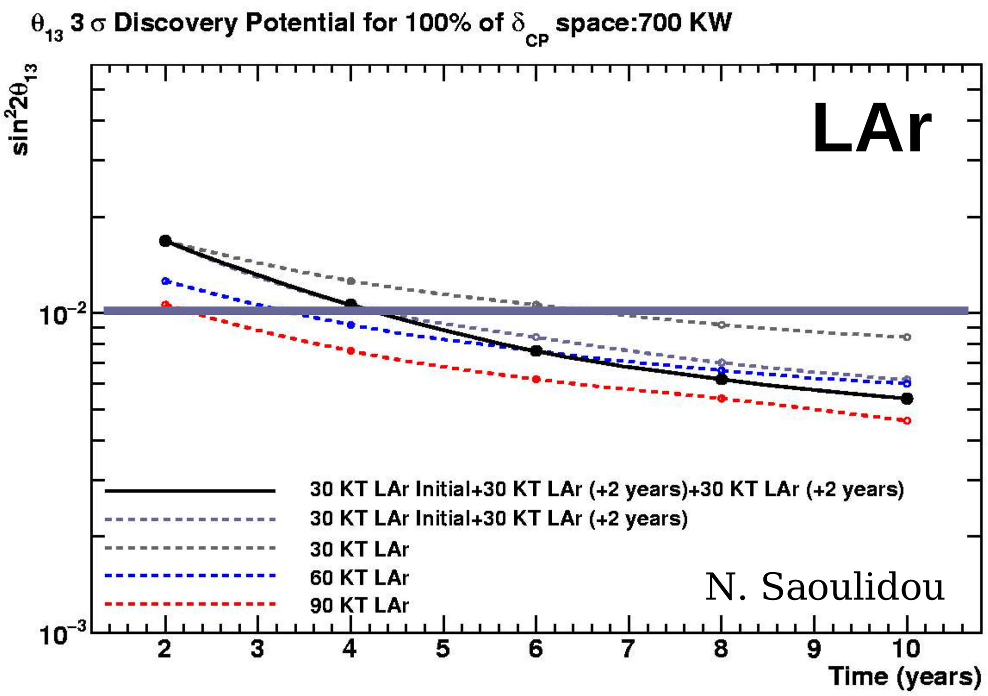


- Easier to protect against purity and safety problems
- Avoids some of the construction and cost issues of very large caverns
- Physics reach is nearly the same!

Sensitivities vs Time for LAr Detector: 700 kW beam

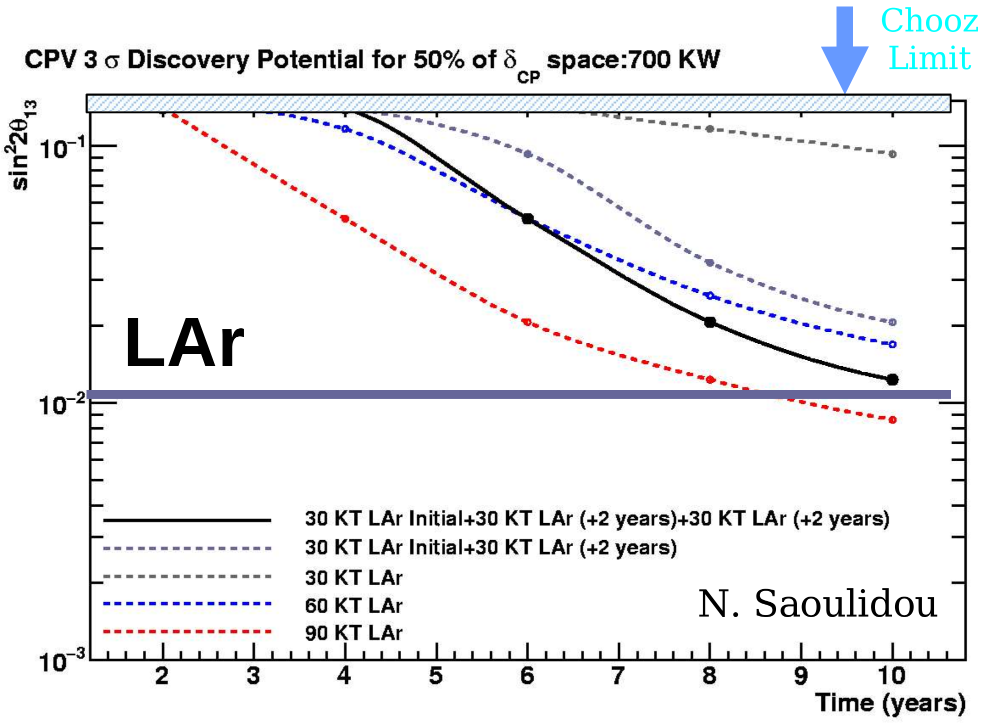
Add 30kton detector modules every 2 years for a total of 3 modules

θ_{13} Discovery Potential for all values of δ_{cp} (100%)



No significant reach is gained when starting from Day 1 with the total Detector Mass, compared to adding Modules every 2 years.

CPV Discovery Potential for 50% of δ_{cp}



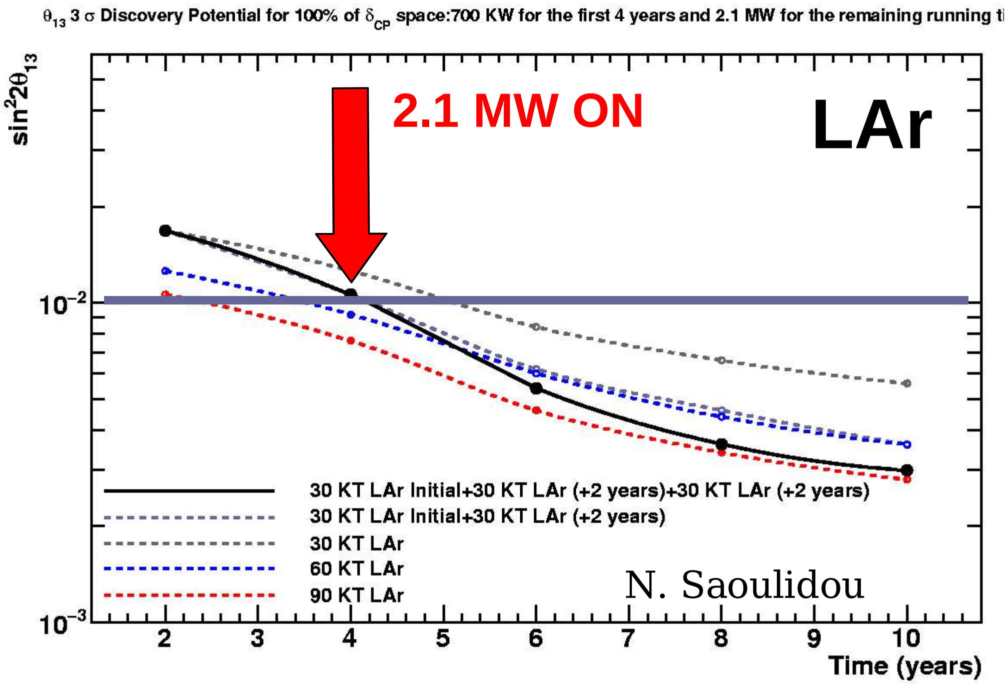
For CPV Discovery, LAr is sensitive beginning with running of first 30kton module

The WC – LAr mass equivalence is 1 – 6 (optimistic) to 1 –3 (very pessimistic)

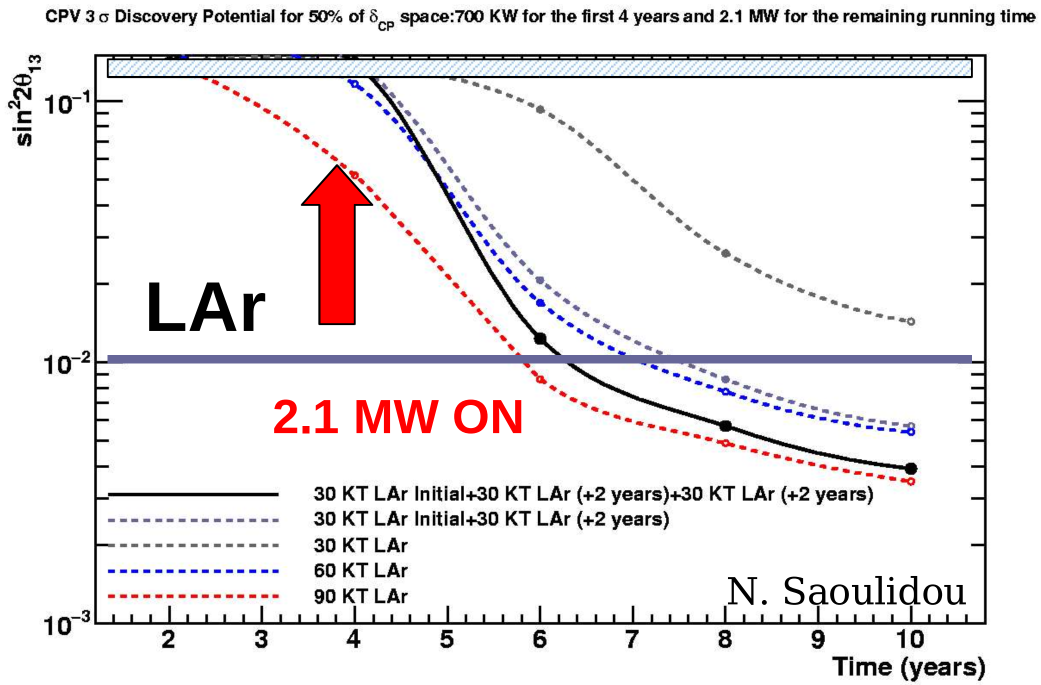
Sensitivities vs Time for LAr Detector: 700kW for first 2 years and 2.1MW for 6 years beyond this...

Add 30kton detector modules every 2 years for a total of 3 modules

θ_{13} Discovery Potential for all values of **δ_{cp}** (100%)



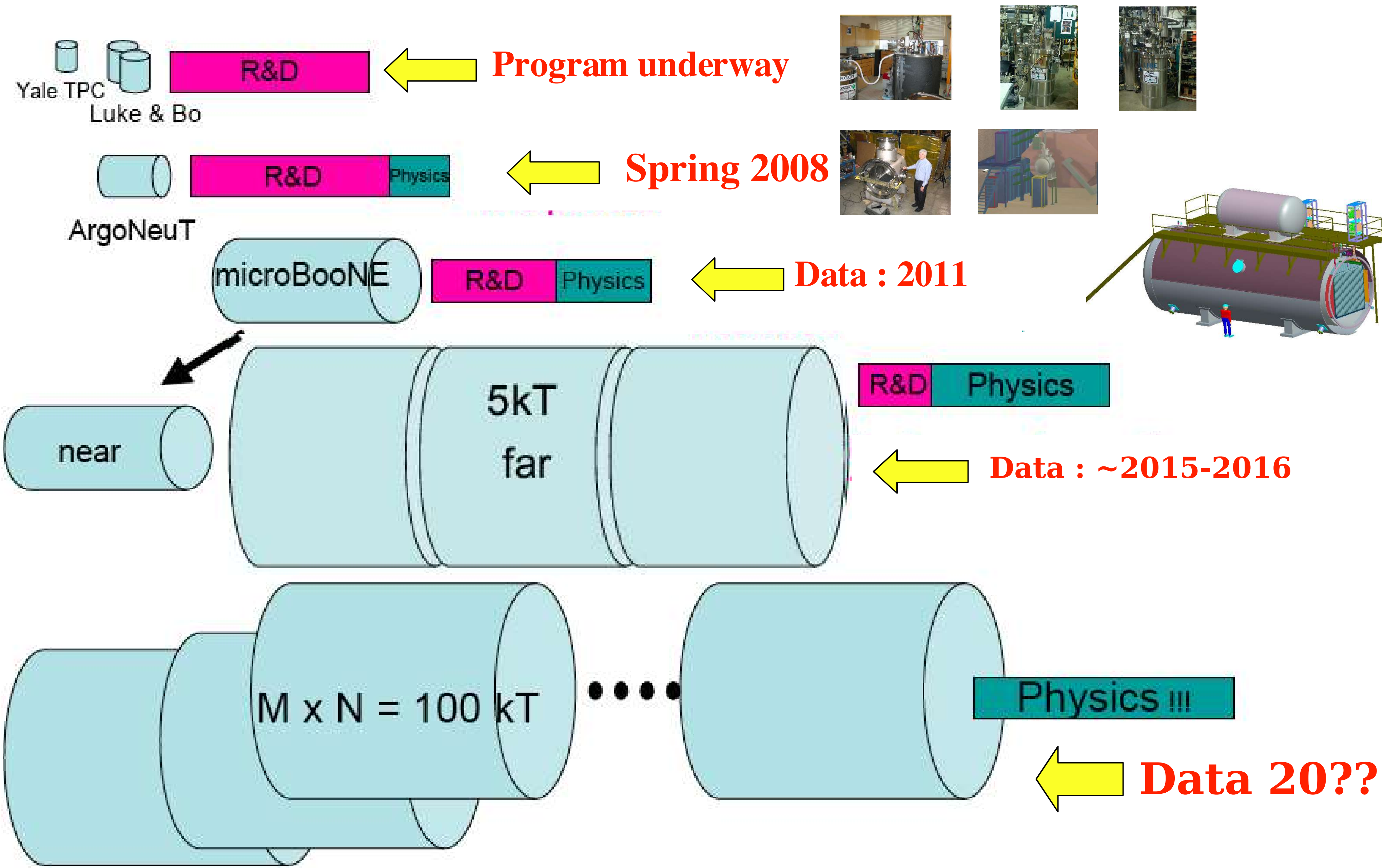
CPV Discovery Potential for 50% of **δ_{cp}**



Of course, reach improved with 2.1MW beam!

The WC – LAr mass equivalence is 1 – 6 (optimistic) to 1 –3 (very pessimistic)

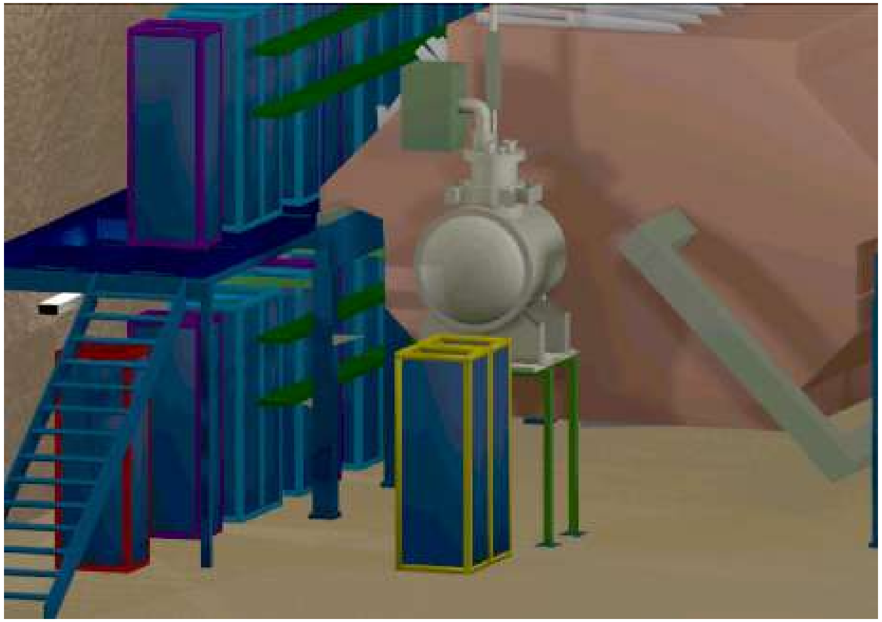
Liquid Argon TPC R&D program in the US



R&D | Physics

ArgoNeuT

Joint NSF/DOE project



0.3 ton active volume

0.5 x 0.5 x 1.0 m^3 TPC; 500 channels

- See neutrino interactions (~150 evts/day)
- Long term running conditions
- Underground siting issues

University of L'Aquila
F. Cavanna

Fermilab
B. Baller, C. James, G. Rameika, B. Rebel

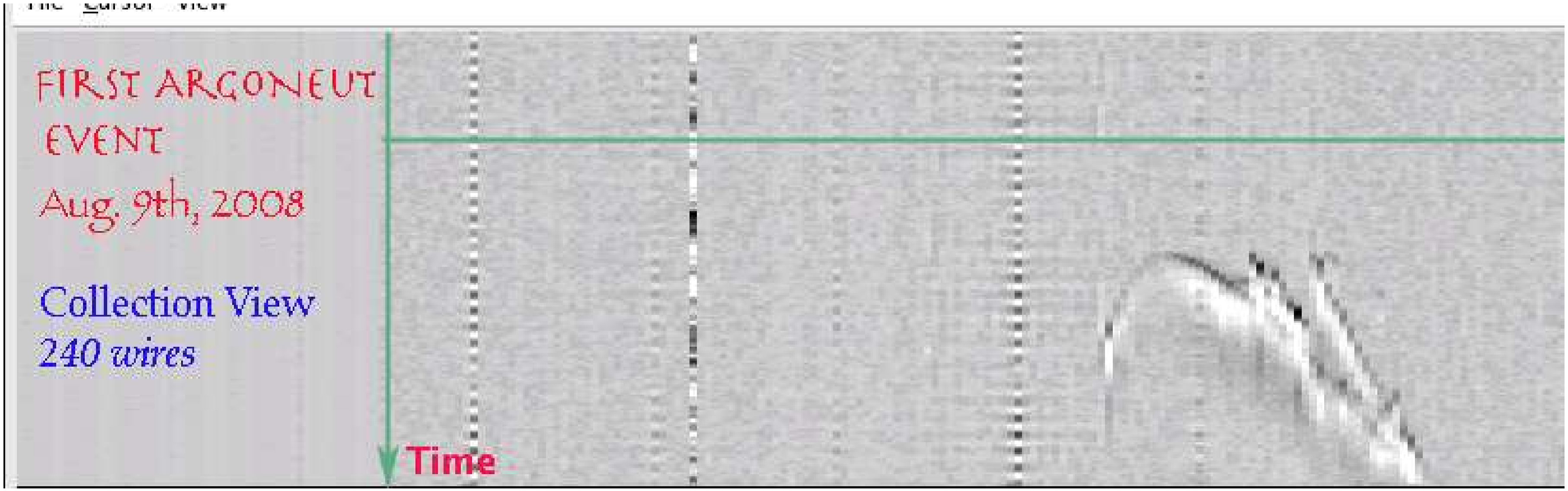
Gran Sasso National Lab
M. Antonello, R. Dimaggio, O. Palamara

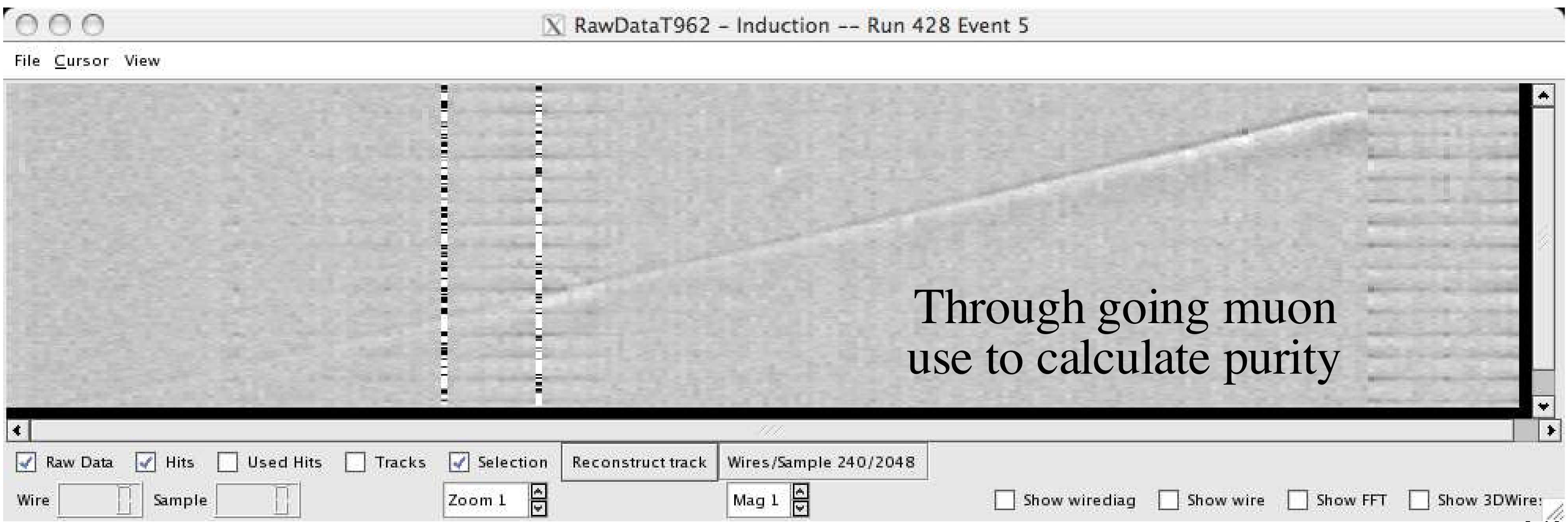
C. Bromberg, D. Edmunds, B. Page
Michigan State University

S. Kopp, K. Lang
University of Texas at Austin

Yale University
C. Anderson, B. Fleming*, S. Linden, M. Soderberg, J. Spitz
*=spokesperson

ArgoNeuT commissioned with LAr for first time on August 4th, 2008. First cosmic tracks seen on August 9th!





ArgoNeuT installation underground in January

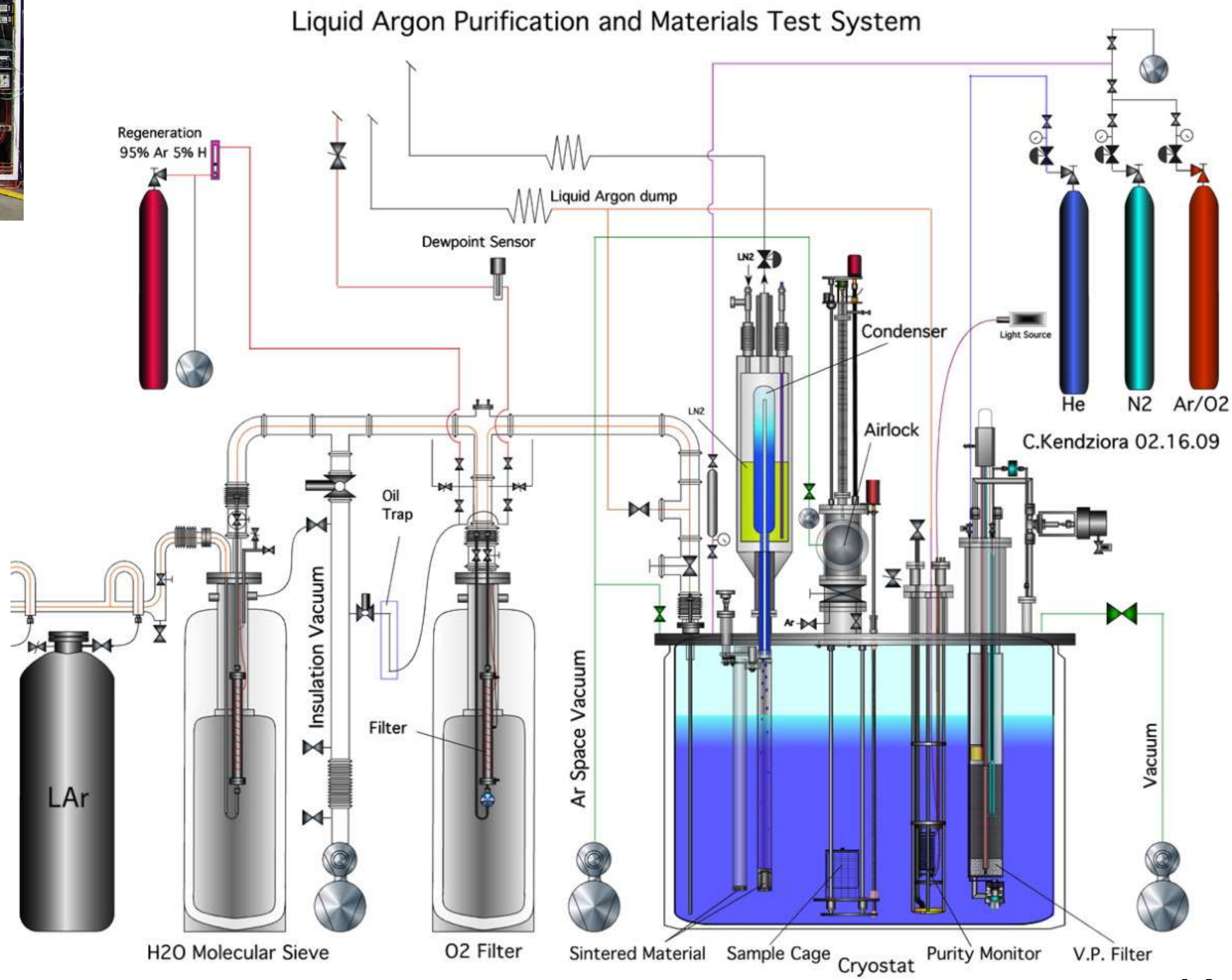
ArgoNeuT being lowered down the NuMI shaft

Wedged in between MINOS near detector and MINERvA

Will fill and start data taking soon

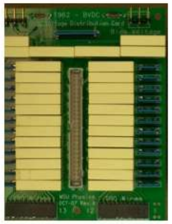
Fermilab Materials Purity Test Stand

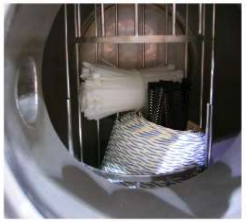
System to study the impact of different materials on purity and effectiveness of different purification techniques



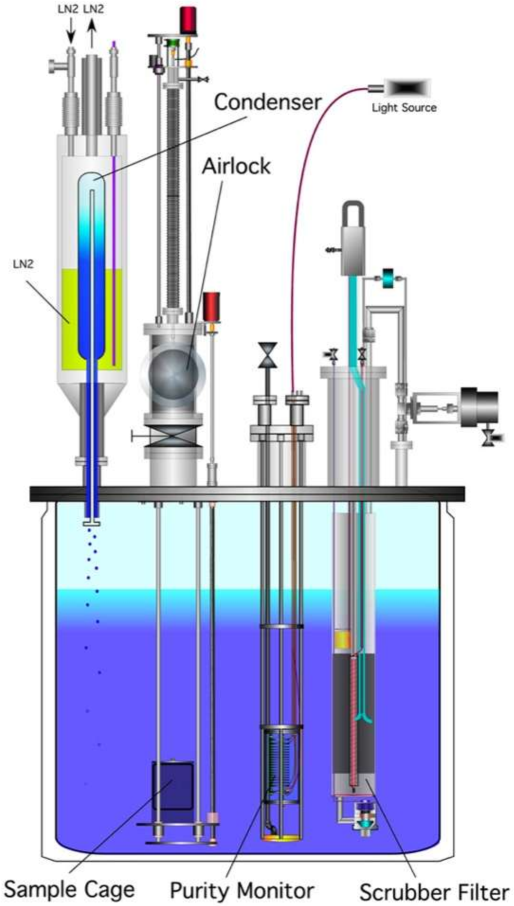
System is running and taking data using different filtering techniques and with samples of materials to be used in detectors

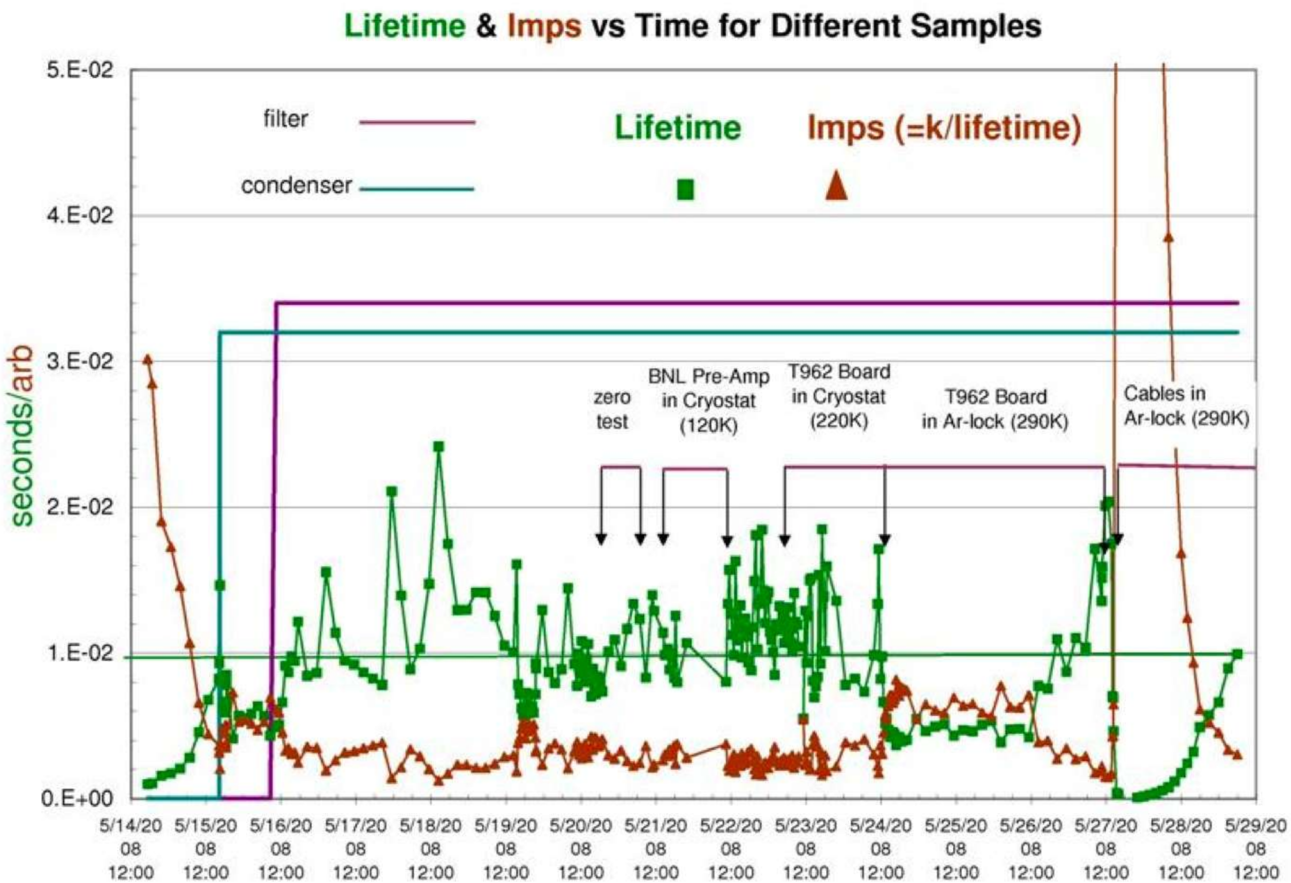

BNL 4-ch Amp


ArgoNeuT Bias Board


Cables/Cable-Tie Bundle

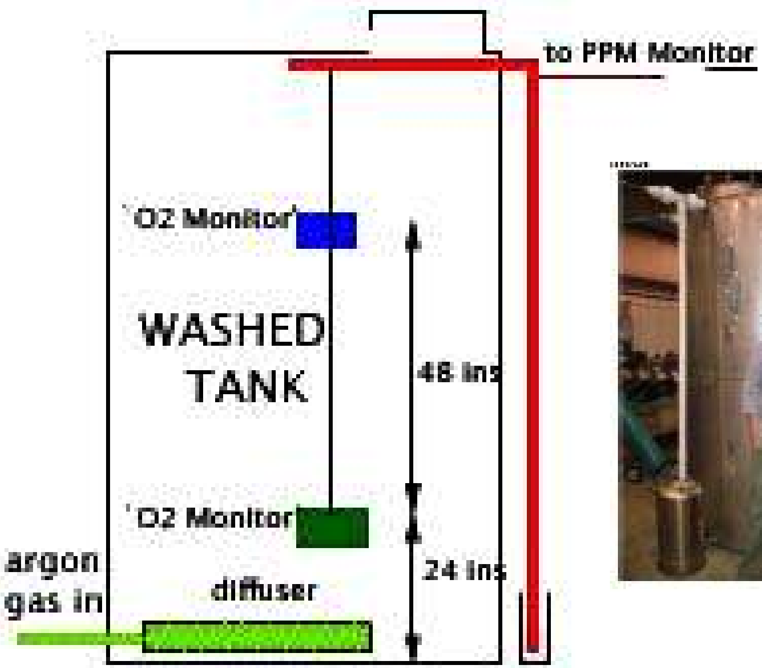
Measurements with the Materials Test System



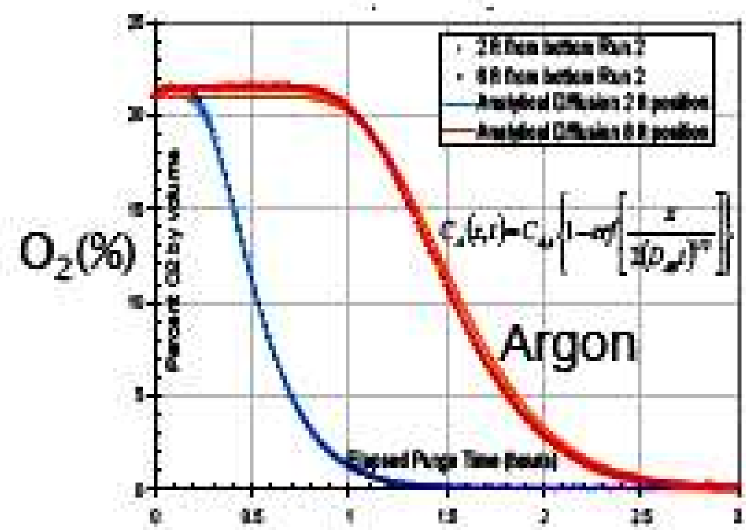


Achieving purity in an un-evacuatable vessel

- Test stand at FNAL
- 20 ton purity demonstrator
- MicroBooNE R&D program



Oxygen content vs. time



2.6 volume changes to reach 100 ppm O_2

- Flush tank with clean Argon gas
- Monitor level of O2 in tank as it is flushed

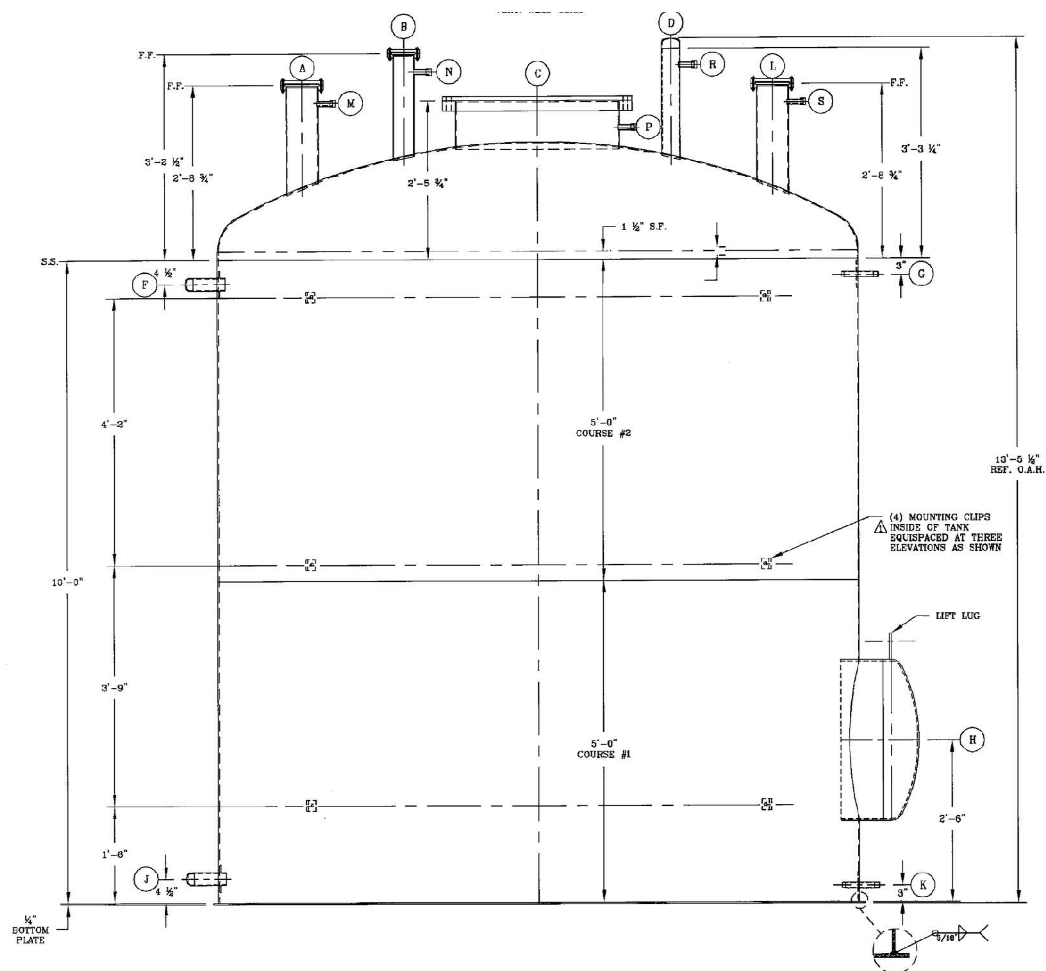
Achieve purity in un-evacuatable commercially built tank

- Clean with gas purge then liquid as getter
- Fill and purify in gas and liquid phases
- Achieve 10ms lifetimes (<0.1 ppb impurities)

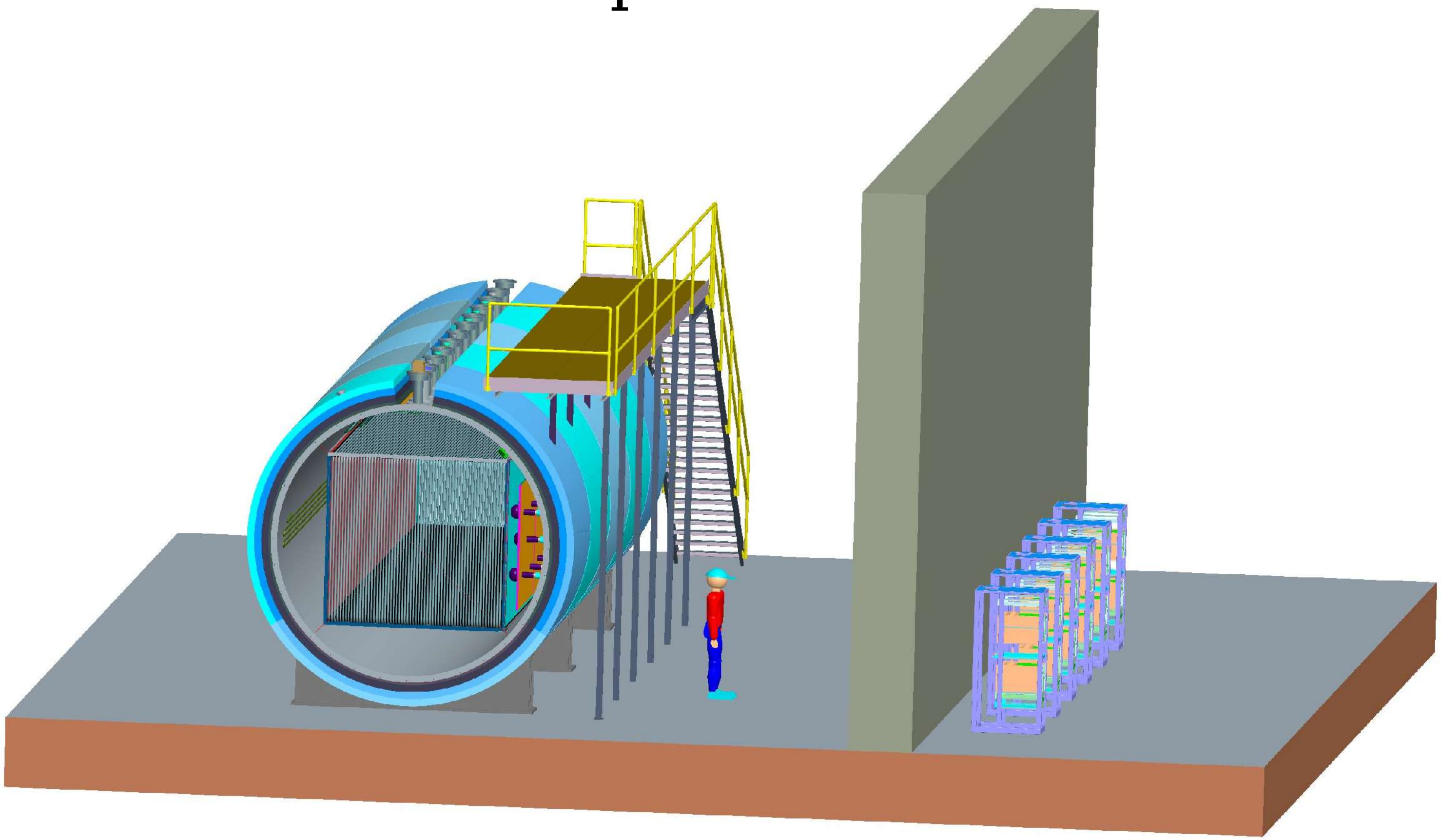
20ton purity demonstrator

smallest tank built using industrial techniques

Test underway: tank is being procured...



MicroBooNE purification program: Achieve purity without evacuation in full physics scale experiment



MicroBooNE Purge test: 6 week program to precede physics run

- 10 volume changes of GAr to reduce O_2 concentrations to 10 ppm
- Recirculate filtered gas or introduce small amount of LAr as getter and continue purification for ~1 month
- Introduce filtered LAr and test for purity

Cold Electronics Development

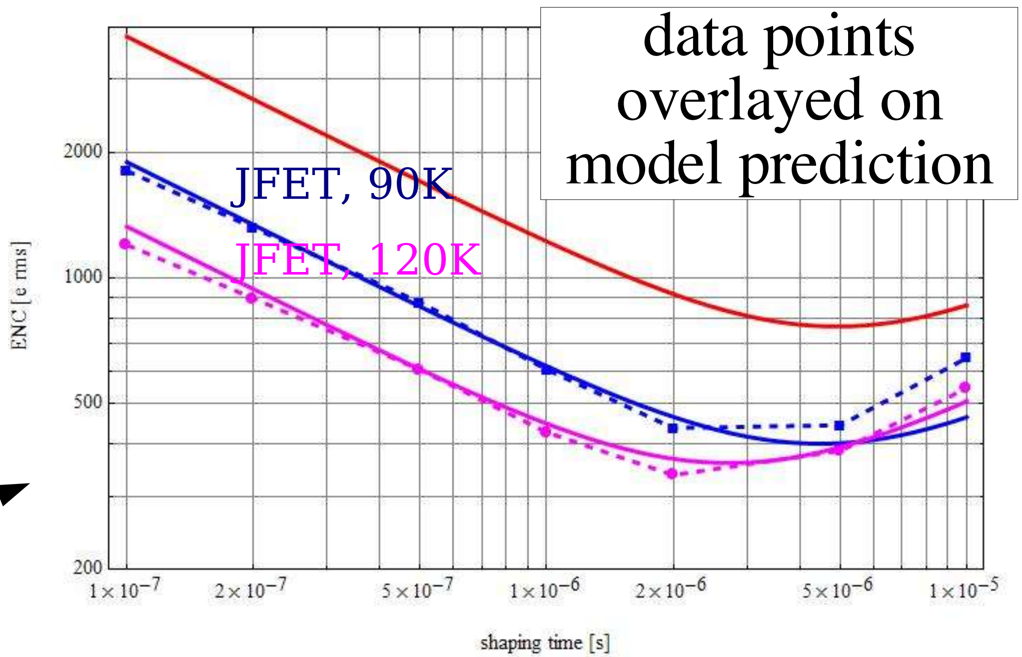
Need for Pre-amplification and multiplexing in LAr
- S/N requirements (need to limit capacitance to electrodes only)
- Geometry – must readout on the sides of the TPC (in LAr)
- Signal feedthroughs: must multiplex to avoid ~1M channels of readout (messy, heat leaks, ...)

Some experience in electronics in LAr but more needed for DUSEL scale detectors...

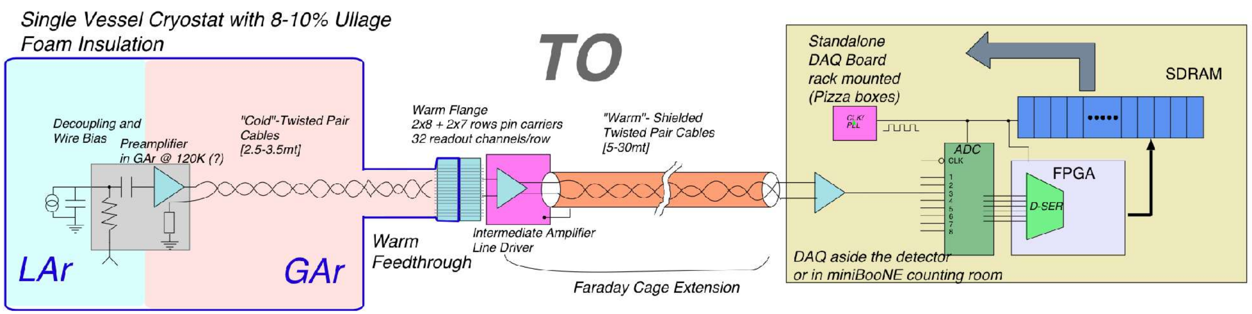
MicroBooNE readout electronics design

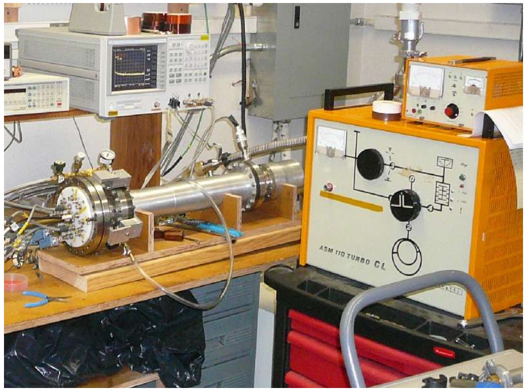
One step towards fully cold electronics....

JFET in GAr ullage:
- low noise at 1-2 μs shaping
- Study S/N levels expected in next generation LArTPCs



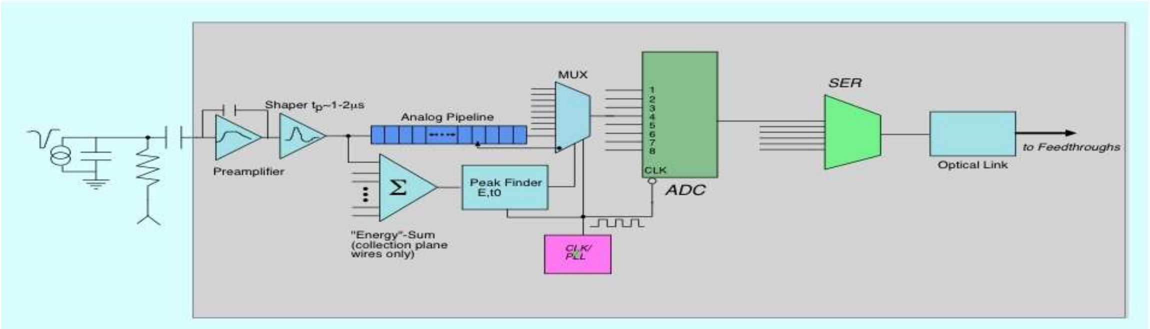
Bench tests of JFET hybrid at Brookhaven: room temp, 90K, 120K





Plan for developing CMOS technology for DUSEL detectors

Fully integrated ASIC with CMOS technology



Preliminary schematic of front-end

1. Investigate technologies and develop models for cryogenic operations

   6 months: up to end of 2008

2. Characterize analog & mixed-signals ASIC already developed towards cryogenic operations:

   3 months

3. Select Technology and develop test structures and sub-circuit (analog and digital): 2-3 fabs

   18 months: beg 2009 / mid 2010

4. Develop readout architecture (charge amplification in current-mode, processing, sampling, storage, multiplexing….)

   3 months

5. Develop ASIC (might be in functional blocks: low-noise, low-power analog, mixed signal readout): 2-3 fabs

   24 months: mid 2010 / mid 2012

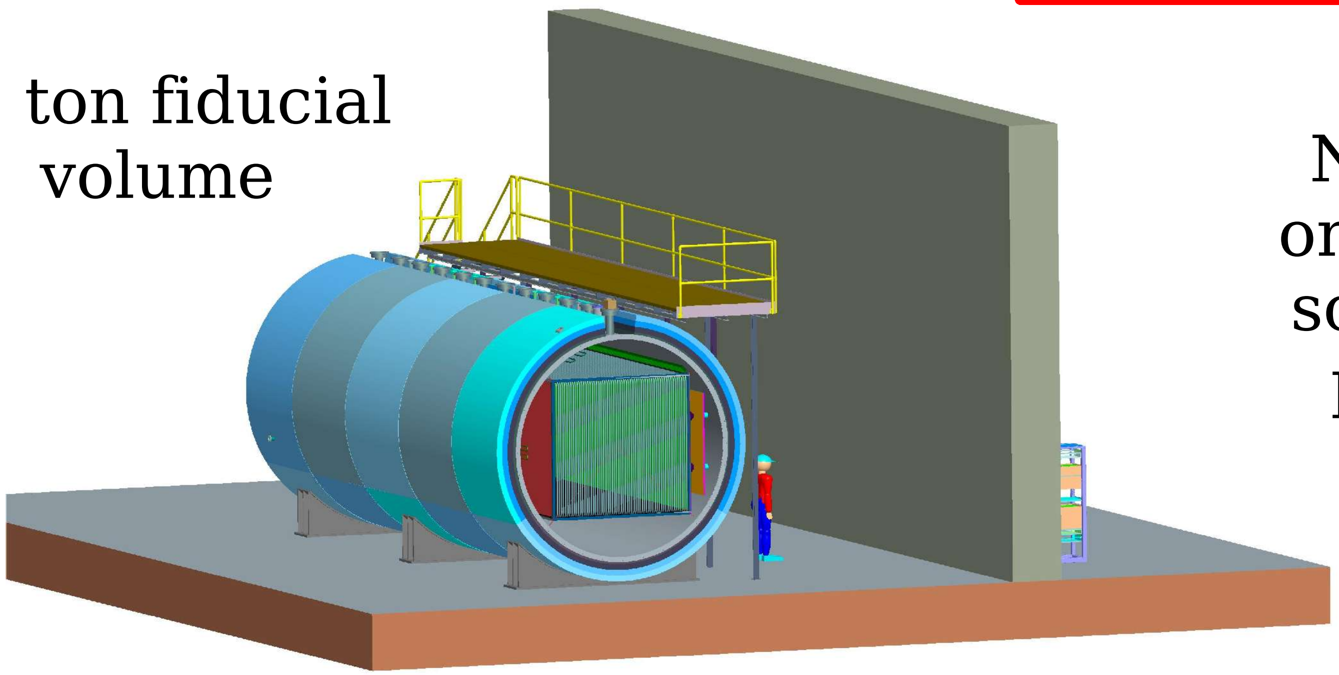
R&D	Physics

MicroBooNE: Full scale experiment R&D towards DUSEL scale detector

- **Purity in a non-evacuated vessel**
- Full systems test of **low noise electronics**
- **Physics Development**
  - See fully contained ν interactions
  - Simulation, reconstruction, analysis
- **TPC Design**

Running detector and physics analysis of real data provides the best way to understand detector strengths and shortcomings

70 ton fiducial volume



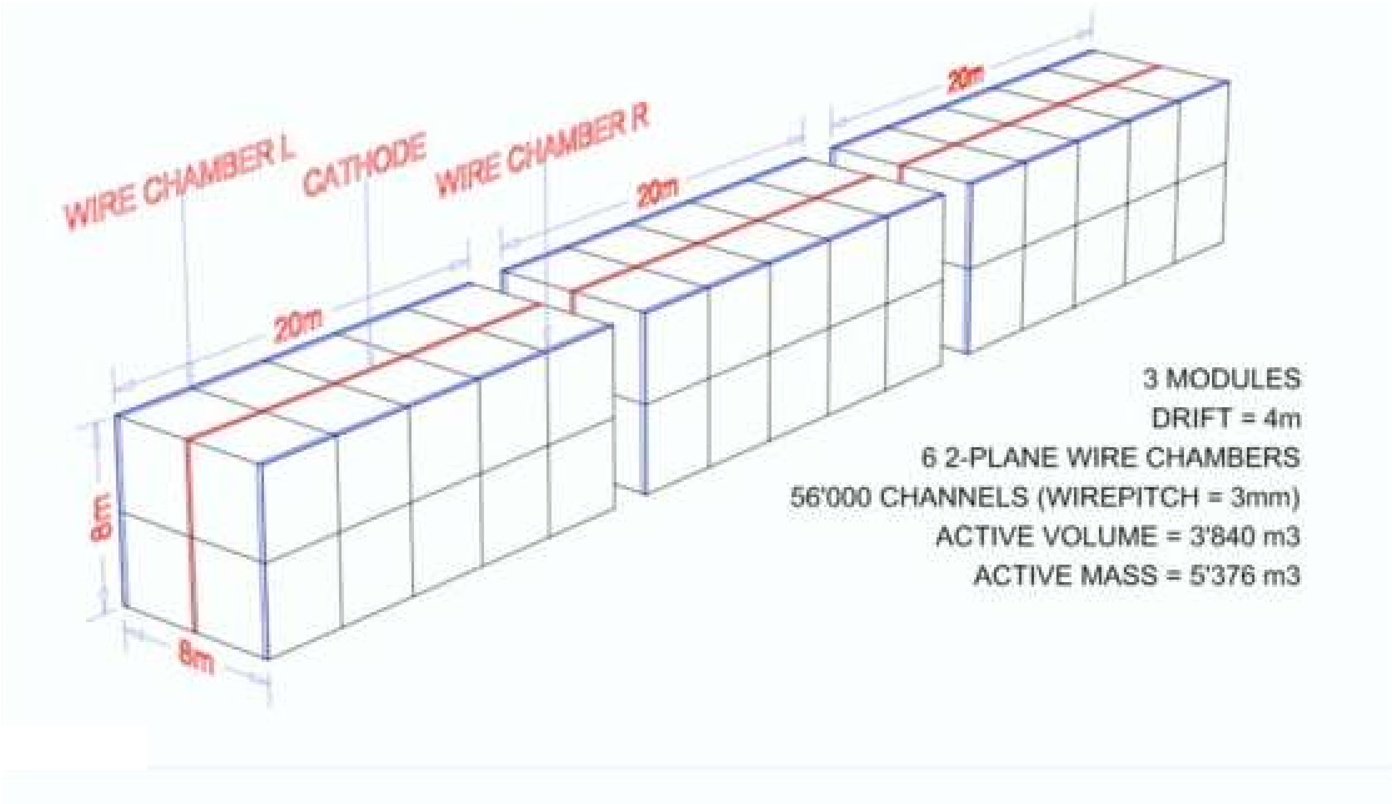
Need to push on MicroBooNE schedule to be prepared for DUSEL!

Next step beyond MicroBooNE, 5ktons at DUSEL

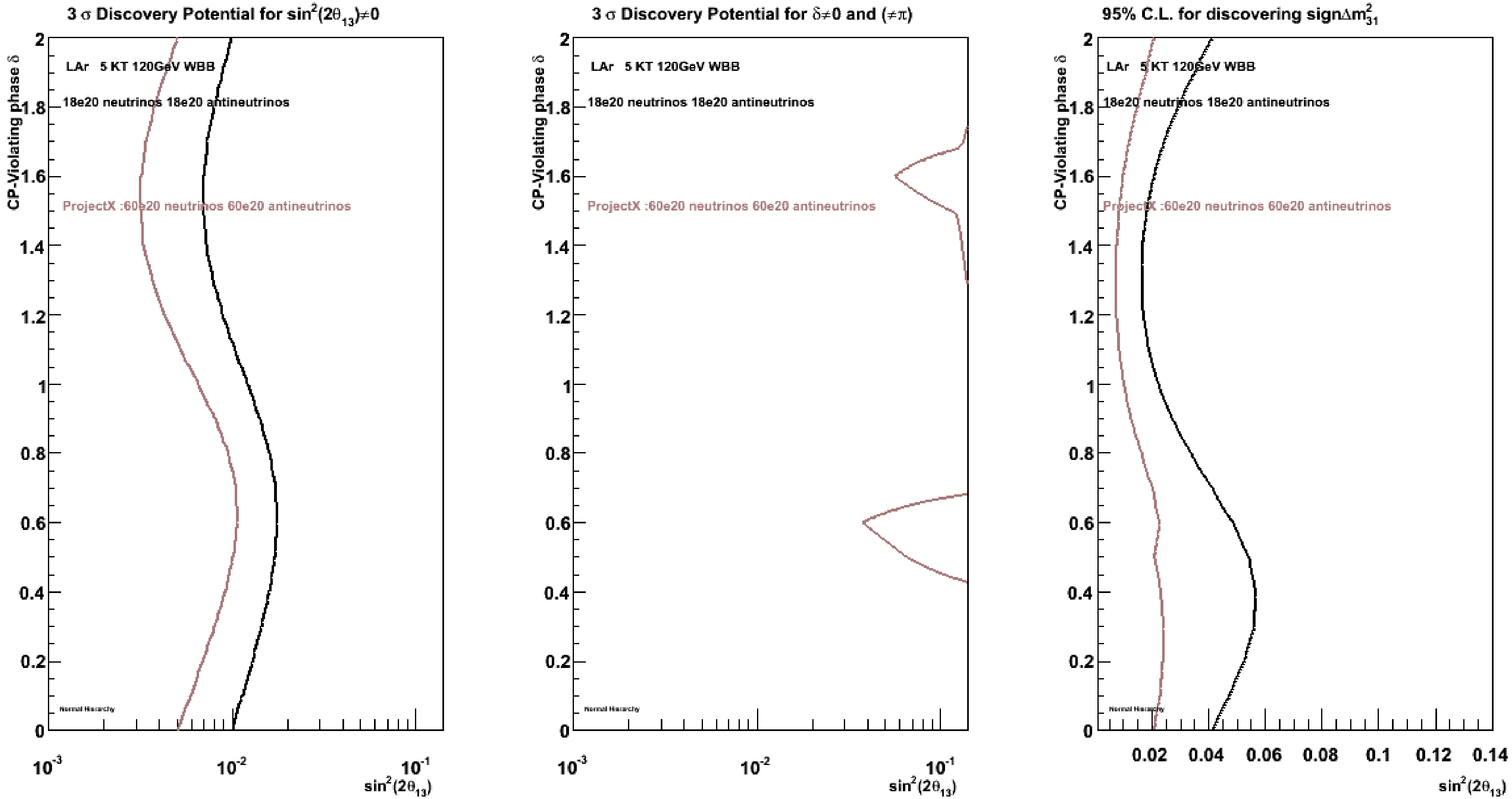
Why 5kton?

- Good physics reach
- sized well for ISE at DUSEL – get started soon!
- Appropriate step in size beyond MicroBooNE
  technically a reasonable step.....

5kton
Concept
(D. Cline,
F. Sergiampietri)

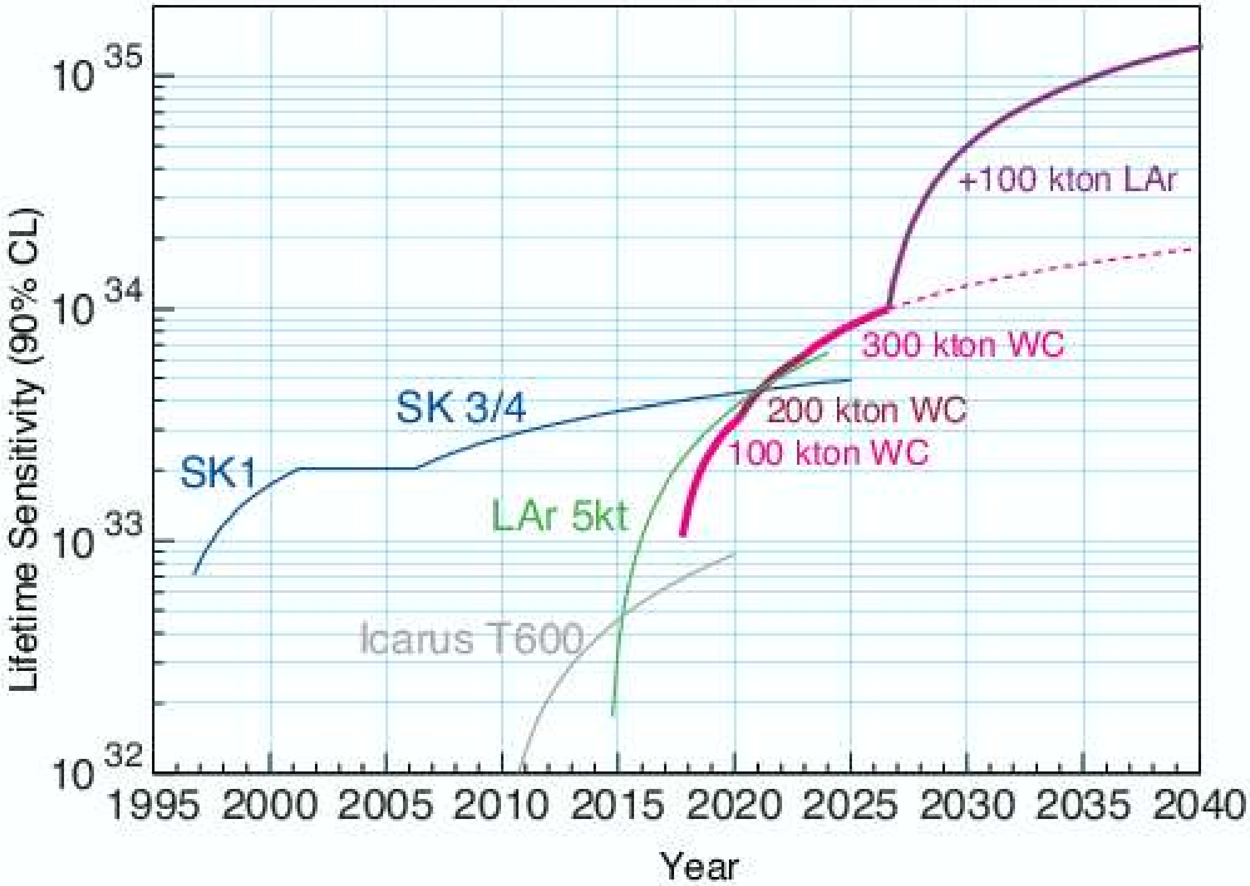


Physics reach of 5ktons



N. Saoulidou

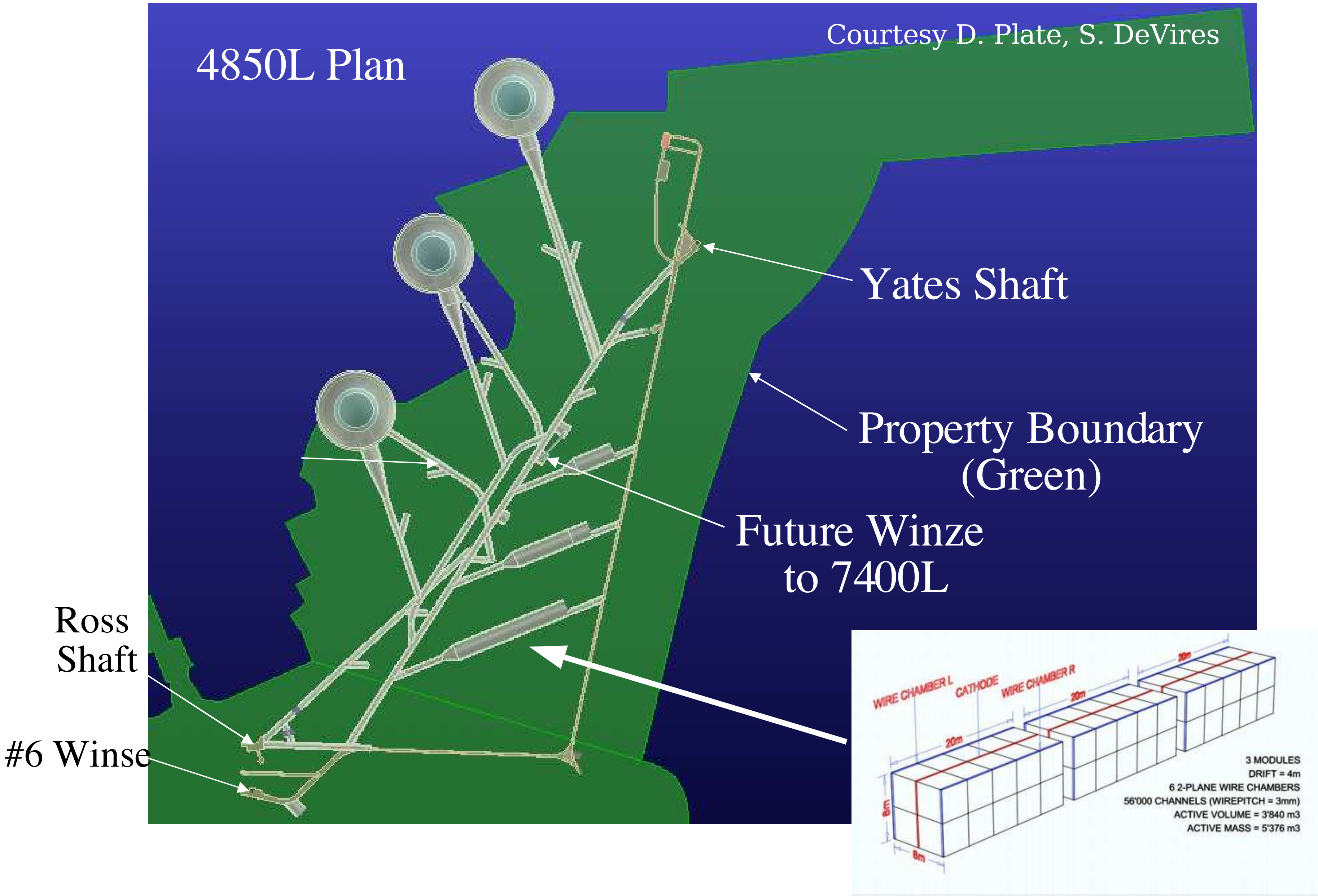
$p \rightarrow K^+\nu$



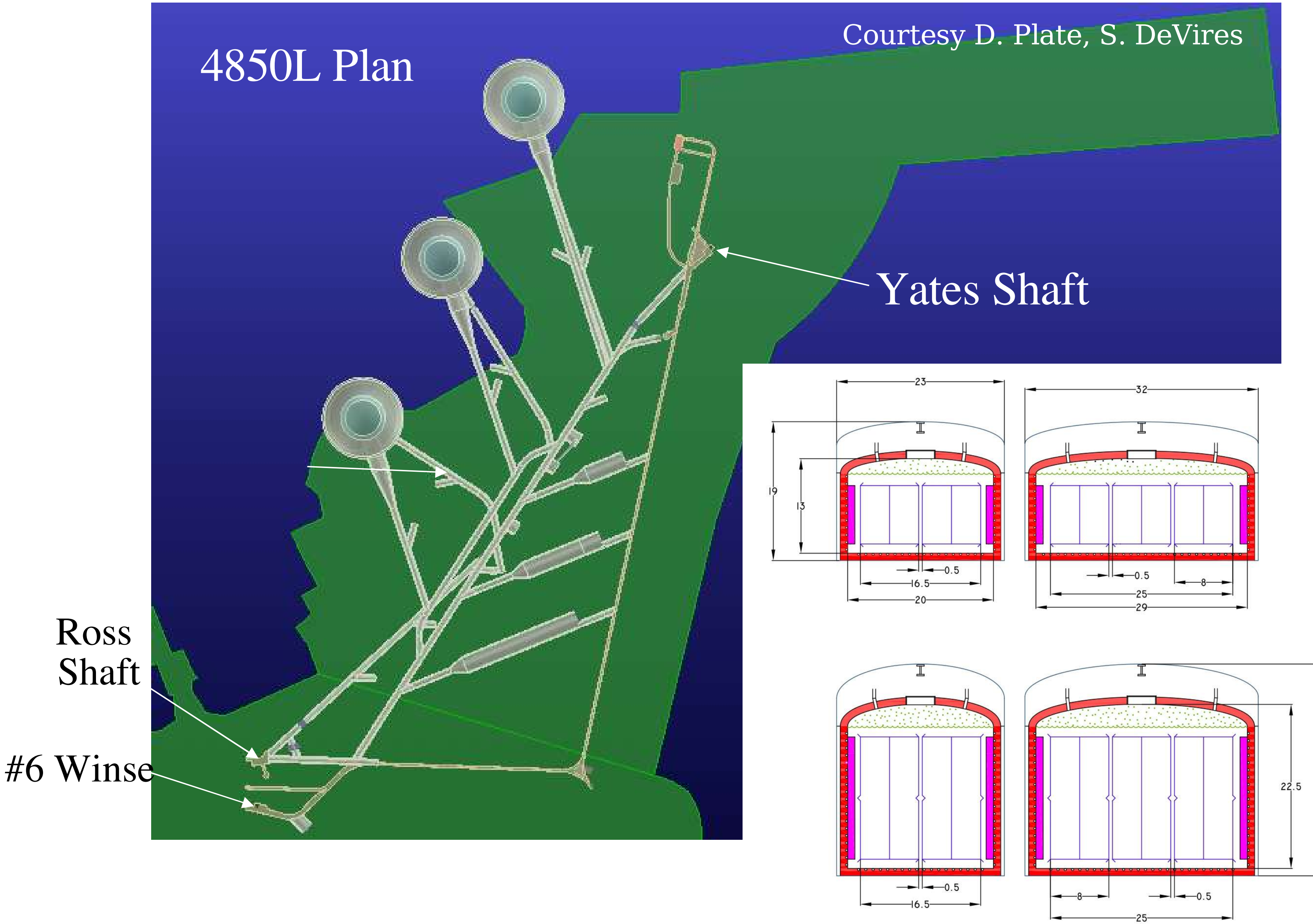
WC efficiency = 0.14
BG = 1.2 evts/100 kty
Nobs = Nbg

LAr efficiency = 0.98
BG = 0.1 evts/100 kty
Nobs = Nbg

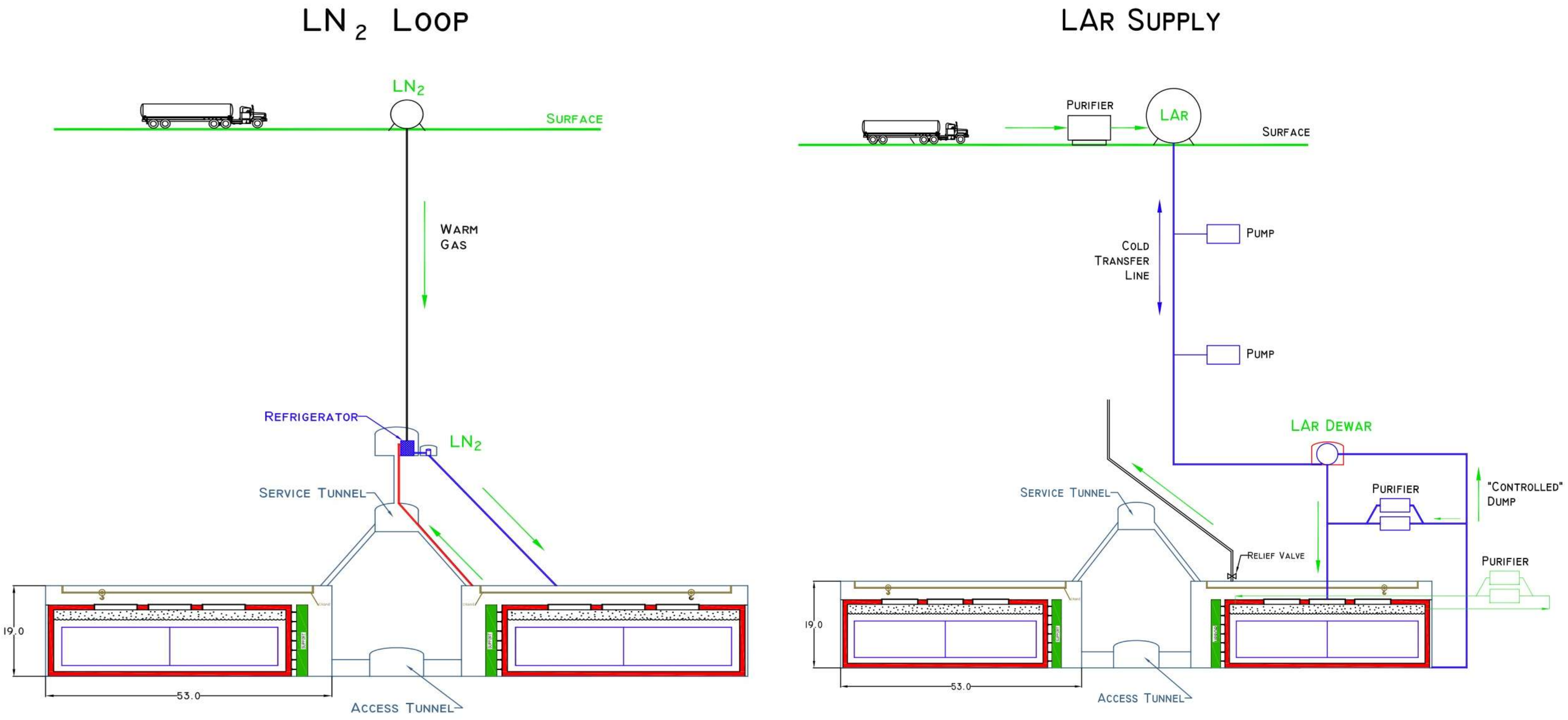
Underground caverns for DUSEL experiments
5kton fits in the largest of the caverns planned for the ISE



Further excavation for modules beyond the 5kton needed



Initial Concepts for Cryogenics Underground



Underground Safety issues:

LAr loss: 0_2 content, reduction of temperature

Mitigation:

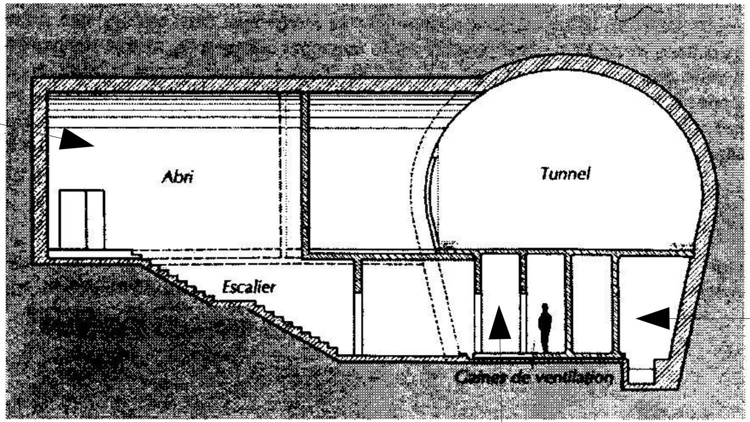
- Design: Use best cryo-techniques to minimize leaks
- Egress/Shelter: In cavern and from cavern

Experience from LNGS industry on bulk transport and storage

Mont-Blanc Safety upgrade

Refuge Shelter with fresh air

Ventilation ducts



Smoke extraction

- Ventilation: Dedicated exhaust shaft
- Freeze/thaw damage: placement and insulation

Understanding Costs:

One of the main focuses of the LAr subgroups
to go hand in hand with design over
the upcoming year

Already ⇒ a number of preliminary costing studies
for massive LarTPCs

Rule of thumb: about equal costs for

- Liquid Argon
- Cryostat/Cryogenics
- Inner detector (TPC/electronics)

100ktons LAr ⇒ $100 M
total cost ⇒ $300 M

Biggest challenges: understanding cost related to
underground siting (ship in a bottle) and
cost per channel of electronics (>1M channels!)

A lot underway, still a lot to do.....

Interest level in LAr program is growing rapidly in US!

- Test stand program: FNAL, BNL, and universities
- MicroBooNE: nearly doubled in size to 50+ scientiests since approval in July 2008
- LAr subgroup of LB to DUSEL collaboration
  - Rapidly growing collaboration list
  - Organizing into collaboration structure, for example...

S4 proposal to the NSF to fund R&D related to underground siting at DUSEL! →

Group Conveners :

Physics Reach: Niki Saoulidou

Cryostat and Cryogenics: Jon Urheim

TPC/PMT/HV: Bo Yu, Hanguo Wang

Electronics: Francesco Lanni

Team of people to push this effort is strong and expanding!

Growing support for the effort is needed to stay on an aggressive timescale...

Baseline plan for 90ktons of LAr gives impressive reach in physics!

While massive LArTPC detectors seemed far off a few years ago – progress in US has proceeded very rapidly...
still lots of R&D to do but on a timescale that is do-able for DUSEL physics

5kton is a great way to start the program!
Fits in the caverns for the ISE physics early on....

Pushing on the timescale for MicroBooNE and finding resources for developing LAr5 will keep the program on this timescale!