

# LBNF Preparing for Construction



**David Lissauer**  
**Brookhaven National Lab.**

D. Lissauer, LBNF Collaboration Meeting

1/22/2015

© 2008 Tele Atlas  
Image © 2008 TerraMetrics  
© 2008 Europa Technologies  
Point: 43°03'56.44" N 95°10'42.53" W Streaming 100%

Eye alt: 1108.62 km

# *What is this talk about?*

- ❖ *A Straw-man Proposal of Scope and Organization for LBNF construction in light of*
  - *International collaboration with many institutions contributing to the near and far detectors construction*
  - *“distributed” construction responsibilities*
  - *A non-standard project organization (for the US)*
- ❖ *Straw-man proposal – is presented to promote discussion! By definition of a “straw man”, is intended to be "knocked down" by something more substantial when that is available.*
- ❖ *Lets focus on the main elements of this plan and not on the small details*

# *What is this talk about?*

❖ *It aims to follow the FNAL director guidelines:*

- *Phased construction starting with a 10 k-ton Far Detector (FD) LAr TPC, followed by additional ~30 k-ton LAr TPC.*
- *Near Detector (ND) technology and thus the design is open.*
- *CDR for 10 k-Ton LAr TPC by fall of 2015.*
- *TDR for the first 10 k-ton by winter of 2016.*
- *Ready to start construction in 2017.*

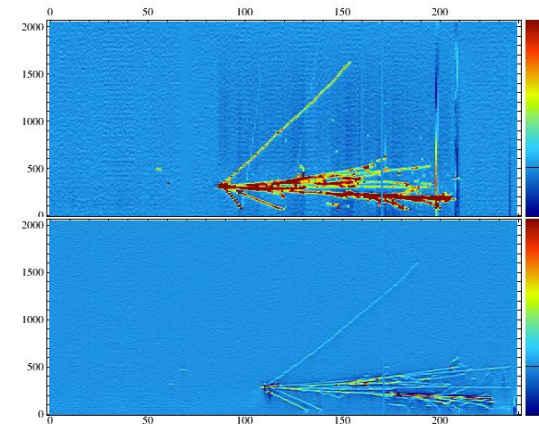
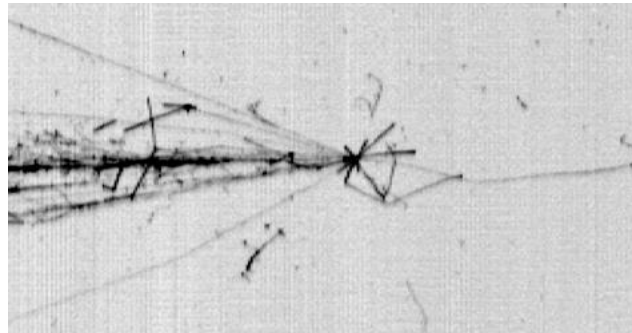
**Dates are soft and might change.**

*NOTE: LBNE and LBNO already had significant part of the ingredients in the plan. This overview will try to emphasis what is needed to start the construction of E-LBNF.*



# Outline

- ❖ “Straw-man” organization of E-LBNF – “Mapping” the LHC model
- ❖ Science Working Groups
  - ❖ Physics, Analysis Tools, Performance
- ❖ Scope of work – (some of ) the tasks ahead
  - ❖ Near Detector
  - ❖ Far Detector
- ❖ Detector Technology Working Groups – “deliverable” matrix.
- ❖ “Distributed construction” model
- ❖ Conclusions



# *“Mapping” LHC to LBNF*

## *❖ The LHC experiments and LBNF have similarities:*

- Both are “international” projects with significant contributions from multiple funding agencies.*
- Large scope coupled with limited or no access require a high level of planning, value engineering, organization and QA/QC.*
- The cost structure varies between the different funding agencies. Resource optimization requires flexibility.*

## *❖ However -*

- Differences exist - thus the mapping should not be one to one.*
- This “straw-man” plan could help in framing the discussion – done right the Future Circular Collider (FCC) experiments will use the LBNF model as a starting point for their organization..*
- The model will evolve as the collaboration takes shape and builds its own unique culture.*

# *Collaboration Responsibilities I*

---

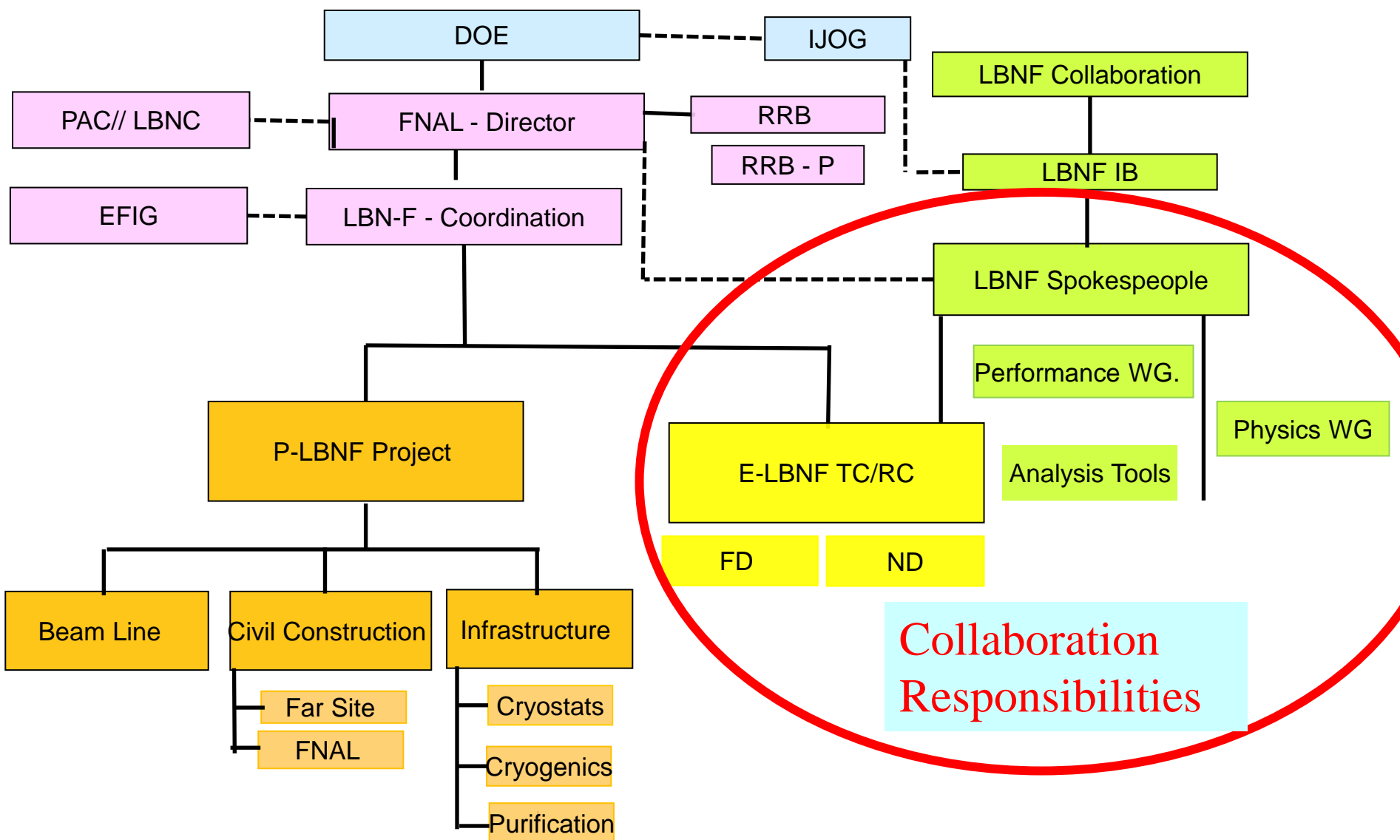
- ❖ *The collaboration responsibilities and thus the principle involvement of the collaborating institutions are via working groups in two main “streams”: Scientific and Technical/Resources.*
- ❖ *Scientific stream include: Developing and defending the scientific case, detector performance specifications, tools for detector optimization (e.g: Tracker granularity, size of veto regions, data compression algorithms), preparation for data analysis.*
  - *The Scientific stream involve mainly physicists with the support of a relatively small professional computing staff.*
  - *The Physics and Performance working groups are critical at this stage to finalize the design.*

# *Collaboration Responsibilities - II*

❖ *Technical Stream: included the design, prototyping construction, integration and installation of the experiment.*

- *Construction is “distributed” and is mainly the responsibility of collaborating institutions (and funding agencies) formalized by an MOU.*
- *The ATLAS Technical Coordinator (TC) and Resource Coordinator (RC) with a dedicated Project Office staff monitored the progress of the construction, organized common items and were responsible for integration and installation of the experiment.*
- *Monitoring by TC included technical progress, QA/AC and were done in Design Reviews, Production readiness reviews and Progress review.*
- *The funding agencies conducted their own reviews with TC participation. They reviewed the cost and status of their specific responsibility. TC intervened if there were serious issues.*
- *Large items (Common Funds) were done mostly through CERN engineering and or other large National Labs that took on responsibility for delivering part of the infrastructure. (e.g. Toroid Magnets was done at CERN, Solenoid KEK, Barrel Cryostat BNL, EC Cryostat – IN2P3)*

# Mapping the High Level Organization - LBNF



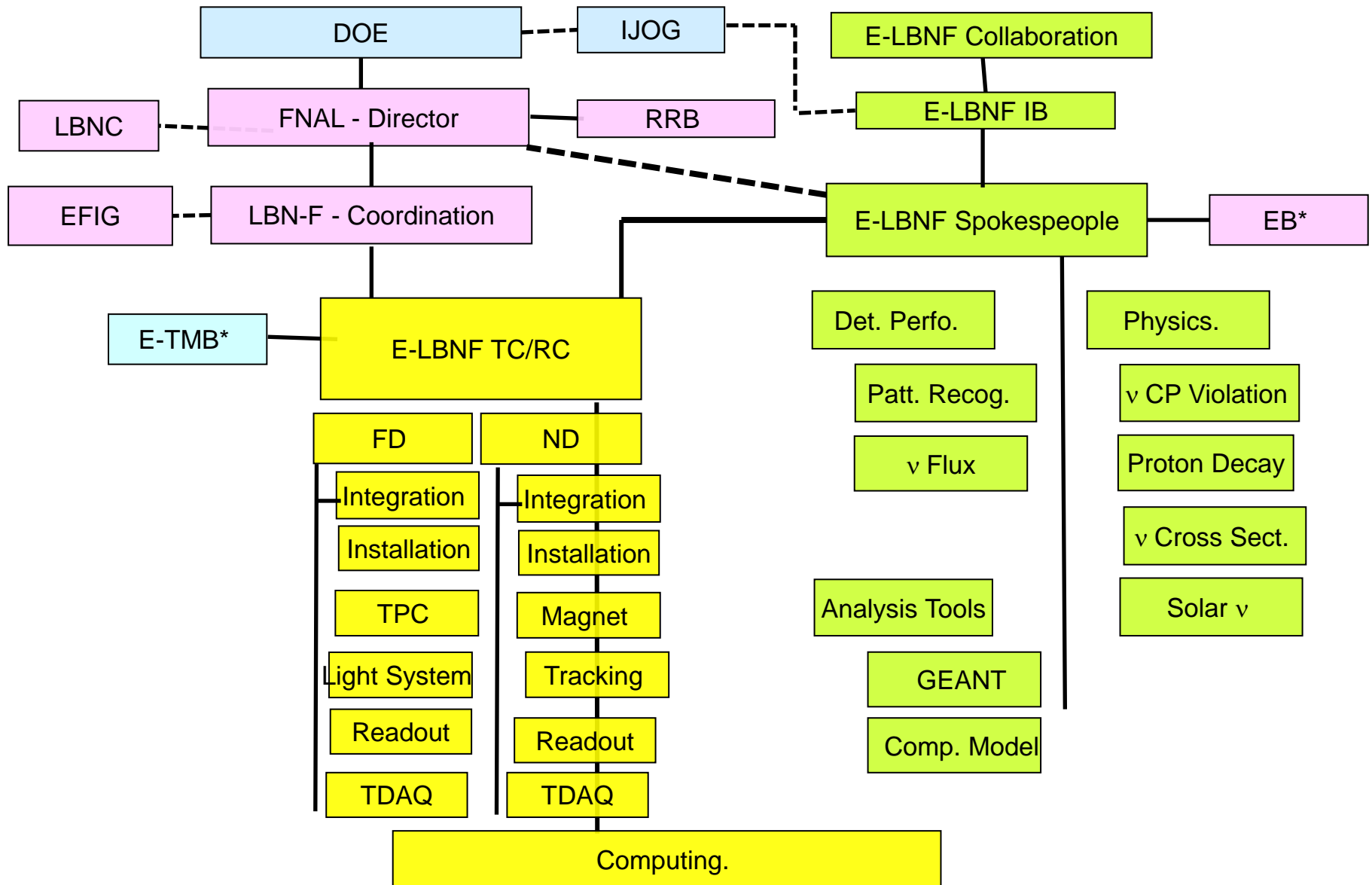


# Glossary

---

- ❖ **LBNF Collaboration:** Self–organized scientific collaboration.
- ❖ **E- LBNF :** LBNF Experiment, Physics groups and Active Detector
- ❖ **P-LBNF:** LBNF Project, Infrastructure and Beam needed for LBNF,
- ❖ **IJOG:** International Joint Oversight Group. High level representative of the funding agencies . (Meets once or twice /year)
- ❖ **RRB:** Resource Research Board. Representative of the funding agencies. (Operational arm of the IJOG – meets 3-4/year)
- ❖ **EFIG:** Experiment Facilities Integration Group. Coordination between the major components of LBNF.
- ❖ **PAC:** FNAL Program Advisory Committee to FNAL Director
- ❖ **LBNC:** LBN Program Advisory Committee to FNAL Director
- ❖ **EB:** Collaboration Executive Board
- ❖ **TMB(S):** Technical Management Boards. Advises Project , TC.

# Mapping the Organization to E- LBNF



# *Physics Working Groups*

---

❖ *Develop the Science case and translate it to detector performance requirements. (examples)*

- *$\nu$  Oscillation Working group*
- *Proton Decay: Signal, backgrounds S/N optimization*
- *Supernova Neutrinos: Trigger, Data taking*
- *Cross Sections*
- *Mass Hierarchy*
- *Sterile  $\nu$*

# *Analysis Tools WG (e.g)*

- *Computing Model for the Experiment:*
  - *Platforms*
  - *Data Storage*
  - *Data Distributions*
- *Library of “certified” code.*
- *Maintain a “baseline” GEANT Model for the experiment including topography.*
- *Backgrounds MC Production*

WG are along these lines exist in LBNE and LBNO.

The Physics Working groups and Analysis Tools Working groups are largely independent either FD, ND and or detector technology.

# *Detector Performance WG (e.g.)*

- *Beam : Optimize beam energy spectrum ( in close collaboration with the Beam Project)*
- *Simulation : Optimize Performance.*
- *Reconstruction : Pattern recognition algorithms (Algorithms might differ between physics topics)*
- *Data compression : Dynamic Range, minimize cables.*
- *Calibration: TPC calibration requirements*
- *Photon Detector working group*
  - *Trigger requirements,*
  - *Localization information*
  - *Calibration requirements*

Effective working groups are critical to converge on an optimal design for both cost, risk and performance.



# *Time Line for 1<sup>st</sup> 10 k-ton TPC.*

---

- ❖ *Time Line assumes a staged approach. Stage one 10 k-Ton followed by additional 30 k-Ton.*
- ❖ *CDR fall of 2015*
- ❖ *TDR in Winter of 2016*
- ❖ *Finalize design of TPC in Spring 2017*
- ❖ *Detector construction 2017-2020*
- ❖ *Detector Installation 2019 – 2021*

*A challenging schedule – requires the new WG to be formally organize and prepare the decisions ASAP.*

# *Decision Process*

❖ *The decision making process needs to be:*

- *Transparent*
- *Have buy-in from all the principle parties*
- *Timely*
- *Rigorous – Requirements, Technical, schedule, cost*

*The process is complicated and needs formal reviews, significant amount of “socialization” coupled with significant caffeine intake.*

*To achieve the schedule the process has to start soon.*

*Close collaborations between ALL parties involved is needed.*

*An Interim small steering group could be establish to start the process.*

# Near Detector - issues

## ❖ Technologies proposed :

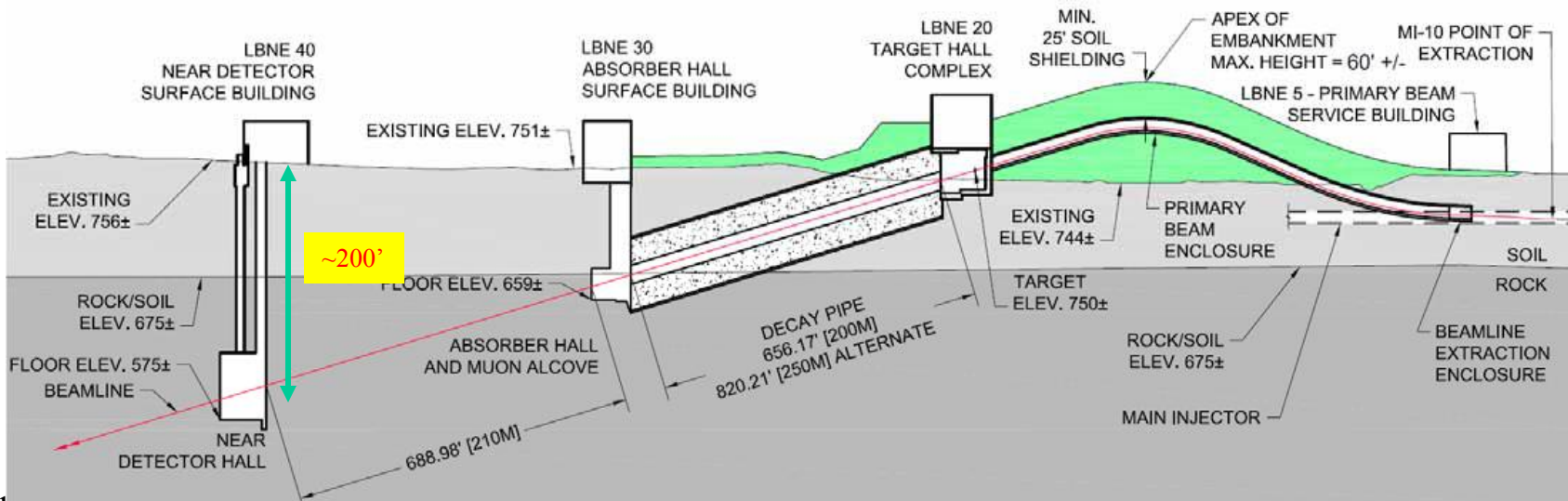
- GAS detectors
- High Pressure Lar
- Liquid Argon

## ❖ Magnetized Detector.

- Full Detector?
- Down stream Muon Spectrometer only.

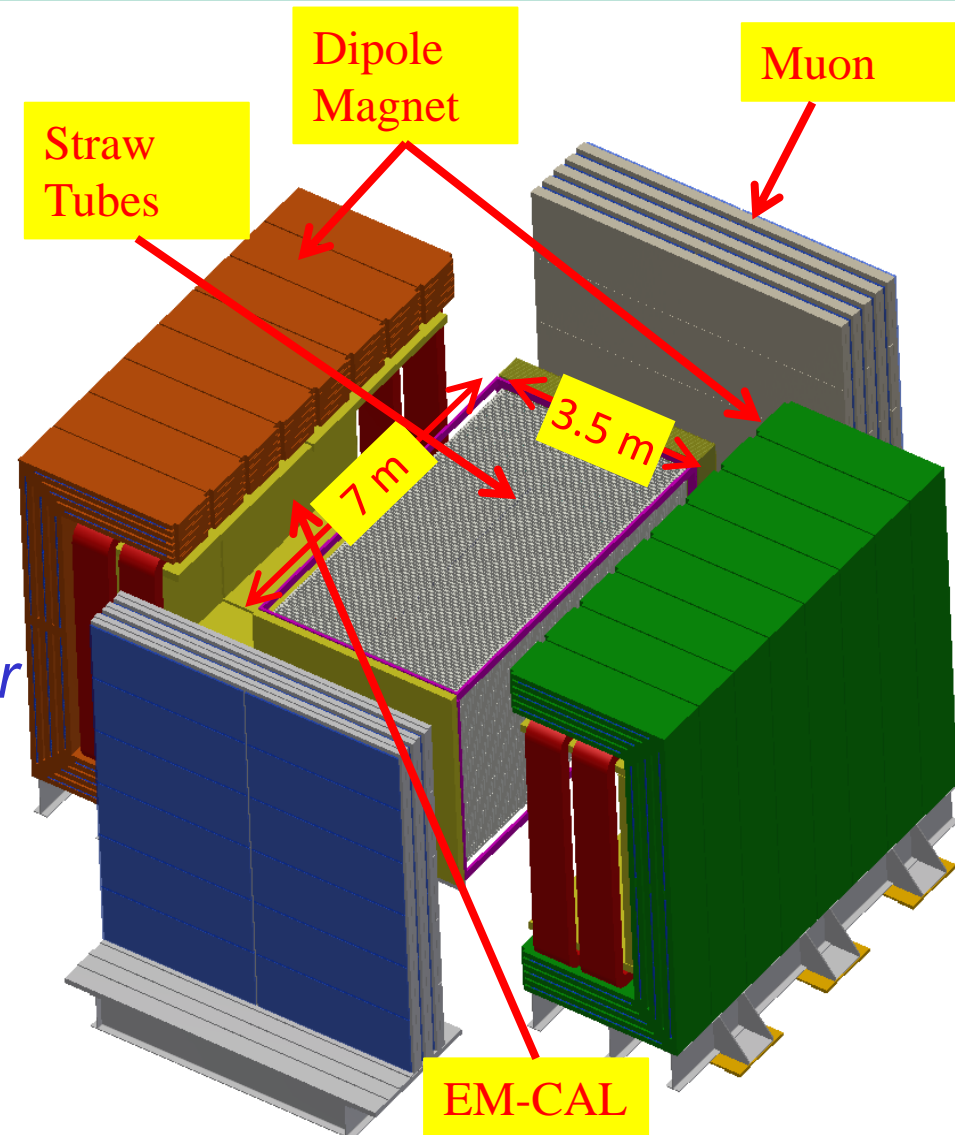
## Note:

- *Hall is 200' underground!*  
*Non trivial installation.*
- *Hall and shaft design should be finalized after the ND conceptual design.*
- *ND potentially has multiple Physics Objective.*

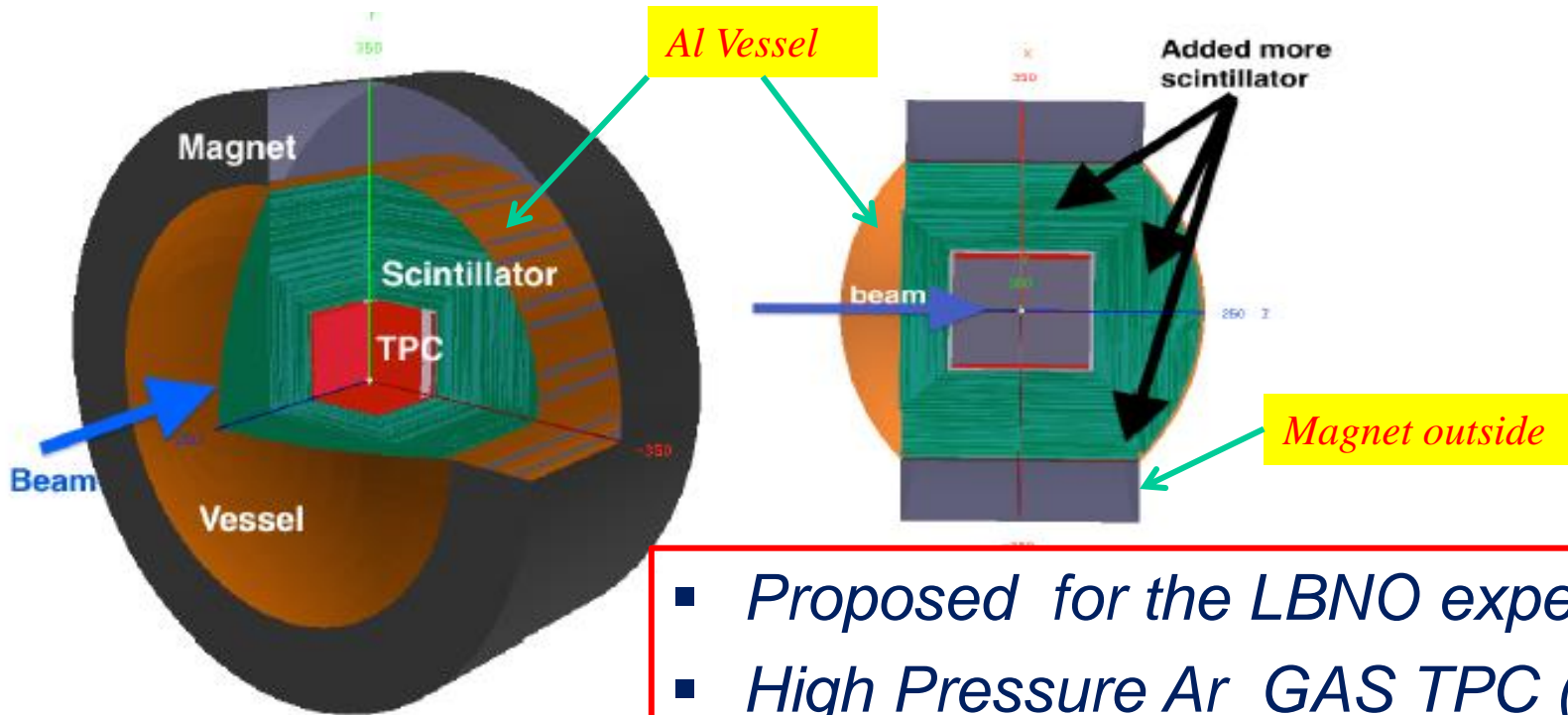


# *ND – Gas Detector*

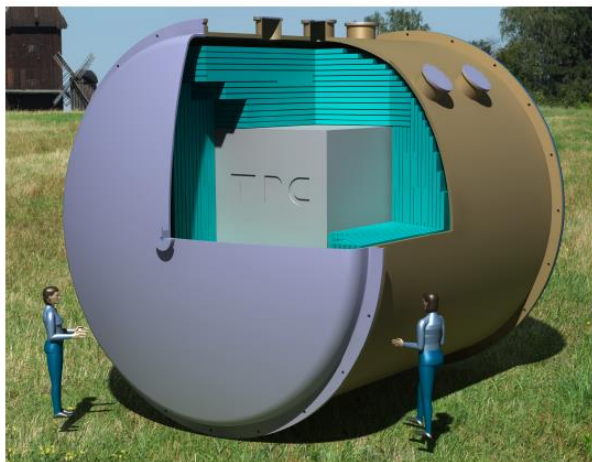
- *Proposed by collaborators led by Indian institutions*
- *High precision straw-tube tracker*
- *embedded high-pressure argon gas target*
- *$4\pi$  electromagnetic calorimeter (Pb scint)  $\Delta E = 6\%/ \text{Root}(E)$*
- *muon identification systems RPC System*
- *Large-aperture dipole magnet (0.4 T)*



# *ND - High Pressure LAr TPC*



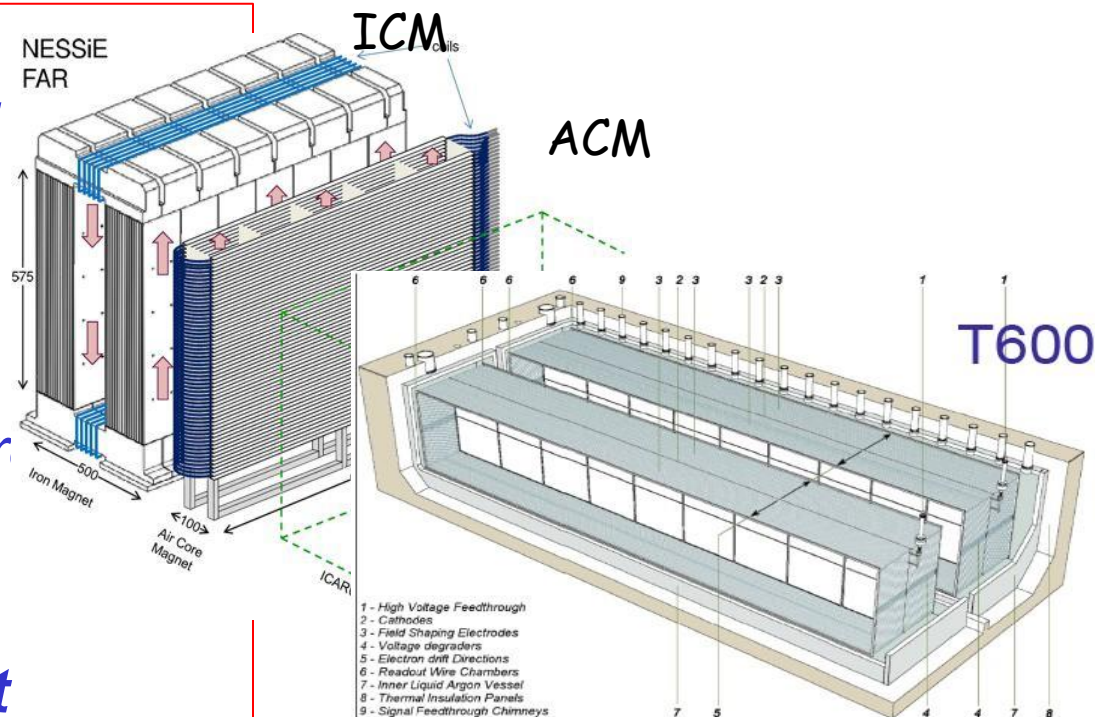
- *Proposed for the LBNO experiment.*
- *High Pressure Ar GAS TPC (0.3 ton)  
2x2x2 meters , 20 atm*
- *72 layers of Scintillators (73 Tons)*
- *All imbedded in LAr*
- *0.5 T Dipole Magnetic Field (500 Tons)*





# *LAr TPC –followed by $\mu$ Spectrometer*

- **LAr TPC** – could use a slightly modified existing detector like ICARUS.
- **Muon Spectrometer:** Followed the TPC. Proposal for a Muon Spectrometer shown here is from the NESSiE collaboration.
- **ACM – Air Core Magnet**  
0.1 T Field  
Precision Trackers
- **ICM – Iron Core Magnet,**  
48 yoke blocks  
1800 + 700 m<sup>2</sup> of RPC



There are additional proposals for a magnetized T150 ton TPC followed by the Muon Spectrometer

# *Near Detector Summary:*

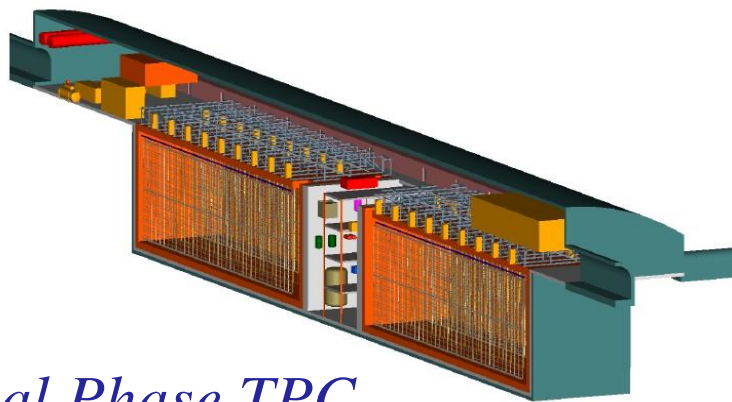
- ❖ *Proposals having varying capabilities and with somewhat different emphasis are being developed.*
- ❖ *Need an agreed concept before civil construction starts.*
  - *Hall Size, Shaft capacity*
- ❖ *Next Steps:*
  - *Formalize the Near Detector Requirements.*
    - *Combined with FD, Stand alone*
  - *Integration and Installation*
    - *Interface of detector installation plan to civil construction*
  - *Optimization of Near Detector*
    - *“Cost Model”, Risks, Complementarity with FD etc.*
  - *Selection of a baseline configuration.*
- ❖ *Utilize the expertize and resources of all interested parties by establishing combined working groups to arrive at an optimal solution – a new hybrid solution might arise.*

# Far Detector: 10 $\rightarrow$ 40 k-ton LAr TPC

## ❖ Two technologies:

### ➤ Single Phase TPC

- Drift of between 2-4 meters.
- No Charge amplification.
- “Flavors” of basic components of the TPC.
- PD system integrated in to the APA

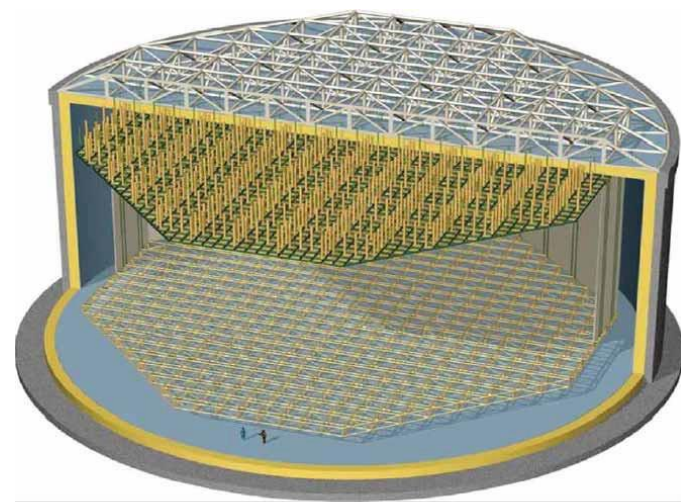


### ➤ Dual Phase TPC

- Drift of order 20 meters.
- Readout plane in the gas  $\rightarrow$  amplification
- PD system independent.

## Disclaimer:

I am more familiar with the single phase solution. The examples used are biased and taken from that technology.



3D Tank & Detector Model Screen Shot (courtesy ETH Zürich)

# *FD – Issues (e.g.)*

## *❖ Is there a “universal” cryostat design ?*

- *Significant saving in design, tooling, excavation can start before down select.*

## *❖ Selection of TPC technology for phase I*

- *Single or double phase, What is the process? Time Line?*

## *❖ Finalize TPC design for the 10 k-Ton*

- *E.g: Finalize TPC supports, FT locations*

## *❖ Baseline photon detection (PD) system .*

- *Is there a common system for both TPC technologies? What can be common?*

## *❖ Baseline readout chain .*

- *Can one develop a common readout? Major components?*

## *❖ Installation and testing plan*

- *Needs to go hand in hand with the design of both the detector and the facility.*

# WG: System Integration

- ❖ *Installation and integration of the detector needs to proceed in parallel to the detector subsystem design.*
- ❖ *System integration will have significant influence on the detailed TPC and PD subsystems design.*
- ❖ *Needs to include less “glamorous” items like: cable plant, connectors, feedthroughs ,power supplies!!*
- ❖ *Installation plan needs to include :*
  - *mechanical installation*
  - *Testing plans for all subsystems: Readout, PD, Calibration , HV etc.*
  - *Repair Scenarios during installation. Broken wire, Damaged Motherboard etc.*
  - *Survey*
- ❖ *Safety issues – confined space ,heights of ~20 meters , underground.*
- ❖ *TC is charged with coordinating this work.*



# *“Universal” Cryostat Design Issues*

## ❖ *“universal” Cryostat?*

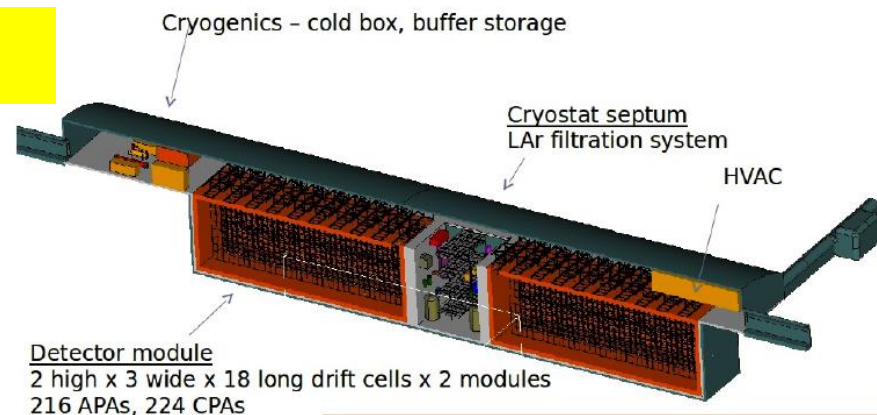
- *Single design repeated  $n$ - time. Assuming 1<sup>st</sup> phase is 10 k-Ton then  $n=4$ .*
- *Decouple the civil construction from the TPC technology choice.*
- *Allow more time for finalizing TPC design.*
- *Significant cost and schedule saving if “truly universal”*
- *Reduce Risk*

## ❖ *“10 k-ton” Cryostat Design Issues? (examples NOT exhaustive)*

- *FT location and Size are different for the two technologies.*
  - *Cryostats might need to have “flavors”*
- *Single Cryostat or two 5 k-Ton Cryostats?*
  - *Single Cryostat has a cost advantage*
  - *Double Cryostat is seen as mitigating risks – including schedule.*
- *Access during installation*
- *TPC Supports – should be able to accommodate both designs*

***Common WG for both technologies.***

***Interface issues finalized in the Interface Group. (EFIG)***



# *FD Cable Routing (e.g)*

## *❖ Cable plant has a significant effect on :*

- *Installation sequence*
- *Location and number of feedthroughs*

## *❖ Options for cable routing:*

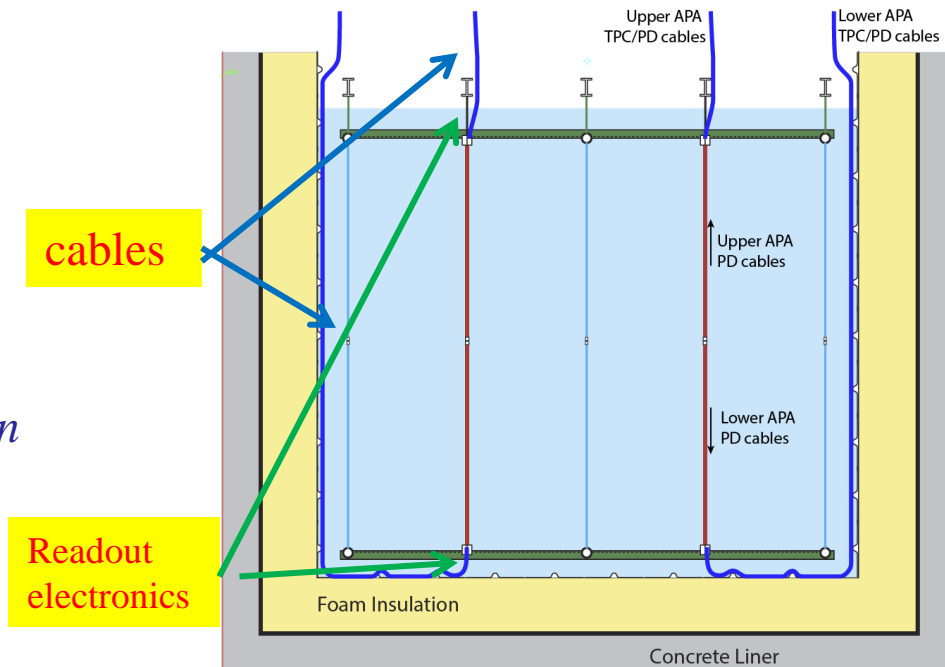
- *Option A: all cables through the APA frame*
- *Option B: Bottom APA route on the floor and then the side of the Cryostat.*

## *❖ Option A has many advantage but depend on reduced number of cables.*

- *Fewer cables*
- *Fewer connectors*
- *Easier installation underground*

## *❖ Choice has implications to:*

- *Installation*
- *APA and PD readout design specification*
- *APA locations (given fixed Cryostat)*
- *FT location*

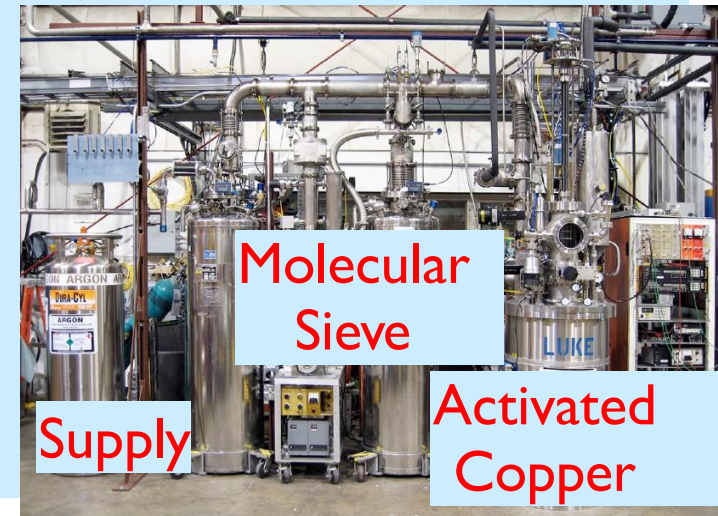


# WG: Material & Purification Certification

❖ *Purification requirements of both technologies might not be very different.*

- *Single phase – shorter drift with no amplification.*
- *Dual Phase – longer drift with amplification.*

- ❑ Certify Material that can be used.
  - ❑ Cables
  - ❑ Motherboard
- ❑ Requirements on recirculation system.
  - ❑ Liquid
  - ❑ Gas region



*Common WG for both technologies.*

**Material Test Stand - FNAL**

# *HV Working Groups:*

❖ *500 Volts/cm → 50 K-Volts / Meter*

➤ *Single Phase → ~150 K-Volts*

➤ *Double Phase → ~ 1 M-Volts*

❖ *Issues:*

➤ *FT*

➤ *HV distribution in the cage*

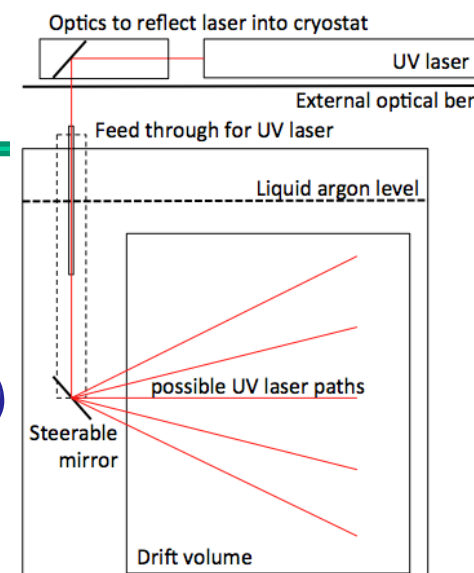
➤ *Protection against breakdown*

➤ *Surface Treatments*

***Common WG for both technologies.***



# TPC Calibration:



Conceptual Design (BERN)

## ❖ Calibration main function is to track:

- Stability of the readout electronics.
- Effective electron life time. (Position dependence)
- Gain stability (Two phase)

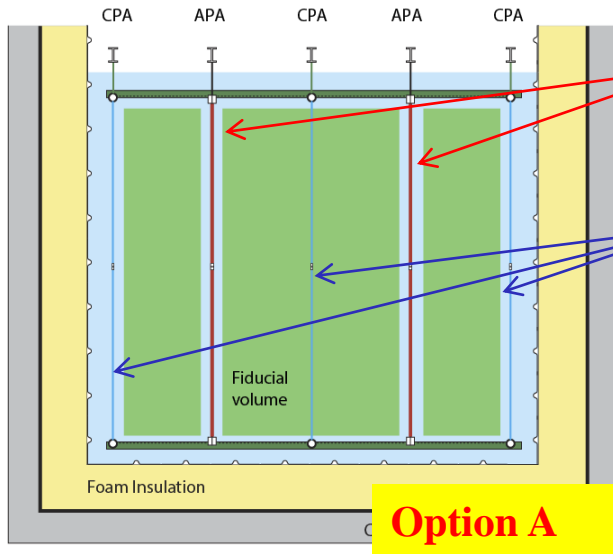
## ❖ Calibration systems:

- Cosmic Rays: What information is there underground? (MC)
- Laser Calibration: Pulse laser generate straight lines.
  - Pulse to pulse stability
  - Confirm sensitivity of  $dE/dX$  measurements to laser light divergence
  - Distribution over large det.
- Purity Monitors
  - Dedicated in the purification system.
- Electronics Calibration:
  - Pulsed injected in each PA. Tests the electronics response only.

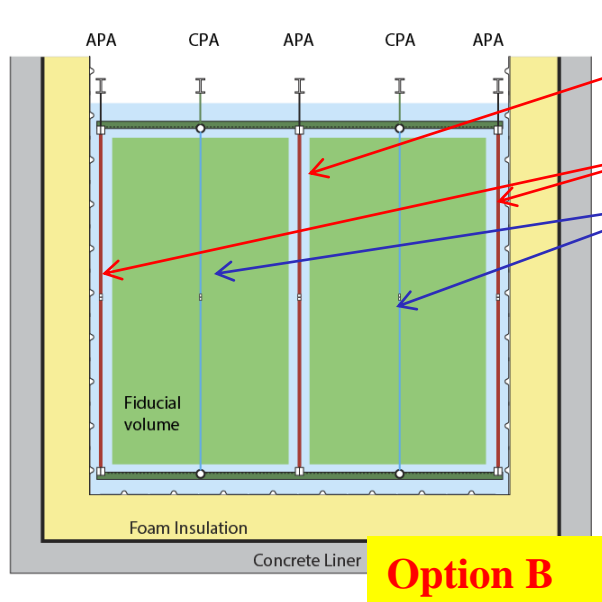
**Common WG for both technologies.**



# APA/CPA Configuration (e.g.)



- ❖ Two rows of double sided APAs (most expensive items in the TPC)
- ❖ 3 CPAs with 2 facing the cryostat, requires larger clearance for HV safety



- ❖ 1 row of double sided APAs
- ❖ 2 rows of single sided APAs.
- ❖ 2 rows of CPAs
- ❖ Improved fiducial/active ratio

Down select and optimization will depend on cost, technical risk,...

# *TPC – Toward a Finalized Design*

---

❖ *TPC main components are:*

➤ *APA Subassembly*

- *Wire frame + Wires*
- *PD system embedded in the APA frame*
- *Anode wires readout*
- *PD readout*

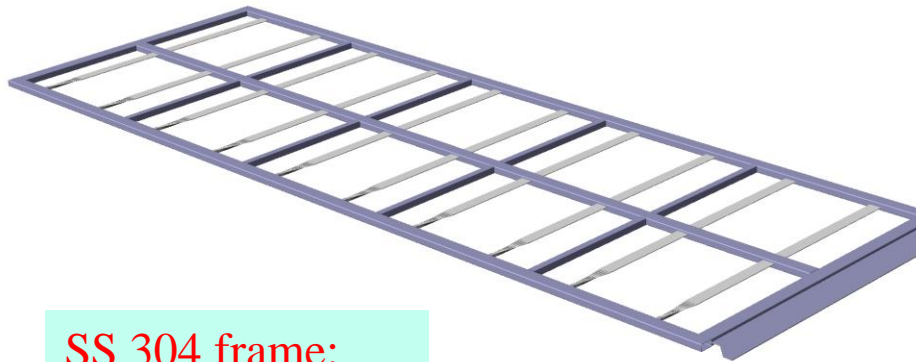
➤ *CPA*

- *HV Connection*

➤ *HV Cage*

- *Field Uniformity*
- *Breakdown protection*

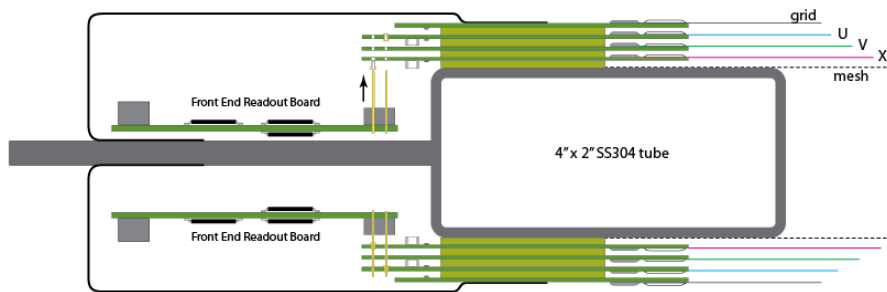
# Anode Plane Assemblies (APA)



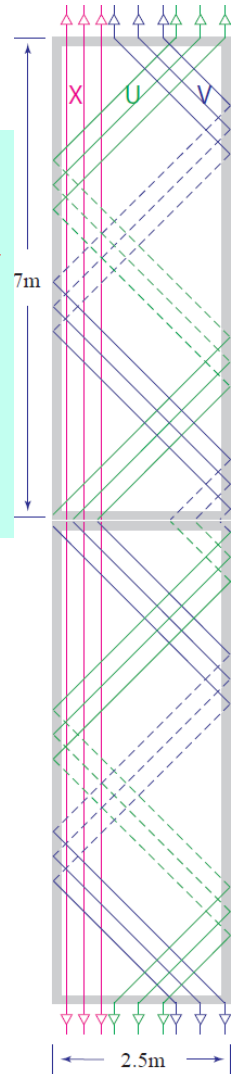
SS 304 frame:  
Weight ~ 250kg

7x2.5 meter active area  
4 planes of wires @ 4.5mm pitch  
2560 sense wires  
3680 wires total  
Electronics on one end of the frame

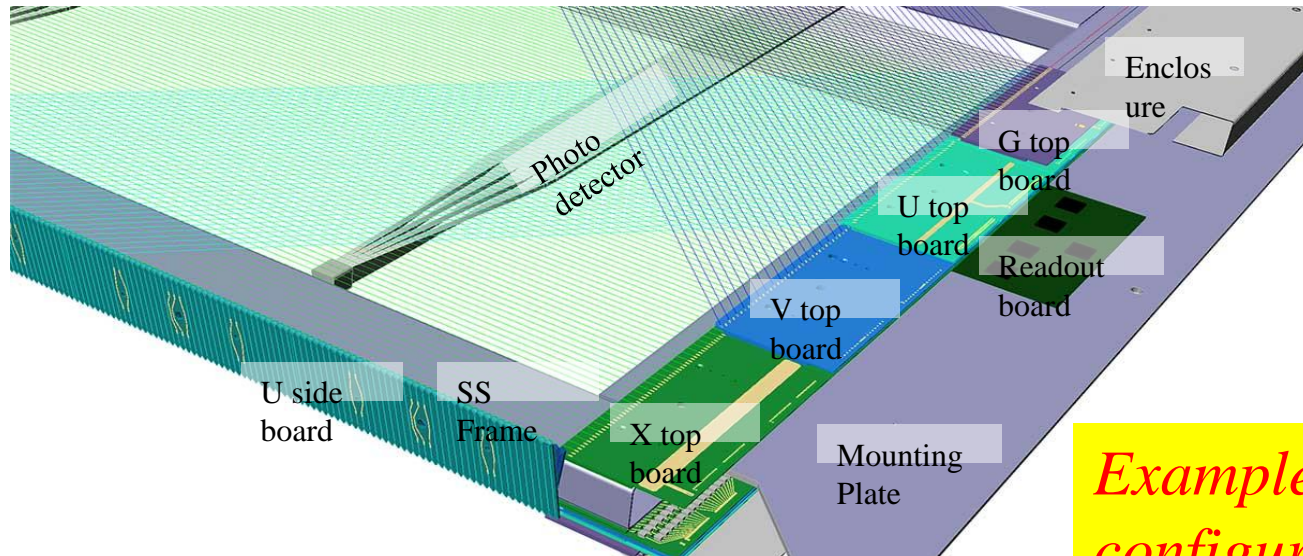
Cross section of the readout end of the APA



**Note:**  
Assembly is bulky and relatively heavy.  
Design needs to allow for “reliable” transportation and “easy” and safe manipulation.



# Anode Plane Options



Close Up view of 35T Prototype.

*Examples of wire configurations leading to different APA design.*

*Form a few “clusters” to construct alternative APA’s.*

*Test in the CERN platform and down select.*

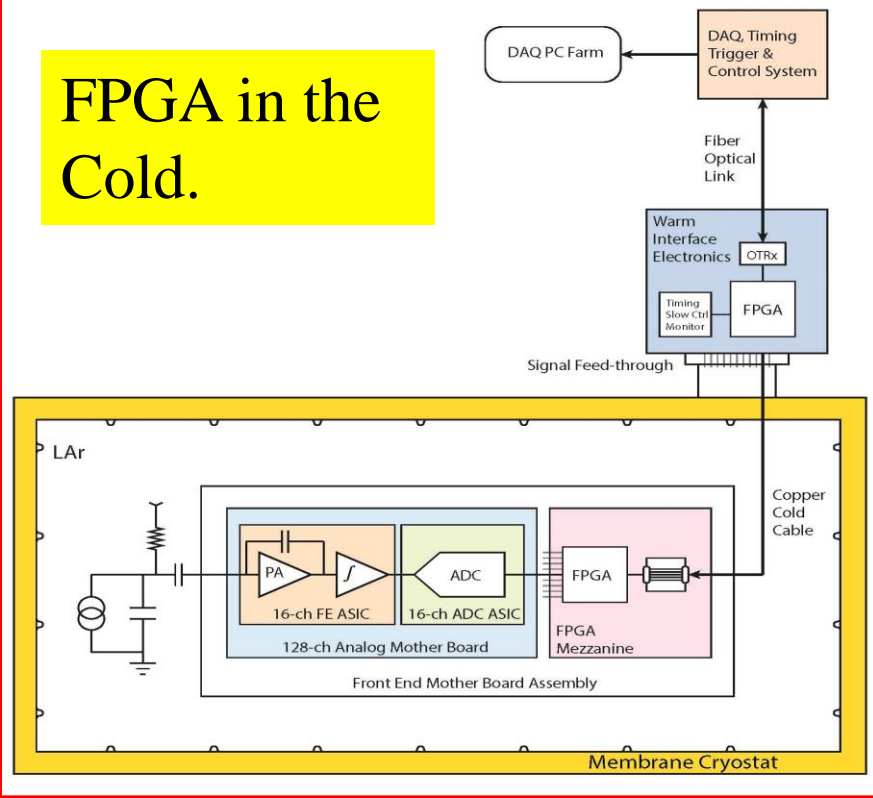
	MicroBooNE	LAr1-ND	LBNE
Wire Angle	Collection wire vertical; two induction plane $\pm 60^\circ$ from vertical	Same as MicroBooNE	Collection wire vertical; 2 induction planes @ $\pm 36^\circ$ (was $45^\circ$ ); grid plane vertical
Wire pitch/type/tension	3mm / Cu+Au plated SS304, 0.15mm / 0.7kg	3mm / CuBe / 0.5kg	Collection wire: 4.8mm Induction wire: 4.7mm / CuBe / 0.5kg
Wire length	Collection wire: 2.3m Induction wire: 4.6m	Collection wire: 4m Induction wire: 2x2.9m	Collection wire: 6m Induction wire: 7.4m
APA active aperture	10.4m x 2.3m Assembled onsite	2.5m x 4m Preassembled and tested	2.3m x 6m Preassembled and tested
Readout & location on APA	Analog front-end on 3 edges	Analog+ADC+multiplexer on two edges	Analog+ADC+multiplexer on one edge
Dead space around APA for tiling	Not designed for tiling ~ 20cm on 4 sides	Designed for tiling on 1 (optionally 4) edge: ~15mm distorted gap	Designed for tiling on 3 edges: ~17mm vertical, ~30mm horizontal distorted gap
APA support	Rest on floor	Suspended on ceiling	Suspended on ceiling

# WG: TPC Readout

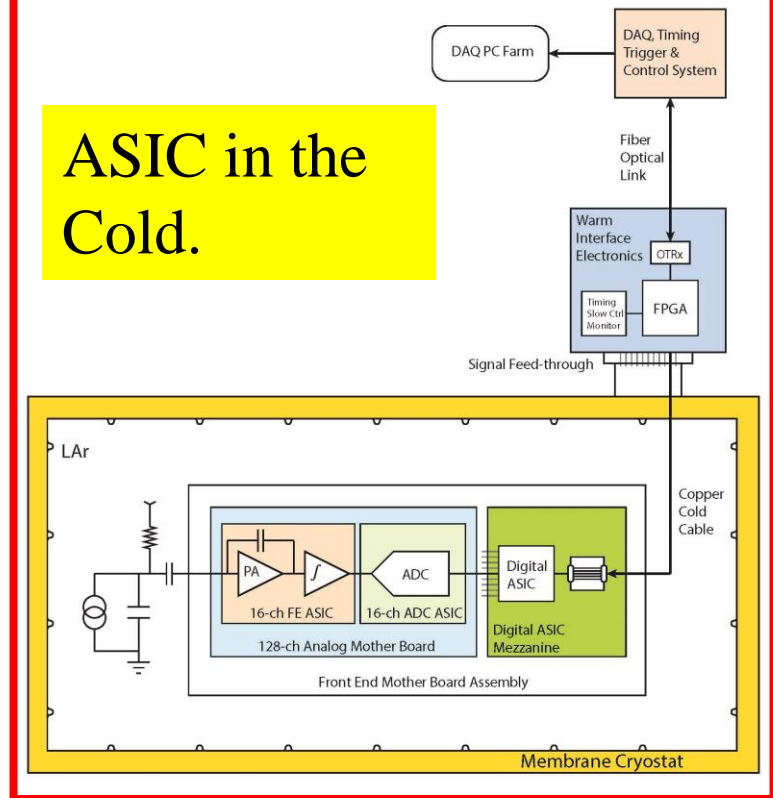
## ❖ Cold Electronic driven by:

- Signal to noise  $\rightarrow$  PA/SA in the cold
- Reduction in Cables  $\rightarrow$  Purity, installation  $\rightarrow$  Multiplexing –ADC  $\rightarrow$  FPGA or ASIC in cold

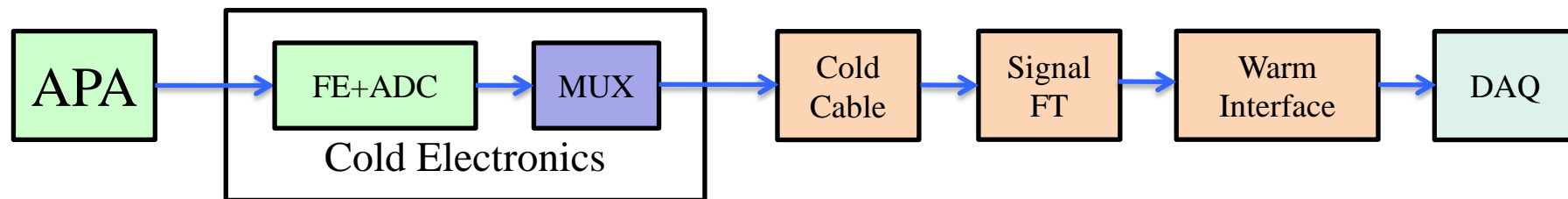
FPGA in the Cold.



ASIC in the Cold.



# TPC Readout Electronics



## ❖ *Anode Plane Assembly*

- *Finalize optimization of electrode design of APA (size, wire angle etc.)*

## ❖ *Cold Electronics*

- *Analog FE + ADC: optimization of ASIC design (calibration, interface etc.)*
- *MUX: choice of digital ASIC or FPGA, based on R&D*
  - *FPGA – Cryogenic life*
  - *ASIC – Design under development.*
- *Digital Links – Power*

## ❖ *Cold Cable and Signal Feed-through*

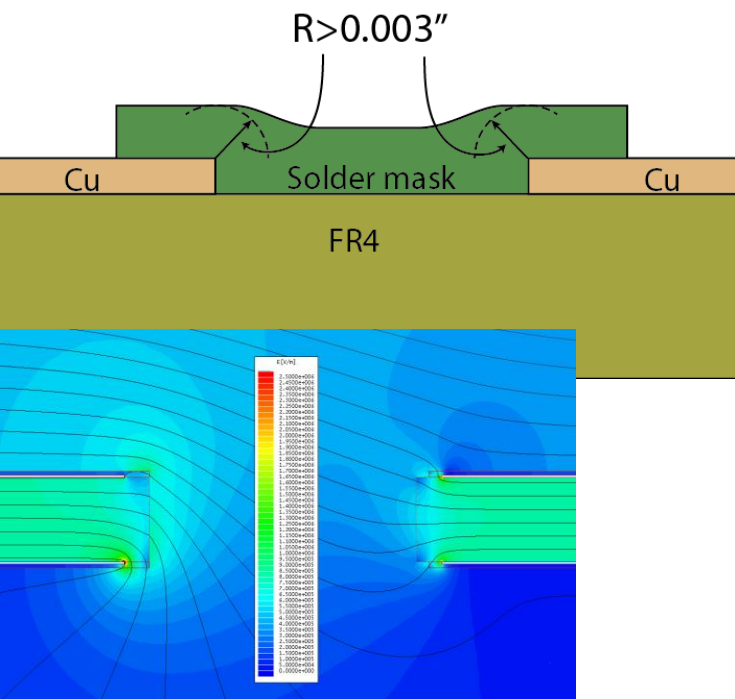
- *Design choice based on system level considerations ( mechanical assembly, reliability etc.)*

## ❖ *Warm Interface to DAQ*

- *Warm interface electronics to provide flexible interface to DAQ system.*



# *HV Field cage*

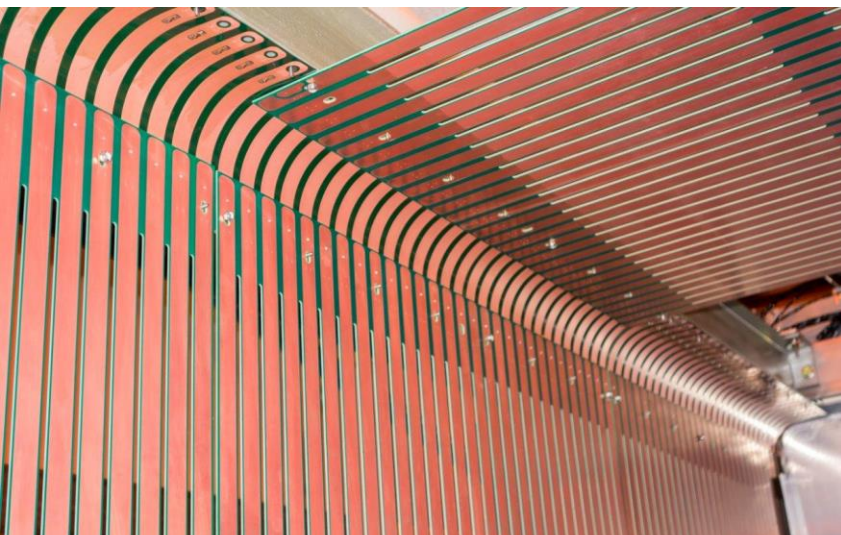


## ❖ Field Cage Options:

- ❖ *ICARUS/MicroBooNE style.  
(Tubes)*
- ❖ *35 Tons – using etched PC  
boards.*

## ❖ Issues:

- ❖ *“Tube” difficult installation,  
cleaning procedure.*
- ❖ *PC Board : How to avoid  
breakdown on the edges of the  
copper strips.*

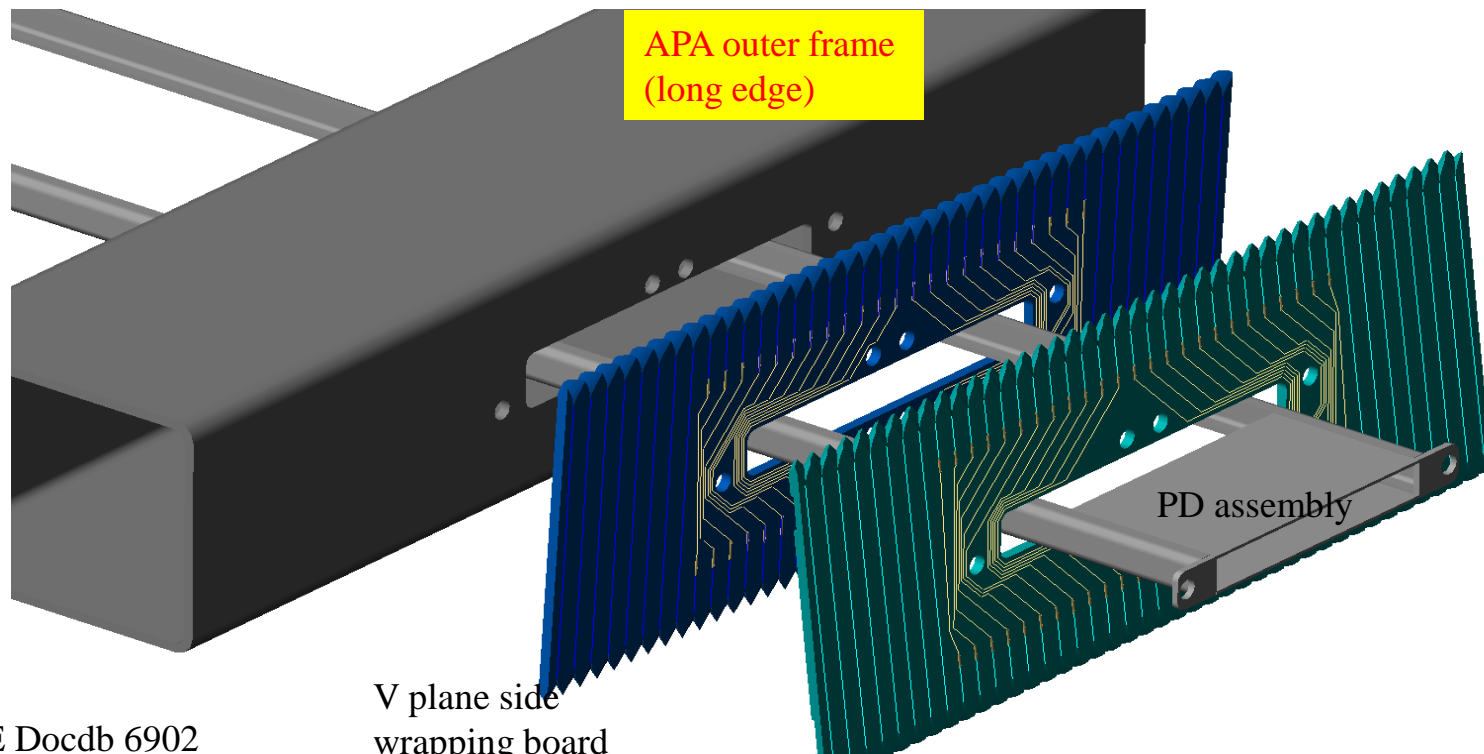


***Common issues for both  
technologies.***

# Photon Detector Subsystem

## ❖ *Interface to the TPC Assembly*

- *The concept of imbedding PD detector in the APA's requires a thicker frame (3").*
- *Examples are: Add slots along the long edges of the APAs.*
  - *Connections to the SiPM or PMT*
  - *Cable installation and multiplexing.*



# WG: Photon Detection System:

## ❖ Scintillator selection:

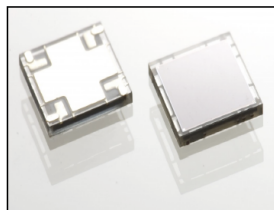
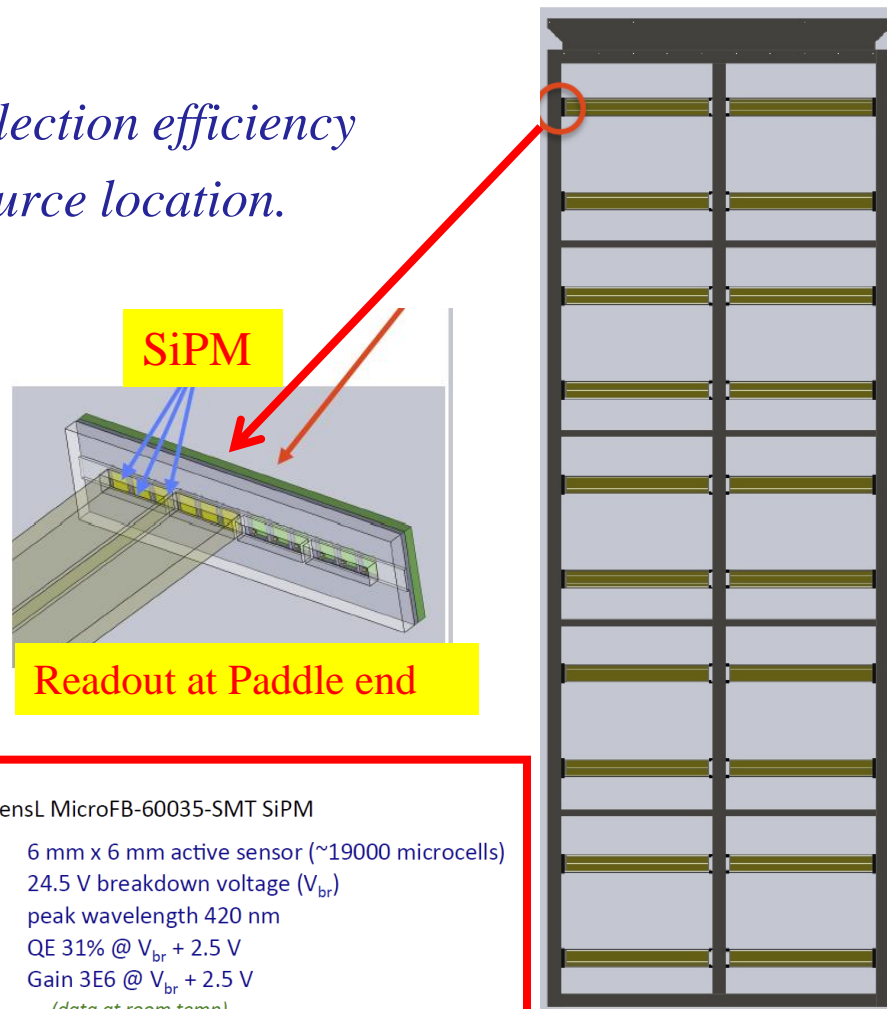
- Is there a single technology suitable for both TPC Technologies?

## ❖ Reflectors:

- Use of reflectors increase the light collection efficiency
- Reduce or loose information on the source location.

## ❖ System shown includes:

- Plastic Bars
- 4 bars/PD
- 3 SiPM/ Bar (Possible PMT?)
- 20 PD / APA
- 80 SiPM



SensL MicroFB-60035-SMT SiPM

- 6 mm x 6 mm active sensor (~19000 microcells)
- 24.5 V breakdown voltage ( $V_{br}$ )
- peak wavelength 420 nm
- QE 31% @  $V_{br} + 2.5$  V
- Gain  $3E6$  @  $V_{br} + 2.5$  V  
(data at room temp)

**Common issues for both technologies.**

APA containing 20 PDs

# WG: PD Light Readout

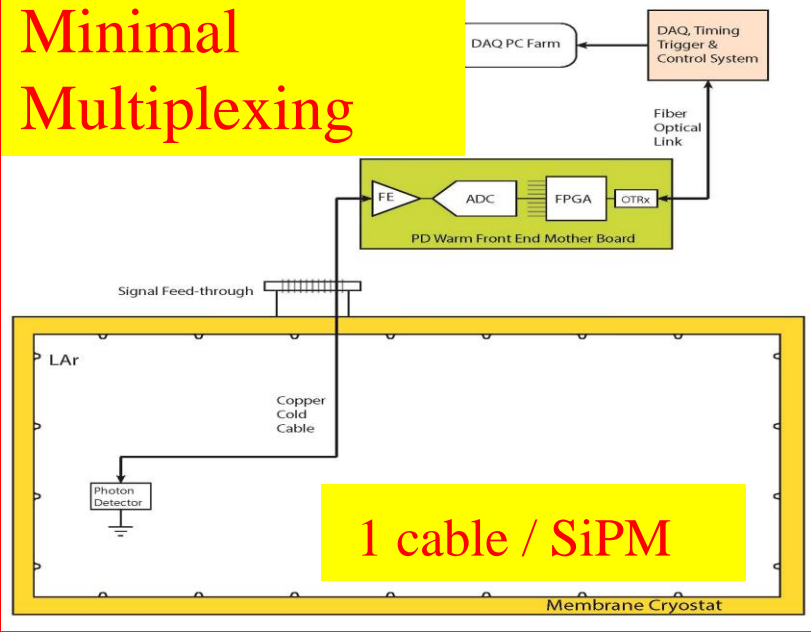
## ❖ *Multiplexing:*

### ➤ *Reduction in cables*

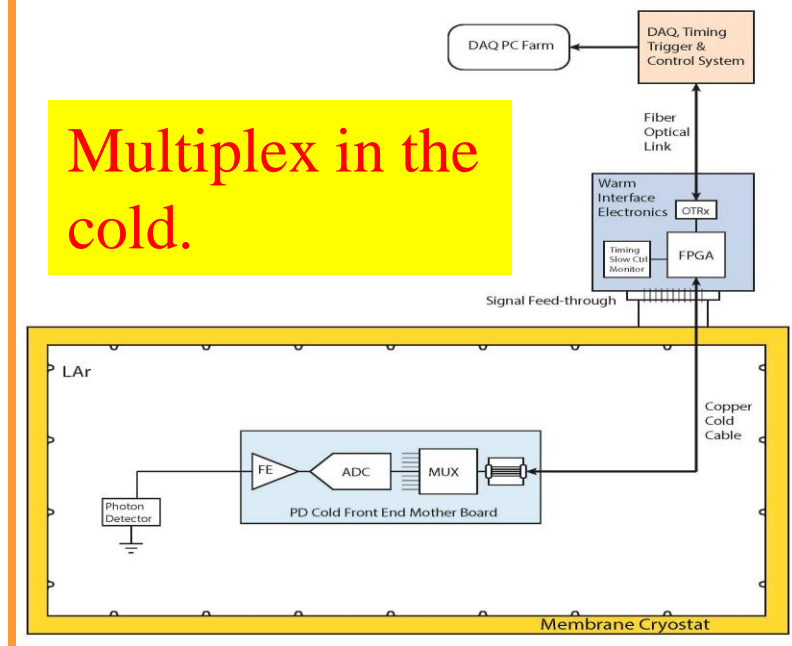
- *Easier Installation*
- *Purification*

*Common WG for both technologies.*

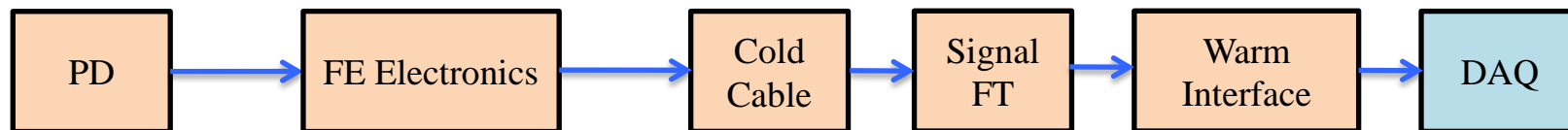
## Minimal Multiplexing



## Multiplex in the cold.



# *Light Readout Electronics*



## ❖ *Photon Detector*

- *Choice of design based on R&D of various light detection systems (acrylic bar, reflector foil, Si PM or PMT etc.)*

## ❖ *FE Electronics*

- *FEE design closely coupled with PD design (number of channels, timing resolution, SiPM or PMT etc.)*
- *PD design and installation requirements will determine the necessity of cold FE, MUX or data compression*

## ❖ *Cold Cable and Signal Feed-through*

- *Choice of design based on system level considerations, better synergized with TPC readout design*

## ❖ *Warm Interface to DAQ*

- *Warm interface electronics to provide flexible interface to DAQ system, design will be based on the choice of PD and design of FE electronics.*

# *Distributed Construction*

---

## *❖ Issues related to “distributed construction model”.*

- *Collaboration, TC and host Lab. buy in to the model.*
- *The institutions must be engaged in the development of the system.*
- *Technical resources need to be matched to the responsibility.*
  - *Possible issue with too large responsibility (lack of resources or expertise)*
  - *Possible issue with too little responsibility (lack of interest)*
- *The funding agencies are aware of the needed resources.*
  - *Needs to sign an MOU*

## *❖ When do we start?*

- *The subsystems need to consider production at the design stage.*
- *Production scenarios developed in parallel to the prototypes.*



# *Distributed Construction - II*

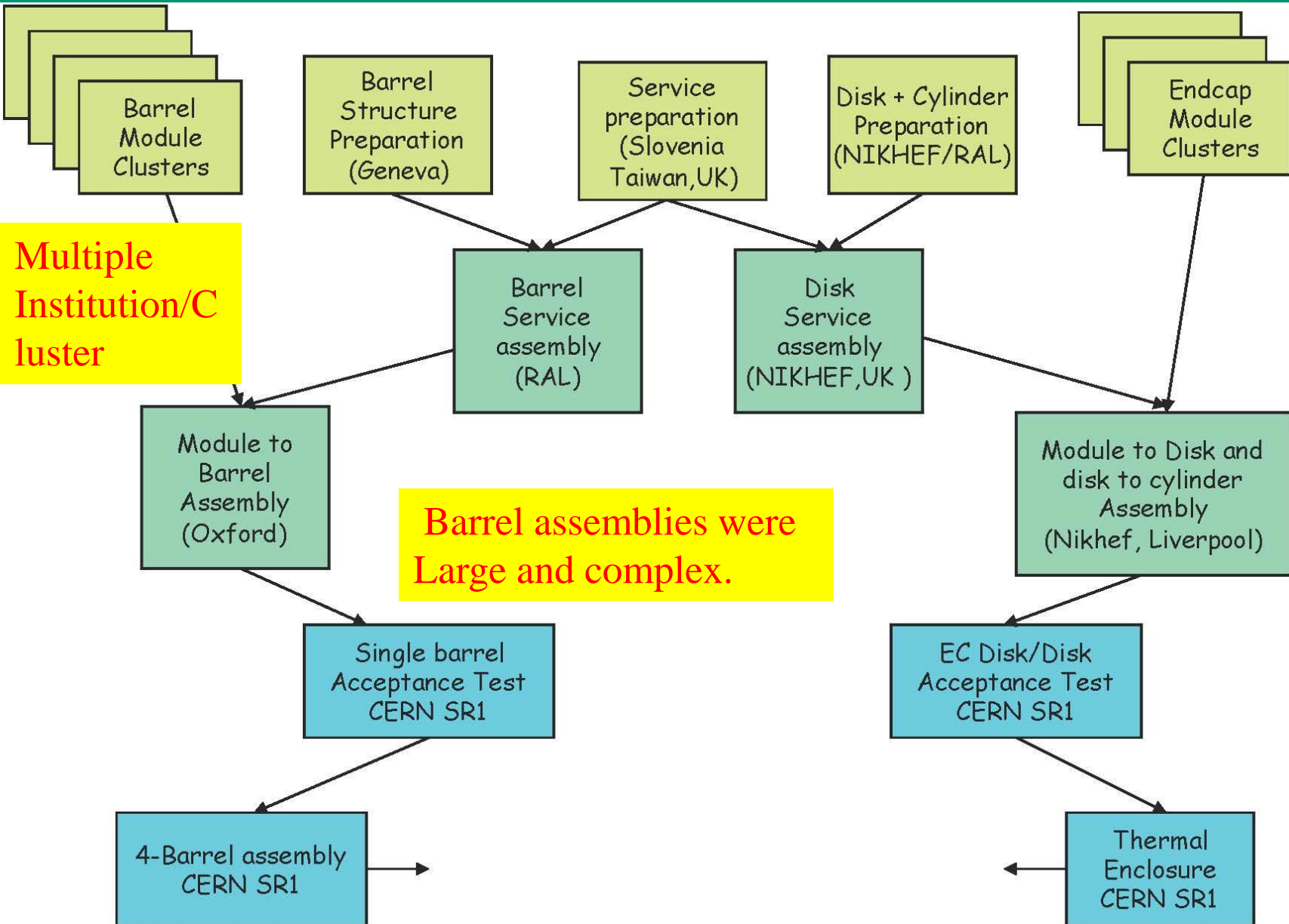
- ❖ *The design consideration of the “production” .*
  - *Define QA/QC for each step*
  - *Define steps need that need to be in the same physical location*
  - *Identical tooling for similar tasks in multiple locations.*
- ❖ *Detector components are constructed by “clusters” or “consortiums” - typically a group of institutions clustered around an “integrating” institution. They take the responsibility to deliver part of the detector.*
- ❖ *The “Cluster” or “consortiums” need not be in close proximity.*
  - *For example in ATLAS:*
    - *ATLAS LAr electronics had two “sub clusters” in the US and in France.*
    - *Tile Calorimeter had a US cluster, a Russian Cluster and a Spanish cluster.*
    - *For Si strips there was a US cluster, a UK cluster and a German cluster.*
  - *Clusters worked closely with each other. Same QA/AC, tooling, etc.*

# *Distributed Construction*

- ❖ *Example ATLAS Muon System:*
- ❖ *MDT tubes , RPC + readout*
- ❖ *A dozen assembly sites for MDT's around the world and a number of RPC sites.*
- ❖ *In the US there were three sites Boston consortium, Univ. Michigan, and Univ. of Washington*
- ❖ *Identical tooling for MDT assemblies.*
- ❖ *The MDT's, RPC's and the electronics boards were shipped to CERN and were integrated on the surface.*
- ❖ *The MDT/RPC assemblies were then installed in the experiments Hall.*
- ❖ *Most of the chambers and electronics were built at Universities.*



# *Distributed Construction- ATLAS Si*



# *Production model for TPC*

❖ *The main TPC assembly components to be delivered underground for final assembly:*

- *APA – including the PD , wire planes and electronics.*
- *HV – cage including HV protection.*
- *CPA*

❖ *There are additional deliverables that are not covered in this example and need to develop their own “consortiums”*

- *Calibration*
- *HV Feedthroughs*
- *Signal Feedthroughs*
- *DAQ*
- *Etc.*

# *Production model for TPC*

## *❖ APA Assembly: (need order of 400-500 APA's)*

- *Reception area in Sanford Lab.*
  - *Receive APA assembly and do final check on surface before installing underground.*
- *2-3 final assembly sites for the APA before shipping to SD. (100-200/Site)*
  - *Integrate the APA wire assembly, PD assembly, Electronic boards, Cables assembly.*
  - *Testing and QA of the full system. Cold?*
- *2-3 sites for APA wire assembly.*
  - *Sites certify the frames and install the wires on the frames.*
  - *At this stage a mechanical cold test using Liq. Nitrogen might be needed.*
- *Identify “Cluster (s)” for PD assemblies*
  - *PD assembly – scintillators wavelength shifter*
  - *Include the SiPM (or PM) installation.*
  - *Testing*
- *Identify “Cluster(s) for cold electronics assembly and testing*

# *Production model for TPC*

## *❖ HV cage Assembly:*

- The construction will depend on the final design.*
- But there will be needs to follow production, certify the components*

## *❖ CPA assembly:*

- Integrate the CPA assembly.*

*The level of QA/QC and thus testing that is needed is significant.*

*Need a 30 year life time with NO access!!*

*No Failure during installation that require extraction of a component.*

*A significant part of this work needs to be led by Post Doc's , graduate students in a distributed way.*



# *The Concept of “Deliverables”*

❖ *The cost structure is different between funding agencies and institutions. ATLAS (CMS) estimated the cost in “CORE units”.*

- *The “Core” cost include: materials , industrial labor, and does not typically include institutional labor, R&D etc.*
- *The estimates is used to assign a “value” to the deliverables the different funding agencies.*
- *Each funding agency tried to balance the need of the experiment, the interest of the groups and available resources (cost, technical)*
- *For the U.S. typically the conversion was between a factor of 2-5 depending on the amount of labor involved.*
- *Once a deliverable is assigned and MOU is signed it is the responsibility of the respective funding agency to cover the cost.*
- *TC review & monitor technical progress and schedule. progress.*

# *Assigning responsibility for Deliverable*

---

- ❖ *The “clusters” grow out of the WG and the R&D work.*
- ❖ *The R&D and prototyping period is the time when “cluster” get formed.*
- ❖ *“Module Zero” 1<sup>st</sup> full size “near final” module is used to certify assembly sites and develop the needed QA/QC procedures.*
- ❖ *Need to take full advantage of the CERN platform for testing full size prototypes and optimize components using charged beams.  
(See M. Nessi)*
- ❖ *Leverage the SBN program at FNAL for understanding performance requirements and testing and than optimizing “Distributed construction” concept. (See D. Schmitz)*

# *Nest Steps:*

## ❖ *CDR:*

*Fall of 2015*

- *Science overview*
- *Performance Specifications – Science Driven ND and FD*
- *Beam*
- *Civil Construction*
- *Detector Infrastructure*
- *Active Detector TPC and PD*

## **Some of the Major Decisions by CDR:**

Performance Specifications for TPC and PD systems.

Feasibility of a “universal” cryostat – conceptual design

Staging plan for 10 K-ton by early 2020’s and next steps to 40 K-ton.

Time line for LAr Technology choice for Phase I (10 K-ton)

Time line for setting the ND configuration.

# *Conclusions:*

- ❖ *LBNF poses a scientific and technical challenge.*
- ❖ *The scope is large and significant Development and down select are needed prior to construction start.*
- ❖ *To achieve the objective of a 10 K-Ton Detector by early 2020's an appropriate structure is needed that will:*
  - *Marshal the collaboration scientific and engineering resources.*
  - *Make decisions in a timely manner based on solid scientific and technical input.*
- ❖ *High priority WG needs to be established soon and key people identified.*

**It takes a village to build a small experiment it takes the world to build a great one.**