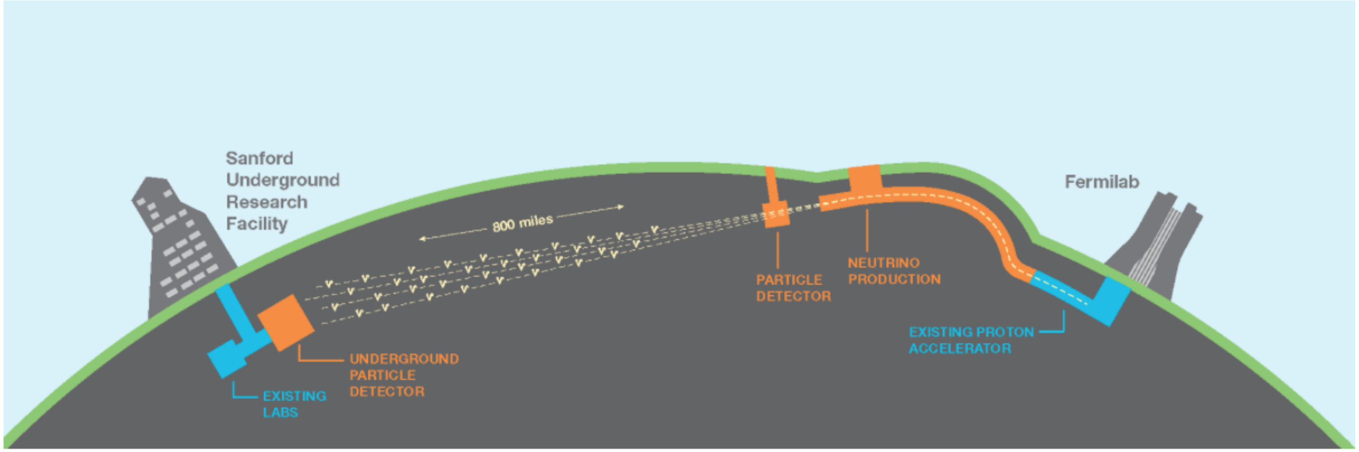
Introduction: Near Detectors

Albert De Roeck

Discussion Meeting

- The Near Detectors are presently being discussed for DUNE and the T2K upgrades.
  - CERN EP-nu so far only a member of DUNE, but synergies are possible, and T2K upgrade may be on the horizon.
- DUNE is gearing up the discussion/plan for the ND
- T2K/DUNE interested people have produced an EOI for HPTPC R&D. CERN has signed this EOI
- We have interest in the HPTPC and Argon Cubes (and maybe others..?)
- A change for a strong European effort in DUNE. Contacts with eg Italy and UK. We should capture that opportunity!
- This is a first informal meeting to collect input from the group and explore strategies how we can get involved



Introduction to the Near Detector Concept Study

DUNE ND Workshop, Fermilab, 27th – 29 March 2017

Go to day ▾

Monday, March 27, 2017

14:30 - 15:20 Introduction
Aims of the Near Detector Concept Study and scientific requirements

14:30 **Goals of the Workshop** *20'*
Speaker: Prof. Mark Thomson (University of Cambridge)
Material: Slides

14:50 **Scientific Goals of DUNE and Near Detector Requirements** *30'*
Speaker: Elizabeth Worcester (BNL)
Material: Slides

15:40 - 16:50 DUNE Near Detector Concepts
Summar of the existing DUNE Near Detector Concepts - FGT, LArTPC and High-Pressure Gaseous Argon TPC

15:40 **Fine-grained Tracker Option** *20'*
Speaker: Prof. BIPUL BHUYAN (IIT Guwahati)
Material: Slides

16:00 **Gaseous-argon TPC option** *20'*
Speaker: Dr. Justo Martín-Albo (University of Oxford)
Material: Slides

16:20 **Liquid-argon TPC Option** *20'*
Speaker: Dr. James Sinclair (University of Bern)
Material: Slides

17:00 - 17:40 Near Detectors of Other Experiments
How near detectors mitigate systematic issues of oscillation analysis in other experiments.

17:00 **Systematic Issues of Oscillation Analysis in T2K** *20'*
Speaker: Prof. Kendall Mahn (Michigan State University)
Material: Slides

17:20 **Systematic Issues of Oscillation Analysis in MINOS and NOvA** *20'*
Speaker: Prof. Mayly Sanchez (Iowa State University)
Material: Slides

- https://indico.fnal.gov/
conferenceOtherViews.py?view=standard&confId=13620

Tuesday, March 28, 2017

09:00 - 10:30 Near Detector Task Force Activities
Role of the near detector in constraining systematics, input from Near Detector Task Force study, fitting machinery (VALOR etc.)

09:00 **Report From Near Detector Task Force** *30'*
Speakers: Dr. Daniel Cherdack (Colorado State University), Prof. Kendall Mahn (Michigan State University)
Material: Slides

09:30 **Progress of Reconstruction Using TRex** *15'*
Speaker: Dr. Jennifer Haigh (University of Warwick)
Material: Slides

09:45 **Simulation of LAr TPC** *15'*
Speaker: Dr. Jonathan Asaadi (University of Texas Arlington)
Material: Slides

10:00 **Analysis Strategy** *15'*
Speaker: Dr. Steve Dennis (University of Liverpool)
Material: Slides

11:00 - 12:35 Near Detector Requirements
Studies addressing requirements or capability relevant to the near detector system.

11:00 **A Method to Evaluate ND Optimization Options** *20'*
Speaker: Dr. Xin Qian (BNL)
Material: Slides

11:20 **Figure of Merits** *20'*
Speaker: Dr. Roberto Petti (University of South Carolina)
Material: Slides

11:40 **Requirements of Near Detector** *20'*
Speaker: Dr. Dan Dwyer (LBNL)
Material: Slides

12:00 **Flux Measurements with nu+e and Low-nu** *20'*
Speaker: Dr. Chris Marshall (Lawrence Berkeley National Laboratory)
Material: Slides

12:20 **Role of DUNE near detector to reduce Systematic Uncertainty** *15'*
Speaker: Dr. Monojit Ghosh (Tokyo Metropolitan University)
Material: Slides

14:00 - 16:00 Detector Technologies
Options for tracking systems, calorimetry, etc.

14:00 **The CALICE highly granular scintillator calorimeters** *30'*
Speaker: Dr. Frank Simon (Max-Planck-Institute for Physics)
Material: Slides

14:30 **Optical Readout of Gaseous Argon TPC** *20'*
Speaker: Dr. Morgan Wascko (Imperial College London)
Material: Slides

14:50 **Detection of Scintillation in Liquid Argon** *10'*
Speaker: Dmitri Denisov (Fermilab)
Material: Slides

15:00 **Cold Electronics for Pixelated Readout of LAr TPC** *20'*
Speaker: Dr. Dan Dwyer (LBNL)
Material: Slides

15:20 **Scintillator Tracker for Near Detector** *20'*
Speaker: Prof. Steven Manly (University of Rochester)
Material: Slides

15:40 **Development of LAPPD** *20'*
Speaker: Andrey Elagin (University of Chicago)
Material: Slides

16:15 - 17:30 New Ideas
Discussion of new ideas including Hybrid detector options and the options for the magnet system

16:15 **Hybrid Detector Options** *25'*
Speaker: Prof. Chang Kee Jung (Stony Brook University)
Material: Slides

16:40 **Near Measurements Conceptual Design Choices and Scientific Strategy** *20'*
Speaker: Dr. Milind Diwan (BNL)
Material: Minutes Slides

Wednesday, March 29, 2017

09:00 - 10:30 Near Detector Concept Study
What are the main considerations for the Near Detector and how do we evaluate options?

09:00 **Recycling KLOE: an eco-friendly possibility** *20'*
Speaker: Sergio Bertolucci (CERN)
Material: Slides

09:20 **How to Evaluate Detector Options?** *30'*
Speaker: Prof. Steven Manly (University of Rochester)
Material: Slides

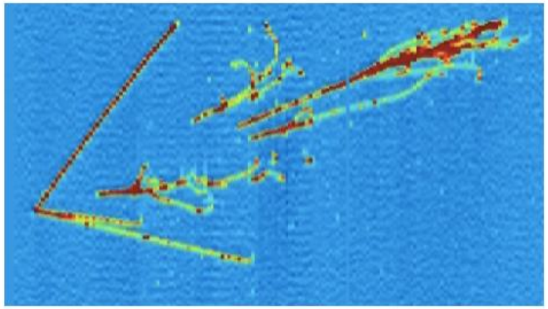
09:50 **Study of Missing pt for NC/CC Processes** *20'*
Speaker: Dr. Chris Marshall (Lawrence Berkeley National Laboratory)
Material: Slides

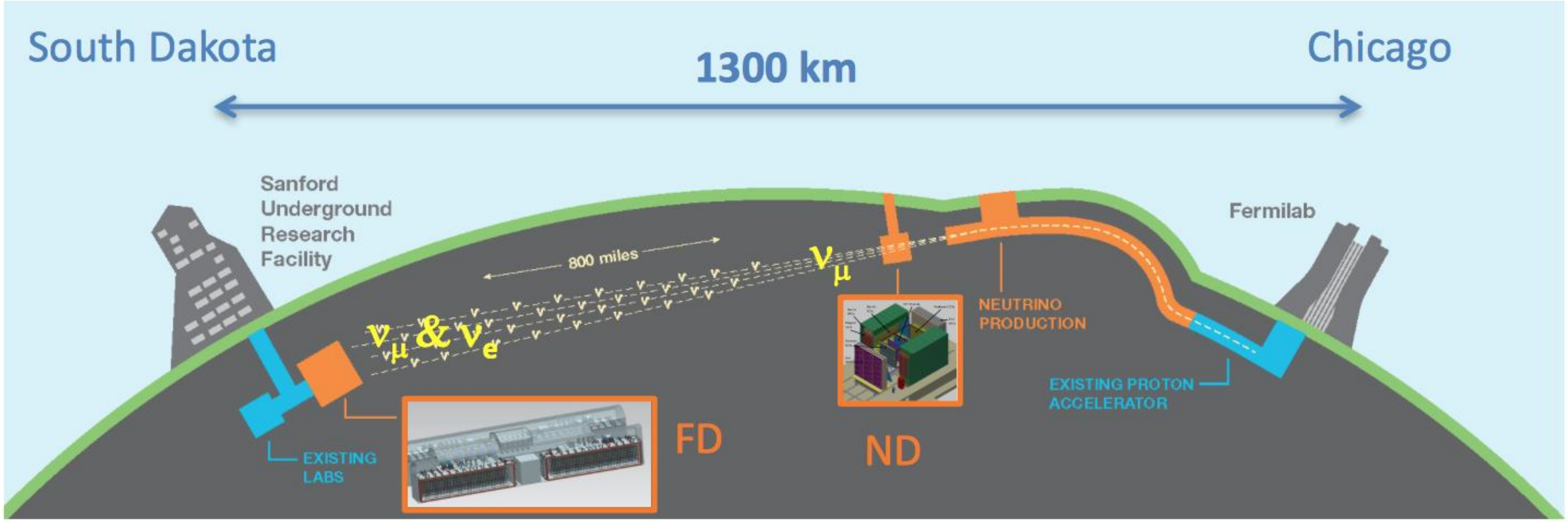
11:00 - 12:30 Next Steps and Closeout
What are the next steps/plans and meeting closeout

11:00 **Near-term Plan of Action** *20'*
Speaker: Prof. Kam-Biu Luk (UC Berkeley)
Material: Slides

DUNE

- **DUNE Scope**
  - **Four 10-kt LAr-TPC Far Detector (FD) modules**
    - Modules #1 and #2: CD-2/3 review in 2019
    - Modules #3 and #4: approval early 2020s
  - **DUNE Near Detector (ND)**
    - CD-2 review in 2019 (CDR)
    - CD-3 review in 2020 (TDR)





Strategy for Near Detector

- **We are at an earlier stage compared to the FD**
  - A number of options have been considered
- **Options: FGT, HP-TPC, LAr-TPC or a hybrid system or**
  - Fine-Grained Tracker (FGT) was the reference design for CD-1R
  - FGT is a good option, but pre-dates the DUNE collaboration
  - In **2017**, the **international DUNE collaboration** needs to **come together** to **agree a concept for the ND**
  - Once agreed, look to build matrix of ND responsibilities
- **Design can not be decoupled from $$$$**
  - Any ND concept needs to have a plausible funding model
  - Shouldn't forget that the ND is a big project in itself, need multi-national contributions

Near Detector Concept Study

- **Charge:**
  - Develop a proposal for a DUNE collaboration near detector **concept** by the end of **2017**
- **Study should:**
  - Ensure that the proposed near detector concept meets the requirements of the primary scientific goals of DUNE.
  - Assume a single near detector hall of a **similar to the CD-1-R design**, located at a distance of between 360 m and **575 m** from the target.
  - Present a plausible funding model for the proposed concept, based on the interests and likely contributions to the detector construction from the international collaboration
  - Focus solely on the design of the Near Detector; the scope of the study does not extend to the design of the LBNF near site facility

Timeline

In the best of worlds…

- **Major milestones/steps**
  - Mar 2017: 3-day DUNE ND Workshop 27th-29th March at FNAL
    - **open to all interested parties, not just DUNE collaboration**
  - May 2017: agree on 2 [or 3] options to pursue
  - Jun 2017: 3-day DUNE ND Workshop to review and document pros/cons of each option and assumed funding model
  - Aug 2017: presentation of options at collaboration meeting and possible down select
  - By the end of 2017: concept agreed by collaboration

ND Concept Study

- Early 2018: "Expressions of Interest" in ND construction
  - **start to identify institutional/national responsibilities**
- By the end of 2018: ND CDR (could be updated FGT CDR)
- By early of 2020: ND TDR for CD-3C review in August

ND Design

How to converge on a concept

- **Needs to be a collaborative effort**
  - not a shoot out
- **Not time for multiple full MC simulations**
  - but have a number of tools in place (from ND task force):
    - MC simulations of FGT, LAr-TPC, HP-GAr-TPC
    - Some reconstruction tools
    - Fitting technology (VALOR)
- **Need to base choices on a number of approaches**
  - identification of key measurements
  - VALOR-style fits
  - Experience

All have merit

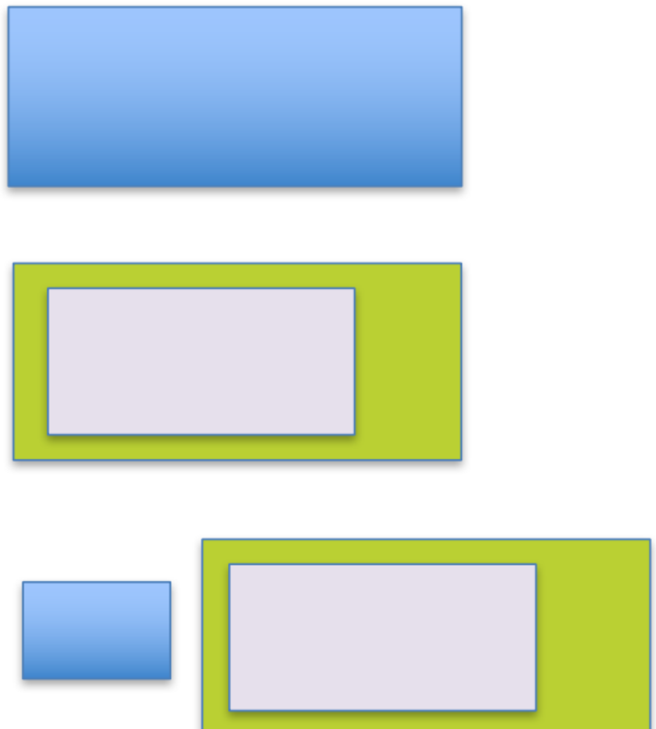
- **Keep in mind $$$ and likely contributions/interests**

Detector options

- **Two basic detector "approaches"**
  - LAr-TPC
    - Functionally the same as the FD
  - Fine Grained Tracker (FGT) = tracker, calorimeters, …
    - Constrain flux/cross sections through highly-capable system
- **Could combine the two approaches in hybrid detector**
- **Then there are multiple options for FGT technologies**
  - e.g. Tracker:
    - Straw tubes (e.g. NOMAD)
    - Gaseous TPC (T2K, HP-GAr-TPC)
    - Scintillator strips (e.g. MINERVA)
- **Don't forget the magnet system**
- **Don't forget pile-up of many ν interactions**

Limiting the parameter space

- **Probably three basic options**
  - **LAr-TPC**
  - **FGT**
  - **Hybrid**



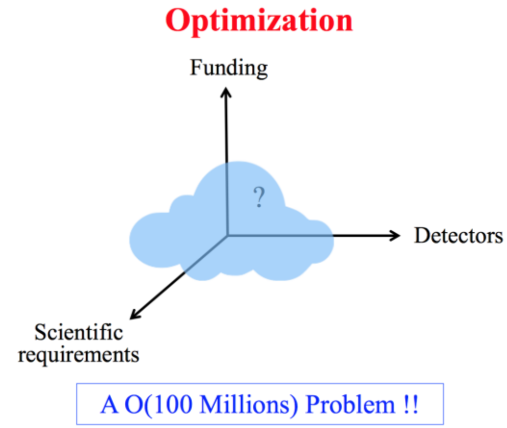
With technology options

Engineering challenges:
cryostat, magnet system

- **Can we quickly limit this parameter space?**

Kam Biu Luk: ND group coordinator
Alfons Weber now co-coordinator

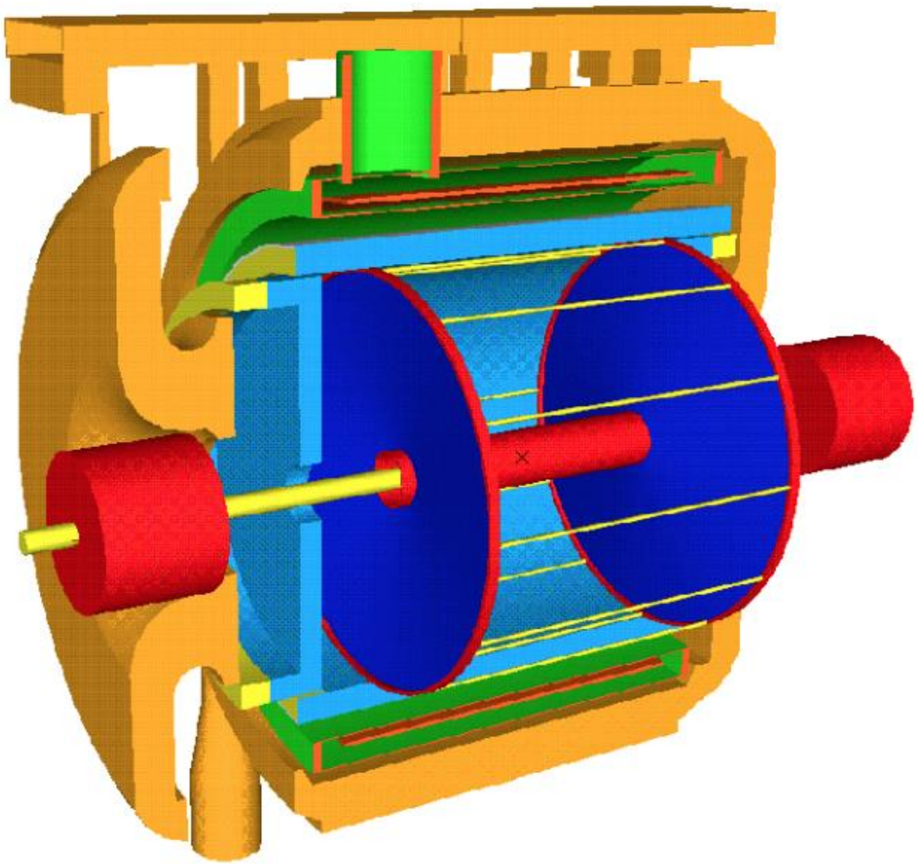
Action Items



- Scientific Requirements
  - Identify golden processes
    - Identify key physical parameters to be measured well
    - Quantify the requirements
  - Establish the baseline of the near site
- Detectors
  - Magnet
  - Liquid-argon TPC
  - High-resolution tracking detector
  - ECal
  - Muon detector

} Hybrid options

The KLOE experiment



Be beam pipe (0.5 mm thick)
Instrumented permanent magnet quadrupoles (32 PMT's)

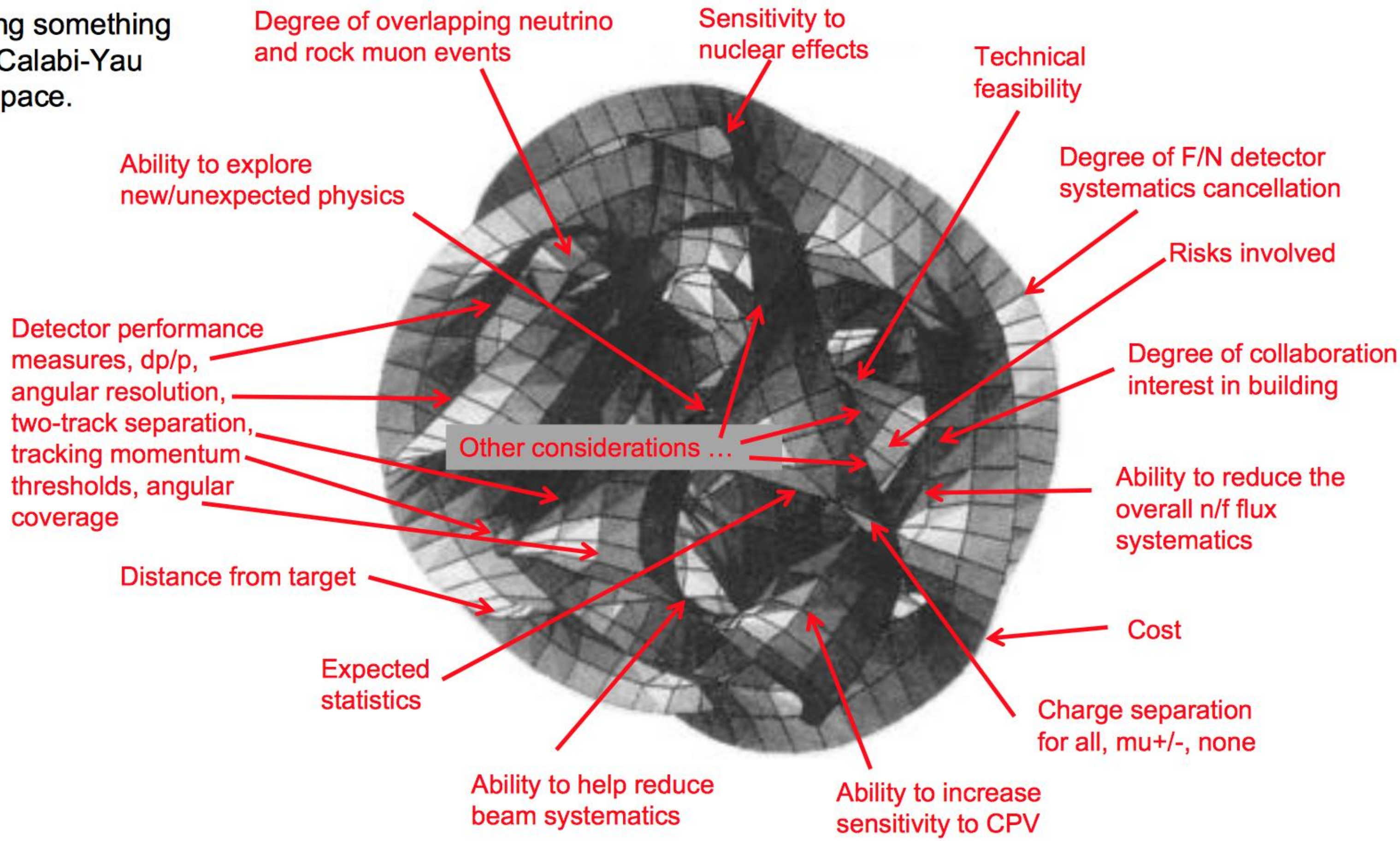
Drift chamber (4 m ∅ × 3.3 m)
90% helium 10% isobutane
12582/52140 sense/total wires

Electromagnetic calorimeter
Lead/scintillating fibers
4880 PMT's

Superconducting coil (5 m bore)
$B = 0.6$ T ($\int B\, dl = 2.2$ T·m)

Italy has decided to you the ND effort (S. Bertolucci)

We are facing something more like a Calabi-Yau parameter space.



Seems to many open questions to me for ‘fast’ decision

Typical questions

- To what extent do we need spectral high precision information from neutrino-electron analysis?
  If needed, is it realistic technically at the required level with beam dispersion?
- To what extent do the proposed LArTPC or FGD cancel detector systematics at the FD?
- To what extent to we need a magnetic field? Do we need for electrons AND muons?
- To what extent will the sample-sample cancellation of uncertainties help? Are we comfortable relying on significant cancellation of cross-section/interaction uncertainty among FD samples? Or do we want to get close to required constraints with ND only?
- How well can we do neutrino-electron scattering in LArTPC

A lot of Discussion…

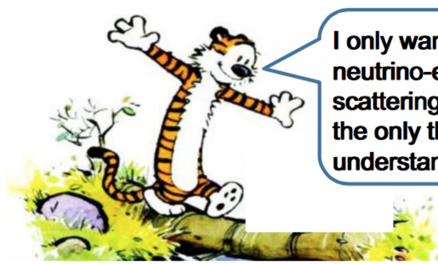
Reasonable people can make good arguments and wind up in rather different places

We should use an ND that is "identical" to the FD. This will cancel nuclear/xsec and detector systematics in the ratio.

Maybe sample-sample comparisons take care of the uncertainties mostly

We need a very powerful detector that is sensitive to new physics, contains Ar target(s), and can extract as much detailed information about the interactions as possible to feed into our models and constrain what happens at the FD.

Constraining the FD with such complex machinery is scary. How do you know when you are right? Can we really understand and model things to the level that we need to have confidence in high precision measurements?



I only want to do neutrino-electron scattering. It's the only thing we understand.

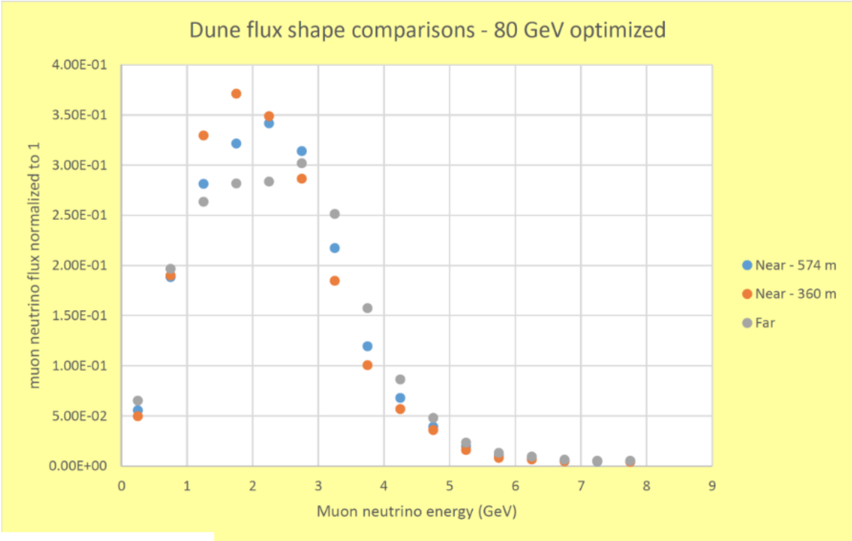
You can't build an ND that is identical to FD! Even if you do, the spectrum is different. So, you really have no choice but to deal with some things not canceling in the F/N ratio. More information from a lighter density detector is helpful. It's better for surprises and provides the ability to measure many processes to inform the fits. Smart people can do many cross-checks for confidence.

Convergence?

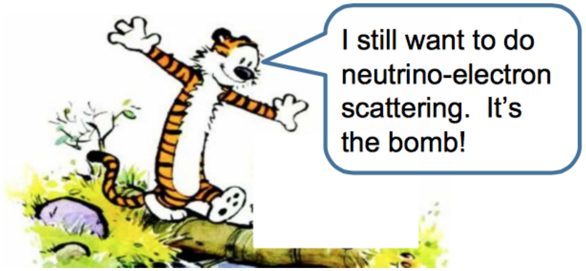
Steven Manly

My opinion:
everybody's right

- ND ≠ FD and $\text{Flux(E)}_{ND} \neq \text{Flux(E)}_{FD}$ and rate dependent effects and differences in readout, etc.
- No choice but to measure/model detector and nuclear/xsec effects and use that information to inform the N/F ratio and its error budget
- Given that, would be nice to have detector that can do spectacular job on flux and xsec as function of E and neutrino type and interaction topology
- Still, also seems prudent to have a component of the ND be as similar to the FD as we can manage in order to reduce the size of the nuclear/xsec and detector-related systematics as much as possible.
- Neutrino-electron scattering is powerful. At the very least it can give a handle on the integral flux and some spectral information. Hooray! This is very hard business. Give me handles! Can we get spectral information to the hoped for precision? Is that precision really needed?



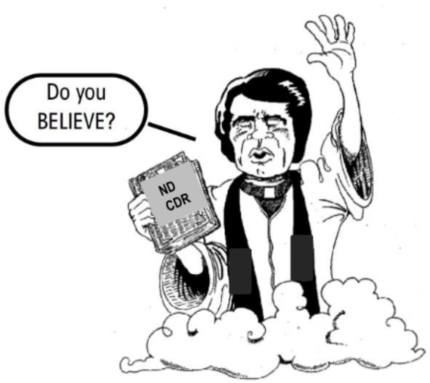
Maybe we can have it all with a hybrid design.



Interest in EP-nu/nu-Platform/CERN

- Hardware activities including electronics, triggers, online etc. Interests?
- R&D on new ideas?
  - Involve also the EP-DT group
- Off-line software development?
- Physics studies (not much time for those)?
- Of course our prime target at CERN is ProtoDune for the near future. Availability of manpower?

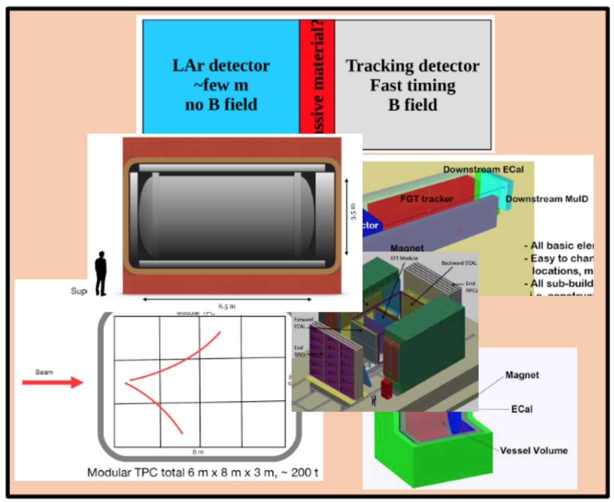
BACKUP



In the end, judgement and maybe even a little faith will come into play, but for now …

Regardless of the candidate technology(ies) for a proposed detector, we need to quantify as best we can (with time/resources available):

- Degree to which detector can reduce detector and nuclear/xsec systematics
- Constraint provided on the flux error at FD
- Performance on basic/exploratory physics via FOM analyses and performance proxies and Valor/CP sensitivity framework
- Technical feasibility, cost, available manpower, etc.
- Other pressing questions, see later in slides



What do we mean by "Hybrid"?

- Hybrid Near Detector ≡ Same "active" target detector w/ FD + FGD
  - K2K ND: a hybrid detector
  - T2K ND: NOT a hybrid detector
    - Lacking active FD target (water) detector
  - MINOS and NOvA NDs: NOT hybrid detectors
    - Functionally identical/similar ND and FD
    - Lacking FGD elements
- Can we consider a hybrid detector for DUNE ND?
  - e.g.) LAr TPC + FGD, HPGAr TPC + FGD or LAr TPC + GAr TPC + FGD
  - What are the pros and cons?

Why go Hybrid?

- Pros: Wider coverage of physics and better handling of systematic uncertainties
  - ¬ Active FD target detector can cancel some major syst. errors (cross section and detector)
  - ¬ Complementary subdetectors can better address physics requirements and syst. errors
- Pros: More versatile to adopt the advance in the neutrino physics
  - ¬ Projecting to the status of our knowledge in 10 years
    - Utilize both the knowledge to be gained from the LAr TPC experiments (ProtoDUNE, CAPTAIN and SBN detectors) and Scintillator detectors (MINERvA, T2K and NOvA)
    - It is likely more robust in dealing with new sources of systematic errors that are unknown today e.g.) 2p2h

Why go Hybrid?

- Pros: More diverse and rich cross-section measurements and ND physics program
- Pros: Broader participation of the collaborating institutions/countries
  - ¬ Each detector option/subdetector must have a champion who has expertise/ track records and plausible path to acquire funding
    - Better matched projects/component and expertise
    - More manageable construction and operation costs for Identifiable projects

    → Higher probability of getting an approval w/ a more credible proposal
- Pros: Can start with all ideas on the table with participation open to all collaborators
  - ¬ Achieve the final design through a collaboration-wide consensus
- Cons: Larger overall costs, although effective burden per institution could be lower

MY NEAR DETECTOR WISH LIST

- The extrapolation Near to Far using functionally similar detectors allows for significant first order systematic uncertainties cancellations in flux x cross section and even detector response. It is a challenge to disentangle these. Therefore my ND wish list includes:
    - Excellent lepton particle ID/energy resolution
    - Excellent hadronic shower energy resolution
        - 4pi containment of hadronic showers
    - Same nucleus/material as far detector
        - Important for neutrino interaction surprises
    - Able to deal with flux/intensity at near site
    - Similar detector response than far detector (hard I know)