Repurposing the 2 X 2 demonstrator

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ArgonCube Collaboration Meeting

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What the hell is he talking about: Motivation

- The theoretical challenges to understanding ν nucleus interactions are daunting.
  - Limited progress has been made over the last decade (ν)
  - Although Nuclear Physics has witnessed tremendous progress in the theoretical and computational tools that produce our understanding of light nuclei and their interactions with electroweak probes (e γ)
- The DUNE science program will likely have to address this issue at some point, if not initially
- Workshops/meetings are being held now and planned for the near future to address this
- **Fundamental Physics with Electroweak Probes of Light Nuclei, June 12 - July 13, 2018**
  - Month long series of meetings addressing many issues

Motiviation II

- One WS in this series is *"From nucleons to nuclei: enabling discovery for neutrinos, dark matter and more" (6/25-29)*
  - **Fundamental properties of neutrinos:**

    How do we relate the fundamental quark-level interactions of the neutrino to the complete nuclear response? What are the capabilities of lattice QCD and ab initio approaches?

    Next-generation experiments are poised to discover leptonic CP violation, explore lepton-number violation, discern the mass hierarchy, and answer other fundamental questions about neutrinos. However, hadronic uncertainties need to be accounted for, experimental constraints should be incorporated, and radiative corrections must be included.
- *Study ν interactions on nucleons (H & D)*

The Big Question

- Can the data come from ν interactions on composites?
  - CH
  - C_3H_6
  - CH_4 & CD_4
- If Yes, then that is certainly the way to go. We have heard about this in detail (to put it mildly).
  - STT
  - 3DST
  - ….
- If No
  - Life gets harder
- As far as I can tell, there is not a consensus in our community regarding the answer to this question
- It would be good to get a statement in this regard out of the upcoming From nucleons to nuclei WS
- Let's assume the answer is a resounding, *"We want Hydrogen"*

So what's the problem?

- **It's the beam stupid**
  - It is underground
- That means (in the US) we have to abide by the NFPA 520 Standard on Subterranean Spaces
  - It's the Law
  - Similar restrictions exist in Europe, the UK and Japan

- And here is the problem:

You can only have ~ 60L

Table 4.1.3.1(b) Maximum Quantity of High-Hazard Material in Use[a] in Closed Systems per Control Area[b]

Material	Class	Solid		Liquid		Gas	
		lb	kg	gal	L	ft^3	m^3
Combustible liquid[c,d]	II			120	454		
	III-A			330	1,249		
	III-B			13,200[f]	49,963		
Combustible fiber							
Loose		100 ft^3	2.8 m^3				
Baled		1,000 ft^3	28 m^3				
Explosives		0.25	0.114	0.25 lb	0.114 kg		
Flammable solid							
Flammable gas							
Gaseous						750[d,e]	21.2
Liquefied				15[d,e]	56.7		
Flammable liquid[c,d]	I-A			30	113.5		
	I-B			60	227		
	I-C			90	340.7		
Combination							
I-A, I-B, I-C				120	454		

However, with sprinklers and fire wall get X4: 240L = 17kg (71g/L)

With fiducial volume cuts -> 10kg of target mass?

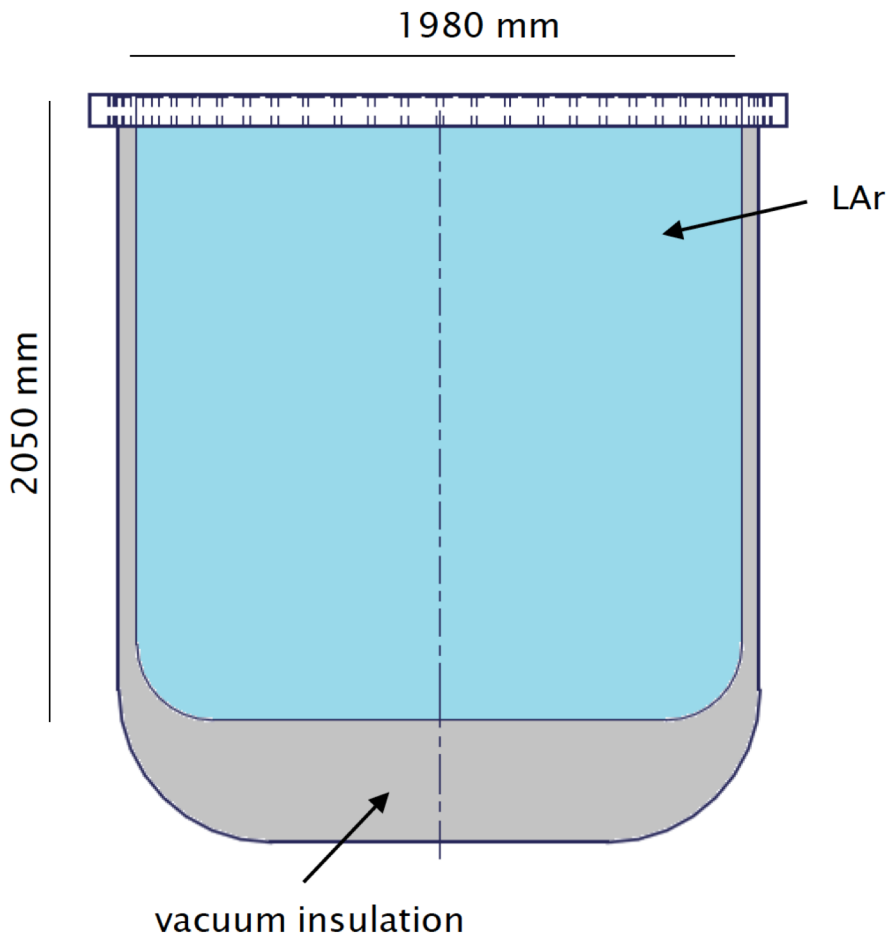
Options

- I met with Jim Kilmer recently to discuss possibilities
  - No difference w/r to operational restrictions gas vs. liquid
  - Not concerned with having electronics in hydrogen volume
  - Believes a valid technical case can be made that safe operation underground with quantities >> than the NFPA 520 limits is possible. Ask for exception
  - He did this for Minerva (2250L)
    - Not approved to move forward
  - The difficulty will be getting the Fire safety professionals at the lab to consider exceptions to NFPA 520.
  - .....
- Another subtlety:
  - Must assure that the "Hydrogen Area" is limited to a region surrounding the detector!

So let's assume we can get past NFPA 520

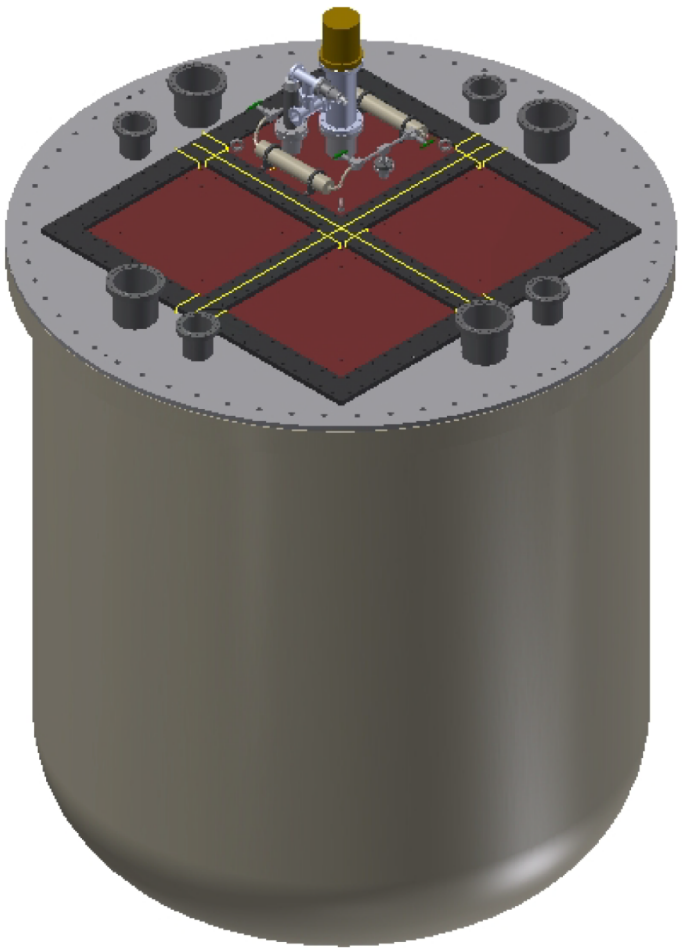
- There is a rather large body of data on Hydrogen gas TPCs
  - Numerous applications in nuclear physics
- Also, has been done at Fermilab:
- In the 1980's a 15 bar H_2 TPC was built for diffraction dissociation of photons on hydrogen, $\gamma p \rightarrow Xp$
  - Active target + tracking (sound familiar?)
  - 1.5kg of H_2
  - Note: If we fill the HPgTPC with 10 bar of H_2, we will have ~ 45kg fiducial target mass. 90kg total
- So using the HPgTPC with H_2 fill is an option, but since the volume is so large, inerting or purging the volume would be complicated.
- A denser detector is an advantage in this regard.

2 X 2 Demonstrator redux



- The 2 X 2 demonstrator provides an excellent platform for an active hydrogen target
- Can reasonably achieve a fiducial target volume of ~ 1m^3
  - 71kg
    - Maybe squeeze out a bit more fiducial target mass?
  - Total volume ~ 6000L
- To my knowledge, this would be the first application of a liquid H_2 TPC.
- And quite a few cryogenic issues to work out also
  - 20K operating temperature

2 X 2 Demonstrator redux II



- Likely will need a dome over the top plate to facilitate inerting with N_2 and then provide proper (sealed) feedthroughs for all cable/hose penetrations.
- Then put the 2 X 2 in a 2hr fire-rated enclosure and again inert with N_2
  - It is an ODH area obviously
  - Can be thin in X_o : Drywall
- ArgonCube just downstream and acts as the catcher

LH_2 TPC

- To my knowledge, this has never been attempted
- Some data on electron transport in H_2 at 77K

ELECTRON TRANSPORT COEFFICIENTS IN HYDROGEN AND DEUTERIUM

By R. W. Crompton,* M. T. Elford,* and A. I. McIntosh*†

[*Manuscript received August* 31, 1967]

- I have not done an exhaustive search, but this is all that I found. These data indicate that the drift velocity and diffusion under these conditions is acceptable.
- R&D on electron transport in LH_2 would need to be done.

Moving forward

- Need very strong statement from neutrino interaction community.
  - Opportunity to get one from upcoming WS?
- Discussions with LBNF need to start soon regarding special needs for ND hall
  - Dedicated vent lines to surface and supply lines to hall
- Engaging Fermilab fire safety personnel is also crucial!!
- If it looks like the safety issues might be approachable, then R&D on electron transport in LH_2 would need to begin.