DHCAL for Neutrinos

José Repond

Argonne National Laboratory

Situation

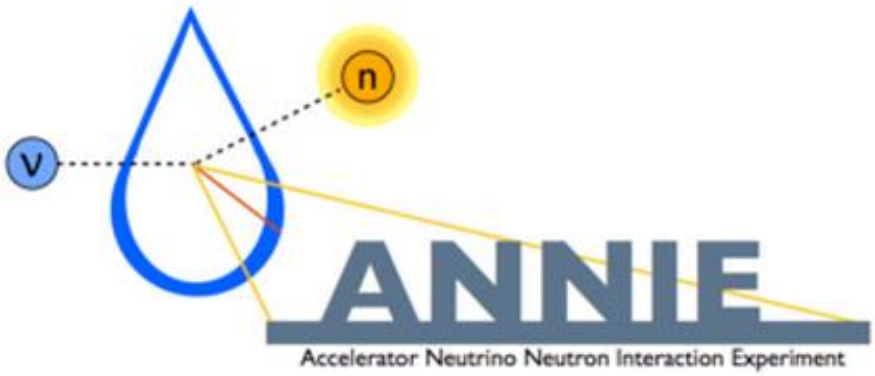
Funding for any DHCAL activities has been **abruptly terminated** by the beginning of FY2015 (October 2014)

The DOE and Argonne management have since **limited all activities**, such as further developments, participation at meetings etc.

In February the DOE requested a **White Paper** on future use of the DHCAL technology

Three experiments have expressed interest in using the existing DHCAL layers or the technology

In addition, we have made some progress with the development of **fast RPCs**

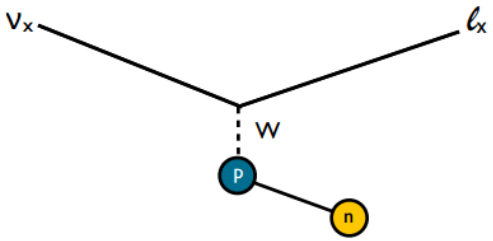


Measurement of the neutron yield of neutrino interactions in Gadolinium-doped Water

→ understanding neutrino-nucleus interactions
→ addressing limiting factor in proton decay searches (neutrino induced backgrounds)

Number of neutrons depends on

a) Type of interaction
b) Momentum transfer



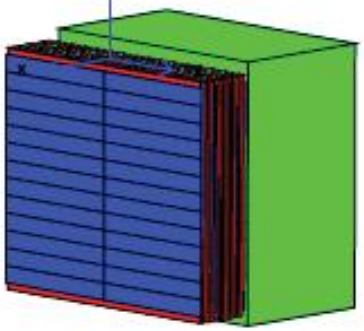
The DHCAL will be used to measure the direction and energy of outgoing muons

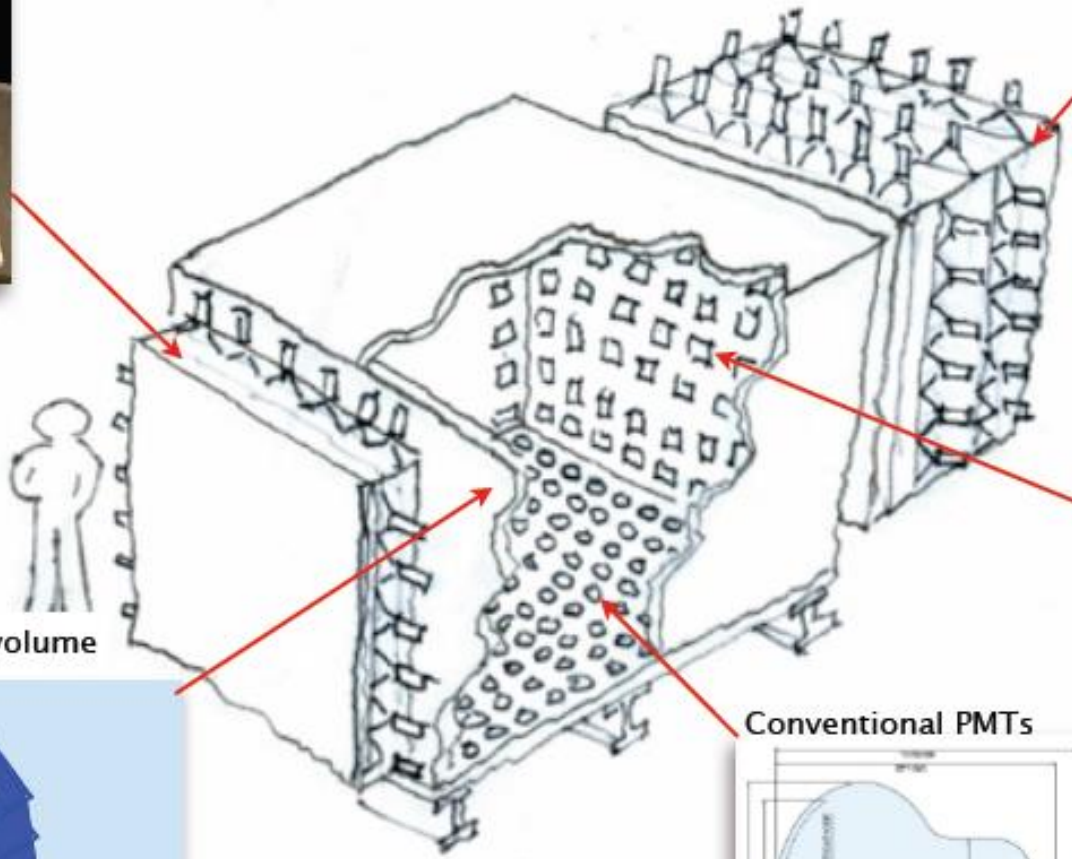
Deployment later this year?

The ANNIE Detector System

Front Anti-Coincidence Counter

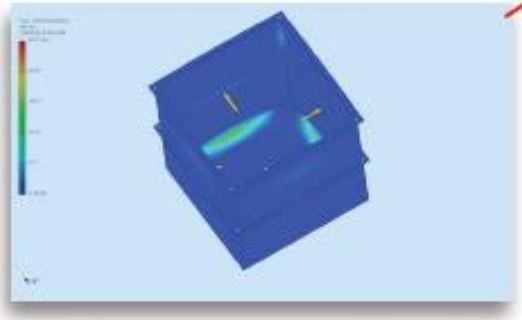
Muon Range Detector



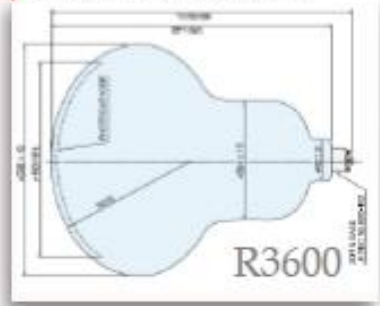


LAPPDs

Gd-loaded water volume



Conventional PMTs



Measurements to be done with ANNIE

Produced neutron(s)

Measured with Large Area Picosecond Photo Detectors (LAPPDs) and conventional phototubes

Outgoing muon

a) Measured with Scintillator-based Muon Range detector

→ crude angular resolution
→ large solid angle

b) Measured with DHCAL layers + additional absorber plates

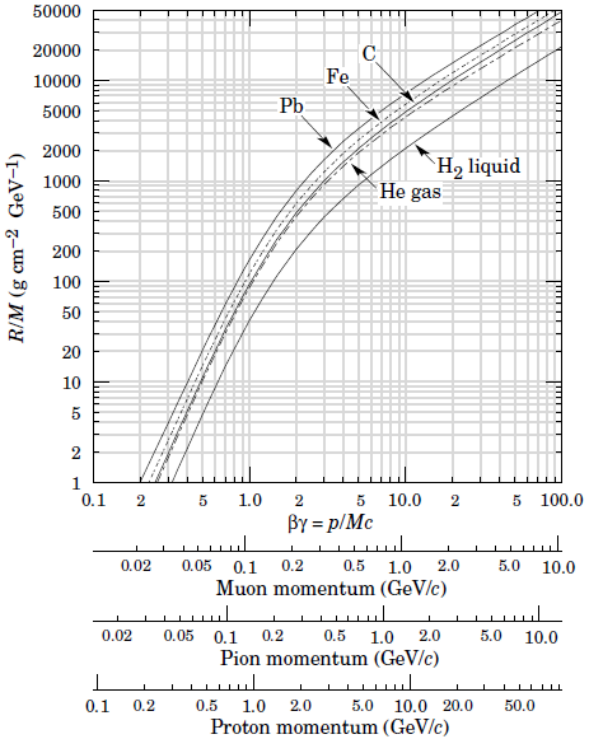
→ much improved angular resolution
→ limited angular acceptance
→ can be moved to cover different solid angles

Depth of DHCAL

Energy of muons estimated through their **range** in the DHCAL

Maximum energy about 1.6 GeV

Material	Thickness	Density [g/cm³]	Thickness [g/cm²]	X_0	λ_1
Copper	2 mm	8.960	1.792	0.14	0.013
Steel	2 mm	7.874	1.574	0.11	0.012
Glass	2 mm	2.230	0.446	0.07	0.005
Teflon	3 mm	2.20	0.440	0.09	0.007
Total			**4.252**	**0.41**	**0.037**



DHCAL Total Thickness = 4.252*50 layers=212.6 g/cm²

Range/M = 212.6 [g/cm²/GeV] …M is the mass of the particle

From PDG 213 [g/cm²] stops ~0.5 GeV/c muons
1.6 GeV muon stops in ~950 [g/cm²]

Need additional 50 layers of 2 cm steel to absorb 1.6 GeV muons (cost ~ $25k)

Revamp and prepare the DHCAL

A) **Study loss of efficiency problem**

Cross-correlate efficiency measurement with physical layer
Measure surface resistivity
Propose solution

B) **Prepare solution to board-bending problem**

Design some matting to insert into the cassettes
Test if readout boards can be made to be flat again

C) **Disassemble all 50+ layers and reassemble with proper solutions**

D) **Design and build new absorber structure**

Short Baseline Neutrino Detector - SBND

Planned neutrino detector

On Fermilab site – 110 m from Fermilab Booster
Part of an ensemble of neutrino detectors at different baselines

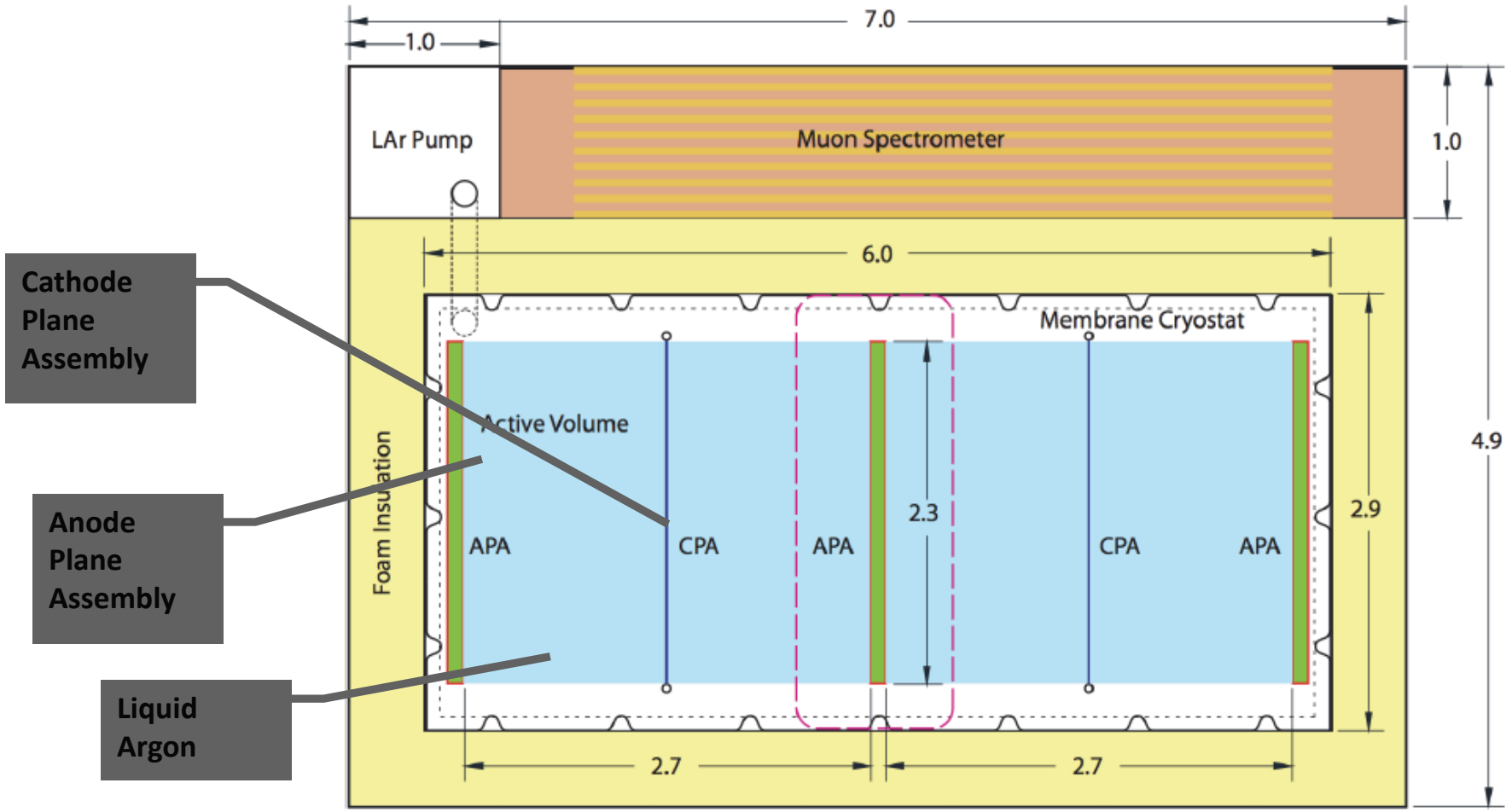
Main detector

Liquid Argon Time-projection Chamber

Physics motivation

Search for CP violation in the lepton sector
Understanding of experimental anomalies at short-baselines (e.g. LSND effect)
Search for oscillations to sterile neutrinos

The Detector Concept



Muon Spectrometer

Role

Identify cosmic ray tracks

Traditional cosmic ray rejection

If track present, veto DAQ for a certain amount of time

Improved muon spectrometer

Track muons and exclude only area in vicinity of track

DHCAL technology

RPCs with 1 x 1 cm^2 pad readout
Attractive solution for tracking muons in 3D
50 Layers available corresponding to ~15 m^2
(Assuming 3 layers deep)

SBND expressed interest

Time scale

First data taking in 2018?

JUNO

Jiangmen Underground Neutrino Observatory

Measurement

Neutrinos from reactor

	Current	JUNO
Δm^2_{12}	~3%	~0.6%
Δm^2_{23}	~5%	~0.6%
$\sin^2\theta_{12}$	~6%	~0.7%
$\sin^2\theta_{23}$	~20%	N/A
$\sin^2\theta_{13}$	~14% → ~4%	~ 15%

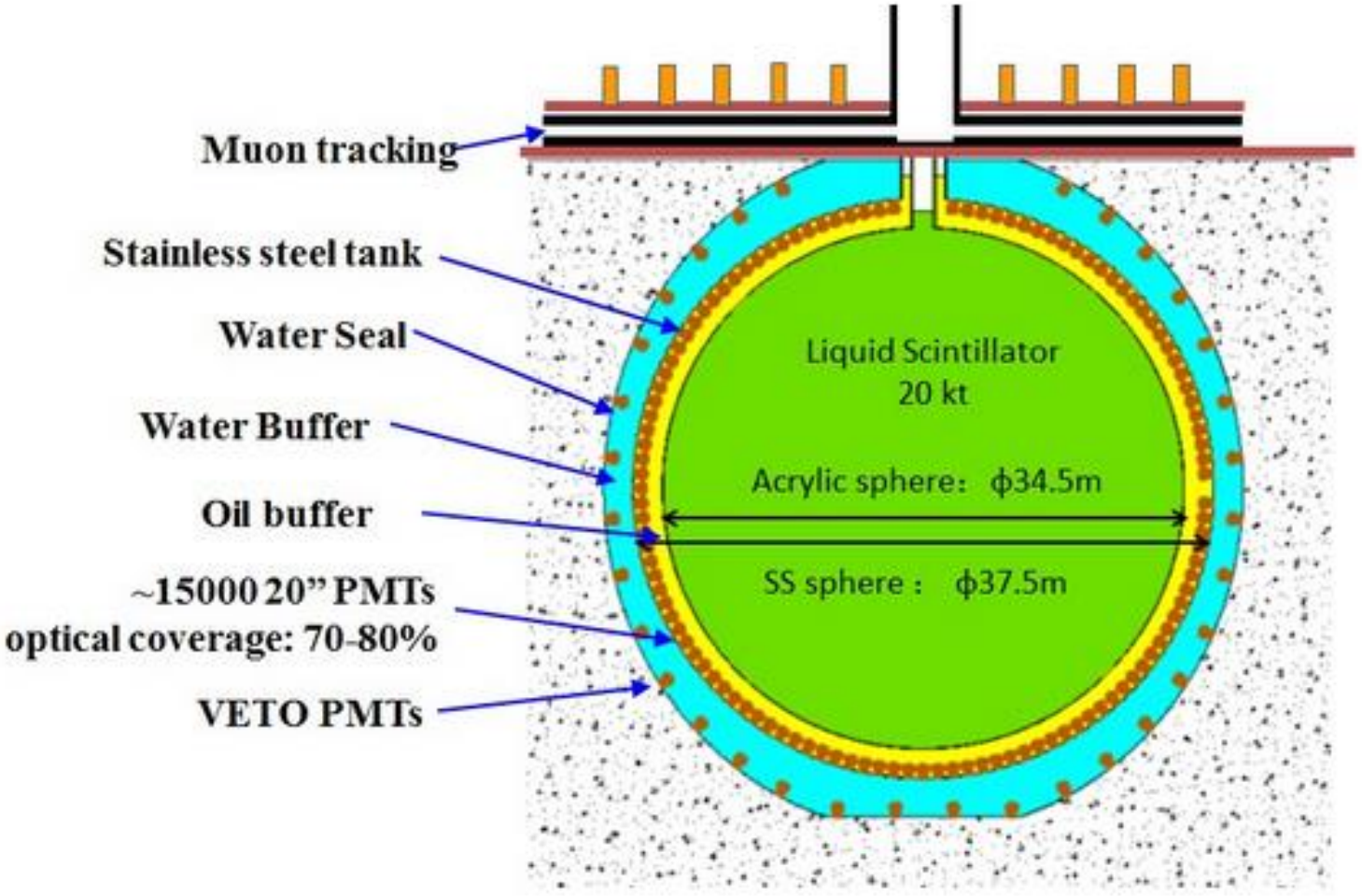
Goal

Establish neutrino mass hierarchy
Measure neutrino mixing angles
+ observe supernova neutrinos
+ study atmospheric, solar and geo neutrinos

Time scale

Construction to start in 2014
To be completed in 2019

Detector Concept



Muon Tracking

Tracking muon versus veto

Reduced dead time

Area

1,600 m^2

DHCAL technology

Ideally suited
Need to build factor of 3x32 more (assuming 3 layers)
Only cover central region?

JUNO expressed interest

Conclusions

After the DHCAL program **was terminated**

Being asked to explore possibilities to re-utilize technology

Several projects **show interest**

ANNIE
SBND
JUNO

Addendum: High-rate RPCs

Semi-conductive glass plates

Several 20 x 20 cm^2 plates in hand
Bulk resistivity measured to be R_{bulk} ~6.3×10^{10} Ωcm
(in comparison, float glass, as used for the DHCAL, has R_{bulk} ~ $4\ 10^{13}$ Ωcm)

Fast RPCs

2 chambers almost completely assembled

Fermilab tests

Planned for early May, 2015