BT Fleming
April 17, 2013

Report from the Intensity Frontier

Take-aways from LArTPC R&D workshop
Thoughts on Instrumentation in near and far future for neutrino physics

Apologies for what is not presented here….

CPAD/Instrumentation Frontier

Outline:

Neutrino physics -> Precision detectors on large scales

- -advances in light collection in Water detectors
  - -Scintillator doping
  - -Gadolinium doping
  - -precision/low "profile" light collection
- -developing massive LArTPCs at reasonable cost
  - -Electronics
  - -Cryogenics
  - -Cryostats
  - -Light Collection
  - -Charge Collection
  - -High Voltage
  - -Calibration
  - -Deployment underground
  - -Magnetization

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Highlights from LArTPC R&D Workshop

Things I won’t cover but were discussed in the fall:

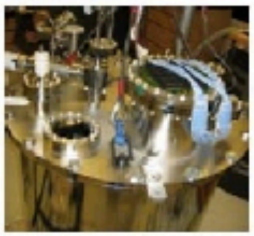
- -Heavy Quark Experiments
- -Rare Processes Experiments

Won’t cover this…..

The Detectors We Want to Use or Have Already Used

The following experiments have used/proposed/been approved/are constructing a detector with LAr as a neutrino detector. I am sorting them by their mass.

Yale TPC



Location: Yale University
Active volume: 0.002 ton
operational: 2007

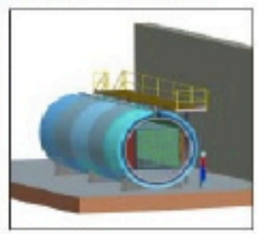
Bo

Location: Fermilab
Active volume: 0.02 ton
operational 2008

ArgoNeuT

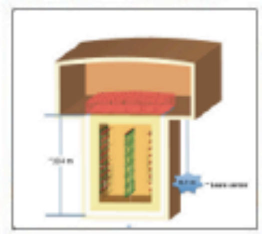
Location: Fermilab
Active volume: 0.3 ton
operational: 2008
First neutrinos: June 2009

MicroBooNE



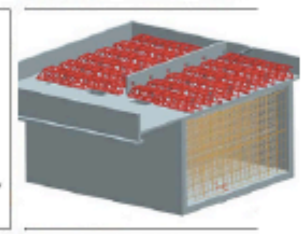
Location Fermilab
Active volume: 0.1 kton
Construction start: 2011

LAr1



Location: Fermilab
Active volume: 1 kton
Construction start: 2016?

LBNE



Location: Homestake
Active volume: 10 kton
Construction start 2020

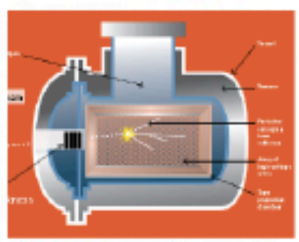
Luke

Location: Fermilab
Purpose: materials test st
Operational: since 2008

LAPD

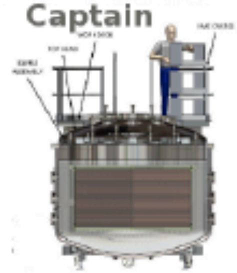
Location: Fermilab
Purpose: LAr purity demo
Operational: 2011

LAriAT



Location: Fermilab
Purpose: LArTPC calibration
Operational: 2013 (phase 1)

Captain



Location: LANL
Purpose: LArTPC calibration
Operational: 2013

R&D for LBNE design is mostly development with focus on cost savings – should make sure to keep options open.....!

Engineering Development

(not always straightforward.....)

- Informed by experiments running or in construction
- Mechanical, Cryogenics, electronics, Costing
  - Electronics-> Cold electronics with LBNE multiplexed in situ
  - High Voltage
  - TPC design for cost and installation
  - Costing models

Customizing the TPC detectors

All TPCs are not made equal. The technology is evolving and different needs dictate different construction choices and challenges. Examples are:

- Spacing between the wires, i.e. wire pitch. Sample values are:
  - 3 mm - MicroBooNE,ICARUS
  - 4 mm - ArgoNeuT
  - 5 mm - LBNE
- Warm vs Cold Electronics
- Electronics sampling time:
  - 0.197 μs - ArgoNeuT
  - 0.4 μs - ICARUS
  - 0.5 μs MicroBooNE, LBNE
- Wrapped wire planes: LBNE, LAr1
- Double Phase Readout - LBNO *(see talk by A. Marchionni)*
- Light Readout:
  - PMTs: MicroBooNE, ICARUS
  - Wavelength Shifter Paddles: LBNE, LAr1
  - SiPMs

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Light Readout in LArTPCs

Conventional readout in LArTPCs: PMTs operable at cryogenic temperatures

-requires wavelength shifting

-requires space!

Low Profile Readout

-SiPMs

-Wave guides + SiPMs

-New ideas?

Photon Detection Overview

2 processes production scintillation light in LAr

$$Ar^* + Ar \rightarrow Ar_2^* \rightarrow 2Ar + \gamma$$

$$Ar^+ + Ar \rightarrow Ar_2^+ + e \rightarrow Ar_2^* \rightarrow 2Ar + \gamma$$

decay from singlet Ar_2^* state: prompt light at 6 ns (~25%)
decay from triplet Ar_2^* state: late light at 1.6 μs (~75%)

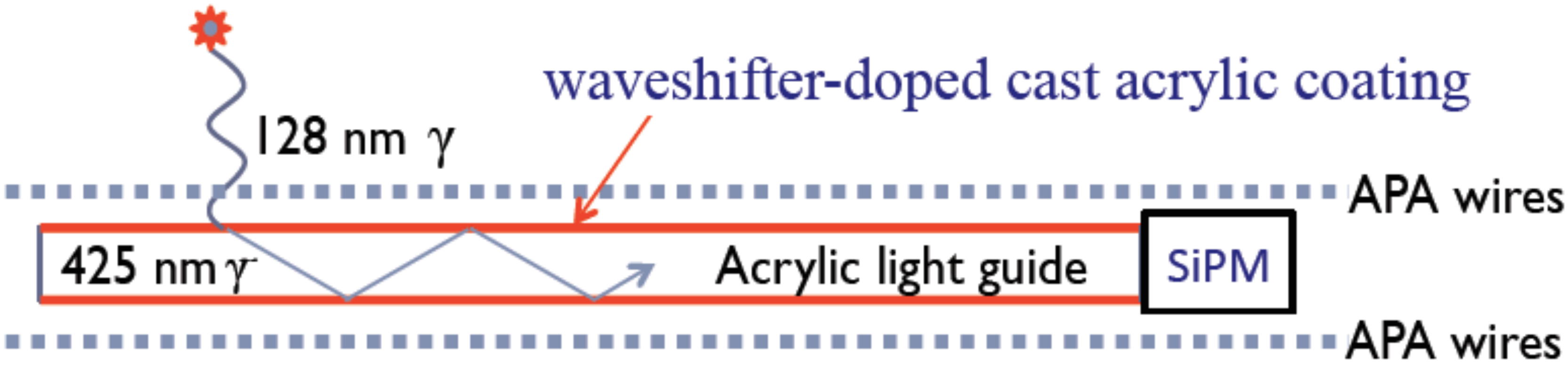
photons emitted in VUV at 128 nm, where

- photodectors are insensitive or expensive
- most materials are opaque
- solution: waveshifter (TPB/bis-MSB) to absorb UV photons and re-emit in the optical

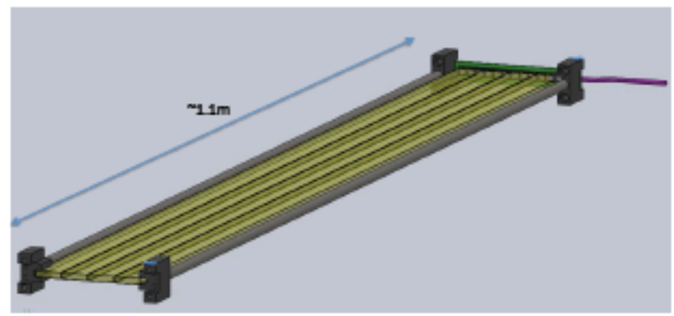
S. Mufson

Basic Element: Light Guide

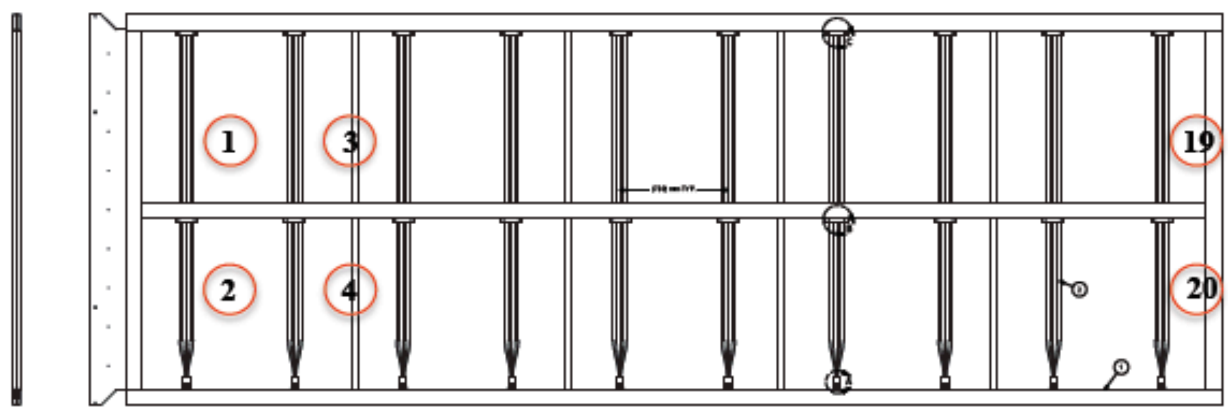
Design



4 light guides ganged into stainless steel Photon Detector Paddle (PDA)



20 PDAs
per APA plane



N. Buchanan
C. State

WLS Fiber-Based Prototype

- Why investigate fibers?
  - Potentially lead to cost savings – gang several channels to single photo-sensor
  - Could be used in a hybrid system with bars or some other "bulk" design
  - ~~Crazy~~ More exotic ideas like instrumenting the CPA with fibers and have sensors located some distance away
- How do you do this? One of three ways…
  - Coat the fibers with WLS (TPB or Bis-MSB)
  - Dope cladding with WLS (or an inner cladding perhaps)
  - Dope fiber core and use very thin cladding

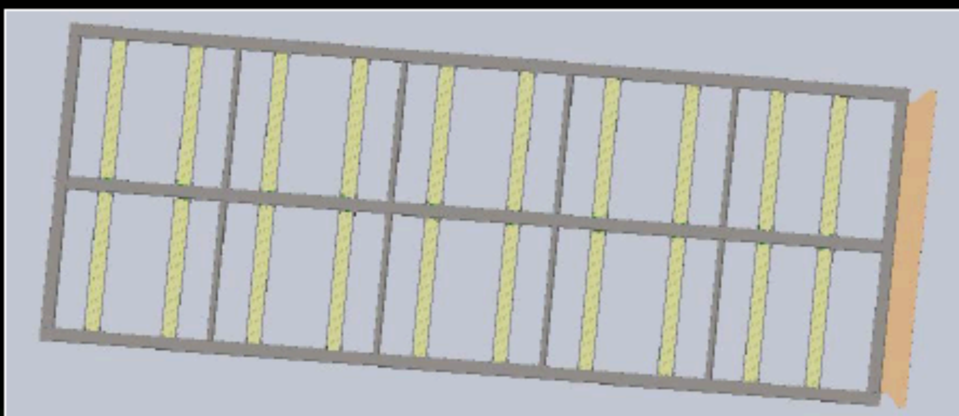
We are starting with the last option – have a sample of Bis-MSB doped fiber from Saint-Gobain (BCF-12 1 mm dia.)

Sent sample to LBNL for Vic to look at with his VUV system (next talk).

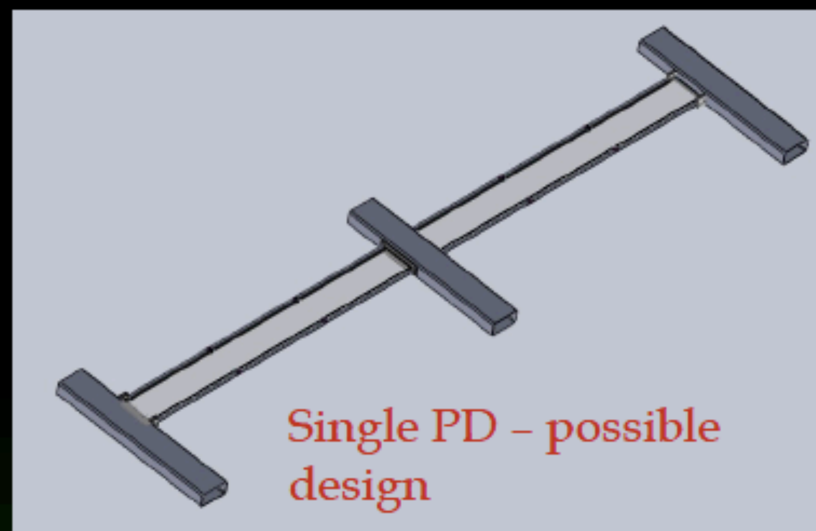
N. Buchanan
C. State

WLS Fiber-Based Prototype

- Design considerations
  - To keep PD design and engineering effort in check it is critical that the fiber-based design fit into the same package as the IU paddles



Fibers assemblies could be used in place of the paddles in this design – or perhaps to fill the empty regions

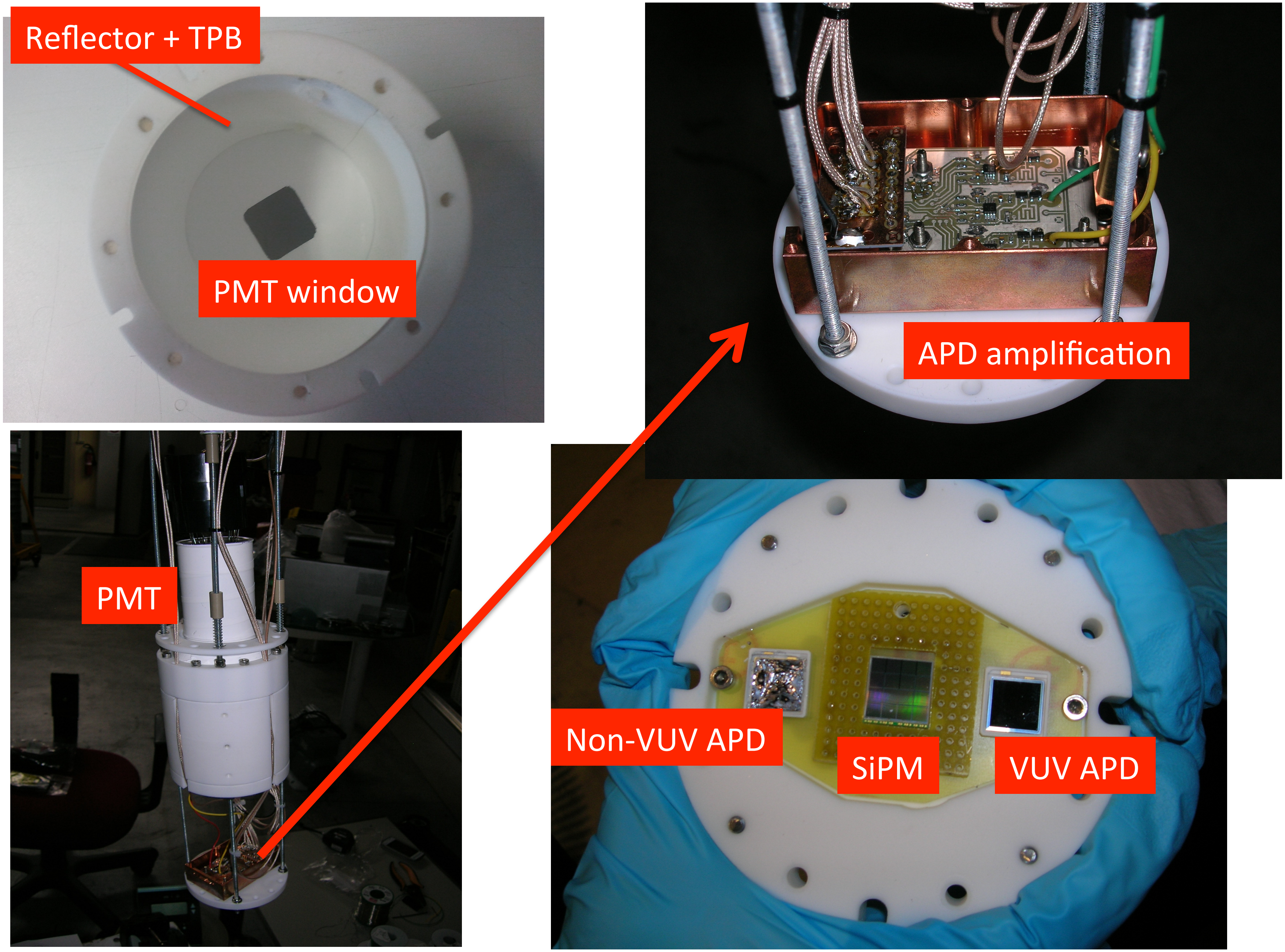


Courtesy Dave Warner

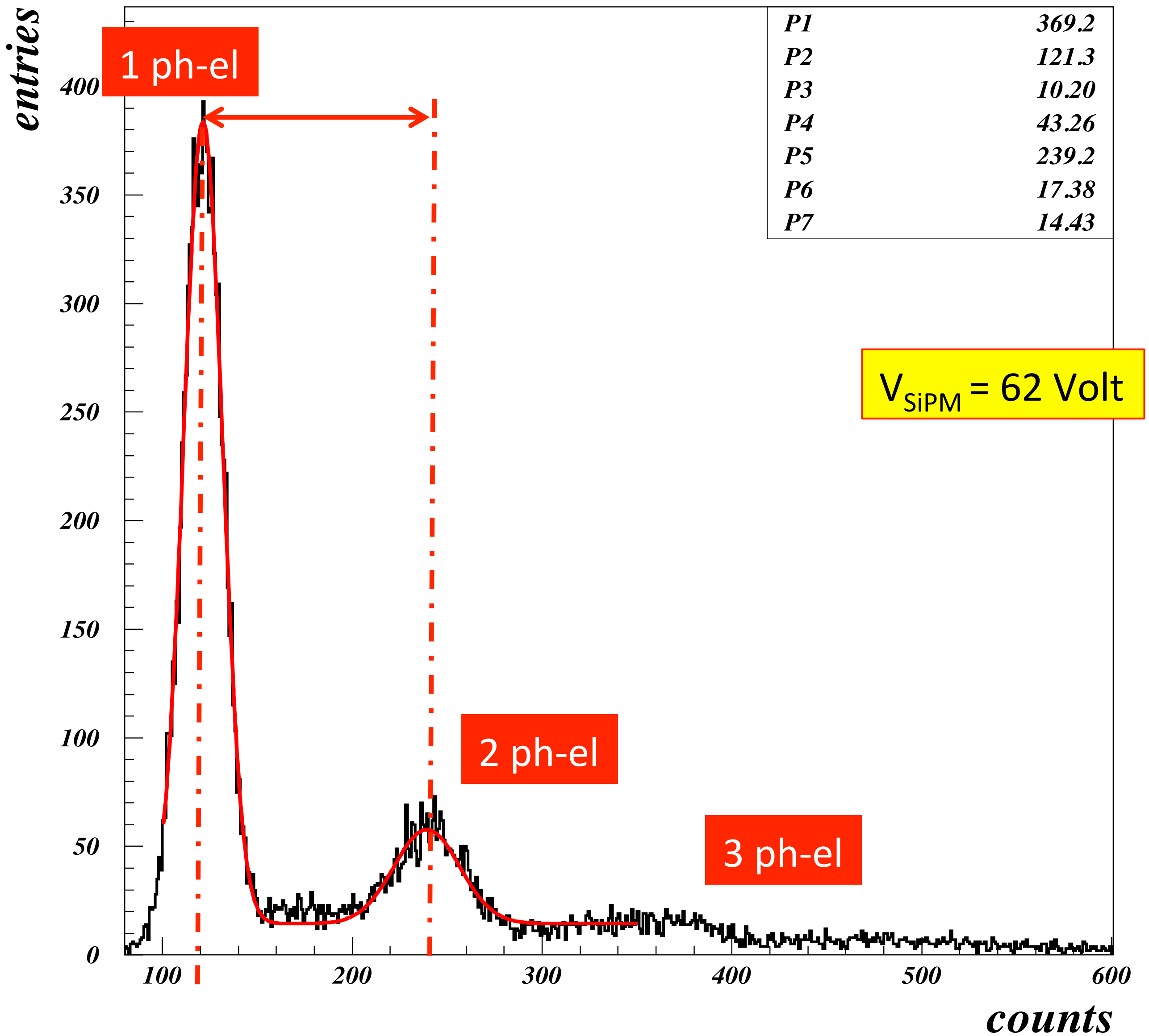
Liquid Argon scintillation read-out with silicon devices

N. Canci, C. Cattadori, A. A. Machado,
S. Riboldi, E. Segreto, C. Vignoli

Experimental set-up (II)



Light yield with SiPM -> SER

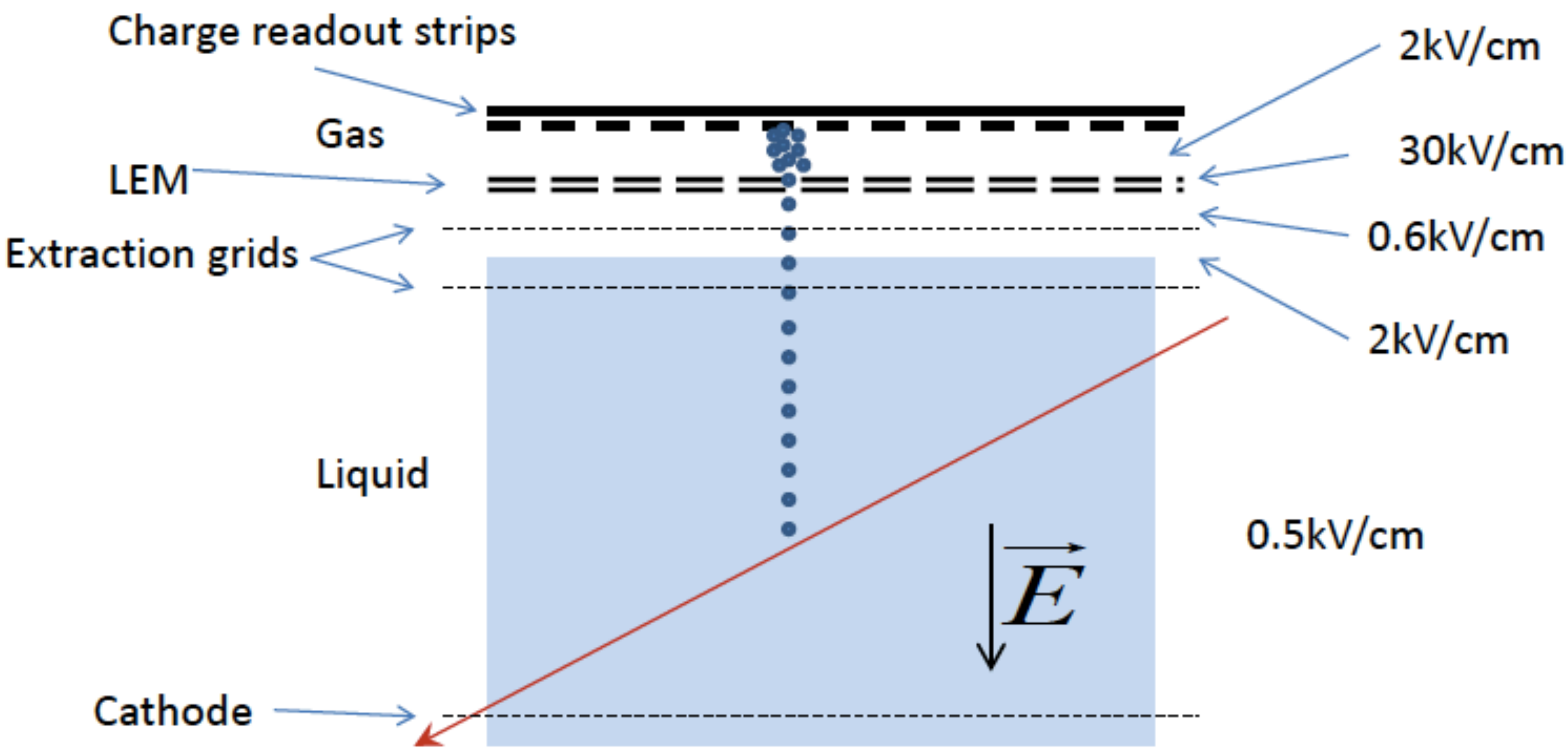


- SiPM signal readout with a *Camberra 2005 charge preamplifier + ORTEC 672 spectroscopy amplifier*;
- Signal acquired with a *multichannel*;
- ***The spectrum of first photo-electrons is very well resolved***;
- The absolute *calibration factor between counts and photo-electrons* is obtained as the ***difference between first phel and second phel position***.

Future plans and Conclusions

- *SiPM* demonstrated to be *an excellent device to be used in LAr* with a Quantum Efficiency higher than that of the most performing cryogenic PMT on the market (Hamamatsu R11065);
- Some easy optimization of the *quenching resistor* could be needed;
- In the near future: characterization of the device with *a laser source* at room and cryogenic temperature (Milano Bicocca);
- Test o*f SiPM with comparable area from a different manufacturer (*FBK) – possibly produced without optical window (VUV sensitive);
- Test of SiPM from FBK and Hamamatsu mounted on low radioactivity substrates;
- Development of fast current amplifier for the read out of the signals;

Double-phase LAr TPC operation

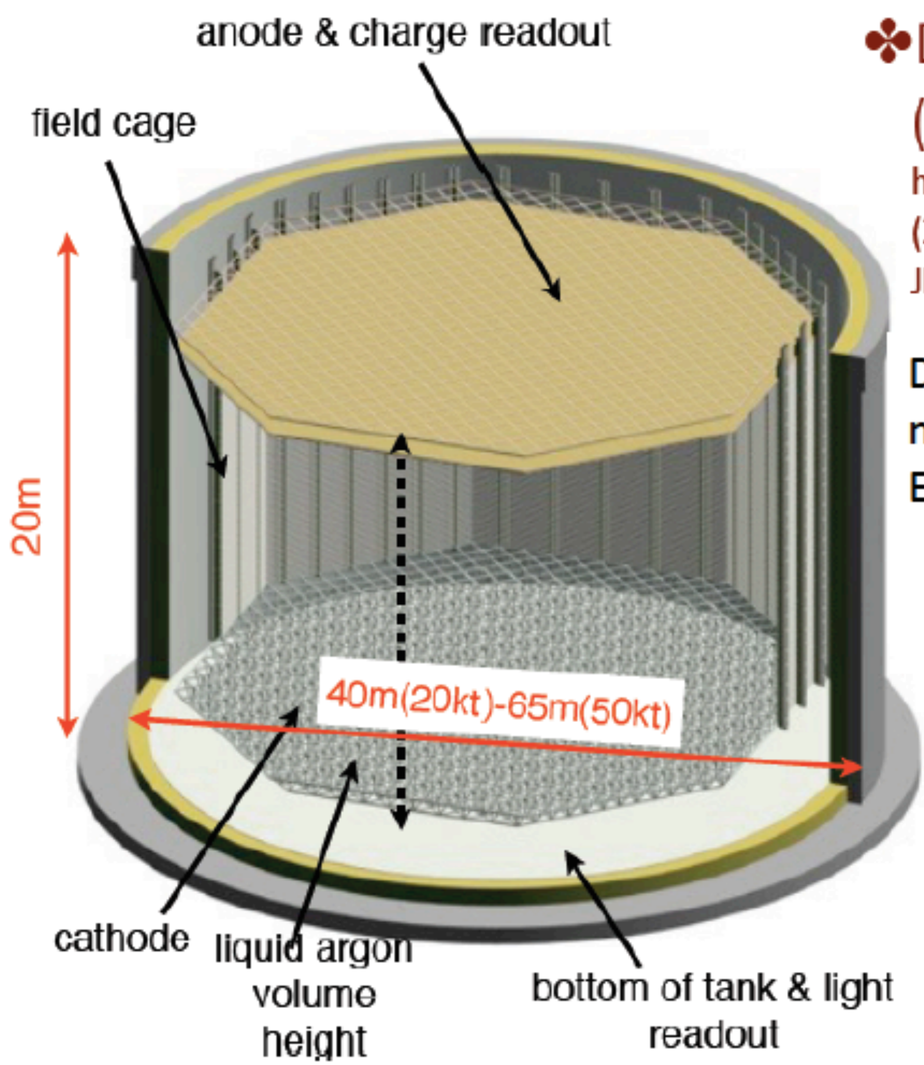


- Distances between layers at the top ~2cm
- LEM thickness ~1mm
- Charge Amplification through LEM ~30

C. Touramanis

C. Touramanis

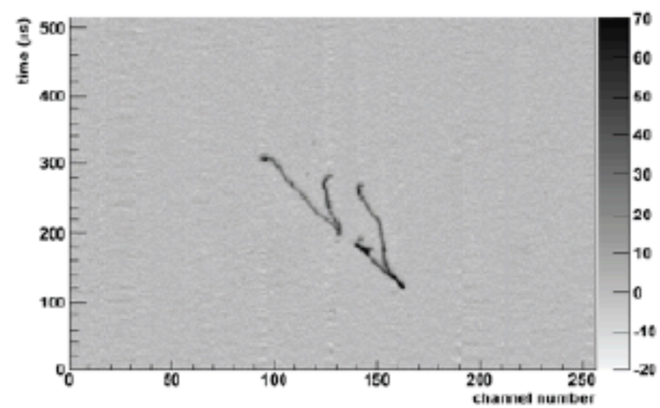
20-50kt GLACIER detector



- Double phase LAr LEM TPC (GLACIER,Venice 2003 !)

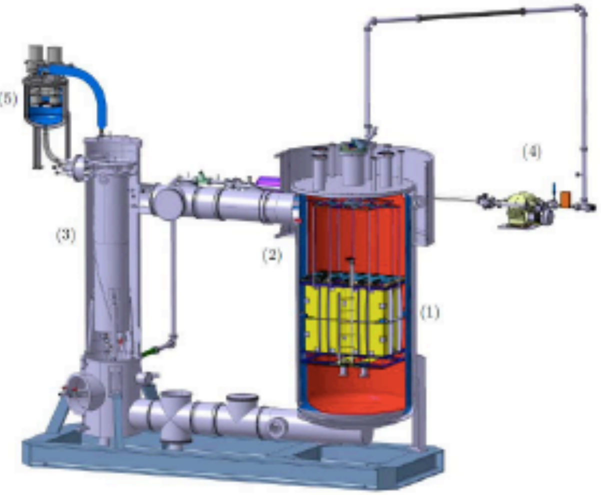
hep-ph/0402110; J.Phys.Conf.Ser. 171 (2009) 012020; NIM A 641 (2011) 48-57; JINST 7 (2012) P08026; arXiv:1301.4817

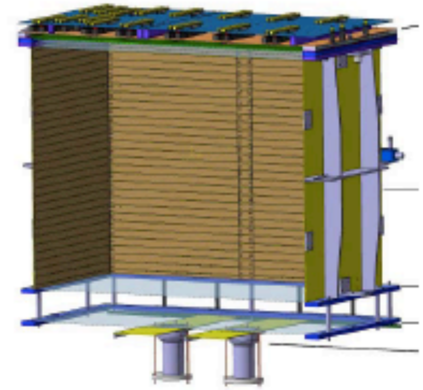
Diffusion coefficients not well known. At 20m drift Expect transv. ~5mm, long. ~3mm

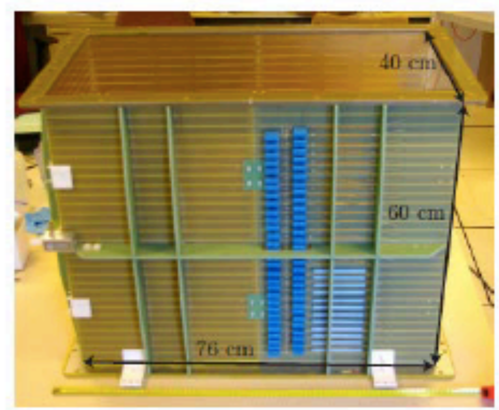


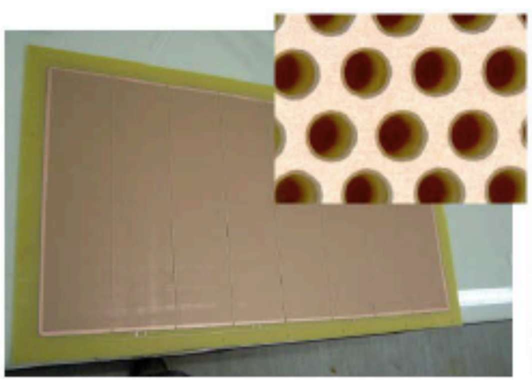
200lt prototype (ETH)

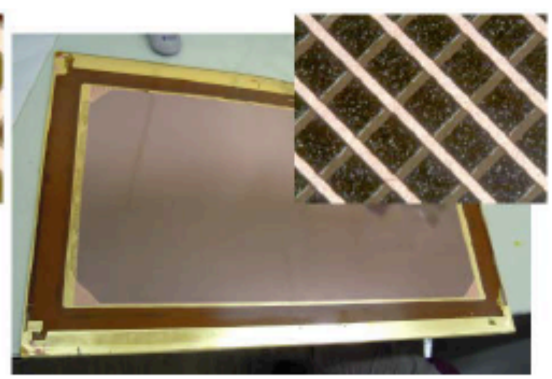
- 1ton ArDM vessel
- 76x40cm^2 readout surface
- 60cm max drift
- 2 TPB-coated PMTs
- LEM (left) with 0.5M holes
- 2D anode (right)
- CAEN (hot) electronics







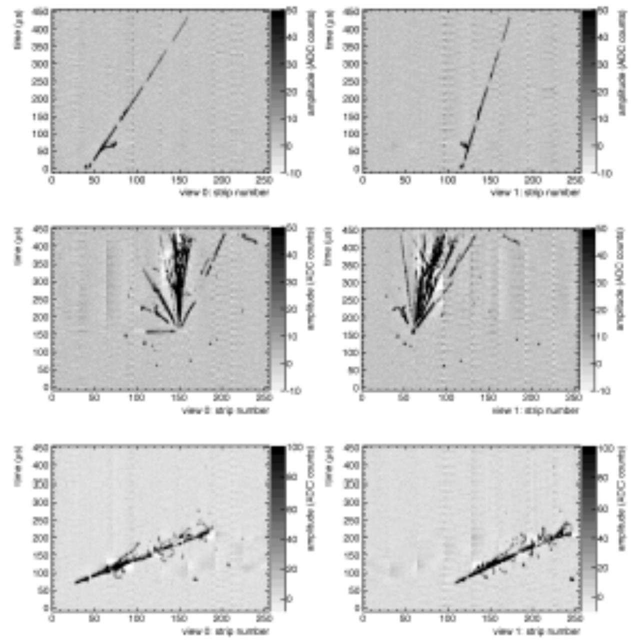




C. Touramanis

200lt prototype (cont.)

- Stable operation for 1 month
- Muon, had. shower, EM shower:
- Coherent noise filtering, QSCAN reconstruction
- Effective gain: 14, s/n > 30 (MIP)
- A. Badertscher et al., JINST 7 (2012) P08026



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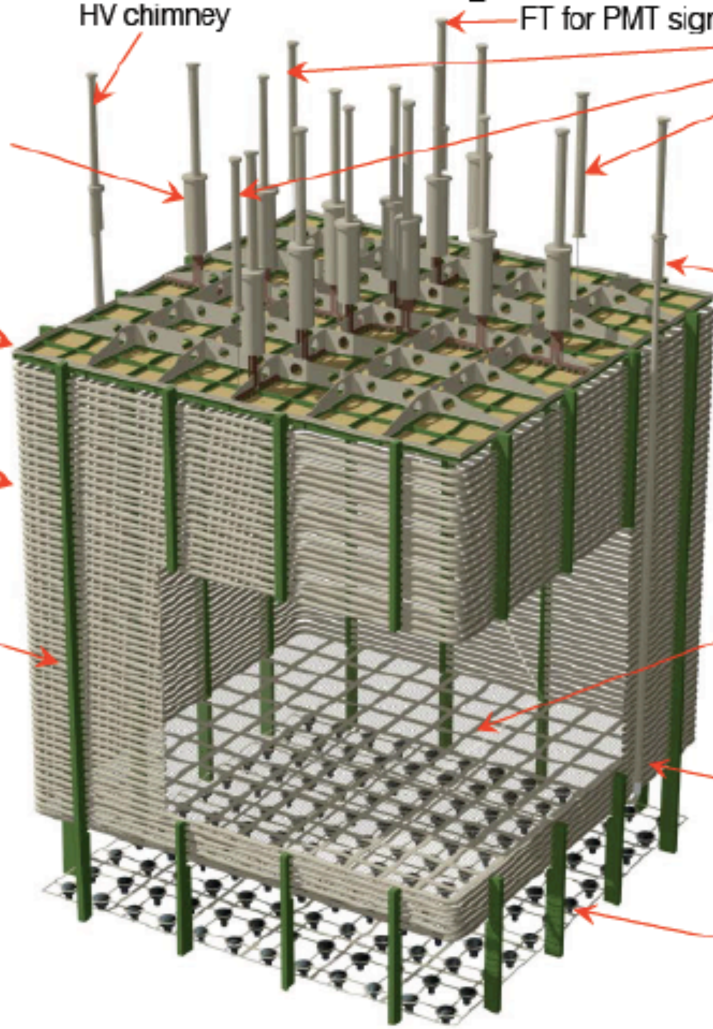
LAGUNA LAr prototype



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology

C. Touramanis

Light Readout in Water Detectors

Conventional readout in Water

-Requires space and large Photo Cathode coverage (translates to cost)

Doping

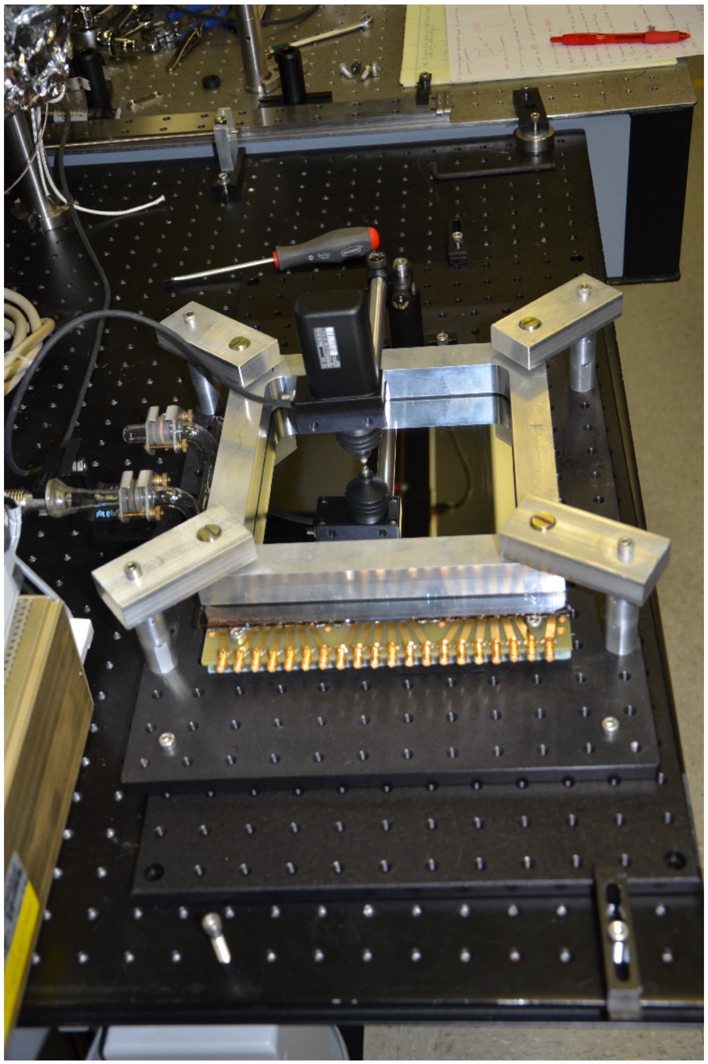
-Scintillator and

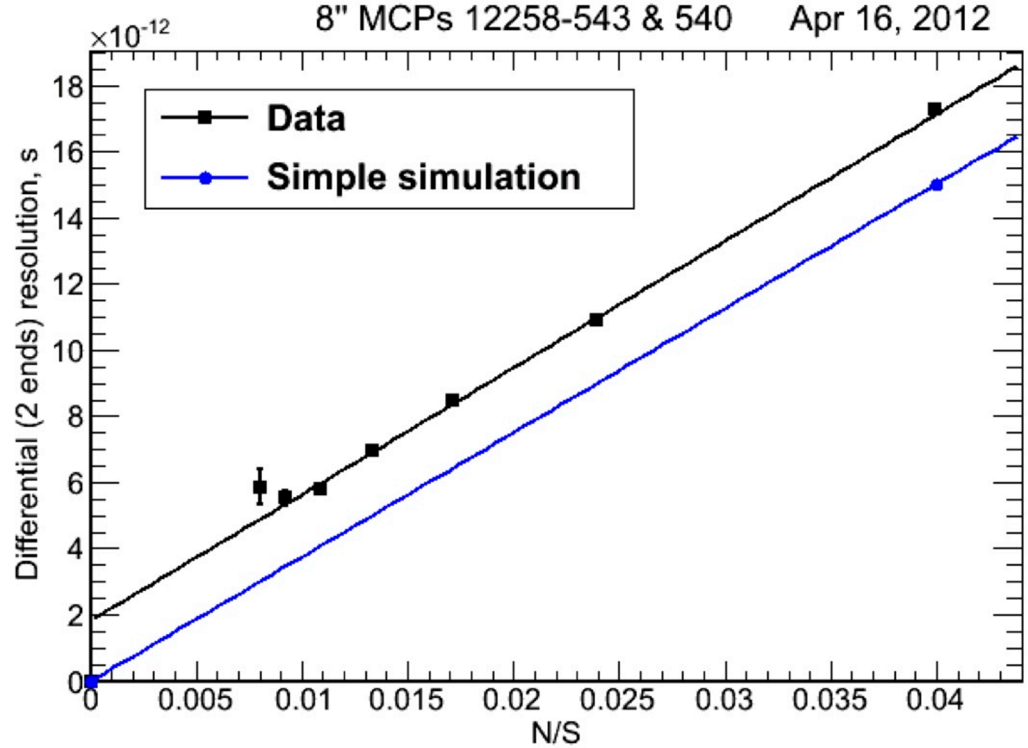
-Gadolinium

The Development of Large-Area Pico-second Photodetectors

Henry Frisch, Enrico Fermi Institute, Univ. of Chicago

For the LAPPD Collaboration

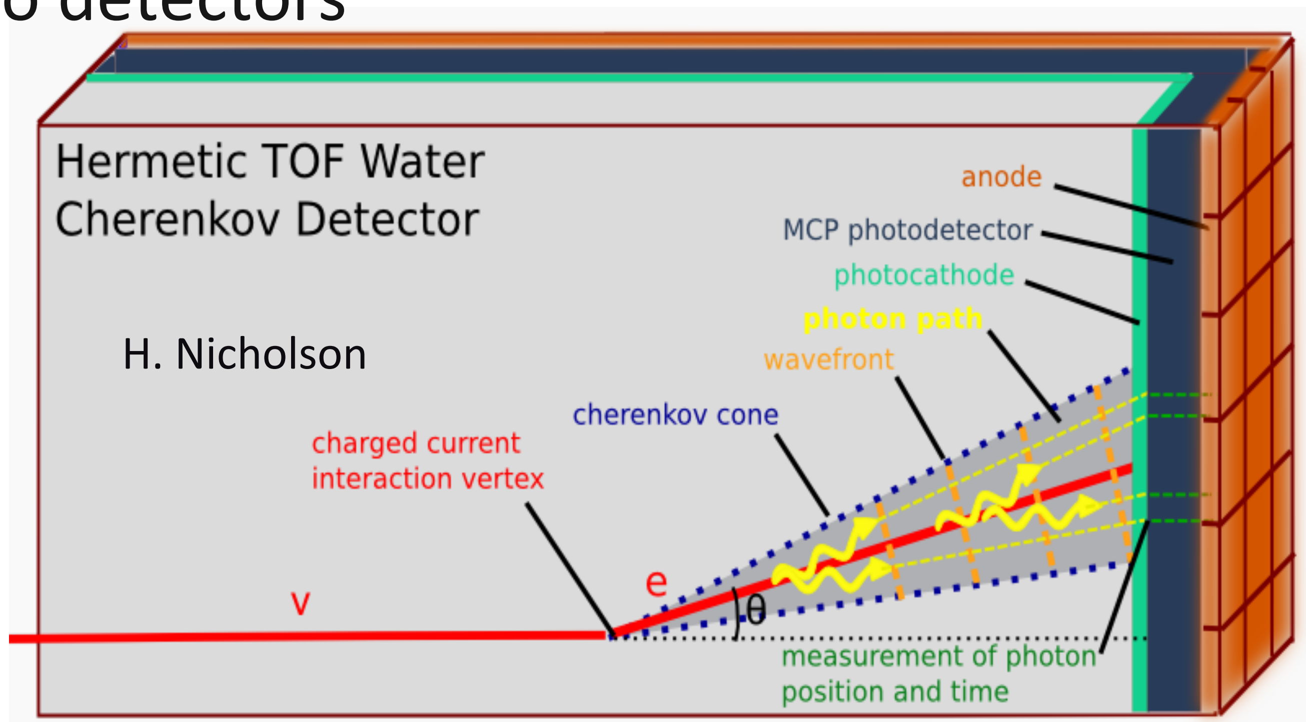




N = RMS of the noise; S = signal amplitude

Neutrino Physics

Need: lower the cost and extend the reach of large neutrino detectors



Approach: measure the arrival times and positions of photons and reconstruct tracks in water

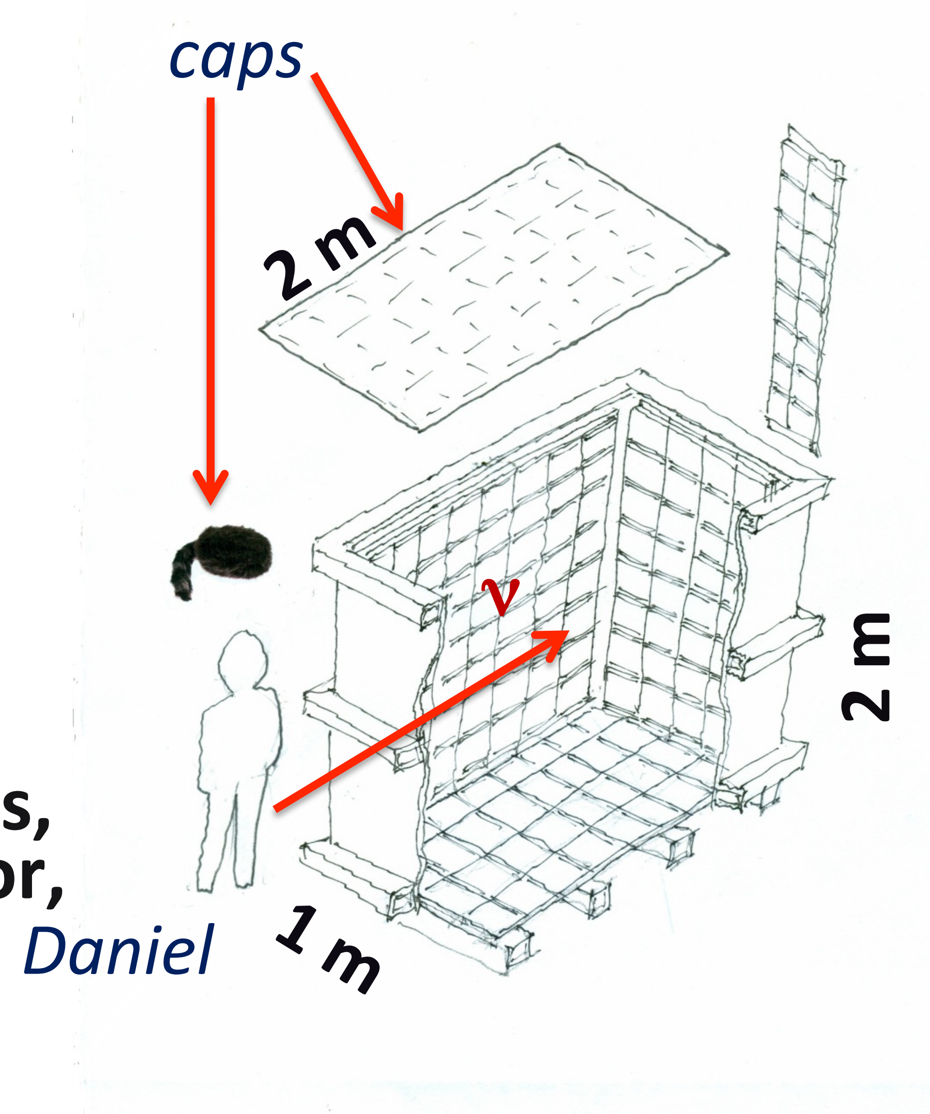
Benefit: Factor of 5 less volume needed, cost.

Competition- large PMT's, Liquid Argon

Daniel Boone*

- Proposal (LDRD) to build a little proto-type to test photon-TPC ideas and as a simulation testbed
- `Book-on-end' geometry- long, higher than wide
- Close to 100% coverage so bigger Fid/Tot volume
- Δx, Δy << 1 cm
- Δt < 100 psec
- Magnetic field in volume
- Idea: to reconstruct vertices, tracks, events as in a TPC (or, as in LiA).

* Think MiniBoone, etc

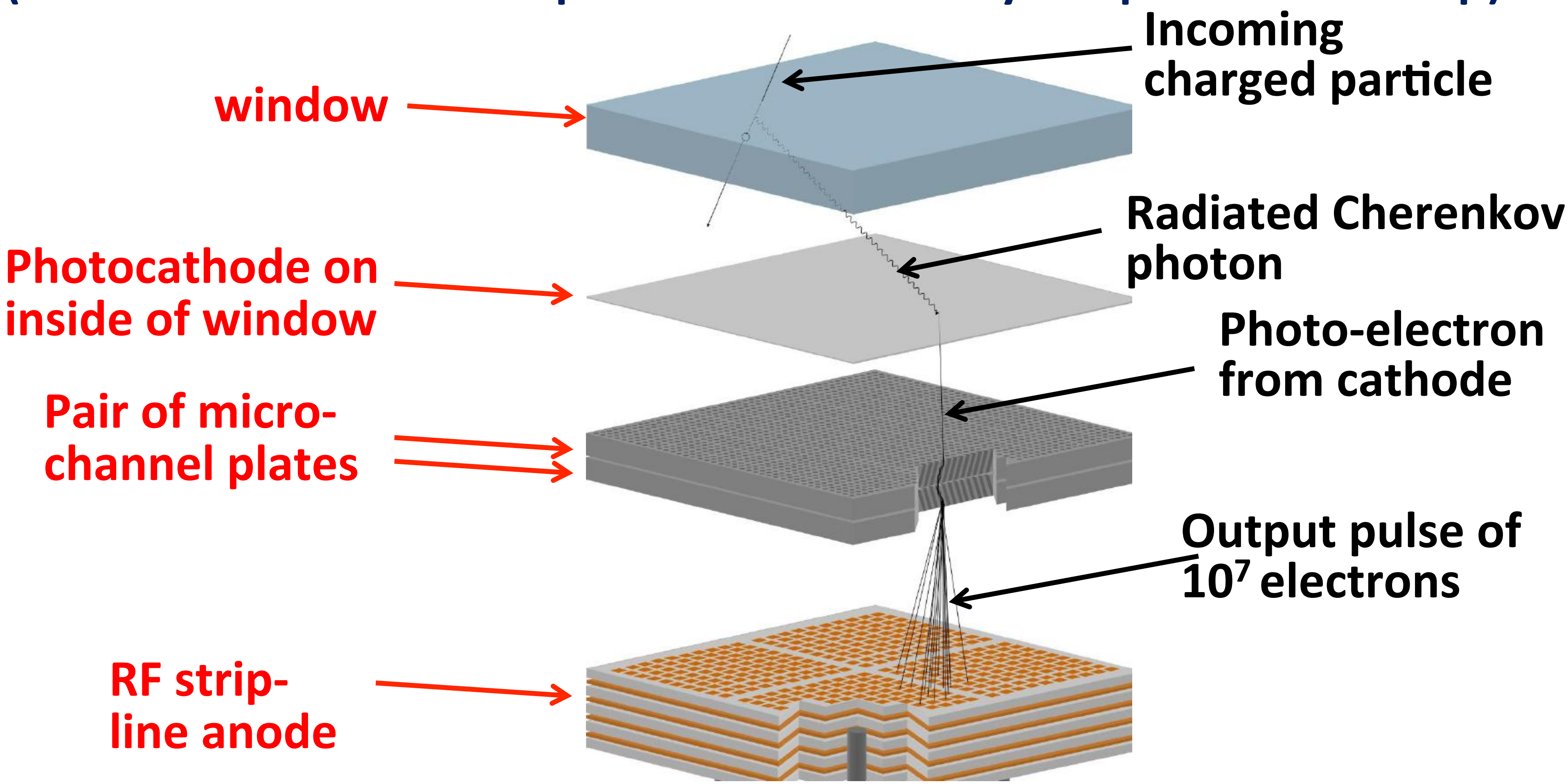


Also ANNIE- Bob Svoboda

How Does it Work?

Requires large-area, gain > 10^7, low noise, low-power, long life, $\sigma(t)$<10 psec, $\sigma(x)$ < 1mm, and low large-area system cost

Realized that an MCP-PMT has all these but large-area, low-cost: (since intrinsic time and space scales are set by the pore sizes- 2-20µ)

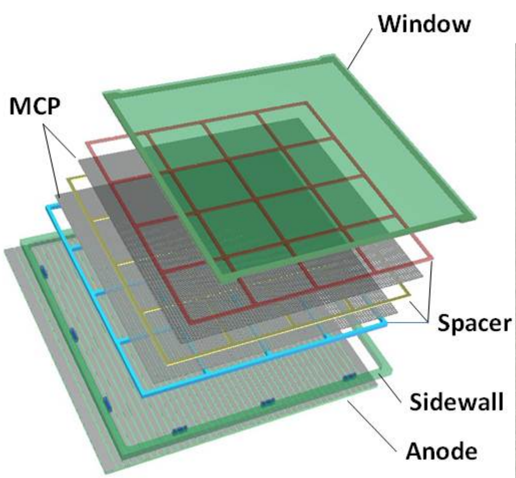


The Half-Meter-Squared SuperModule

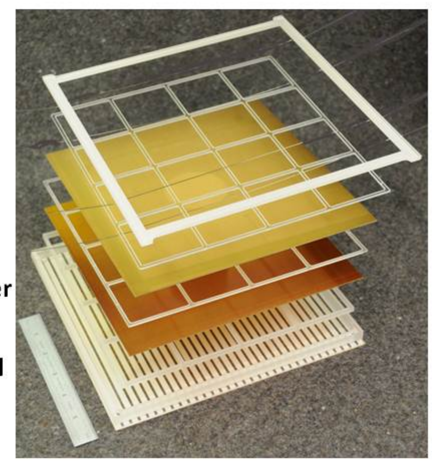
A SuperModule holds 12 tiles in 3 tile-rows. 15 waveform sampling ASICS on each end of the tray digitize 90 strips. 2 layers of local processing (Altera) measure extract charge, time, position, goodness-of-fit

A `tile' is a sealed vacuum-tube with cathode, 2 MCP's, RF-strip anode, and internal voltage divider

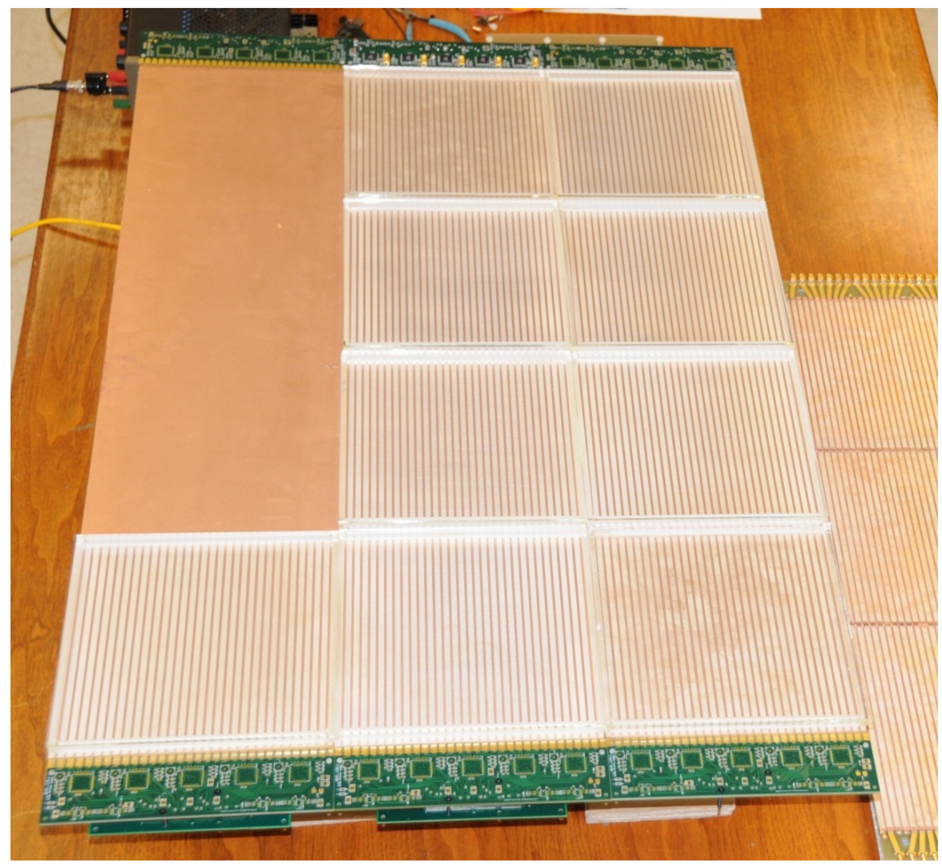
HV string is made with ALD



Design Drawing - September 2010



Actual Glass Parts - April 2012



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General take-aways

- Significant advances in precision neutrino detection recently
- Room for optimization (Development)
- New ideas and development in light collection (and other areas) are key for better detectors (LArTPCs and WC)
- Beware to state that we don't need R&D, for example, for LBNE, we can say we are ready but can do better…..
- *Apologies for what is not covered here!*

Experiment	Measurement	Reach	Technology	Characteristic	Requirement	Limitation
			Silicon Tracking			
			Silicon Tracking			
			Silicon Tracking			
			Photo Sensors			
			Photo Sensors			
			Photo Sensors			

Experiments grouped by technology and listed according to timescale

Near Term

Mid Term

Far Term

From Marcel's talk

Backups

R&D for muon experiments

- Grateful recipient of last decade's R&D efforts in pixels, SiPMs, in-vacuo technologies
- Challenges now are associated with making them work in real experiments

- Example:
  - 50 μm HV-MAPS pixels developed with ILC R&D now being implemented in μ3e experiment at PSI
  - ~0.1% X_0 per layer

50 μm Si pixel+
25 μm Kapton flex cable with Al traces+
25 μm Kapton support

- Future R&D mainly focused on muon production
  - Higher surface muon yields from spallation targets, narrower pulse width and tunable time structure, cold muon beams