Homogeneous Detectors:

Technology and Performance

Ion Stancu

University of Alabama

Workshop on Neutrino Measurements at SNS

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Running Homogeneous Detectors

- MiniBooNE: mineral oil Cherenkov imaging
- KamLAND: mineral oil doped with scintillator
- SNO: heavy water
- SuperK: water Cherenkov imaging
- AMANDA: ice Cherenkov imaging

Why Homogeneous Detectors?

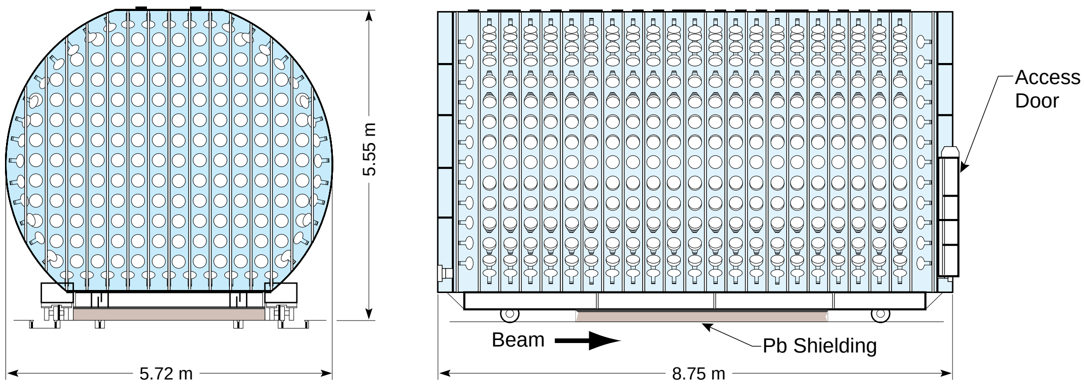
- Relatively simple to build
- Relatively simple to instrument
- Relatively simple to operate (stable in time)
- Relatively low maintenance

What Determines the Medium?

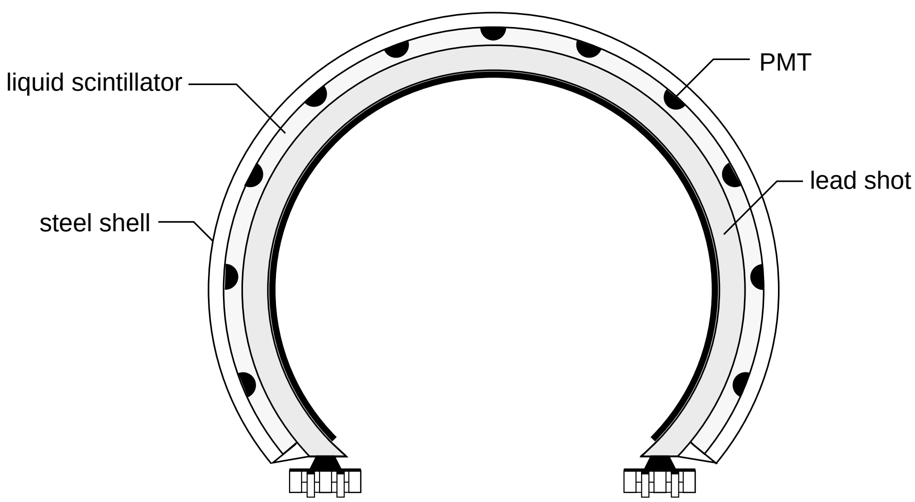
- Physics (e.g., SNO)
- Scintillator solubility (e.g., oil versus water)
- Optical properties

What Determines the Size and Shape?

- LSND: 101.2 m^3 (for $d > 35$ cm fiducial volume) of mineral oil and 0.031 g/l of b-PBD (butil-phenyl-bipheny-oxydiazole)



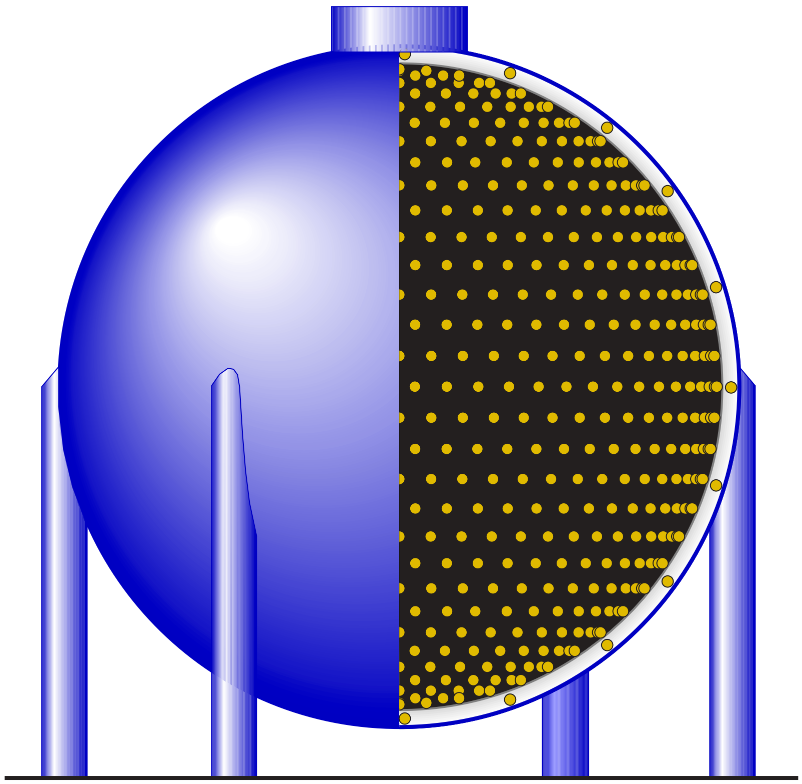
Has to fit into the existing E–225 veto shield (292 5" EMI PMTs):



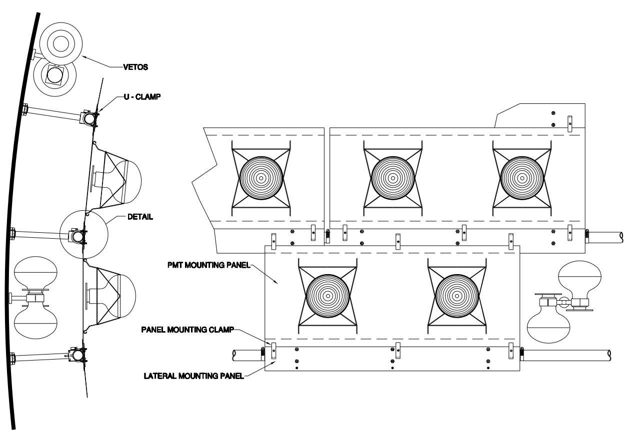
Tank: 1220 8" Hamamatsu R1408 PMTs (25% photocathode coverage)

Veto: active and passive.

- MiniBooNE: 517.3 m^3 (for $d > 50$ cm fiducial volume) of mineral oil



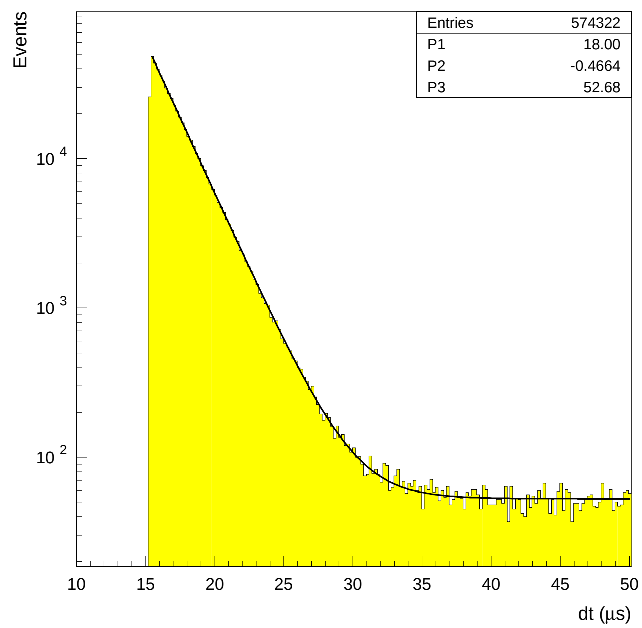
Maximize the volume to surface ratio



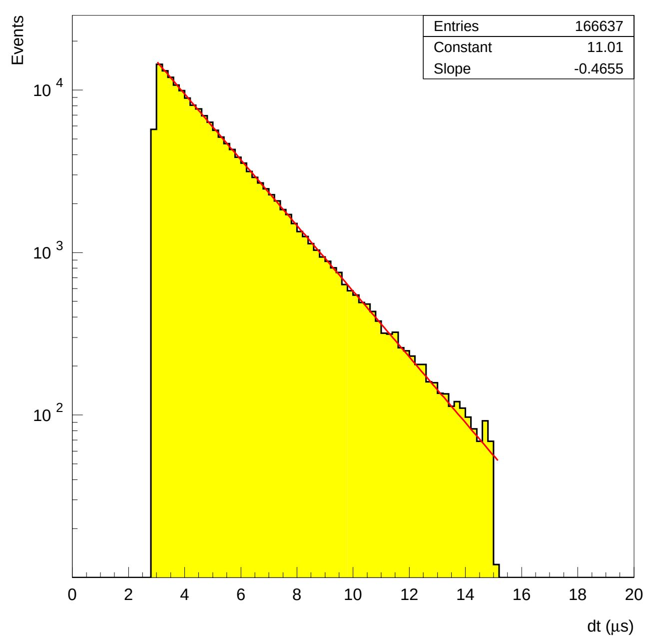
- 1280 8” Hamamatsu PMTs (322 R5912 + 958 R1408): 11% photo-cathode coverage. Active veto: 240 8” Hamamatsu R1408 PMTs.

Calibration

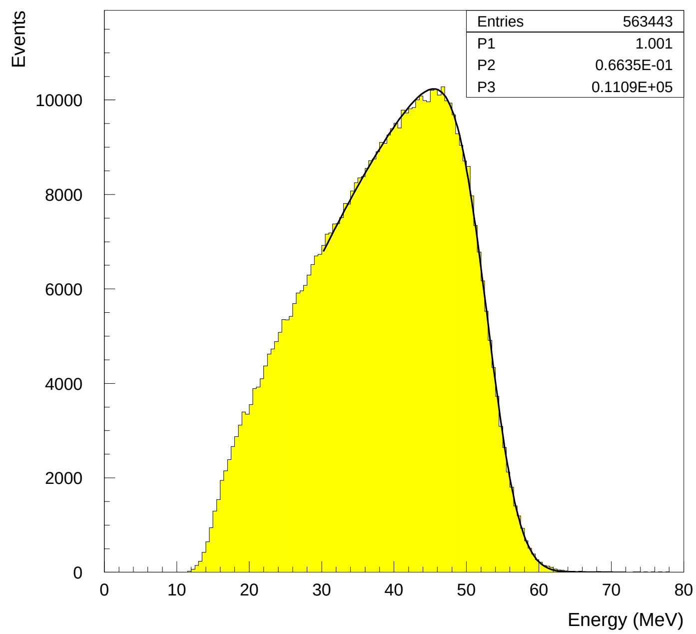
- Laser flasks (fixed positions): PMT gains, time offsets and slewing
- Michel electrons: LSND



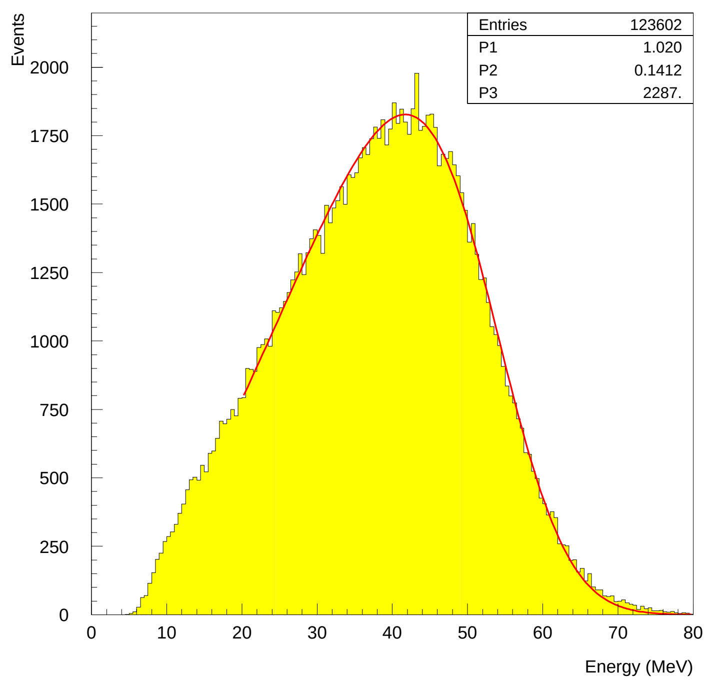
MiniBooNE



LSND: 6.6% (multiplicity = 600 hits at the endpoint) – expect 4%

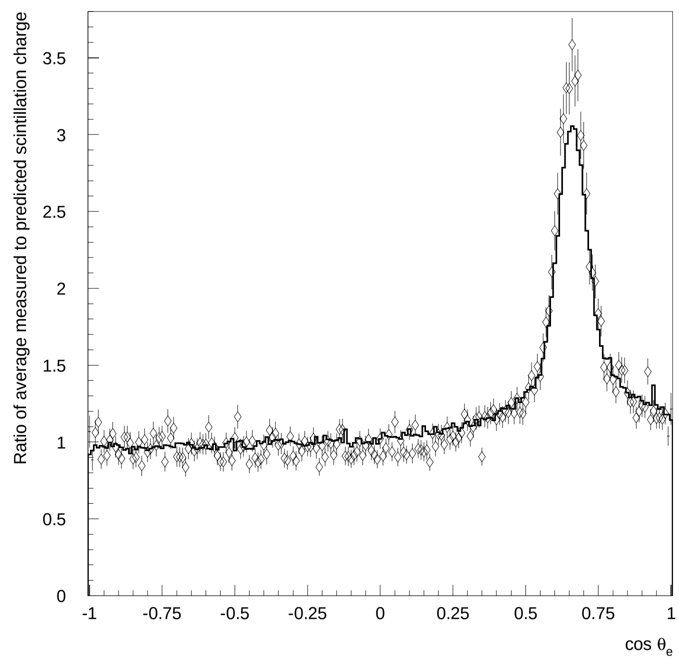


MiniBooNE: 14.0% (multiplicity = 150 hits at endpoint) – expect 8%

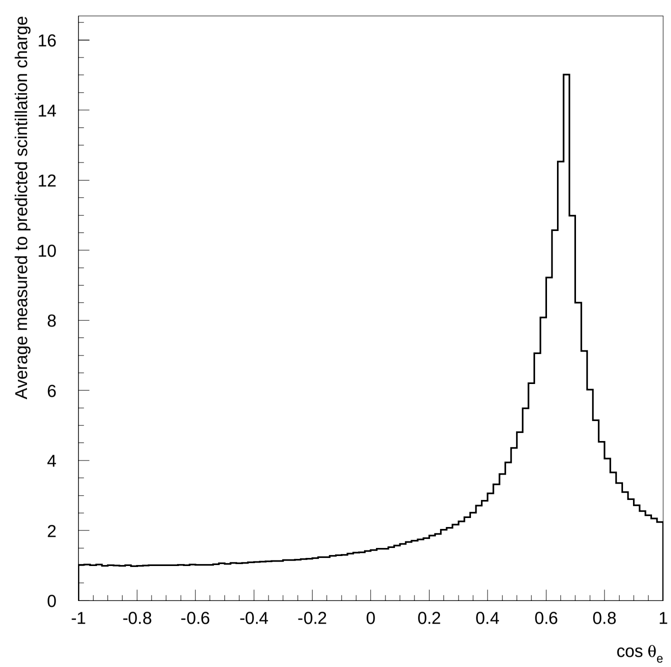


Directional vs Isotropic Light

LSND 1:5

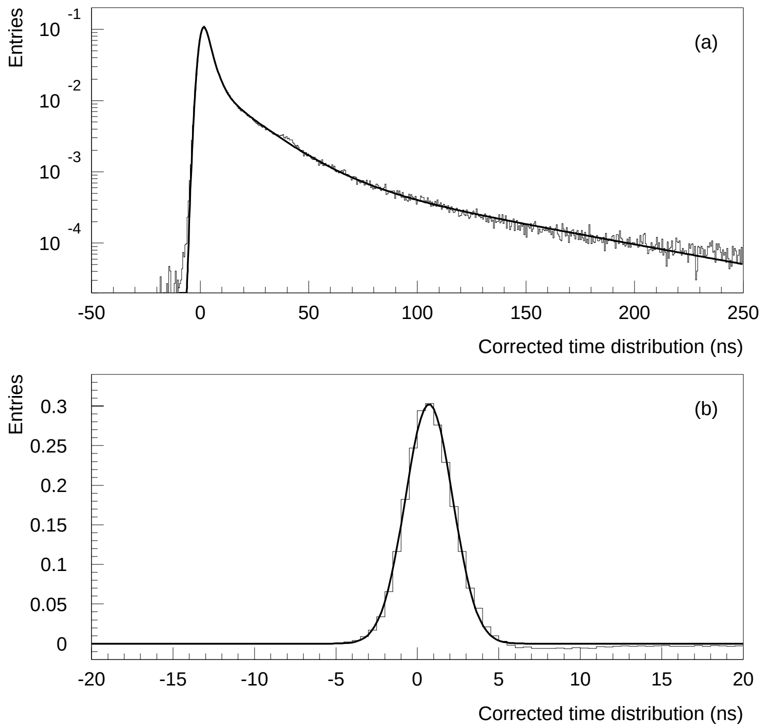


MiniBooNE 2:1

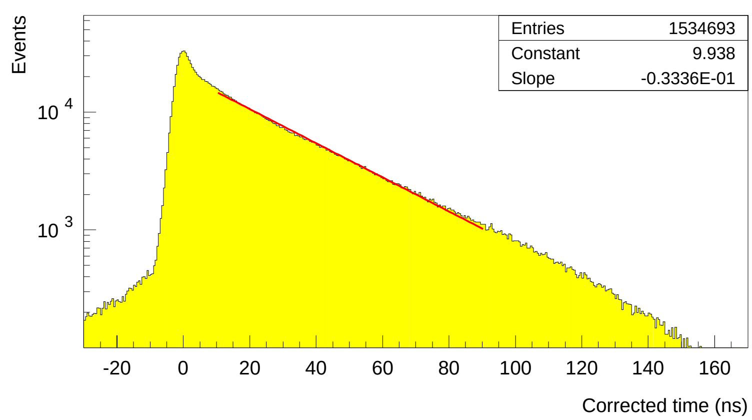


Prompt vs Delayed Light

LSND: time constants = few, tens and hundreds of ns



MiniBooNE: time constant = 30 ns



Reconstruction Accuracy

- LSND standard χ^2-minimization:

  position/angular resolution: 30 cm and 12°, respectively

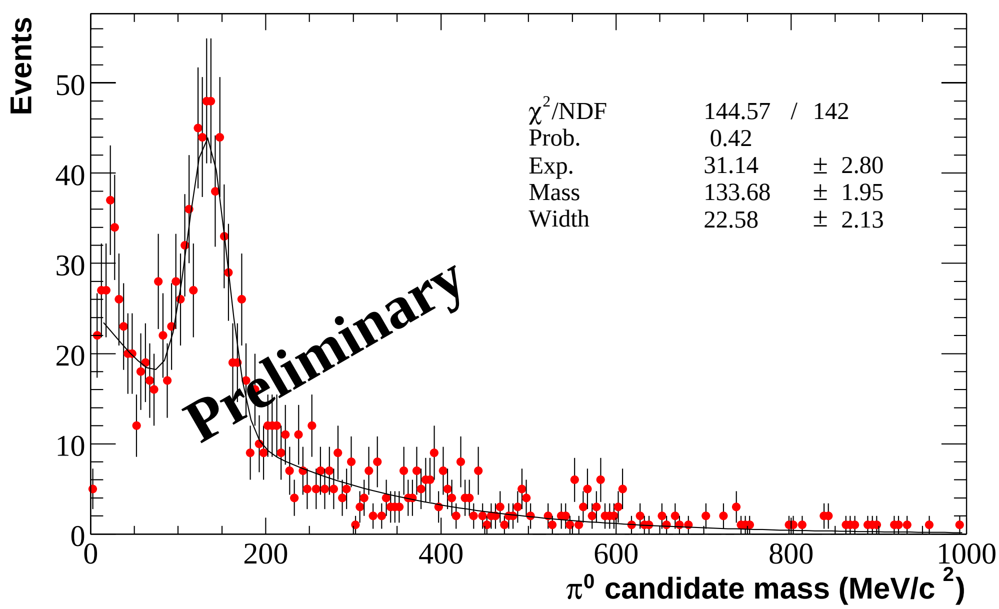
- LSND maximum likelihood reconstruction:

  position/angular resolution: 11 cm and 6°, respectively

- MiniBooNE maximum likelihood reconstruction:

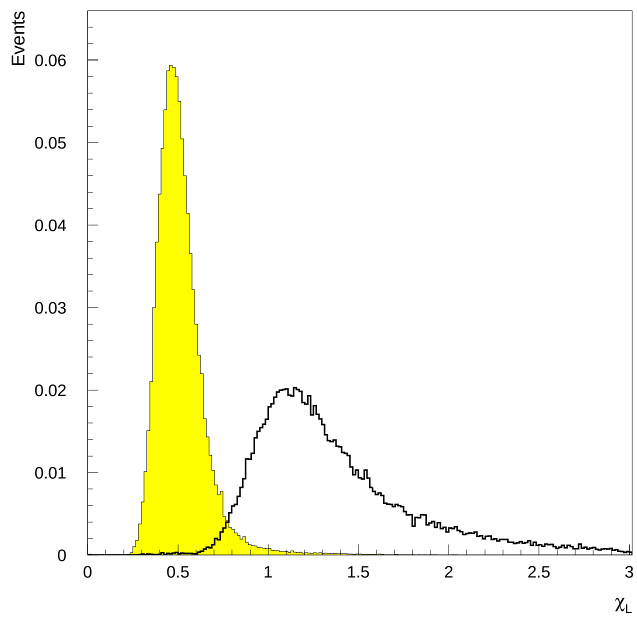
  position/angular resolution: 20 cm and 3°, respectively

  energy resolution: 14% → 11% (preliminary)

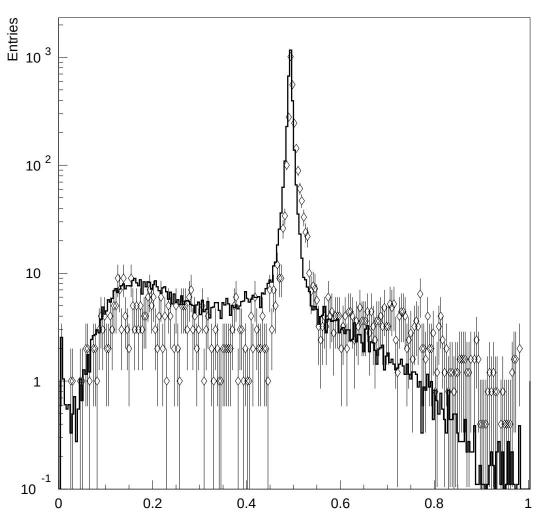


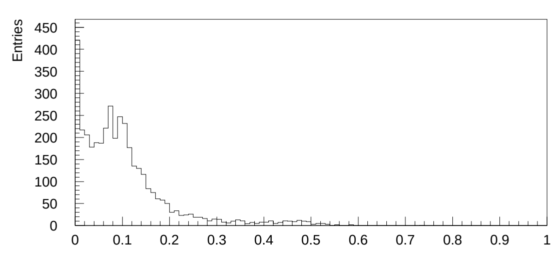
Particle Identification

LSND "standard" PID parameter, χ_L (L=Louis)



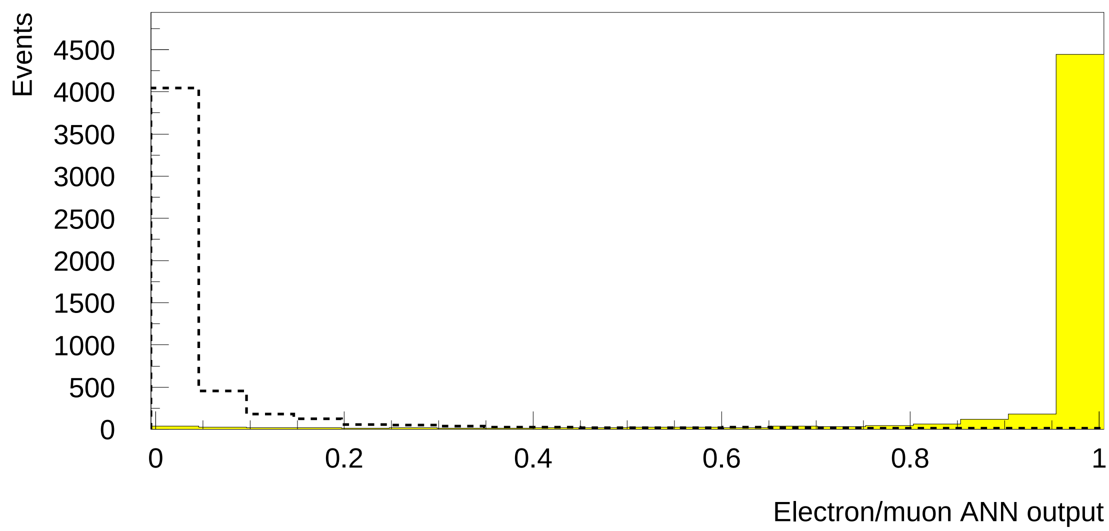
LSND decay-in-flight PID: the fitted Cherenkov fraction

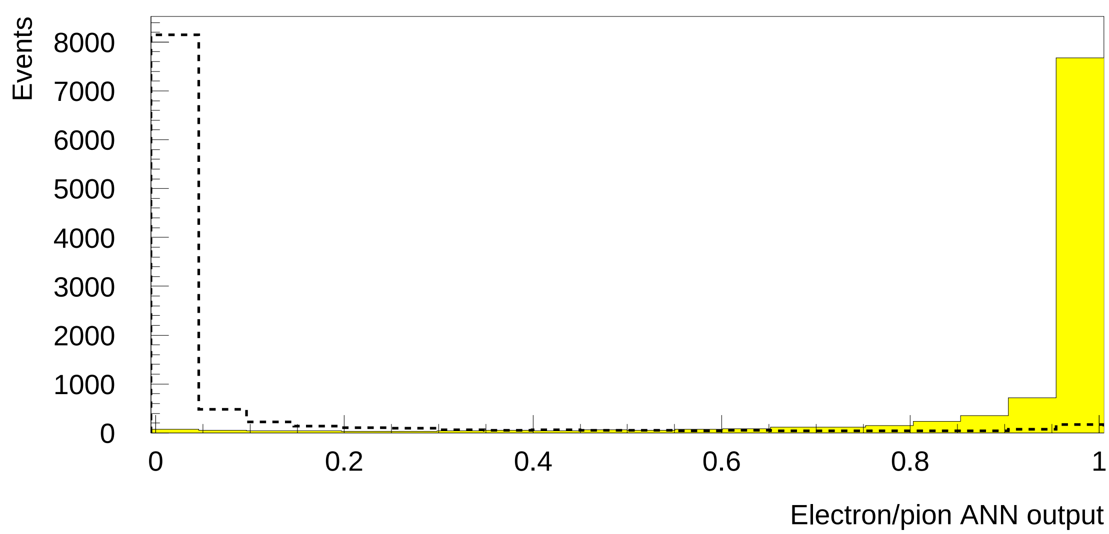




MiniBooNE PID: artificial neural networks

- Electron/muon ANN: 15 input variables
- Muon contamination: 10^{-3}





- Electron/pion ANN: 25 input variables
- Pion contamination: 10^{-2}

Electron efficiency = 50%

The SNS2 Homogeneous Detector

Role:

- measure X-sections for materials in aqueous solutions (see GvD's talk)
- provide X-check for the segmented detector
- provide neutrino flux normalization

Size: 3 m $\times$ 3 m $\times$ 3 m = 27 m^3 (maximum volume).

Coverage: 300 8" PMTs (50 per side): 18% (ad literam).

Fiducial volume:

- wall to PMT equator distance = 20 cm
- PMT equator to PMT tip distance = 7 cm
- minimal fiducial volume distance (from PMT tip) = 35 cm
- effective length $= 3\,\mathrm{m} - 2 \times (0.62\,\mathrm{m}) = 1.76\,\mathrm{m} \Rightarrow V_{eff} = 5.5\,\mathrm{m}^3$

Note: fiducial distance $> 25\,\mathrm{cm} \Rightarrow V_{eff} = 7.5\,\mathrm{m}^3$

Questions for the SNS2 Homogeneous Detector

- Are the 8” PMTs appropriate for this job?
- Should we consider 5” PMTs perhaps?
- What coverage? Same: would need a total of $768 = 300 \times (8/5)^2$
- Should we consider other technologies? (large area CCD, ...)
- What is the desired ratio of CER-to-SCI ratio?

  (could be medium dependent/limited)

What We Need:

- understand optical properties of the media:

  (attenuation length, scattering, scint. solubility, time constants, etc.)
- understand long-term behaviour of the media
- moveable calibration source(s): laser/radioactive sources
- understand optical response of the PMTs/CCDs/...
- understand the electronics response (LSND/MiniBooNE style)

Test detector partially instrumented (e.g., one side) $\rightarrow$ Michel electrons