Requirements for a 2 km tracking detector

Clark McGrew

September 17, 2003

My Benchmark Goals

Reconstruct neutrino spectrum using pure quasi-elastic events.

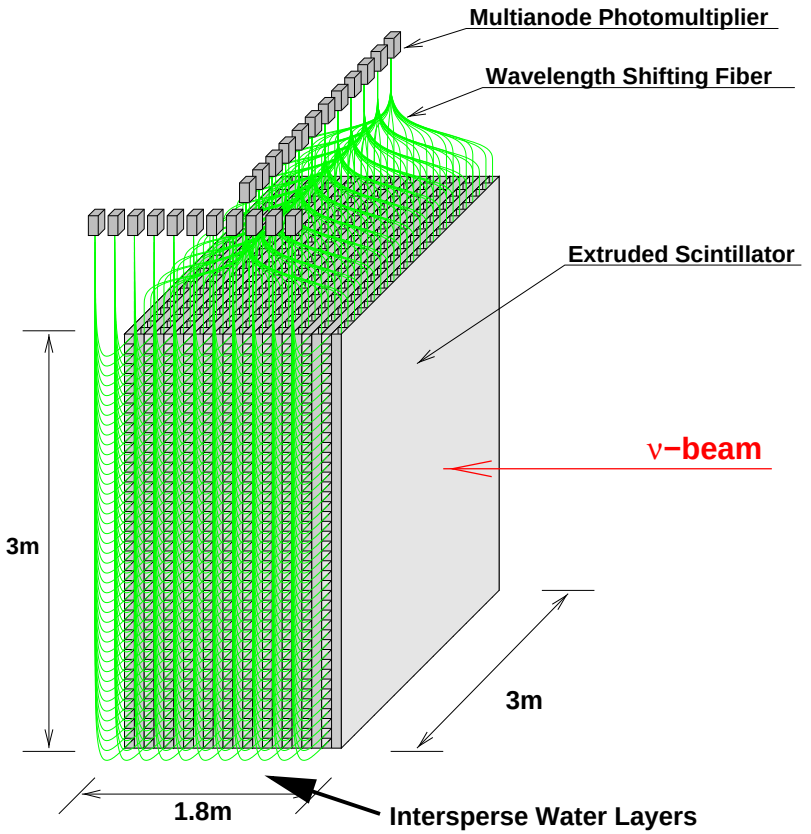
Requirements:

- Sensitive between 400 MeV and 950 MeV (e.g. at osc. max.)
- Must see muon *and* proton.
- Must reconstruct vertex in water.
- Must identify proton.

Tools:

- Neutrino spectrum: K2K
  - A bit harder than JHF off-axis beam.
- Interaction Model: NUANCE (from D. Casper)
- Range Tables: GEANT 4.4 (from A. Sarrat)

A Proto-type: The SciBar Detector



Pro

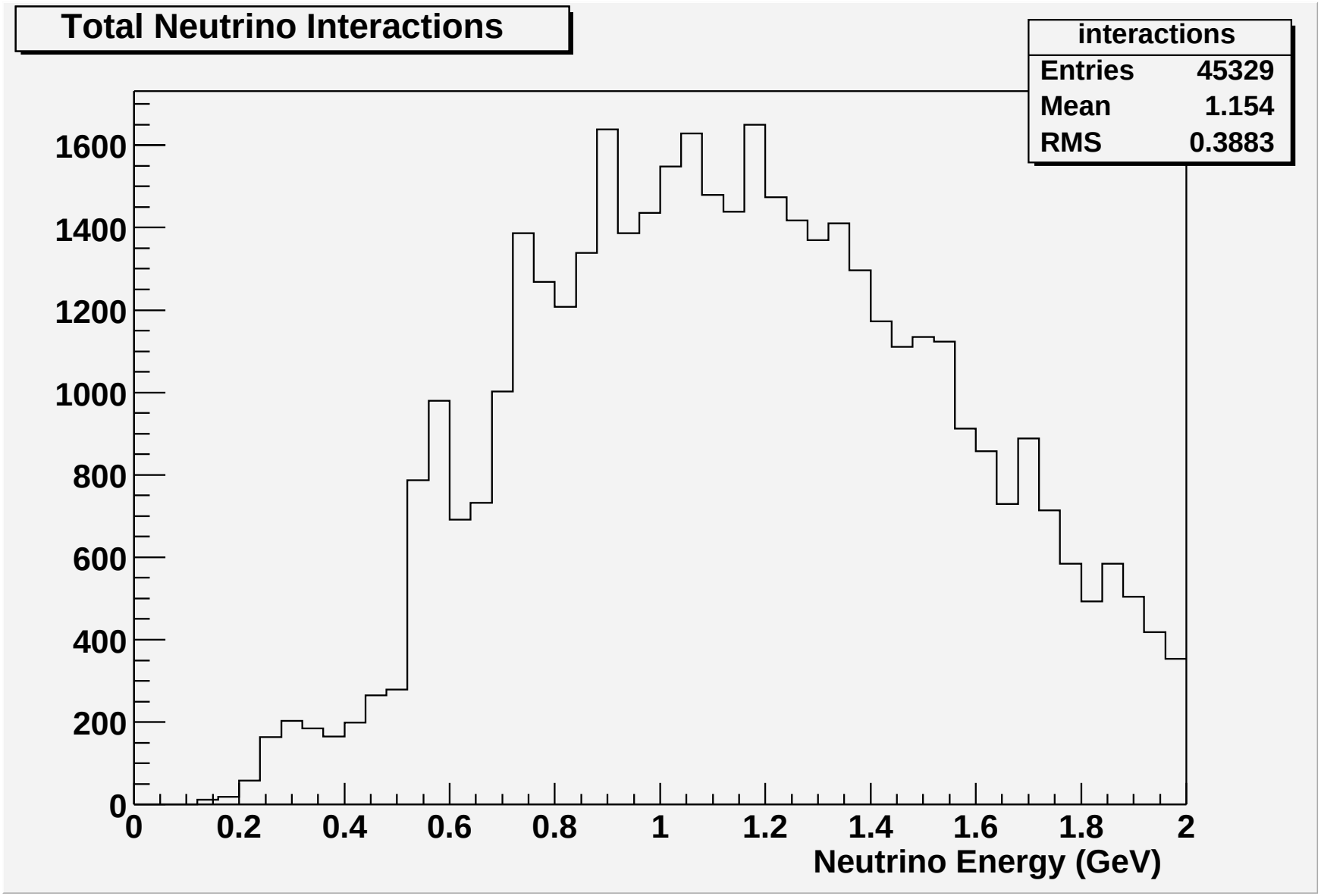
- Excellent proton/pion ID
- Large fiducial mass

Con

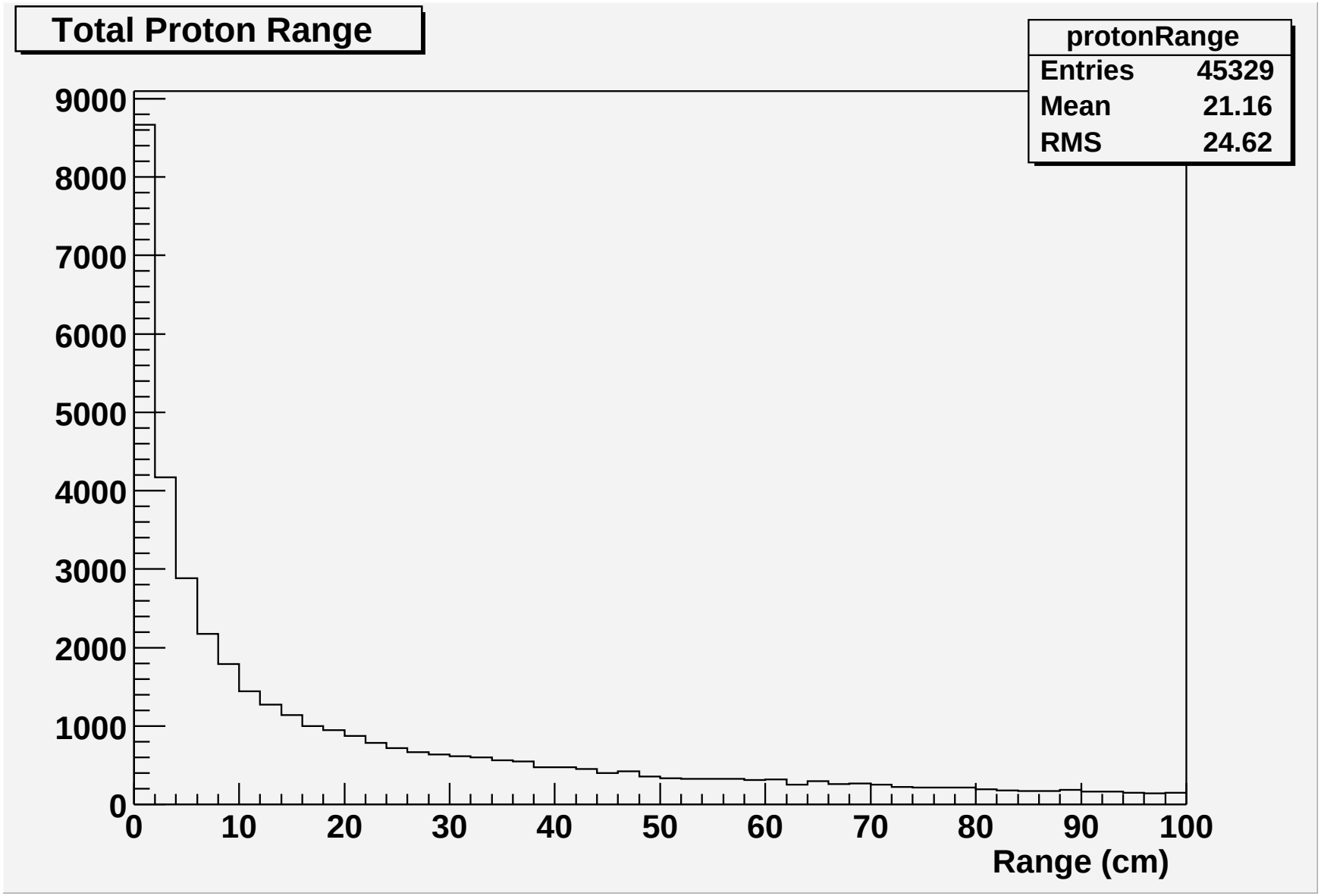
- No water target

Can we put water between the active layers?
How thick are the layers?

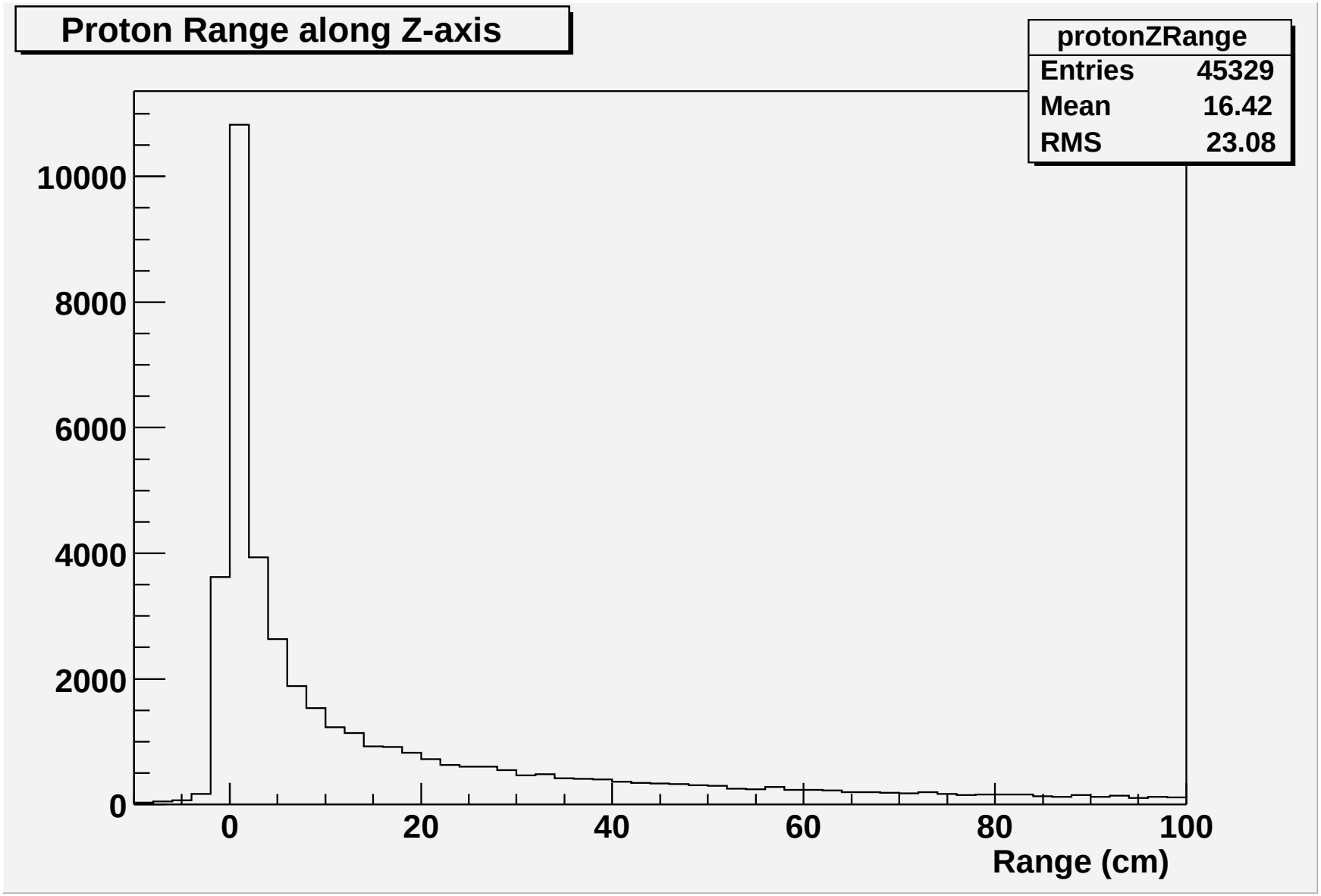
Neutrino Energy Spectrum



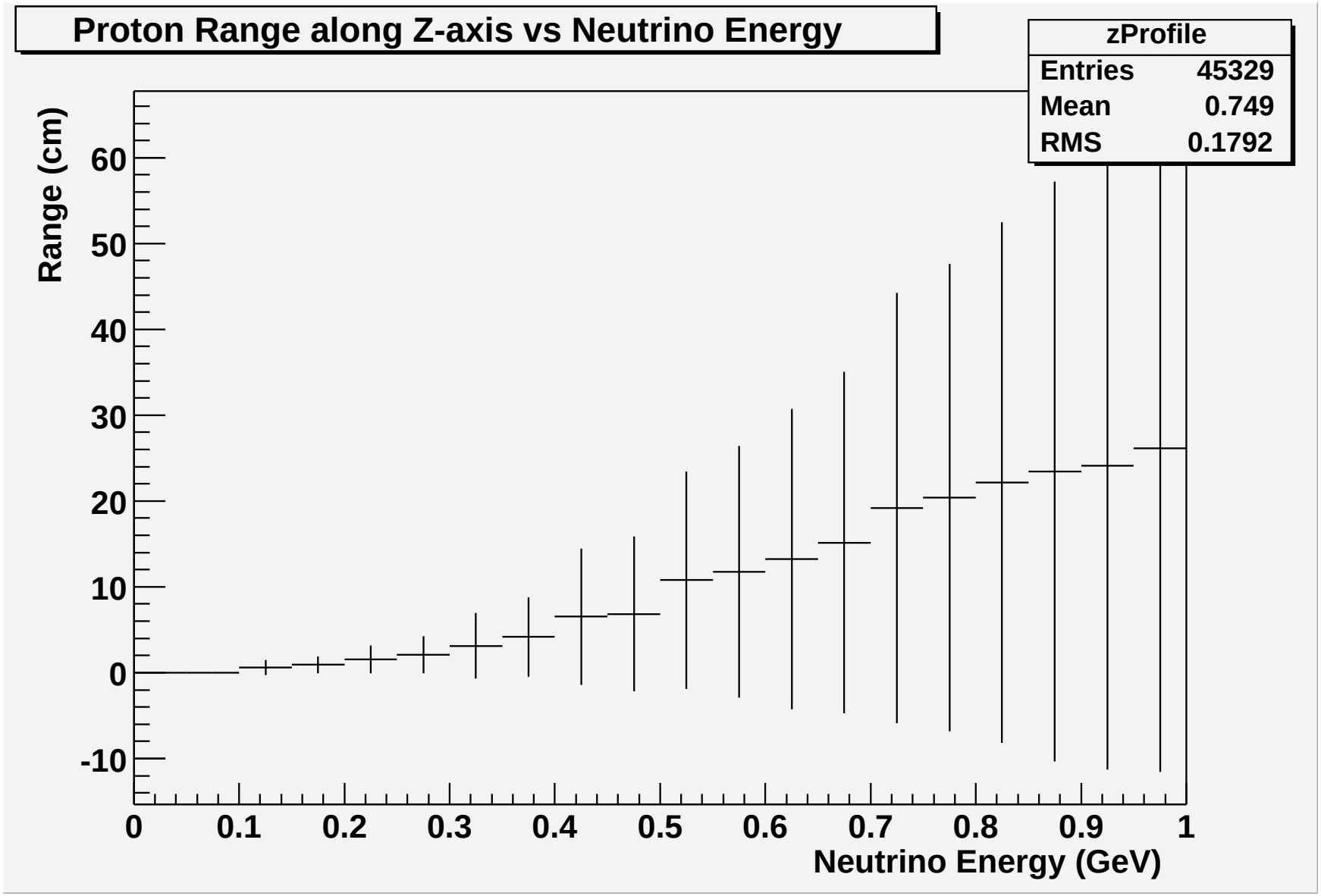
Proton Range



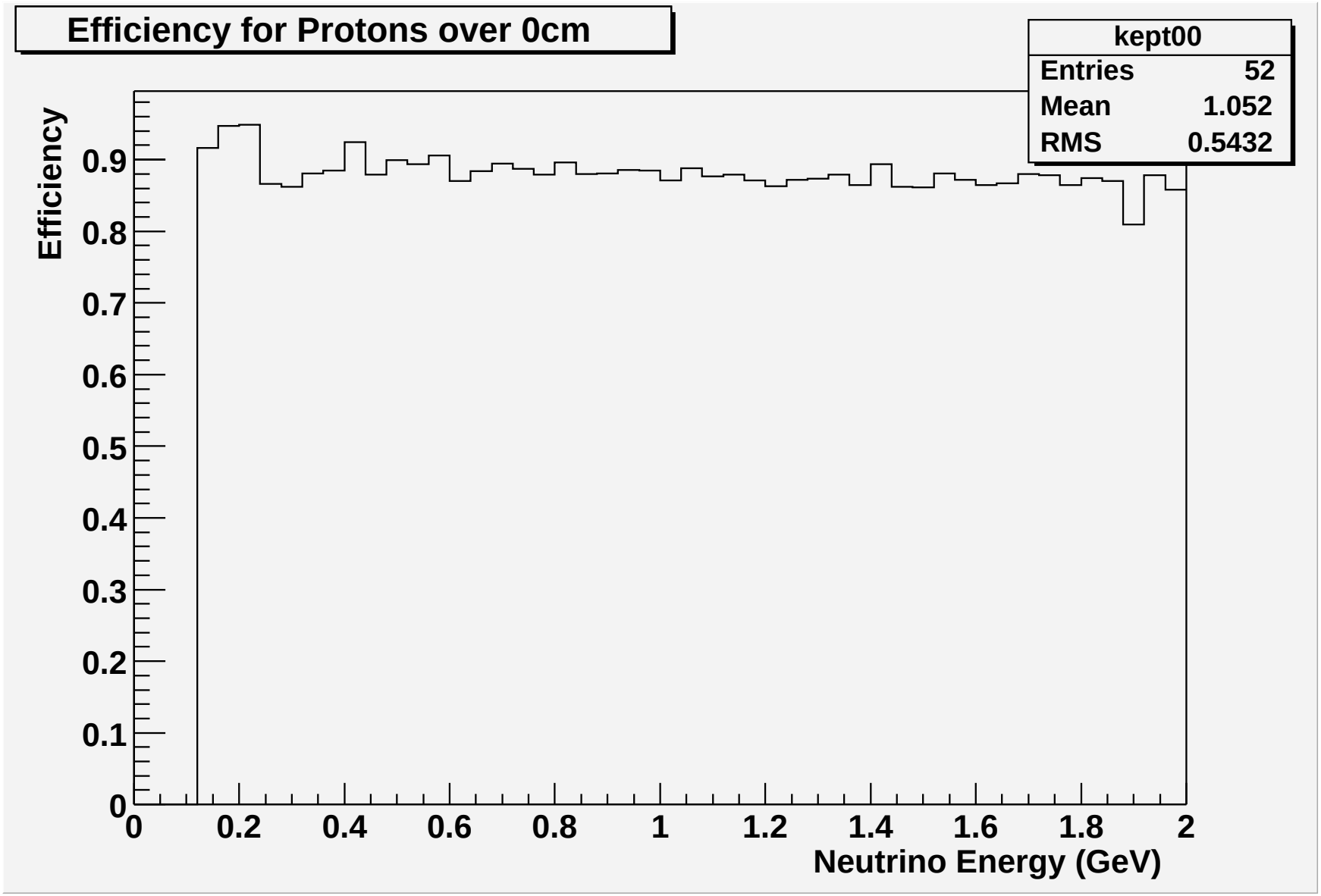
Proton Range Along Beam Direction



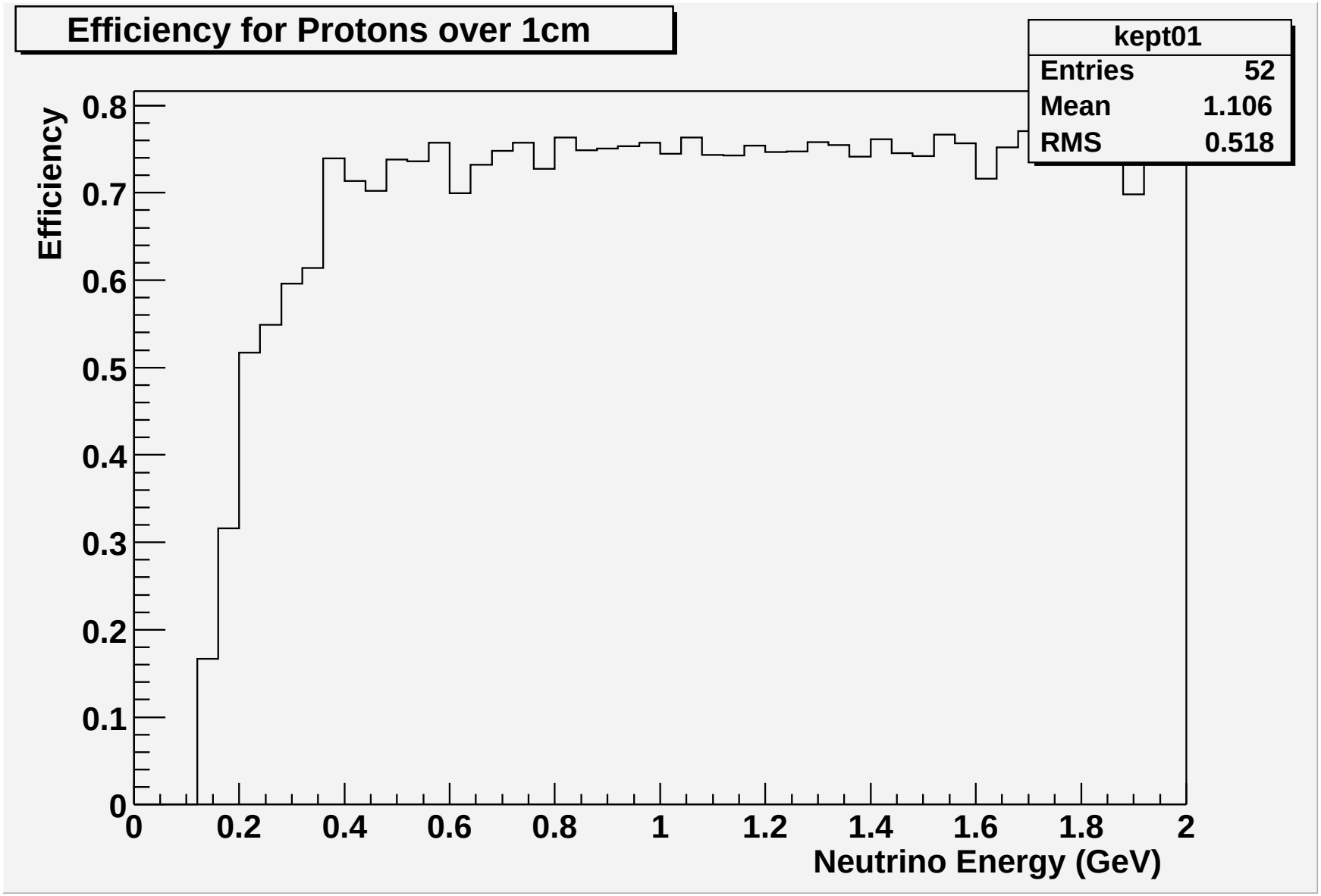
Proton Z-Range v.s. Neutrino Energy



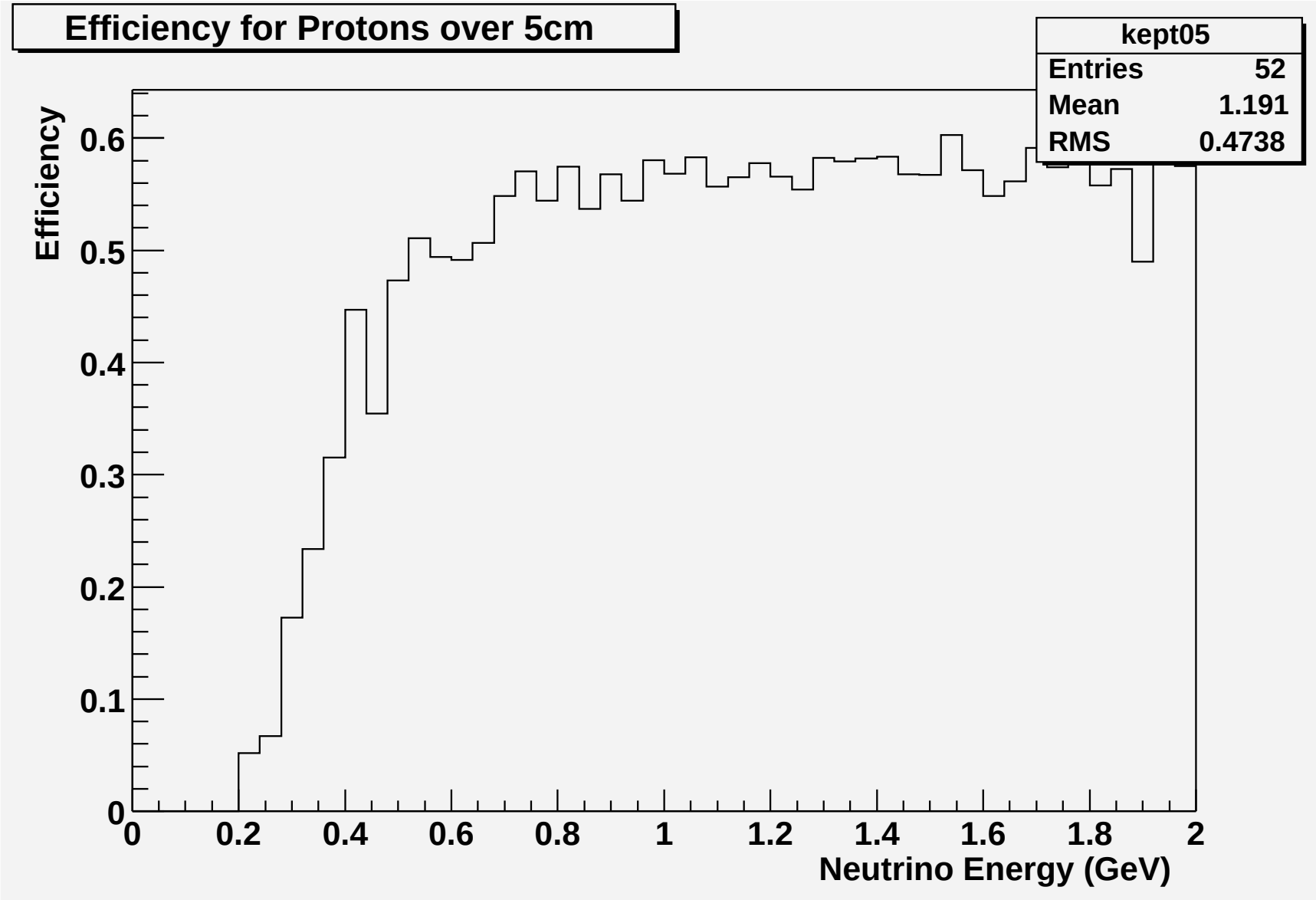
Efficiency if “forward” protons IDed



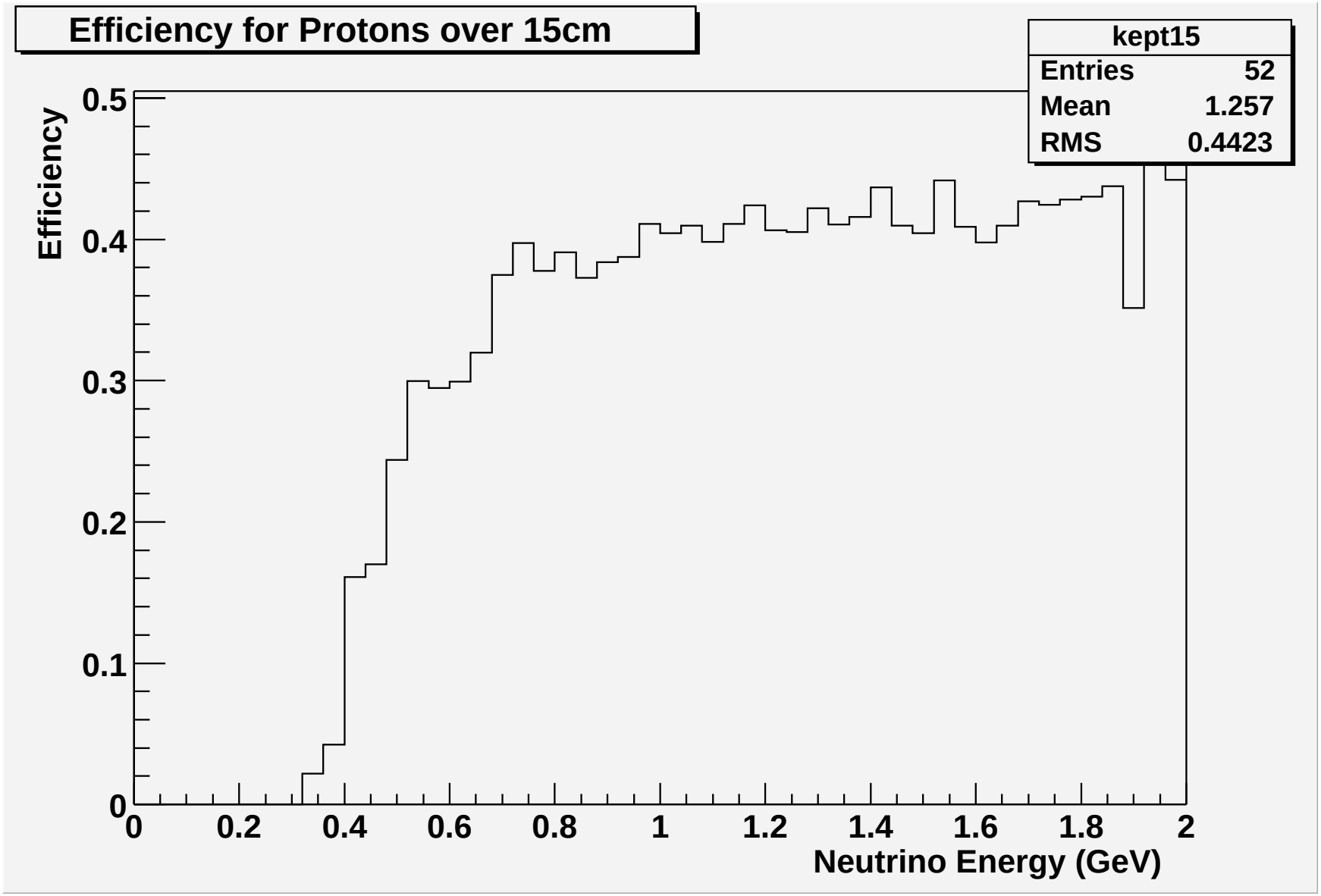
If 1cm Along Z is Required to ID



If 5cm Along Z is Required to ID



If 15cm Along Z is Required to ID



How Thick Can the Water Layers Be?

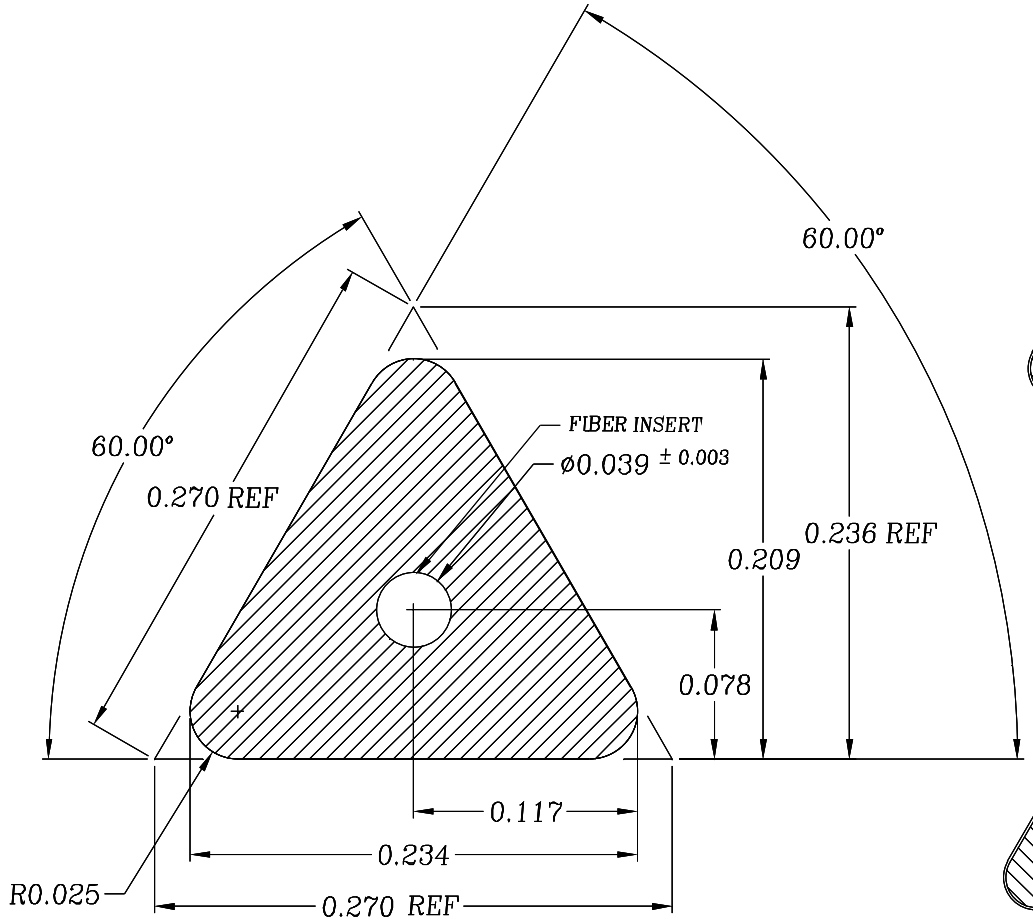
- Efficient reconstruction requires proton identification with less that $\sim$5 cm of range along the beam axis.
  - For a flat efficiency: 1 cm ID is required.
- Identification with multiple “thick” layers will kill efficiency in the relevant energy range (400–1000 MeV).
  - Implies thin water layers with short “ID range”.

Current Ideas: Fine-Grain Bars

The D0 Pre-Shower Detector.

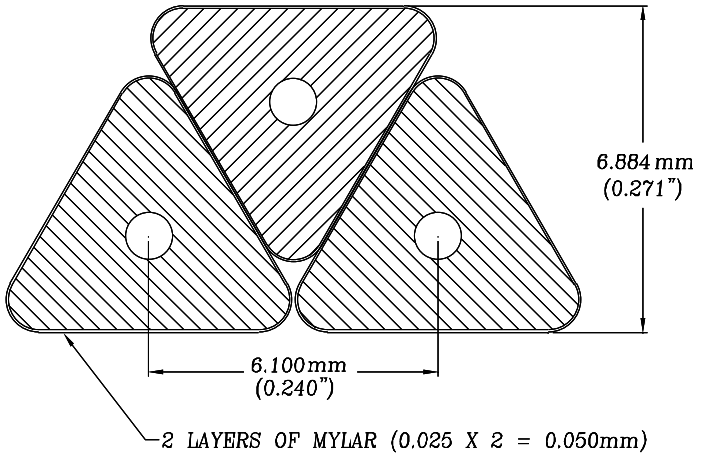
- Use extruded bars of scintillator (diameter ~ 5 mm)
- Collect light using WS fibers
- Instrumented with 8 channel VLPCs.
  - Quantum Efficiency: 60 – 80% in visible
- Yield: 4 – 11 p.e./MIP/layer (with 11 m clear + 3 m WS fiber)
  - Good PID when particle passes through a few layers
- Track Resolution: 550 μm per singlet layer
- Direction Resolution: 2 mrad per xuv layer

D0 Pre-Shower Singlet Layer

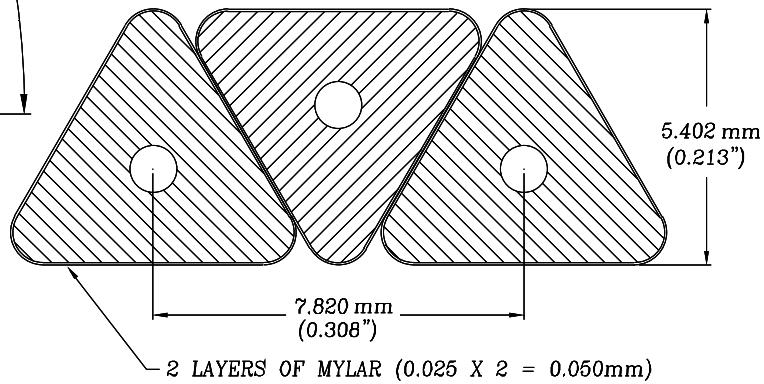


a.) CPS-FPS SCINTILLATOR GEOMETRY

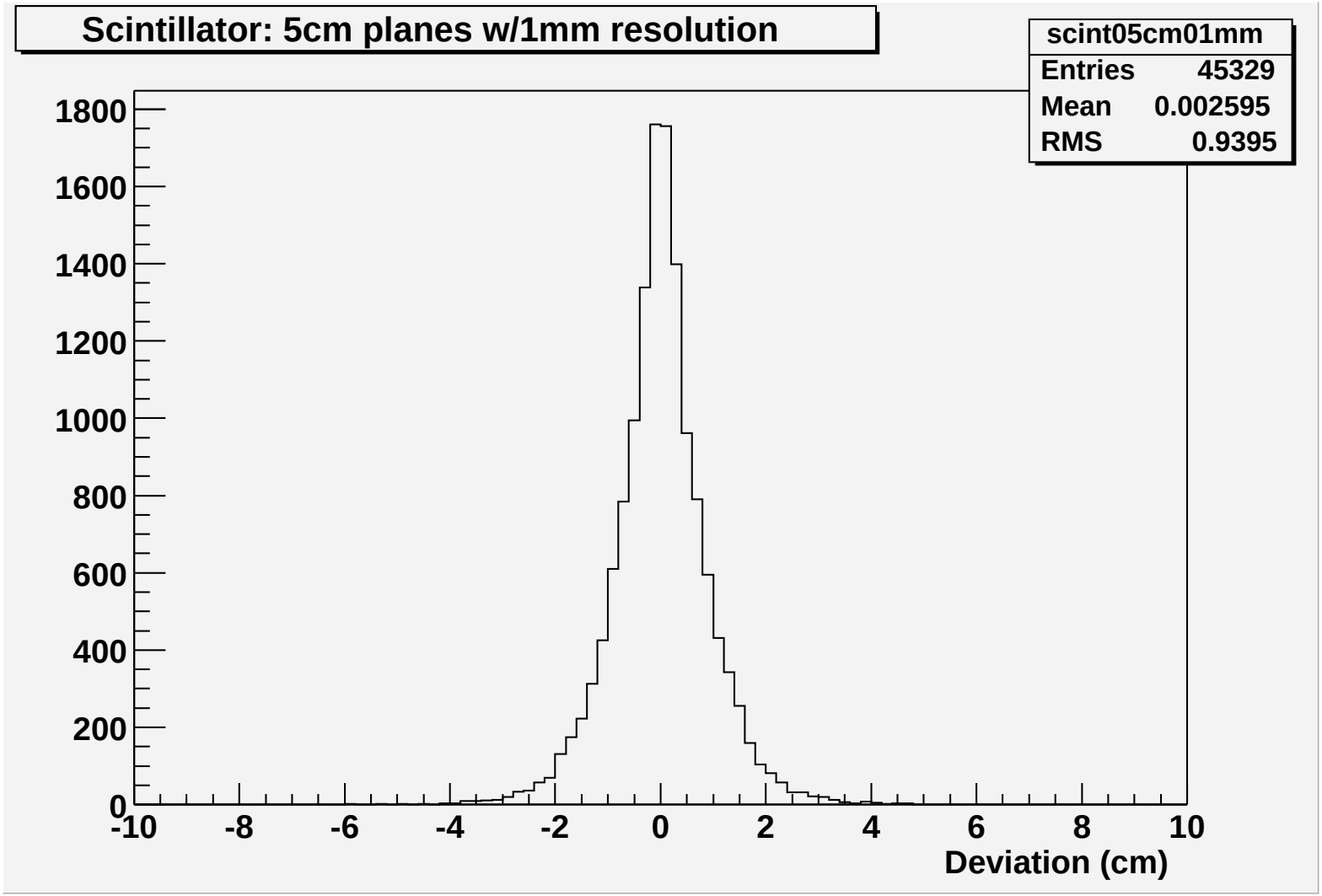
b.) FPS TEST BEAM PROTOTYPE



c.) FINAL FPS GEOMETRY



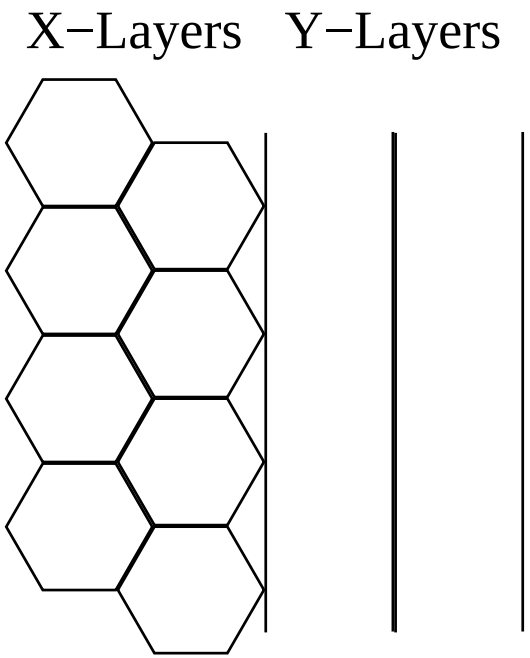
Vertex Resolution with 5cm Layers



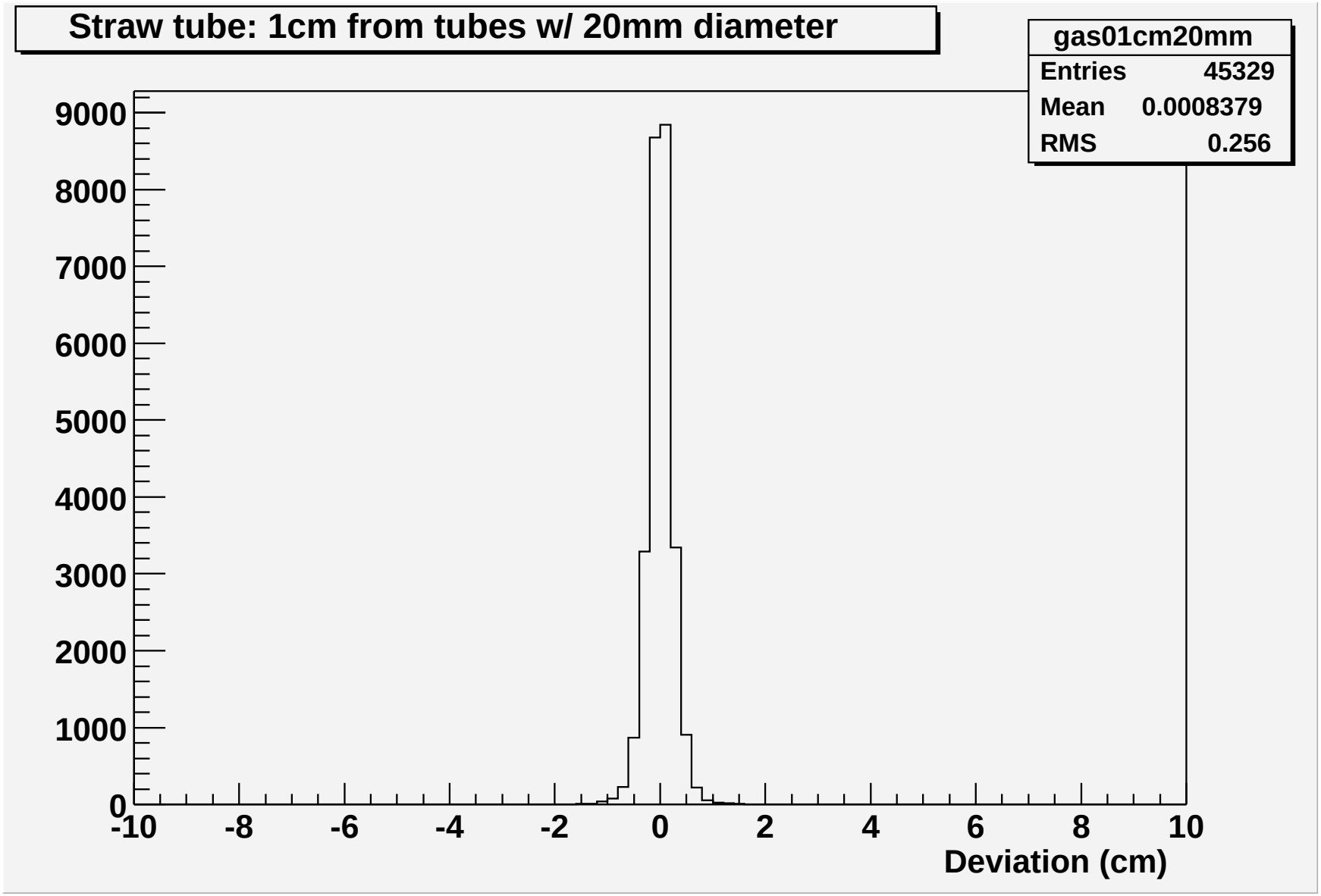
Resolution 5cm from active layer.

What About Straw Tubes?

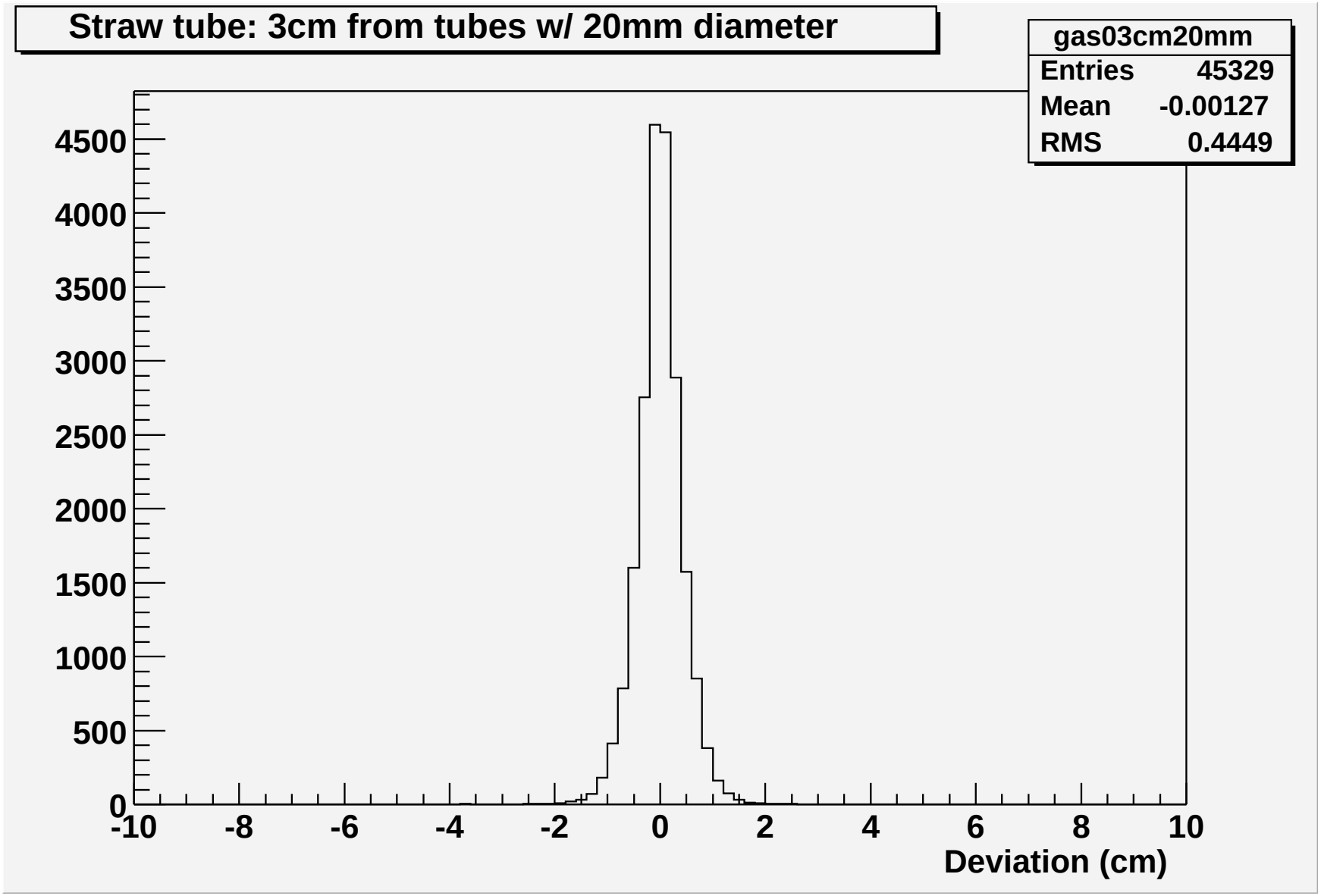
- Position resolution: 50 μm to 300 μm
  - Assume 200 μm.
- Assume 4 rows of tubes per 1 layer of water.
  - Two X rows and two Y rows.
  - Fit using 1 layer.



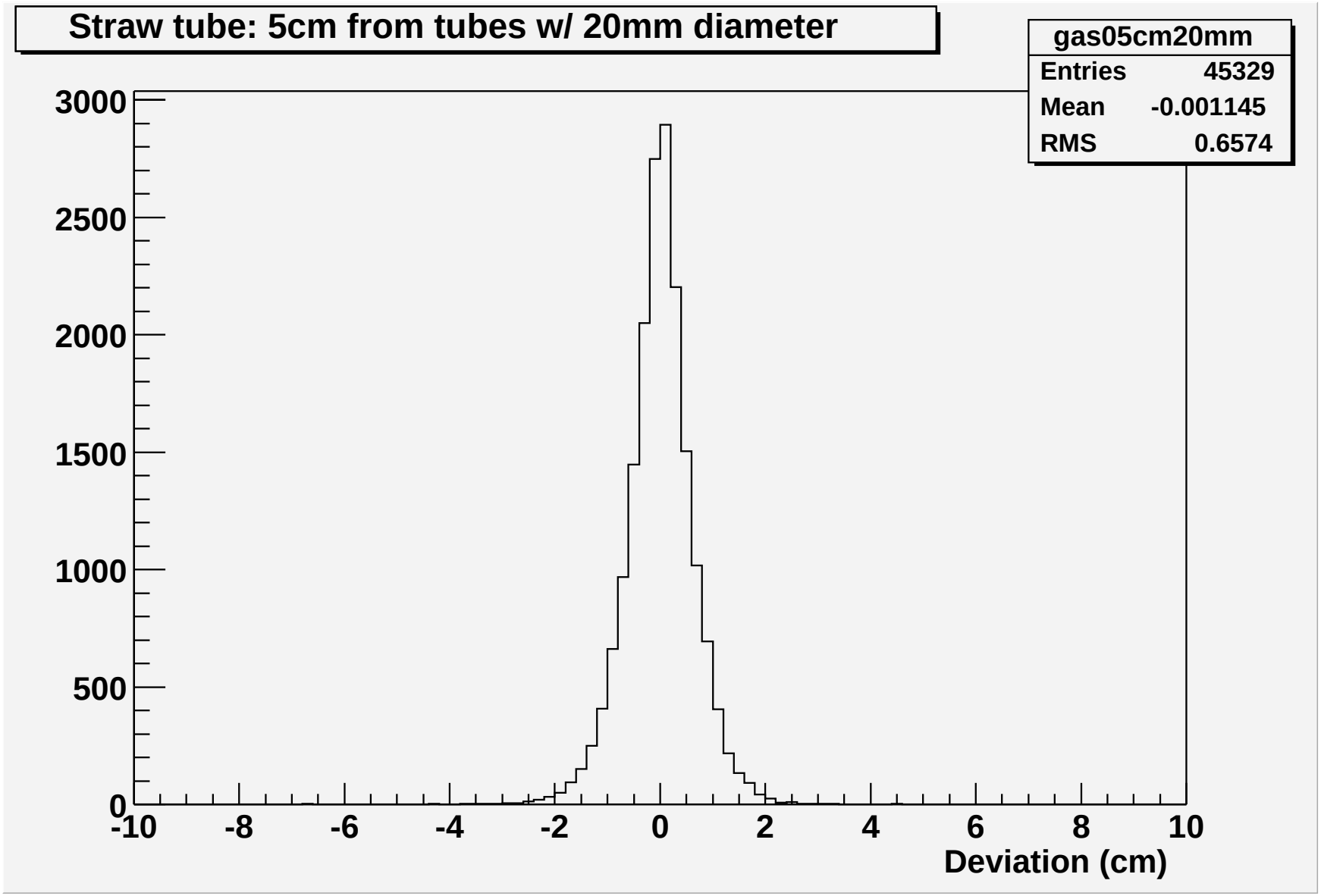
Resolution at 1 cm from Layer



Resolution at 3 cm from Layer

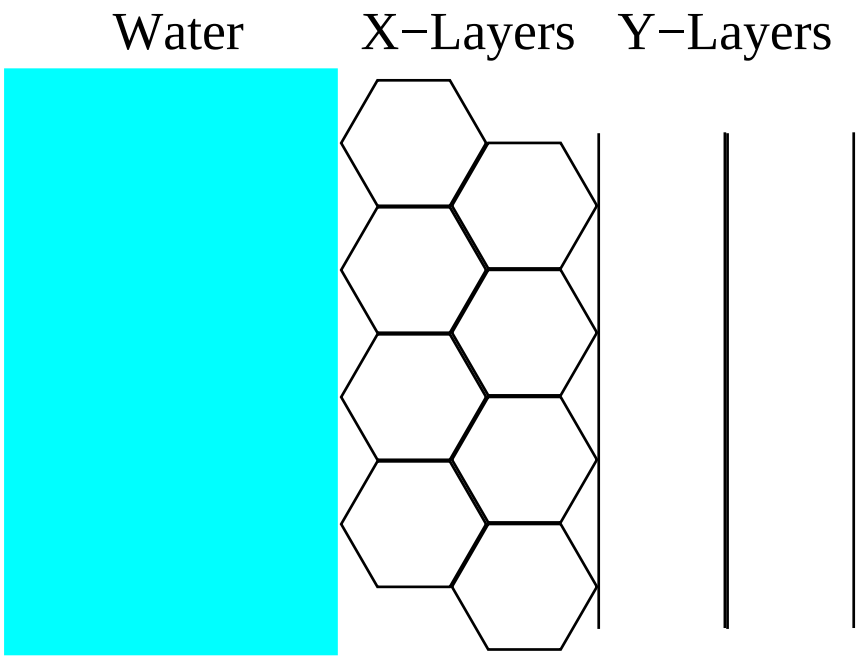


Resolution at 5 cm from Layer



A Straw Man Straw Tube Detector

- Water layer: 5 cm
- Tracking layers: 4 layers of 20 mm straw tubes
  - two X layers
  - two Y layers
- Fiducial volume in water 1 cm – 3 cm from tracking layer.



Conclusions and Questions

- QE reconstruction implies identifying protons quickly (<5 cm travel along beam b).
  - This seems to favor scintillator based designs.
- Fiducial volume definition requires good tracking resolution.
  - This seems to favor straw tube designs.
- Questions:
  - Can straw tubes achieve proton/pion separation?
  - Can a straw tubes be mixed with water without a lot of extra material?
  - Can we export VLPC?
  - Are there alternative technologies (e.g. avalanche diodes)?