Progress on a prototype ‘Optical Time-Projection Chamber (OTPC)’

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Optical TPC

• The idea: one application of LAPPDs is a fine resolution (timing+spatial) tracking detector using ‘drifted’ Cherenkov light
• Can build a prototype to demonstrate charged particle tracking in water. Scalable when LAPPDs available
A prototype OTPC

• Use commercial 2x2 in$^2$ Planacon MCPs
• Add mirrors to enhance light collection coverage
• Employ PSEC4 readout
1024 Pad Anode Planacon -> 32 strip transmission line readout

Greg Sellberg (FNAL), magician, does bonding
A prototype OTPC:: 40 kg water detector

Drawing courtesy of Rich Northrop
A prototype OTPC:: 40 kg water detector

Watertight, inside surface painted matte spray paint as cheap light absorber
Chroma :: a high performance optical photon simulation for particle physics detectors [With the assistance of a CUDA-enabled GPU]

“MiniLBNE” with 12” PMTs in Chroma
Credit: Stan Seibert
Optical TPC prototype in Chroma:

- Planacon MCPs
- Mirrors
- Muon track
Optical TPC prototype in Chroma, importing 3D Inventor models
Comparing GeV, thru-going Muon trajectories: 0 deg ['straight'] and 5 degrees along –y ['angle'].

• Both tracks start at center top of cylindrical detector.
• Time resolution=30 ps
Time projection of Cherenkov light

Reflected from opposite side of cylinder

Δt between direct and reflected

Cherenkov wavefront

Time [ns]

z [mm]
Time projection along z axis

Straight Angle
Time projection along azimuth

Straight

Angle
Photon Time histograms at each MCP
Simple reconstruction

- Using ray-tracing, can fit analytically for trajectory

\[ \theta(t, \phi) - \theta_C = \cos^{-1}\left(\frac{\Delta t}{\Delta z} v(\lambda)\right) \]

\[ r(t, \phi) \approx \frac{\Gamma}{2} \left[ D (1 + \sin(\theta + \theta_C)) - v(\lambda) \Delta t \sin(\theta + \theta_C) \right] \]

where \[ \Gamma = 1 + \frac{\tan \theta}{\tan \theta_C} \]

- And further can independently solve for \( \theta_C \)
Fitting the Direct Light

The angle, $\theta + \theta_c$ of the particle is extracted from the fits.

- $\theta + \theta_c \sim 42$ deg
- $\theta + \theta_c \sim 37.4$ deg
Fitting the Reflected Light

Straight Angle
Fitting the Reflected Light

Straight

$\Phi = 0^\circ$
$\Phi = 60^\circ$

Angle

Since particle has inclination in y-direction, only $\Phi = 60^\circ$ shows angular dependence.