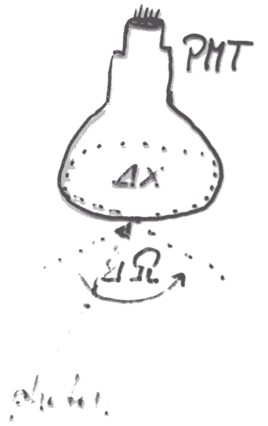
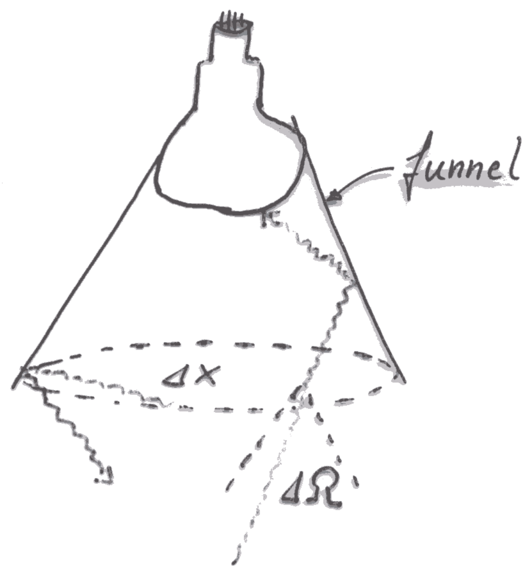
Measuring Cerenkov light in neutrino telescopes

need: large area photon detector → PMT

increase light collection with funnel ?





$\Delta X = A_{PMT}$

$\Delta\Omega \approx 2\pi$

$\Delta X = A_{funnel}$

$\Delta\Omega < 2\pi$

Liouville theorem:

$$V_{ph} = \Delta p \cdot \Delta x = \text{const}$$

$$\Rightarrow \Delta\Omega \cdot \Delta x = \text{const.}$$

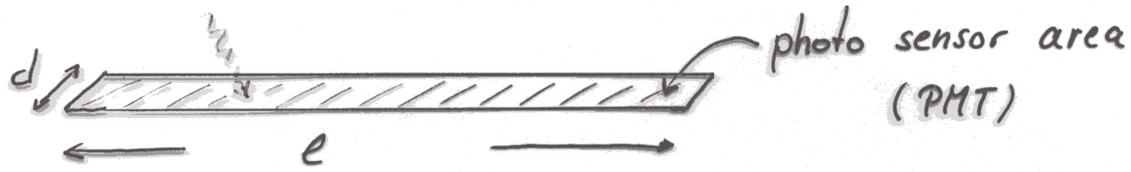
Antares: $\Delta\Omega \simeq 2\pi$ needed

$\Rightarrow$ funnel doesn't help!

overcome Liouville: create new photons

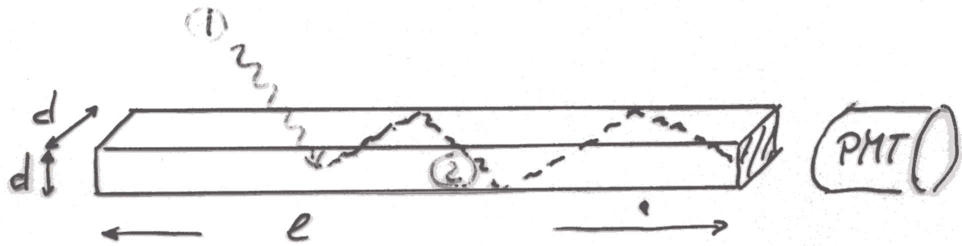
example:

1) version 1: PMT



$A = d \cdot \ell \qquad \Delta\Omega = 2\pi \qquad \boxed{A_{PMT} = A}$

2) version 2: WLS + PMT



$A = d \cdot \ell \qquad \Delta\Omega = 2\pi \qquad \boxed{A_{PMT} \ll A}$

to be considered:

sensor area gain factor: f_g ☺

photon ① – ② factor: f_{loss} ☹

losses due to photon transformation:

1) absorption of incoming photon: f_{abs}

probability $\sim e^{-d/d_0}$

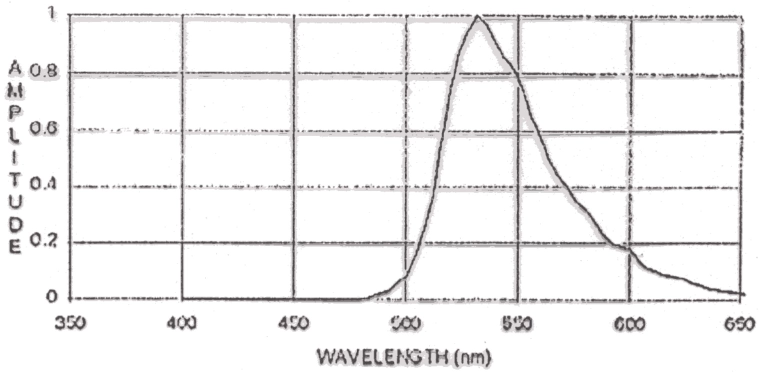
2) Transformation efficiency: f_{trans}

creation of new photon

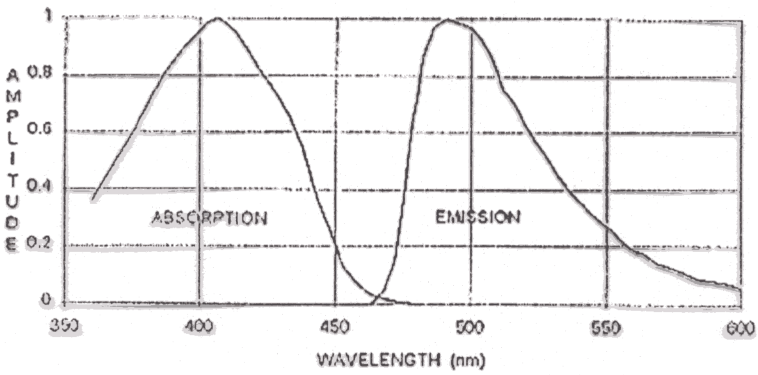
3) acceptance within cone of total reflection: f_{cone}

$$f_{loss} = f_{abs} \cdot f_{trans} \cdot f_{cone}$$

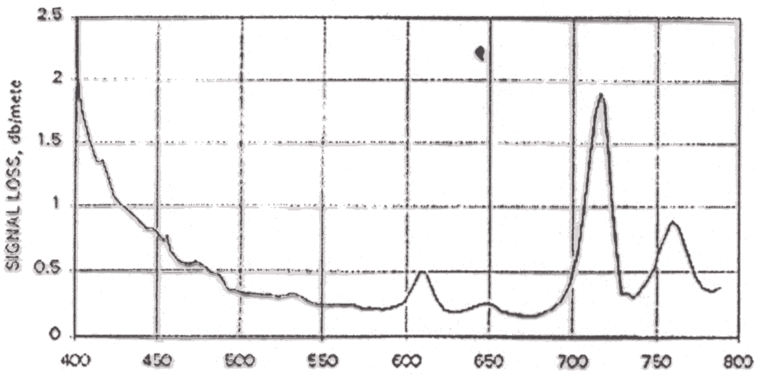
$$\approx 0{,}9 \cdot 0{,}5 \cdot 0{,}2 \approx 0{,}1$$



Optical Spectra - BCF-92

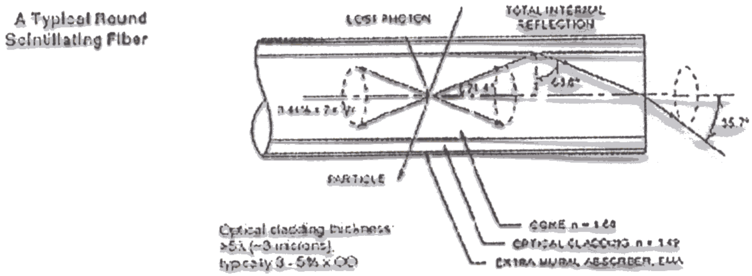


Attenuation vs. Wavelength - BCF-98



Standard Plastic Scintillating/Wavelength Shifting/Optical Fibers

A Typical Round Scintillating Fiber



Return to Light Guide/Wavelength Shifting Material - Fiber

Request Literature

General Description

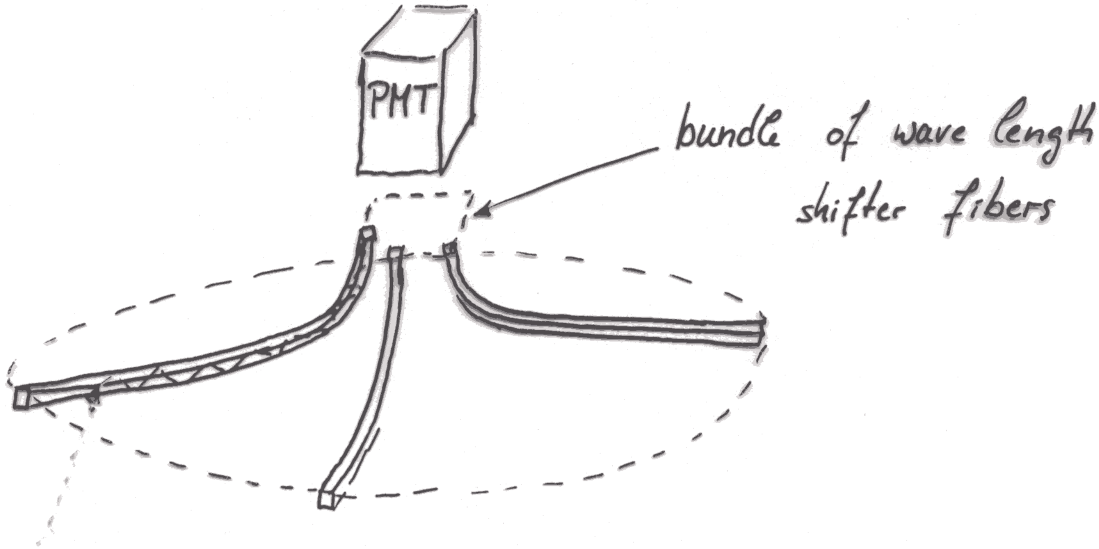
Standard Bicron fibers consist of a polystyrene-based core and a PMMA cladding as shown. In addition, Extramural Absorber (EMA) can be used to eliminate optical crosstalk.

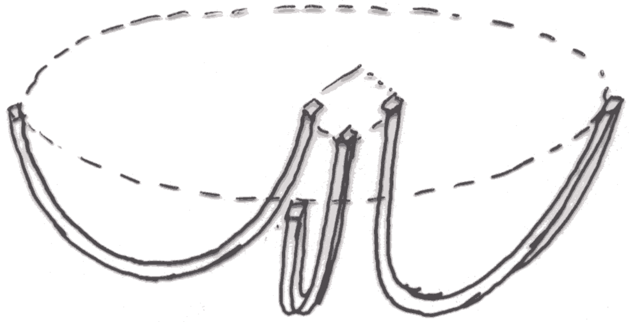
The scintillating core contains fluorescent dopants selected to produce the desired scintillation, optical and radiation-resistance characteristics. Often, one property is enhanced while another is mildly compromised. In small fibers the fluor concentration is increased, usually at the cost of light attenuation length.

The cladding is far thicker than the principles of optics require. This extra thickness provides robust physical protection for the core. It is also a particularly effective optical conduit over distances reaching 30 cm, utilizing the 25% trapping efficiency created by its interface with air.

Standard Formulations

realisation of WLS + PMT for a neutrino telescope:





example:

$r_a = 96\ cm$
$r_i = 15\ cm$

$U = 2\pi r_a = 603\ cm$

$d = 2\ mm$ fiber thickness

$N = \frac{2\pi r_a}{d} = 3015$ fiber number

$h = \frac{r_a}{r_i} = 6{,}4$

$A_F = N \cdot d^2 = 120\ cm^2 = 11 \times 11\ cm^2$ PMT area

$\Delta t = \frac{r_a}{c} = 3{,}3\ ns$ time light travel

$A_{sens} = \pi(r_a^2 - r_i^2) = 28250\ cm^2$ sensitive area

$A_{eff} = f_{loss} \cdot A_{sens} = 2800\ cm^2$ eff. sens. area

$A_{PMT} = 500\ cm^2$ Antares PMT

aspects:

- PMT area relatively small (low noise!)
- separate optimization of components
  PMT, WLS, ..
- embed fibers in plastic
- system gets large (!)

here in terms of a small number of critical parameters. This discuss
considers a fraction of the total number of parameters which have actua
measured (see [59, 60, 61]).

The effective photocathode area (A_{eff}^{PC}) is defined as the detection ar
photocathode weighted by the collection efficiency. It was measured by
the entire photocathode surface with a collimated blue LED.

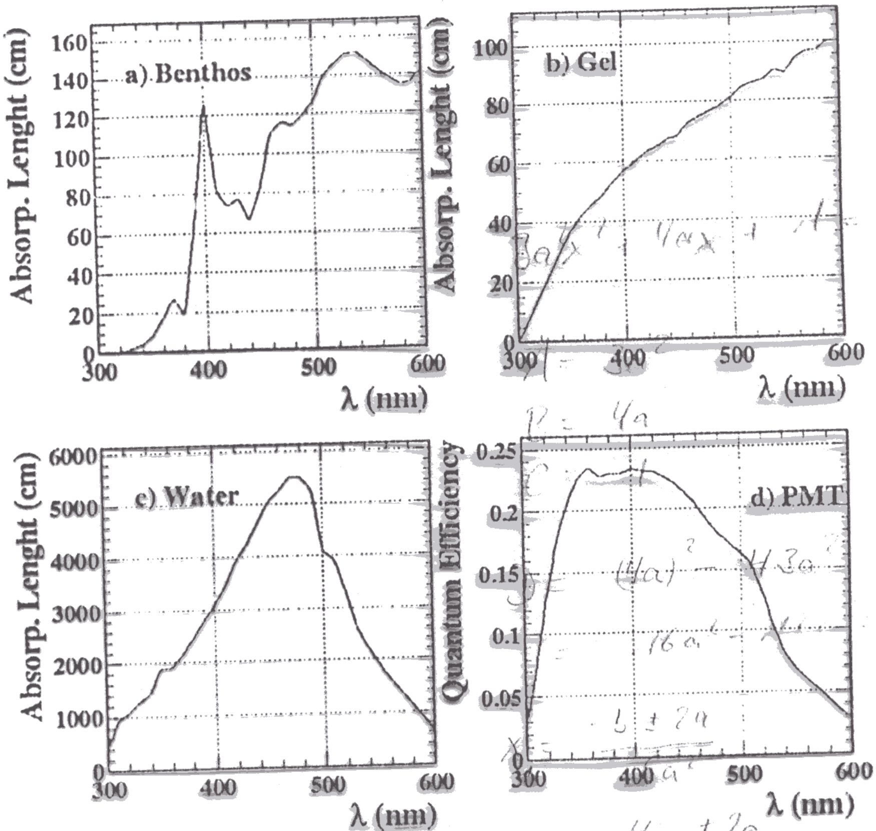


Figure 5.4: Attenuation length of (a) the Benthos sphere, (b) silicone gel
water; (d) quantum efficiency for the Hamamatsu photomultiplier tubes.

Electromagnetic interference in the optical module induces noise a
anode. It is expected that this will not exceed 5 mV (rms). This noi
the gain at which the PMT is operated. A factor of 10 between th