Light production

- Cross-check previous estimates
  - PDG/RPP: 10 photons/MIP/1mm fiber
  - 24 cm BCAL = 120 mm fiber material
    = 1200 photons/MIP (both ends included)
  - MIP deposits 24 MeV, perpendicular incidence
  - 1200 /0.024 GeV = 50,000 photons/GeV(deposited)
    x 0.12 is = 6000 photons/GeV(showering particle energy)

PDG, 28.3, 2008

28.3.3. Scintillating and wavelength-shifting fibers : The clad optical fiber is an incarnation of scintillator and wavelength shifter (WLS) which is particularly useful [33]. Since the initial demonstration of the scintillating fiber (SCIFI) calorimeter [34], SCIFI techniques have become mainstream [35]. SCIFI calorimeters are fast, dense, radiation hard, and can have leadglass-like resolution. SCIFI trackers can handle high rates and are radiation tolerant, but the low photon yield at the end of a long fiber (see below) forces the use of sensitive photodetectors. WLS scintillator readout of a calorimeter allows a very high level of hermeticity since the solid angle blocked by the fiber on its way to the photodetector is very small. The sensitive region of scintillating fibers can be controlled by splicing them onto clear (non-scintillating/non-WLS) fibers. A typical configuration would be fibers with a core of polystyrene-based scintillator or WLS (index of refraction n = 1.59), surrounded by a cladding of PMMA (n = 1.49) a few microns thick, or, for added light capture, with another cladding of fluorinated PMMA with n = 1.42, for an overall diameter of 0.5 to 1 mm. The fiber is drawn from a boule and great care is taken during production to ensure that the intersurface between the core and the cladding has the highest possible uniformity and quality, so that the signal transmission via total internal reflection has a low loss. The fraction of generated light which is transported down the optical pipe is denoted the capture fraction and is about 6% for the single-clad fiber and 10% for the double-clad fiber. The number of photons from the fiber available at the photodetector is always smaller than desired, and increasing the light yield has proven difficult. **A minimum-ionizing**

j **particle traversing a high-quality 1 mm diameter fiber perpendicular to its axis will produce fewer than 2000 photons, of which about 200 are captured. Attenuation may eliminate 95% of these photons in a large collider tracker.** A scintillating or WLS fiber is often characterized by its attenuation length, over which the signal is attenuated to 1/e of its original value. Many factors determine the attenuation length, including the importance of re-absorption of emitted photons by the polymer base or dissolved fluors, the level of crystallinity of the base polymer, and the quality of the total internal reflection boundary. Attenuation lengths of several meters are obtained by high quality fibers. However, it should be understood that the attenuation length is not necessarily a measure of fiber quality. Among other things, it is not constant with distance from the excitation source and it is wavelength dependent. So-called cladding light causes some of the distance dependence [36], but not all. The wavelength dependence is usually related to the higher re-absorption of shorter wavelength photons once absorbed, re-emitted isotropically and lost with 90% probability and to the lower absorption of longer wavelengths by polystyrene. Experimenters should be aware that measurements of attenuation length by a phototube with a bialkali photocathode, whose quantum efficiency drops below 10% at 480 nm, should not be naively compared to measurements utilizing a silicon photodiode, whose quantum efficiency is still rising at 600 nm.

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Fig. 1 sketches the matrix of fibers in the bcal and can be used to estimate the response to minimum ionizing tracks. The fibers cover 49% of the area of the matrix. Assuming that minimum ionizing tracks sample the fibers uniformly, the energy deposited will be $22.5\,cm \times 0.49 \times 2\,MeV/cm/0.12 \sim 184$ MeV, where we take the energy loss in scintillator at 1-2 GeV to be about 2 MeV/cm. This estimate is consistent with the recent calculation [2] reported at the Bcal readout meeting that normal incident 1 GeV muons deposit 170 MeV.

These (184 MeV, 170 MeV) can't be the 'deposited energies.' The MIP deposited energy must be ~23 MeV.

The number of photons per GeV of incident photon energy is a key parameter. I take this number to be 10,500 photons/GeV/side, or a total of 21,000 photons/GeV [3]. We also take 10 readout channels per side, or 20 per module, and the gate for a signal to be 100 ns. With these definitions we get the following:

$$N_{phGeV} = \mathbf{21000} \quad (2)$$

Where does 21000 come from? I get 6000 from PDG estimate. Factor of 3 will have substantial impact on specs.

Note: http://argus.phys.uregina.ca/gluex/DocDB/0008/000808/002/BCAL_readout_07.pdf implies even a much bigger number, like > 50000.