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The NuMI WBB for ν_τ Appearance Experiments

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The NuMI baseline neutrino beam design uses two parabolic horns with nominal current 200 kA. This beam design allows to cover in three steps a wide range of neutrino energies. Corresponding wide band neutrino beams labeled as PH2(le), PH2(me) and PH2(he) use the same horns and power supply system, although with different targets and the horns set in different positions ("The NuMI Facility Technical Design Report", October, 1998).

This short report presents a study of the PH2 WBB design possibilities for ν_τ appearance experiments. Calculations have been made for PH2-modified horns in a case of 725 m long decay region (the 675 m decay pipe and the 50 m distance from the target to begin of the decay pipe). The ν_τ CC event rate was calculated assuming oscillations with $\sin^2(2\theta) = 1$ and $\delta m^2 = 0.001 \text{ eV}^2$. Figure 1 shows $\sigma(\nu_\tau)/\sigma(\nu_\mu)*P_{osc}$ as function of energy calculated for these values of oscillation parameters and for $L = 730 \text{ km}$.

Figures 2 and 3 give ν_τ event rates at the MINOS far detector as functions of the target and second horn locations calculated by M.C. program HALO for the ME and HE target designs respectively. The ν_τ event rate equal to 1 corresponds in both Figures to the ν_τ event rate of the PH2(me) neutrino beam. The ME target design assumes the 1.2 m long graphite fin target with average density reduced by air gaps between segments to 0.78 from its nominal value. The HE target differs from the ME one by greater length (1.56 m) and smaller average density (0.64). In these calculations the proton beam had Gaussian distributions in both horizontal and vertical planes with $\sigma_x = 0.71 \text{ mm}$ and $\sigma_y = 1.42 \text{ mm}$.

As it follows from these plots, the total ν_τ event rate reaches its maximum value in the focusing system with the second horn located $\sim 40 \text{ m}$ downstream the first horn (it corresponds to the second horn location for the PH2(he) wide band beam). For such second horn location more dense ME target gives 4–5% smaller total ν_τ event rate than that for the HE target. Both ME and HE targets should be located in this case closely to the first horn than the target in the original PH2(he) design.

Figures 4 and 5 show ν_μ and ν_τ neutrino spectra at the MINOS far detector calculated by GNUMI for three different wide band neutrino beams. Summary of total neutrino event rates for these WBB beams are given in Table 1. Results of GNUMI runs are located in /usr/minos/data01/ihep/ file area.

WBB	Target/Gap	ν_μ CC	ν_τ CC	Results in:
PH2(me)	ME/0.1 m	1277	2.26	me_wbb/job71-74
PH2(he)	HE/1.5 m	2519	3.72	he_wbb/job45-48
PH2(he)	HE/2.4 m	2823	3.71	he_wbb/job51-54

Table 1: Total ν_μ and ν_τ ($\sin^2(2\theta) = 1$, $\delta m^2 = 0.001 \text{ eV}^2$) event rates for different wide band beam designs. Gap is a distance between downstream end of the target and upstream end of the first horn.

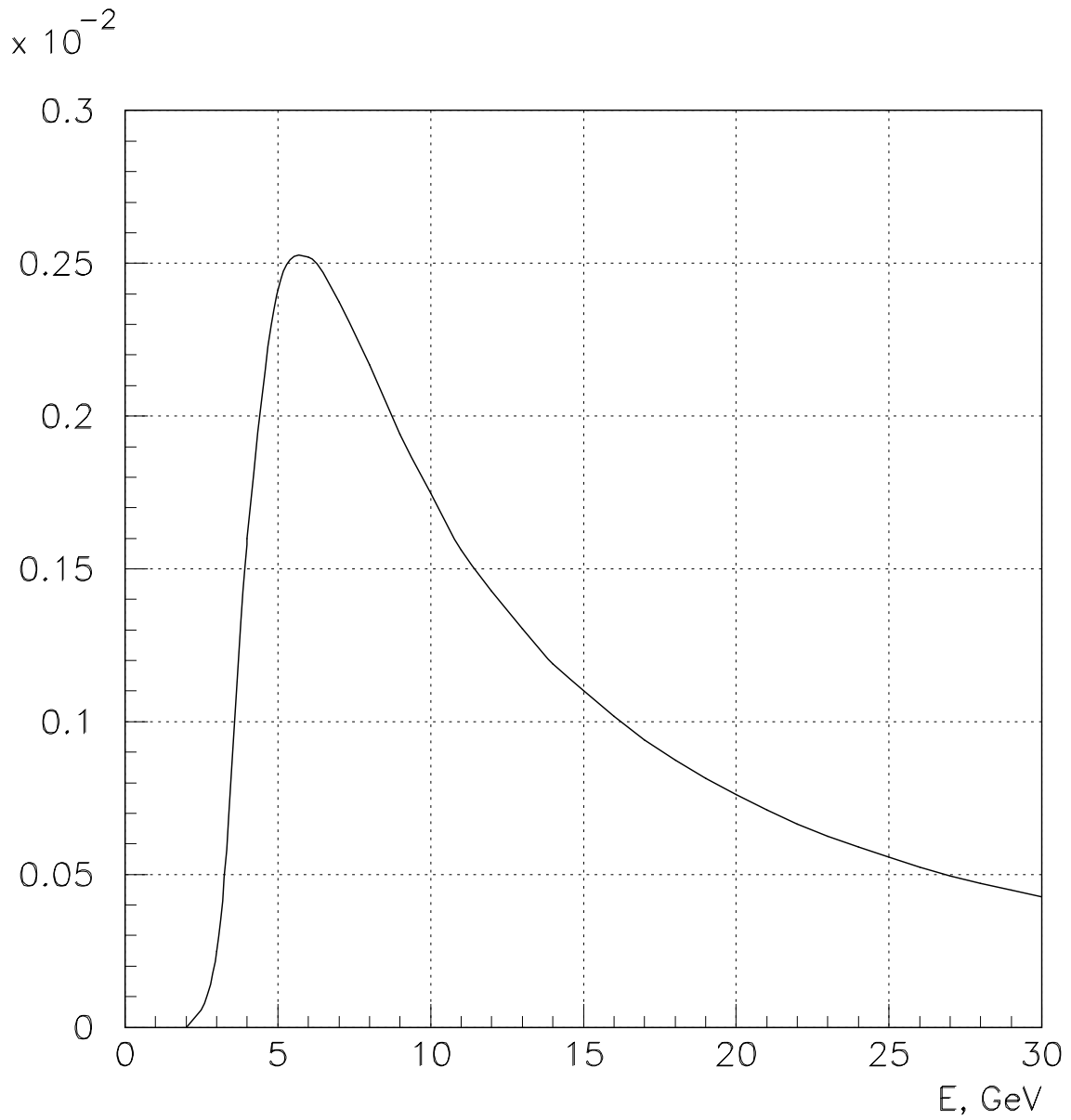


Figure 1: The ratio of ν_τ and ν_μ CC cross sections times oscillation probability for $\sin^2(2\theta) = 1$, $\delta m^2 = 0.001 \text{ eV}^2$ and $L = 730 \text{ km}$.

PH2M WBB Design.

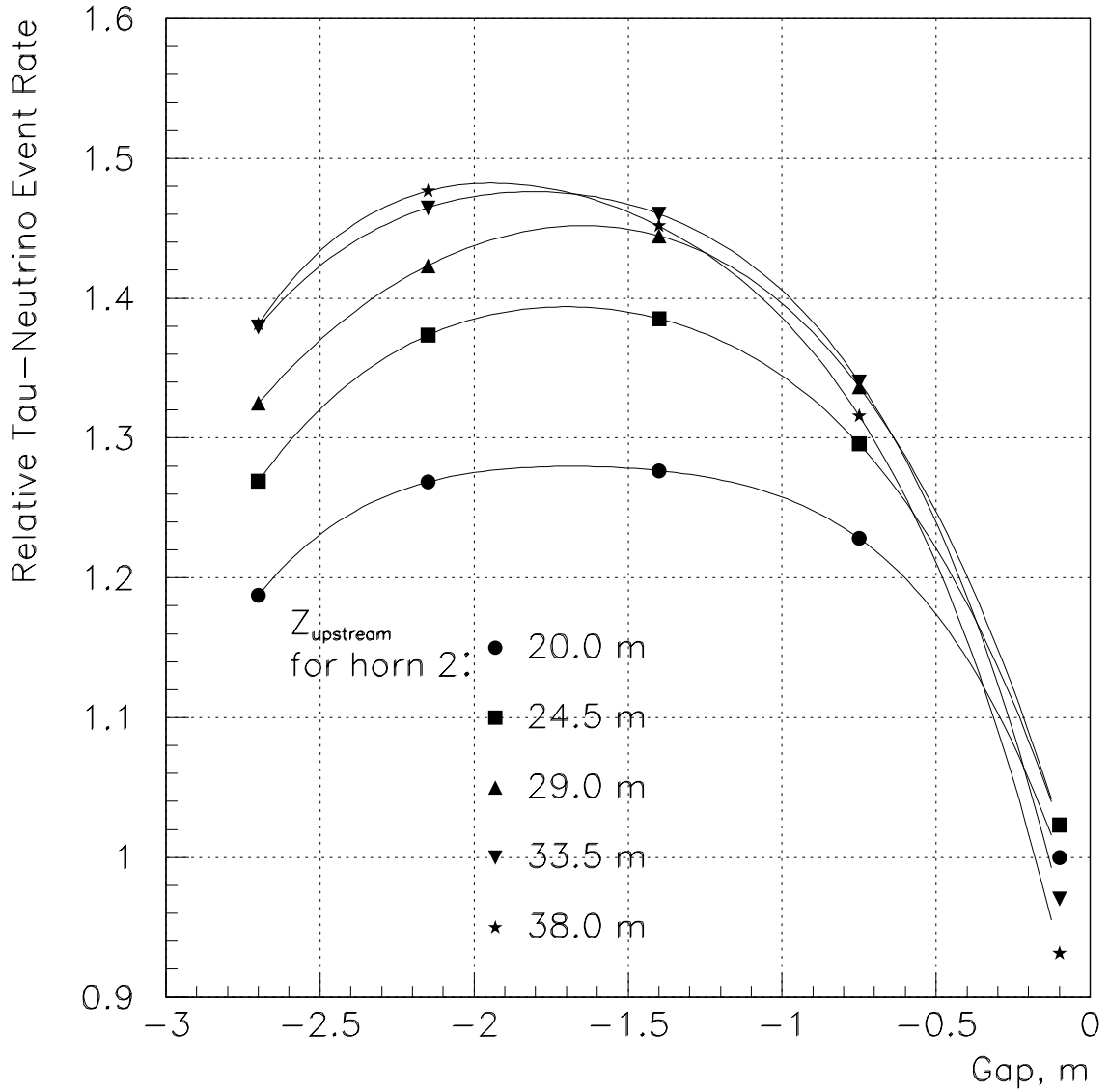


Figure 2: Relative ν_τ CC event rates as functions of the target and second horn locations for the ME target with the length of 1.2 m and average density of 0.78. Gap is a distance between downstream end of the target and upstream end of the first horn ($Z = 0$).

PH2M WBB Design.

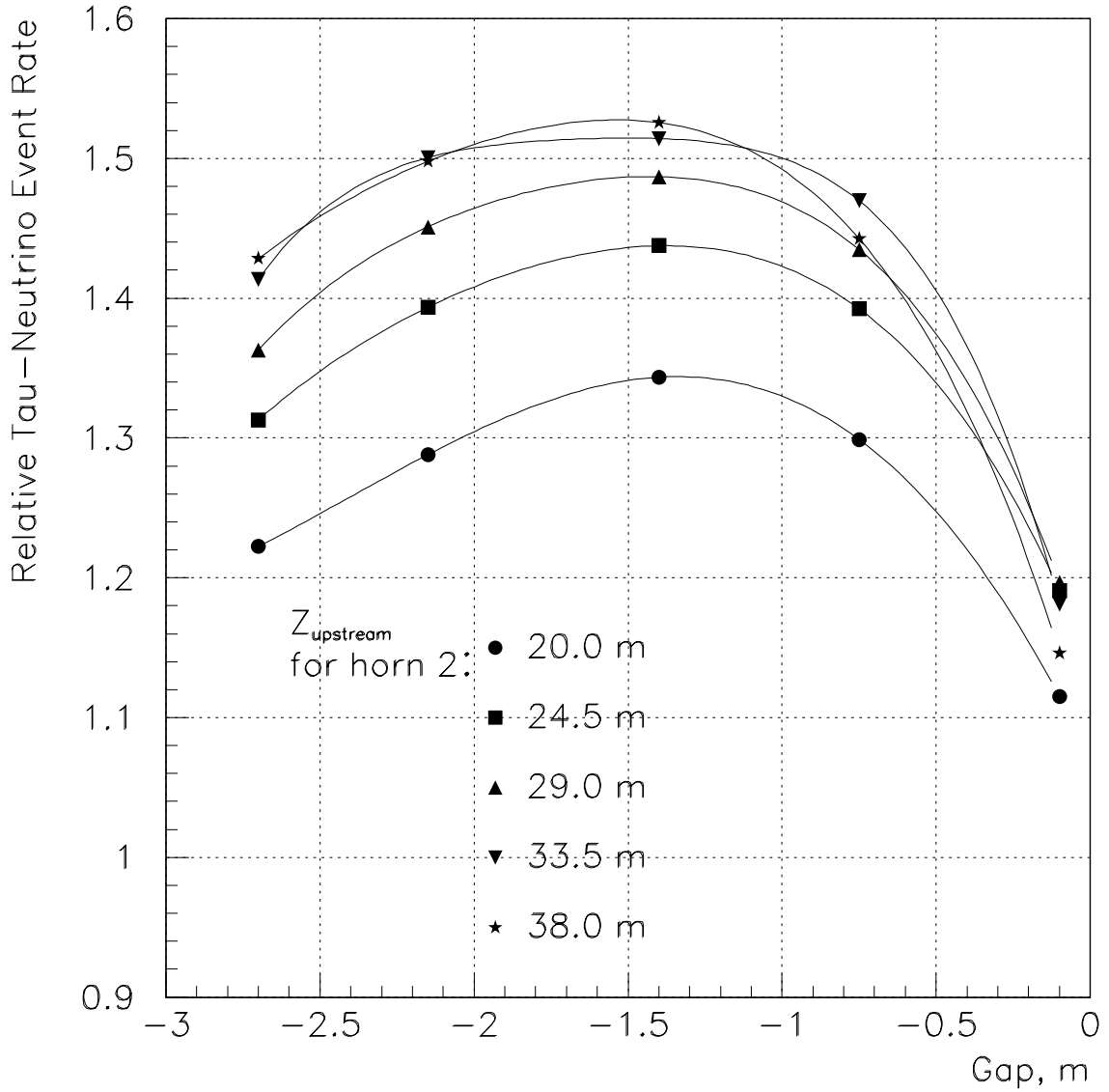


Figure 3: Relative ν_τ CC event rates as functions of the target and second horn locations for the HE target with the length of 1.56 m and average density of 0.64. Gap is a distance between downstream end of the target and upstream end of the first horn ($Z = 0$).

WBB. Far Detector NuMu Event Rate.

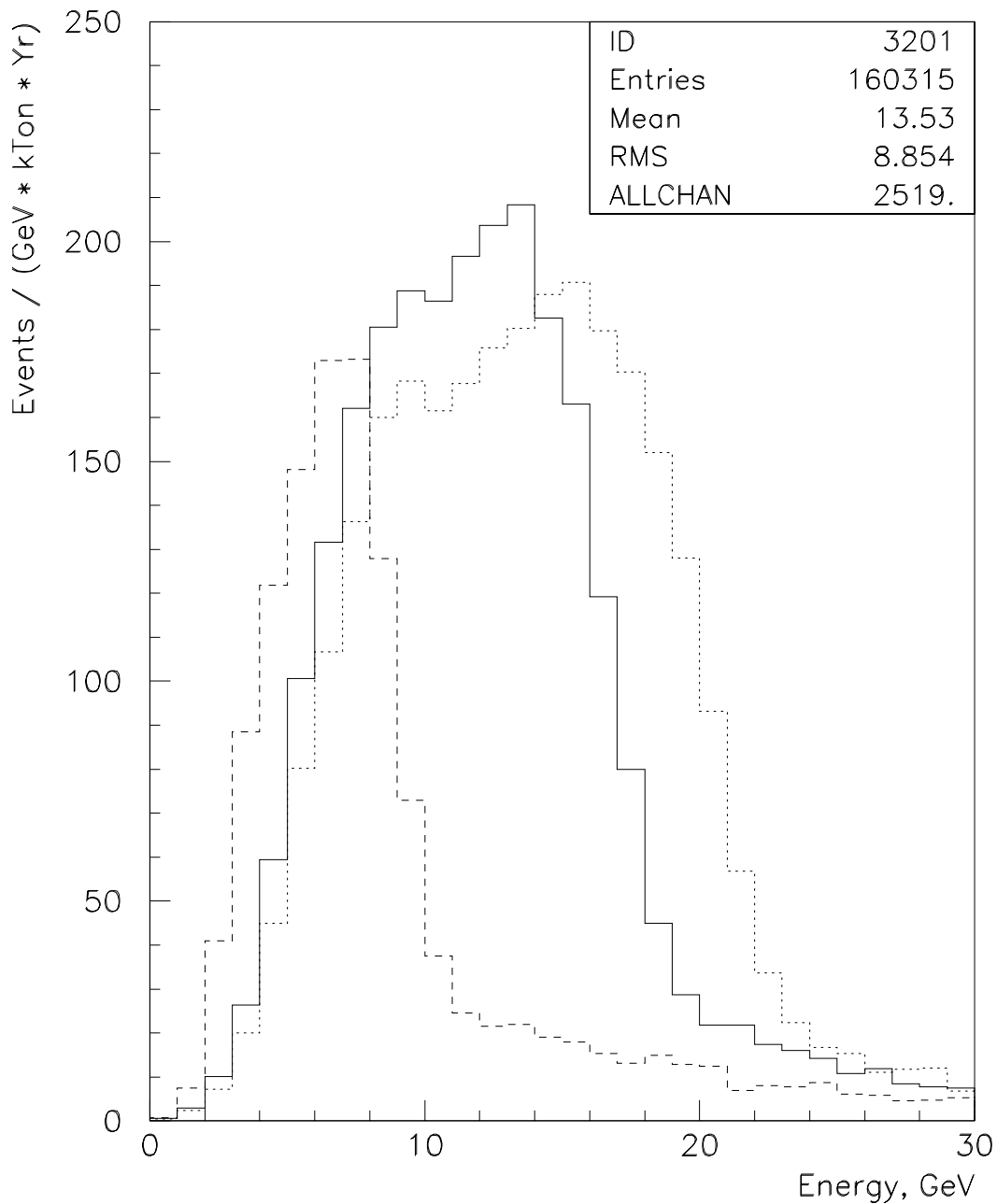


Figure 4: ν_μ CC event rates for different WBB designs. Dashed line corresponds to the PH2(me) beam, solid and dotted lines correspond to the PH2(he) beams with the target located 1.5 m and 2.4 m upstream the first horn (see also Table 1).

WBB. Far Detector NuTau Event Rate.

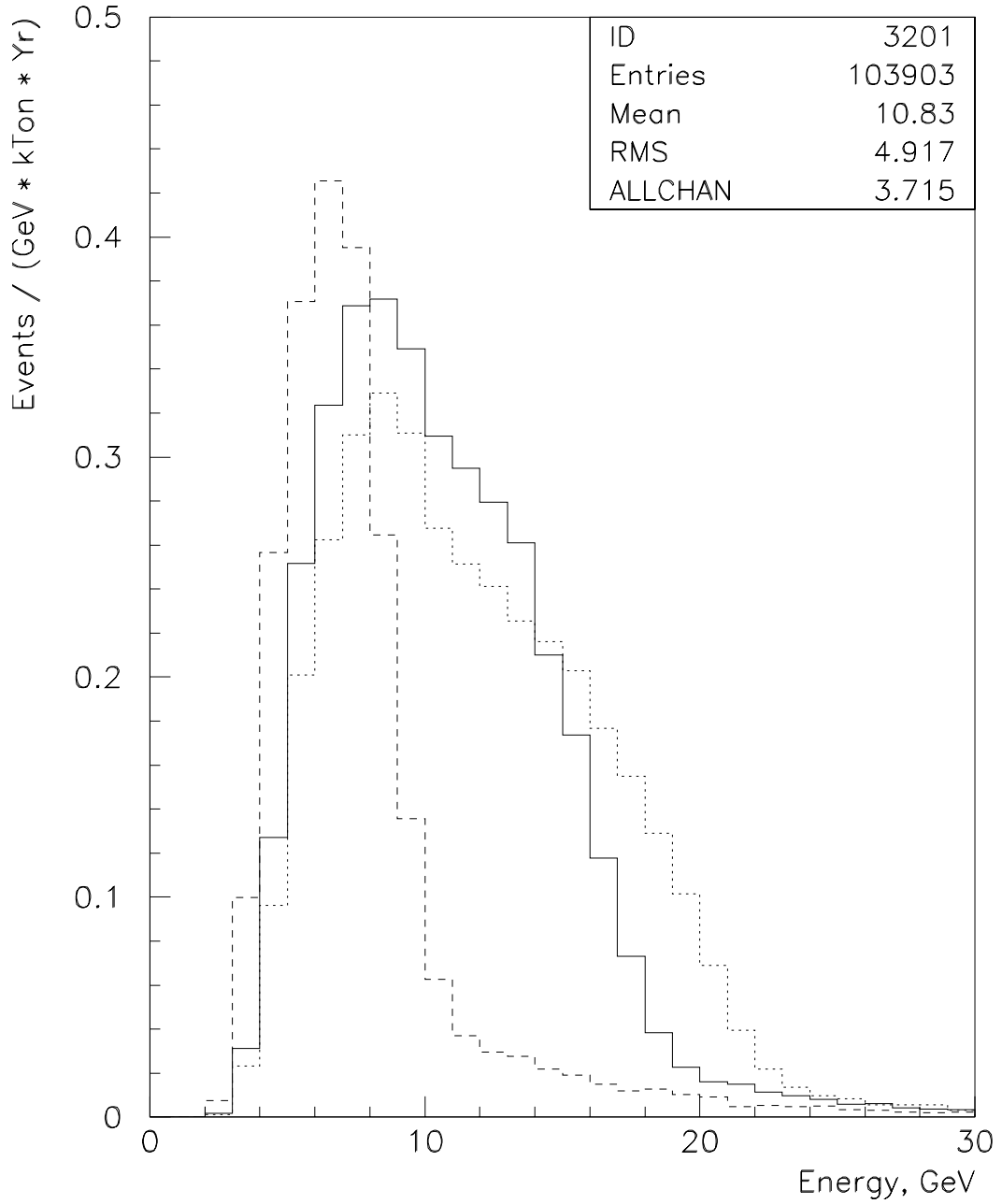


Figure 5: ν_τ CC event rates for different WBB designs. Dashed line corresponds to the PH2(me) beam, solid and dotted lines correspond to the PH2(he) beams with the target located 1.5 m and 2.4 m upstream the first horn (see also Table 1).