DREAM Test Beam 2006

The Papers

Richard Wigmans

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Contributions of Čerenkov Light to the Signals from Lead Tungstate Crystals

N. Akchurin[a], L. Berntzon[a], A. Cardini[b], G. Ciapetti[c], R. Ferrari[d], S. Franchino[d], G. Gaudio[d], J. Hauptman[e], H. Kim[a], F. Lacava[c], L. La Rotonda[f], M. Livan[d], E. Meoni[f], H. Paar[g], A. Penzo[h], D. Pinci[c], A. Policicchio[f], S. Popescu[i], G. Susinno[f], Y. Roh[a], W. Vandelli[d] and R. Wigmans[a, 1]

[a] *Texas Tech University, Lubbock, USA*
[b] *Università di Cagliari and INFN, Sezione di Cagliari, Italy*
[c] *Università di Roma I and INFN Roma La Sapienza*
[d] *Università di Pavia and INFN, Sezione di Pavia, Italy*
[e] *Iowa State University, Ames, USA*
[f] *Università di Cosenza and INFN Sezione di Cosenza, Italy*
[g] *University of California at San Diego, La Jolla, USA*
[h] *INFN Trieste, Italy*
[i] *CERN, Genève, Switzerland*

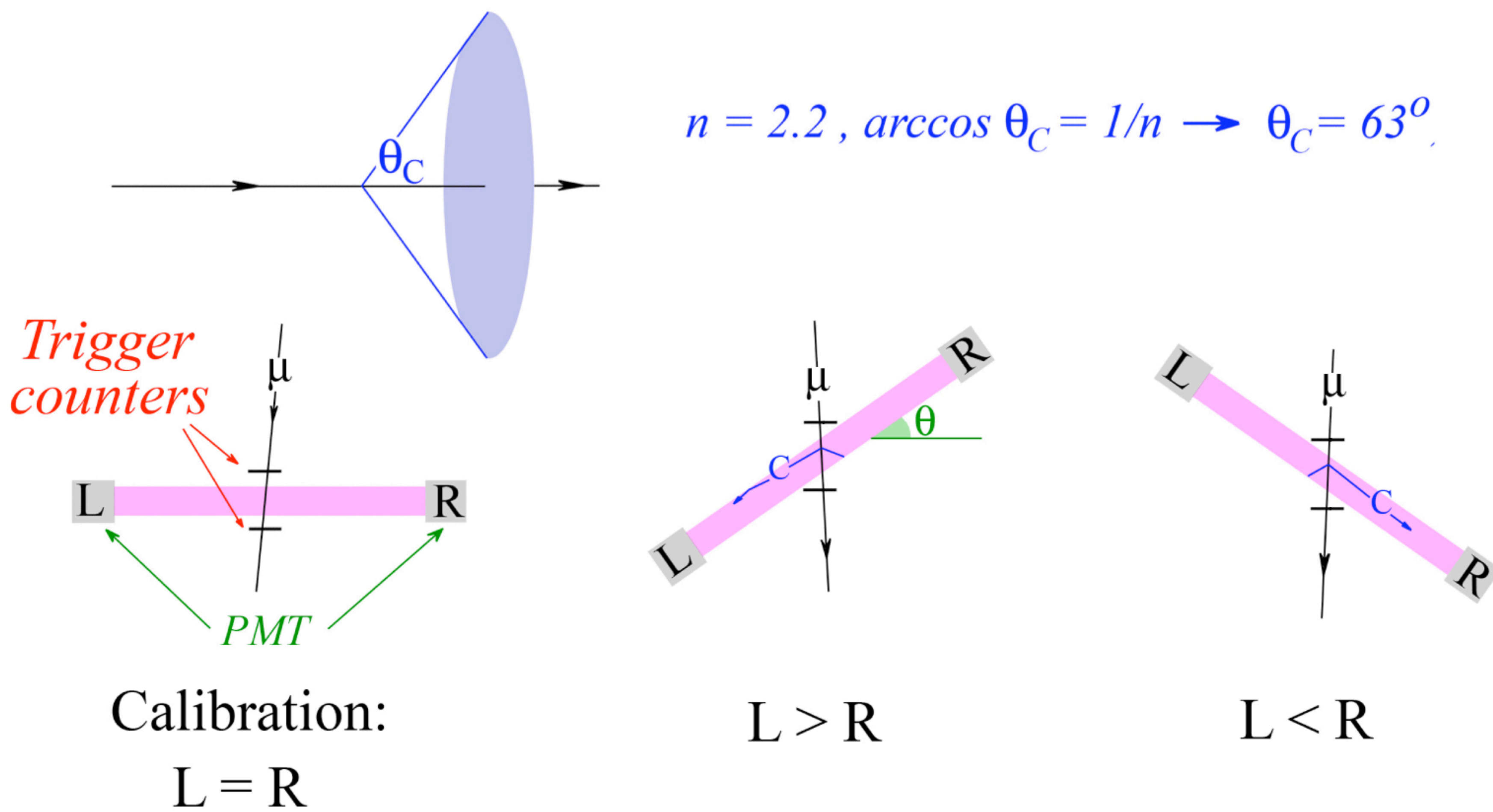

Fig. 1. Principle of the asymmetry measurement used to establish the contribution of Čerenkov light to the signals from the $PbWO_4$ crystals. Depending on the orientation, this directionally emitted light contributes differently to the signals from the left and right photomultiplier tubes.

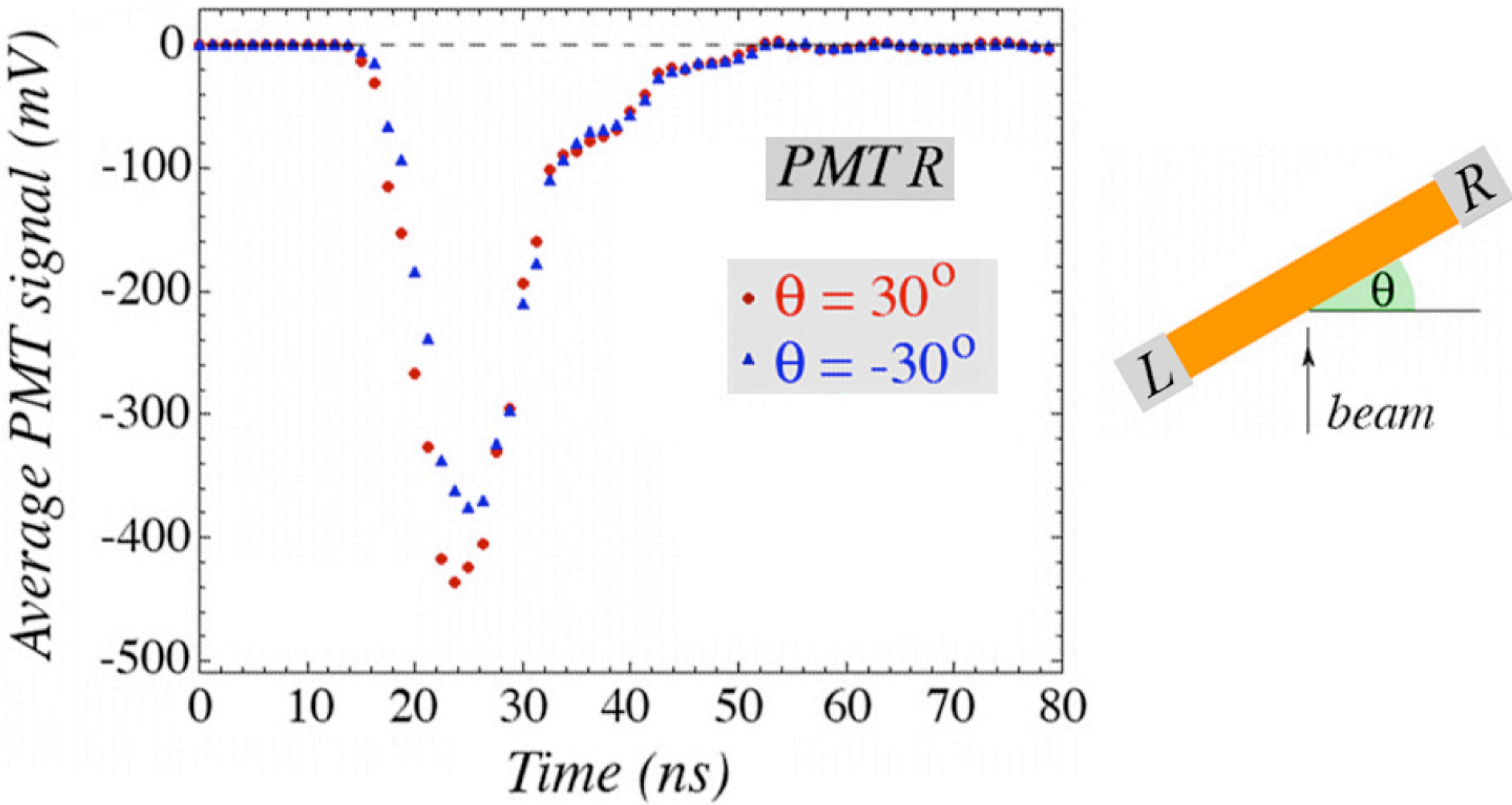

Fig. 2. Average time structure of the signals measured with the PMT reading out one end (R) of a $PbWO_4$ crystal traversed by 10 GeV electrons, for two different orientations of the crystal. At $\theta = 30°$, Čerenkov light contributes to the signals, at $\theta = -30°$, it does not.

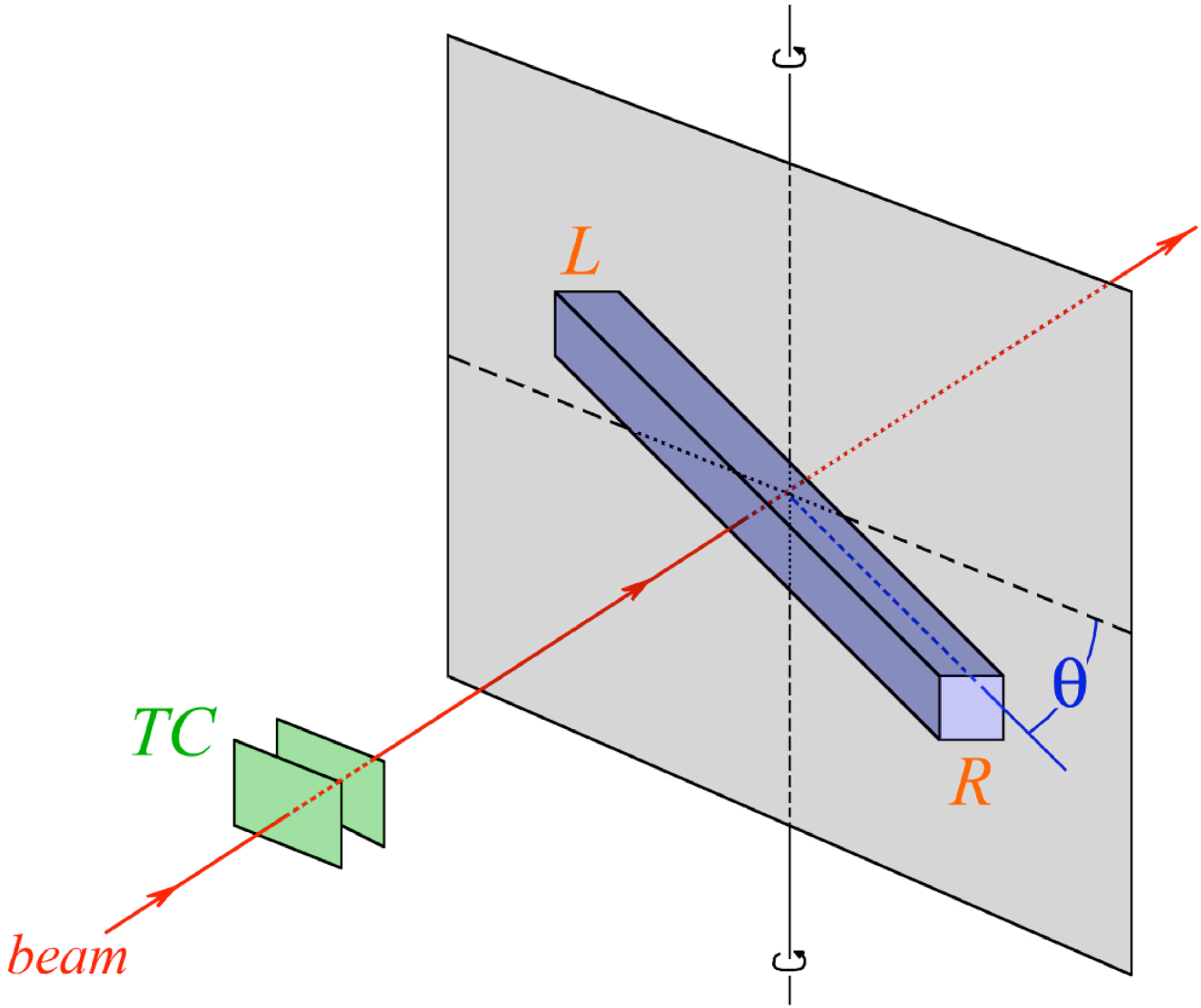

Fig. 3. Experimental setup in which the beam tests were performed.

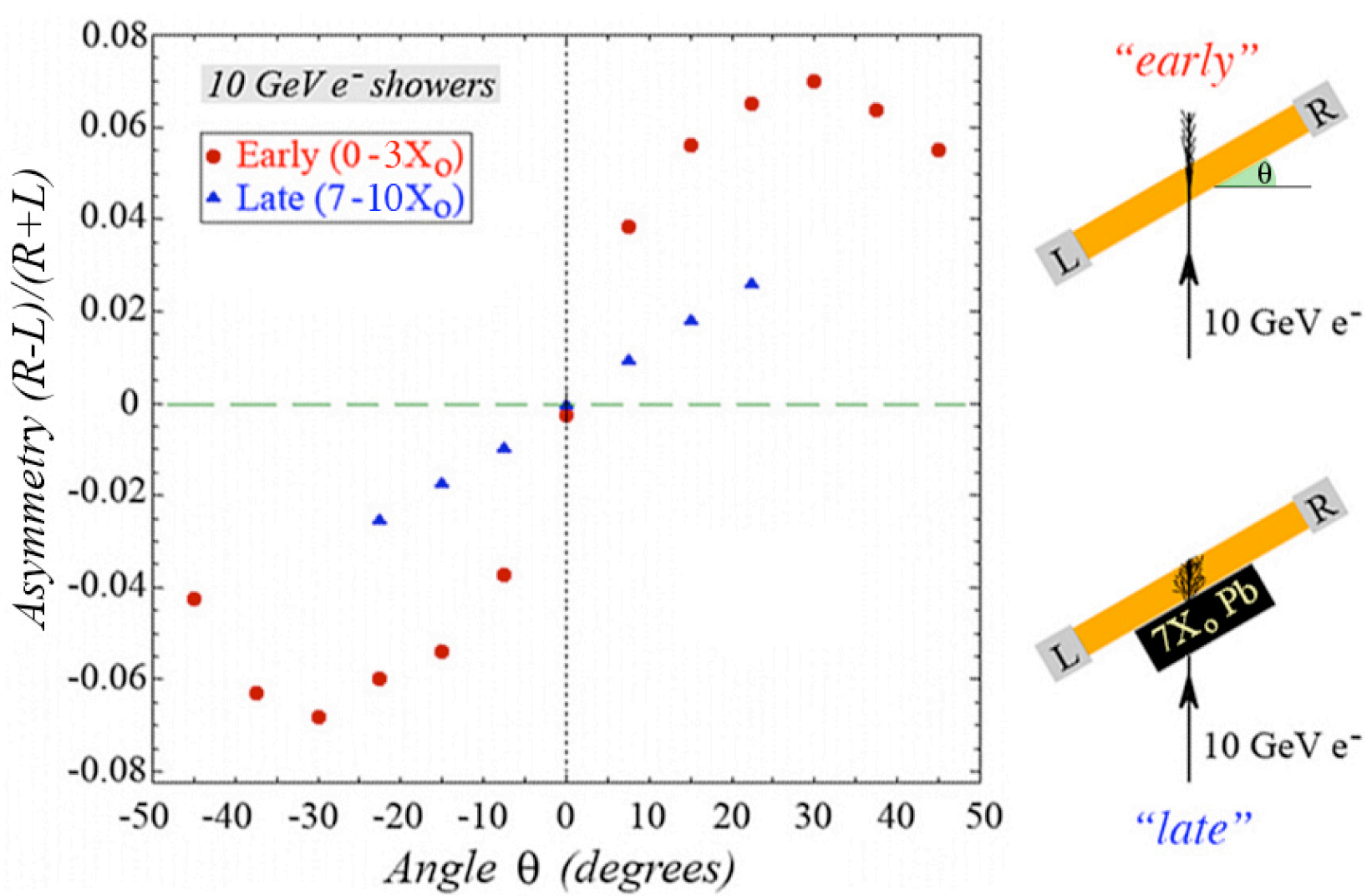

Fig. 4. Left-right response asymmetry measured for 10 GeV electrons showering in a $2.5X_0$ thick $PbWO_4$ crystal, as a function of the orientation of the crystal (the angle θ). Results are shown for the early and the late components of the showers. The latter measurements were obtained by placing 4 cm of lead upstream of the crystal.

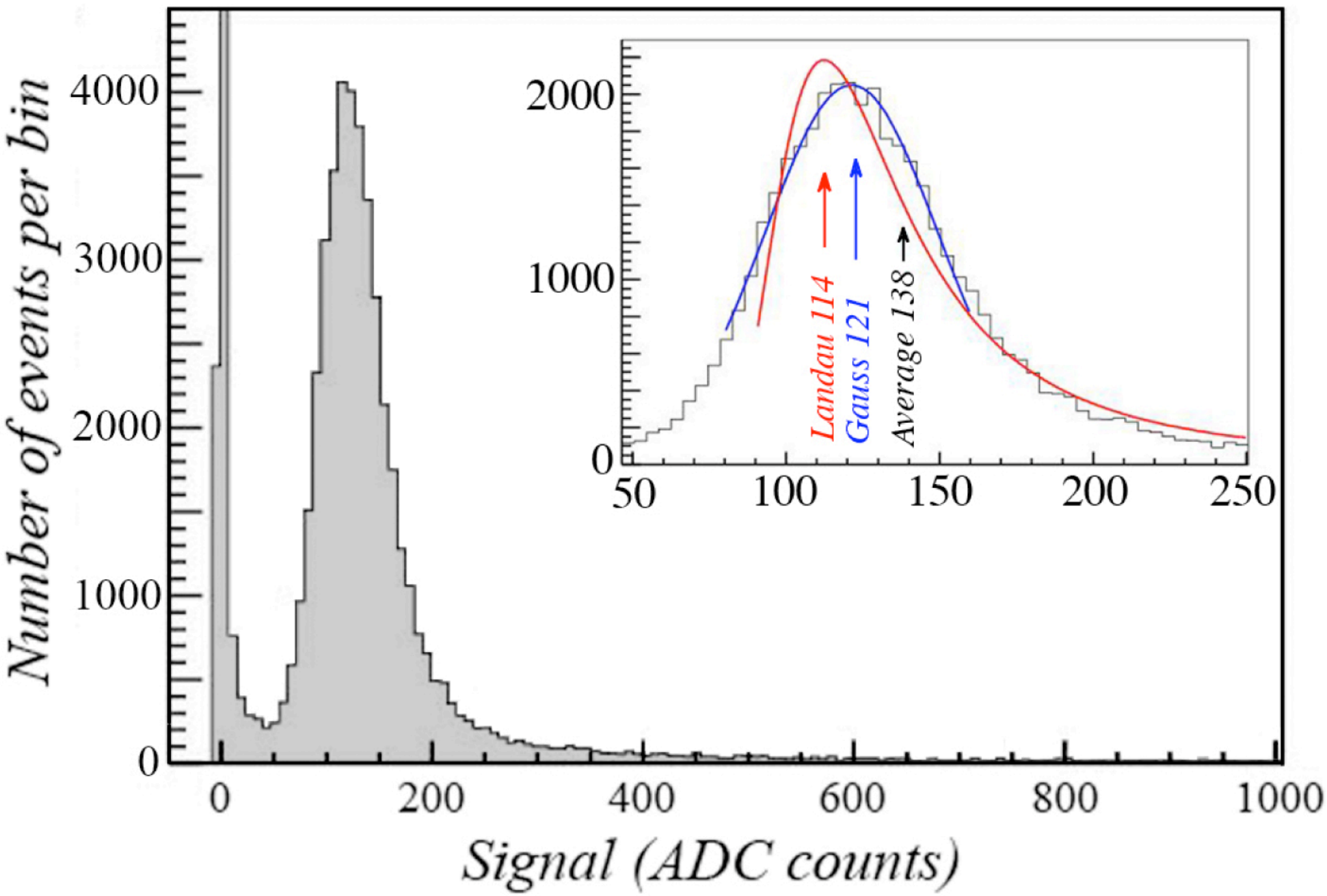

Fig. 5. Signal distribution for 150 GeV μ^+ traversing the $2.5X_0$ thick $PbWO_4$ crystal perpendicularly ($\theta = 0$). The insert shows the results of fits to the most probable signal region. See text for details.

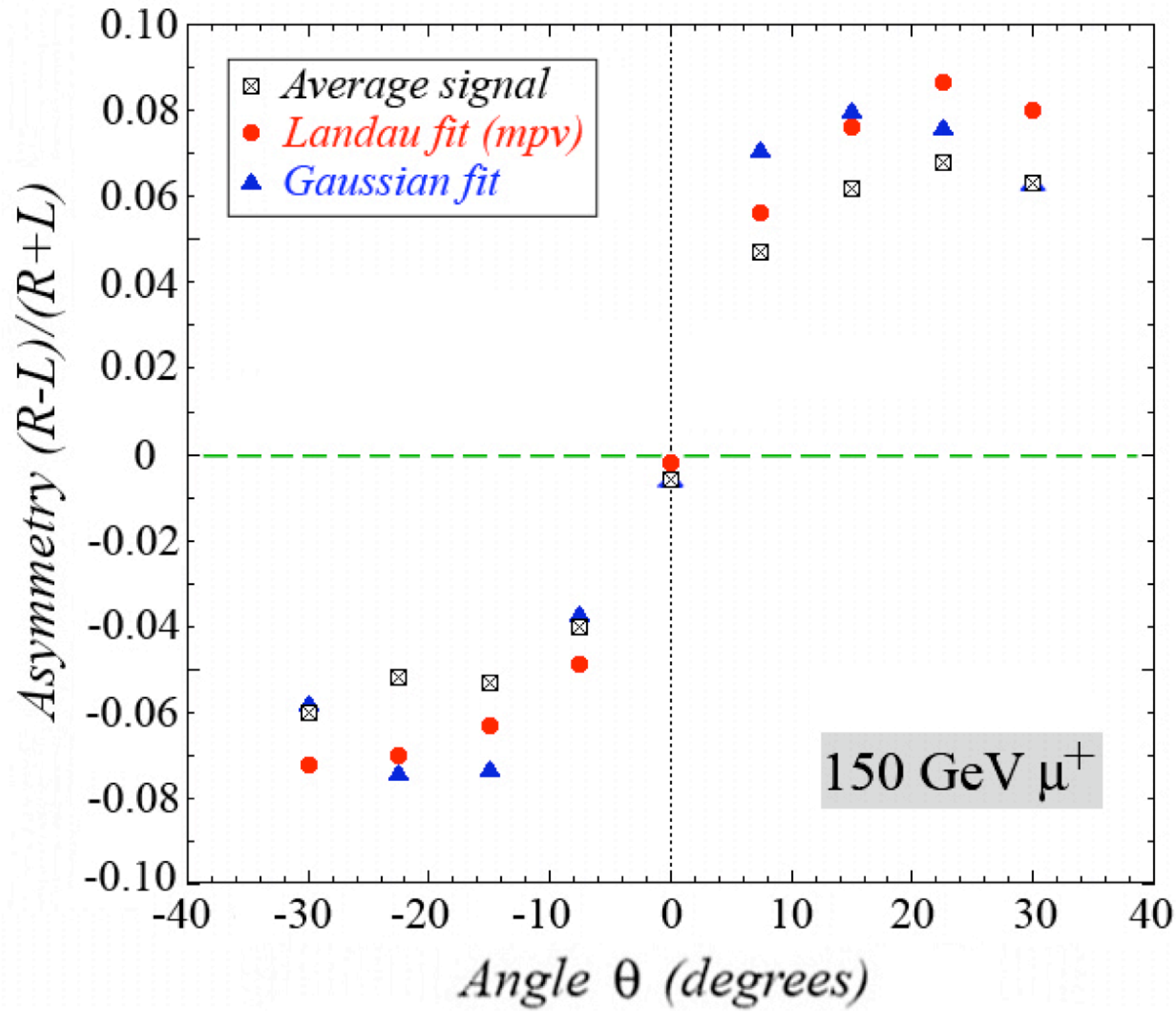

Fig. 6. Left-right response asymmetry measured for 150 GeV muons traversing a $2.5X_0$ thick $PbWO_4$ crystal, as a function of the orientation of the crystal (the angle θ). The asymmetry concerns the *most probable* signal value derived from a Landau fit (the triangles) or a Gaussian fit (the closed circles), or the average signal value (the open squares).

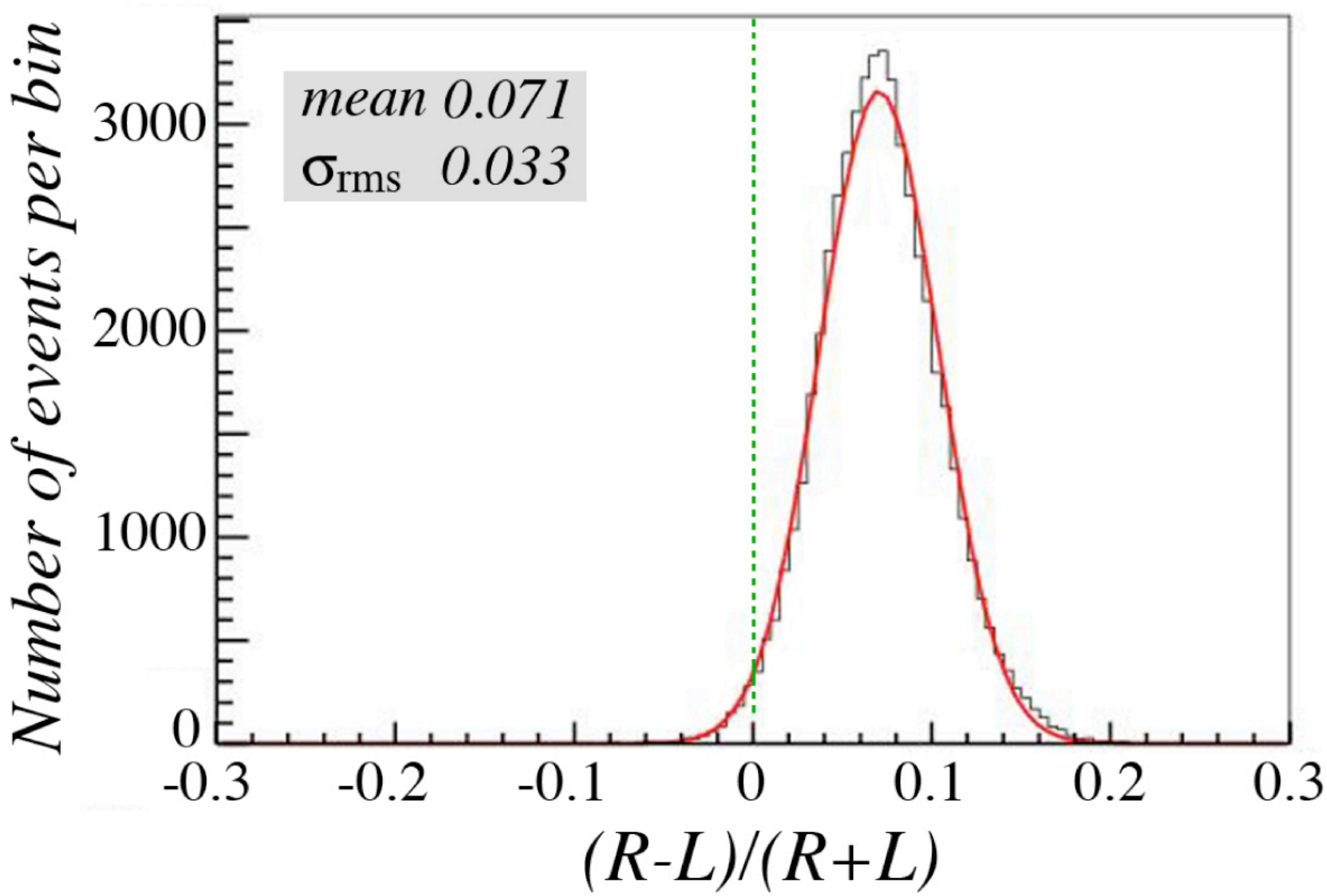

Fig. 7. Distribution of the left-right response asymmetry, measured for 10 GeV electrons traversing the crystal at $\theta = 30^{\circ}$, together with the results of a Gaussian fit.

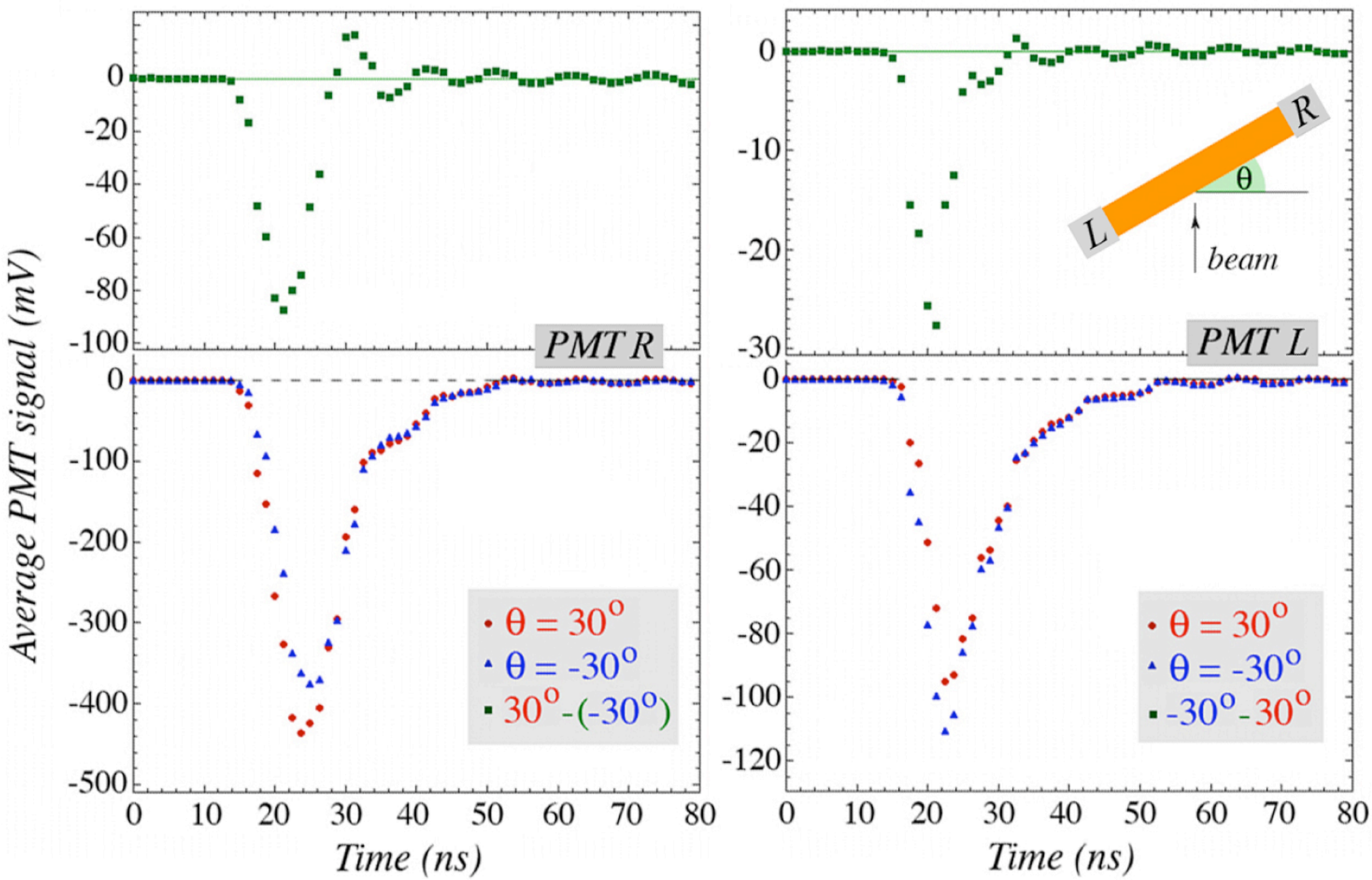

Fig. 8. Average time structures of the signals measured in the left (L) and right (R) photomultiplier tubes that detect the light produced by 10 GeV electrons in a $2.2X_0$ thick $PbWO_4$ crystal. The bottom plots show these signals for angles $\theta = \pm 30^\circ$, for PMTs R and L, respectively. The top plots show the difference between the two orientations, *i.e.,* the PMT's response function to a prompt Čerenkov component in the signal.

Dual-Readout Calorimetry with Lead Tungstate Crystals

N. Akchurin[a], L. Berntzon[a], A. Cardini[b], G. Ciapetti[c], R. Ferrari[d], S. Franchino[d], G. Gaudio[d], J. Hauptman[e], H. Kim[a], F. Lacava[c], L. La Rotonda[f], M. Livan[d], E. Meoni[f], H. Paar[g], A. Penzo[h], D. Pinci[c], A. Policicchio[f], S. Popescu[i], G. Susinno[f], Y. Roh[a], W. Vandelli[d] and R. Wigmans[a, 1]

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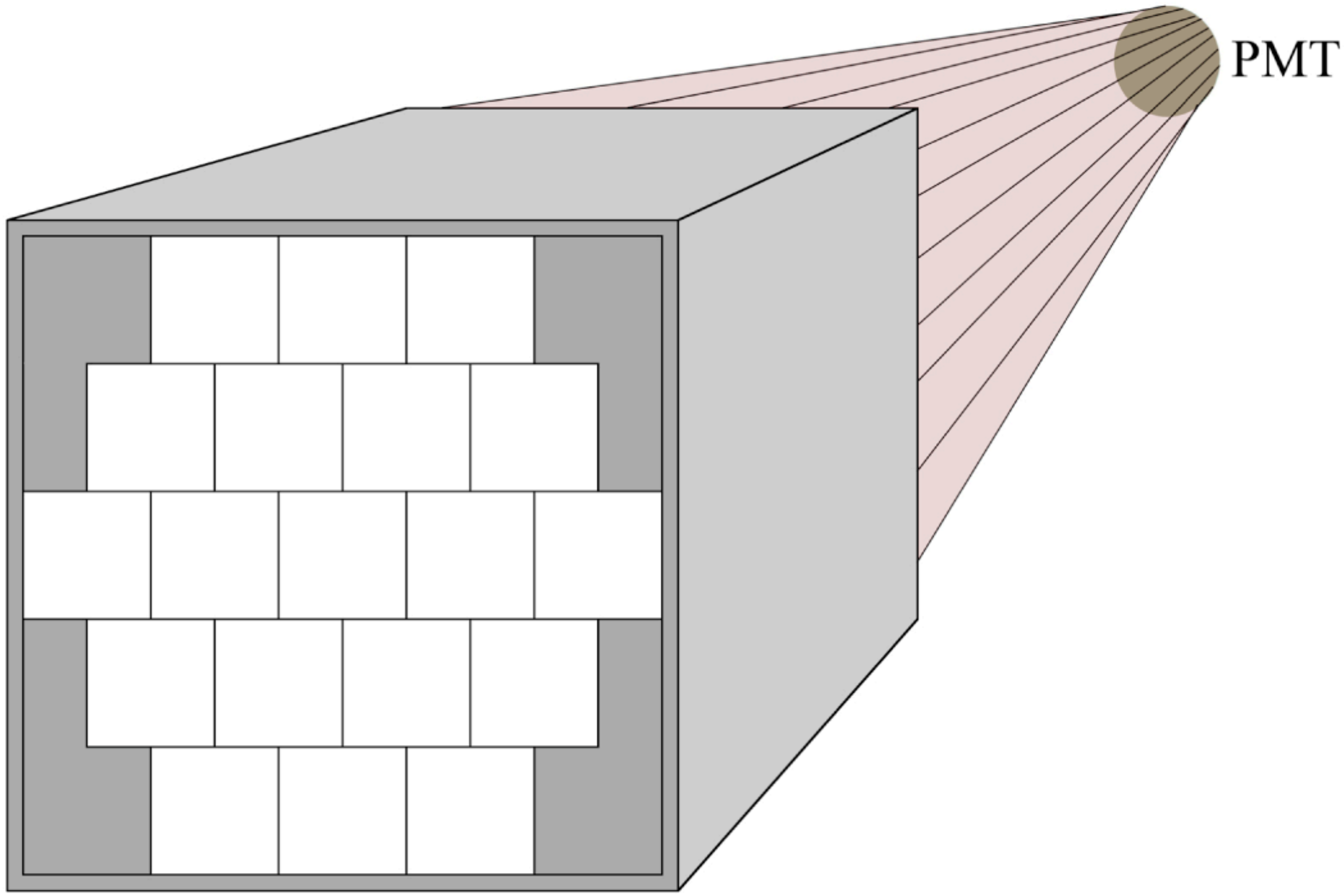

Fig. 1. The lead tungstate electromagnetic section of the calorimeter system.

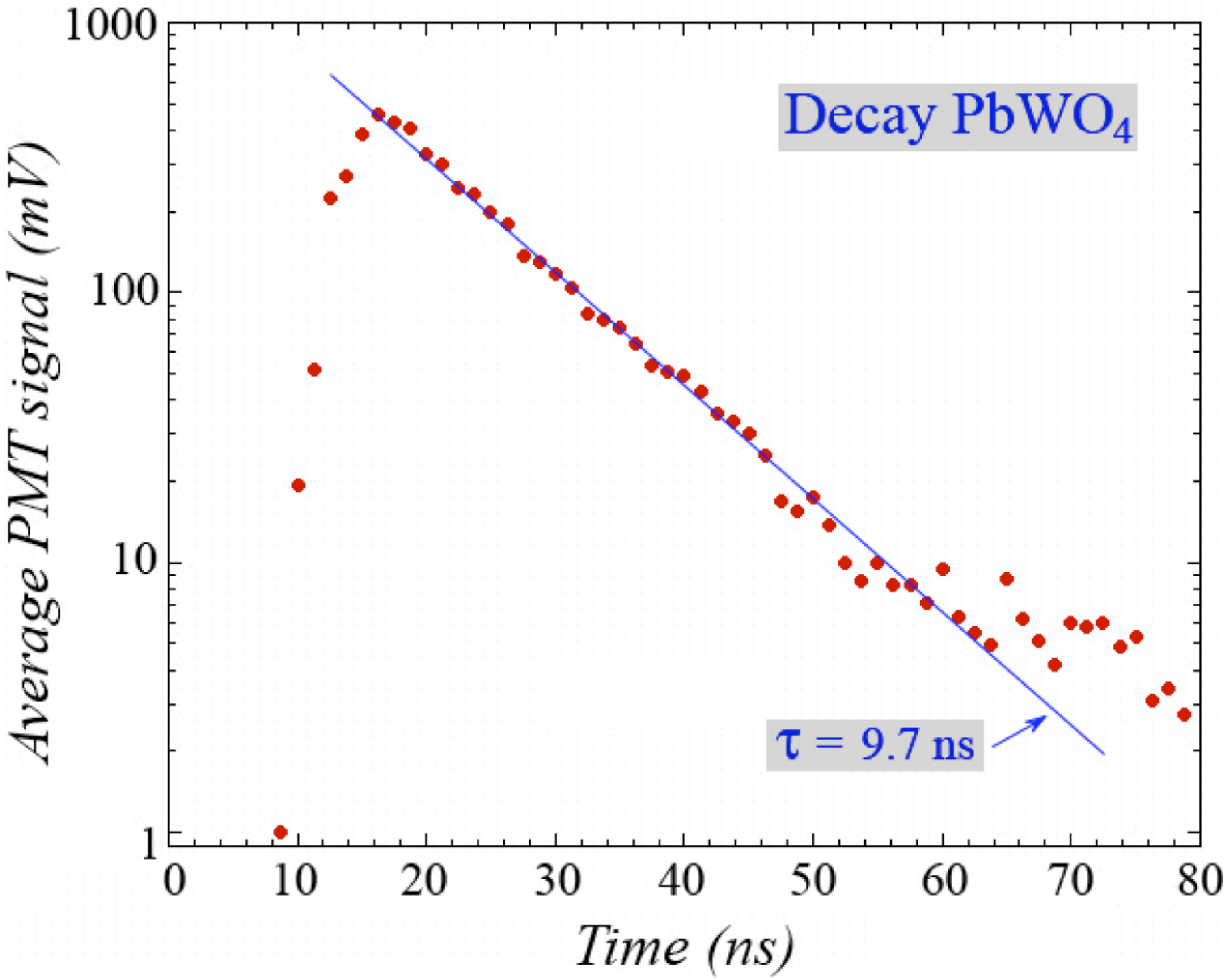

Fig. 2. Average time structure of the signals from 50 GeV electron showers in the lead tungstate crystals.

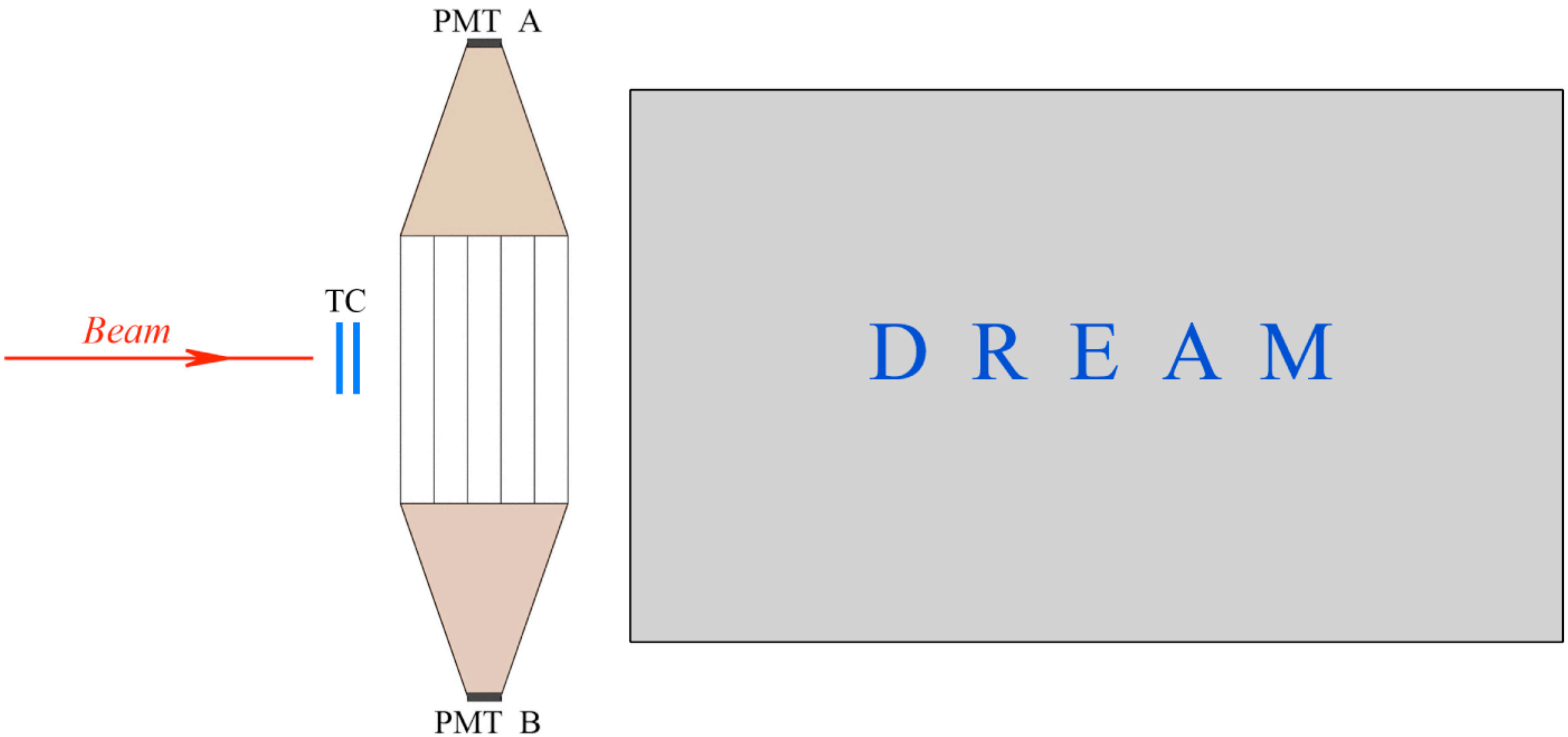

Fig. 3. The detector setup used for calibrating the ECAL channels (PMT's A and B).

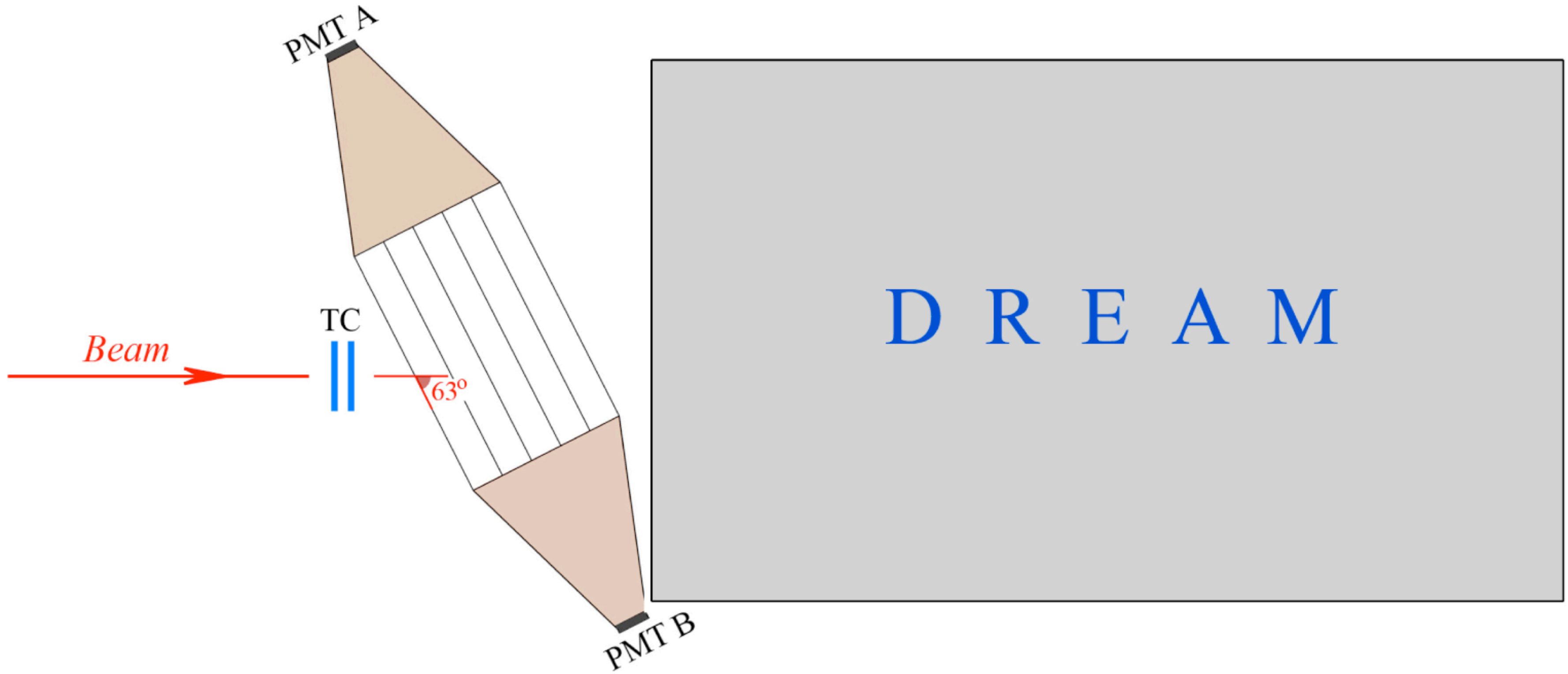

Fig. 4. The detector setup used for studying the Čerenkov contributions to the ECAL signals.

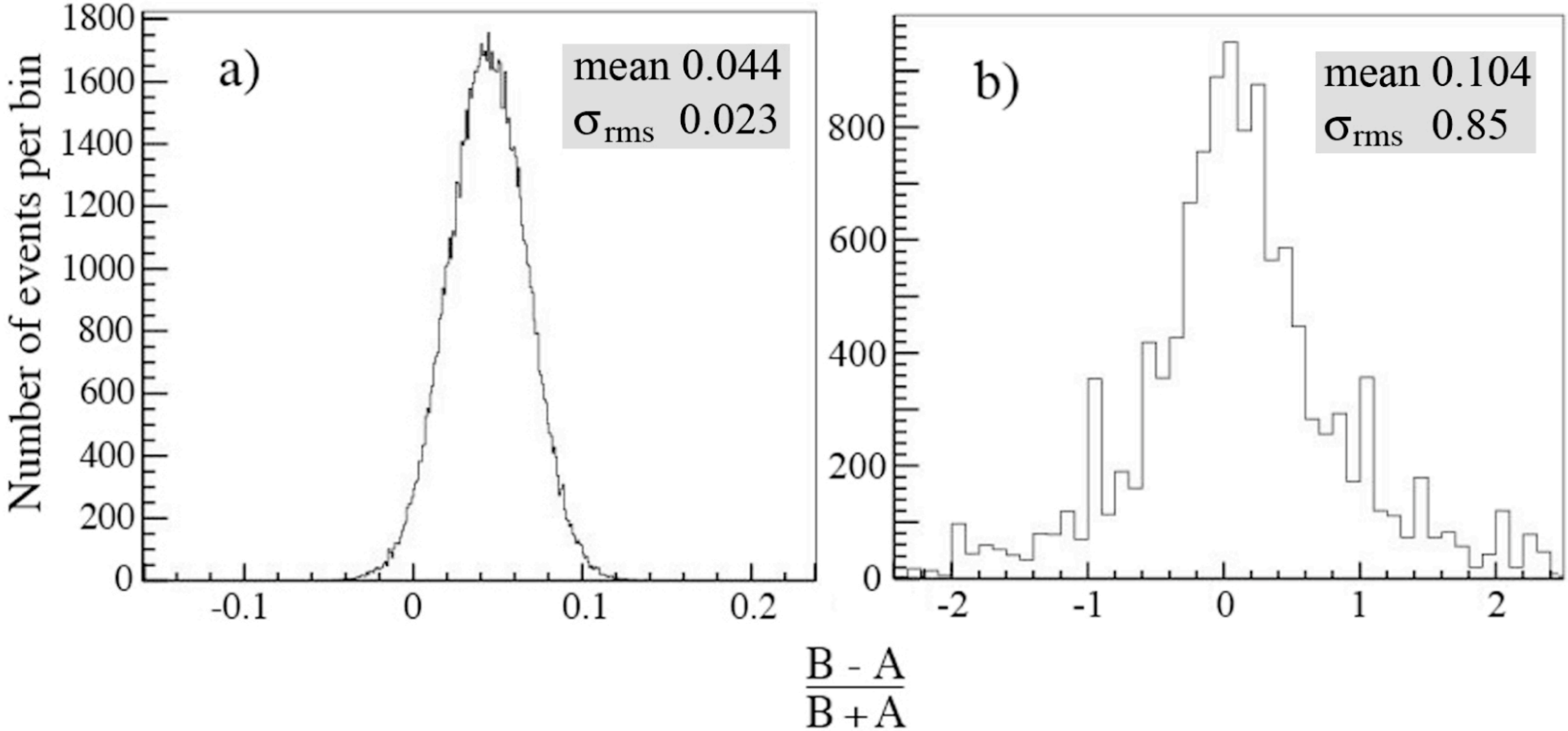

Fig. 5. Distribution of the Forward/Backward asymmetry for 50 GeV electron signals (a) and 50 GeV μ^+ signals (b) in the lead tungstate ECAL.

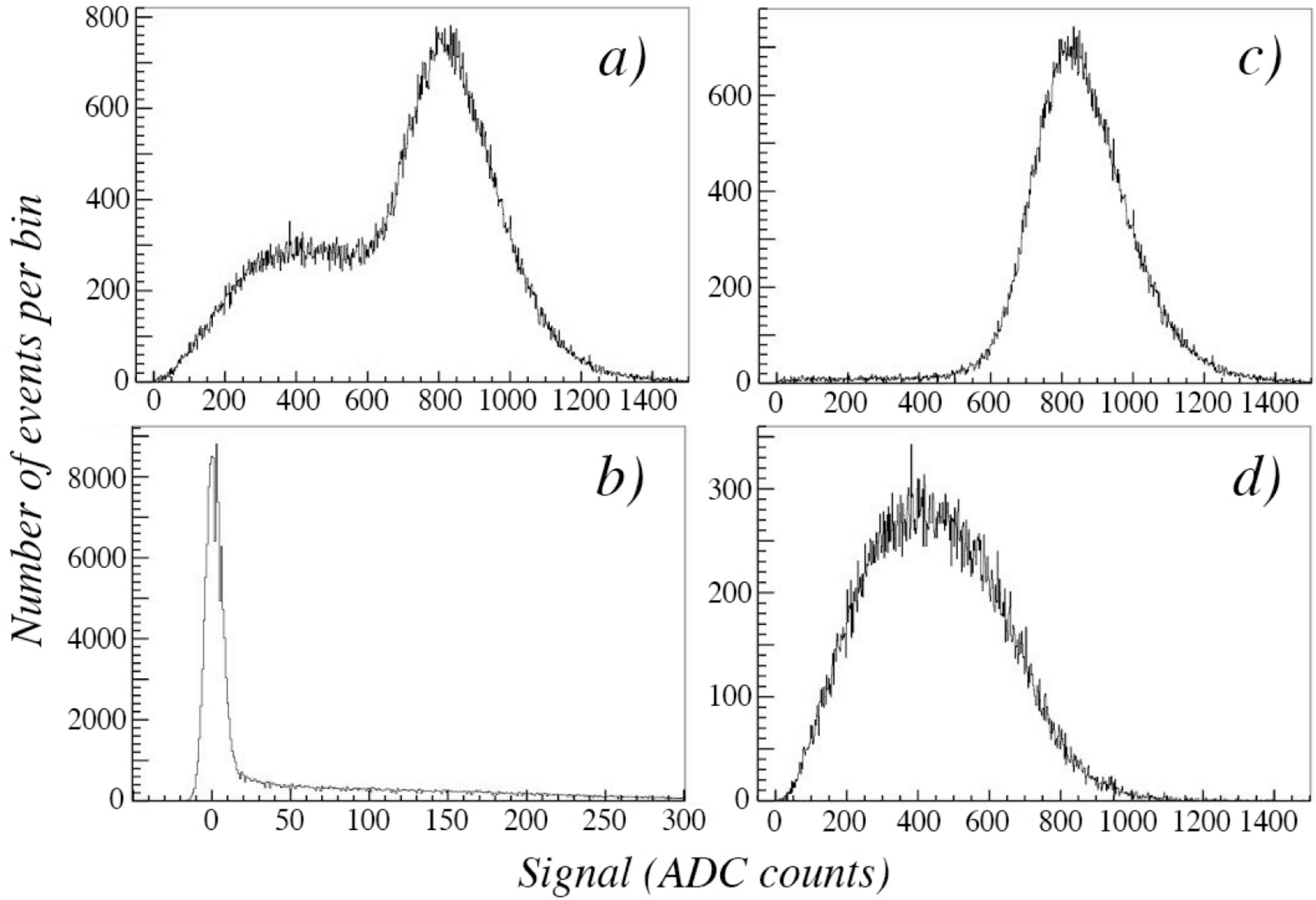

Fig. 6. Signal distributions for 50 GeV π^+ in the ECAL/HCAL system. Shown are the total signal distributions in the HCAL (a) and in the ECAL (b), as well as the signal distributions in HCAL for pions that gave a mip signal in the ECAL (c) and for pions that produced a larger signal in the ECAL (d). The HCAL signals concern the scintillating fibers only.

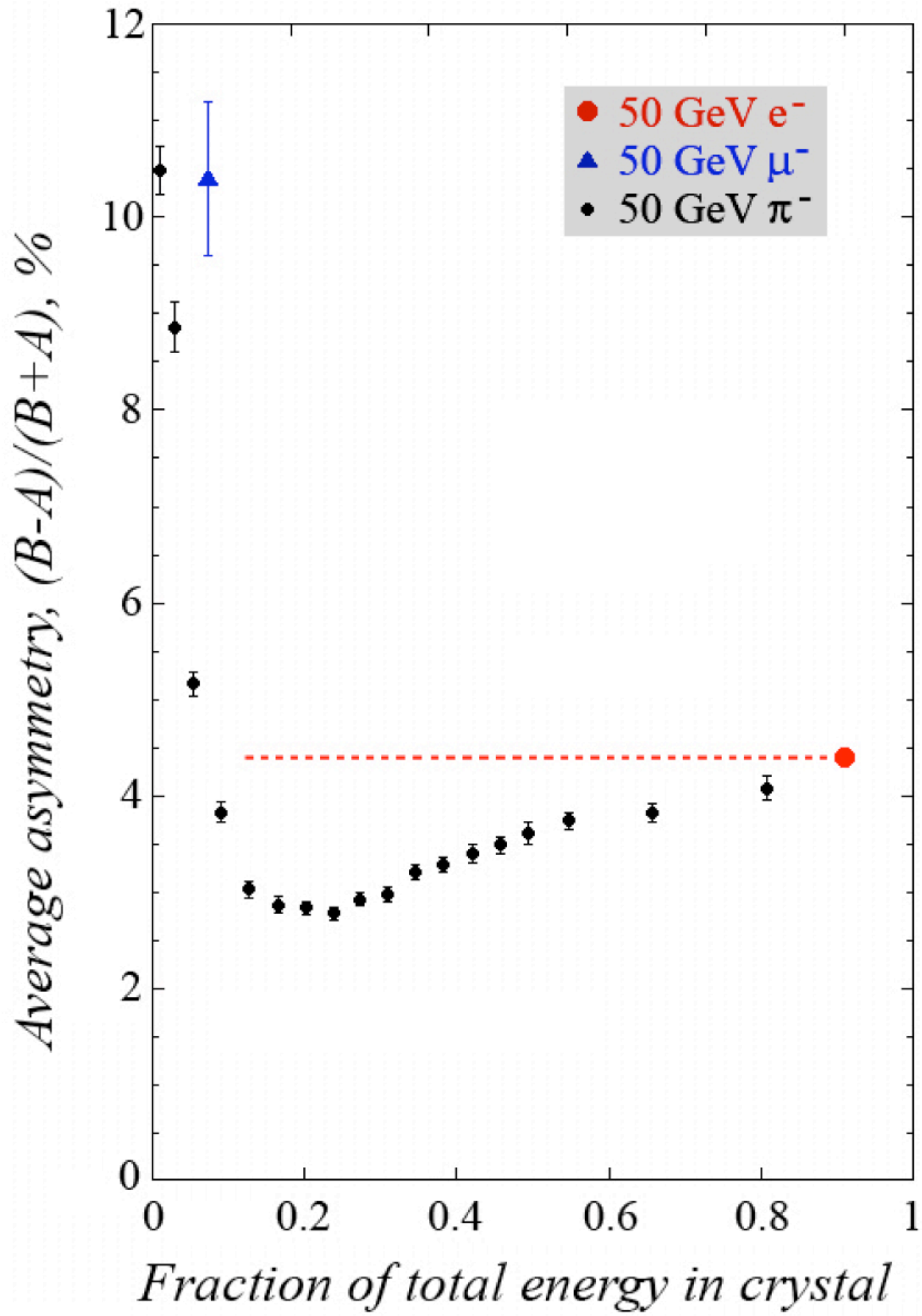

Fig. 7. Average Forward/Backward asymmetry for 50 GeV pion signals in the lead tungstate ECAL, as a function of the energy fraction deposited by the beam particles in this detector.

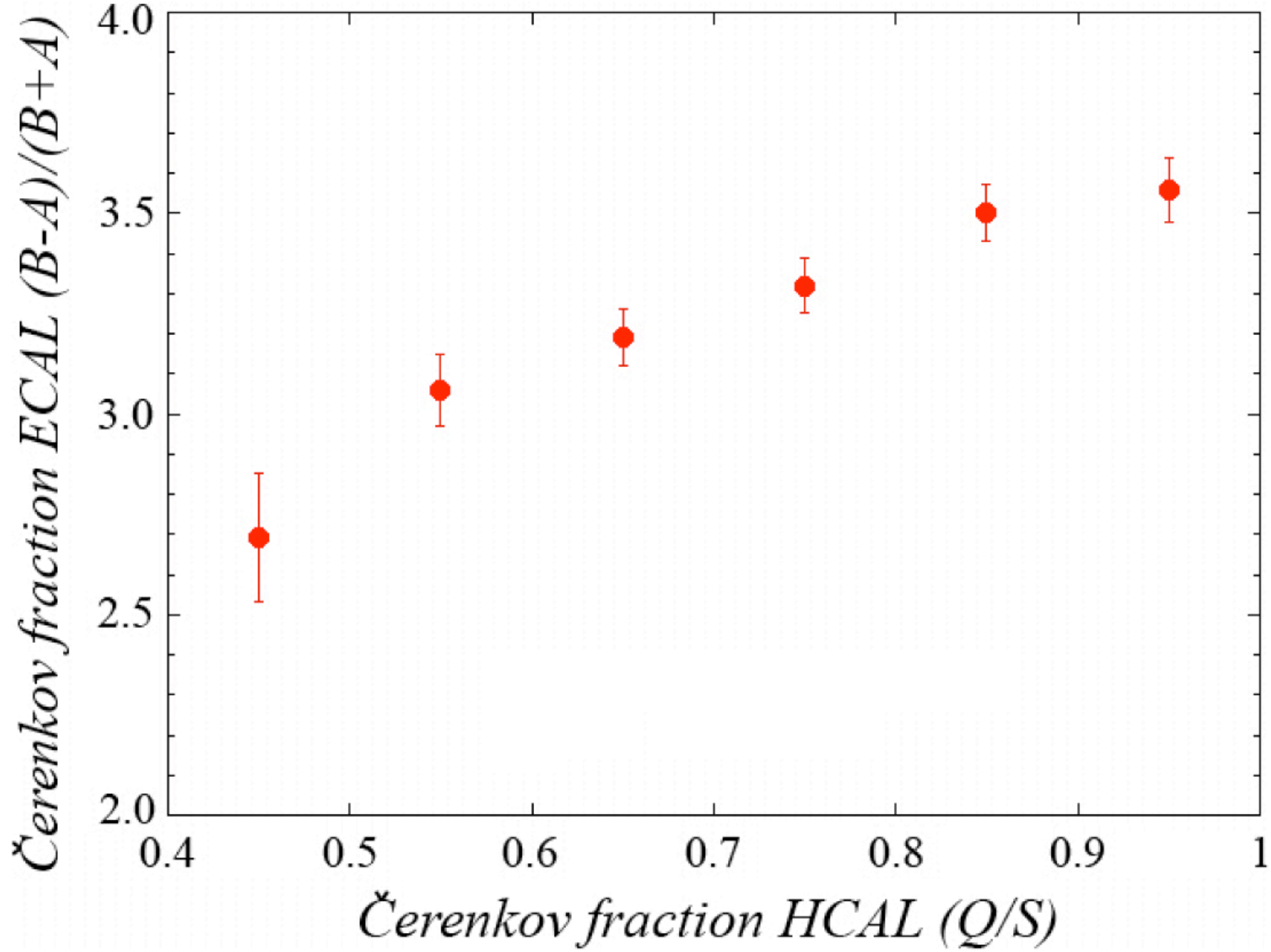

Fig. 8. Correlation between the average fractions of Čerenkov light measured in the ECAL and HCAL signals, for 50 GeV pions starting their showers in the ECAL, and depositing at least 10 GeV in the crystals.

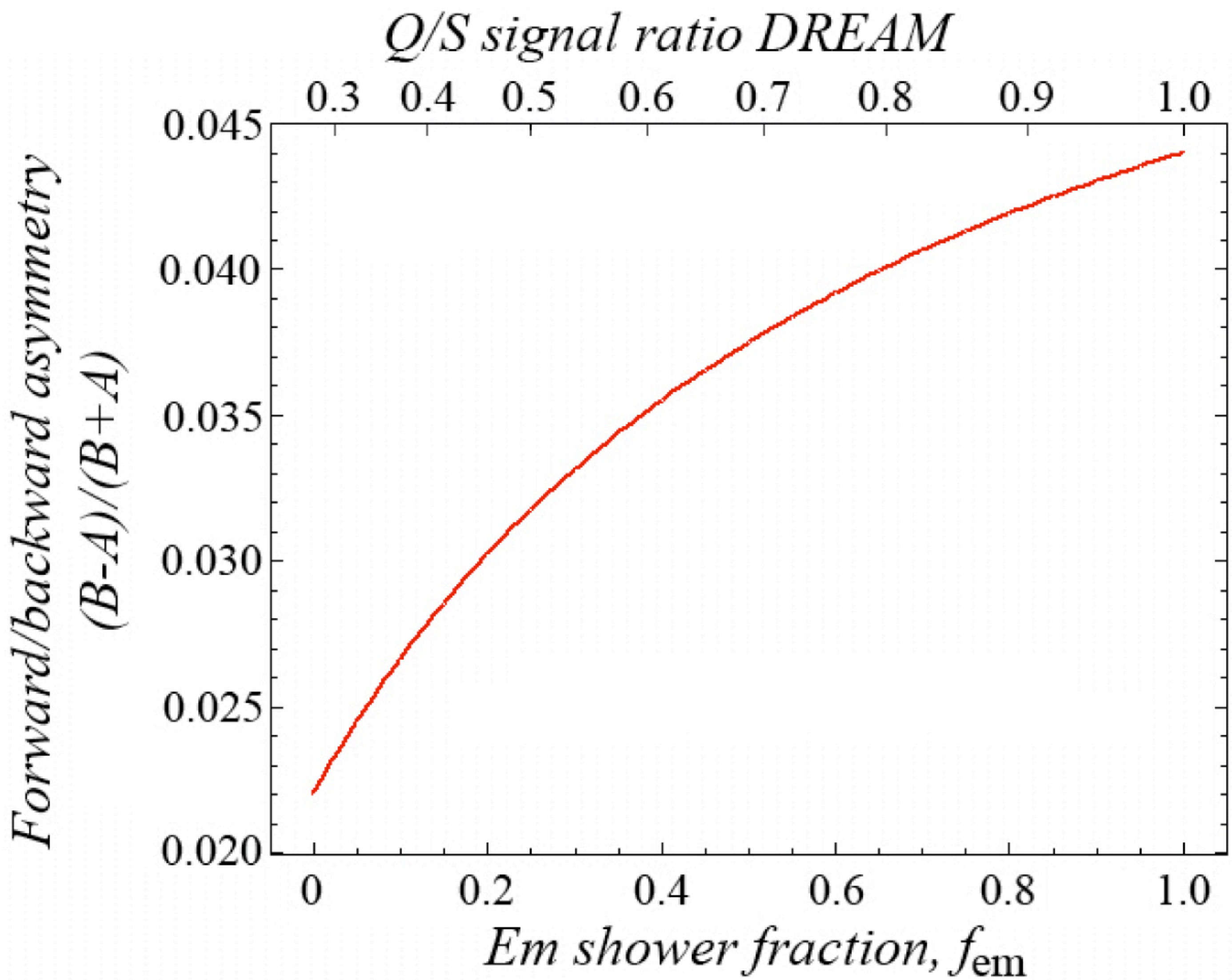

Fig. 9. Relationship between measured quantities and the em shower fraction. The measured quantities concern the Q/S signal ratio measured in the DREAM hadronic section (top horizontal axis) and the forward/backward signal asymmetry measured in the crystal ECAL (vertical axis).

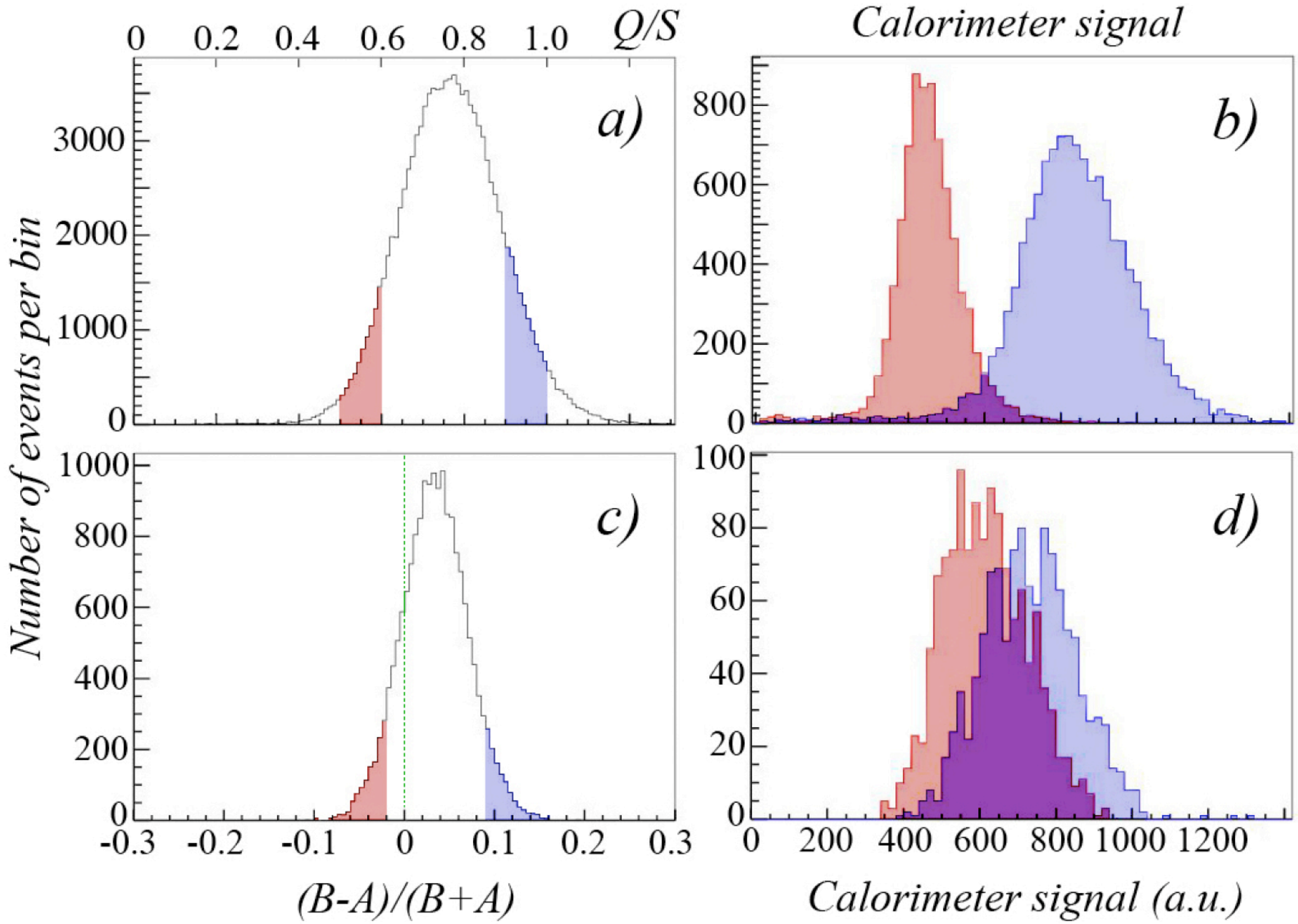

Fig. 10. Total calorimeter signal distribution for 50 GeV π^+ (*right*), for different choices of variables that select the em shower content (*left*). Diagram b shows the total quartz signal for two different Q/S bins, indicated in diagram a, for pions that penetrated the crystal ECAL. In diagram d, the distribution of the sum of the DREAM scintillator signals and crystal signal B is displayed, for two different choices of the ECAL asymmetry parameter, shown in diagram c. The latter distributions concern events in which at least 10 GeV was deposited in the ECAL.

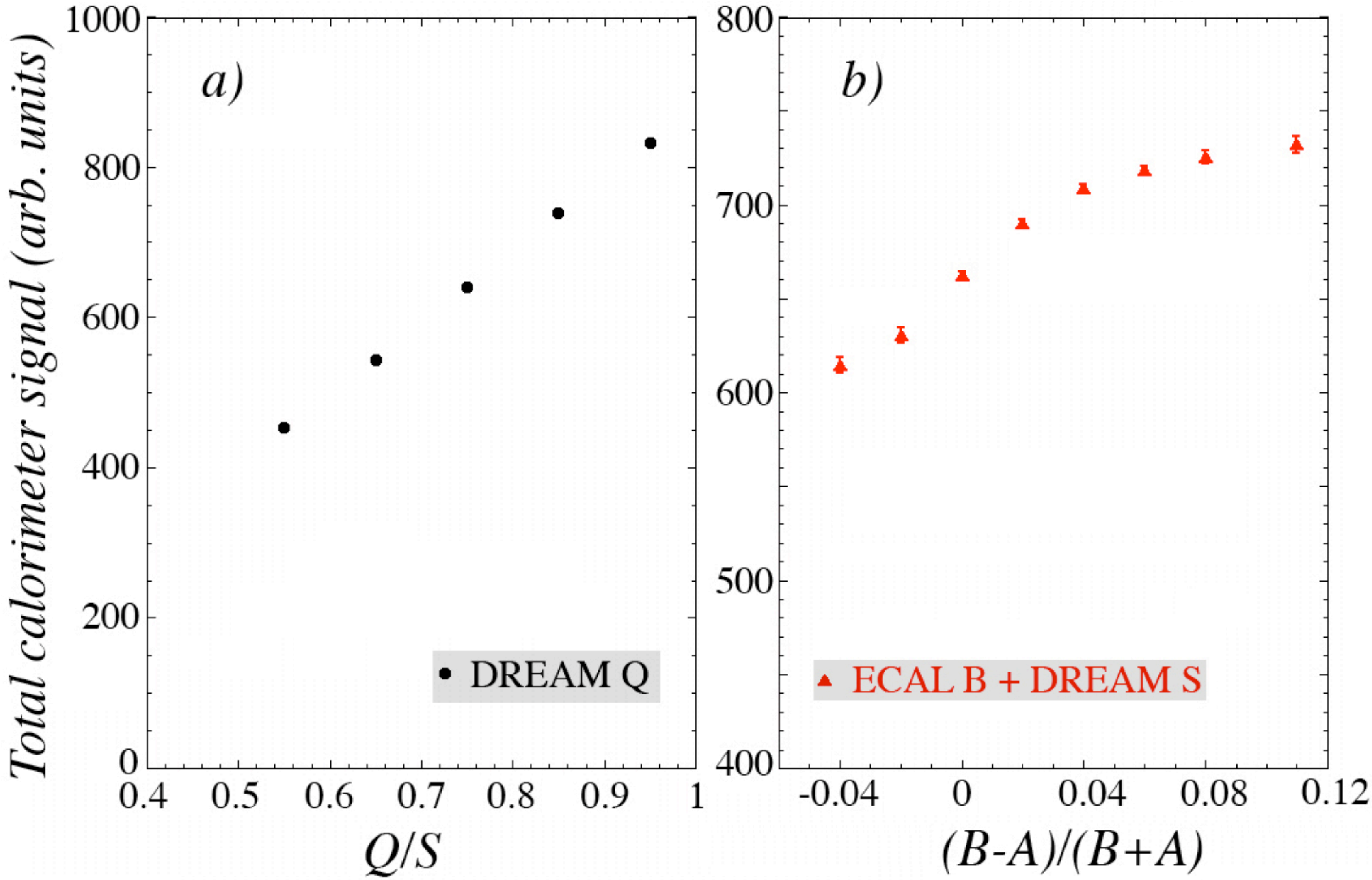

Fig. 11. Average total calorimeter signal for 50 GeV π^+, as a function of variables that select the em shower content. Diagram a shows the total quartz signal as a function of the Q/S signal ratio, for pions that penetrated the crystal ECAL. In diagram b, the sum of the DREAM scintillator signals and the downstream crystal signal (B) is displayed, for events in which at least 10 GeV was deposited in the ECAL.

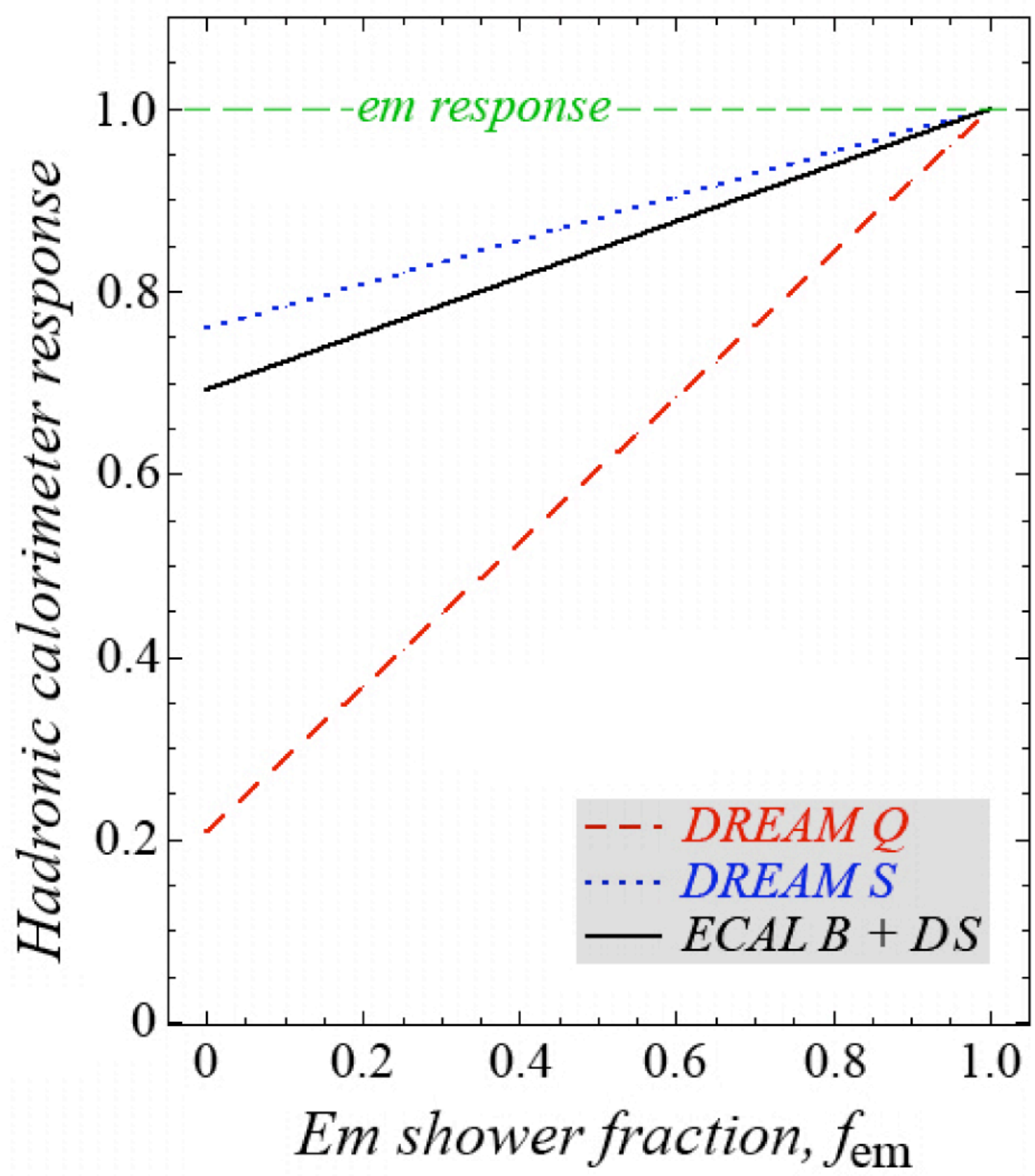

Fig. 12. The hadronic calorimeter response as a function of $f_{\rm em}$ for different signals and signal combinations, which reflect the degree of non-compensation. See text for details.

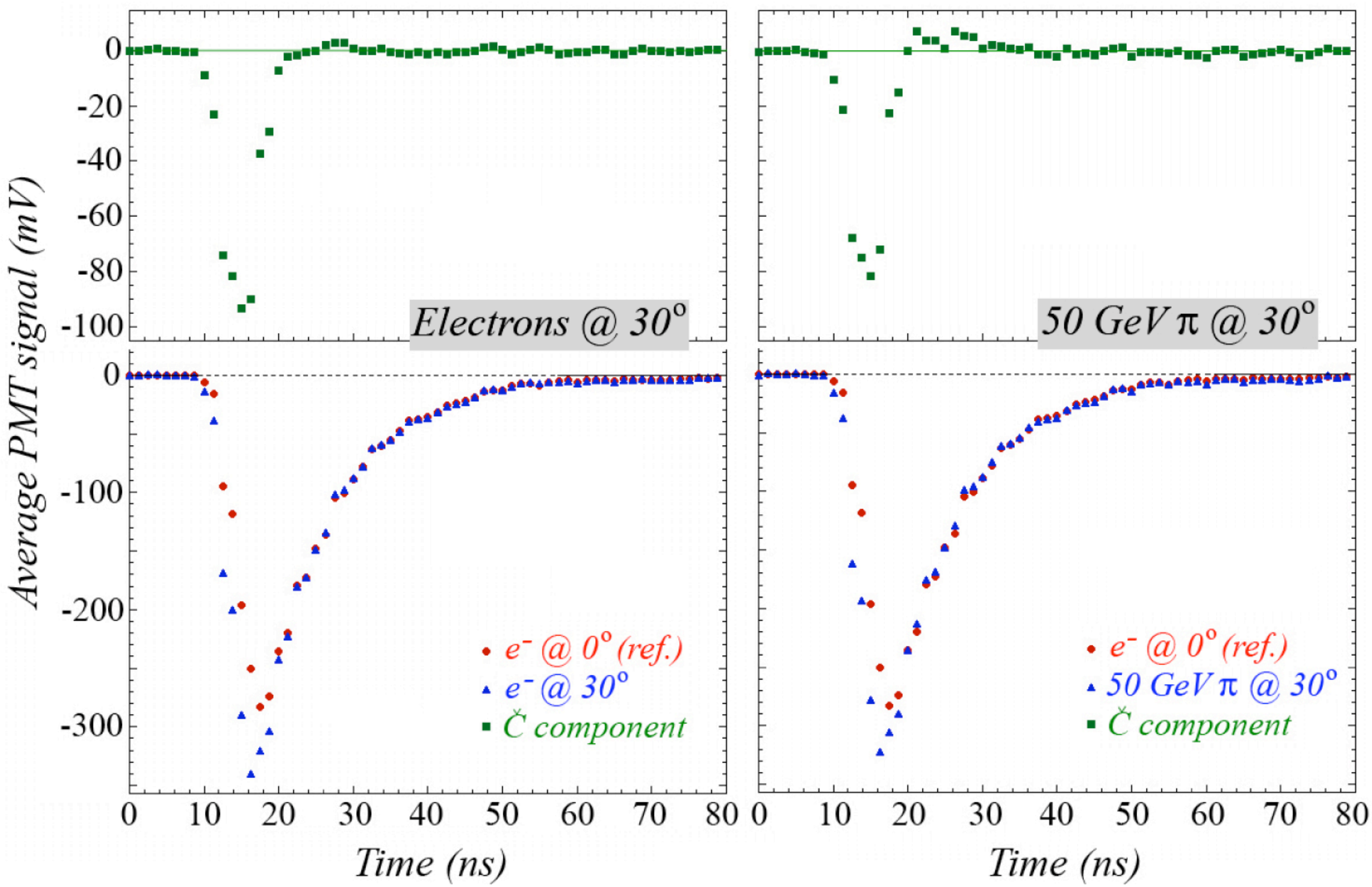

Fig. 13. Time structure of the signals from 50 GeV electron showers in the lead tungstate crystals, measured with detectors located at 90° and 60° with respect to the beam line, for 50 GeV electron (a) and pion (b) showers. The top graphs show the difference between the time structures recorded at the two different angles.

Measurement of the Contribution of Neutrons to Hadron Calorimeter Signals

N. Akchurin[a], L. Berntzon[a], A. Cardini[b], G. Ciapetti[c], R. Ferrari[d], S. Franchino[d], G. Gaudio[d], J. Hauptman[e], H. Kim[a], F. Lacava[c], L. La Rotonda[f], M. Livan[d], E. Meoni[f], H. Paar[g], A. Penzo[h], D. Pinci[c], A. Policicchio[f], S. Popescu[i], G. Susinno[f], Y. Roh[a], W. Vandelli[d] and R. Wigmans[a, 1]

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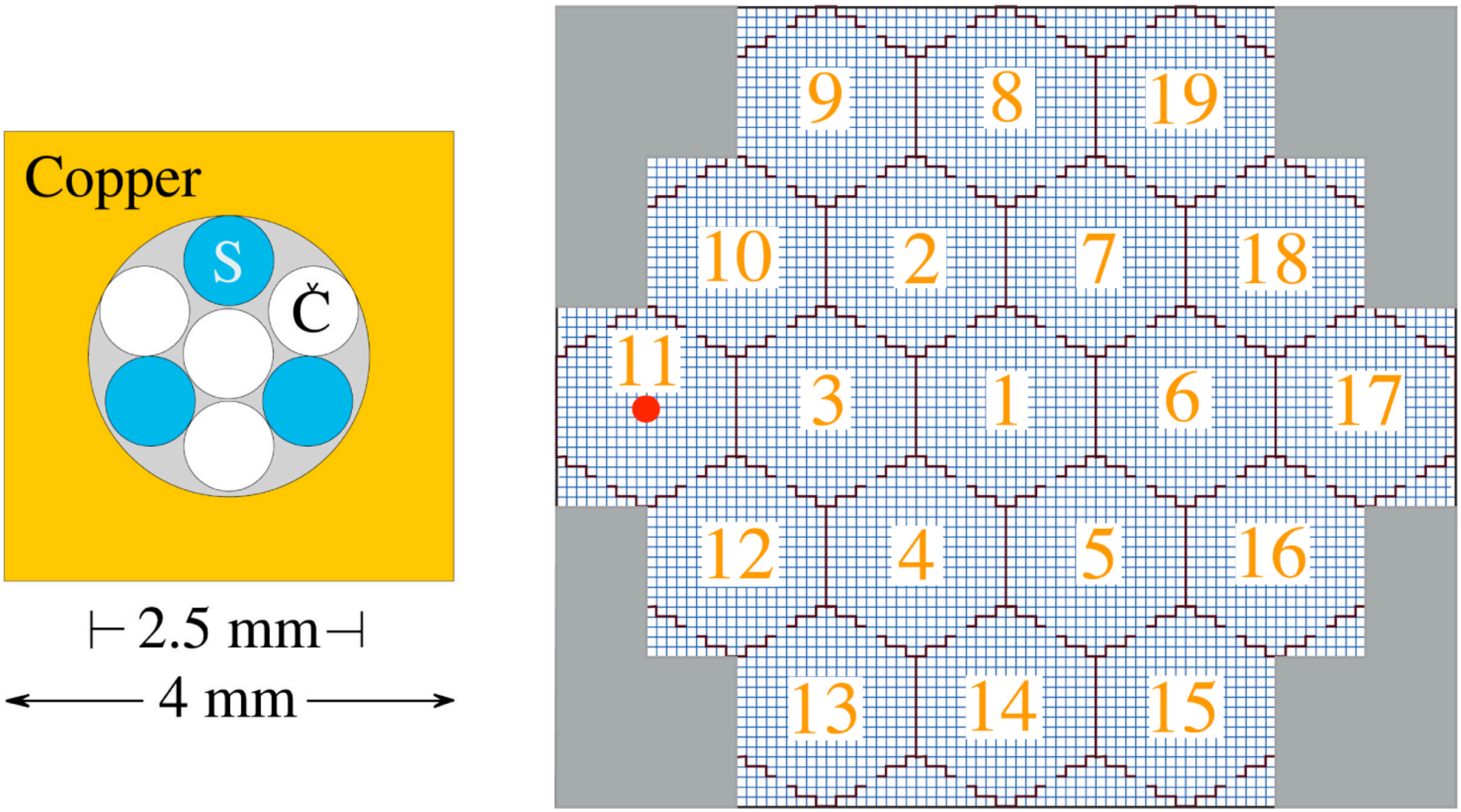

Fig. 1. The basic building block of the DREAM calorimeter is a 4 × 4 mm^2 extruded hollow copper rod of 2 meters length, with a 2.5 mm diameter central hole. Seven optical fibers (4 undoped and 3 scintillating fibers) with a diameter of 0.8 mm each are inserted in this hole, as shown in the left diagram. The right diagram shows a cross section of the calorimeter, which consists of 19 hexagonal towers. The impact point of the beam (center of tower #11) is indicated as well.

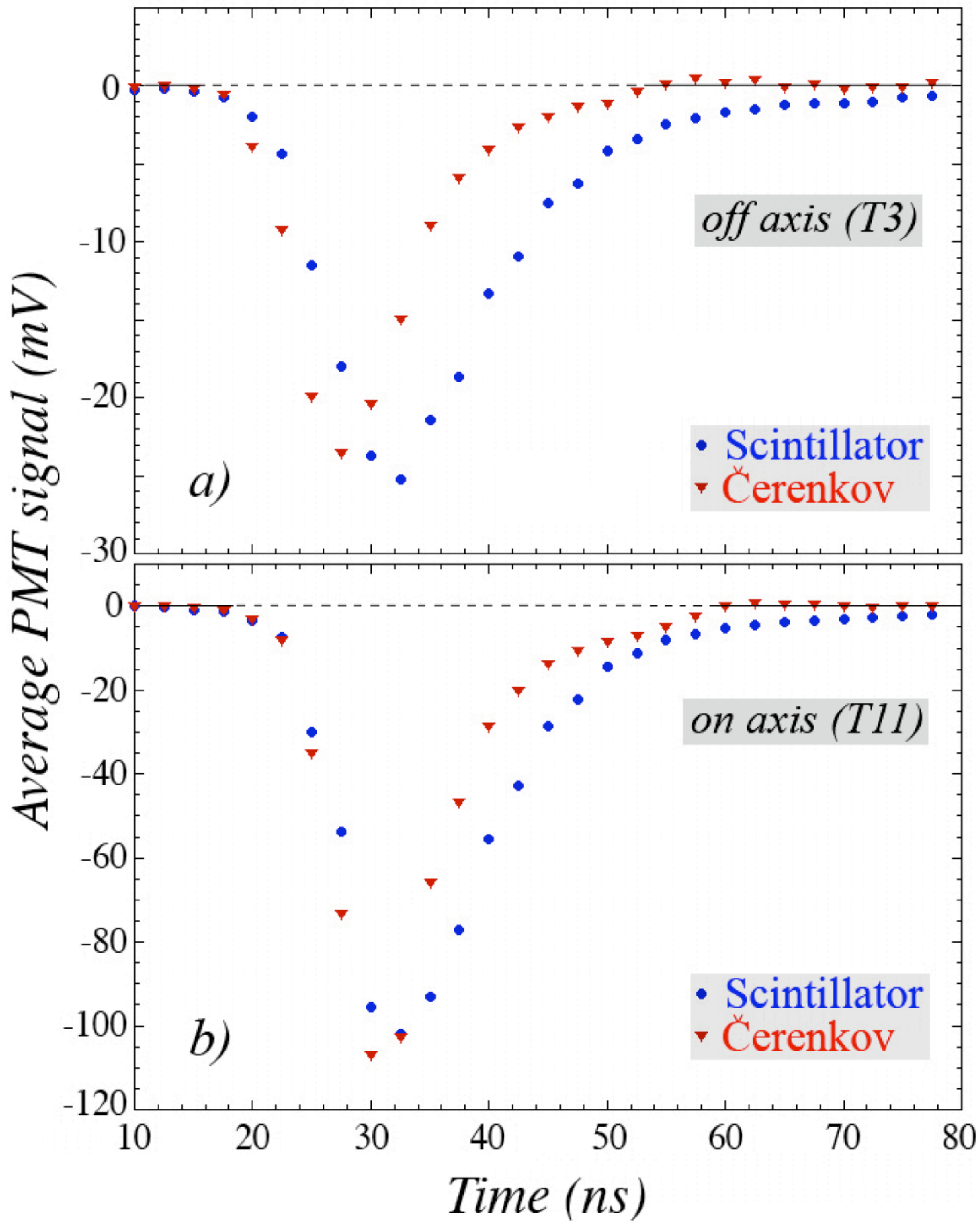

Fig. 2. Average time structure of the scintillator and Čerenkov signals measured for 100 GeV π^+ showers in a DREAM tower (#11) located on the shower axis (b) and in a tower (#3) located at a distance of 72 mm off-axis (a).

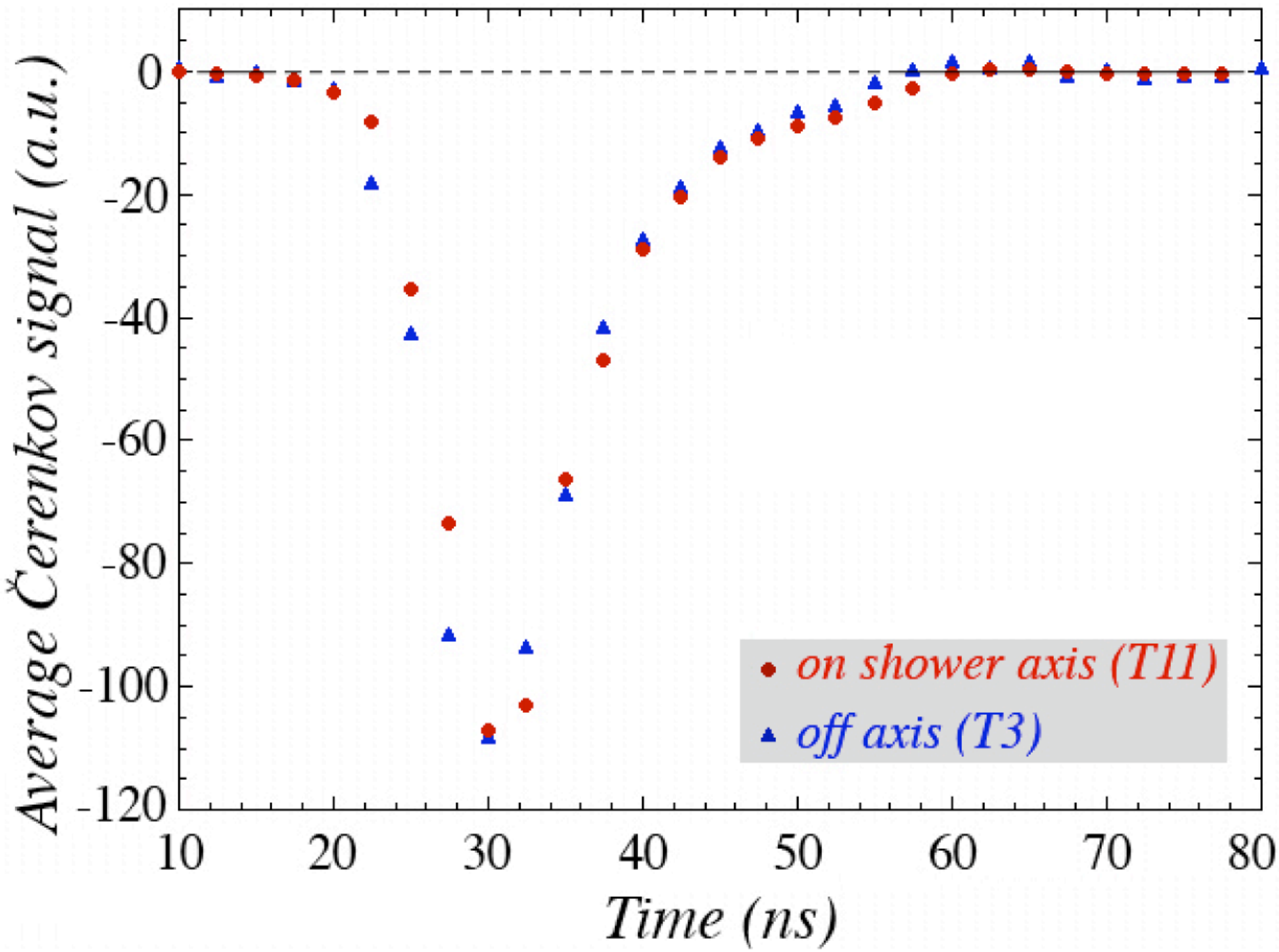

Fig. 3. Comparison of the average time structure of the Čerenkov signals measured for 100 GeV π^+ showers in a DREAM tower (#11) located on the shower axis and in a tower (#3) located at a distance of 72 mm off-axis. The signals have been normalized such that the integral over the pulse shape is the same in both cases.

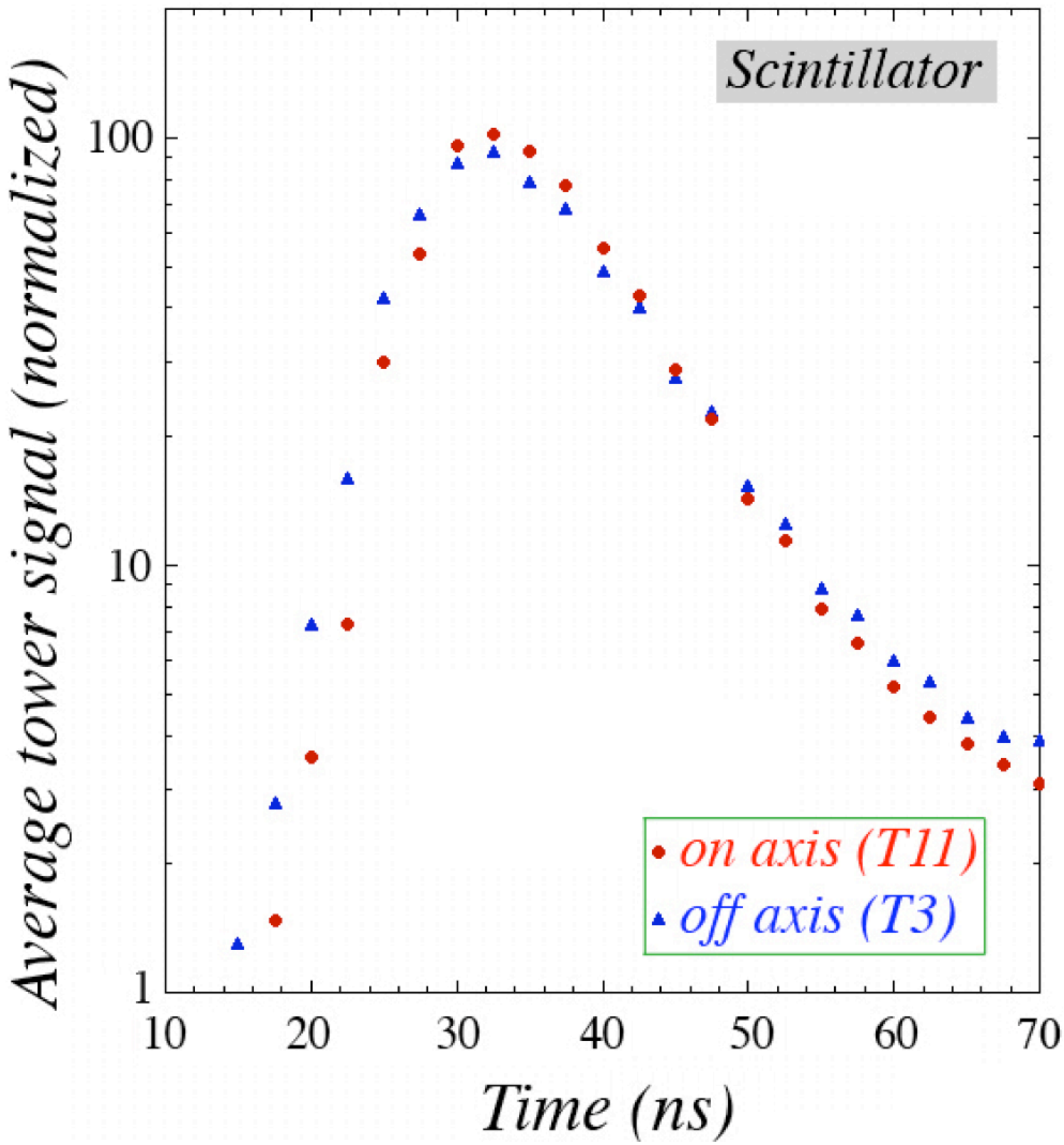

Fig. 4. Comparison of the average time structure of the scintillator signals measured for 100 GeV π^+ showers in a DREAM tower (#11) located on the shower axis and in a tower (#3) located at a distance of 72 mm off-axis). The measured signals have been inverted.

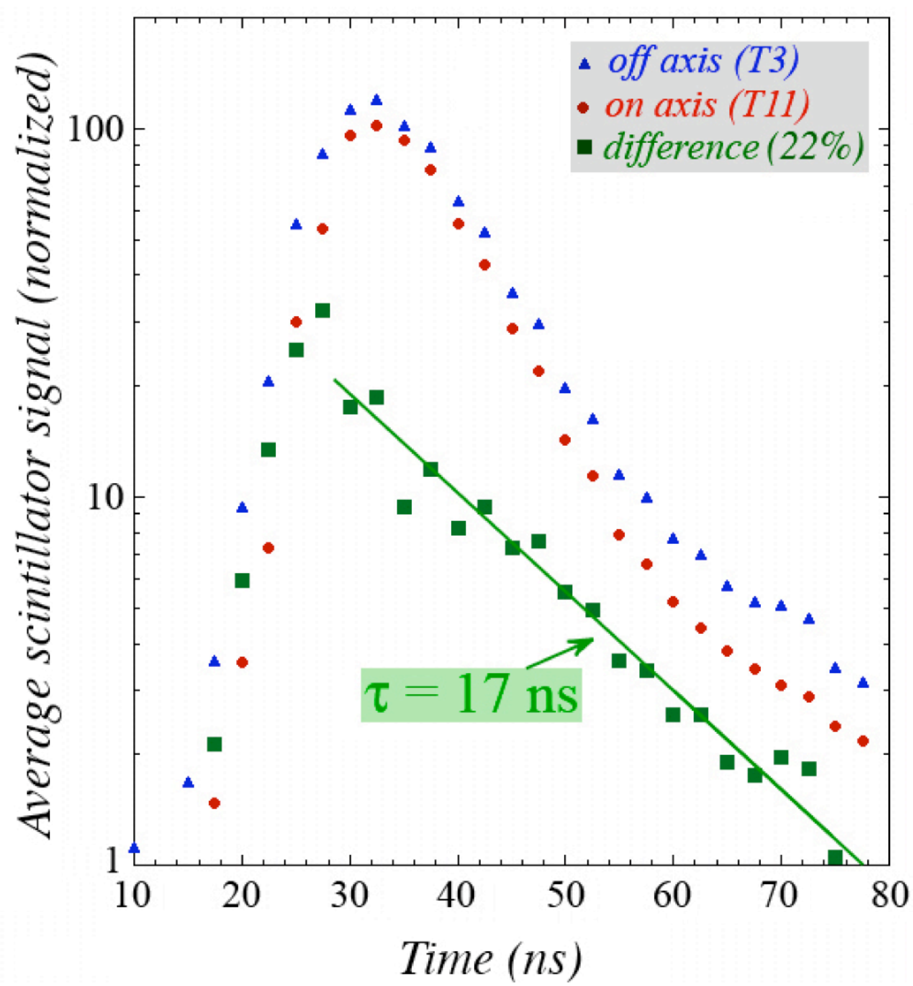

Fig. 5. Comparison of the average time structure of the scintillator signals measured for 100 GeV π^+ showers in a DREAM tower (#11) located on the shower axis and in a tower (#3) located at a distance of 72 mm off-axis), as well as the difference between the two shapes, which have been normalized such that this residual is well described by an exponential shape. See text for details.

We should also analyze the Tower #1 data, where the relative neutron contribution should be even larger. However, the signals are very small. But it is worth trying.