Calorimeter Ideas
CMS ECAL+HCAL

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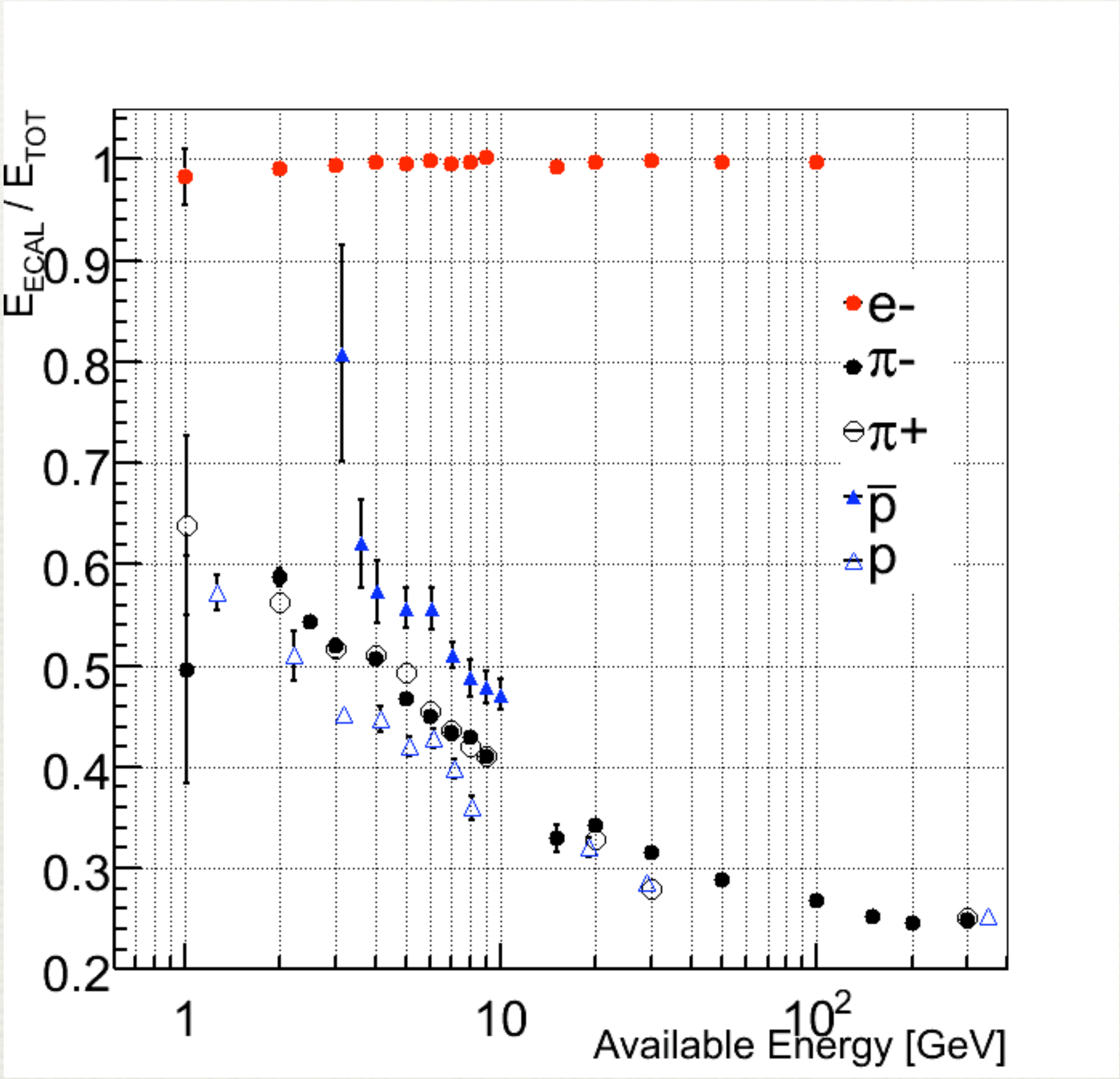
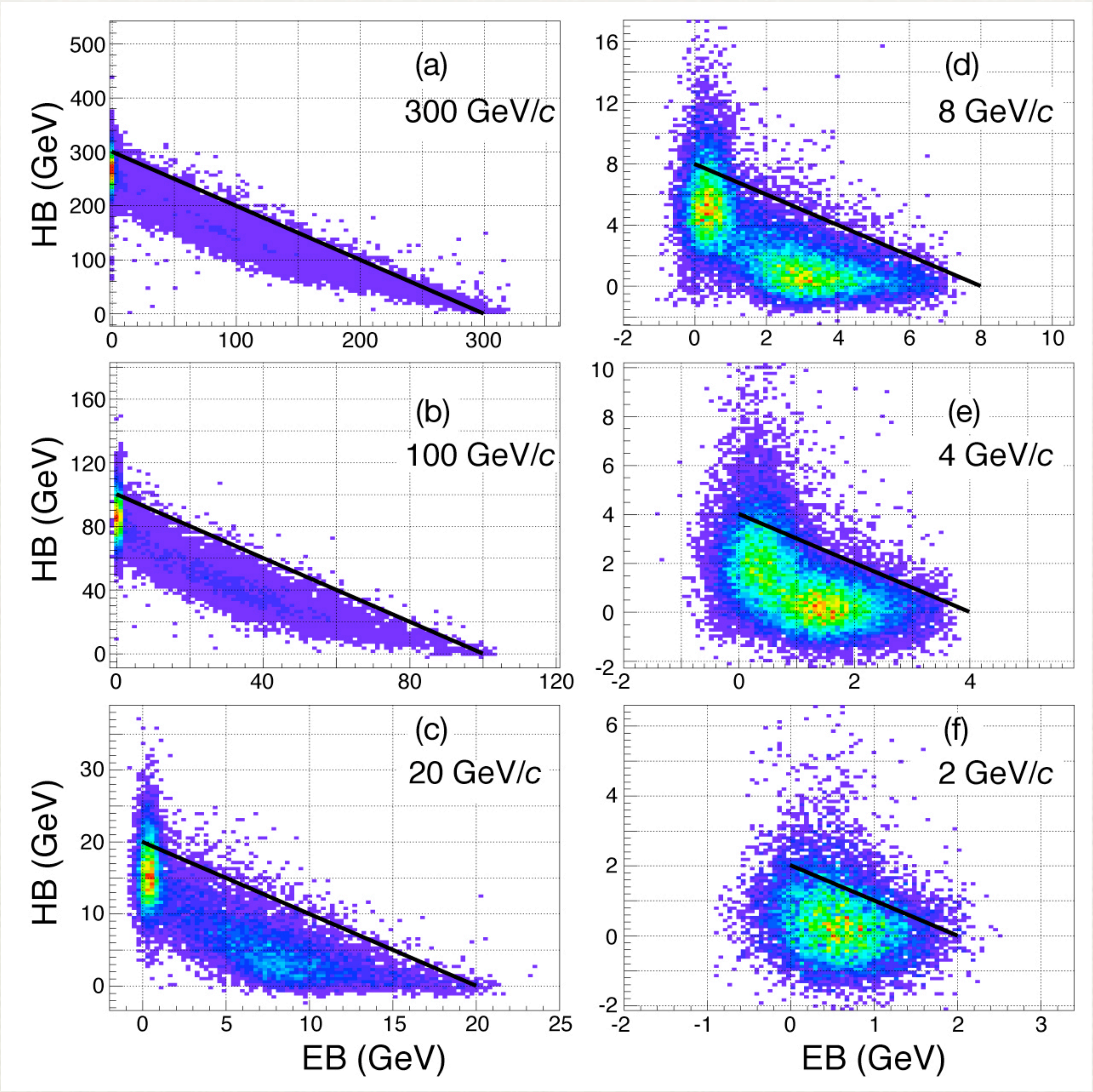
ECAL+HCAL - I (TB06 Data)



ECAL+HCAL - II (TB06 Data)



- The *e/h* ratios are very different for the ECAL (~2.4) and the HCAL (~1.35).
- It is not trivial too “add” the signals from the two systems correctly, especially for jets.
- It maybe possible to do something about this event-by-event.
- TB06 data help us understand the details of the combined systems.

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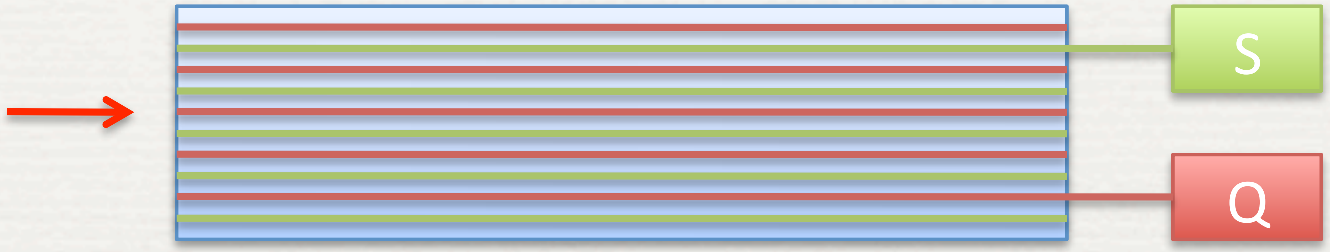
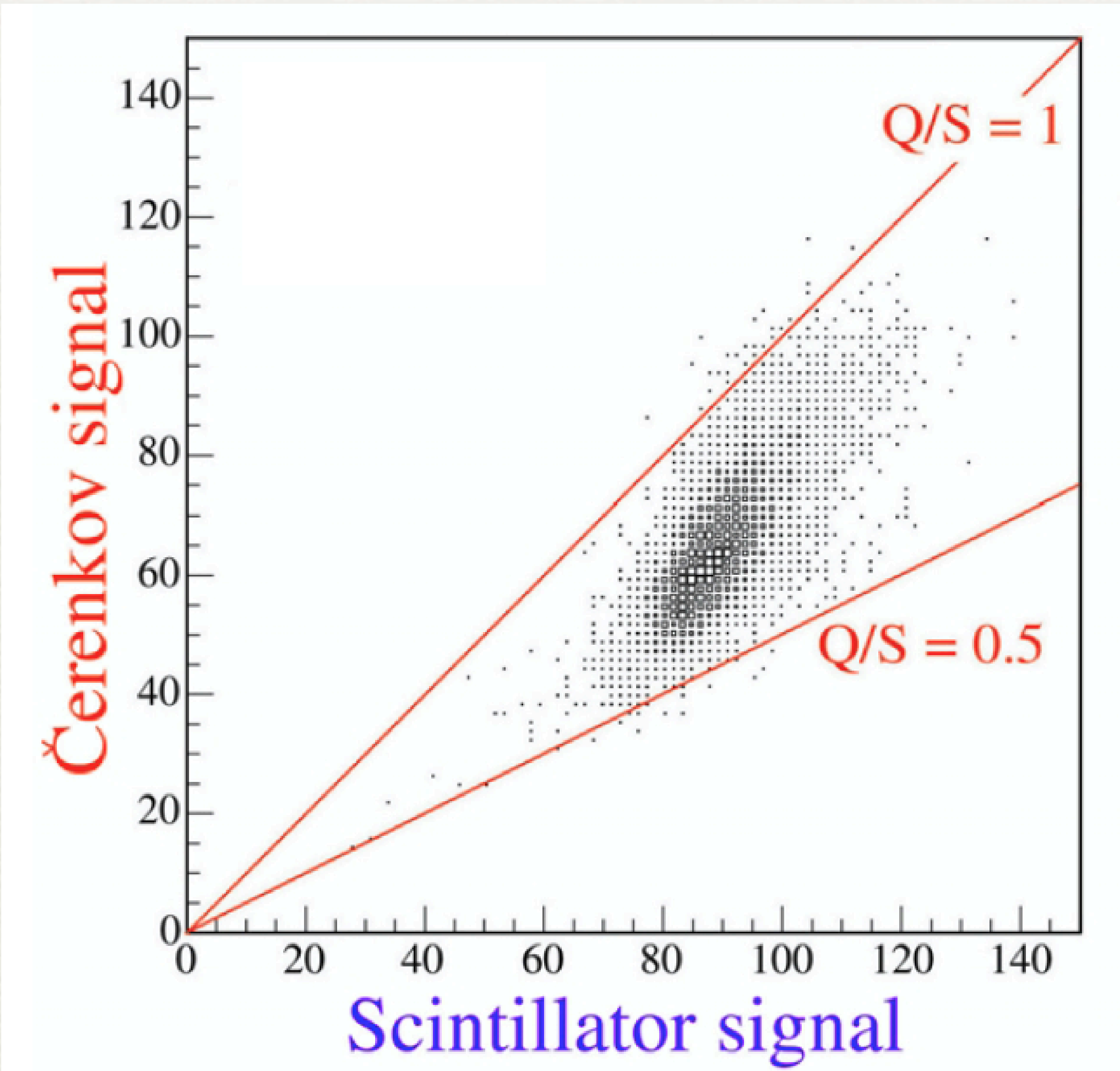
Configuration #1





$$Q = E\left[f_{\rm em} + \frac{1}{(e/h)_{\rm Q}}(1 - f_{\rm em}) \right]$$

$$S = E\left[f_{\rm em} + \frac{1}{(e/h)_{\rm S}}(1 - f_{\rm em}) \right]$$

$$(e/h)_{\rm Q} = 4.7$$

$$(e/h)_{\rm S} = 1.3$$

$$\frac{Q}{S} = \frac{f_{\rm em} + 0.21(1 - f_{\rm em})}{f_{\rm em} + 0.77(1 - f_{\rm em})}$$

$$E = \frac{S - aQ}{1 - a}$$

$$a = \frac{1 - (h/e)_S}{1 - (h/e)_Q} \sim 0.3$$

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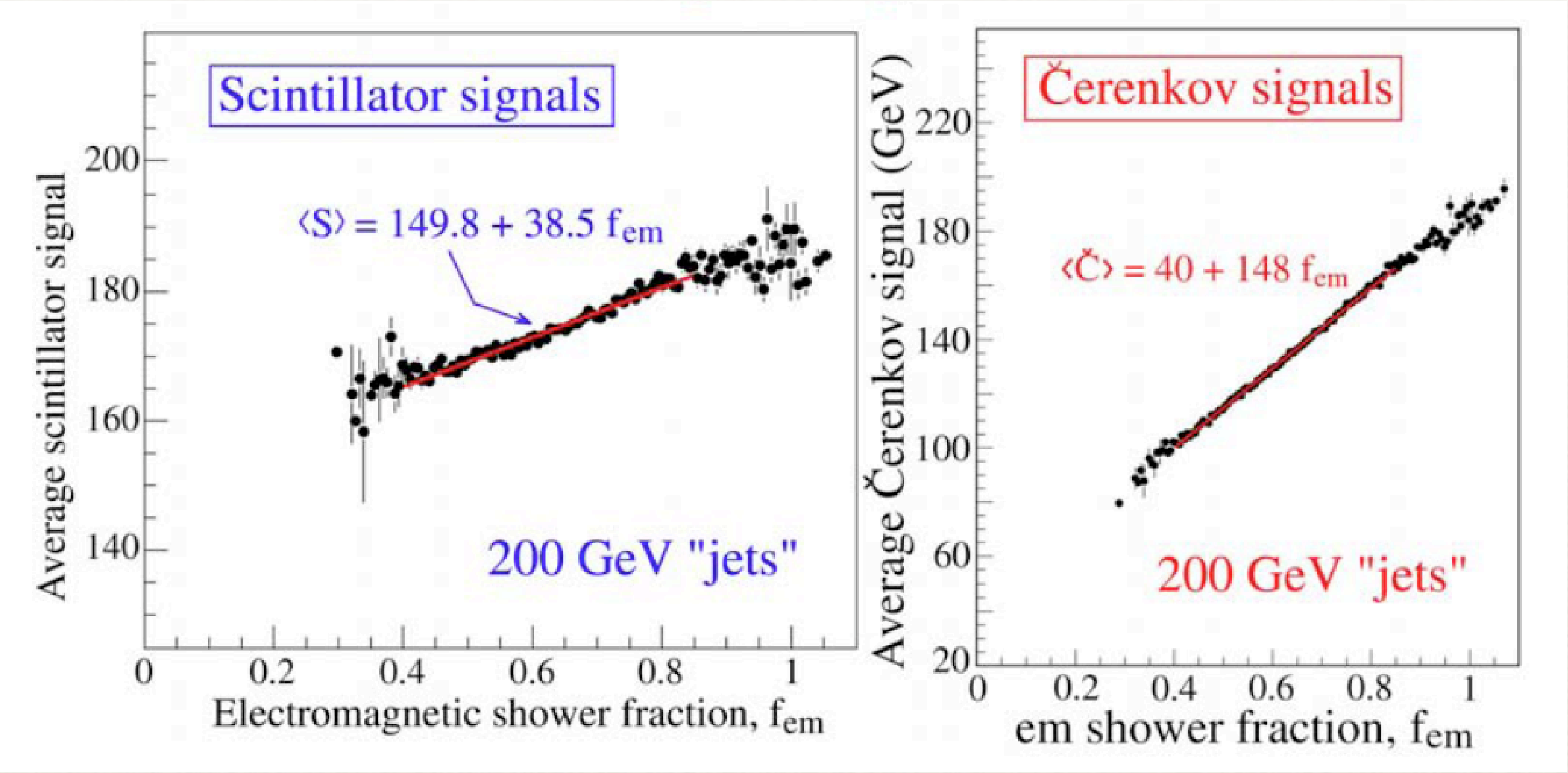
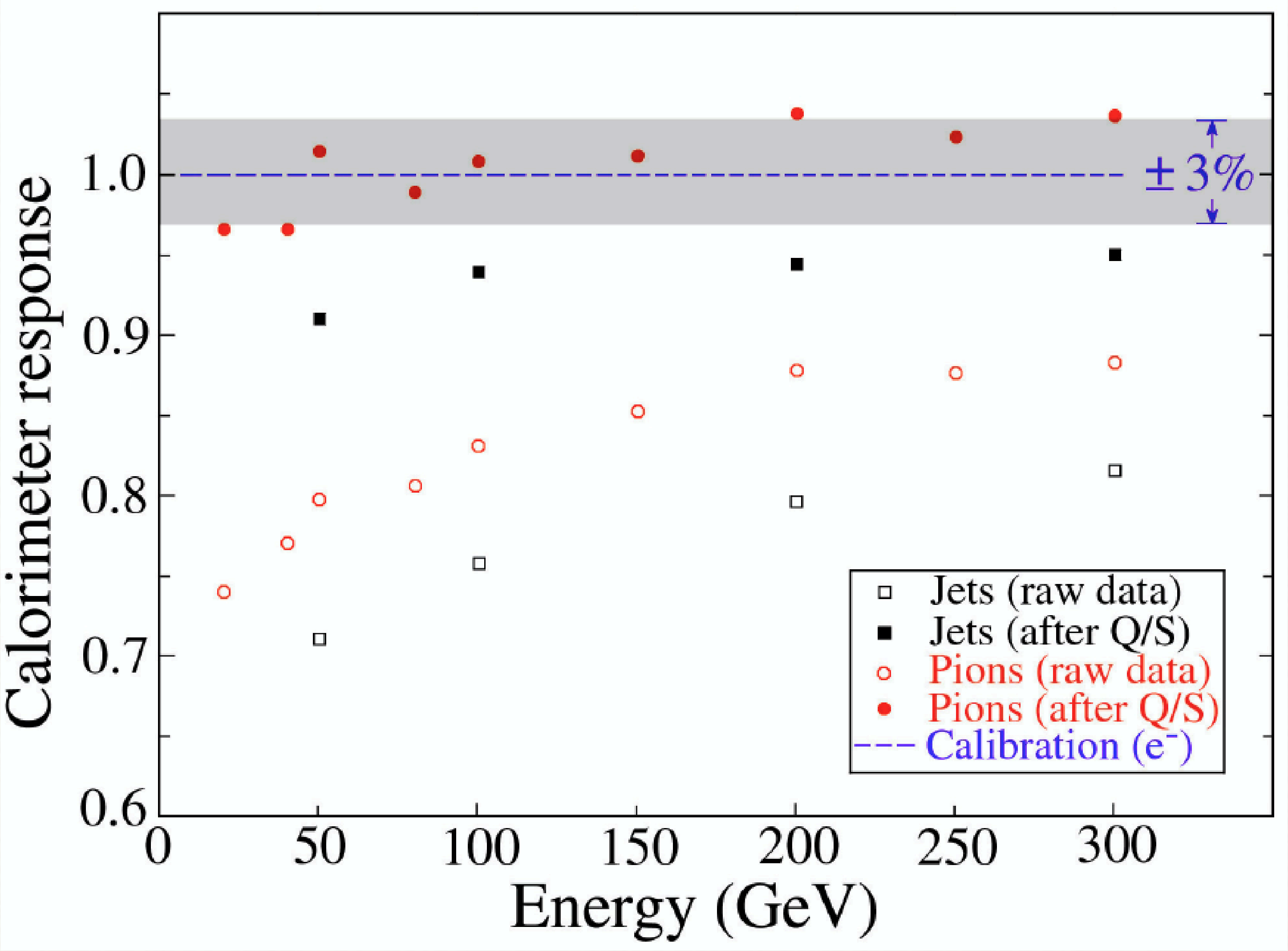
Configuration #1 - We can measure *e/h*



$$R(f_{em}) = p_0 + p_1 f_{em} \qquad with \qquad \frac{p_1}{p_0} = e/h - 1$$

Cu/scintillator e/h = 1.3 Cu/quartz e/h = 4.7

Configuration #1 - We can correct signals



$$S_{corr} = S_{meas}\left[\frac{1 + p_1/p_0}{1 + f_{em} \cdot p_1/p_0}\right]$$

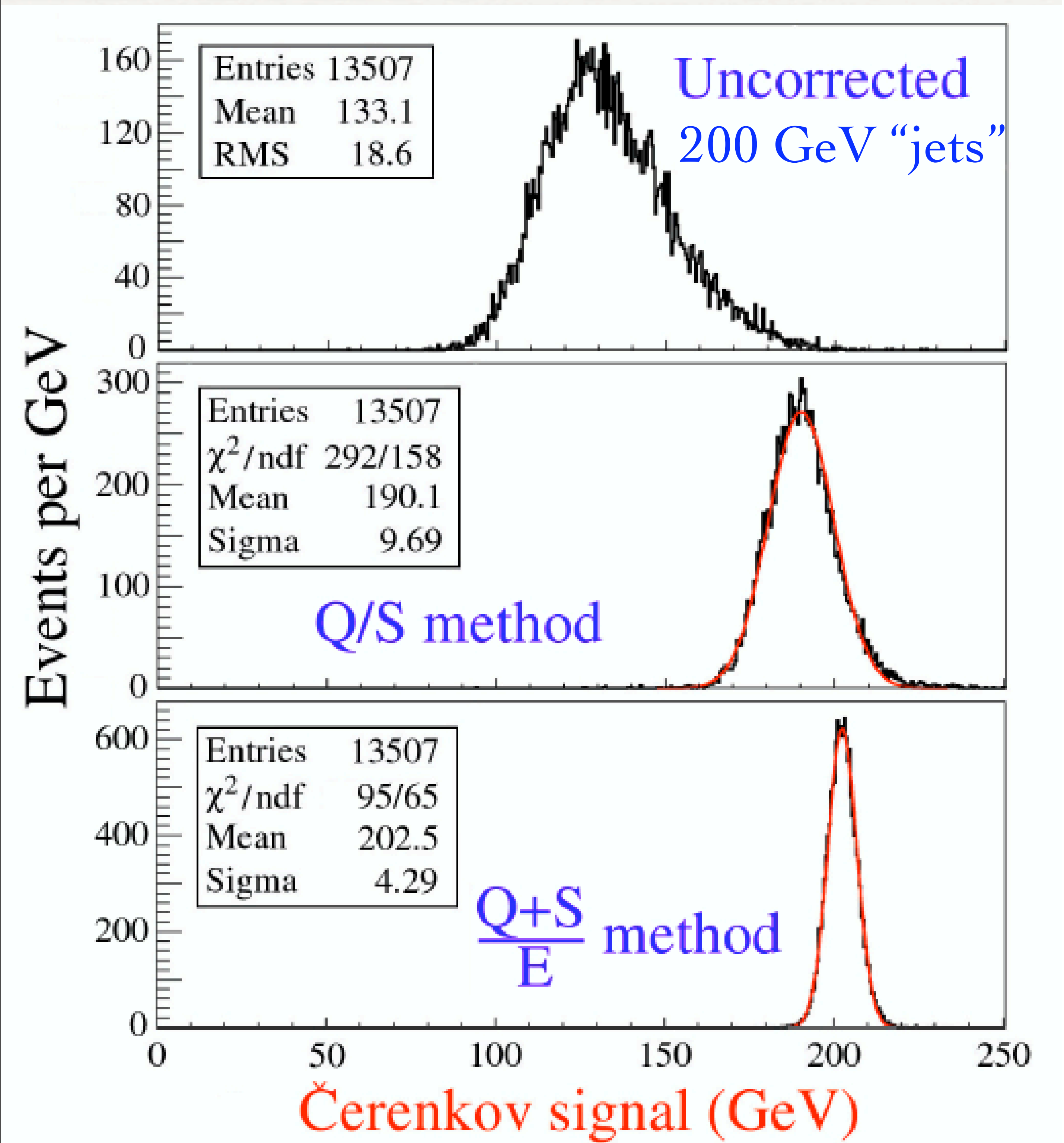
$$p_1/p_0 = (e/h)_S - 1$$

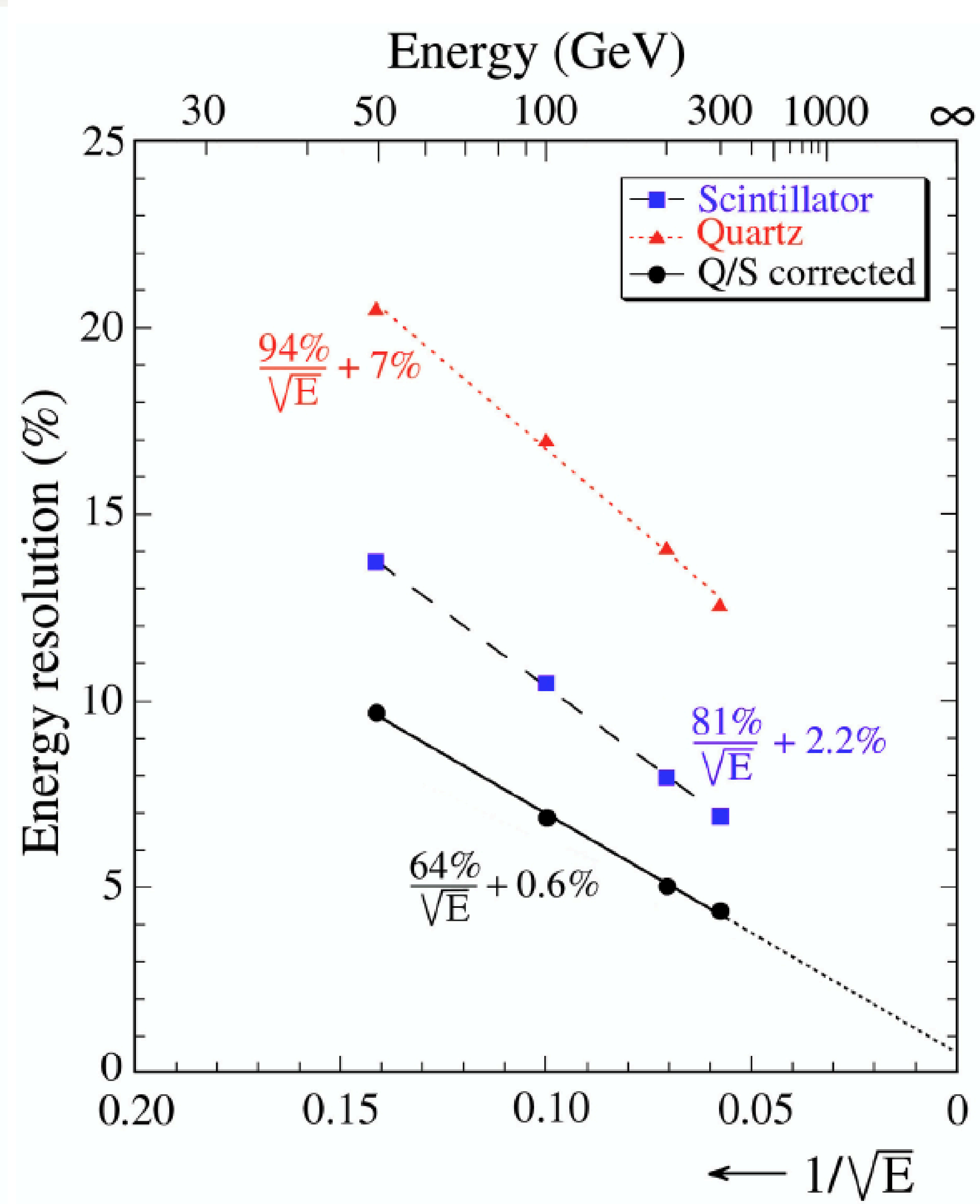
$$Q_{corr} = Q_{meas}\left[\frac{1 + p_1/p_0}{1 + f_{em} \cdot p_1/p_0}\right]$$

$$p_1/p_0 = (e/h)_Q - 1$$

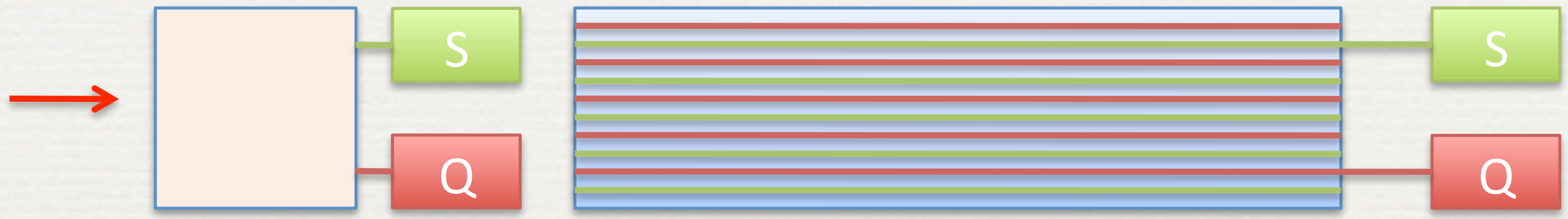
- The correction allows to recover response linearity for single hadrons.
- The same correction also help restore linearity for multi-particles for a calorimeter that is calibrated with electrons only.

Configuration #1 - Improve Energy Resolution Significantly





Configuration #2



- In this configuration, the ECAL is assumed to be homogenous (*e.g.* $PbWO_4$). The trick of separating Cherenkov light (Q) from the scintillation light (S) relies on the pulse shape and the emission spectrum.
- The HCAL can be S alone as well as S and Q.

Configuration #2 - $PbWO_4$ - I

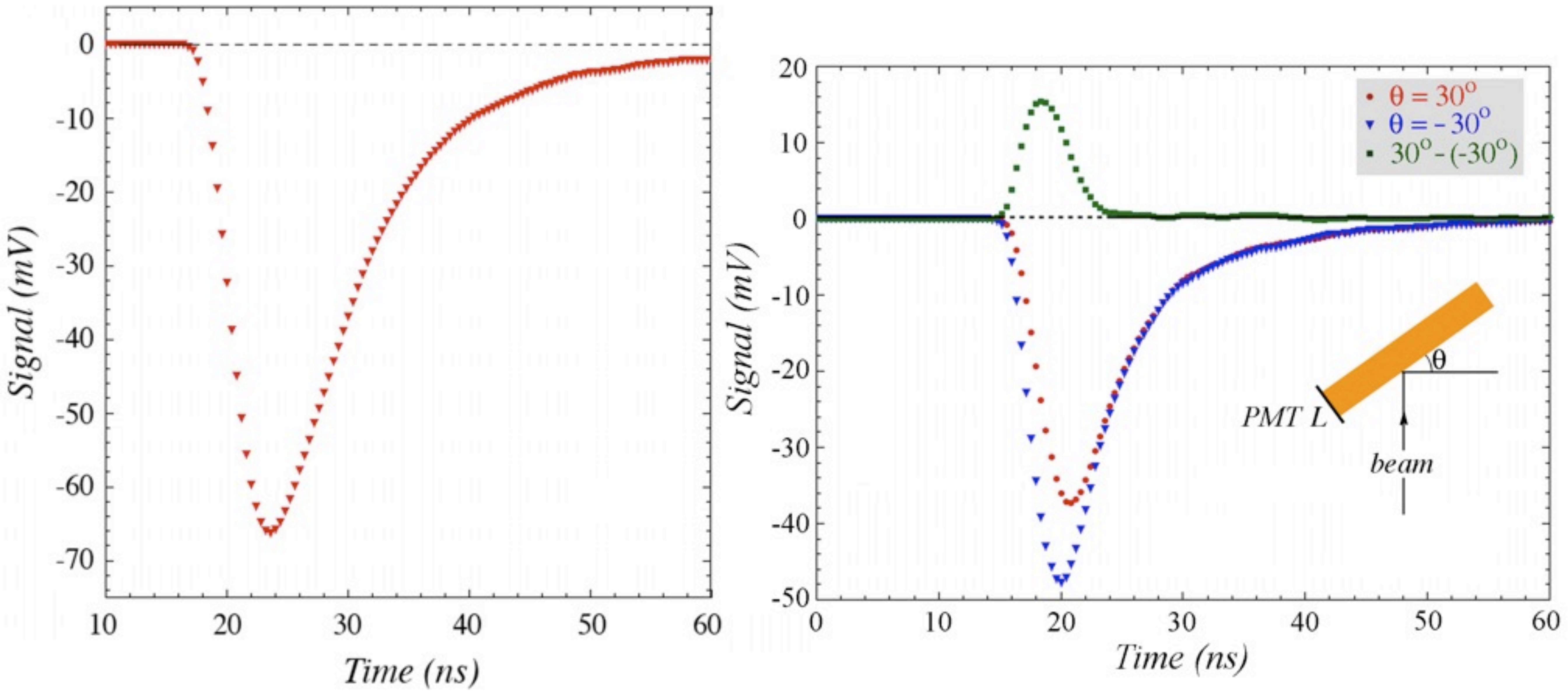
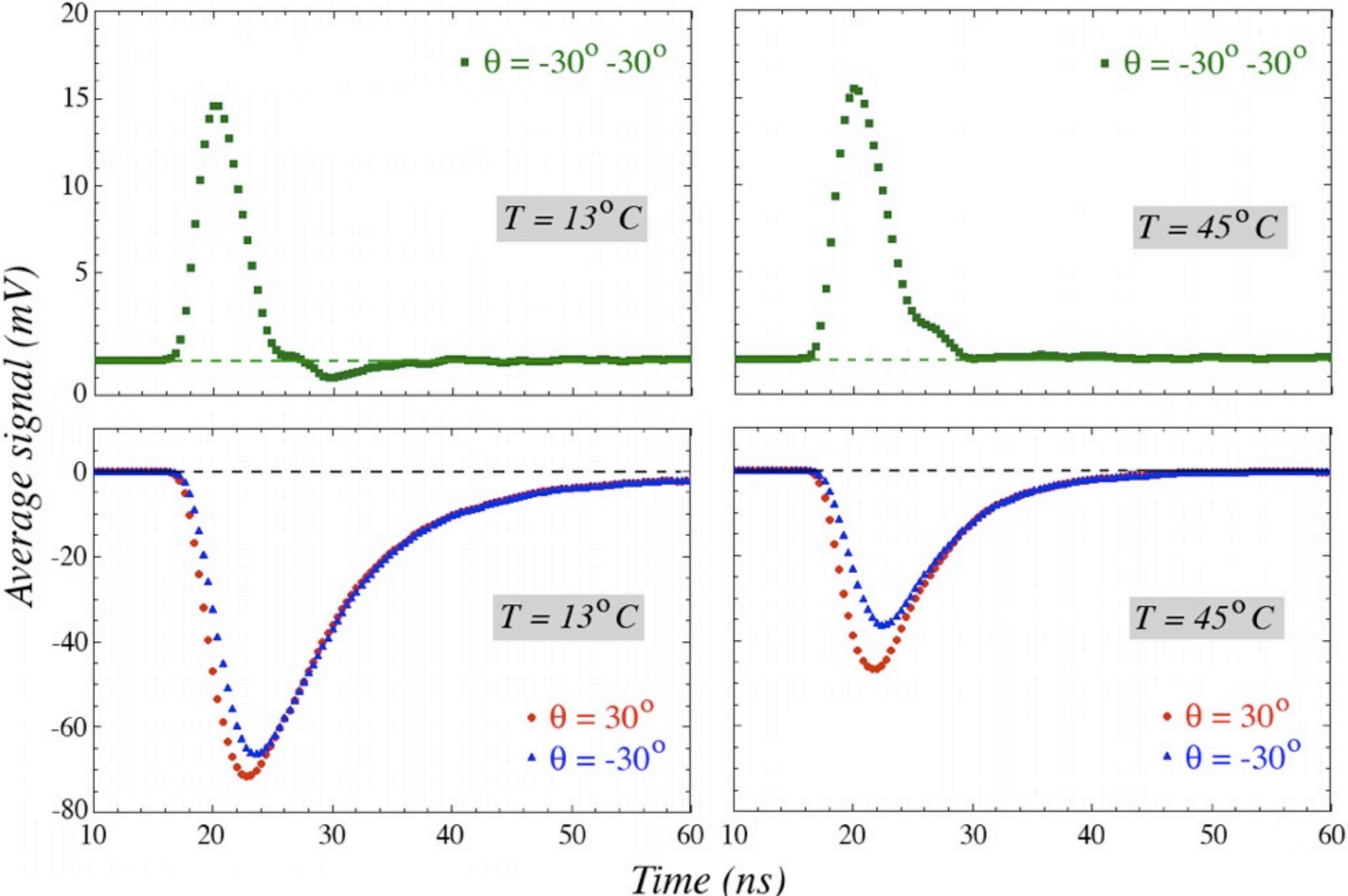


Figure 12: Average time structure of the signals measured with the PMT reading out one end (L) of a $PbWO_4$ crystal traversed by 10 GeV electrons, for two different orientations of the crystal, and the difference between these two time distributions. At $\theta = -30°$, Čerenkov light contributes to the signals, at $\theta = 30°$, it does not [14, 15]. When the crystal was read out from the other side, the prompt excess signal was detected for $\theta = 30°$, and was absent for $\theta = -30°$ [15].

Configuration #2 - $PbWO_4$ - II



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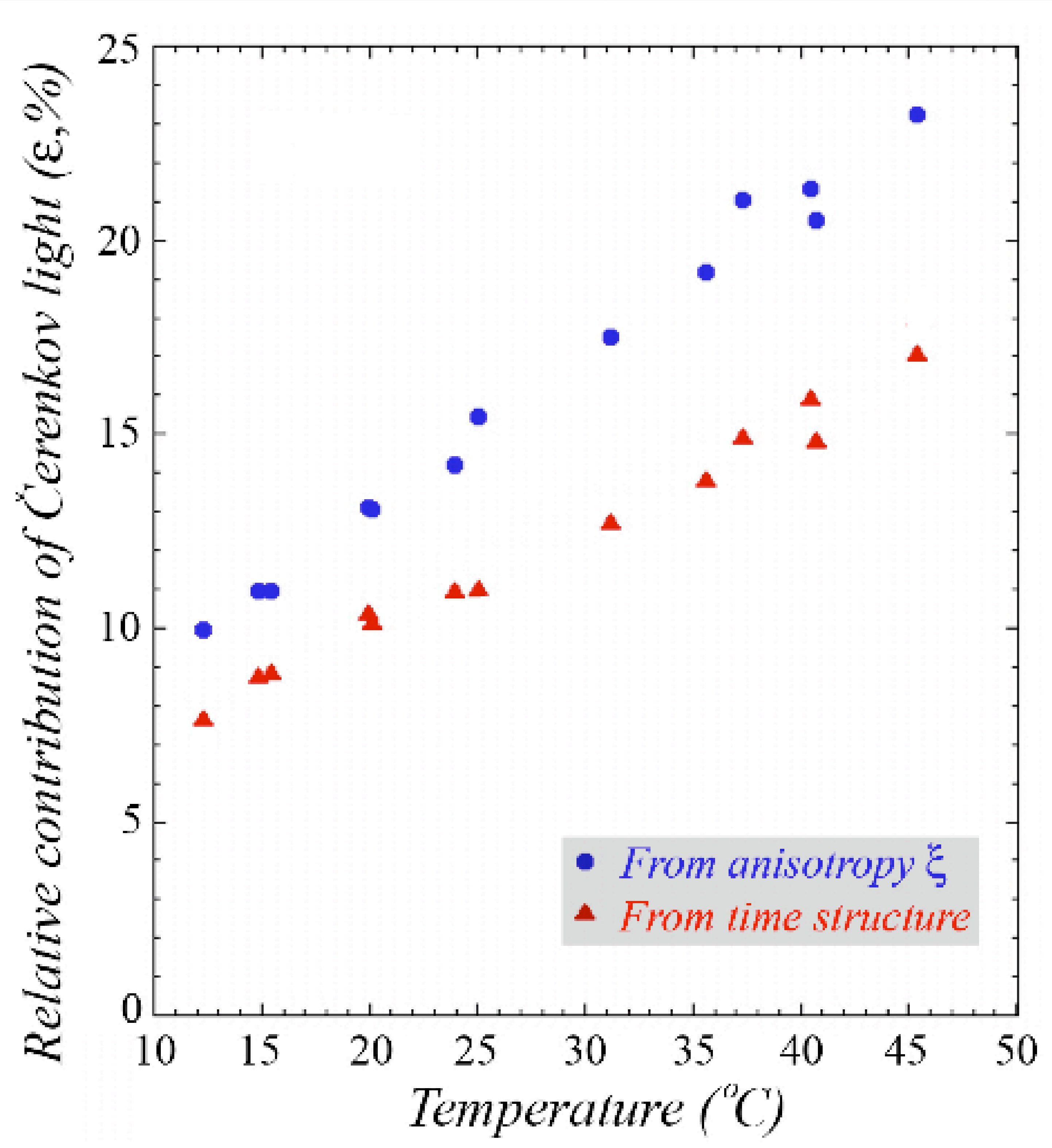
Configuration #2 - $PbWO_4$ - III

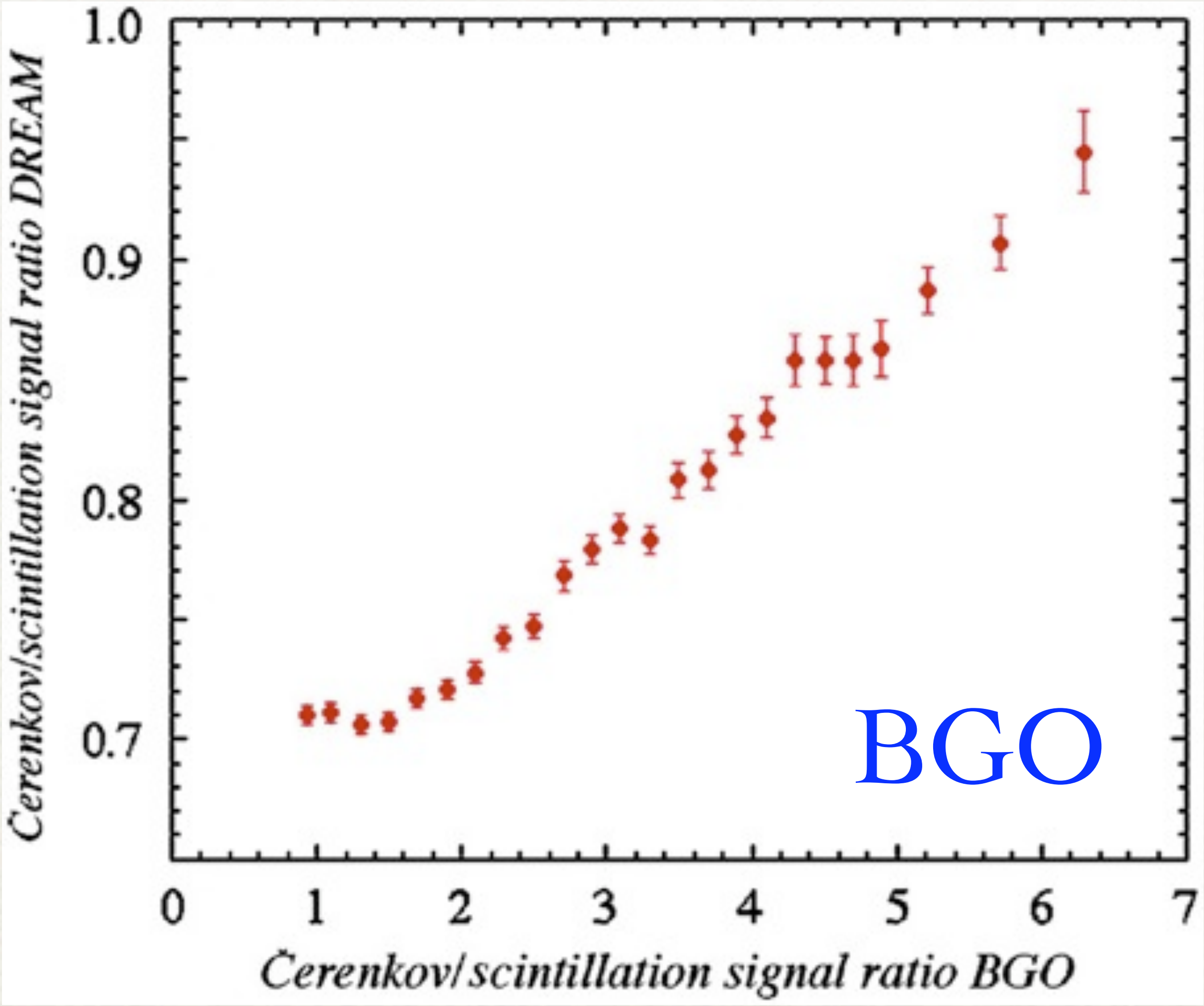


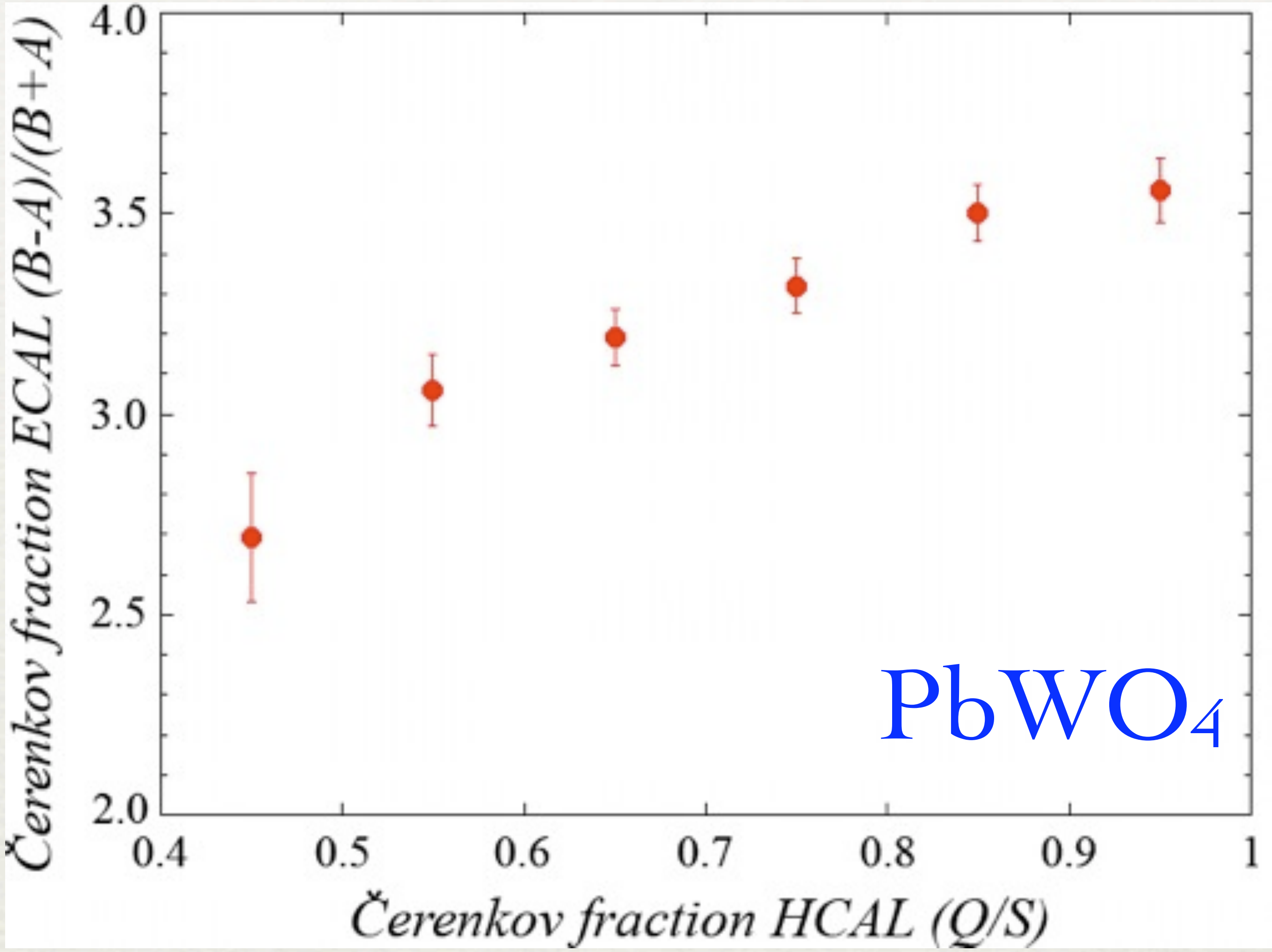
It is important to quantify the relative Cherenkov light contribution to the total light output. This is can be quantified in different ways.

$$\xi(\theta) = \left|\frac{R_\theta - R_{-\theta} - L_\theta + L_{-\theta}}{R_\theta + R_{-\theta} + L_\theta + L_{-\theta}}\right|$$

What does CMS do about the Cherenkov light?

Configuration #2 - ECAL & HCAL Correlation





Neither crystal is ideal although it is easier to work with BGO as evidenced by a stronger correlation in a wider dynamic range between the crystals and the dual-readout HCAL module.

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Configuration #3 - I

1. This is the CMS configuration plus a Cherenkov radiator in between. The function of the radiator is to measure the fluctuations in the neutral pion content in hadronic showers event-by-event with some efficiency.
2. $f_{em} \sim Q_{Cherenkov}/(S_{ECAL} + S_{HCAL})$ and $E\sim(S^*_{ECAL}+S^*_{HCAL}+Q^*_{Cherenkov})$
3. Forget about ECAL Q itself? ECAL Pulse shaping electronics probably does not allow separation. Maybe later...
4. Hadronic shower max is ~between the ECAL and HCAL (~1.1 interaction lengths).
5. BGO+Quartz+S configuration data exist and analyses is in progress.
6. Simulations have started (December CMS Week).

Configuration #3 - II