Simulation Studies of a Total Absorption Dual Readout Calorimeter

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Sampling Study

50.0% sampling: we read every other layer.

33.3% sampling: we read one out of three layers.

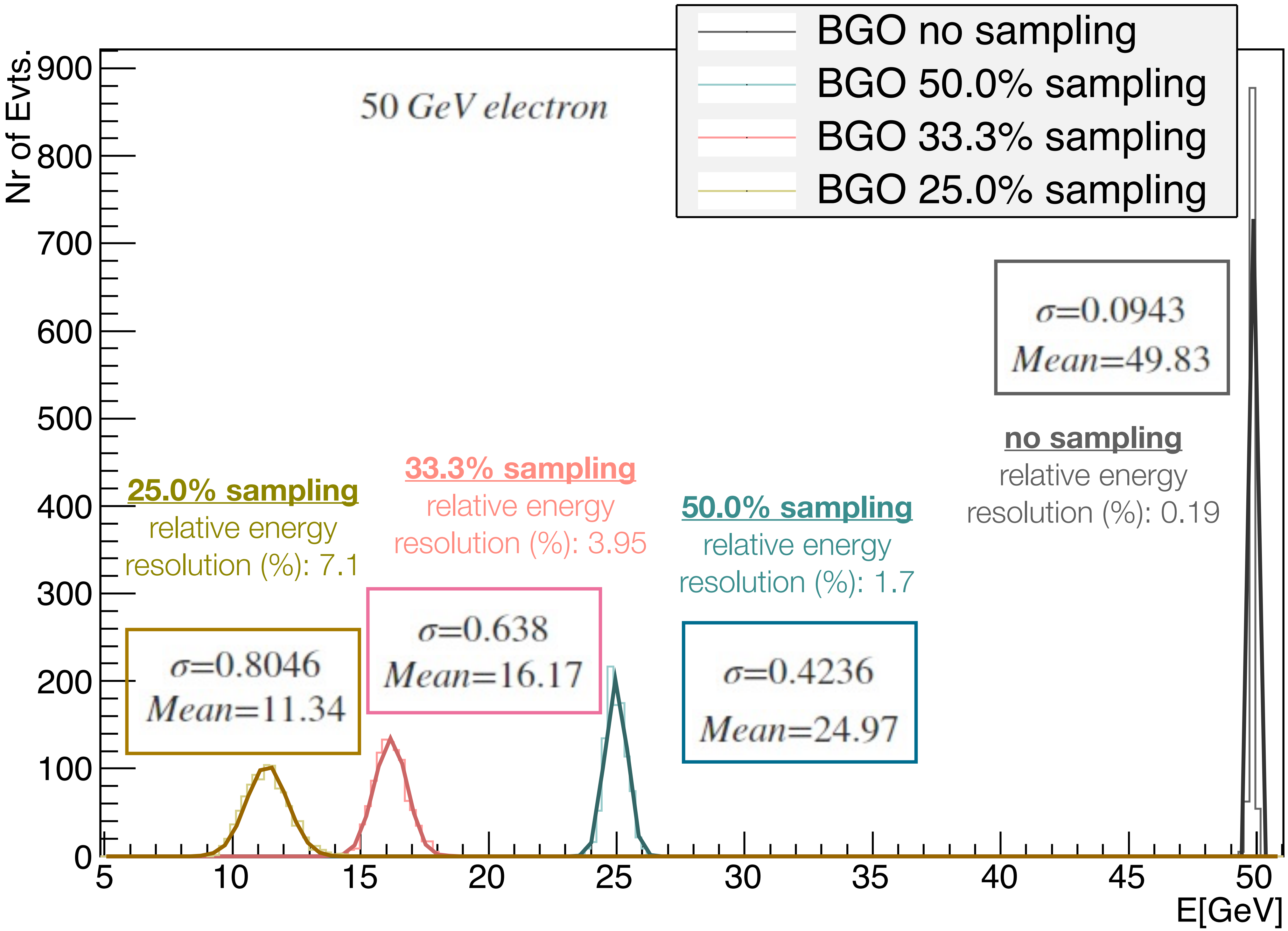
25.0% sampling: we read one out of four layers.

In all cases we read the first layer!

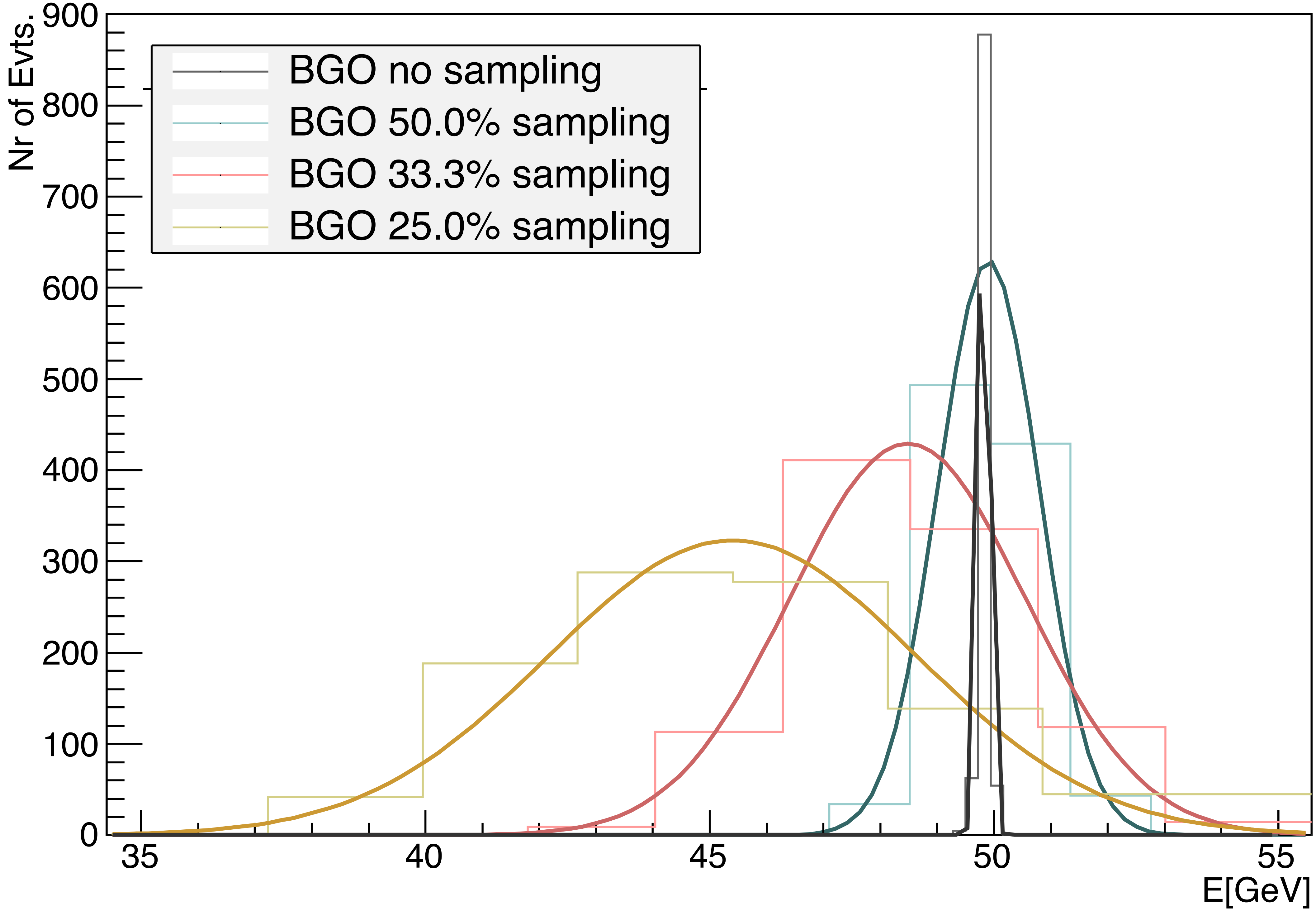
Longitudinal segmentation with respect to incoming beam!

- Each layer is 2.5 cm thick
- 100 layers in total

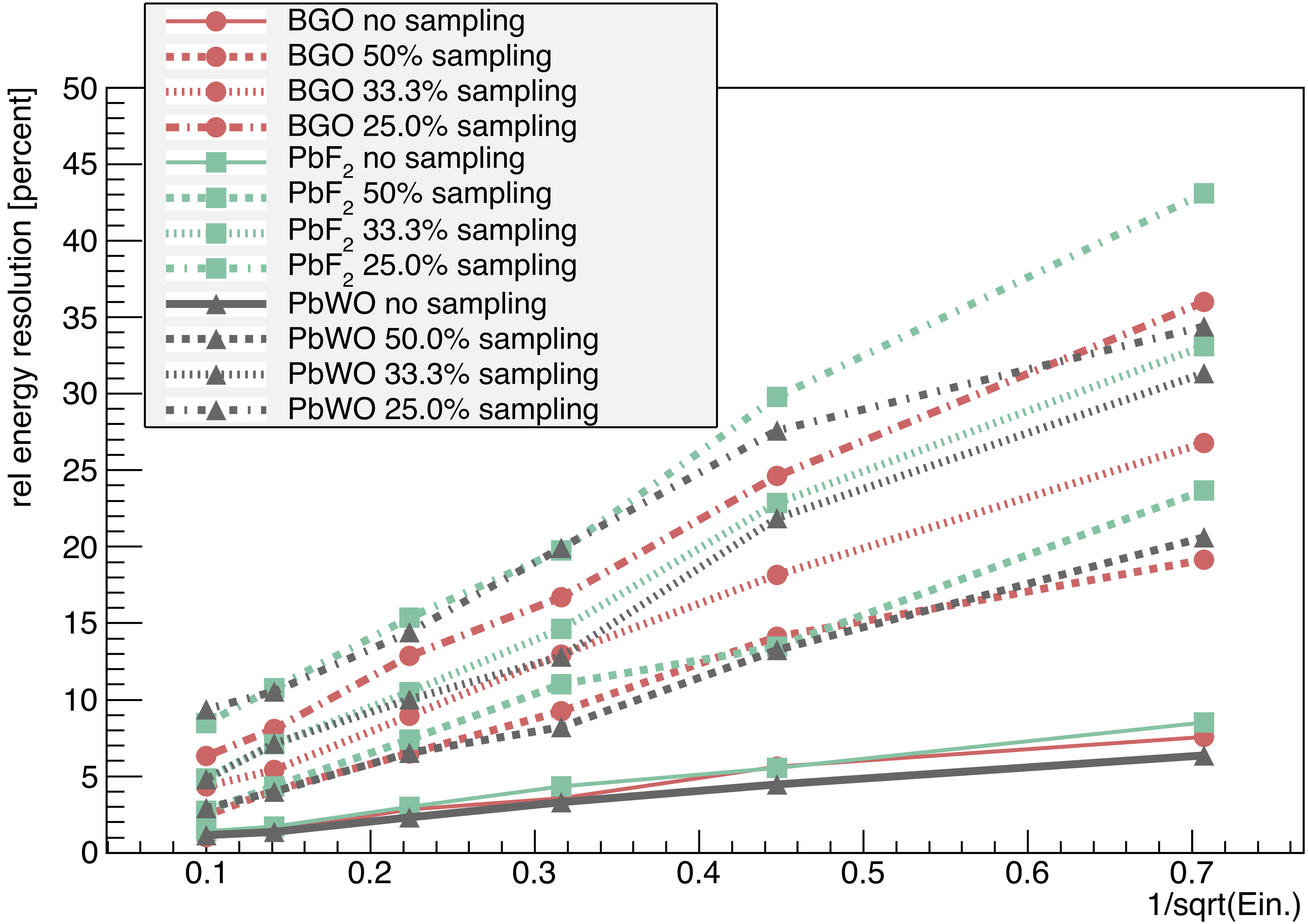
Uncorrected electron distribution (all sampling fractions)



Uncorrected electron distribution (all sampling fractions)



Relative energy resolution for single incident pion



Relative energy resolution for single incident pion

Parameterizing the curves according to:

$$\sigma = c_1 + \frac{c_2}{\sqrt{E_{in}}}$$

	c1	c2
BGO no sampling	0.0294	10.4486
BGO 50.0% sampling	0.1577	25.6327
BGO 33.3% sampling	0.5561	35.4617
BGO 25.0% sampling	2.56	41.2215
PbF2 no sampling	0.3002	11.7708
PbF2 50.0% sampling	-0.3909	33.5525
PbF2 33.3% sampling	0.2620	47.2442
PbF2 25.0% sampling	2.5051	57.9573
PbWO no sampling	0.3355	8.7765
PbWO 50.0% sampling	-0.2179	29.3491
PbWO 33.3% sampling	0.3643	44.3474
PbWO 25.0% sampling	5.3464	43.4995

Contribution from sampling to energy resolution

Energy resolution can be parameterized as a linear function:

$$\sigma_E = c_1 + \frac{c_2}{\sqrt{E_{\mathrm{in}}}}$$

And we can extract the resolution factor introduced by sampling by using:

$$\sigma_E = \sqrt{\sigma^2_{\mathrm{intrinsic}} + \sigma^2_{sampling}}$$

Where the intrinsic sigma comes from the un-sampled data and sigma E comes from the results we get after we introduce the sampling to our calibration program That way we calculate the contribution to overall resolution as:

$$\sigma_{sampling} = \sqrt{\sigma^2_{\mathrm{E}} - \sigma^2_{intrinsic}}$$

Contribution from sampling to energy resolution

BGO 50% sampling

Energy [GeV]	σ_E	$\sigma_{intrinsic}$	$\sigma_{sampling}$
2	0.2450	0.1049	0.2214
5	0.2780	0.1044	0.2577
10	0.2828	0.1050	0.2626
20	0.2435	0.1138	0.2153
50	0.2615	0.0974	0.2427
100	0.2366	0.1076	0.2107

BGO 33.3% sampling

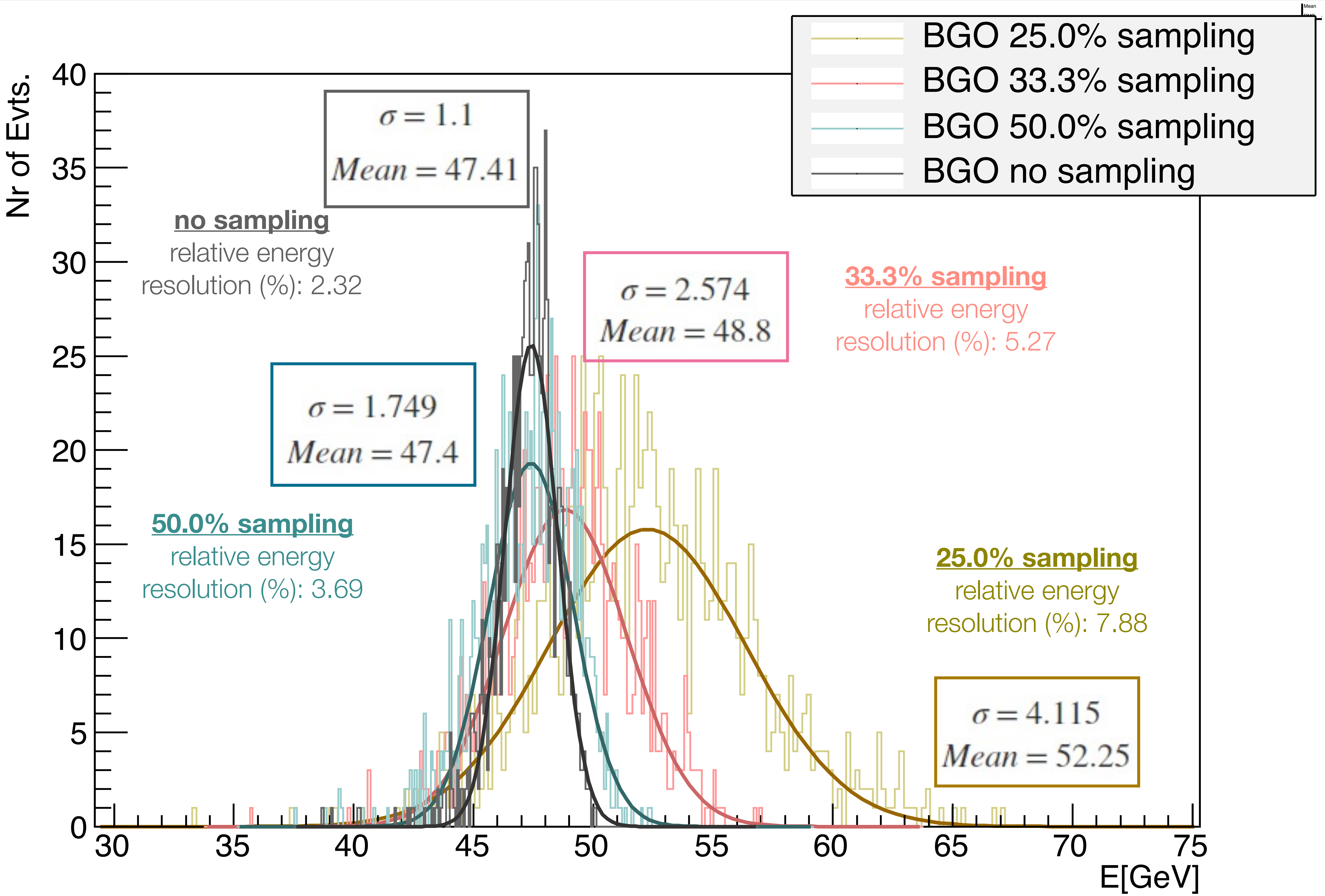
Energy [GeV]	σ_E	$\sigma_{intrinsic}$	$\sigma_{sampling}$
2	0.3584	0.1049	0.3427
5	0.3771	0.1044	0.3624
10	0.3776	0.1050	0.3627
20	0.3766	0.1138	0.3590
50	0.3769	0.0974	0.3641
100	0.4075	0.1076	0.3930

$$\sigma_E = \sqrt{\sigma^2_{\text{intrinsic}} + \sigma^2_{sampling}}$$

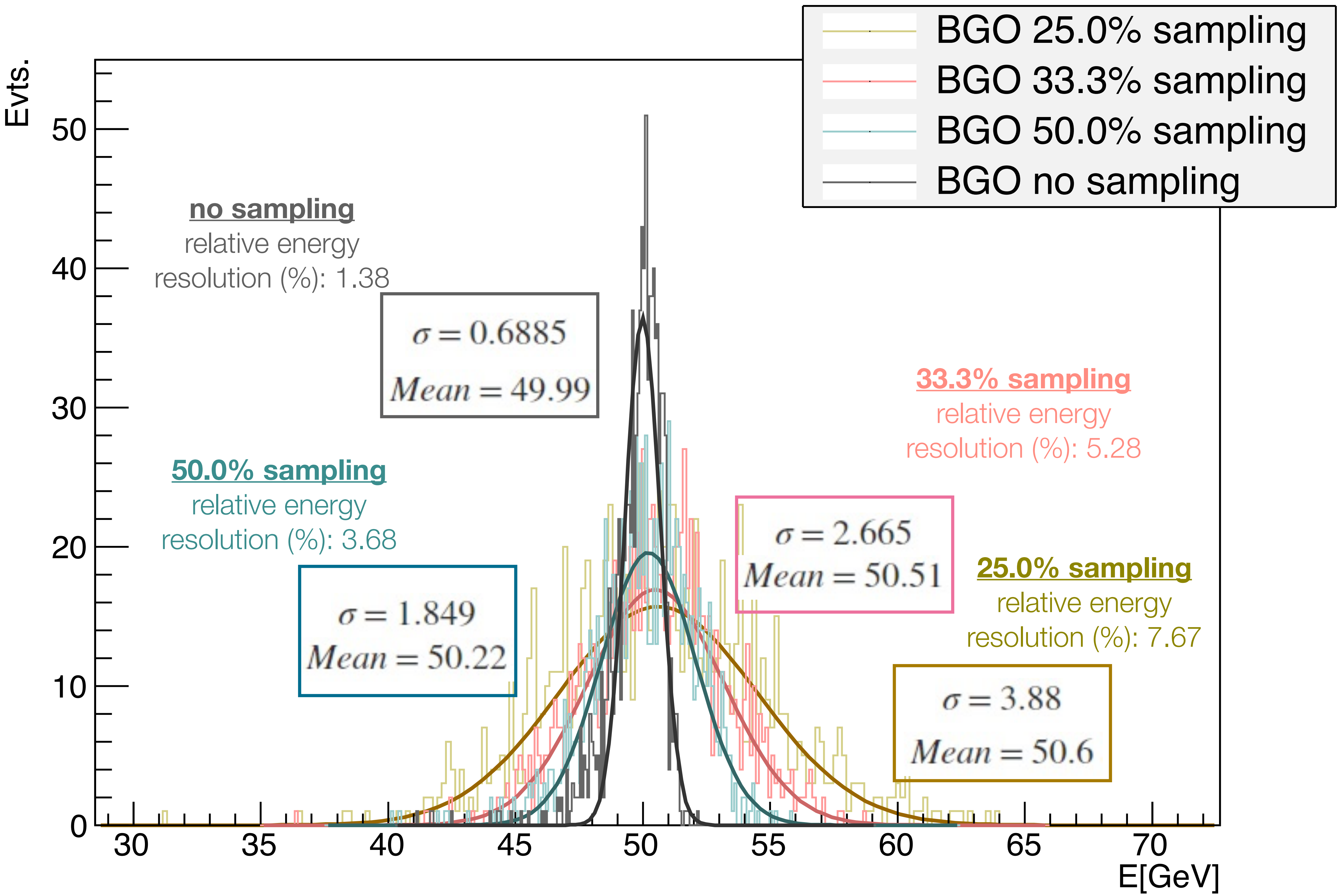
BGO 25% sampling

Energy [GeV]	σ_E	$\sigma_{intrinsic}$	$\sigma_{sampling}$
2	0.4324	0.1049	0.4195
5	0.4893	0.1044	0.4780
10	0.4987	0.1050	0.4875
20	0.5136	0.1138	0.5008
50	0.5487	0.0974	0.5399
100	0.5864	0.1076	0.5766

Pion energy distribution after calibration to scintillation and Cherenkov light response 50.0 GeV pion



Pion energy distribution after dual readout correction for 50.0 GeV incident pi-



33.3% sampling fraction detailed study

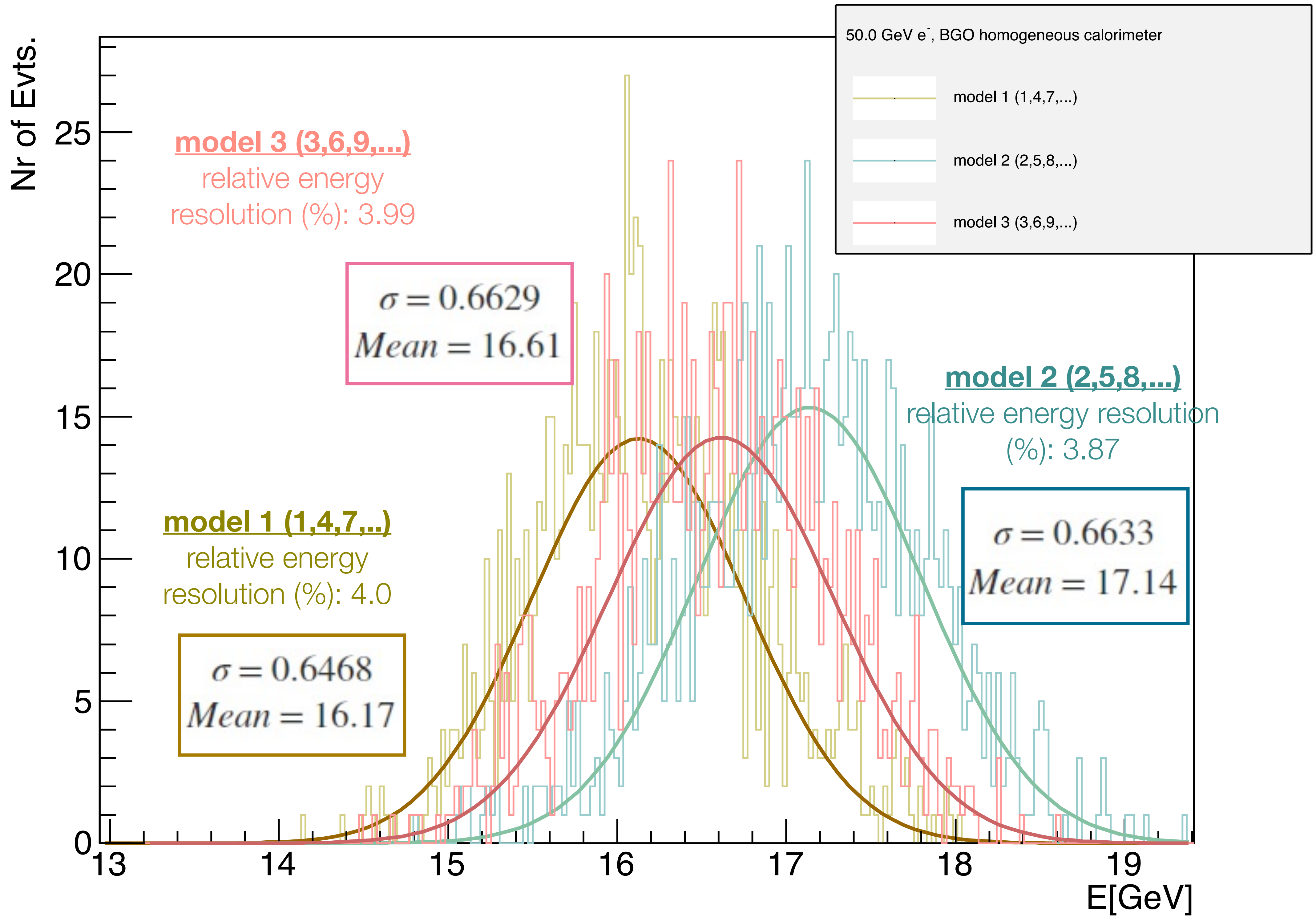
33.3% sampling fraction detailed study

To study the effect the longitudinal profile of the em shower has on sampling resolution.

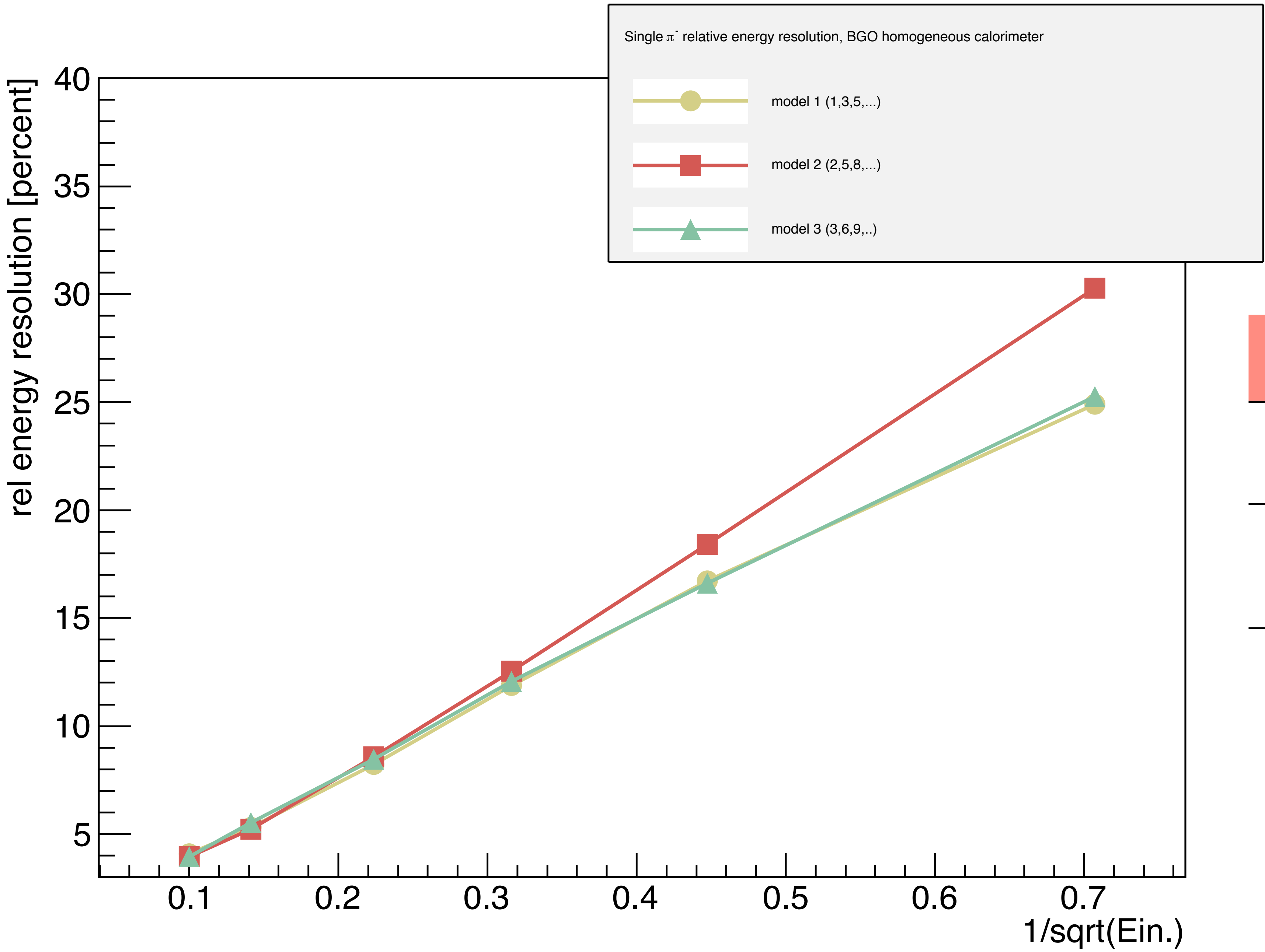
Radiation length comparable to layer width

3 scenarios:
- model 1 (1,4,7,...)
- model 2 (2,5,8,...)
- model 3 (3,6,9,...)

Uncorrected electron distribution (3 scenarios)



Relative energy resolution for single incident pion



$$\sigma = c_1 + \frac{c_2}{\sqrt{E_{in}}}$$

	c1	c2
model 1 (1,4,7,...)	-0.9507	43.7488
model 2 (2,5,8,...)	0.614062	34.809
model 3 (3,6,9,...)	0.0409	33.6348

Contribution from sampling to energy resolution

$$\sigma_E = \sqrt{\sigma^2_{\text{intrinsic}} + \sigma^2_{sampling}}$$

BGO 33.3% sampling model 1 (1,4,7,...)

Energy [GeV]	σ_E	$\sigma_{intrinsic}$	$\sigma_{sampling}$
2	0.3584	0.1049	0.3427
5	0.3771	0.1044	0.3624
10	0.3776	0.1050	0.3627
20	0.3766	0.1138	0.3590
50	0.3769	0.0974	0.3641
100	0.4075	0.1076	0.3930

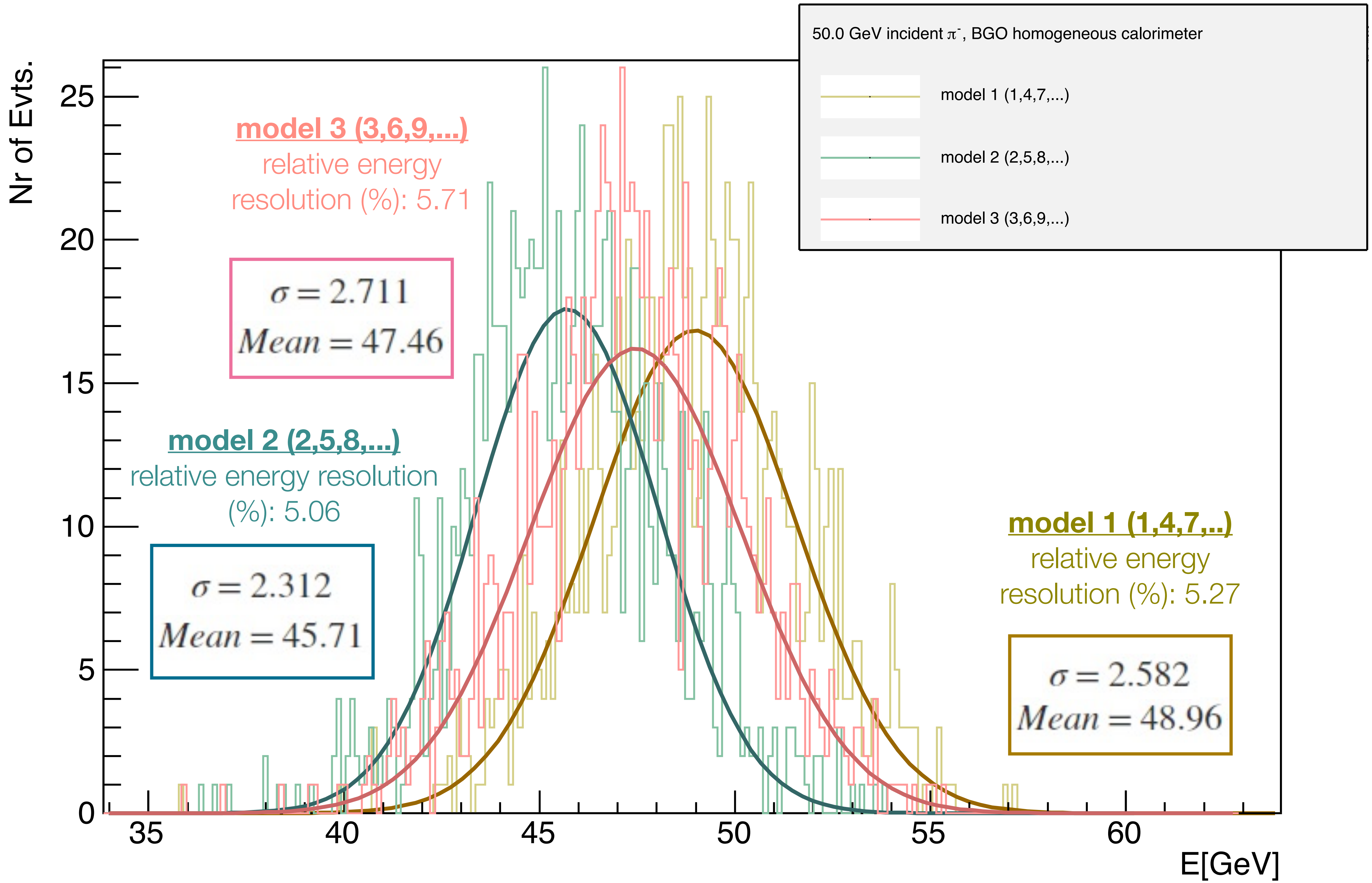
BGO 33.3% sampling model 2 (2,5,8,...)

Energy [GeV]	σ_E	$\sigma_{intrinsic}$	$\sigma_{sampling}$
2	0.4282	0.1049	0.4152
5	0.4119	0.1044	0.3984
10	0.3962	0.1050	0.3820
20	0.3835	0.1138	0.3662
50	0.3701	0.0974	0.3571
100	0.3942	0.1076	0.3792

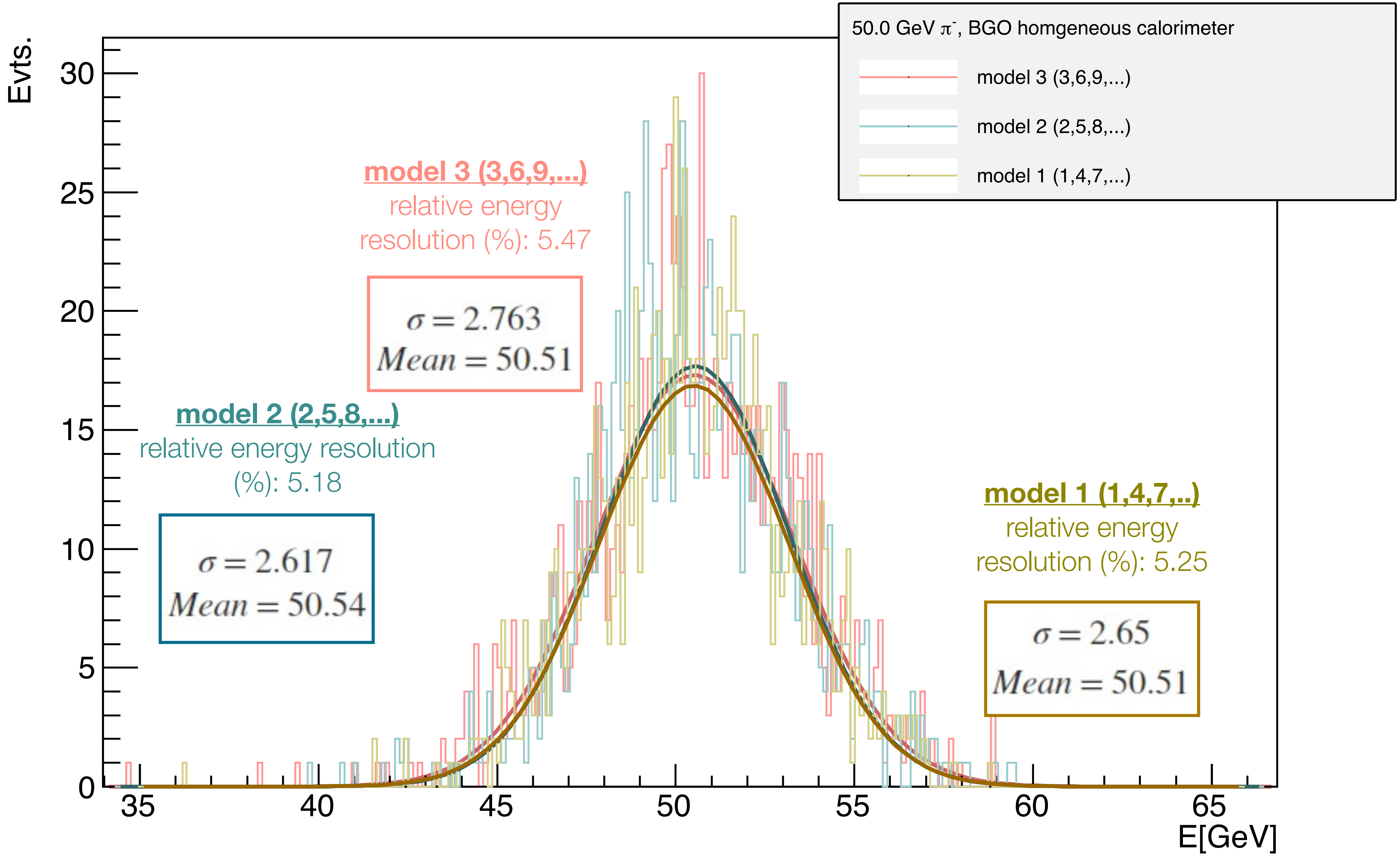
BGO 33.3% sampling model 3 (3,6,9,...)

Energy [GeV]	σ_E	$\sigma_{intrinsic}$	$\sigma_{sampling}$
2	0.3572	0.1049	0.3414
5	0.3715	0.1044	0.3565
10	0.3814	0.1050	0.3667
20	0.3781	0.1138	0.3606
50	0.3907	0.0974	0.3784
100	0.3947	0.1076	0.3798

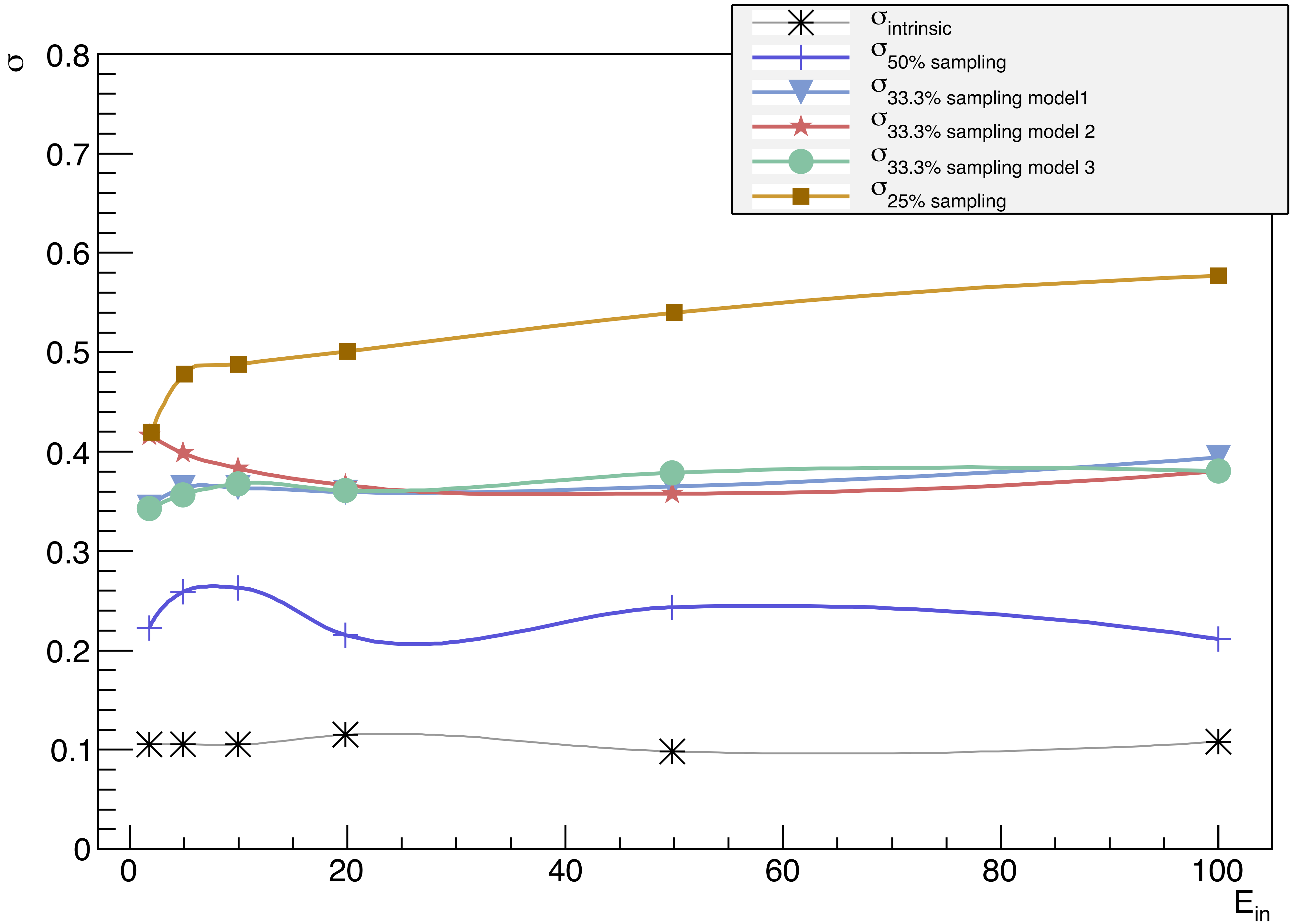
Pion energy distribution after calibration to scintillation and Cherenkov light response 50.0 GeV pion



Pion energy distribution after dual readout correction for 50.0 GeV incident pi-

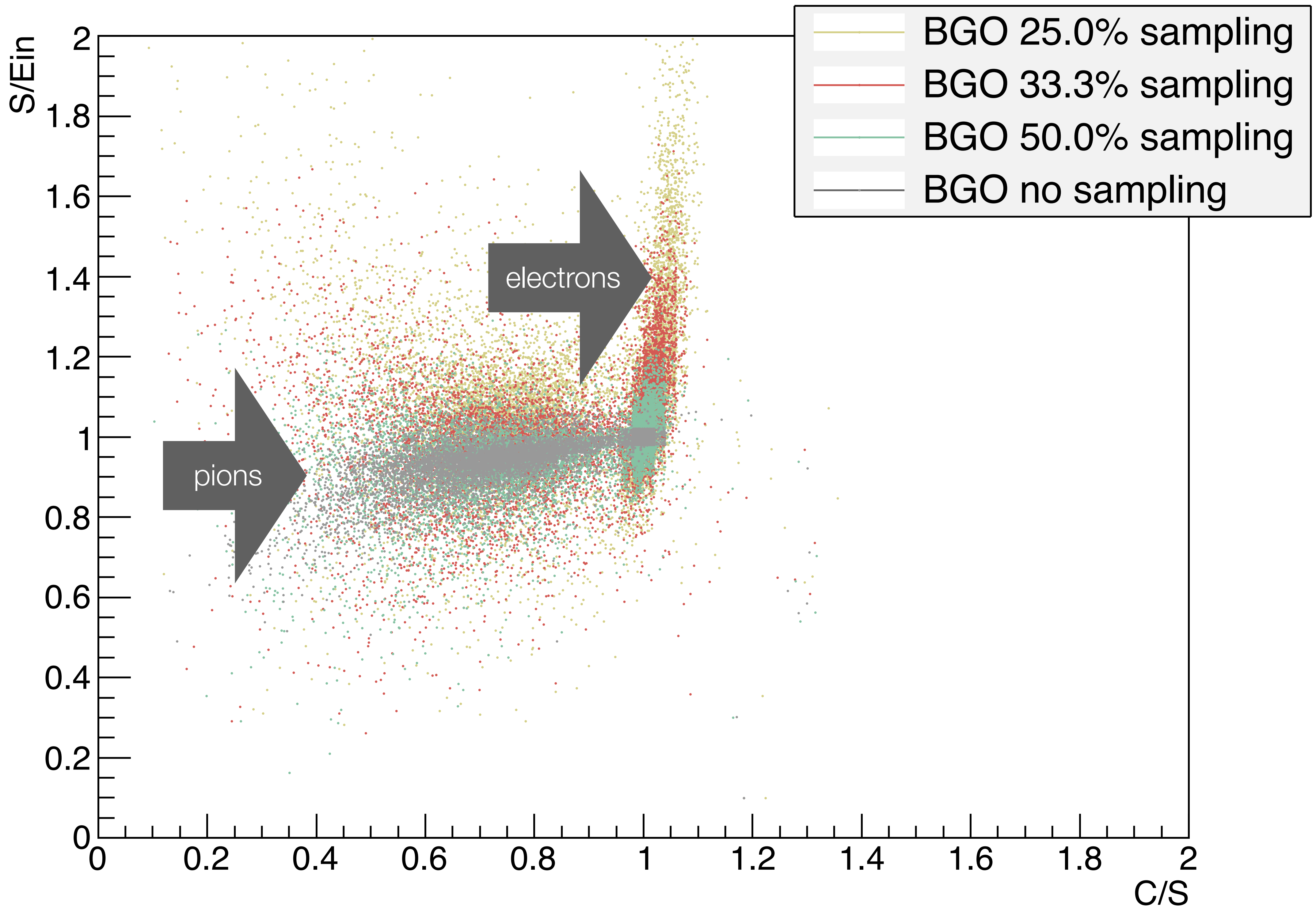


Contribution from sampling to relative energy resolution

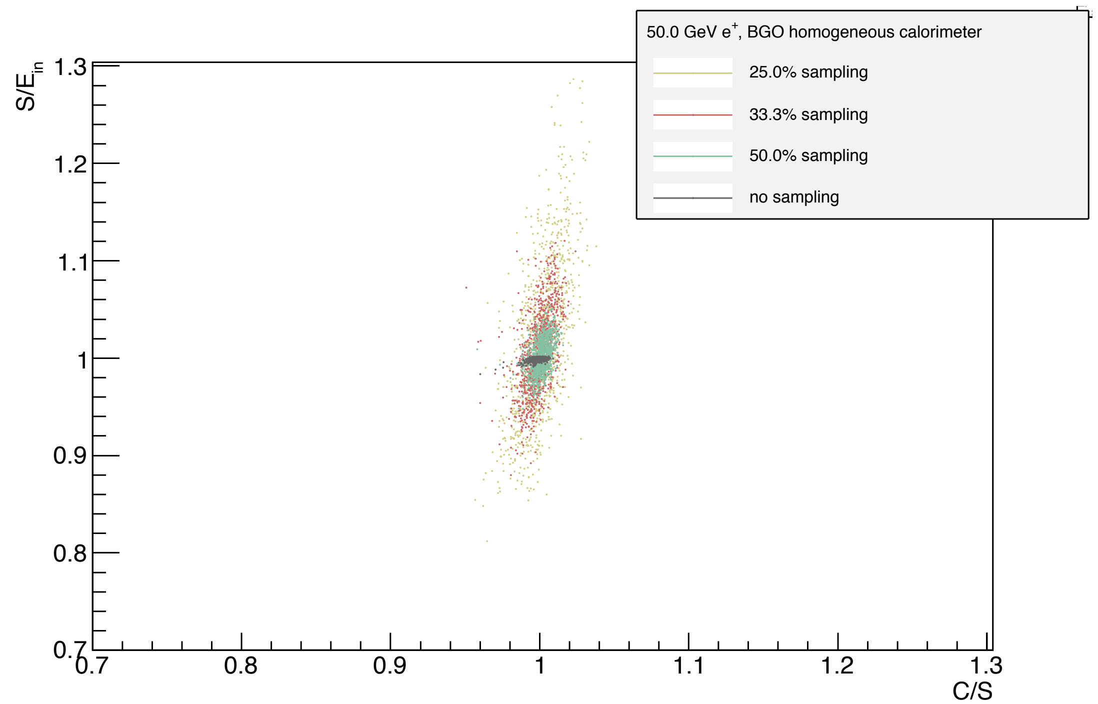


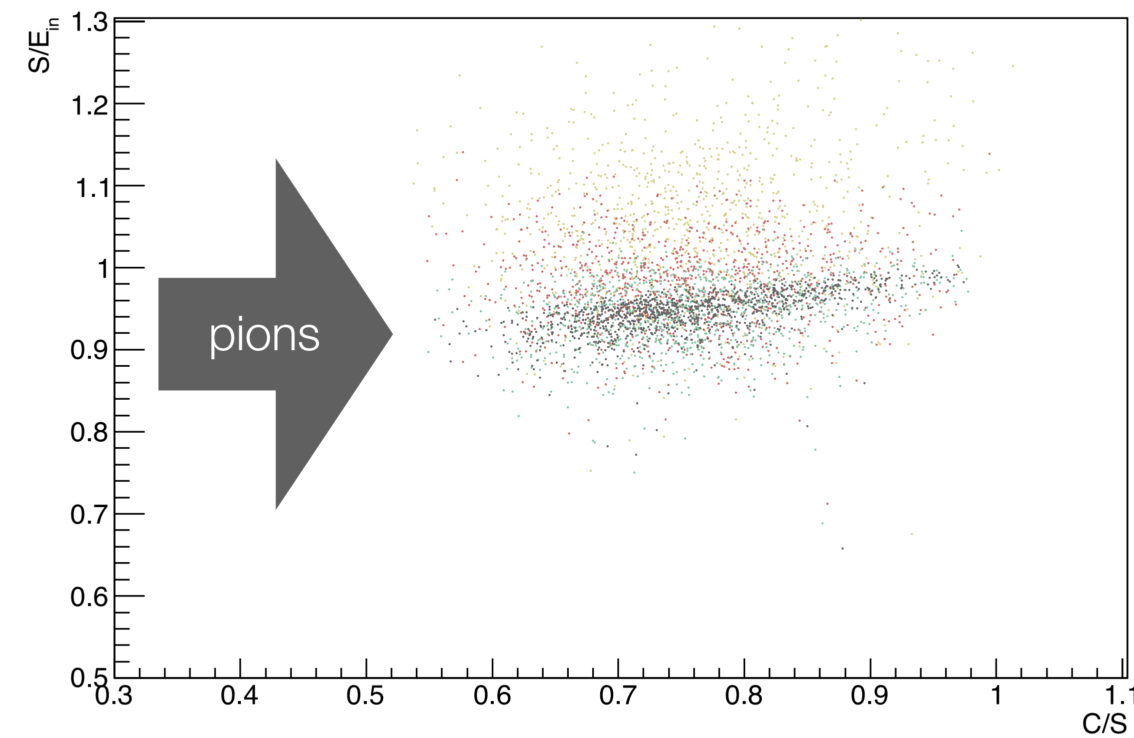
Dual readout correction function calculations

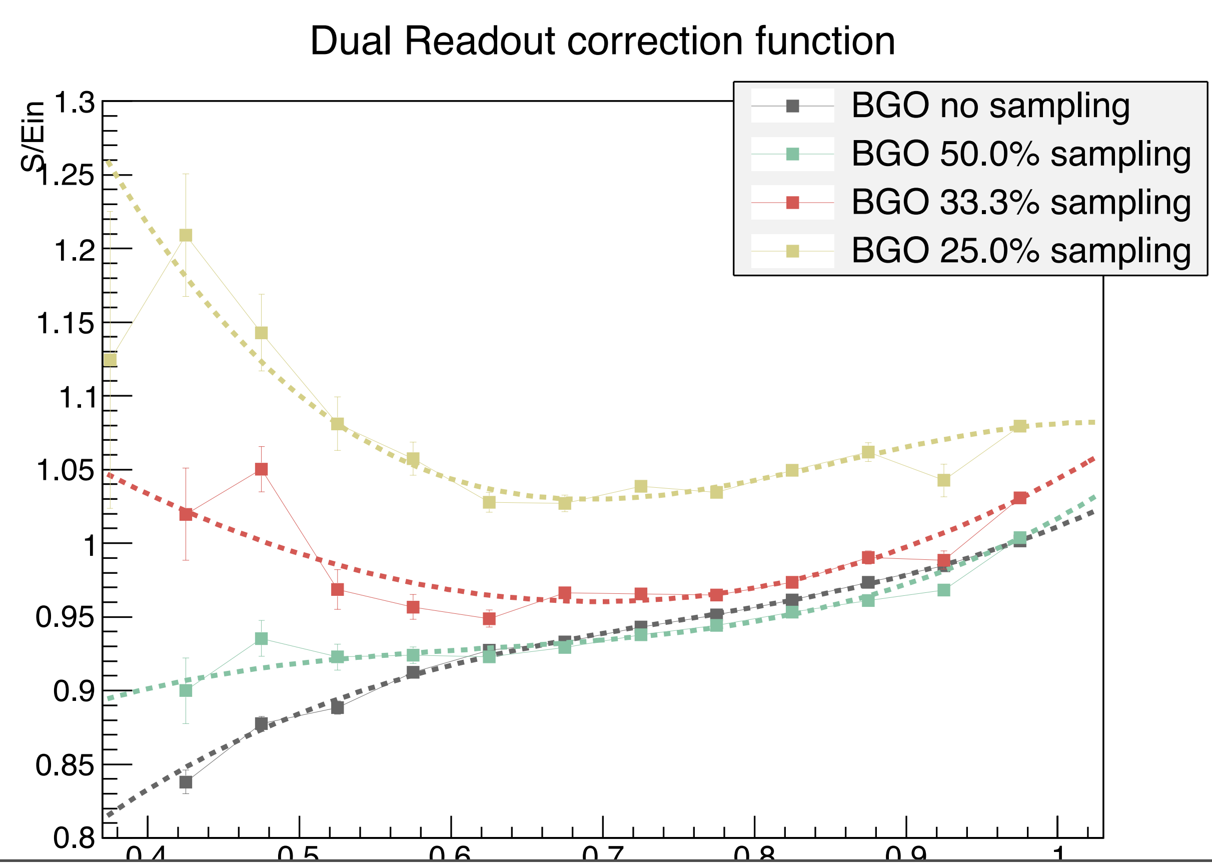
S/E & C/S plot for electrons and pions, all energies



Dual readout correction function







New calorimeter segmentation

New calorimeter segmentation

We build our calorimeter from 1 mm wide layers (longitudinally). *Previously cubes 25 mm in length.*

- We keep calorimeter volume size.
- Reduces the effect of having radiation length comparable to cell width.
- Reduces running time for CaTS.
- Reduces the amount of storage space needed for output files.

6m, 40 s	vs	3m, 48 s
14 MB		3.1 MB

New calorimeter segmentation

$5.0\ GeV\ \pi^-$

cube segmentation: $Mean = 4.318$, $\sigma = 1.753$

sheet segmentation: $Mean = 4.296$, $\sigma = 1.98$

The error margin for 100 events ~ 0.1.