Simulation Studies of a Total Absorption Dual Readout Calorimeter

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Electromagnetic fraction & hadronic response to Cherenkov and Scintillation Light

We calculate the *electromagnetic fraction* ($\langle f_{em} \rangle$ *energy deposited by any* γ*, positron, electron, or* π^0 *into the calorimeter*), the π^0 fraction ($\langle f \pi^0 \rangle$ *energy deposited by* $\pi^0{}' s$).
We then fit our results to an empirical power law:

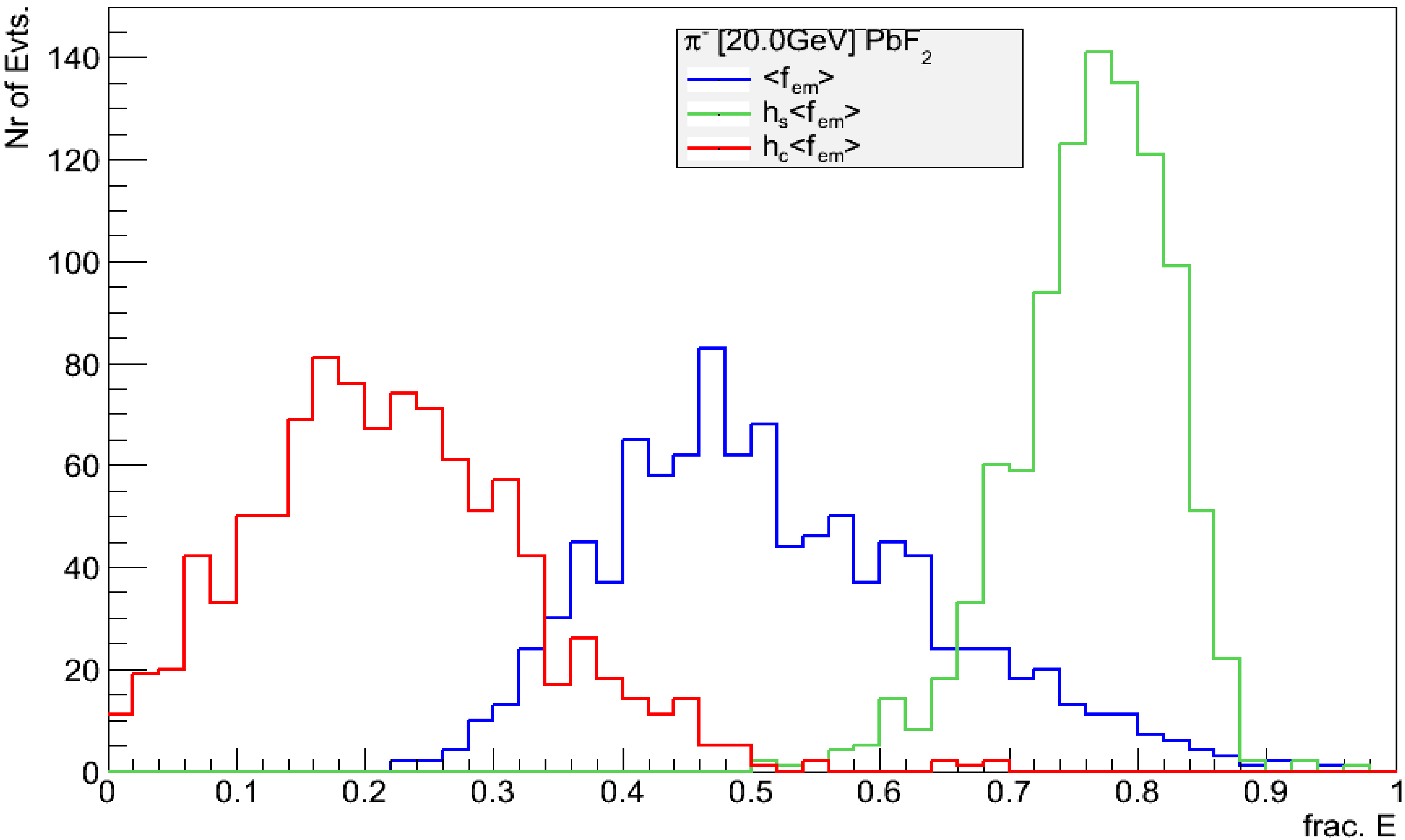
$$\langle f_{em}(\pi^0) \rangle = 1 - \left(\frac{E}{E_0}\right)^{m-1}$$

We also calculate the *hadronic response* to *scintillation* and *Cherenkov* light:

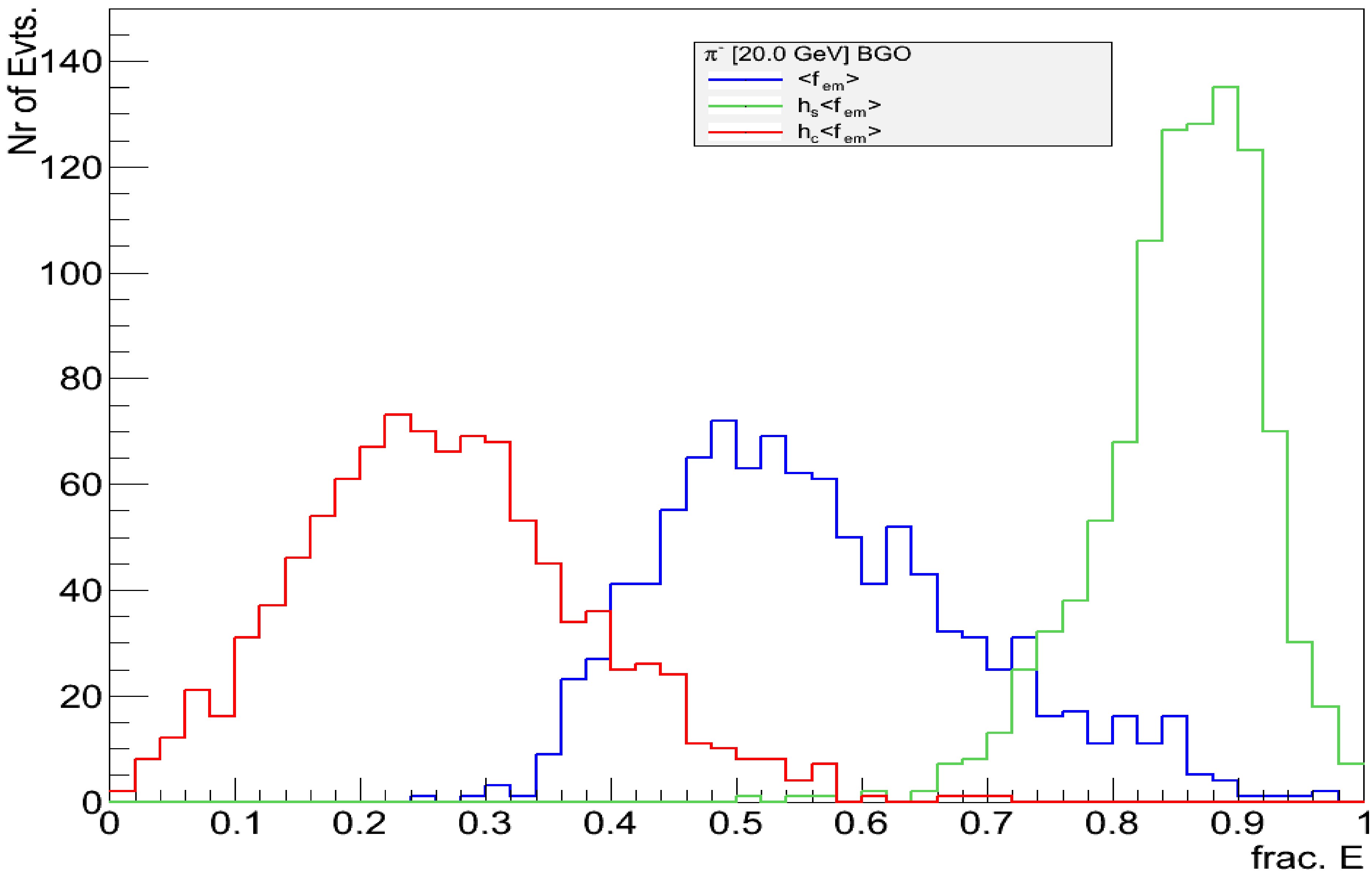
$$h_s = \left(\frac{E_{scint}}{E_i} - f_{em}\right)\frac{1}{1-f_{em}} \qquad h_c = \left(\frac{E_{Ceren}}{E_i} - f_{em}\right)\frac{1}{1-f_{em}}$$

All of these in a event-by-event basis!

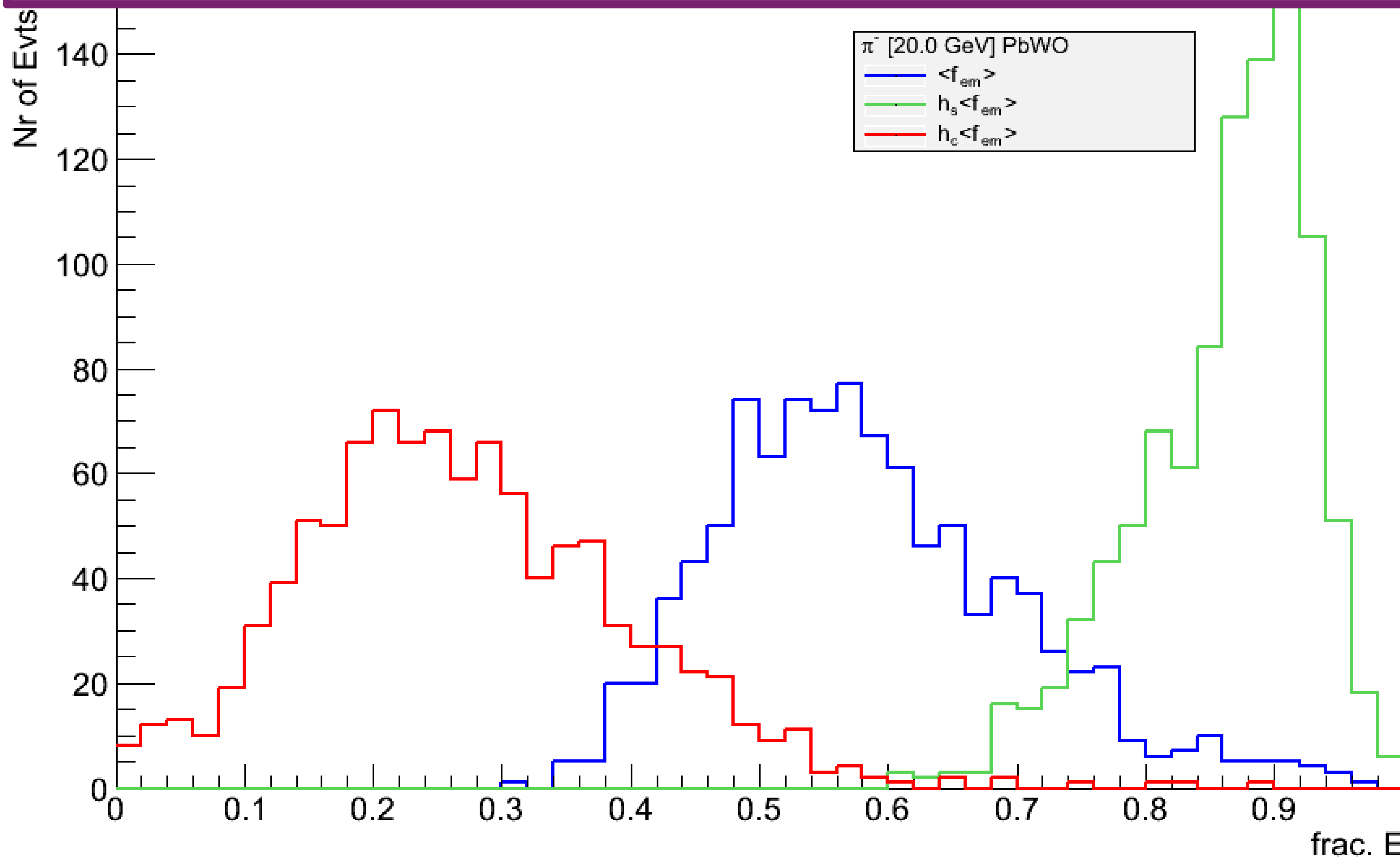
Electromagnetic fraction & hadronic response



Electromagnetic fraction & hadronic response



Electromagnetic fraction & hadronic response



Sampling Studies

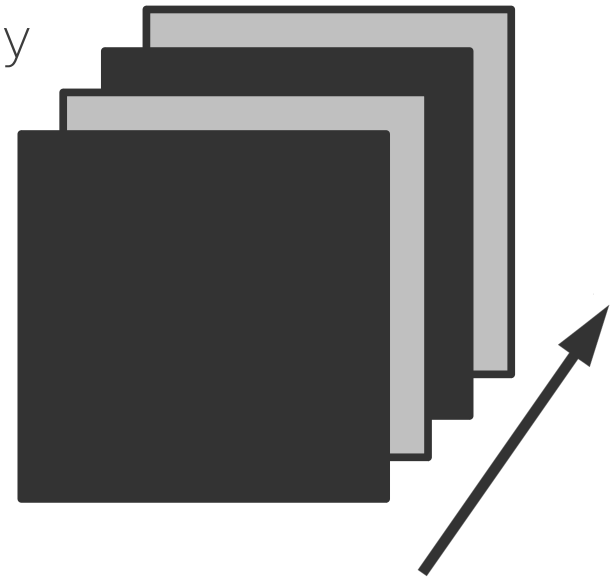
We use a *½ sampling fraction* (reading energy deposited in 50% of the total volume of the calorimeter).

Position inside the calorimeter is given by a vector *(x,y,z)* and the center of this coordinate system is at the center.

Position and layer number are related by:

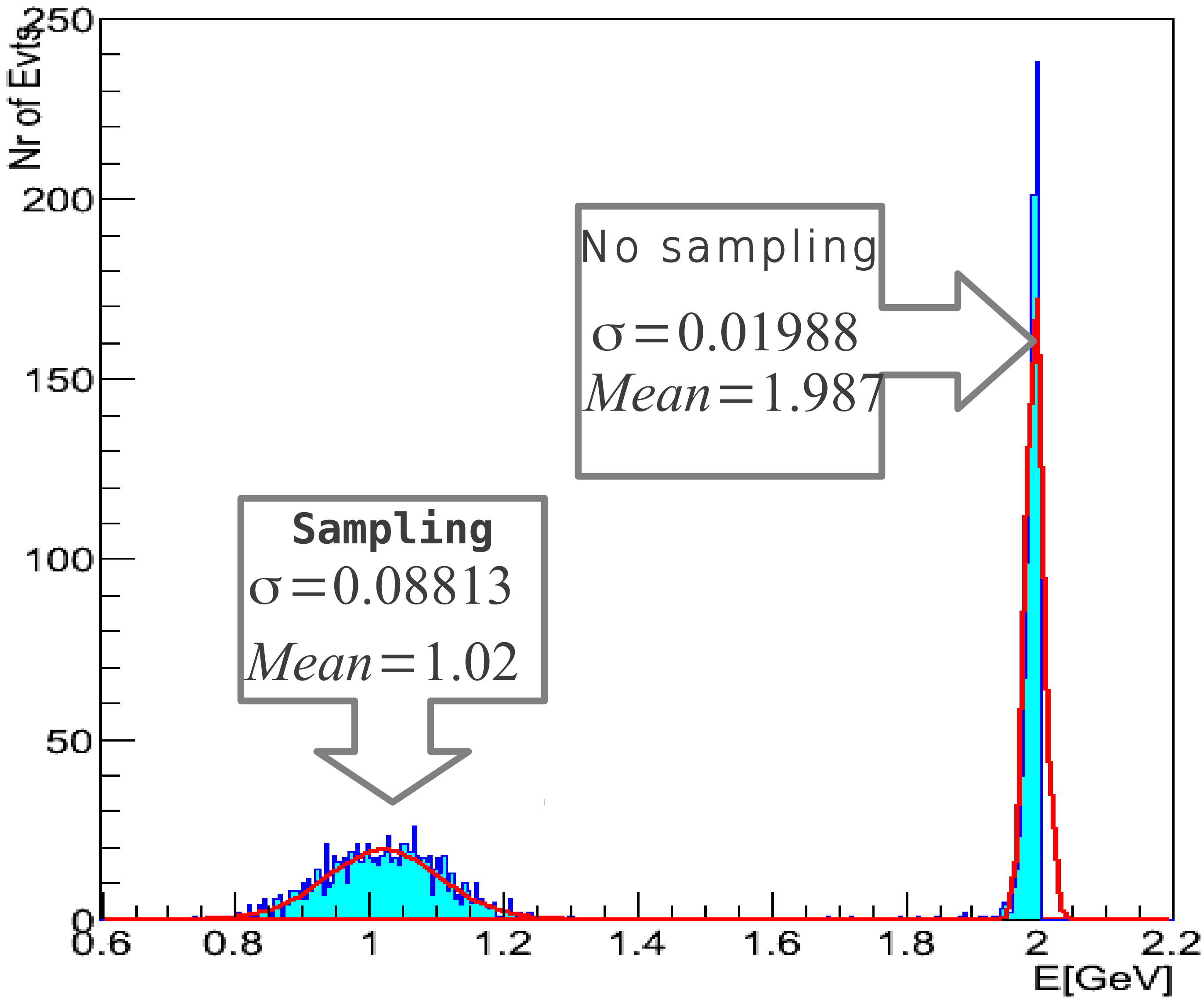
$$layer = \frac{z}{cell\ size} + \frac{number\ of\ cells}{2}$$

We read *odd layers* only (first layer being 1).

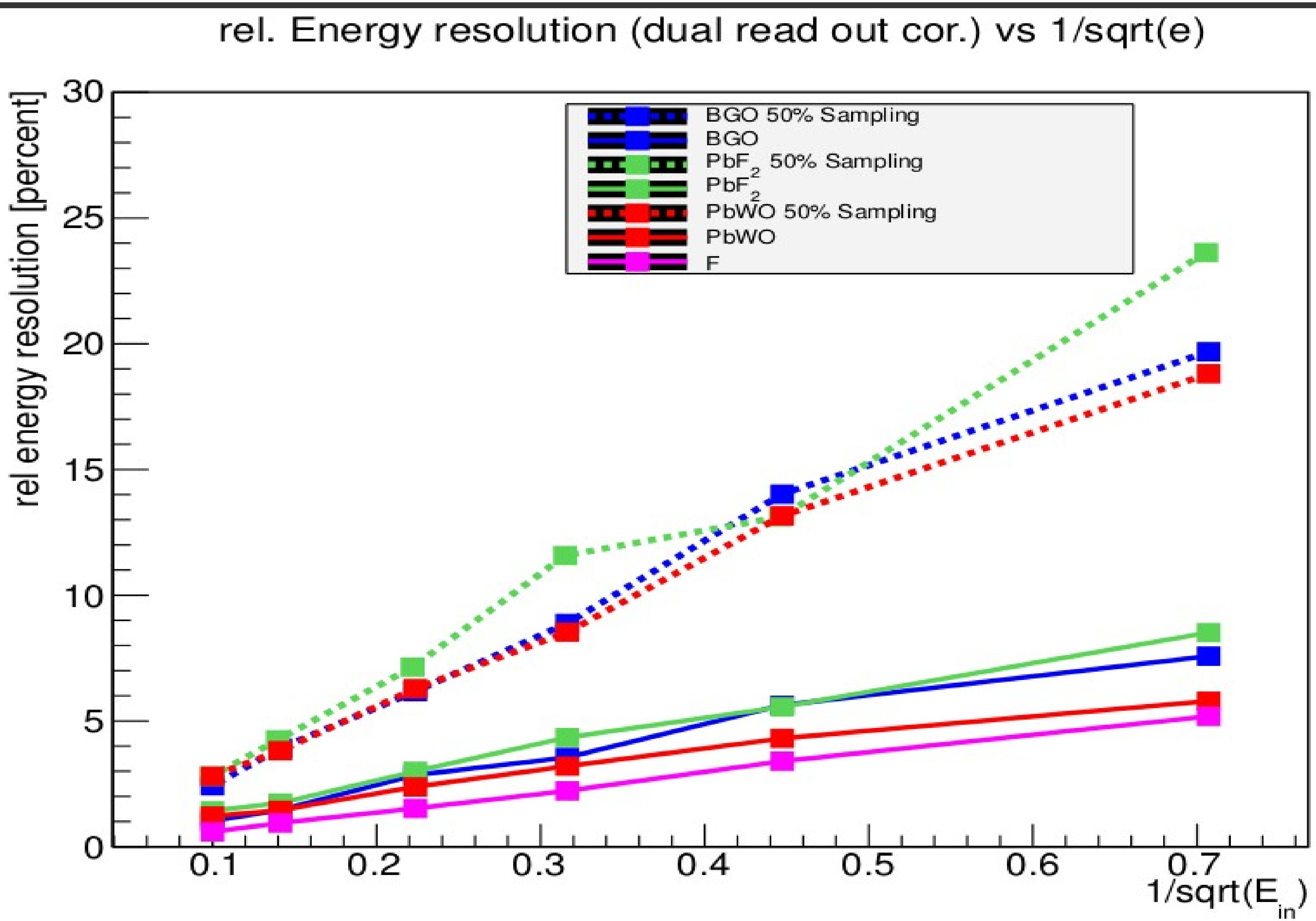


Layers in longitudinal direction *wrt* incoming beam!

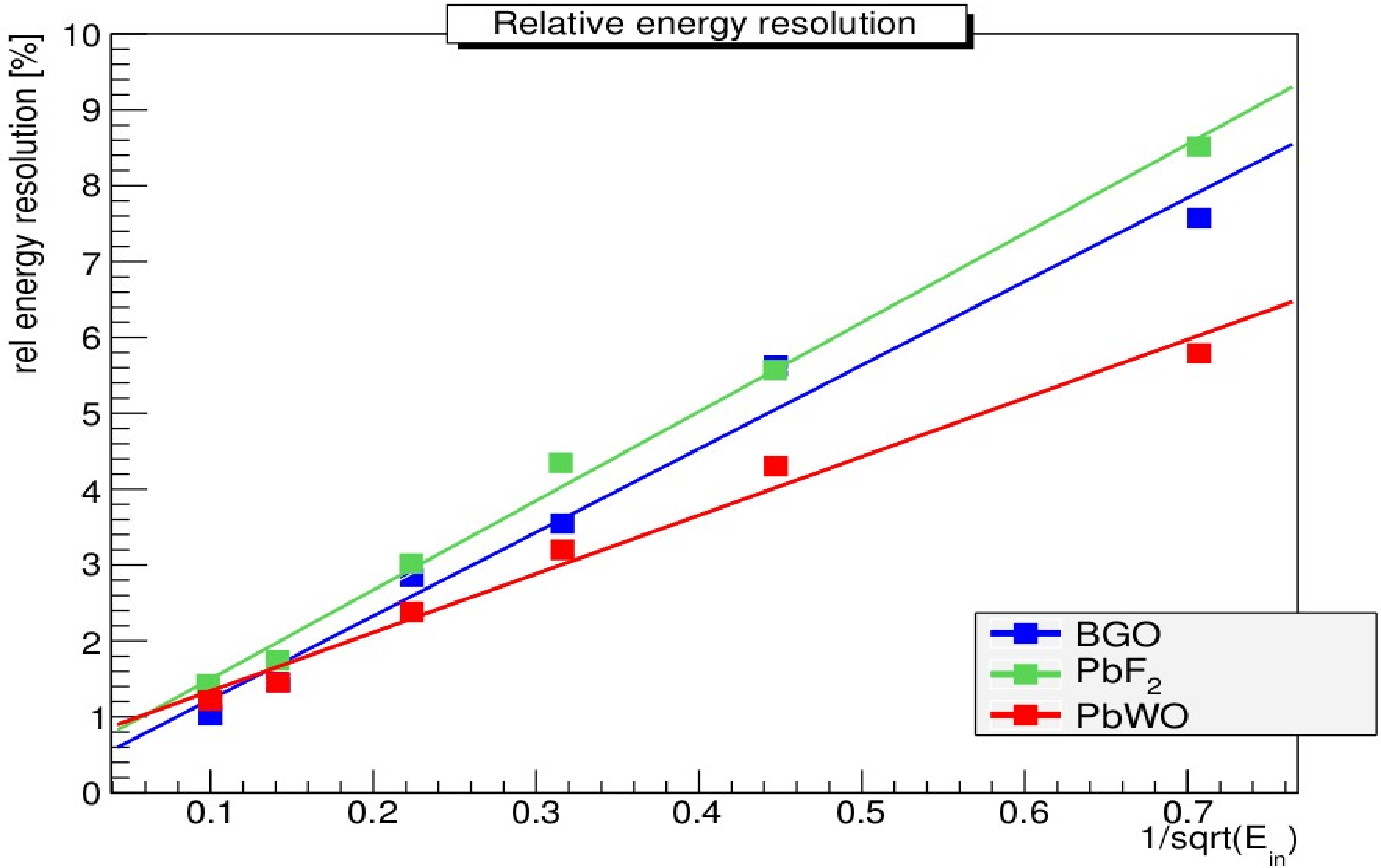
Electron energy distribution



Energy resolution



Energy resolution



Energy resolution

Energy resolution can be parameterized as a linear function:

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

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

$$\sigma_E = \sqrt{\sigma_{\text{material}} + \sigma_{sampling}}$$

Linear fit parameters for energy resolution after sampling

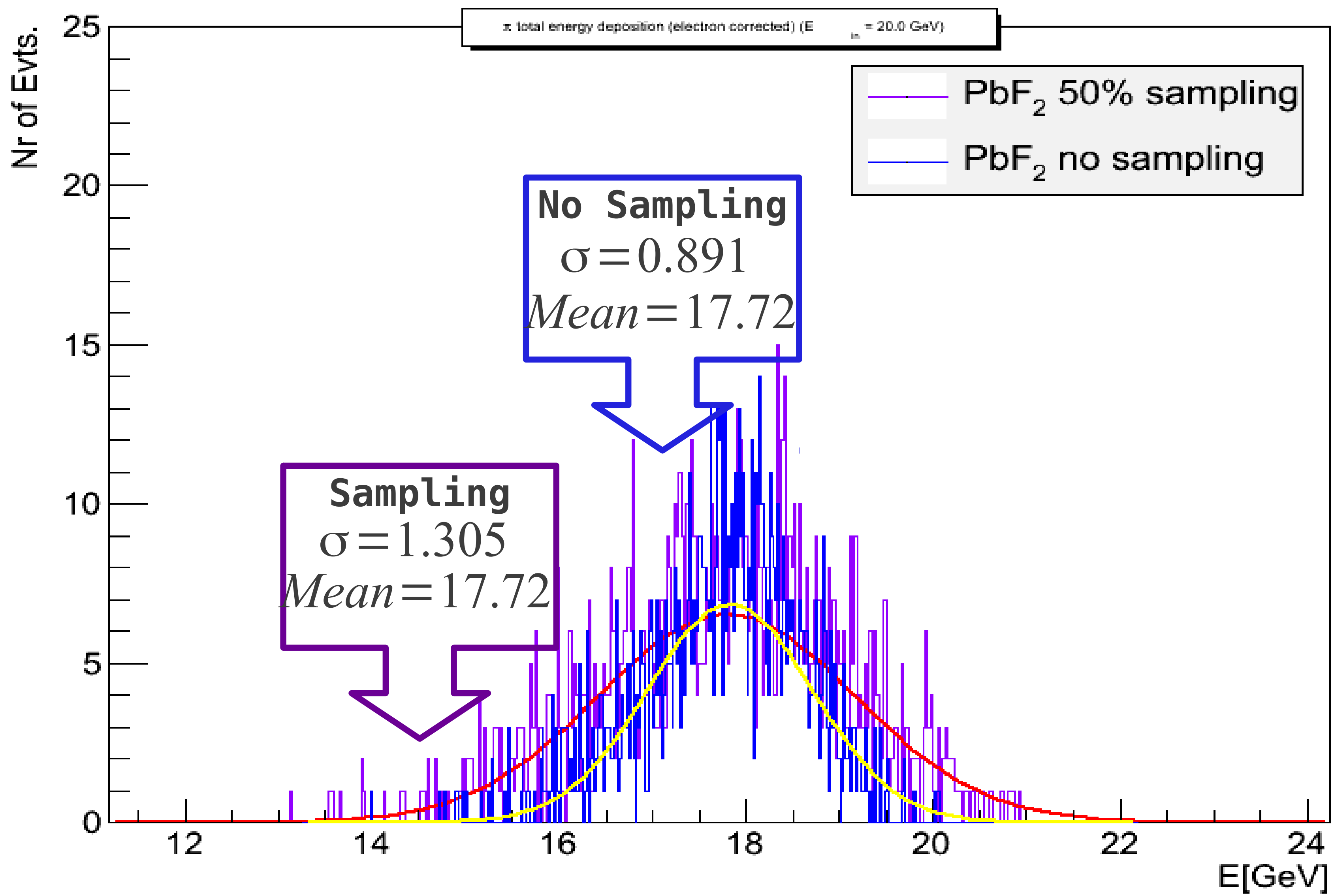
$$c_1 = -0.423$$

$$c_1 = 33.5$$

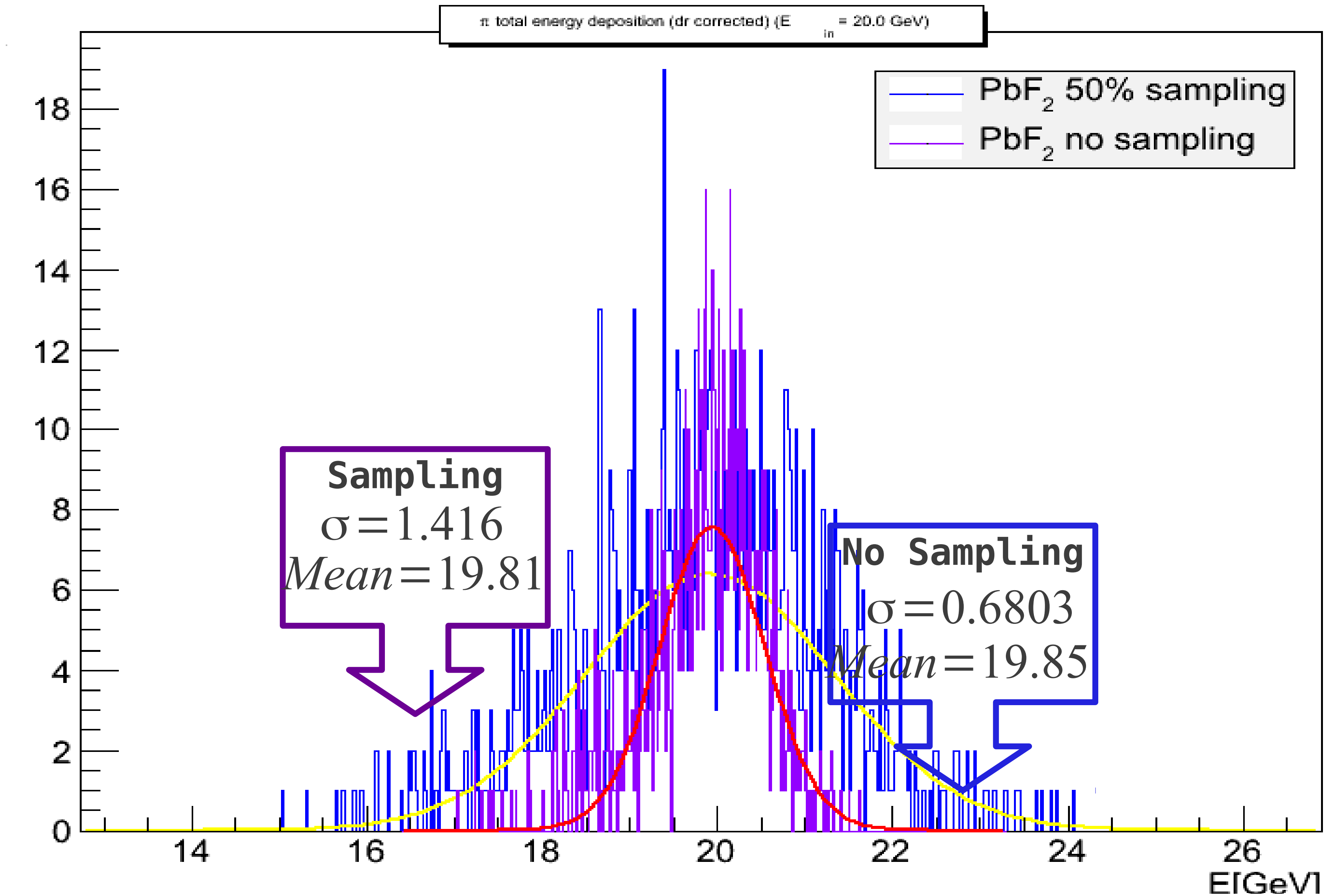
E [GeV]	$\sigma_{material}$	$\sigma_{sampling}$
2	8.51	21.65
5	5.56	13.45
10	4.34	9.19
20	2.99	6.4
50	1.73	3.95
100	1.43	2.55

All this for PbF_2!

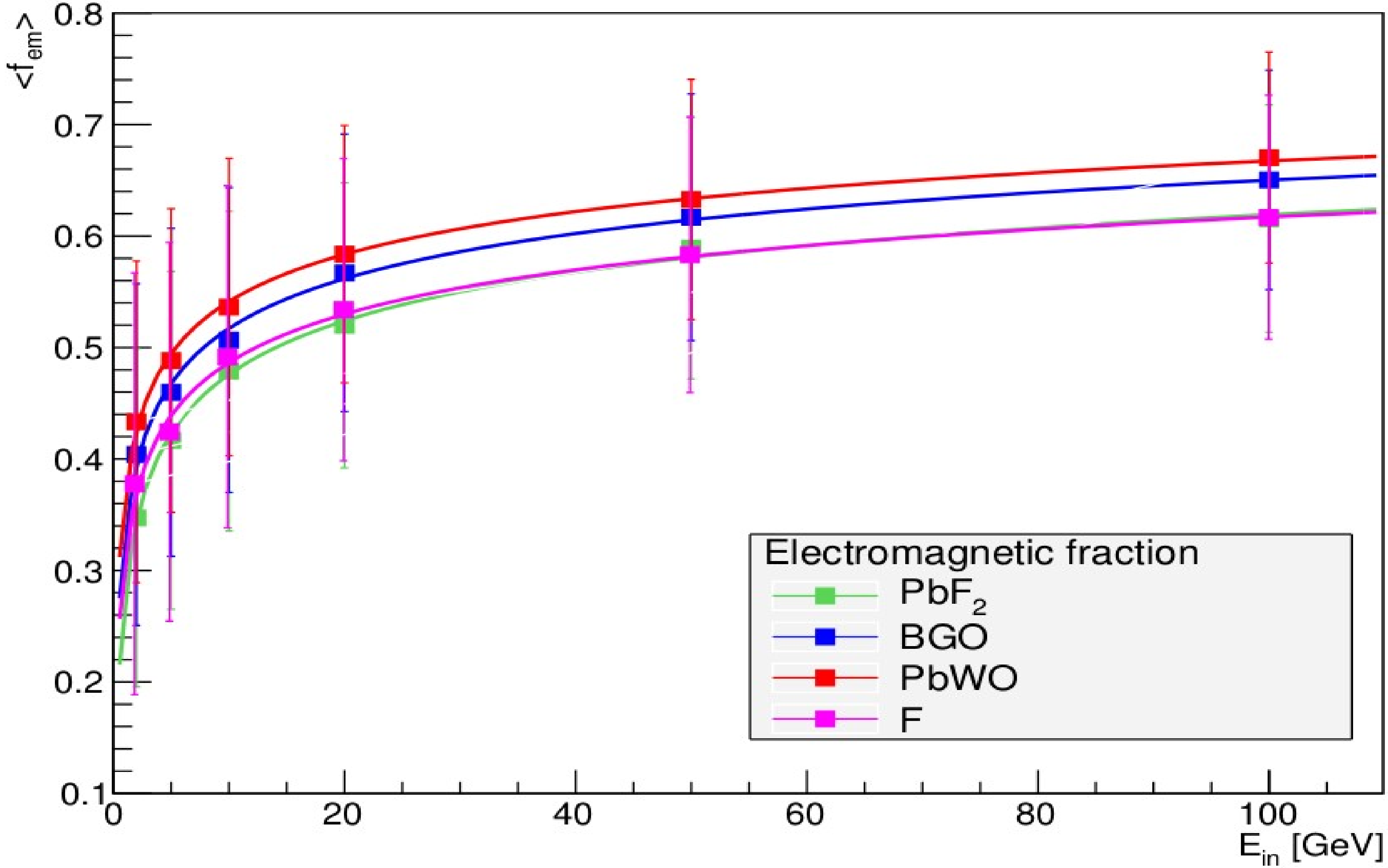
After correction to electron response:



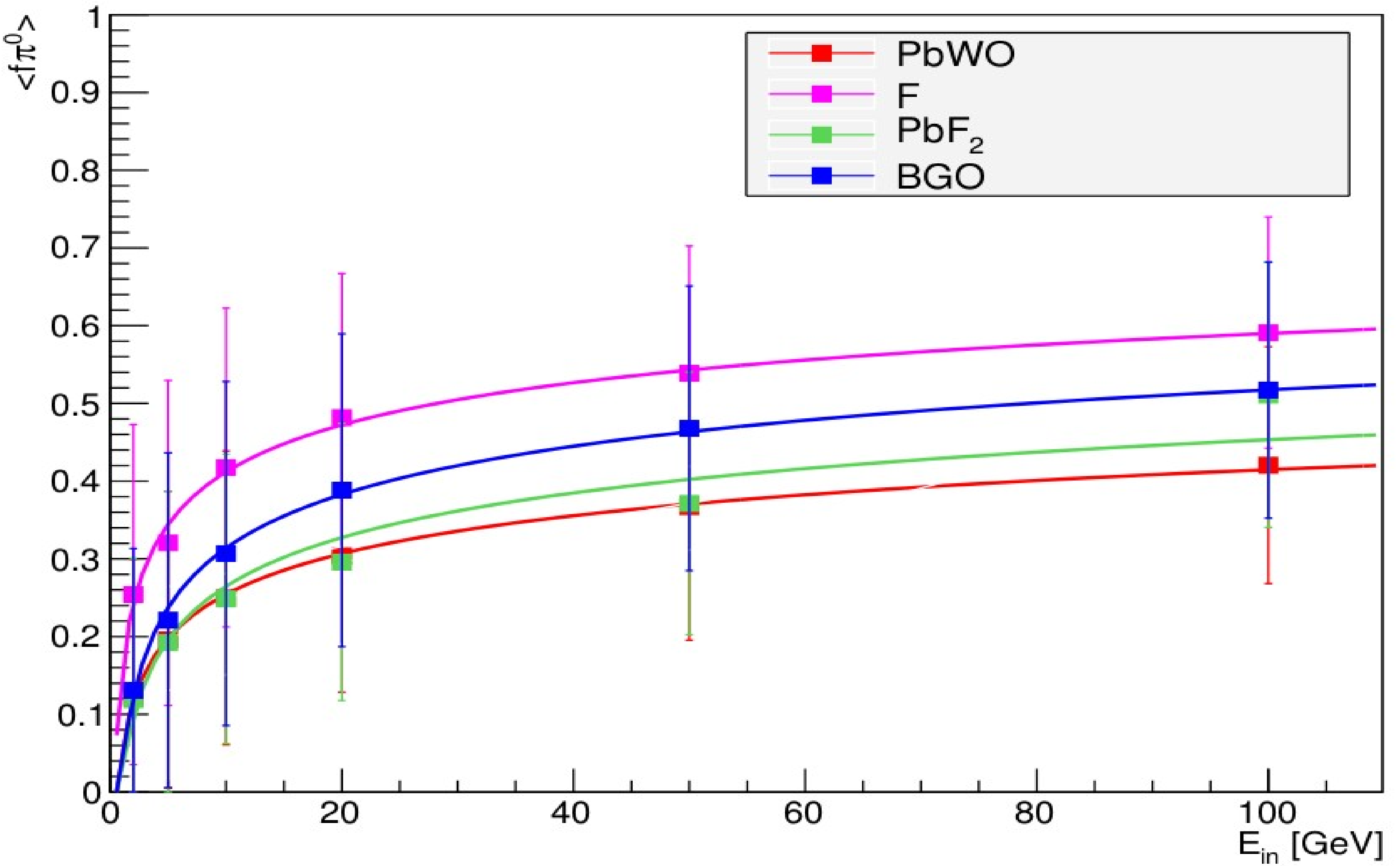
After dual readout correction:



Electromagnetic fraction



Pi0 fraction

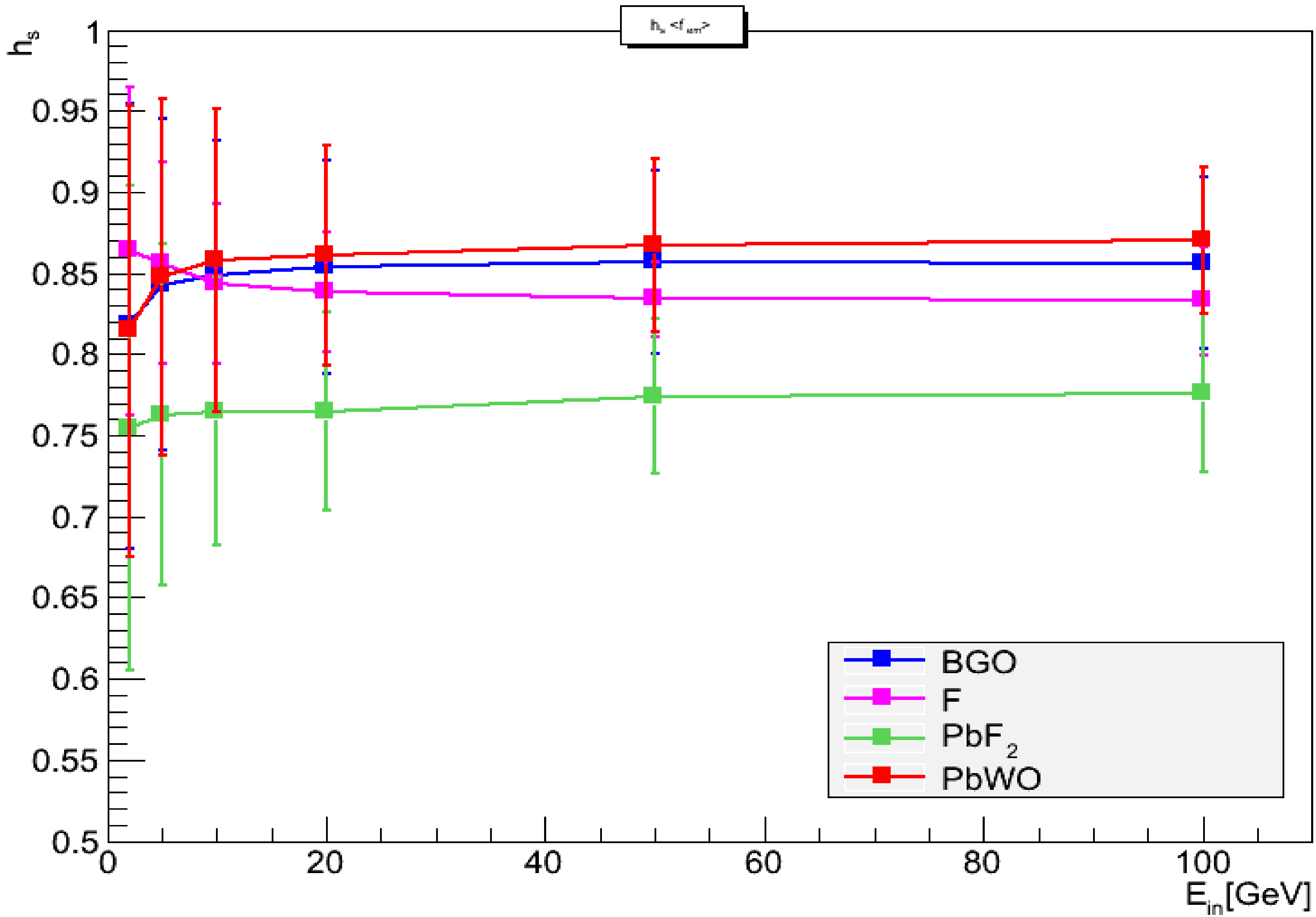


Electromagnetic & Pi0 fraction

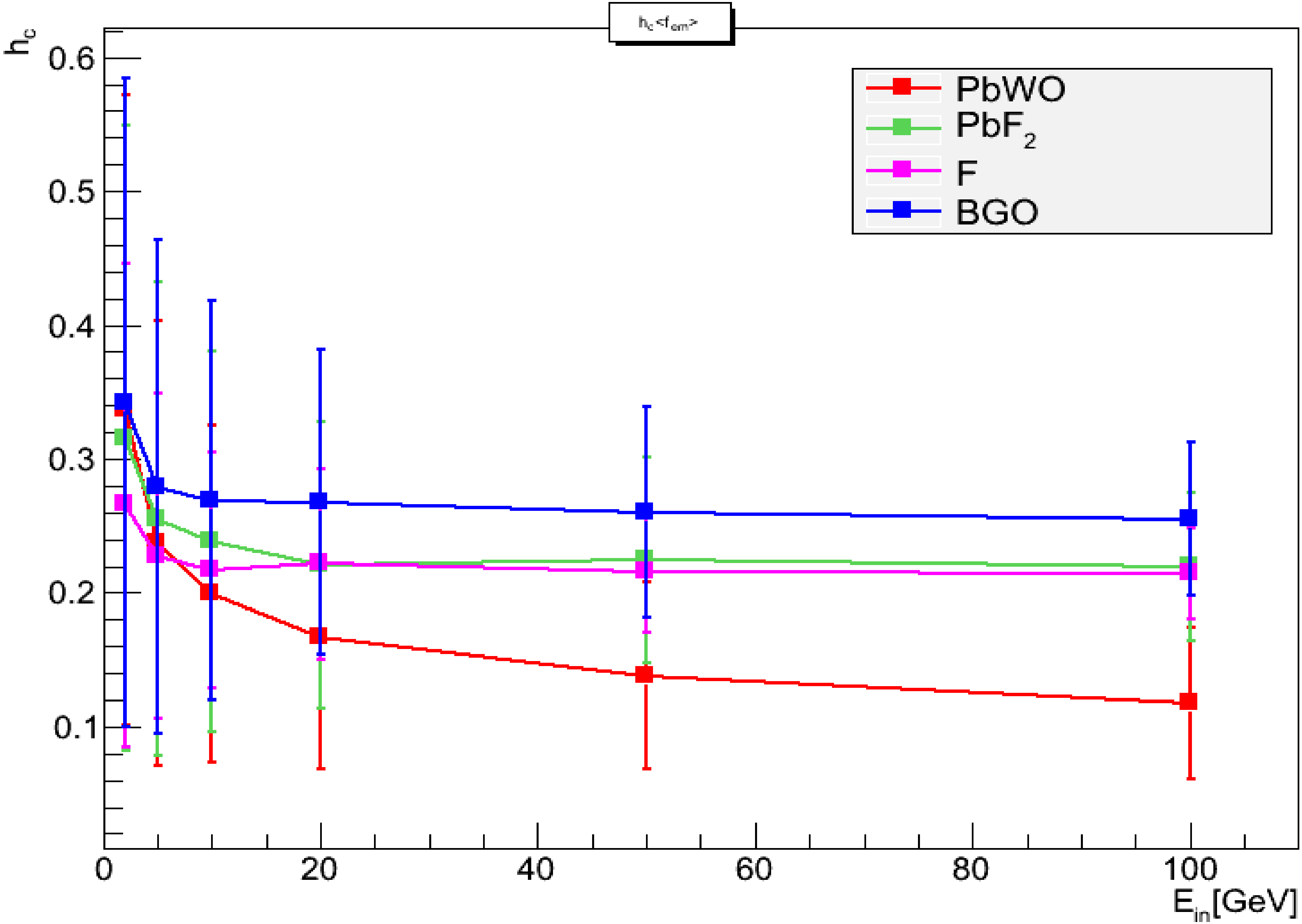
$$\langle f_{em}(\pi^0)\rangle = 1 - \left(\frac{E}{E_0}\right)^{m-1}$$

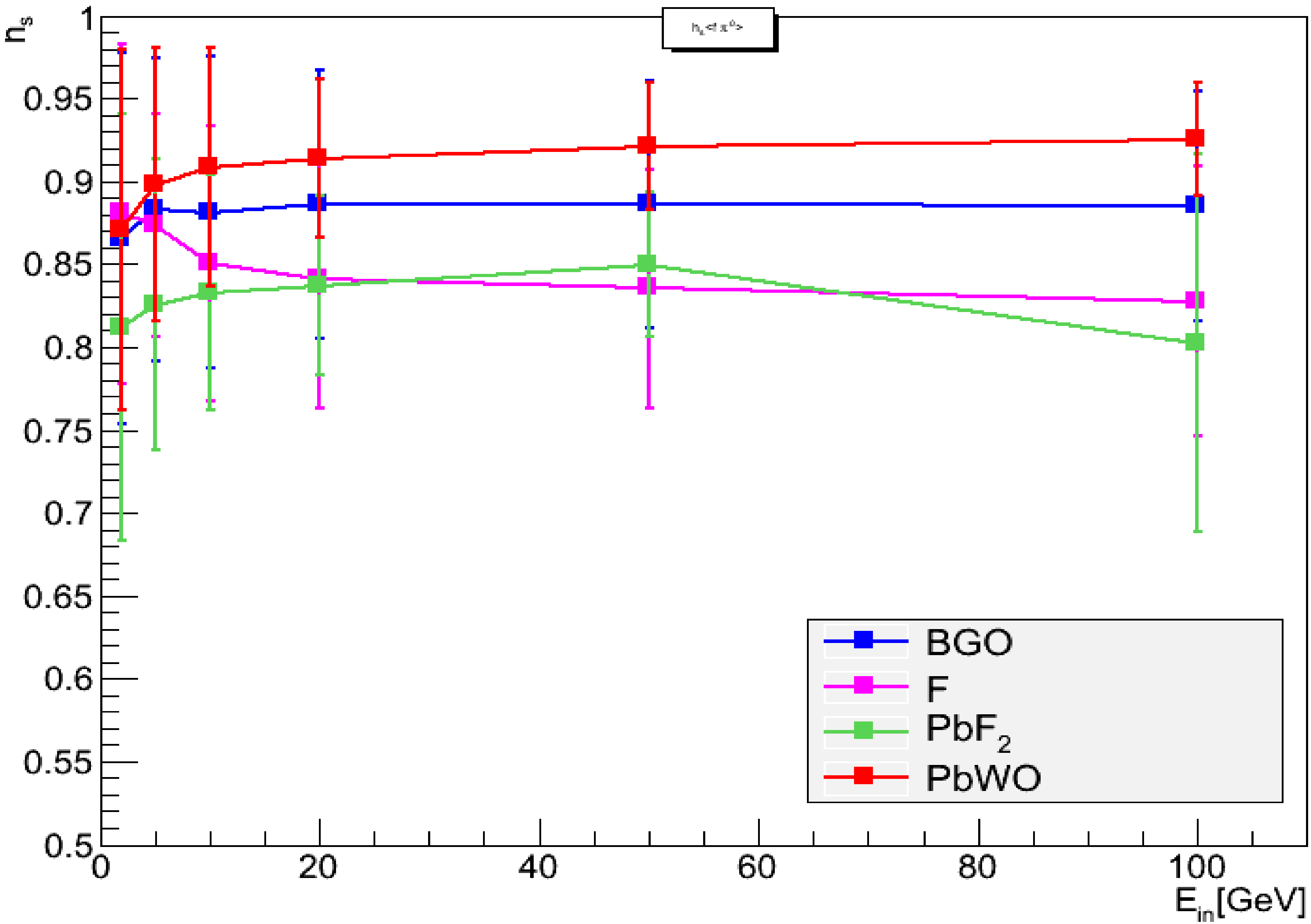
$\langle f_{em}\rangle$	E0	m
PbWO	0.614	0.895
PbF2	0.919	0.871
BGO	0.849	0.847

$\langle f_{\pi^0}\rangle$	E0	m
PbWO	0.614	0.895
PbF2	0.919	0.871
BGO	0.849	0.847

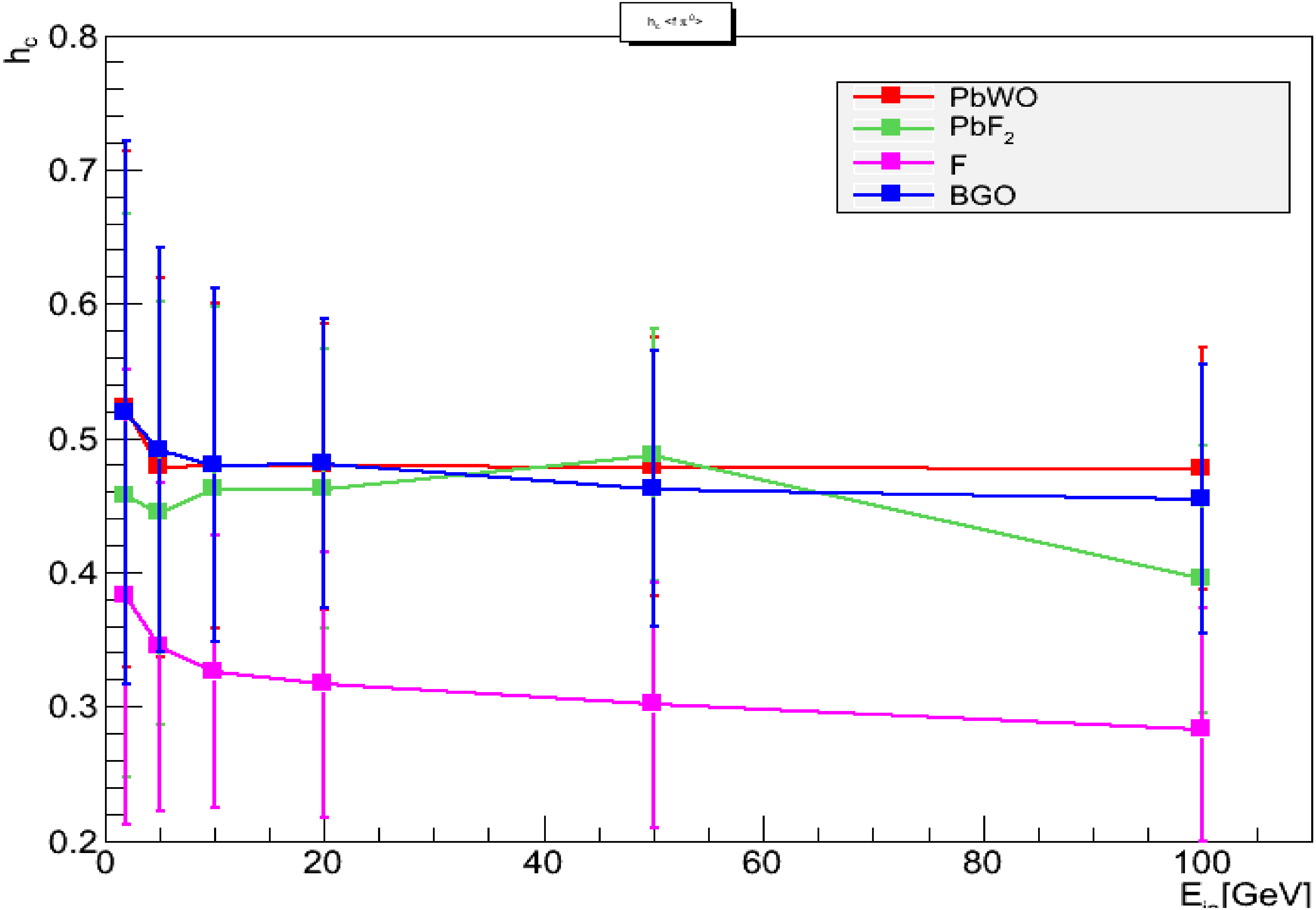


h_s
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
20
40
60
80
100
E_{in}[GeV]
BGO
F
PbF_2
PbWO


h_c<f_em>
h_c
0.6
0.5
0.4
0.3
0.2
0.1
PbWO
PbF_2
F
BGO
0
20
40
60
80
100
E_in[GeV]



n_s
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
20
40
60
80
100
E_{in}[GeV]
BGO
F
PbF_2
PbWO

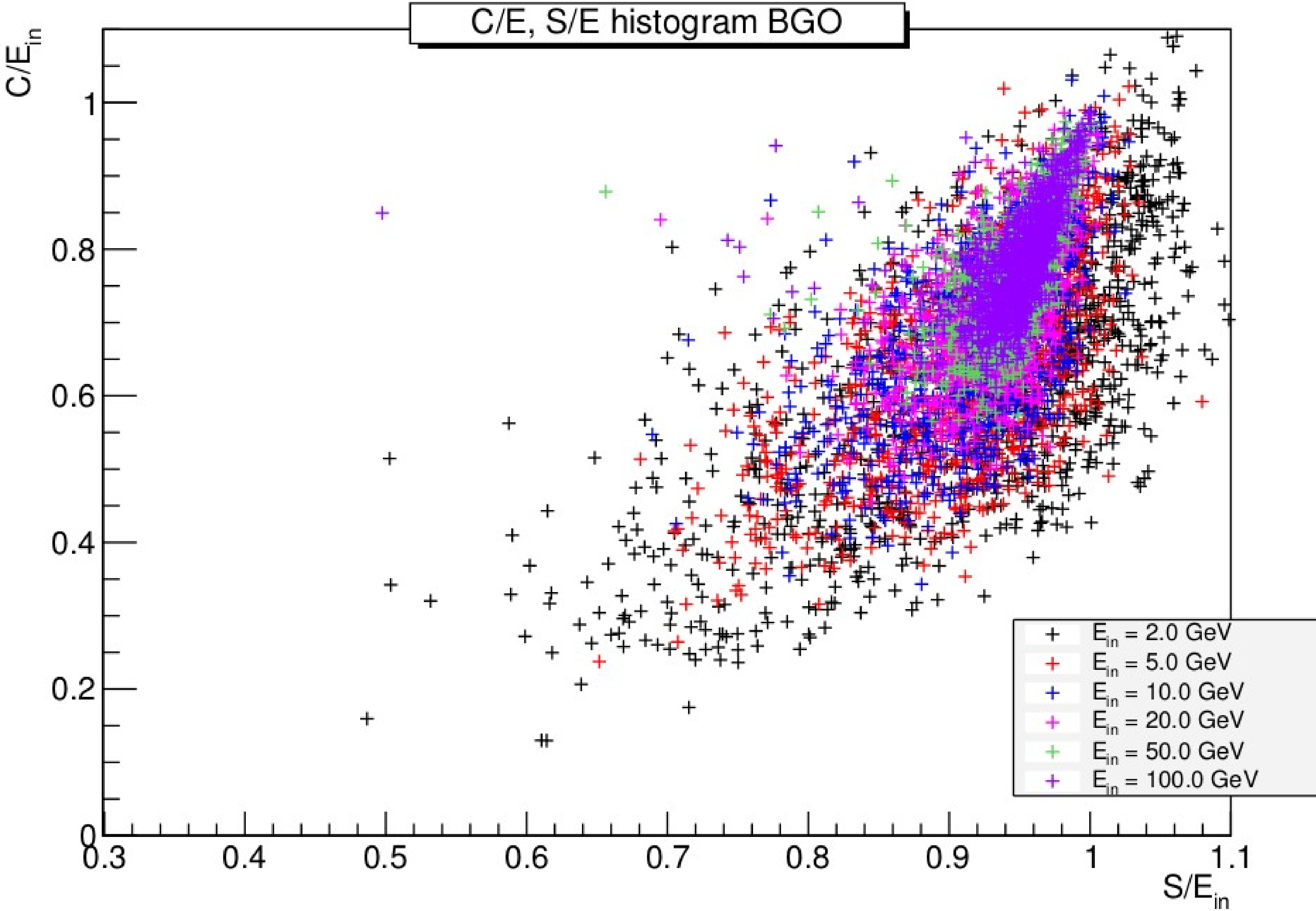


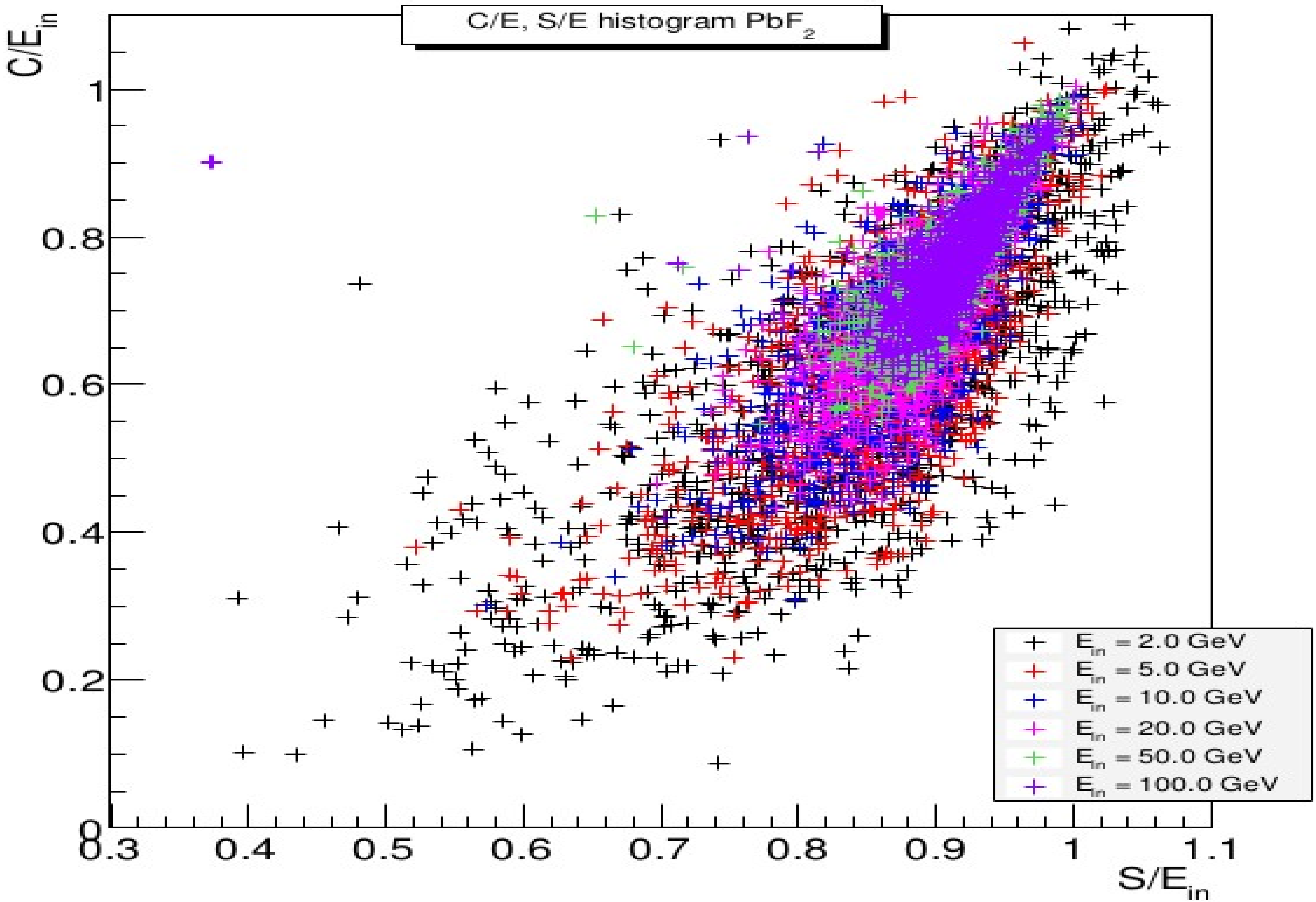
h_c <f π^0>
h_c
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
20
40
60
80
100
E_{in} [GeV]
PbWO
PbF_2
F
BGO

Values for hs & hc for electromagnetic and pi0 fractions

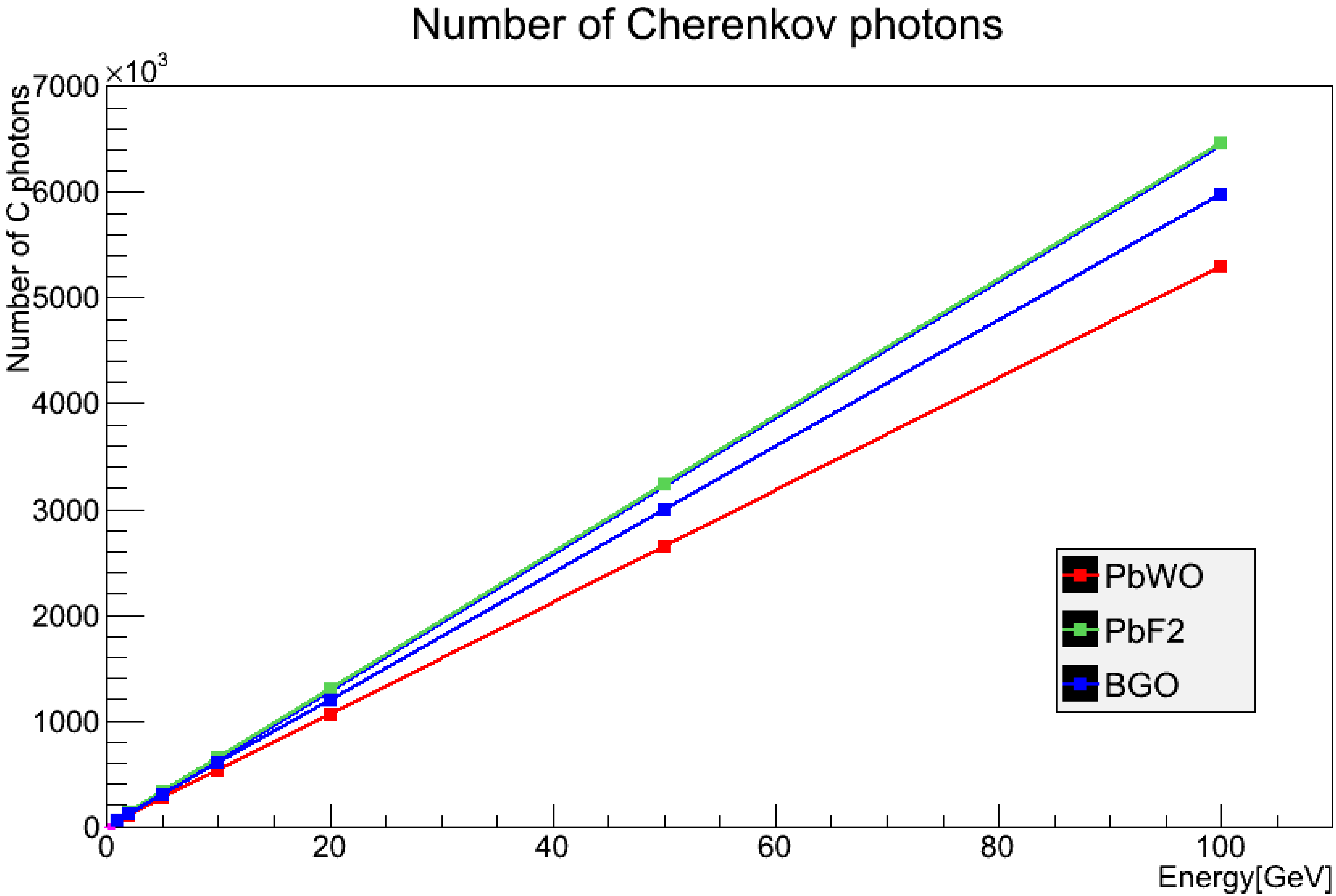
Energy [GeV]	PbF_2			BGO			PbWO		
	$\langle f_{em} \rangle$	hs	hc	$\langle f_{em} \rangle$	hs	hc	$\langle f_{em} \rangle$	hs	hc
2	0.3472	0.7537	0.3156	0.404	0.8173	0.3412	0.4333	0.8144	0.3754
5	0.4167	0.7626	0.2549	0.4599	0.8429	0.2753	0.4883	0.8473	0.2989
10	0.4787	0.7642	0.2385	0.5067	0.8484	0.2688	0.5363	0.8579	0.2855
20	0.5199	0.7642	0.2205	0.5669	0.8536	0.2674	0.5937	0.8608	0.2706
50	0.5892	0.7733	0.225	0.6169	0.8571	0.2593	0.6328	0.8676	0.2662
100	0.6156	0.7753	0.2193	0.6550	0.8562	0.2546	0.6703	0.8706	0.2685

Energy [GeV]	PbF_2			BGO			PbWO		
	hs	hc	$\langle f_{\pi^0} \rangle$	hs	hc	$\langle f_{\pi^0} \rangle$	hs	hc	$\langle f_{\pi^0} \rangle$
2	0.8113	0.4571	0.1189	0.8654	0.5185	0.1309	0.8706	0.5656	0.1213
5	0.8521	0.4441	0.1924	0.883	0.4905	0.2211	0.898	0.5379	0.196
10	0.8327	0.4615	0.2485	0.8812	0.4795	0.3069	0.9082	0.5504	0.2497
20	0.8362	0.4621	0.2959	0.8858	0.4803	0.3883	0.9139	0.5589	0.3039
50	0.8493	0.4873	0.3714	0.8862	0.4615	0.4668	0.921	0.5692	0.3673
100	0.8015	0.3944	0.5109	0.8852	0.4538	0.5172	0.9247	0.5801	0.4205


C/E, S/E histogram BGO
C/E_in
S/E_in
0
0.2
0.4
0.6
0.8
1
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
E_in = 2.0 GeV
E_in = 5.0 GeV
E_in = 10.0 GeV
E_in = 20.0 GeV
E_in = 50.0 GeV
E_in = 100.0 GeV



C/E, S/E histogram PbF_2
C/E_{in}
S/E_{in}
0
0.2
0.4
0.6
0.8
1
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
E_{in} = 2.0 GeV
E_{in} = 5.0 GeV
E_{in} = 10.0 GeV
E_{in} = 20.0 GeV
E_{in} = 50.0 GeV
E_{in} = 100.0 GeV


Number of Cherenkov photons
×10³
Number of C photons
7000
6000
5000
4000
3000
2000
1000
0
0
20
40
60
80
100
Energy[GeV]
PbWO
PbF2
BGO