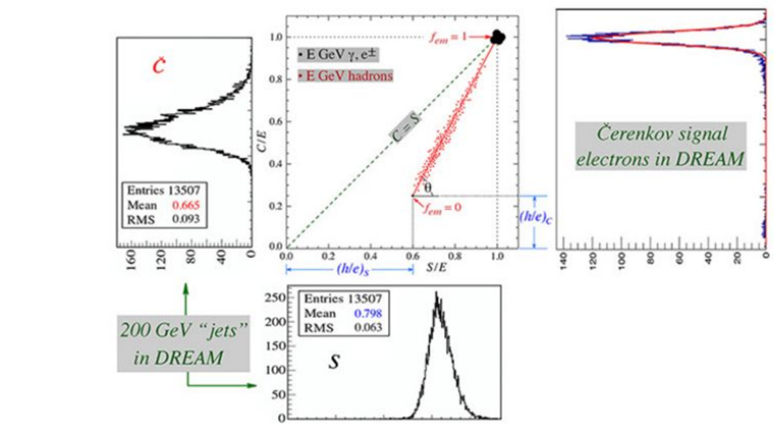
Working on understanding of Dual Readout correction



As discussed in the draft paper https://www.overleaf.com/read/yrryzxmkfztd#36f123 , if this is all there is, you can predict the resulting dual-readout corrected resolution using a simple formula

$$S = E_{true}(f + (1-f)h_s)$$

$$C = E_{true}(f + (1-f)h_c)$$

$$\cot\theta = \frac{1-(h/e)_S}{1-(h/e)_C} = \chi$$

$$E = \frac{S - \chi C}{1-\chi}$$

$$\sigma_E = \frac{1}{h_s - h_c}\sqrt{(1-h_c)^2\sigma_s^2 + (1-h_s)^2\sigma_c^2 - 2(1-h_s)^2(1-h_c)^2 f_{res}^2 \cdots}$$

$$\sigma_E = \sqrt{\frac{\sigma_s^2}{(1-\chi)^2} + \frac{\chi^2\sigma_c^2}{(1-\chi)^2} - 2\frac{(h_s-h_c)^2\chi^2 f_{res}^2}{(1-\chi)^4}}$$

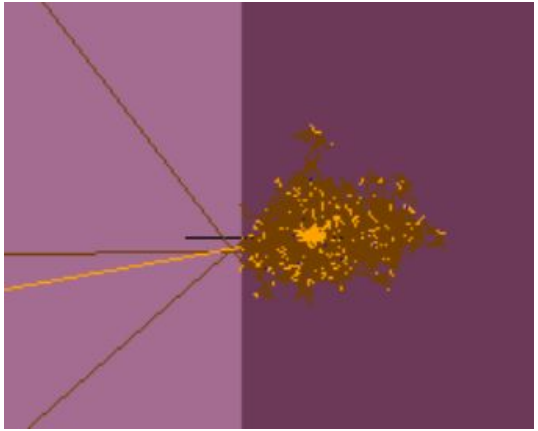
$$h_s = \frac{<S> - <f>}{1 - <f>} \qquad (13)$$

and

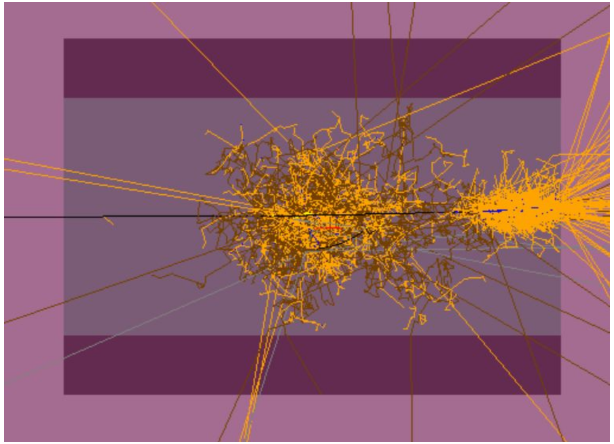
$$h_c = \frac{<C> - <f>}{1 - <f>} \qquad (14)$$

Does this work in reality? Try for several different detectors (with variations)

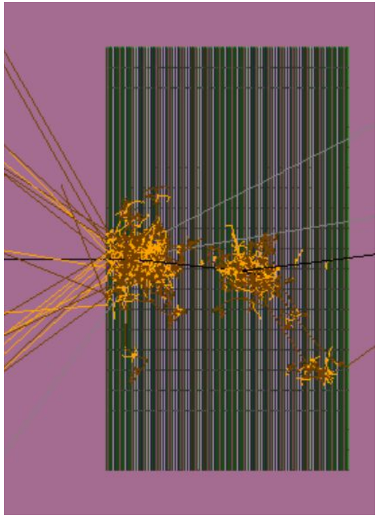
Pure crystal



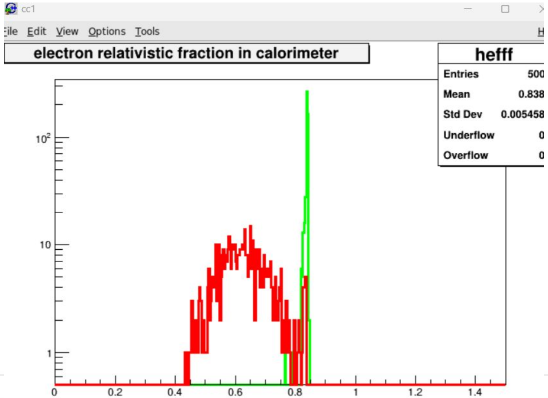
fiber

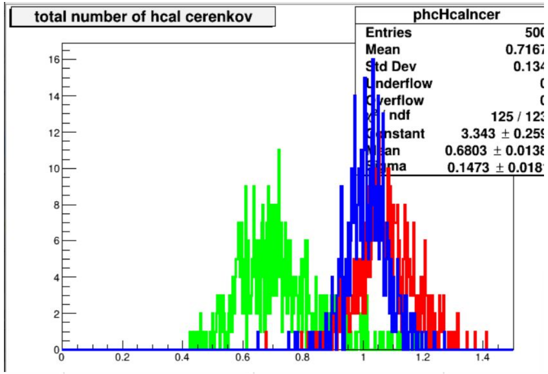


sampling



Example: fiber





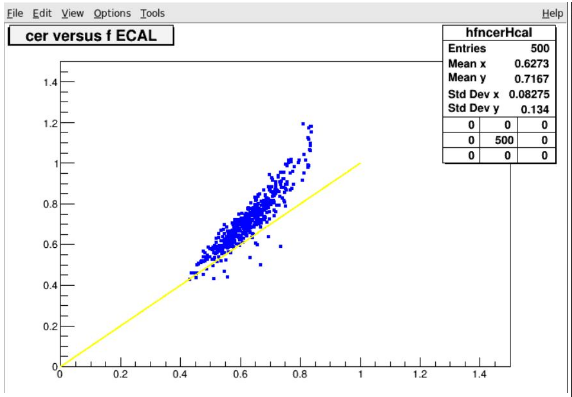
https://docs.google.com/spreadsheets/d/1AoCcL5XvGohQQqpohezopCMmQso9FfMwVF6cv5fjAAs/edit?usp=sharing

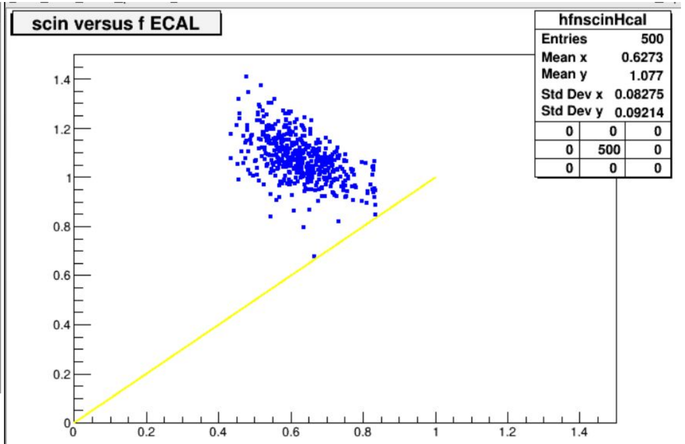
	f_mean	f_rms		mean scint	rms scint		mean cer	rms cer		mean dual	rms dual	
smaller	0.644	0.073	0.113354037	0.8	0.0456	0.057	0.6338	0.09638	0.1520668981	0.992	0.0358	0.03608870968
larger	0.634	0.0687	0.108359621	0.91	0.0325	0.03571428571	0.674	0.1035	0.1535608309	0.99	0.0293	0.0295959596
middle start	0.64	0.0633	0.09890625	1.07	0.026	0.02429906542	0.69	0.0908	0.1315942029	1	0.0342	0.0342
big samp	0.59	0.077	0.130508474	1.13	0.1086	0.09610619469	0.65	0.13	0.2	1	0.0623	0.0623
small samp	0.66	0.086	0.130303030	0.752	0.15	0.1994680851	0.51	0.2	0.3921568627	0.95	0.283	0.2978947368
fiber	0.623	0.0775	0.124398073	1.06	0.0807	0.07613207547	0.684	0.137	0.2002923977	1.01	0.0686	0.06792079208
big samp edge cut												

	hs	hc	(1-hc)^2sigm	(1-hs)^2sigma_c^2	sum	sqrt(sum)	2(1-hs)^2(1-hc)^2frms^2	prediction	measured/predic	dual/scint
smaller	0.4382022472	-0.02865168539	0.002200221	0.002931796617	0.00513201794	0.07163810397	0.003559363932	0.0849445601	0.4248501568	0.6331352575
larger	0.7540983607	0.1092896175	0.000837991	0.000647744222	0.001485735988	0.03854524598	0.0004528343335	0.0498423567	0.5937913364	0.8286868687
middle start	1.194444444	0.1388888889	0.000501262	0.000311718642	0.000812980987	0.02851282146	0.0002246709286	0.02297851936	1.488346549	1.407461538
big samp	1.317073171	0.1463414634	0.008594646	0.001699048186	0.01029369482	0.1014578475	0.0008687579912	0.0829243056	0.7512875695	0.6482412523
small samp	0.2705882353	-0.4411764706	0.046732266	0.0212816609	0.06801392734	0.2607947993	0.01634582149	0.3193558098	0.9327988648	1.493445614
fiber	1.159151194	0.1618037135	0.004575499	0.0004754019236	0.005050901656	0.07106969576	0.0002137689706	0.06973447016	0.9739916561	0.892144233

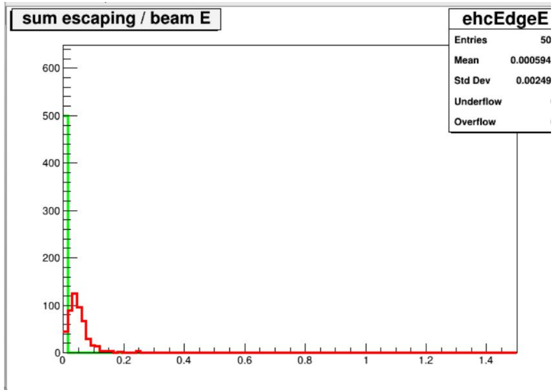
Seems to work. But doesn't work for others

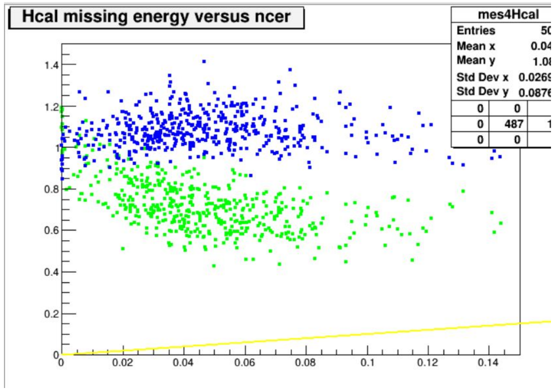
What contributes to correlations between S and C? Let's look at the fiber calorimeter



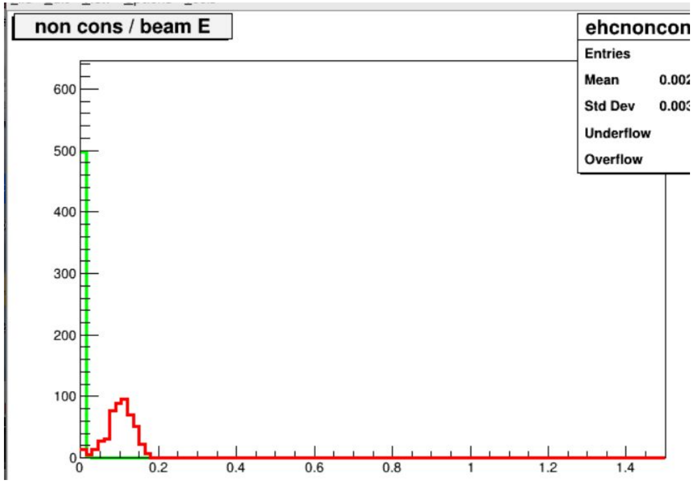


They are correlated via f, with different correlations (needed for Dual trick to work)

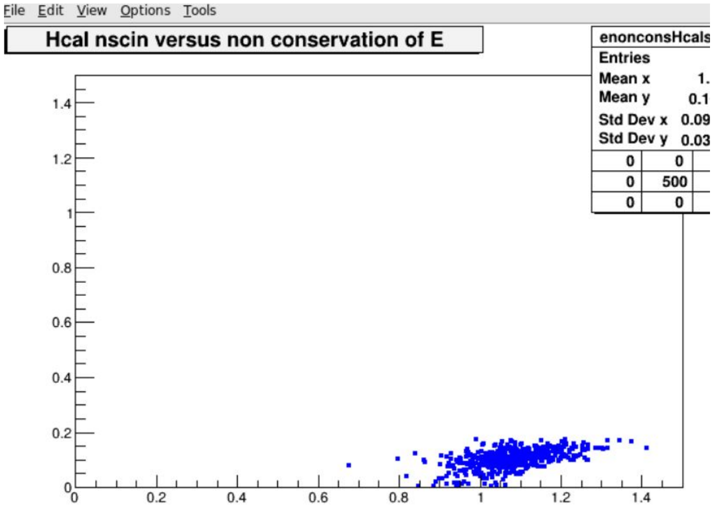


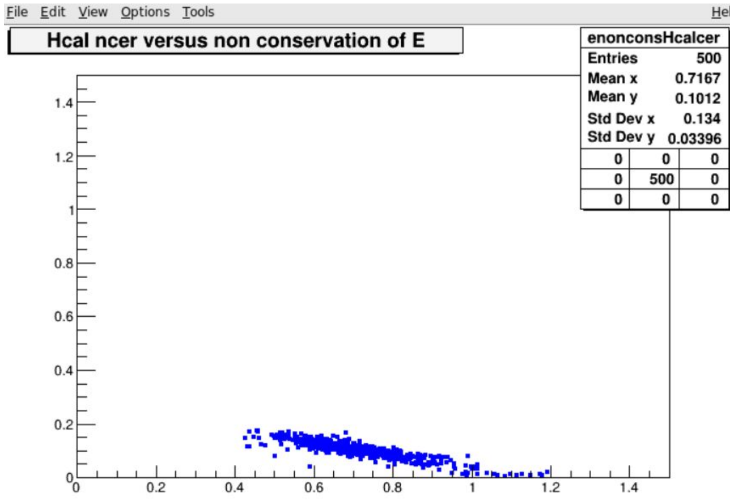


They are also correlated (with different correlations) via energy leaving the calorimeter and hitting the edge detector



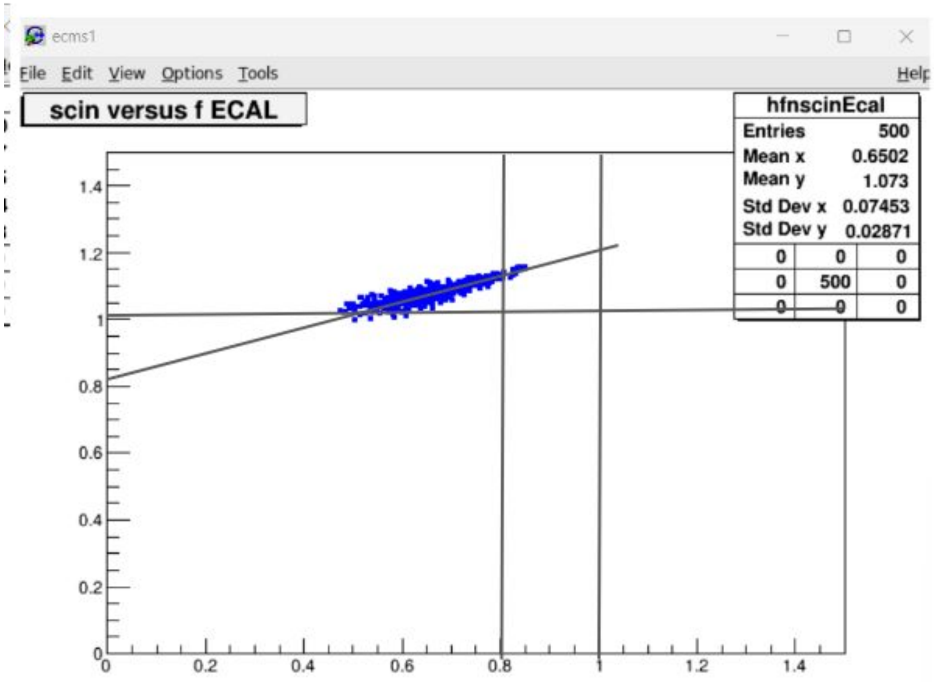
I also calculate another variable, which is the beam energy - the edge energy - all ionizing energy deposits. I call it "non conservation" and attribute it to energy losses to nuclear binding energy



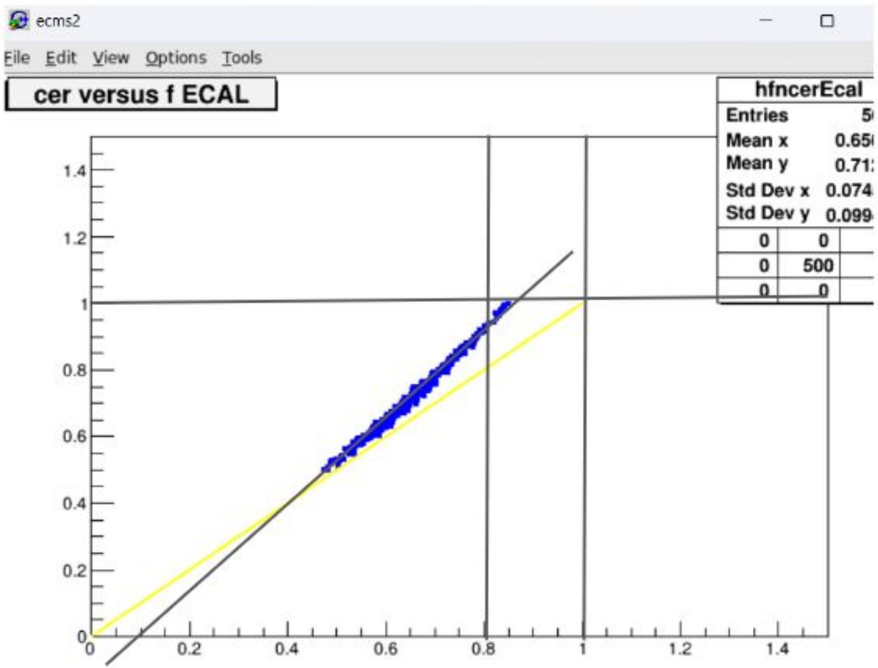


These plots look very different for the different calorimeters. And the dual readout formula assumes that the correlation comes only through f. But if there are additional sources of correlation, the formula will underpredict the improvement due to the dual readout correction.

The formula as I use it assumes that for a pure EM shower, the calibration for a 20 GeV electron and a 20 GeV pion are the same. This does not seem to be true for a large crystal ecal where the particle starts in the center of the detector



ecms1
File Edit View Options Tools Help
scin versus f ECAL
hfnscinEcal
Entries 500
Mean x 0.6502
Mean y 1.073
Std Dev x 0.07453
Std Dev y 0.02871
0 0 0
0 500 0
0 0 0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4



ecms2
File Edit View Options Tools
cer versus f ECAL
hfncerEcal
Entries
Mean x
Mean y
Std Dev x
Std Dev y
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0 500
0 0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4

Summary: The dual readout correction is complicated and I need to think a bit more before I understand it completely and its relation to all the underlying physics

For more plots, see https://docs.google.com/presentation/d/1Qcvmiye53-4aa8COdn4I61vRrcqEoECRSiHxxOVnf-0/edit?usp=sharing