Dual Readout Resolution

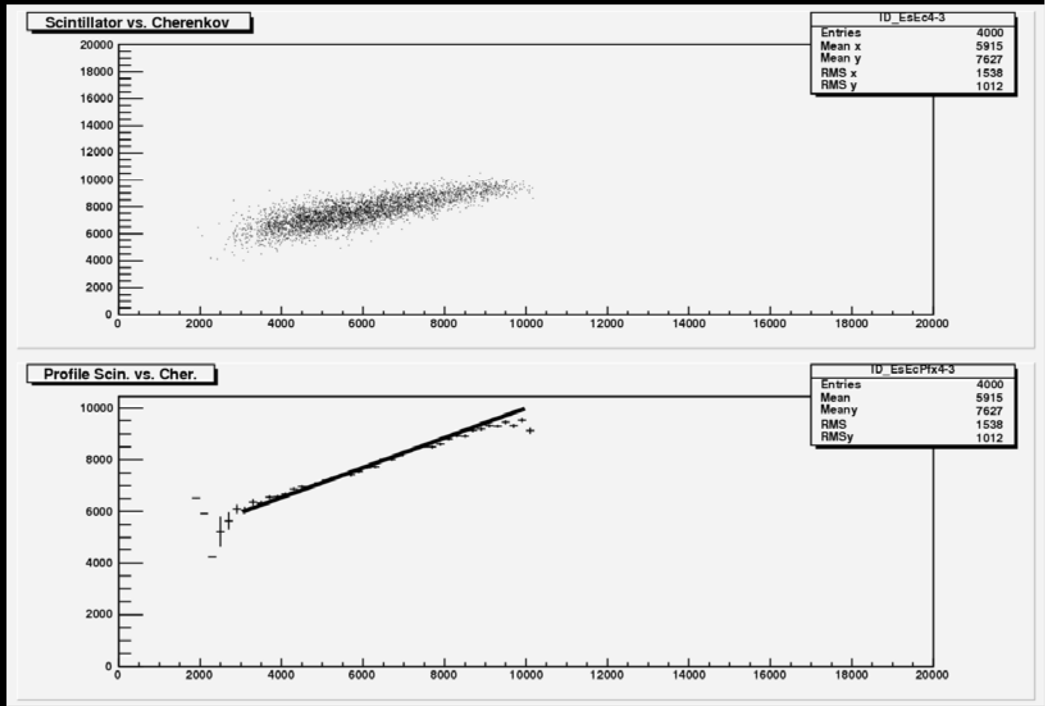
- This time use samples with 10000 layers
  - Scintillator signal by summing appropriate eche[i]
  - Cherenkov signal by summing appropriate echeph[i]
- Analysis a-la-Wigmans (NIM A537 (2005))
  - Q = Cherenkov signal
  - S = Scintillator signal

$$
\begin{aligned}
Q &= E(f + r_q(1-f)) = E(r_q + (1-r_q)f) \\
S &= E(f + r_s(1-f)) = E(r_s + (1-r_s)f)
\end{aligned}
$$

  - r_q (r_s) = intrinsic h/e for cherenkov (scintillator) calorimeter
  - Q and S calibrated on electrons

Signal Correlations (1)

- Correction exploits correlations between Q and S signal
  - Physics suggests that λ is a parameter which varies slowly with energy
  - Linear correlation appears consistent with data



$$
\begin{aligned}
S &= \frac{1-r_s}{1-r_q} Q + E\left(1 - \frac{1-r_s}{1-r_q}\right) \\
&= \lambda Q + E(1-\lambda)
\end{aligned}
$$

Signal Correlations (2)

- Two ways to determine λ:
  - Slope of line fit of S vs. Q data (as in previous formula: E fixed)
  - From statistical correlation and errors:
    - $\lambda = \sigma_{qs}/\sigma^2_q$
  - The two methods give very similar results
    - Statistical correlation returns the optimal resolution

Energy Dependence

- Checked stability of λ for several combinations

Scintillator Thickness (mm)	Cherenkov Thickness (mm)	λ-fit 1GeV	λ-stat 1 GeV	λ-fit 10 GeV	λ-stat 10 GeV	λ-fit 20 GeV	λ-stat 20 GeV
3	2	0.4915	0.5559	0.5848	0.5468	0.5808	0.5602
3	10	0.4868	0.5514	0.5815	0.5435	0.5783	0.5614
3	20	0.4816	0.5465	0.5836	0.5448	0.5782	0.5594
3	40	0.4928	0.5149	0.5824	0.5545	0.5780	0.5641
10	2	0.4888	0.5172	0.5836	0.5386	0.5795	0.5552
10	10	0.4852	0.5172	0.5814	0.5391	0.5787	0.5520
10	20	0.4728	0.4991	0.5802	0.5366	0.5792	0.5551
10	40	0.4676	0.4742	0.5792	0.5365	0.5781	0.5581
20	2	0.4803	0.4661	0.5790	0.5262	0.5769	0.5430
20	10	0.4760	0.4758	0.5804	0.5324	0.5779	0.5476
20	20	0.4756	0.4647	0.5777	0.5327	0.5775	0.5495
20	40	0.4538	0.4307	0.5753	0.5267	0.5756	0.5531
30	2	0.4682	0.4229	0.5771	0.5109	0.5725	0.5346
30	10	0.4755	0.4438	0.5765	0.5196	0.5762	0.5418
30	20	0.4691	0.4368	0.5767	0.5203	0.5756	0.5447
30	40	0.4402	0.3932	0.5685	0.5181	0.5661	0.5415
40	2	0.4614	0.3759	0.5763	0.5028	0.5714	0.5205
40	10	0.4668	0.4106	0.5755	0.5087	0.5756	0.5358
40	20	0.4506	0.3969	0.5721	0.5117	0.5725	0.5412
40	40	0.4523	0.3553	0.5762	0.5157	0.5746	0.5304

-Fairly stable with configuration
-Fairly stable with energy
-> small variation 10 -20 GeV
- > 15% variation 1 – 10 GeV

Energy corrections (1)

❖ Energy Dependent:

- Add back the lost energy

$$S' = S + \lambda(E - Q)$$

  - Works very well in any configuration, but … we are not supposed to know E!

$$\sigma_{S'} = \sqrt{\sigma_s^2 - \lambda^2\sigma_q^2}$$

❖ Energy Independent:

- Solve for E eliminating the EM fraction f in the equations:

$$S' = \frac{S-\lambda Q}{1-\lambda} \qquad \sigma_{S'} = \frac{\sqrt{\sigma_s^2-\lambda^2\sigma_q^2}}{1-\lambda}$$

  - Compete with $1/(1-\lambda)$ degradation
  - Works only for certain configurations

Energy Corrections (2)

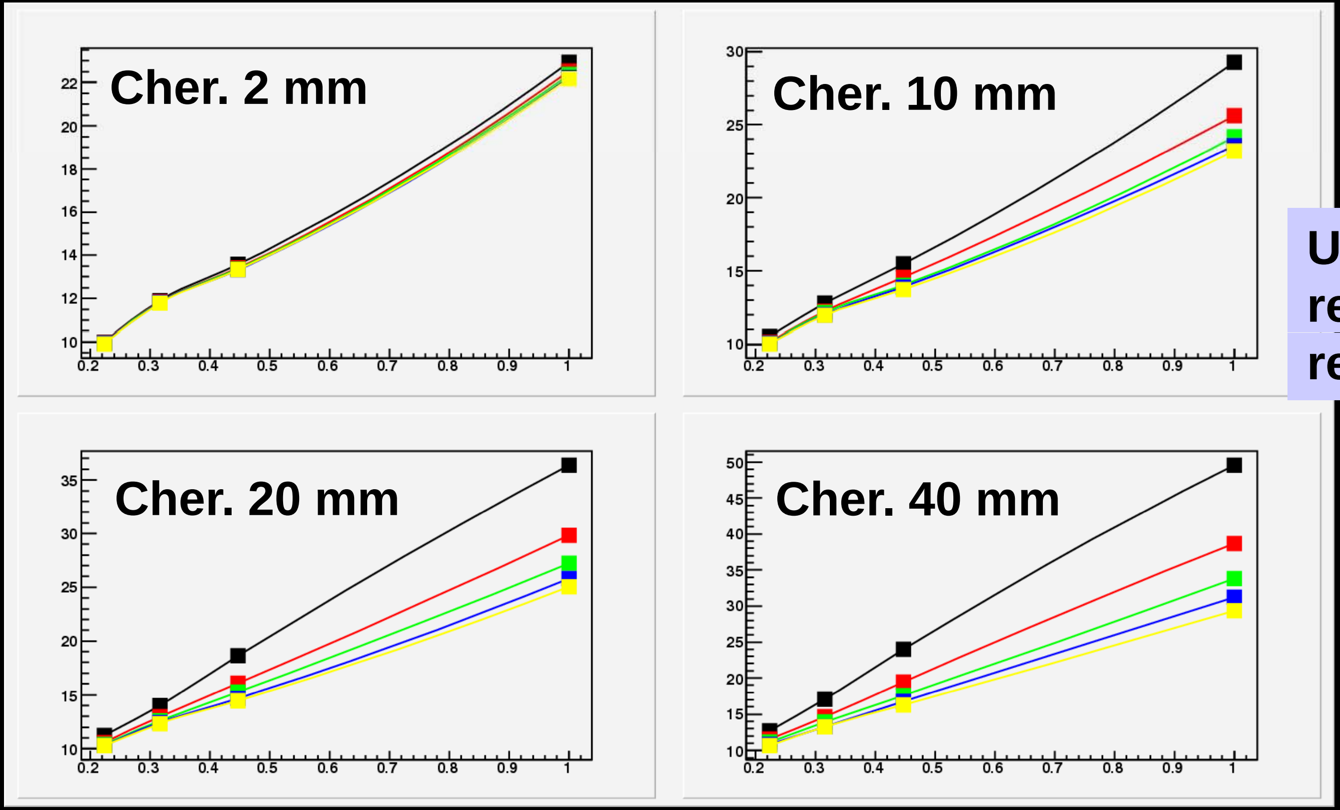
❖ Hard to find good configurations!

Scintillator Thickness (mm)	Cherenkov Thickness (mm)	Scint. only	Cher. only	En. Ind. (λ from fit)	En. Dep. (λ from fit)	En. Dep. (λ from stat.)	En. Ind. (λ from stat)
3	2	11.90	25.63	8.81	3.66	3.67	8.25
3	10	12.80	25.59	12.55	5.25	5.30	11.84
3	20	14.02	25.59	16.32	6.79	6.87	15.40
3	40	17.07	25.57	22.98	9.95	10.06	22.23
10	2	11.84	25.81	8.91	3.71	3.71	8.23
10	10	12.24	25.72	10.66	4.46	4.49	9.95
10	20	12.98	25.65	13.48	5.66	5.72	12.61
10	40	14.64	25.62	18.29	7.69	7.80	17.19
20	2	11.82	26.09	9.45	3.97	3.97	8.61
20	10	12.14	25.86	10.58	4.43	4.46	9.76
20	20	12.59	25.76	12.29	5.18	5.23	11.45
20	40	13.88	25.73	16.45	6.98	7.08	15.31
30	2	11.80	26.43	10.06	4.24	4.22	8.92
30	10	11.99	26.18	10.52	4.44	4.46	9.55
30	20	12.42	25.99	12.22	5.16	5.21	11.17
30	40	13.31	25.85	15.00	6.46	6.55	13.92
40	2	11.78	26.70	10.30	4.35	4.32	8.99
40	10	11.95	26.38	10.90	4.61	4.62	9.71
40	20	12.32	26.12	12.16	5.19	5.23	11.03
40	40	13.27	26.00	15.06	6.36	6.45	13.73

-All configurations with improvement of corrected energy resolution require unreasonable amounts of scintillator

Energy dependence (1)

- Study σ_E/E vs $1/\sqrt{E}$ for all configurations
  - Determine slope and constant term



Uncorrected relative resolutions

Energy Dependence (2)

- En. Ind. Correction:
  - Slope improves only at very small sampling fractions
  - Constant term does the opposite
- DREAM test beam:
  - Slope (corr): 49 (41)%
  - C.term (corr): 7 (4.2)%

Scint. Thick. mm	Cher. Thick. mm	Scintillator Slope %	Scintillator C. term %	En. Ind. Corr. Slope %	En. Ind. Corr. C. term %	En. Dep. Corr. Slope %	En. Dep. Corr. C. term %
3	2	16.49	6.40	23.76	0.61	11.18	0.12
3	10	24.18	4.99	33.57	1.15	17.65	-0.24
3	20	32.46	3.94	39.21	3.46	22.93	-0.06
3	40	47.42	2.26	44.24	7.90	28.22	1.44
10	2	16.02	6.48	22.68	0.90	11.47	0.07
10	10	19.81	5.80	29.33	0.78	15.09	-0.16
10	20	24.78	5.06	34.61	1.73	19.60	-0.36
10	40	35.04	3.68	40.93	4.42	26.75	-0.37
20	2	15.81	6.52	21.95	1.44	12.25	0.06
20	10	18.01	6.15	26.22	1.24	14.50	-0.14
20	20	21.55	5.65	30.74	1.83	17.74	-0.24
20	40	29.15	4.61	36.95	3.62	24.44	-0.49
30	2	15.66	6.55	20.89	2.02	12.72	0.14
30	10	17.29	6.29	24.47	1.71	14.31	-0.04
30	20	19.86	5.92	27.89	2.18	16.81	-0.08
30	40	26.26	4.97	34.34	3.21	23.34	-0.60
40	2	15.60	6.55	20.44	2.37	13.71	0.02
40	10	16.82	6.37	23.09	2.19	14.47	0.01
40	20	18.92	6.12	26.02	2.63	16.99	-0.14
40	40	23.90	5.52	31.05	3.78	22.19	-0.42

Conclusions

- Found two classes of energy corrections which compensate f_{EM} fluctuations
- Only one is energy independent
  - Works only for some configurations, typically requiring large amounts of scintillator
  - Cannot find a configuration which performs as DREAM with only 2% scintillator sampling fraction
- What is the magic of DREAMs?