Test beam proton calorimetry

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These are the final results of the test beam proton calorimetry study in the 20TRAK/20ECAL and 20ECAL/20HCAL detectors.

We expect excellent agreement after Rik's Birks' constant tuning. The events in Rik's study are the clean stopping sample of protons in this calorimetry study.

The methodology follows Rik's pion calorimetry.

Tech note is in progress, TN051, docdb:9986.

Test beam analyses serve two purposes:

1. To quantify data/MC agreement to set a systematic error on big detector analyses.

2. To identify improvements to the MC to improve data/MC agreement; both tunings and bug fixes.

Regarding #2, the MC in this study is proto-Eroica, not Resurrection. The proposed improvements are:

1. Birks' constant tuned to data.
2. Geometry tuned to material assessment.
3. Hit aggregation respects Birks' suppression (disabled here).
4. Geant neutron settings corrected.

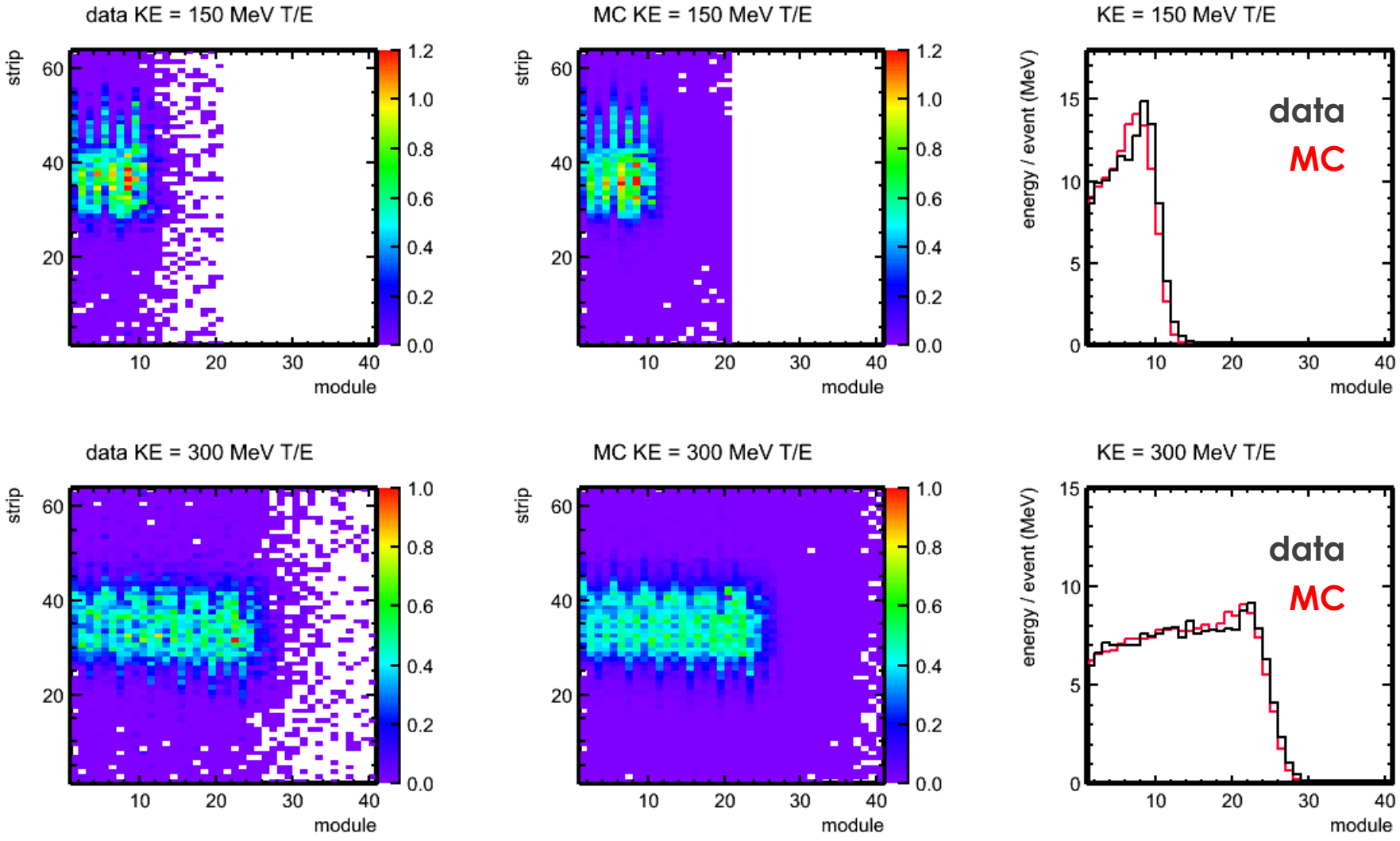
The above is a ~5% effect for protons, Resurrection/Eroica, mostly from Birks' constant (details in a later talk in this session).

The data has backgrounds from two sources:

1. *Muons from upstream pion decays -*
   Removed with an algorithm that tosses events with obvious second particles entering the front of the detector, but occasionally, a collinear muon will pass or a muon will enter the side of the detector.

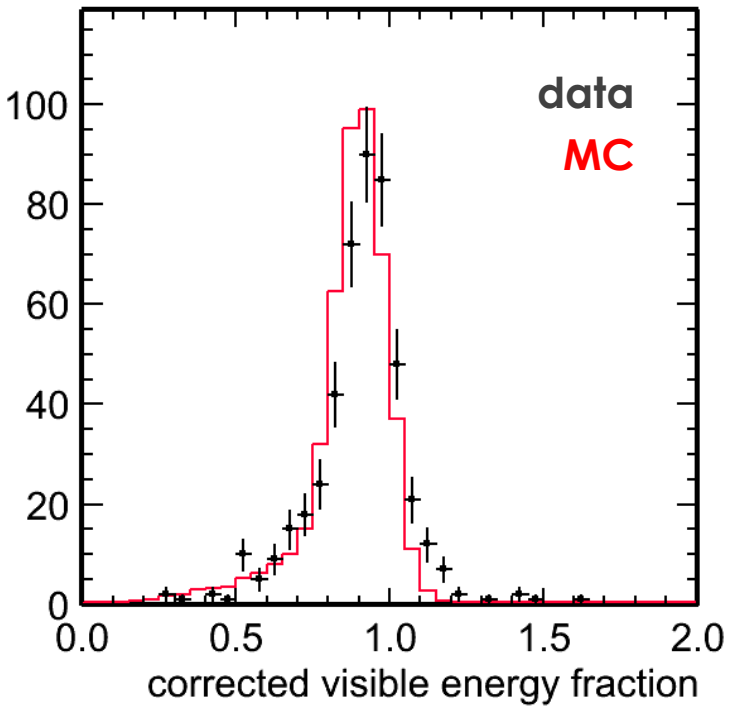
2. *Low energy neutrons -*
   These amount to ~4 MeV per event (calorimetrically weighted) and are distributed in time both before and after the proton. The early ones are obviously background, the later ones may be from the proton interaction.

To further reduce background, in the lowest energy bins (≤ 150 MeV T/E, ≤ 200 MeV E/H), only the upstream sub-detector is integrated calorimetrically; the downstream sub-detector is used as a muon veto. For mid-range energies (≤ 300 MeV T/E, ≤ 750 MeV E/H), the entire detector is summed, but the last 4 planes are a muon veto. At high energies, there is no veto.

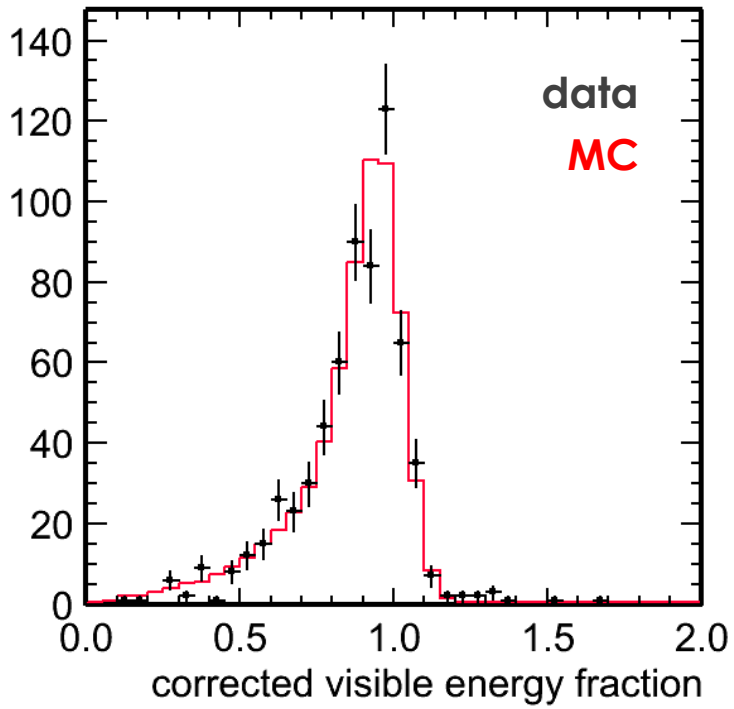


2D occupancy plot and 1D projection for KE = 150 MeV and 300 MeV in the 20TRAK/20ECAL detector. More in the plot dumps attached to the docdb entry.

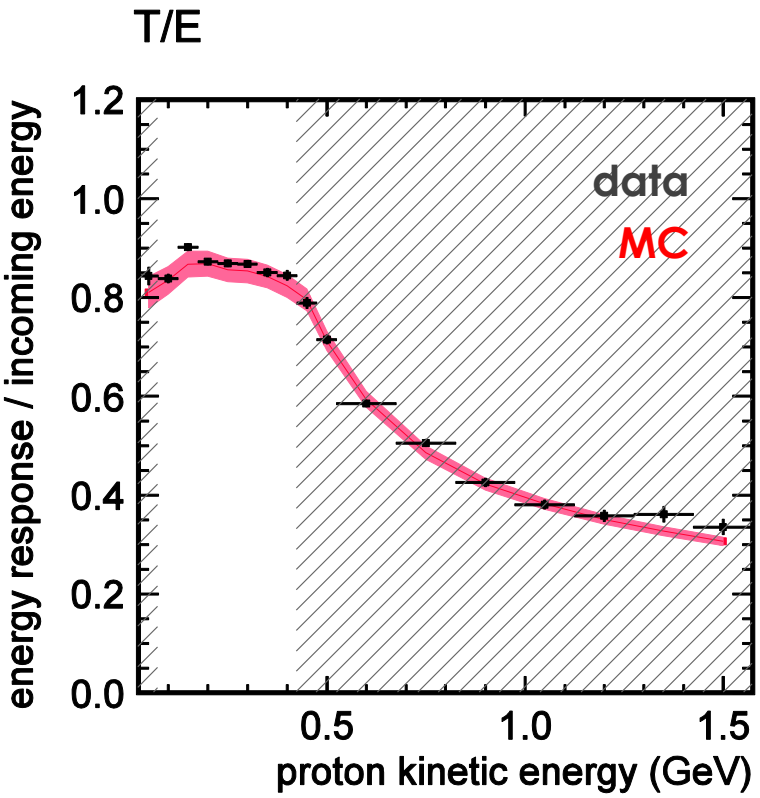
KE = 150 MeV T/E

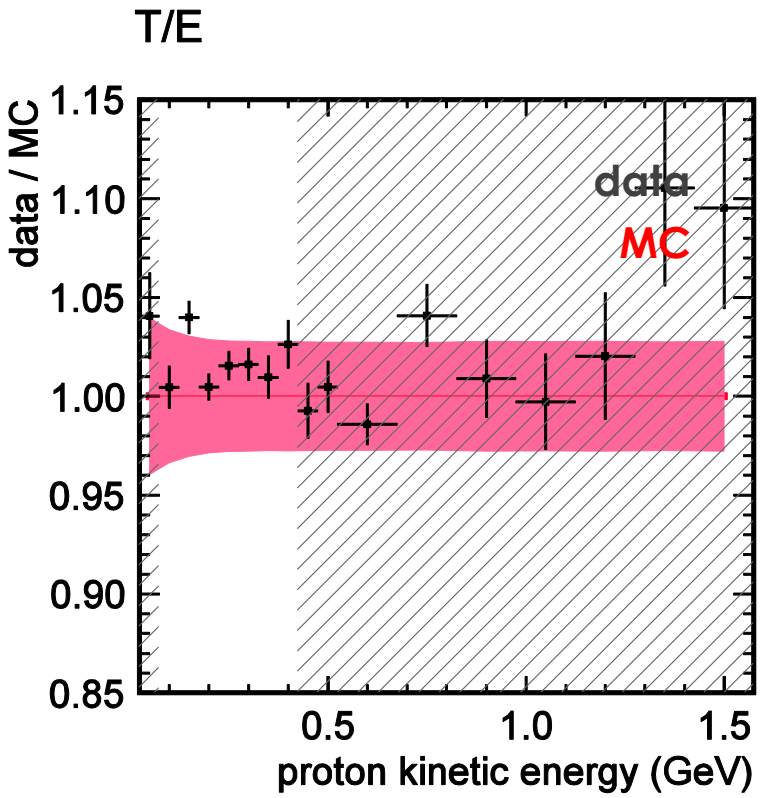


KE = 300 MeV T/E

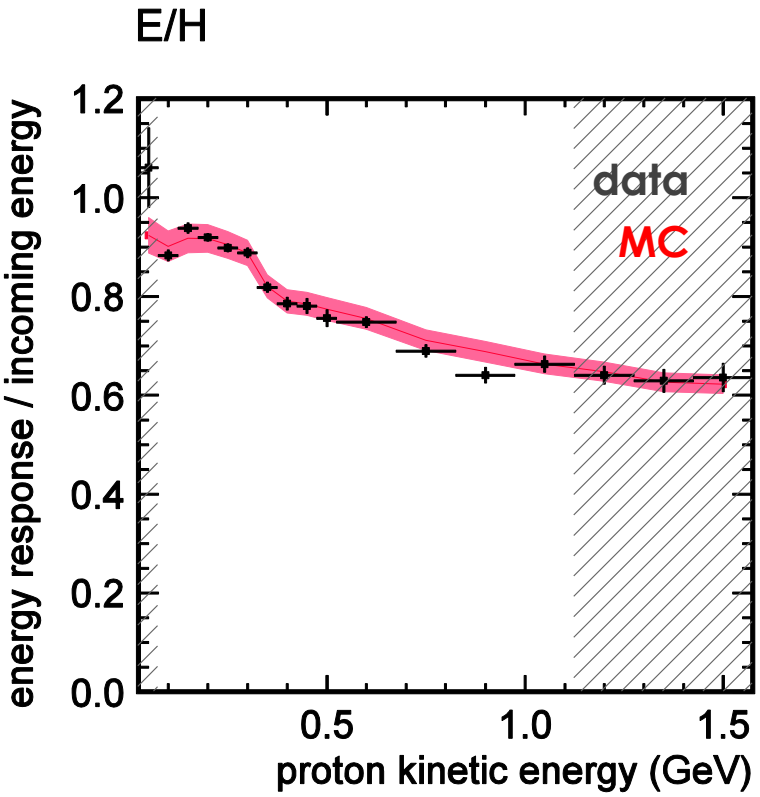


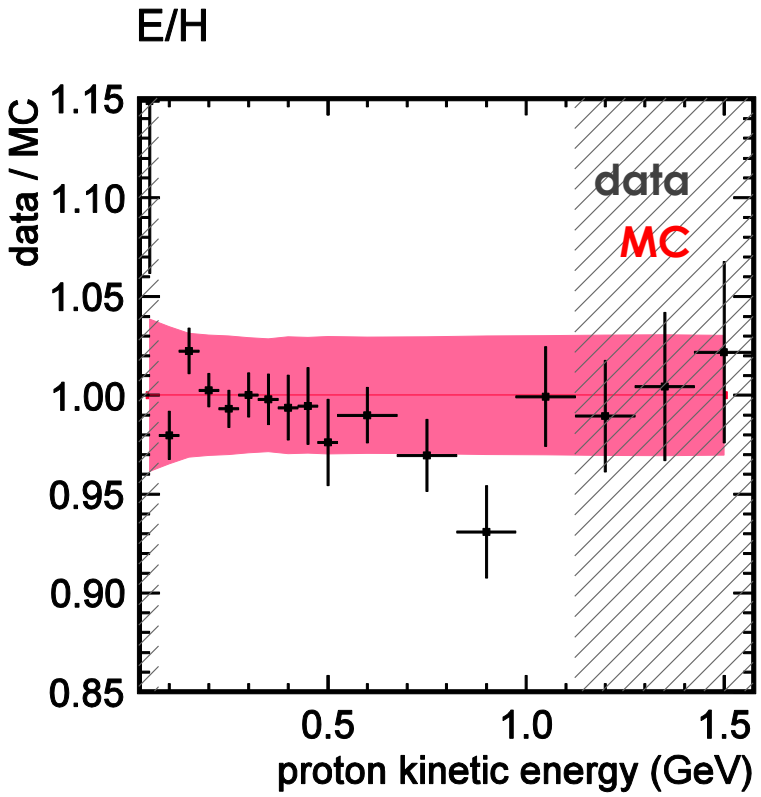
Corrected visible energy fraction = calorimetric energy / KE for the same two bins. More in the plot dumps attached to the docdb entry.



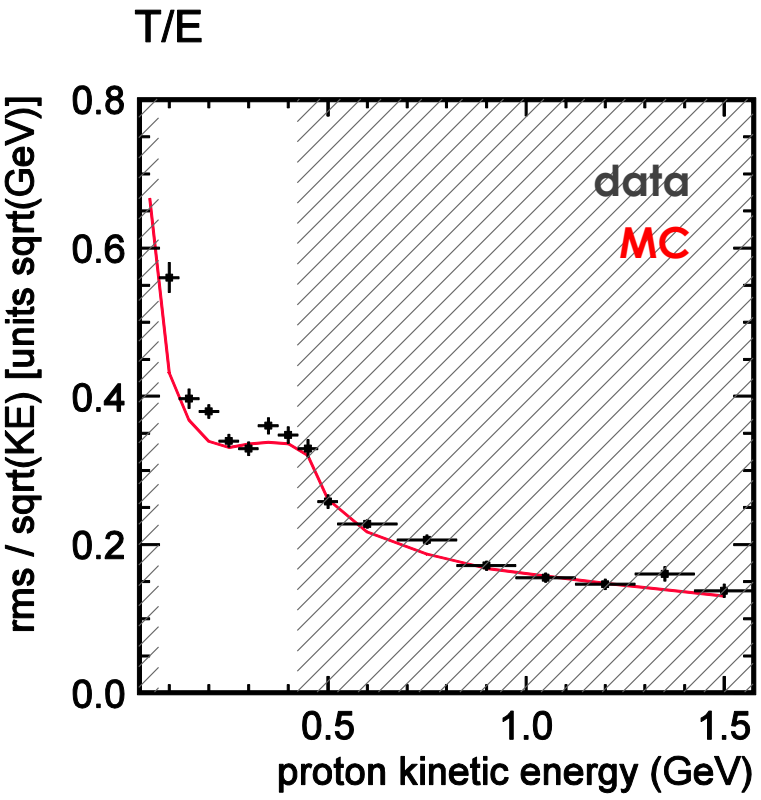


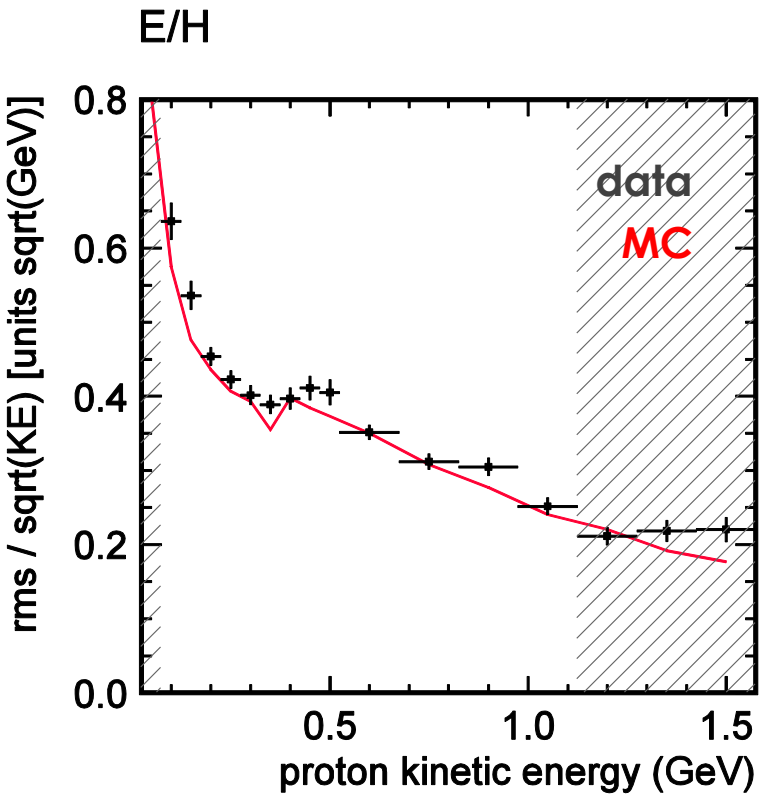
Energy response / incoming energy = mean of calorimetric energy / KE. Data plotted with statistical errors; MC with systematic. The hatching blocks poor statistics (left) and poor containment (right). 20TRAK/20ECAL detector. Data/MC fit is 1.6%; systematic error is 2.8% at 400 MeV.





Energy response / incoming energy = mean of calorimetric energy / KE. Data plotted with statistical errors; MC with systematic. The hatching blocks poor statistics (left) and poor containment (right). 20ECAL/20HCAL detector. Data/MC fit is -1.1%; systematic error is 3.0% at 1 GeV.

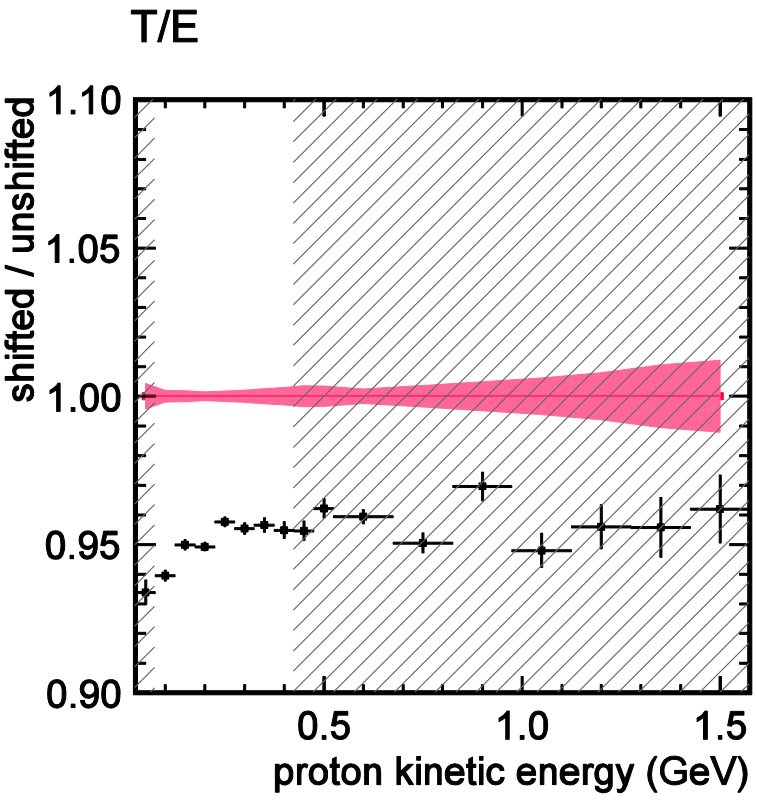


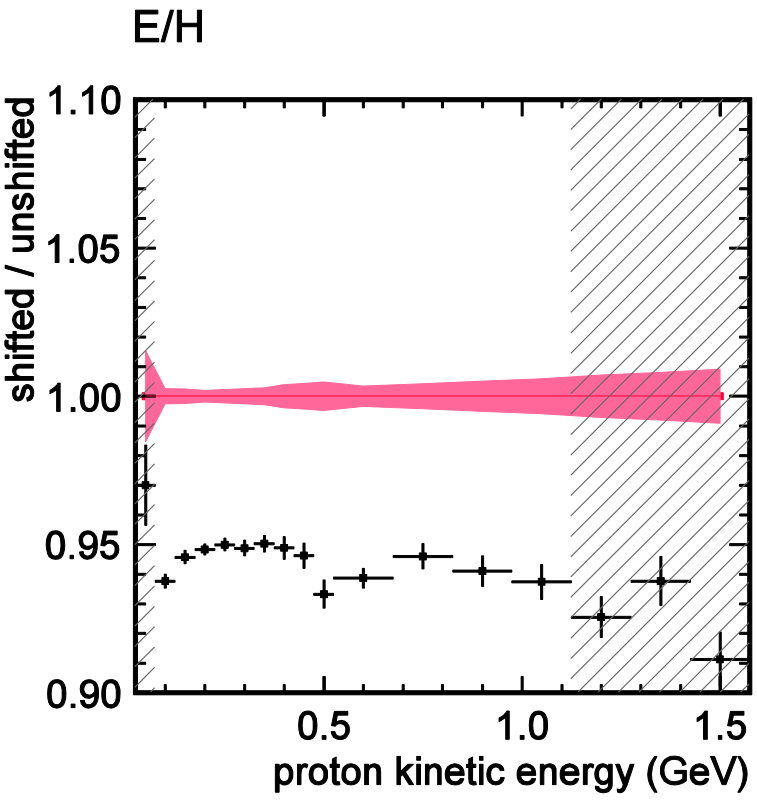


RMS / sqrt(KE) of calorimetric energy / KE.

error	T/E	E/H
MEU/LY	0.6%	0.6%
cross-talk	0.7%	0.9%
LPos	0.3% (100 MeV)	0.3% (100 MeV)
PMT non-linearity	0.7%	0.7%
Birks' constant	2.0% (100 MeV) 0.9% (400 MeV)	2.0% (100 MeV) 1.2% (1 GeV)
scintillator mass	1.5%	1.5%
lead mass	0.2% ($\geq$ 300 MeV)	0.4%
iron mass	N/A	0.4% ($\geq$ 400 MeV)
WC Al foil mass	0.7% (100 MeV)	0.7% (100 MeV)
beamline momentum	1.9%	1.9%
adjacent time slices	0.3%	0.6%
quadrature sum	3.4% (100 MeV) 2.8% (400 MeV)	3.5% (100 MeV) 3.0% (1 GeV)

Summary of systematic errors.





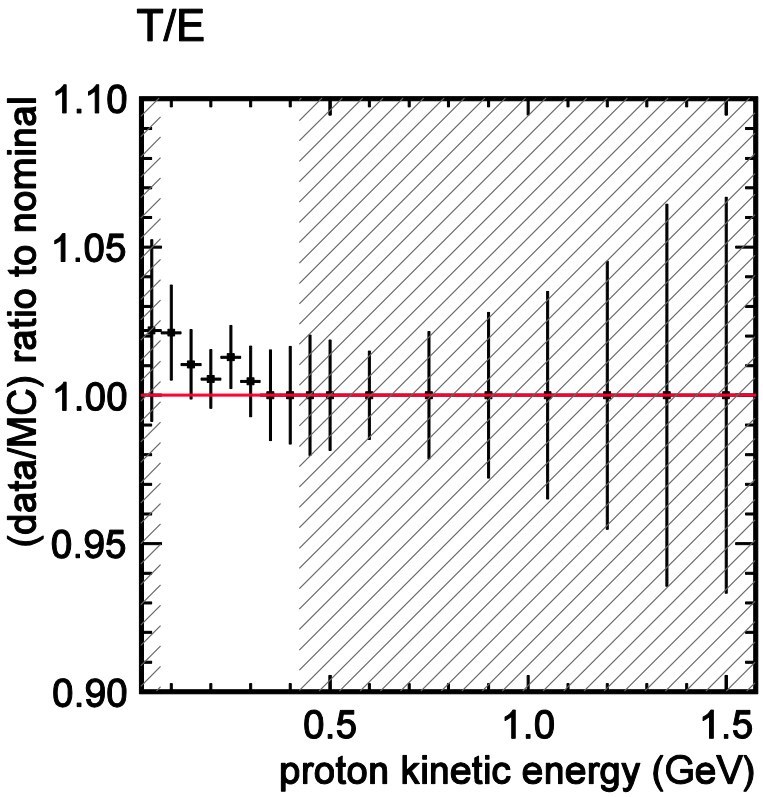
Resurrection over proto-Eroica MC,
ratio of mean calorimetric energy / KE.
Fit is -4.9% (T/E), -5.4% (E/H).

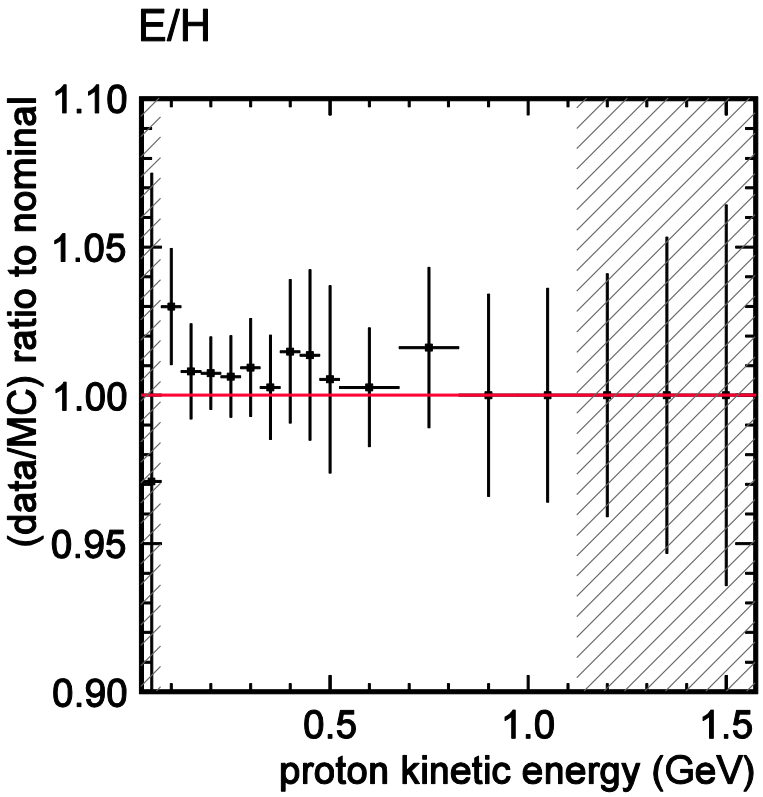
Systematic error on the calorimetric reconstruction of protons:

3%

+5% for Resurrection? Hang around for Rik's talk.

.. back up ..





Data/MC double ratio, disabling the muon vetoes and always calorimetrically integrating the full detector over the nominal.