Plans to improve absolute energy scale calibration of the CAL

There are several ideas on how to decrease the systematic uncertainties in absolute energy scale calibration of the CAL, noticed in data/MC comparison for 2006 beam test.

- We can use proton and GCR tracks crossing a crystal at small angles alpha to horizontal (i.e. with big angles theta to vertical axis) to intercalibrate the peaks of energy depositions from nuclei with different charge:
    - On the step 1, using the energy deposition of vertical protons as a reference, we measure the nonlinearity for energies 10-40 MeV and get the quenching factor for He
        - protons at alpha=90 degrees (theta=0) have most probable energy deposition 10.6 MeV in a crystal
        - protons at alpha=0.25 rad (14 degrees) to horizontal plane have the most probable energy deposition ~40 MeV (very precisely measured for crystals in layer 0 because angle alpha is measured by tracker and multiple scattering in CsI is small yet)
        - by looking at the evolution of pathlength-corrected energy deposition versus full (uncorrected) energy deposition we'll get the measurement of CAL nonlinearity in the energy range 10-40 MeV, completely independent from charge injection calibration
        - by finding the alpha angle at which protons have the same most probable energy deposition as vertical He we'll measure the quenching factor of He for on-orbit energy spectrum independently of charge injection calibration.
    - on the step 3 Applying the same procedure to Li ions, we'll get nonlinearity in the region 90-360 and quenching factor for Be (MPV~160 MeV) and B (MPV ~250 MeV)
    - on the step 4 we reach 1000 MeV and will get quenching factors for C, N and O
    - on the step 5 we reach 4 GeV and and get quenching factors for all nuclei up to Si and S (MPV ~2.5 GeV)
    - on the step 6 we measure nonlinearity up to 10 GeV and get quenching factor for elements from Ar to Fe (MPV ~8 GeV)
    - on step 7 we measure nonlinearity upto 40 GeV, or even upto 70 GeV (the end of dynamic range) if using minimum alpha angle ~0.1 rad (~5 degrees)
    - Systematic uncertainty on each step is to be defined, but it is definitely much less than 1%, as we always compare energy depositions having exactly the same spectrum shape (just scaled). If this uncertainty will be ~0.3% on each step , the resulting uncertainty at 70 GeV per crystal will be ~2%

- We can use the model of CsI scintillation to predict the light yield for particles of different mass and charge and thus account for antiquenching effect for electromagnetic showers
    - Recently Eric Grove found a paper published in 2001, which confirms and explains the difference in light yield produced in CsI crystals by electrons and alphas similar to the "antiquenching" effect seen in our test in GSI (2003 & 2006) and on-orbit:
        - Dependence of Scintillation Characteristics in the CsI(Tl) Crystal on Tl Concentrations Under Electron and Alpha Particles Excitations
    - This paper gives rather comprehensive model of CsI scintillation mechanism, which could be used to predict the light yield for particles of different charge, mass and energy
    - We plan to implement this model and try to tune the parameters (mainly doppant concentration and scintillation time constants for different mechanisms) to fit simultaineously GSI 2003 data at 1.0 and 1.7 GeV/nucleon, GANIL data at low energies and on-orbit data (> 4 GeV/nucleon with known spectrum)
    - Once model parameters are defined, it can be used to predict the "antiquenching" effect for electromagnetic showers and see if it could explain the data/MC discrepancy seen in 2006 Beam Test.
    - In the NIM paper presenting the results of 2003 GSI beam test the conclusion was made that there are no signs of quenching /antiquenching effect for showers
    - but this conclusion was based on the results of 2002-2003 CERN beam test, where energy depositions per crystal were mostly above 1 GeV, while the non-linear behaviour of data/MC ratio in 2006 Beam Test was noticed mainly in the energy range 100-1000 MeV per crystal
        - the energy calibration in 2002-2003 beam tests was based on 50 GeV muons from the beam lines, which could be affected by antiquenching effect because of relativistic rise in ionization density.
            - that could explain that while both muons and showers are affected by antiquenching effect, their ratio is unchanged