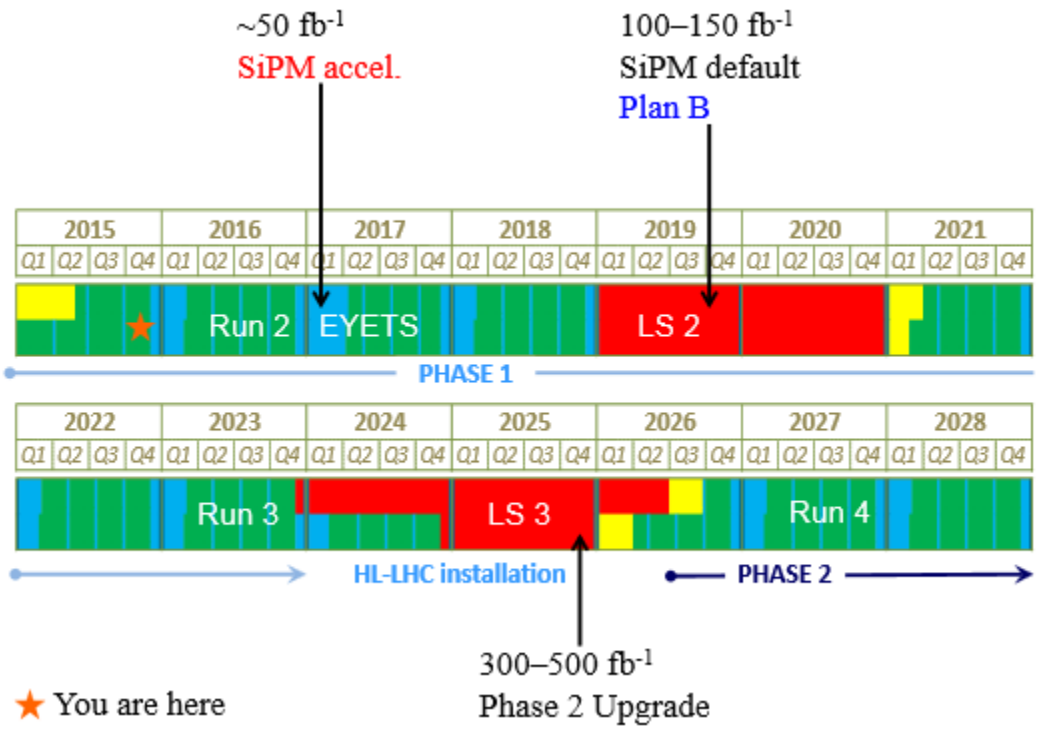
Luminosity Projection:

The SiPM are a "free lunch" . They should be installed ASAP. There is no other comparable light gain on the horizon.



Assume a 1 year run has 100 hr/week, 30 weeks/year. 2016 – 30 /fb, 2017, 2018 – 120 /fb. (60 /fb/year) 2021, 2022, 2023 - 300 /fb (100 /fb/year). This assumes LHC improves both before and after LS2 in delivering /fb/year.

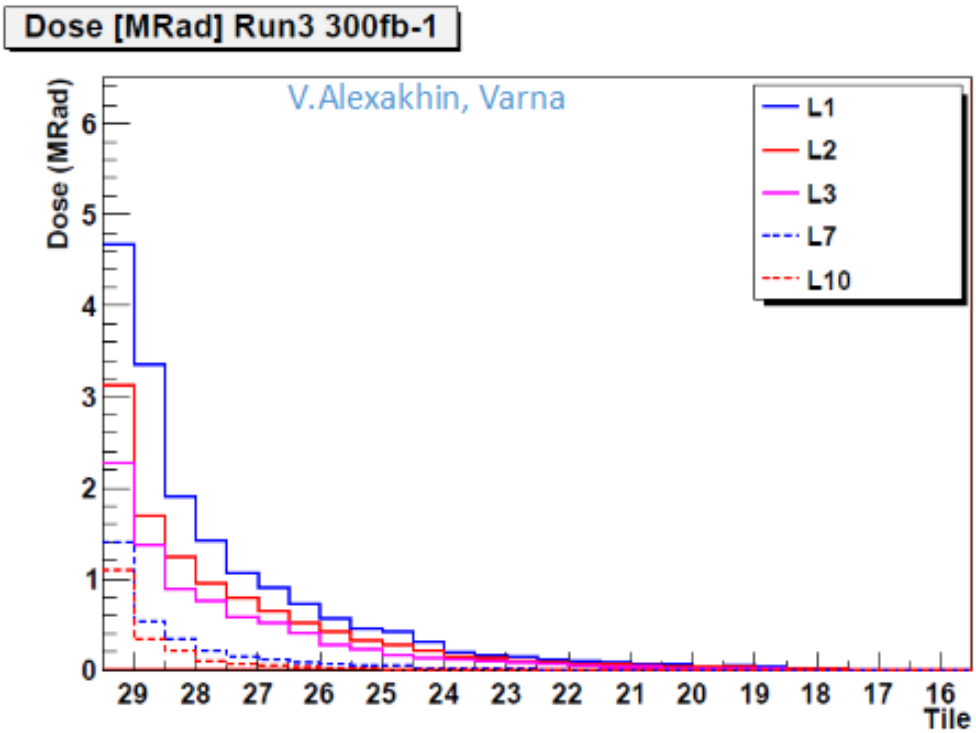
Total is 25 (now) + 30 + 120 + 300 = 475 /fb. (450 /fb in future)

For 2016 the lumi rate is then 0.01 /fb/hr. For 2017 and 2018, 0.02 /fb/hr and for 2021-2023 0.033 /fb/hr. These assumptions allow one to assign a does rate dependent degradation.

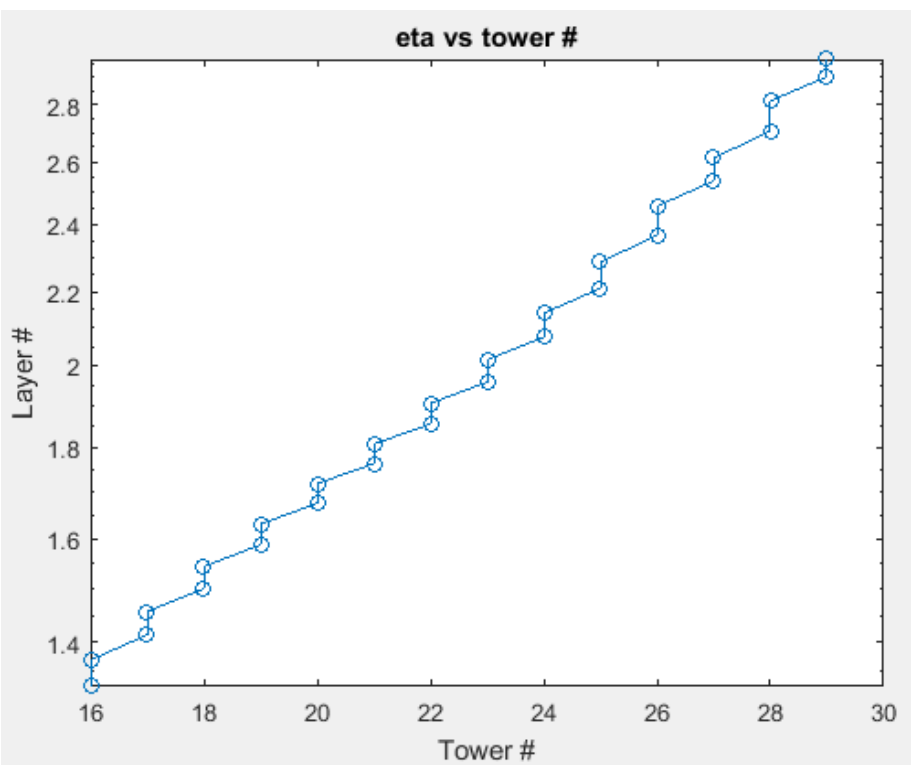
Total Dose – by Layer and Tower:

The raddam model is taken from Fluka at 13 TeV. The towers are split in 2 and are then simply averaged. That split gives an idea of the possible non-uniformities induced by the radiation damage. The Fluka dose is 300 /fb.

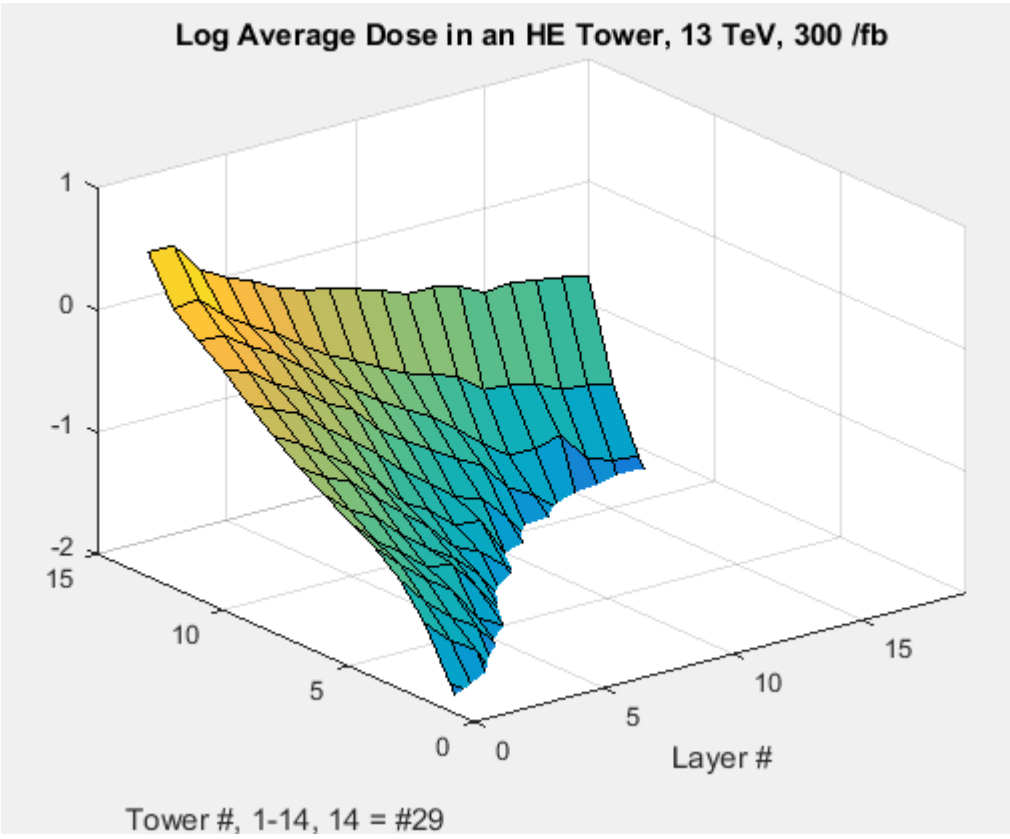
The dose map has 18 depth segments (layers) and 14 |y| values (towers). The plot below shows the Fluka dose from Vadim Alexakhin.



This plot shows the eta values for the 14 towers ranging from ~ 2.9 to ~ 1.35. Each tower # has a larger and smaller eta value where the doses are averaged for a estimated tower dose.



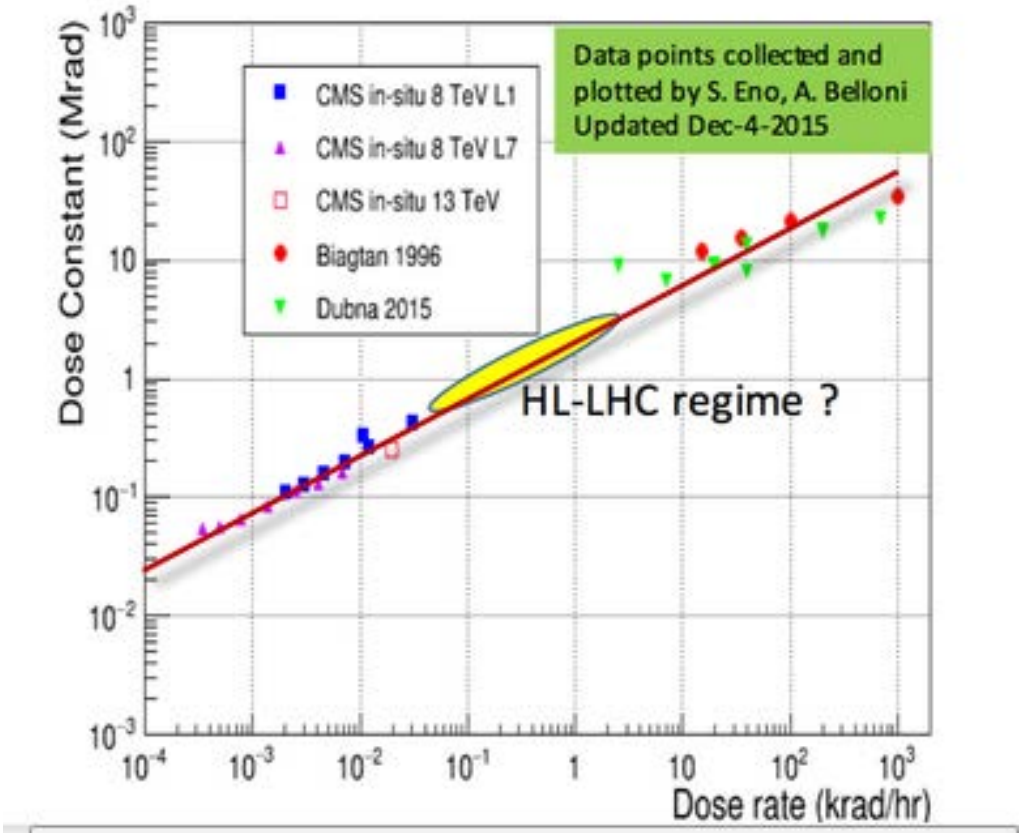
The complete dose map for 300 /fb as a function of Layer # and Tower # appears below. The Tower # is the plot # + 15 so that Tower 14 -> 29.



Appropriate Damage Coefficients:

There is uncertainty in the dose rate. In order to avoid that, assume the 2012 Run was appropriate to 20 /fb. Then the dose rate for 2016 is 30/25 the dose rate for 2012. A constant "dose constant" has not been assumed here, but 3 different ones appropriate for the 3 running periods. The assumption is that 2012 was a "normal run" and future runs will also be "normal" but with higher luminosity, 2x in the second period and 3.3 x in the third period.

In the case of the damage coefficient a simple power law (shown below) was used where D(Mrad) = 2.3 (Dose Rate (krad/hr))^0.49. This form is consistent (roughly) with all the data (collected by Sarah Eno) both at high and low dose rates and represents our best estimate of future behavior of HE. However there is a gap in the dose rate data where future running will occur. Basically the dose rate is assumed to be scaled to the delivered luminosity for a given year and bootstrapped to a dose constant.



Under those assumptions, the constant is 0.41 Mrad for Run I, and 0.45, 0.63 and 0.81 Mrad for the future 3 running periods. The damage coefficients were applied for the 3 distinct running periods – 30 /fb in 1 year, 120 /fb in 2 years and 300 /fb in 3 years. The cumulative light efficiency is shown below alongside a previous estimate.

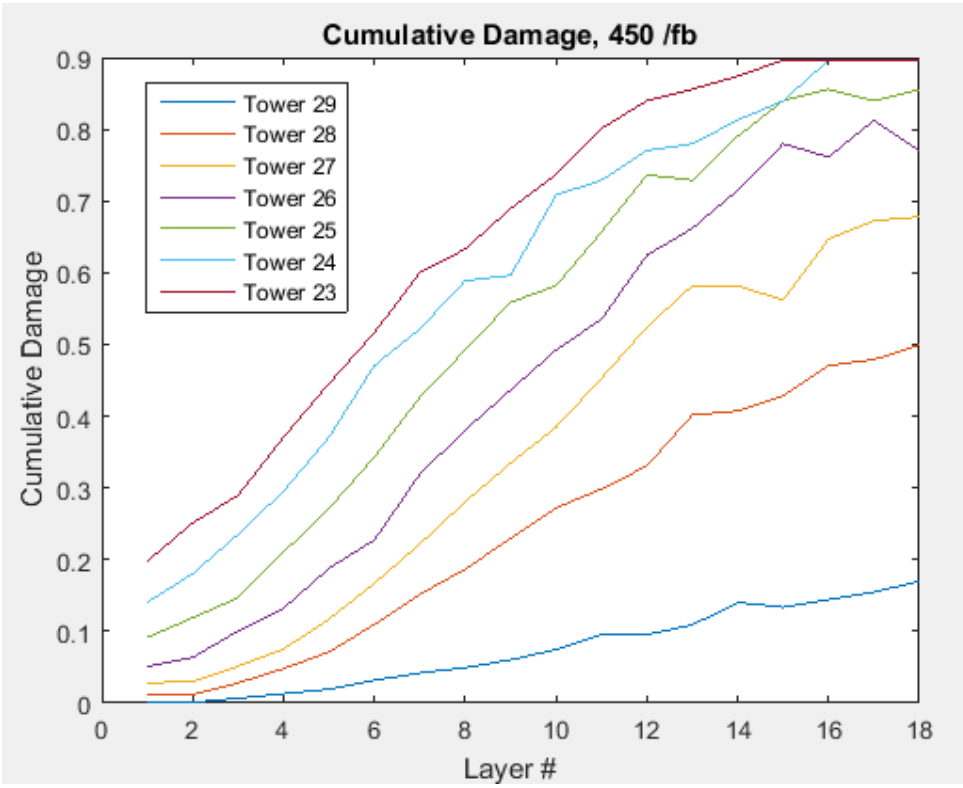
For towers at eta # < 26 (eta < 2.4) all Layers have at least 10% light output. Tower # 28 has > 10% residual light after layer ~ 6. It remains to evaluate the jet response to this aging. By jets we mean PF jets where EE and tracking are deployed. In addition the HE longitudinal segmentation can be optimized in order to preserve as much jet and MET functionality as possible. After that an informed decision on PlanB can be made.

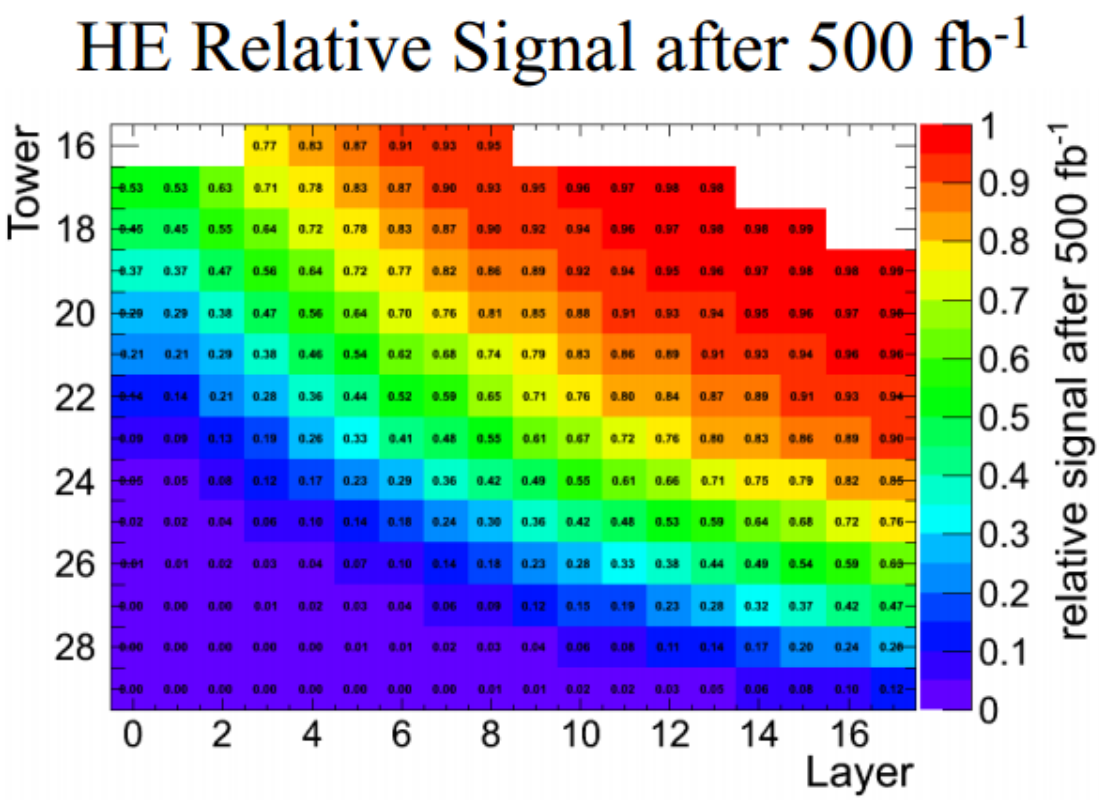
Taking the observed dose rate into account means a substantially enhanced light output. For example for Tower # 27 the light in the first 10 layers in the 2 plots is:

500 /fb: 00 00 00 01 02 03 04 06 09 12

450/fb: 03 03 05 07 12 17 22 28 33 39

So, the predicted light output might be 5x in tower # 27 if the dose rate effect is invoked.





Corrections and Re-Calibrations:

For HE the scint is 0.9 mm thick while the brass is 5 cm thick (density 8.5). There are 14 towers in |y| and 18 layers in depth. A mip would deposit 1.35 MeV per layer. Or 23 MeV total (muon). Given a brass to scint sampling fraction of ~ 47, that means an effective deposit of ~ 1.1 GeV.

Plots shown in Nov. show muon peaks of 3.5 GeV and 0.8 GeV which are in the ballpark. The fractional widths of these muon signals indicate that the number of pe is < 10 when undamaged. Therefore, it is quite unlikely that a muon calibration can be maintained throughout the running period.

An alternative is to use QCD dijets with a tag jet in the ~ undamaged barrel region. Dijet balancing could then be used. A typical VBF jet has Pt ~ 30 GeV or an energy of 300 GeV at |y| ~ 3. Using TB results shown last week that means (62 pe/GeV) an undamaged yield of 18600 pe. Some of the energy ~ ½, or ~ 9300 pe undamaged, goes into EE. On average the HE ½ energy is distributed as the dose.

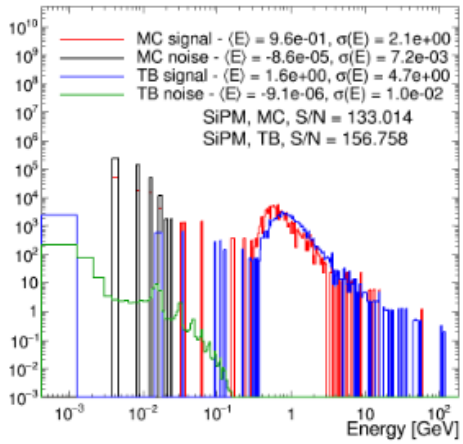
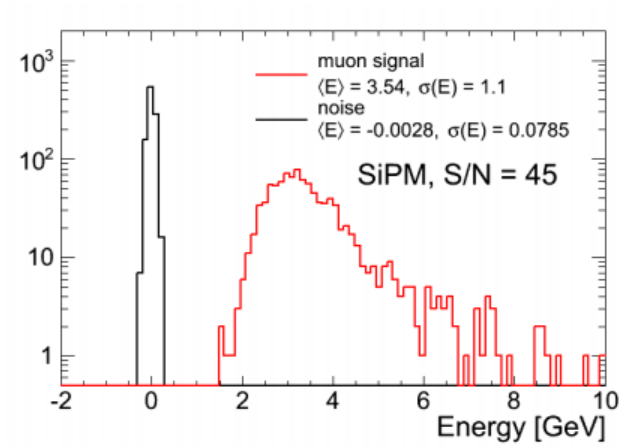
It would appear that there are sufficient pe using SiPM. Clearly the depth segments allow for independent reweighting each segment and perhaps appealing to the front ECAL – and deeper back HE "continuity" across the most damaged areas .

The reweighting depends on shower shape and the chosen depth segmentation, so details need to be addressed.

It seems clear that single pe SiPM noise has to be part of the Monte Carlo model since the 1 pe signal peak can provide a calibration to track in time as long as it can be resolved from the noise.

Clearly, a more exact model of signal extraction for each longitudinal compartment must be made before one can assess the Physics response of HE as it ages before LS3. The HE should be aged up until the start of LS3 in order to assess the viability of HE throughout the 3 running periods and the necessity for PlanB.

SiPM MC vs. TB



Quantity	MC	TB
fC/GeV	900	3742.19
fC/pe	10	60.30
pe/GeV	90	62.06