First Look at H4 Beam test results on HFS time resolution with MIPS

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Our development of Deep Depleted Avalanche Diodes (aka HyperFastSilicon) for high rate fast timing perhaps started in earnest in 2010 and was carried out in a number of venues ("The single electron Project" at the ATF, Kirk's original DOE award, CMS support through Joel, Vivian and now Lothar, the CERN RD50 Group with Michael Moll) and has several promising new awards (Kirk's just funded DOE award, The RMD SBIR, continued support from Lothar and RD50/51 CERN groups, Mitch's continued enthusiastic support).

Although we have had important testbeam data (ATF, Frascati, PSI, DESY, PS, SPS) which has provided really good experience in working with these detectors and their reliability (ie potentially catastrophic mis-steering of the beam at Frascati) and guided the FEE development of Mitch and the need for better packaging, this project has been set back by lack published results.

Although we certainly have consistency shown (analyses by me, Eric Delagnes and Lu) better than ~16 picosecond time jitter with a laser based MIP model, we haven't, up to now, had a satisfactory analysis of the time performance with MIP data.

For this reason whenever we revisited the topic of publication we have felt we were not there yet.

I think we are now there.

So I am now writing this to see who of the people involved over the years would now like to push ahead and get "The Paper" out. I think it would be best to pool the corporate knowledge in completing the analysis.

What we lacked in the previous data was a solid independent time reference which we now appreciate (from the simulation) is needed to disentangle the contribution to time jitter from Landau/Vavilov fluctuations. Although it seems like an obvious investment to buy a couple  $8-10k MCP-PMTs from Hamamatsu we never had the money before. Luckily the LHC Instrumentation Division offered 2 for this month's testbeam run.

We also owe a lot to the RD51 collaborators who prepared a very professional testbeam run- and Michele who joined to take the SAMPIC data.

Preliminary results:

In the plots below you will find that we, so far, have obtained a time resolution of **32 picoseconds** with high energy muons. The analysis is based on a technique that I feel best suits the significant Landau contribution in the detectors as they are currently built with RMD.
It is neither the CFD method nor a low fixed threshold. I'm not sure anyone has used it before but I see no reason why this analytic method couldn't be implemented in analog hardware.

Recognizing that the "early part" of the signal leading edge comes from e-h pairs formed near/in the amplification region, where the effect of Landau fluctatuations was found to be smallest, this analysis derives time from the "well behaved" initial part of the leading edge (below ~250 mV in the H4 running conditions). It is analogous to deriving a constant fraction time without using the peak of the pulse, which should be dropped because it integrates the Landau jitter. We derive locally the constant fraction denominator.

It is very likely that the final result will be even better. I list a few reasons for this:

1) this is only a short run corresponding to a small fraction of the data.
2) I have been unable to take credit for the more precise t0 that I also obtain using CFD method on the MCP. I don't yet understand why this doesn't improve over taking simply the max bin with 20GSa/s sampling.
3) Because the sensor in Mitch's preamplifier box was not well-aligned with the mount provided, it is not well centered on the beam. We are partially using the sensor edge and 30% of triggers have no HFS signal.

4) It is likely that, because of (3), the tracking chamber data, which I didn't use so far, will show better resolution in the "fiducial volume". We should make sure that Mitch's new box (for August run) will allow the sensor to align correctly.
5) The analysis I did is still a little ad hoc and might benefit from further realistic signal simulation.
6) We may do a bit better with the SAMPIC data which includes also other HFS sensors and has 11 bit rather than 8 bit digitization.

But even so I think the result is nice and attach it below: