Forward ECAL readout questionnaire responses

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Two additional questions about prototyping:
- Is there a physical prototype already available (how you read it out, etc. Or when is it planned)
FY24

- Do you already have a waveform from the SiPM output available (picture or data)
tbd.

SiPM information/requirements (not exactly ASIC-related, but good information to have):
- manufacturer
Hamamatsu, S14160-6015PS

- size [mm] (individual chip)
6x6 mm^2

- bias range (min & max that need to be set) [V]
33 V to 47 V

- operating overvoltage (planned) [V]
2 V (TBC)

- stability required [mV]
10 mV (0.5% of overvoltage)

- bias voltage accuracy (IF NEEDED, for using pre-calibration voltages) [%]
0.05% (will mean gain set within 1% of expected, if using absolute voltage to set initial gains; note from Hamamatsu we will have Vbr controlled to 20 mV (another 1% error) so the overall gain uncertainty by setting absolute voltages is about 1.4%)
[Since this exceeds the stability spec it is to be interpreted as accuracy of the mean (over time scale of hours).]

- bias voltage current (max, after lifetime irradiation) [uA]
1 mA is the plan, for now

- bias voltage temperature compensation (or will SiPM temperature be controlled instead)?
Yes, temperature compensated bias

- array of SiPM/channel [how many; series/parallel scheme]
4 SiPM in parallel

- capacitance/channel
10 nF

- #pixel/channel
638k

- dynamic range required/channel [pC]
(minimum signal important to detect is discussed below (Hit requirements))
5.8 nC (at OV = 2 V, as planned but TBC)
This is 100 GeV at planned light yield 1000 pixels/GeV

FEB signal processing requirements:
(Preamp information)
- linearity requirement [max nonlinearity % over full range, or a more detailed spec]
1 - 2 % (needs some discussion)

- gain stability (w.r.t. time/drift, internal noises of the FEB, FEB temperature, external interferences) [%]
<0.5% (i.e. we'd allow 1% total gain stability, 0.5% from bias voltage stability and 0.5% from FEB analog circuits)

- peak time (or max peak time to avoid pile-up) [ns]
As needed, but up to 200 ns probably fine.

- charge resolution [% of full scale or a more detailed spec, e.g. % of signal at various signal sizes]
We propose that this is determined as the resolution that would raise the overall energy resolution by less than 10% compared with a same detector and SiPM's but a perfect readout system (0% resolution).
The planned overall energy resolution is
(10-12%)/sqrt(E/1GeV) summed in quadrature with (2%) .
This means the energy resolution contributed solely by the readout system must be
<42% * ((10-12%)/sqrt(E/1GeV) summed in quadrature with (2%)) .

In terms of charge, the resolution of the readout system must be (taking 11% /sqrt(E) here)
< 4.6%/sqrt(q/58pC) summed in quadrature with 0.84% .

If the readout were implemented with **noiseless** *linear* analog signal processing feeding into a single **ideal** ADC measuring just one point, the minimum bit resolution is 14 bits. (This is governed by smallest signal, 0.29pC (see below):
log(sqrt((0.046/sqrt(0.29/58))**2+0.0084**2)*0.29*sqrt(12)/5800.)/log(2) = -13.1).
(If we take 100 MeV as smallest signal of interest, then 11 bits are needed.)
The smallest signal of interest is a key parameter which needs further discussion.

[The rms resolution of an ideal N-bit ADC in terms of full scale signal is 1/(2^N * sqrt(12))]

- Time-of-hit resolution [ns]
1 ns (rough value, but this seems appropriate)

- double-pulse resolving time [ns] (i.e. readout of two pulses separated by less than this **may have pileup errors or may be seen as one pulse**)
Not sure - see rates, below. A few hundred ns probably is fine.

Hit processing / streaming readout requirements:
- Hit threshold [pC] (OR a more detailed spec over detector geometry if appropriate)
0.29 pC (this is 5 pixels, or 5 MeV; maybe too low at highest eta?)

- Hits defined by something more than each channel independently? (Default answer "no")
No, just single channel criteria for a hit, probably just a level crossing of waveform

- Hit rate (physics+background) per channel maximum [kHz] (OR a more detailed spec over detector geometry if appropriate)
<50 kHz… more refined statements need further work but this probably can be lowered

- Does the hit rate requirement apply independently to all channels or has to be understood with some correlation in mind?
The improved rate requirement may be stated with some correlation in mind.

Slow control:
- SiPM bias current monitoring [Yes / combined / none]
Yes; maybe combined 2 or 4 towers to reduce cost

- temperature monitoring [Yes/No]
Yes

Accessibility of the FEB and RDO:
- FEB on detector [Yes/No]

Yes

- FEB accessibility [During run/between runs] (Radiation tolerance)
Between runs, endcap opened, central detectors rolled out(?)
Radiation tolerance as determined needed for the location

- FEB-RDO minimum distance [m]
6 - 25 m depending on if RDO in racks or mounted directly on endcap structure periphery

- RDO on detector [Yes/No] (default No)
No. (In crates in racks?)

- RDO accessibility/location (Radiation tolerance)
Accessible (at least if in racks); little radiation.