

Dear Anadi,

Thank you for your comments. We addressed all of them and detailed answers are added below.

Thank you very much for the new draft. I find the paper improved significantly with respect to the first version. You have already received a large number of comments so I removed overlaps as much as I can below (but a few of the comments may be the same as other reviewers).

Thank you and cheers,

Anadi

General comments

- Check the consistency in using Fig. (in the sentence) and Figure (at the beginning) - same goes for tables, sections,

...

I checked for “Figure”/”Fig.”. For “Table” here it says that it should always be “Table”:

<https://twiki.cern.ch/twiki/bin/view/Sandbox/GeorgeAlversonSandbox>

Kept “Section”.

- You still have several updates to make highlighted in red → ok, fixed. Only remaining item is Fig. 46 which still needs to be made by analyzers.
- There is some inconsistency in the way you quote numbers smaller than 10 in the text (2 vs two) → should be fixed, check again with LE
- make sure you use Phase 1 pixel detector (and not pixel Phase 1 ...) everywhere in the paper → ok
- make sure you use a consistent tense (present, past, ...) → done to the best of my knowledge, to be check again with LE
- please double check that you quote the same operating temperature everywhere in the paper → ok, -22C everywhere.
- after having read the paper for 2nd time I am wondering whether it would be useful to add a dictionary? You have a lot of acronyms that are (correctly) defined only once.

Considering the length of the paper finding the definition is not always simple → ok, added.

- Please check the bib: some references are missing a space between the initial and the last name, spurious symbols like "-", → ok, done.
- In general I am not sure writing the name of the functions is appropriate for a paper. It is good for an internal note targeting CMS collaborators who have access to the code. I would remove all instances. → ok, names of functions/tests have been removed.

Line by Line

- Abstract: move "as its innermost sub-detector" at the end of the sentence; I would replace forward/background with end-cap → ok
- L50 up to a MAX instant. lumi ... → ok
- L53 have been exceeded --> would have been exceeded → no, they actually have been exceeded and we were running the Phase-0 detector at a lumi above the design lumi at the beginning of Run 2.
- Section 2: I would the logical order of sentences by starting from "The detector layout is optimized ..." Then "During L1 a new beam pipe" and closing with " as a result the CMS phase 1 pixel detector consists of ..." → ok
- Fig 1 I would add the radius values of the original detector and the Z for both, or remove all numbers (given that you have the table below). The right diagram is redundant? → ok, removed numbers and right diagram.
- What is a shell? Please review all definitions (shell, half cylinder, quadrant,...) → shell now introduced as follows: "The BPIX detector mechanically consists of two half-barrels (Fig. 2 with a length of 540 mm, each divided into four layers (called half-shells)".
Half-cylinders introduced on L98 and now used consistently.
Quadrant now introduced for FPIX, removed for BPIX.
- Tab 1: you don't show the number of ladders/rings? → no, forgot to remove from caption. Fixed now.

- Fig 3 It would be great to use the same template if at all possible. What is the "sensitive" material? Also I don't think you have contributions from "other"? As Katja wrote there is a typo in the title bottom right. Please increase fonts.

→ “Sensitive” is the sensor material. What other term would you suggest?

Labels have been increased and “other” category removed.

x/Λ_0 is NOT a typo. This has been discussed at the approval of the plots. I quote: “ x is the distance traversed by the simulated neutrino for one step in the G4 simulation, So, for every step, the neutrino will traverse different parts(sub-detector/material) in the detector and then we have the corresponding radiation lengths (X_0) and Interaction lengths (Λ_0) for those(sub-detectors/materials) in that step.”

This is also consistent with previous material budget plots as for instance in the Phase-1 TDR Fig. 1.5.

- Section 3: I would cite the size of the pixel here since you nicely describe that some of them are x2 as large etc → ok
- Tab 2 invert dose and fluence in caption; also fix f_{inv} → ok
- L147 I would state that it is parallel to the beam line or z axis (the B lines are not necessarily parallel everywhere) → Kept, since the pixel orientation wrt magnetic field is important for the LA.
- Section 3.1.: I find the description of the sensor type to appear too late. It is more interesting to know that we have n-in-n than how many vendors were used. → the reason why the vendors are mentioned first, is to motivate the choice of the different designs. Kept as is.
 - o I would move the operational details :159-166 to the end → ok
 - o L167-172 to after L195 → same comment as above.
- L158 I would not write "have been continued" since studies should be completed by the time a detector is installed → changed to: “Studies with irradiated sensors had been continued...”. The sentence refers to after the installation or the original detector. In this sense it is ok to continue the studies and check if the sensors also survive fluences well above what was needed for the original detector.
- L172 I would not write "both suitable for operation".

They must be! → ok, removed.

- L176-177 These sentences may be merged. → yes, done.
- L178 "Another advantage of" --> "This effect is less prominent in..." → sentence is removed due to other comment.
- L179 higher than? not clear what you refer to → higher than if one would collect holes. Should be more clear now.
- L189 remove "are" → ok
- L218/226 start the sentence with "Three/Eight sensors ..." → ok
- L299/300 do we have results to show? → Results are shown in Ref [12].
- L302 what was the expected and observed value? → Design parameters are given in Table 3.
- L307 conceived --> developed → ok
- Fig 7 I would leave the results up to 650-700 MHz/cm² to show the margin → ok
- L375 "some probability" - can you quantify? → no, it depends on the transistor design (as stated in the previous sentence). This is just meant to say that every transistor is affected by SEU.
- L385 do you have any updated results to include? → no, is out of the scope of this paper.
- L389 I would write "three module designs" → ok
- L408/409 same sentence? → following sentence has been removed.
- L439 more automated with respect to? → The process used for the original FPIX in the reference. Changed to this sentence: "The bump bonding procedure relied on a more automated version (Datacon APM2200) of the process used by the vendor RTI for the original FPIX detector (FC150) [27]."
- L446 I would drop "finally" it has a negative connotation → ok
- L449 This sentence does not flow well. Can you reword it? I assume you want to say that "After failing modules have been reworked, the yield rose to 90%"? → yes, changed.
- L556 do we have uncertainties on these 2 values? → added the RMS of the distributions as errors.
- Fig 11 I assume you'll produce these 2 plots with the

same format? → yes, done.

- Fig 12 caption: calibrate --> calibration → ok
- Fig 13 caption: the statement "is determined for the module qualification" is not clear. Please clarify → changed “for” to “during”.
- L569 please rearrange the numbers in brackets (there is no correspondence) → changed according to your suggestion to: “In total, 1634 (141) modules were built for BPIX L2-L4 (L1), out of which 1246 (117) were accepted for installation and 1088 (96) were installed”
- L571 "a bit lower" is too vague, can you please quantify? → statement is removed
- Also I would try to provide % wherever possible for both BPIX and FPIX → the yields for FPIX are discussed in the module production to motivate why there was (initially) no bare module test for FPIX. Prefer not to repeat it here.
- Fig 15 I think you want to rework this Fig as well (legend is really small) → yes, done.
- L592 "detector mechanics are attached" is jargon please reword → is “connected” better?
- L647, 648 an example where exact definition of quadrant, shell is needed → rephrased.
- Fig 19 top: it is hard to really understand the Fig. Do we have a better one? also the bottom one may not need the insert → unfortunately there is no better figure. Can be removed, if desired.
- L670 what values of pressure? → at 200 bar, added.
- L824 It would be good to slightly expand on this: what modules, how many, → The test setups are described in the DAQ paper, reference [17], so I don't see the need to expand it here.
- L911 Why wasn't FPIX tested in the same way? → Less tests were made for FPIX, which is ok because the BPIX chain is more complex (in the original version this was also indicated in the text, but has been lost due to other comments), and because the people who did the BPIX tests also developed the DC-DC converter boards themselves. I

would leave it like this, in particular because references and pictures are mainly on the BPIX measurements.

- Section 6.3 (and later on when you describe the installation): it would be very helpful if you had a schematics of the connections of the pixels to the cavern services → unfortunately such a figure does not exist and will take quite a bit of time to make. There is Fig. 7.1 from the Pixel Phase 1 TDR which could be added to the power section if desired.
- L957 We cannot use the word "believe". We could use "it was determined that ..." → ok
- L965 can you reference a paper? → unfortunately not, as there is no write-up for the FEAST v2.3 at this point.
- L1001 is this at the end of life? → yes, for an irradiated detector at high-luminosity. Added reference to TDR.
- Fig 32 I admit that the difference between the 2 plot except for the assumed load is not clear. Shouldn't we show only one with the correct expected load? → The two plots show the results from the two different BPIX L2 cooling loops that were used in the mockup. They are both with expected nominal load, the difference comes from the fact that the number of modules per loop is not the same.
- L1092 how was it improved? → sentence is removed.
- L1124 This sentence is not completely clear. What "the hub address is set before mounting ..." how is it set? → "by removing the wirebond" as stated in the second part of the sentence.
- L1135 how many modules in a group? → 11-16 modules. Added.
- L1140 foru --> four → ok
- L1153 what does a slice contain? → Sentence changed to: "The components of the pixel detector DAQ and powering system used during the testing, allowed to test one sector at a time."
- At the end of the BPIX and FPIX integration section I would specify the final number of non functional modules and % of channels → done on L1181 and L1234. Added % for

FPIX.

- The BPIX is much more detailed than the FPIX section. Can this be consolidated? → Since this is referring to the installation section, I do not see a big unbalance. L1254-1276 are descriptions which apply both to BPIX and FPIX. Then there are L1277-1299 for BPIX and L1290-1305 for FPIX. As a matter of facts, things which are introduced for BPIX and also apply for FPIX are not repeated.
- L1319 Fig --> Figure → ok
- Fig 42 Can you clarify the trend exhibited by the uncertainties? why is the uncertainty increasing with DAC given that it is the spread among channels? → The figure has been reverted back to the version in which the individual channels are shown.
- L1408 The in time threshold is different from what reported in Tab 3 → yes, because Tab 3 are the design goals. In this case we did not reach it. As stated in the text.
- Fig 44 adjust the position of the sub figures → merged in one figure.
- L1417 were --> where → no, this is correct.
- L1496 what do you exactly mean with SEU cross sections? → the number of SEU events per unit of fluence
- L1499 and 1514 there seems to be a tension between "very minor" and "10%"? → This is what is said. SEUs go mostly unnoticed, however with some probability vital circuits are affected. In case of the "10%" a vital circuit was affected...
- L1533-44 It is not always clear what Fig you are referring you, I suggest you have a look → This part has been changed according to Andrea's comments
- Fig 47 caption: what is the definition of "broken cluster"? → This part has been changed according to Andrea's comments
- L1552 please spell out LA as Lorentz Angle here → ok
- L1555-1572 I find this part a bit hard to follow.
 - o It would be better if you started by showing the evolution of V_{dep} versus luminosity (as determined from a proper fit) and then relate that to the V_{bias} applied to the sensor.

o I assume you don't have the values for different modules (old and new) for the same lumi? The significance of the comparison as it is now is slightly diminished because of the different lumi.

o It would also be preferable if you explained each plot separately and in detail.

§ please use fb-1 everywhere (replace pb-1)

§ Top right: is the difference observed scaling according to the dose as expected?

§ Bottom left: why is the cluster size of old module 52/fb) smaller than that of old modules (32/fb)?

§ Similar questions for Bottom Right

→ This part has been removed.

• Tab 5 I would use Vbias instead of HV → ok

• Fig 51 this figure is very hard to read even on the laptop.

Please reformat it. You could have 2 plots instead of 1 reducing the number of points, increasing legend size etc → Figure and legend have been improved.

• 1596 suppose --> supposed → ok

• going to max voltage is jargon, applying max V is better → ok

• L1594 and needs --> which needs (the power needs to be removed, not the leakage current) → ok

• The leakage current can be --> The increase of leakage current can be ... → ok

• 1603 please specify the value of the scale factor and why they differ layer to layer → Fig removed.

o Explain why the ratio data/sim is different from 1 for each layer at the start → Fig removed.