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## Rutgers group

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General:

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✗ As stated in lines 150-150, is not the first evaluation of the AFEs, but the first rigorous application of CMS criteria to the measurements. To make this point better, perhaps this should be stated in the introduction instead of the end of section 2.

In this paper, the introduction is actually the first two sections, I split it in two for better clarity. So, I cannot talk about the evaluation before introducing the chip and explaining that there are 3 AFEs to evaluate – this is why it is at the end of Section 2.

✓ The "chosen" AFE is none of the three - it's modified LIN, and it only has been simulated, not tested in hardware. This probably also should be emphasized. It is definitely confusing that Figure 7 shows the modified, not tested AFE.

It was also measured in a test chip and verified after irradiation as well. It was stated before but to make really clear I added a sentence: “ The improved design of the LIN AFE was also implemented in a test chip and verified before and after irradiation.”

✓ The tests were done at -10C. What is the reason for the choice? Does it matter that it's warmer than the expected CMS environment?

The tests were done at -10C because the lab cooling system cannot go lower. I added a sentence about it. It should not matter much for the results if it is done at -10 or lower, what matters is that it was cold and not room T. Or do we need to explain this?

✓ In the title and elsewhere in the text: replace "Phase-2" with "High Luminosity LHC" or "HL-LHC" as appropriate.

We concluded that Phase-2 is ok. But I change in the main title and the Section 1 title, For the rest I kept Phase-2 since I defined it in the beginning.

✗ Some clarification is required on the following: Line 60 states two pitches are considered: 100 x 25 and 50 x 50 but line 93: states 50 um pitch in the demonstrator. So, has the choice been made already? This needs some clarity. Perhaps the 50x50 is a tighter constraint on the pixel unit cell from an electronic layout point of view?

Confusion here: The two pitch options are for the sensor and the 50x50 in the demonstration is the pitch of the pixel chip. The latter was chosen and is fixed. For each measurement I specify which sensor pixel pitch was used. I think I explained the distinction between sensor and chip in a clear way?

✗ Should CMS requirements (Section 3) be discussed before the discussion about the proposed design? Please consider moving that section up.

I don't think it is good to discuss the requirements for the AFE selection before explaining what an AFE is and saying that there are actually 3 options.

✗ Section 5,6: Are these "after irradiation"? Should be consistent with Section 4?

No, none of the measurements were done after irradiation, except in Section 4. It is precised in the text.

Line-by-line:  
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✓ line 13: the NEW Inner Tracker

✓ line 15: processes --> digitizes

✓ line 21: "Moreover a saturation" --> "Moreover, a saturation" (add comma)

✓ lines 22-23: "The Synchronous front-end showed a very good timing performance, but also a higher noise." --> "The Synchronous front-end showed very good timing performance, but also higher noise."

✓ lines 23-24: "The Linear front-end had the slowest time response:" --> I think the ":" should be replaced by a ";"

✓ line 44: inner tracker does not record TRAJECTORIES. It records hits used to reconstruct trajectories.

I replaced « tracker is recording trajectories » with « tracker is detecting trajectories »

✗ line 45: remove the sentence "it will be entirely replaced..." Clear form the context, and does not provide the actual information (e.g. what radiation dose current IT would die in, what is its granularity and how it affects reconstruction, etc)

I think it is good to clearly state that the tracker will be completely replaced

✗ line 53: latest? Is it not final? Change it to "proposed" if it's not final?

I put "latest" because it has changed several times and different versions have been published (e.g. in the TDR it is slightly different. And it is not 100% sure that it is The Final)

✓ line 54: barrel part --> barrel component

✓ line 62: billions --> billion

✓ line 62: "The mass of the detector has to be as low as possible" --> "The detector design strives for a minimal mass of the detector"

✓ line 71: "passive components and connectors, called high density interconnect" --> "passive components and connectors, called the high-density interconnect"

✓ line 73: The signal PRODUCED in the sensor is TRANSMITTED to ...

● line 75: Here and in few other places where comparisons of the old and new detector: consider moving them all up to the beginning of section 2? (latency, trigger rate, pixel size, radiation dose)

I did not understand the point, but in any case, the info appears always in the section where it is relevant for an explanation.

✓ line 75: "Only after receipt of a Level-1 trigger signal the hit information" --> "Only after receipt of a Level-1 trigger signal is the hit information"

I rather changed the sentence this way: « The hit information is sent to the back-end DAQ only after the receipt of the Level-1 trigger. »

● line 87: Is "intellectual property" spelled out not to define IP-blocks? May be just drop "intellectual property"?

● line 92: drop ", as it was sharing reticle..." -> what's the point of spelling it out? It's a test chip anyway, no reason for it to be the same size.?

This was Jorgen's comment to add it, so I kept it.

✓ line 96-97: long sentence. Break it up as follows: "The analogue-to-digital conversion is performed by the analogue front-end (AFE), whose basic structure (shown in Figure 3) consists of" --> "The analogue-to-digital conversion is performed by the analogue front-end (AFE), whose basic structure is shown in Figure 3. It consists of"

✓ Section 3 title: perhaps consider instead "AFE evaluation criteria" or something similar. "CMS requirements" sounds too general.

I changed it to "CMS requirements for the analogue front-end"

● line 114: 8x8 pixel cores: are those 2x2 assemblies of the analog islands? If so, please say it explicitly.

No, one pixel core = 8x8 pixels = 4x4 analog islands – Should I specifically mention this? Anyways I added that the analog island is 2x2 so the math is quickly done.

✓ line 172: how much fluence did the 150 um sensor get? It's in the Figure, but should be here as well.

✓ line 187: The CMS --> The CMS collaboration

- ✗ line 189: what does "higher radiation tolerance is privileged" mean? It is never actually spelled out WHAT the spec for radiation dose? It would be good to do that. It seems that there are 4 different numbers: total dose in layer 2, total dose in layer 1, and dose in layer 1 for two different scenarios for layer 1 replacement. Would be good to have them all shown in one place (e.g. in a table?)

We don't have a specification for the radiation tolerance because the simulated numbers keep increasing, that's why we did not want to state a hard number. Moreover, the dose in layer 2 was never used – where is this coming from? We just know that 500Mrad is not enough and that we want the radiation tolerance to be as high as possible.

- line 195: what is the exact justification for setting the noise threshold 100 times below the occupancy? The tracking studies referred to later do not mention it.

With this requirement we would have 1% of spurious hits at the maximum in the detector which sounds reasonable. Should I say this explicitly?

- ✓ line 220: "The impact of the charge resolution on the tracking performance" --> "The impact of charge resolution on tracking performance"

- ✓ line 221: "The simulation of the tracking performance for the reconstruction of single muons" --> "Simulation of tracking performance for the reconstruction of single muons"

- ✗ line 392: Isn't CMSSW used already in some of the previous MC simulation studies? If so, then this description should be mentioned earlier (e.g. section 3). Also, CMSSW isn't as important as saying that it's a Geant based simulation etc.

I don't know. I think not actually.

- line 395: what kind of hits are used for this? Are they from particles that we have a chance of reconstructing? (i.e. should not include loopers, low pT secondaries, etc)

I think it actually exactly includes loopers and those are the part of the intrinsically late hits. But I will verify this info.

- line 399: what kind of events were generated? And what constitutes a hit here? Is hit = pixel with charge? Since charge sharing is important, this should be very clearly specified. It may not be terrible if the time walk makes second pixel in a cluster detected in a different crossing - while there would be effect on spatial resolution, the other hit could clearly still be used for pattern recognition.

I would need to check this with the simulation group.

- ✓ line 406: plot --> replace with figure or graph

- ✓ line 426: "...variations in the length of the electrical links, the jitter and" --> "...variations in the length of the electrical links, jitter and"

✓ line 489: " However, given the radiation levels expected in CMS, such operation range  
--> "However, given the radiation levels expected in CMS, such an operation range"

✓ Section 8: Conclusion --> Conclusions

Figures:

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✓ Figure 1:

- \* Move description of the brown TEPX ring to figure caption instead of the footnote.
- \* Also the gray line should be explained or removed. Beampipe envelope?

✗ Figure 7: Please make two versions of it, as tested and as proposed after fixes.

*This is the circuit as it is implemented in the RD53A (which is the topic of the paper)*

✓ Figure 9:

- \* Add on each figure themselves somewhere that one is before and the other is after the irradiation. (not just in caption)
- \* Also, is this figure relevant? It's not the Phase-2 pixel area, and not the expected irradiation dose, right?

*It was just to show the expected signal to justify the required threshold, even if it is a bit different in the final sensor it will be similar.*

✓ Figure 11:

- \* add "blue" and "green" in figure caption where appropriate. Also explicitly mention the meaning red line in caption.

● Figure 12:

- \* add to figures that this is from simulation.
- *Not important it is in the caption and the other simulation figures don't mention it.*

- \* caption should mention that the simulation is single muons.
- *Do we really need this level of details in the caption? It is explained in the text...*

- \* why not also mention the colors in the caption?
- *It was already there.*

● Figure 15:

- \* What is "out of scale: 5.8%"? Why not "Overflows"?
- Should I replace it with "overflow" ?*



Figure 14:

\* minor comment, but it may be nice to have these three figures show (a), (b), (c), to have a consistent figure naming scheme as in Figure 13 and others.



Figure 22:

\* similar comment as for Figure 14

\* Also, should there be a horizontal red line corresponding to the expected operational threshold? – This figure is a single pdf for better alignment so I cannot use the latex subfigure numbering, unless it is really need I would leave it as it is?

\* May be would be good to have it shown in Fig 21 as well.

– Fig.21 is just to show how a time walk looks like it is not a result or whatever!

Figure 24:



\* It would be easier to guide the eye if it says: denoted "e" etc... Or put in italics?



\* The simulated modified LIN should be presented in this plot, too. – As we said it is better for storytelling to not to put yet the modified LIN here.



Figure 26:

\* similar comment as for Figure 24

