

## Review - Perugia

# The CMS Phase-1 Pixel Detector Upgrade

### GENERAL:

1) We have noted that sometimes there is the serial comma and then we ask to uniform along the text. → ok, done.

2) Consider to change “position” (position resolution, position measurement, recording the position...) with “impact position” or “crossing point” or...

Only “position” seems too general → usually means hit position. We consider this to be implicit.

## Abstract

Last sentence: performance -> performances → prefer to keep as is

## 1 - Introduction

L 50: “has” -> “includes” → ok

L 51: it seems there is a double spacing between “system” and “the” → fixed

L 52: “space points” -> “tracking coordinates” → prefer to keep as is

L 55: it seems there is a double spacing between “4” and “,” → ok

L 70: “reviewed” -> “described” → ok

L71: performance -> performances → keep singular

L71: is -> are → keep singular

L72-74: the entire sentence appears a little bit twisted and should be simplified → kept as is

L 79: insert a comma between “system” and “as” → ok

## 2 - Design of the CMS Phase-1 pixel detector

### Type A

L86: “, improving” “, thus improving” → rephrased

L86: remove comma after “reconstruction” → no, we use Oxford comma

L88: closer -> closest → ok

L88: mettere “mm” -> “cm” → fixed

L90: and 160mm, respectively → left as is.

L90: remove comma after “109mm” → is Oxford comma

L 90: “at” -> “having” → kept

L91: remove comma after “396mm” → is Oxford comma

L92: compared to that -> compared to the one → ok

Table1: BPIX table -> is the z position column really needed? It doesn't add any important info → kept for completeness

L100: “design” -> “dimensional” → ok

L143: “The ability to cope with expected hit rates...” → “The ability to cope with an

expected hit rate...” → prefer to keep plural as the hit rate is different for each layer and disk position

Fig 1: “Upgrade” in the figure -> I would use Phase1 Upgrade → ok

L147: luminosity -> add as will be shown in chapter 11 → ok

Table 2: remove “pixel” from the title of the second column → no, kept, because it specifies that it is “pixel hit rate” as opposed to “cluster hit rate”

Type B

General: CMS unit are cm not mm. Please consider to switch to cm → this comment applies to the radii mainly. Prefer to keep mm since then it is consistent and same units as used for instance for ROC size and mechanical description of overlaps.

L 70: The word “review” appears as an action that involves a subsequent modification,

which is not true; it should be changed with analysis or assessment, etc. → changed to “described”

L95-99: Maybe you can introduce here that BPIX and FPIX are two completely independent components, both mechanically and electronically. → ok, instead added on L100.

Ls 102-104: this sentence appears not clear in terms of the logic counting of the disks.

Perhaps, if there are 3 disks, it should be said before that each disks is divided in the

inner and outer part (3 x 2) and then each part is divided in half-disk (6 x 2), for mechanical reasons, to have 12 half-disks. → it is three disks on each side, so six disks in total, so 12 half-disks.

L128: I would say that it almost unchanged in the barrel region while it is reduced, w.r.t.

the original one, for  $|\eta| > 1$ . → yes, changed.

## 3 - Silicon Sensor Modules

Type A

L157: add after “chip” the following “, or two in case of L1 modules,” → ok

L239: The LA depends strongly -> strongly depends → kept as is.

L254: Maybe here a sub-sub section like 3.2.1 PSI46dig could help the reader. Then if you agree a 3.2.2 should start before line 308, similarly → had subsubsections in earlier iterations of the paper. Removed based on reviewers comments.

Fig 6: I would specify here (legend / caption ) that psi46 is for the original pixel detector,

while psi46dig for the phase-1 → ok

L400: of of -> drop one → ok

L412: in the TBM a -> in the TBM, a → ok

Table 4: is the third column necessary? → it is said in the text that a TBM09 has 2 readout links and a TBM08 one link, but prefer to also have it here in the overview table.

L425: all have -> have all → kept as is.

L427: modules are of identical design -> have an identical design → ok

L435: dicing. The yield -> dicing; the yield → prefer period

L435: 53%^2 -> remove the apix → prefer to keep it

L477: all have -> have all → kept as is.

L539: there is no response -> there was no → ok

Type B

L213: <111> Taking into account the higher interface defects of <111> crystal

orientation, why do you use this crystal orientation? → <111> crystal orientation has also some advantages: less prone to channeling or spiking. As the higher oxide charge (especially before irradiation) is low enough not to cause any problems we did not change

the process. I would prefer not to touch the text.

L243-249. Radiation damage studies on sensors are not described. It is possible to find

results in the references, but probably a summary could be useful. Have you tested the

sensors up to 800V after irradiation? → Since this information has already been published in the TDR, we decided not to put it here. Ref [8] shows irradiated sensors with up to 1100V.

In Section 3.2 the main characteristics of the upgraded ROCs have been reported.

· Nevertheless, the authors did not comment about power consumption requirements. It is interesting to know the power consumption of the redesigned chips and the adopted strategies in the analog and digital design.

· The authors should also comment on static and on dynamic power consumption of the chips.

Add a paragraph after line 297 about the PSI46 and after 323 about the PROC.

L256: why don't you add a block diagram of the ROC? → Mostly because at the level of simplified block diagrams the two chips have not changed much with respect to the old phase-0 PSI46. The diagrams for PSI46 have been published in a NIM paper from 2006 (see ref 15) and republishing them would not make much sense.

L297: I would emphasize the gain in efficiency from the phase-0 to the phase-1 roc and

the modification that has been introduced in the phase-1 roc to cure such inefficiency.

- one additional metal layer in the ROC

- Several of the original 16 DACs have been removed and replaced by fixed voltage levels in order to simplify the ROC tuning.

- In the double column periphery

the buffer size of time stamp and data buffer have been increased, from 12 to 24 cells the former and from 32 to 80 cells the latter, in order to store the larger amount

of data foreseen .

- A second readout stage

has been introduced to reduce the dead time wasted in waiting for a readout token.

To fit the overall changes the ROC size has been increased by 4 mm.

→ most of these things have been mentioned. See lines 288-297.

It is not very relevant that an additional metal layer was used. Change in ROC size is mentioned in the table.

Modified the sentence starting in line 288 to :

“The main changes for the PSI46dig compared to PSI46 include the increase of the size of the data (from 32 to 80) and time-stamp (from 12 to 24) buffers to store ...”

L336: can you add a reference here to some documentation for the new ROC ? → there is no public document that we could cite.

L411 the authors write, “Therefore, with some probability, every transistor in the pixel detector readout chain will be affected by SEUs.....” The reviewer suggest that the authors write a number instead of “some” if available.  
Yes, we do have this number but it is very technology and supply voltage dependent.  
That is it is vert specific to our design.

We could add a sentence in line 412, after “Therefore, with some probability ...” the following sentence

“For the specific CMOS technology and supply voltage used in the design of the ROC and TBM chips the SEU probability is XXX for unprotected transistors and YYY for protected ones.

L503: Up to four modules could be tested in parallel on each setup -> Not really. In

Perugia we could test up to 4 modules in parallel only in the cold box, for the xray we could parallelise 3 modules, while the calibration test we could test 1 module per time. → yes, but this is the meaning of “up to”.

L507: I would say here that all the modules underwent to 3 different tests: cold box, high-rate xray and cailbration, with the first two that were used to get the final grade of the module and decide whether it could be used for the final detector or discarded.

The you can describe the single tests in subsections 3.6.1, 3.6.2, 3.6.3 → had subsubsections before, were removed due to other reviewers comments. We do have the structure you suggest. First tests in cold-box, then x-ray high-rate tests and calibrations.

## 4 - Mechanics

Type A

L 648-650: the sentence should be moved after the sentence "Modules are mounted on the inward and outward facing sides of the inner and outer ladders, respectively." to

make more readable and logic the text. → ok

L 649: substitute “1” with “1.0” → ok

Ls 656, 676, 764, 765, 771 and figure 18 caption: substitute “made from” with “made of” → left as is

L 670f: the quotes are very small and hard to read, they should be enlarged → technical drawing. Kept.

All the figures: capital letters should not be used after the colons → kept (if you mean Fig:... then this is used in CMS papers)

Ls 667-669: substitute “In Segment B the opto hybrids are placed” with “The opto-hybrids are placed In Segment B”. → ok

L 668: figure 24 is too far away from the position where is cited in the text. → Figures are only place at top or bottom of page. Bottom of page 32 does not fit, so it is top of page 33.

Ls 671, 695, 750 and the rest of the text: a comma to divide thousands or millions

should be inserted: for instance: (1,970) (1,225) (1,000) → kept current style.

L 704 and the rest of the paper: is it not z+ and z- instead of +z and -z? → no.

L 712: the acronym CNC does not appear in the glossary → added

Ls 716-717: the sentence “Because of the tight tolerances needed in the laser welding process high-precision tube alignment is achieved” is not clear → why not? The smaller the tolerances, the smaller the differences in the tube diameters at the joints and thus the better the alignment.

L 723: insert a comma between “production” and “a” → ok

L 748: figure 22 appears before figure 21 in the text: the order should be changed → ok

L 783: the acronym PEEK does not appear in the glossary → ok, added.

Type B

L 671: “z > 1970 mm” Supposing that the service cylinder is 1.7 meter+half of BPIX

(0.54/2=0.27 m) this quotation is the endo of the segment A? It is not clear what represents. → removed as it does not add much.

Ls 754-760: is it possible to provide the air temperature during the acquisition of the thermal image? → no, don't have this information.

## 5 - Readout Architecture and Acquisition System

## 6 - Power System

L 911: after ASIC add “controller”; remove “chip implements” and add “the converters

are designed implementing” → ok, for the latter.

L 912: remove completely the line and use “at the switching frequency” → ok

L 913 remove “ and ... voltage” → ok

L 917 remove “delivery ... stopped” and change to “converter can be switched on and

off” → left, as this defines what “off” means. (not completely off, but just output voltage off).

L 927 remove “AC ... noise” and change to “the noise arising from the switching ripple” → ok

## 7 - Cooling

Type A

L 1035: substitute “in the vicinity of” with “near” → ok

L 1041: sometimes the word “thermodynamic” is used, sometimes “thermodynamical”,

please be consistent. → ok, changed to “thermodynamic”

L 1061: add “an” between “providing” and “ample” → ok

L 1080: move the L up before figure 29. → no figure has to be at top of page.

L 1085: remove the two “in” → ok

L 1099: insert a comma after the word “constraints” → ok

L 1095: remove the word “in” → ok

L 1105: substitute “10” with “10.0” → ok

Ls 1113-1116: sometimes the present tense is used, sometimes the past tense, please

be consistent → ok

L 1116: add a comma after the word “start-up” → ok

L 1123: add a comma after the word “detector” → ok

L 1127: figure 30 is positioned before its citation in the text → figure has been removed

L 1130: add a comma after the word “performed” → ok

L 1135: add a comma after the word “results” → ok

L 1136: add a comma after the word “operation” → ok

L 1139: substitute “leakage current” with “it” → ok

L 1149f: the caption of figure 31 is too long: part of the explanation should be transferred to the text. → prefer to keep it in the caption.

Type B

Ls 1043-1044: talking about the capillaries as small restrictions is a bit misleading as

they might be confused with orifices; capillaries are part of pipes with smaller diameters

respect to the rest of the cooling loop → Simplified to: “The passage of the fluid through capillaries, at the entrance of the detector,...”

L 1058 and 1060: the ambient environment does not “leak” heat to the detector; the word leak is more appropriate when the heat goes where it is not supposed to go. → changed to “spreading”

L 1122: The mockup was composed by two cooling loops (perhaps). Authors should

specify it in this section. → yes, added.

## 8 - Pilot System

none

## 9 - Integration, testing and installation

Type A

L1186: was carried -> were carried → no, singular

L1189: had occurred -> remove had → no, past perfect.

L1211: remove commas after “steps” and after “placed” → no, kept.  
L1215: “within the slots to fit into the tight space and...” → “within the slots to fit into the tight space available and...” → ok  
Figure 35 caption: “BPIX service half-cylinder during assembly. Service half-cylinder mechanics with power boards and cooling loops installed (left), and fully equipped BPIX service half-cylinder (right).”  
“BPIX service half-cylinder during assembly: mechanics with power boards and cooling loops installed (left) and fully equipped BPIX service half-cylinder (right).” → ok  
L1220: one sector could be tested at a time -> one sector at a time could be tested → ok  
L1296 - 1298: rephrase, it not clear → ok  
L1318: to the number previously installed -> to the previous one → prefer to keep as is.  
L1326: has been installed -> had be → ok

#### Type B

L1363: Was it done only in 2018? Why not in 2017 just after the original installation? → this is a full-scale analysis. Only done with 2018 data.

## 10 - Detector Calibration

L1373 - “and cooling was available” -> “and the cooling available” → ok  
L1428 “due to the larger cross talk noise” -> if already discussed should be pointed where → said in sentence  
L1456: “In addition the new ROC to be used in the replaced L1 will have a much lower cross-talk noise.” → “In addition the new ROC which will be used in the new L1 will have a much lower cross-talk noise.” → ok  
L1469 - “30 charge values” -> Is it meaningful? What’s the charge value / pC conversion factor and in which range? → sentence removed  
L1473: remove comma after “data-taking” → ok

## 11 - Operation and Performance

#### Type A

L1496-97 supply -> power supply → ok  
L1501: damage -> damages → singular  
L1519 - 1520: I would remove this space here, you are still on the same topic → introduced because of other comment.  
L1528: “or tracks” -> “tracks” → rephrased  
L1532: cosmic ray muons -> cosmic muons → ok  
L1541 - “remedy” -> “recovery” → ok  
L1541 - “Most” -> “Most of the” → ok  
L1634: with the efficiency the -> with the efficiency, the → ok

#### Type B

L1486 - “was due to an issue with the clock distribution in one sector.” -> any reference? → no, not available.  
L1537: I would add 1 or 2 plots on the alignment measurements here. → goes beyond the scope of the paper. Alignment paper in preparation.  
Table 5: Is it really necessary to put the LA value in a Table with only one row? LA value for 2018 start and Run2 end could be added as well. → This is done on

purpose. We do not want to present any historical evolution since this will be covered by the planned performance paper.

L1645: Student's t function -> can you put a reference here? → no needed. Also not done for Gaussian.