Minutes for the CEPC detector CDR mini-review

Time: November 10-11, 2017

Location: IHEP (A415)

Reviewers:

Alexandre Glazov (DESY)

Charlie Young (SLAC)

Sebastian Grinstein (Barcelona)

Alberto Belloni (Maryland)

Jianming Qian (Michigan)

Walter Snoeys (CERN) (Offline)

Daniela Bortoletto (Oxford) (Offline)

Franco Grancagnolo (INFN)

LianTao Wang (Chicago)

Attending:

Hongbo Zhu, Suen Hou (Vidyo), Qun Ouyang, Qingyuan Liu, Joao, Huirong Qi, Haijun Yang, Tao Hu, Zhigang Wang, Boxiang Yu, Feipeng Ning, Liang Li (Vidyo), Manqi Ruan, Gang Li, Yaquan Fang, Zhijun Liang, Zhaoru Zhang

General Comments from the reviewers:

Comments from Charlie

Re-organization proposal:

I believe it is better to describe each of the two detector concepts as complete entities in individual chapters. Based on what I have heard, there is consensus that this is the preferred organization from the technical point of view. The alternative is to collect all trackers from the two concepts into one chapter; collect all the calorimeters from the two concepts into another chapter; and so on. This appears to be motivated more by sociological worries than technical.

Thinking about the two concepts, I see their fundamental difference is the calorimeter. Once the calorimeter choice is made, the substantive differences follow. [And non-substantive decisions can end up being the same or different.] PFA wants large field to spread out particles and nothing between tracker and calorimeter for linkage. Dual readout calorimeter is more tolerant of additional dead material and allows the tradeoff of having the coil inside the calorimeter to save cost. The drift chamber tracker can function with a 2-T field but does not require it – this is one I would call non-substantive choice. In the attached document organization proposal, I also included some text that one might want to consider for the document to explain these technical as well as sociological points. Blue and indented text is this text, and black is comments.

Some general comments.

(1) We need a chapter on detector requirements. This should be at the level of resolution goals rather than how they are achieved. For example, talk about X% momentum resolution rather than magnet field strength and dimensions or measurement point resolution. Similarly, talk about energy resolution of Y% rather than the number of sampling layers. It is up to the detector concept chapters to make that translation.
(2) Make sure that numbers within the document are internally consistent from one chapter to another, e.g. 3 T vs 3.5 T. And in cases where we offer an option to improve something, also include any negative impacts. For example, we say in one place to go from 10 x 10 mm2 to 20 x 20 mm2 calorimeter cells to reduce power. I believe that would increase the necessary dynamic range (which we have not quite satisfied even before the change). It is not that we need to have

solved the problem already, but we need to include it so the pluses and minuses are all on the table.

(3) Many of the sub-detector sections look like they are articles for NIM rather than part of the CEPC CDR. They sometimes trace the development path of the particular detector technology. I suggest that we focus on the one version that we think will go into the CEPC detector. They sometimes describe the test-beam DAQ system — this is irrelevant to the CDR and can be dropped. Some talk about performance improvements when the technology is already a large factor better than required for CEPC. Again, it should be dropped.

(4) I think that in general offering two technology options for a detector sub-system is fine. There is also nothing wrong to offer one when there is nothing else comparable. In particular, the muon detector section has way too many options. I strongly prefer to keep only the RPC here because RPC is cheap and easily satisfies all the requirements while the other technology options solve problems we do not have, e.g. rate capability or position resolution. They are more expensive and some are unproven for the scale needed for CEPC. Including obviously non-competitive options in the CDR tells the reader we are incapable of simple decisions. Note that this is a Conceptual Design Report. It does not lock us into only those options that are listed in it. If another technology becomes more appealing in cost vs performance, we are free to adopt it in the eventual detector.

(5) Performance numbers should be based on simulation or even better on a realistic measurement, and not on speculation that it ought to be some number or other. One example is the scintillator bar readout of imaging calorimeter. These bars are 5 mm x 45 mm, with two orthogonal orientations. The "cell size" of 5 mm x 5 mm is applicable for MIP, but it does not apply for a shower. We need to evaluate properly the performance with 5 mm x 45 mm strips.

Comments from Jianming:

- The CDR should present one baseline detector concept. I'd suggest not to present other possibilities as options, not the second detector concept. Terminology should be clear. For example, the full silicon tracker is an option for the tracking detector, by itself it is not a detector concept.

(1) Each subdetector chapter should state clearly at the beginning performance requirements that are considered for the proposed detector concept(s). It may mean some repetitions if the performance requirements for all sub-detectors are summarized in an early Chapter, but I think it is important to begin the chapter with this information.
(2) The overall sub-detector geometry should be presented clearly. For each sub-detector concept, estimates of number of channels, volume or weight of potential cost-driving materials should be included.
(3) For sub-detectors with multiple concepts, there should be a section discussing pros and cons of each concept. A simple collection of multiple concepts makes things a bit disjoint.
(4) Ideally it will be good to have a table for each sub-detector concept summarizing most important parameters and information. Many important numbers are embedded in the text, but it will be much easier for a reader to find the information if they are summarized in a table.
(5) At least for the baseline concept, each sub-detector should have a complete schematic.
(6) The presentation flow, level of details and format of each sub-detector chapter should be harmonized.
(7) Each sub-detector option should discuss areas that R&D's are required.
(8) There should be text on triggers and readout. I don't think these are problems, but trigger and DAQ concepts need to be included in CDR. Confusion about the trigger and DAQ are already apparent at the mini-review.
(9) a nice, simple schematic for the baseline detector concept. I suspect it will be used widely in presentations.

Comments from S. Grinstein

- Not particular to Chapter 4, but in general I am a bit confused about the CDR structure. Usually these documents follow something on the line of:
  - ✓ Physics motivation → requirements (for example, to obtain such measurement with such statistical error one needs such luminosity, or to study such Higgs decay mode such b-tagging efficiency is needed).
  - ✓ Detector Layout (initial layout needed to be able to do performance studies...)

- ✓ Performance→ detector requirements (for example: such position resolution requires such pixel size, and such luminosity such radiation hardness)
- ✓ The last step, detector requirements to specifications, is done in a later stage, much closer to actual construction, since detailed specifications can limit the technical options at some level.

The Vertex chapter should then start with the detector requirements, as it is indeed done in 4.1. However, I have not been able to find the motivation for such requirements, which thus seem arbitrary. The later section on "Jet flavor tagging" on Chapter 11 does not provide requirements.

- In the line of the comment above, I would think that the section 4.3"performance of the baseline [vertex detector]" should not belong to Chapter 4, but on the performance chapter. While Chapter 4 focuses on the technical options, the current and future R&D activities.
- The fact that the same layout as for the ILD has been adopted with no real justification (??) gives a poor impression.
- The work already done within the CEPC effort so far (CMOS, SOI2) is missing some detail. This can be added in a concise manner, with short text and references.
- I think the technology section needs to be updated.
  - ✓ It mentions DEPFETs in a positive light (I think they are not an option). It mentions the R&D of ALICE as "gaining momentum", when is is already well done and in production.
  - ✓ Contrary to what it says, ALPIDE reached the power dissipation of 40mW/cm2, but the radiation hardness is in fact on the edge (0.6 Mrads, but not sure if this is the limit of the technology or the tests).
  - ✓ Also HV/HR CMOS are lately collectively called depleted-CMOS (since technologies tend to offer different resistivity anyhow). The classification is now small or large fill factors.
  - ✓ The SOI paragraph can be improved and the "HV-CMOS" text is not correct anymore.
- Is the vertex detector replaceable? Was wondering if this could be an alternative for a technology not so radiation hard, but with other advantages...
- What is the assumed composition of the beam pipe? Does it include Au coating?

- I would recommend including a section in Ch4 that explains the common “front-end issues” of the devices. Trigger operation mode, electronics in pixel, etc.
- If readout speed is a concern, then depleted sensors (like SOI2 or depleted CMOS), are a better option than technologies that collect change by drift.

Big discussion on structure of CDR

- Currently, Ch 6 gives the impression that dual calorimeter is a plug-and-play option for the PFA approach, however in reality, we are talking about two detector concepts. This should be more clearly presented in the CDR
- Consider to restructure along the following lines
  - ✓ Introduction (executive summary of the full project)
  - ✓ Physics motivation
  - ✓ Detector concept A (vtx+TPC/all si + PFA...)
  - ✓ Detector concept B (vtx´ + drift chambers + dual...)
  - ✓ Performance (of baseline)
  - ✓ Summary

Overall recommendation (mail Joao from reviewers)

- Better interaction between simulation and performance
- More manpower... also specific to CDR preparation (editorial team)

Comments for each chapter

Chapter 2: Theory

Liantao says that his charge/goal is to produce 60 pages for physics introduction for CEPC. He does not have the text available yet, but he has a table of contents. They are collecting contributions at this point and text is not coherent yet.

They will have three parts. The physics cases are:

1) CEPC can be measure things well/high-level precision. Include things from white paper on Z factory. Less than 10 pages.

2) Higgs physics/higgs factory

3) Exotics physics

Contents

Some of the studies to be included are based on simulation, but not all of them.

- Include comparison with other experiments, but make sure comparisons with other accelerators are done with consistent scenarios.

- Emphasize that H—>ZZ can be used as a probe of physics that is sensitive to Higgs triple coupling. No other option can do Higgs triple couplings well anyway. New physics that would affect the Higgs triple coupling, would like affect Z couplings as well.

- Need to include the following:

    - WW threshold physics

    - Flavor physics charm/b-physics. (we should check how well we can do charm physics compared to other machines (LHC, BES).

    - Z pole measurements above include measurements around the Z pole

Charlie: Is there a physics issue that imposes the requirements for Kaon identification that are discussed in the detector part? Not clear!

Sasha: How important is it to measure ccbar? Should be highlighted in this section to justify the detector requirements.

Joao: Results in the theory section need to be consistent with the performance expected for the detector, taking into account things like the 3 Tesla magnet. Should be careful that numbers/results in CDR and White paper should not be the same, if the magnet field is going to be different.

Charlie: Agrees that all results in CDR should be obtained for 3 Tesla, independently of how we obtain them (extrapolation, or direct estimation). Everyone agrees we cannot have two documents with two magnetic fields values, and exactly the same results.

Chapter 11: Physics simulation:

(1) For the ECAL cell size, the current 10mm cannot do the passive cooling. The passive cooling request is about 20 mm.10 mm should be highly appreciated for EW measurements which need further evaluation. If we want to achieve passive cooling at 10mm, the power consumption need to be reduced by a order of magnitude. Temporarily we use 10mm, but it can be improved later.
(2) For the Nlayer of ECAL, it is hard to reduce from 30 to 20, but we can improve the algorithm and have different kinds of attempt.
(3) W mass measurement precision~4%, WW threshold -> depolarization is possible
(4) precision measurement of ee->mumu is in process, have a student work on it.
(5) benchmark should not only include Higgs, Z/W related process should also be considered. Choose some interesting process. For every analysis, do not make a copy of paper and note, summarize to one page. Liantao suggested to briefly describe each analysis, only mention the simulation sample and results, other information is referred to the white paper.

    Charlie suggested more focus on the channel related to the performance study, for example, H->mumu channel is used for momentum measurement….

(6) move first section (physics requirement) to chapter 3; geometry section only show new geometry;
(7) Lianyou: Since the performance study has the correlation with the different energy region, have we consider the difference of the performance with different energy region? Manqi: now only depend on low energy region, because of the time scale, the high energy region study will be discussed in the future.
(8) Should we add 2T in CDR? it is nice to have some study for 2T, but the timescale is not sure.
(9) make sure the luminosity measurement is described in performance chapter.

General Remarks for the Physics Performance by Manqi:

(1) The performance requirement should be made explicit and integrated at Chapter 3.

These performance requirements plays a key role to synchronize the entire detector CDR. It should serve as the reference for the physics requirement to each sub detector system. If applicable, sub-detector sections should present evidences that could satisfy these requirements.

(2) The detailed simulation/study to the Physics Performance is appreciated. In general, the current study at simulation level leads to a clear description of the physics potential/physics requirement at the Higgs operation. Several key points still need to be addressed, i.e,

EW

Systematic Control

Passive cooling operation

However, dedicated input is needed to give much solid conclusions. i.e., a complete description of the DAQ and its power consumption is needed to understand the Passive cooling performance.

The Current Simulation is based on Benchmark Detector Geometry. (TPC + Si/W ECAL + RPC HCAL)

Thus, once we discuss the performance of other technologies, i.e, Scintillator ECAL, we cannot refer to the Benchmark Detector geometry.

(3) The potential on flavor physics is not fully evaluated. Which could/should be set as one of the future task. In principle (as agreed by Sasha), the entire history of jet fragmentation cascade could be traced –leads to great physics potential & is certainly an interesting topic to pursue in the future.

Comments from Daniela, on Chapter 3:

(1) The description of the baseline detector is missing 3.3.1

(2) designed to collider electron and positron => designed to collide electron and positron
(3) While for W and Z operations, independent RF cavities are used, and 5220 and 10900 bunches, respectively,
(4) are spreading in equal distance over the full ring. => Independent RF cavities are used for W (Z) operation resulting in 5220 (10900) bunches spread in equal distance over the full ring.
(5) They give rise to both primary and secondary particles to enter the detector. They can cause radiation damage, increase the detector and degrade the detector performance. ->They give rise to both primary and secondary particles entering the detector, causing radiation damage and degrading the detector performance.
(6) Synchrotron radiation, as often considered one of the most critical backgrounds at circular machines, are being evaluated, preliminary results turns out promising
(7) though. -> The effect of synchrotron radiation, one of the most critical backgrounds at a circular machine, is being evaluated. Preliminary results indicate such background is manageable.
(8) For the machine operation at Higgs, => For the machine operation at the ZH threshold,
(9) The annual TID and NIEL at the inner most detector layer are around 2.5 MRad and 1012 1MeV neq/cm2, respectively. In this case I would continue the previous sentence -> For the machine operation at the ZH threshold, the maximum hit density at the first vertex detector layer is estimated to be 2.5 hits/cm2·BX while the annual TID and NIEL are…
(10) Safety factors of 10 are always applied. => A safety factor of 10 is applied to all these estimates
(11) Pi0 the zero should be a superscript not a subscript

Comments from Walter, on Chapter 3:

on the technology: I think “sharing the same pixel technology” should be clarified. Perhaps you could use the same manufacturing technology, but I guess you would probably not like to use the ALPIDE as is. In addition a finer line width technology could be available offering smaller pixel pitch and better position resolution.

Chapter 10: MDI

(1) Do we have plans to replace the vertex detector during the run? You should make sure they are replaceable.
   - Engineering need to make sure whether the inner part is replaceable, the time scale for the upgrade would be long

(2) The IAC suggested to have more statements to explain the details in the MDI chapter, in addition to the plots.

(3) The tracking system for the CDR is fixed at this point, but modifications can be introduced afterwards.

(4) Need to clarify the engineering input needed for the CDR

(5) Forward physics requires separation between electrons and photons by LumiCal. Can it be done?

(6) Add comments to justify why 3 Tesla field is OK.

Given the beam backgrounds, what is the occupancy on the detector per cm^2?

Comments from Daniela:

(1) The description of the baseline detector is missing 3.3.1

(2) designed to collider electron and positron => designed to collide electron and positron

(3) While for W and Z operations, independent RF cavities are used, and 5220 and 10900 bunches, respectively, are spreading in equal distance over the full ring. => Independent RF cavities are used for W(Z) operation resulting in 5220 (10900) bunches spread in equal distance over the full ring.

(4) They give rise to both primary and secondary particles to enter the detector. They can cause radiation damage, increase the detector and degrade the detector performance. ->They give rise to both primary and secondary particles entering the detector, causing radiation damage and degrading the detector performance.

(5) Synchrotron radiation, as often considered one of the most critical backgrounds at circular machines, are being evaluated, preliminary results turns out promising though. -> The effect of synchrotron radiation, one of the most critical backgrounds at a circular machine, is being evaluated. Preliminary results indicate such background is manageable.

(6) For the machine operation at Higgs, => For the machine operation at the ZH threshold,

(7) The annual TID and NIEL at the inner most detector layer are around 2.5 MRad and 10121MeV neq/cm2, respectively. In this case I would continue the previous sentence -> For the machine operation at the ZH threshold, the maximum hit density at the first vertex detector layer is estimated to be 2.5 hits/cm2·BX while the annual TID and NIEL are...

(8) Safety factors of 10 are always applied. => A safety factor of 10 is applied to all these estimates

(9) Pi0 the zero should be a superscript not a subscript

Chapter 4: Vertex:

Comments from Jianming:

the presentation of the <1% detector occupancy requirement can give people the misimpression that the occupancy could be a problem when in fact the expected occupancy (~0.01%?) is far smaller. This needs to be commented on.

Comments from S. Grinstein

- Page 11, introduction. “... the need for a vertex detector with low material budget and high spatial resolution.” I think the order should be reversed, the important issue is the position resolution, low material budget is a consequence of this.
- Page 11, introduction. “As required for the precision physics program, the CEPC vertex detector is designed to achieve excellent impact parameter resolution...”. I think this is not really justified so far in the document. It is not clear which is the target impact parameter resolution.

- Page 12, section 4.1. reference power-pulsing
- Page 12, section 4.1. “..readout time shorter than 20us...”. Where does this number come form?
- Page 12, section 4.1. Need to add TID and NIEL limits
- Page 12, section 4.2. “...exactly as that of the ILD detector.”. Again, does not read well.
- Page 12, section 4.2. What is the distance separating the two layers on the same ladder? Has it been optimized?
- Page 12, section 4.2. “the impact parameter resolution can reach the requirements by using the single point resolutions provided in the table”. Which is the impact parameter resolution required?
- Page 13, section 4.2. “The preliminary studies for optimization to evaluate the sensitivity of the results on the chosen parameters had been done, for the purpose of assessing the impact of the detector geometries and material budgets on required flavor-tagging performance.” I am not sure I understand the sentence.
- Page 13, section 4.3.1. “ambitious impact parameter resolution”. Not sure what it the target of this value.
- Page 16, section 4.5. Suggest: “The history of silicon pixel vertex detector can be traced back to LEP era, when it was introduced in the DELPHI experiment [5]. Significant progress has been made over the last 20 years [6].”
- Page 16, section 4.5. “mild compared to the ILC”... but it is not mild, it is of the same order.
- Page 16, section 4.5. “To fulfill...the vertex detector must be...”
- Page 16, section 4.5. “practical” → feasible
- Page 17, section 4.5. I think the paragraph on DEPFETs is too optimistic for the technology. DEPFETs are not rad hard, not fast (20us/frame is slow) and need extra electronics... The figure also seems odd for a technology that is probably discarded.
- Page 17, section 4.5. “The HR-CMOS” section based on ALICE needs to be updated (see general comments above).
- Page 17, section 4.5. SOI:

- ✓ while I agree SOI2 has great potential, I would not say that the isolation issues have been solved until the radiation hardness is studied. Or it has been already? If so, then must add the sentence and reference.
- ✓ I have my doubts that 3D integration is really an option on the current relatively short timescale of the CEPC.
- ✓ Note that HV-CMOS is not longer proposed in ATLAS for AC coupled devices, but good results have been obtained on fully monolithic AMS productions (though with high power dissipation ~100mW/cm2). Also note that TJ 180nm with process modification to ensure a larger drift area, is being pursued in ATLAS.

- Page 18, section 4.6. “another pixel chips layer” → “...with another sensor pixel layer.”
- Page 18, section 4.6. “So a suitable cold plate, which is coupled with...”
- Page 19, section 4.6. STAR-PXL. It says that the PXL system uses air cooling with 170mW/cm2, but for the CEPC 50mW/cm2 are needed? Why the difference?
- Page 19, section 4.6. So for CEPC vertex detector, the suitable cooling method will be determined according to the sensor option and the power consumption. → actually, since the cooling adds material, it is part of the overall optimization, sensor technology, power, cooling...
- Page 19, section 4.6. “Simulation and module prototype studies should be carried out to find suitable designs that can meet requirements of stability, cooling and the performance of the vertex detector.” Unclear to me what “designs” mean.
- Page 19, section 4.7. “The technology options in Section 4.5 are able to meet each individual requirement” → “Each technology option in Section 4.5 is able to meet some of the requirements of the CEPC vertex detector (low material, ...).”
- Page 19, section 4.7. Again, not sure if 3D integration will be ready in the current time scale of the project.
- Page 20, section 4.7.1 I think this section can be improved with some concrete results and references. Some corrections.
  - ✓ ...have started chip design using... → ...have started chip designs using...

- ✓ one uses simple 3T analog... →one uses the simple three transistor (3T) analog amplification circuit...

- Page 20, section 4.7.2. Here is says 2.8 um resolution, but in other places just 3 um.
- Page 20, section 4.7.2. to be resistive to the TID → to be able to sustain the expected TID
- dose...
- Page 20, section 4.7.2. “When it comes to...low power design” → this paragraph mentions the modification of the TJ process (reference needed) but seems to repeat the SOI2 process that was mentioned before (in 4.7.1), so it is future or current?

Comments from Walter:

Table 4.1: Instead of having significantly different specifications for the first two layers, I think it would be perfectly reasonable at this stage to assume the same specifications for all layers, you could even take a position resolution of 2.8 μm and a readout time of 1 μs for all layers. Clearly we have not yet met all specifications in the recent developments, but we are not that far:

The ALPIDE power consumption in the 4.12 cm^2 matrix is 22.2 mW for the analog, strongly dominant, and 3.2 mW for the digital, or per unit area around 5 mW/cm^2 and less than 1 mW/cm^2, respectively. Dividing the pixel pitch by 2 would yield about 20 mW/cm^2 for the analog. The ALPIDE overall power consumption is higher because of the peripheral circuit, where I believe significant power savings could be realized.

The density can be obtained with a smaller line width technology, although further development in TJ and SOI with modifications on the architecture may actually succeed integrating the pixel in a much smaller area even without a smaller line width. The area savings may actually be in the front end, where the filtering capacitor is at present quite large, and/or in the architecture. The priority encoder in ALPIDE is significantly routing limited, but another architecture may require only a reduced number of metal lines. It is true that a smaller pixel pitch could be achieved with special 3D assembly techniques, and you can mention this, but I believe a fully monolithic approach is still preferred. In addition, a smaller line width technology will allow power savings in the analog, but also in the digital due to the smaller parasitic capacitances and the lower supply voltage (CV^2).

Table 4.3 Cooling method: the cooling for ALICE was indeed designed for 300 mW/cm^2, but it became clear afterwards that the power consumption for the ALPIDE could be reduced significantly (see above). I think this should be mentioned as otherwise the 300 mW/cm^2 could be misleading. Even with the periphery included the ALPIDE does not exceed 40 mW/cm^2.

Comments from Daniela Bortoletto

(1) You should explain more clearly why you take a=5 and b=10 as design values and how these are connected to the performance goals.
(2) Radiation levels are not yet fixed. Currently it is stated that the TID is X00 kRad and the dose X 1E10 1 MeV neq/cm2, respectively. I assume that you use a specific program to evaluate them. A reference here would be good even if more details are given in Chapter 10. Or at least mention what are the dominant backgrounds.
(3) It would be great to comment in more details about the results of the figures. For example, in the case of fig. 4.2 you can see good agreement between full and fast simulation.
(4) Figure 4.3 where are the dashed Lines ????
(5) What is the pixel size that is assumed? For the ILD I see 17 um. Is the same size assumed here?
(6) Many references are missing
(7) The statements on the HV-CMOS architecture seems very negative. Furthermore, some HR-CMOS options with HV add on might be interesting. I would soften this part or remove it and discuss only DEPFET, HR-CMOS and SOI.
(8) In section 4.2 you seem to emphasize that the layout includes 3 double layers, but later on especially in the beginning of section 4.6 you indicate that there are including six concentric layers… Is the double layer set up important or not ? You should really indicate what is the baseline.

(9) Style: There should be a space between number and units 1GeV => 1 GeV etc, Units should NOT be in italics.

Detailed comments

Page 11

(1) p the track momentum => p should be in italics
(2) a=5 and b=10 are taken as the design values for the CEPC vertex detector.
(3) The design values of the parameters a (in italics) and b (in italics) of the CEPC vertex detector are taken be equal to 5 and 10 respectively.
(4) The main performance goals should comply with the following specifications on the system ….I think that you want to say that
(5) The main physics performance goals can be achieved by meeting the following specifications on the system
(6) detector will have to operate in continues (spelling) mode => detector must operate in continuous mode
(7) if air cooling is intended inside the sensitive volume of the vertex detector.
(8) If the detector is air cooled

Page 12

As shown in figure 4.1 it consists of three cylindrical and concentric double layers

mounted on ladders, which are the basic mechanical structure, with high spatial resolution pixel sensors on both sides. => As shown in figure 4.1 it consists of three cylindrical and concentric layers of double-sided ladders located at radii between16 and 60 mm with respect to IP. The ladders, which are the main mechanical structure, support high spatial resolution pixel sensors on both sides.

The CEPC vertex detector is designed to deliver six precise space-points for each charged particle traveling the detector, between radii of 16 mm to 60 mm with respect to IP. => The CEPC vertex detector is designed to deliver six precise space-points for charged particle traversing the detector.

According to the simulation results (see Section 4.3), the impact parameter resolution can reach the requirements by using the single point resolutions provided in the table. => Extensive simulation studies (see Section 4.3) show that the chosen configuration with the single point resolutions listed in table 4.1 achieve the required impact parameter resolution.

Page 12-13

The identification of b/c-quark jets (called "flavor-tagging") plays an important role in physics analysis, where signal events with b/c-quark jets in the final state have to be separated requirements on the precise determination of impact parameter of the charged tracks embedded in the jets. => The identification of b/c-quark jets (called "flavor-tagging") is essential in physics analysis where signal events with b/c-quark jets in the final state have to be separated. Flavor tagging requires the precise determination of the impact parameter of charged tracks embedded in the jets

Page 13

(1) fast simulation with the LiC Detector TOY simulation and reconstruction framework (LDT) => the LiC Detector TOY fast simulation and reconstruction framework (LDT)
(2) The preliminary studies for optimisation to evaluate the sensitivity of the results on the chosen parameters had been done. => The preliminary studies for optimisation to evaluate the sensitivity of the results on the chosen parameters have been done
(3) the material budget for the detection layers of the vertex detector has been varied. => the material of the vertex detector layers has been varied.
(4) the resolution will be degraded => the resolution degrades
(5) by varying the single-point resolution for the simulation of the vertex layers by worse of 50% w.r.t. the baseline values. => by worsening the single-point resolution of the vertex layers by 50% w.r.t. the baseline values.

(6) The resulting resolutions for high and low track momenta … are shown => The resulting impact parameter resolution for high a low momentum tracks…is shown
(7) For both pixel sizes ....but you do not seem to give explicitly the pixel sizes.
(8) Here they exceed the target value? In the barrel ? at 100GeV ? Do you need here ? otherwise you could link the two sentences with an and.

Page 15

(1) dominate, the corresponding => dominate and the corresponding
(2) of the vertex layers 1 and 2 to the IP => of the first double vertex layer from the IP
(3) In figure 4.5 you only seem to vary the distance of the first double layer.
(4) the resulting transverse impact parameter resolutions at theta=85 degrees as function of the momentum with different radial distance of the innermost barrel vertex layer to the IP => the resulting transverse impact parameter resolution at theta =85 degrees as a function of the momentum and for different radial distances of the innermost double layer from the IP

Page 16

(1) The history of silicon pixel vertex detector could be traced back to LEP era, when it was introduced in the DELPHI experiment [5], and significant progress has been made over the last 20 years => The first silicon pixel vertex detector was introduced in the DELPHI experiment [5] at LEP in 1995. Significant progress has been made over the last 20 years.
(2) There have been lots of R&D efforts towards pixel sensors for vertex tracking in the future particle physics experiments [7], driven by track density, single point resolution and radiation level. => Considerable R&D efforts have taken place to develop pixel sensors for vertex tracking at future particle physics experiments, driven by track density, single point resolution and radiation levels.
(3) the detector challenges => the detector challenges for the CEPC

(4) To fulfill these requirements of system level, the vertex must be based on sensor technologies which push for fine pitch, low power and fast readout. => To fulfil these requirements at system level, sensor technologies which achieve fine pitch, low power and fast readout must be selected.
(5) In the CEPC case it is a unique scenario that might be more requiring than previous applications => In fact the CEPC vertex detector is more demanding than previous applications.
(6) In the ILC[1] and CLIC[8], for example, the power consumption is expected to be significantly reduced by choosing operation of power pulsing, but it is not practical for CEPC => The power consumption for the ILC[1] and CLIC[8] vertex detectors is expected to be significantly reduced by choosing power pulsing operation, but this is not a practical option for the CEPC .
(7) Some other experiments such as the STAR[9], BELLEII[10] and ALICE upgrade[11] do their readout continuously the same way the CEPC does. => Other experiments such as STAR[9], BELLEII[10] and ALICE upgrade[11] readout continuously as the CEPC.
(8) However, they require less in terms of IP resolution and material budget. => However, they have less stringent requirements in terms of IP resolution and material.
(9) A sensor technology that fits perfectly in needs of the CEPC does not exist. A few options are listed here for being either close to it or having outstanding potential => None of the existing sensor technologies fits perfectly the needs of the CEPC but there are a few that are close or/and have the potential to achieve the needed performance.

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As the thermal simulation of the BELLEII staves shown in figure 4.6, 1W for sensitive area and another 1W for switcher located within the acceptance can be cooled

by a gentle air flow, while the major heat of 16W in total for readout ASICs located out of acceptance can be removed by massive CO2 cooling. => The thermal simulation of the BELLEII staves in figure 4.6 shows that the power dissipated in the sensitive area (1 W) and by a switcher located within the acceptance (1 W) can be cooled by a gentle air flow, while the large power dissipated by the ASICs (16 W) can be located outside the acceptance where CO2 cooling can be used.

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(1) 64.4mm*12.5mm = > 64.4 mm × 12.5 mm
(2) With a sensitive area of 64.4mm*12.5mm, it seems applicable as the inner most layers of the CEPC. => The sensitive area of 64.4mm*12.5mm matches the dimensions of the innermost layers of the CEPC.
(3) A rough estimate results in 2.5W/ladder in sensitive area and 50μs/frame readout speed due to finer pixel pitch required by the CEPC. => A rough estimate for the CEPC requirements indicates a dissipation of 2.5 W/ladder in the sensitive area and a 50μs/frame readout speed due to finer pixel pitch.
(4) It needs further investigation as the largest possible size of a half stave is limited to be inside a 6-inch wafer, the length of outer layers gets out of reach for the DEPFET. => These preliminary estimates need further investigation. Furthermore, the largest possible size that can be achieved by the DEPFET technology is limited by the 6-inch wafer used to fabricate these detectors making the outer layers of the CEPC out of reach.
(5) The HR-CMOS is gaining momentum from R&Ds for the ALICE upgrade. Considering success of the MAPS (its predecessor) in the STAR and rapid progress achieved in the ALICE upgrade, HR-CMOS is possibly the most mature technology for an application like the CEPC. It has been approved to meet every single aspect of requirements
(6) of a CEPC-like detector. => Monolithic Active Pixels (MAPS) have been used successfully at STAR (reference). The R&D for the ALICE upgrade (reference) has led to many improvements in the HR-CMOS technology, which appears to be the most compelling technology for the CEPC, since it meets all requirements.
(7) The SOI is an option with great potential. The issue of coupling between sensor and circuit has been well understood and is addressed properly. => The Silicon

on Insulator technology (SOI) (reference) has also great potential. The issue of the coupling between sensor and circuit has been well understood and is now solved (reference)

(8) Which keep the MPW running steadily=> which guarantee the availability of Multi Project Wafers

(9) and being apt to 3D integration => is suitable for 3D integration

(10) both chips with fine pitch and chips with complicated function for over 3 years => SOI chips with fine pitch and with complicated functions for over 3 years

(11) lead to good S/N ratio, which benefits an optimum solution of low power and fast readout. => lead to good S/N ratio and therefore low power and fast readout.

(12) The criteria of being able to cope with continuous colliding and to still remain low power distinguished the 3 sensor options out of other technologies on market. => Meeting the criteria of low power continuous operation makes these sensor options interesting for the CEPC.

(13) consume large amount of current in pixel level and rely on power pulsing heavily. => consume large currents at pixel level and rely on power pulsing heavily

(14) HV-CMOS[15] is proposed more like a hybrid sensor and only minimum electronics on chip. The current R&D efforts are focusing on ATLAS-alike architectures and are definitely not suitable for precise measurement on an electron-positron collider. => Some HV-CMOS [15] options aim at providing more intelligent sensors with minimum electronics on chip. The current R&D efforts focusing on ATLAS-like architectures and are also not suitable for the precise measurements that are the goal of an electron-positron collider.

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(1) Pixel chips => Pixel sensors
another pixel chips layer => another layer of pixel sensors

(2) The ladder design of other experiments can be as references, such as STAR pixel detector (PXL), the upgrade of ALICE inner tracking system (ITS) and BELLEII pixel detector (PXD), especially ILD vertex system, which takes

double-sided ladder as an alternative ladder design. => Ladder designs similar to the STAR pixel detector, the ALICE ITS, the BELLE II PXD, and the ILD double-sided ladder are under consideration.

(3) The key point of the cooling system design of the vertex detector must balance the conflicting demands of efficient heat dissipation with a minimal material budget. => The cooling system of the CEPC vertex detector must balance the conflicting demands of efficient heat dissipation with a minimal material budget.

(4) So suitable cold plate, which is coupled with pixel sensors, with high thermal conductivity and low material budget should be taken into account in the ladder design => Therefore a suitable, high thermal conductivity and low material budget, cold plate coupled with pixel sensors should be implemented in the ladder design

(5) the corresponding material budget of each layer of the aforementioned experiments. => the corresponding material of each layer of the aforementioned experiments.

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but a specific design is needed to meet the combination of all. => but R&D is needed to select the specific design which can achieve the combination of all these criteria.

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(1) With the consideration of low material budget, two monolithic pixel technologies, CPS and SOI, are used for the sensor R&D.=> Due to the low material budget demand, the CEPC R&D is now focused on two monolithic pixel technologies, CPS and SOI.

(2) (define CPS CMOS Pixel Sensors the first time you use this acronym, note that you have a typo in table 4.3 DEPFET not DEPFEET)

(3) chip design using different technologies => chip designs using different technologies

(4) of sensing diode => of the sensing diode

(5) When it comes to SOI R&D activities, two designs that adopt an aggressive
(6) strategy have been submitted. =>Two designs that adopt the SOI technology have also been submitted
(7) Compared to column discriminator, the in-pixel one can eliminate the large analog driven current which results in a largely reduced power consumption. => An in-pixel discriminator can reduce analog current therefore lead to reduced power consumption
(8) How to shrink the pixel size and achieve a single point resolution of 2.8μm is a question that may be solved by adding extra enhancement to the TowerJazz 0.18 μm process or Lapis 0.2μm process. => Enhancements of the TowerJazz 0.18 μm or the Lapis 0.2μm process are needed to shrink the pixel size and achieve a single point resolution of 2.8μm
(9) When it comes to the radiation tolerance, TowerJazz process is expected to be resistive to the TID => The TowerJazz process is expected to be sufficiently radiation hard for the expected TID
(10) By the introduction of Double-SOI and the optimization of transistor doping recipe (LDD, lightly doped drain), its TID tolerance has been improved dramatically => The TID tolerance of the SOI process has been improved dramatically by the introduction of Double-SOI and the optimization of transistor doping recipe (LDD, lightly doped drain)
(11) construction of module => construction of modules

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Most of these issues have to be solved with future R&D work for the CEPC, exploring synergies with other experiments which have similar requirements. => Most of these issues will be address by R&D for the CEPC and by exploring synergies with experiments which have similar requirements.

Chapter 5: Tracking System

5.1 Silicon:

Comments from S. Grinstein

(1) Again, no clear requirements presented for the tight
(2) Why 50um thickness for CMOS? This is a large area detector, thinning to 50um may have yield implications.
(3) There are some contradictions regarding the cooling strategy. While the simulation seems to assume air cooling, the text mentions micro channel cooling. In but are micro channels realistic? I think micro cooling might not be an option for the CEPC, given the large area of the detector.
(4) The chapter mentions DC-Dc converters for powering? But DC-DC converters are very bulky, would introduce material budget. Both ATLAS and CMS adopted serial powering for the HL-LHC update.
(5) How to address large area CMOS sensors (otherwise restricted to reticle size of 2x3cm2)? Should the chapter include a few words in this aspect.

5.2 TPC

Remarks from Huirong:

(1) Physics requirements and TPC detector should be clear including some principle concepts.

Physics requirements would be referred to ILD parameters for Higgs physics.

- Momentum
- resolution
- dE/dx
- r-phi
- resolution
- Two tracks resolution

The specific concepts about the TPC gaseous detector should be defined in the text and the diagrams of geometry should be simplified.

The details describe texts would be added for every diagrams.

(2) Every short conclusion and result should be based on the reference or R&D.

In general, some updated information or results would be included from LC-TPC collaboration group's simulation and experiment in 2016 and 2017.

- dE/dx
- r-phi resolution
- N_eff

Critical issues would be focused on the IBF , detector module and Calibration.

(3) The design of the endplate, readout pad size, readout channels, geometry and module should be given in the part.
- Layers of the endplate would be sensitive with the dE/dx.
- Electronics readout channels estimated
- The number of the detector module is in the endplate.

(4) The prototype, method of calibration, critical R&D should be clearly given.
- How to calibrate for the drift velocity?
- How to deign the TPC detector module and prototype?

(5) Interface of TPC detector with Vetex and ECAL should be included.

The specific room of the TPC detector with Vetex and ECAL should be defined as the interface.

- Cooling system
- Gas supply
- Electronic readout cable and power
- ..

5.3 All-silicon

(1) For CDR, we don't need to decide the choice for TPC and All-silicon.

(2) Weiming: Now we have two option for the all-silicon, we need to decide which one will be written in CDR
(3) Charlie: the important question is about the material???? Weiming: we are doing the R&D, to get it more realistic.
(4) We need active cooling that will add material.

Comments from Wlater:

Full silicon tracker: if one considers a full silicon tracker, then I would include an option realized with MAPS as well.
These would be large areas, but traditional Si sensors may not be cheaper than MAPs (actually they are likely to be more expensive per unit area). The large volume to be produced in that case should give a cost advantage. In that sense it may actually be worth investigating if implementing a full silicon tracker with a single device like in ALICE could be envisaged or not.

5.4 Drift Chamber

(1) Joao: Do you consider the vertex?
Franco: simulation with general vertex and the performance is only on tracking. They will implement the integrated simulation included the vertex fit to CEPC.
(2) Clarlie: What is the value after clustering timing? -- 80micron resolution
(3) In the forward region, including the front-end electronic, the thickness is 5% radiated
(4) Z operation is in test

Chapter 6: Calorimeter:

6.1 ECAL

(1) For Slides11, the top left and right plots are not normalized, so we can't compare them directly. And the bottom plot in the slides is different with the one in the CDR, we should choose a finalized plot.
(2) Now the baseline in based on silicon, no simulation for scintillator yet. We should get the simulation for s
(3) If we need big cell size to 20 by 20, we need larger dynamic region, however, it relates to larger electronic. We should consider it seriously. Maybe 20 by 20 is too much, we can choose an optimization of 10 layer. It needs the simulation to confirm it.
(4) We should make sure whether the 50 ps is the goal, or just a nice expectation. If it is a goal, the scintillator will not satisfy.
(5) We didn't consider the cost in CDR, we should have an estimation for it and find out a reasonable method.

6.2 HCAL

(1) Reduce the number of layers from 48 to 40 based on the simulation. In order to meet with the physics requirement with 3~4% for integrated, the related analysis is still in process.
(2) Charlie: What is the number of photon electron that can achieve the physics requirement? Maybe 15 is ok?
Boxiang Yu: Deciding this number need to consider the dynamic region, 20 is a reasonable value. With this number, considering the threshold of noise, the detector efficiency can reach 95%, and dynamic region is 100.
(3) From simulation, water cooling for RPC is 2.5 C for the performance. But how to control the region stable is important. As a reference, 3 degree enough from other article
(4) why 3by3 is baseline? If the SiPM needs cooling, it is better to change the size to 5by5 for cooling.
Haijun: not sure, need to do the simulation.
(5) Introduction chapter more focus on PFA calorimeter, dual-readout option also need 1~2 paragraph for introduction.

(6) There is too much details for calorimeter chapter, some details are not needed, trying to simplified (eg. DAQ software name..). Then, dual-readout section has too much details, just give the idea and performance requirement. DR52 is just for set up (for reference), it can not directly used as the baseline.
(7) Should we reconsider the structure of CDR? As the current version has many different concept, should we firstly describe the baseline in one chapter, and put other concept in another chapter. It needs more discussion.

Comment from Alberto:

they are about a couple of topics that are currently missing from the Calorimeter chapter:

(1) engineering constraints: after all, in the CMS TP we did have some finite-element-analysis results demonstrating the feasibility of the endcap calorimeter. At the moment, there are no words about how the calorimeters can be built and held in place, if I remember correctly.

(2) radiation damage: a ballpark estimate is that it will be about 2 orders of magnitude smaller than LHC calorimeters, which essentially means that there are no problems. The CDR currently does not mention at all the topic, I believe it should be explicitly stated that some thought went into it

Comments from Jianming:

I think some justifications are needed for the very fine readout proposed. Most of the collider calorimeters built so far have less than 5 readout layers, this is a far cry from the proposed concept with 30 or 40 active readout layers.

Comments from S. Grinstein

(1) Looks like the Calorimeter chapter has too many details and options.
    a) May be better to present a realistic baseline and options?
(2) Again, missing link between physics motivation and physics requirements
(3) The first option presented, the PFA, looks a bit like an overkill

a) Is cost realistic for the Silicon option

(4) I would estimate a 10EUR/cm2 cost just for silicon
(5) Charlie checked that for the SID they predicted 3$/cm2
(6) But 1 mm thick silicon is likely to be more expensive (?)
    a) 20 ps resolution would have to be justified
(7) Note that 20 ps is not realistic for standard silicon (or not proven yet)
(8) While ~50 ps has already been demonstrated by CMS HGCAL (see Alberto´s slides)
(9) Inconsistencies between slides and Fig 6.8
(10) Right now, it looks like the requirement of 3%-4% for jet energy resolution is not achieved.

Comments from Wlater:

Also in calorimetry I would mention MAPS. For calorimetry, one could increase significantly the granularity with MAPs, and it is being proposed to then just count the number of hit pixels, but I think more simulations are needed to study the performance of such a calorimeter in more detail.

6.3 Dual-readout

(1) There is too much details in the current version, it is better to just give the idea and performance in the CDR.
(2) The DR52 geometry is just for the reference, which can not be directly used as a baseline, the design should be based on the CEPC requirement and try to achieve the physics requirement.
(3) We have the geometry description in Moka, but without the reconstruction
(4) outside coil need simulation considering magnet
(5) Since the dual-readout and PFA Calorimeter are totally different concepts, should we separate it to a new chapter? No, We can put DR inside calorimeter, just a option. We need more discussion for the structure of CDR.

Chapter 7: Magnet

(1) why choose shilding scenario?
It can be lighter and more compact (without iron yoke). But it is not a strong reason for choosing this option.
(2) how to support the inner solenoid from the outer solenoid? R21-05:00

have the connection between inner and outer.

(3) The shear strength is larger than the required (20MPa) → from simulation

The direction of the shear is around the cable

How to do the shear text? A machine….

(4) Charlie estimated 60km of cable for the HTS option. How many people use it so far?

Not widely used. Need study and research. Cooperate with other Lab for the R&D. HTS cable is also used for accelerator magnet.

(5) simulation field map: currently the simulation for MDI is just mechanic, without b field.

Comments from S. Grinstein

•What is the advantage of the active shielding scenario vs the default one?

•Charlie estimated 60km of cable for the HTS option. How does it compare with other systems already built?

Chapter 8: Muon

(1) P4: Signal efficiency > 95% for muon pT>4GeV with 8 layers
physics reason?
Liang said they need check compare with pre-CDR which is around 100%, what is the difference? What is the physics requirement for the parameters listed in P4.

(2) Current simulation doesn't consider reconstruction; we should get the reconstruction before CDR public. 3 months is enough for reconstruction based on cluster matching with generator. Liang will contact Manqi to teach new people for Arbor methods, and will have regular group meeting for it.

(3) RPC and R_well are baseline. Other methods need feasibility; we can not put all the methods in CDR. We'd better write a justification for muon detector at the beginning of this chapter.

Comments from Jianming:

- why such complicated muon system? Muon momentum should be measured very precisely in the inner detector, only muon ID is required.

Comments from S. Grinstein

- May be too many options for the muon system. Concentrate on RCP and uRWell technologies?

Other options could be mentioned briefly, but no need to cover them all in the CDR.