­Reviewer #1: It is a very nice paper with excellent results. The only worry I would have is after-pulsing in MCP-PMT when large energy deposits happen. This effect could worsen with MCP-PMT aging.

**Ask Sergey how to answer this**

Reviewer #2: The paper is the continuation of previous research on the Shower Maximum Detectors. The previous two publications reported on the results obtained with MCP-PMTs where ~12 ps and 27 ps timing resolution was achieved with the same MCP PMTs, with nearly 100% detection efficiency. The present paper concentrates on the spatial resolution which can be achieved with a shower detector by implementation of a pixelated photomultiplier.

It is not clear to me why the reported results in the present paper are substantially worse in terms of timing resolution compared to previous results (nothing wrong with the results, obviously, just not clearly explained).

* **We have improved the introduction, particularly in distinguishing the current study and the previous studies. We have also clarified in the text the uses of the different types of MCP-PMTs in this study.**
* **The reason why the timing resolution results are different between the current study and the previous studies is that the devices used are different. Time resolution of 12 and 27 ps were obtained using two Photek 240 MCP-PMTs for electromagnetic showers. The improvement from 27ps to 12ps was obtained after improving the level of noise and the pulse reconstruction algorithms. For Photonis XP85011, we obtained 37ps resolution in the past, which is consistent with the results reported in the current study – after performing the time measurement correction. The reason that Photonis XP85011 performs worse than Photek 240 is due to the larger pore size and significantly worse uniformity across the sensitive area.**
* **The present paper in addition investigates the improvement in time resolution from the addition of more granular readout. We have clarified this in the third paragraph of the introduction.**

It is not clear as well what is needed for the ultimate shower detector, as the three articles are addressing different detector characteristics. What should be the final device - provide both timing and spatial information on the shower, requirements on the resolution, etc?

* **We have clarified the final goal as well as the steps we took along the way in the updated draft.**
* **Our previous papers describe the path towards this goal as follows:**
  + **Ref [2] demonstrated indirectly that MCP detectors are sensitive to secondary particles from EM showers**
  + **Ref [3] showed directly the signal response of MCP detectors to secondary shower particles – as we used a device that allows to effectively turn off the photocathode**
  + **Ref [4] studied the impact of the EM shower fluctuations on the time resolution, and demonstrated that the impact is limited at the 10ps level**
  + **In this paper, we study the impact of a highly segmented readout for such devices, and demonstrated that a proper combination from independent readout channels preserves good time resolution**
* **The final device should provide both spatial and temporal resolution that is granular enough to distinguish the pileup particles from those that originate in the primary interaction. Time resolution of 20-30ps is desired, with spatial resolutions below the mm level.**

I also think it will be very useful if authors write the present manuscript explicitly explaining what is targeted in the present article and how it is different from the previous two papers.

* **Agreed, and DONE, we added the descriptions above into the text.**

I think the authors should revise the manuscript explaining several points listed below, before the paper is published.

In general - no description of detector parameters is given at all, no gain, voltages, modes of operation are described at all. How can one find out what is detected by the XP85011 detector. Not explained even whether the output signal is amplified at all, before it is digitized, what is the MCP gain, geometry, distance to the anode, etc. The authors obviously are very familiar with all that and assume the reader may know it, but I think it should be explicitly explained in the paper as it may strongly affect the results. Otherwise how the information reported in the paper can be used by other scientists in their research?

* **We have added these detailed information and the parameters of the MCP-PMTs that are used.**

Abstract: "We further the study of microchannel plate photomultipliers" - not correct English

* **Fixed**

Abstract: "A method for measuring the arrival time … is  presented, and is found to be better than 40 ps." - not correct English in the last part of the sentence.

* **Fixed**

P.1. "advantage of MCP's is their capability for pixelated readout," - capability of pixelated readout does not read right.

* **Changed to “highly segmented”**

P.1. "The energy of the electromagnetic showers is reconstructed using the total collected charge and the positions are reconstructed using a simple energy-weighting algorithm." - The total charge after the MCP amplification can be strongly non-proportional to the energy of the shower as MCP amplification is highly non-linear process and saturation can have strong effects.

* **From our experience working with these MCP devices, and for the energy range that we have typically probed (4 – 32 GeV), we observed a linear relationship between the charge response out of the MCP to the energy of the incoming electron. This linear response is primarily driven by the linearity in the multiplicity of secondary shower particles that have energies that the MCP can detect. We are not operating in the range where MCP saturation is a problem. We added a sentence and a couple of citations in the introduction with further explanations on this aspect.**
* **For the experimental setup that is described in this paper, we unfortunately did not perform the energy scan, so we do not have a plot that explicitly demonstrates this. However, in subsequent beam tests since the study that is being reported here, we did perform the energy scan measurement (using a newer Photonis MCP that does not have a photocathode) and do observe the linear behavior. A report or future publication on this newer study is under preparation.**

Also please explain briefly at least what is the "a simple energy-weighting algorithm", how timing is calculated with it?

* **We have added a reference to Section 4 where the expression for the algorithm is given in Eq. 1**

P.2 "A differential Cherenkov counter, located further upstream of the MTEST location, was used to enhance the purity of electrons and to suppress pions." How a counter can clean up the beam? Please explain

* **Done, added “by requiring a signal consistent with a passage of electrons through the device”**

Throughout the article: Term XP85011 MCP is used. MCP is a glass disk, with no electronics. How a glass disk can detect events? Please use a different term, may be MCP-PMT?

* **DONE**

P. 2 ""on the on the…"

* **DONE**

P.2. Please explain how Photek 240 MCP is used as a reference detector. Now I have to guess. Is that used as a coincidence detector, or used to measure the time difference between the first and the second MCP PMT?

* **We have added the description of the usage of the photodectors in Section 3. We measure the time difference between the first and second MCP-PMTs. The Photek 240 is used as a start time counter, and has been clarified in Section 3.**

P.4. How 4 DRS4 digitizers can process so many input channels, is each of them is multichannel device?

* **We have tried to clarify this in the past paragraph of Section 2, re-phrasing it into “In order to allow a synchronized readout of four separate DRS4 units we split the signals from the Photek 240 MCP-PMT into four, and connected them to each of the four DRS4 units, thus achieving a ``calibration'' between the four different units.”**

P.4. "Each time sample is approximately 0:2 ns in time." - does that mean that ADC operates at 5 GHz rate?

* **Yes, the DRS4 samples the pulse at 5 GSamples/second**

Figure 4. If one pixel is ignored, how the position of even can be recovered with such a good accuracy?

* **Figure 4 is shows the mean charge per pixel, average over all events. As such, this figure is not a measurement of position of the shower, but is simply an occupancy plot, and indicates that shower is centered roughly in the upper half of the central pixel. Using Eq.1 we then try to measure the position of the shower event-by-event as a centroid of the shower. The position measurement is obtained from the pattern of signals shared among the remaining 8 pixels.**

Figure 9: "Notice how the highest-signal-pixel method for picking the time-stamp value is significantly worse." Please explain the highest pixel method (just pick the pixel with the highest signal?

* **Yes, as you say this is simply the Δt with respect to pixel with the highest signal. The figure caption has been modified to improve the clarity.**

Figure 10 and results: The timing of the measured event, as I understand from the article, depends strongly on the event gain. It is a typical detector walk, which can be fixed by implementation of constant fraction discriminator. Please explain in the article whether it was used and if not may be mention that this problem can be solved not by a calibration but by a CFD.

* **The methods we used are fully described in Section 3. As described, we do not use a CFD: the time measurement is performed by measuring the sigma of Gaussian fit to the Δt distribution between the start and stop signals. We are not sure what the reasons for this effect are, and since we have not studied whether CFD can fix it, we cannot assert so in the paper.**

P.9. "The initial … scaling is encouraging as it indicates that further granularity may improve the time resolution." - at some point signal-to-noise ratio becomes important and should dominate the errors leading to resolution degradation. May be worth mentioning how far from that is your current setup (again no gain per event, per pixel is given in the paper at all, cannot even guess what is your signal to noise for the present setup and whether it can still be improved).

**We have improved the sentence, and clarified the discussion concerning the improvement with further granularity. The sentence now reads: “The initial $1/\sqrt{N}$ scaling is encouraging as it indicates that the time jitter across different pixel channels arise primarily from uncorrelated sources, and that further granularity may improve the time resolution provided that the signal is sufficiently large compared to noise”**

P.10: "We report our results on position and time resolution measurements of secondary emission based calorimeters." As far as I know the MCP gain can be so non-linear, how the calorimeter then rely on it? There can be very strong disproportionality between the energy of input signal and the output charge from the MCP. How many particles are detected for a typical shower, what is the MCP gain, any saturation, please explain why your approach can use MCP device in a calorimeter.

* **We have added a couple of sentences with citations pointing to the relationship between the number of secondary shower particles (and MCP signal) and the energy of the incident electron. As we discussed in the answers to a previous question above, we explicitly measured the energy response in the range available at the Fermilab testbeam in a subsequent measurement and that measurement did show a linear response. The results of that measurement are being prepared for another paper. We did not perform the same measurement for the study using the device as discussed in this paper.**

Reference 3 and 4 has the same title?

* **Fixed, thank you!**