MATHUSLA Meeting Comments

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Physics Goals and Flowdown to Technical Specifications

1. Develop specifications for the detectors, like time and coordinate resolution, distance between planes, number of planes, decay volume sizes, etc. based on physics goals of the experiment (i.e. identification of LLP signatures, identification of cosmic ray and collision backgrounds, study of cosmic ray air showers etc.).
2. Providing reliable estimates of the actual expected backgrounds is critical. Assumption that the detector is "background free" is strong (and important) and current proposal has no quantitative estimates to prove this statement.
3. Potential upgrades to study LLPs, in the case if they are discovered, have to be analyzed, while should not complicate extensively baseline design.
4. Why LLP signals can't be detected by ATLAS/CMS as missing energy has to be better studied/explained. Comparison of MATHUSLA search sensitivity with ATLAS/CMS HL-LHC sensitivity for similar channels.
5. Cosmic rays program for the baseline design and size has to be clearly spelled out, especially what physics the baseline MATHUSLA 100 can do much better than other existing or proposed detectors.
6. Begin understanding how the underground detector (ATLAS/CMS) and surface detectors depend on each other. Discussions followed by negotiations will likely be necessary. It is difficult to start this too early.

Detector layout and design

7. Optimization of the detector design, based on physics goals of the experiment, is critical. A few specific examples
    a. How many planes of RPCs (or other detectors) are needed in the top detection layer?
    b. It looks as having a number of planes of detectors at the bottom of the detector will help to reduce various backgrounds substantially (as well as providing sensitivity to quasi back-to-back LLP decays). Same might be the case for the sides of the detector. Estimates to understand importance of such layers are important.
    c. It's worth investigating whether the grouping of the tracking layers is optimal. Equal spacing has some advantages but, for instance, an arrangement of two groups of several close layers separated by around 4 m could have advantages (both in timing and tracking).
    Perhaps the separation of these super layers could also be reduced. Effectively each super layer gives a mean time and a trajectory. The superlayer may also be

easier to support and may simplify (reduce volume of) environmental containment. The disadvantage of course is that there is no knowledge of what happened in the gap.

8. Close cooperation with CERN civil engineering and mechanical construction will benefit producing acceptable and technically sound design.
9. The buried detector solution developed at this meeting is very attractive. It minimizes surface ugliness for the neighbors. More importantly, it is likely to simplify installation and repairs. To follow up, investigate the cost of excavation of a concrete lined pit. Get support concepts for these light detectors that minimizes structure - a few concepts to optimize are likely to be in order.
10. It is important to understand the effects of footprint early. If fitting in the near-CMS site causes big efficiency change, then experiment may not be able to be executed reasonably. Compared with the cost of the detector, extra land to do it right is likely to be cheap.
11. What is minimal energy of a particle needed to create “a track”?
12. Seriously consider not using high GWP or heavy flammable gases. Many experiments, around the globe, working in this direction and MATHUSLA has to be active part of these activities.
13. Ideally, detectors that are looking back at the IP want to live on a sphere, where covering a chunk of solid angle is materially most efficient. A detector sited flat on the surface is necessarily an inefficient use of resources. The concept of a tilted detector helps to improve efficiency in detector coverage and should be investigated further.
14. Installation concepts are critical. Can’t afford to build a bridge crane. Can’t afford to keep a commercial crane with long reach on site. Possibility to rely on CERN mobile cranes? Rail system for installation?
15. A plausible arrangement for providing the services for the baseline design should be developed including electrical power, (for detector, readout, trigger farm), gas (if baseline), environment control, etc, with estimates of power, mass flow etc. This will help develop ballpark cost-estimate for both construction and operation.
16. Detector reliability needs to be determined. Service requirements and schemes for detector removal need to be developed. If you are in the center, is this like going to space? In determining detector reliability required, what are the effects of lost towers? What is tolerable for the physics?
17. What is the dependency of the angular resolution on the entering angle of the track?
18. A strawman detector element should be defined for the detector technology options. Data exists. Mine it! This should be an exercise that the collaboration performs in the near term.
19. The usefulness of the analog pad readout for the baseline RPC-based design needs to be better justified, even though it is a relatively low cost addition.

Triggering, DAQ, reconstruction and simulation

20. In consultation with CMS develop basics of how “correlation” with CMS events can be achieved.
21. Provide estimates for total rate of data from MATHUSLA for continuous readout (per year).
22. What are basic ideas of reconstruction, especially how to use time in addition to space coordinates?
23. How amplitude and time are measured in “continuous readout” mode?

Test setup and R&D

24. It is critical to have preliminary results from the test stand at CERN for the next level of document. (eg track reconstruction, upward going rate with beam on, beam off etc).There is not much time left with LHC beam on before 2021. Very good, systematic progress has been made in equipping and commissioning the test stand, but temporary reinforcement of the team, including a few experienced people, may pay dividends. The proponents must acquire data, make sure it is good, analyze it, and report the results.
25. Plan for R&D of specific detector/electronics/DAQ/triggering options has to be developed and become part of the experiment planning/activities.

Organization, Schedule, Cost, Resources

26. Some form of the collaboration organization with at least contact persons defined will benefit planned experiment interactions with various bodies, such as LHCC, European Strategy and others.
27. The problem of finding the resources to progress from LOI to TP needs to be addressed soon.
28. It would be useful to come up with a realistic estimate for construction time. This will influence/be driven by the flow of funding.
29. Develop “the experiment timeline” with major milestones, like R&D stage, funding stage, construction stage, data collection and data analysis stage with estimated years for start/duration of each activity.
30. Cost estimates should be either reasonably well done (for the full experiment) or better not presented to create impression of a “cheap experiment”. Estimates of person power required will also be useful.
31. Quote contingencies as appropriate to indicate the maturity of cost estimates.
32. Define the detector baseline, add some headroom, then look at descoping if cost is too high. Don’t be surprised if costs are dominated by other (than detectors) items. Don’t chintz the detector at the beginning. Infrastructure is not cheap, but is usually more amenable to optimization for cost. This is the primary place for value engineering.
33. Production organization should (as proposed for baseline) concentrate on (ideally) 2 suppliers (or one plus a credible back-up) making each major component of the detector and shipping them to a final assembly site (probably CERN). This will best take

advantage of the industrial scale of the quantities needed. A proliferation in the number of full-process manufacturing sites should be avoided.

The Proposal Presentation

34. Concentrate in the proposal on the baseline size of the detector, as having different sizes in different places of the proposal is confusing. Options for larger (smaller) detectors could then be summarized in one place of the proposal.
35. Mention that the detector is “scalable”, so you can start data collection with partial detector.
36. The next stage document for the experiment design should make more use of tables. In general, tables are useful and not to be disdained, because they are an efficient way to transfer quantitative information.
37. The Document for the Workshop is uneven in its handling of topics. For some topics, great detail is available; for others not so much. For instance, mention of electronics is negligible. There is more discussion of it for the test stand than for parts of the experimental detector. On the other hand, there are, appropriately, lots of details for trigger concepts. The text reads as a snapshot of where people have spent their time.
38. The Next Steps section of the Document needs to be more than a paragraph: more details, better notional timeline with milestones for getting things done.