sPHENIX EMCal Review

Review Date: 20 August 2015

sPHENIX EMCal Review Committee:
Steve Bellavia
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Mike Sivertz (Chair)

Presentations:

13:00 – 13:30	sPHENIX Overview *30′*	John Haggerty
13:30 - 13:55	EMCAL Conceptual Design *25′*	Craig Woody
13:55 - 14:20	EMCAL Simulation *25′*	Jin Huang
14:20 - 14:45	Mechanical Design *25′*	Christian Cullen
14:45 - 15:10	Module Production *25′*	Sean Stoll
15:10 - 15:30	Readout Electronics, Sensors, and Trigger *20′*	Eric Mannel
15:30 - 15:50	Installation and Integration *20′*	Don Lynch
15:50 - 16:15	Cost and Schedule *25′*	Edward O'Brien
16:15 - 17:15	Executive session *60′*	
17:15 - 17:35	Close Out *20′*	

The committee was asked to evaluate the design, testing, and prototype performance specifications of the EMCal towers, as well as assess the readiness of the management team to carry out the project.

The most general description of the committee's response is that the EMCal design seems extremely promising, but needs to be specified in a more formal way. Chapter 2 of the sPHENIX Upgrade Proposal describes how the design choices are driven by the physics goals, and how the aspects of the detector are crucial to meet those goals. The review presentations should follow the Physics-Driven Detector Requirements more closely, making clear how the choice of design parameters is motivated by the physics goals. Below are listed some of those parameters, as we were able to glean from the presentations.

What are the EMCal performance specs?

- Energy resolution: 12%/√E for single $e^{\pm}$ and γ. Does this energy resolution drive the design of the EMCal? Can it be relaxed? The energy resolution of the EMCal was measured and reported on, but there was no performance specification for what energy resolution would be required to meet the physics goals of sPHENIX, for instance the separation of the Upsilon(2S) and (3S) based on EMCal alone, or the mass resolution of the Y(1S) as the simulations include both the EMCal and inner tracking with the latter still awaiting a detector choice. We were shown test beam results with normal incidence;

make sure that the performance of the EMCal towers is studied at all relevant incident angles.

- Uniformity: ±20% without filter. ±5% with filter. Does this contribute significantly to the energy resolution? Was the 12% energy resolution measured with or without the filter? Do you need/plan to produce a custom filter for every tower? No specification was given for uniformity, yet there was a filter designed to help meet some goal. Can the optimization of the light guides improve the uniformity of the response?
- Cracks/Dead Zones: "Minimal" (Woody, slide 2) should be replaced by a metric that can be studied in the simulation. This is a parameter that was not sufficiently specified in the EMCal performance specs. In a related issue, variations in the response of the EMCal as a function of track location or angle caused by variations in density due to fibre misalignment, bubbles in the epoxy/powder mixture, or dead fibres will have the same effect as cracks between towers. When giving the fabrication specs for the towers, a maximum number of dead fibres per tower should be quoted. It impacts the design to the extent that it drives the W/epoxy layer at the boundaries of each tower. The entire issue of cracks and dead zones can probably be incorporated into a specification of the uniformity of calorimeter response.
- Speed of response: Good. Not specified.
- Noise floor: The largest component in the noise will probably come from the neutron damage to the electronics and SiPMs. It was mentioned that this could be compensated for by cooling the SiPMs. The noise from reasonable amounts of neutron damage (1e11 n/cm^2) should be included in the simulation to see whether cooling is required, and to what degree it would be necessary. Perhaps added single photoelectron noise is not a concern, even if there were a great deal of it; i.e. 1e13 n/cm^2. Simulation results will tell us. Perhaps the noise can be specified in terms of a signal-to-noise ratio
- Compensation: Noncompensation in the EMCal contributes to the constant and stochastic term in the HCal energy resolution. Probably not an issue at 100%/√E.
- MIP response: Not reported on. Refer to the e/h separation.
- π^0 identification: Not reported on. Since this is likely to play an important role in the ongoing calibration of the EMCal, it is crucial to see mass resolution plots of pi-zeros from realistic event simulations, including noise.
- Hadronic response: Not important, except as it plays into e/h separation. See below.
- e/h: separation as a function of energy and multiplicity
- Mass resolution at the Upsilon and other masses
- Radiation Hardness: The rad hardness of some of the component parts in the readout chain has been measured, but the impact of the added noise on the energy/mass resolution has not been studied sufficiently in simulation. This could be very important as some cooling options could have a significant impact on the EMCal design. In addition to the impact on noise, single event effect cross sections need to be measured for the readout electronics located inside the detector to ensure operability. Has the epoxy used in construction of the towers been tested for rad hardness? The rad hardness of the COTS electronics must be tested, and it should be a defined requirement for production.
- For COTS electronics purchases, lot-to-lot variations should be taken into account, or eliminated via single lot purchase.
- SiPM Gain/Temperature stability: Because of the large thermal coefficient in the gain of the SiPMs, the temperature stability needs to be included as a spec for the EMCal design.

- Trigger latency and dead time: (Is this part of the EMCal review, or is there a separate trigger/electronics review?)

Are the EMCal performance specs sufficiently defined?

- In general, the EMCal performance specs need better definition. It is not clear what requirement is driving the design. Is it energy resolution for EM showers? Is it mass resolution for the Upsilons? Is it e/pi separation? From the presentations, it appeared that e/pi separation was most crucial in the design of the EMCal. If this is the case, then that needs to be stated more clearly. Other properties of the EMCal were left unspecified. If they impact the design, then they should be defined. If they do not impact the design, then that should be stated, or minimal goals should be given, and met. In particular, the specifications should be given for
    - e/pi separation
    - energy resolution (needed, rather than achieved)
    - mass resolution for pi-zeros
    - mass resolution for Upsilon(1S,2S,3S) as a function of pseudorapidity
    - uniformity/cracks
    - noise

Are all of the key steps in R&D and prototyping identified and understood?

- The key design parameter is the choice of 1D or 2D projectivity. Until this choice is made, the design cannot proceed. This choice impacts the e/pi separation which is crucial for Upsilon reconstruction. The collaboration is working to complete the simulations needed to evaluate this choice. The simulations need to address the impact of the design on lateral shower leakage. The simulations and evaluations need to be concluded prior to the decision on projective geometry so that realistic production scenarios can be incorporated into the overall schedule.
- The simulation work for heavy ions is much more developed than pp simulation. If pp physics results are part of the mission of sPHENIX, then further pp simulation should be accomplished before the EMCal design is finalized, including the effects of multiple interactions per beam crossing and possible pileup.
- The cooling system specs need to be defined. It is not clear how the decision on water versus air will be made, and if the EMCal team has all the tools needed to make the decision. This decision impacts the dead material inside the EMCal in a very significant way, if water-cooling is chosen.
- 3D printing has been critical for the R&D up to this point. sPHENIX and/or Physics need to provide access to a 3D printer of the quality of the Instrumentation Division printer.

Are appropriate time and resources allocated to each step?
Have all the necessary resources been identified?
Have the technical and management teams been identified to carry out the project?
Have all of the major steps for construction and installation been identified and understood?

- The committee was concerned that not enough attention had been given yet to a grounding plan. This is not an EMCal issue, of course, but needs to be addressed on an experiment-wide level. Identify a person responsible for this vital task.

- Once the EMCal design parameters have been finalized, a well defined production QA plan needs to be drawn up.

Are the time and resources allocated for each construction and installation step reasonable and appropriate?

- Since single EMCal sectors must be removable for maintenance, it might be helpful to foresee some space for radial movement to easily separate one sector from the remainder of the EMCal.
- Perform a detailed finite element analysis of the structure and components of the EMCal to better predict deformations and stress in all components, including the HCal.
- Since the EMCAL is mounted inside the HCAL, how can it be that the HCAL is on the critical path but not the EMCAL? EMCAL installation can only happen once the HCAL is there.
- While prototyping is underway with test beam scheduled for early 2016, a prototype manager was not identified in the EMCal Organization chart.

What is your assessment of the status of the Project documentation including WBS, WBS dictionary, design documents, cost documents, etc? Are there key documents that are currently missing or incomplete that will be needed for the November Cost and Schedule review?

- The committee was not provided a copy of the full WBS resource schedule, so we are not in a position to judge the adequacy of the manpower available.
- A "deliverable-oriented" WBS structure would be preferable to the current "time-phased" WBS structure, where e.g. design, prototype & production are separate L3 items in the WBS.
- The RLS is far more developed than needed for CD-0, which is impressive. For the foreseen schedule with CD2/3 following CD1 within ~6 months, this might be necessary. For CD2/3, EVMS tracking for several months needs to be demonstrated, so the CD1 baseline would need to be used for that. This also implies a switch to Primavera from MS project before CD1. A bottom up contingency estimate with corresponding risk registry is still needed. The assignment labor-band → individuals still needs to be completed, taking pre-existing time commitments of the individuals into account to avoid >100% FTE loads. RAM, BoE and quote documentation still needs to be generated.
- Create an Interface Control Document (ICD) and Interface Definition Drawing (IDD) to clearly specify to the HCal what is required for the EMCal support structure.

These results have been combined into a list of Findings, Comments and Recommendations below.

EMCal R&D, testing and prototyping

- Finding
  - The specification of cracks/dead regions/bad fibers is driven by manufacturing tolerances
- Comment
  - This seems like the wrong orientation.
- Recommendation
  - Use the physics goals to define the tolerances required for these and all EMCal parameters.
- Finding
  - e/pi separation is a sensitive function of the projectivity of the EMCal towers.
- Comment
  - Much work has already been done to build and test 1D and 2D projective tower modules, as well as simulate the performance for EM showers and hadronic showers.
- Recommendation
  - Complete the prototype testing and simulation work required to evaluate the projective tower design before the selection of projective geometry method is decided. Report on the impact of the design choice on e/pi separation and Upsilon mass resolution.
- Finding
  - Epoxy is poured into molds holding the fibre strands and tungsten powder to form EMCal towers.
- Comment
  - Fabrication may cause dislocations and bubbles in the W/SciFi/Epoxy matrix.
- Recommendation
  - Slice up a prototype module to see how uniform the tower interior is. Consider studying how a vacuum pump could improve the distribution of epoxy in the towers. Define a method to ensure the appropriate Q/A for tower fabrication during production.
- Finding
  - Light guide design for the towers has not been optimized.
- Comment
  - Light guides could have a significant impact on the uniformity of response of the towers.
- Recommendation
  - Include a plan to optimize the light guide design.

Design

- Finding
  - Power dissipation is 250 mW/channel in the EMCal.
- Comment
  - Because of the severe temperature dependence of the gain of the SiPMs, and the sensitivity to radiation damage induced dark current, the SiPMs may need to be

cooled. This cooling to room temperature could be forced air or water. Is cooling to room temperature sufficient, or will the electronics need to be cooled more? This choice has a major impact on the EMCal design.

- Recommendation
  - Complete the studies needed to make this decision before the November review.
- Finding
  - For pp running, multiple interactions will contribute to the events in the EMCal for every event.
- Comment
  - RHIC beam intensity is expected to increase for running in the sPHENIX era.
- Recommendation
  - Evaluate the EMCal performance using simulations that assume a factor of 2 increase in the proton beam intensity, i.e. a factor 4 in interaction multiplicity in each event.
- Finding
  - EMCal sectors are hung off 2 rails mounted on the inner HCal, with bearing blocks on the EMCal sectors.
- Comment
  - It can be difficult to align all the separate float parts in this mounting scheme
- Recommendation
  - Find a manufacturer who will provide sets of two parallel rails to mount on the HCal, and 2 sets of similarly aligned bearing blocks to mount on each EMCal to avoid all the survey/alignment work in-house.

Production

- Finding
  - Stainless steel is being used for the EMCal sector structure, as well as the HCal.
- Comment
  - Not all SS is completely nonmagnetic. Also, working of the SS sheet can cause it to become magnetic.
- Recommendation
  - Test samples of the SS that is going to be used in the fabrication of the sectors, as well as the HCal.
- Finding
  - Tungsten used in the EMCal.
- Comment
  - Impurities in the W can cause the W to be magnetic.
- Recommendation
  - Test samples of the W before going into production.
- Finding
  - 32 sectors of EMCal are required
- Comment
  - There may be problems in the manufacture or installation of an EMCal sector.
- Recommendation
  - Build at least one spare sector of EMCal, as a hot spare.

Installation

- Finding
    - EMCal is hung off the inner HCal.
- Comment
    - EMCal can cause deflection of the inner HCal or deformation of the EMCal support structure.
- Recommendation
    - Study the expected deflections, either through modeling or bench tests before the design is finalized.

Management

- Finding
    - There is no Technical Board yet established.
- Comment
    - Probably no need yet for a Technical Board.
- Recommendation
    - No action.
- Finding
    - WBS is time-organized with no schedule contingencies rather than deliverable-organized.
- Comment
    - There is still a lot of uncertainty about production. It has not been determined whether it will be fabricated in-house or commercially.
- Recommendation
    - No action at this time.
- Finding
    - The schedule is MS Project-based.
- Comment
    - MS Project does not allow for enough oversight.
- Recommendation
    - Transition to Primavera at the earliest possible opportunity.
- Finding
    - There is no Risk Registry yet.
- Comment
    - It is important to develop a Risk Registry before CD-2/3.
- Recommendation
    - Put effort into completing the Risk Registry.

Costs

- Finding
    - Students and Scientists come at no cost to the project.
- Comment
    - Make the most use of students in the testing of production EMCal towers
- Recommendation
    - Make the most use of students in the testing of production EMCal towers

- Finding
    - Project costs do not yet have contingency built in.
- Comment
    - Need contingency
- Recommendation
    - Add 35% contingency to the cost estimate until there is a better understanding of the production plan. Also include 18% overhead, assuming BNL will grant a Large Project overhead rate to sPHENIX.
- Finding
    - No backup documentation was provided.
- Comment
    - The committee cannot really evaluate the cost of the EMCal without more documentation.
- Recommendation
    - BoEs need to be provided.

Schedule

- Finding
    - There is only 6 months to get from CD-1 to CD-2/3.
- Comment
    - 6 months seems very tight.
- Recommendation
    - Get as much work completed before CD-1 to prepare for the CD-2/3 transition. The Project Plan is already well developed for a CD-0 level project. At a minimum, plans for long lead items should be in place well ahead.
- Finding
    - The EMCal schedule is a straight-duration schedule. There is no funding profile built in. There is no float.
- Comment
    - This represents a risk to the project. Funding profiles are often not optimal for the fabrication of new detectors/experiments.
- Recommendation
    - Build in a realistic funding profile into the overall schedule
- Finding
    - Availability of students and technicians is a challenge
- Comment
    - Manpower limitations are likely to be a bottleneck for the schedule.
- Recommendation
    - Evaluate how using Tungsten Heavy Powder can be used to fabricate the towers, alleviating manpower demands and improving schedule contingency. However, a well-vetted plan B should be in place.
- Finding
    - HCal is the critical path item
- Comment

    - EMCal is mounted on the inner HCal, so it must be installed after the HCal. How can the HCal be the critical path when the EMCal is installed after the HCal?
- Recommendation
    - Reevaluate the critical path for sPHENIX.