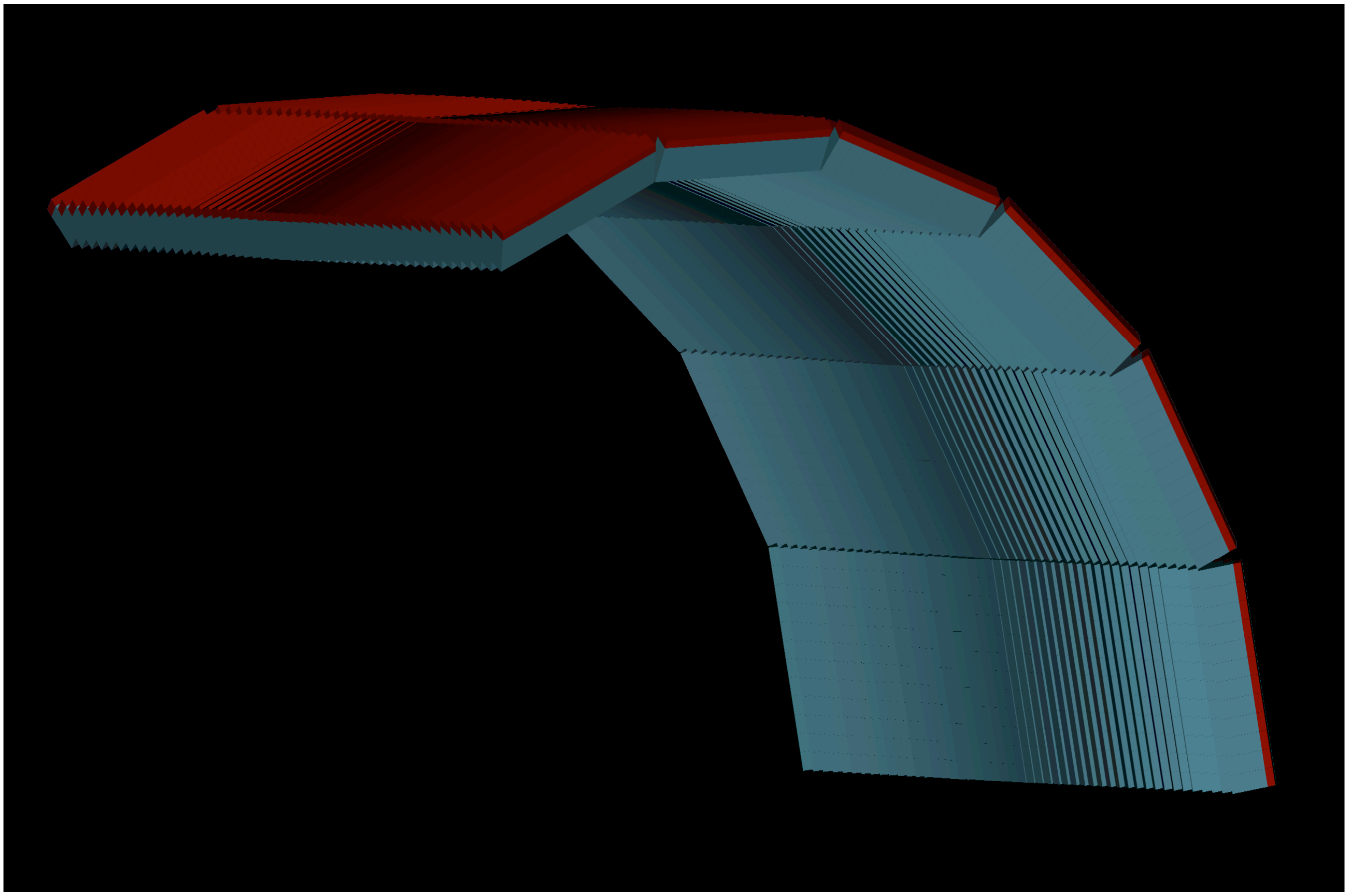
ALICE –USA EMCal R&D Proposal FY05 - FY08



Contents

I. Introduction

In this document, we proposes to continue R&D for a calorimeter addition to the ALICE experiment at CERN through a 2.5 year time period beginning Q4 of FY05 through the end of first Q1 of FY08. The present R&D proposal addresses critical issues of risk that must be settled before a calorimeter construction project can be undertaken commencing in FY08 to support a US driven high P_T physics program in ALICE.

While the entire scope of this R&D request is aimed at mitigating risk in the MIE construction project, the exact split between R&D and construction is still a matter of discussion . In this proposal, we adopt our preferred split of R&D and MIE, our so called "Plan-A", which allows the earliest US participation in ALICE physics running. Other plans which reduce the scope of the R&D phase of the project can also be considered at the expense of some of the early LHC running. Those plans are not considered explicitly here.

The proposed R&D activities are time-critical. The early LHC running schedule is now firmly established with all detectors expected to close up for pp running summer of 2007 and the first PbPb run expected late 2007 or early winter 2008, effectively contiguous with the pp running. The remaining opportunities to address US EMCal integration and infrastructure installation issues are now very limited and well understood. To eventually come successfully into phase with the LHC running schedule with a US calorimeter construction project that will provide increased detector acceptance, year by year, throughout the early PbPb run schedule, it is essential that these issues be addressed now under this proposed R&D program.

In particular, to preserve the eventual opportunity to install a US electromagnetic calorimeter - to be built during a construction project commencing in FY08 - the ALICE-USA collaboration must at a minimum carefully address technical risk associated with support of the large EMCal in ALICE and must meet the last installation opportunity for this support structure in August 2006. Additionally, to allow a low risk, rapid ramp-up to full production during a construction phase of the project – as required to ensure programmatic success within the early years of the LHC run plan - we must address technical, cost and schedule risks associated with both module and super module production.

Faced with the looming startup of the LHC physics program, the present R&D program aims to mitigate the otherwise very significant risks to the overall project physics scope, cost and schedule that will result from the delayed project start. In particular, the present R&D program is designed to ensure that the eventual MIE project for full detector acceptance can be undertaken at a well-understood cost and on a schedule, relative to the LHC running schedule, that insures that the physics goals of the ALICE-USA collaboration can be met. To accomplish this, the present R&D program must: (i) move the proposed detector from its present concept to proof of principle in a prototype test beam measurement; (ii) control the EMCal integration volumes through the development and documentation of an EMCal super-module integration and installation plan; (iii) conduct R&D necessary to control cost, schedule and technical risks associated with critical detector components; (iv) establish the suitability of the EMCal support and installation scheme and meet the final installation opportunity for this structure through the fabrication, installation and test of a structural support in close collaboration with CERN and ALICE, (v) fabricate and install a preproduction prototype super module prior to the 2007 close-up date.

To be fully effective, given the constraints of the LHC running schedule, the proposed R&D project must be followed immediately by a construction project that efficiently completes the full calorimeter scope. At the conclusion of this R&D proposal , therefore, we give an update on the current estimated cost to completion of the full calorimeter scope from the end of the R&D project. At the present time, we expect substantial international contributions[1] to the EMCal construction project are likely commencing in FY08. This can be expected to substantially reduce the total US cost while at the same time it underscore that it is vital that the US exercise immediate leadership of electromagnetic calorimetry in ALICE via this R&D program.

The following executive summary gives an item-by-item overview of the R&D requests and their relation to overall project goals. The order of the items is, as listed above, approximately chronological through the R&D program and not a priority ranking. For example, the principal technical and programmatic risk to the project is item (iv), the suitability of the support structure concept and its critical path installation window.

I.1 Executive Summary

(i) Detector Prototype for Test Beam Studies

1. A Shashlik detector technology was adopted over competing technologies in the first round of this R&D program as providing an overall detector configuration that could be implemented at the lowest possible cost consistent with the very challenging ALICE integration environment. While most aspects of this technology are safely regarded as well understood, there are a number of fundamental conceptual changes that must be adopted in the ALICE application. These required changes are central to the success of the ALICE-EMCal project and thus must be carefully studied and optimized in this R&D program to minimize cost and schedule risk and ensure a detector functionality consistent with physics requirements.

2. Given the significant discovery potential of heavy ion physics[2] at the LHC, it is an essential component of the success of project that the ALICE-USA collaboration participates in the first several LHC PbPb runs. However,

[1] Discussions with Italian and French groups have commenced that suggest up to ~$5M in non-US contributions will begin to become available in 2008 and beyond.

[2] http://www.sc.doe.gov/production/henp/np/nsac/nsac.html

any realistic ALICE-EMCal fabrication and installation schedule is very tight with respect to the turn-on of the LHC physics program. Important prerequisites to the eventual installation of US-EMCal modules that stand to potentially delay the installation of modules must be addressed as early as possible to minimize serious risk to the project schedule. The approval of the ALICE-USA TDR by the ALICE Technical Board and the LHCC is such a prerequisite. A prototype detector test beam demonstration of a match between our detector performance and physics requirements will be a key element of our TDR. Given the uncertainties in the availability of accelerator resources for test beams, it is prudent to proceed with this pre-TDR test beam activity as early as possible consistent with accelerator availability to avoid potentially serious risk to the schedule. Test beam time is preliminarily scheduled at Fermi Lab for the fall of 2005.

3. The assembly of the calorimeter modules is very labor intensive. Ab initio cost estimates of such labor-intensive activities are notoriously imprecise. To minimize the potential risk to the project cost estimate that this uncertainty entails, a substantial prototype is assembled to permit the exploration of assembly scenarios under realistic manpower, tooling and space conditions.

   The detector test beam prototype is discussed further in section II.i.

(ii) Integration/Installation

There are a number of matters of integration that are essential to verify and insure the continued compatibility of our detector with installation and use in ALICE - for example, detector volume or routing pathway conflicts or conflicting installation or service access conflicts, etc. Until our detector is fully integrated and in the ALICE database, we continue to be exposed to delaying and potentially costly changes. Some integration concerns, particularly related to the support structure and super modules, i.e. the largest and heaviest pieces to be handled in the ALICE underground area, also arise in connection with the TDR. This document must be approved at CERN prior to construction start. Thus as a matter of both cost and schedule control it is essential to proceed with a a number of pre-TDR issues including a full integration exercise at this time. This is a very high priority for ALICE engineering and without a prompt start of this activity, they are not prepared to continue to ensure the compatibility the US calorimeter with integration in ALICE.

R&D activity centered on installation and integration issues is discussed further in section II.ii.

(iii) Production Module Prototypes R&D

As part of the test beam detector prototyping program described above, one would like to simultaneously explore in detail the cost exposure associated with all commercially fabricated components of the calorimeter modules. Unfortunately, this is not so easily accomplished as a byproduct of the assembly of the first test beam prototype because components for this first prototype detector are built, part-by-part by technicians, not using the extensive mass production methods that are utilized in the final detector. For this reason, a separate R&D activity is devoted to the detector component process engineering associated with the mass production of certain critical module components. Furthermore, since it is estimated that over one year of effort is needed to qualify and test all the procedures associated with the commercialization of critical components, the work described here must also be completed as soon as possible to minimize schedule risk and ensure participation in the earliest PbPb runs.

It is important not to underestimate this step in the R&D process. The LHC-B electromagnetic calorimeter, for example, suffered considerable schedule delay and cost increase as a result of unexpected loss of precision at the last minute when the Pb radiator fabrication process was turned over to a well-known industrial source. The present R&D program aims to avoid this sort of risk in the ALICE-USA calorimeter project.

R&D activities in support of the commercialization of detector construction is discussed further in section II.iii.

(iv) EMCal Support Structure

The EMCal support structure is the most significant element of technical and schedule risk. As explained in section II, the EMCal support structure concept must be explored and tested separately within the R&D program as a critical element to the viability of the ALICE-USA EMCal as a component of the ALICE detector. As a matter of technical risk control, it is deemed essential to perform a full weight, in situ, test of the support structure. A single installation opportunity remains in the ALICE construction schedule late in FY06 which will allow these tests to be completed <u>before commencing a full calorimeter construction project</u>.

If the FY06 support structure installation opportunity is missed, the next *potential* opportunity does not arise, given the present LHC running schedule, until the end of FY08. However, this late installation scenario requires LHCC approval since it requires an extended LHC shutdown including substantial disassembly of LHC shielding in the vicinity of the L3 magnet. Since this approval is not obvious, this must be regarded as creating very significant risk for the project as a whole. Furthermore, this late installation scenario clearly precludes US participation in the first run. Participation in the first PbPb run is one of the primary goals of the ALICE-USA project because the LHC is a machine with great discovery potential at a new energy frontier.

The support structure R&D program is thus designed to mitigate substantial technical risk while at the same taking advantage of a possibly unique installation opportunity vital to the ultimate success of the project. These matters are discussed further in section II.iv.

(v) Super Module Fabrication, Installation and Test

The final milestone of the ALICE-USA R&D program calls for the fabrication, installation in ALICE and test of a full, pre-production, super-module with the LHC PbPb beams. This work, effectively a sector test for the full calorimeter project, constitutes the final cost, schedule and technical risk management step of the R&D program. All fabrication, integration and installation scenarios are tested and the detector modules are operated in the PbPb collision environment with the final readout electronics. Beyond this, however, the PbPb collision environment is clearly the most challenging background environment ever encountered in a nuclear physics experiment and this full test of the proposed detector in this environment is an essential risk control step for the entire physics scope of the proposed calorimeter addition to ALICE.

As a side benefit to its essential risk control function, the super module will also have sufficient acceptance to test all of the physics observables that can be addressed in "single – arm", i.e. inclusive, measurements not requiring the full calorimeter acceptance. These include transverse energy production, inclusive π^o and direct photon spectra to moderate P_T (including jet quenching), and inclusive electron spectra as a probe of heavy quark production and elliptic flow, etc. As a consequence, therefore, the ALICE-USA collaboration will potentially participate in many of the first significant results and/or discoveries to come from measurements at the new energy frontier at the LHC. The super module R&D activity is discussed further in section II.v.

II. Proposed R&D Activities

In this section we present the proposed R&D scope in some detail. The associated WBS and detailed WBS Dictionary are then presented in section III.

(II.i) Test Beam Detector Prototype (WBS 1.1)

Much of the preliminary work for the detector prototype was completed in FY04 and early FY05. A number of conceptual designs were explored and detailed simulations of cost/performance comparisons were made. Simulations were conducted to examine jet, π^o and γ performance versus detector design parameters. In the end, a shashlik geometry has been adopted over tile/fiber configurations as the most cost effective approach compatible with the unique demands of the ALICE integration environment. A conceptual drawing of the full detector is shown on the cover page of this document.

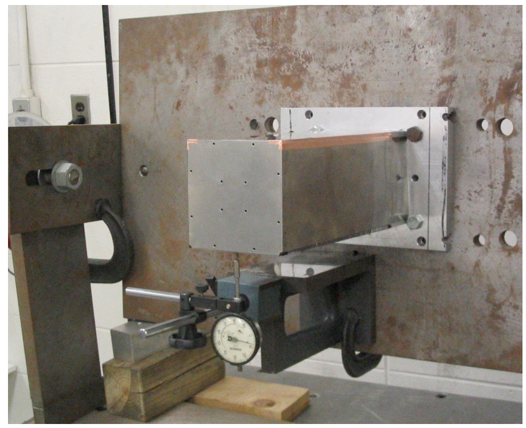


Fig. 1 A mechanical prototype of a 4-tower module under going structural testing

Our detector concept differs in a number of essential respects from all former shashlik implementations. Most notably, our detector is projective in the η direction over the full range $|\eta| \leq 0.7$ and is entirely supported from its back surface. Thus our detector modules are trapezoidal in shape and are each structurally independent permitting them to be mounted in any orientation (Figure 1). A substantial amount of mechanical prototyping and analysis of individual detector modules[3] has led to a stable structure design – exhibiting very small deflections under its own weight (~ 50 µm) - with very little dead material in the active detector volume[4]. This latter condition is very important for the precision shower shape measurements that are a required part of our physics program.

The present R&D proposal will conclude this mechanical prototyping effort (WBS 1.1.1). The mechanical prototyping work will be expanded to include portions of super modules[5] of sufficient size to demonstrate the stability of these units under realistic lift conditions and at all orientations encountered in ALICE. Because of their size, the super modules will require rather complex handling during transport down the long vertical shaft to the

[3] A module is a detector structure comprising 4 towers in a 2x2 arrangement.

[4] Each module has a 30µm stainless steel skin. There is no dead material between towers in a single module.

[5] The super modules span ~20° in ϕ and 0.7 in η. They are the structural units lifted and handled at installation. In our case a super module contains 12x24 modules.

ALICE underground area[6]. In all former shashlik implementations, modules have been stacked like building blocks and mechanical stability issues such as those addressed here were trivial. In the present application, stability and lifting tests are an essential component of the detector conceptual design process and will be required at the time of the TDR as a central feature of the safety analysis of the structure. As such, the proposed pre-TDR studies are an essential part of both project technical and schedule risk control.

In parallel with these mechanical studies, detailed optical studies of tower prototypes in the first R&D cycle have led to fiber and scintillator composition selections. Cosmic ray tests have established an interim estimate of ~2500 photo electrons per GeV for our tower design when used in conjunction with the selected PHOS APD. As part of the prototype R&D, our optical studies will be concluded (WBS 1.1.2) with the aim of optimizing the photo electron yield at acceptable global and local non-uniformity[7] through scintillator surface and edge treatment, interlayer diffuse reflector choice[8] and fiber density studies. Tracked cosmic rays will be used to probe the tower response down to distance scales of ~1mm necessary to adequately resolve the local non-uniformity before committing to the final tower design. The optimized optical design will be integrated in the proposed R&D program into a 64 tower prototype detector configured with PHOS style APD's and preamps. Indeed, a full PHOS electronics chain will be assembled and the system will be tested using mixed beams at FNAL in the late fall.

The assembly of the 64 tower prototype (WBS 1.1.3) will be carried out with levels of manpower, manpower training and space appropriate to that intended for the final mass production detector. The construction activity is designed to be of sufficient scope to provide accurate labor cost estimate for the full project which is in turn essential to the development of a credible project schedule. The 64 tower prototype construction activity is thus a key component of the project risk management program.

The test beam activity (WBS 1.1.4) using a close to final version[9] of our readout electronics will be designed to demonstrate a match between detector performance and physics requirements and is thus an important step in the project risk control program. In particular, the physics reach of the proposed ALICE-USA program relies heavily on the proposed detector performance and it is essential to verify that the present conceptual design meets the requisite levels of performance. Features of the detector performance that are central to the ALICE-USA physics program but are not easily simulated - such as shower shape distortions at module boundaries - will be an important part of our measurements. Electrons, hadrons and muons will be studied over a wide momentum range with electrons studied with fine spatial resolution sufficient to probe the magnitude

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[6] The actual super module lifting and installation plan is developed under WBS 1.2.2.2

[7] This refers to the transverse optical non-uniformity within a single tower which appears with characteristic widths equal to the full tower width and interfiber spacing respectively.

[8] It is well known that Dupont Tyvek provides the best diffuse surface reflectivity of most readily available materials. In the present application, however, Tyvek is not a suitable choice since its coefficient of friction with the scintillator surface is so low that it results in modules that are mechanically unstable in our mounting configuration under reasonable compression forces.

[9] We will use a copy of the PHOS readout chain. This readout package may receive some fine-tuning to shaping times for the final ALICE-USA readout system.

of shower shape distortions at module boundaries. Depending on beam quality and intensity, some π^o reconstruction may be attempted to further verify our understanding of transverse electromagnetic shower shapes in the detector.

The hadronic response of the detector will also be studied in detail. These measurements are essential to benchmark our simulations of jet reconstruction and to help quantify our understanding of the response of our detector to the complex soft hadronic background in PbPb events at the LHC. This is an important first step in demonstrating the suitability of the chosen technology to the complexities of the LHC environment.

As noted above, this will be the first large-scale implementation of a projective shashlik detector. We have made extensive simulations on the influence of essential structural materials and the detector-stacking scenario on detector performance. The present conceptual design has been carefully tuned to minimize the effects of dead material necessarily associated with the projective geometry. As a feature of our risk control program, therefore, the test beam measurements will verify these simulations. To accomplish this, the prototype will be constructed such that it can be quickly stacked and restacked to allow configurations appropriate to both η=0.0 and η=0.7 to be separately tested in-beam.

(II.ii) Integration/Installation studies (WBS 1.2)

The ALICE construction project is rapidly approaching its final stages and major installation activities will commence soon. At that time all significant detector subsystems will be part of an overarching integration plan. The continued viability of the proposed ALICE-USA EMCal as an ALICE subsystem requires that we participate in the final phases of the ALICE integration exercise and that we adopt a full time presence at CERN as members of the ALICE integration team. There are a number of matters of integration that are essential to verify and insure the compatibility of our detector with installation and use in ALICE. Of particular importance are the resolution of integration boundaries with TOF and TRD and the associated competing routing pathways. Access and stay clear volumes required for installation and service, repair and replacement must be finalized. Until our detector is fully integrated in the ALICE database, we continue to be exposed to delaying and potentially costly changes triggered by other subsystems. Thus as an important matter of cost and schedule control it is essential to proceed with an integration exercise (WBS 1.2.1 and 1.2.3) that will establish all of the relevant detector volumes, routing paths, power and cooling, etc.

A number of integration concerns also arise in connection with the TDR which must be approved at CERN prior to construction start. Of these, the most significant is the status of our installation plan for both the support structure and the super modules themselves. The size of the support structure requires that it be transported down to the L3 underground area in pieces and then assembled at the entrance to the L3 magnet at the underground level. Furthermore, it is expected that the support structure cannot be installed with any significant fraction of the LHC beam shielding at the L3 area in place which sets a very high premium on installing the support structure prior to close-up of the LHC for the first run. The super modules, on the other hand, must be installed over time during relatively short LHC shutdowns in the coming years and the TDR must present a well engineered plan to accomplish this with minimal disruption to the accelerator. The installation tooling concept and its interface with the support structure for the calorimeter as well as with both ALICE and LHC must be documented and schematic installation schedules formulated (WBS 1.2.2 and 1.2.3). In an effort to mitigate serious risk to the overall project schedule, work on this important element of the TDR must be performed under the current R&D effort.

(II.iii) Component Process Engineering R&D (WBS 1.3)

The cost estimate for the calorimeter depends heavily on the commercialization of a number of detector components. As part of the detector prototyping program described above, one would like to simultaneously explore cost exposure associated with commercially fabricated components of the calorimeter modules. Unfortunately, this is not so easily accomplished as a byproduct of the first test beam prototype because components the prototype detector are built part by part by technicians and instrument makers - not using the extensive mass production methods which are utilized in the final detector. For this reason, a separate R&D activity is devoted to the process engineering associated with the mass production of certain critical detector components. In the present conceptual design of detector modules, approximately 9 separate components are produced by plastic injection molding and 3 others are produced by demanding, high precision laser-cut / metal stamping techniques. The former includes all the scintillator tiles and the latter includes all the Pb radiators. Similarly, the optical fiber bundles (WBS 1.1.2) used in the prototype will be produced by hand whereas automated techniques must be employed in the final detector. In total, over 750k parts in all in the final detector are thus produced with materials and by techniques that cannot be explored in detail in the normal course of producing the test beam detector prototype. This large number of parts creates a very substantial cost and schedule exposure that is not addressed as part of the 64 tower detector prototype. It is estimated that over one year of effort within the present group is needed to qualify and test all the parts and procedures associated with the mass production of critical components. The work described here must be completed as soon as possible as a measure to control schedule risk and ensure participation in the first PbPb run.

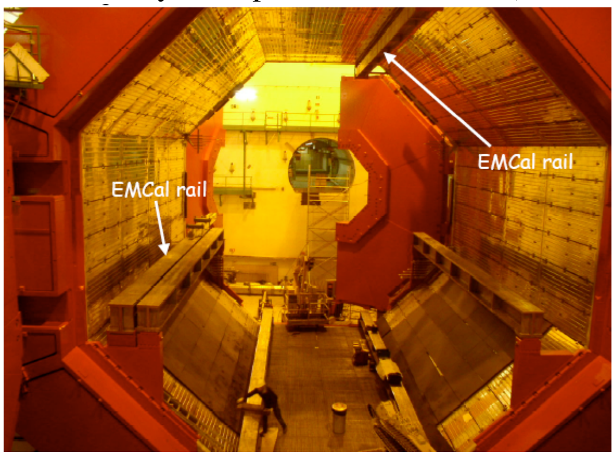

Fig. 2. The L3 magnet with a total of 6 full-length rails shown installed. Two near the bottom of the magnet will support the PHOS, two near the midplane will support the TPC and all the other central detectors, and one in the midplane and one near the top of the magnet have been designed and installed to support the ALICE-USA

(II.iv) EMCal support structure (WBS 1.4)

The addition of a large electromagnetic calorimeter to the ALICE experiment presents a number of very significant and unique engineering challenges. The coil surface of the L3 magnet is continuous and allows no radial connections from the interior volume of the magnet to the surrounding yoke. The original L3 design assumed an experiment integration based on a massive central hub, supported at the ends, outside the magnet, from which all the subsystems that made up the full hermetic L3 detector were supported. This approach is not compatible with the needs of a heavy ion experiment so an alternate approach was developed in the design of the ALICE experiment that uses a system of rails that span the full length of the L3 magnet and permit the support of a cylindrical space frame, coaxial with the colliding beams from which the TPC and all other ALICE detectors could be mounted. The rails are supported only at the two ends of the magnet thus transferring the full weight of the experimental apparatus to the "door frames" of the magnet and thus to a very limited area on the magnet's understructure. The addition of an electromagnetic calorimeter in this integration environment, which increases the weight that must be supported by ~200T, requires a separate set of rails to permit the addition of an overarching support structure from which the calorimeter can be mounted. These rails, an early critical path element of the ALICE construction project, have already been installed within the L3 magnet (Figure 2).

As with the rest of the experiment, the 200T weight of the proposed calorimeter is transferred through the door frames to the concrete pad which comprises the floor of the L3 hall. Engineering studies undertaken prior to the installation of the rails judged that there is sufficient holding capacity, with modest safety factor, available to support the weight of the ALICE-USA calorimeter. This engineering judgment is critical to the eventual success of the EMCal project and the ALICE-USA physics program. As a matter of technical risk control, therefore, it is deemed advisable to perform a dedicated test of the support structure under full load before committing to the construction of the full calorimeter. To accomplish this test, we must fabricate the proposed support

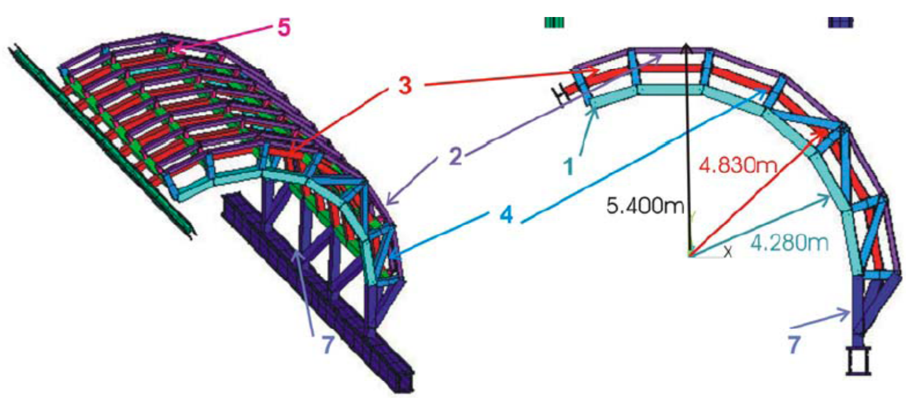

Fig. 3 An overview of the present support structure concept to span 120 degrees in azimuth supported by the lower and upper

structure spanning the full length of the L3 magnet and test the impact of the proposed loading on the L3 magnet yoke.

Furthermore, as noted in the introduction, in addition to the technical risk described above, there is a critical schedule risk to the project that arises if the support structure is not installed at the end of FY06 prior to ALICE close-up for the first pp run. The alternative, which has been discussed in the past, is to seek authorization from the LHCC for the necessary installation time required to disassemble sufficient LHC shielding to permit an installation of the support structure in late FY08. This approach would result in considerable cost increases and, more importantly, clearly entails substantial project risk since the decision to permit the late installation cannot be guaranteed at this time. Furthermore, such an approach precludes US participation in the first run which is an important goal of the ALICE-USA collaboration. Many potential discoveries wait to be uncovered in even the first few events from the hotter denser QGP at the LHC and US electromagnetic calorimetry may provide important insights.

Consequently we reject this FY08 installation option as a viable scheduling scenario. Thus both to mitigate the technical risk associated with the support structure concept and control the critical risk associated with the project schedule, we must fabricate the proposed support structure to allow a full weight test in time for a late FY06 installation.

In summary, the support structure R&D is undertaken to:

- Minimize technical risk by verifying the suitability of the L3 door frames and magnet foundations under the support structure attachment points
- Minimize technical risk by verifying support structure deflections over the TPC under load
- Minimize technical risk by verifying module installation procedures before closure of area
- Minimize schedule and programmatic risk due to loss of installation window
- Enable participation of US EMCal in first year of Pb+Pb running

(v) Pre-Construction Super Module (WBS 1.5, 1.6, 1.7 and 1.9)

A fully instrumented super module will be fabricated using methods and materials explored in the R&D program described in the preceding sections and installed in the ALICE experiment prior to close up for the pp run. This will permit a full sector test of the calorimeter and is the final cost, schedule and technical risk management exercise for the full calorimeter project. Substantial technical risk is minimized through a full evaluation of detector performance in the real LHC, PbPb environment which is essential to demonstrating a match between the proposed detector technology and the ALICE-USA physics requirements in the previously unexplored environment of PbPb collisions at

LHC energies. As a major side benefit, a number of “single-arm”, i.e. inclusive physics observables can be explored with this first super module allowing significant participation of the ALICE-USA collaboration in the first PbPb discovery run.

III Costs and Schedule

The cost roll up to WBS level 1 and funding profile for the proposed R&D is given below in table 1.

Table 1. Level 1 WBS for the proposed R&D scope with the incremental costs per super module in the out years also indicated

	B	C	X	AC	AD	AE	AF	AG	BH	BM
2–4		Version 1.7 6-29-05	R&D Phase FY05 to FY08						Construction Phase approximate incremental cost per super module	
5–6	WBS Number	WBS Name	Total Contingency	Total Project Cost	FY05 Cost	FY06 Cost	FY07 Cost	FY08 Costs	Total Contingency	Total Project Cost
7	1	ALICE-USA EMCAL	$555,182	$4,245,969	$169,434	$1,132,536	$2,515,065	$428,935	$116,677	$775,481
8										
9	1.1	Detector Prototype	$40,622	$136,906	$324	$136,581	$0		$0	$0
70	1.2	EMCal Integration	$24,323	$286,997	$34,812	$176,464	$75,721	$0	$0	$0
83	1.3	Process Engineering	$58,456	$338,816	$0	$180,671	$158,145		$0	$0
144	1.4	EMCal Support Structure	$159,071	$1,066,500	$63,036	$223,582	$779,883		$0	$0
175	1.5	Super Module	$204,814	$1,026,150	$0	$0	$946,623	$79,528	$72,589	$376,443
239	1.6	Module and Component Test	$11,571	$53,865	$0	$0	$53,865	$0	$3,981	$20,216
245	1.7	Electronics	$26,131	$198,409	$0	$0	$0	$198,409	$26,131	$198,409
266	1.8	EMCal Software	$0	$0	$0	$0	$0		$0	$0
278	1.9	EMC Conv. Sys.	$9,874	$76,777	$0	$0	$76,777	$0	$4,648	$28,254
289	1.10	Project Management and Integration	$20,320	$1,061,548	$71,262	$415,238	$424,052	$150,997	$1,446	$73,340
301										
302	1.11	Computing		$0	$0	$0	$0	$0	$7,882	$78,818

The costs shown here take advantage of institutional contributions applicable to FY05 and FY06. These institution contributions are above and beyond contributions from the base program which are very substantial but are not accounted for in the WBS. The institutional contributions in FY05 and 06 are outlined in table 2.

Table 2. FY05 Institutional Contributions

Institution	Amount	Scope	WBS
ORNL	$125k	Electronics R&D	1.7.1.19
WSU	$ 120k	Test Beam Prototype	1.1.3
WSU	$ 42k	Integration	1.2.1 and 1.2.2

The full scope of the proposed R&D is accomplished for the following funding profile:

FY05:	$ 164k (Q4)
FY06:	$ 1092k
FY07:	$ 2494k
FY08:	$ 424k (Q1)
R&D TPC:	$ 4246k

In addition, we show in table1 that the incremental costs per super module is $775k in the out years leading to a TPC for the construction phase of $8525k. For the full project scope of 12 installed and instrumented super modules, the TPC is $12,771k. As noted earlier in this document, however, we are working on international contributions to this project that will potentially reduce the TPC by the order of $5M.

The optimum funding profile for completing the R&D and the full construction scope is given in table 3.

Table 3. Optimum funding profile for the full R&D plus construction scope

R&D				Construction		
FY05	FY06	FY07	FY08			
$169	$1,133	$2,515	$429			
				FY08	FY09	FY10
				$3,100	$3,100	$2,325

As noted in the introduction, much of the R&D discussed here is time critical. Table 4. Lists the summary milestones fro this R&D effort by WBS level 2. The full WBS for the R&D phase of the project is given in appendix A

Table 4. R&D summary milestones by WBS level 2

WBS	Description	Milestone
1.1.1	Mechanical Analysis/Prototypes	05/01/06
1.1.2	Tower Optical Studies	09/27/05
1.1.3	Prototype Construction	11/21/05
1.1.4	Prototype Test Beam	01/02/06
	Critical Milestone: Test Beam Completed	**01/03/06**
1.2.1	EMCal Detector Integration	01/11/07
1.2.2	Pre-CDR/TDR Work	09/22/05
1.3.1	Injection Molded Parts	01/25/07
1.3.2	Laser cut parts	01/23/07
1.4.1	EMCal Support Structure Design	01/12/06
1.4.2	Module Support Structure Procurement	07/13/06
1.4.3	Module Support Structure Installation	08/24/06
	Critical Milestone: Support Structure Installed	**08/24/06**
1.5.1	Parts and Components	05/31/07
1.5.2	Assembly	08/10/07
1.5.3	Installation	08/24/07
	Critical Milestone: Super Module Installed	**08/24/07**
1.7.1	Electronics	03/16/07
1.73	Test Calibrate	05/18/07
1.8.1	OnLine	05/18/07
1.8.2	OffLine	10/05/07
1.9.1	Conventional Sys. Cooling	05/04/07
1.9.1	Conventional Sys. LV Power	04/20/07
	Critical Milestone: Super Module Ready	**10/15/07**

Appendix A

ALICE USA EMCal R&D WBS

	B	C	X	AC	AD	AE	AF	AG
2								
3		**Version 1.7 6-29-05**	**R&D Phase FY05 to FY08**					
4								
5			Total	**Total**				
6	**WBS Number**	**WBS Name**	**Contingency**	**Project Cost**	**FY05 Cost**	**FY06 Cost**	**FY07 Cost**	**FY08 Costs**
7	**1**	**ALICE-USA EMCAL**	**$555,182**	**$4,245,969**	**$169,434**	**$1,132,536**	**$2,515,065**	**$428,935**
9	**1.1**	**Detector Prototype**	**$40,622**	**$136,906**	**$324**	**$136,581**	**$0**	
10								
11	1.1.1	Mechanical Analysis/Prototypes	$5,370	$32,646	$2,127	$30,519	$0	
12	1.1.1.1	Module Studies	$320	$2,127	$2,127	$0	$0	$0
13	1.1.1.1.1	Prototypes	$320	$2,127	$2,127	$0	$0	$0
14	1.1.1.1.2	FEA	$0	$0	$0	$0	$0	$0
15	1.1.1.2	Super Module Studies	$5,051	$30,519	$0	$30,519	$0	$0
16	1.1.1.2.1	Prototypes	$5,051	$30,519	$0	$30,519	$0	$0
17	1.1.1.2.2	FEA	$0	$0	$0	$0	$0	$0
18								
19	1.1.2	Tower Optical Studies	$4,120	$17,954	$2,573	$15,381	$0	
20	1.1.2.1	Fiber Bundle/Coupling	$3,570	$15,202	$1,198	$14,005		
21	1.1.2.1.1	Cryogenic Polishing Tools	$1,027	$4,351		$4,351		
22	1.1.2.1.2	Aluminizing tools	$2,299	$9,654		$9,654		
23	1.1.2.1.3	Prototype Studies	$244	$1,198	$1,198			
24	1.1.2.2	Scintillator Treatment	$550	$2,752	$1,376	$1,376		
25	1.1.2.2.1	Diffuse reflector studies/comparisons	$409	$2,054	$1,027	$1,027		
26	1.1.2.2.2	Prototype Edge Treatment	$141	$697	$349	$349		
27								
28	1.1.3	Prototype Construction	$27,735	$183,529	$75,123	$108,405	$0	$0
29	1.1.3.1	Pb Radiator	$6,842	$46,903	$27,088	$19,816	$0	$0
30	1.1.3.1.1	Design	$158	$939	$939			
31	1.1.3.1.2	Procure	$1,843	$16,566	$16,566			
32	1.1.3.1.3	Tooling	$1,929	$9,583	$9,583			
33	1.1.3.1.4	Fabricate	$2,872	$19,352		$19,352		
34	1.1.3.1.5	QA/QC	$39	$464		$464		
35	1.1.3.2	Scintillator	$5,535	$34,501	$7,367	$27,134		
36	1.1.3.2.1	Design	$158	$939	$939			
37	1.1.3.2.2	Procure	$712	$6,428	$6,428			
38	1.1.3.2.3	Tooling	$802	$4,074		$4,074		
39	1.1.3.2.4	Fabricate	$3,810	$22,580		$22,580		
40	1.1.3.2.5	QA/QC	$53	$480		$480		
41	1.1.3.3	Structures	$5,417	$36,212	$19,975	$16,237		
42	1.1.3.3.1	Design	$810	$5,455	$5,455			
43	1.1.3.3.2	Procure	$1,221	$11,153	$11,153			
44	1.1.3.3.3	Tooling	$647	$3,367	$3,367			
45	1.1.3.3.4	Fabricate	$2,740	$16,237		$16,237		
46	1.1.3.4	Fibers	$6,459	$39,148	$20,694	$18,454		
47	1.1.3.4.1	Design	$270	$1,600	$1,600			
48	1.1.3.4.2	Procure	$2,515	$19,094	$19,094			
49	1.1.3.4.3	Tooling	$805	$3,645		$3,645		
50	1.1.3.4.4	Cookie Fab	$195	$978		$978		
51	1.1.3.4.5	Fiber Prep	$1,140	$5,792		$5,792		
52	1.1.3.4.6	Fiber Bundle Fab	$285	$1,448		$1,448		
53	1.1.3.4.7	Mixer Fab	$1,157	$5,865		$5,865		
54	1.1.3.4.8	QA/QC	$92	$727		$727		
55	1.1.3.5	Final Assembly	$2,646	$11,314	$0	$11,314		
56	1.1.3.5.1	Tooling	$1,526	$6,342		$6,342		
57	1.1.3.5.2	Stacking/welding	$757	$3,278		$3,278		
58	1.1.3.5.3	Fibers/Mixer/APD/PA	$363	$1,694		$1,694		
59	1.1.3.6	Calibration and Test	$837	$4,450	$0	$4,450		
60		Cosmic pre-calibration	$837	$4,450		$4,450		
61	1.1.3.7	Electronics/APD's R&D	$0	$11,000		$11,000		
62								
63	1.1.4	Prototype Test Beam	$3,396	$22,277	$0	$22,277	$0	
64	1.1.4.1	Site Supplies and services	$170	$1,287	$0	$1,287	$0	
65	1.1.4.1	Shipping/Rigging	$1,528	$7,534	$0	$7,534	$0	
66	1.1.4.1	Technicians	$1,697	$13,456	$0	$13,456	$0	
67								

	B	C	X	AC	AD	AE	AF	AG
67								
68	1.1.5	Institutional Contribution		-$119,500	-$79,500	-$40,000		
69								
70	**1.2**	**EMCal Integration**	**$24,323**	**$286,997**	**$34,812**	**$176,464**	**$75,721**	**$0**
71								
72	1.2.1	EMCal Detector Integration	$13,617	$79,702	$19,925	$59,776	$0	
73	1.2.1.1	Design/Data Base Work	$11,023	$65,331	$16,333	$48,998		
74	1.2.1.2	Prototypes	$2,258	$10,318	$2,579	$7,738		
75	1.2.1.3	EA Travel	$335	$4,054	$1,013	$3,040		
76	1.2.2	Pre-CDR/TDR Work	$10,707	$59,548	$14,887	$44,661	$0	
77	1.2.2.1	Support Structure Integration Concept	$5,291	$28,170	$7,043	$21,128		
78	1.2.2.2	Super Module Integration Concept	$3,816	$22,616	$5,654	$16,962		
79	1.2.2.3	Prototypes	$1,600	$8,761	$2,190	$6,571		
80	1.2.3	WSU Detector Integration @ CERN	$0	$147,748	$0	$72,027	$75,721	
81	1.2.4	Institutional Contribution		$0	$0			
82								
83	**1.3**	**Process Engineering**	**$58,456**	**$338,816**	**$0**	**$180,671**	**$158,145**	
84								
85	1.3.1	Injection Molded Parts	$30,062	$180,671	$0	$180,671	$0	
86	1.3.1.1	Scintillator Tiles	$6,907	$36,622		$36,622		
87	1.3.1.1.1	Design	$607	$4,091		$4,091		
88	1.3.1.1.2	Tool & Die Work	$4,467	$18,209		$18,209		
89	1.3.1.1.2	WSU Tooling	$731	$3,135		$3,135		
90	1.3.1.1.2	Prototypes	$782	$6,910		$6,910		
91	1.3.1.1.3	Shipping/Customs	$320	$4,277		$4,277		
92	1.3.1.2	Optical Mixer	$2,330	$12,127		$12,127		
93	1.3.1.2.1	Design	$246	$1,789		$1,789		
94	1.3.1.2.2	Tool & Die Work	$1,761	$8,631		$8,631		
95	1.3.1.2.3	Prototypes	$322	$1,707		$1,707		
96	1.3.1.3	Fiber guide	$1,170	$6,451		$6,451		
97	1.3.1.3.1	Design	$246	$1,789		$1,789		
98	1.3.1.3.2	Tool & Die Work	$601	$2,955		$2,955		
99	1.3.1.3.3	Prototypes	$322	$1,707		$1,707		
100	1.3.1.4	Fiber Grommet	$1,402	$7,586		$7,586		
101	1.3.1.4.1	Design	$246	$1,789		$1,789		
102	1.3.1.4.2	Tool & Die Work	$833	$4,090		$4,090		
103	1.3.1.4.3	Prototypes	$322	$1,707		$1,707		
104	1.3.1.5	Fiber Cover	$1,590	$8,509		$8,509		
105	1.3.1.5.1	Design	$246	$1,789		$1,789		
106	1.3.1.5.2	Tool & Die Work	$1,021	$5,013		$5,013		
107	1.3.1.5.3	Prototypes	$322	$1,707		$1,707		
108	1.3.1.6	Rear Matrix Plate	$4,193	$21,536		$21,536		
109	1.3.1.6.1	Design	$370	$2,683		$2,683		
110	1.3.1.6.2	Tool & Die Work	$3,501	$17,145		$17,145		
111	1.3.1.6.3	Prototypes	$322	$1,707		$1,707		
112	1.3.1.7	Front Matrix plate	$4,193	$21,536		$21,536		
113	1.3.1.7.1	Design	$370	$2,683		$2,683		
114	1.3.1.7.2	Tool & Die Work	$3,501	$17,145		$17,145		
115	1.3.1.7.3	Prototypes	$322	$1,707		$1,707		
116	1.3.1.8	Front Cover	$2,087	$11,859		$11,859		
117	1.3.1.8.1	Design	$246	$1,789		$1,789		
118	1.3.1.8.2	Tool & Die Work	$1,518	$8,364		$8,364		
119	1.3.1.8.3	Prototypes	$322	$1,707		$1,707		
120	1.3.1.9	Module Mounting Plate	$3,613	$18,698		$18,698		
121	1.3.1.9.1	Design	$370	$2,683		$2,683		
122	1.3.1.9.2	Tool & Die Work	$2,921	$14,307		$14,307		
123	1.3.1.9.3	Prototypes	$322	$1,707		$1,707		
124	1.3.1.10	Engineering Oversight	$2,579	$35,748		$35,748		
125								
126	1.3.2	Laser Cut/Stamped Parts	$28,394	$158,145	$0	$0	$158,145	
127	1.3.2.1	Pb Radiator Plates	$21,096	$105,787			$105,787	
128	1.3.2.1.1	Design	$832	$6,037			$6,037	
129	1.3.2.1.2	Vendor Tooling	$16,274	$79,655			$79,655	
130	1.3.2.1.3	WSU Tooling	$2,663	$11,001			$11,001	
131	1.3.2.1.4	Materials	$223	$2,483			$2,483	
132	1.3.2.1.5	Prototypes	$1,104	$6,610			$6,610	

	B	C	X	AC	AD	AE	AF	AG
130	1.3.2.1.3	WSU Tooling	$2,663	$11,001			$11,001	
131	1.3.2.1.4	Materials	$223	$2,483			$2,483	
132	1.3.2.1.5	Prototypes	$1,104	$6,610			$6,610	
133	1.3.2.2	Front Compression Plate	$3,133	$17,405			$17,405	
134	1.3.2.2.1	Design	$524	$3,801			$3,801	
135	1.3.2.2.2	Vendor Tooling	$1,844	$9,035			$9,035	
136	1.3.2.2.3	Prototypes	$766	$4,568			$4,568	
137	1.3.2.3	Rear Compression Plate	$3,133	$17,405			$17,405	
138	1.3.2.3.1	Design	$524	$3,801			$3,801	
139	1.3.2.3.2	Vendor Tooling	$1,844	$9,035			$9,035	
140	1.3.2.3.3	Prototypes	$766	$4,568			$4,568	
141	1.3.2.4	Engineering Oversight	$1,032	$17,549			$17,549	
142								
143								
144	**1.4**	**EMCal Support Structure**	**$159,071**	**$1,066,500**	**$63,036**	**$223,582**	**$779,883**	
145								
146	1.4.1	EMCal Support Structure Design	$24,978	$215,582	$63,036	$152,547	$0	
147	1.4.1.1	Design Costs (WSU)	$1,523	$12,187	$12,187	$0	$0	
148	1.4.1.1.1	EA Labor	$293	$1,848	$1,848			
149	1.4.1.1.2	EA Travel	$197	$3,829	$3,829			
150	1.4.1.1.3	EN Labor	$1,033	$6,510	$6,510			
151	1.4.1.2	Design Costs (LBL)	$23,455	$203,395	$50,849	$152,547		
152	1.4.1.2.1	EA Labor	$14,700	$127,473	$31,868	$95,604.45		
153	1.4.1.2.2	EN Labor	$8,755	$75,923	$18,981	$56,942.08		
154								
155	1.4.2	Module Support Structure CERN Procurement	$123,955	$789,531	$0	$9,648	$779,883	
156	1.4.2.1	Procurement - WSU Costs	$908	$9,648	$0	$9,648	$0	
157	1.4.2.1.1	EA Labor	$153	$1,671		$1,671		
158	1.4.2.1.2	EA Travel	$218	$2,093		$2,093		
159	1.4.2.1.3	EN Labor	$537	$5,885		$5,885		
160	1.4.2.2	Procurement - CERN Costs	$123,047	$779,883		$0	$779,883	
161	1.4.2.2.1	EA Labor	$0	$0		$0		
162	1.4.2.2.2	Support Structure	$123,047	$779,883		$0	$779,883	
163								
164	1.4.3	Support Structure Installation/Test	$10,138	$61,387	$0	$61,387	$0	
165	1.4.3.1	Installation - WSU Costs	$3,427	$33,555		$33,555		
166	1.4.3.1.1	EN Oversight	$1,250	$12,824		$12,824		
167	1.4.3.1.2	EA Labor	$332	$3,409		$3,409		
168	1.4.3.1.3	TE Labor	$605	$6,205		$6,205		
169	1.4.3.1.4	EA/TE Travel	$1,240	$11,116		$11,116		
170	1.4.3.2	Installation - CERN Costs	$6,711	$27,832		$27,832		
171	1.4.3.2.1	EA Labor	$276	$1,624		$1,624		
172	1.4.3.2.2	LHC Riggers	$6,435	$26,209		$26,209		
173								
174								
175	**1.5**	**Super Module**	**$204,814**	**$1,026,150**	**$0**	**$0**	**$946,623**	**$79,528**
176								
177	1.5.1	Super module design	$31,728	$269,898	$0	$0	$269,898	$0
178	1.5.1.1	EA Labor (LBL)	$14,700	$127,473	$0	$0	$127,473	$0
179	1.5.1.2	EN Labor (LBL)	$8,755	$75,923	$0	$0	$75,923	$0
180	1.5.1.3	Travel and supplies (LBL)	$3,570	$27,027	$0	$0	$27,027	$0
181	1.5.1.4	EN Labor (WSU travel, labor)	$4,703	$39,476	$0	$0	$39,476	$0
182								
183	1.5.2	Parts and Components	$74,620	$318,164	$0	$0	$318,164	$0
184	1.5.2.1	Module parts	$33,890	$192,382	$0	$0	$192,382	$0
185	1.5.2.1.1	Front Plate	$383	$2,148	$0	$0	$2,148	$0
186	1.5.2.1.2	Front Weld Plate	$762	$4,545	$0	$0	$4,545	$0
187	1.5.2.1.3	Back Plate	$383	$2,148	$0	$0	$2,148	$0
188	1.5.2.1.4	Al varient of back plate	$15	$92	$0	$0	$92	$0
189	1.5.2.1.5	Al varient of frontplate	$15	$92	$0	$0	$92	$0
190	1.5.2.1.6	Back Weld Plate	$762	$4,545	$0	$0	$4,545	$0
191	1.5.2.1.7	Strap	$947	$5,864	$0	$0	$5,864	$0
192	1.5.2.1.8	Grommet	$408	$2,285	$0	$0	$2,285	$0
193	1.5.2.1.9	Fiber covers	$511	$2,849	$0	$0	$2,849	$0
194	1.5.2.1.10	Module Mount	$1,182	$6,869	$0	$0	$6,869	$0
195	1.5.2.1.11	Scintillator Tile	$4,319	$24,228	$0	$0	$24,228	$0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	B	C	X	AC	AD	AE	AF	AG
196	1.5.2.1.12	Lead Absorber	$13,555	$74,699	$0	$0	$74,699	$0
197	1.5.2.1.13	Tyvek Sheet	$532	$2,965	$0	$0	$2,965	$0
198	1.5.2.1.14	Fibers	$7,424	$43,738	$0	$0	$43,738	$0
199	1.5.2.1.15	Light guide / diffuser	$1,082	$6,018	$0	$0	$6,018	$0
200	1.5.2.1.17	LED, Optical fibers and prisms	$1,609	$9,299	$0	$0	$9,299	$0
201	1.5.2.2	Super Module parts	$40,730	$125,782	$0	$0	$125,782	$0
202	1.5.2.2.1	Eta Spine Zero*	$6,303	$25,220	$0	$0	$25,220	$0
203	1.5.2.2.2	Eta Spine Mid*	$0	$0	$0	$0	$0	$0
204	1.5.2.2.3	Eta Spine End*	$0	$0	$0	$0	$0	$0
205	1.5.2.2.4	Super Back	$34,084	$95,350	$0	$0	$95,350	$0
206	1.5.2.2.5	fasteners	$343	$5,212	$0	$0	$5,212	$0
207								
208	1.5.3	Assembly	$82,884	$358,561	$0	$0	$358,561	$0
209	1.5.3.1	Assembly Tooling and supplies	$71,503	$265,243	$0	$0	$265,243	$0
210	1.5.3.1.1	module assembly tooling	$11,262	$41,200	$0	$0	$41,200	$0
211	1.5.3.1.2	Super mod assy tooling -WSU	$19,423	$63,632	$0	$0	$63,632	$0
212	1.5.3.1.3	Lead handling assembly fixtures	$8,739	$31,861	$0	$0	$31,861	$0
213	1.5.3.1.4	Lead Environmental Controls	$26,235	$94,450	$0	$0	$94,450	$0
214	1.5.3.1.5	Assembly supplies	$1,113	$7,111	$0	$0	$7,111	$0
215	1.5.3.1.6	RTV System and Supplies	$1,605	$13,590	$0	$0	$13,590	$0
216	1.5.3.1.7	Module Shipping Fixtures	$3,127	$13,399	$0	$0	$13,399	$0
217	1.5.3.2	Detector Assembly	$11,381	$93,318	$0	$0	$93,318	$0
218	1.5.3.2.1	stacking modules	$711	$9,043	$0	$0	$9,043	$0
219	1.5.3.2.2	machine modules	$2,452	$17,798	$0	$0	$17,798	$0
220	1.5.3.2.3	welding	$1,466	$12,709	$0	$0	$12,709	$0
221	1.5.3.2.4	fiber insertion	$970	$9,369	$0	$0	$9,369	$0
222	1.5.3.2.5	fiber cover fiber bundle and epoxy	$1,121	$12,274	$0	$0	$12,274	$0
223	1.5.3.2.6	polish fiber attach mixer	$1,810	$13,143	$0	$0	$13,143	$0
224	1.5.3.2.7	attach APD	$366	$3,177	$0	$0	$3,177	$0
225	1.5.3.2.8	close up	$366	$3,177	$0	$0	$3,177	$0
226	1.5.3.2.9	assemble spine	$1,875	$10,509	$0	$0	$10,509	$0
227	1.5.3.2.10	pack	$244	$2,118	$0	$0	$2,118	$0
228	1.5.4	Installation	$15,581	$79,528	$0	$0	$0	$79,528
229	1.5.4.3	Site Supplies and Services	$255	$1,931	$0	$0	$0	$1,931
230	1.5.4.4	Module Installation (WSU Costs)	$1,632	$9,540	$0	$0	$0	$9,540
231	1.5.4.5	Module Installation - CERN Costs	$850	$6,435	$0	$0	$0	$6,435
232	1.5.4.6	Electronics Installation fixtures	$1,215	$5,531	$0	$0	$0	$5,531
233	1.5.4.7	Electronics Installation institutional cost	$1,377	$10,425	$0	$0	$0	$10,425
234	1.5.4.8	Site tools, fixtures, test equipment and supplie	$2,338	$19,825	$0	$0	$0	$19,825
235	1.5.4.9	Module transportation and handling	$7,266	$23,369	$0	$0	$0	$23,369
236	1.5.4.10	Module Storage Facility at CERN	$649	$2,473	$0	$0	$0	$2,473
237								
238								
239	**1.6**	**Module and Component Test**	**$11,571**	**$53,865**	**$0**	**$0**	**$53,865**	**$0**
240								
241	1.6.1	Tests and Analysis	$11,571	$53,865	$0	$0	$53,865	$0
242	1.6.1.1	APD Test	$4,561	$21,459			$21,459	$0
243	1.6.1.2	Cosmic Ray test/calibrate	$7,010	$32,407			$32,407	$0
244								
245	**1.7**	**Electronics**	**$26,131**	**$198,409**	**$0**	**$0**	**$0**	**$198,409**
246	1.7.1	Electronics Procurement	$26,131	$323,409	$125,000	$0	$0	$198,409
247	1.7.1.1	Preamp	$6,012	$41,432	$0	$0	$0	$41,432
248	1.7.1.2	Pre Amp Cable	$815	$3,998	$0	$0	$0	$3,998
249	1.7.1.3	FEE	$3,741	$35,779	$0	$0	$0	$35,779
250	1.7.1.4	Fee Crates	$746	$7,147	$0	$0	$0	$7,147
251	1.7.1.5	TRU	$567	$5,429	$0	$0	$0	$5,429
252	1.7.1.6	RCU	$299	$2,868	$0	$0	$0	$2,868
253	1.7.1.7	TRU to RCU cables	$45	$198	$0	$0	$0	$198
254	1.7.1.8	RCU to DAQ Fibers	$1,702	$6,943	$0	$0	$0	$6,943
255	1.7.1.9	HV supplies NIM Modules	$22	$213	$0	$0	$0	$213
256	1.7.1.10	HV NIM Bins	$19	$209	$0	$0	$0	$209
257	1.7.1.13	HV Cables and Connectors	$71	$461	$0	$0	$0	$461
258	1.7.1.14	Internal Cables	$982	$3,493	$0	$0	$0	$3,493
259	1.7.1.16	LED Driver	$2,523	$8,119	$0	$0	$0	$8,119
260	1.7.1.17	Electronics test/calibrate	$0	$0	$0	$0	$0	$0
261	1.7.1.18	APD's	$8,588	$82,122	$0	$0	$0	$82,122

	B	C	X	AC	AD	AE	AF	AG
262	1.7.1.19	Electronics R&D		$125,000	$125,000		$0	$0
263	1.7.2	Institutional Contribution		-$125,000	-$125,000	$0	$0	$0
264	1.7.3	Electronics Test Calibrate	$0	$0	$0	$0		
265								
266	**1.8**	**EMCal Software**	**$0**	**$0**	**$0**	**$0**	**$0**	
267	1.8.1	EMCal Contribution to on line	$0	$0	$0	$0	$0	
268	1.8.1.1	Software	$0	$0		$0	$0	
269	1.8.1.2	Travel	$0	$0		$0	$0	
270	1.8.1.3	Materials/Supplies	$0	$0		$0	$0	
271	1.8.2	EMCal Contribution to off line	$0	$0	$0	$0	$0	
272	1.8.2.1	Software	$0	$0			$0	
273	1.8.2.2	Travel	$0	$0			$0	
274	1.8.2.3	Supplies	$0	$0			$0	
275	1.8.3	Institutional Contribution	$0	$0	$0	$0	$0	
276								
277								
278	**1.9**	**EMC Conv. Sys.**	**$9,874**	**$76,777**	**$0**	**$0**	**$76,777**	**$0**
279	1.9.1	FEE Water Cooling	$6,671	$62,746	$0	$0	$62,746	
280	1.9.1.1	Water cooled heat exchangers	$2,528	$21,662			$21,662	
281	1.9.1.2	Tubing, connectors, Misc. parts	$2,396	$20,847			$20,847	
282	1.9.1.3	Electrical supplies	$1,251	$10,617			$10,617	
283	1.9.1.4	Travel	$495	$9,620			$9,620	
284	1.9.2	LV Power and Control	$3,203	$14,031	$0	$0	$14,031	
285	1.9.2.1	Module LV Power Blocks	$278	$1,241			$1,241	
286	1.9.2.2	LV Cables and Connectors	$849	$3,520			$3,520	
287	1.9.2.3	LV DC Power Supplies	$2,077	$9,270			$9,270	
288								
289	**1.10**	**Project Management and Integration**	**$20,320**	**$1,061,548**	**$71,262**	**$415,238**	**$424,052**	**$150,997**
290	1.10.1	WSU Project Management	$20,320	$405,124	$9,001	$157,155	$157,155	$81,814
291	1.10.2.1	WSU Purchasing / budget tracking / personnel ma	$9,425	$209,795	$0	$83,918	$83,918	$41,959
292	1.10.2.1.1	Office Assistant	$822	$18,301	$0	$7,320	$7,320	$3,660
293	1.10.2.1.2	Administrative Assistant	$8,603	$191,494	$0	$76,598	$76,598	$38,299
294	1.10.2.2	Contract project manager	$4,121	$91,723	$0	$30,574	$30,574	$30,574
295	1.10.2.3	WSU Travel (integration and management)	$5,353	$90,011	$9,001	$36,004	$36,004	$9,001
296	1.10.2.4	WSU Office Supplies	$293	$2,797	$0	$1,259	$1,259	$280
297	1.10.2.5	WSU Postage and shipping (Fed. Ex., etc.)	$325	$3,108	$0	$1,554	$1,554	
298	1.10.2.6	WSU Review and Proposal Expenses	$804	$7,691	$0	$3,846	$3,846	
299	1.10.3	LBNL Deputy Contract Project Manager	$0	$656,424	$62,261	$258,083	$266,897	$69,183
300	1.10.4	Institutional Contribution		$0		$0	$0	$0
301								
302	**1.11**	**Computing**		**$0**	**$0**	**$0**	**$0**	**$0**