MUSE PROJECT MANAGEMENT

1. Description of the research objectives motivating the facility proposal
2. Comprehensive statement of the science requirements to be fulfilled by the proposed facility (to the extent possible identifying minimum essential as well as desirable quantitative requirements), which provide a basis for determining the scope of the associated infrastructure requirements;
3. Description of the Educational Outreach and Broader Societal Impacts associated with the purpose of the facility, including the scope of work, budget and schedule.
4. Description of the infrastructure necessary to obtain the research and education objectives
5. Work breakdown structure (WBS)
6. Work breakdown structure dictionary defining scope of WBS elements
7. Project budget, by WBS element
8. Description of the basis of estimate for budget components
9. Project risk analysis and description analysis methodology
10. Contingency budget and description of method for calculating contingency
11. Project schedule (and eventually a resource-loaded schedule)
12. Organizational structure
13. Plans and commitments for interagency and international partnerships
14. Acquisition plans, sub-awards and subcontracting strategy
15. Project technical and financial status reporting, function of the PMCS, and description of financial and business controls
16. Project governance
17. Configuration control plans
18. Contingency management
19. Internal and institutional oversight plans, advisory committees, and plans for building and maintaining effective relationships with the broader research community that will eventually utilize the facility to conduct research
20. Quality control and quality assurance plans
21. Environmental plans, permitting and assessment
22. Safety and health issues
23. Systems engineering requirements
24. Systems integration, testing, acceptance, commissioning and operational readiness criteria
25. Plans for transitioning to operational status
26. Estimates of operational cost for the facility

1. Description of the research objectives motivating the facility proposal

The objective of this proposal is to measure determine the charge radius of the proton from the scattering of electrons and negative muons, and positrons and positive muons, using the same apparatus. The goal is for a combined systematic and statistical uncertainty of about 0.012 fm for both the muon and electron.

2. Comprehensive statement of the science requirements to be fulfilled by the proposed facility (to the extent possible identifying minimum essential as well as desirable quantitative requirements), which provide a basis for determining the scope of the associated infrastructure requirements;

Described in TDR.

3. Description of the Educational Outreach and Broader Societal Impacts associated with the purpose of the facility, including the scope of work, budget and schedule.

The broader impact of this project is primarily in the training of students and young scientists, at the undergraduate, graduate, post-doctoral, and junior faculty levels. The institutions involved in this project have trained large numbers of students of each type, including from minority populations. The training they have received in the process of doing basic research has led to careers in a variety of areas, from medical physics to national security, in addition to continued work in fundamental physics research. The MUSE experiment will broaden the perspective of American students by having them work in an international collaboration at an international laboratory, which will prepare them effectively to become prominent global scientists of the next generation. With the broad interest in the proton radius puzzle, MUSE has the potential to be broadly inspirational beyond the current scientific community.

4. Description of the infrastructure necessary to obtain the research and education objectives

Described in TDR.

5. Work breakdown structure (WBS)

The MUSE project consists of several fairly self contained elements, which form the natural basis for the WBS. The WBS is shown in the table below. Each WBS, except for WBS 9 corresponds to a detector/subsystem needed for the detector. WBS 9 relates to the integration and testing of all elements at PSI.

WBS #	Title	Manager
1	Frames & Design	Gilman
2	Scintillating Fiber	Ron
3	Cerenkov	Gilman
4	Straw Chambers	Ron
5	Cryo-target	Briscoe
6	Electronics	Downie

7	Scintillators	Strauch
8	GEM	Kohl
9	Installation	Gilman

6. Work breakdown structure dictionary defining scope of WBS elements

See attached document.

7. Project budget, by WBS element

See attached document.

8. Description of the basis of estimate for budget components

Each WBS will have list of components and basis of estimate. A summary is attached.

9. Project risk analysis and description analysis methodology

We will use the risk analysis techniques described in the PBMOK 3rd Edition.

10. Contingency budget and description of method for calculating contingency

We will use the FNAL system as applied to MINERvA. See attached document.

11. Project schedule (and eventually a resource-loaded schedule)

See attached document.

12. Organizational structure

The overall guidance of the experiment is given by the spokespersons: R. Gilman (Rutgers), E. Downie (GWU), and G. Ron (Hebrew University). The construction project will be led by R. Ransome (Rutgers) and W. Briscoe (GWU). The WBS breakdown with WBS managers is given in the attached organizational chart.

13. Plans and commitments for interagency and international partnerships

The experiment will take place at the Paul Scherrer Institute, Villigen Switzerland. The laboratory's commitment will be the installation of the beam line and associated hardware/software, maintenance of the liquid hydrogen target, and providing the beam. A commitment letter is attached.

14. Acquisition plans, sub-awards and subcontracting strategy

Purchase of either off-the-shelf items or specialty components is detailed in the BOE documents associated with each WBS. There will be no subcontracting.

15. Project technical and financial status reporting, function of the PMCS, and description of financial and business controls

Financial reports will be submitted to the Project Manager. The technical status will be reported to and reviewed by the Spokespersons and Project Manager.

16. Project governance

The project manager and assistant project managers will

17. Configuration control plans

All changes in scope with cost variance greater than $5000 or time to completion variance greater than 4 weeks must be submitted to Project Manager for review. Any change in scope with significant impact on the physics goals must be reviewed and approved by Project Manager and Spokespersons.

18. Contingency management

Contingency reserves will be determined through an analysis of the risks and contingency estimates of each WBS. The Project Manager will have the responsibility for allocation of reserves.

19. Internal and institutional oversight plans, advisory committees, and plans for building and maintaining effective relationships with the broader research community that will eventually utilize the facility to conduct research

N/A.

20. Quality control and quality assurance plans

Each WBS will list quality control plan. See attached document for a summary of each WBS.

21. Environmental plans, permitting and assessment

N/A.

22. Safety and health issues

The project construction does not involve the use of exceptionally hazardous materials or work conditions. The construction will take place primarily at university laboratories. All university safety requirements will be met. The primary safety hazard is the cryogenic target.

23. Systems engineering requirements

These are described in items 24 and 25 below.

24. Systems integration, testing, acceptance, commissioning and operational readiness criteria

Test Run in 2015, testing 2016 with trial runs.

25. Plans for transitioning to operational status

Follows from 24.

26. Estimates of operational cost for the facility

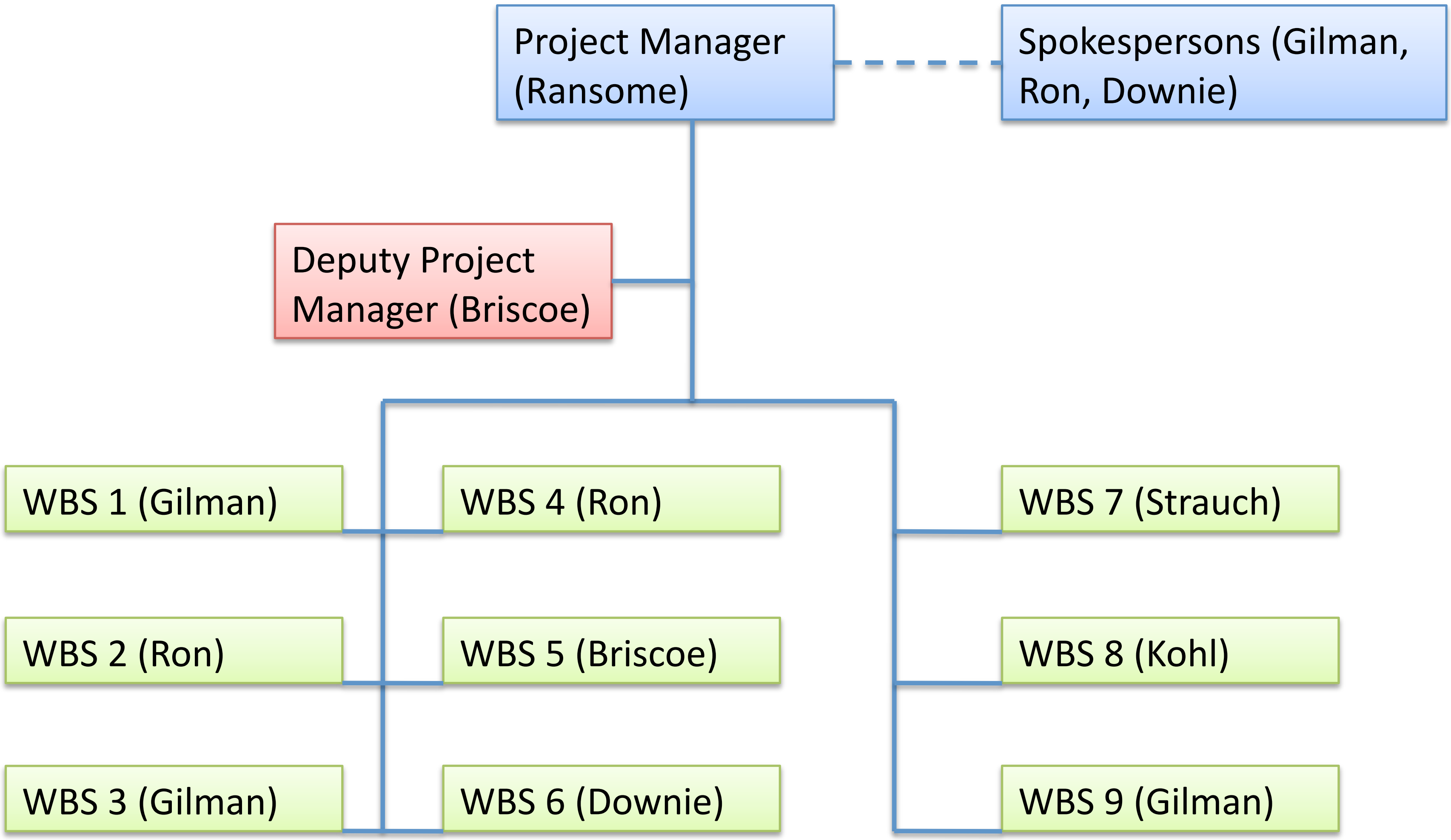
I believe we will primarily need a cost of travel/salaries for participants. We may need a statement from PSI on operations.

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency
1	Frames & Design	$18,205	$24,550	$11,971	$4,378	$54,726	$59,105
2	Scintillating Fiber	$46,920	$70,000	$13,410	$15,640	$130,330	$145,970
3	Cerenkov	$202,400	$4,000	$1,750	$5,621	$208,150	$213,771
4	Straw Chambers	$350,713	$201,000	$50,250	$72,236	$601,963	$674,199
5	Cryo Target	$217,000	$395,968	$348,383	$124,170	$912,351	$1,036,521
6	Electronics & DAQ	$416,697	$156,456	$81,357	$78,918	$654,510	$733,428
7	Scintillator	$331,685	$89,335	$21,140	$53,579	$442,160	$495,739
8	GEM	$28,434	$2,000	$1,680	$3,211	$32,114	$35,325
Total		$1,612,054	$943,309	$529,942	$357,752	$3,036,305	$3,394,057

Travel Summary	total	Rutgers	GW-Briscoe	GW-Downie	S. Carolina	Hampton	Tel-Aviv	Hebrew
Year 1	$226,553	$50,720	$44,141	$93,168	$3,272	$29,452	$0	$5,800
Year 2	$400,742	$88,608	$43,472	$160,729	$20,721	$75,012	$6,400	$5,800
Year 3	$440,942	$106,528	$93,799	$112,571	$56,472	$71,572	$0	$0
Year 4	$413,405	$97,056	$93,799	$93,168	$56,472	$72,910	$0	$0
Total	$1,481,641							

WBS	Title	Scope	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	Risk evaluation
1	Frames	Will build support table and support frames for detectors. The support table will hold the detectors. Support frames will be constructed for the scintillators, veto detector, and beam monitor. Must be delivered in time for 2015 test run.	$18,205	$24,550	$11,971	$4,378	$54,726	$59,105	This WBS has minimal risk from cost, schedule, or technical objectives.
2	Scintillating Fiber	Construct scintillating fiber detector. Must be delivered for 2015 test run.	$46,920	$70,000	$13,410	$15,640	$130,330	$145,970	Minimal risk
3	Cerenkov	Construct two sapphire Cerenkov counters. Must be delivered for 2015 test run.	$202,400	$4,000	$1,750	$5,621	$208,150	$213,771	Minimal risk
4	Straw Chambers	Will build 4 straw tube chambers, with approximately 3000 straws and 10% spares. One chamber to be delivered by 2015 test run.	$350,713	$201,000	$50,250	$72,236	$601,963	$674,199	Schedule risk due to uncertain construction time
5	Cryo-target	Build 4 cm long liquid hydrogen target. Must be delivered for full run in 2016	$217,000	$395,968	$348,383	$124,170	$912,351	$1,036,521	Minimal risk
6	Electronics &DAQ	Will order and test electronics and DAQ system. Half must delivered for 2015 test run. Write analysis software adequate for initial checking of system in first year, adequate for full run in second year.	$416,697	$156,456	$81,357	$78,918	$654,510	$733,428	Primary risk is in DAQ speed, which could lead to longer running times or poorer statistics than planned
7	Scintillator	Construct two time of flight plastic scintillator walls plus veto detector. Half of TOF, plus beam be delivered for 2015 test run	$331,685	$89,335	$21,140	$53,579	$442,160	$495,739	Minimal risk
8	GEM	Maintain current GEM detectors. Improve speed to specs.	$28,434	$2,000	$1,680	$3,211	$32,114	$35,325	Primary risk is in readout speed, which could lead to longer running times or poorer statistics than planned
9	Installation	Coordination of installation.			$0				
			$1,612,054	$943,309	$529,942	$357,752	$3,036,305	$3,394,057	

#	Info	WBS-Code	Title	Giv. Plan. Dur.	ID	Flag	# Predecessors	Actual Start	Exp. Duration	Expected Start	Expected End	Milestone	Resources	% ...pl.
0			**MUSE**		128				2.7 years	2/3/14	7/27/16			0%
1		1	**Frames & Design**		7				1.87 years	3/1/14	11/18/15			0%
2		1.1	**Table**		36				1.12 years	3/1/14	3/13/15			0%
3		1.1.1	Design table	9 months	47			3/1/14	9 months	3/1/14	11/7/14	☐		0%
4		1.1.2	**Buy table parts**		125		3; 135		1 month	11/10/14	12/5/14			0%
5		1.1.2.1	rotary bearings	1 month	92				1 month	11/10/14	12/5/14	☐		0%
6		1.1.2.2	extrutions for frame	1 month	4				1 month	11/10/14	12/5/14	☐		0%
7		1.1.2.3	linear bearings	1 month	67				1 month	11/10/14	12/5/14	☐		0%
8		1.1.3	**Machine & assemble table**		74		4		1.5 months	12/8/14	1/16/15			0%
9		1.1.3.1	machine donuts and table	1 month	30				1 month	12/8/14	1/2/15	☐		0%
10		1.1.3.2	machine extrusions	1 month	98				1 month	12/8/14	1/2/15	☐		0%
11		1.1.3.3	assemble table	2 weeks	91		9; 10		2 weeks	1/5/15	1/16/15	☐		0%
12		1.1.4	**Ship and assemble table**		60				2 months	1/19/15	3/13/15			0%
13		1.1.4.1	Ship to PSI	1 month	113		8		1 month	1/19/15	2/13/15	☐		0%
14		1.1.4.2	Assemble table at PSI	1 month	1		13		1 month	2/16/15	3/13/15	☐		0%
15		1.2	Table ready at PSI		86		14		0 hours	3/13/15	3/13/15	☑		0%
16		1.3	**Scintillator and Veto**		48				1.42 years	7/1/14	10/21/15			0%
17		1.3.1	Design scintillator frames	6 months	96			7/1/14	6 months	7/1/14	12/15/14	☐		0%
18		1.3.2	Build first scintillator frame	2 months	66		17; 135		2 months	12/16/14	2/9/15	☐		0%
19		1.3.3	Ship first frames to PSI	1 month	54		18		1 month	2/10/15	3/9/15	☐		0%
20		1.3.4	Build second scint. frames	2 months	38		18; 136		2 months	7/2/15	8/26/15	☐		0%
21		1.3.5	Ship second set to PSI	1 month	120		20		1 month	8/27/15	9/23/15	☐		0%
22		1.3.6	Assemble at PSI	1 month	80		21		1 month	9/24/15	10/21/15	☐		0%
23		1.3.7	Veto design	2 months	8		17		2 months	12/16/14	2/9/15	☐		0%
24		1.3.8	Build veto	1 month	103		23		1 month	2/10/15	3/9/15	☐		0%
25		1.3.9	Ship veto to PSI	1 month	14		24		1 month	3/10/15	4/6/15	☐		0%
26		1.4	**Beam Monitor**		68				5 months	7/2/15	11/18/15			0%
27		1.4.1	Design beam monitor	2 months	61		23; 136		2 months	7/2/15	8/26/15	☐		0%
28		1.4.2	Build beam monitor	1 month	15		27		1 month	8/27/15	9/23/15	☐		0%
29		1.4.3	Ship to PSI	1 month	122		28		1 month	9/24/15	10/21/15	☐		0%
30		1.4.4	Assemble PSI	1 month	42		29		1 month	10/22/15	11/18/15	☐		0%
31		2	**Scintillating Fiber**		40				1.21 years	7/2/14	8/11/15			0%
32		2.1	**Order Materials**		99		135		6 months	7/2/14	12/16/14			0%
33		2.1.1	Order Fiber	6 months	64				6 months	7/2/14	12/16/14	☐		0%
34		2.1.2	Order PMTs	6 months	53				6 months	7/2/14	12/16/14	☐		0%
35		2.1.3	Order tools	2 months	107				2 months	7/2/14	8/26/14	☐		0%
36		2.2	Prototype	1 month	112		32		1 month	12/17/14	1/13/15	☐		0%
37		2.3	Construct fibers	3 months	16		36		3 months	1/14/15	4/7/15	☐		0%
38		2.4	Mount fibers	1 month	43		37		1 month	4/8/15	5/5/15	☐		0%
39		2.5	Testing	1 month	76		38		1 month	5/6/15	6/2/15	☐		0%
40		2.6	Ship to PSI	2 weeks	20		39		2 weeks	6/3/15	6/16/15	☐		0%
41		2.7	Test at PSI	2 months	59		40		2 months	6/17/15	8/11/15	☐		0%
42		3	**Cerenkov**		105				1.87 years	2/3/14	10/21/15			0%
43		3.1	Design Cerenkov	5 months	85				5 months	2/3/14	6/20/14	☐		0%
44		3.2	**Buy materials first part**		77		135		4 months	7/2/14	10/21/14			0%
45		3.2.1	Buy first 4 tubes	4 months	109				4 months	7/2/14	10/21/14	☐		0%
46		3.2.2	Buy sapphire	3 months	73				3 months	7/2/14	9/23/14	☐		0%
47		3.2.3	Buy assembly materials	1 month	45				1 month	7/2/14	7/29/14	☐		0%
48		3.3	Assemble	2 months	33		44		2 months	10/22/14	12/16/14	☐		0%
49		3.4	Ship to PSI	1 month	13		48		1 month	12/17/14	1/13/15	☐		0%
50		3.5	First set at PSI		51		49		0 hours	1/13/15	1/13/15	☑		0%
51		3.6	Buy 5 tubes	4 months	9		136		4 months	7/2/15	10/21/15	☐		0%
52		3.7	Buy mounting fixtures	1 month	34		136		1 month	7/2/15	7/29/15	☐		0%
53		3.8	Frame for 2nd cerenkov	2 months	71		52		2 months	7/30/15	9/23/15	☐		0%
54		3.9	Install at PSI	1 month	90		53		1 month	9/24/15	10/21/15	☐		0%
55		4	**Straw Chambers**		87		135		1.83 years	7/2/14	3/8/16			0%
56		4.1	Order straw material	6 months	11				6 months	7/2/14	12/16/14	☐		0%
57		4.2	Order gas system	2 months	118				2 months	7/2/14	8/26/14	☐		0%
58		4.3	Set up clean room	2 months	57		135		2 months	7/2/14	8/26/14	☐		0%
59		4.4	Manufacture Jigs	2 months	111		135		2 months	7/2/14	8/26/14	☐		0%
60		4.5	Design chamber mounting	2 months	127		135		2 months	7/2/14	8/26/14	☐		0%
61		4.6	manufacture straws ch 1	2 months	75		56; 58; 59		2 months	12/17/14	2/10/15	☐		0%
62		4.7	manufacture gas dist.	2 months	95		57		2 months	8/27/14	10/21/14	☐		0%
63		4.8	machine chamber mounting	2 months	6		60		2 months	8/27/14	10/21/14	☐		0%
64		4.9	assemble & test ch 1	2 months	65		61; 63		2 months	2/11/15	4/7/15	☐		0%
65		4.10	ship to PSI	1 month	69		64		1 month	4/8/15	5/5/15	☐		0%
66		4.11	Commission ch 1 at PSI	1 month	97		65		1 month	5/6/15	6/2/15	☐		0%
67		4.12	Ch 1 ready at PSI		19		66		0 hours	6/2/15	6/2/15	☑		0%
68		4.13	Purchase 2nd gas system	1 month	21		61		1 month	2/11/15	3/10/15	☐		0%
69		4.14	Build ch 2-4	9 months	119		64		9 months	4/8/15	12/15/15	☐		0%
70		4.15	Ship ch 2-4 to psi	1 month	2		69		1 month	12/16/15	1/12/16	☐		0%
71		4.16	Commision at PSI	2 months	79		70		2 months	1/13/16	3/8/16	☐		0%
72		5	**Cryo-target**		37				2.28 years	3/1/14	4/5/16			0%
73		5.1	Set up lab	3 months	28			3/1/14	3 months	3/1/14	5/23/14	☐		0%
74		5.2	Do Design	4 months	55			3/1/14	4 months	3/1/14	6/20/14	☐		0%
75		5.3	Order major elements	2 months	25		74; 135		2 months	7/2/14	8/26/14	☐		0%
76		5.4	Construct prototype	2 months	56		75		2 months	8/27/14	10/21/14	☐		0%
77		5.5	Test and eval. of prototype	2 months	5		76		2 months	10/22/14	12/16/14	☐		0%
78		5.6	Redesign and 2nd proto.	2 months	115		77		2 months	12/17/14	2/10/15	☐		0%
79		5.7	Test and final design	2 months	46		78		2 months	2/11/15	4/7/15	☐		0%
80		5.8	Target Cell design		23		79		0 hours	4/7/15	4/7/15	☑		0%
81		5.9	Const. Scatt. Chamb. & cells	2 months	82		79		2 months	4/8/15	6/2/15	☐		0%
82		5.10	Test and Evaluate	3 months	29		81		3 months	6/3/15	8/25/15	☐		0%
83		5.11	Test complete system	2 months	10		82		2 months	8/26/15	10/20/15	☐		0%
84		5.12	Review	1 month	72		83		1 month	10/21/15	11/17/15	☐		0%
85		5.13	Ship and set up	2 months	93		84		2 months	11/18/15	1/12/16	☐		0%
86		5.14	In situ testing	1 month	108		85		1 month	1/13/16	2/9/16	☐		0%
87		5.15	Final review	2 months	24		86		2 months	2/10/16	4/5/16	☐		0%
88		5.16	Ready to Run		117		87		0 hours	4/5/16	4/5/16	☑		0%
89		6	**Electronics & DAQ**		17				2.17 years	7/2/14	6/28/16			0%
90		6.1	Order first half electronics	6 months	52		135		6 months	7/2/14	12/16/14	☐		0%
91		6.2	Mounting/order cables	2 months	114		90		2 months	12/17/14	2/10/15	☐		0%
92		6.3	Manufacture/Install cables	2 months	44		91		2 months	2/11/15	4/7/15	☐		0%
93		6.4	Develop DAQ	1 year	130		135		1 year	7/2/14	6/2/15	☐		0%
94		6.5	Install and test complete DAQ	2 months	62		92; 93		2 months	6/3/15	7/28/15	☐		0%
95		6.6	DAQ ready for test run		129		94		0 hours	7/28/15	7/28/15	☑		0%
96		6.7	Order 2nd half electronics	6 months	102		136		6 months	7/2/15	12/16/15	☐		0%
97		6.8	Optimize DAQ	1 year	131		94		1 year	7/29/15	6/28/16	☐		0%
98		6.9	Install and complete DAQ	3 months	12		96		3 months	12/17/15	3/9/16	☐		0%
99		6.10	Final test of DAQ	3 months	58		98		3 months	3/10/16	6/1/16	☐		0%
100		6.11	Write initial analysis program	1 year	132		135		1 year	7/2/14	6/2/15	☐		0%
101		7	**Scintillators**		31				2.15 years	4/1/14	3/22/16			0%
102		7.1	Design scint., beam mon., veto	1 month	146			4/1/14	1 month	4/1/14	4/28/14	☐		0%
103		7.2	**Procure materials**		134		135FS+1 month		10.85 months	7/30/14	5/28/15			0%
104		7.2.1	Order scintillator	2 months	136				2 months	7/30/14	9/23/14	☐		0%
105		7.2.2	Order PMTs	2 months	135				2 months	7/30/14	9/23/14	☐		0%
106		7.2.3	Order Supplies	1 month	145				1 month	7/30/14	8/26/14	☐		0%
107		7.2.4	Order backing structure	1 month	144			5/1/15	1 month	5/1/15	5/28/15	☐		0%
108		7.2.5	Order shipping crates	1 month	142			5/1/15	1 month	5/1/15	5/28/15	☐		0%
109		7.3	**Construction**		133				1.58 years	9/24/14	3/8/16			0%
110		7.3.1	Test PMTs	1.25 months	140		105		1.25 months	9/24/14	10/28/14	☐		0%
111		7.3.2	Beam Monitor	2 months	138		110		2 months	10/29/14	12/23/14	☐		0%
112		7.3.3	Veto Detector	2 months	137		111		2 months	12/24/14	2/17/15	☐		0%
113		7.3.4	TOF-batch 1	1.5 months	143		112		1.5 months	2/18/15	3/31/15	☐		0%
114		7.3.5	TOF-batch 2	1.5 months	139		113		1.5 months	4/1/15	5/12/15	☐		0%
115		7.3.6	TOF-batch 3-8	2.75 months	141		114		2.75 months	5/13/15	7/28/15	☐		0%
116		7.3.7	Beam Mon, Veto first half TOF ready		147		115		0 hours	7/28/15	7/28/15	☑		0%
117		7.3.8	TOF-batch 9-12	4 months	149		115		4 months	7/29/15	11/17/15	☐		0%
118		7.3.9	TOF-batch 12-16	4 months	148		117		4 months	11/18/15	3/8/16	☐		0%
119		7.3.10	TOF second half ready		150		118		0 hours	3/8/16	3/8/16	☑		0%
120		7.4	**Shipping**		151				8.5 months	7/29/15	3/22/16			0%
121		7.4.1	Ship first half	0.5 months	153		116		2 weeks	7/29/15	8/11/15	☐		0%
122		7.4.2	Ship second half	0.5 months	152		118		2 weeks	3/9/16	3/22/16	☐		0%
123		8	**GEM**		89		135		5.25 months	7/2/14	11/25/14			0%
124		8.1	Order electronics	3 months	154				3 months	7/2/14	9/23/14	☐		0%
125		8.2	Commission electronics	1 week	157		124		1 week	9/24/14	9/30/14	☐		0%
126		8.3	Make cables	2 weeks	158				2 weeks	7/2/14	7/15/14	☐		0%
127		8.4	test system	1 month	155		125; 126		1 month	10/1/14	10/28/14	☐		0%
128		8.5	Ship system	1 month	156		127		1 month	10/29/14	11/25/14	☐		0%
129		9	**Installation**		32				1.49 years	3/16/15	7/27/16			0%
130		9.1	Install table and GEM	2 weeks	83		15; 128		2 weeks	3/16/15	3/27/15	☐		0%
131		9.2	Install for test run	2 months	78		25; 30; 41; 49; 94; 100; 116; 130		2 months	11/19/15	1/13/16	☐		0%
132		9.3	Ready for test		124		131		0 hours	1/13/16	1/13/16	☑		0%
133		9.4	Install for final run	2 months	35		54; 67; 70; 88; 99; 118; 132		2 months	6/2/16	7/27/16	☐		0%
134		10	**NSF Funding**		88				1.09 years	7/1/14	7/1/15			0%
135		10.1	Funding Part 1		41			7/1/14	1 day	7/1/14	7/1/14	☐		0%
136		10.2	Funding Part 2		101			7/1/15	1 day	7/1/15	7/1/15	☐		0%


Project Manager (Ransome)
Spokespersons (Gilman, Ron, Downie)
Deputy Project Manager (Briscoe)
WBS 1 (Gilman)
WBS 2 (Ron)
WBS 3 (Gilman)
WBS 4 (Ron)
WBS 5 (Briscoe)
WBS 6 (Downie)
WBS 7 (Strauch)
WBS 8 (Kohl)
WBS 9 (Gilman)

Summary of Basis of Estimates and Risk Assessment

WBS-1 Detector Frames and Support Table

The items in WBS 1 are straight-forward frames and holders. Designs are still in a preliminary stage. The estimates are based on past experience and discussions with machine shop. The total cost is a small, so even with a substantial uncertainty the cost-risk is small. The schedule and technical risks are minimal.

WBS-2 SciFi Detector

Scintillating fiber technology is well established. The primary costs are the fibers and phototubes. Costs are based on recent quotes. The labor estimate is based on past experience. There is low technical, cost, or schedule risk.

WBS-3 Beam Cerenkov Detectors

The major cost for the Cenenkov detector is for the phototubes. The PMT cost estimate is based on a recent quote. There is little schedule, technical, or cost risk.

WBS-4 Straw Tube Tracker

The straw tube chambers are based on standard technology, using the design and techniques developed for the PANDA detector. Cost estimates are primarily based on the PANDA experience, and recent quotes for the straws. There is relatively little cost or technical risk. Straw construction is labor intensive and there is some uncertainty on the time for construction. The primary risk is to the schedule.

WBS 5 – Cryo Target

The cryo-target is based on well established and tested technology. The costs for materials and labor are based on recent experience with similar targets. The technical, cost, and schedule risks are small.

WBS 6 – Electronics/DAQ/Analysis

The primary cost in this WBS is for electronics are off-the-shelf items. Recent quotes are available for most items. The other cost is for tuning the software to enable data acquisition at the highest rates desired. The cost and technical risks are small. There is moderate risk to the schedule based on the uncertainty achieving the highest rates.

WBS 7 – Scintillator

The scintillator detectors are based on proven technology. The primary cost is for materials and are all based on recent quotes. The cost, schedule and technical risks are small.

WBS-8 GEM

The GEM detectors already exist. The major issue is achieving the desired data acquisition rate.

Summary of WBS requirements and quality control.

WBS-1 Detector Frames and Support Table

Requirements:

Rotary stage position reproducible to about 0.5 mil or 10 um, corresponding to angular repeatability of < 0.1 mr.
Translation stage movement distance known to 1 mm, with angle changes less than 0.1 mr horizontal x 1 mr vertical.
Supports detectors.

Quality Control:

Careful mechanical construction
Survey
laser pointing

WBS-2 SciFi Detector

Requirements:

Timing resolution better then 1ns per fiber (becomes better than ~700ps when demanding 2 planes).
Position resolution – Fiber size 2mm.
Efficiency better then 95%/plane (better than 99% when demanding 2/3 planes).

Quality Control:

Resolution and timing:

Cosmics tests at TAU.
Beam tests at PSI.

Efficiency:

Cosmics tests at TAU.
Online testing at PSI.

WBS-3 Beam Cerenkov Detectors

Requirements:

Timing resolution better then 0.1 ns.
Efficiency about 99% or better for muons.

Quality Control:

Timing resolution:

Cosmic and beam tests at PSI, with respect to fact scintillator.
Vary angle of Cerenkov wrt beam.

Efficiency:

Beam testing at PSI, with tracking or scintillator stack.

WBS-4 Straw Tube Tracker

Requirements:

150 um position resolution on hit straws (giving a 1mr angular resolution with 2 chambers).
At least 95% efficiency (giving better than 99.999% efficiency for 3 out of 5).
Time resolution not critical.
Position repeatability of the chamber to within 10 um

Quality Control

Resolution:

Test individual straws with a radioactive source.
Test multiple planes with source.
Test chambers at PSI with GEM tracking.

Efficiency:

Test straws/planes with cosmics.
Online testing at PSI.

Repeatability:

Tests at PSI with GEMs/Frames.

WBS 5 – Cryo Target

Requirements

Cylindrical liquid hydrogen target with length of 4 cm and diameter of 4 cm.

WBS 6 – Electronics/DAQ/Analysis

Requirements

3 KHz data acquisition rate.

WBS 7 – Scintillator

Requirements:

- Average detection efficiency $\varepsilon > 0.95$.
- Average time resolution, $\sigma < 70$ ps.

Quality Control

- BC-404 Scintillators are inspected for damages, inclusions, and refraction index inhomogeneities
- Hamamatsu R9779 PMTs are tested for signal integrity, signal-to-noise ratio, gain, HV requirements, and magnetic field shielding
- Counter Pre-Check: Counters are inspected for void-free glued PMT-to-scintillator transition and light tightness, set to final gain-balanced HVs
- Counter Full-Check: With Three-Bar-Method position dependent and overall time resolutions, effective speed of light, left and right attenuation lengths (BAL and TAL) are programmatically analyzed and automatically stored
- Database: All acquired information is stored and retraceable

WBS-8 GEM

Requirements:

1. <100 um position resolution (giving better than 1mr angular resolution with 3 GEMs). Achieved 75 um at OLYMPUS.
2. At least 95% efficiency (has been established with OLYMPUS, investigations are ongoing). Can use any-2-of-3 to define track for higher efficiency.
3. No time information; GEMs require external trigger
4. GEM track to provide reference direction for scattering angle measurement
5. Readout speed of 2 kHz at 20% deadtime, corresponding to 200 usec readout time per event

Steps to achieve fast readout:

Currently 400 Hz readout rate has been established for two telescopes, where the readout time per event has been 1.8ms. A 200 us readout per event is needed to achieve 2 kHz at 20% deadtime.

One can gain a factor 2 by implementing block transfer of 32-bit words, and another factor 2 by using only one telescope, i.e. 500 usec. However, another factor 2.5 is needed.

With the existing system design, one can gain another factor 3 by using three VME crates with three CPUs and MPD FPGA boards, respectively, i.e. by adding another two. Hampton has one spare VME crate with CPU and MPD from OLYMPUS still available. Reading out with one VME crate per GEM will require a slight reconfiguration of the telescope cabling. The cost for this approach is included in this WBS.

Alternatively, it has been discussed to avoid the VME bus limitation by employing a UDP protocol via PCI bus. This option will be explored further but requires R&D and hence involves certain risks. It would be desirable to establish the required readout speed with the GEM telescope as soon as possible, therefore the funds are requested in the first year.

One telescope along with one MPD is now on its way from PSI back to Hampton, where one set of VME crate and CPU is available. The additional two sets of VME crate with CPU and MPD will be set up and tested at Hampton University in fall 2014 before the new electronics are shipped to PSI.

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE	Notes
1	Frames & Design							Quotes and esstimates based on prev. exp.	
1.1	Table					$0	$0		
1.1.1	Design table					$0	$0		
1.1.2	Buy table parts					$0	$0		
1.1.2.1	rotary bearings	$3,355		$939	$344	$4,294	$4,638		
1.1.2.2	extrusions for fram	$4,000		$1,120	$410	$5,120	$5,530		
1.1.2.3	linear bearings	$2,100		$588	$215	$2,688	$2,903		
1.1.3	Machine & assemble table		$4,800	$1,344	$492	$6,144	$6,636		
1.1.3.1	machine donuts and table	$7,000		$1,960	$717	$8,960	$9,677		
1.1.3.2	machine extrusions			$0	$0	$0	$0		
1.1.3.3	assemble table			$0	$0	$0	$0		
1.1.4	Ship and assemble table		$8,000	$2,240	$819	$10,240	$11,059		
1.1.4.1	Ship to PSI		$5,000	$1,400	$512	$6,400	$6,912		
1.1.4.2	Assemble table at PSI			$0	$0	$0	$0		
1.2	Table ready at PSI			$0	$0	$0	$0		
1.3	Scintillator and Veto			$0	$0	$0	$0		
1.3.1	Design scintillator frames			$0	$0	$0	$0		
1.3.2	Build first scintillator frame	$1,500	$1,500	$840	$307	$3,840	$4,147		
1.3.3	Ship first frames to PSI			$0	$0	$0	$0		
1.3.4	Build second scint. frames			$0	$0	$0	$0		
1.3.5	Ship second set to PSI		$4,000	$1,120	$410	$5,120	$5,530		
1.3.6	Assemble at PSI			$0	$0	$0	$0		
1.3.7	Veto design			$0	$0	$0	$0		
1.3.8	Build veto	$250	$250	$140	$51	$640	$691		
1.3.9	Ship veto to PSI			$0	$0	$0	$0		
1.4	Beam Monitor			$0	$0	$0	$0		
1.4.1	Design beam monitor			$0	$0	$0	$0		
1.4.2	Build beam monitor			$0	$0	$0	$0		
1.4.3	Ship to PSI			$0	$0	$0	$0		
1.4.4	Assemble PSI		$1,000	$280	$102	$1,280	$1,382		
	total	$18,205	$24,550	$11,971	$4,378	$54,726	$59,105		

Rutgers Travel	week	2 week	month	PD housing	Total	F&A	Total
Jun 14		2			$7,400	$2,072	$9,472
Dec 14		2			$7,400	$2,072	$9,472
Jan 15 Collab	2				$5,100	$1,428	$6,528
PD	2				$5,100	$1,428	$6,528
PD housing				12,000	$12,000	$6,720	$18,720
Year 1					$37,000	$13,720	$50,720
June/July 15		4			$14,800	$4,144	$18,944
Dec 15		4			$14,800	$4,144	$18,944
Jan 16 Collab	2				$5,100	$1,428	$6,528
May /June 16		4			$14,800	$4,144	$18,944
PD	2				$5,100	$1,428	$6,528
PD housing				12,000	$12,000	$6,720	$18,720
Year2					$66,600	$22,008	$88,608
Shifts		8			$29,600	$8,288	$37,888
Jan 17 Collab	2				$5,100	$1,428	$6,528
May /June 17		2			$7,400	$2,072	$9,472
PD	2				$5,100	$1,428	$6,528
PD housing				12,000	$12,000	$6,720	$18,720
Expert housing			4		$21,400	$5,992	$27,392
Year 3					$80,600	$25,928	$106,528
Shifts		8			$29,600	$8,288	$37,888
Jan 18 Collab	2				$5,100	$1,428	$6,528
PD	2				$5,100	$1,428	$6,528
PD housing				12,000	$12,000	$6,720	$18,720
Expert housing			4		$21,400	$5,992	$27,392
Year 3					$73,200	$23,856	$97,056

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE	Notes
2	Scintillating Fiber							Materials from quotes, labor estimate	Assume 12% contingency
2.1	Order Materials								
2.1.1	Order Fiber	$8,400		$1,260	$1,159	$9,660	$10,819		
2.1.2	Order PMTs	$27,520			$3,302	$27,520	$30,822		
2.1.3	Order tools/connectors	$11,000		$1,650	$1,518	$12,650	$14,168		
2.2	Prototype				$0	$0	$0		
2.3	Construct fibers				$0	$0	$0		
2.4	Mount fibers				$0	$0	$0		
2.5	Testing				$0	$0	$0		
2.6	Ship to PSI				$0	$0	$0		
2.7	Test at PSI				$0	$0	$0		
	Labor		$70,000	$10,500	$9,660	$80,500	$90,160		
2	Total	$46,920	$70,000	$13,410	$15,640	$130,330	$145,970		

Labor	Tech	GS
	$20,000	$50,000
	4 months FTE	2 years FTE
Travel		
Year 2	$6,400	
	GS for comissioning	

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE	Notes
3	Cerenkov								
3.1	Design Cerenkov								
3.2	Buy materials first part								
3.2.1	Buy first 4 tubes	$87,600			$2,868	$87,600	$90,468		
3.2.2	Buy sapphire	$5,050			$253	$5,050	$5,303		
3.2.3	Buy assembly materials	$1,125		$315		$1,440	$1,440		
3.3	Assemble		$2,000	$560	$2,500	$2,560	$5,060		High contingency for uncertain mounting
3.4	Ship to PSI					$0	$0		
3.5	First set at PSI					$0	$0		
3.6	Buy 5 tubes	$107,500				$107,500	$107,500		
3.7	Buy mounting fixtures	$1,125		$315		$1,440	$1,440		
3.8	Frame for 2nd cerenkov		$2,000	$560		$2,560	$2,560		
3.9	Install at PSI					$0	$0		
	Total	$202,400	$4,000	$1,750	$5,621	$208,150	$213,771		

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE	Notes
4	Straw Chambers							Quotes, PANDA experience	assume 12% contingency
4.1	Order straw material	$295,750			$35,490	$295,750	$331,240		3500 straws
4.2	Order gas system	$15,132			$1,816	$15,132	$16,948		
4.3	Set up clean room	$15,000	$5,000	$1,250	$2,550	$21,250	$23,800		
4.4	Manufacture Jigs	$1,000		$0	$120	$1,000	$1,120		
4.5	Design/build chamber mounting	$3,000	$5,000	$1,250	$1,110	$9,250	$10,360		
4.6	manufacture straws ch 1			$0	$0	$0	$0		
4.7	manufacture gas dist.			$0	$0	$0	$0		
4.8	machine chamber mounting		$5,000	$1,250	$750	$6,250	$7,000		Machine shop
4.9	assemble & test ch 1			$0	$0	$0	$0		
4.1	ship to PSI		$2,000	$500	$300	$2,500	$2,800		
4.11	Commission ch 1 at PSI			$0	$0	$0	$0		
4.12	Ch 1 ready at PSI			$0	$0	$0	$0		
4.13	Purchase remaing gas system	$20,831		$0	$2,500	$20,831	$23,331		
4.14	Build ch 2-4			$0	$0	$0	$0		
4.15	Ship ch 2-4 to psi		$4,000	$1,000	$600	$5,000	$5,600		
4.16	Commision at PSI			$0	$0	$0	$0		
	Labor		$180,000	$45,000	$27,000	$225,000	$252,000		
	Total	$350,713	$201,000	$50,250	$72,236	$601,963	$674,199		
	Labor summary	Tech	GS						
		$60,000	$120,000						
		1 FTE	4 FTE						
		1/2 for 2 years	2 student, 2 years each						
	Travel for commissioning								
	Year 1	$5,800							
	Year 2	$5,800							
		1 GS 1 month, each year							

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE	Notes
5	Cryo-target							Estimates based on recent similar projects	
5.1	Set up lab	$0	$0	$0	$25,000	$0	$25,000		Done by GW, contingency if need outside work
5.2	Do Design	$0	$0	$0	$25,000	$0	$25,000		Done byPSI, contingency if need outside work
5.3	Order major elements	$214,000	$0	$142,480	$29,700	$356,480	$386,180		$65,000 equipment no F&A
5.4	Construct prototype	$0	$15,000	$7,800	$624	$7,800	$8,424		300 hours machine shop @$50/hr
5.5	Test and eval. of prototype	$0	$0	$0	$0	$0	$0		
5.6	Redesign and 2nd proto.	$0	$5,000	$2,600	$208	$2,600	$2,808		100 hours machine shop
5.7	Test and final design	$0	$2,000	$1,040	$83	$1,040	$1,123		40 hours machine shop
5.8	Target Cell design	$0	$0	$0	$0	$0	$0		
5.9	Const. Scatt. Chamb. & cells	$0	$20,000	$10,400	$832	$10,400	$11,232		400 hours machine shop
5.10	Test and Evaluate	$0	$5,000	$2,600	$208	$2,600	$2,808		100 hours machine shop
5.11	Test complete system	$0	$0	$0	$0	$0	$0		
5.12	Review	$0	$0	$0	$0	$0	$0		
5.13	Ship and set up	$3,000	$2,000	$1,040	$323	$4,040	$4,363		40 hours shop to build crates
5.14	In situ testing	$0	$0	$0	$0	$0	$0		
5.15	Final review	$0	$0	$0	$0	$0	$0		
5.16	Ready to Run	$0	$0	$0	$0	$0	$0		
	Labor		$346,968	$180,423	$42,191	$527,391	$569,583		
	Total	$217,000	$395,968	$348,383	$124,170	$912,351	$1,036,521		

	Labor breakdown					
	Tech	PD	GS	Fringe	F&A	Total
5	$151,200	$63,600	$72,000	$60,168	$180,423	$527,391
	2 years FTE	1 year FTE	2 years FTE			

GW-Briscoe Travel Summary

Time of stay	Estimated cost
1 week	$2,550
2 week	$3,700
1 month	$5,350

	1 week	2 week	Months	total	F&A	Contingency	Total w/o cont.	Total
June beam test	1	2	0	$9,950	$5,174	$1,512	$15,124	$16,636
Dec test	2	1	0	$8,800	$4,576	$1,338	$13,376	$14,714
Jan collab meeting	3	0	0	$7,650	$3,978	$1,163	$11,628	$12,791
Year 1 travel				$26,400	$13,728	$4,013	$40,128	$44,141
Nov test run	4	0	0	$10,200	$5,304	$1,550	$15,504	$17,054
Jan collab meeting	2	0	0	$5,100	$2,652	$775	$7,752	$8,527
June installation	0	0	2	$10,700	$5,564	$1,626	$16,264	$17,890
Year 2 travel				$26,000	$13,520	$3,952	$39,520	$43,472
Jan Collab meeting	2	0	0	$5,100	$2,652	$775	$7,752	$8,527
shifts 8 * 2 weeks		8		$29,600	$15,392	$4,499	$44,992	$49,491
4 months GS			4	$21,400	$11,128	$3,253	$32,528	$35,781
Year 3 travel				$56,100	$29,172	$8,527	$85,272	$93,799
Jan Collab meeting	2			$5,100	$2,652	$775	$7,752	$8,527
4 months GS		8		$29,600	$15,392	$4,499	$44,992	$49,491
shifts 8*2 weeks			4	$21,400	$11,128	$3,253	$32,528	$35,781
				$56,100	$29,172	$8,527	$85,272	$93,799

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE	Notes
6	Electronics & DAQ								
6.1	Order first half electronics	$198,692			$27,107	$198,692	$225,799	Quotes	
6.2	Mounting/order cables					$0	$0		
6.3	Manufacture/Install cables	$10,800			$2,000	$10,800	$12,800		
6.4	Develop DAQ					$0	$0		
6.5	Install and test complete DAQ					$0	$0		
6.6	DAQ ready for test run					$0	$0		
6.7	Order 2nd half electronics	$207,205			$30,785	$207,205	$237,990		Includes RAID array
6.8	Optimize DAQ					$0	$0		
6.9	Install and complete DAQ					$0	$0		
6.10	Final test of DAQ					$0	$0		
6.11	Write initial analysis program					$0	$0		
	Labor		$156,456	$81,357	$19,025	$237,813	$256,838		
	Total	$416,697	$156,456	$81,357	$78,918	$654,510	$733,428		

Labor breakdown

PD	GS	Fringe	Total
$63,600	$72,000	$20,856	$156,456
1 year FTE	2 years FTE		

Item	Total	Ist round		2nd round			contingency	1st	2nd
23 TRB3	82,309	11 TRB3	39,365	12 TRB3	42,944			1968	2147
304 PADIWA & 74 adapter boards	70,418	All PADIWA	70,418					3521	
22 CAEN V792	104,428	11 v792	52,214	11v792	52,214			10,087	10,087
A 392	7,675	7 A392	3,838	7 A392	3,838			741	741
V 2718 VMEPCI bridge	14,108	3 bridges	8,465	2 bridges	5,643			1,411	941
A 3818C - PCIe Optical link	6,939	2 links	6,939					980	
VME8011 21-slot crate with power supply	15,840	2 crates	7,920	2 crates	7,920			6,810	6,810
V9778 - 16 chan I/O register	12,712	3 registers	9,534	2 registers	6,356			1,589	1,059
Totals	314,428		198,692		118,914			27107	21785

GW-Downie Travel

Travel Summary

Time of stay	Estimated cost
1 week	$2,550
2 week	$3,700
1 month	$5,350

		1 week	2 week	Months	total	F&A	Contingency	Total w/o cont.	Total	
2014	June beam test	0	2	0	$7,400	$3,848	$1,687	$11,248	$12,935	
	Dec test	0	2	0	$7,400	$3,848	$1,687	$11,248	$12,935	
	PD travel	0	0	1	$5,350	$2,782	$1,220	$8,132	$9,352	9300
2015	Jan collab meeting	3	0	0	$7,650	$3,978	$1,744	$11,628	$13,372	9300
	Cable install	0	0	2	$10,700	$5,564	$2,440	$16,264	$18,704	
	Other install	0	4	0	$14,800	$7,696	$3,374	$22,496	$25,870	
	Year 1 travel				$53,300	$27,716	$12,152	$81,016	$93,168	
										9300
2015	Nov test run	0	4	2	$25,500	$13,260	$5,814	$38,760	$44,574	
2016	Jan collab meeting	3	0	0	$7,650	$3,978	$1,744	$11,628	$13,372	
	Spring Install	0	4	2	$25,500	$13,260	$5,814	$38,760	$44,574	
2016	June installation	0	6	0	$22,200	$11,544	$5,062	$33,744	$38,806	
	Final Tests of DAQ	0	3	0	$11,100	$5,772	$2,531	$16,872	$19,403	
	Year 2 travel				$91,950	$47,814	$20,965	$139,764	$160,729	
2017	Jan Collab meeting	3	0	0	$7,650	$3,978	$1,744	$11,628	$13,372	
	Shifts/checkout	0	11	0	$40,700	$21,164	$9,280	$61,864	$71,144	
	Resident Expert	0	0	3	$16,050	$8,346	$3,659	$24,396	$28,055	
	Year 3 travel				$64,400	$33,488	$14,683	$97,888	$112,571	
2018	Jan Collab meeting	3	0	0	$7,650	$3,978	$1,744	$11,628	$13,372	
	Shifts	0	8	0	$29,600	$15,392	$6,749	$44,992	$51,741	
	Resident Expert	0	0	3	$16,050	$8,346	$3,659	$24,396	$28,055	
	Year 3 travel				$53,300	$27,716	$12,152	$81,016	$93,168	

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE	Notes
7	Scintillators							Quotes, past experience	
7.1	Design scint., beam mon., veto					$0	$0		
7.2	Procure materials					$0	$0		
7.2.1	Order scintillator	$78,540			$12,566	$78,540	$91,106		
7.2.2	Order PMTs	$187,272			$13,109	$187,272	$200,381		
7.2.3	Order Supplies	$18,058	$0	$0	$3,431	$18,058	$21,489		
7.2.4	Order backing structure	$44,215			$9,285	$44,215	$53,500		
7.2.5	Order shipping crates	$3,600	$21,600	$1,188	$5,541	$26,388	$31,929		include shipping cost in labor
7.3	Construction					$0	$0		
7.3.1	Test PMTs					$0	$0		
7.3.2	Beam Monitor					$0	$0		
7.3.3	Veto Detector					$0	$0		
7.3.4	TOF-batch 1					$0	$0		
7.3.5	TOF-batch 2					$0	$0		
7.3.6	TOF-batch 3-8					$0	$0		
7.3.7	Beam Mon, Veto first half TOF ready					$0	$0		
7.3.8	TOF-batch 9-12					$0	$0		
7.3.9	TOF-batch 12-16					$0	$0		
7.3.10	TOF second half ready					$0	$0		
7.4	Shipping					$0	$0		
7.4.1	Ship first half					$0	$0		
7.4.2	Ship second half					$0	$0		
	Labor		$67,735	$19,952	$9,646	$87,687	$97,333		
	Total	$331,685	$89,335	$21,140	$53,579	$442,160	$495,739		

Labor	GS stipend+tuition	UG salaries	Fringe
	$30,275	$32,832	$4,628

South CarolinaTravel costs

	Collaboration meeting	Installation	Shifts/on site	On site student	F&A	Total
Year 1	$2,460				$812	$3,272
Year 2	$2,460	$13,120			$5,141	$20,721
Year 3	$2,460		$26,880	$13,120	$14,012	$56,472
Year 4	$2,460		$26,880	$13,120	$14,012	$56,472

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE	Notes
									Contingency assumed
8	GEM								10%
8.1	Order electronics	$26,934			$2,693	$26,934	$29,627		
8.2	Commission electronics				$0	$0	$0		
8.3	Make cables	$1,500		$720	$222	$2,220	$2,442		
8.4	test system				$0	$0	$0		
8.5	Ship system		$2,000	$960	$296	$2,960	$3,256		
	Total	$28,434	$2,000	$1,680	$3,211	$32,114	$35,325		

Hampton Travel	1 week	2 week	1 month	Student	total	F&A	Total
June 2014	0	2	0	0	$7,400	$3,552	$10,952
Dec 2014	0	2	0	0	$7,400	$3,552	$10,952
Jan Collab	2	0	0	0	$5,100	$2,448	$7,548
Year 1					$19,900	$9,552	$29,452
Aug 15 install	0	0	4	1.00	$26,750	$10,272	$37,022
Nov test	0	0	3	1.00	$21,400	$7,704	$29,104
Jan 16 collab	2	0	0	0.25	$6,438	$2,448	$8,886
Year 2					$54,588	$26,202	$75,012
Shifts	0	2	4	4.00	$50,200	$13,824	$64,024
Jan 17 Collab	2	0	0	0.25	$5,100	$2,448	$7,548
Year 3					$55,300	$16,272	$71,572
shifts	0	2	4	4	$50,200	$13,824	$64,024
Jan 18 collab	3	0	0	0.00	$7,650	$3,672	$11,322
Year 4					$57,850	$17,496	$75,346