Project Overview Documents

MUSE Project Management
Project Organizational Chart
Time Commitment of Senior Personnel
WBS Dictionary and summary
Cost Summary
Summary of Travel costs
Schedule (Gantt chart)
Risk Assessment
Summary of Specs and Quality Control
WBS individual details
Contingency Guidelines
Risk Assessment Guidelines

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 cross sections for elastic scattering from the proton of electrons and negative muons, and positrons and positive muons, using the same apparatus. The cross sections will be used to compare electron to muon scattering, positive polarity to negative polarity scattering, and to extract the proton radius. The goal is for generally sub-percent level uncertainties, allowing the proton radius to be extracted with a combined systematic and statistical uncertainty of about 0.012 fm for both the muon and electron.

The proton charge radius can be determined by scattering charged leptons from protons, or by measuring the Lamb shift in hydrogen or muonic hydrogen. The radius determined from the scattering of electrons and Lamb shift in hydrogen are in good agreement, with values of 0.8791 ± 0.0079 fm and 0.8758 ± 0.0077 fm, respectively. The most precise measurement from muonic hydrogen of 0.84087 ± 0.00039 fm disagrees with the electron based measurements by about 7αμγισ. No accepted explanation has yet been found. This discrepancy, along with the muon g-2 discrepancy and the cosmic positron excess, gives hints of new physics. No measurement of the radius using muon scattering exists.

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;

In order to resolve the discrepancy, the facility must be able to measure the scattering of muons and electrons at the sub-percent level. In order to study possible two-photon exchange effects, measurements using scattering of both positive and negative muons, as well as positrons must be done. The critical elements are: hydrogen target, particle identification, good scattering angle determination, high tracking efficiency, and a data acquisition rate of about 2 kHz with dead-time of 15% or less.

These elements led to the following design elements:

(1) A liquid hydrogen target to ensure adequate rate and low background (rather than CH2 which requires a large background subtraction).

(2) Particle ID: The beam is a mixture of electrons, muons, and pions. Particle ID can be achieved by a combination of timing relative to the accelerator RF and time of flight measurements. Cerenkov and scintillating fiber detectors provide the needed timing. The good time resolution of the Cerenkov detectors allows suppression of events from muons in the beam decaying into electrons (and undetected neutrinos). Scintillation detectors for the scattered particles are needed to cleanly identify scattered particles and trigger the data acquisition.

(3) Scattering angle: The divergence of the beam is sufficiently large that tracking of the incident beam particles is needed to adequately determine the scattering angles. GEM detectors provide this measurement. The scintillating fiber tracking allows separation of multiple tracks by timing. The outgoing scattering angle is determined by a straw tube

chamber. The straw tubes have good resolution and the multiple layers provide high efficiency.

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 continuing to 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

The infrastructure consists of the πM1 beam-line at PSI and the detector assembly described above. The PSI beam-line provides a mixed particle beam, with a momentum range of 100-500 MeV/c.

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 base the risk analysis on techniques described in the PBMOK 3rd Edition.

10. Contingency budget and description of method for calculating contingency

We will be guided by the FNAL system as applied to MINERvA. See attached document. A significant part of the budget is related to purchase of components in Europe and travel to Europe, giving an uncertainty in currency exchange rate. For purposes of this project, we have assumed a first year exchange contingency of 10% and 15% for the subsequent years. Travel costs contingency is assumed at 10% for the first year, with an additional 5% per year to account for inflation. 10% contingency is also estimated for uncertainty on time needed for set-up and running the experiment.

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 Manager will govern the project, with full consultation of the spokespersons and WBS managers.

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. Contingency of less than $5000 will be at the discretion of each WBS manager. The Project Manager will consult with all WBS managers for any allocation request greater than $25,000, but will have final say on all allocations.

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

1. Detectors all connected to DAQ, read out, and decoded successfully, with

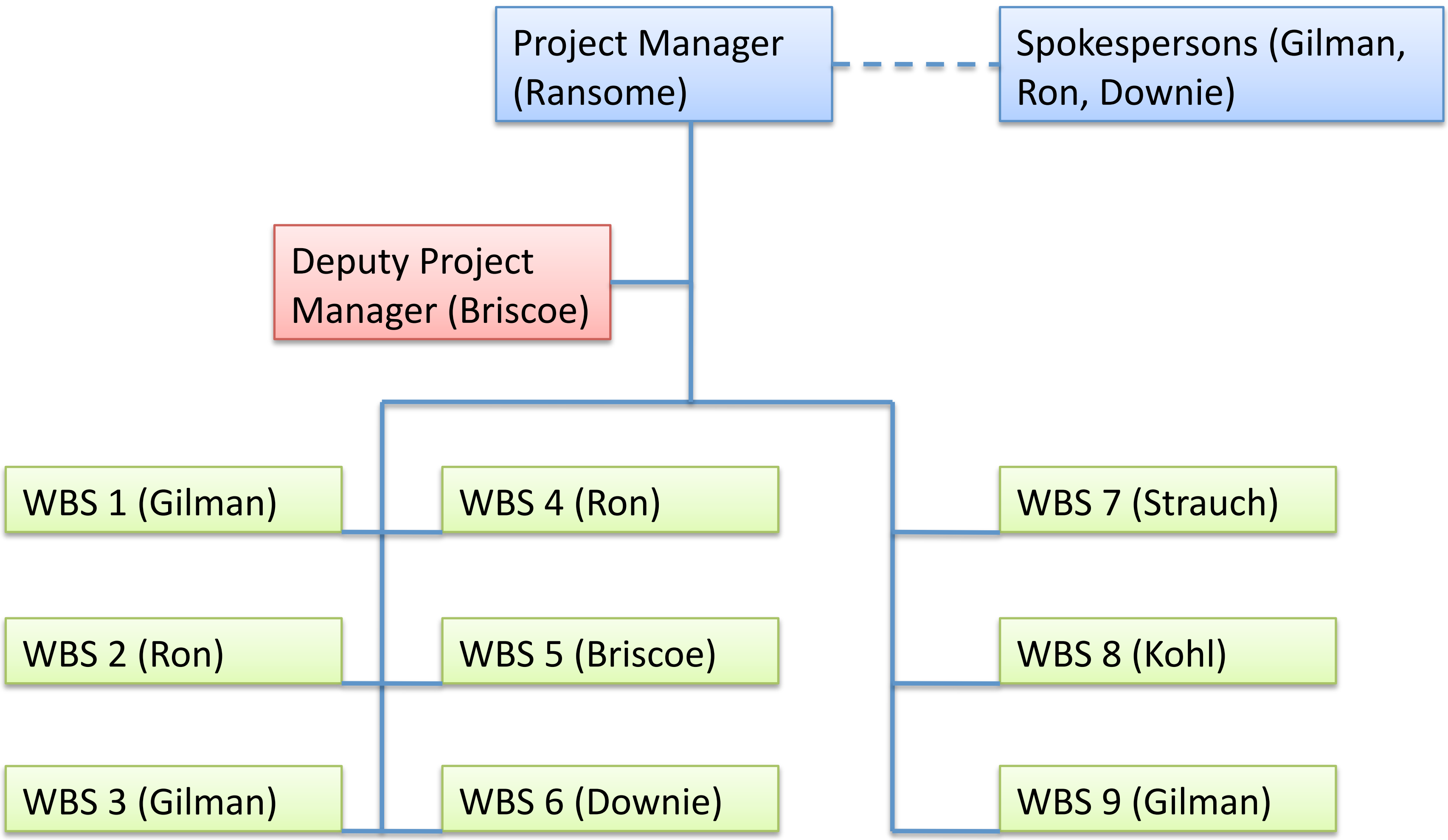
trigger functioning at level to read out detectors.
2. Various calibrations runs and performance confirmed, at least at low rates
   a) beam Cerenkov efficiency and timing
   b) SciFi efficiency and time resolution, and alignment wrt GEMs
   c) GEMs read out in ~0.15 ms time scale, tracking efficiently, 3 hit events show <100 um resolution
   d) Veto efficiency confirmed (can offset and put it in beam)
   e) Beam Monitor efficiency and time resolution confirmed
   f) STT position, track finding, and efficiency calibrated by measurements with STT rotated to be in beam.
   g) Scintillator plane performance check - pulse heights and timing - by running beam through them.
   h) Trigger performance checked with combination of real data and random signals.
   i) DAQ readout rate ability can be checked with pseduodata (pulser signals) and monitoring readout on scope.

25. Plans for transitioning to operational status

Follows from 24.

26. Estimates of operational cost for the facility

Cost to this project will be travel funds. Cost of running the beam and detectors will be paid by PSI.


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)

Time Commitment of Senior Personnel – Year 1

Institution	Name	Position	FTE	Responsibility
Rutgers	R. Gilman	Professor	0.55	Spokesperson, WBS 1,3 manager
Rutgers	R. Ransome	Professor	0.20	Project Manager
GWU	E. Downie	Asst. Prof.	0.30	Spokesperson, WBS 6 manager
GWU	B. Briscoe	Professor	0.36	Deputy Project Manager, WBS 5 manager
GWU	A. Afanasev	Professor	0.20	Theory support
S. Carolina	S. Strauch	Assoc. Prof.	0.35	WBS 7 manager
S. Carolina	R. Gothe	Professor	0.10	WBS 7
S. Carolina	Y. Ilieva	Assoc Prof.	0.10	WBS 7
Hampton	M. Kohl	Assoc. Prof.	0.20	WBS 8 manager
Hebrew U.	G. Ron	Asst. Prof.	0.35	Spokesperson, WBS 2,4 Manager
Tel Aviv	E. Piasetzky	Professor	0.15	WBS 2
Tel Aviv	J. Lichtenstadt	Professor	0.15	WBS2

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	$12,587	$54,726	$67,313	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.	$69,442	$70,000	$17,505	$29,115	$156,947	$186,062	Minimal risk
3	Cerenkov	Construct two sapphire Cerenkov counters. Must be delivered for 2015 test run.	$205,494	$4,000	$3,094	$27,115	$212,588	$239,703	Minimal risk
4	Straw Chambers	Will build 4 straw tube chambers, with approximately 3000 straws and 15% spares. One chamber to be delivered by 2015 test run.	$426,875	$161,436	$40,282	$160,105	$628,593	$788,698	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	$386,428	$271,633	$208,193	$875,061	$1,083,254	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.	$413,519	$165,996	$86,317	$86,564	$665,832	$752,396	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	$87,687	$442,160	$529,847	Minimal risk
8	GEM	Maintain current GEM detectors. Improve speed to specs.	$28,434	$2,000	$1,680	$5,174	$32,114	$37,288	Primary risk is in readout speed, which could lead to longer running times or poorer statistics than planned
9	Installation	Coordination of installation.		$414,000	$107,640	31298.4	$521,640	$552,938	Minimal risk
			$1,710,654	$1,317,745	$561,262	$647,838	$3,589,661	$4,237,500	

WBS-Code	Title		M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	% contingency		
1	Frames & Design		$18,205	$24,550	$11,971	$12,587	$54,726	$67,313	23.0%		
2	Scintillating Fiber		$69,442	$70,000	$17,505	$29,115	$156,947	$186,062	18.6%		
3	Cerenkov		$205,494	$4,000	$3,094	$27,115	$212,588	$239,703	12.8%		
4	Straw Chambers		$426,875	$161,436	$40,282	$160,105	$628,593	$788,698	25.5%		
5	Cryo Target		$217,000	$386,428	$271,633	$208,193	$875,061	$1,083,254	23.8%		
6	Electronics & DAQ		$413,519	$165,996	$86,317	$86,564	$665,832	$752,396	13.0%		
7	Scintillator		$331,685	$89,335	$21,140	$87,687	$442,160	$529,847	19.8%		
8	GEM		$28,434	$2,000	$1,680	$5,174	$32,114	$37,288	16.1%		
9	Installation			$425,802	$110,709	$32,191	$536,511	$568,702	6.0%		
Total			$1,710,654	$1,329,547	$564,331	$648,731	$3,604,532	$4,253,263			
Travel Summary	total including inflation	Contingency	Rutgers	GW-Briscoe	GW-Downie	S. Carolina	Hampton	Tel-Aviv	Hebrew	Temple	Inflation adjustment
Year 1	$242,916	$72,875	$50,720	$40,128	$113,544	$3,272	$29,452	$0	$5,800	$31,752	0
Year 2	$387,285	$135,550	$88,608	$39,520	$139,764	$20,721	$73,656	$7,360	$5,800	$19,756	$11,855.55
Year 3	$445,877	$156,057	$106,528	$85,272	$97,888	$56,472	$74,122	$0	$0	$0	$25,595.16
Year 4	$430,466	$150,663	$97,056	$85,272	$81,016	$56,472	$74,122	$0	$0	$0	$36,528.67
Total	$1,506,544	$515,145									
Construction travel	$630,200	$208,424									
Total	$838,625										
Operations Travel	$876,343	$306,720									
	$1,183,064										
Total Travel	$2,021,688										
Budget construction	$4,234,733										
Contingency	$857,155	20.2%									
Total	$5,091,888										
Operations budget	$876,343										
Contingency	$306,720	35.0%									
Total	$1,183,064										
Total request	$6,274,952										

Travel summary by institution	# of people staying for 1 week	# of people staying for 2 weeks	# of person-months for trips > 1 month				
	week	**2 week**	**month**	**PD housing**	**Total**	**F&A**	**Total**
GWU - Briscoe							
June 14	1	2			$9,950	$5,174	$15,124
Dec 14	2	1			$8,800	$4,576	$13,376
Jan 15 Collab	3				$7,650	$3,978	$11,628
Year 1 Total					$26,400	$13,728	$40,128
Nov 15	4	0			$10,200	$5,304	$15,504
Jan 16 Collab	2	0			$5,100	$2,652	$7,752
June 16	0		2		$10,700	$5,564	$16,264
Year 2 Total					$26,000	$13,520	$39,520
Shifts	0	8			$29,600	$15,392	$44,992
Jan 17 Collab	2	0			$5,100	$2,652	$7,752
GS	0		4		$21,400	$11,128	$32,528
Year 3 Total					$56,100	$29,172	$85,272
Shifts	0	8			$29,600	$15,392	$44,992
Jan 18 Collab	2	0			$5,100	$2,652	$7,752
GS	0		4		$21,400	$11,128	$32,528
Year 4 Total					$56,100	$29,172	$85,272
GWU - Downie							
June 14	0	2			$7,400	$3,848	$11,248
Dec 14	0	2	1		$12,750	$6,630	$19,380
Jan 15 Collab	3				$7,650	$3,978	$11,628
spring install		4	2		$25,500	$13,260	$38,760
summer test			4		$21,400	$11,128	$32,528
Year 1 Total					$74,700	$38,844	$113,544
Nov 15	0	4	2		$25,500	$13,260	$38,760
Jan 16 Collab	3	0			$7,650	$3,978	$11,628
winter install	0	4	2		$25,500	$13,260	$38,760
spring test		3			$11,100	$5,772	$16,872
summer work		6			$22,200	$11,544	$33,744
Year 2 Total					$91,950	$47,814	$139,764
Shifts	0	8			$29,600	$15,392	$44,992
Jan 18 Collab	3	0			$7,650	$3,978	$11,628
Shifts/checkout		3			$11,100	$5,772	$16,872
PD	0		3		$16,050	$8,346	$24,396
Year 3 Total					$64,400	$33,488	$97,888
Shifts	0	8			$29,600	$15,392	$44,992
Jan 18 Collab	3	0			$7,650	$3,978	$11,628
PD	0		3		$16,050	$8,346	$24,396
Year 4 Total					$53,300	$27,716	$81,016
Hampton							
June 14	0	2			$7,400	$3,552	$10,952
Dec 14	0	2			$7,400	$3,552	$10,952
Jan 15 Collab	2				$5,100	$2,448	$7,548
Year 1 Total					$19,900	$9,552	$29,452
Aug 15 -PI, PD	0	0	3		$16,050	$7,704	$23,754
Aug 15 -Student			2		$10,700	$0	$10,700
Nov 15	0	0	3		$16,050	$7,704	$23,754
Nov 15 -Student			1		$5,350	$0	$5,350
Jan 16 Collab	2	0			$5,100	$2,448	$7,548
Jan 16 Collab-student	1	0			$2,550	$0	$2,550
Year 2 Total					$55,800	$17,856	$73,656
Shifts -PI, PD	0	2	4		$28,800	$13,824	$42,624
Shifts-student			4		$21,400	$0	$21,400
Jan 17 Collab	2	0			$5,100	$2,448	$7,548
Jan 17 Collab-student	1	0			$2,550	$0	$2,550

Year 3 Total					$57,850	$16,272	$74,122
Shifts -PI, PD	0	2	4		$28,800	$13,824	$42,624
Shifts-student			4		$21,400	$0	$21,400
Jan 18 Collab	2	0			$5,100	$2,448	$7,548
Jan 18 Collab-student	1	0			$2,550	$0	$2,550
Year 4 Total					$57,850	$16,272	$74,122
Hebrew Univ.							
GS straw setup			1		$5,800.00	$0.00	$5,800.00
Year 1 Total					$5,800.00	$0.00	$5,800.00
GS straw setup			1		$5,800.00	$0.00	$5,800.00
Year 2 Total					$5,800.00	$0.00	$5,800.00
Rutgers							
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 Total					$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
Year 2 Total					$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 Total					$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 4 Total					$73,200	$23,856	$97,056
South Carolina							
Jan 15 Collab	1				$2,460	$812	$3,272
Year 1 Total					$2,460	$812	$3,272
Jan 16 Collab	1				$2,460	$812	$3,272
Installation			2		$13,120	$4,330	$17,450
Year 2 total					$15,580	$5,141	$20,721
Jan 17 Collab	1				$2,460	$812	$3,272
GS on site			2		$13,120	$4,330	$17,450
Shifts		7			$26,880	$8,870	$35,750
Year 3 total					$42,460	$14,012	$56,472
Jan 18 Collab	1				$2,460	$812	$3,272
GS on site			2		$13,120	$4,330	$17,450
Shifts		7			$26,880	$8,870	$35,750
Year 4 total					$42,460	$14,012	$56,472
Tel Aviv							
GS Sci Fi setup		1			$6,400	$960	$7,360
Year 2 Total					$6,400	$960	$7,360
Temple							
GS at HU					$25,200	$6,552	$31,752
Year 1 Total					$25,200	$6,552	$31,752
GS			2		$10,700	$2,782	$13,482
Year 2 Total					$10,700	$2,782	$13,482

#	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%

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.

WBS	WBS	Item	Risk	Probability	Impact				Remedy
	sub item				Cost	Time	Scope	Quality	
1	1.1	Support Table	Design is preliminary, cost increase, added design time	0.3	0.2	0.1	0.05	0.05	
	1.3	Scintillator frame	Design is preliminary, cost increase, added design time	0.3	0.2	0.1	0.05	0.05	
	1.4	Beam monitor frame	Design is preliminary, cost increase, added design time	0.3	0.2	0.1	0.05	0.05	
2	2.1.1	Order fiber	cost increase	0.3	0.2	0.05	0.05	0.05	
	2.1.2	Order PMT	cost increase	0.3	0.2	0.05	0.05	0.05	
			Doesn't meet efficiency or timing specs.	0.3	0.2	0.05	0.1	0.1	
3	3.3	Cerenkov	Doesn't meet specs	0.2	0.2	0.1	0.05	0.1	
4	4.1	Order materials	cost increase	0.3	0.2	0.1	0.05	0.05	
	4.5	Chamber mount	cost increase	0.3	0.2	0.1	0.05	0.05	
	4.9	Chamber 1	takes too long to build	0.3	0.2	0.2	0.05	0.05	
	4.14	Chamber 2-4	takes too long to build	0.3	0.2	0.2	0.05	0.05	
5	5.3	Order major elements	cost increase	0.3	0.2	0.05	0.05	0.05	
	5.4	Construct prototype	Unable to find qualified tech	0.2	0.4	0.2	0.05	0.05	
	5.5	test of prototype	failure of prototype	0.3	0.2	0.4	0.05	0.05	
	5.11	test complete system	failure of system	0.1	0.2	0.2	0.05	0.05	
6	6.1	Order electronics	cost increase	0.3	0.2	0.1	0.05	0.05	
	6.4	Develop DAQ	extra time to develop DAQ	0.3	0.4	0.4	0.1	0.05	
	6.7	Order 2nd half electronics	cost increase	0.3	0.2	0.1	0.05	0.05	
7	7.2	Materials for Scintillator	cost increase	0.3	0.2	0.05	0.05	0.05	
	7.3	Construction	takes longer than expected	0.3	0.2	0.05	0.05	0.05	
8	8.1	Order electronics	cost increase	0.3	0.2	0.2	0.05	0.05	
	8.4	Test system	unable to get speed needed	0.5	0.4	0.4	0.2	0.2	

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
1	Frames & Design							Quotes and estimates 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	$988	$4,294	$5,282	
1.1.2.2	extrusions for fram	$4,000		$1,120	$1,178	$5,120	$6,298	
1.1.2.3	linear bearings	$2,100		$588	$618	$2,688	$3,306	
1.1.3	Machine & assemble table		$4,800	$1,344	$1,413	$6,144	$7,557	
1.1.3.1	machine donuts and table	$7,000		$1,960	$2,061	$8,960	$11,021	
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	$2,355	$10,240	$12,595	
1.1.4.1	Ship to PSI		$5,000	$1,400	$1,472	$6,400	$7,872	
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	$883	$3,840	$4,723	
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	$1,178	$5,120	$6,298	
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	$147	$640	$787	
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	$294	$1,280	$1,574	
	total	$18,205	$24,550	$11,971	$12,587	$54,726	$67,313	

SciFi	start date	end date	M&S or Labor	Cost	F&A	Contingency	Total w/o contingency	BOE			
8 PMTs				$22,742	$0	$2,274	$22,742	Quote	292800 Yen/each	$2,843	Contingency based on 10% currency fluctuation
Send out orders for SciFi, WLS Fibers, PMTs	31-Jul-14	27-Jan-15	M&S	$31,700	$4,755	$7,291	$36,455	Estimate			20% contingency
Design mounting structures	31-Jul-14	29-Sep-14	Labor			$0	$0	Estimate			
Order cutting/polishing tools	31-Jul-14	29-Sep-14	M&S	$15,000	$2,250	$3,450	$17,250	Quotes			20% cotingency
Design Bases + Electronics	31-Jul-14	29-Sep-14	Both					E-Shop	From non NSF/DOE Sources		
Prototype construction	01-Feb-15	03-Mar-15	Labor								
Construct fibers	01-Mar-15	30-May-15	Labor								
Machine frames	01-Apr-15	01-May-15	Labor								
Mount Fibers	01-Jun-15	01-Jul-15	Labor								
Commisioning tests at TAU	01-Jul-15	31-Jul-15	Labor								
Shipping to PSI	01-Aug-15	31-Aug-15	Labor								
Tests at PSI (Beam + Cosmics)	01-Sep-15	31-Oct-15	Labor								
Total M&S				$69,442	$7,005	$13,015	$76,447				
Labor				$70,000	$10,500	$16,100	$80,500				
total				$139,442	$17,505	$29,115	$156,947				

Labor		F&A	Contingency	20%
Technician year 1	$15,000	$2,250	$3,450	
year 2	$5,000	$750	$1,150	
GS year 1	$25,000	$3,750	$5,750	
GS year 2	$25,000	$3,750	$5,750	
	$70,000	$10,500	$16,100	

WBS 3	Beam Cerenkov part	start date	end date	M&S or Labor	M & S & E Cost	External Skilled Paid Labor	Emplyee / Student	BOE	Funding Source	Cost to Sponsor	Contingency	Reason for Contingency	F&A	Total Equipment only	Contingency equipment only
3.1	Design frame for 1st Cerenkov	1-Apr-2014	1-Sep-2015	Labor	$0			existing manpower	NSF/DOE	$0				$0	
3.2	beam test of Photek, Photonis	15-Jun-2014	30-Jun-2014	travel - $6,000 asked separately				recent experience for 1 1-week + 1 2-week trips	NSF/DOE	$0	$300	recent experience for trip costs variations		$0	
3.2	Order first 4 Photek MCP-PMT 240's	1-Aug-2014	1-Dec-2014	Equipment	$87,600			Photek quote, 1/24/2014	NSF / DOE	$87,600	$8,760	10% based on currency fluctuations		$87,600	$8,760
3.3	Order sapphire bars	1-Aug-2014	1-Nov-2014	Equipment	$5,050			DelMar Photonics quote, 2/6/14	NSF / DOE	$5,050	$505	10% based on currency fluctuations	$1,414	$6,464	$505
3.4	Order 5 mounting fixtures	1-Sep-2014	1-Oct-2014	Equipment	$125			purchase of 3d printed mounting fixture in October 2013	NSF/DOE	$125	$2,500	contingency is for machined mounting fixtures		$125	$2,500
3.5	Supplies	1-Sep-2014	1-Oct-2014	Labor	$0			all existing, do not expect to need	NSF/DOE	$0	$100	In case electrical tape or optical grease or ... needed...		$0	$100
3.6	Construct frame for 1st prototype	1-Sep-2014	30-Nov-2014	parts & labor	$1,000	$2,000		Estimate based on crude design, to produce in Rutgers machine shop	NSF/DOE	$3,000	$1,000	Only crude design exists, not costed by machine shop	$840	$1,840	$1,000
3.7	Test of available equipment at PSI	1-Dec-2014	20-Dec-2014	$3,500 asked separately				recent experience for 2-week trips to Switzerland	NSF/DOE	$0	$300	recent experience for trip costs variations		$0	$0
3.8	Order first 5 more Photek MCP-PMT 240's	1-Aug-2015	1-Dec-2015	Equipment	$107,500			Photek quote, 1/24/2014	NSF/DOE	$107,500	$10,750			$107,500	$10,750
3.9	Order 5 mounting fixtures	1-Sep-2015	1-Oct-2015	parts	$125			purchase of 3d printed mounting fixture in October 2013	NSF/DOE	$125	$2,500	contingency is for machined mounting fixtures		$125	$2,500
3.10	Dress rehearsal run at PSI	Nov 1, 2015	Dec 20, 2015	$7,000 asked separatrly				recent experience for 2 2-week trips to Switzerland	NSF/DOE	$0	$600	recent experience for trip costs variations		$0	$0
3.11	Data analysis	Nov 1, 2015	Feb 1, 2016		$0			existing manpower						$0	$0
3.12	Design frame for 2nd Cerenkov	1-Feb-2016	1-Apr-2016	Labor	$0				NSF/DOE	$0				$0	$0
3.13	Construct frame for 2nd prototype	1-Apr-2016	1-May-2016	parts & labor	$1,000	$2,000		Estimate based on crude design, to produce in Rutgers machine shop	NSF/DOE	$3,000	$1,000		$840.00	$1,840	$1,000
3.14	install Cerenkov at PSI and commission	1-May-2016	1-Jun-2016	$7,000 asked separately				recent experience for 2 2-week trips to Switzerland	NSF/DOE	$0	$600	recent experience for trip costs variations		$0	
													$3,094	$205,494	$27,115

WBS-Code	Title	M&S	Labor	F&A	Contingency	Total w/o Contingency	Total with Contingency	BOE
4	Straw Chambers							Quotes, PANDA experience
4.1	Order straw material	$364,000			$113,000	$364,000	$477,000	
4.2	Order gas system	$17,550			$2,633	$17,550	$20,183	
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	
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	$26,325		$0	$3,949	$26,325	$30,274	
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		$140,436	$35,032	$35,094	$175,468	$210,562	
	Total	$426,875	$161,436	$40,282	$160,105	$628,593	$788,698	

Labor summary	Tech	HU GS		Temple GS	Travel Temple GS for construction
	$0	$60,000	Stipend	$43,026	$25,200
	1 FTE	2 FTE	Fringe+ tuition	$12,210	
	1/2 for 2 years	1 student, 2 years		9 month year 1, 12 month year 2	
	F&A	$15,000	F&A	$13,480	$6,552
					$31,752

WBS 5	Cryogenic Hydrogen Target	start date	end date	M&S or Labor	M & S & E Cost	External Skilled Paid Labor	Emplyee / Student	BOE (labor is max estimated requirement for task)	Funding Source	Cost to Sponsor	Contingency	Reason for Contingency	Total
5.1	Bring Cryolab to Safe Operating State	1-Mar-2014	1-Jun-2014	Both	$18,000	$5,000	$2,000	Internal University Proposal	GWU	$0	$25,000	Internal Funding Not Approved	$25,000
5.1.1	Design Drawings	1-Mar-2014	1-Jul-2014	Labor	$0	$20,000	$0	Average Cost to Other Projects	PSI	$0	$25,000	Need to use another designer	$25,000
5.1.2	Order Instrumentation, Hardware, and Monitoring Devices	1-Jul-2014	1-Sep-2014	Both	$135,000	$0		Adjusted Cost based on other recent projects	NSF/DOE	$135,000	$31,050	price fluctuations	$166,050
5.1.3	Order Cryopump - Cold Head	1-Jul-2014	1-Sep-2014	Equipment	$30,000	$0		Internet Price Listings and adjusted cost to other recent projects - asking for quotes	NSF/DOE	$30,000	$6,900	price fluctuations - design variation	$36,900
5.1.4	Order Components of Motion System	1-Jul-2014	1-Sep-2014	Equipment	$35,000	$0		Adjusted costs from other recent projects	NSF/DOE	$35,000	$8,050	price fluctuations - design variation	$43,050
5.1.5	Order Material/Supplies for Scattering Chamber, Cell, Target Ladder, Holders and Railings	1-Jul-2014	1-Sep-2014	M&S	$14,000	$0		Adjusted costs from other recent projects	NSF/DOE	$14,000	$3,220	price fluctuations - design variation	$17,220
5.1.6	Prototype Cells and Cell Holders Machining and Assembly	1-Sep-2014	1-Nov-2014	Labor	$0	$10,000		200 hrs $50/hrs =$10,000 Machinist --two months each Tech and Students	NSF/DOE	$10,000	$2,300	price fluctuations - design variation	$12,300
5.1.7	Build Test Stand Chameber	1-Sep-2014	1-Nov-2014	Labor	$0	$5,000		100 hrs $50/hrs =$5,000 Machinist --- two months each Tech and Students	NSF/DOE	$5,000	$1,150	price fluctuations - design variation	$6,150
5.1.8	Pressure, Vacuum, Destructive Tests of Cell Prototypes	1-Nov-2014	1-Jan-2015	Labor	$0	$0		Two months each for Tech, Postdoc, Students	NSF/DOE	$0	$0		$0
5.1.9	Evaluation - Design Modification	1-Jan-2014	1-Feb-2015	Labor	$0	$0		One month each for Tech, Postdoc, Students	NSF/DOE	$0	$0		$0
5.1.10	Prototype of Modified Cells	1-Feb-2015	1-Mar-2015	Labor	$0	$5,000		100 hrs $50/hrs =$5,000 Machinist --- one month each Tech, Post Doc and Students	NSF/DOE	$5,000	$1,150		$6,150
5.1.11	Second Round of Tests - Cold Test of Cells	1-Mar-2015	1-Apr-2015	Labor	$0	$0		One month each Tech, Post Doc and Students	NSF/DOE	$0	$0		$0
5.1.13	Final Review of Design and Modifications	1-Apr-2015	1-May-2015	Labor	$0	$2,000		40 hrs $50/hrs =$2000 Machinist --- one month each Tech, Post Doc and Students	NSF/DOE	$2,000	$460		$2,460
5.1.14	Construction of Scattering Chamber	1-May-2015	1-Jul-2015	Labor	$0	$10,000		200 hrs $50/hrs =$10,000 Machinist --one month each Tech and Students	NSF/DOE	$10,000	$2,300	price fluctuations - design variation	$12,300
5.2.1	Construction of Cells	1-May-2015	1-Jul-2015	Labor	$0	$10,000		200 hrs $50/hrs =$10,000 Machinist --one month each Tech and Students	NSF/DOE	$10,000	$2,300	price fluctuations - design variation	$12,300
5.2.2	Tests of Cells and Scattering Chamber	1-Jul-2015	1-Sep-2015	Labor	$0	$0		Two months each Tech, Post Doc and Students	NSF/DOE	$0	$0		$0
5.2.3	Evaluation - Modifications	1-Sep-2015	1-Oct-2015	Labor	$0	$5,000		100 hrs $50/hrs =$5,000 Machinist --- one month each Tech, Post Doc and Students	NSF/DOE	$5,000	$1,150		$6,150
5.2.4	Second Round of Tests of Scattering Chamber and Cells Including motion test and test of emergency conditions	1-Oct-2015	1-Dec-2015	Labor	$0	$0		One month each Tech, Post Doc and Students	NSF/DOE	$0	$0		$0
5.2.5	Evaluation and Readiness Review	1-Dec-2015	1-Jan-2016	Labor	$0	$0		One month each Tech, Post Doc and Students	NSF/DOE	$0	$0		$0
5.2.6	Construct Boxes for Shipping and Packing	1-Jan-2016	1-Feb-2016	Both	$1,000	$2,000		40 hrs Carpentry Shop -- One month each Tech and Students	NSF/DOE	$3,000	$690	price fluctuations - design variation	$3,690
5.2.7	Shipping, Receiving and Unpacking	1-Feb-2016	1-Mar-2016	Both	$2,000	$0		One month each Tech and Students	NSF/DOE	$2,000	$460	price fluctuations	$2,460
5.2.8	In Situ Assembly and Testing	1-Mar-2016	1-Apr-2016	Labor	$0	$0		One month each Tech, Post Doc and Students	NSF/DOE	$0	$0	design variation - unforseen needs	$0
5.2.9	PSI Safety Engineering Review and Modifications to Make Compliant	1-Apr-2016	1-May-2016	Labor	$0	$0		One month each Tech, Post Doc and Students	NSF/DOE	$0	$0	design variation - unforseen needs	$0
5.3	Turn over to PSI	1-May-2016	1-Jun-2016	Labor	$0	$0		One month each Tech, Post Doc and Students	NSF/DOE	$0	$0		$0
				cost to project	$217,000	$49,000	$2,000			$266,000	$111,180	Does not include Travel, Fringe and imdirects	$377,180

WBS 6	Electronics & DAQ	start date	end date	M&S or Labor	M & S & E Cost	External Skilled Paid Labor	Emplyee / Student	BOE	Funding Source	Cost to Sponsor	Contingency	Reason for Contingency	Total
6.1	Order first half of electronics	1-Jun-2014	1-Dec-2014	Labor & Equipment	$195,514			CAEN & GSI Quotes	NSF / DOE	$195,514	$27,000	EUR / USD exchange + loss of CAEN discount + possibly having to buy more expensive crates	$222,514
6.2	Organisation of mounting / power / infrastructure issues at PSI	1-Mar-2014	1-Sep-2014	Labor					NSF / DOE	$0			$0
6.3	Work on DAQ drivers & readout to improve speed	1-Jul-2014	31-Jun-2016	Labor					NSF/DOE	$0			$0
6.4	Receive delivery of electronics at PSI, and verify functionality	1-Dec-2014	1-Mar-2015	Labor					NSF/DOE	$0			$0
6.5	Mounting of electronics in "final" positions	1-Feb-2015	1-Apr-2015	Labor					NSF/DOE	$0			$0
6.6	Planning, prototyping and ordering cable components	1-Apr-2015	1-Jun-2015	L & E	$10,800		$3,200	Estimates based on catalogue parts costs	NSF/DOE	$14,000	$2,000	Changing connector requirements / exchange rate estimates	$16,000
6.7	Cable manufacture, testing & installation, mounting on table where appropriate	1-Jun-2015	1-Sep-2015	Labor					NSF/DOE	$0			$0
6.8	Installation of DAQ software & integration of complete DAQ to read out all components.	1-Aug-2015	1-Oct-2015	Labor					NSF/DOE	$0			$0
6.9	Update quotes and place orders for remaining electronics	1-Jun-2015	1-Aug-2015	Labor	$118,914			CAEN & GSI Quotes	NSF/DOE	$118,914	$22,000	EUR / USD exchange + loss of CAEN discount + possibly having to buy more expensive crate	$140,914
6.10	Update quotes & place order for RAID array	1-Jun-2015	1-Aug-2015	Labor	$88,291			DELL Quote	NSF/DOE	$88,291	$9,000	10% fluctuation due to price change / increased storage need	$97,291
6.11	Receive delivery of electronics & RAID Array at PSI, and verify functionality	1-Dec-2015	1-Mar-2016	Labor & Equipment					NSF/DOE	$0			$0
6.12	Install electronics in final position and complete cabling	1-Mar-2016	1-Apr-2016	Labor					NSF/DOE	$0			$0
6.13	Install software and complete integration of new DAQ components	1-Apr-2016	1-May-2016	Labor					NSF/DOE	$0			$0
6.14	Final testing & improvement of DAQ software	1-May-2016	1-Jul-2016	Labor					NSF/DOE	$0			$0

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			$28,091	$187,272	$215,363		
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	$68,561	$442,160	$510,721		

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

WBS 8	GEM detectors	start date	end date	M&S or Labor	Cost	BOE	F&A	cotingency
8.1	Purchase of spare electronics							
8.1.1	Order 2 VME crates	1-Jul-14	1-Oct-14	Equipment	$14,464	Quote/previous order		$2,459
8.1.2	Order 2 VME CPUs	1-Jul-14	1-Oct-14	Equipment	$6,170	Quote/previous order		$1,049
8.1.3	Order 2 MPDs	1-Jul-14	1-Oct-14	Equipment	$6,300	Quote		$1,071
8.1.4	Supplies for cabeling and connectors	1-Jul-14	1-Oct-14	Supplies	$1,500	Estimated	$720	$255
8.2	Establish fast readout							$0
8.2.1	Commission new electronics	1 week after D6	2 weeks after C9			Time per piece		$0
8.2.2	Make cables	1 week after D6	4 weeks after C9					$0
8.2.3	Test combined system	1 week after D10	4 weeks after C11					$0
8.3	Ship 2 crates	1 week after D11	4 weeks after C12		$2,000	estimated / previous shipment	$960	$340
	Total				$30,434	0	$1,680	$5,174

WBS 9	Item	Labor	F&A	Contingency	
	Rutgers Post-doc on site for preparations, years 1 and 2	$206,700	$53,742	$15,627	stipend, $75,000/year, fringe 37.8%, F&A 26%
	Rutgers Post-doc on site for running expt, years 3 and 4	$219,102	$56,967	$16,564	6% increase in salary
	total	$425,802	$110,709	$32,191	

Procedure for Estimating Contingency
January 24, 2006

This document gives the procedure for estimating contingencies on the MINERvA project. There are different procedures, depending on if the task is predominantly M&S or if it is Labor. The M&S contingency table is the one that has been adopted by BABAR The labor contingency tables have been developed by Bob Bradford and Deborah Harris.

The most important part of filling out these tables is that it forces you to think about the risks. If after filling out the table you get a contingency you are not comfortable with, simply include that in the BOE and provide the contingency you are comfortable with, and a justification (i.e. imagine you are constrained to hire a full extra person for the job if it takes more effort than expected: then the contingency would have to cover one extra person, not just a fraction of a person).

I. M&S Contingency

Factor (R)	Technical	Design	Cost	Schedule
0	Not used	Detailed design more than 50% complete	Not used	
1	Existing Design; off the shelf hardware	Not used	Off-the-shelf or catalog item	Not used
2	Minor modifications to an existing design	Not used	Vendor quote from established drawings	Not used
3	Extensive modifications to an existing design	Not used	Vendor quote with some design sketches	No schedule impact on any other item
4	New design; nothing exotic	Preliminary design more than 50% complete; some analysis done	In-house estimate based on previous experience	Not used
6	New design; different from established designs;existing technology	Not done	In-house estimate for item with minimal experience but related to existing capabilities	Delays completion of non-critical subsystem item
8	New design; requires some R&D, but does not advance the state of the art	Conceptual design phase; some drawings; many sketches	In-house estimate for item with minimal experience and minimal in-house capability	Delays completion of critical subsystem item
10	New design; development of new technology; advances state-of-the art	Not used	Top-down estimate from analogous programs	Not used
15	New design; well beyond current state-of-the-art	Concept only	Engineering judgment	Not used
Weight	**2%**	**2%**	**1%**	**1%**

Example: (yellow indicates calculated values)

Total Cost	Technical	Design	Cost	Schedule	Total	Cont
10000	4	15	4	8	0.5	$5,000

II. Labor Contingency

Labor Contingency is evaluated differently, depending on if the task is to be performed once (like designing a detector stand), or if it is to be performed many times (like assembling a scintillator plane). In either case there are four categories that should be evaluated, and the contingency is again the sum of the Risk factor times the weight. The following two tables give the guidance for non-repetitive and repetitive tasks. A detailed explanation of the repetitive task categories follows the last table.

A. Labor Contingency Estimator: Non-repetitive Tasks

Factor (R)	Personnel Experience	Procedure Definition	Similarity to Prior Work	Task Duration
1	Experienced professional who has done this before	Design and procedures finalized	Identical work in the past at this institution	2 years
3	Experienced professional who hasn't done this before	Well-defined process	Identical work done at other institution	6 months
7	New professional	Some details understood	Similar work done at this facility	2 months
10	Undergraduate or graduate	Conceptual only	Similar work done at different facility	2 weeks
15	Summer student	None exists	None	Few days
Weight	2%	2%	1%	1%

$$\%C = \sum_i R_i W_i$$

Example: (yellow indicates calculated values)

Total Cost	Personnel Experience	Procedure Definition	Similarity to Prior Work	Task Duration	Total	Contingency
10000	4	15	4	3	0.45	$4,500

B. Labor Contingency Estimator: Repetitive Tasks

Factor	Startup	Duration Estimate	Reliance on Vendors	Task Duration
1	Task rehearsed; experienced crew	Estimate from similar experience	(1) Vendors reliable; (2) significant float before item(s) needed; (3) can easily find alternate vendor.	2 years
3	Minor recent changes to protocol; some new labor.	Estimate from related experience with minor differences.	Vendor reasonably reliable, but not replaceable. Reasonable float in schedule.	6 months
7	Significant changes to protocol or to labor	Estimate from experience with understood but significant differences.	Vendor reasonably reliable, but not replaceable. Not much float in schedule.	2 months
10	Significant changes to protocol and significant new hires.	Engineer's estimate	Vendors unreliable (task not prototyped); and not replaceable. Minimal schedule float.	2 weeks
15	Procedure unrehearsed; entirely new crew.	Physicist's estimate	Vendor unreliable (WBS task not prototyped); Minimal schedule float, item on/near critical path.	Few days
Weight	2	1	1	1

$$\%C = \sum_i R_i W_i$$

Example: (yellow indicates calculated values)

Total Cost	Startup	Duration Estimate	Reliance on Vendors	Task Duration	Total	Contingency
1000	4	15	4	3	0.3	$300

Repetitive Task Contingency Categories:

1. Startup: With repetitive tasks, delays are most likely related to an under-estimated startup time. It's always the first few units that will require the most time – building the first module or assembling the first PMT box. During startup, the labor are still familiarizing themselves with the production process, and they are relatively unskilled. By the time a few units has been produced, everyone is an expert, bugs in the production process have been addressed, and things should be moving along smoothly. Chances for contingency here are going to be related to the experience of the workforce and the procedural definition of the task. For example: How much of the your labor force was newly hired for the job? Did any of the workers help construct prototypes? How closely did the prototype resemble the final product? Have there been any significant changes in tooling or the production process since the prototyping effort?

2. Duration Estimate: This category deals with the rate of production after startup. Ideally, total durations for a long-term production process are based on some assumed rate (i.e. – assembling 5 PMT boxes per week, building 1 scintillator plane per day). This rate is scaled by the total number of deliverables to produce the total task duration. How certain are you of the rate? Did you estimate the rate from prototyping? If so, how realistic was the prototyping effort? Did you scale from MINOS? Is this an engineer's estimate? A physicist's estimate? Granted, the last two estimates are "rough": clearly not all physicists warrant the same contingency factor, nor do all engineers.

3. Reliance on vendors: Links to other WBS tasks (or vendors) pose risks to a schedule. For example, module assembly relies on delivery of steel frames from WBS8 and packaged scintillator from WBS3. Will a delay in shipment of a delivery impact your schedule? You might consider how reliable a vendor has been in the past, or how complex the component is you are receiving (Are you waiting on stock steel tubing, or is the deliverable more complex)? If there is a significant delay, can you find an alternate vendor? Also, what is the delivery schedule? If all shipments are to be received before you open your factory, then you minimize contingency due to a vendor delay. If the deliverables come in multiple shipments, with some shipments coming after your factory is running, then you risk having a cost contingency (standing army problem) in the event of a delay.

4. Duration of task: This is the length of your 85% CL task duration that goes into project. Longer tasks have more flexibility in overcoming vendor delays, bad startups, etc.

Defined Conditions for Impact Scales of a Risk on Major Project Objectives (Examples are shown for negative impacts only)					
	Relative or numerical scales are shown				
Project Objective	Very low /.05	Low /.10	Moderate /.20	High /.40	Very high /.80
Cost	Insignificant cost increase	<10% cost increase	10-20% cost increase	20-40% cost increase	>40% cost lincrease
Time	Insignificant time increase	<5% time increase	5-10% time increase	10-20% time ilncrease	>20% time increase
Scope	Scope decrease barely noticeable	Minor areas of scope affected	Major areas of scope affected	Scope reduction unacceptable to sponsor	Project end item is effectively useless
Quality	Quality degradation barely noticeable	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction unacceptable to sponsor	Project end item is effectively useless

This table presents examples of risk impact definitions for four different project objectives. They should be tailored in the Risk Management Planning process to the individual project and to the organization's risk thresholds. Impact definitions can be developed for opportunities in a similar way.

Figure 11-5. Definition of Impact Scales for Four Project Objectives

Probability and Impact Matrix

Probability	Threats					Opportunities				
0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05
0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04
0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03
0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02
0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01
	0.05	0.10	0.20	0.40	0.80	0.80	0.40	0.20	0.10	0.05

Impact (ratio scale) on an objective (e.g., cost, time, scope or quality)

Each risk is rated on its probability of occurring and impact on an objective if it does occur. The organization's threshold for low, moderate or high risks are shown in the matrix and determine whether the risk is scored as high, moderate or low for that objective.