

Fermilab E906/Drell-Yan Management Plan

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1 Overview of the Fermilab E906 Drell-Yan experiment

Building on the success of the Fermilab E866/NuSea experiment, the Fermilab E906/Drell-Yan experiment was proposed to measure the partonic structure of the nucleon and of nuclei. This experiment will use a 120 GeV proton beam extracted from the Fermilab Main Injector. The experiment was approved by the Fermilab PAC, originally in 2001. This decision was reaffirmed in 2006. It is scheduled to begin collecting data in 2009; although, Fermilab has expressed an interest in running the experiment as soon as the upgrade and reconfiguration of spectrometer is complete. This upgrade and reconfiguration consists of six main tasks, divided by funding source:

1. Fabricating new coils for the first focusing magnet (Argonne, DOE/ONP);
2. Upgrades to scintillator hodoscopes, Stations 3 and 4 (Abilene, DOE/ONP); and
3. Upgrades to tracking chambers, Stations 1 and 4 (Colorado, Los Alamos, DOE/ONP);
4. Upgrades to scintillator hodoscopes, Stations 1 and 2 (Illinois, NSF);
5. Upgrades to tracking chambers, Stations 2 and 3 (Rutgers, NSF);
6. Constructing a new, more flexible and selective triggering system (Rutgers NSF).

From the above list, tasks 1, 2 and 3 will be funded by the DOE/Office of Nuclear Physics and tasks 4, 5 and 6 will be funded through university NSF grants. Additional information about these tasks may be found in the experiment's proposal to the Fermilab PAC¹. None of these upgrades are technically challenging and the collaboration, composed of physicist from 11 institutions including the core institutes from previous Fermilab Drell-Yan experiments, has the necessary experience and skills to successfully complete these upgrades.

This document will outline the management structure, plans and controls which will be used by the collaboration to ensure that the upgrade and reconfiguration of the spectrometer is achieved by the collaboration safely, within the budgeted resources and on schedule. Equally important to the success of this experiment are the tasks for which Fermilab bears primary responsibility. These tasks will be governed by Memorandum of Understanding between the collaborating institutes and Fermilab.

1.1 Overview of the Experiment Management Plan

The goal of this plan is to outline the necessary management structures and controls needed for E906/Drell-Yan collaboration to reconfigure and upgrade the spectrometer to enable the experiment can reach its scientific goals in a safe, cost effective and efficient manner. This management plan will help ensure these goals are reached by establishing:

- A formal management structure;
- Appropriate reporting mechanisms and schedules; and
- Plans and controls for managing the cost, schedule and contingency.

In addition to Fermilab's substantial contributions to the experiment, the spectrometer reconfiguration is will be divided into six separately funded tasks, three funded from DOE/ONP and three from the NSF. This document will first present the six tasks into which the spectrometer upgrade has been divided in Sec. 1.3. The full work breakdown structure (WBS) is presented in Sec. 5. The formal management structure is presented in Sec. 2, and reporting is discussed in Sec. 3. Plans and controls for managing the contingency in the cost and schedule are discussed in Sec. 4. Finally, to give credit where due, parts of this management plan were

modeled after and wording taken from parts of the Jefferson Laboratory QWeak Experiment Project Management Plan.²

1.2 Overview of the Scientific Goals of Fermilab E906/Drell-Yan

In the Drell-Yan process, a quark (antiquark) in the beam hadron annihilates with an antiquark (quark) in the target. In the limit of large x -Feynman (x_F) only the beam quark and target antiquark terms are important; and hence, Drell-Yan scattering is able to probe the antiquark sea of the target hadron. It can also measure interactions of the initial state quark in the nuclear medium. Several previous Drell-Yan experiments have already exploited these properties but were limited by statistics to relatively low values of parton fractional momentum, x . At fixed x , the Drell-Yan cross section scales as the inverse of the square of the center-of-mass energy (i.e. approximately as $1/E_{beam}^2$). Because of this, at the lower beam energy (120 GeV) of the Fermilab Main Injector, the Drell-Yan cross section is a factor of seven higher than in previous Fermilab Tevatron (800 GeV beam) Drell-Yan experiments. At the same time, most backgrounds (primarily J/ψ production) scale with the square of the center-of-mass energy. As such, they will be suppressed in a Main Injector experiment, allowing for an increase in instantaneous luminosity of a factor of seven. Thus, for the same running time, a factor of almost 50 times more Drell-Yan events may be recorded. The Fermilab E906 collaboration will exploit this to make several important physics measurements at larger values of x than previously achievable.

While perturbative Quantum Chromodynamics (QCD) provides a good description of the evolution of the proton's parton distributions, it provides no clues as to their origins. With Drell-Yan's sensitivity to the antiquark distributions, it can be used to measure the ratio of anti-down to anti-up (\bar{d}/\bar{u}) quarks in the proton. As measured in previous Drell-Yan experiments, this ratio is far from unity for moderate values of x —indicating a significant non-perturbative component in the proton's sea. At larger values of x , the data appear to show the relative size of the \bar{d} and \bar{u} distributions becoming more equal, possibly indicating that the perturbatively generated sea is becoming dominant. Fermilab E906 will have the reach to study this region and determine the ratio of \bar{d}/\bar{u} from measurements with liquid hydrogen and deuterium targets.

As $x \rightarrow 1$, there is considerable uncertainty in the distributions of valence quarks. In part, this is due to a lack of proton data, and in part, due to uncertainties in nuclear effects, which are significant as $x \rightarrow 1$, even in deuterium. The absolute Drell-Yan cross section is sensitive to these high- x parton distributions in the beam proton. Data from the previous Drell-Yan experiment show a possible trend in which next-to-leading order cross section calculations tend to under-predict the measured cross section. This could, perhaps, be attributed to the uncertainty in the ratio d_v/u_v as $x \rightarrow 1$. The proton-proton absolute cross section measurements from Fermilab E906 will provide the data—free of nuclear corrections—needed to determine the behavior of $4u(x)+d(x)$ at high- x with good statistical precision.

When the proton is contained in a nucleus, the proton's parton distributions appear to be modified. In addition to hydrogen and deuterium, data will be collected on a variety of nuclear targets to study these changes. Pions in meson exchange models of nuclear binding should lead to an enhancement of the antiquark sea in nuclei when compared to deuterium. While this was not seen by previous Drell-Yan experiments, the large statistical uncertainty at high x allowed

considerable freedom for models used to describe the Drell-Yan data. Due to the increased cross section at higher x Fermilab E906 will be able to significantly constrain these models. Absolute cross section measurements on deuterium will provide a measurement of $\bar{u}(x) + \bar{d}(x)$, a quantity so far only accessible through neutrino deep inelastic scattering cross section measurements on heavy nuclear targets. At the same time, the absolute cross section measurements on nuclear targets will determine how nuclear effects might influence the interpretation of the neutrino data.

Finally, the Drell-Yan process can be used to study the interactions of fast, colored partons traversing cold nuclear matter. Since the final state particles, muons, only interact electromagnetically and not strongly, only the initial state strong interactions of the incident quarks are apparent. This makes Drell-Yan an ideal laboratory to study the energy loss of partons in nuclei—a subject of considerable interest to the Relativistic Heavy Ion community. Several models have been proposed to describe the energy loss process. By comparing different nuclei, previous Drell-Yan experiments have placed limits on parton energy loss within the context of these models. Because the lower beam energy will provide both higher statistics and increased sensitivity to energy loss, this experiment will be able to measure this energy loss and quantitatively distinguish between competing models.

1.3 Overview of the Spectrometer Upgrade and Reconfiguration

The reconfigured spectrometer that will be used in the E906 measurements leans heavily on the collective experience of Fermilab E605, E772, E789 and E866/NuSea for the best technique to handle high luminosities in fixed target Drell-Yan experiments. The apparatus is optimized for events with large x_2 and $x_F \approx 0.2$. For scale, the muons generated by a 7 GeV virtual photon with $x_F = 0.2$ that decays perpendicular to the direction of motion (in the virtual photon rest frame) will in the laboratory have momentum of 33 GeV, an opening angle of 210 mrad and transverse momentum of 3.5 GeV. A sketch of the apparatus with trajectories for muons is shown in Figure 1 (non-bend plane view) and Figure 2. The key features of the apparatus are:

- Relatively short ($<15\%$ interaction length, L_I) targets to minimize secondary reactions in the target.
- Two independent magnetic field volumes, one to focus the high transverse momentum (p_T) muons and defocus low p_T muons and one to measure the muon momenta.
- A 15 L_I hadron absorber to remove high transverse momentum hadrons.
- A 30 L_I beam dump at the entrance of the first magnet.
- Zinc and concrete or iron walls for muon identification at the rear of the apparatus (located after Station 3 and between the planes of Station 4).
- Maximum use of existing equipment consistent with the physics goals.

While the lower beam energy is a great advantage in terms of cross section, background rates and statistics, it has two disadvantages relative to 800 GeV experiments:

- The corresponding lower particle energies lead to increased probabilities for muonic decay of the produced hadrons. This is partially compensated by reducing the target-to-hadron-absorber distance to 1.3-1.8 m.
- The lower energy muons multiple scatter more easily in the hadron absorber.

As discussed in the proposal¹, much of the apparatus consists of equipment recycled from previous experiments. This represents a significant saving in funds, but at the same time creates some risk until the exact condition of these components is evaluated. Fermilab will also be devoting significant resources to providing the infrastructure necessary for this experiment.

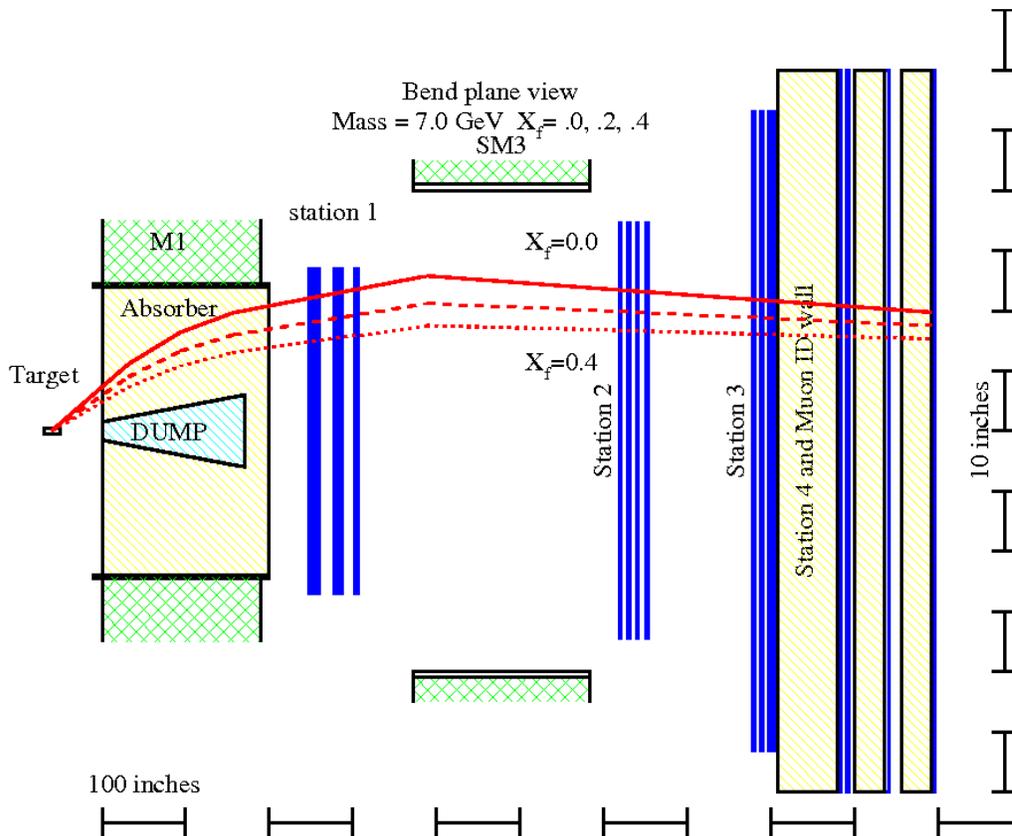


Figure 1 Bend plane view of the trajectories of one of the two muons resulting from the muonic decay of a 7 GeV virtual photon (which has x_F of 0.0, 0.2 or 0.4) in the E906 spectrometer. Note the expanded transverse scale.

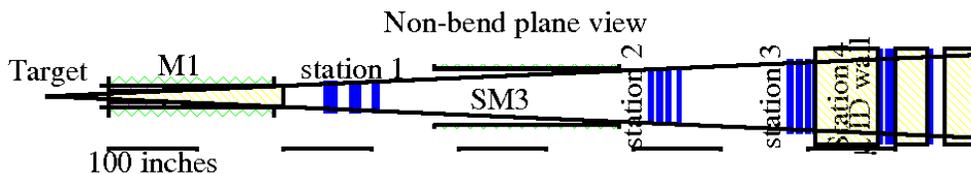


Figure 2 Non-bend view of the E906 spectrometer with the correct longitudinal to transverse aspect ratio.

The upgrade of the spectrometer for E906 is divided and funded as six separate tasks. The WBS for the project is listed in Sec 4. In terms of the WBS the tasks funded through DOE/ONP are

1. Spectrometer Magnet Upgrade (WBS 1.1, 1.2, 1.3, 1.4.2, 1.5, 1.6.2 and 2.4)
2. Hodoscope Stations 3 and 4 (WBS 2.1.1 and 2.1.3)
3. Tracking Stations 1 and 4 (WBS 2.2.1 and 2.2.4).

The tasks funded by the NSF through university grants are

4. Hodoscope Stations 1 and 2 (WBS 2.1.2)
5. Tracking Stations 2 and 3 (WBS 2.2.2 and 2.2.3)

6. Trigger upgrade (WBS 2.3).

In addition to other tasks related to staging the experiment, Fermilab has been asked to take responsibility for

7. Magnet Assembly (most of WBS 1.4, 1.6)

8. Chamber gas systems (WBS 2.2.5, 2.2.6).

These and other Fermilab responsibilities will be outlined in a separate memorandum of understanding (MOU). These tasks were specifically listed in the WBS since they directly affect the schedule of the upgrade. Finally, while most of the tasks have been divided based on the source of funding for the major capital equipment components, there are non-capital equipment tasks that include

9. Offline computing (WBS 2.5)

This division is also presented in Table 1. While the division of the DOE portion of the upgrade into three separate projects that are funded through their respective lead institutions relieves the pressure of a \$2M limit in Total Estimated Cost (TEC), it also divides the contingency between the individual projects, so that it must be managed on an individual project basis rather than in a pool for the entire spectrometer upgrade.

Table 1 This table lists the projects within the spectrometer upgrade, the lead institute, the Project Manager and the funding sources.

Project	WBS	Lead Institution	Project Manager	Additional Institutions	Primary Funding
Magnet	1.2.4	Argonne	J. Jagger		DOE/ONP
Hodo. Sta. 3 & 4	2.1.1 2.1.3	Abilene	R.S. Towell		DOE/ONP
Track Sta. 1 & 4	2.2.1 2.2.4	Colorado	E. Kinney	Los Alamos	DOE/ONP
Hodo. Sta. 1 & 2	2.1.2	Illinois	N.C.R. Makins		NSF
Track Sta. 2 & 3	2.2.2 2.2.3	Rutgers	R. Gilman		NSF
Trigger	2.3	Rutgers	R. Gilman		NSF
Magnet Assembly	1.4 1.6	Fermilab	C. Brown J. Jagger		
Chamber Gas Syst.	2.2.5 2.2.6	Fermilab	C. Brown		
Offline Computing	2.5	Los Alamos	M. Leitch, P.E. Reimer	Argonne, Abilene	

2 Management Organization

This section outlines the organization of the management for the upgrade of the spectrometer and the responsibilities of each position. The primary goal of the management structure and the overall responsibility of the managers is to complete this upgrade and reconfiguration safely, within the proposed budget and on schedule. The responsibilities for each position outlined here begin with the adoption of this management plan and end once the experiment is commissioned.

The persons currently holding each of the positions enumerated here are listed in Table 2 with the Project Managers given in Table 1 and the Work Package Managers given with the WBS in Sec. 4. People may have multiple roles within this management structure. The management structure is shown schematically in Figure 3.

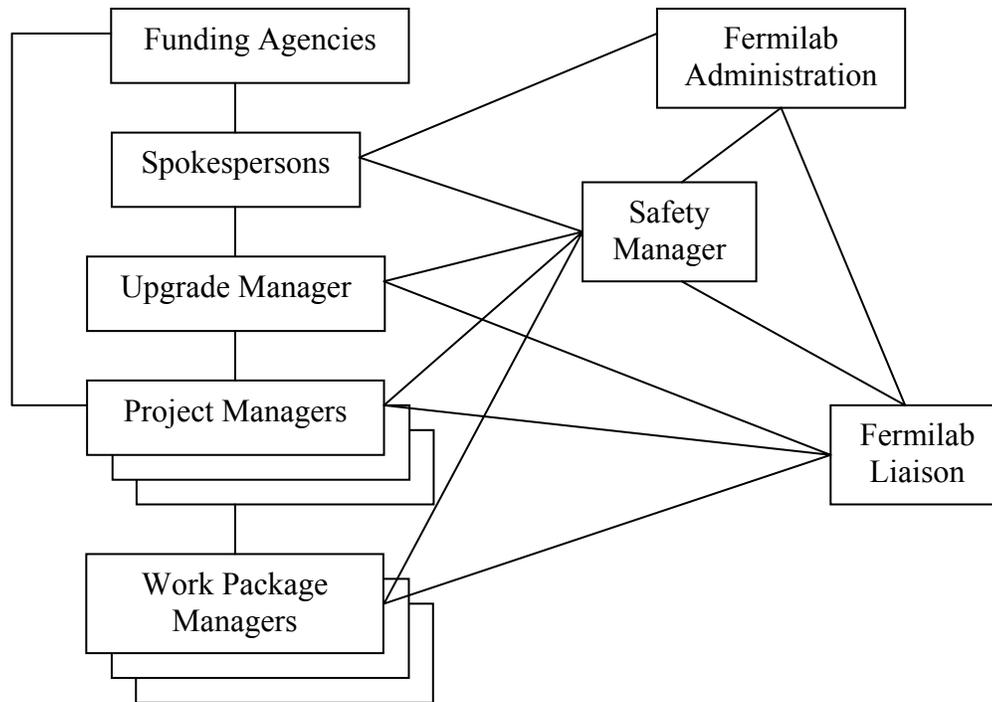


Figure 3 Management structure for the E906 Spectrometer Upgrade.

2.1 Spokesperson(s)

The spokesperson has the overall responsibility for ensuring that the spectrometer as reconfigured will be able to meet the scientific goals of the experiment. As such, the spokespersons have responsibility for oversight of all aspects of the upgrade. They are also the contact through which project information is transmitted to Fermilab management and the DOE/Office of Nuclear Physics. The spokespersons will act on behalf of the collaboration in interactions with these institutions.

2.2 Upgrade Manager

The Upgrade Manager is responsible for the overall management of the spectrometer upgrade. This person reports to the Spokespersons and is responsible to the collaboration to ensure that all equipment is completed on schedule and within the allotted budget. The Upgrade Manager is responsible for tracking the progress of the upgrade both in cost and schedule. In this role, the Upgrade Manager will receive and review the progress reports specified in Sec. 3. She or he is responsible for coordinating and integrating the efforts between the subsystems. She or he shall formulate the guidelines for making changes to either budget and schedule or performance, including the handling of contingency funds. She or he will receive and review progress reports (Sec. 3) from the Project Managers and ensure that they are distributed to the collaboration.

2.3 Safety Manager

Ensuring that the upgrade of the spectrometer is done in a safe manner is the responsibility of every member of the collaboration. The Safety Manager serves as a communication point to resolve any issues regarding safety. Every member of the collaboration should feel free and is encouraged to discuss any matter of safety in the experiment with the Safety Manager. He or she will work closely with the appropriate ES&H contacts at Fermilab to resolve any issues related to the safe upgrade of this spectrometer. He or she will also aid the spokespersons in obtaining the necessary safety approvals before the operation of the experiment begins (Operational Readiness Clearance and Operational Permit).

2.4 Fermilab Liaison

This person is responsible for coordinating all activities between the collaboration and Fermilab. This includes (but is not limited to) working with the various Fermilab divisions to ensure that the necessary infrastructure is in place and available for the experiment, coordinating the necessary support to install the various spectrometer elements and serving as a day-to-day contact point between the collaboration and Fermilab.

Table 2 E906 management positions and the current holder of these positions.

Position	Person	Affiliation
Spokespersons	Paul E. Reimer	Argonne
	Don Geesaman	Argonne
Upgrade Manager	Paul E. Reimer	Argonne
Safety Manager	Chuck Brown	Fermilab
Fermilab Liaison	Chuck Brown	Fermilab

2.5 Project Managers

Project managers are responsible managing the individually funded projects within the experimental upgrade. They, in collaboration with the spokespersons, are responsible for communication with the funding agency for their project. A Project Manager leads and oversees the specifications, design, schedule, maintenance and operation of his or her Project. They must keep the costs incurred by their Project from exceeding the available contingency for that Project. He or she will ensure that the project meets the schedule and performance specifications for that project. He or she will make regular reports on the progress and budget of the project to the Upgrade Manager as outlined in Sec. 3. Regular and timely communication with the Upgrade Manager is an essential component of these obligations. This insures the project management team is aware of any cost or schedule trends. She or he will also ensure that the entire project is carried out in a safe manner.

2.6 Work Package Managers

The upgrade project is described by a work breakdown structure given in Sec. 4. The manager of each work package is listed in that section. The Work Package is the basic structural element that is used to keep track of and organize this work. The managers of each Work Package are to lead and oversee the specifications, design, schedule, maintenance and operation of his/her Work Package. The Work Package Leaders are obliged to keep the costs incurred by their Work

Package from exceeding the available contingency for that Work Package. He/she is also committed to keeping the progress of his/her Work Package activities consistent with the agreed upon schedule, and for making sure the agreed upon performance specifications will be met. Regular and timely communication with the Project Manager is an essential component of these obligations. This insures the project management team is aware of any cost or schedule trends. Work Package Leaders agree to respond to requests for information from the Project Manager in a timely. She or he will also ensure that the Work Package is completed in a safe manner.

2.7 Collaboration

The ultimate success of the experiment depends not on the management structure but on the efforts of the individual collaborators. The collaboration has the responsibility to carry out the tasks necessary to complete this upgrade in a timely manner. It is expected that every member of the collaboration will have some role in the completion of this upgrade. Their efforts are coordinated by the people holding the positions outlined above. Finally, and very significantly, the individual members of the collaboration are responsible for completing the upgrade safely.

3 Reporting

In order to keep the management and collaboration informed of the progress of the spectrometer reconfiguration, formal progress reports will be required quarterly. These reports will be generated by the Project Managers with input from the Work Package Managers and transmitted to the Upgrade Manager. They will be made available to the collaboration (a web posting is sufficient and notification via the collaboration mailing list is sufficient) and provided to the funding agencies and Fermilab management *if requested*.

These reports are meant to inform the collaboration, management and funding agencies of the status of the experiment and to make schedule delays or cost overruns apparent at the earliest possible time. They are not meant to be burdensome on the project managers. These reports should contain:

1. A brief narrative report on the accomplishments, progress and problems during the reporting period,
2. The status of the project's schedule, and
3. The status of the project's budget and use of contingency.

For the larger projects, these may be divided by WBS entries for additional clarity. To successfully generate the quarterly progress reports, the Project Manager must receive input in a timely fashion from each of the Work Package Leaders which include all of the points listed above, specific to that Work Package.

4 Contingency

The division of the upgrade into separately funded projects has the advantage that it relaxes constraints imposed on the TEC of \$2M. It has the consequence that the upgrade as a whole is not able to hold the contingency funds in a common pool and reallocate it as necessary between the projects. Within each project, contingency was estimated for individual WBS entries; although, the contingency is not directly "owned" by any particular WBS entry, but rather by the individual project. Conservative budget estimates were used for the new equipment in the budget, and this is then reflected by modest contingency. The budget and contingency are more

fully discussed in the funding proposal to DOE³. In the case of the legacy equipment, contingency is more difficult to estimate. There is basically a binary decision, where either the equipment is available and in working equipment or it is not. This applies in particular to the electronics and delay cables for the Station 1 MWPC, and to a lesser extent to the other front end electronics which will be used. This contingency has not yet been included in the budget. The status of this equipment will be evaluated; and its condition and the need for contingency discussed with the appropriate funding agencies.

In order to monitor the use of contingency and provide an overall understanding of the budget for the experiment, the following guidelines should be used and notifications made when spending contingency funds on any individual WBS entry:

- Up to 50% of contingency—Notify Project Manager and include in quarterly report
- Between 50% and 100% of contingency—Notify Project Manager immediately so that it can be evaluated within the budget of that project. Notify the Upgrade Manager and include in quarterly progress report.
- Between 100% and 125% for the individual WBS, but not exceeding the project's total contingency—Notify Project Manager, Upgrade Manager and Spokespersons immediately. Include in quarterly progress report,
- Greater than 125% for the individual project and greater than \$10k or a situation in which the total contingency for the project would be exceeded—Notify Project Manager, Upgrade Manager and Spokespersons immediately. Include in quarterly progress report. Spokespersons and Project Manager will clarify the situation and discuss with appropriate funding agency. **Every effort must be made to avoid this level of use of contingency.**

The percentages are the percentage of contingency that was estimated for that particular WBS entry.

5 Work Breakdown Structure

The detailed WBS for the upgrade is given below.

1. E906 magnet reconfiguration

Coils for the new focusing magnet represent the bulk of the funds requested for this experiment. The coils will be designed by Argonne and fabricated by an outside vendor. Preliminary design work for these coils has already begun. J. Jagger is leading this effort at Argonne. The magnet will then be assembled by Fermilab using the new coils and the flux return yoke from the old SM12 magnet.

1.1. Design

1.1.1. Coil design

Complete design of pair of 7 layer window frame coils, including utility connections (power and water) and insulation. Preliminary work is already.

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Oct. 2006	Duration:	6 Months

Cost:	\$32,000	Critical Path:	No
Resources:	Magnet Engineering, Magnet Design and Drafting		

1.1.2. Conductor specification

The magnet will use 1.6 in square hollow aluminum (1350 alloy) conductor.

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Mar. 2007	Duration:	1 Month
Cost:	\$9,000	Critical Path:	No
Resources:	Magnet Engineering, Magnet Design and Drafting		

1.1.3. Field simulation

Basic field calculations have been completed. This simulation will ensure that the magnet and pole tips as designed will deliver the expected field. The effort for this task will be provided by physicists within the collaboration (Argonne and Fermilab)

Lead Institute:	Argonne	WP Manager:	P.E. Reimer
Start Date:	Jan. 2007	Duration:	2 Months
Cost:		Critical Path:	No
Resources:			

1.1.4. Pole tip design

The magnet will use tapered pole pieces. This task is only for the design of these pole pieces. Fabrication is in 1.4.3.

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Apr. 2007	Duration:	1 Month
Cost:	\$12,000	Critical Path:	No
Resources:	Magnet Engineering, Magnet Design and Drafting		

1.1.5. Assembly drawings

Final assembly drawings for the magnet, pole tips and beam dump. These may be somewhat more complicated in the case of a vertical bend magnet if the experiment is located in MWest.

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Nov. 2007	Duration:	1.5 Months
Cost:	\$19,000	Critical Path:	No
Resources:	Magnet Engineering, Magnet Design and Drafting		

1.1.6. Supervision of fabrication

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Nov. 2007	Duration:	16 Months
Cost:	\$60,000	Critical Path:	No
Resources:	Magnet Engineering		

1.2. Conductor purchase

Purchase aluminum conductor for delivery to coil fabrication vendor. (This does not apply if Everson Tesla is selected as the coil fabrication vendor, since the conductor was included their budgetary estimate.) Bids will be solicited in late FY2007 and the purchase is timed to take place with FY2008 money. This matches time estimates from Sigma Phi on estimated initial tooling and setup time for coil fabrication. The estimate is based on a quote from Alconex Specialty Products dated Oct. 2006.

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Nov. 2007	Duration:	6 Months
Cost:	\$362,000	Critical Path:	No
Resources:	Magnet Engineering, Magnet Design and Drafting (included in 1.1.2 and 1.1.6)		

1.3. Coil purchase

In fall 2005, preliminary drawings for the coils were sent to five possible vendors for budgetary estimates. Four responded with estimates. Three of these vendors were contacted for updated estimates for this review (Oct. 2006): Sigma Phi, Everson Tesla and Alpha Magnetics. Everson Tesla and Sigma Phi's estimates were substantially similar, once additional shipping from France and the conductor cost were added to the Sigma Phi estimate. Alpha Magnetics' estimate was somewhat lower. The coil will be fabricated at the most economical vendor, but for the purpose of this estimate, the highest estimate of these three was chosen, Sigma Phi (converted at 1€ = \$1.30). The three vendors not specifically divide the funding into the three categories below, but did have similar funding profiles. The money requested for this purchase is split over two fiscal years, FY2007 and FY2008. As this is *the* critical path element and the schedule is funding limited until the completion of these coils, having the money for this and the conductor purchase (1.2) could cut up to 5 months from the project's duration. The time estimates are also taken from the Sigma Phi budgetary estimate. Everson Tesla's delivery time estimate was half of Sigma Phi's. Alpha Magnetic did not provide a delivery time estimate.

1.3.1. Bid and contract

This is a time allowance for bidding and letting the contract for coil fabrication

Lead Institute:	Argonne	WP Manager:	P.E. Reimer
Start Date:	Nov. 2007	Duration:	1.5 Months
Cost:		Critical Path:	Yes
Resources:	Magnet Engineering, Magnet Design and Drafting (included in 1.1.6)		

1.3.2. Tooling Design and Setup

Both Everson Tesla and Sigma Phi's estimates required an initial payment, with Everson Tesla specifically designating this for tooling. This money was included in the FY2007 budget

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Dec. 2007	Duration:	3 Months
Cost:	\$283,000	Critical Path:	Yes
Resources:	Magnet Engineering (included in 1.1.6)		

1.3.3. Fabrication

We are planning to have the vendor selected, tooling built and ready to use by the start of FY2008, when the money for this purchase is requested.

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Mar. 2008	Duration:	8 Months
Cost:	\$661,000	Critical Path:	Yes
Resources:	Magnet Engineering (included in 1.1.6)		

1.3.4. Delivery to Fermilab

This assumes delivery from Sigma Phi, in France, to Fermilab. Naturally, delivery from a domestic vendor will be less expensive and will be considered in the overall bid process

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Oct. 2008	Duration:	1.5 Months
Cost:	\$26,000	Critical Path:	Yes
Resources:			

1.4. Magnet assembly

1.4.1. Yoke modification

The yoke will be constructed from pieces of the old SM12 yoke. Because the weight of these blocks exceeds the capacity of the crane in either KTeV Hall or MWest, they will need to be cut. Additional modification are necessary because the gap of the new magnet is approximately 10 in narrower than SM12. The cost of these modifications is included in the estimated Fermilab impact.

Lead Institute:	Fermilab	WP Manager:	C. Brown
Start Date:	Oct. 2008	Duration:	2 Months
Cost:		Critical Path:	No
Resources:			

1.4.2. Beam dump modification/fabrication

Several options are being considered by Fermilab for the beam dump, including modifying the existing (but radioactive) bump, using the existing dump but with larger pole pieces or fabricating a new dump. This cost is included in the estimated

Fermilab impact.

Lead Institute:	Fermilab	WP Manager:	C. Brown
Start Date:	Oct. 2008	Duration:	2 Months
Cost:		Critical Path:	No
Resources:			

1.4.3. Pole tip fabrication

Tapered pole pieces are reasonably straight forward, large blocks of machined steel.

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Sept. 2008	Duration:	3 Months
Cost:	\$54,000	Critical Path:	No
Resources:			

1.4.4. Magnets fittings, core and assembly aids

All the additional water fittings and electrical connection flags not included in 1.3 above. This includes the cost of the inner supports to hold the coils during the assembly if the magnet is mounted as a vertical bending magnet in MWest. These costs would be reduced by locating the experiment in NM4 (KTeV).

Lead Institute:	Argonne	WP Manager:	J. Jagger
Start Date:	Aug. 2008	Duration:	2 Months
Cost:	\$71,000	Critical Path:	No
Resources:			

1.4.5. Assembly

Fermilab is responsible for the assembly of the magnet with the coils and pole tips from Argonne. This cost is included in the Fermilab impact statement.

Lead Institute:	Fermilab	WP Manager:	C. Brown
Start Date:	Dec. 2008	Duration:	1.5 Months
Cost:		Critical Path:	Yes
Resources:			

1.5. Post assembly magnet activities

1.5.1. Magnet field mapping

Map field of M1 magnet after assembly using Ziptrack. Primary effort will come from Argonne physicists and support staff.

Lead Institute:	Argonne	WP Manager:	P.E. Reimer
Start Date:	Jan. 2009	Duration:	2 Months
Cost:		Critical Path:	Yes
Resources:	Fermilab Ziptrack		

1.5.2. Stack hadron absorber

To minimize hadrons in the remainder of the spectrometer, the M1 magnet aperture is filled with a combination of carbon, copper and borated polyethylene. These must be put in place after the field of the magnet has been mapped. This task will involve effort from the entire collaboration.

Lead Institute:	Argonne	WP Manager:	P.E. Reimer
Start Date:	Mar. 2009	Duration:	1 Month
Cost:		Critical Path:	Yes
Resources:	Collaboration Labor		

1.6. KTeV/SM3 Magnet

1.6.1. Magnet relocation and/or assembly

Move KTeV Magnet to appropriate location (or assemble SM3 if the experiment is located in MWest). The KTeV magnet is designed to be "easily" moved (for a several hundred ton magnet).

Lead Institute:	Fermilab	WP Manager:	C. Brown
Start Date:	Jan. 2009	Duration:	1 Month
Cost:		Critical Path:	No
Resources:			

1.6.2. Magnet field mapping

Map field of M2 magnet (either KTeV or SM3) using Ziptrack. Primary effort will come from Argonne physicists and support staff. Field maps already exist of the KTeV magnet.

Lead Institute:	Argonne	WP Manager:	P.E. Reimer
Start Date:	Mar. 2009	Duration:	2 Months
Cost:		Critical Path:	Yes
Resources:	Fermilab Ziptrack		

2. E906 spectrometer upgrade

2.1. Hodoscope Upgrades

E906 will be replacing the E866 hodoscope material. The primary reason for this is the age of the material, some dating from E605 in 1982. Upon inspection of some left over material from the 1989 upgrade of Station 2, significant crazing was discovered in some of the material. In the analysis of the E866 absolute cross section data large efficiency corrections (up to 20%) were necessary for some specific hodoscope elements.

2.1.1. Phototube quality control

E906 will require 384 photomultiplier tubes. Approximately 160 will be reused from the E866 hodoscope array (double ended readout is being added to hodoscope

stations 3 and 4). An additional 250 phototubes will be recovered from the Argonne HEP contribution to the ZEUS experiment at DESY. These tubes will need to be tested before use; although no problems are expected.

Lead Institute:	Abilene	WP Manager:	R. Towell
Start Date:	Jan. 2008	Duration:	4 Months
Cost:	\$2,000	Critical Path:	No
Resources:	Photomultiplier Test Facility		

- 2.1.1.1. Construct photomultiplier test facility
- 2.1.1.2. Test ZEUS photomultiplier tubes
- 2.1.1.3. Test E866/NuSea photomultiplier tubes

2.1.2. Station 1 and 2 hodoscopes

The scintillator for hodoscope stations 1 and 2 will be taken from the HERMES muon hodoscopes. It will need to be re-cut and polished before use in E906. New light guides will be fabricated.

Lead Institute:	Illinois	WP Manager:	N.C.R. Makins
Start Date:	Jan. 2008	Duration:	5 Months
Cost:	\$15,000	Critical Path:	No
Resources:			

- 2.1.2.1. Machine and polish HERMES scintillator
- 2.1.2.2. Purchase light guides
- 2.1.2.3. Hodoscope assembly
 - 2.1.2.3.1. Scintillator, light guide and photomultiplier assembly
 - 2.1.2.3.2. Wrapping hodoscope units
 - 2.1.2.3.3. Light-leak checking
 - 2.1.2.3.4. Efficiency quality control
- 2.1.2.4. Hodoscope mounting in experimental hall
- 2.1.2.5. Quality control checks *in situ*

2.1.3. Station 3 and 4 hodoscopes

The scintillator for hodoscope stations 3 and 4 will be purchased new. Estimates for the cost of new scintillator come from a quote for "diamond milled" scintillator from Eljen Technologies in Texas. A quote has also been requested from Bicron.

Lead Institute:	Abilene	WP Manager:	R. Towell
Start Date:	Apr. 2008	Duration:	5 Months
Cost:	\$151,000	Critical Path:	No
Resources:			

- 2.1.3.1. Scintillator purchase
 - 2.1.3.1.1. Order material
 - 2.1.3.1.2. Receiving material quality control
- 2.1.3.2. Light guide purchase

- 2.1.3.2.1. Order material
- 2.1.3.2.2. Receiving material quality control
- 2.1.3.3. Hodoscope assembly
 - 2.1.3.3.1. Scintillator, light guide and photomultiplier assembly
 - 2.1.3.3.2. Wrapping hodoscope units
 - 2.1.3.3.3. Light-leak checking
 - 2.1.3.3.4. Efficiency quality control
- 2.1.3.4. Hodoscope mounting in experimental hall
- 2.1.3.5. Quality control checks *in situ*

2.2. Tracking

2.2.1. Station 1

New MWPC's will be constructed for station 1 to handle the expected rates. These estimates are assuming the use of a wire winding facility at Fermilab with labor primarily supplied by the collaboration. Electronics and delay for this MWPC is being recovered from Fermilab E871. These will be evaluated in Summer 2007.

Lead Institute:	Colorado	WP Manager:	E. Kinney
Start Date:	Jan. 2008	Duration:	18 Months
Cost:	\$170,000	Critical Path:	No
Resources:	Fermilab wire winding facilities		

2.2.2. Station 2

E906 will reuse the E866 Tracking Station 2. Initial evaluation of the chambers will start in Summer 2007. The amount of work deemed necessary at that time will determine the actual start date for this task. This task will be done in parallel with 2.2.3.

Lead Institute:	Rutgers	WP Manager:	R. Gilman
Start Date:	Dec. 2008	Duration:	6 Months
Cost:	\$4,000	Critical Path:	No
Resources:			

2.2.3. Station 3

E906 will reuse the E866 Tracking Station 3. Initial evaluation of the chambers will start in Summer 2007. The amount of work deemed necessary at that time will determine the actual start date for this task. This task will be done in parallel with 2.2.2.

Lead Institute:	Rutgers	WP Manager:	R. Gilman
Start Date:	Dec. 2008	Duration:	6 Months
Cost:	\$4,000	Critical Path:	No
Resources:			

2.2.4. Station 4

E906 will reuse the E866 Tracking Station 4. An initial evaluation of this equipment will take place in Summer 2007, and the WP start date may be adjusted accordingly

Lead Institute:	Los Alamos	WP Manager:	P. McGaughey
Start Date:	Dec. 2008	Duration:	6 Months
Cost:	\$7,000	Critical Path:	No
Resources:			

2.2.5. Station 1 gas mixing and distribution

A fast gas will be used in Station 1 because of high rates. We are planning on using an 80:20 mixture of CF_4 :isobutane which will be recirculated. Some of the equipment for the recirculation system may be recovered from the HERMES RICH system which the Argonne MEP group already owns. Fermilab is responsible for this system and for flammable gas safety. These costs are included in Fermilab's impact assessment. The cost represents possible expenses for Argonne related to this system

Lead Institute:	Fermilab, Argonne	WP Manager:	C. Brown
Start Date:		Duration:	
Cost:	\$3,000	Critical Path:	No
Resources:			

2.2.6. Station 2, 3 & 4 gas mixing and distribution

Stations 2, 3 and 4 will run a 50:50 mixture of Ar :ethane. Fermilab is responsible for the system and for flammable gas safety. These costs are included in Fermilab's impact assessment. The cost represents possible expenses for Argonne related to this system.

Lead Institute:	Fermilab, Argonne	WP Manager:	C. Brown
Start Date:		Duration:	
Cost:	\$3,000	Critical Path:	No
Resources:			

2.3. Trigger

The trigger system will be, in concept, similar to the E866 trigger system. This system was based on finding "roads" for likely candidate positive and negative muons through the spectrometer in the bend-z plane and in the non-bend-z plane separately. The positive and negative roads were then paired into an event candidate. For E906, this logic will be implemented in a custom FPGA module.

2.3.1. Design

Lead Institute:	Rutgers	WP Manager:	R. Gilman
Start Date:	Sept. 2007	Duration:	6 Months

Cost:	\$50,000	Critical Path:	No
Resources:			

2.3.2. Prototype

Lead Institute:	Rutgers	WP Manager:	R. Gilman
Start Date:	Feb. 2008	Duration:	6 Months
Cost:	\$26,000	Critical Path:	No
Resources:			

2.3.3. Testing and revision

Lead Institute:	Rutgers	WP Manager:	R. Gilman
Start Date:	Aug. 2008	Duration:	2 Months
Cost:	\$13,000	Critical Path:	No
Resources:			

2.3.4. Fabrication

Lead Institute:	Rutgers	WP Manager:	R. Gilman
Start Date:	Feb. 2009	Duration:	1 Month
Cost:	\$14,000	Critical Path:	No
Resources:			

2.3.5. Installation and integration

Lead Institute:	Rutgers	WP Manager:	R. Gilman
Start Date:	Apr. 2009	Duration:	1 Month
Cost:		Critical Path:	No
Resources:			

2.4. DAQ

The data acquisition will be done within the framework of the CODA system from JLab. Many members of the collaboration are familiar with the CODA system. Data will initially be stored locally and then spooled to the Fermilab computer center as a background task. The expected data rate is 200 Hz during the 5 s spill for a 1.5 kB event size, or a time averaged 1.5 kB/s.

2.4.1. CODA setup

This is the setup of the Linux-based machine on which CODA will run, installation of the basic software, interfacing with the VME-based ROC's and disk system for local data storage.

Lead Institute:	Argonne	WP Manager:	K. Hafidi
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Start Date:	Jan. 2008	Duration:	4 Months
Cost:	\$40,000	Critical Path:	No
Resources:			

2.4.2. Test LeCroy 3377 Modules

Fermilab Prep electronics pool has sufficient LeCroy 3377 multi-hit TDC's for this experiment. Fermilab does not, however, have sufficient resources to test all the modules before the experiment. Prep has offered to provide a test setup for these units and the collaboration will provide the labor.

Lead Institute:	Abilene	WP Manager:	R. Towell
Start Date:	Jan. 2008	Duration:	5 Months
Cost:		Critical Path:	No
Resources:	Fermilab test setup		

2.4.3. FERA readout

The LeCroy 3377 units will be read through the FERA bus. Currently, the CODA system has no interface to FERA. We plan to use a FERA to VME interface for readout of these units.

Lead Institute:	Argonne	WP Manager:	K. Hafidi
Start Date:	Jan. 2008	Duration:	8 Months
Cost:	\$15,000	Critical Path:	No
Resources:			

2.4.4. Latch readout

For the Station 1 MWPC, Station 4 Prop tubes and the hodoscopes, the experiment will use the Nevis bus system for readout. The electronics and cabling will come from E866 and E871.

Lead Institute:	Argonne	WP Manager:	P.E. Reimer
Start Date:	Jan. 2008	Duration:	11 Months
Cost:		Critical Path:	
Resources:			

2.4.5. Integration and testing

Lead Institute:	Argonne	WP Manager:	K. Hafidi
Start Date:	Feb. 2009	Duration:	3 Months
Cost:		Critical Path:	No
Resources:			

2.5. Offline computing

2.5.1. Monte Carlo

A "fast" Monte Carlo program already exists which traces muons through the spectrometer and reconstructs their tracks including effects from multiple scattering and energy loss. A GEANT Monte Carlo tracking all particles through the beam dump/hadron absorber to tracking Station 1 also exists. This would either extend the GEANT Monte Carlo to cover the entire spectrometer or adapt the full E866 Monte Carlo to the new spectrometer. In addition to the lead institute, physicists from Argonne, Abilene and Maryland will be working on this task.

Lead Institute:	Los Alamos	WP Manager:	M. Leitch
Start Date:	Jul. 2007	Duration:	24 Months
Cost:		Critical Path:	No
Resources:			

2.5.2. Analysis

The analysis will be based on the already existing E866 analysis package, which has been maintained for the previous Drell-Yan experiments by Los Alamos. Los Alamos will update this software for the new detector configuration and event format. In addition to the lead institute, physicists from Argonne and Illinois will be working on this task.

Lead Institute:	Los Alamos	WP Manager:	M. Leitch
Start Date:	Jul. 2007	Duration:	24 Months
Cost:		Critical Path:	No
Resources:			

6 Revisions of WBS and Management Plan

It is recognized that over the course of this project, it may be necessary to revise the Management Plan, the WBS or the schedule. These revisions will be coordinated by the Upgrade Manager. Revisions may be initiated by any member of the collaboration. Minor revisions will be to the WBS must be approved by the effected Project Manager, the Upgrade Manager and the Spokesperson(s). Major revisions to the WBS or to the Management Plan must be submitted to the collaboration for discussion and approval. (This may take place by e-mail, during collaboration phone conferences or at collaborations meetings.) The current version of this management plan as well as a revision history will be kept on the collaboration's web page.

7 Summary

This document has outlined a management structure and WBS for the upgrade of the Drell-Yan spectrometer for the Fermilab E906 experiment. The upgrade is divided into six independently funded tasks—three funded by DOE/ONP and three by the NSF—in addition to Fermilab's contributions.

¹ P.E. Reimer, D.F. Geesaman *et al.* "Drell-Yan Measurements of Nucleon and Nuclear Structure with the Fermilab Main Injector: E906", Proposal to the Fermilab PAC, 29 September 2006 (unpublished).

² The QWeak Experiment Project Management Plan, June 28, 2004, Version 4.0, R. Carlini *et al.* spokespersons.

³ P.E. Reimer, D.F. Geesaman *et al.* “Drell-Yan Measurements of Nucleon and Nuclear Structure with the FNAL Main Injector: Funding proposal submitted to The United States Department of Energy,” 22 February 2005 (unpublished)