High Energy Physicist Resources Through the Decade

HEPAP Task Force on Physicist Resources

February 17, 2006

Executive Summary: A survey by a HEPAP Task Force of the scientific personnel needs of currently running and future experiments in High Energy Physics has been compared with a survey of essentially 100% of the DOE and NSF funded university groups and national laboratory scientific staffs for the years 2004-2009. The results suggest possible issues of concern for maintaining the scientific strength at the Tevatron experiments, and to a lesser degree, the SLAC B-factory experiment. The Task Force concludes that 1) maximizing the physics return from running experiments and preparing for an active role in the LHC experiments may tax the U.S. physicist resources. 2) The next two years will be crucial in terms of understanding the extent of this possible problem in light of a number of important uncertainties which will be clarified in that time. 3) Navigating the transition to LHC will require an unprecedented coordination among the running experiments, their laboratory managements, the U.S. ATLAS and CMS collaborations, and DOE and NSF.

1 Introduction

The High Energy Physics Advisory Panel (HEPAP) requested a detailed survey of Physicist Resources for the entire United States High Energy Physics (HEP) program. This report presents the results of this survey which was conducted from September of 2004 through June of 2005. It seeks to compare researchers plans with the needs of a suite of current and planned experiments.

Experimental HEP research is an enterprise which can require hundreds of physicists per experiment—thousands for the Large Hadron Collider (LHC) projects. How limited human resources are distributed within the experimental programs is critically important to their successful scientific outcomes. The following is a brief reminder of the magnitude of the tasks and personnel requirements of large high energy physics experiments in order to set the scale for the detailed results which follow.

2 Background

There are basically two different kinds of experimental HEP programs: those which require large national laboratory particle accelerators and those which rely on naturally occurring beams of particles from extraterrestrial sources. For both of these kinds of experiments, most of the internal leadership, much of the engineering, and almost all of the extraction of the physics results is performed by university researchers. These are entrepreneurial, independently directed groups of a few to 10s of faculty who divide their efforts among projects of their choosing—only indirectly accountable to their peers and their universities. The funding of this university program is managed by both the Office of High Energy Physics (OHEP) at the Department of Energy (DOE) and the Elementary Particle Physics (EPP) program within the Physics Division of the National Science Foundation (NSF). The funding of each group is through peer-reviewed awards distributed to successful grantees. The standard success measures for university groups are twofold: first, successful completion of any hardware and/or software deliverables is a significantly positive outcome but second, the most important measure of success is their contributions to the physics programs at the laboratories in which they work.

Large facilities are proposed through physics community consensus, but the actual design, construction, and running of these facilities is through tightly-managed government oversight from OHEP and EPP of their respective laboratories. Because of significant national investments, performance of these facilities is quite visible and judged on quantifiable measures such as luminosity delivered, which is an engineering outcome, not a scientific one.

So, success relies on the coupling of focused, accountable national laboratories with the individual efforts of self-directed university researchers. Optimal linkage is not guaranteed and the possibility exists that the distribution of university research efforts might be insufficient to adequately extract the science. This task force was formed as a reaction to concern expressed by HEPAP in the Spring of 2004 that such an imbalance could conceivably develop between on-going and future experiments.

2.1 HEP Experiments: It Takes a Village

Understanding the magnitude of the effort required is necessary in order to put the results of this survey in context and to appreciate the decisions faced by university researchers. Broadly, there are four significant efforts required in order to carry accelerator-based experiments from conception to completion.

2.1.1 The Operational and Physics Analysis Tasks

1. The particle accelerator. These are large, national infrastructures located at national laboratories employing hundreds to thousands of people. The host nation is typically responsible for the design, construction, and running of the accelerator complex.

2. The experimental detector. The devices used to detect the many particles produced in high energy particle collisions are huge combinations of possibly dozens of different detection technologies, hundreds of individual components, and millions of channels of high-speed electronics. While the large infrastructure elements of these detectors (e.g., superconducting magnets) are typically the responsibilities of the host laboratories, much if not most of the other elements of the detector are designed, built, installed, and maintained by other laboratory and university technical groups. Usually teams of many dozens of physicists are required in order to maintain the hardware of a large detector once constructed.

3. The computing effort. Increasingly, computing is a highly technical and specialized part of any experiment. The overall scale is enormous in the large accelerator-based projects: hundreds of thousands of lines of code, petabytes of stored data, thousands of individual computer processors, managed and programmed by hundreds of laboratory and university physicists and computer specialists. The computing required by modern HEP experiments is roughly divided into four separate efforts.

   (a) The data collection itself is managed by an on-line computing system which directs the run parameters that characterize the detector's choice of which events to write and manages all real-time detector monitoring and calibration.

   (b) The data reduction responsibilities are relegated to large farms of hundreds of devoted processors which take the raw data from the detector and produce event records which are analyzable as physical quantities. These data collection and reduction stages are located at the host laboratories, but their programming may very well be the responsibilities of outside physicists.

   (c) The physics data analysis is done on the reduced data by people according to constantly evolving strategies and priorities. This work is increasingly performed at universities and laboratories from around the world.

   (d) Large-scale simulations are required for proper understanding of the signals and backgrounds. This Monte Carlo effort differs for every experiment, but again, increasingly these responsibilities may be distributed throughout the world.

   All four of these computing efforts require highly specialized personnel for design, programming, maintenance, and upgrading. Hundreds of people are involved on a regular basis and management of such large software efforts in a research environment presents special challenges. University researchers usually lead and are involved in all four of these computing efforts.

4. The physics analysis effort. The analysis efforts in large HEP experiments present a significant management challenges. The landscape is constantly shifting and the deployment of personnel and resources to priority analyses must be carefully done and constantly re-evaluated. A balancing act is the result: mixing the overall "prize" of reaching a new understandings of nature with the shifting personnel pool of temporary populations of literally hundreds of graduate students and post docs and their faculty supervisors. The responsibility chain is an informal one, and accountability is peer-pressure driven, rather than as direct as it would be in industry or government–since researchers are largely university-based. Yet, it all works: It is not unusual for large experiments to have 200 individual physics measurements ongoing at any time. Each of these is managed in a competitive group environment led by usually one or two university-based physicists. It is a highly person-intensive effort and, because of the nature of some experiments, must literally be re-invented on a periodic basis as data sets become larger and the backgrounds and systematic uncertainties become more pernicious. It is difficult to appreciate and plan for the magnitude of physics analysis efforts and they are often underestimated.

2.1.2 The Personnel Effort

University and laboratory personnel must be involved during all phases of an experiment's lifetime which can be over decades. The different communities which are involved include the following:

1. Host laboratory researchers. These professionals include senior staff scientists, junior staff scientists, engineering physicists, and post doctoral researchers plus host laboratory engineering and technical staff. These personnel are resident at the experiment and often take on specialized technical and managerial as well as scientific research responsibilities.

2. U.S.-based University researchers, including faculty, senior research associates, post doctoral researchers, graduate students, and undergraduate students plus university engineering and technical staff. Of these personnel, typically post docs and graduate students are resident at the host laboratory, while faculty travel back and forth from their home institutions. University researchers typically design all or parts of the detector components and attempt to maintain those components throughout the lifetime of the experiment. Post docs and graduate students are typically expected to split their efforts between detector construction and/or maintenance and physics analysis, with post docs often progressing to leadership roles within the physics analysis structure. Faculty often participate in all aspects of the experiments, but divide their time among university duties, advisory duties, grant-management responsibilities, and experimental commitments. Faculty participation is key: all graduate student and post doc personnel are directly associated with individual faculty members. If a faculty member moves from one experiment to another, those student and post doc lines move with him/her. It is not unusual for faculty to participate on more than one experiment, sometimes even at nominal effort in order to continue these important personnel contributions to an older experiment.

3. Non-U.S.-based University researchers. HEP is an international effort and many dozens of foreign institutes are actively involved in U.S. based experiments. Just like the U.S. based researchers, foreign collaborators come from the ranks of faculty, senior research associates, post doctoral researchers, graduate students, and undergraduate students plus university engineering and technical staff.

4. Collaborating laboratory researchers from U.S. and foreign institutes. Scientific staff from laboratories other than the host laboratory are often involved in remote projects. These researchers also involve senior staff scientists, junior staff scientists, and post doctoral researchers plus engineering and technical staff.

That this vast effort typically works well is a testimony to the dedication of the individual researchers themselves, the support given to them by their home institutions, and the cooperative relationship among and between many funding agencies and national laboratories. There are stresses in this arrangement: attention from the government focuses on the laboratories' luminosity performance measurables, while the university researchers are focused on the health of their grants and their reputations within the competitive environments of their academic departments which are closely tied to scientific results. This study attempts to evaluate how well the needs of the experiments match the planned, but constrained, efforts of the university research community.

2.2 History

During the Spring 2004 HEPAP meeting, the University Representatives presented results of a first-pass survey of major experiments, who were asked to project their needs for 2005-2009, and a census of their current deployment of scientific personnel for 2004. The projections were in two categories: Operations and Analysis and guidance was supplied to help them to categorize their experiment's effort. These results—admittedly rough—suggested in especially the Operations category that even mature experiments would expect to maintain a significant effort requiring similar numbers of scientists in the years beyond even 2007. This appeared to possibly conflict with the scientific personnel expectations for new projects, namely ATLAS, CMS (at CERN) and BTeV (at Fermilab).

HEPAP concluded that this situation merited a closer, more comprehensive study which included new features and the Chair of HEPAP agreed to form a Task Force and charge them with this new survey responsibility.

2.3 Task Force and Charge

The Task Force membership is included in the Appendix, as is the specific Charge. A summary of the charge is as follows:

- Survey the major experiments for their needs in personnel for the years 2004-2009. This was interpreted to include division of effort into the same two Operations and Analysis areas as the 2004 survey. These were tightly defined in the letter of introduction (reproduced in the Appendix). The personnel categories were: Faculty/Senior Laboratory Staff, Post Doctoral Associates, and Graduate Students. For only the 2004 (census) year, breakdown into U.S. and foreign personnel was requested. For other years, only total required effort was requested.
- Survey every PI from all NSF and DOE experimental high energy physics university groups and laboratory scientific staffs for their project plans for the years 2004-2009. The personnel categories were Faculty/Senior Laboratory staff (each laboratory was solicited for their research staffs planned effort), Senior Research Associates, Post Doctoral Associates (PD), and graduate students (GS). In addition, information for the year 2004 was requested for off-base-grant personnel. The PIs were instructed to assume constant effort based on their 2004 totals and to count research fractions (RF), not FTEs.

3 Requests and Actions

3.1 To PIs and Experimental Spokespersons

Each of the two groups (PIs and Spokespersons) were provided fictional examples and spreadsheets for their reply. A web site was maintained that kept a running total of FAQs that emerged as people worked on their responses and, as the project continued, also listed the specific groups who had responded. Collection of the data, especially from the PIs, took from September, 2004 through May of 2005. In the end, a nearly 100% response rate was obtained. Table 1 shows a summary of the totals. The experiments which were queried were: DØ CDF, BaBar, Minos, BTeV, CLEO, MECO,

CATEGORY	TOTALS
University Groups	194
NSF Supported Groups	81
DOE Supported Groups	136
Projects with more than 1 PI	53
Total Group-Projects	603
Average Projects per Group	~ 3
Total number of faculty/staff	717
Total number of research scientists	340
Total number of post doctoral asociates	547
Total number of graduate students	712

Table 1: Characteristics of the university and laboratory research group data submitted in the PI responses.

KOPIO, MiniBooNE, SUPER K, ATLAS, CMS, SNAP, STACEE, VERITAS, LIGO, AUGER, MINERvA. All 18 experiments replied and all provided the appropriate information.

3.2 Data Collection, Processing

Data were in hand by the end of May, 2005. The Spokesperson (SP) information was combined by hand into a single, separate spreadsheet. The PI information was combined from the 194 separate spreadsheets into a single, 21,000 cell spreadsheet for Pivot Table manipulation, sorting, and calculations. Hand checks were done separately by two Task Force members against PI surveys covering two large, different collaborations. No errors were discovered in the mechanics of combining the data and only marginal errors found in the actual PI-supplied spreadsheets for those collaborations (in all, this encompassed approximately 80 separate PI submissions). The labeling of the various experiments and projects that people participate in were rationalized by hand into sometimes generic categories to facilitate analysis.

3.3 Presentations

Whitmore and Brock reported status and preliminary results at the September, 2004; February, 2005; May, 2005; and July, 2005 (the final report) HEPAP meetings. Slides from those presentations can be found at the HEPAP website (http://www.science.doe.gov/hep/agenda.shtm). In addition, Whitmore briefed the Fermilab PAC in June of 2005 and Brock briefed the DØ and CDF collaborations in June of 2005.

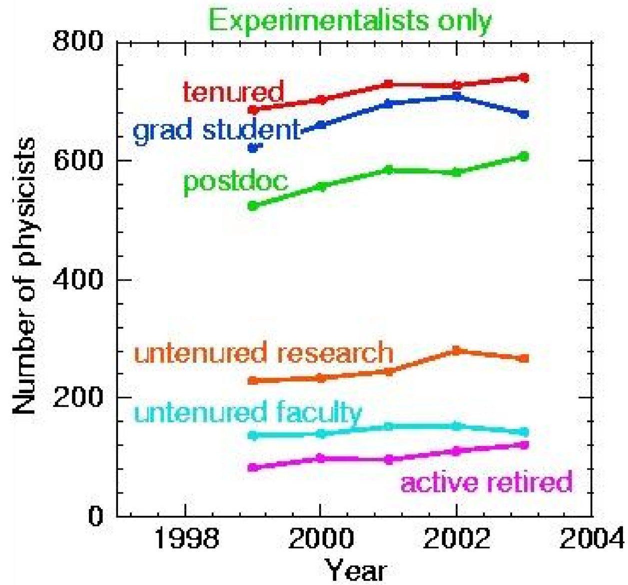

Figure 1: PDG Census for HEP experimentalists only, including university scientists and scientific staff from laboratories.

4 Results

The first piece of information that could be extracted was a comparison with the mature Census of U.S. Particle Physicists done annually by the "HEPFolk" group within the Particle Data Group at Lawrence Berkeley Laboratory (http://hepfolk.lbl.gov/census/summary/). Figure 1 shows the history available from this survey for the indicated categories of scientists. The PDG survey counts people and this corresponds directly to the sum over projects of the research fraction of each scientist reported by the PIs. For comparison, then, the totals of all Ph.D. scientists from the PI submitted data are shown in Figure 2. The 2004 numbers should correspond most closely to the PDG entries for their most recently published (2003) results. One can see points of interest in these results. First, the agreement between the PI survey and the PDG results is reasonable: for the former, just above 1600; and for the latter (sum of tenured faculty, untenured faculty, untenured research faculty, and post docs), about 1770. Such a difference of about 10% seems to characterize typical uncertainties for most of the results of this survey. Likewise, the numbers of students and the count of postdocs-plus-research associates from Table 1 is similarly close to those quantities in the PDG survey.

Second, one sees that now and in the future, roughly half of the experimental HEP community is or will be involved in non-collider based experiments and half in collider-based experiments. For practical purposes, we define "collider-based experiments" as the Tevatron experiments (DØ and CDF), the electron-positron experiments (CLEOc and BaBar), and the LHC experiments (ATLAS and CMS). (Sometimes, we will distinguish between ongoing collider experiments and future collider experiments for the obvious separation of non-LHC and LHC.)

Finally, one can see, although the rules of the PI survey were constant effort, that some growth

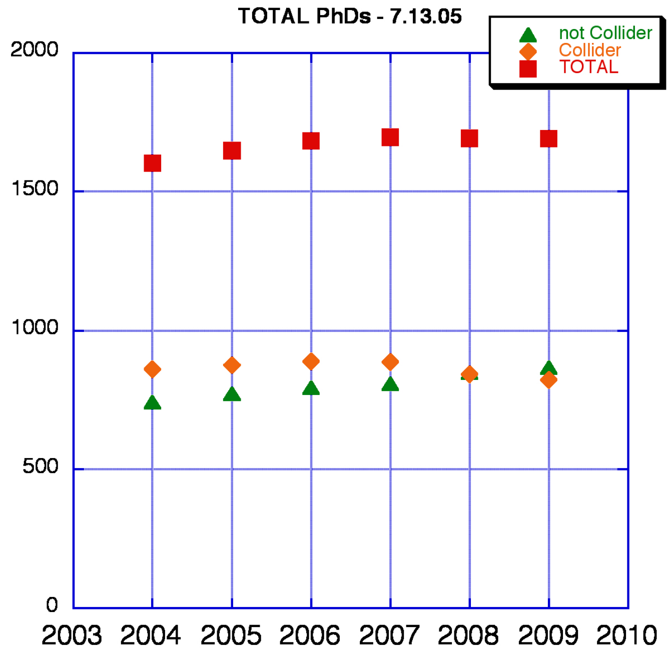

Figure 2: The total number of experimentalists from the PI survey of universities and laboratories for all PH.D. personnel categories.

seems to have crept into the results as the red boxes do rise in the 2005-07 period[1].

4.1 Characterization of the Principal Investigator Results

While there was utility in the use of research fractions (RF), namely the above comparison of heads and the ability to quickly assess the constant-effort ground rule correspondence, the experiments report effort in terms of FTE. RF clearly would overcount FTE: a faculty person whose time is divided into 50% teaching and 50% on one particular research project would report 100% RF on that project. However, for post docs and graduate students the two measures are almost always the same, RF = FTE. It is not unusual for experiments to internally weight university faculty by a 50% factor to account for teaching, traveling inefficiencies, and departmental responsibilities. On the other hand, host laboratory[2] senior scientists (also called "faculty" in this survey) have a RF much closer to an FTE, typically at least RF $\simeq$ 0.8 FTE. A scaling was used to compare the PI data with the SP data and an "Estimated FTE" measure was defined for the faculty counting as

$$\text{ESTFTE(FAC)} \equiv 0.5(\text{university professor RF}) + 1.0(\text{host laboratory staff RF})$$

[1]The BTeV experiment was problematic. During the reporting period, the BTeV experiment was cancelled and so the results are ambiguous: the early-responding PIs report their intentions to remain on BTeV, while late responders chose to sometimes evolve their original BTeV plans into something else. In what follows, where there are comparisons to be made, BTeV was not included. In all other situations, those who indicated BTeV as their future plans were ignored in the presentation of projections. This undercounts the non-BTeV experiments which those people have subsequently joined. The level of uncertainty is tens of faculty overall. The RSVP project was cancelled after this summary was completed, but it too constituted less than 10% of the total.

[2]Defined as the laboratory at which a particular experiment is located.

(with the approximation that host lab staff are fully counted) and was used for all "faculty" counting. It was then added to the PD and GS measures according to RF = FTE. Subsequent plots will indicate when either "FTE" or "ESTFTE" is used.

4.2 Characterization of the Experiments' Spokesperson Results

Characterization of the needs for an experiment is a problematic calculation. For running experiments, the evaluation of the requirements for data taking and hardware and software system maintenance is a relatively straightforward assessment—for this category, spokespersons tended to estimate their uncertainties as approximately $\pm 10\%$. Assessing the analysis needs is much more difficult, even for running experiments. Analysis usually involves the same people as Operations, with different fractions of individuals at different times contributing to both. Analysis intensity tends to follow integrated luminosity increases. A typical hadron collider experiment might change its analysis techniques once or twice a year, including large quantities of data only when those new techniques are understood and the systematic uncertainties have been properly estimated. Next, there will be a period of quiescence when software and algorithm changes are discouraged and the physics analysis is extracted and the papers are written. Such changes in techniques can be especially significant for the hadron collider experiments where added integrated luminosity is often accompanied by effects which can only be understood when the instantaneous luminosity actually rises. Tracking, energy scale, and selection algorithms can be significantly more complicated with pile-up and noise and the effort allocated to algorithms has to follow the problems as they are uncovered. Finally, the need for Monte Carlo event generation and analysis must necessarily increase with integrated luminosity and typically rises faster than the luminosity jumps. This is a significant effort as well. So: assessment of Analysis needs for running experiments is difficult.

For future experiments, such as those at the LHC, an estimate of future personnel is really something other than needs in the same sense as that of the running experiments. What seems to have been the case for ATLAS and CMS is a reporting of a mixture of real effort ongoing in construction and commissioning (something like Operations and carrying a similar $\pm 10\%$ uncertainty) plus an internal collaboration census of their groups' intentions for the future. Assessment of Analysis needs is therefore even more problematic than for the running experiments. In what follows, care has been taken to not use the word "NEEDS" for the LHC experiments; rather, what is "Anticipated" is probably a better description for what the U.S. ATLAS and CMS managers were able to provide.

4.3 Comparisons

The PI dataset is an interesting collection of information about the plans that U.S. high energy physicists have over the next half-decade. Some of it is reproduced here for general interest, not necessarily bearing directly on the charge. A snapshot of the results is shown in Fig. 3 which compares the accounting of the experiments' totals and U.S. populations as reported by the Spokespeople for 2004 with those as summed from the PI submissions for that year. This shows good agreement between the two datasets for this year which is used as a normalization for what follows in projecting U.S. totals.

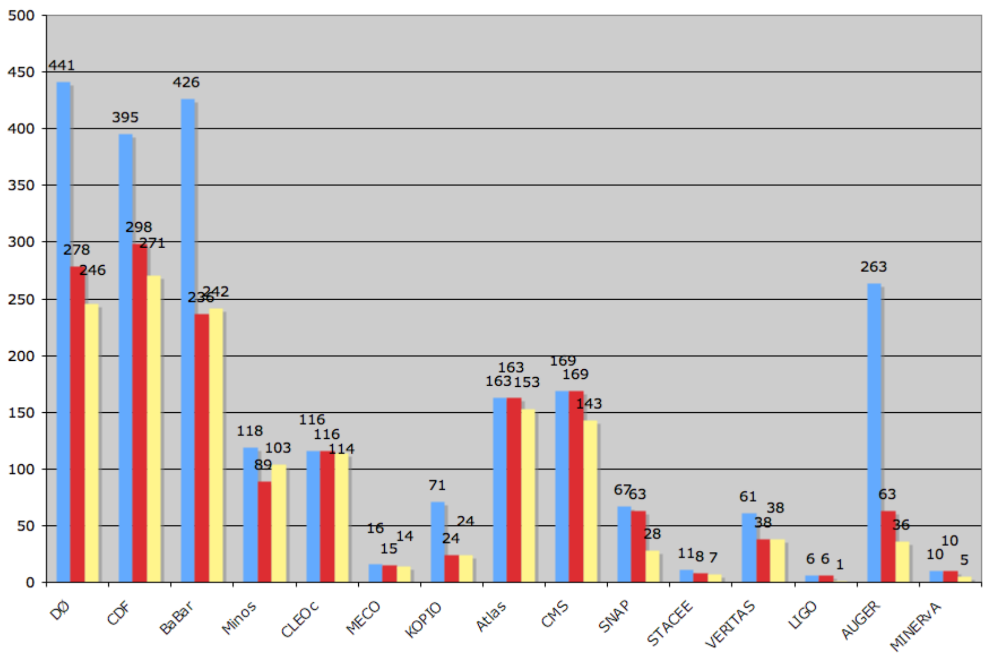

Figure 3: The 2004 totals for all experiments in the survey. The blue bars are the total experiments' populations, the red are those from U.S. institutions. Both are reported by the SP. The yellow bars are the total ESTFTE for the U.S. PI's.

4.3.1 General Results

The first comparison that can be made is between the reports of the Spokespersons and those of the PI's. Since the latter are, by definition, only for U.S. physicists and institutions, the U.S. 2004 totals are the direct comparison quantity. Figure 4 shows the projections submitted by PIs for combinations of neutrino experiments, those which derive their beams from accelerators (MiniBooNE, MINOS, NOvA, T2K, Minerva, and NuTeV) and those which derive their beams from extraterrestrial sources or reactor sources (AMANDA, Double Chooz, IceCube, K2K, KamLand, SNO, SuperK and some smaller experiments). This figure also displays the ILC planning projections.

Figure 5 shows the projections by PIs for a collection of astrophysics experiments including Cosmic Ray experiments (AUGER, CACTUS, CHICOS, CREAM, CROP, FLASH, HiRes, Milagro, STACEE, and VERITAS), dark-energy/dark-matter search experiments (CAST, CDMS, COUP, DES, DRIFT, eBubble, LSST, UNO, SuperCDMS, XENON, and ZEPLIN II), and other astrophysics experiments not include in the FIRST two categories (CMB, GLAST, LIGO, SDSS, and SNAP). The sum total of all of the personnel in these experiments (collectively, non-collider) sums to approximately 480 in 2004 and rises to just under 600 ESTFTEs by 2009. In addition to topic-comparisons, Figures 6 and 7 show comparisons for future experiments and currently running experiments among the set of 18-1 (less BTeV) which were specifically surveyed. Figure 6 shows what the spokespeople replied as "needs" or "anticipation" for the current experiments (the falling orange diamonds for DØ , CDF, BaBar, Minos, CLEO, MiniBooNE, SUPER-K, STACEE, LIGO, AUGER, and MINVERvA) and the future experiments (rising green triangles for ATLAS, CMS,

Figure 4: From the PI data: Accelerator-based neutrino experiments, orange diamonds; non-accelerator-based neutrino experiments, green triangles; and ILC preparation, red squares.

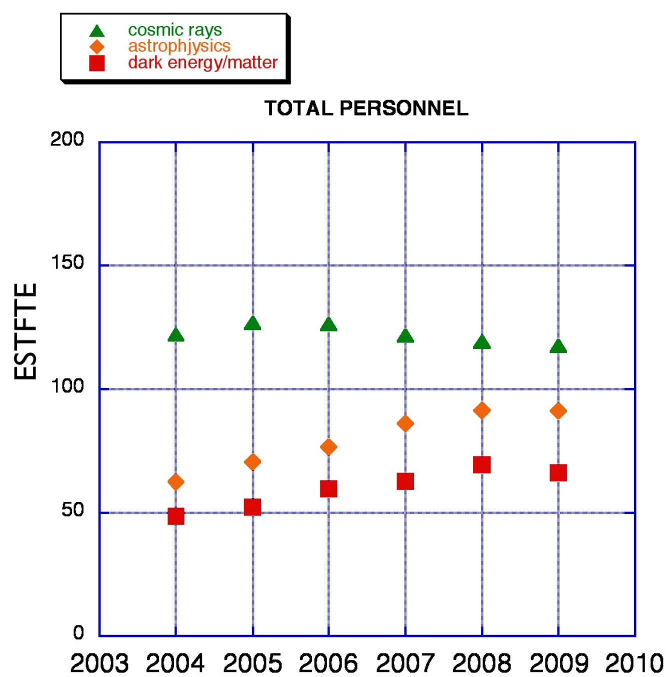

Figure 5: From the PI data: Cosmic ray experiments, green triangles; general astrophysics experiments, orange diamonds; and dark-energy, dark-matter experiments, red squares.

SNAP, MECO, KOPIO, and VERITAS). The totals are shown as the red squares. One can immediately see that the anticipated personnel resources are expected by the projects (SP) to rise by about 10% over time. Figure 7 shows the same information for the same categories, but from the PI plans. The red squares here demonstrate that, on the whole, the constant effort instruction was followed. The blue circles in Fig. 7 are the total PI reponses for all experiments, suggesting that the choice of the 18 queried experiments accounts for approximately 80% of the total U.S. experimental effort in 2004.

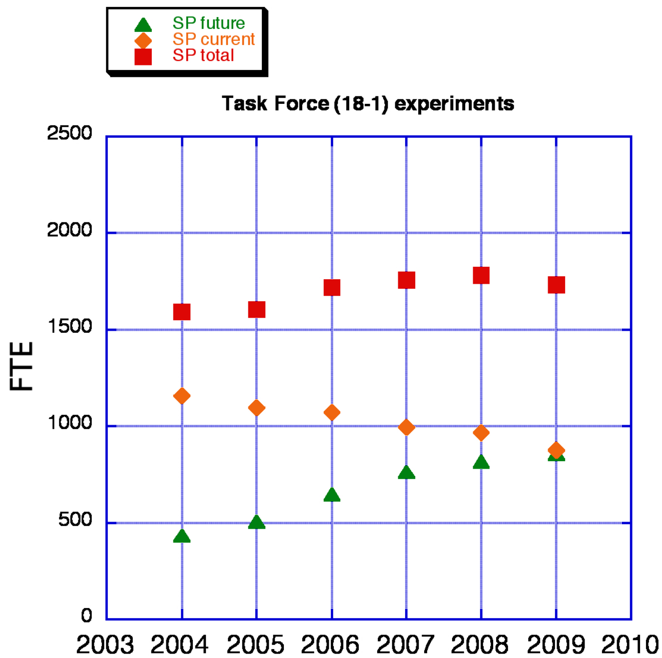

Figure 6: Spokesperson-submitted "needs" for running experiments, orange diamonds; future experiments, green triangles; and the sum, red squares. BTeV is not included.

4.3.2 Collider Experiments

This section reports a direct comparison between what the experiment's SP reports and what the PIs plan for the four large current collider experiments, BaBar, CLEOc, DØ , and CDF, and the two large future collider experiments, ATLAS and CMS. In all cases, the unit from the PI data is ESTFTE. The comparison is for U.S. personnel only and, in order to make this comparison, it was assumed that the trend for U.S. participation in the experiments scales at the same fraction reported for 2004. For example, the DØ experiment has 80% U.S. participation in the sum of all personnel categories, summed over Operations and Analysis. The SPs reported the total needs for 2005-2009 and these needs totals have been scaled in this report by 80% to estimate the fraction of needs which can be anticipated to come from U.S. sources. Figure 8 shows the experiment's SP's expectations, scaled to the U.S. fractions, for CLEOc and BaBar (closed triangles and squares). Overlaid are the PI responses from CLEOc and BaBar groups (open triangles and squares). As can be seen, for both experiments, anticipated end-dates seem to lead to both the SPs' and the

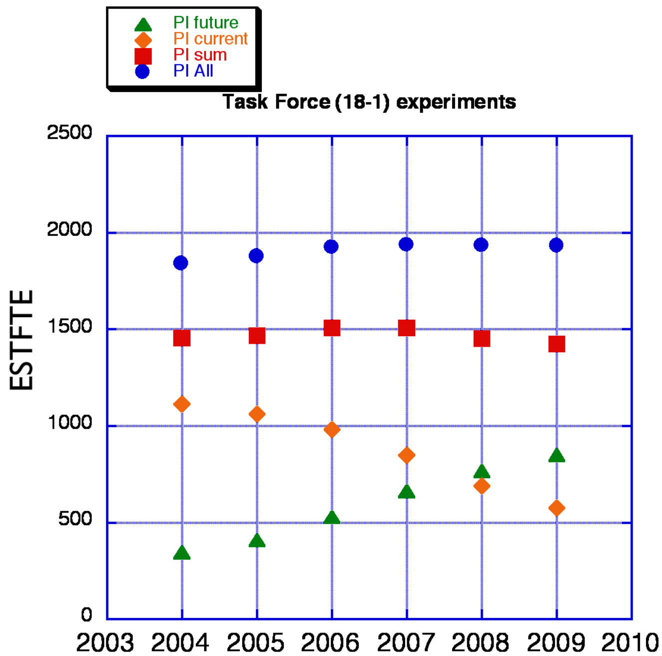

Figure 7: PI-submitted plans for the same 18-1 set of experiments above with the symbols referring to the same subsets, as in Fig. 6. The additional blue circles show the projected personnel for all experiments referred to by PIs.

PIs' predictions falling in time. Also, note that in both cases, the PIs' plans fall somewhat faster than the experiments' expectations.

Figure 9 is a complicated plot which demonstrates a number of issues. Basically, it shows the same quantities as in Figure 8, but for the DØ CDF, ATLAS, and CMS experiments.

First, consider the Tevatron experiments: The red squares show the results of the CDF collaboration for the experiment's needs (closed squares, in U.S.-scaled totals) and the PIs' plans (open squares). Similarly shown are the results for the DØ collaboration in the blue circles (closed and open, for SP's and PI's, respectively)[3]. There are a number of important conclusions that can be drawn from this subset of Figure 9:

- The needs of both experiments do not significantly fall off in time. This reflects a number of things, some of which are touched on in the introduction, such as the burden that integrated and instantaneous luminosity increases place on analysis and the construction and integration of significant upgrades in the 2006-2007 period.
- The expectations for both experiments are very similar to one another in overall totals and in time-dependence.
- The overall levels and time-dependence of the PI plans are nearly identical for the two exper-

[3]The drop between 2006 and 2007 reflects the completion of the upgrade which is more comprehensive for DØ than for CDF.

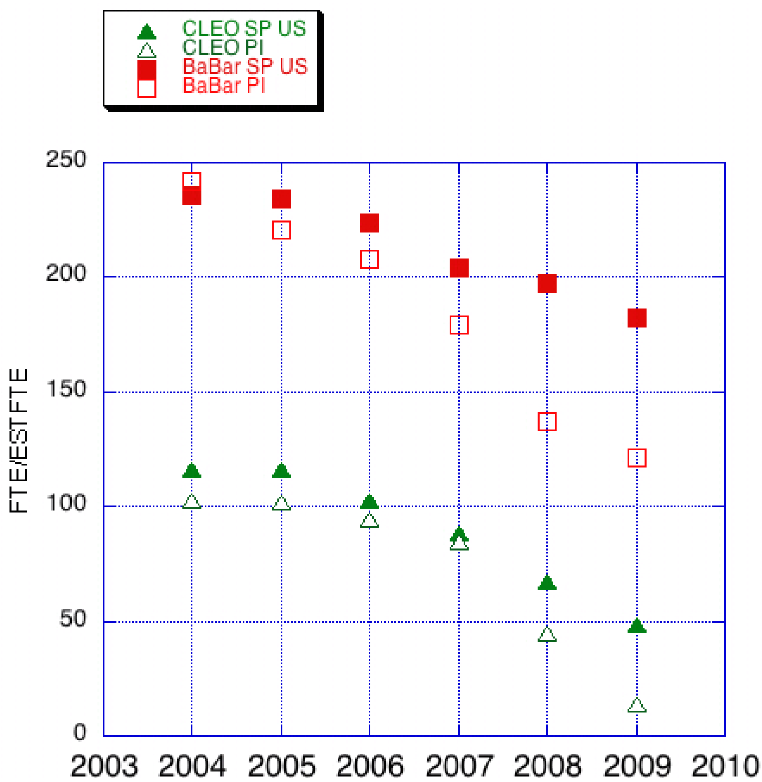

Figure 8: The spokespersons' expectations and PIs' plans for CLEOc (solid green triangles and open green triangles, respectively) and BaBar (solid red squares and open red squares, respectively).

iments.

- The level of university effort which PIs project as involved at CDF and DØ appears to be significantly below the indicated need.

Finally, in the lower part of the plot, the smaller blue-circles and red-squares show the Operations-only needs for both experiments.

Next, consider the LHC experiments: Overlaid on Figure 9 are the "anticipated" numbers of scientists expected by the U.S. ATLAS (closed green triangles) and U.S. CMS (closed orange diamonds) managements for this time period. In addition, the PIs' plans for involvement in these two future experiments are displayed (open green triangles and open orange diamonds). A number of interesting conclusions can be drawn from this information:

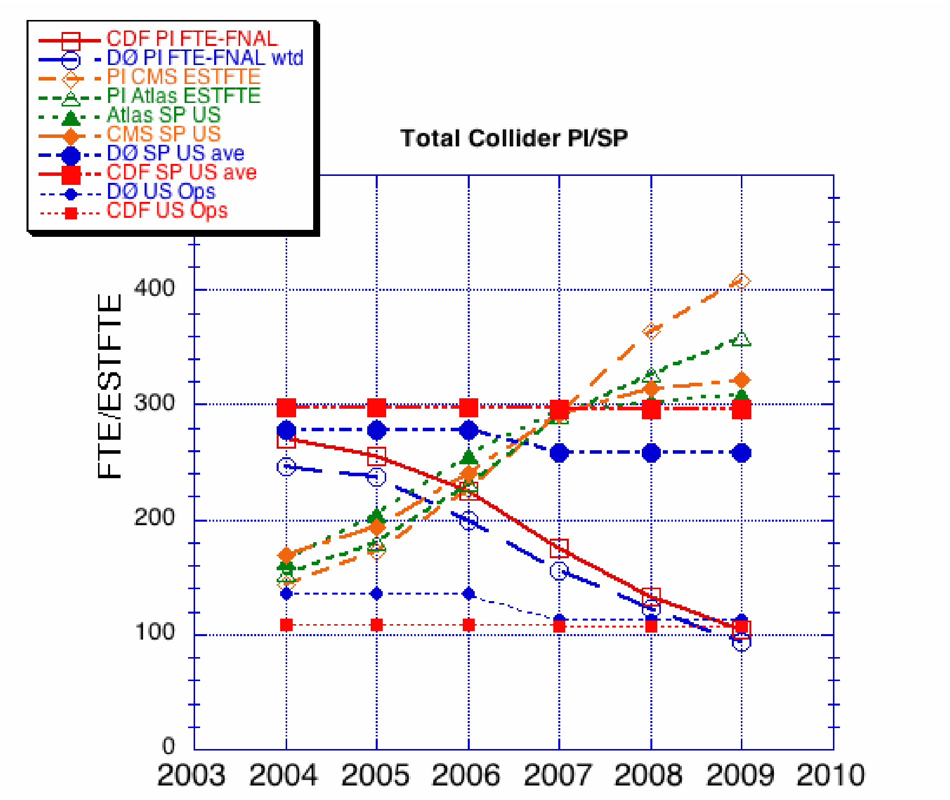

Figure 9: SP and PI results are compared for the Tevatron and CERN experiments. The large solid symbols report U.S. SP operations plus analysis responses for CDF(red squares), DØ (blue circles), CMS(orange diamonds), and ATLAS(green triangles). The open symbols report the PI responses for the same experiments. The small solid symbols at the bottom are the operations-only SP responses for CDF and DØ .

- The "anticipated" numbers for both LHC experiments are very similar to one another in overall totals and in time-dependence.

- The "anticipated" numbers of both experiments rise through the mid-decade and appear to flatten at about the time of anticipated LHC turn-on (2007).
- The PI plans track both of the experiments' "anticipated" totals until approximately 2007, but then both continue monotonically upward through the end of the decade.
- The overall levels and time-dependence of the PI's plans are very similar for the two experiments.
- The total projected numbers of PI involvement in 2009 for CDF and DØ is approximately 200 ESTFTE and for ATLAS and CMS it is approximately 750. For 2004, these totals are approximately 520 and 300, respectively. These numbers reflect the fact that the total number of people on LHC experiments will not come solely from CDF and DØ but also from CLEOc and BaBar.

As just noted, the source of LHC scientists seems to be largely from the existing collider program. Figure 10 shows the total collider program split into components from those who are on running experiments (CLEOc, BaBar, DØ and CDF, green triangles) and those who are on the future LHC experiments (orange diamonds), and the sum (red squares). Within this particular sub-community, it appears that the constant effort boundary condition was adhered to and that the CLEOc and BaBar communities will contribute significantly to the overall LHC complement. Figure 11 shows the same trends reported for the SP effort predictions. Clearly, the "needs" show a rise in the form of a bump, which begins to subside as the electron-positron machines shut down.

5 Followup for the Tevatron Program

The significant fall-off below "needs" for DØ and CDF shown in Fig. 9 was serious enough that a second effort was mounted in June, 2005 to probe for more details and possible causes. As noted above, both experiments were apprised of the situation and a second questionnaire was created by the Task Force which went to the U.S. membership of the DØ Institutional Board and the CDF Executive Board. The motivations for this were:

- The apparent correlation among the nearly 80 independent university groups for the two (independent) experiments deserved exploration.
- The significant fall-off suggested in 2006 appeared to be coherent and yet unplanned.
- The two experiments continued to find establishing "needs" a problematic exercise and yet it was the driving concern in comparing to the PI results.
- Any far-future (beyond 2007?) circumstance is highly uncertain in all respects, both for the experiments and for the PIs.
- All in all, these results suggest a problem could develop and the underlying causes were worth exploring.

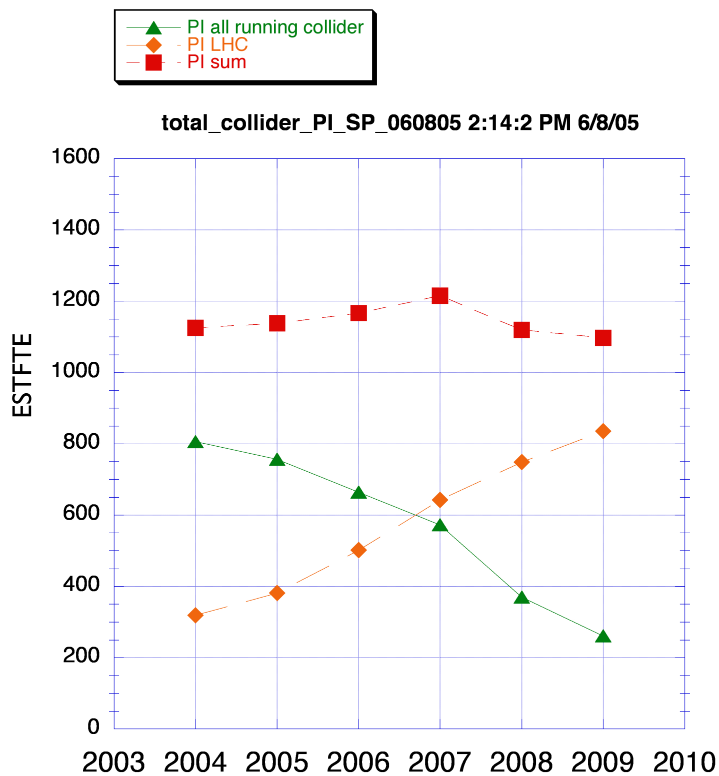

Figure 10: The PI responses for the U.S. collider program. The falling green triangles are for the currently running collider experiments while the rising orange diamonds are for the two LHC experiments. The red squares are the sum of the two.

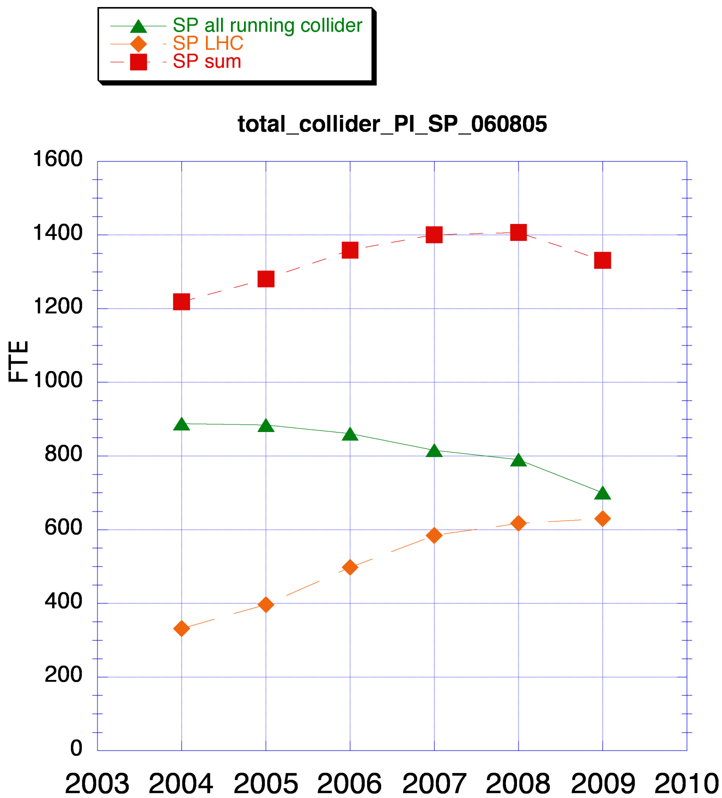

Figure 11: The SP responses for the U.S. collider program. The falling green triangles are for the currently running collider experiments while the rising orange diamonds are for the two LHC experiments. The red squares are the sum of the two.

The questionnaire was comprised of the following seven questions:

1. Do these results surprise and/or concern you?
2. Would you have liked to have kept a greater presence in DØ or CDF during the 2006-9 period than your response suggested?
3. If you would have, what led to your decision to respond with a significant reduction in plans for CDF or DØ ?
4. What factors influenced your projection to 2007?
5. What would you have needed to believe about your particular circumstances in order for you to have responded with a greater presence in DØ or CDF?
6. Should CDF and DØ collaborations just live with this apparent plan or should the tevatron community promote a managed transition? Do you have a sense of what would constitute a managed transition?
7. Would these apparent results - especially #C and #D[4]- have led you to have responded differently if you had known beforehand?

Despite the short time for response before the HEPAP July, 2005 meeting, the Task Force was pleased to receive responses from about half of the institutions polled. They were analyzed by members of the Task Force and the following summary was produced and presented to HEPAP in July 2005.

- It was emphasized by all: Outstanding physics will come from the Tevatron. Some noted that redirection of physicist effort away from CDF and DØ can compromise that physics and that premature migration could cause post docs and graduate students to miss necessary experience which will be essential for LHC physics analyses.
- Two rationales dominated the respondents' account for their shifts from Tevatron to LHC:
  - LHC Physics: All recognize the guarantee of new physics at LHC and some indicated a need to participate in LHC on Day 1.
  - Perception of agency pressure: Some reported implicit and/or explicit directives from their funding agency to shift their efforts from the Tevatron to the LHC.
  - 60% indicated "physics" was their rationale while 45% indicated "agency pressure" (these numbers include 9% who indicated both).
- The constant effort constraint was a reason for an apparent coherent response away from the Tevatron with 65% of the respondents noting that with incrementally more resources they could devote additional students or post docs to the Tevatron program.
- Small groups have a special problem as theirs is a binary, either-or decision.

[4] "#C and #D" refer to items in the cover-letter which referred to the PI projections: more-LHC than anticipated and a fall-off in Tevatron plans compared to "needs".

- Essentially all respondents were in favor of a managed transition from the Tevatron experiments to the LHC. Some suggested for the Tevatron experiments:
  - specific ideas for streamlining of operations, analysis, code changes;
  - more inclusion of Laboratory technical people into traditional physicist roles;
  - prioritizing of physics goals;
  - and the need for close coordination among all stakeholders which ultimately leads to a transition strategy.

    Some indicated that they would need assurance that should they conform to a transition strategy that funding losses would not result.

6 Conclusions

The conclusions of the Task Force were unanimous. It is important to keep in mind: 1) The Constant Effort requirement was a severe constraint. 2) The timeframe was problematic since it encompassed three critical uncertainties, about which there can only be speculation in 2005:

1. With full planned luminosity totals, the potential for exciting physics results from SLAC, CESR, and the Tevatron is as high now as when these experiments were first proposed.
2. The LHC schedule continues to hold firm, but there are concerns about a possible delay. Any schedule change announcement is not expected before July of 2006 and any slippage would have a significant effect on PIs' plans for ending their planned involvement in running experiments.
3. Uncertainties about the future luminosity performance of either the Tevatron or the SLAC B-factory would similarly have an impact on PI's plans for their continued involvement in these programs.

In what follows, these three items are referred to as the "3 uncertainties."

1. The committee concludes that maximizing the physics return from the Tevatron and BaBar while simultaneously preparing for an active US role in ATLAS and CMS may tax physicist resources of the US HEP community. This is true especially when factoring in the other efforts planned and underway in neutrino physics, astrophysics, cosmology, and cosmic ray physics.
2. With respect to the Tevatron and LHC, the next two years will be crucial in terms of understanding the evolution of the "3 uncertainties," but the field cannot wait to see whether this will prove to be the case.
3. Although one cannot be sure that additional resources will be required, navigating this transition will require an unprecedented, active **coordination** among a) the running collider experiments (primarily, BaBar, DØ and CDF), b) their laboratory managements, c) US ATLAS and US CMS, and d) the funding agencies in order to avoid a serious problem.

(a) The Tevatron presents special challenges: There might be a serious problem at the Tevatron beginning within 1-2 years from now for those groups trying to redirect to LHC while simultaneously maintaining sufficient strength in CDF and DØ . (For BaBar, a similar situation appears to be less severe and less likely.)

(b) A focused effort to maintain the Tevatron and B-factory efforts of a small number of specialized groups/personnel may be required in order to alleviate potential problems—if necessary, a few-year supplement to University Program budget might be required.

This **coordination** should start immediately and conclusions be reached in a matter of a few months in order that plans can be formulated and remedies negotiated very soon.

7 Appendices

7.1 Task Force Membership

The Membership of the Task Force included:
Prof. Jim Whitmore, NSF, Pennsylvania State University (co-chair)
Prof. Raymond Brock, Michigan State University (co-chair)
Dr. Joel Butler, Fermi National Accelerator Laboratory
Prof. Sekhar Chivukula, Michigan State University
Dr. Glenn Crawford, Department of Energy
Dr. Howard Gordon, Brookhaven National Laboratory
Prof. Young-Kee Kim, University of Chicago
Prof. Usha Mallik, University of Iowa
Prof. William Molzon, University of California, Irvine
Dr. John Womersley, Fermilab and Department of Energy

7.2 Charge

The charge to the Working Group from Professor Fred Gilman, Chairperson of HEPAP was transmitted on July 18, 2004.

Formation of a Working Group to Study HEP Manpower Following the discussion at the last HEPAP meeting, a Working Group is being formed to assess the question: Does the field have the manpower to carry out the experiments to which the U.S. program is committed until the end of the decade? The members of the Working Group will be drawn from both the HEP community and the agencies, DOE and NSF. To answer the question at hand, each university and laboratory group will be requested to give its plan for the distribution of faculty/staff/postdocs/students among the various projects with which they are involved for each year through 2009. The funding assumption is constant level of effort, starting with 2004 as the base year. These data will be compared with those supplied by the relevant collaborations, who will each be asked for their minimum year-by-year manpower needs. In addition, for on-shore experiments, their year-by-year expected U.S. and non-U.S. contributions will be requested.

An initial report from the Working Group will be presented to HEPAP at its meeting on September 23-24, 2004.

7.3 Breakdown of Collider Responses

Figures 12 and 13 present the collider experiments responses in the following projections: Operations/Analysis for Faculty/Staff, Post Docs, and Graduate Students. Included are both the total "needs" reported and the scaled U.S. expectations as described in the text.

7.4 Materials

7.4.1 To Principal Investigators

The letter sent to the Principal Investigators of every experimental grant from the Office of High Energy Physics (DOE) and the Elementary Particle Physics Program (NSF). Included was a spreadsheet which is imaged following the letter.

```
August 24, 2004

Dear PI/contact person

We have a rich physics program involving two categories of experiments during the 2004-2009
timeframe:  those either currently running or those coming on line.  These experiments involve
considerable public investment and literally thousands of person-years and it is essential
that we plan to fulfill these obligations through to publication of physics results.  The first
step to developing such a plan is a careful understanding of our physicist resources.  Accordingly,
at the April 2004 HEPAP meeting, a basic question was asked:  Does the field have the people
to adequately carry out the experiments to which it is committed until the end of the decade?

In order to address this question, Fred Gilman, Chair of HEPAP, has formed a Working Group
to consider this matter, with Chip Brock and Jim Whitmore designated as co-chairs.  The following
is the charge to this group:

(Charge followed)

As you can see, this is a two-pronged approach:

1.  Each NSF and DOE supported university and laboratory group is being asked how it expects
to distribute its current resources among various projects, through FY2009 and this message
is designed to solicit this information from your group according to directions below.

2.  In addition to the PI survey, a complementary question is being asked of the spokespersons
of all current and planned experiments for the same time period:  What are the required levels
of effort needed to keep each experiment running through FY2009?

The working assumption behind this approach is that these two surveys will provide two data
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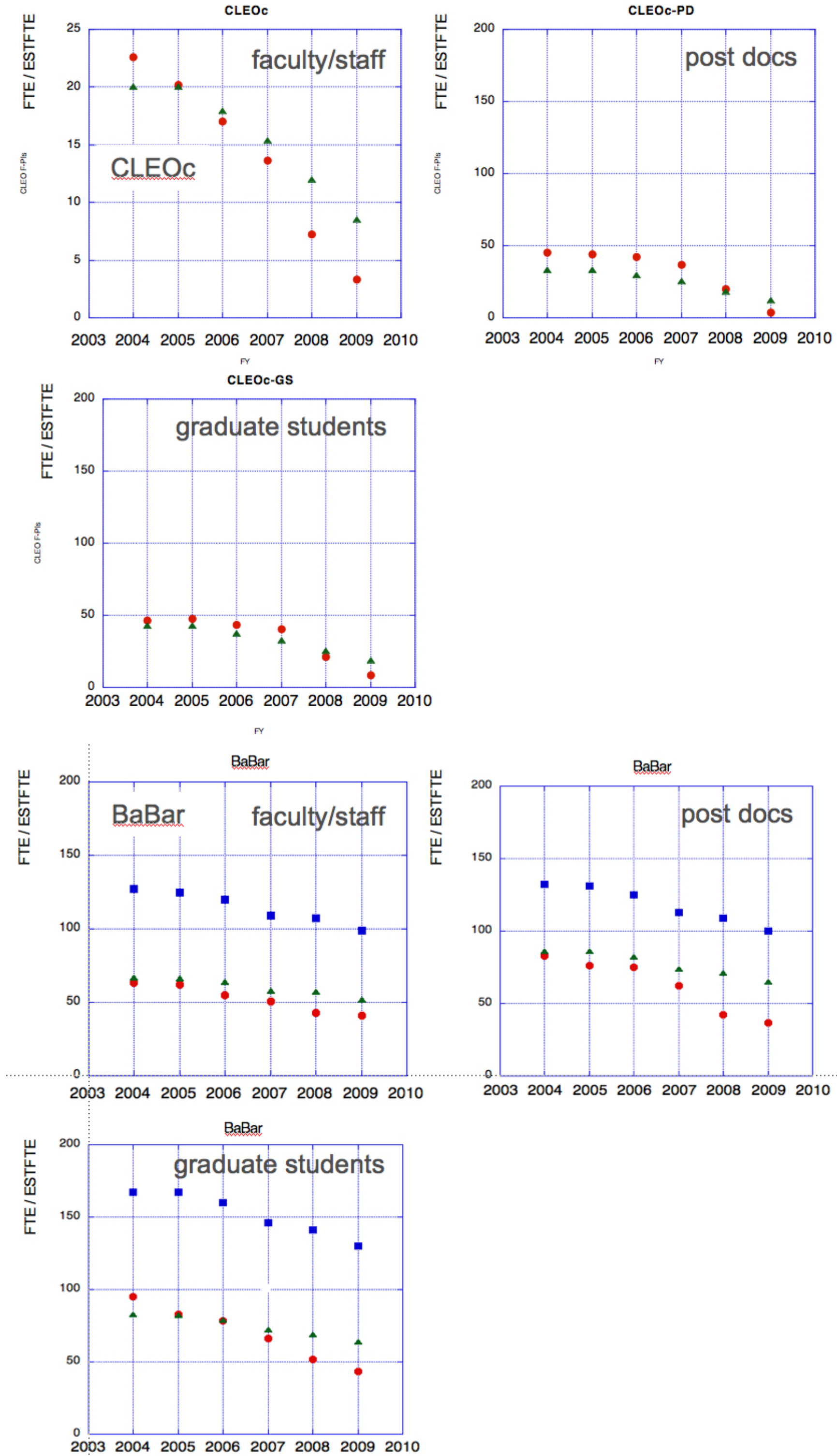

Figure 12: SP responses (blue squares for total, green triangles for U.S. component) compared with PI responses (red circles) for faculty, post docs, and graduate students. The top triplet is for CLEOc and the bottom triplet is for BaBar.

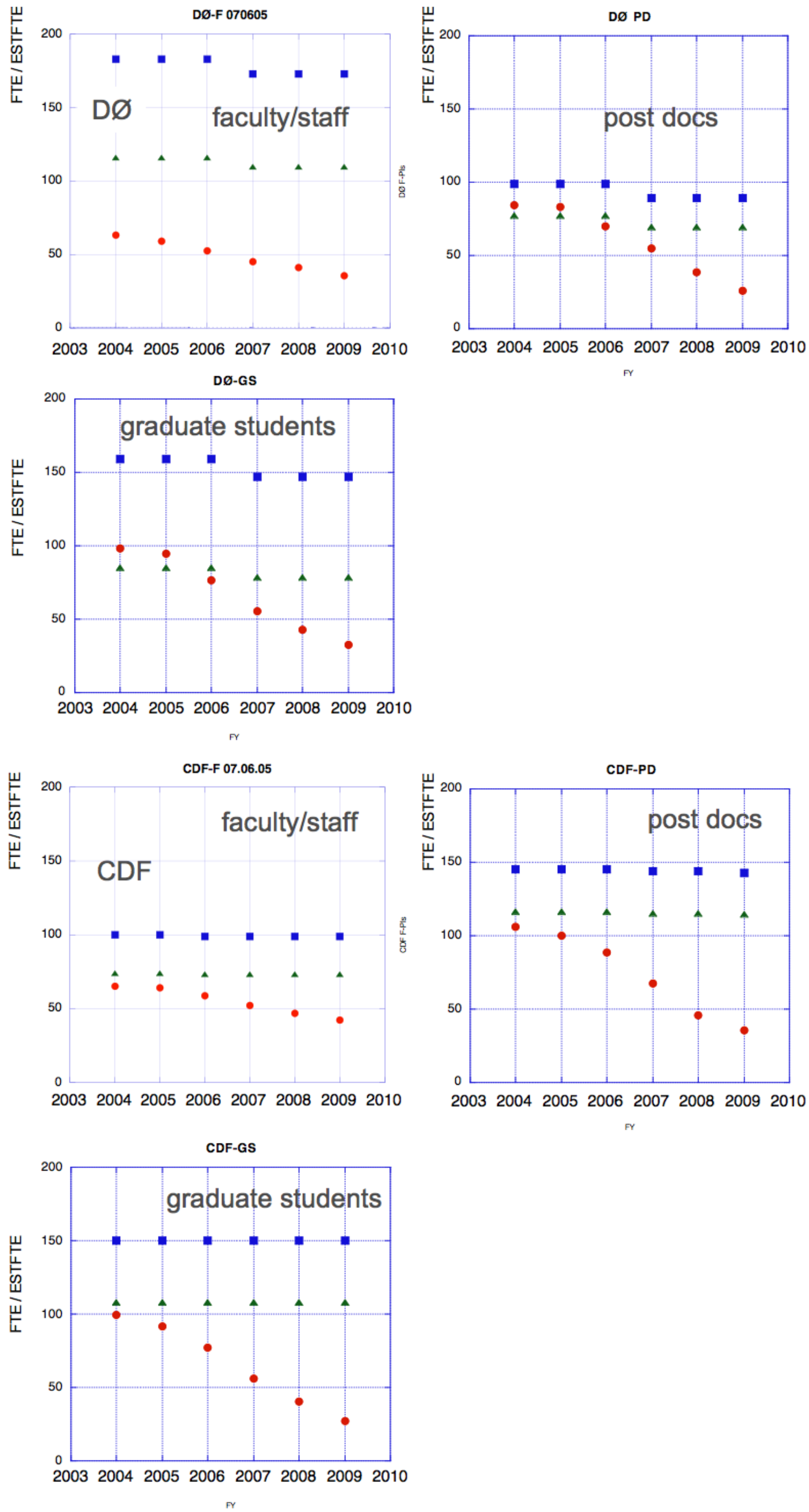

Figure 13: SP responses (blue squares for total, green triangles for U.S. component) compared with PI responses (red circles) for faculty, post docs, and graduate students. The top triplet is for DØ and the bottom triplet is for CDF.

points: anticipated needs from the experiments compared with an extrapolation of current effort from the PIs.

Here is where you come in: To help us address this important issue, please provide us with the following information under the assumption that your funding will correspond to a constant level of effort starting in FY2004 and going through FY2009. Partly as a result of this study, we will learn whether this is an acceptable assumption or not, but please use it for answering this survey. Please note that you are being designated as the only contact person for your grant, so let us know quickly if you wish to re-assign this responsibility to someone else.

Attached is an excel spread-sheet (labeled Your group) to format your response in order to provide uniform data. The spread-sheet (labeled Example) contains an example of a hypothetical groups entry to help you. Please enter information in the Yellow areas.

Issues:

1) For this survey, we are only interested in personnel who appear in the mastheads of publications and contribute to the maintenance, operations and/or analysis of experiments. Definitions of FTE for Faculty (Fac): enter the fraction of the persons RESEARCH time; Research Scientist (RS): enter the fraction of the persons TOTAL time; Postdoc (PD): enter the fraction of the persons TOTAL time (realizing that part of their activities will likely be data analysis); Graduate Student (GS): enter the fraction of the persons TOTAL time (realizing that part of their activities will likely be data analysis);

2) IF you have strong reasons to change the assumption of constant level of effort (eg a new faculty member coming in a particular year), please state your reasons.

3) Note that the first year of this survey is an accounting of your current effort and as such are presumably precise numbers. Since the strategy for the survey is constant effort, the sum of each category of personnel is expected to remain equal to the FY2004 totals (although see note 4) through the FY2005-2009 period. Please estimate the split among projects with the realization that the accuracy may only be at the level of 0.5 FTE.

4) Since there may be cases where you wish to change FTEs between categories, for this study please use the following conversions: 2 postdocs = 1 Research Scientist or 1 other; and 2 graduate students = 1 postdoc. While these are not intended as direct financial equivalents, they may be useful guides for converting effort between classes of individuals.

5) Please include physicist efforts on both accelerator experiments as well as non-accelerator projects (eg CDMS, GLAST). In addition, please include past (eg analysis continuing), current and future projects.

6) Finally, since there are personnel funded in some groups that receive support from off-base funds (such as project funds, funding from your Department or from your State, etc), please identify the number and type of such people supported in your group for FY2004. We do not ask you for future commitments of this type in future years. These personnel should be listed as Others and will only appear in the 5th line of Table 2 in the spread-sheet. If case of questions, comments, etc, please contact one of us.

In order to report to HEPAP promptly, please try to respond to this request by Thursday, September 30, 2004. We would like as many responses as possible by this date, but we fully realize that with the summer and the approaching start of university semesters this may be hard. Please do your best!

Finally: please send your completed excel file and any questions to:

hepexp@pa.msu.edu

7.4.2 To Experimental Spokespersons

The letter sent to the spokespersons of DØ CDF, BaBar, Minos, BTeV, CLEO, MECO, KOPIO, MiniBooNE, SUPER K, Atlas, CMS, SNAP, STACEE, VERITAS, LIGO, AUGER, MINERvA is below. Included was a spreadsheet which is imaged following the letter. August 30, 2004
To: U.S. Spokespersons of major HEP experiments
From: Jim Whitmore and Chip Brock, for the HEPAP Working Group on Physicist Resources
Re: Request from HEPAP to Experimental Spokespersons
Incl: Working Group Membership; Example; Excel workbook (separate attachment)

We have a rich physics program involving two categories of experiments during the 2004-2009 timeframe: those either currently running or those coming on line. These experiments involve considerable public investment and literally thousands of person-years and it is essential that we plan to fulfill these obligations through to publication of physics results. The first step to developing such a plan is a careful understanding of our physicist resources. Accordingly, at the April 2004 HEPAP meeting, a basic question was asked: Does the field have the people to adequately carry out the experiments to which it is committed until the end of the decade?

In order to address this question, Fred Gilman, Chair of HEPAP, has formed a Working Group to consider this matter, with Chip Brock and Jim Whitmore designated as co-chairs. The following is the charge to this group:

(Charge followed)

As you can see, this is a two-pronged approach:

1. Each NSF and DOE supported university and laboratory group is being asked how it expects to distribute its current resources among various projects, through FY2009 as a constant-effort evaluation.

2. This message to you is the complementary survey of experiments for an evaluation of their needs for the same time period: What are the required levels of effort needed to keep your experiment running and producing physics results/publications through FY2009.

The working assumption behind this approach is that these two surveys will provide two data points: anticipated needs from the experiments compared with an extrapolation of current effort from the PIs.

Here is where you come in: To help us address this important issue, please provide us with the following information. Please note that you are being designated as the only contact person for your experiment, so let us know quickly if you wish to re-assign this responsibility to someone else. We realize that some of you have been through a similar exercise several months ago when Fred and Chip asked for current and future estimates of physicist resources needs. The discussion by HEPAP of that exercise has prompted this more in-depth analysis as follow-up.

This present request is now for a bottoms-up estimate of your needs, starting with this year (FY2004) and projecting through FY2009 with a special emphasis on making sure that data from each experiment are in the same currency. The original spreadsheet from last spring has been intentionally replicated as much as possible. So, please assess your needs to maintain and operate your experiment at a realistic minimum level of effort. There are two emphases in this assessment: a reasonably precise accounting of the current effort within your experiment (the FY2004 numbers) and an accurate estimate of your experiments needs for out-years. In order to be concise, were trying to assess these needs within two broad areas:

a) Maintenance and Operations[5]

(including Construction & Commissioning for experiments approved and under construction and/or undergoing upgrades), largely focused on data-taking operations with respect to detectors and beams and

b) Data Analysis[6].

It would be helpful if you would include short notes on what issues may constitute the high-priority attention in each of the coming years within these categoriescomment areas are included in the spreadsheet. At the very bottom of the spreadsheet is an open area for Any general comments. In this area you can put any information that you think would be of value to the survey.

It is expected that many people will carry multiple roles within your collaboration. For FY2004, this should be relatively straightforward. For the out-years, we realize that this is an estimate, with decreasing precision as time goes on. Wherever appropriate, please give your needs estimates in terms of FTEs of various categories of collaborators, using the following metrics:
Notes:

For this survey, we are only interested in physicist effort: personnel who appear in the mastheads of publications and contribute to the maintenance, Operations and/or Analysis of your experiment.

Definitions of FTE for Faculty and Laboratory Scientists (Fac): enter the fraction of the persons RESEARCH time. Please break out faculty as sum total US University/Lab Scientist and non-US institution for 2004 only.

Postdoc and Research Scientists (PD): enter the fraction of the persons TOTAL time (realizing that part of their activities will likely be data analysis); Please break out post docs as university, non-US institution; and host laboratory for FY2004 only.

Graduate Student (GS): enter the fraction of the persons TOTAL time (realizing that part of their activities will likely be data analysis) Please break out graduate students as total US University and non-US institution for FY2004 only.

[5]Operations with respect to computing would include those efforts that go toward regular, production data handling and initial data reduction: operating analysis farms, maintaining cluster operations, scheduling job submission on (sometimes worldwide) clusters, and database designs and maintenance. Physicists from laboratories and universities often lead these efforts. So...the key for overall Operations is on the continuing, largely predictable, tasks of operating (or constructing/commissioning) equipment, taking and processing data and making it available.

[6]Analysis would center on development, including algorithm development for object id and device calibrations, as well as physics results analysis and Monte Carlo development. As "regular" physics analyses proceed, ID, scale determination, things involving deep detector understanding, are often revisited and pursued in parallel or in concert with the physics groups. So, we explicitly include these activities within Analysis, and recognize that predictability is more complicated than for Operations.

Uncertainty

This is a difficult exercise. Except for the FY2004 census (which should be nearly exact), extrapolation involves estimates of varying degrees of confidence. We hope that you can estimate to 10% for Operations, at least. Attached is an excel workbook to format your response in order to provide uniform data. It contains two worksheets, the first one (labeled FORM) is the blank form. Please fill out only the yellow spaces. In the second worksheet (labeled EXPT A) is a very simple example, the characteristics of which are attached as at the end of this document.

If case of questions, comments, etc, please contact one of us. Also an FAQ website has been established for the parallel PI survey and as they become available, entries from questions regarding this survey will be added. The URL for the FAQ page is:

http://www.pa.msu.edu/~brock/file_sharing/FAQ_survey.htm

In order to report to HEPAP promptly, please try to respond to this request by Thursday, September 30, 2004. We would like as many responses as possible by this date, but we fully realize that with the summer and the approaching start of university semesters this may be hard. Please do your best! Please send your completed excel file and any questions to: hepexppa.msu.edu

The Physicist Resource Working Group Illustrative Example

In order to clarify what FTE meanshere is an example for a overly simplified, fictional collaboration for EXPT A (corresponding to the EXPT A tab in the workbook):

FY04: 100 total authors 40 faculty (the FTE measure is research time, presumed to be 50% of their clock time)

- split 30 US and 10 foreign

- 20 of the US faculty and all foreign faculty are full research-time on EXPT A

- 10 of the US faculty are split evenly between EXPT A and some other experiment

- all faculty are presumed to be full-time analysis

- so, the total faculty FTE for EXPT A = 20+5+10 = 35 10 US lab physicists (FTE measure is research time)

- all lab staff are presumed to be 50% analysis and 50% operations

- so, the total faculty + lab staff FTE for EXPT A = 35 + 10 = 45 30 graduate students (FTE measure is clock time) (20 US, 10 foreign)

- 20 graduate students presumed to be 100% analysis (10 US, 10 foreign)

- 10 graduate students presumed to be 100% operations (5 US, 5 foreign) 20 post docs (FTE measure is clock time) (14 US; 6 foreign)

- all post docs are presumed to be 50% analysis

- all post docs are presumed to be 50% operations

FY05: needs

Include an upgrade to a detector component that will require 2-equivalent additional FTE post docs for operations for one full year. The analysis needs are presumed to have not changed from FY04. FY06: needs

Commissioning of the upgrade: this only requires 1 FTE post doc. Since the new device will require less effort in maintenance than the old one (which required 2.5 FTE post docs), there will be a net reduction, compared to the FY2004 level, of 1.5 FTE post docs.

The analysis needs are presumed to have not changed from FY05.