Report on the Scientific Review of the Forward Silicon Vertex (FVTX) upgrade for the PHENIX Experiment.

Review held on July 9,10 2007

This document, focusing upon the FVTX, is edited from the Report of the committee, which reviewed the FVTX and Nose Cone Calorimeter (NCC) upgrades together.

Executive Summary

The Department of Energy (DOE), Office of Nuclear Physics (NP) completed its Scientific Review of two proposed detector upgrades to enhance the relativistic heavy ion and proton spin physics research programs of the PHENIX (Pioneering High Energy Nuclear Interaction eXperiment) Experiment at RHIC. A panel of six experts convened at Brookhaven National Laboratory (BNL), Upton, New York on July 9-10, 2007, and evaluated the proposals titled "Technical Design Report for a Nosecone Calorimeter (NCC) for the PHENIX Experiment" and "Technical Design Report of the Forward Silicon Vertex Tracker (FVTX)" submitted by BNL.

The scientific merit of the proposed research by the PHENIX collaboration was judged to be important by the review panel. The proposed FVTX and NCC detector upgrades provide PHENIX with new capabilities with the potential for making quality measurements that could yield significant physics results.
The panel members raised questions about the ability to extract physics results using the proposed detectors, including their integrated performance in PHENIX. The significance of the proposed research depends on the ability to extract physics results and the sensitivity that can be reached for several key measurements identified in the proposals. For some measurements the review panel believed that while conceptual arguments were presented which appeared plausible, interesting and significant, the progression from measurement to physics interpretation to advancement of the primary goals was not always clearly demonstrated. They believed that the ability to extract physics results from these key measurements needed to be demonstrated through realistic and complete simulations.

These simulations need to be finished with high priority so that the level of detector performance can be established. The high-level performance parameters for the FVTX detector upgrade were deemed appropriate for the identification of displaced vertices.

The impact of the results of the proposed measurements, if obtained as claimed, would be significant in the context of current and planned world-wide capabilities. Notably, the semi-leptonic decay of beauty/charm quarks measurements, χ_c production and photon-hadron correlations, are unique to RHIC and complementary to ALICE and CMS heavy ion experiments at higher beam energies. The direct photon data needed to access gluon polarization $\Delta G(x)$ will not be available anywhere outside of RHIC. The $\delta q(x)$ transversity measurement, if feasible, could have a significant impact, providing better statistical accuracy than can be obtained elsewhere. The proposed capabilities of PHENIX were not compared to those being developed by the STAR collaboration so the reviewers were not able to evaluate how unique the PHENIX measurements will be at RHIC.

The PHENIX collaboration needs to clarify the role and utility of the FVTX and NCC detector upgrades in determining the flavor dependent longitudinal quark spin, $\Delta q(x)$, through the decay of $W^{\pm}$ bosons.

The reviewers considered the method of extraction of the flavor dependent quark polarization from muon tagged W's to be difficult due to high backgrounds and the lack of sufficient kinematic information to determine the Bjorken x of the quark interaction. Improving the Bjorken x resolution would increase the significance of the impact of the $\Delta q(x)$ measurements on the broader international effort.

The PHENIX collaboration should identify the effort of the key research groups who will develop and lead the new detector capabilities for producing science. The panel could not evaluate the commitments of the research groups as the PHENIX collaboration did not present detailed workforce projections that were requested in advance of the review.

The ability to extract physics results from these detectors is essential to the success of their planned science program. The two recommendations made in this report must be addressed before proceeding to the technical reviews of the detector upgrades.

DOE Recommendations

I. Each detector group should demonstrate and document scientific feasibility for two or more topics of high importance and submit to DOE for evaluation. PHENIX should submit to DOE a report documenting these studies for evaluation, prior to a technical review.

Introduction

On July 10th, 2007, the Director of the Research Division of the Office of Nuclear Physics (ONP) completed a Scientific Review of two proposed detector upgrades of the PHENIX Experiment at RHIC. A panel of six experts (Dr. Robert Roser, Fermi National Accelerator Laboratory; Dr. Paul Reimer, Argonne National Laboratory; Dr. Hartmut F.W. Sadrozinski, University of California, Santa Cruz; Dr. Lanny Ray, University of Texas, Austin; Dr. Hank Crawford, Space Sciences Laboratory, University of California, and Prof. Michael Murray, University of Kansas) met at Brookhaven National Laboratory (BNL) and evaluated the proposals titled “Technical Design Report for a Nosecone Calorimeter (NCC) for the PHENIX Experiment” and “Technical Design Report of the Forward Silicon Vertex Tracker (FVTX).” Dr. Gulshan Rai, Program Manager for the Heavy Ion Nuclear Physics Program, chaired the review, and Dr. Gene Henry, Director for the DOE Nuclear Physics Research Division, Dr. Jehanne Simon-Gillo, Director of the Facilities and Project Management Division, and Dr. Brad Tippens, Program Manger for the Medium Energy Nuclear Physics Program, were also present.

The main goals of the Relativistic Heavy Ion Collider (RHIC) research program at Brookhaven National Laboratory (BNL) are the discovery of the novel ultra-hot, high density, state of matter predicted by the fundamental theory of strong interactions and the elucidation of the spin structure of the nucleon.

The PHENIX experiment is one of two highly successful, large-scale experiments operating at RHIC, participating in the discovery of the strongly interacting Quark-Gluon Plasma (sQGP) and publishing initial results for the contribution to the proton spin by gluons (i.e. $\Delta G(x)$, at $x \sim 0.1$).

Motivated by discoveries made at RHIC, the PHENIX collaboration believes it has identified compelling questions and thus new scientific opportunities that require capabilities beyond the baseline PHENIX detector configuration. The collaboration has proposed the construction of two supplementary detector upgrades: the Forward Silicon Vertex Tracker (FVTX) and the Nose Cone Calorimeter (NCC). The extended capabilities provided by these modest detector upgrades are also formulated in BNL’s 5 year (thru ~ 2011) mid-term strategic plan for RHIC.

The FVTX is designed to complete, together with the barrel VTX, the 4π spatial coverage of the interaction region of PHENIX with pixilated silicon sensors. The FVTX detector is expected to determine the position of displaced event vertices to better than 100μm within 2π coverage in φ and rapidity range coverage of 1.2 to 2.4. The FVTX technology concept is well advanced, with detailed plans existing for the silicon elements, readout chips and electronics. A new readout chip, designed to enable the FVTX signal to participate in the level 1 trigger, is being designed and is the R&D critical path item.

The primary purpose of this review was to evaluate the scientific merit, significance and feasibility of attaining measurements utilizing the proposed FVTX and NCC detector upgrades. The Office of Nuclear Physics needed to understand what important progress in scientific knowledge will occur after the new capabilities become operational. In carrying out this charge, each panel member was asked to evaluate and comment on:

- The significance of specific scientific questions identified by the community and laboratory which they believe can be addressed by data acquired during the first three years of operations;

- The feasibility of the approach or method proposed to carry out the proposed program;

- The impact of the planned scientific program on the advancement of nuclear physics in the context of current and planned world-wide capabilities; and

- The experimental and theoretical research efforts and technical capabilities needed to accomplish the proposed scientific program.

The result of this review would establish the scientific need for the new capabilities, and in turn, the critical technical performance parameters necessary to assure that the science can be accomplished. In addition, collaboration plans would be examined to establish the commitments and resources of principal investigators and their research groups who will support and exploit the future new capabilities.

The review consisted of formal presentations made by the proponents of the NCC and FVTX proposals. The agenda included a question and answer session and closed executive sessions for panel deliberations. The review was concluded by the Heavy Ion Program Manager who conveyed his preliminary analysis of the reviewers' concordant remarks as well as critical opinions in a close-out session with BNL and PHENIX management.

The panelists were also asked to submit their individual evaluations and findings in a "letter report" covering all aspects of the charge letter. The executive summary and the accompanying DOE ONP recommendations are based largely on the information contained in these letters reports. A copy of the charge letter (Appendix A) and the agenda (Appendix B) are included.

The significance of specific scientific questions identified by the community and laboratory which they believe can be addressed by data acquired during the first three years of operations.

the FVTX’s capability to resolve displaced event vertices includes the following:

- observation of color screening in heavy ion and d + Au collisions by resolving the J/ψ, ψ' and ϒ mesons in the forward muon arms;

- determination of the heavy quark energy loss mechanism via detection of displaced vertices of open charm and beauty decays (D, B🕘 ➚+X, B🕘J/ψ + x 🕘 x+μ+μ);

- determination of the gluon spin contribution to the proton, ΔG(x), at low x ($\sim 10^{-3}$) via heavy quark production;

- distinguishing the quark and gluon orbital angular momenta (L_z) contributions to the proton spin;

- determining the gluon Sivers distribution from D-meson production; and

- testing the non-universality of the Sivers function by comparing DIS with Drell-Yan production; QCD predicts that the Sivers effect measured in DIS and Drell-Yan production will have opposite signs.

The panel believes the gamma (γ)-hadron/jet correlations, χ_c states and the charm and beauty measurements are significant goals for the Heavy Ion research program while the gluon polarization (ΔG) determinations via A_{LL}^{γ}, transversity distributions determined through single spin asymmetries and the test of the Sivers effect in Drell-Yan reversing sign from that of Deep Inelastic Scattering (DIS) are recognized as significant goals for the Spin Program. The most important of these is considered to be the low x determination of ΔG(x). Overall, the review panel believes the physics case for the proposed research is generally strong, but they are critical in their remarks on several key topics. The proponents of the detector upgrades had presented many conceptual arguments which appeared plausible and interesting, but the passage from measurement to physics interpretation was not clearly demonstrated. The reviewers’ reports point to a lack of quantification on how most measurements would be used to answer the primary physics questions outlined in the two proposals.

It should be noted that much of the science associated with the NCC proposal such as the ΔG at low x and the χ_c measurements require the presence of the FVTX and/or the VTX to obtain the desired performance from the NCC. The NCC alone would not be sufficient.

The W physics program is recognized as one of the driving forces behind the 500 GeV Spin Program. PHENIX proposes to measure the flavor separation of quark and anti-quark distributions, $\Delta q(x)$, through the decay of $W^{\pm}$ bosons. The proposals indicated the two detector upgrades were important for reducing background for tagging W production by high p_T muons. During the review, the FVTX and the NCC were presented as merely helpful to the W program, and there was some confusion as to whether the background suppression would be accomplished by an absorber alone, the FVTX and NCC, or some combination. The PHENIX collaboration needs to clarify the role and utility of the FVTX and NCC detector upgrades for the W physics program soon since that program is expected to start in the next few years. Due to the brief presentation made at the review, the panel requested a more detailed presentation of the W program on the second day. The reviewers considered the method of extraction of the flavor dependent quark polarization from muon tagged W's to be difficult due to high backgrounds and the lack of sufficient kinematic information to determine the Bjorken x, the momentum fraction carried by the participant quarks. The proponents showed a Δx resolution of ± 0.1 at $x = 0.5$, which is considered to be marginal for the physics goals. The reviewers considered this poor resolution would weaken the potential impact of these measurements on the broader international effort.

The feasibility of the approach or method proposed to carry out the proposed program

For both the FVTX and NCC detector upgrades, the panel found the presentations and documentation lacked specificity as to how many of the proposed measurements could be carried out, and in turn, how they would advance the scientific goals. The panel was not able to evaluate the feasibility of several important measurements.

In this regard, for both the Spin and Heavy Ion Programs, the PHENIX collaboration should have focused on a few important measurements where it had clearly demonstrated efficacy, feasibility and completeness of analyses. The reviewers' reports provide more detailed feedback on the issue of demonstrating feasibility, and thus, two recommendations are made following specific commentary on each proposed detector.

Forward Silicon Vertex Detector

A major concern with the FVTX is the lack of a simulation study demonstrating track matching between the FVTX and the muon arms. This is a very challenging task and should be done with realistic backgrounds in the FVTX and with the various configurations required to do the different physics programs, such as including the NCC and any additional absorber.

Heavy Ion Program:

The FVTX will be able to measure distance of closest approach (DCA) of charged particle tracks from the primary collision vertex. The ability to resolve the displaced vertex, requiring a resolution of ~100 μm, appears to be achievable. It was stated in the proposal and during the presentations that track matching was simulated using ideal tracking in the FVTX. The panel views the task of track matching from the outer to inner tracking detectors, where the track density is increasing, as being "notoriously" difficult. The identification of open charm and beauty decays relies on well-matched tracks and the observation that the decay muon that comes from a beauty meson typically has a larger pt with respect to the original meson than the decay muon that comes from the original D meson. These shortcomings suggested the identification method was at best statistical and, therefore, the FVTX group had not demonstrated the separation of beauty mesons from charmed mesons. Simulations with full FVTX tracking with realistic hit position errors and expected backgrounds are needed to demonstrate the feasibility of the proposed FVTX physics program.

The analysis required to reach the physics understanding was largely unelaborated. It was not demonstrated how the energy loss would be investigated for the heavy quarks in a correlation measurement. In a gamma-jet analysis the energy of the parton can be determined from the gamma in a 2-body collision; but it was not shown how this tagging could be used to look at heavy quark propagation effects in the medium created in Au+Au collisions.

The panel believed the FVTX is a valuable addition to the background elimination by cutting out muons from light quark decays that could allow reconstruction of ψ'.

Spin Program:

HERMES and COMPASS have measured Δq with Semi Inclusive Deep Inelastic Scattering (SIDIS), and it will be studied at JLab with the 12 GeV Upgrade. At PHENIX, Δq is extracted from the asymmetry measurements of the decay of the W bosons. In principle, this represents a much cleaner method for doing this measurement, since no knowledge of fragmentation functions is needed. In PHENIX, W bosons are tagged solely by the observation of a very high p_T muon. Unfortunately, there exists a significant background from lower p_T muons that are erroneously reconstructed as high p_T muons. It was claimed that this background could be removed by an additional absorber and by a number of additional cuts on the data; however, this was not demonstrated. The reviewers thought that this measurement might be plausible without the FVTX, although the FVTX could reduce the background by several orders of magnitude.

The determination of Δq (the "W physics program") is the driving physics behind the 500 GeV spin program. It was difficult for the panel to evaluate that driver given the very brief treatment presented at the review. The current default plan is to install a sufficiently thick absorber that reduces the hadronic background but this plan may have adverse consequences for the Heavy Ion program. The FVTX will be used instead of the absorber if sufficient background rejection can be demonstrated. The panel found it difficult to assess the feasibility of a W physics program and the respective roles of the FVTX and NCC upgrades. W studies in the proposal are still in the early stages and the track fitting uses perfect pattern recognition rather than full track finding. This could have a bearing on overall efficiency. A clear path moving from the identification of a W candidate based upon a stiff isolated muon track to performing a measurement on the W-asymmetry was not presented.

The panel believes the most important spin result possible with the FVTX and the NCC is ΔG(x). Clean and redundant determinations of ΔG(x) at low x from measurements of different processes or "channels" are necessary to understand the proton's spin. Even so, the most theoretically simple determination of this function will come from the direct photon measurement in the NCC. At RHIC energy, heavy flavor is produced through gluon-gluon interactions and so the measurement of A_{LL}^{QQbar} determines the square of ΔG (*i.e.* there is no sign information). Using the FVTX, the uncertainties in this measurement are decreased by a factor of approximately 5. The FVTX appears to be effective in the reduction of background contamination that in turn reduces the systematic scale uncertainty in the measurement from 40% to 10%. Still, the ability to distinguish between beauty and charm production was not demonstrated. Since these mesons have substantially different A_{LL} values the quality of this separation will contribute substantially to the extraction of ΔG.

In the regime of transverse spin physics, non-zero single spin asymmetries were initially measured by Fermilab E704. These effects could be attributed to initial state Sivers distributions, final state Collins fragmentation, or higher twist effects. Many single spin asymmetry experiments have difficulty disentangling the competing Sivers and Collins effects, although HERMES has demonstrated the existence of both effects. Theoretical efforts are underway to link the Sivers distributions to the orbital angular momentum (L_z)

of the partons in the nucleon. This is the remaining unmeasured element of the “spin crisis.” The FVTX group will attempt two Sivers measurements:

1) For the Sivers distribution of gluons, the FVTX will tag D decays in single spin asymmetry (SSA). The c-cbar pair is formed either through g-g fusion or s-channel q-qbar annihilation. At leading twist, the interacting gluons carry no *transverse* spin and so the final state charm quarks will not exhibit any Collins fragmentation effects, providing a clean probe of the Sivers gluon distribution. The FVTX has sensitivity to this in the central x_F region. Both the VTX and FVTX upgrade have access to this physics, but the proposal isn’t clear on how well the measurement can be done with either one alone or the combined pair.

2) The Sivers distribution in DIS is of the opposite sign from the Sivers distribution in Drell-Yan production. The FVTX should be able to measure the Sivers distribution in Drell-Yan production which can then be compared to existing DIS measurements. Predictions give a 1-10% asymmetry for RHIC. This measurement requires very high luminosity (~250 pb^{-1}) with transverse beam polarization.

Recommendations:

I. Each detector group should demonstrate and document scientific feasibility for two or more topics of high importance and submit to DOE for evaluation. PHENIX should submit to DOE a report documenting these studies for evaluation, prior to a technical review.

nuclear physics in the context of current and planned world-wide capabilities

The proposed capabilities of PHENIX were not compared to those being developed by the STAR collaboration. Therefore the panel could not evaluate the broader impact at RHIC of these upgrades. PHENIX presented little information on the scientific impact of the ongoing VTX detector upgrade, particularly regarding its Beauty and Charm measurement program. Despite the lack of information, reviewers found:

PHENIX proposes to measure the flavor separation of quark and anti-quark distributions, $\Delta q(x)$, through the decay of $W^{\pm}$. Previously $\Delta q(x)$ has been measured through semi-inclusive DIS (SIDIS) at HERMES and in the future at the 12 GeV JLab. The W decay measurement, in principle, offers a much cleaner theoretical interpretation since it does not depend on extensive knowledge of fragmentation functions.

QCD predicts that the Sivers effect measured in DIS and Drell-Yan will have opposite signs. This is a fundamental prediction that must be tested according to one reviewer's opinion. The PHENIX measurement of Drell-Yan will be sensitive to the sea and valence quarks. The PAX experiment at FAIR (GSI) will provide a complementary measurement for valence quarks on the same timescale.

The $\delta q(x)$ transversity measurement, if feasible, will have a significant impact on the field of transversity. Similar data will be available from HERMES and COMPASS (and eventually JLab 12 GeV operations). PHENIX will benefit from better statistical precision than the HERMES or COMPASS measurements, although no direct comparison was shown. Data from the JLab 12 GeV Upgrade will be at a significantly lower Q^2 making it more difficult to interpret. Overall, while these data will not be unique, they have the potential of being of significantly better quality in terms of statistical precision and theoretical interpretability.

Recommendations: None

The experimental and theoretical research efforts and technical capabilities needed to accomplish the proposed scientific program

Experimental Research Effort

The PHENIX collaboration did not present detailed workforce projections that were requested in advance of the review. The panel could not evaluate the commitments of the research groups who would lead and exploit the new capabilities.

Theoretical Research Effort

Further development of theory is needed to reliably extract some of the spin observables. Given their importance, opportunities exist for BNL and the RHIC collaborators to drive the theoretical effort

The theoretical framework to extract $\Delta G(x)$ from the direct photon measurement appears to be well established and has already been used in pervious data analyses. To place the Sivers and $\delta q(x)$ transversity measurement in the overall context of the proton's fundamental properties, significant theoretical work is still needed. According to one reviewer, there is a large and continuing effort to do just this. The $\delta q(x)$ measurement also requires knowledge of the Collins fragmentation functions. These are being measured at Belle in e^+e^- collisions.

The panel believes the measurement of $|\Delta G(x)|$ through D and B decays will not be as significant as the direct photon data because only the absolute value is measured and heavy flavor production is not as clearly understood. It will also be difficult to determine the x-dependence of ΔG from the measured p_T dependence—a topic that was not addressed. The theoretical path to extracting $|\Delta G(x)|$ from A_{LL}^{QQbar} is still under development. Thus these data are not theoretically as clean as prompt photon data for extracting $\Delta G(x)$.

Transverse spin physics is an emerging field and significant theoretical work is needed to understand the meaning of the proposed measurements of the Sivers distributions. In particular, the connection between the Sivers distribution and orbital angular momentum is not well established. The panel thinks this work is being undertaken by numerous groups worldwide. This work is apparently being driven by experiments outside the RHIC program.

Forward Silicon Vertex Detector

The FVTX has many small international and U.S. partners, and strong management will be important. While there is some common workforce between the FVTX groups and the groups involved in the ongoing construction of the PHENIX vertex detector (VTX), the reviewers believe coordination of effort could be better.

The panel believes much work has been done on the mechanical layout to reduce incompatibilities.

Technical Comments:

The critical R&D tasks to be performed on FTVX are:

- Development of the readout ASIC FPHX

This is an ASIC based on an existing version developed for BTeV, allowing data driven operation. In addition, it is a low-power ASIC. Two groups are involved (LANL and FNAL). Changes required are reduction of the gain and in the number of readout channels/chip. This development is on the critical path.

- Silicon sensor development

There is some uncertainty in the specifications (e.g. AC- vs. DC-coupling) which should be clarified soon, since it impacts the ASIC design.

- Data transmission

Data are being continuously transmitted while the detectors are active. The immunity to pickup on the long data lines on the HDI's should be tested soon.

- Read-Out Controller

The FPGA-based ROC is central to the DAQ system and needs careful software design.

- Software

The FVTX tracking code needs to be upgraded to permit full end-to-end simulation and reconstruction of events.

The panel believes the high-level technical performance parameters for the FVTX are appropriate for the identification of displaced vertices.

Appendix A: Charge Memorandum

The Physics Research Division of the Office of Nuclear Physics is organizing a Science Review of the Forward Vertex Detector (FVTX) and the Nose Cone Calorimeter (NCC) for the PHENIX detector at the Relativistic Heavy Ion Collider (RHIC). As you are aware, this review will take place at Brookhaven National Laboratory (BNL) on July 9-10, 2007. The Laboratory should submit on behalf of the PHENIX collaboration a proposal for each detector to the Office of Nuclear Physics by June 29, 2007.
The primary purpose of this review is to evaluate and articulate the merit and significance of the proposed scientific program for the FVTX and NCC for the PHENIX detector at RHIC. Specifically, this office would like to evaluate what important progress in scientific knowledge will occur within the first three years after the new capabilities become operational. In carrying out this charge, each panel member is asked to evaluate and comment on:

- The significance of specific scientific questions identified by the community and laboratory which they believe can be addressed by data acquired during the first three years of operations;

- The feasibility of the approach or method proposed to carry out the proposed program;

- The impact of the planned scientific program on the advancement of nuclear physics in the context of current and planned world-wide capabilities; and

- The experimental and theoretical research efforts and technical capabilities needed to accomplish the proposed scientific program.

The results of this review should establish the scientific need for the new capabilities, and in turn, the critical technical performance parameters necessary to assure that the science can be accomplished. The review presentations should present a plan that identifies, as specifically as possible, research groups and leaders who will support and exploit the new capabilities to address the proposed scientific program.
Dr. Gulshan Rai will be the chair of this review assisted by Dr. Brad Tippens. Please coordinate with Dr. Rai concerning the contents of the proposal and other materials to be provided by the Laboratory to the reviewers. The first day will consist of presentations by the Laboratory and the PHENIX collaboration, and executive sessions. The second day will include executive session and report writing, and brief close-out. The panel members have been instructed to contact Kelly Smith at BNL at 631-344-4901 or E-mail at kellys@bnl.gov regarding any logistics questions. Word processing and secretarial assistance should be made available during the review.

I greatly appreciate your efforts in preparing for this review. It is an important process that allows our office to understand the scientific need for the projects as well as their feasibility. I look forward to a very informative and stimulating visit.

Sincerely,
Eugene A. Henry
Director
Physics Research Division
Office of Nuclear Physics

Appendix B: Agenda and List of Reviewers

Physics Building, Room 2-160
BNL, July 9-10

<u>July 9</u>
8:30-9:00 Exec session
9:00-9:20 BNL overview (15+5) Tom Ludlam
Role of FVTX and NCC in BNL's scientific planning for RHIC
9:20-9:50 PHENIX upgrade program (20+10) Ed O'Brien
Role of FVTX and NCC in PHENIX scientific program and impact on the advancement of nuclear physics in the context of planned and worldwide capabilities.
9:50-10:40 Physics motivation NCC+FVTX: HI (30+20) Axel Drees

- *Scientific questions (Heavy Ion) that drive these upgrades*
- *Feasibility of the proposed upgrades to address these questions*

10:40-10:55 Break
10:55-11:45 Physics motivation NCC+FVTX: spin (30+20)
Matthias Grosse-Perdekamp

- *Scientific questions (Spin) that drive these upgrades*
- *Feasibility of the proposed upgrades to address these questions*

11:45-1:00 Working lunch (exec)
1:00-1:55 NCC concept and implementation (40+15) Richard Seto

- *Detailed presentation of feasibility: design parameters; simulations; etc.*
- *Analysis and theoretical effort required to achieve results in the first 3 years of operation*

1:55-2:40 NCC Status; R&D; scientific & technical resources (30+15)
Edouard Kistenev
2:40-3:00 NCC Discussion (20)
3:00-3:15 Break
3:15-4:10 FVTX concept and implementation (40+15) Melynda Brooks

- *Detailed presentation of feasibility: design parameters; simulations; etc.*
- *Analysis and theoretical effort required to achieve results in the first 3 years of operation*

4:10-4:55 FVTX Status; R&D; scientific & technical resources (30+15) Dave Lee
4:55-5:15 FVTX Discussion (20)
5:15-7:00 Exec session
<u>July 10</u>
8:30-9:00 Exec session

9:00-10:30 Follow-up discussion: homework results
10:30-4:00 Panel work (working lunch)
4:00-4:30 Closeout

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