Review of the PHENIX Forward Calorimeter (FOCAL)

Brookhaven National Laboratory, January 19th, 2009

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(I) Executive Summary

We thank the FOCAL group in PHENIX for the clear presentation of the large body of work it has carried out in preparation of a proposal for a new forward electromagnetic calorimeter (FOCAL) in PHENIX. The proposed upgrade promises to significantly improve the ability of PHENIX to contribute to four core components of the RHIC science program as defined through NSAC milestones:

(a) Determination of the gluon polarization $\Delta G(x)$ at low x and measurement of the integral gluon spin contribution, $\Delta G=\int_0^1 \Delta G(x)dx$, to the proton spin (NSAC milestone HP12-2013).
(b) Study of nucleon structure in Nuclei at small x. (NSAC milestone DM8-2012).
(c) Tests of fundamental QCD predictions for transverse spin asymmetries in jet-photon production (NSAC milestone HP13-2015).
(d) Measure jet and photon correlations in A+A collisions from medium RHIC Energies (NSAC milestone DM10-2010).

For the formal FOCAL proposal we recommend to focus on the first three milestones. We also point out that the precise knowledge of parton distribution functions in nuclei at

low x will make it possible to describe the initial state in heavy ion collisions at RHIC and the LHC quantitatively and thus remove the fundamental initial state uncertainty that presently limits the comparison between theory and experiment in heavy ion physics.

The FOCAL physics program critically depends on its ability to reconstruct photons in proton-proton and deuteron-ion collisions. The simulation studies presented suggest that photon measurements in the FOCAL will be feasible. However, it will be necessary to adapt the simulation to the latest detector configuration. It will be valuable to compare the simulation to the detector response that will be observed in the planned beam tests of FOCAL brick.

The proposed tungsten-silicon sampling calorimeter technology appears to be the only technology able to provide this capability in the limited space available in PHENIX. We notice that this technology has been used previously in various cosmic ray experiments and has been under study for application at the International Linear Collider by the CALICE collaboration. The FOCAL has sought advice from groups and individuals that have significant previous experience with this technology and we recommend further strengthening of these collaborative efforts.

The physics program described by the FOCAL group is of high scientific importance. In its present detector configuration PHENIX completely lacks the ability to make contributions in addressing HP13-2015. PHENIX appears also limited in its capability to probe nucleon structure at low x (DM8-2012 and HP12-2013). The proposed forward electromagnetic calorimeter promises to greatly enhance the physics capabilities of PHENIX in these highly important areas of the RHIC program. Therefore, we strongly encourage the FOCAL group to carry out simulation studies that will demonstrate the impact of future FOCAL measurements in these three areas: detailed and quantitative comparisons to existing experimental capabilities in PHENIX and STAR will help to present a strong case to funding agencies. It will be important to develop presentation material that is clear and accessible explaining the physics case, hardware and technology choices as well as the simulation studies. We recommend strongly that PHENIX management should support a aggressive R&D schedule that will make it possible to develop a full proposal by the Fall of 2009.

It appears that a significant effort will be necessary to carry out the required simulation work and to establish the feasibility and the unique contributions of the FOCAL in thorough simulations that include event generation, GEANT, reconstruction and analysis of the Monte Carlo data. We recommend to form 4 FOCAL physics study groups (d-A, heavy ion, Delta-G and transverse spin). In order to have a proposal ready by September it appears that each group requires an experienced group leader at 0.2 FTE and 1 (for Delta-G) or 2 (all others) graduate students or postdocs at 0.5 FTE each. PHENIX management should assist in forming these groups. Presently, such a group already has been formed for transverse spin and strong leaders are in place for the heavy ion and Delta-G study groups. A leader for the d-A study group needs to be identified and a total of 5 graduate students or postdocs at 0.5 FTE each in addition to the manpower available in the transverse spin study group.

(II) The Physics Case

II.1 Polarization of the Gluon Field in the Proton

Findings:
The measurement of the gluon polarization is a NSAC milestone. The measurement of the gluon polarization at low x and the determination of the first moment of the gluon spin distribution, that is the total gluon spin contribution to the proton spin, are of great scientific importance. Advanced simulations including the FOCAL response were presented for direct photons. Event generator level simulations are available for double spin asymmetries in di-hadron production. Simulations for gamma-jet were not shown.

Comments:
To truly address the impact of the FOCAL to the measurement of $\Delta G(x)$ at small x and its first moment, it is important to base the simulations on the latest understanding of the polarized parton distributions, DSSV, and fragmentation functions, DSS. We suggest to use the large error bands for DSSV at low x to demonstrate the impact the FOCAL will have in determining the gluon distribution at small x. It is also interesting to provide simulations for GS-C as a prototype of a gluon polarization with a large contribution at low x.

Emphasis should be given to show that having a FOCAL will in fact allow access to the *x*-distribution of the Gluons directly without making model assumptions on the *x*-shape of the polarized Gluon distribution. Having such data would challenge the current model assumptions made on the shape of the polarized Gluon distribution and would allow determining a true systematic error on the shape assumption. A powerful channel for this should be double spin asymmetries in jet-photon production. We note that the PHENIX abilities to measure jets still will have to be established both at mid-rapidity with the VTX and the central arms as well as with the FOCAL in the forward direction.

No comparison with existing capabilities in STAR and PHENIX and their physics reach was given.

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Recommendations:
(1) A physics study group should be formed to fully explore the possibilities to measure the gluon spin distribution with the FOCAL. In addition to it's leader (at 0.2 FTE) we expect that 1 graduate student or postdocs at 0.5 FTE will be needed to complete the necessary simulation work in time for a proposal

(2) Use DSSV for polarized PDFs and DSS for fragmentation functions.

(3) Study the potential of jet-photon production towards sensitivity at low x and the ability to resolve the x-dependence of the gluon polarization. We believe that it will be necessary to study PHENIX' ability to measure jets both with the FOCAL as well as with the VTX + central arms (this task should be shared with the d-A and transverse spin study groups).

(4) For all channels (A_{LL} for photons, di-hadrons, gamma-jet) carry out simulations at the event generator level with the detector response taken from the FOCAL test beam measurements in June.

(5) For the "highest impact channel" carry out detailed simulations: event generator followed by GEANT, detector response, reconstruction and final physics plots with comparisons to expectations from models. The detector response should be calibrated with results from the beam test of one FOCAL brick.

(6) Compare to existing capabilities in STAR and PHENIX.

II.2 Structure of Nucleons in Nuclear Matter

Findings: The study of nucleon structure in Nuclei at small x is a NSAC milestone. It is proposed to measure the gluon momentum distribution at low x in gamma-jet production. Simulation results for the jet finding efficiency in the FOCAL and the angular resolution for the jet axis were shown. Projected statistical errors for the ratio of $G_{Au}(x)/G_p(x)$ were shown and found to be as small as 5% for x~0.01. The scientific importance of the channel is well established and work on detailed simulation studies has begun.

Comments:
γ-jet correlations is the golden channel for the study of gluon distributions and their modification in nuclei, and seems to be the right choice for the signature physics in d+Au for the FOCAL. The physics to be pursued here is gluon saturation, or shadowing; the discussion should be not limited to just one model, the Color Glass Condensate (CGC) model that has been put forward to explain the dynamics of high gluon densities. Shadowing is an alternative picture for the depletion of low-momentum gluons but is either largely phenomenological or comes from models that treat the coherence effects in nuclear matter seen by a certain probe and production.

From the review presentation it remains unclear if the γ or the jet is to be detected (and triggered on) in the FOCAL. Plots in Mickey Chiu's talk show jets in the pseudo-rapidity range from 1.2 to 3 so apparently the jets would be in the FOCAL. If so, it is then unclear how well a calorimeter without a hadronic section can adequately measure jets. Similarly it yet has to be established how well jets can be measured with the VTX + central arms.

The EPS08 shadowing is extreme and can be excluded by the PHENIX J/ψ measurements in d+Au collisions, and probably by several other measurements. As a result, the range of the uncertainty of the nuclear modified gluon structure function is smaller.

A number of details from the simulations were left unanswered by the presentations. For example the actual size of the fiducial area used for the gamma-jet simulations, the fraction of fiducial area over the total active area, the meaning of the 15 GeV E_T jet cut

and the overall jet efficiency. It is important to better specify and address these details for the written FOCAL proposal.

The most important simulation result, $R_{pAu}(x)$, in Mickey Chiu's presentation (slide 14) shows the expected statistical uncertainties from the γ-jet measurement. It is unclear how complete a simulation was performed to obtain this result and it is also unclear if the present FOCAL layout was used. Systematic uncertainties will play an important role in measuring $R_{pAu}(x)$ and presently have not been estimated. We suggest that the resulting uncertainties (statistical + systematic) be plotted for two sets of fake points, one for R_{pA} = 1.0 and one for EKS98 shadowing (similar to what has been done for different energy-loss theories in the FVTX physics justification). This allows one to evaluate how discriminating the measurements can be for distinguishing the different theoretical expectations, particularly on their deviation from no suppression (R_{pA} = 1). A few additional shadowing curves on the plot besides EKS98 (but not EPS08) would also be appropriate.

It is unclear what the integrated luminosities (p+p and d+Au) that are used here correspond to. They appear to be 240/10.7 = 22 times larger then p+p run-6, and 450/80 = 5.6 times larger than d+Au run-8. Are these luminosity projections from the CA-D five-year projection document? In the latest version (Fischer, 2/23/08) we find for "2013E", with a PHENIX factor of 1/3 (as seen in Run8 d+Au). For p+p, Max = 470 pb^{-1}, Min = 133 pb^{-1}; this seems consistent with the 240 pb^{-1} used here. For d+Au there seems to be no number in this document.

Recommendations:

(1) A physics study group should be formed to fully explore the FOCAL potential for d-A physics. In addition to its leader (at 0.2 FTE) we expect that 2 graduate students or postdocs at 0.5 FTE will be needed to complete the necessary simulation work in time for a proposal

(2) Emphasize the importance of these measurements not only in order to advance our understanding of gluon saturation physics, but also to provide a theoretically understood baseline for A+A measurements, and a critical baseline for the LHC heavy ion program where p+A measurements will be a long time coming, and where suppressed gluons will underlie all measurements and must be known. We suggest that this should be advertized as its own important physics motivation for the FOCAL upgrade, see section II.5.

(3) The main physics channel, gamma-jet, should be studied with the full simulation chain including event generation, GEANT, detector response to reconstructed $G_{Au}(x)/G_p(x)$.This simulation will have to be carried out with the final proposed FOCAL configuration (and not the old NCC configuration). We believe that it will be necessary to study PHENIX' ability to measure jets both with the FOCAL as well as with the VTX + central arms (this task should be shared with the two spin study groups).

(4) A complete explanation and full simulation needs to be provided for jet detection and triggering in the FOCAL.

(5) The range of uncertainties for the nuclear modification of the gluon momentum distribution GA(x)/Gp(x) should be not be based on ESP08, but on the more moderate PDF's such as EKS98.

(6) In addition to the focus on γ-jet correlations as a probe of gluon saturation at small x or forward rapidity, a number of other physics topics should be mentioned. We do not propose to carry out a full chain of simulations on these channels. However, it may be possible to back up these channels with fast simulations at the event generator level using parameterizations of the detector response from either GEANT or test beam results.

a. Anti-shadowing is supposed to occur at backward rapidity (moderate x). A 2nd FOCAL detector could naturally explore this region in d+Au collisions simultaneously with the studies of gluon saturation or shadowing at forward rapidity with the 1st FOCAL detector.
b. A precise measurement of χ_C in p+p and d+Au collisions would be an important piece of the quarkonia physics puzzle. Precise knowledge of the fraction of J/ψ's from χ_C in both p+p and d+Au is important for understanding the J/ψ, and for understanding cold nuclear matter effects on the χ_C compared to the J/ψ, which are probably substantially different and therefore interesting in their own right.
c. Can the detector address the mono-jet prediction of the Color-Glass Condensate model?
d. The measurement of two π^0's has the ability to isolate the precise x value of the partons that produce the π^0's, as discussed in the spin part of the FOCAL physics discussion. Is this not of interest here in d+Au collisions as well?

(7) Use consistent numbers for integrated luminosity for projections. The FVTX proposal for instance uses, 33 pb^{-1}/week for p+p, and 62 nb^{-1}/week for d+Au; consistent with the ratio between p+p and d+Au used here. In recent physics statements from the FVTX an integrated luminosity of 84 pb^{-1} for a run including all efficiencies has been used for p+p. The source of the integrated luminosity numbers should be precisely indicated, should be consistent throughout the discussion of the FOCAL physics expectations, and should match those used by other PHENIX upgrades.

(8) Compare to existing capabilities in STAR and PHENIX. Comment on competition from LHC (study of high parton densities in the forward direction in p-p).

II.3 Frontier in Hard Scattering QCD: Transverse Spin

Findings:
The physics case for transverse spin measurements with the FOCAL was presented. The transverse spin structure of the proton is an extremely active field currently, with great progress made both in theory and experiment over the past seven years. Quark transversity distributions remain as the last poorly known piece in describing the proton at leading-twist. The first moment of transversity distributions, the tensor charge, can be

calculated in lattice QCD ab initio. In addition measurements of transverse-momentum-dependent distributions such as the Sivers and Boer-Mulders distributions will provide information for first time on the dynamics of the partons within the nucleon.

The possibility of measurements of the transversity and Sivers distributions was discussed. The measurements include a test of the predicted process dependence of the Sivers distribution function via the transverse single-spin asymmetry of gamma-jet production. The photon would be measured in the FOCAL, while the jet would be reconstructed using the future silicon vertex detector (VTX) in PHENIX, plus the existing central arm spectrometers. Testing this process dependence would be a very high-impact measurement; the expected sign change of the asymmetry in semi-inclusive DIS versus hadronic collisions is a fundamental prediction in QCD. With semi-inclusive DIS measurements already available, the field is specifically awaiting experimental results from proton-proton collisions. The high importance of the measurement is reflected by the fact that it is an NSAC milestone, set for 2015.

The transverse spin physics capabilities of the FOCAL are still in the early stages of study and development; no simulations of expected detector performance relevant to transverse spin measurements were shown. A Transverse Spin Task Force (TSTF), formed shortly before the review, is actively working on the development of this part of the proposal.

Comments:
Without the forward calorimeter upgrade, PHENIX will not be able to achieve the transverse spin NSAC milestone. The anticipated physics result is of such fundamental importance to QCD that independent measurements with both RHIC experiments will help to achieve general acceptance of these RHIC results in the wider community. In order to reach the 2015 milestone, the FOCAL should be installed and commissioned no later than 2013.

Despite the present lack of detailed studies it seems clear that the FOCAL will significantly enhance the transverse spin capabilities of PHENIX. With he ability to measure neutral pions, direct photons, and jets over 2π in azimuth in a pseudo-rapidity region $1 < |\eta| < 3$, several straightforward inclusive transverse asymmetry measurements would become possible. The expected asymmetries would be large, $A_N \sim 0.1$ and significant interest from the field outside BNL would be certain.

One of the main capabilities gained by installation of the FOCAL would be the ability to measure forward jets; without the ability to reconstruct jets, it appears that the overall motivation for the detector would be significantly weakened. Careful studies of the jet capabilities in PHENIX, both for the FOCAL (and the VTX + central arms) will be needed.

Recommendations:
(1) A transverse spin physics study group has been formed. The study group should evaluate if it has sufficient manpower and should submit a informal but written simulation plan to the FOCAL project management by April. We estimate that the

manpower needed is 2 graduate students or postdocs at 0.5 FTE in addition to the study group leader at 0.2 FTE.

(2) Detailed studies should be performed to demonstrate that the FOCAL used in conjunction with the silicon vertex detector and central arm would in fact make the measurement of Sivers process dependence in jet-photon possible. Determine what minimum integrated luminosity would be needed to achieve the 2015 milestone. The group should be able to answer whether or not a staged approach to installation would impact achievement of this milestone.

(3) Demonstrate how well the transversity distribution could be accessed by measurement of the spin-dependent azimuthal distribution of neutral pions within jets, i.e. the Collins asymmetry for neutral pions. This measurement will require the reconstruction of jet-axis and jet-energy. It needs to be determined how well this can be done with the presented FOCAL layout as a electromagnetic calorimeters.

(4) Initiate studies of the possibility to measure transverse spin asymmetries with the FOCAL in Drell Yan e^+e^- production. Determine the minimum luminosity required for a measurement testing the process dependence of A_{UT} Sivers asymmetries in Drell Yan.

(5) Determine to what extent the transverse spin measurements enabled by the FOCAL complement/overlap with the capabilities of STAR.

II.4 Bulk Properties of Quark Parton Matter from Near Side Correlations.

Findings: The physics of near-side correlations observed in heavy ion collisions was presented. STAR first observed these correlations over large pseudo-rapidity intervals between the trigger and associate particle on the near side. This observation is referred to as the "ridge". It is believed that the ridge arises from the bulk media response to the ultra-relativistic final state particles emerging from hard scattering reactions in the medium. At the present time the origin of this near side correlations is poorly understood and additional data over large pseudo rapidity intervals and at high p_T will be needed to guide theory. The FOCAL can be used to study the ridge in combination with the PHENIX central arm detectors and the MPC with significantly larger rapidity intervals. The measurement will be performed with high p_T trigger gammas in the FOCAL to be correlated with hadrons and leptons in the central arm and neutral pions in the MPC. Leptons in the central arm in combination with information from the VTX should make it possible to tag heavy flavor production. Initial studies of gamma trigger efficiencies in the FOCAL were shown for central and peripheral events.

In addition to the study of near side correlations the following possible physics topics were mentioned.

- Study of energy loss in medium via π^0 R_{AA} at forward rapidity
- Direct photons
- Charmonium production and suppression: $\chi c \rightarrow \gamma + J/\psi$

- High resolution reaction plane determination for geometry and path length dependence studies
- Critical point search through E_T fluctuations

Comments:
The committee believes that the near side correlations first discovered in STAR warrant further study and if confirmed would provide a new highly interesting angle on the media response.

The significant increase of acceptance from the FOCAL for high p_T probes will have a dramatic impact on the physics with high p_T probes and particle correlations. However, it may be challenging to establish the centrality range for which measurements relying on photon-pion separation in the FOCAL will be possible. Despite these difficulties, the committee believes that the FOCAL will be heavily utilized for heavy ion physics in PHENIX.

Exploring exciting opportunities in heavy ion physics with the FOCAL will help to form a broad and strong group of "true scientific" FOCAL collaborators. Forming such a group, reaching from heavy ion physics to "A-dependence of nucleon structure" and "spin physics" will be necessary before PHENIX will be able to operate the FOCAL and to carry out FOCAL data analysis in the long-term.

For the proposal we recommend to focus on d-A including a determination of the initial state of heavy ion collisions and spin physics. This recommendation aims to maximize the chances of success for external review given the outcome of the previous NCC review process. In a second step it still will be highly important to establish the heavy ion physics case with the FOCAL through careful simulations.

Recommendations:
(1) A strong heavy ion physics study group should be formed. PHENIX management must assist in recruiting sufficient manpower. It seems that initially 2 graduate students or postdocs who can spend 50% or more of their time would be adequate. The leader of the study group should be available at the level of 0.2 FTE.

(2) We recommend that the heavy ion study group initially should focus on studies measuring the initial state for heavy ion collisions with the FOCAL (see II.5). We consider this area as very important for the success of the proposal. These studies should be carried out in close collaboration with the d-A physics study group.

(3) Following the studies on the possibility to determine the initial state in heavy ion collisions with the FOCAL the heavy ion physics study group should expand to other topics and carefully establish the utility of the FOCAL in heavy ion physics. Ridge physics appears to be the best starting point for such an effort The time scale for this effort stretches well beyond the proposal and review in the fall of 2009. We expect that

studying the FOCAL utility for the physics of bulk properties will require 3 graduate students or postdocs half of their time for 6 months.

(4) The impact of the FOCAL on the study of near side correlations should be determined with simulations that start from event generator (with embedded correlated pairs) over GEANT, detector response and tracking to the reconstructed ridge. Results from this study should be included in the proposal and review in the fall.

II.5 The Initial State in Heavy Ion Collisions

Findings:
This topic was not discussed in the review.

Comments:
Precise knowledge of parton distribution functions in nuclei at low x will be required to describe the initial state in heavy ion collisions at RHIC and the LHC quantitatively. It might be possible to obtain the initial state with good precision through photon-jet events in deuteron-ion collisions using the FOCAL and the PHENIX central arms. The precise knowledge of the initial state would remove the fundamental initial state uncertainty that presently limits the comparison between theory and experiment in heavy ion physics and enable the advertized program to explore the properties of the quark parton matter formed at RHIC quantitatively with the RHIC II luminosity and detector upgrades.

Recommendations:
(1) Consider the possibility to advertize the initial state uncertainty in heavy ion collisions as an important ingredient of the RHIC II physics program and study the possibility to precisely measure the initial state with the FOCAL in d-A collisions.

(2) The necessary simulation work should be carried out by the d-A and heavy ion physics study groups.

(III) Hardware and Technology

Findings:
A modified design (compared to the NCC) of a forward W+Si sampling electromagnetic calorimeter was presented. The material presented on the FOCAL hardware and technology was insufficiently detailed to allow for an in-depth understanding of the detector's technical design, features and expected performance.

The calorimeter is assembled from bricks. Each brick consists of a sandwich of tungsten plates and 21 500um thick silicon layers with $15x15mm^2$ pads and 8 layers of 300 um thick silicon layers with 0.5 mm wide strips. Each brick is divided in three longitudinal sections. The total thickness of the calorimeter is 21 electromagnetic radiation lengths. The energy resolution estimated from GEANT simulations is $\Delta E/E \sim 20.2\%/\sqrt{E} + 0.3\%$. The separation of overlapping photons is possible down to cluster separation distances of 3 mm, corresponding to a π^0 energy of 40 GeV.

At the front end an FPGA based pipelined signal processing is used to determine pulse height and timing information and to form trigger primitives. With this new concept a timing resolution of 0.5 ns is seen in simulations.

Comments:
From the information given it is not possible to assess the general risk for the proposed technology choice towards the successful completion of the project. A comparison with existing or planned tungsten silicon sampling calorimeters was not given.

The beam tests with a brick fully assembled and tested in test beam will answer questions that remained open during the review and will be very valuable as input for the external review in the fall.

The readout concept seems plausible, but needs to be checked for integration. The readout and trigger plans have not yet been vetted with PHENIX DAQ and trigger group.

It appears that the algorithm to extract the timing from the fADC has not been implemented in a FPGA and tested and it was not studied if the implementation of this algorithm may have an impact on the trigger latency or any other performance of the readout needed in the PHENIX front end/DAQ/trigger environment.

A quantitative discussion of the possible impact from radiation damage was not given.

The presentations did not clearly address what π^0 - γ separation can be really reached vs. momentum/energy of the particles.

A clear explanation why the hadronic part of the calorimeter was removed was not given. This decision seems especially strange as a lot of the physics presented calls for jet detection. This design choice should be much better motivated. This needs to be presented in upcoming reviews with greater clarity.

A discussion of the vendor justification for the silicon was not given. It should be stated if the decision was entirely based on cost or if there were there performance parameters (eg. radiation hardness) that determined the decision.

A breakdown of the FOCAL hardware project was not given. It is not clear what the sub tasks are or who the sub task managers are or what the institutional responsibilities are. Does this imply that all work will be done by the small BNL group with some external "vendor-groups" for tungsten, silicon and electronics?

Recommendations:
(1) It was stated during the review that the project is "shovel ready". We recommend generating the documentation that will demonstrate this as soon as possible. This will be needed for the FOCAL proposal and the external review in the fall and there is no reason to further wait. We recommend:

(I) Schedule review of FEE, DAQ & trigger by PHENIX DAQ group for April 2009.

(II) Schedule presentation of the FOCAL design at a DC upgrades meeting in the May core week. This presentation should make the case for the FOCAL design choice and should include (a) the mechanical design, discussion of related applications of W-Si technology (c) justification of the EMC design choice (ie. why is it ok to drop the hadronic section) (d) plans for brick beam test (e) discussion of radiation hardness (f) discussion of silicon vendor choices (g) discussion of project organization on the hardware side (sub-tasks, sub task leader, institutional responsibilities) (h) summary of the FEE, DAQ & trigger review in April.

(2) Provide write up of a quantitative discussion of issues concerning radiation hardness.

(3) Provide write up assessing technology choice and related risks in light of other applications of W-Si calorimeter technology.

(4) Provide a write up explaining vendor choices including the relevant performance criteria.

(5) Provide justification that proposed "jet-based" physics can be carried out with an EMC.

(6) The time measurement algorithm proposed should be implemented in an FPGA and tested. The timing resolution quoted seems very good; this numbers should be verified in the planned test beam.

(7) Carry out brick beam tests as soon as possible and use test beam results to provide detector response functions for the simulation effort.

(8) Provide organizational breakdown of the hardware project to PHENIX management (sub tasks, sub task leaders, institutional responsibilities) by the first week of April.

(IV) Organization, Management, Manpower and Schedule

Findings:

An overall schedule was presented for FOCAL North+South. The proposal will be submitted in 2009. Start of construction is foreseen in 2010 with a first large scale test in PHENIX in 2011. The first FOCAL will be completed in 2013 and the second FOCAL in 2014. A final decision with regards to the scope, two versus one FOCAL detector has not yet been taken.

The budget for one FOCAL side was given as $3.4 million. This was subdivided into a first installation stage (2012) with silicon pad readout for $1.9 million and a second

installation stage (2013) of strip readout planes for gamma-pion separation at $1.5 million. The funding plan is to apply for BNL capital funds for the first integration stage and for RIKEN or NSF funds for the second integration stage.

A list of 89 collaborators from 18 institutions was given. A discussion of management and project organization was not provided.

Comments:

The schedule is ambitious. Experience suggests that the full simulation and development of one of the physics topics according to the new DOE standards takes about 1 FTEY. We estimate that it will require about 3-4 FTEY to fully develop the proposal in all physics areas: low-x/d-A, gluon polarization, transverse spin and heavy ion physics.

The schedule discussion is very coarse and with the information given it cannot be determined if the schedule is close to a realistic scenario.

The costing base and the contingency estimates were not given and it is not possible at this time to evaluate the budget. However, reliable budget estimates will be important in weighing the different funding scenarios.

It is planned to use BNL capital to fund the first integration stage of one FOCAL. This might impact the ability of PHENIX to proceed on other projects that are also funded through BNL capital funds. The DAQ upgrade and possible replacements of the DCMs or the central tracking chambers come to mind as possible examples.

The plan to solicit funding from RIKEN will require strong participation from RIKEN personnel and the assignment of significant project responsibilities to RIKEN personnel. Likewise the plan to obtain funding from the NSF will require (a) strong University group(s) with strong leadership ability in the field of the proposed physics. Again it will be important to assign significant project responsibilities to these group(s).

From the presentation it is unclear how much manpower is available for the project. The list of institutions and collaborators contains groups and people that already have significant responsibilities in PHENIX and others who collaborate on external experiments. A project of this size will require about 15 FTE every year through completion of detector commissioning.

The organizational structure of the project was not discussed. It is unclear what the subtasks are and who the subtask managers are. It is unclear what the institutional responsibilities are.

Recommendations:

(1) Provide a revised list of collaborators, listing only collaborators who will participate with more than 0.2 FTE in calendar year 2009.

(2) Provide a breakdown of subtasks, subtask managers and institutional responsibilities. In addition to the technical tasks the full development of a physics channel should be defined as such a subtask (eg. d-Au physics study group). Schedule a review of the organizational structure by PHENIX management in May.

(3) With *great* urgency: provide sufficient manpower to the physics study groups. It seems that each group will need 1-2 graduate students or postdocs who can spend 50% (or more) of their time to develop a proposal by the fall. PHENIX management should assist with finding the necessary manpower.

(4) Report a detailed plan: schedule and leadership + manpower for the physics study groups to PHENIX management in April.

(5) Determine level of needed FTEs (for R&D, construction and operation modes) and if necessary engage in recruiting new collaborators.

(6) Provide budget with detailed information on costing base and contingency as input to a decision on the funding strategy. Schedule a PHENIX internal FOCAL budget review in June 2009 with the goal to decide funding strategy.

(V) Recommendations for the Near Term Schedule

Recommendations:
We summarize the meetings and reviews proposed in this document in order to prepare for a proposal and the subsequent external review of the project in the fall of 2009.

(1) First week of April, 2009: Provide written plan including schedule and leadership + manpower for the physics study groups to PHENIX management.

(2) First week of April, 2009: Provide written breakdown of the organizational structure for the hardware side of the project (sub tasks, sub task leaders, institutional responsibilities) to PHENIX management.

(3) April, 2009: Review of FEE, DAQ & trigger by PHENIX DAQ group.

(4) May, 2009: Review FOCAL technology and design choice for PHENIX DC. Present the material that will enter the proposal. Present also a detailed simulation plans + goals and review manpower and structure of the physics study groups.

(5) May, 2009: Review of organizational structure (sub-tasks, sub-task managers, institutional responsibilities, FTE available, FTE needed etc.) by PHENIX management.

(6) June, 2009: PHENIX internal FOCAL budget review.

(7) June or July, 2009: Organize workshop on Forward Physics with the PHENIX detector upgrades.

(8) July, 2009: Organize FOCAL collaboration meeting: results from brick beam tests, review simulation progress, define simulation tasks left open, assign proposal writing assignments.

(9) September, 2009: Present proposal to PHENIX DC&EC.

(10) October, 2009: External review.

(VI) Appendix

(A) Charge for the PHENIX Review of the Forward Calorimeter Upgrade

PHENIX is developing a plan to build a calorimeter that will enable the experiment to detect and measure jets and electromagnetic showers at forward pseudo-rapidities. The detector concept involves compact calorimeter modules composed of active silicon sensors with tungsten absorber to be positioned at the current location of the copper absorber on the PHENIX Central spectrometer magnet. The forward calorimeter (FOCAL) would be configured with four preshower silicon-strip layers and two longitudinal electromagnetic segments using silicon pad readout. Highlights of the physics objectives include:

- Measure ΔG over a broad x range through direct γ and two-π^{o} correlation measurements at forward rapidities.
- Measure contributions of quark angular momentum to the spin of the proton by studying transverse spin effects using γ + jet correlations.
- Study nuclear gluon pdf's by measuring γ + jet correlations in p+A or d+A collisions. Study gluon shadowing, anti-shadowing and Color Glass at high gluon densities.
- Use γ + jet and jet + jet correlations to study bulk medium properties of the sQGP in A+A collisions.

The charge to the review committee is to assess the state of the plans for the FOCAL. Determine whether the physics justification and technical design is sufficiently mature to proceed to the stage of writing a project proposal. Evaluate the appropriateness of the technology choices, the potential impact of the physics program and the likelihood the physics objectives can be obtained through the proposed approach.

PHENIX expects that the recommendations from this review will serve as an important guide to the writing of a detector proposal and valuable preparation for an external project review we anticipate holding in the next 9 to 12 months.

We request that the review committee provide an initial appraisal of all these issues at the conclusion of the review to be followed by a written report to BNL Management within three weeks of the meeting

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The review committee's evaluation of the PHENIX FOCAL project, even at this early stage, is a very valuable contribution to both PHENIX and BNL's effort to manage the project to a successful conclusion. Thank you for your willingness to participate in this process.

(B) Agenda for the Review of the PHENIX Forward Calorimeter (FOCAL)

Monday January 19, 2009 (Physics Building, Room 2-160)

10:00	Executive Session	
10:20	Scientific Motivation and Project Concept	R. Seto (30+10)
11:00	Longitudinal spin measurements, proton and nuclear structure (p+p, p+A, d+A)	M. Chiu (20+10)
11:30	Transverse spin measurements w/polarized protons	J. Lajoie (20+10)
12:00	Bulk medium property studies in A+A collisions	C. Vale (20+10)
12:30	Lunch	
1:30	Technical Design of FOCAL and Test Beam Plans	E. Kistenev (20+10)
2:00	FOCAL electronics	A. Sukanov (20+10)
2:30	Initial Project Plan, Cost and Schedule	R. Seto (20+10)
3:00	Break	
3:15	Executive Session	
3:45	Review Close Out	

(C) Review Committee

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