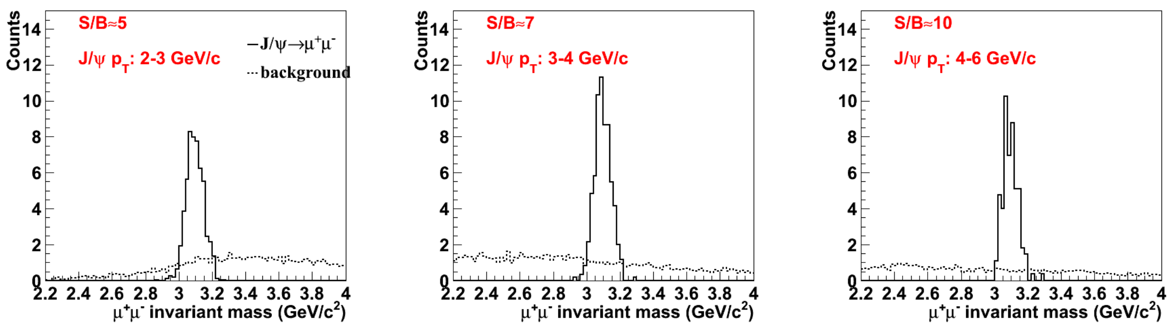
Reply to MTD review recommendations

Physics justification:

Recommendations:

Calculate the backgrounds vs. transverse momentum.

Reply: We simulated the expected di-muon invariant mass distribution from J/ψ and background in d+Au collisions as a function of transverse momentum (p_T). Please find the plots in three different p_T bins (2-3, 3-4, 4-6 GeV/c) below.



The p+p equivalent luminosity shown above is about 9 pb^{-1}. For the background reconstruction, the inclusive muon spectra in 200 GeV d+Au collisions were used. In central Au+Au collisions, the signal over background ratio for J/ψ is about 2/1 in 2-3 and 3-4 GeV/c and 3/1 in 4-6 GeV/c utilizing the inclusive muon spectra obtained in 200 GeV Au+Au collisions for the background reconstruction and assuming that J/ψ production follows N_{bin} scaling.

Identify the STAR group or groups that will be in charge of MTD physics analysis and detector operations once the detector is complete.

Reply: Several institutions in the MTD group will pursue research in MTD physics. These are BNL, UC Berkeley, UC Davis, Rice, USTC, TAMU, Tsinghua Univ., and VECC. There are also other institutions from STAR who are interested in the MTD physics. Below we list the topics and the institutions.
Upsilon dissociation and production mechanism: BNL, UC Davis, TAMU, Tsinghua Univ.
J/psi elliptic flow and nuclear modification factors: BNL, USTC, Tsinghua Univ.
e-muon correlations: BNL, LBL, Purdue, USTC
di-muon continuum: BNL, LBL, Purdue, Rice, USTC
Bottom production (B→J/psi X → di-muon X): BNL, LBL, Purdue, TAMU
Muonic hydrogen-like atoms: BNL, UC Berkeley, Kent, SINAP, VECC
Cosmic ray muon bundles: BNL, Rice

Once the detector is complete, the MTD will be maintained and operated as part of the existing TOF system. All operations and maintenance aspects for the MTD, which include the HV, LV, slow controls, and electronics monitoring, are the same or very similar to those in the existing TOF systems. The institutions that maintain TOF and will maintain the MTD are Rice, UT Austin and BNL.

Make the physics case of the MTD project crisper. Organization of topical workshops may be useful.

Reply: We are aware that, from theoretical calculations, there are factor-of-two uncertainties for quarkonium dissociation temperatures predicted by Lattice QCD. We have already had some internal discussions. We would like to hold a workshop of "quarkonia production and dissociation in heavy ion collisions" this summer after the Quark Matter 2011 conference.

Here we would like to remind you that among many exciting perspectives, we will be able to collect a large sample of J/ψ events and to separate different Upsilon states with a clear advantage over electron decay channels due to the reduced Bremsstrahlung radiation and Dalitz decay background. The MTD will also provide a unique measurement of $\mu-e$ correlations from heavy-flavor decays. Shown in the top frame of Fig. 8 is the $J/\psi \rightarrow \mu^+\mu^-$ with a signal-to-background ratio of 6:1. The background di-muon pairs are simulated from the inclusive muon yields obtained in d+Au collisions. In central Au+Au collisions, the signal over background ratio for J/ψ is about 2 utilizing the inclusive muon spectra obtained in 200 GeV Au+Au collisions for the background reconstruction and assuming that J/ψ production follows N_{bin} scaling.

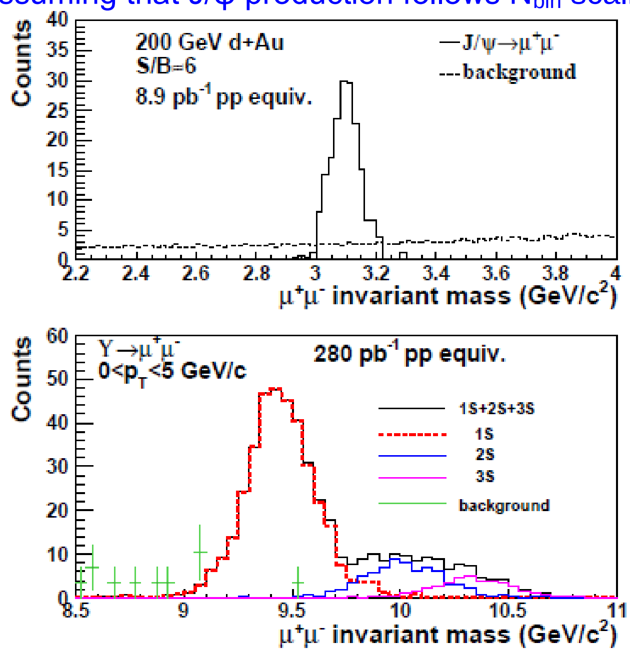


Figure 8. The expected di-muon invariant mass distribution from J/ψ and background in d+Au collisions (top panel); the invariant mass distribution of di-muon decayed from Υ at $0<p_T<5$ GeV/c (bottom panel). The different Υ states can be separated. The equivalent p+p luminosity is also shown in the figure.

Shown in the bottom frame of Fig. 8 is the invariant mass distribution of di-muons from Upsilon decays simulated in the STAR geometry. Clearly, the different Upsilon states (Υ(1*S*), Υ(2*S*), and Υ(3*S*)) can be separated through the di-muon decay channel while Bremsstrahlung energy losses of electrons present a challenge for the separation due to the detector material, including future inner tracker upgrades at STAR.

Another important physics topic at RHIC is to measure the thermal radiation signature using di-leptons in the intermediate mass region. The ccbar correlation contribution in this mass region has to be subtracted in order to obtain the thermal radiation spectrum. The future detector upgrade with the Heavy Flavor Tracker (HFT) at STAR will provide precise charm cross section measurements, however the measurements of *ccbar* correlations will still be challenging if not impossible. An independent approach is proposed with the proposed MTD, μ−*e* correlations, to measure the contribution from heavy flavor correlations to the di-electron or di-muon continuum. This will make it possible to access the thermal radiation in the intermediate mass region.

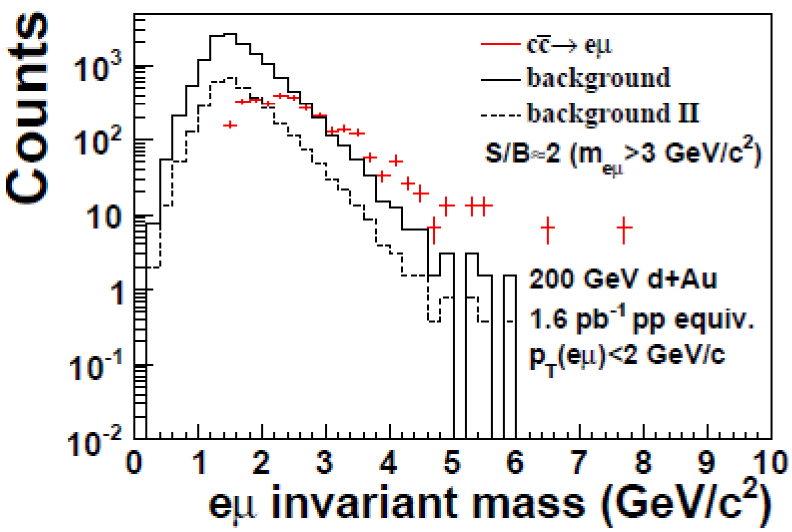


Figure 9. The expected electron-muon correlation from charm pair production and from random background in d+Au collisions. The equivalent p+p luminosity is also shown in the figure.

Shown in Fig. 9 are the simulation results of the electron-muon invariant mass distribution from charm pair production and from background. The cross symbols represent the signal. The solid line represents the background, obtained using random combinations between the photonic electron yields measured in d+Au collisions and inclusive muon yields shown in later sections. The signal-to-background ratio for charm pair production is 2:1, if the invariant mass of the electron-muon pair is larger than 3 GeV/c^2 and its p_T is less than 2 GeV/*c*. The photonic electrons can be paired with other particles in the TPC, which will lead to a factor of 2 rejection. The inclusive muons can be associated with the TOF hits, resulting in at least another factor of 2 rejection. If we include these rejection factors, the background will be reduced by a factor of 4, as shown by the dashed line. The signal-to-background ratio for the electron-muon correlation is significantly enhanced. In central Au+Au collisions, with the same cuts, the signal over background ratio is a factor of 6 smaller compared to what we show in d+Au collisions. Please note that we utilized the inclusive muon spectra as our input to estimate the background for *J/ψ*→*μ+μ-*, Υ→*μ+μ-* and *μ-e* correlations shown above. The timing cut was not applied to obtain the inclusive muon spectra thus it can be considered that our S/B estimation for the three physics measurements is conservative.

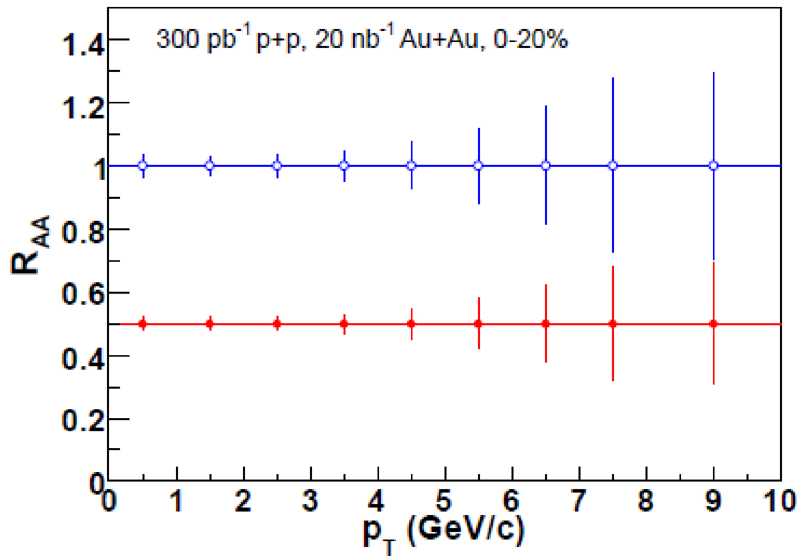


Figure 10. The J/ψ R_{AA} precision projection as a function of p_T with 20 nb^{-1} Au+Au and 300 pb^{-1} p+p collisions at 200 GeV with the optimized MTD system at STAR.

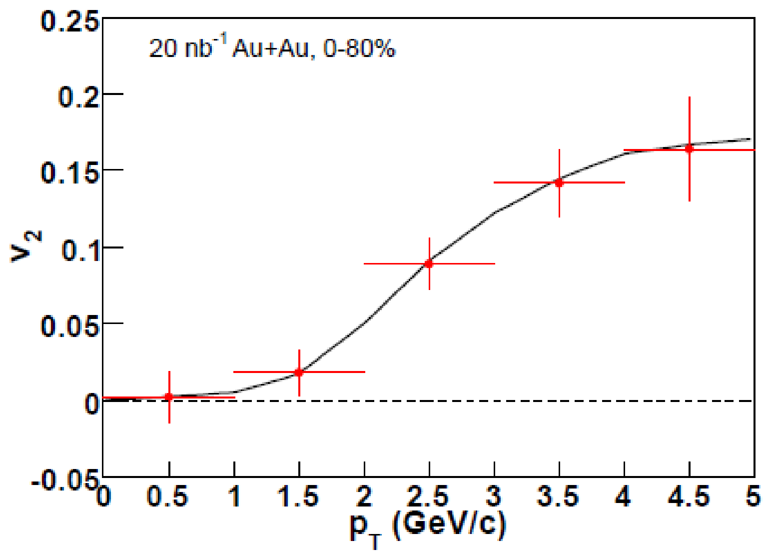
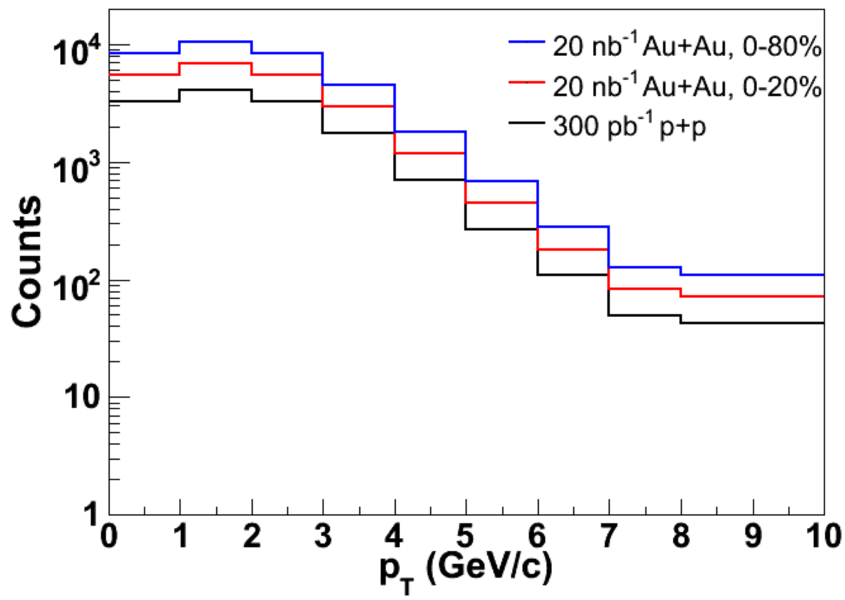


Figure 11. The J/ψ v_2 precision projection as a function of p_T with 20 nb^{-1} Au+Au collisions at 200 GeV with the optimized MTD system at STAR.

In the RHIC-II era, when 20 nb^{-1} and 300 pb^{-1} luminosity for Au+Au and p+p collisions is delivered, we expect to get precise *J/ψ* and Υ measurements in p+p and Au+Au collisions. Figure 10 and 11 show the precision projection of *J/ψ* R_{AA} and v_2 as a function of p_T .



The figure above shows the J/ψ yields versus p_T in 20 nb^{-1} Au+Au collisions and 300 pb^{-1} p+p collisions with the full MTD system.

Figure 12 shows the precision projection of Υ R_{AA} as a function of centrality. 20 nb^{-1} Au+Au collisions and 300 pb^{-1} p+p collisions have been used for the projection. These measurements are essential to advance our understanding of the QCD matter created at RHIC.

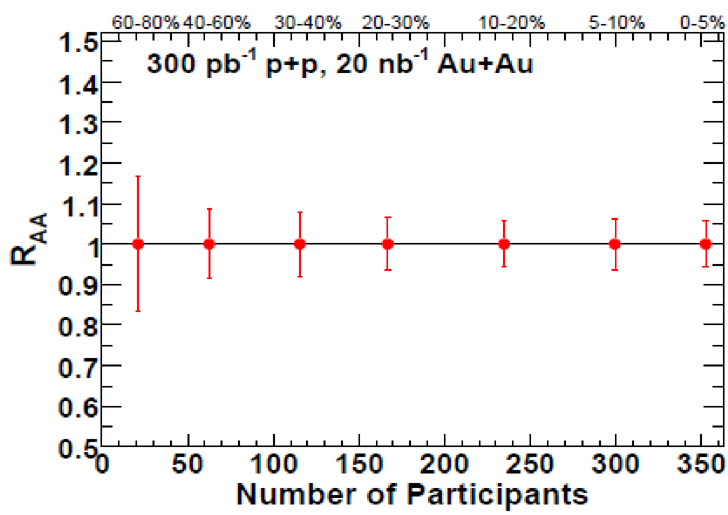


Figure 12. The Υ R_{AA} precision projection as a function of centrality with 20 nb^{-1} Au+Au and 300 pb^{-1} p+p collisions at 200 GeV with the optimized MTD system at STAR.

Compared to the di-muon decay, the di-electron decay channel from different Upsilon states either suffers from a low luminosity at low material budget or suffers from a high material budget at high luminosity era. For example, the precision projection for Upsilon(1S) decay into di-electrons at RHIC with low material budget (without HFT) is shown as the blue symbols in Fig. 13. 2 nb^{-1} Au+Au collisions is used for the projection. At RHIC II era, with 20 nb^{-1} Au+Au collisions, the precision projection for Upsilon(1S) decay into di-electrons is shown in red symbols. However, with HFT inner detector materials, the Bremsstrahlung radiation for the electrons will prevent a clear separation between different Upsilon states in the di-electron decay channel.

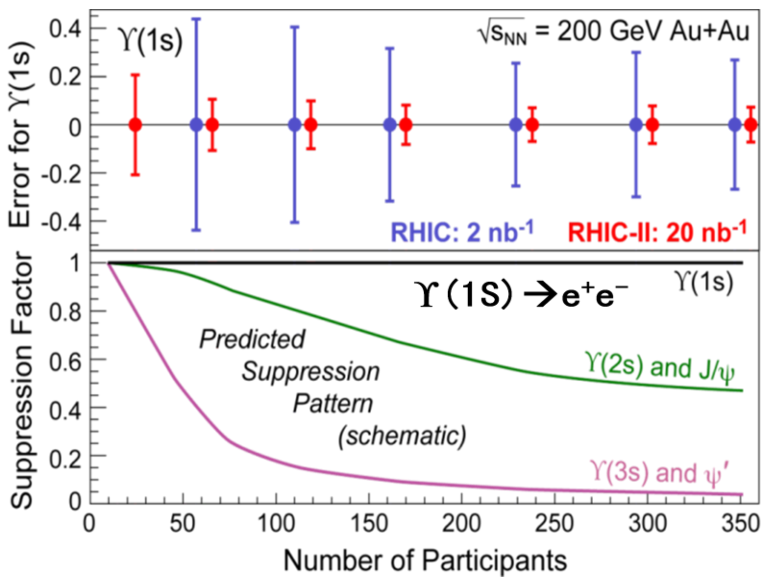


Figure 13. The precision projection for Upsilon(1S) decay into di-electrons versus centrality with 2 nb^{-1} and 20 nb^{-1} 200 GeV Au+Au collisions respectively.

Table 2 shows Y → μ^{+}+μ^{-} statistics at the RHIC-II era with the optimized MTD system at STAR.

Table 2. The Υ statistics estimation for different collision systems at RHIC-II era. Deli. Lumi.: delivered luminosity in 12 weeks in 2013. Samp. Lumi.: sampled luminosity in 12 weeks in 2013. According to the efficiency of STAR, we use 70% as the estimation. Min. Lumi.: required sampled luminosity with 10% precision on $\Upsilon(3S)$ state. Min. Lumi.II: required sampled luminosity with 10% precision on $\Upsilon(2S+3S)$ measurement.

collision system	Deli. Lumi.	Samp. Lumi.	Υ counts	Min. Lumi.	Min. Lumi.II
200 GeV p+p	480 pb^{-1}	336 pb^{-1}	930	420 pb^{-1}	150 pb^{-1}
200 GeV p+p	200 pb^{-1}	140 pb^{-1}	390		
500 GeV p+p	1200 pb^{-1}	840 pb^{-1}	6970	140 pb^{-1}	50 pb^{-1}
200 GeV Au+Au	22 nb^{-1}	16 nb^{-1}	1770	10 nb^{-1}	3.8 nb^{-1}

If indeed the luminosity and run plan do not allow a good measurement in 200 GeV p+p collisions, the relative yields of different Y states can be obtained from other beam energies as a baseline. The numbers shown in the table are mainly to show the yields based on various luminosities. The relative yields of Y(1S), Y(2S) and Y(3S) states have been measured at *pbar + p* collisions at CDF *sqrt(*s_{NN})= 1.8 TeV and at p+p, p+d, and p+Cu collisions at fixed target experiment with proton incident energy 800 GeV. The measurements indicate that the relative yield has little dependence on beam energy. At RHIC, the precise measurement on the relative yields of the three states in 500 GeV p+p collisions can provide the reference on the measurements in 200 GeV Au+Au collisions, thus whether the Y(2S) or Y(3S) state melts or not in Au+Au collisions can be determined and the temperature of the QGP can be inferred.

Design and Technology:

Recommendations:

Demonstrate performance of the MTD preproduction module and electronics design in a test beam and in the RHIC environment for Run-11.

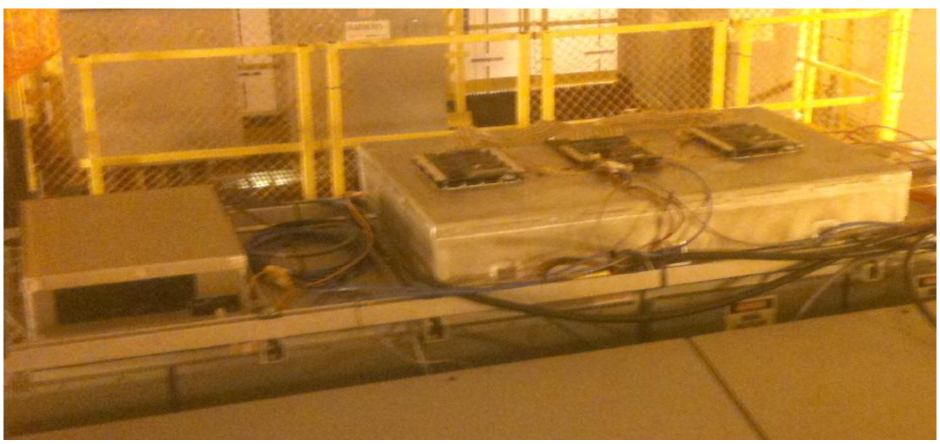
Reply: The status of the MTD11 production prototype project as of today (December 22, 2010) is as follows. Four complete mechanical structures were built and tested (three are needed for Run-11). Four large MRPCs (two from Tsinghua University and two from USTC) were delivered to UT-Austin. One of the MRPCs from USTC has five 250 µm gaps instead of the six 250 µm gaps used in the other modules. Four full trays were assembled at UT, each containing one MRPC and the complete electronics. The trays were sealed, leak-tested, filled with gas, and then tested in detail for HV stability and current, noise rates, and strip correlations. There are no dead channels, and the hits correlations (signals at the two ends of each strip) look very good. The noise rates and HV currents are low. Three of these trays (two of the 6x250µm modules, and one 5x250µm module) were delivered to BNL on December 12.

The mechanical support structures and various ancillary cabling (HV, LV, trigger information, clock, control cables, and gas tubing) between the platforms and the tray installation locations in STAR were installed by the STAR Technical Support Group in advance of this delivery.

The trays were installed on December 13, and Freon R134a gas flow was begun that same day. Two photographs of the three “MTD11” trays (one from the side and one from above), and a view of the “MTD9” prototype and the THUB DAQ interface that will read out all of the MTD trays, are shown below as presently installed for Run-11. The commissioning of the new DAQ interface, and the connections of these trays to the STAR Trigger system, is underway.

The voltage control software was updated. High voltage was applied to the MTD11 and MTD9 trays on December 16. All trays hold full voltage at reasonable currents. The work on the online monitoring software to accommodate the new trays during STAR shift operations is underway.

A workshop will be held in China March 30-April 1, 2011 before the mass production of the modules in China begins to discuss the module performance in the beam tests, with cosmic rays, and in STAR.



Budget, Schedule, Resources and Management:

Recommendation:

Revise the MTD project budget to include contingency at levels commensurate with typical DOE capital construction projects.

Reply: We have re-estimated the contingencies for all items the MTD project budget. The contingency estimation is based on risk factors and weights for technical, cost, schedule, and design aspects. The risk assignment method is identical to that of the STAR TOF project and similar to other DOE capital construction projects. A copy of the MTD project budget with contingency and a copy of the risk assignment procedure are attached.

Develop a resource-loaded schedule as soon as possible and present it to BNL Management. This will enable better management and tracking of the project in addition to a better understanding of the total project cost.

Reply: We have used Microsoft Project 2010 to produce an MTD project management file. Attached is the resource-loaded schedule.

Work with BNL Management to establish a realistic budget profile for this project.

Reply: We are working with BNL Management to establish a realistic budget profile for this project. A copy of the required funding by fiscal year based on the current MTD project management file is attached.

Comment: The collaboration assumes involvement of DOE supported institutions. An understanding and agreement with their respective research program managers about their work on this project should be sought as early as possible.

Reply: The spokesman has collected updated MOUs from all participating institutions. The project has been discussed with DOE program managers by the spokesperson and institutional PI's.