MVTX project

The sPHENIX detector, currently under development, is designed to study the microscopic nature of the quark-gluon plasma (QGP) by measuring ultra-high rates of fully reconstructed jets and high precision upsilon spectroscopy to determine the temperature dependence of the QGP. The experiment is aimed at addressing scientific questions prioritized in the 2015 NSAC Long Range Plan, especially enhancing the physics reach afforded by the Relativistic Heavy Ion Collider (RHIC). Bottom quark jets and B-mesons produced at RHIC offer a unique capability to understand the properties of QGP through studying the mass dependence of parton energy loss mechanisms in the QPG medium as well as the temperature dependence of QGP transport parameters.

Reconstruction and identification of B-mesons requires precision tracking close to the interaction point with high detection efficiency. The proposed upgrade of the sPHENIX experiment with a vertex detector (MVTX) based on Monolithic Active Pixel Sensors, located close to the interaction point, will ensure that sPHENIX is capable of performing such key measurements and will enable precision measurements of open bottom production at mid-rapidity over a broad momentum range around the b-quark mass where mass effects are expected to play most significant roles. The MVTX detector will also significantly improve charm baryon measurement and enable heavy-flavor correlation measurements at RHIC (see Appendix 1).

The MVTX detector will use the latest generation MAPS silicon sensors (ALPIDE) developed by the ALICE collaboration, providing a very fast integration time (a few micro-seconds) and very low material budget (less than 0.5% radiation length per layer). This will enable a high tracking efficiency and excellent impact parameter resolution, ideal for heavy quark reconstruction at the very high rates provided by RHIC. The main technical challenges are the development of the ALPIDE readout systems to meet the sPHENIX DAQ requirements, and the global mechanical integration of the MVTX with the rest of the sPHENIX tracking detectors. The LANL group is presently working on the readout R&D through LDRD support and will complete the final design of readout system in 2018. MIT will be leading the engineering design to fulfil the sPHENIX requirements, and the production of the support carbon structures will be performed by LBNL. A list of the main institutions and expected contributions is shown in Appendix 2.

The designs of the final MVTX readout and the conceptual mechanical systems will be completed through LANL's LDRD effort. This is not part of the requested project funds, but it is crucial to bring the project to a high level of maturity and to reduce the risks. The estimated cost of the final design efforts, procurement, assembly and installation into the sPHENIX experiment is estimated to be $6.6M. The cost includes 35% contingency and assumes production of the staves using the ALICE facility at CERN immediately following the ALICE production, which significantly reduces the cost and technical risks of the MVTX detector.

The MVTX schedule starts the first quarter of FY19 to be ready for beam in the 1st quarter of FY23. The schedule, cost and technical risks are optimized by concatenating the MVTX production at CERN to the ALICE production, which gives a window for MVTX production starting first quarter of FY19. One of the highest risks that would impact the project is that the ALICE CERN facility would no longer be available for MVTX. Mitigation strategies to address this issue would be to free some funds in advance to secure the production at CERN.

The preliminary organization of the MVTX project is presented in Appendix 3.

Appendix -1 Key Physics Measurements

The MVTX will enable precision measurements of open bottom R_{AA} and v_2 in sPHENIX via inclusive and exclusive decay reconstruction at low p_T covering down to nearly zero p_T and via the jet-tagging at high p_T covering up to 40 GeV/c in p_T. With the large acceptance of sPHENIX detector, MVTX will also open up other new heavy-flavor correlation measurements at RHIC. These studies are complementary to the heavy flavor program at LHC and must be done to achieve the science goals highlighted in 2015 NSAC LRP - "probe the inner workings of QGP by resolving its properties at shorter and shorter length scales."

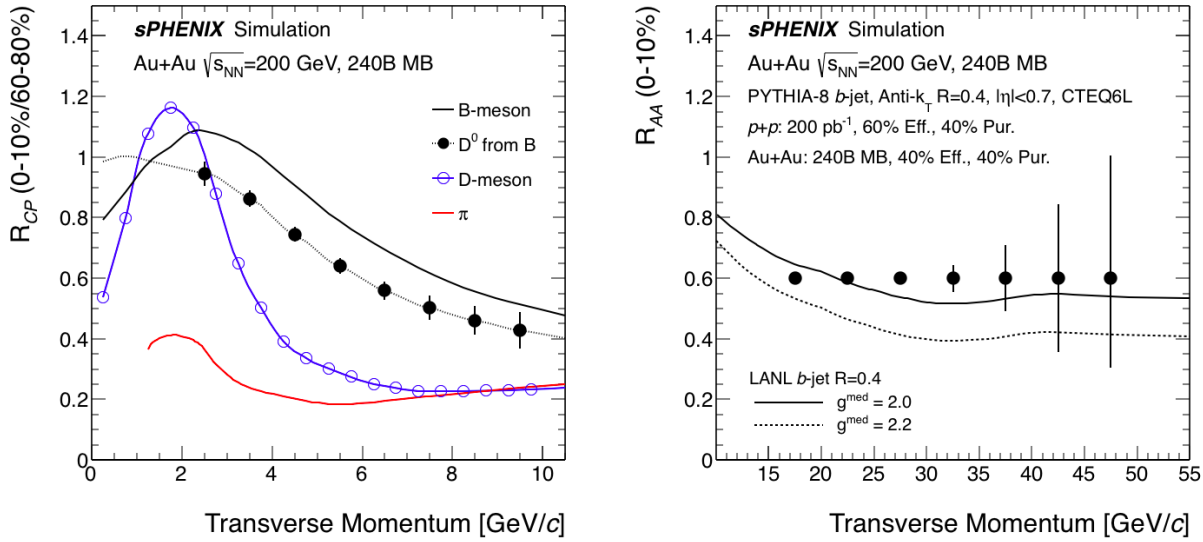

Figure 1: Projected nuclear modification factors (R_{AA}/R_{CP}) of D^0 mesons, non-prompt D^0 mesons from B-hadron decay, and b-jet with MVTX.

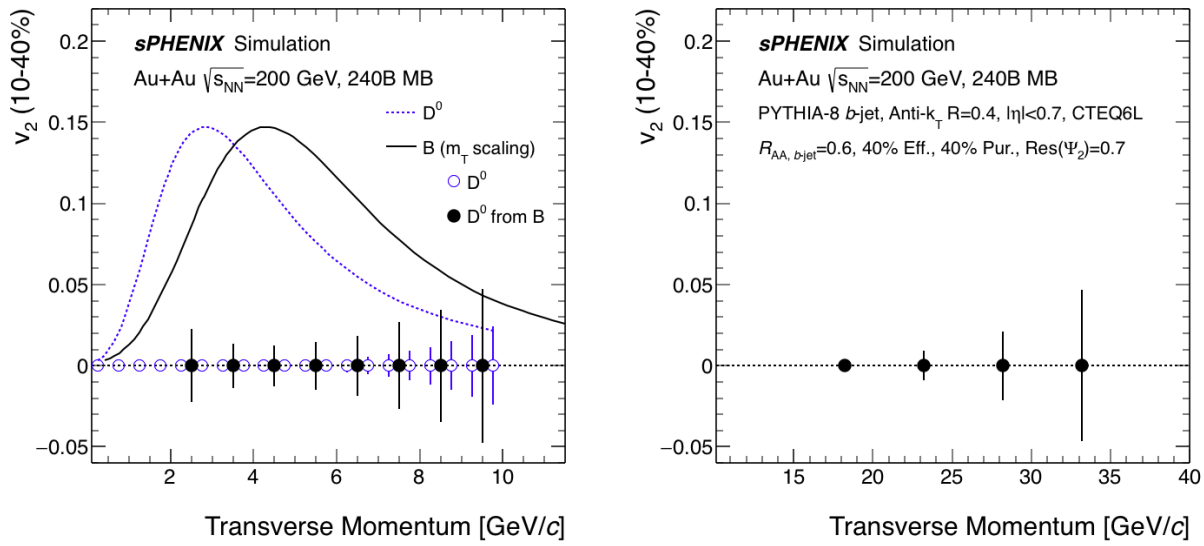

Figure 2: Projected elliptic flow (v_2) measurements of D^0 mesons, non-prompt D^0 mesons from B-hadron decay, and b-jet with MVTX.

Appendix - 2 MVTX institutions Responsibilities and Resources

LANL: Overall readout and mechanical system integration, project management;
Staff, postdoc and electronics and mechanical engineering support.
LBNL: Carbon structure production, detector assembly and test, power system, project management;
Staff, postdoc and engineering support, carbon structure factory
MIT: Global mechanical system integration and cooling; stave production and test at CERN;
Staff, postdoc, students and engineering support.
BNL: Global system integration and services, safety and monitoring, project management
Staff, engineer and technicians
Univ. of Texas at Austin: Readout Unit production and test, readout firmware development;
Staff, postdoc and students.
Univ. of Colorado: b-jet simulations and future hardware;
Staff, postdoc and students.
Czech Groups: MAPS stave assembly and test,
Staff, postdoc, students, and electronics engineering support
Iowa State Univ.: Detector assembly and test, simulations;
Staff, postdoc and students.
Florida State Univ.: Offline and simulations;
Staff, postdoc and students.
Univ. of New Mexico: Cable test and simulations
Staff, postdoc and students
New Mexico State Univ.: Offline tracking and simulations
Staff, postdoc and students.
Georgia State Univ.: Online software, monitoring and trigger
Staff, postdoc and students.
UCLA: Readout electronics test and simulations
Staff, postdoc and students.
UCR: Detector assembly and test, simulations
Staff, postdoc and students.
Yonsei Univ.: MAPS chip test, QA, simulations, readout electronics test
Staff, postdoc and students
RIKEN/RBRC: Mechanical integration, track pattern recognition and simulations
Staff, postdoc
Purdue Univ.: Detector assembly and test, simulations.
Staff, postdoc and students, has a silicon lab.
CCNU: MAPS stave assembly and test
Staff, postdoc and students, silicon pixel lab with engineering support

Appendix 3. Preliminary MVTX organisation