A faster pixel detector for open bottom hadron measurements at RHIC

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Abstract

In high-energy nuclear collisions at RHIC, heavy flavor quarks are produced from initial hard partonic scattering processes. Their interactions with a nuclear medium are sensitive to the medium properties. The Heavy Flavor Tracker (HFT) has been successfully integrated into the STAR experiment at RHIC since early 2014. Based on the state-of-the-art Monolithic Active Pixel Sensor (MAPS) technology, the HFT allows precise measurements of open charm mesons (D^0, $D^{\pm}$ and D_s) as well as the first measurements of open charm baryons (Λ_c) and bottom hadron production in heavy-ion collisions over a wide range of transverse momentum. In this poster we propose a faster pixel detector, based on the next generation of MAPS technology, for precise bottom hadron measurements to study the flavor dependence of partonic energy loss in Au+Au collisions at RHIC. The advantages of the new MAPS sensors are that they have a much better radiation tolerance and a much faster integration time (< 20 μs), which allow for improved operation in high luminosity environment with less pile-up hits and better tracking efficiency. With the faster pixel detector and integrated luminosities of 10 nb^{-1} for Au+Au collisions and 60 pb^{-1} for p+p collisions at $\sqrt{s_{NN}}$ = 200 GeV to be recorded, the nuclear modification factor (R_{AA}) for non-prompt J/ψ and D^0 from beauty decays and b-tagged jets can be measured with good precision according to Monte Carlo simulations. Such precision measurements on bottom production will complete the heavy flavor and jet physics programs at RHIC, and will be complimentary to similar measurements at the LHC.

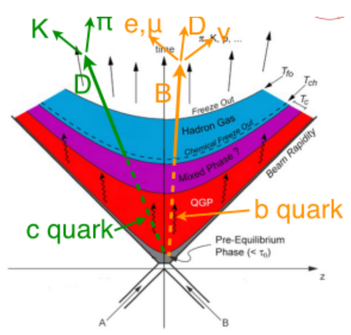
1. Heavy Flavor Quarks

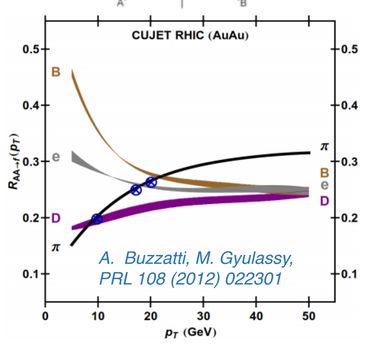
Heavy quark tomography

- Produced mostly from initial hard partonic scatterings at RHIC energies; exposed to the entire evolution of the Quark-Gluon Plasma (QGP)
- Either yield or mass not (significantly) altered within the QGP

Sensitive to medium properties

- Compare measurements of light, charm and bottom quarks to disentangle radiative vs. collisional energy losses
- Extraction of temperature-dependent parton transport coefficients needs precise measurements of charm and bottom quark energy losses at both low and high transverse momentum (p_T) from RHIC





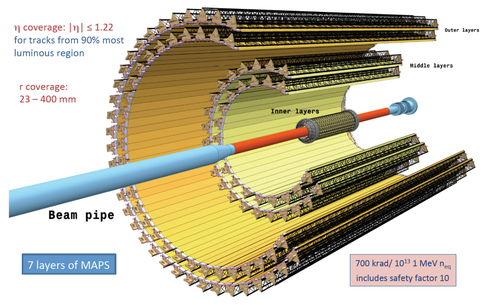
4. HFT+ for Bottom Production Measurements

Motivation for a faster pixel detector (HFT+):

- Measure bottom hadrons at the RHIC energy in 2022+ period
- Complimentary to similar measurements at the LHC

HFT+ requirements:

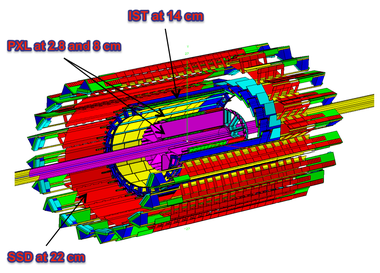
- Next-generation fast MAPS sensors
  - ✓ Next-generation MPAS will be used for ALICE ITS upgrade
  - ✓ Integration time reduced from 186 μs to < 20 μs
- Detector capable of being operated at high luminosity
  - ✓ CAD projects $L \sim 100x10^{26}$ $cm^{-2}s^{-1}$ at 2022+
  - ✓ ZDCx rate ~ 100 kHz
- Preserve low material budget ($0.4\%X_0$) in the inner layer
- Preserve high detection efficiency in high luminosity environment

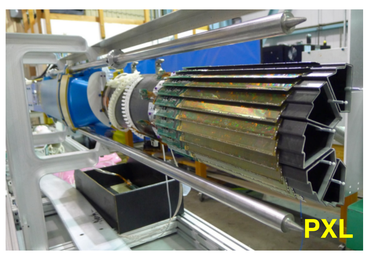


ALICE ITS Upgrade

J. Phys. G 41 (2014) 087002

2. Heavy Flavor Tracker at STAR

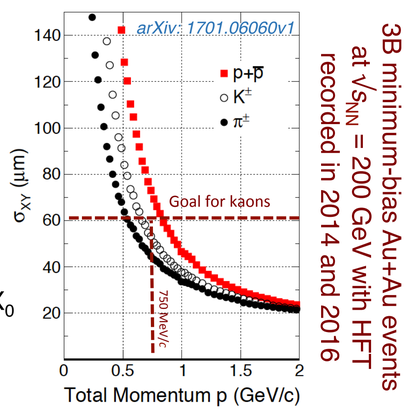




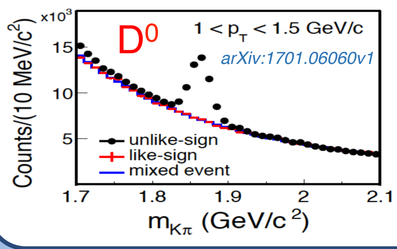
PXL: 2-layer MAPS, 360M pixels, 20μmx20μm, inner layer $0.4\%X_0$

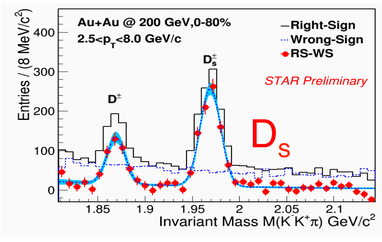
IST: 1-layer single-sided double-metal silicon pad detector

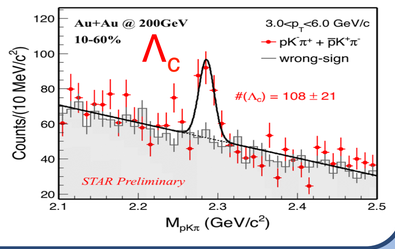
SSD: 1-layer double-sided single-metal silicon strip detector



3B minimum-bias Au+Au events at $\sqrt{s_{NN}}$ = 200 GeV with HFT recorded in 2014 and 2016

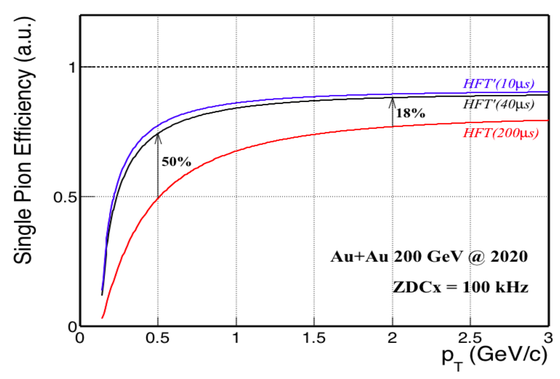






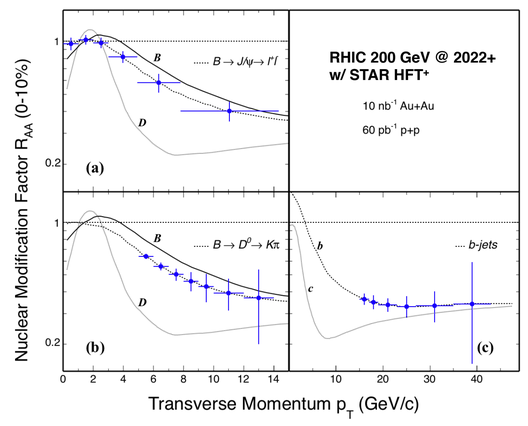
5. HFT+ Simulations

Efficiency: fast vs. slow pixel detector



HFT (~200 μs) → HFT+ (< 20 μs)

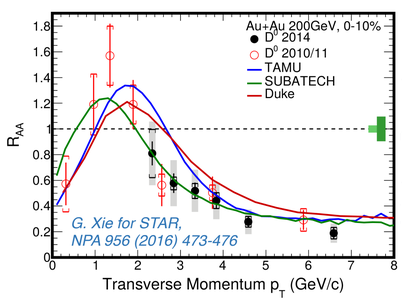
HFT+ flagship measurements

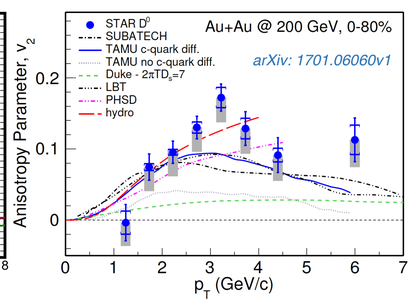


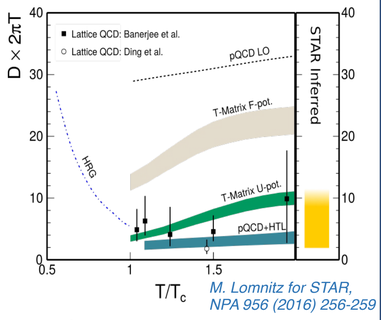
Projected statistical errors for R_{AA} (0-10%) based on RHIC pp and AuAu running in 2022+

- The proposed HFT+ is complementary to ALICE ITS at the LHC and sPHENIX at RHIC.
- The bottom quark measurements will complete the heavy flavor and jet programs at RHIC.

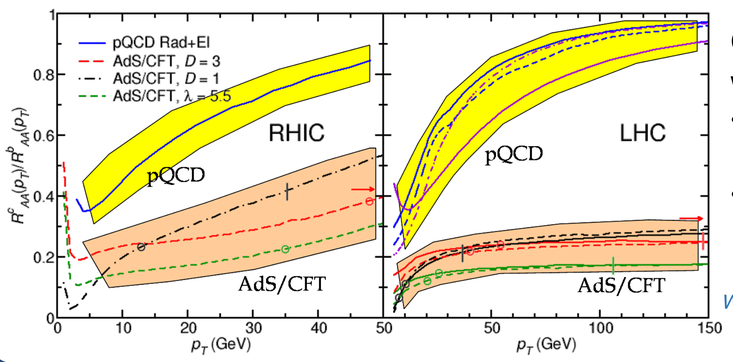
3. Heavy Flavor Program at STAR







- Models with charm quark diffusion coefficient of ~2-12 describe STAR D^0 R_{AA} and v_2 data. Lattice calculations are consistent with values inferred from data!
- Measurements of bottom quarks at RHIC are essential for fully understanding the energy loss mechanisms, or mass- and temperature-dependent parton transport coefficients of the QGP. Does bottom quark diffuse in the QGP at RHIC energies and if so how much?



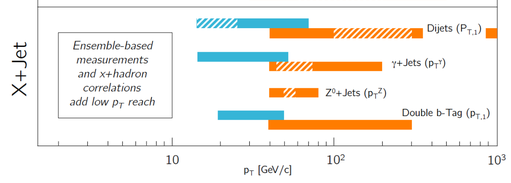
Open bottom production over a wide range of momentum:

- Flavor dependence of parton energy loss
- Cleaner extraction of medium transport properties $\boldsymbol{D_{HQ}}$

W. Horowitz and M. Gyulassy, arXiv:0710.0703

6. Summary and Outlook

- STAR HFT has precisely measured open charm hadron production.
- A faster silicon tracker, HFT+, combined with particle identification will allow precision measurement of bottom hadrons at RHIC. This is important for extracting the parton flavor dependent energy loss and understanding the properties of the medium created in high-energy nuclear collisions at RHIC.



	2014	2015	2016	2017	2018	2019	2020	2021	2022+
RHIC	STAR HFT PHENIX (F)VTX Precision charm			Spin	Isobaric	BES-II			HFT+ @ RHIC Open bottom
LHC	LS1	Run 2 (x10 statistics)				LS2		ALICE ITS upgrade CMS/ATLAS upgrades Run 3 (x100 statistics)	

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The STAR Collaboration

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