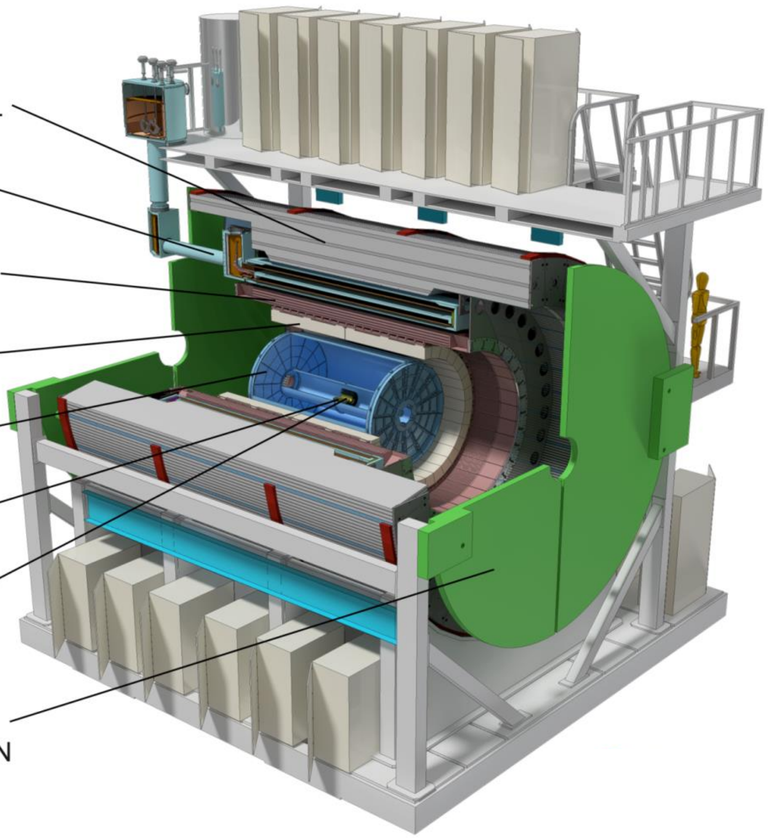
Heavy Flavor capabilities of the sPHENIX experiment

Hugo Pereira Da Costa (CEA-Saclay, LANL)

on behalf of the sPHENIX collaboration

April 14, 2021

The sPHENIX detector



Acceptance:

- full azimuth
- $|\eta| \sim 1$
- 0.2 GeV/c < p_T < 40GeV/c

Magnet: Babar 1.5 T super conducting solenoid

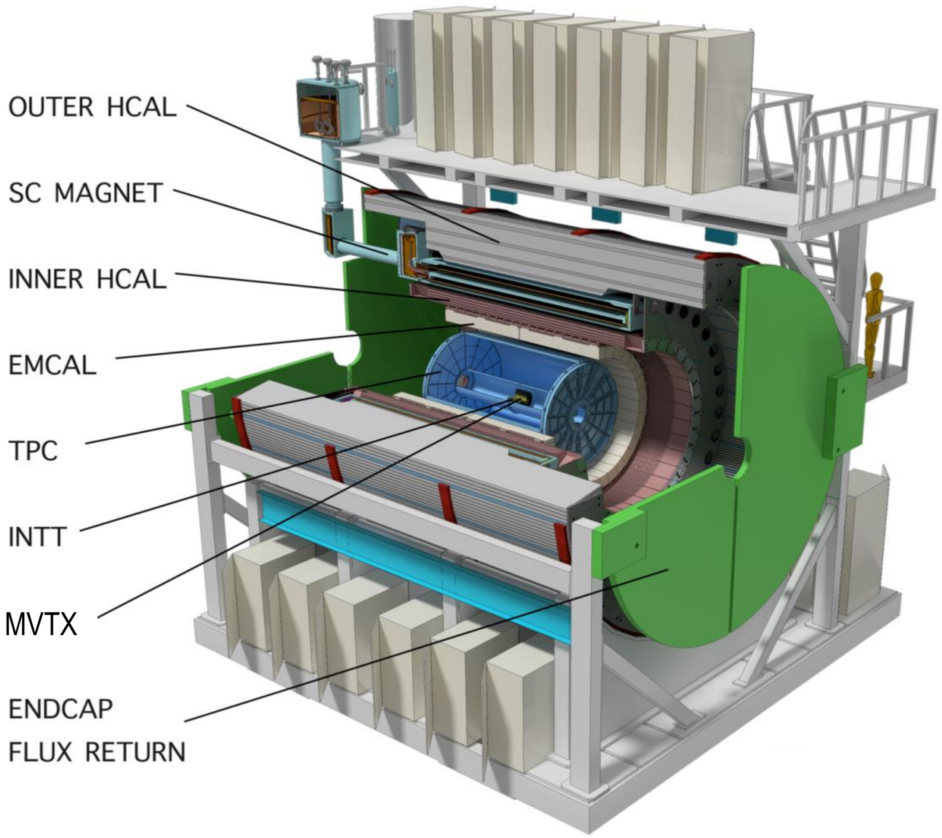
Tracking:
3 MAPS layers (MVTX)
2 silicon strips layers (INTT)
QuadGEM-based TPC

Calorimetry:
Electromagnetic calorimeter (EMCAL)
Inner and Outer Hadronic Calorimeters

Collision rate: 50kHz (Au-Au), 3MHz (pp)

Data acquisition rate: 15 kHz

The sPHENIX detector



Construction: now until end of 2021

Installation: 2022

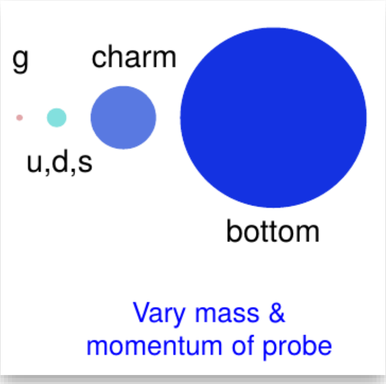
Data taking: from 2023 to 2025
(before start of EIC construction)

Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\|z\| < 10$ cm	Samp. Lum. $\|z\| < 10$ cm
2023	Au+Au	200	24 (28)	9 (13)	3.7 (5.7) nb^{-1}	4.5 (6.9) nb^{-1}
2024	$p^{\uparrow}p^{\uparrow}$	200	24 (28)	12 (16)	0.3 (0.4) pb^{-1} [5 kHz] 4.5 (6.2) pb^{-1} [10%-str]	45 (62) pb^{-1}
2024	$p^{\uparrow}$+Au	200	–	5	0.003 pb^{-1} [5 kHz] 0.01 pb^{-1} [10%-str]	0.11 pb^{-1}
2025	Au+Au	200	24 (28)	20.5 (24.5)	13 (15) nb^{-1}	21 (25) nb^{-1}

[BUP] sPH-TRG-2020-001

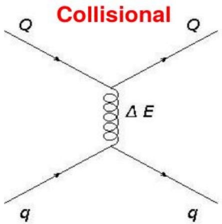
Heavy Flavor physics motivation

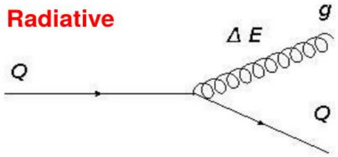
sPHENIX goal: study the inner structure of the QGP formed in 200 GeV Au-Au collisions over a wide range of length and energy scales

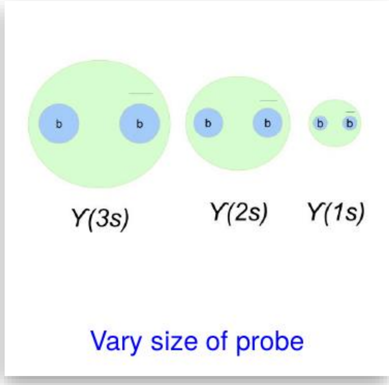


Open Heavy Flavor:

- Energy loss in QGP; interplay between collisional and radiative
- Transport coefficients and in particular HQ diffusion coefficient
- Hadronization in the QGP (baryon to meson ratio)







Quarkonia:

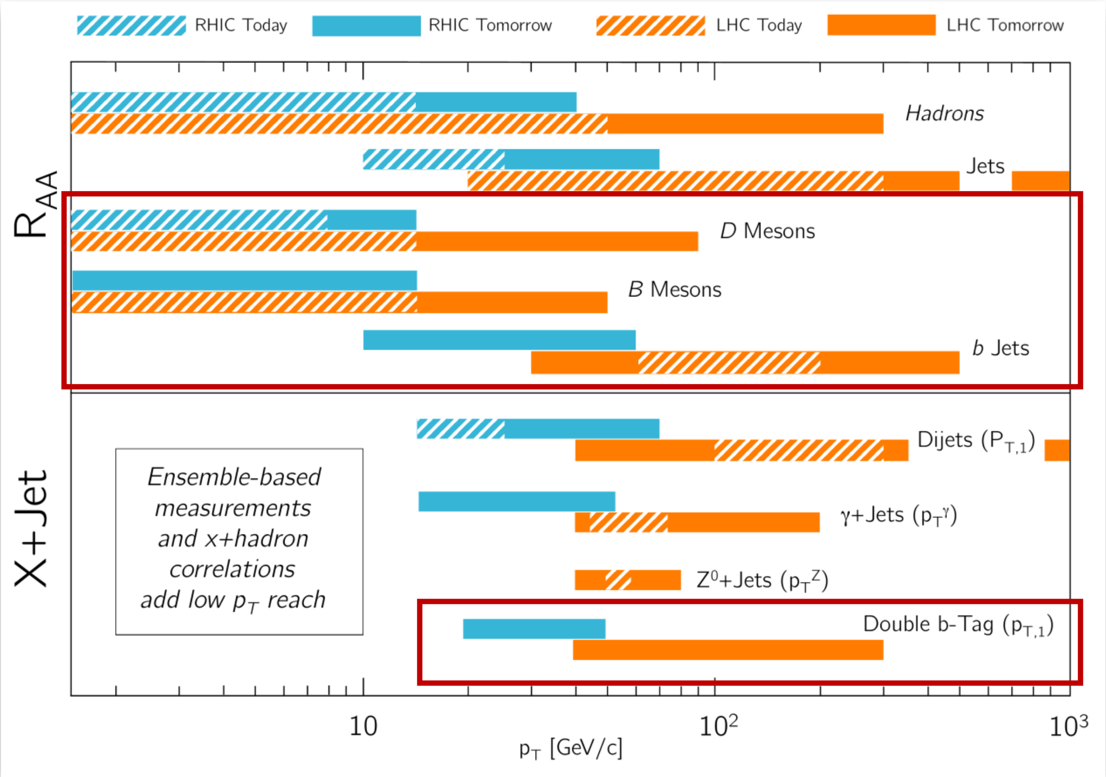
Long history of measurements at SPS, RHIC, LHC (J/Ψ, Ψ(2S), Y(nS))

Color screening in the QGP

Sequential suppression

Measure of QGP temperature

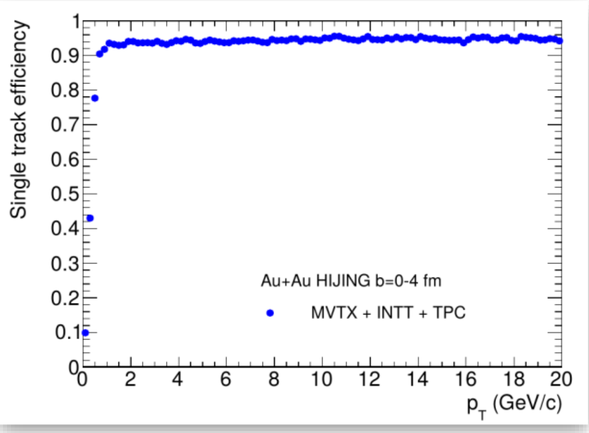
sPHENIX projections in one slide

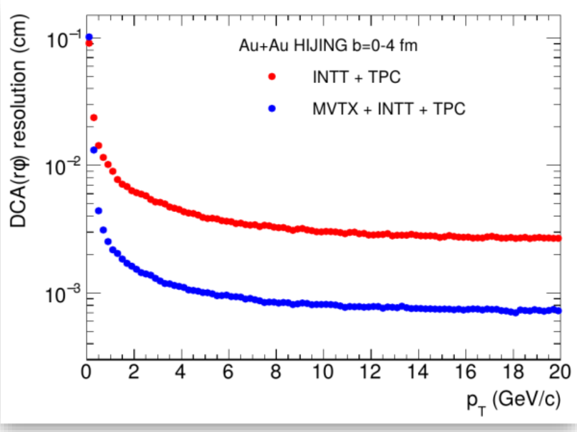


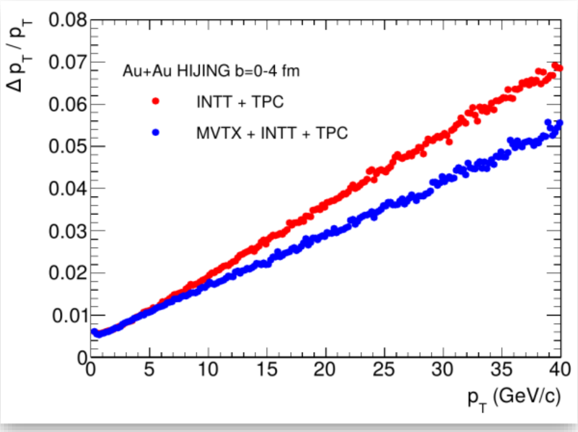
with respect to past RHIC experiments sPHENIX will bring unprecedented precision and p_T range for charm and first, precise beauty measurements

For jet capabilities, see talk by Yeonju Go, Thursday

Performance relevant to Heavy Flavor - Tracking





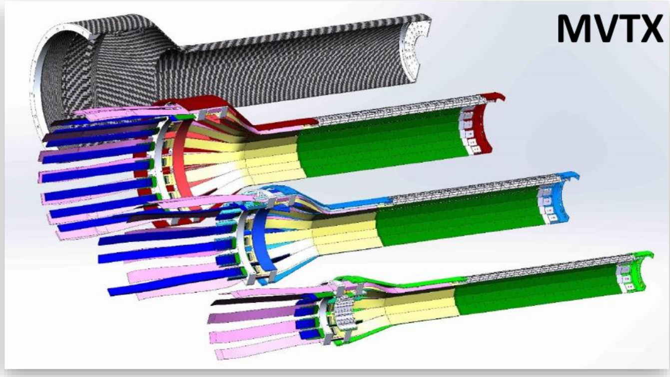


sPH-HF-2018-001

High tracking efficiency (>90%). Good for rare probes

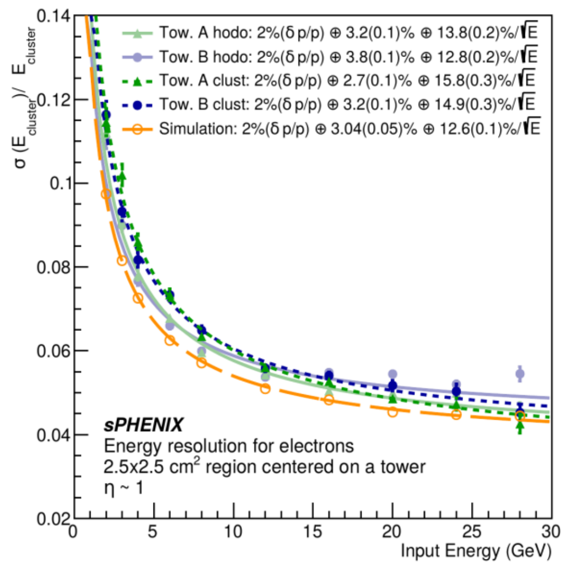
DCA resolution critical for HF measurements
(need < 50 μm for p_T = 1 GeV/*c* pion)

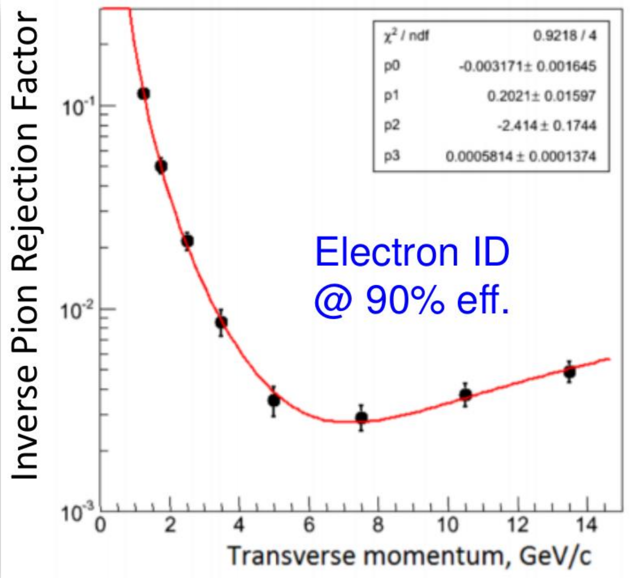
Momentum resolution is critical for Upsilon program and other inv. mass measurements
(need < 125 MeV/c^2 at Υ mass)

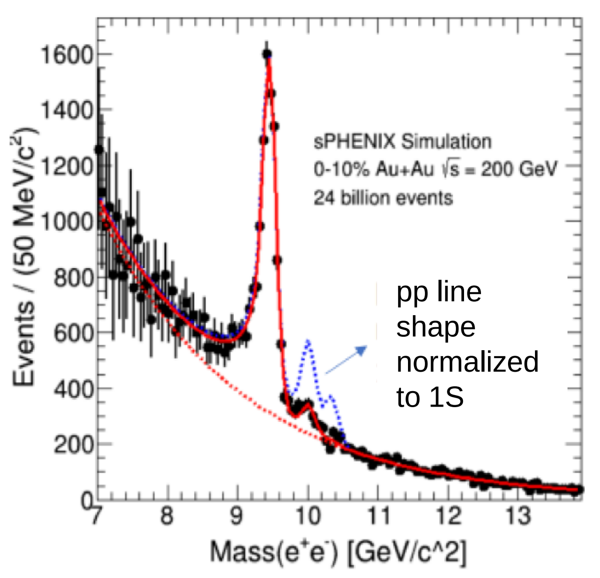


MVTX detector improves DCA significantly, and to a lesser extent, momentum resolution

electron ID, Upsilon reconstruction





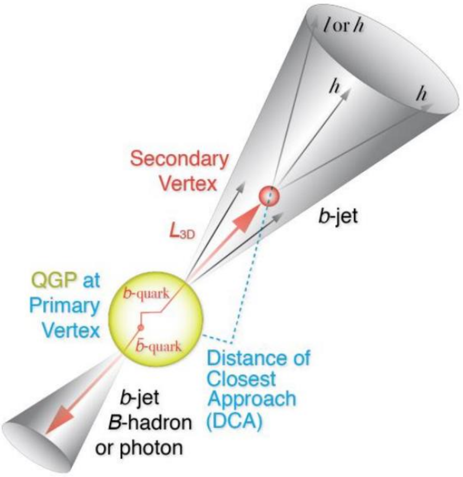


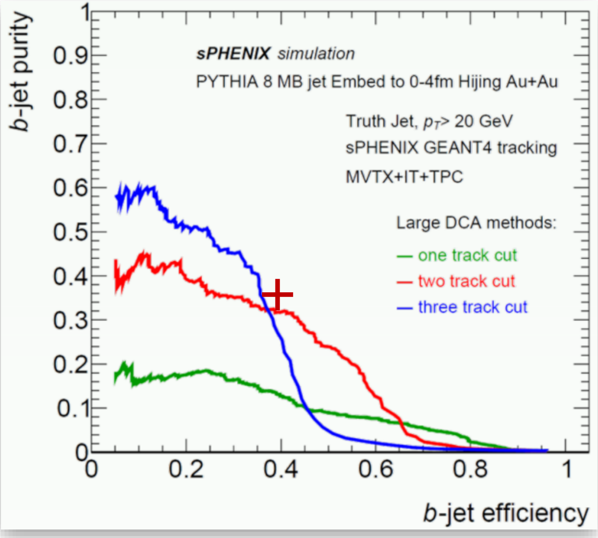
IEEE Trans.Nucl.Sci. 68, 2 (2018)

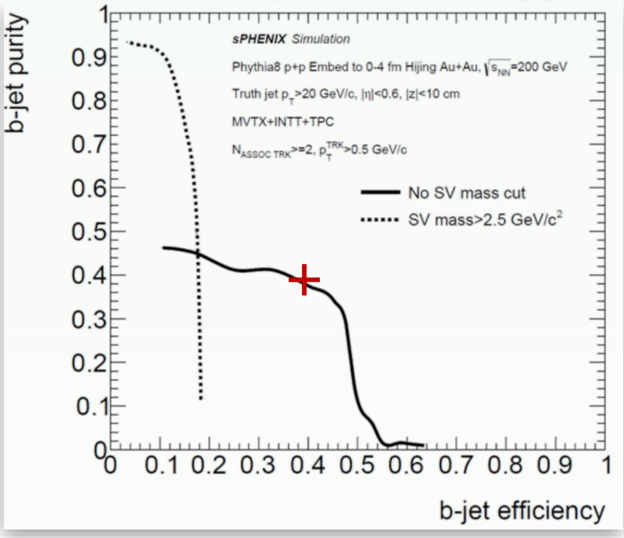
EMCAL energy resolution allows good rejection factor for π/K/p with E/p requirement

Upsilon inv. mass resolution < 125 MeV/c^2 - allows separation between Y(nS) states

b-jet tagging







Two approaches are followed:

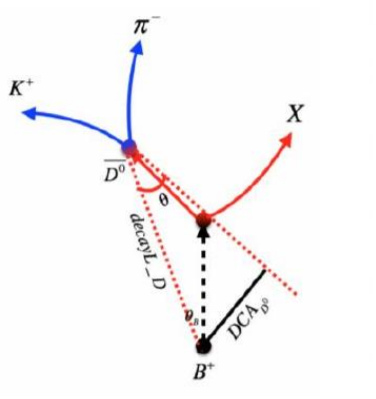
- counting number of high-DCA tracks belonging to same jet
- secondary vertex reconstruction

Target working point for b-tagged jets: efficiency 40%, purity 40% (CMS *medium* settings - PRL. 113, 132301 (2014))

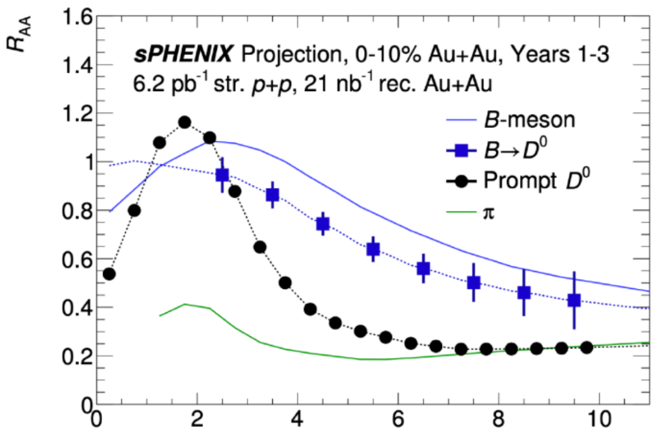
Both approaches allow to reach that point

Adding mass cut on secondary vertex brings improved purity

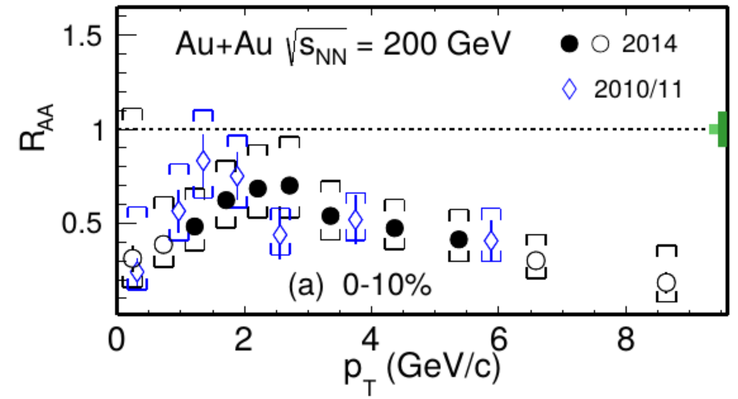
Open Heavy Flavor projections - Nuclear modification factor



$B \rightarrow \overline{D^0} + X$ (B.R. 60%)



[BUP] sPH-TRG-2020-001



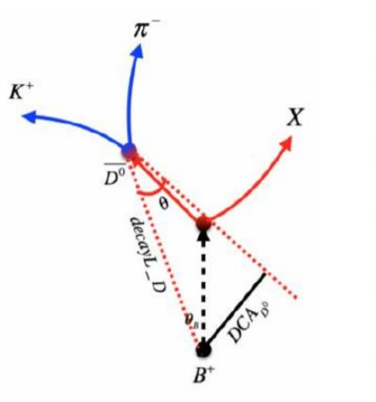
STAR PRC 99, 034908 (2019)

B-mesons from non-prompt D^0

Precise measurements provide discrimination between transport models

Study interplay between collisional and radiative energy loss

Open Heavy Flavor projections - Elliptic flow



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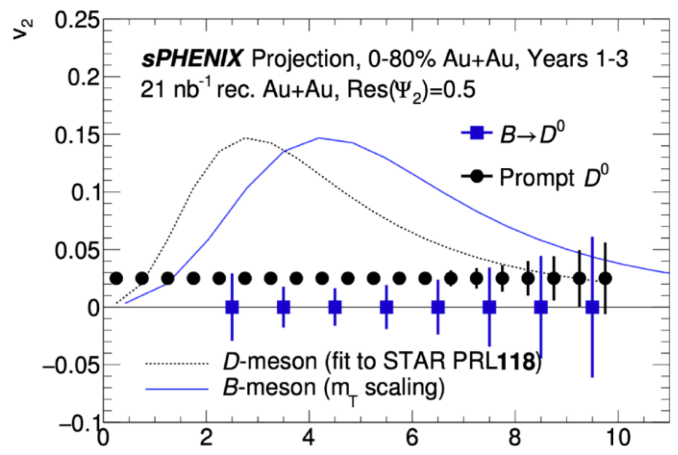

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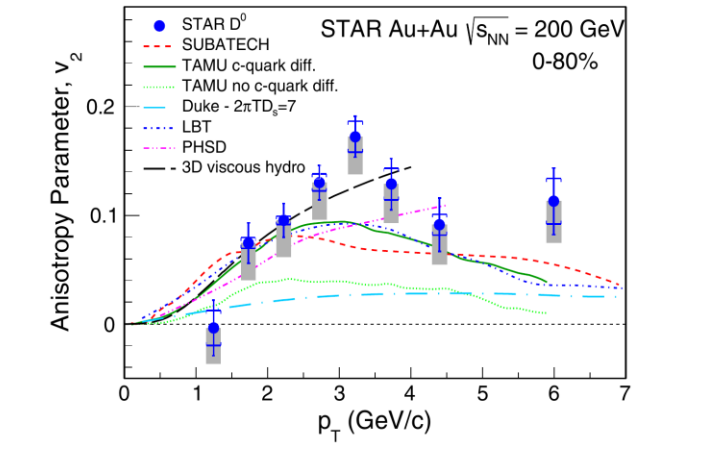
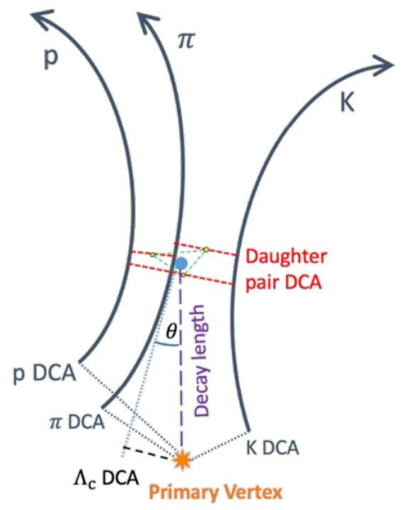


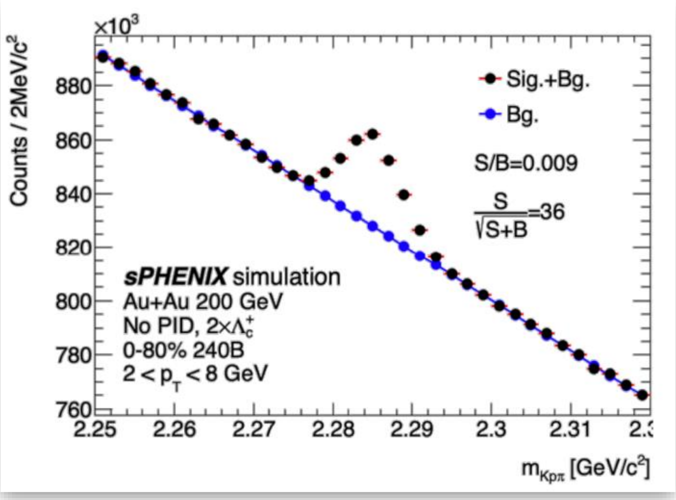
STAR PRL 118, 212301 (2017)

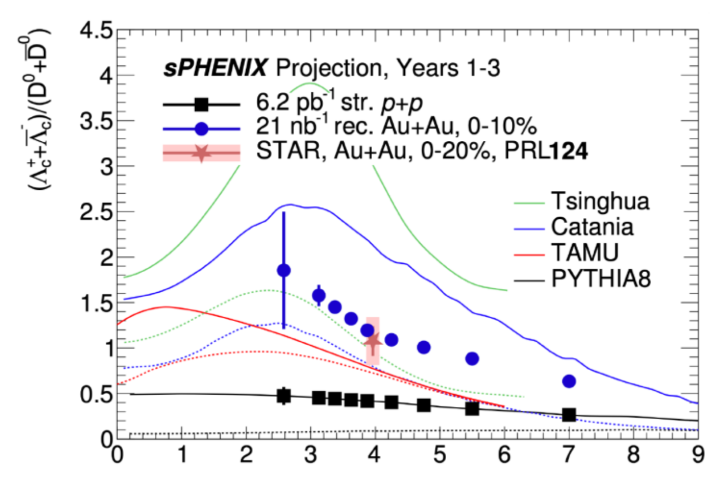
Critical to measure R_{AA} and v_2, because it is challenging for models to describe both simultaneously

v_2 (and R_{AA} centrality dependence) → path-length dependence of Eloss, HQ diffusion coefficient in the QGP

Heavy flavor hadronization







$\Lambda_c \to K p \pi$, $D_0 \to K\pi$

[BUP] sPH-TRG-2020-001
STAR PRL 124, 172301 (2020)

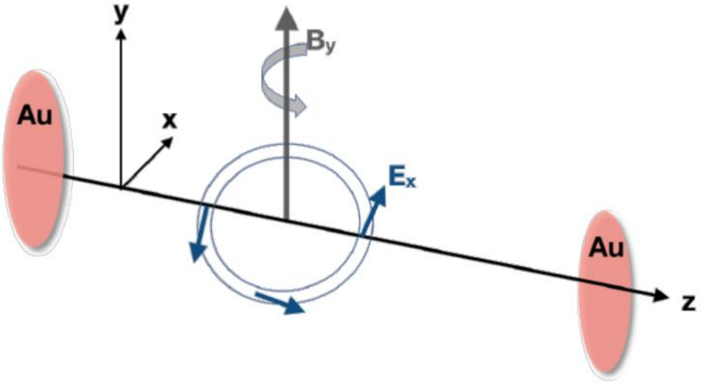
STAR measured significantly larger Λ_c/D^0 in AA wrt PYTHIA pp calculations

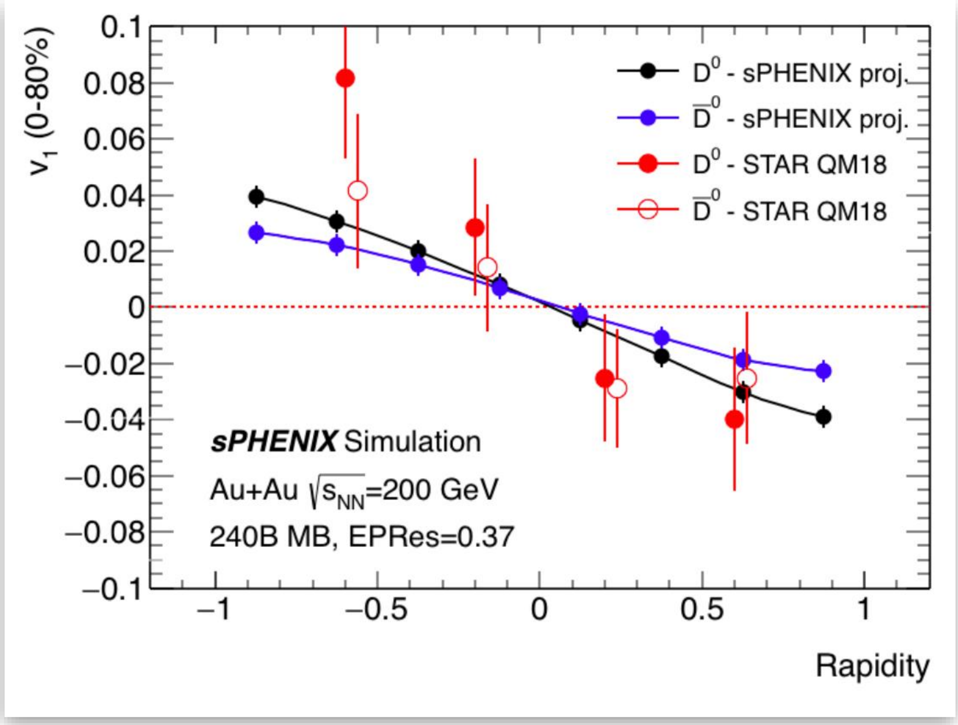
Relevant to understanding hadronization in the QGP (coalescence)

Sizable contribution from hadrons to total charm cross section in AA

sPHENIX will provide measurement over $3<p_T<8$ GeV/c range, to better discriminate between models

D meson directed flow v_1





v_1 related to initial tilt of QGP source

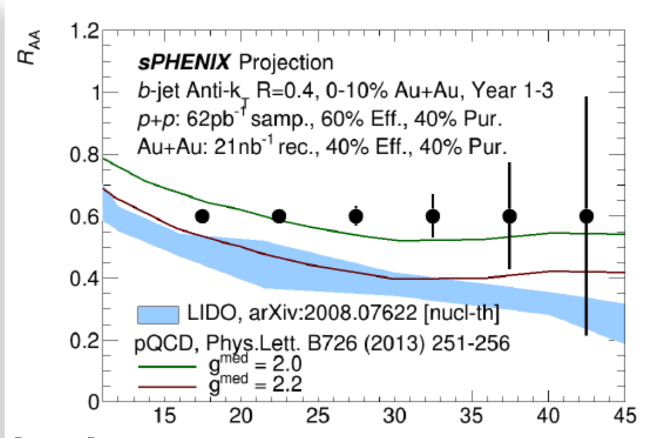
larger v_1 predicted for HF due to T dependence of coupling to QGP

Differences between D^0 and D^0bar attributed to initial magnetic field resulting from collision

sPHENIX will provide enough statistics to pin down possible difference between D^0 and D^0bar

STAR PRL 123, 162301 (2019)

b-tagged jets projections



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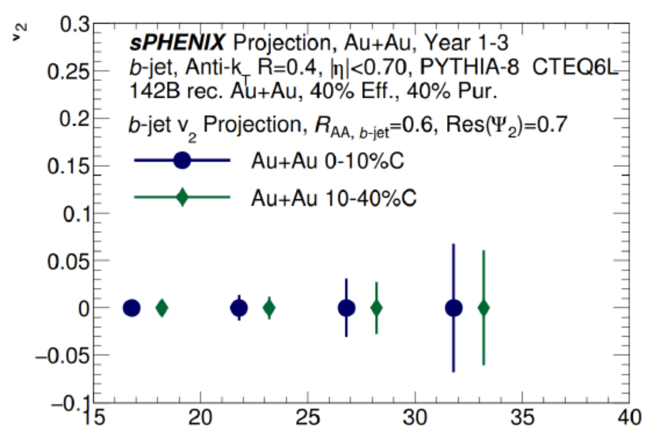

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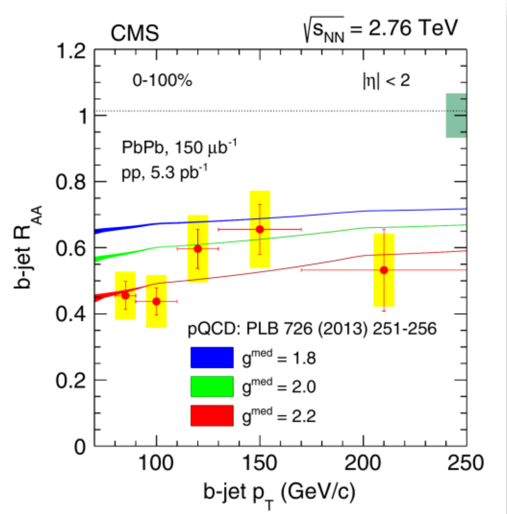


CMS, PRL 115, 029903 (2015)

Complementary to single hadron measurements

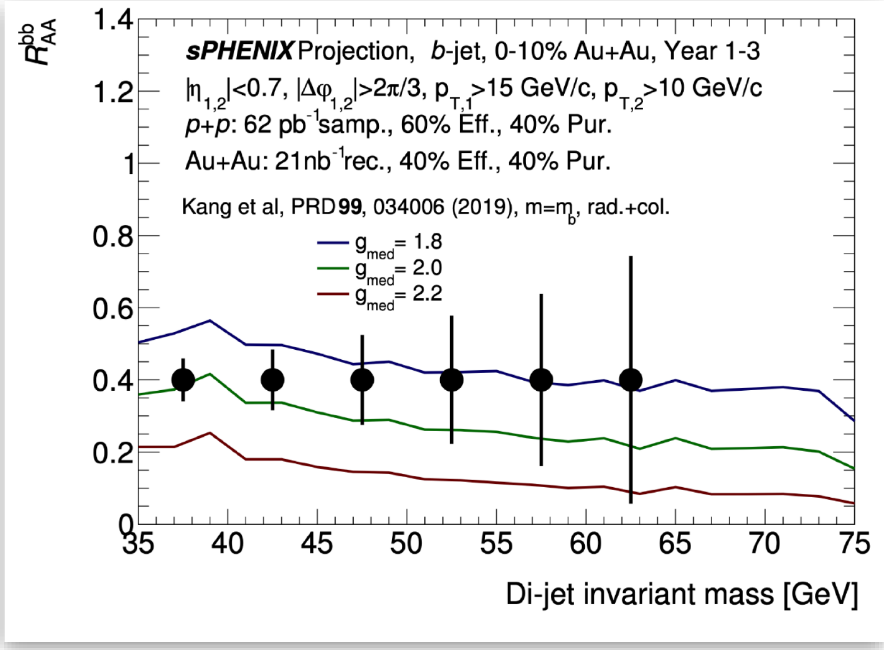
Jets provide better access to parton-level quantities

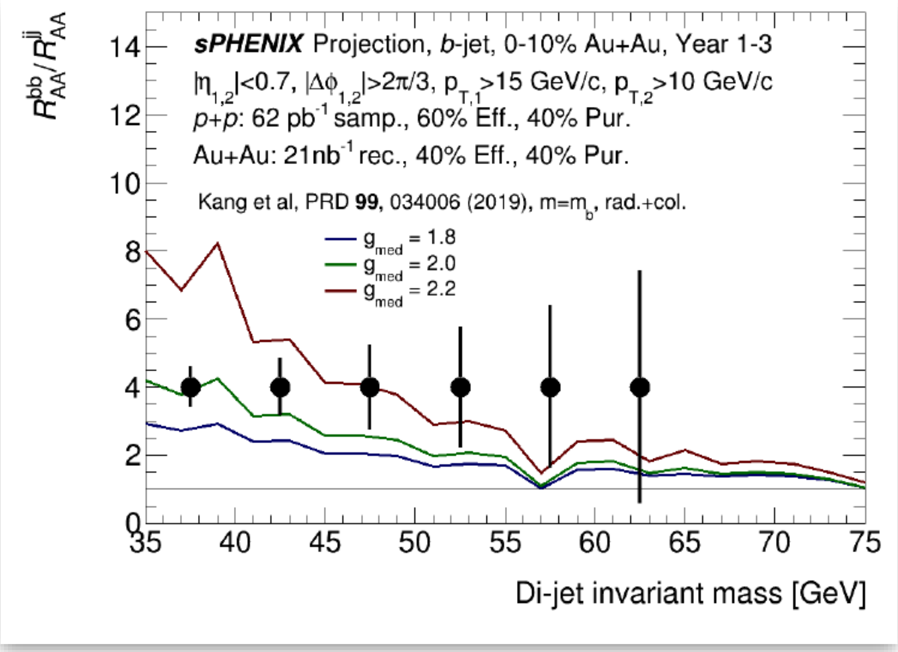
sPHENIX relevant p_T range: 15-45 GeV/c

Expect to be dominated by radiative energy loss

Strong constraints on transport models

di-b-jets projections

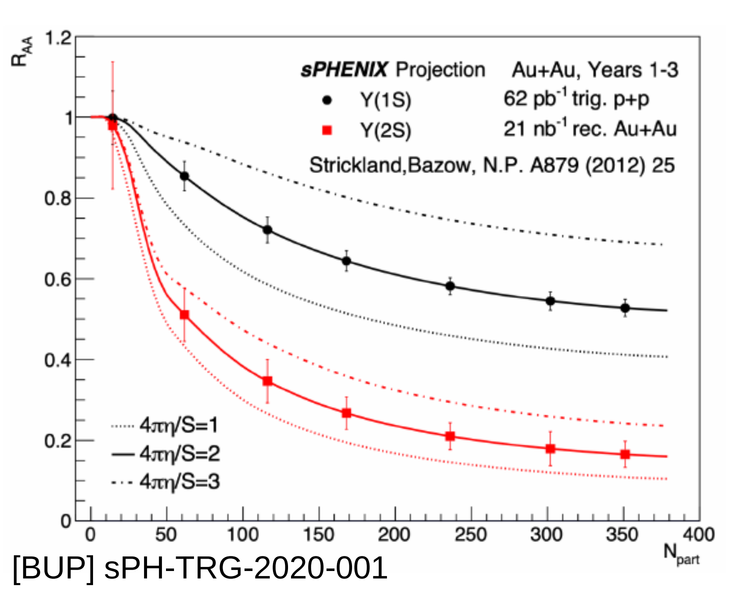




[BUP] sPH-TRG-2020-001

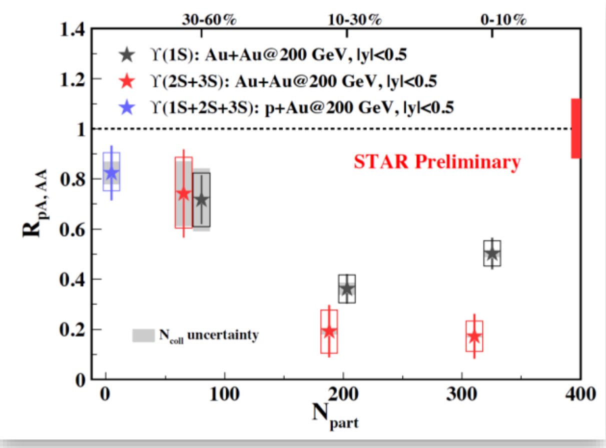
Proposed in Kang, Reiten, Vitev, Yoon, PRD 99, 034006 (2019)
Studying di-b-jets suppresses contribution to b production from gluon splitting (already disfavored at RHIC wrt LHC)
Measuring di-jet inv. mass is complementary to p_T imbalance
Provides enhanced sensibility to transport properties (here g_{med}, jet-to-medium coupling)
Illustrate close collaboration with theory community to make the most of the apparatus/data

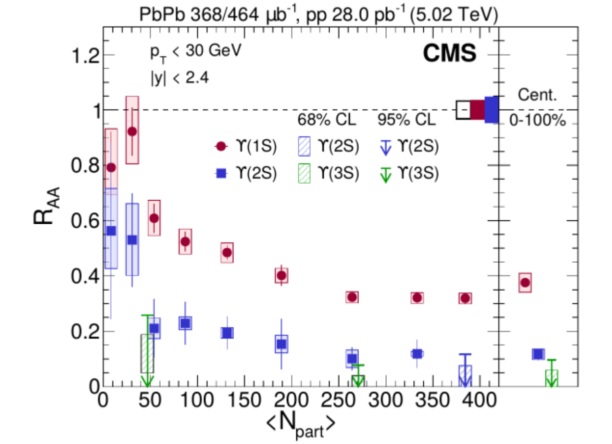
Upsilons projections



[BUP] sPH-TRG-2020-001

To be compared to





CMS, PLB 790 (2019) 270

Much improved precision wrt available measurements at RHIC

Similar to what is achieved at LHC

Comparison to LHC critical to understand temperature dependence

Y(3S) measurement challenging due to anticipated full suppression. Will provide CL.

Summary and outlook

sPHENIX will:

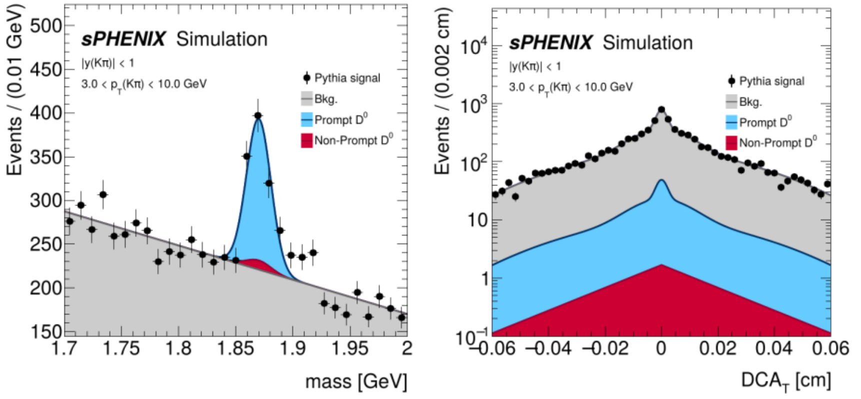
- bring improved measurements to RHIC in the charm sector (statistics, p_T range)
- bring new, precise measurements in the beauty sector (both open and hidden)
- thus bridge the gap to LHC experiments

Outlook:

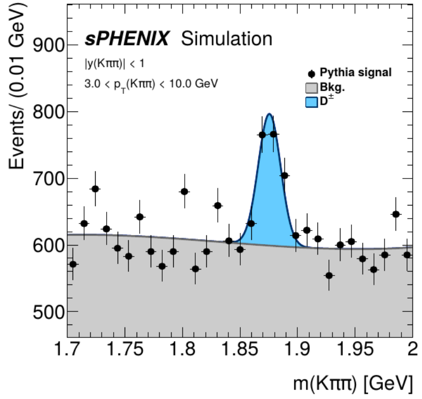
- (from Justin's talk) sPHENIX is ~half completed. In time for first data taking in 2023
- first Mock Data Challenge early 2021 to
  sharpen our production, tracking and analysis tools (ACTS, KFParticle ...),
  consolidate the projections presented here with e.g. realistic tracking, more accurate detector description, etc.
  study new channels (e.g. D^+, D^*, D_s ...)

Early MDC1 output

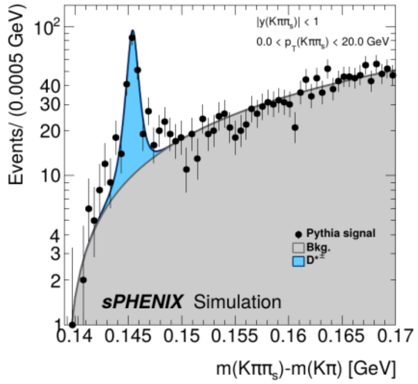
c,b→D^0→Kπ



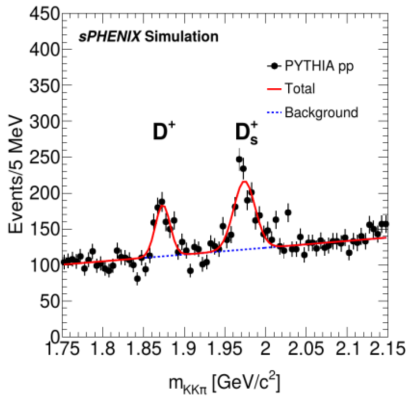
$D^+ \to K^+\pi^+\pi^-$



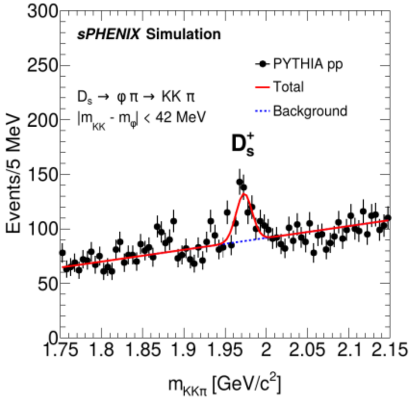
$D^{*+} \to D^0\pi^+ \to K^+\pi^+\pi^-$



$D_s^+ \to K^+K^-\pi^+$



$D_s^+ \to \Phi\pi^+ \to K^+K^-\pi^+$



sPH-HF-2021-001

PYTHIA 8.3 pp + ccbar, bbbar events

KFParticle to handle decay kinematics

No PID information, except for D_s

Thank you!