Heavy Flavor at sPHENIX

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on behalf of the sPHENIX collaboration

9th June 2021

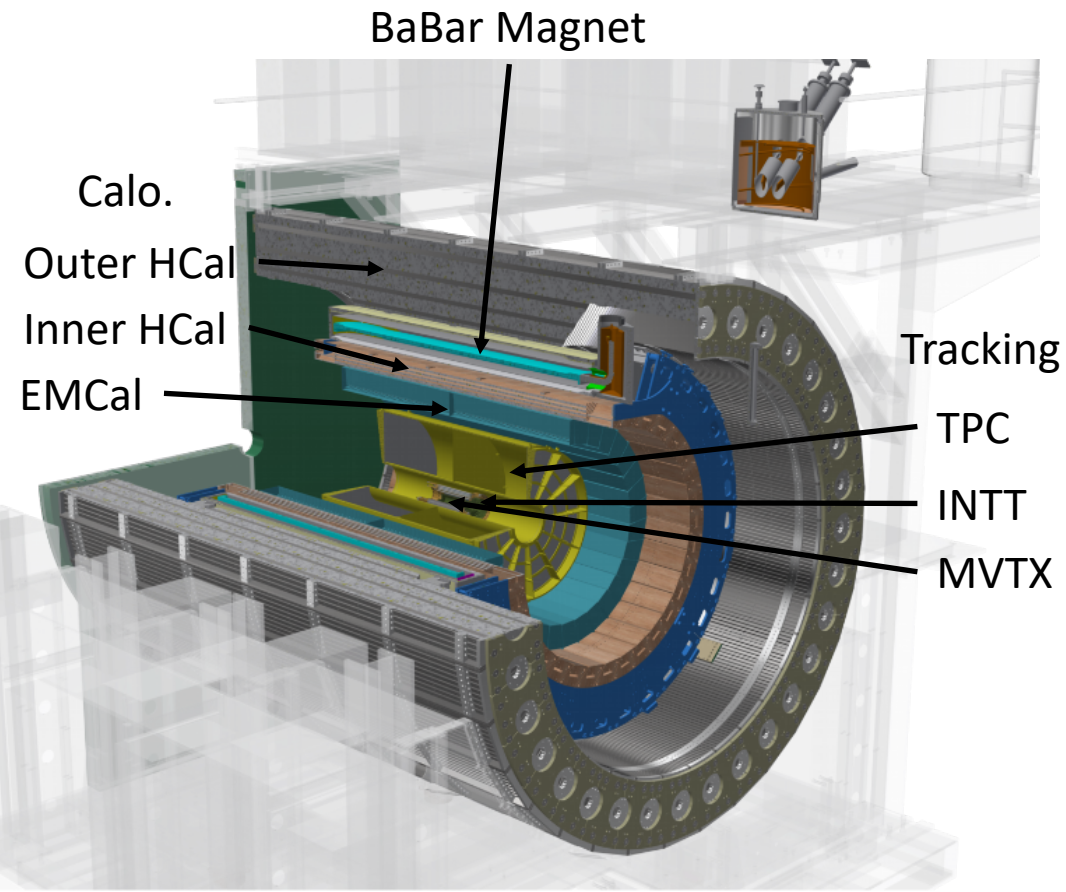
RHIC/AGS Annual Users' Meeting

The path to HF physics

- The four questions to getting physics results at a detector:

1. What features of your detector enable your physics?
2. How much data will be available?
3. What physics questions will you aim to answer?
4. Is everything in place to allow you to answer this?

sPHENIX Overview



First run year	2023
Trigger Rate [kHz]	15
Magnetic Field [T]	1.4
First active point [cm]	2.5
Outer radius [cm]	270
$\|\eta\|$	$\leqslant$1.1
$\|z_{vtx}\|$ [cm]	10
N(AuAu) collisions*	1.43x10^{11}

* In 3 years of running

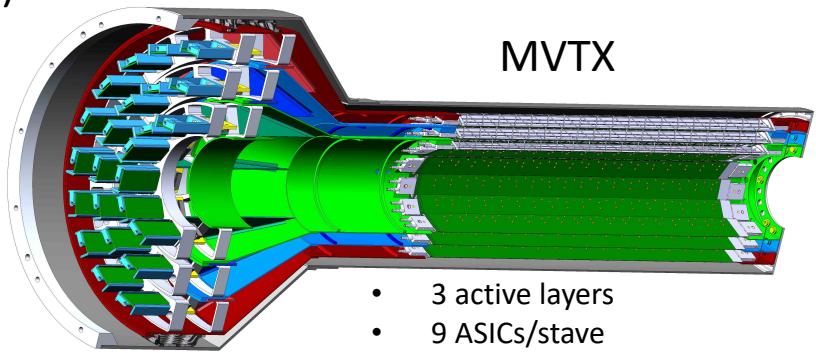
Unlocking HF at sPHENIX

- Tracking currently consists of 3 sub-detectors; Pixel Vertex Detector (MVTX), Intermediate Silicon Tracker (INTT), Time Projection Chamber (TPC)

The Maps VerTeX detector

- Comprises of 3 layers of monolithic active pixel sensors using the ALICE ALPIDE
- The front-end readout uses the ALICE Readout Unit
- The back-end uses the ATLAS FELIX

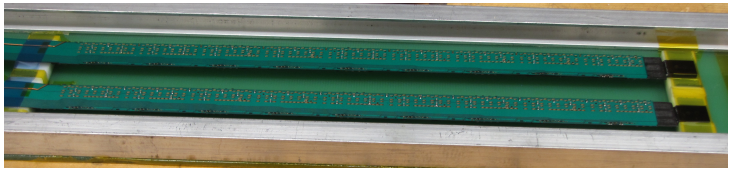
MVTX



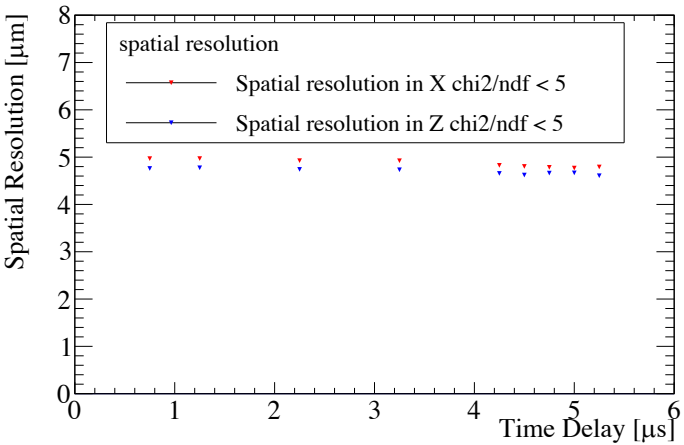
- 3 active layers
- 9 ASICs/stave
- 27 cm active length/stave

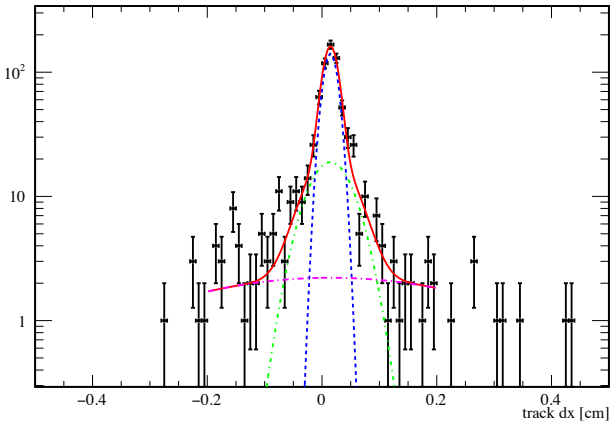
ALPIDE thickness [µm]	50
Pixel size [µm] / matrix	29 x 27 / 1024 x 512
Technology	180nm CMOS
Power Consumption [mW/cm^2]	40 (mean), 300 (peak)
Stave Material Budget	0.3% X_0
ToT	A few µs (tunable)
XZ spatial resolution [µm]	< 6

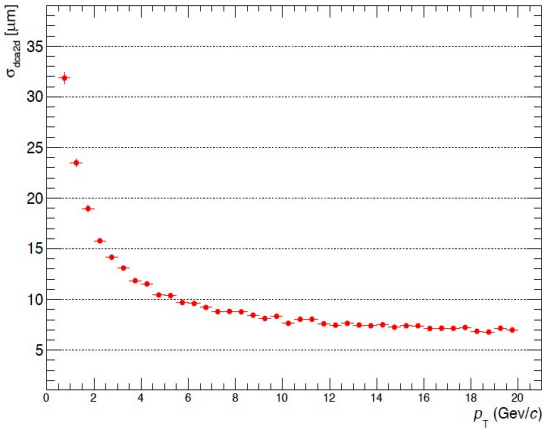
MVTX staves



Unlocking HF at sPHENIX

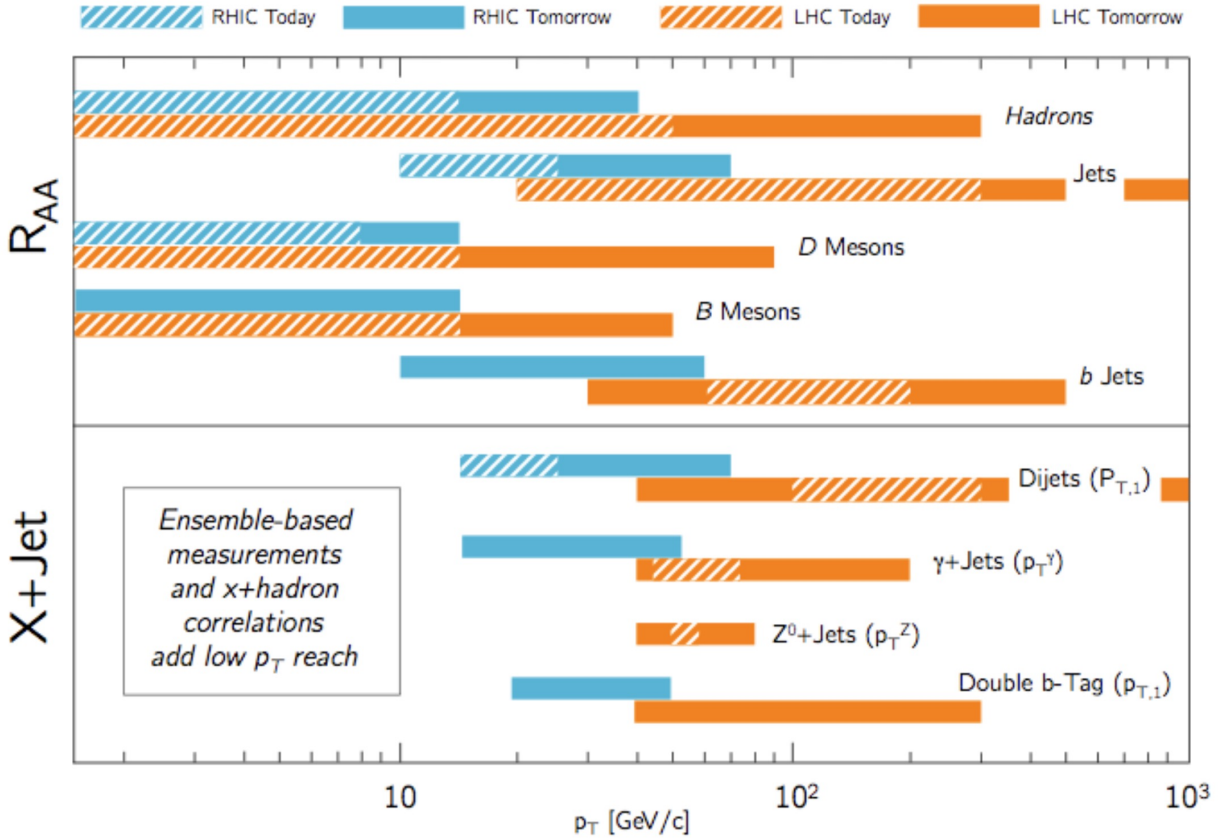






Left – MVTX spatial resolution as a function of trigger delay
Middle – MVTX track resolution from cosmics
Right – sPHENIX DCA_{XY} resolution (simulation)

LHC vs RHIC


RHIC Today
RHIC Tomorrow
LHC Today
LHC Tomorrow
R_{AA}
Hadrons
Jets
D Mesons
B Mesons
b Jets
X+Jet
Ensemble-based measurements and x+hadron correlations add low p_T reach
Dijets ($P_{T,1}$)
γ+Jets (p_T^{γ})
Z^0+Jets (p_T^Z)
Double b-Tag ($p_{T,1}$)
10
10^2
10^3
p_T [GeV/c]

sPHENIX Run Plan

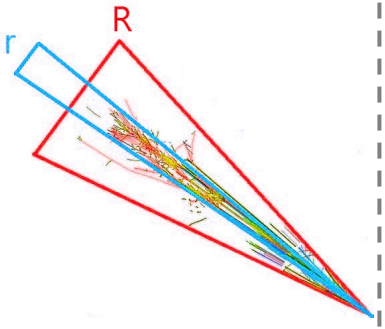
[sPH-TRG-2021-001]

Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\lvert z\rvert$ <10 cm	Samp. Lum. $\lvert z\rvert$ <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}

Core Physics Program

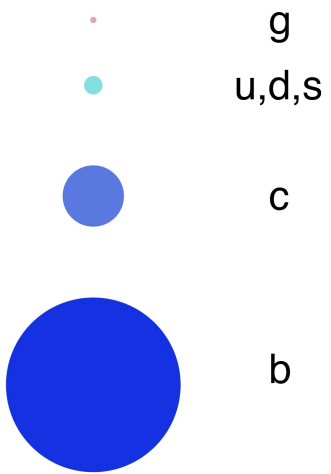
Jet correlation & substructure

Vary momentum/ angular size of probe



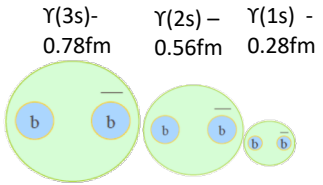
Parton energy loss

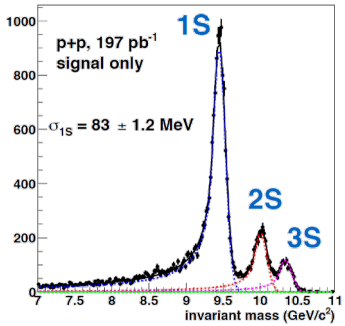
Vary mass/ momentum of probe



Upsilon spectroscopy

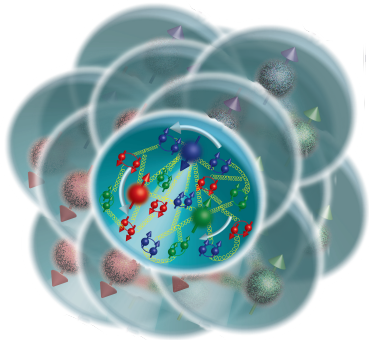
Vary size of the probe





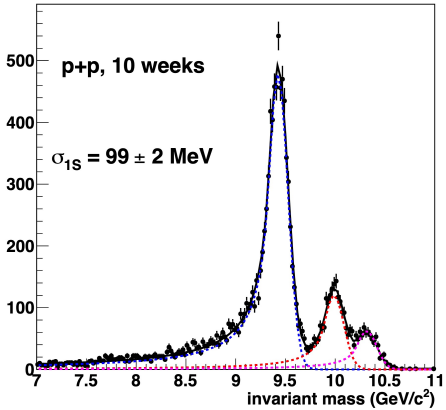
Cold QCD

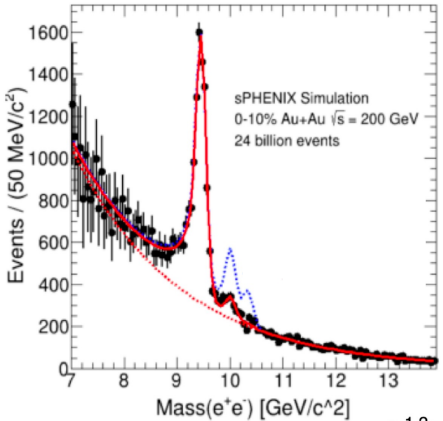
Vary temperature of QCD matter

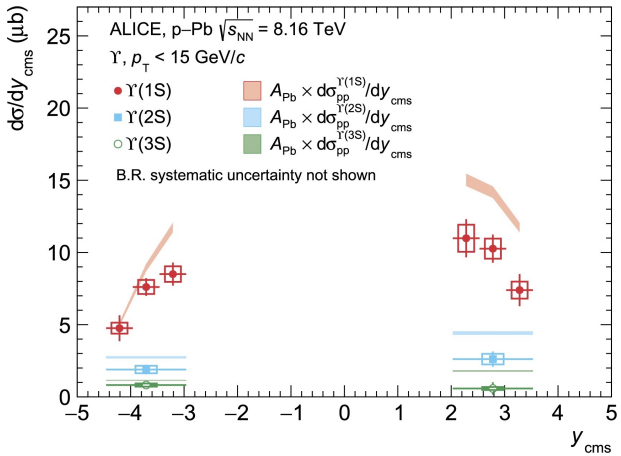


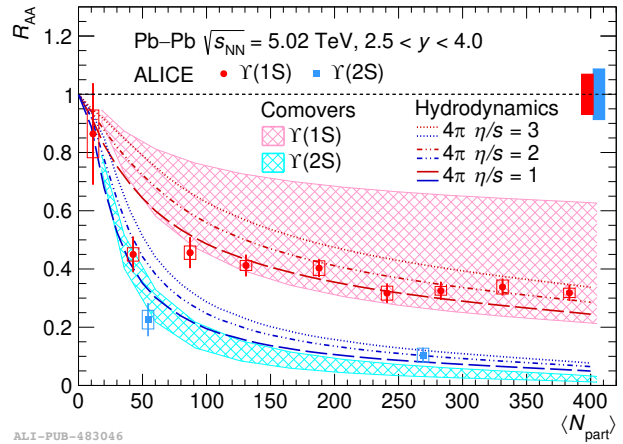
Upsilon spectroscopy

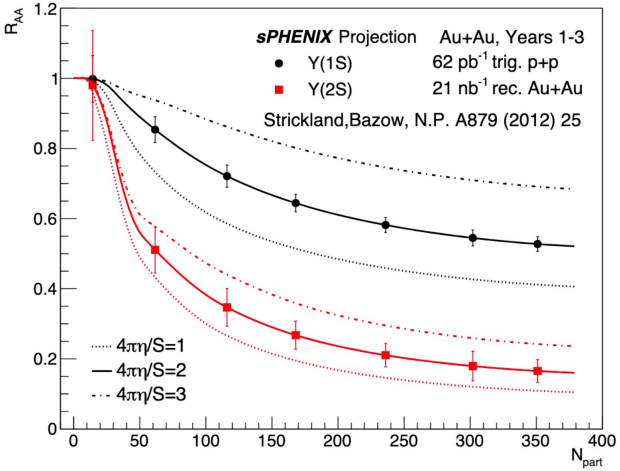
[PLB 806 (2020) 135486]
[arXiv:2011.05758]





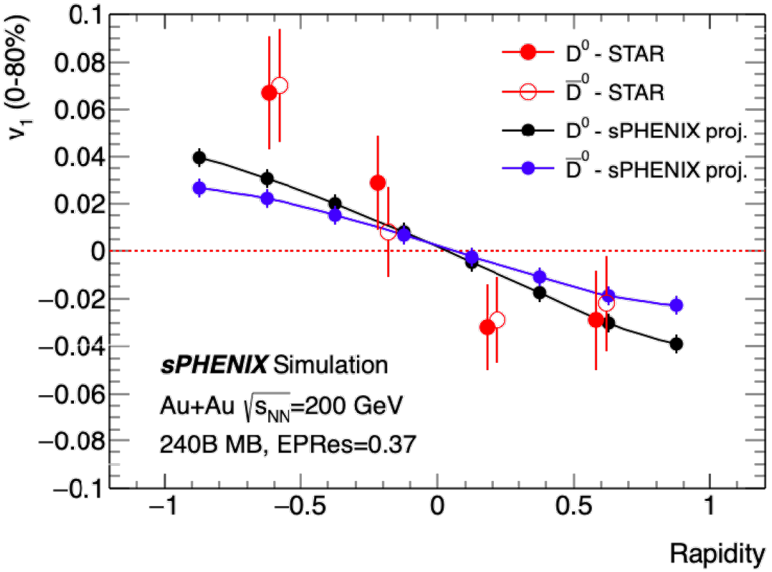




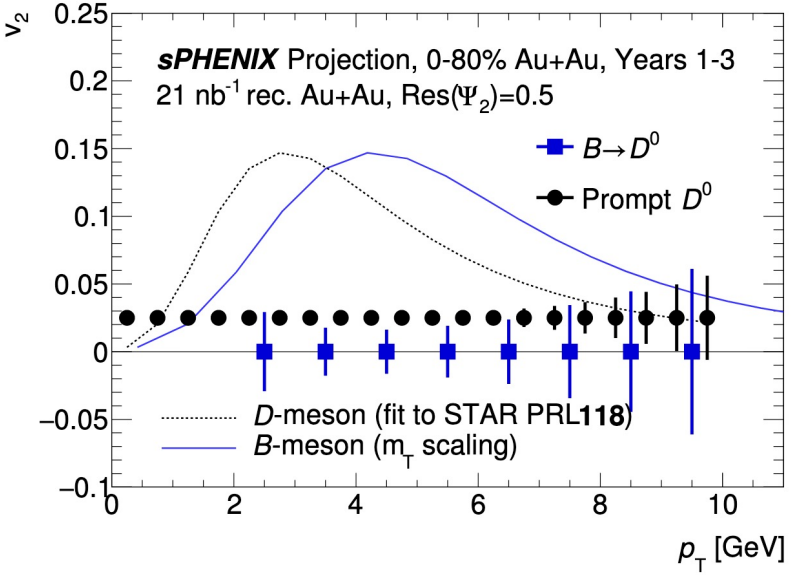


D^0 v_1 and v_2

[PRL 123 (2019) 162301]



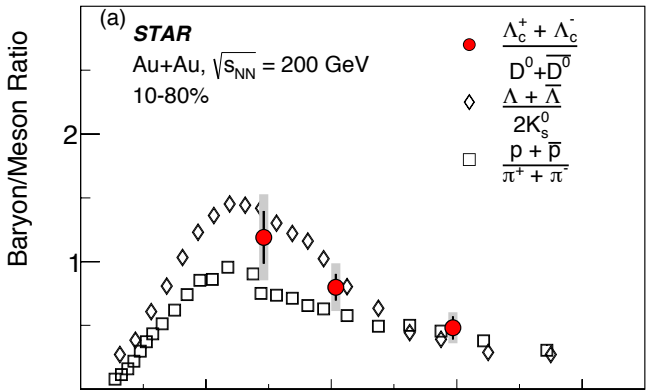
[PRL 118 (2017) 212301]

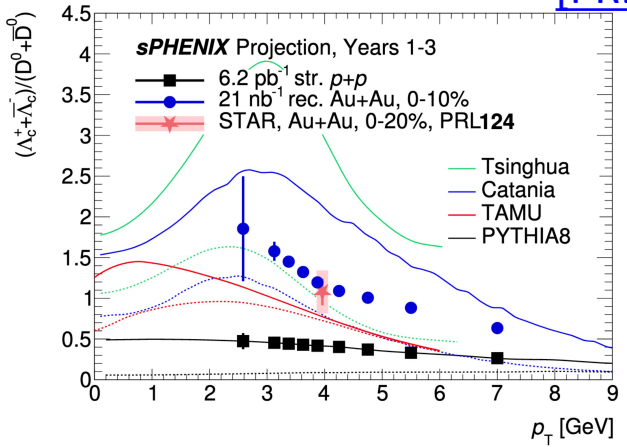


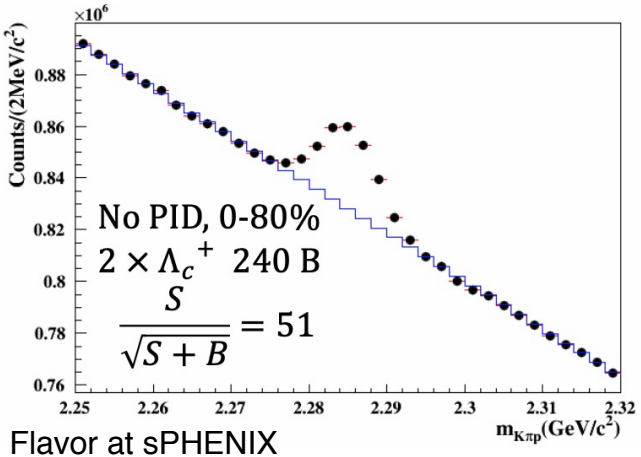
- Prediction that transient mag. field can influence v_1
- This effect is odd under charge-conjugation, resulting in splitting
- D^0 is complicated, requires good production knowledge

Λ_c^+ coalescence?

[PRL 124 (2020) 172301]

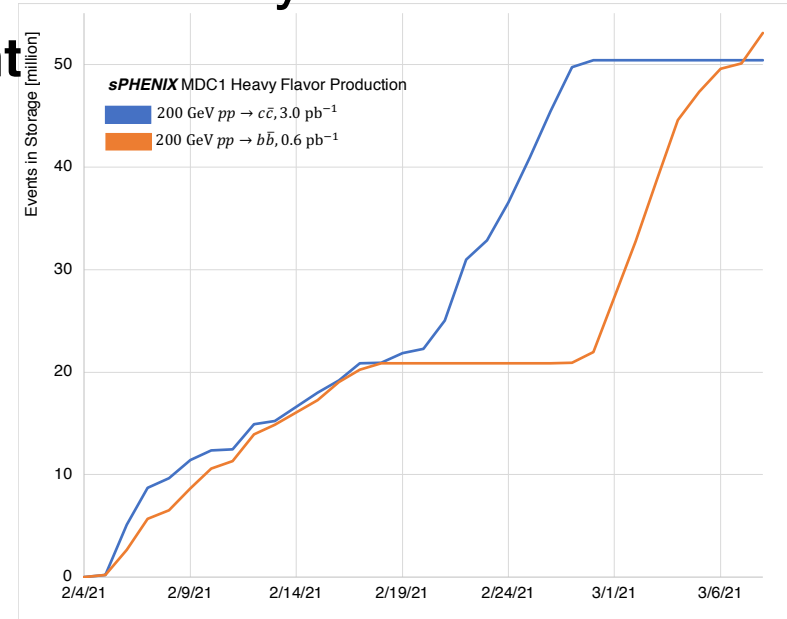






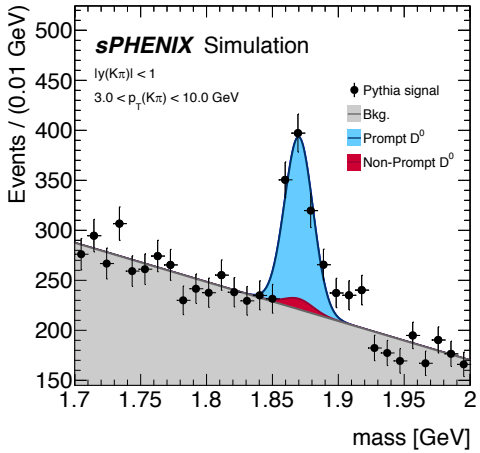
Marching to data-taking

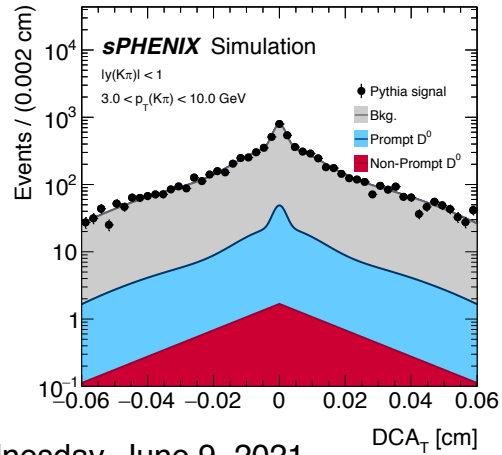
- sPHENIX data taking commences in 2023
- We want to know day-one capabilities and be ready to go
- Large simulation campaign performed in early 2021
  - **What is our throughput and footprint**
  - **How do we co-ordinate analyses**
  - **What can we do on day-one**
- HF sample consists of:
  - **50M $c\bar{c}$ events (3 days of *pp* data)**
  - **50M $b\bar{b}$ events (3 years of *pp* data)**
  - **50M min-bias events (pending)**



$D^0 \rightarrow K^-\pi^+$

[sPH-HF-2021-001]

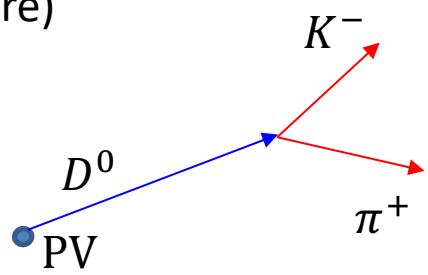


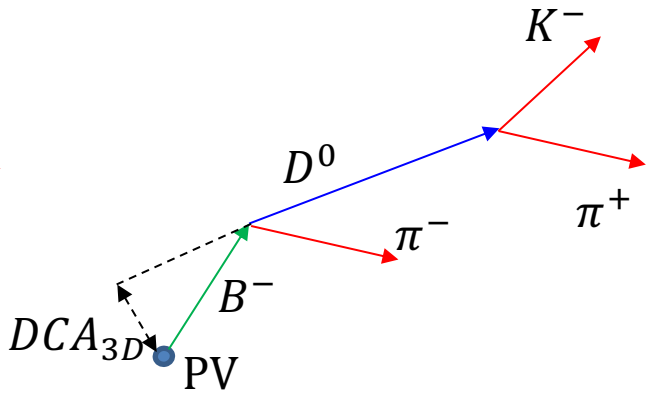


- Simulation campaign allows for good tests of:

1. Pre-existing infrastructure
2. New packages
3. Integration of external packages (ACTS from ATLAS and KFParticle from CBM)

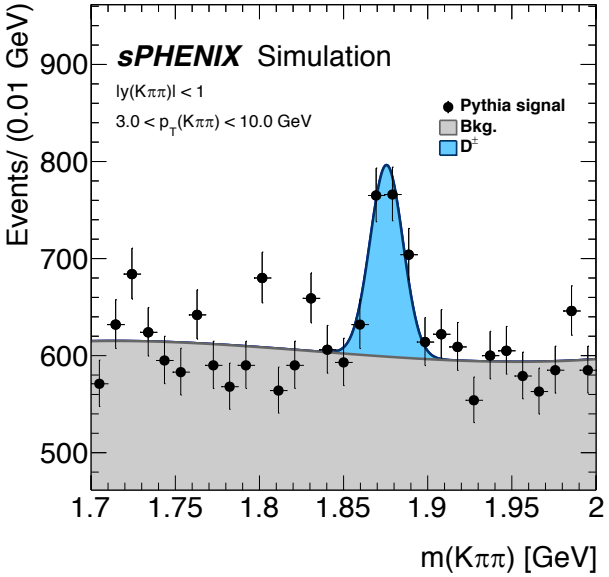
- Prompt/non-prompt separation performed by kinematic reconstruction of b-hadrons or DCA measurements (and more)

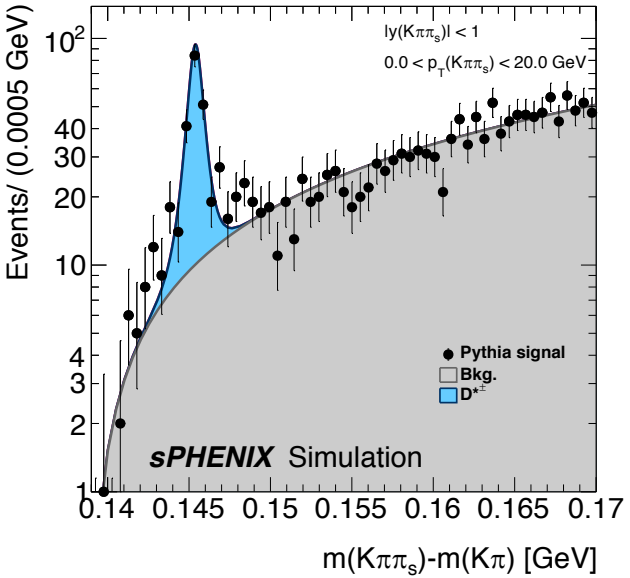




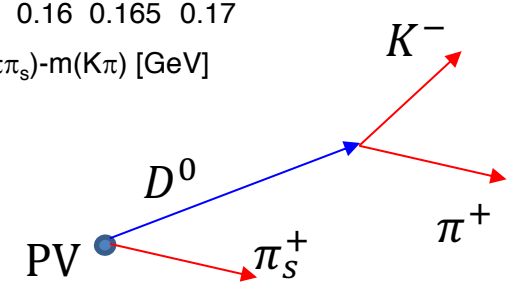
$D^{*+} \rightarrow D^0(\rightarrow K^-\pi^+)\pi_s^+$

[sPH-HF-2021-001]





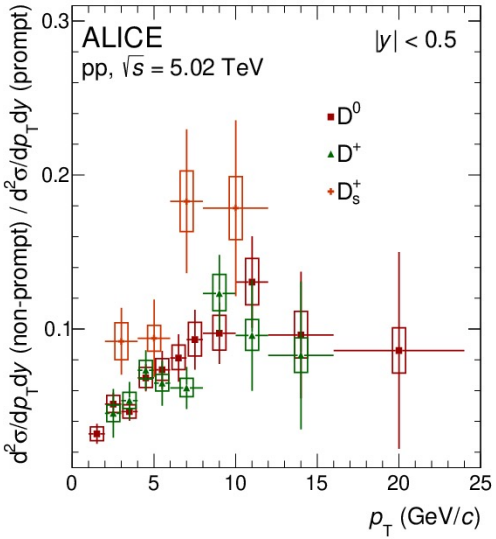
- D^{*+} decays promptly
- Requires good handle on PV, SV and tracking
- In PDG: $m(K\pi\pi_s) - m(K\pi) = 145.426(2)$
- This channel fully defines D^0 flavor at production

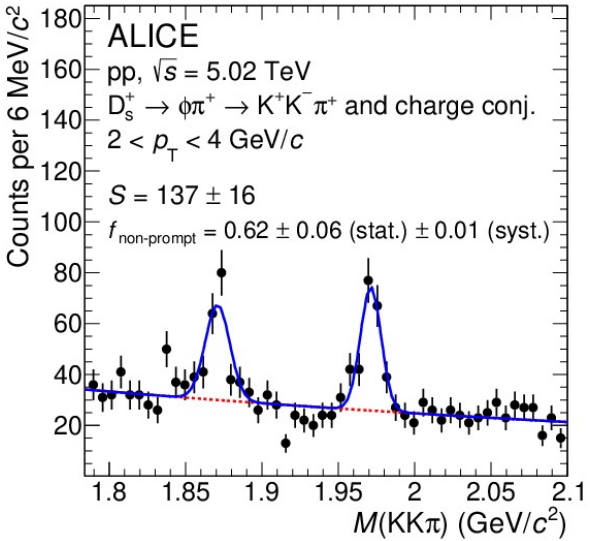


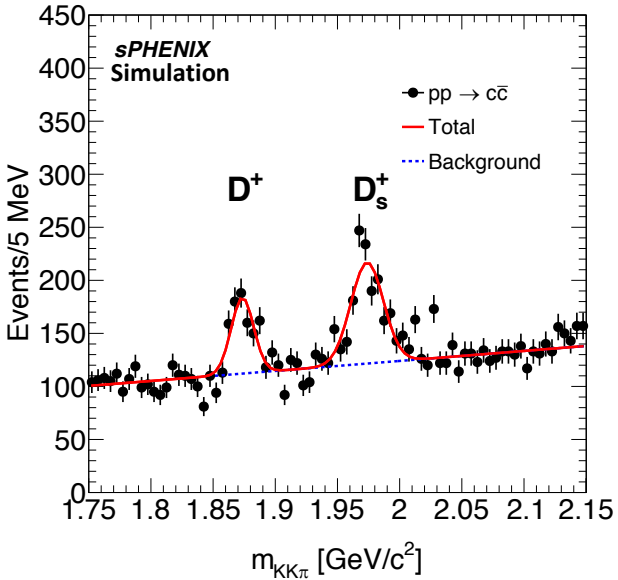
$D^+_{(s)} \to K^+K^-\pi^+$

[sPH-HF-2021-001]

[JHEP 2105 (2021) 220]







Left - non-prompt/prompt production cross-sections as measured by ALICE

Middle - $K^+K^-\pi^+$ invariant mass spectrum as seen in ALICE data

Right - $K^+K^-\pi^+$ invariant mass spectrum as seen in sPHENIX simulations

Conclusions

- sPHENIX's design enables precision physics with b-hadrons at RHIC
- The beam delivered by RHIC will give large samples of heavy flavor particles for study
  - Bean Use Proposal has been submitted and we're listening to RHIC for any developments
- Our physics goals are well understood
  - Large statistics will greatly reduce statistical uncertainties
  - Lower pT reach (compared to LHC) will help probe new regions
- The collaboration are working hard to prepare for day-one