Heavy Flavor Physics with sPHENIX

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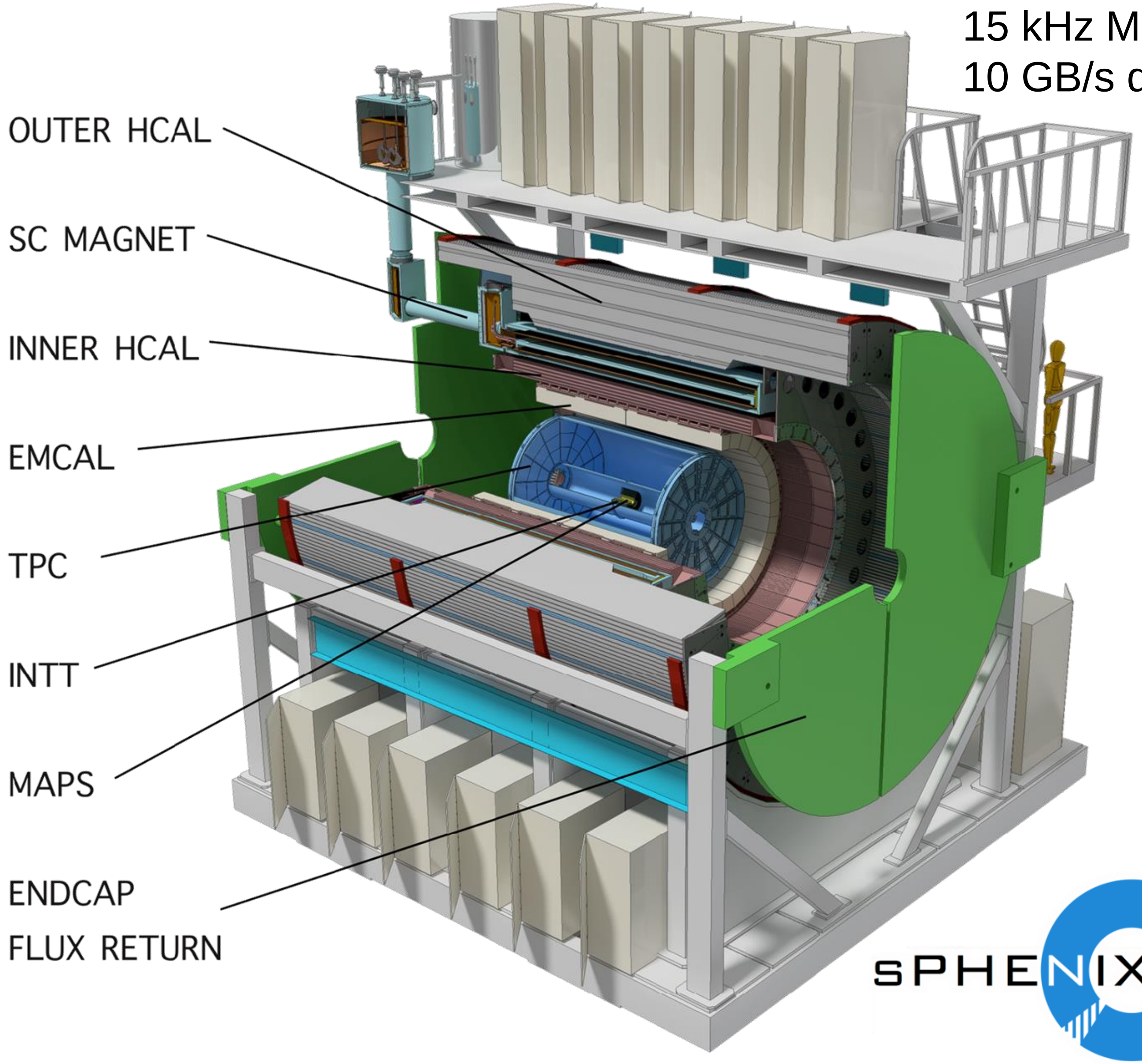
For sPHENIX collaboration

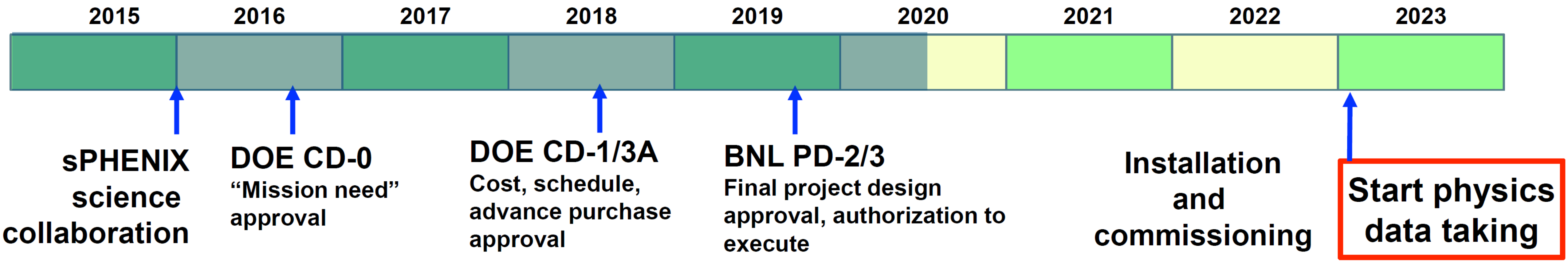
BROOKHAVEN NATIONAL LABORATORY

15 kHz MB AuAu trigger
10 GB/s data logging



sPHENIX Detector

sPHENIX schedule



Baseline program:

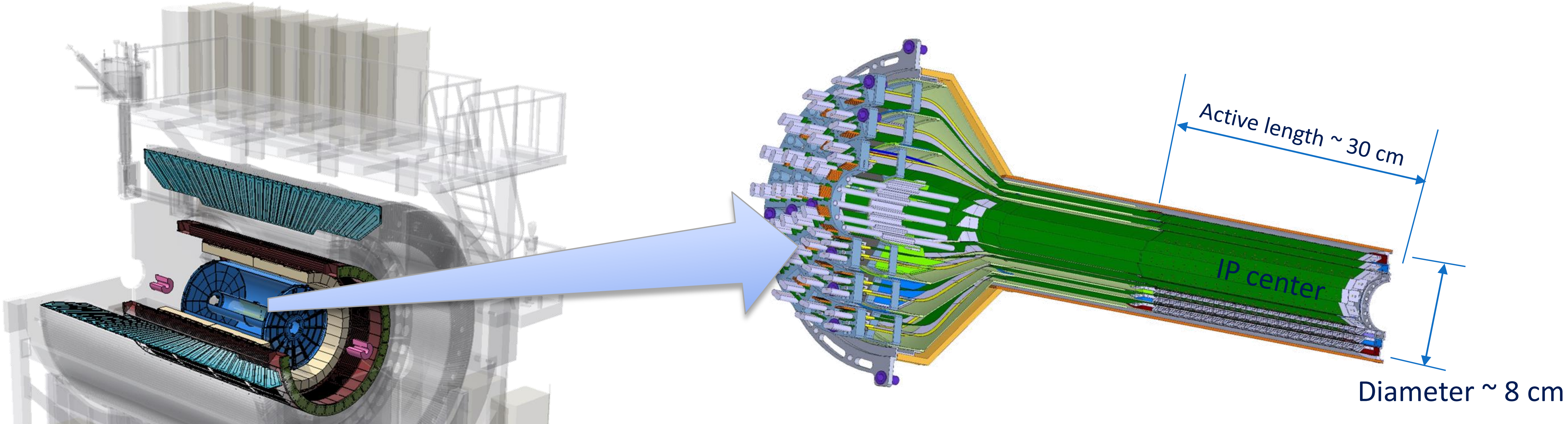
Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
Year-2	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}

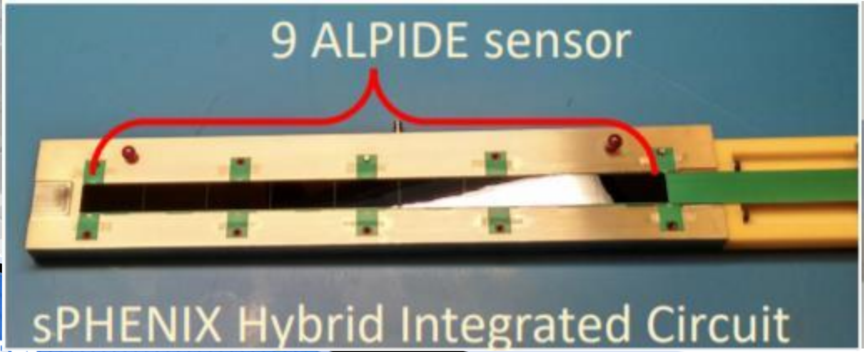
Possible extension:

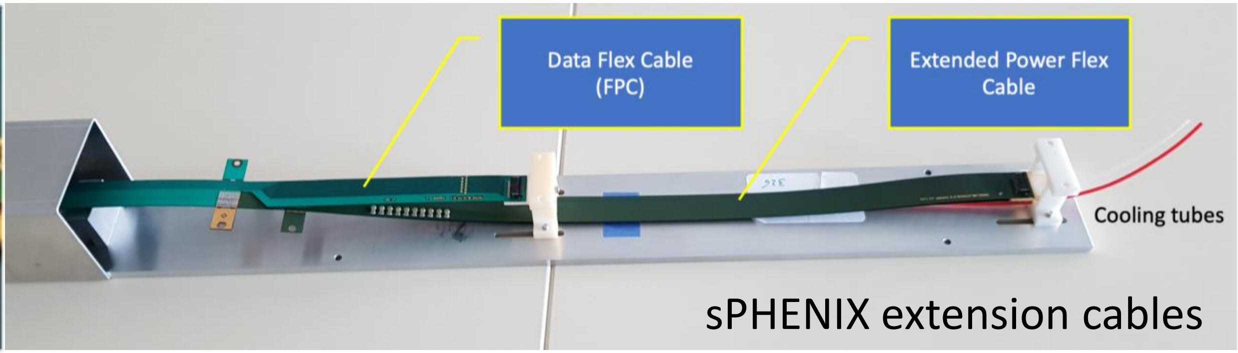
Year-4	p+p	200	23.5	—	149 pb^{-1}	783 pb^{-1}
Year-5	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

Inner MAPS silicon vertex tracker

- Staves are identical to ALICE inner barrel staves, sPHENIX ext. cable
- Under production in CERN facility operated by ALICE (see also talk: G. Innocenti)

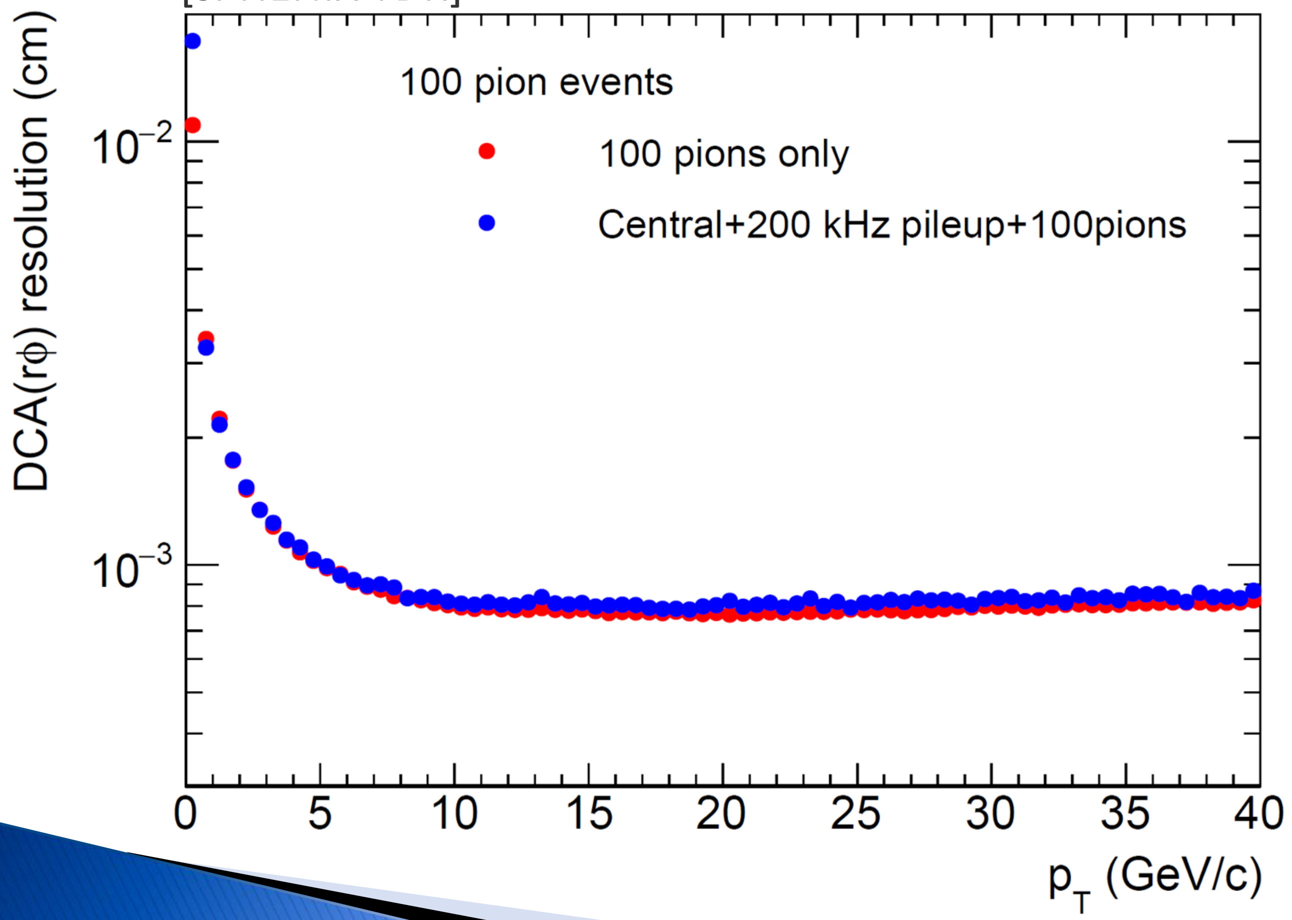




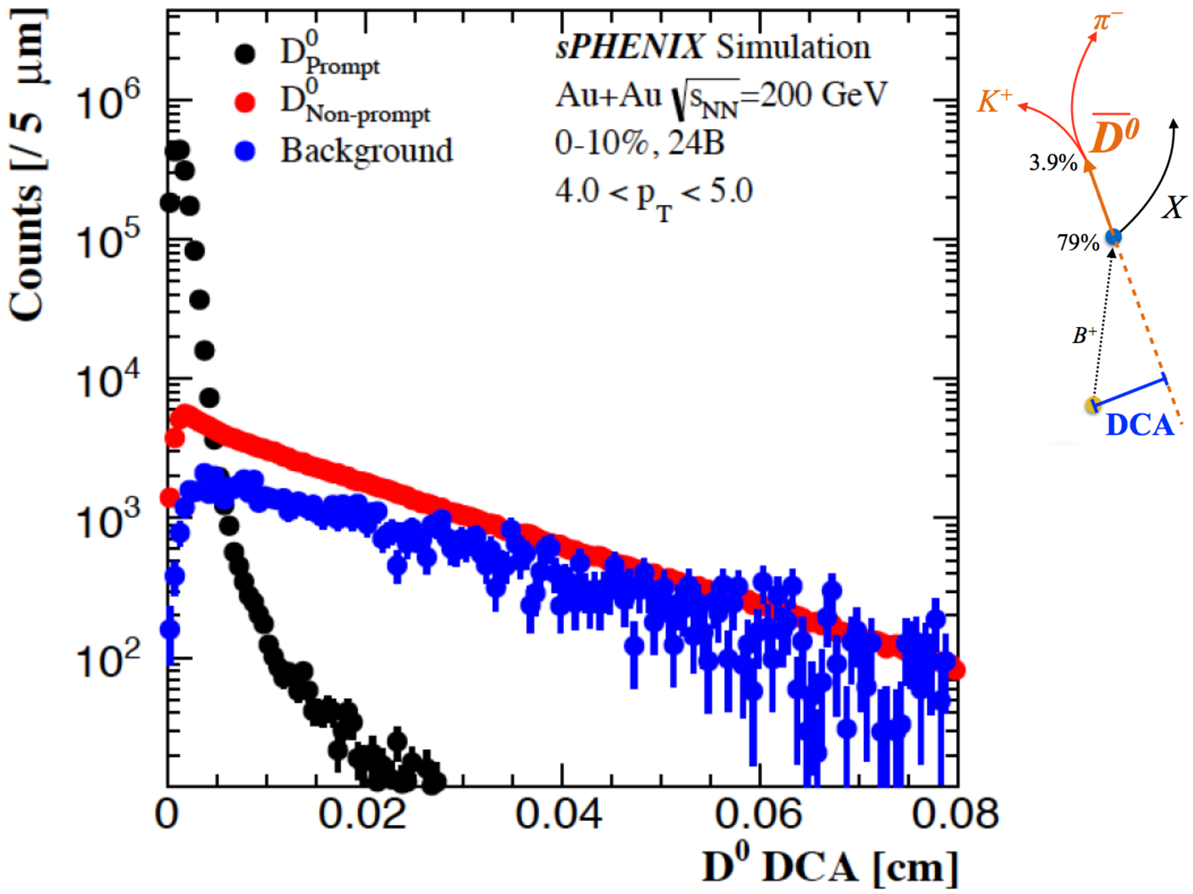


Cleanly separate open bottom meson via DCA

DCA resolution of charged pions
[sPHENIX TDR]



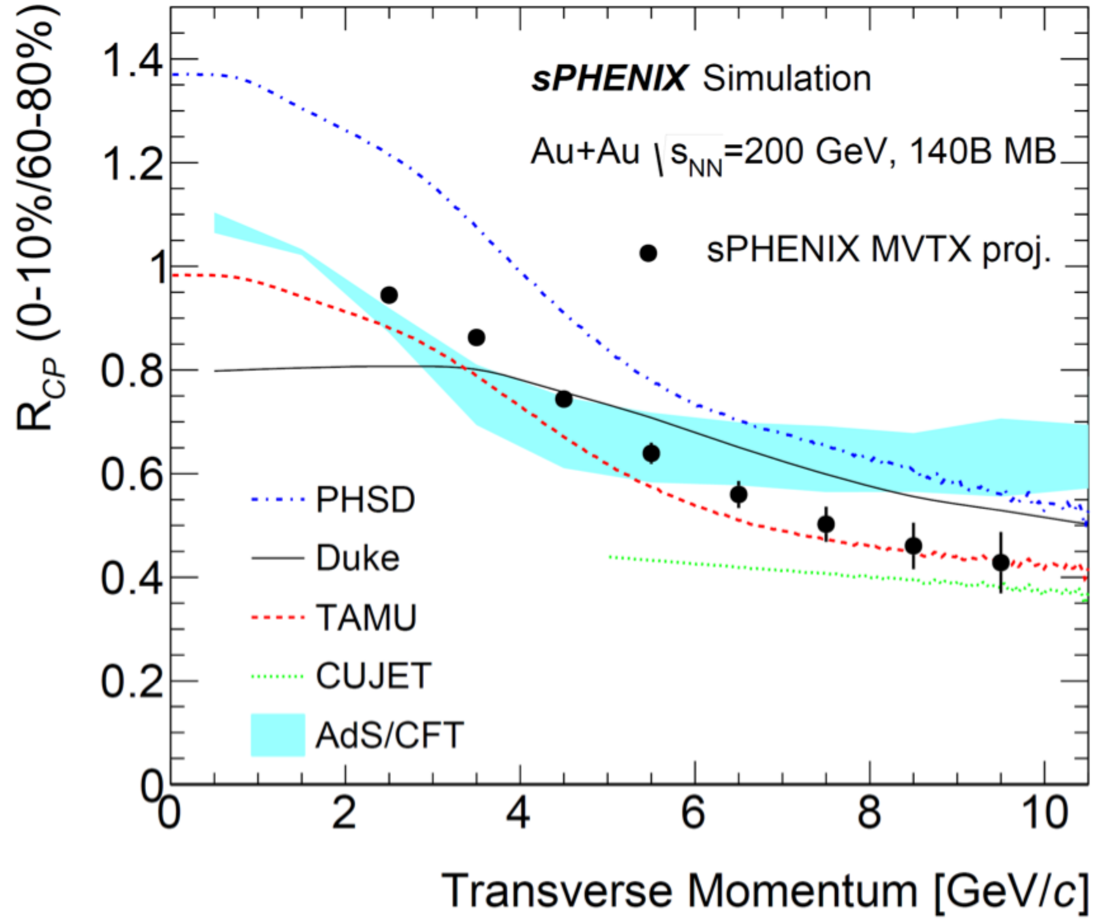
Prompt and non-prompt D-meson DCA
[sPH-HF-2017-002]

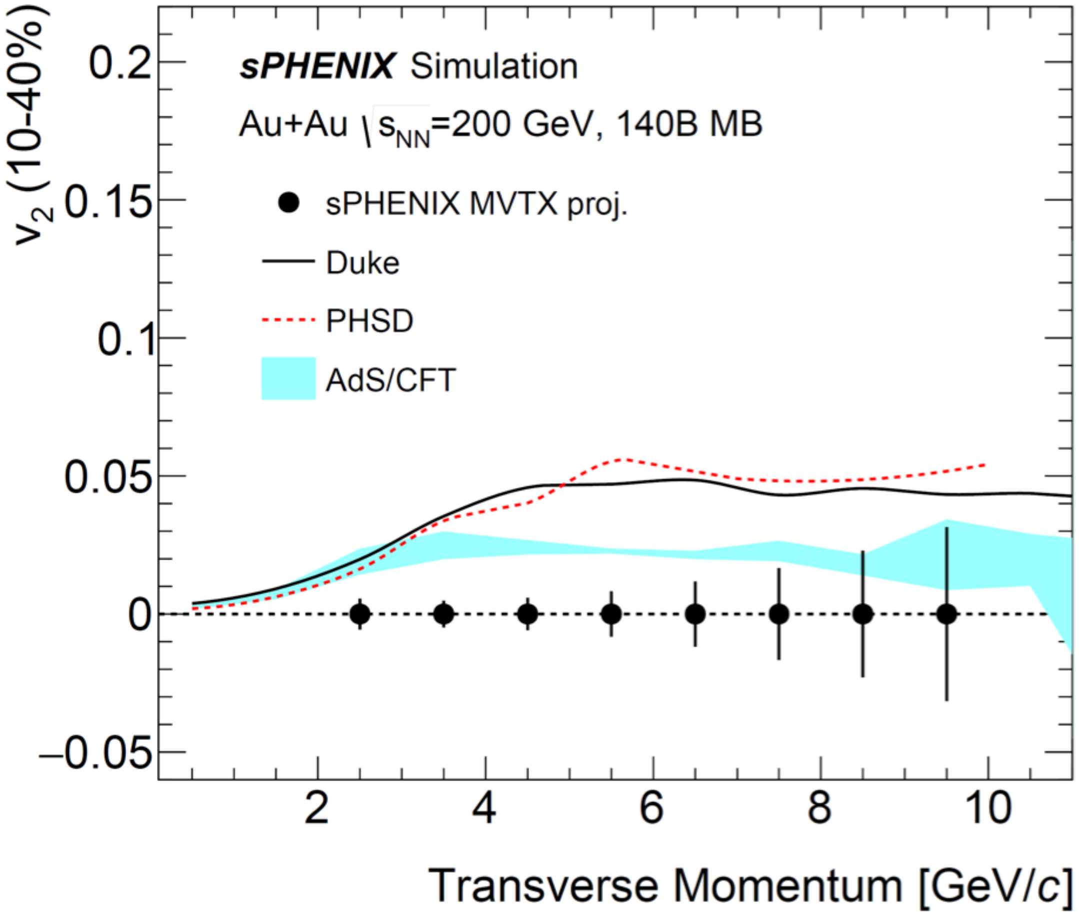


Access b-quark suppression/v2 via non-prompt D

- Clean access to E-loss mechanism and spatial diffusion coefficient at RHIC energy

[sPH-HF-2017-002] Non-prompt D^0 meson

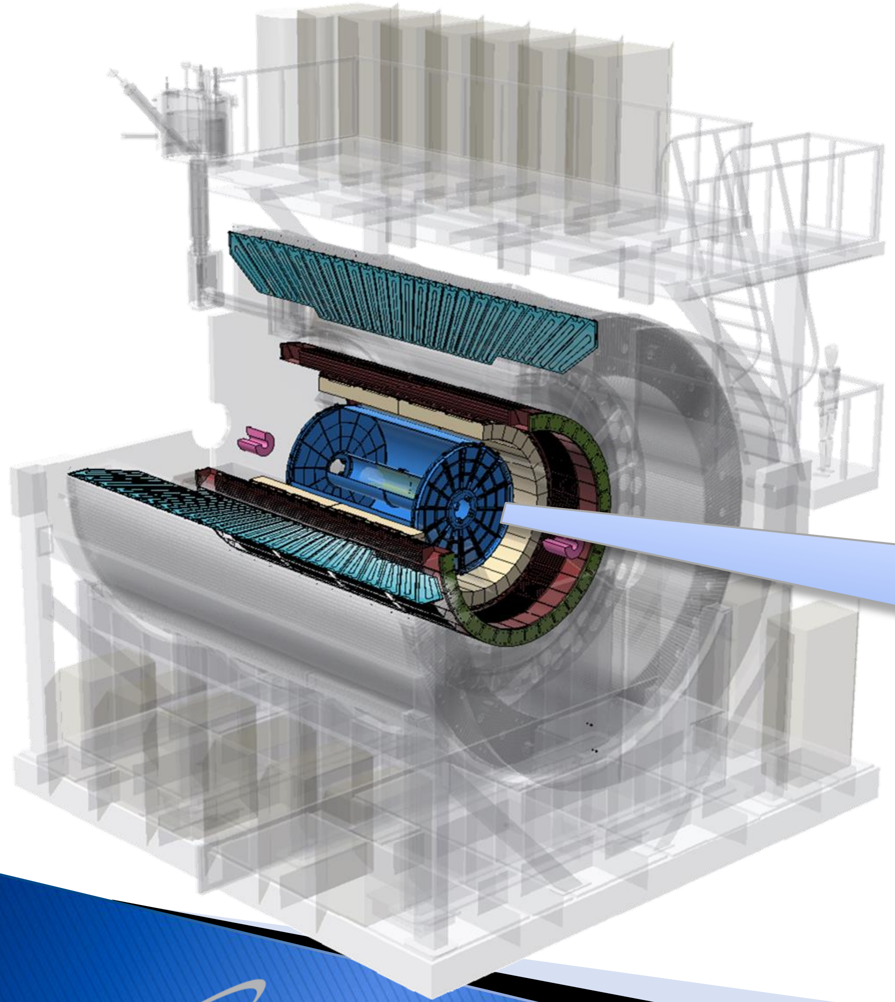


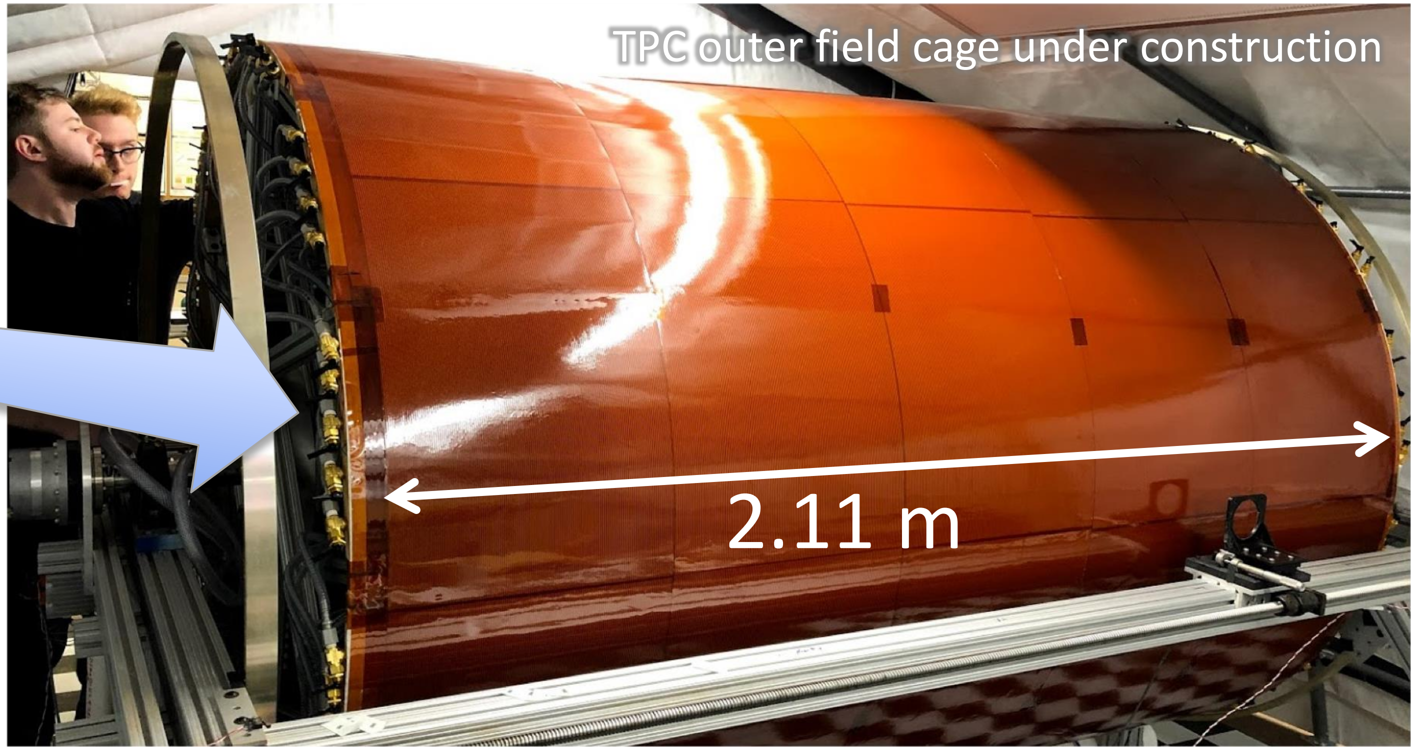


Outer tracking system

Precision tracker with high rate capability

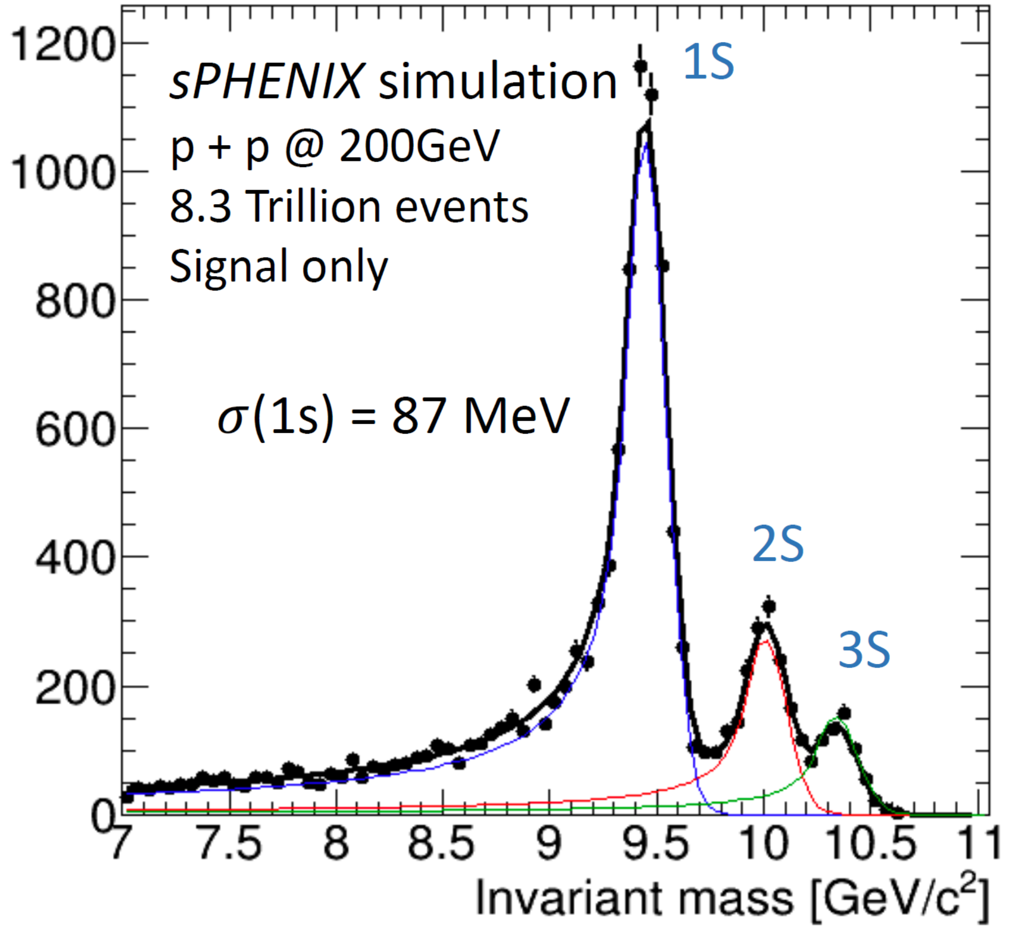
- 1.4 T super conducting solenoidal magnet
- Compact next generation TPC with streaming readout
- Silicon strip tracker bridging TPC and MAPS, time stamping

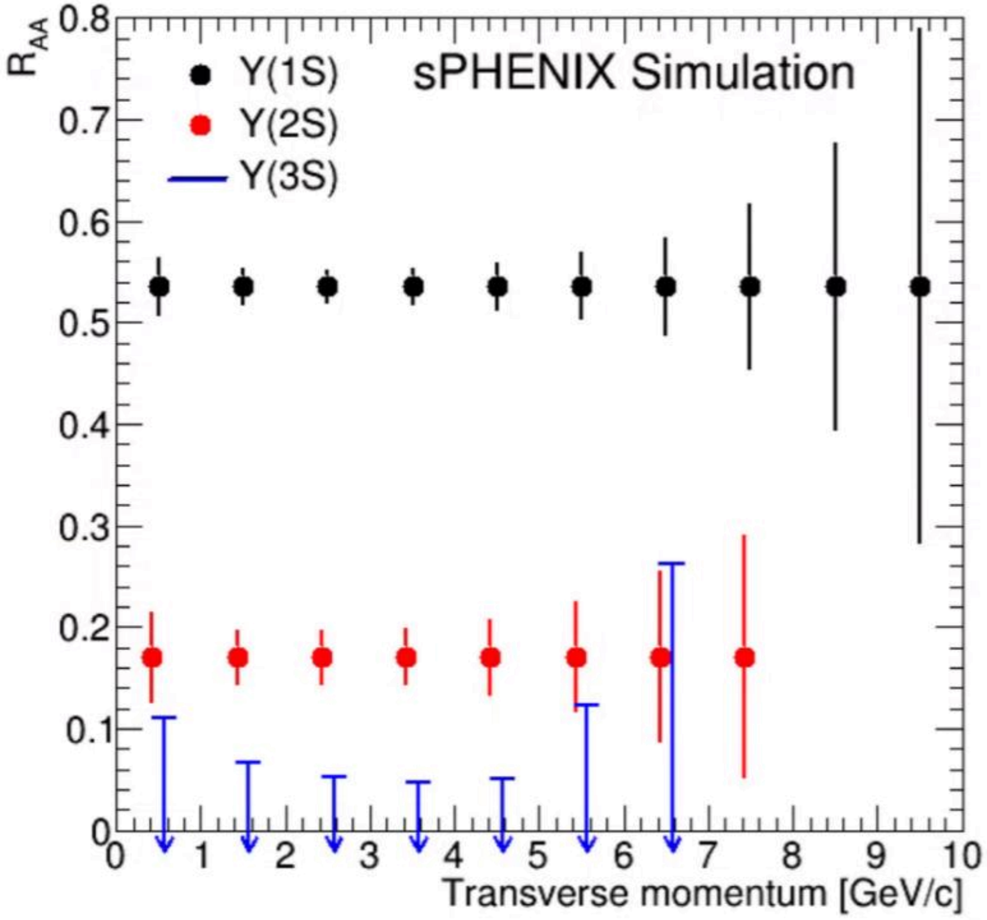




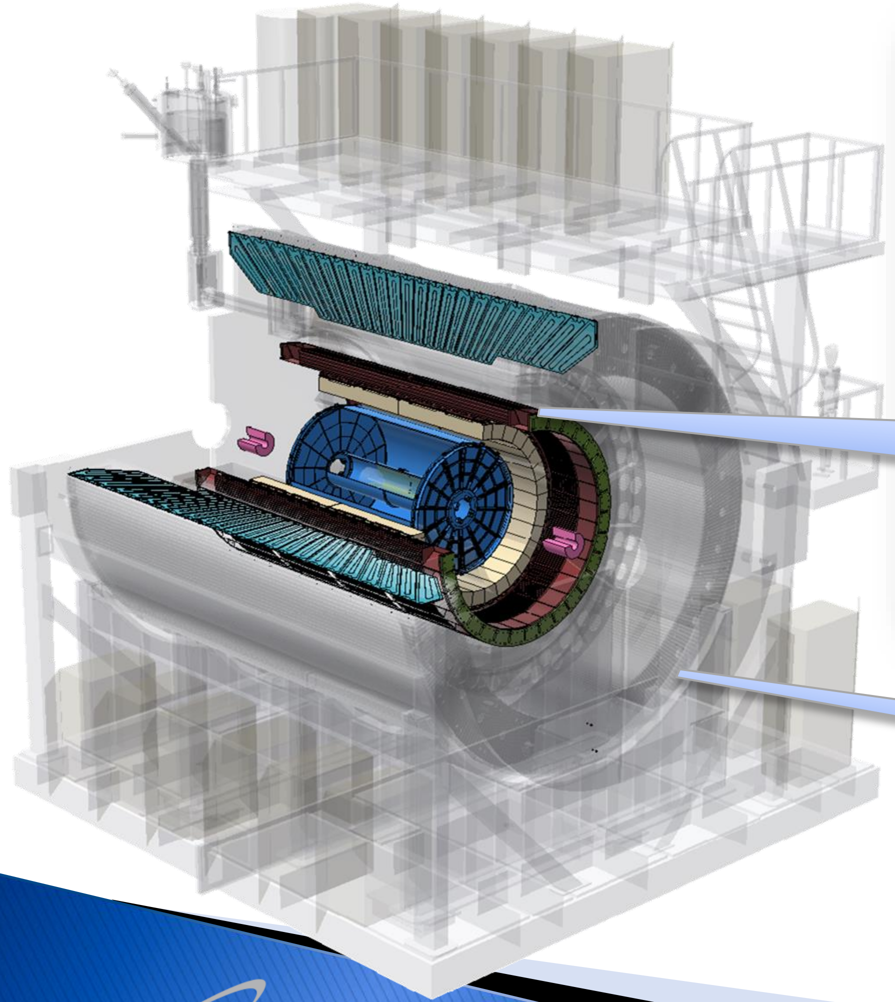
Upsilon Spectroscopy

- Precision tracking → First separated three Upsilon states @ RHIC





EM + hadronic calorimetry: calorimetric jet

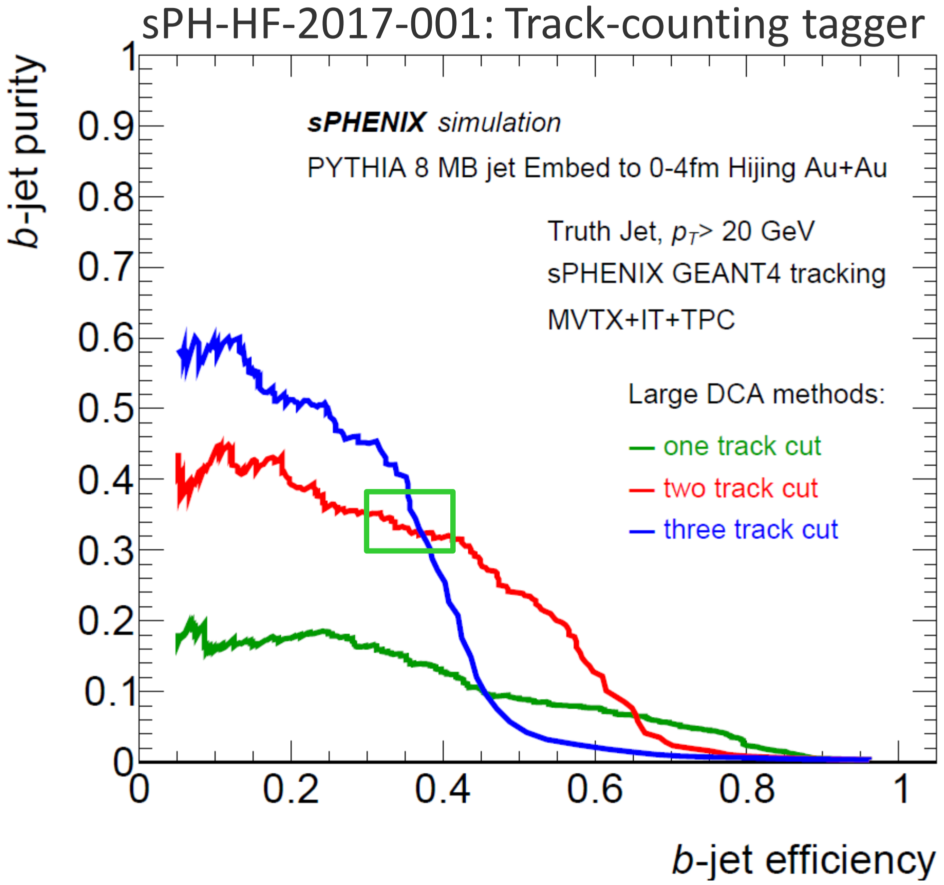


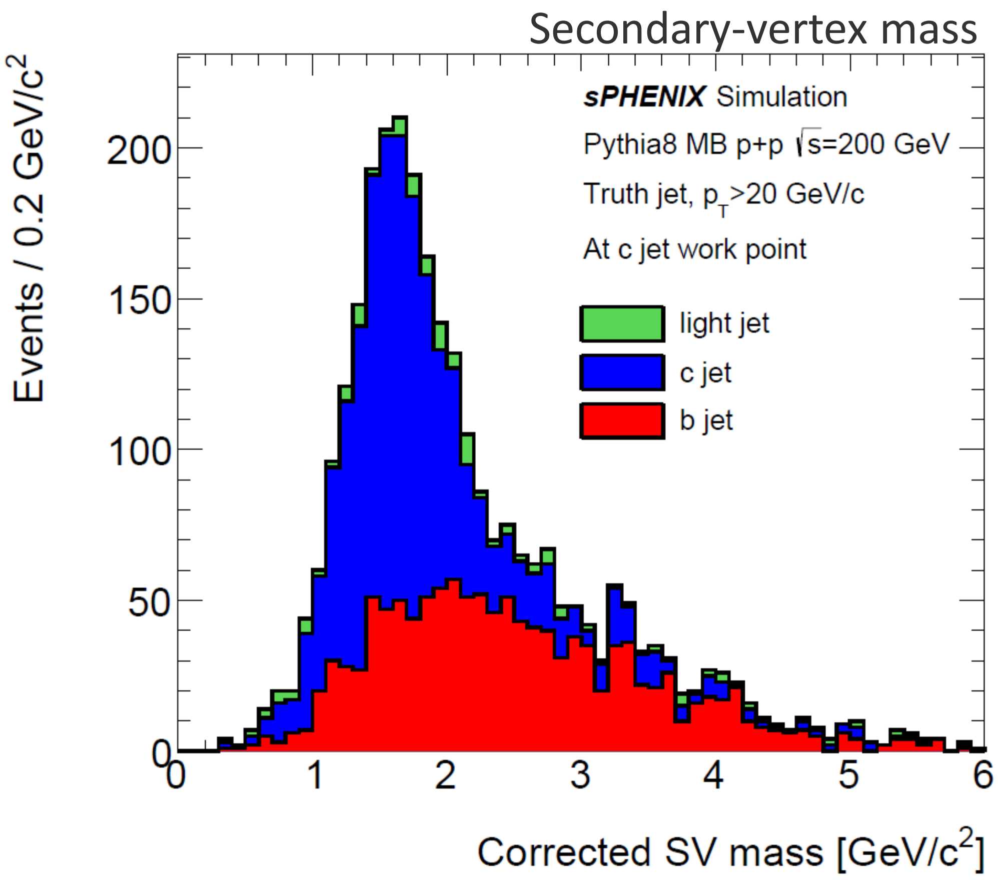
sPHENIX EMCal: sector-0

sPHENIX outer HCal sectors

Combining calo.-jet and precision vertex: *b*-jet tagging

- Demonstrate b-jet capability: tagging algorithms evaluated using full detector HI simulation
- Reaching a promising working point in central Au+Au collisions





CMS work-point, Phys. Rev. Lett. 113, 132301 (2014) See also talk: J. Wang for CMS data

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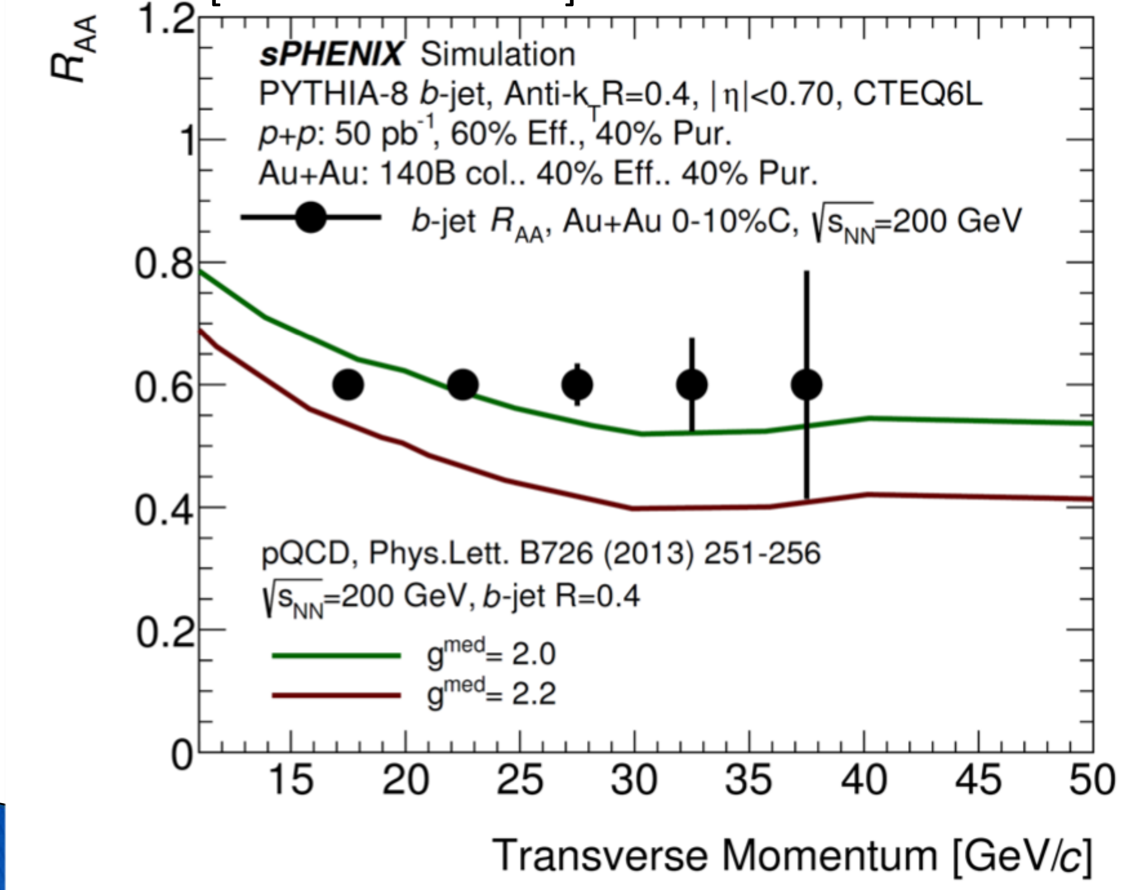
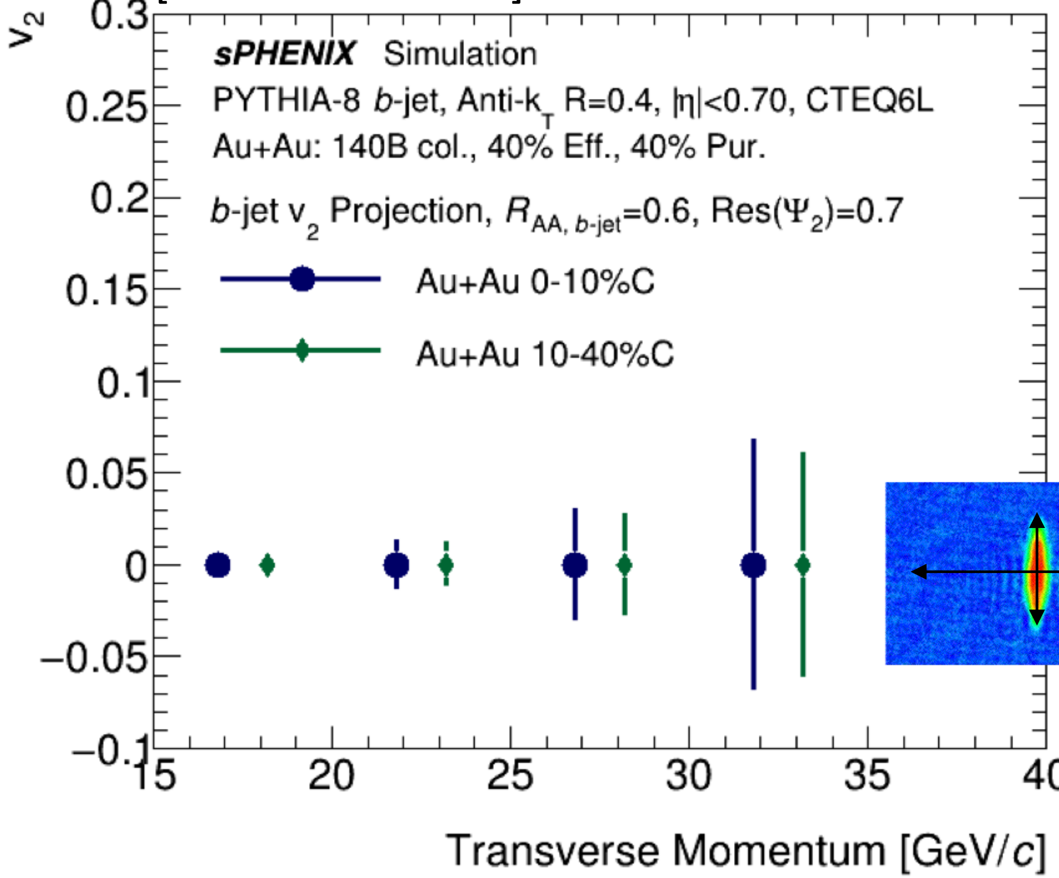
sPHENIX *b*-quark jet

- Transition from non-perturbative to perturbative regions, strong model constraint

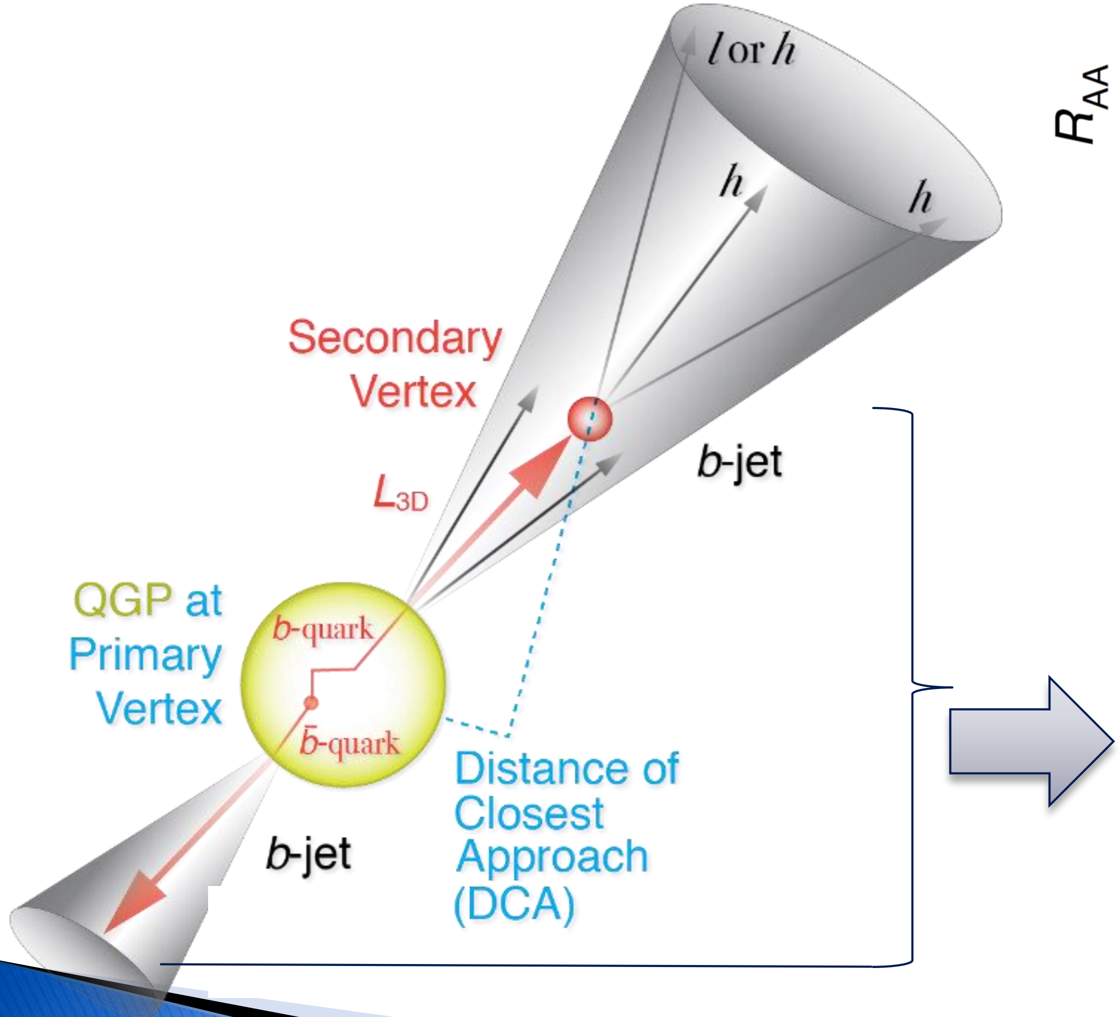
[sPH-HF-2017-001]

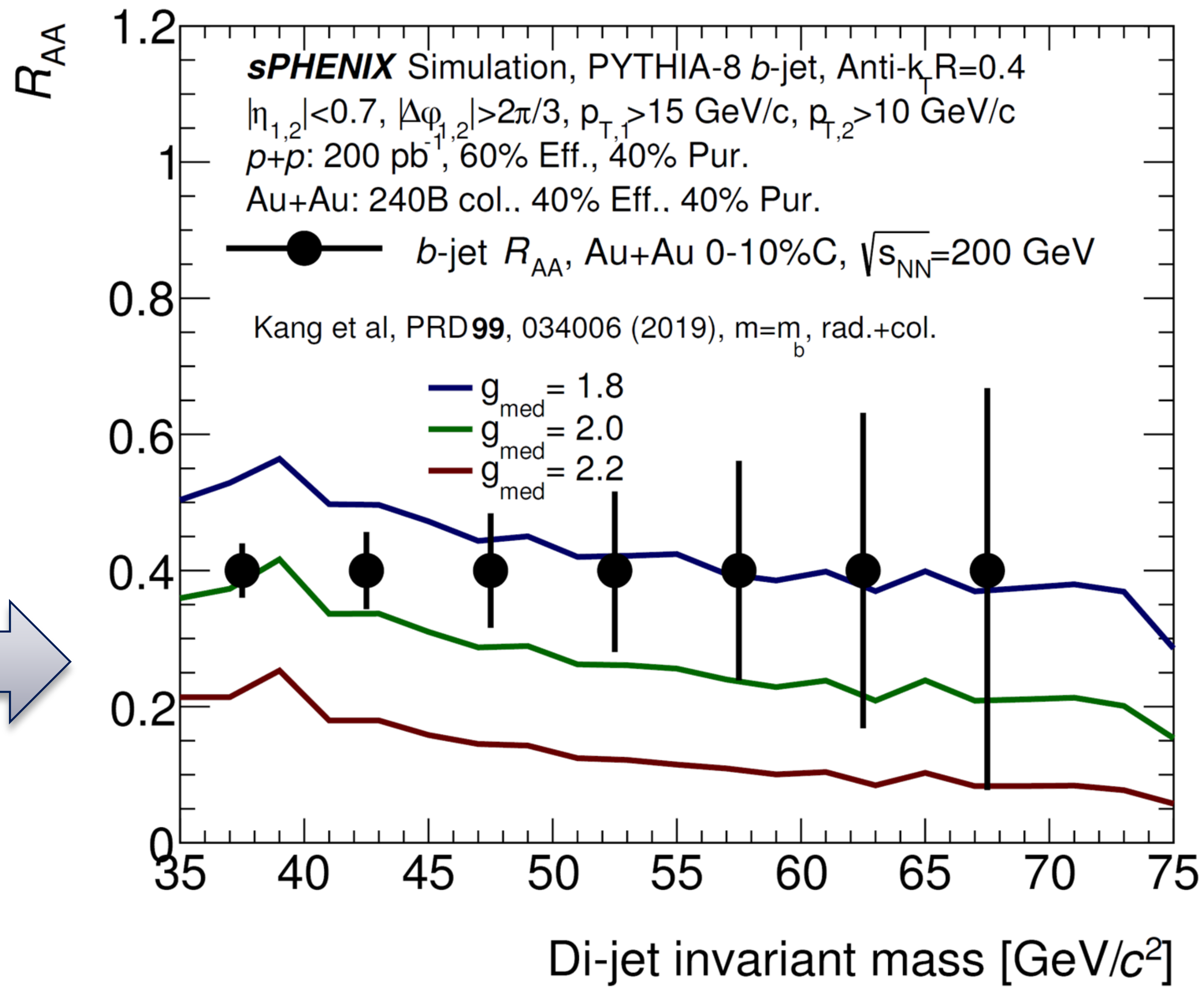


[sPH-HF-2017-001]



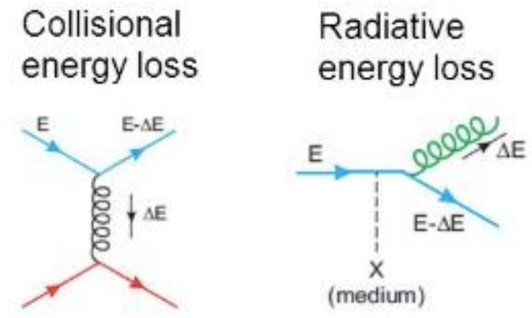
Bottom quark jet pairs → Enhanced sensitivity





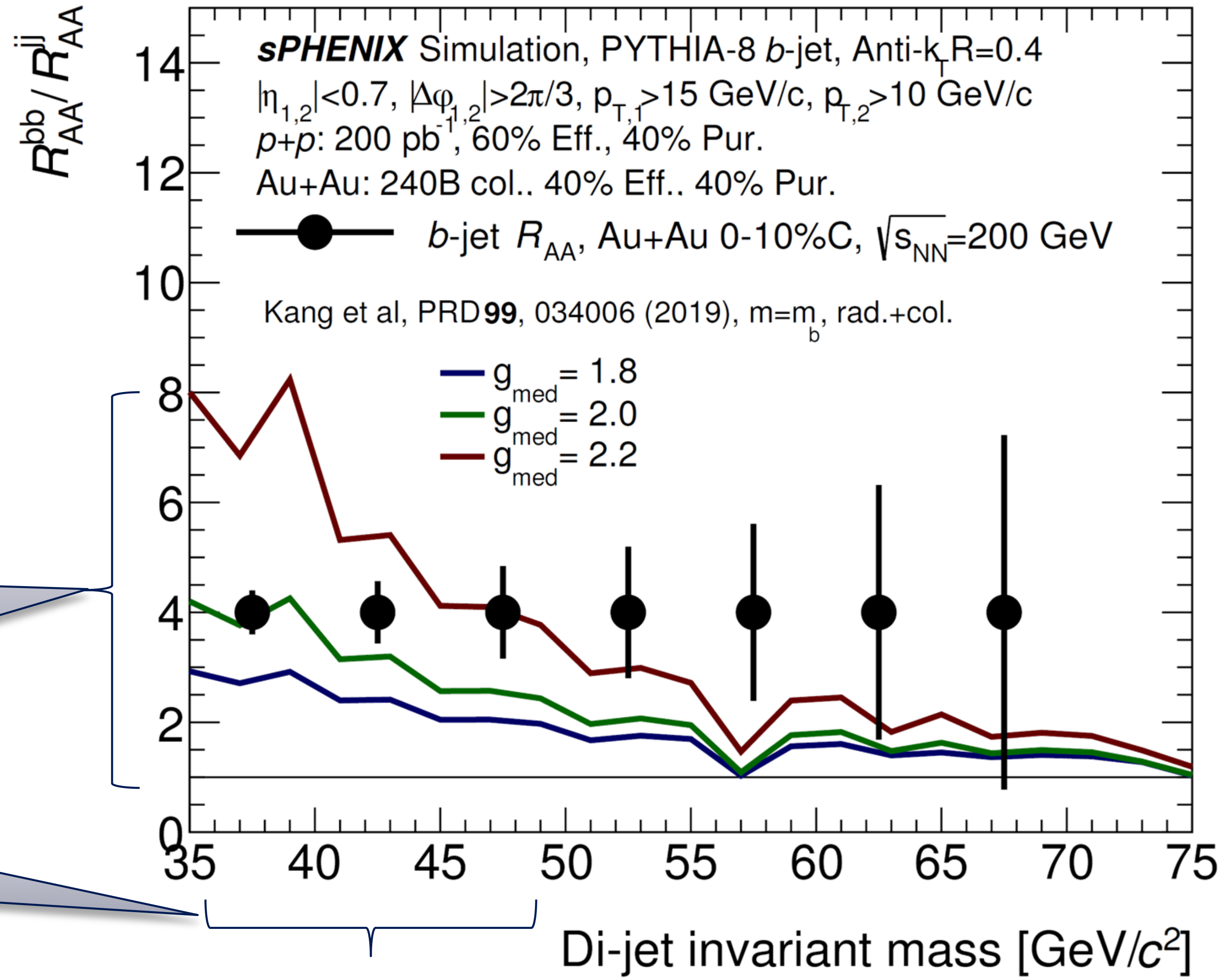
b-jet vs light jet → differentiating energy loss mech.

b/light ratio on RAA
Partial exp. systematic uncert. cancelation



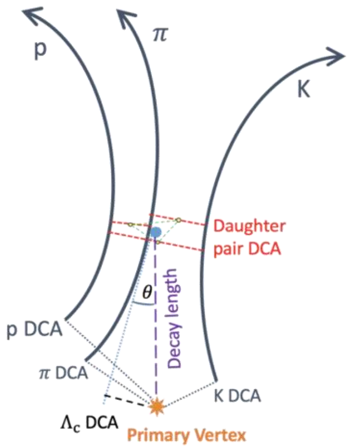
1-8 times mass effect!
x2 effect vs 10% variation on g_{med}!

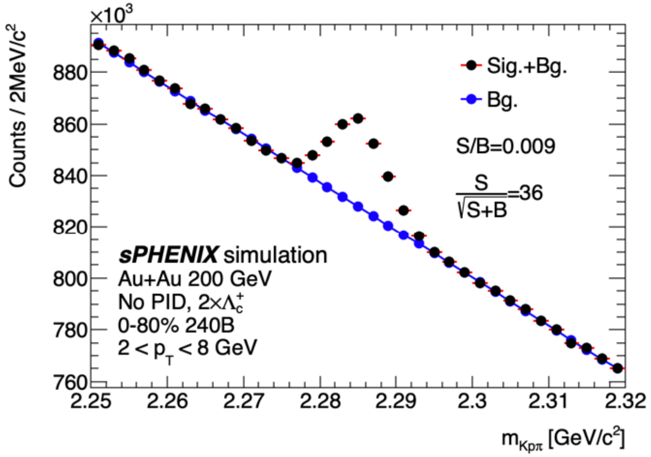
Unique region in the RHIC kine.
@ max sensitivity to mass eff.

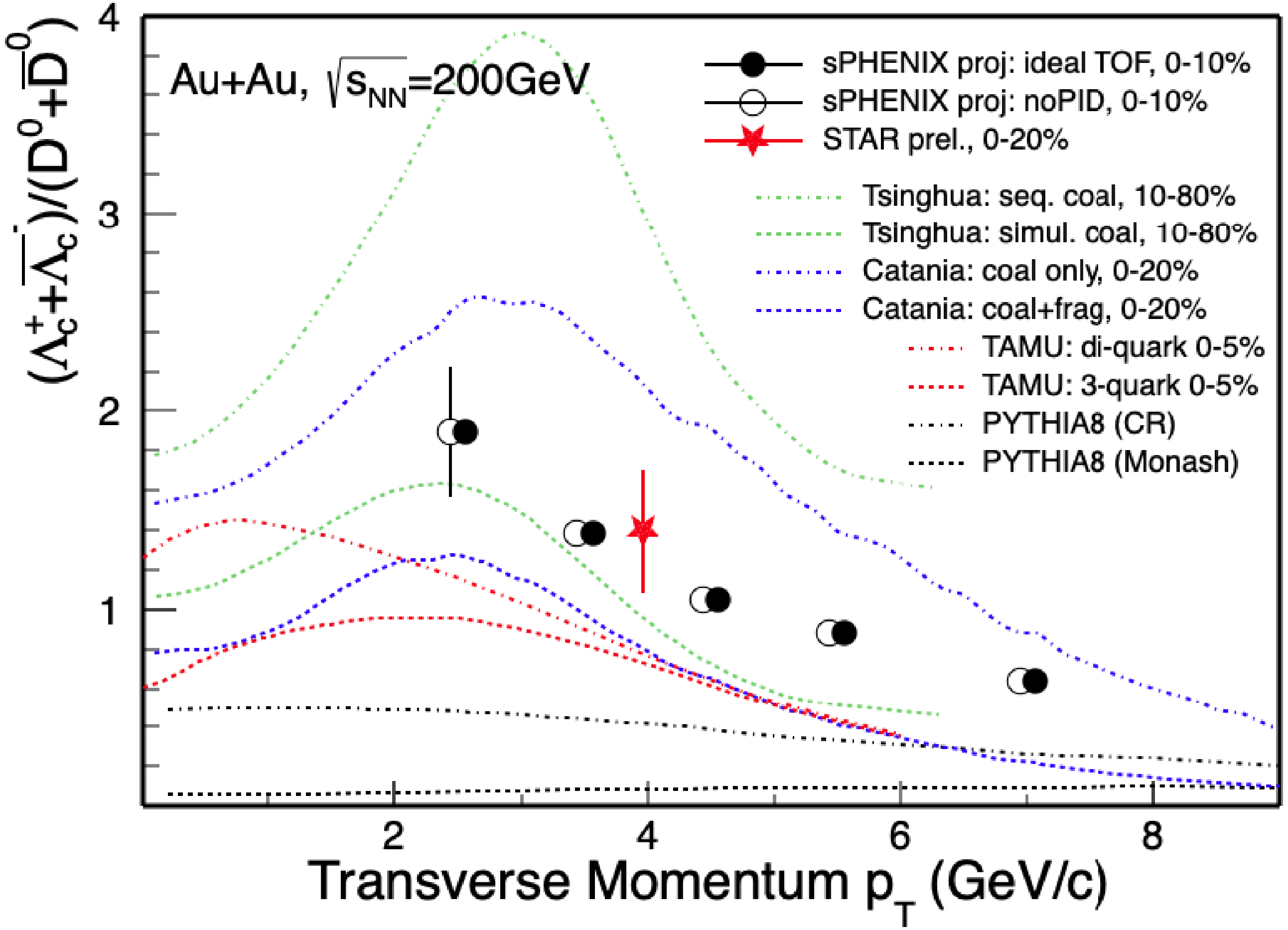


Charm hadronization via Λ_c/D ratio

- Constraints HF hadronization mechanisms
- Ingredient of precision total charm cross section



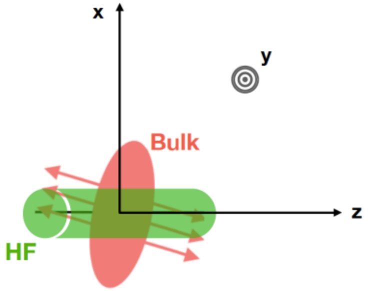




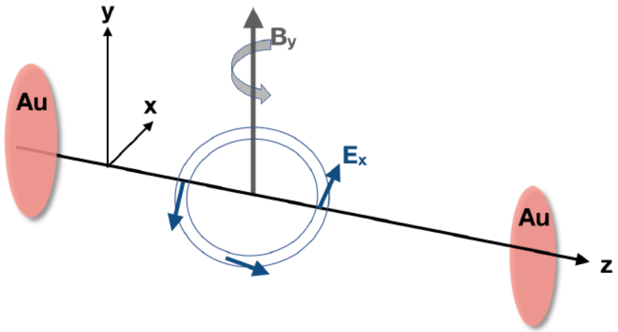
See also talk: Xin D. for STAR data

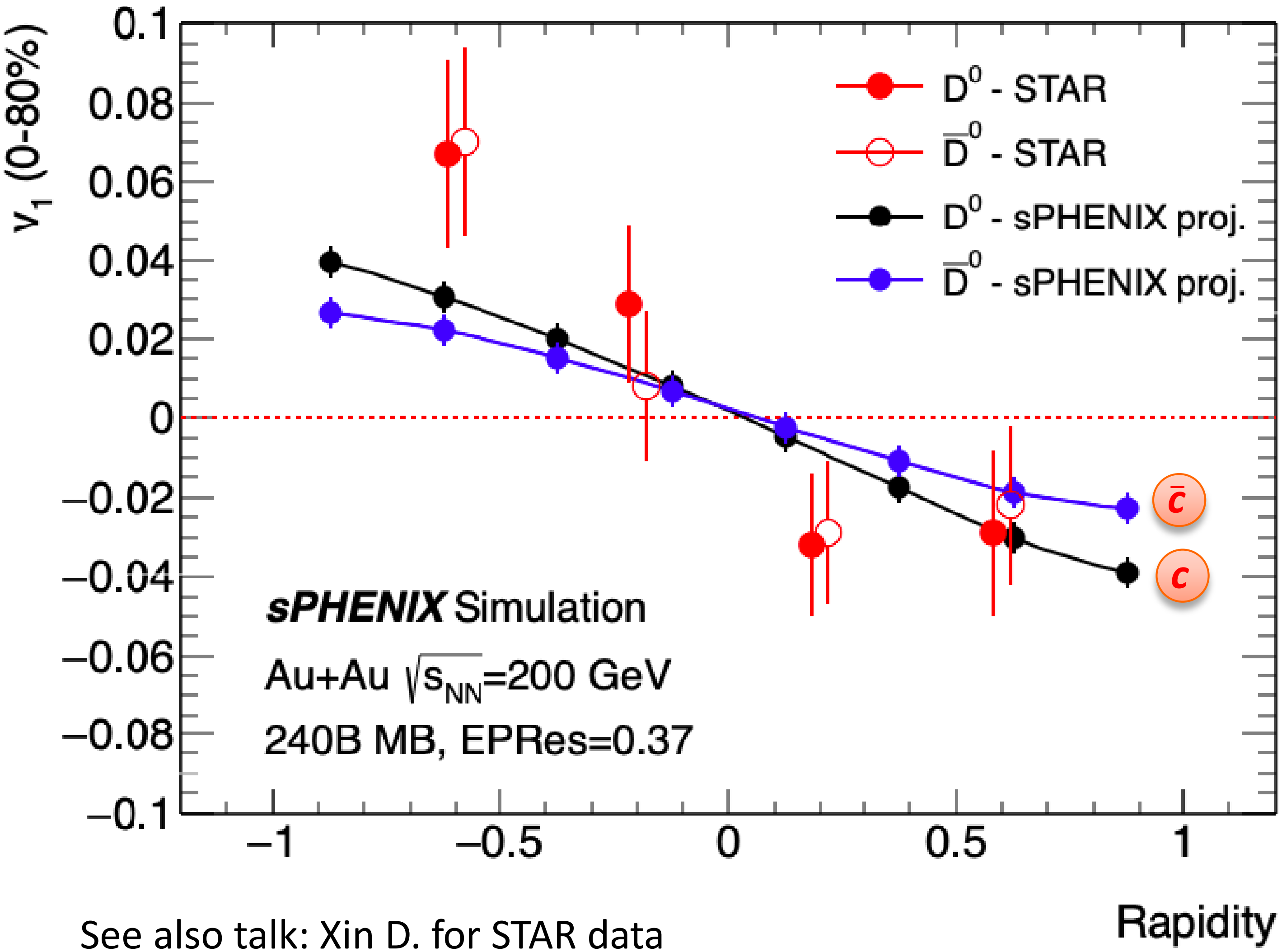
Charm v_1 (via prompt D_0)→ initial geom. & *B*-field

- v_1: Geometry tilt of QGP source



- Δv_1: Initial magnetic field

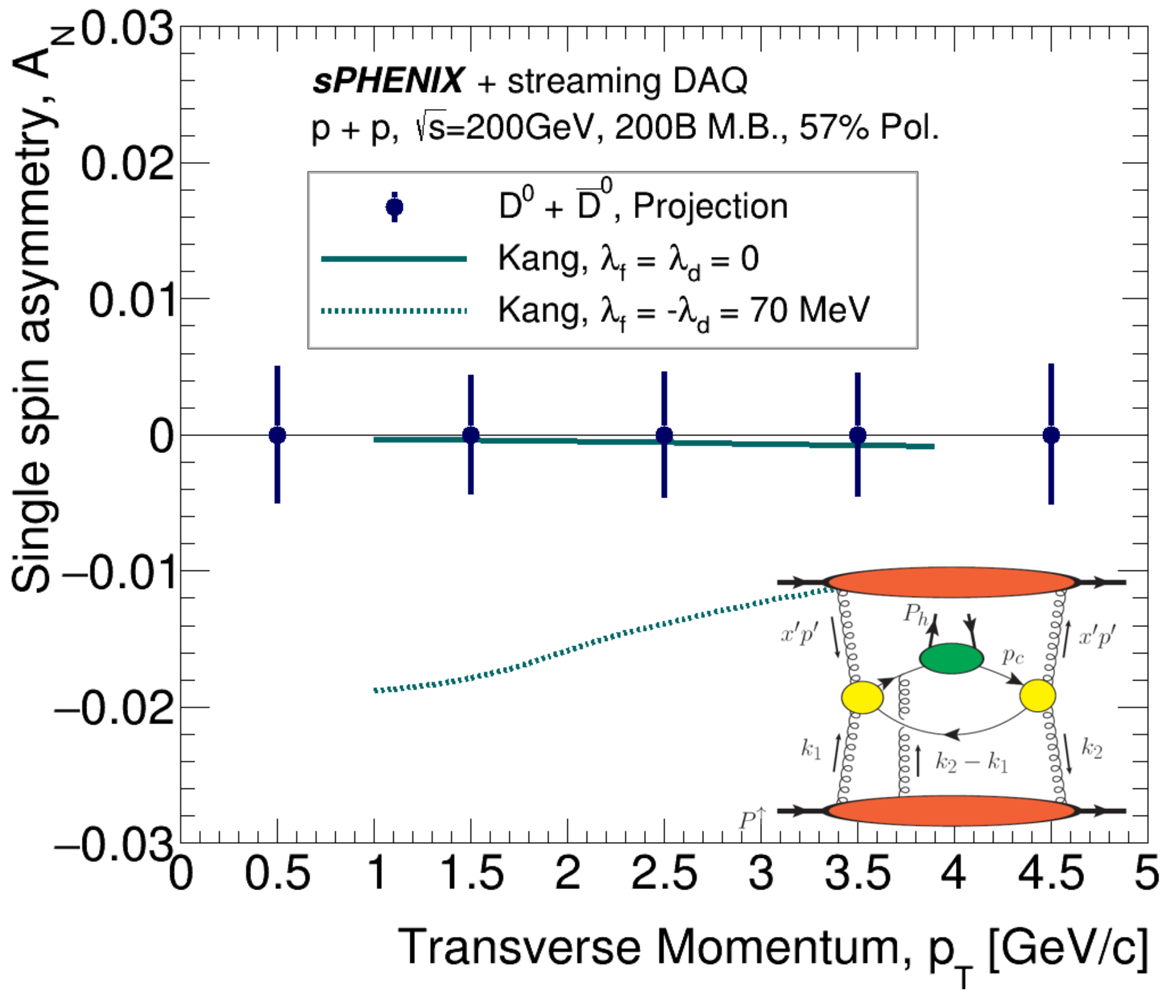




See also talk: Xin D. for STAR data

New opportunities in p+p collisions

- Low pT HF trigger challenging in small system : see also talk Q. Hu
- Exploring streaming DAQ recording 200Billion M.B. $\vec{p}+\vec{p}$ collisions in tracker w/o trigger bias.
  New ideas, examples:
  - D^0 Single spin asymmetry → Tri-gluon correlation
  - Exploring capabilities in high multiplicity p+p collisions
  - Future data mining for any new searches



Summary

- sPHENIX to enable many precision HF measurement at RHIC
- Construction on-going, data taking starts 2023!

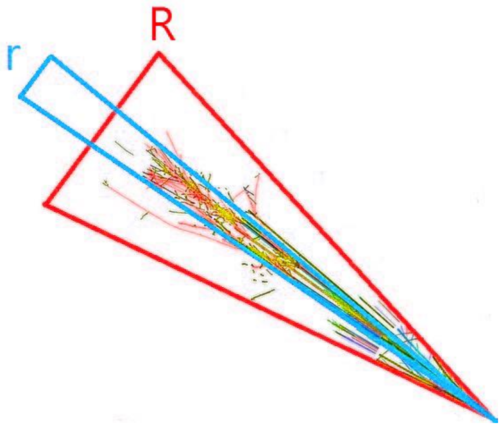
July-2019 sPHENIX collaboration meeting @ Lehigh University

Extra information

sPHENIX Core physics programs

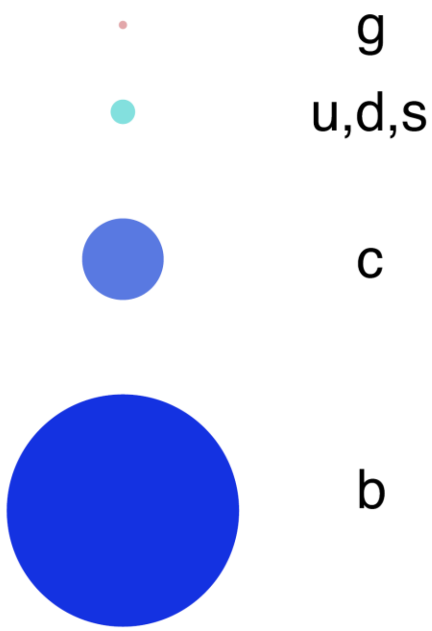
Jet cor. & substructure

Vary momentum/angular size of probe



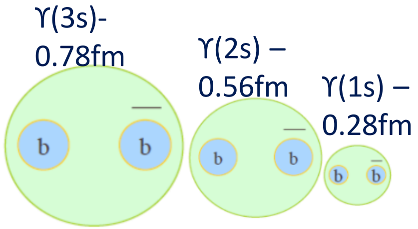
Parton energy loss

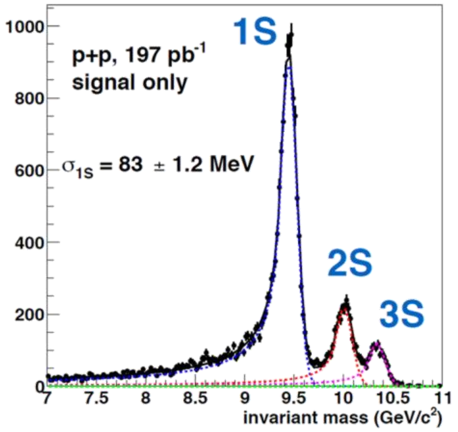
Vary mass/momentum of probe



Upsilon spectroscopy

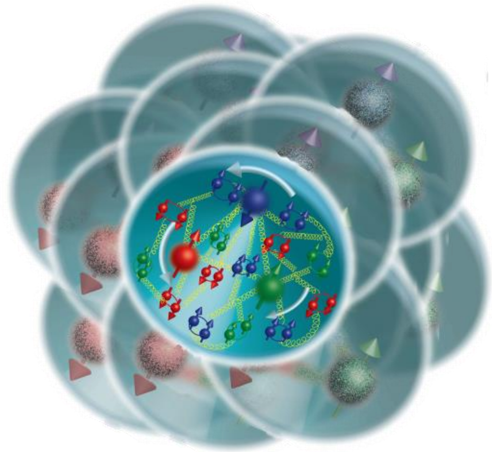
Vary size of the probe



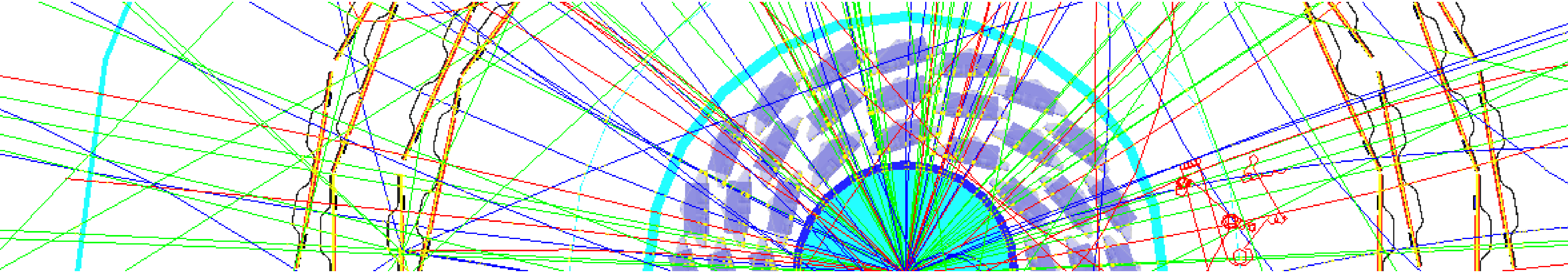


Cold QCD

Vary temperature of QCD matter

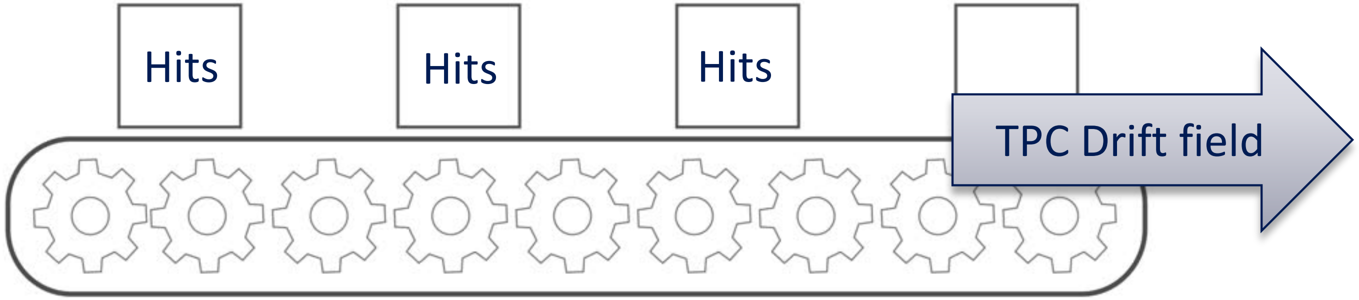


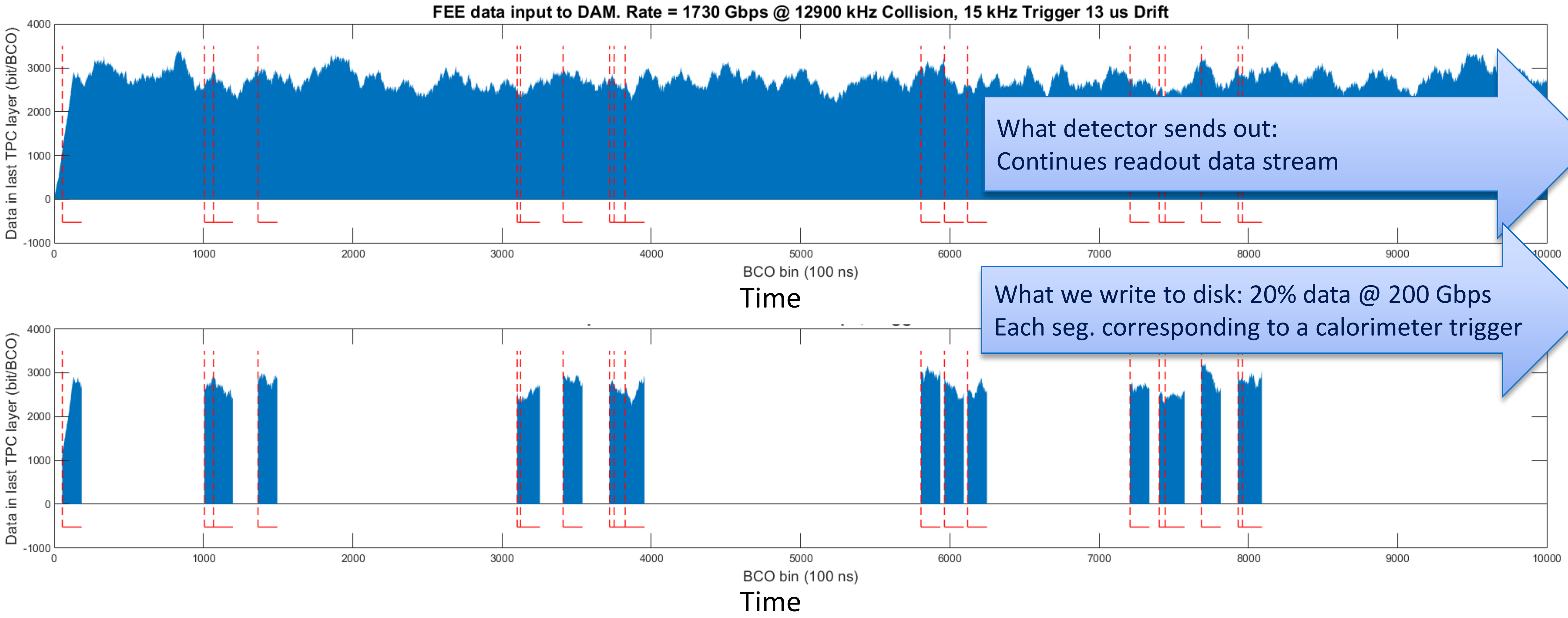
Challenge in $p + p$ collisions for heavy flavor hadrons



- They are rare processes (1 in 10k collisions w/ a D^0 hadron detectable)
- In a traditional triggered experiment:
  Difficult to trigger for hadronic decay of low p_T heavy flavor hadron
  - Nonetheless, if one would like to try:
    sPHENIX ML open data https://github.com/sPHENIX-Collaboration/HFMLTrigger

TPC data stream in sPHENIX triggered DAQ



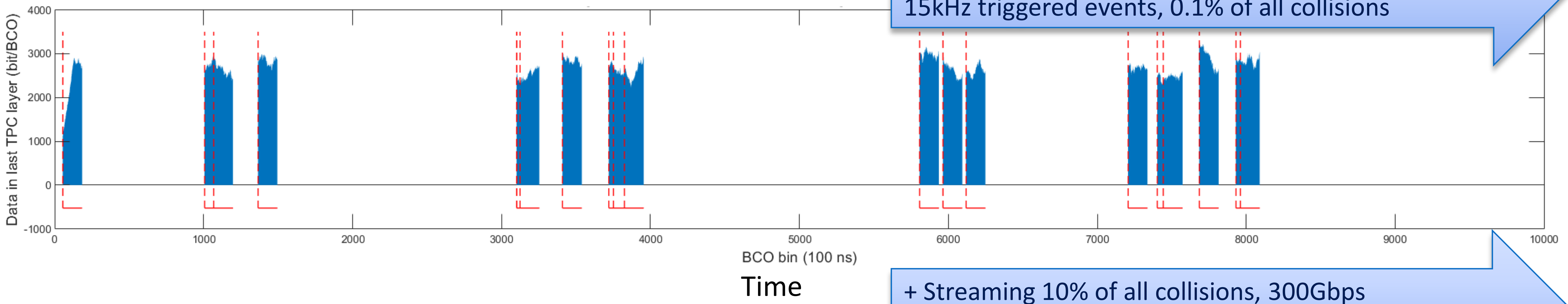


What detector sends out:
Continues readout data stream

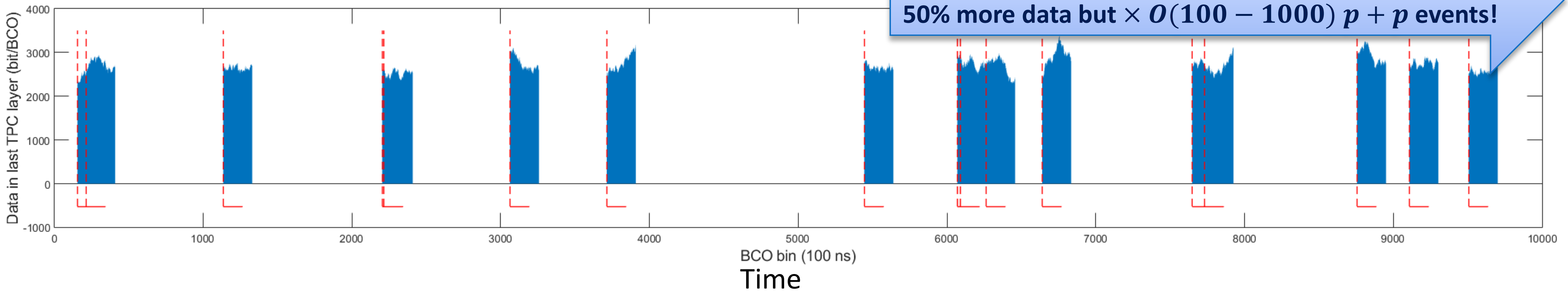
What we write to disk: 20% data @ 200 Gbps
Each seg. corresponding to a calorimeter trigger

Extending streaming time window, a partial triggerless DAQ → $\times\, O(100)$ gain in statistics!

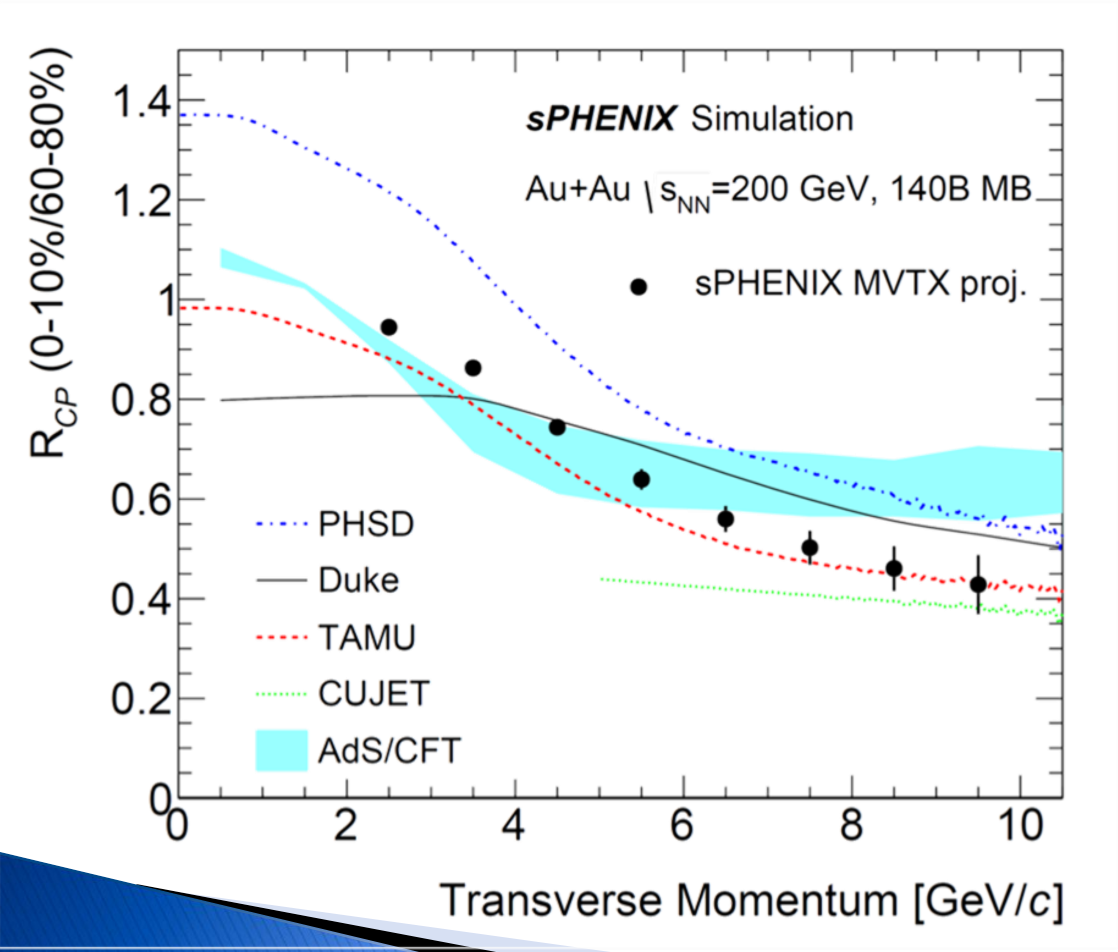
What we write to disk, 200 Gbps
15kHz triggered events, 0.1% of all collisions

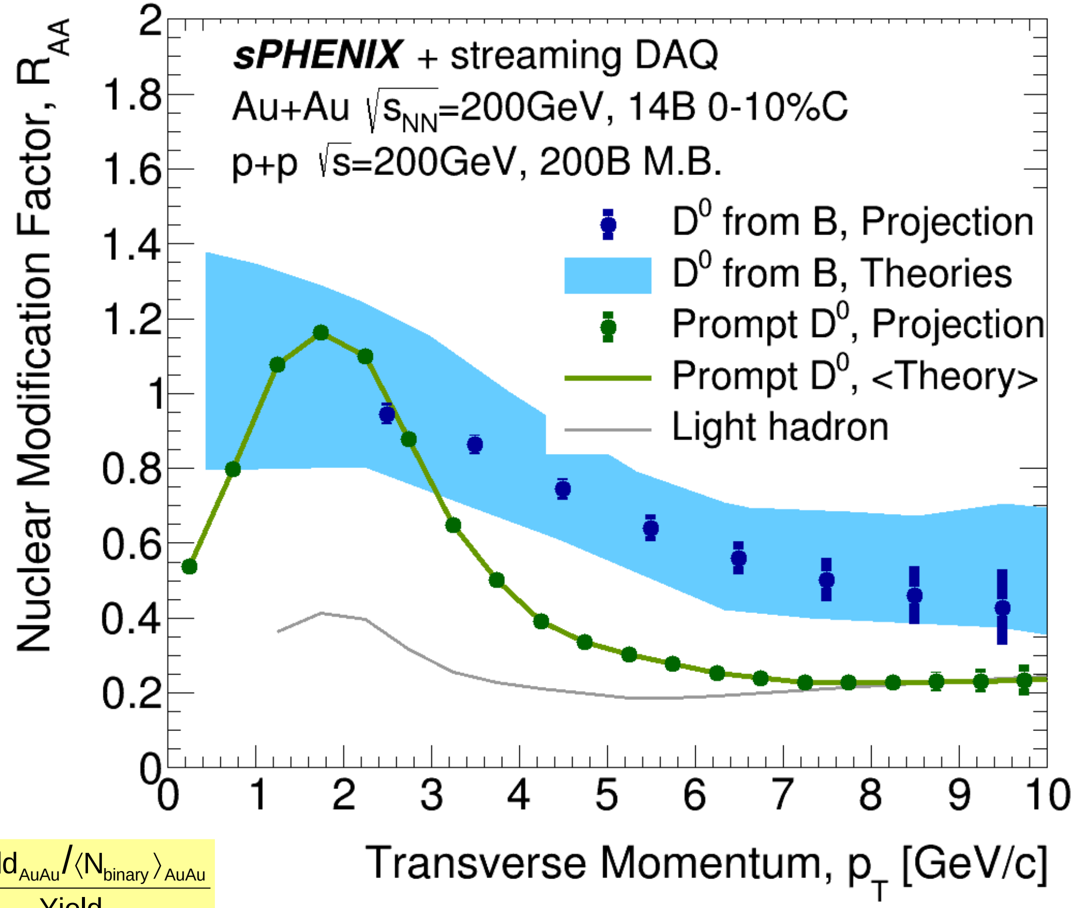


+ Streaming 10% of all collisions, 300Gbps
50% more data but $\times\, O(100-1000)\ p+p$ events!



Physics gain of sPHENIX streaming DAQ: Recovering heavy flavor meson baseline

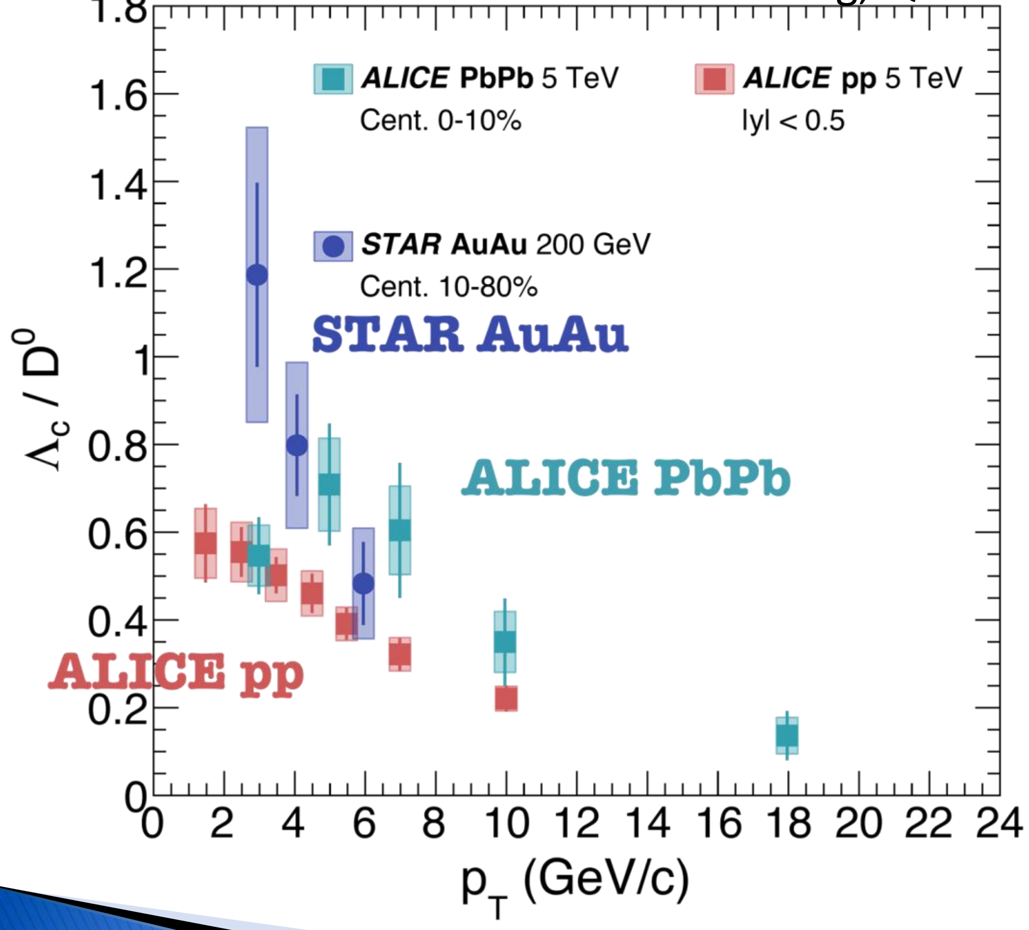


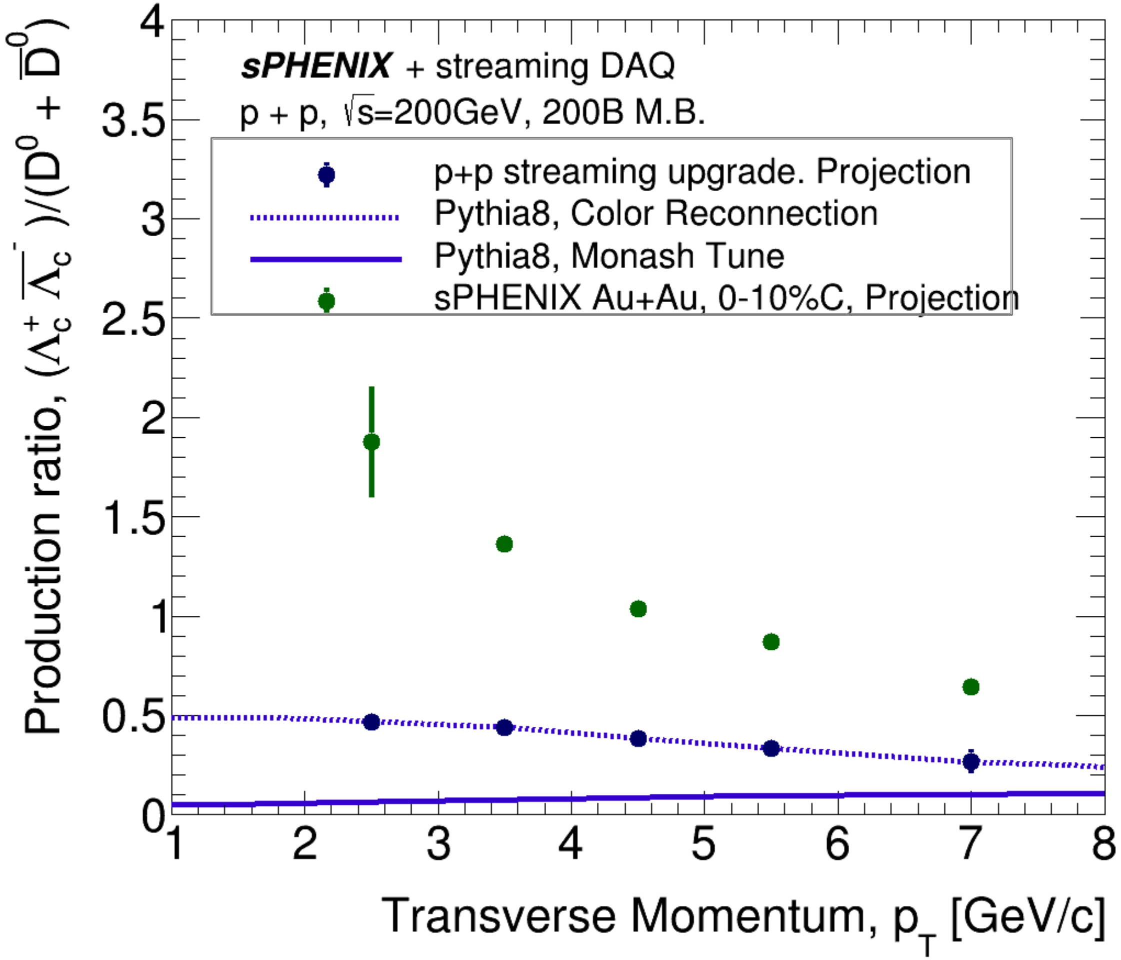


$$R_{AA} = \frac{Yield_{AuAu} / \langle N_{binary} \rangle_{AuAu}}{Yield_{pp}}$$

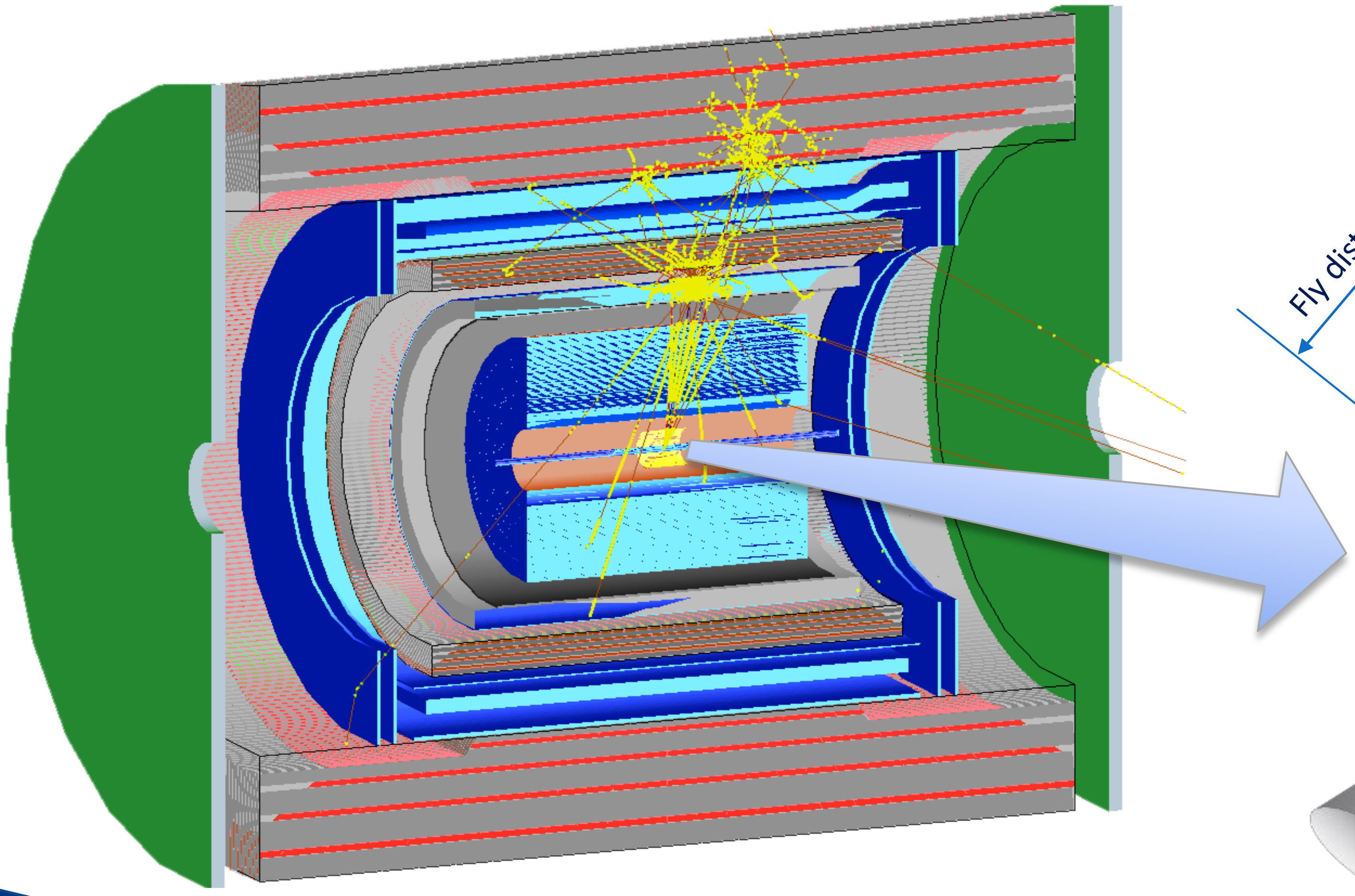
Physics gain of sPHENIX streaming DAQ: Baseline for Λ_c and charm hadronization

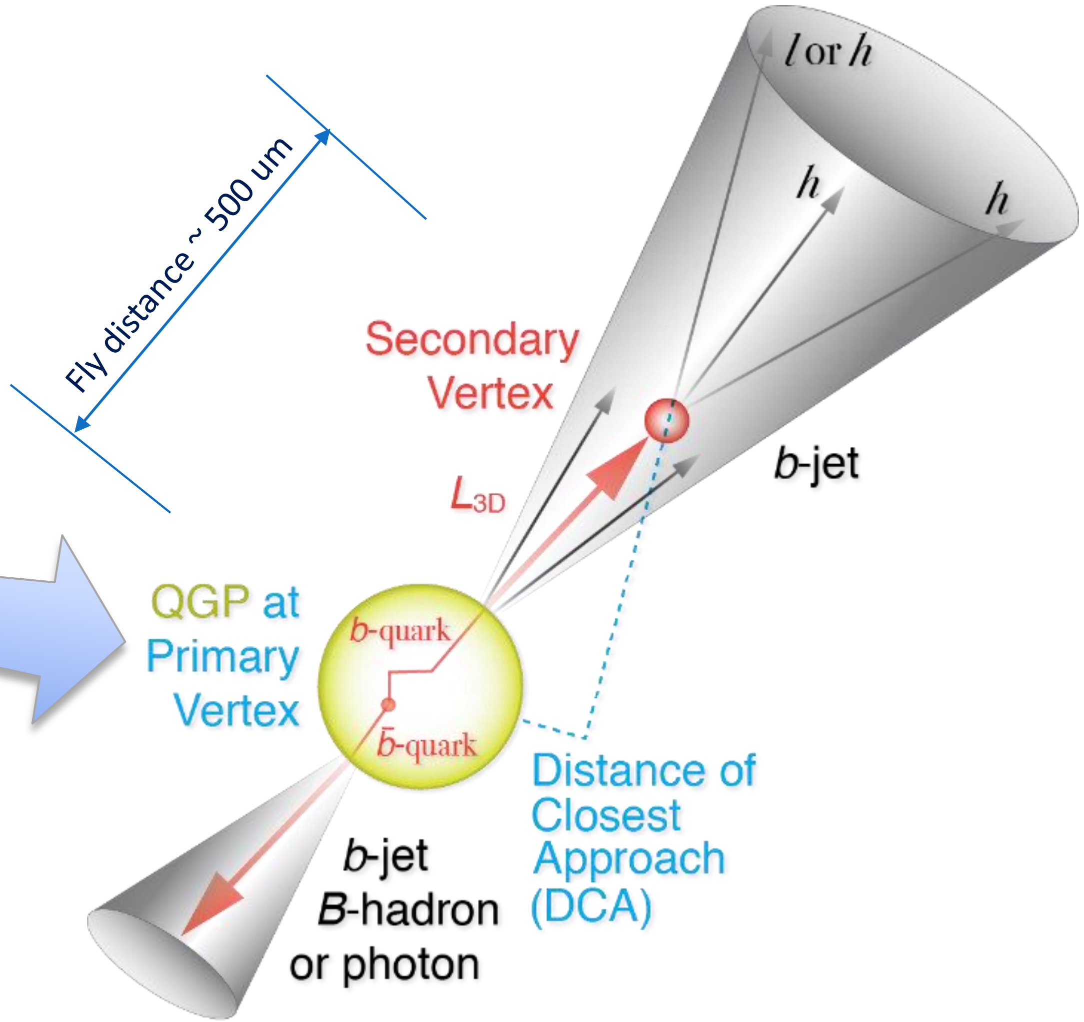
J. Wang, QM19



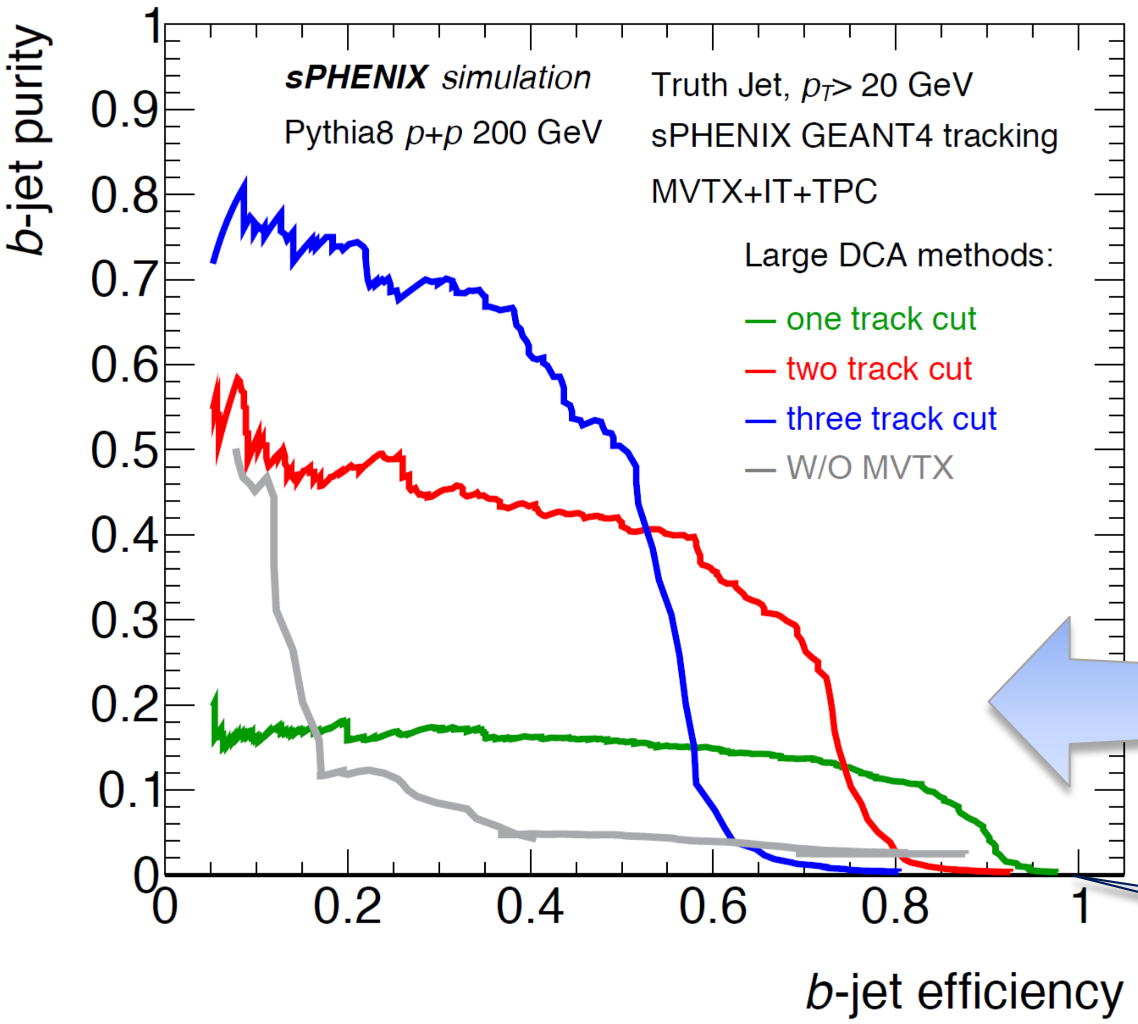


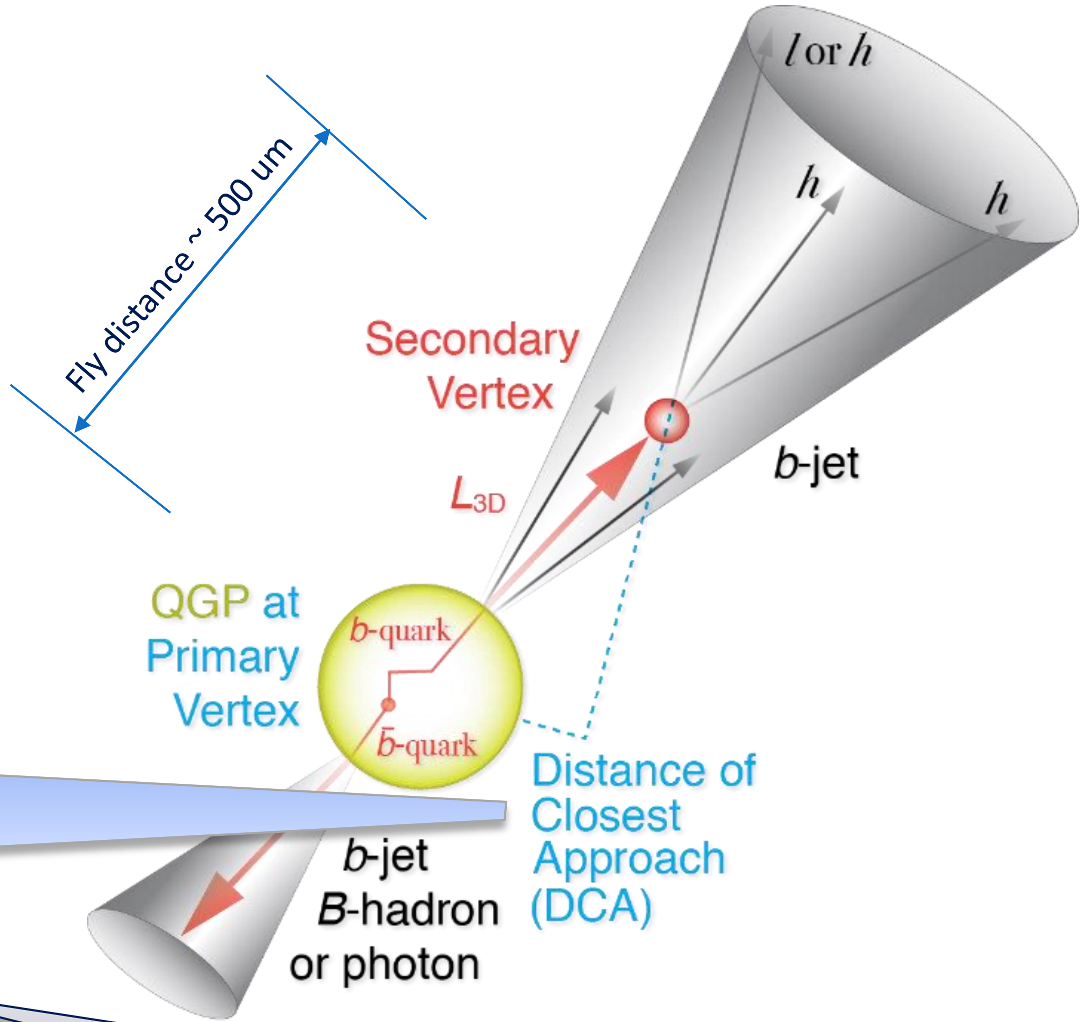
b-jet detection





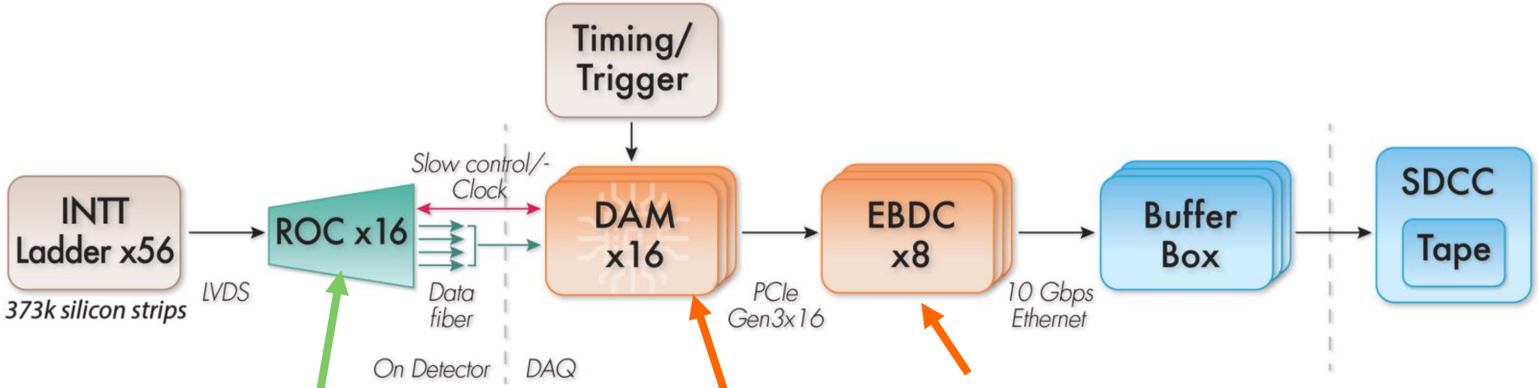
b-jet detection



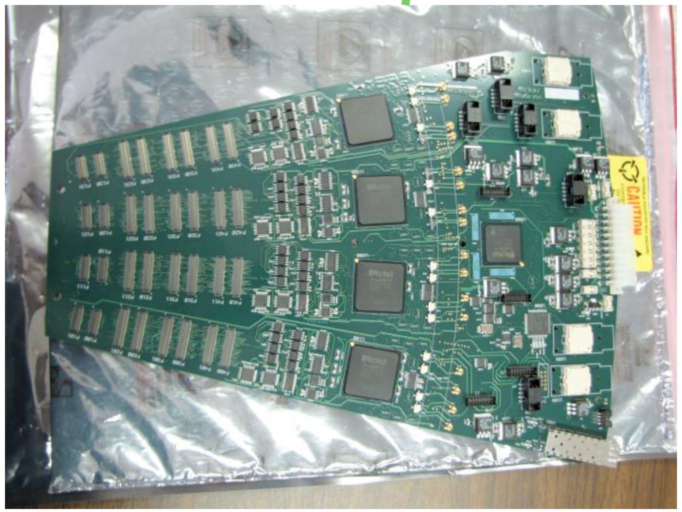


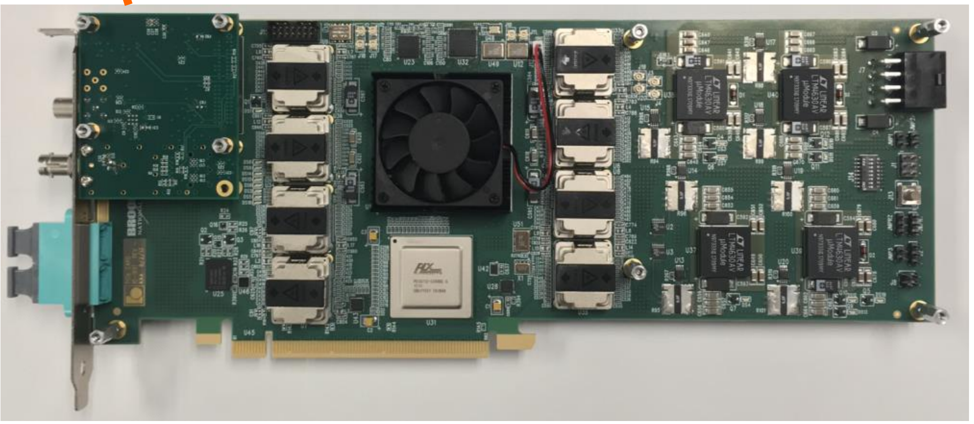
Natural abundance < 1%

Then it may looks like this

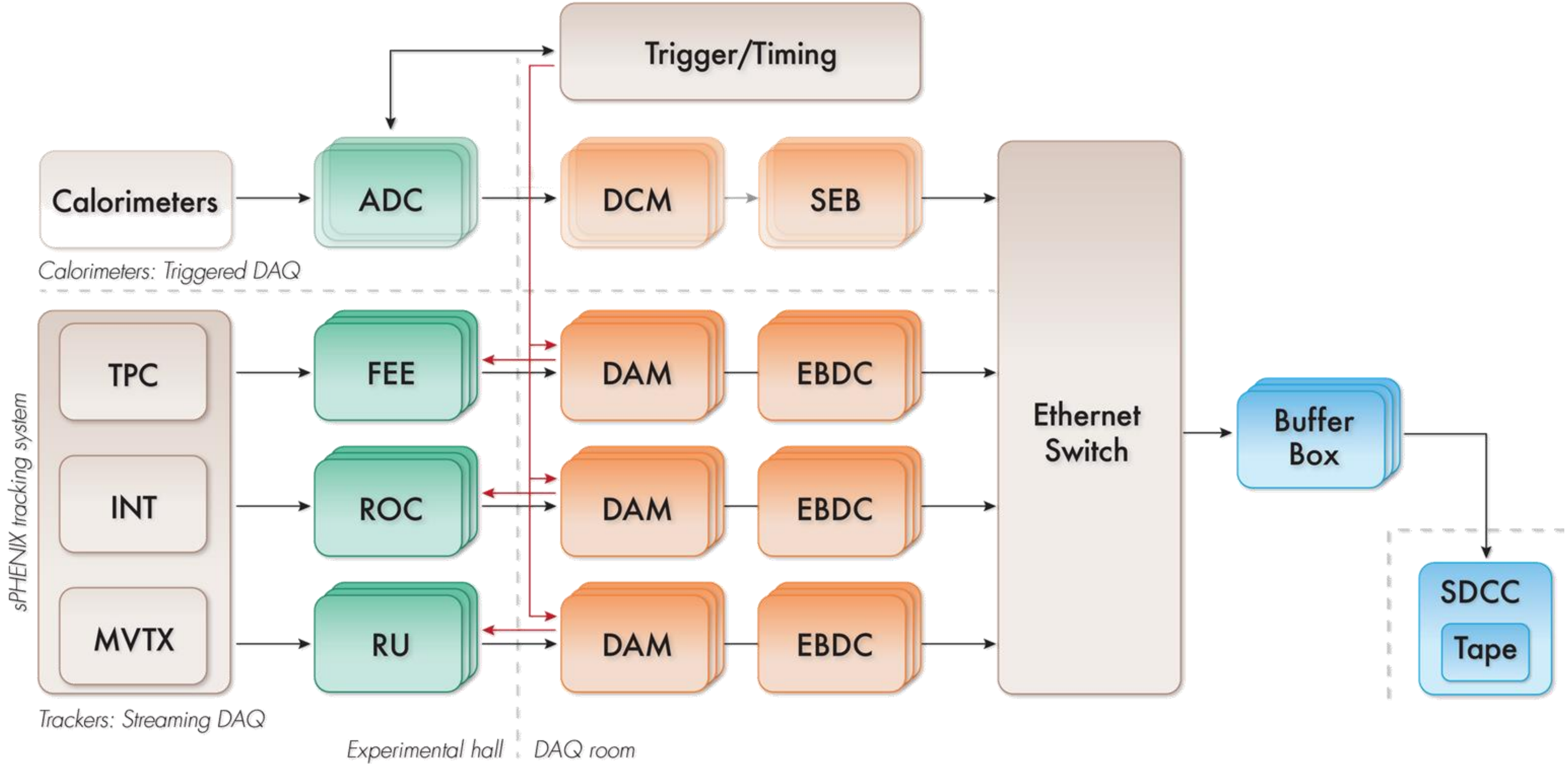


Relatively low-load commodity server
@ ~0.1 Gbps << TPC





→ Streaming DAQ for sPHENIX trackers



See also DAQ talk, M. Purschke

Observables → x500 improvement

		Year-2 in current setup	Year -2 w/ Streaming tracker	Year -2+4 w/ Streaming tracker
M.B. $p+p$	Data recorded	1k Hz M.B. trigger with 2×10^{-4} of M.B. collisions triggered	10% M.B. events streaming recorded	
	Statistics	0.4 Billion M.B. events 0.01 pb^{-1} recorded	200 Billion M.B. events 5 pb^{-1} recorded	800 Billion M.B. events 20 pb^{-1} recorded
Physics reach	$B \to D^0 \to \pi K$	250 events	120k events	500k events
			Reference in R_{AA} for B→D^0	
	$D^0 \to \pi K$ pair	250 events	120k events.	500k events
			Diffusion of c-quarks in angular space	
	$\Lambda_c \to \pi K p$	500 events	250k events.	1M events
			Charm hadronization in p+p; reference for $A + A$	
	Prompt D^0→πK	75k events	40 Million events.	150 Million events
			Pinging down tri-gluon correlation via single spin asymmetry	

A conservative working point