Future Cold-QCD Physics Program with sPHENIX

Jin Huang (BNL)

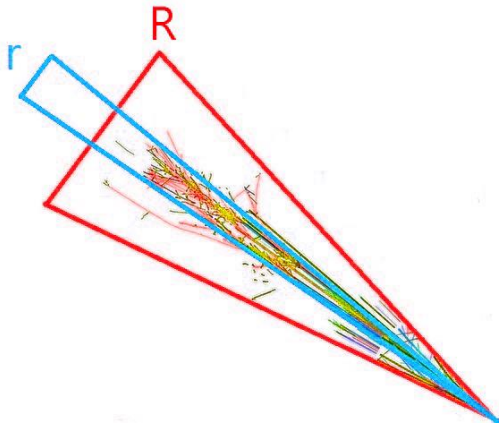
For the sPHENIX collaboration

sPHENIX

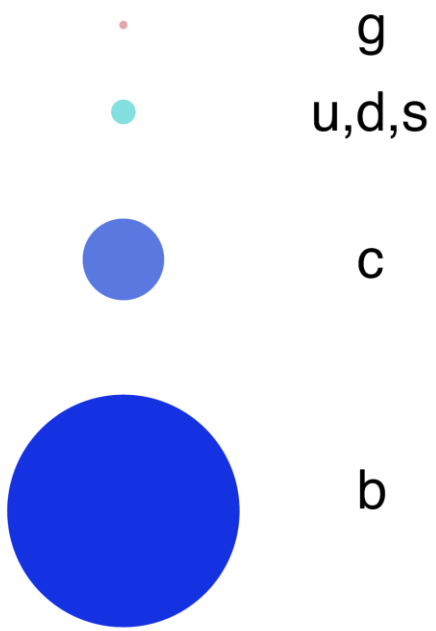
Brookhaven National Laboratory

Core physics programs

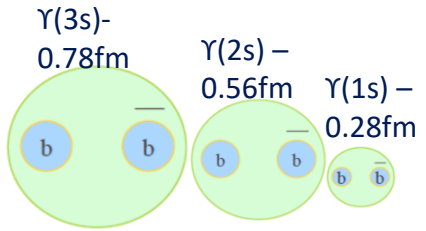
Jet cor. & substructure
Vary momentum/angular size of probe

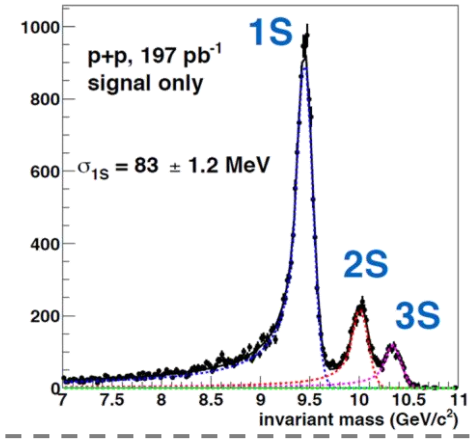


Parton energy loss
Vary mass/momentum of probe

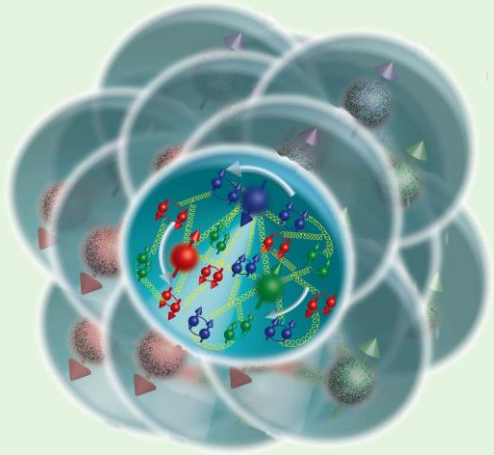


Upsilon spectroscopy
Vary size of the probe





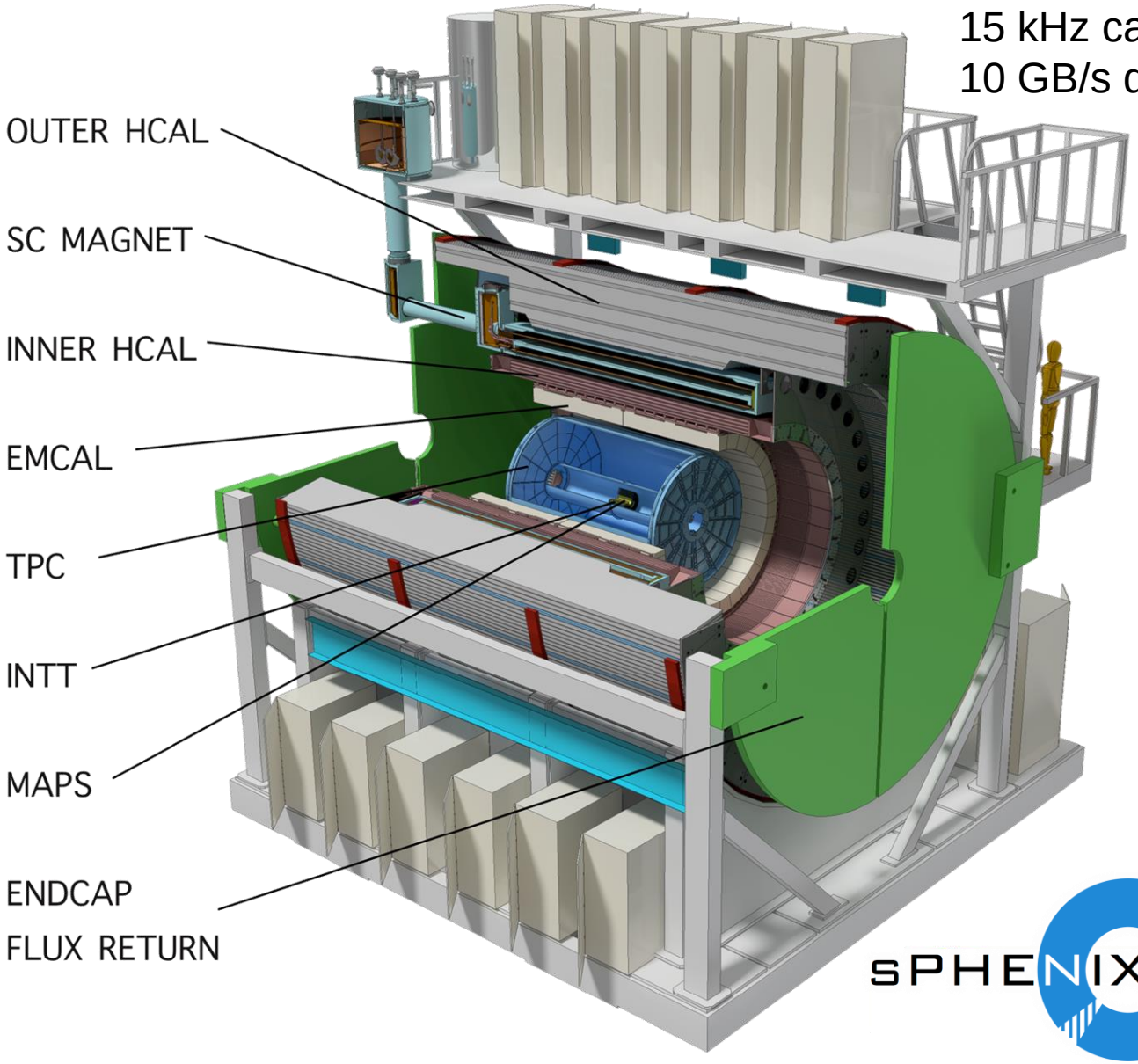
Cold QCD
Vary temperature of QCD matter



See also talks: C. Dean on Wed, E. Umaka on Thu

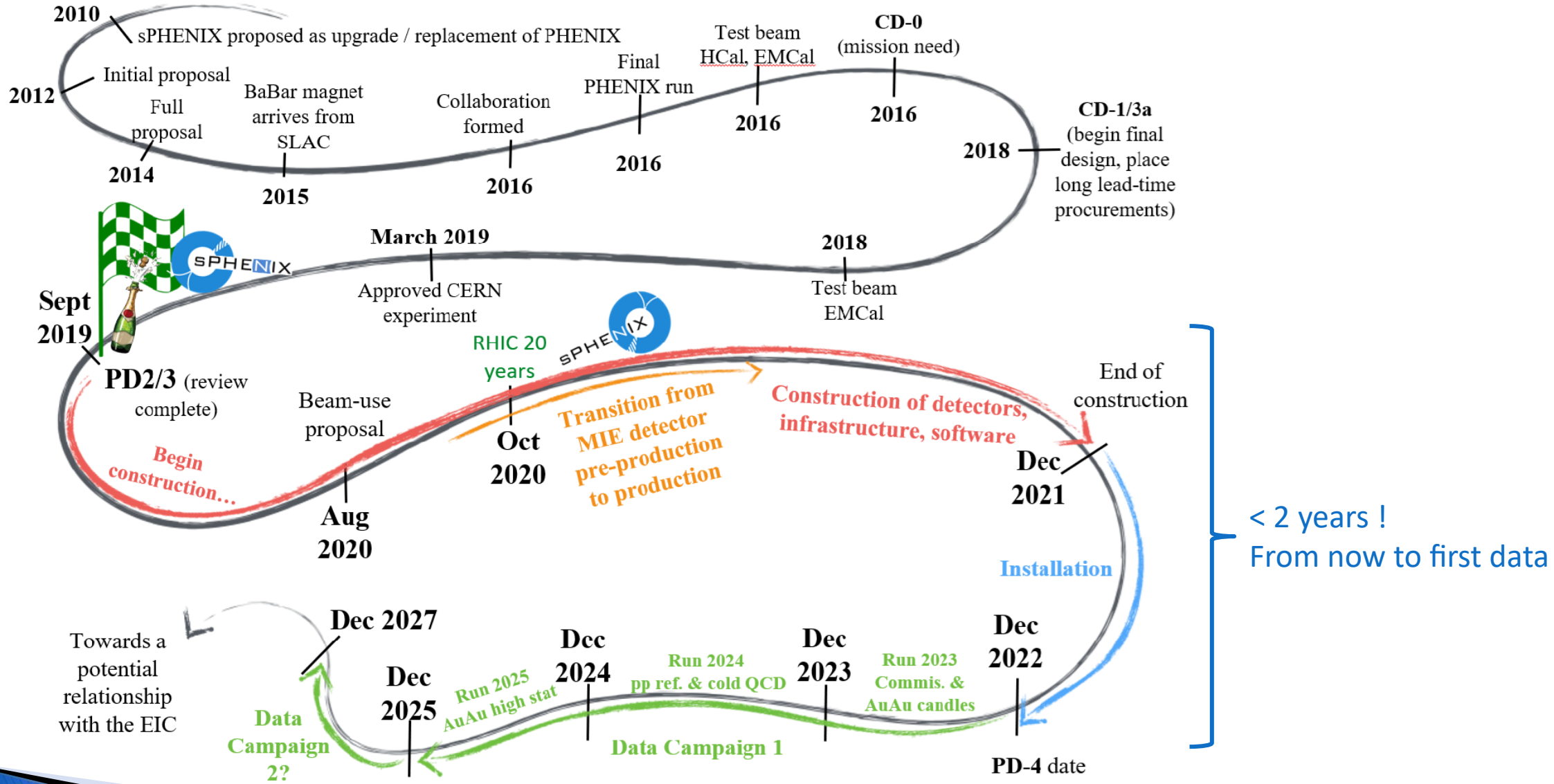
This talk

15 kHz calo trigger + 10% streaming DAQ
10 GB/s data logging



sPHENIX Detector

Also proposed upgrades of event plane detector, Micromegas outer tracker

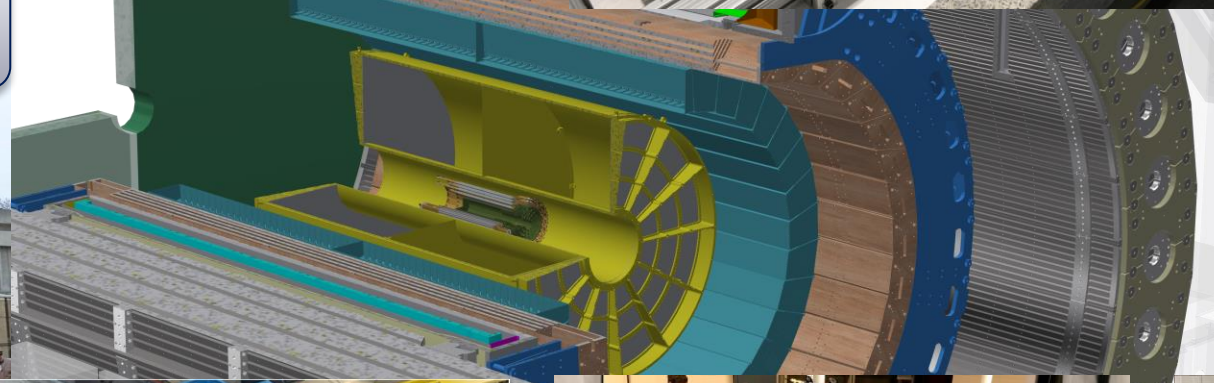

2010
sPHENIX proposed as upgrade / replacement of PHENIX
2012
Initial proposal
Full proposal
2014
BaBar magnet arrives from SLAC
2015
Collaboration formed
2016
Final PHENIX run
2016
Test beam HCal, EMCal
2016
CD-0 (mission need)
2016
2018
CD-1/3a (begin final design, place long lead-time procurements)
March 2019
Approved CERN experiment
2018
Test beam EMCal
Sept 2019
PD2/3 (review complete)
Begin construction…
Beam-use proposal
Aug 2020
RHIC 20 years
Oct 2020
Transition from MIE detector pre-production to production
Construction of detectors, infrastructure, software
End of construction
Dec 2021
Installation
Dec 2022
Dec 2023
Run 2023 Commis. & AuAu candles
Dec 2024
Run 2024 pp ref. & cold QCD
Dec 2025
Run 2025 AuAu high stat
Data Campaign 1
Data Campaign 2?
Dec 2027
Towards a potential relationship with the EIC
PD-4 date
< 2 years !
From now to first data

Outer Hadronic Calorimeter

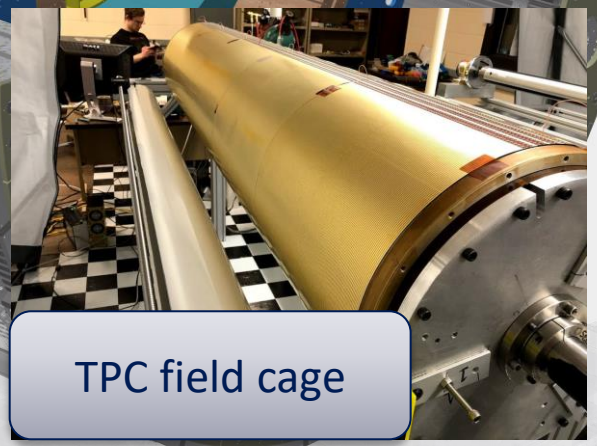
EMCal half sector

Inner HCal

1.4T magnet, tested at BNL



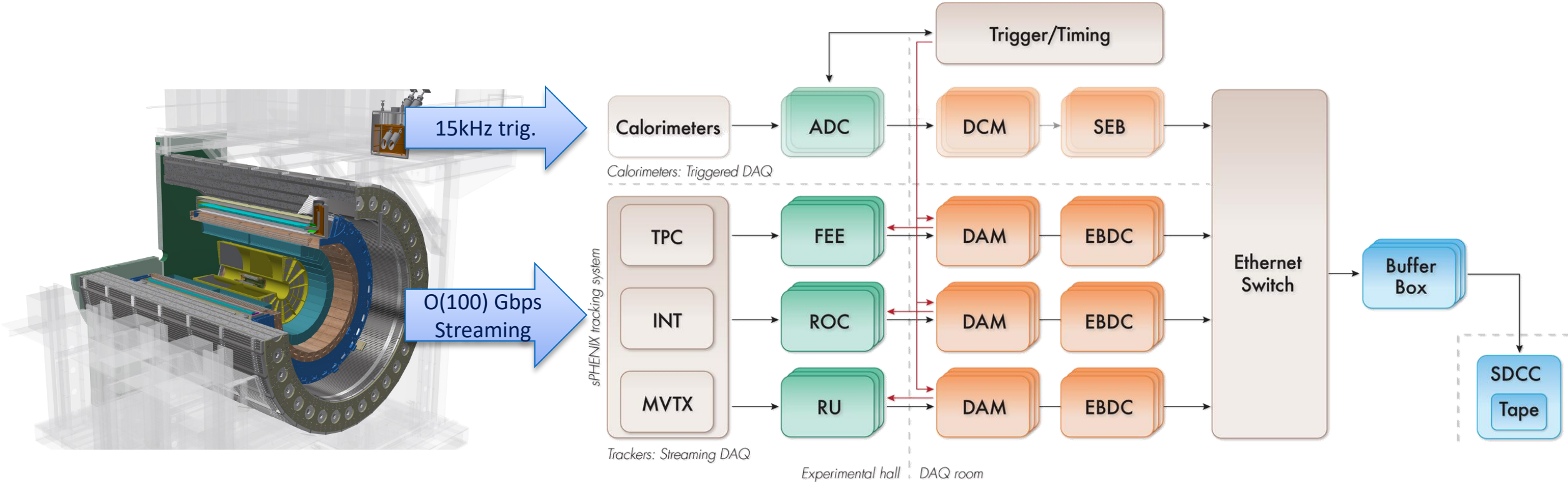
Detector support cradle



TPC field cage

TPC endcap support

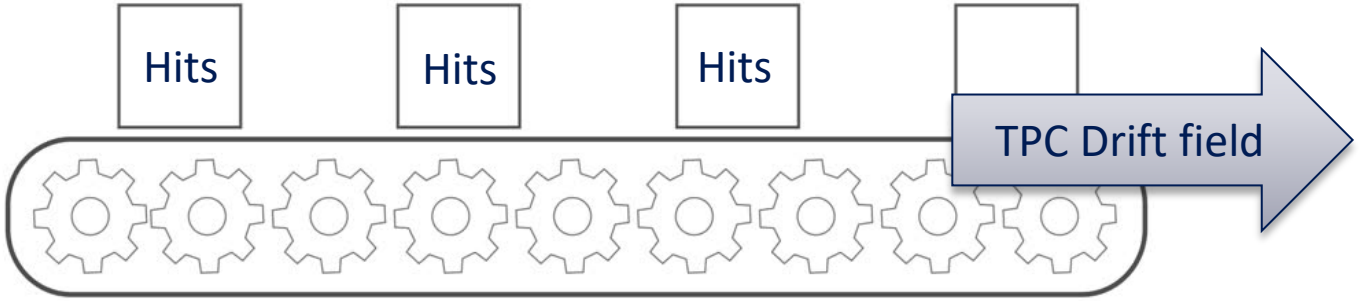
sPHENIX trigger-streaming hybrid DAQ

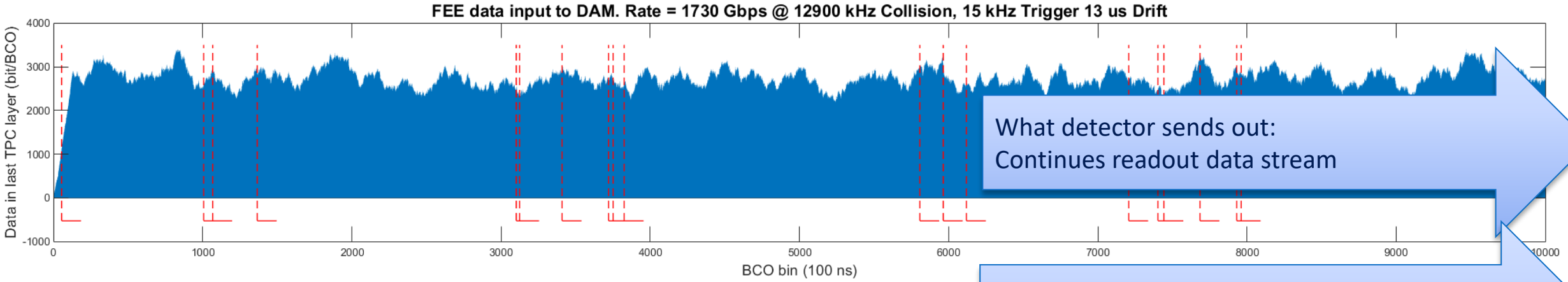


All sPHENIX tracker support streaming readout → Plan to archive 10% all pp collisions in streaming mode:

- Allowing un-triggerable measurement, e.g. low p_T HF→h
- Increasing spin-tagged M.B. p+p/p+A collisions by 2 to 3 orders of magnitude
- Data preservation from the collection stage for the last high-energy polarized hadron collisions → new analysis w/ EIC

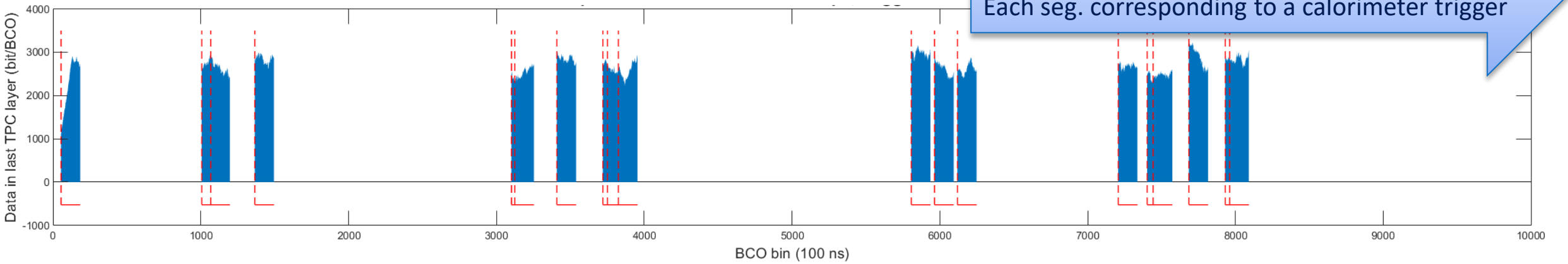
TPC data stream in sPHENIX triggered DAQ





Time

What detector sends out:
Continues readout data stream

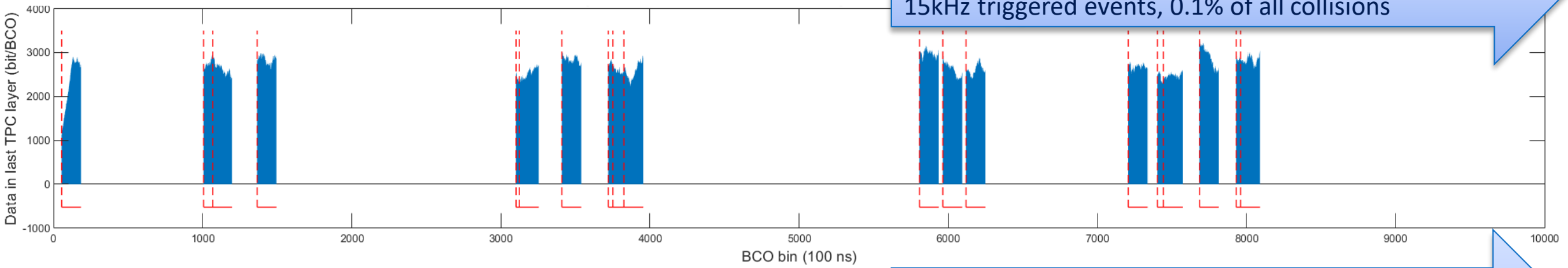


Time

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

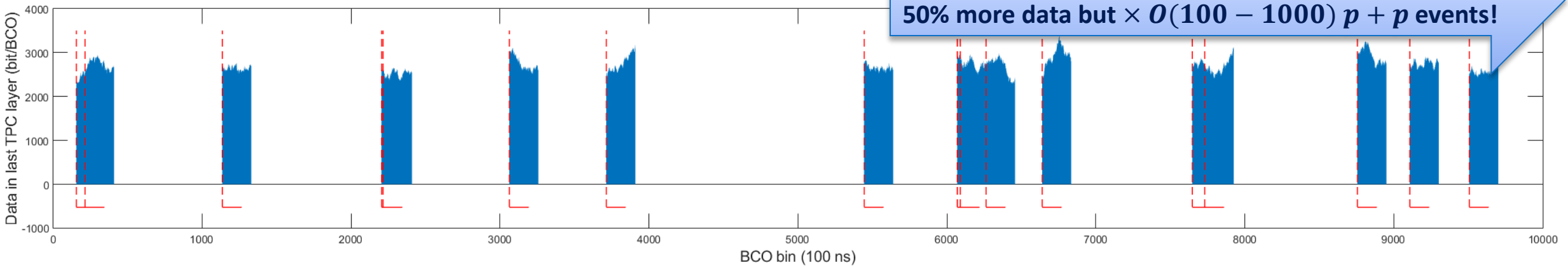
Extending streaming time window, a partial triggerless DAQ → $\times O(100)$ gain in statistics!

What we write to disk, 40 Gbps
15kHz triggered events, 0.1% of all collisions



Time

+ Streaming 10% of all collisions, 60Gbps
50% more data but $\times O(100-1000)\ p+p$ events!



Time

Proposed run schedule, year 1-3

sPHENIX BUP2021 [sPH-TRG-2021-001], 24 (& 28) cryo-week scenarios

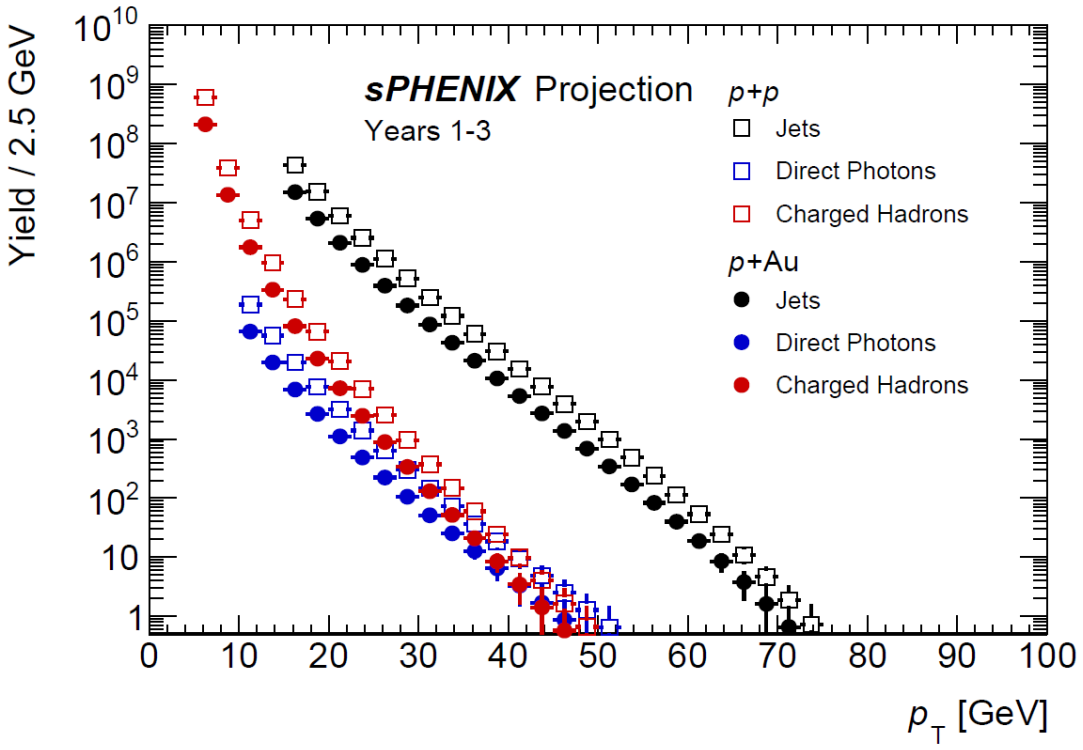
Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\lvert z\rvert$ <10 cm	Samp. Lum. $\lvert z\rvert$ <10 cm
2023	Au+Au	200	24 (28)	9 (13)	3.7 (5.7) nb^{-1}	4.5 (6.9) nb^{-1}
2024	$p^{\uparrow}p^{\uparrow}$	200	24 (28)	12 (16)	0.3 (0.4) pb^{-1} [5 kHz] 4.5 (6.2) pb^{-1} [10%-str]	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}

sPHENIX asked to consider 20-28 week runs in 2024

- (Trans-)polarized $p+p$, $p+A$ with streaming readout for 28 weeks in Run24
- But short Run24 would endanger the $p+A$ data!

sPHENIX cold QCD observables and opportunties

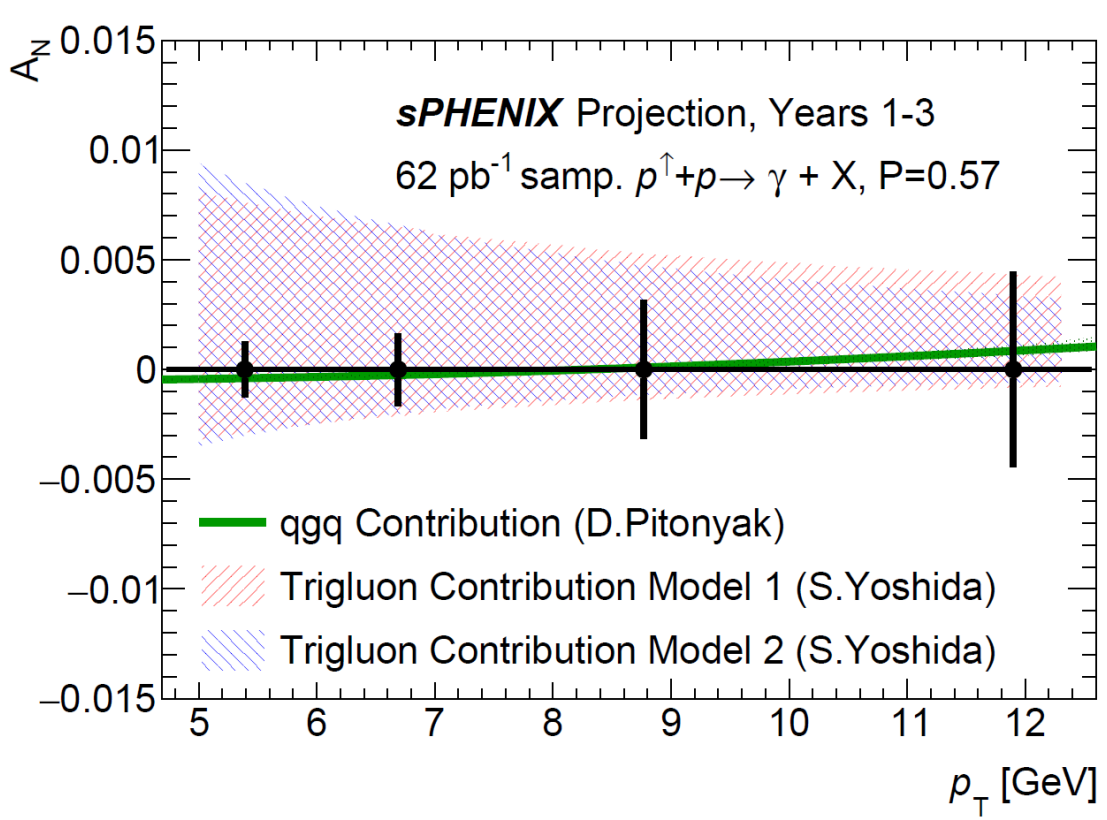
sPHENIX BUP2021 [sPH-TRG-2021-001]

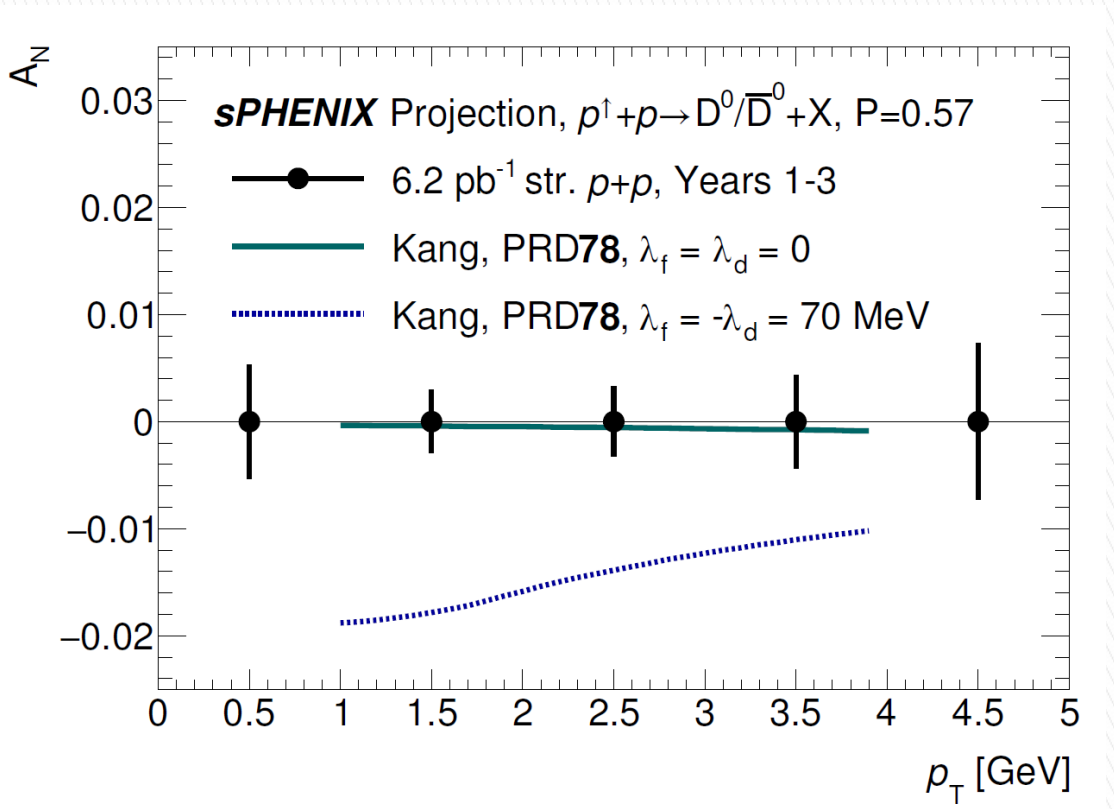


- Transversely polarized observables
  - Sievers-type tri-gluon correlation: γ, HF
  - Hadron AN, pp vs pA: h
  - Sivers effects: γ-jet, di-jet
  - Transversity via Collins FF & IFF: h in jet, di-h
- Spin-averaged observables
  - Quarkonia polarization: J/ψ, Υ
  - nPDF: h, jet, di-jet, γ-jet
  - Hadronization, pp vs pA: h in jet, γ-jet, di-jet

Gluon dynamics via γ, HF TSSA

sPHENIX BUP2021 [sPH-TRG-2021-001]





TSSA of prompt photon
EMCal-based trigger

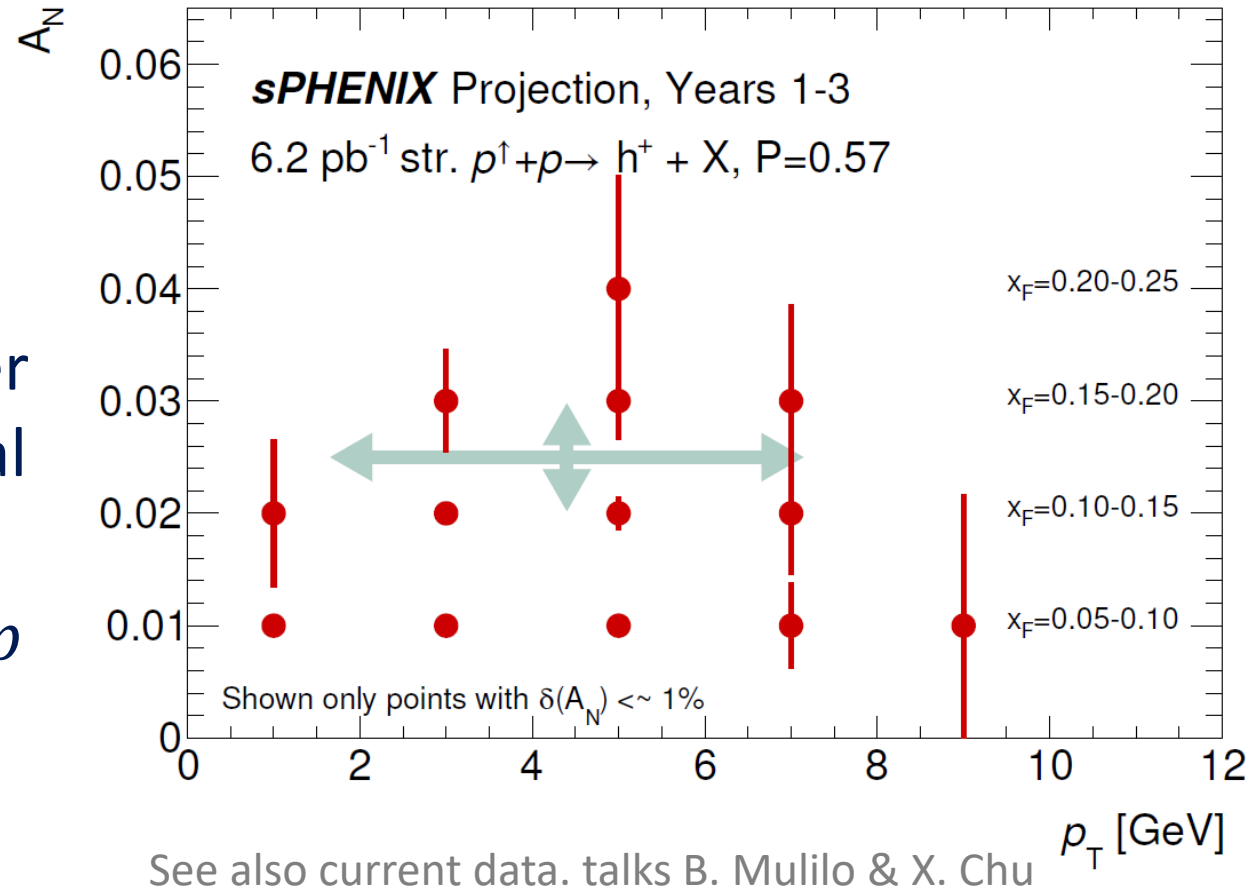
TSSA of prompt $D^0\rightarrow\pi K$
Enabled by streaming readout

[see also current PHENIX results in talk by B. Mulilo]

Nature of hadron A_N in pp and its nuclear modification

- PHENIX and STAR show significant different suppression of hadron A_N from pp to pA in distinct kinematic regions [see talks B. Mulilo & X. Chu]
- sPHENIX hadron A_N will explore wider region to help disentangle initial/final state effects
- Enabled by streaming recorded $p + p$ collision from far vertex collisions

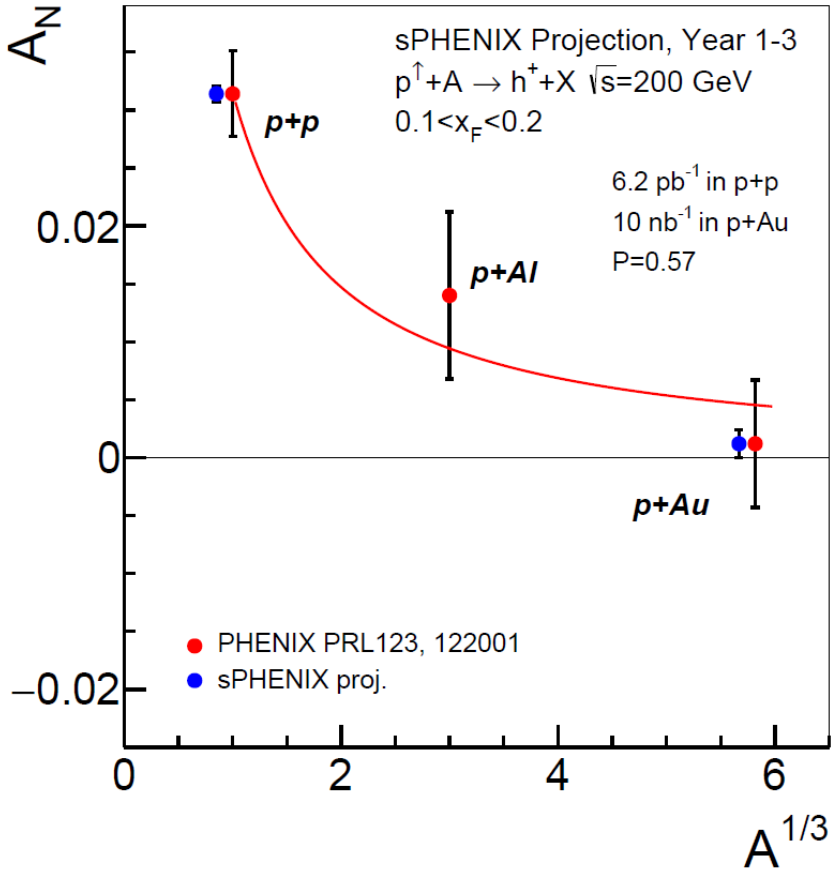
sPHENIX BUP2021 [sPH-TRG-2021-001]

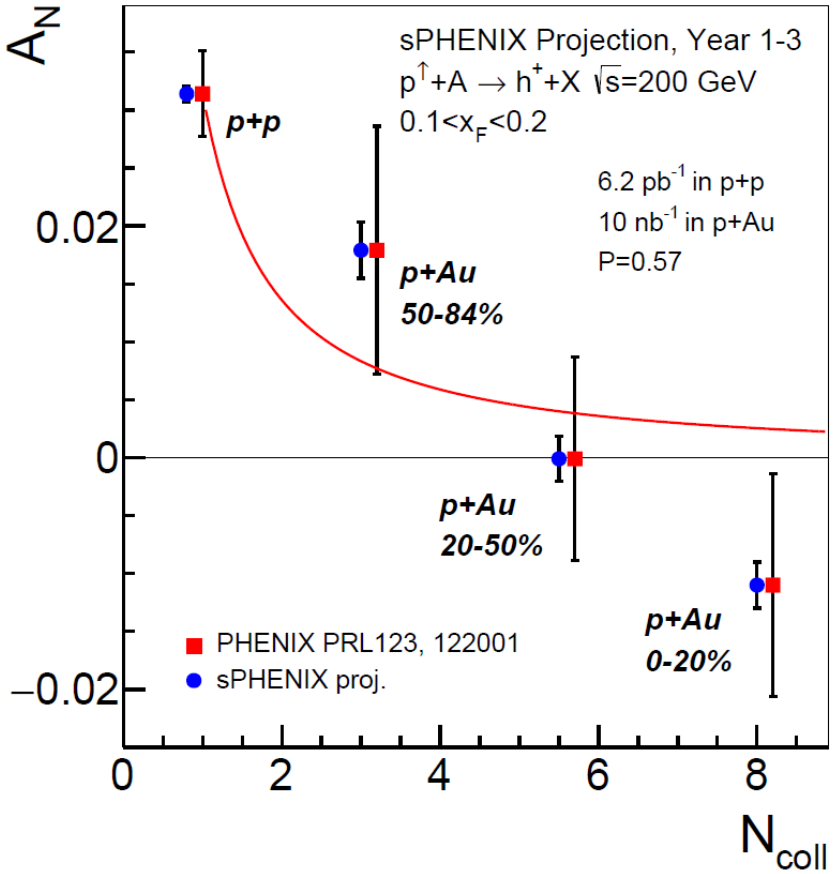


See also current data. talks B. Mulilo & X. Chu
PHENIX, PRL123, 122001
STAR, PRD103 (2021) 072005

Nature of hadron A_N in pp and its nuclear modification

sPHENIX BUP2021 [sPH-TRG-2021-001]

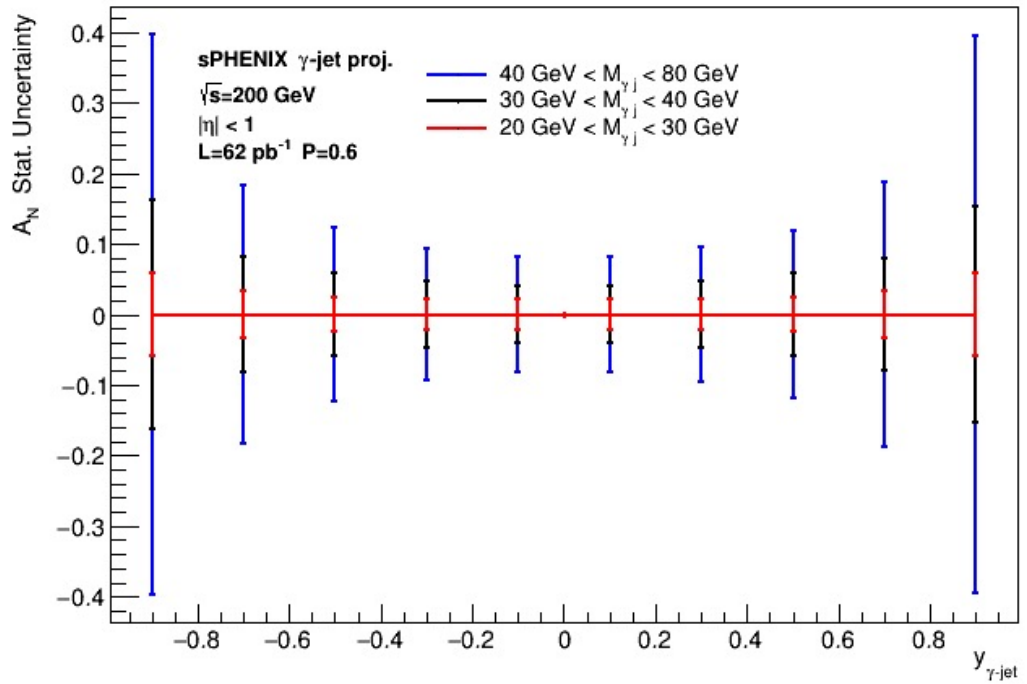




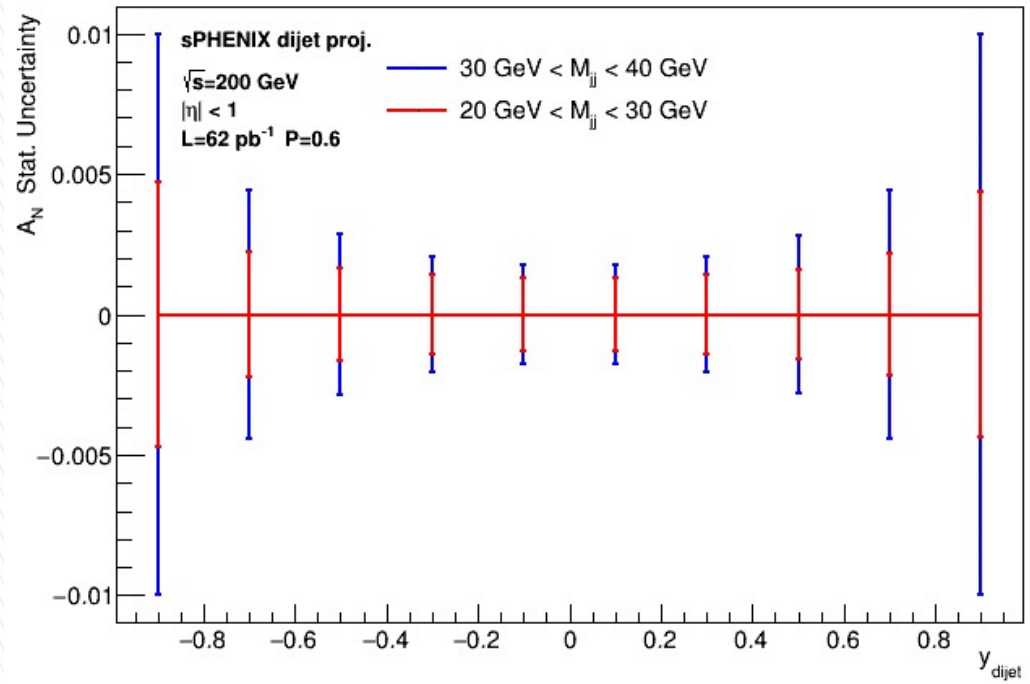
Tremendous improvement comparing to the published PHENIX data

Sivers effects via γ-jet, di-jet

- Enabled by high stat. calorimetric jet/photon detection provided by sPHENIX
- Exploring ideas of spin dependent γ-jet, di-jet correlation observables e.g. p_{out}, co-planarity, charge-tagged jets



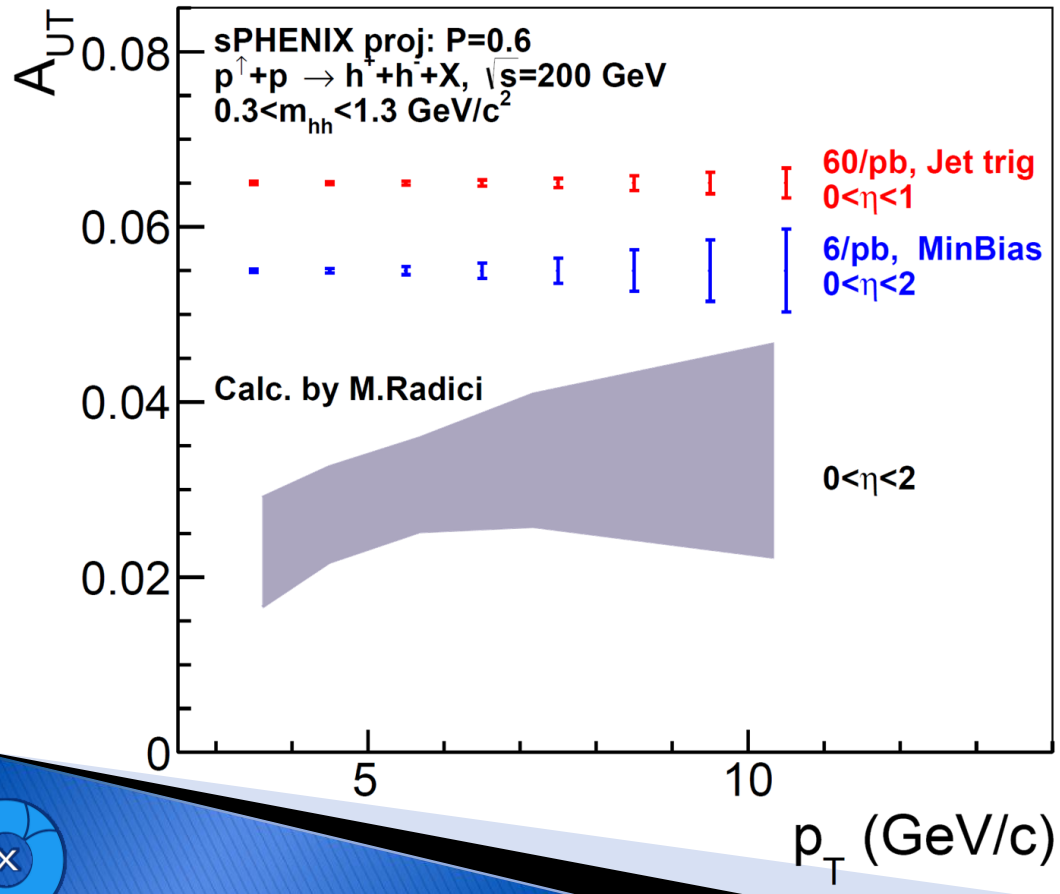
Photon-jet

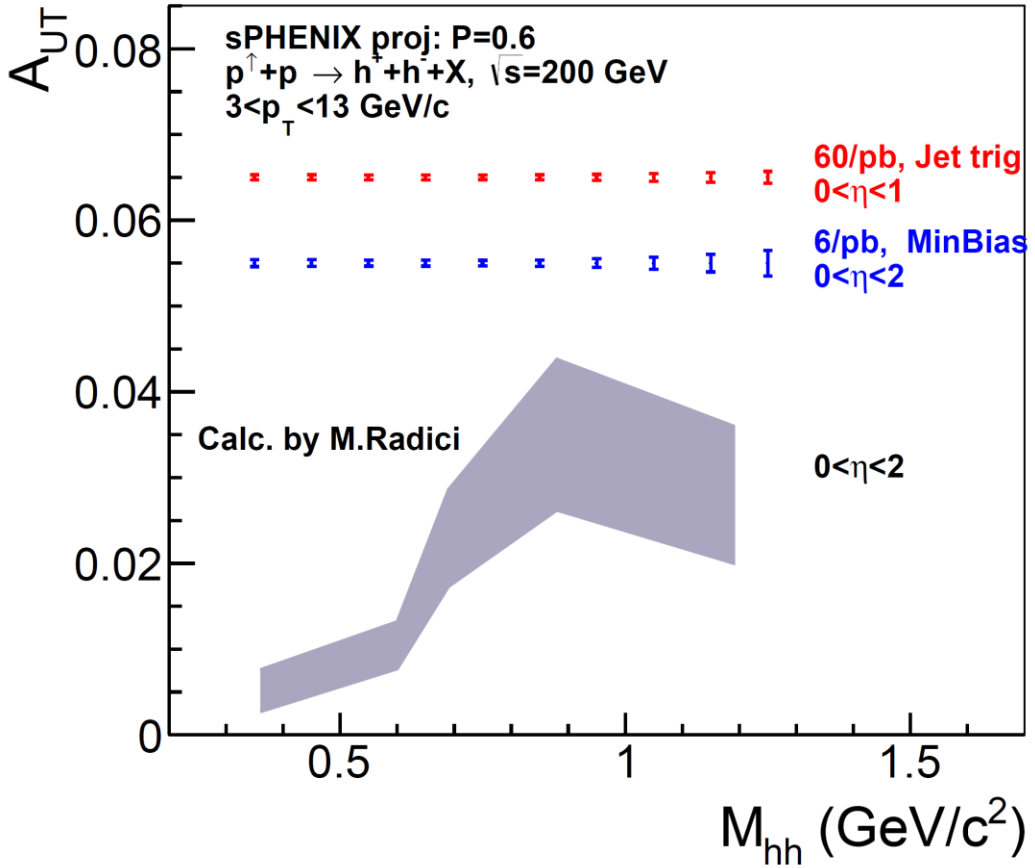


Di-jets

Transversity via charged particle IFF

- Tremendous stat. enabled by both calorimetric jet trigger and streaming readout
- Need theory collaboration in the treatment of no-PID charged tracks & multi-dim binning

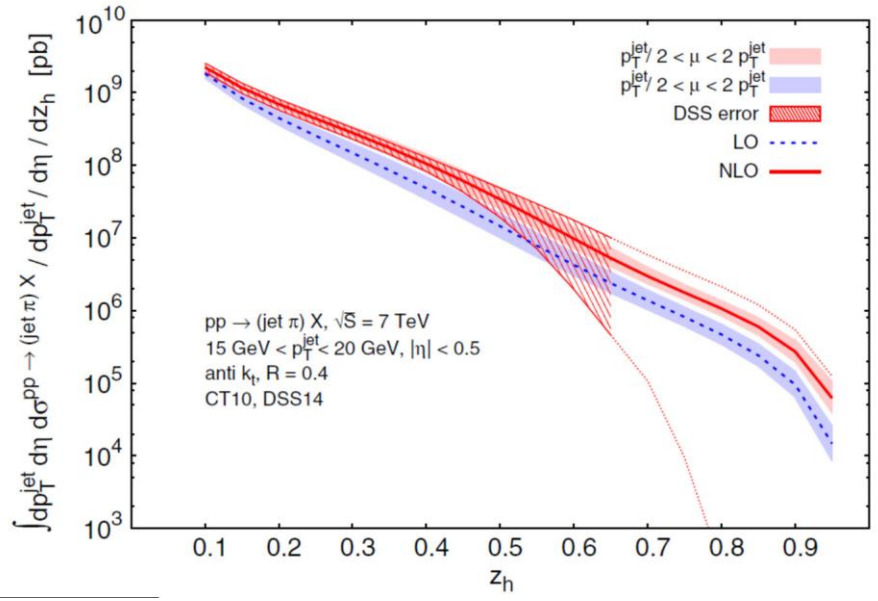


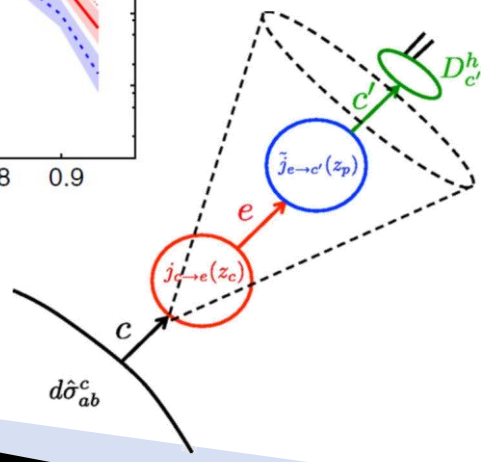


Fragmentation in p+A

- Access gluon fragmentation function (FF) in $p+p$, $p+A$ via jet FF
- Calorimetric triggered jet + precision tracking

Kaufmann et al. Phys.Rev.D 92 5, 054015





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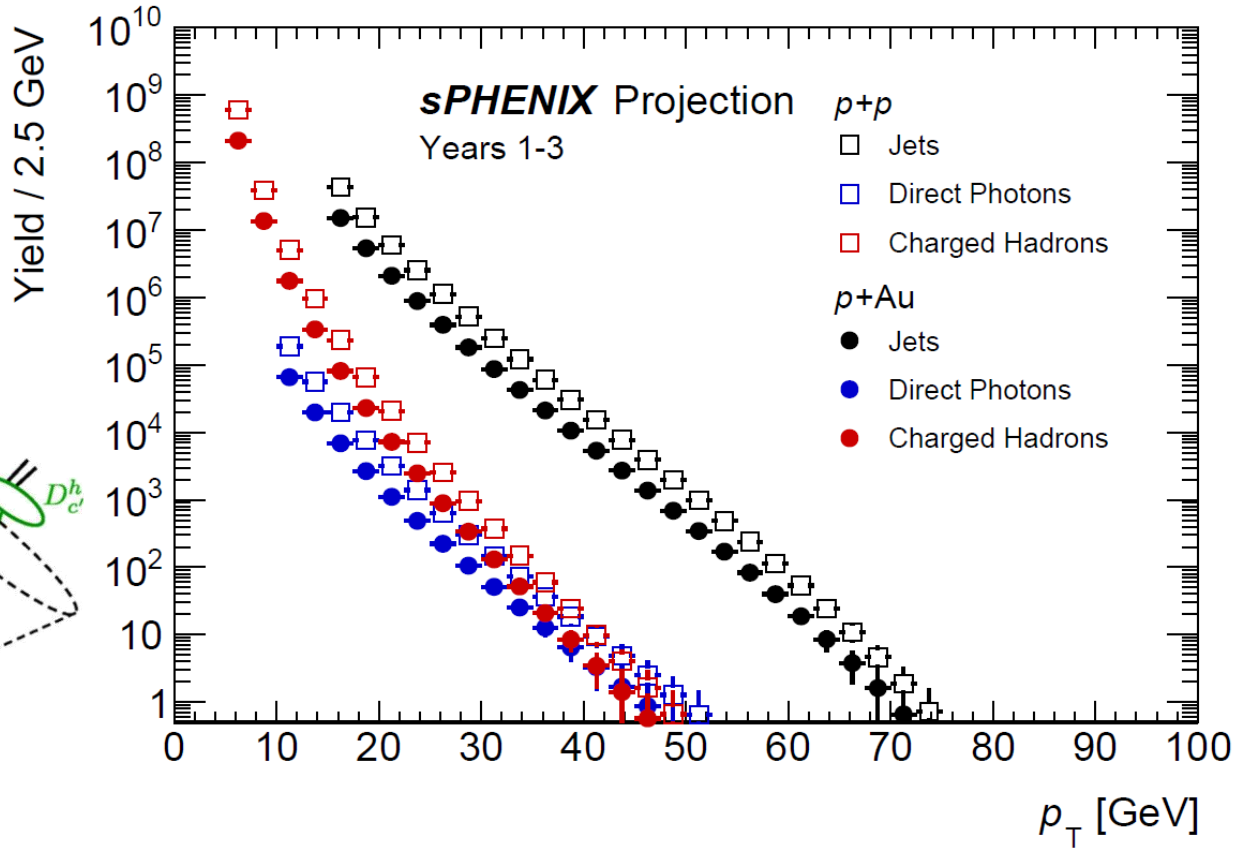
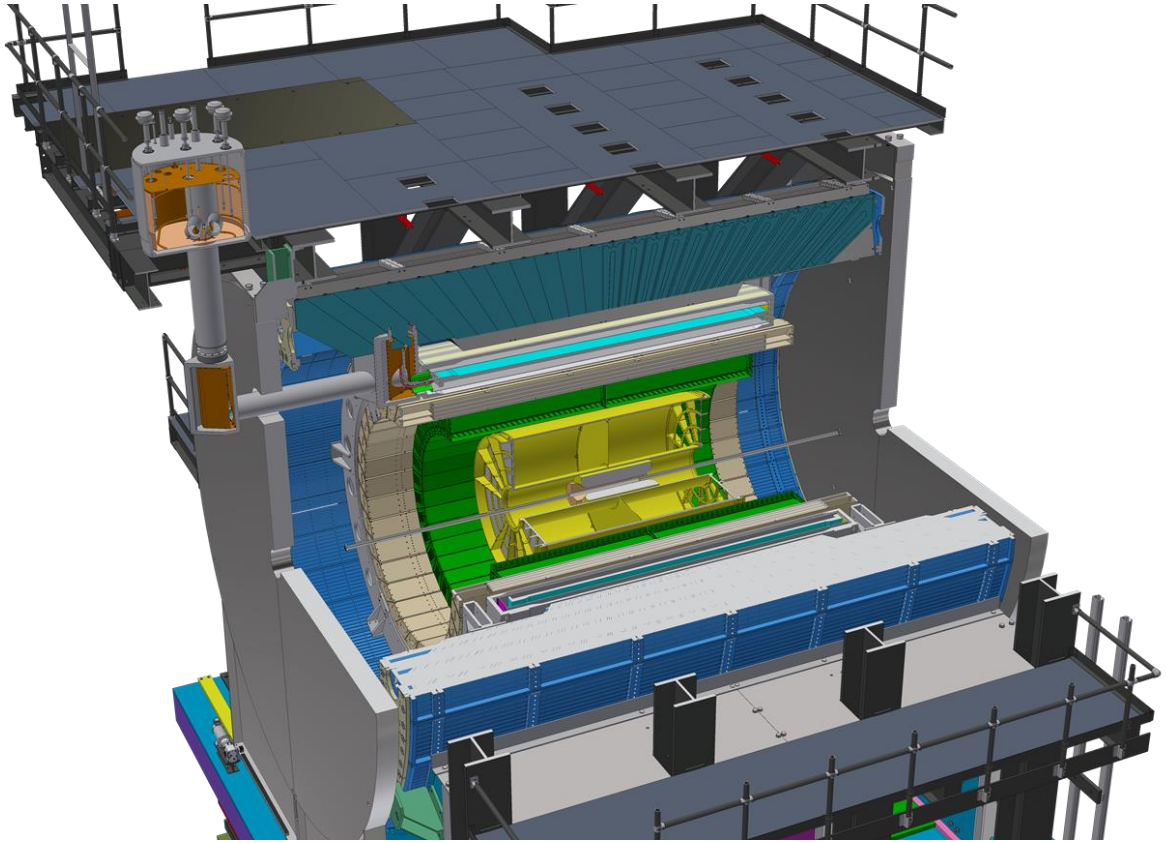
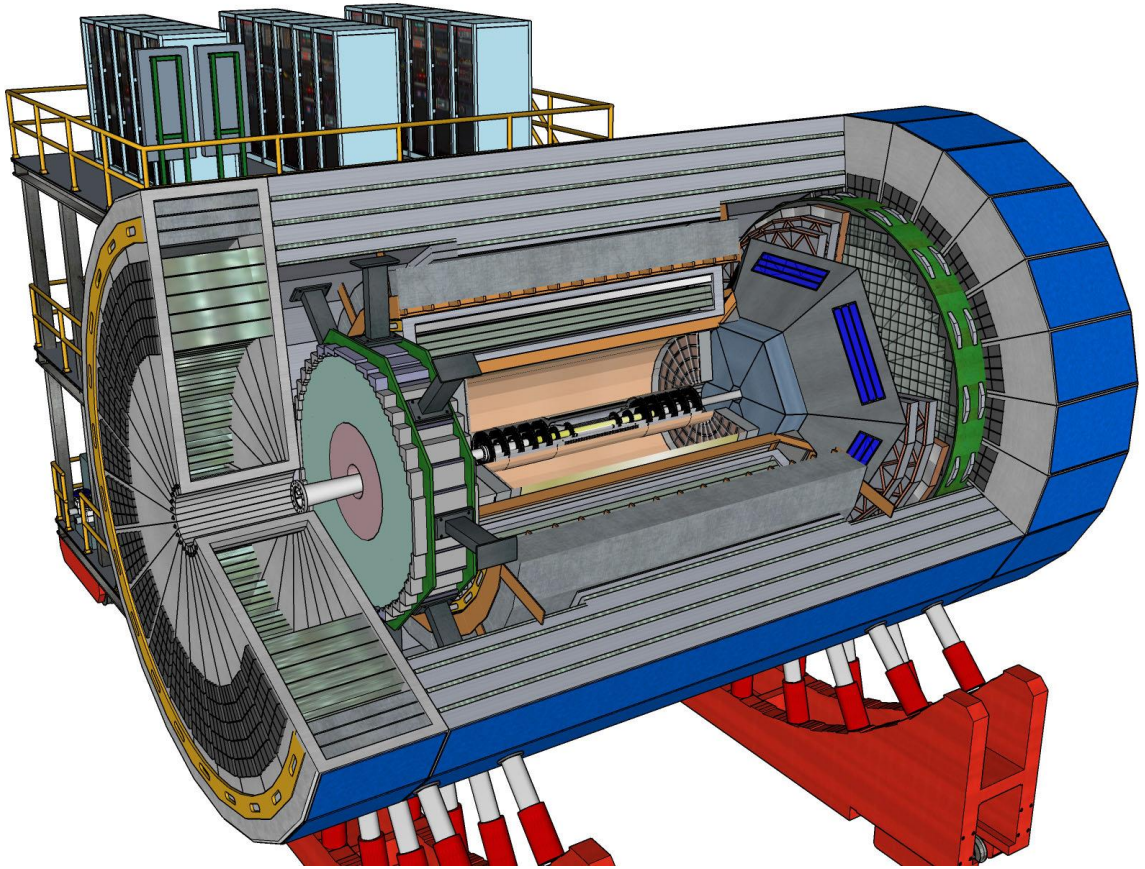


sPHENIX and EIC

sPHENIX, under construction



ECCE EIC exp. proposal [See talk by J. Lajoie, Wed]



Summary

- A rich data set of transversely polarized $p+p$, $p+A$ data planned in sPHENIX Run24
  - Importance of a long Run24 for completing both $p+p$, $p+A$ program
- High stat. observables uniquely enabled by high rate calo trigger and tracker's streaming capability
- Address puzzles and explore new directions: gluon dynamics, origin of A_N, spin/nuclei as tool to study QCD

sPHENIX BUP2021 [sPH-TRG-2021-001]