sPHENIX Jet Physics Program

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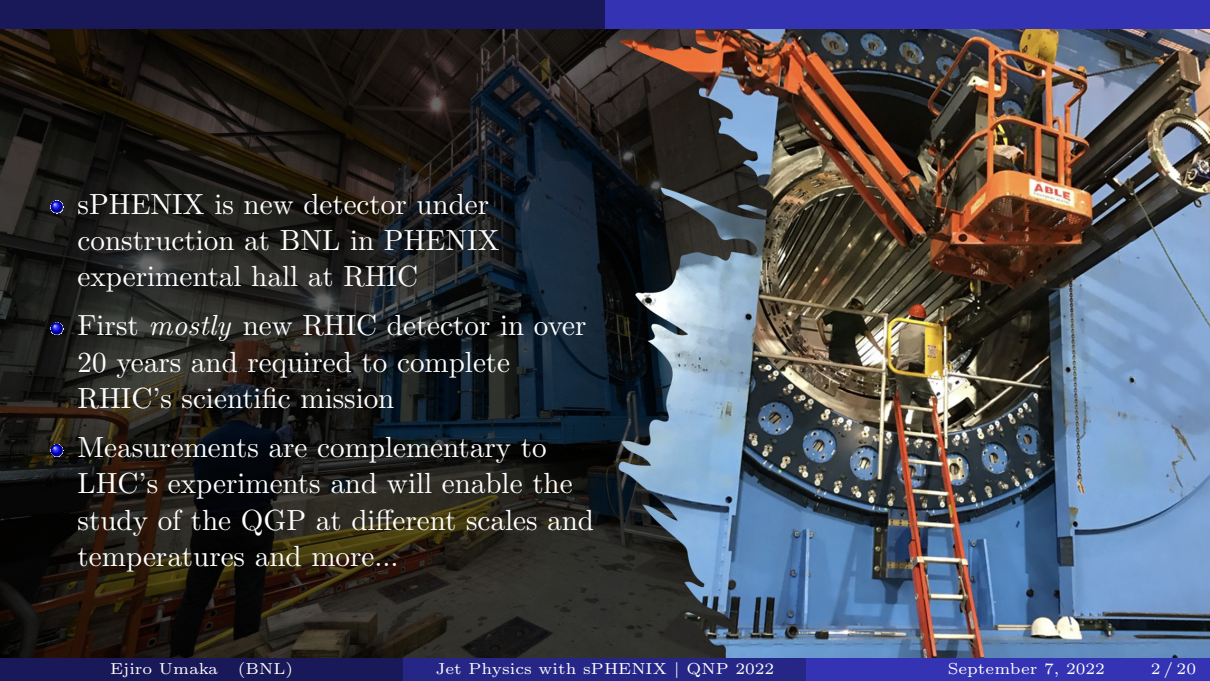
on behalf of the sPHENIX Collaboration

The 9th International Conference on Quarks and Nuclear Physics

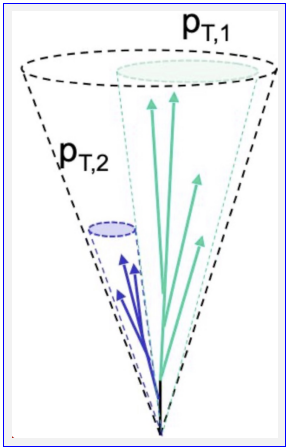
September 7, 2022

- sPHENIX is new detector under construction at BNL in PHENIX experimental hall at RHIC
- First *mostly* new RHIC detector in over 20 years and required to complete RHIC's scientific mission
- Measurements are complementary to LHC's experiments and will enable the study of the QGP at different scales and temperatures and more...



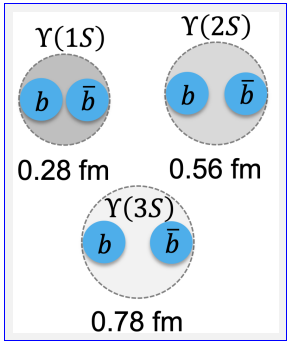
sPHENIX Core Physics Program

Jet correlations & structure



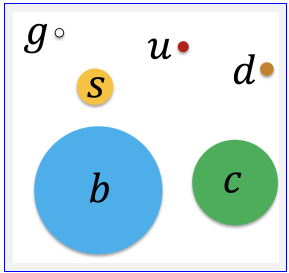
vary p_T & angular size

Quarkonium spectroscopy



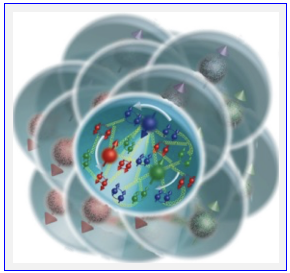
vary probe's size

Parton energy loss



vary p_T & mass

Cold QCD

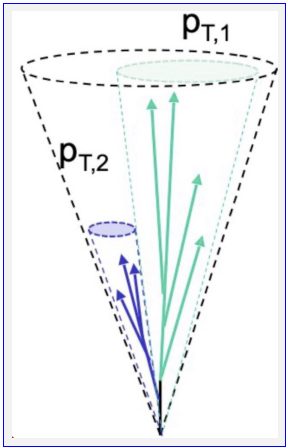


spin & nuclear effects

This talk will focus on the jet physics program

sPHENIX Core Physics Program

Jet correlations & structure



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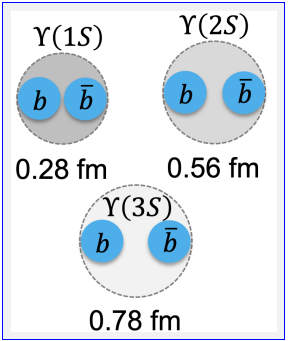

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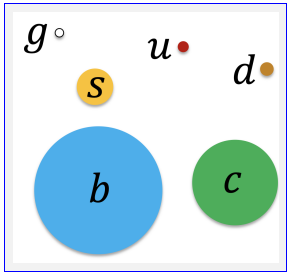

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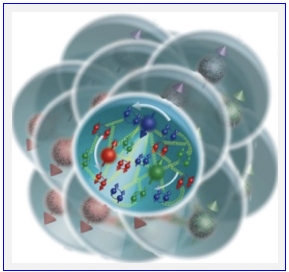
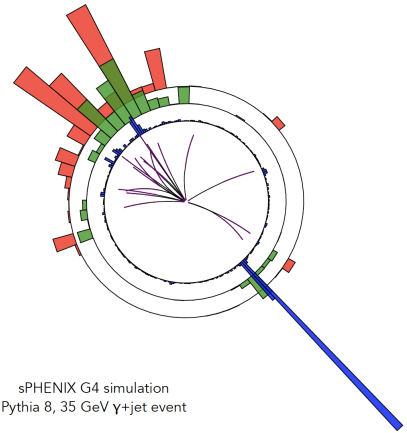


spin & nuclear effects

This talk will focus on the jet physics program

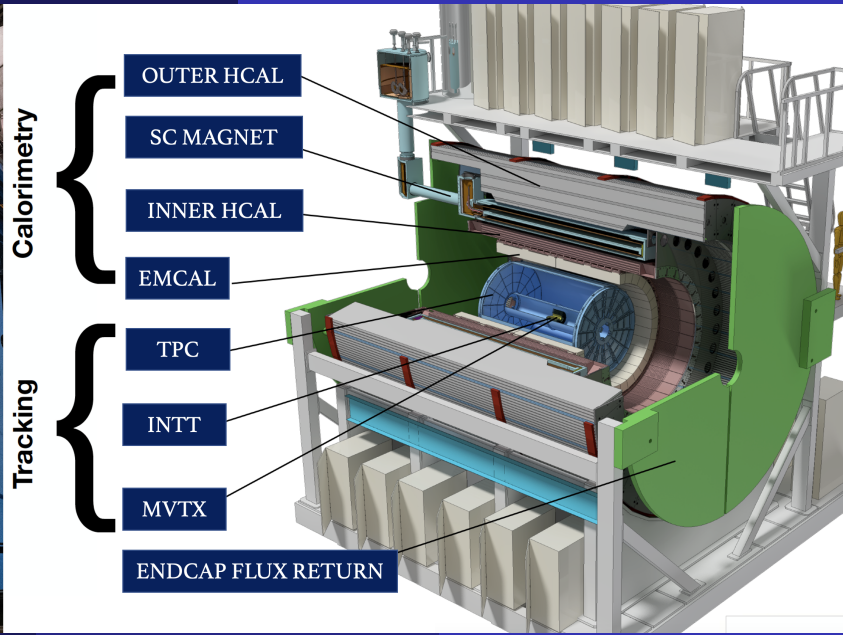
Overview of the Jet Physics Program



sPHENIX G4 simulation
Pythia 8, 35 GeV γ+jet event

- Jet correlations with event planes, photons, and dijets
- Jet substructure in Au+Au and p+Au
- Heavy-flavor jets, and their substructure
- Nuclear modification factors of small and large R jet, R_{AA} double ratios...

sPHENIX DETECTOR



sPHENIX DETECTOR

High data rate (15 kHz)

Acceptance:

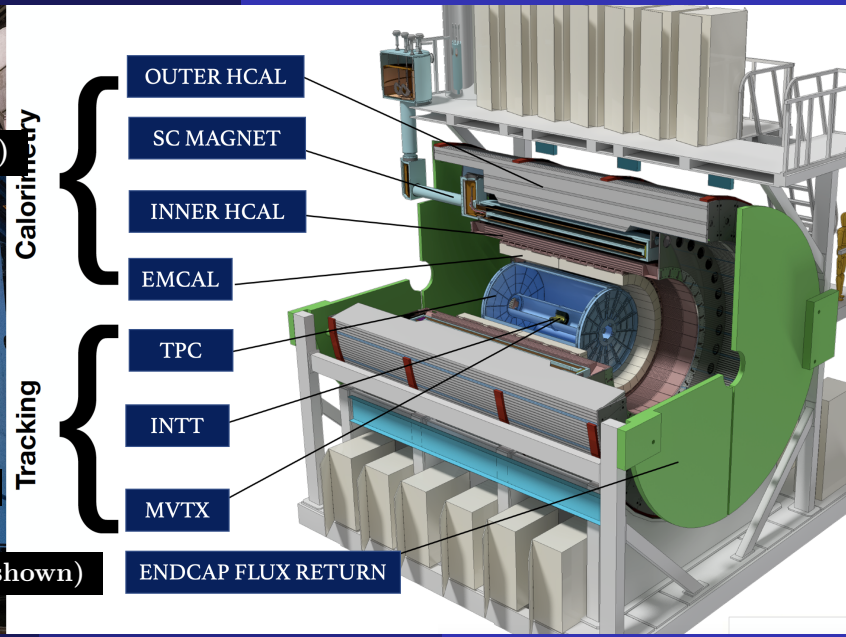
$|\eta| \leq 1.1$, full azimuth

Triggered readout for the calorimeters

Streaming readout for tracking

Event characterization by sEPD & MBD

fwd sub-detectors (not shown)

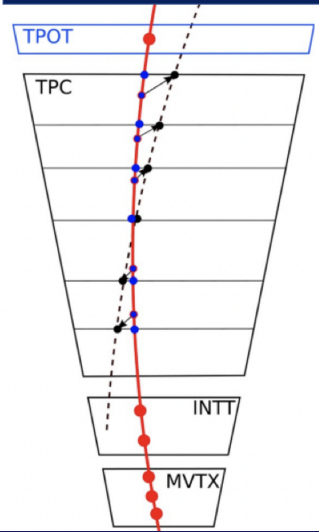


CALORIMETRY

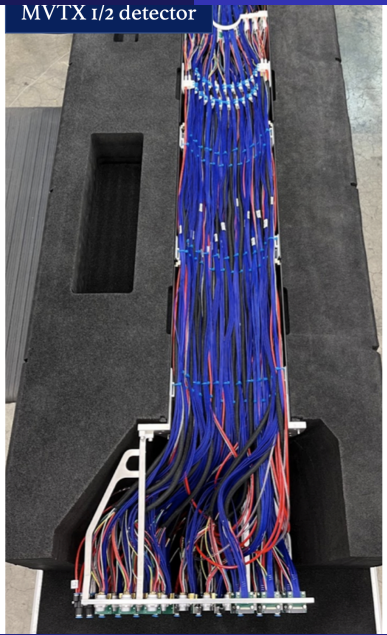
- **HCALs**: First mid-rapidity HCALs at RHIC! Composed of plastic scintillating tiles with embedded WLS fibers + tilted (steel) & Al plates for the (OHCAL) & IHCAL
- **EMCAL**: Composed of scintillating fibers in tungsten & epoxy. $\sigma_E/E < 15\%/\sqrt{E} \oplus 5\%$. Tile segmentation ($\Delta\eta \times \Delta\phi$): $\approx 0.025 \times 0.025$ (EMCAL), $\approx 0.1 \times 0.1$ (HCALs)

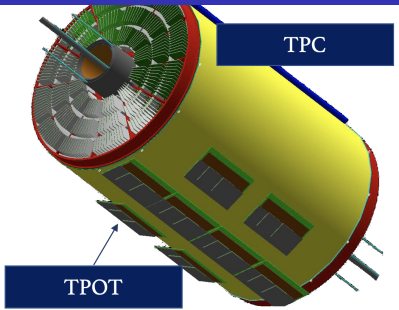
Jet measurement: the HCALs large acceptance allows for improved jet resolution, complete jet measurement, unbiased p+p triggering and extended p_T reach for single hadrons

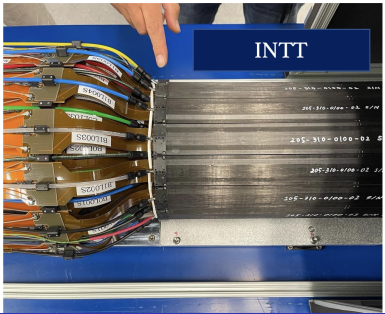
TRACKING



MVTX 1/2 detector







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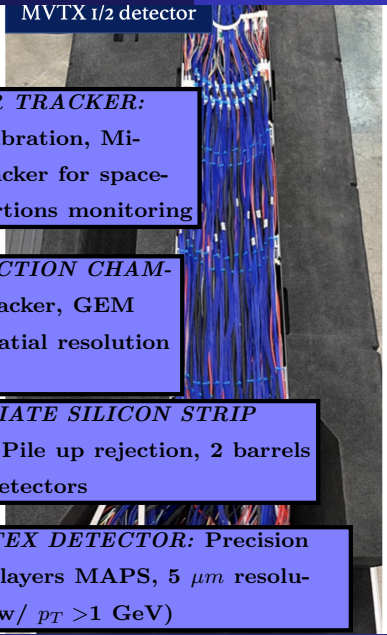
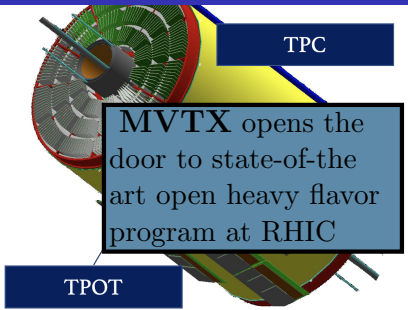


TPC OUTER TRACKER: **Tracking calibration, Micromegas tracker for space-charge distortions monitoring**

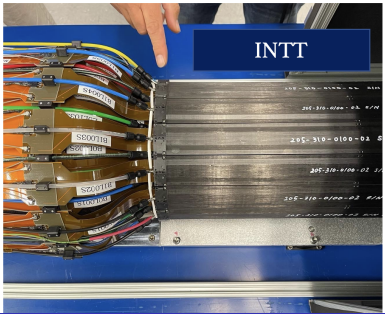
TIME PROJECTION CHAMBER: **Main tracker, GEM technology, spatial resolution** $< 200\ \mu m$

INTERMEDIATE SILICON STRIP TRACKER: **Pile up rejection, 2 barrels of Si strip detectors**

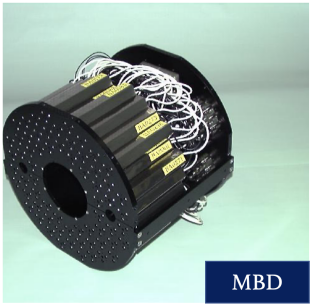
MAPS VERTEX DETECTOR: **Precision vertexing, 3 layers MAPS, 5** μm **resolution (tracks w/** $p_T > 1$ **GeV)**

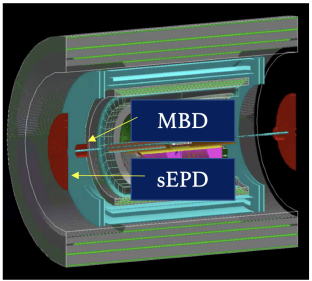


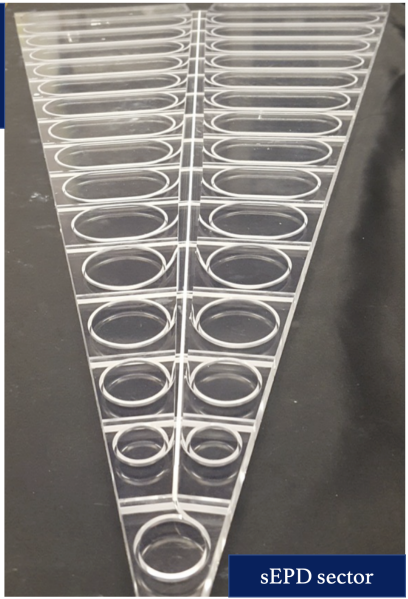
MVTX opens the door to state-of-the art open heavy flavor program at RHIC



EVENT CHARACTERIZATION







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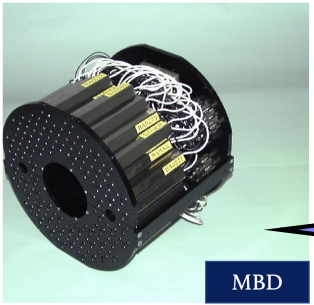
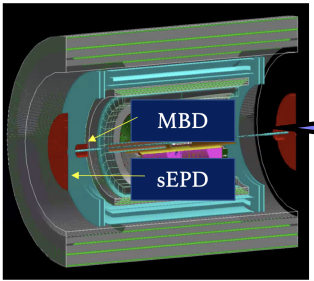
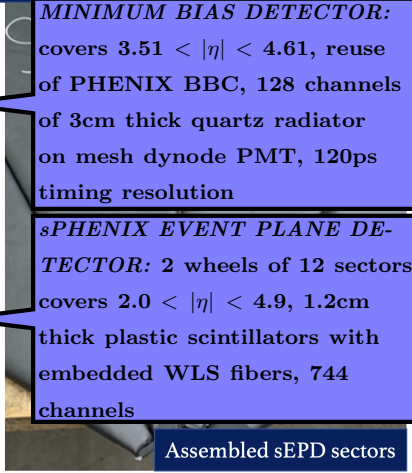
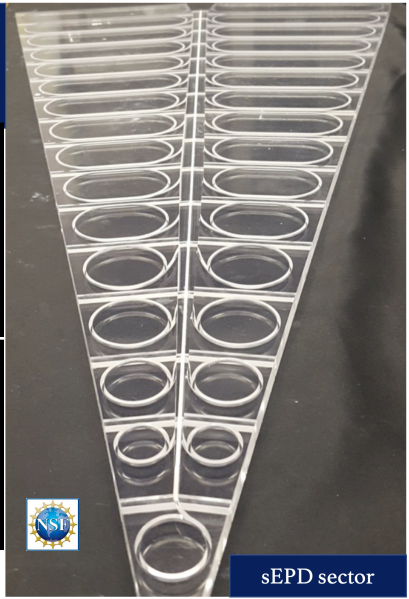


MINIMUM BIAS DETECTOR: **covers $3.51 < |\eta| < 4.61$, reuse of PHENIX BBC, 128 channels of 3cm thick quartz radiator on mesh dynode PMT, 120ps timing resolution**



sPHENIX EVENT PLANE DETECTOR: **2 wheels of 12 sectors covers $2.0 < |\eta| < 4.9$, 1.2cm thick plastic scintillators with embedded WLS fibers, 744 channels**





sPHENIX 3-Year Run Plan

★ First data in March 2023

sPHENIX Beam Use Proposal (BUP) sPH-TRG-2020-001, August 31, 2020

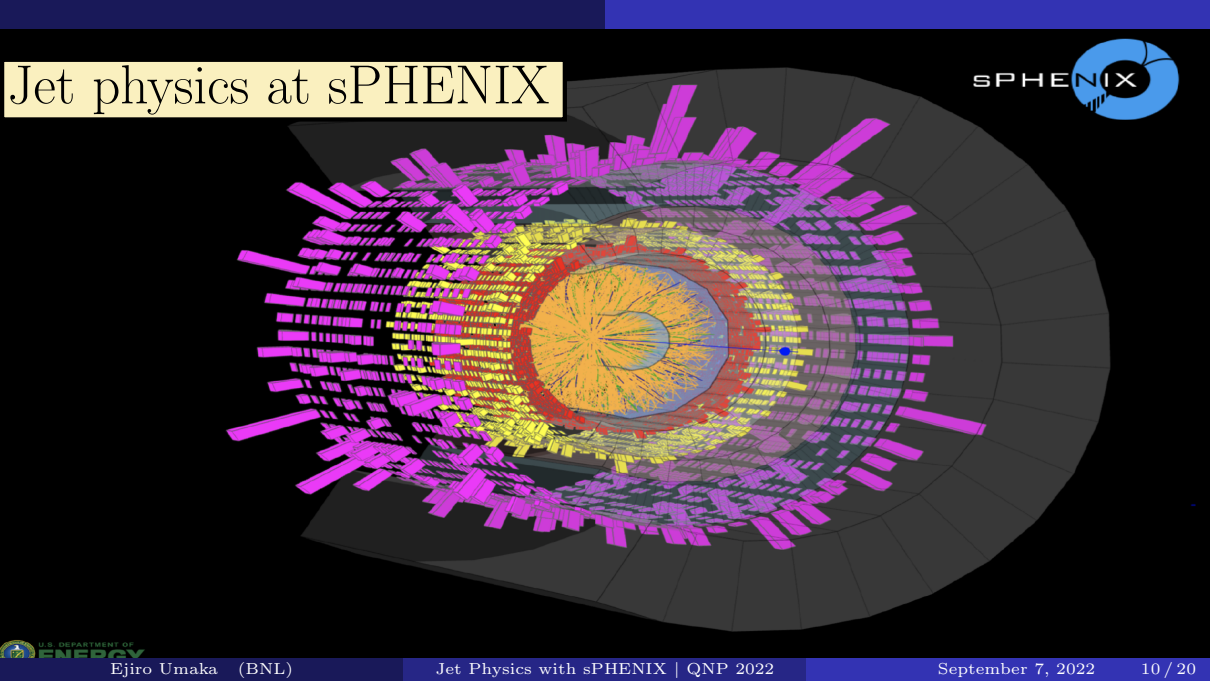
Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\lvert z\rvert$ <10 cm	Samp. Lum. $\lvert z\rvert$ <10 cm
2023	Au+Au	200	24 (28)	9 (13)	3.7 (5.7) nb^{-1}	4.5 (6.9) nb^{-1}
2024	$p^{\uparrow}p^{\uparrow}$	200	24 (28)	12 (16)	0.3 (0.4) pb^{-1} [5kHz] 4.5(6.2) pb^{-1} [10%-str]	45 (62) pb^{-1}
2024	$p^{\uparrow}$+Au	200	–	5	0.003 pb^{-1} [5kHz] 0.02 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}

Year 1: commissioning & first physics in Au+Au

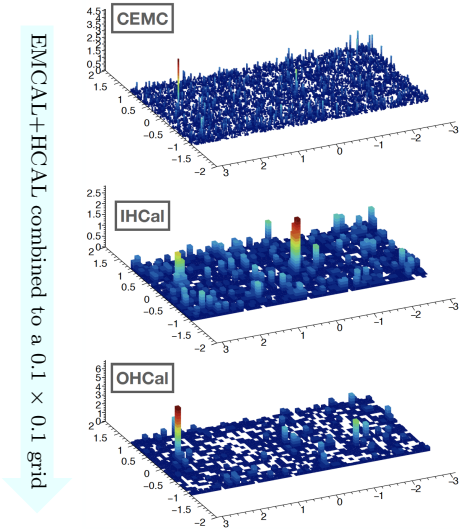
Year 2: $p^{\uparrow}$+$p^{\uparrow}$, $p^{\uparrow}$+Au: HI reference set and cold QCD

Year 3: very large Au+Au dataset (141 billion events in total)

Jet physics at sPHENIX

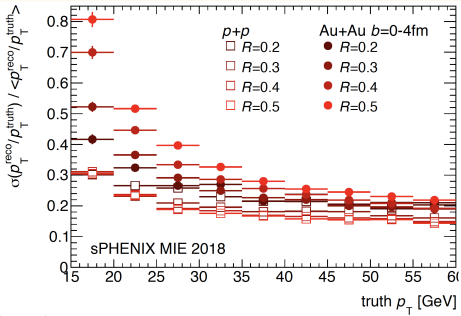


Calorimeter jet reconstruction in sPHENIX



Pythia dijet event embedded in sHIJING

Good JER, better w/ smaller R jet, in p+p, & high p_T



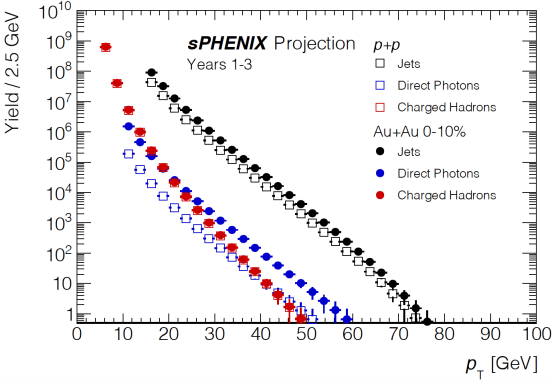
ATLAS style iterative UE subtraction procedure

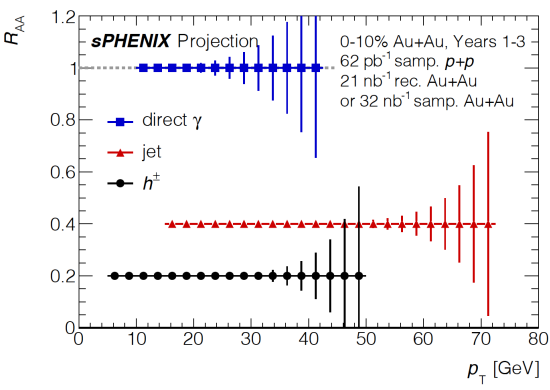
$$\frac{d^2E_T}{d_\eta d_\phi} = \frac{dE_T}{d_\eta}\left(1 + 2\sum_n v_n cos(n(\phi - \Psi_n))\right)$$

1. Reconstruct R=0.2 seed jets, determine v_2 for the event (w/o) towers $< \eta = 0.4$ of seed jet **2.** Determine background E_T in η strip & subtract it from seed jets **3.** Redetermine UE estimation & subtract from calorimeter towers, then run jet finding on subtracted towers.

Statistics for high p_T probes

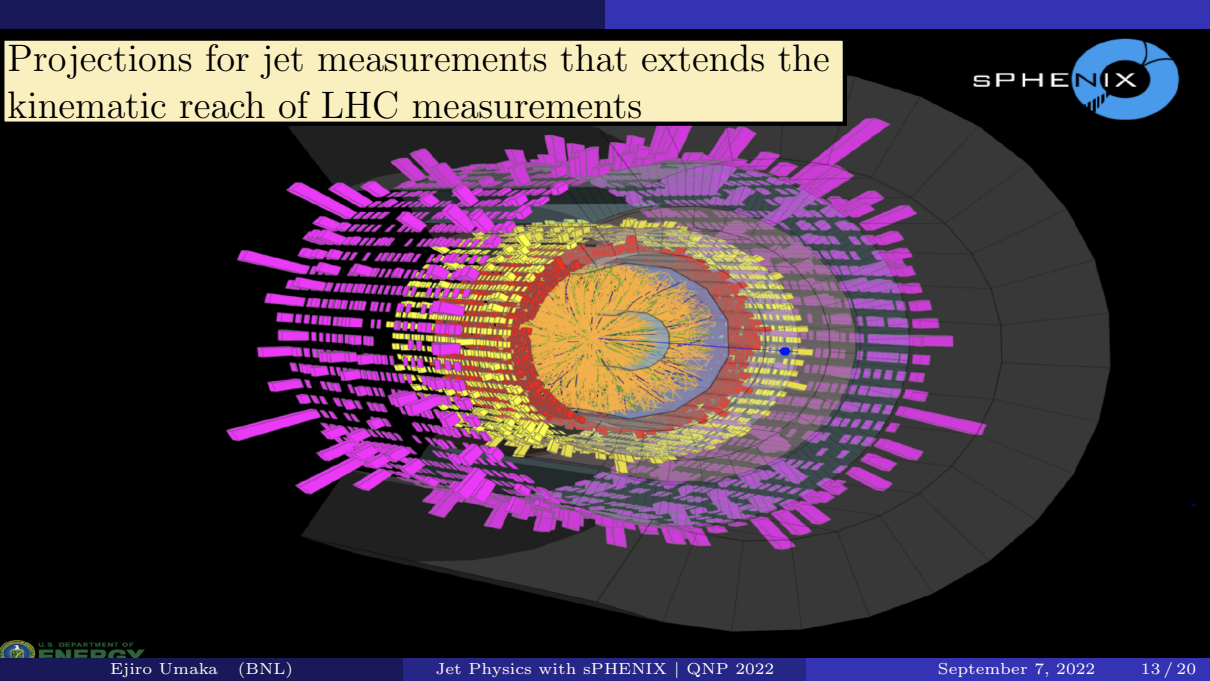
[BUP] sPH-TRG-2020-001



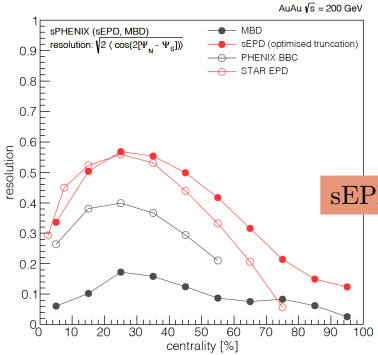


- Kinematic reach out to $\approx$ 70 GeV for jets, $\approx$ 50 GeV for photons (left figure)
- Allows for inclusive jet R_{AA}, γ-jet, jet substructure measurements and more...
- Kinematic reach allows for overlap with LHC measurements

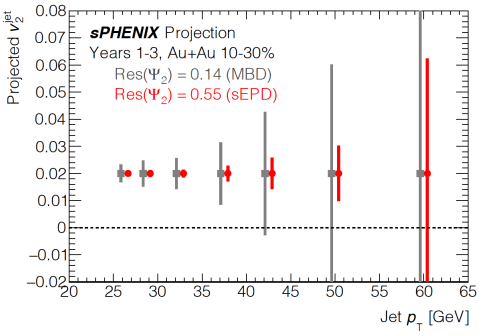
Projections for jet measurements that extends the kinematic reach of LHC measurements



Jet correlations with event planes



sEPD resolution



- Higher resolution event plane resolution achieved with the sEPD
- sEPD's higher resolution allows measurement of the modification of the jet yield with respect to the reaction plane (jet v_2) $\Rightarrow$ path-length dependent energy loss
- Measurement overlaps with LHC experiments and provides access to the $p_T < 50$ GeV region

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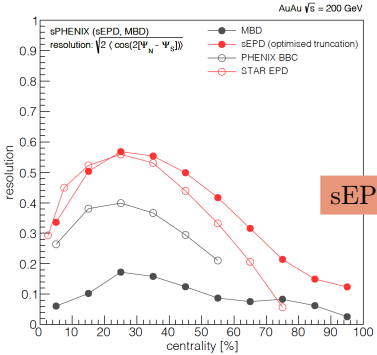

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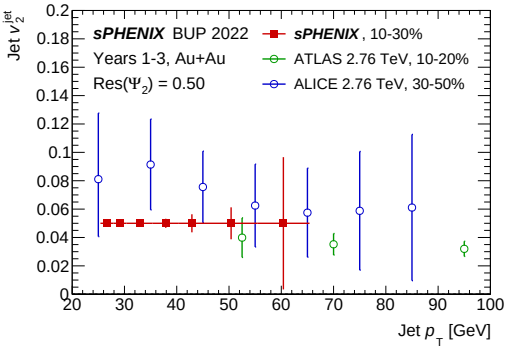

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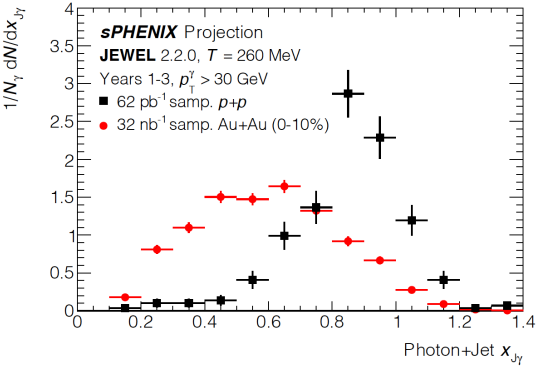
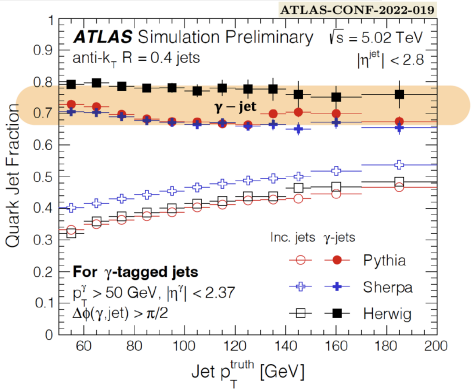
Photon-jet correlations





- Higher quark fraction in γ tagged jets than inclusive jets $\Rightarrow$ study flavor dependence of energy loss
- γ does not interact with the QGP $\Rightarrow$ constrains the initial jet p_T. sPHENIX projections of the p_T imbalance, $x_{j\gamma} = p_T^{jet}/p_T^\gamma$, at lower p_T extends the kinematic reach. (ATLAS $p_T^\gamma > 79.6$ GeV)

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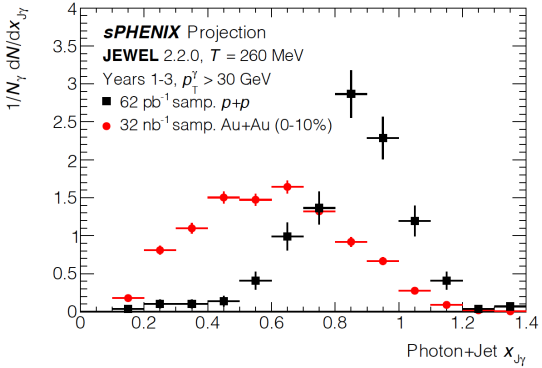

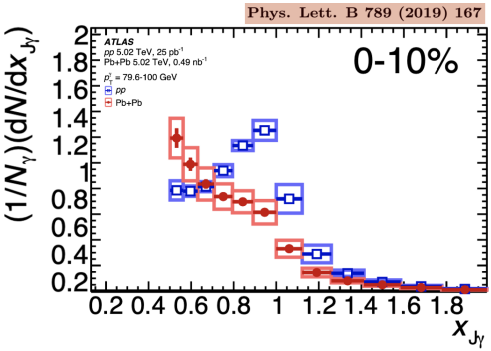

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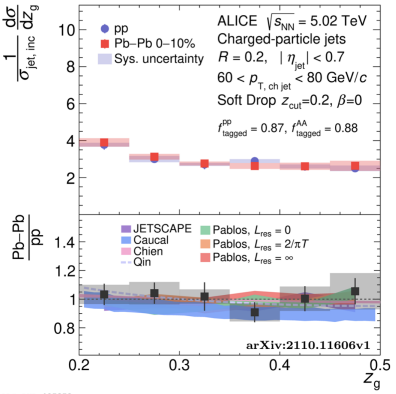
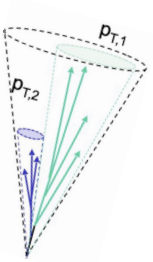
Jet substructure





sub-jet splitting function:

$$z_g = \frac{min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

- Evolution of the parton shower ⇒ substructure observables (z_g, θ_g). z_g measured at ALICE show no modification in p+p & Pb+Pb, also shows agreement with model predictions
- High statistics with 3 years data at sPHENIX allows extension of the measurement to lower p_T

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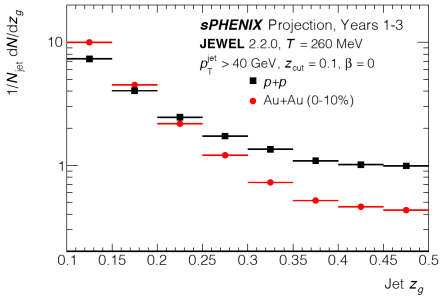

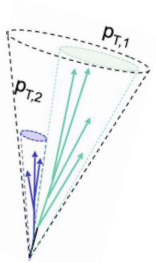

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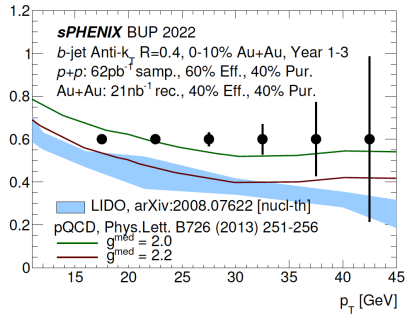
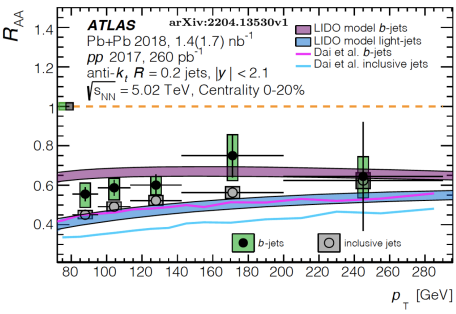
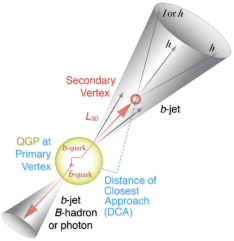
Heavy-flavor jets

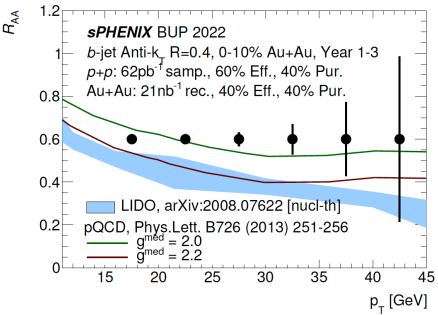


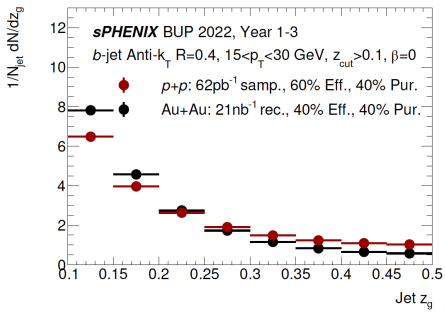


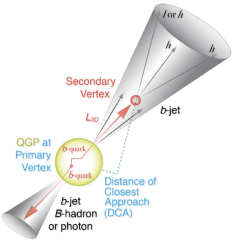


- High precision & data rate of sPHENIX opens the door to *b-jet* measurements at RHIC! ATLAS b-jet measurement in 0-20 % are less suppressed than inclusive jets
- *b-jet* measurement possible at lower p_T than inclusive jet due to stronger UE suppression (b-tagging) at sPHENIX
- Large yield of identified *b-jets* will allow for differential studies of their properties ⇒ sub-jet splitting fraction z_g ⇒ mass dependence of the parton shower evolution

Heavy-flavor jets







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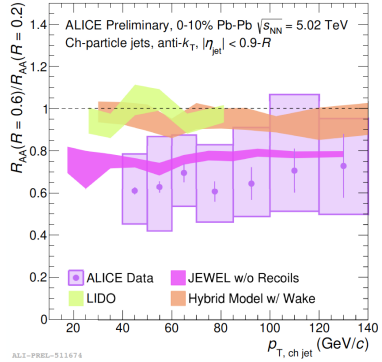
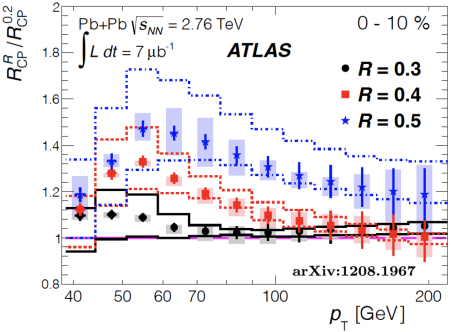
R dependence of jet R_{AA}





- Jet R_{AA} ratios probe the interplay of out-of-cone energy loss & angular distribution of medium response effects. (Left) ALICE R = 0.6 jets **more** suppressed, (Right) ATLAS R = 0.5 jets **less** suppressed. Caveats: R_{AA} (ALICE), ML UE subtraction vs. R_{CP} (ATLAS) ...
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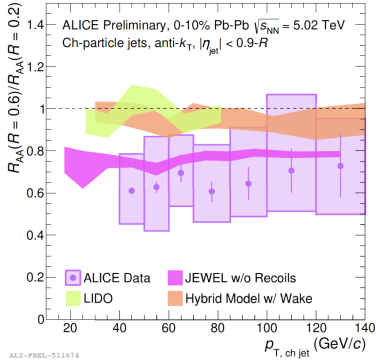

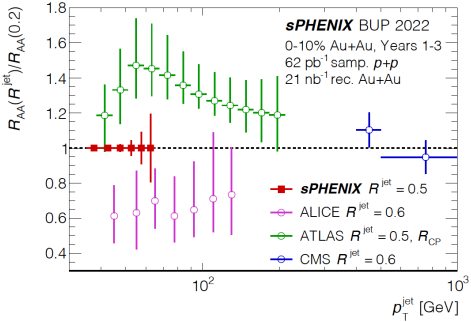

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Summary

sPHENIX is on its way to ushering a new era of precise jet and heavy flavor measurements at RHIC

Installation for the HCALs is complete, the EMCAL is ongoing, the tracking detectors will start soon!

Event characterization detectors and commissioning will follow

sPHENIX has been rolled into data-taking position!

First data collection scheduled for March 2023!


Thank you!