The sPHENIX Experiment at RHIC

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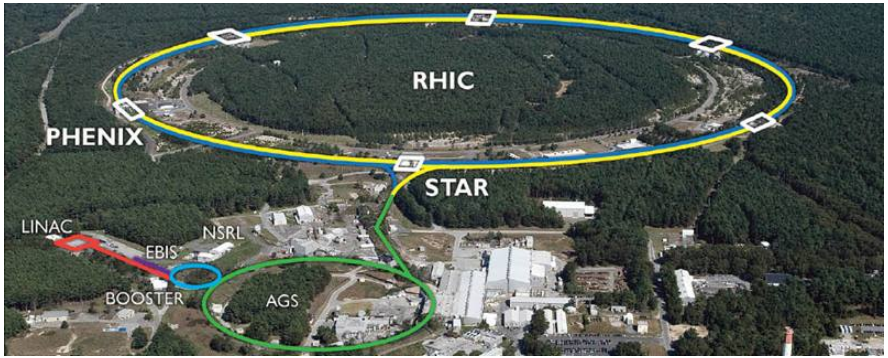
ICHEP

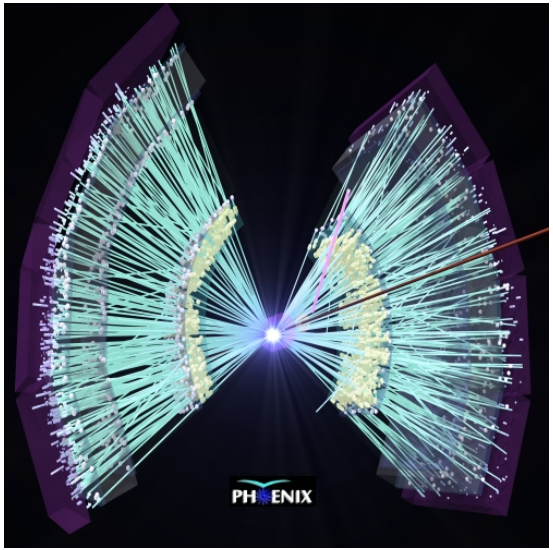
Contents

- What is sPHENIX?
- Tracking overview
- Calorimetry overview
- Current status (how has Covid-19 affected us?)
- Prospects for heavy flavor physics in heavy ion collisions

What is sPHENIX?

- Super PHENIX is the successor to the Pioneering Hadron Electron Nuclear Interaction eXperiment (PHENIX)
- A barrel detector designed to study heavy flavor and jet physics in a heavy ion environment
- Uses both new technology and technology shared with other experiments



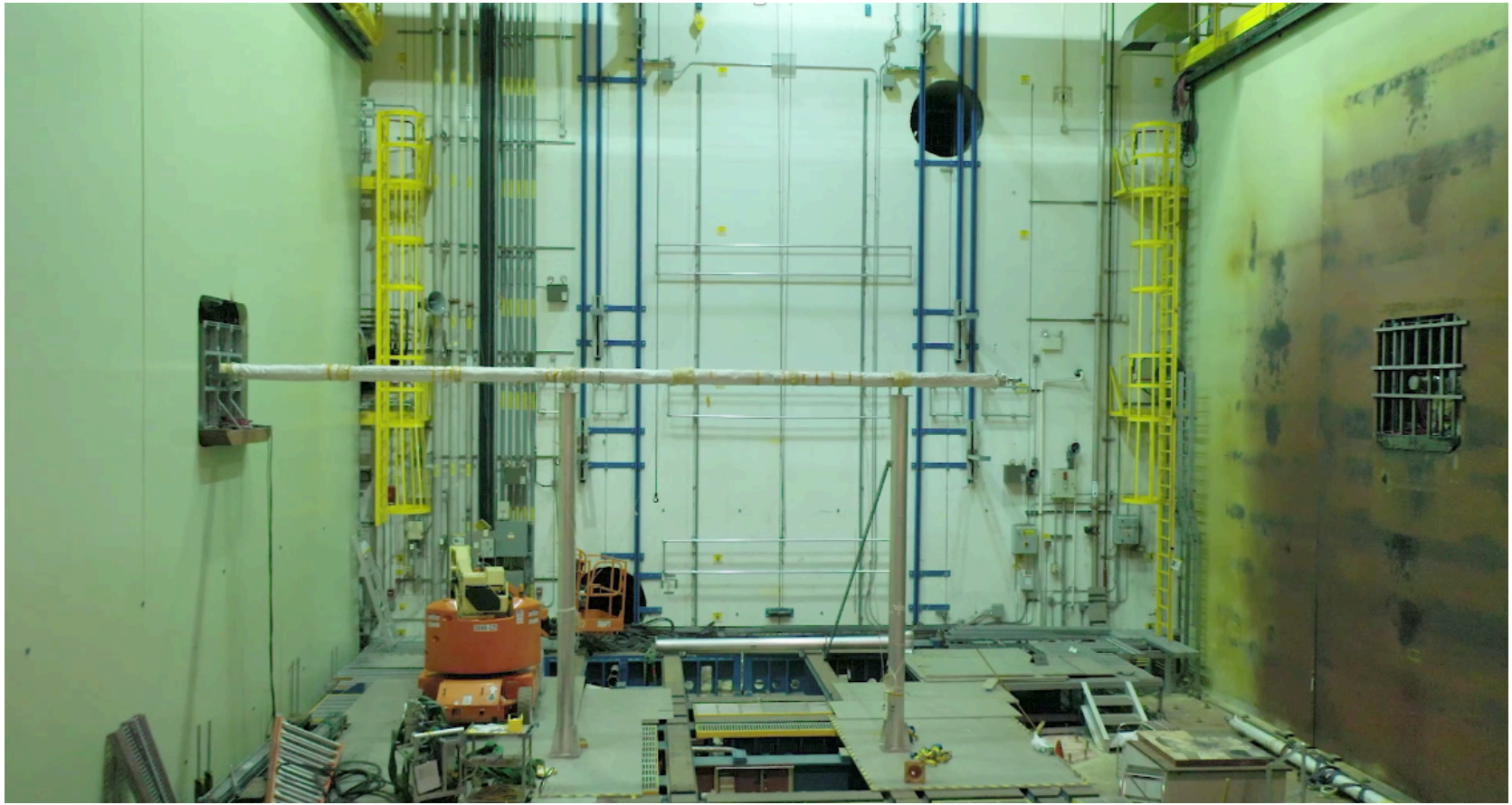


- Located in the PHENIX experimental hall, IP-8
- Last PHENIX data taking was 2016
- Data taking expected to begin in 2023

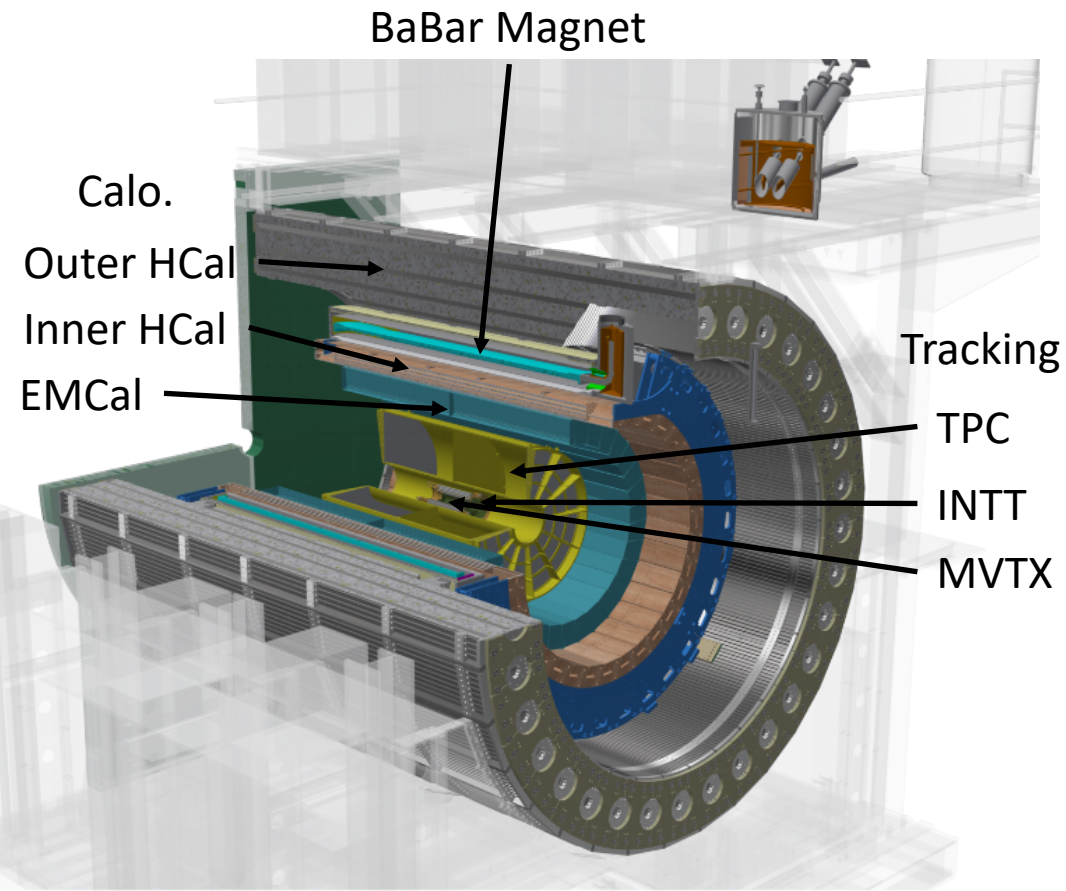
Top – The location of PHENIX at RHIC

Left – A PHENIX event display

What is reused from PHENIX?



What is sPHENIX?



First run year	2023
$\sqrt{s_{NN}}$ [GeV]	200
Trigger Rate [kHz]	15
Magnetic Field [T]	1.4
First active point [cm]	2.5
Outer radius [cm]	270
$\lvert\eta\rvert$	$\leqslant$1.1
$\lvert z_{vtx}\rvert$ [cm]	10
N(AuAu) collisions*	1.43×10^{11}

* In 3 years of running

Tracking at sPHENIX

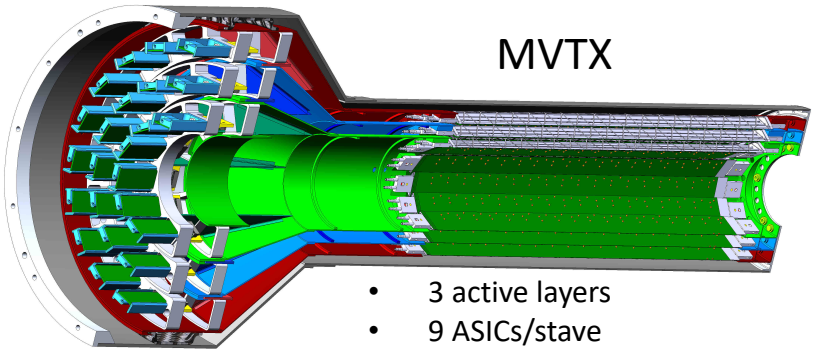
- Tracking currently consists of 3 sub-detectors; MVTX, INTT, TPC
- Task force studying the addition of a 4th sub-detector

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

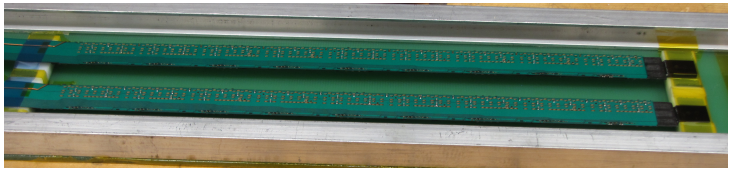
ALPIDE thickness [µm]	50
Pixel size [µm] / matrix	29 x 27 / 1024 x 512
Technology	180nm CMOS
Power Consumption [mW/cm^2]	40 (mean), 300 (peak)
Stave Material Budget	0.3% X_0
Timing resolution	A few µs (tunable)
XZ spatial resolution [µm]	< 6

MVTX

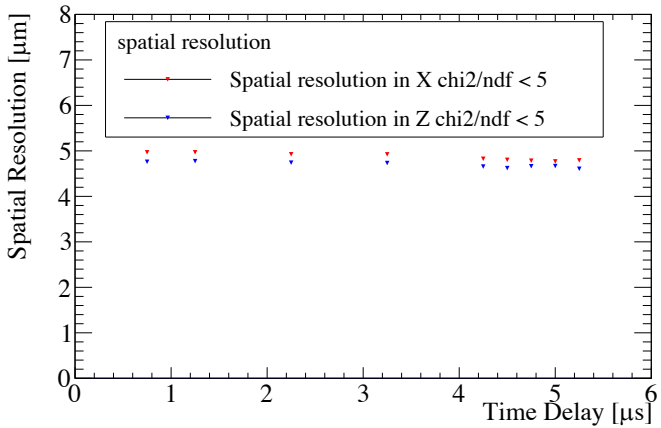


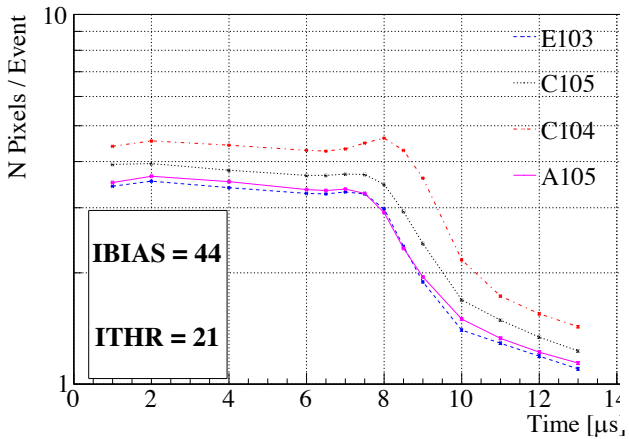
- 3 active layers
- 9 ASICs/stave
- 27 cm active length/stave

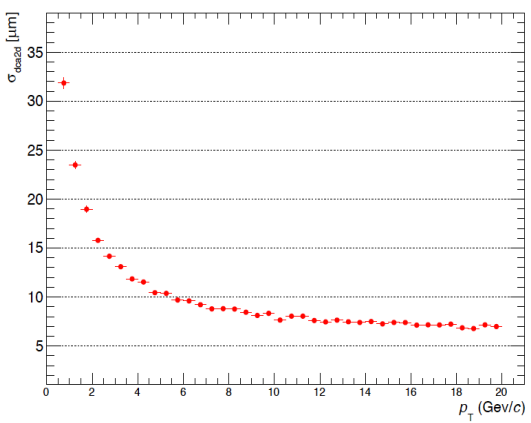
MVTX staves



Tracking at sPHENIX







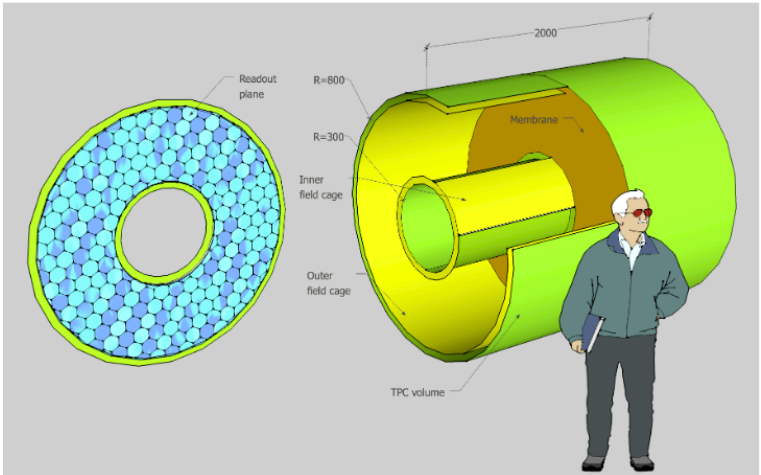
Left – Spatial resolution as a function of trigger delay

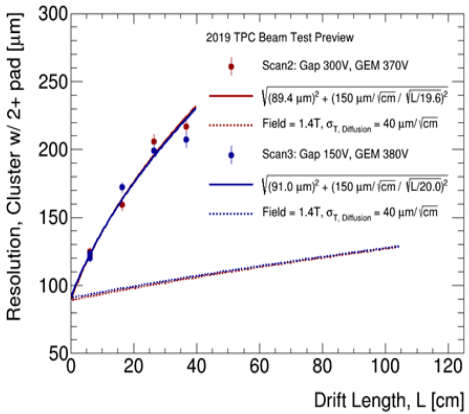
Middle – Mean number of pixels fired per event as a function of trigger delay for different pixel settings for four different staves. (The RHIC trigger latency is ~4μs)

Right – IP_{XZ} resolution (simulation)

Tracking at sPHENIX

- Compact TPC, 20 < r [cm] < 78 (active volume > 30cm)
- Spatial resolution < 200 μm
- dE/dx resolution of ~6.6%
- Charge collection enabled by GEMs and measured by the ALICE SAMPA
- IBF is minimized, TPC is live at all times
  - IBF < 0.5% at a few kV in GEMs
- A task force is studying the space-charge effects

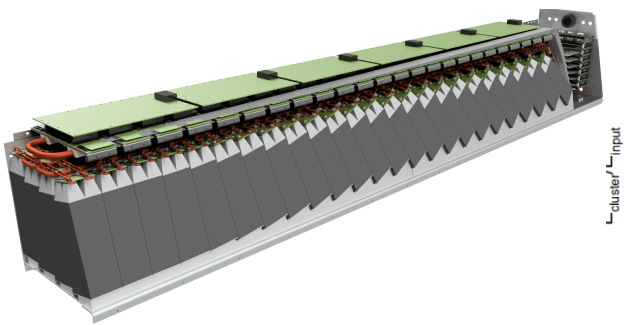


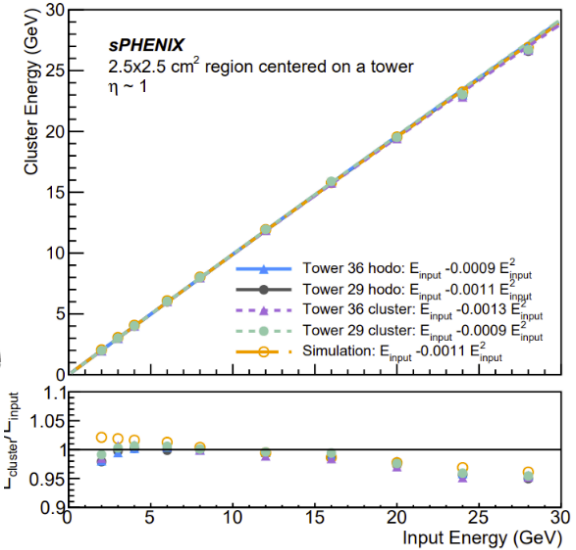


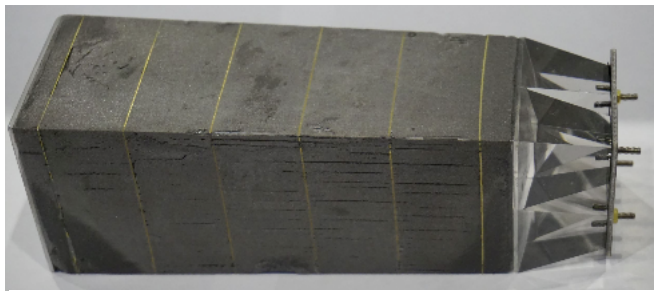
Top – Overview of TPC structure
Bottom left – Resolution of the TPC; solid line is measured, dashed line is extrapolated to sPHENIX magnetic field
Bottom right –TPC field cage

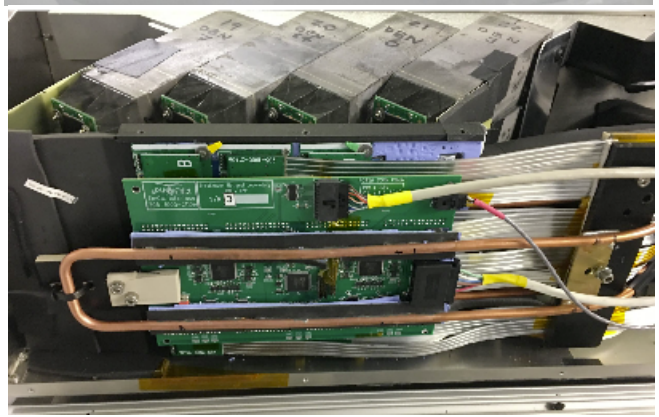
EM calorimetry at sPHENIX

- Sampling EMCal, using SciFi in tungsten and epoxy
- 20.1X_0 and 0.83λ_{int}
- $\sigma/E \leq 16\%/E \oplus 5\%$
- 90 < r [cm] < 116
- No. towers = 24576
- Readout:
  Hammamatsu MPPC SiPM





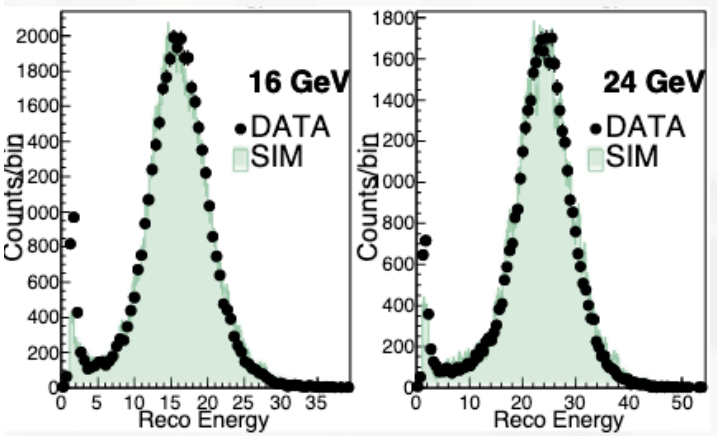


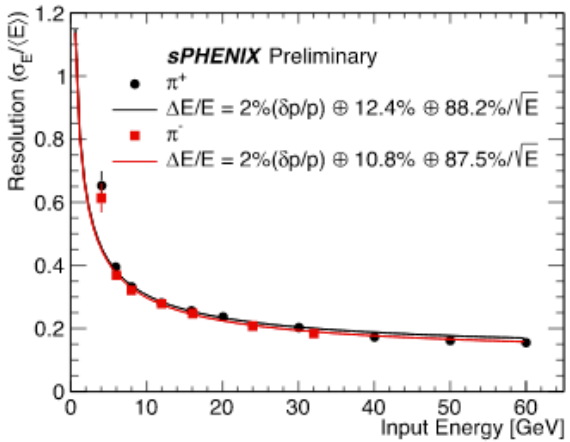


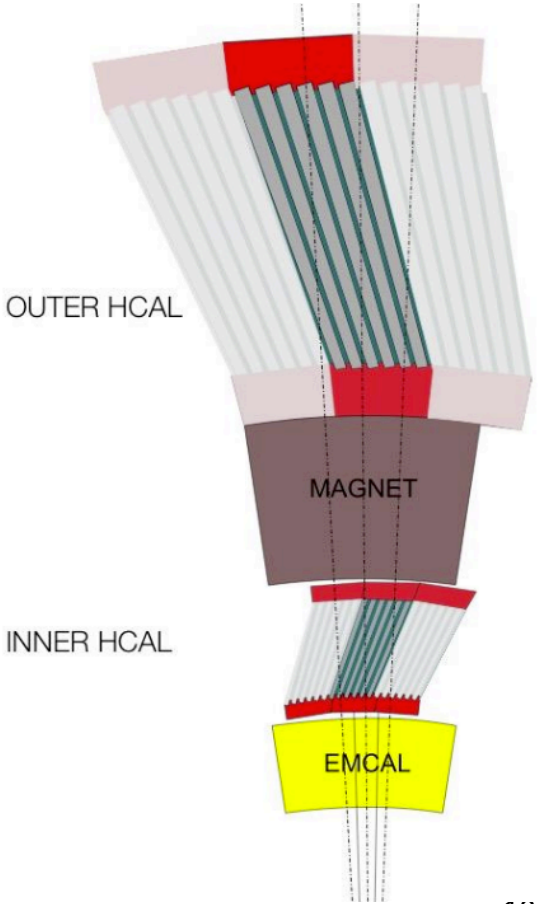
Top – A completed EMCal block. Bottom left – Design of an EMCal sector (IP is towards the left). Bottom middle – Cluster energy vs input energy. Bottom right – EMCal prototype

Hadron calorimetry at sPHENIX

- Two segments on either side of the magnet
- Alternating tiles of steel (outer) or aluminium (inner) and scintilla
- $3.8\lambda_{in}$
- r [cm] < 270
- Same electronics as EMCal
- Outer HCal also acts as magnet return and support







Left – Reconstructed energy of pions. Middle – $\pi^{\pm}$ resolution
Right – Cross-section of the calorimetry and magnet in sPHENIX

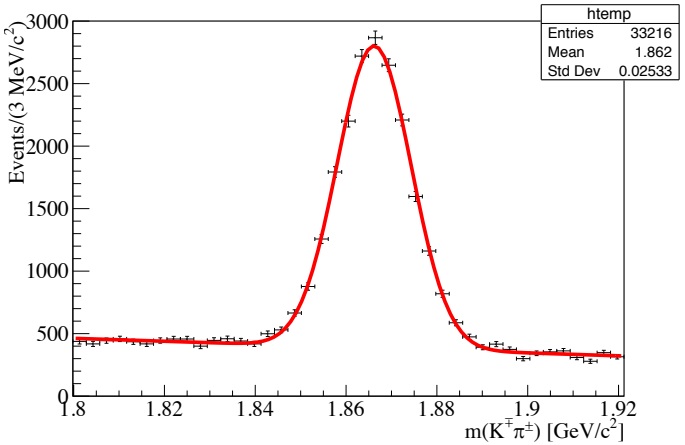
Current production status

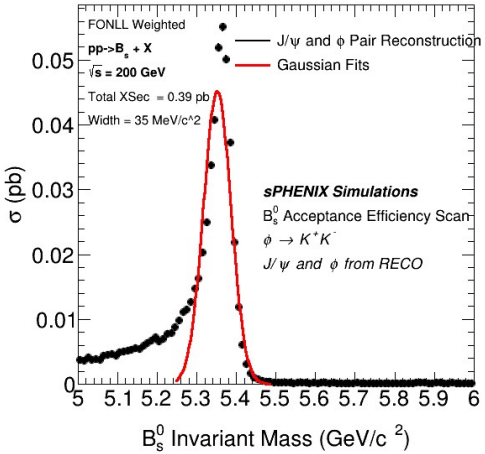
- Experimental hall is cleared and ready for construction
- MVTX: Staves production has resumed at CERN and all RU's are delivered
- TPC: Cooling of electronics is now under test and GEMS are ordered from CERN
- ECAL: All tungsten and SiPMs are delivered, 70% of the tiles and fibres received
- HCAL: Assembly has resumed after Covid-19 shutdown
- Analysis and software:
  Simulations are improving daily, now adding secondary materials such as service material
  Track and vertex reconstruction have hard working, dedicated task-forces
  Event reconstruction tools are progressing well
  Several physics topical groups exist:
  Heavy flavour, cold GCD, jets and quarkonia

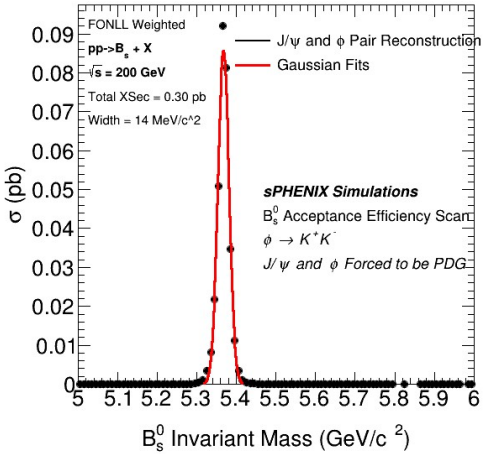
Bottom – OHCal tiles

Physics potentials

- Major focus of experiment is c/b-quark studies in Heavy Ions
- Their masses are greater than Λ_{QCD} and T_{QGP}
- Can use pQCD without thermal production of hadrons as temperature drops
- c and b see the complete QGP evolution

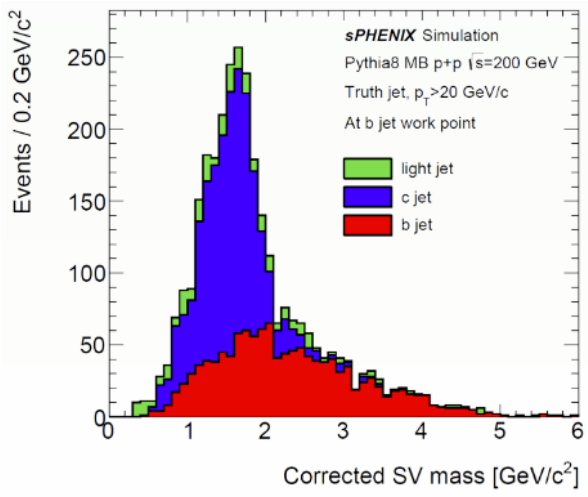


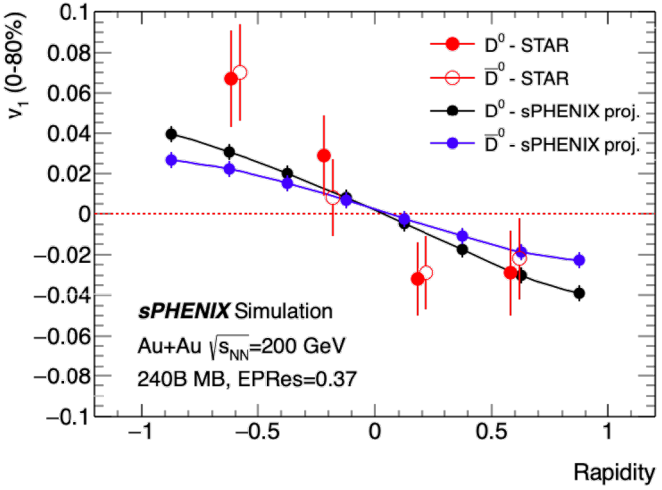


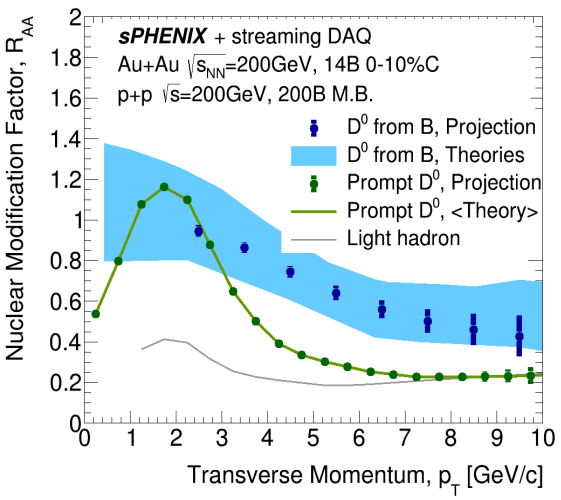


Left – $K^{\mp}\pi^{\pm}$ reconstruction
Middle and right – $e^+e^-K^+K^-$ reconstruction
(middle – without mass constraints, right – with mass constraints)

Physics potentials







Left – c/b jet distributions from secondary vertex mass
Middle – Directed flow predictions from D^0
Right – R_{AA} predictions from prompt and non-prompt D^0

Conclusions

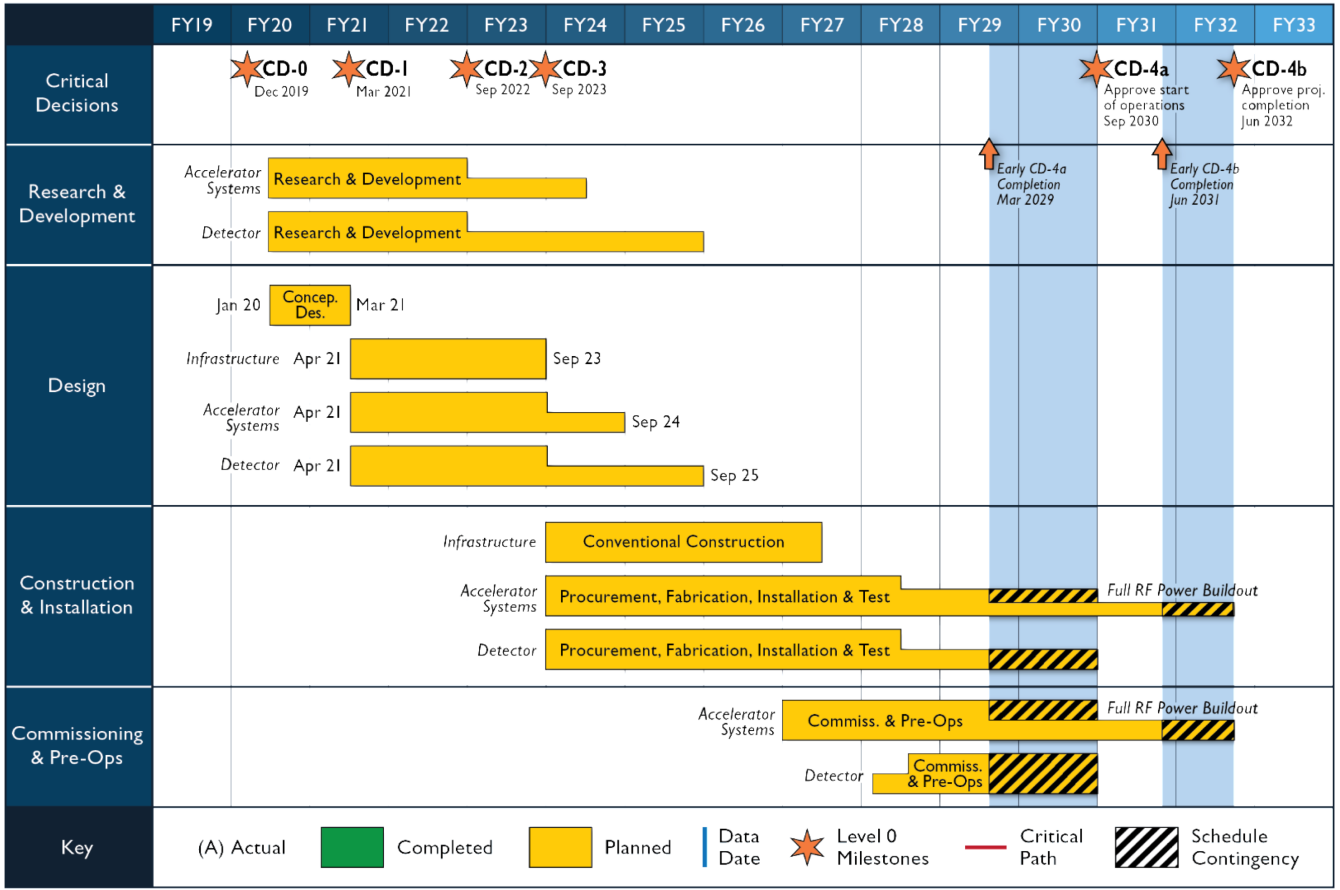
- sPHENIX is a next generation detector heavy ions
- Expertise taken from the PHENIX collaboration and several others
- Each subdetector is well suited for precision heavy flavour measurements in HI
- These measurements are complimentary to the LHC
- Production and construction is progressing on schedule
- The collaboration has adapted to the challenges posed by the pandemic
- sPHENIX is on track to collect data in 2023 – 2025
- Let's see what the next few years holds

Thank you

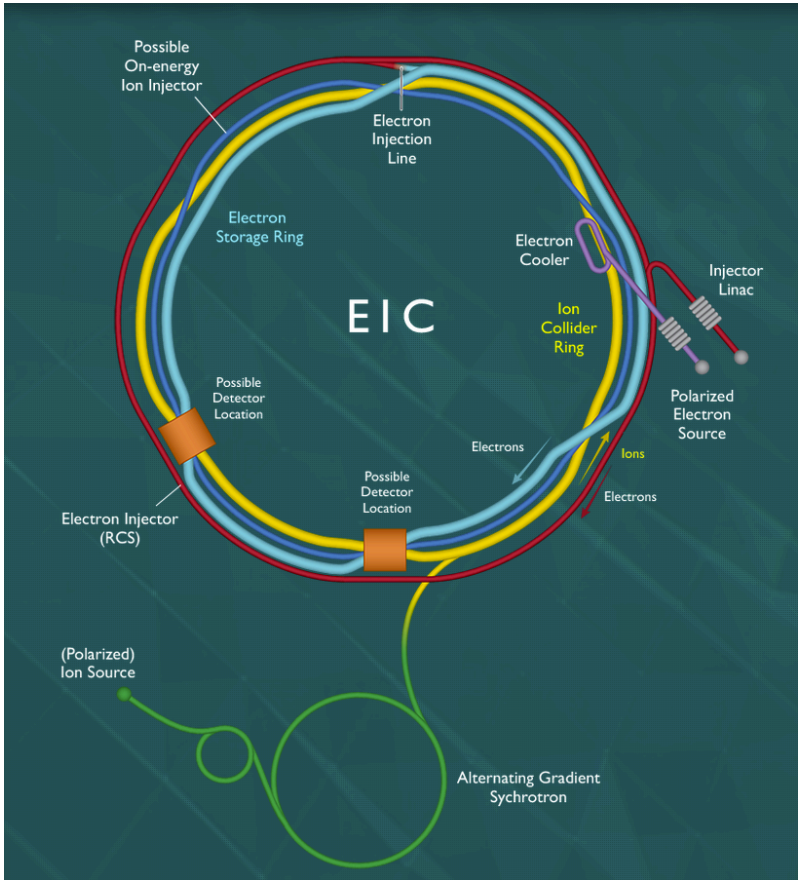
Back Up

ePHENIX

Electron Ion Collider Schedule



EIC Design

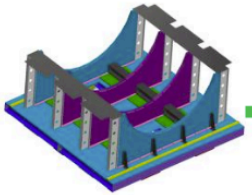


[https://www.bnl.gov/eic/]

Run schedule

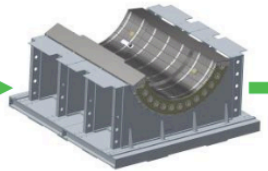
Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
Year-2	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
Year-4	p+p	200	23.5	—	149 pb^{-1}	783 pb^{-1}
Year-5	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

(1) Cradle Base, AH



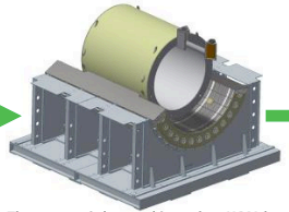
The base will be built on top of the AH rails

(2) oHCAL Sector 1-13, AH



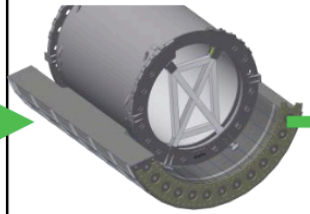
Magnet mount hardware is also attached

(3) Magnet mount, AH



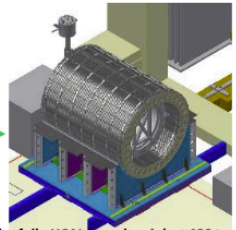
The magnet is lowered in to the oHCAL bore

(4) Inner Rings, AH



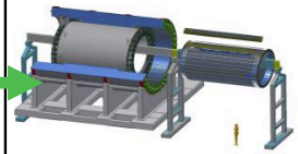
The rings also work to stabilize the magnet

(5) oHCAL Sector 14-32, AH



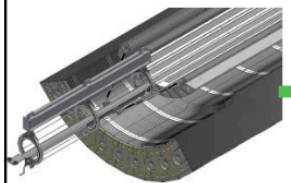
The full oHCAL barrel weighs ~480 tons

(6) Inner HCAL



The iHCAL barrel slides in from the North

(7) EMCAL

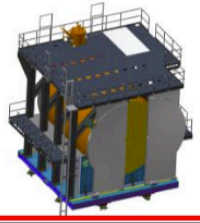


There are 64 EMCAL sectors each installed one at a time with a special tool

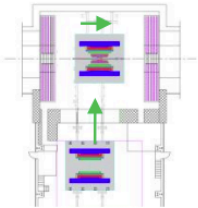
(8) Open Shield Wall

Work on sPHENIX will stop for the time needed to remove the shield wall

(9) Carriage, platforms, Pole Tips, AH

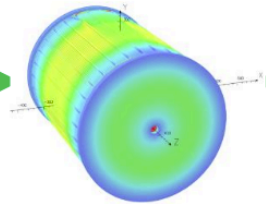


(10) Move sPHENIX to IR



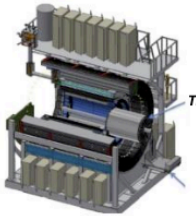
There is a 5-foot move North in the IR

(11) Connect, Map Magnet



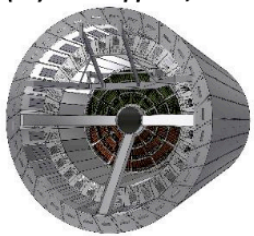
Results from an sPHENIX OPERA EM FEA

(12) TPC, IR



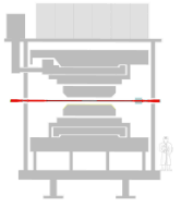
TPC slides in the EMCAL bore from North

(13) INTT Supports, IR



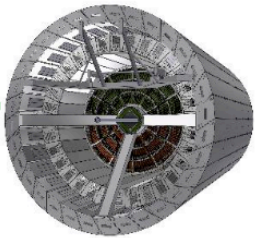
iHCAL, EMCAL, TPC and INTT Supports

(14) Beam Pipe Install. IR

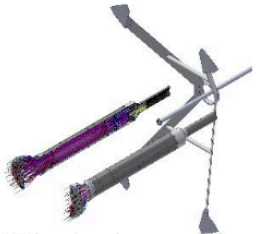


Beam pipe is supported temporarily as a few locations for MVTX installation

(15) INTT Device, IR

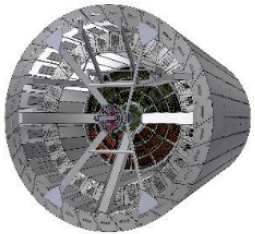


(16) MVTX, IR

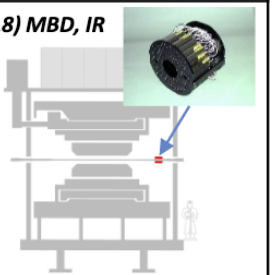


MVTX has a 2mm clearance to the beam pipe

(17) Secure Beam pipe, IR

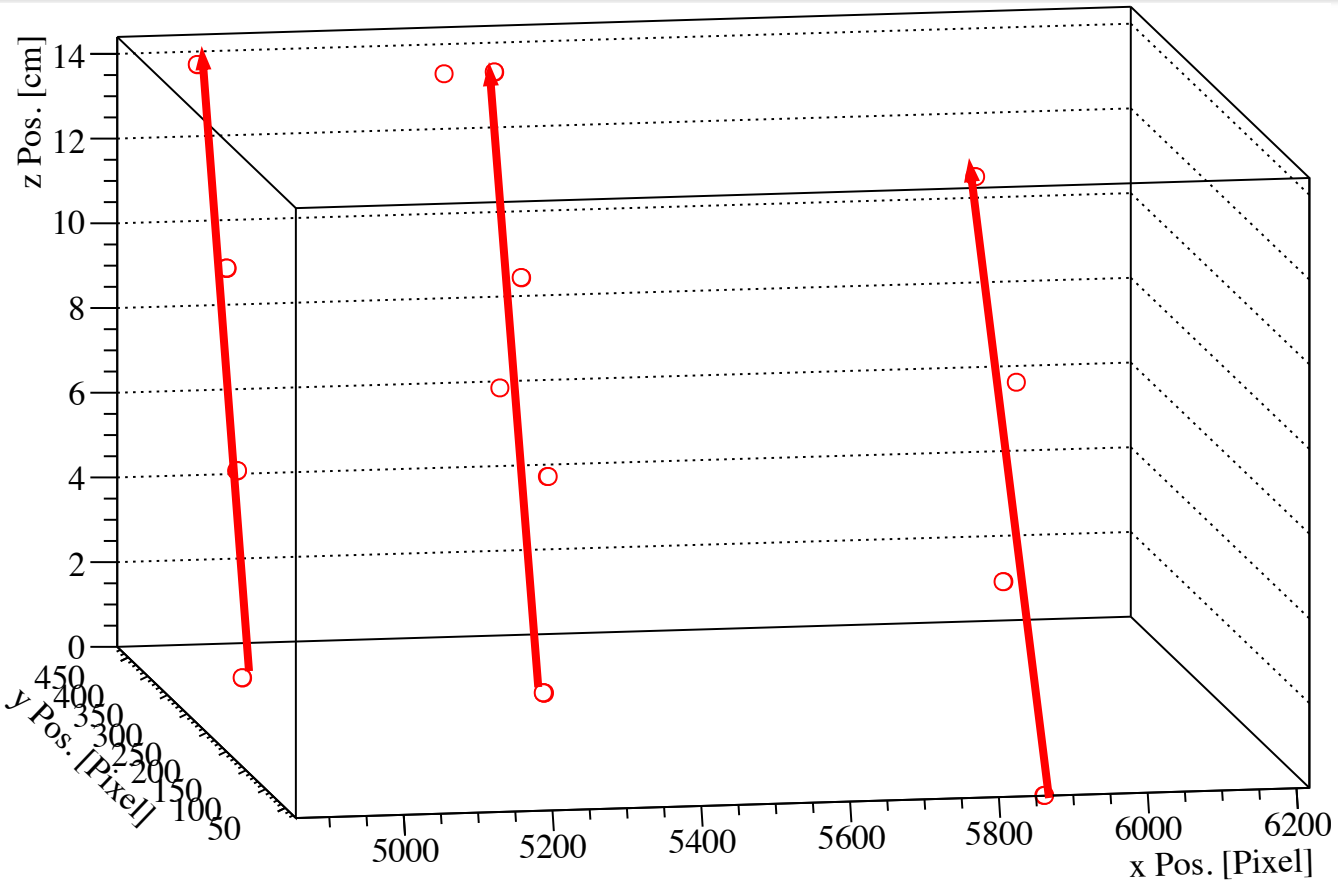


(18) MBD, IR



4th tracking detector

Tracking at sPHENIX



Reconstructed tracks from proton-lead collisions. Taken at the 2019 MVTX test beam at Fermilab. No alignment has been performed

Magnetic Map