The sPHENIX Experiment at RHIC

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28th July 2020

ICHEP

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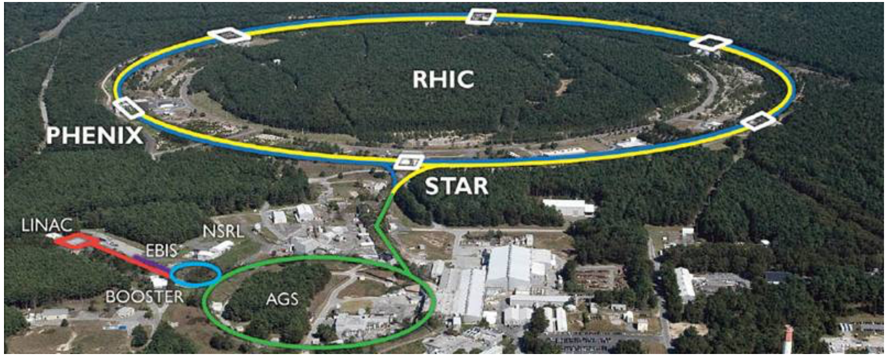
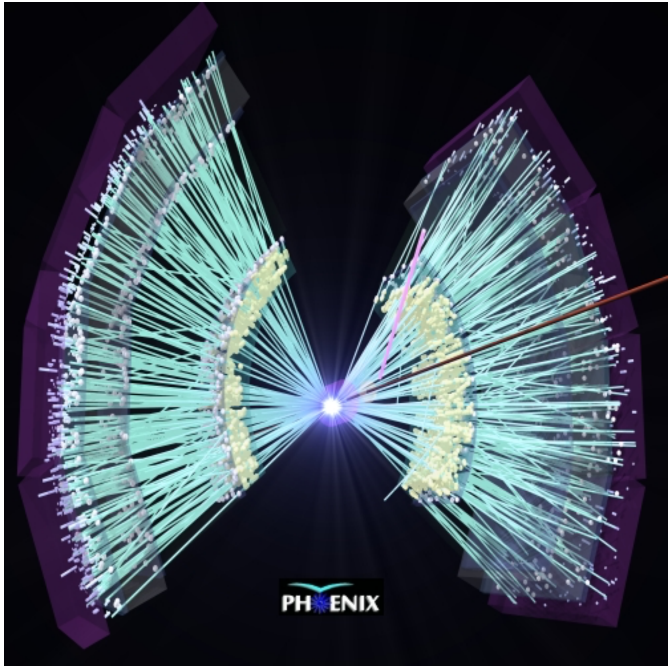
- Current status (how has Covid-19 affected us?)
- Prospects for heavy flavor physics in heavy ion collisions

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



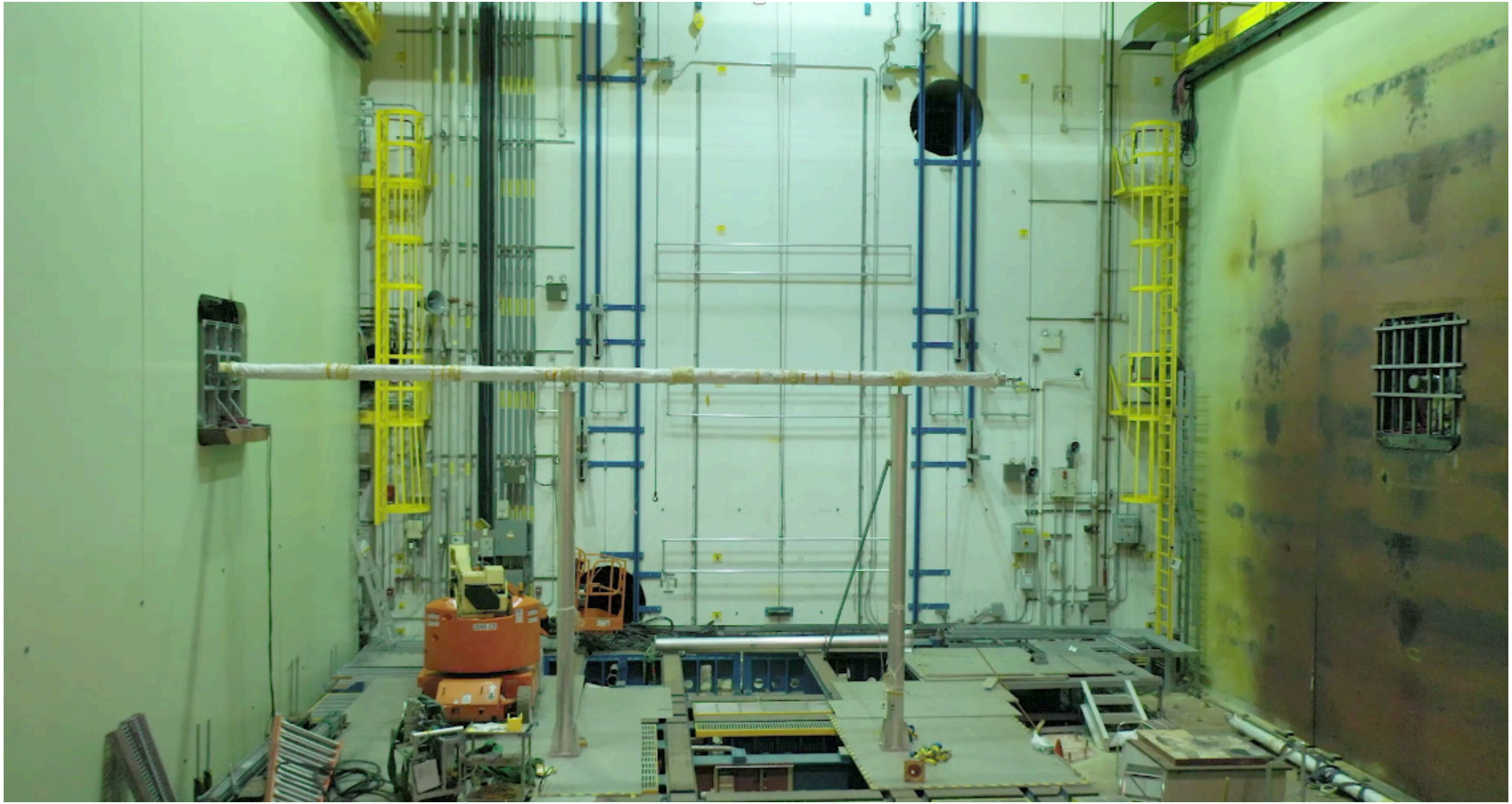


- Located in the PHENIX experimental hall, IP-8
- Last PHENIX data taking was 2016
- Data taking expected to begin in 2023

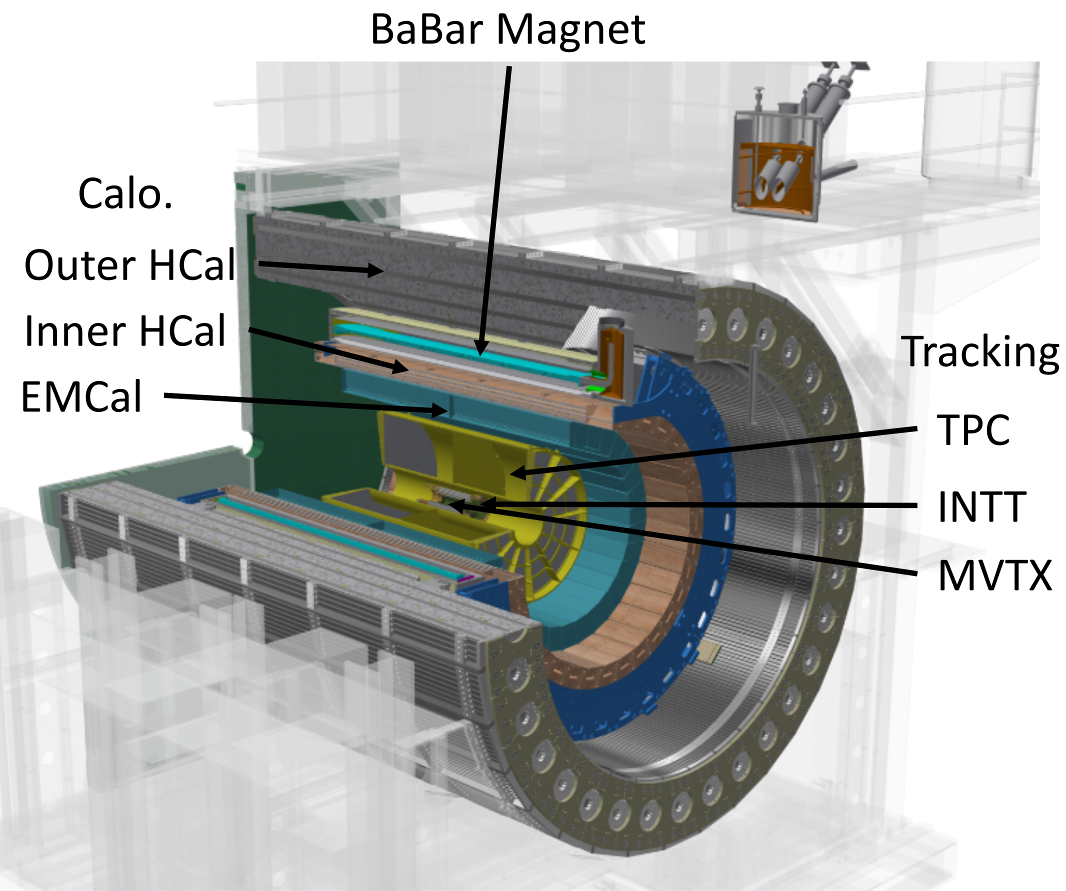
Top – The location of PHENIX at RHIC

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*	$1.43\text{x}10^{11}$

* In 3 years of running

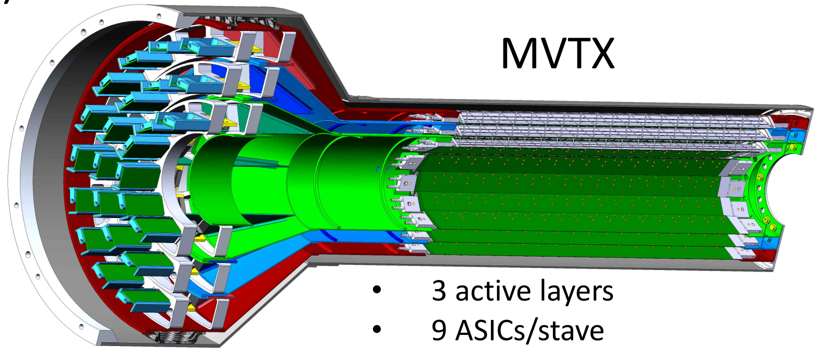
Tracking at sPHENIX

- 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

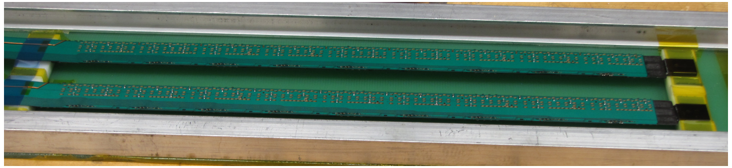
MVTX



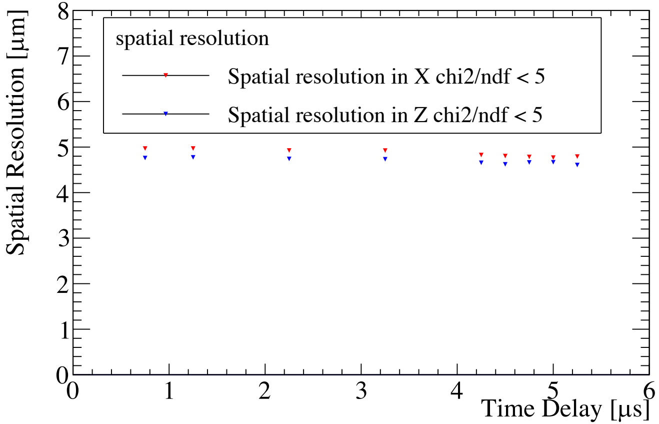
- 3 active layers
- 9 ASICs/stave
- 27 cm active length/stave

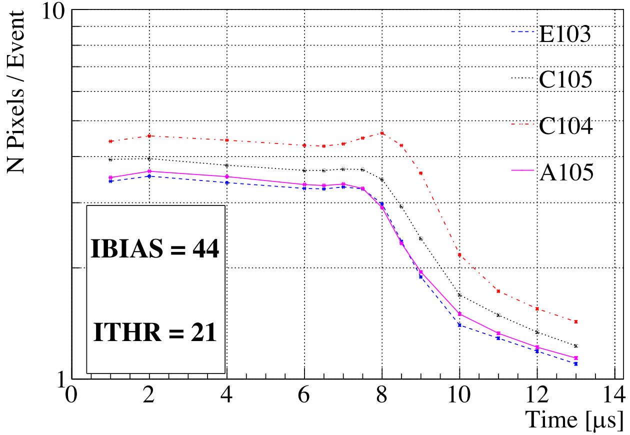
ALPIDE thickness [μm]	50
Pixel size [μm] / matrix	29 x 27 / 1024 x 512
Technology	180nm CMOS
Power Consumption [mW/cm^2]	40 (mean), 300 (peak)
Stave Material Budget	0.3% X_0
Timing resolution	A few μs (tunable)
XZ spatial resolution [μm]	< 6

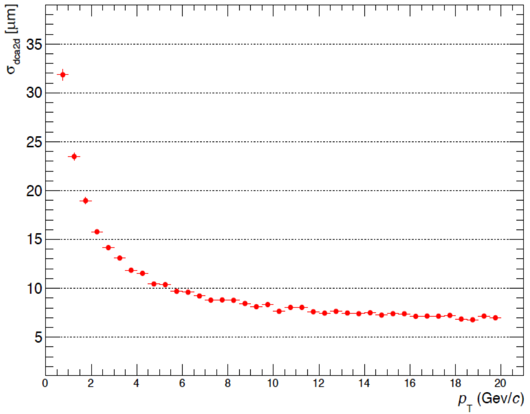
MVTX staves



Tracking at sPHENIX







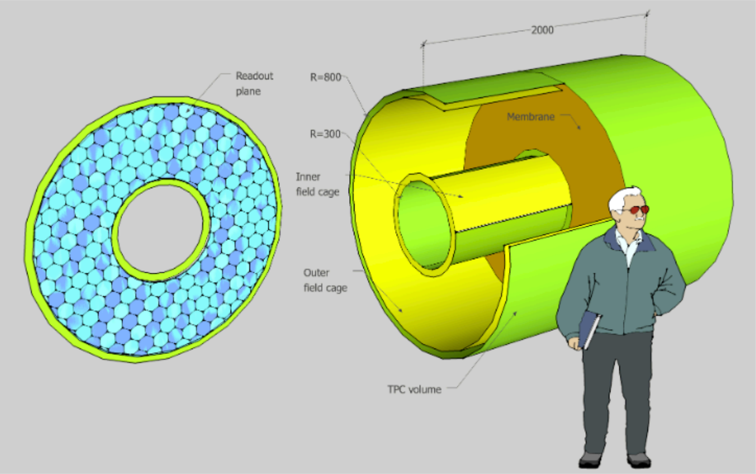
Left – Spatial resolution as a function of trigger delay

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

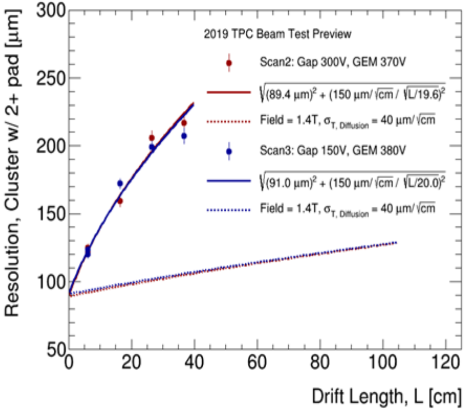
Right – IP_{XZ} resolution (simulation)

Tracking at sPHENIX

- Compact TPC, 20 < r [cm] < 78 (active volume > 30cm)
- Spatial resolution < 200 μm
- 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

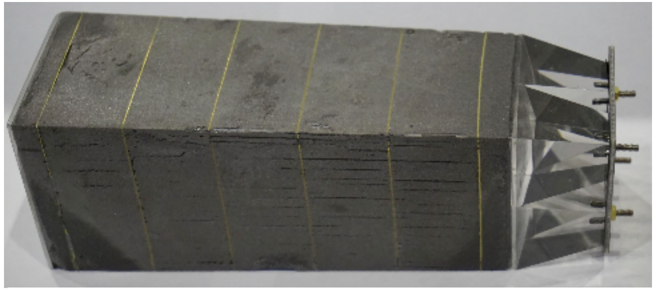


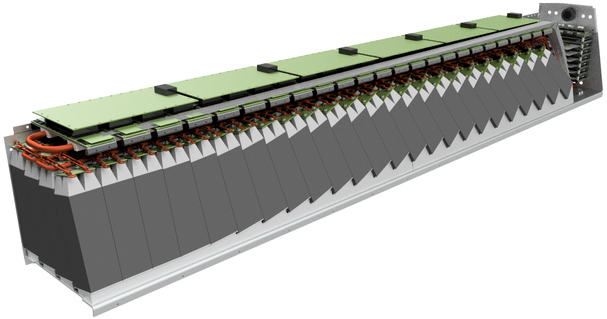
Top – Overview of TPC structure
Bottom left – Resolution of the TPC; solid line is measured, dashed line is extrapolated to sPHENIX magnetic field
Bottom right –TPC field cage

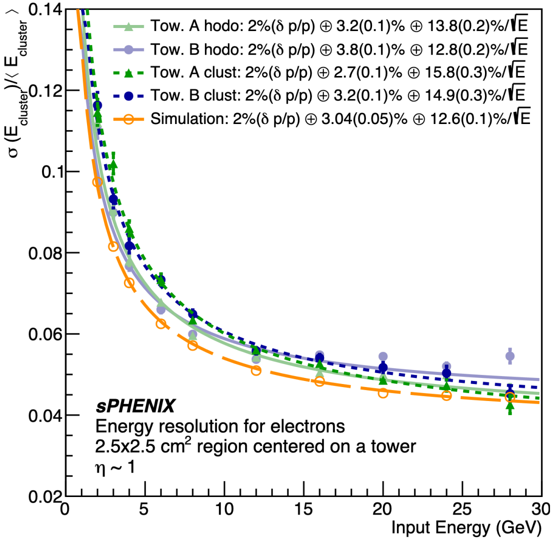


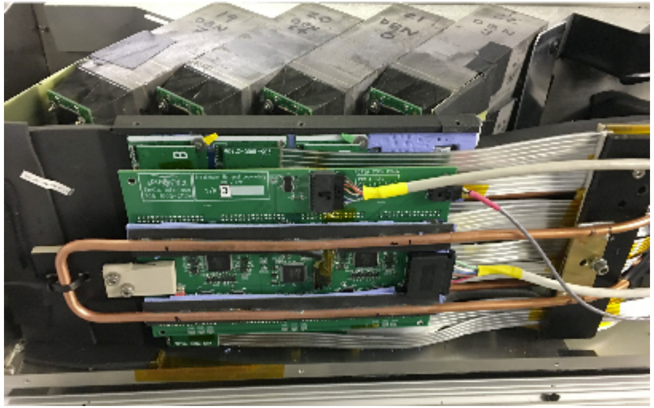
EM calorimetry at sPHENIX

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





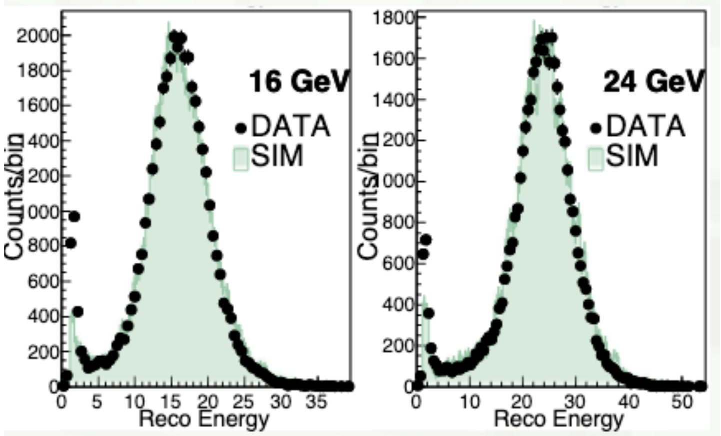


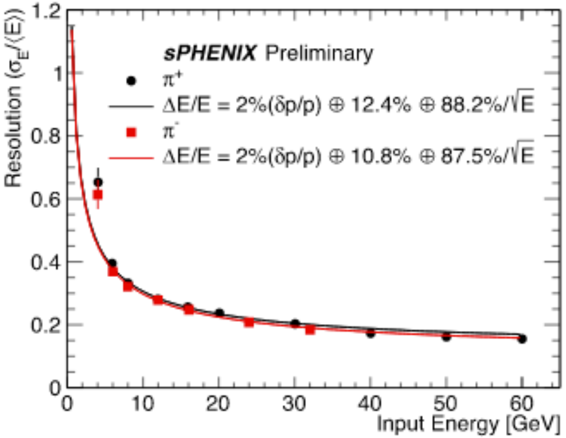


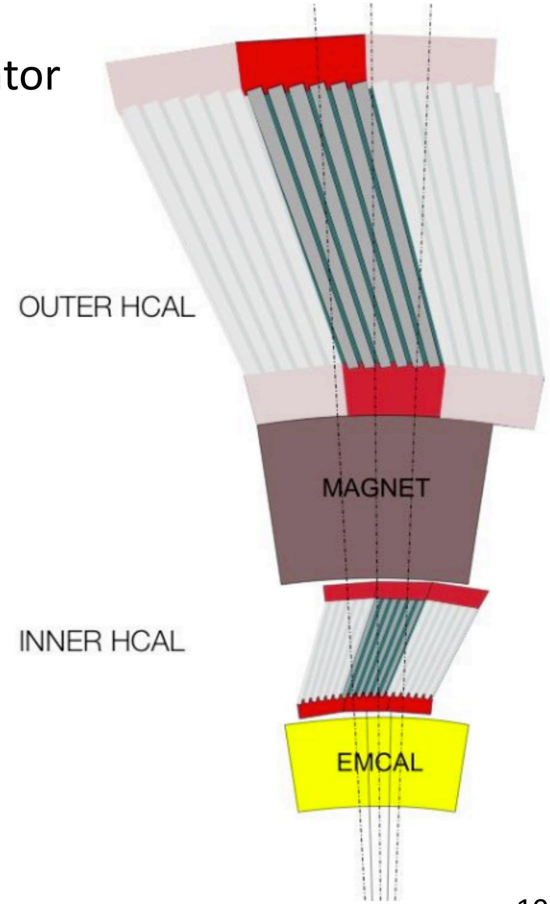
Top – A completed EMCal block. Bottom left – Design of an EMCal sector (IP is towards the left). Bottom middle – Cluster energy vs input energy. Bottom right – EMCal prototype

Hadron calorimetry at sPHENIX

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





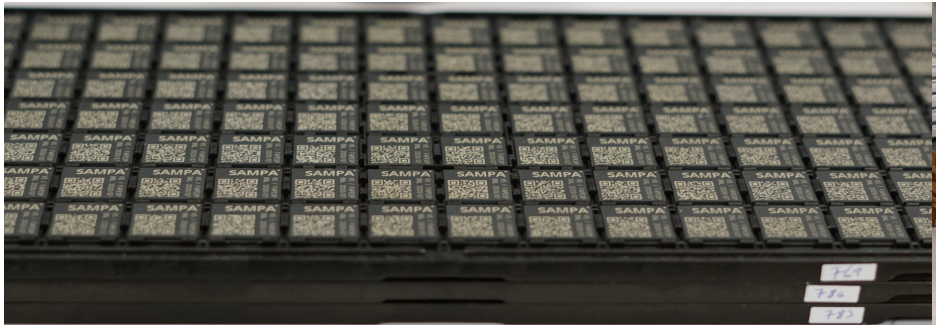


Left – Reconstructed energy of pions. Middle – $\pi^{\pm}$ resolution

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
- Staff, post-docs and students are returning to labs or adapting to work-from-home

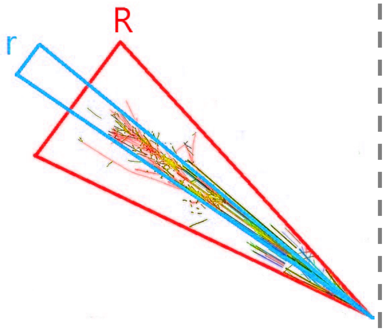


Left – Delivered SAMPA chips. Right - OHCal tiles

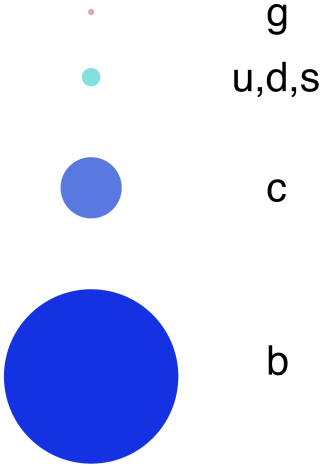
Core Physics Program

<u>Jet correlation & substructure</u>

Vary momentum/ angular size of probe



<u>Parton energy loss Vary mass/ momentum of probe</u>



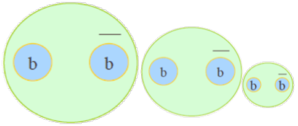
<u>Upsilon spectroscopy</u>

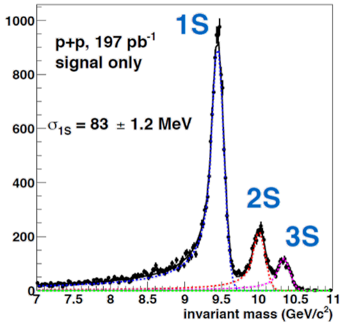
Vary size of the probe

ϒ(3s)- 0.78fm

ϒ(2s) – 0.56fm

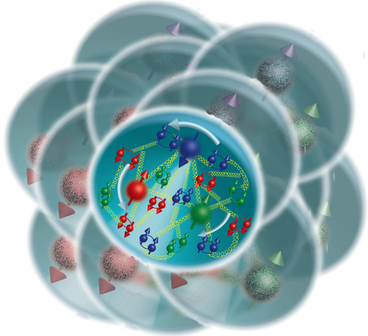
ϒ(1s) - 0.28fm





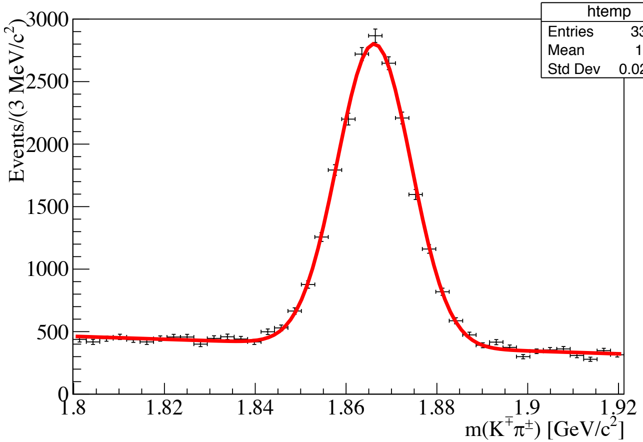
<u>Cold QCD</u>

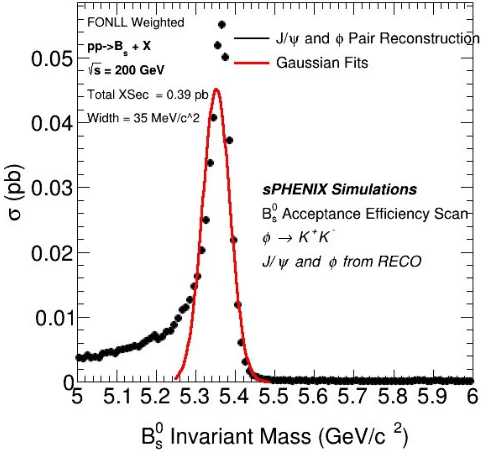
Vary temperature of QCD matter

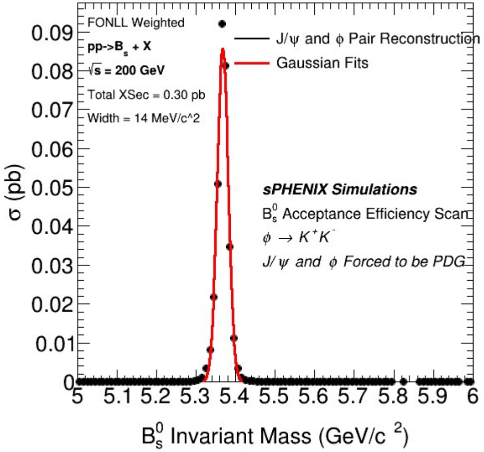


Physics potentials

- 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

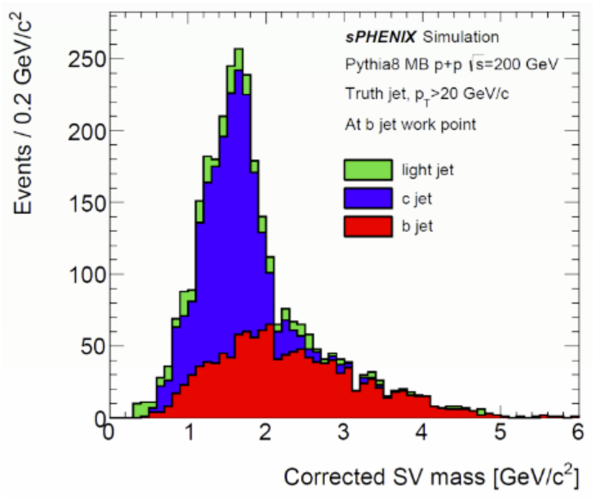


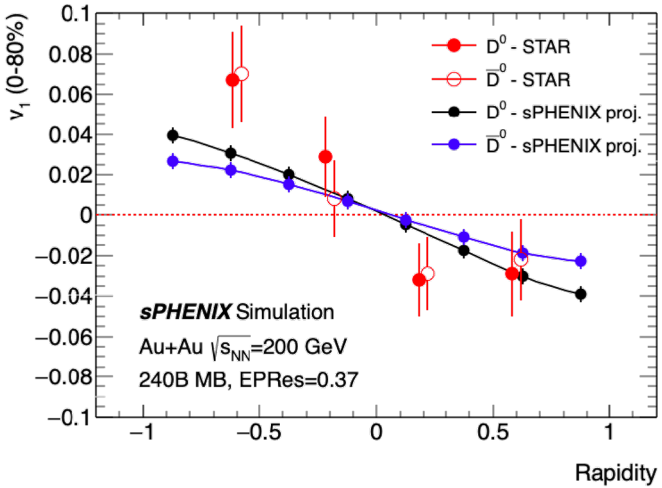


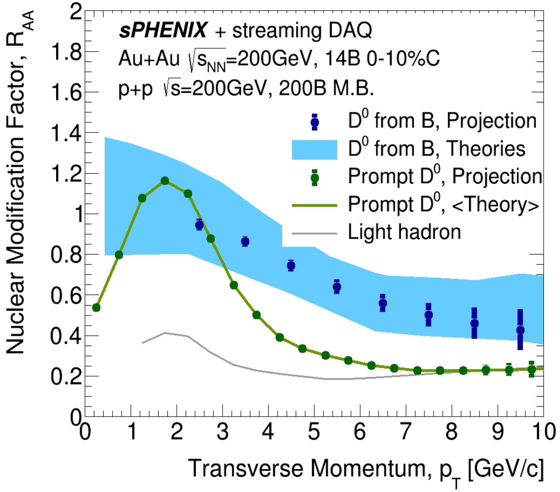


Left – $D^0 \rightarrow K^{\mp}\pi^{\pm}$ reconstruction
Middle and right – $B_s^0 \rightarrow J/\psi(\rightarrow e^+e^-)\phi(\rightarrow K^+K^-)$ reconstruction
(middle – without mass constraints, right – with mass constraints)

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

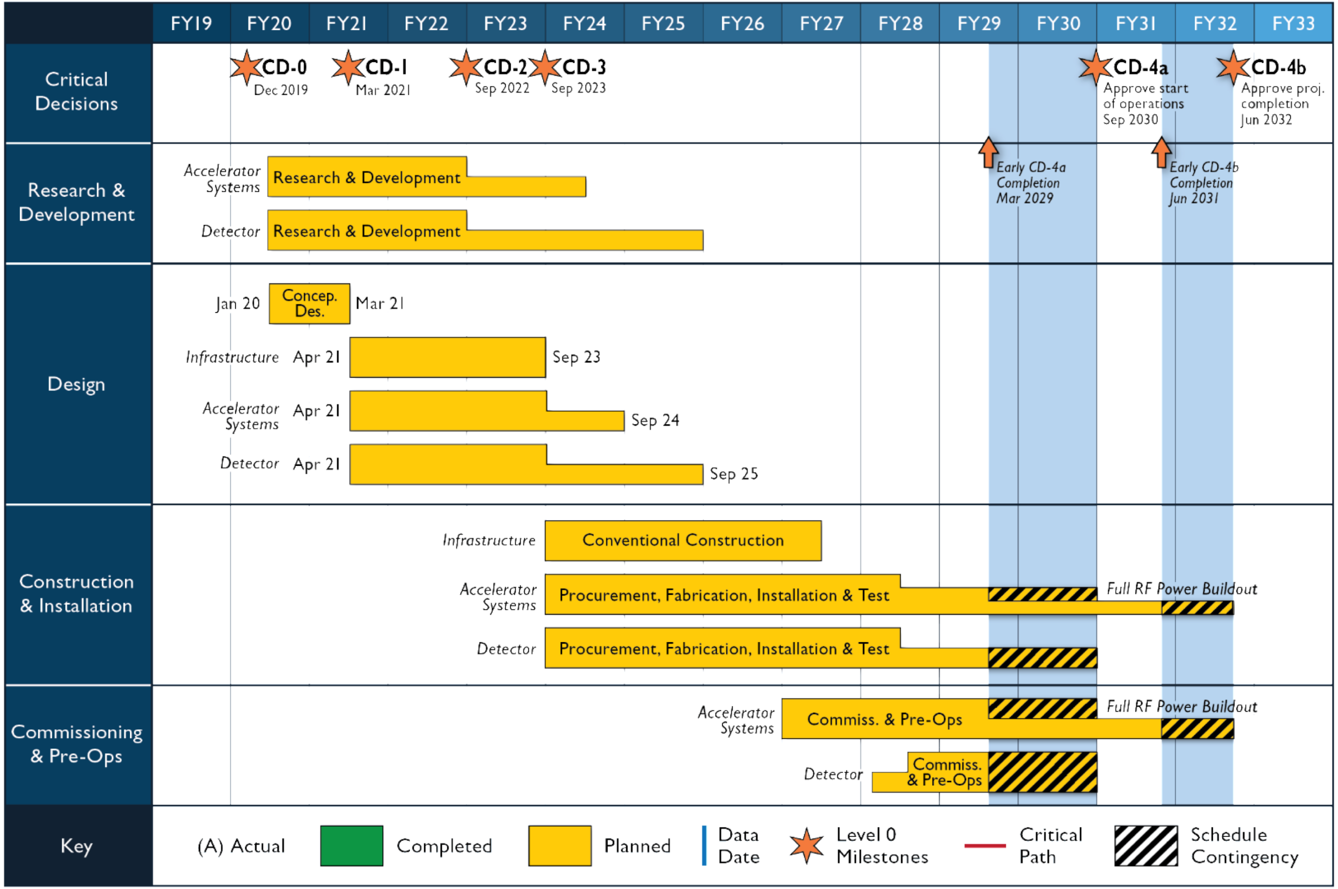
Conclusions

- 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

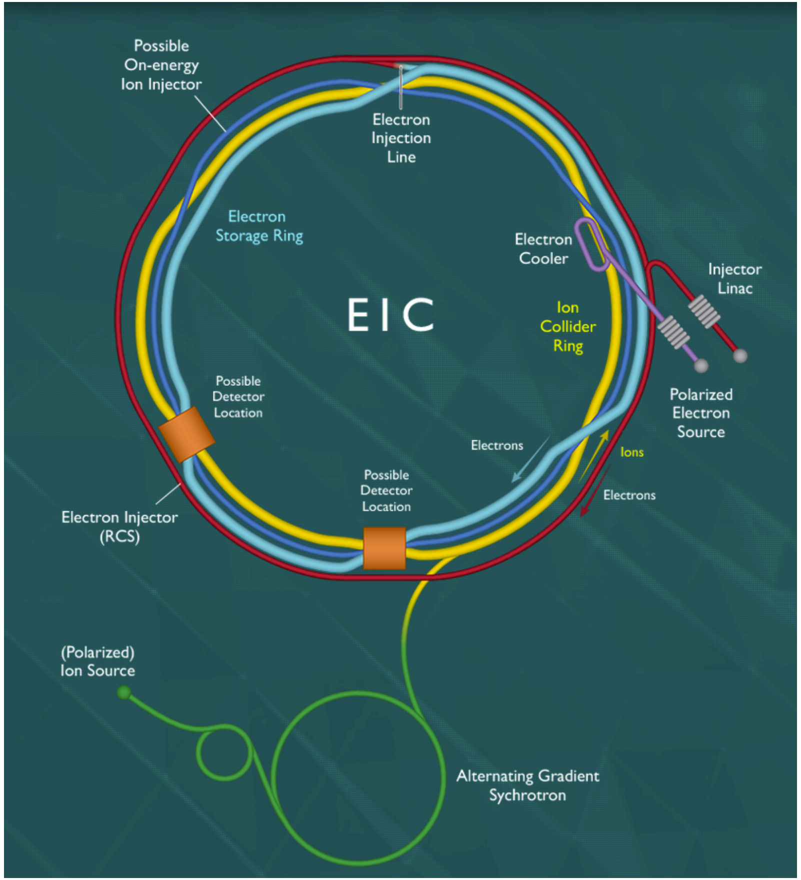
Thank you

Back Up

Electron Ion Collider Schedule



EIC Design

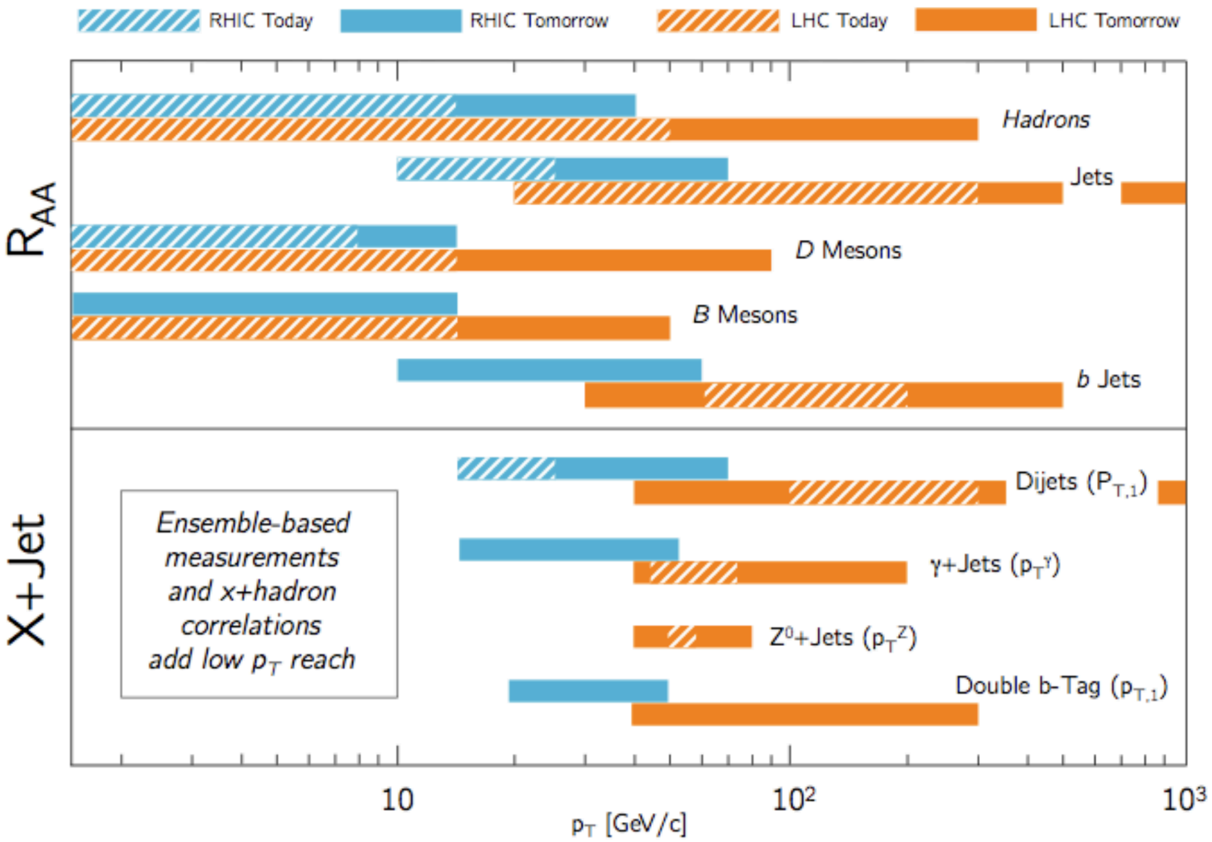


[https://www.bnl.gov/eic/]

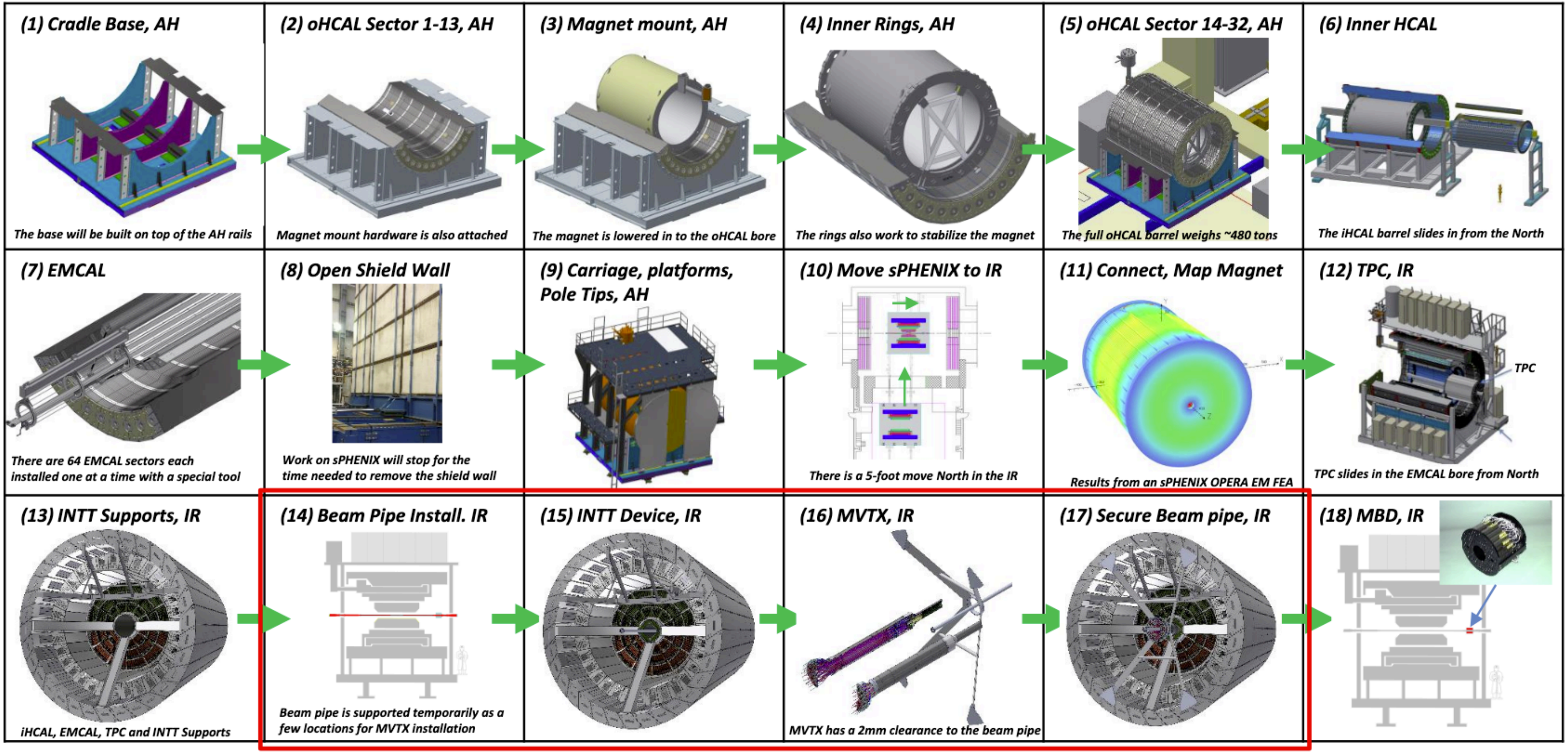
Run schedule

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}

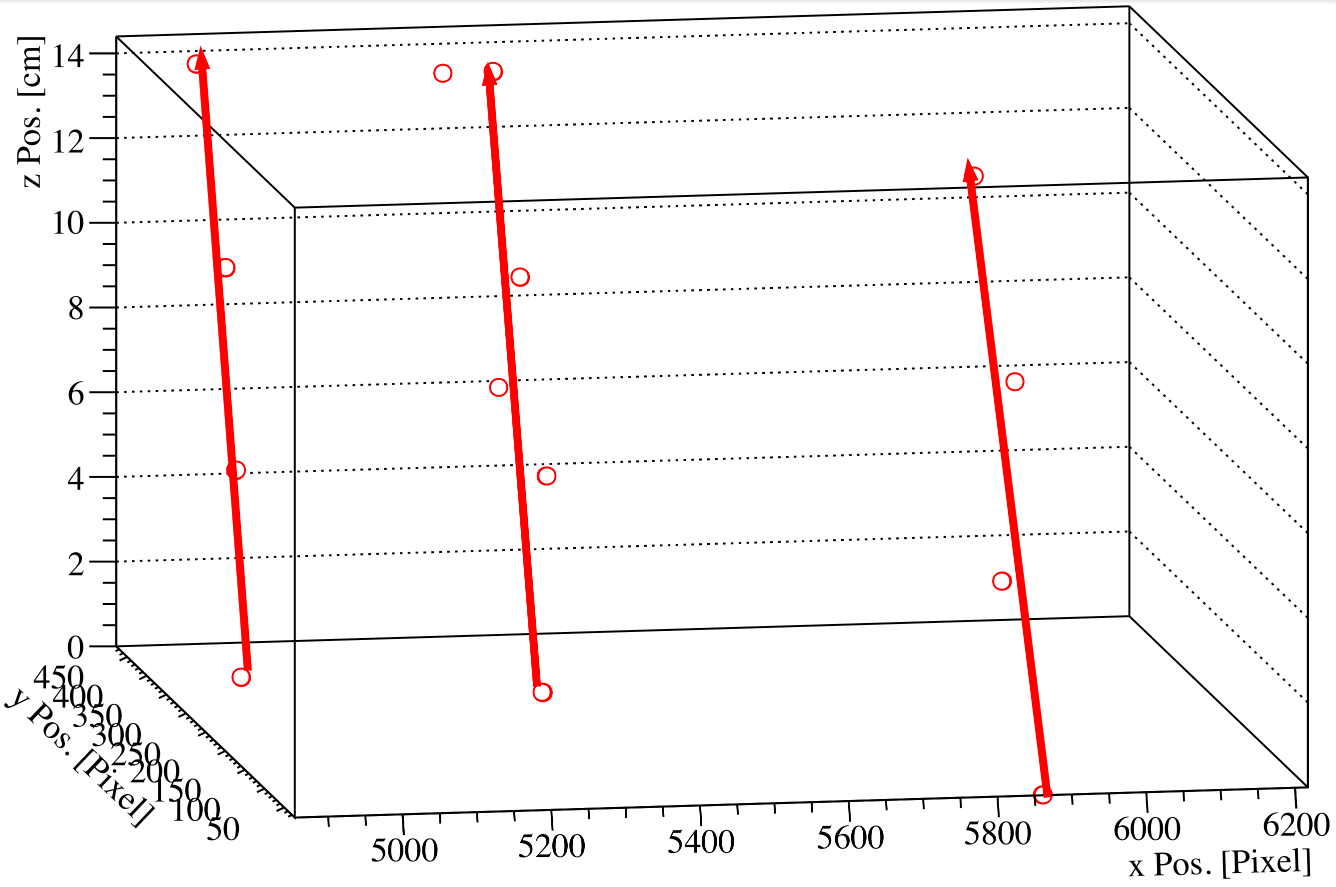
LHC vs RHIC


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

Installation



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