OAK RIDGE National Laboratory

Requirements, status, and plans for track reconstruction at the sPHENIX experiment

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ORNL
April 21, 2020

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U.S. DEPARTMENT OF ENERGY

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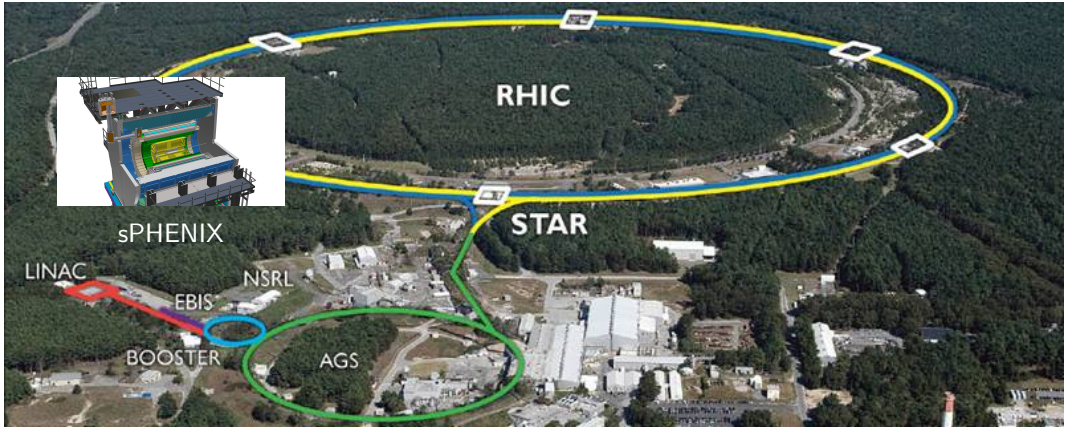
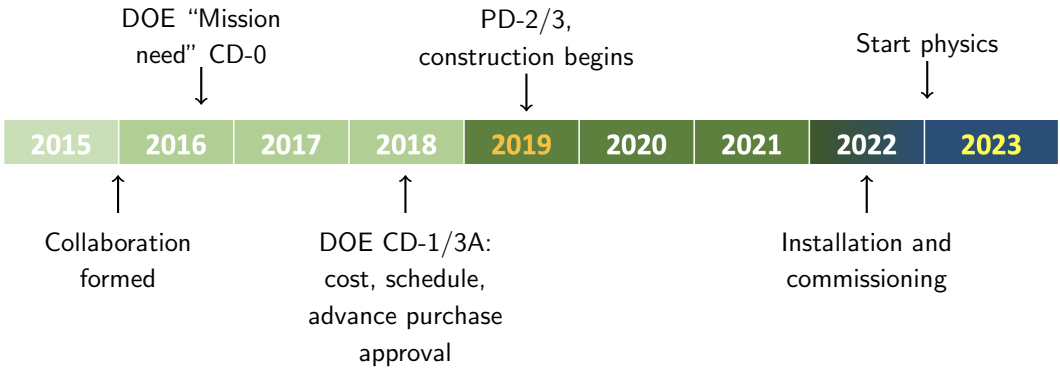
Next Generation of QCD at RHIC



The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory

Collaboration Timeline

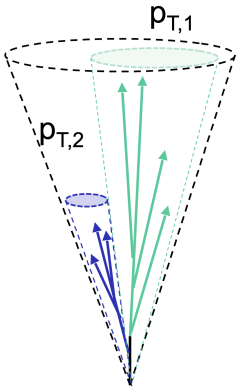


sPHENIX Physics Program

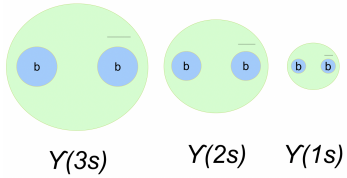
- 2015 Nuclear Physics Long Range Plan:
- "Probe the inner workings of the Quark-Gluon-Plasma by resolving its properties at shorter and shorter length scales. The complementarity of [RHIC and the LHC] is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX."

sPHENIX Physics Program

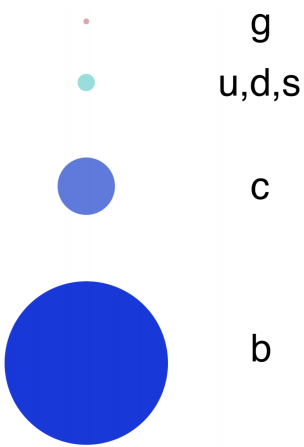
Jet Substructure



Upsilon Spectroscopy



QCD Flavor Physics



sPHENIX Physics Program

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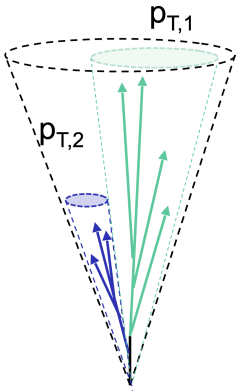

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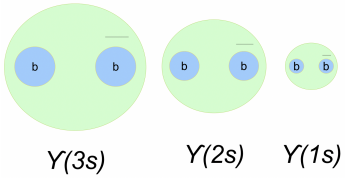
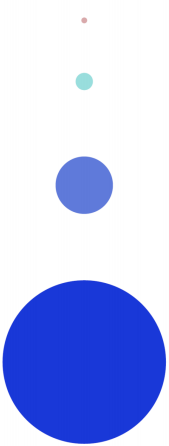


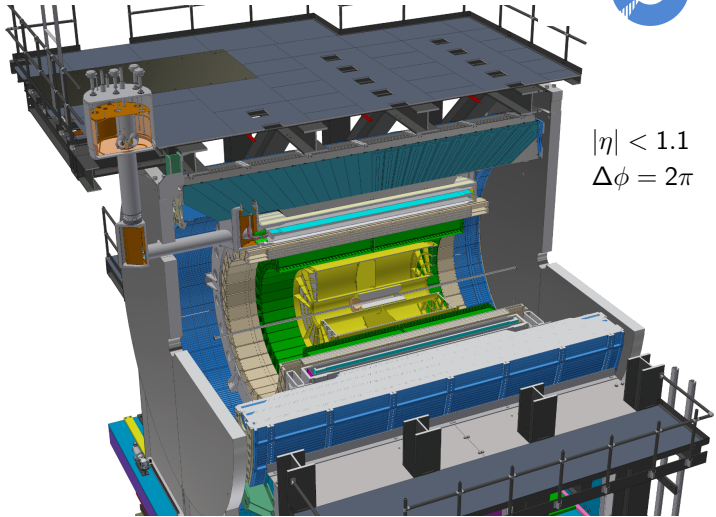
TRACKING!

QCD Flavor Physics



sPHENIX Detector

- MAPS Vertex Detector (MVTX)
- Intermediate Tracker (INTT)
- TPC
- EMCal
- Inner HCal
- Outer HCal



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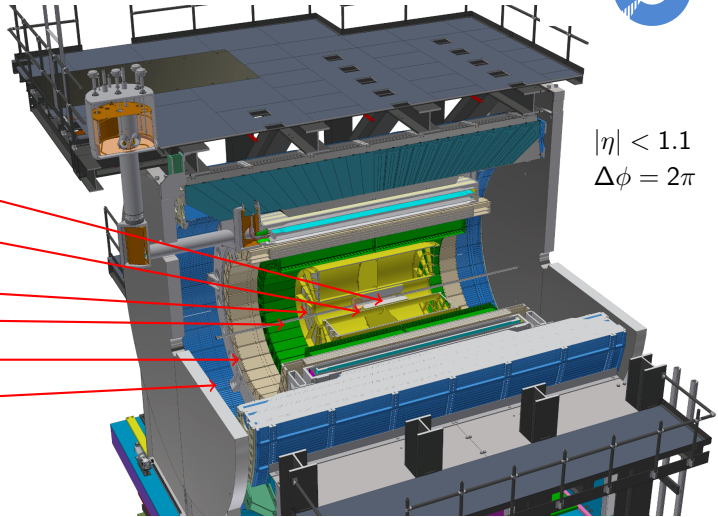
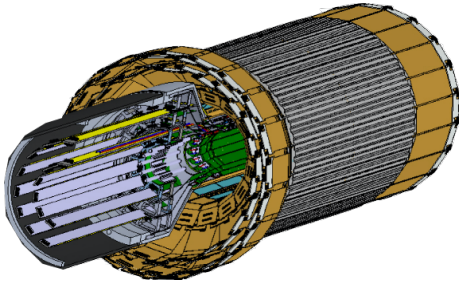


$|\eta| < 1.1$
$\Delta\phi = 2\pi$

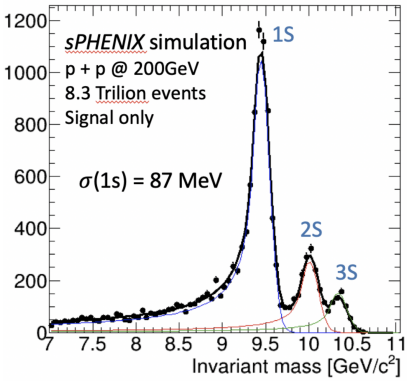
Tracking Detectors



- MVTX
  - Monolothic Active Pixel Sensor (MAPS)
  - 3 layers, based on ALICE ITS
- INTT
  - Two layers of silicon strips

- Compact, continuous readout TPC
- ∼160k channels

Physics Requirements on Tracking



- Identify e^+e^- pairs with Υ resolution less than 100 MeV
  - $\sim$1.2% tracking resolution for 4-8 GeV tracks
- Resolve high momentum tracks for jet substructure measurements
  - Translates to $\Delta p/p \simeq 0.2\% \cdot p$

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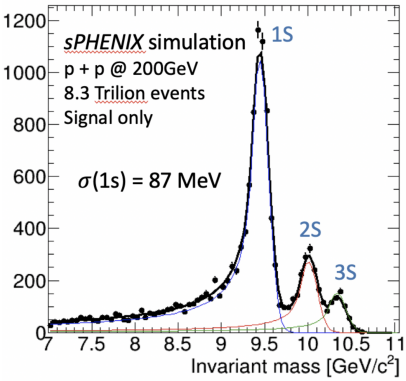

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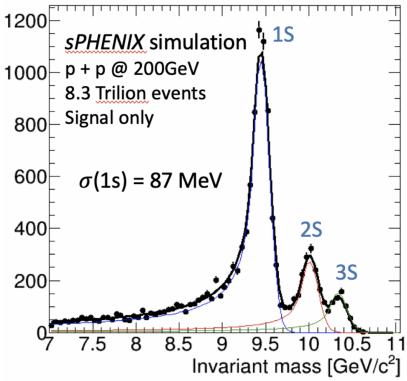

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- High reconstruction efficiency due to smaller Υ and jet cross section signals at RHIC $\sqrt{s} = 200$ GeV
- Robustness against large background environments - potential for out of time pile up sampled in the TPC due to long integration time

Constraints

- RHIC will deliver Au+Au collisions up to ∼200 kHz
  - On average, 3-8 pileup events per bunch crossing
- sPHENIX will record Au+Au collisions at 15 kHz
  - Will result in ∼100 billion events in a 22 week run

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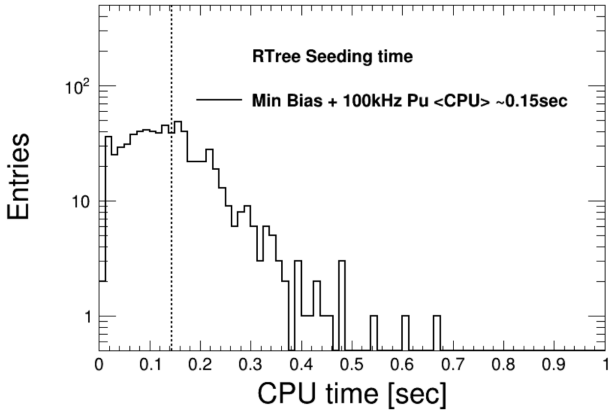
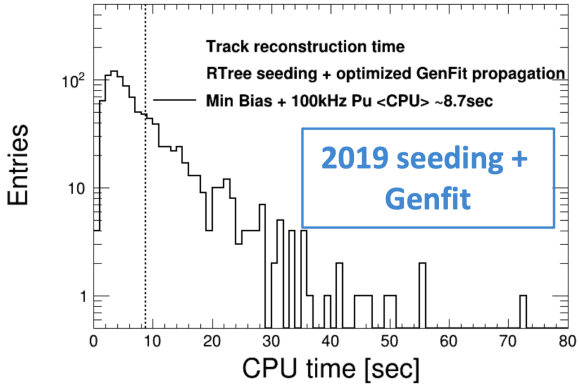
- Over 3 year running period, will collect ∼250 Petabytes of data!
- Data processing planned for fixed latency, finite size computing center at BNL
- Require high speed, efficient, and precise tracking in an environment where $\mathcal{O}(100{,}000)$ hits are expected
- Need to reduce tracking time to 5 seconds per event in these conditions

Current Status: Track Seeding

- Previously using Hough seeding
- Actively exploring Cellular Automaton seeding using RTrees
  - Geometric indexing gives seeds based on nearest neighbors
  - Simplified track estimate to provide to track propagator
- Seeding time reduced by orders of magnitude (!) in MinBias + pile up
- Cellular Automaton shows indications of further improvements



Current Status: Track Propagation and Fitting



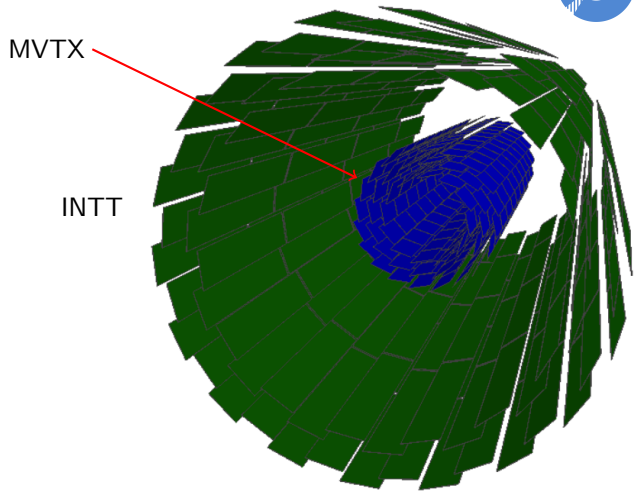
- Track propagation performed using GenFit
- Currently average $\sim$9 seconds for track reconstruction in realistic environment
  - Goal is $<$ 5 seconds per event
- Actively exploring ACTS for track propagation and fitting

A Common Tracking Software (ACTS)

- Acts is a software project being developed by ATLAS/Belle2/LHCb (and other) collaborators
- Intended to be an experiment independent set of track reconstruction tools
- Performant and flexible algorithms for track reconstruction
- See also Xiaocong Ai's and Bastian Schlag's talks at CTD2020

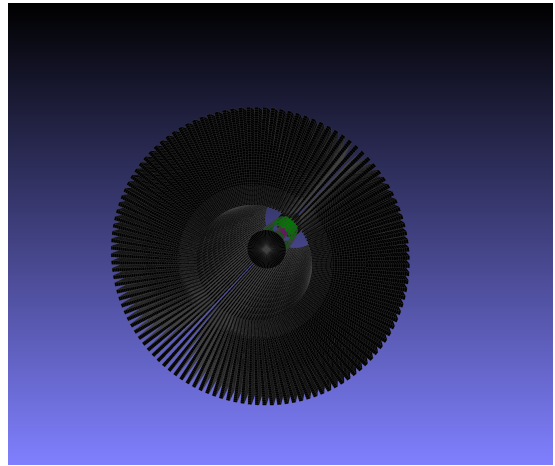
sPHENIX and ACTS

- ACTS contains a ROOT TGeo plugin
- Like most experiments, sPHENIX has a full Geant4 description
- Provide ACTS with (already created) `TGeoManager` object to build tracking detectors
- ACTS creates Surfaces that correspond to TGeo objects in the G4 description



TPC in ACTS

- Currently ACTS does not support continuous TPC geometries
- At the moment, we build Acts::PlaneSurfaces ourselves that approximate the TPC readout geometry
- In discussion with developers on a flexible fitter which creates Acts::Surfaces on-the-fly based on where clusters are identified in TPC



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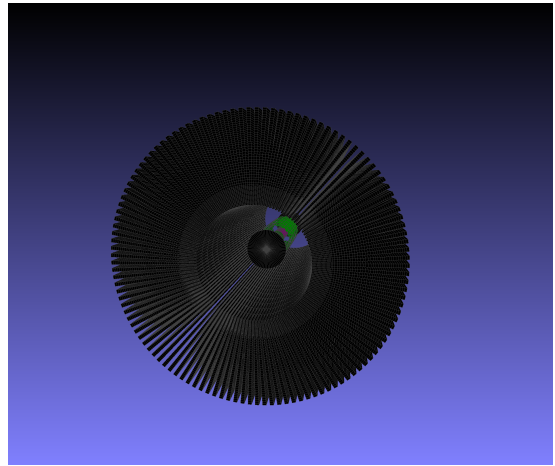
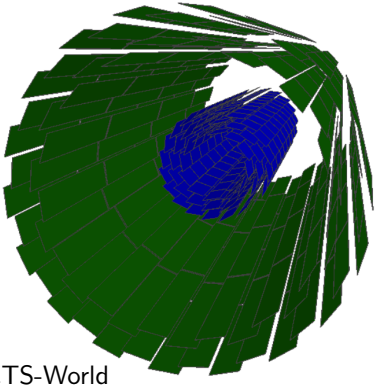
- In discussion with developers on a flexible fitter which creates Acts::Surfaces on-the-fly based on where clusters are identified in TPC
- Additional detector geometries in ACTS could be useful for other experiments, e.g. Belle2, future Electron-Ion Collider detector...

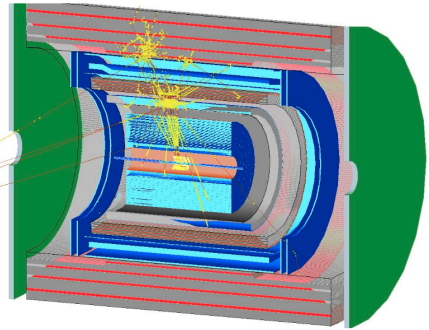


TGeo and ACTS Interactions



ACTS-World

`std::map<TGeoNode, Acts::Surface>`

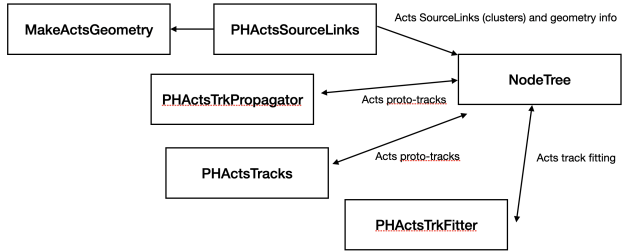


Geant4-World

- Software design is intended to keep sPHENIX specific code within sPHENIX
  - Allows simple updates of ACTS, simplified debugging
- Construct maps that correlate TGeo objects to Acts::Surfaces

Software Design

- sPHENIX software is open source at github.com
- Designed for flexibility - can interchange the various seeding, propagating, fitting algorithms available



Conclusions

- sPHENIX is a dedicated jet and heavy flavor experiment being constructed at the Relativistic Heavy Ion Collider
- Computational challenges: Reconstruct ∼100 billion heavy ion collisions on a fixed computational center
- Track reconstruction dominates current event reconstruction time - aim to get below 5 seconds per event (down from 9 seconds)
- Exploring ACTS as a track reconstruction toolkit in sPHENIX
- Expect to see results in the next few months!

Back up

Kalman Propagating/Fitting

KalmanCombinatorialFilter

- Takes:
  - Seeded track from Hough/RSeed/CA seeding process
  - All clusters in event, transformed to Acts::SourceLinks
- Track propagating results returned to sPHENIX, for use in track fitting

KalmanFilter Track Fitter

- Takes:
  - Proto-track: Track seed and list of associated clusters (Acts::SourceLinks)
- Returns fitted track to sPHENIX, for further analysis