



# Heavy Ion Physics with ALICE at LBNL

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LBNL

# What is ALICE?



## A Large Ion Collider Experiment

- One of 4 large experiments at the LHC at CERN
- Specially designed to study heavy-ion collisions



**41 countries**  
**176 institutes**  
**1800 members**

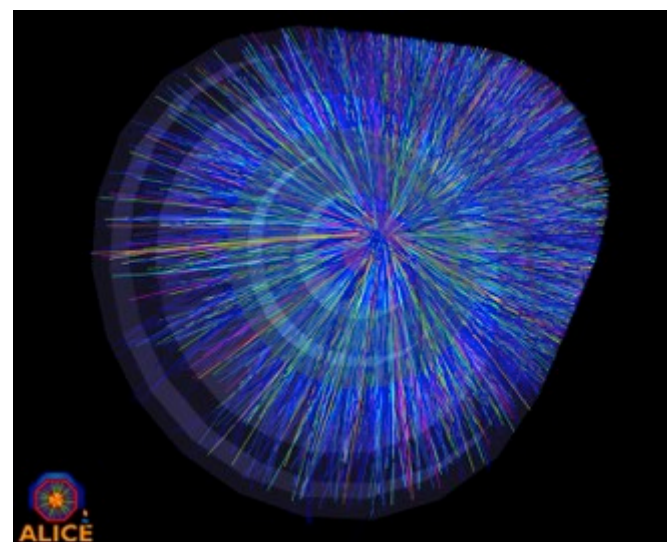
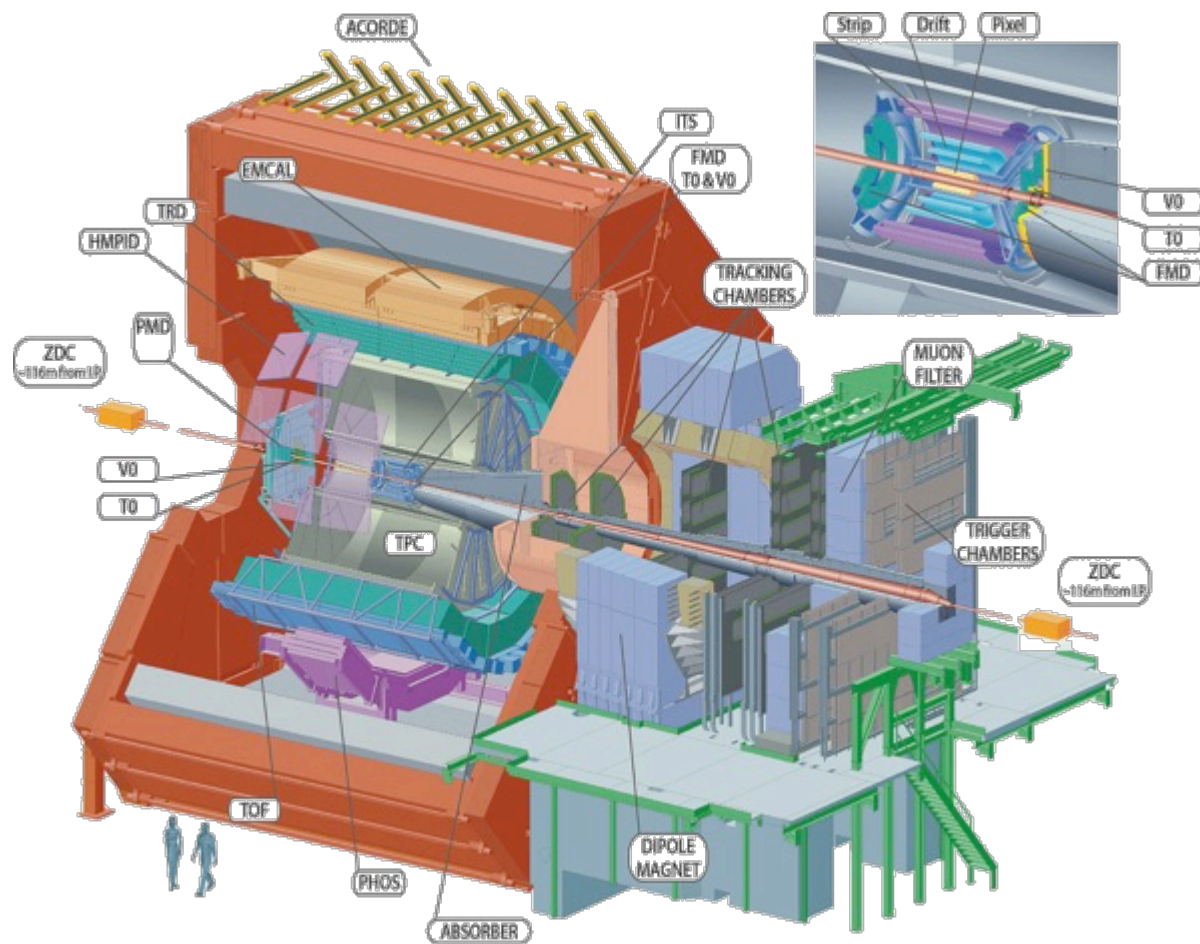
A Large Ion Collider Experiment

**ALICE COLLABORATION**  
AS JANUARY 2018



- **Staff/Professors**: Leo Greiner, Barbara Jacak, Peter Jacobs, Spencer Klein, Yue Shi Lai, Mateusz Plokson, Jeff Porter
  - **PostDocs**: Nicole Apadula, Miguel Arratia, Alberto Collu, James Mulligan
  - **Graduate Students**: Fernando Torales Acosta, Dhruv Dixit, Alwina Liu
  - **Undergraduate Students**: Winston DeGraw, Erica Zhang
- Opportunities for analysis and hardware projects
  - Shift taking at CERN
    - Meet collaborators & hands on learning at the experiment

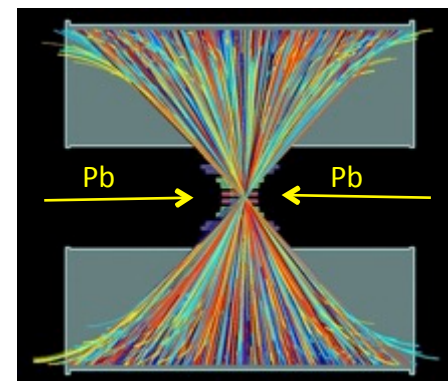
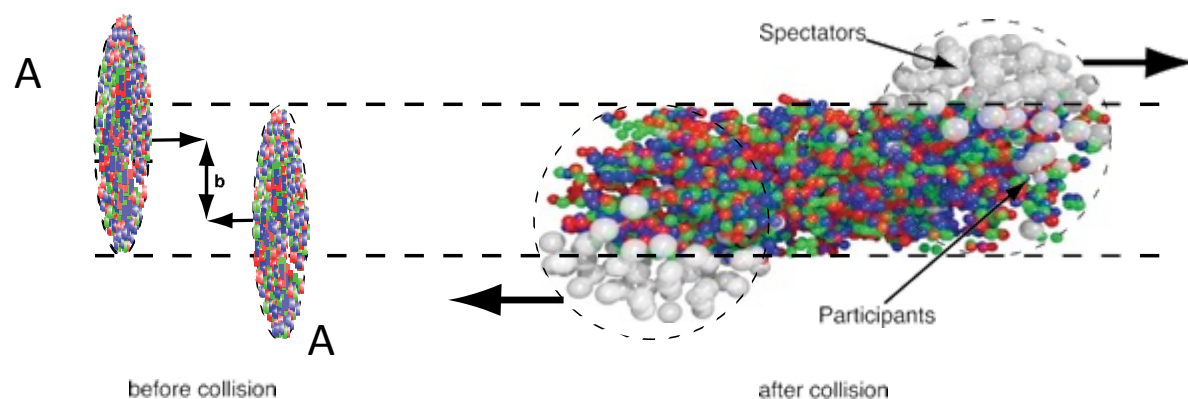
# The ALICE Detector





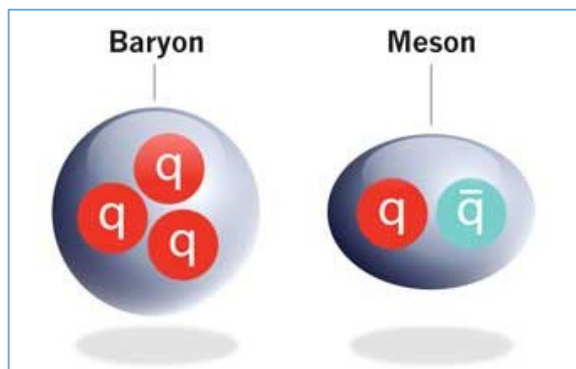
# ALICE: A study of the QGP

ALICE is designed to study the physics of strongly interacting matter at extreme conditions of energy density and temperature, and in particular the properties of the Quark Gluon Plasma (QGP), using nucleus-nucleus (A-A) collisions



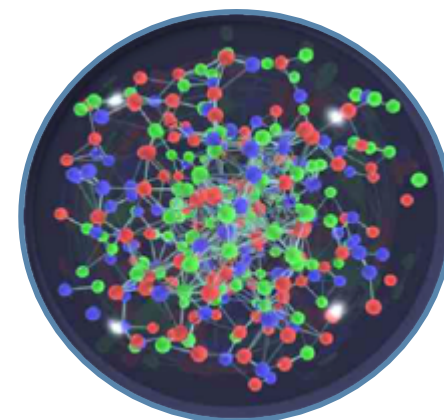
LHC Pb-Pb collision (ALICE, Sep 2011)

QCD: quarks and gluons are confined inside hadrons

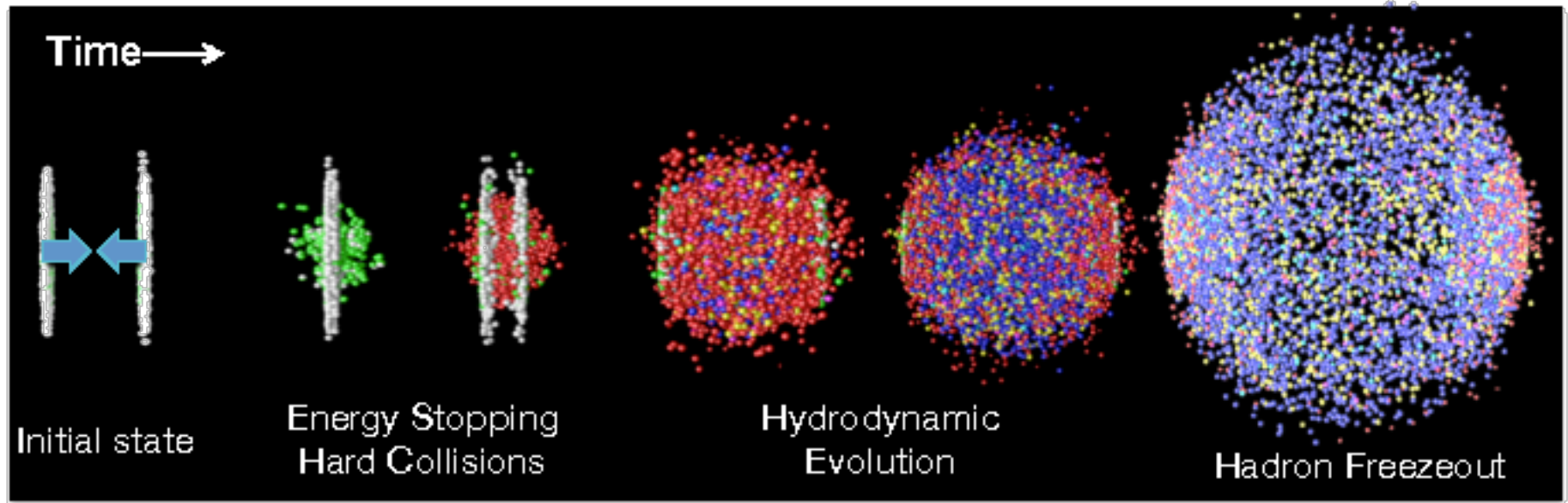


At high energy density and temperatures matter undergoes a phase transition: QGP

State of matter  $\sim 10 \mu\text{s}$  after big bang



# A Heavy Ion Collision



Time

< fm/c

O(1) fm/c

O(10) fm/c

- This all happens within  $\sim 10^{-22}$  seconds!
- Too fast to probe directly  $\rightarrow$  must look at the particles that stream to the detectors

# Studying the QGP

- QGP confirmed at RHIC & the LHC
- What are its properties?
  - **It is a liquid!**
  - **It is HOT!**
  - **It is dense/opaque!**
- We don't know everything, so we turn some knobs. We can vary:
  - The system size → change the ion (Pb, Au, Cu, Xe, etc.)
  - The number of particles produced → look as a function of how “head on” the collision is
  - The energy → RHIC vs LHC
  - Kinematic region → look forward, backward, and in the transverse plane
  - Go to small systems → p+A
  - And many more!



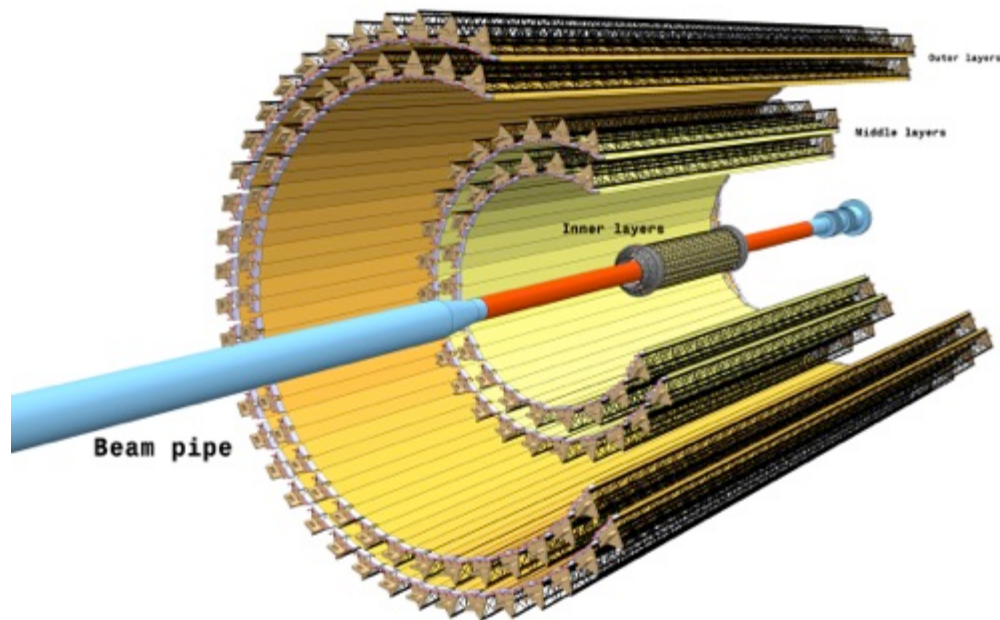
# The ITS Upgrade

7 layer barrel geometry,  
fully equipped (~24000 chips) with dedicated **MAPS**:

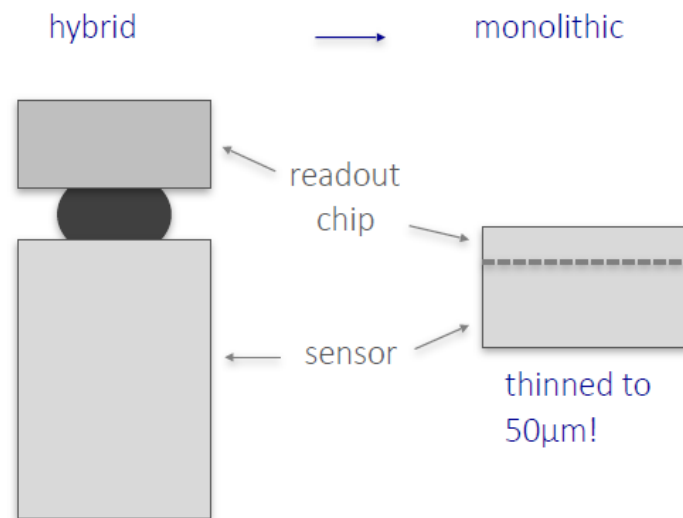
**ALice Pixel DEtector (ALPIDE)**

r-coverage: 23 – 400 mm

$\eta$  coverage:  $|\eta| \leq 1.3$



## Monolithic Active Pixel Sensors



Material /layer : 0.3%  $X_0$  (IB), 1%  $X_0$  (OB)

12.5 G-pixel camera (~10 m<sup>2</sup> active Si)  
Binary read-out

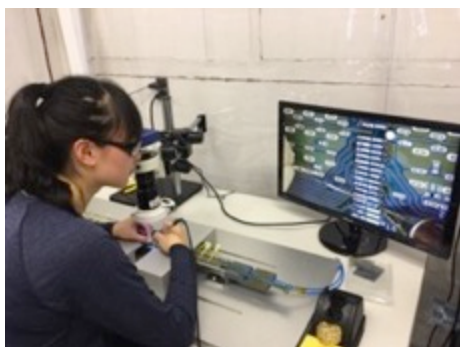
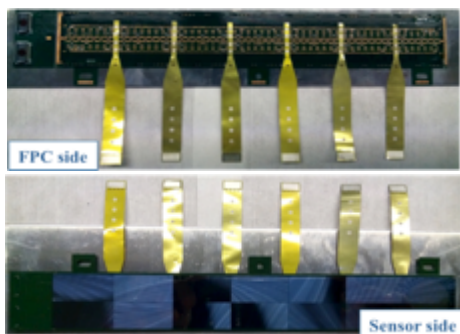


# The ITS Upgrade at LBL

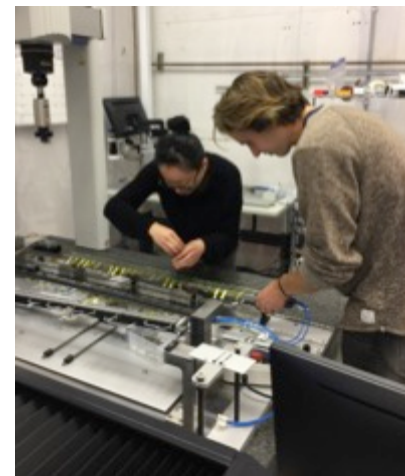
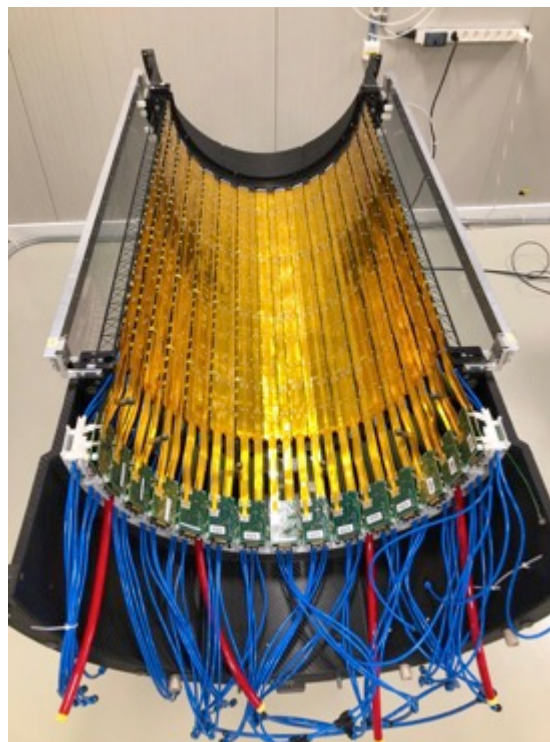
**LBL RNC group is the project leader for the ALICE-USA ITS upgrade construction project**

- ▣ Assembly & testing of Middle Layer staves
- ▣ **Production Ongoing - To be completed Oct '19**

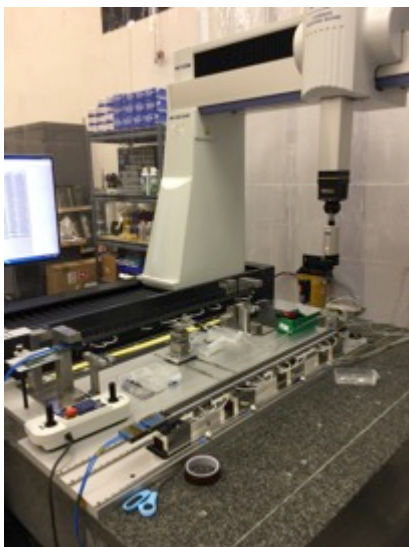
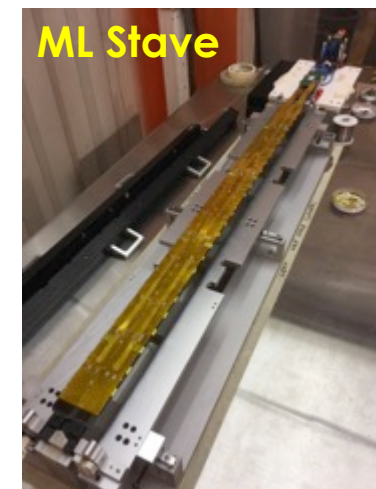
**Silicon Modules**



**Bottom Half of Layer 4**



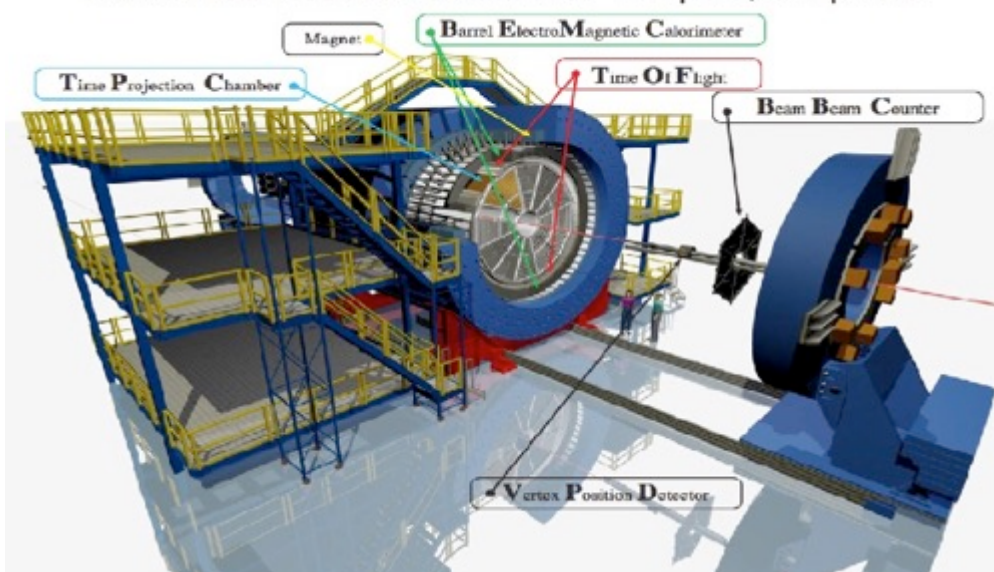
**ML Stave**



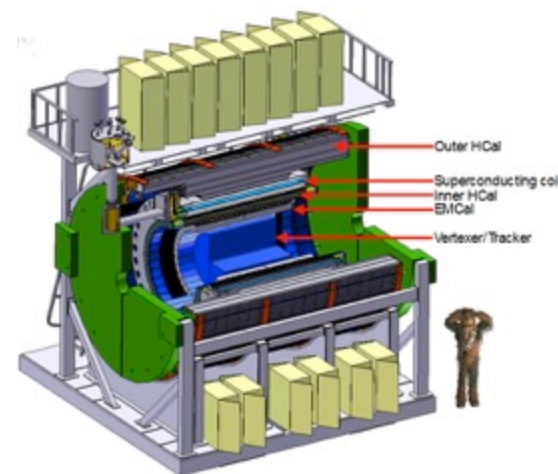
**Coordinate Measuring Machine (CMM)**

## LBL RNC Group works on more than just ALICE

Solenoidal Tracker At RHIC :  $-1 < \eta < 1, 0 < \phi < 2\pi$

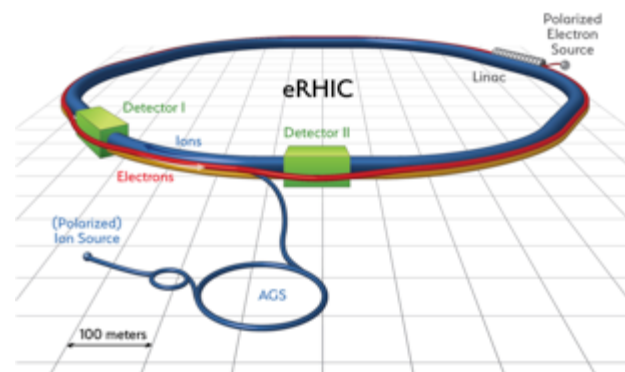


■ STAR detector at RHIC



■ sPHENIX set for data taking after 2022

■ Future eIC



# What is there in store for you?

- Testing/Commissioning of the new ITS upgrade
  - Time at CERN and hands-on learning about ALICE
- Exciting physics opportunities!
  - Machine learning for new ways to study the QGP
  - LHC Run-3 in 2021 will bring higher luminosities → more data!
  - STAR, sPHENIX, eIC
- Physics with the ITS
  - B-jets with a focus on energy loss and substructure
  - Simulations needed

# Any Questions?

- Contact Info:
- Nicole Apadula
- [NicoleApadula@lbl.gov](mailto:NicoleApadula@lbl.gov)

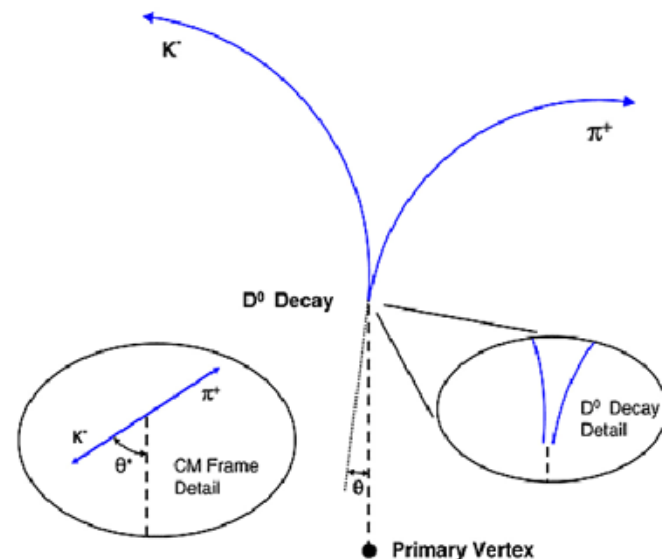


# How do we study the QGP?

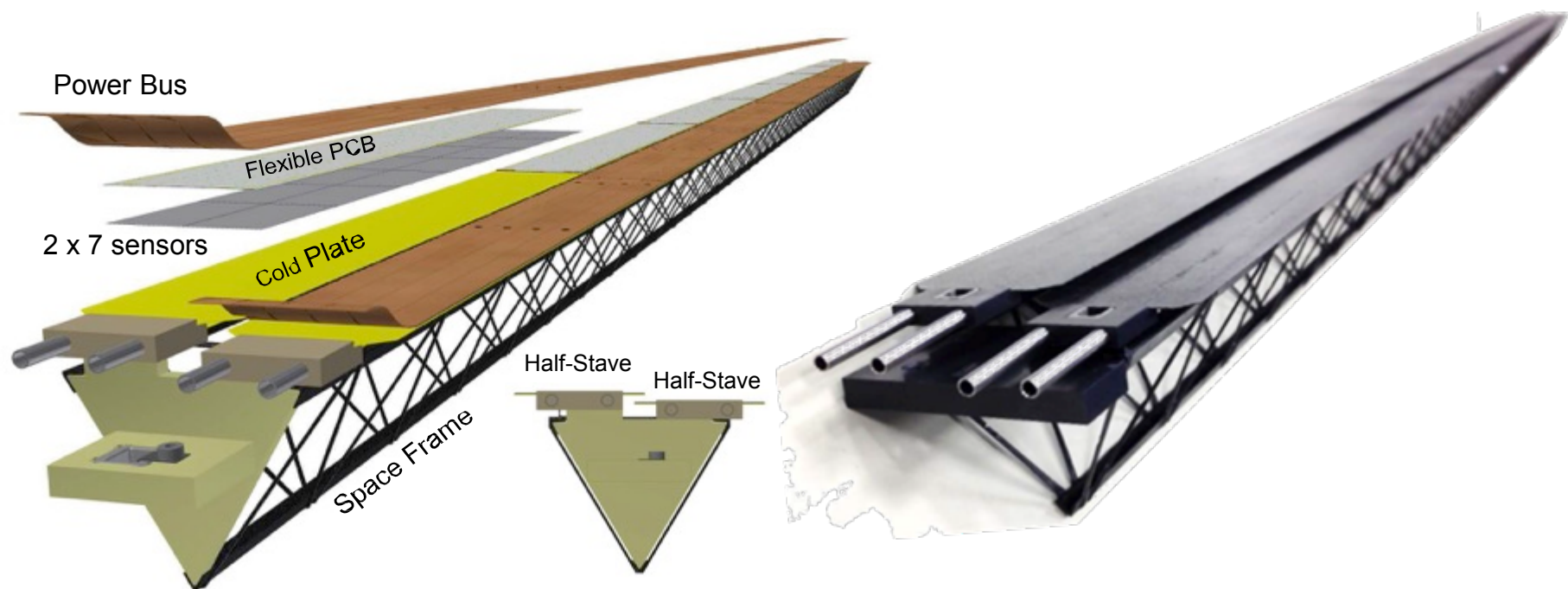
## QGP is nearly “perfect” liquid and highly opaque to partons

- Hard probes → Heavy quarks
- $m_{c,b} \gg \Lambda_{\text{QCD}}$ 
  - Large mass → short formation time
  - Experience full evolution of medium
  - Information about energy loss
- Need good vertex resolution, tracking, & lots of data!
  - New Upgrades coming!
  - Good time to be a new grad student!

Charm ( $m_c \sim 1.5 \text{ GeV}$ )  
Bottom ( $m_b \sim 5 \text{ GeV}$ )



# ITS Outer Barrel



## Outer Barrel (OB)

## LBL built Middle Layers in Red

<radius> (mm): 194, 247, 353, 405

Nr. staves: 24, 30, 42, 48

Nr. Chips/layer: 6048 (ML), 17740 (OL)

Power density < 100 mW / cm<sup>2</sup>

Length (mm): 900 (ML), 1500 (OL)

Nr. modules/stave: 4 (ML), 7 (OL)

Material thickness: ~ 1% X<sub>0</sub> Throughput  
(@100kHz): < 3Mb/s × cm<sup>-2</sup>