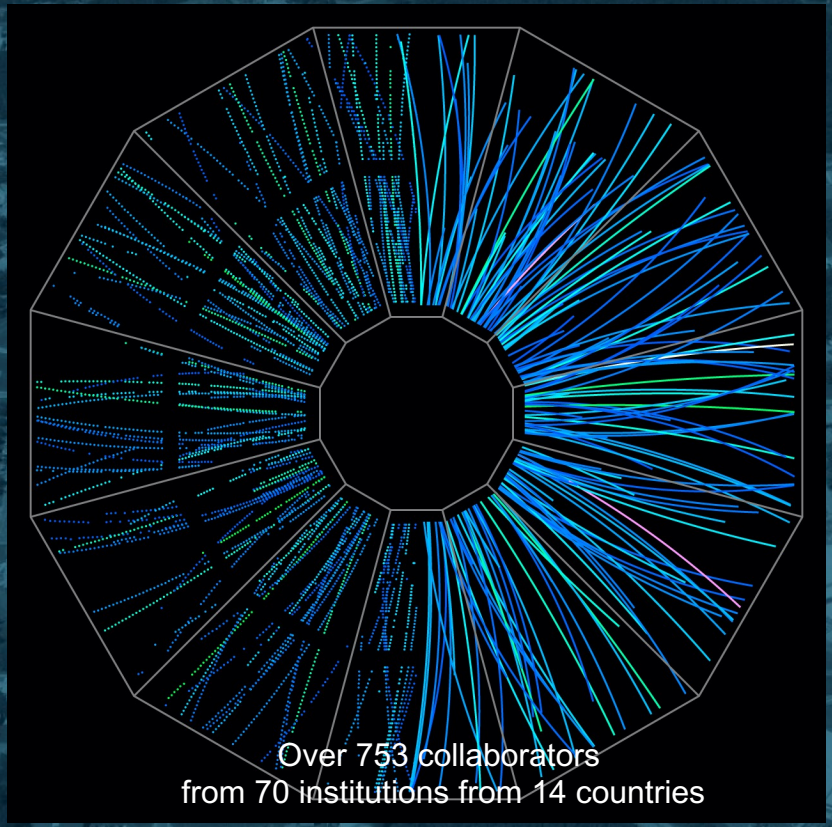
Introduction of STAR detector

Lijuan Ruan (BNL)
Email: ruan@bnl.gov

Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY



@BrookhavenLab

BNL part of NuSteam program

It was supposed to be onsite. The unique advantage would be hands on experiences on hardware and software, data acquisition etc.

It becomes remote because of pandemic. We still would like to focus on the knowledge of detectors, hardwares, how scientists utilize the unique tools/detector hardware pieces to get interesting physics.

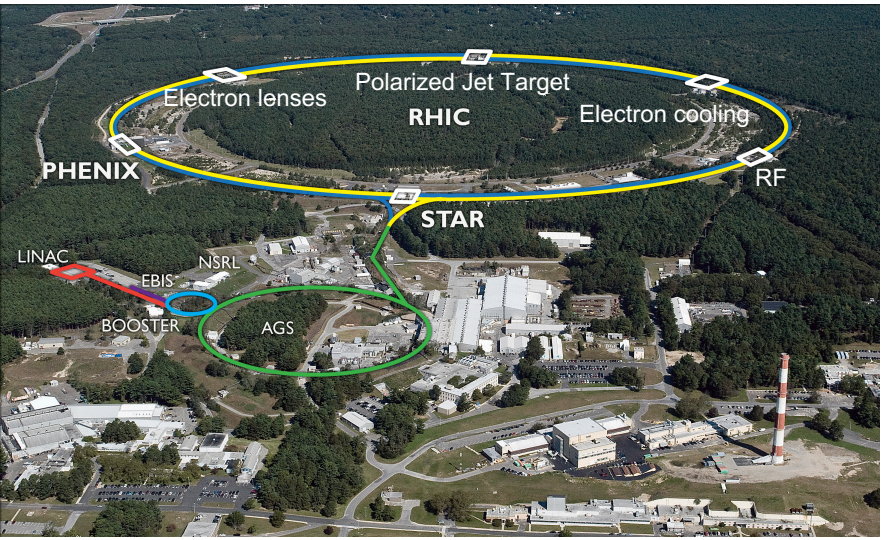
There are two parts: one focuses on STAR heavy ion program, the other on neutrino program.

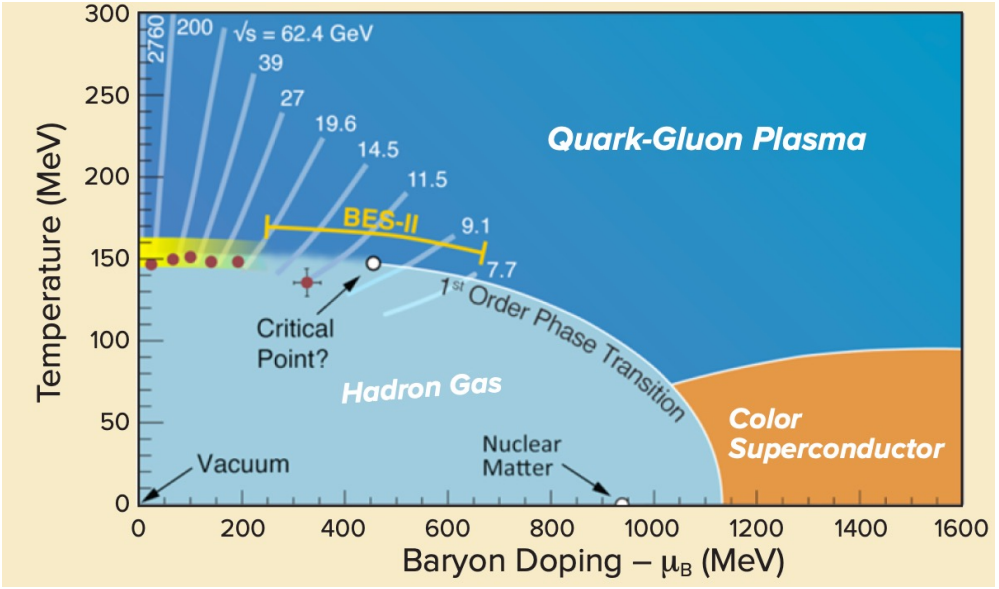
My lecture is an introduction of STAR program and detector

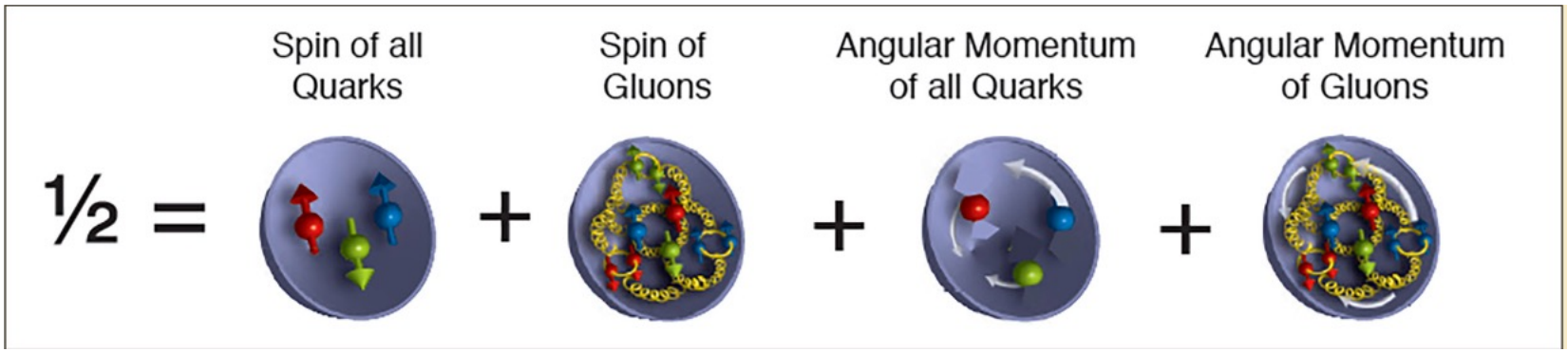
RHIC @ Brookhaven National Laboratory

21 years of RHIC operation

The mission of RHIC







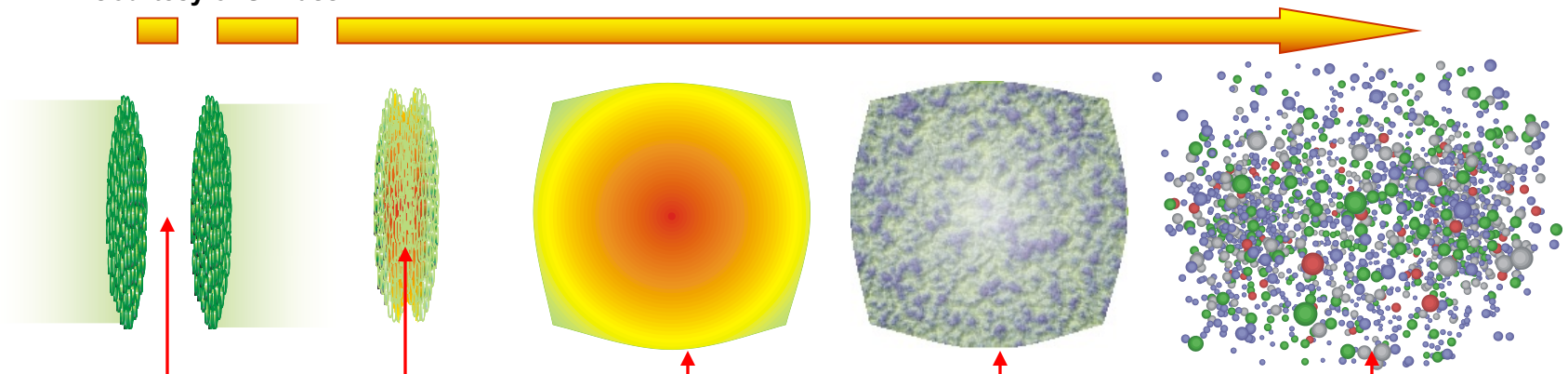
To probe the inner workings of the Quark-Gluon Plasma

To map the phase diagram of QCD

To study the spin puzzle of proton

Relativistic heavy ion collision

Courtesy of S. Bass



Initial state

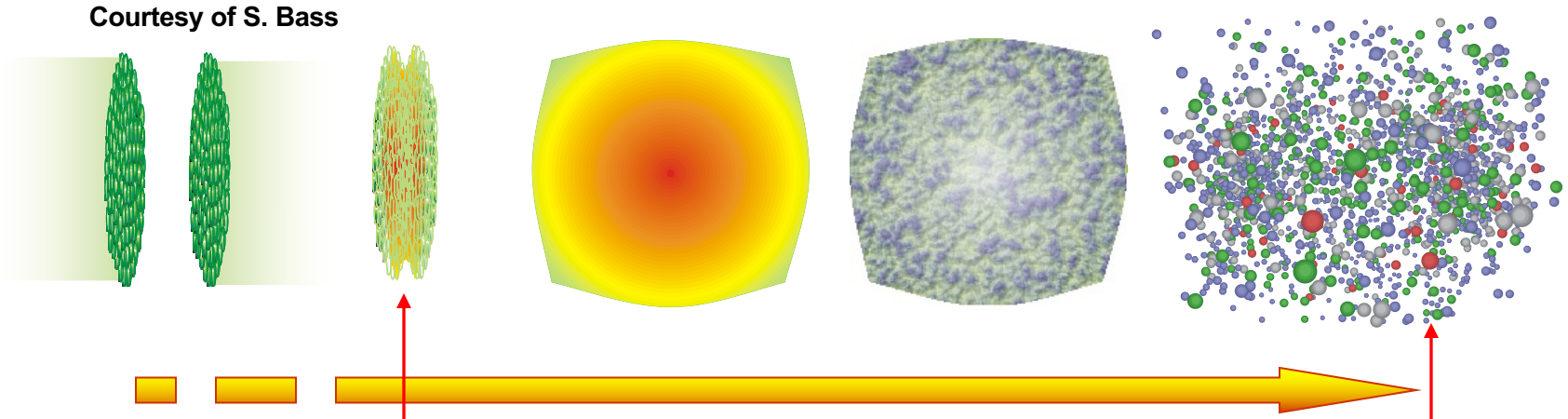
Collision

QGP

Hadronization

Freeze out:
Chemical and kinetic

Physics Goals at RHIC



Identify and study the properties of matter with partonic degrees of freedom.

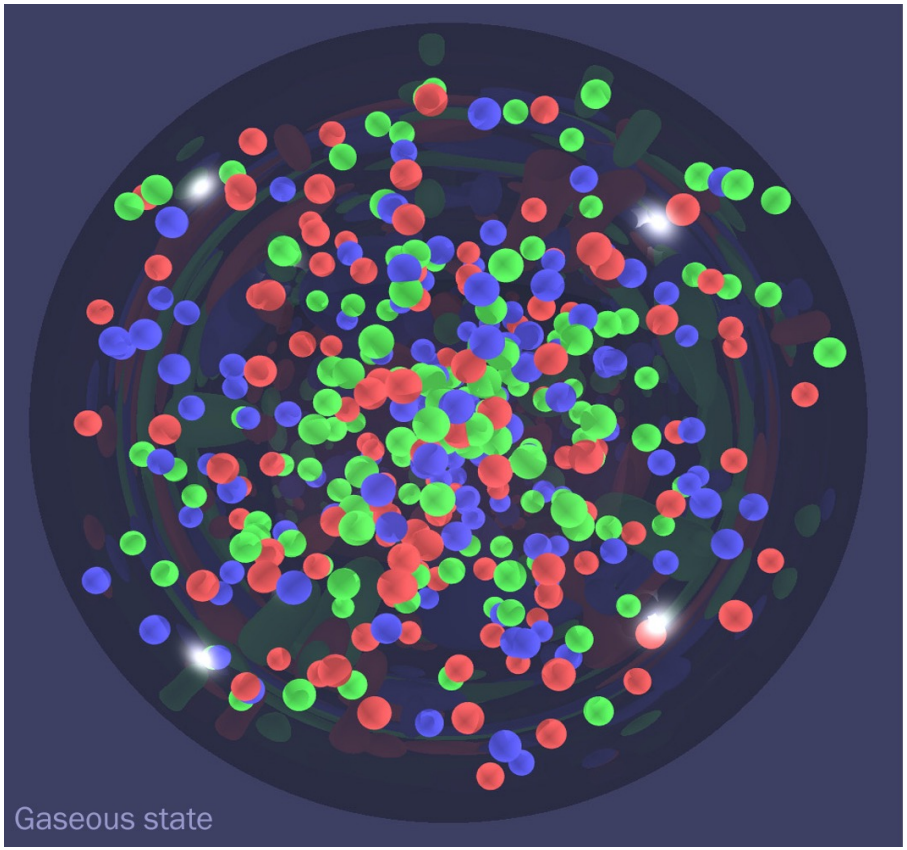
Penetrating probes

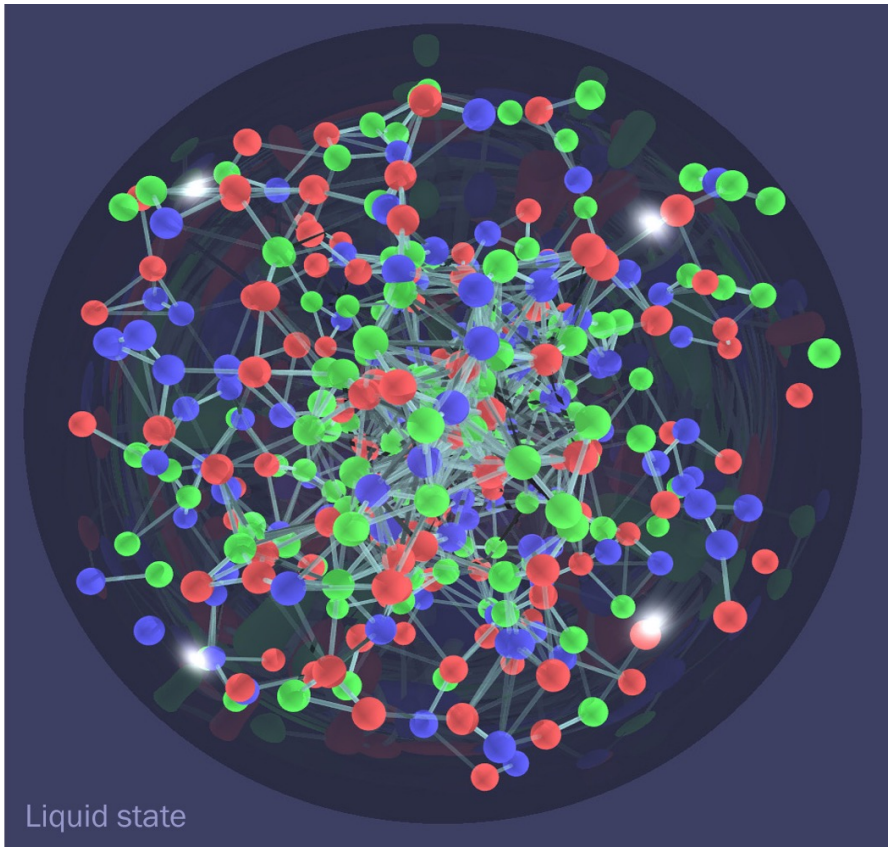
- "jets" and heavy flavor

Bulk probes

- v_2 → partonic collectivity
- spectra at low p_T, particle ratios.

Perfect Liquid discovery

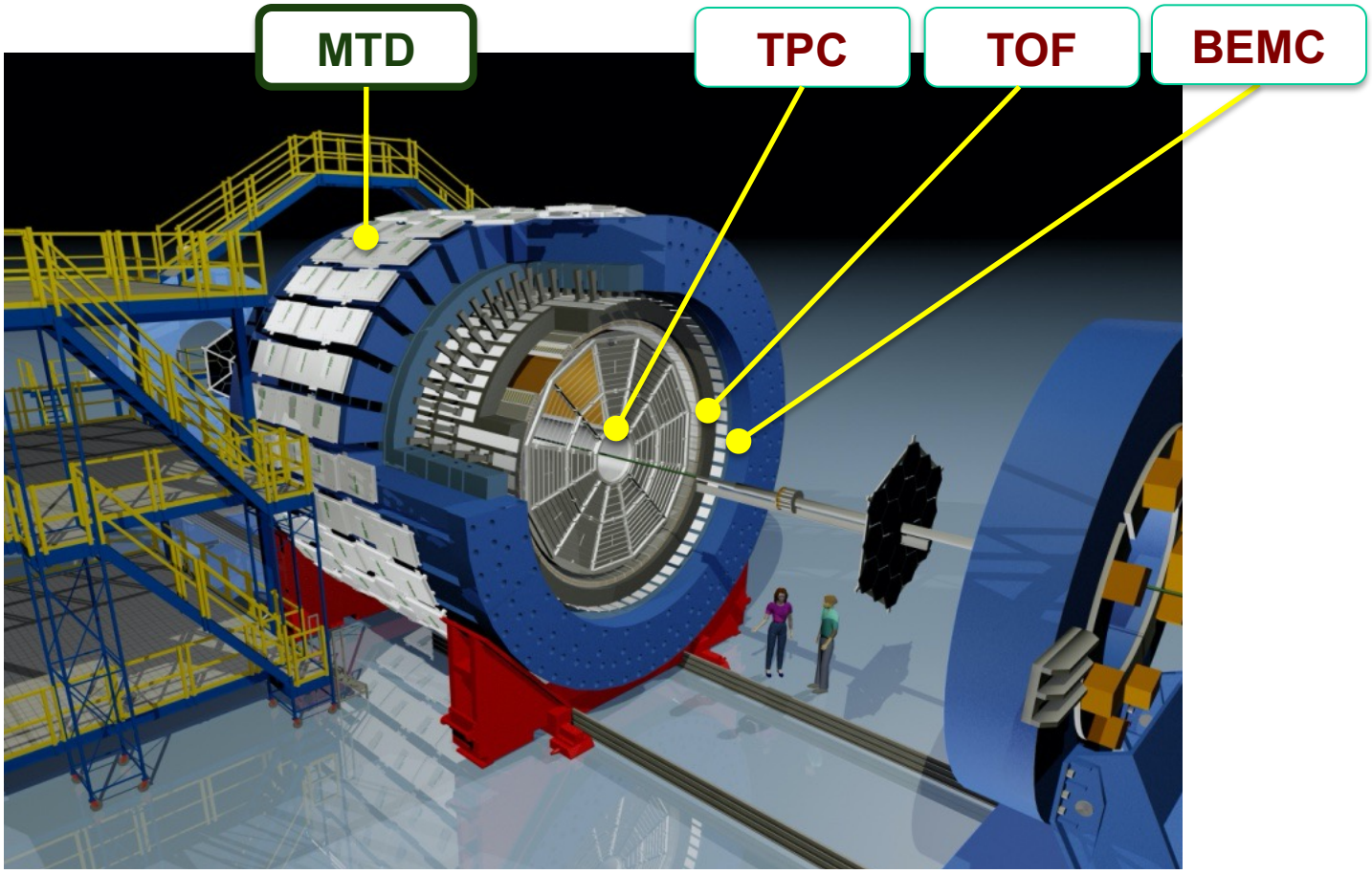




In 2005, BNL announced a discovery of perfect liquid at RHIC

https://www.bnl.gov/newsroom/news.php?a=110303

The STAR Detector

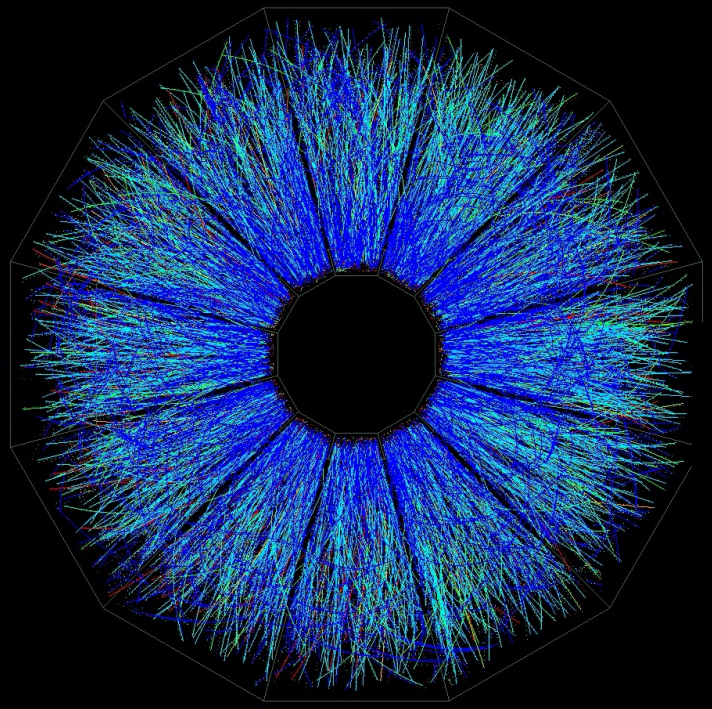


Solenoidal Tracker at RHIC (1200 tons)

Time Projection Chamber

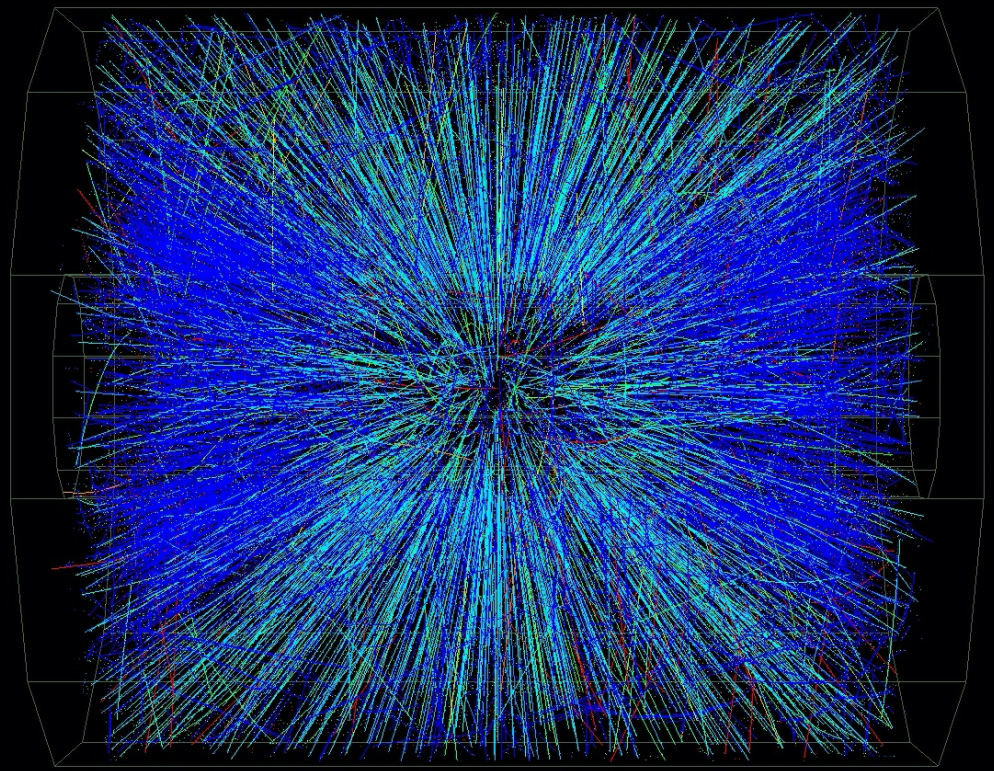
1. **Second largest device of its kind ever built**
2. **3D camera to take photos of the collisions**
3. **Measure ionization energy loss (dE/dx) and momentum**

^{197}Au + ^{197}Au Collisions at RHIC



Central Event

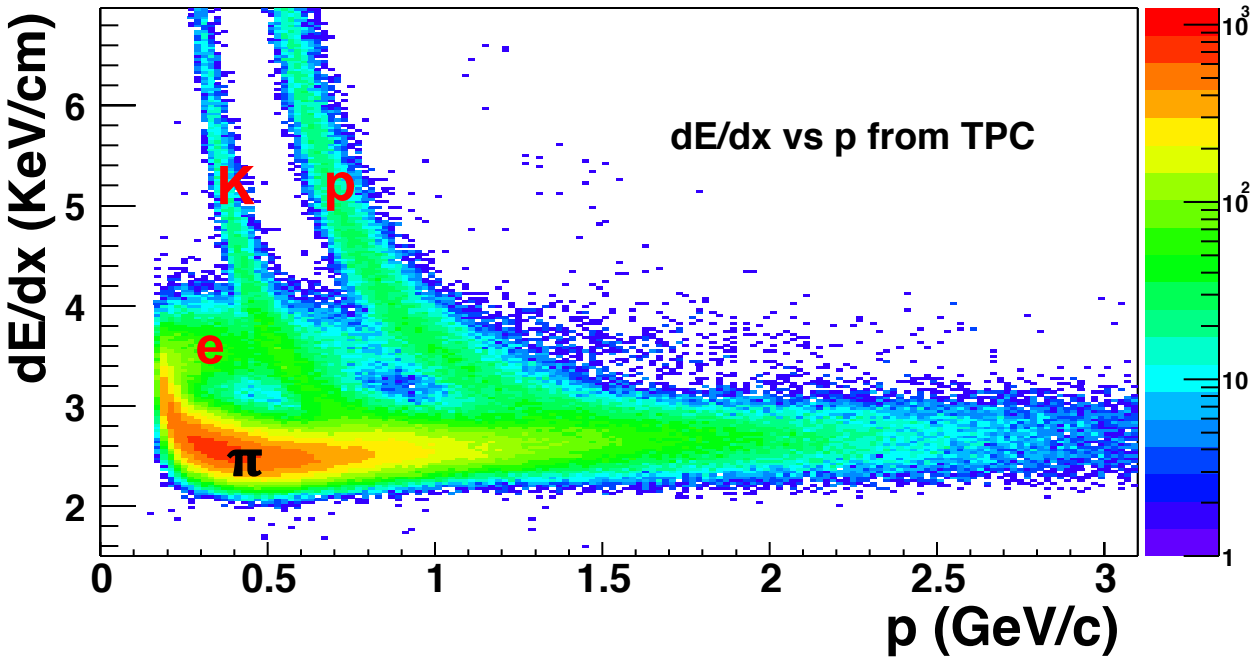
$E = m c^2$



STAR

(real-time Level 3)

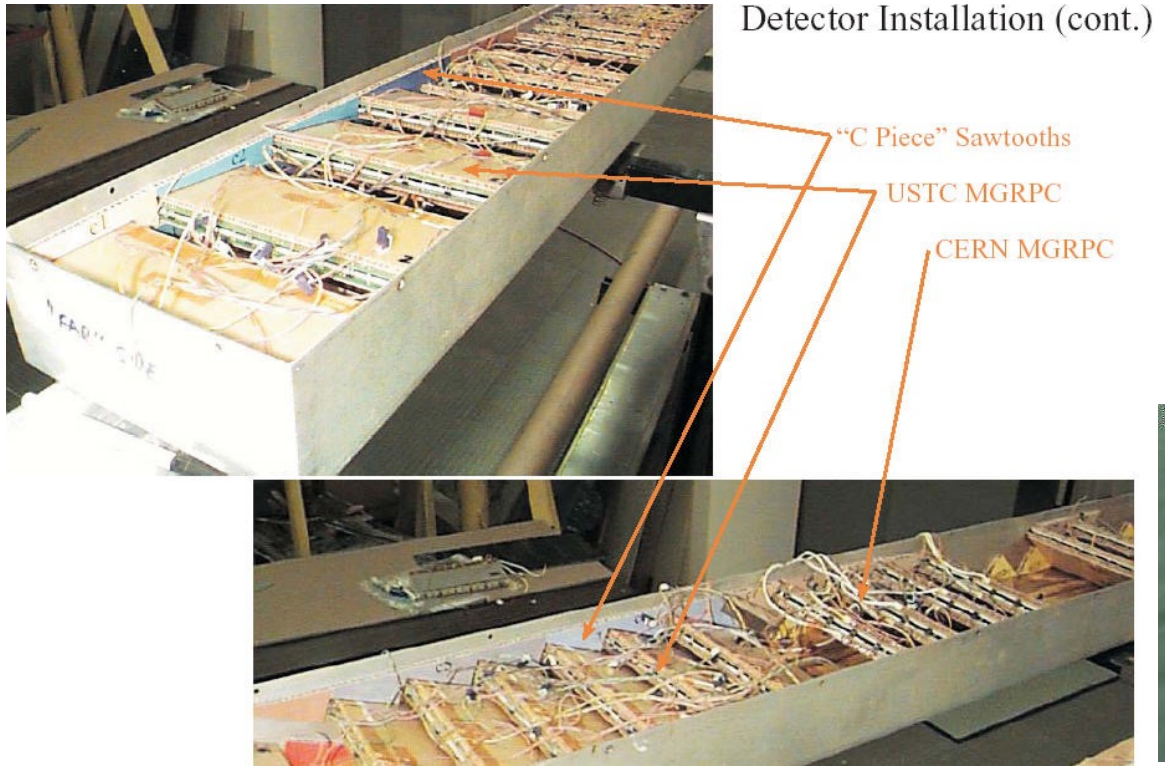
Particle identification

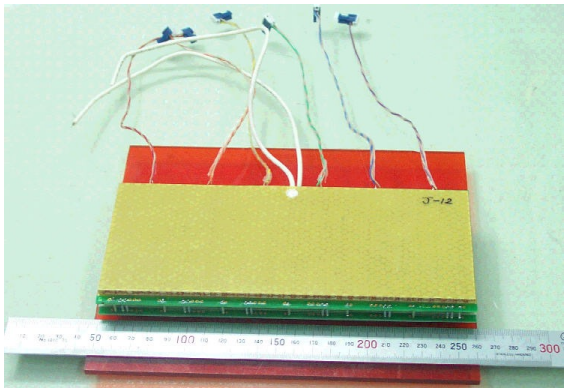


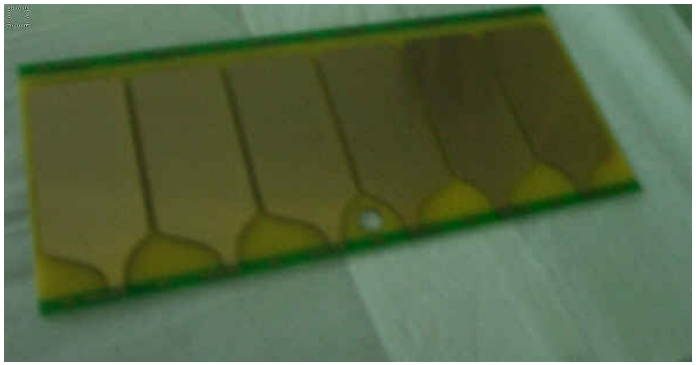
Electrons are difficult to find. Pion/kaon identification less than 1 GeV/c, proton identification less than 1.5 GeV/c

Need new experimental tool to extend particle identification to higher momentum.

MRPC TOFr 2003





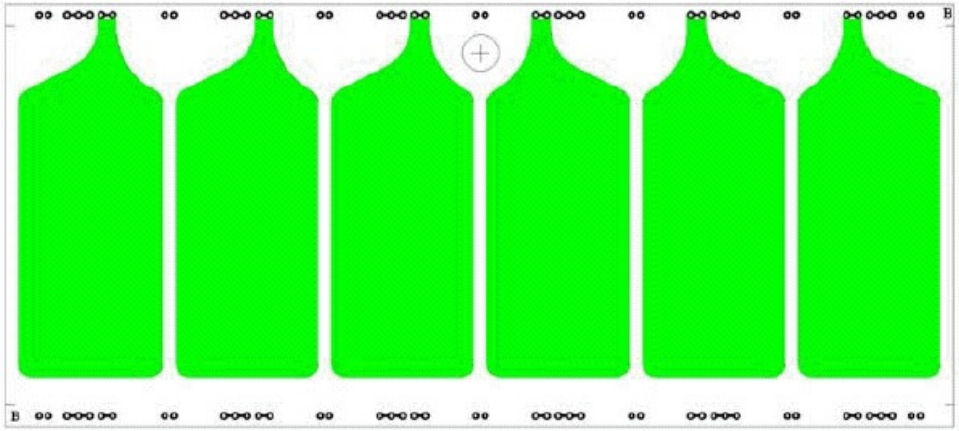


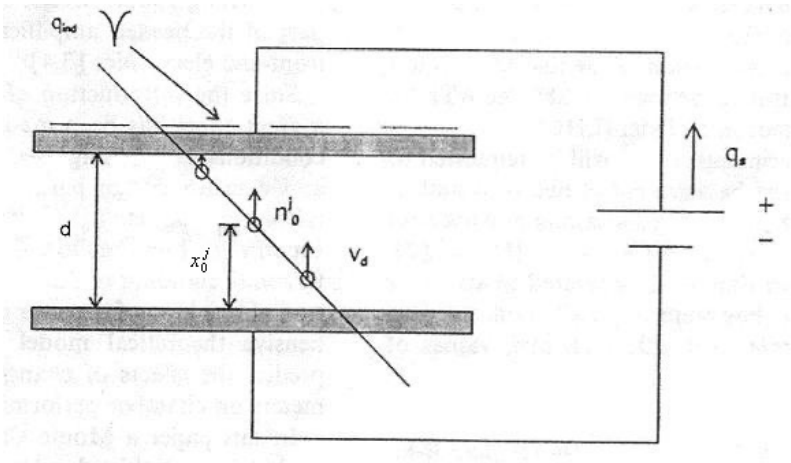
Multigap Resistive Plate Chamber (MRPC) Technology

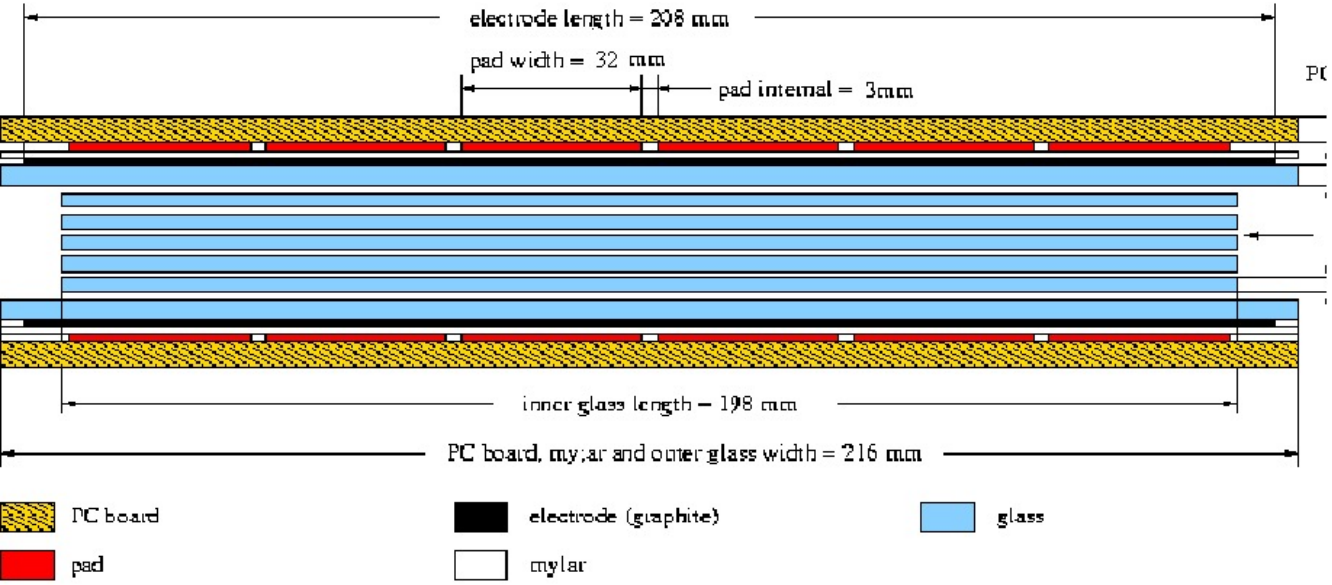
low cost, high timing resolution $<100 \times 10^{-12}$ second

A prototype tray (TOFr) was installed in 2002-2003

Structure of MRPC Module



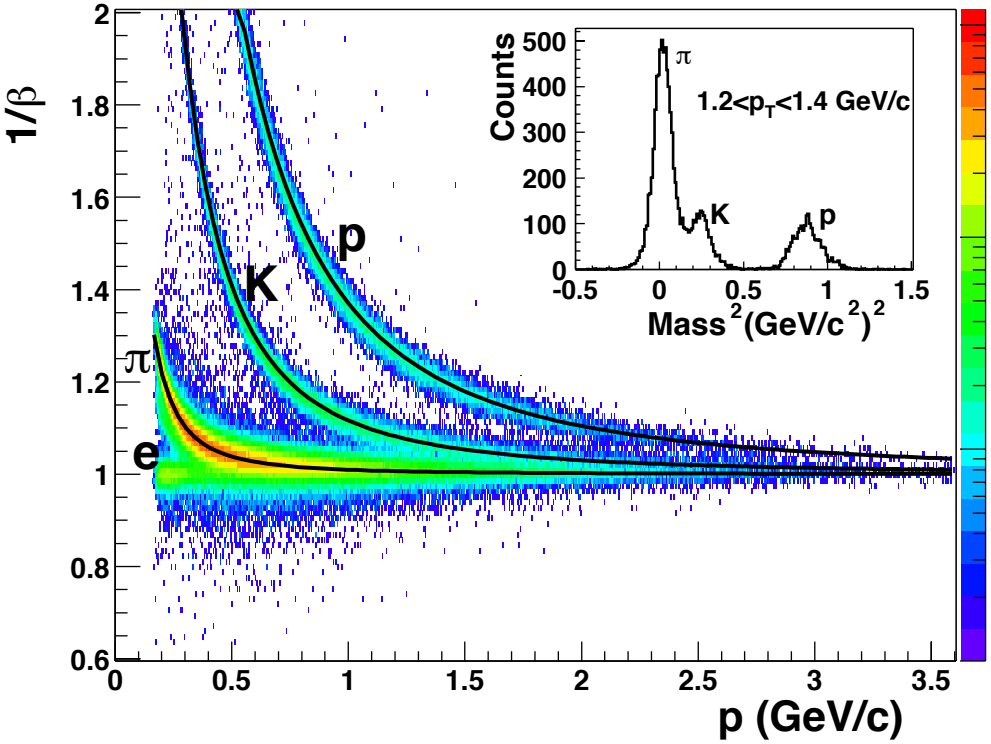




Read out pad size：3.15cm×6.3cm, gap：6×0.22mm

M. Abbrescia et al., Nucl. Instr. and Meth. A 398 (1997) 173-179
M. Abbrescia et al., Nucl. Instr. and Meth. A 431 (1999) 413-427

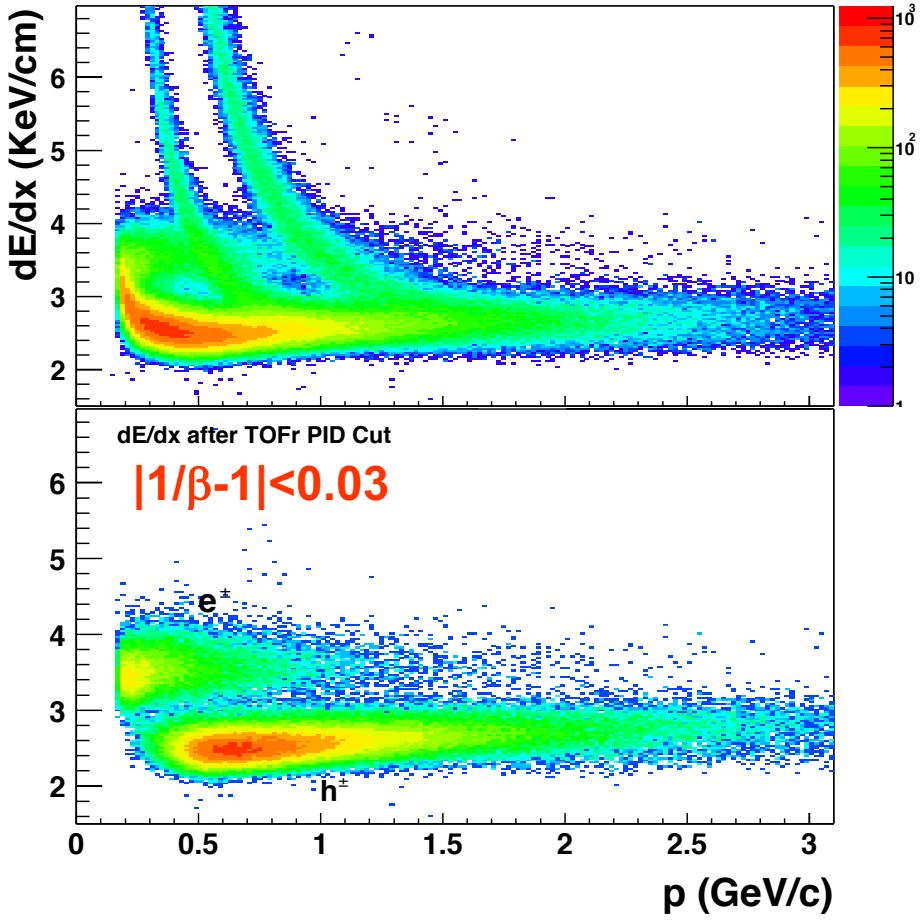
Particle identification from TOFr



STAR Collaboration, PLB616(2005)8

Curve: $$\frac{1}{\beta} = \sqrt{\frac{m^2}{p^2} + 1}$$

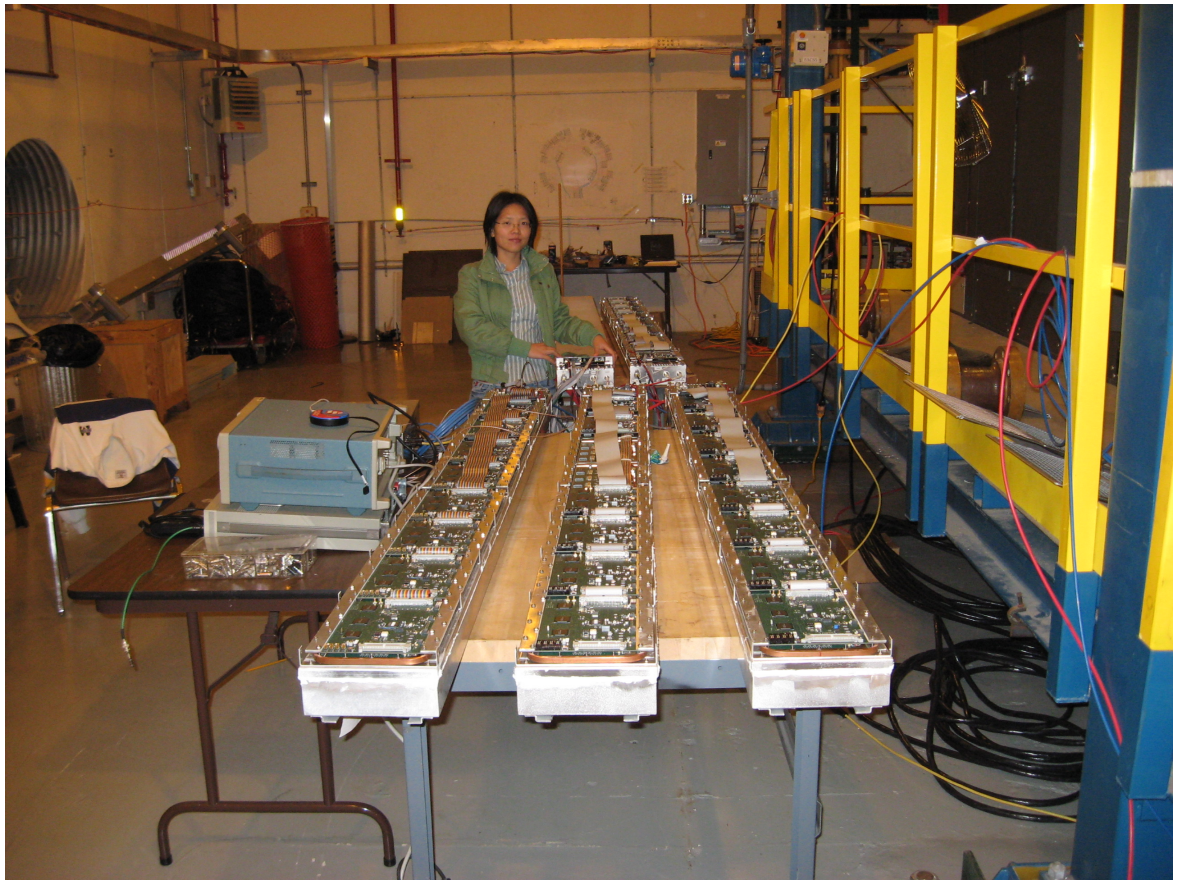
Electron identification



Clean electron samples!

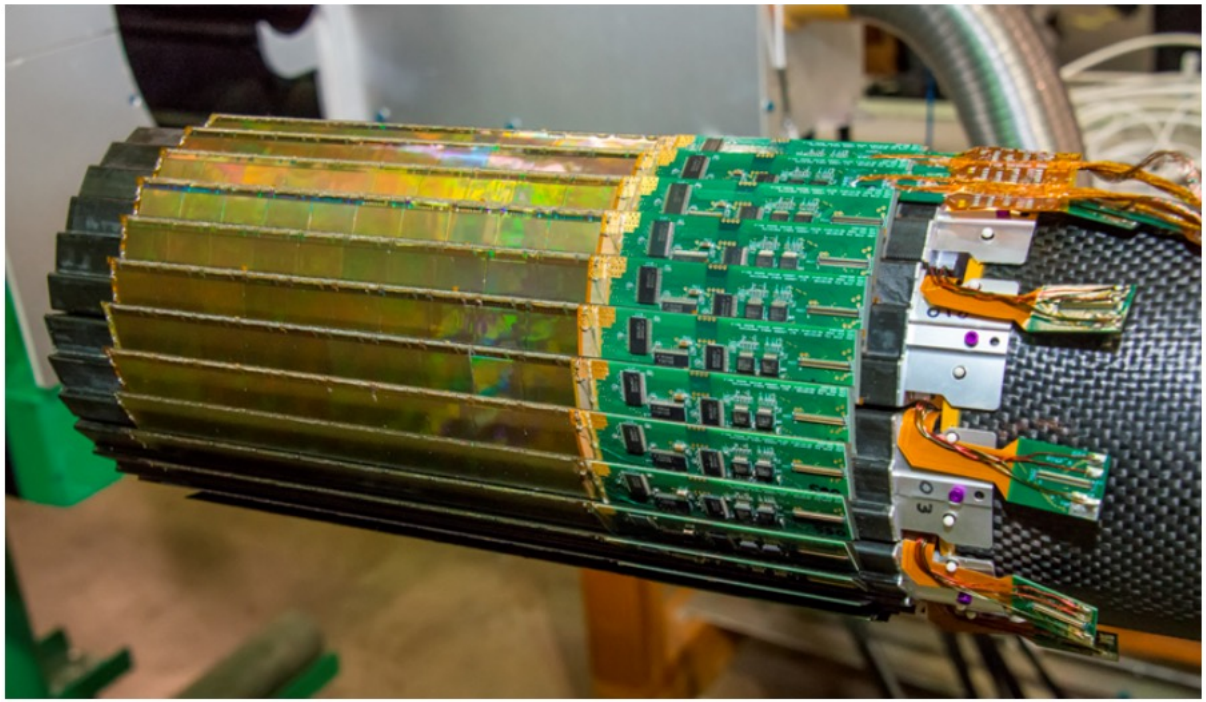
STAR Collaboration, PRL94(2005)062301

Time of Flight Detector upgrade



US-China Collaboration, 120 units in total:
2008: 4%; 2009: 72%; 2010: 100%

HFT and MTD

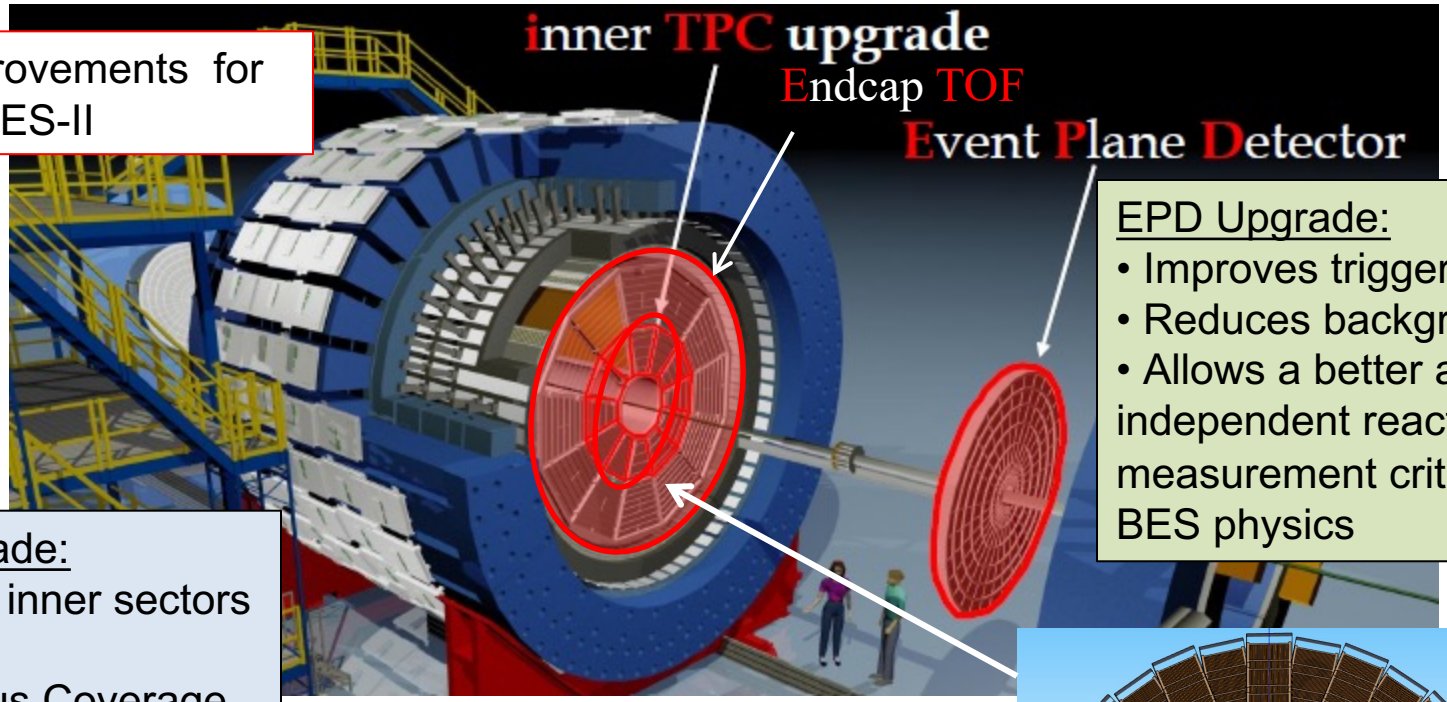


PiXeL detector for STAR Heavy Flavor Tracker, first application of start-of-the-art thin Monolithic Active Pixel Sensors (MAPS) technology in a collider.
https://arxiv.org/pdf/1710.02176.pdf

Heavy Flavor Tracker in Runs 2014-2016: open heavy flavor
Muon Telescope Detector: closed heavy flavor (Rongrong Ma's lecture)

STAR detector at BES-II

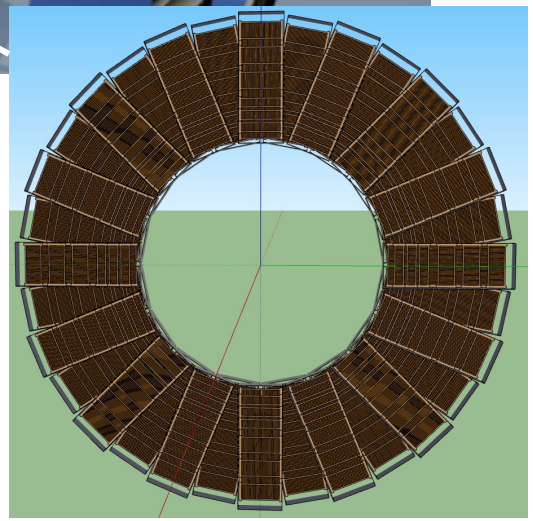
Major improvements for BES-II



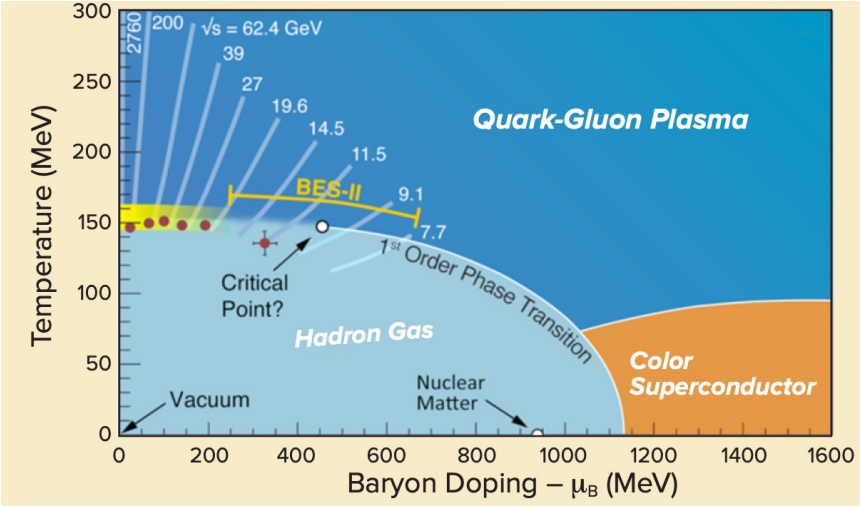
EPD Upgrade:
- Improves trigger
- Reduces background
- Allows a better and independent reaction plane measurement critical to BES physics

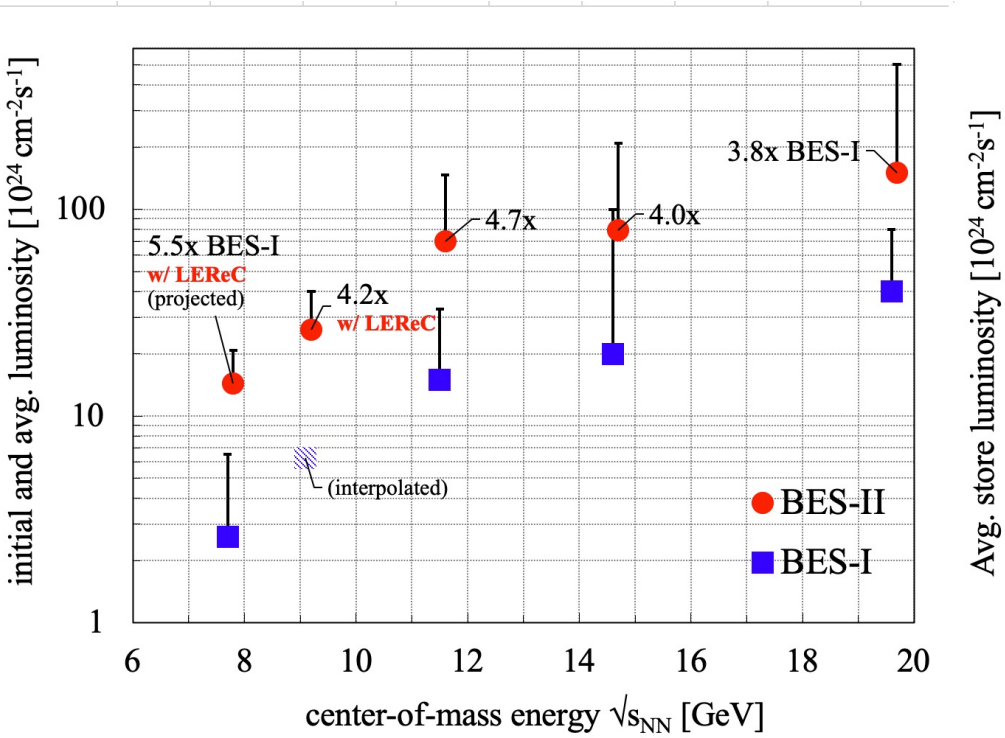
iTPC Upgrade:
- Replaced inner sectors of the TPC
- Continuous Coverage
- Improves dE/dx
- Extends η coverage from 1.0 to 1.5
- Lowers p_T cut from 125 MeV/c to 60 MeV/c

EndCap TOF Upgrade:
- Rapidity coverage is critical
- PID at η = 1 to 1.5
- Improves the fixed target program
- Provided by CBM-FAIR



Beam Energy Scan II in 2019-2021



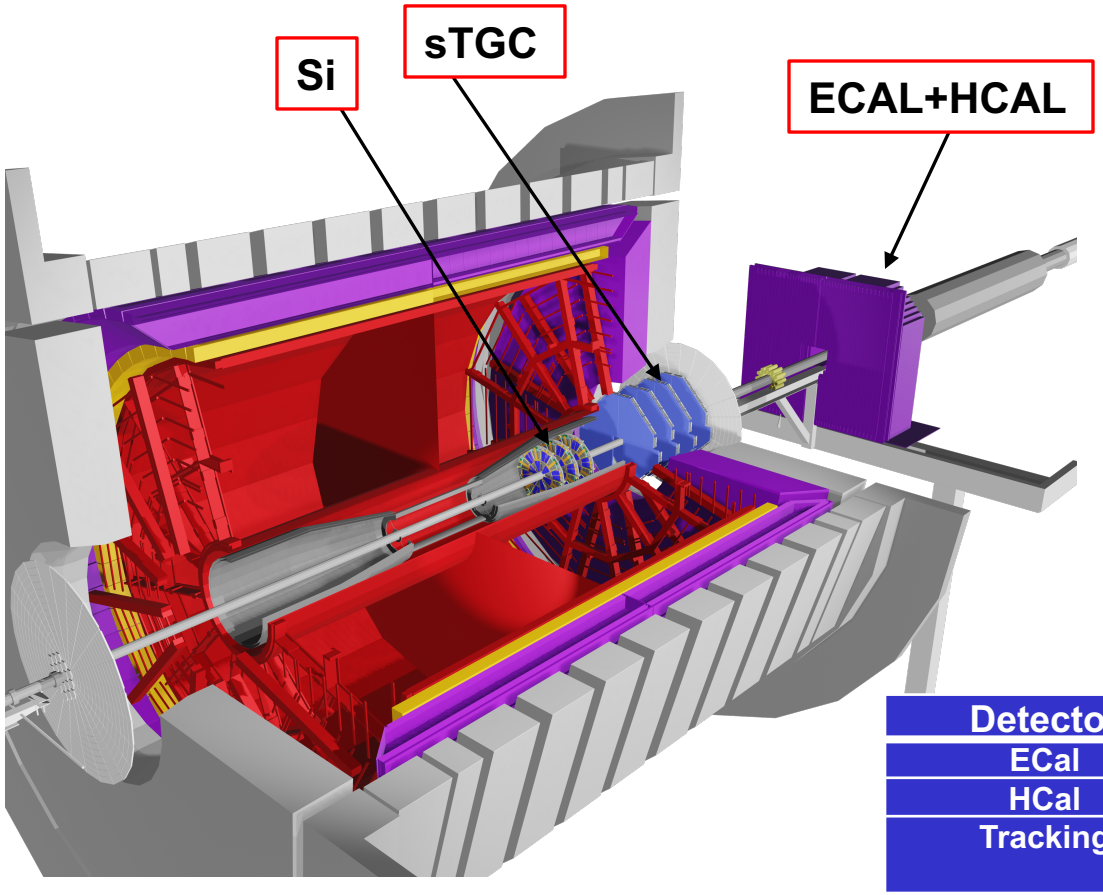


RHIC is unique to map the phase diagram of QCD:

Beam energy scan II: collision energies 7.7, 9.1, 11.5, 14.5, 19.6 GeV and many fixed-target energies

In 2021, collected the last collider data set at 7.7 GeV, completed the BES-II program.

STAR forward upgrades for 2022-2025



At 2.5<η<4

- Jets
- PID (π^0, γ, e, Λ)
- charged particle momentum resolution 20-30% at $0.2<p_T<2$ GeV/c
- event-plane reconstruction and trigger capability

Detector	pp and pA	AA
ECal	~10%/√E	~20%/√E
HCal	~50%/√E+10%	---
Tracking	charge separation photon suppression	$0.2<p_T<2$ GeV/c with 20-30% $1/p_T$

To probe the inner workings of the Quark-Gluon Plasma

To study the spin puzzle of proton

Si: Zhenyu Ye's lecture; sTGC: Isaac Upsal's lecture; forward tracking: Daniel Brandenbug

Two additional STAR lectures

Data acquisition: Jeff Landgraf

High level trigger, hypertriton reconstruction: Hongwei Ke

You will hear neutrino related lectures on Aug. 18 and 19

Most importantly, we hope you enjoy the program.

The format

A teacher will give a lecture and some homework

You are expected to work on your homework in the afternoon

Feel free to send out questions to teachers by email.

On Aug 20, we ask each student to give a 10 mins presentation on what they learn and what they are interested in.

Today's homework

- Read this following publications
- https://drupal.star.bnl.gov/STAR/publications/star-detector-overview
- https://drupal.star.bnl.gov/STAR/publications/star-time-projection-chamber-unique-tool-studying-high-multiplicity-events-rhic
- https://drupal.star.bnl.gov/STAR/publications/star-maps-based-pixel-detector-0
- Next: STAR live tour (by Prashanth Shanmuganathan)