STAR Experiment at NCKU

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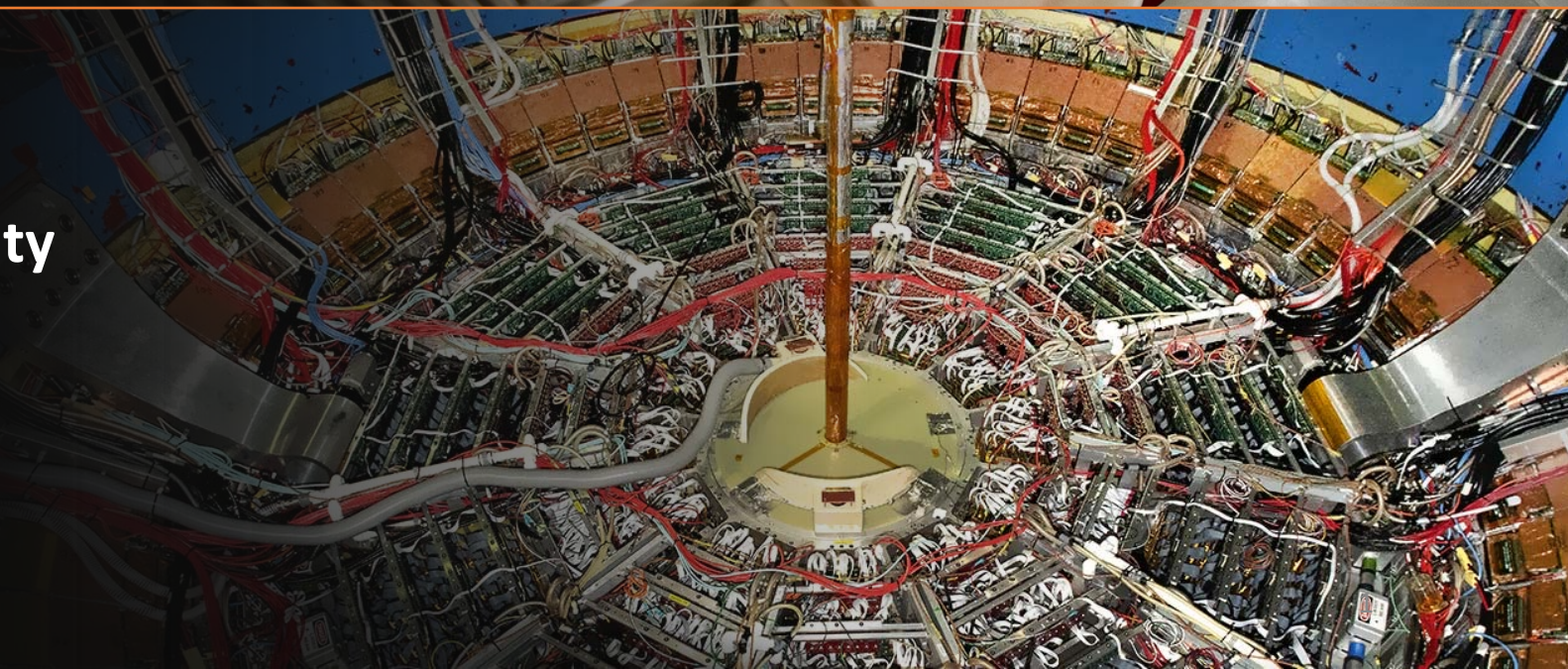
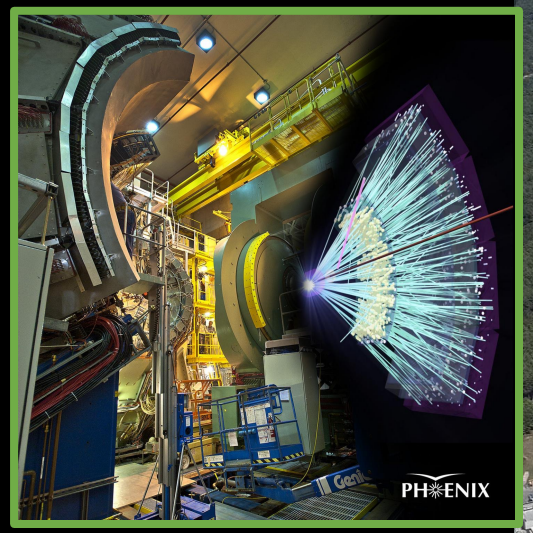
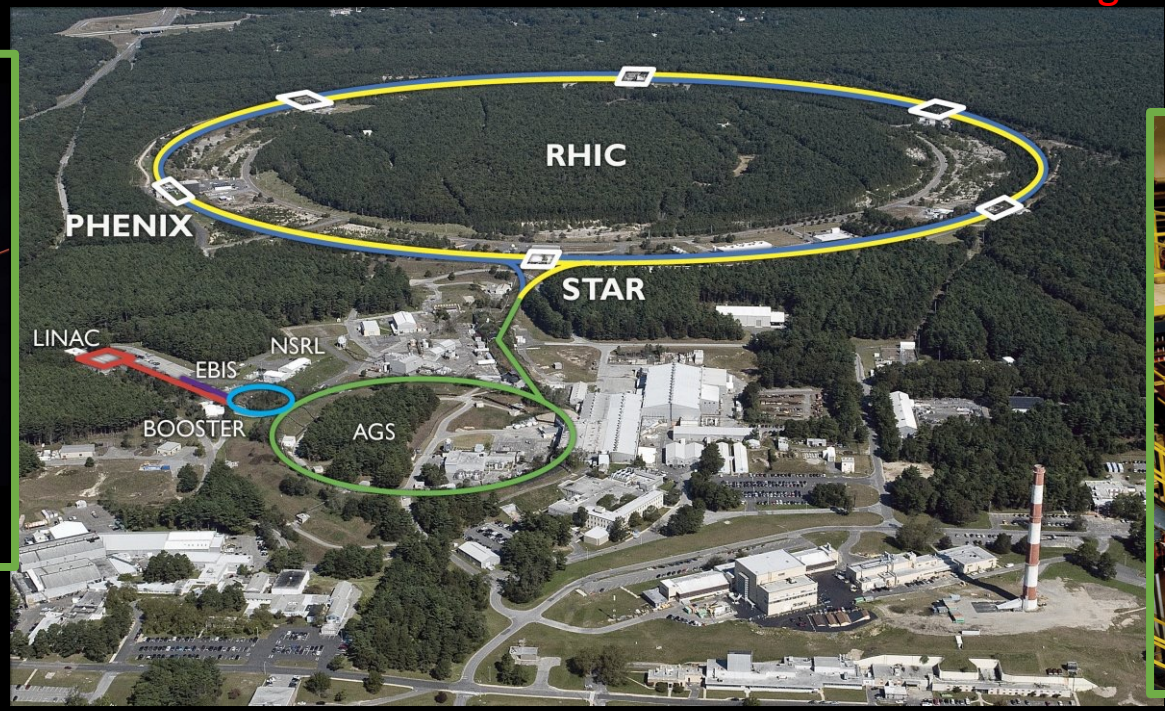


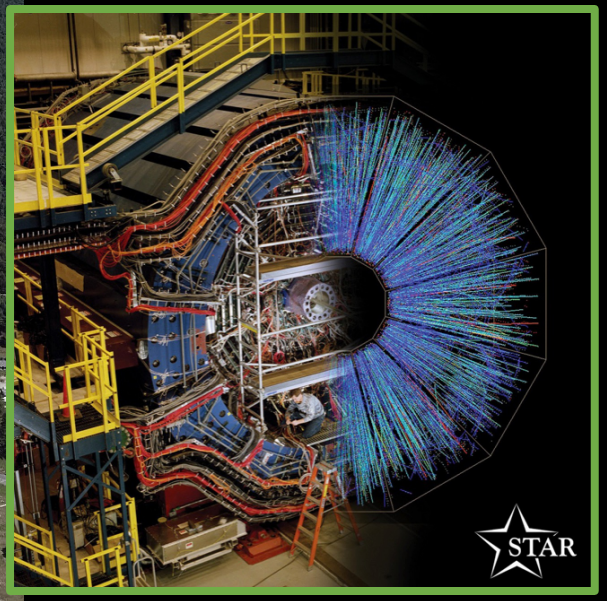
Relativistic Heavy Ion Collider (RHIC)

- **The most versatile particle collider**
  - The only **polarized proton** collider in the world
  - Type of collision particles: p+p, p+Au, Au+Au, d+Au, U+U, Zr+Zr, …
  - The center-of-mass energy for Au+Au collision: 3.5 - 7.7 - 200 GeV

Fixed Target mode Collider mode

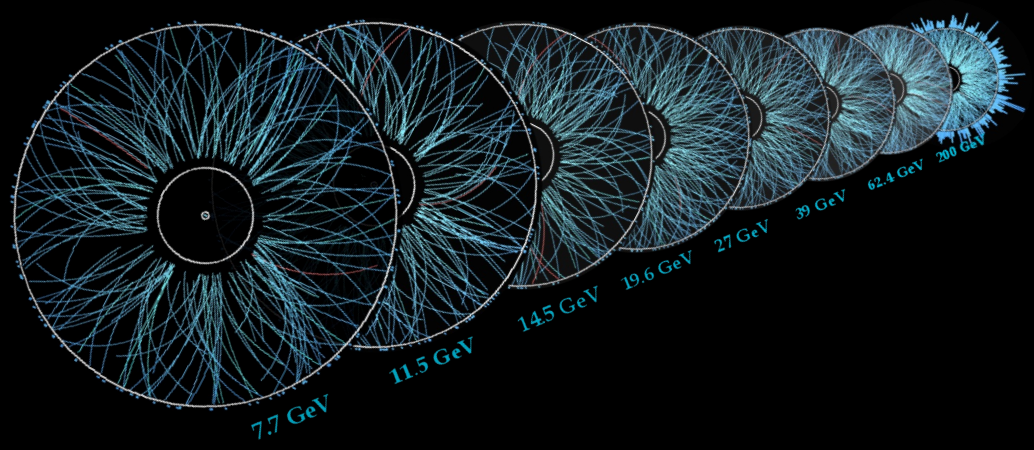


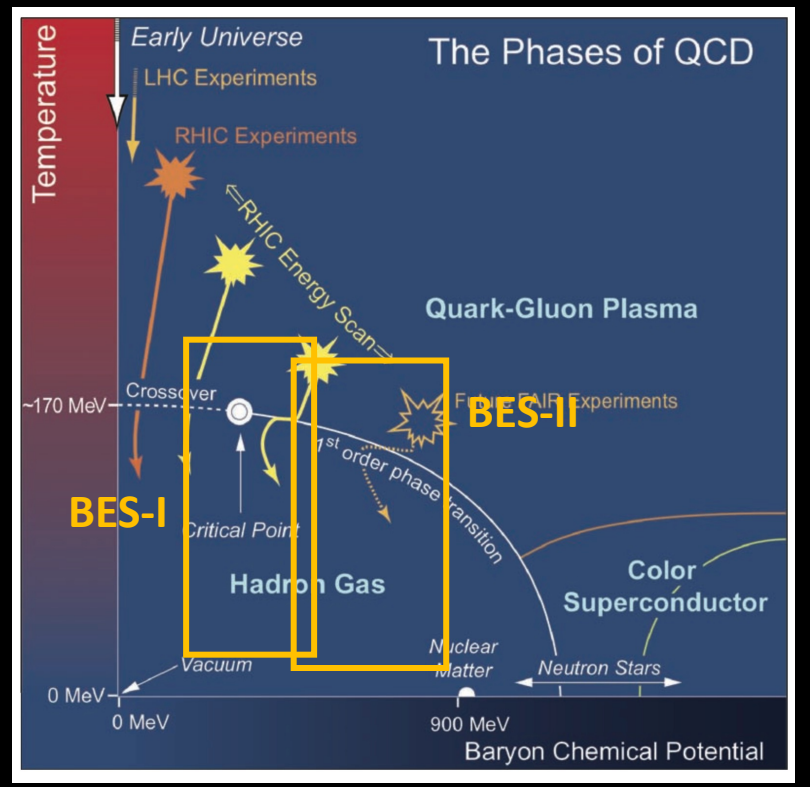




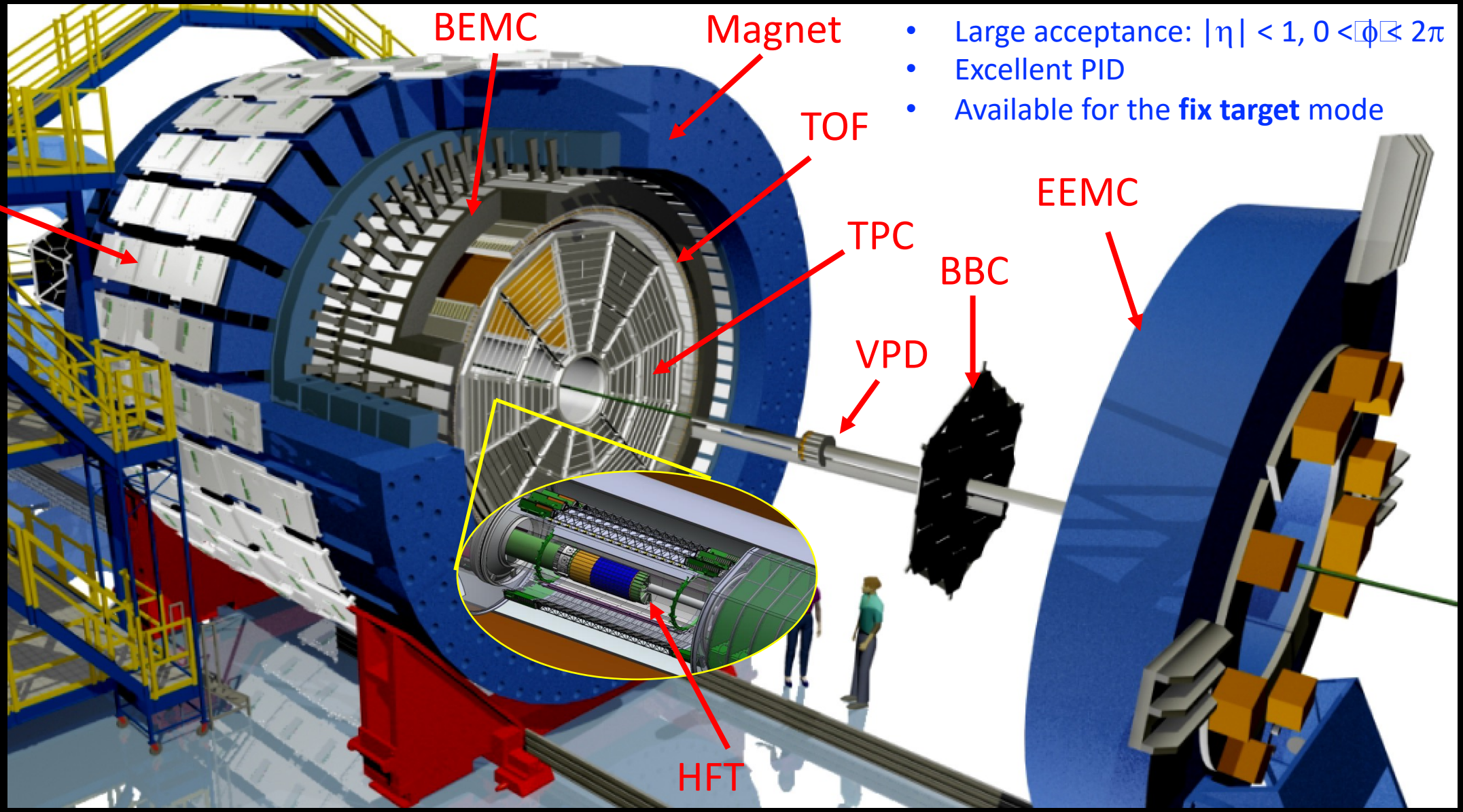
Beam Energy Scan (BES) Programs @ RHIC

- RHIC provides an unique opportunity to explore the QCD phase diagram with different collision energies
  - ➔ Search for QCD critical point, 1st order phase transition, turn-off of QGP, etc.
- **BES-I** (2010 – 2011, 2014): $\sqrt{s_{NN}}$ = 7.7, 11.5, 19, 27 and 39 GeV
- **BES-II** (2019 – 2021):
  - Collider mode: $\sqrt{s_{NN}}$ = 7.7, 9.1, 11.5, 14.5, 19.6 GeV
  - Fixed Target mode: $\sqrt{s_{NN}}$ = 3.5, 3.9, 4.5, 5.2, 6.2, 7.7 GeV



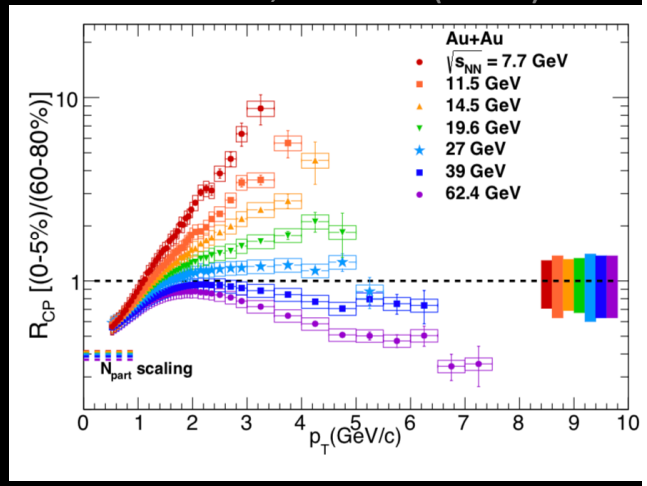


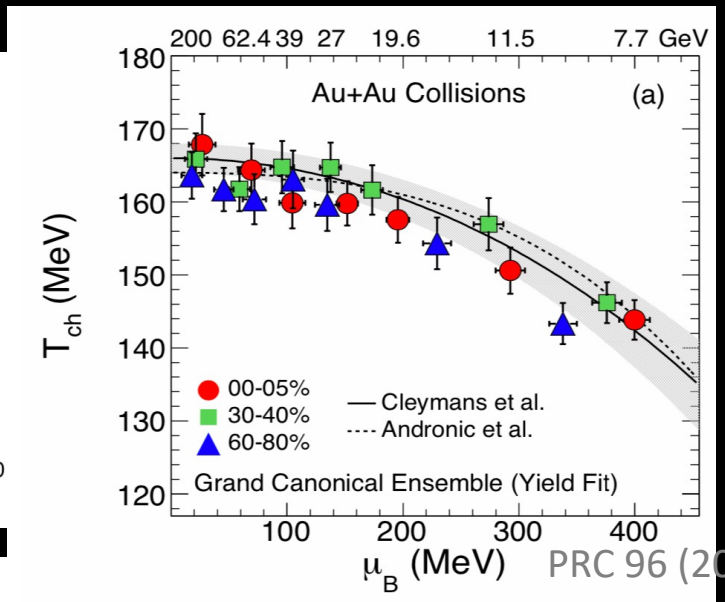
The STAR Detector for BES-I



Selected Results from BES-I

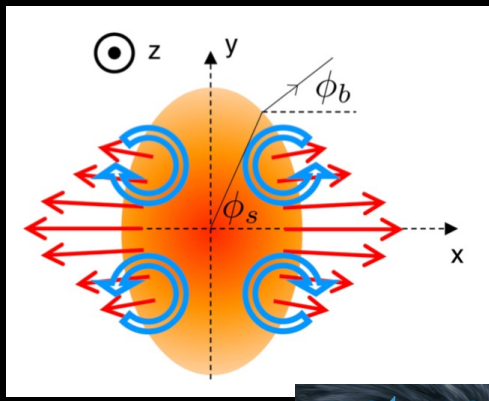
PRL 121, 032301 (2018)

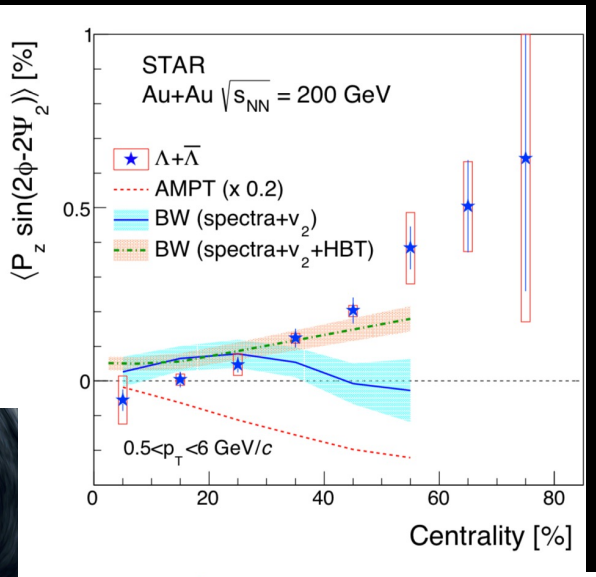


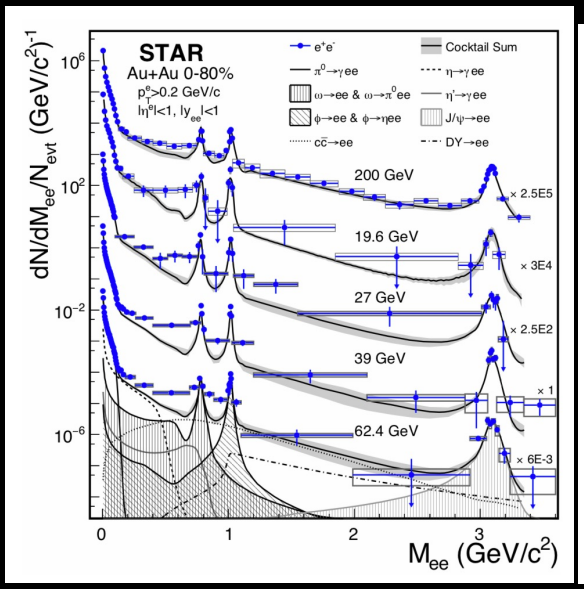


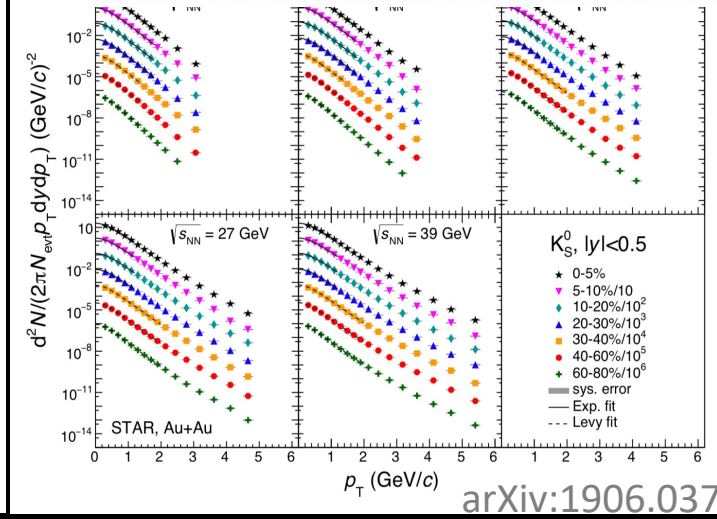
PRC 96 (2017) 44904

arXiv:1905.11917

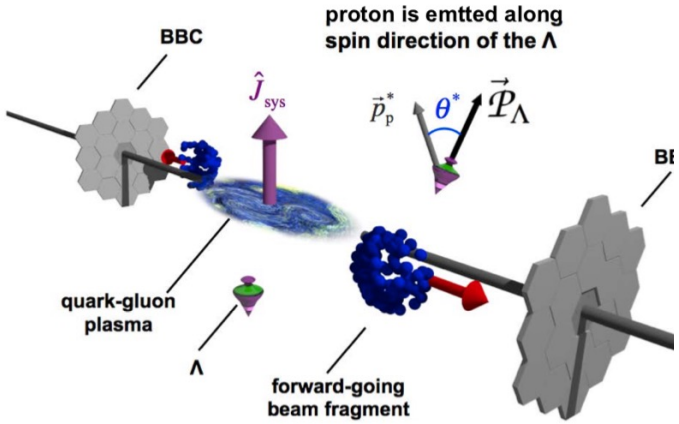


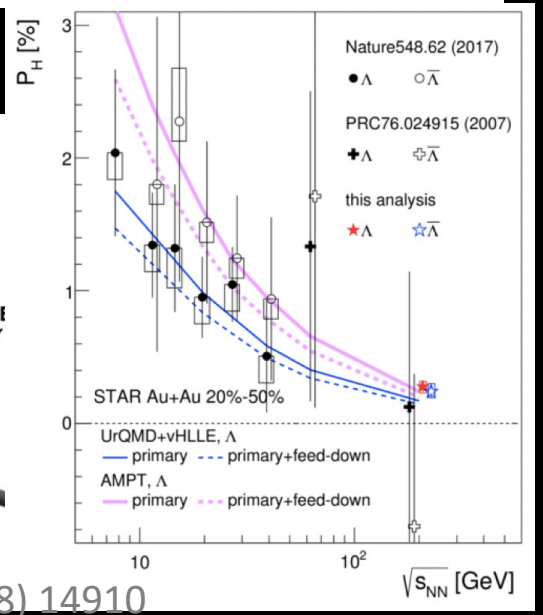






arXiv:1906.0373

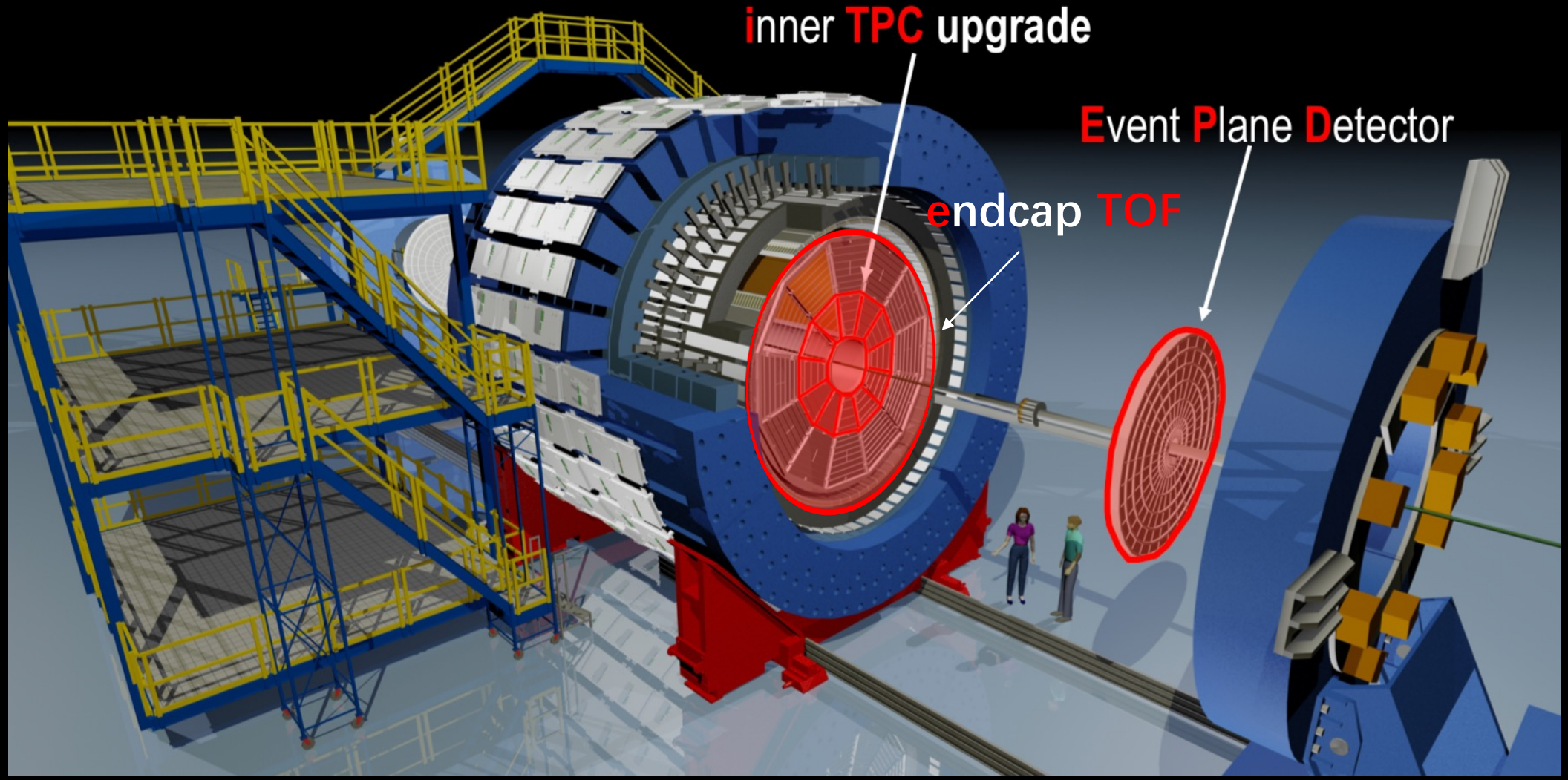




PRC 98 (2018) 14910

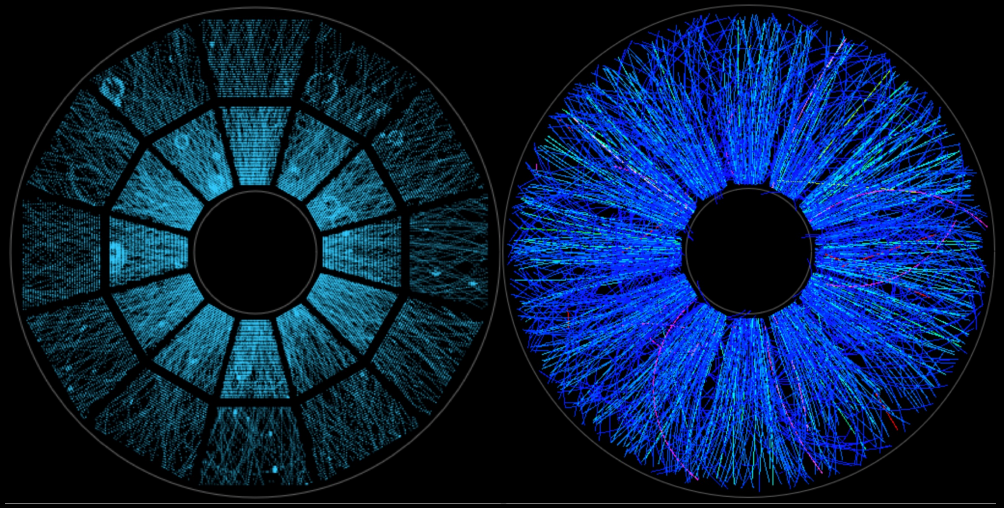
STAR Detector Upgrades for BES-II

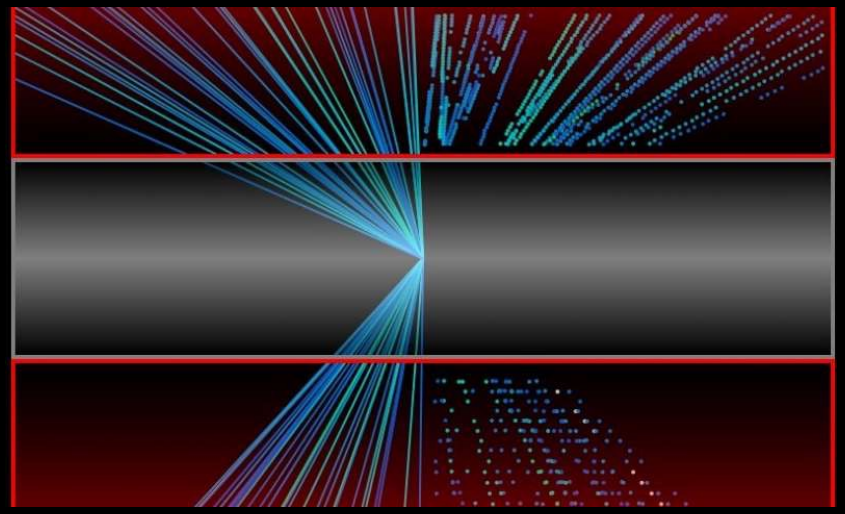
- RHIC: improve luminosity for low energy beams with ***e-cooling***

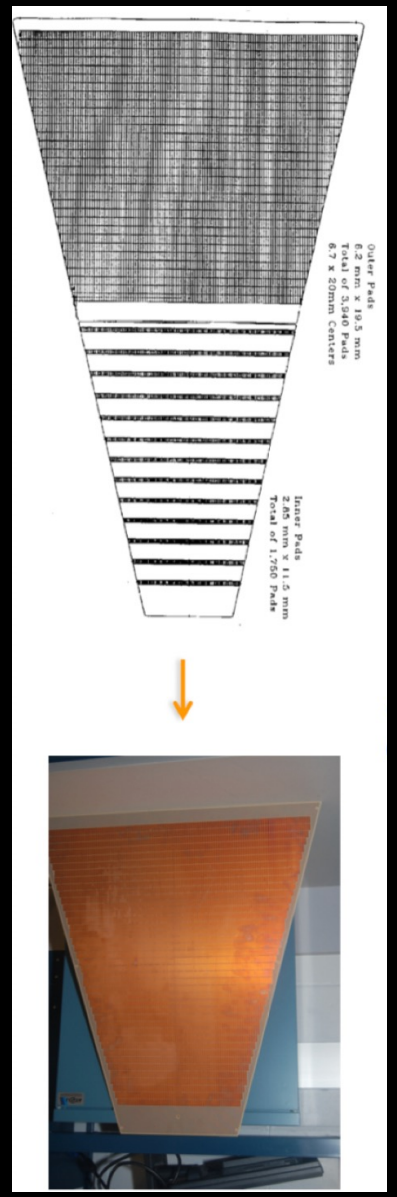


inner Time Projection Chamber (iTPC)

- Rebuild the inner sectors of the TPC to improve:
  - Continuous coverage
  - Better dE/dx resolution
  - Extend η acceptance from 1.0 to 1.5
  - Lower p_T cut from 125 MeV/c to 60 MeV/c
  - Better p_T resolution
- Started operation in STAR since 2018

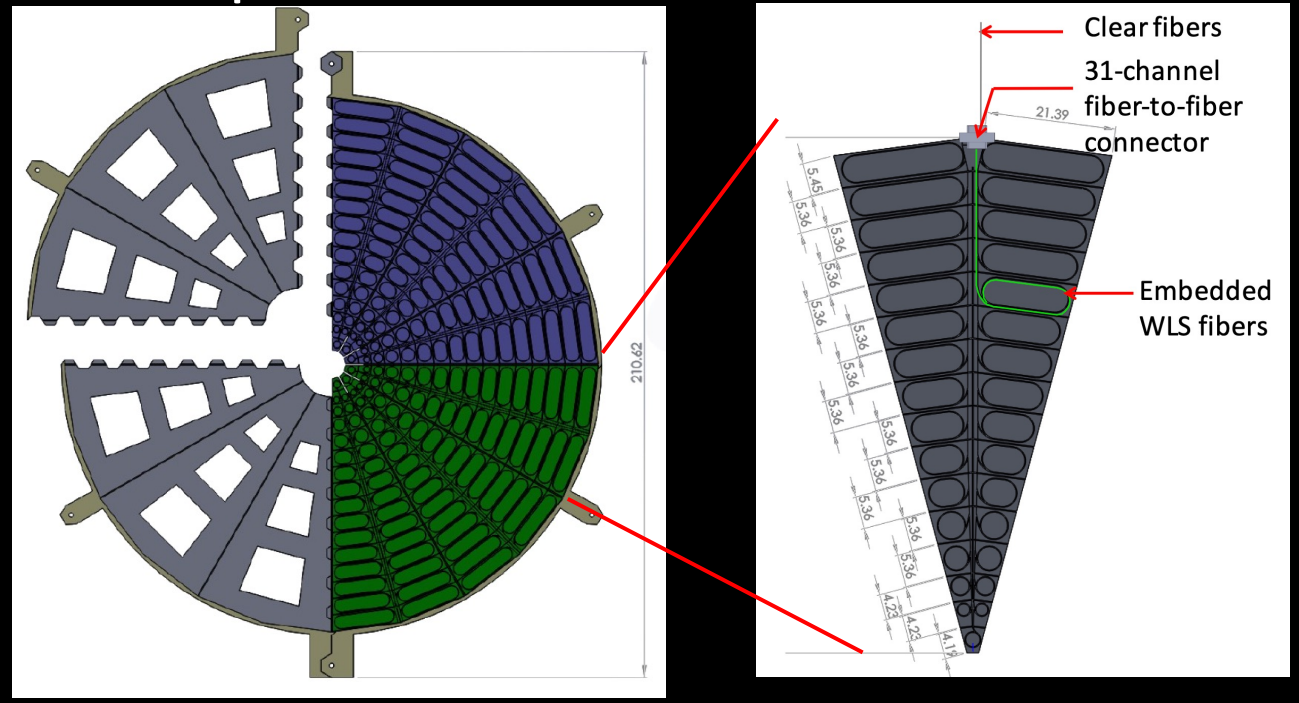


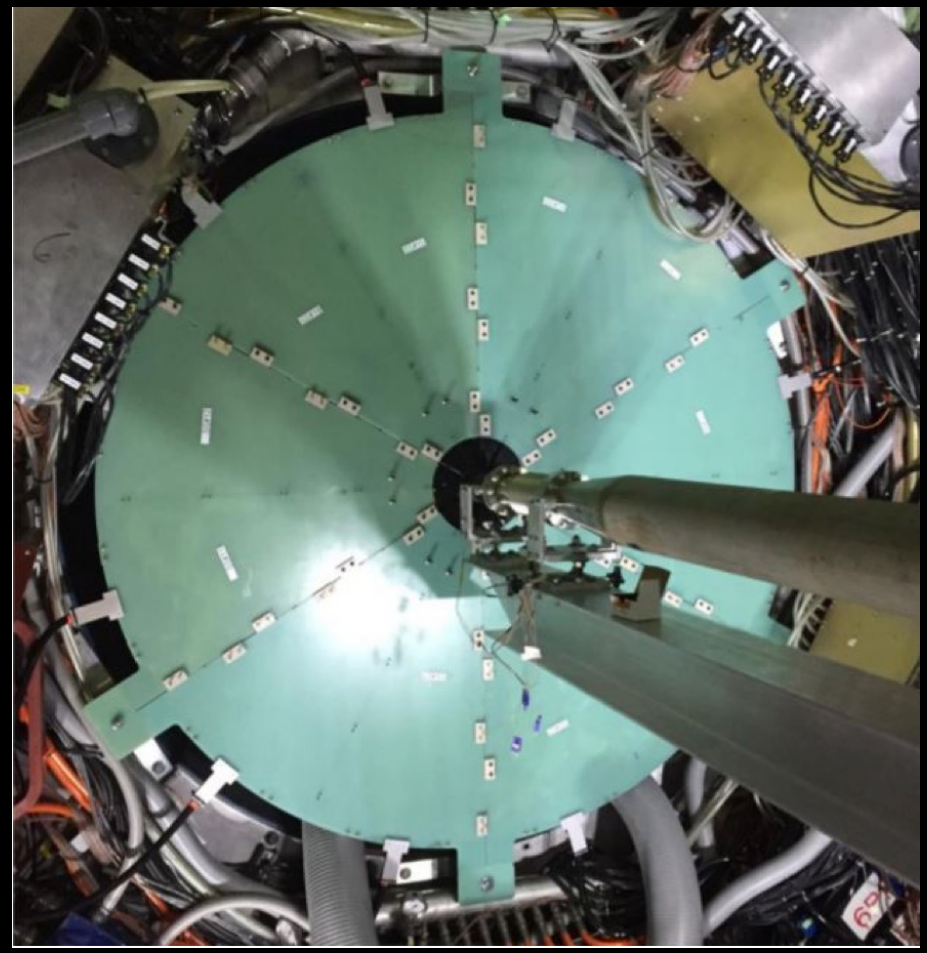




Event Plane Detector (EPD)

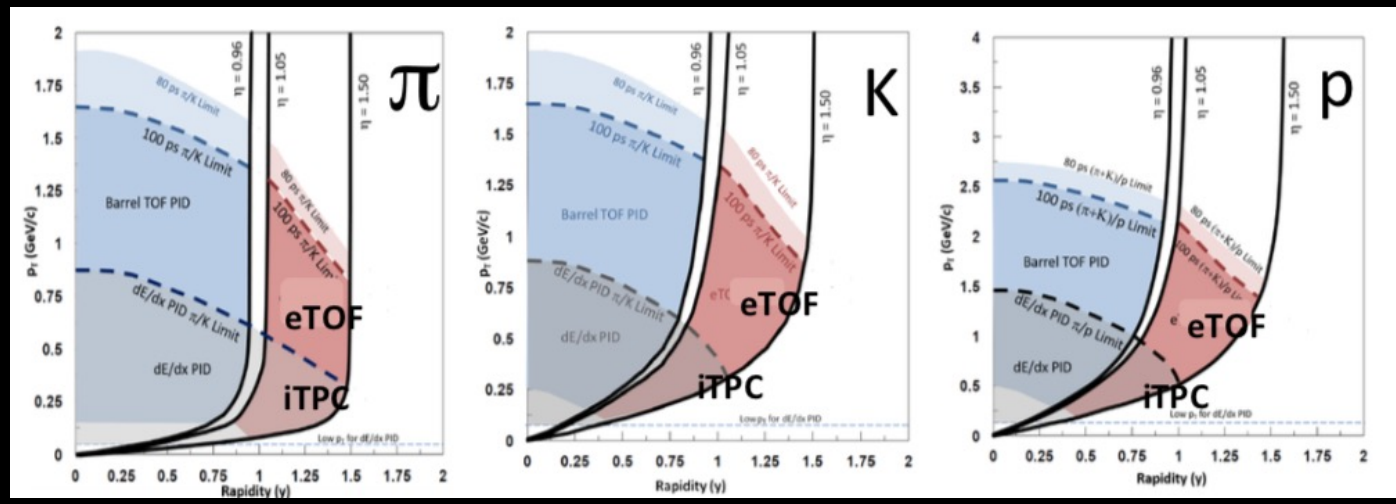
- Dedicated for event plane determination, centrality definition and triggering
  - Large η coverage: $2.1 < |\eta| < 5$
  - Excellent timing resolution: ~ 1 ns
- Started operation in STAR since 2018

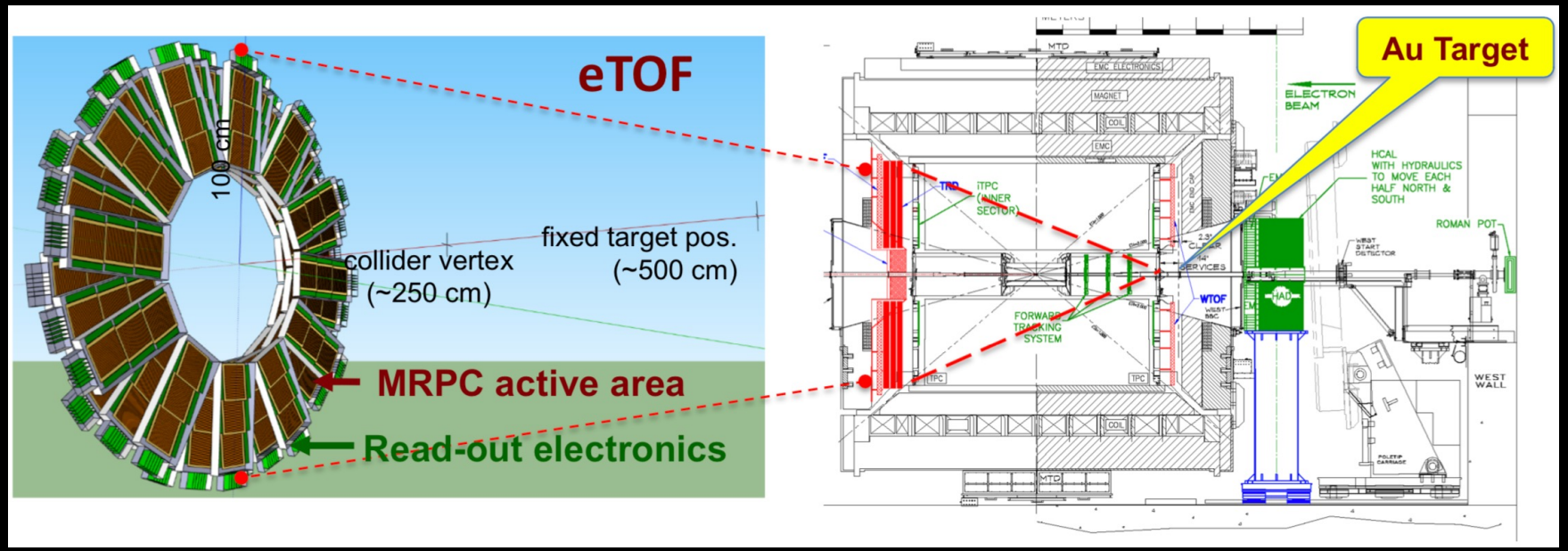




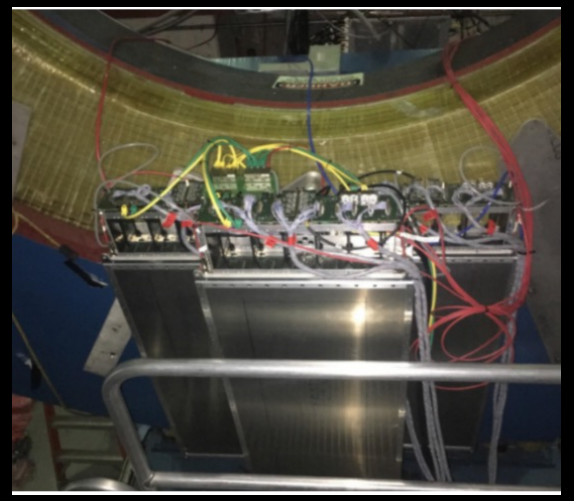
endcap Time-of-Flight (eTOF)

- Installed on one side of STAR (part of FAIR CBM Phase-0)
- Improve PID in $1.1 < \eta < 1.6$
- Started operation in 2018

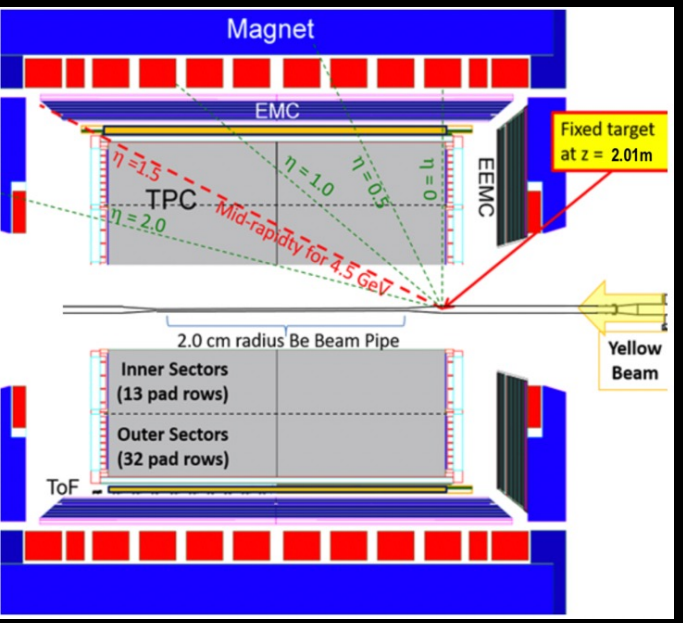


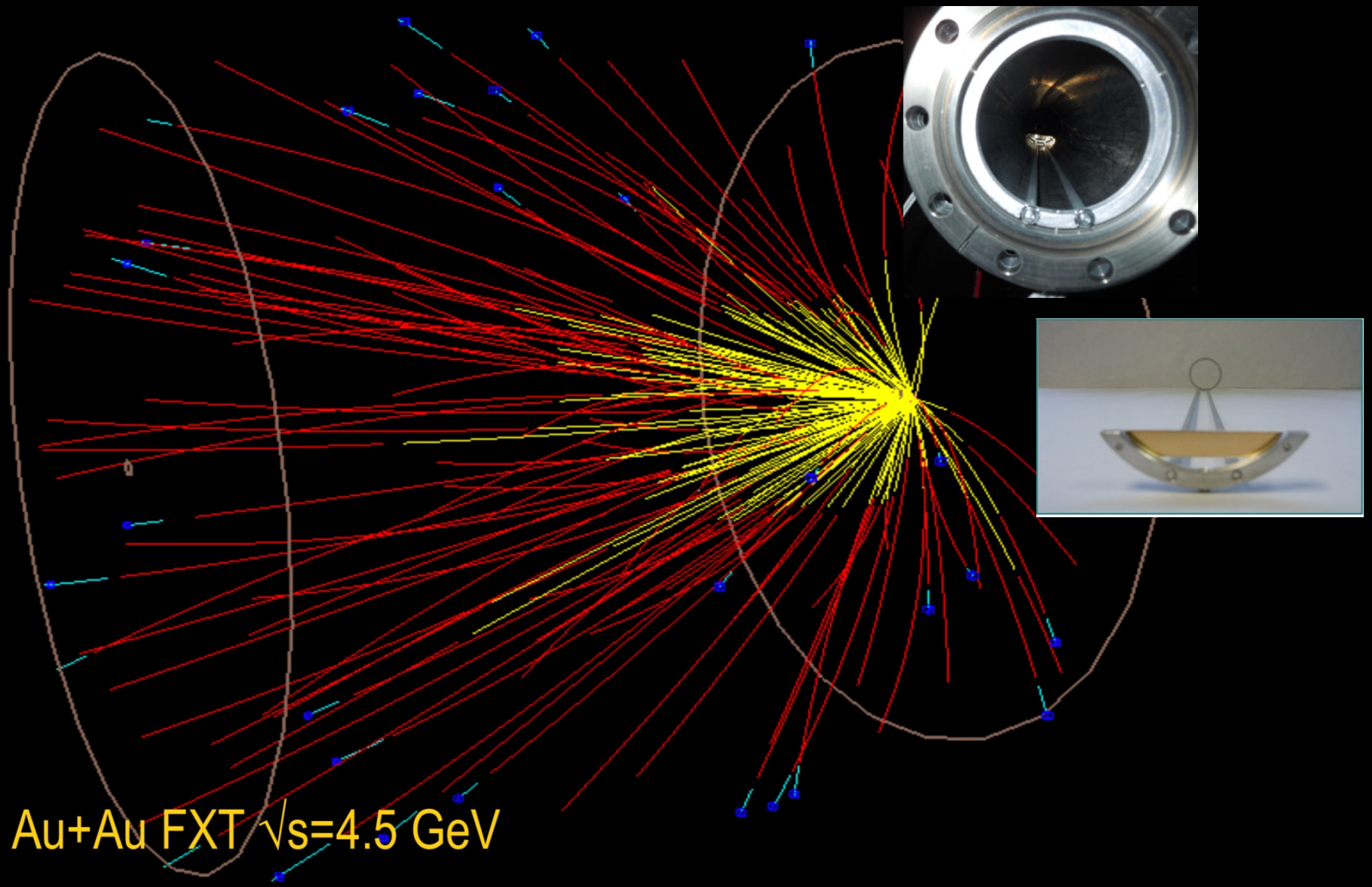


3 modules



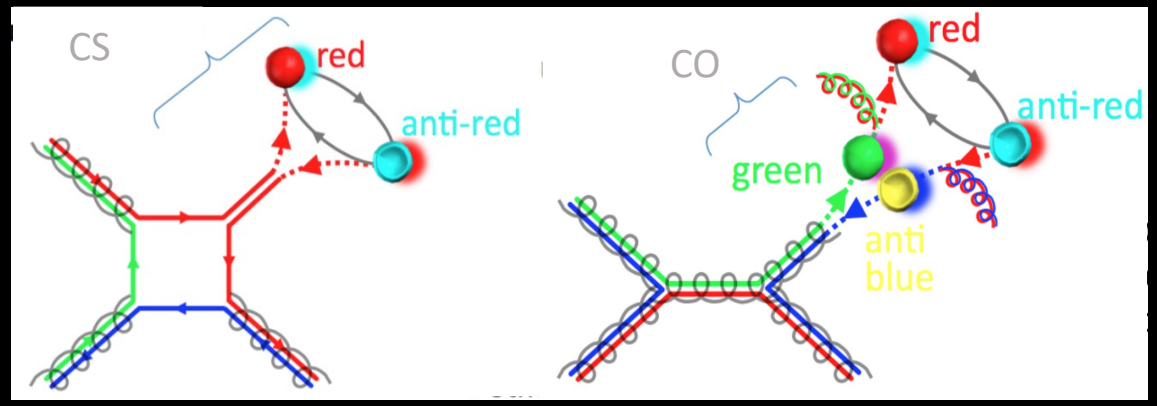
Fixed Target Au+Au Collisions in STAR

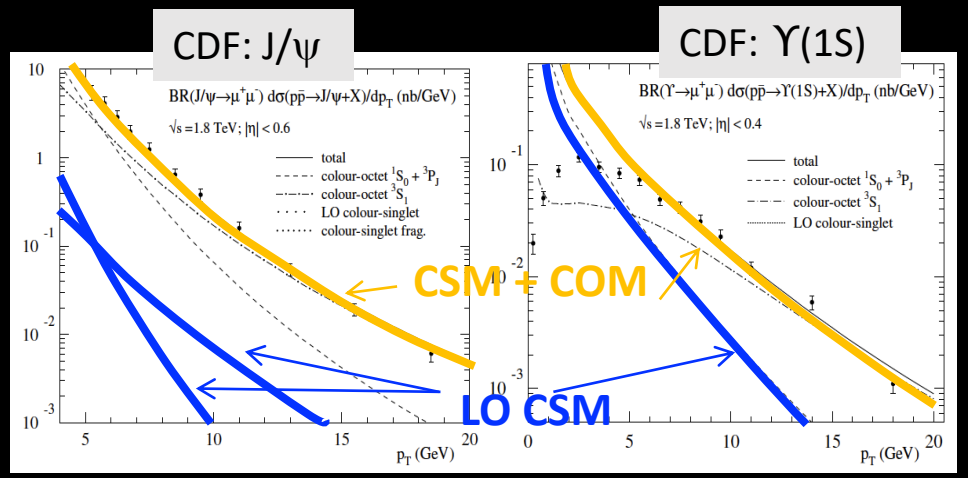


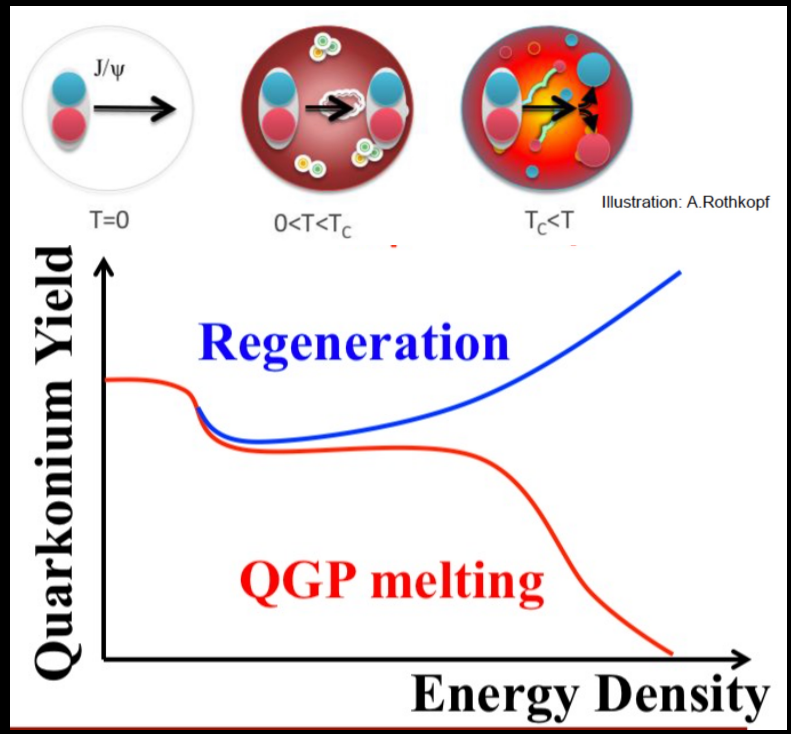


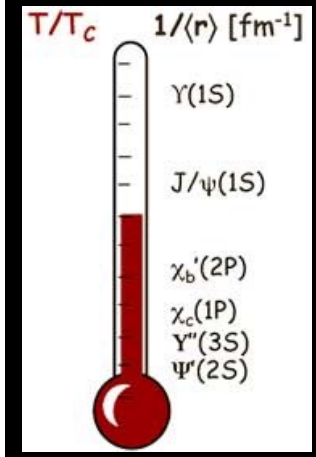
Physics Analyses @ NCKU

- Mainly focuses on heavy flavor physics (quarkonium) in both p+p, p+A and A+A collisions
- J/ψ and ϒ production, R_{AA}, with jet, v_2, …



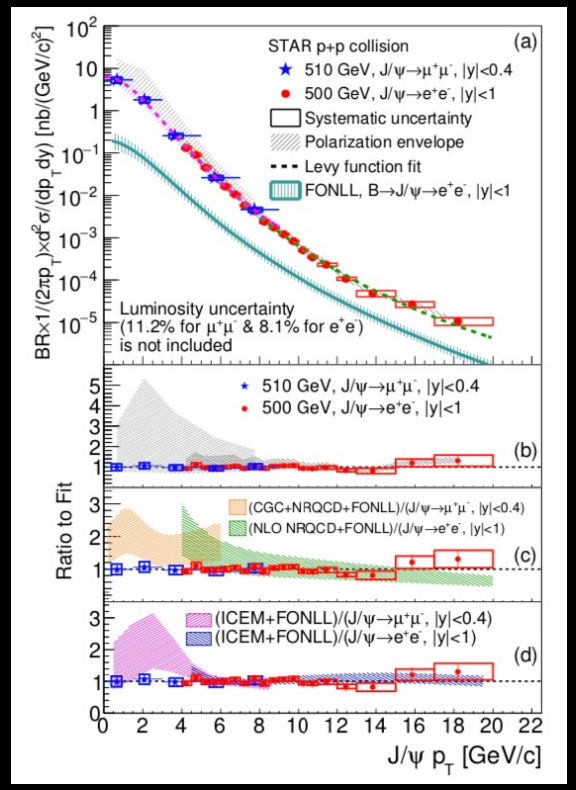


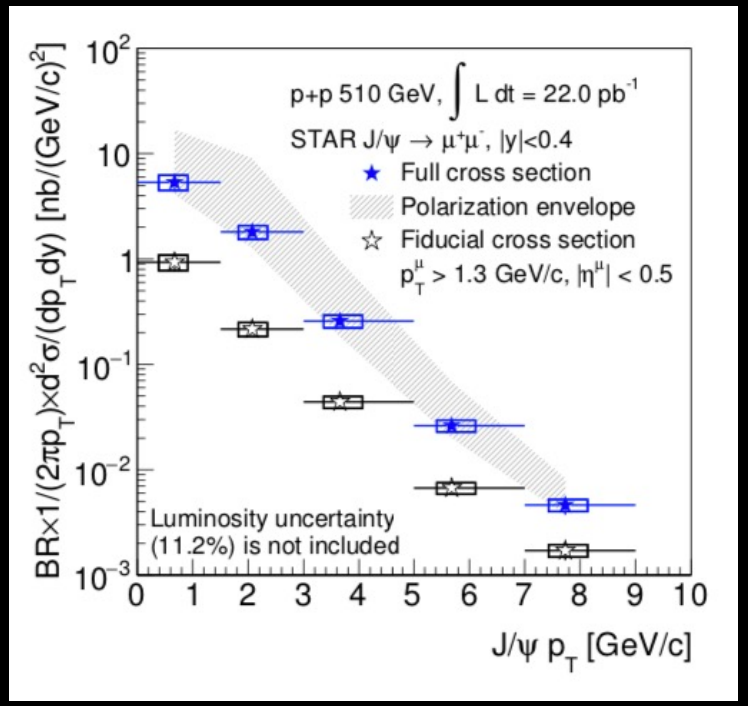


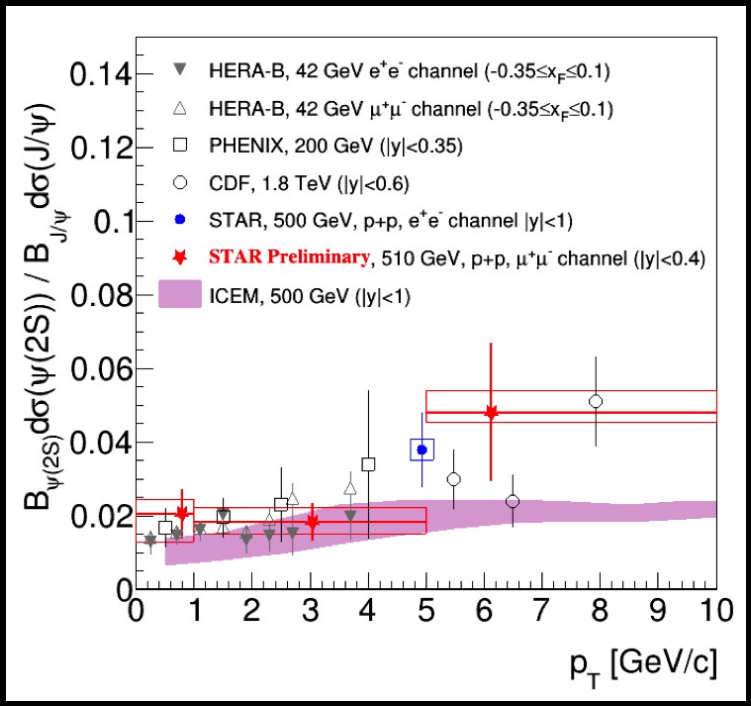


STAR Experiment: J/ψ @ p+p 500 GeV

- Precision measurement of J/ψ production cross-section in pp collisions at RHIC highest energy
- Consistent with CGC+NRQCD, NLO NRQCD calculations and ICEM
- ψ(2S) to J/ψ ratio follows the world trend (adding 2017 data)



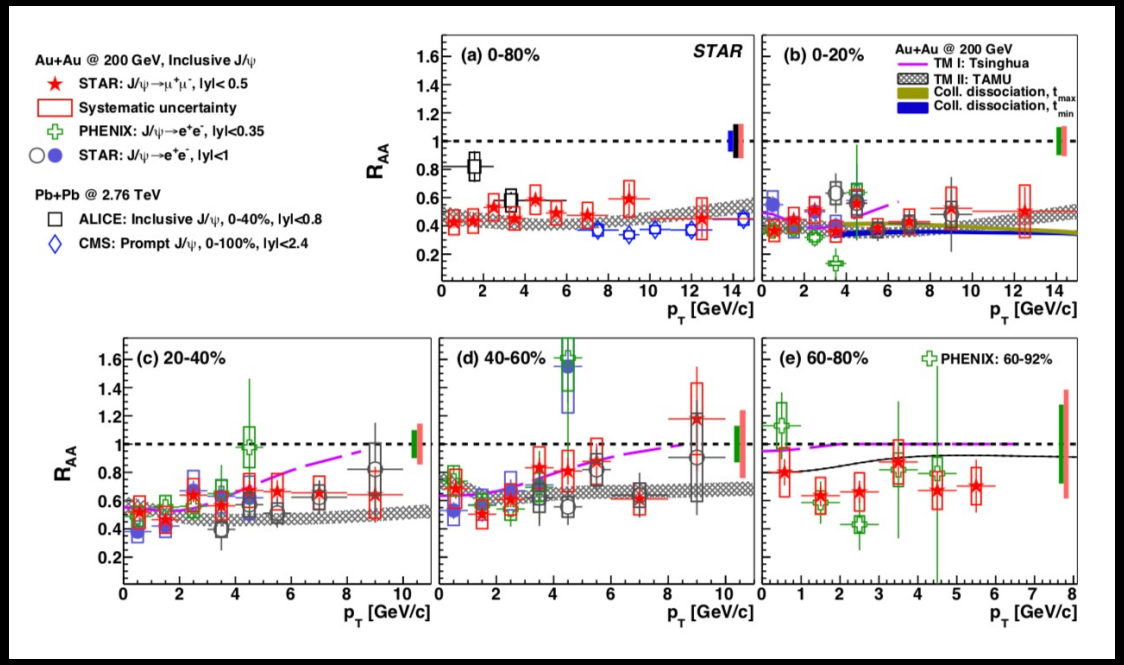


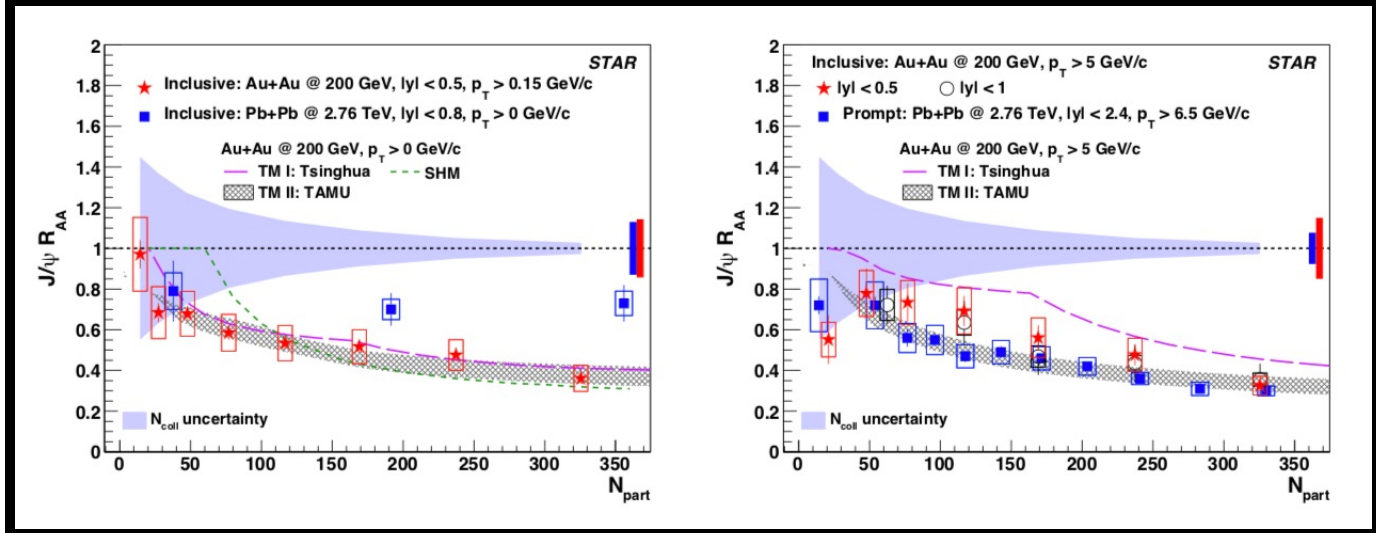


Phys. Rev. D 100, 052009, 2019

STAR Experiment: J/ψ @ Au+Au 200 GeV

- No obvious p_T dependence in R_{AA} in 0 - 20% centrality bin
- Suppression at low p_T: dissociation, Cold Nuclear Matter (CNM) effect, regeneration
- Strong suppression at high p_T in central collisions is a clear sign of dissociation
- RHIC vs. LHC
  - p_T > 0 GeV/c: Larger contribution from regeneration at LHC
  - p_T > 5 GeV/c: lLarger dissociation rate at LHC

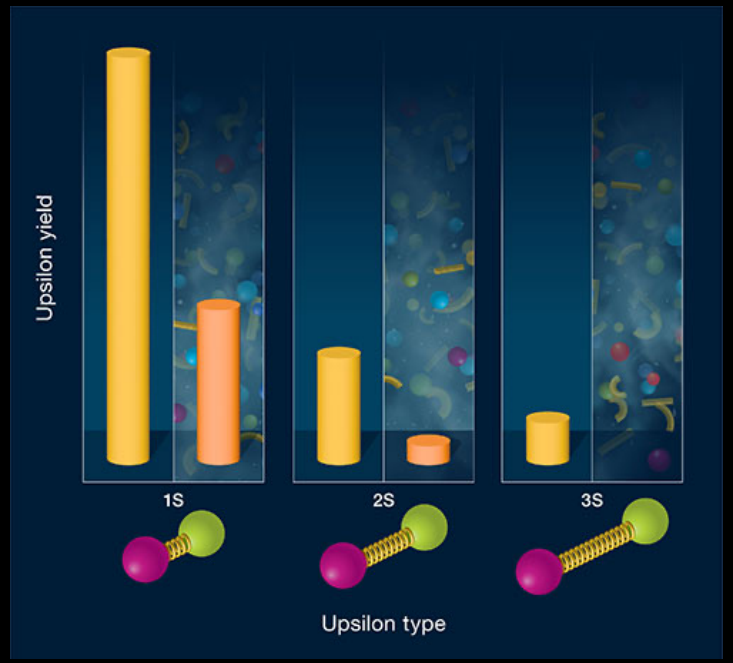


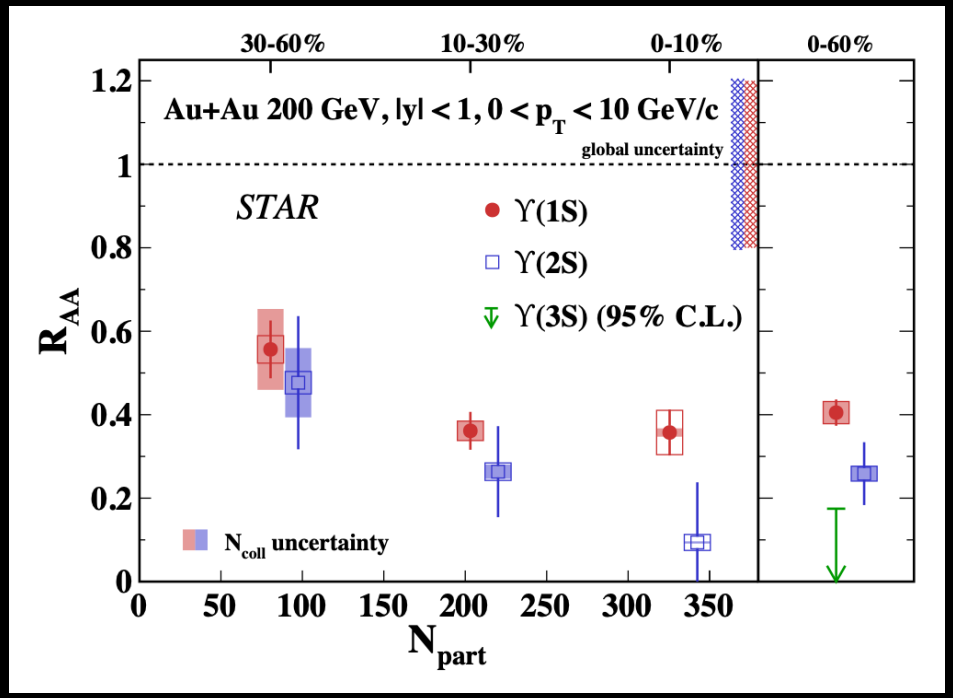


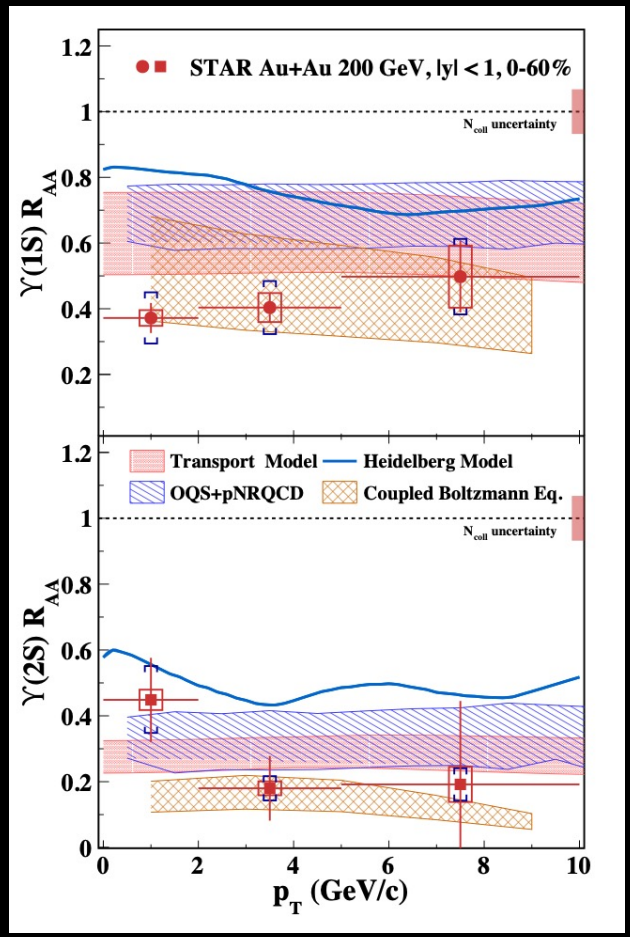
PLB 797 134917, 2019

STAR Experiment: Υ(ns) @ Au+Au 200 GeV

- Suppression increasing with centrality
- Υ(2S) and Υ(3S) is more suppressed than Υ(1S), in central collisions → **Sequential melting**
- RHIC vs. LHC:
  - Υ(1S): similar suppression as the CMS measurement
  - Υ(2S+3S): hint of less suppression at RHIC than at LHC



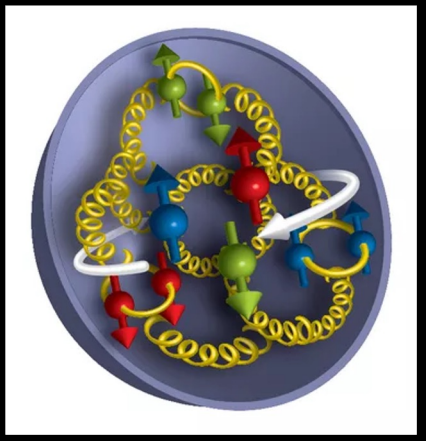




Phys. Rev. Lett. 130 (2023) 112301

Cold QCD Program @ RHIC (2021+)

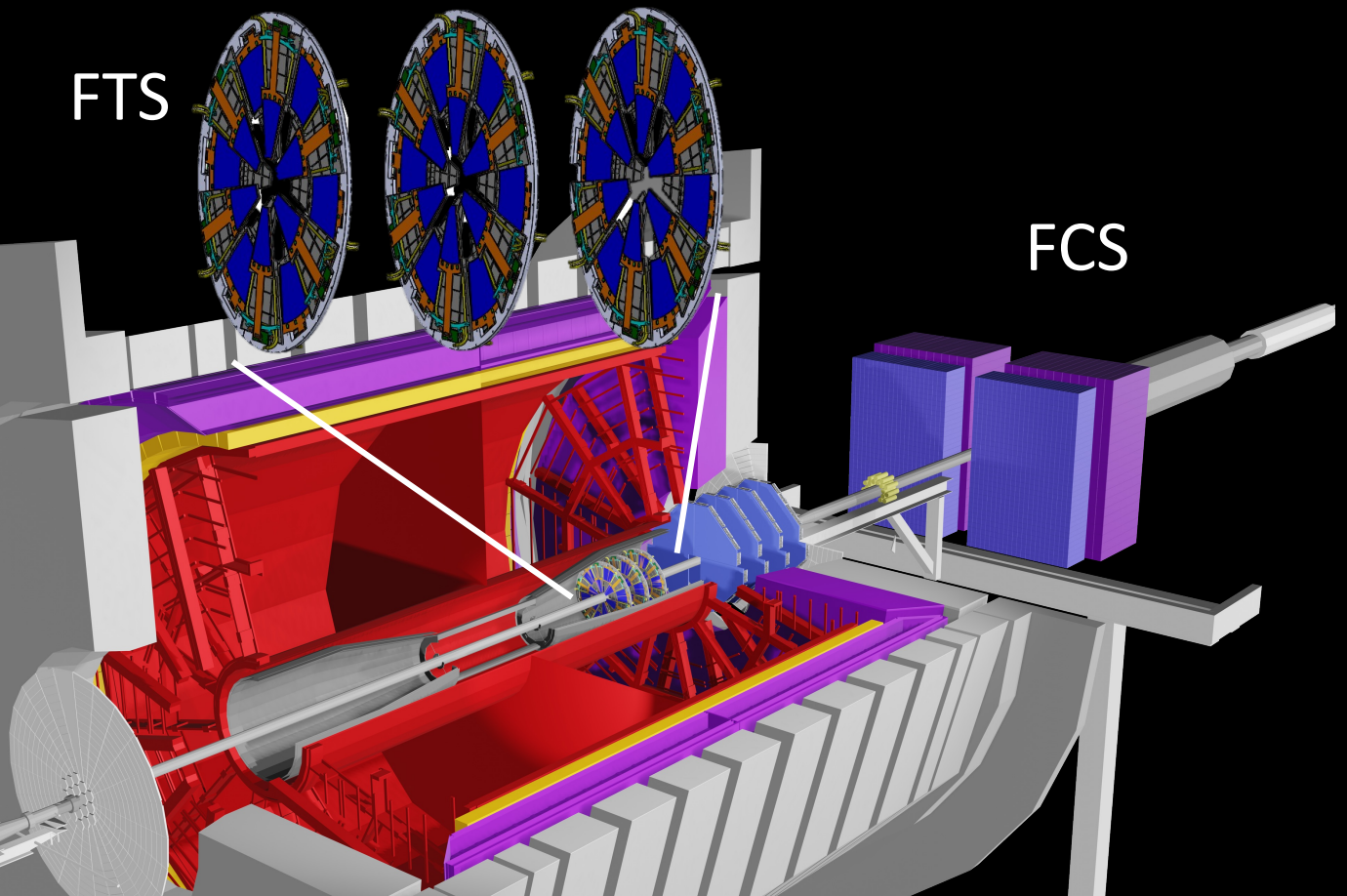
- RICH provides unique opportunity to understand
  - How do sea quarks and gluons contribute spins to nucleon?
  - How do the confined hadronic states emerge from these quarks and gluons?
  - And more…



	Year	√s (GeV)	Delivered Luminosity	Scientific Goals	Observable	Required Upgrade
Potential running	2021/22	p↑p @ 510	1.1 fb^{-1} 10 weeks	TMDs at low and high x	A_{UT} for Collins observables, i.e. hadron in jet modulations at $\eta > 1$	ECal+HCal+Tracking
	2021/22	$\overrightarrow{p}\overrightarrow{p}$ @ 510	1.1 fb^{-1} 10 weeks	Δg(x) at small x	A_{LL} for jets, di-jets, h/g-jets at $\eta > 1$	ECal+HCal
In parallel with sPHENIX running		p↑p @ 200	300 pb^{-1} 8 weeks	Subprocess driving the large A_N at high x_F and h	A_N for charged hadrons and flavor enhanced jets	ECal+HCal+Tracking
		p↑Au @ 200	1.8 pb^{-1} 8 weeks	initial state and hadronization in nuclear collisions signatures for Saturation	R_{pAu} direct photons and DY Dihadron, g-jet, h-jet, diffraction	ECal+HCal+Tracking
		p↑Al @ 200	12.6 pb^{-1} 8 weeks	A-dependence of nPDF, A-dependence for Saturation	R_{pAl}: direct photons and DY Dihadrons, g-jet, h-jet, diffraction	ECal+HCal+Tracking

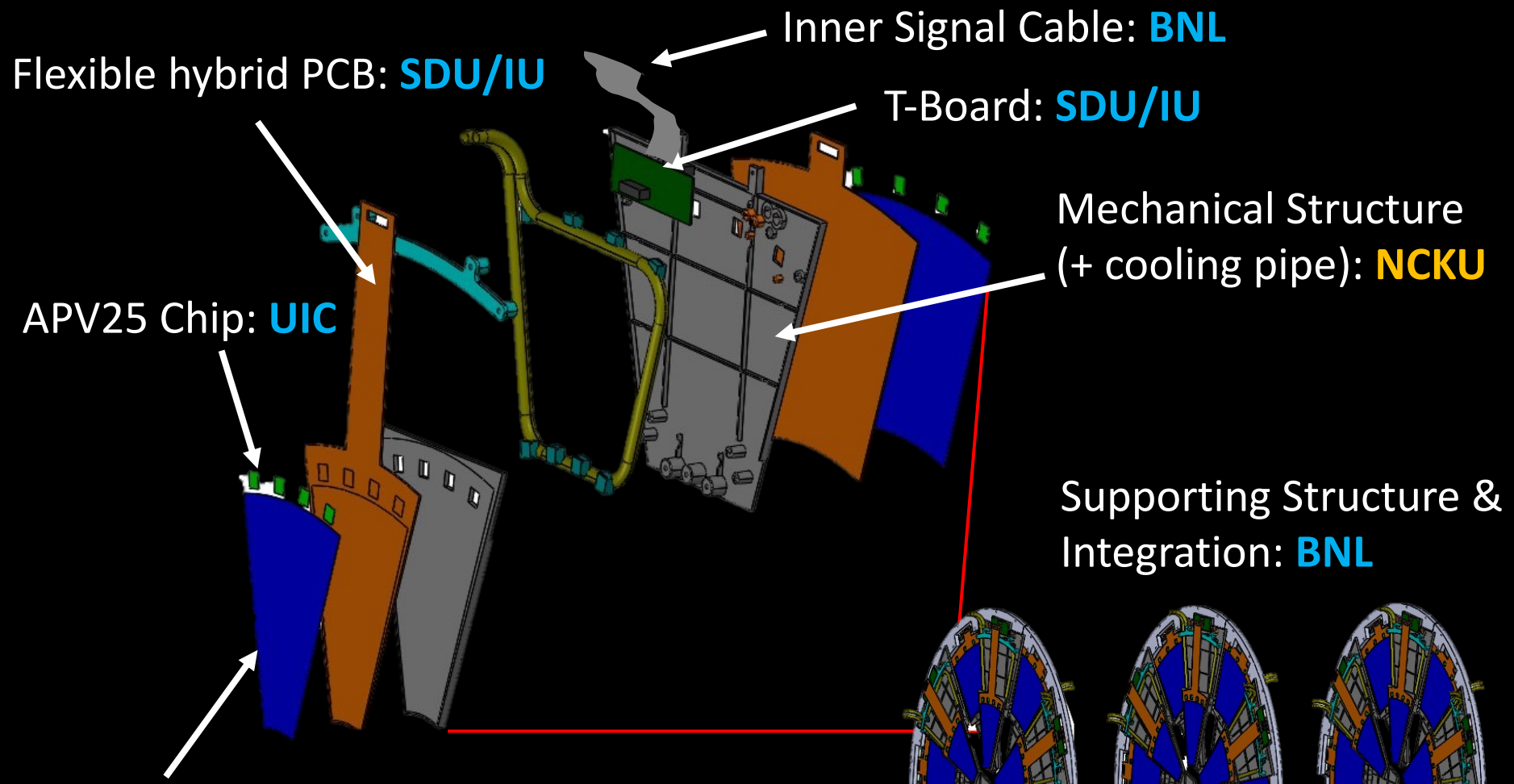
STAR Forward Upgrades

- STAR installed the forward upgrades including **Calorimeters (ECAL & HCAL)** and **Trackers (silicon tracker & sTGC)** dedicated for studying the nuclear structure, QGP, and so on



Detector	pp and pA	AA
ECAL	~10%/√E	~20%/√E
HCAL	~60%/√E	---
Tracking	Charge separation Photon suppression	$0.2 < p_T < 2$ GeV/c with 20 – 30% $1/p_T$

STAR Forward Upgrades – Silicon Tracker



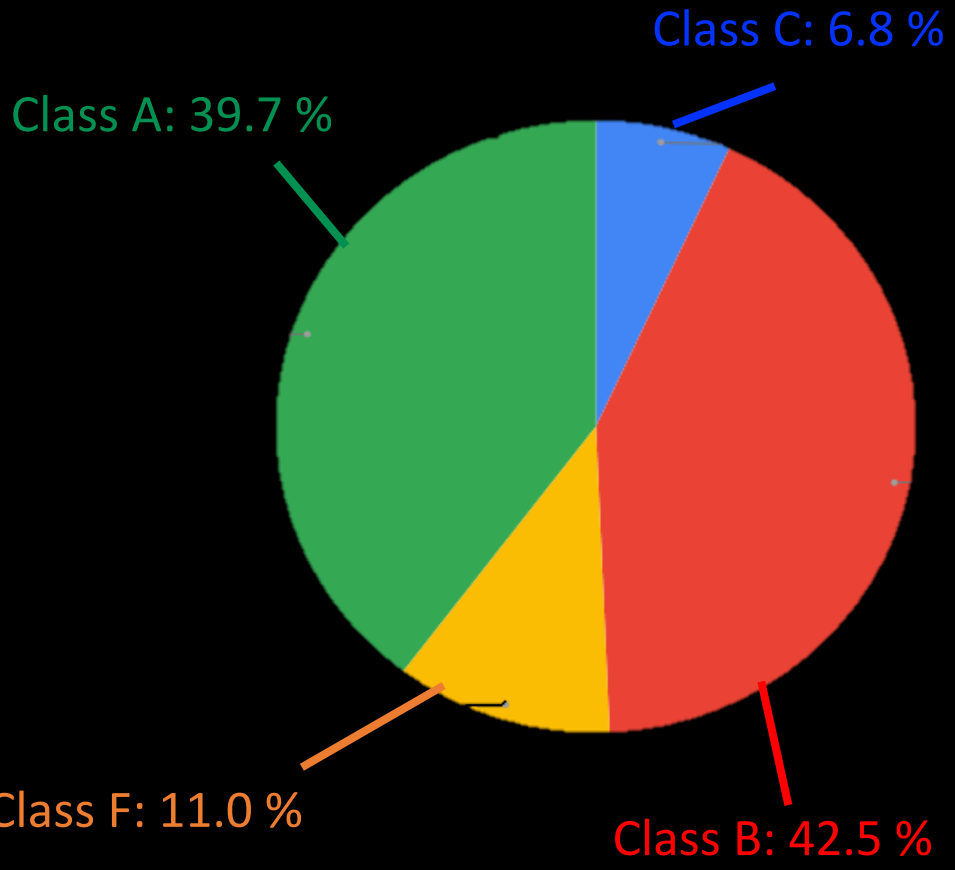
Cooling BNL/NCKU

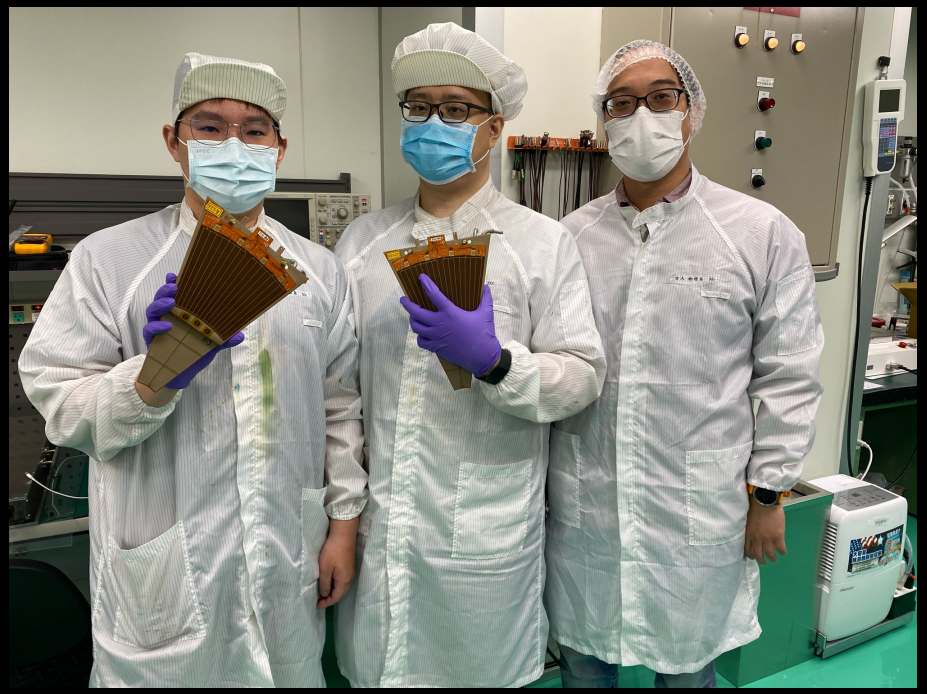
Simulation: UIC/NCKU

STAR FST Modules Assembly @ TIDC

- Total 73 modules are produced

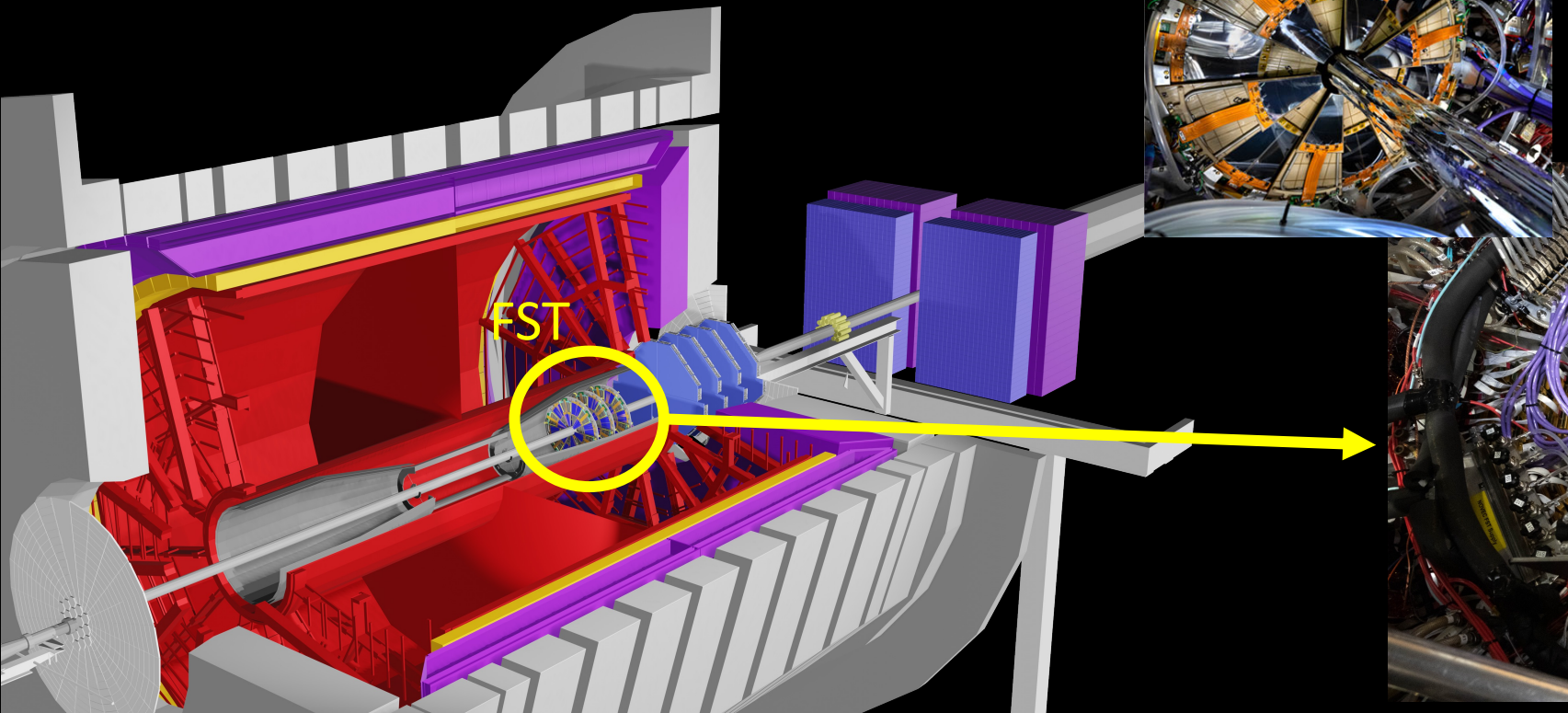
→ **Successful rate ~89%**

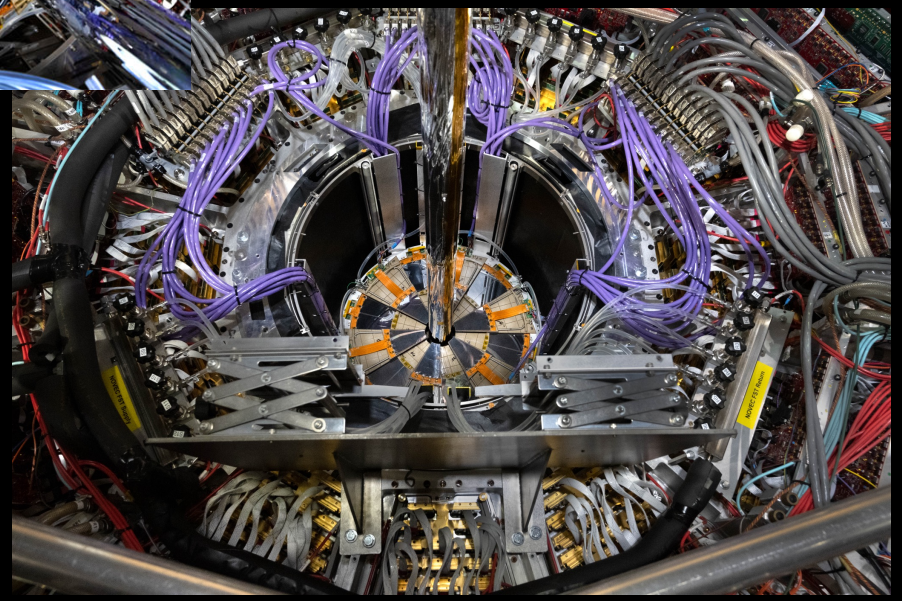




STAR Forward Silicon Tracker: Installation

- NCKU designed and manufactured the mechanical structure for the silicon tracker and is working on the sensor development
- Installed at STAR in August 2021





Summary

- STAR experiment is one of the most important high energy nuclear physics experiments in the world
- NCKU dedicates into physics analysis and detector R&D + construction
- More important and interesting results will be available soon