Recent Results from STAR

In-Kwon YOO for the STAR Collaboration

Department of Physics
Pusan National University

BARYONS07 Internat'l Conference

Outline

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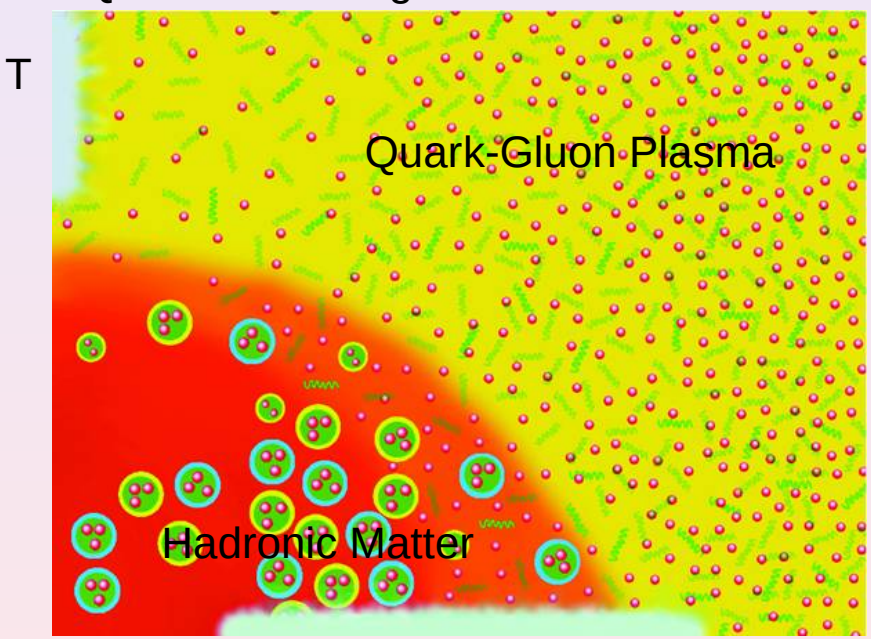
Matter in Extremes : Quark-Gluon Plasma

QCD Phase diagram of Nuclear Matter



- Lattice QCD predicts a phase transition from hadronic matter to a deconfined state of quarks, Quark-Gluon Plasma
- At RHIC Energies : Partons are expected to loose energy in the hot and dense QCD matter
- sQGP : Strongly Interacting QGP
- Perfect Liquid : no viscosity, opaque QGP

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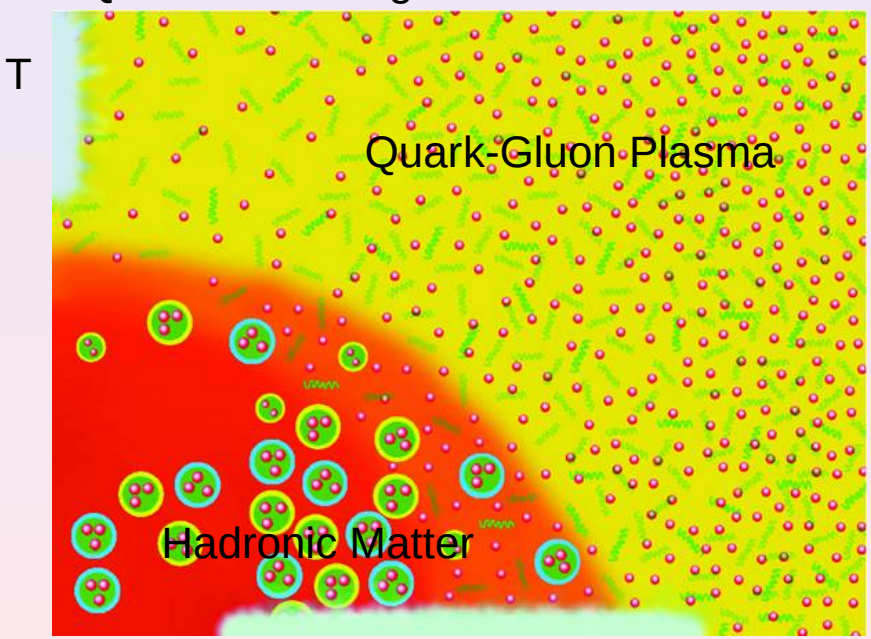

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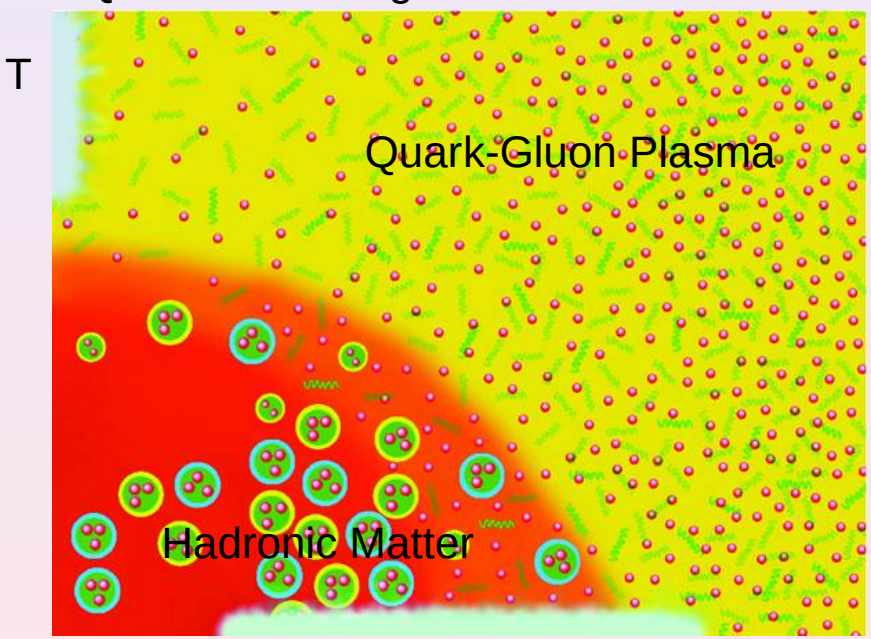

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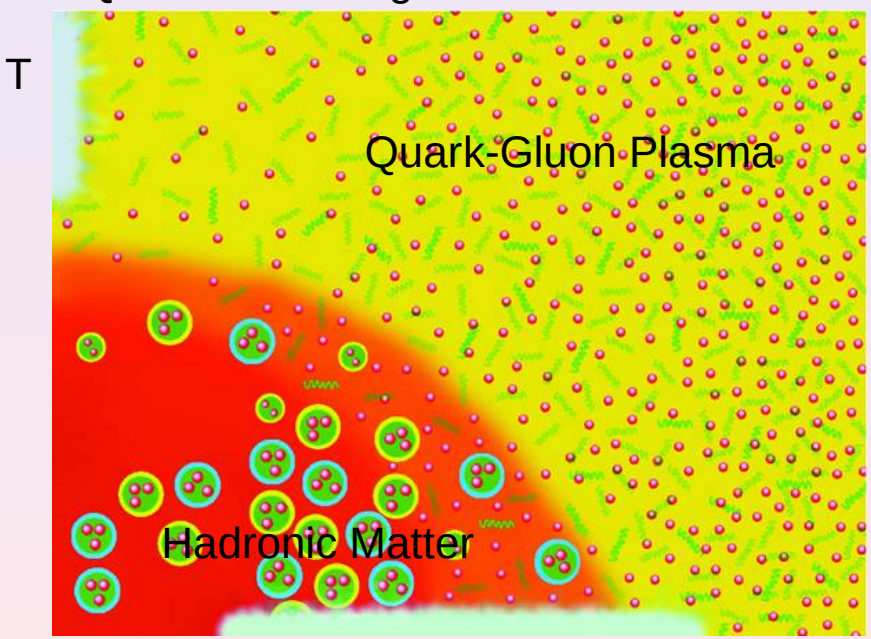

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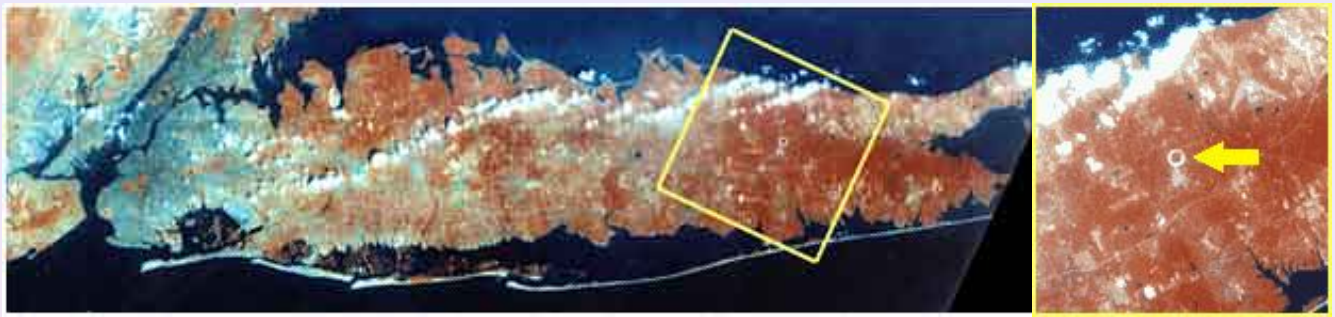
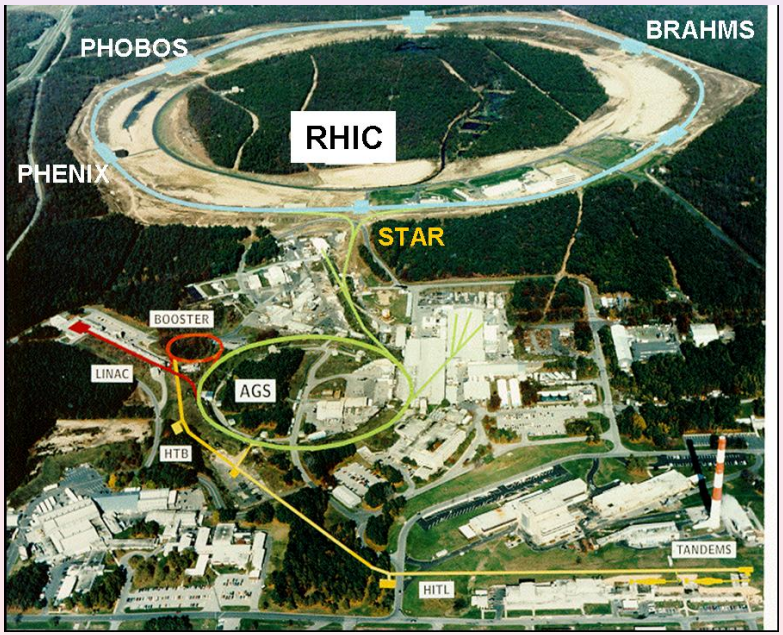
Relativistic Heavy Ion Collider at BNL





- AuAu at $\sqrt{s}$ =19.6, 62, 130, 200 AGeV
- CuCu at $\sqrt{s}$ =200 AGeV
- dAu at $\sqrt{s}$ =200 AGeV
- polarized pp at $\sqrt{s}$ =200 AGeV

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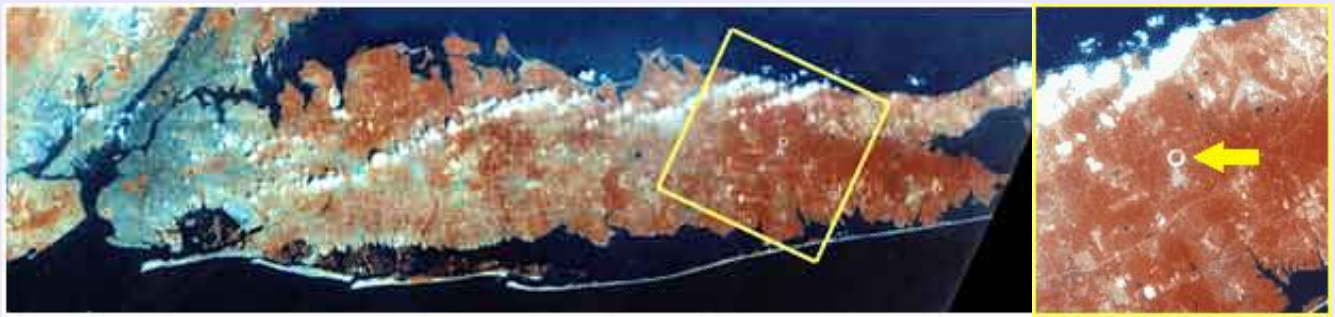

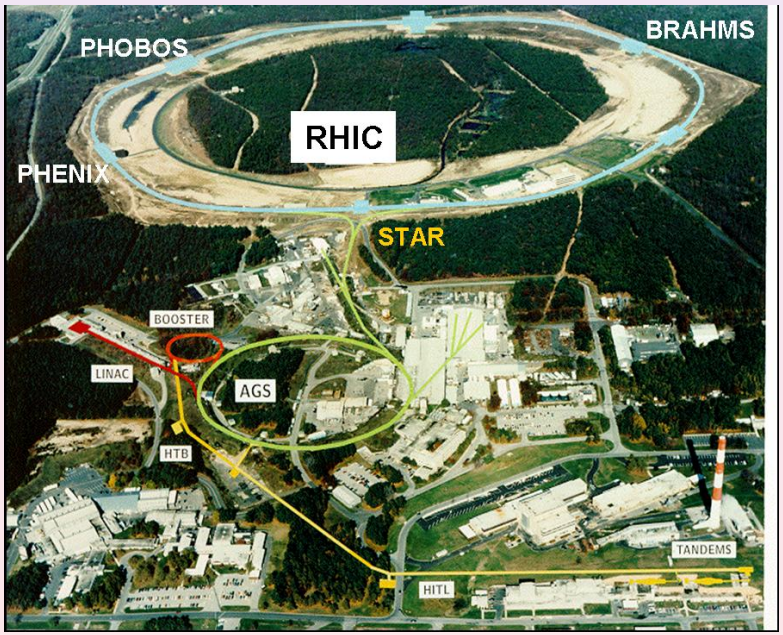

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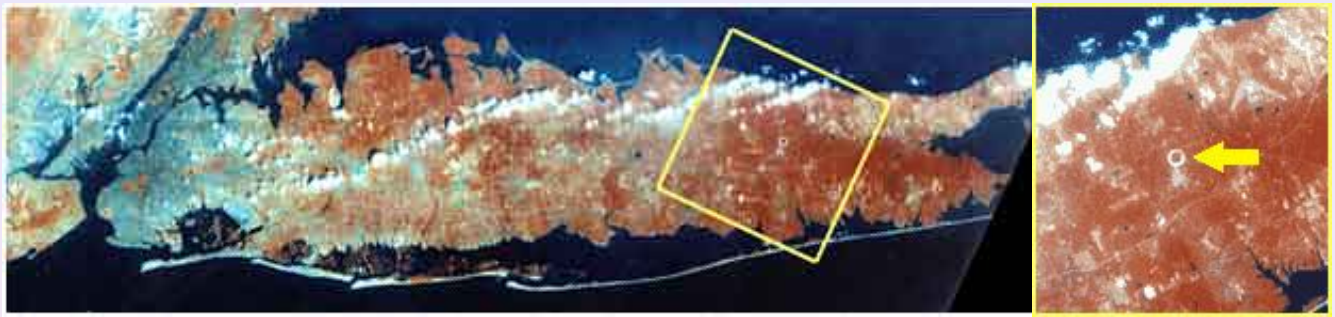

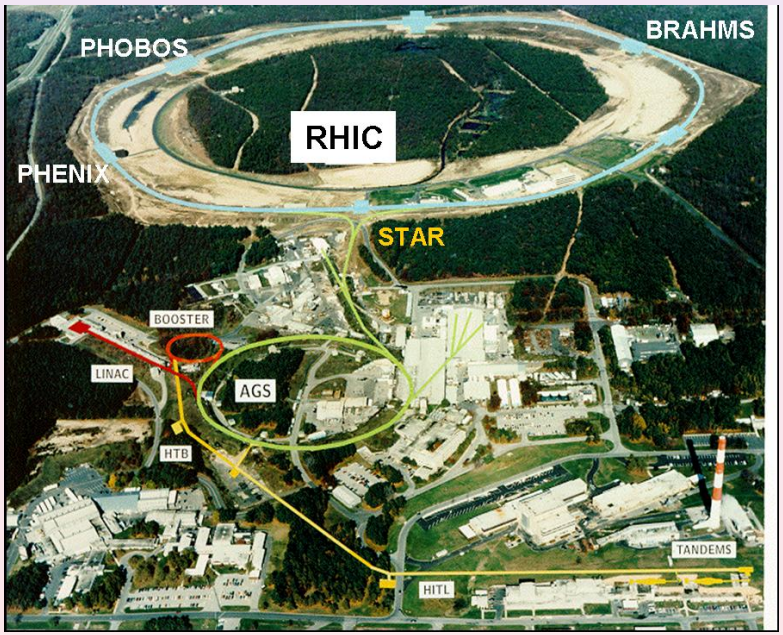

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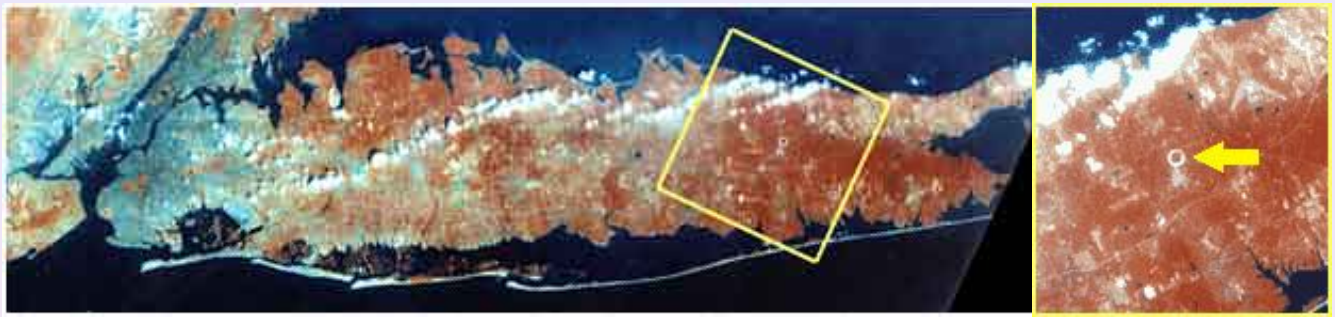

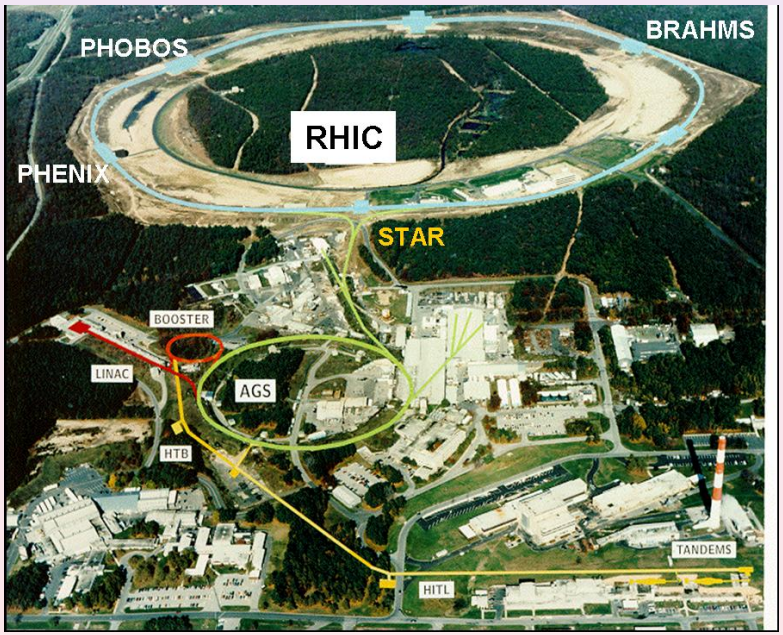

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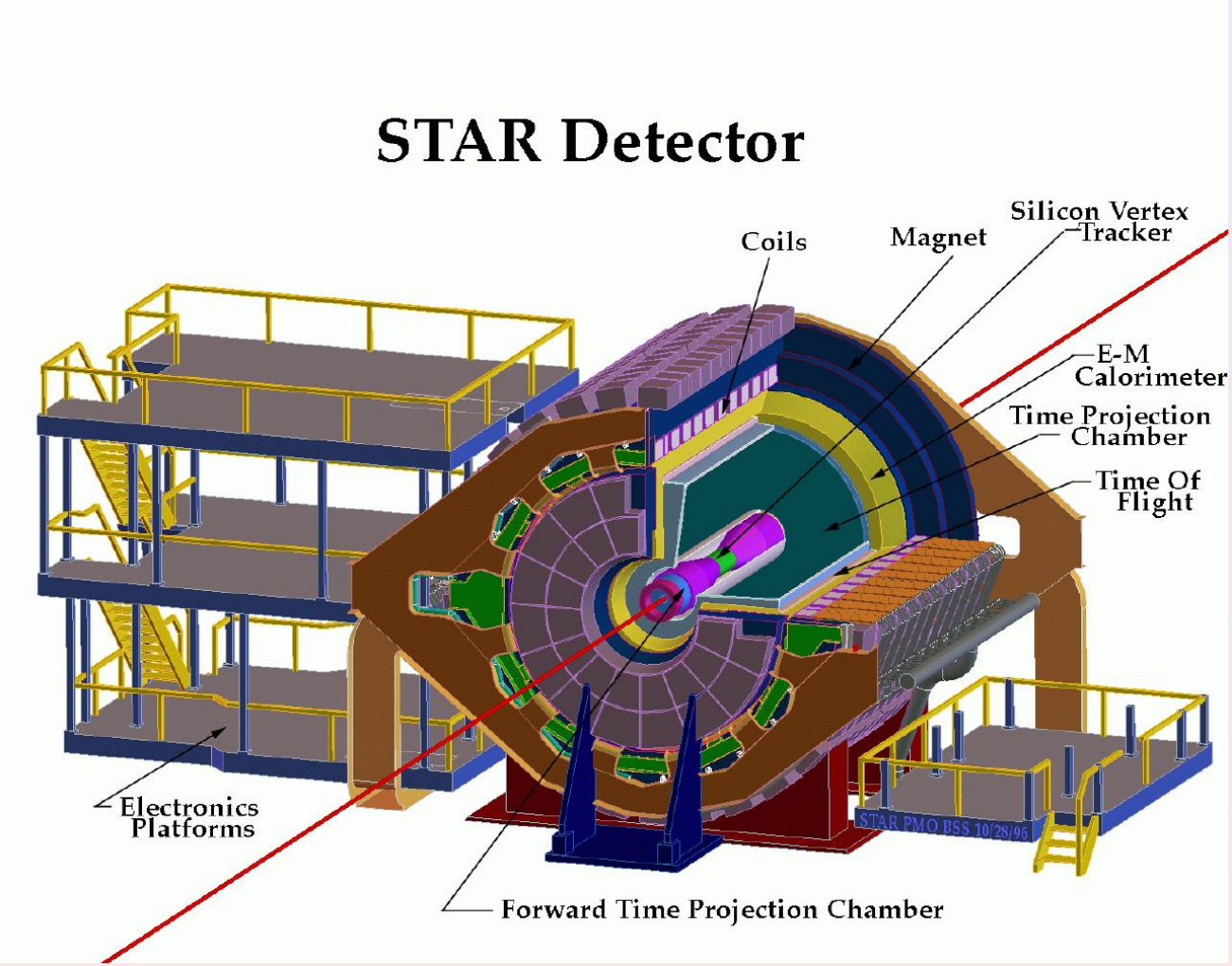
Solenoidal Tracker At Rhic



STAR Detector Configuration

Magnet and Coils

Barrel EMC

Central Trigger Barrel

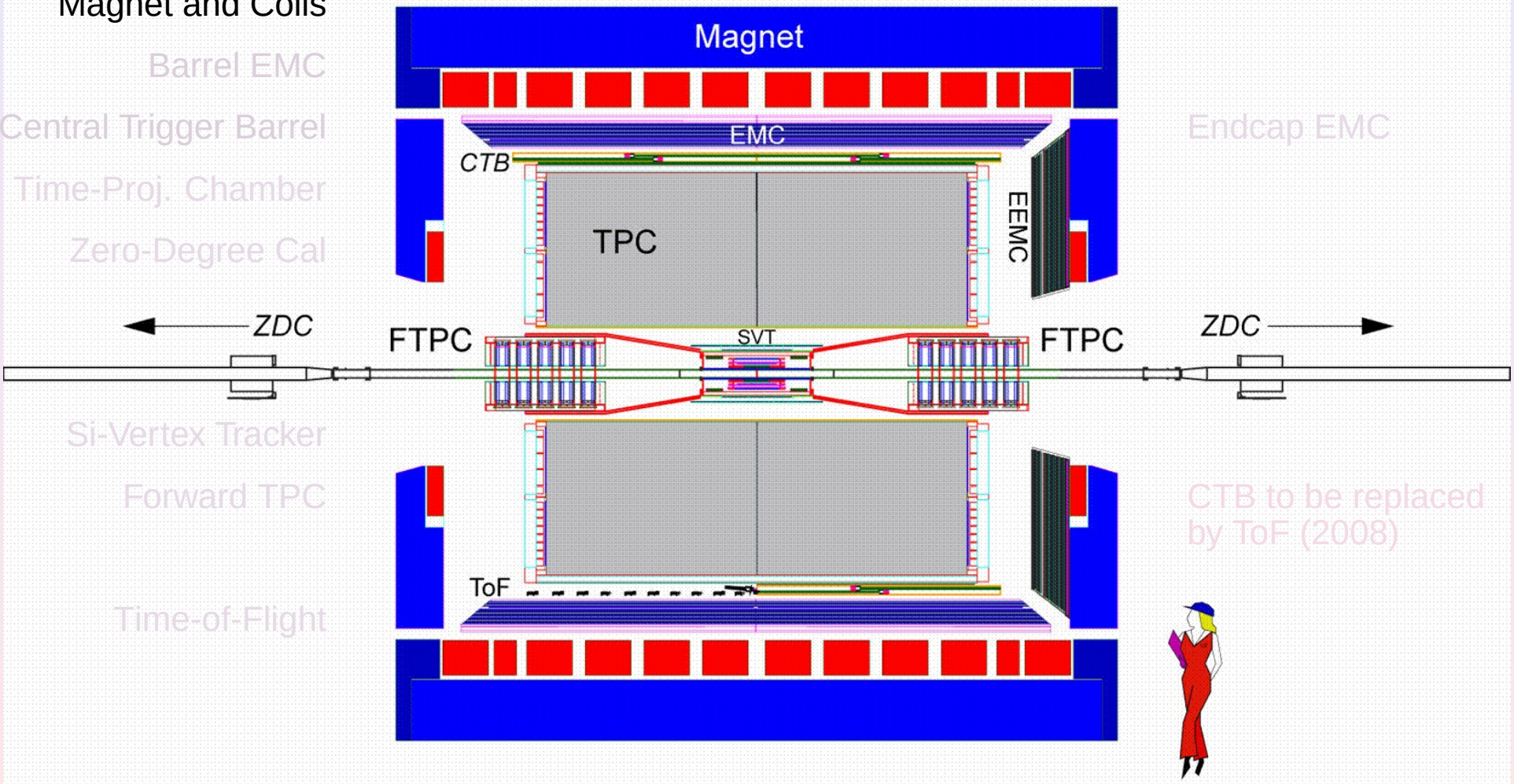
Time-Proj. Chamber

Zero-Degree Cal

Si-Vertex Tracker

Forward TPC

Time-of-Flight



Endcap EMC

CTB to be replaced by ToF (2008)

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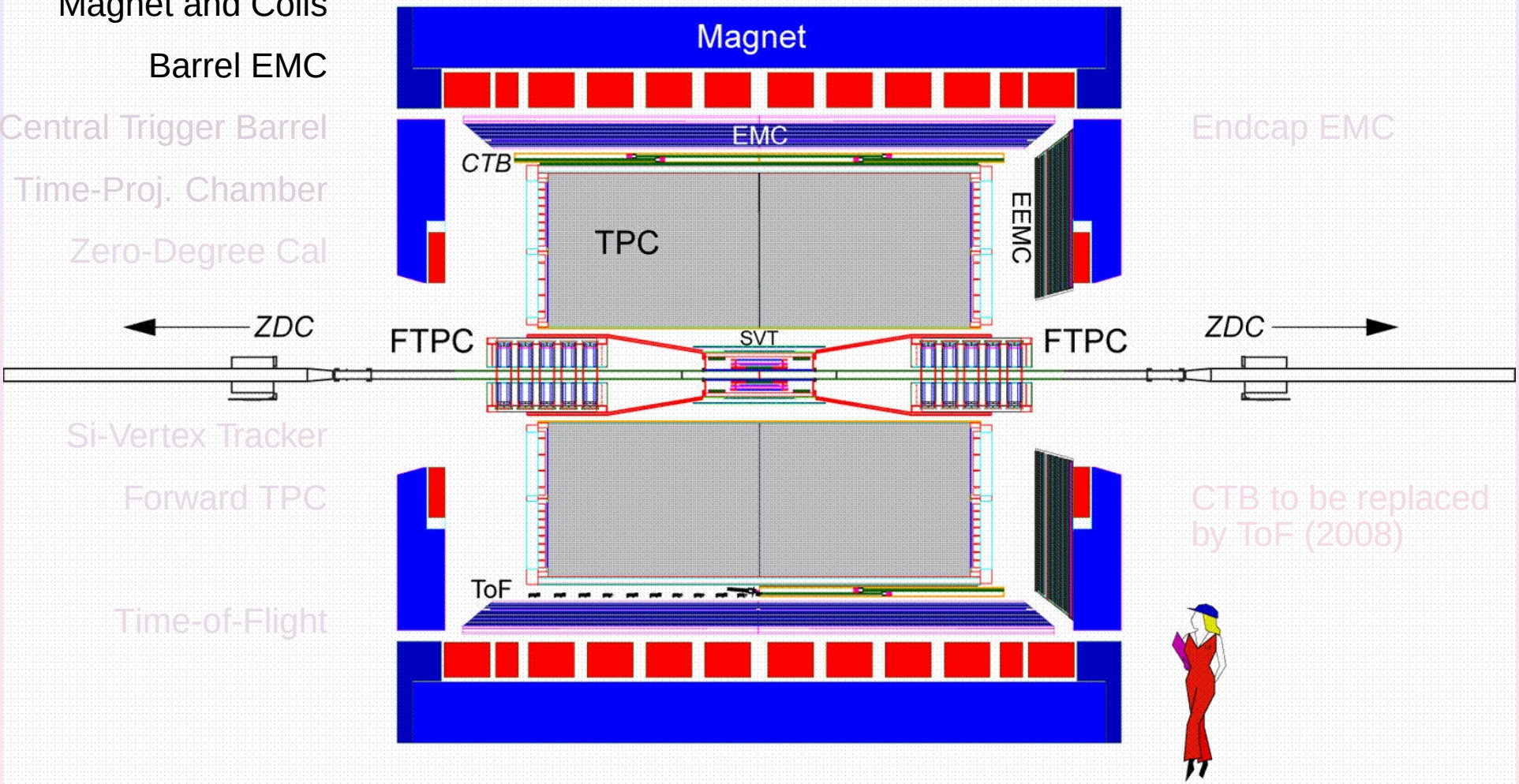

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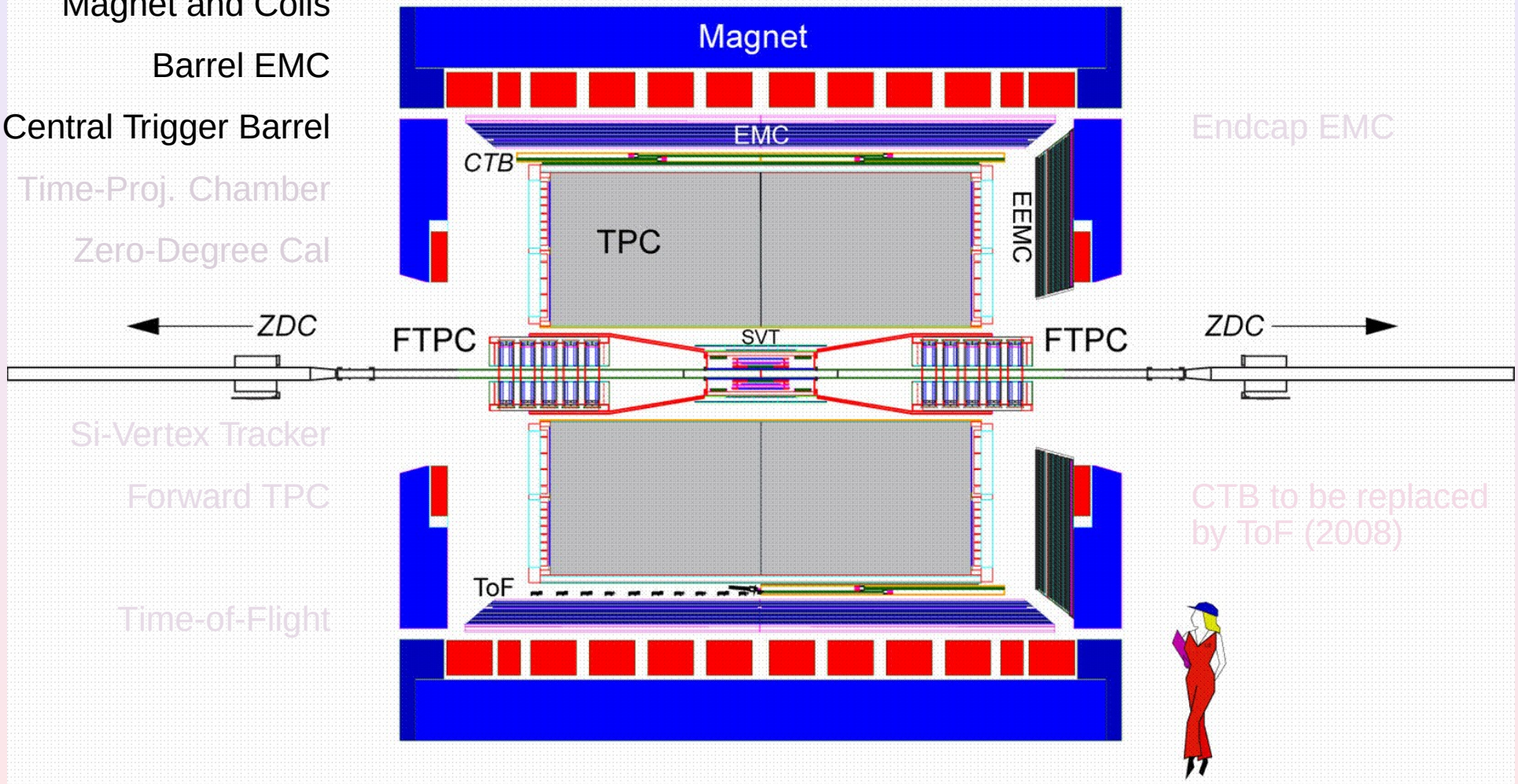

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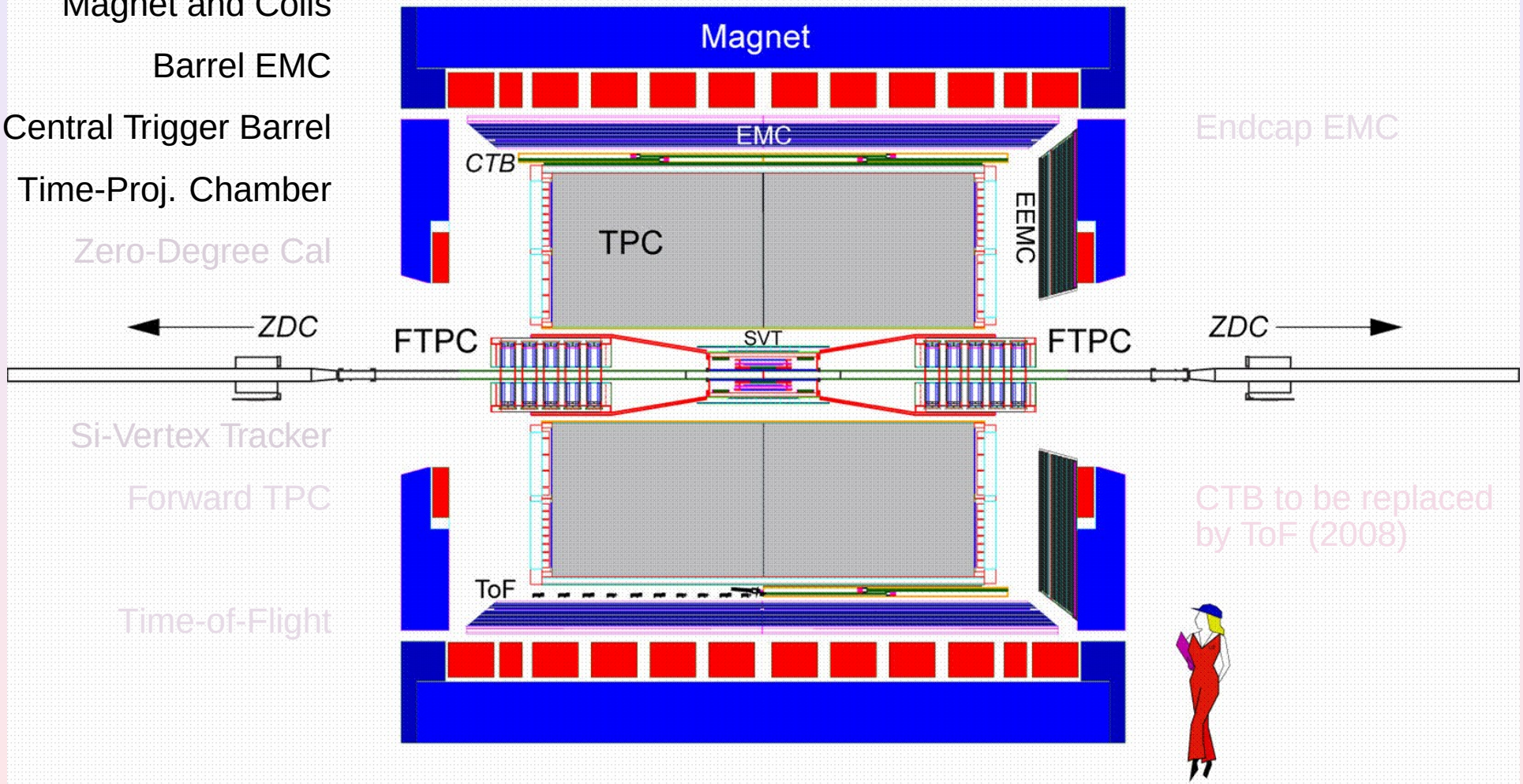

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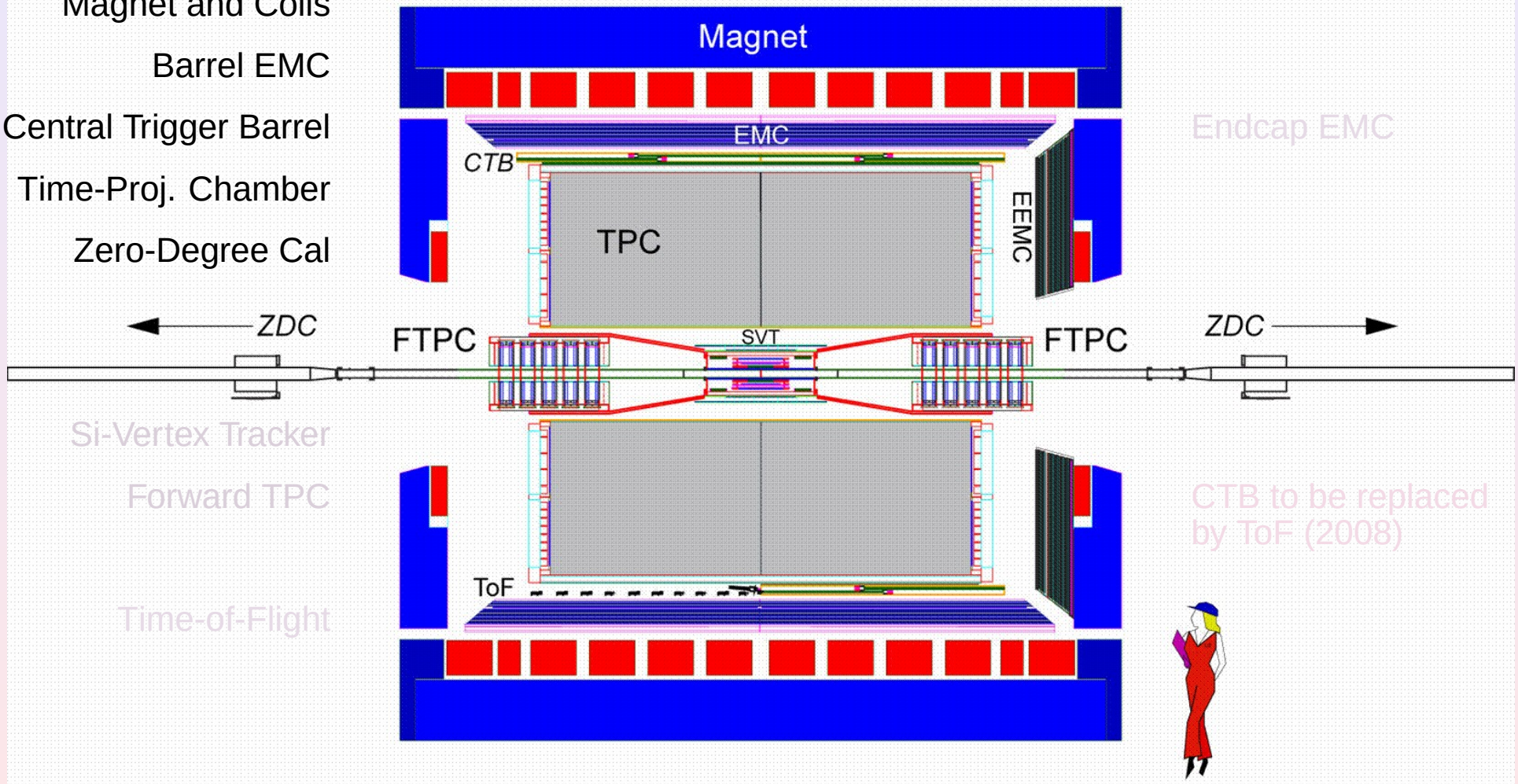

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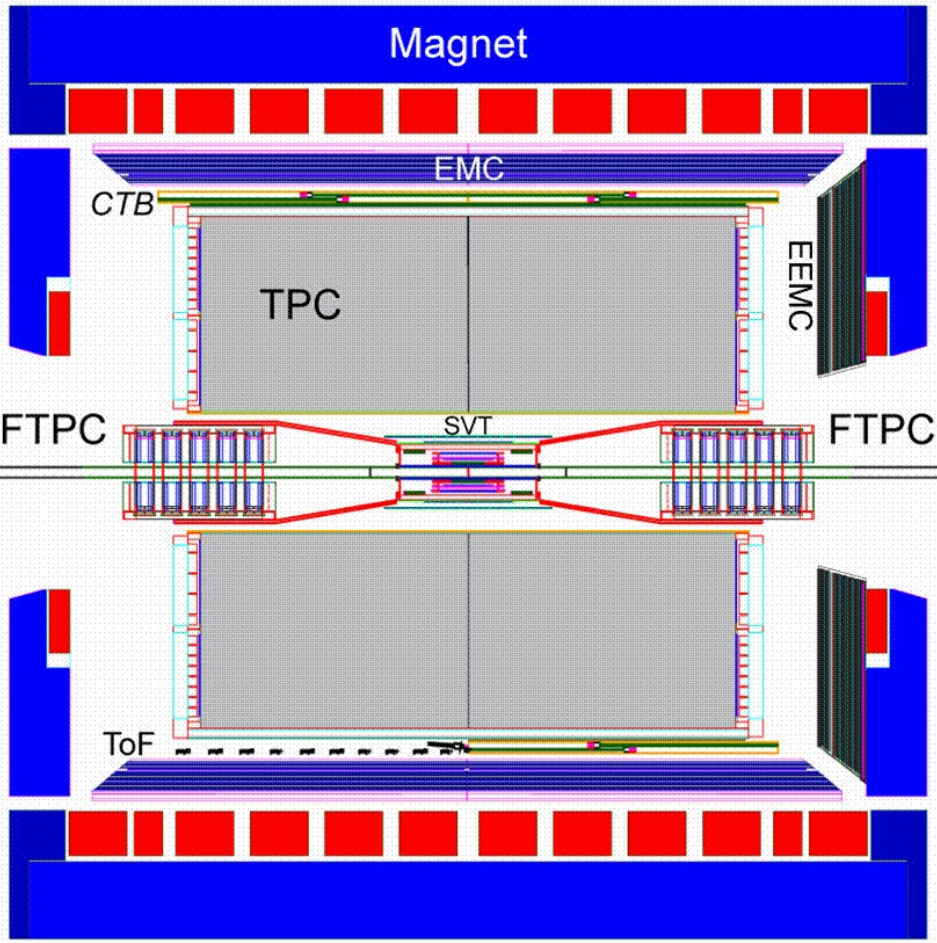

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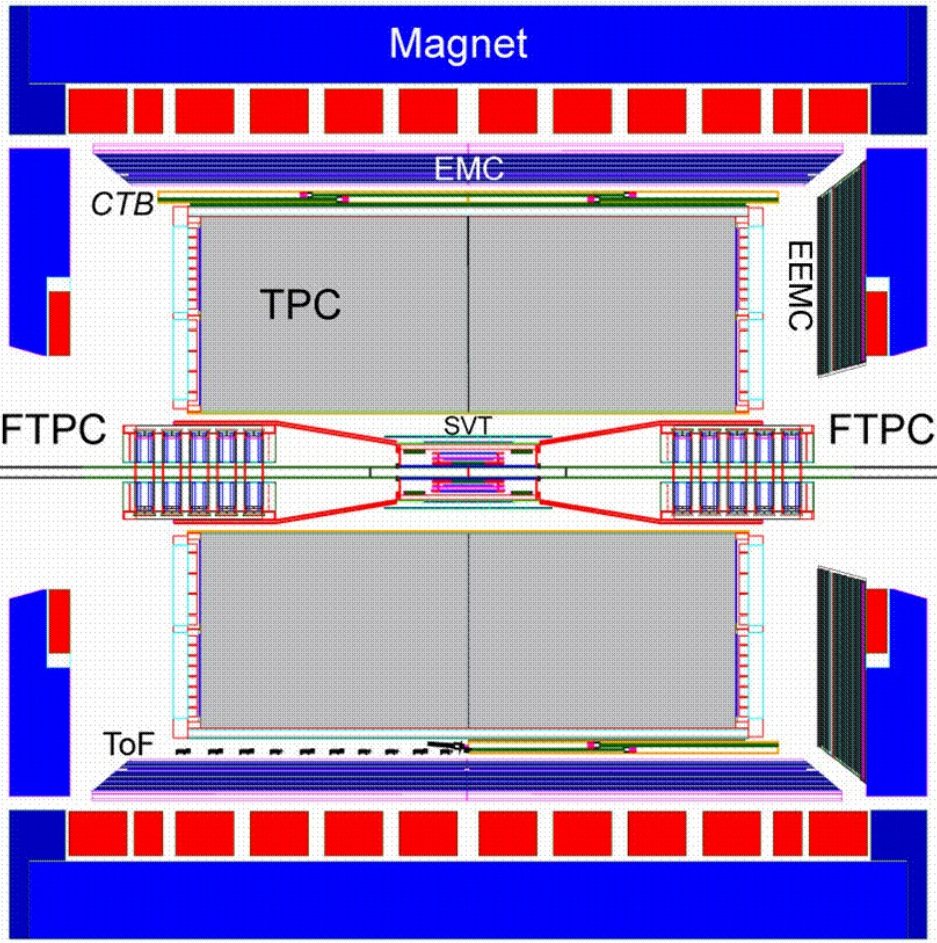

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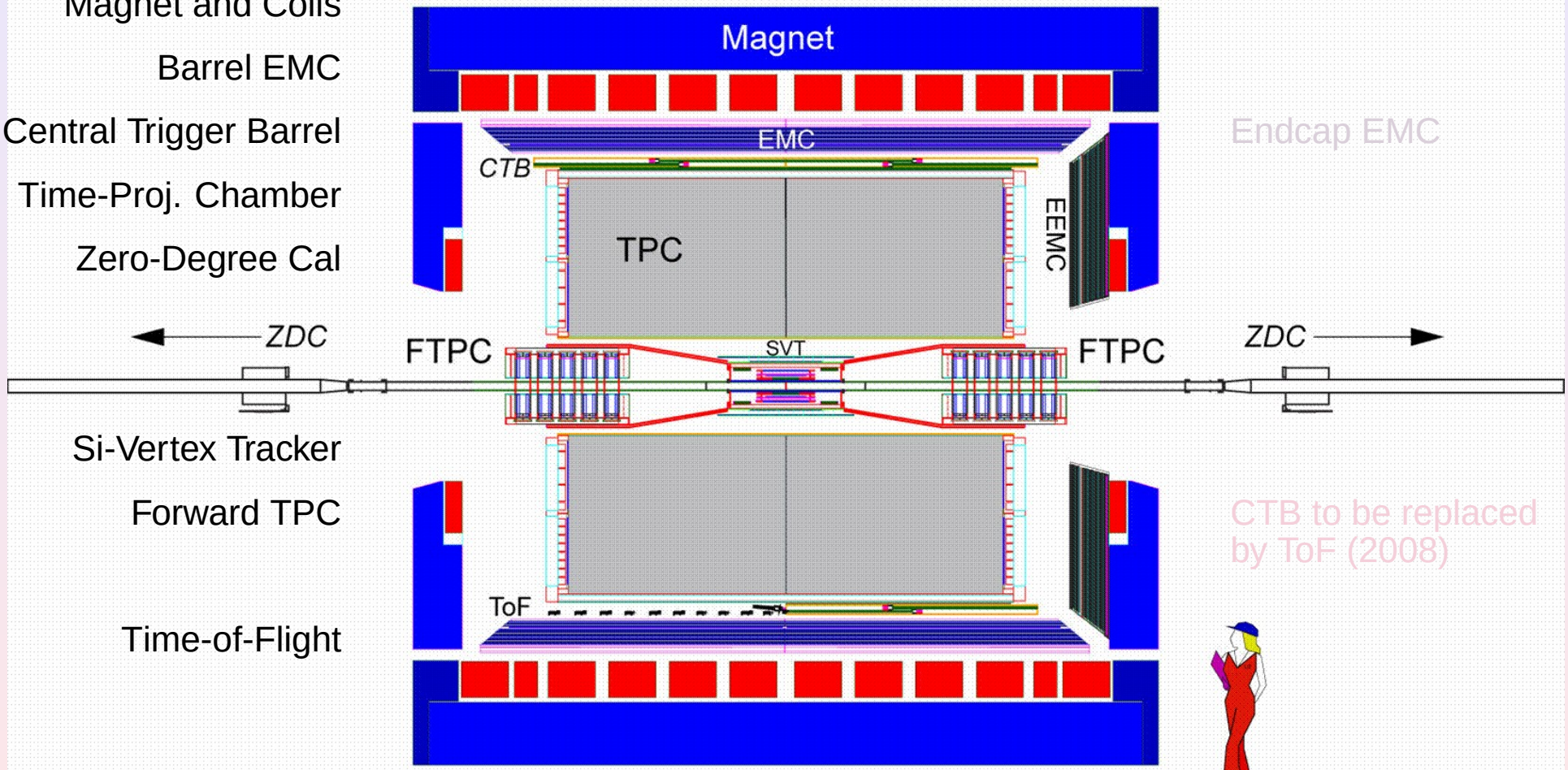

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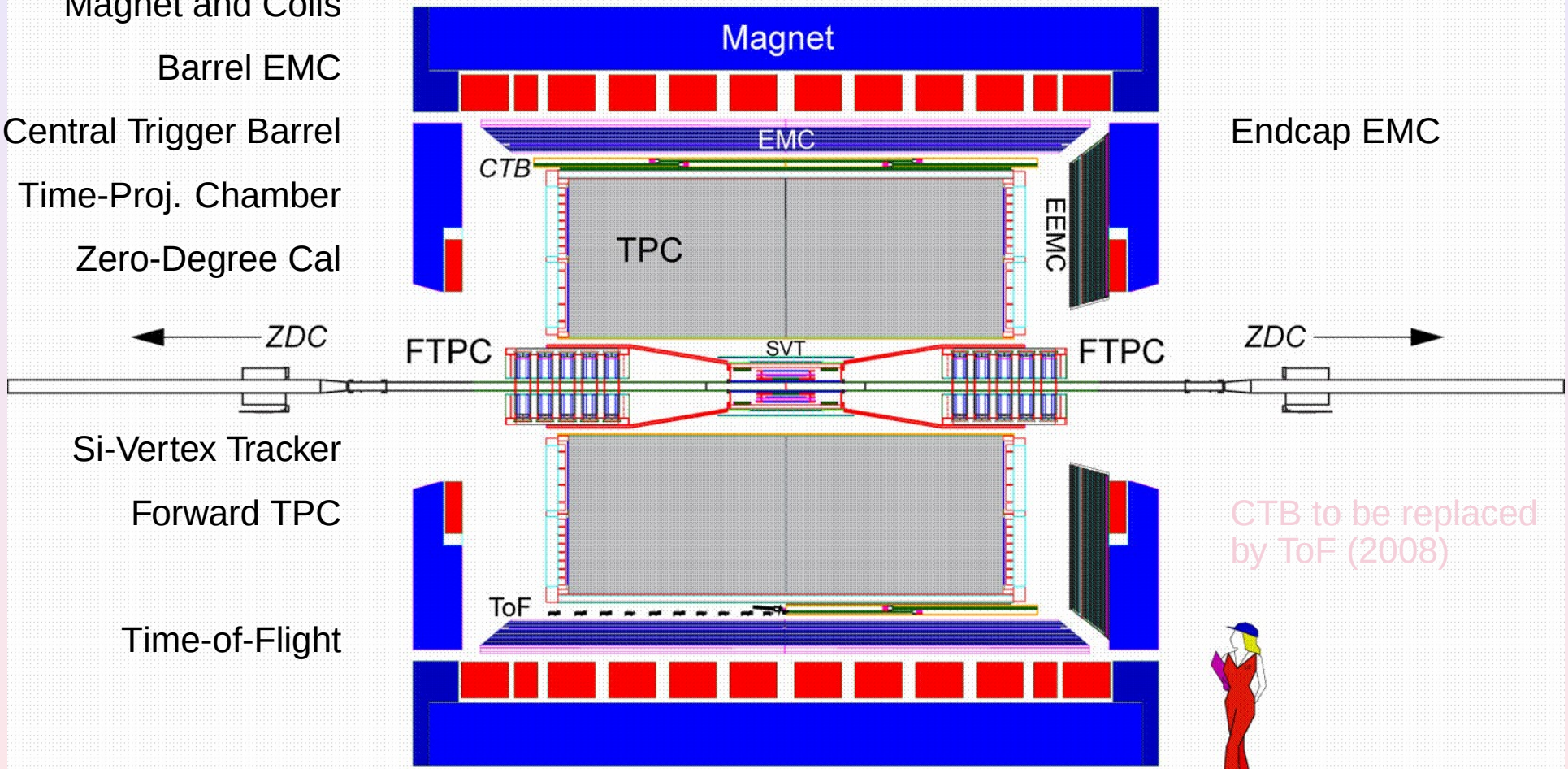

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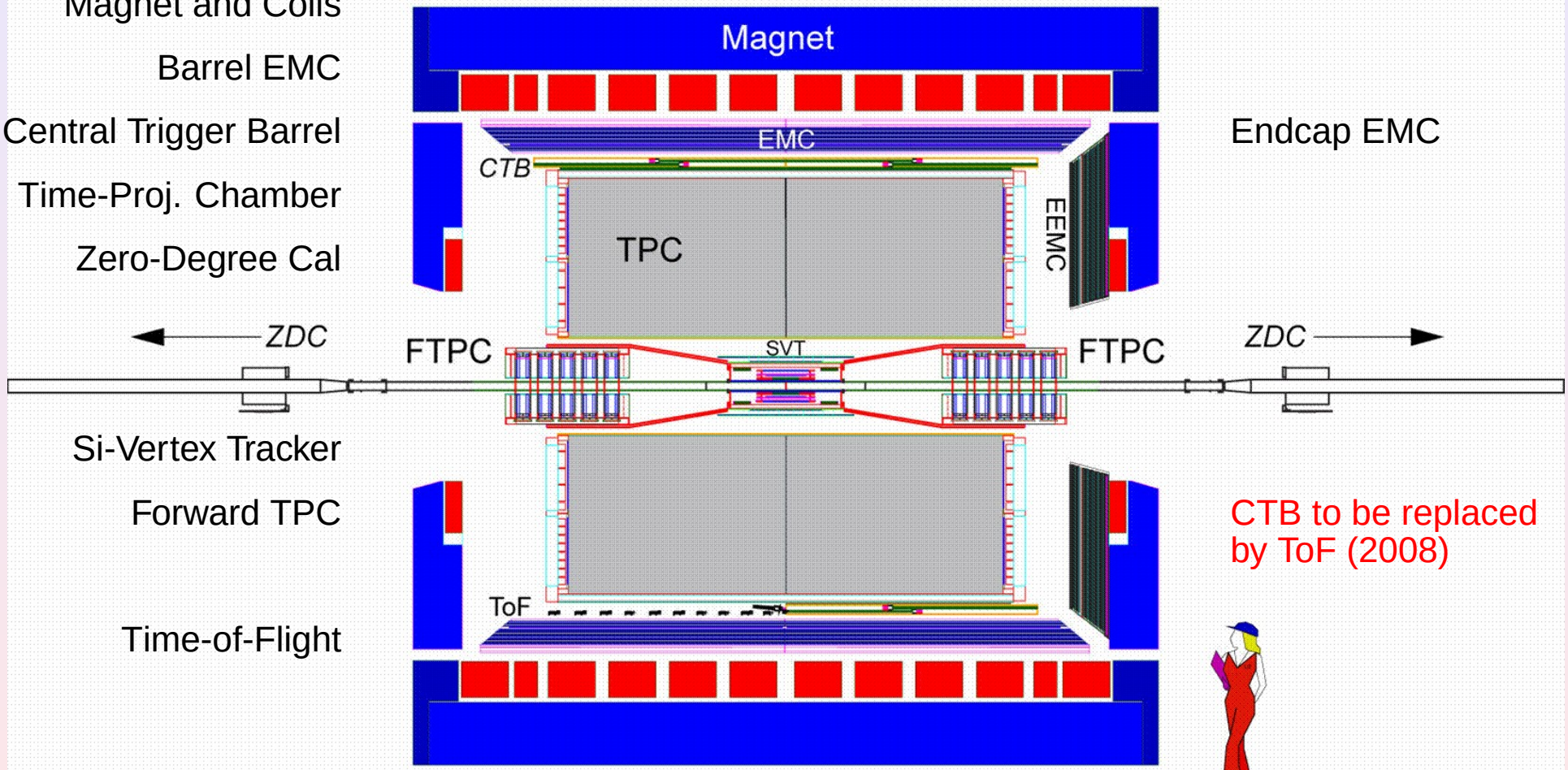

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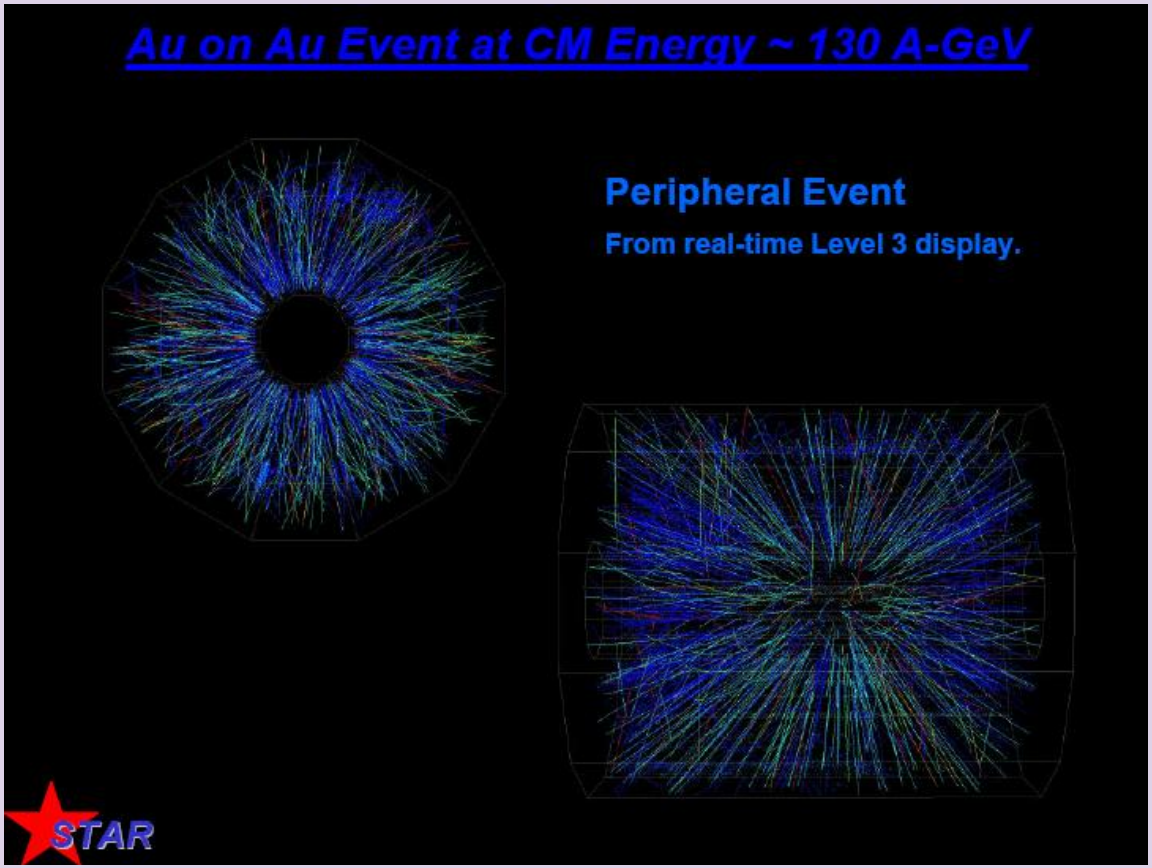
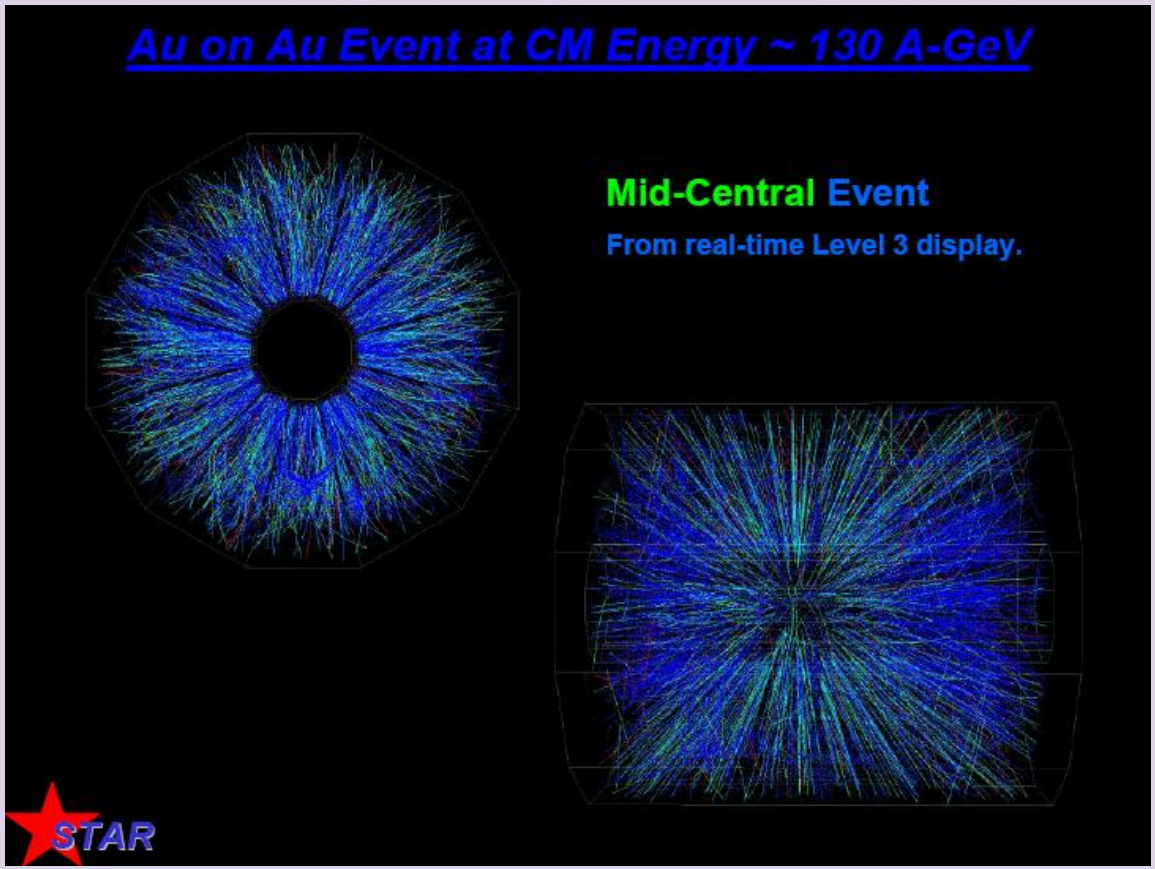
AuAu Collisions at $\sqrt{s} = 130$ AGeV

AuAu Peripheral Collisions



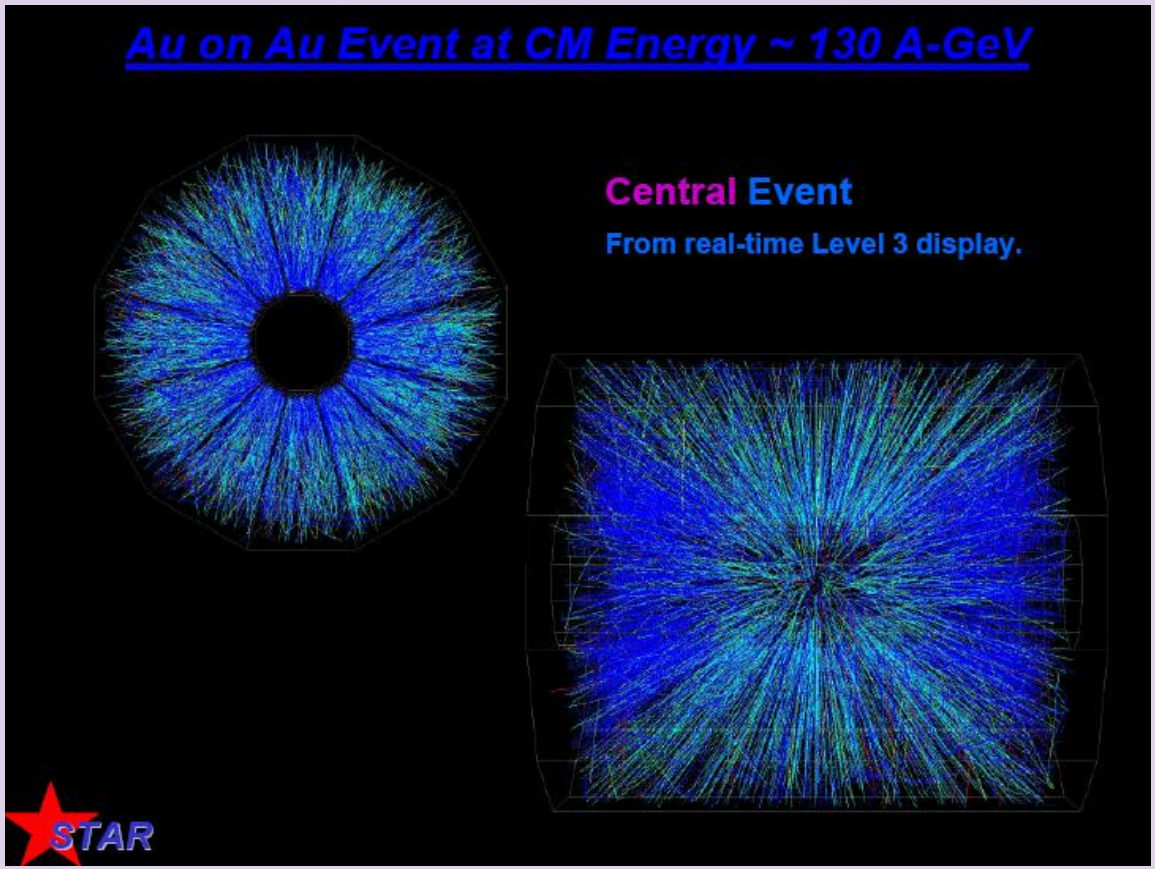
AuAu Collisions at $\sqrt{s} = 130$ AGeV

AuAu Mid-Central Collisions



AuAu Collisions at $\sqrt{s} = 130$ AGeV

AuAu Central Collisions

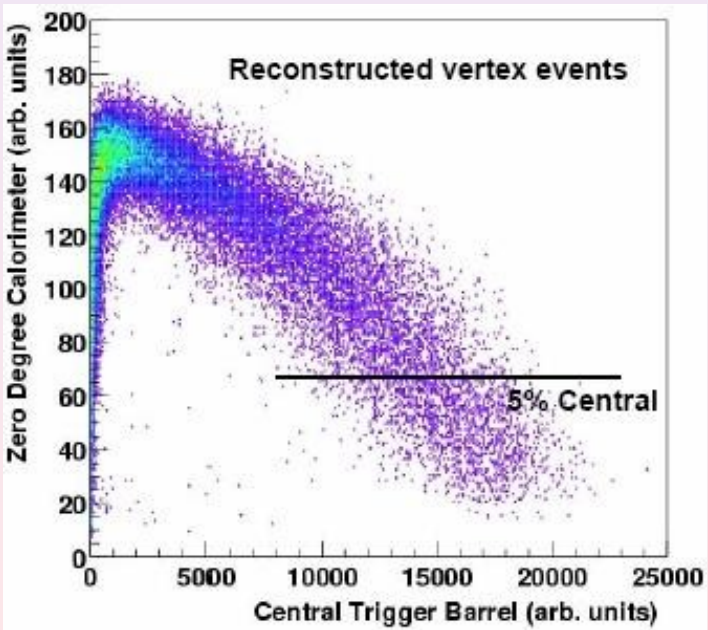


Outline

Centrality Selection and PID

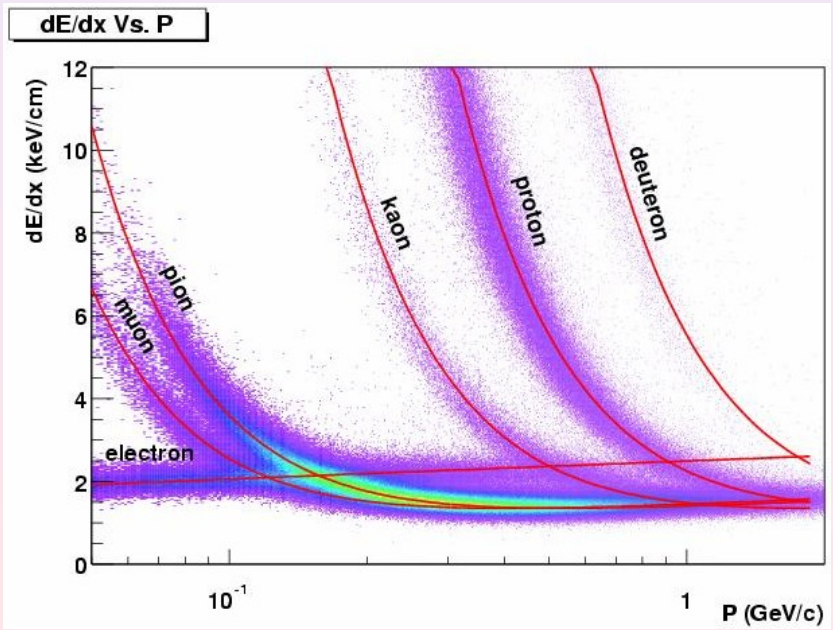
Centrality Trigger

- ZDC
- CTB
- Multiplicity cut n_{ch}/n_{max}



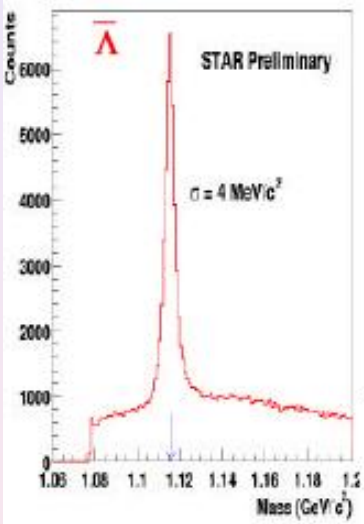
dE/dx-PID

- $\sigma(dE/dx) \sim 0.08$
- $p \lesssim 0.7 GeV$ for K/π
- $p \lesssim 1.0 GeV$ for $\bar{p}/p$



Topological Resonance Reconstruction

topology



Decay vertices

$K_s \rightarrow \pi^+ + \pi^-$

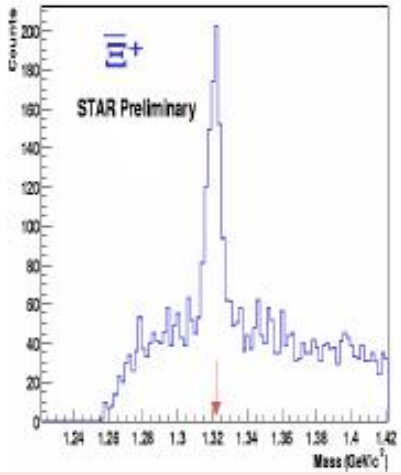
$\Lambda \rightarrow p + \pi^-$

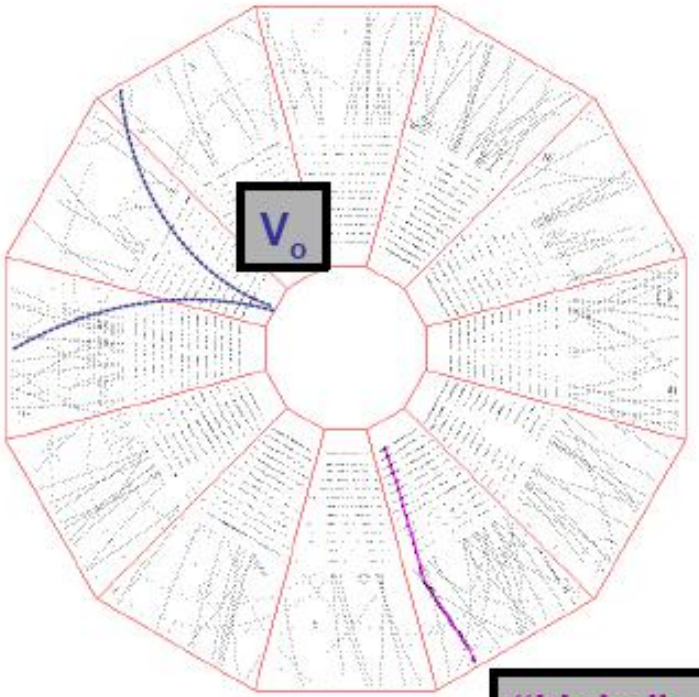
$\bar{\Lambda} \rightarrow \bar{p} + \pi^+$

$\Xi^- \rightarrow \Lambda + \pi^-$

$\bar{\Xi}^+ \rightarrow \bar{\Lambda} + \pi^+$

$\Omega \rightarrow \Lambda + K^-$





"kinks":

$K^{\pm} \rightarrow \mu^{\pm} + \nu$

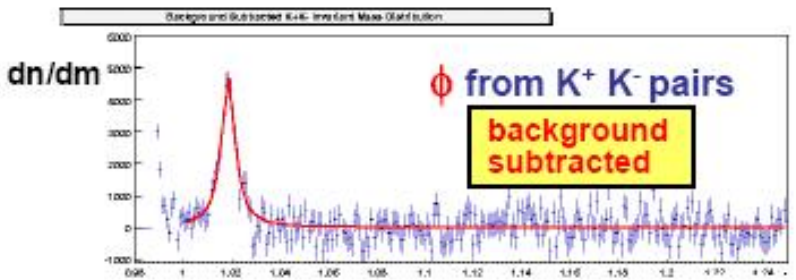
Combinatoric Resonance Reconstruction

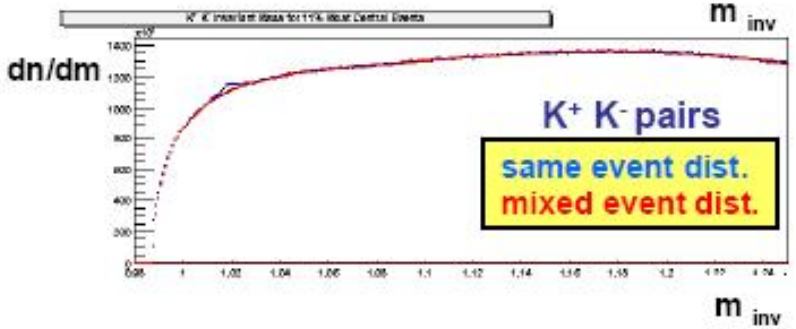
Combinatorics

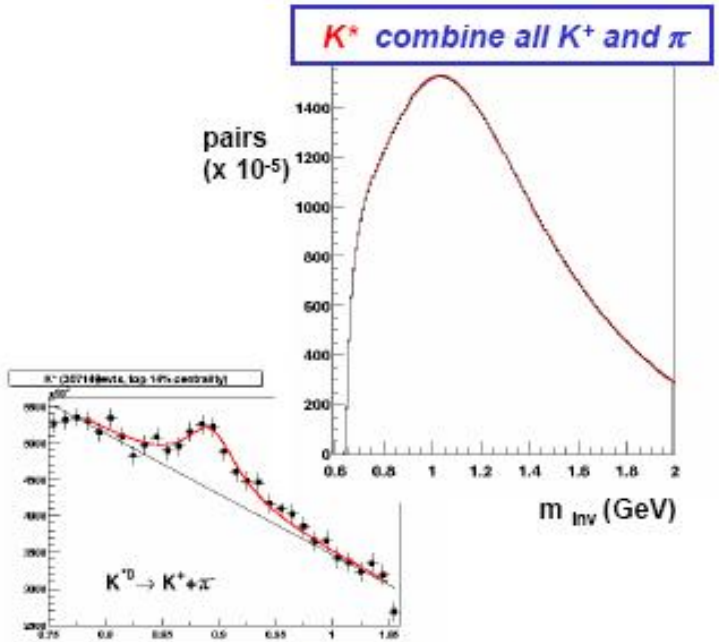
$K_s \rightarrow \pi^+ + \pi^-$ $\quad \phi \rightarrow K^+ + K^-$

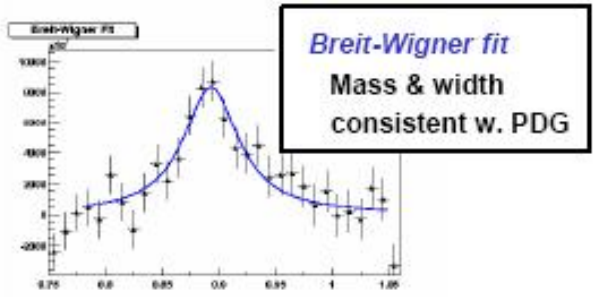
$\Lambda \rightarrow p + \pi^-$ $\quad \bar{\Lambda} \rightarrow \bar{p} + \pi^+$

$[\rho \rightarrow \pi^+ + \pi^-]$ $\quad [\Delta \rightarrow p + \pi^-]$









Open Charm Production at STAR

Hadronic Decay Channels

- $D^0 \rightarrow K\pi$ B.R. : 3.83%
- Direct clean probe (signal in invariant mass distribution)
- Difficulty: large combinatoric background (especially in high multiplicity environments)
- Event-mixing and/or vertex tracker needed to obtain signal

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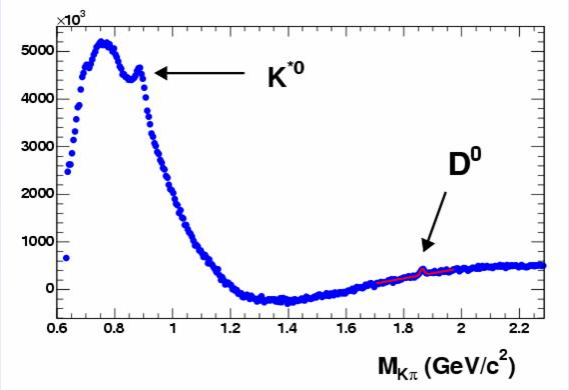

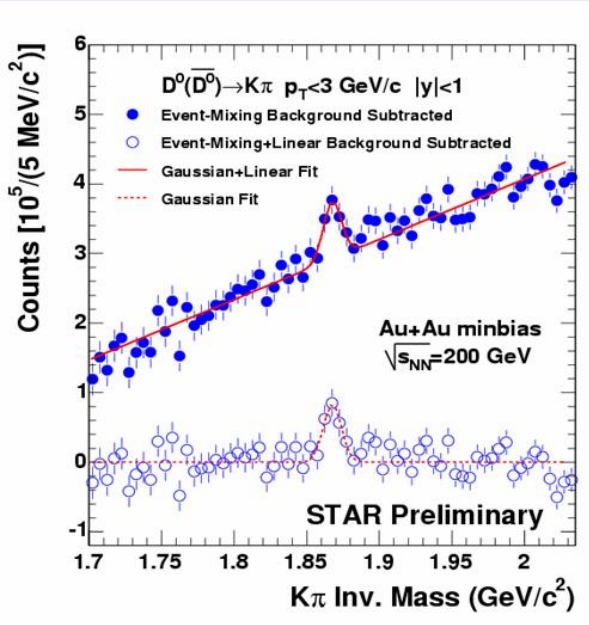

Open Charm Production in AuAu vs. dAu

AuAu vs. dAu

- $d\sigma_{CC}^{NN}/dy|_{y=0}$ higher than NLO in pp
- $d\sigma_{CC}^{NN}/dy|_{y=0}$ follows binary collision scaling (N_{bin})
  $\rightarrow$ charm production in early stage of collisions, as expected
- Publication in preparation
  (pp and d+Au results already published in PRL 94, 062301 (2005))

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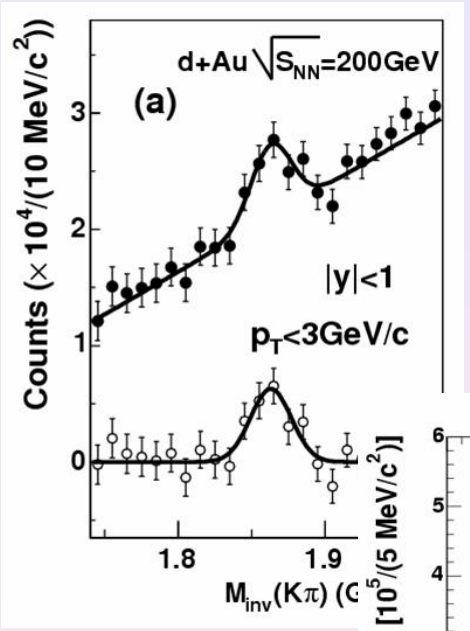

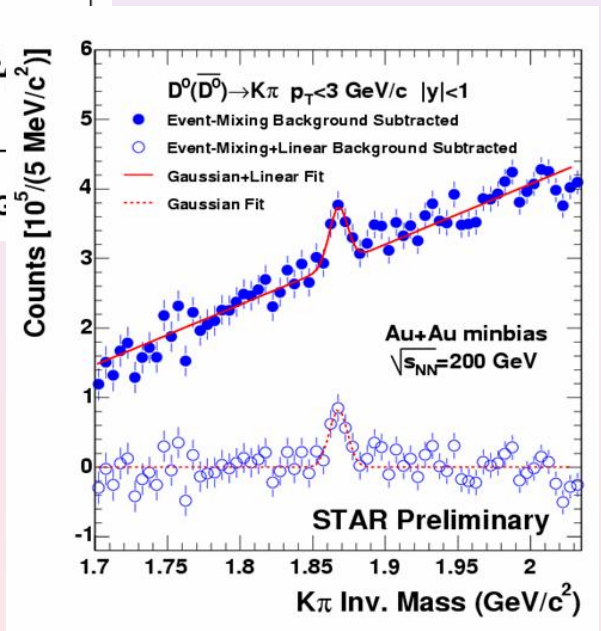

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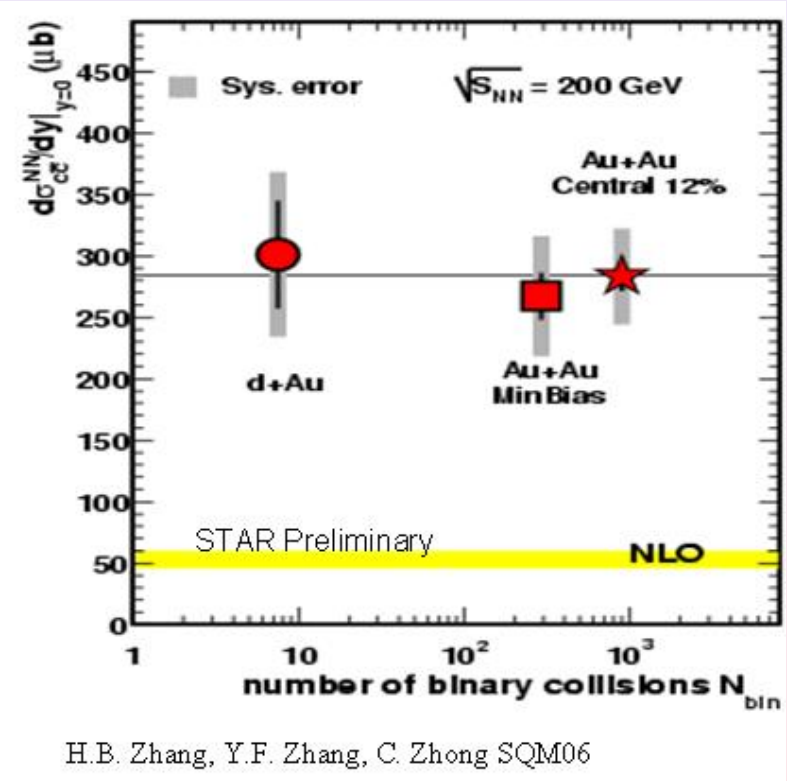

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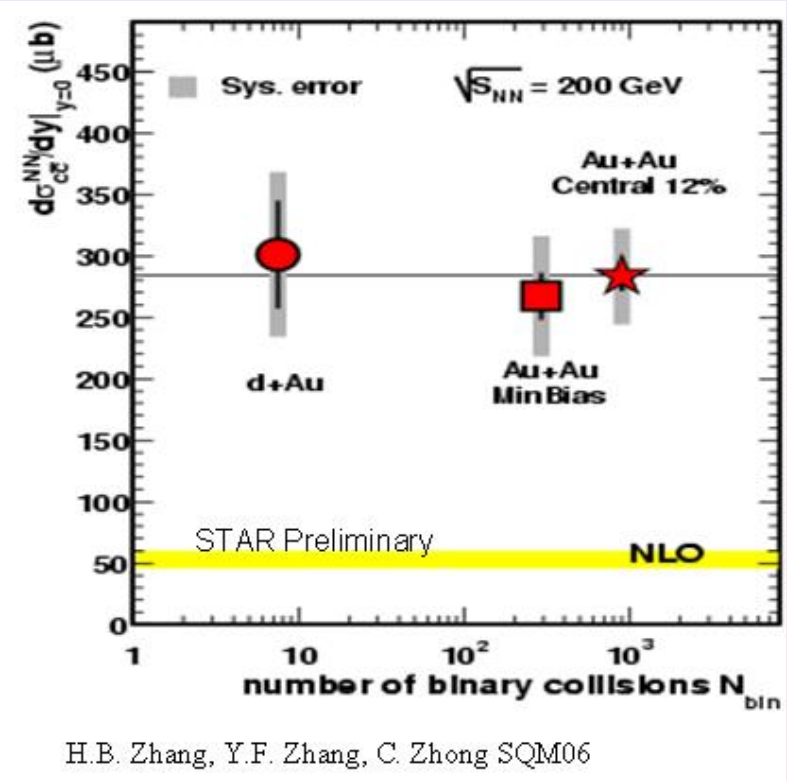

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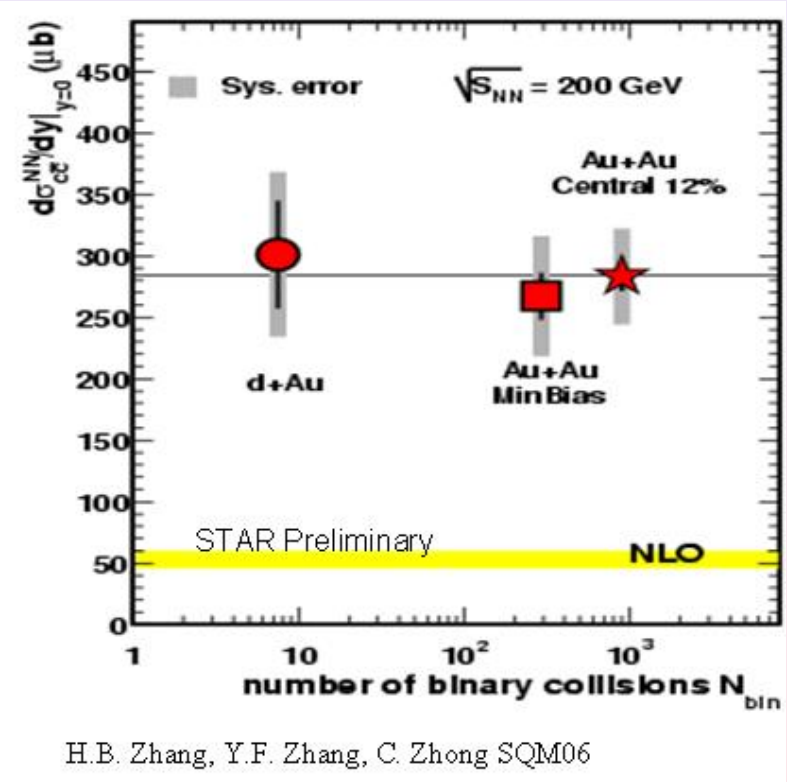

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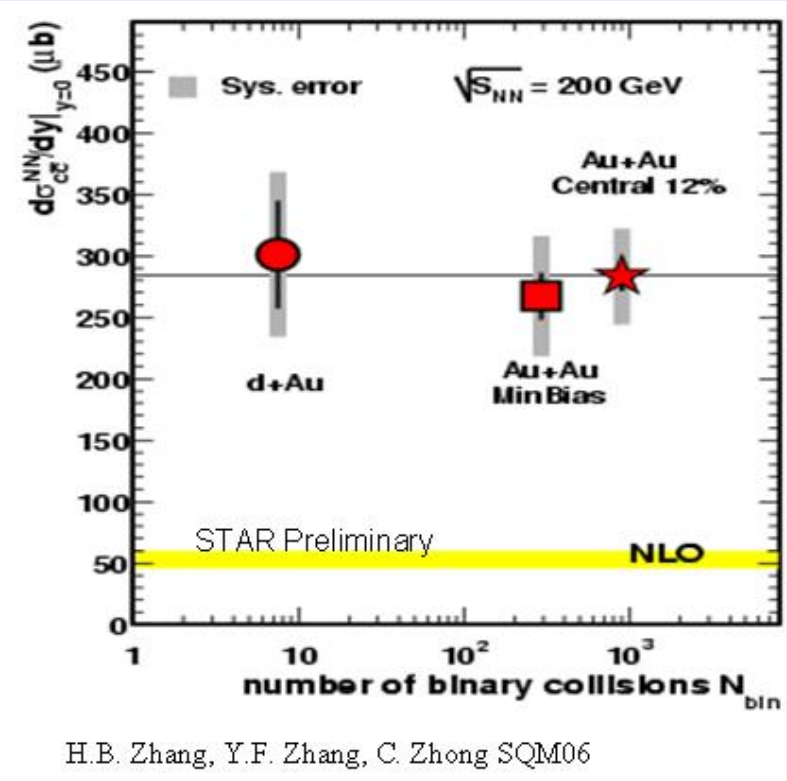

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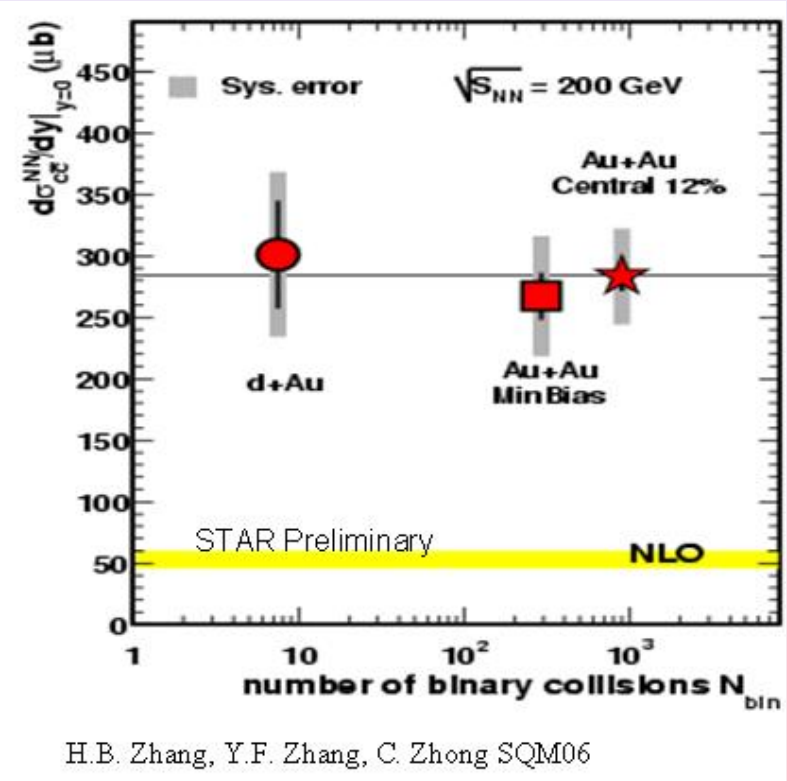

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$D_s^+[c\bar{s}]$, $D_s^-[\bar{c}s]$

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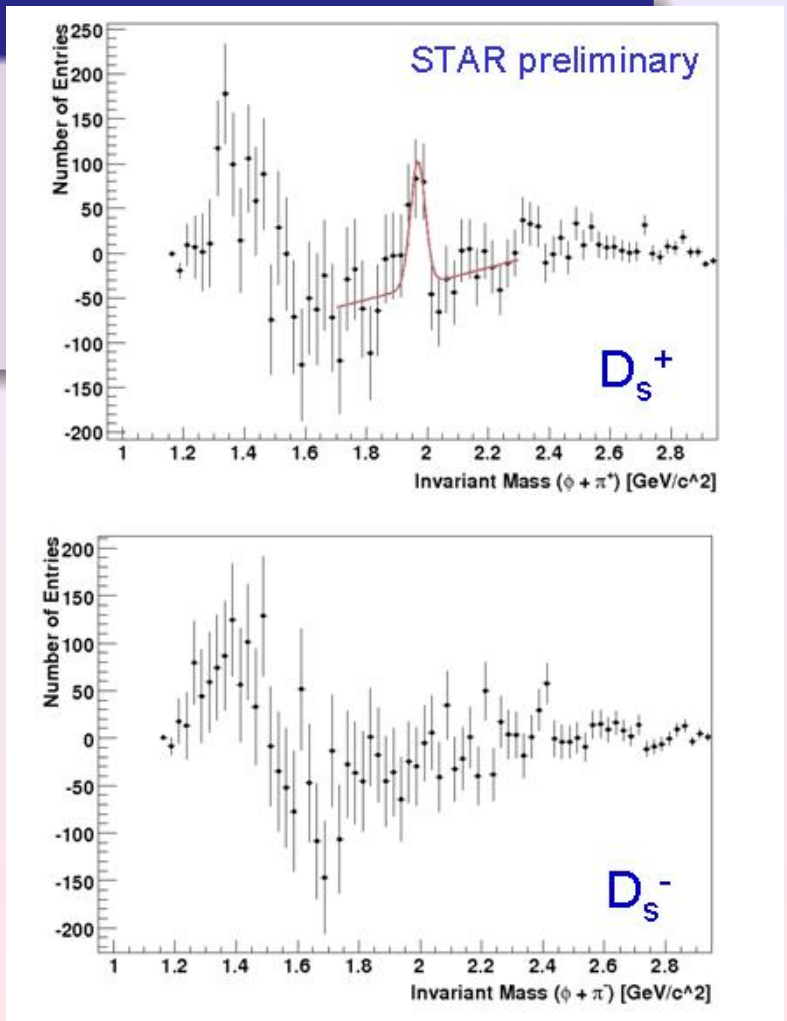
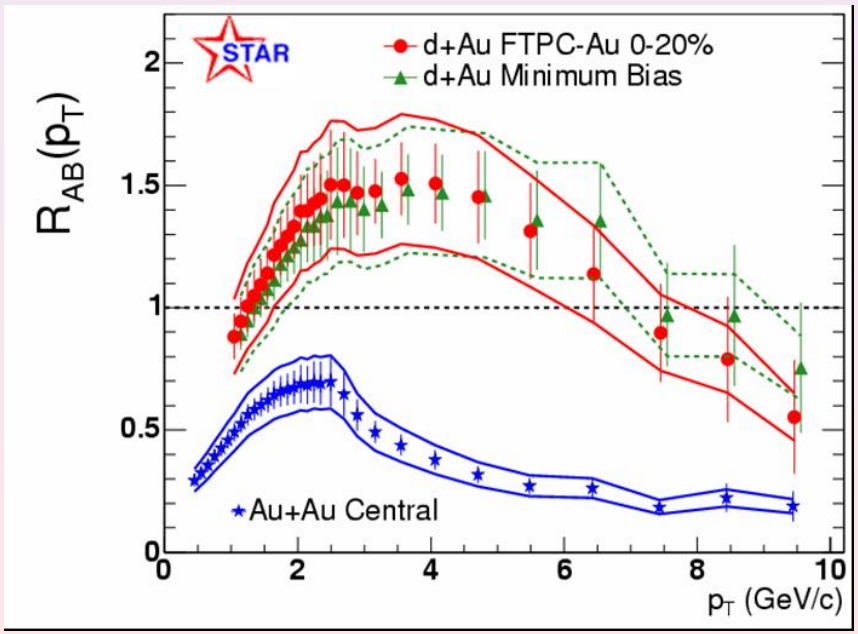


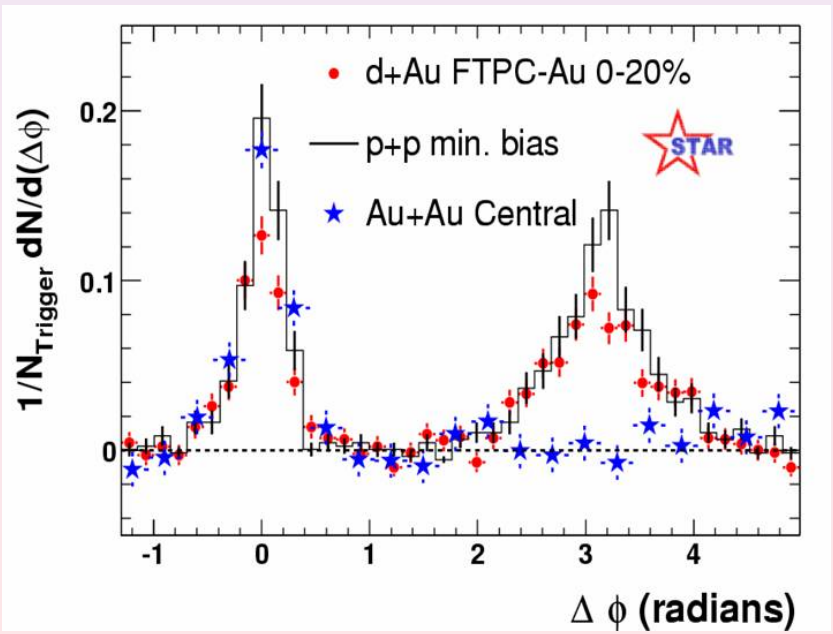
Outline

What has been observed at RHIC

Jet Quenching : Evidence for sQGP

- Strong high-p_T particle suppression in central Au+Au
- Parton energy loss in created medium
- Strong evidence for a dense, opaque, non-viscous state of matter (perfect liquid)





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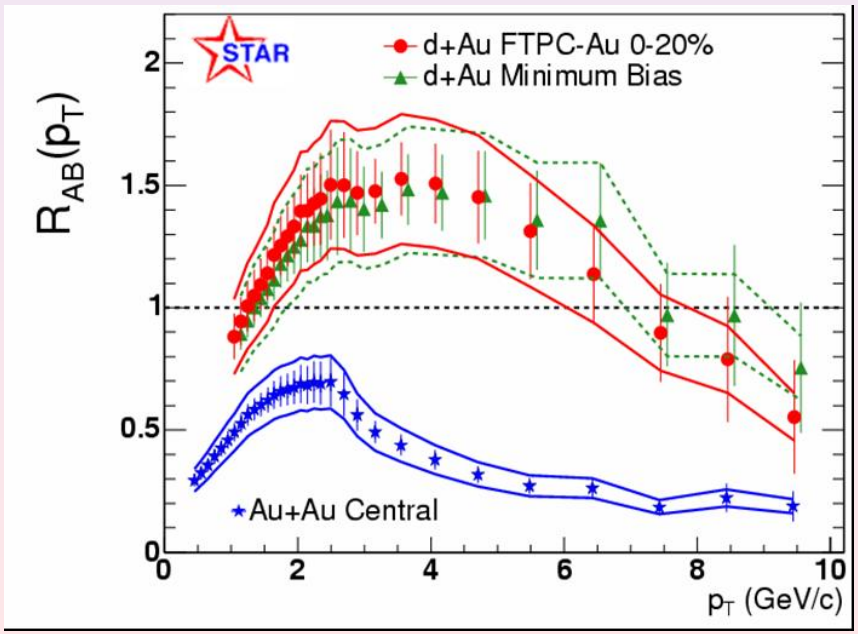

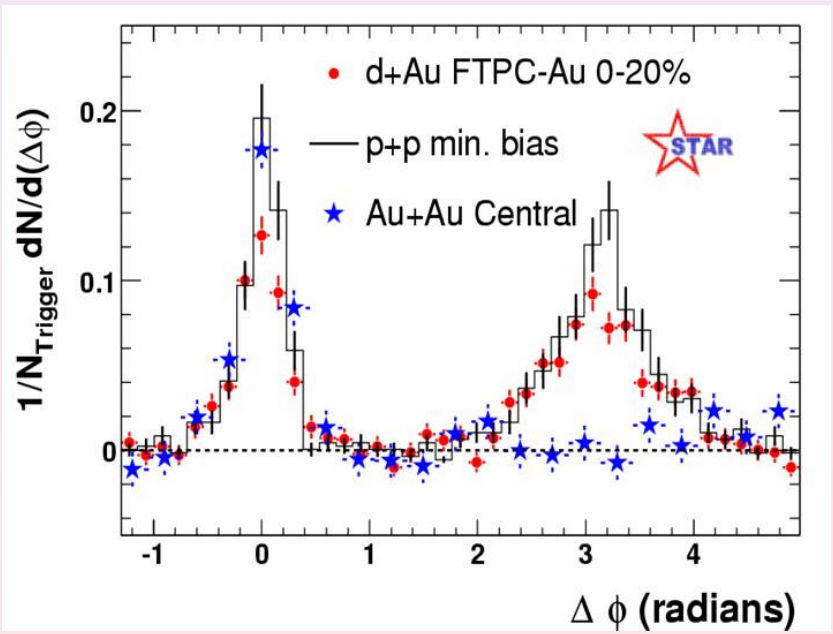

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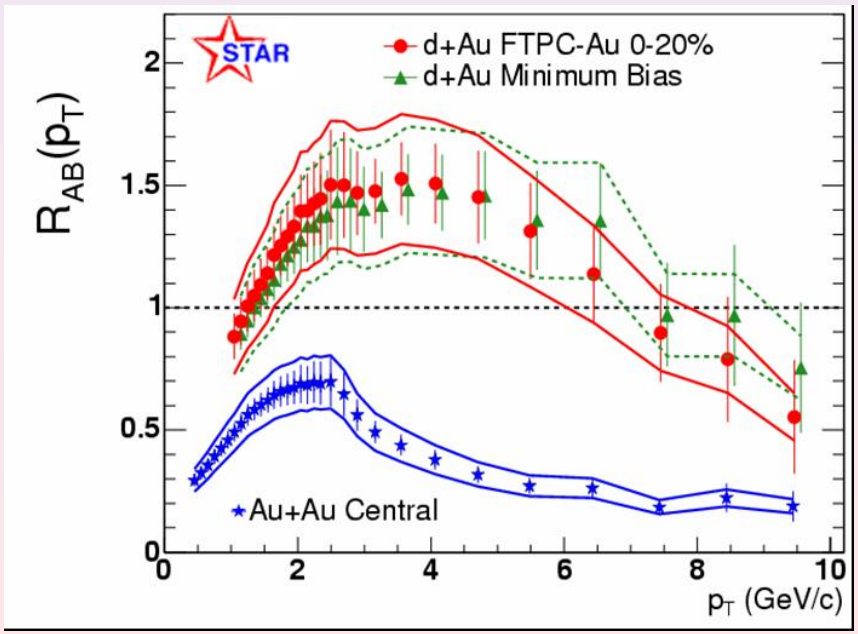

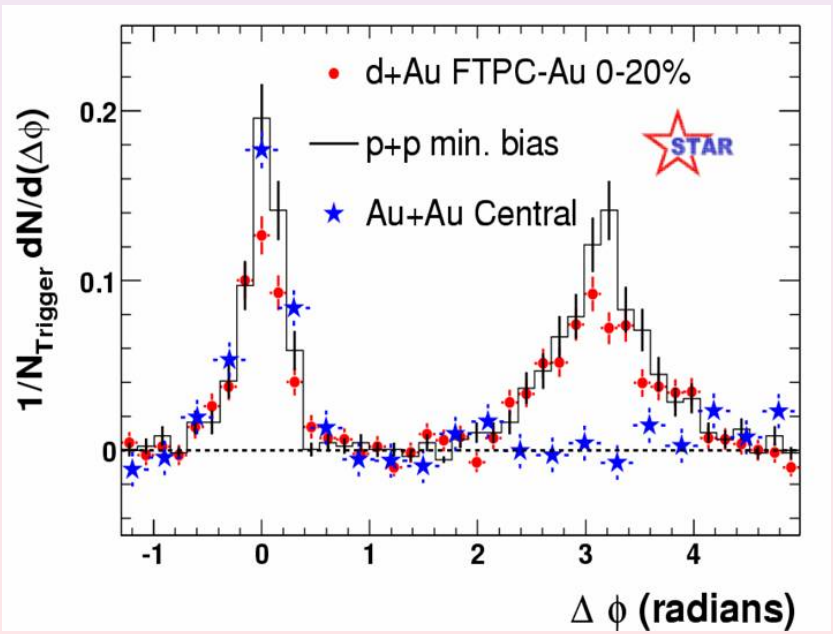

Perfect Liquid in the early Universe

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The theory-experiment comparison suggests that central Au+Au collisions at RHIC produce dense, rapidly thermalizing matter characterized by

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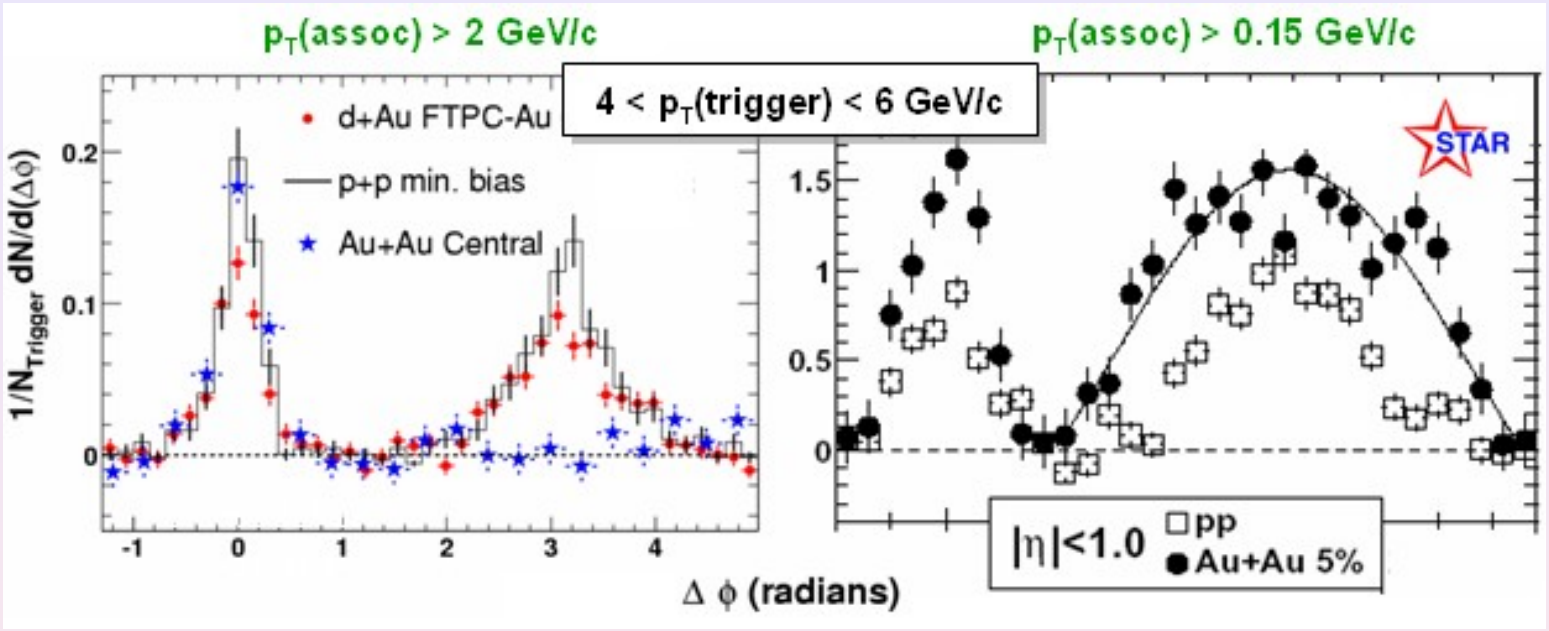
Azimuthal Correlation - Where has the away-side 'Jet' gone?



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  → increase of away-side particle production
- Hard-Soft : away-side spectra approaching the bulk
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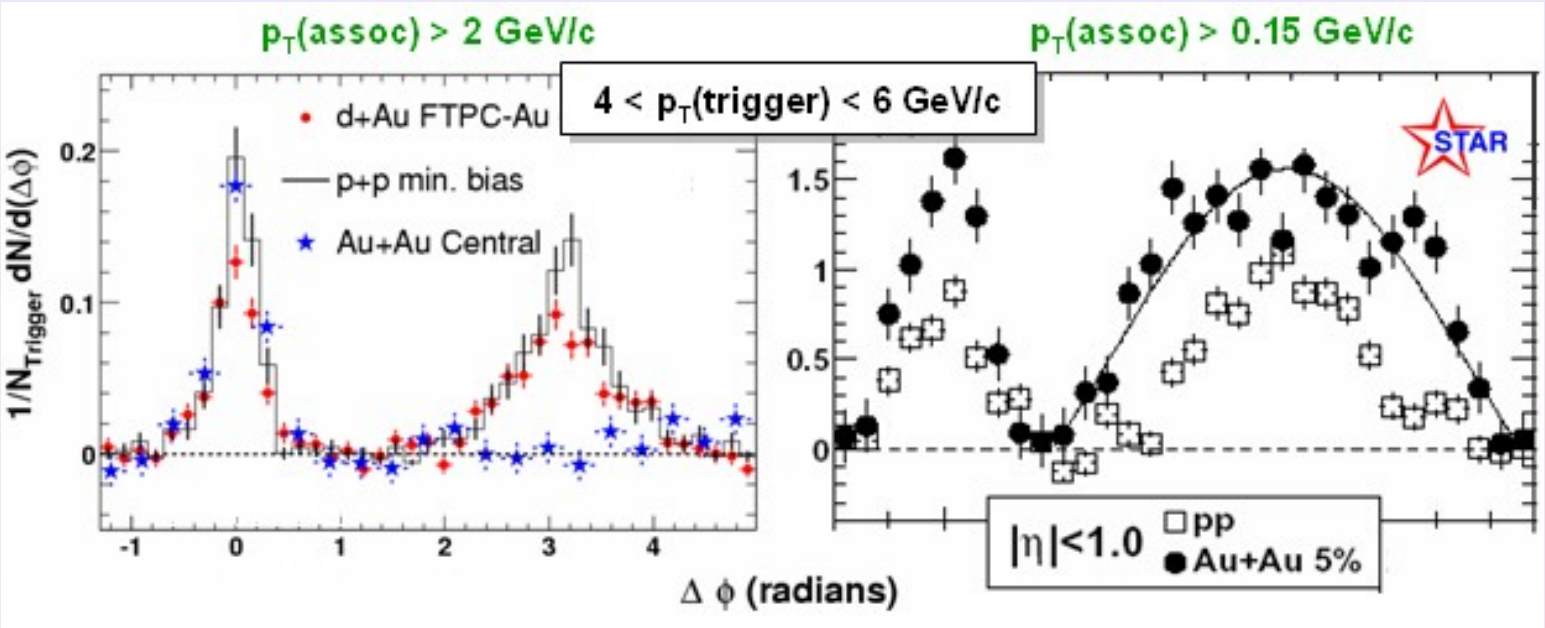

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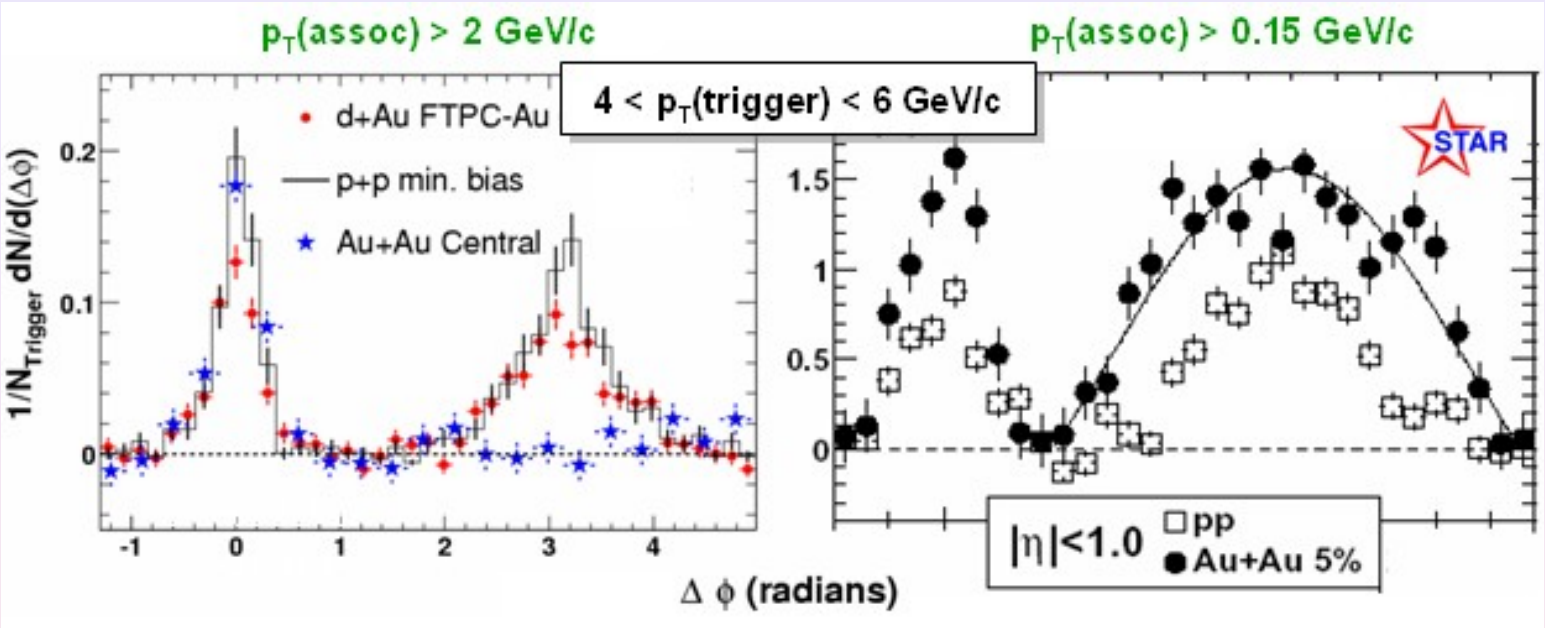

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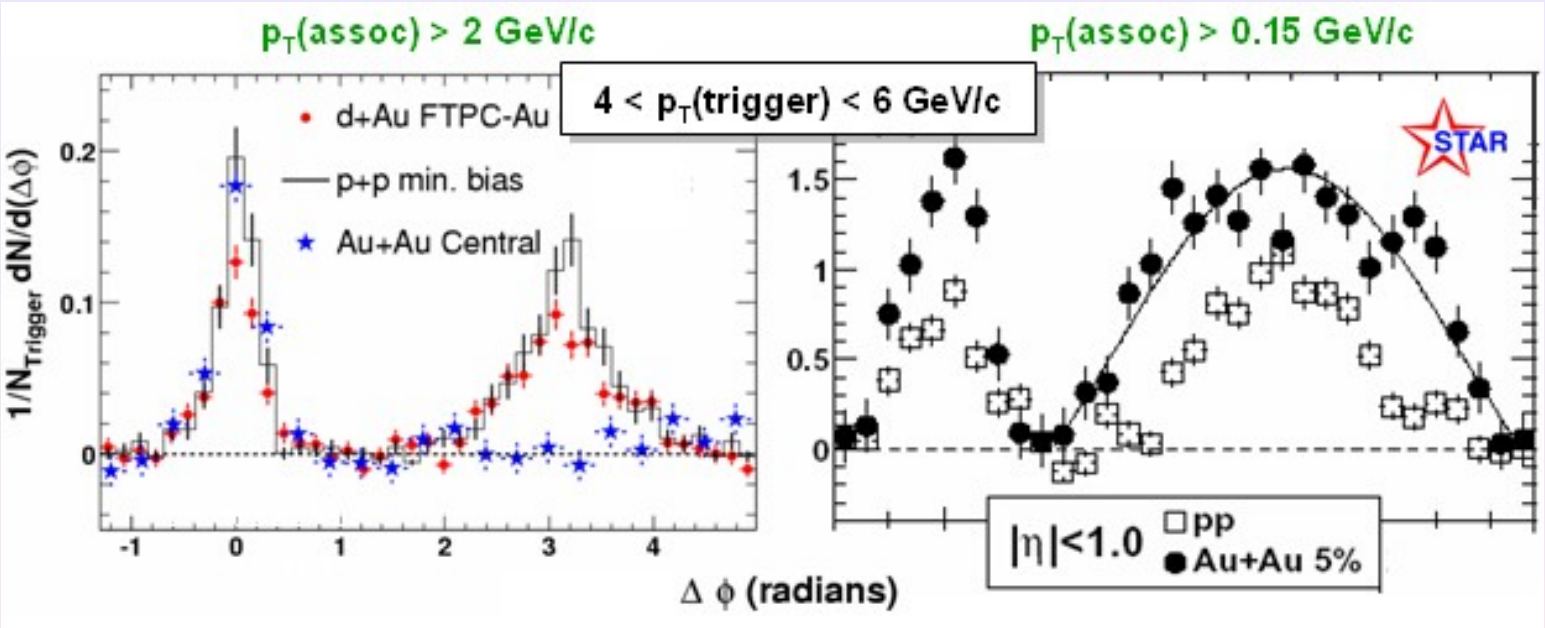

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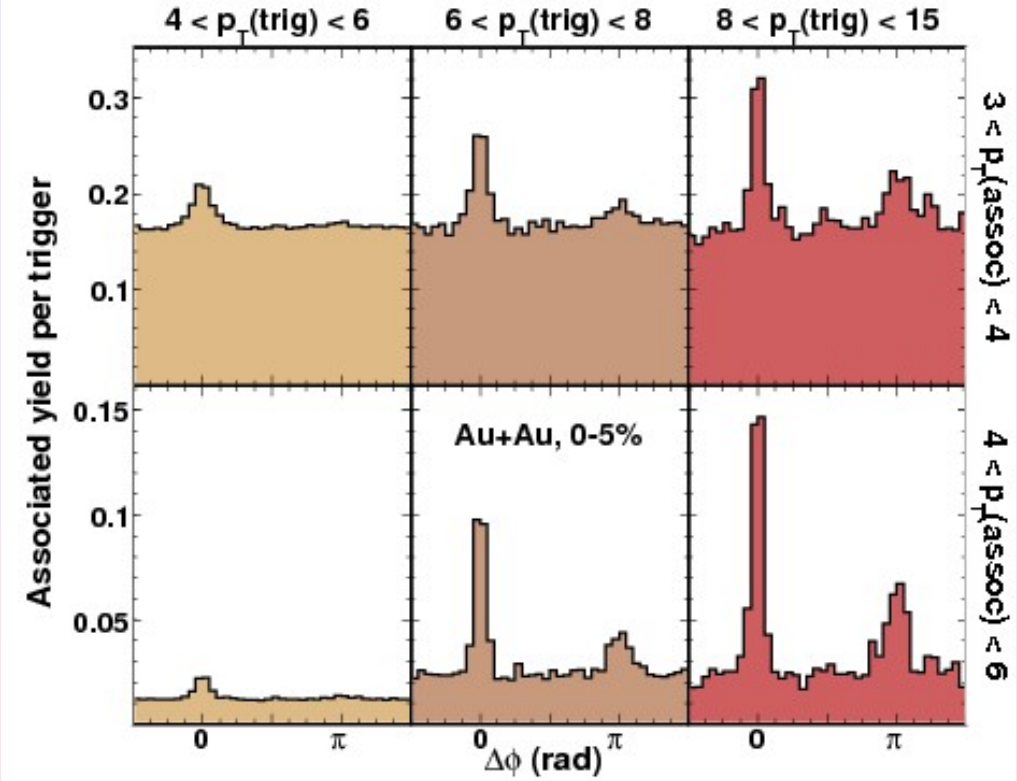

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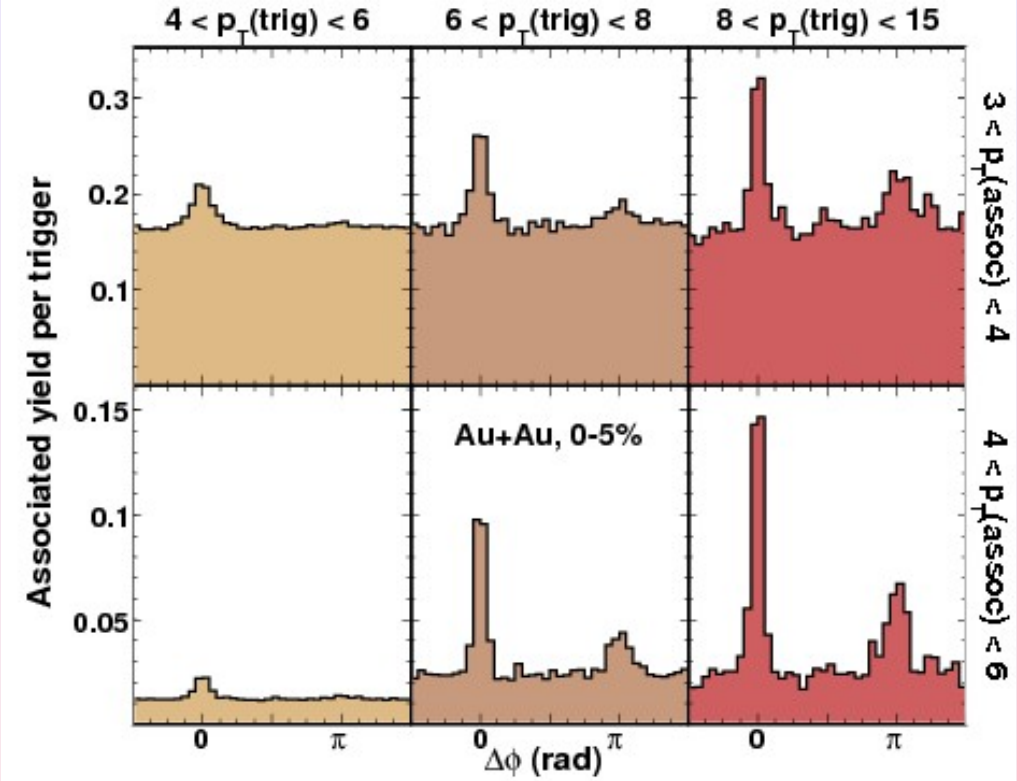

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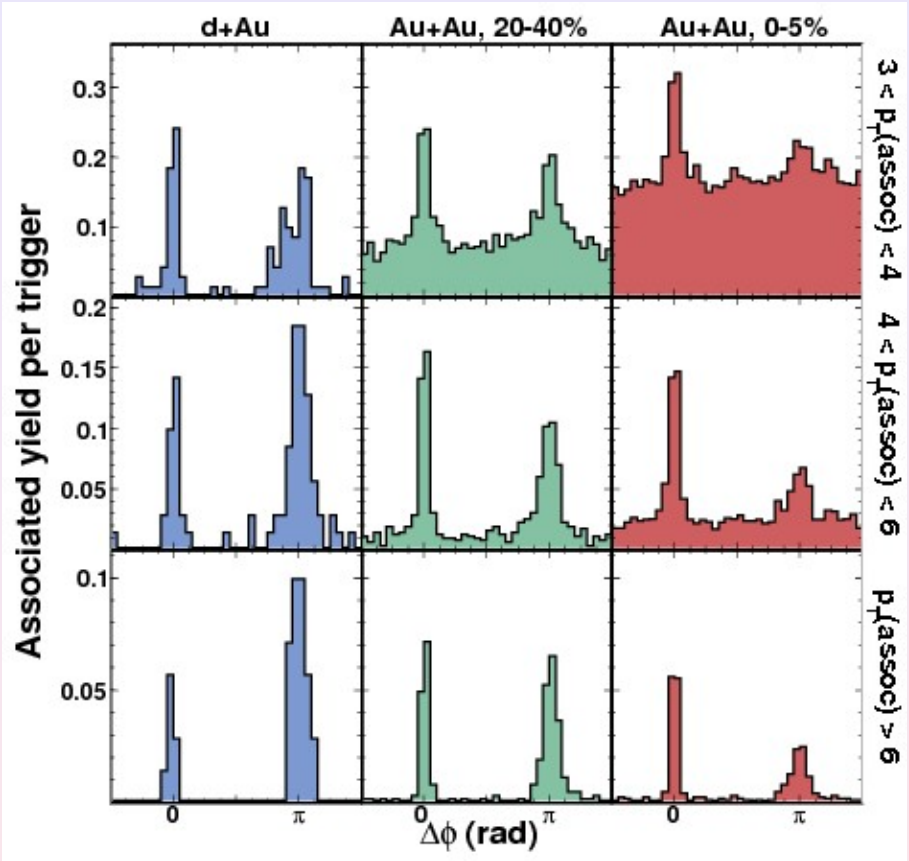

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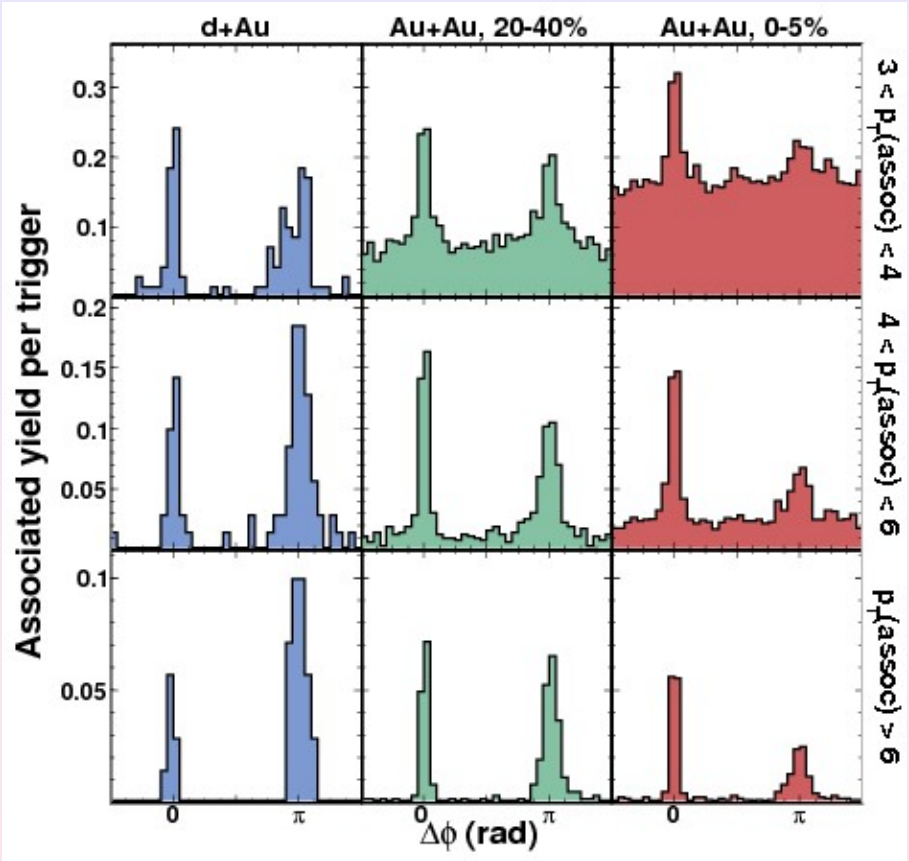

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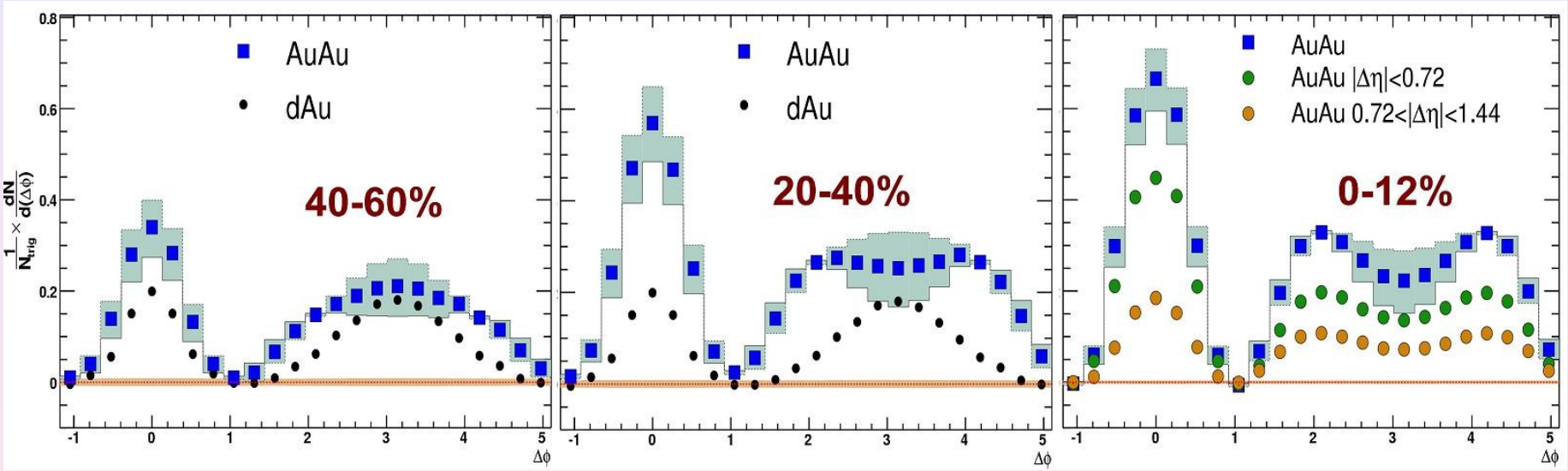

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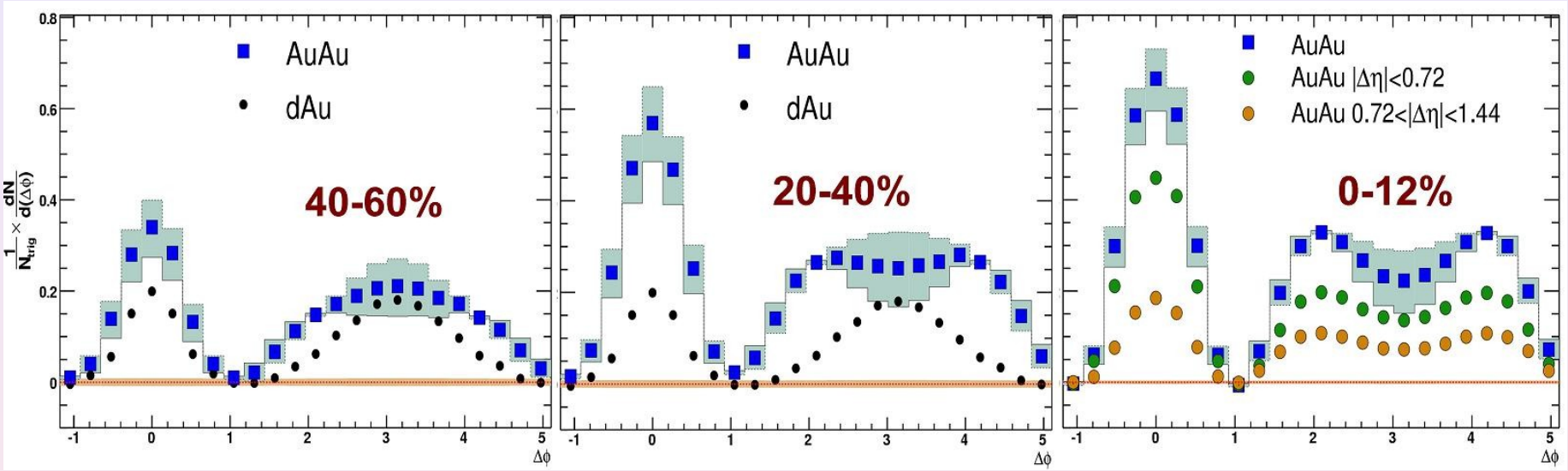

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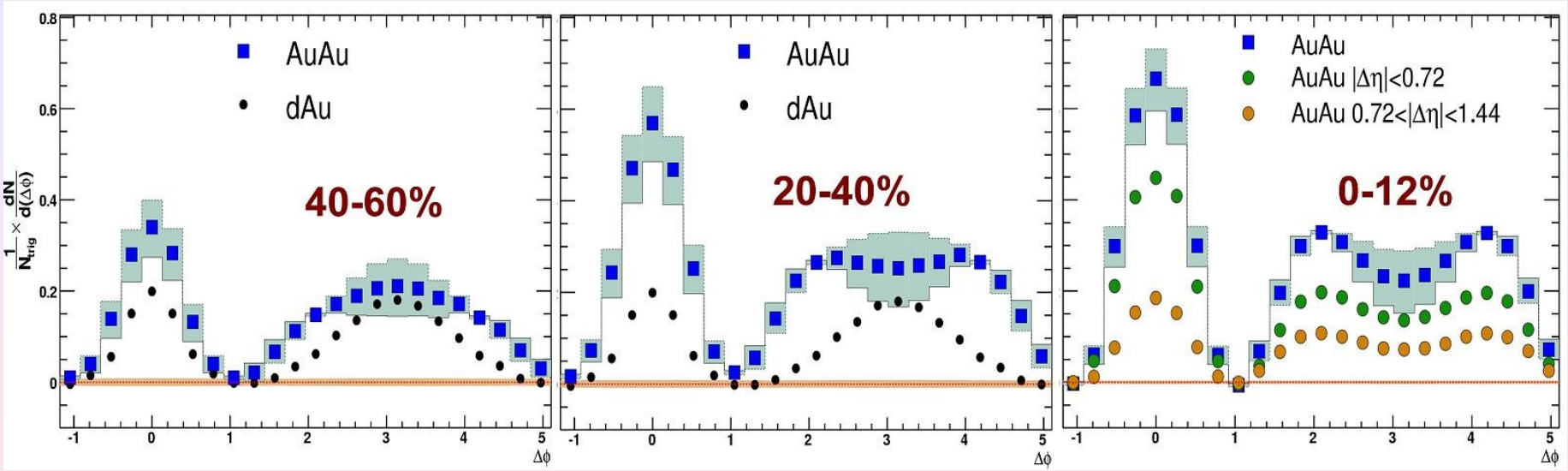

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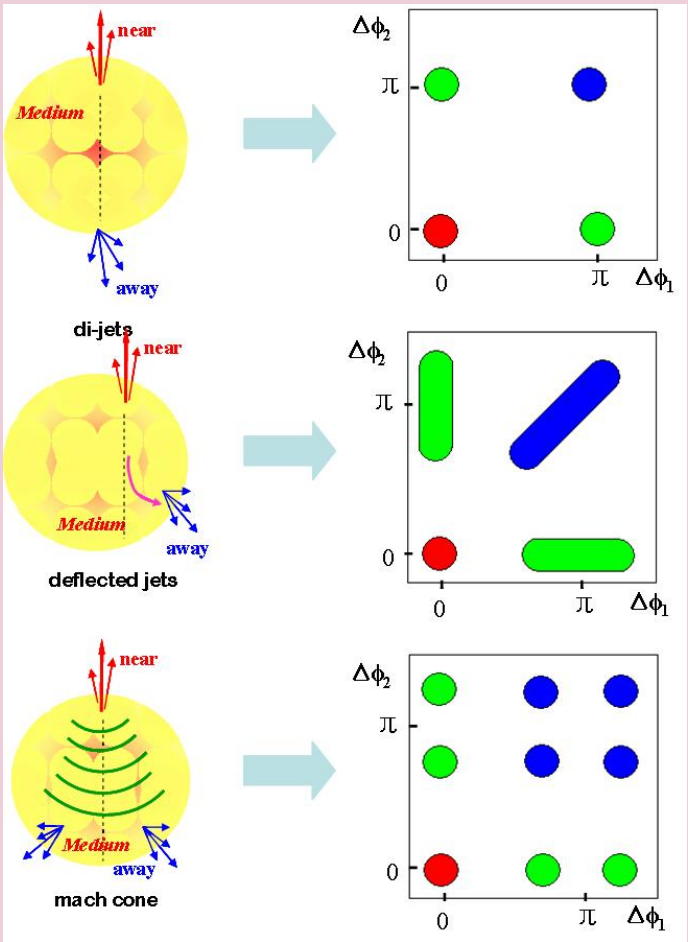

PHENIX

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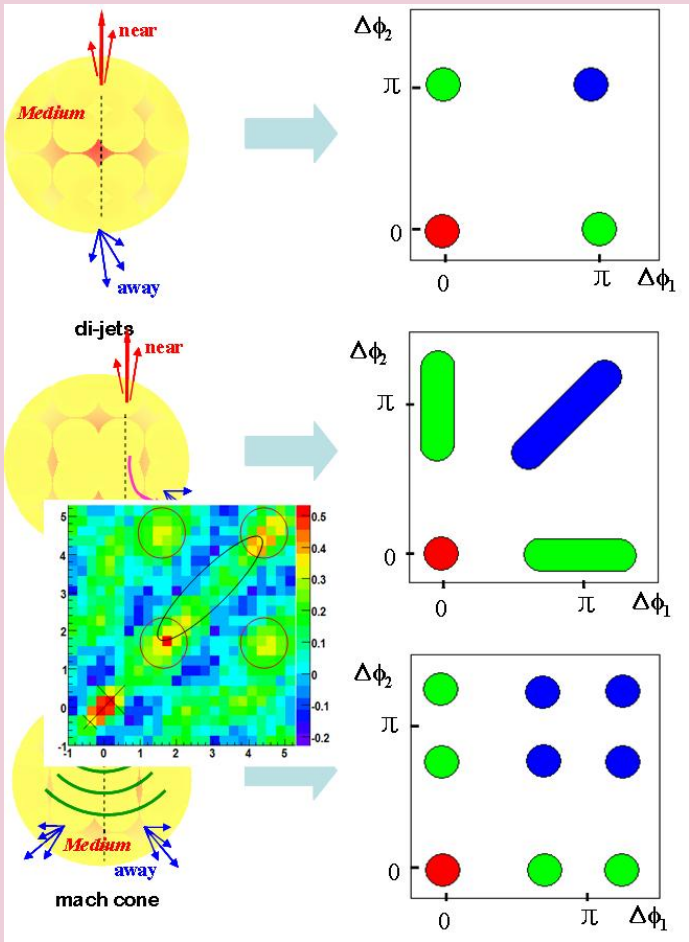

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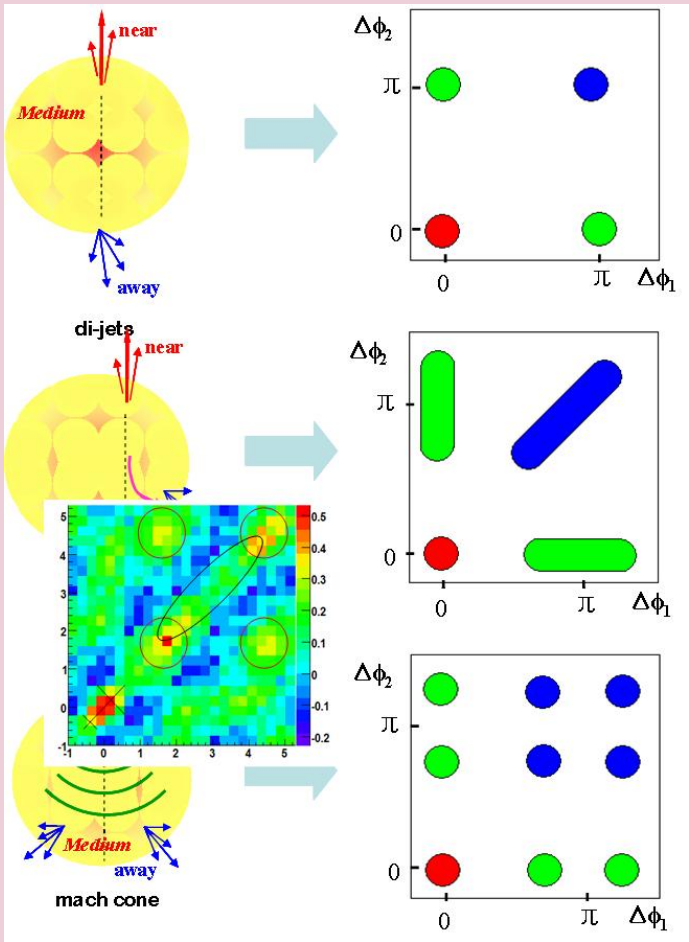

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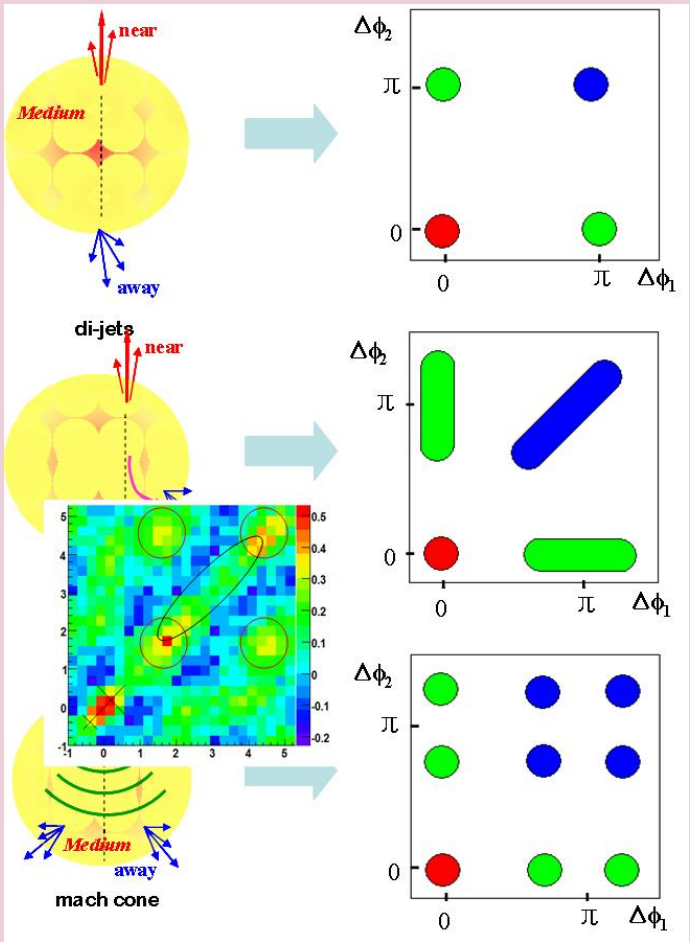

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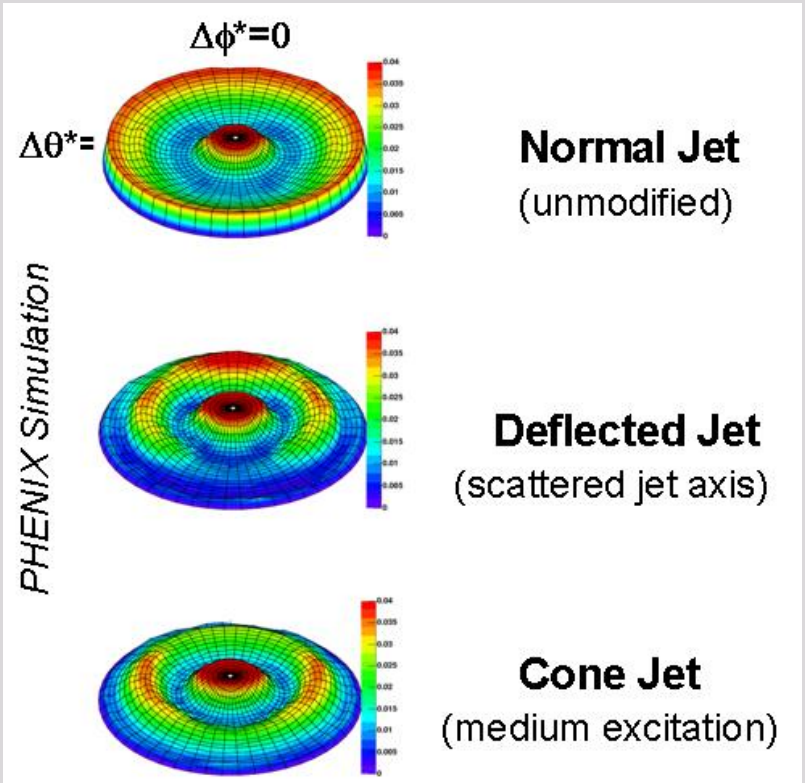

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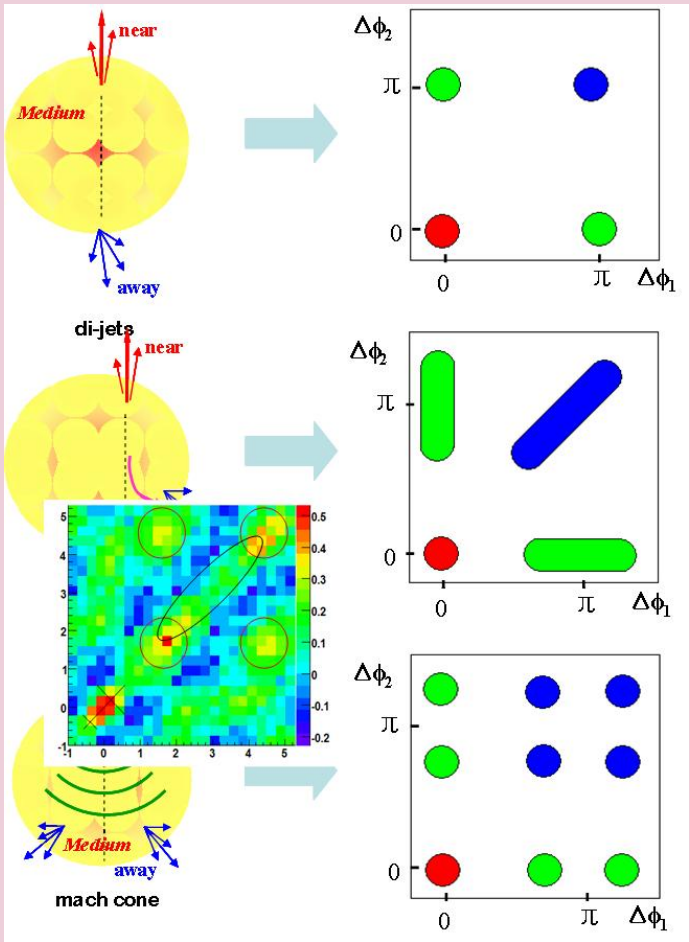

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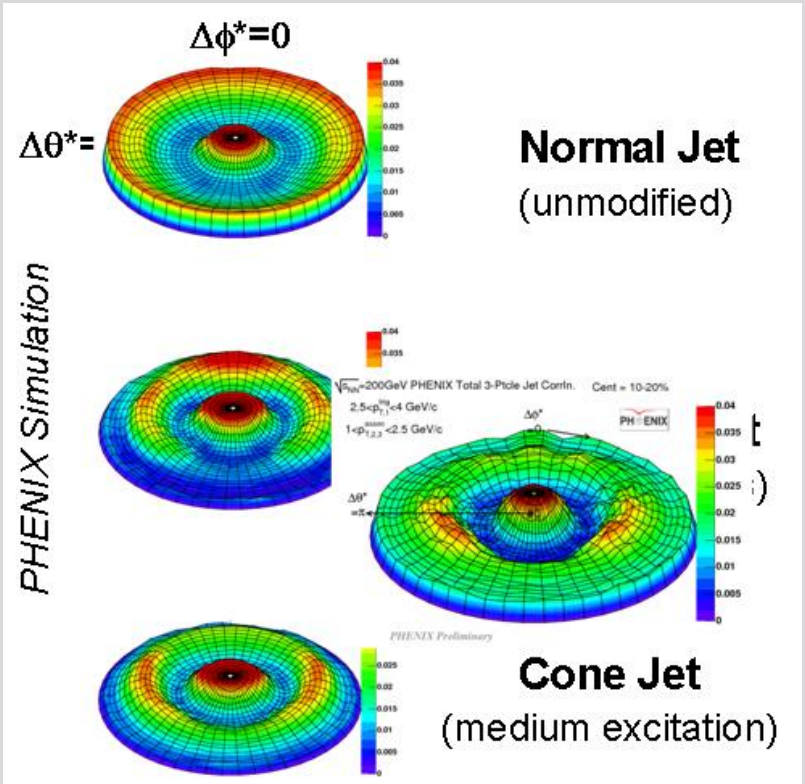
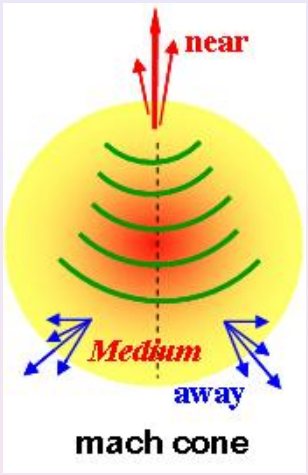


Mach-cone Shock waves



Mach-cone Shock Waves

- a fast thermalization mechanism through dispersing energy into collective modes of shock waves.

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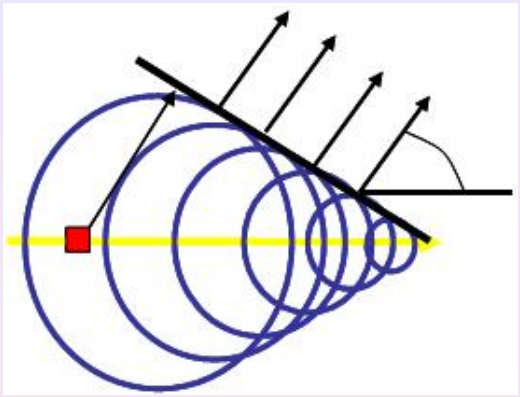

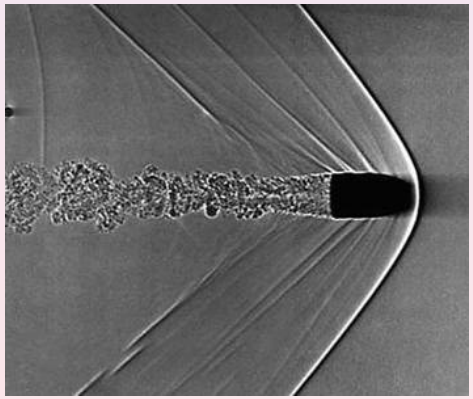

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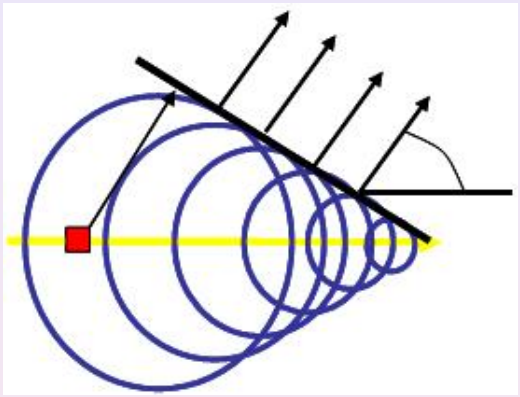

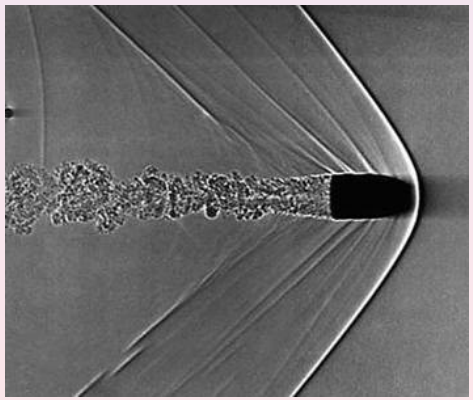

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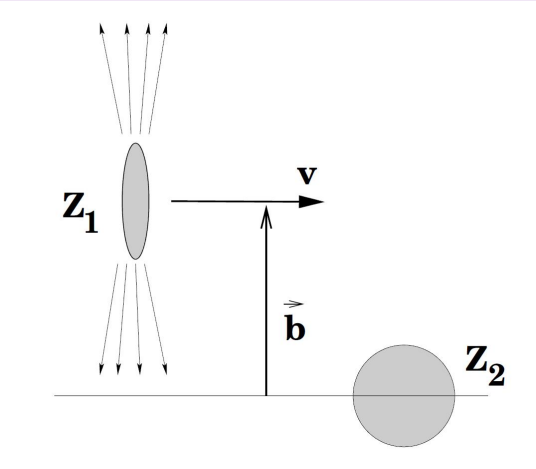
Ultra-Peripheral Heavy-Ion Collisions (UPC)



Photon-Nucleus Interaction

- Nuclei miss each other geometrically: $b > R_1 + R_2$
- No nucleon-nucleon collisions
- Strong electromagnetic fields ($\propto Z^2$) act for very short time
- Photon exchange, photon-photon or photon-nucleus interactions
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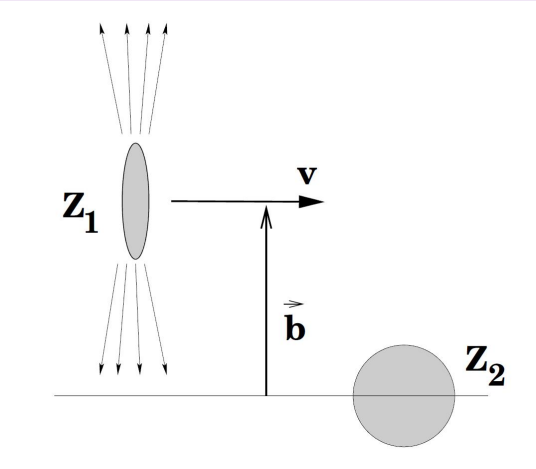

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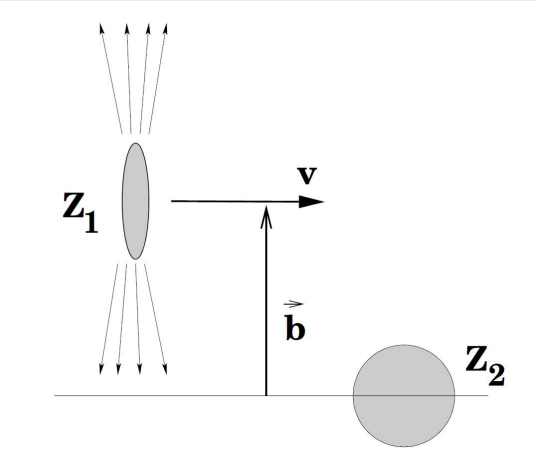

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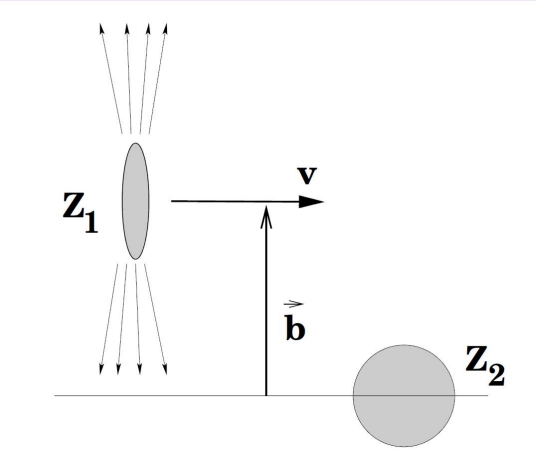

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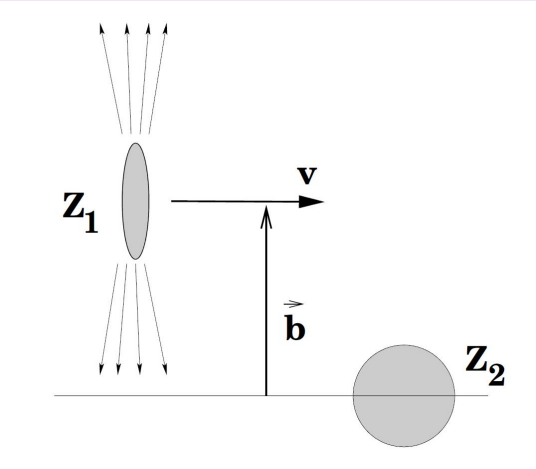

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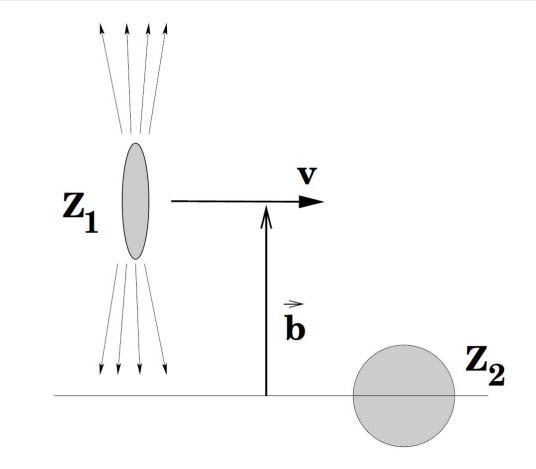

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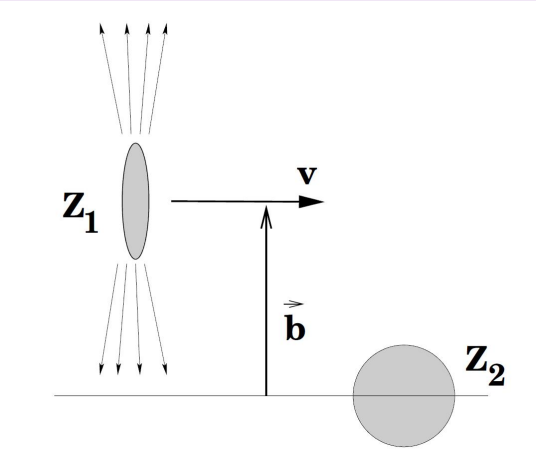

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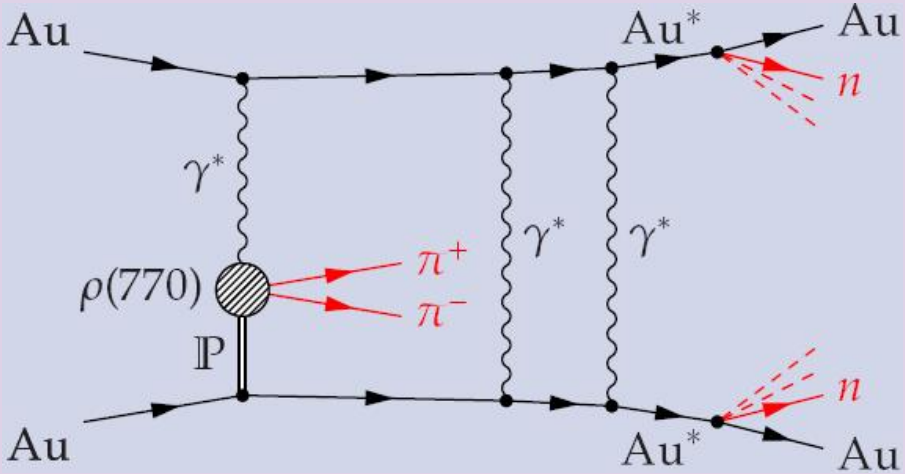
- Nuclear Coulomb excitation, e^+e^- pair and meson production, and vector meson production
- Vector meson production in photonuclear interactions
- pp2pp Project : Wlodek Guryn's talk

ρ Production in UPC at STAR

$\rho(770)$ production with nuclear excitation, S. Klein et al. PRL 89, 272302 (2002)



- 2 oppositely charged tracks with vertex
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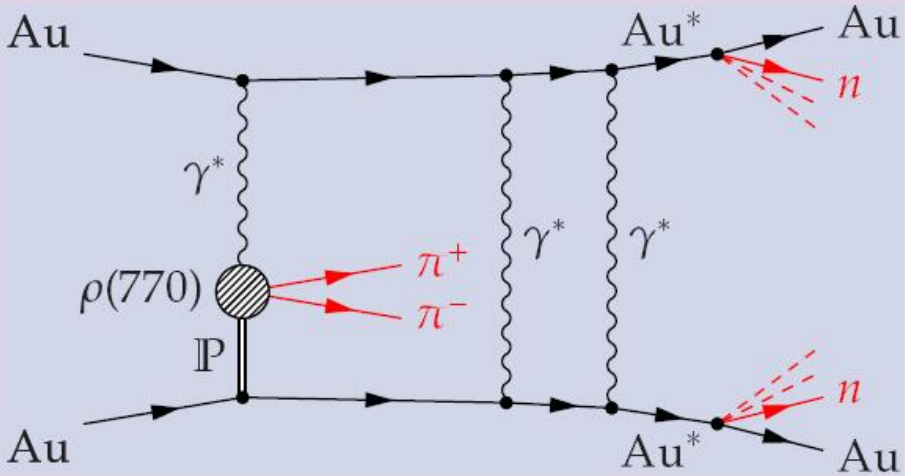

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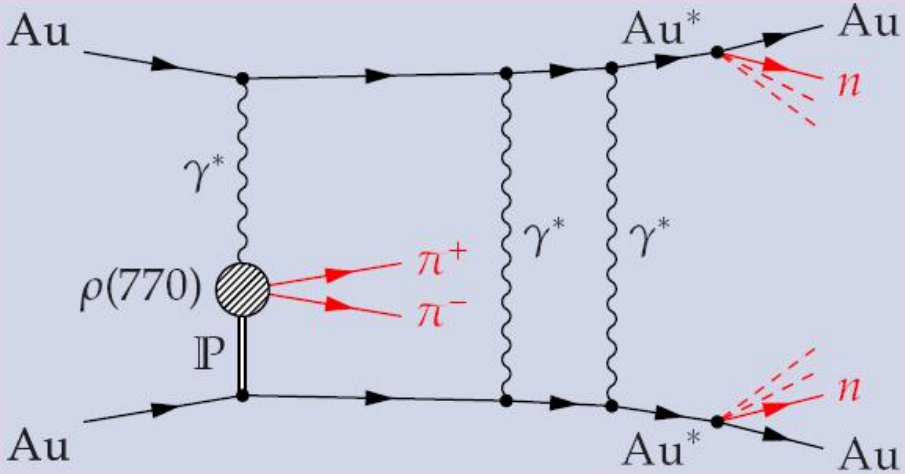

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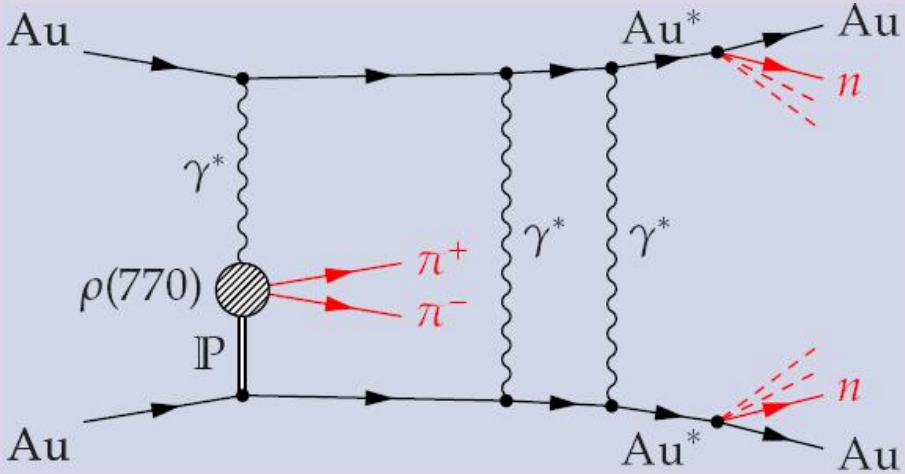

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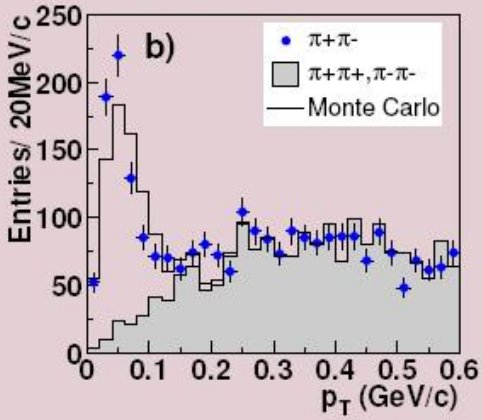
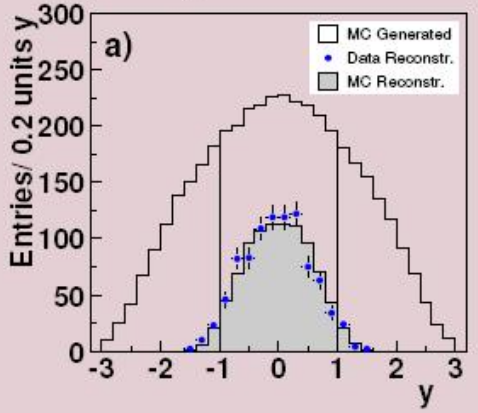
ρ Production in UPC at STAR - Results

ρ production with nuclear excitation in Au $\times$ Au @ $\sqrt{s_{NN}} = 130$ GeV

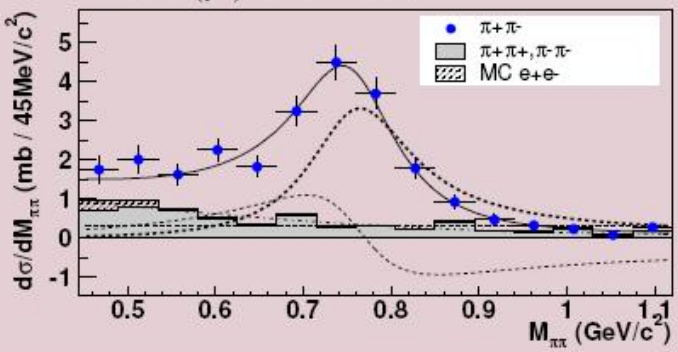
p_T^ρ spectrum



Rapidity distribution



$d\sigma(\rho)/dM_{\pi\pi}$



- Total cross section: $\sigma_{\text{tot}} = (460 \pm 220_{\text{stat.}} \pm 110_{\text{sys.}})$ mb
  S. Klein *et al.* PRL **89**, 272302 (2002)
- Theoretical prediction: $\sigma_{\text{tot}} = 350$ mb
  S. Klein *et al.* PR **C60**, 014903 (1999)

The ρ' Meson

Excited ρ' States

- PDG : 2 poorly known states:
  $\rho(1450) : m = (1459 \pm 11)$ MeV/c^2, $\Gamma = (147 \pm 40)$ MeV
  $\rho(1700) : m = (1720 \pm 20)$ MeV/c^2, $\Gamma = (250 \pm 100)$ MeV
- Quark models predict 5$|q\bar{q}\rangle$ ρ-like meson states below 2.2 GeV/c^2 -
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Inclusion of possible exotic $|q\bar{q}g\rangle$ and $|q\bar{q}q\bar{q}\rangle$ states

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ρ' Production in UPC - Experimental Signature

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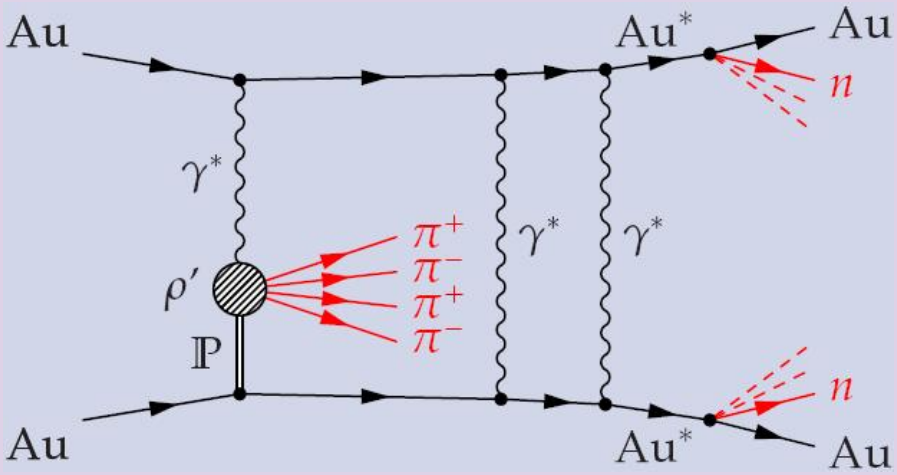

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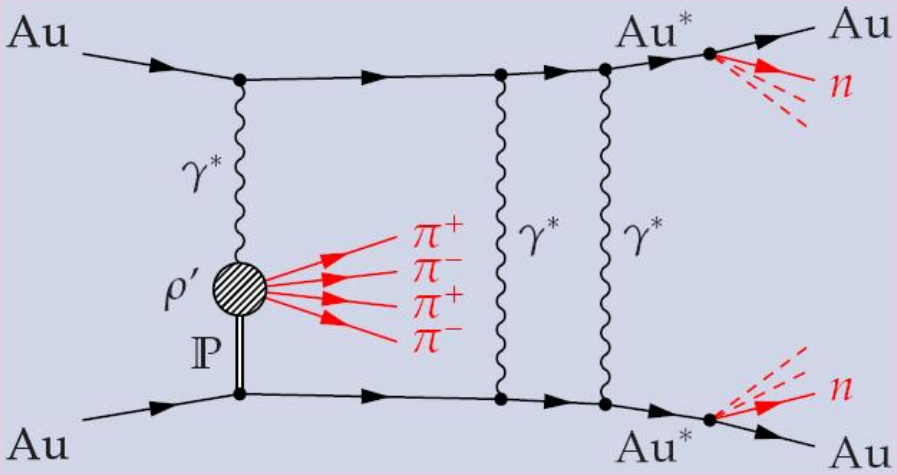

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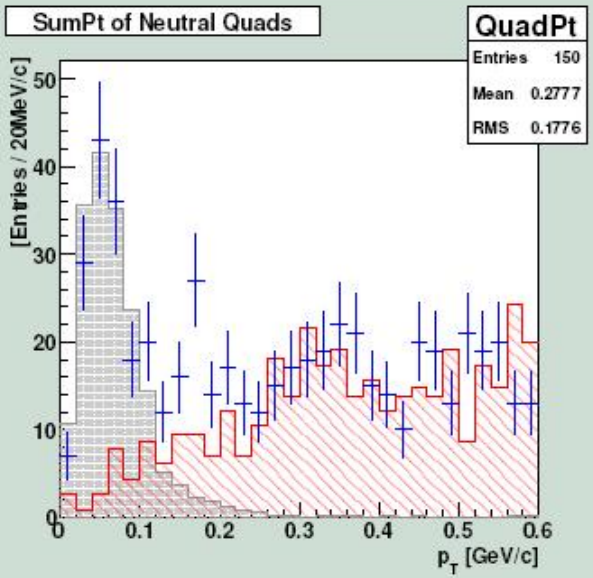
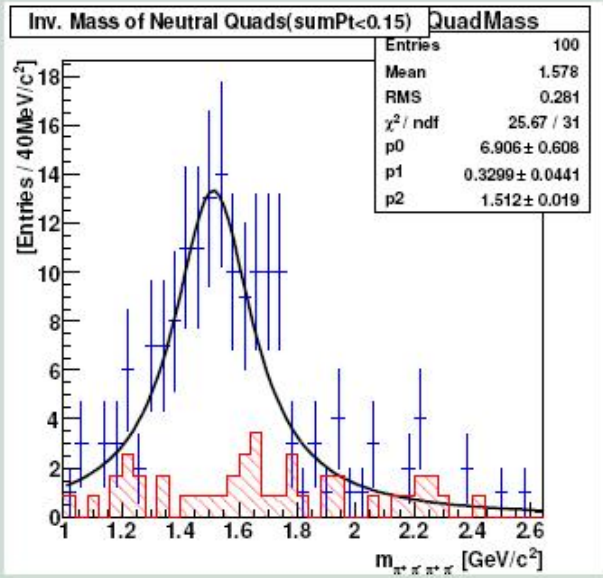
ρ' - the first preliminary Results from Pilot Run

Au × Au @ $\sqrt{s_{NN}}$ = 200 GeV : 3.9 M 4-prong events — Byoung-Chul Kim, PNU





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RUN7 AuAu at $\sqrt{s} = 200$AGeV : Measurement of ρ'

- Expect ~ 300 ρ' $\Rightarrow \Delta\sigma/\sigma \sim 10\%$

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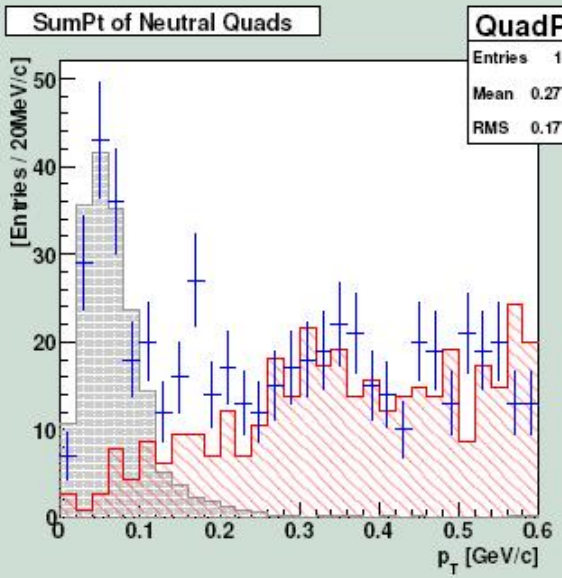

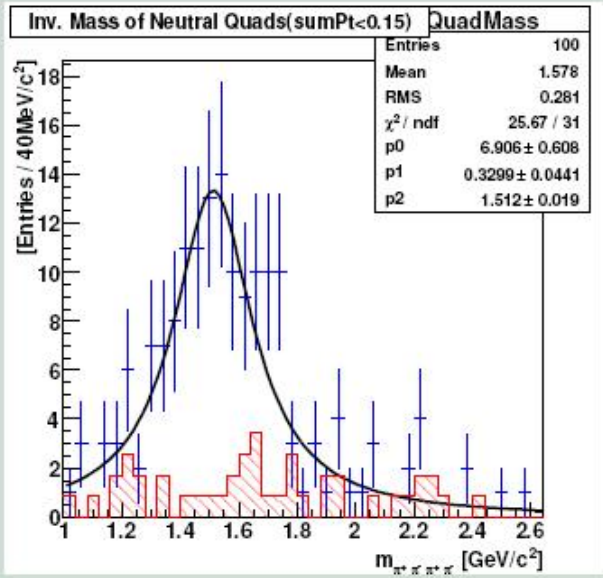

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- Open Charm Measurement and Preliminary Results at dAu vs. AuAu follow binary collision scaling (N_{bin})
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Time of Flight

- Replaces central trigger barrel
- Multi-gap resistive plate chambers (MRPC) using ALICE technology
- 23 000 channels (6 slats x 32 plates x 120 trays)
- Full coverage of TPC acceptance (2π in ϕ, $|\eta| < 1$)
- Intrinsic time resolution $\approx$ 85 ps

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- cover two cylindrical layers :
  - one layer at approximately 2.5 cm radius
  - the other at approximately 7 cm radius
  - A ladder is approximately 20 cm long

Even more fruitful and unexpected break is waiting for us in the future! Thanks for your attention!

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STAR Collaboration

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- China : IHEP - Beijing, IPP - Wuhan, USTC, Tsinghua, SINAP, IMP Lanzhou
- Croatia : Zagreb University
- Czech Republic: Nuclear Physics Institute
- England: University of Birmingham
- France: Institut de Recherches Subatomiques Strasbourg, SUBATECH - Nantes
- Germany: Max Planck Institute, Munich University of Frankfurt
- India: Bhubaneswar, Jammu, IIT-Mumbai, Panjab, Rajasthan, VECC
- Korea: Pusan National Universiy
- Netherlands: NIKHEF
- Poland: Warsaw University of Technology
- Russia: MEPHI - Moscow, LPP/LHE JINR - Dubna, IHEP - Protvino
- U.S. Labs : Argonne, Lawrence Berkeley, and Brookhaven National Labs
- U.S. Universities : UC Berkeley, UC Davis, UCLA, Caltech, Carnegie Mellon, Creighton, Illinois-Chicago, Indiana, Kent State, MIT, MSU, CCNY, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale