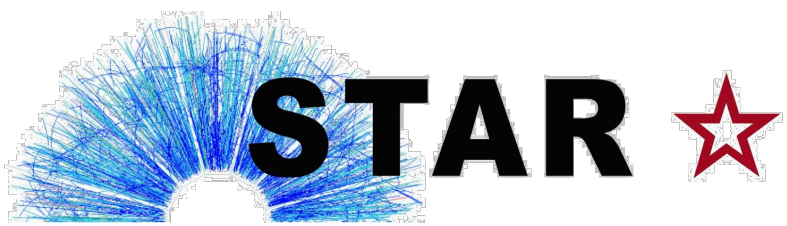


Strange and Multi-strange Hadron Production in O+O Collisions at $\sqrt{s_{NN}}$ = 200 GeV

Iris Ponce for the STAR Collaboration

Yale University

STAR 25-year Celebration

December 17 - 18th

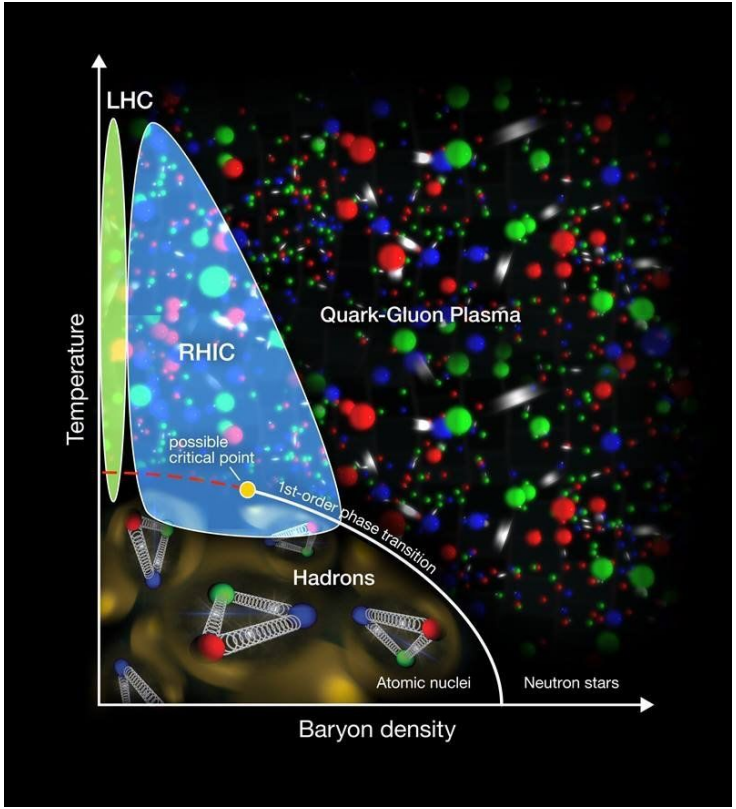
Supported in part by:

U.S. DEPARTMENT OF ENERGY | Office of Science

Wright Lab

QCD and the QGP

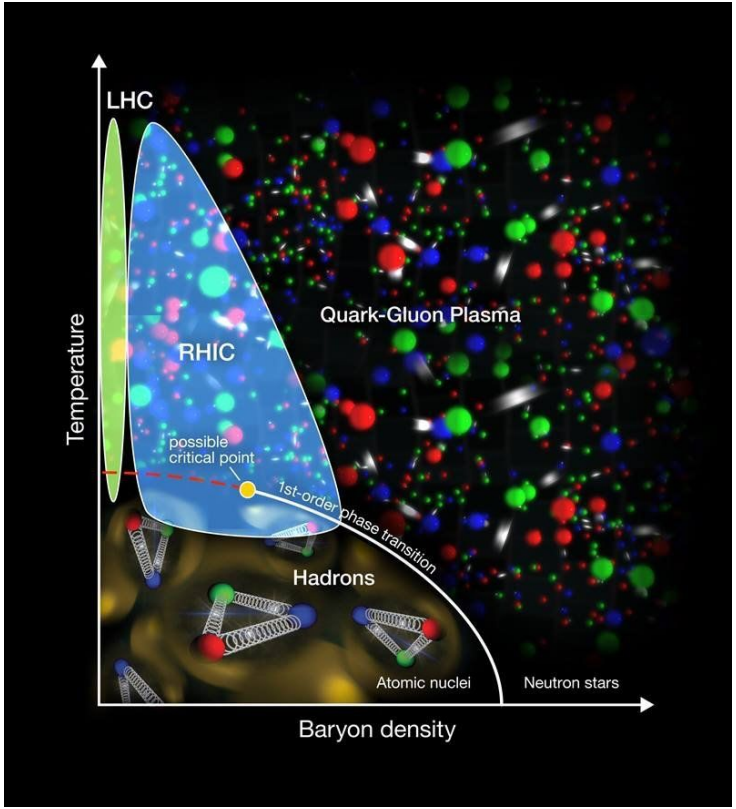
- At high temperatures QCD matter becomes a new state of matter called the Quark-Gluon plasma (QGP).
  - Deconfined strongly coupled fluid.



https://www.bnl.gov/newsroom/news.php?a=121072

QCD and the QGP

- At high temperatures QCD matter becomes a new state of matter called the Quark-Gluon plasma (QGP).
  - Deconfined strongly coupled fluid.
- Its existence was predicted in 1975 and experimentally discovered in the early 2000s.
- The QGP is predicted to have existed in the early universe
  - First μs after the Big Bang



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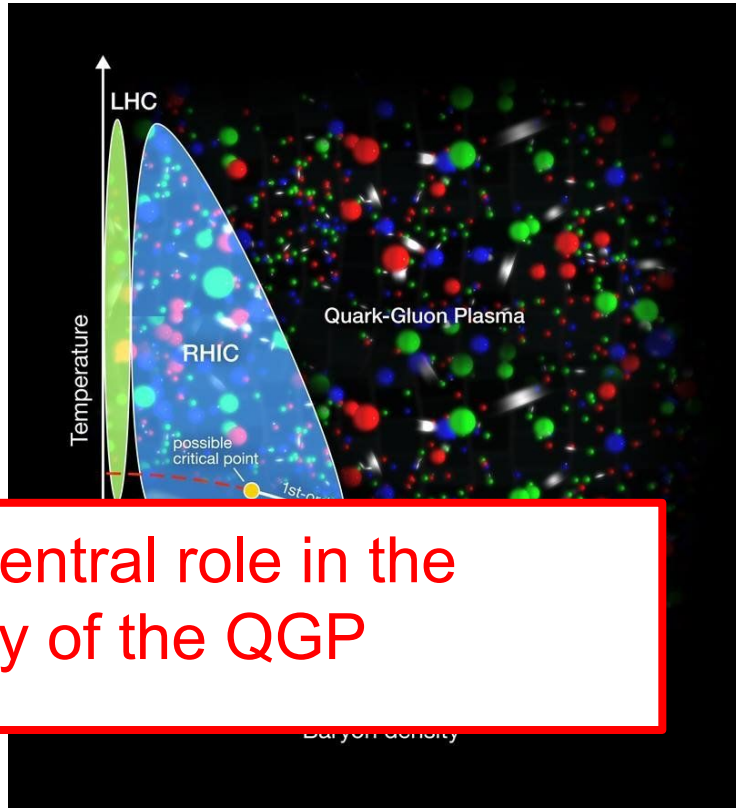

STAR has played a central role in the experimental study of the QGP

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RHIC Does It All!

RHIC's versatility has enabled STAR to collect a uniquely diverse range of data sets throughout its lifetime

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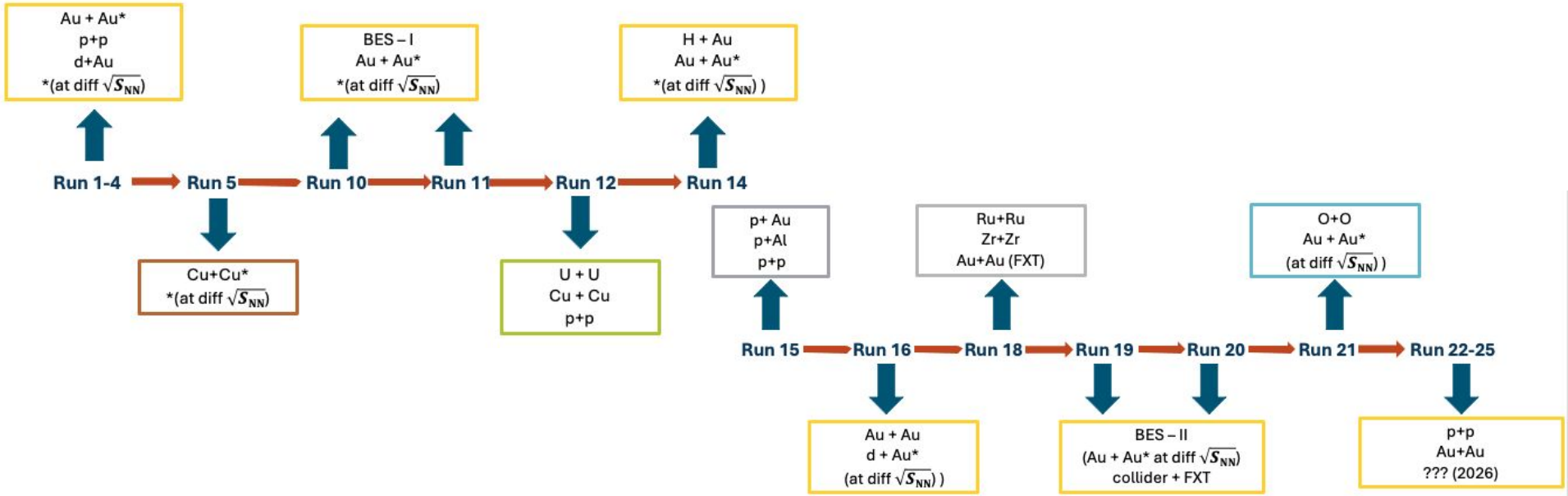

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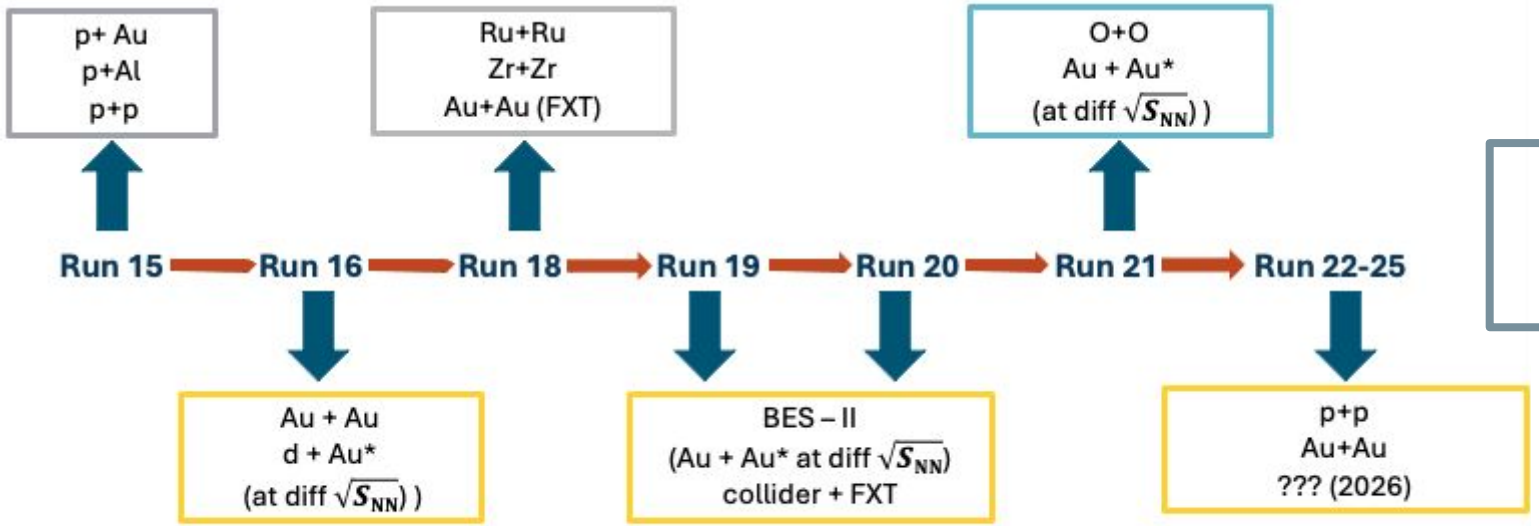

Nine collision systems in the last decade!

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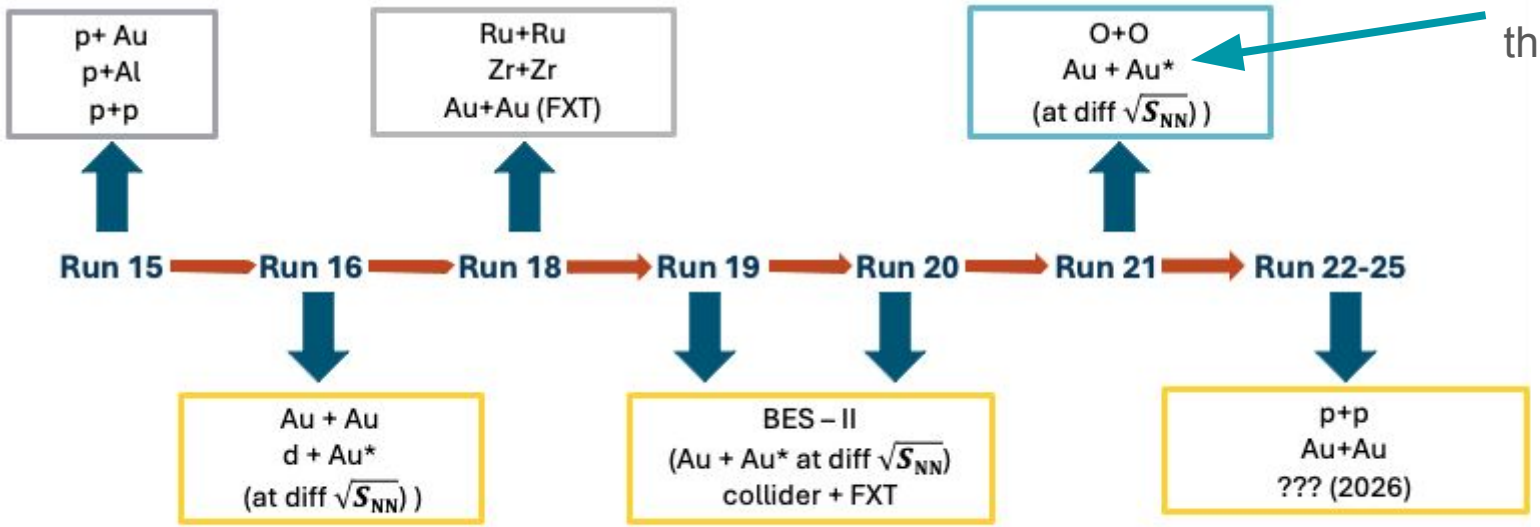

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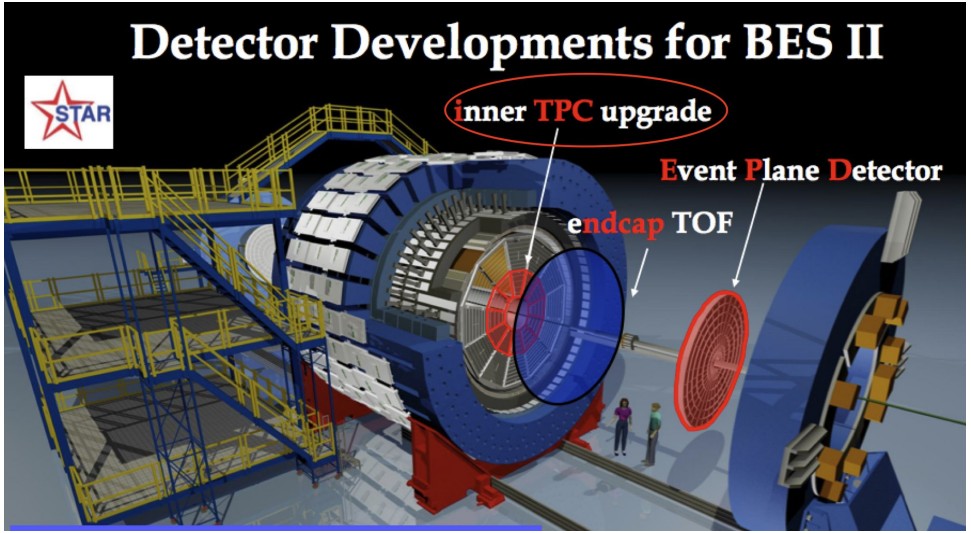
O+O Run Information at STAR

- The Solenoidal Tracker at RHIC (STAR) has been operating since 2000.

- From 2018 on, STAR had two detector upgrades: iTPC and eTOF
  - Improved coverage:
    From $|\eta| < 1.0$ => $|\eta| < 1.5$
  - Lower p_T coverage 125 MeV => 60 MeV
  - Extended PID with eTOF



Picture: Alex & Maria Schmah
Q. Xu. (STAR). 8th Workshop on Hadron Physics (2016)

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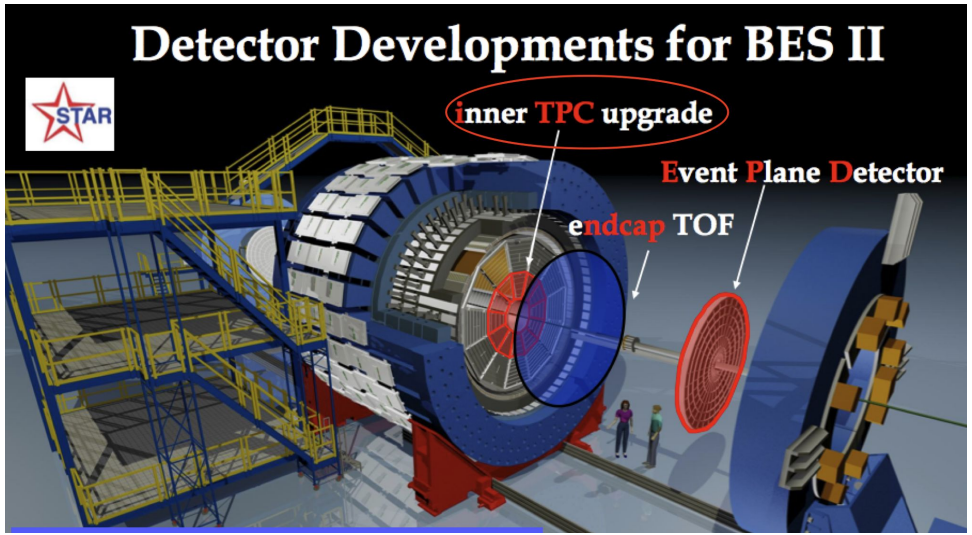
  - Lower p_T coverage 125 MeV => 60 MeV
  - Extended PID with eTOF
- There are ~650M O+O minimum bias events total at $\sqrt{s_{NN}}$ = 200 GeV.
  - ¼ of the O+O run was taken with the magnetic field reversed.
    - Testing calibration and TPC distortions



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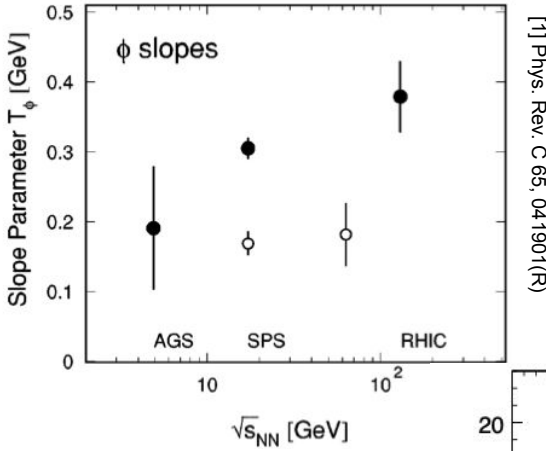
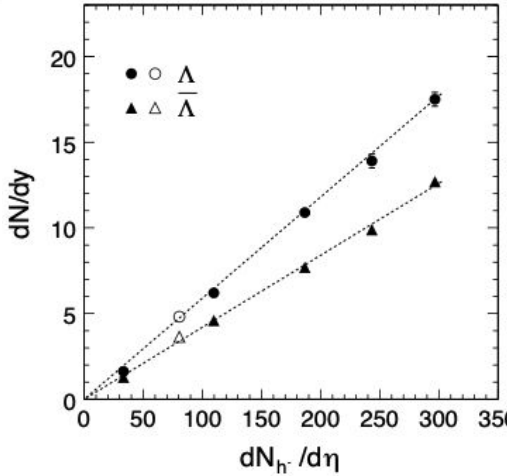
Next Stage: STAR Contributions to Strangeness Enhancement/Production Studies

First Results On Strangeness

- The first results on strange hadron production were published in 2002.
  - ϕ production at mid-rapidity[1]
  - Λ and Λ-bar production at mid-rapidity[2]



[1] Phys. Rev. C 65, 041901(R)



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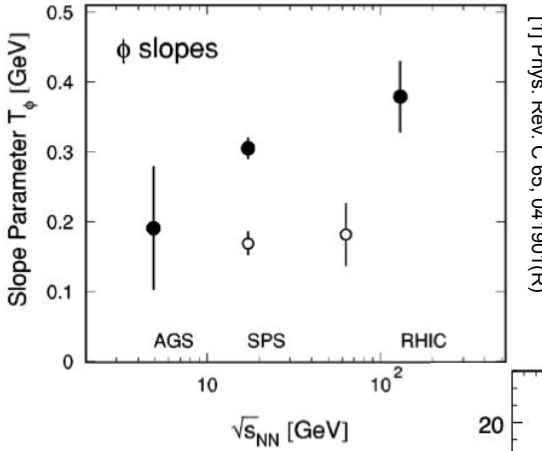
- Both analysis on Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV.
  - Dataset lasted 5.3 weeks and delivered 20 μb^{-1} => last run periods STAR has collected more than 20 μb^{-1} in a day!



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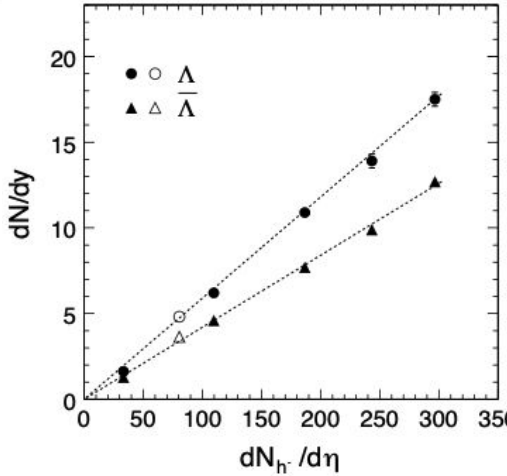

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Strangeness Enhancement and the QGP

- Strangeness enhancement was one of the first observables predicted as a signature of the QGP.
- The thermal production of s-$\bar{s}$ quark pairs is favorable in the QGP since the $\bar{s}$-s masses are close to the QGP transition temperature ~157 MeV.
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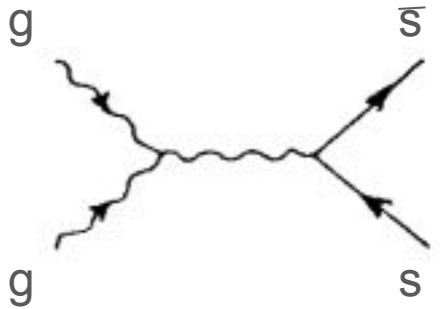

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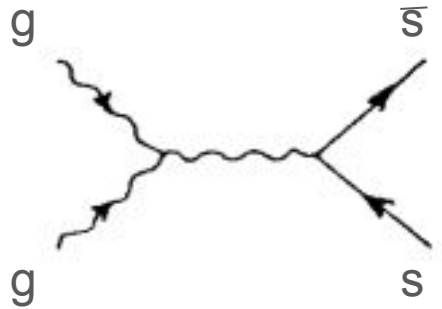
  - 2 x m_s ~192 MeV
  - There are abundant thermal gluons in the QGP medium.
- The production of multi-strange ($\Xi^{\pm}$,$\Omega^{\pm}$) hadrons are more sensitive to the existence of QGP.



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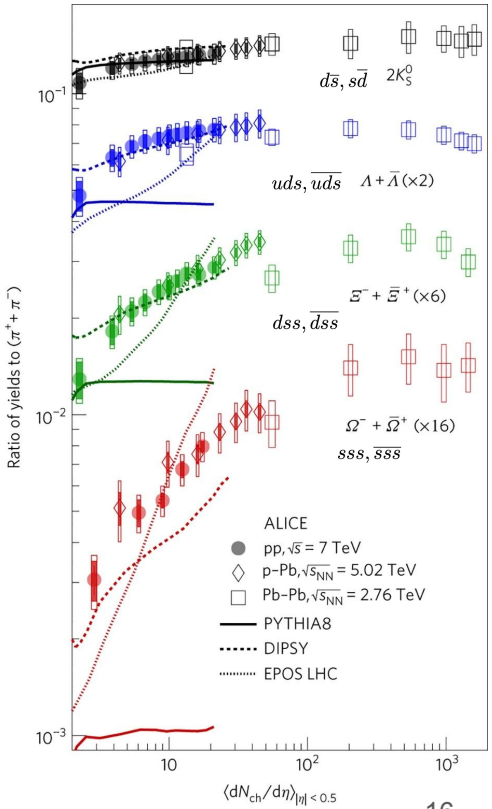

ALICE. Nat. Phys., 13, 535 (2017)

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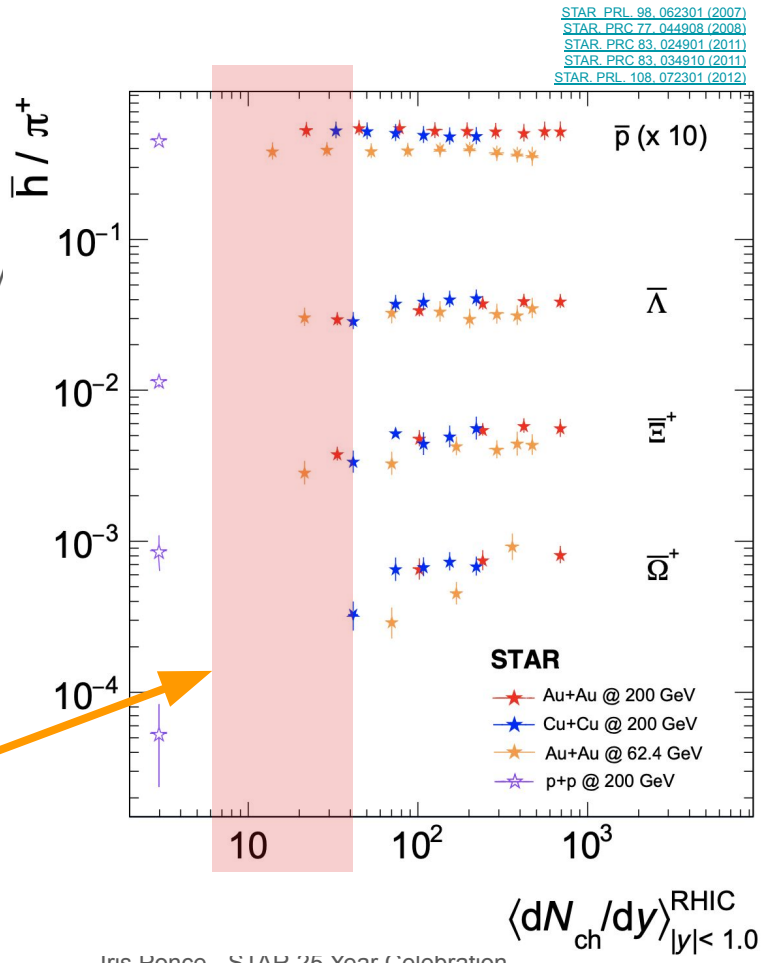
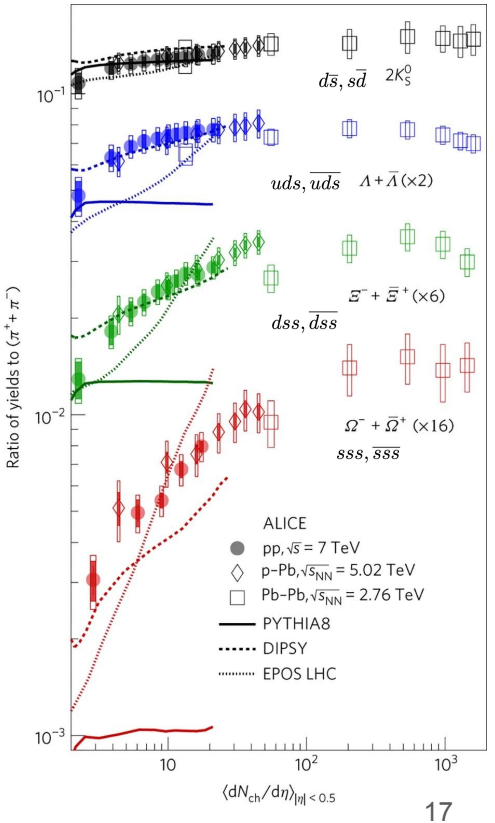
However, there is a notable data gap in the low multiplicity region





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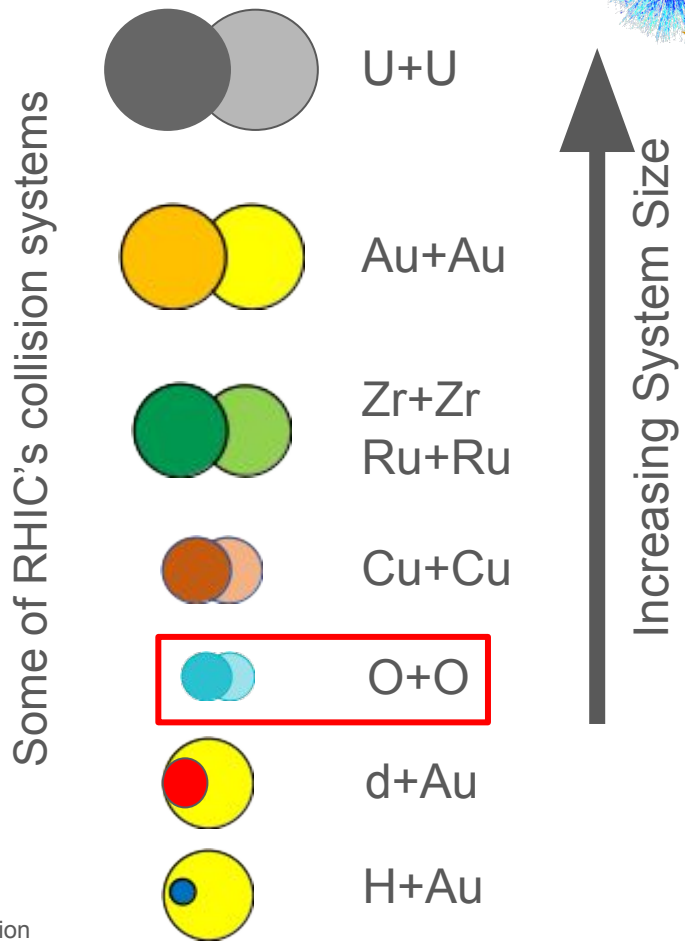

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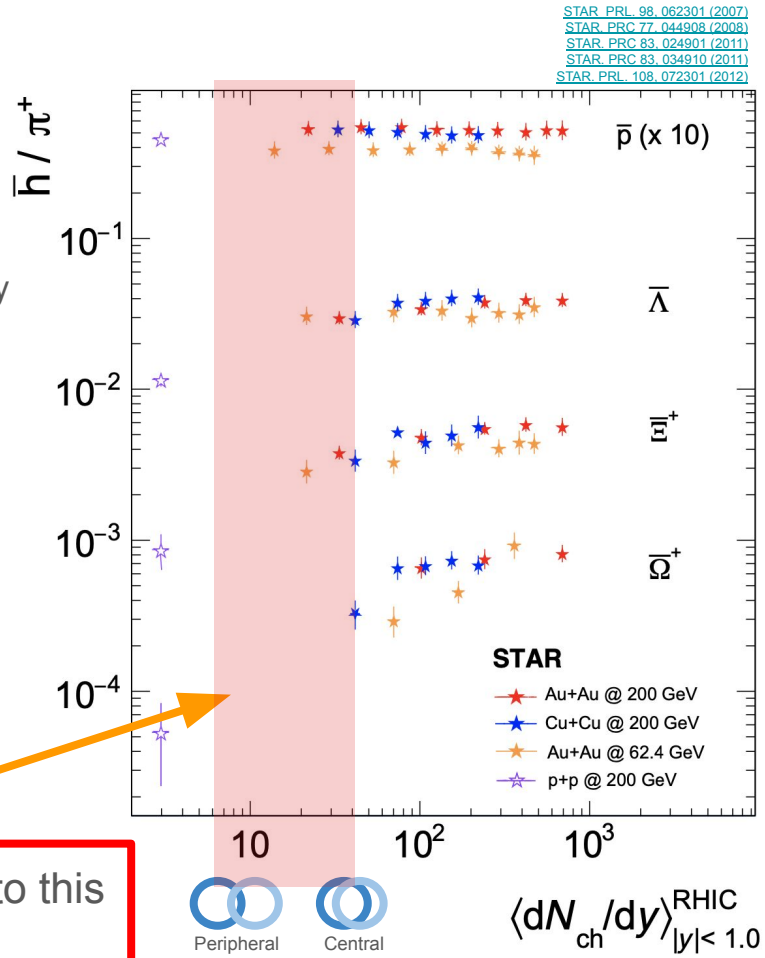


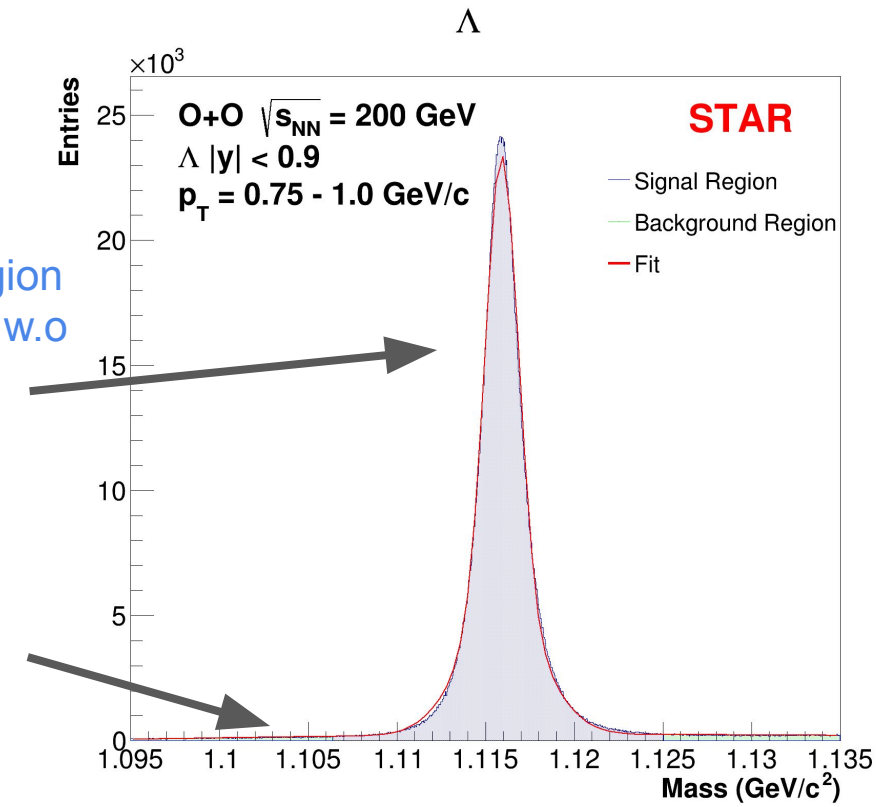
O+O's multiplicity can extend to this unexplored region

Corrected p_T spectrum for Λ's in Central O+O Collisions

- The p_T spectra is calculated from the Λ's invariant mass distributions in different momentum ranges.

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

For the Λ Signal Extraction:



The blue region is the signal w.o background subtraction.

The green region is the background region (very small)..

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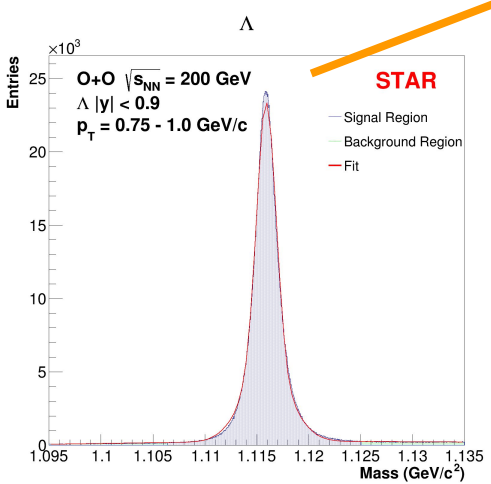

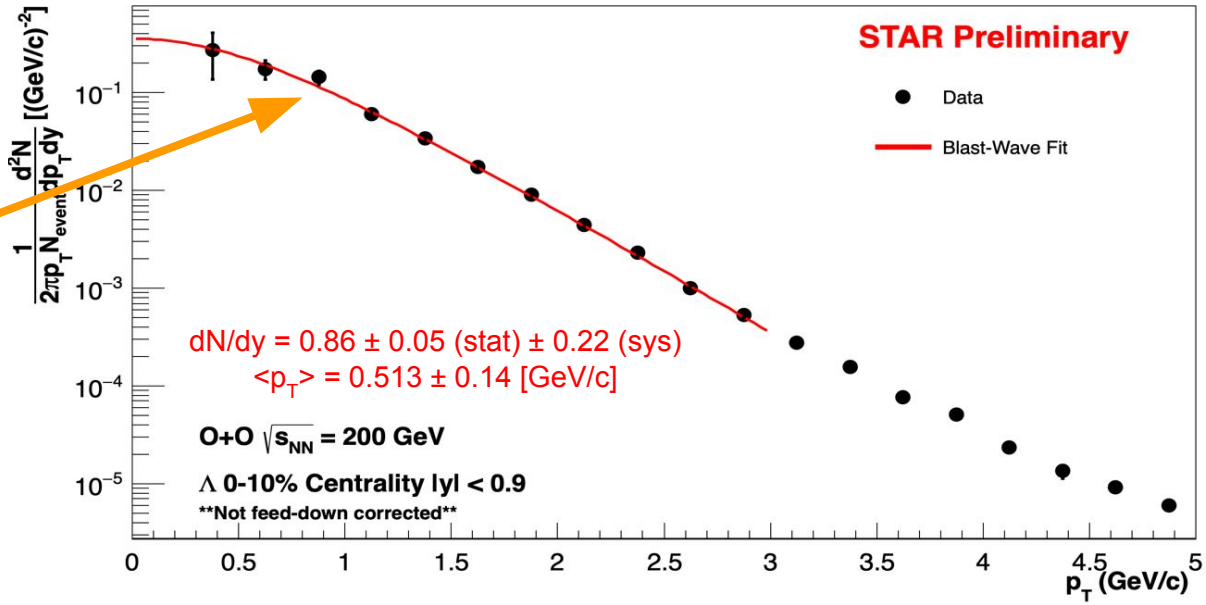

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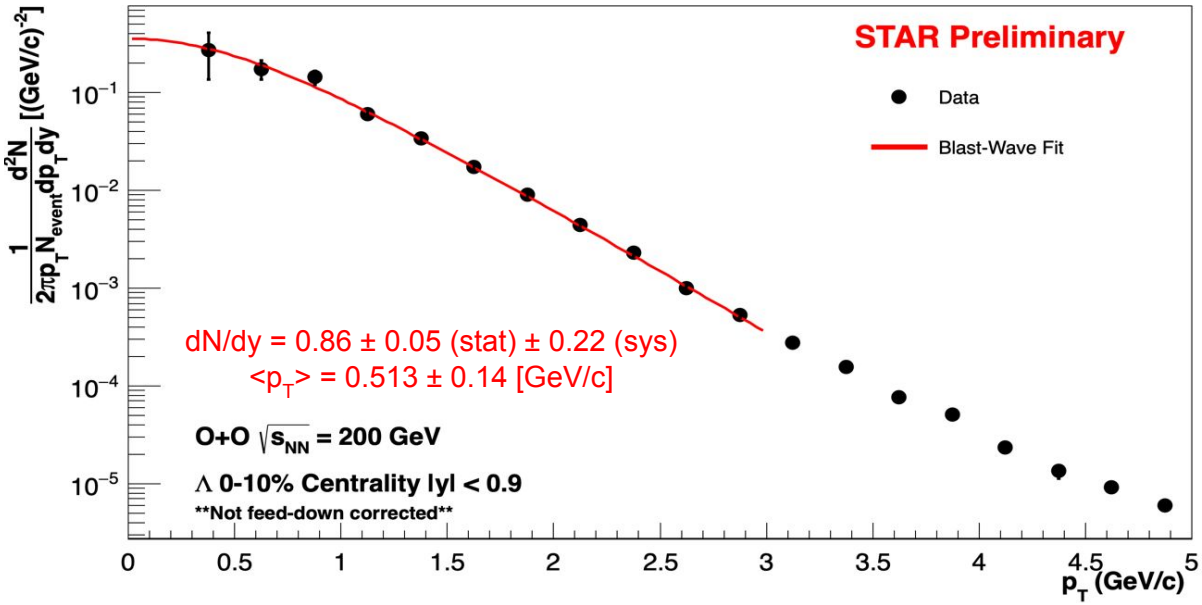
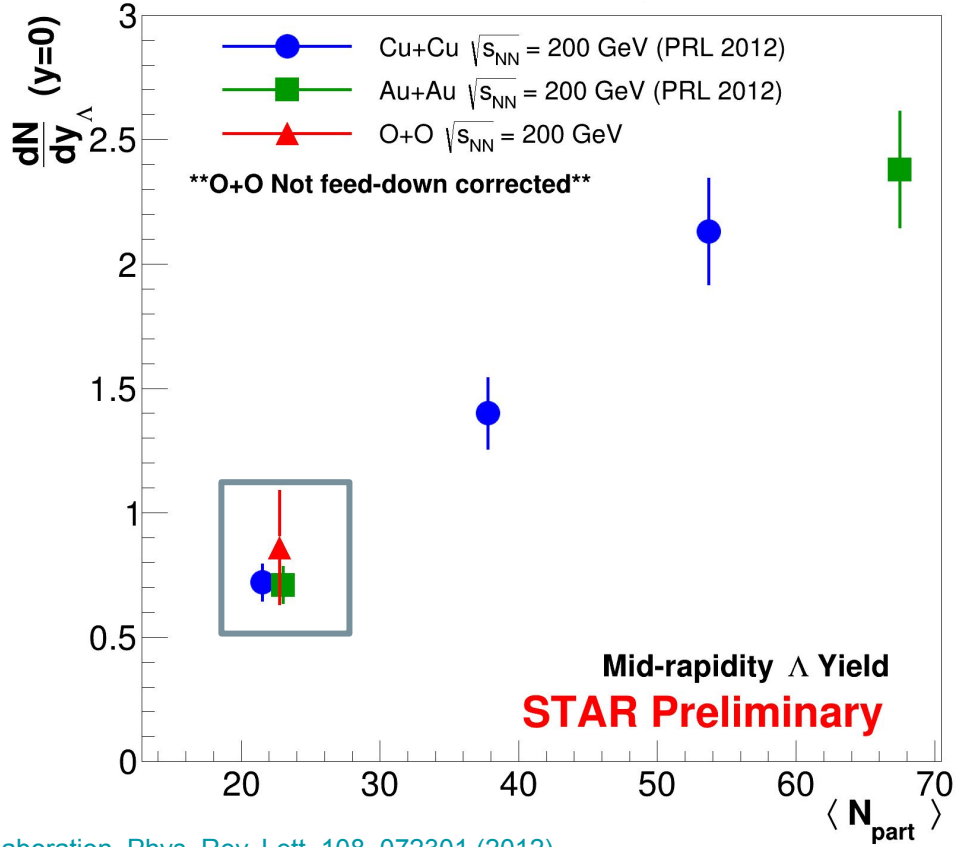
- The p_T spectra is corrected using the reconstruction efficiency with Monte Carlo simulations.
  - MC_{reco} /MC_{input}
- The Λ p_T spectra is the average of both magnetic field configurations.



Comparing the O+O yield to similar Collision Systems



Integrating the Λ p_T spectrum from 0 to ∞ the yield (dN/dy) is 0.86 ± 0.05 ± 0.22

**O+O yield is not feed-down corrected.

STAR Collaboration. Phys. Rev. Lett. 108, 072301 (2012)

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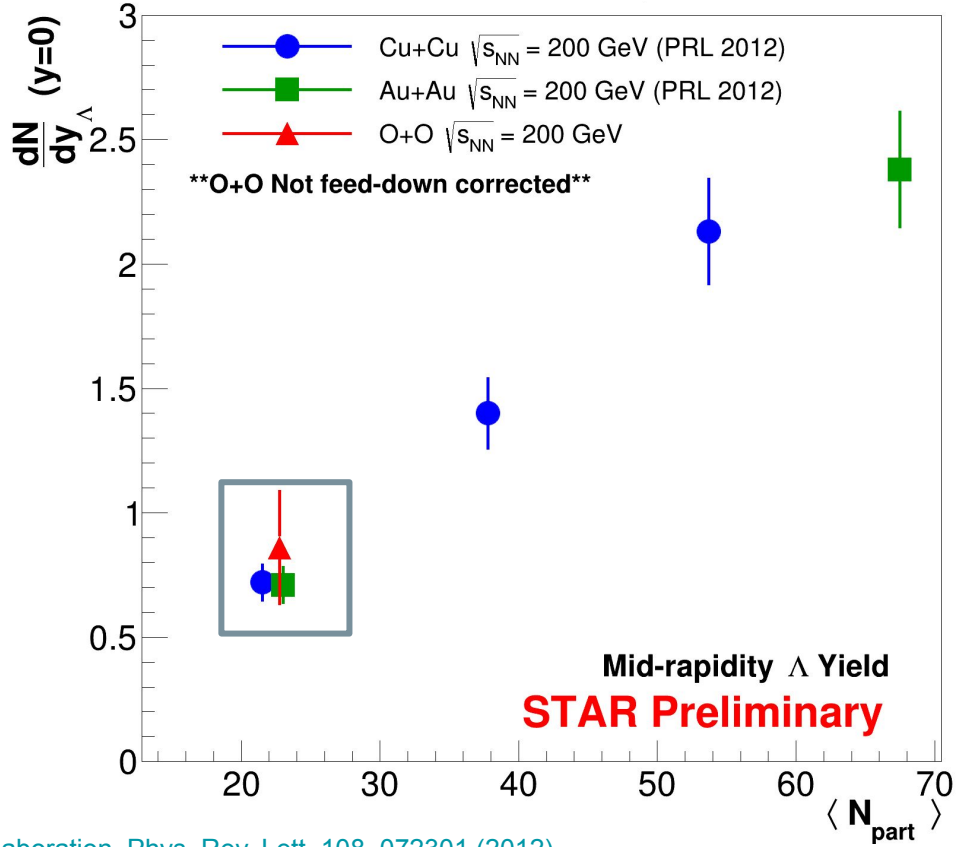

Most central O+O collisions have a similar $< N_{part} >$ as peripheral Au+Au collisions.

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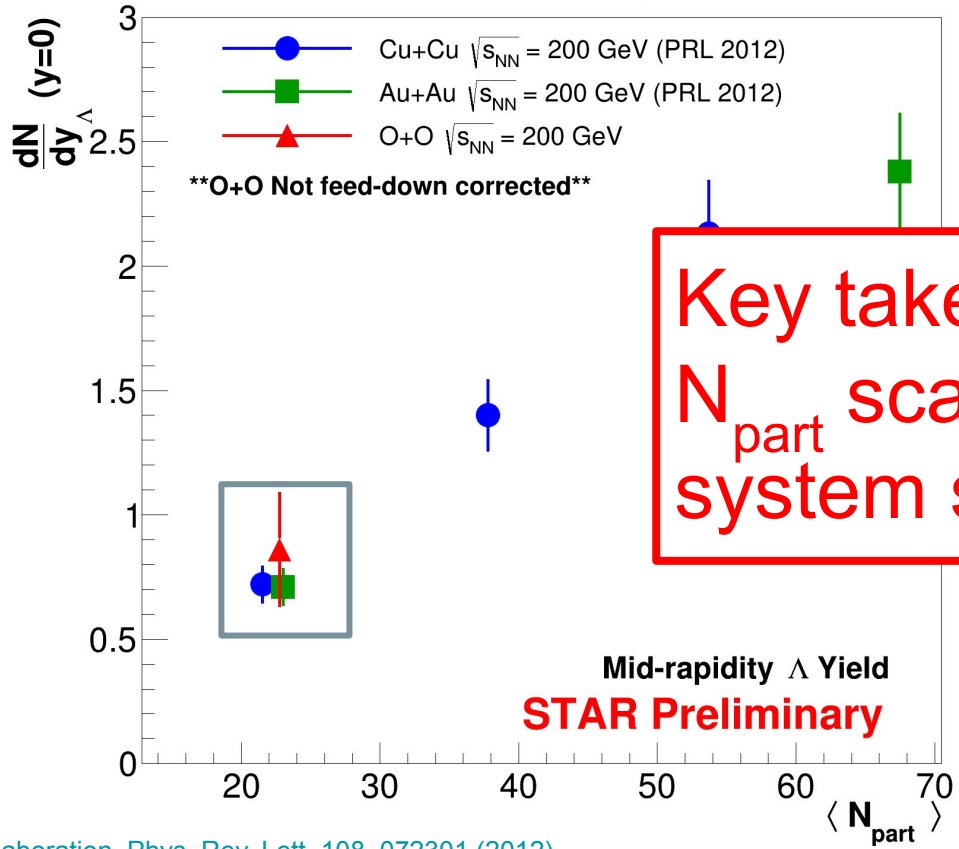

Most central O+O collisions have a similar $\langle N_{part} \rangle$ as

Key takeaway: Yields show N_{part} scaling rather than a system size dependence

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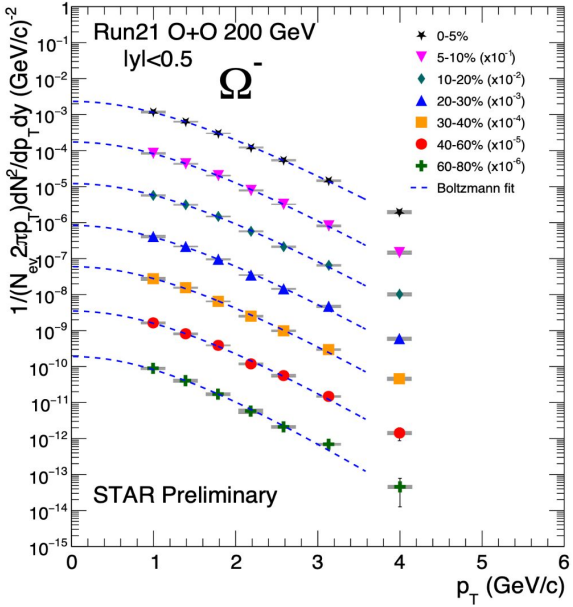
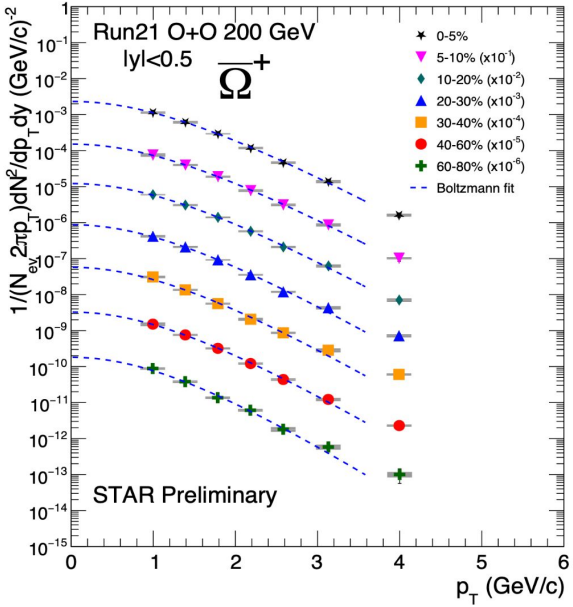
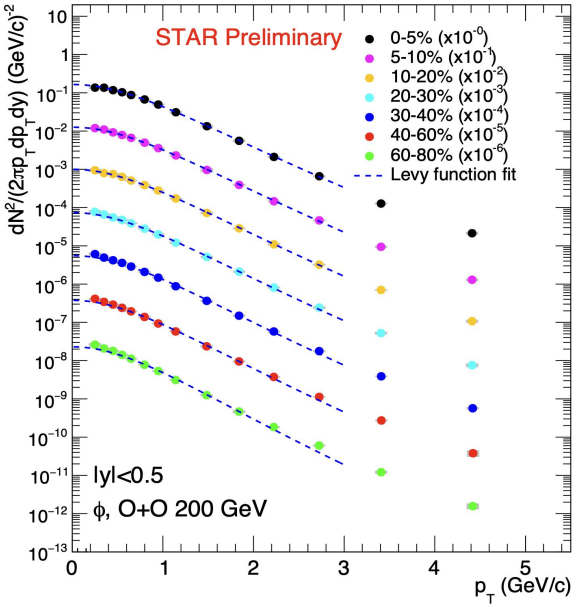
Next step: Perform a differential p_T dependent studies

p_T spectra for multi-strange hadrons







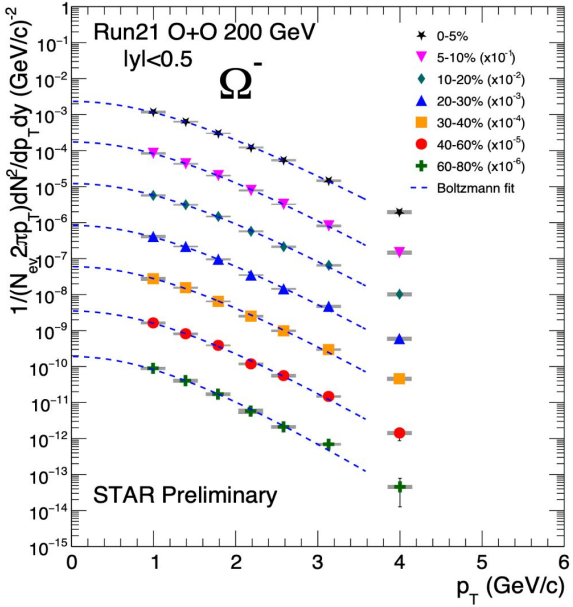
QM25: Xiongxiong Xu poster 812

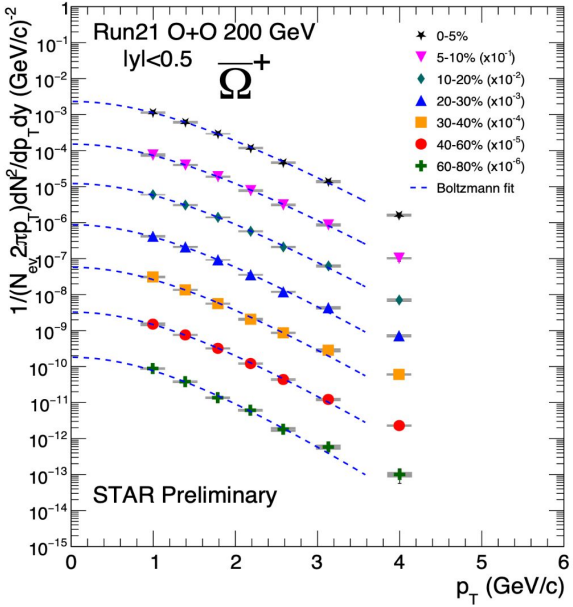
QM25: Weiguang Yuan Session 29

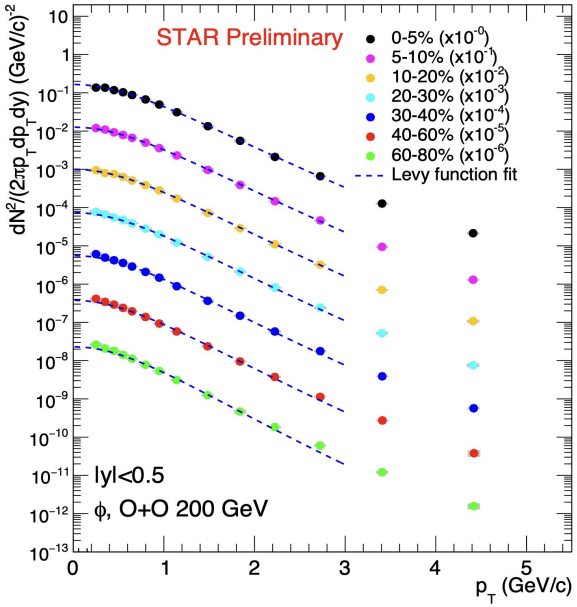
Ω- (sss) → Λ + K^-

ϕ (ss-bar) → K^+ + K^-

p_T spectra for multi-strange hadrons







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There is good coverage through 0 - 80% centralities for multi-strange hadrons.

Ω/ϕ Ratio With Different Collision Systems

- In Au+Au collisions at $\sqrt{S_{NN}}$= 200 GeV significant Ω enhancement over ϕ has been observed at intermediate p_T
  - Enhancement is consistent with production through coalescence

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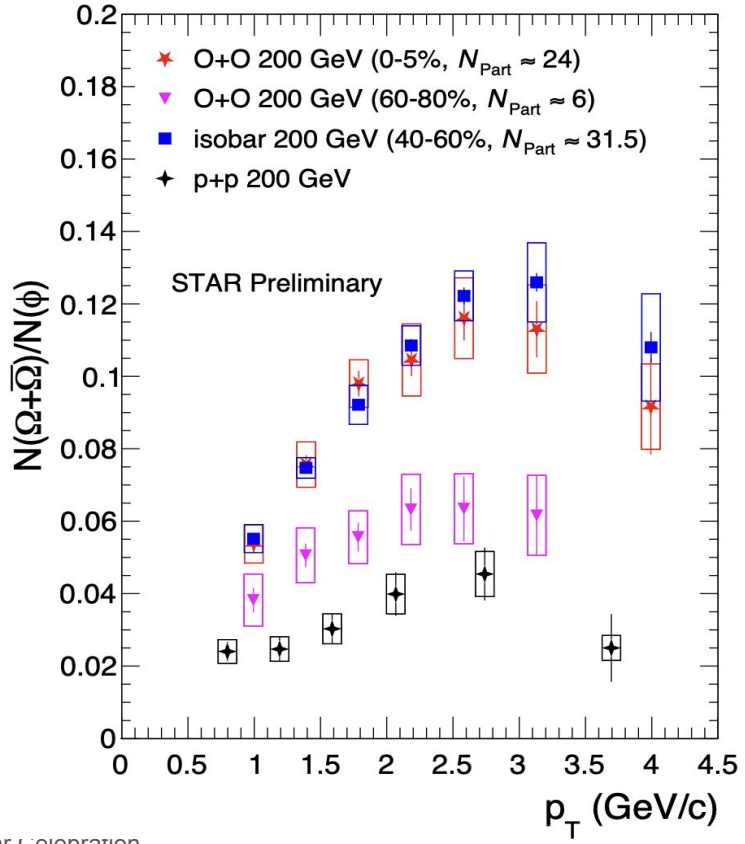
- Ω/ϕ enhancement is observed in O+O collisions.
  - Consistent with peripheral isobar results (comparable N_{part})



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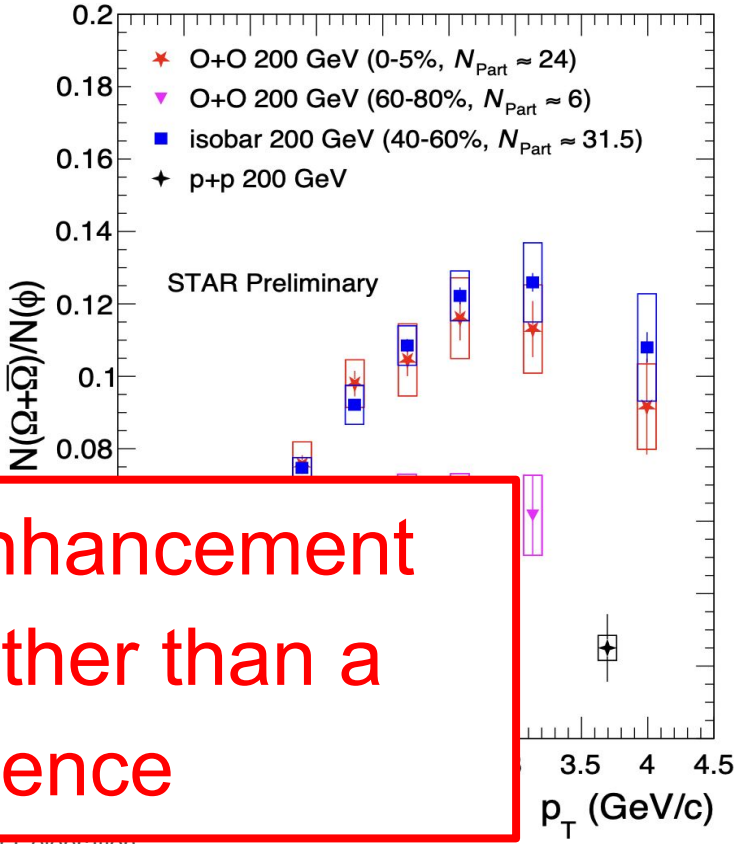
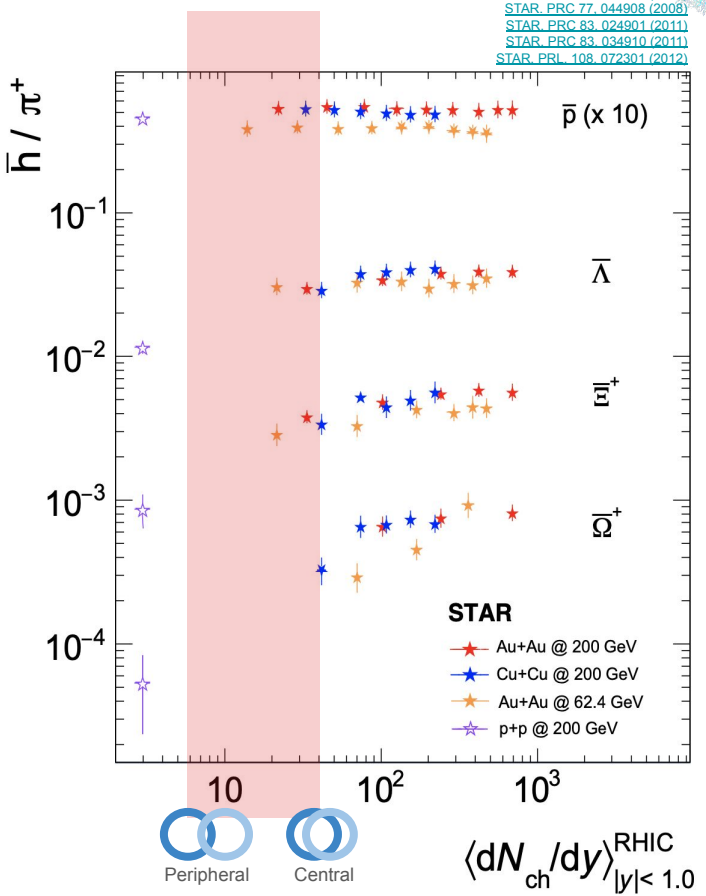


Key takeaway: Ω/ϕ enhancement shows N_{part} scaling rather than a system dependence

QM25: W
Yuan Ses
QM25: X
Xu poster

Outlook

- The O+O dataset provides a unique physics opportunity for STAR:
  - A system bridging small and large collision systems
    - The O+O dataset can fill in the gaps in the low multiplicity regions in the ratio of strange hadron production to the pion yield for the STAR data.



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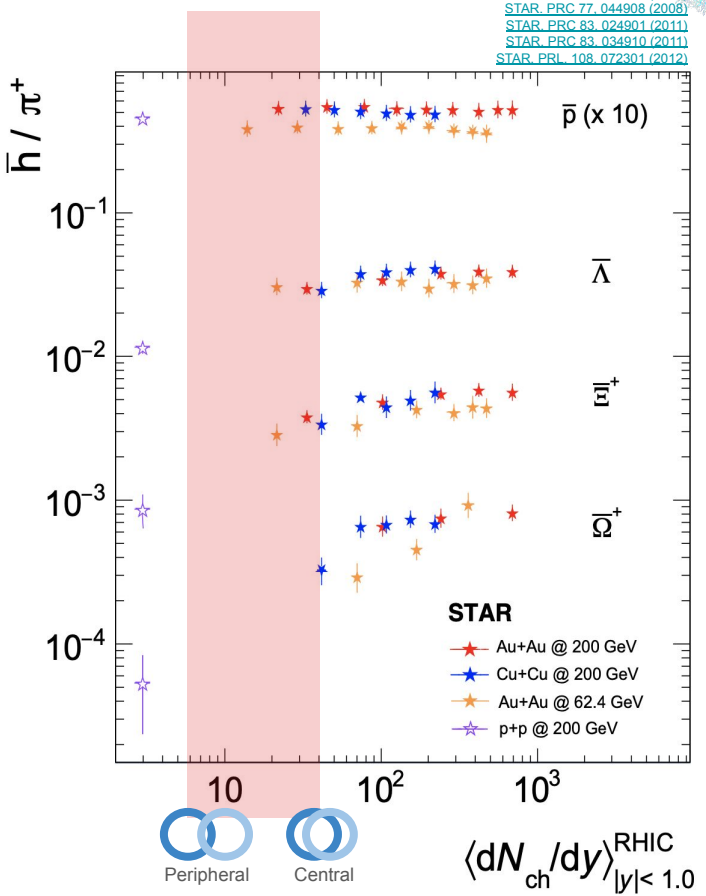

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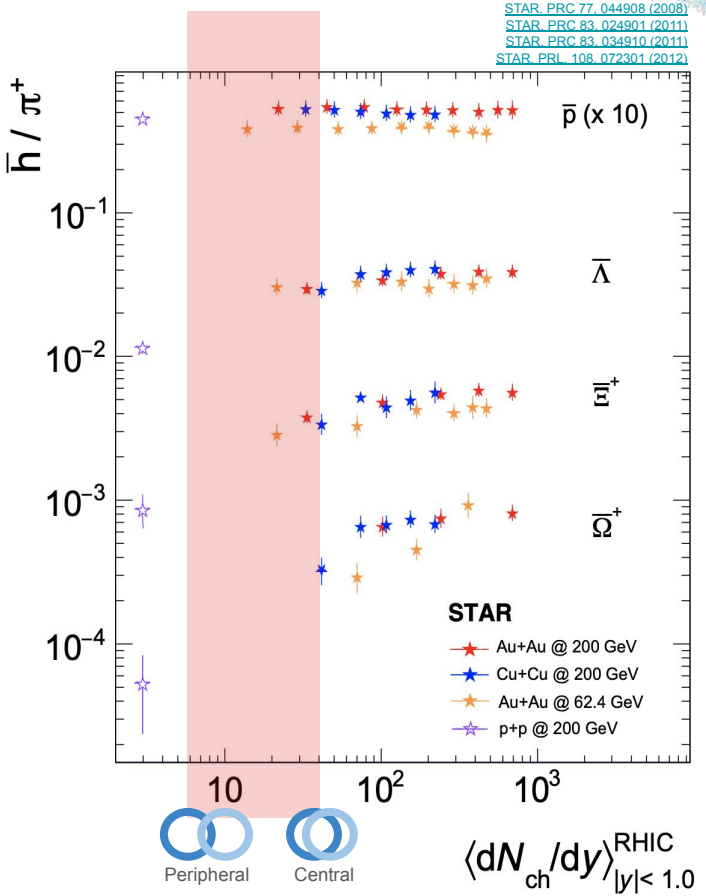
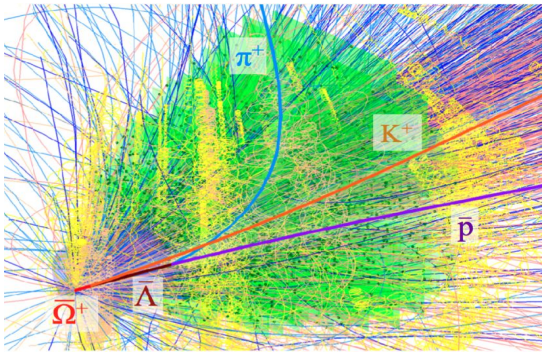
- Recent results provide strong indications of jet suppression in O+O.
  - New studies on strangeness production in O+O collisions are essential to explore additional potential QGP signatures in this system



Backup

Reconstructing Lambdas and Signal Extraction

- Using Kalman Filter Particle (KF Particle) reconstruction algorithm.
  - Standard reconstruction for decayed particles.
  - Initially developed for other heavy ion experiments but was adapted in 2018 for STAR.



M. Kocan. WEJCF. (2019)

Particles To Be Reconstructed

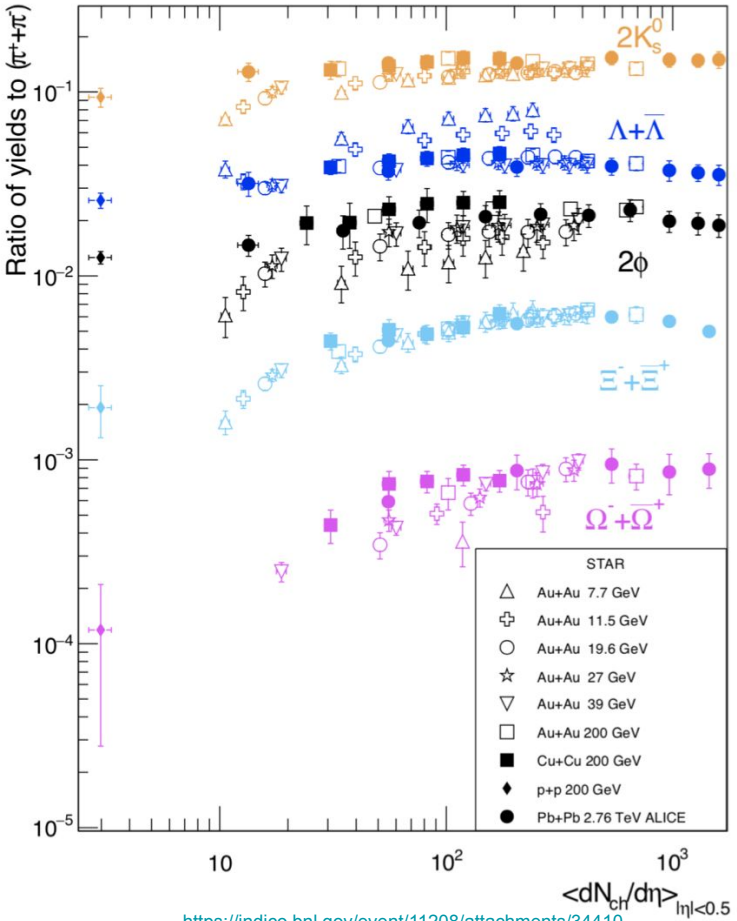
These are some strange hadrons and mesons that are short-lived and decay via hadronic channels!

Particle	Strangeness	Mass (MeV)	Decay Mode	Branching Ratio
$\phi(1020)$	0	$1{,}019.461 \pm 0.020$	K^+K^-	49.5 %
K^0_s	±1	497.611 ± 0.013	$\pi^+\pi^-$	69.20 %
Λ	-1	$1{,}115.683 \pm 0.006$	$p\pi^-$	64.1 %
Ξ^-	-2	$1{,}321.71 \pm 0.07$	$\Lambda\pi^-$	99.887%
Ω^-	-3	$1{,}672.45 \pm 0.29$	ΛK^-	67.8%

PDG Live

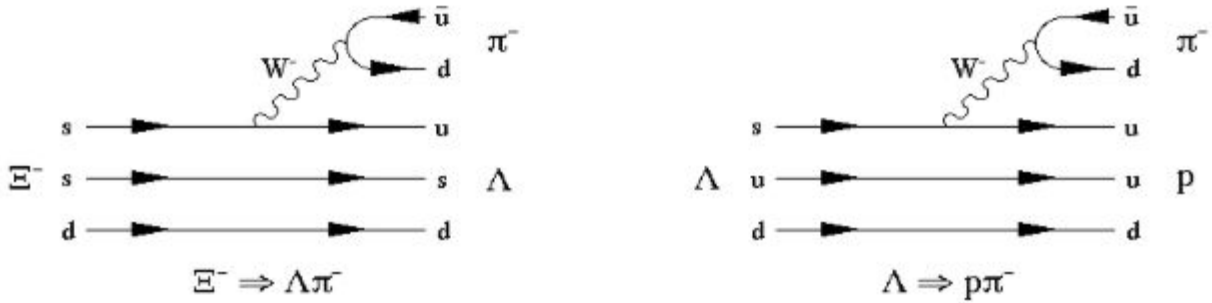
- This presentation will focus on **Λ**'s.
- The **Ξ**$^-$,**Ω**$^-$, **ϕ** , and K^0_S results will follow soon.

Full spectra with BES yields



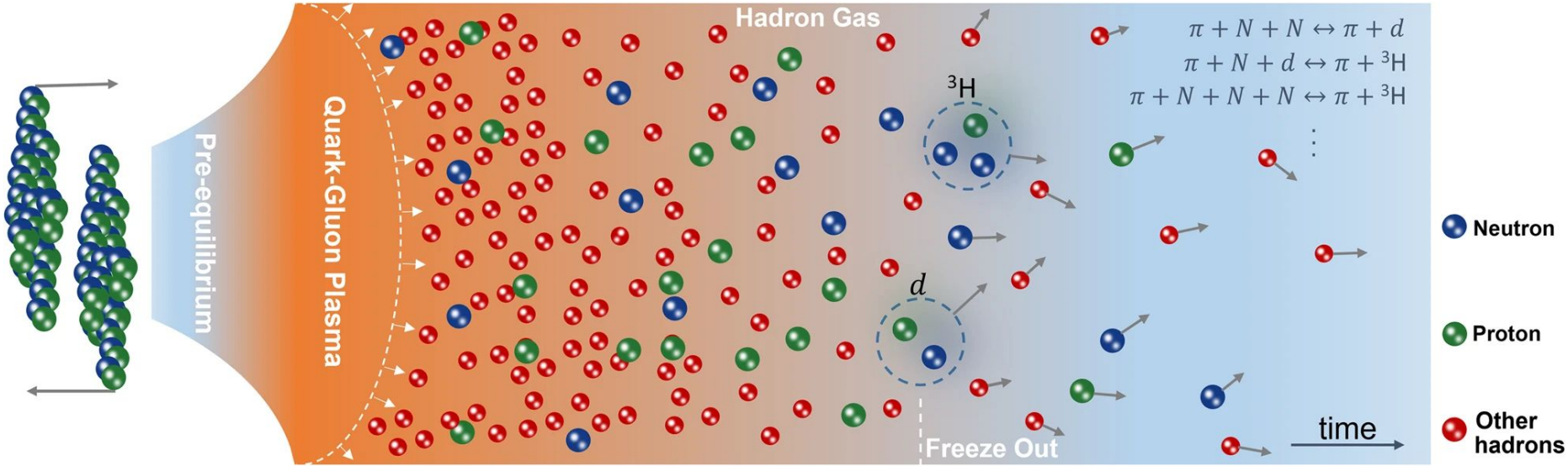
https://indico.bnl.gov/event/11208/attachments/34410/55818/zhu_BNL_nuclear_seminar_2021.pdf

Weak Decay Modes - Feynman Diagrams



https://ppd.fnal.gov/experiments/e871/public/phys_slides.html

Coalescence



https://www.nature.com/articles/s41467-024-45474-x/figures/1