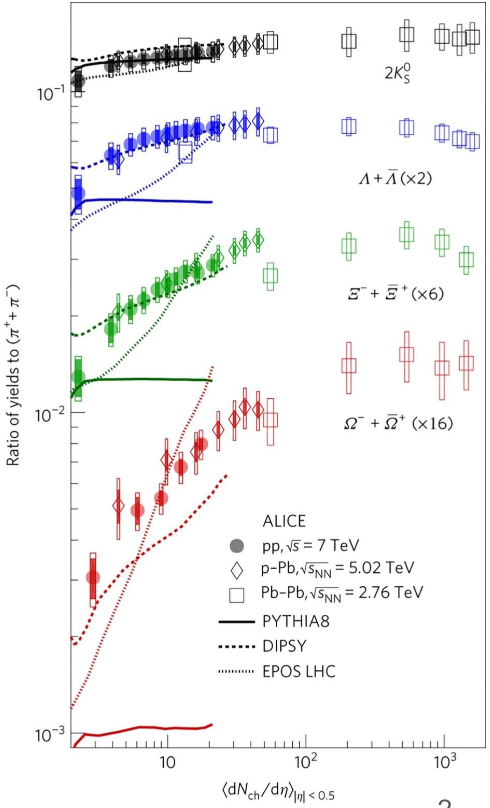
Strangeness Production in O+O Collisions at $\sqrt{s_{NN}}$ = 200 GeV

Iris Ponce for the STAR Collaboration
Yale University
CPOD 2024

Motivation

- A smooth increase in the ratio of strange hadron production to the pion yield as a function of multiplicity has been found in various collision systems (p+p, p+A, A+A).



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

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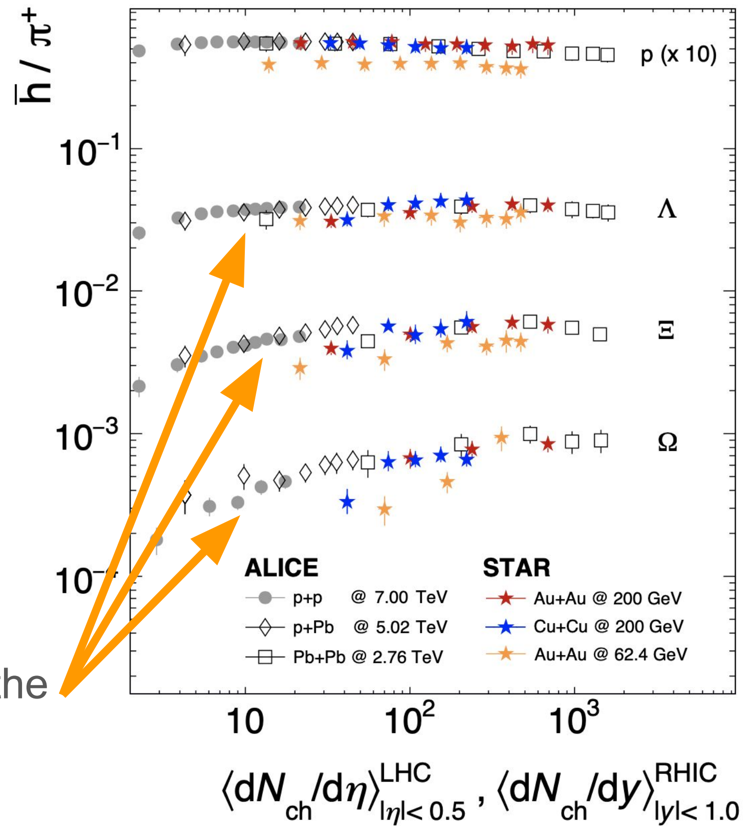
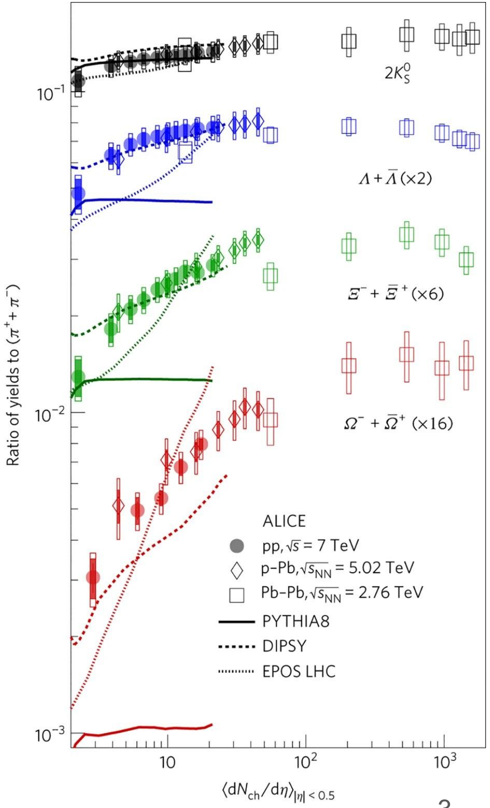
*X. Zhu. BNL Nucl. Phys. Seminar. (2021)



STAR has some data gaps on the low multiplicity regions.



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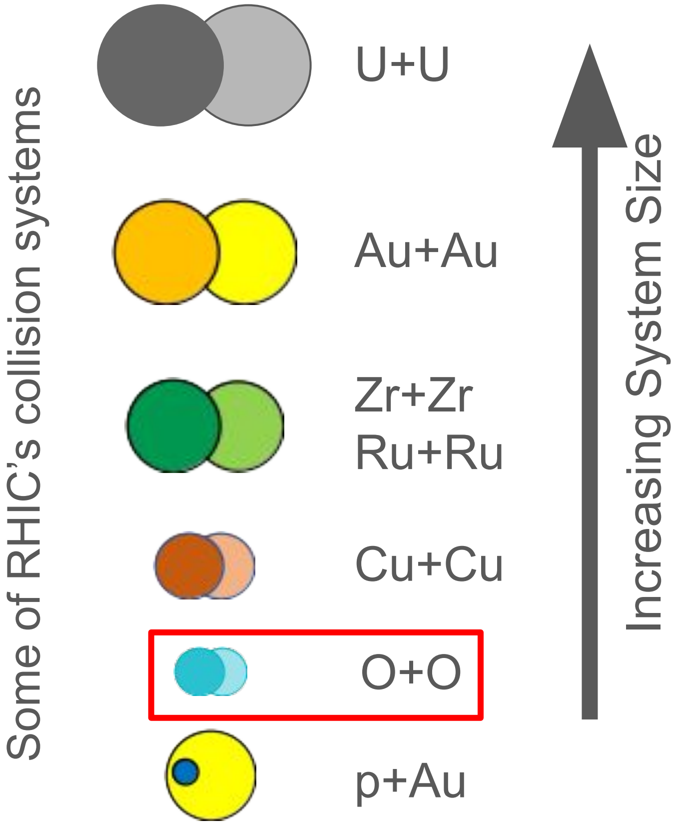
- Oxygen is one of the smallest ions used at RHIC.
  - Fill in the gap low multiplicity regions when in the ratio of strange hadron production to the pion yield.
  - Allows a more straightforward geometry mapping with centrality than those asymmetric small system collisions like He+Au, or d+Au



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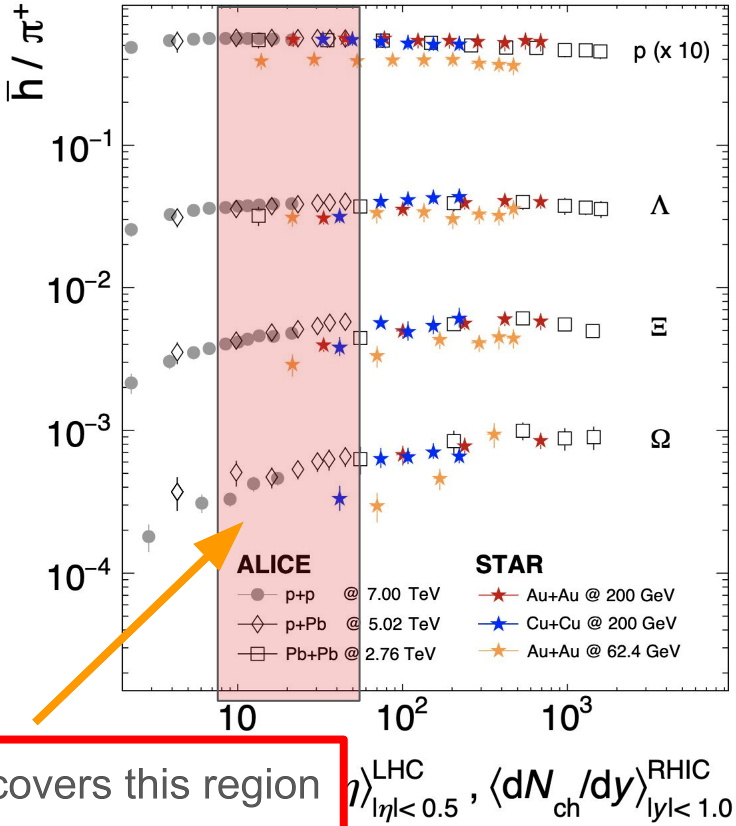


O+O’s multiplicity range covers this region

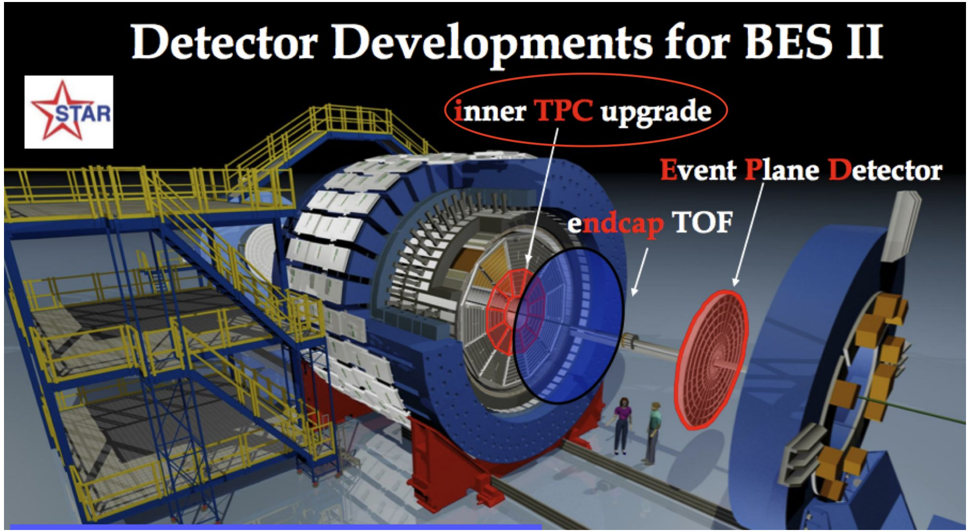
O+O	Multiplicity
0-10%	37
10-20%	29
20-40%	18
40-60%	11
60-80%	6

O+O Run Information at STAR

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

- From 2021 on, STAR had two detector upgrades: iTPC and eTOF
  - The O+O run is one the first runs with the iTPC installed
    - Improved coverage: $|\eta| < 1.5$ from $|\eta| < |1.0|$

- There are ~650M O+O minimum bias events total.
  - ¼ of the O+O run was taken with the magnetic field reversed.



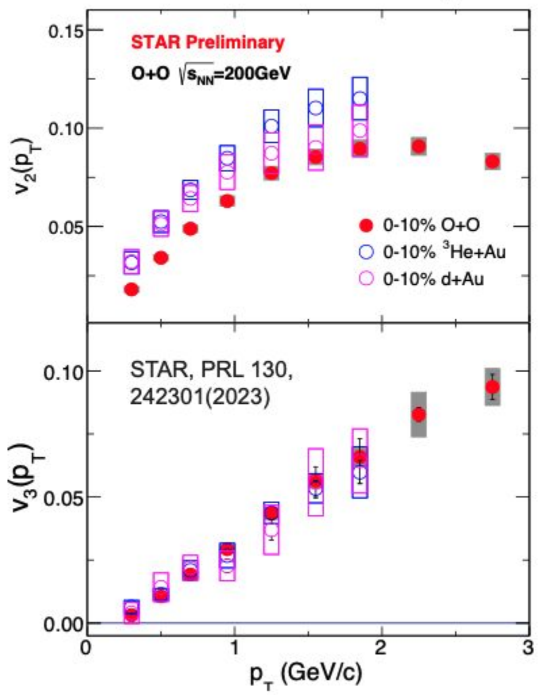
Q. Xu. (STAR Collaboration). 8th Workshop on Hadron Physics (2016)

Flow Measurements in O+O collisions shown in QM2023

Bulk Results:

Similar N_{part} to ^{3}He-Au

$v_2(O+O) < v_2(d+Au) \approx v_2(^3He+Au)$
$v_3(O+O) \approx v_3(d+Au) \approx v_3(^3He+Au)$



S. Huang (STAR Collaboration). QM2023

Particles To Be Reconstructed

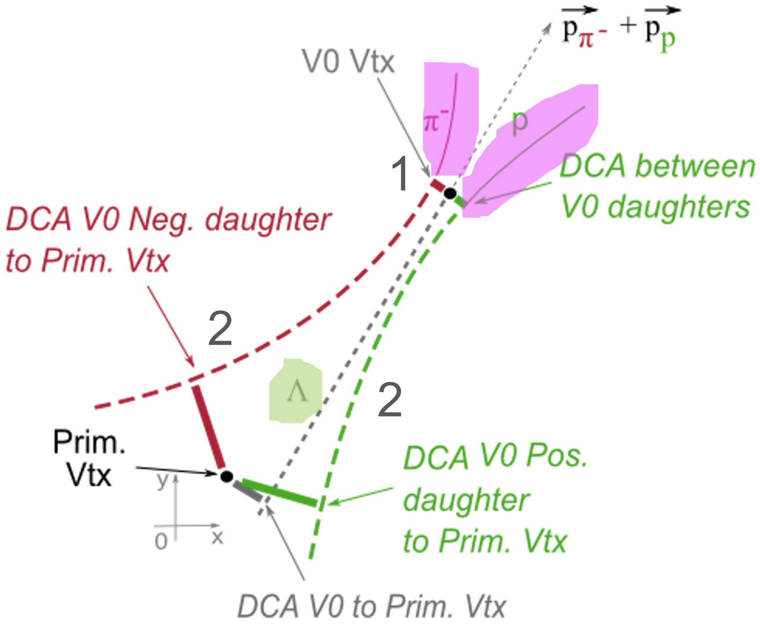
I am interested in reconstructing particles with s-quarks, as listed below.

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

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

Reconstruction Details and Topological Cuts

1) **MaxDistanceBetweenParticlesCut** (DCA between daughters): 5 cm
2) **LCut** (DCA to primary vertex): > 1 cm
3) **Chi2Cut2D** (cut on χ^2 of the particle fit): > 20
4) **ChiPrimaryCut** (cut on χ^2 of the tracks to the PV to divide tracks into primary and secondary) : > 3.
5) **ChiPrimaryCut2D** (cut on χ^2 of the track to the PV): > 3.
6) **LdLCut2D** (cut on the distance to PV normalized on the error): > 3
7) **Vz** < | 145 | cm
8) **Vr** < 2 cm
9) **nHitsFit** > 15



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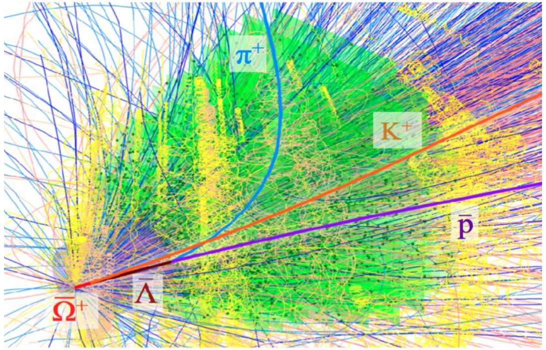
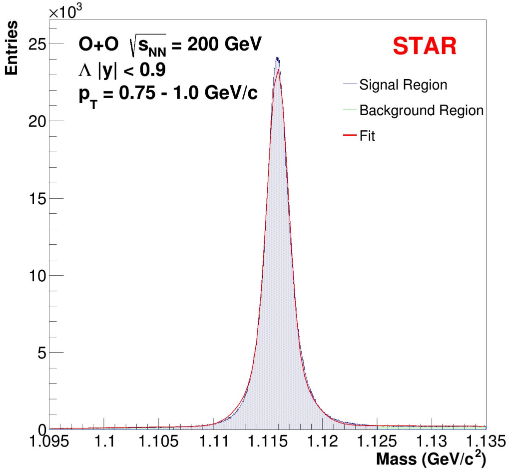
Reconstructing Lambdas and Signal Extraction

- 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)

Λ



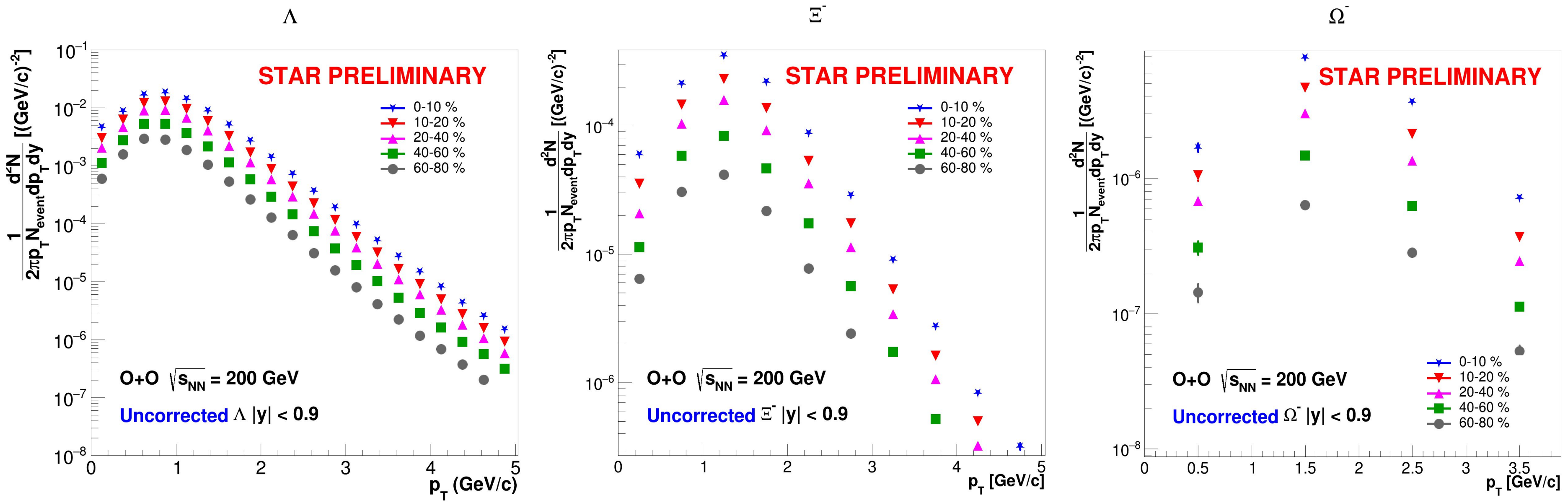
For the Λ Signal Extraction:

- The signal (without background subtraction) region is [μ-3σ,μ+3σ], and the background region is [0 to μ-3σ, μ+3σ to Xmax].

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

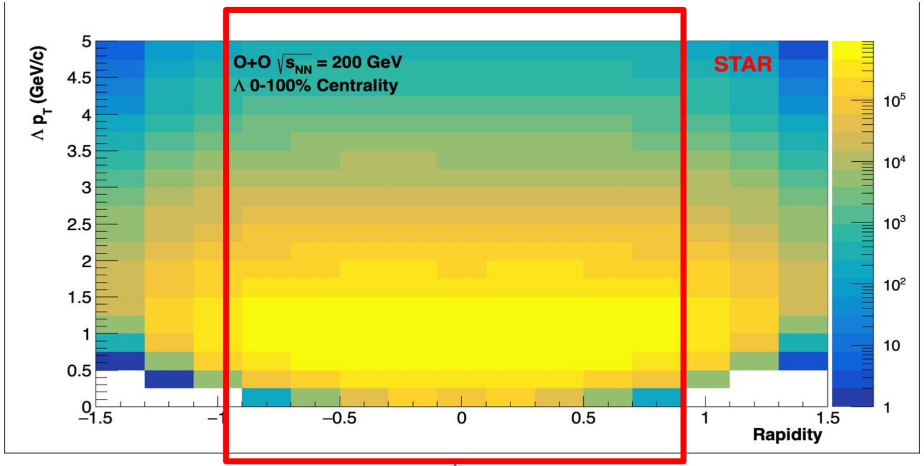
The yellow region is the background region.

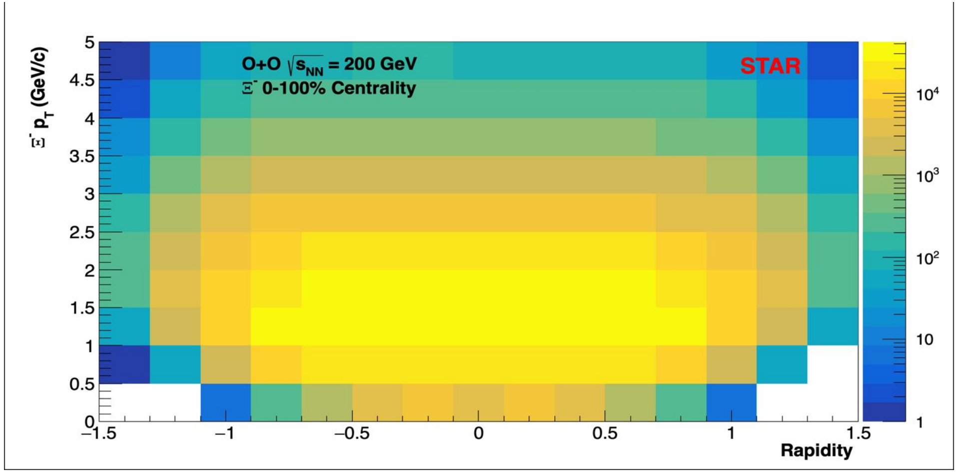
Raw Spectra



The large statistics, improved pT and rapidity coverage enables STAR to have good statistics for multi-strange hadrons.

What does our rapidity coverage looks like?



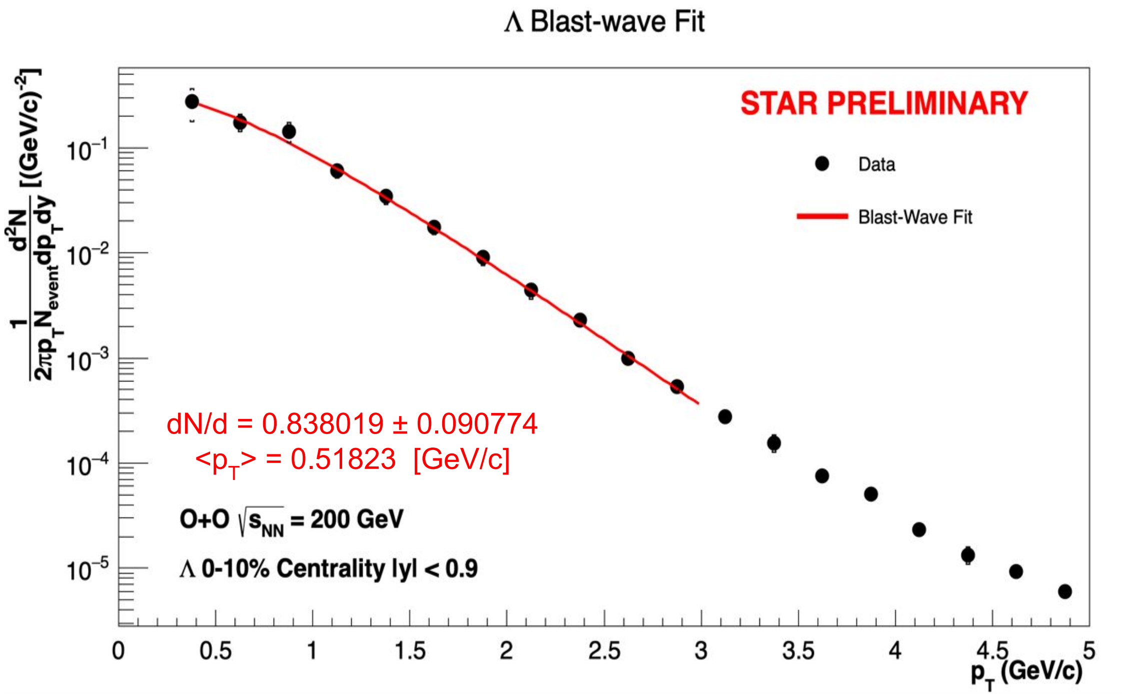


The iTPC provides extended coverage.

The rest of the talk will focus on this phase-space.

Corrected p_T spectrum for Λ's in O+O

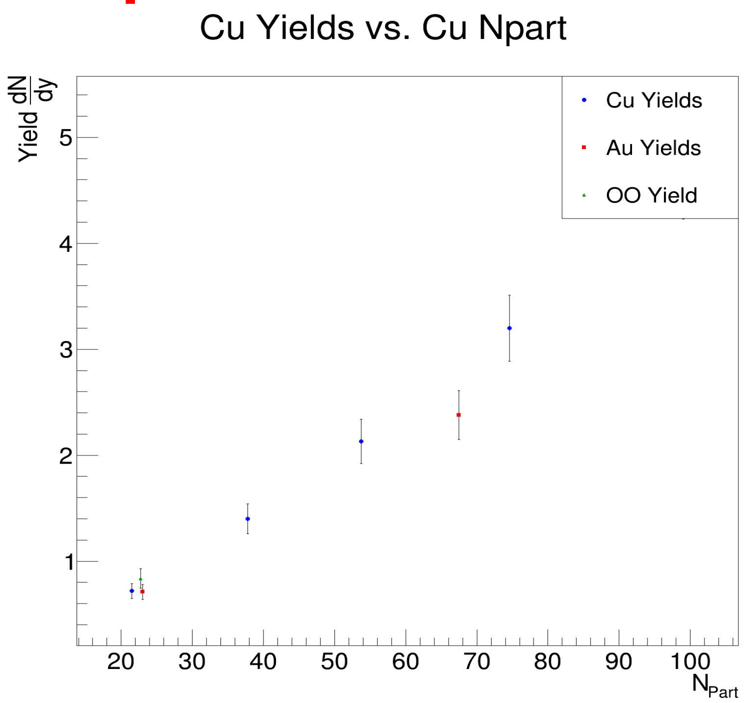
- The p_T spectra is calculated from the Λ's invariant mass distributions for the different momenta.
- The reconstruction efficiency is calculated using monte carlo which is embedded in real data and then propagated through the detector simulation.
- The Λ spectra is the average of both magnetic field configurations.



Chi-square value of the fit: 0.958593
Degrees of freedom: 6
Chi-square / NDF: 0.159765

Comparing the O+O yield to similar Collision Systems

plot will be prettier



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

Most central O+O collisions have a similar Npart as peripheral Au+Au collisions.

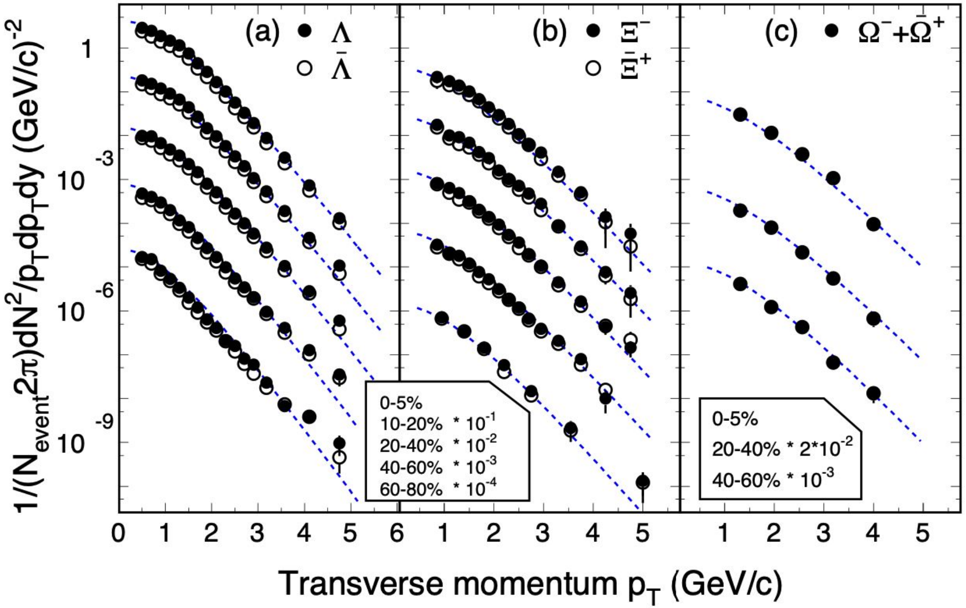
Integrating the Λ pT spectra from 0 -> ∞ the yield (dN/dy) is 0.834 ± 0.13**

**Note yield is not feed-down corrected.

Next Steps for Analysis

- Extend the analysis to other hyperons.
  - The raw p_T spectra have been made but is pending the corrections.
- Calculate the yields from corrected spectra.
- Calculate the pion yield.
- Apply feed-down corrections to spectra for yield calculations.
- Use thermal model for freeze-out parameter (e.g. μ_B , T_{ch}) calculations.

Transverse momenta distribution for Au+Au at $\sqrt{s_{NN}}$ = 200 GeV



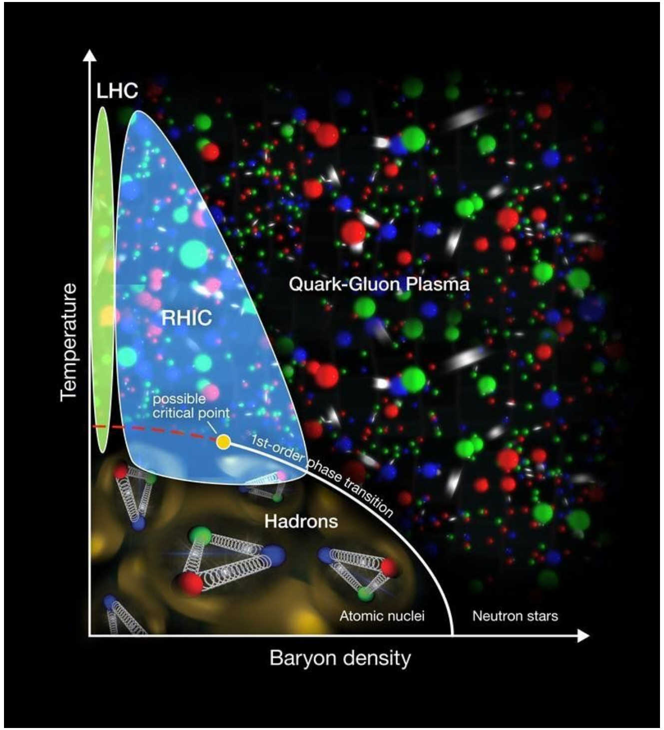
STAR Collaboration. Phys. Rev. Lett. 98, 062301 (2007)

STAR's other strangeness results at CPOD

- Y. Zhou presented measurements of K_s^0, Λ, Ξ^- production at $\sqrt{s_{NN}}$ = 3 - 4.5 GeV in Au + Au collisions.
  - Soon there will be more measurements from BESII too.

- Y. Leung presented on hypernuclei production at $\sqrt{s_{NN}}$ = 3-4.5 GeV and 7.7 - 27 GeV.

- Covering different phase-space of the QCD diagram!



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

Conclusions

- The O+O at $\sqrt{s_{NN}}$ = 200 GeV is a newer data set for STAR.
- 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.
- I present the first yield calculation for Λ's in the 0-10% centrality region for O+O.
- With the great statistics there will be interesting results for the near future!

Backup(?)