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).
  - LHC and STAR* have produced this ratio.

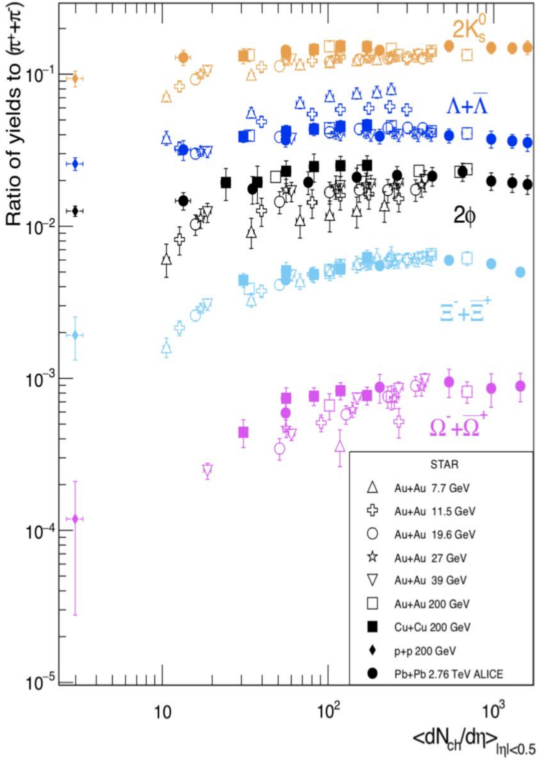
S = ±1

S = -1

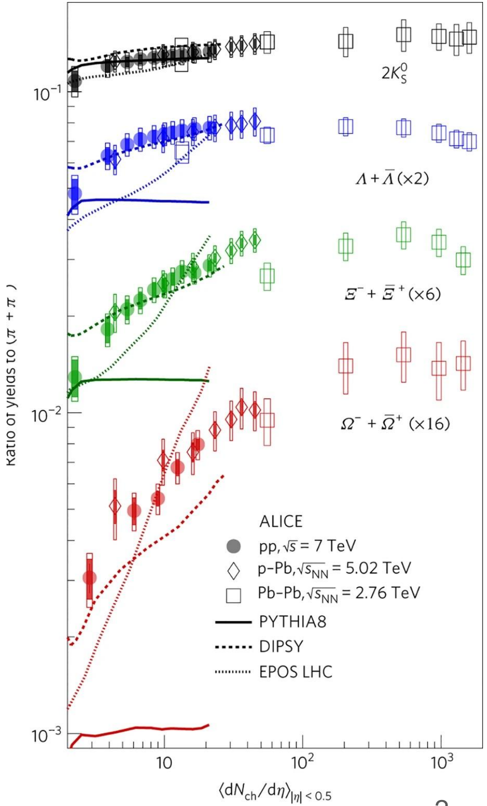
S = 0

S = -2

S = -3



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



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

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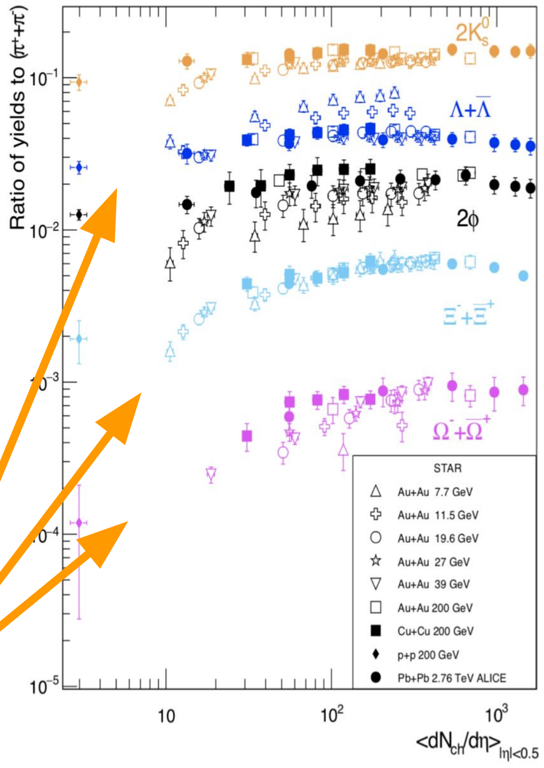

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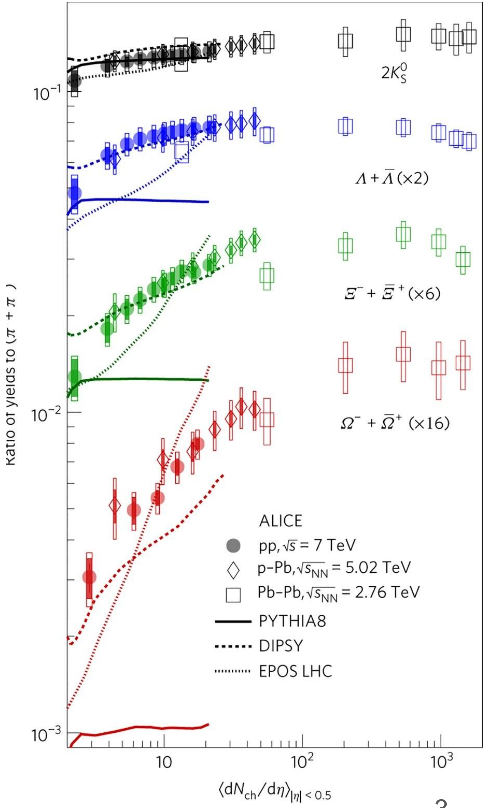

ALICE Collaboration. Nat. Phys., 13, 535 (2017)

STAR has some data gaps on the low multiplicity regions.

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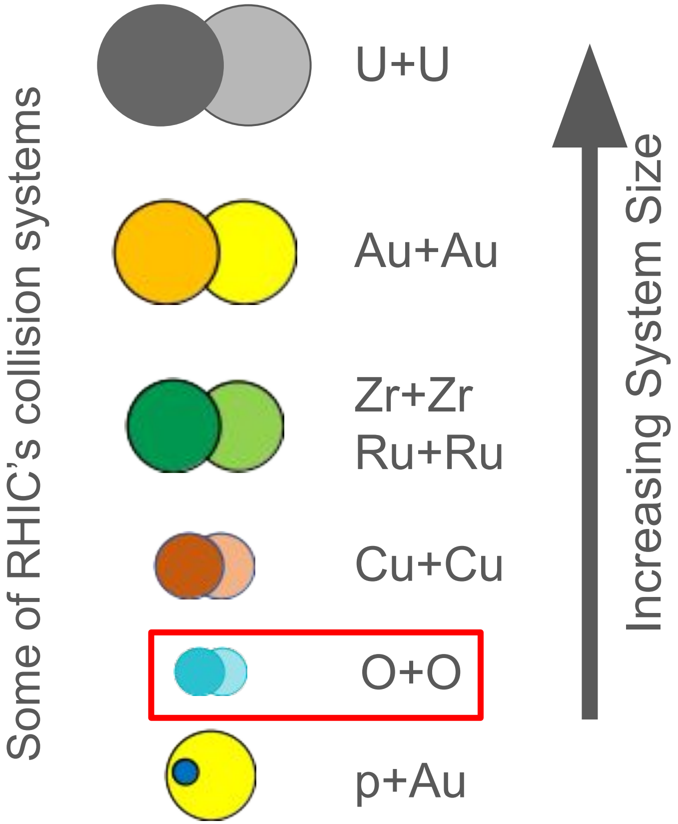
- Oxygen is one of the smallest ions used at RHIC.
  - Fill in the gap low multiplicity regions when in the ratio of strange hadron production to the pion yield.
  - Allows a more straightforward geometry mapping with centrality than those asymmetric small system collisions like He+Au, or d+Au

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



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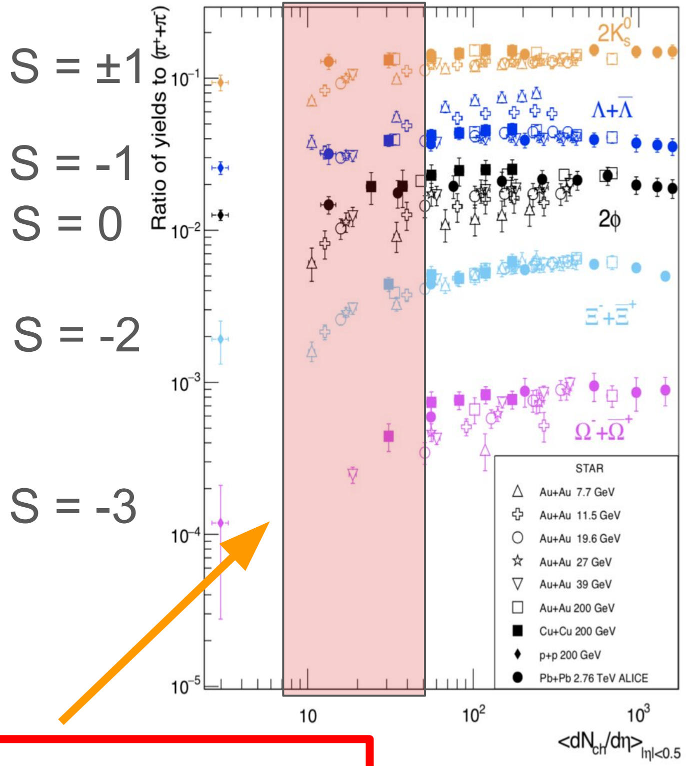

O+O's multiplicity range covers this region

Nucl. Phys. Seminar. (2021)

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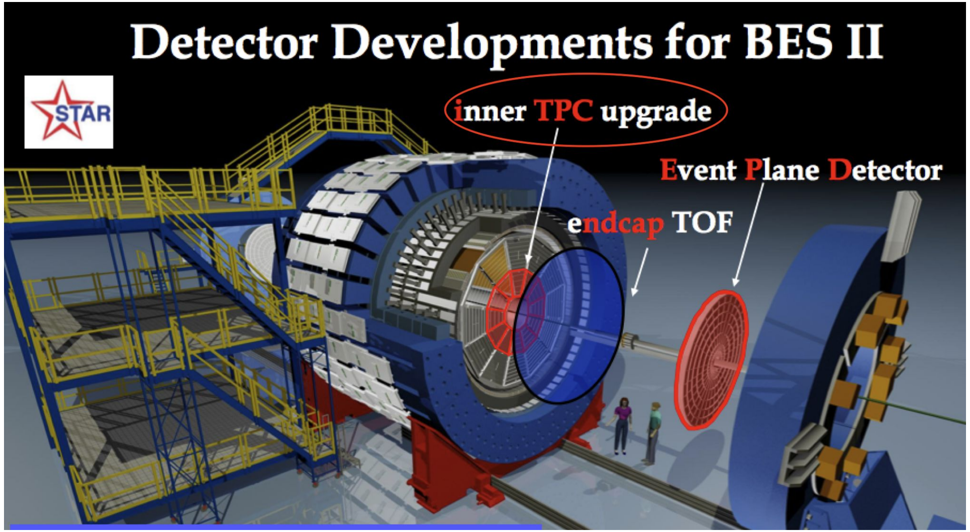
60-80%	6

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 657.32 M O+O 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)

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Iris Ponce - Yale University

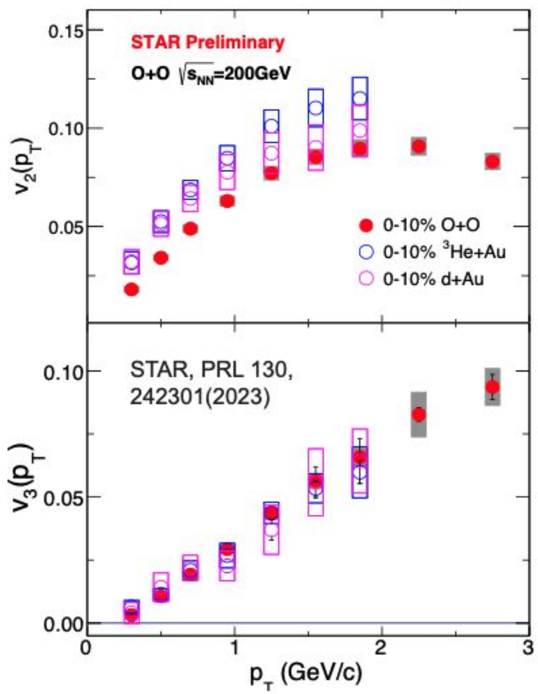
Previous O+O Analyses shown in Quark Matter 2023

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.

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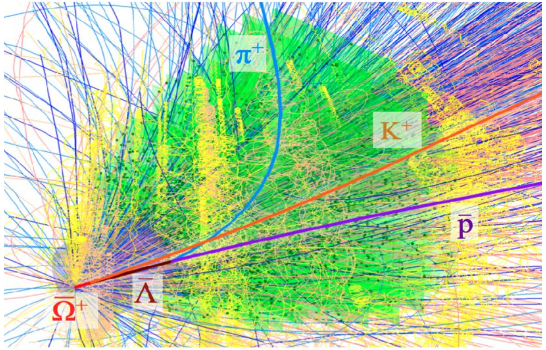
Reconstructing Lambdas and Signal Extraction

- 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.



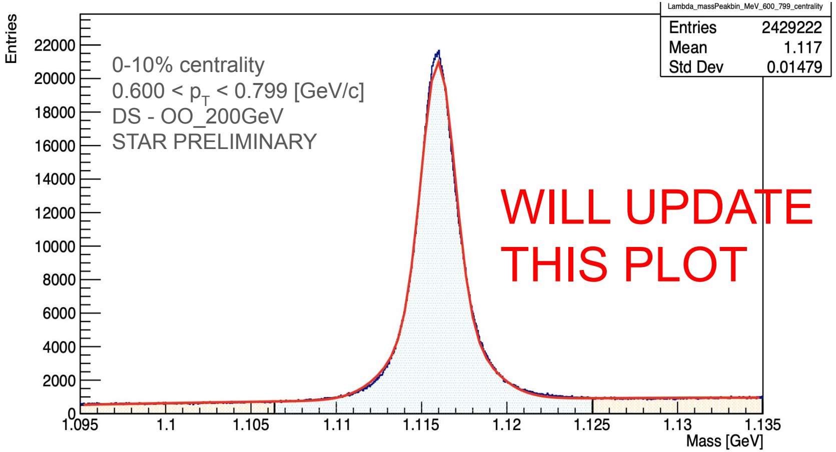
M. Kocan, WEJCF. (2019)

For the Λ Signal Extraction:

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

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

The yellow region is the background region.



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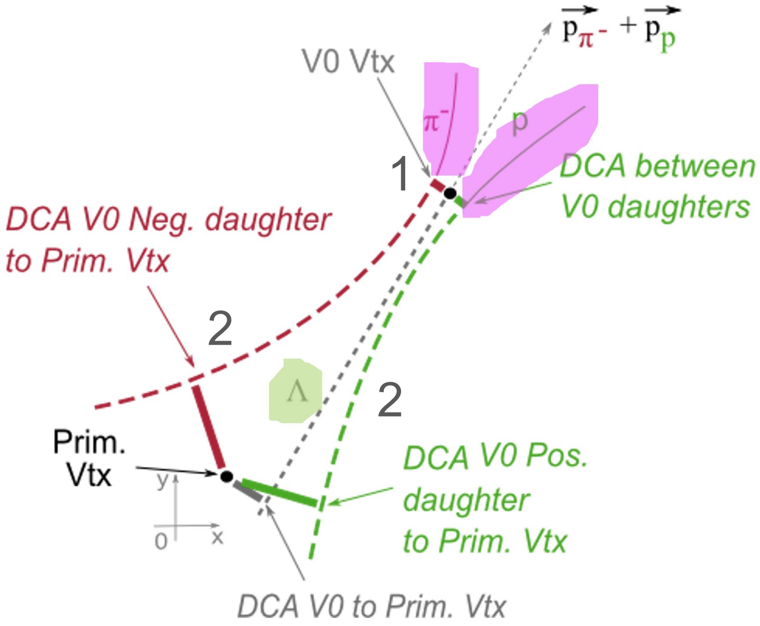
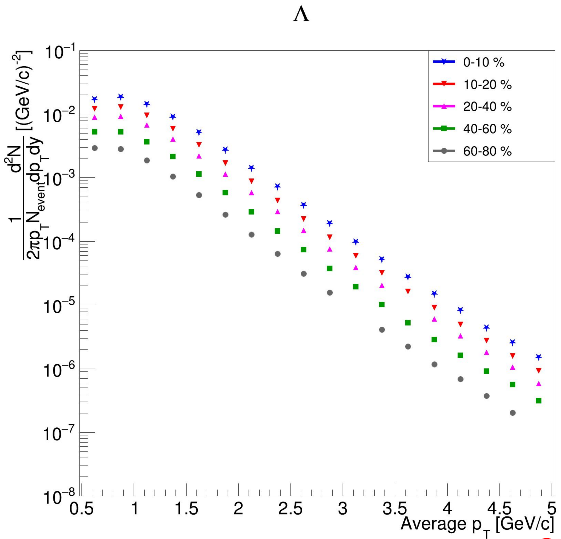
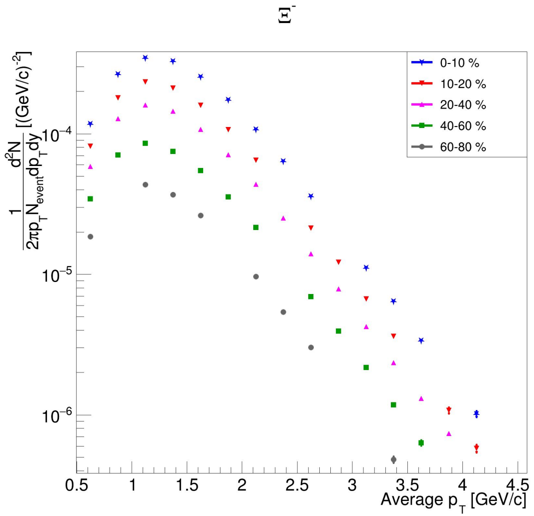
Reconstruction Details and Topological Cuts

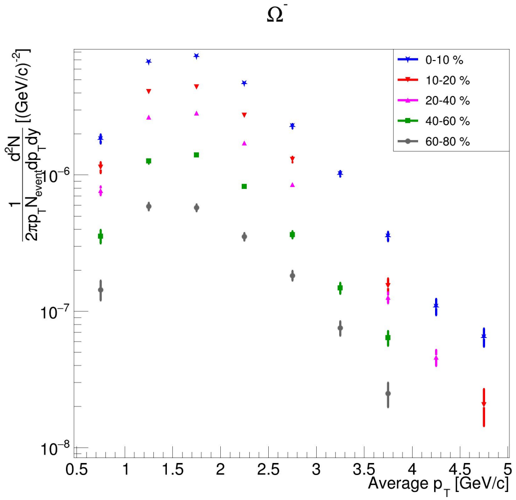
1) **MaxDistanceBetweenParticlesCut** (DCA between daughters): 5 cm
2) **LCut** (DCA to primary vertex): 1 cm
3) **Chi2Cut2D** (cut on χ^2 of the particle fit): 20
4) **ChiPrimaryCut** (cut on χ^2 of the tracks to the PV to divide tracks into primary and secondary) : 3.
5) **ChiPrimaryCut2D** (cut on 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



Raw Spectra







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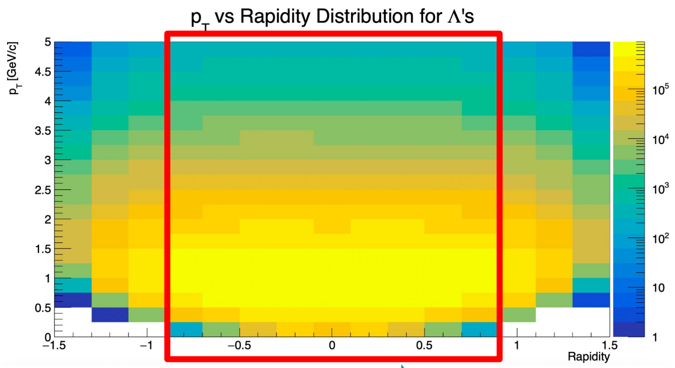
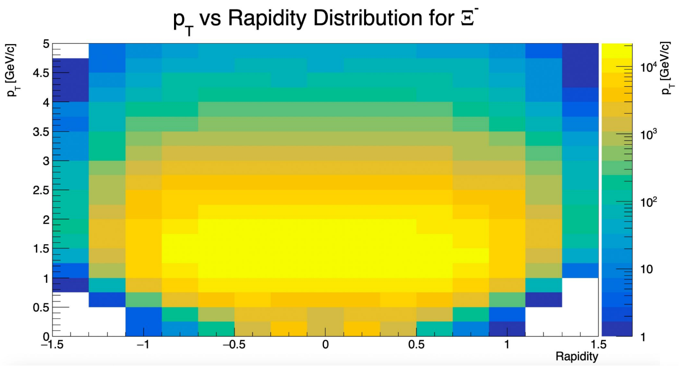
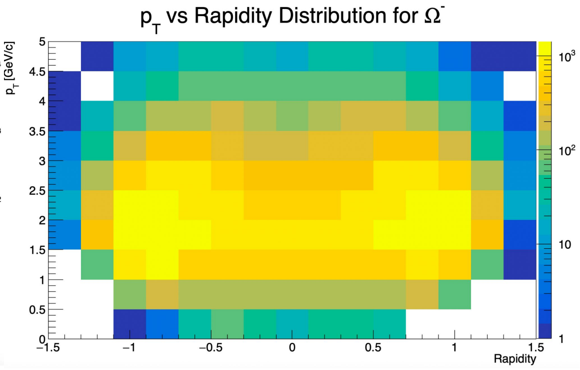
The large statistics, improved pT and rapidity coverage enables STAR to have good statistics for multi-strange hadrons.

What does our rapidity coverage looks like?





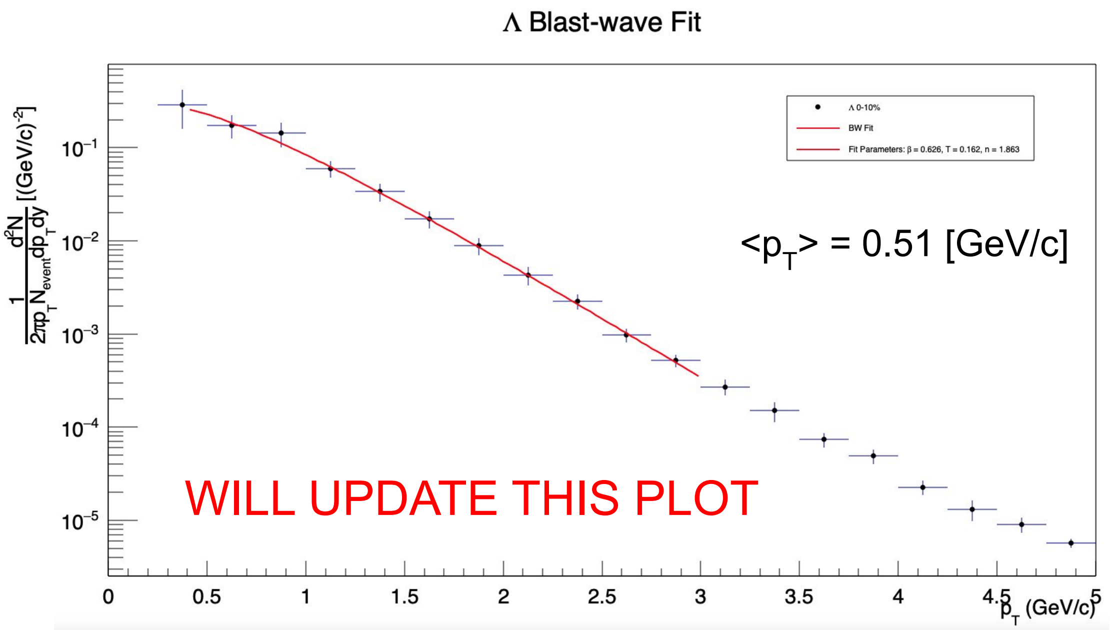


The iTPC provides extended coverage.

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

Corrected p_T spectra 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

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Comparing the O+O yield to similar Collision Systems

change to plot not tables

O+O	< N_{part}>
0-10%	22.75
	<N_{coll}>
0-10%	27.62
	Multiplicity
0-10%	37
10-20%	29
20-40%	18
40-60%	11

Mid-rapidity dN/dy for Cu+Cu and Au+Au at $\sqrt{s_{NN}}$ = 200 GeV

Cu+Cu	40-60%
$\langle N_{part} \rangle$	21.5±0.5
K_S^0	2.24±0.23
Λ	0.72±0.07
$\bar{\Lambda}$	0.60±0.06
Ξ	0.08±0.01
$\bar{\Xi}$	0.07±0.01
$\Omega + \bar{\Omega}$	0.015±0.003
Au+Au	60-80%
$\langle N_{part} \rangle$	23.0±1.2
K_S^0	2.14±0.19
Λ	0.71±0.07
$\bar{\Lambda}$	0.55±0.04

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

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

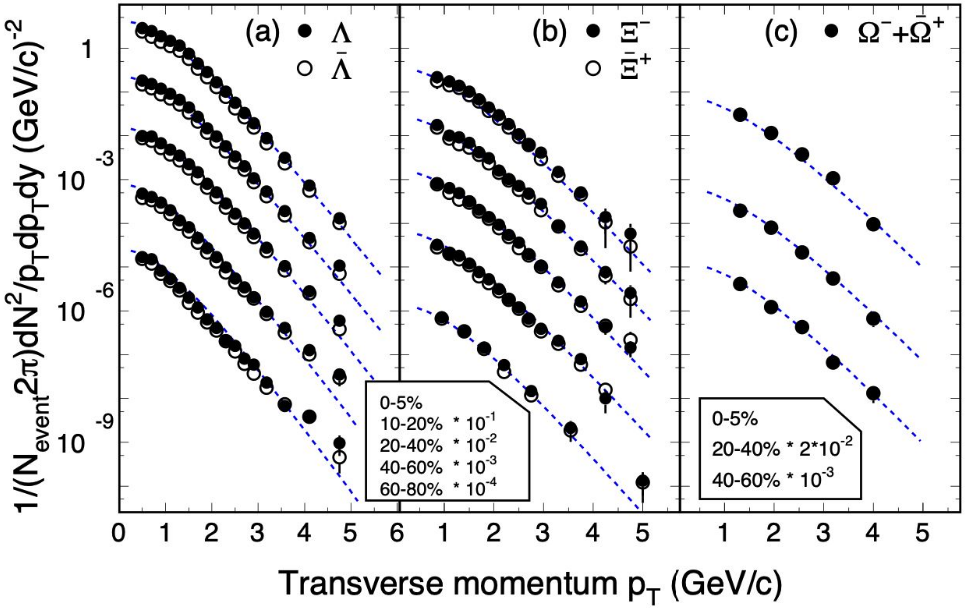
Integrating the Λ pT spectra from 0 -> ∞ the yield (dN/dy) is 0.834 ± 0.13**

**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)

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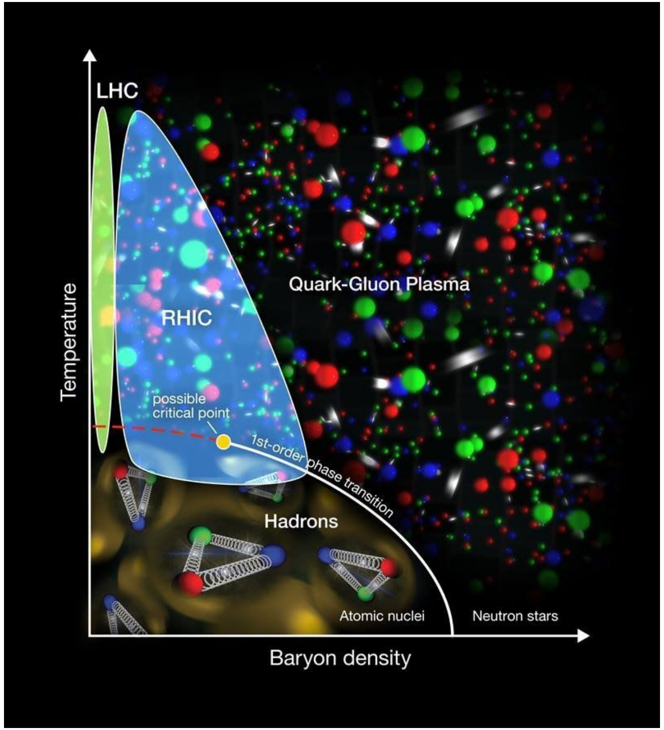
STAR's other strangeness results at CPOD

- 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(?)