



Measurement of proton- Ξ correlation function in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at RHIC-STAR

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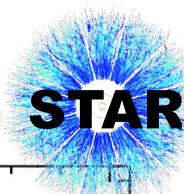
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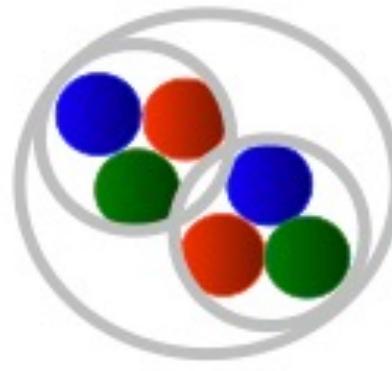


- ☆ *Introduction*
- ☆ *STAR Experiment*
- ☆ *Particle Identification and Reconstruction*
- ☆ *Results: Correlation Function*
- ☆ *Summary and Outlook*

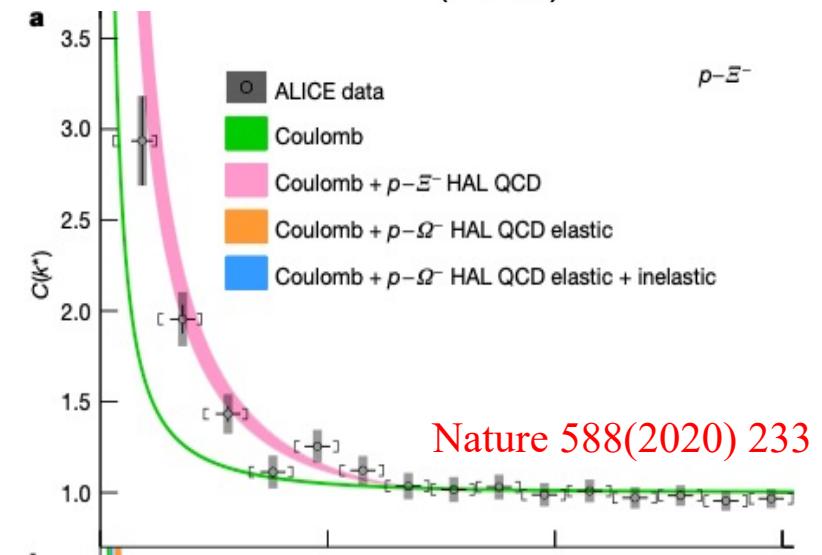
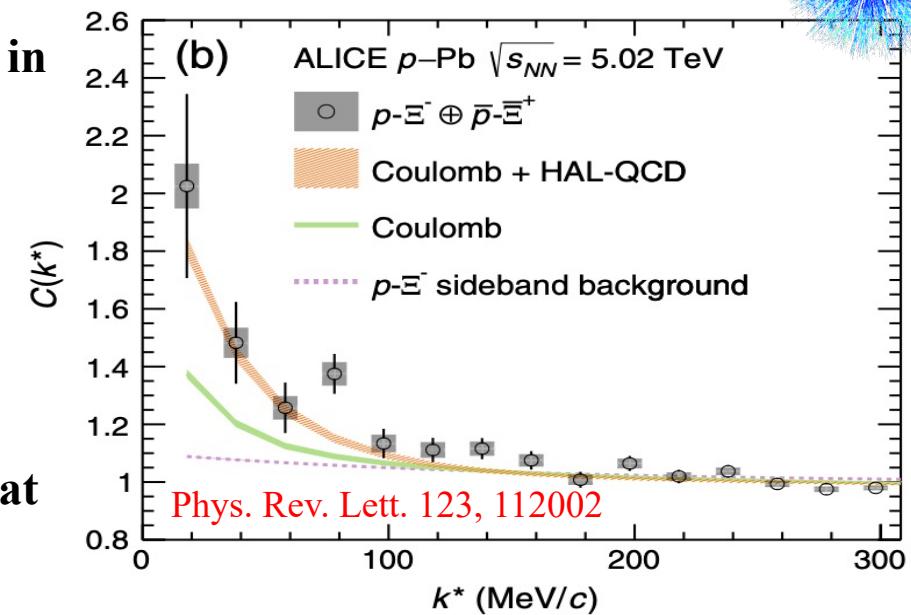
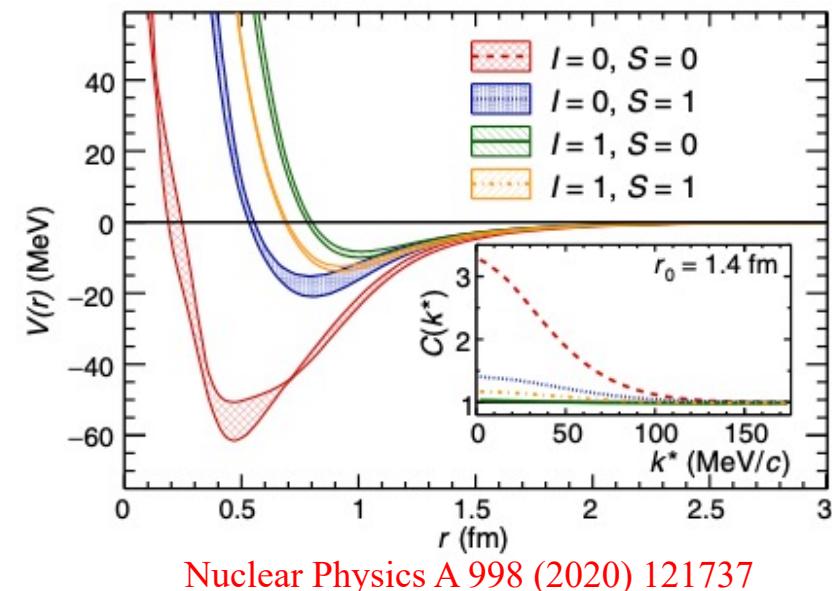
Introduction



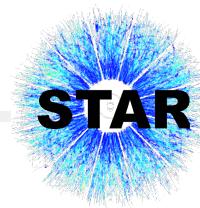
- ☞ Baryon-baryon interaction in the S=-2 sector has attracted attention in relation to the possible existence of H-dibaryon. So far no clear experimental evidence for any such bound states has been found.
- ☞ Lattice QCD potentials (HAL-QCD Collaboration) -- Predicted an attractive interaction in $p\text{-}\Xi^-$.
- ☞ An attractive $p\text{-}\Xi^-$ interaction is observed in p-Pb and pp collisions at ALICE.



Hexaquark
Baryon-Baryon molecule



Femtoscopy: Short-Range Correlation



★ Correlation function (Theory): $C(k^*) = \int S(r^*) |\Psi(k^*, r^*)|^2 d^3 r^*$

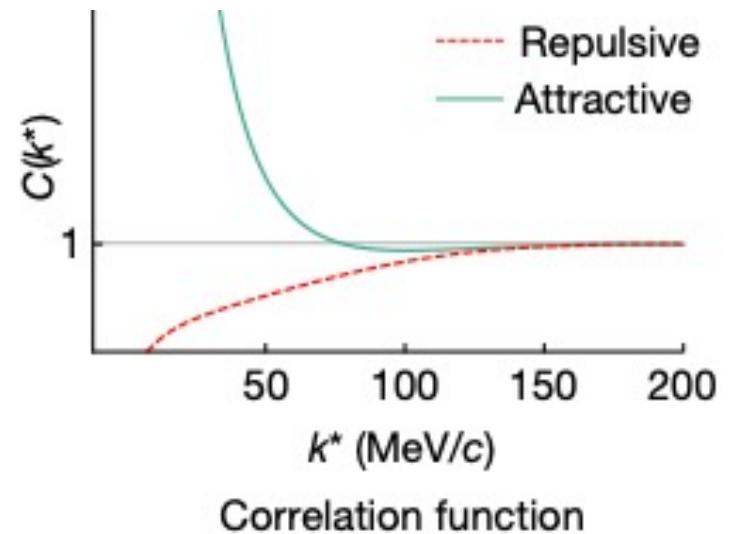
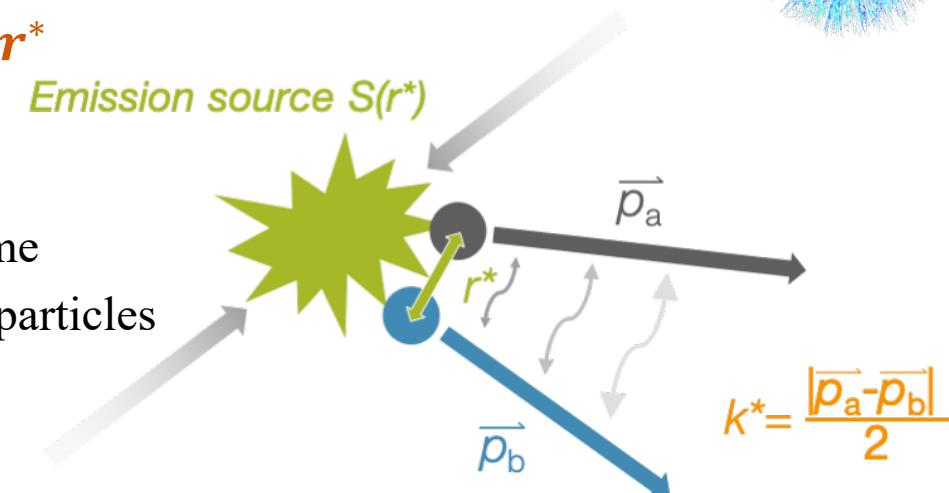
- ★ $S(r^*)$ is emission source function
- ★ $|\Psi(k^*, r^*)|$ is two-particle wave function
- ★ k^* — relative momentum between two particle in pair reference frame
- ★ r^* is the relative distance between the points of emission of the two particles

★ Correlation function (Experiment): $C_{measured} = \frac{A(k^*)}{B(k^*)}$

- ★ $A(k^*)$ — signal correlation from same events
- ★ $B(k^*)$ — background correlation from mixed events

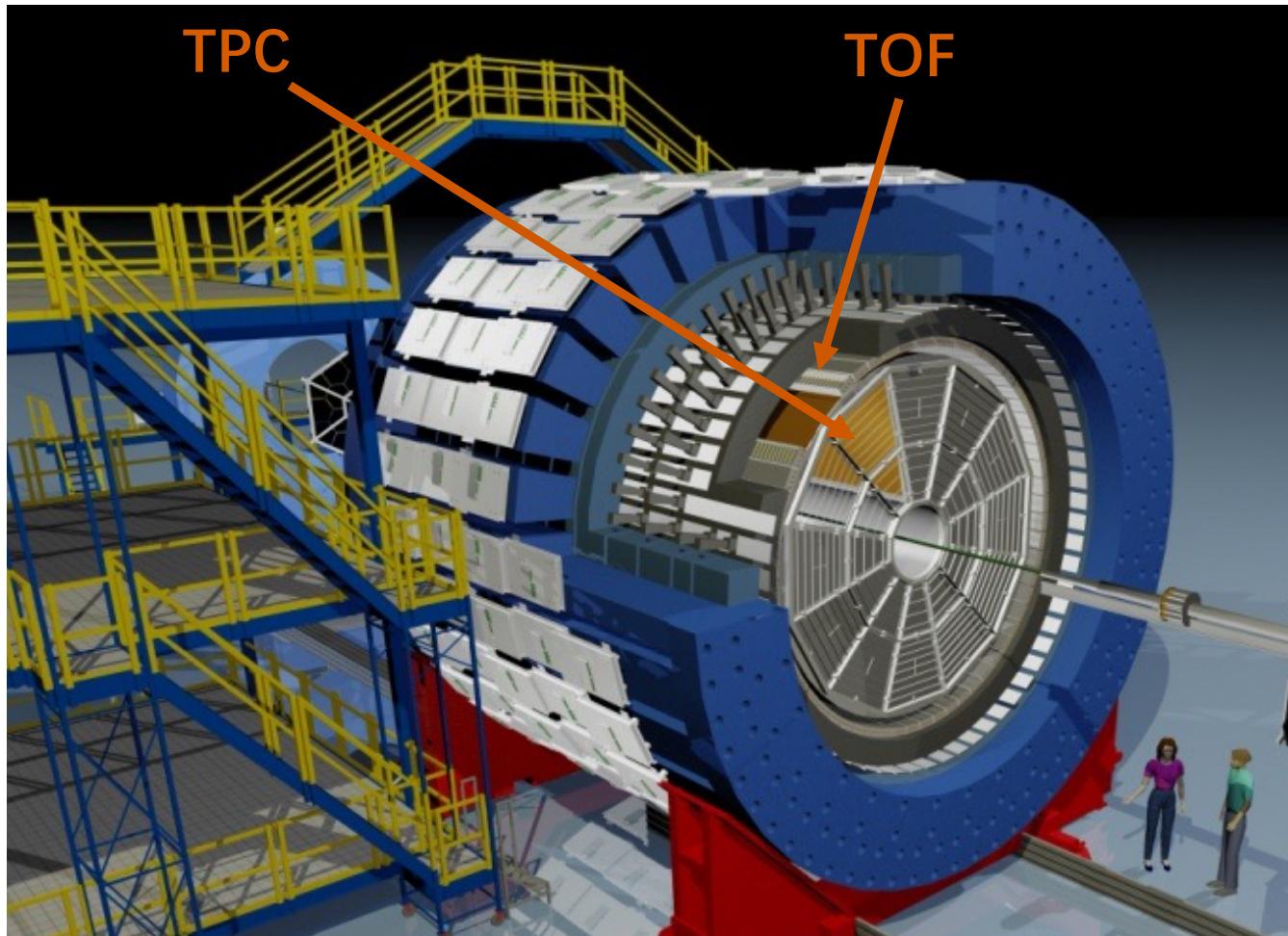
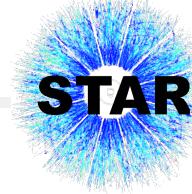
★ Purity Correction: $C'(k^*) = \frac{C_{measured}(k^*) - 1}{Pair\ purity(k^*)} + 1$

- ★ Pair purity = Pid purity * Fp purity
- ★ Pid purity is the probability of correct proton and Ξ^- identification
- ★ Fp purity is the probability of being a primary particle
 - ★ For proton: 0.6 for central and 0.7 for peripheral
 - ★ For Ξ^- : 0.436 (Terminator2 model estimation)



Nature 588 232 (2020)

The Solenoidal Tracker At RHIC(STAR)



- Excellent Particle Identification
- Large, Uniform Acceptance at Midrapidity

Time Projection Chamber (TPC)

- ✓ Charged Particle Tracking
- ✓ Momentum reconstruction
- ✓ Particle identification from ionization energy loss (dE/dx)
- ✓ Pseudorapidity coverage $|\eta| < 1.0$

Time-of-Flight (TOF)

- ✓ Particle identification m^2
- ✓ Pseudorapidity coverage $|\eta| < 0.9$

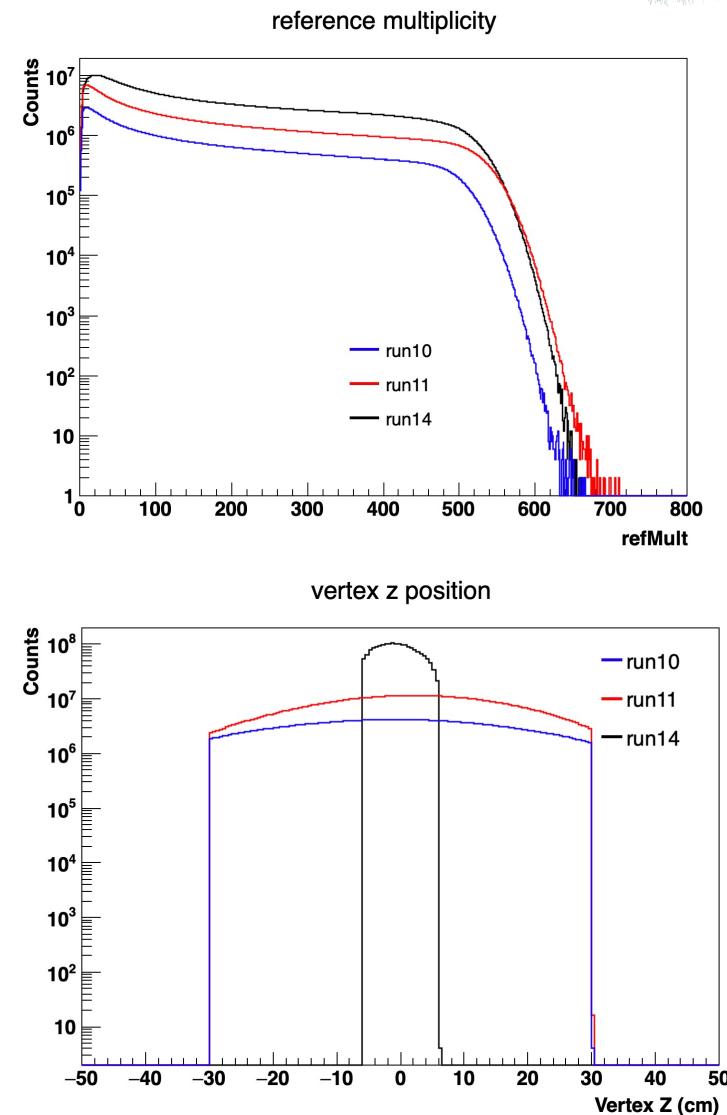
Data Set



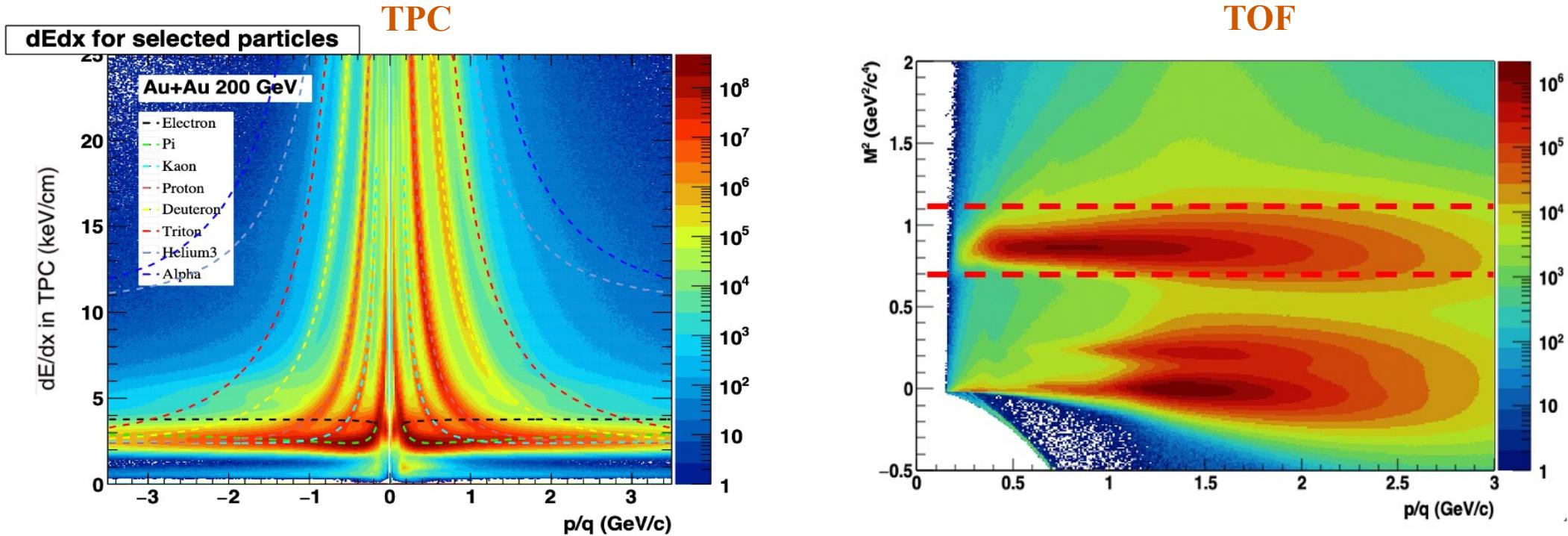
- Au+Au at $\sqrt{s_{NN}} = 200$ GeV taken in 2010, 2011 and 2014

	Trigger ID (minimum bias)	$ V_z , V_r ,$ $ V_z-V_{pd} $	Events
run10	260001 260011	$ V_z < 30\text{cm}$	$\sim 211\text{M}$
	260021 260031	$ V_r < 2\text{cm}$	
		$ V_z-V_{pd} < 3\text{cm}$	
run11	350003 350013	$ V_z < 30\text{cm}$	$\sim 410\text{M}$
	350023 350033	$ V_r < 2\text{cm}$	
	350043	$ V_z-V_{pd} < 3\text{cm}$	
run14	450005 450015	$ V_z < 6\text{cm}$	$\sim 900\text{M}$
	450025 450050	$ V_r < 2\text{cm}$	
	450060	$ V_z-V_{pd} < 3\text{cm}$	

- Total statistic : **~1.5 Billion**
- refMult : $p_T > 0.1 \text{ GeV/c}$, $\text{DCA} < 3\text{cm}$
 $\text{nhitsFit} \geq 10, |\eta| < 0.5$
- Track selection: $\text{nhitsFit} \geq 15, \text{nhitsDeDx} \geq 5,$
 $\text{nHitsFit/nHitsMax} \geq 0.52, pT > 0.15 \text{ GeV/c}$



Particle Identification



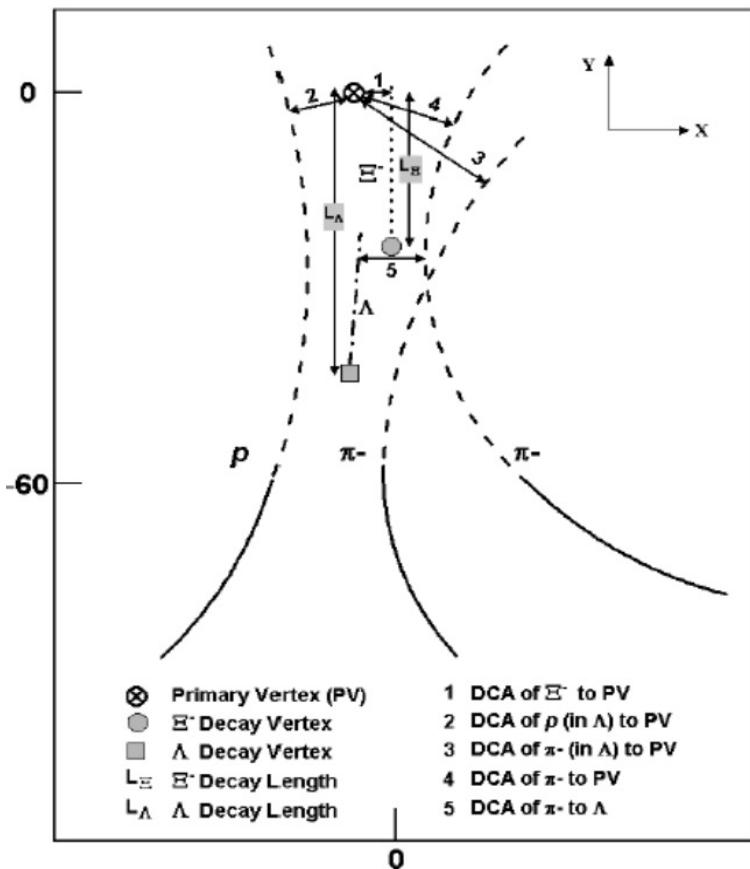
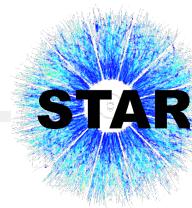
★ TPC (dE/dx) and TOF (m^2) for proton and pion particle identification

- ☞ Proton: $|N_{\sigma,p}| < 3 \ \&\& \ 0.6 < M^2 < 1.20 \ (\text{GeV}/c)^2 \ \&\& \ p_T > 0.15 \ \text{GeV}/c \ \&\& \ dca > 0.5 \text{cm} \ \&\& \ |y| < 1$
- ☞ Pion: $|N_{\sigma,pion}| < 3 \ \&\& \ -0.15 < M^2 < 0.2 \ (\text{GeV}/c)^2 \ \&\& \ p_T > 0.15 \ \text{GeV}/c \ \&\& \ dca < 1.5 \text{cm} \ \&\& \ |y| < 1$

★ Tighter PID cuts for proton used for correlation function

- ★ $\text{nhitsFit} > 20 \ \&\& \ |N_{\sigma,p}| < 2 \ \&\& \ 0.75 < m^2 < 1.15 \ (\text{GeV}/c)^2$
- ★ dca of proton $< 0.5 \text{ cm}$ (avoid self-correlation)
- ★ $0.5 < p_T < 2.5 \ \text{GeV}/c, |y| < 1.0$
- ★ Purity of proton : $>98\%$

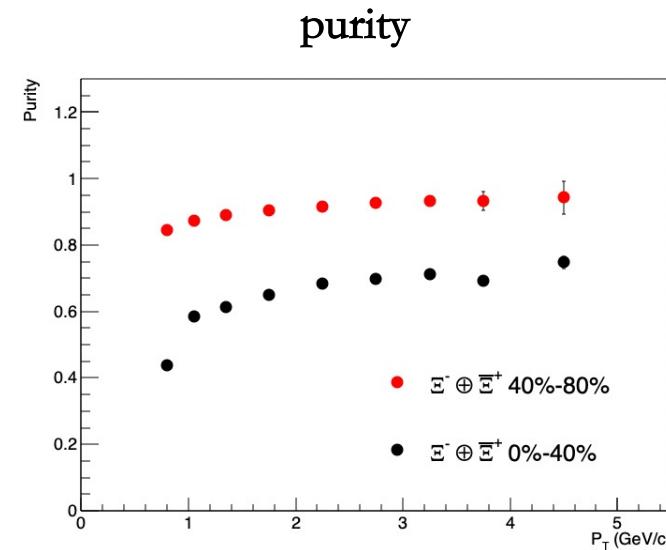
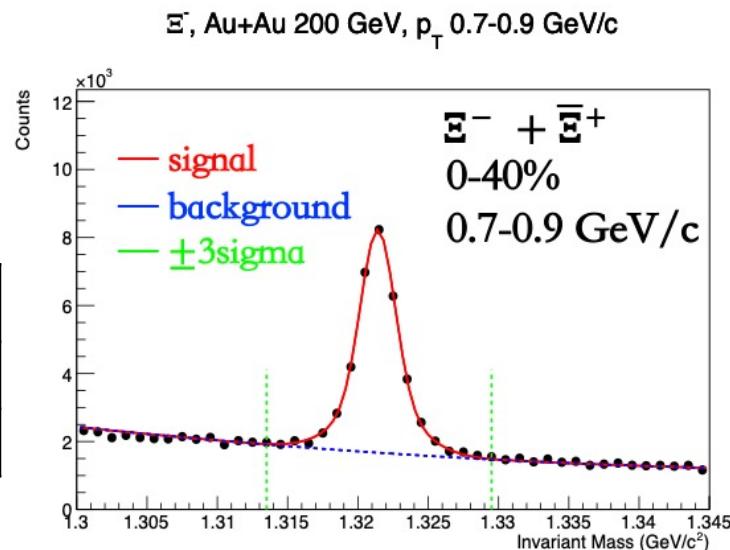
Particle Reconstruction



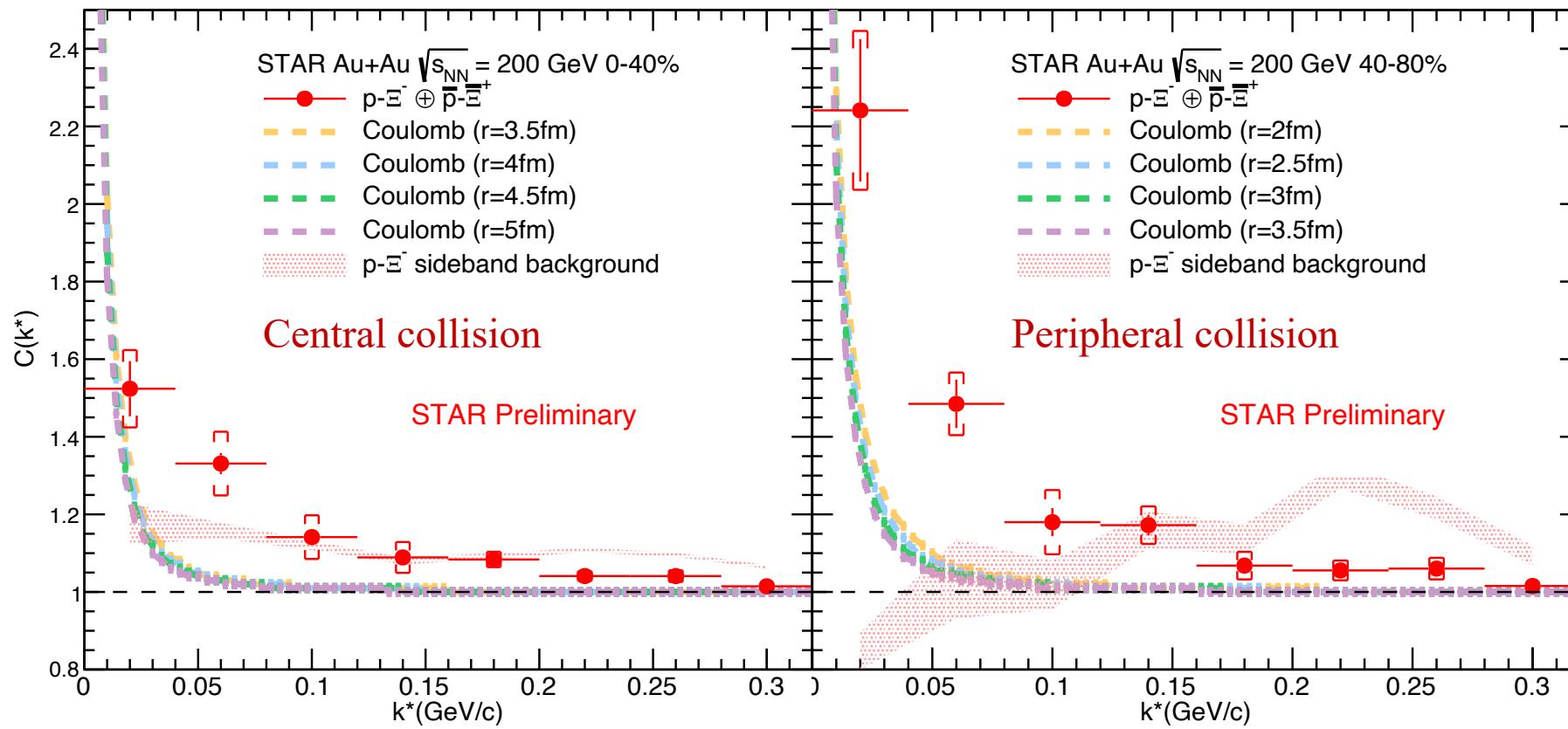
Particle	Decay	Branch Ratio	$c\tau$ (cm)
$\Xi^- (\Xi^+)$	$\Lambda(\bar{\Lambda}) + \pi^-(\pi^+)$	99.887%	4.91
$\Lambda(\bar{\Lambda})$	$p(\bar{p}) + \pi^-(\pi^+)$	63.9%	7.89

★ Ξ^- selection:

- ★ Use Helix method (Long method) for Ξ^- reconstruction
- ★ A set of topological cuts are applied to reduce the background (See back up slides)
- ★ Signal: Double-gaussian function
- ★ Background: 2nd Polynomial function
- ★ $|M_{\Xi^-} - M_{pdg}| < 0.007 \text{ MeV}/c$ are used to calculate CF
- ★ Combine $p\Xi^-$ and $\bar{p}\Xi^+$ to improve signals counts



Results : Correlation Function

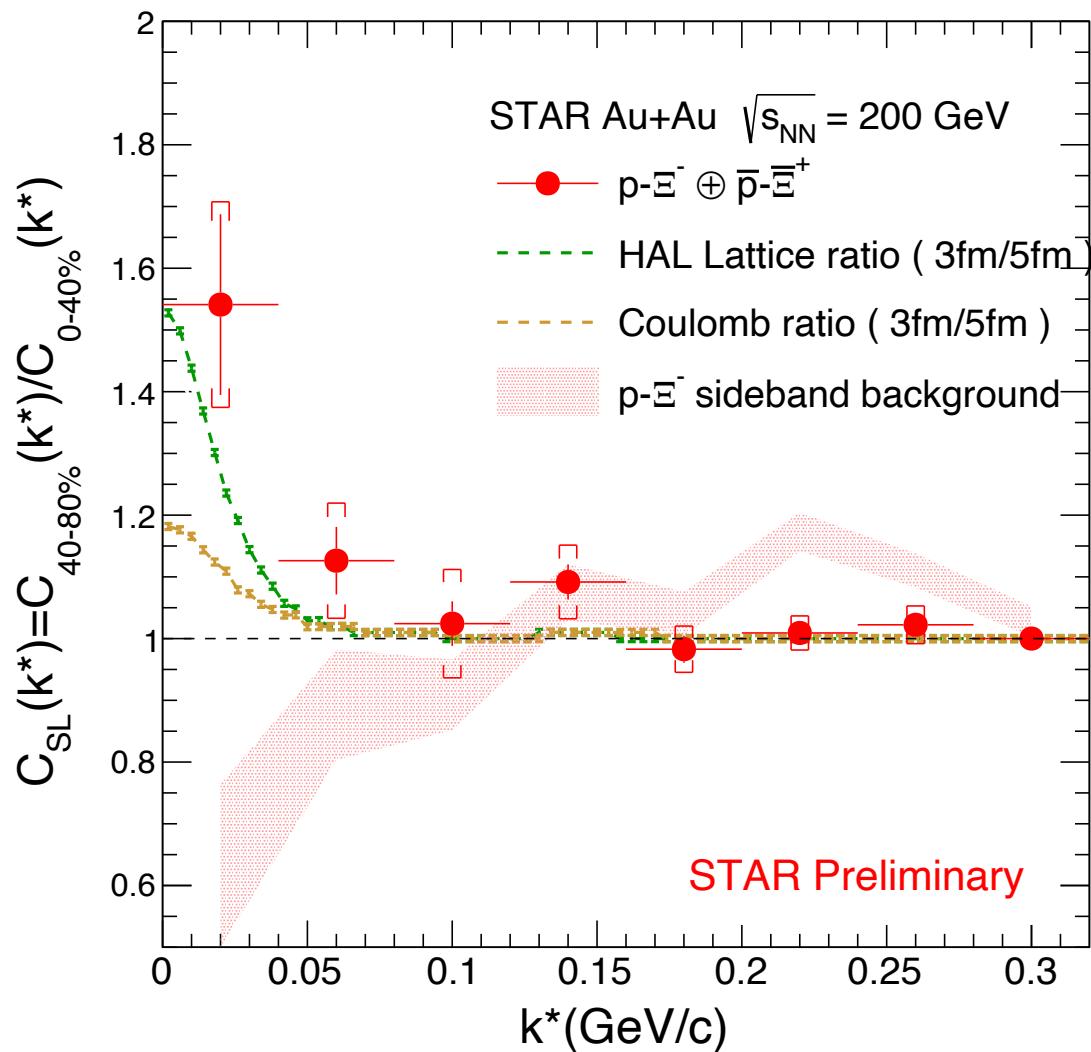


- Measured correlation functions enhance above unity – Attractive interaction in $p\Xi$ pairs
- Enhancement above Coulomb at two centralities [1][2] --- Observation of the strong interaction
- Sensitive to the source size, more attractive interaction in small system
- Feed-down corrected, residual correlations are not corrected

[1] Nuclear Physics A 982(2019) 359-362

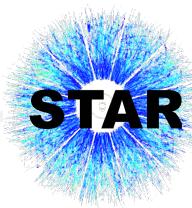
[2] Nature volume 527, pages345–348(2015)

Results : Correlation Function



- ★ The ratio $C_{SL}(k^*) = \frac{CF(\text{small system})}{CF(\text{large system})} = \frac{CF(40\%-80\%)}{CF(0\%-40\%)}$ provides direct access to strong interaction of $p\Xi^-$ without much contamination from the Coulomb^[1]
- ★ Enhancement above Coulomb --- Hints presence of strong interaction in $p\Xi^-$
- ★ Follow HAL Lattice theory prediction

[1] Nuclear Physics A 967 (2017) 856–859



- ☆ The first measurement of correlation function for p- Ξ^- from Au+Au collisions at $\sqrt{s_{NN}} = 200 \text{ GeV}$
- ☆ The measured correlation functions from central and peripheral collisions and ratio are compared with the Coulomb potential. And they all show an enhancement above Coulomb, indicates the existence of strong interaction in p- Ξ^- pairs

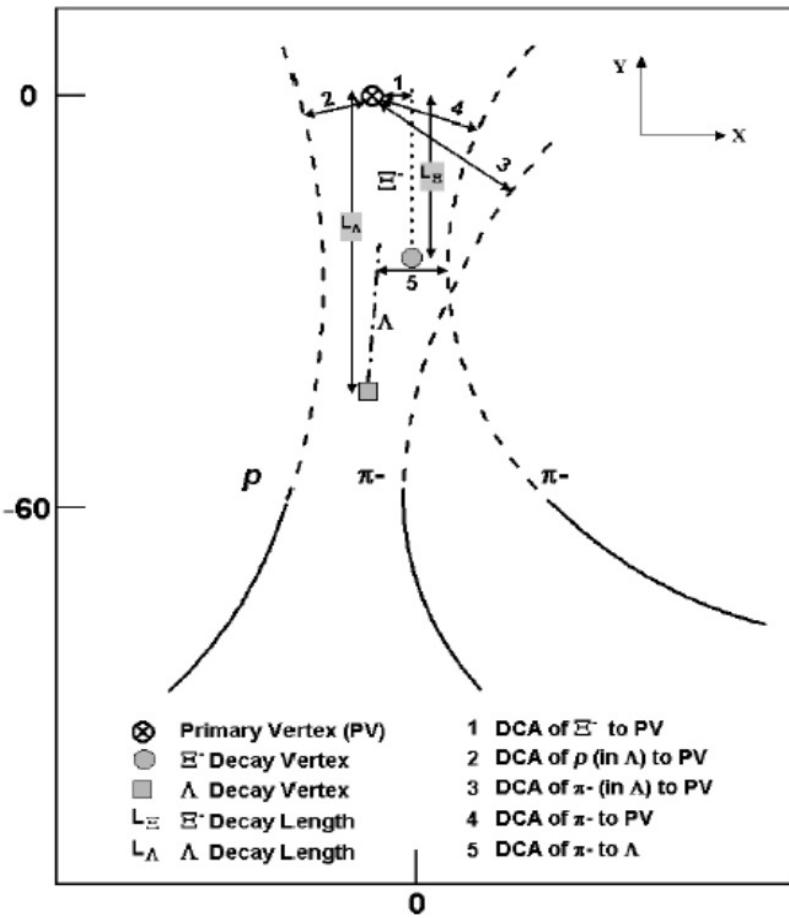
Outlook

- Fit correlation function to extract physics parameters (source size, scattering length and effective range)
- Look into more decay channels of H-dibaryon (p- Ω , $\Lambda\Lambda$)
- Few body interaction and bound state search (d- Λ , d- Ξ , d- Ω)

Thank you !

Back up

Ξ^- Reconstruction



$\Xi^-(\bar{\Xi}^+) \rightarrow \Lambda(\bar{\Lambda}) + \pi^-(\pi^+)$, 99.887%

$\Lambda(\bar{\Lambda}) \rightarrow p(\bar{p}) + \pi^-(\pi^+)$, 63.9%

	Run10 && Run11		Run14	
	0-40%	40%-80%	0-40%	40-80%
DCA p to Ξ^-	>0.7cm	>0.5cm	>0.8cm	>0.5cm
DCA π to Ξ^-	>1.1cm	>1.0cm	>1.2cm	>1.0cm
DCA π to Ξ^-	>0.7cm	>0.8cm	>1.0cm	>0.8cm
DCA p to π	<0.7cm	<0.8cm	<0.6cm	<0.8cm
DCA π to Λ	<0.8cm	<0.8cm	<0.6cm	<0.8cm
DCA Λ to PV	>0.3cm	>0.2cm	>0.4cm	>0.2cm
DCA Ξ^- to PV	<0.7cm	<0.8cm	<0.6cm	<0.8cm
DL(Λ)	>5.5cm	>5cm	>6.0cm	>5cm
DL(Ξ^-)	>3.4cm	>3.4cm	>3.4cm	>3.4cm
Rapidity(Ξ^-)	[-1,1]	[-1,1]	[-1,1]	[-1,1]
Colinear angle cut	<0.12	<0.2	<0.10	<0.2
nSigmaProton	<2	<2	<2	<2
nSigmaPion	<3	<3	<3	<3
nSigmaBach	<3	<3	<3	<3