SINAP and plan for ALICE-FCPPL

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Outline

- SINAP-STAR/ALICE group
- Highlights from SINAP-STAR group
- From STAR to ALICE/Plan for ALICE analysis
- Summary


Jiading Campus:
(1) Thorium-based nuclear energy system ;
(2) Basic research divisions: nuclear physics, physical biology,
water science & technology


Zhangjiang Campus:
(1) Shanghai Synchrotron Radiation Facility
(2) X-ray Free electron Laser

Nuclear Physics Division, SINAP

- **(1) RHIC-STAR physics**
- **(2) LHC-ALICE physics**
- (3) Radioactive beam physics
- (4) Laser-electron Gamma Source construction
- (5) Laser-nuclear physics
- (6) Dark matter searching (PandaX Coll. @ JPL)

~20 staffs, ~40 PhD & Master Students

SINAP-STAR/ALICE group

SINAP-STAR

- Staff(6): Yu-gang Ma、Jin-hui Chen、Guo-liang Ma、Chen Zhong、Song Zhang、Wei Li
- Graduate student(5): Zheng-qiao Zhang、Yi-fei Xu、Long Ma、Chen-sheng Zhou、Mao-wu Nie

SINAP-ALICE

(from 2017.1)

- **Staff(6+1): Yu-gang Ma, Jin-hui Chen, Song Zhang, Chen Zhong、Wei Li, Qiye Shou, +one people (2018)**
- **Graduate student(3+5): Jun-Jee He, Liu-yao Zhang, Xin-li Zhao, +one (every year)**

STAR's Papers with PA from SINAP

★17 papers as principal author from SINAP-STAR group

★STAR's 2 papers in Nature, 1 paper in Science, 4 papers in Physical Review Letters

★~20 proceeding papers

★277 STAR Papers

★STAR Collaboration: 57 institutes from 12 counties (area), 593 collaborators

Physics analysis at SINAP-STAR

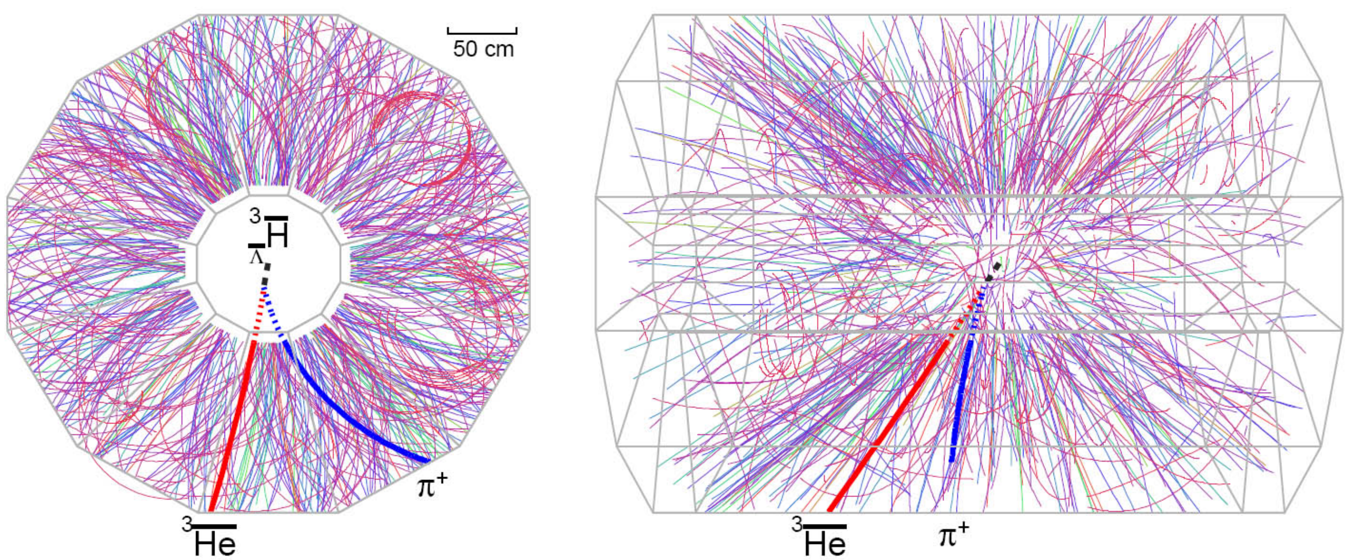
- **Strangeness dynamics**
  - ✓ **(anti-)hypertriton, lifetime, branch ratio**
  - ✓ **exotic particle searching**
- **Interaction between antimatter**
- **Heavy flavour**
  - ✓ **non-photonic electron-hadron correlation**
  - ✓ **charm hadron-charge hadron correlation**
  - ✓ **Elliptic flow of J/Ψ**
- **Updates for High Level Trigger (HLT)**

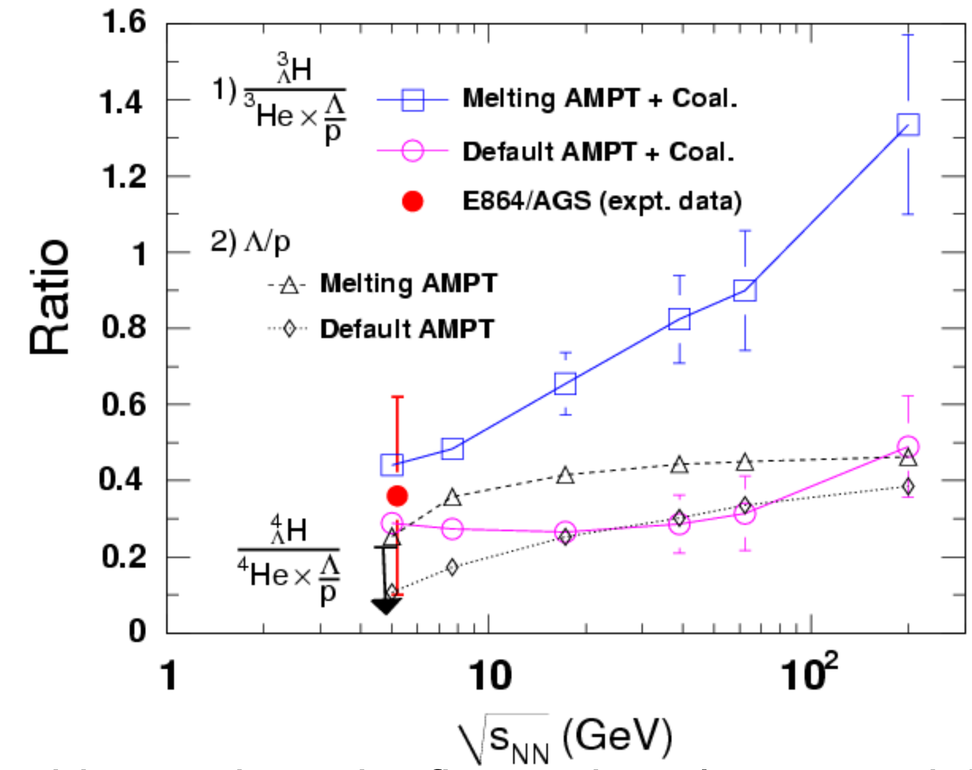
Highlights from SINAP-STAR group

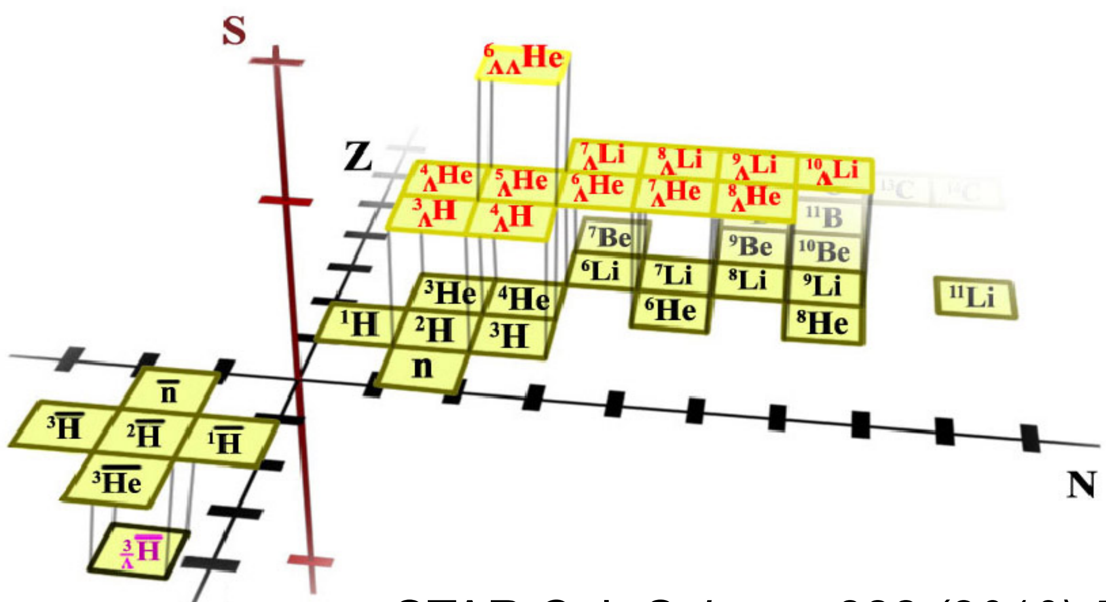
The anti-hypertriton observation

Science
AAAS

Observation of an Antimatter Hypernucleus
The STAR Collaboration, *et al.*
Science **328**, 58 (2010);
DOI: 10.1126/science.1183980







STAR Col. *Science* ***328*** *(2010) 58-62*

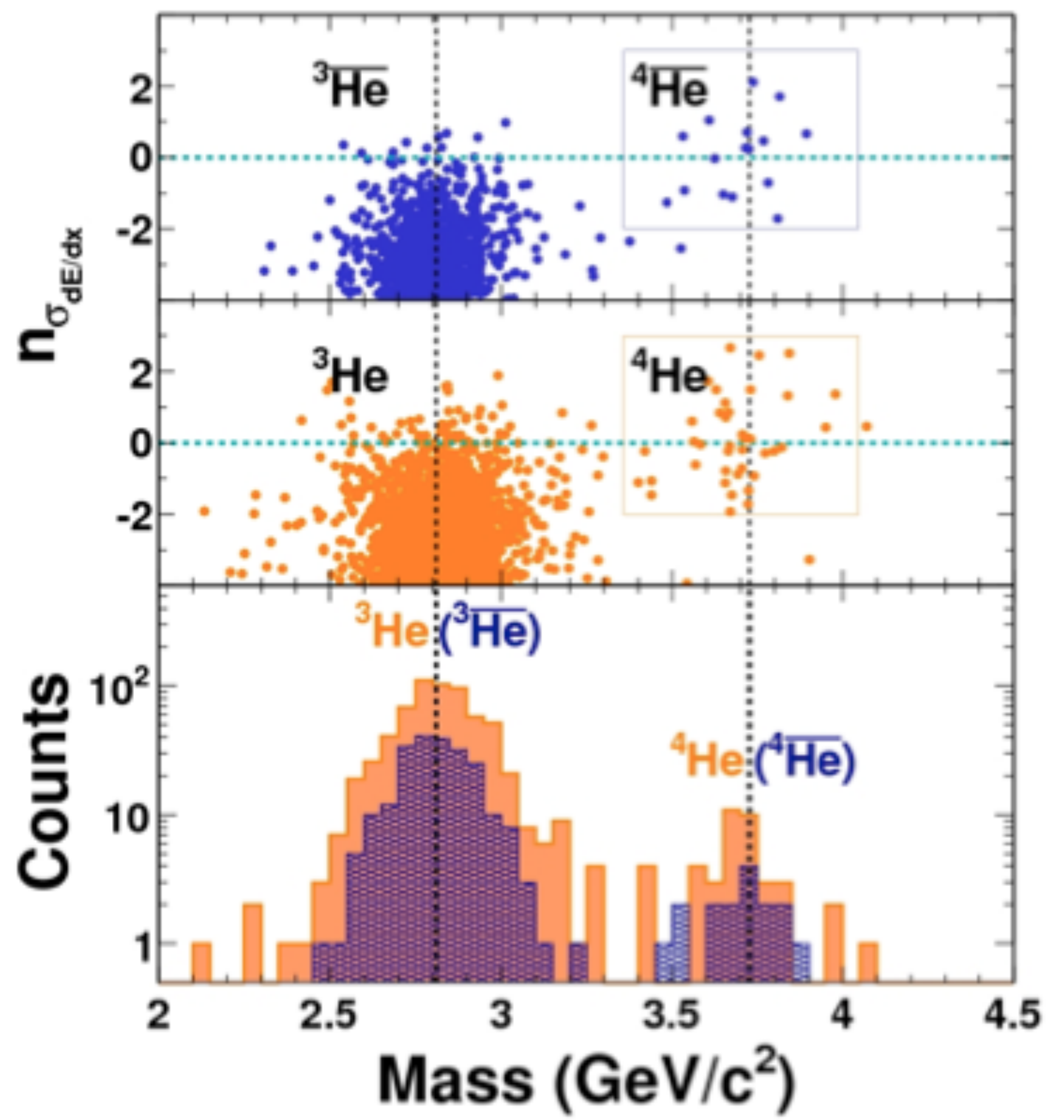
- Anti-hypertriton, the first anti-nucleus containing an anti-strange quark, extends the 3-D chart of nuclides into the new octant of strange anti-matter
- Strangeness popular factor represents the strength of local baryon-strangeness correlation, experimental probe for QCD phase transition.
S. Zhang et al., *Phys. Letts. B* ***684*** *(2010) 224*

Observation of the anti-helium4

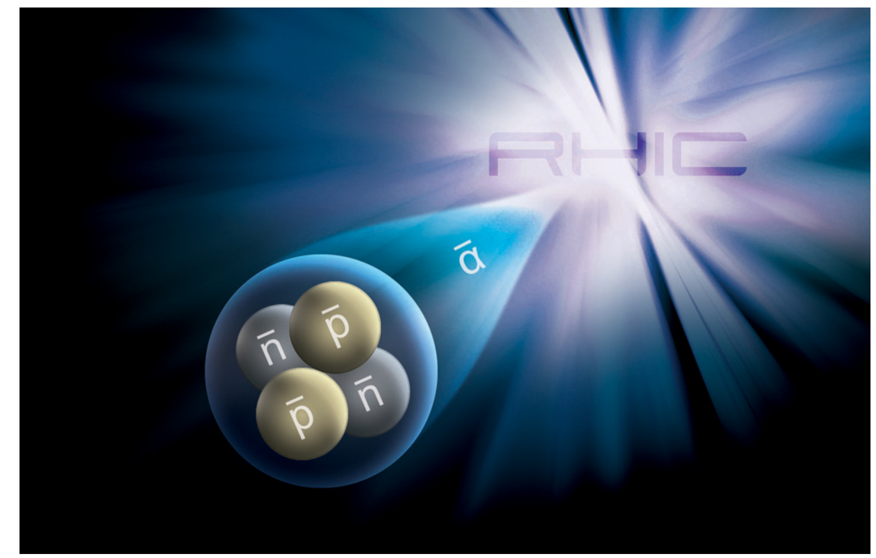
nature

Observation of the antimatter helium-4 nucleus

The STAR Collaboration*



Mass ID with TOF



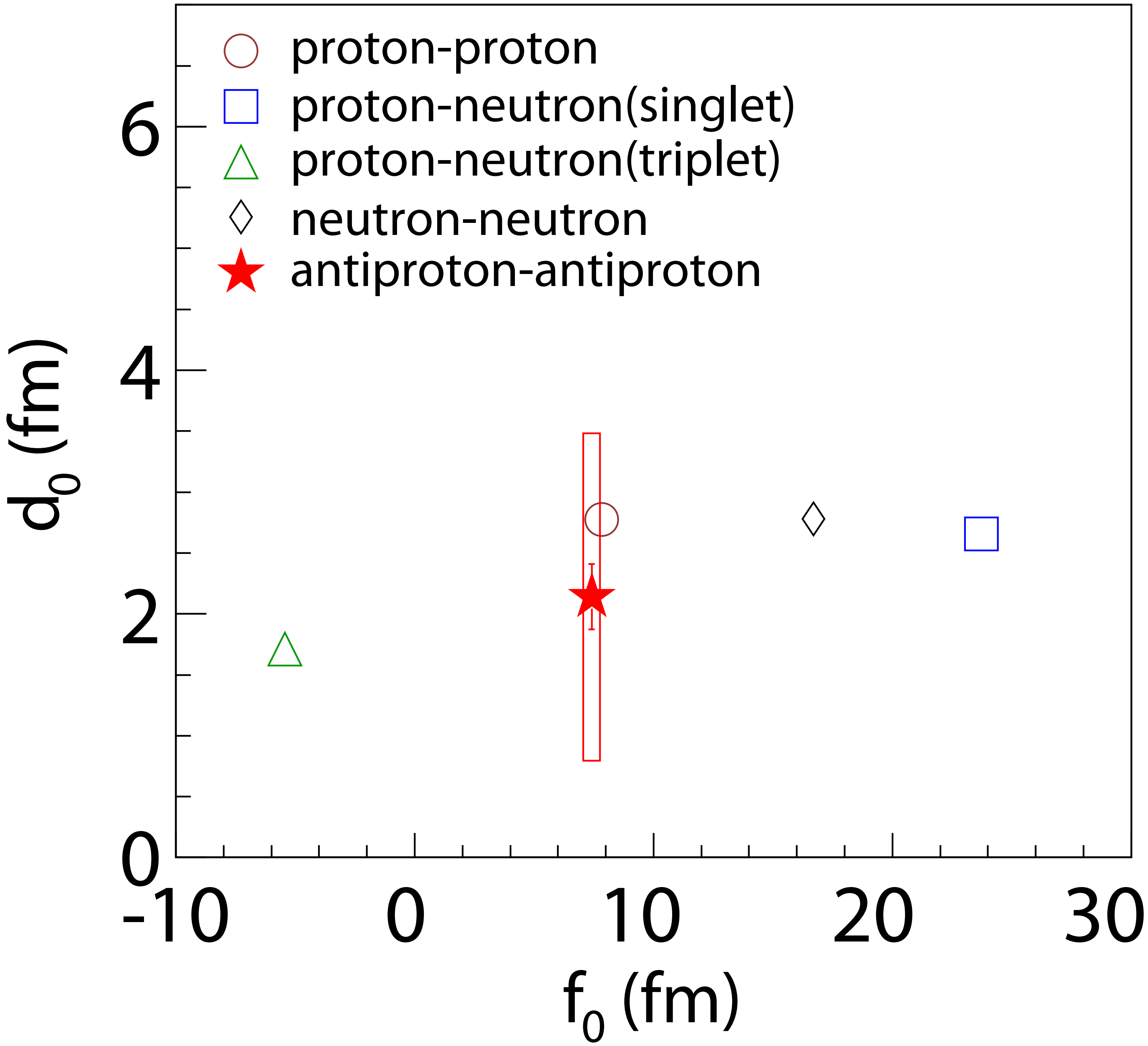
★ 18 anti-helium4, the heaviest antinucleus ever detected, were identified in STAR data

STAR Col.: ***Nature 473 (2011) 353***

Liang Xue (SINAP), Quark Matter 2011 talk;
2013 Excellent CAS PhD Dissertation;

Antiproton interaction

- ✓ Basic parameters for particle interactions: within error range, f0(pbar-pbar)=f0(p-p)   d0(pbar-pbar) =d0(p-p)
- ✓ Obey CPT theorem: Charge, Parity, and Time Reversal Symmetry



nature

527, 325 (2015)

Principal authors

Y. G. Ma, Q. Y. Shou, A. Tang, K.F. Xin, Z.Q. Zhang, M. Lisa et al.,

This work is a part of Mr. Zhenq-qiao Zhang (SINAP), one of Yu-Gang Ma's PhD students,
PhD Dissertation (2017)

From STAR to ALICE

✓antimatter interaction

✓hypernuclei

✓**exotic projects**

✓heavy flavour

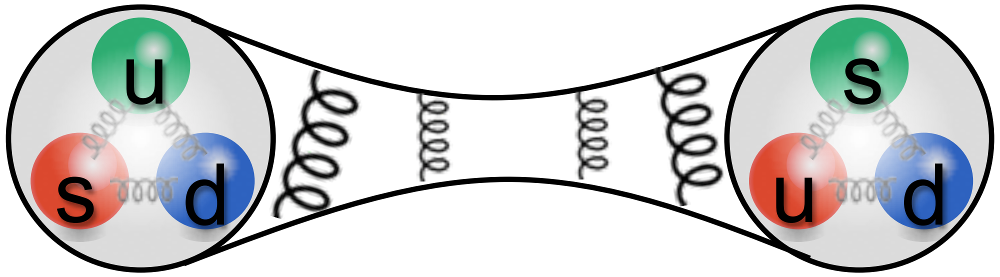
✓ALICE upgrade

Di-baryon searching

- **H particle**
- **Di-Omega**
- **N-Omega**
- **discussion on measurements**

Why dibaryon?

- **Provide more information about the short-range behaviour of (p)QCD (fm scale)**
- **Directly supply the evidence of the quark-gluon degrees of freedom in hadrons and hadronic systems**



Dibaryon system

- **deuteron-like states: weekly bound, d, ΞΩ, ΞΞ**
- **ΔΔ-like (d*) states: relatively deeply bound, but widths of the states much broader, only week decay modes, binding energy a few tens of MeV**
- **ΩΩ-like states: deeply bound states with narrow widths, strong decay mode exists, binding energy can reach one hundred MeV**

Q. B. Li et al., Nuclear Physics A 683, 487 (2001)

H particle

- In 1977, Jaffe predicted that double strange dibaryon made of six quark (*uuddss*) may be deeply bound below the Λ-Λ threshold due to strong attraction from color magnetic interaction based on the bag model calculation

Phys. Rev. D **15**, 267 (1977);
Phys. Rev. D **15**, 281 (1977)
Phys. Rev. Lett. **38**,195 (1977); **38**, 617(E)(1977)

- Properties : $J^P = 0^+$, mass : (1.9-2.8) GeV/c^2

$$\psi(\mathrm{H}) = \sqrt{\frac{1}{8}}\psi(\Lambda\Lambda) + \sqrt{\frac{4}{8}}\psi(\mathcal{N}\Xi) - \sqrt{\frac{3}{8}}\psi(\Sigma\Sigma)$$

- Since prediction, dedicated measurements have been performed to look for the H dibaryon signal, but its existence remains an open question

- Binding energy from QCD calculation:
  - ✓NPLQCD: 17 MeV, PRL-106-162001(2011)
  - ✓HAL: 30-40 MeV, PRL-106-162002(2011), PTP-124-591(2010)
  - ✓A.W.Thomas et al. (LQCD), 13+-14 MeV above the di-Lambda threshold, most likely unbound, PRL-107-092004(2011)
  - ✓Chiral constituent quark model: 7 MeV, PRC-85-045202(2012)
- Experiment: STAR, Λ-Λ correlation, not exclude the existence of H particle though the strength of the Λ-Λ interaction is week, PRL-114-022301(2015)

Di-Ω

- **Chiral quark model:** *Z. Y. Zhang et al., NPA-625-59 (1997); PRC-61-065204 (2000)*
  - ✓suggest a di-Omega dibyaryon search in heavy ion collision experiments
  - ✓Binding energy 100 MeV, lifetime 2 times of free Omega's
  - ✓More likely a six-quark particle with large binding energy and short relative distance (RMS=0.84 fm) between two Omegas
- **AMPT (including reaction listed):**

  C. M. Ko, Z. Y. Zhang,PLB-624-210(2005)

No.	Channel	$\sqrt{s_0}$	A	α	β	δ
I	$\Omega + \Omega \to (\Omega\Omega)_0 + \gamma$	3.345	20.16	0.63	0.25	1.44
II	$\Omega + \Omega \to (\Omega\Omega)_0 + \eta$	3.777	3988.23	1.77	0.13	1.10
III	$\Omega + \Omega \to (\Omega\Omega)_0 + \eta'$	4.187	79.02	3.24	3.08	5.89
IV	$\Omega + \Omega \to (\Omega\Omega)_0 + \phi$	4.249	506.35	2.71	2.96	7.18
V	$\Omega + \Xi \to (\Omega\Omega)_0 + K$	3.722	18.93	2.07	2.62	5.99
VI	$\Omega + \Xi \to (\Omega\Omega)_0 + K^*$	4.123	322.55	2.27	2.33	7.79
VII	$\Omega + N \to (\Omega N)_2 + \gamma$	2.611	5.85×10^{16}	3.44	4.95×10^{-9}	0.19
VIII	$\Omega + N \to (\Omega N)_2 + \pi$	2.750	1.69×10^{8}	2.52	2.40×10^{-3}	0.44
IX	$\Omega + (\Omega N)_2 \to (\Omega\Omega)_0 + N$	4.278	1888.36	1.09	–	–

  - ✓production probability of 2.8x10^{-6} per event for central Au+Au collisions at centre of mass energy 130 GeV
  - ✓week decays: (1) Omega-Omega->pi^{-}+Xi^{0}+Omega^{-}, (2) Omega-Omega->pi^{0}+Xi^{-}+Omega^{-}
  - ✓nomesonic decay: Omega-Omega->Xi^{-}+Omega^{-}
- **Quark-delocalization color-screening model:** *H. Pang et al., PRC-70-035201(2004)*
  - ✓H particle and di-Omega, loosely bound system similar to deuteron, binding energy about few MeV

NΩ

- **MIT bag model: in 1987 MIT bag model predicted NΩ dibaryon which is stable with respect to strong decay** *T. Goldman et al., PRL-59-627 (1987)*

- **Quark-Delocalization color-screeing model (QDCSM) and chiral quark model (ChQM)** *H. Pang, J. Ping, F. Wang, T. Goldman, E. Zhao, PRC-69-065207 (2004); H. Pang, J. Ping, L. Chen, F. Wang, T. Goldman, PRC-70-035201 (2004); M. Chen, H. Huang, J. Ping, F. Wang, PRC-83-015202 (2011); H. Huang, J. Ping, F. Wang, PRC-92-065202 (2015)*

  - ✓**NΩ, madly attractive, mass: 2549 MeV (QDCSM) or 2528 (ChQM)**
  - ✓**compact six-quark state, a narrow dibaryon resonance**
  - ✓**decay mode: NΩ->Λ+Ξ (spin=0, decay width 12 KeV), (spin=1, decay width 22 KeV);**
  - ✓**suggest NΩ correlation analysis to identify the bound state**

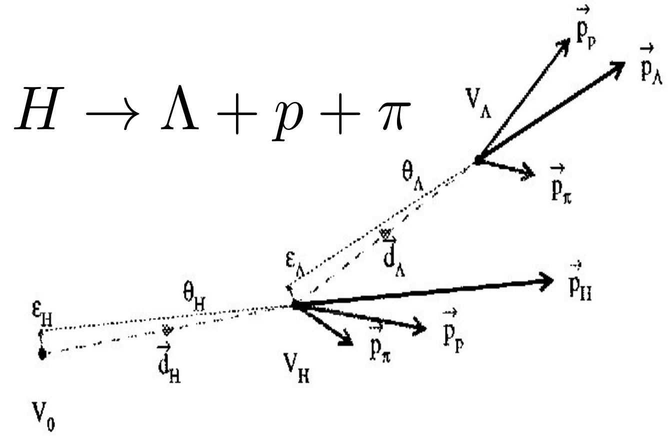
- **Lattice QCD: bound state of NΩ whose binding energy 19 MeV with error of 5 MeV, HAL Collaboration, NPA-928-89 (2014)**

Discussion on measurements (I)

- **Invariant mass reconstruction:**
  - ✓ **directly conform the existence of dibaryon**
  - ✓ **but more complicated for background from multi-daughter and the uncertain decay width**

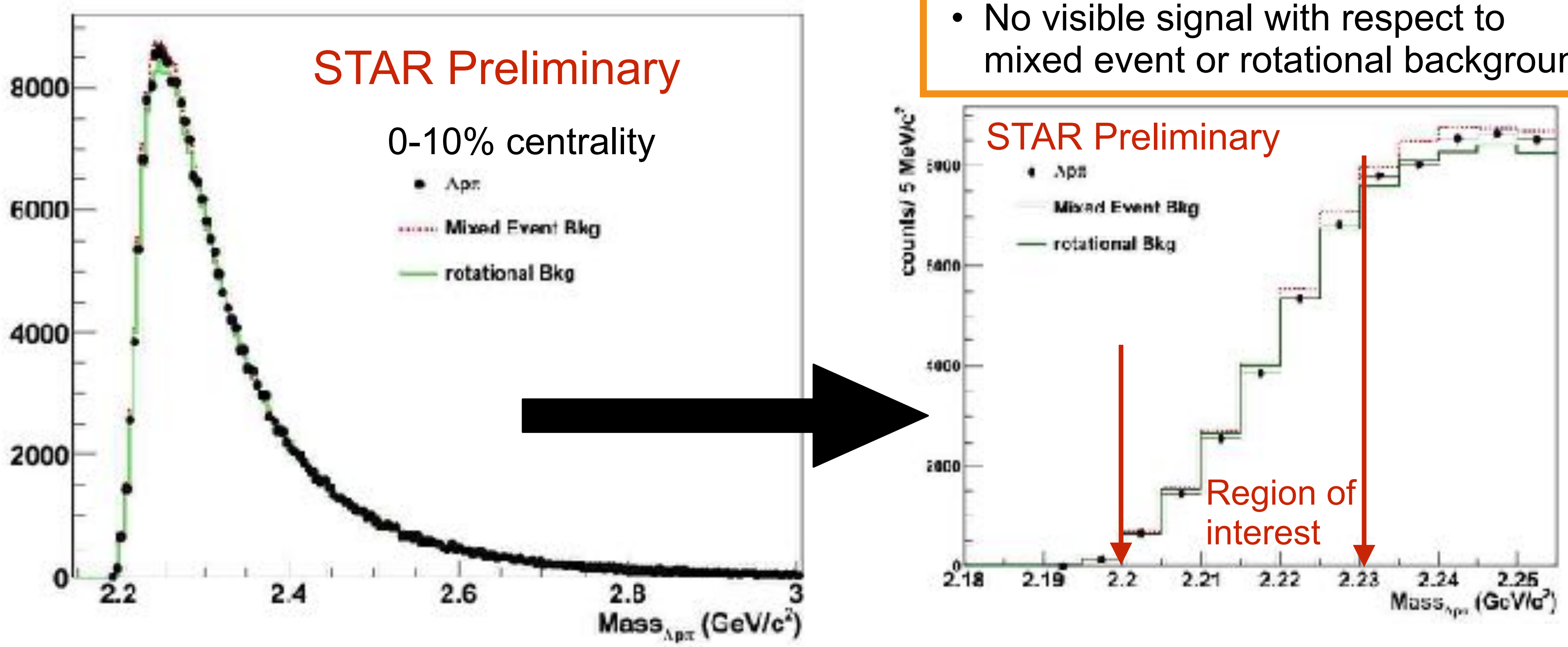
☑ Topological reconstruction of $\Lambda p\pi$ to look for H
- Mass range: 2.2 < m_H < 2.231 GeV/c^2

$$H \to \Lambda + p + \pi$$



N. Shah for STAR Col. Nucl. Phys. A 914 (2013) 410

Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.



- No visible signal with respect to mixed event or rotational background

Discussion on measurements (II)

- **correlation method: two identified particles decay mode, model depended, only provide the interaction is attractive or not**

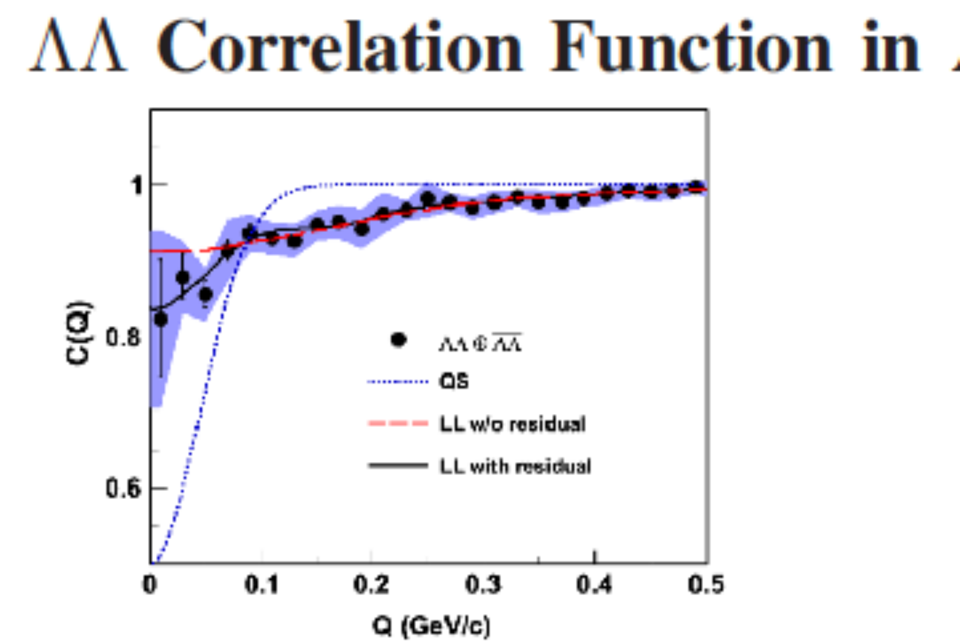
  ✓ **N-Omega correlation analysis to identify the bound state, H. Huang, J. Ping, F. Wang, PRC-92-065202 (2015)**

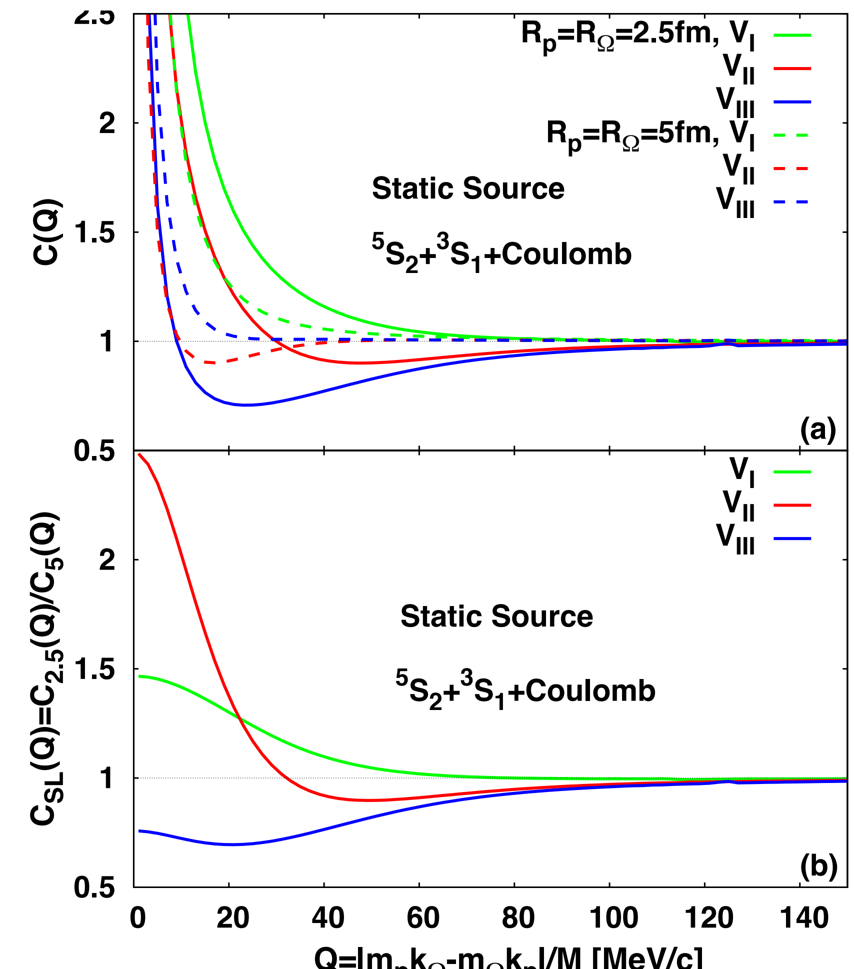
  ✓ **The ratio of correlation functions between small and large collision system is proposed to be a new measure to extract the strong p-Omega interaction without much contamination from the Coulomb attraction, K. Morita, A. Ohnishi, F. Etminan, T. Hatsuda, arXiv:1605.06765 [hep-ph] (2016)**

  ➡ **VI: weaker attraction**

  ➡ **VII: shallow bound state**

  ➡ **VIII: deep bound state**





Summary

- Introduction to SINAP-group on heavy ion collision physics
- High lights from SINAP-STAR group
- Plan for ALICE physics analysis
  - ✓ Antimatter interaction
  - ✓ Hypernuclei researching
  - ✓ **Dibaryon searching**
  - ✓ Heavy flavour measurements