Nuclear physics activities around Shanghai and international collaborations for high energy nuclear physics in China

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The 8th Asian Nuclear Physics Association Symposium (ANPhA2016)
November 24 (Thu) – 25 (Fri), 2016
Graduate School of Science, Tohoku University, Sendai, Japan

outline

- Nuclear Physics around Shanghai
- Int. Coll. of high energy nuclear physics


RUSSIA
KAZAKSTAN
Almaty
Bishkek
Ürümqi
Turpan
Kashgar
Xinjiang
Karakoram Highway
MONGOLIA
Ulann Baatar
Haerbin
Shenyang
Beijing
Dalian
Pyongyang
Tianjin
Seoul
Qufu 1545m
Osaka
Yinchuan
Xining
Lanzhou
Zhengzhou
Tibet
CHINA
Xi'an
Nanjing
Shanghai
Huangzhou
Wuhan
Chengdu
Delhi
Lhasa
Kathmandu
Thimphu
Longgong Caves
Fuzhou
Taipei
INDIA
Kunming
Dhaka
Kolkata (Calcutta)
Guangzhou
Nanning
TAIWAN
Hong Kong
Macau
MYANMAR
Hanoi
Haikou
0
1000 km

Some related institutions

- Shanghai Inst. of Applied Physics (rename from Shanghai Institute of Nuclear Research in 2003)
- Shanghai Jiatong Univ.
- Fudan Univ.
- East China Normal Univ.
- Shanghai Univ.
- Nanjing Univ. (Jiangsu Prov.)
- Sotheast Univ. (Jiangsu Prov.)
- Nanjing Normal Univ. (Jiangsu Prov.)
- USTC (Anhui Prov.)
- Central China Normal Univ (Hubei Prov.)
- Huzhou Univ. (Zhejiang Prov.)

Big Research Funds & Chinese Talents in Nucl. Phys.

Large scale Research Funds (the Major State Basic Research Development Program, also known as 973 project) (30M CNY/5y):

中华人民共和国科学技术部
Ministry of Science and Technology of the People's Republic of China

- Unstable nuclear physics & nuclear astrophys (I) (2001.1-2005.9 G2000077401), Prof. Wenqing Shen
- Unstable nuclear physics & nuclear astrophys (II, III) (2008.1-2012.8; 2013.1-2017.8), Prof. Yanlin Ye
- Nuclear Matter at extreme high temperature and density (2014.1-2018.8), Prof. Yu-Gang Ma
- High compression matter at FAIR-CBM (2015.1-2019.8), Prof. Nu Xu

NSFC Key Important Funds (20M/5years):

- Underground nuclear astrophys (2015.1-2019.12, 20M CNY/5y), Prof. Weiping Liu

NSFC Innovation Team Funds (12 M CNY/6years):

国家自然科学基金委员会
NSFC
National Natural Science Foundation of China

- RIB Physics (Prof. Wenlong Zhan)
- Nuclear astrophys (Prof. Weiping Liu, 2011.1-2016.12)
- Heavy ion Physics (Prof. Yu-Gang Ma, 2015-2020.12)

CAS Academician Members (under 80 years old):

中国科学院
CHINESE ACADEMY OF SCIENCES

- Wengqing Shen (SINAP)
- Wenlong Zhan (IMP)

Fellows of the American Physical Society (APS Fellow)

APS physics

- Jie Meng (Int. Forum of Phys., APS)
- Yu-Gang Ma (Div. of Nucl. Phys., APS)

National Distinguished Young Scholars Recipients (in Nucl. Phys. filed)

NSFC selects 200 distinguished scholars each year in all science fields (under 45 years old). It is almost the highest reputation for Chinese young scholar. Usually, one or two each year for nuclear physics.

1997: Yu-Gang Ma (SINAP)
1998: Wenlong Zhan (IMP)
1999: Pengfei Zhuang (Tsinghua U.)
2000: Jie Meng (PKU)
Weiping Liu (CIAE)
Yuhu Zhang (IMP)
2001: Zhongzhou Ren (Nanjing U.)
2002: Bingsong Zhou (IHEP)
2004: Yuxin Liu (PKU)
2005: Furong Xu (PKU)

2008: Xiaohong Zhou (IMP)
Enke Wang (CCNU)
2009: Hushan Xu (IMP)
2010: Fengshou Zhang (BNU)
2011: Qun Wang (USTC)
2012: Yumin Zhao (SJTU)
2014: Qiang Zhao (IHEP)
2015: Shangui Zhou (ITP)
2016: Liewen Chen (SJTU)

Only 19 for nuclear physics from 1997

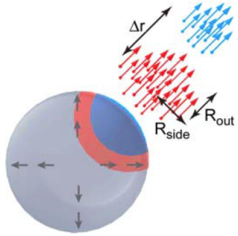
SINAP activities in Nuclear Physics

- Radioactive nuclear beam physics
- SLEGS (Shanghai Laser-Elec. Gamma Source)
- Nuclear Theory & phenomenology
- Laser Nucl. Phys
- Int. Collaborations:

  RHIC-STAR & LHC-ALICE for Relativistic HIC

  CUORE (0vbb)

  PandaX (dark matter)

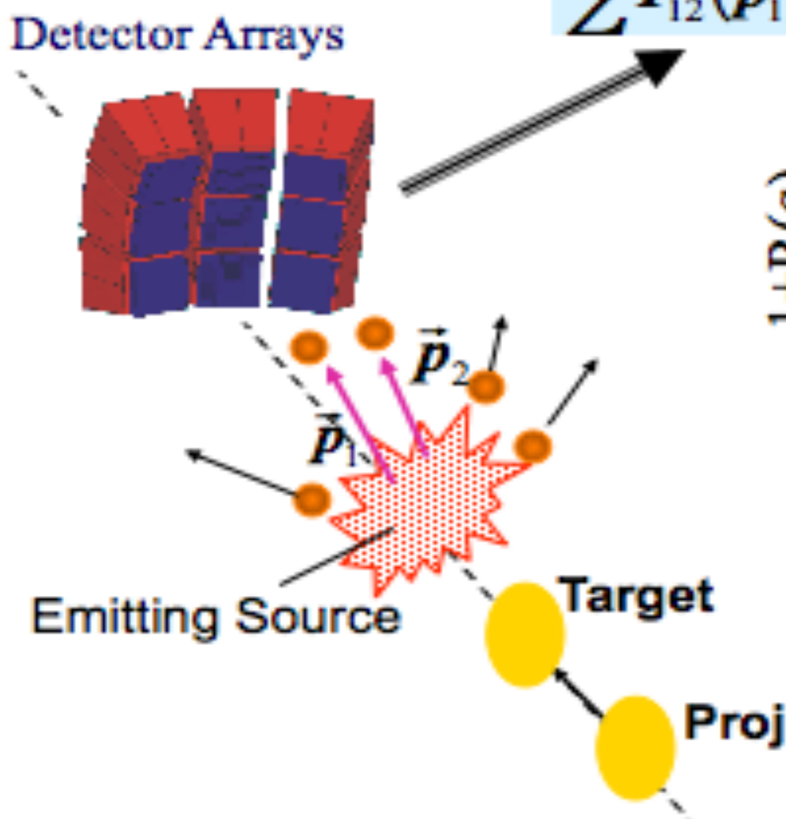


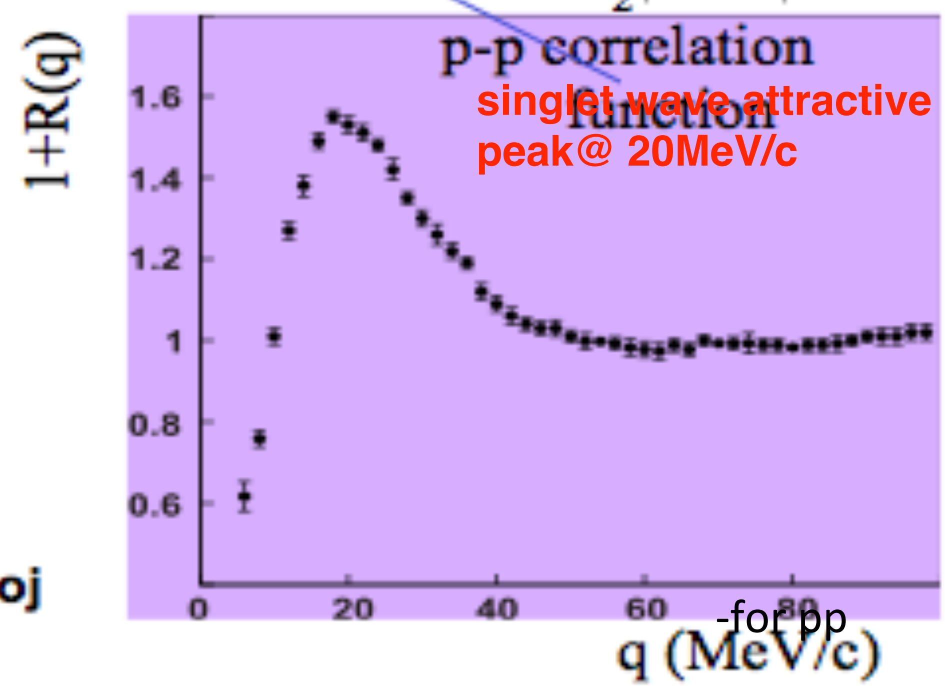
1. Radioactive nuclear beam physics

Two-Proton correlation functions

$$\sum Y_{12}(\vec{p}_1,\vec{p}_2)=[1+R(q)]\cdot\sum Y_1(\vec{p}_1)\cdot Y_2(\vec{p}_2)$$

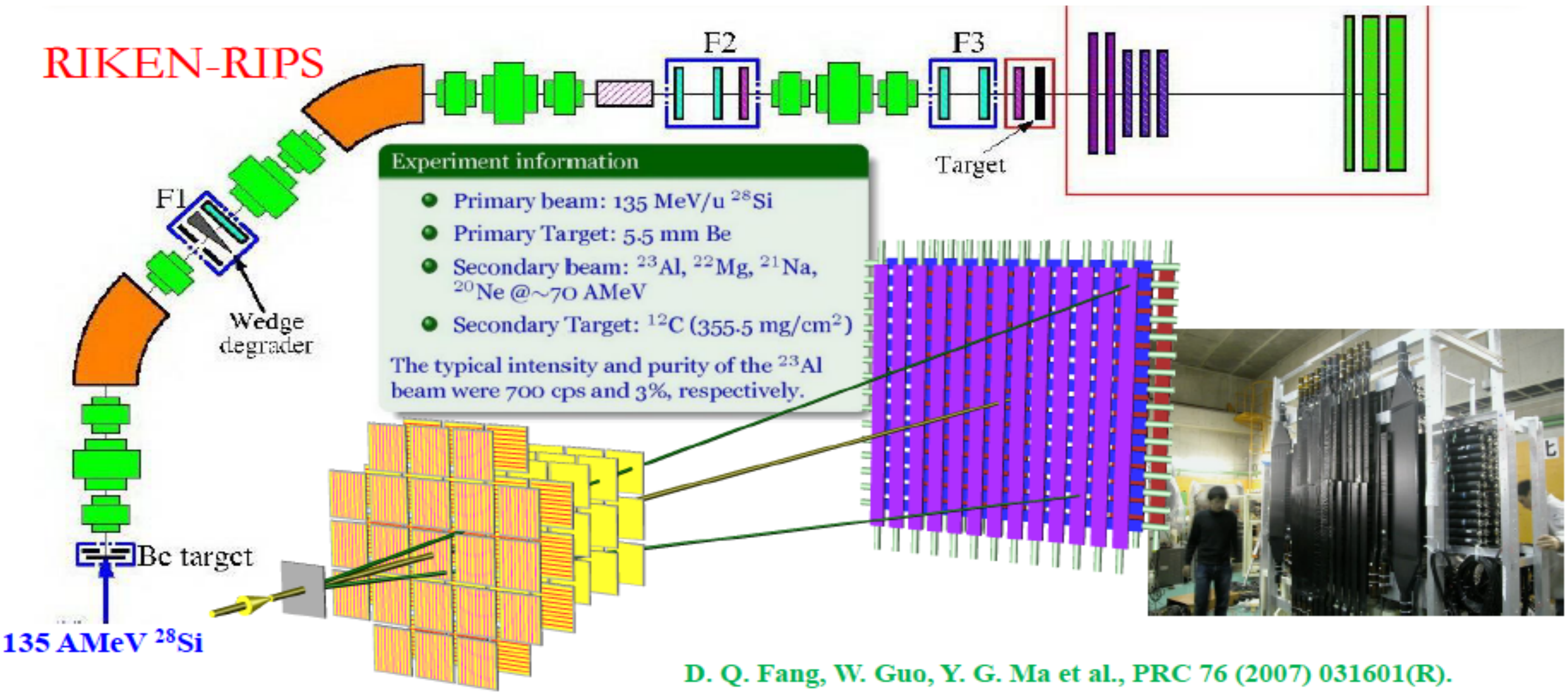
$$q=\frac{1}{2}\left|\vec{p}_1-\vec{p}_2\right|$$



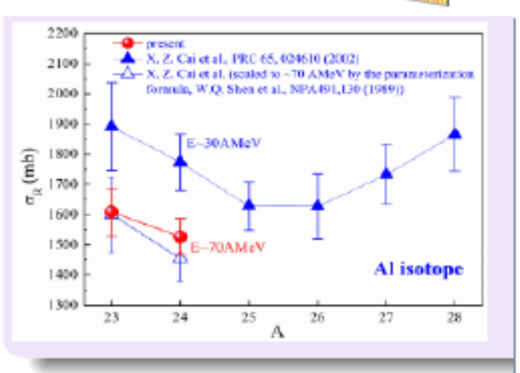


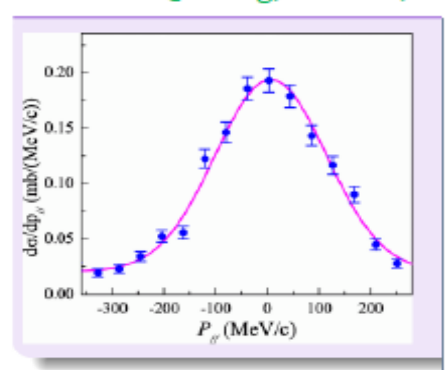
R(q) sensitive to the space-time properties of emitting sources

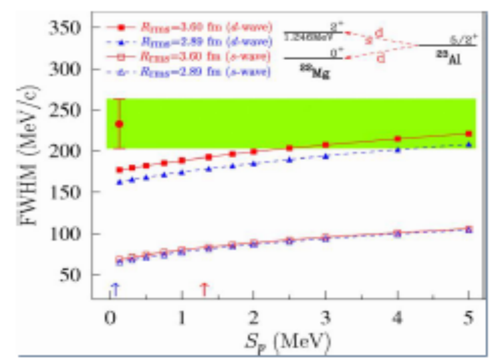
Eg. Collaboration with RIKEN



D. Q. Fang, W. Guo, Y. G. Ma et al., PRC 76 (2007) 031601(R).







Physics Letters B 743 (2015) 306–309

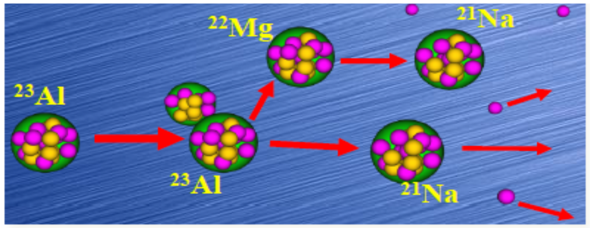
Contents lists available at ScienceDirect

Physics Letters B

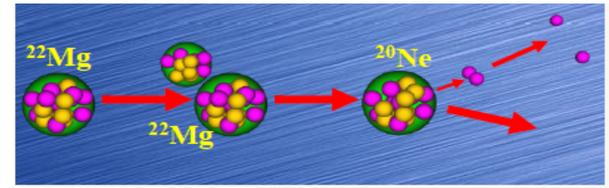
www.elsevier.com/locate/physletb

Different mechanism of two-proton emission from proton-rich nuclei ^{23}Al and ^{22}Mg

Y.G. Ma [a], D.Q. Fang [a], X.Y. Sun [a], P. Zhou [a], Y. Togano [b], N. Aoi [b], H. Baba [b], X.Z. Cai [a], X.G. Cao [a], J.G. Chen [a], Y. Fu [a], W. Guo [a], Y. Hara [c], T. Honda [c], Z.G. Hu [d], K. Ieki [c], Y. Ishibashi [e], Y. Ito [e], N. Iwasa [f], S. Kanno [b], T. Kawabata [g], H. Kimura [h], Y. Kondo [b], K. Kurita [c], M. Kurokawa [b], T. Moriguchi [e], H. Murakami [b], H. Ooishi [e], K. Okada [c], S. Ota [g], A. Ozawa [e], H. Sakurai [b], S. Shimoura [g], R. Shioda [c], E. Takeshita [b], S. Takeuchi [b], W.D. Tian H.W. Wang [a], J.S. Wang [d], M. Wang [d], K. Yamada [b], Y. Yamada [c], Y. Yasuda [e], K. Yoneda [b], G.Q. Zhang [a], T. Motobayashi [b]

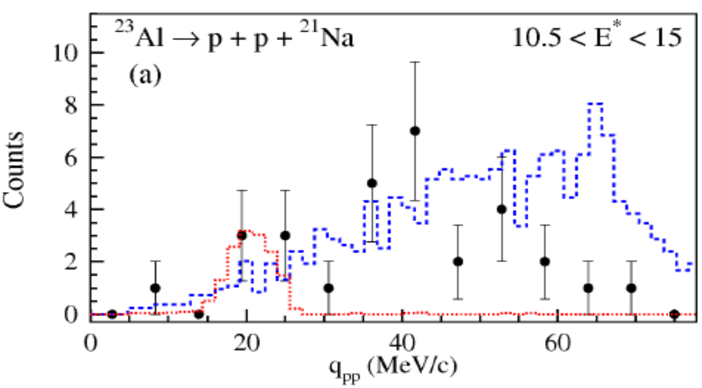


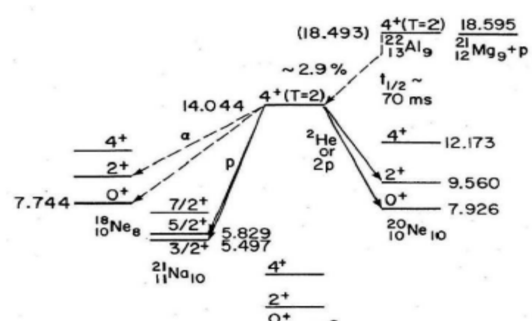
1773	35	(3/2)+	A C	%p=100.
2575	34		C	%p=100.
3197	19	(3/2)+	A C	%p=100.
3718	31	(5/2)+	A C	%p=100.
4200	40	(7/2)+	A	%p=100.
11780	40	(5/2)+	A	%p=0.10 5; %2p=3.6 4.
				Jπ: IAS to ^{23}Si parent.

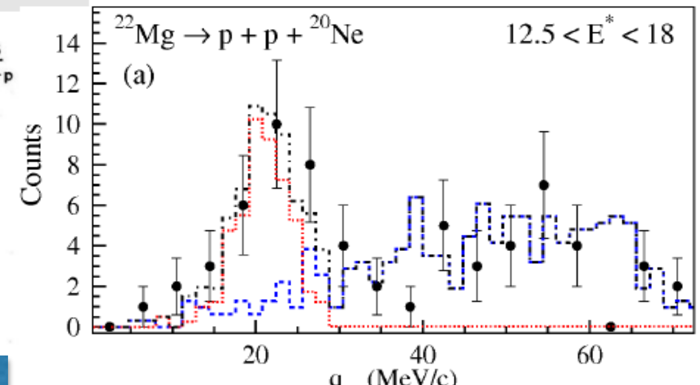


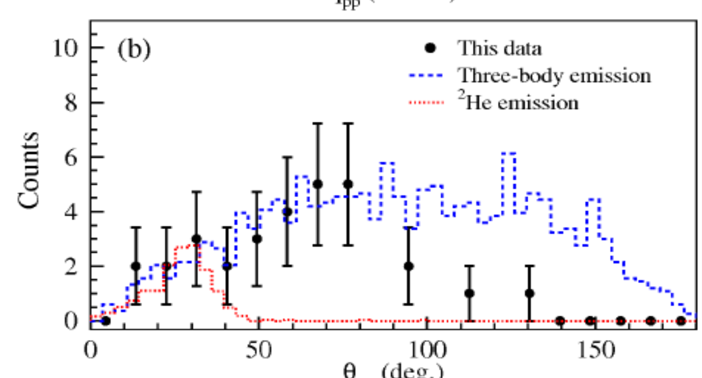
^{23}Al → ^{21}Na + 2p

^{22}Mg → ^{20}Ne + 2p





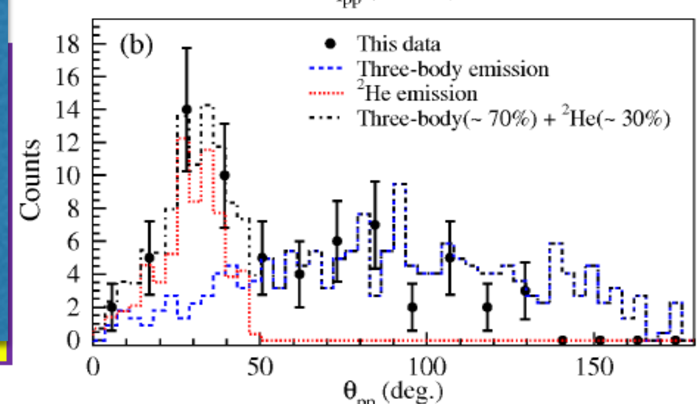




Different 2p emission mechanism for 23Al and 22Mg:

(1) 23Al —three body decay or cascade emission;

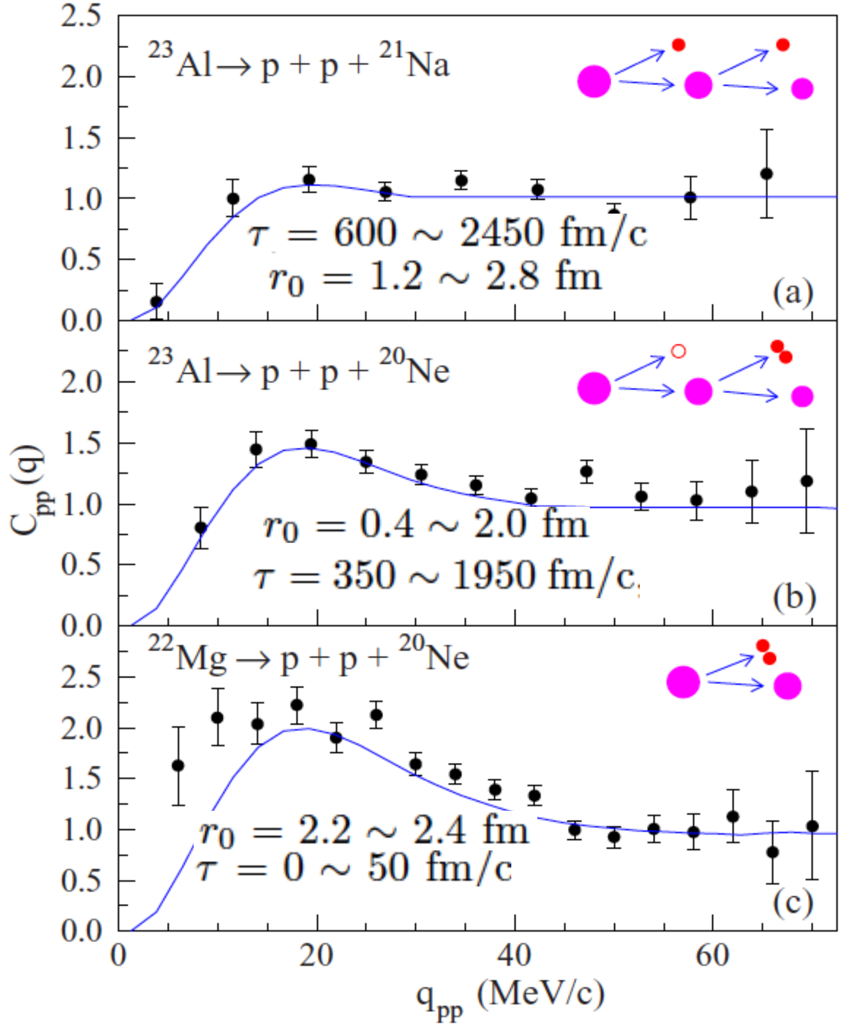
(2) 22Mg - strong 2p emission component

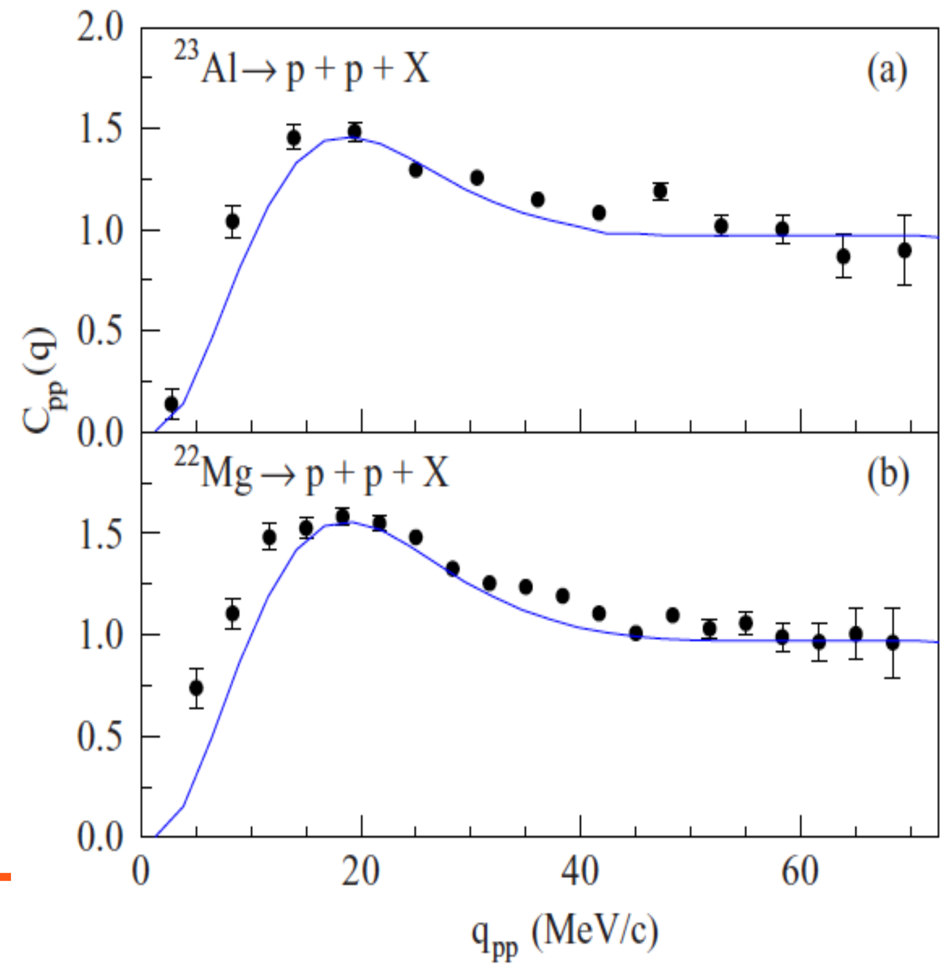


PHYSICAL REVIEW C **94**, 044621 (2016)

Proton-proton correlations in distinguishing the two-proton emission mechanism of ^{23}Al and ^{22}Mg

D. Q. Fang,[1,*] Y. G. Ma,[1,†] X. Y. Sun,[1] P. Zhou,[1] Y. Togano,[2] N. Aoi,[2] H. Baba,[2] X. Z. Cai,[1] X. G. Cao,[1] J. G. Chen,[1] Y. Fu,[1] W. Guo,[1] Y. Hara,[3] T. Honda,[3] Z. G. Hu,[4] K. Ieki,[3] Y. Ishibashi,[5] Y. Ito,[5] N. Iwasa,[6] S. Kanno,[2] T. Kawabata,[7] H. Kimura,[8] Y. Kondo,[2] K. Kurita,[3] M. Kurokawa,[2] T. Moriguchi,[5] H. Murakami,[2] H. Ooishi,[5] K. Okada,[3] S. Ota,[7] A. Ozawa,[5] H. Sakurai,[2] S. Shimoura,[7] R. Shioda,[3] E. Takeshita,[2] S. Takeuchi,[2] W. D. Tian,[1] H. W. Wang,[1] J. S. Wang,[4] M. Wang,[4] K. Yamada,[2] Y. Yamada,[3] Y. Yasuda,[5] K. Yoneda,[2] G. Q. Zhang,[1] and T. Motobayashi[2]





PRL 113, 032506 (2014) PHYSICAL REVIEW LETTERS week ending 18 JULY 2014

Giant Dipole Resonance as a Fingerprint of α Clustering Configurations in ^{12}C and ^{16}O

W. B. He (何万兵),[1,2] Y. G. Ma (马余刚),[1,3,*] X. G. Cao (曹喜光),[1,†] X. Z. Cai (蔡翔舟),[1] and G. Q. Zhang (张国强)[1]
[1]Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China
[2]University of the Chinese Academy of Sciences, Beijing 100080, China
[3]Shanghai Tech University, Shanghai 200031, China

PHYSICAL REVIEW C 91, 044302 (2015)

New measurement of the excited states in ^{11}B via elastic resonance scattering of ^{10}Be + p

Y. D. Liu (刘应都),[1,2] H. W. Wang (王宏伟),[1] Y. G. Ma (马余刚),[1,3,*] X. G. Cao (曹喜光),[1] G. Q. Zhang (张国强),[1] D. Q. Fang (方德清),[1] M. Lyu (吕明),[1,2] W. B. He (何万兵),[1,2] Z. T. Dai (代智涛),[1,2] C. Li (李琛),[1] C. L. Zhou (周铖龙),[1] S. Q. Ye (叶绍强),[1,2] C. Tao (陶城),[1,2] J. Wang (王佳),[1,2] S. Kumar,[1] J. L. Han (韩建龙),[4]

The Astrophysical Journal Letters, 817:L5 (6pp), 2016 January 20 doi:10.3847/2041-8205/8

NEW ASTROPHYSICAL REACTION RATE FOR THE ^{12}C(α, γ)^{16}O REACTION

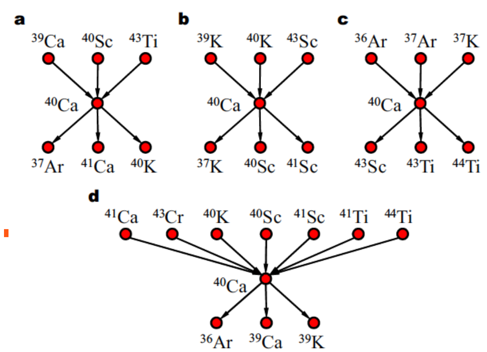
Zhen-Dong An[1,2], Yu-Gang Ma[1,3], Gong-Tao Fan[1], Yong-Jiang Li[1], Zhen-Peng Chen[4], and Ye-Ying Sun[5]
[1]Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China; ygma@sinap.ac.cn

SCIENTIFIC REPORTS

OPEN

Multilayer Network Analysis of Nuclear Reactions

Liang Zhu[1,2], Yu-Gang Ma[1,3], Qu Chen[4,5] & Ding-Ding Han[4,5]



Running Facility: Shanghai Synchrotron Radiation Facility

- Layout: 100MeV Injector+ 3.5GeV Booster + 3.5GeV SR +7 Beam Line &1.44B RMB
- Started from Dec. 2004, the 1st Light 2007, Finished 2009
- 5 Beam Lines just finished, in operation
- SSRF-II Projects: New 16 beam lines including SLEGS will start soon (2016~2020) (1.6B RMB)

Shanghai Inst. of Applied Physics

2. Shanghai Laser-Electron Gamma Source @SINAP

Shanghai Synchrotron Radiation Facility (SSRF)-II (2017-2021)

16 beamlines, SLEGS is 1 of them:

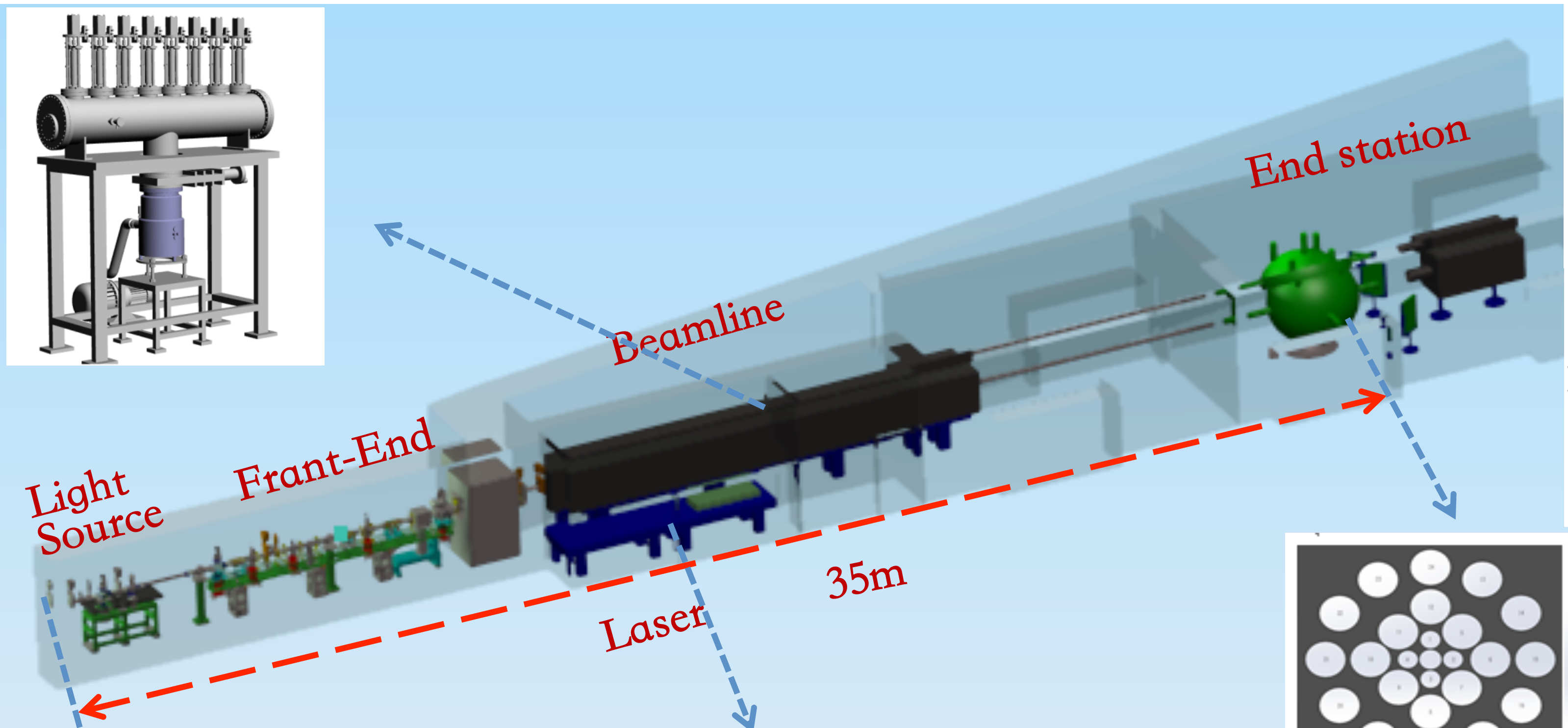
E_gamma 0.4-20.MeV; Delta_E: ~5%;

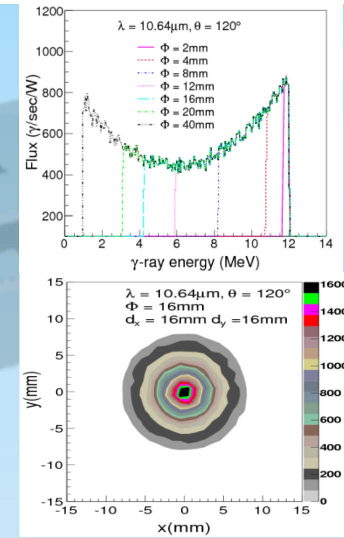
D_theta: 0.5mrad; Flux: 10^5 -10^7 phs/s

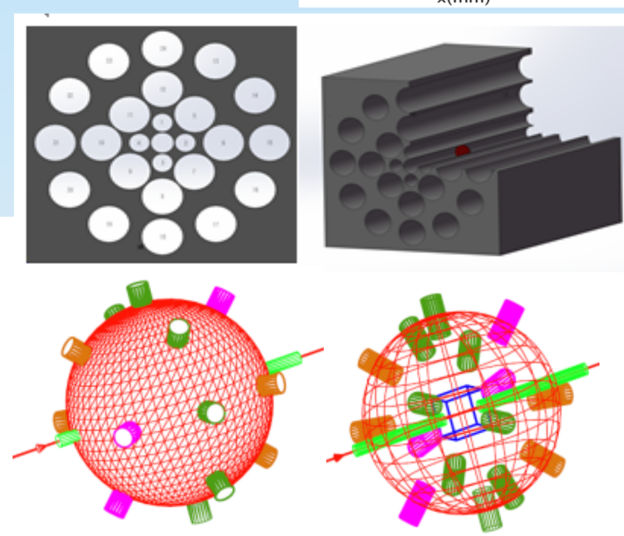
Shanghai Laser Electron Gamma Source @ SSRF

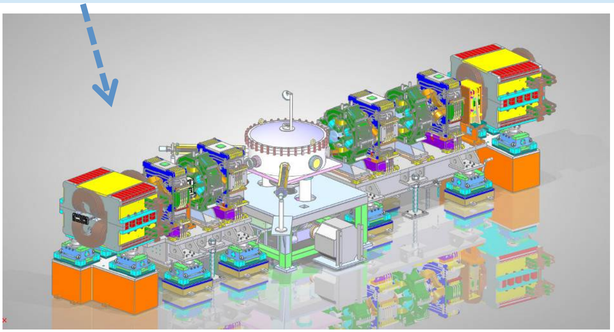
(Start to construct and will be in operation in 2020)

Energy range： 0.4-20.MeV; Energy resolution ： ~5%; Divergence angle： 0.5mrad;
Flux： 10^5 -10^7 phs/s










DIAMOND GEM-100L (10.6 μm)

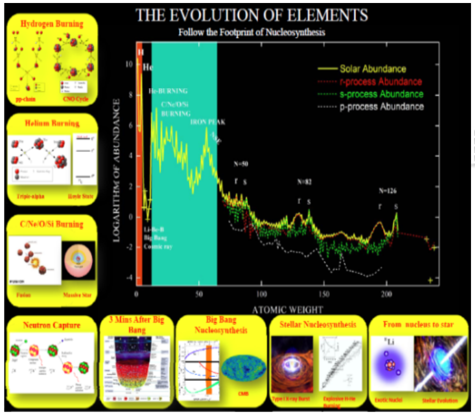
Liquid-Cooled RF-Excited OEM Industrial CO_2 Laser

Features
- Outstanding beam quality and stability
- Highly compact and lightweight, two-piece package
- All-metal seals for long life
- Low-cost OEM configuration
- Interchangeable laser heads and RF supplies
- Linear polarization
- Wide operating power range
- Fast rise/fall time
- Up to 100% duty cycle operation

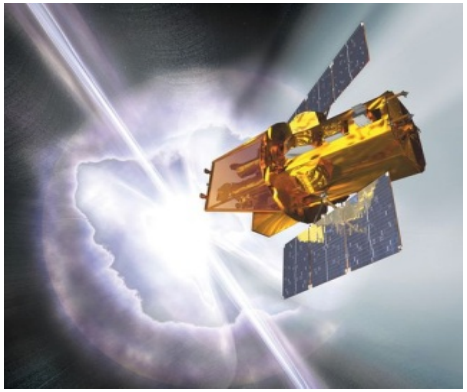
SLEGS for nuclear physics & applied physics

- Photo−nuclear physics:
  - Nuclear Astrophysics： nuclear reactions which have a critical impact on stellar evolution and nucleosynthesis of elements
  - Nuclear structure GDR and NRF, etc.
- Research on the anti-γ radiation properties of aerospace device and calibration for the X/γ detector equiped on aerospace device
- Nuclear waste transmutation research and nuclear safety,
- Gamma-ray imaging techniques (in particular: isotope imaging technology), etc.

Nuclear Astrophysics

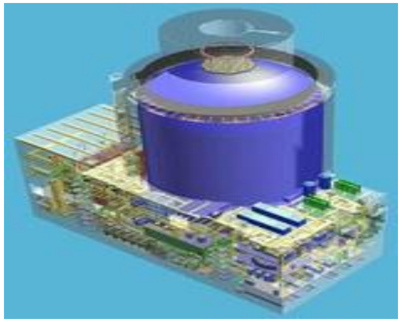


Space (radiation hardened)



Nuclear technology and data

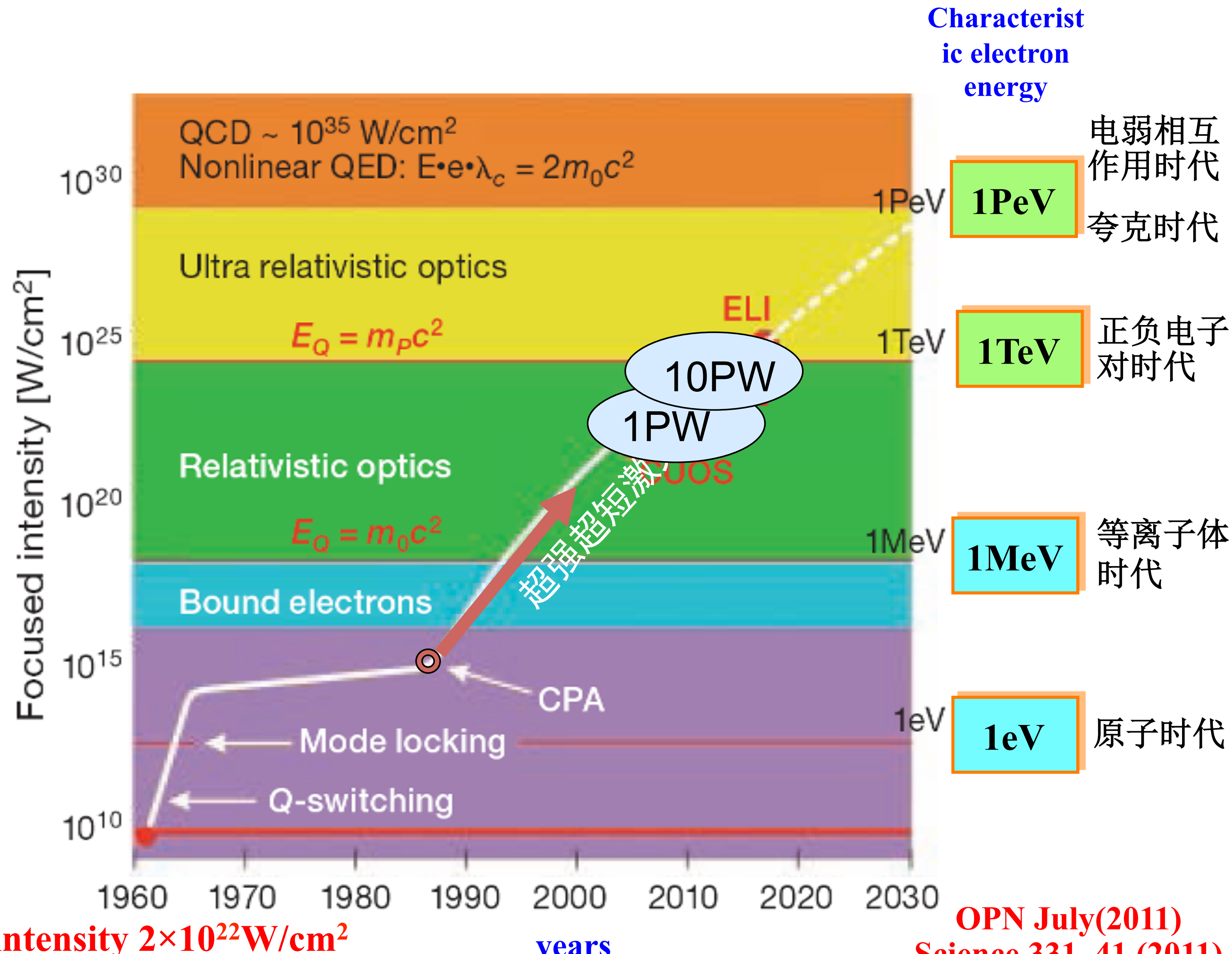
nuclear explosion



Nuclear reactor

Isotope Detection

Laser-matter interaction： super-short， super-intense pulse



Max. photon intensity 2×10^{22}W/cm^2

photon intensity of γ burst 10^{20}W/cm^2 *

OPN July(2011)

Science 331, 41 (2011)

* New Scientist， April 9, 2008

Shanghai Jiaotong Univ.

- Nuclear Theory Group

  Nuclear Sym Energy; nuclear structure etc

- Dark Matter Detect：

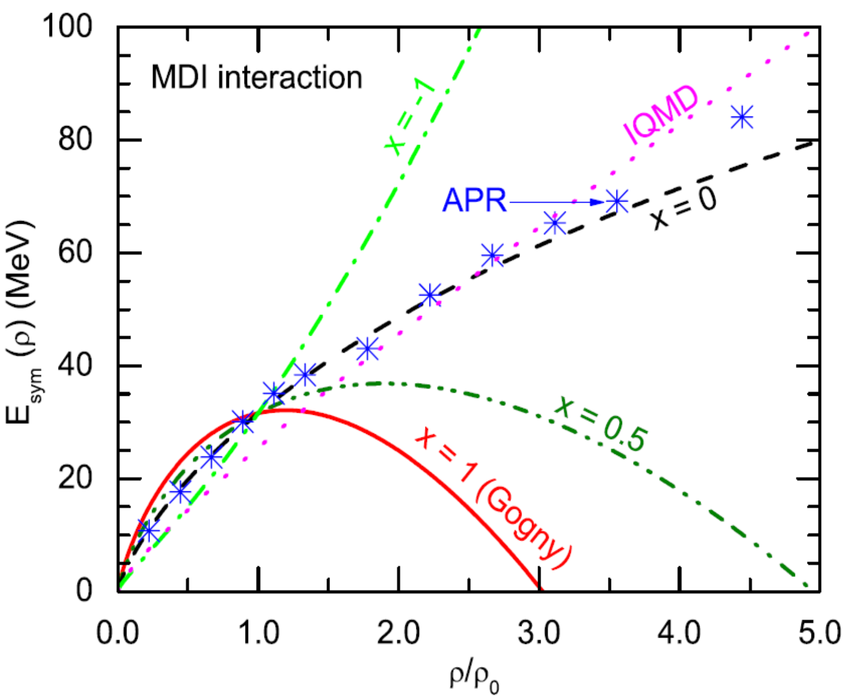
  PandaX (Liquid-Xe)@JPS Lab

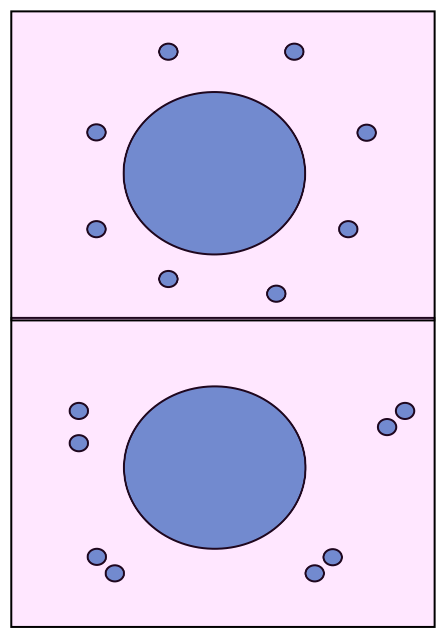
- Int. Coll. On High Energy Physics：

  ATLAS@LHC

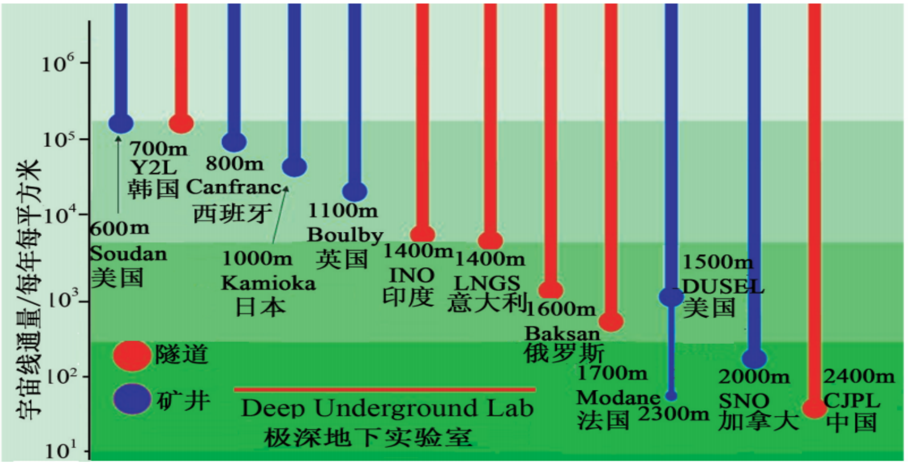
Nuclear theory

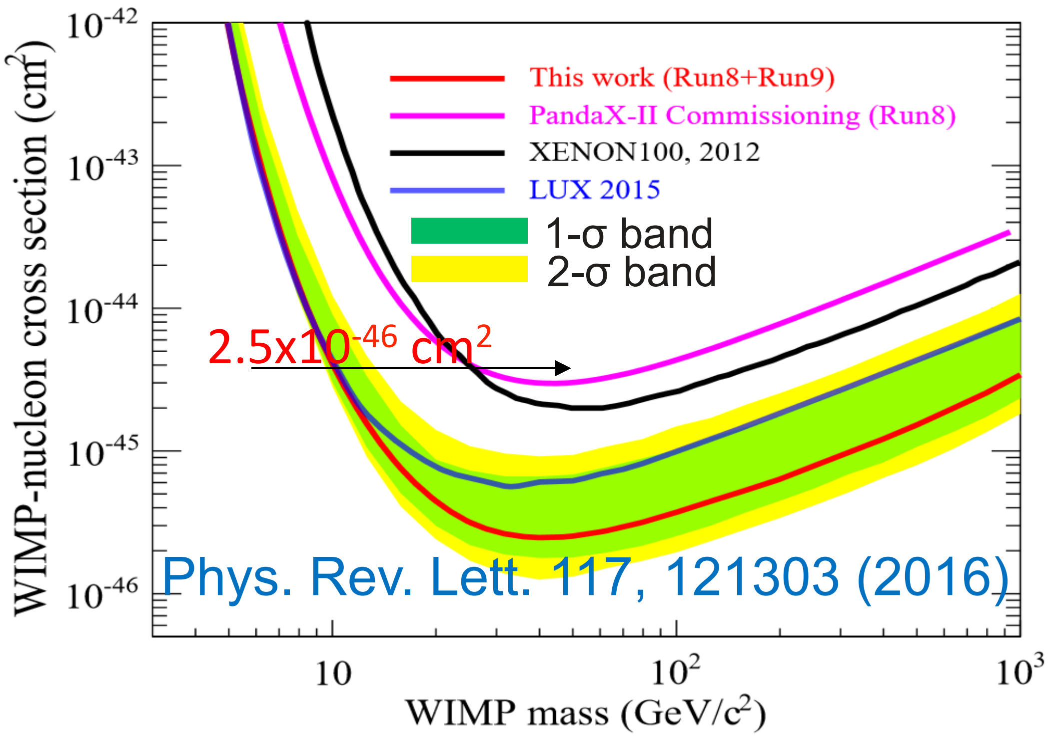
- Lie-wen Chen, Symmetry Energy
- Yu-min Zhao, nuclear pair
- Yang Sun, Shell models

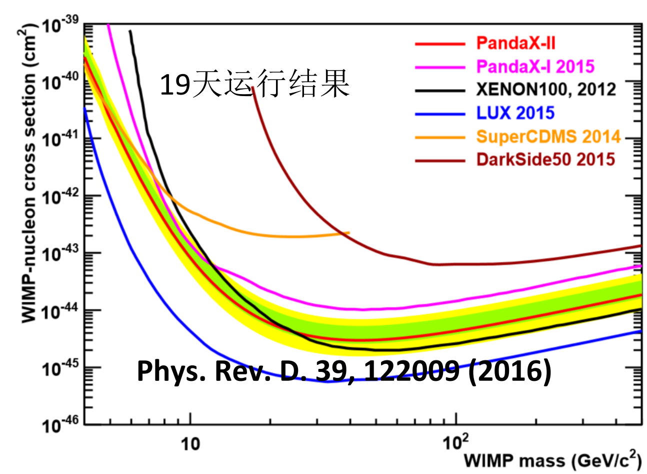




PandaX Recent results







Fudan Univ.

- **Theory** (Xuguang Huang & Zhenghua Li)**:**
  Nuclear Theory for Chiral effects at RHIC
  and three-body force (Xuguang Huang & Zhenghua Li)

- **Experiments** (Huanzhong Huang):

  Develop a QCD Physics Research Program →
  plan to join STAR Coll. & EIC

  Develop bolometer technology for a 0vbb Exp
  at China Jinping Underground Lab

Chiral effects in RHIC

Rep. Prog. Phys. **79** (2016) 076302 (27pp) doi:10.1088/0034-4885/79/7/076302

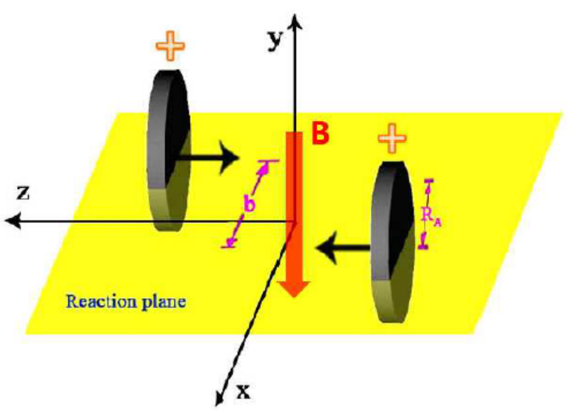
Review

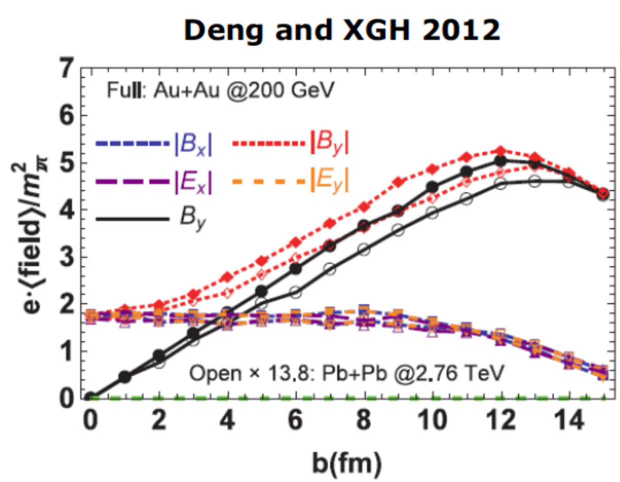
Electromagnetic fields and anomalous transports in heavy-ion collisions—a pedagogical review

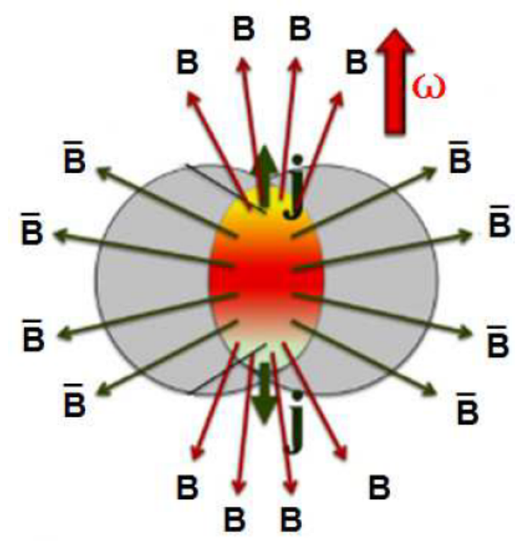
Xu-Guang Huang

Physics Department and Center for Particle Physics and Field Theory, Fudan University, Shanghai 200433, People's Republic of China

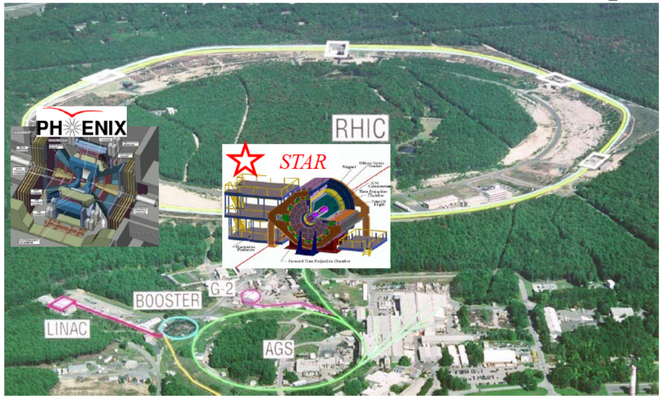
HICs generate not only hot QGP but also magnetic fields



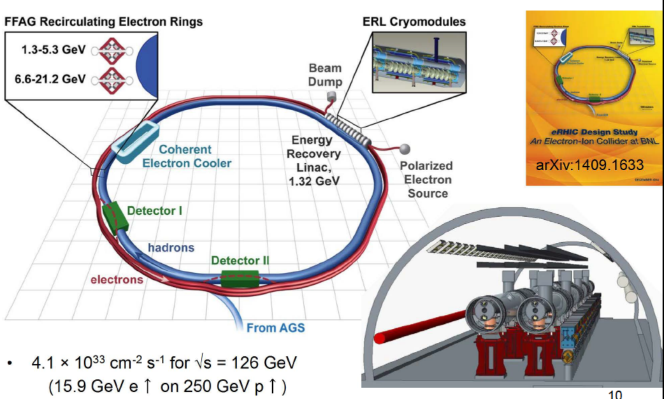




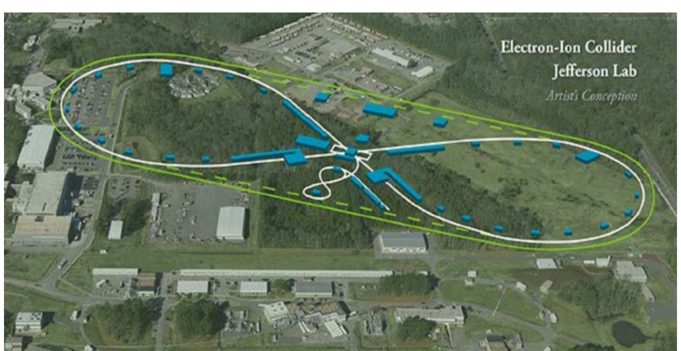
Experimental plans



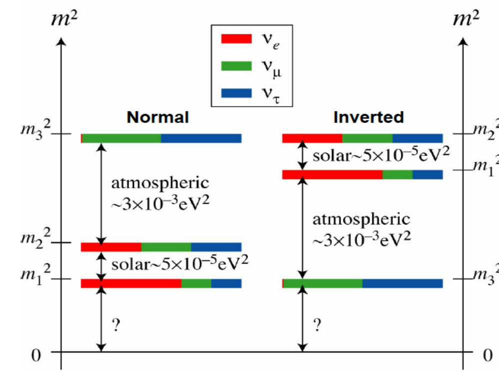
EIC at BNL: eRHIC



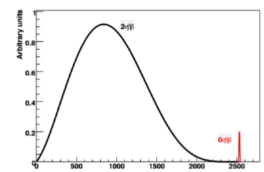
- 4.1×10^{33} cm^{-2} s^{-1} for $\sqrt{s}$ = 126 GeV (15.9 GeV e↑ on 250 GeV p↑)

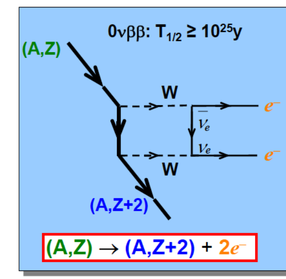


Neutrino Masses and Hierarchy



Dirac or Majorana Neutrinos?

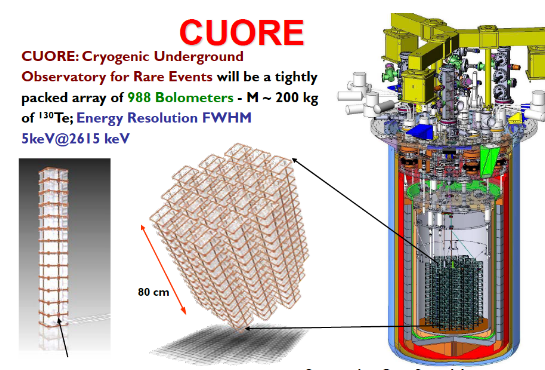




Majorana → neutrino = anti-neutrino
Lepton Number violation ! Leptogenesis for M-antiM asymmetry ! 16

CUORE

CUORE: Cryogenic Underground Observatory for Rare Events will be a tightly packed array of 988 Bolometers - M ~ 200 kg of ^{130}Te; Energy Resolution FWHM 5keV@2615 keV



19 CUORICINO-like towers with 13 planes of 4 crystals each

- Operated at Gran Sasso laboratory
- Special cryostat built w/ selected materials
- Cryogen-free dilution refrigerator
- Shielded by several lead shields

17

Nanjing Univ.

- Theory

  Nuclear structure (Z. Ren,   C. Xu)

  hadron physics (F. Wang, H. Zong, ...)

- International Coll.

  ATLAS （Shenjian Chen)

Univ. of Sci. & Tech. of China

- Theory
  RHIC physics (Qun Wang)

- Experimental
  RHIC-STAR, Dark Matter search, Symmetry

- Detectors & Nuclear Electronics
  STAR-ToF,   Muon Telescope Detector, …

Central China Normal Univ

- Experimental
  Int. Coll. :
  STAR@RHIC, ALICE@CERN, CBM@Fair
  (more than 10 faculties)

- Theory
  QCD & phenomenology
  (more than 10 faculties)

- Detectors
  Pixel , ALICE ITS upgrade, D-cal

Huzhou Univ.

- Nuclear theory:
  nuclear structure & reaction
  ~ 10 faculties

- Plan to do RHIC physics and Cold atom phys
  Fuqiang Wang

others

- Other nuclear theoretical peoples

  ECNU (Theory: hypernuclei, particle phys)

  Shanghai Univ. (Theory: RHIC theory)

  Tongji Univ. (Theory: Nucl Structure)

  Shanghai Eng. Univ. (Theory: Part. phys)

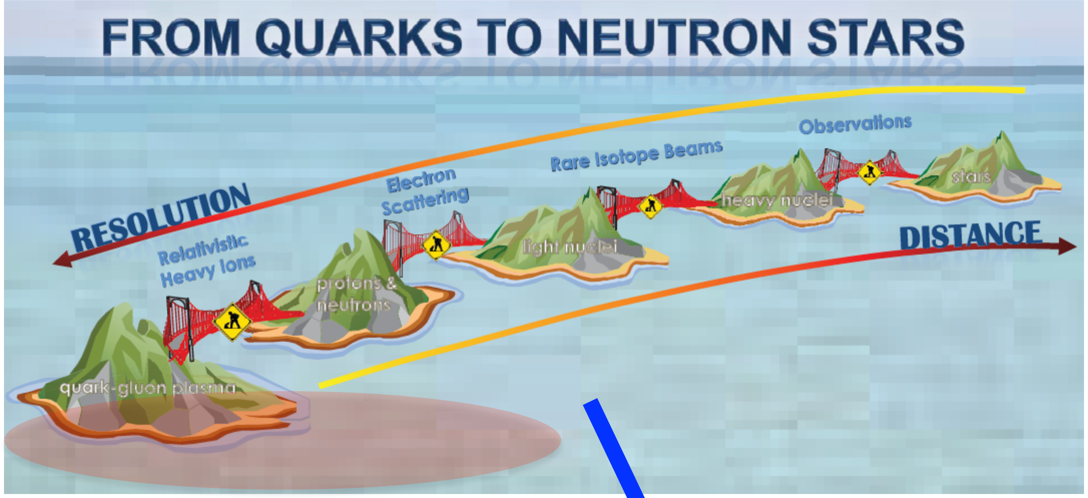
  ....

International Coll. on High Energy Nucl Phys.

--with STAR @ RHIC

-- with ALICE @ LHC

-- with J-LAB

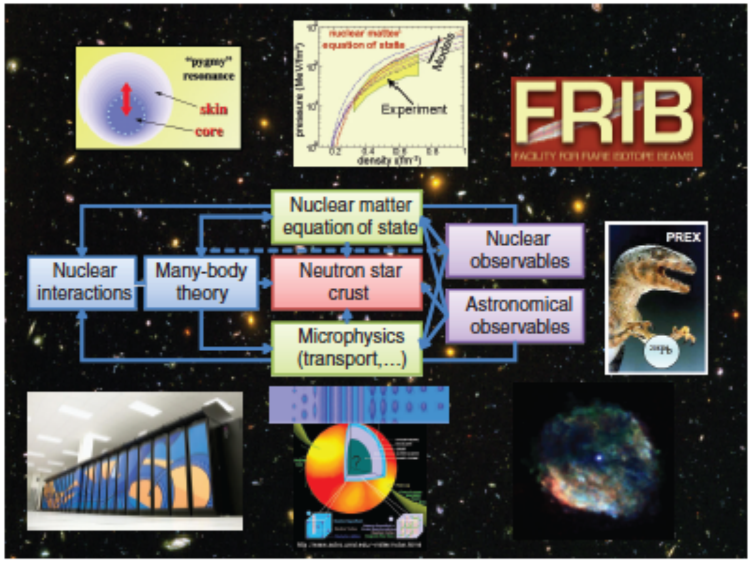


Institutions:

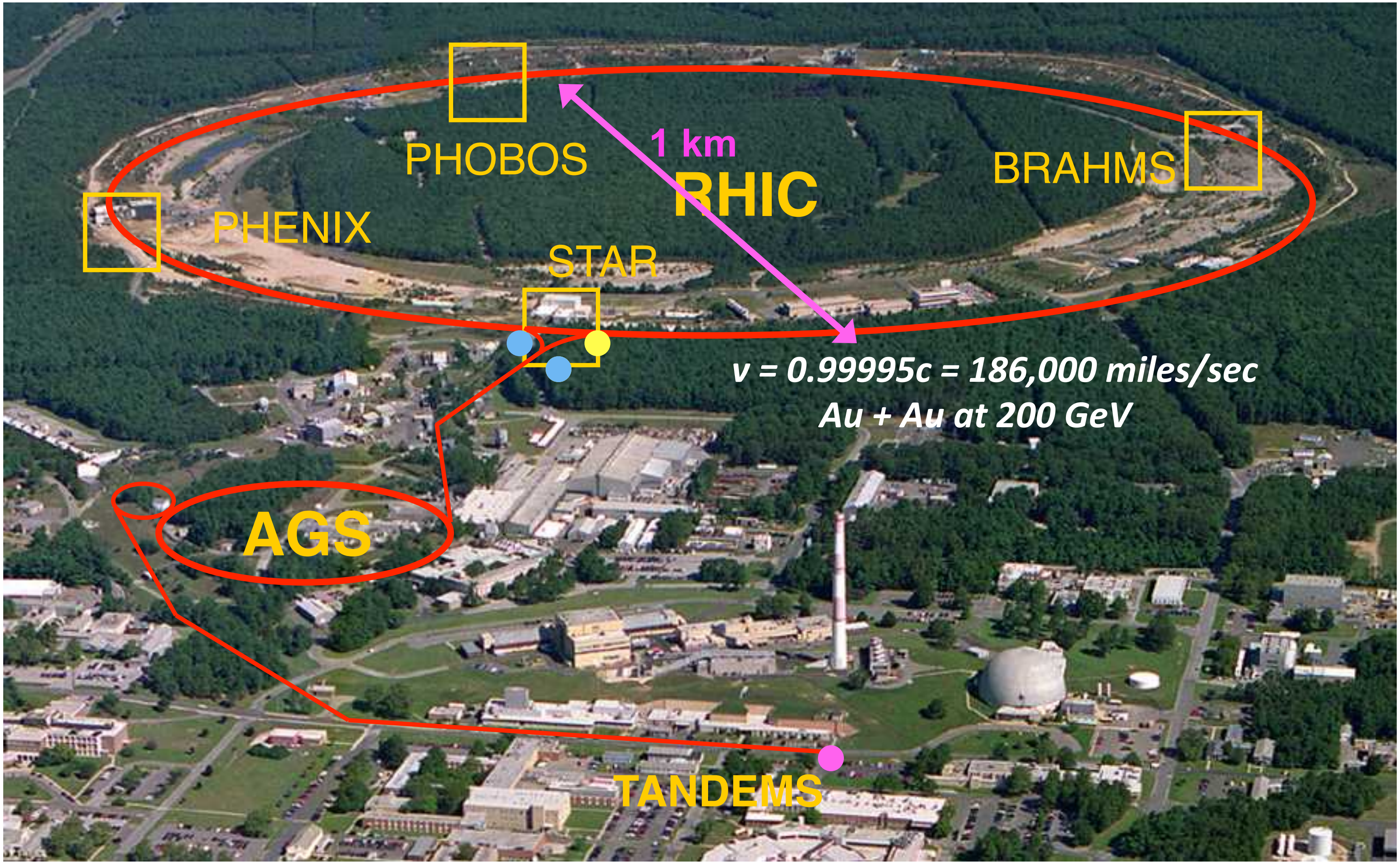
--RHIC-STAR（SINAP, USTC, TsingHua U., ECNU, IMP, SDU)）

--LHC-ALICE: ECNU, CIAE, SINAP, USTC

--J-lab: USTC, Lanzhou U etc.

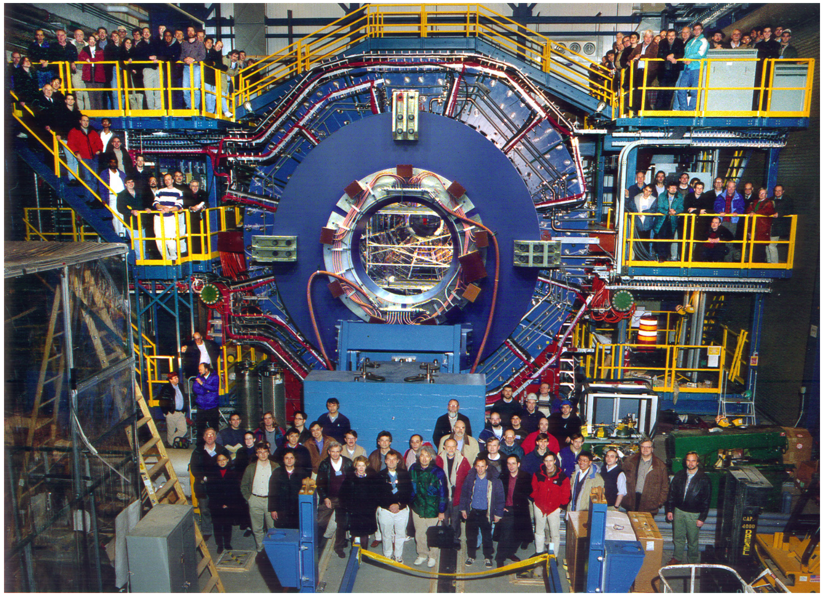


RHIC@ BNL



PHOBOS
1 km
RHIC
BRAHMS
PHENIX
STAR
v = 0.99995c = 186,000 miles/sec
Au + Au at 200 GeV
AGS
TANDEMS

The STAR Collaboration



Brazil: Universidade de Sao Paolo

China:

CCNU, IMP, Shandong U.

SINAP, Tsinghua, USTC

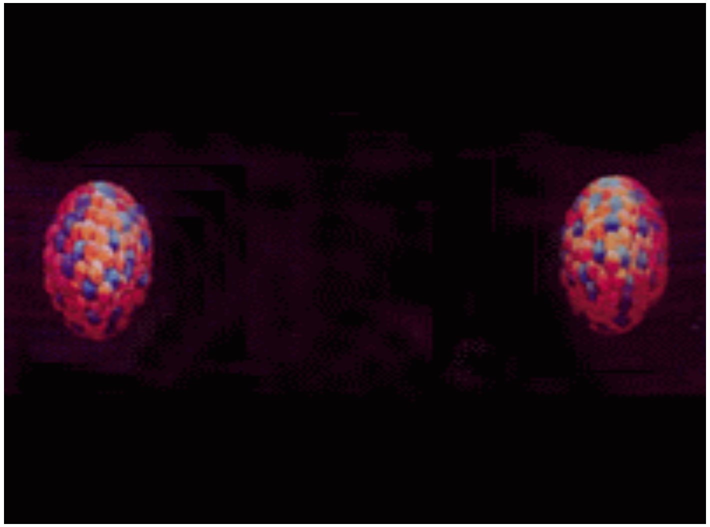
England: University of Birmingham

France: SUBATECH – Nantes

Institut de Recherches Subatomiques,Strasbourg

Germany: Max Planck Institute – Munich University of Frankfurt

India: Bhubaneswar, Kolkata, Mumbai , Panjab, Rajasthan



Poland: Warsaw University, Warsaw University of Technology

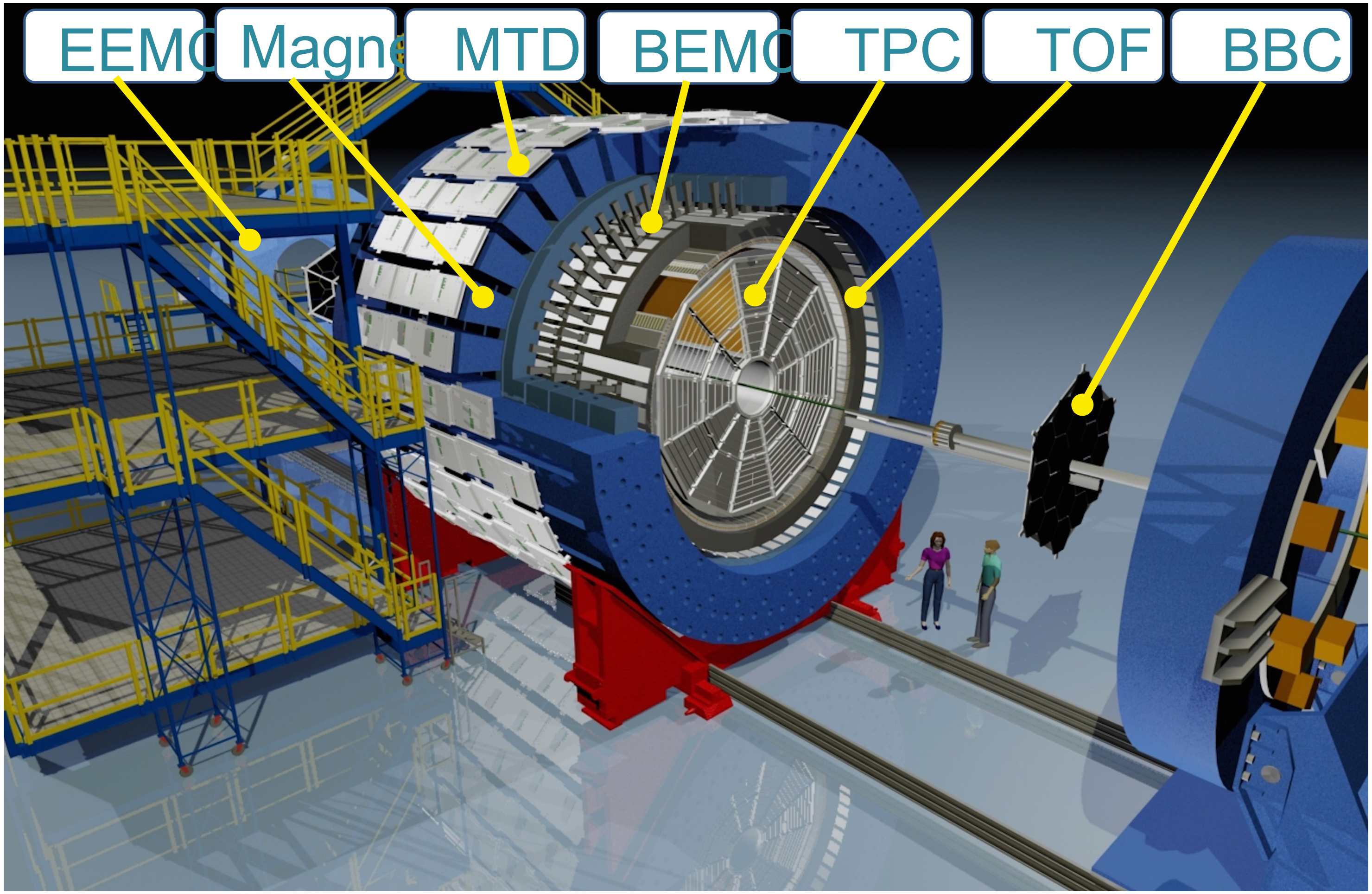
Russia: MEPHI – Moscow, LPP/LHE JINR–Dubna, IHEP -Protvino

U.S. Labs: Argonne, Berkeley, Brookhaven National Labs

U.S. Universities: Arkansas, UC Berkeley, UC Davis, UCLA, Carnegie Mellon, Creighton, Indiana, Kent State, MSU, CCNY, Ohio State, Penn State, Purdue,Rice, Texas A&M,

UT Austin, Washington, Wayne State, Yale

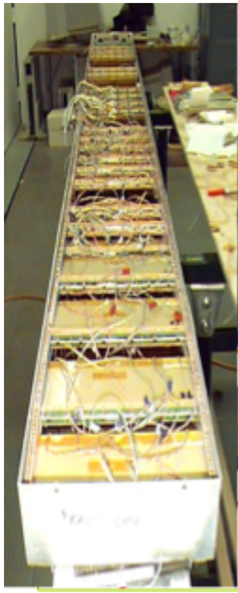
RHIC-STAR

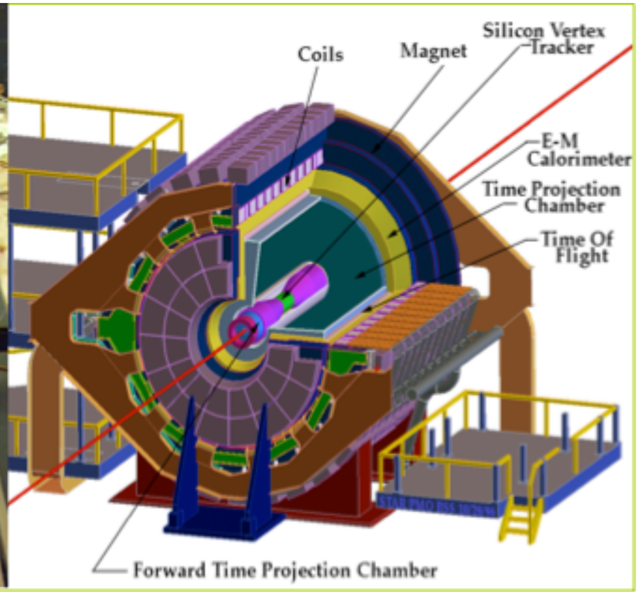


Full 2π coverage; Pseudorapidity coverage ~ ±1 unit

Detect R&D from China groups: TOF, MTD, iTPC, HLT

What Chinese contributes for STAR?   the TOF!





- Present STAR Spokesperson: Zhangbu Xu
- STAR-China groups: SINAP(CAS); USTC; CCNU; ThU; IMP (CAS); SDU;
- 2006-2009, China group contributed for a Full Time of Flight Detectors which are based on MRPC techniques for STAR
- Project Leader & Convenor : Yu-Gang Ma

STAR Large-Area Time-of Flight (TOF) Management Plan
Signature Page

STAR Collaboration approval:
Geary Eppley, Project Manager — date 1/4/2006
Timothy Hallman, STAR Spokesman — date 12/20/2005

Brookhaven National Lab approval:
Thomas Ludlam, BNL Project Oversight Manager — date 12/20/05
Samuel Aronson, BNL Assoc. Laboratory Director, HENP — date 12/22/05

DOE approval:
Michael Butler, Federal Project Director — date 12/21/05.
Jehanne Simon-Gillo, Program Manager — date 1/11/06.

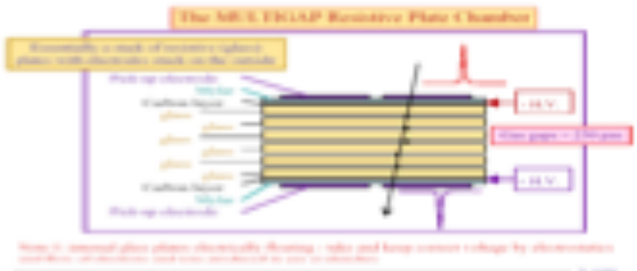
Concurrence of STAR TOF Collaborators in China:
Yu-Gang Ma, Chinese Academy of Sciences — date 12/27/05.

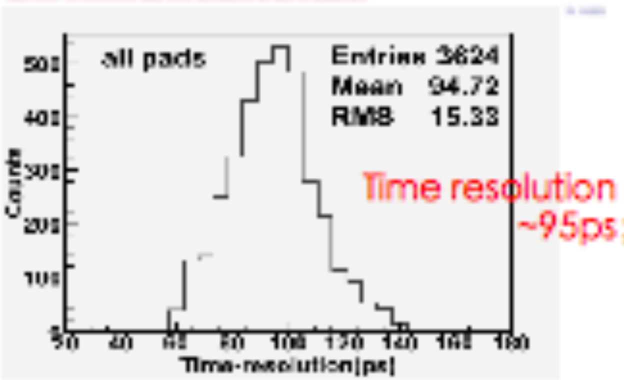
STAR

STAR-Time of Flight

USTC &Thsinghua U.

STAR-TOF consists of 4032 MRPC modules, it improves the PID at higher Pt, and extend STAR physics capibility much! Chinese STAR Team contributed on the hardware construction





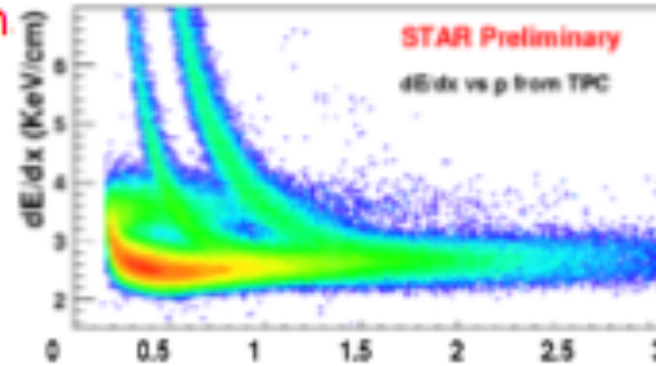
MRPC module

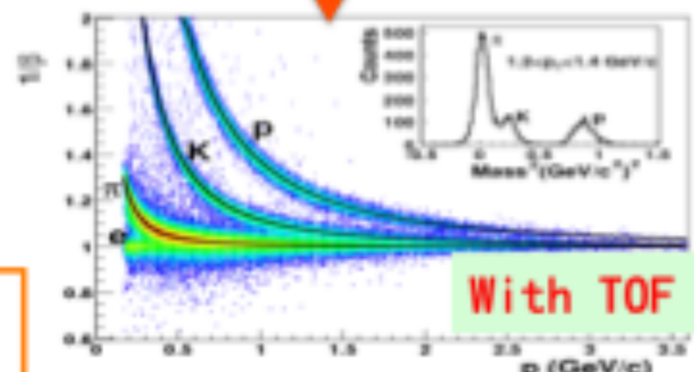
↓

MRPC quality control and mass production

↓

Barrel TOF: 4032 MRPC modules

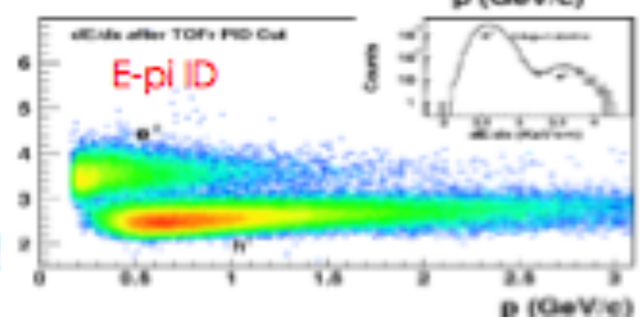




Before TOF, **After TOF**

(π, K)ID~0.6 → ~1.6 GeV/c

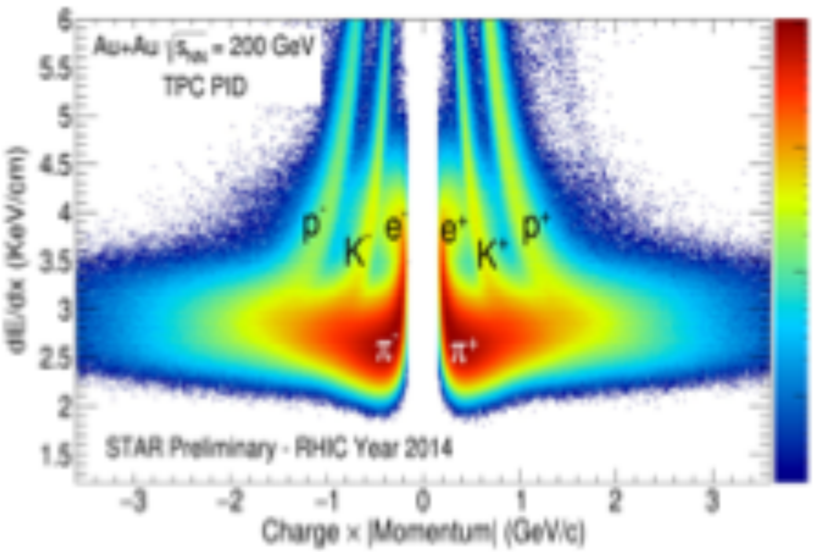
(π, K)-p ID~1.2 → 3 GeV/c.



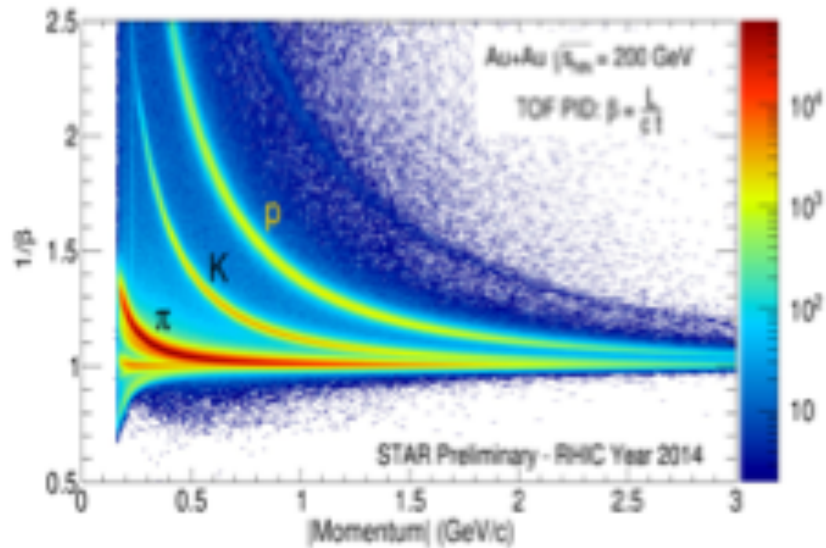
The 1st large-scale TOF runs in HI Collider !

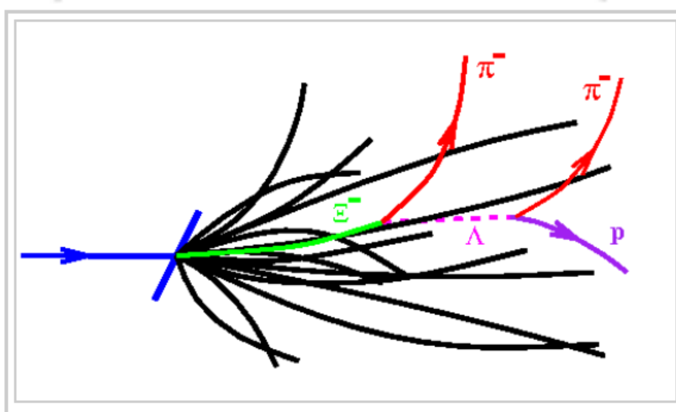
Particle Identification

Time Projection Chamber:
Tracking, PID (dE/dx)



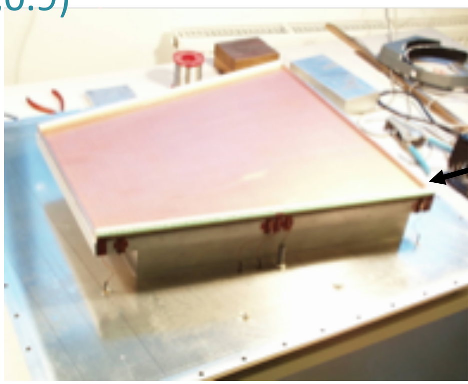
Time Of Flight detector:
PID (1/β)

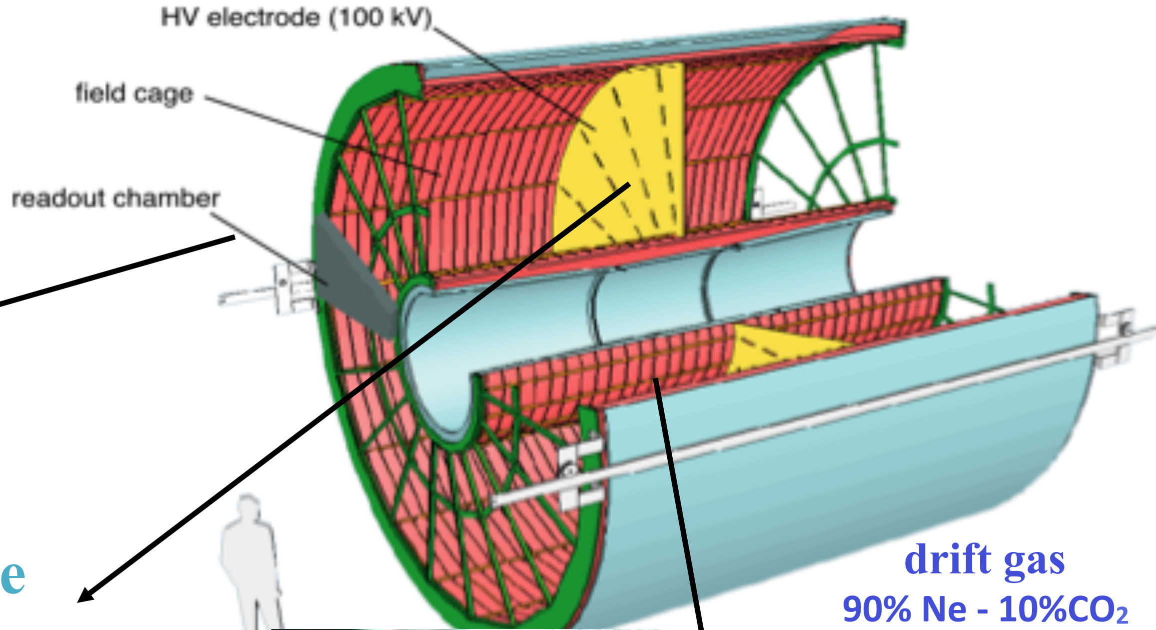




Time Projection Chamber

- largest ever: 88 m^3
- 570k readout channels @ 2000
  for tracking and PID via dE/dx
  (-0.9,0.9)

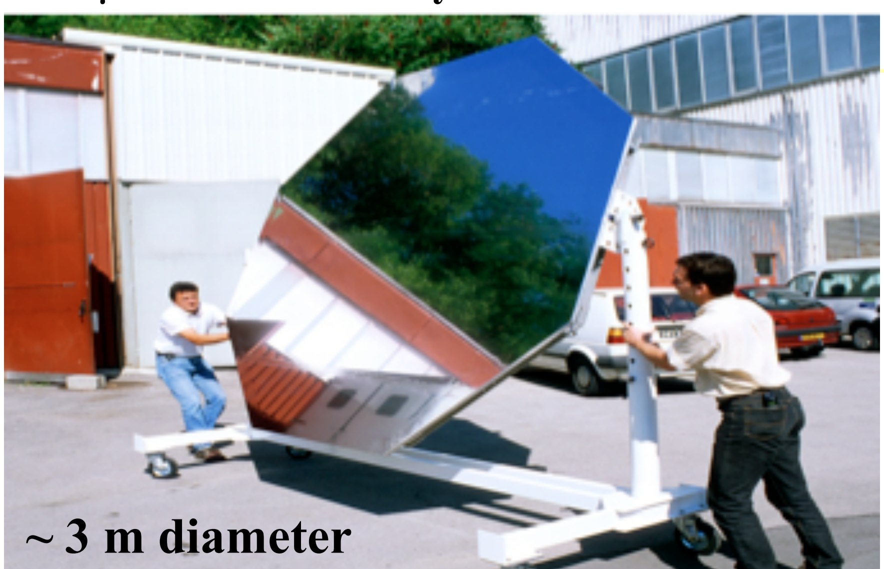




drift gas
90% Ne - 10%CO_2

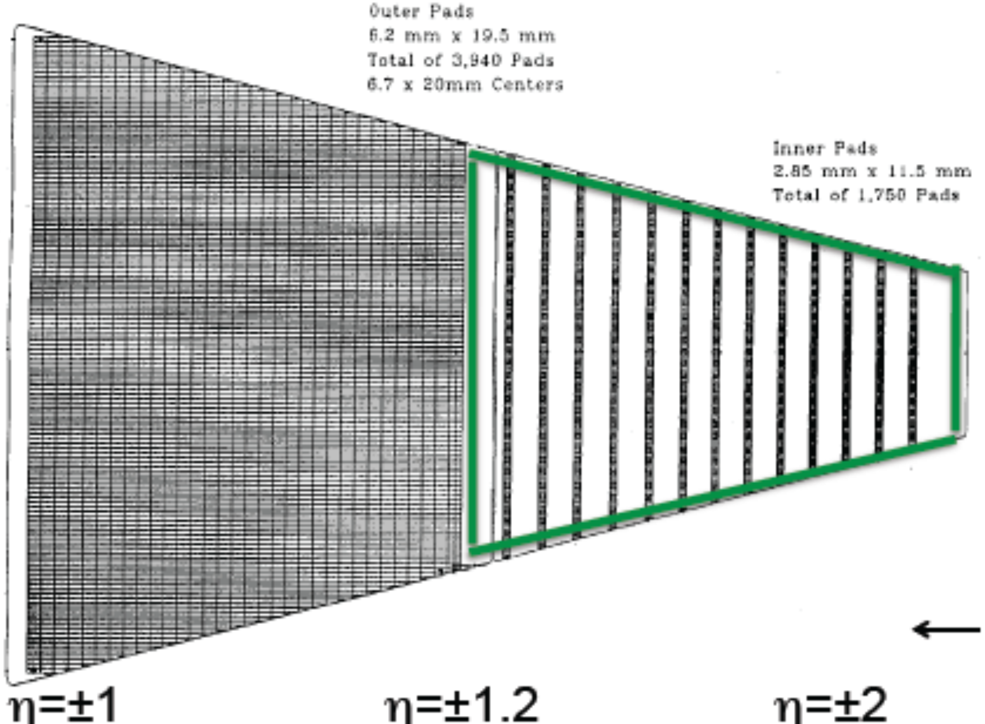
Central Electrode Prototype

25 µm aluminized Mylar on Al frame



TPC Inner Sector Upgrade (iTPC)

- Staggered readout
  - Only 13 maximum possible points
    - Issues in Tracking: recognition and resolution
  - Only reads ~20% of possible gas path length
    - Inner sectors essentially not used in dE/dx
- Essentially limits TPC effective acceptance to |η|<1



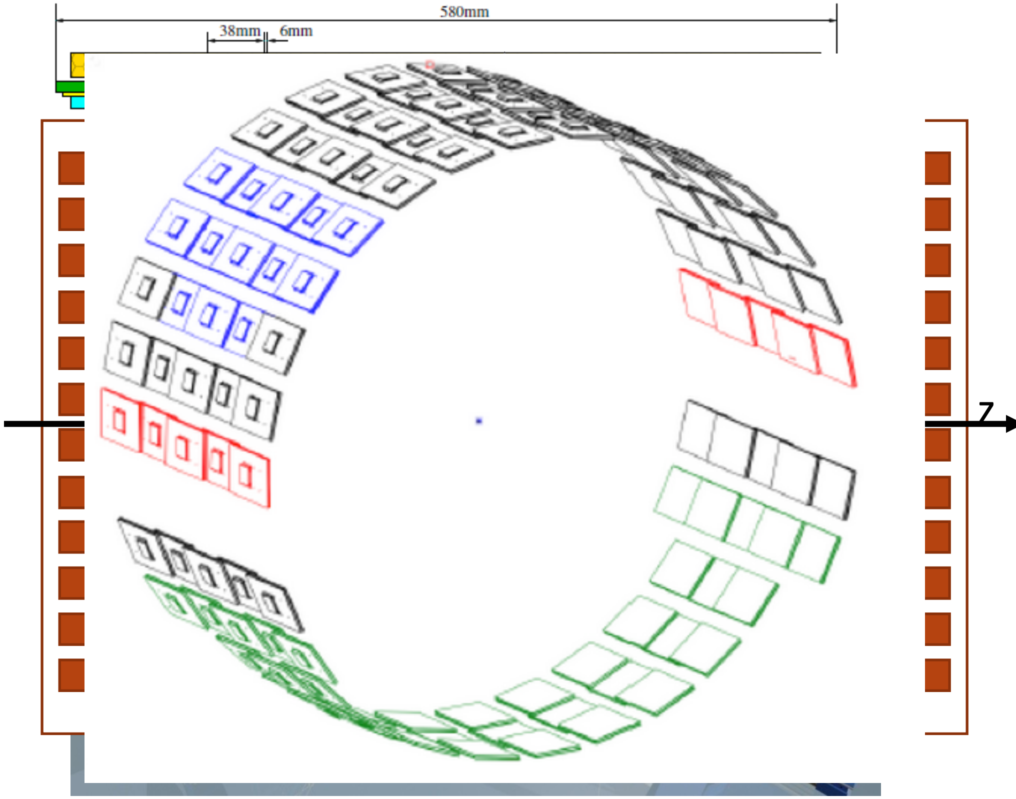
Inner TPC Upgrade:

1. MWPC (SDU/SINAP)
   ATLAS sTGC
   Chinese 973 project
2. Mechanics (LBL/BNL)
   Eric Anderson (PI)
3. Electronics (BNL/ALICE)
4. Complete in 2017

STAR

Muon Telescope Detector (MTD)

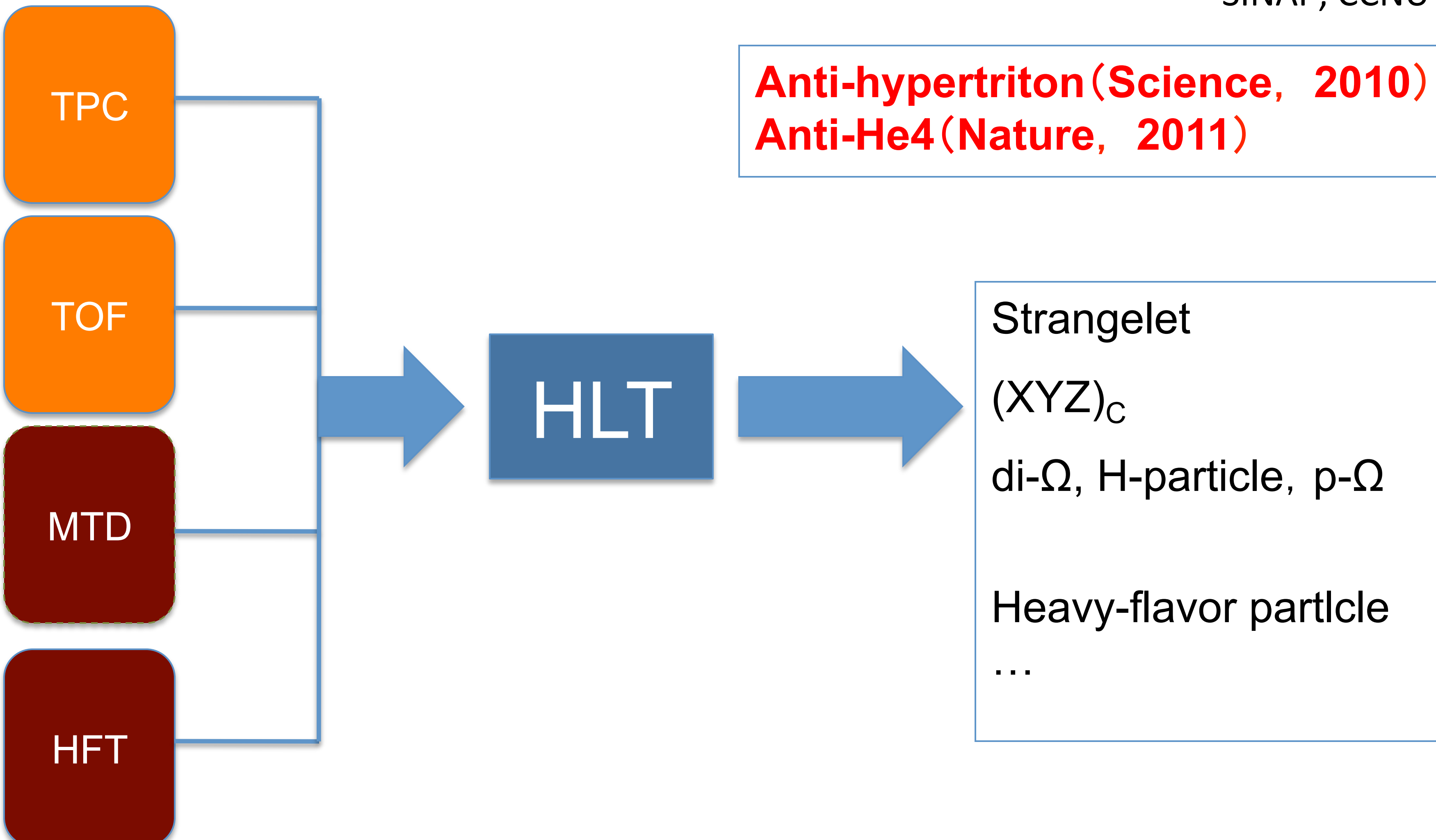
- Installed on the outside of STAR magnet
- Based on Multi-gap Resistive Plate Chamber (MRPC)
- 30 backlegs
- 3 or 5 modules in a backleg
- 12 double end readout strips in a module
- z: along strips and backlegs
- y: perpendicular to strips and backlegs
- 30 backlegs, 122 modules, 1464 readout strips, 2928 readout channels
- Be fully operational from 2014



STAR-High Level Trigger (HLT) upgrade

SINAP, CCNU

Anti-hypertriton（Science，2010）
Anti-He4（Nature，2011）



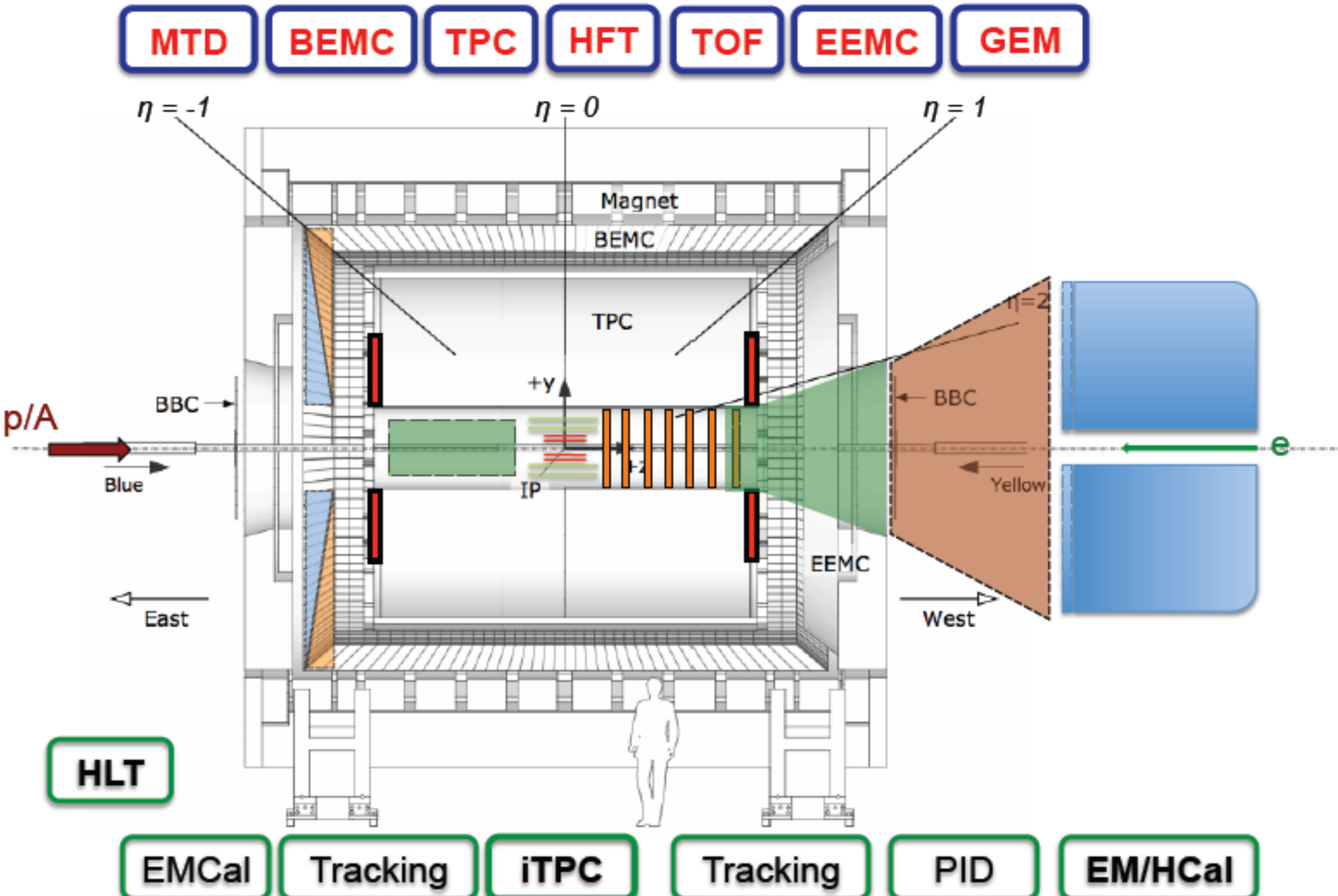
After STAR-HFT、MTD, more physics opportunites at STR 。HLT upgrade will improve the online reconstruction speed and then perform emergent physics project asap.

UPS Unpacking

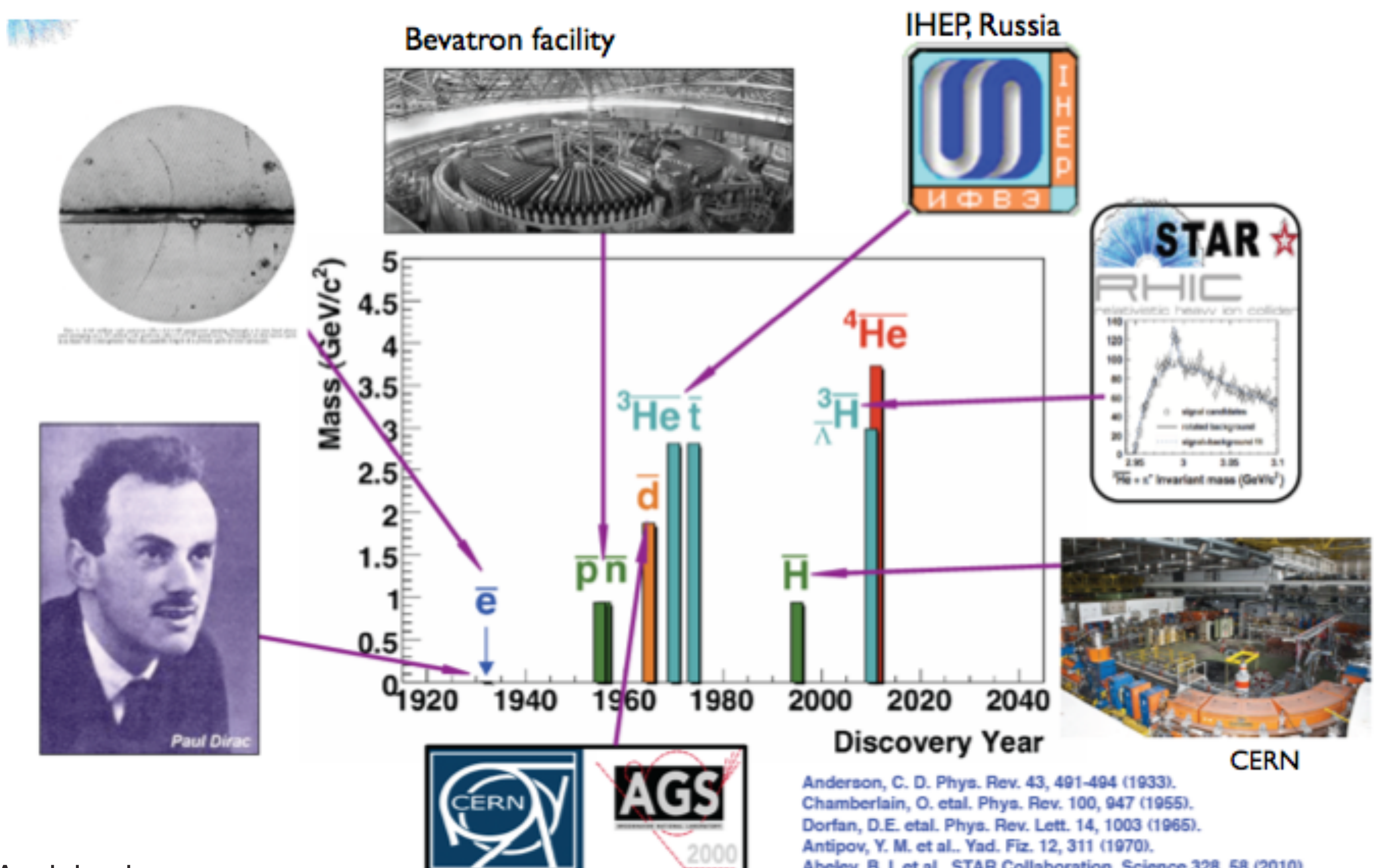
Integration Completed

Installation

STAR Forward Upgrade Plan (~2018)



History of antimatter particles

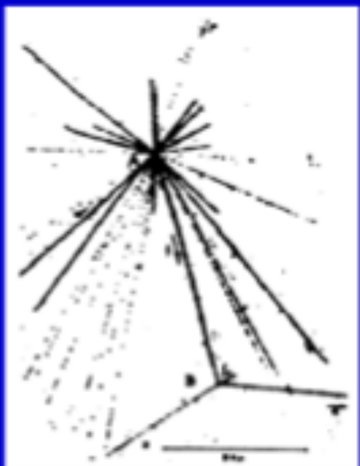


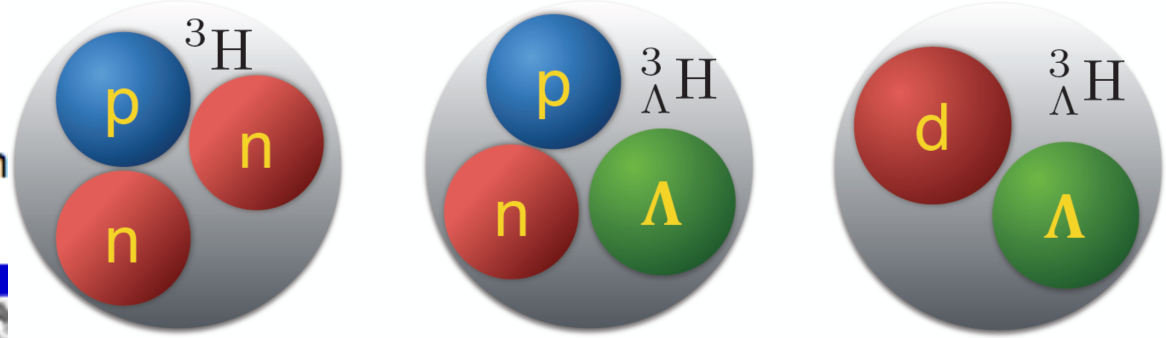
Anderson, C. D. Phys. Rev. 43, 491-494 (1933).
Chamberlain, O. etal. Phys. Rev. 100, 947 (1955).
Dorfan, D.E. etal. Phys. Rev. Lett. 14, 1003 (1965).
Antipov, Y. M. et al.. Yad. Fiz. 12, 311 (1970).
Abelev, B. I. et al., STAR Collaboration. Science 328, 58 (2010).
Abelev, B. I. et al., STAR Collaboration. Nature 473, 353 (2011).
Andresen. et al., The ALPHA Collaboration. Nature Physics 7, 558 (2

A minireview:
Y. G. Ma, J. Chen, L. Xue, Front. Phys., 2012, 7(6): 637–646

Hypernucleus

Nucleus which contains at least one h
in addition to nucleons.





The first hypernucleus was discovered by Danysz and Pniewski in 1952. It was formed in a cosmic ray interaction in a balloon-flown emulsion plate.

M. Danysz and J. Pniewski, Phil. Mag. 44 (1953) 348

No one has ever observed
any antihypernucleus before 2010

Hypernuclei of lowest A

$$^{3}_{\Lambda}H(n+p+\Lambda)$$

$$^{3}_{\bar{\Lambda}}\overline{H}(\bar{n}+\bar{p}+\overline{\Lambda})$$

- Y-N interaction: a good window to understand the baryon potential
- Binding energy and lifetime are very sensitive to Y-N interactions
- Hypertriton: ΔB=130±50 KeV; r~10fm
- Production rate via coalescence at RHIC depends on overlapping wave functions of **n+p+**Λ in final state
- Important first step for searching for other exotic hypernuclei (double-Λ)

Data-set and track selection

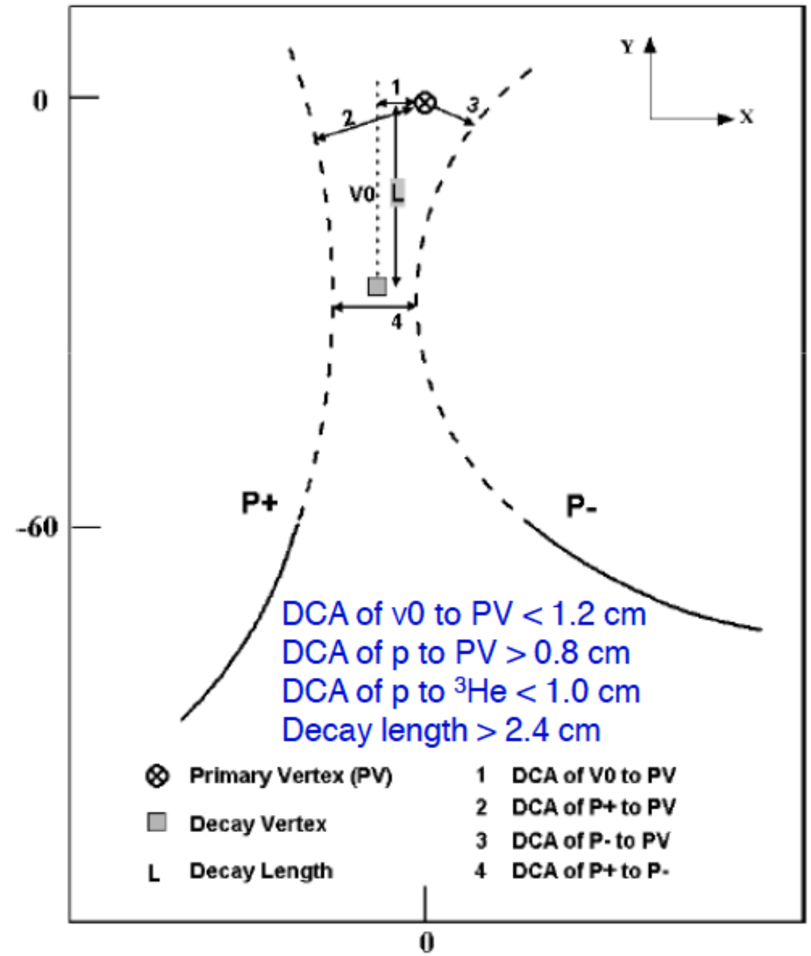
$^{3}_{\Lambda}H$ mesonic decay, m=2.991 GeV, B.R. 0.25;

$$^{3}_{\overline{\Lambda}}\overline{H} \rightarrow {}^{3}\overline{He} + \pi^{+}$$

$$^{3}_{\Lambda}H \rightarrow {}^{3}He + \pi^{-}$$

- Data-set used, Au+Au 200 GeV
  - ✓~67M Run7 MB,
  - ✓~23M Run4 central,
  - ✓~22M Run4 MB,
  - ✓|VZ| < 30cm
- Track quality cuts, global track
  - ✓nFitsPts > 25, nFitsPts/Max > 0.52
  - ✓nHitsdEdx > 15
  - ✓P_t > 0.20, |eta| < 1.0
  - ✓Pion n-sigma (-2.0, 2.0)

Secondary vertex finding technique



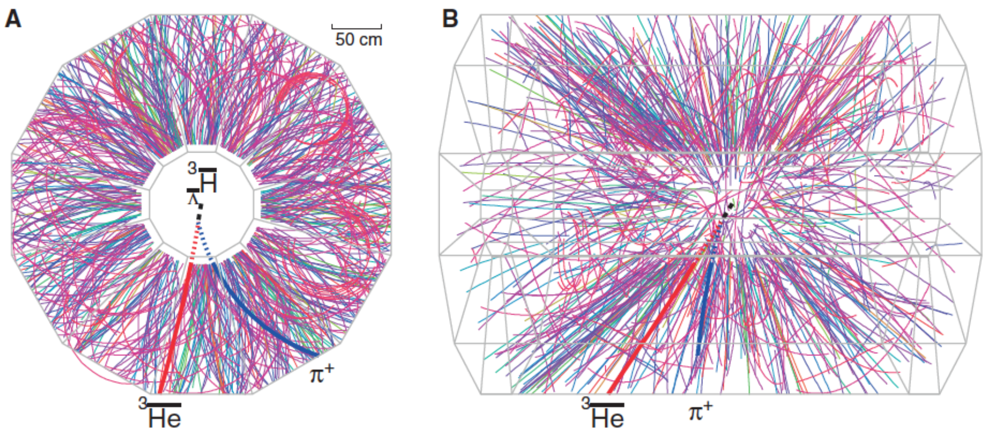
DCA of v0 to PV < 1.2 cm
DCA of p to PV > 0.8 cm
DCA of p to ^{3}He < 1.0 cm
Decay length > 2.4 cm

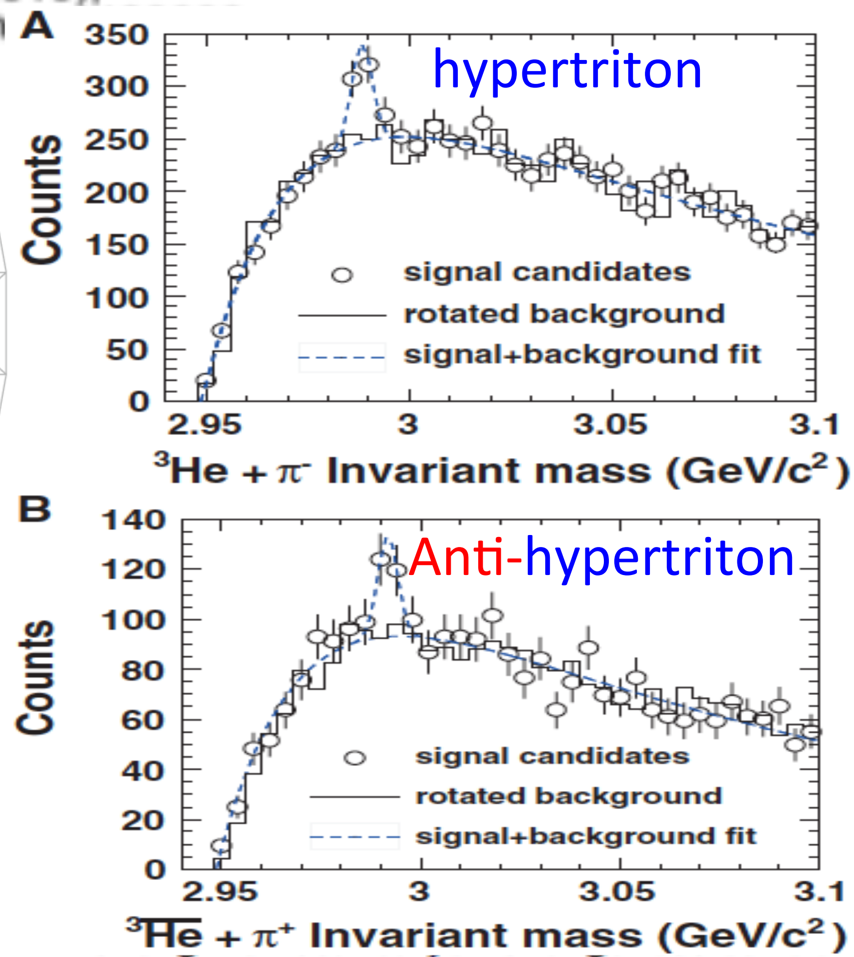
The anti-hypertriton observation

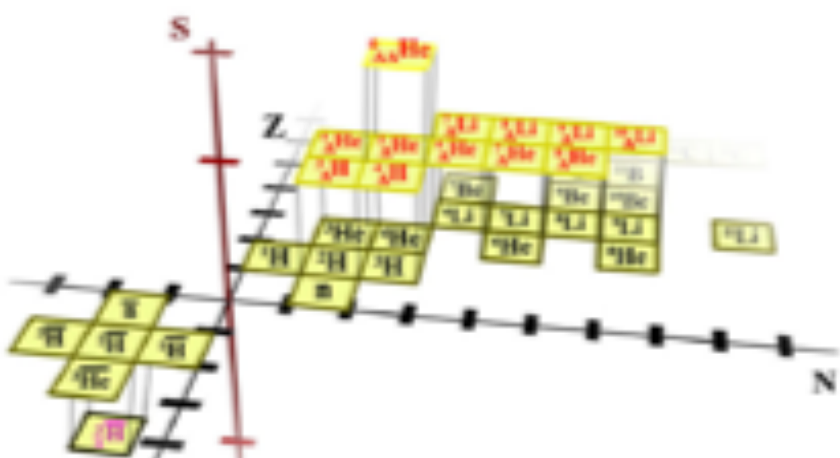
Jinhui Chen (SINAP), APS G. E. Valley Prize, 2012

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

Principal authors: SINAP etc

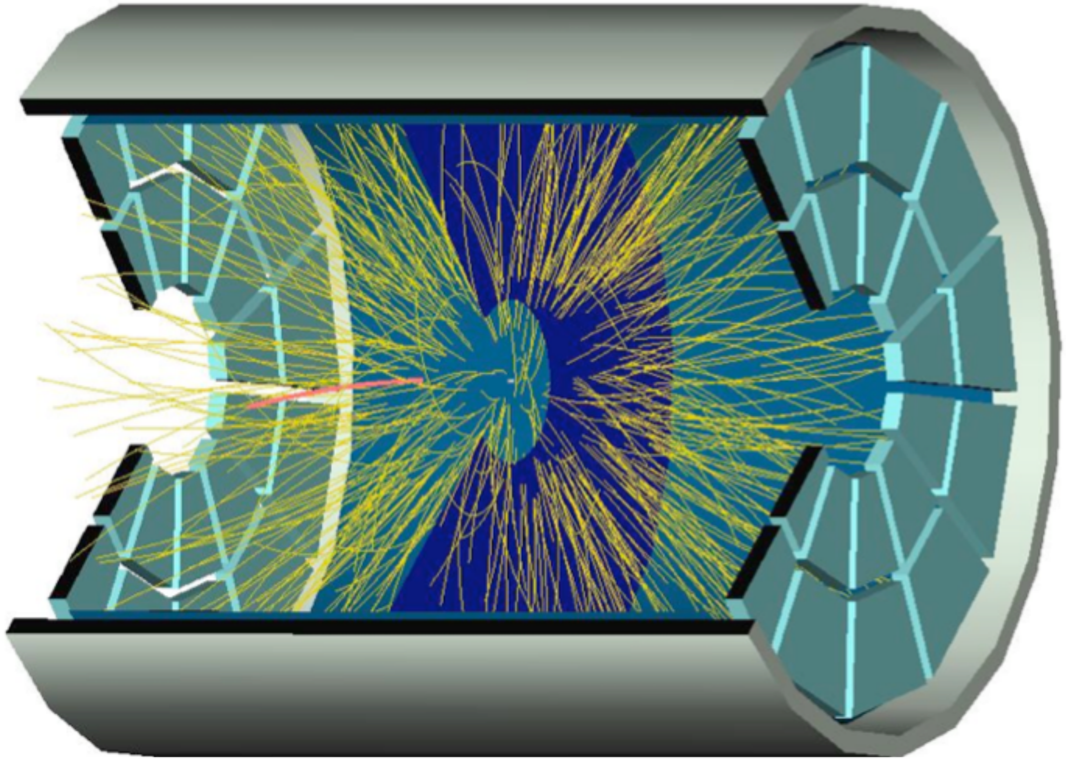


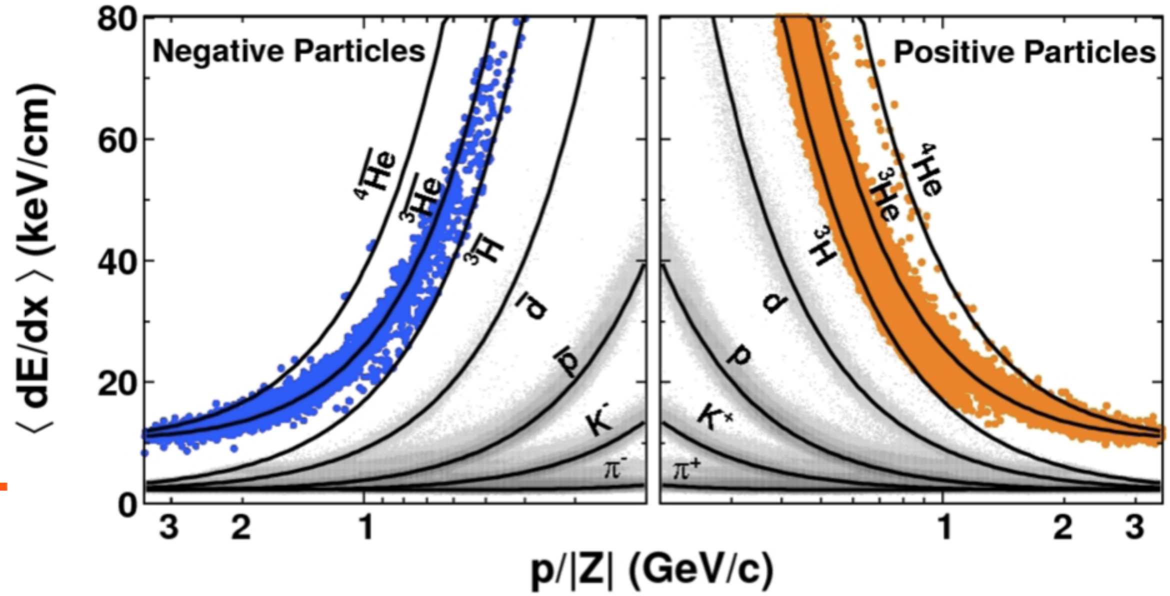




STAR Col. Science 328 (2010) 58-62

experimental probe for QCD phase transition.
S. Zhang et al., *Phys. Letts. B 684 (2010) 224*

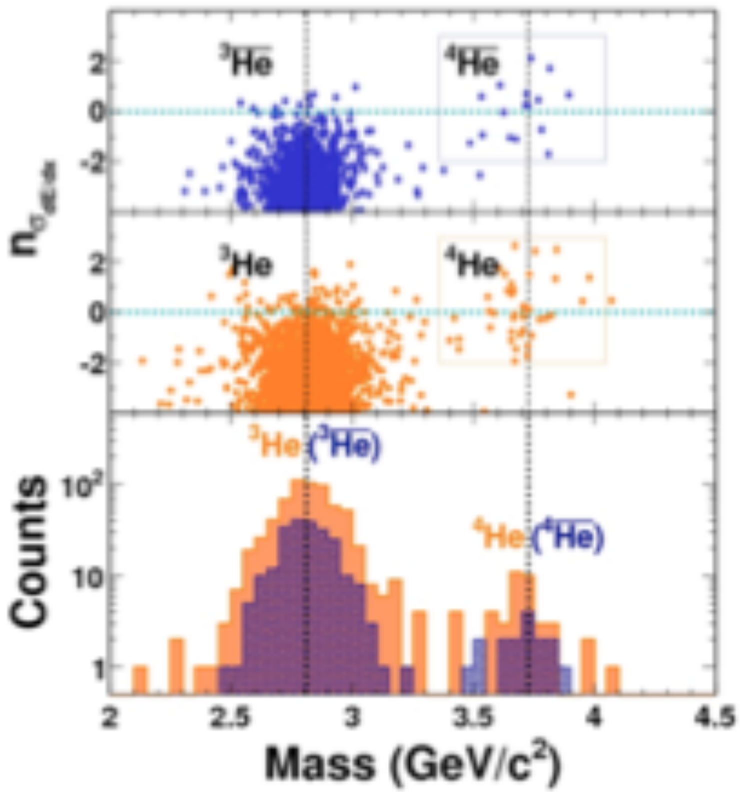



Negative Particles
Positive Particles
⟨ dE/dx ⟩ (keV/cm)
p/|Z| (GeV/c)
0
20
40
60
80
3
2
1
1
2
3
$^4\overline{He}$
$^3\overline{He}$
$^3\overline{H}$
$\bar{d}$
$\bar{p}$
K^-
π^-
^4He
^3He
^3H
d
p
K^+
π^+

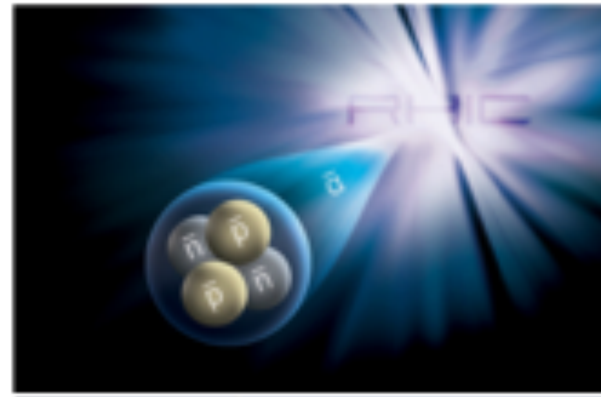
Observation of the anti-helium4

Observation of the antimatter helium-4 nucleus

The STAR Collaboration*



Mass ID with TOF



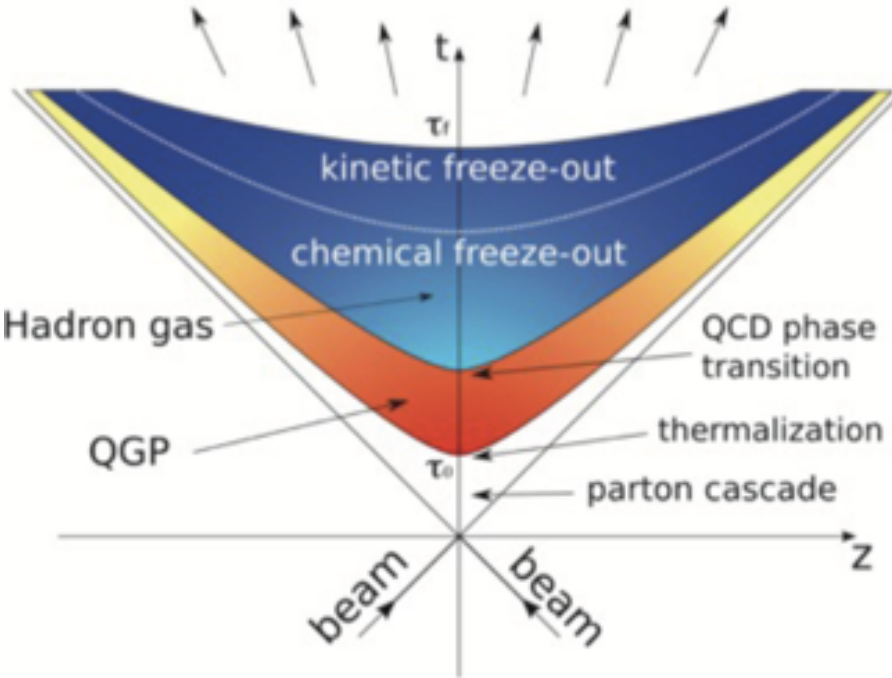
★ 18 anti-helium4, the heaviest antinucleus ever detected, were identified in STAR data

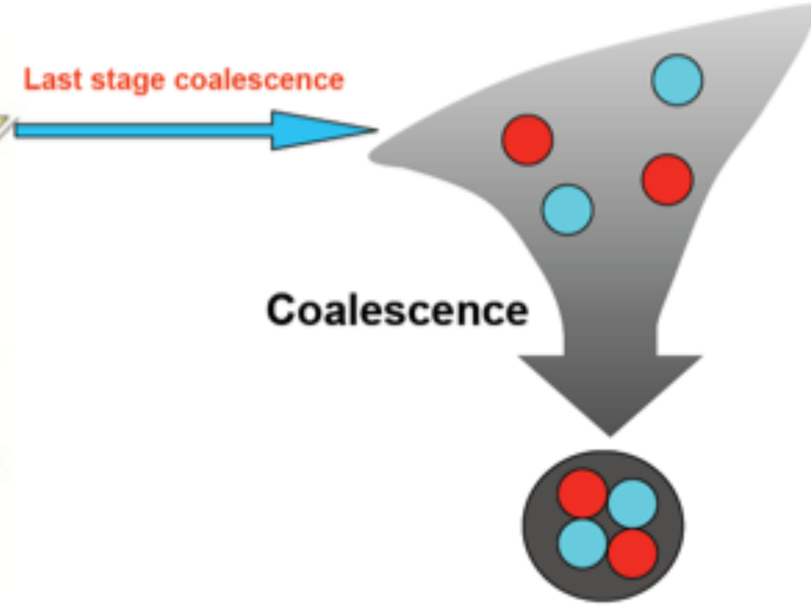
STAR Col.: *Nature 473 (2011) 353*

Liang Xue (SINAP), Quark Matter 2011 talk; PhD Thesis@2013

How to understand the production of anti-nuclei @ RHIC：coalescence

Production mechanism





$$E_A \frac{d^3N_A}{d^3p_A} \propto B_A(E_p \frac{d^3N_p}{d^3p_p})^A$$

The formation of light anti(nuclei), anti (hypernuclei) by coalescence occurred at the last stage of heavy ion collisions, when the system is already reached its kinetic freeze-out temperature.

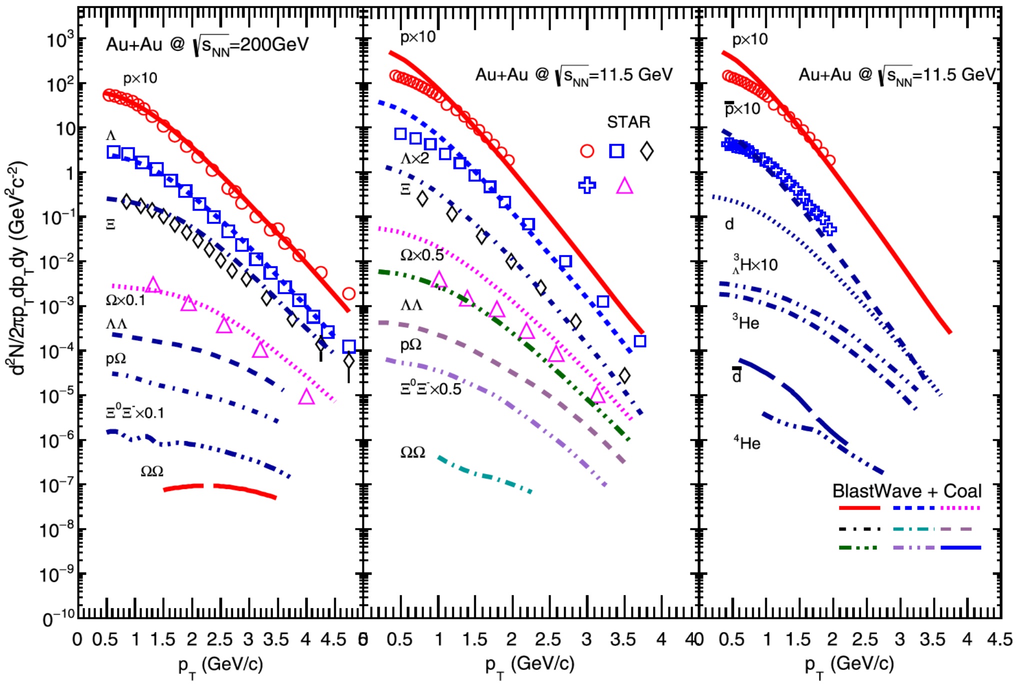
Sato, H. & Yazaki, K. Phys. Lett. B 98, 153-157 (1981)
Butler, S. T. & Perarson, C. A. Phys. Rev. Lett. 7, 69-71 (1961)
B. I. Abelev et al. (Star Collaboration) arXiv 0909.0566v1

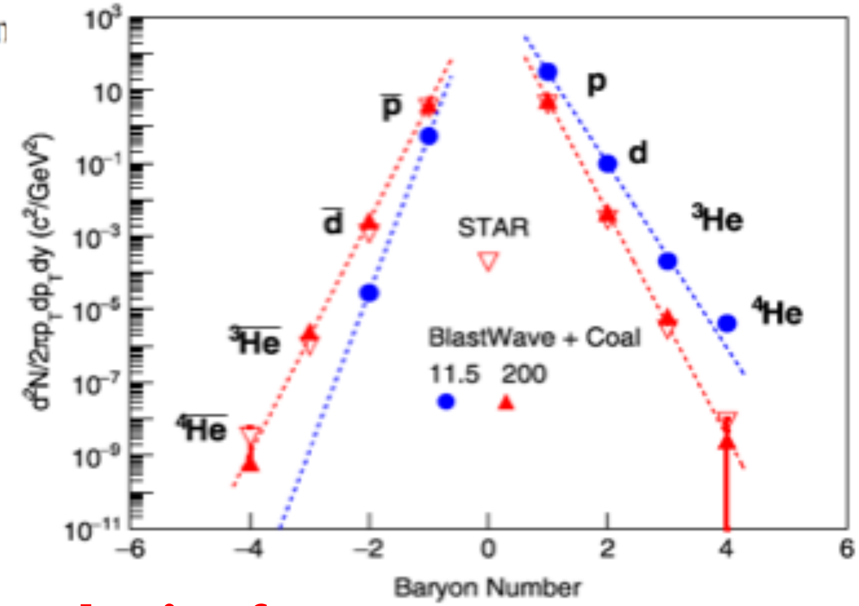
Antimatter aSymmetry at different energies

Production of multistrange hadrons, light nuclei and hypertriton central Au+Au collisions at $\sqrt{s_{NN}} = 11.5$ and 200 GeV

N. Shah *, Y.G. Ma, J.H. Chen, S. Zhang
Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China

Physics Letters B 754 (2016) 6–10





In hydrodynamic blast-wave model +coalescence model:
L. Xue, YGM et al., PRC 85,064912 (2013);
N. Saha, YGM et al., PLB 754, 6 (2016)

reduction factors:

1 more nucleon: 1.2×10^3
1 more antinucleon: 1.5×10^3 @ 200GeV
1 more nucleon: 0.33×10^3
1 more antinucleon: 1.95×10^4 @ 11.5GeV

The difference in reduction factor between matter and antimatter shows a significant energy (temperature) dependence.

Nucleon number scaling of Elliptic flow @ STAR data also support Coalescence mechanism for light nuclei production!

(Nucleon–number scaling of Elliptic flow was 1st proposed by YGM et al.)

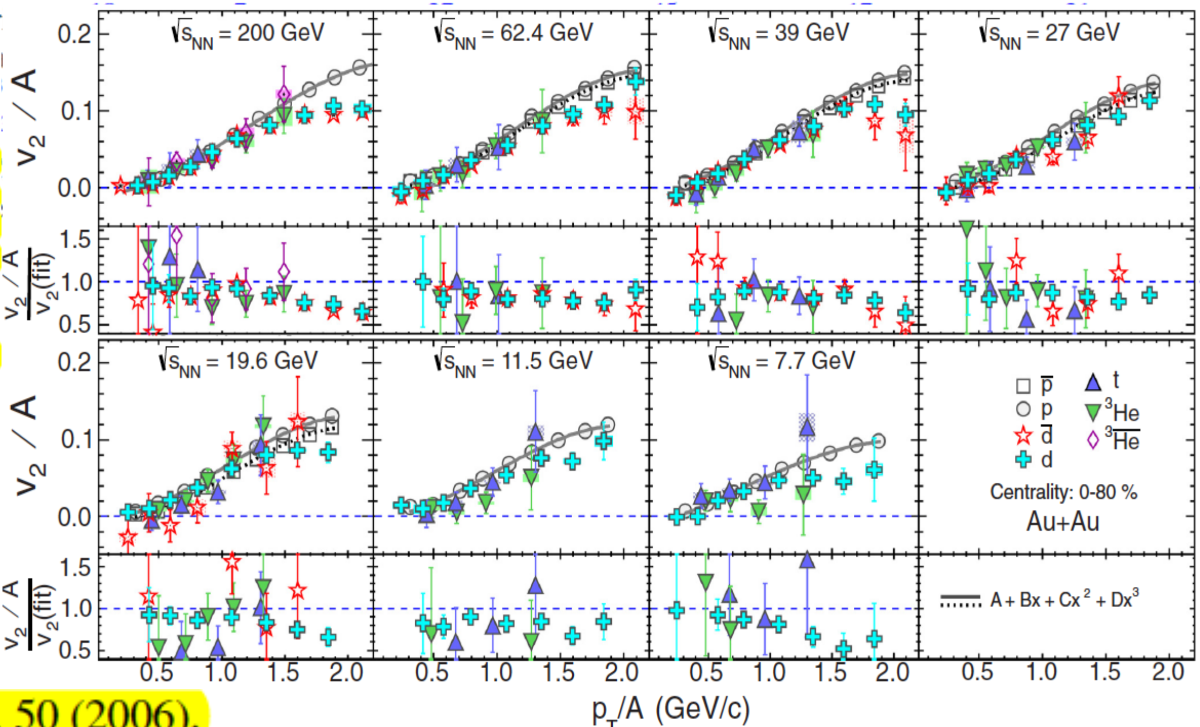
PHYSICAL REVIEW C **94**, 034908 (2016)

Measurement of elliptic flow of light nuclei at $\sqrt{s_{NN}}$ = 200, 62.4, 39, 27, 19.6, 11.5, and 7.7 GeV at the BNL Relativistic Heavy Ion Collider

L. Adamczyk,[1] J. K. Adkins,[20] G. Agakishiev,[18] M. M. Aggarwal,[31] Z. Ahammed,[49] I. Alekseev,[16] A. Aparin,[18] D. Arkhipkin,[3]

Figure 9 presents the light-nuclei v_2/A as a function of p_T/A, where A is the atomic mass number of the corresponding light nuclei. The main goal of this study is to understand whether light (anti) nuclei production is consistent with coalescence of (anti) nucleons. The model predicts that, if a composite particle were produced by coalescence of n number of particles that are very close to each other in phase space, then $v_2(p_T)$ of the composite will be n times that of the constituents [46]. In Fig. 9 it is observed that the (anti) nuclei v_2/A closely follows v_2 of p ($\bar{p}$) for p_T/A up to 1.5 GeV/c. The scaling behavior holds ($p_T/A <$ 1.5 GeV/c) within 5%–20% for all beam energy range presented. The scaling behavior of these nuclei suggest that d ($\bar{d}$) within $p_T <$ 3.0 GeV/c and t, ^{3}He ($^3\overline{\text{He}}$) within $p_T <$ 4.5 GeV/c might have formed via the coalescence of nucleons (antinucleons).

almost similar magnitude of v_2 for all collision energies. The fact that all the light-nuclei v_2 generally follow an atomic mass number scaling indicates that the coalescence of nucleons might be the underlying mechanism of light-nuclei formation in high-energy heavy-ion collisions. This observation is further



[46] T. Z. Yan *et al.*, Phys. Lett. B **638**, 50 (2006).

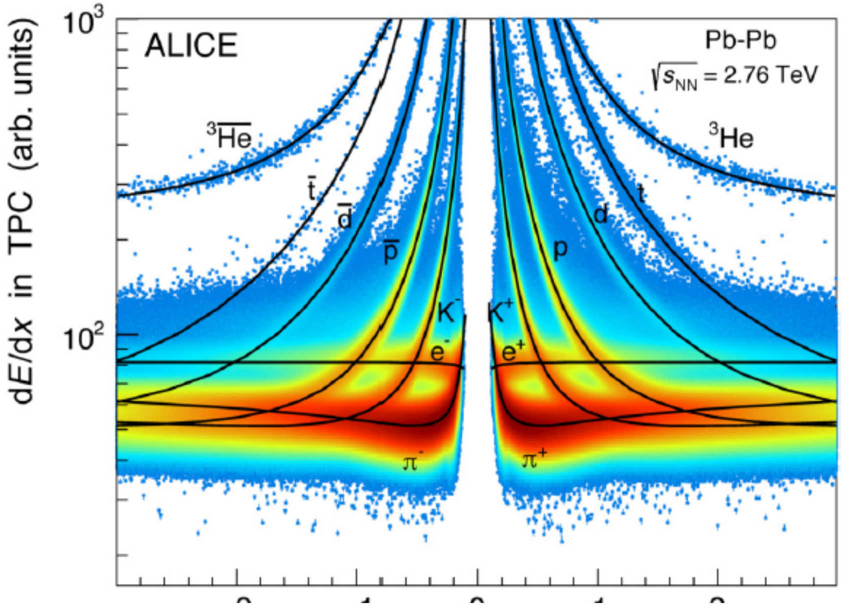
PHYSICS LETTERS B

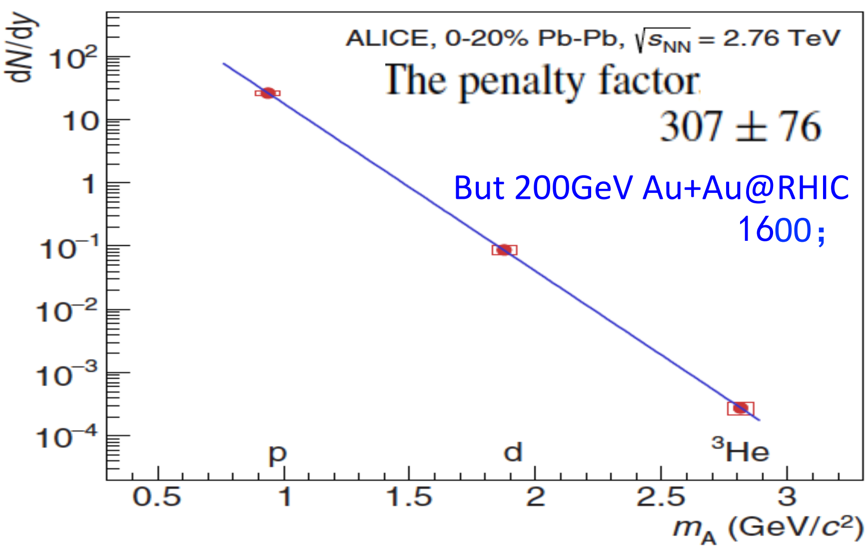
Scaling of anisotropic flow and momentum-space densities for light particles in intermediate energy heavy ion collisions

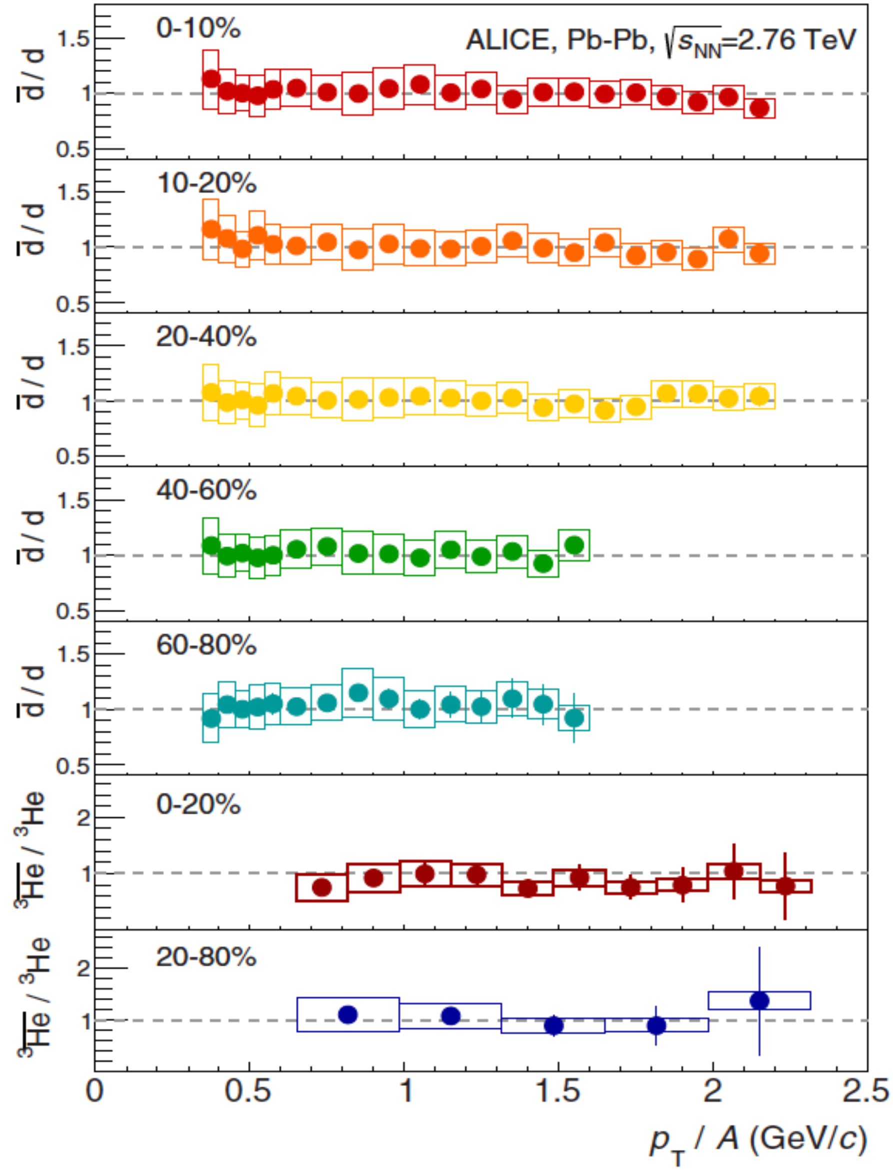
T.Z. Yan [a,b], Y.G. Ma [a,*], X.Z. Cai [a], J.G. Chen [a], D.Q. Fang [a], W. Guo [a,b], C.W. Ma [a,b], E.J. Ma [a,b], W.Q. Shen [a], W.D. Tian [a], K. Wang [a,b]

For Pb+Pb@2.76TeV, more rich antinuclei has been produced all ratios of pbar/p, d-bar/d, He3-bar/He3 ~1

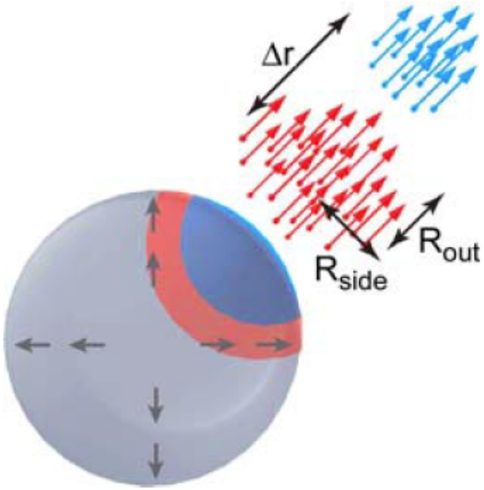
$\bar{d}/d = (\bar{p}/p)^2$ $\quad {}^3\overline{\mathrm{He}}\,/\,{}^3\mathrm{He} = (\bar{p}/p)^3$







Femtoscopy Analysis



Correlation Function(CF):

$$C_{measure}(k^*) = \frac{A(k^*)}{B(k^*)}$$

A(k*) - real pair,
B(k*) - pair from mixed events
k* - half of relative momentum between two particles

Residual correlation

Inside our (anti)proton sample, there are secondary (anti)protons that are indistinguishable from primordial ones. Taking the case for proton as an example, two main weak decay channels give the most contribution :

$$\Lambda \rightarrow p + \pi^- \qquad \sim 26\%$$

$$\Sigma^+ \rightarrow p + \pi^0 \qquad \sim 5\%$$

As the Lambda decay contribute the most secondary (anti)protons, in our analysis we only consider the contribution from Lambda decay.

Nuclear force : scattering length (f_0) and effective range (d_0)

$$C_{meas}(k^*_{pp}) = 1 + x_{pp}[C_{pp}(k^*; R_{pp}) - 1] + x_{p\Lambda}[\widetilde{C}_{p\Lambda}(k^*_{pp}; R_{p\Lambda}) - 1] + x_{\Lambda\Lambda}[\widetilde{C}_{\Lambda\Lambda}(k^*_{pp}; R_{\Lambda\Lambda}) - 1] \quad (1)$$

CF

wave function

$$\psi^{S(+)}_{-k^*}(r^*) = e^{i\delta_c}\sqrt{A_c(\eta)}\left[e^{-ik^*r^*}F(-i\eta,1,i\xi) + f_c(k^*)\frac{\tilde{G}(\rho,\eta)}{r^*}\right]$$

Scattering amplitude

$$f_c(k^*) = \left[\frac{1}{f_0} + \frac{1}{2}d_0 k^{*2} - \frac{2}{a_c}h(\eta) - ik^* A_c(\eta)\right]^{-1}$$

f_0 is related to the cross section.

At low energy limit, the scattering cross section is given by

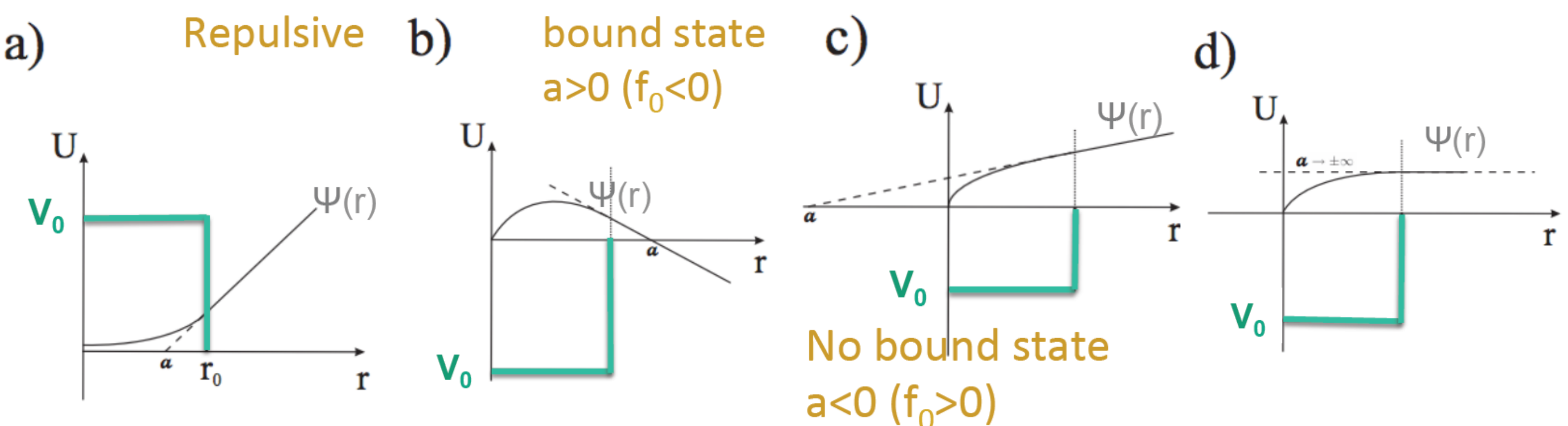
$$\sigma = 4\pi f_0^2$$

d_0 is related to the range of the potential.

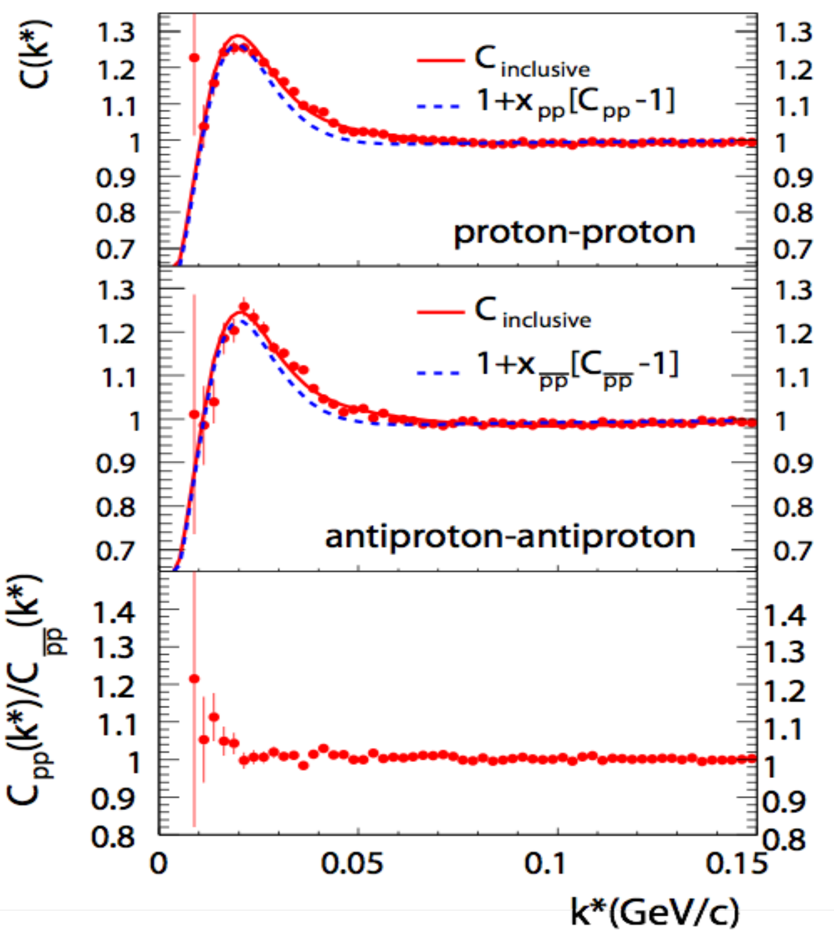
In the case of square well potential, d_0 is the range (radius) of the potential.

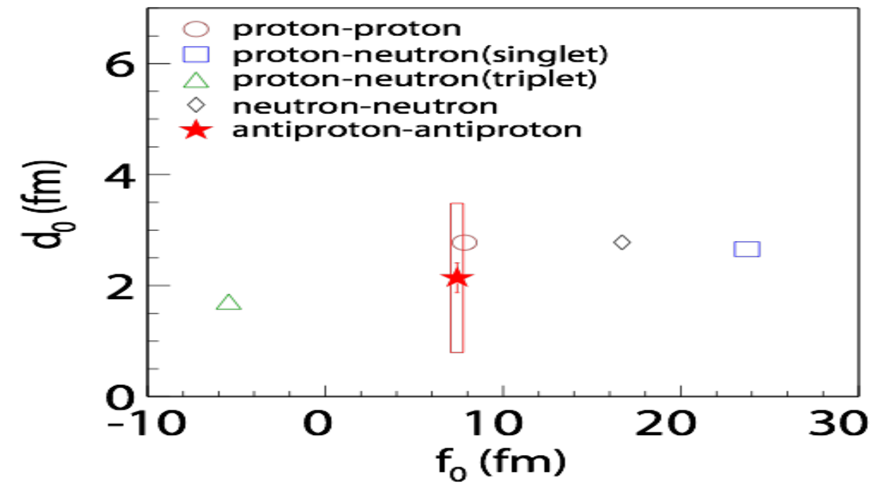
For a short range potential, f_0 and d_0 are related to the s-wave scattering phase shift δ_0 and the collision momentum k by :

$$k\cot(\delta_0) \approx \frac{1}{f_0} + \frac{1}{2}d_0 k^2$$



Correlations and the ratio



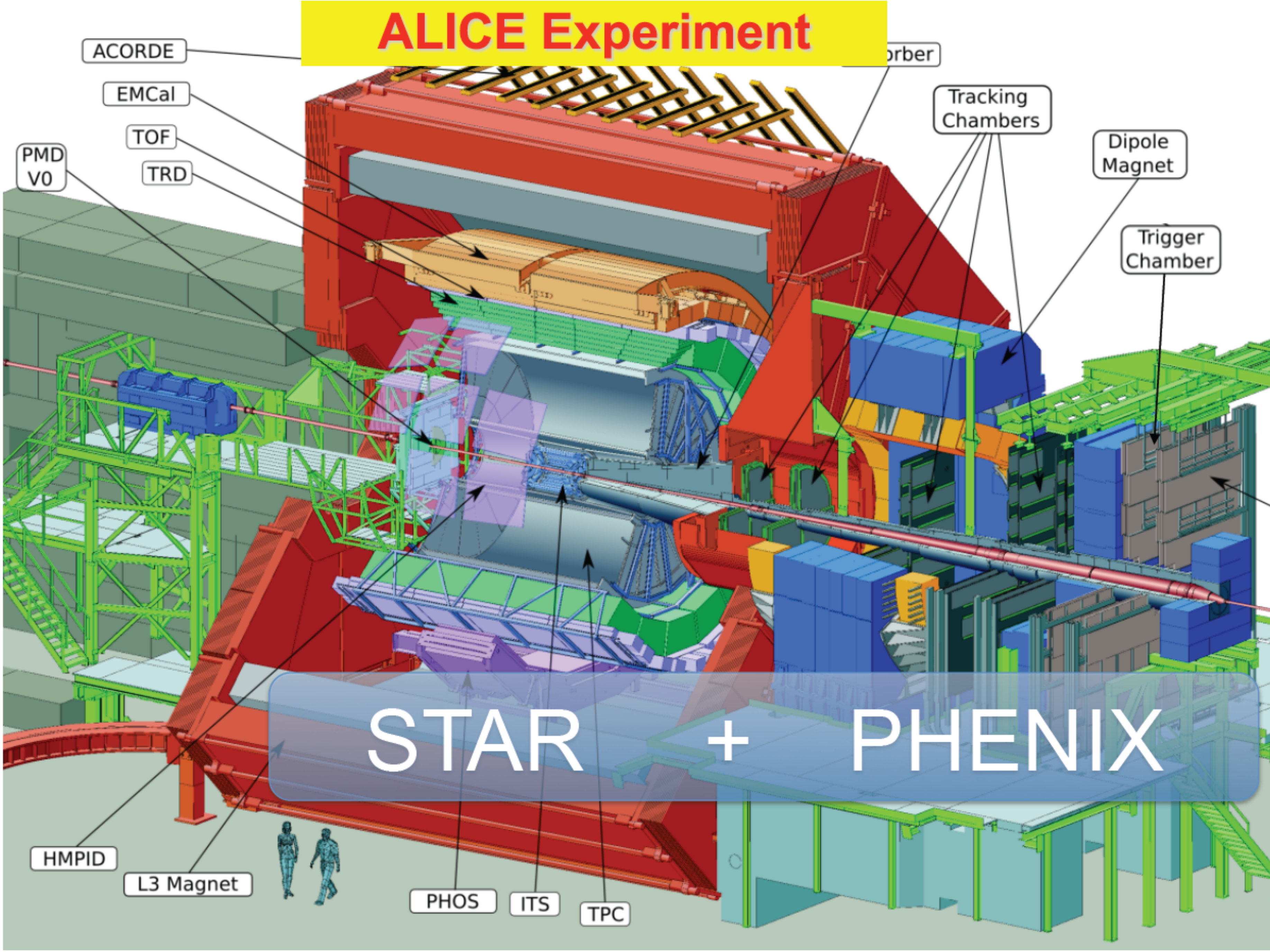


For pbar-pbar CF,
$R=2.80\pm0.02$fm , $f_0=7.41\pm0.19$fm,
$d_0=2.14\pm0.27$fm;

- **f0 and d0 for the antiproton-antiproton interaction are consistent with the ones for the proton-proton interaction （within errors）**
- **It provides input for descriptions of the interaction among antiprotons, one of the simplest systems of anti-nucleons(nuclei).**
- **A quantitative verification of CPT symmetry still works!**

STAR principal authors:
Z.Q. Zhang， Y. G. Ma， A. Tang et al.

Z.Q. Zhang （SINAP） , PhD Thesis (2017)


ALICE Experiment
ACORDE
EMCal
TOF
TRD
PMD
V0
orber
Tracking Chambers
Dipole Magnet
Trigger Chamber
HMPID
L3 Magnet
PHOS
ITS
TPC
STAR + PHENIX

ALICE-China Team

China Team(6 Institutes, 27 staffs, 17 PhD students)

Central China Normal University (CCNU), Wuhan

(Full member, 13 staffs, 10 PhD students)

China Institute of Atomic Energy (CIAE)

(full member, 2 staffs, 2 students)

University of Science & Technology of China（USTC）, Hefei

(Full member, 4 staffs, 2 PhD students)

Shanghai Institute of Applied Physic (SINAP), Shanghai

(Full member, 5 staffs, 3 PhD students)

Huazhong University of Science & Technology（HUST）

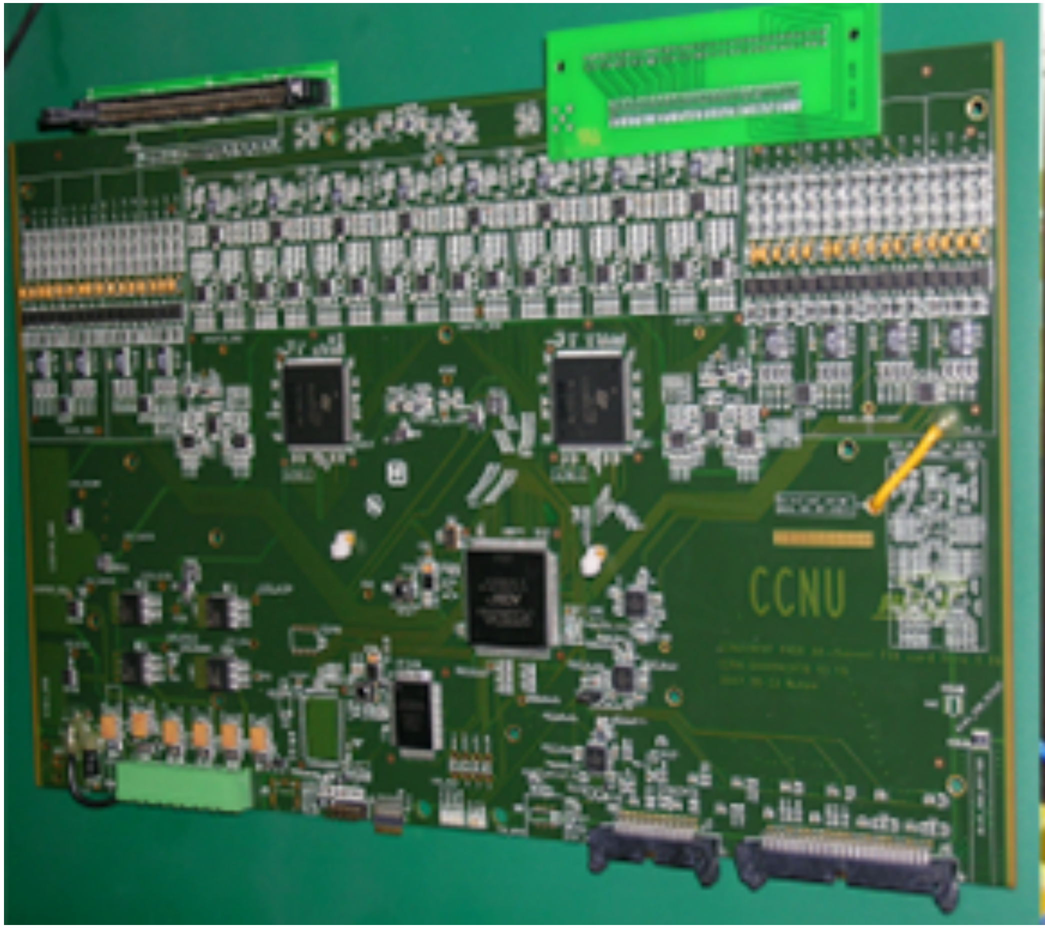
(Associate member，3 staffs)

Hubei University of Insductries

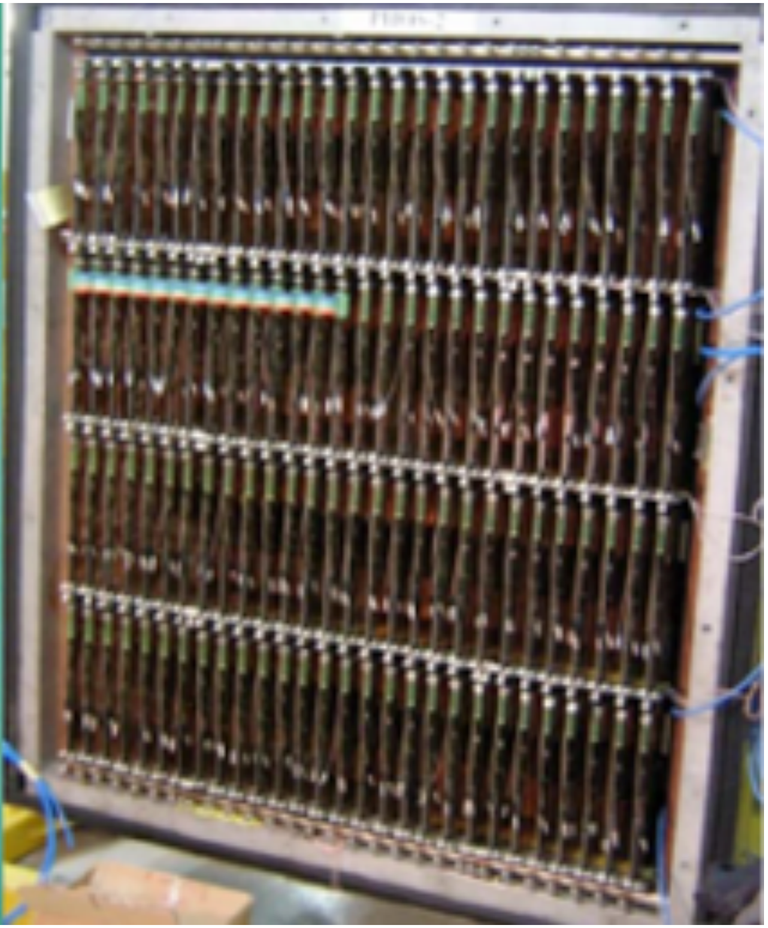
(Full member, 1 staffs)

ALICE PHOS front-end electronics

R&D of front end of electronics (FEE)

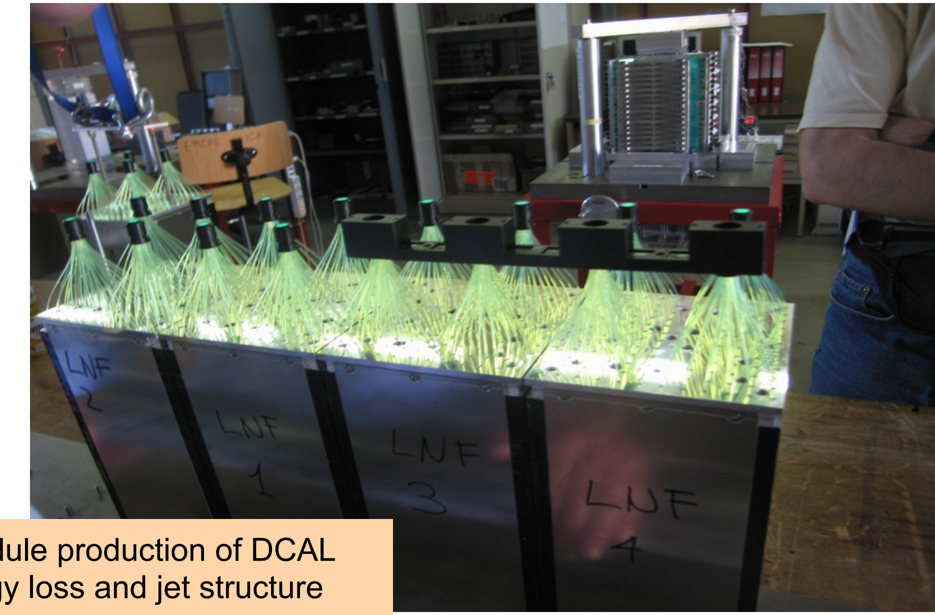


FEE array



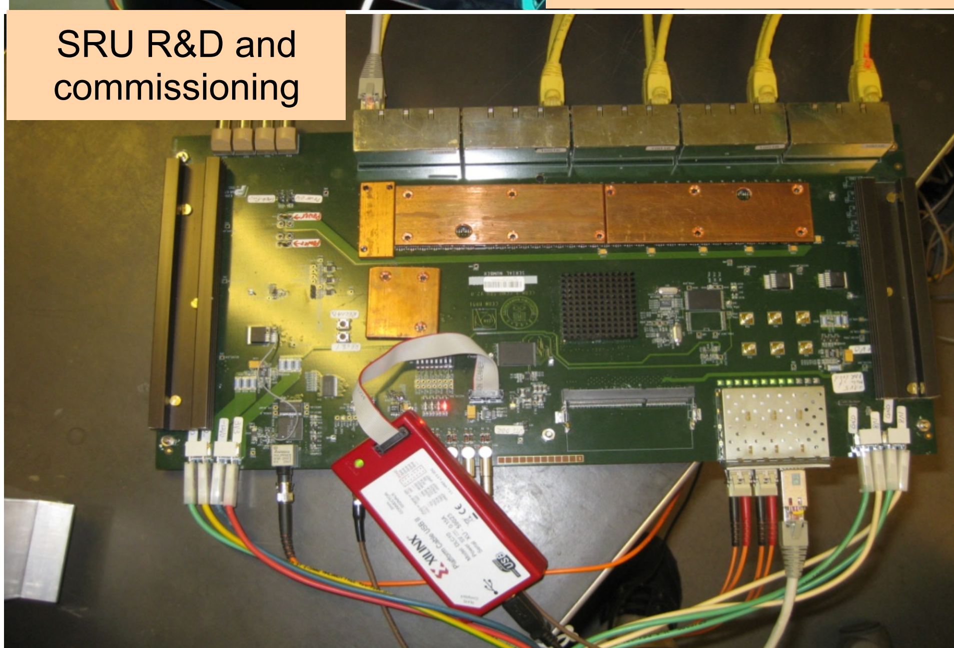
- R&D and massive production for full PHOton Spectrometer (PHOS: four super-modules)
- Observe photon and jets

ALICE Di-jet Electro-magnetic Calorimeter (DCAL) and Scalable Readout Unit (SRU)



R&D and one super module production of DCAL
To observe parton energy loss and jet structure

SRU R&D and commissioning



Physics topics

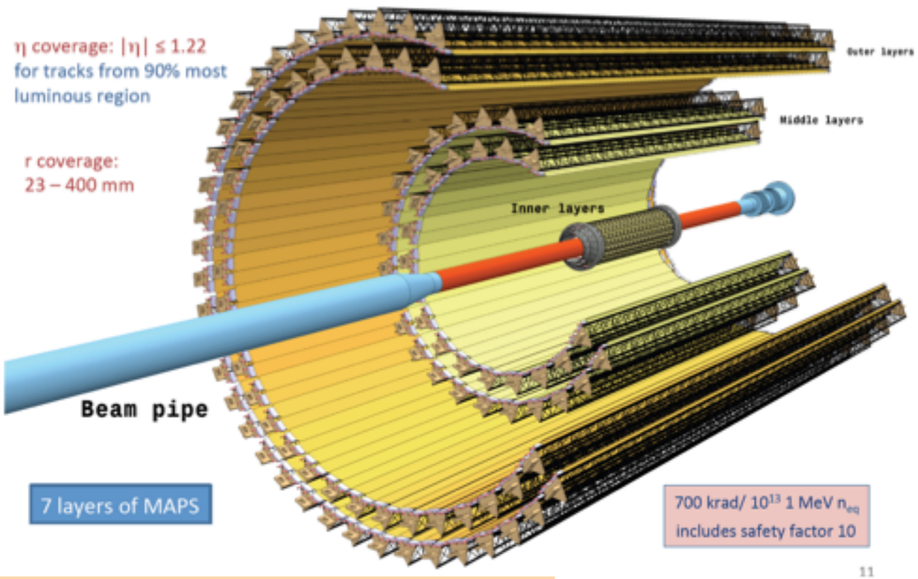
1. Nuclear modification study to study the parton energy loss mechanism
   1) Heavy-flavor hadron decays;
   2) Neutral meson production and correlation
   3) jet production and its structure

2. Flow measurements to probe the partonic collectivity
   1) (Multi-)strange particles
   2) Muons from heavy-flavor hadron decay

3. High multiplicity measurements to study multiple partonic interaction in pp collisions
   1) Charged production of High Multiplicity at13 TeV;
   2) Strangeness production of high multiplicity at 13 TeV.

Details seeing backup

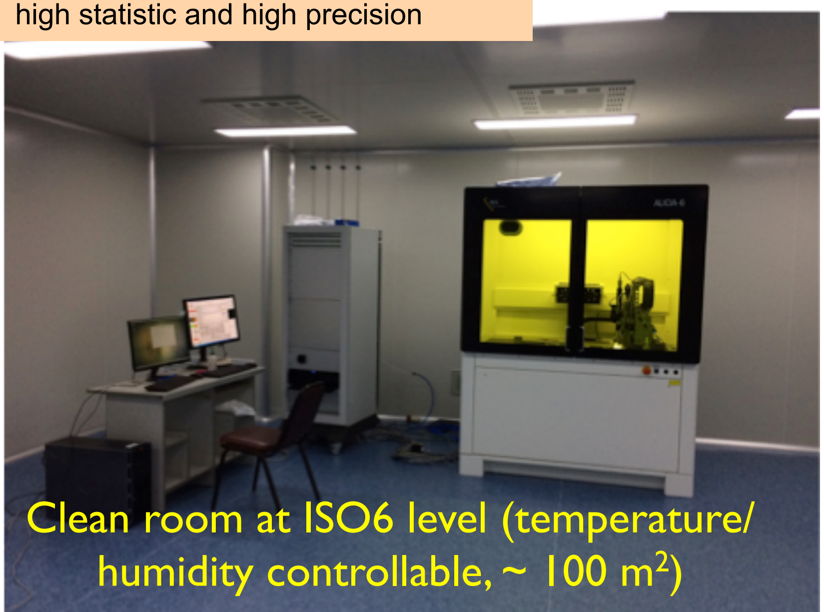
ALICE ITS Upgrade at CCNU



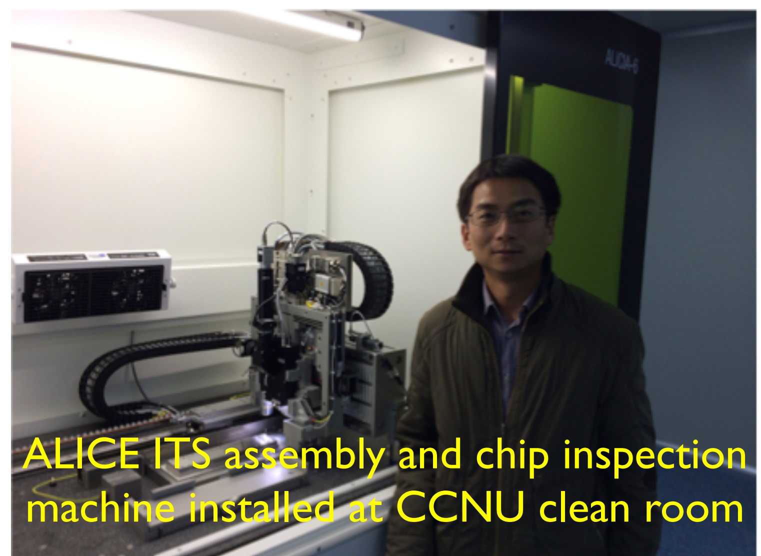
To study heavy quarks and quarkoniums with high statistic and high precision

China team-Efforts and Plan:

- ALICE ITS chip design:
- (1) Chip matrix readout architectures; (2) pixel analog Front-end revision and optimization.
- Chip-Flexible PCB interconnection R&D
- Chip performance testing
- Construct 406 ITS modules at Wuhan lab (2032 modules in total for ITS outer 4 layers)



Clean room at ISO6 level (temperature/ humidity controllable, ~ 100 m^2)



ALICE ITS assembly and chip inspection machine installed at CCNU clean room

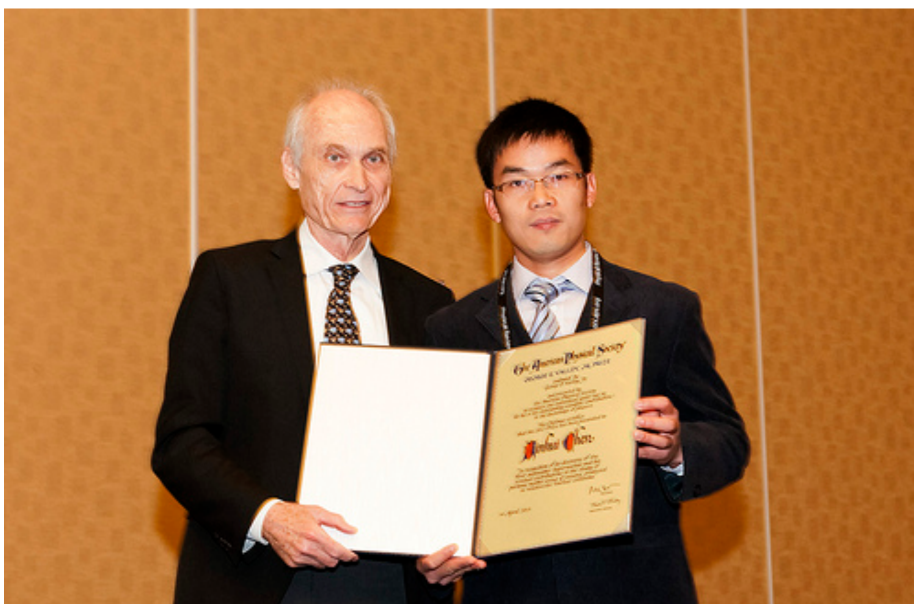
International Prizes

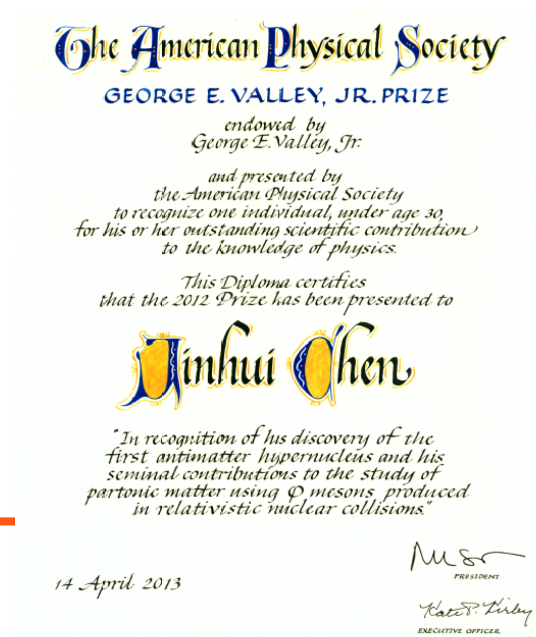
2012 George E. Valley Jr. Prize Recipient

Jinhui Chen (SINAP)
Chinese Academy of Science

Citation:

"*In recognition of his discovery of the first antimatter hypernucleus and his seminal contributions to the study of partonic matter using φ mesons produced in relativistic nuclear collisions.*"





The American Physical Society

GEORGE E. VALLEY, JR. PRIZE

endowed by
George E. Valley, Jr.

and presented by
the American Physical Society
to recognize one individual, under age 30,
for his or her outstanding scientific contribution
to the knowledge of physics.

This Diploma certifies
that the 2012 Prize has been presented to

Jinhui Chen

"In recognition of his discovery of the
first antimatter hypernucleus and his
seminal contributions to the study of
partonic matter using φ mesons produced
in relativistic nuclear collisions."

14 April 2013

PRESIDENT

EXECUTIVE OFFICER

全球华人物理和天文学会

International Organization of Chinese Physicists and Astronomers

2) Achievement in Asia Award (AAA Poe Prize) Winners–

Yugang Ma (Shanghai Institute of Applied Physics)

Citation:

"For his leadership of the Chinese STAR Collaboration in the construction of the multi-gap resistive plate chambers for the STAR time-of-flight detector and for his pioneering research on anti-hypertriton, anti-Helium-4 and di-electron production from Au + Au collisions at RHIC."

IWND which was supported by ANPhA (reported in Nuclear Physics News)

meeting reports

The 5th International Workshop on Nuclear Dynamics in Heavy-Ion Reactions (IWND2016)

summary

- Nuclear physics & particle physics activities are growing in Shanghai and nearby cities. So do in China-wide.
- SINAP is also expanding its nuclear physics activities:

  Now: RNB Phys, RHIC phys, Theor. Nucl. Phys, 0vbb, dark-matter

  New: ALICE, laser-ele. Gamma source, laser-nucl phys

- Hope to have more cooperation with you

Thanks for your attentions!