Studies of hypernuclei with heavy ion beams, nuclear emulsions and machine learning

HYP2022, June 27th – July 1st, Prague, 2022

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FRS/NUSTAR department,

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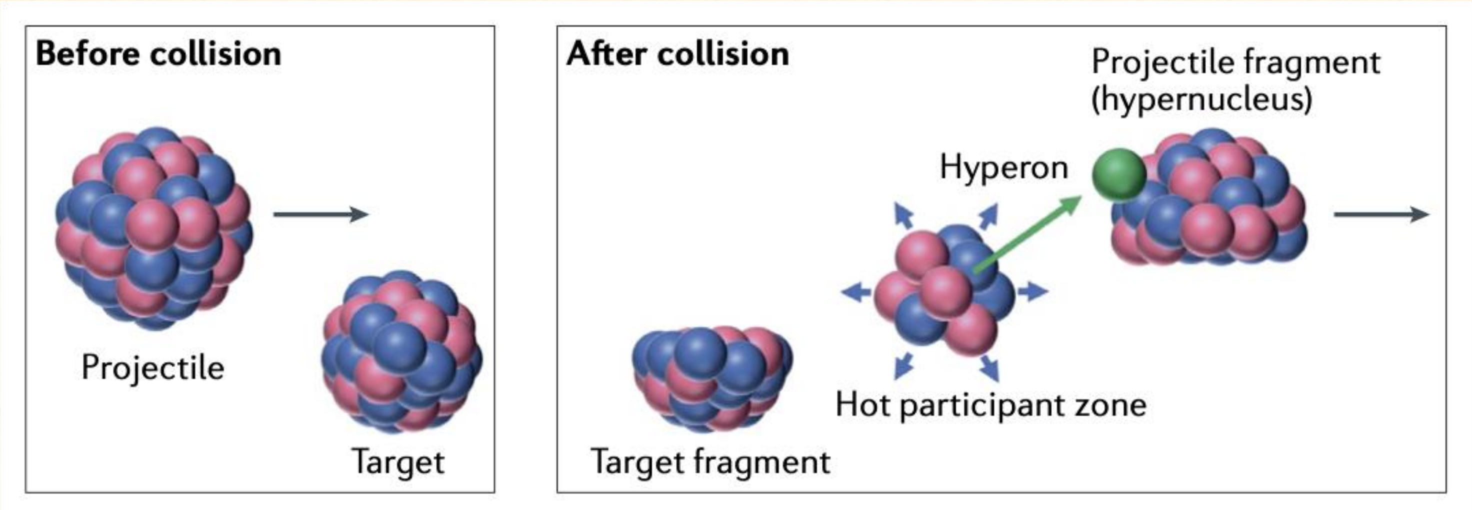
Germany

School of Nuclear Science and Technology,

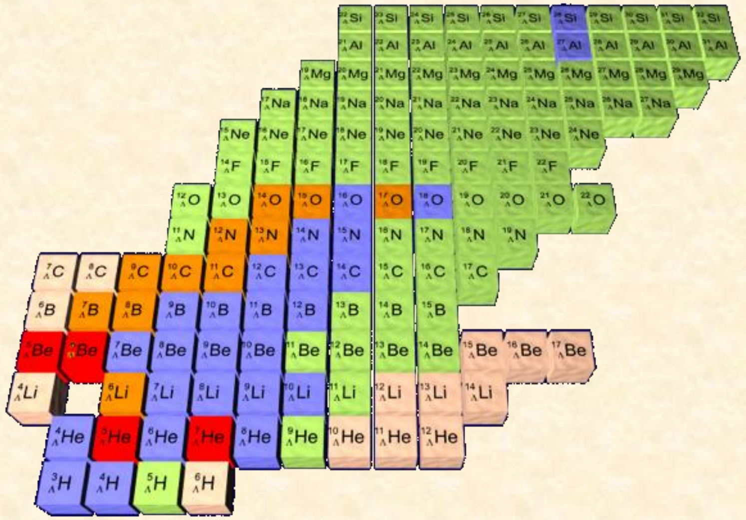
Lanzhou University,

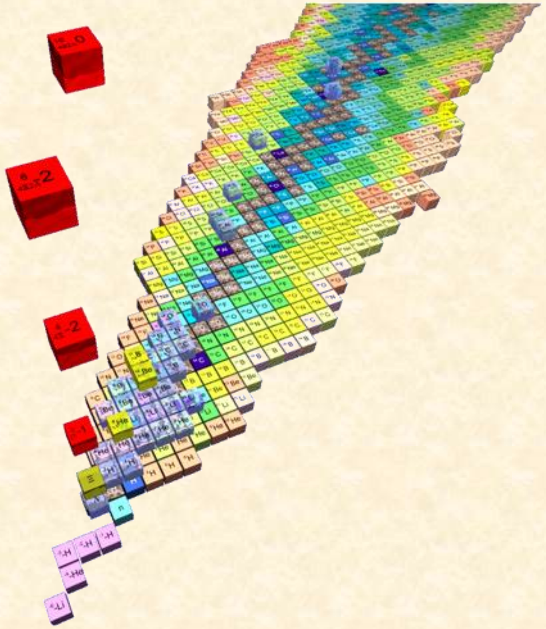
China

Our way to produce hypernuclei



TRS et al., Nature Reviews Physics 3, 803-813 (2021)



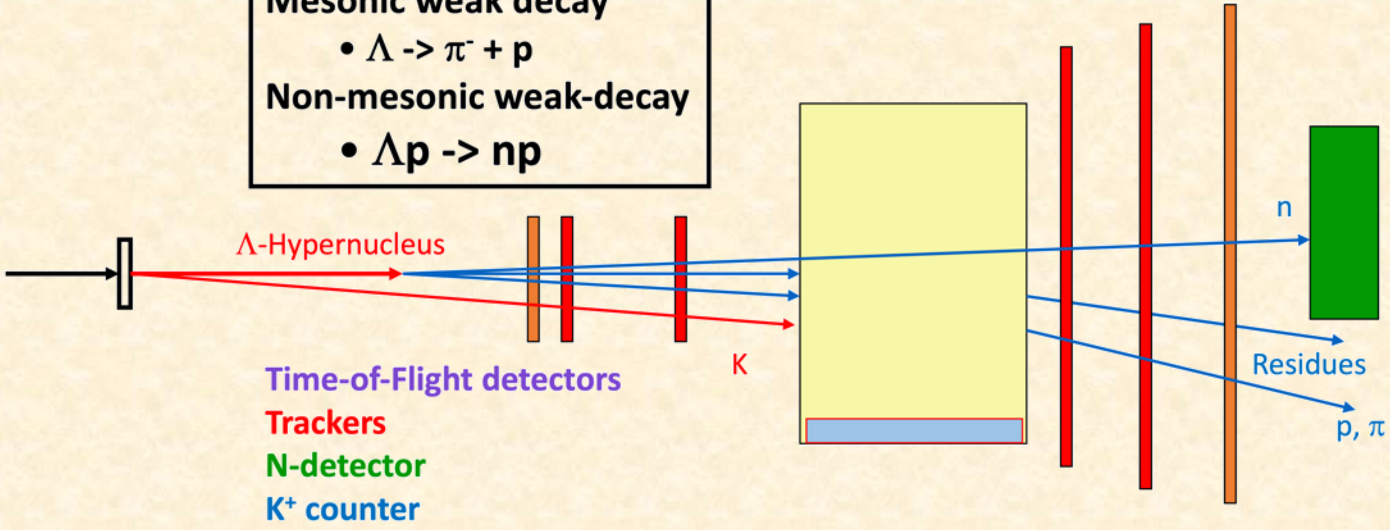


Mesonic weak decay

- $\Lambda \rightarrow \pi^- + p$

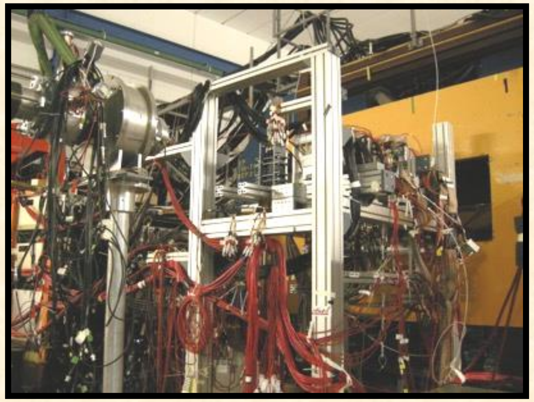
Non-mesonic weak-decay

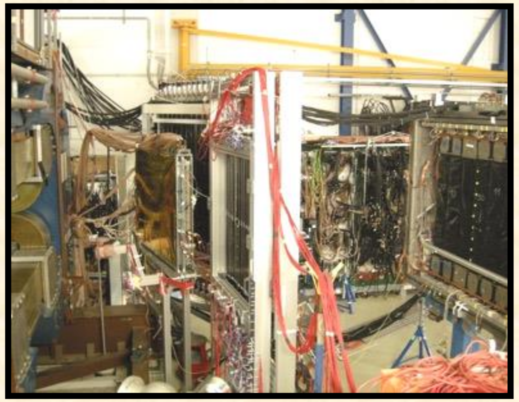
- $\Lambda p \rightarrow np$

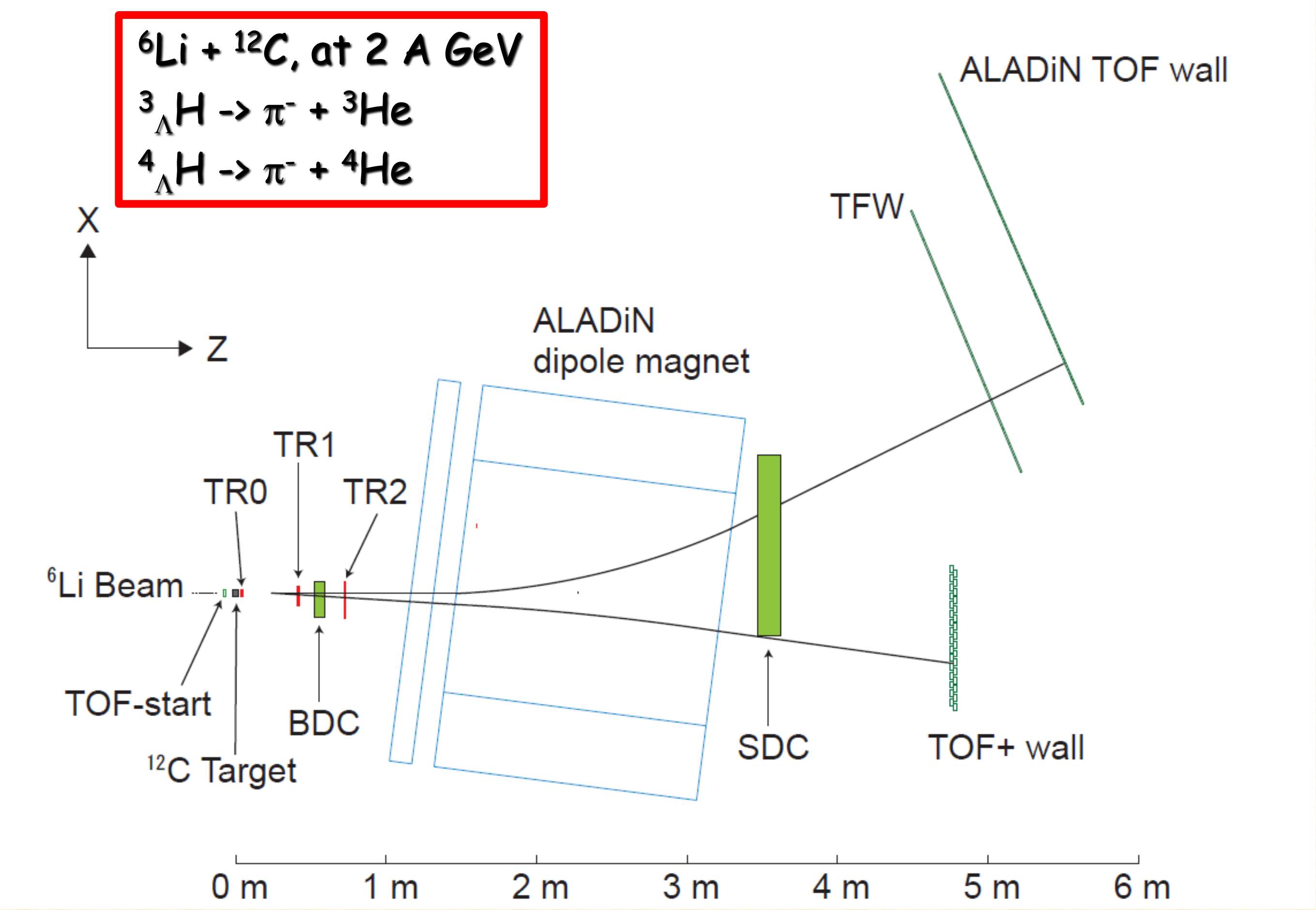


Pioneering experiment: HypHI Phase 0 (2009)

- To demonstrate the feasibility of precise hypernuclear spectroscopy with ^{6}Li primary beams at 2 A GeV on a carbon target







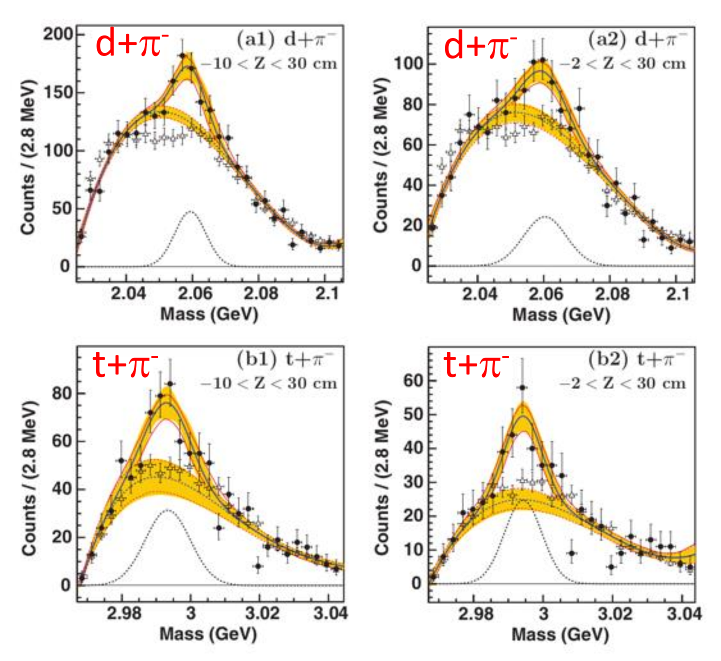
Two puzzles initiated by HypHI

Signals indicating nnΛ bound state

All theoretical calculations are negative

- E. Hiyama et al., Phys. Rev. C89 (2014) 061302(R)
- A. Gal et al., Phys. Lett. B736 (2014) 93
- H. Garcilazo et al., Phys. Rev. C89 (2014) 057001

and much more publication

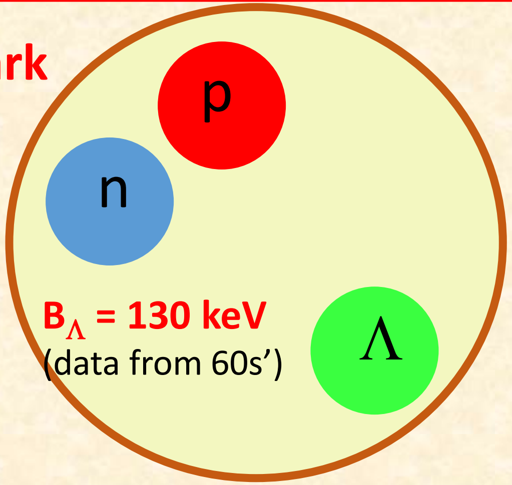


C. Rappold et al., PRC 88 (2013) 041001

Short lifetime of $^{3}_{\Lambda}H$ C. Rappold et al., Nucl. Phys. A 913 (2013) 170

- HypHI Phase 0: 183^{+42}_{-32} ps

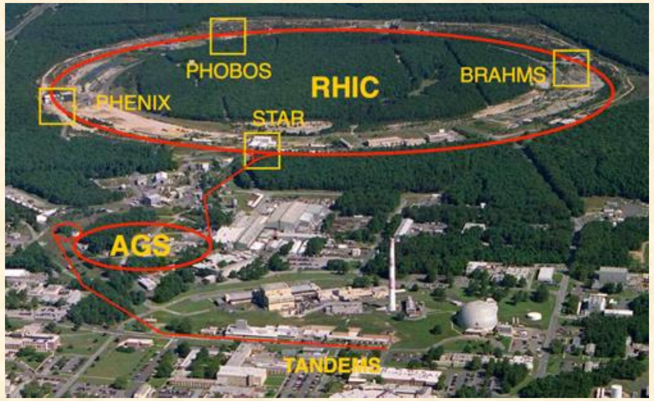
Benchmark



$\tau(^{3}_{\Lambda}H)$ should be equal to $\tau(\Lambda$, 263 ps)

Lifetime of hypertriton

STAR at RHIC



ALICE at LHC

No theories to reproduce the short lifetime

STAR: 155^{+25}_{-22} ps

↓

142^{+24}_{-21} ps

↓

221±15 ps

PRL 128 (2022) 202301

HypHI
183^{+42}_{-32} ps

ALICE: 181^{+54}_{-39} ps

↓

237^{+34}_{-38} ps

PLB 128 (2019) 134905

Very recent result from STAR

PHYS

Measurements of ${}^{3}_{\Lambda}$H

M. S. Abdallah,[5] B. E. Aboona,[55] J.
M. M. Aggarwal,[41] Z. Ahammed,[6]
F. G. Atetalla,[29] A. Attri,[41] G. S. Averichev,[28] V. Bairathi,[53] W. Baker,[10] J. G. Ball Cap,[20] K. Barish,[10] A. Behera,[52]
P. Federic,[38] J. Fedorisin,[28] C. J. Feng,[37] Y. Feng,[44] P. Filip,[28] E. Finch,[51] Y. Fisyak,[6] A. Francisco,[64] C. Fu,[11] L. Fulek,[2]

Hot topics in nuclear experiments:
STAR, ALICE, J-PARC, ELPH and WASA-FRS

We would provide one data point with very small errors

The combined results are 221 + 15(stat) + 19(syst) for ${}^{3}_{\Lambda}$H and 218 + 6(stat) + 13(syst) for ${}^{4}_{\Lambda}$H. As shown in Fig. 2, they are consistent with previous measurements from ALICE [7,8], STAR [10,11], HypHI [9], and early experiments using imaging techniques [3–5,10,42–48]. Using all the available experimental data, the average lifetimes of ${}^{3}_{\Lambda}$H and ${}^{4}_{\Lambda}$H are 200 ± 13 ps and 208 ± 12 ps, respectively, corresponding to (76 ± 5)% and (79 ± 5)% of τ_{Λ}. All data from ALICE, STAR, and HypHI lie within 1.5σ of the global averages. These precise data clearly indicate that the ${}^{3}_{\Lambda}$H and ${}^{4}_{\Lambda}$H lifetimes are considerably lower than τ_{Λ}.

S. W. Wissink, R. Witt, J. Wu, J. Wu, Y. Wu, B. Xi, Z. G. Xiao, G. Xie, W. Xie, H. Xu, N. Xu,
Q. H. Xu,[49] Y. Xu,[49] Z. Xu,[6] Z. Xu,[9] G. Yan,[49] C. Yang,[49] Q. Yang,[49] S. Yang,[45] Y. Yang,[37] Z. Ye,[45] Z. Ye,[12] L. Yi,[49] K. Yip,[6]
Y. Yu,[49] H. Zbroszczyk,[62] W. Zha,[48] C. Zhang,[52] D. Zhang,[11] J. Zhang,[49] S. Zhang,[12] S. Zhang,[18] X. P. Zhang,[57] Y. Zhang,[26]
Y. Zhang,[48] Y. Zhang,[11] Z. J. Zhang,[37] Z. Zhang,[6] Z. Zhang,[12] J. Zhao,[44] C. Zhou,[18] Y. Zhou,[11] X. Zhu,[57]
M. Zurek,[4] and M. Zyzak[17]

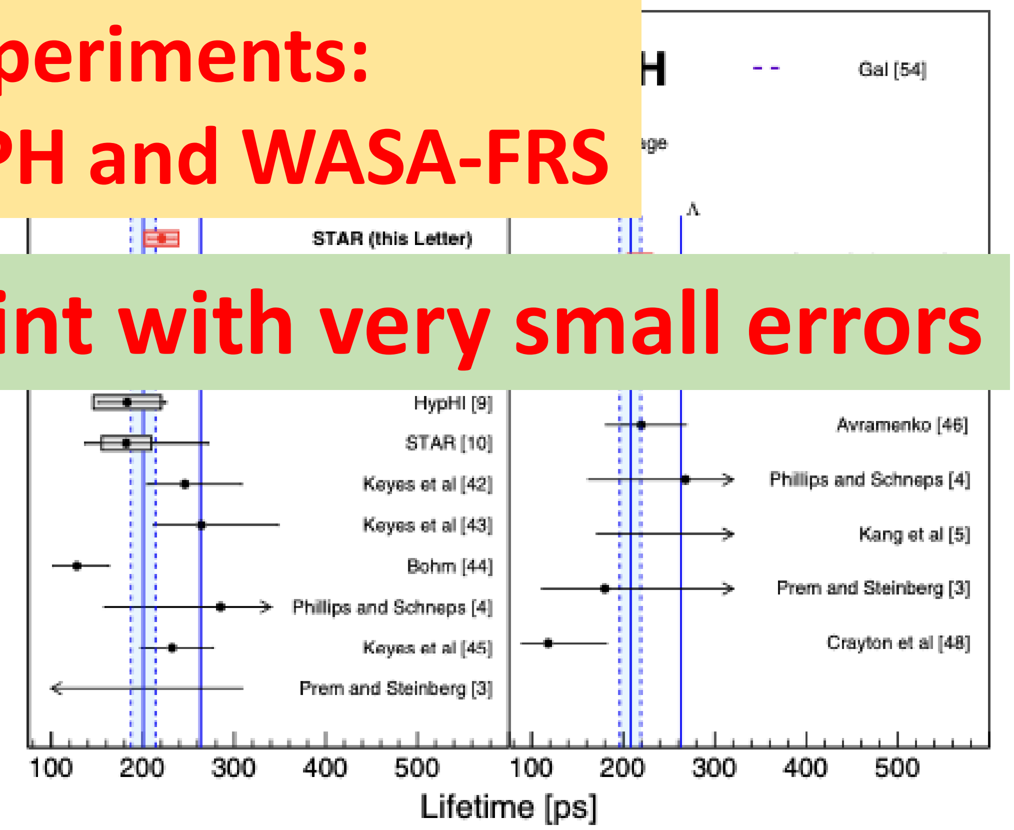


FIG. 2. ${}^{3}_{\Lambda}$H (a) and ${}^{4}_{\Lambda}$H (b) measured lifetime, compared to previous measurements [3–5,7–11,42–48], theoretical calculations [49–54], and τ_{Λ} [41]. Horizontal lines represent statistical uncertainties, while boxes represent systematic uncertainties. The experimental average lifetimes and the corresponding uncertainty of ${}^{3}_{\Lambda}$H and ${}^{4}_{\Lambda}$H are also shown as vertical blue shaded bands.

Binding energy of hypertriton

NATURE PHYSICS | VOL 16 | APRIL 2020 | 409–412 | www.nature.com/naturephysics

nature physics

LETTERS

https://doi.org/10.1038/s41567-020-0799-7

Check for updates

Measurement of the mass difference and the binding energy of the hypertriton and antihypertriton

The STAR Collaboration*

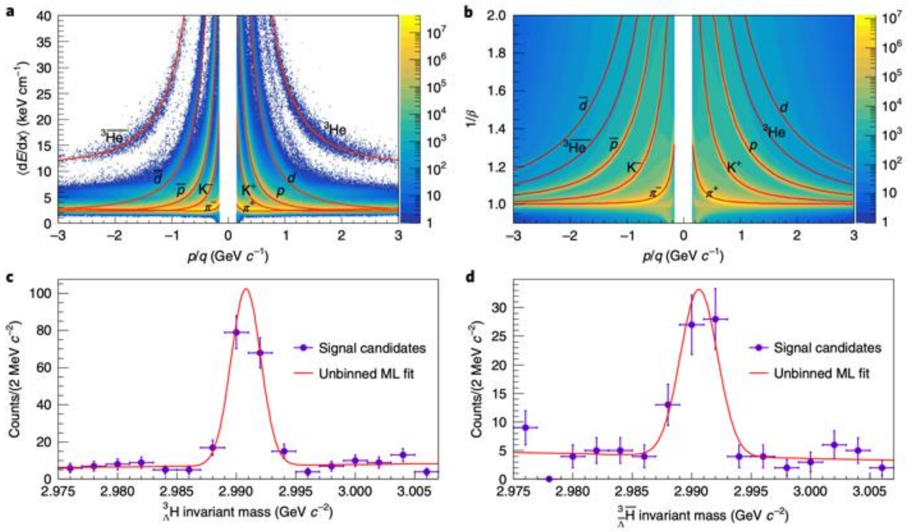


Fig. 2 | Particle identification and the invariant mass distributions for $^3_\Lambda$H and $^3_\Lambda\overline{\mathrm{H}}$ reconstruction. a,b, ⟨dE/dx⟩ (mean energy loss per unit track length in the gas of the TPC) versus p/q (where p is the momentum and q is the electric charge in units of the elementary charge e) (**a**) and $1/\beta$ (where β is the speed of a particle in units of the speed of light) versus p/q (**b**). ⟨dE/dx⟩ is measured by the TPC and $1/\beta$ is measured by the TOF detector in conjunction with the TPC. In both cases, the coloured bands show the measured data for each species of charged particle, while the red curves show the expected values. Charged particles are identified by comparing the observed ⟨dE/dx⟩ and $1/\beta$ with the expected values. **c,d**, Utilizing both 2-body and 3-body decay channels, the invariant mass distributions of $^3_\Lambda$H (**c**) and $^3_\Lambda\overline{\mathrm{H}}$ (**d**) are shown. The error bars represent statistical uncertainties (s.d.). The red curves represent a fit with a Gaussian function plus a linear background, using the unbinned maximum likelihood (ML) method.

The Λ binding energy, B_Λ, for $^3_\Lambda$H and $^3_\Lambda\overline{\mathrm{H}}$ is calculated using the mass measurement shown in equation (1). We obtain

$$B_\Lambda = 0.41 \pm 0.12(\mathrm{stat.}) \pm 0.11(\mathrm{syst.})\ \mathrm{MeV} \qquad (3)$$

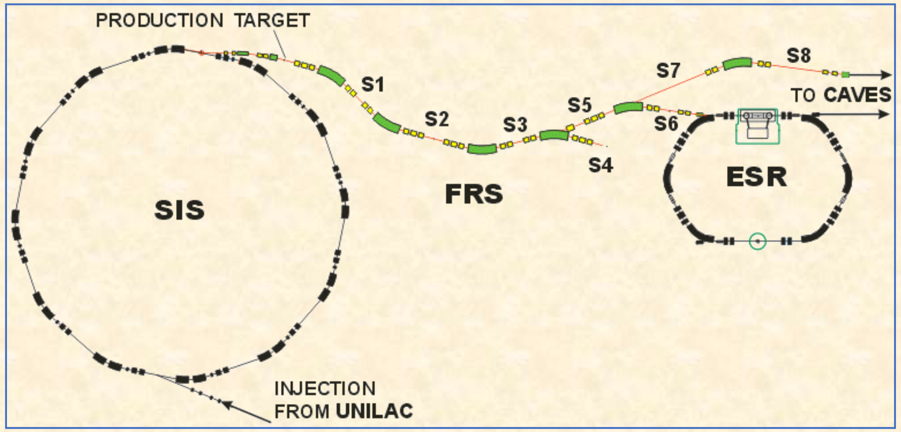
average value of 0.13 ± 0.05(stat.) MeV. When applied to our value of 0.41 ± 0.12(stat.) MeV it yields a significantly smaller value of $7.90^{+1.71}_{-0.93}$ fm. The larger B_Λ and shorter effective scattering length suggest a stronger YN interaction between the Λ and the relatively low-density nuclear core of the $^3_\Lambda$H (ref. [36]). This, in certain models, requires SU(3) symmetry breaking and a more repulsive YN interaction at high density, consistent with implications from the range of masses observed for neutron stars[5].

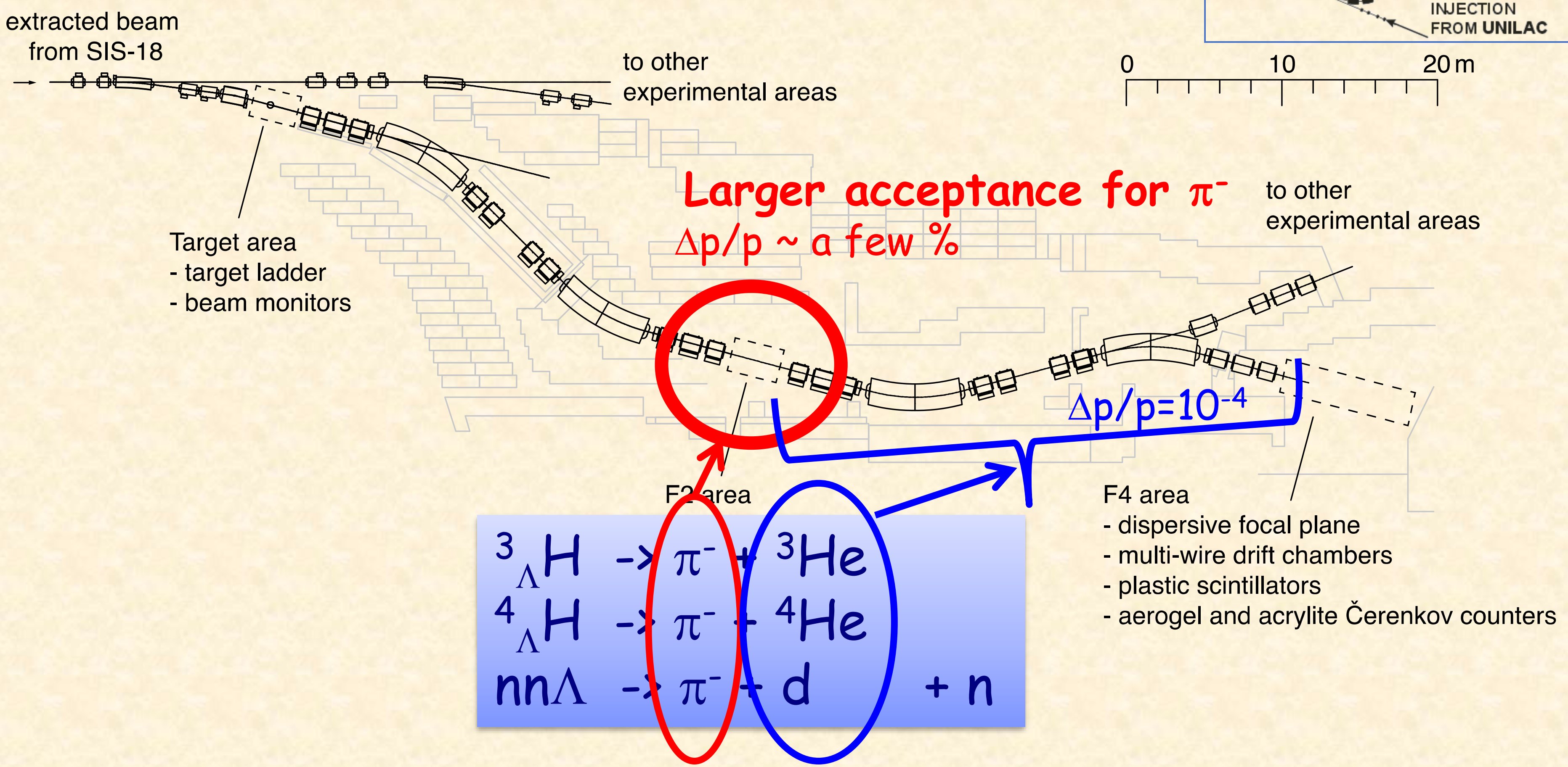
Former value by emulsion (data from 60's)

0.13 ± 0.05 MeV

Our challenges on
the hypertriton lifetime

The novel technique with FRS at GSI





With $^{6}Li+^{12}C$ at 2 A GeV

2012:

Started the new hypernuclear project with the FRS

- Ideas with two dipole magnets at S2 of FRS

2015: NUSTAR defines the project as Day-1

2016:

Ideas with the WASA detector

2017:

Proposal approved with the highest priority

2017-2018:

Preparation for moving WASA from FZJ Juelich

2019 -:

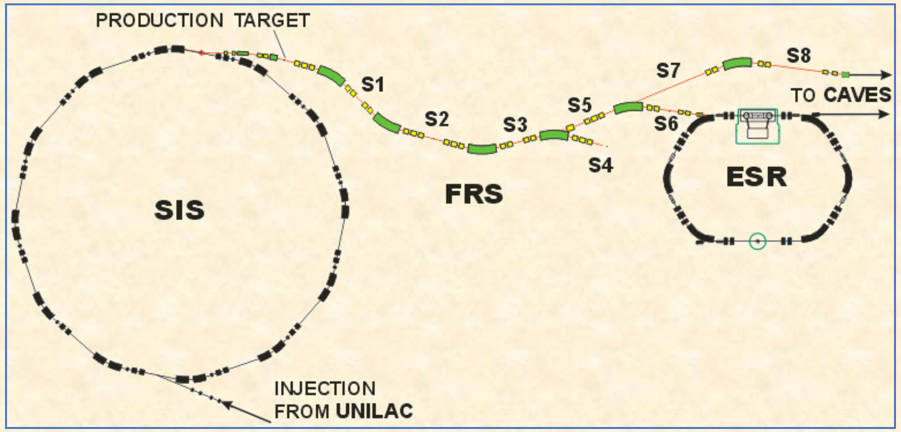
Preparation at GSI

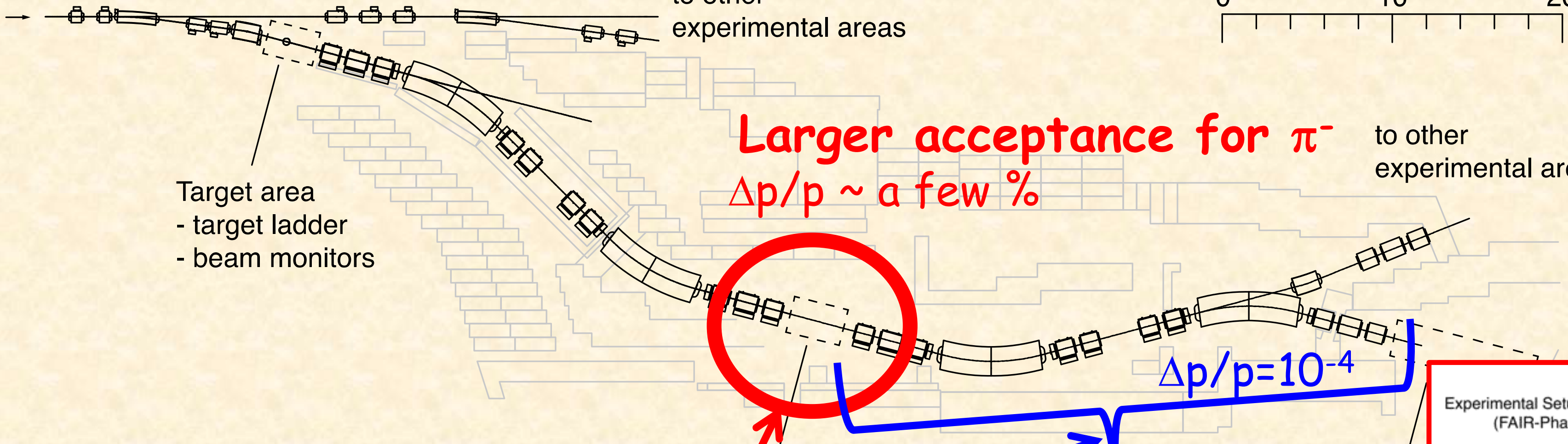
2022:

Experiment

- **February: S490, η'-nucleus**
- **March: S447, Light hypernuclei**

The novel technique with FRS at GSI





Larger acceptance for π^-

$\Delta p/p$ ~ a few %

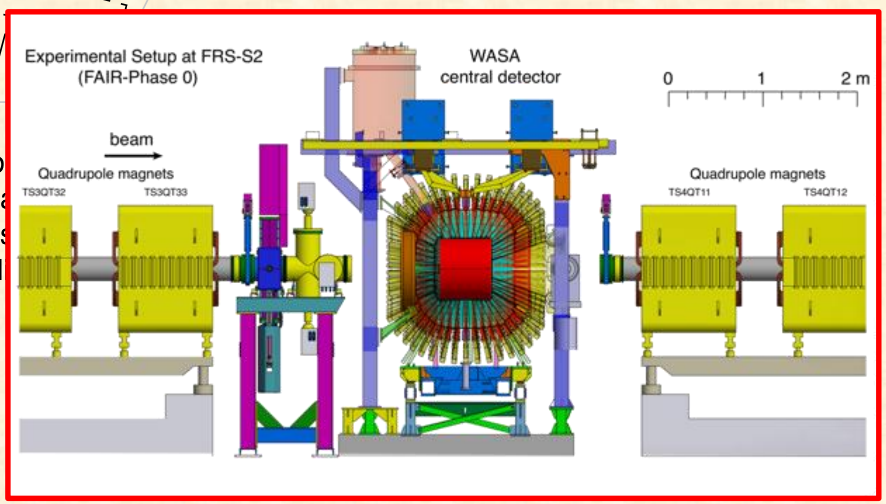
$\Delta p/p=10^{-4}$

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

$^{4}_{\Lambda}H \rightarrow \pi^- + {}^{4}He$

$nn\Lambda \rightarrow \pi^- + d + n$

With $^{6}Li+^{12}C$ at 2 A GeV



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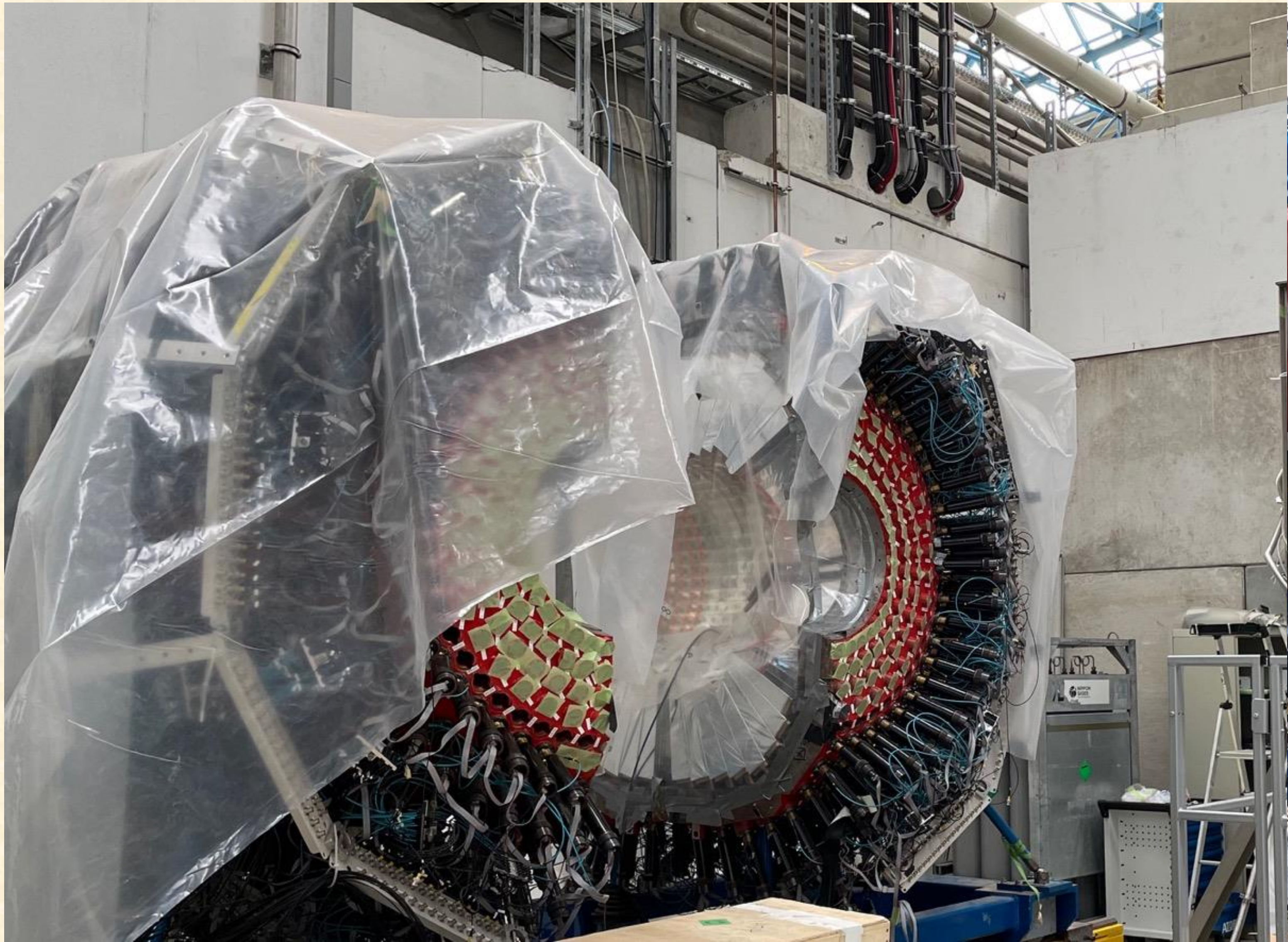
- Hiring Tobias Weber as a permanent staff in my GSI group at GSI
- Professor position at Lanzhou University

March 2019: WASA moved from Juelich to GSI



Yoshiki Tanaka (RIKEN)


Vasyl Drozd (GSI, Groningen, RIKEN)

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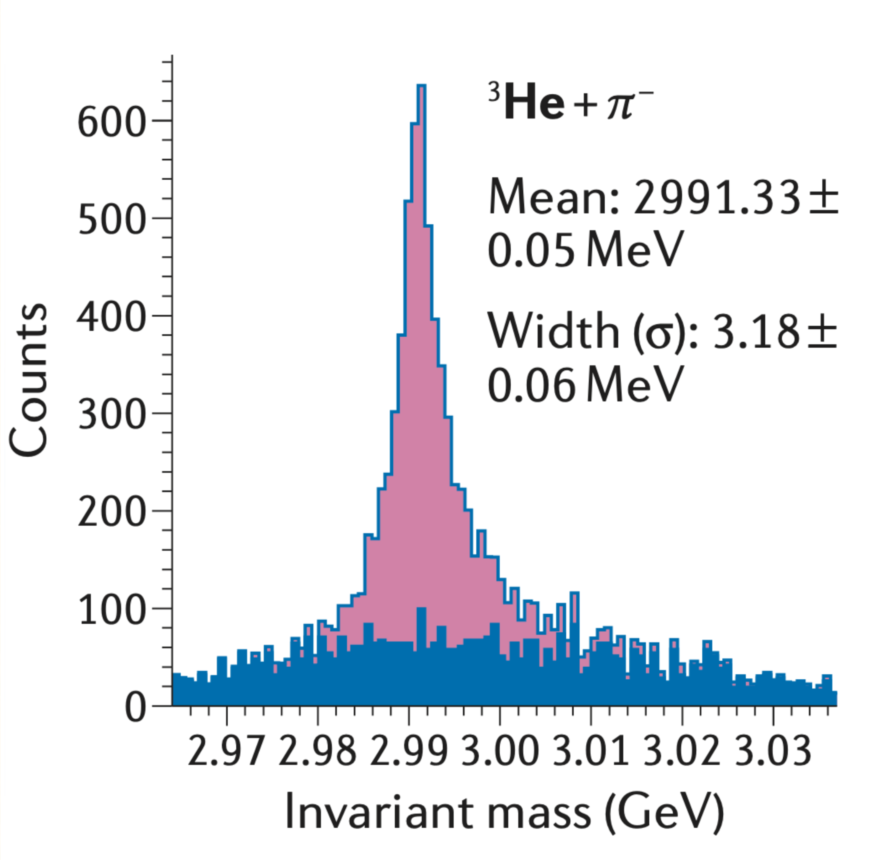
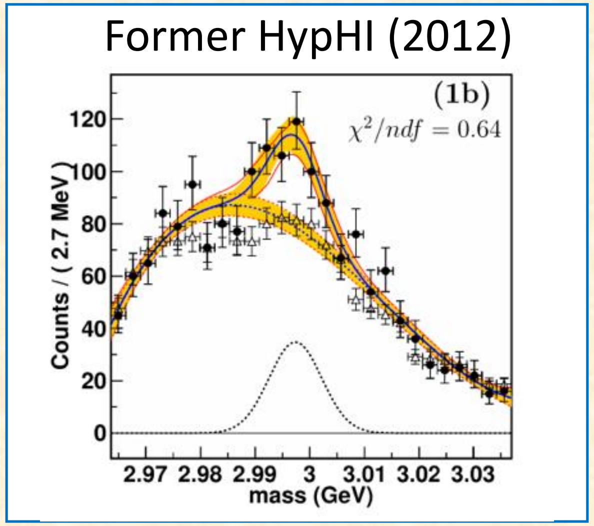
2020 -: COVID-19

Expected performance of the WASA-FRS at GSI

Expected results by updated MC simulations



4 days measurement



target position: z=25 cm
vertex z cut: 35 – 50 cm
#layer(MDC): > 6
cldst cut: < 0.3 cm

TRS et al., Nature Reviews Physics 3, 803-813 (2021) Supplement

Mass resolution:

- 3.2 MeV/c^2 (1 T field)
- 1.5 times better than HypHI

Statistics

- About 5800 in the peak for 4 days
- 38 times more than HypHI
- 120 σ significance

Expected Lifetime accuracy

- **8 ps**
- 5 times better than HypHI

The existence or not of nnΛ will be confirmed with large confidence level

Also with GNN

→ Talk by Hiroyuki Ekawa, 18:00 on Wednesday (Wed-Iva)

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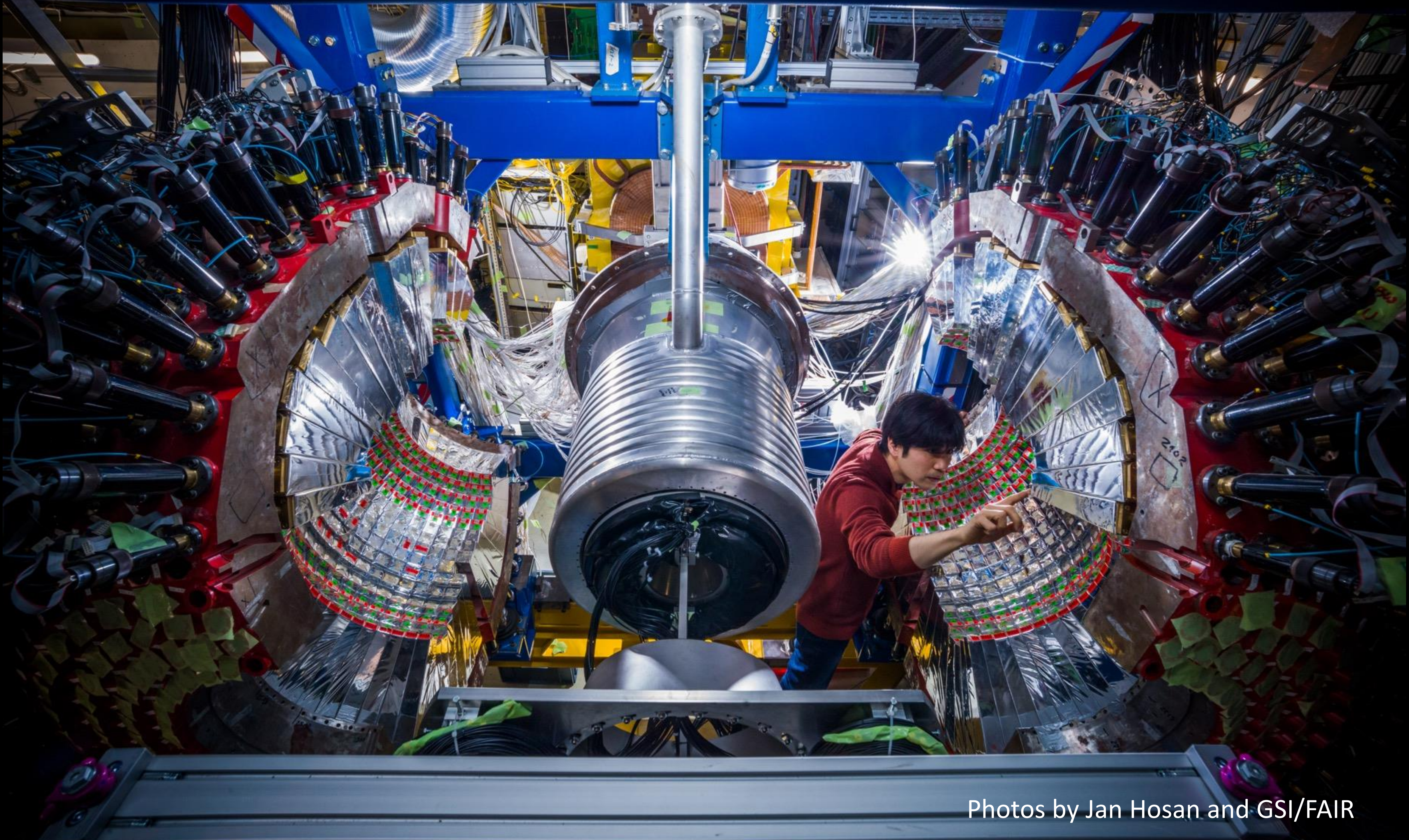
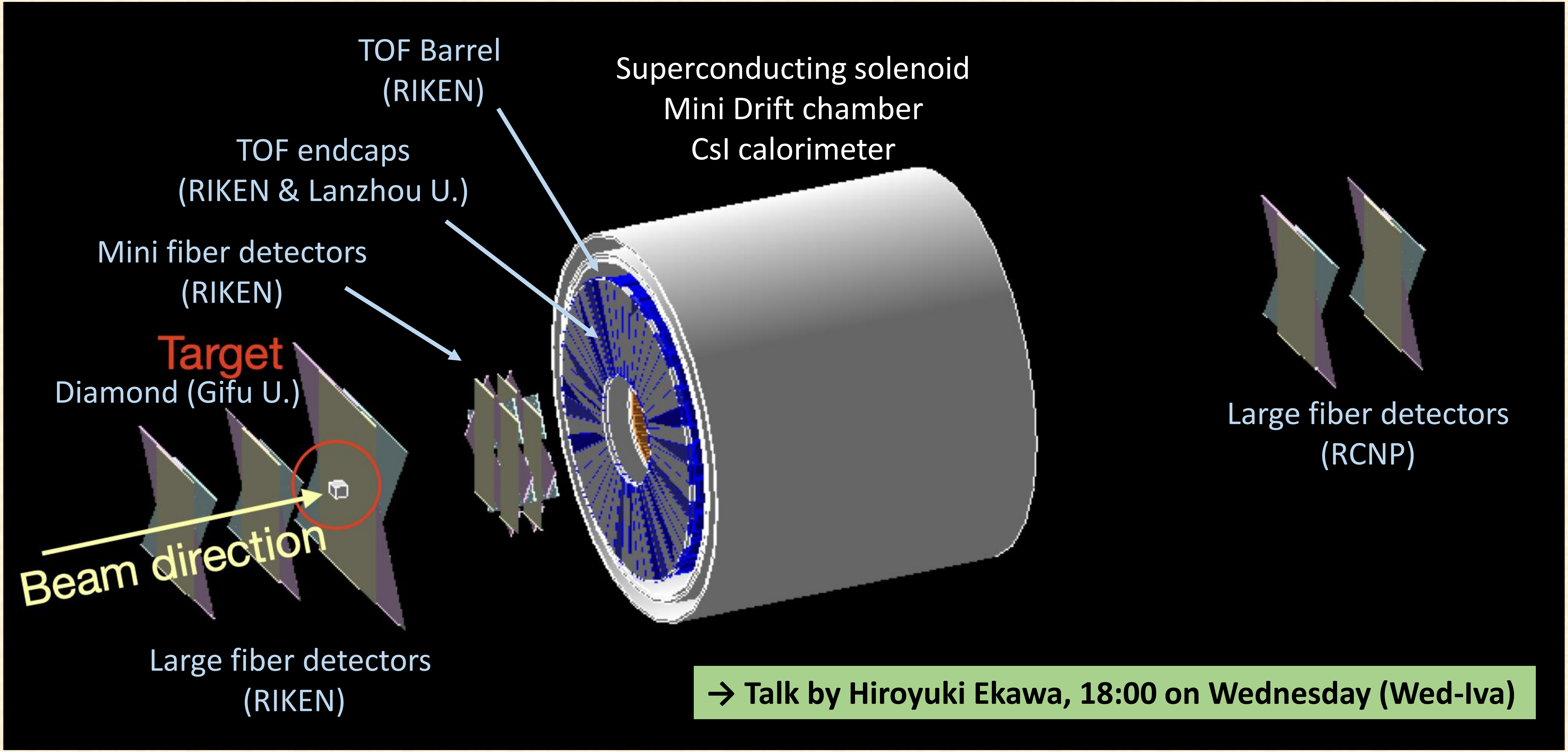
2020 -: COVID-19

2022 -: the war in Ukraine



Photos by Jan Hosan and GSI/FAIR

The WASA-FRS experiment at GSI (FAIR Phase 0)



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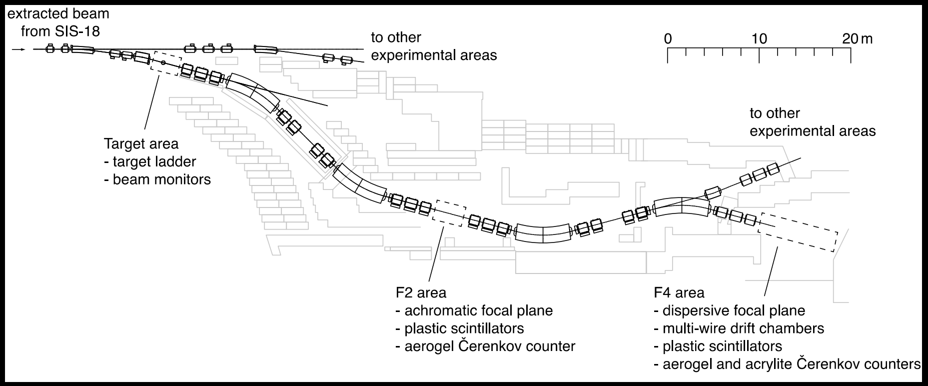
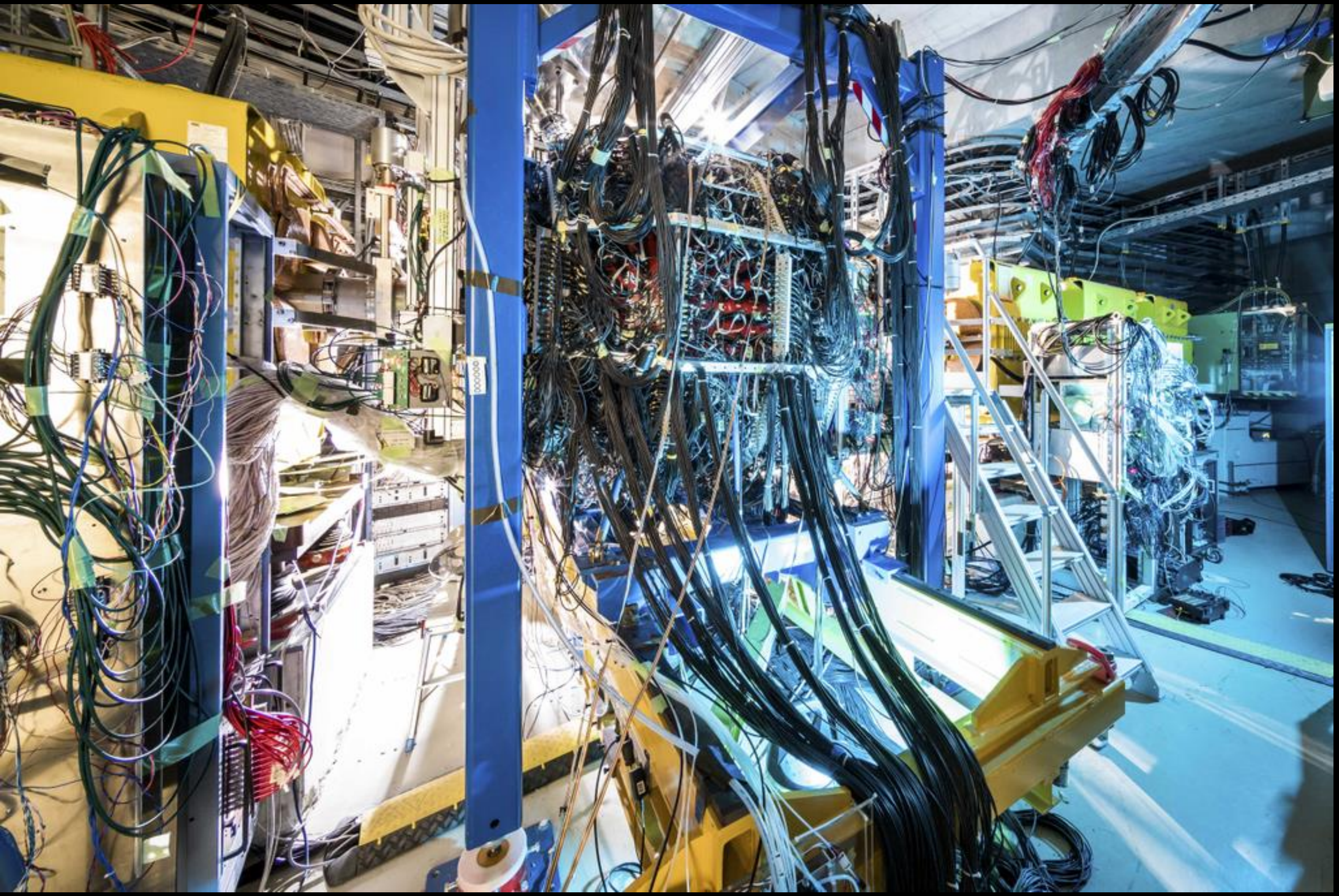
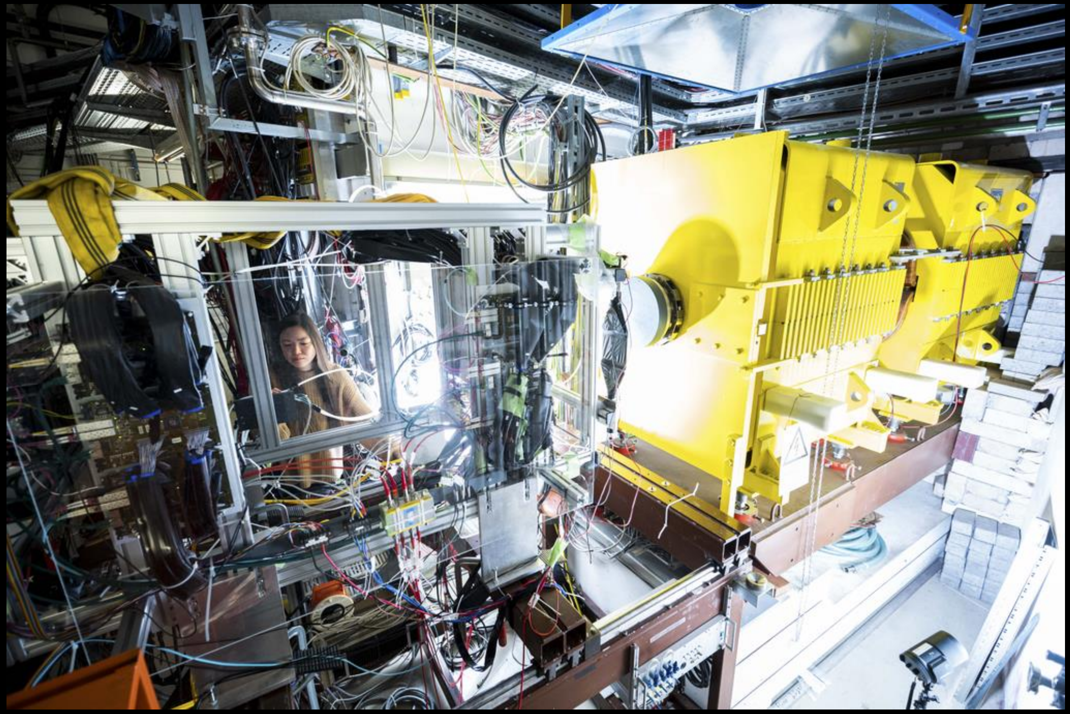




WASA at S2 of FRS



S4 of FRS

Photos by Jan Hosan and GSI/FAIR

Experiment at JLab searching for nnΛ

PHYSICAL REVIEW C **105**, L051001 (2022)

Letter

Spectroscopic study of a possible Λ*nn* resonance and a pair of Σ*NN* states using the $(e, e'K^+)$ reaction with a tritium target

B. Pandey,[1] L. Tang,[1,2,*] T. Gogami,[3,4] K. N. Suzuki,[4] K. Itabashi,[3] S. Nagao,[3] K. Okuyama,[3] S. N. Nakamura,[3] D. Abrams,[5] I. R. Afnan,[6] T. Akiyama,[3] D. Androic,[7] K. Aniol,[8] T. Averett,[9] C. Ayerbe Gayoso,[9] J. Bane,[10] S. Barcus,[9] J. Barrow,[10] V. Bellini,[11] H. Bhatt,[12] D. Bhetuwal,[12] D. Biswas,[1] A. Camsonne,[2] J. Castellanos,[13] J-P. Chen,[2] J. Chen,[9] S. Covrig,[2] D. Chrisman,[14,15] R. Cruz-Torres,[16] R. Das,[17] E. Fuchey,[18] C. Gal,[5] B. F. Gibson,[19] K. Gnanvo,[5] F. Garibaldi,[11,20] T. Gautam,[1] J. Gomez,[2] P. Gueye,[1] T. J. Hague,[21] O. Hansen,[2] W. Henry,[2] F. Hauenstein,[22] D. W. Higinbotham,[2] C. Hyde,[22] M. Kaneta,[3] C. Keppel,[2] T. Kutz,[17] N. Lashley-Colthirst,[1] S. Li,[23,24] H. Liu,[25] J. Mammei,[26] P. Markowitz,[13] R. E. McClellan,[2] F. Meddi,[11] D. Meekins,[2] R. Michaels,[2] M. Mihovilovič,[27,28,29] A. Moyer,[30] D. Nguyen,[16,31] M. Nycz,[21] V. Owen,[9] C. Palatchi,[5] S. Park,[17] T. Petkovic,[7] S. Premathilake,[5] P. E. Reimer,[32] J. Reinhold,[13] S. Riordan,[32] V. Rodriguez,[33] C. Samanta,[34] S. N. Santiesteban,[23] B. Sawatzky,[2] S. Širca,[27,28] K. Slifer,[23] T. Su,[21] Y. Tian,[35] Y. Toyama,[3] K. Uehara,[3] G. M. Urciuoli,[11] D. Votaw,[14,15] J. Williamson,[36] B. Wojtsekhowski,[2] S. Wood,[2] B. Yale,[23] Z. Ye,[32] J. Zhang,[5] and X. Zheng[5]
(Hall A Collaboration)

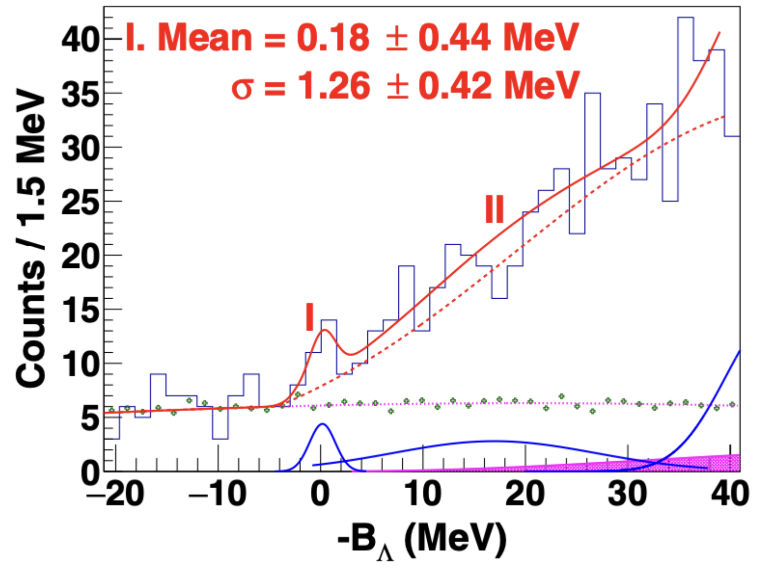


FIG. 5. The enlarged mass spectrum around the Λ*nn* threshold. Two additional Gaussians were fitted together with the known contributions (the accidentals, the Λ quasifree, the free Λ, and the ^{3}He contamination). The one at the threshold is for the small peak, while the broad one is for the additional strength above the predicted quasifree distribution.

Possibility for nnΛ

However, different interpretation from the same collaborati

- K. Itabashi et al., Few Body Syst. 63 (2022) 1, 16 (January 2022)
- K.N. Suzuki et al, PTEP, Volume 2022, Issue 1, January 2022, 013D01

We have 1.8 x 10^8 deuterons recorded at S4

What to be studied/concluded (soon)

Invariant mass and lifetime

- ${}^{3}_{\Lambda}H$
- ${}^{4}_{\Lambda}H$
- Λ

Existence or not of the nnΛ state

- By invariant mass and lifetime with $d+\pi^-$

Challenges with heavier projectile, ^{12}C

- ${}^{3}_{\Lambda}H$
- ${}^{9}_{\Lambda}B$ (proton rich hypernucleus)

→ **Talk by Hiroyuki Ekawa, 18:00 on Wednesday (Wed-Iva)**

The WASA-FRS collaboration (only core members)

- **<u>High Energy Nuclear Physics Laboratory, RIKEN, Japan:</u>**
  H. Ekawa, Y. Gao, Y. He, A. Kasagi, E. Liu, A. Muneem, M. Nakagawa, T.R. Saito, Y. Tanaka, A. Yanai, J. Yoshida, H. Wang
- **<u>HRS-HYS group, GSI, Germany</u>**
  H. Alibrahim Alfaki, V. Drozd, T.R. Saito, T. Weber
- **<u>FRS/SFRS Research Group, GSI, Germany:</u>**
  K.-H. Behr, B. v. Chamier Gliszezynski, T. Dickel, S. Dubey, J. Eusemann, D. Kostyleva, B. Franczak, H. Geissel, E. Haettner, C. Hornung, P. Roy, C. Scheidenberger, P. Schwarz, B. Szczepanczyk, M. Will, J. Zhao
- **<u>Meson Science Laboratory, RIKEN, Japan:</u>**
  K. Itahashi, R. Sekiya
- **<u>Instituto de Estructura de la Materia – CSIC, Spain:</u>**
  S. Escrig, C. Rappold
- **<u>Cryogenic Department, GSI, Germany:</u>**
  A. Beusch, H. Kollmus, C. Schroeder, B. Streicher
- **<u>Experiment Electronics Department, GSI, Germany:</u>**
  H. Heggen, N. Kurz, S. Minami
- Detector Laboratory, GSI, Germany:
  C. Nociforo, E. Rocco
- Nuclear Spectroscopy Group, GSI, Germany:
  M. Armstrong, N. Hubbard, K. Wimmer
- Super-FRS Project, GSI, Germany:
  F. Amjad, E. Kazantseva, R. Knöbel, I. Mukha, S. Pietri, S. Purushothaman, H. Weick
- Target Laboratory, GSI, Germany:
  B. Kindler, B. Lommel
- Institut für Kernphysik, Technische Universität Darmstadt, Germany:
  G. Schaumann
- University of Applied Sciences, Giessen, Germany:
  S. Kraft
- Department of Engineering, Gifu University, Japan:
  A. Kasagi, K. Nakazawa
- ESRIG - Energy and Sustainability Research Institute Groningen, University of Groningen, The Netherlands:
  V. Drozd, M. Harakeh, N. Kalantar-Nayestanaki, M. Kavatsyuk
- Institute of Modern Physics, China
  L. Duan, Y. Gao, E. Liu, J. Ong, X. Tang
- Institute of Physics, Jagiellonian University, Poland
  A. Khreptak, M. Skurzok
- Department of Low and Medium Energy Physics, Jožef Stefan Institute, Slovenia
  Z. Brencic
- Department of Physics, Kyoto University, Japan:
  R. Sekiya
- School of Nuclear Science and Technology, Lanzhou University, China
  Y. He, J. Ong, T.R. Saito, X. Tang
- Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Germany
  P. Achenbach, J. Pochdzalla
- Michigan State University, USA:
  D. Morrissey
- Universidad de Santiago de Compostela, Germany:
  J. Benlliure, M. Fontan, A. Gonzalez, G. Jimenez, J. Rodríguez-Sánchez

Young Driving Forces in the WASA-FRS project

- Yoshiki Tanaka
  (staff, High Energy Nuclear Physics Lab., RIKEN)
- Vasyl Drozd
  (Ph.D. student, HRS-HYS group, GSI, and Groningen Univ.)
- Philipp Schwarz
  (Engineer, FRS/SFRS research group, GSI)
- Tobias Weber
  (Engineer, HRS-HYS group, GSI)
- Hiroyuki Ekawa
  (postdoc, High Energy Nuclear Physics Lab., RIKEN)
- Samuel Escrig
  (Ph.D. student, CSIS-Madrid)
- Yiming Gao
  (Ph.D. student, High Energy Nuclear Physics Lab., RIKEN, and IMP-Lanzhou)
- Ayumi Kasagi
  (Ph.D. student, High Energy Nuclear Physics Lab., RIKEN, and Gifu University)
- Enqiang Liu
  (Ph.D. student, High Energy Nuclear Physics Lab., RIKEN, and IMP-Lanzhou)
- Manami Nakagawa
  (postdoc, High Energy Nuclear Physics Lab., RIKEN)
- Cristophe Rappold
  (Group leader, CSIS-Madrid)
- Ryohei Sekiya
  (Ph.D. student, Meson Science Lab., RIKEN, and Kyoto University)
- Ayari Yanai
  (Master student, High Energy Nuclear Physics Lab., RIKEN, and Saitama University)

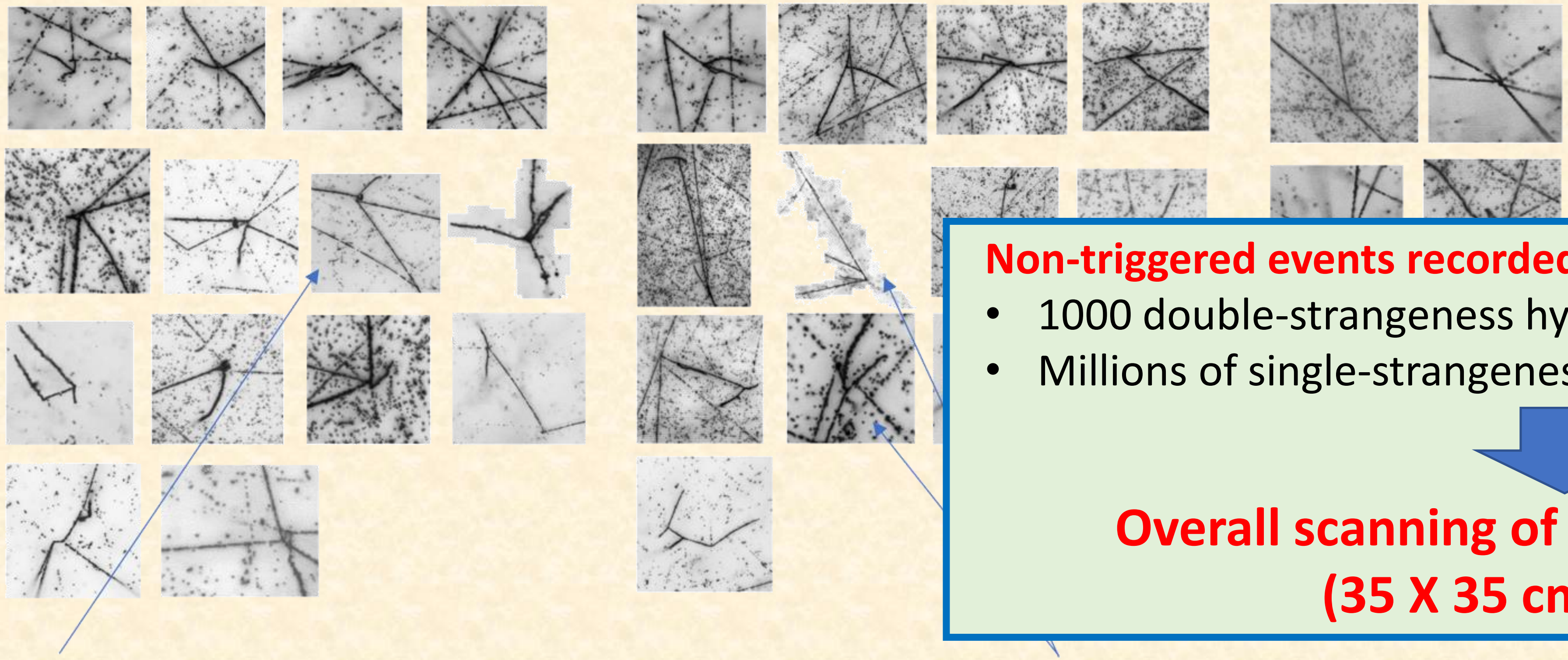
Part of the WASA-FRS collaboration

Photo by Gabi Ott (GSI/FAIR)

How about
the hypertriton binding energy?

Results from J-PARC E07 (Hybrid method)

$\Lambda\Lambda$ candidates: 14 | Twin Λ events: 13 | Others: 6



Non-triggered events recorded in 1000 emulsions sheets

- 1000 double-strangeness hypernuclear events
- Millions of single-strangeness hypernuclear events

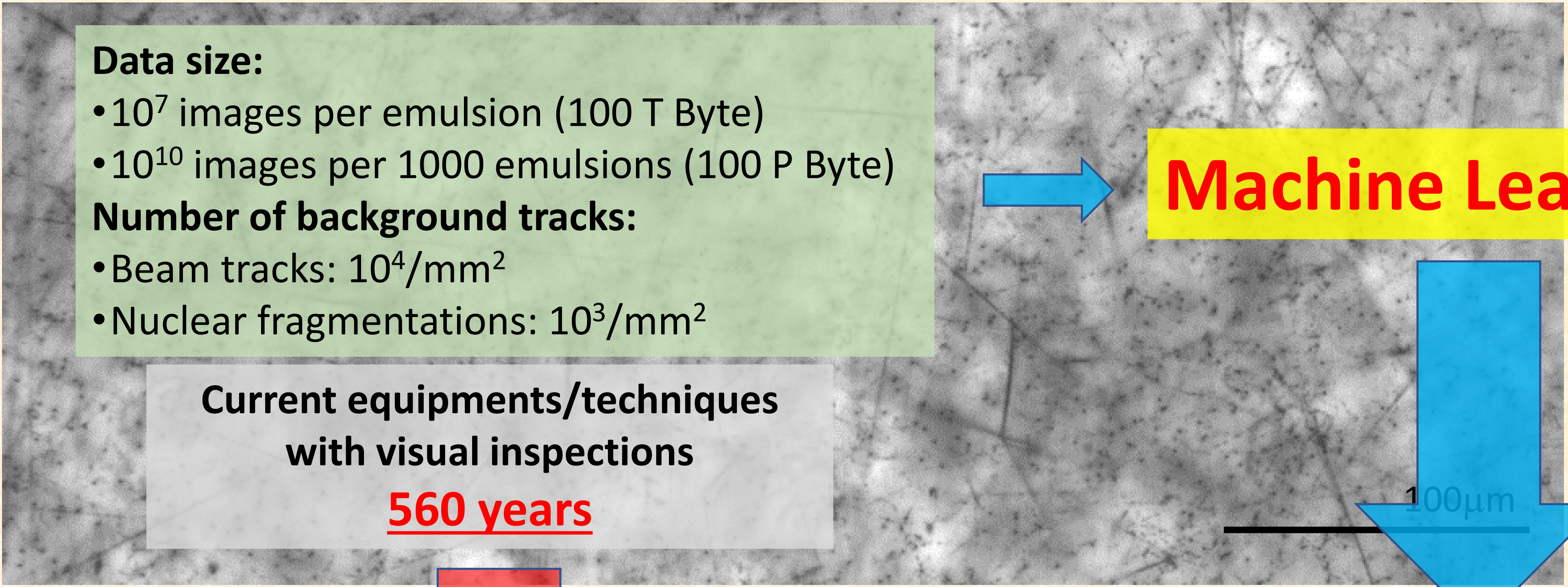
Overall scanning of all emulsion sheets
(35 X 35 cm^2 X 1000)

$_{\Lambda\Lambda}$Be
H. Ekawa et al., Prog. Theor. Exp. Phys. 2019, 021D02

$^{15}_{\Xi}$C
S. H. Hayakawa et al.,
Physical Review Letters, 126, 062501 (2021)

→ Talk by Manami Nakagawa, 17:45 on Wednesday (Wed-Iva)

Overall scanning for E07 emulsions



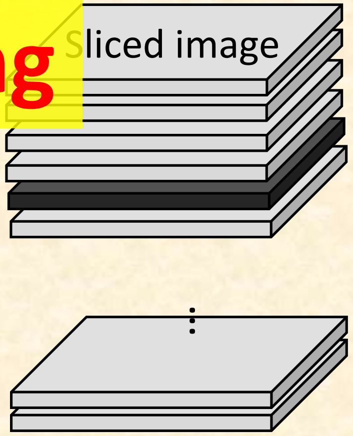
Data size:
- 10^7 images per emulsion (100 T Byte)
- 10^{10} images per 1000 emulsions (100 P Byte)

Number of background tracks:
- Beam tracks: $10^4/mm^2$
- Nuclear fragmentations: $10^3/mm^2$

Current equipments/techniques with visual inspections
560 years

3 years

Machine Learning



Millions of single-strangeness hypernuclei
1000 double strangeness hypernuclei (formerly only 5)

→ Talk by Manami Nakagawa, 17:45 on Wednesday (Wed-Iva)

Emulsion scanning system at HENP/RIKEN

Five microscope stations for emulsions

- Three stations are operational since April 2020
- Two additional stations from Gifu University are arrived TODAY

On June 28th, 2022

Challenges for Machine Learning Development

MOST IMPORTANT:

- **Quantity and quality of training data**

However,

No existing data for hypertriton with emulsions for training

What have been done since 2020:

Production of training data

- Monte Carlo simulations
- Image transfer techniques, GAN(Generative Adversarial Networks)

Detection of stopped-hypertriton decay (^{3}He + π^{-})

- Mask R-CNN model

→ Talk by Manami Nakagawa, 17:45 on Wednesday (Wed-Iva)

Discovery of the first hypertriton event in E07 emulsions

nature reviews physics

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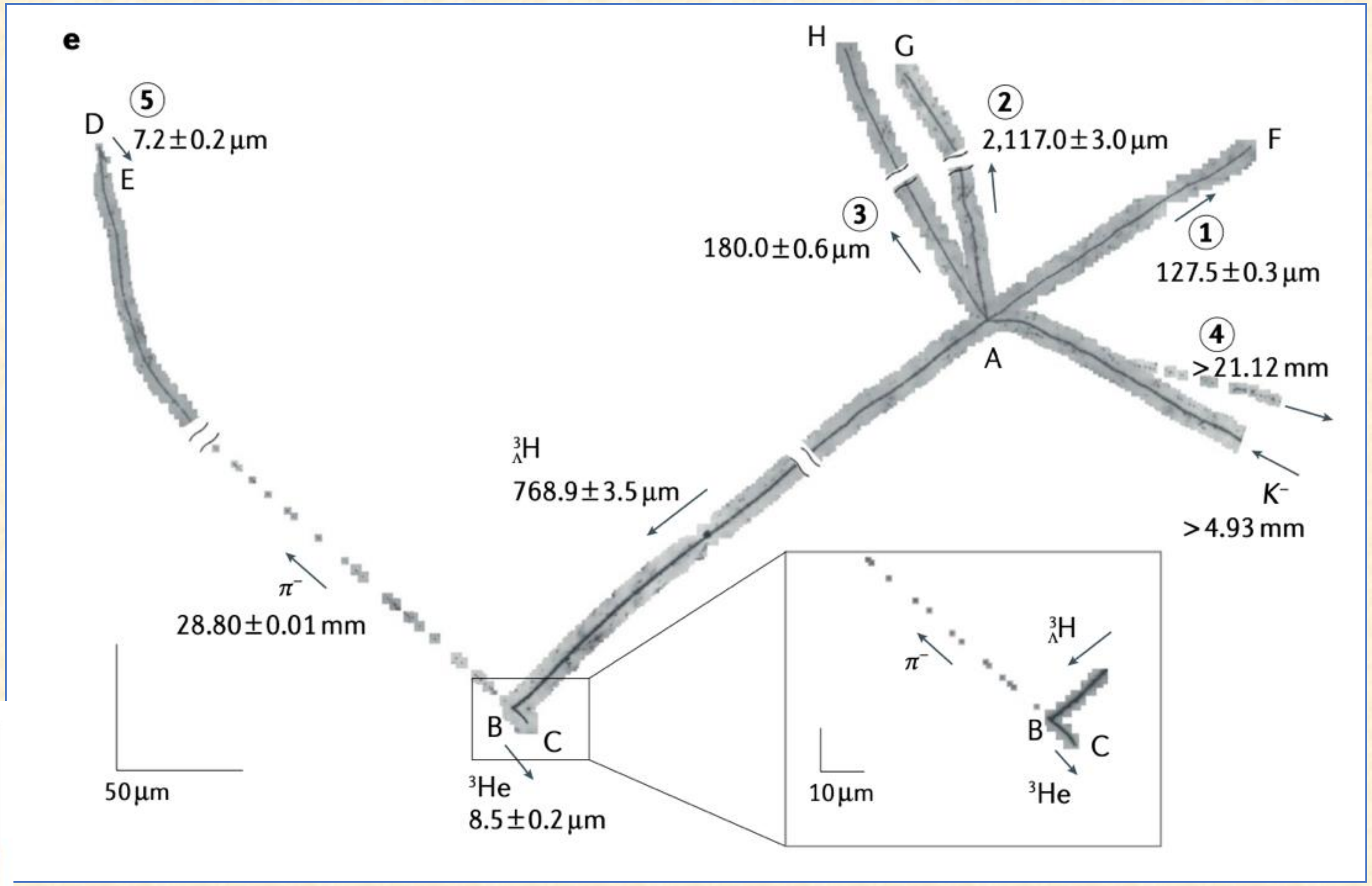
nature > nature reviews physics > perspectives > article

Perspective | Published: 14 September 2021

New directions in hypernuclear physics

Takehiko R. Saito, Wenbou Dou, Vasyl Drozd, Hiroyuki Ekawa, Samuel Escrig, Yan He, Nasser Kalantar-Nayestanaki, Ayumi Kasagi, Myroslav Kavatsyuk, Enqiang Liu, Yue Ma, Shizu Minami, Abdul Muneem, Manami Nakagawa, Kazuma Nakazawa, Christophe Rappold, Nami Saito, Christoph Scheidenberger, Masato Taki, Yoshiki K. Tanaka, Junya Yoshida, Masahiro Yoshimoto, He Wang & Xiaohong Zhou

Nature Reviews Physics (2021) | Cite this article



TRS et al., Nature Reviews Physics, 803-813 (2021)
Cover of December 2021 issue

Guaranteeing the determination of the hypertriton binding energy SOON

Precision: 28 keV

E. Liu et al., EPJ A57 (2021) 327

→ Talk by Manami Nakagawa, 17:45 on Wednesday (Wed-Iva)

Nuclear Emulsion + Machine Learning Collaboration

- High Energy Nuclear Physics Laboratory, RIKEN, Japan
  Michi Ando, Wenbo Dou, Hiroyuki Ekawa, Yiming Gao, Chiho Harisaki, Yan He, Risa Kobayashi, Hanako Kubota, Enqiang Liu, Manami Nakagawa, Nami Saito, Takehiko R. Saito, Shohei Sugimoto, Yoshiki Tanaka, Junya Yoshida, Masahiro Yoshimoto, He Wang
- Instituto de Estructura de la Materia, Consejo Superior de Investigaciones Científicas (CSIC), Spain
  Christophe Rappold
- Department of Engineering, Gifu University
  Ayumi Kasagi, Kazuma Nakazawa
- Faculty of Engineering Sciences, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology, Pakistan
  Abdul Muneem
- Institute of Modern Physics, Chinese Academy of Sciences, China
  Yiming Gao, Enqiang Liu
- School of Nuclear Science and Technology, Lanzhou University, China
  Yan He, Takehiko R. Saito
- Graduate School of Artificial Intelligence and Science, Rikkyo University, Japan
  Masato Taki
- Department of Physics, Saitama University, Japan
  Wenbo Dou, Shohei Sugimoto
- Department of Physics, Tohoku University, Japan
  Junya Yoshida

Administration:

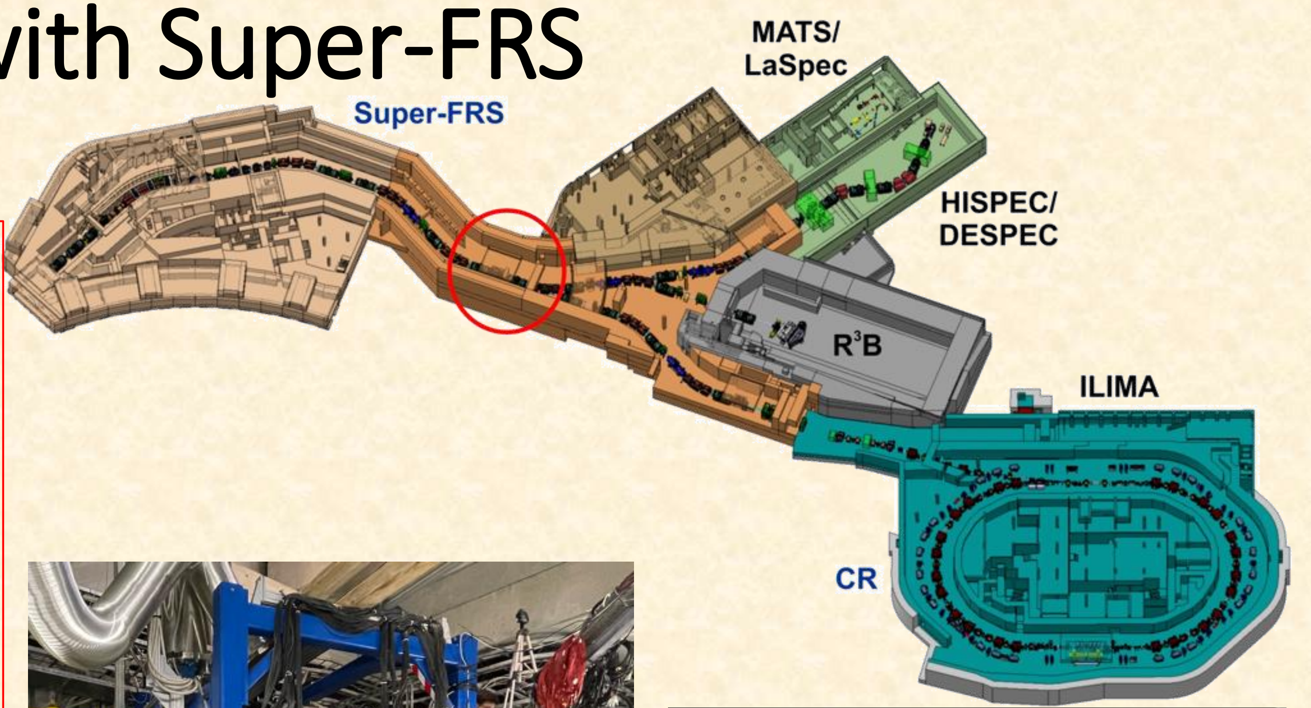
•High Energy Nuclear Physics Laboratory, RIKEN

Yukiko Kurakata

Perspective

Hypernuclear experiments with Super-FRS

One of Day-1 experiments of NUSTAR at FAIR

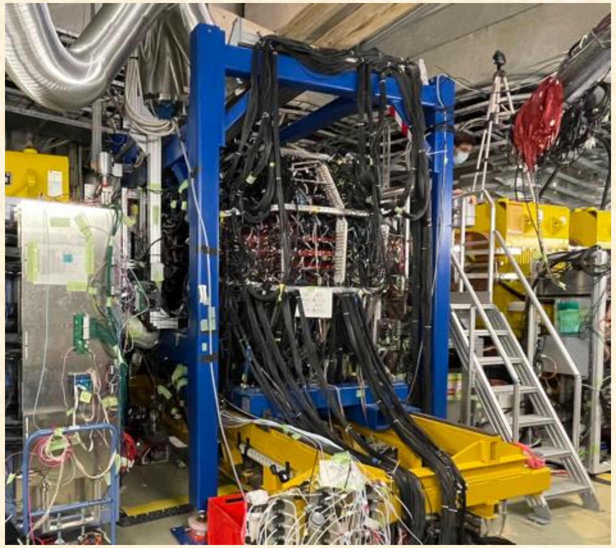


Single-strangeness hypernuclei
Up to A~20
Also with multibody-decay channels

- Hypernuclear lifetime
  very precisely
- Hypernuclear binding energy
  reasonably precise
- Hypernuclear resonance
- **Hypernuclear cross section and kinematics**
  Revealing the production mechanism

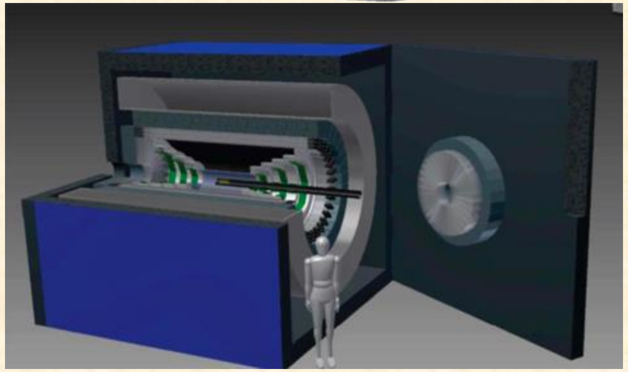
- Proton rich hypernuclei
  with proton-rich RI-beams
  C. Rappold et al., Phys. Rev. C 94, 044616 (2016)

- **Extremely neutron-rich hypernuclei**
  with charge exchange reactions
  MISSING MASS method
  TRS et al., EPJ A57 (2021) 159



Upgrading the WASA

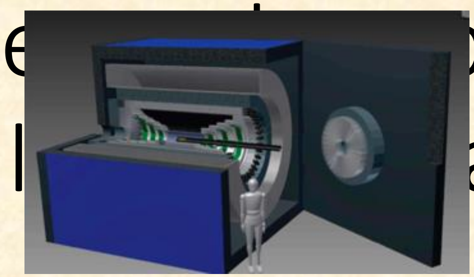
- Inner drift chamber
  In progress with the MOST fund at Lanzhou University
- Magnet upgrade with MgB_2 and Cryocooler

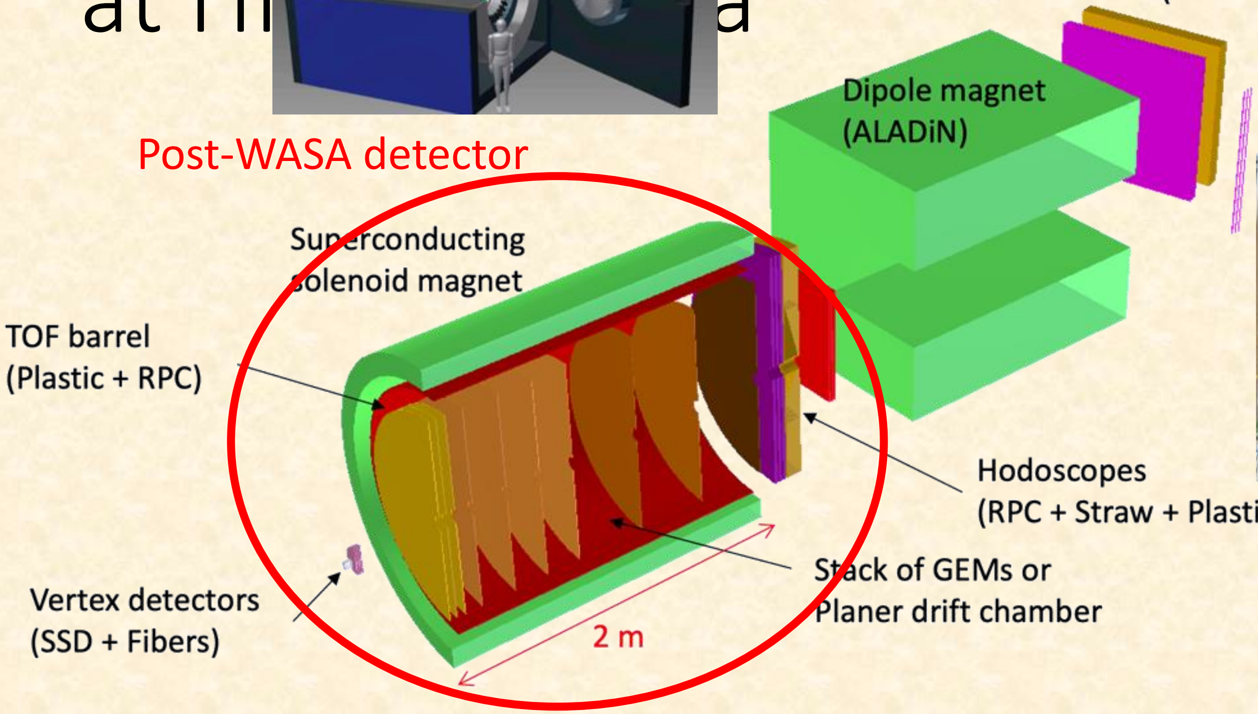


New detector development

- Large super-conducting solenoid
- Inner- and outer-detectors

Hype… roject (4.25 A GeV) at HI… a





$d + \Xi^- \rightarrow {}^{3}_{\Xi^-}n \rightarrow n\Lambda\Lambda$

$t + \Xi^- \rightarrow {}^{4}_{\Xi^-}n \rightarrow nn\Lambda\Lambda$

${}^{3}He + \Xi^- \rightarrow {}^{4}_{\Xi^-}H \rightarrow {}^{4}_{\Lambda\Lambda}H$

${}^{4}He + \Xi^- \rightarrow {}^{5}_{\Xi^-}H \rightarrow {}^{5}_{\Lambda\Lambda}H$

${}^{6}Li + \Xi^- \rightarrow {}^{7}_{\Xi^-}He \rightarrow {}^{7}_{\Lambda\Lambda}He$

${}^{6}Li + \Xi^- \rightarrow {}^{7}_{\Xi^-}He \rightarrow {}^{6}_{\Lambda\Lambda}He + n$

${}^{7}Li + \Xi^- \rightarrow {}^{8}_{\Xi^-}He \rightarrow {}^{8}_{\Lambda\Lambda}He$

${}^{9}Be + \Xi^- \rightarrow {}^{10}_{\Xi^-}Li \rightarrow {}^{10}_{\Lambda\Lambda}Li$

${}^{10}Be + \Xi^- \rightarrow {}^{11}_{\Xi^-}Li \rightarrow {}^{11}_{\Lambda\Lambda}Li$

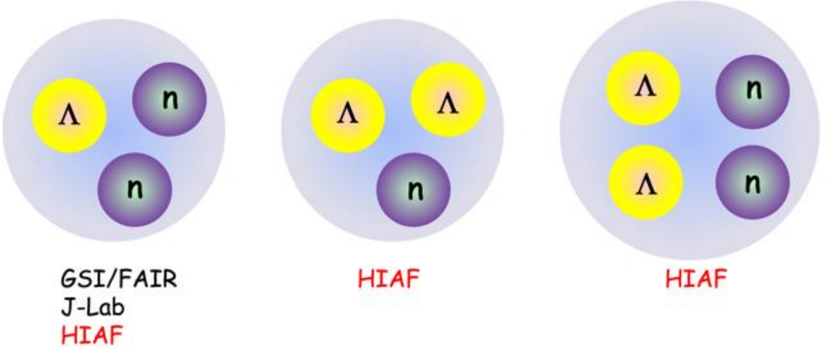
${}^{10}B + \Xi^- \rightarrow {}^{11}_{\Xi^-}Be \rightarrow {}^{11}_{\Lambda\Lambda}Be$

${}^{11}B + \Xi^- \rightarrow {}^{12}_{\Xi^-}Be \rightarrow {}^{12}_{\Lambda\Lambda}Be$

	Single-strangeness hypernuclei	Double-strangeness hypernuclei
Observation per week	6 X 10^6	6 X 10^2
Lifetime accuracy	**~ 1 ps**	**~ 10 ps**
Binding energy accuracy	~ 100 keV	Sub MeV

Hypernuclear scattering experiment feasible

Femto Neutron Stars
(named by Josef Pochodzalla)



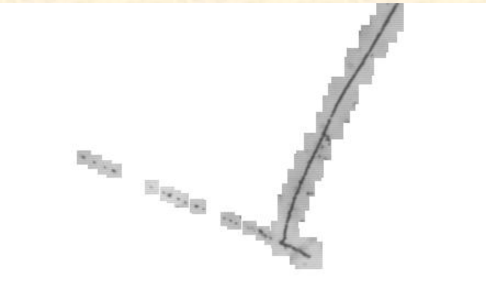
Precise measurement of Hypernuclei

Binding energy

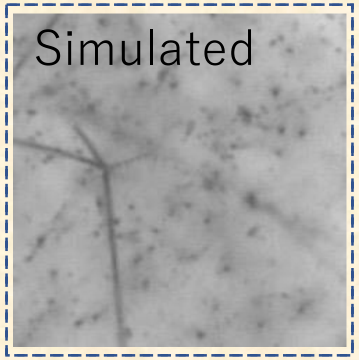
$^{3}_{\Lambda}$H, $^{4}_{\Lambda}$H, $^{4}_{\Lambda}$He, $^{5}_{\Lambda}$He…

Chage symmetry breaking

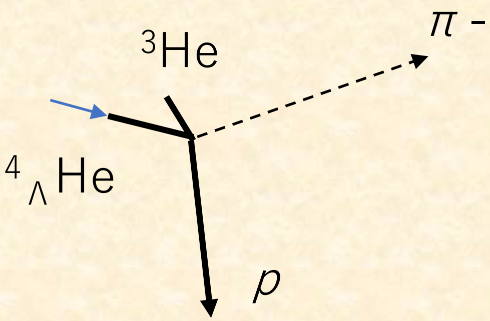
$^{4}_{\Lambda}$H (2-body decay)



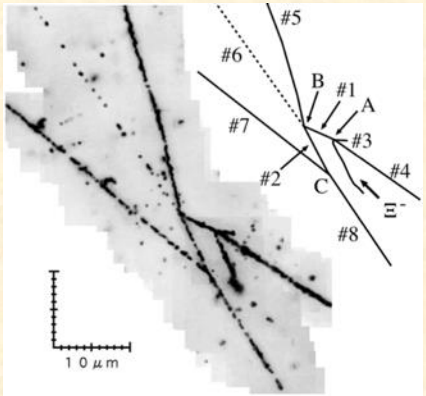
$^{4}_{\Lambda}$He (3-body decay)

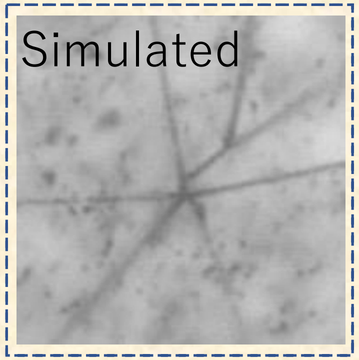


10 μm

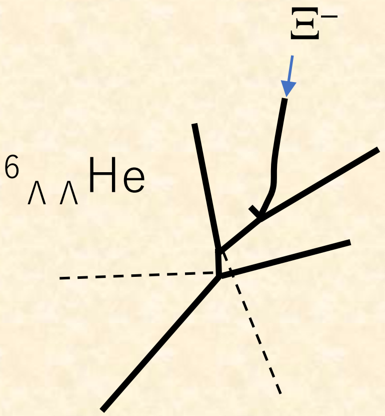


Double-strangeness hypernuclei





10 μm



Measurements for Lifetime, Decay mode, Magnetic moment Hypernuclear scattering etc…

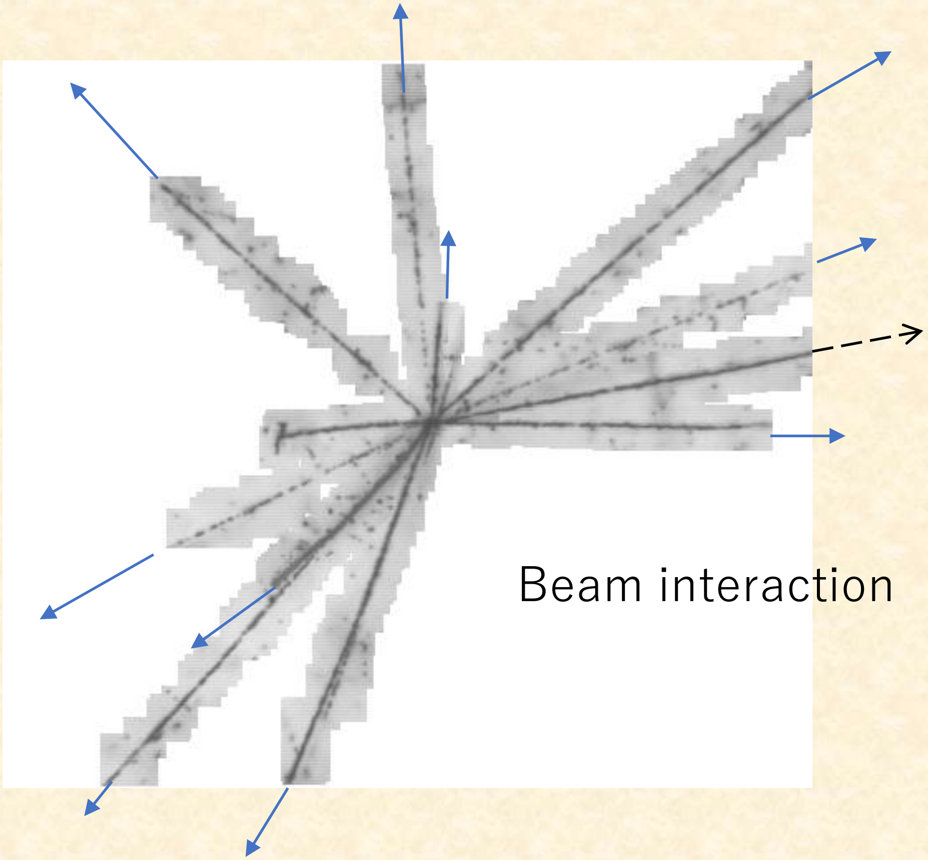
at FAIR in Germany（S = -1)

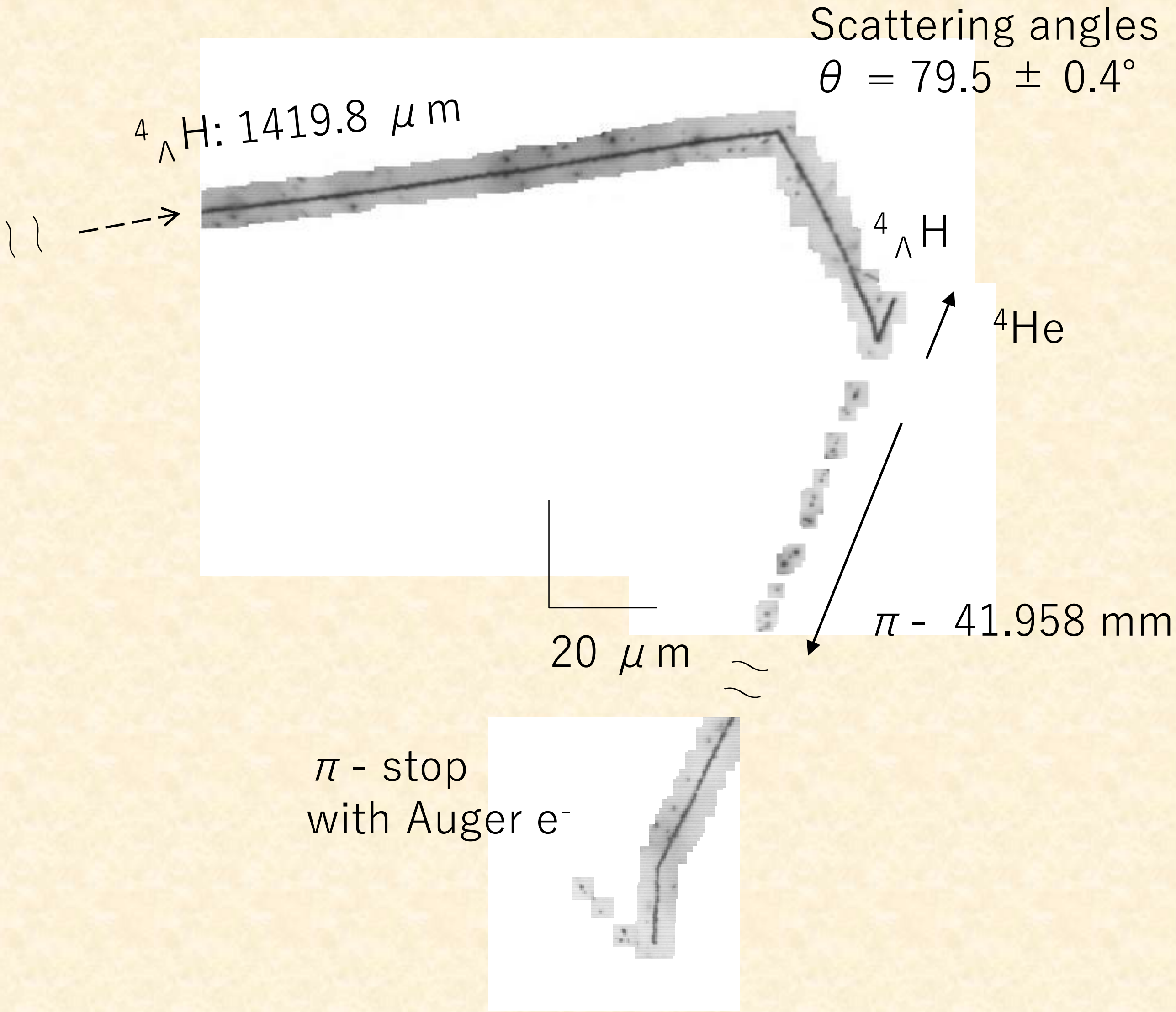
at HIAF in China (S = -2)

→ Talk by Manami Nakagawa, 17:45 on Wednesday (Wed-Iva)

New discovery 1:

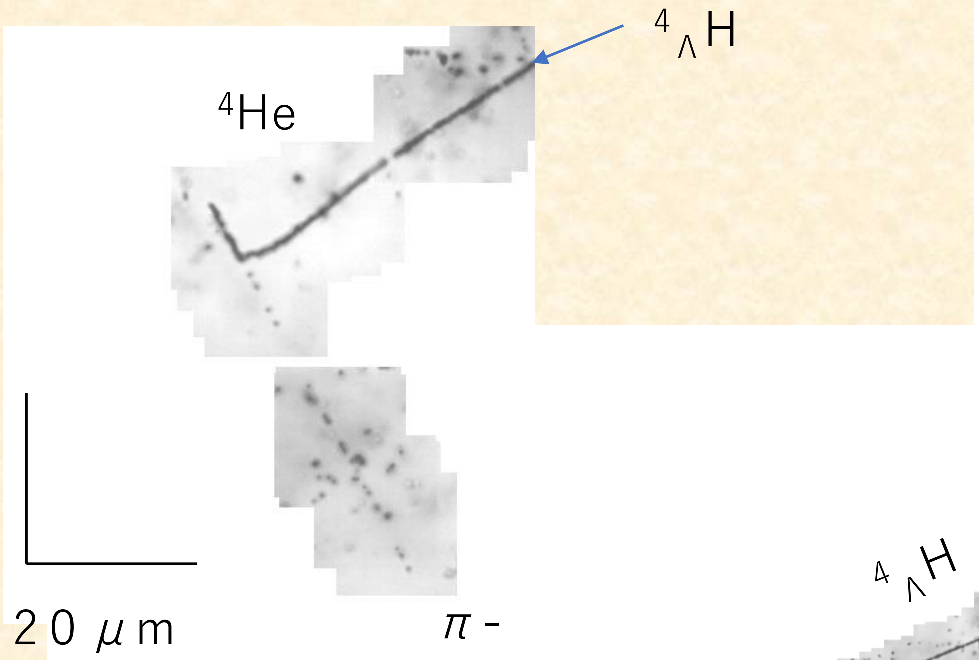
Hypernuclear scattering

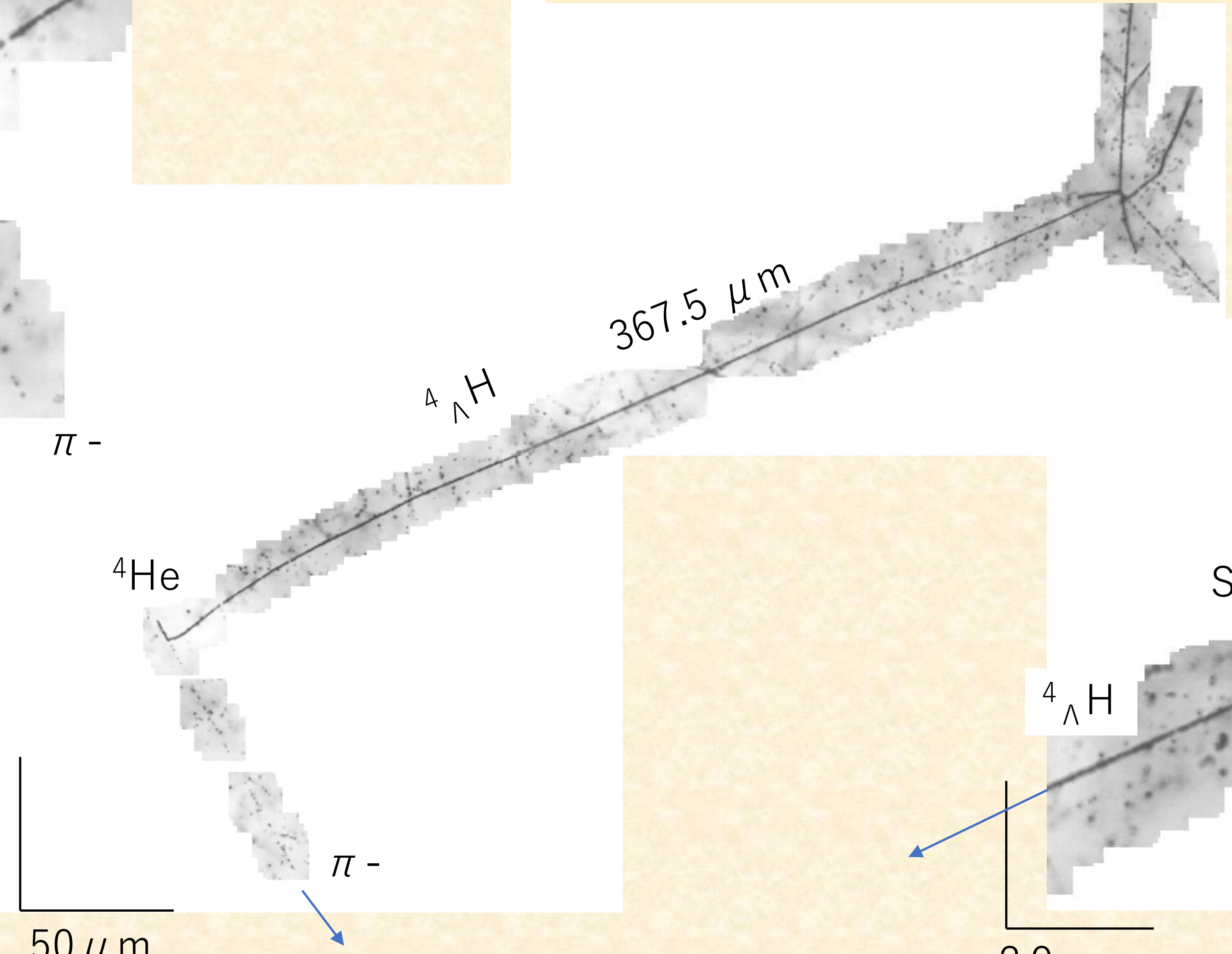


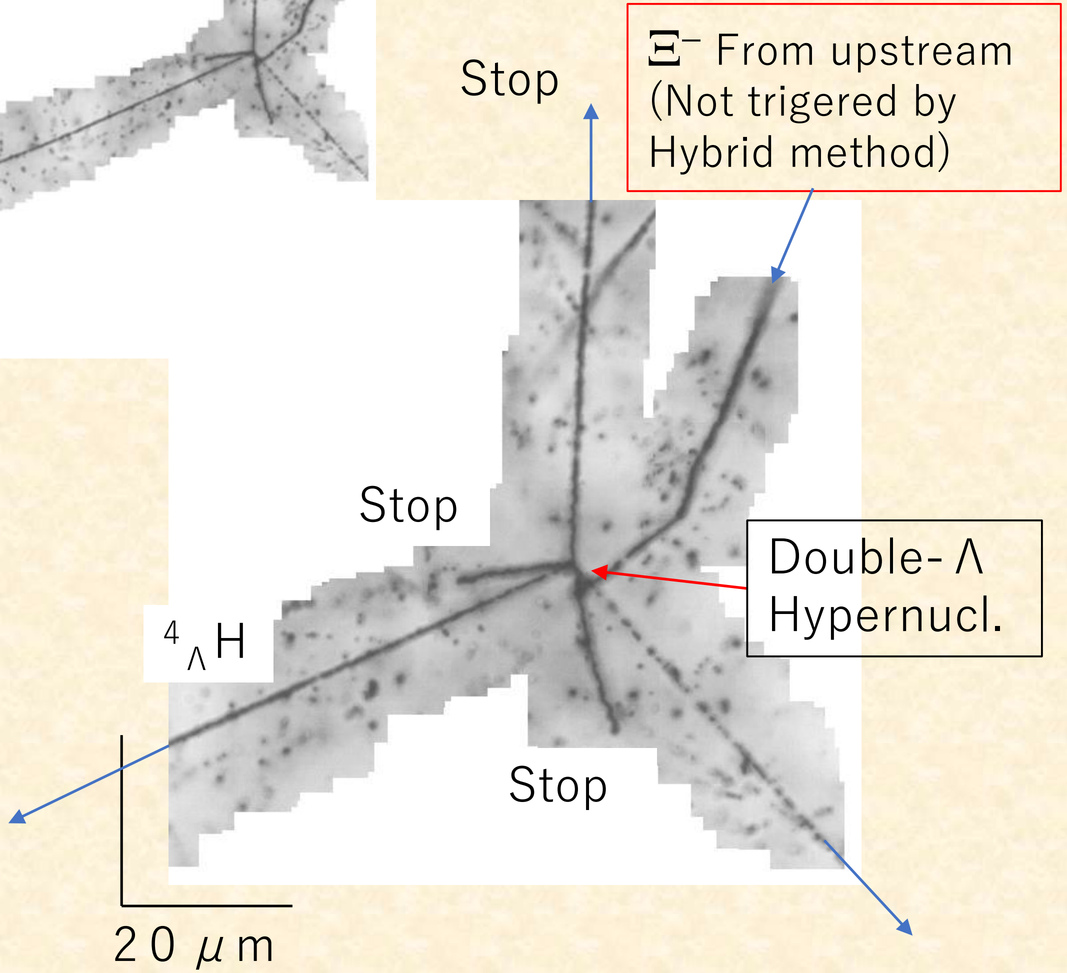


New discovery 2:

Discovery of double-Λ hypernucleus as a biproduct of $^{3}_{\Lambda}H$ search







Summary

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Perspective | Published: 14 September 2021

New directions in hypernuclear physics

Takehiko R. Saito ✉, Wenbou Dou, Vasyl Drozd, Hiroyuki Ekawa, Samuel Escrig, Yan He, Nasser Kalantar-Nayestanaki, Ayumi Kasagi, Myroslav Kavatsyuk, Enqiang Liu, Yue Ma, Shizu Minami, Abdul Muneem, Manami Nakagawa, Kazuma Nakazawa, Christophe Rappold, Nami Saito, Christoph Scheidenberger, Masato Taki, Yoshiki K. Tanaka, Junya Yoshida, Masahiro Yoshimoto, He Wang & Xiaohong Zhou

Nature Reviews Physics (2021) | Cite this article

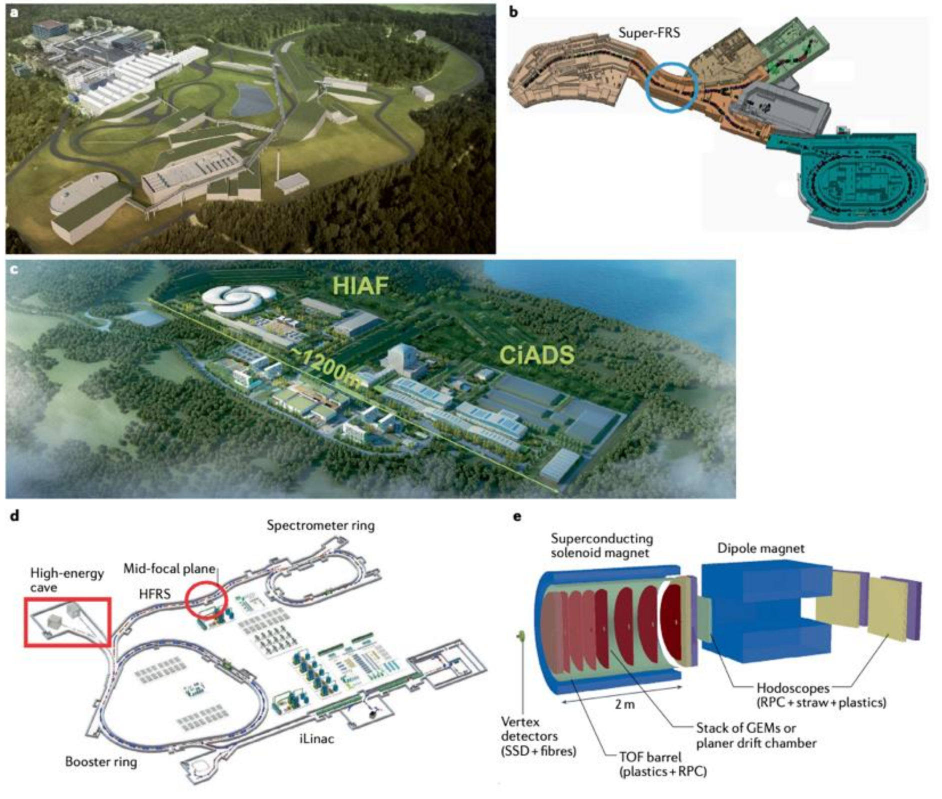


Fig. 3 | **Upcoming hypernuclear experiments. a** | A rendered bird's-eye view image of the Facility for Antiproton and Ion Research (FAIR) facility. **b** | A schematic layout of the NUSTAR facility. The Super-FRS is shown with its pre-separator and main separator in light brown and orange, respectively. A dedicated experimental setup for hypernuclear experiments will be installed in the mid-focal plane, indicated by the blue circle. **c** | A rendered bird's-eye view image of the High Intensity Heavy-ion Accelerator Facility (HIAF), together with the China initiative Accelerator Driven System (CiADS). **d** | Layout of the HIAF accelerator complex. **e** | The proposed detector setup in the high-energy cave. A part of the setup with the superconducting solenoid magnet will also be used in the mid-focal plane (indicated by the red circle in panel **d**) of the high-energy fragment separator (HFRS). GEMs, gas electron multipliers; RPC, resistive plate chamber; SSD, Si-strip detector; TOF, time-of-flight. Panel **b** is adapted with permission from REF.[76].

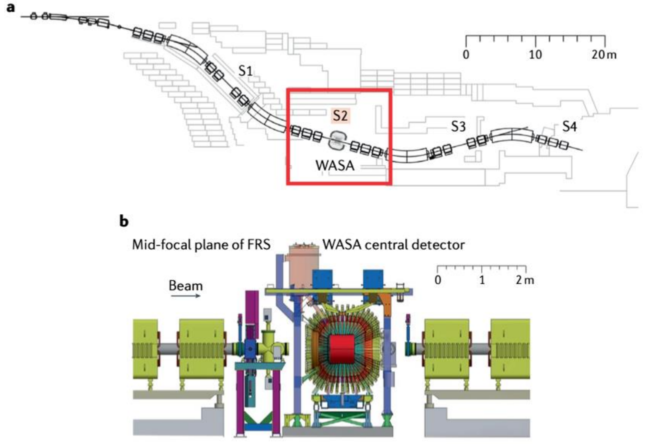
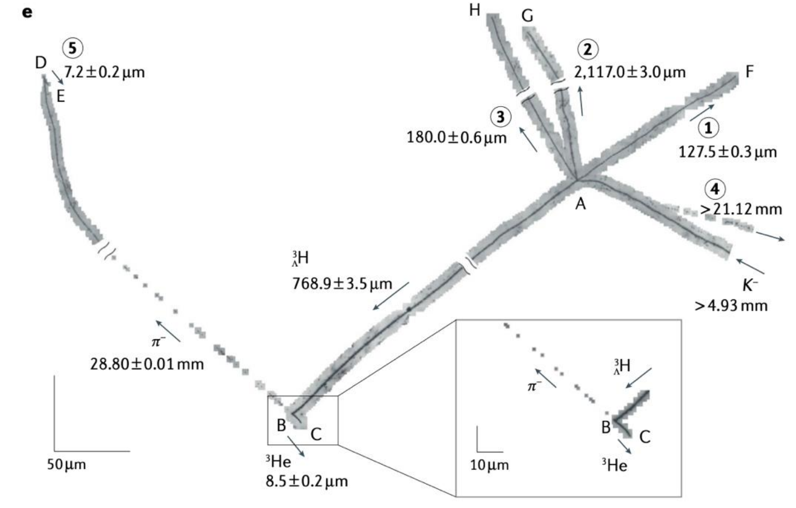
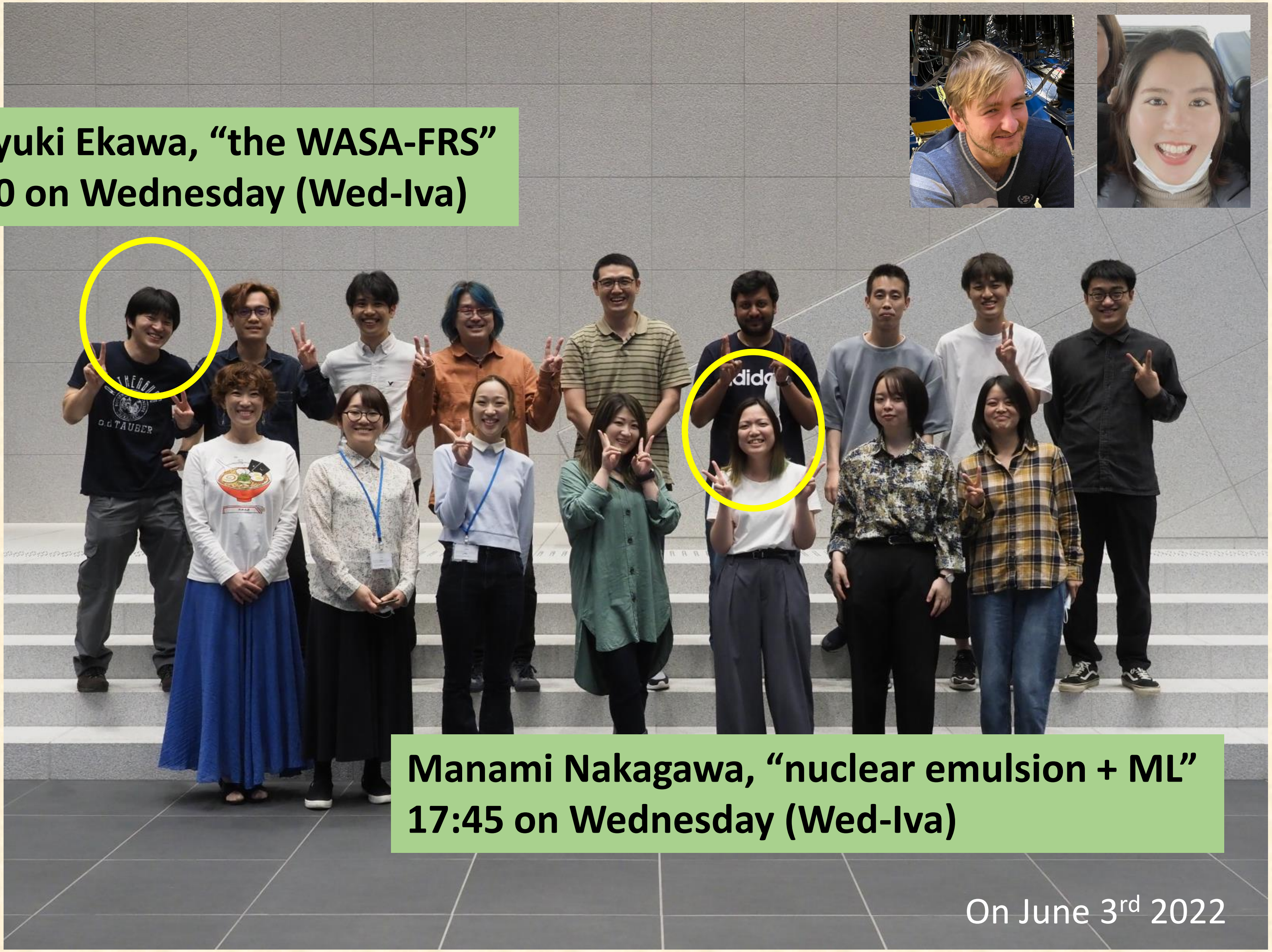


Fig. 1 | **The WASA-FRS hypernuclear experiment. a** | Schematic drawing of the fragment separator (FRS) at GSI. The ^{6}Li primary beams at 2 A GeV are delivered to the diamond target located at the mid-focal plane of the FRS, referred to as S2, to produce hypernuclei of interest. Residual nuclei of the π^- weak decays of hypernuclei are transported from S2 to S4 in the FRS, and measured precisely with a momentum-resolving power of 10^{-4}. The π^- mesons produced by the hypernuclear decays are measured at S2 by the Wide Angle Shower Apparatus (WASA) central detector. **b** | The WASA central detector. Panel **b** is adapted with permission from REF.[76].



TRS et al., Nature Reviews Physics, 803-813 (2021)

High Energy Nuclear Physics Lab. at RIKEN since 2019



Hiroyuki Ekawa, “the WASA-FRS”
18:00 on Wednesday (Wed-Iva)

Manami Nakagawa, “nuclear emulsion + ML”
17:45 on Wednesday (Wed-Iva)

On June 3rd 2022

Assistant:
- Yukiko Kurakata

Staff researchers:
- Yoshiki Tanaka
- He Wang

Postdocs:
- Hiroyuki Ekawa
- Manami Nakagawa

Ph.D. students:
- Vasyl Drozd
- Yiming Gao
- Yan He
- Ayumi Kasagi
- Enqiang Liu
- Abdul Muneem

Master students:
- Shohei Sugimoto
- Ayari Yanai

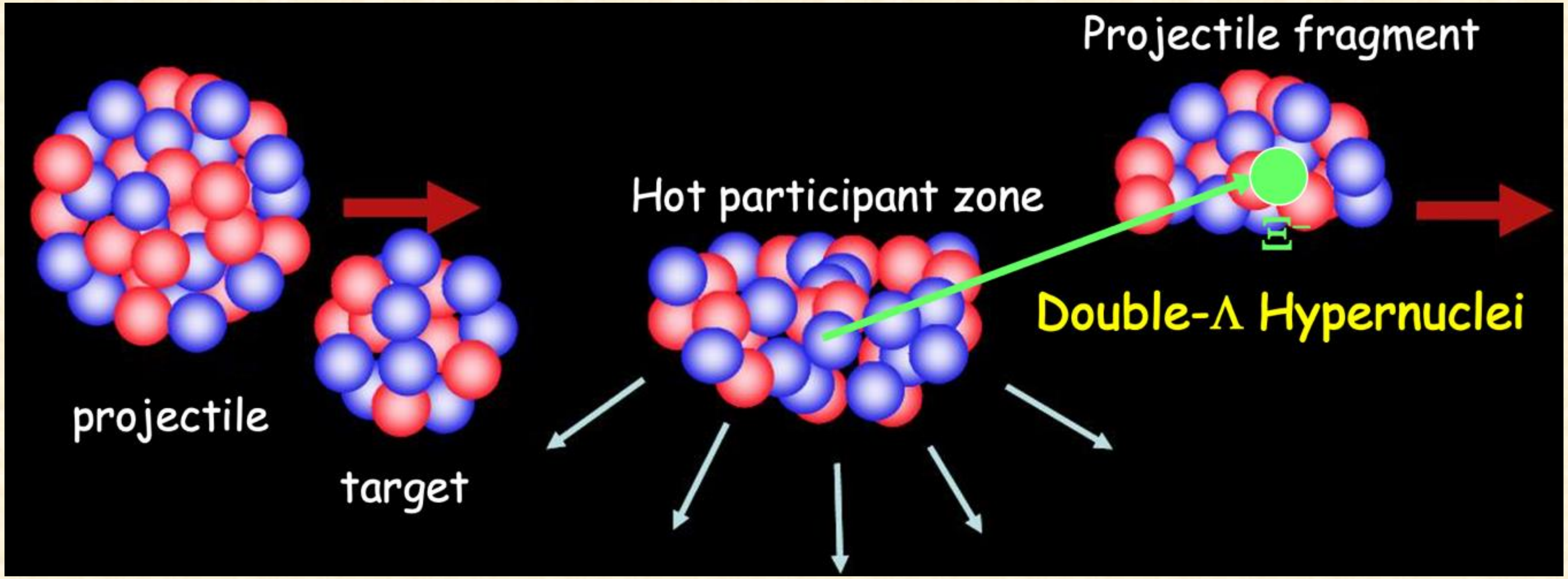
Technical staffs:
- Michi Ando
- Chiho Harisaki
- Risa Kobayashi
- Hanako Kubota

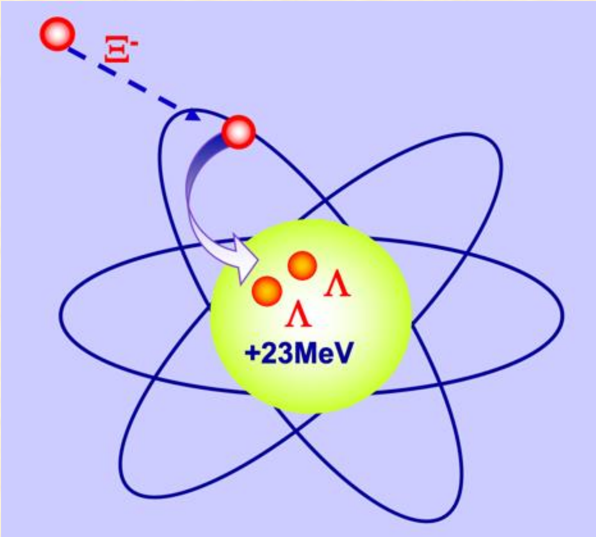
Chief scientist:
- Take R. Saito

Spare slides

Hypernuclear project at HIAF in China

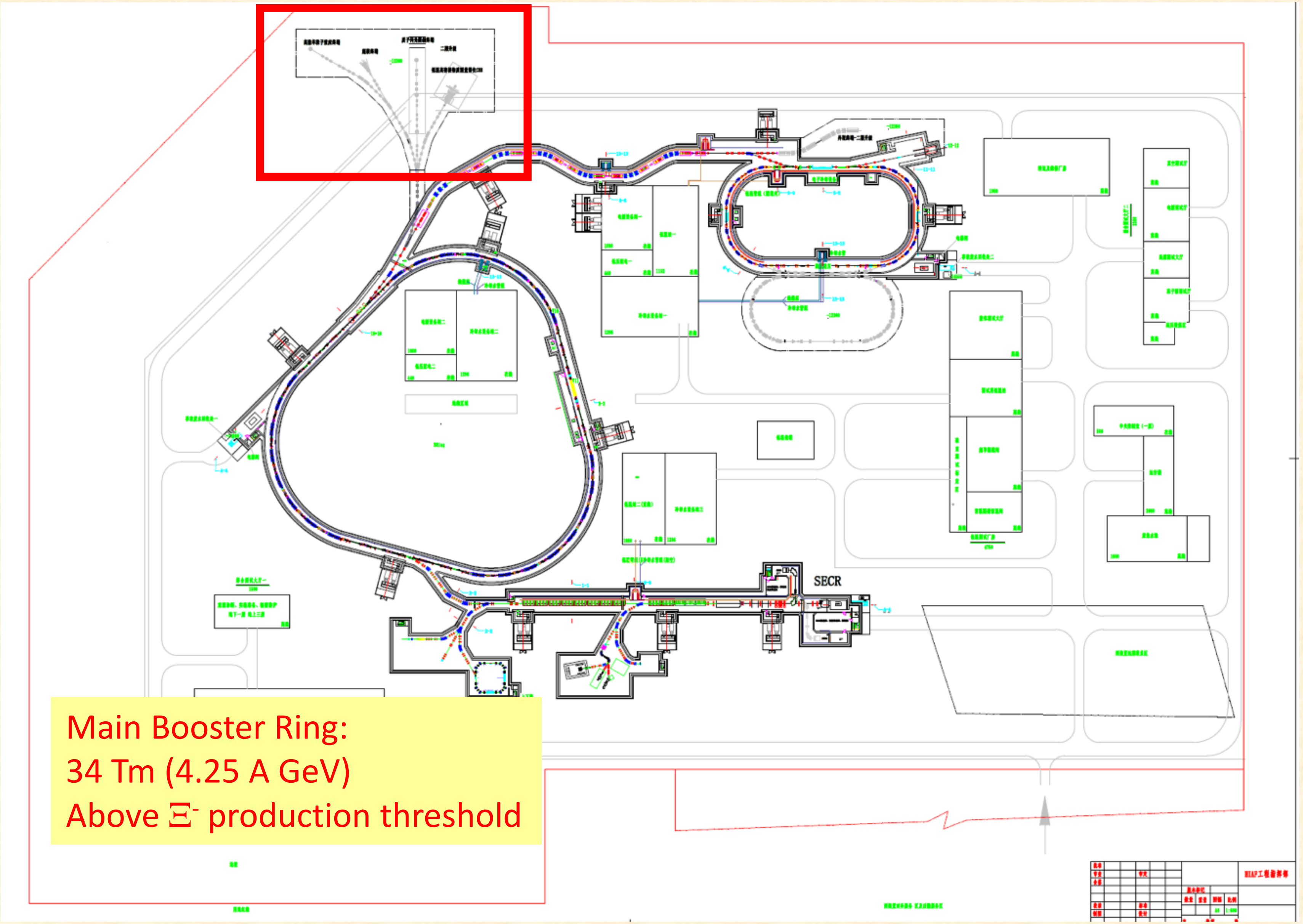
Towards double-strangeness hypernuclei: E > 3.75 A GeV





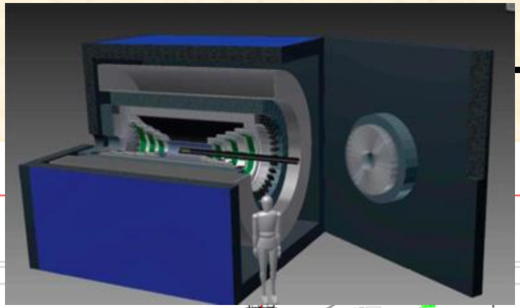
Huge variety of
- Λ hypernuclei
- Σ hypernuclei
- Ξ hypernuclei
- Double-Λ hypernuclei

Hypernuclear project at HIAF in China

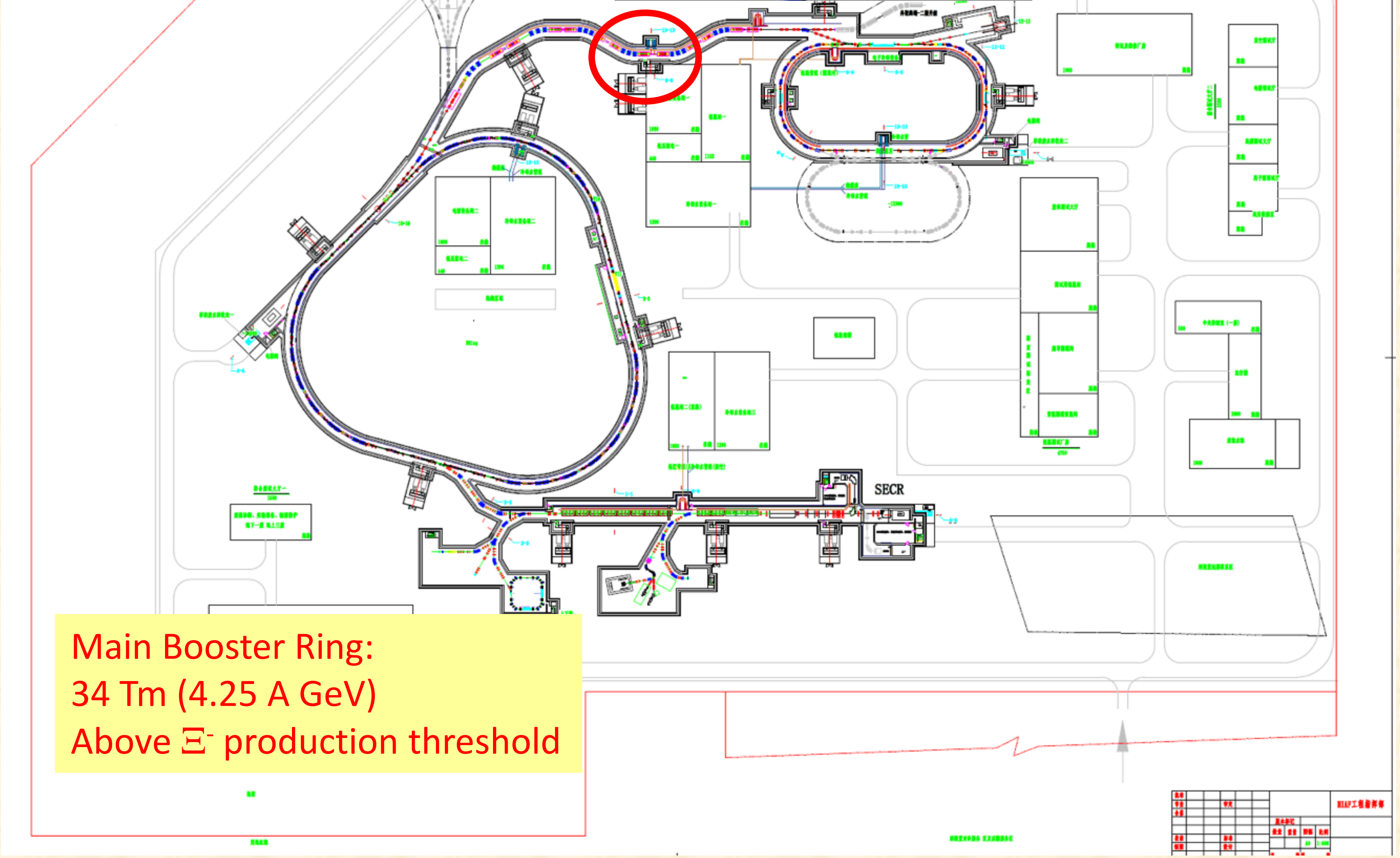


Main Booster Ring:
34 Tm (4.25 A GeV)
Above Ξ^- production threshold

Hypernuclear … HIAF in China



Hypernuclear and nuclear physics



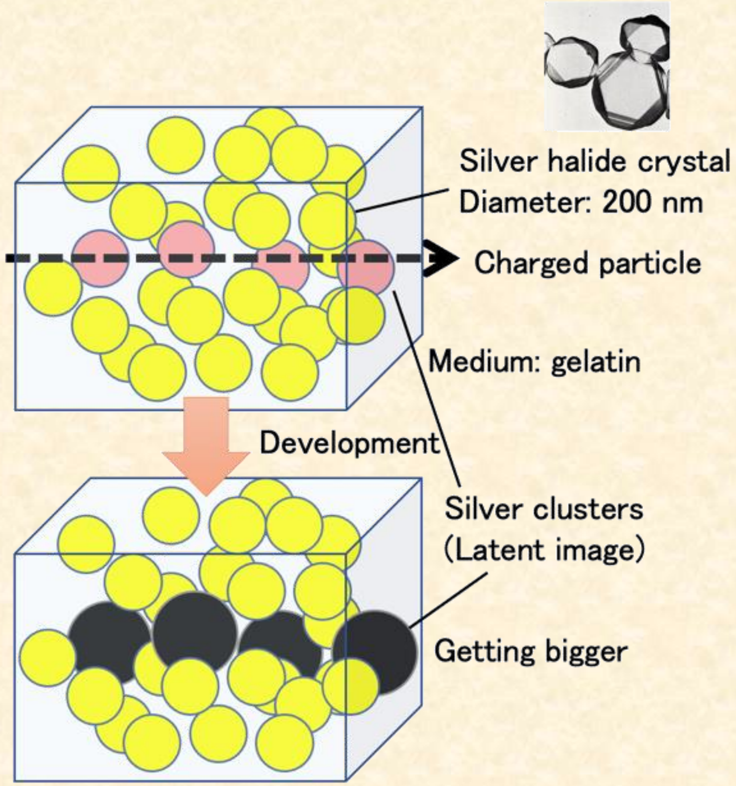
Main Booster Ring:
34 Tm (4.25 A GeV)
Above Ξ^- production threshold

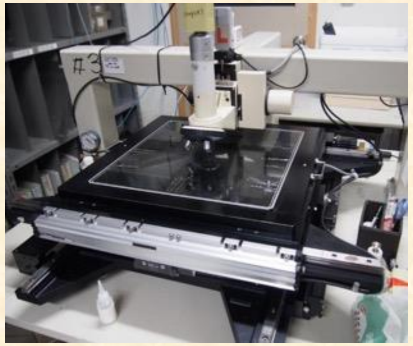
<u>Nuclear Emulsion</u>:

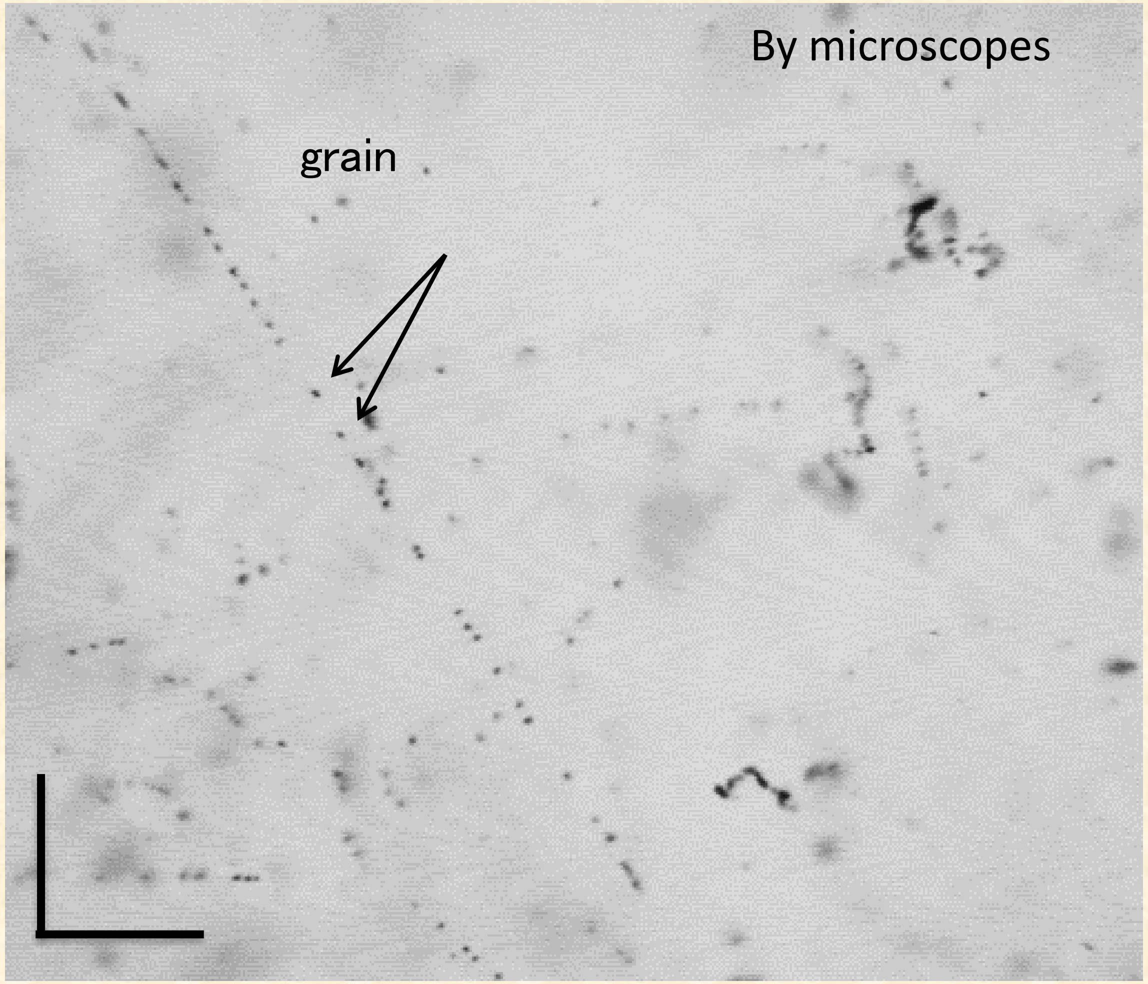
Charged particle tracker with

<u>the best spatial resolution</u>

<u>(easy to be < 1 μm, 11 nm at best)</u>



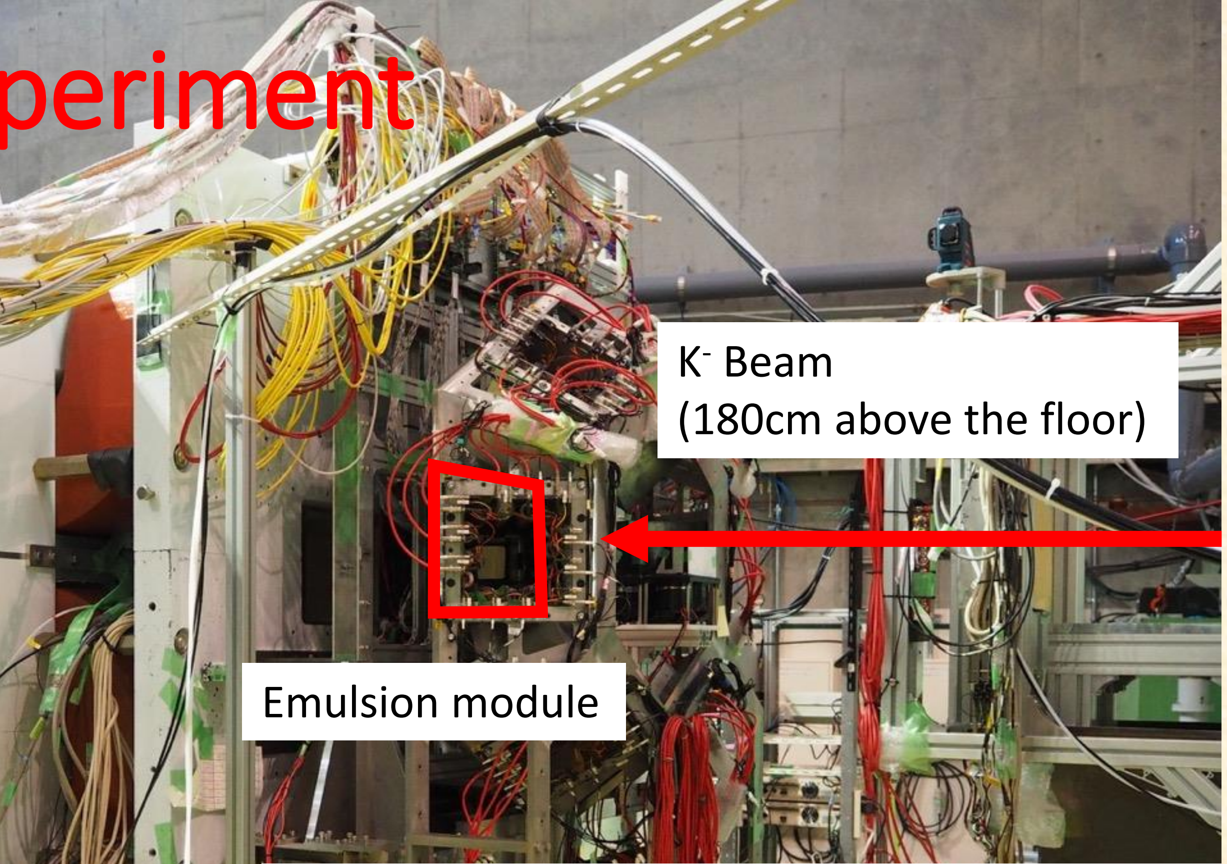


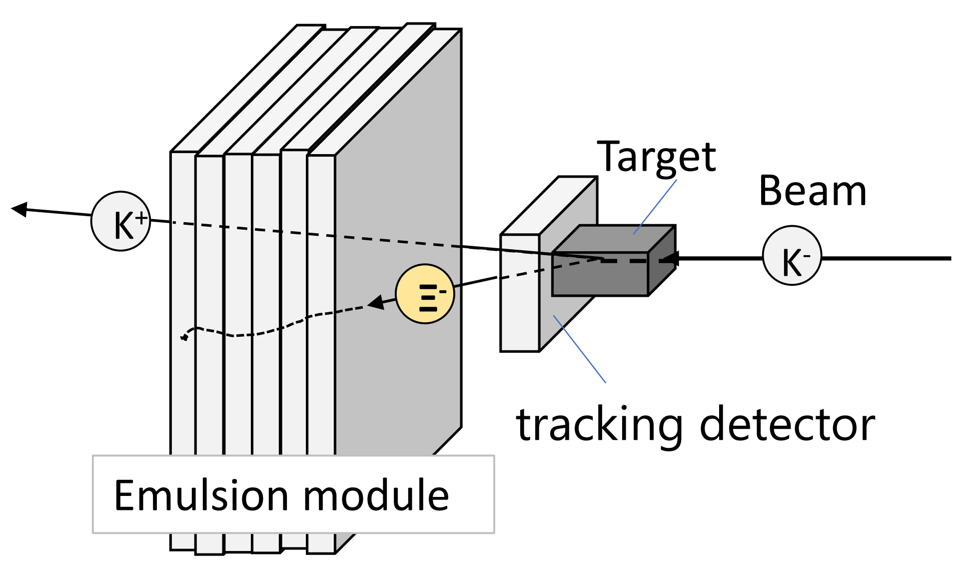


20μm

J-PARC accelerator facility

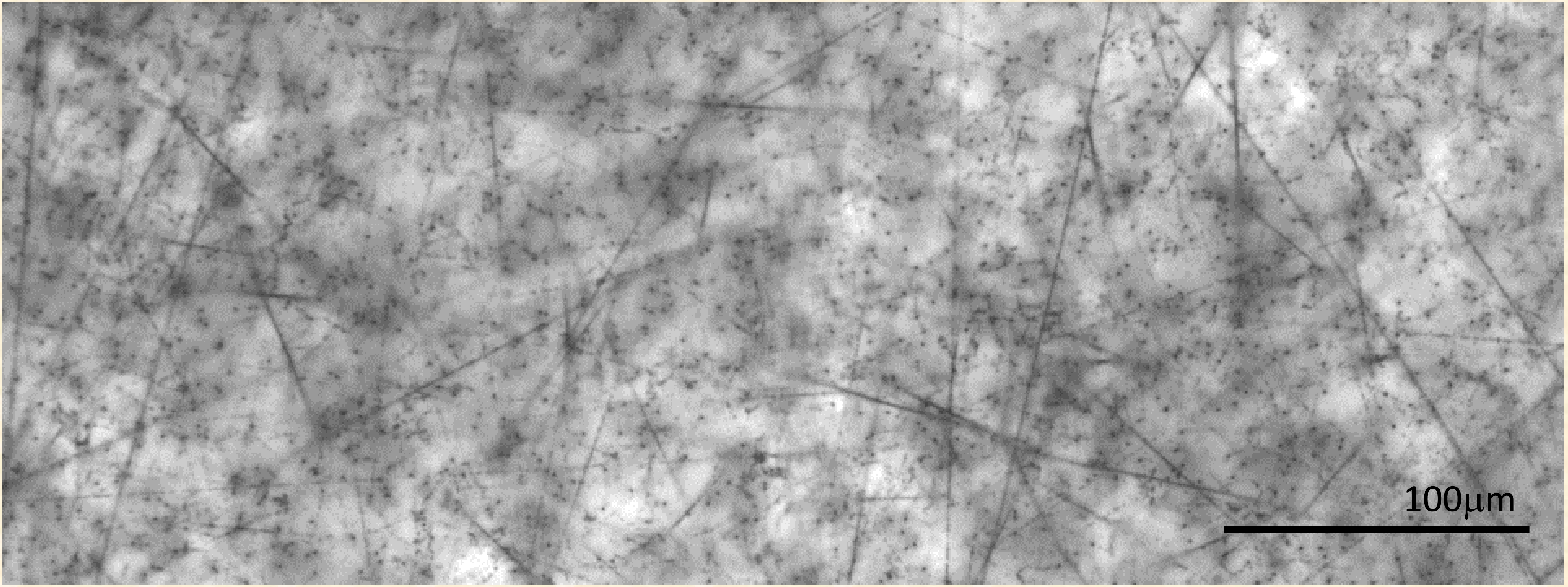
J-PARC E07 experiment

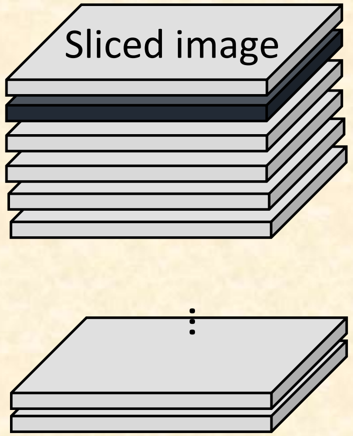




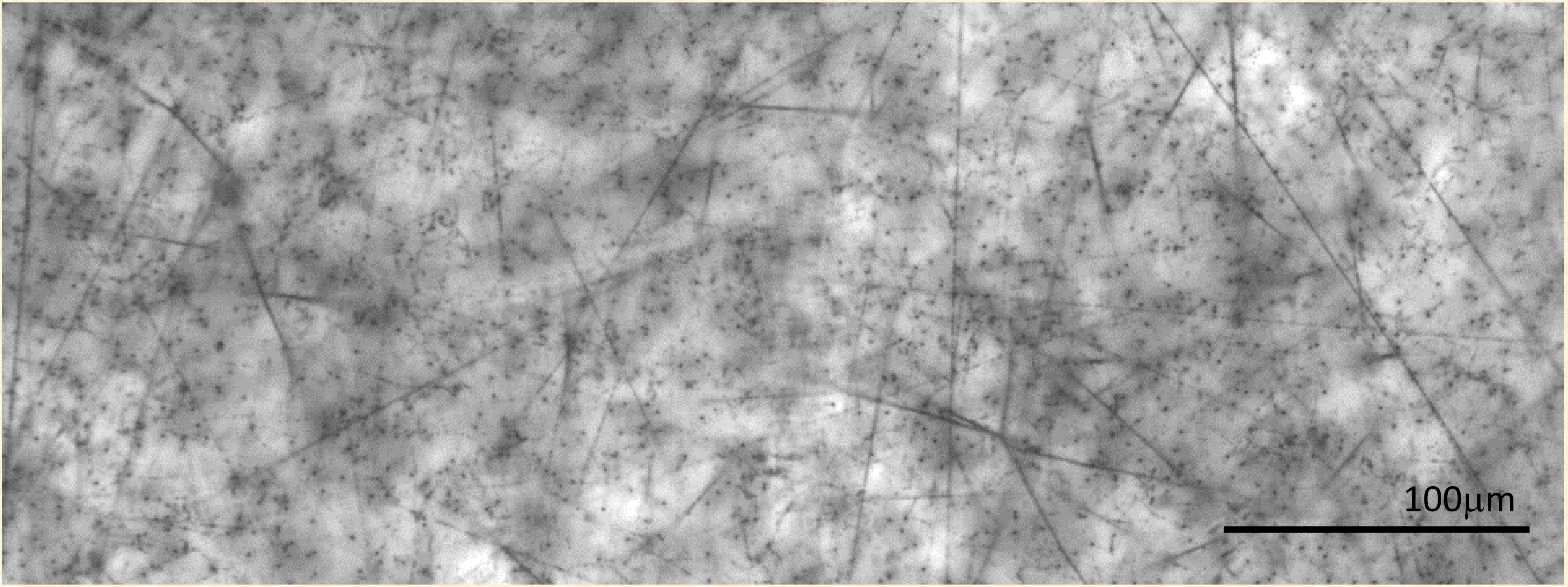
Experimental apparatus
2016-2017
J-PARC, Ibaraki, Japan

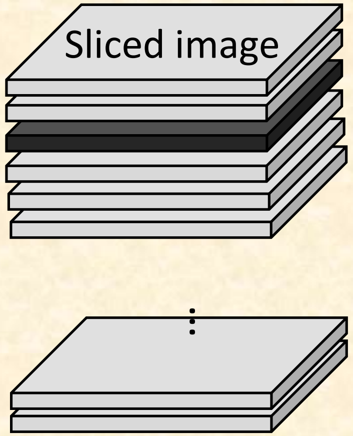
Overall scanning for E07 emulsions



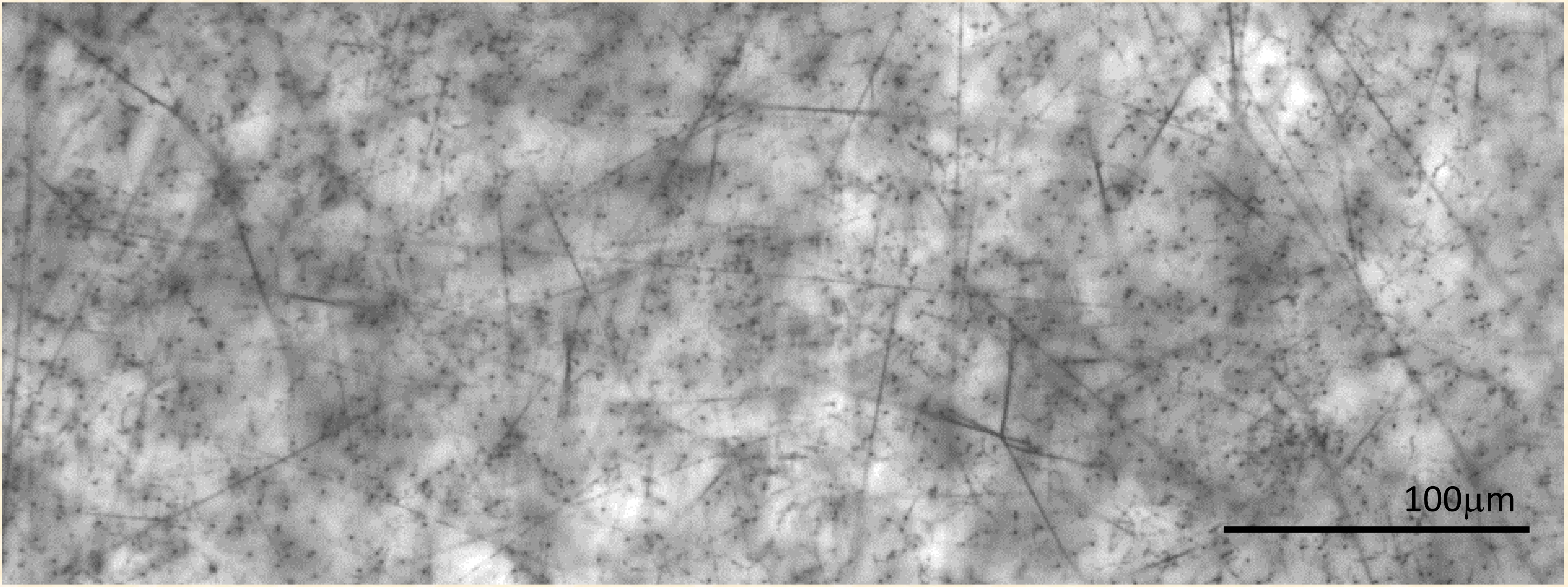


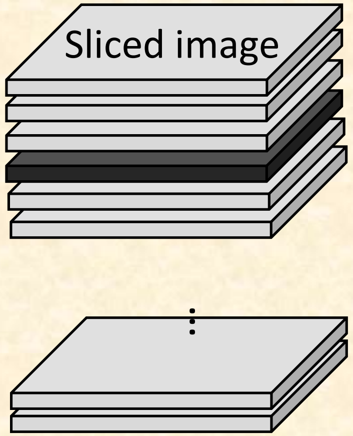
Overall scanning for E07 emulsions



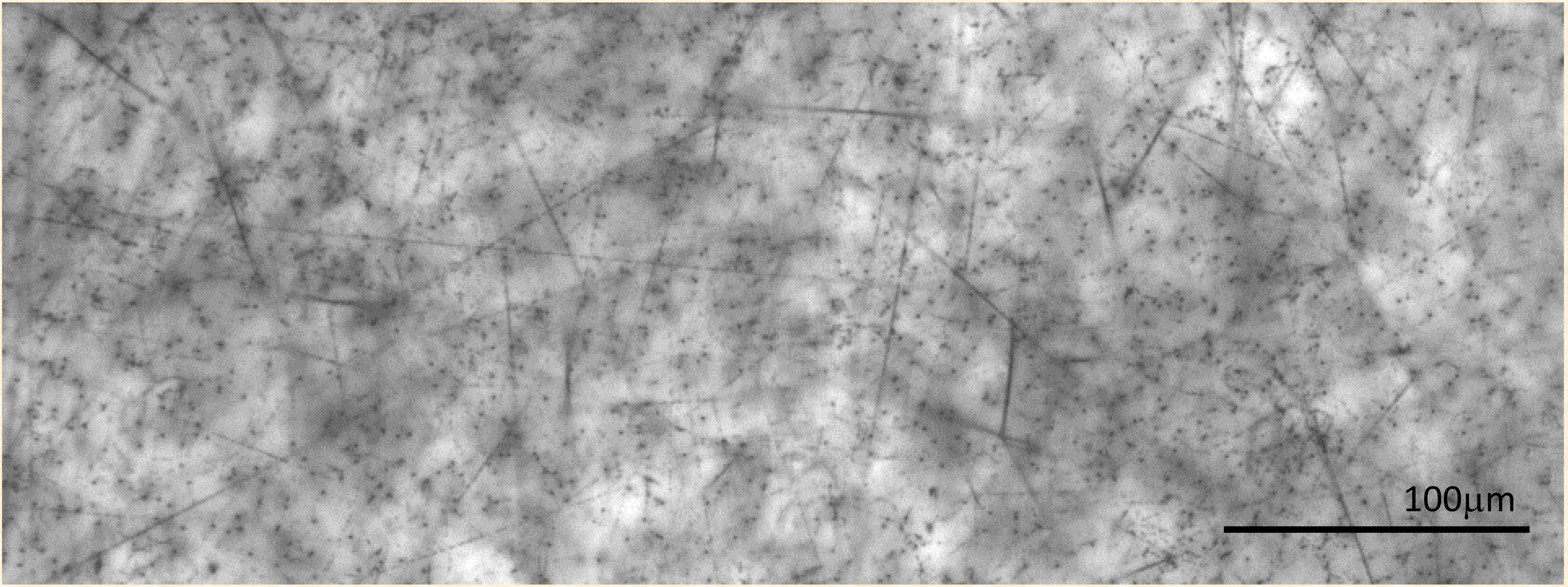


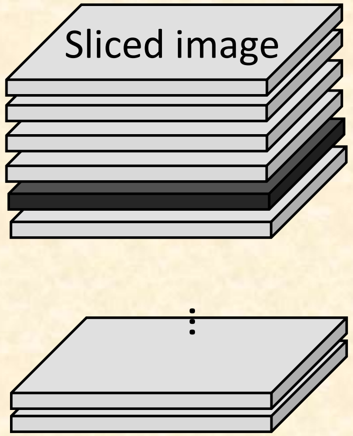
Overall scanning for E07 emulsions





Overall scanning for E07 emulsions



Analysis of J-PARC E07 data with Machine Learning

Hypertriton detection and binding energy

Development of the Machine Learning model with Convolutional Neural Network (CNN)

With real data for training

Completed
J. Yoshida et al.,
Nuclear Instrument and Method A, 989 (2021) 164930

Detecting α-decay events for calibrating the emulsion sheet (density, shrinkage, ...)

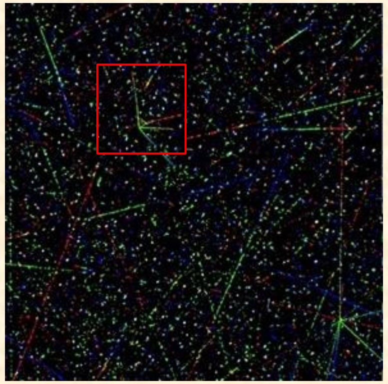
Starting in April 2020

Challenge:
No training data for hypertriton

Production of training data

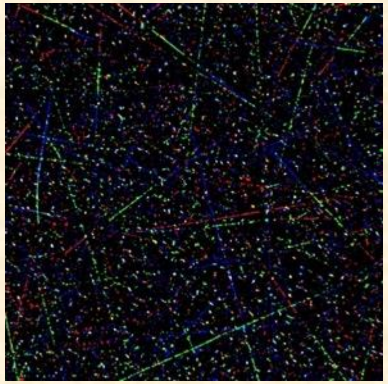
Monte Carlo simulations and GAN(Generative Adversarial Networks)

Binarized tracks from MC simulations
+ background from the real data

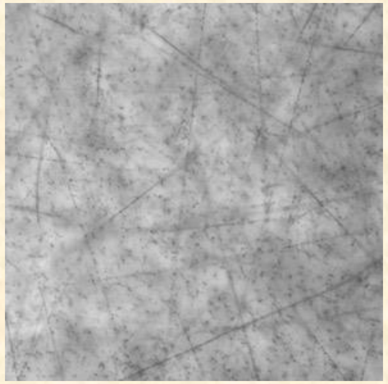


Imitated
emulsion image

GAN: pix2pix



Binarized (like for simulations)



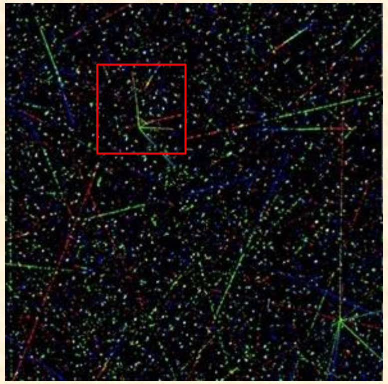
Real emulsion image

→ Talk by Manami Nakagawa, 17:45 on Wednesday (Wed-Iva)

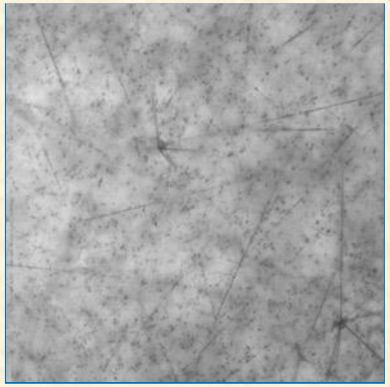
Production of training data

Monte Carlo simulations and GAN(Generative Adversarial Networks)

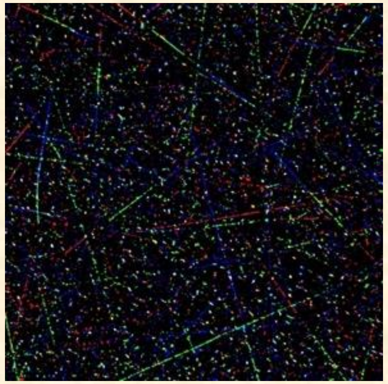
Binarized tracks from MC simulations
+ background from the real data



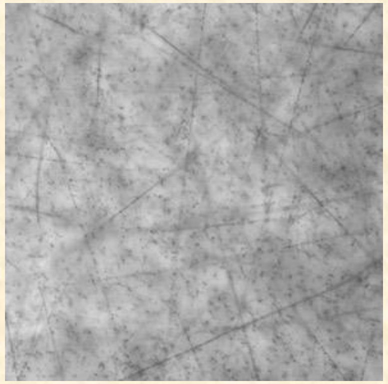
Produced training data



GAN: pix2pix



Binarized (like for simulations)

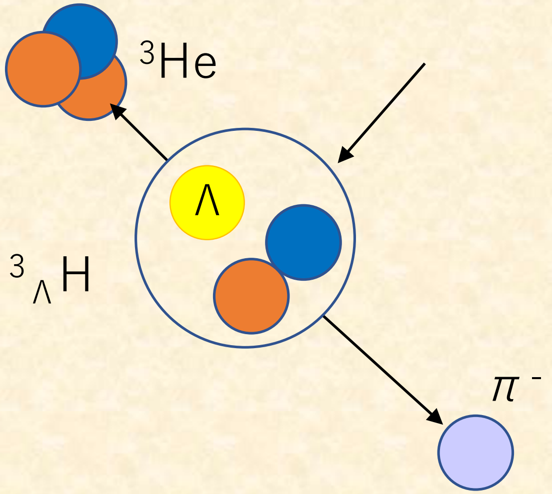


Real emulsion image

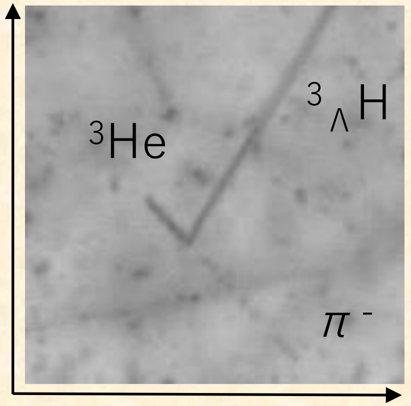
→ Talk by Manami Nakagawa, 17:45 on Wednesday (Wed-Iva)

Hypertriton search with Mask R-CNN

Two body decay of $^{3}_{\Lambda}H$



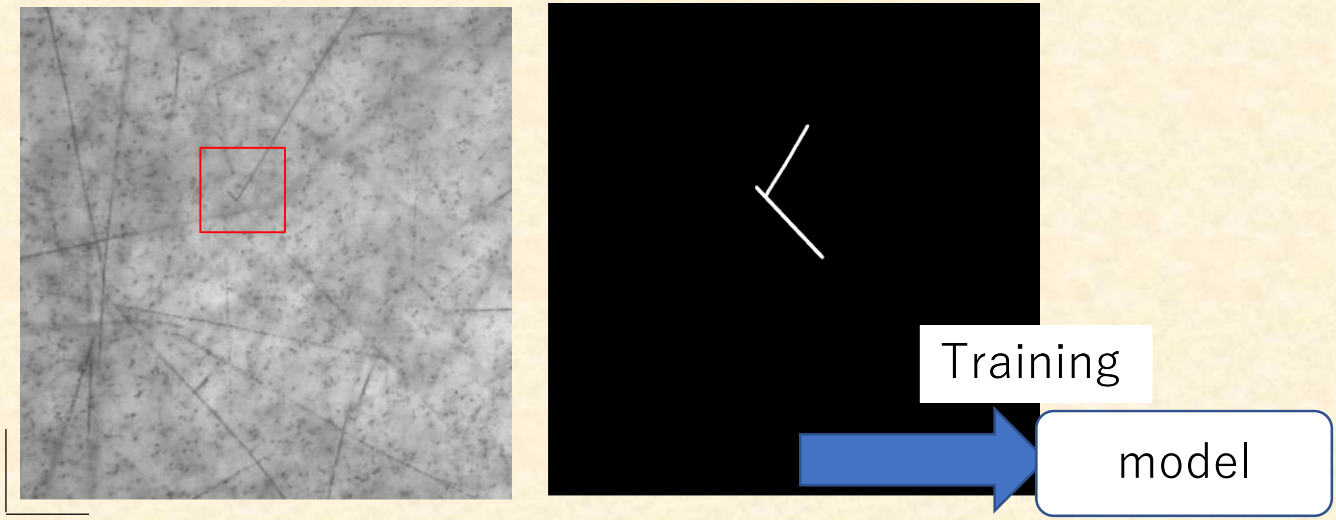
Simulated image



50 μm

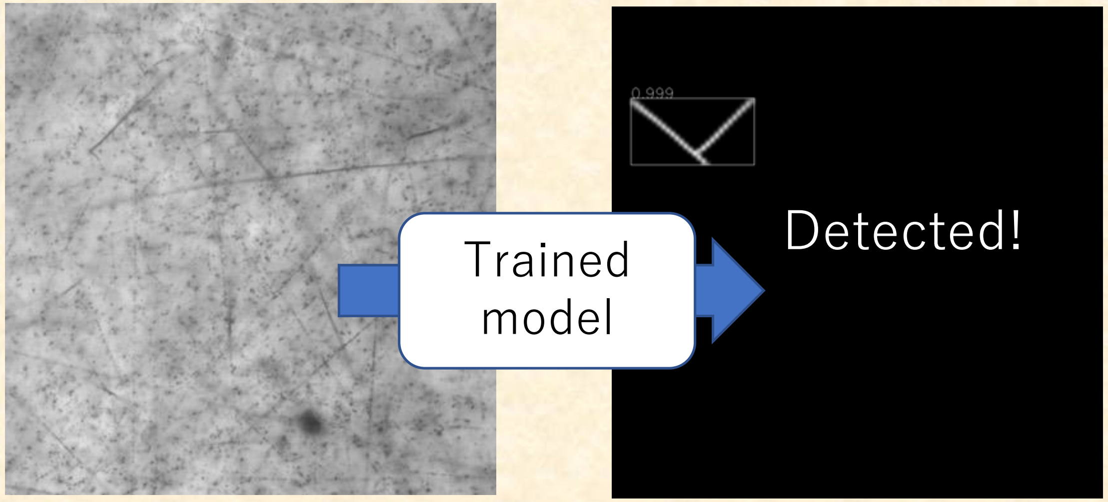
Training dataset (Simulated images)

Image | Mask



50 μm

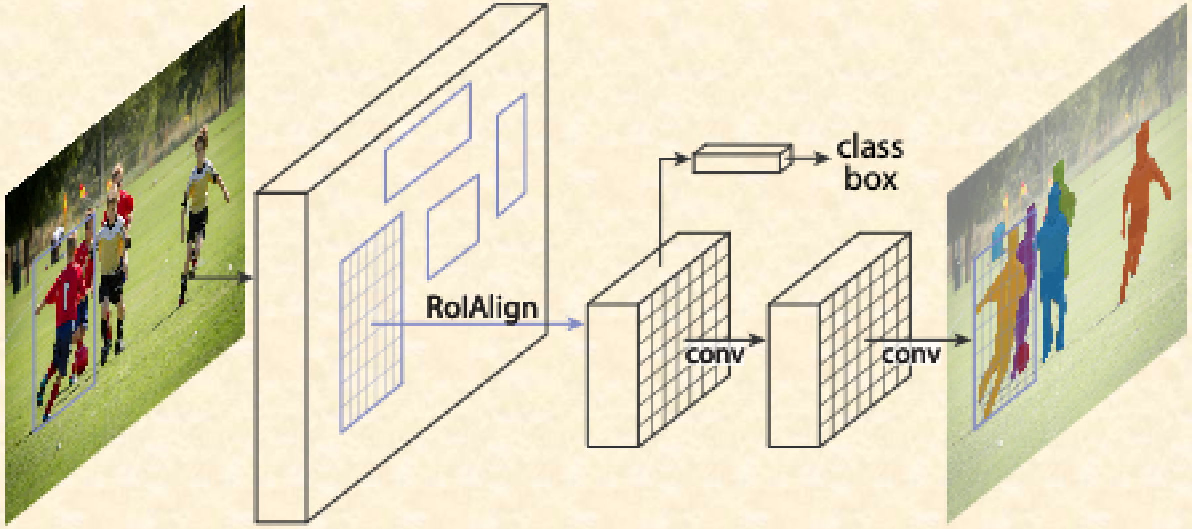
Real image

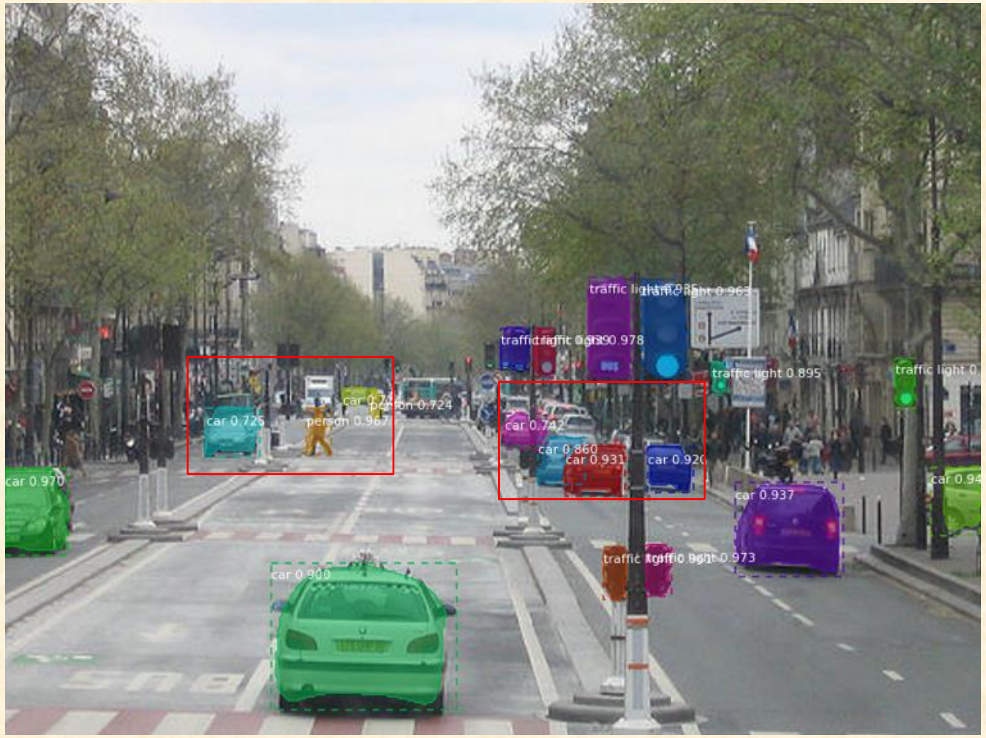


→ Talk by Manami Nakagawa, 17:45 on Wednesday (Wed-Iva)

Detection of hypertriton events

With Mask R-CNN model



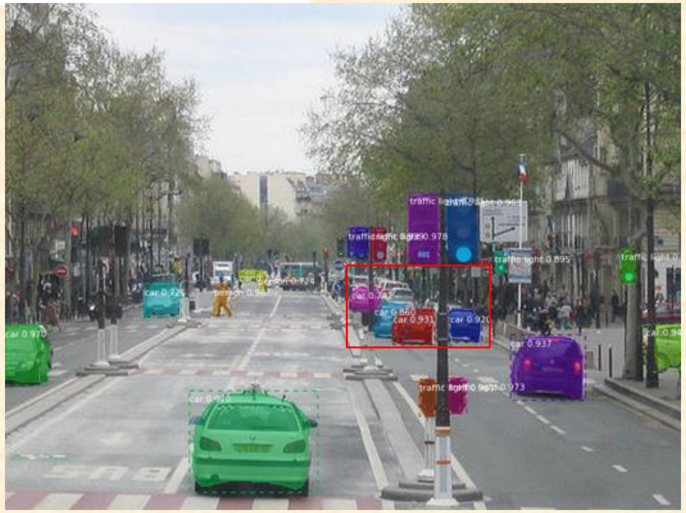


Detection of each object

At large object density

Training of Mask R-CNN with Simulated image

Mask R-CNN



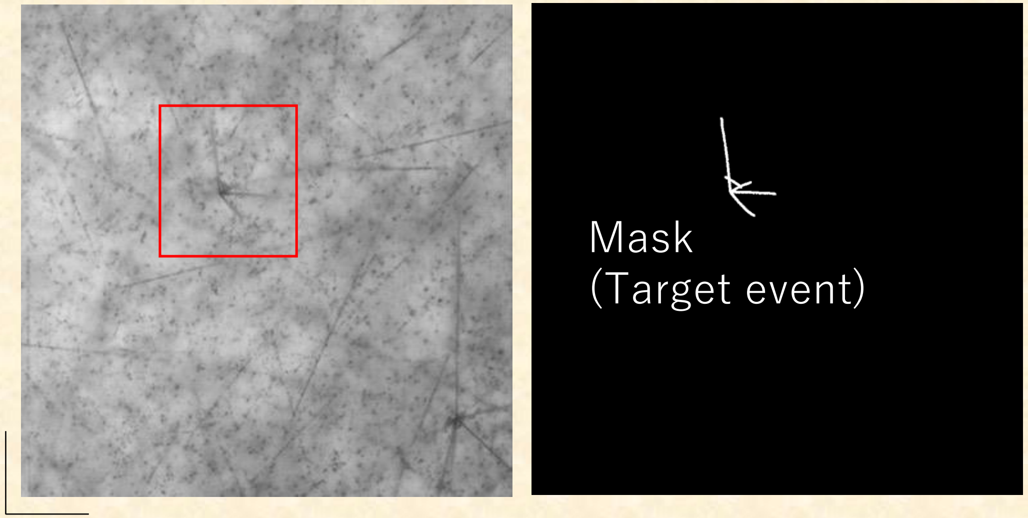
Example of training dataset

Image Mask

A Pedestrian dataset

https://www.cis.upenn.edu/~jshi/ped_html/

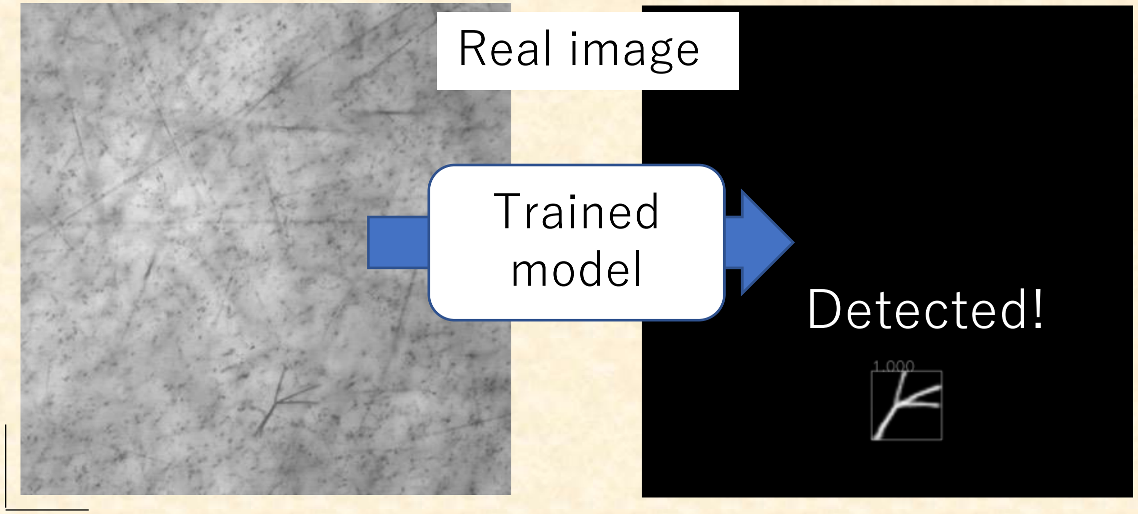
Training data (Simulated image)



50 μm

Masks are automatically produced

Performance of α-decay detection



50 μm

Efficiency = No. detected/No. total
Purity = Truth Positive/No. candidates

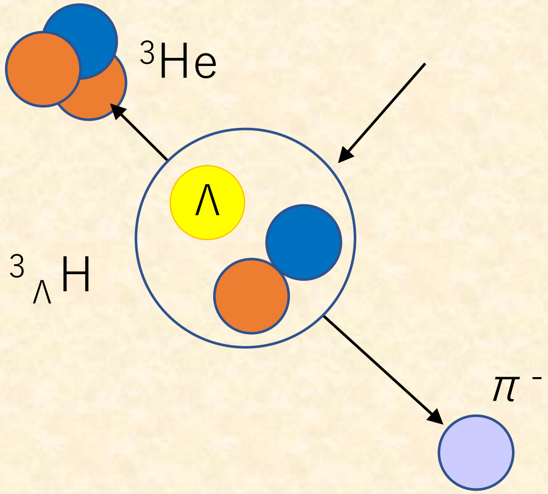
	Efficiency [%]	Purity [%]
Vertex picker	~40%	~1%
Mask R-CNN	~80%	~20%

→ 2nd step done

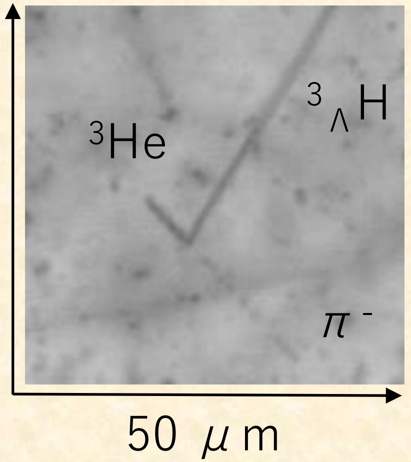
A.Kasagi et.al,
To be submitted to Computer Physics Communications

Hypertriton search with Mask R-CNN

Two body decay of $^{3}_{\Lambda}H$

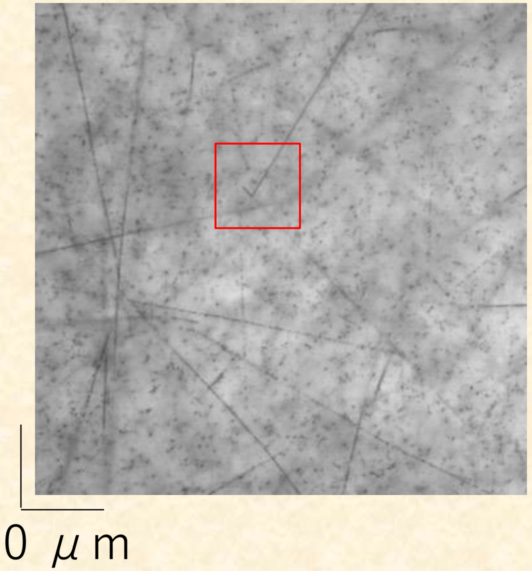


Simulated image

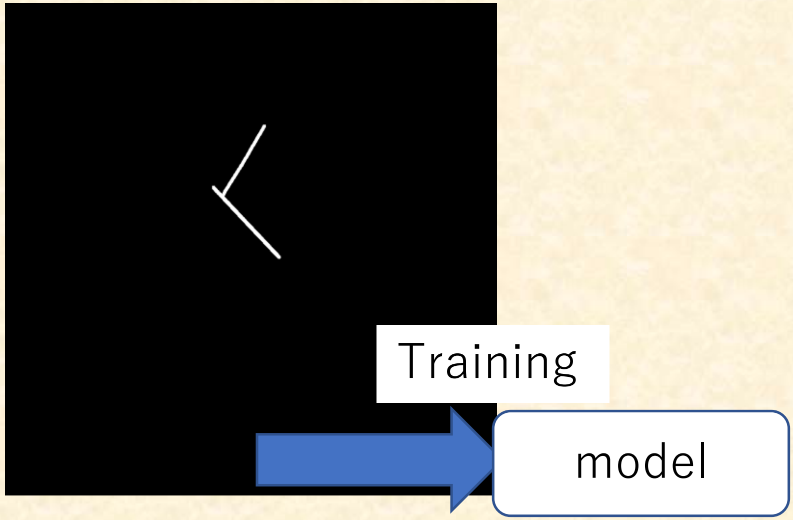


Training dataset (Simulated images)

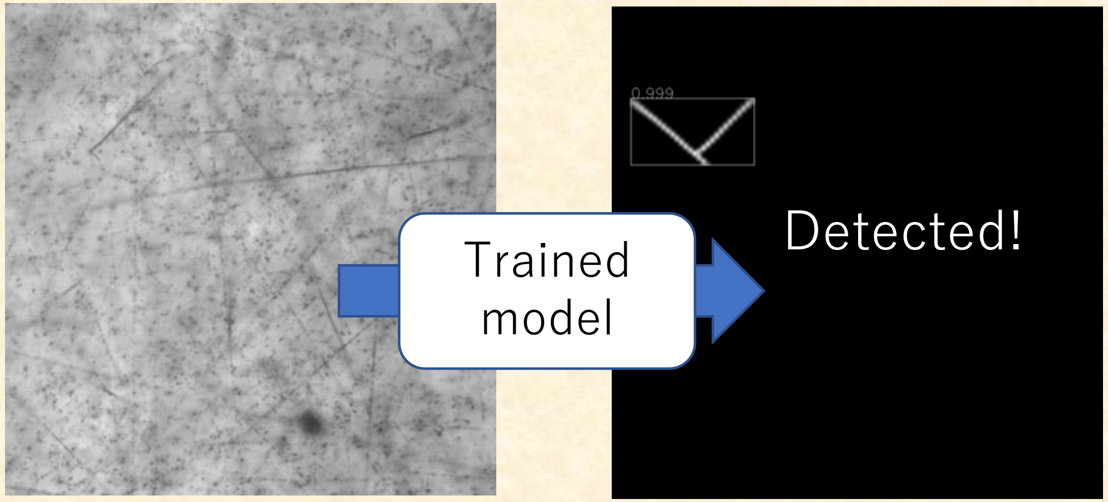
Image



Mask



Real image



Analysis of J-PARC E07 data with Machine Learning

Hypertriton detection and binding energy

Development of the machine learning model (mask-R CNN) with training data produced by Monte Carlo simulations and GAN technique

Completed
A. Kasagi et al.,
To be published

Development of the Machine Learning model with Convolutional Neural Network (CNN)

With real data for training

Completed
J. Yoshida et al.,
Nuclear Instrument and Method A, 989 (2021) 164930

Detecting α-decay events for calibrating the emulsion sheet (density, shrinkage, …)

Starting in April 2020

Challenge:
No training data for hypertriton

Systematic error for hypertriton B_Λ with emulsion

Approximately 28 keV

Eur. Phys. J. A (2021) 57:327
https://doi.org/10.1140/epja/s10050-021-00649-8

THE EUROPEAN PHYSICAL JOURNAL A

Check for updates

Regular Article - Experimental Physics

Revisiting the former nuclear emulsion data for hypertriton

E. Liu[1,2,3,a], A. Kasagi[2,4], H. Ekawa[2], M. Nakagawa[2], T. R. Saito[2,5,6], J. Yoshida[2,7]

[1] Institute of Modern Physics, Chinese Academy of Sciences, 509 Nanchang Road, Lanzhou 730000, Gansu Province, China
[2] High Energy Nuclear Physics Laboratory, Cluster for Pioneering Research, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
[3] School of Nuclear Science and Technology, University of Chinese Academy of Sciences, No.19(A) Yuquan Road, Shijingshan District, Beijing 100049, China
[4] Graduate School of Engineering, Gifu University, 1-1 Yanagido, Gifu 501-1193, Japan
[5] GSI Helmholtz Centre for Heavy Ion Research, Planckstrasse 1, 64291 Darmstadt, Germany
[6] School of Nuclear Science and Technology, Lanzhou University, 222 South Tianshui Road, Lanzhou 730000, Gansu Province, China
[7] Department of physics, Tohoku University, Aramaki, Aoba-ku, Sendai 980-8578, Japan

Received: 17 September 2021 / Accepted: 27 November 2021

Communicated by Klaus Peters

Recent theoretical calculation

Revisiting the hypertriton lifetime puzzle

A. Pérez-Obiol,[1] D. Gazda,[2] E. Friedman,[3] and A. Gal[3,*]
[1] *Laboratory of Physics, Kochi University of Technology, Kami, Kochi 782-8502, Japan*
[2] *Nuclear Physics Institute, 25068 Řež, Czech Republic*
[3] *Racah Institute of Physics, The Hebrew University, Jerusalem 91904, Israel*
(Dated: July 9, 2020)

Other recent theoretical works

For hypertriton:
Effective field theory
F. Hildenbrand et al., Phys. Rev. C 102, 064002 (2020)

- $R = \Gamma_{3He} / (\Gamma_{3He} + \Gamma_{pd})$ is sensitive to the binding energy

For nnΛ:
Pionless effective field theory
S.-I. Ando et al., Phys. Rev. C 92, 024325 (2015)
F. Hildenbrand et al., Phys. Rev. C 100 034002 (2019)
Not yet excluding the bound state

Concluding remarks. Reported in this work is a new microscopic three-body calculation of the ${}^3_\Lambda$H pionic two-body decay rate $\Gamma({}^3_\Lambda\mathrm{H} \to {}^3\mathrm{He} + \pi^-)$. Using the $\Delta I = \frac{1}{2}$ rule and a branching ratio taken from experiment to connect to additional pionic decay rates, the lifetime $\tau({}^3_\Lambda\mathrm{H})$ was deduced. As emphasized here $\tau({}^3_\Lambda\mathrm{H})$ varies strongly with the small, rather poorly known Λ separation energy $B_\Lambda({}^3_\Lambda\mathrm{H})$; it proves possible then to correlate each one of the three distinct RHI experimentally reported values $\tau_{exp}({}^3_\Lambda\mathrm{H})$ with a theoretical value $\tau_{th}({}^3_\Lambda\mathrm{H})$ that corresponds to its own underlying $B_\Lambda({}^3_\Lambda\mathrm{H})$ value. The $B_\Lambda({}^3_\Lambda\mathrm{H})$ intervals thereby correlated with these experiments are roughly $B_\Lambda \lesssim 0.1$ MeV, $0.1 \lesssim B_\Lambda \lesssim 0.2$ MeV and $B_\Lambda \gtrsim 0.2$ MeV for ALICE, HypHI and STAR, respectively. New experiments proposed at MAMI on Li target [39] and at JLab, J-PARC and ELPH on ^{3}He target [40] will hopefully pin down precisely $B_\Lambda({}^3_\Lambda\mathrm{H})$ to better than perhaps 50 keV, thereby leading to a unique resolution of the 'hypertriton lifetime puzzle'.

STAR, HypHI, ALICE: **from 121 to 270 ps**

Eur. Phys. J. A (2021) 57:159
https://doi.org/10.1140/epja/s10050-021-00470-3

THE EUROPEAN PHYSICAL JOURNAL A

Check for updates

Regular Article - Experimental Physics

Novel method for producing very-neutron-rich hypernuclei via charge-exchange reactions with heavy ion projectiles

Takehiko R. Saito[1,2,3,a], **Hiroyuki Ekawa**[1], **Manami Nakagawa**[1]

[1] High Energy Nuclear Physics Laboratory, Cluster for Pioneering Research, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
[2] GSI Helmholtz Centre for Heavy Ion Research, Planckstrasse 1, 64291 Darmstadt, Germany
[3] School of Nuclear Science and Technology, Lanzhou University, 222 South Tianshui Road, Lanzhou 730000, Gansu Province, China

Received: 20 February 2021 / Accepted: 18 April 2021

Communicated by Alexandre Obertelli

Abstract We propose a novel method for producing very-neutron-rich hypernuclei and corresponding resonance states by employing charge-exchange reactions via pp(^{12}C, ^{12}N K^+)nΛ with single-charge-exchange and ppp(^{9}Be, ^{9}C K^+)nnΛ with double-charge-exchange, both of which produce ΛK^+ in a target nucleus. The feasibility of producing very-neutron-rich hypernuclei using the proposed method was analysed by applying an ultra-relativistic quantum molecular dynamics model to a ^{6}Li + ^{12}C reaction at 2 A GeV. The yields of very-neutron-rich hypernuclei, signal-to-background ratios, and background contributions were investigated. The proposed method is a powerful tool for studying very-neutron-rich hypernuclei and resonance states with a hyperon for experiments employing the Super-FRS facility at FAIR and HFRS facility at HIAF.

the nature of fragmentation reactions of heavy ion beams, the isospin values of the produced hypernuclei were widely distributed. Therefore, neutron-rich and proton-rich hypernuclei could be studied.

One of the problems revealed by the results of the HypHI Phase 0 experiment is the possible existence of an unprecedented bound state of a Λ-hyperon with two neutrons, denoted as Λnn ($^3_\Lambda$n) [3]. Neutral nuclear states with neutrons and Λ-hyperons are of particular interest because the natures of these states should have an impact on our understanding of the deep cores of neutron stars. However, theoretical calculations have shown negative results for the existence of Λnn bound states [4–7]. Although there is disagreement between the results of the HypHI Phase 0 experiment and theoretical calculations, whether or not the Λnn state can exist has recently become a hot topic in experimental and theoretical

Press release at RIKEN on September 14th

with Gifu University, Rikkyo University and Tohoku University


交通アクセス　お問い合わせ　English Site　報道関係者の方　理研在籍者・OBの方　理研寄附金

理化学研究所

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理研について　研究室紹介　研究成果（プレスリリース）　広報活動　産学連携　採用情報

Home > 研究成果（プレスリリース） > 研究成果（プレスリリース）2021

いいね！77

2021年9月14日
理化学研究所
岐阜大学
東北大学
立教大学

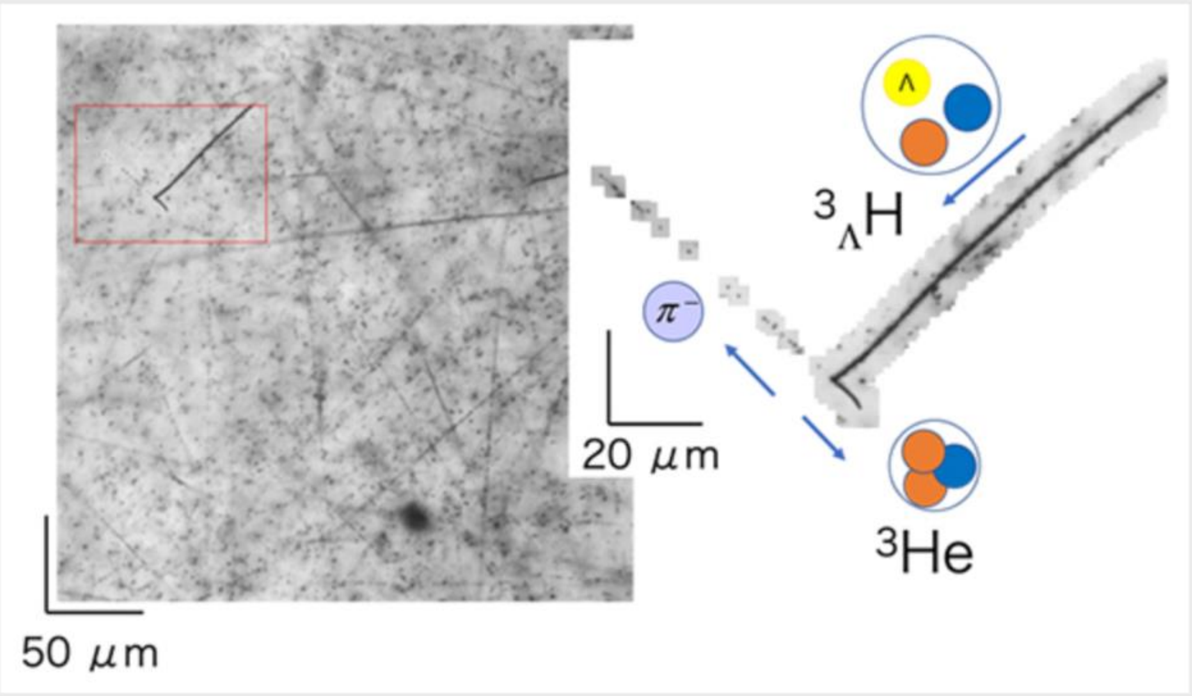
← 前の記事　↑ 一覧へ戻る　→ 次の

ハイパー核の束縛エネルギー精密測定へ

－ハイパートライトンパズルの解明に向けて－

理化学研究所（理研）開拓研究本部齋藤高エネルギー原子核研究室の齋藤武彦主任研究員、岐阜大学教育学部・工学研究科の仲澤和馬シニア教授、大学大学院理学研究科の吉田純也助教、立教大学大学院人工知能科学研究科の瀧雅人准教授らの国際共同研究グループは、大強度陽子加速器施設「PARC」[1]においてK中間子[2]ビームが照射された写真乾板データを、独自に開発した機械学習[3]モデルによって解析し、ハイパー核[4]の一種であ「ハイパートライトン[4]」の生成と崩壊の事象を可視的に検出することに成功しました。

本研究成果は、写真乾板からハイパートライトンを大量に効率良く検出できることを示しており、その束縛エネルギー[5]を世界最高精度で決定することで「ハイパートライトンパズル」と呼ばれる謎の解決への貢献が期待できます。



発見されたハイパートライトンの崩壊事象

https://www.riken.jp/press/2021/20210914_3/

Also in Japanese newspapers

2021年 10月25日月曜 美濃 飛騨 岐阜新聞Web

ホーム 岐阜のニュース 国内外 岐阜のスポーツ FC岐阜 おでかけ・グル エンタメ

トップページ > 岐阜のニュース > 科学

Google はこの広告の表示を停止しました

ハイパー核の飛跡、ＡＩで検出成功、宇宙誕生の解明に道筋　岐阜大の仲澤シニア教授ら

2021年09月15日 09:27

国立研究開発法人の理化学研究所（理研）は１４日までに、岐阜大の仲澤和馬シニア教授らが参加する国際共同研究グループが、物質を構成する原子の中心にある原子核の研究で、原子核の一種であるハイパー核のうち最も軽い「ハイパートライトン」が生成されてから崩壊するまでの飛跡を効率的に検出することに成功したと発表した。近年技術的な進化が著しい人工知能（ＡＩ）を活用することで、人の手では数百年かかる検出作業が数年に短縮するという。

研究グループは理研の研究員を中心に、仲澤シニア教授ら国内外の研究者１５人で組織。岐阜大大学院の笠置歩さんも理研の大学院生リサーチ・アソシエイトとして参加した。物質の構造や起源を探るための研究の一環で、宇宙誕生の解明につながるとしている。

実際に検出されたハイパートライトン（３ΛH）の崩壊までの飛跡（左）と仕組み。崩壊後にパイマイナス中間子（π－）とヘリウム３原子核（３He）が左右に放出されている。単位にある「μm」はマイクロメートルで、１μmは１０００分

１３日の記者説明会で解説した理研の齋藤武彦主任研究員によると、原子核を構成する陽子と中性子の間に働く引力を調べる中で、鍵となるのが特殊な原子核であるハイパー核だという。ただ、ハイパー核の理論の基準となるハイパートライトンの性質は未知のままで、原子核と粒子の間に働く引力などが正確に測定されていない課題があった。

研究グループは、２０１６～１７年に仲澤シニア教授が茨城県東海村の大強度陽子加速器施設「Ｊ－ＰＡＲＣ」で行った実験で得られ、ハイパートライトンの飛跡が記録されていると思われる１３００枚の写真乾板に注目。これまでは顕微鏡を使って人の目で丹念に探す必要があったが、ＡＩで自動検出する手法に挑戦した。

ＡＩが検出の参考にする飛跡の観測写真はないものの、飛跡情報をシミュレーションし、モデルとなる模擬画像を画像変換技術を用いて作成。それと同じものを写真乾板の膨大な記録から抜き出そうと、車の自動運転などにも使われる物体検出の技術を使い、ハイパートライトンが生成されてから崩壊するまでの飛跡の自動検出に成功した。今後も複数の飛跡を検出することで、未知だったハイパートライトンの性質を世界最高精度で明らかにできるという。

齋藤主任研究員は「物質の成り立ちの解明への大きな一歩になる」とし、仲澤シニア教授も「これまでの理論が根底から変わるかもしれない」と話している。研究結果をまとめた論文は１４日、英文の科学雑誌「Ｎａｔｕｒ

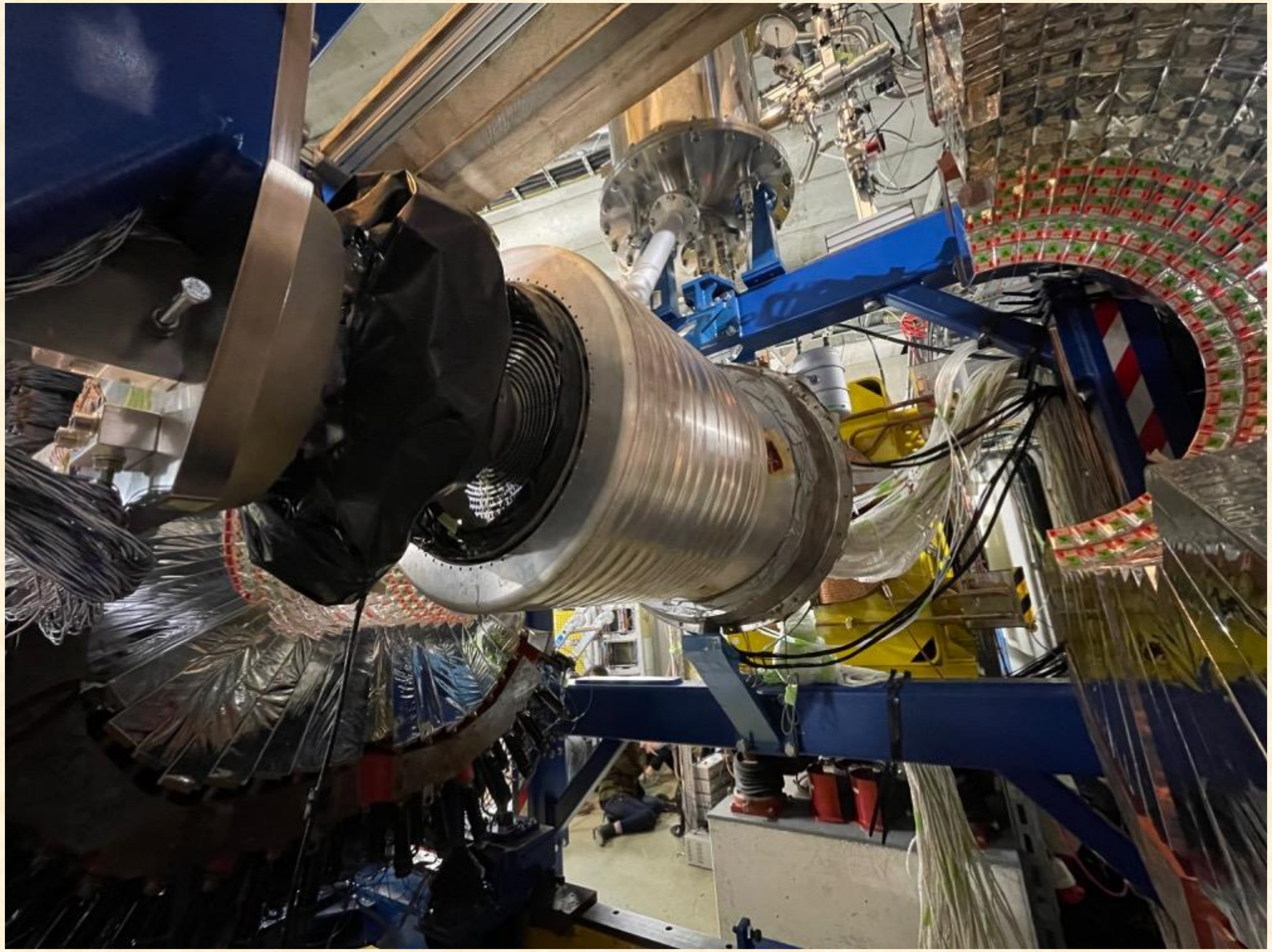
Gifu Shinbun, September 15th 2021

Akahata Shinbun, September 18th 2021

Additional press release in CSIS-Madrid in December 2021

Superconducting magnet

- Superconducting solenoid
- Excited up to 1 T
- New cryogenic and control systems developed by GSI and High Energy Nuclear Physics Lab. at RIKEN



Mini Drift Chamber (MDC)

- 1738 drift tubes
- 17 stereo layers
  - ✓ 9 layers parallel to the beam axis
  - ✓ 8 layers with small skew angles (6-9 degrees)
- New readout system with Clock-TDCs developed by GSI

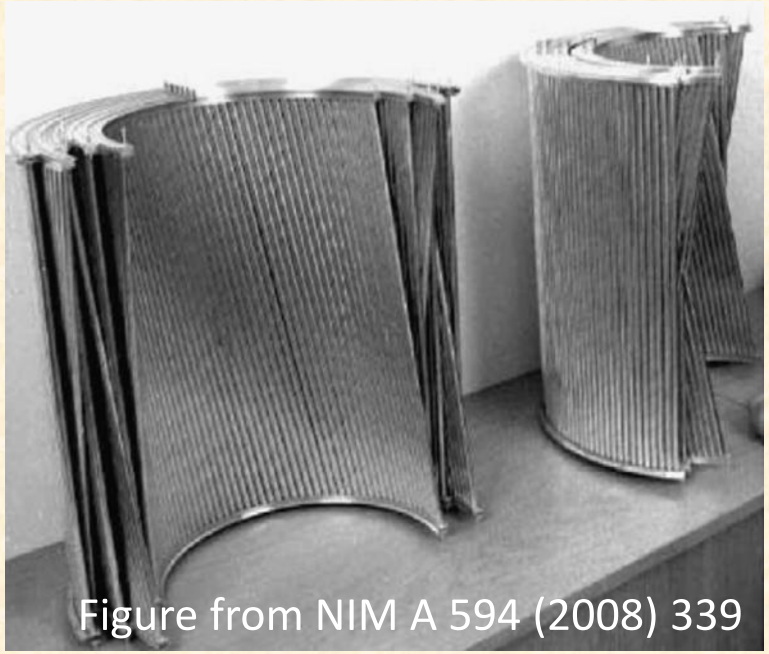
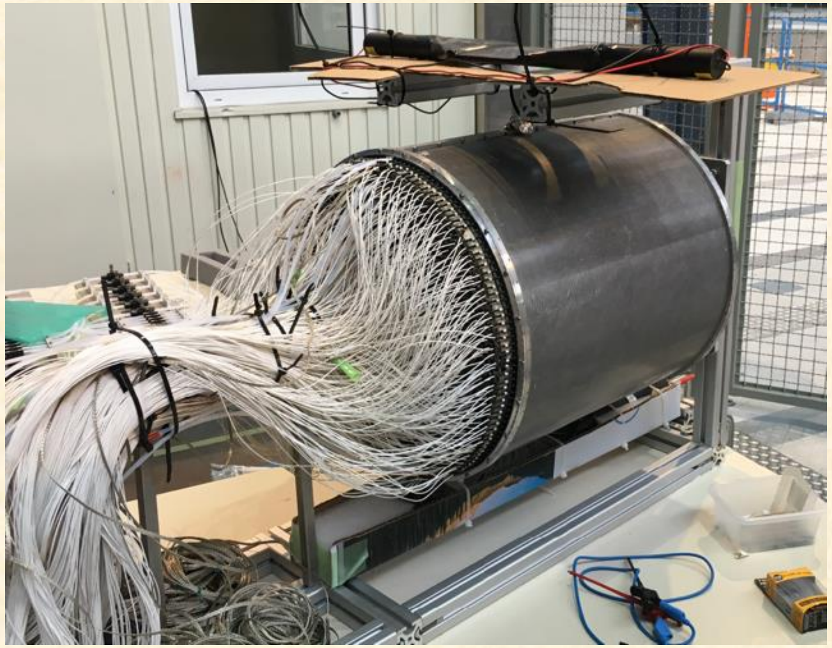


Figure from NIM A 594 (2008) 339

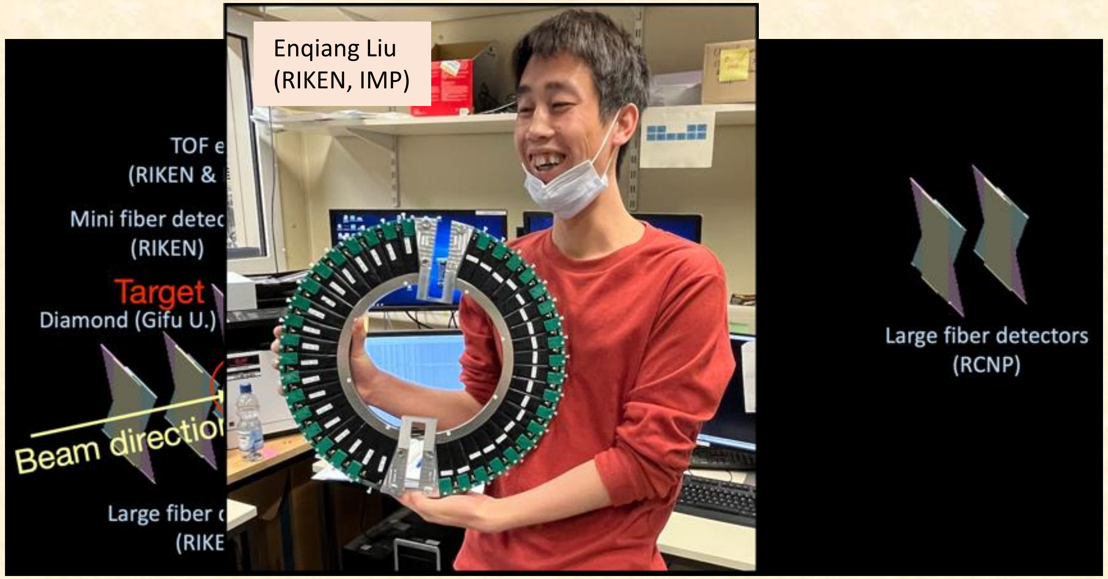


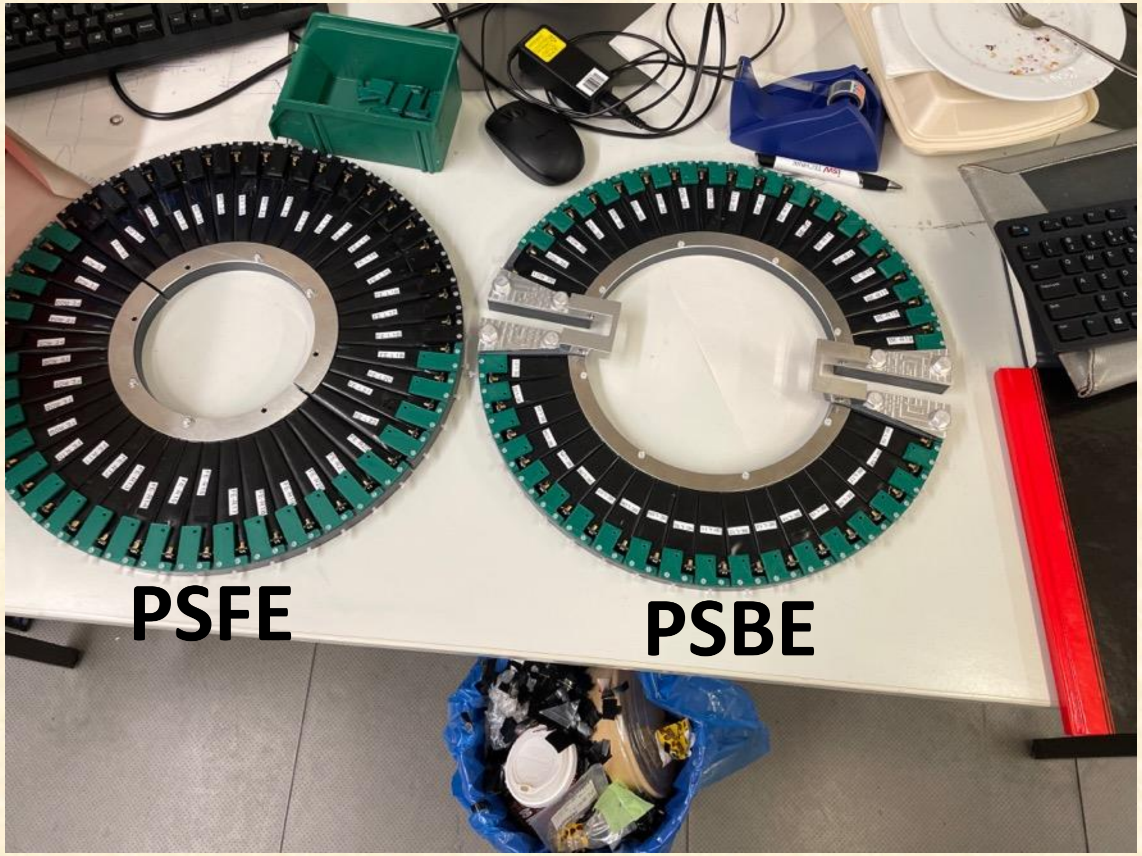
Plastic Scintillator Barrel (PSB)

- Newly developed by Meson Science Laboratory at RIKEN
- MPPCs readout in both-ends
- Wave form readout implemented
- Time resolutions
  - ✓ 140 ps with TDC/QDC
  - ✓ 70 ps with wave-forms

Plastic End-caps (PSFE & PSBE)

- Newly developed by High Energy Nuclear Physics Lab. at RIKEN, Lanzhou University and GSI
- 44 sector-plastics for PSFE, 38 sectors for PSBE
- MPPCs readout with TDC/QDC
- Additional wave-form readout implemented for PSFE

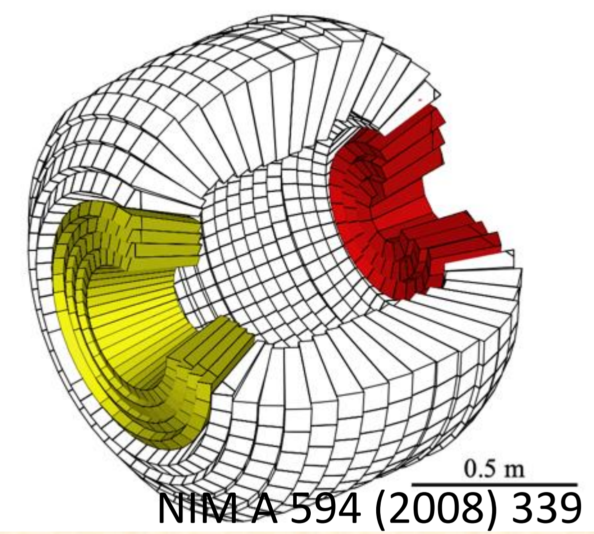




CsI calorimeter

- 1020 CsI crystals
- New readout system with FEBEX developed by GSI
- High energy gamma-rays from π^0 decay
- Charge particle PID with ΔE(PSB)-ΔE(CsI)
- Participating in tracking

Ayumi Kasagi
(RIKEN, Gifu U.)



NIM A 594 (2008) 339

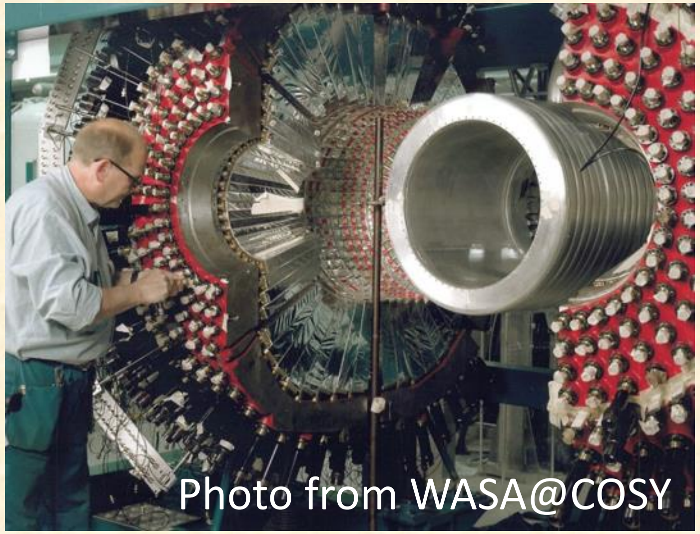
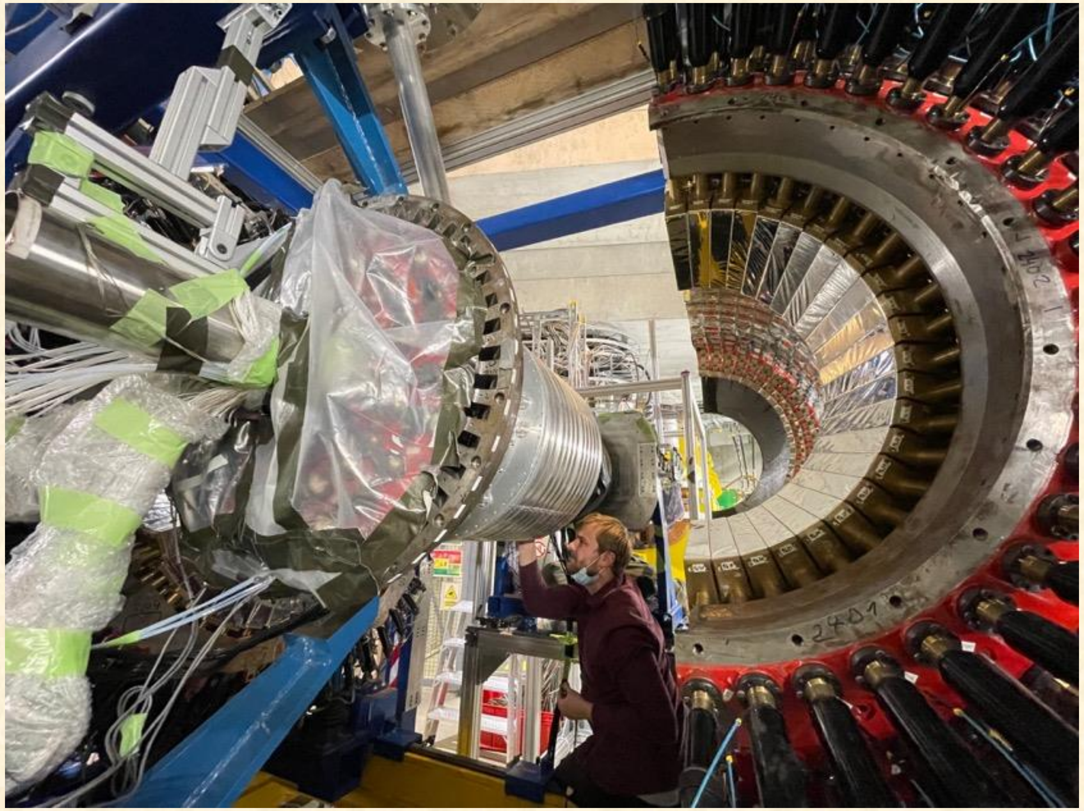
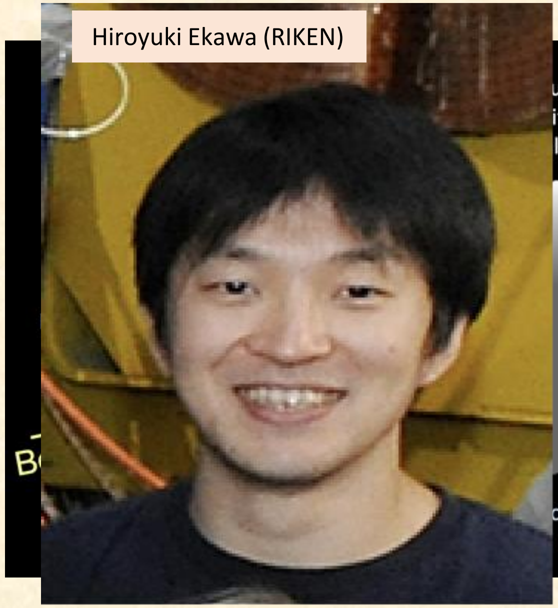


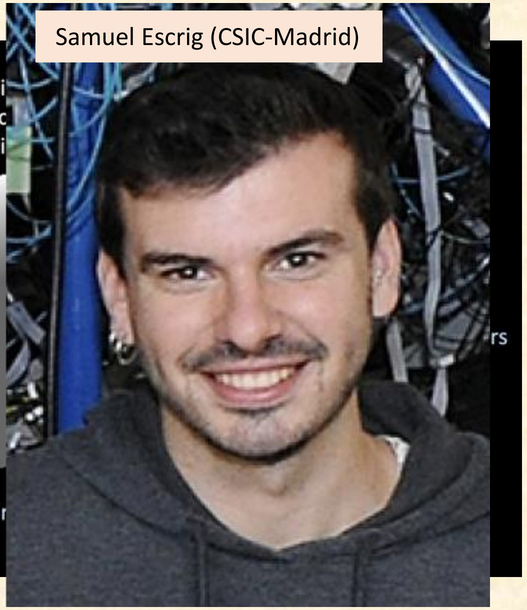
Photo from WASA@COSY

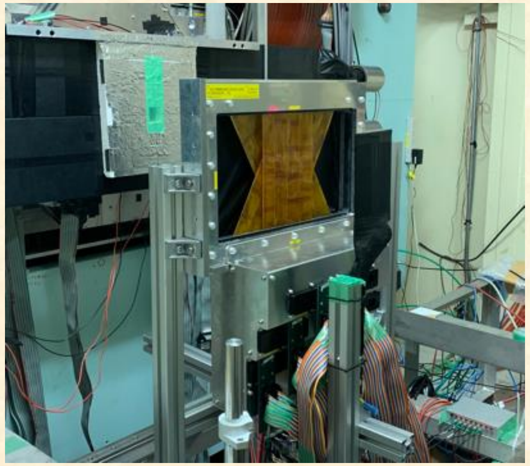


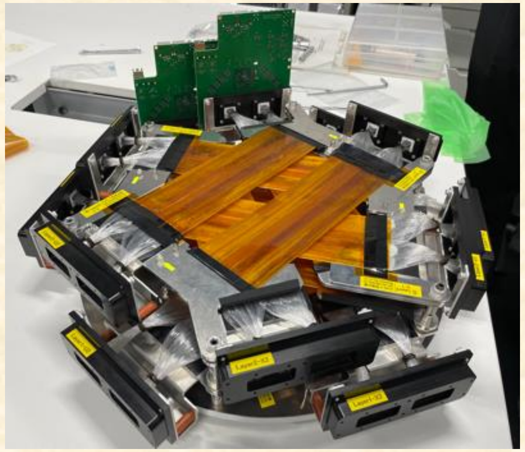
Scintillating fiber detectors

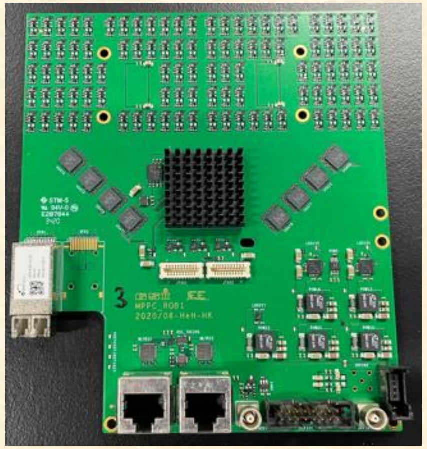
- 5 large stations developed by High Energy Nuclear Physics Lab. at RIKEN and by RCNP
- Mini fiber station developed by High energy Nuclear Physics Lab. at RIKEN
- xx’-uu’-vv’, fibers with a dimeter of 0.5 mm
- Matrix (8X8)-MPPC readout
- Readout electronics (MPPC_rob) developed by GSI

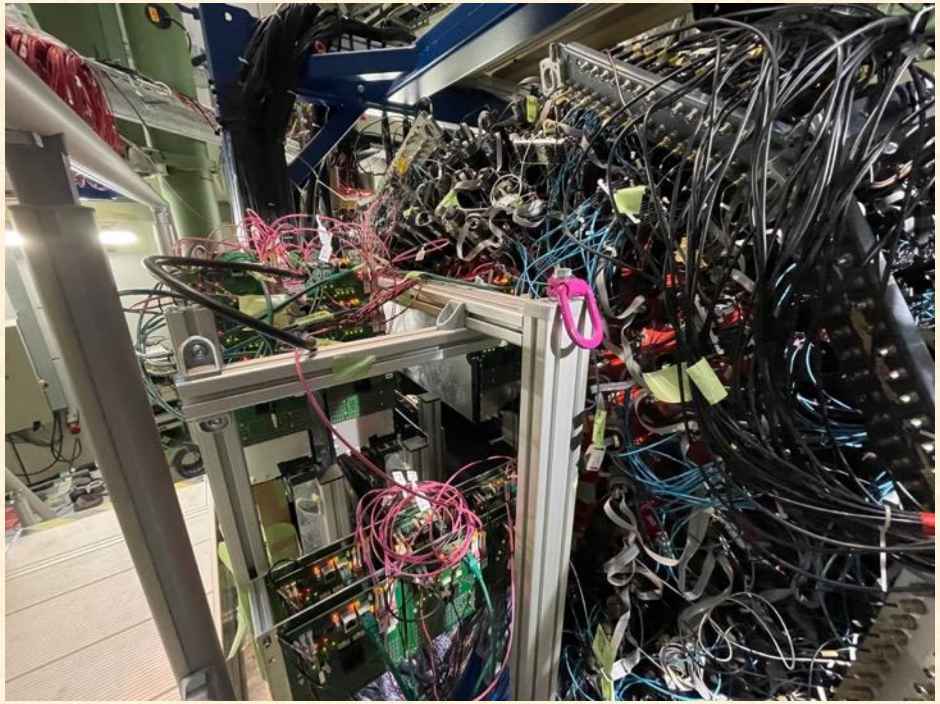






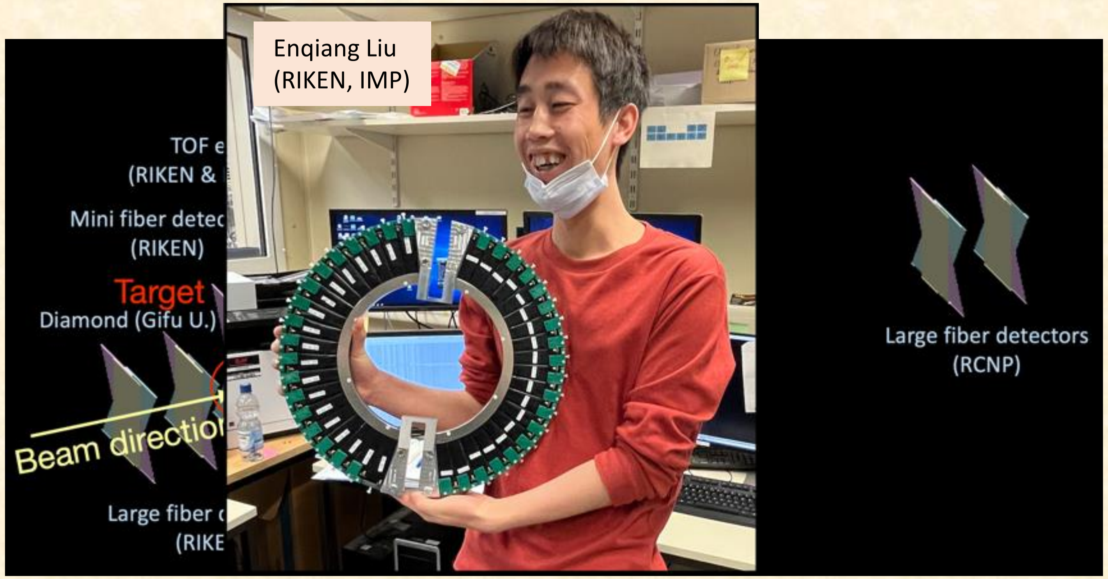


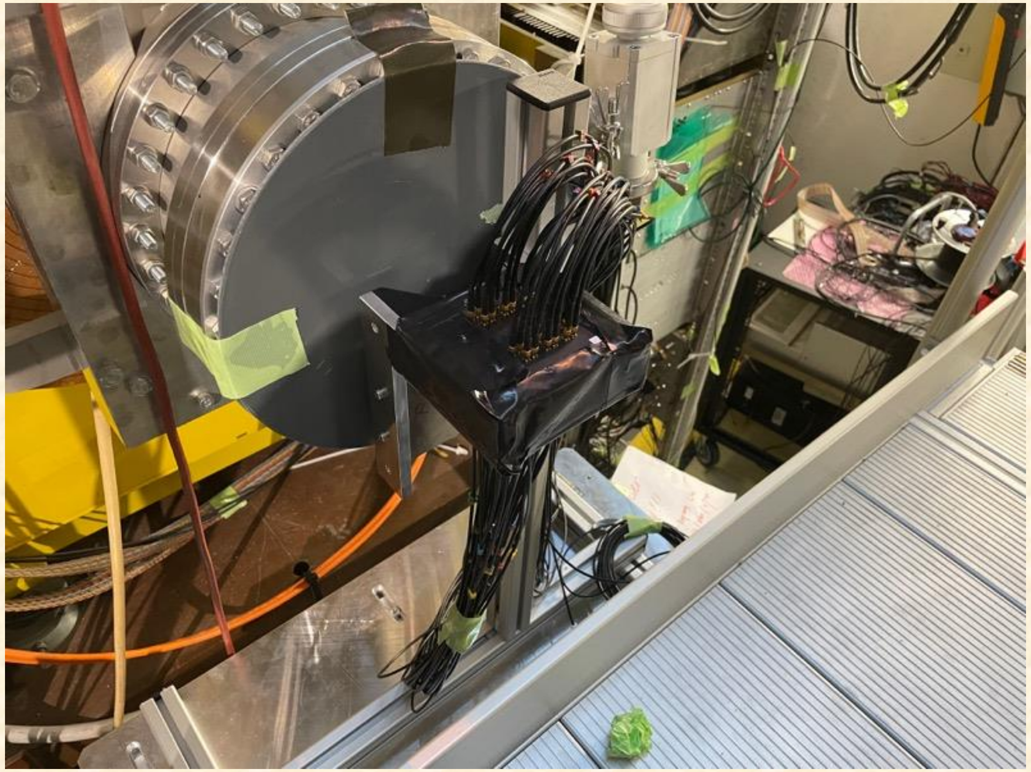




T0 counter

- Newly developed by High Energy Nuclear Physics Lab. at RIKEN, GSI and Lanzhou University
- 28 plastic fingers (1.5 mm X 1.5 mm X 28 mm)
- MPPCs readout in both-ends
- Time resolutions
  - ✓ Better than 100 ps with TDC/QDC





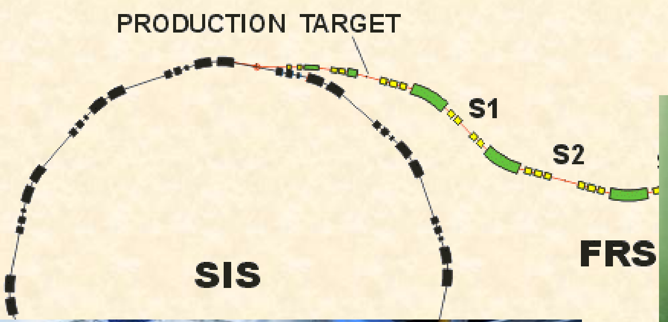
FRS detectors

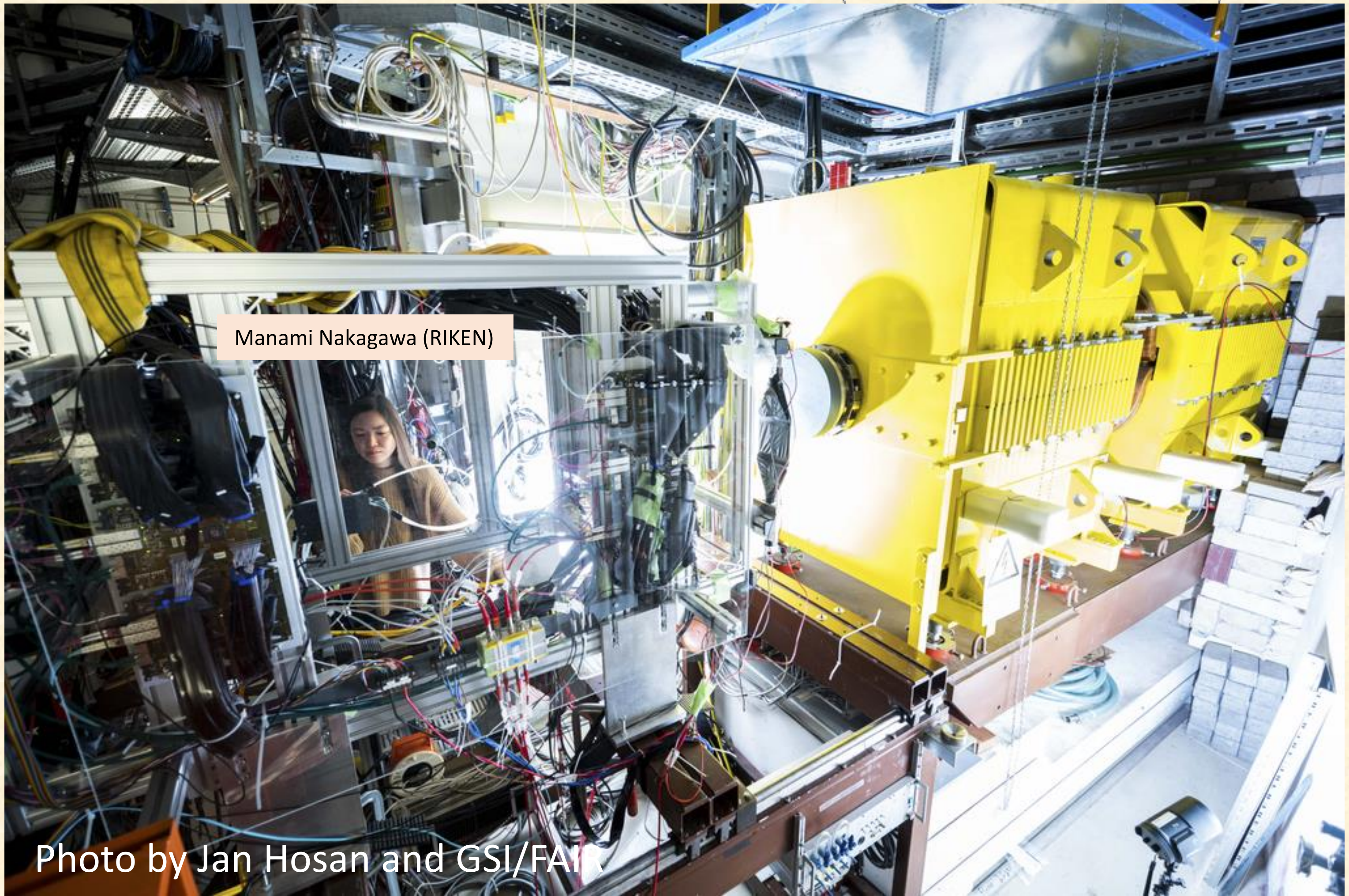
S3:

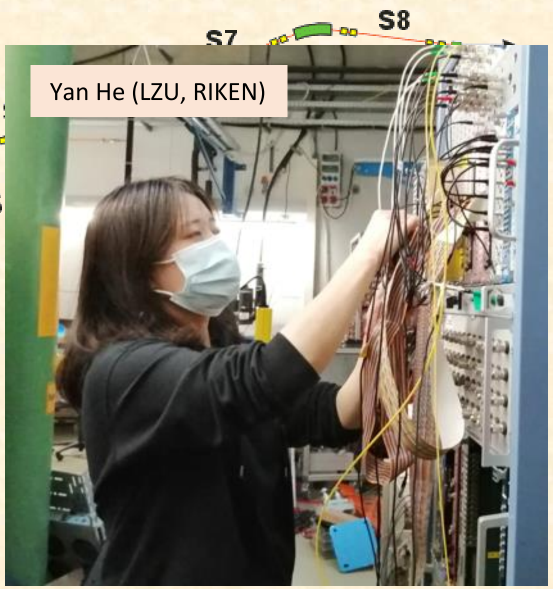
- Plastic scintillators and TPC

S4:

- MWDC, plastic scintillators and Cherenkov detector







Very tight schedules for WASA at FRS

October 2021 – January 2022 (only 4 months)

- Finalizing all the detectors and commissioning
- Integration of the data acquisition systems
- Implementation of the cryogenic system for the superconducting magnet
- Development of the online-monitoring system

December 2021

- Final test for the superconducting magnet
- Decision to purchase 8000 litre liquid-He from the company
  - 120 k Euro from GSI and 120 k Euro from RIKEN (High Energy Nuclear Physics Lab, CPR)

Additional difficulties

- COVID-19
- The war in Ukraine (from February 24th, 2022)

The WASA-FRS HypHI experiment

With ^{6}Li beams at 1.96 A GeV:

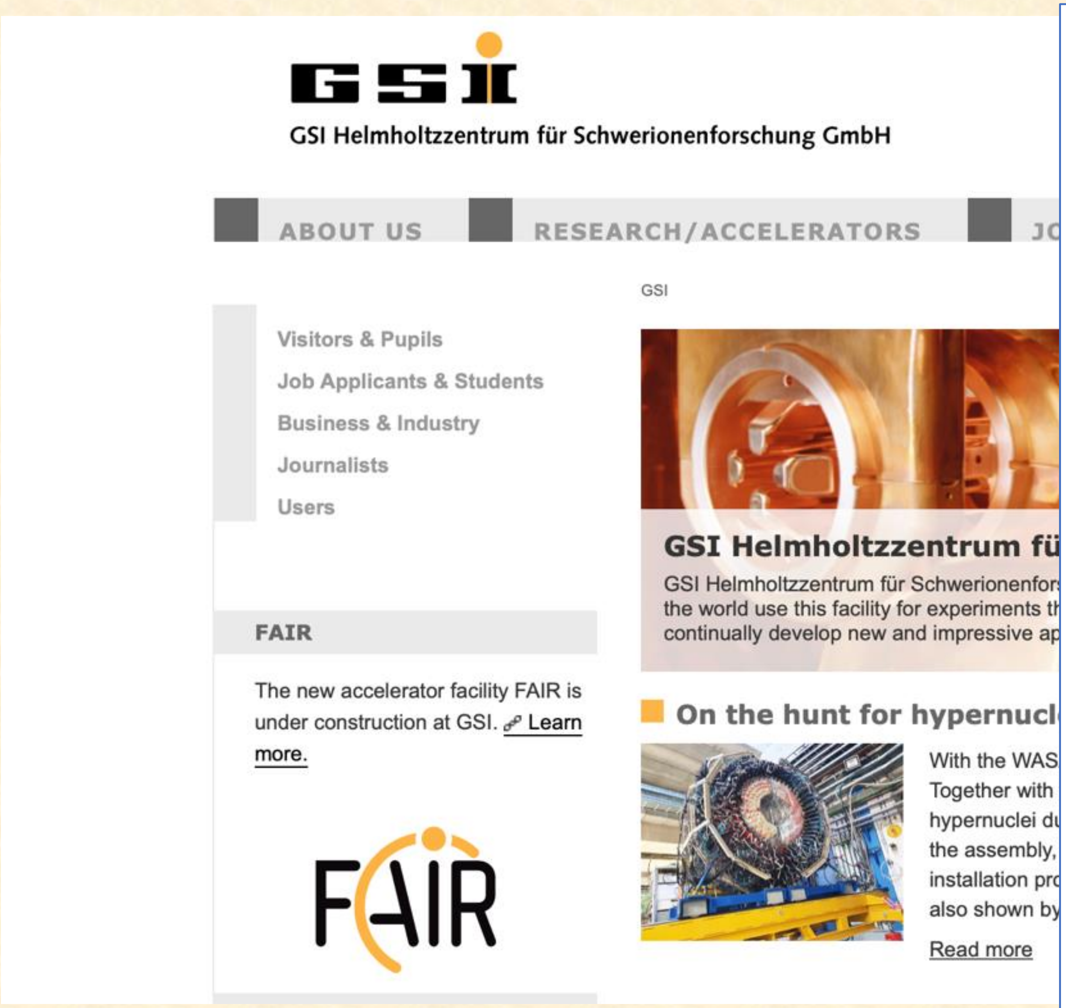
- ^{3}He at S4 (near the projectile rapidity) : 3.3 X 10^{8} (40 hours 56 minutes, 5569 files)
- d/^{4}He at S4 (near the projectile rapidity) : 2.7 X 10^{8} (43 hours 51 minutes 5251 filles)

  the ratio of d/4He is approximately 2/1
- Protons at S4 (mid-rapidity) : 5.3 X 10^{6} (3 hours 9 minutes, 680 files)

With ^{12}C beams at 1.96 A GeV:

- ^{3}He at S4 (near the projectile rapidity) : 1.0 X 10^{8} (13 hours 29 minutes, 1861 files)
- ^{9}C at S4 (near the projectile rapidity) : 2.4 X 10^{5} (in the same data set of ^{3}He)

GSI press release on October 21st, 2021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The new accelerator facility FAIR is under construction at GSI. Learn more.

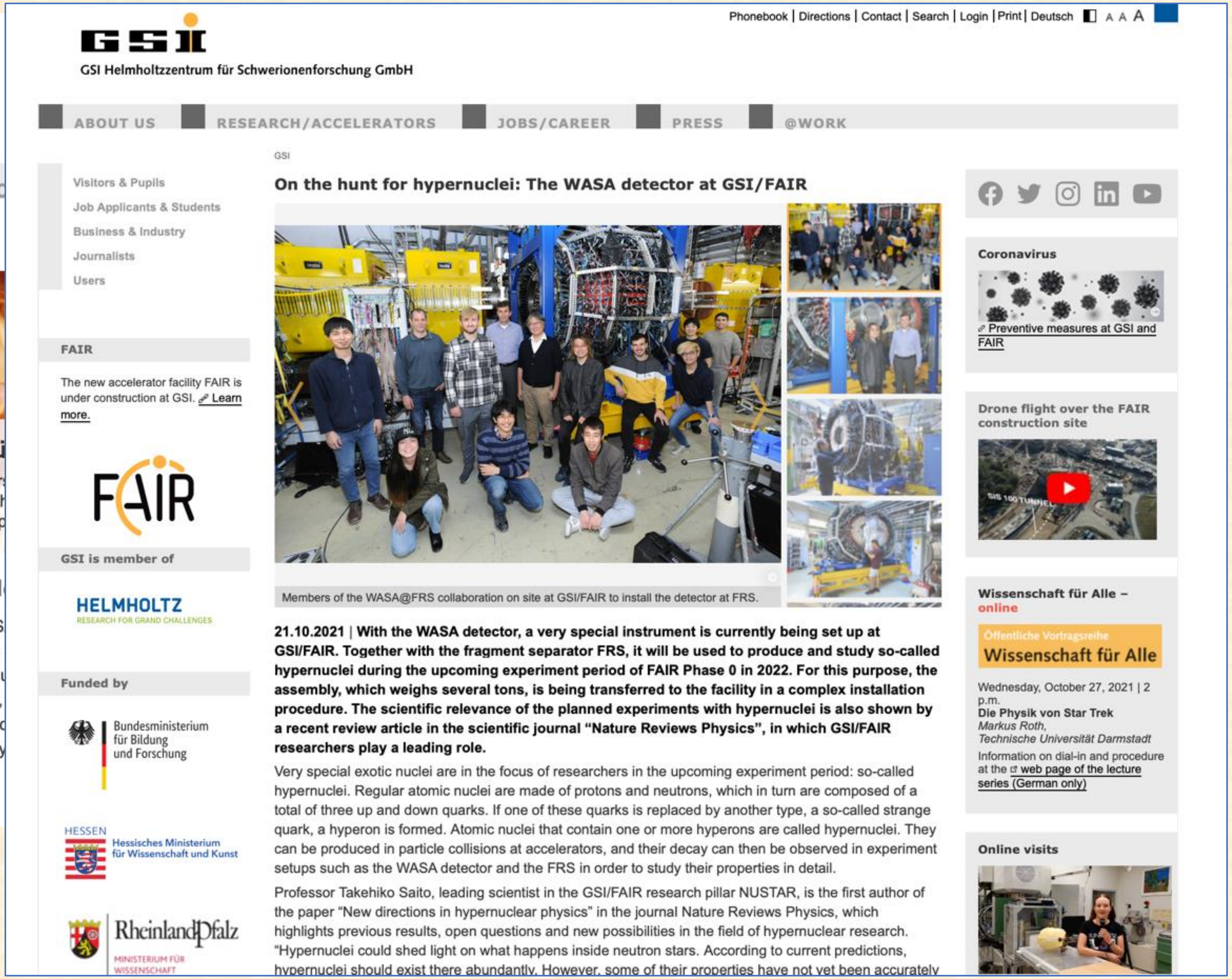
GSI

GSI Helmholtzzentrum fü
GSI Helmholtzzentrum für Schwerionenfor
the world use this facility for experiments t
continually develop new and impressive ap

On the hunt for hypernucl

With the WAS
Together with
hypernuclei du
the assembly,
installation pro
also shown by

Read more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GSI

On the hunt for hypernuclei: The WASA detector at GSI/FAIR

Members of the WASA@FRS collaboration on site at GSI/FAIR to install the detector at FRS.

21.10.2021 | With the WASA detector, a very special instrument is currently being set up at GSI/FAIR. Together with the fragment separator FRS, it will be used to produce and study so-called hypernuclei during the upcoming experiment period of FAIR Phase 0 in 2022. For this purpose, the assembly, which weighs several tons, is being transferred to the facility in a complex installation procedure. The scientific relevance of the planned experiments with hypernuclei is also shown by a recent review article in the scientific journal "Nature Reviews Physics", in which GSI/FAIR researchers play a leading role.

Very special exotic nuclei are in the focus of researchers in the upcoming experiment period: so-called hypernuclei. Regular atomic nuclei are made of protons and neutrons, which in turn are composed of a total of three up and down quarks. If one of these quarks is replaced by another type, a so-called strange quark, a hyperon is formed. Atomic nuclei that contain one or more hyperons are called hypernuclei. They can be produced in particle collisions at accelerators, and their decay can then be observed in experiment setups such as the WASA detector and the FRS in order to study their properties in detail.

Professor Takehiko Saito, leading scientist in the GSI/FAIR research pillar NUSTAR, is the first author of the paper "New directions in hypernuclear physics" in the journal Nature Reviews Physics, which highlights previous results, open questions and new possibilities in the field of hypernuclear research. "Hypernuclei could shed light on what happens inside neutron stars. According to current predictions, hypernuclei should exist there abundantly. However, some of their properties have not yet been accurately

Coronavirus
Preventive measures at GSI and FAIR

Drone flight over the FAIR construction site

Wissenschaft für Alle – online
Öffentliche Vortragsreihe
Wissenschaft für Alle
Wednesday, October 27, 2021 | 2 p.m.
Die Physik von Star Trek
Markus Roth,
Technische Universität Darmstadt
Information on dial-in and procedure at the web page of the lecture series (German only)

Online visits

In newspapers

Austrian national newspaper, Der Standard

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46 Postings

EXOTISCHE PARTIKEL

Teilchenphysiker auf der Jagd nach Hyperkernen

Hyperkerne, die in Neutronensternen in großer Zahl vorgekommen könnten, sollen mit dem WASA-Detektor erforscht werden

23. Oktober 2021, 10:12 46 Postings

Herkömmliche Atomkerne bestehen aus Protonen und Neutronen. Zerlegt man diese Atombausteine weiter, stellt man fest, dass sie sich aus insgesamt drei sogenannten Up- und Down-Quarks zusammensetzen. Neben drei weiteren Quark-Arten, den Charm-, Top- und Bottom-Quarks, existieren auch noch die Strange-Quarks. Diese seltsamen Partikel haben bei Kollisionen von Elementarteilchen eine vergleichsweise lange Lebensdauer.

Ersetzt man ein Up- oder Down-Quark eines Protonens oder Neutrons durch ein solches Strange-Quark, dann erhält man ein Hyperon. Atomkerne, in denen ein oder mehrere Hyperonen eingebaut sind, heißen Hyperkerne. Sie lassen sich mithilfe von Teilchenkollisionen an Beschleunigern erzeugen. Diese durchaus exotischen Hyperkerne will man nun mithilfe des WASA-Detektors, einem neuen Messgerät am GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, näher unter die Lupe nehmen.

Die Messgeräte des WASA-Detektors ragen wie Stacheln nach außen. Der riesige WASA-Aufbau besteht aus Szintillations- und Gasdetektoren, die geladene und neutrale Teilchen nachweisen können.

Foto: G. Otto, GSI/FAIR

Hyperkerne in Neutronensternen

"Die Hyperkerne könnten Licht auf die Vorgänge im Inneren von Neutronensternen werfen. Nach aktuellen Vorhersagen sollten Hyperkerne dort sehr zahlreich vorkommen", sagt Takehiko Saito, leitender Wissenschafter beim Forschungsprojekt NUSTAR. Allerdings sind einige ihrer Eigenschaften noch

https://www.derstandard.at/story/2000130648525/teilchenphysiker-uf-der-jagd-nachhyperkernen-nach

pro-physic in Germany

Das Physikportal pro-physik.de

NACHRICHTEN ZEITSCHRIFTEN STELLENMARKT PRODUKTE ANBIETER MULTIMEDIA VERANSTALTUNGEN

Panorama

Hyperkerne im Visier

22.10.2021 - Der WASA-Detektor in Darmstadt wird Teilchenspuren aus hochenergetischen Kernkollisionen verfolgen.

Ganz besonderen exotischen Atomkernen wollen die Wissenschaftlerinnen und Wissenschaftler in der kommenden Experimentierzeit nachjagen: Hyperkernen. Gewöhnliche Atomkerne bestehen aus Protonen und Neutronen, die sich wiederum aus insgesamt drei Up- und Down-Quarks zusammensetzen. Ersetzt man eins der Quarks durch ein Strange-Quark, erhält man ein Hyperon. Atomkerne, in denen ein oder mehrere Hyperonen eingebaut sind, heißen Hyperkerne. Sie lassen sich mithilfe von Teilchenkollisionen an Beschleunigern erzeugen. Anschließend können ihre Zerfälle in Messaufbauten wie dem WASA-Detektor und dem FRS am GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt beobachtet und ihre Eigenschaften im Detail untersucht werden.

Abb.: Die Messgeräte des WASA-Detektors ragen wie Stacheln nach außen. Der riesige Aufbau besteht aus Szintillations- und Gasdetektoren, die geladene und neutrale Teilchen nachweisen können. (Bild: G. Otto, GSI / FAIR)

https://www.pro-physik.de/nachrichten/hyperkerne-im-visier

Also in ESNAF (Turkey) and Phys Org

Another GSI press release on May 16th, 2022

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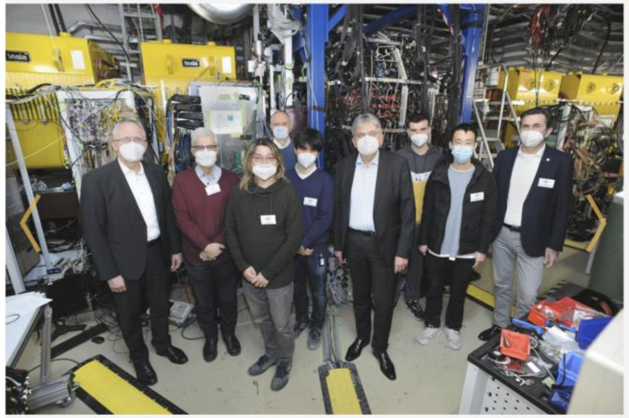
GSI

GSI/FAIR directors visit WASA detector setup at the fragment separator FRS



At the detector setup

16.05.2022 | "It is very impressive to see how such a large collaboration of international scientists works together and I am impressed by the great scientific achievements", says Professor Paolo Giubellino, the Scientific Managing Director of GSI and FAIR. Together with his colleagues Jörg Blaurock and Dr. Ulrich Breuer, the Technical Managing Director and the Administrative Managing Director of GSI and FAIR, he visited the WASA detector, which is presently installed at the GSI fragment separator FRS, a few days after the successful commissioning of the experiment in February and March 2022. All three directors wanted to obtain first-hand information of this milestone experiment and get a direct impression of the ongoing work and its first results.

In the meantime, several experiments have been performed successfully to search for and study very special exotic atoms, especially mesic atoms and hypernuclei. The experiments build on a long-standing and intense collaboration between GSI and RIKEN, Japan's largest comprehensive research institution renowned for high-quality research in a wide range of modern scientific disciplines.

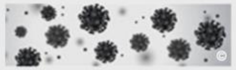
Regular atomic nuclei are made of protons and neutrons, which in turn are composed of a total of three up and down quarks. They form the nucleus and, together with the surrounding electrons, an atom. If one of the quarks in the nucleus is replaced by another type, a so-called strange quark, a hypernucleus is formed. Hypernuclei can be produced in energetic particle collisions at accelerators, and their decay

Drone flight over the FAIR construction site

Task Force Ukraine

Task Force on dealing with the effects of the war in Ukraine

Coronavirus



Preventive measures at GSI and FAIR

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Öffentliche Vortragsreihe
Wissenschaft für Alle

Wed, June 15, 2022 | 2 p.m.
Das Rätsel der Dunklen Materie: Dem unsichtbaren Universum auf der Spur
Kathrin Valerius,
Karlsruher Institut für Technologie

Information on dial-in and procedure at the web page of the lecture series (German only)