

A wide-angle, low-perspective photograph of the J-ARC Main Ring, a large-scale particle accelerator. The image shows a long, curved tunnel with a polished, reflective floor that mirrors the overhead lighting and structural elements. The ceiling is supported by a complex network of metal beams and pipes. The overall color palette is a cool, monochromatic blue. A semi-transparent white rectangular box is overlaid in the center of the image, containing the title and author information.

# J-ARC-HI

## J-ARC Heavy-Ion Project

Masakiyo Kitazawa  
for J-ARC-HI Collaboration

# J-**P**ARC

= Japan **Proton** Accelerator Research Complex

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= Japan **Proton** Accelerator Research Complex



Hiroshima

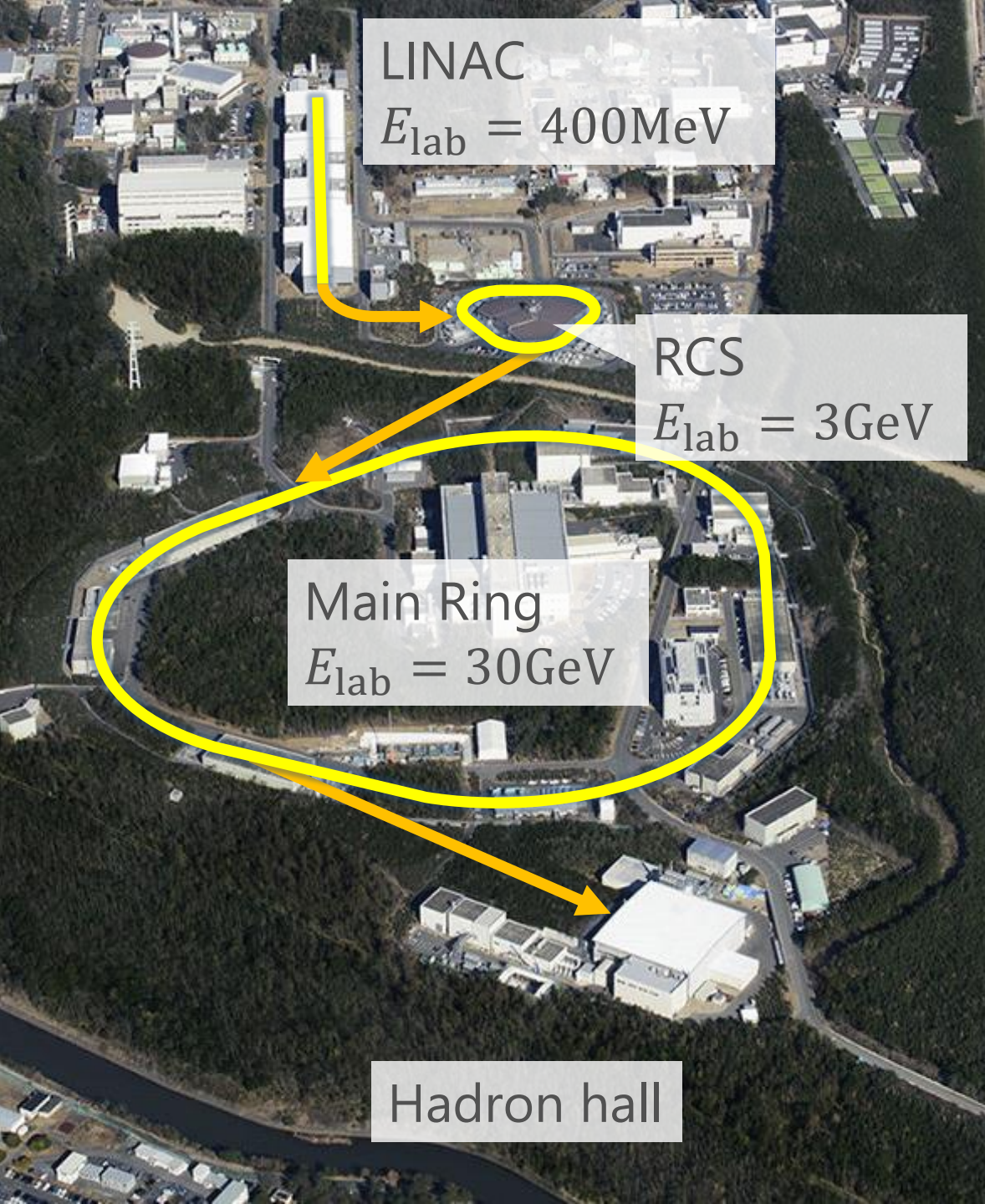
Kyoto

**J-PARC**

Tokyo







LINAC  
 $E_{\text{lab}} = 400\text{MeV}$

RCS  
 $E_{\text{lab}} = 3\text{GeV}$

Main Ring  
 $E_{\text{lab}} = 30\text{GeV}$

Hadron hall

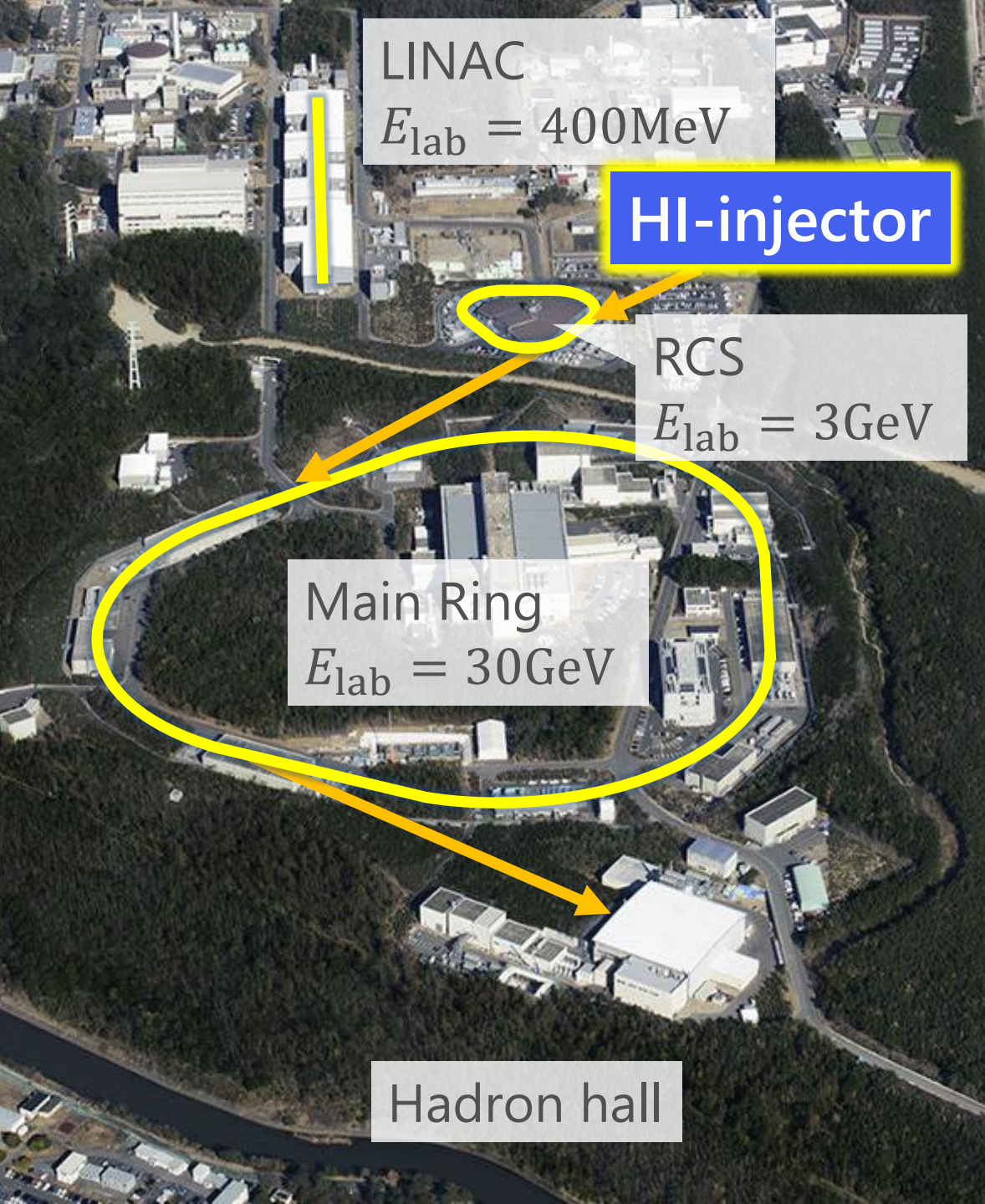
## Accelerators

- LINAC
- RCS
- Main Ring(MR)
- High intensity  $I = 1\text{MW}$

## Purposes

- Hadron/Nuclear physics
- Neutrino physics
- Material/Life science





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# J-PARC-HI

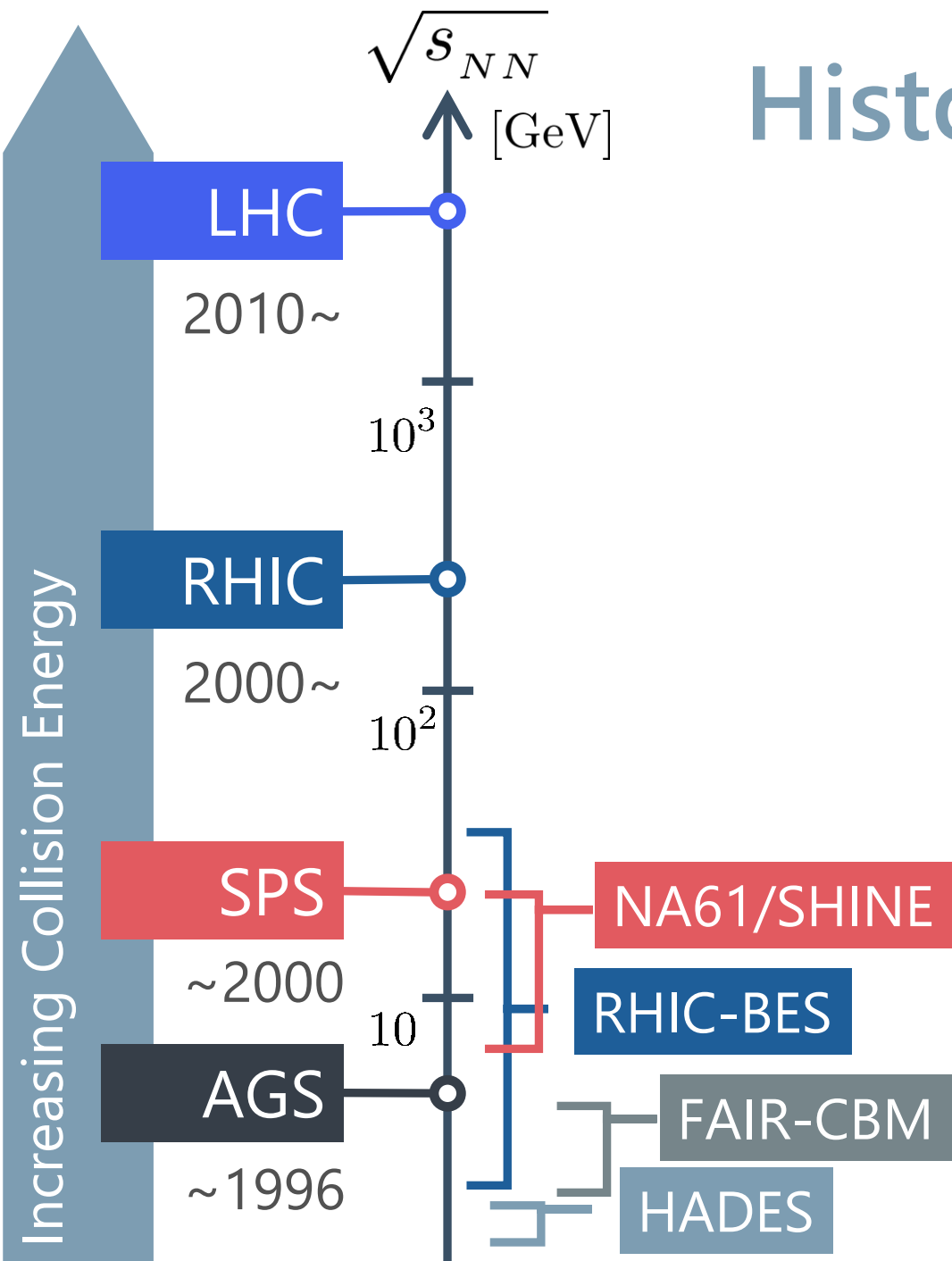
J-PARC Heavy Ion

High intensity

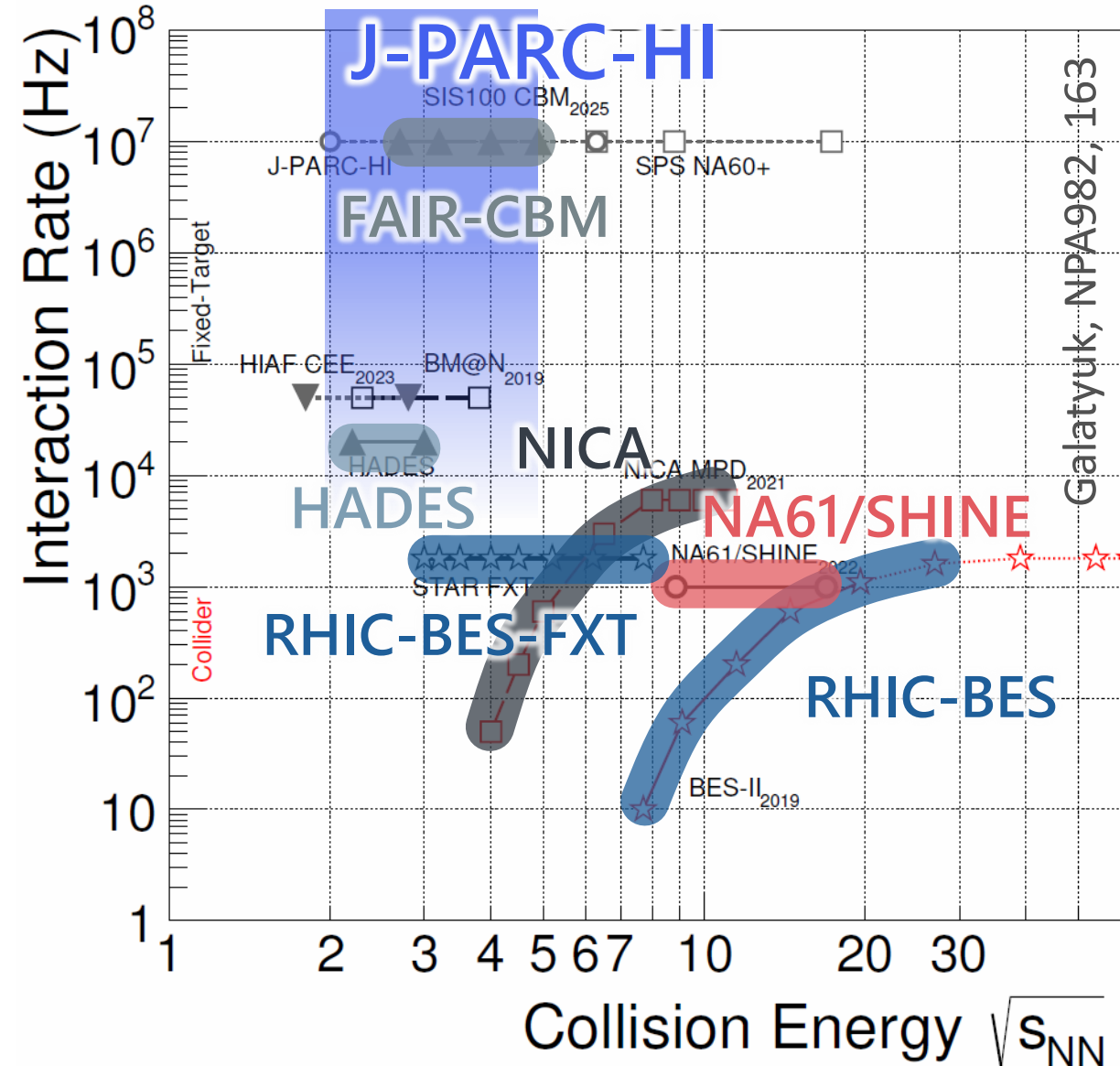
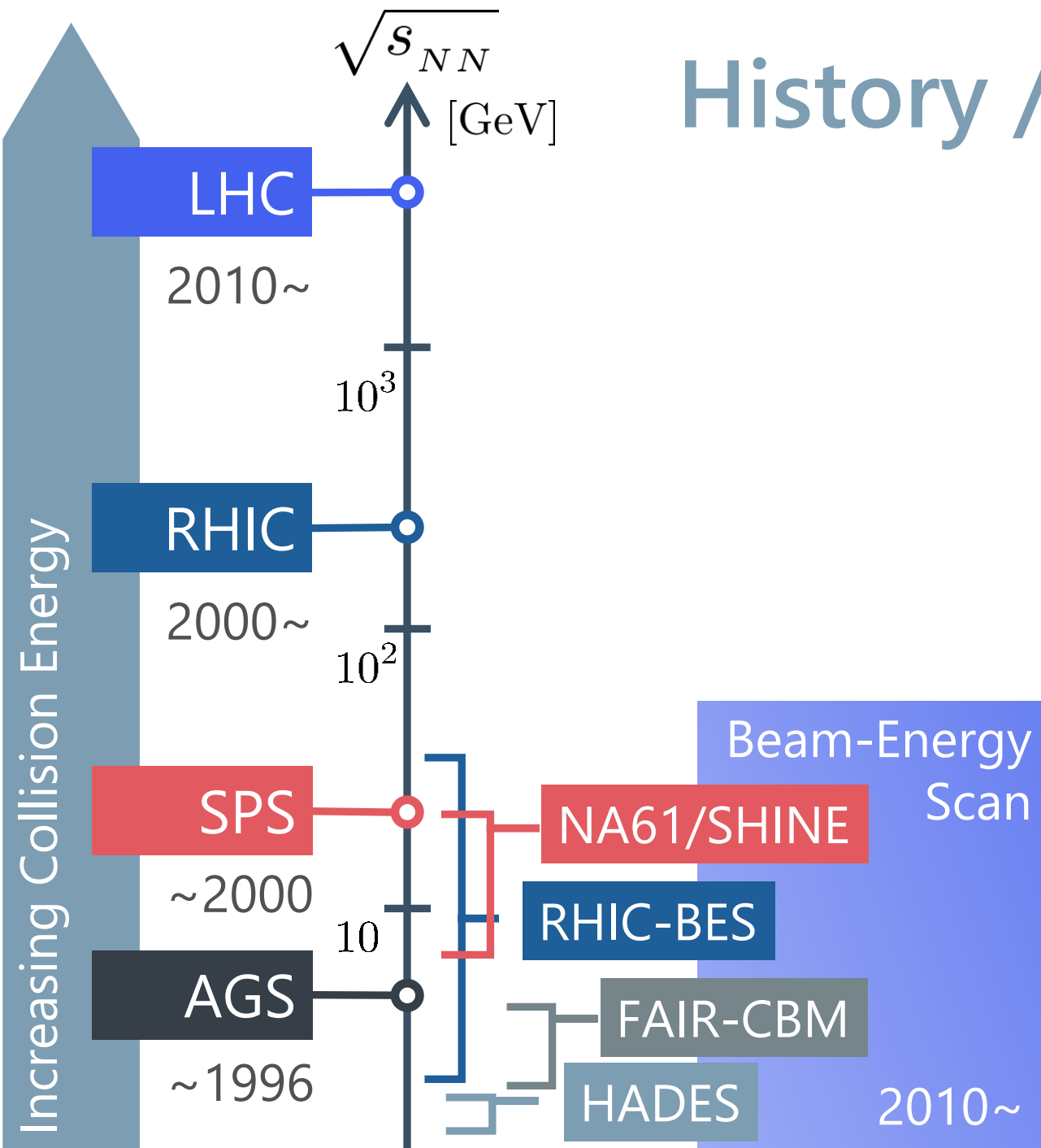


Intermediate energy

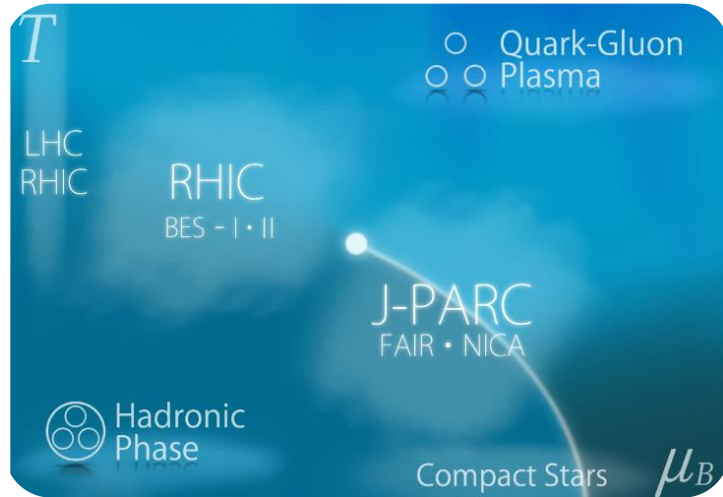
# History / Current Status of HIC



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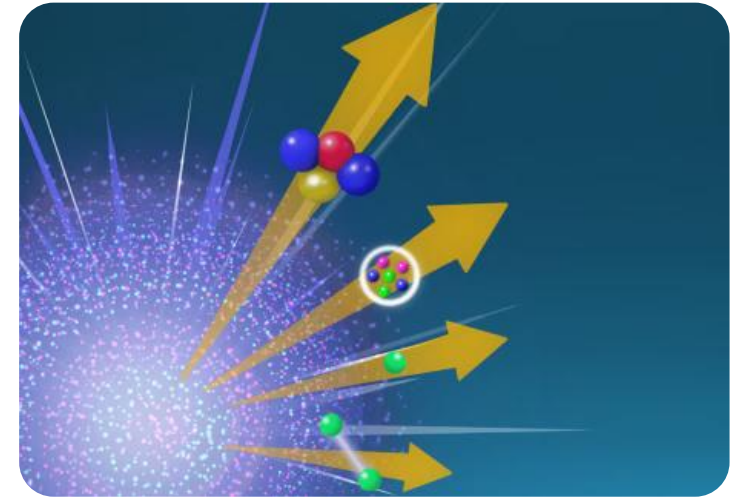


# Physics Goals



Exploring

Extremely Dense Medium



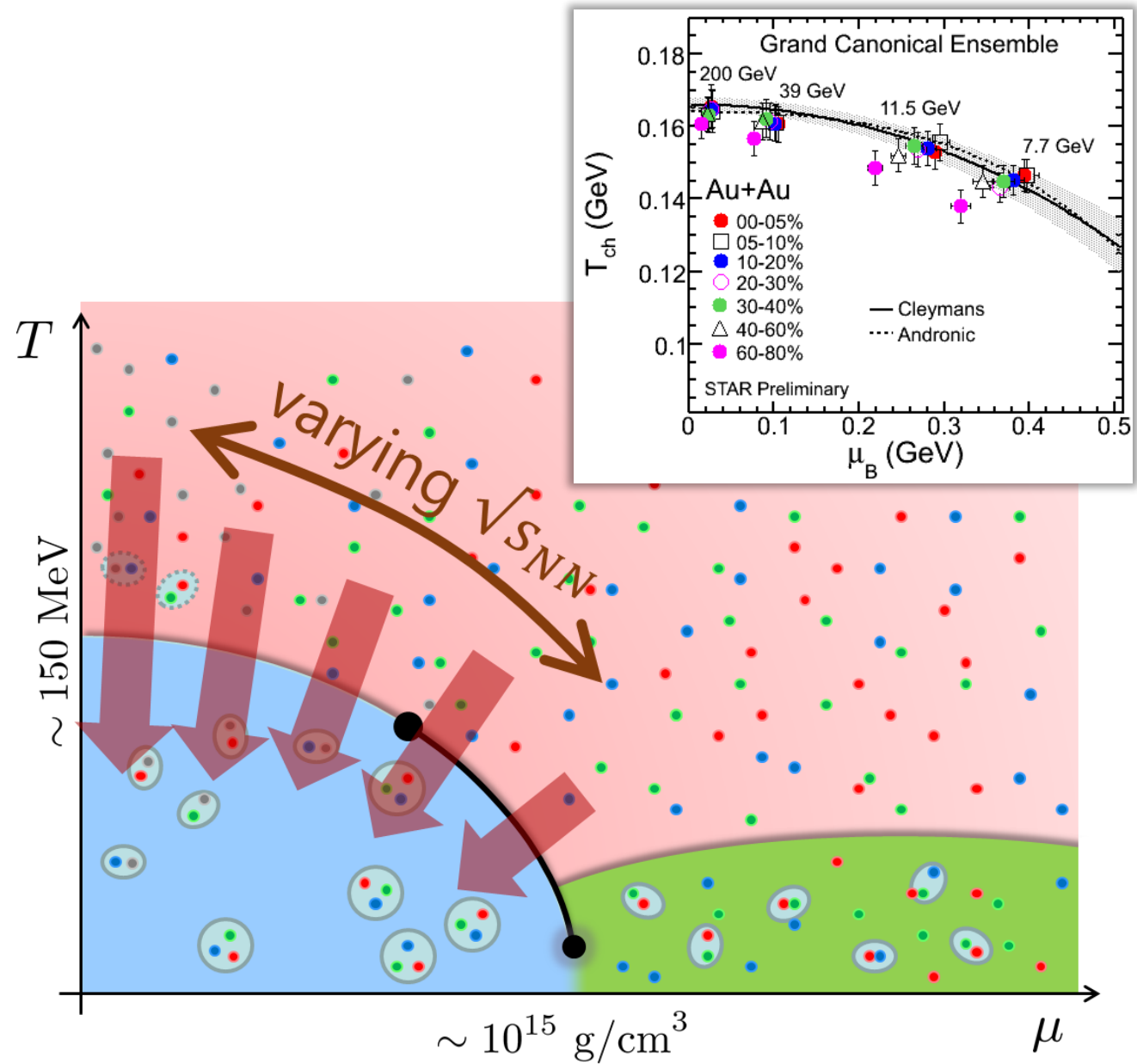
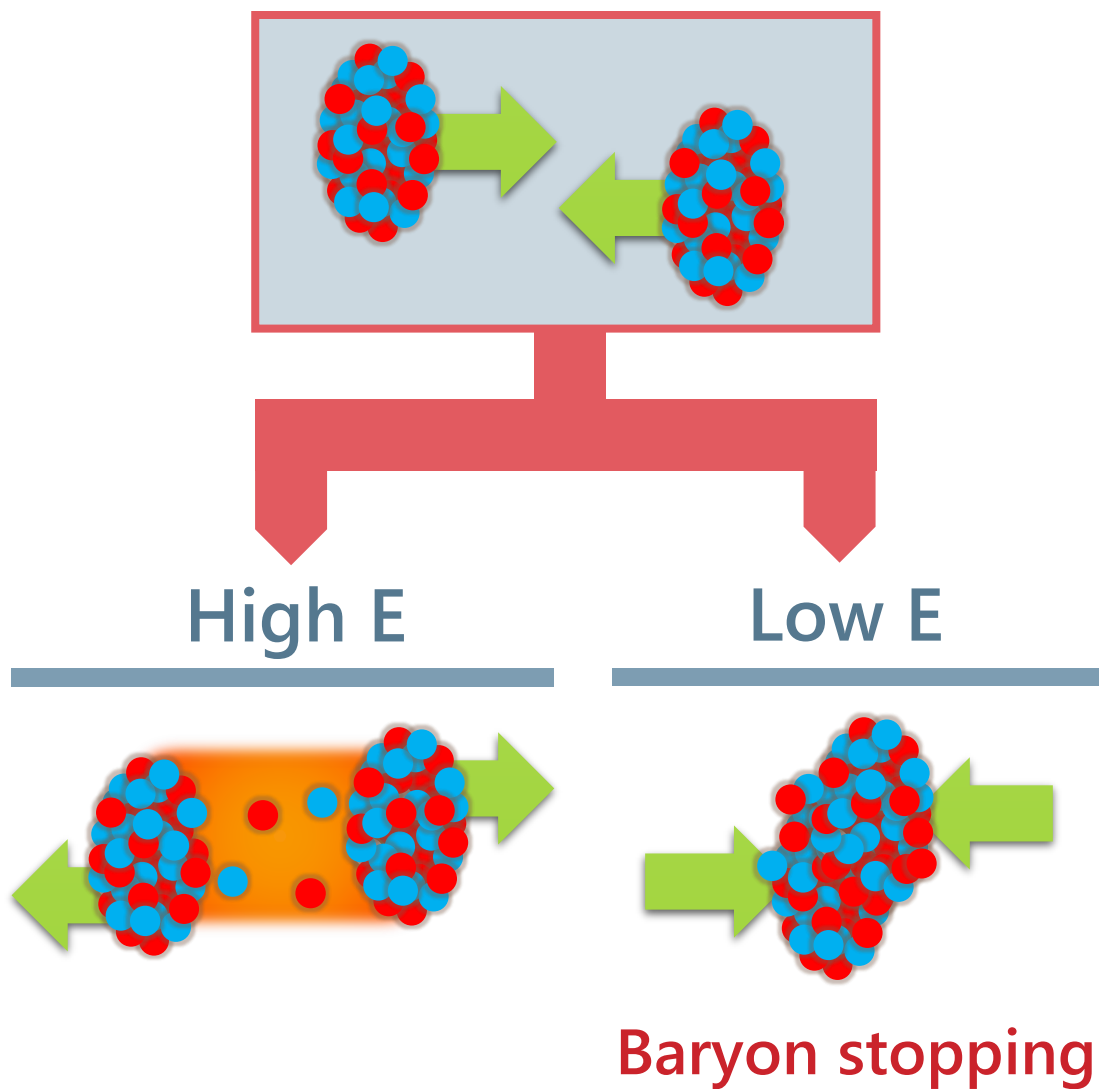
Search for

Rare Hadronic/Hypernuclear Events

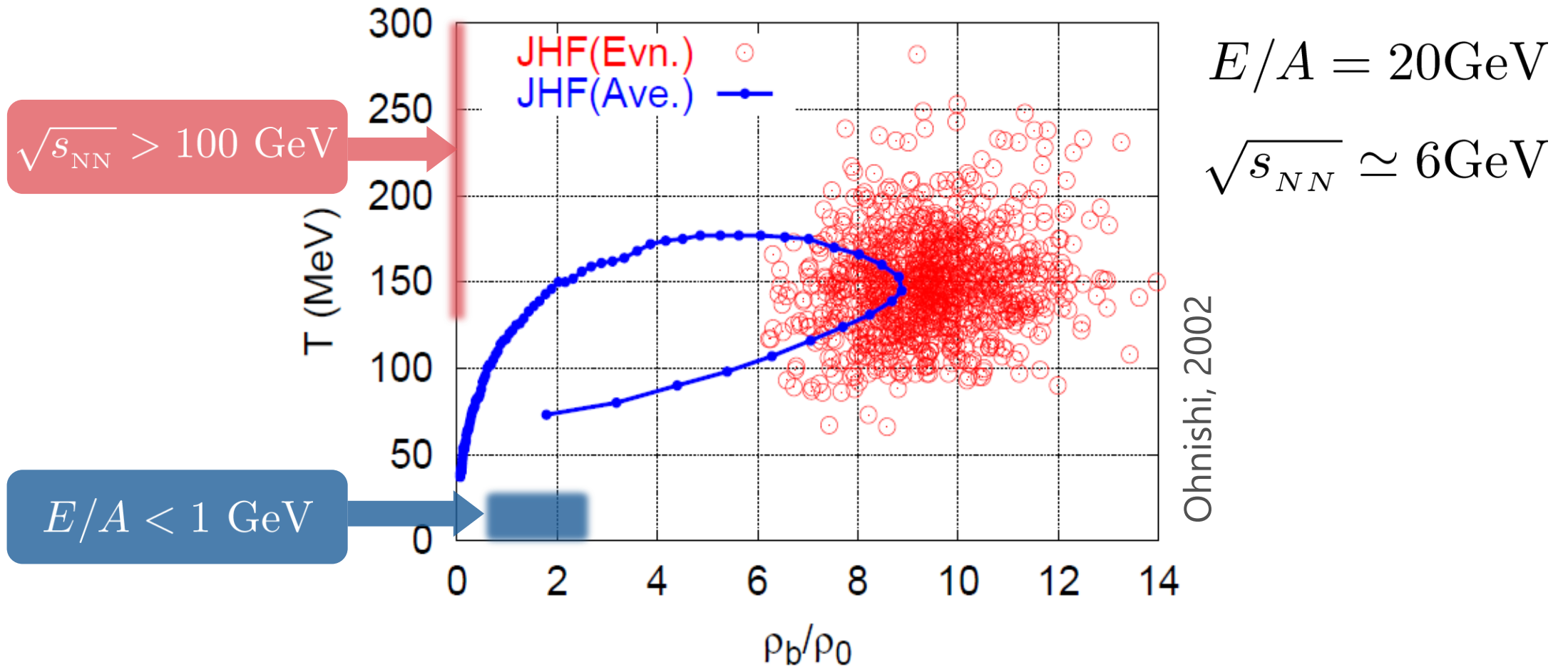


# Beam-Energy Scan

STAR, 2012



# J-PARC-HI = Highest Baryon Density



Quark-Gluon Plasma

# Exploring Dense Medium



Equation of state



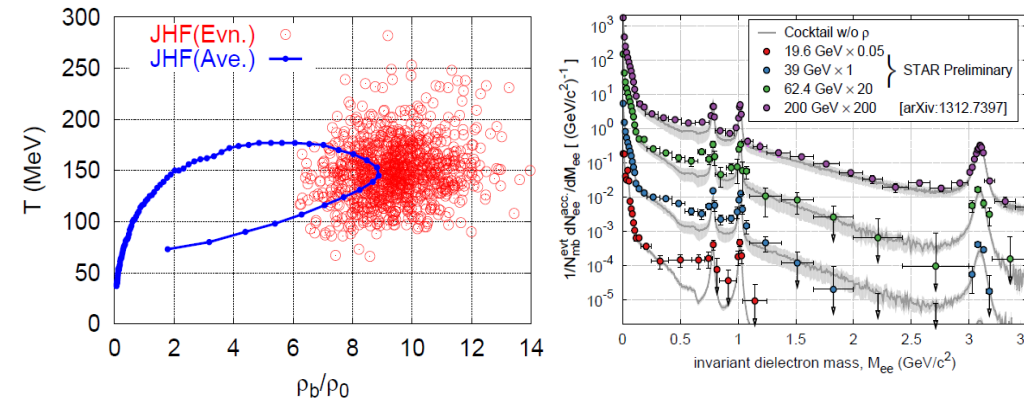
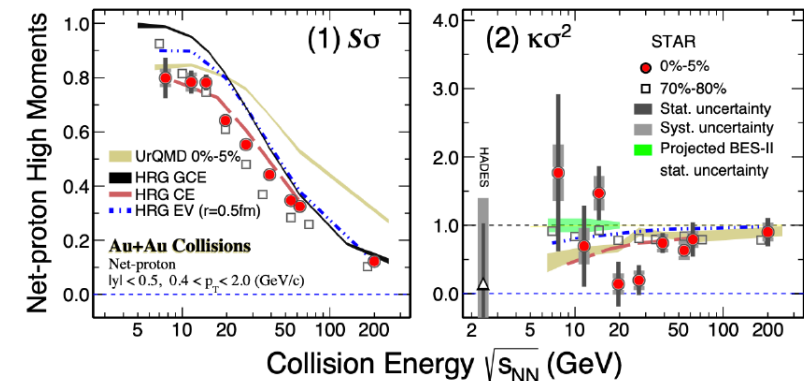
QCD critical point /  
1st order transition /  
Color superconductivity



Dilepton production rate



Event selection /  
Higher correlations



J-PARC  
FAIR • NICA

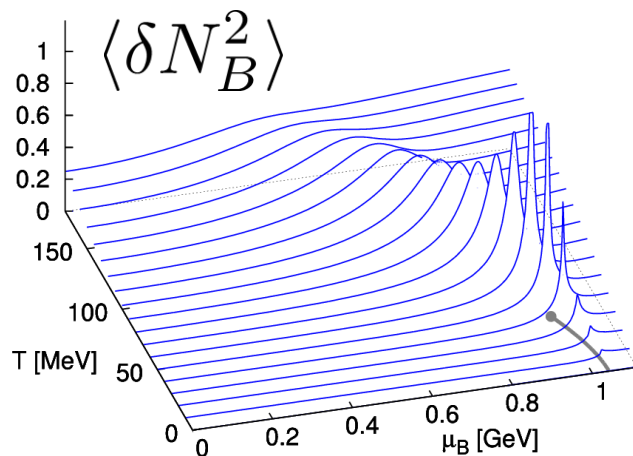
Compact Stars



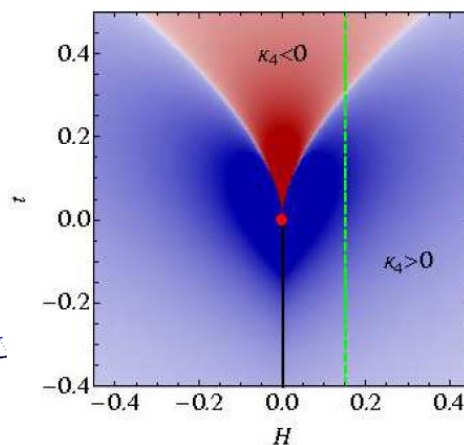
# Event-by-event Fluctuations

## Conserved charge fluctuations

- Higher-order cumulants
- Signal of QCD CP

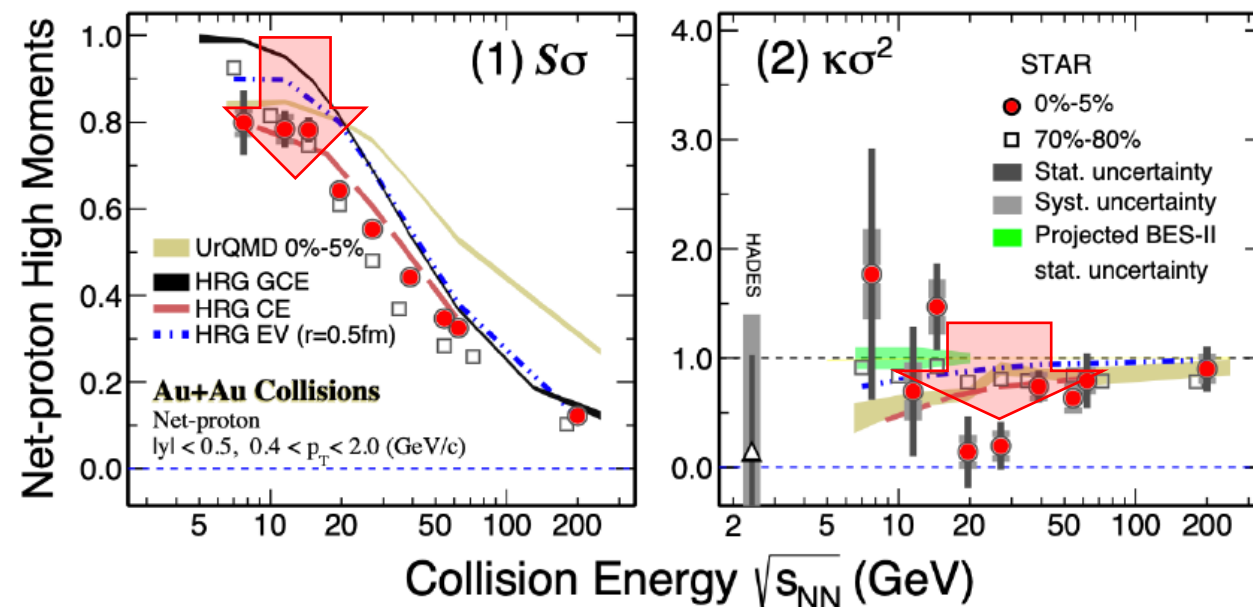


Asakawa, Ejiri, MK (2009)



Stephanov (2011)

## Experimental Result STAR (2022)

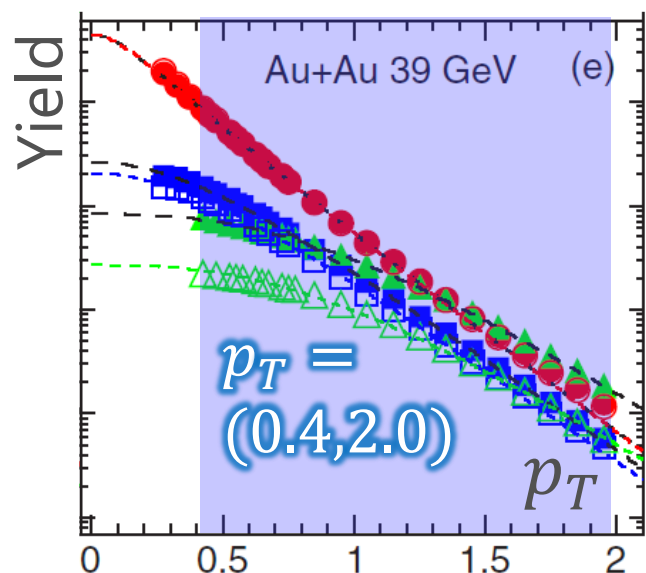


# Baryon/Charge Cumulant Ratio

MK, Esumi, Nonaka, 2205.10030

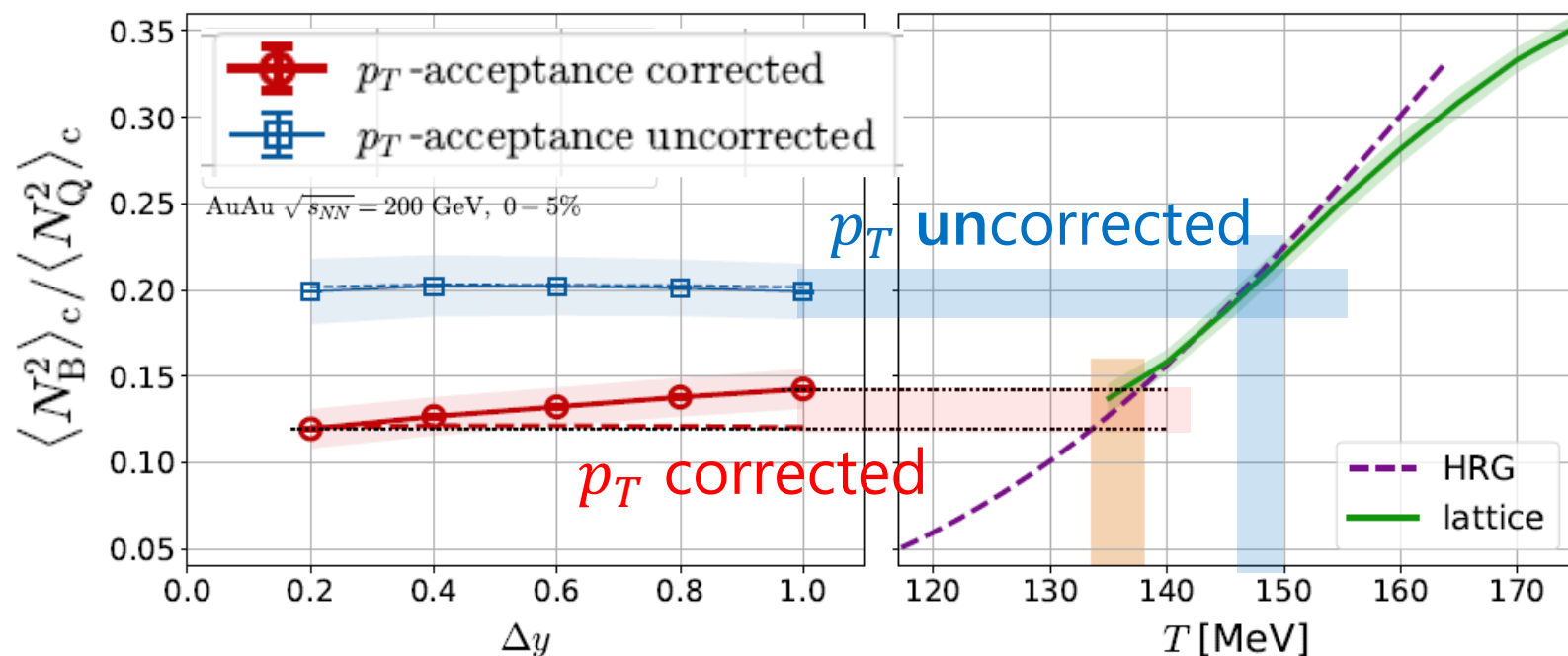
$$\langle N_B^2 \rangle_c / \langle N_Q^2 \rangle_c \simeq \chi_2^B / \chi_2^Q$$

$p_T$ -acceptance correction



- Electric charge: 49%
- Protons: 82%

STAR, 200GeV  $\longleftrightarrow$  Lattice QCD + HRG

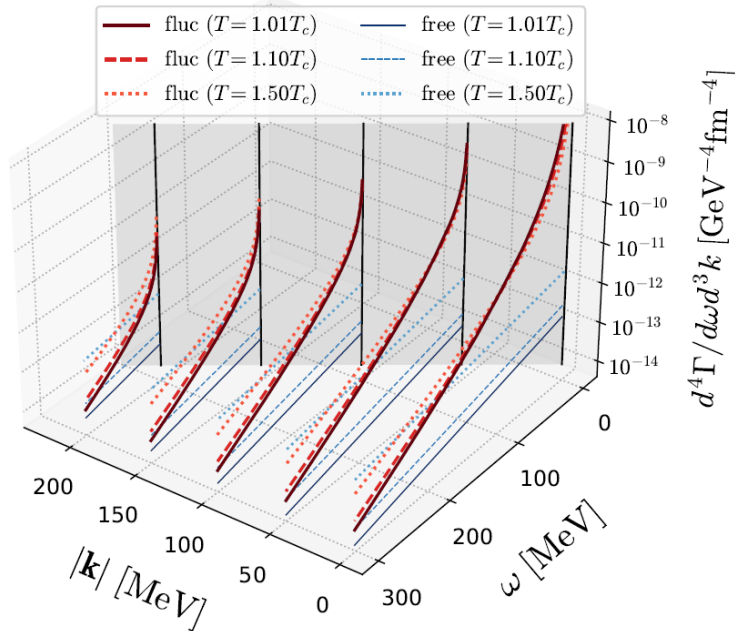


- Finite acceptance modifies the ratio strongly.
- Wider acceptance is necessary.

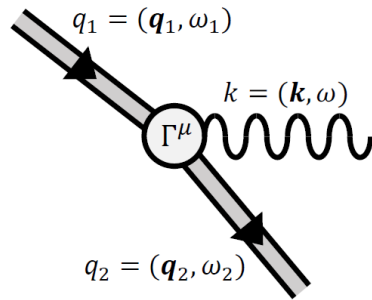
# Dilepton at Ultra-Low-Mass Region

## Signal for color SC?

Anomalous dilepton production due to soft modes at phase boundary



$d^4\Gamma/d\omega d^3k$  [ $\text{GeV}^{-4}\text{fm}^{-4}$ ]



Nishimura, MK,  
Kunihiro  
2302.03191  
2201.01963



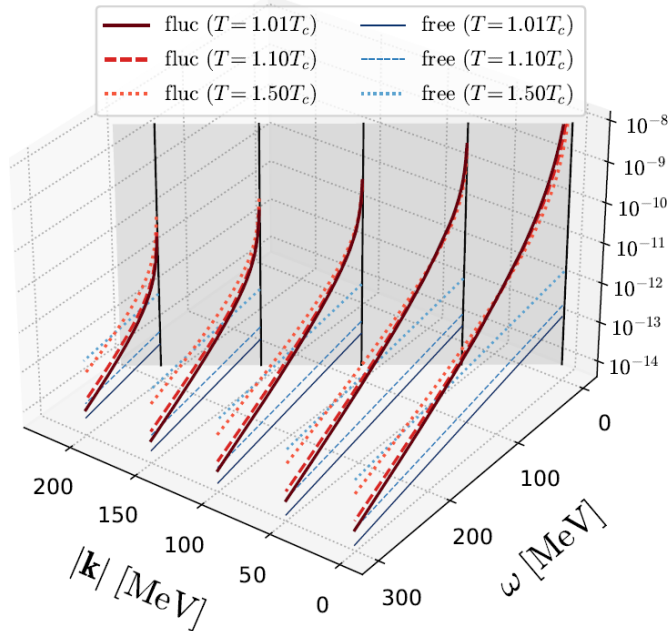
- Competition with pion Dalitz
- Momentum dependence



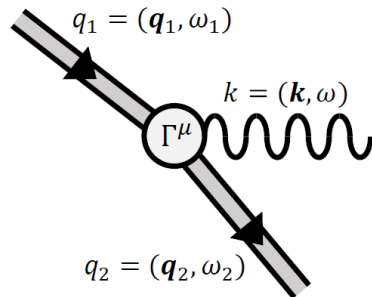
# Dilepton at Ultra-Low-Mass Region

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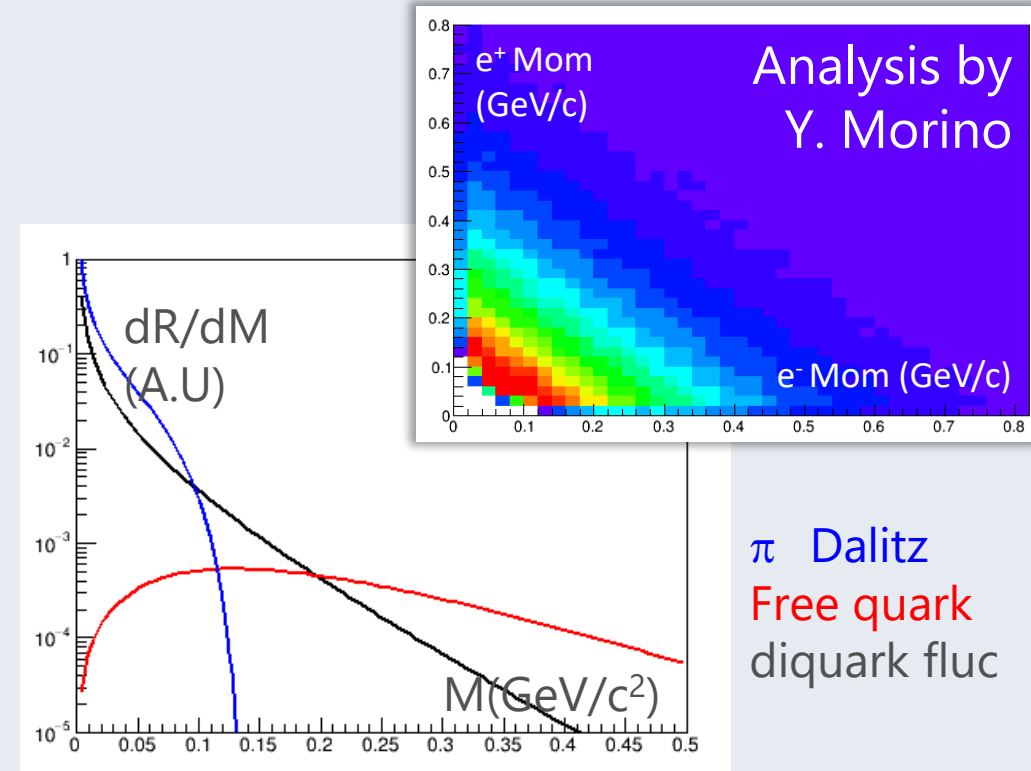
$$d^4\Gamma/d\omega d^3k \text{ [GeV}^{-4}\text{fm}^{-4}\text{]}$$



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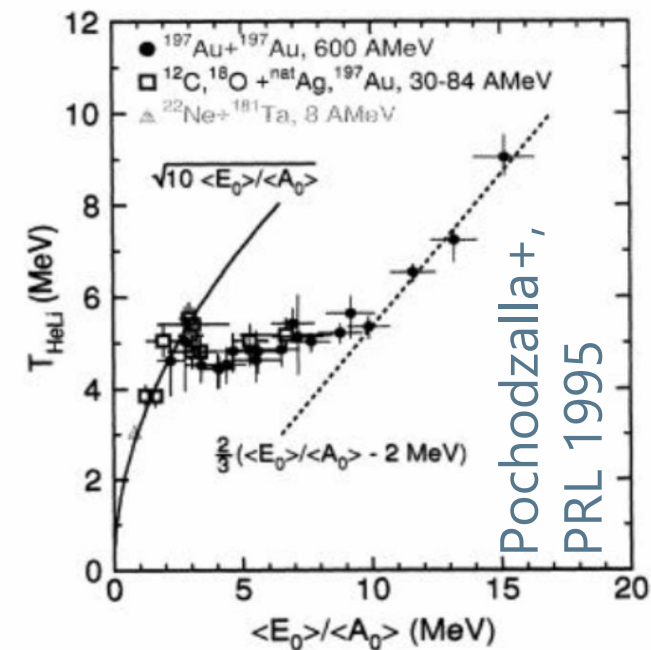
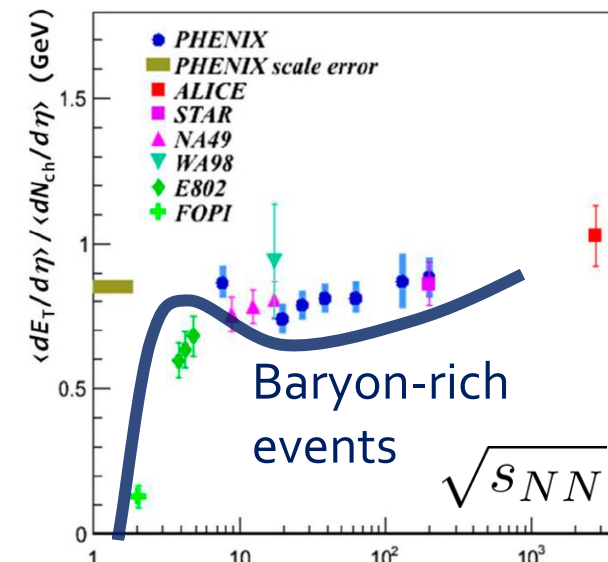
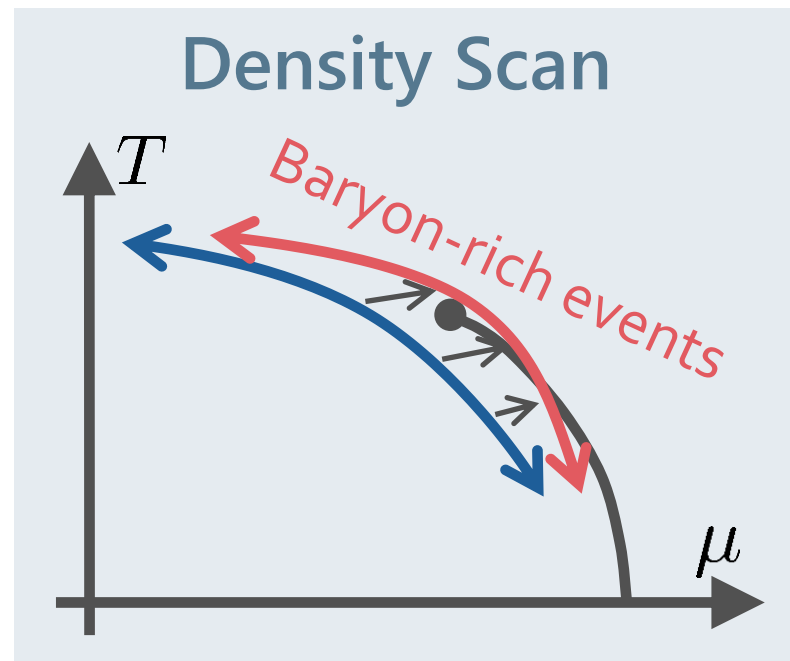
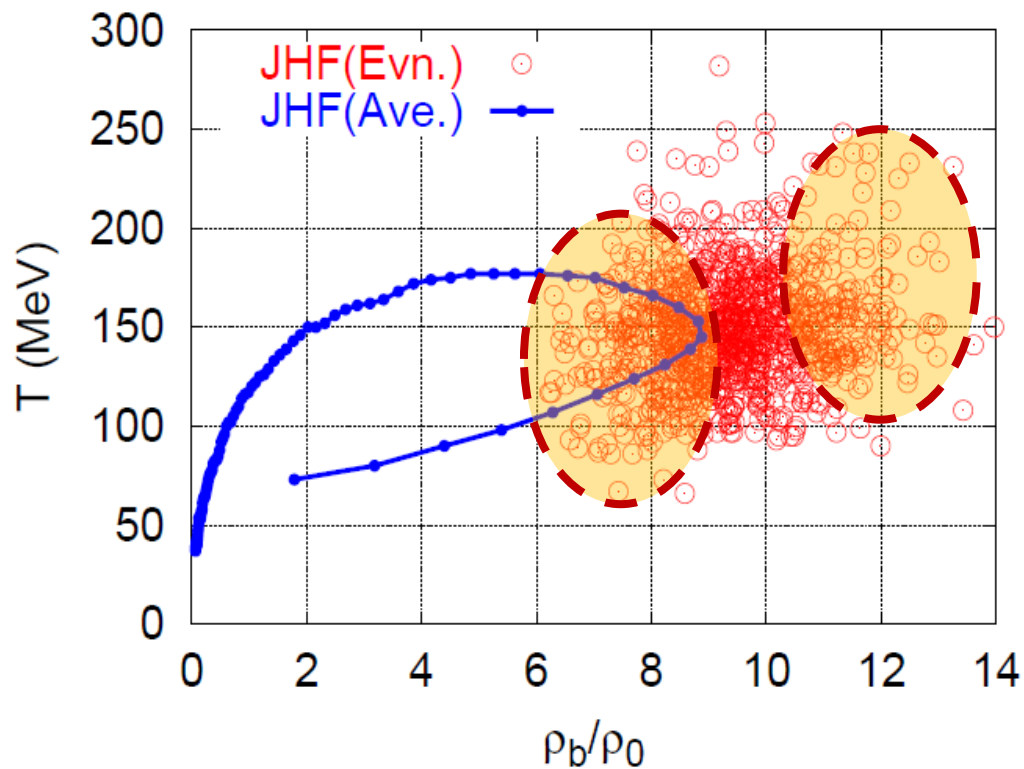
## Experiments



- Competition with pion Dalitz
- Momentum dependence

Study of experimental observability has just started!

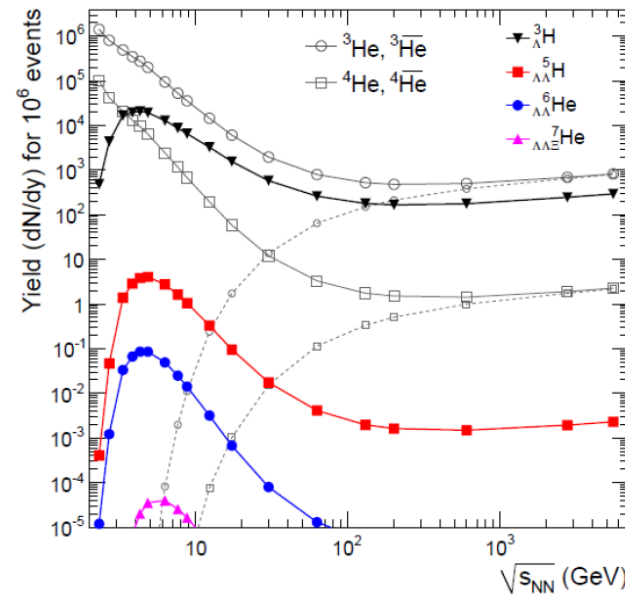
# Event Selection



■ Event selections via highest baryon/energy density will allow us a detailed study of QCD phase diagram.

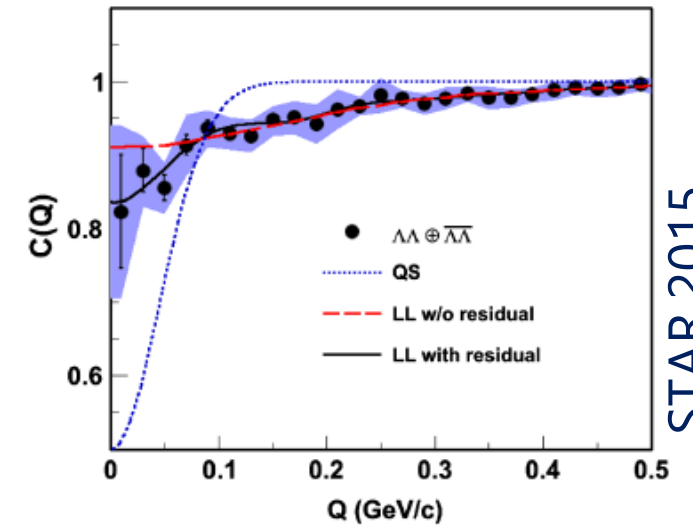
# Hadron/Hypernuclear Physics

## Hypernuclei



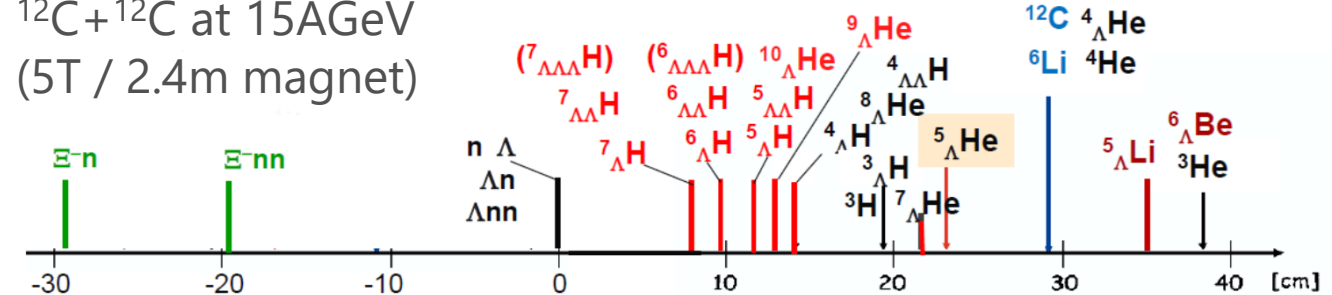
## Correlation functions

→ hadron interaction



STAR, 2015

${}^{12}\text{C}+{}^{12}\text{C}$  at 15A GeV  
(5T / 2.4m magnet)





J-PARC-HI

# Future Plan

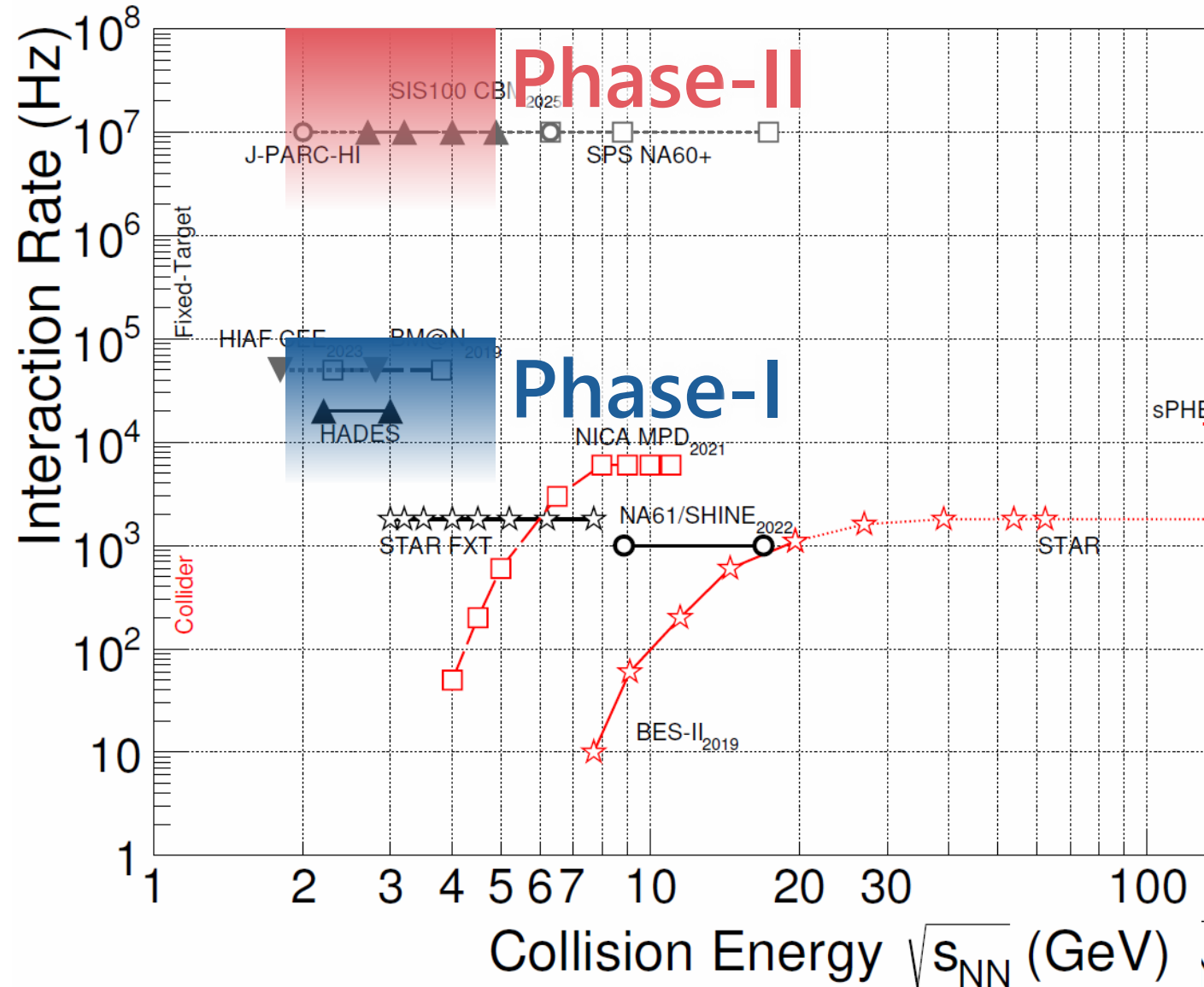
# J-PARC-HI Staging Plan

## Phase-I

- KEK-BS booster
- E16+ $\alpha$  spectrometer

## Phase-II

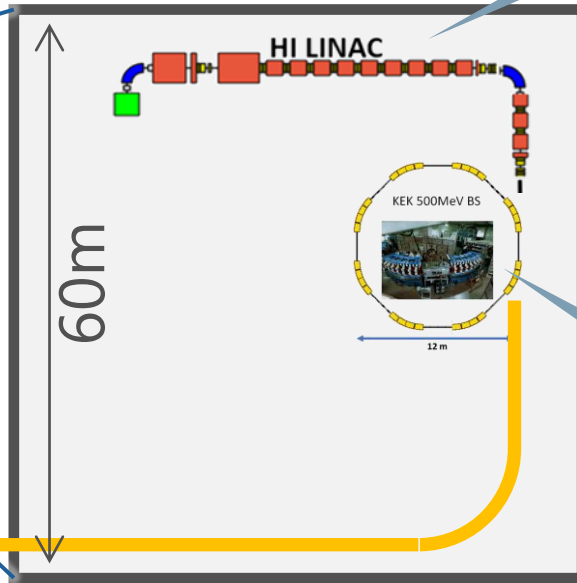
- NEW HI booster
- NEW spectrometer



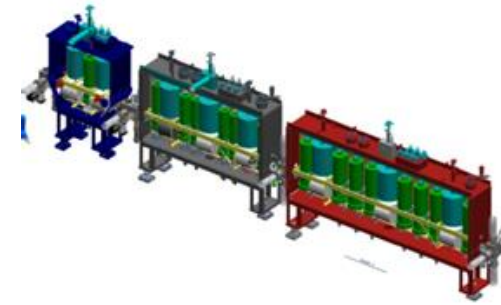
# Staging of HI Booster



Phase-I



HI LINAC



KEK 500MeV BS

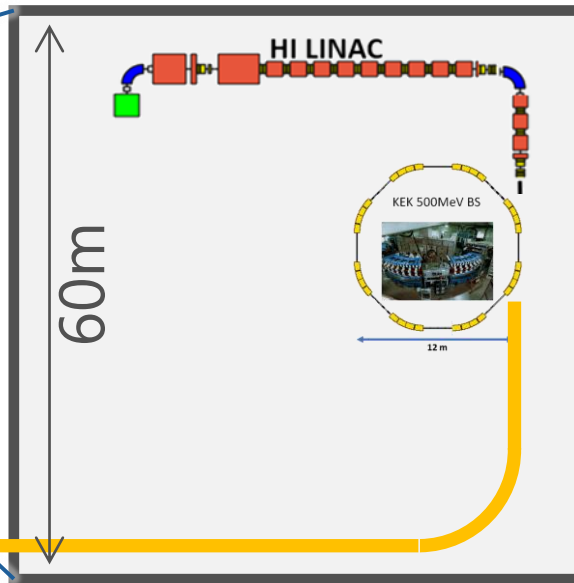


$\sim 10^5 \text{ Hz}$

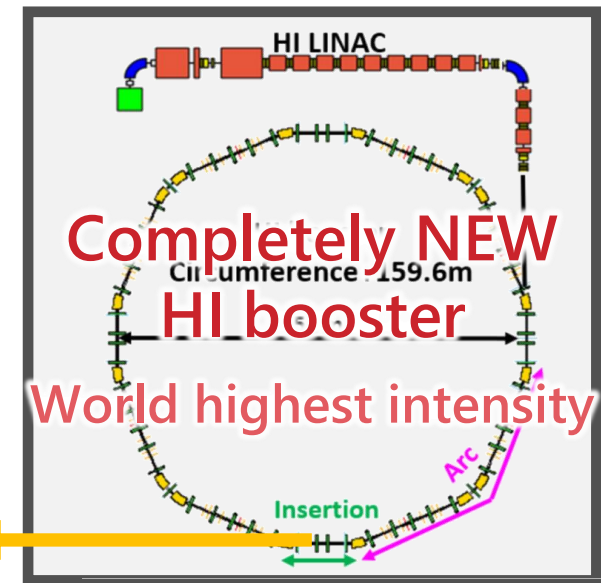
# Staging of HI Booster



## Phase-I



## Phase-II



Interaction rate

$$\sim 10^5 \text{ Hz}$$

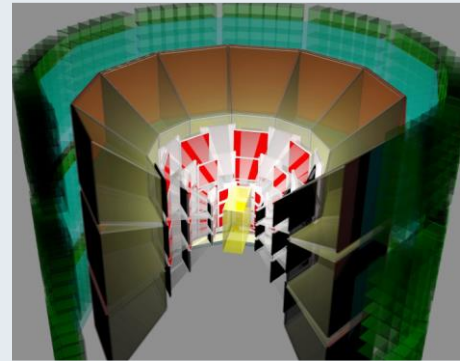
$$\sim 10^8 \text{ Hz}$$



# Detector Phase-I

## E16 Spectrometer

- $\phi \rightarrow e^+e^-$ ,  $\phi \rightarrow K^+K^-$
- In-medium mass modification
- Pilot data taking in June

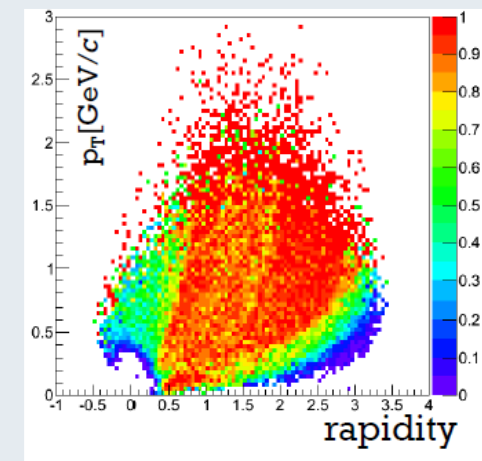
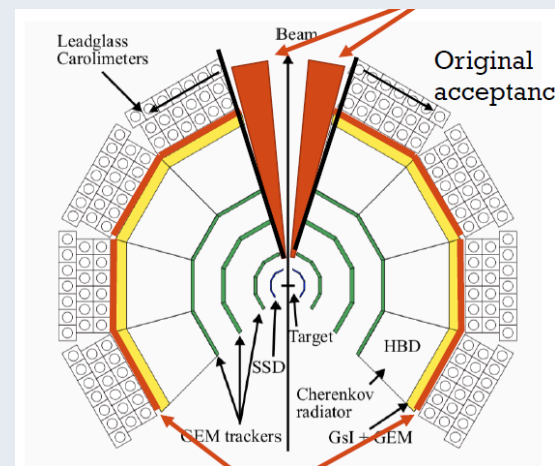


**UPGRADE**

## E16+ $\alpha$

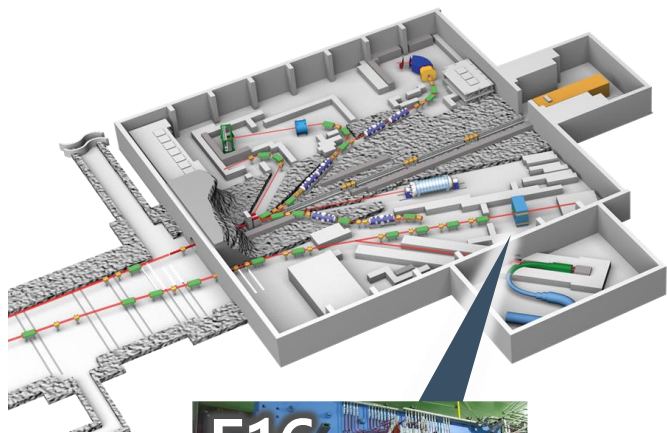
Upgrade forward region for high-multiplicity counting

➤ Hadron/lepton measurement at wide acceptance

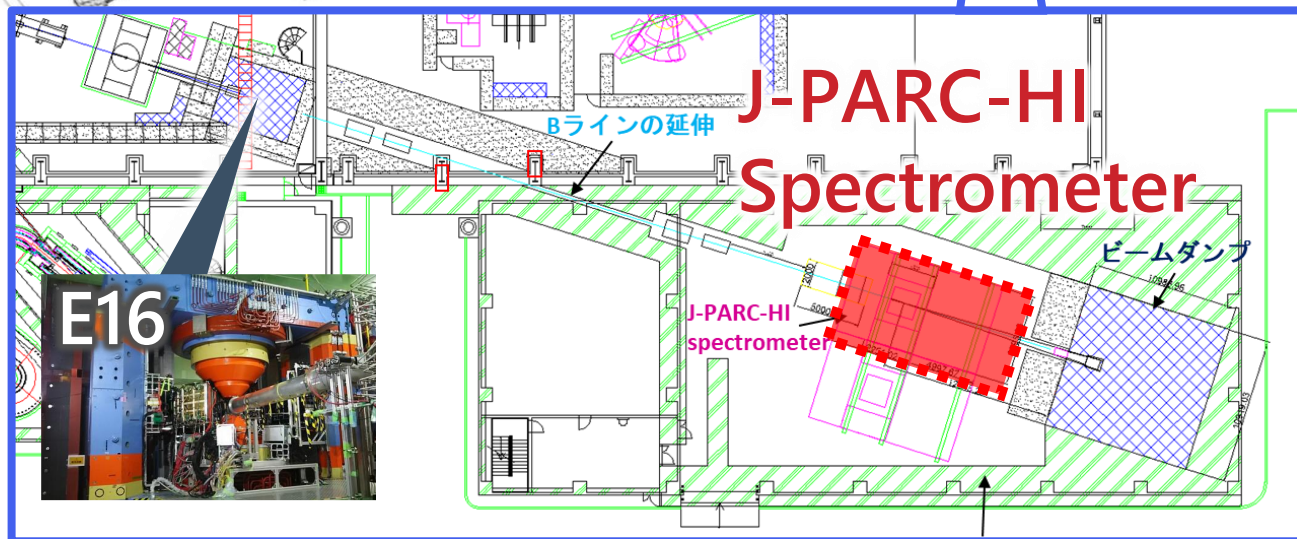
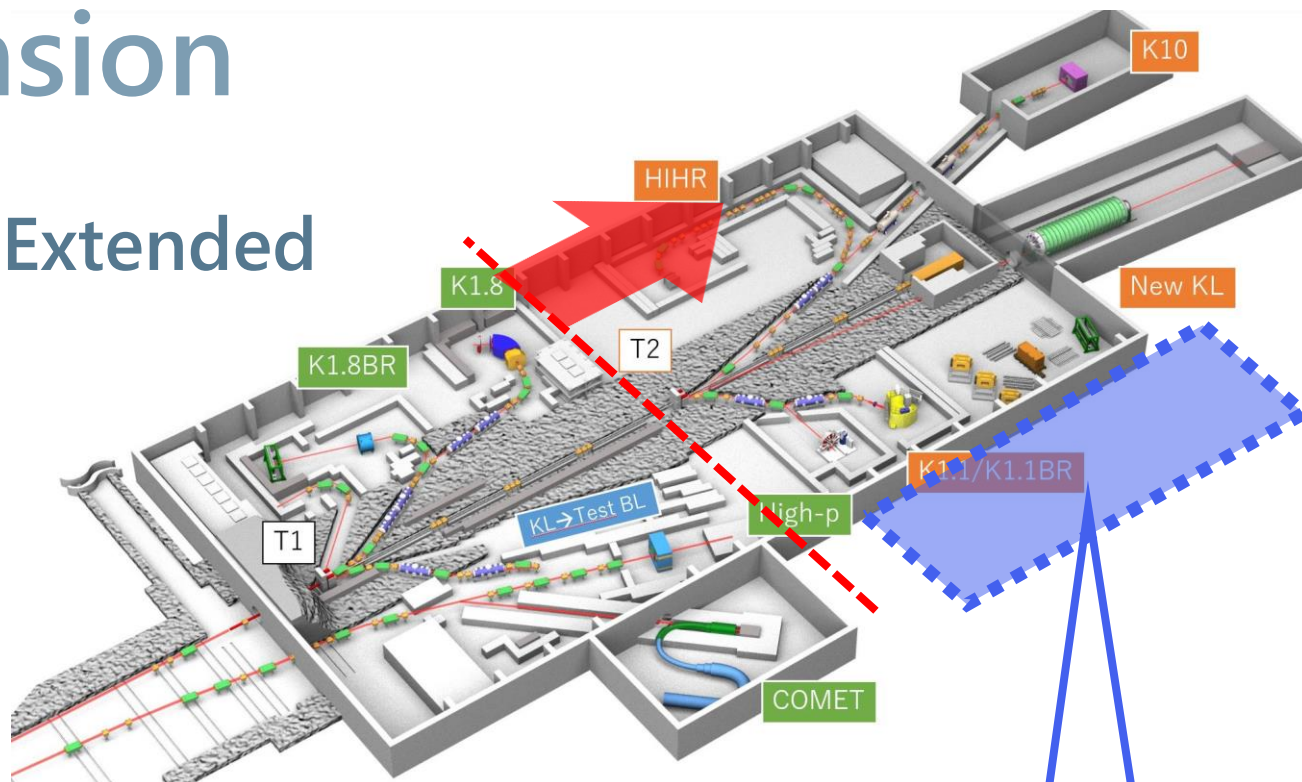


# Hadron Hall Extension

Present



Extended

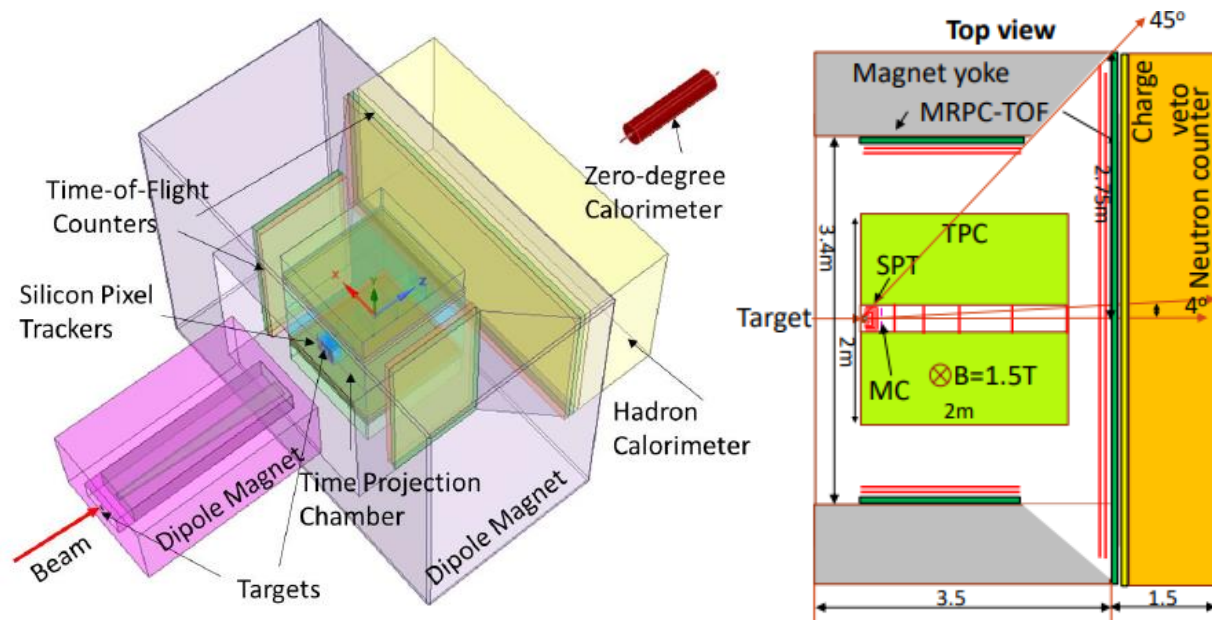


- Top priority at KEK-PIP2022
- J-PARC-HI spectrometer will be installed in an annex

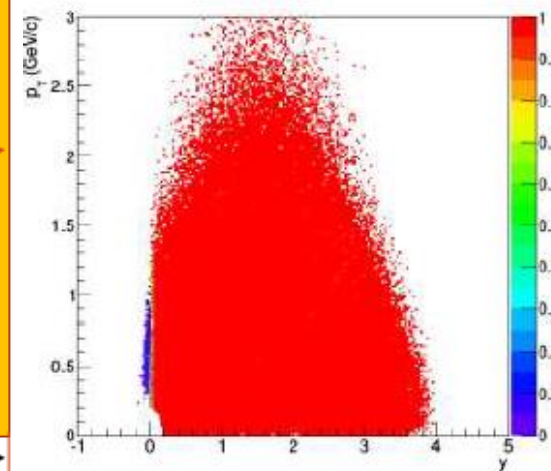
# Detector Phase-II

- $4\pi$  acceptance, high-intensity beam
  - Precise measurement of fluctuations, dileptons
  - Detailed design are under discussion

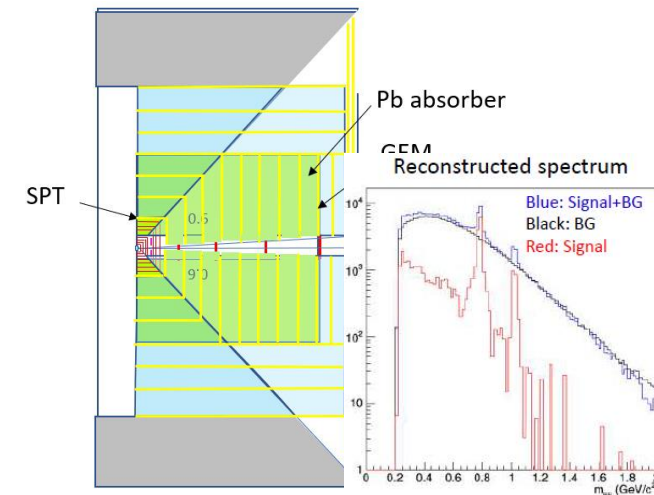
## Hadron calorimeter + hyper-nuclear measurement



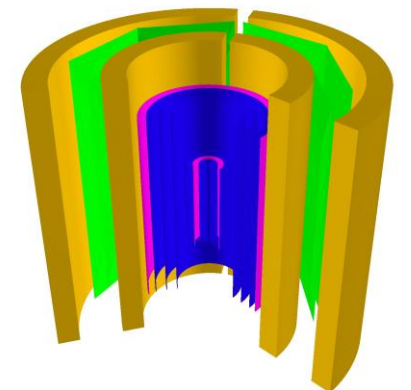
acceptance



## Dimuon Setup



## ALICE3-like dipole





# Current Status of J-PARC-HI



Proposal (Phase-I)  
submitted to  
J-PARC PAC



Detailed design (HI  
acceleration, cost,  
schedule) started **officially**



Support from  
nuclear physics  
community in Japan



J-PARC-HI is an official future project of J-PARC



孔子·論語

Confucius

欲速則不達

want

promptly

then

not

establish

Haste makes waste

# J-PARC-HI Collaboration



and **138** members in total

**Exp.:** J. K. Ahn , K. Aoki, S. Ashikaga, O. Busch, M. Chiu, T. Chujo , P. Cirkovic , T. Csorgo , D. Devetak , G. David, M. Djordjevic, S. Esumi , P. Garg, R. Guernane , T. Gunji , T. Hachiya , H. Hamagaki , S. Hasegawa, B. S. Hong, S. H. Hwang, Y. Ichikawa, T. Ichisawa , K. Imai, M. Inaba, M. Kaneta , H. Kato, B. C. E. J. Kim, X. Luo, Y. Miake , J. Milosevic, D. Mishra, Y. Morino, L. Nadjdjerdj , S. Nagamiya , T. Nakamura, M. Naruki , K. Nishio , T. Nonaka, M. Ogino, K. Oyama , K. Ozawa, T. R. Saito, A. Sakaguchi , T. Sakaguchi , S. Sakai, H. Sako, K. Sato, S. Sato, S. Sawada, K. Shigaki , S. Shimansky , M. Shimomura, M. Stojanovic , H. Sugimura, Y. Takeuchi, H. Tamura, K. H. Tanaka, Y. Tanaka, K. Tanida, N. Xu, S. Yokkaichi, I. K. Yoo

**Theor.:** Y. Akamatsu, M. Asakawa, K. Fukushima, H. Fujii , T. Hatsuda , M. Harada, T. Hirano, K. Itakura M. Kitazawa , T. Maruyama , K. Morita, K. Murase A. Nakamura, Y. Nara, C. Nonaka, A. Ohnishi, M. Oka

**Acc.:** E. Chishiro , H. Harada, Y. Hashimoto, N. Hayashi, K. Hirano, H. Hotchi , K. Ishii, T. Ito, M. Kinsho , R. Kitamura, A. Kovalenko, J. Kamiya , N. Kikuzawa , T. Kimura, Y. Kondo, H. Kuboki , Y. Kurimoto, Y. Liu S. Meigo , A. Miura, T. Miyao , T. Morishita , Y. Morita, K. Moriya, R. Muto, T. Nakanoya , K. Niki, H. Oguri , C. Ohmori , A. Okabe, M. Okamura, P. K. Saha , K. Sato, Y. Sato, T. Shibata, T. Shimokawa , K. Shindo , S. Shinozaki, M. Shirakata , Y. Shobuda , K. Suganuma , Y. Sugiyama, H. Takahashi, T. Takayanagi , F. Tamura, J. Tamura, N. Tani , M. Tomisawa , T. Toyama, Y. Watanabe, K. Yamamoto, M. Yamamoto, M. Yoshii, M. Yoshimoto

# Summary

## J-PARC-HI will

- realize high-precision HI experiments to explore
  - extremely dense QCD
  - hadron/hypernuclear physics
- be realized through the staging plan:
  - Phase-I: Experiment exploiting existing equipment
  - Phase-II: Full-spec experiment

## Still many things to do



- We need continuous support from community.
- New challengers are welcome!

# WHBM2023

- This weekend
- Registration still open

Workshop on Highly Baryonic Matter at RHIC-BES and Future Facilities  
--- beyond the Critical Point towards Neutron Stars ---



April 29-30 (Sat-Sun) 2023, Room-1D201/1D204, Area-1, Univ. of Tsukuba

## Workshop on Highly Baryonic Matter at RHIC-BES and Future Facilities --- beyond the Critical Point towards Neutron Stars — (WHBM 2023)

29-30 April 2023  
Central Area 1, Tsukuba Campus, University of Tsukuba  
Asia/Tokyo timezone

Overview

Overview



# Many Thanks



for your attention



to J-PARC-HI Collaboration



for your continuous support



to ATHIC2023 Organizers

