Studying high-density baryonic matter at J-PARC Heavy-Ion Project
Hiroyuki Sako (JAEA / U. Tsukuba) for J-PARC-HI Collaboration
Goals of J-PARC-HI (I)

Exploring dense matter

- Search for QCD Phase structures
  - 1st order phase transition, QCD Critical Point, Color superconductor
  - Event-by-event fluctuations, dileptons

- Properties of dense matter
  - Maximum density, EOS, transport properties (viscosity), etc.
  - Flow
    → Studies of neutron stars

- Chiral symmetry restoration
  - Medium modification of vector mesons
  - Dileptons

QCD Phase diagram

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Goals of J-PARC-HI (II)

Studies of multi-strangeness production

- Efficient production of strangeness at J-PARC
- Search for rare multi-strangeness systems
  - Hypernuclei, strangelet, dibaryons, etc.
- Study of hyperon interactions
  - Femtoscopy
    → EOS of strange hadronic/quark matter

Hypernuclei

\[
\text{J-PARC-HI}\]

\[K^+ / \pi^+\]

\[
\text{Yield (dN/dy) at 100 GeV}
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A. Andronic, PLB697 (2011) 203

\[\Lambda\Lambda \text{ correlation function}\]

A. Andronic, PLB697 (2011) 203

STAR, PRL114 (2015) 022301
Accelerators and experiments for J-PARC-HI

**HI Booster Ring**
- **Phase 1:** KEK-PS booster ($10^8$Hz) (~2026)
- **Phase 2:** New booster ($10^{11}$Hz) (~2032)

**Hadron Experimental Facility**

- **HI beam rate** $\sim 10^{11}$ Hz (World’s highest intensity beam)
- **$E_{\text{lab}}(U) = 1$-12 AGeV**
- **$\sqrt{s_{\text{NN}}}(U) = 1.9$-4.9 GeV**

**Proton beam line**
- **H Linac:** 0.4 GeV
- **U$^{66+}$** → 67 AMeV
- **U$^{86+}$** → 735 AMeV
- **U$^{92+}$** → 11.2 AGeV
- **3 GeV RCS (p)**
- **0.4 → 3 GeV**
- **MLF**
- **p/HI**
- **proton (existing)**
- **HI (under plan)**

**Extended proton beam line**
- **Beam dump**
- **Radiation shield**

**J-PARC-HI spectrometer**

1. **p+A experiment (E16) (2020-)**
   - Baseline data and detector R&D for HIC
2. **Phase-I ($10^8$Hz)**
   - Upgraded E16
3. **Phase-II ($10^{11}$Hz)**
   - Large acceptance spectrometer
Di-electron measurement at Phase I

Proposal submitted in July 2022
T with ~6% stat. errors can be expected from $M_{ee} > 1.1$ GeV/c$^2$ of $T \sim 150$ MeV

Upgraded E16 spectrometer (p+A) for HIC
- Forward trackers
- EM calorimeter: PbGl→PWO$_4$
- Zero degree calorimeter

100 days run, 0.1% sys error assumed for combinatorial background subtraction (PHENIX, ALICE)

P. Senger, CBM, Particles 2020, 3(2), 320-335
Phase II experiments

- Identified charged particles \( \Leftrightarrow \) Dimuon
- \( \sim 4\pi \) acceptance
  - Silicon Pixel Tracker and TPC
  - Pb absorbers and GEM trackers
  - MRPC-TOF
- Interaction rate : \( \leq 10 \) MHz
  - Triggerless DAQ system
- Centrality : Multiplicity counter + Zero-degree calorimeter
- Hypernuclei with closed geometry setup

Summary and outlook

J-PARC-HI : Studies of QCD phase structures of dense matter and multi-strangeness systems with world’s highest-rate HI beam of \( 10^{11} \) Hz

Measurements of fluctuations, dileptons, and multi-strangeness systems

Staging: \( p+A \rightarrow A+A \) at Upgraded E16 (Phase I) \( \rightarrow \) Large acceptance spectrometer (Phase II)
  - Di-electron experiment in \( p+A \) (E16) started in 2020 (Talk by M. Ichikawa (Apr. 7))
  - \( \phi \rightarrow K^+K^- \) in \( p+A \) (E88) being prepared (Poster 3T 11_1 by S. Sato (Apr. 8))
  - First experimental proposal submitted (July 2021) (Poster 3T 15_2 by Y. Morino (Apr. 8))

Aiming for the start of the Phase-I experiment after Hadron Hall Extension (~2026)