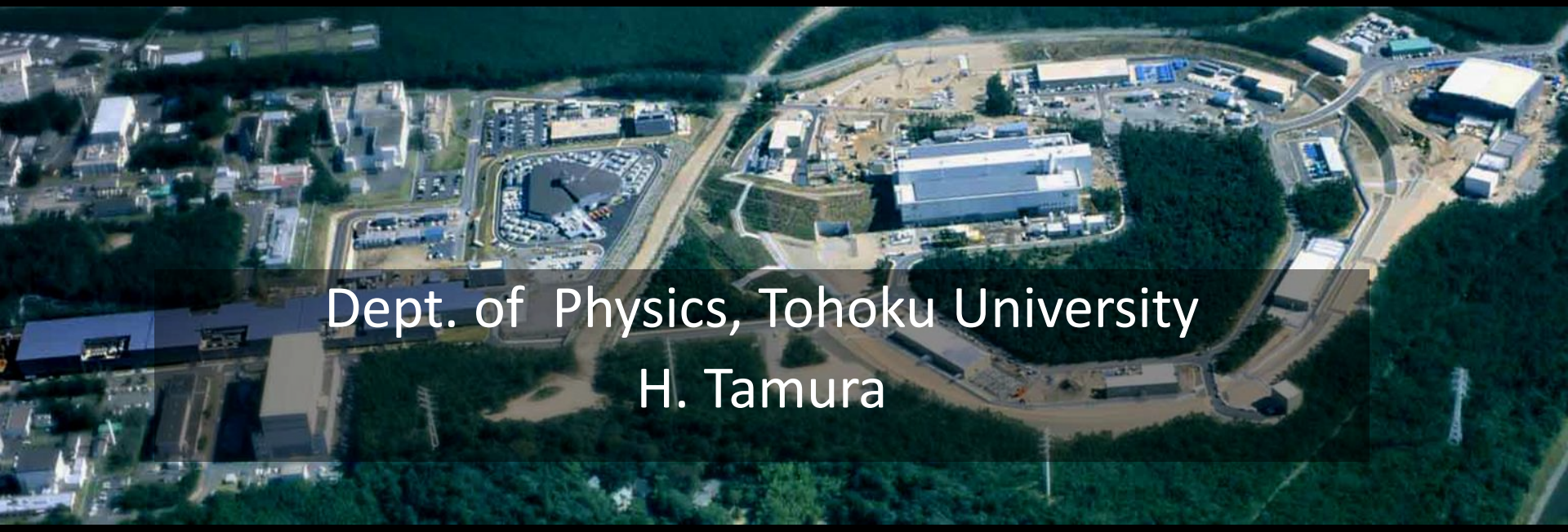
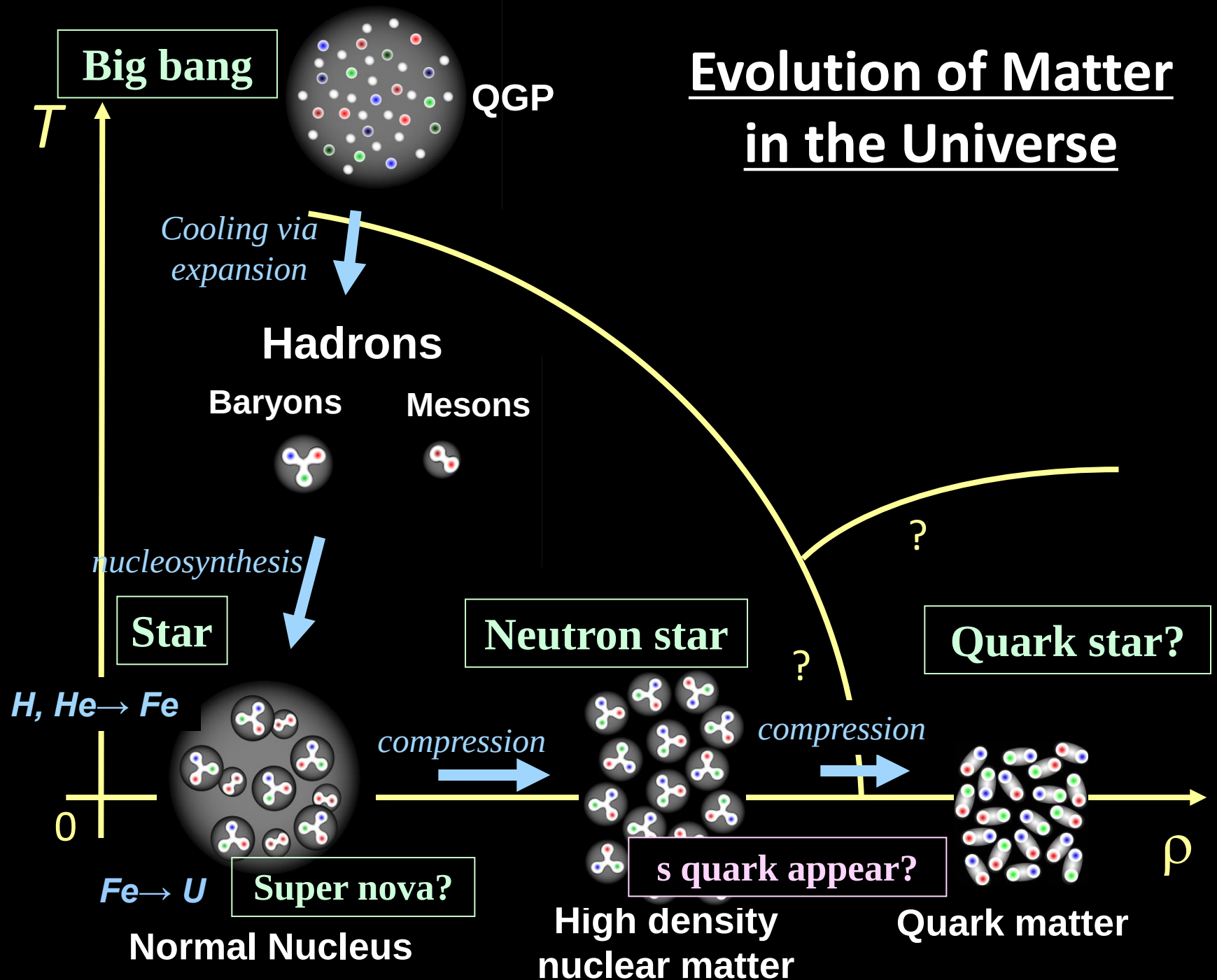


Future Prospect of Hadron/Nuclear Physics at J-PARC (in place of a summary talk)



Dept. of Physics, Tohoku University
H. Tamura

Evolution of Matter in the Universe



Evolution of Matter in the Universe

Big bang

T

QGP

RHIC, LHC

High energy HI collisions

Cooling via
expansion

Hadrons

Hadron Physics

ELPH, LEPS

Mesons

High-density HI collisions

Nuclear/Hadron Physics
in Japan

Unstable Nuclei

RIBF

J-PARC

Neutron star

$H, He \rightarrow Fe$

Precision
Spectroscopy

RCNP

Super nova?

Normal Nucleus

Strangeness
nuclear physics

JLab

High density
nuclear matter

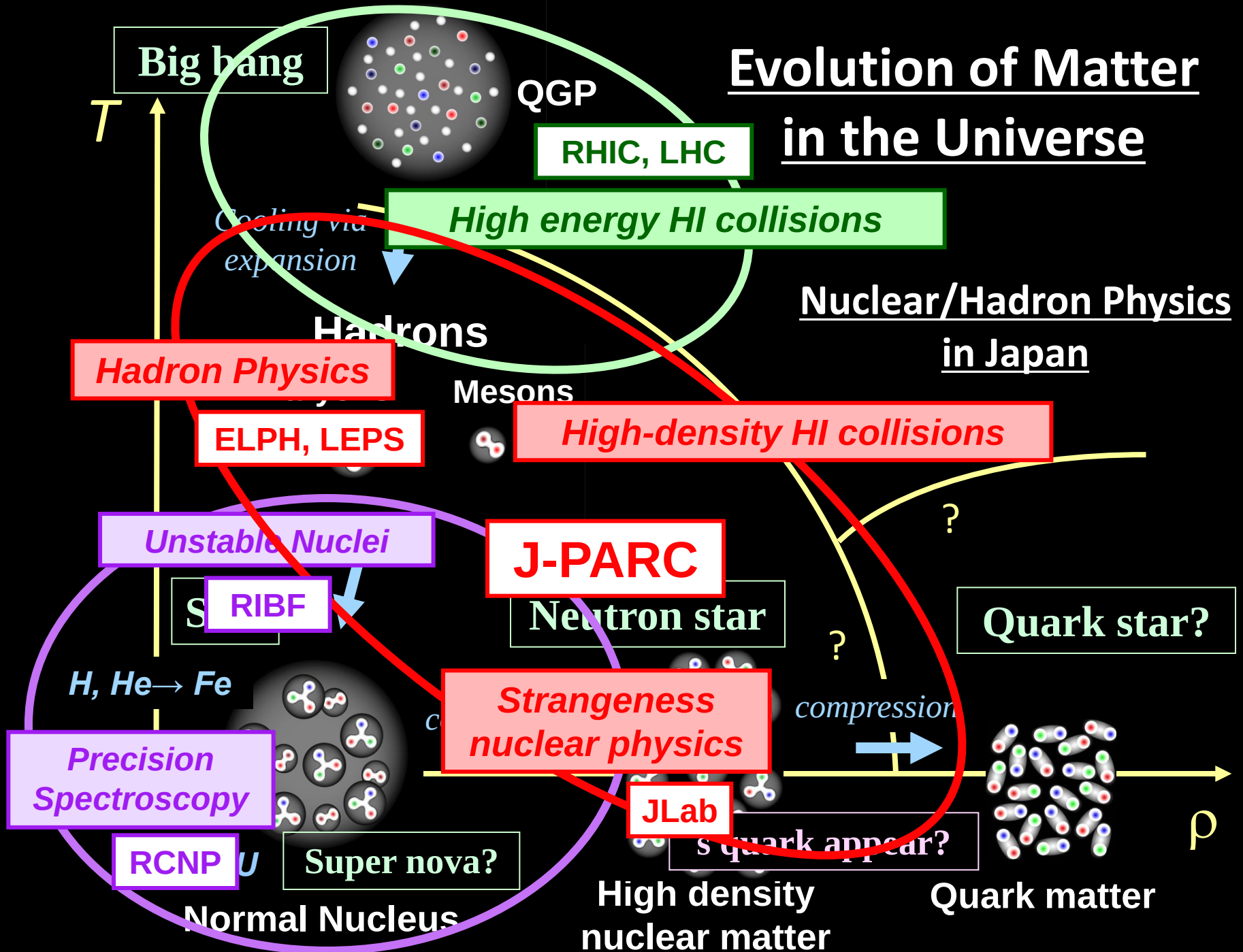
compression

Quark appear?

Quark star?

Quark matter

ρ



Mission of J-PARC Hadron Hall

Elementary Particle Physics

QCD

QGP

**color s.c.
quark matter**

confinement?

constituent mass?

J-PARC

How are hadrons formed?

**Hadron
structure?**

Hadrons

**hadronic
matter**

Baryon-baryon interactions?

How are nuclei formed?

Nuclei

**nuclear
matter**

Science of "Matter" (atoms, condensed matter, chemistry, biology)

Physics at Hadron Hall

Questions

Quark to Hadron

Origin of mass

Confinement

Hadron structure

Hadron to Nucleus

Baryon-Baryon forces

Hadron and Interaction in matter

Nuclear (Hadronic) matter

Experiments

Spectra and Properties of Hadrons

Hadron properties in nuclei

Search for exotic hadrons

Quark structure inside nucleon

Mesonic nuclei

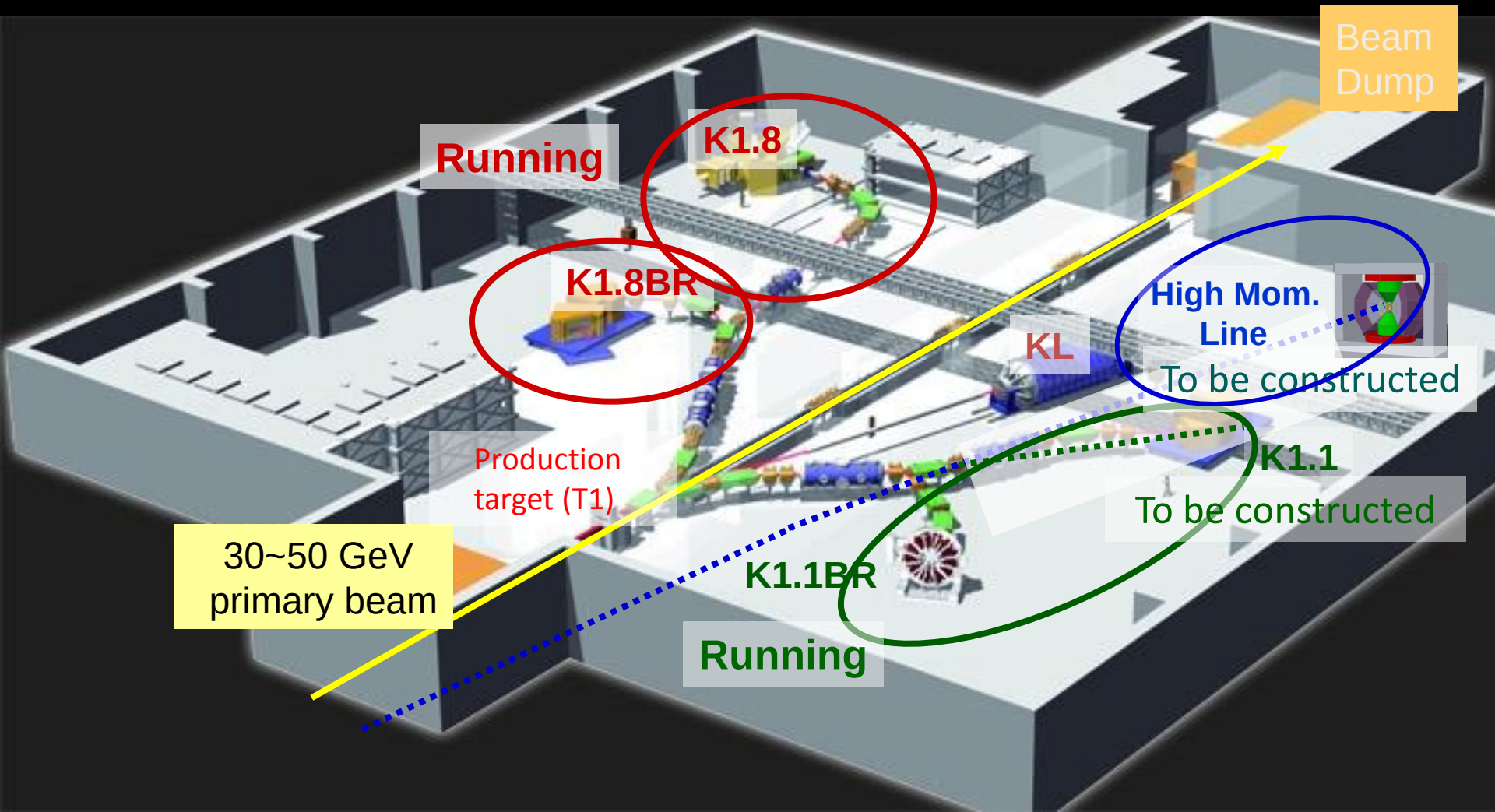
Hypernuclei

YN scattering

Hadron production on nuclei

High density AA collisions

Present status of J-PARC Hadron Hall and nuclear/hadron physics



approved / proposed (incl. LOI)

Present status of J-PARC

an

$S = -2$ systems
quite unique at J-PARC

γ spectroscopy of Λ hyp.

n-rich Λ hypernuclei

Ξ hypernuclei

$\Lambda\Lambda$ hypernuclei

Ξ -atomic X rays

H dibaryon search

Θ^+ search

K-pp bound states

Weak decays of Λ hyp.

Pion double charge exchange

Σ p scattering

ω nucleus

K-pp bound states

K^- atomic X rays

$\Lambda(1405)$

η nucleus

ϕ nucleus

Running

K1.8

K1.8BR

Production
target (T1)

30~50 GeV
primary beam

Finished / running / waiting

Hadron mass in nuclei

Nucleon quark structure

Charmed baryons

High Mom.

Line

be constructed

K1.1

$S = -1$ systems

Running

γ spectroscopy of Λ hyp.

Weak decays of Λ hyp.

Σ -nuclear systems

ϕ nucleus

Θ^+ study by K^+d

Θ^+ hypernuclei

Necessity for Hadron Hall extension

■ Too small area $\Leftrightarrow$ KEK-PS x2.4, BNL-AGS x4.1

■ Only 4 beam lines $\Leftrightarrow$ KEK-PS $\sim$ 7 lines, BNL-AGS $\sim$ 15 lines

-> Ineffective operation (“output per operation cost” is bad.)

Long waiting queue of approved experiments

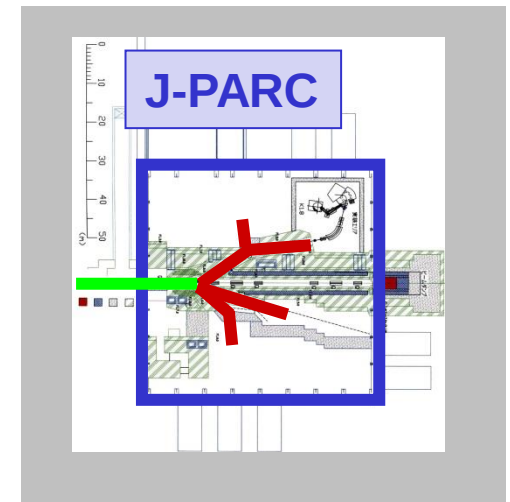
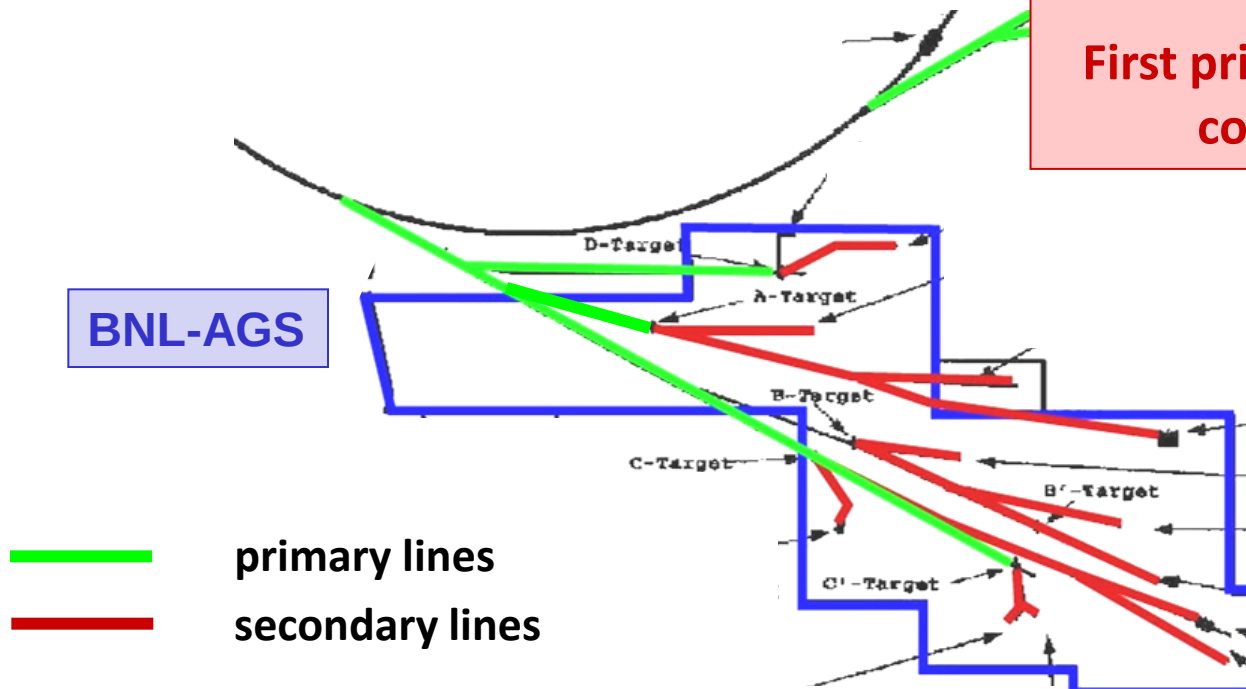
(At K1.8/K1.8BR lines, 6960 hours = more than 6 years)

-> Discourage users in the world. Predominance will be lost.

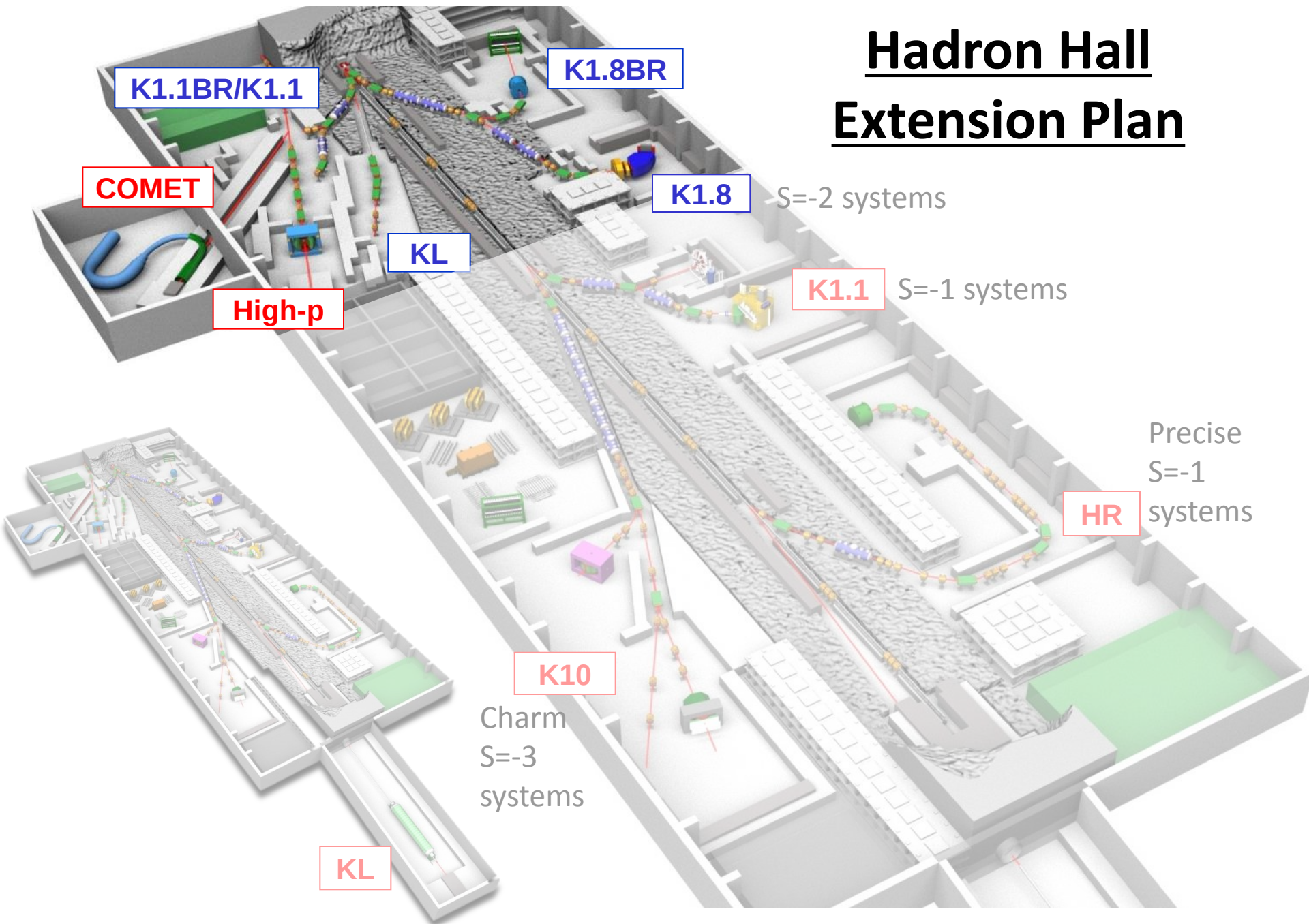
-> Limited variety of experiments

Extremely urgent !

First priority in nuclear physics community in Japan

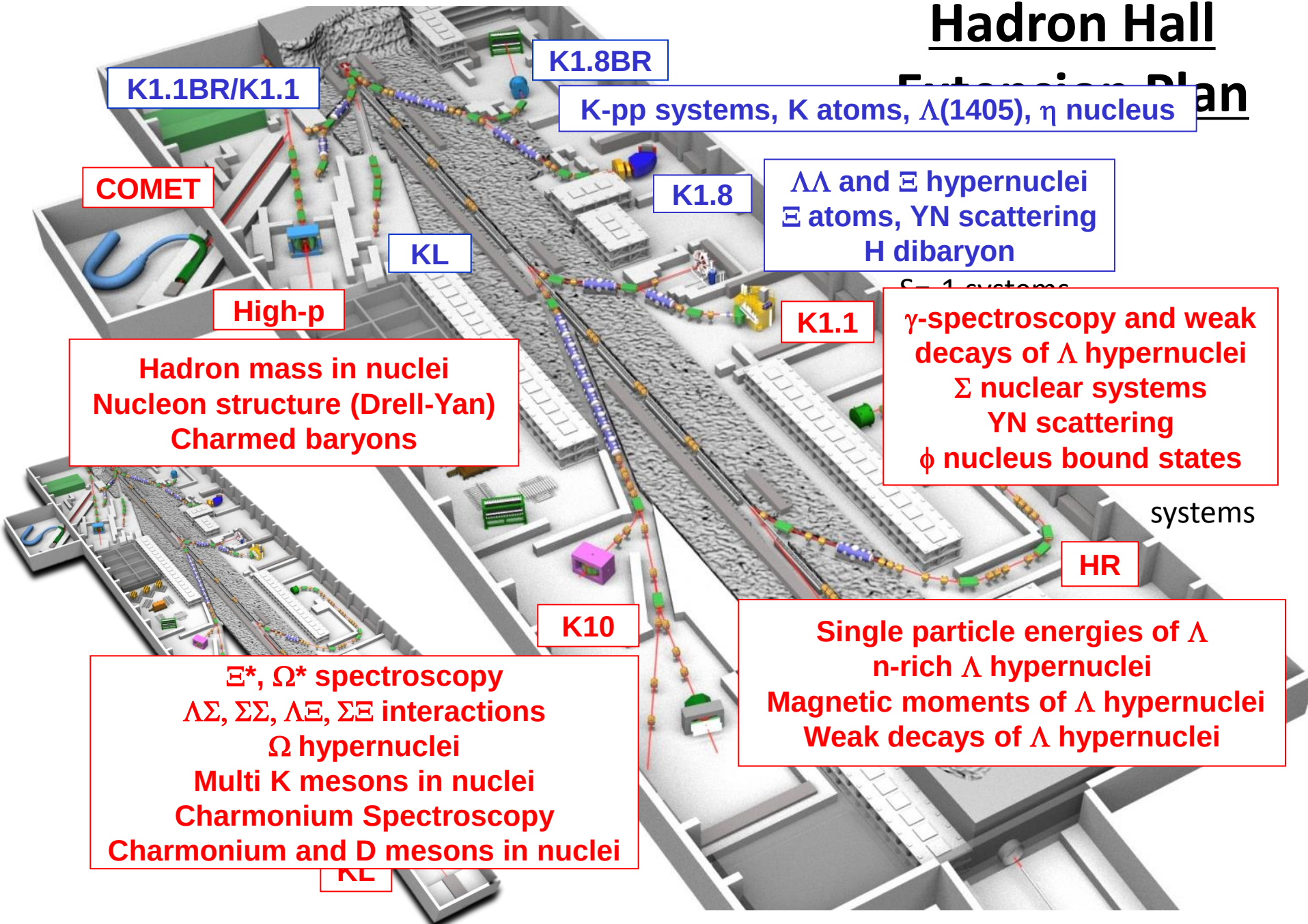


Hadron Hall Extension Plan



Hadron Hall

Extension Plan



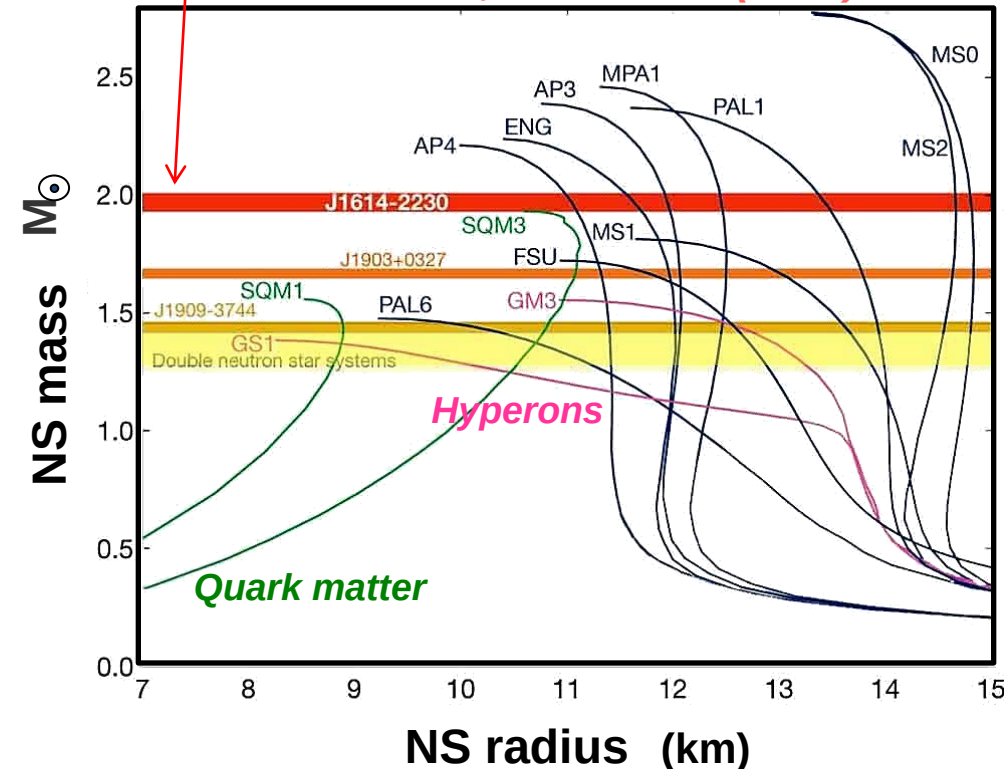
A key issue: Mystery in high-density EOS

- Hyperons must appear at $\rho \sim 2 \rho_0$ in neutron stars
- EOS with hyperons (or kaons) too soft $\rightarrow$ cannot support $\sim 2 M_{\text{sun}}$ NS

Serious problem in nuclear physics

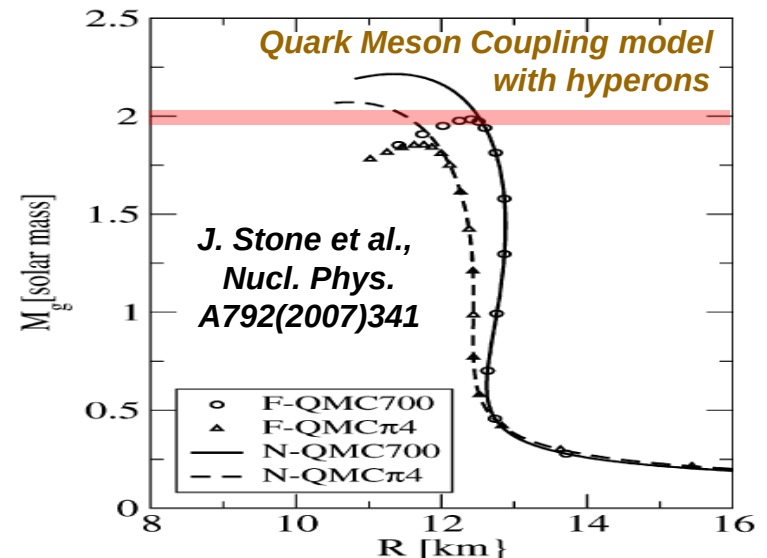
Theoretical frameworks are wrong.

Demorest et al., Nature 467 (2010) 1081



How to solve the problem?

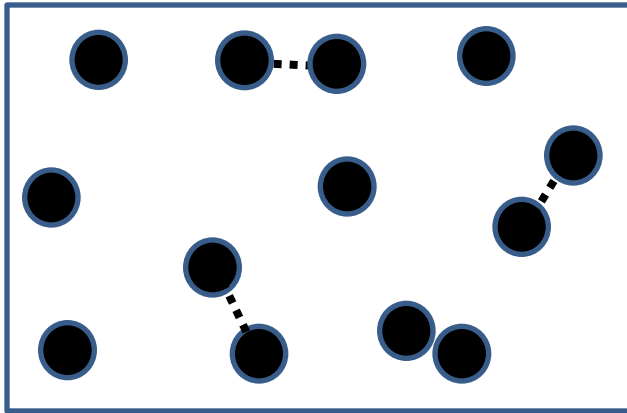
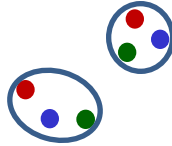
- Strong repulsion in three-body force (NNN, YNN, YYN, YYY)
- Change of meson-baryon coupling constants
- Phase transition to quark matter (quark star or hybrid star)



Toward a correct description of high-density nuclear/hadronic matter

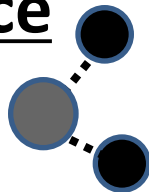
Correct description of hadron structure

Exotic hadrons
Charm hadrons
Properties of hadron excited states



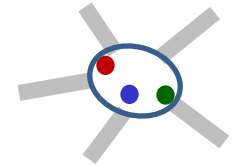
Correct treatment of three-body nuclear force

3N / 4N nuclear systems



Correct description of BB interactions

YN, YY forces from hypernuclei
and YN scattering



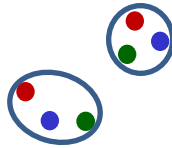
Understanding of hadron properties in nuclear matter

Single particle levels in hypernuclei
Magnetic moments and
weak decays of hyperons in nuclei
Kaonic and other mesonic nuclei

Toward a correct description of high-density nuclear/hadronic matter

Correct description of hadron structure

Exotic hadrons
Charm hadrons
Properties of hadrons

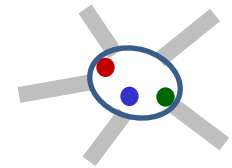
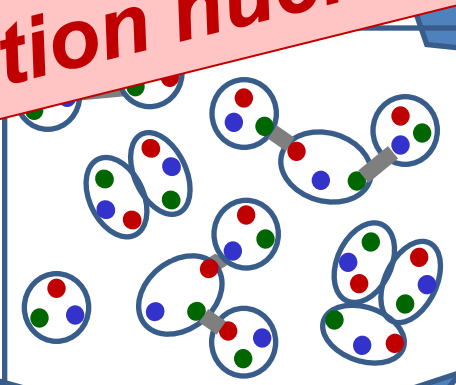
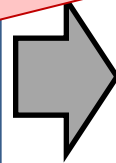


Correct description of BB interactions

YN, YY, ...

nuclei

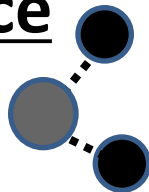
We need to construct a “new-generation nuclear physics”.



Understanding of hadron properties in nuclear matter

Correct treatment of three-body nuclear force

3N / 4N nuclear systems



Single particle levels in hypernuclei
Magnetic moments and weak decays of hyperons in nuclei
Kaonic and other mesonic nuclei

Problems and prospect

- *Increase of running cost*
after shutdown of nuclear power plants in Japan
Also competition with SuperKEKB (?)
- *Severe competition between the hadron,*
muon(COMET), and neutrino(T2K) programs

For the future hadron program at the extended Hadron Hall, physics impact and experimental feasibilities have to be seriously investigated.
Strong collaboration between theorists and experimentalists are essential.

**Thank you for your excellent
presentations and valuable discussions
in the workshop.**