Physics with HI Beams at J-PARC

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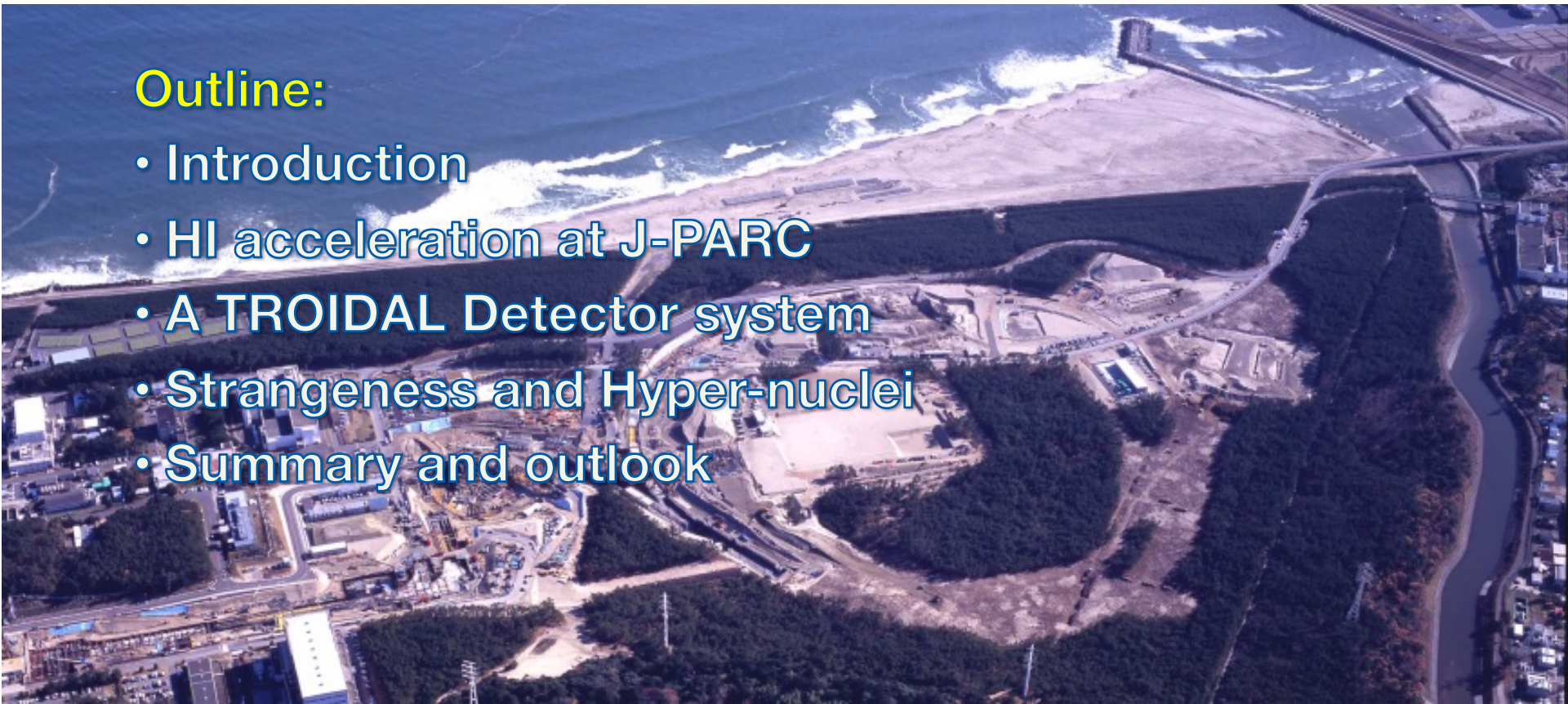
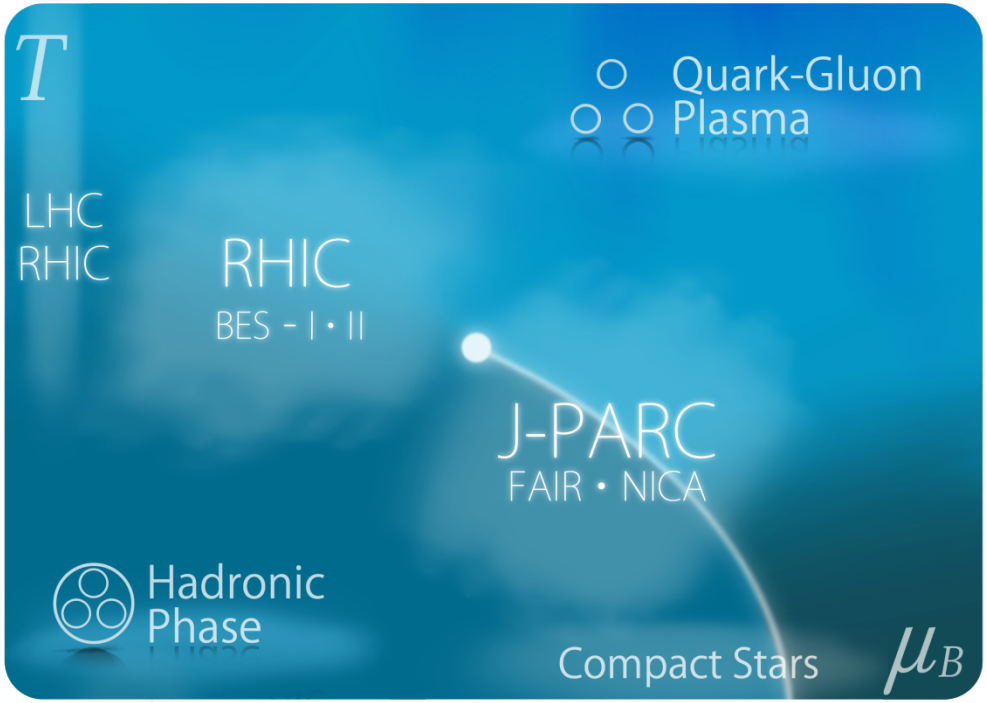


INTRODUCTION

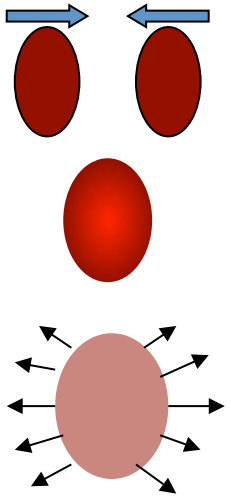
Goals of J-PARC HI Project

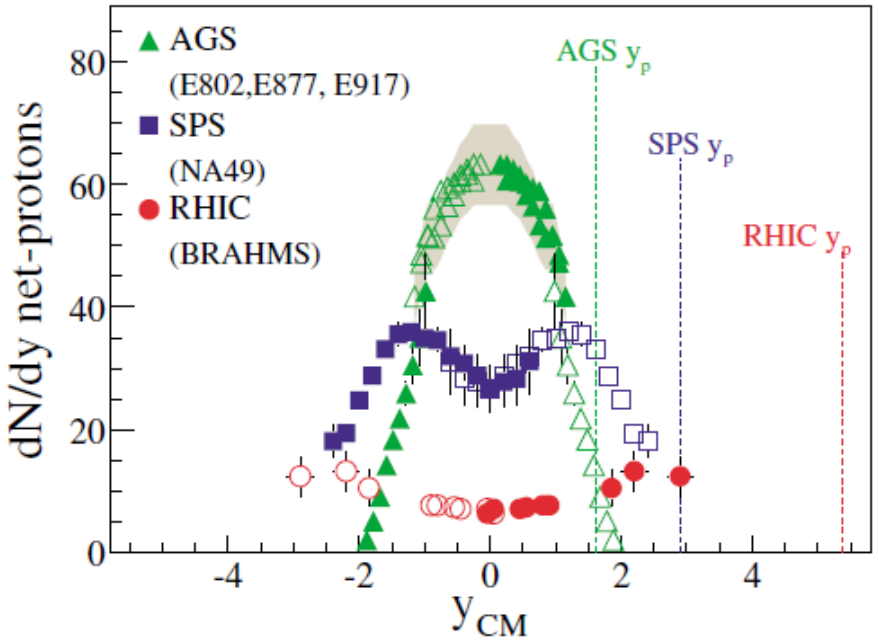
- Exploration of QCD phase structure at very dense regime
  - QCD phase structures (critical point & phase boundary) at high density regime are yet to be explored
- Study of hadron/nuclear properties relevant to neutron star core
  - Hypernuclei, strangelet, …

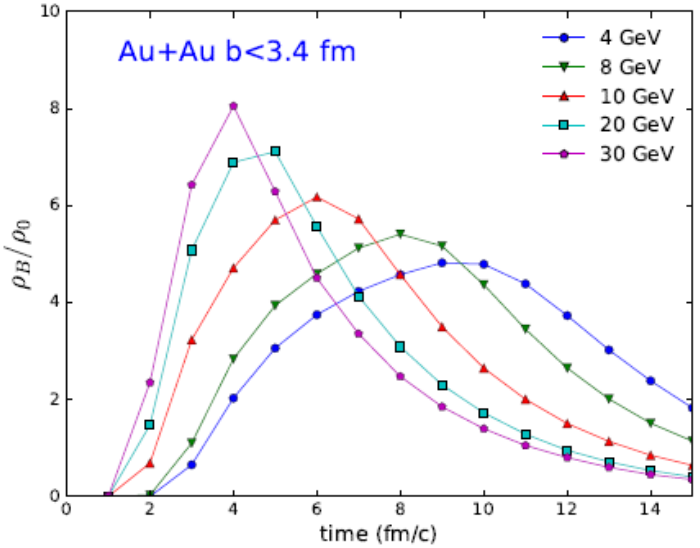


Baryonic QCD Matter

- Large baryon stopping in HI collisions at small $\sqrt{s_{NN}}$ (4~6GeV@J-PARC/AGS)



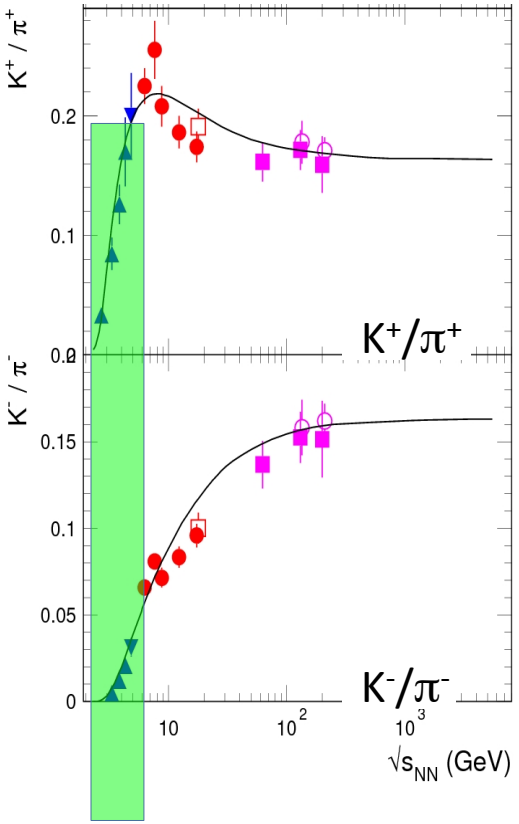




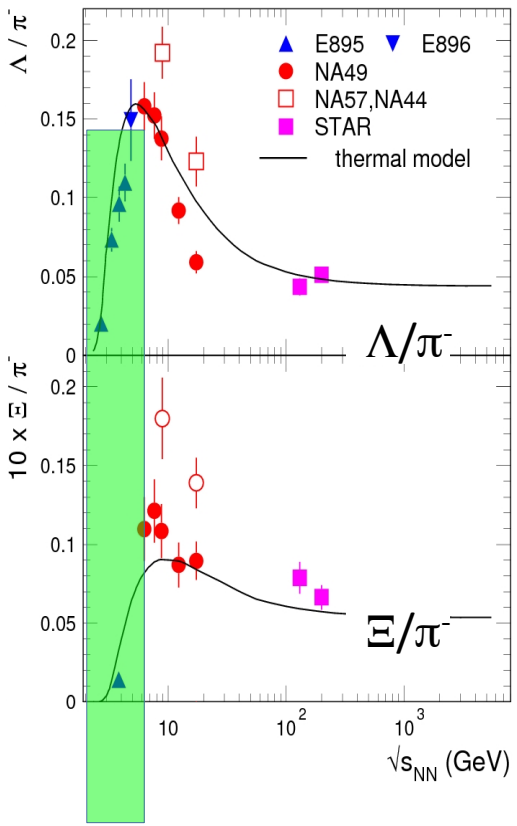
JAM model by Y. Nara, et al, PRC61,024901(1999)

Strangeness production at J-PARC

- $(K^+, \Lambda, \Xi)/\pi$ ratio have maximum at $\sqrt{s_{NN}}$~5GeV
  → **Strangeness fraction largest around J-PARC energy**



J-PARC

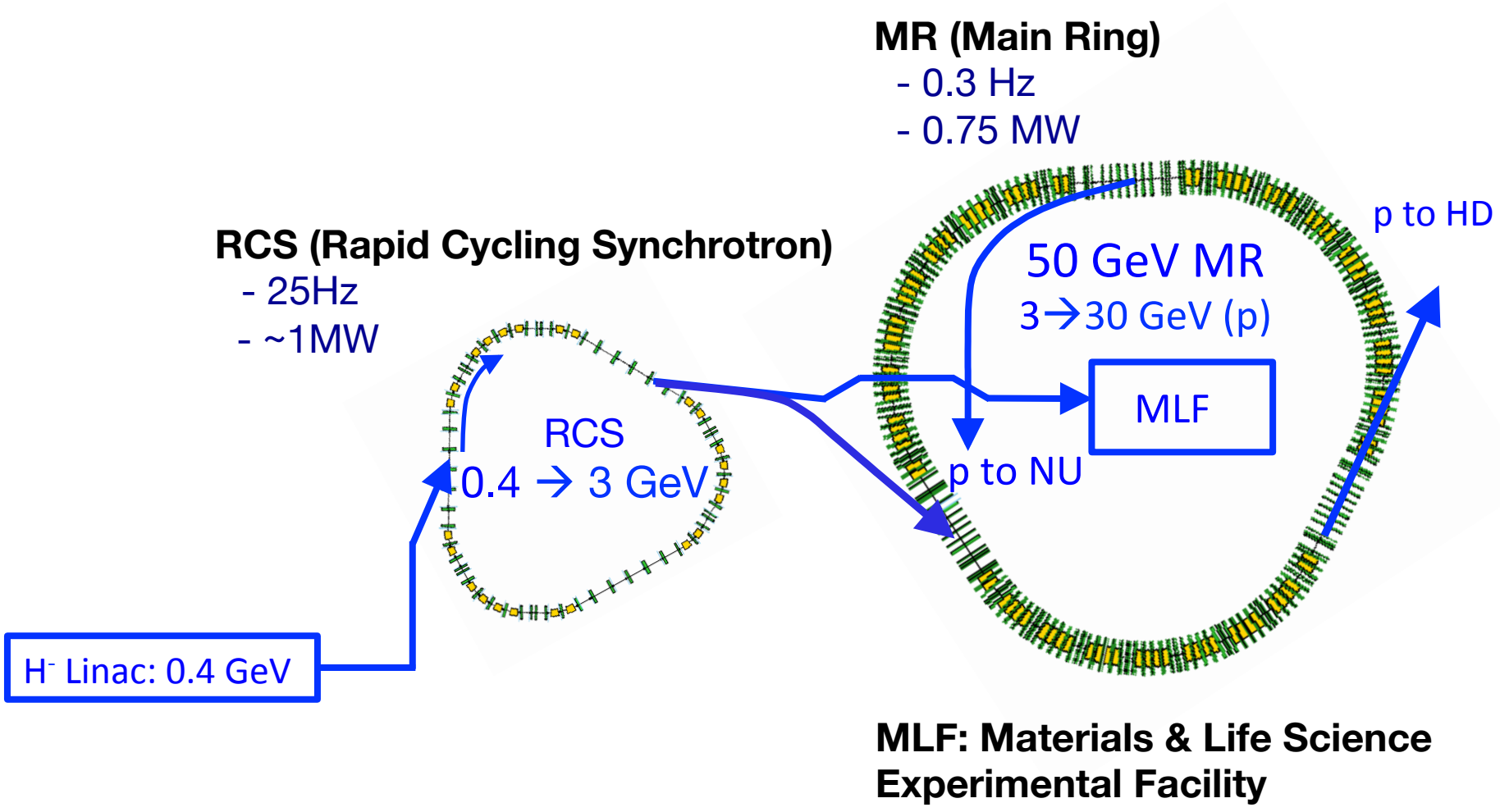


J-PARC

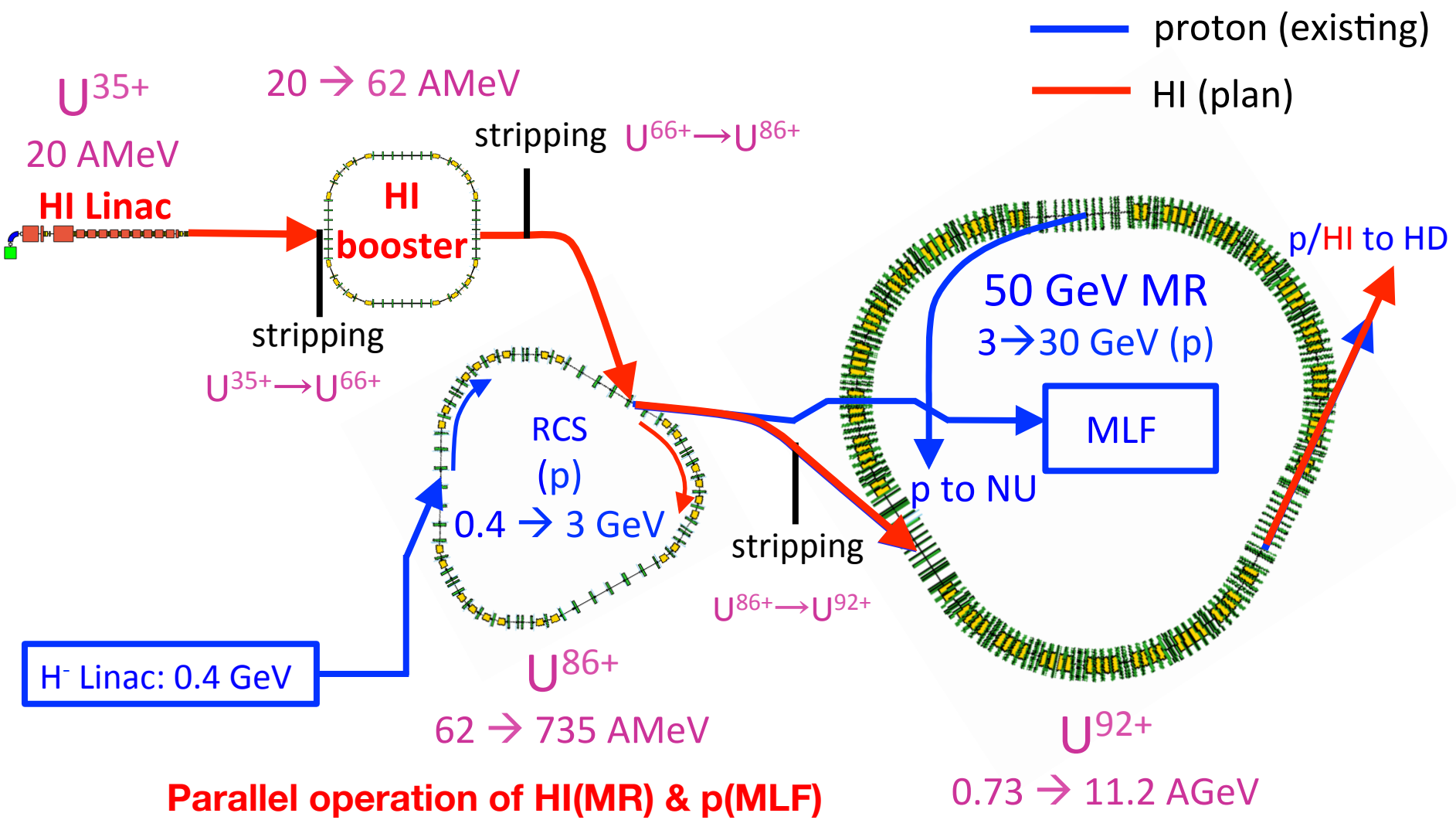
NPA772(2006)167

HI ACCELERATION AT J-PARC

J-PARC Proton Accelerator Scheme

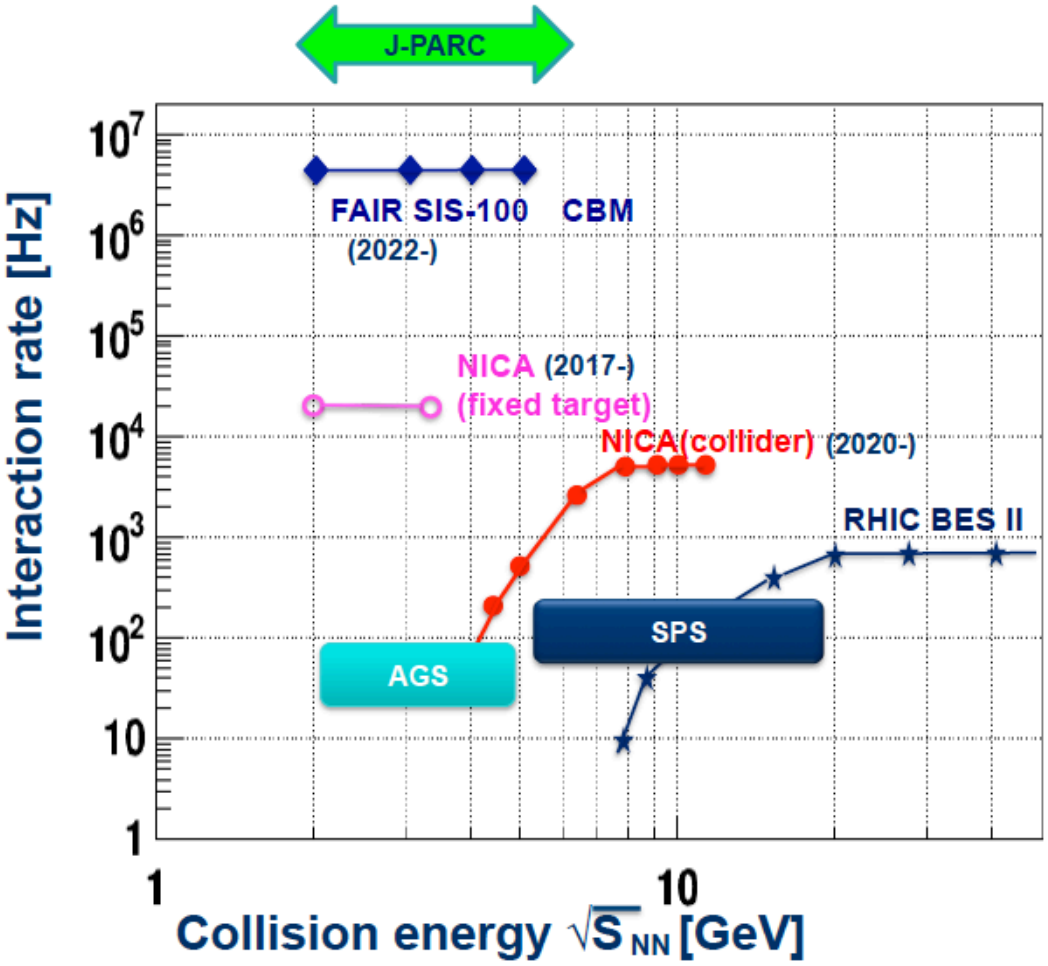


J-PARC HI Accelerator Scheme



J-PARC-HI beam

- E_{lab} = 1-19 AGeV ($\sqrt{s_{NN}}$ = 1.9-6.2 GeV) for ^{238}U
- Beam intensity = 10^{11} pps (interaction rate of 10^8 Hz with a 0.1 % interaction target)
- 5 min run at J-PARC corresponds to 1 year at AGS



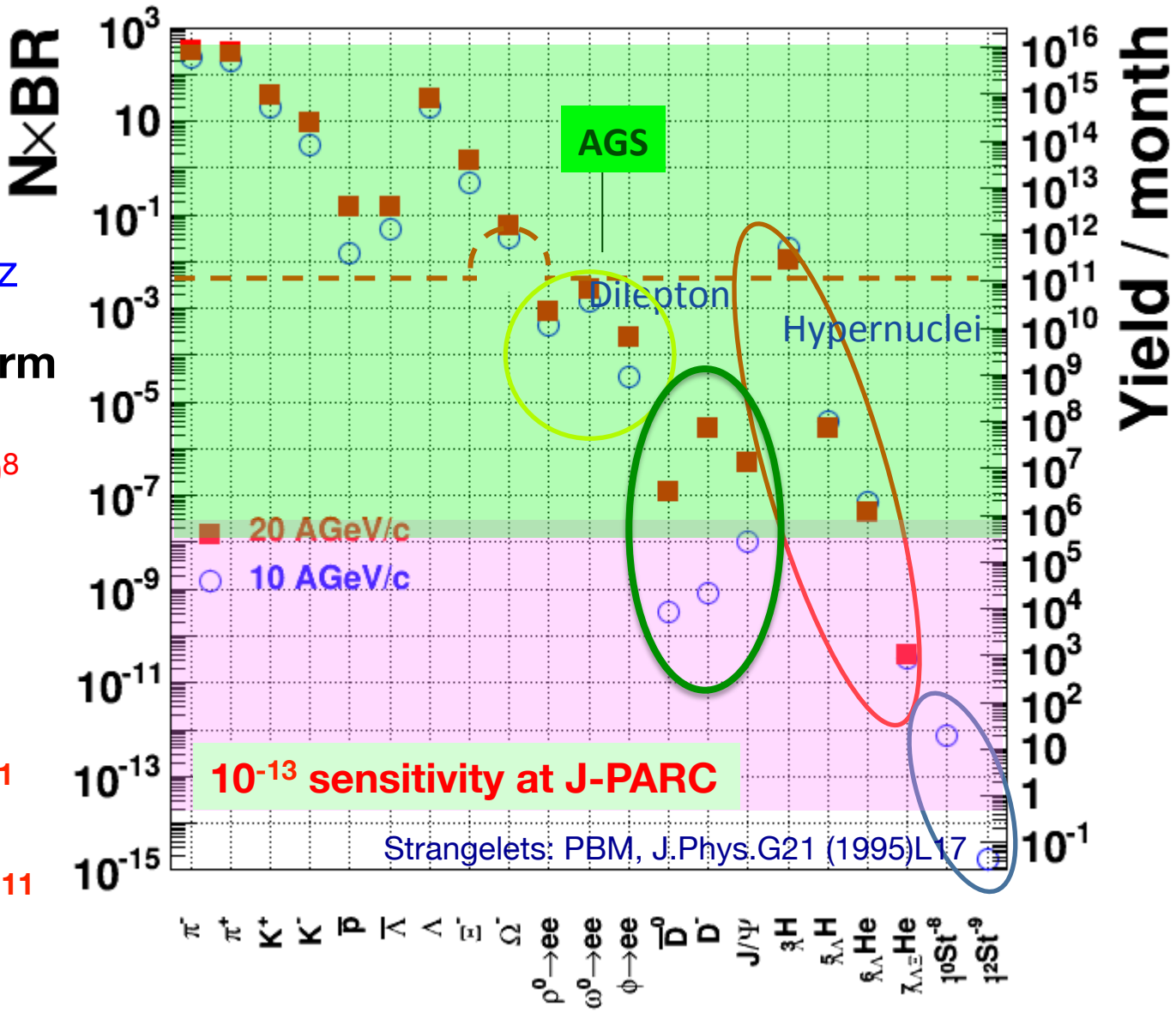
Expected Particle Yields

In a month run, with
10^{10} Hz beam rate
& 0.1 % target
→ event rate = 10^7 Hz

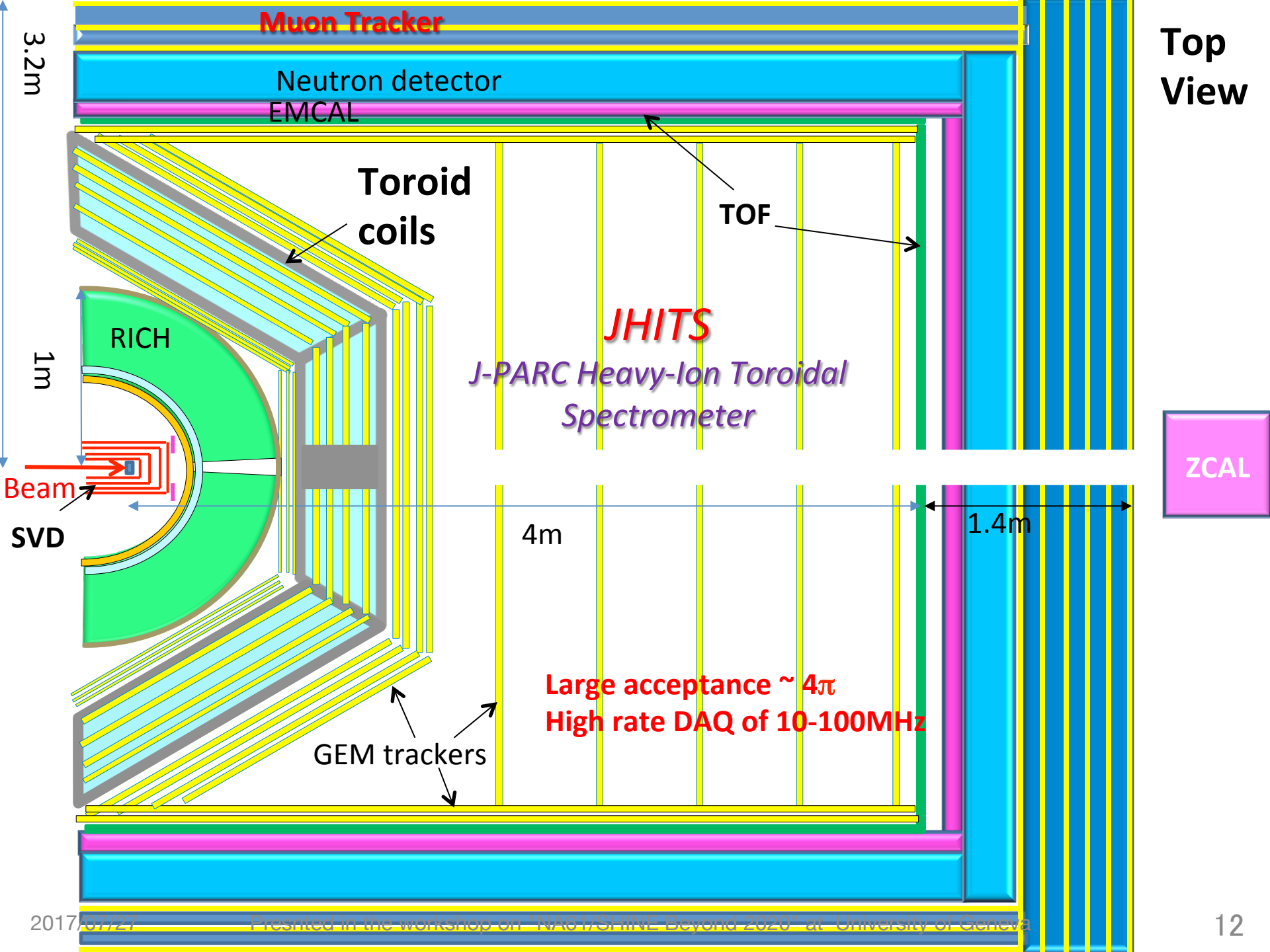
Open & Hidden Charm
- at 20 AGeV
> D mesons: 10^6-10^8
> J/Ψ: 10^7
- at 10 AGeV
> D mesons: ~10^4
> J/Ψ: ~10^5

ρ, ω, ϕ → **ee: 10^9-10^{11}**

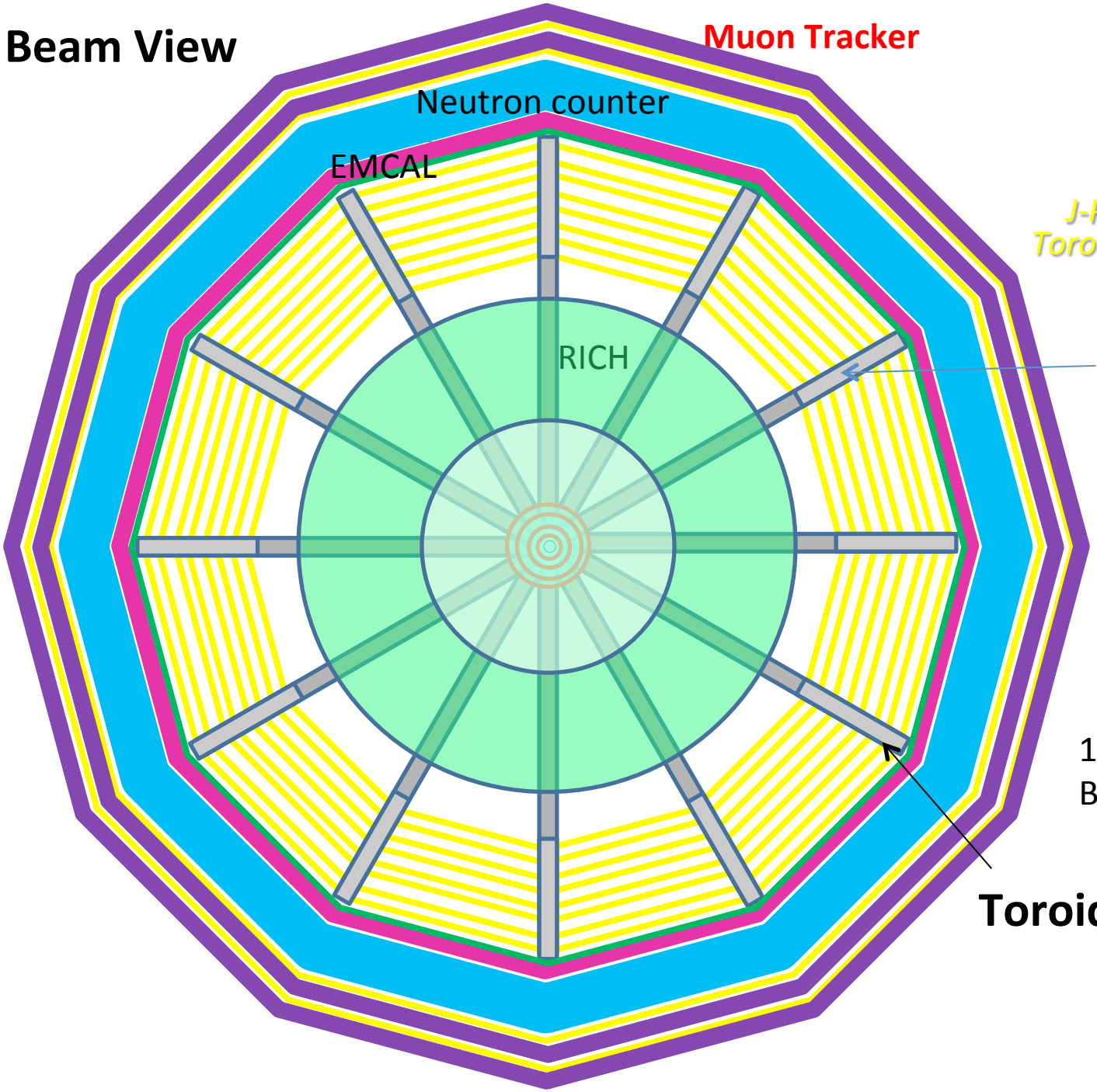
Hypernuclei: 10^3 -10^{11}



A TROIDAL DETECTOR SYSTEM


Muon Tracker
Neutron detector
EMCAL
Toroid coils
TOF
RICH
JHITS
J-PARC Heavy-Ion Toroidal Spectrometer
3.2m
1m
Beam
SVD
4m
1.4m
ZCAL
Large acceptance ~ 4π
High rate DAQ of 10-100MHz
GEM trackers
Top View

Beam View



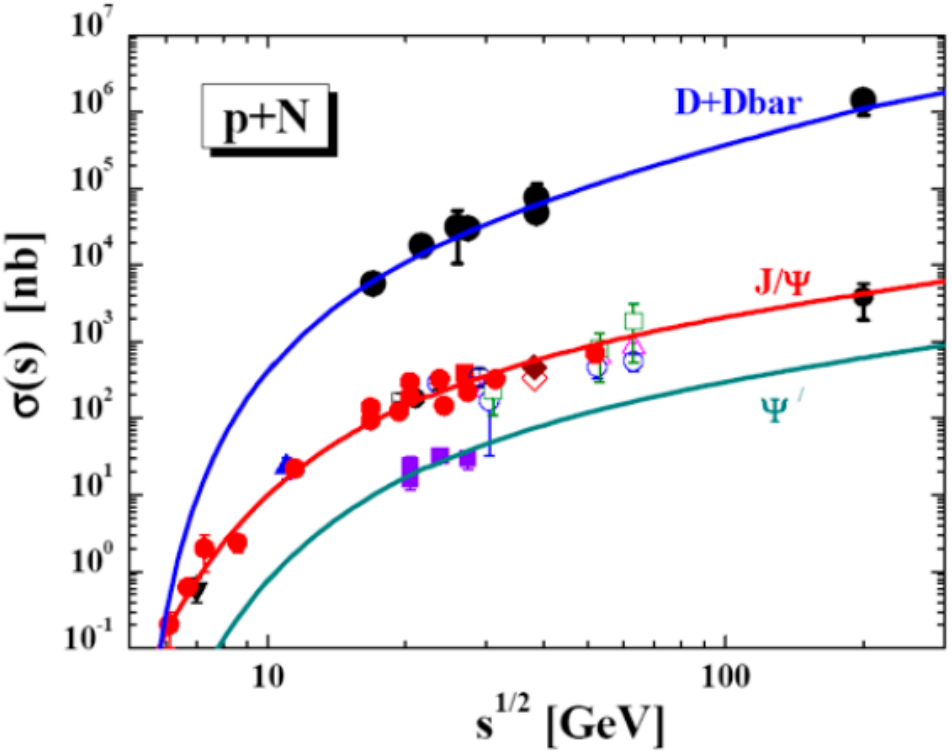
JHITS
J-PARC Heavy Ion Toroidal Spectrometer

Coils = insensitive area

12-fold coils
Bϕ variations ~+-20%

Toroid coils

Production of Charmed Particles



CBM Physics Book,
W. Cassing, E. L. Bratkovskaya and
A. Sibirtsev, Nucl. Phys. A 691 (2001) 753

- Open charm
  - Energy loss in hadronic/ partonic media
  - Local equilibration
- J/ψ
  - Very complicated process beyond naïve suppression scenario
- J-PARC energies are close to production thresholds
  - D (5.07 AGeV) & J/ψ (4.77 AGeV)
  - A good playground to see sub-threshold effects?

Low-mass Dileptons

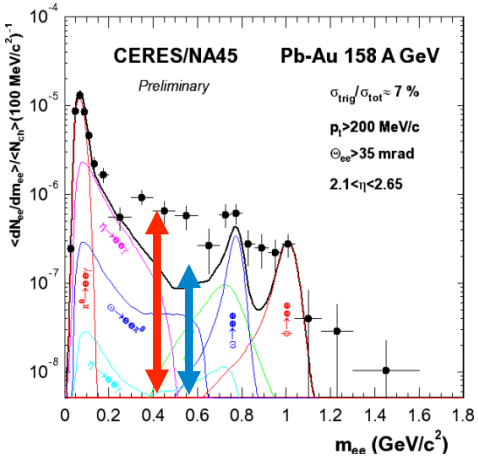
No measurement at J-PARC energy region

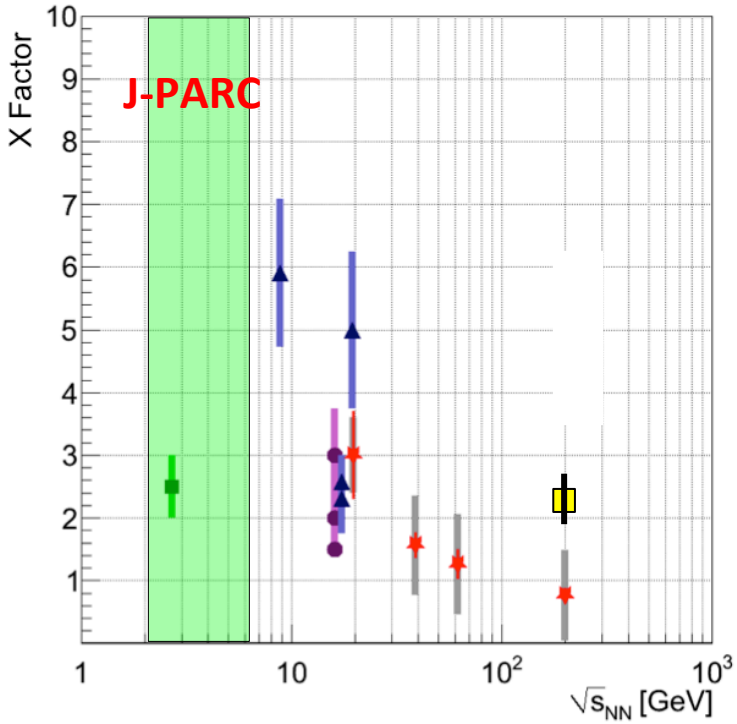
Maximum X-factor at J-PARC energies?

- Dielectron measurement
  - Main background: γ conversion at low mass
- Dimuon measurement
  - Main background: μ from p, K decays
  - Higher rate beam can be used

- Background from charm decay is small

- 3-orders higher statistics at J-PARC compared to CERES





Expected Dilepton Spectra

Generated

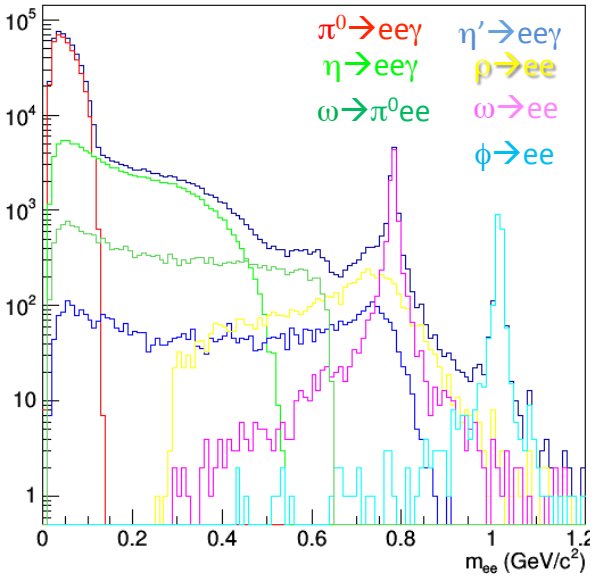
Reconstructed

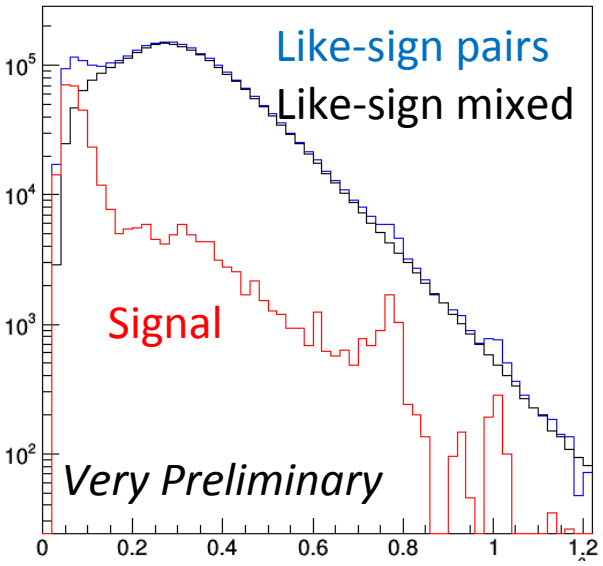
Dielectrons

$\theta_{ee}>5^o$
$2^o<\theta<80^o$
$p_T>0.1$ GeV/c

e^+e^- cocktail (8.6 M events)

No γ external conversion



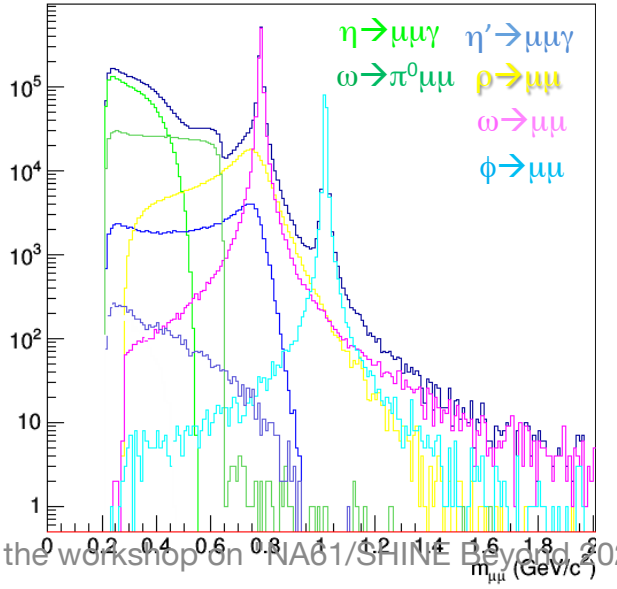


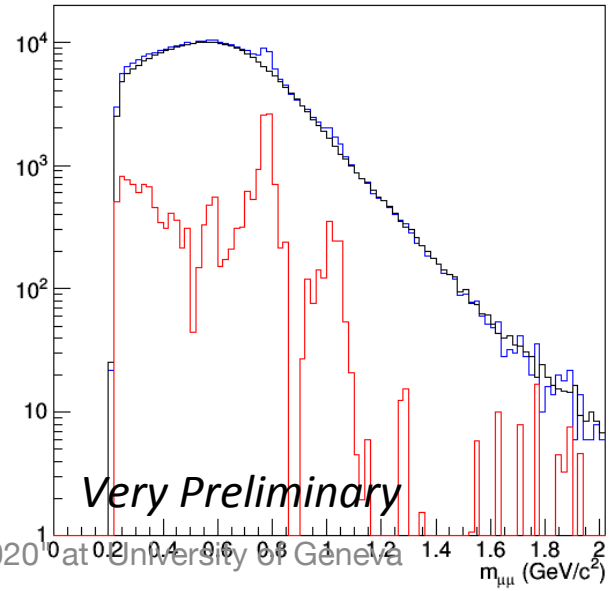
Dimuons

$\theta_{ee}>2^o$
$2^o<\theta<80^o$
$p_T>0.1$GeV/c

$\mu^+\mu^-$ cocktail (0.6 M events)

With K, π weak decay background



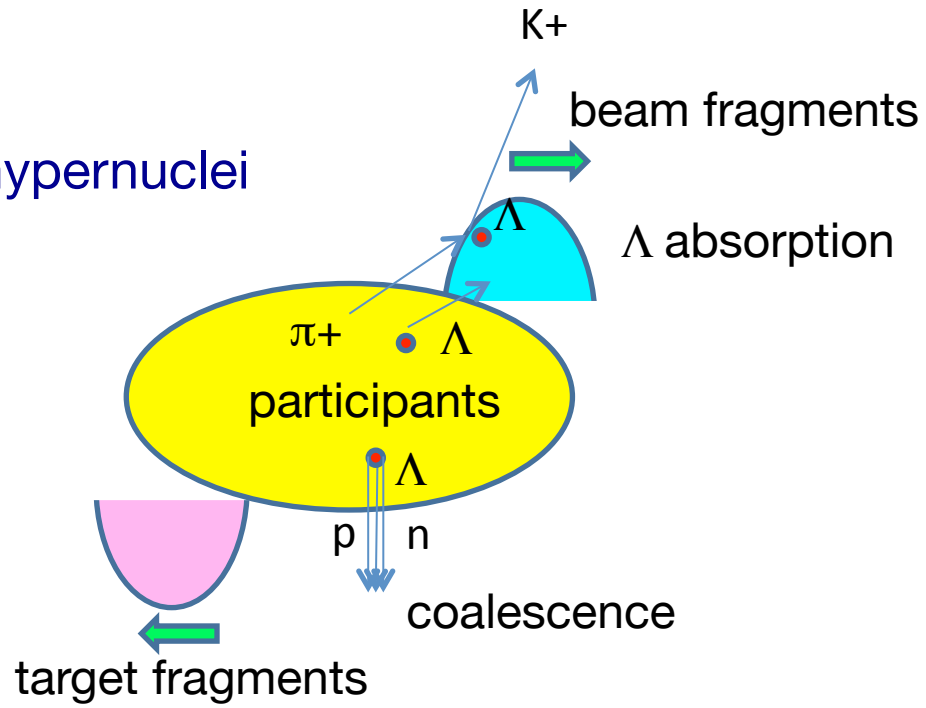


STRANGENESS & HYPERNUCLEI

Hypernuclear Production in HI Collisions

At Stopping Regime

- Participant region
  - Nuclear coalescence -> light hypernuclei
- Beam fragment region
  - Λ absorption in fragments
  - (π^+, K^+) interaction

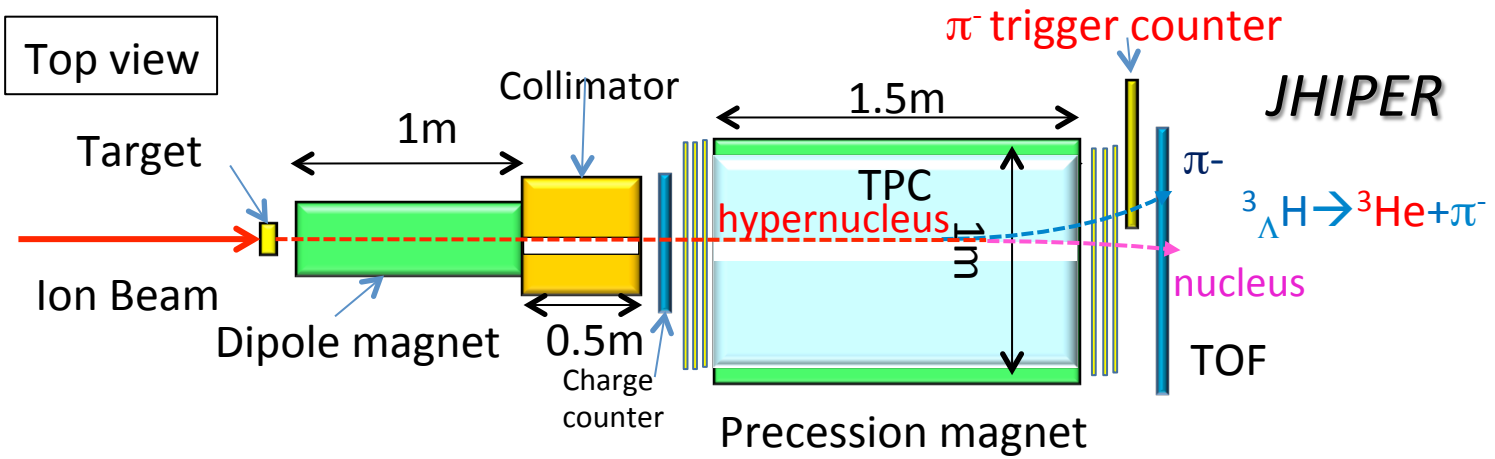


- *Measurements in the beam fragment region will be interesting*

Advantage of HI Beams over Kaons

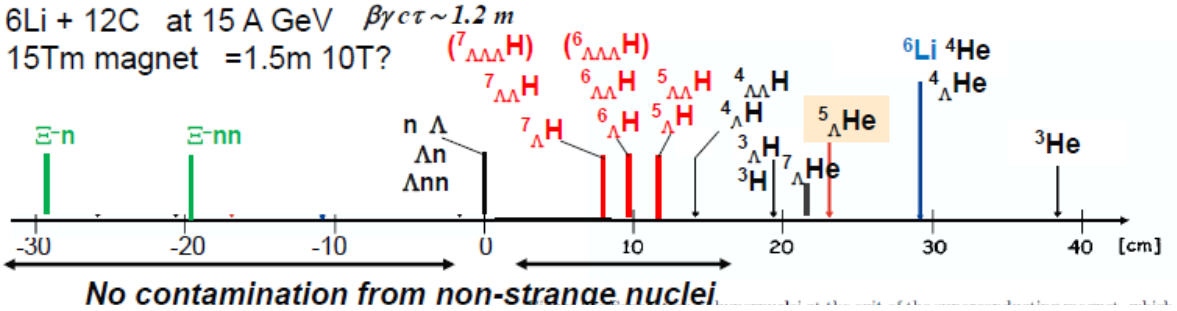
- Production of exotic hypernuclei
  - S = -3 Hypernuclei
  - Double hypernuclei
  - Neutron-rich/proton-rich hypernuclei, not accessible with Kaon beams
- Study of properties; lifetime & magnetic moment
  - Hypernuclei at beam rapidity
  - Difficult with meson beams, due to short decay length
  - Magnetic moment
    - Never succeeded!
    - Sensitive to hyperon wave function inside hypernucleus
    - Spin and angular momentum structure
    - Spin-dependent YN interaction

Hypernuclear spectrometer



- Experiment with full beam rate may be feasible
  - At 10^7 Hz interaction rate, trigger rate will be ~4.0×10^3 Hz

1. Two−magnet setup; a sweeper magnet with strong field + a magnet for momentum analysis and spin precession
2. Weak decays of hypernucleus to π- and a nucleus is measured by the TPC



SUMMARY AND OUTLOOK

Summary & Outlook

- HI acceleration at J-PARC is under serious consideration
- Revisit hot matter at very high baryon density, with capability of accumulating high-statistics data
- A TOROIDAL setup is under consideration
  - study of particle production with high precision in the central rapidity region, including open and close charms and low mass pairs
  - particle correlation …
- A forward spectrometer system for hypernuclei (& strangelet)