EXPERIMENTAL STUDY OF FINITE DENSITY MATTER AT J-PARC

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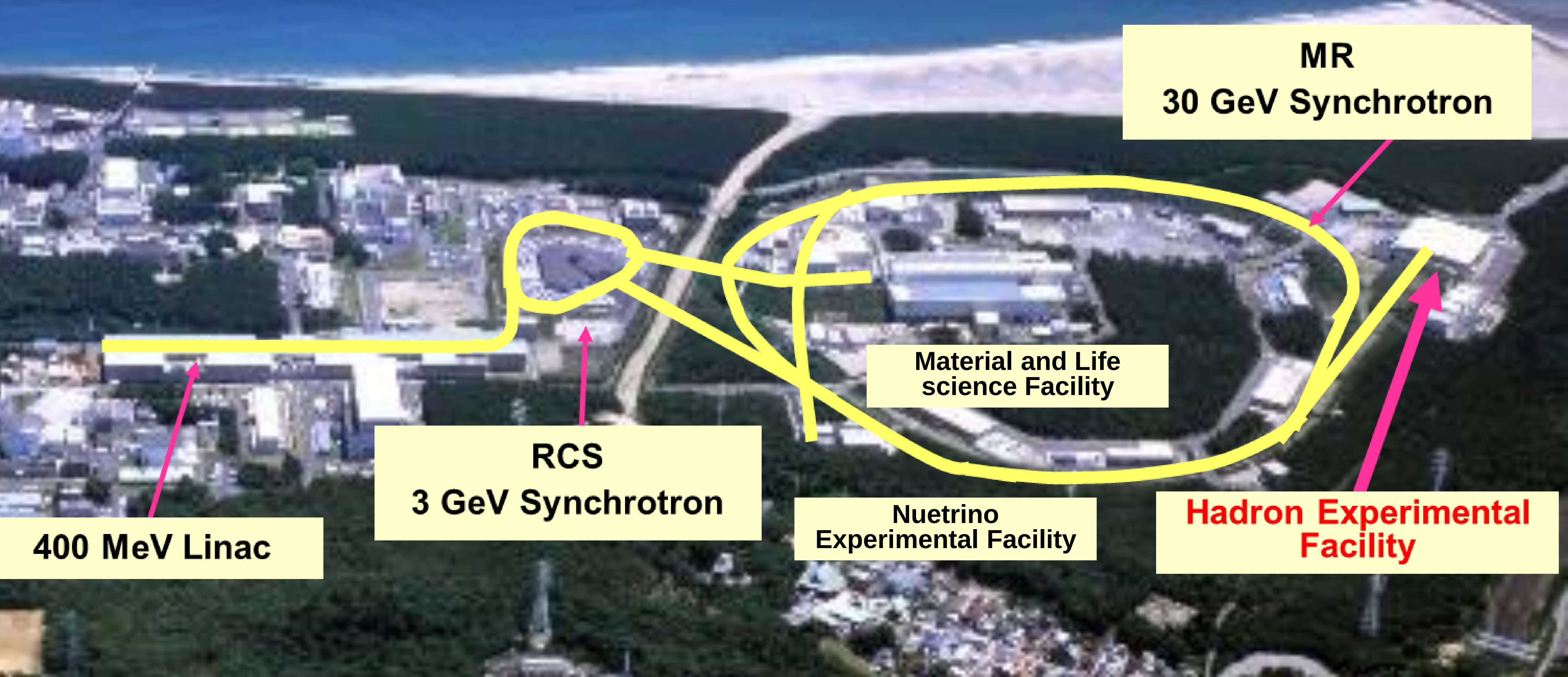
J-PARC (Japan Proton Accelerator Research Complex)



FINITE DENSITY MATTER AT J-PARC

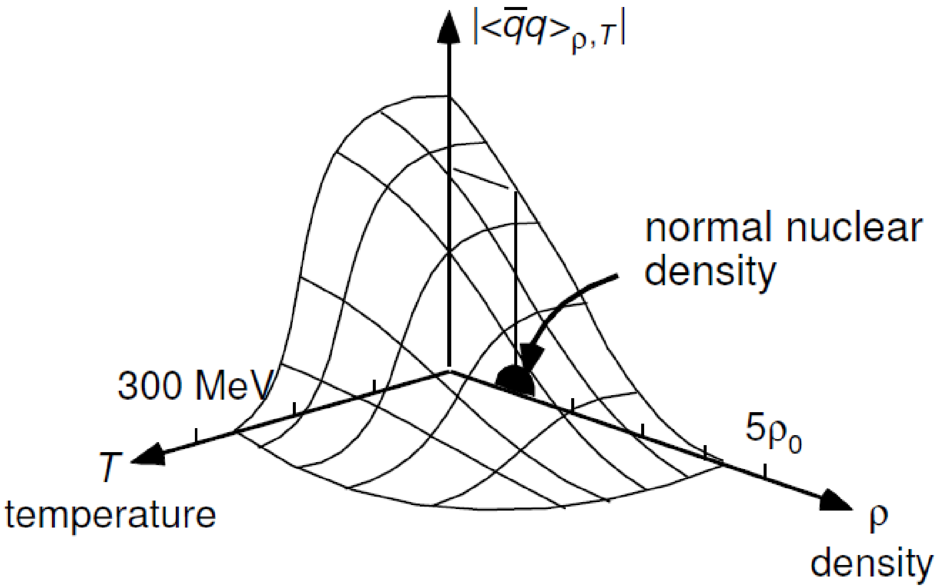
- Nucleus as a finite density QCD matter
  - Partial restoration of Chiral symmetry

- Heavy Ion Physics program at J-PARC
  - Properties of QCD phases and QCD matters
  - Hadron Physics in a finite density matter

CHIRAL SYMMETRY AND "QCD MATTER"

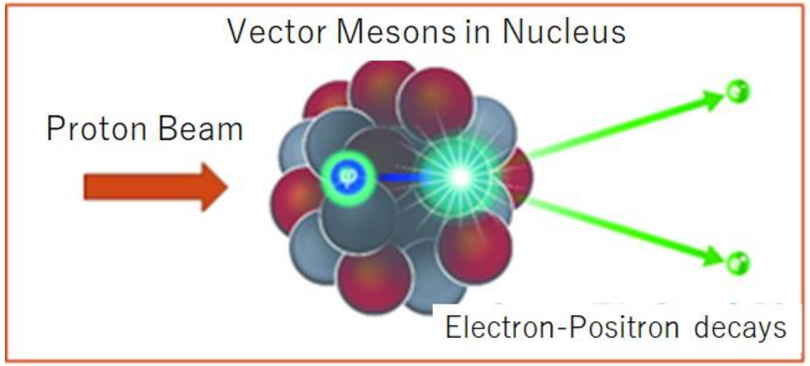
- Chiral symmetry is one of the most important properties to characterize the QCD matter
- Masses of hadrons are generated by the spontaneous breaking of the chiral symmetry
  - π mesons can be understood as NG bosons.
- The chiral symmetry in "QCD matter" can be restored in finite temperature and/or density media.
  - Expectation value of the vacuum ($\langle\bar{\psi}\psi\rangle$) is an order parameter of chiral symmetry
- Even at normal nuclear density, we can expect visible restoration of Chiral Symmetry
  - Hadron properties can be changed in nucleus

W. Weise, Nucl. Phys. A553(1993)59c



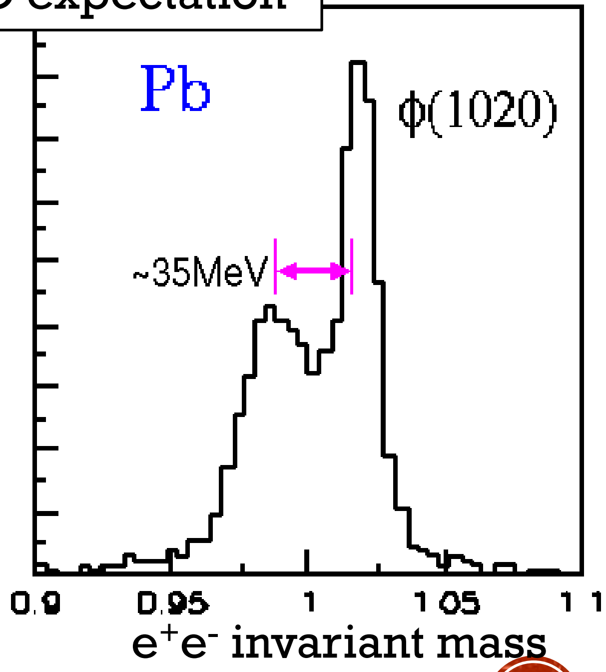
VECTOR MESONS IN NUCLEUS

- Mass spectra of vector mesons are sensitive to a partial restoration of the chiral symmetry in a finite temperature and/or density media
  - The mass spectra can be modified due to a partial chiral symmetry restoration in a nucleus
- A new experiment is being carried out to measure vector meson mass spectra in pA collisions (J-PARC E16)
  - A primary beamline and a new spectrometer are constructed



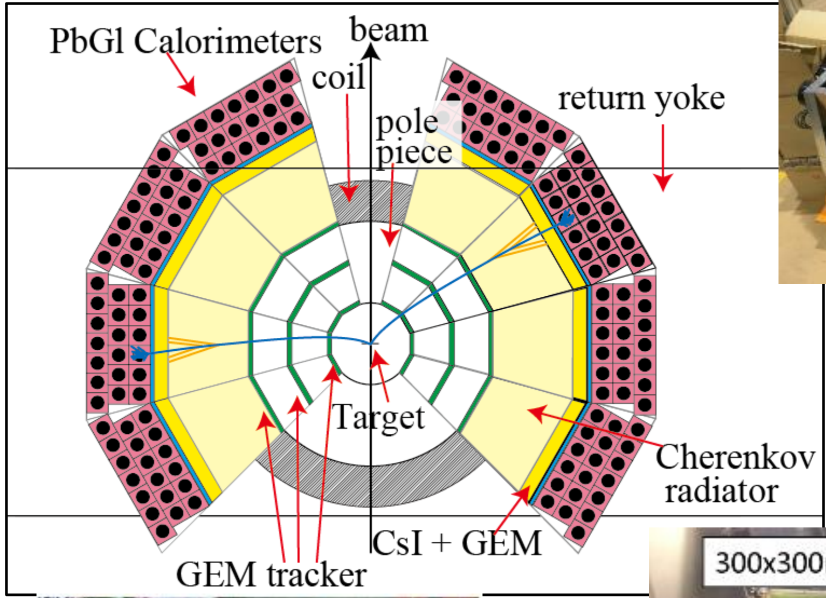
Reaction

J-PARC expectation

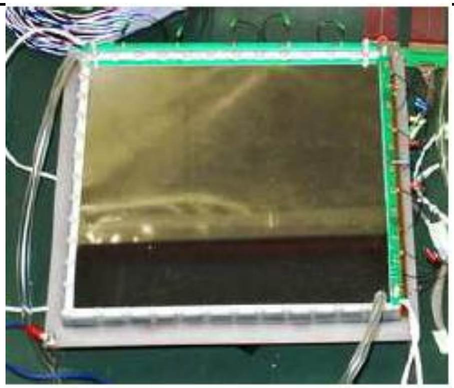


J-PARC E16 SPECTROMETER

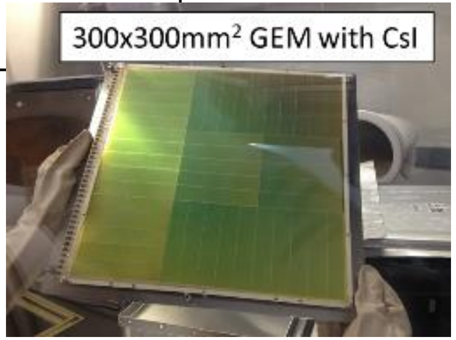
- High beam intensity and large acceptance in target rapidity region to collect huge statistics
  - 10^{10} protons per spill
  - Counting rate: 5 kHz/mm^2 (maximum)
- Good momentum resolution to detect a small modifications of the mass spectra
- Detectors
  - Silicon Strip Detector : Tracking
  - GEM Tracker: Tracking
  - Hadron Blind Detector: eID (Cherenkov)
  - Lead Glass EM Calorimeter: eID



Calorimeter



GEM Tracker

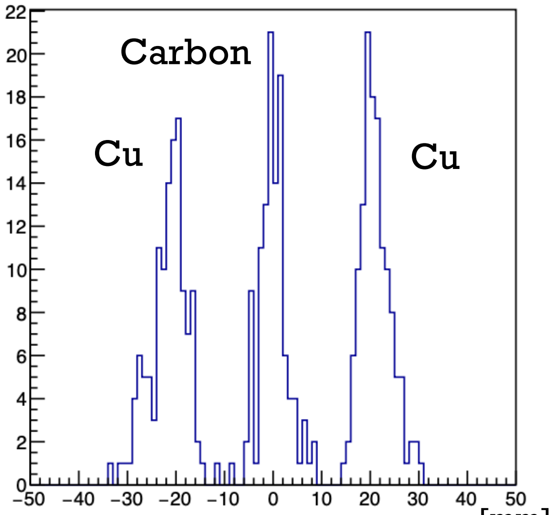


Cerenkov Photo Detector

STATUS OF THE EXPERIMENT

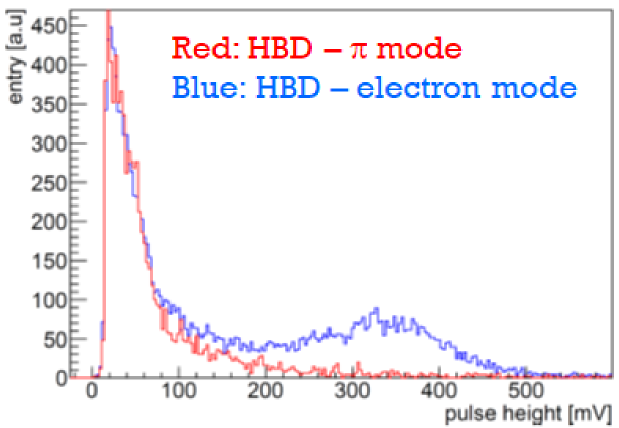
- First beam: May 24, 2020.
- Commissioning runs: June 2020 and June 2021
  - All detectors, triggers, and DAQ worked well
  - Detector performance in commissioning data

Track reconstruction



Reconstructed Target Profile

Electron Identification



Pulse Hight Distribution of Lead Glass

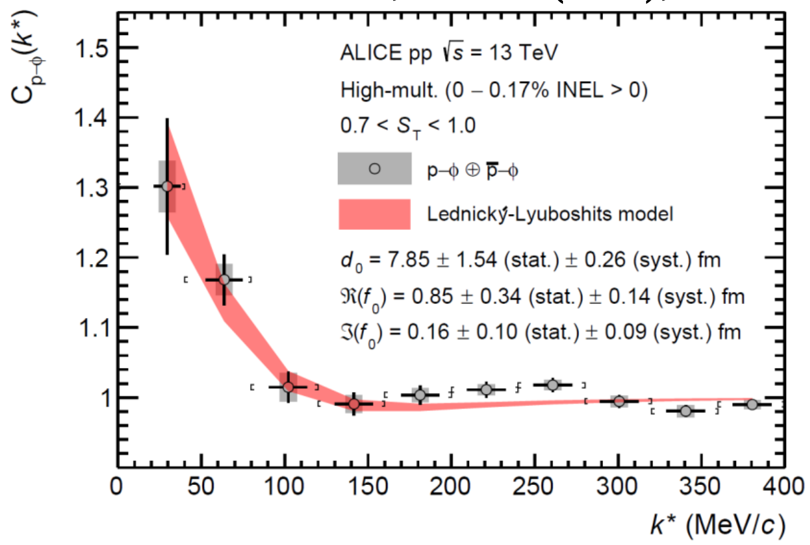
Photo of Spectrometer

Pilot data has been taken
Physics Run in 2024

NOTE: ΦN INTERACTIONS AND MASS

- Mass of ϕ meson in a QCD medium can be related with ϕN interactions also.
- ALICE shows the attractive strong interaction between a proton and a ϕ meson using two-particle correlations measurements
  - Consistent with LEPS results (W.C. Chang *et al.*, PLB658(2008), 209)
  - Significantly larger than CLAS results (I. I. Strakovsky *et al.*, PRC101(2020), 045201)
- The result suggest a large mass modification of ϕ meson

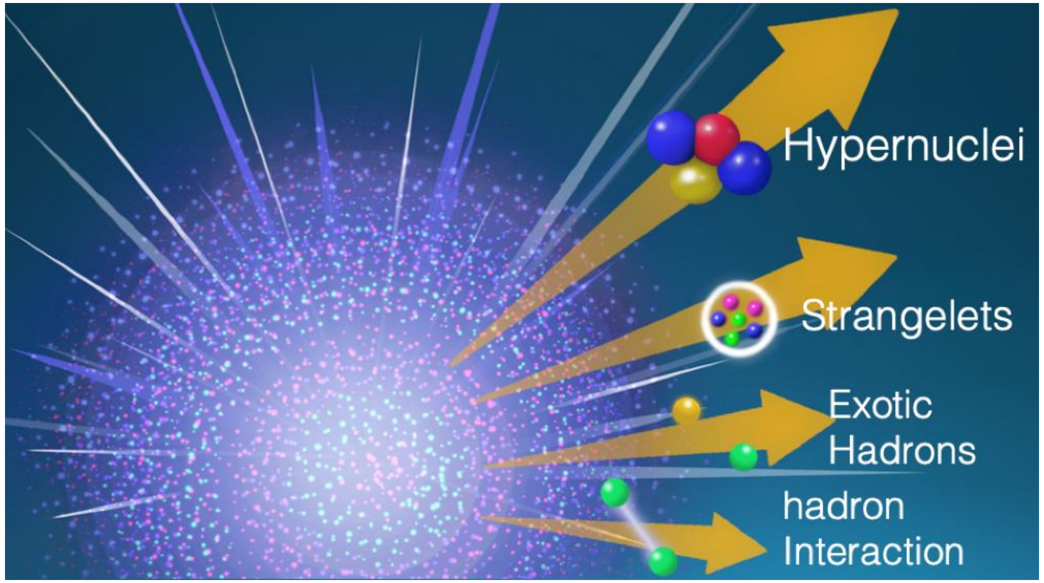
ALICE, PRL 127 (2021),172301



J-PARC HEAVY ION PROJECT

- Main Physics topics
  - QCD phase structure in high density region
  - Study of hadron physics in a finite density matter

- Heavy Ion Beam specifications
  - Beam Energy: $\sqrt{s_{NN}} \sim 2 - 5$ GeV
  - Species: Up to Uranium
  - Maximum Beam Intensity: 10^{11} Hz



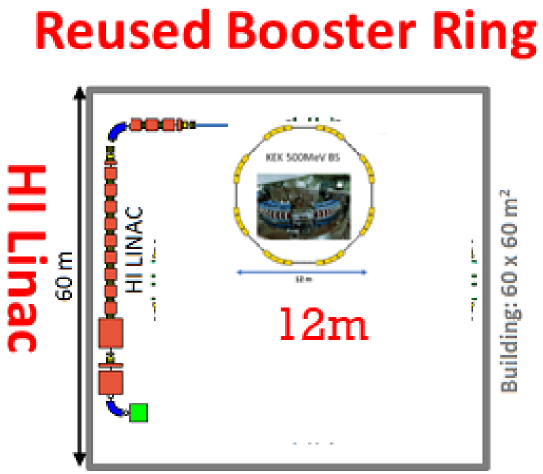
FACILITIES TO BE UPGRADED FOR HEAVY ION

- New Heavy Ion Injector (LINAC and BOOSTER)
- New Experimental area and Spectrometers

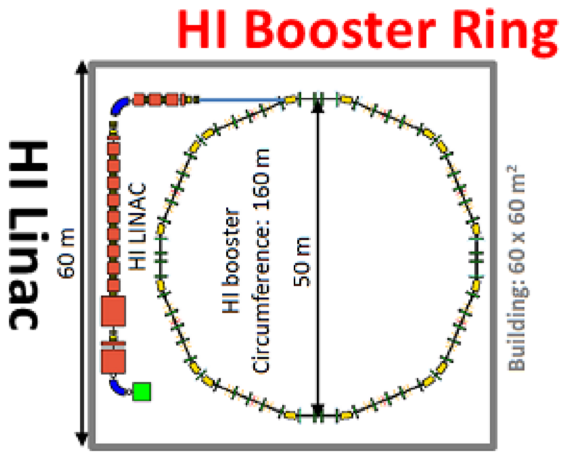
STAGING PLAN

- On-going
  - pA collisions using existing beam line and spectrometer
    - Main Physics topic: Vector meson measurements in e^+e^- decay modes
  - + Upgrades of the spectrometer for hadron measurements
  - Pilot data for Heavy Ion physics
- Phase I
  - New LINAC and reuse of KEK-PS booster
  - Upgrades of the existing spectrometer
  - Beam Intensity: 10^8 Hz for Au
- Phase II
  - New Booster and New spectrometer
  - Final configuration

Phase 1

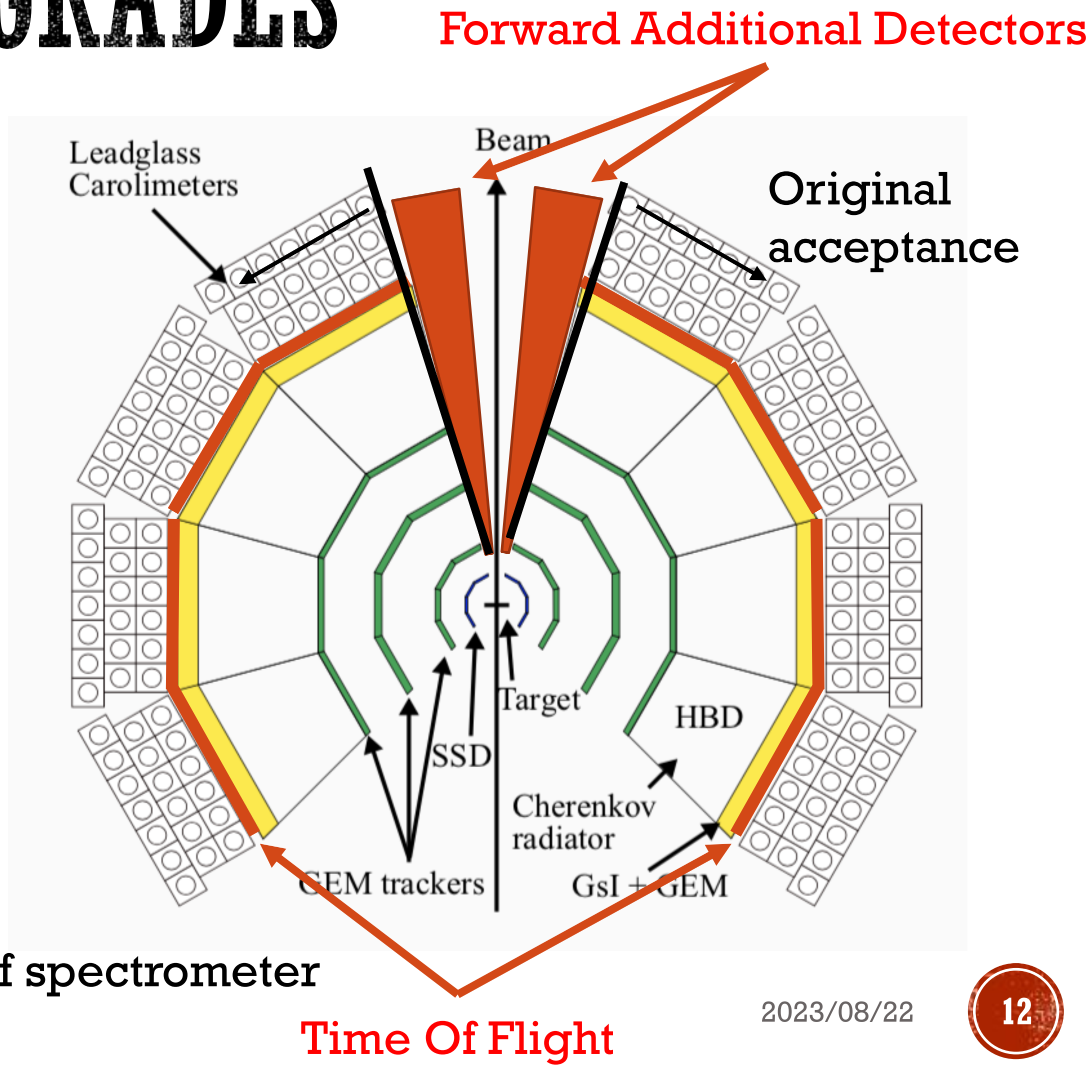


Phase 2



HEAVY ION: PHASE I EXPERIMENT AND SPECTROMETER UPGRADES

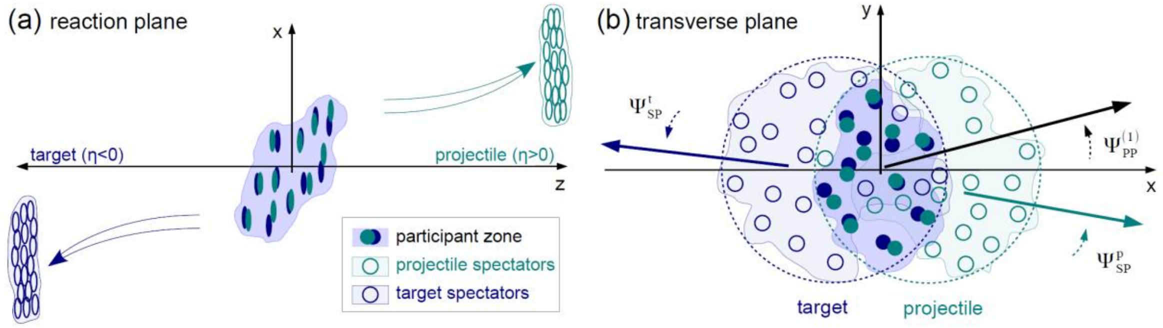
- Physics Goal of phase I experiment
  - Hadron interactions in dense medium
  - Search for a quark phase
    - Flow, Two particle correlations
    - Di-electron
- Heavy Ion beams
  - Species: Au
  - Intensity: 10^8 Hz
- Detector Upgrades
  - <u>Hadron measurements</u>
    - It will be partially installed for pA experiment
  - <u>Additional detectors in forward region</u>



Schematic view of spectrometer

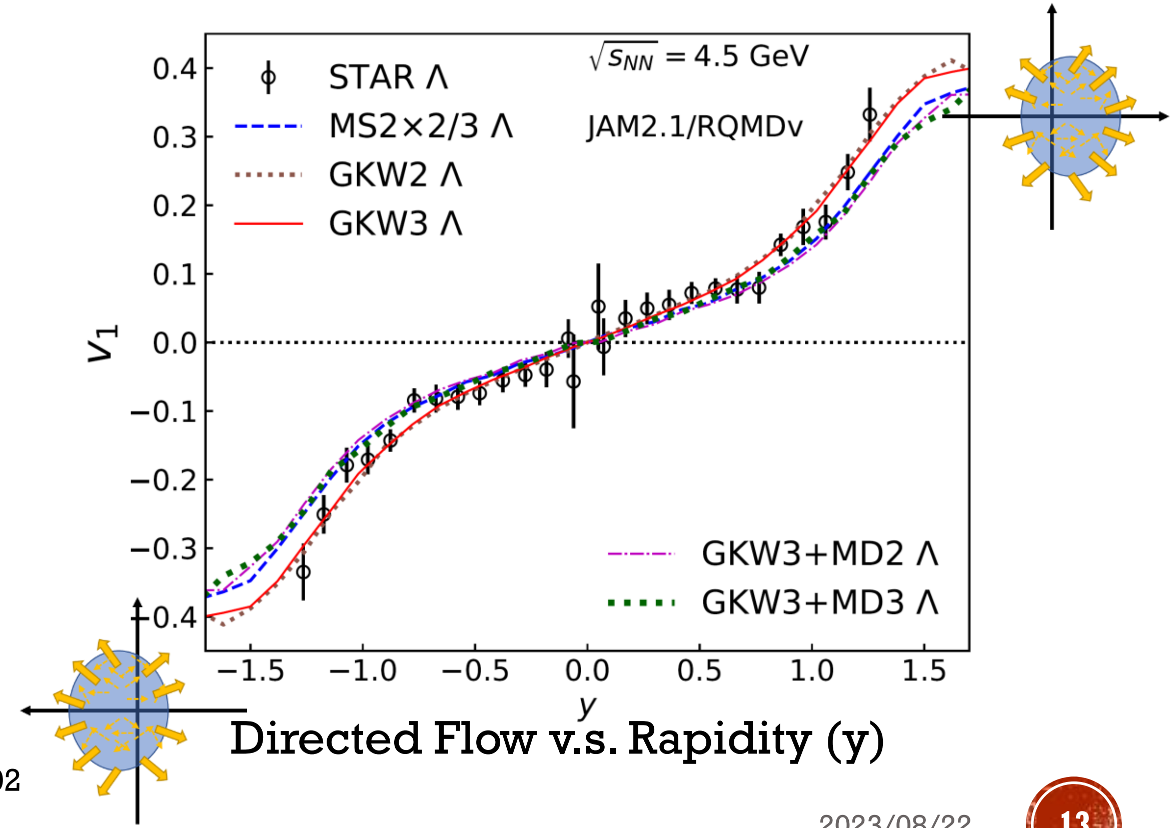
EQUATION OF STATE (DIRECTED FLOW)

- Particle emissions (flows) are basic observables in heavy ion collisions
- Example:
  - Directed Flow
    - Sensitive to the Equation-Of-State
    - First harmonic coefficient: v_1
    - $f(\phi; y, p_t) \propto 1 + 2\sum v_n(y, p_t)\cos(n\phi)$



Phys. Rev. Lett. 111 (2013) 232302

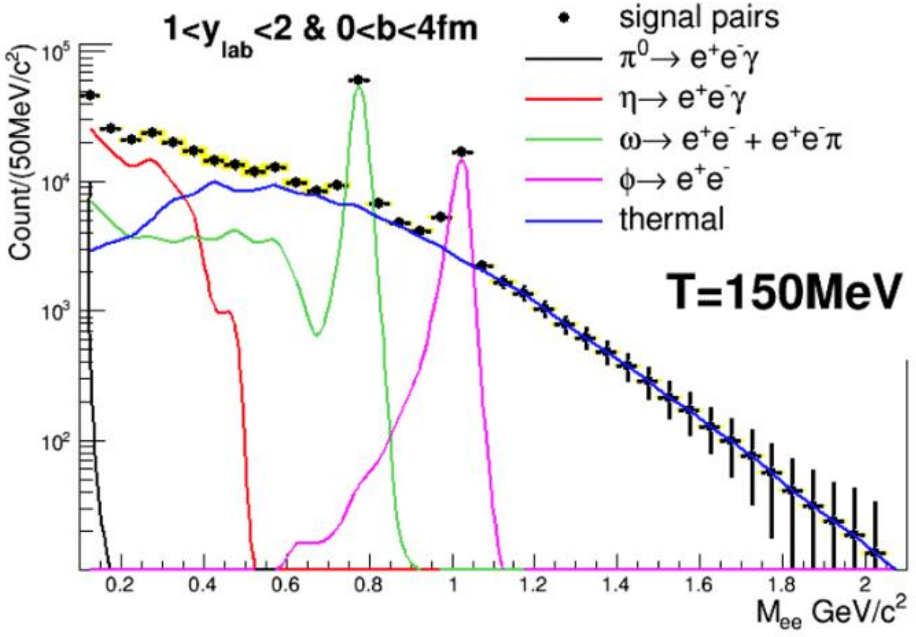
Data: STAR PRL 1708.0713; PLB 2108.00908
Calc: Y. Nara et al., PRC 106 (2022)4, 044902



Directed Flow v.s. Rapidity (y)

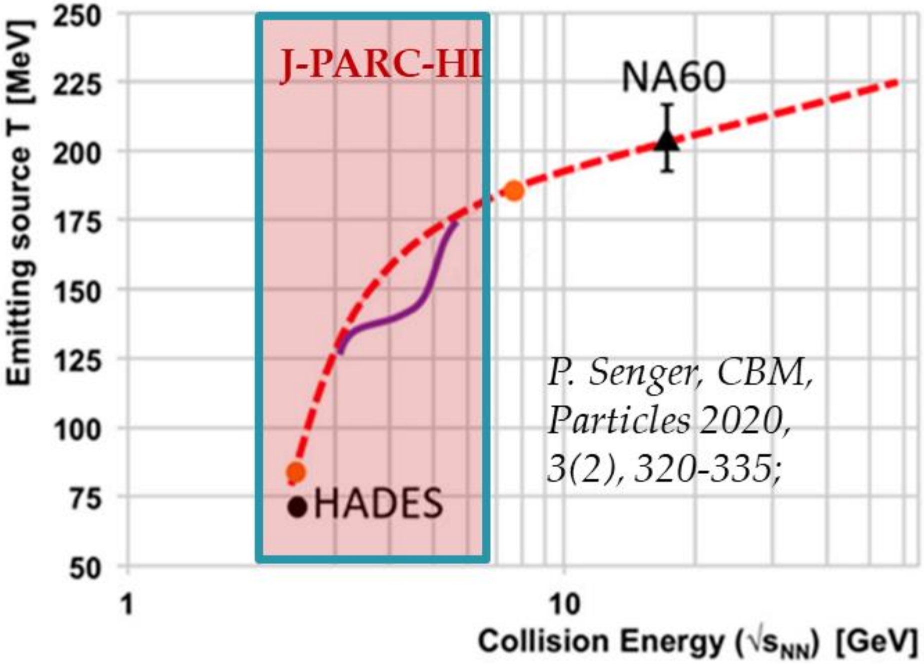
TEMPERATURE OF THE MATTER

Temperature measured by radiation of di-electrons



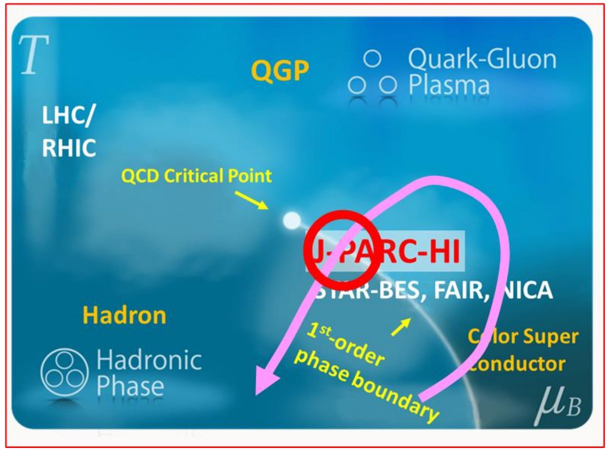
Expected e^+e^- mass spectrum with radiation

Non-monotonic behavior shows a phase transition

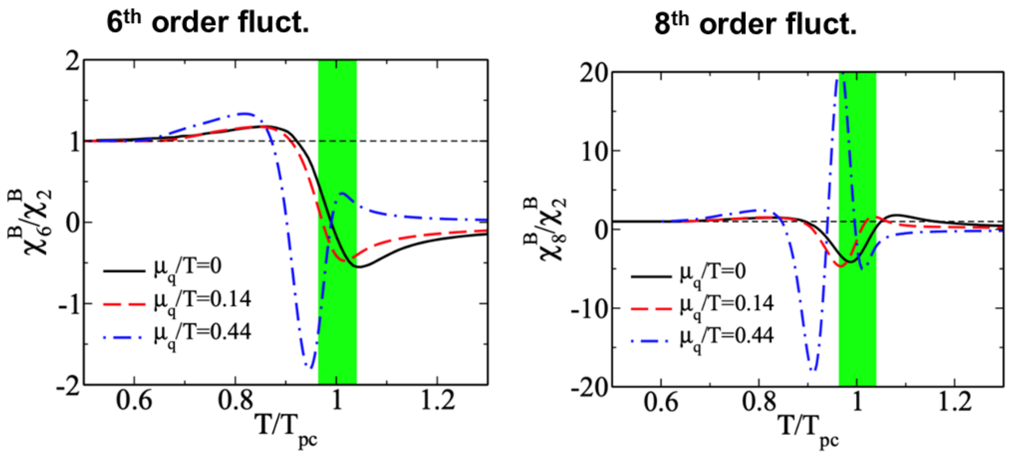


Temperature as a function of collision energies

FLUCTUATION AT THE PHASE TRANSITION

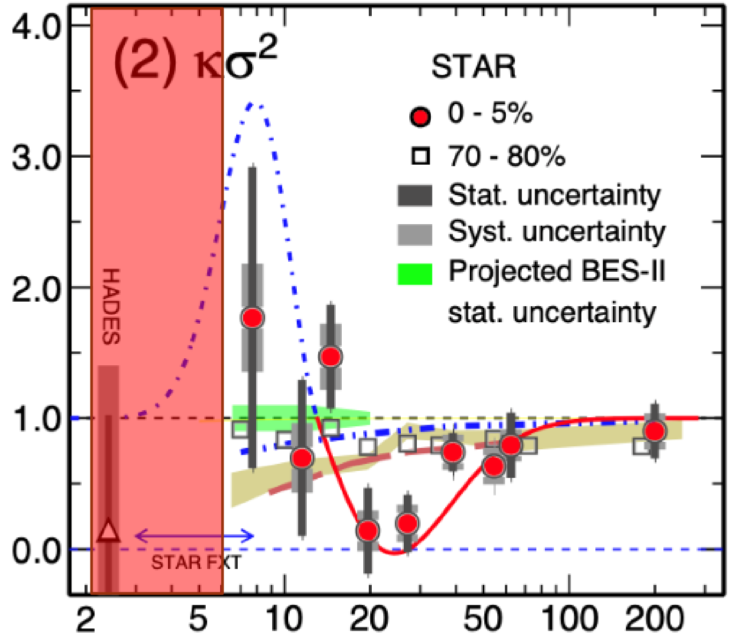


- Event by Event fluctuation of conserved variables have a sensitivity for the phase transition
  - correlation length, critical point
- Higher order fluctuations are essentially important
  - Need huge statistics and uniform acceptance



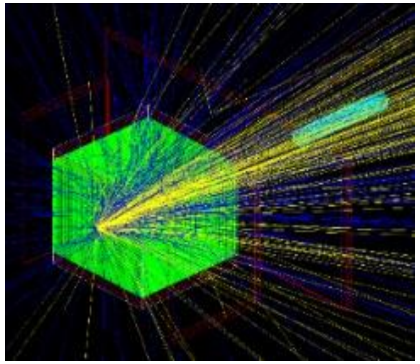
Eur. Phys. J. C 71 (2011) 1694

J-PARC RHIC-STAR, PRL 126(2021) 092301

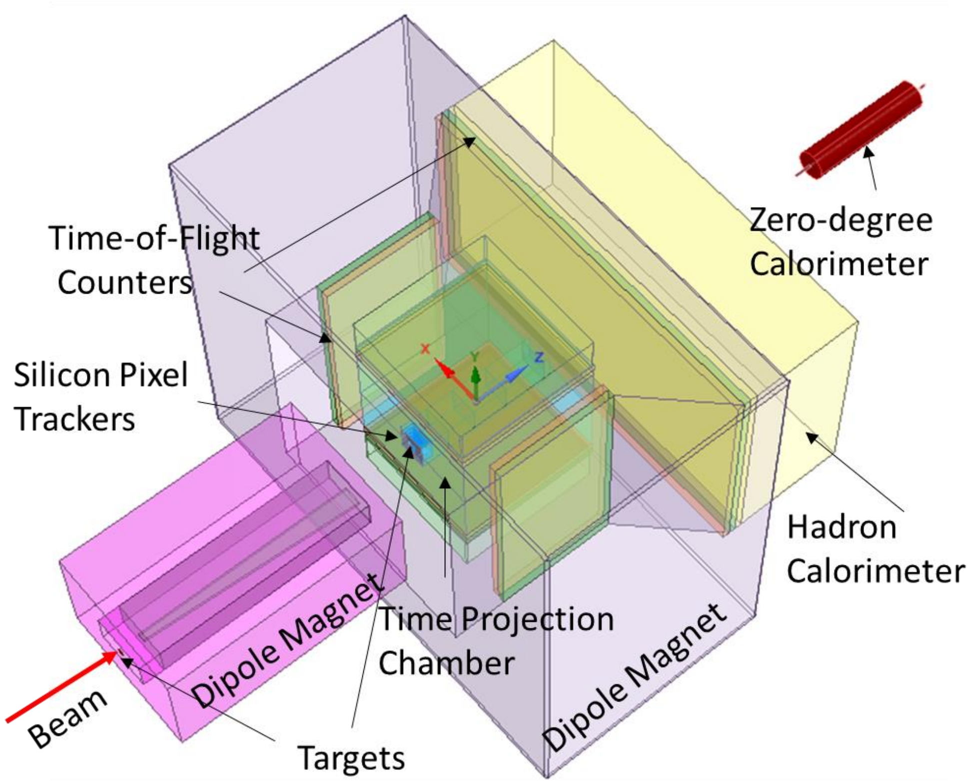


4th order moment v.s. collision energies

PHASE II: SPECTROMETER



- Experiment with High-intensity beam (10^{11} Hz)
- Large acceptance and low p_T tracking detector
  - higher flows, fluctuations, charmed hadrons
  - Detailed detector designs are still under discussion
- Current plan
  - Hadron Spectrometer
    - Dipole + TPC
    - Large Acceptance for Correlations, Fluctuations
  - Hyper-nuclei Spectrometer
    - Closed configuration
    - Hadron Spectrometer + Sweeping magnet



Schematic view of Hyper-nuclei spectrometer

SUMMARY

- We are performing experimental studies of finite density matter at J-PARC
  - pA experiments
  - Future Heavy Ion experiments
- We are performing a new experiment to study mass spectra of vector mesons in nucleus, since mass spectra of the vector mesons can be modified due to a finite density effects.
  - Hadron mass is dynamically generated by a spontaneous breaking of chiral symmetry in the medium and closely related with properties of QCD medium
- Future Heavy ion experiments at J-PARC are planned to study hadron physics and high-density matter
- Significant Facility upgrades are required for Heavy Ion experiments
  - We need Linac and Booster for heavy ion acceleration
  - New Spectrometer and new experimental area

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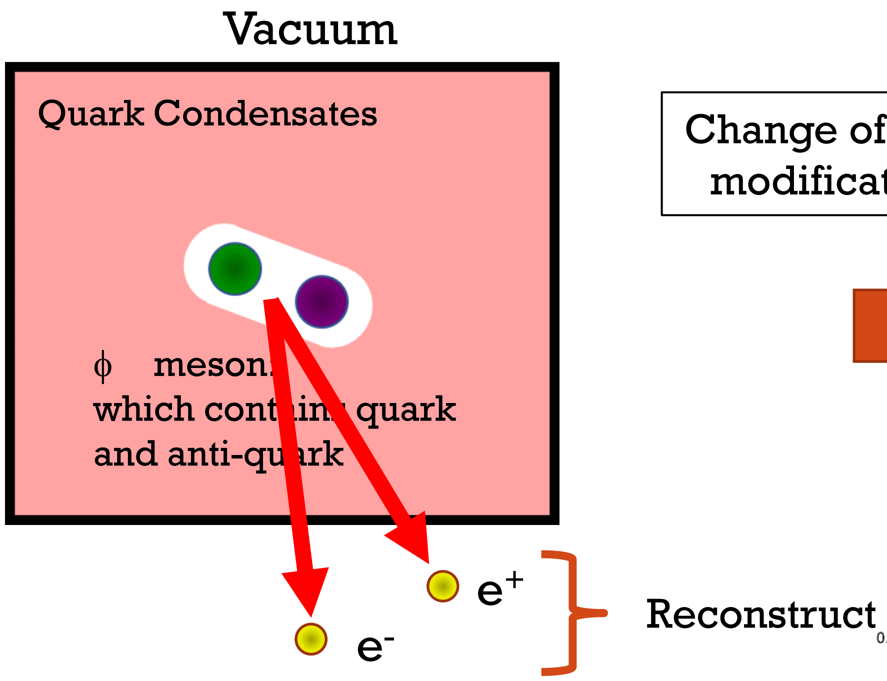
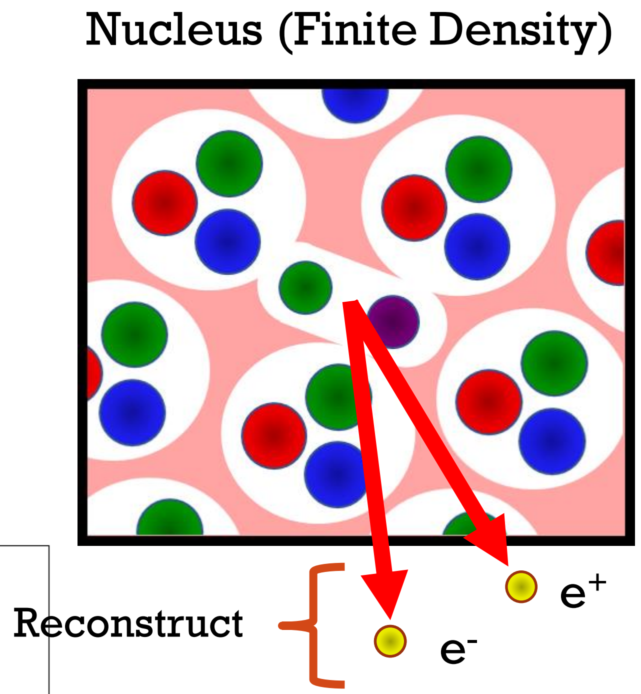
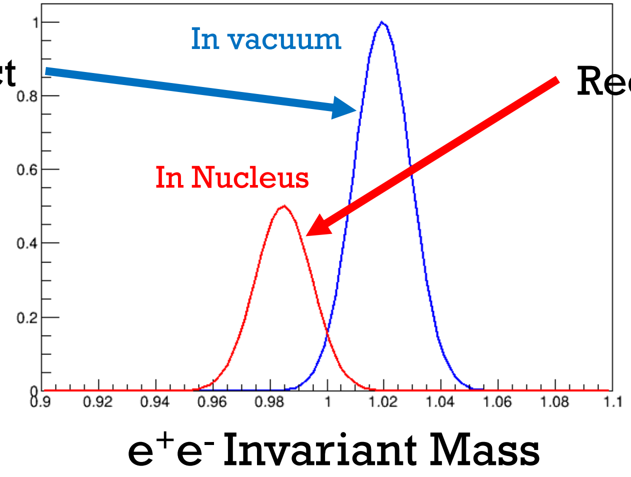
BACK UP

MEASUREMENTS OF VECTOR MESONS



Change of quark condensates and modifications of mass spectrum





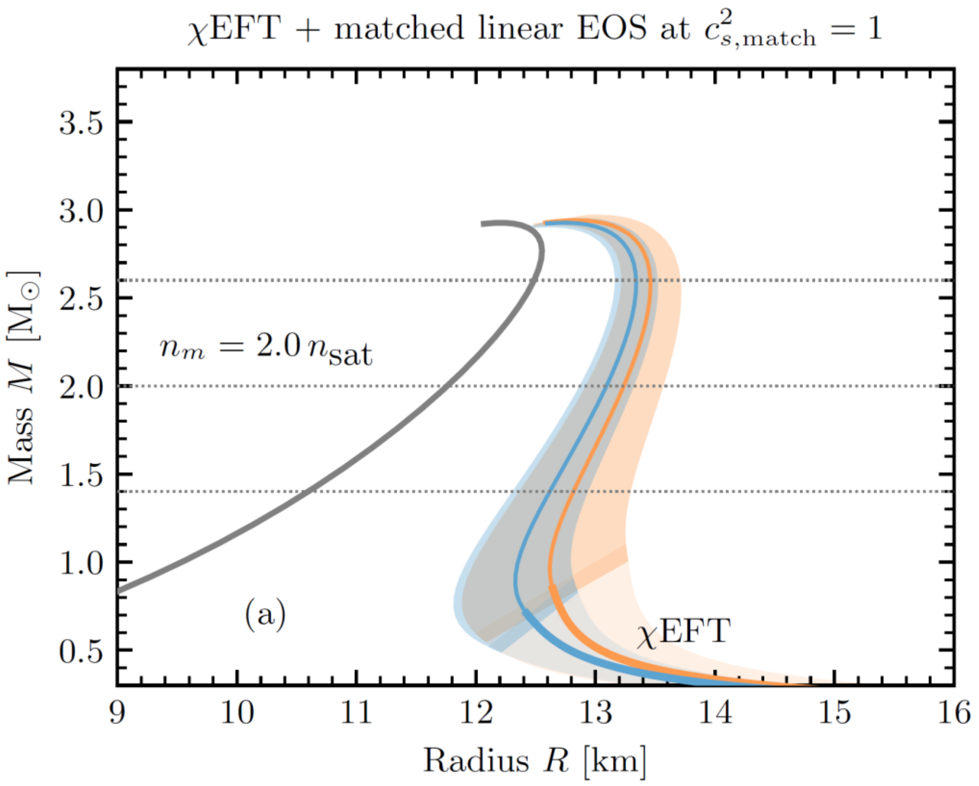
Spectral Change:
(Partial) Restoration of chiral symmetry

EXAMPLE: NEUTRON STAR EOS

- Basic information of the interactions can be measured at the current J-PARC
- Extrapolation to the higher density region is necessary
  - χEFT
  - Linear (causal) EOS
  - Chiral Functional Renormalization Group
    - M. Drews, W. Weise, PPNP 93(2017) 69
  - Constrains from GW and multi-messenger data
    - E. Annala et al., Nature Phys. 16 (2020) 907

- **<u>Experimental information at the high-density region is essential</u>**

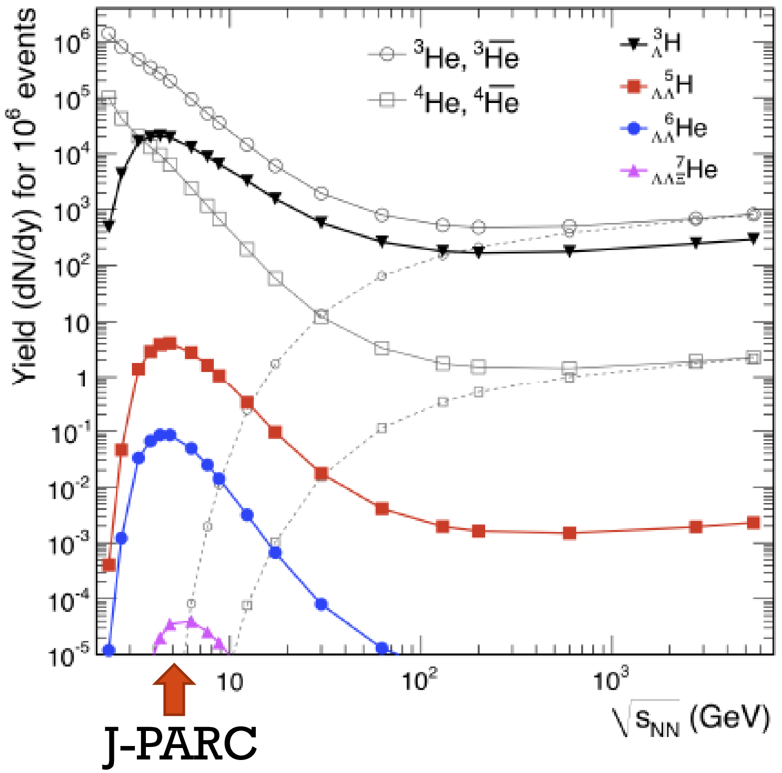
C. Drischler et al., PRC103(2021) 045808



STUDIES ON HADRON PHYSICS

- Many particles including short-lived resonances are produced
- Measurements of hadrons can give fruitful information about hadron interactions
  - Properties of emitted hadrons are determined by their interactions
- Correlation analysis which are performed at "High Energy" heavy ion collisions can be done
- In addition, study of interactions in a finite density circumstance can be done

A. Andronic *et al.*, PLB697 (2011) 203

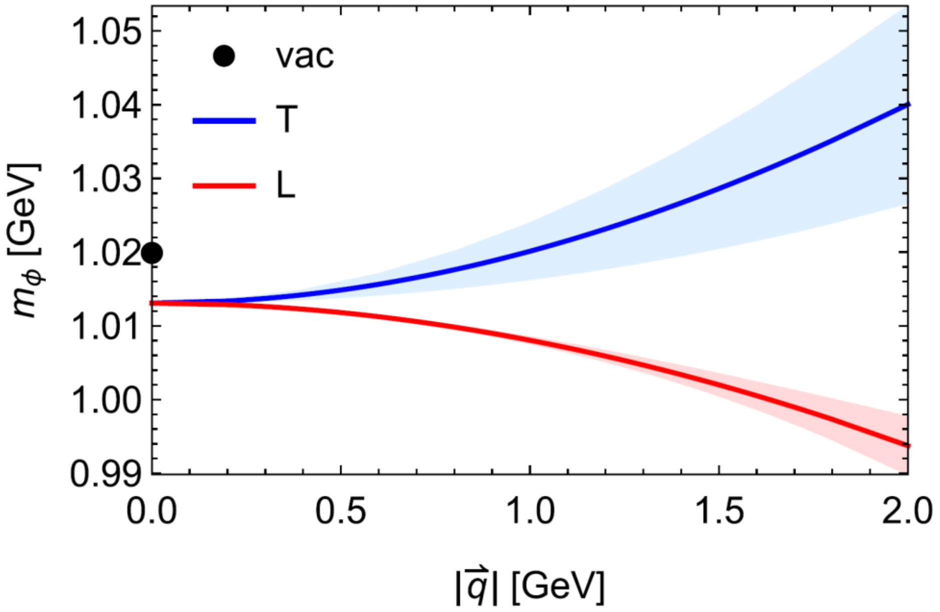


Expected Hypernuclei production

CHIRAL SYMMETRY RESTORATION

Polarization and mass shift

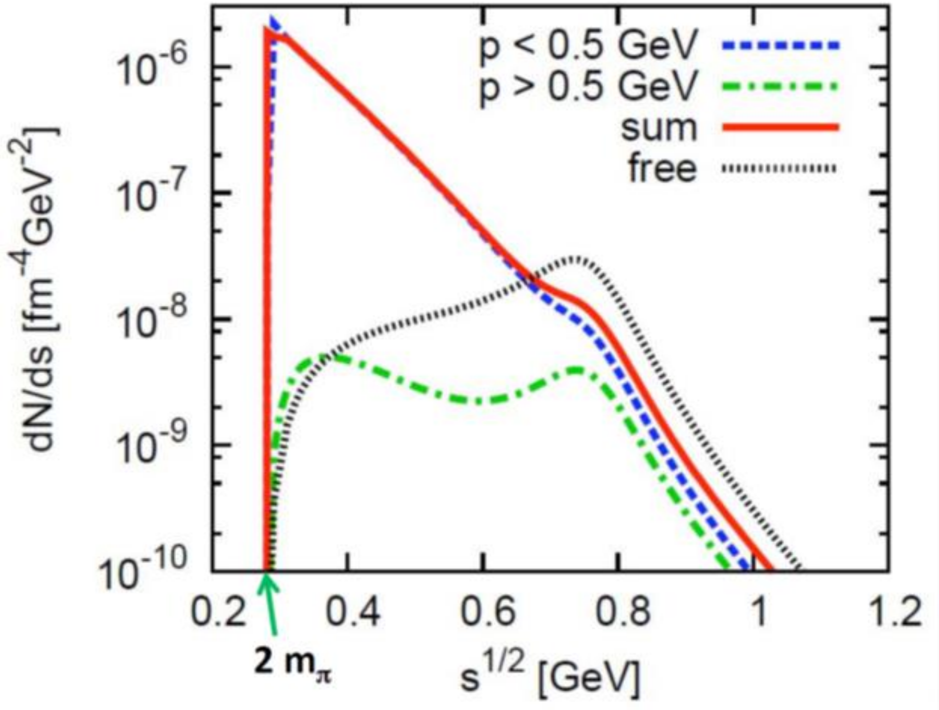
H. Kim and P. Gubler, PLB805 (2020) 135412



Mass of ϕ meson v.s. Momentum

Chiral partner through interferences

M. Harada and C. Sasaki, PRC 80 (2009)054912

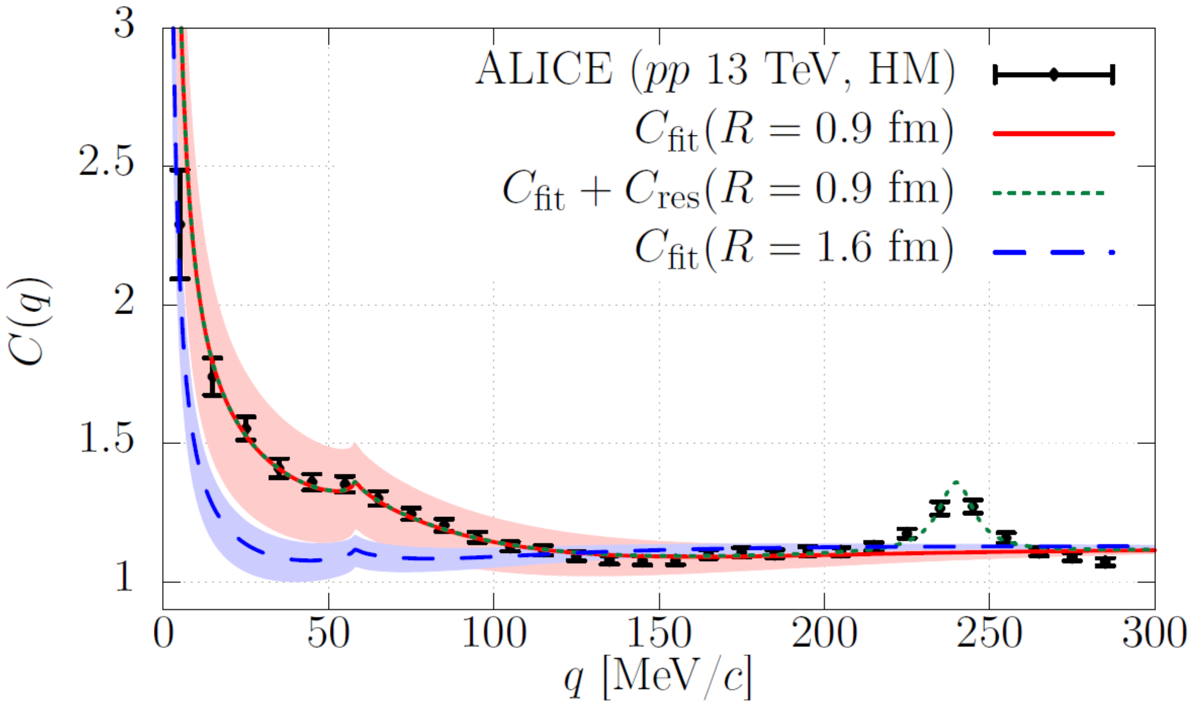


Mass spectrum of e^+e^-

OBSERVABLES: PARTICLE CORRELATIONS

- Two particle correlation function:
  - $C(q) \sim \int d^3r S(r) \left|\varphi^{(-)}(q,r)\right|^2$
  - $C = C(qR, R/a_0)$
    - a_0: Scattering length
    - R. Leduicky, et al., Sov. J. Nucl. Phys. 53 (1982) 770
- Information on hadron interactions can be extracted
  - Interactions of exotic hadrons or short-lived resonances
  - Interactions in low momentum limit

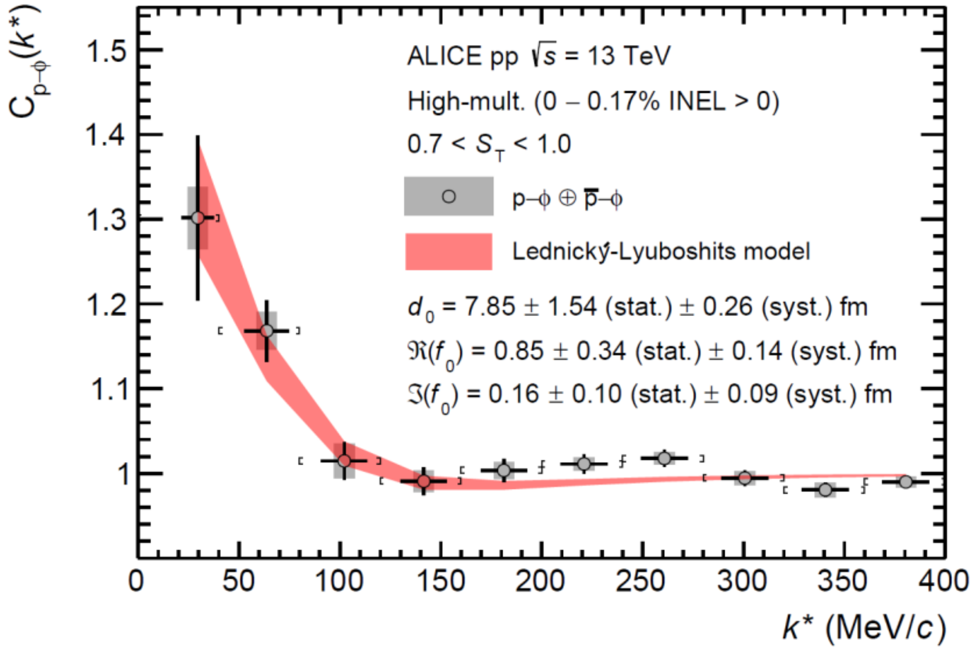
Y. Kamiya et al., PRL 124(20)13, 132501



APPLICATIONS: PARTICLE CORRELATIONS

- Interactions in a finite-density matter
  - Vector meson and nucleon interactions
    - Mass modifications and chiral symmetry restorations
  - Pseudo-scalar and nucleon interactions
    - Changes of scattering amplitude in a matter discussed by Dr. Y. Ichikawa
- Hadron Structure
  - Combined with binding energy data, hadron internal structure (compositeness) can be discussed
    - Example: $\Xi\alpha$ interaction discussed by Dr. Y. Ichikawa
  - When the thermalization of the matter is achieved, statistics of productions can provide the structure information
    - cf: ExHIC collaboration, PPNP 95(2017) 279

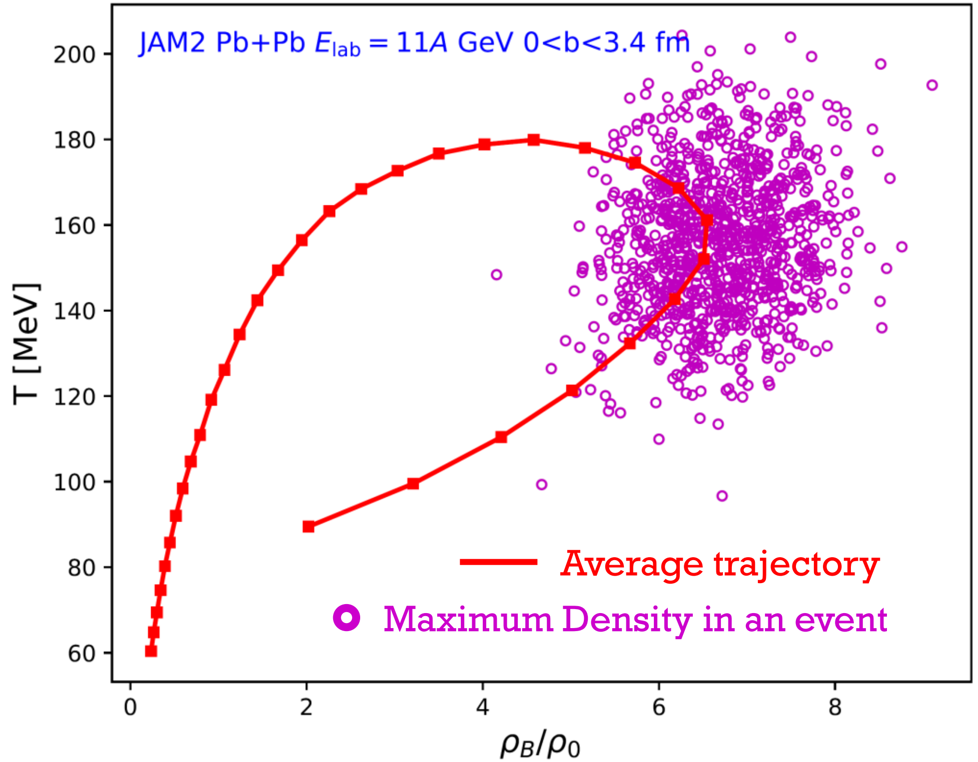
ALICE, PRL 127 (2021),172301



DIRECT STUDY OF HIGH-DENSITY MATTER

- Search for QCD Phase structures
  - 1st order phase transition
  - Color superconductor
    - Di-quark correlations
- Properties of dense matter
  - EOS, transport properties (viscosity), etc.
  - Chiral symmetry

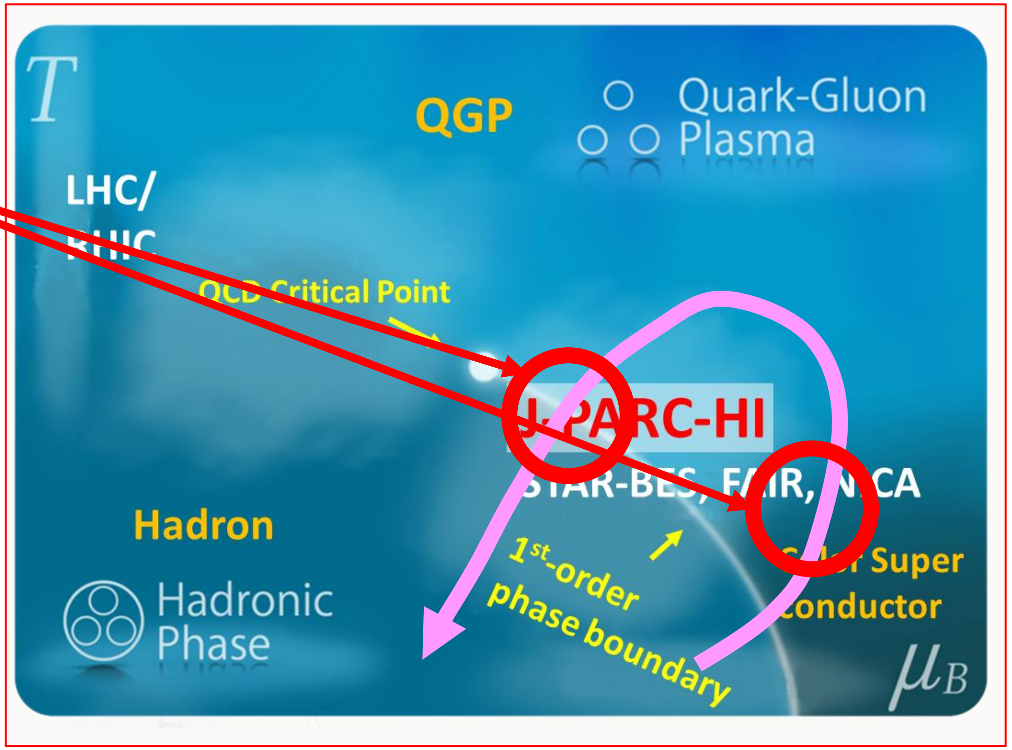
JAM2 Calculation by Y. Nara:
https://gitlab.com/transportmodel/jam2



Calculated Temperature and Density

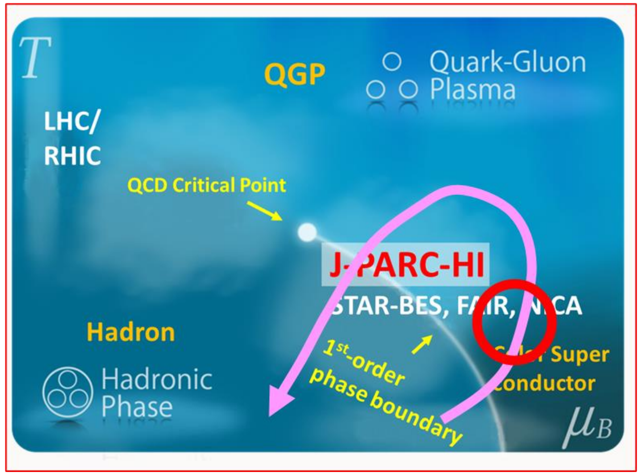
PHASE TRANSITION AND OBSERVABLES

- Generated matter has dynamical trajectory on the QCD phase diagram
- When the matter cross the phase boundary, significant changes of measurements can be expected
- Quark-Hadron Phase transition
  - Temperature
  - Particle Fluctuation
- Color-superconductivity
  - Low mass di-electron emissions

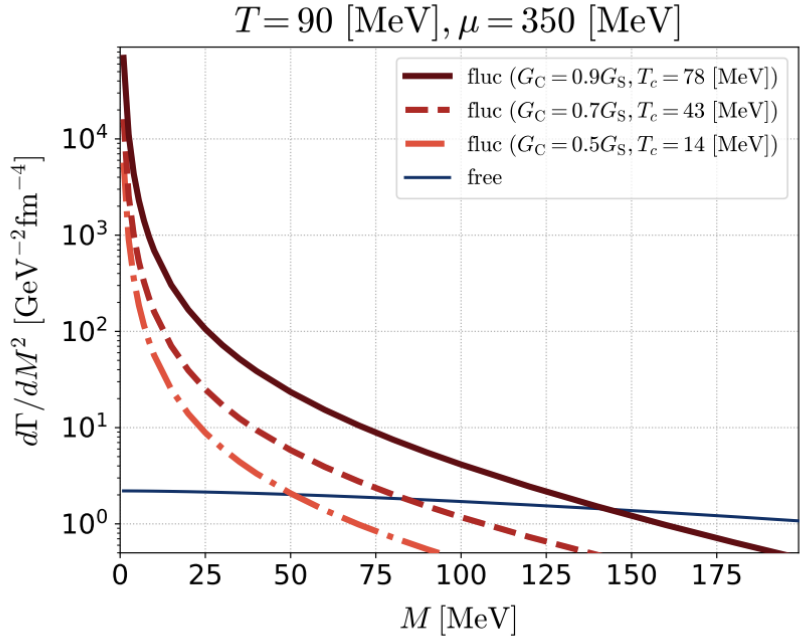


PHASE TRANSITION AND COLOR SUPERCONDUCTIVITY

- Color Superconductivity
  - Di-quark correlations in a high-density matter
- Realistic signatures of the existence of the superconductivity phase are still under discussion
- One promising signature is an enhancement of dilepton mass spectra
  - “Soft-mode” photon self-energy due to dynamical diquark fluctuation develop near the phase boundary
  - Discussions for measurements lead by Dr. Y. Morino



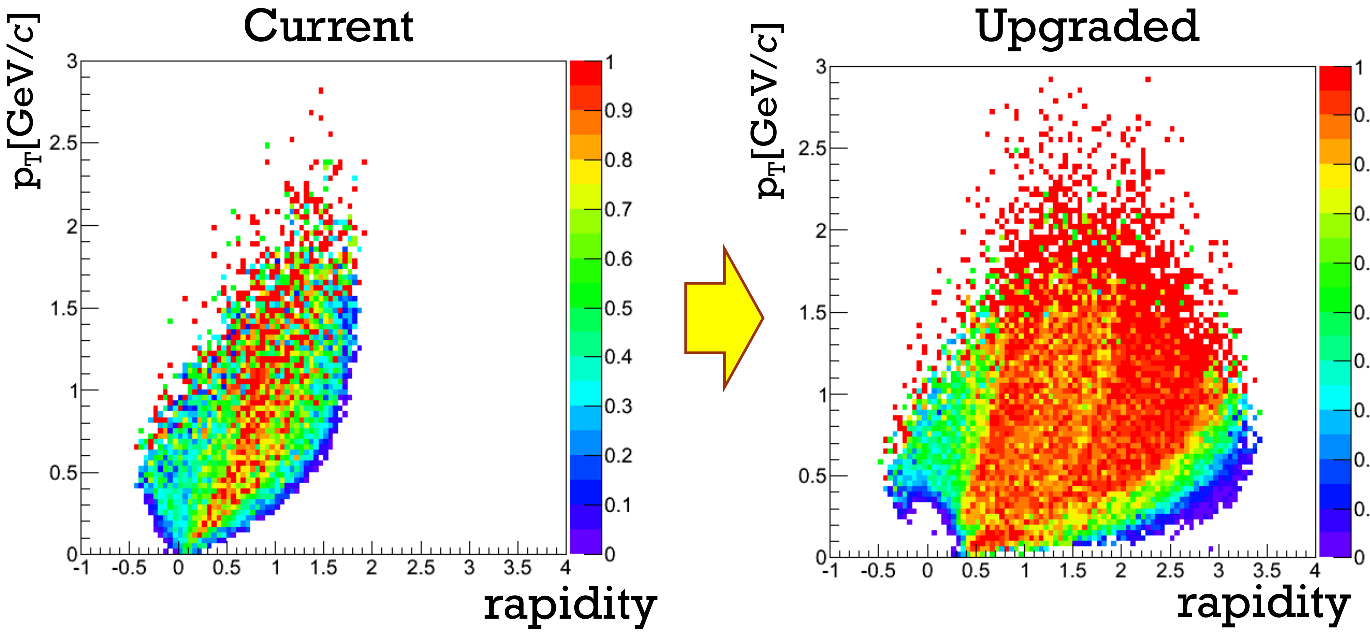
T. Nishimura, M. Kitazawa, T. Kunihiro,   PTEP 2022, 093D002



Calculated e^+e^- mass spectrum with the phase transition

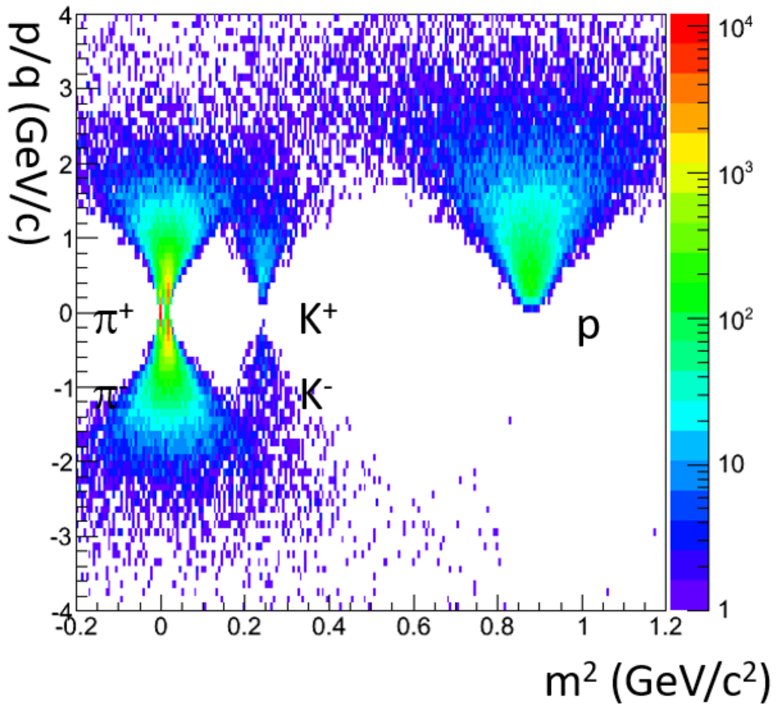
HADRON MEASUREMENTS CAPABILITIES

- Enhance the rapidity region with forward detectors



Proton acceptance in A+A

Enough particle ID capabilities



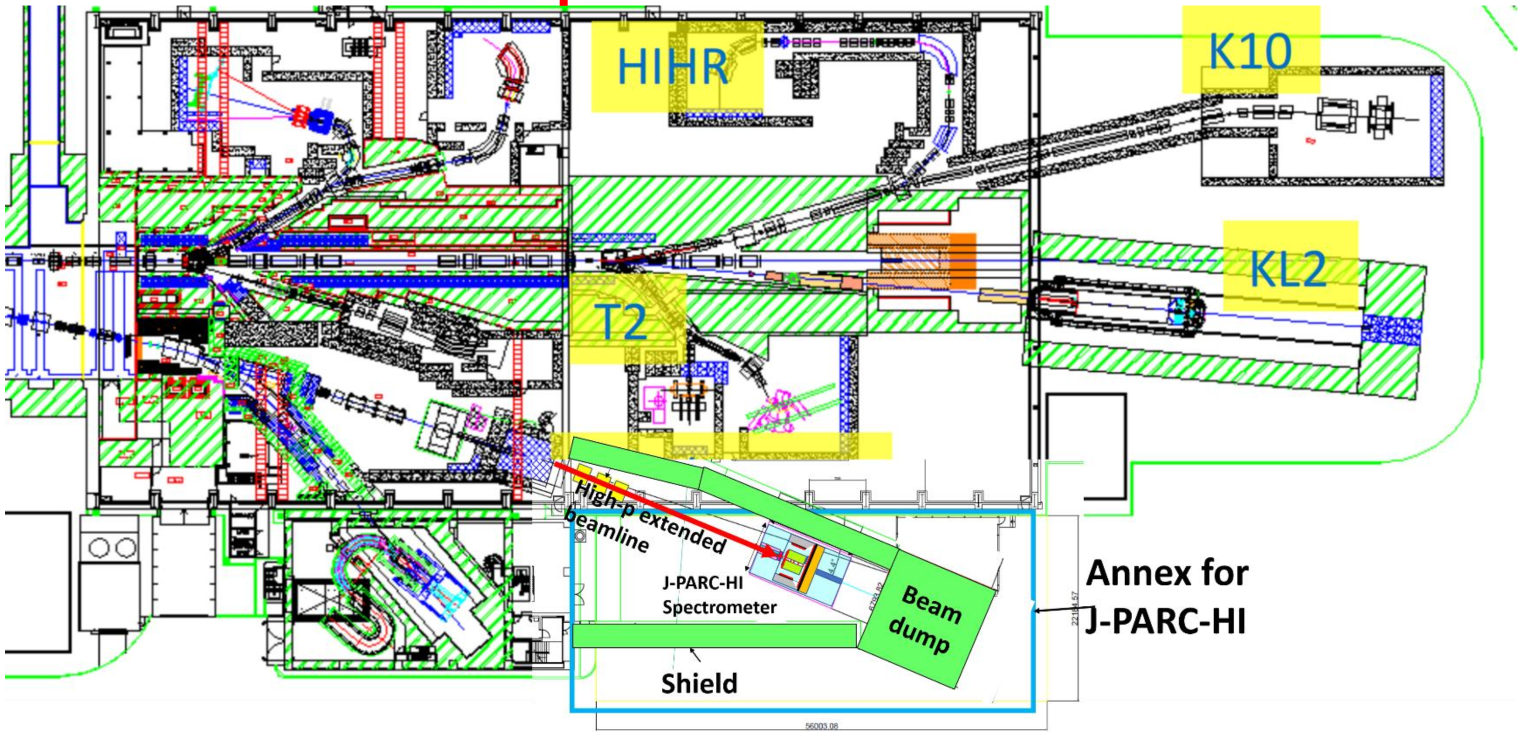
Momentum vs. Mass^2

PHASEII: UPGRADES OF EXPERIMENTAL AREA

Current
Experimental Hall

Upgrade Plan of the
Experimental Hall

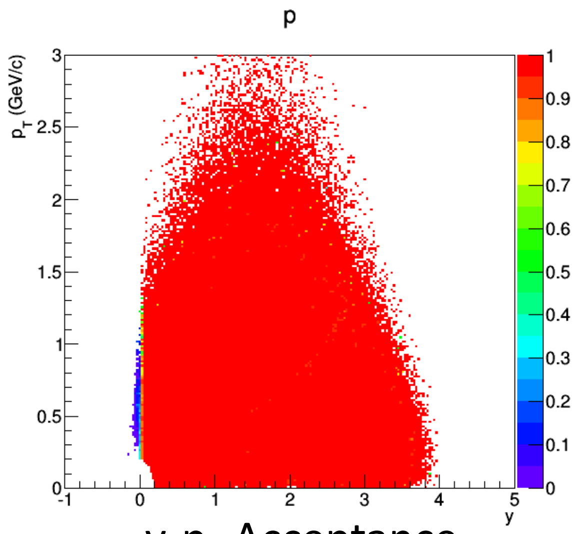
New Production target
& New beamlines



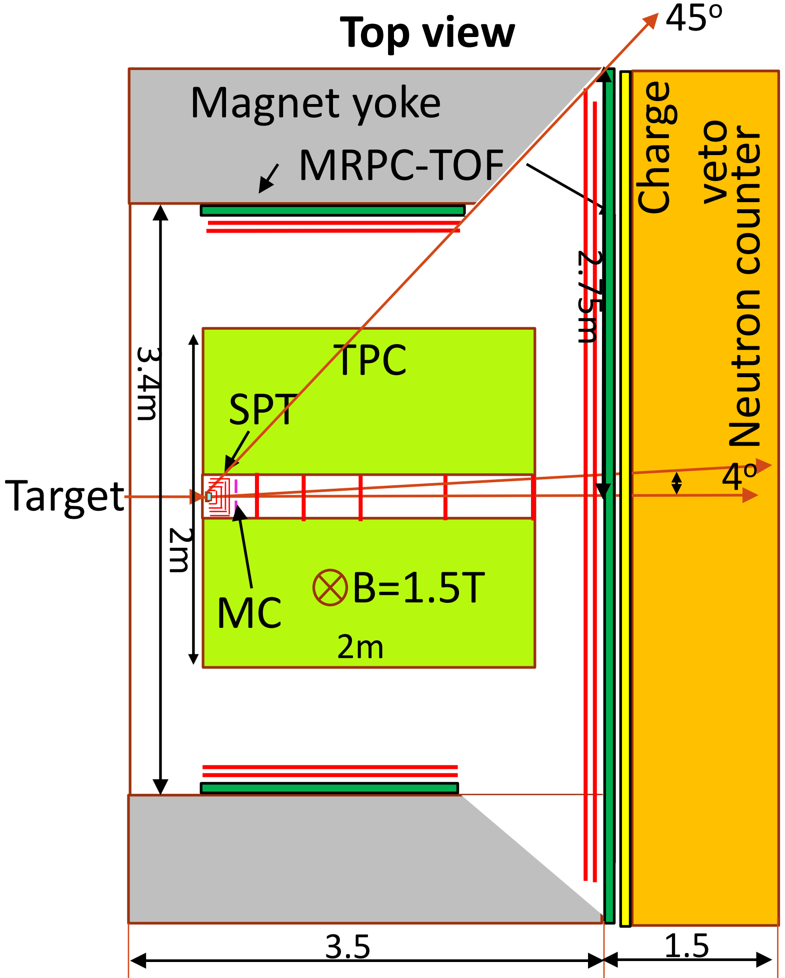
PHASE II: HADRON MEASUREMENTS

- Identified charged particles for ~4π acceptance
  - Silicon Pixel Tracker (SPT) ($\theta < 4^\circ$)
  - TPC ($\theta > 4^\circ$)
  - MRPC-TOF for particle identifications
- Trigger-less DAQ and high-rate counting

- Enhance the physics capabilities for rare events, fluctuations, higher order flows.



y-p_T Acceptance



Schematic view of Hadron spectrometer

134 members :

J-PARC-HI Collaboration

Experimental and Theoretical Nuclear Physicists and Accelerator Scientists

Experiment

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. Kim, 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

Theory

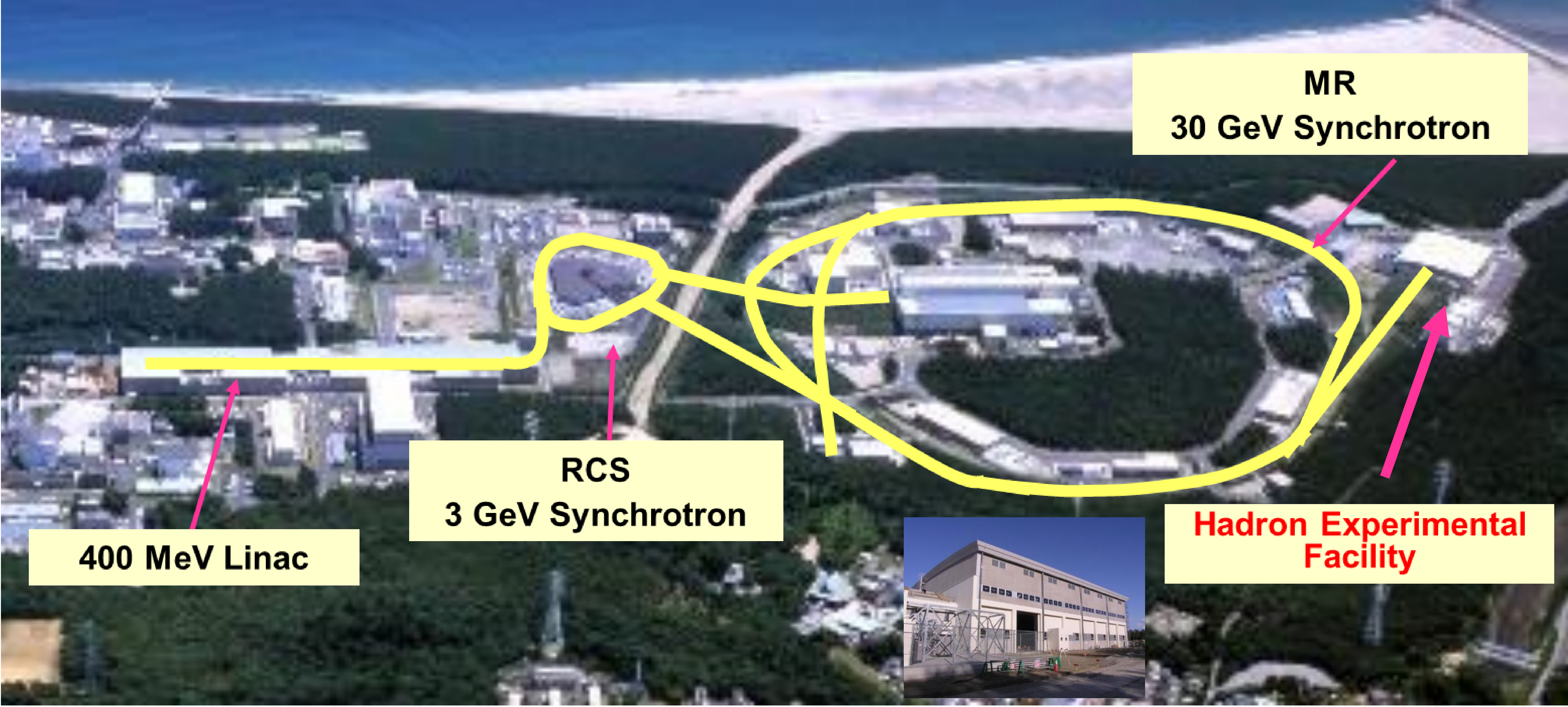
Y. Akamatsu, M. Asakawa, K. Fukushima, H. Fujii, T. Hatsuda, M. Harada, T. Hirano, K. Itakura, M. Kitazawa, T. Maruyama, K. Morita, K. Murase, A. Nakamura, Y. Nara, C. Nonaka, A. Ohnishi, M. Oka

Accelerator

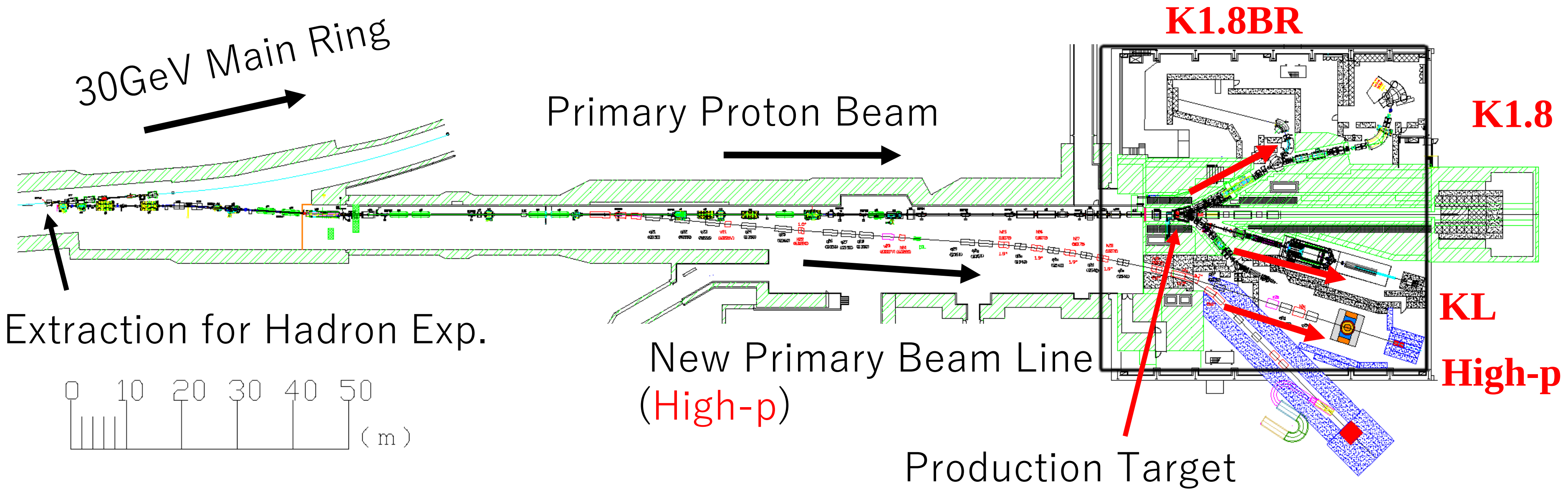
E. Chishiro, H. Harada, Y. Hashimoto, N. Hayashi, K. Hirano, H. Hotchi, K. Ishii, T. Ito, M. Kinsho, R. Kitamura, A. Kovalenko, J. Kamiya, N. Kikuzawa, T. Kimura, Y. Kondo, H. Kuboki, Y. Kurimoto, Y. Liu, S. Meigo, A. Miura, T. Miyao, T. Morishita, Y. Morita, K. Moriya, R. Muto, T. Nakanoya, K. Niki, 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

ASRC/JAEA, J-PARC/JAEA, J-PARC/KEK, Tokyo Inst. Tech, Hiroshima U, Osaka U, U Tsukuba, Tsukuba U Tech, CNS, U Tokyo, Tohoku U, Nagasaki IAS, Kyoto U, RIKEN, Akita International U, Nagoya U, Sophia U, U Tokyo, YITP/Kyoto U, Nara Women's U, KEK, BNL, Mainz U, GSI, Central China Normal U, Korea U, Chonbuk National U, Pusan National U, JINR, U Belgrade, Wigner RCP, KRF, Stony Brook U, Bhaba Atomic Research Centre, Far Eastern Federal U, Grenoble U

J-PARC (Japan Proton Accelerator Research Complex)



HADRON EXPERIMENTAL FACILITY



Name	Species	Energy	Intensity
K1.8	$\pi^{\pm}, K^{\pm}$	< 2.0 GeV/c	~10^5 Hz for K^+
K1.8BR	$\pi^{\pm}, K^{\pm}$	< 1.0 GeV/c	~ 10^4 Hz for K^+
KL	K_L	2.0 GeV/c (Ave.)	~ 10^7 Hz for K^0

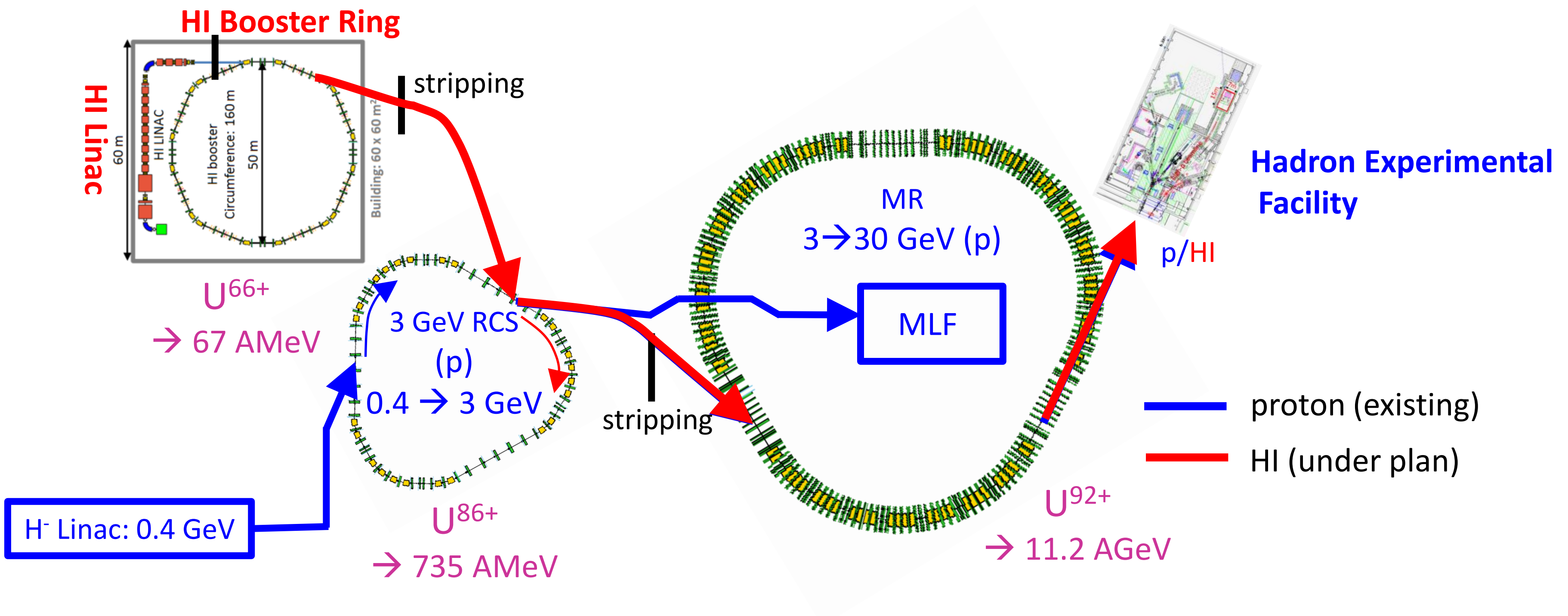
New Beamline

High-p	primary	30GeV	~ 10^{10} Hz
	Unseparated	< 20GeV/c	~ 10^8 Hz

HI ACCELERATION SCHEME AT J-PARC

Proton beam rate (slow extraction)
- 5.5×10^{13}/cycle (currently)
- 1.2×10^{14}/cycle (2022)

- HI beam rate ~10^{11} Hz
- E_{lab} (U) = 1-12 AGeV
- $\sqrt{s_{NN}}$ (U) = 1.9-4.9 GeV



MINIMUM UPGRADES (ACC. PART)

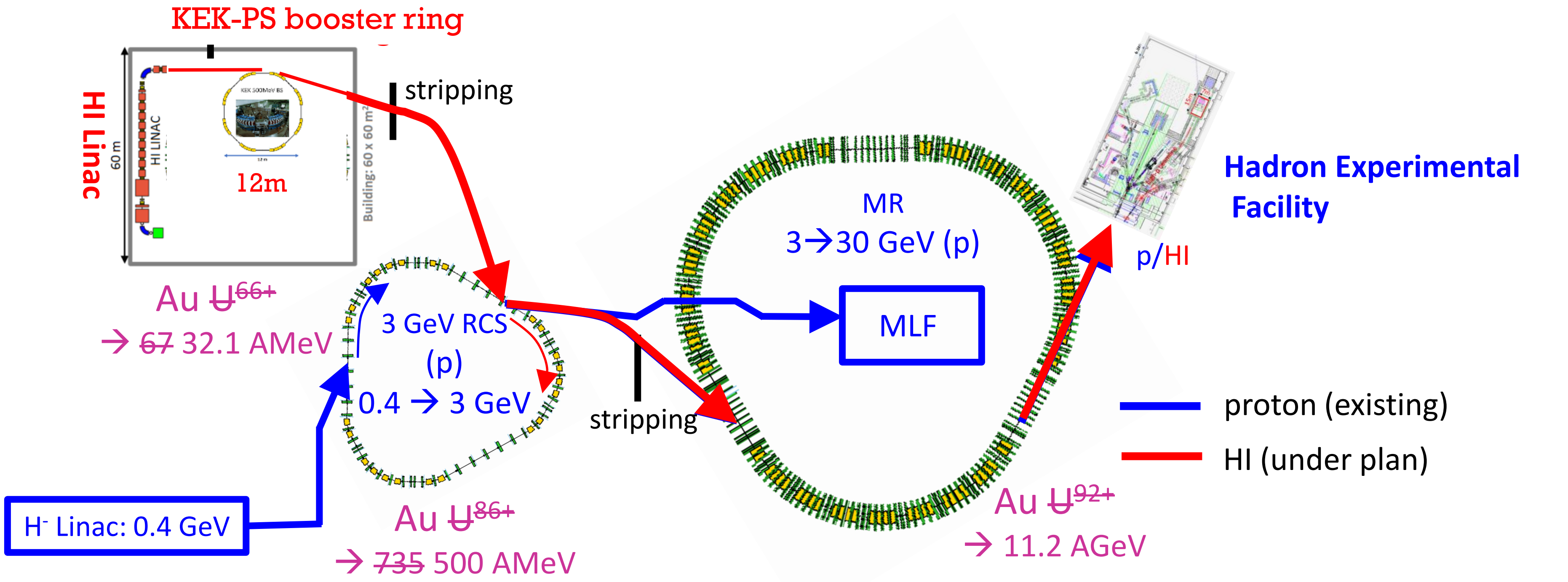
Heavy Ion LINAC

- Budget request as a low energy heavy ion project
- Reuse of cavities which is used at JAEA Tandem

Booster

- Reuse of KEK-PS Booster Ring (KEK-BS)

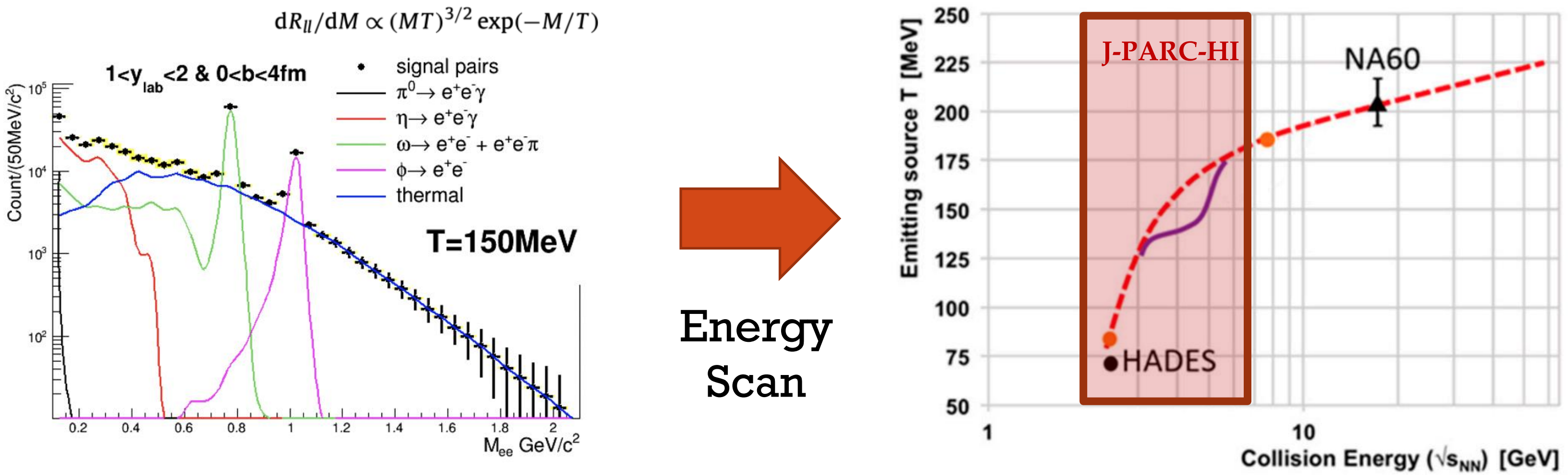
- HI beam rate $\sim 10^{\cancel{11}8}$ Hz
- E_{lab} (U) = 1-12 AGeV
- $\sqrt{s_{NN}}$ (U) = 1.9-4.9 GeV



Intensity is limited by KEK-BS, which is a small ring and no flexible optics. Space charge effect is at a negligible level because the beam intensity is 10^{-3} lower than that of proton beam at present.

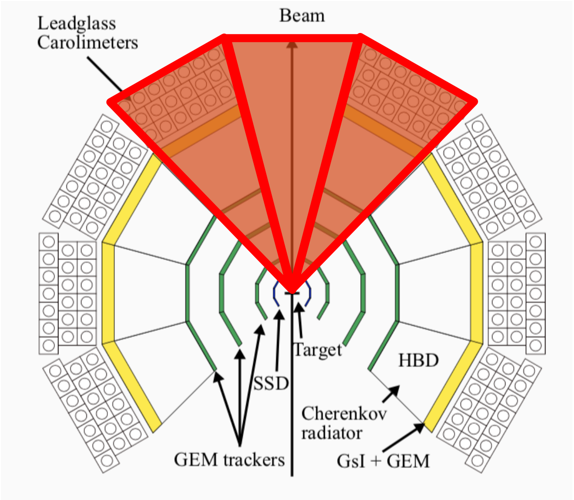
EXPERIMENT W EXISTING E+E- SPECTROMETER

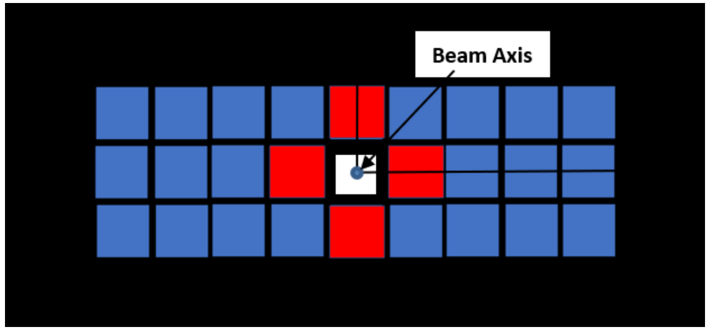
- Dielectron measurements in heavy-ion collisions at J-PARC with E16 upgrade
  - 10^8 beam/spill, IR rate ~ 50 kHz with 0.035 mm Au target (~0.1% int. length)
- Experimental area will be used as it is
- First Proposal is submitted to J-PARC Program Advisory Committee in this July
  - Temperature and yield measurements of di-electrons above M_{ee} > 1 GeV
    - Search for a (onset of) partonic matter
    - "Caloric curve" to map out the phase diagram below $\sqrt{s_{NN}}$ < 10 GeV



REQUIRED UPGRADES OF THE SPECTROMETER

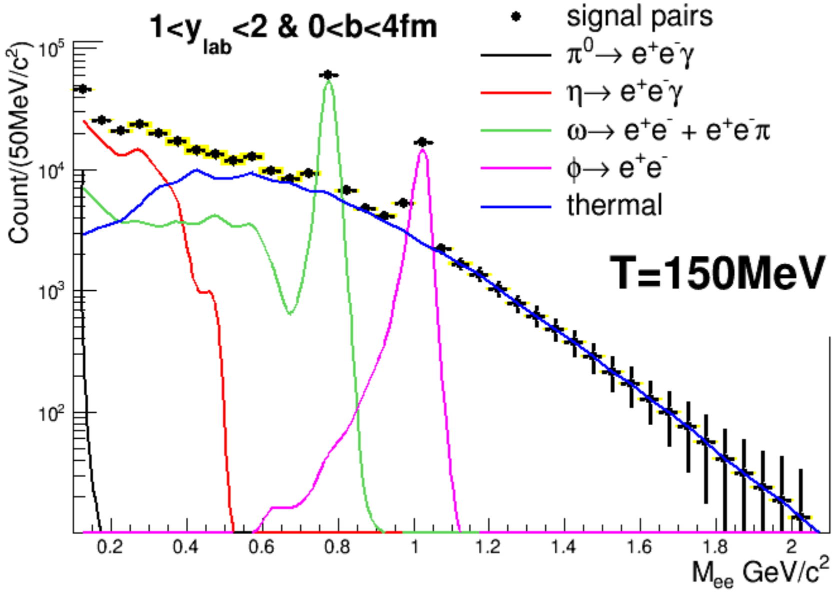
- The most forward modules should be upgraded to cope with a high hit-multiplicity environment
  - Hit occupancy should be reduced and finer segments are required
- Tracking device
  - The most inner GEM Trackers must be upgraded and replaced with SSDs
- Electron identification detectors
  - Lead glass calorimeter must be upgraded to finer segmented detectors
    - Lead Tangsten (PWO_4 is a candidate)
- Zero degree calorimeter
  - New detector for a centrality determination
- Readout and DAQ system
  - Current system assume 1 kHz event trigger
  - New system should be run at 50kHz interactions

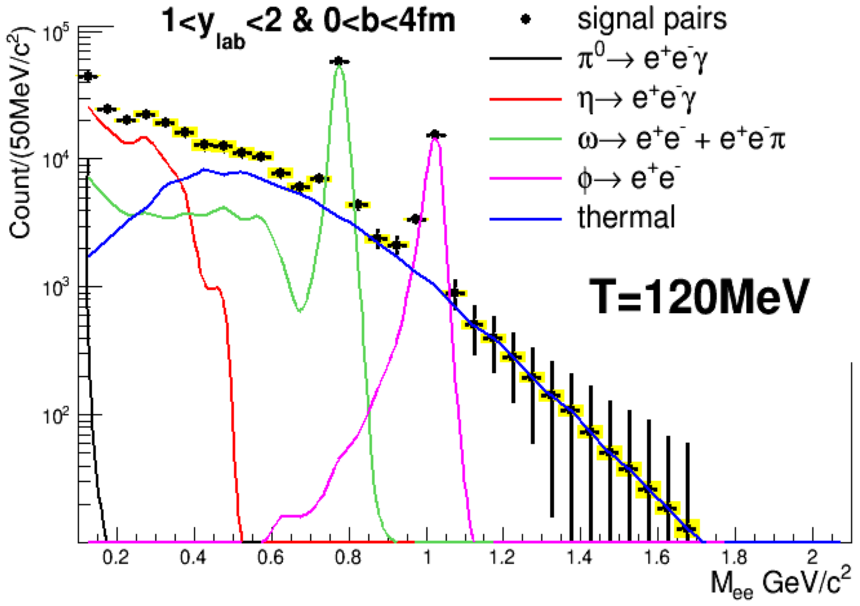




EXPECTED MASS DISTRIBUTIONS

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





- ~ 6% accuracy of T can be expected from M_{ee}>1.1GeV/c^2 in the case of 150 MeV
- ~10% accuracy of T can be expected from M_{ee}>0.9GeV/c^2 in the case of 120 MeV
- ~20% accuracy of integrated excess yield (0.4<M_{ee}<0.7GeV/c^2)
  (sys error from the known resonances is dominated)

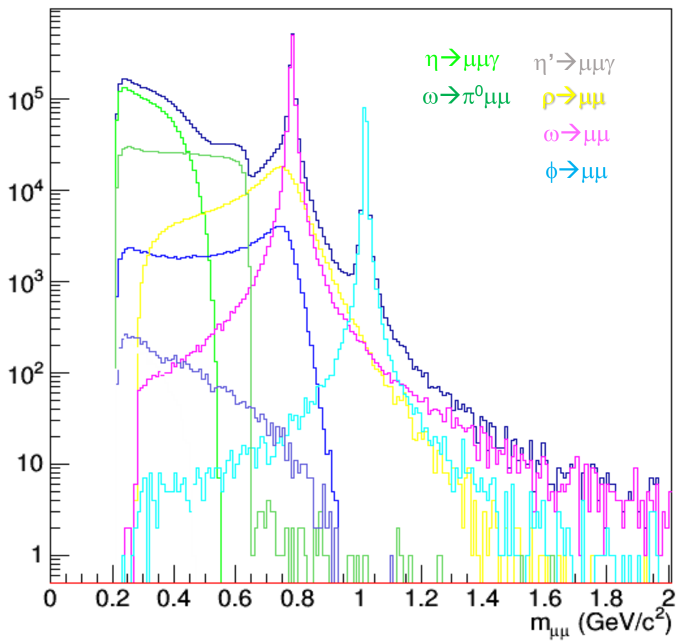
EXPECTED DIMUON SPECTRUM

We have evaluated performance of our dimuon spectrometer

- Embed $\mu^+\mu^-$ into JAM events and process by GEANT
  - U+U, $\sqrt{s_{NN}}$=4.5 GeV, Min. bias JAM events
- Reconstruct tracks passing through 4 λ_I muon absorbers

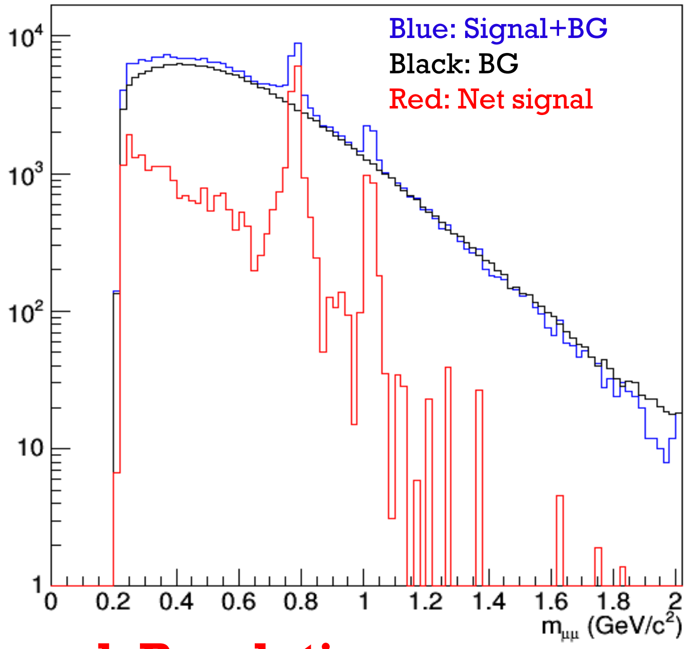
θ_{ee}>2°, 2°<θ<80°, p_T>0.1GeV/c

Generated cocktail



U+U $\sqrt{s_{NN}}$=4.5 GeV, Min-bias (54k)

Reconstructed spectrum



Enough Resolution even in low mass region

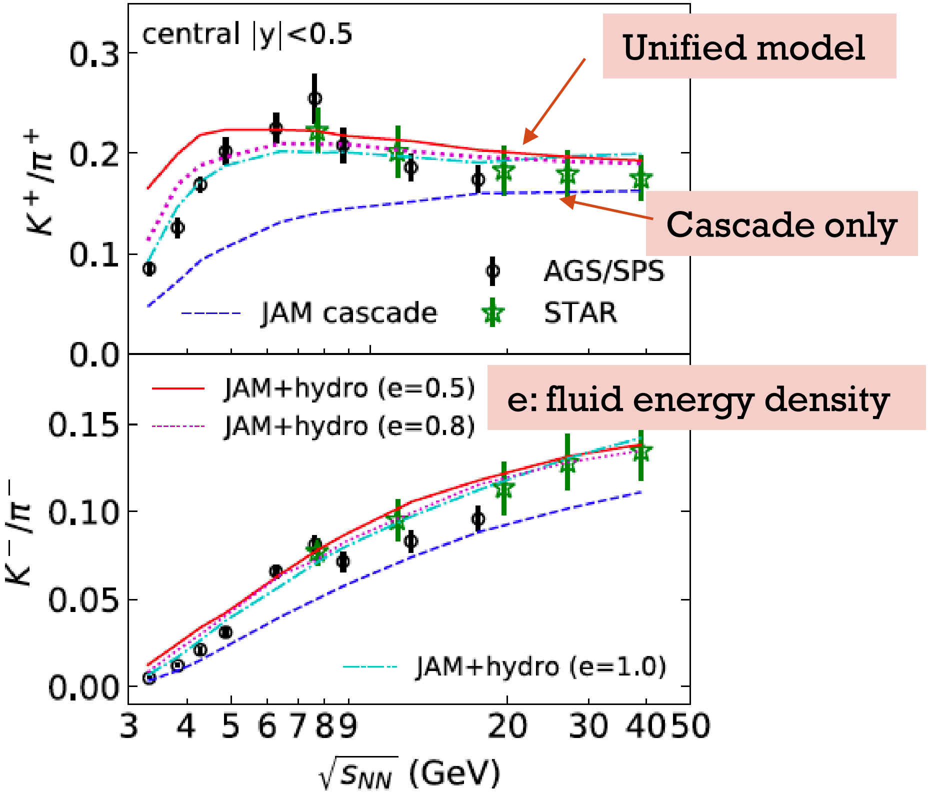
DEVELOPMENTS OF FURTHER OBSERVABLES

Calculations for thermalized phase are being developed by a collaboration of theoretical groups

Example: A Japanese group develops an "unified" hydro-cascade model

- Simultaneously evolve both fluid element and hadrons in time
  - High density hadrons → "parton fluid"
  - Cooled "parton fluid" → hadrons
- Unified model describes data well, while cascade only doesn't
  - It seems we can expect parton fluid phase even at the J-PARC energy

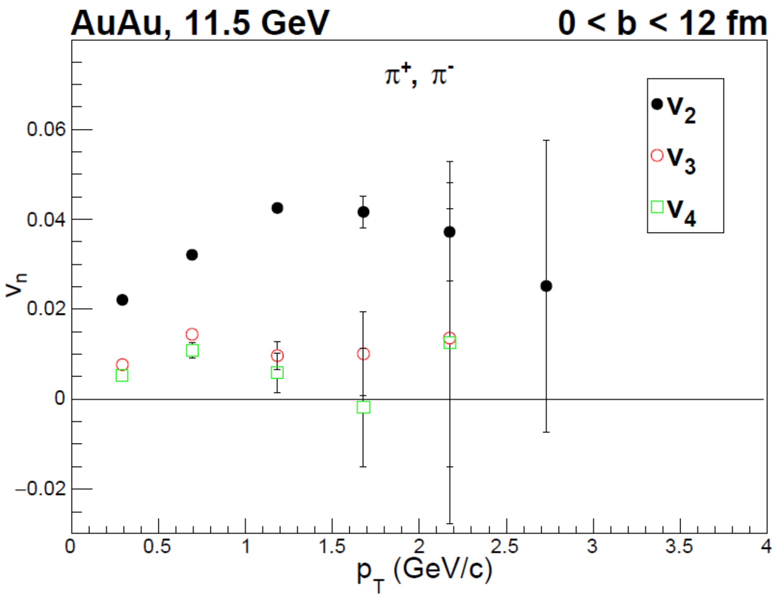
Akamatsu, et.al, PRC**98**, 024909 (2018)



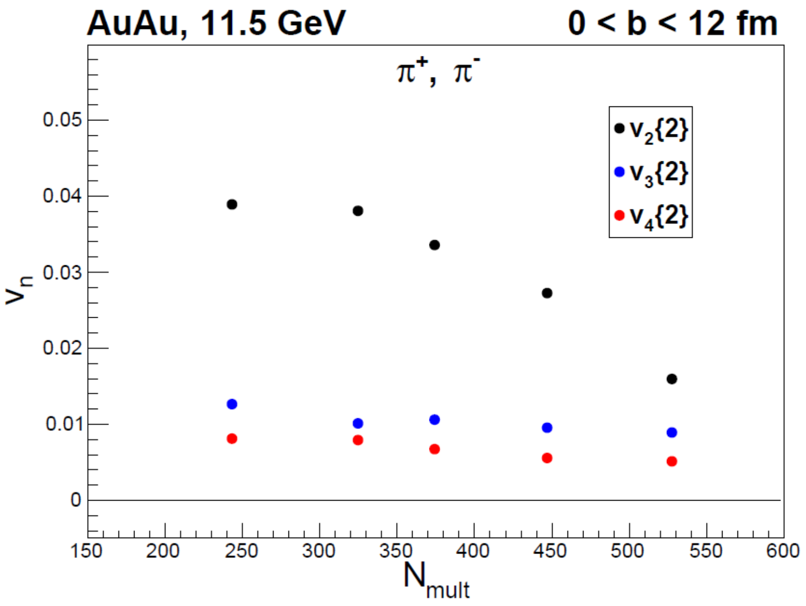
FLOW MEASUREMENTS

- Using the developed model, significance of flow measurements are evaluated
  - Au+Au events of hydro + JAM cascade model (JAM-1.9043)
  - Higher-order flow can be measured for study of "fluid" properties of generated medium

Higher-order harmonics
with 2-particles correlation (4.5 M events)

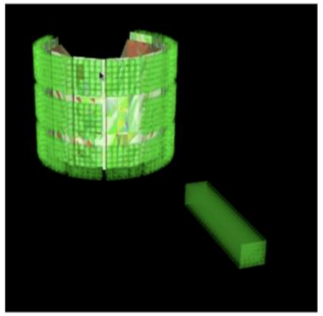


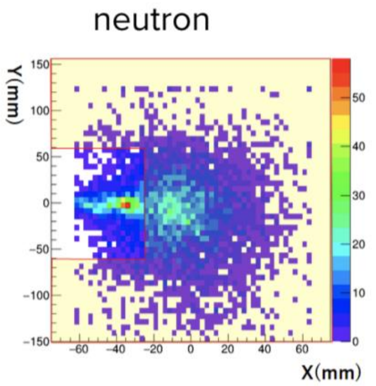
Higher-order harmonics
with Cumulants (54M events)

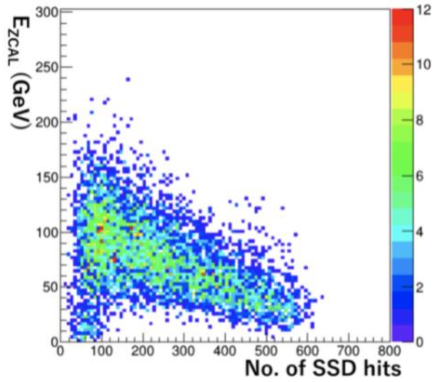


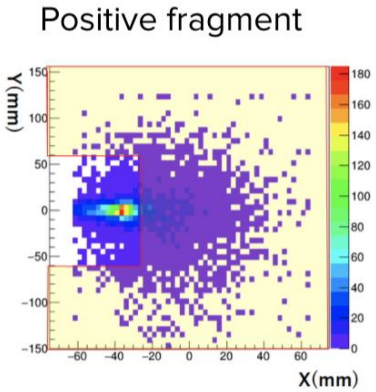
E16 UPGRADE: ZERO DEGREE CALORIMETER

- Centrality is defined with the number of SSD hits and the energy deposit at zero-degree calorimeter (ZCAL)
- **ZCAL**
  - Located at 4.5m downstream from the target (just in front of the beam dump)
  - Dimension: 15cm(x)x30cm(y)x50cm(z)
  - $4.0\lambda_I/11.3X_0$ Tungsten-MPPA fiber sampling calorimeter (based on RHIC ZDC)
  - Acceptance to avoid positive fragments and beam but detect neutrons



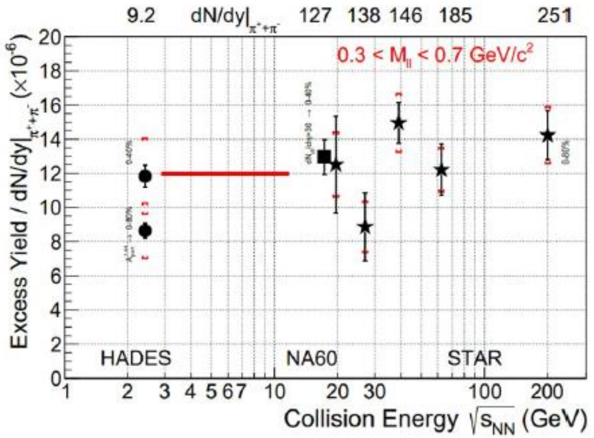






FEASIBILITY STUDIES : INPUTS

- Thermal dielectrons



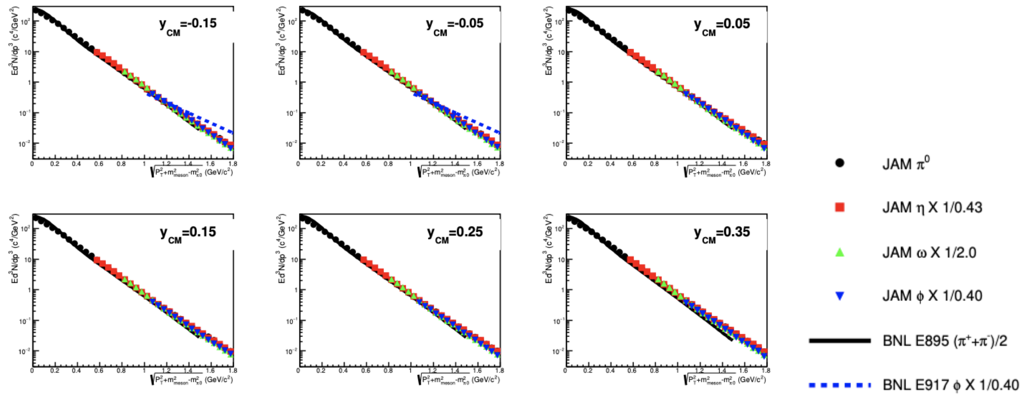
- dN_{ee}/dy ($0.3<M_{ee}<0.7$ GeV/c^2) = 1.2×10^{-5} x $dN_{\pi+-}/dy$ (105)
- $dN_{ee}/dM \propto (MT)^{3/2}\exp(-M/T)$
- $dN_{ee}/dPt \propto \exp(-Pt/T)$

Two cases studied

- T = 150MeV (cross-over transition)
- T = 120MeV (1st order phase transition)

Dielectrons from hadronic decays

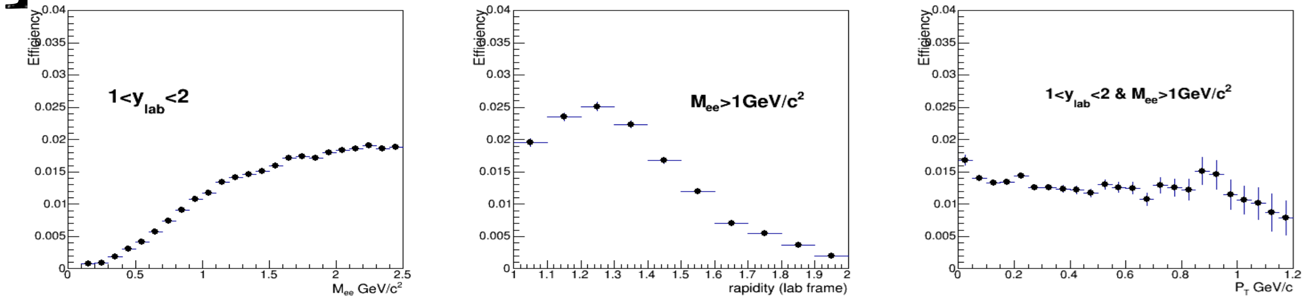
JAM event generator for Au+Au at 10 A GeV/c



- Dielectron pairs are transported into GEANT4 simulation
- Full E16 acceptance & E16 achieved eID capability considered
- Tracking inefficiency due to high multiplicity effects taken into account

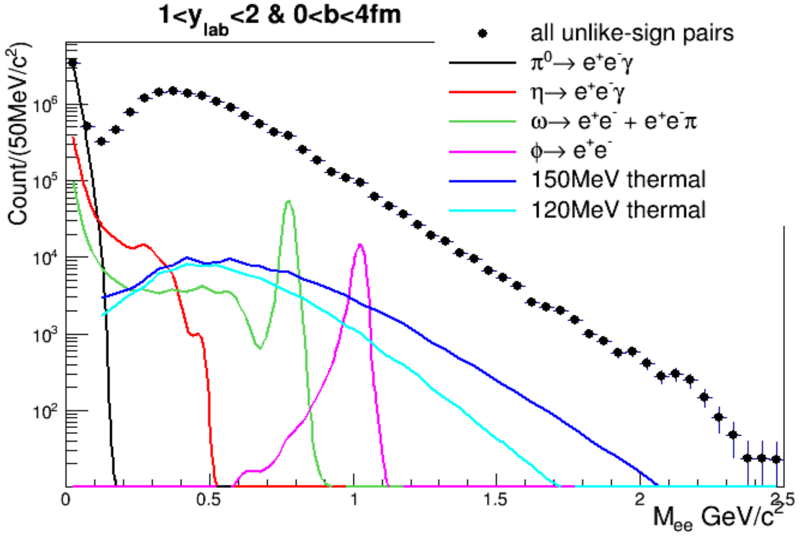
EFFICIENCIES AND RAW MASS DITRIBUTIONS

- Pair Efficiencies
  - Multiplicity effects not included

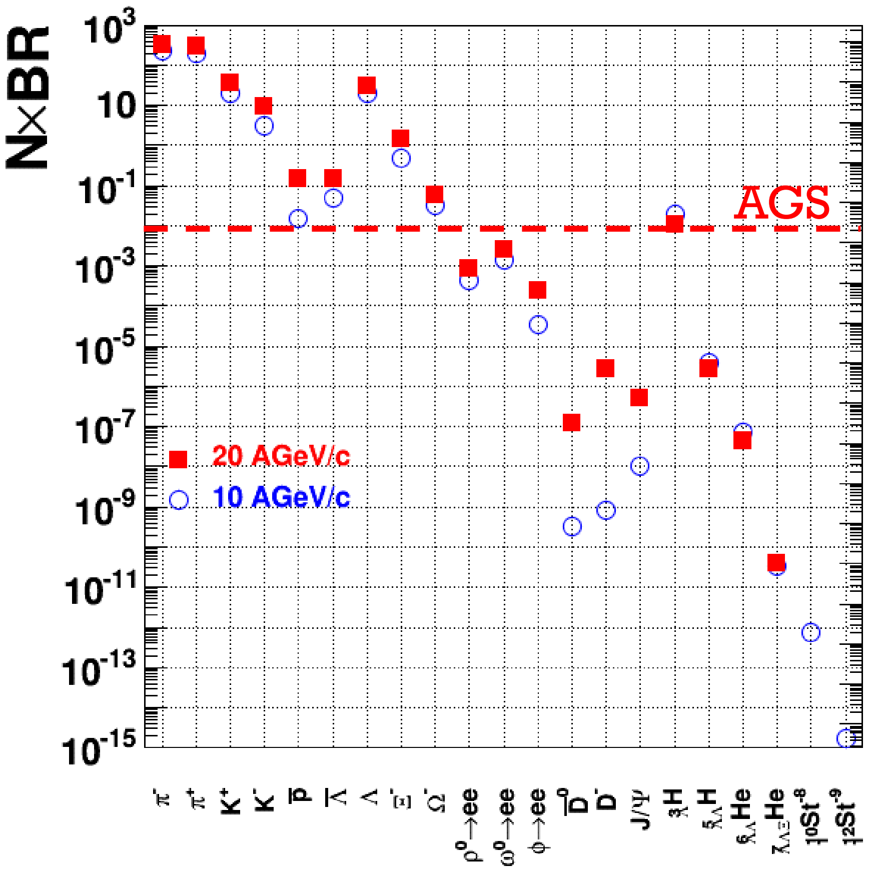


- Raw Mass Distributions
  - Thermal photons
  - known resonance decay $\pi^0 \rightarrow ee\gamma$, $\eta \rightarrow ee\gamma$, etc..
  - γ conversion in the target
  - miss ID π^{+-}
  - Combinatorial pairs

1x10^8/spill 10 AGeV Au beam x 100 days run
0.035 mm Au target(∼0.1% int. length)



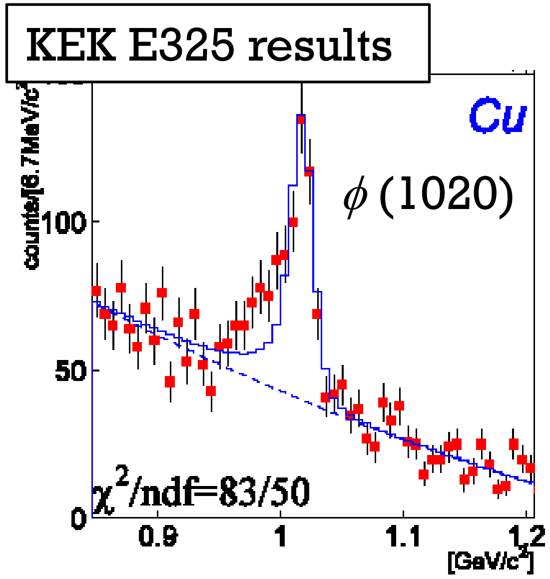
PRODUCTION RATE



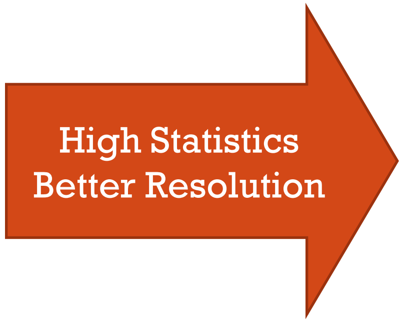
HSD calculations in FAIR Baseline Technical Report (Mar 2006)
A. Andronic, PLB697 (2011) 203
P. Braun-Munzinger J.Phys.G21 (1995)L17

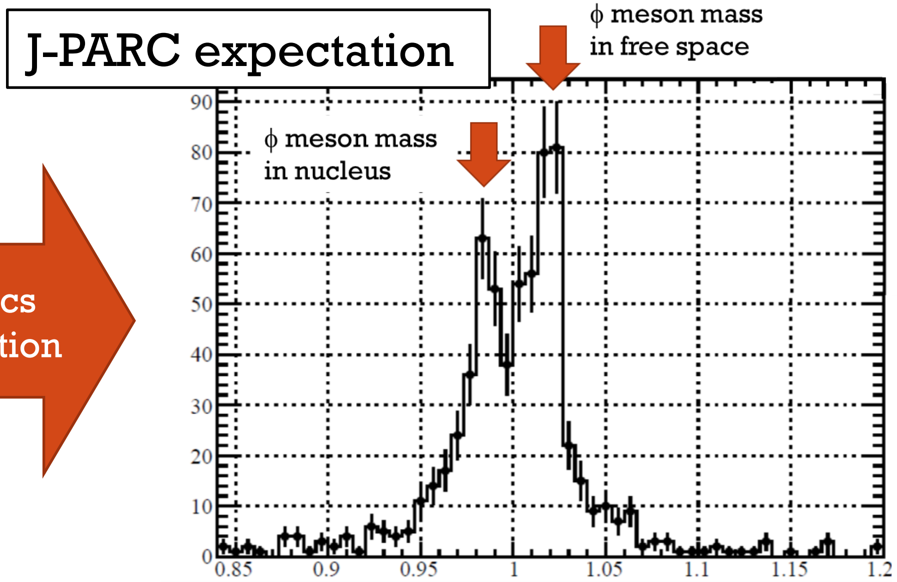
VECTOR MESONS IN NUCLEUS

- Spectral changes of vector mesons in QCD medium provide crucial information on the non-trivial structure of QCD medium
  - Spontaneously broken chiral symmetry and its (partial) restoration in a finite density matter.
  - Upgrades of the KEK-PS E325 experiment



e^+e^- invariant mass

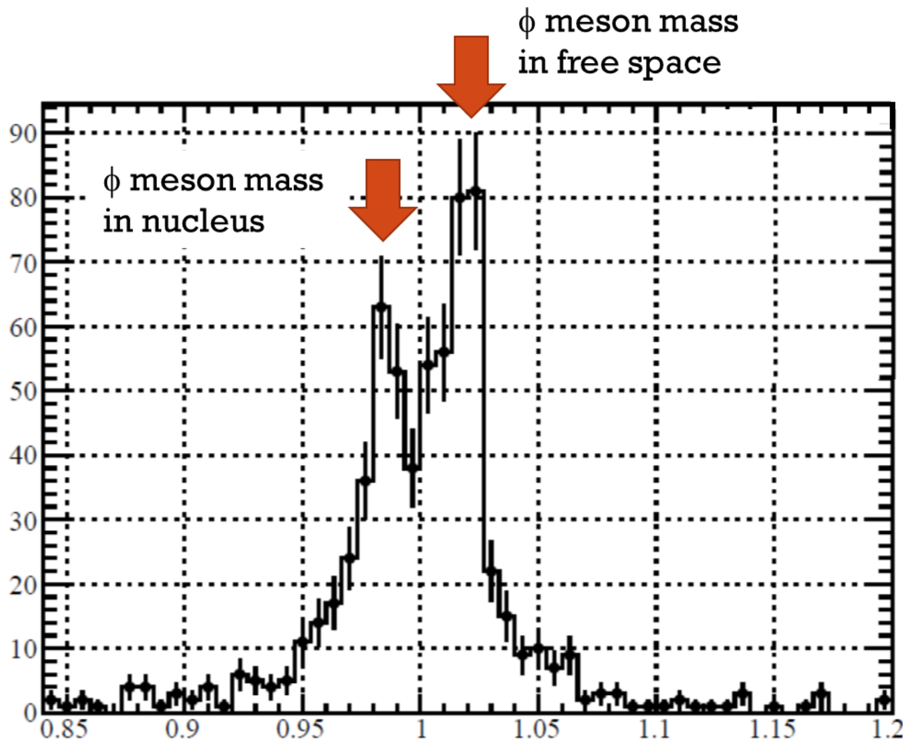




e^+e^- invariant mass [GeV/c^2]

EXPECTED RESULTS FOR THE FIRST EXP.

- Measurements of changes of hadron properties in a nucleus
    - Hadron mass can be changed in a finite density due to a partial restoration of chiral symmetry
- Same effects are expected in a high energy heavy ion collisions
- Much clear measurements can be done in a nucleus

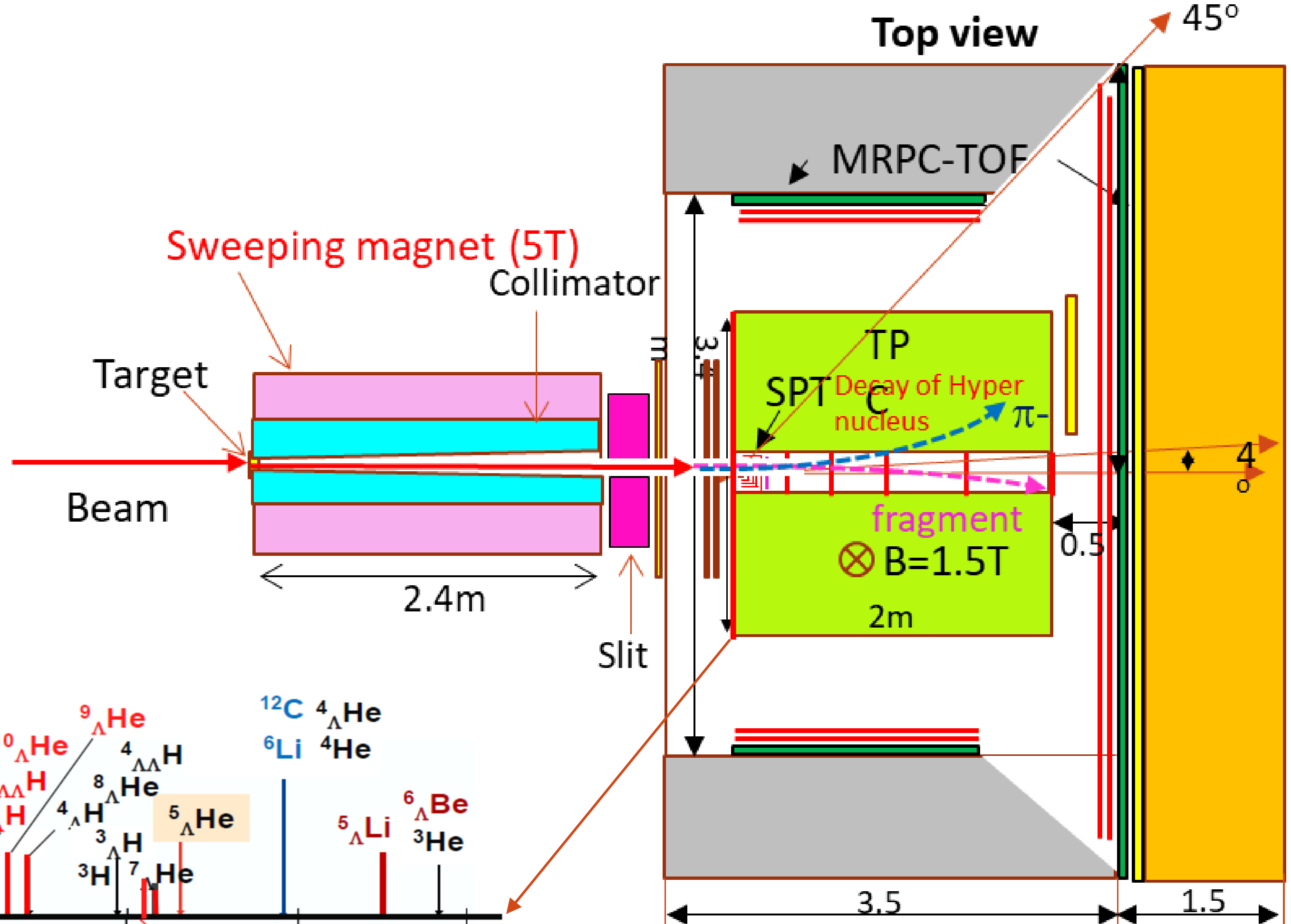


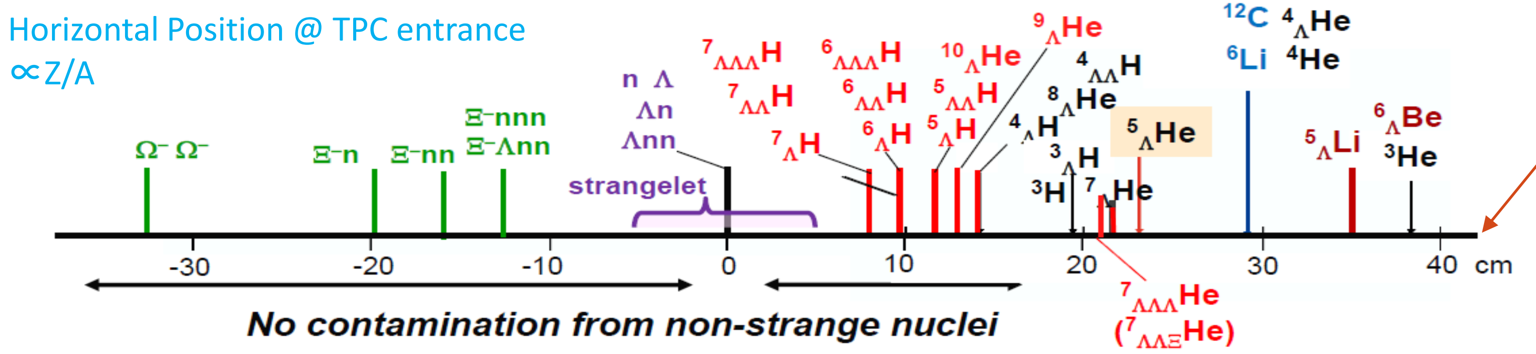
e^+e^- **invariant mass** [GeV/c^2]

Expected Mass spectrum

HYPER-NUCLEI SPECTROMETER

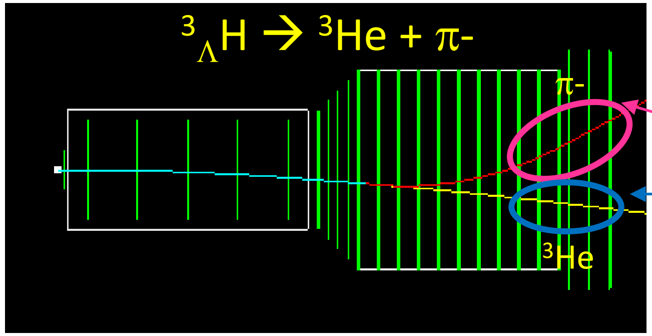
- Closed geometry : Sweeping magnet and Collimator
  - Limit the acceptance to beam rapidity
  - Only beam and fragments can reach 2nd dipole magnet
  - Interaction Rate : ~100 MHz
- Lifetime and Magnetic moment of hypernuclei
- Search for new hypernuclei and strangelet





Schematic view of Hyper-nuclei spectrometer

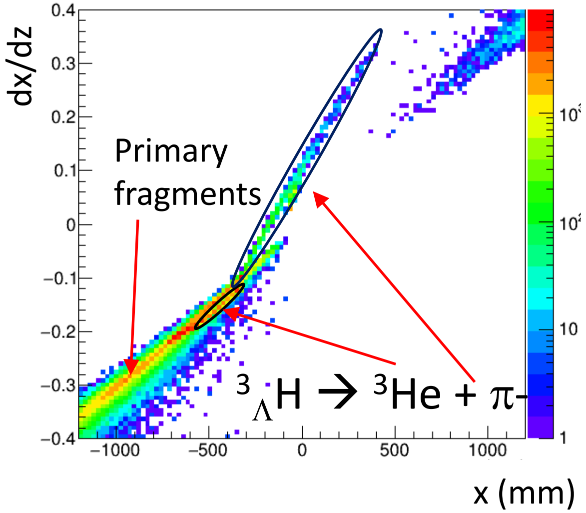
AN EXAMPLE OF EXPECTED RESULT: $^{3}_{\Lambda}\mathrm{H}$



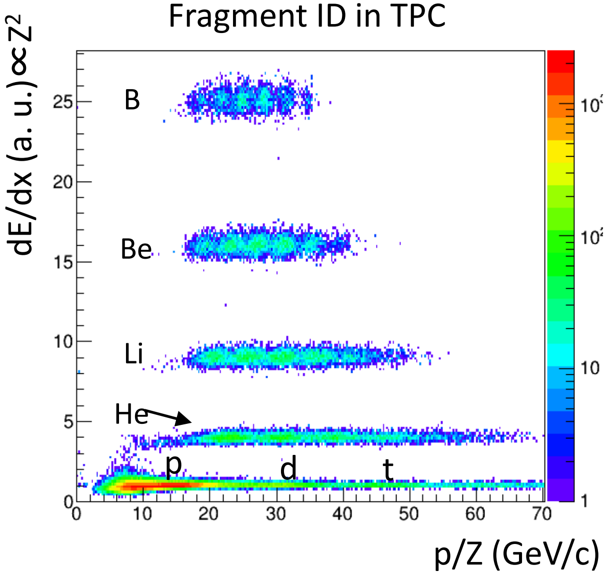
$^{3}_{\Lambda}$H embedded in JAM C+C events

1. Tag π- with the track angle and position
2. Identify fragment by Z and p/Z
3. Invariant mass of (π-, fragment) pair

Horizontal position vs angle



Fragment ID in TPC



Reconstructed π- ^{3}He invariant mass