

A Japanese perspective

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University of Tsukuba

RHIC & AGS Users' Group Open Forum Meeting
(Planning Perspectives for the Long Range Plan)

October 9, 2014





Science Council of Japan

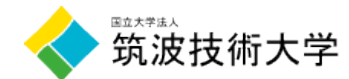
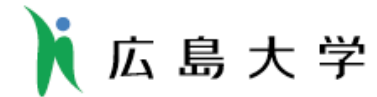
“ 22nd Master plan”

- March 2014, adapted our proposal for as a large scale research project by Science Council of Japan.
- [Project title] Exploring Quark–Gluon–Plasma with new phase of high–energy heavy–ion experiments
- [Project summary] “We conduct experiments in high–energy heavy ion collisions (RHIC–PHENIX and LHC–ALICE) under the international collaborations, and explore the science of a new phase of matter, Quark Gluon Plasma (QGP), which is believed to exist right after the Big Bang of the universe.”
- [Project duration] 2014 to 2019: PHENIX/ ALICE experiments detector upgrades, 2014 to 2023: Study on QGP.

Japanese institutes, members

(high energy heavy ion, experimental physics)

- Hiroshima U. (T. Sugitate, K. Shigaki, K. Homma)
- RIKEN (Y. Akiba, Y. Goto, H. Enyo, S. Yokkaichi)
- U. Tokyo CNS (H. Hamagaki, T. Gunji, Y. Watanabe)
- U. Tsukuba (Y. Miake, S. Esumi, T. Chujo, H. Masui)
- Tsukuba U. of Tech. (M. Inaba)
- Nagasaki Inst. of Applied Science (K. Oyama)
- JAEA (H. Sako et al.)
- KEK (K. Ozawa et al.)



Questions to be answered in next decade

- QGP properties (viscosity and transport coeff.) and their temperature dependence.
- QGP medium response
- hadron mass and chiral symmetry restoration
- Initial condition, mechanism of early thermalization of QGP
- QCD phase structure

Key measurements

(1) Jets, direct photons


(2) Higher harmonics (hadron, photon, light / heavy quark)

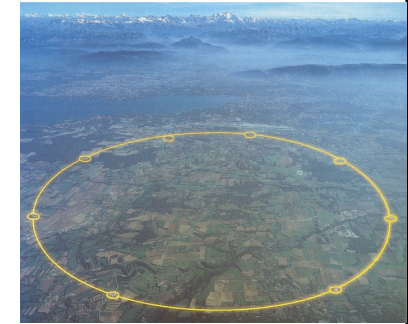
(3) Lepton pair measurements



high rate
readout &
high p_T
observables

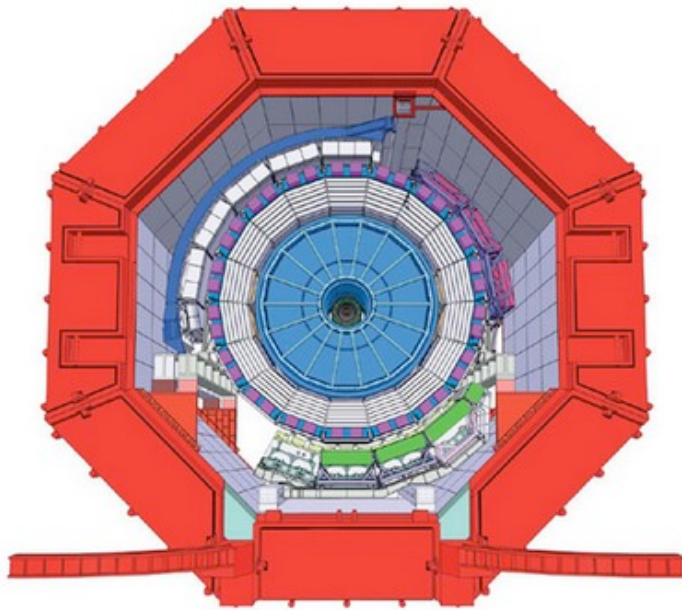
LHC run plan

- **2013.02 - 2014:**
 - LHC Long Shutdown 1 (LS1)  **Right now**
 - **ALICE upgrade: DCAL EMCal**, TRD installation
- **2015, 2016, 2017:**
 - Physics run @ $\sqrt{s_{NN}} = 5.1$ TeV in Pb-Pb, 13 TeV in p-p
- **2018:**
 - LHC Long Shutdown 2 (LS2)
 - Detector upgrade for high luminosity LHC
 - **ALICE upgrade:** Silicon upgrade, **GEM-TPC installation**
- **2019, 2020, 2021, 2022:**
 - High luminosity LHC (p-p, Pb-Pb each year)
 - **50kHz Pb-Pb, x 100 statistics**
 - **ALICE upgrade: FOCAL** direct photon detector (under consideration)

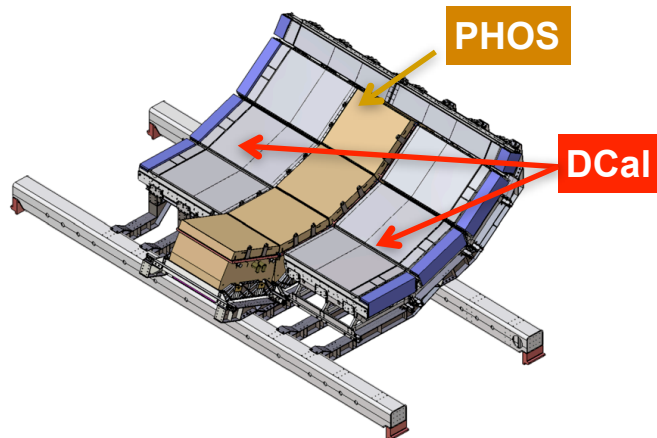


ALICE Dijet Calorimeter (= DCal)

Tsukuba



- solenoid magnet (surrounds)
- ITS (small ring, centre)
- TPC ("spoked wheel")
- TRD ("stripes")
- TOF
- DCAL
- EMCAL
- HMPID

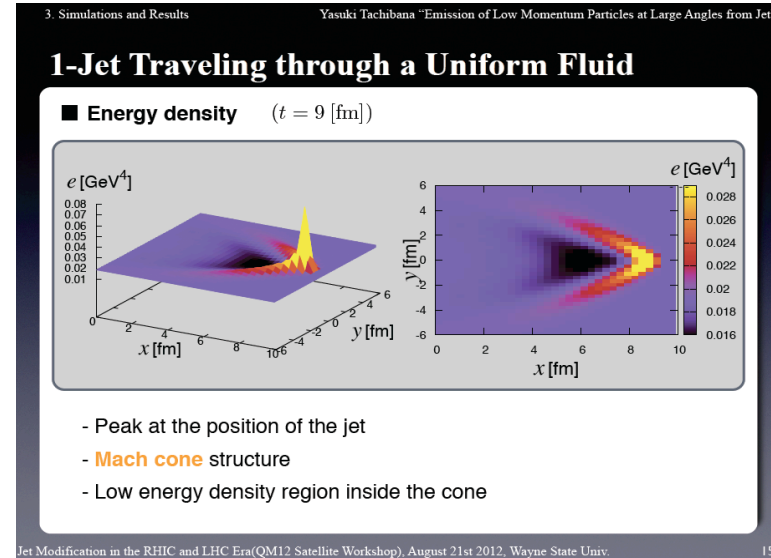
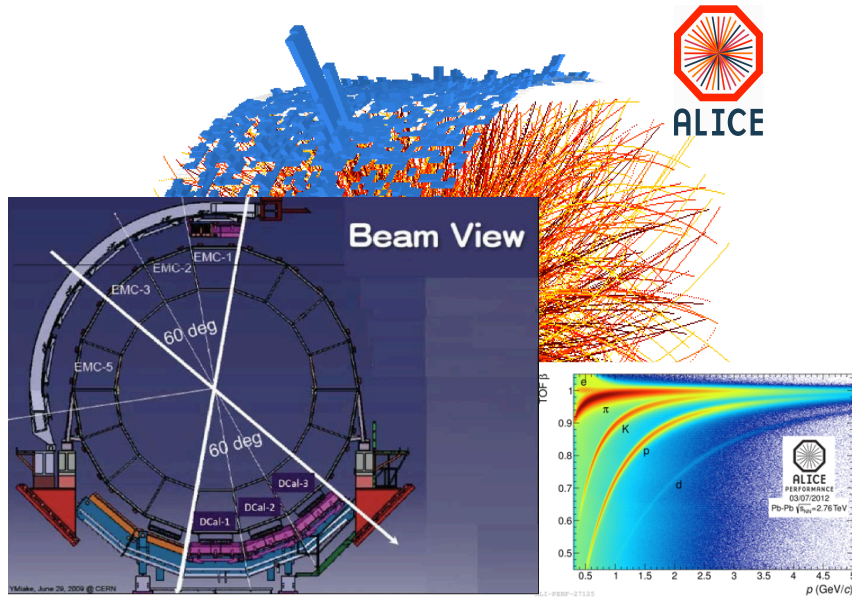


- Full jet reconstruction.
 - $R = 0.4$, $p_T \sim 150$ GeV/c
 - gamma, jet L1 trigger, improve di-jet efficiency, study on medium response w/ jet



DCal supper module (2013.09 @ CERN)

Medium response with jets by DCAL



3+1 hydro + jet (Tachibana, Hirano) QM2012

- ALICE hadron PID capability (0.15 – 20 GeV/c) with photon and jets (jet axis)
 - Jet medium response with low p_T particles
 - QGP bulk (PID spectra, v_n , HBT) and di-jet energy balance
 - di-jet, γ -jet, h-jet, ...
- Access to QGP properties: c_s , EOS (possibility of gluon shock wave)
- Needed high rate TPC, since it needs correlation measurements with charged particles

ALICE upgrade (after LS-2, 2018-)

ALICE upgrade; high rate capability

- ✓ GEM-TPC continuous high rate readout (Tokyo CNS)
- ✓ PHOS high rate readout (Hiroshima)
- ✓ ITS Silicon high rate readout
- ✓ DAQ (Nagasaki [plan])



ALICE

Tokyo CNS
Hiroshima
Nagasaki

For LHC high luminosity upgrade, Pb-Pb @50kHz
Record all MB events, x100 statistics
(Unique capability in ALICE)

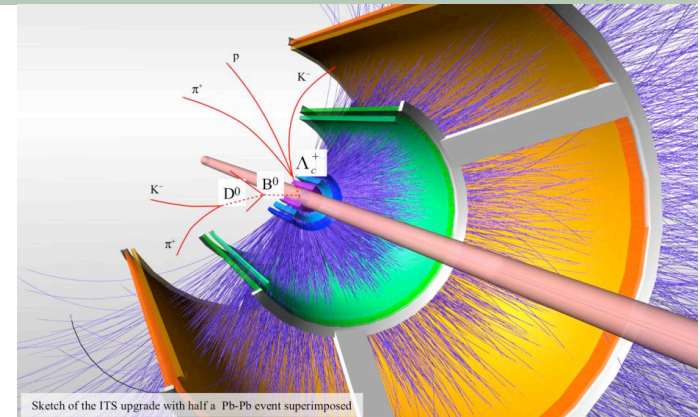
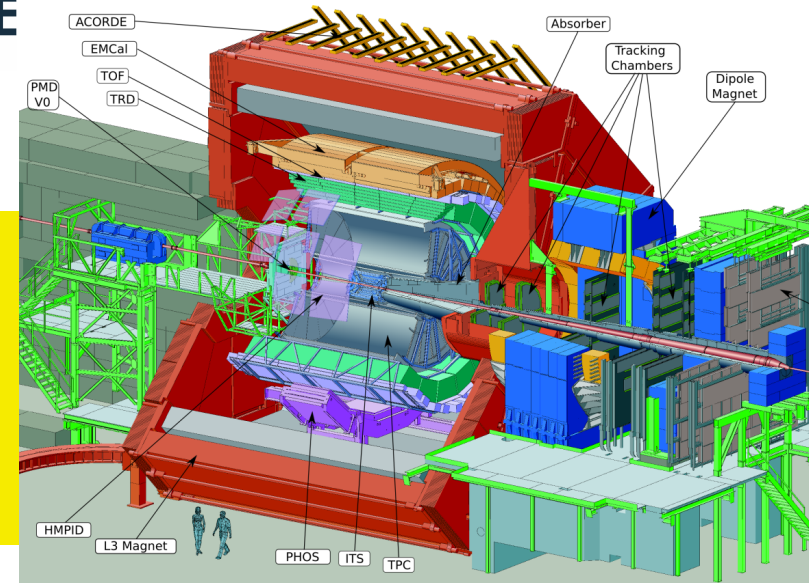
→ Access to high precision measurements and rare probes

Physics Goals:

Measure

- heavy quarks, photons, lepton pairs azimuthal anisotropy,
- Jet w/ PID hadron simultaneously

→ QGP medium response, heavy quark and strongly coupling system (thermalization, strength of coupling)



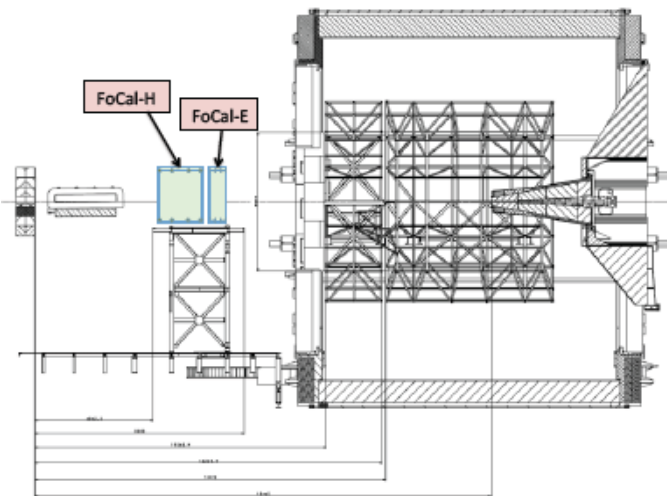
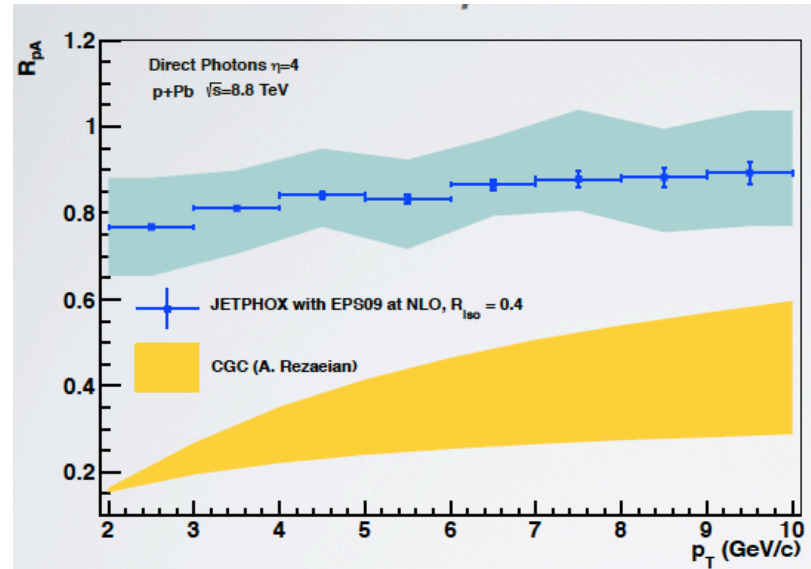
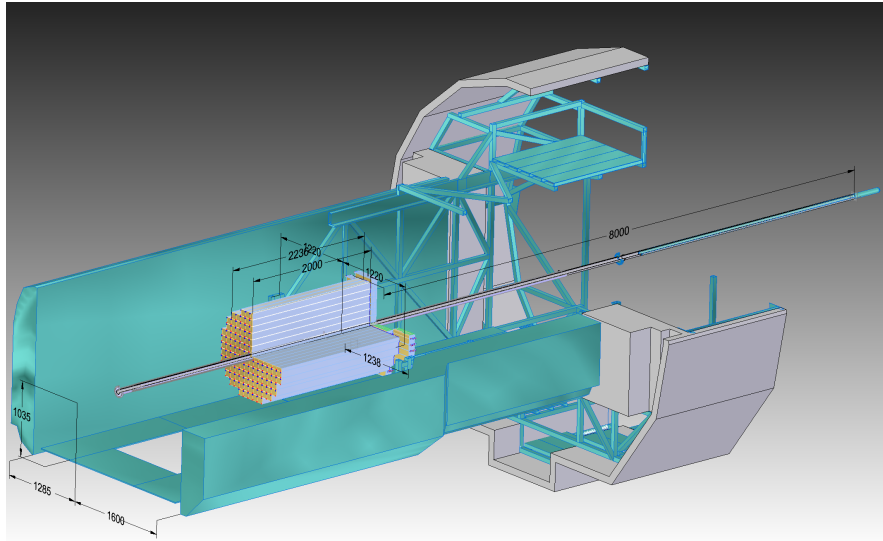
FOCAL

Tsukuba
Tokyo CNS

Direct photon R_{pA} ($\eta = 4$)

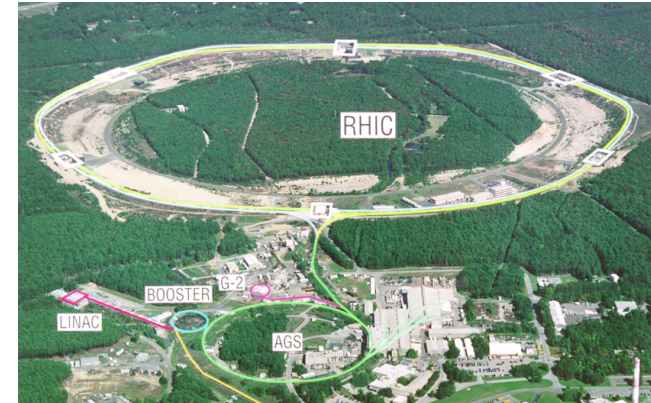
CGC vs. normal nuclear effects

linear evolution, shadowing



- cover $\eta = 3-5$ for direct photon measurements (Tsukuba, Tokyo CNS)
- EM + hadron Cal.
- Under consideration as ALICE upgrade plan
- **Goal:** CGC, determination of initial condition, early thermalization of QGP.

RHIC run plan



- 2014 (Au+Au 200 GeV with F/VTX),
- 2015 (p-Au, p-Si, p-Cu, p-p, d-Au, $^3\text{He}+\text{Au}$ @ 200 GeV with MPC-EX),
- 2016 (high statistics A+A):
- 2017 (shutdown, BES-II Luminosity upgrade)
- 2018 - 2019 (**BES-II**), **5-20 GeV Au+Au**
- 2020 (shutdown, eRHIC construction start, sPHENIX construction)
- 2021, 2022: **sPHENIX physics run**
- **Long 200 GeV Au-Au, with sPHENIX, p-p, d-Au 200 GeV**
- 2023, 2024 (shutdown, **eRHIC/ ePHENIX** construction)

sPHENIX

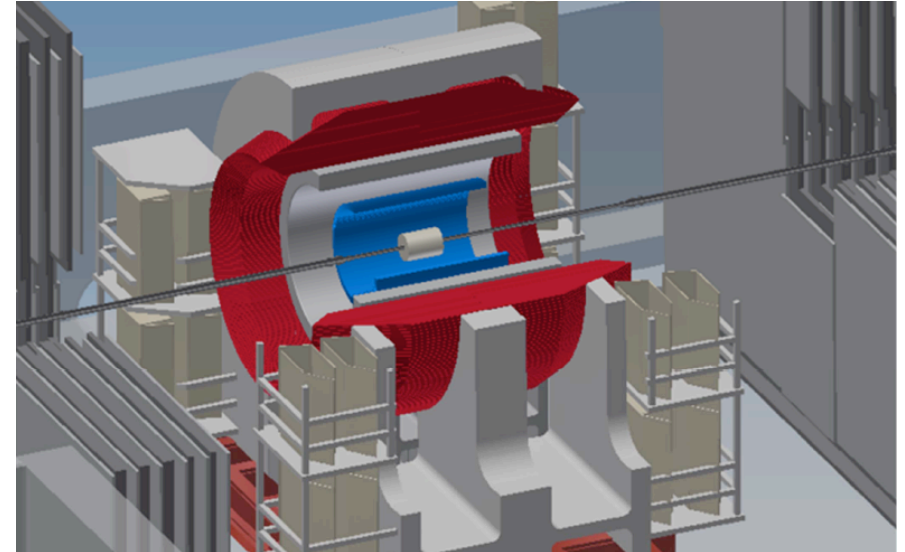
RIKEN
Hiroshima

Japanese contributions to sPHENIX

- ✓ Silicon tracer (RIKEN)
- ✓ Pre-shower (Hiroshima)

Jet, heavy quark measurements:

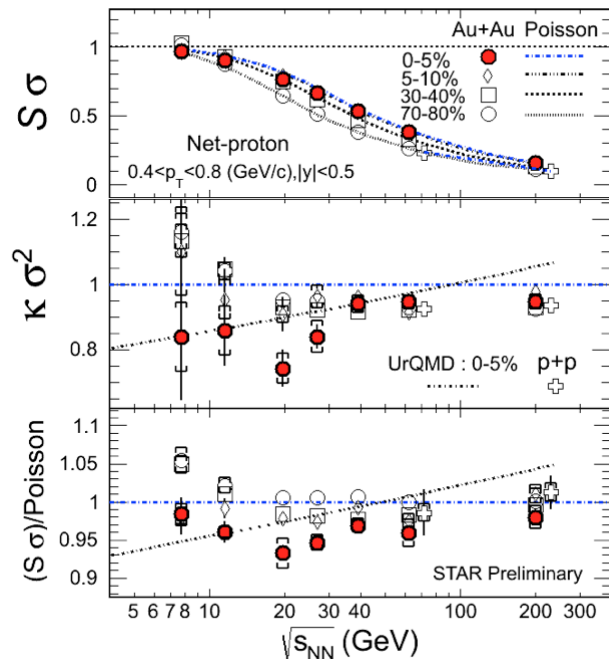
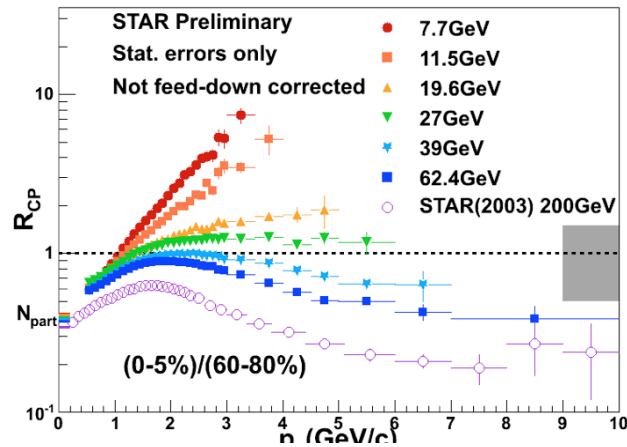
→ Temperature dependence of energy loss in QGP, transport co-efficient



[RIKEN's strategy]

- 1) Build Silicon tracker in mid-rapidity in sPHENIX to complete the scientific program at RHIC.
- 2) Conduct forward physics program using polarized p+p, p+A for spin.
- 3) Transition from sPHENIX to ePHENIX at eRHIC. Conduct physics program in e+A (e.g. Gluon saturation), e+p (nucleon structure 3D imaging)

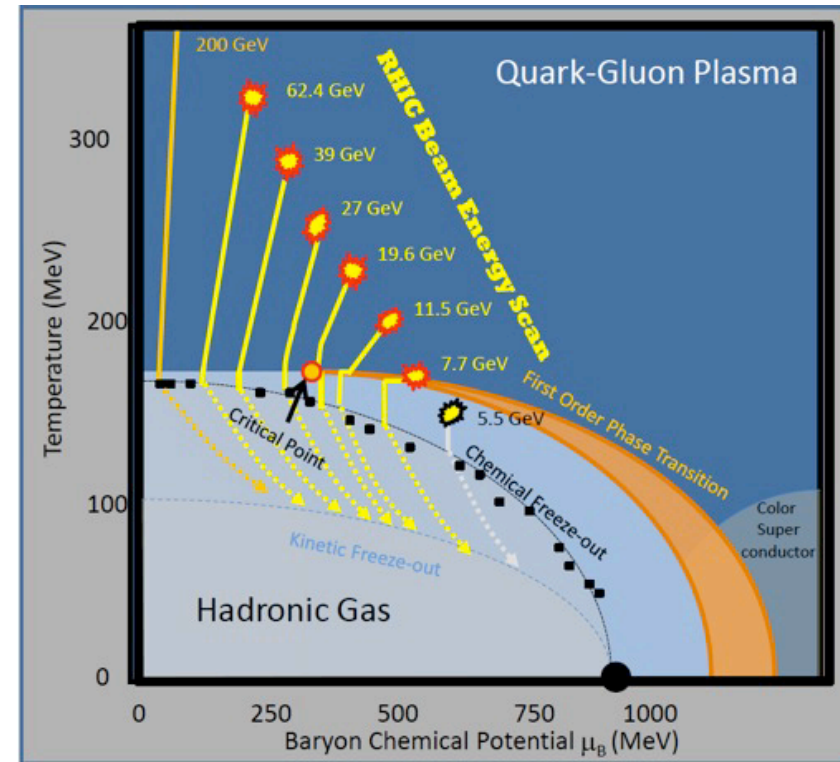
QCD phase structure



$$\sigma^2 = \langle (N - \langle N \rangle)^2 \rangle$$

$$S = \langle (N - \langle N \rangle)^3 \rangle / \sigma^3$$

$$\kappa = \langle (N - \langle N \rangle)^4 \rangle / \sigma^4 - 3$$

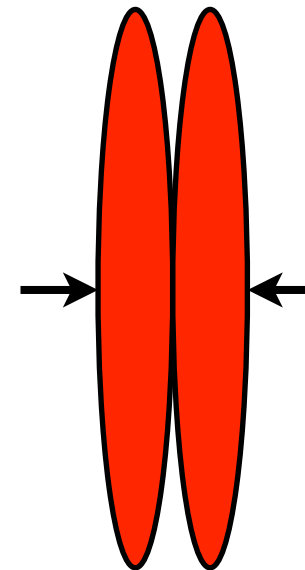


- RHIC BES-II @ RHIC, search for a critical behavior.
- A Japanese group also is seeking a possibility to join the RHIC BES-II at STAR (2018-2019).

Consideration of Heavy Ion Physics at J-PARC; 10-15 GeV/A ($\sqrt{s_{NN}} = 4.5-5.4$ GeV)

- Light to heavy ion (U) acceleration with new ion source (ECR, laser, EBIS)
- **Measurements which were not measured at AGS, new physics.**

- Fluctuations (# of particles, p , v_n etc.)
 - ➔ **QCD critical point, QCD phase mapping**
- lepton pairs, photon, σ meson (?)
 - ➔ **Chiral symmetry restoration, thermal photons**
- multiple-strangeness (strangelet search)
- double, triple hyper nuclei
- charmed hadron (J/Ψ , D)
 - ➔ **Exotic hadron/nucleus, charm physics**
- hadron gas properties
- **Properties of high density nuclear matter**



J-PARC HI Collaboration

S. Nagamiya (JAEA/KEK/RIKEN)

H. Sako, K. Imai, K. Nishio, S. Sato (ASRC/JAEA)

H. Harada, P. K. Saha, M. Kinsho, J. Tamura, (J-PARC/JAEA)

K. Ozawa, Y. Liu (J-PARC/KEK)

T. Sakaguchi (BNL)

K. Shigaki (Hiroshima Univ.)

T. Chujo (Univ. of Tsukuba)

T. Gunji (CNS, Univ. of Tokyo)

M. Kaneta (Tohoku Univ.)

2014/9/27

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* Cooperation with GSI.

** Collaboration with J-PARC E-16 exp. (K. Ozawa et al.) for p-A physics and detector R&D.¹⁵

**J-PARC
(JAEA & KEK)**

400 MeV H Linac

**3 GeV Rapid Cycling
Synchrotron (RCS)**

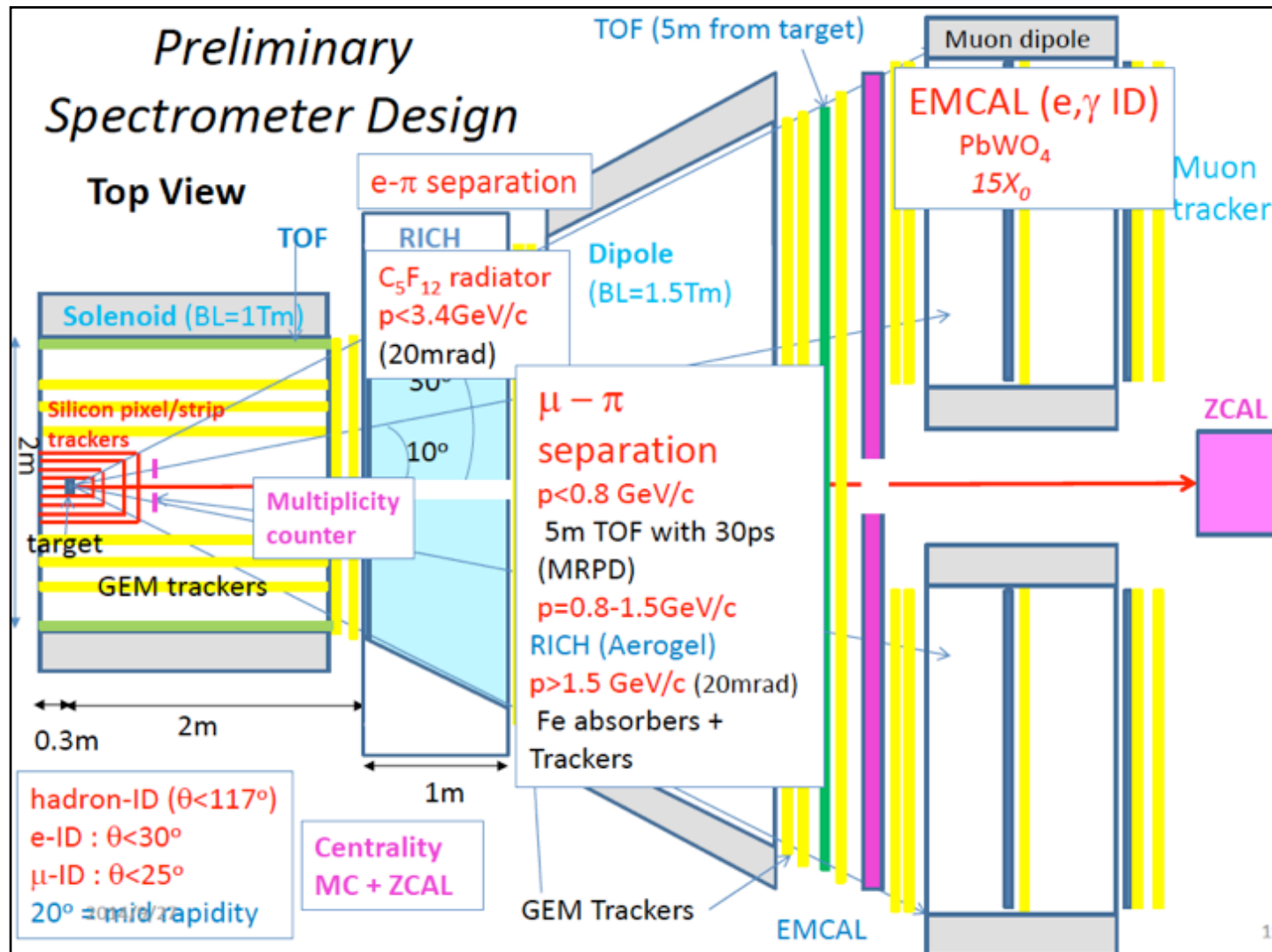
1 MW

**50 GeV Main Ring
Synchrotron (MR)
[30 GeV at present]**

0.75 MW

- JFY 2006 / 2007**
- JFY 2008**
- JFY 2009**

**Hadron
Experimental
Hall (HD)**



* White paper writing by March 2015.

* Theory workshop on physics of HI at J-PARC (end of Nov. 2014)

Summary

- Our proposal (ALICE, sPHENIX) has been adapted by Science Council of Japan (2014), as one of the “Master Plans”.
- In next 10 years (2015-2025), Japanese experimental groups will continue strong involvements in ALICE, (s/e)PHENIX, and also we are planning to conduct HI physics program at J-PARC, to answer fundamental questions on QGP and QCD.

