From Japan to Norway and onwards to the Big Bang

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From Japan to Norway (2008-2018)

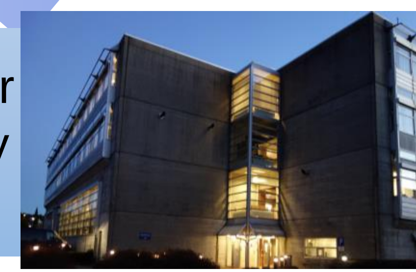
University of Stavanger

Postdoctoral appointments:
Bielefeld – Bern – Heidelberg

PI and scientific manager:
University of Heidelberg

PhD course:
The University of Tokyo

Associate Professor and PI at University of Stavanger



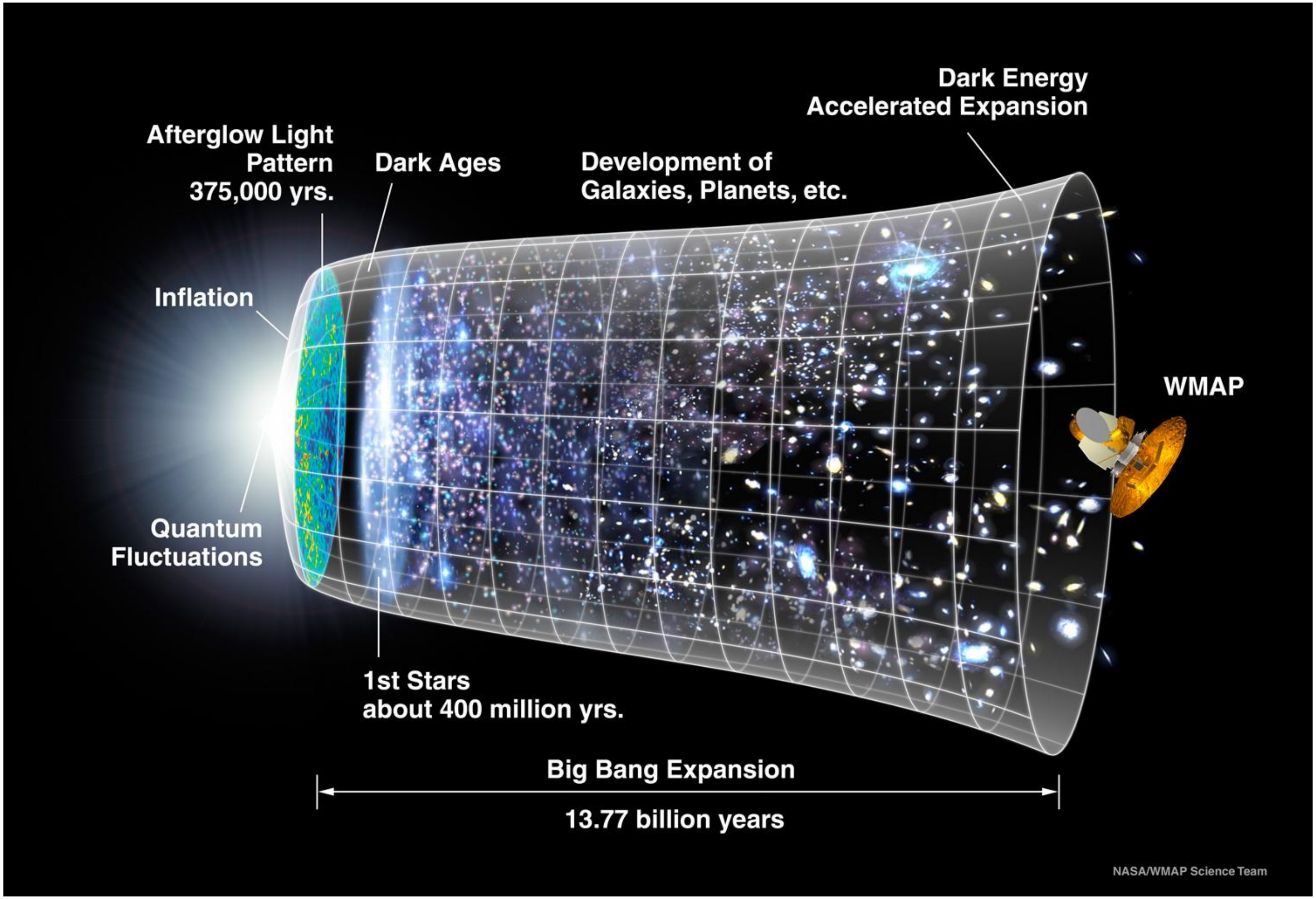
supervisor: T. Hatsuda, now RIKEN iTHEMS

3-year MEXT + DAAD PhD scholarship

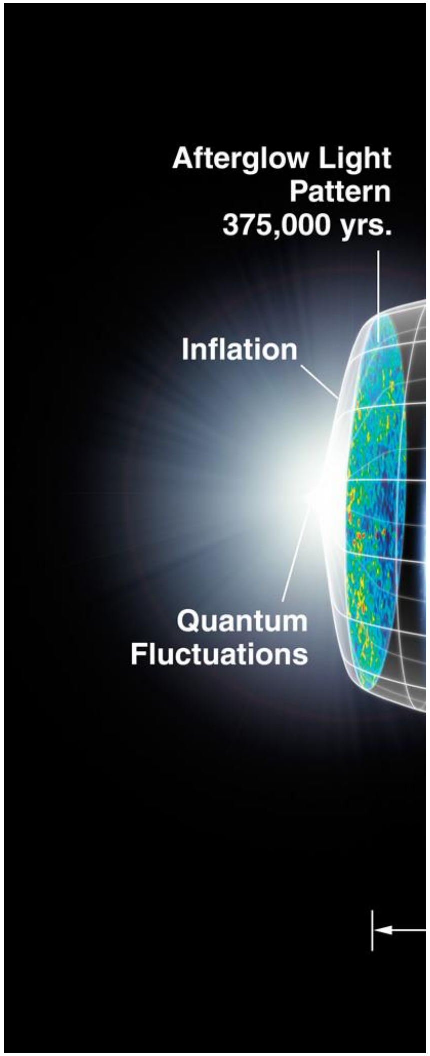
4-year RCN YRT – FRIPRO grant

- Both MEXT and RCN play a key role in my scientific career

Towards the BigBang



Towards the BigBang from Japan



Yukawa - 1949

Tomonaga - 1965

Koshiba - 2002

Nambu - 2002

Kobayashi - 2008

Maskawa - 2008

Kajita - 2015

7/29 Nobel Laureates of Japanese origin with direct con-nection to the early universe

How to probe the early universe?

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ESA – Planck satellite

KEK laboratory – Super KEKb Accelerator (Tsukuba, Japan)

CERN laboratory – LHC (Geneva, Switzerland)

Observe the **remnants** of the early universe: cosmic microwave background

Recreate the conditions close to the big bang in the laboratory via **particle colliders**

Heavy-ion collisions at CERN

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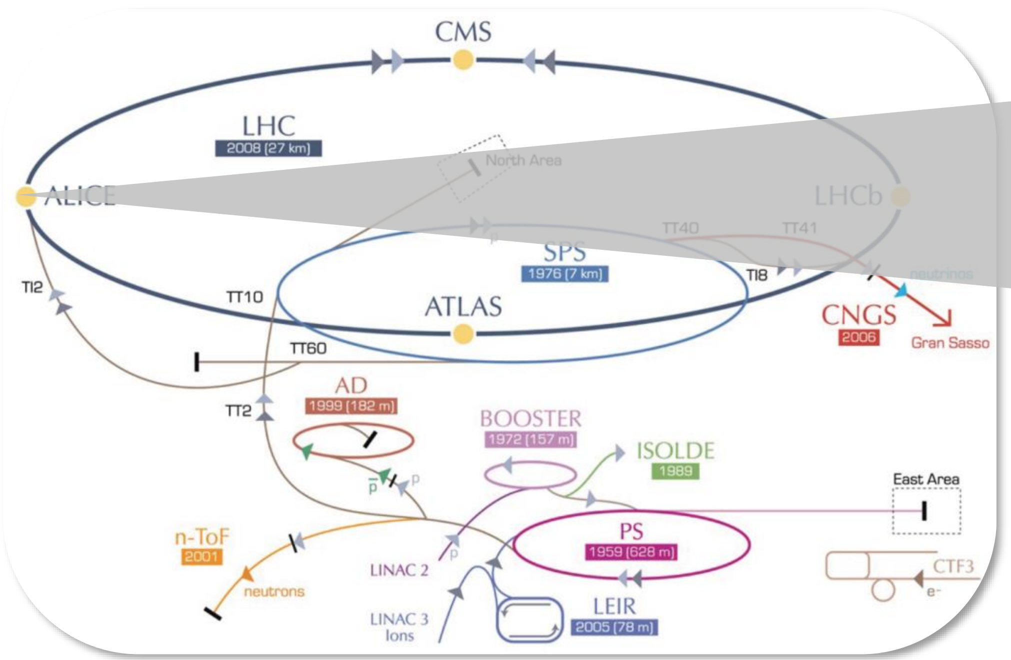
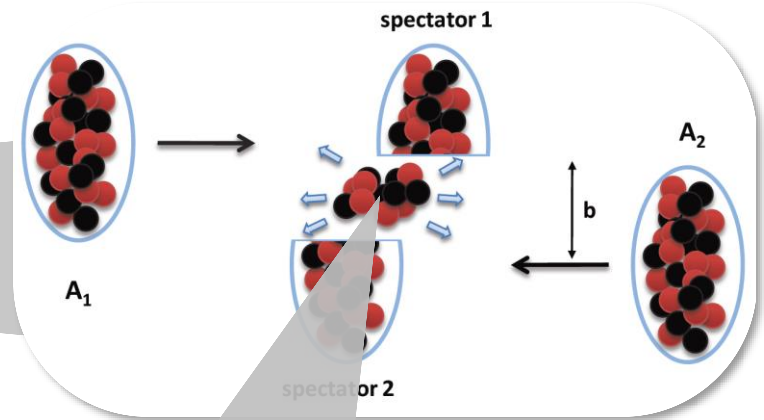
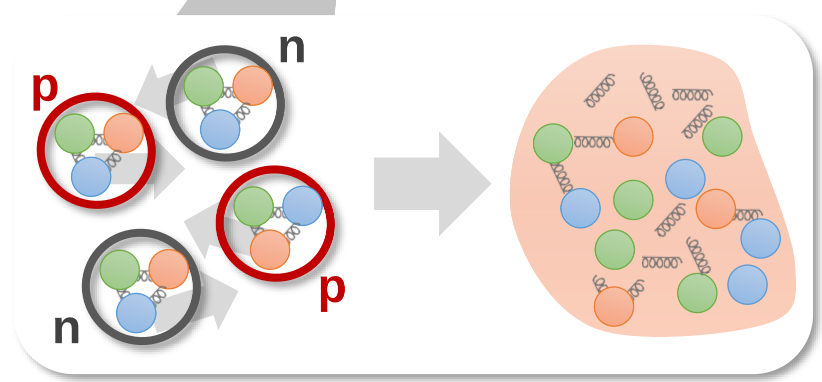
- Norway & Japan are both **active contributors** to CERN and the LHC





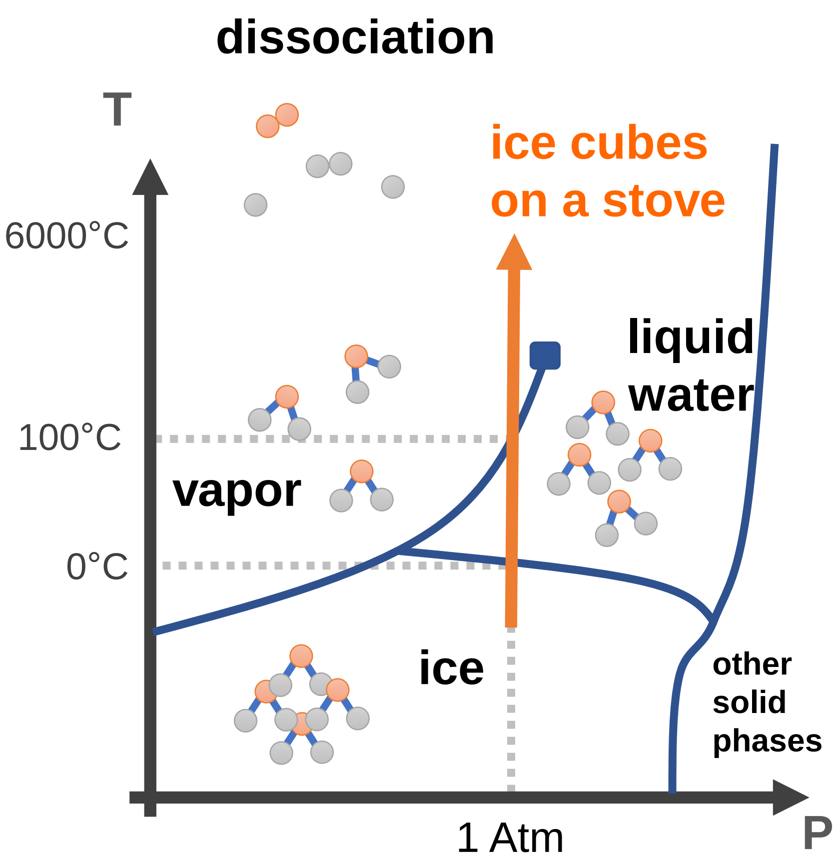


- Directed kinetic energy via scattering into undirected Ekin: **temperature**

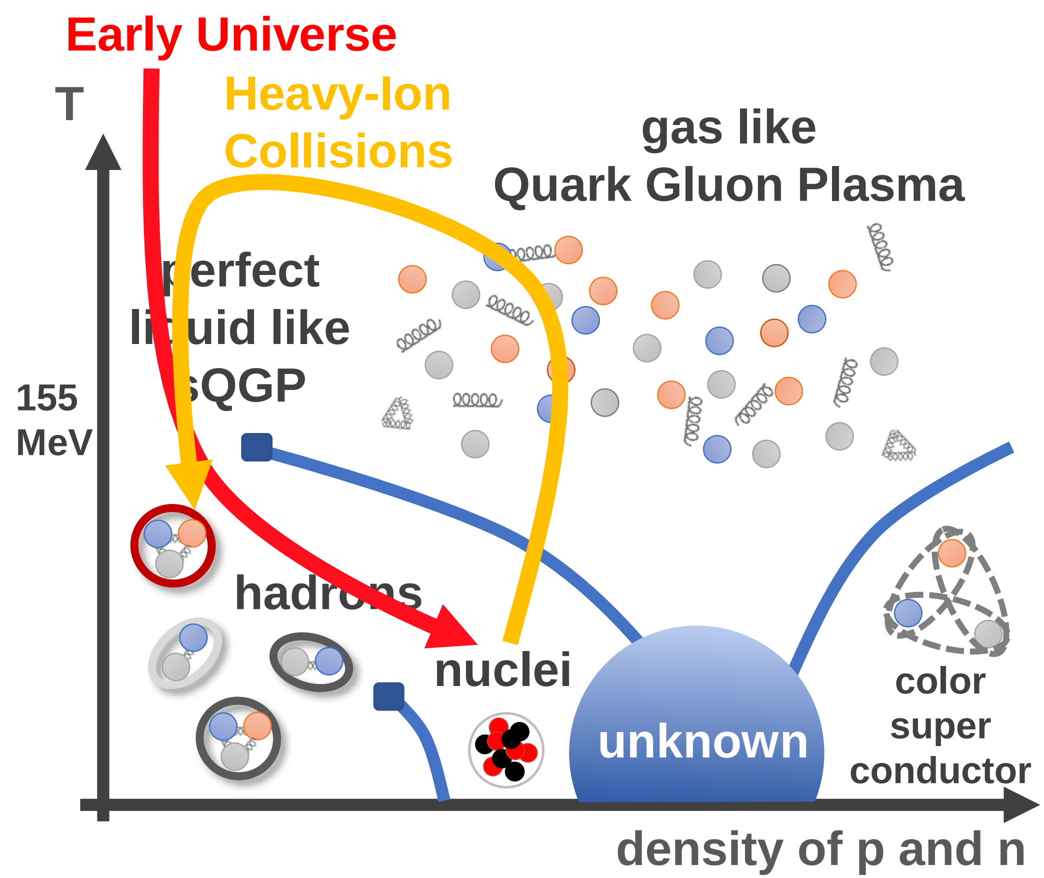
  At the LHC: $\mathbf{T_{HIC}}$ > **200.000 x T(core of the sun)** = 200 MeV

Phases of matter

Water – H_2O



Nuclear matter – protons/neutrons



- Nuclear matter transitions into liquid-like state of quarks and gluons

The Quark Gluon Plasma

Quarkonium as QGP thermometer

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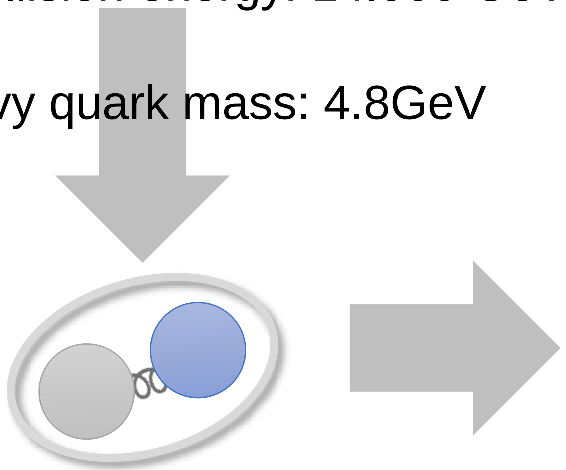
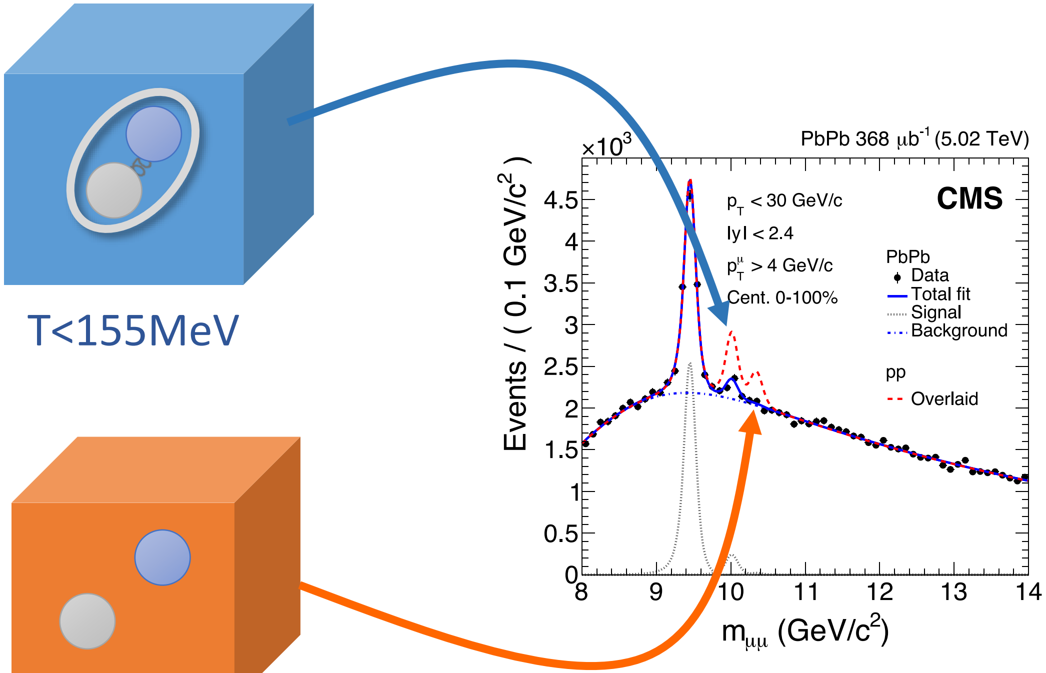
- Reactions in HIC are too fast to probe by e.g. laser spectroscopy (10^{-22}s)
- Need to use particles created in collision ($E=mc^2$) as thermometer

LHC collision energy: 14.000 GeV

Heavy quark mass: 4.8GeV



Bound state of a heavy quark and anti-quark (**Quarkonium**)



T>>155MeV

Collaboration on HIC & Quarkonium

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How to describe thermal Quarkonium intuitively with an in-medium potential?

PRL 108, 162001 (2012) PHYSICAL REVIEW LETTERS week ending 20 APRIL 2012

Complex Heavy-Quark Potential at Finite Temperature from Lattice QCD

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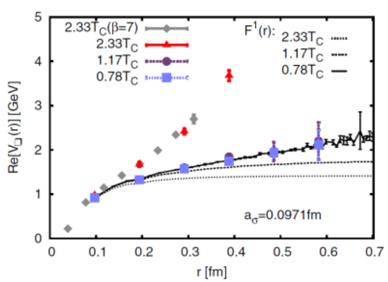
(Received 15 August 2011; published 18 April 2

We calculate for the first time the complex potential between a heavy temperature across the deconfinement transition in lattice QCD. The rea potential at each separation distance *r* is obtained from the spectral functio We confirm the existence of an imaginary part above the critical tempe function of *r* and underscores the importance of collisions with the gluonic e heavy quarkonia in the quark-gluon plasma.

DOI: 10.1103/PhysRevLett.108.162001 PACS numbers: 12.38.G



How do the earliest moments of a heavy-ion collision look like?

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Non-Abelian chiral instabilities at high temp on the lattice

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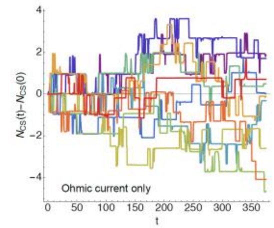

Quarkonium themalization as open-quantum-systems

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Quantum dissipation of a heavy quark from a nonlinear stochastic Schrödinger equation

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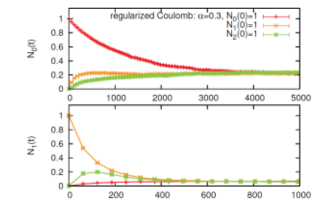

- Step by step towards understanding heavy quarkonium in HICs

One more thing: Supercomputing

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- Task at hand: need to solve the Quantum Field Theory “QCD”

$$G(x) = \int \mathcal{D}U\mathcal{D}[\bar{\psi},\psi]\big(\bar{\psi}(y)\gamma_\mu\psi(y)\big)\big(\bar{\psi}(y+x)\gamma_\mu\psi(y+x)\big)^\dagger \times \exp\Big[-\int d^4x\Big\{\bar{\psi}_i(\gamma_\mu D_\mu - m)\psi - \frac{1}{4}F^a_{\mu\nu}F^{\mu\nu}_a\Big\}\Big]$$

25.000.000 dimensional integrals: needs high performance computing

NERSC – USA
Edison

RIKEN – Japan K computer

NOTUR – Norway
Vilje

- Both Japan and Norway maintain supercomputing infrastructure in Top500

Societal benefits and spin-offs

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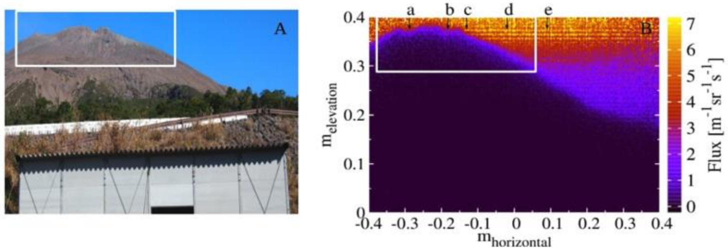
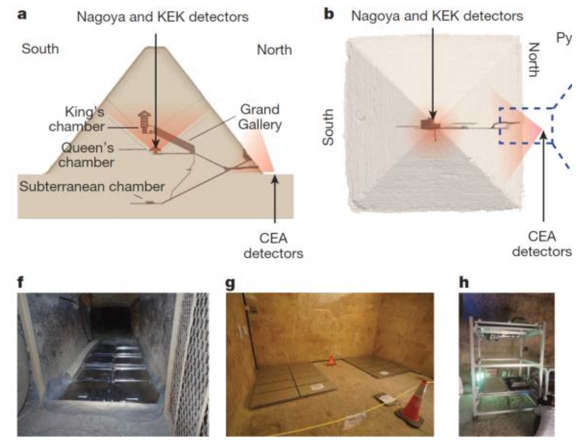
Recently: Bergen develops ion therapy center

http://www.hirt-japan.info/en/what/japan.html



Volcano monitoring in Japan via muon tomography
Scientific REPOrts | (2018) 8:3207



Reexamination of Egyptian Pyramids by a Japanese led team
Nature, Vol 552, Dec. 2017

Heavy-ion **radiation therapy** with much improved precision over protons

Novel **imaging techniques** with application to geology and archeology (national security, material testing…)

Conclusion

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- Particle accelerator experiments provide a window into the early universe
- Theorists deploy supercomputing to understand the phase structure of nuclear matter under extreme temperatures
- **Quarkonium** particles are a viable candidates for a HIC thermometer: strong and **ongoing collaboration** with Japanese colleagues.
- A central result of the past decade: protons and neutrons go over to a novel phase at T>155MeV

The Quark-Gluon-Plasma

- The quest for nuclear matter in extreme conditions has led to relevant and beneficial spin-off technology: accelerators & detectors

Takk for oppmerksomheten – ご清聴ありがとうございました

Backup slides

MEXT PhD scholarship

University of Stavanger

- Complete academic freedom: tuition & cost of living paid
  - Free choice of supervisor / university (if competitively accepted)
  - No teaching duties, similar to JSPS D1-3 students
  - Covers the whole doctoral course if academic record excellent
- Japanese language training provided (for PhD Japanese not necessary)
- Alumni club for networking after end of studies

→ The **three years in Tokyo** were important to **jumpstarting my scientific career** and provide a **lifelong link to Japan** and its scientific community.