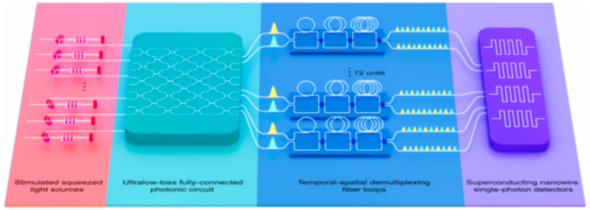
2.4 China

☆ Yulin Wu et al
“Strong Quantum Computational Advantage Using a Superconducting Quantum Processor”
Phys. Rev. Lett. 127, 180501 (2021)

☆ Yu-Hao Deng et al.
“Gaussian Boson Sampling with Pseudo-Photon-Number-Resolving Detectors and Quantum Computational Advantage"
Phys. Rev. Lett. 131, 150601 (2023)

University of Science and Technology of China



two-mode squeezed state photon sources

2.5 Japan

RIKEN RQC-FUJITSU Collaboration Center

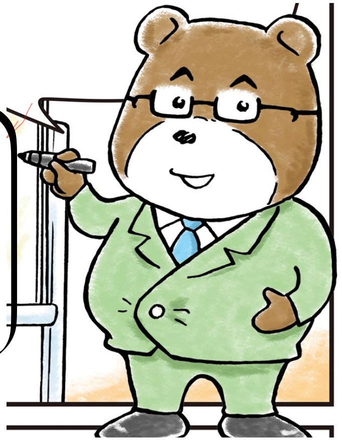
64 quantum bits

Not for Nakamura!

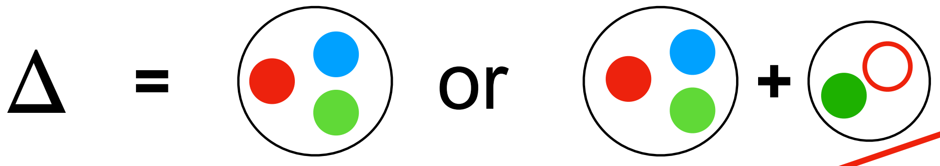
2.6 Some recent references

- L. Mazur et al (HotQCD collaboration)
  “SIMULATeQCD: A simple multi-GPU lattice code for QCD calculations"
  arXiv:2306.01098v2
- E. Mendicelli et al
  “Investigating how to simulate lattice gauge theories on a quantum computer”
  arXiv:2308.15421v1
- C. W. Bauer et al.
  “Quantum Simulation for High-Energy Physics”
  PRX Quantum 4, 027001 (2023)
- Y.Sato et al.,
  “Variational quantum algorithm based on the minimum potential energy for solving the Poisson equation”
  arXiv:2106.09333v2
- K Tamura and Y Shikano
  “Quantum Random Number Generation with the Superconducting Quantum Computer IBM 20q Tokyo”
  eprint.iacr.org/2020/078.pdf

For Numerical simulations, the random numbers are important !



3. Possible use of the quantum computer:



Of course, 3 quark state

No, No. Of course, N+pi state

- What is Delta baryon ?

  $\Delta = \{qqq\}$ or $N\pi = \{qqq\} + \bar{q}q$

  Which operator describe the nature better ?

  Quantum compter power may provide the answer.

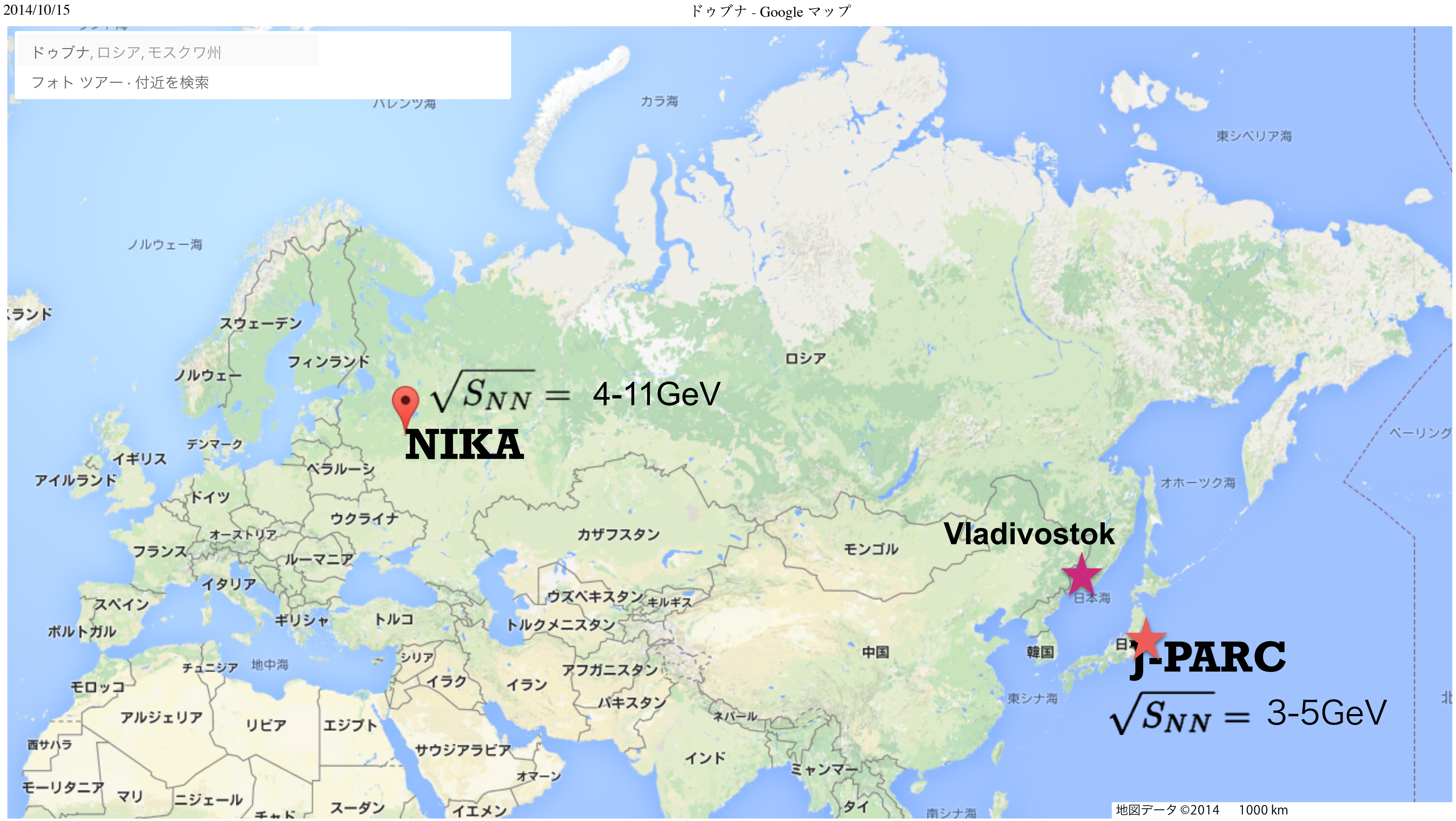
You need very high quality lattice.

- Thanks to its high performance, quantum computer may give us the answer.

  The size of Δ (Form Factor) can be determined without parameter ?

The energies of NIKA and J-PARC accelerators are not high.

But, they are useful to study hadron behaviors.



2014/10/15 ドゥブナ - Google マップ

$\sqrt{S_{NN}} =$ 4-11GeV

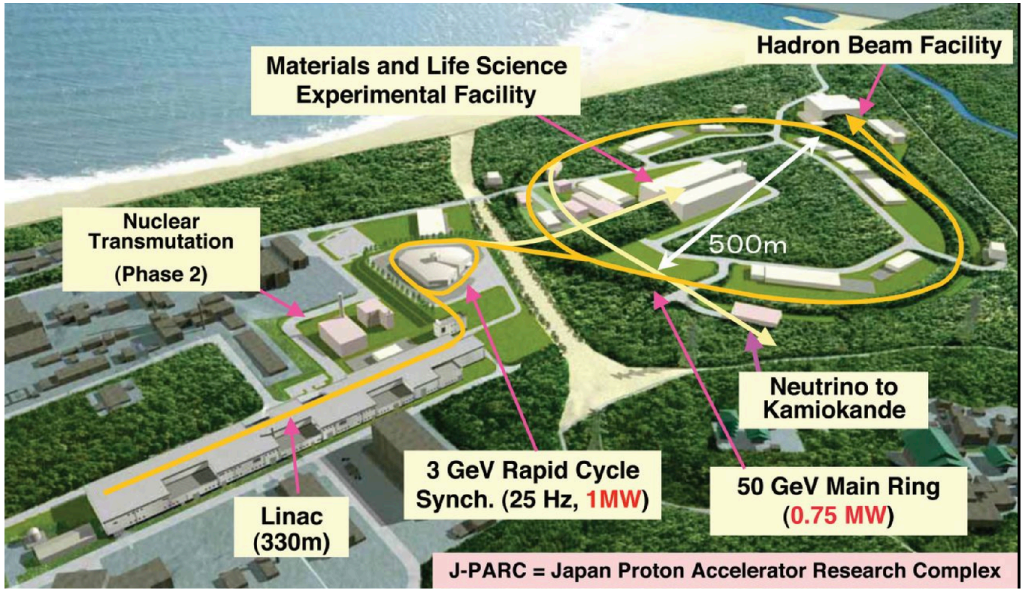
NIKA

Vladivostok

J-PARC

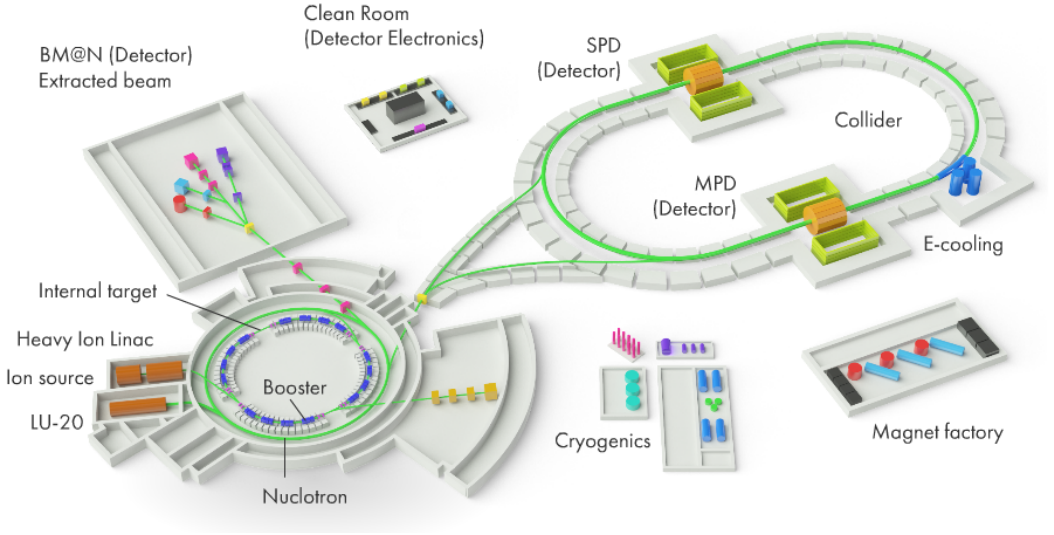
$\sqrt{S_{NN}} =$ 3-5GeV

J-PARC (Japan Proton Accelerator Research Complex)



High Intensity Beam

NICA (Nuclotron-based Ion Collider fAcility)

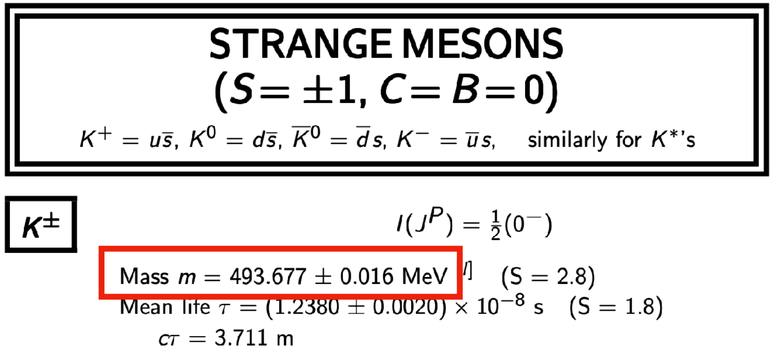


Prof. Atsushi Hosaka@Osaka Univ. said

It is good to start from Strange hadrons

They can be measured at J-PARC and NICA.

(Charm hadrons are heavy and we need very fine lattice)



STRANGE MESONS
$(S = \pm 1, C = B = 0)$

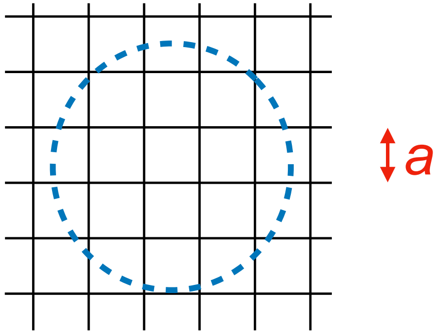
$K^+ = u\bar{s}$, $K^0 = d\bar{s}$, $\overline{K}^0 = \bar{d}s$, $K^- = \bar{u}s$, similarly for K^*'s

$K^\pm$ $I(J^P) = \frac{1}{2}(0^-)$

Mass $m = 493.677 \pm 0.016$ MeV (S = 2.8)
Mean life $\tau = (1.2380 \pm 0.0020) \times 10^{-8}$ s (S = 1.8)
$c\tau = 3.711$ m

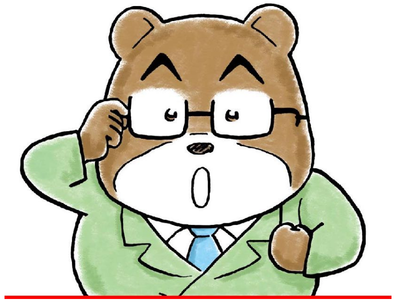
m~500MeV

1/m~0.4 fm



$$\frac{1}{a} \sim m$$

The lattice space should be at least a few *fm.*
I am poor, but I can try !

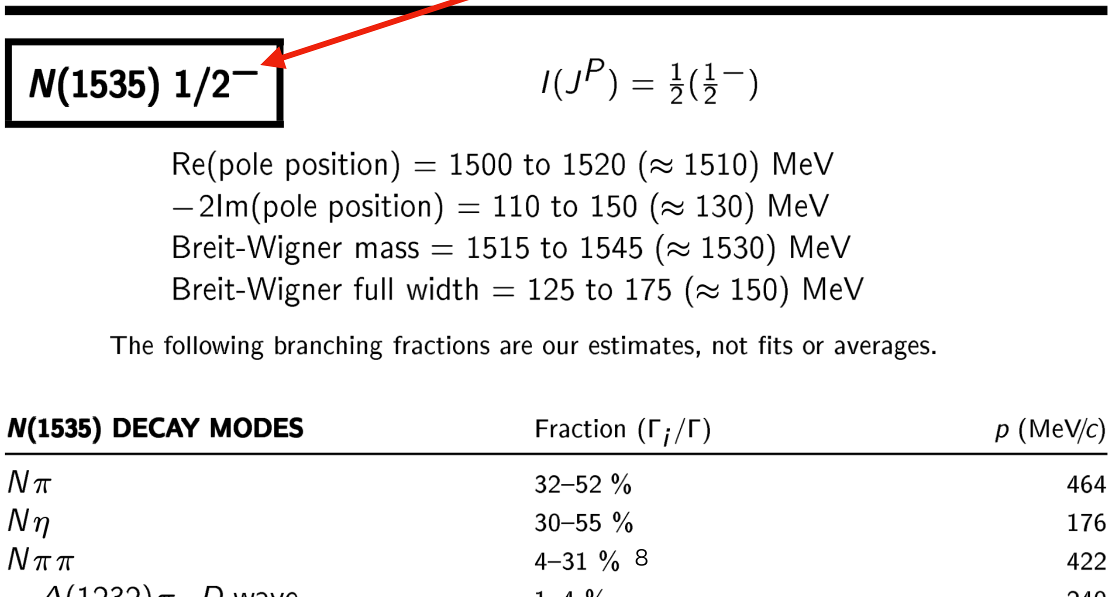


I understand Δ is intersting ($\Delta = \{qqq\}$ or $N\pi = \{qqq\} + \bar{q}q$)
Is there similar situation in the s-quark sector ?

Yes, N*(1535)+K

But, note that the parity of this resonance is minus.
Then, L = 0
where L is the angular momentum of K-Λ.

Different from Δ case (L=1)



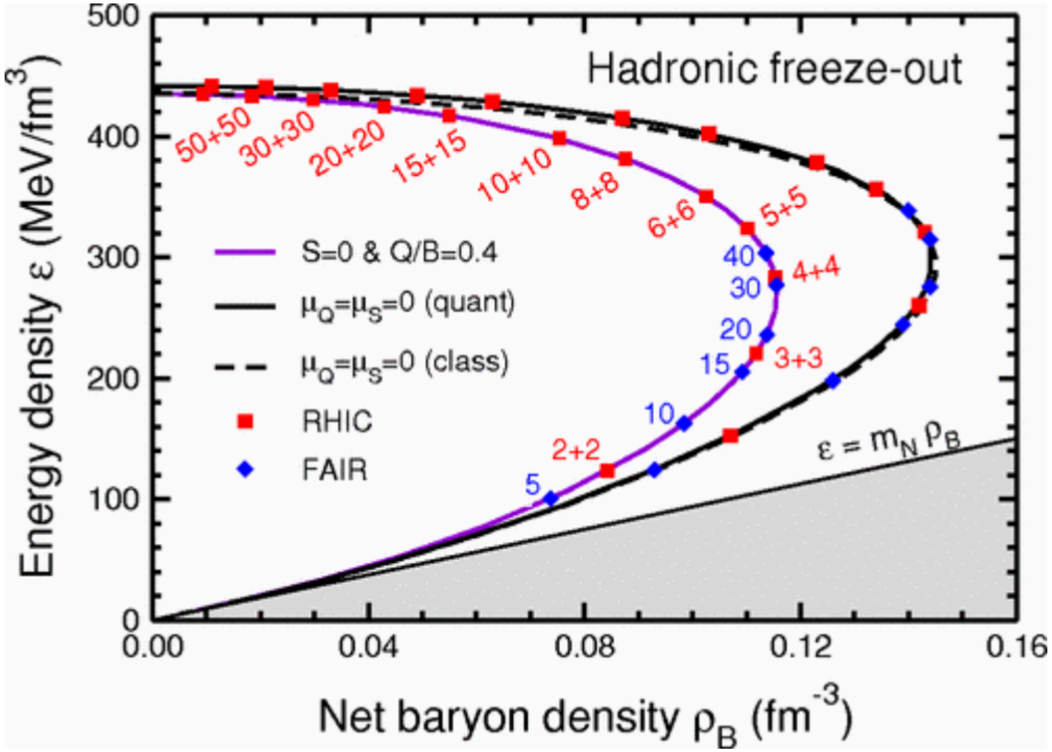
N(1535) 1/2⁻

$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$

Re(pole position) = 1500 to 1520 (≈ 1510) MeV
−2Im(pole position) = 110 to 150 (≈ 130) MeV
Breit-Wigner mass = 1515 to 1545 (≈ 1530) MeV
Breit-Wigner full width = 125 to 175 (≈ 150) MeV

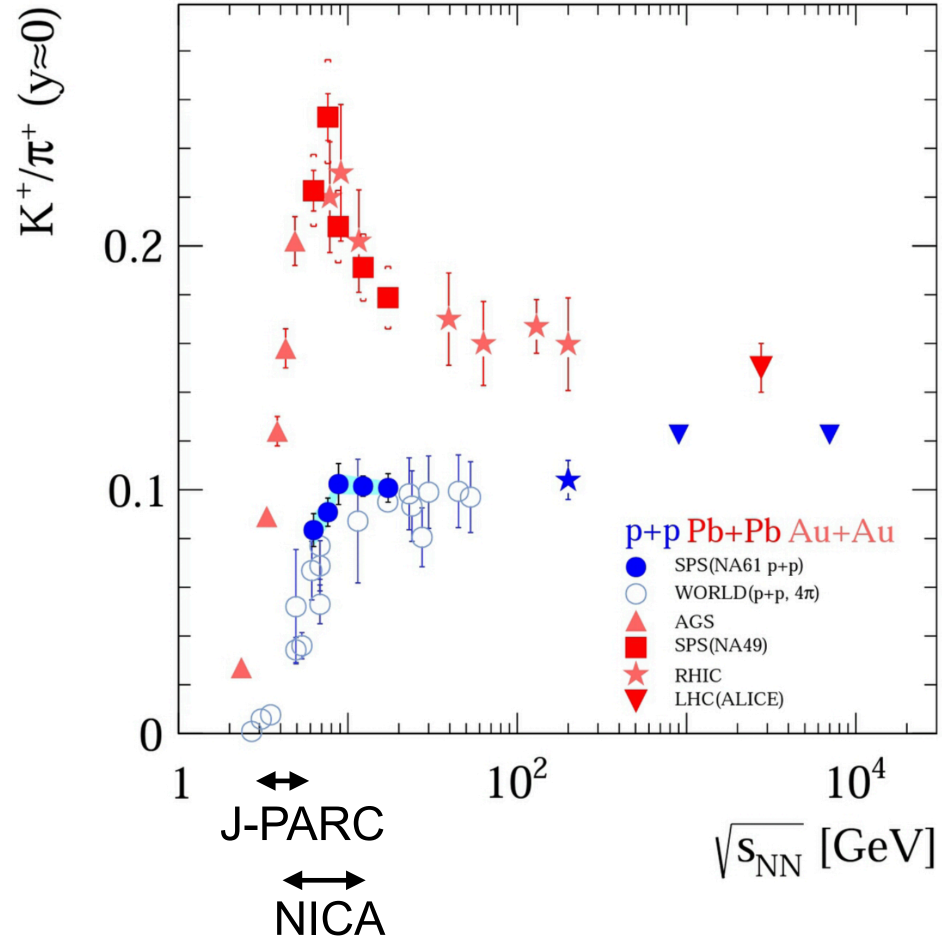
The following branching fractions are our estimates, not fits or averages.

N(1535) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\pi$	32–52 %	464
$N\eta$	30–55 %	176
$N\pi\pi$	4–31 %	422



Randrup, Cleymans
Phys. Rev. C74 (2006) 047901

K/pi ratio
(Wiki-pedia)



4. Conclusion

> If you can't fly, then run. If you can't run, then walk. If you can't walk, then crawl. But whatever you do, you have to keep moving forward.
>
> Martin Luther King

- Our possible next research subject is Strange hadrons
- Out tools are **lattice simulations** and **effective models**. If we have a chance to use quantum computers, we can get decisive achievements.

See the next talk by Wolfgang.

- At this moment, unfortunately, our collaboration has no chance to use quantum computers.
  But

If you can’t use a quantum computer, then, make a quantum computer.
If you cannot make a quantum computer, use a simulator for writing program.

References

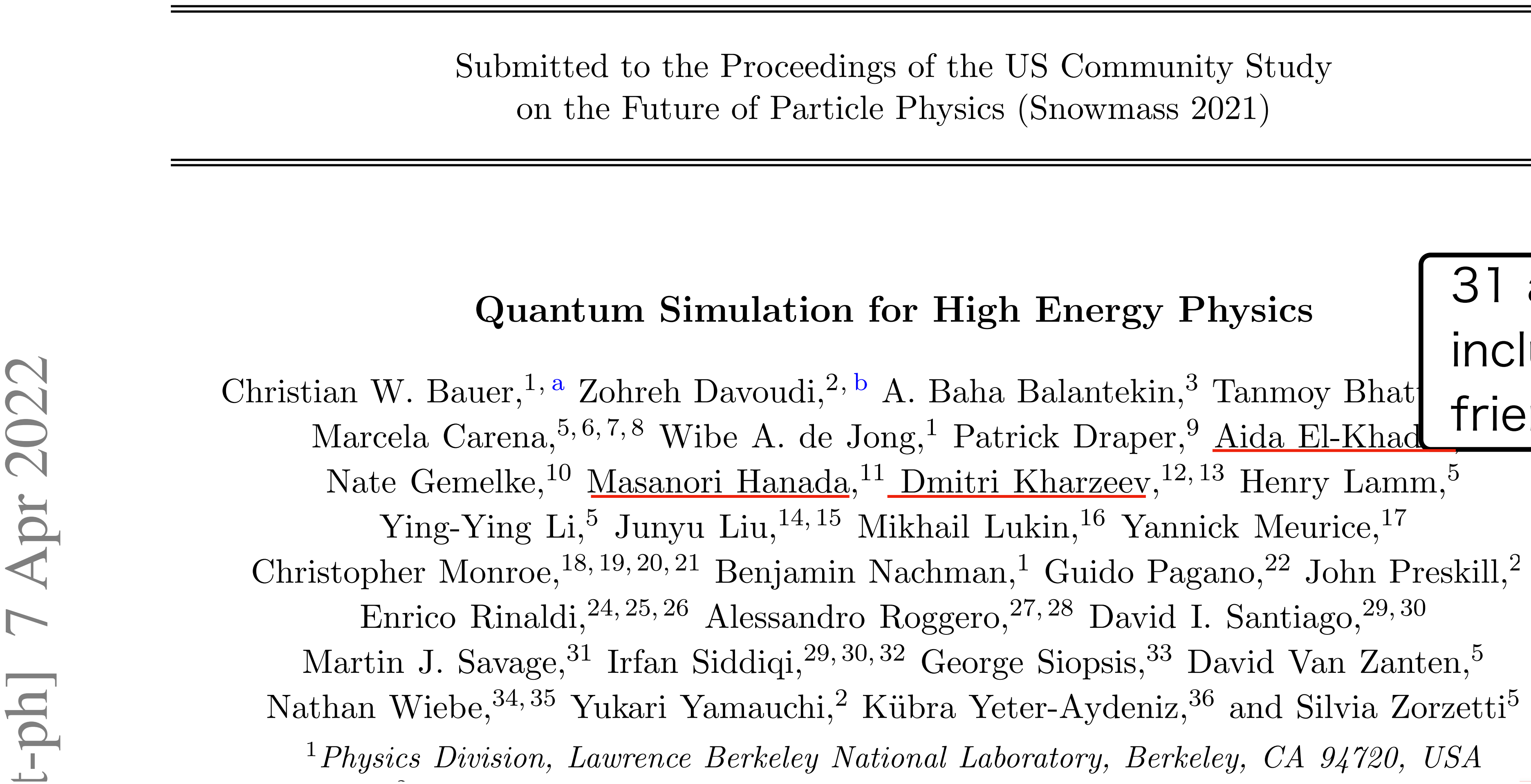
Natalie Klco

Calculating Nature Naturally: Toward Quantum Simulation of Quantum Fields (2020)

PhD Dissertation

C .W. Bauer et al., “Quantum Simulation for High Energy Physics”

arXiv:2204.03381



Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

Quantum Simulation for High Energy Physics

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31 authors
including many
friends !

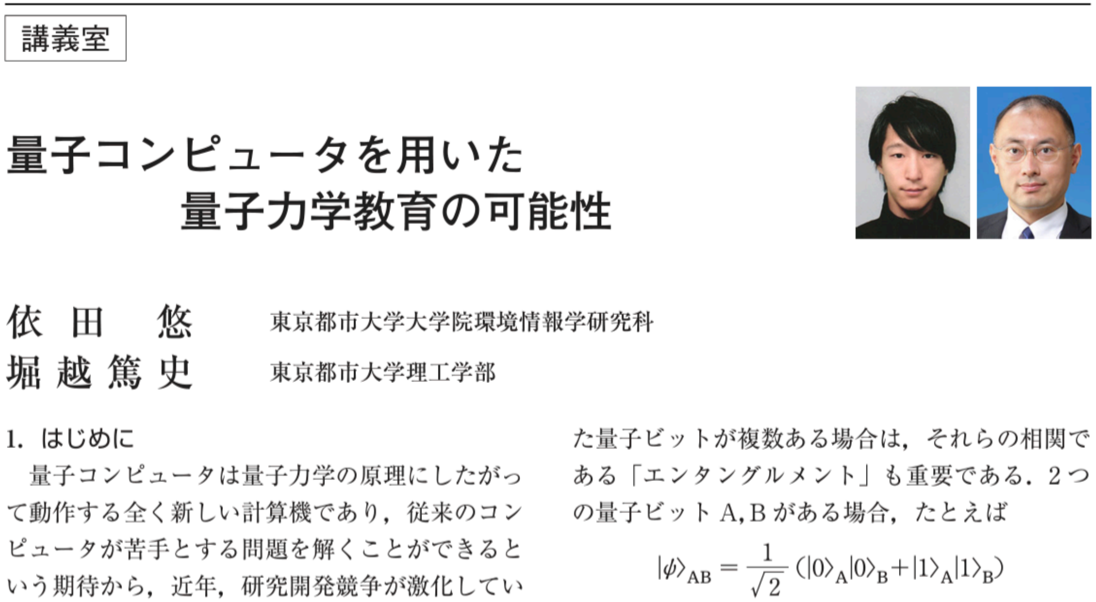
National Academies of Sciences (2018)
https://nap.nationalacademies.org
“Quantum Computing: Progress and Prospects”

1 Progress in Computing
2 Quantum Computing: A New Paradigm
3 Quantum Algorithms and Applications
4 Quantum Computing's Implications for Cryptography
5 Essential Hardware Components of a Quantum Computer
6 Essential Software Components of a Scalable Quantum Computer
7 Feasibility and Time Frames of Quantum Computing

- I thank Prof. Zakharov for noticing me this report.

Y. Ida and A. Horikoshi

“Computer Education at Universities using the quantum computers”
Vol.26, page 71 (2020)
In Japanese
https://www.jstage.jst.go.jp/article/peu/26/2/26_71/_pdf



講義室

量子コンピュータを用いた量子力学教育の可能性

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堀越篤史　東京都市大学理工学部

1. はじめに

量子コンピュータは量子力学の原理にしたがって動作する全く新しい計算機であり，従来のコンピュータが苦手とする問題を解くことができるという期待から，近年，研究開発競争が激化してい

た量子ビットが複数ある場合は，それらの相関である「エンタングルメント」も重要である．2つの量子ビットA, Bがある場合，たとえば

$$|\phi\rangle_{\mathrm{AB}} = \frac{1}{\sqrt{2}}(|0\rangle_{\mathrm{A}}|0\rangle_{\mathrm{B}}+|1\rangle_{\mathrm{A}}|1\rangle_{\mathrm{B}})$$

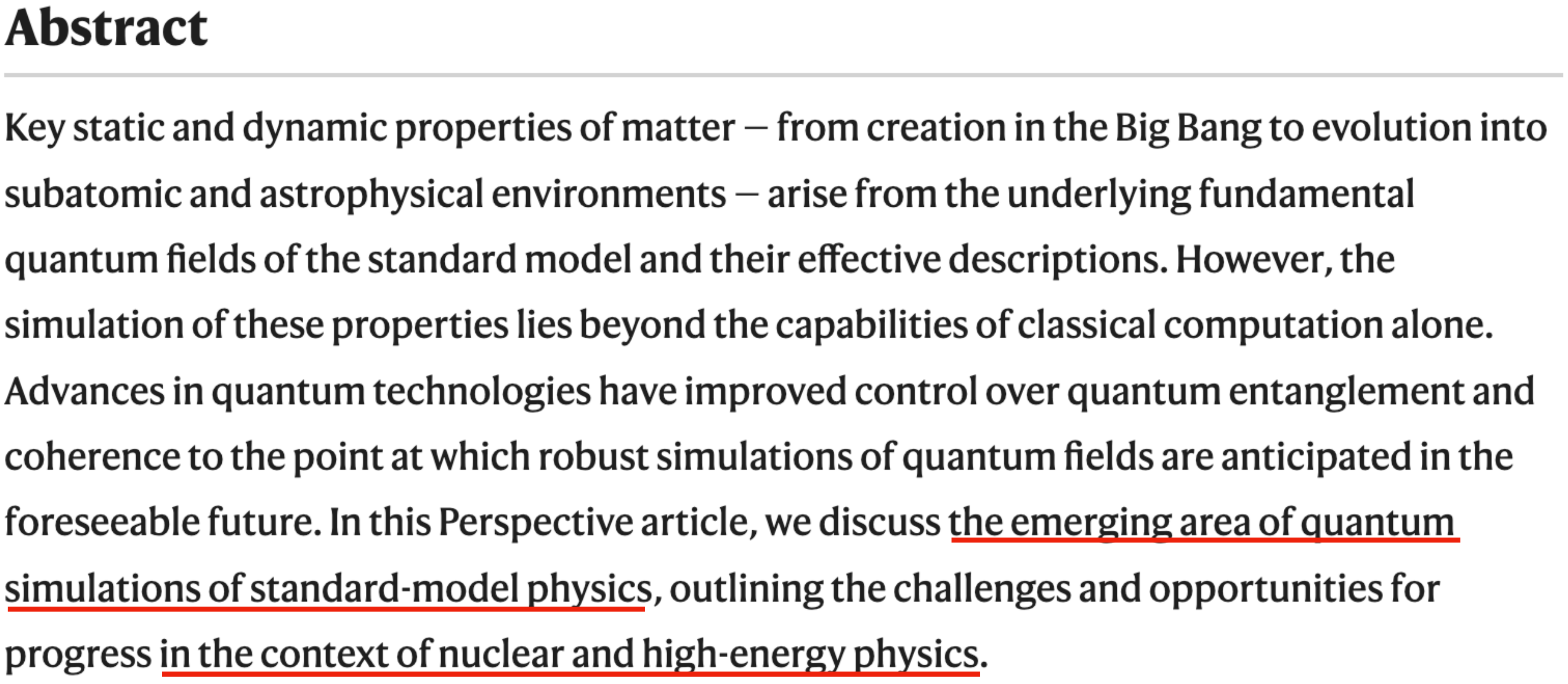
A possible approach

- 2+1 dynamical simulation (qqs)
  and to measure hadronic observables
  with the strangeness.

↑

- To construct strange mesons and baryon operators,
  1. quench → 2. dynamical quarks but no strangeness,
  → 3. dynamical q+s

Bauer, C.W., Davoudi, Z., Klco, N. *et al.*
“Quantum simulation of fundamental particles and forces”
Nat. Rev. Phys. **5**, 420–432 (2023).
https://doi.org/10.1038/s42254-023-00599-8



Abstract

Key static and dynamic properties of matter – from creation in the Big Bang to evolution into subatomic and astrophysical environments – arise from the underlying fundamental quantum fields of the standard model and their effective descriptions. However, the simulation of these properties lies beyond the capabilities of classical computation alone. Advances in quantum technologies have improved control over quantum entanglement and coherence to the point at which robust simulations of quantum fields are anticipated in the foreseeable future. In this Perspective article, we discuss the emerging area of quantum simulations of standard-model physics, outlining the challenges and opportunities for progress in the context of nuclear and high-energy physics.

Possible Targets: Strange Hadrons

Mesons (|s|=1)

K^+(u$\bar{s}$) K^0(d$\bar{s}$) K^-(s$\bar{u}$) $\bar{K}^0$(s$\bar{d}$)

Baryons (s= -1) Σ^{*+}(uus) Σ^{*0}(uds) Σ^{*-}(dds0

Baryons (s= -2) Ξ^{*0}(uss) Ξ^{*-}(dss)

Baryons (s= -3) Ω^-(sss)

Important subjects that are not discussed today

- Quantum Fourier Transportation
- Grover’s algorithm
- Shor’s algorithm
- Deutsch-Jozza algorithm
- Error-tolerable quantum computing