

# Quantum Computing within HEP

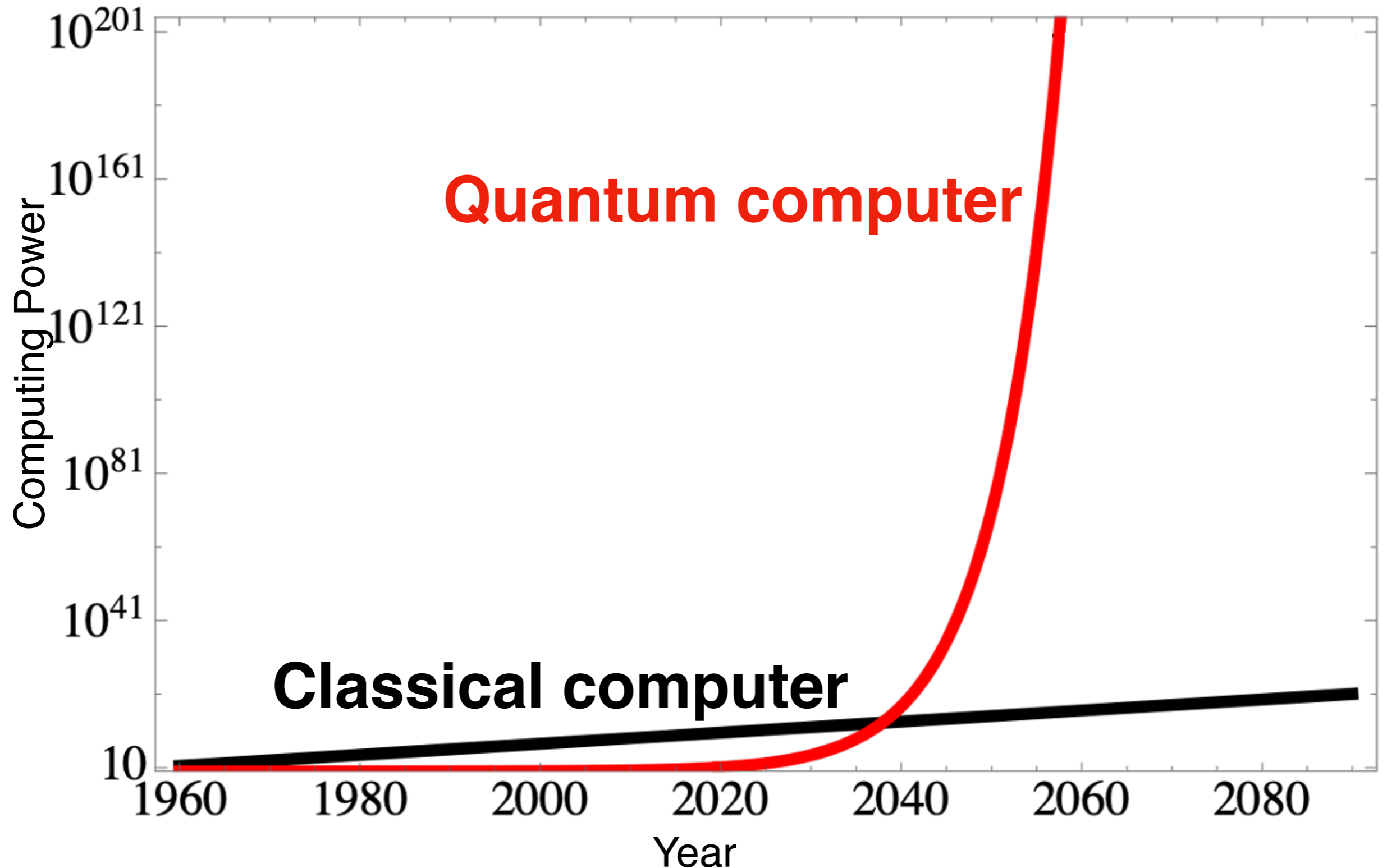
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LBNL



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The standard argument for quantum computing is that it outperforms a classical computer exponentially



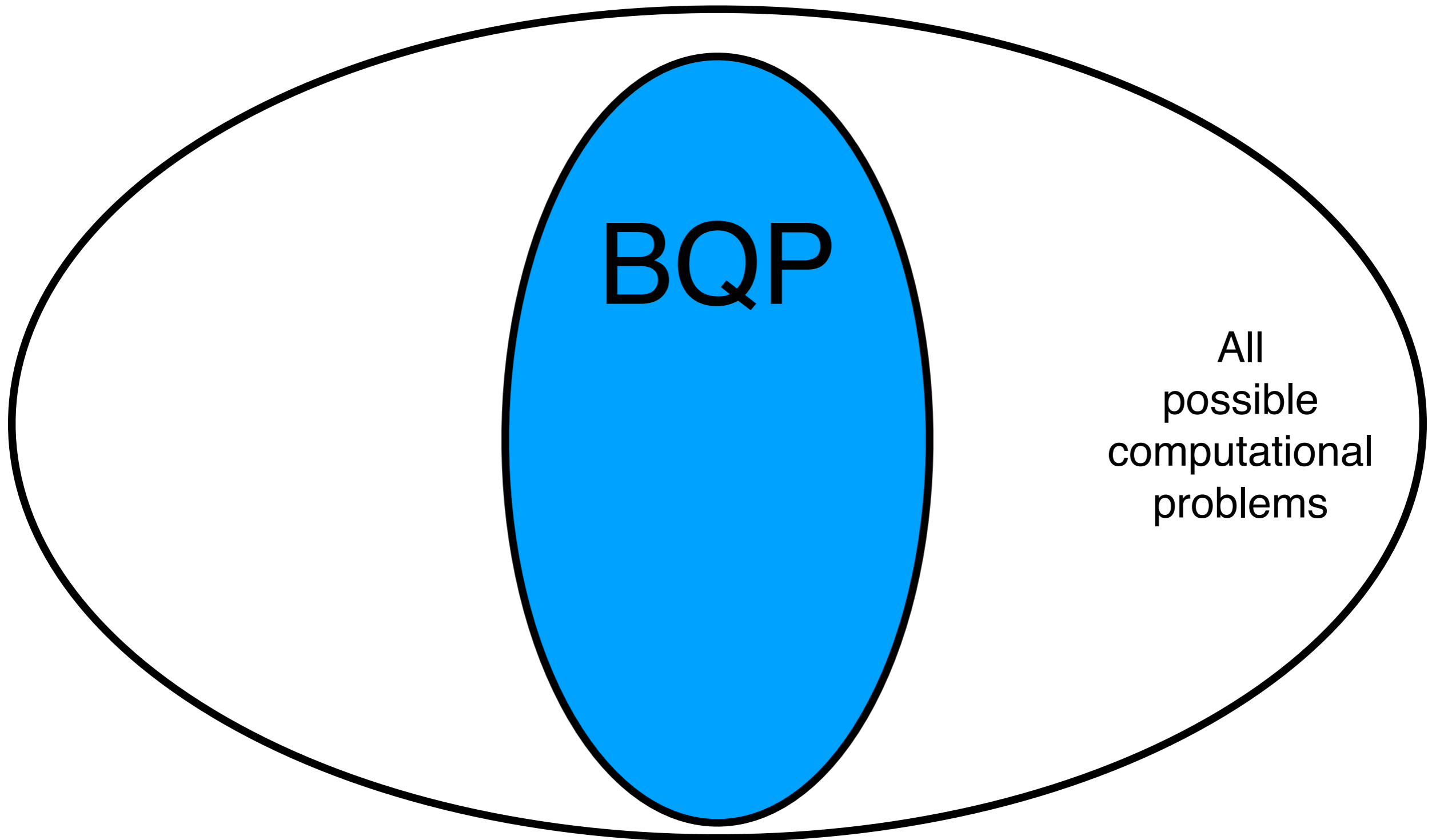
**But quantum computers can not solve all problems, and not always exponentially faster than a classical computer**



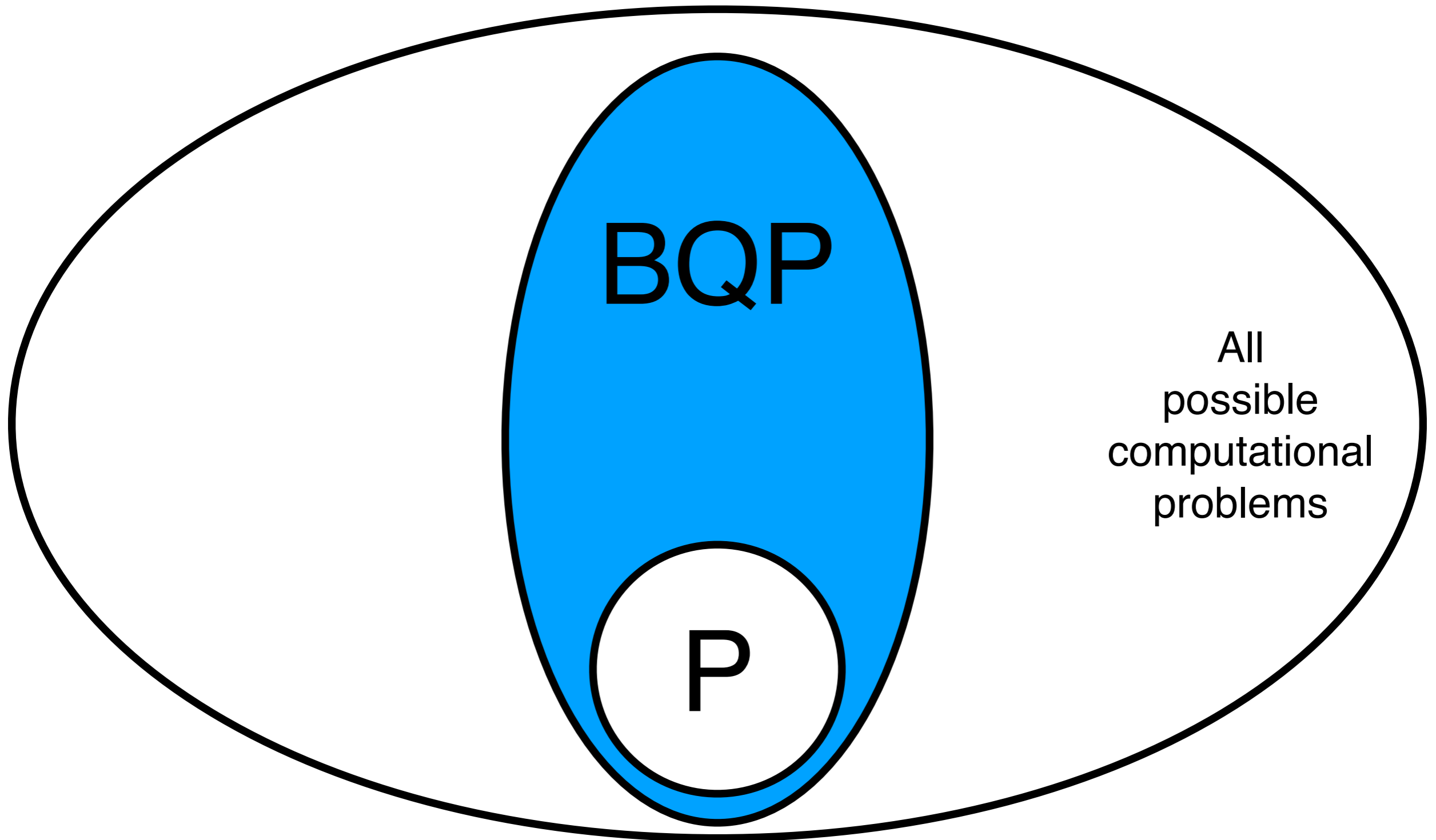
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All  
possible  
computational  
problems

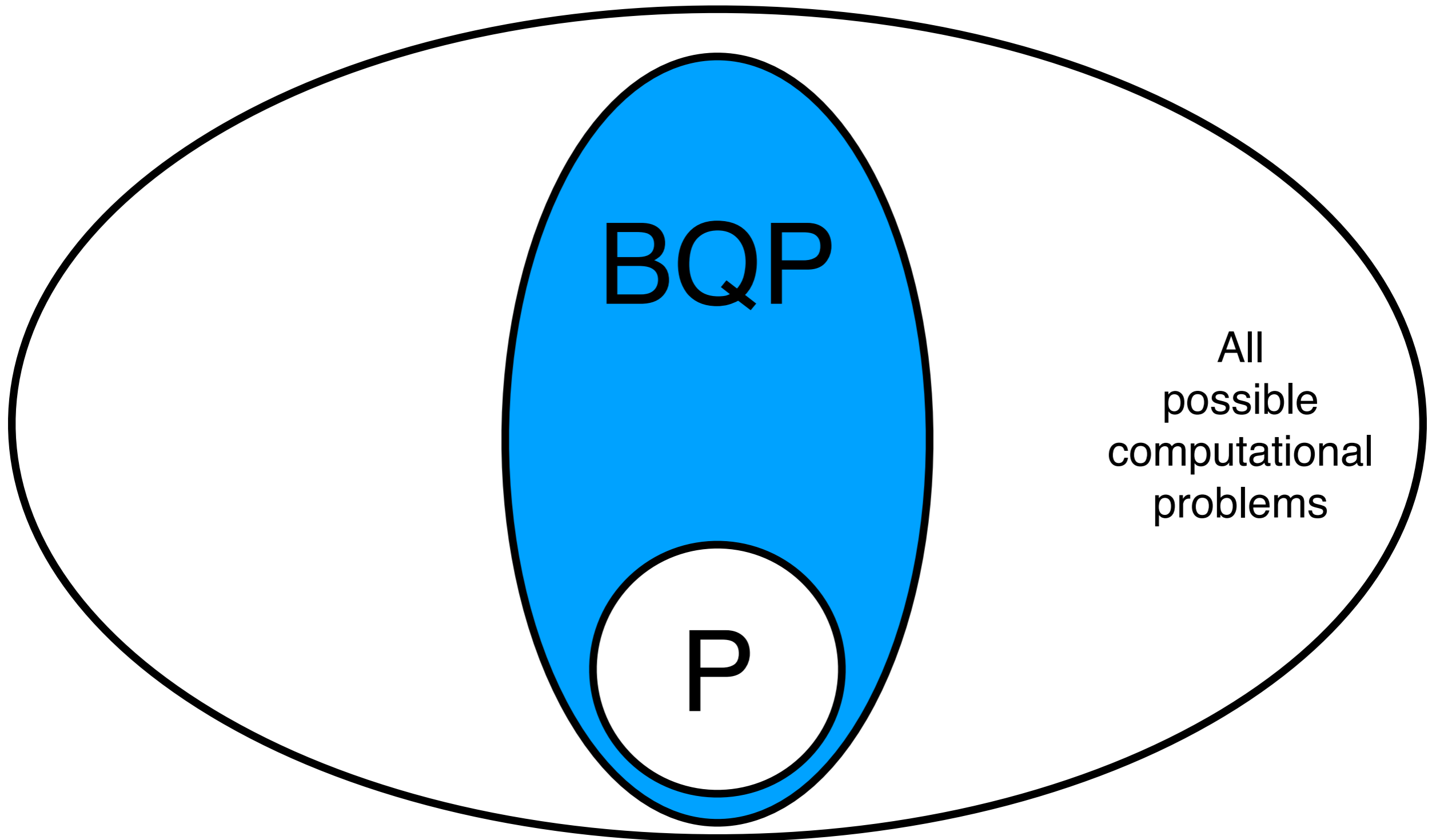
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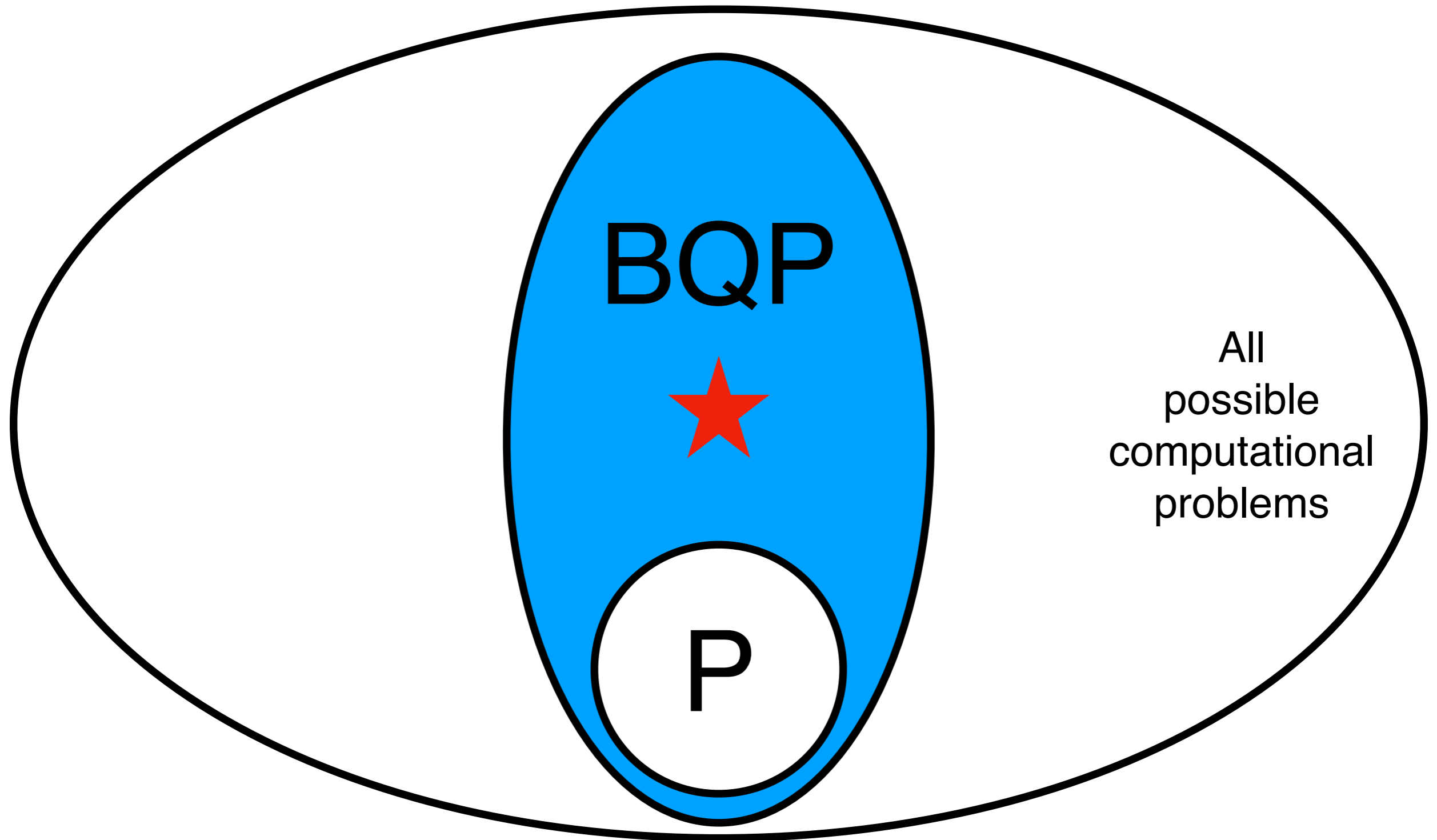
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Need HEP problems for which a quantum computer outperforms a classical computer

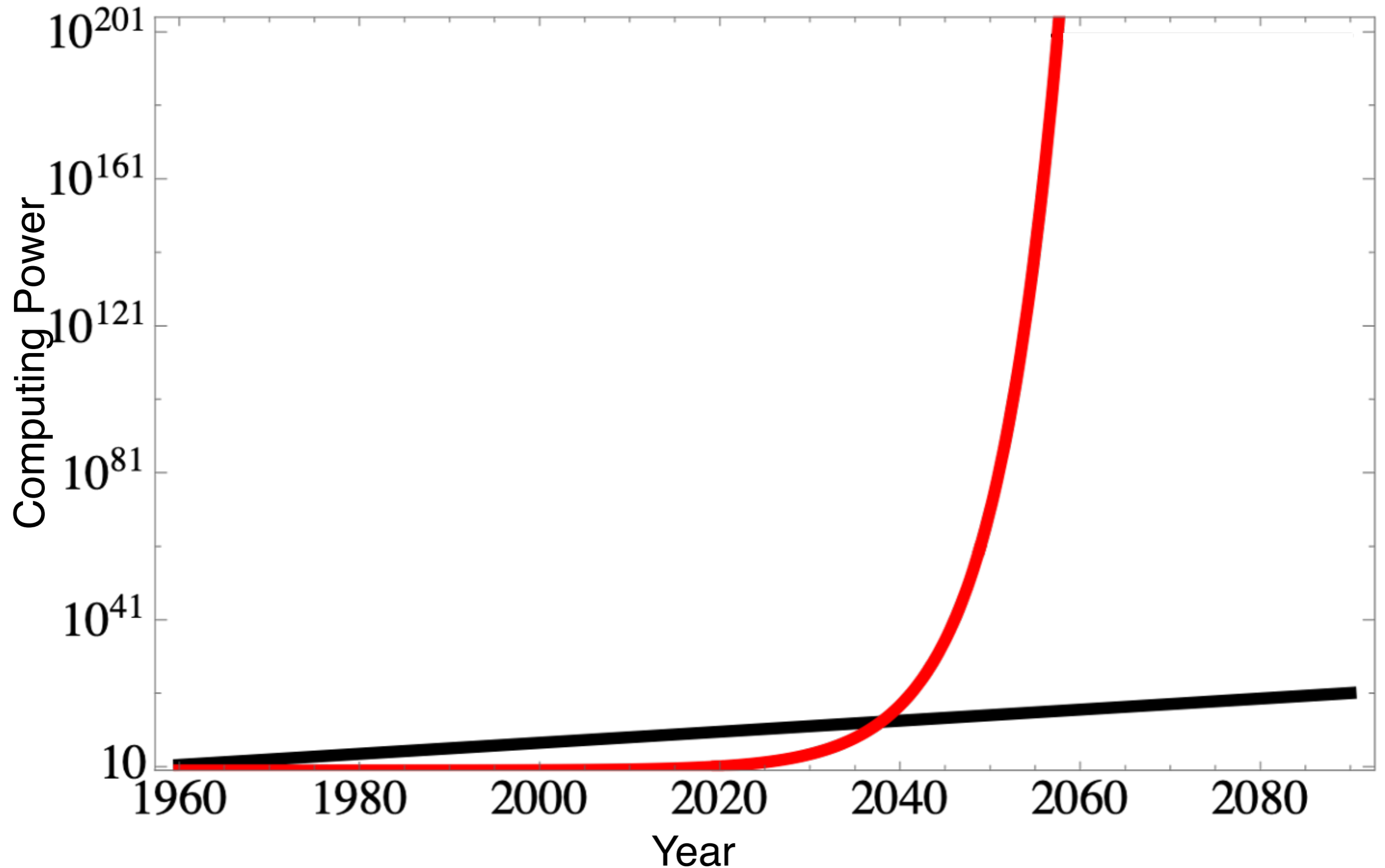


# Need HEP problems for which a quantum computer outperforms a classical computer





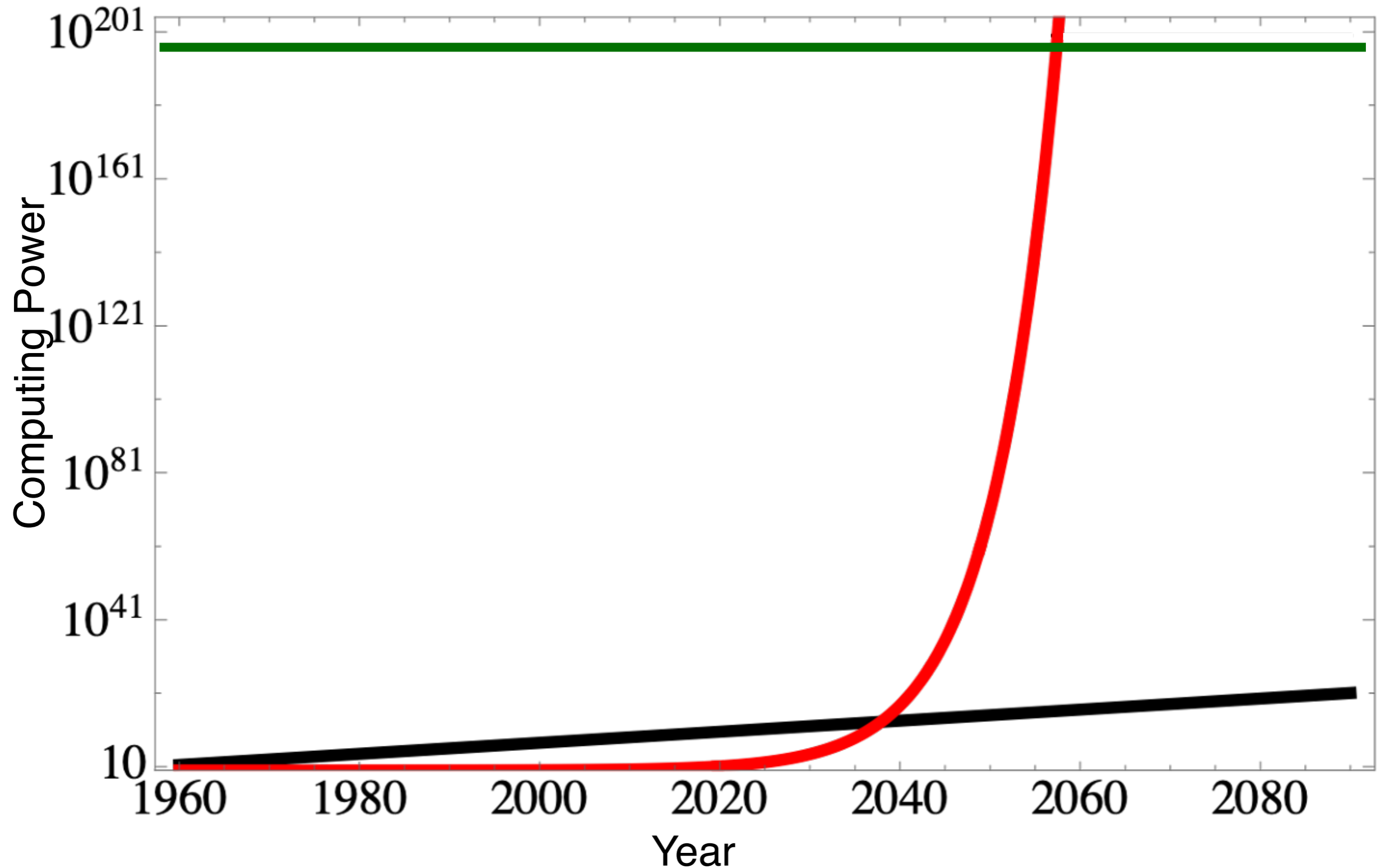
The important message is that there are transformational problems in HEP for which QC outperforms CC



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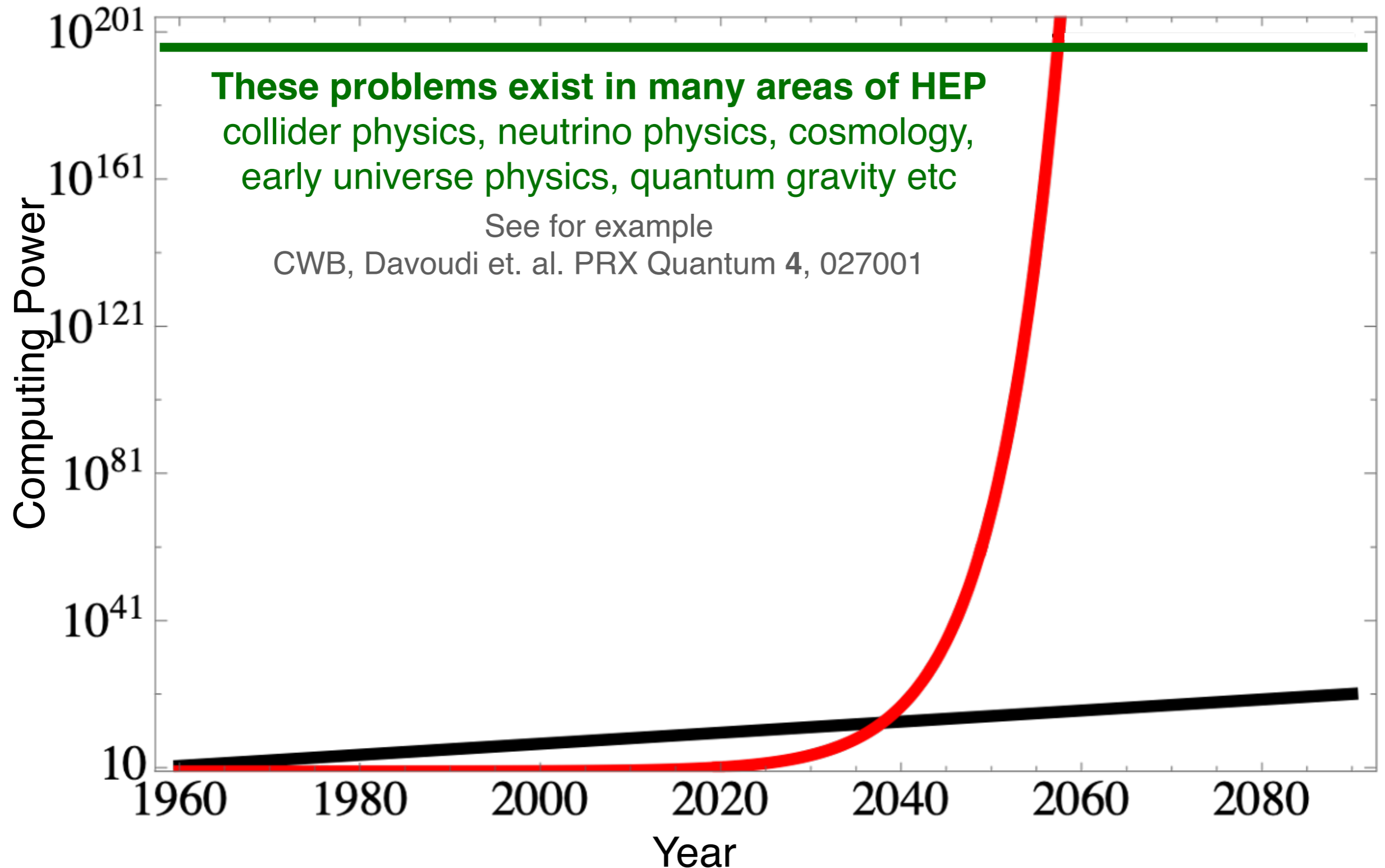
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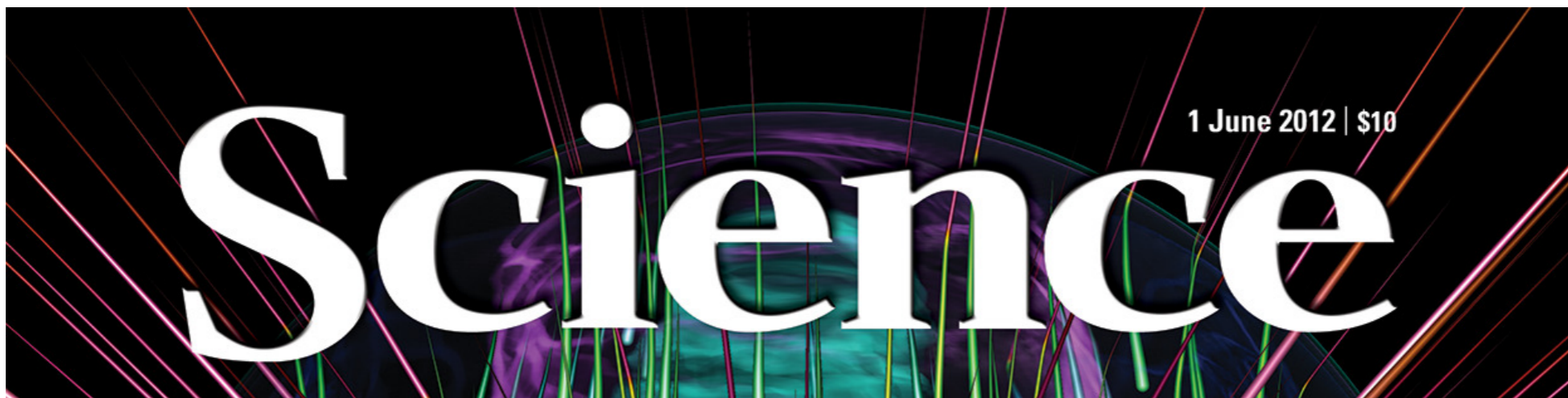


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# The important message is that there are transformational problems in HEP for which QC outperforms CC





# Quantum Algorithms for Quantum Field Theories

Stephen P. Jordan,<sup>1\*</sup> Keith S. M. Lee,<sup>2</sup> John Preskill<sup>3</sup>

Quantum field theory reconciles quantum mechanics and special relativity, and plays a central role in many areas of physics. We developed a quantum algorithm to compute relativistic scattering probabilities in a massive quantum field theory with quartic self-interactions ( $\phi^4$  theory) in spacetime of four and fewer dimensions. Its **run time is polynomial** in the number of particles, their energy, and the desired precision, and applies at both weak and strong coupling. In the strong-coupling and high-precision regimes, our quantum algorithm **achieves exponential speedup over the fastest known classical algorithm.**

Jordan, Lee, Preskill, Science **336**, 1130, 2012

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There are many questions in particle physics that we would love to have numerical answers to

How do particles hadronize in particle colliders?

What are the values of non-perturbative objects?

What happens to field theories at large temperatures / chemical potential

Simulations of QFTs dual to weakly coupled gravitational theories

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# The QIS community is rapidly advancing to build large quantum systems in laboratory setting

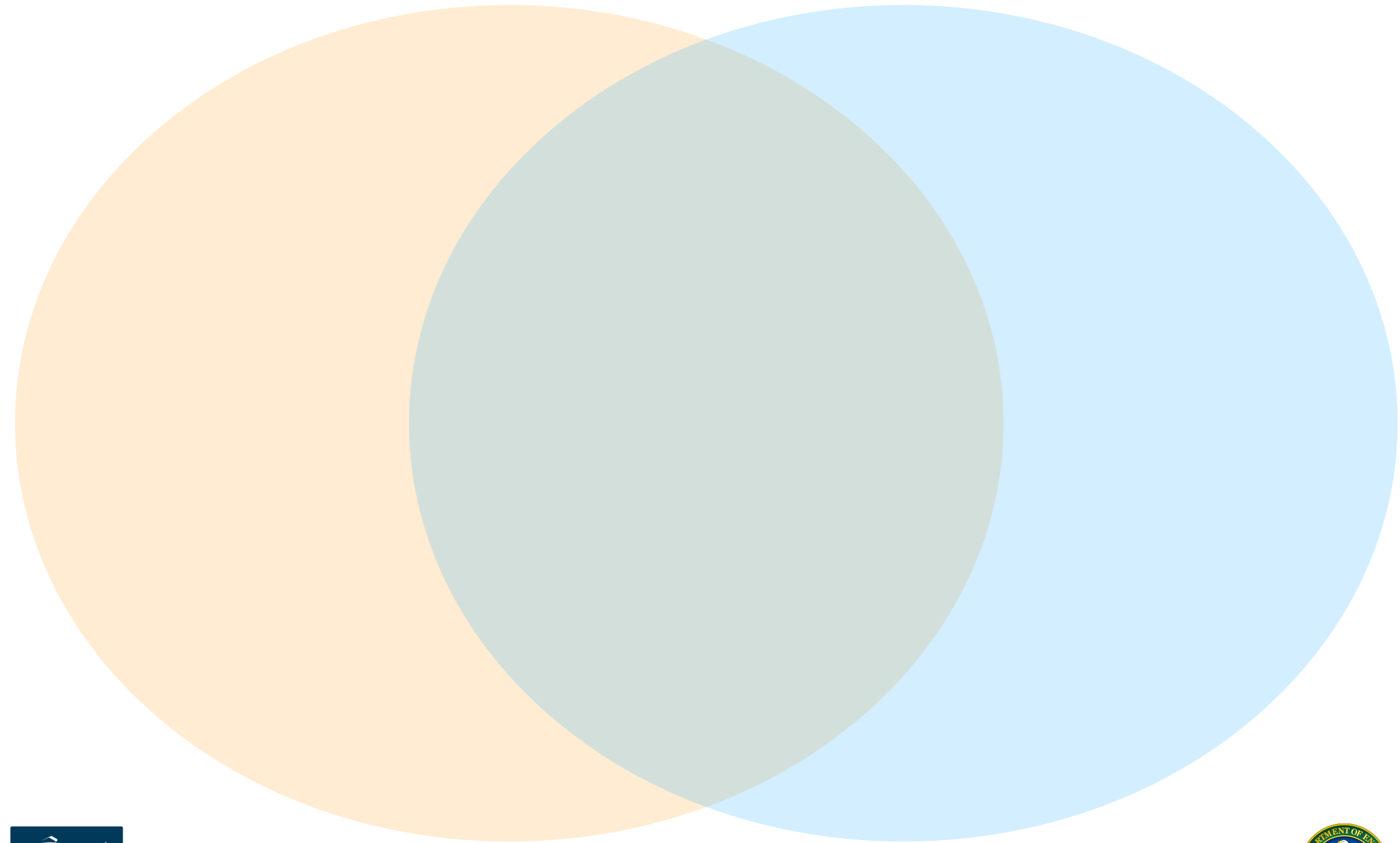
Many different approaches to build such systems (neutral atoms, trapped ions, superconducting circuits, ...)

Enough control to over to program quantum systems

Key problems where quantum computers outperform classical computers

Large community of scientists used to simulating field theories on these devices

# Embracing the QIS within HEP has huge advantages for both fields



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QIS gives new computational tool for numerical control of key questions in HEP





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Provides important benchmark applications and high profile scientific targets to QIS



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QIS gives new computational tool for numerical control of key questions in HEP



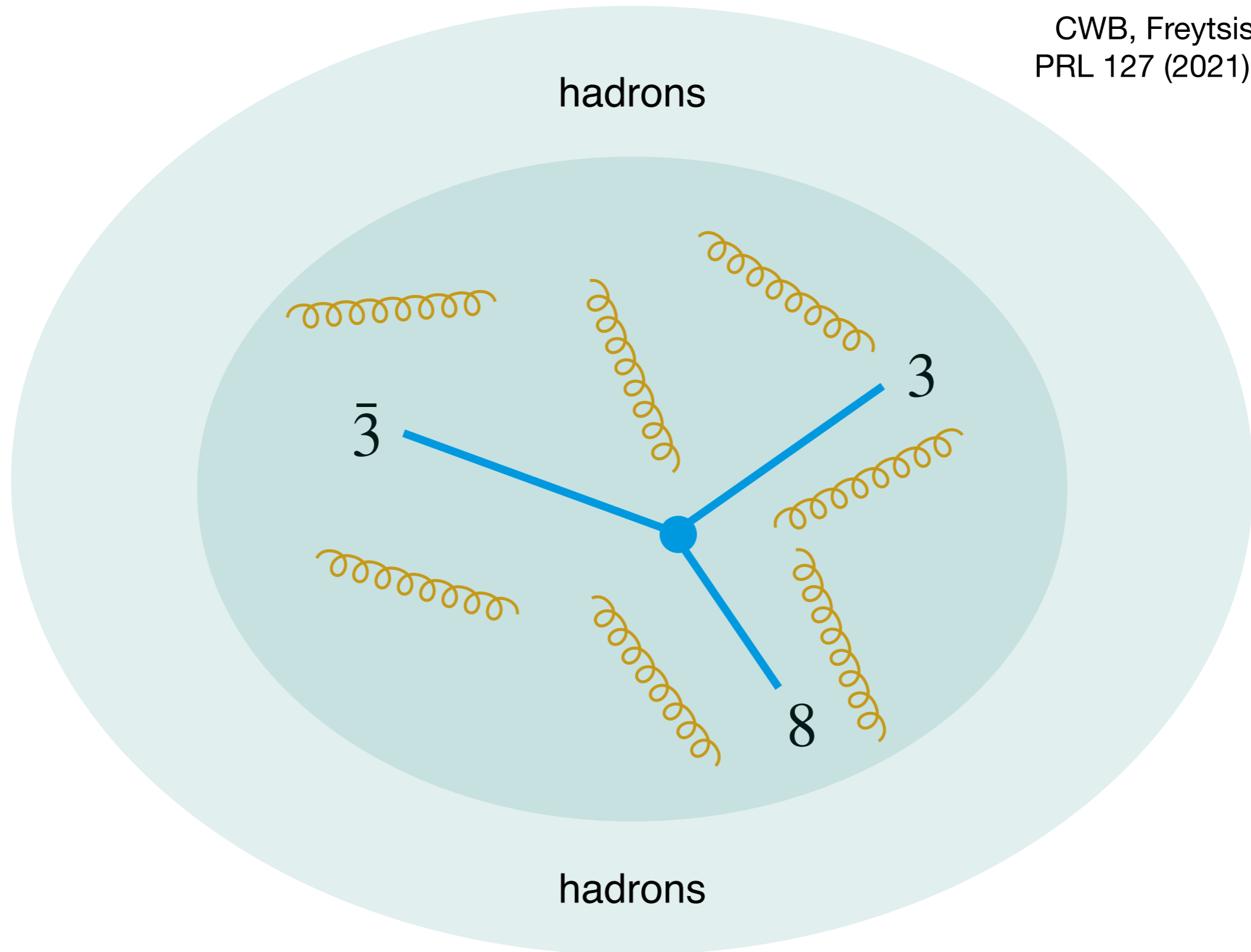
Allows scientists from both fields to learn about QFTs in regimes that have not previously been tackled



Provides important benchmark applications and high profile scientific targets to QIS

# One of things one can compute on quantum computers is soft function describing color reconnection at colliders

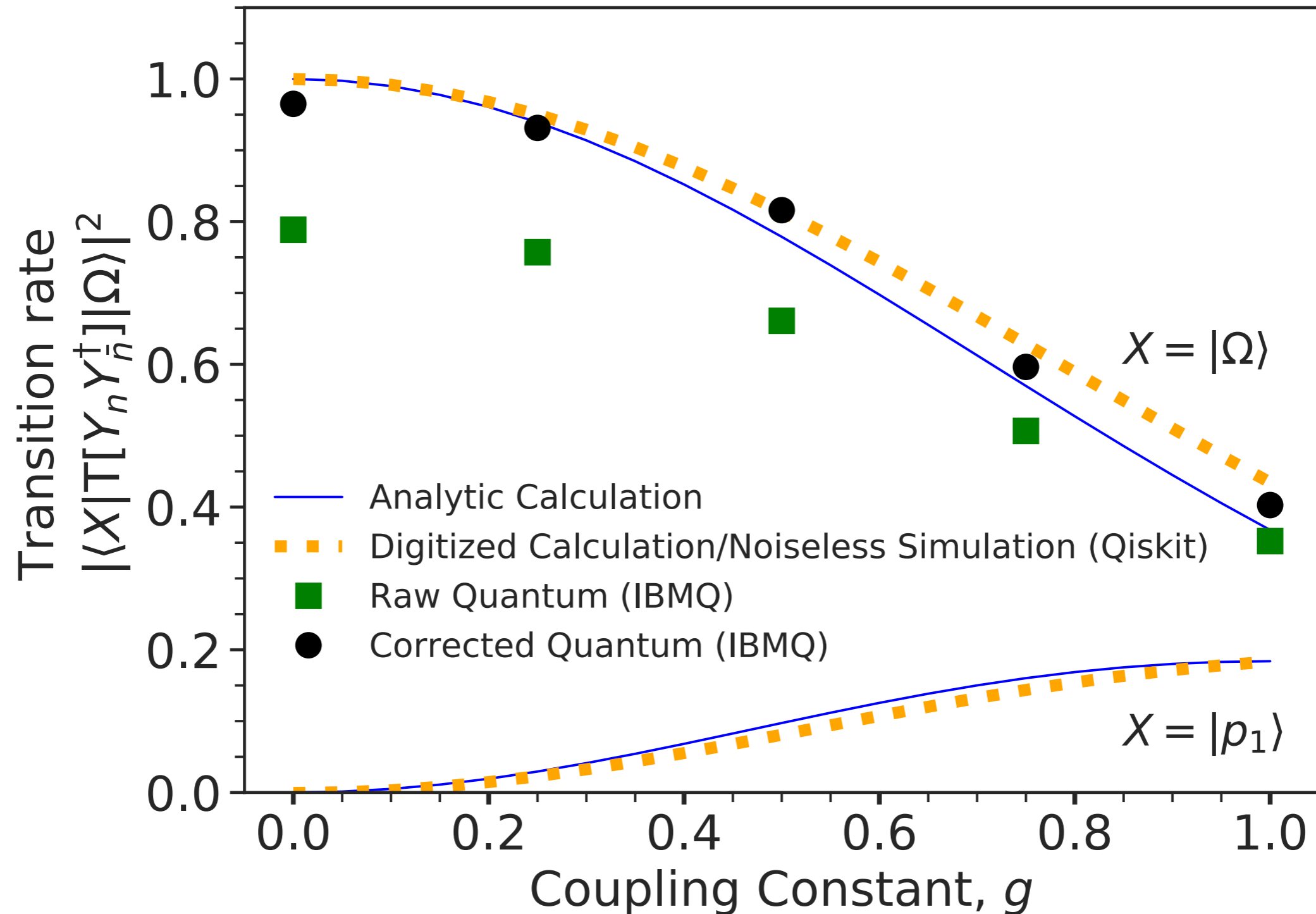
CWB, Freytsis, Nachman,  
PRL 127 (2021) 21, 212001



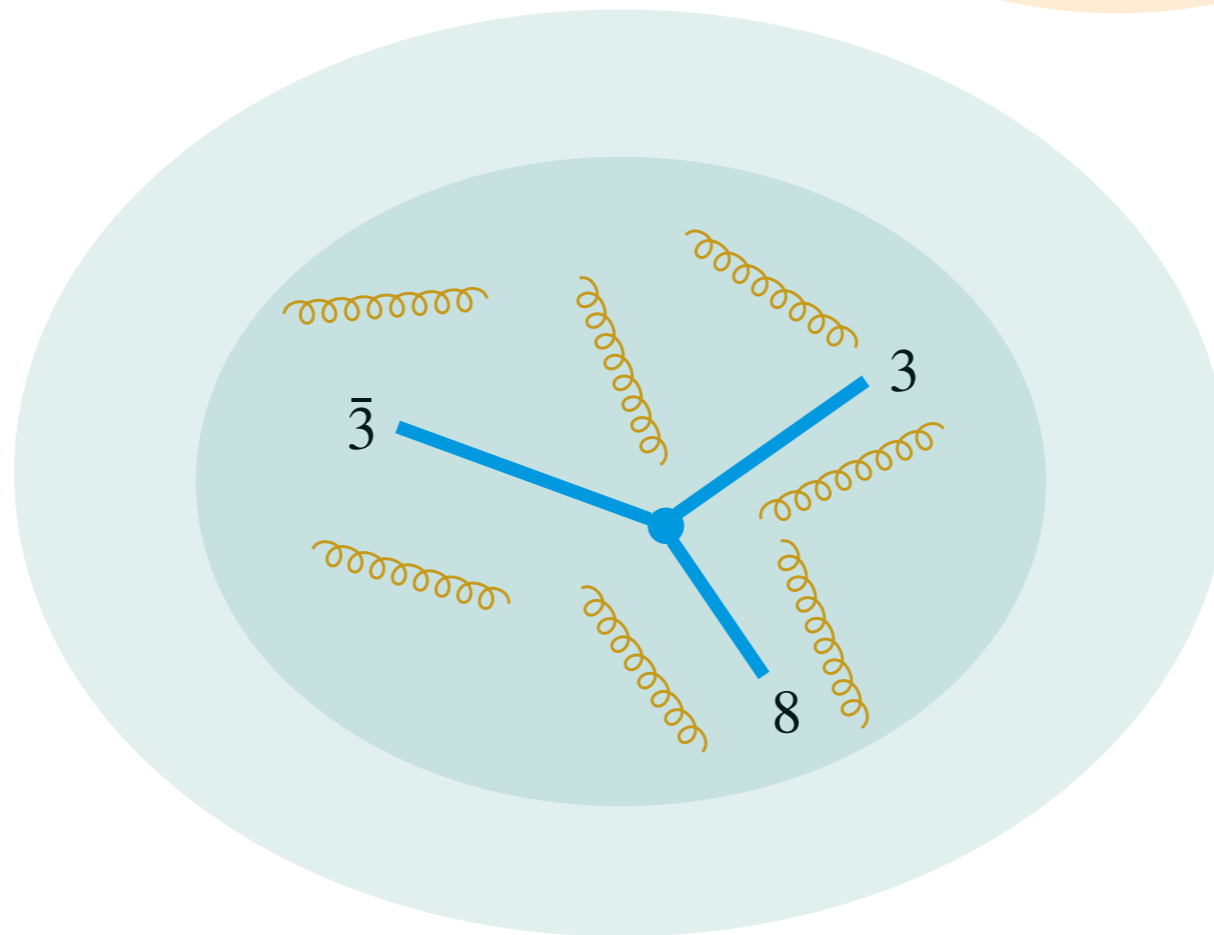
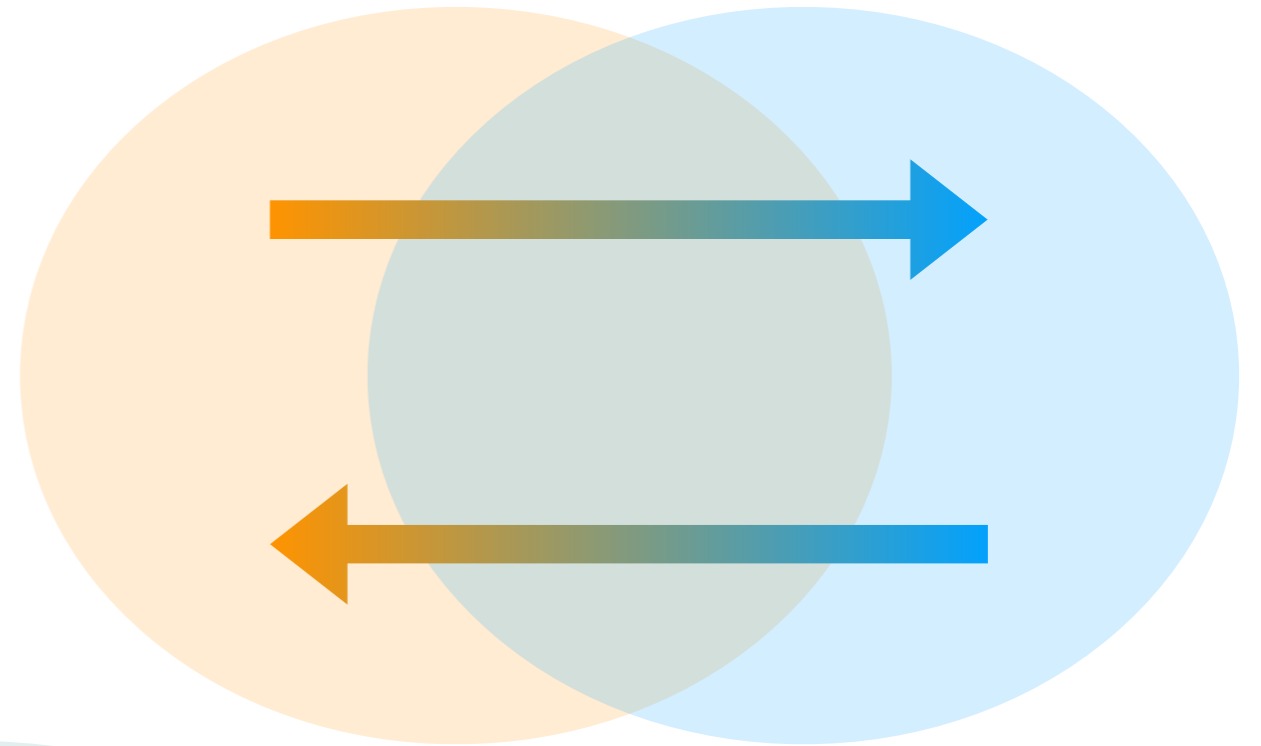
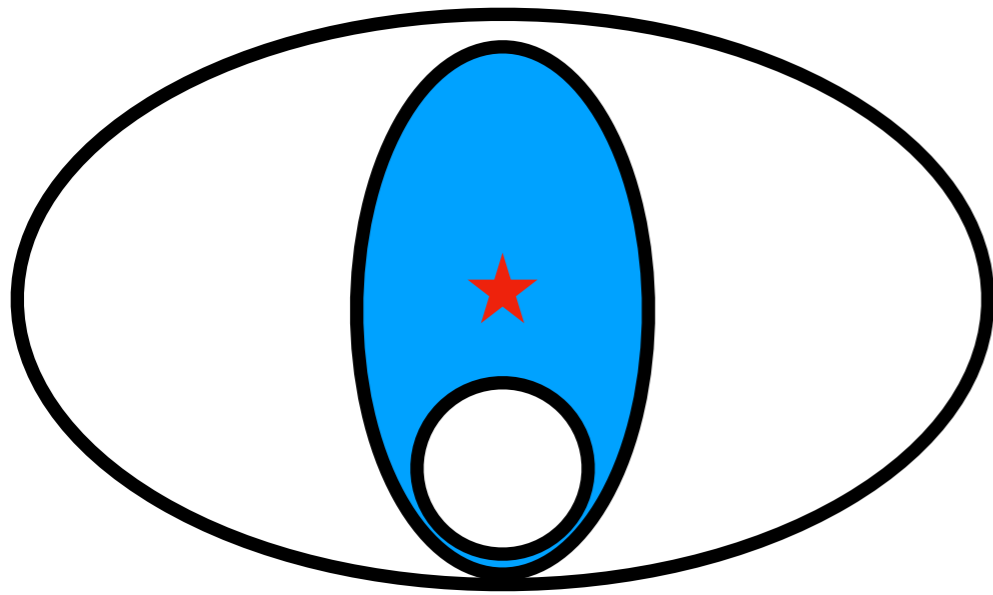
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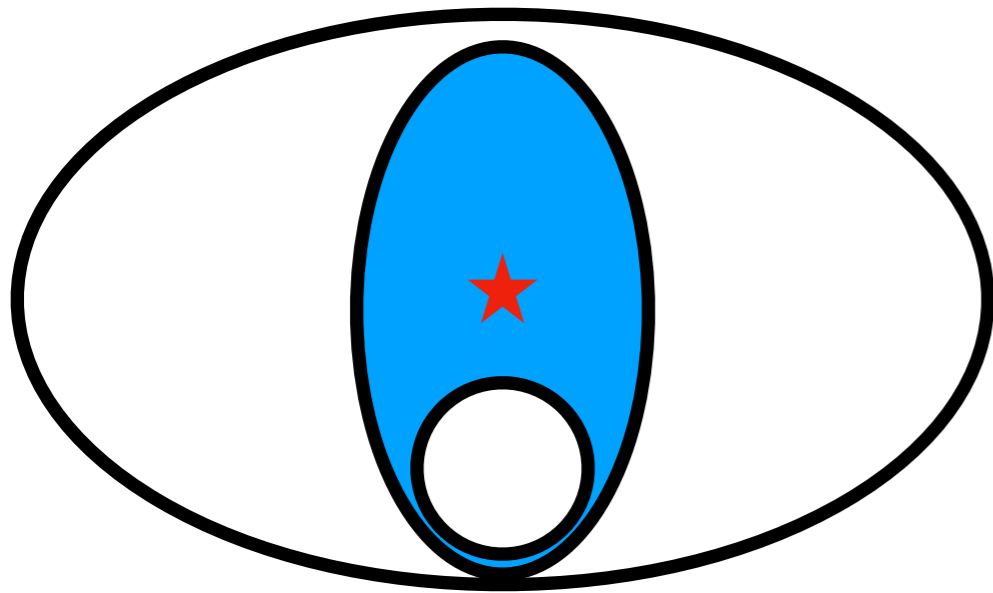
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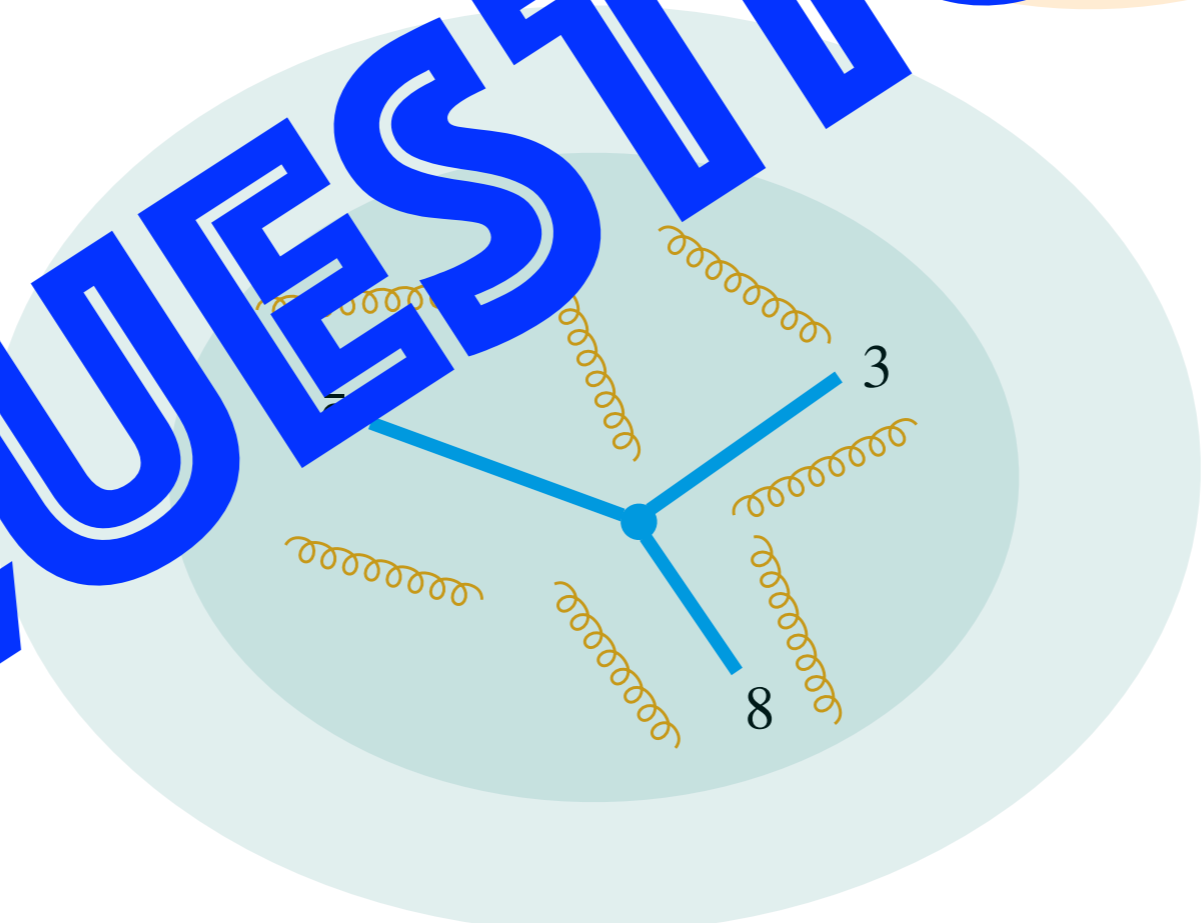
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# QUESTIONS?



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