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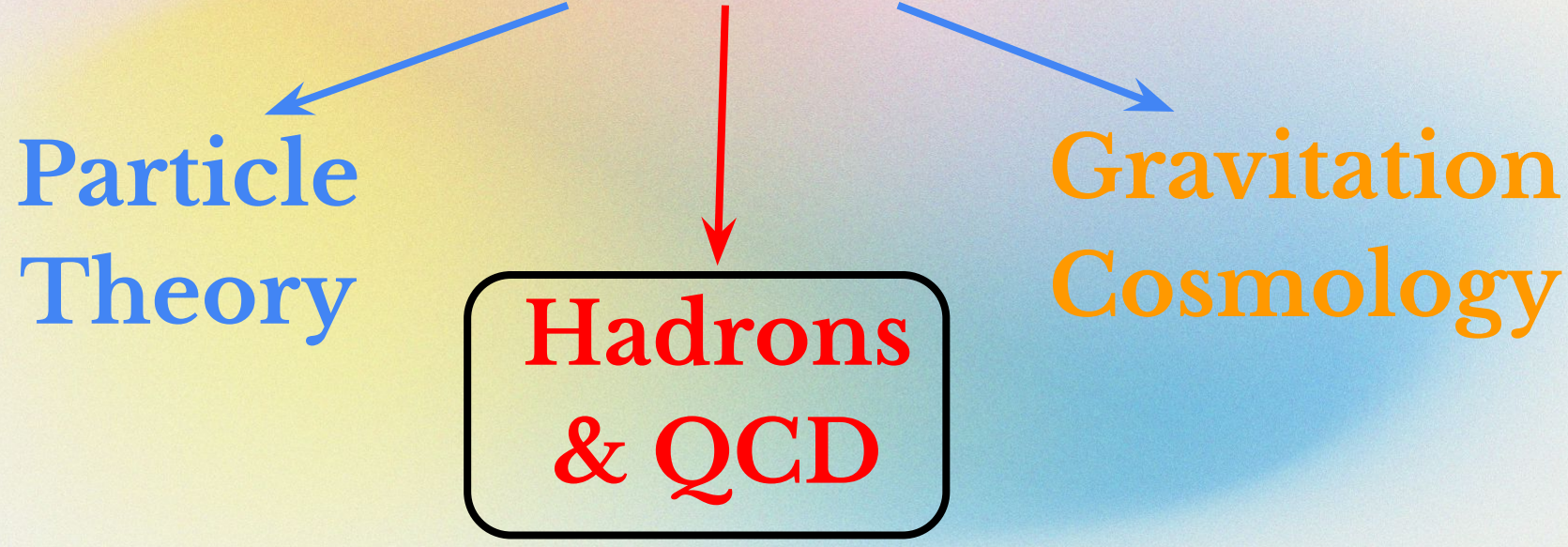
Effective Theory Group



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Hadron theory & QCD

Jose Peláez, Ignazio Scimemi, A. Gomez-Nicola

Clara Peset, Alexey Vladimirov, Andrea Vioque

Jacobo Ruiz de Elvira, Pia Zurita,

Felipe J. Llanes-Estrada

(yours truly)

Antonio Dobado, Juan J. Sanz-Cillero

Spectroscopy

Nucleon structure

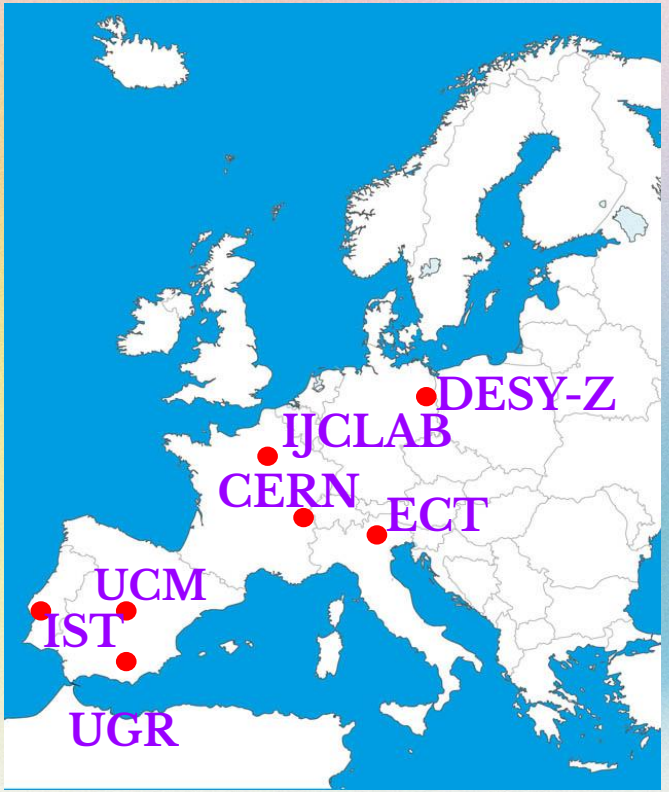
Hadrons in medio

2 Packages in STRONG2020

Analytically continue to...

- TMD Portal
- AI4HSI

Now onto a new initiative



For the 2025 Hadron Infrastructure Proposal

Nantes, July 2nd 2025

HEQUBA

Hadron Enigmas;

Quantum Budgeting and Appraisal

Bringing quantum computing to hadrons

DIS:

Hadrons understandably break apart

A clock jet ???

Thank confinement

Fragmentation function: from screw to clock

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In parton terms

$$\mathbf{d_{(0),h/j}(z)}\,\langle j, p_1 | j, p_2 \rangle$$

$$\equiv \frac{Tr_{\text{color}}}{N_{c,j}} \sum_X \langle j p_1 | h, X_{\text{out}} \rangle \langle h, X_{\text{out}} | j, p_2 \rangle$$

$$\frac{1}{\sigma_0}\frac{d\sigma^h}{dx} =$$

$$\sum_i \int_x^1 \frac{dz}{z} C_i(z, \alpha_s(\mu), q^2/\mu^2) d_i^h(x/z, \mu)$$

Fitted, not calculated

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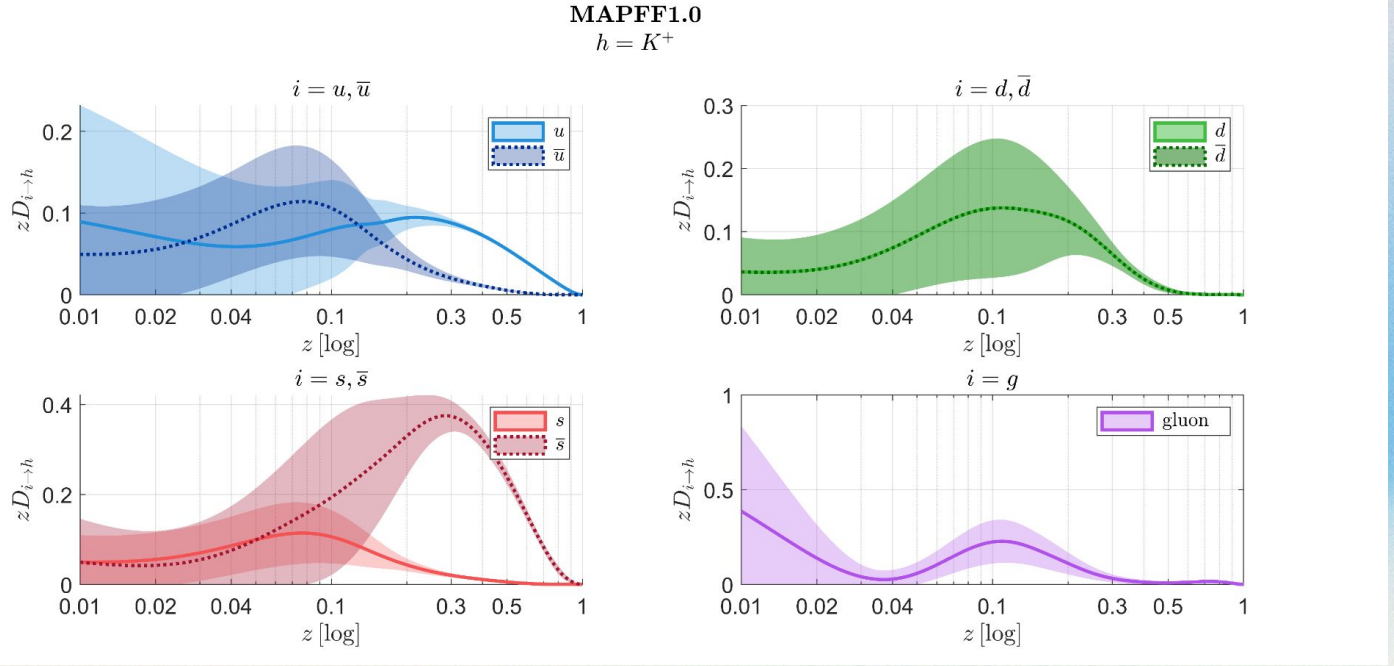
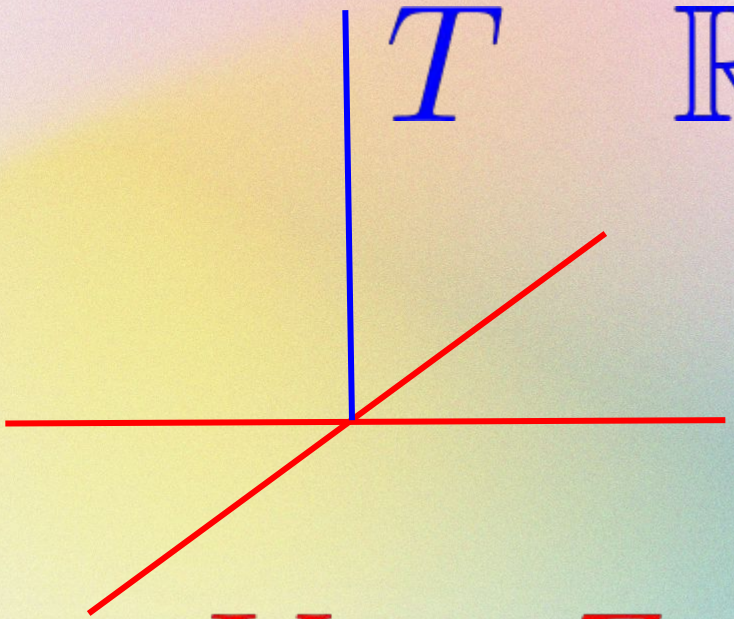


NPA 1036

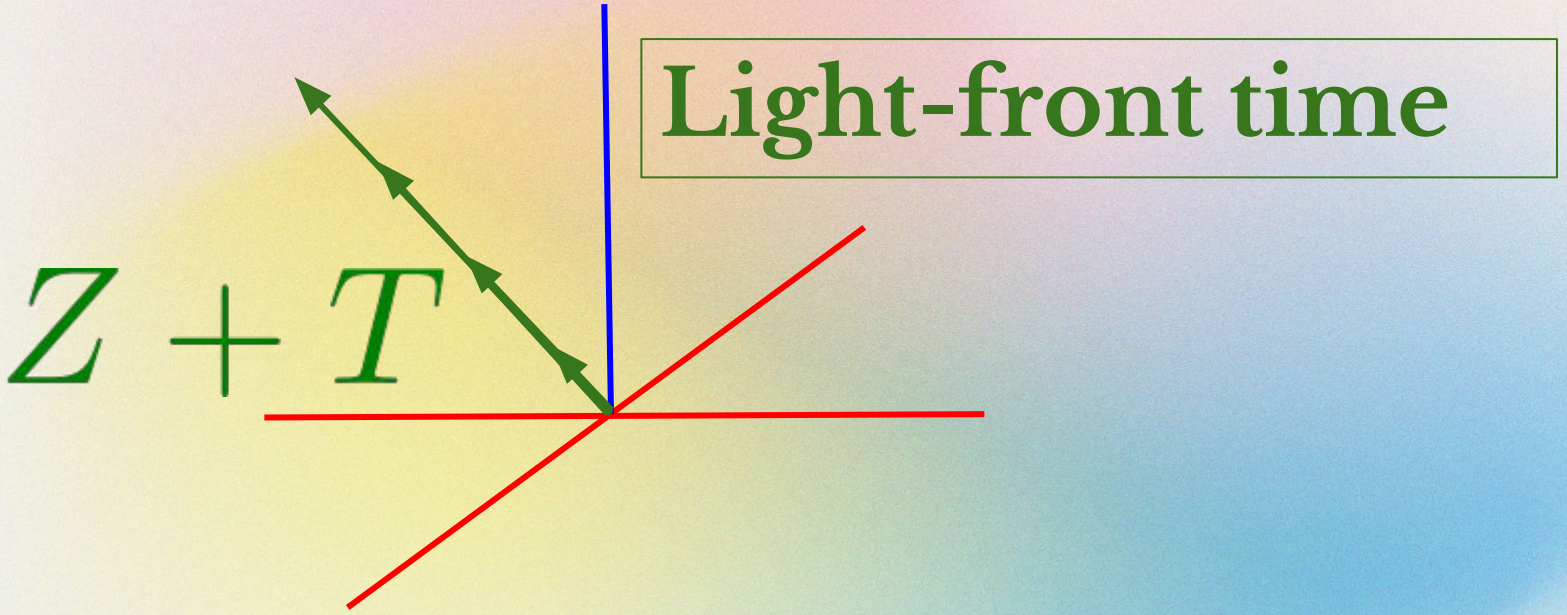
(2023) 122670

Fragmentation functions

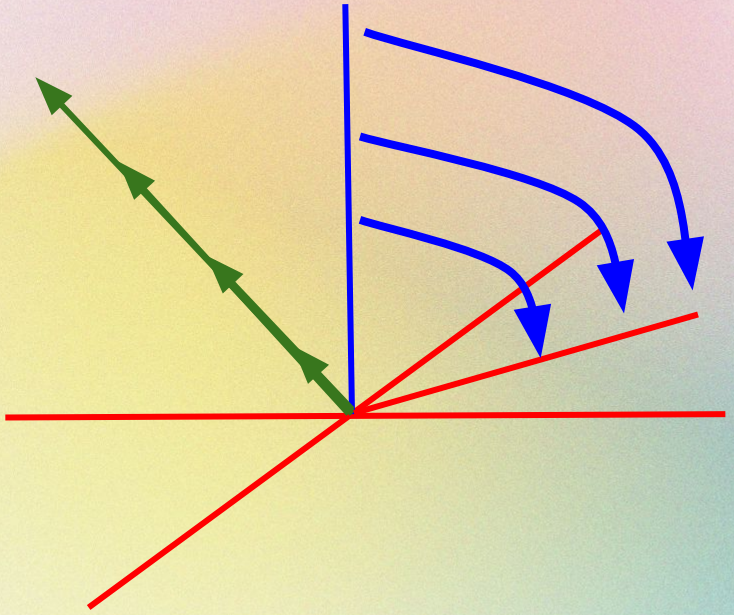


$$X - Y - Z \qquad \mathbb{R}^3$$

Fragmentation functions



Fragmentation functions

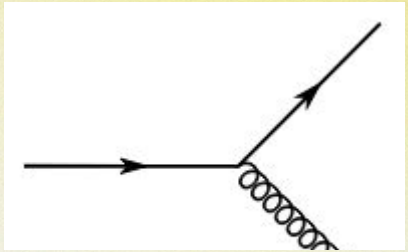


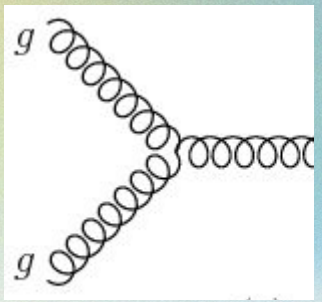
Lattice QCD:

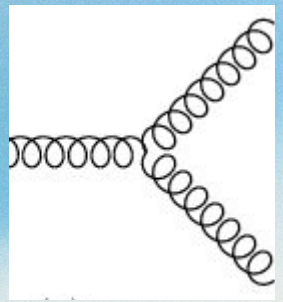
$$\mathbb{R}^4$$

On a quantum computer

$$e^{i(Ht)_{LF}} = \prod \left(e^{-iH_1 \Delta x_+} \cdot e^{-iH_2 \Delta x_+} \cdot e^{-iH_3 \Delta x_+} \ldots \right)$$

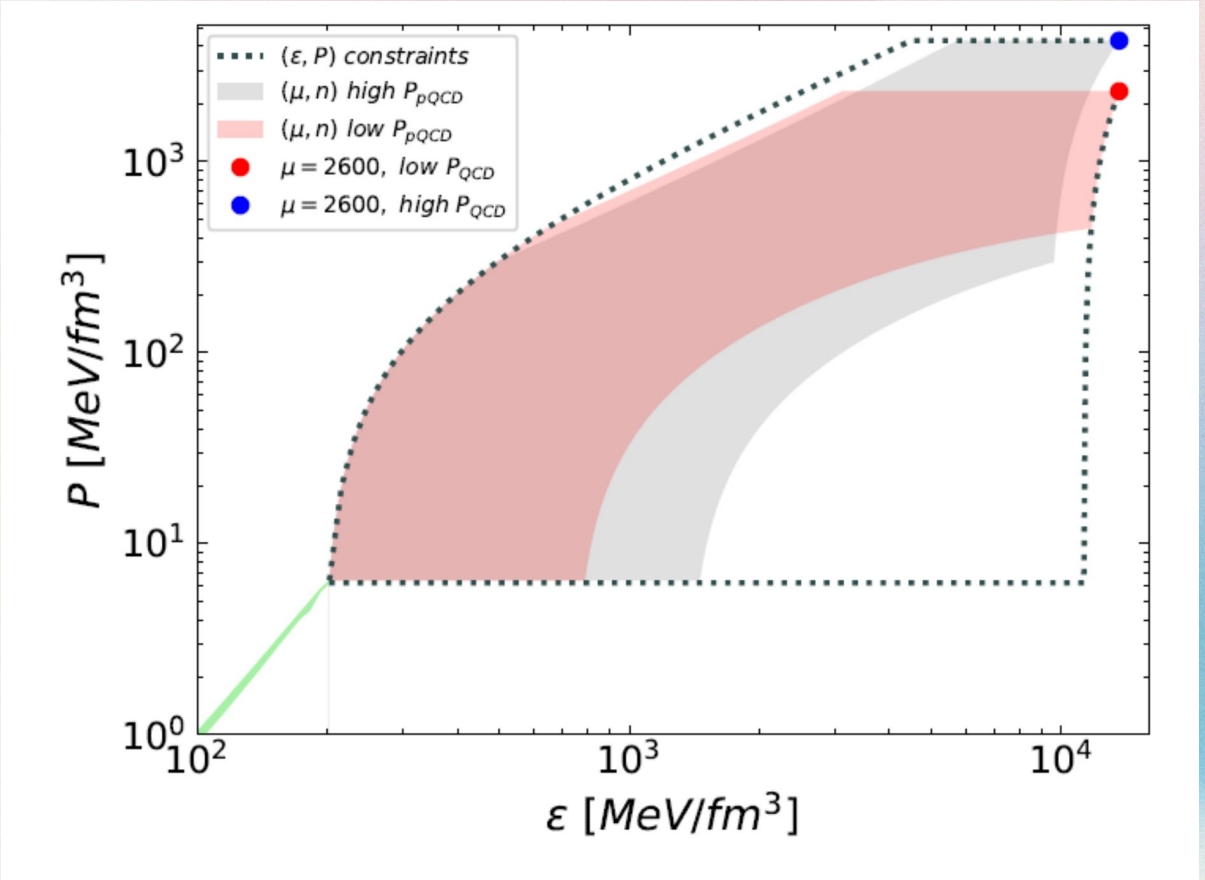






Nuclear and Neutron Star Matter

Equation of state uncertainty



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Nuclear data @ low density,

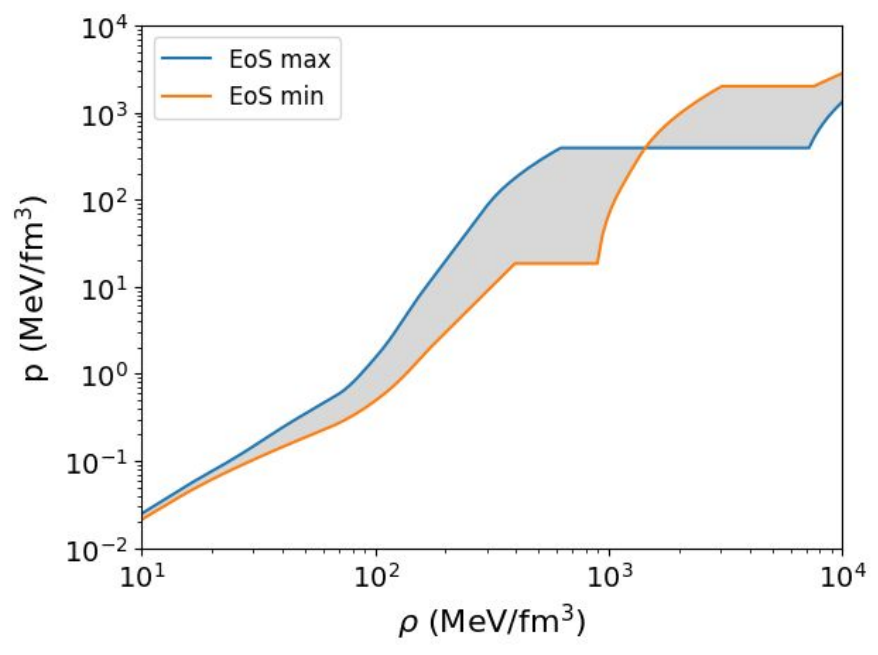
pQCD @ high

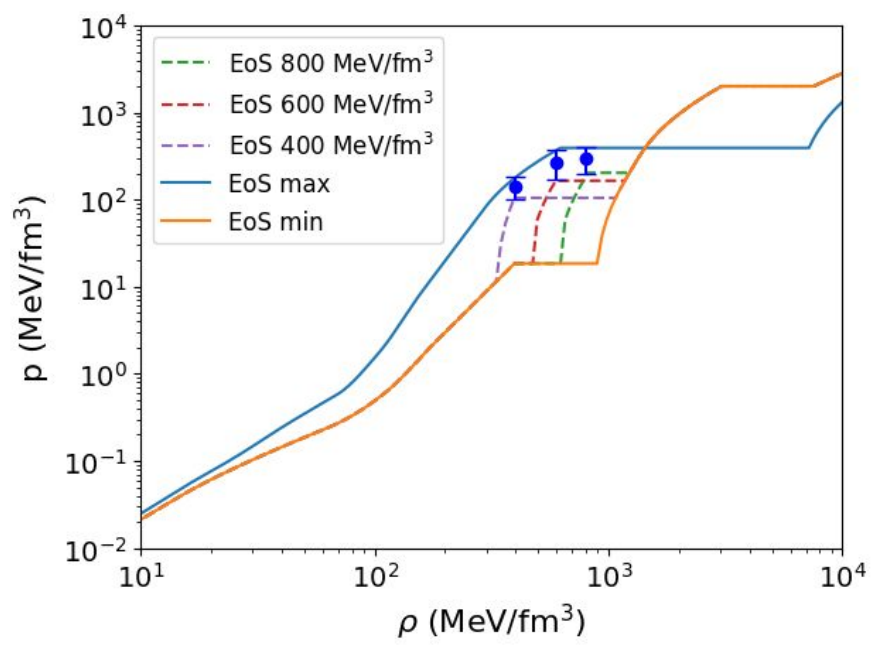
Chiral PT

Causality, Stability

2410.14776 [nucl-th]

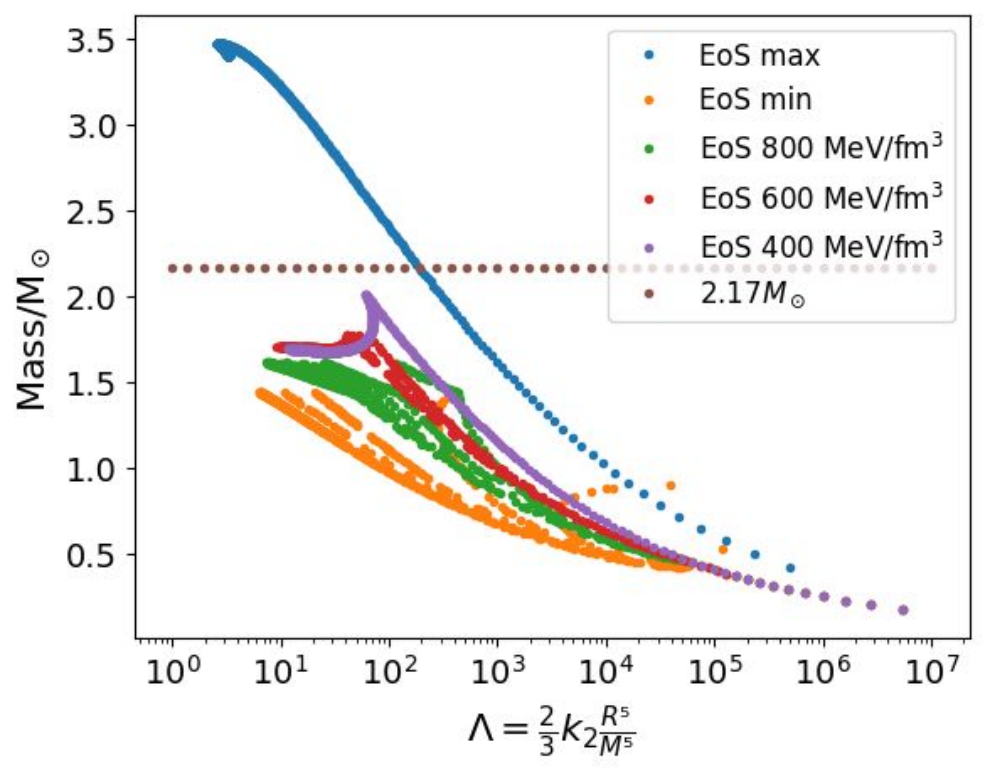
Reduce it with quantum computer?





Courtesy of N.J. de Dios Bilbao

Impact astrophysical observables



No sign problem on a Q. Computer

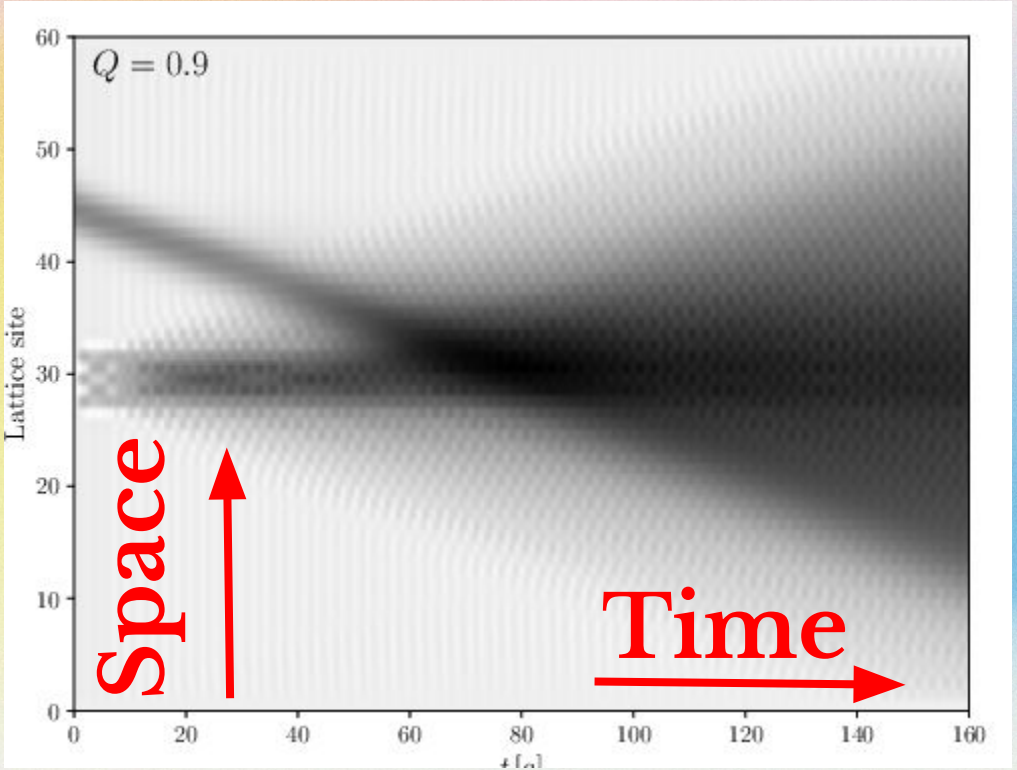
Unlike in conventional lattice

$$Z(\mu_B) = \int \mathcal{D}U \underbrace{\det M(\mu_B, U)}_{\notin \mathbb{R}} e^{-S_g[U}$$

Out of equilibrium systems

E.g. entropy production by a jet

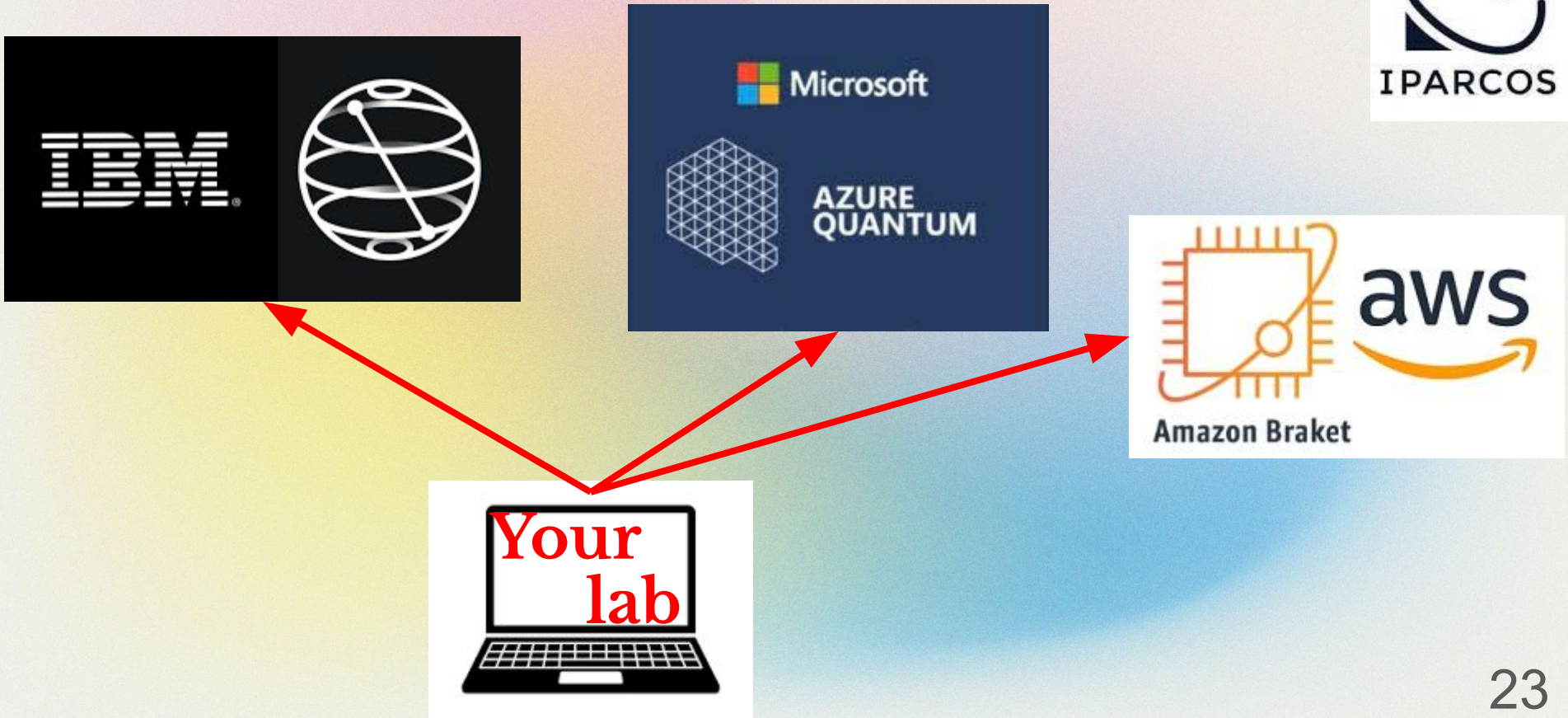
Jet
+
Medium



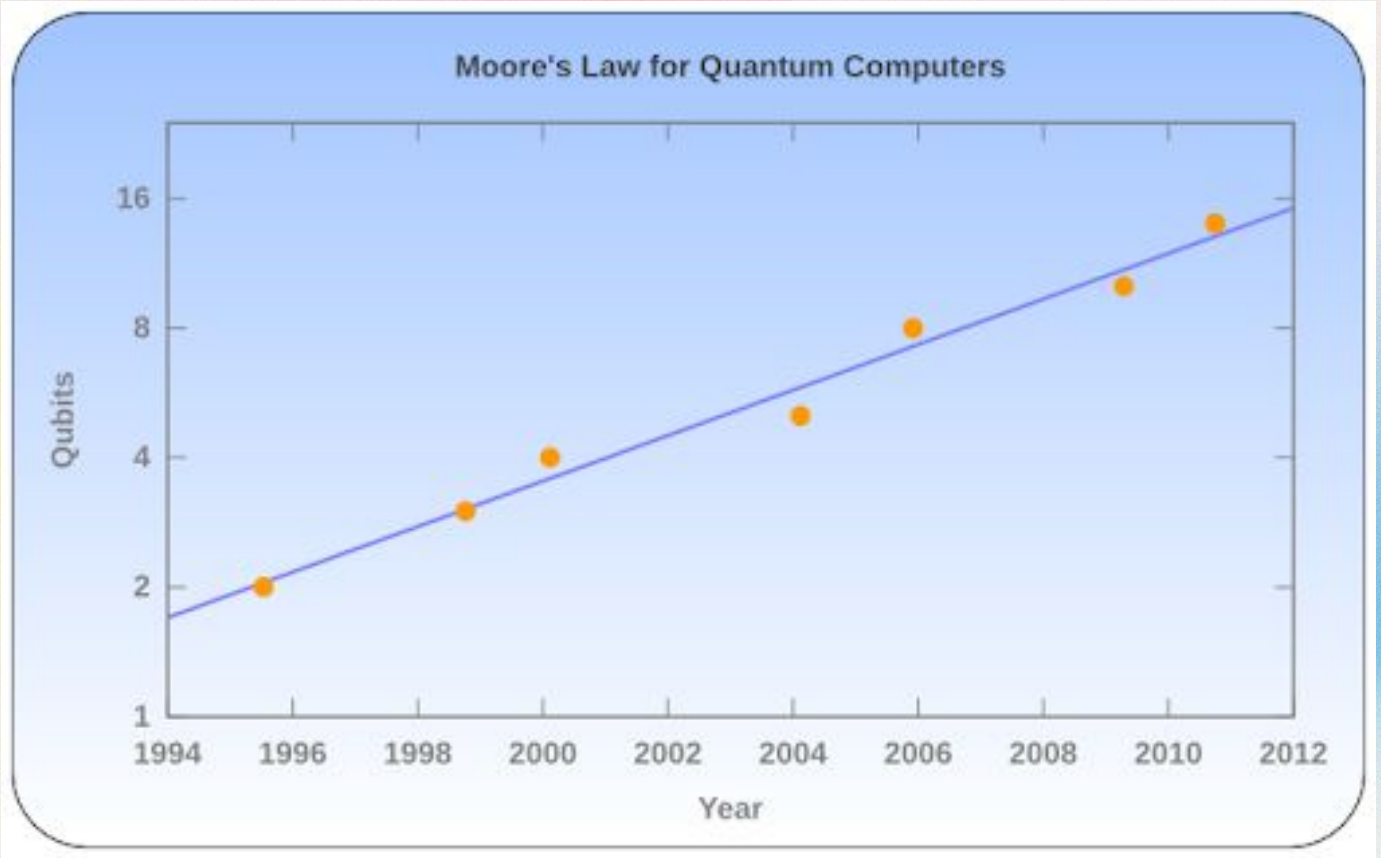
Schwinger Model
Barata & Rico
2502.17558

Quantum Computer? What Quantum Computer?

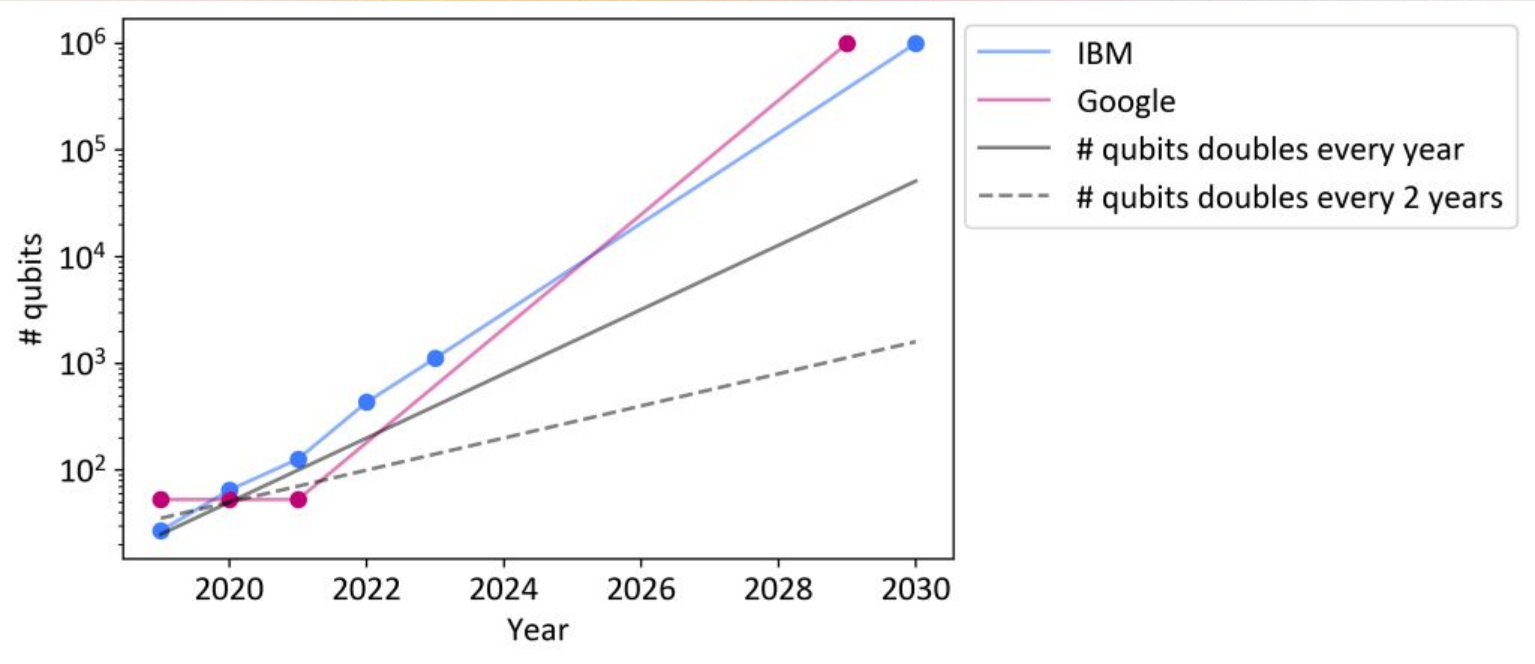
A case for Virtual Access



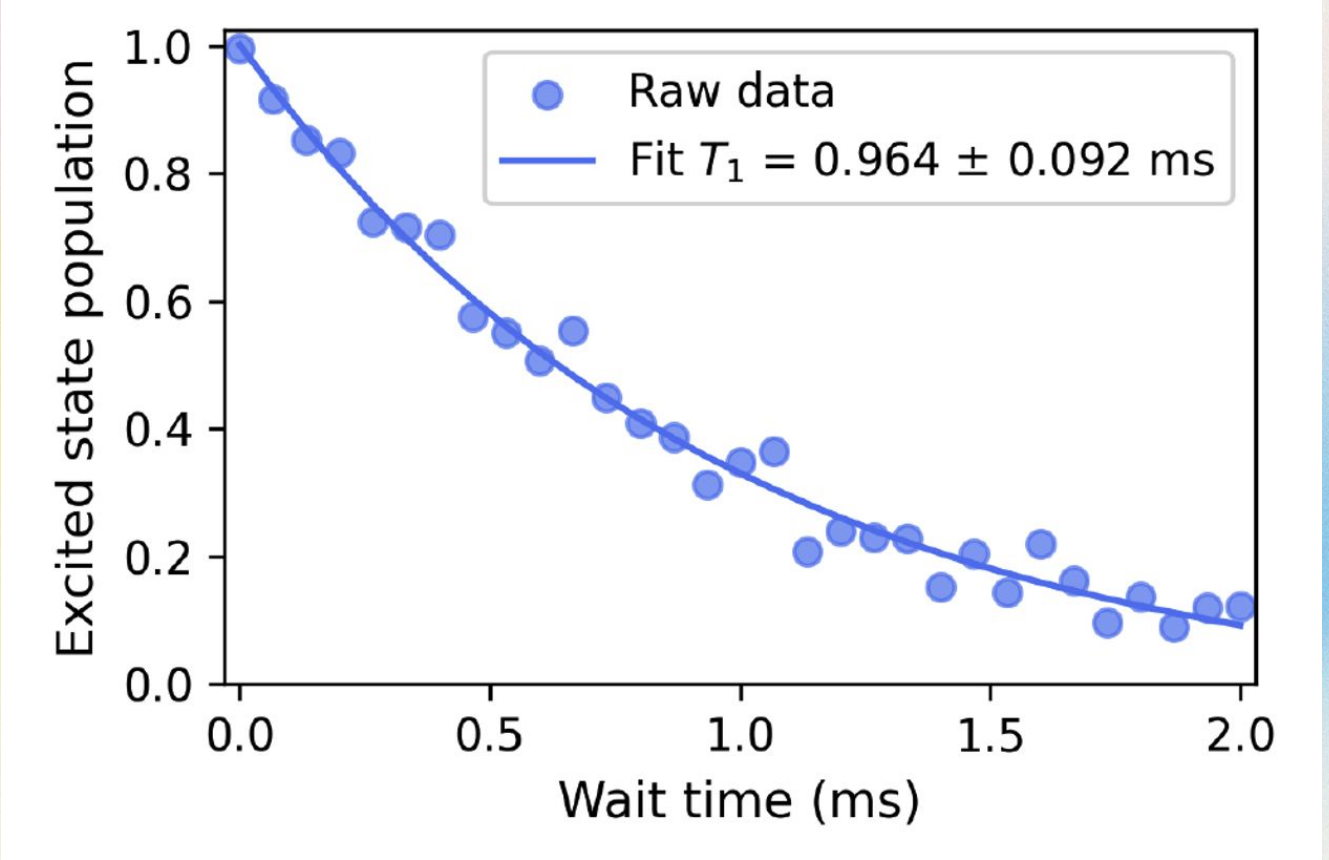
When in practice?



When in practice?



Decoherence



- Current calculations not really advantageous
- Need 5-10 years
- Prepare our field: budget & appraise quantum techniques

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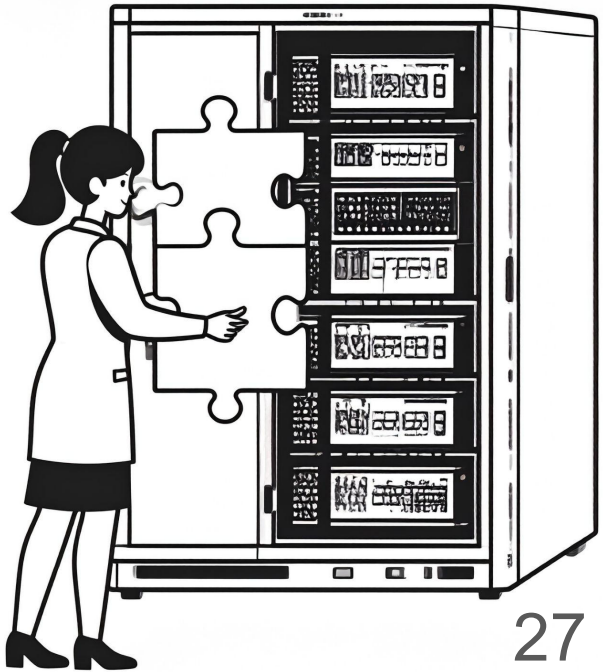

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HEQUBA: current budget

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200k euro in **personnel** costs: Postdoc / Instructor

50k euro in **travel and networking** costs (assistance for two workshops)

(depending on final number of participant institutes)

20k euro in small **hardware**

30k in **external** provision of cloud **computing**

300k euro total (3% of the overall grant)

Currently interested parties...

Institution	Geographical location	Contact members	Additional collaborators
Conseil Européen pour la Recherche Nucléaire CERN	Geneva, Switzerland	Sofia Vallecorsa	Enrique Rico Ortega, Joachim Kopp
Deutsches Elektron Synchrotron	Zeuthen, Germany	Stefan Kühn	Karl Jansen
European Center for Theoretical Nuclear Physics and Related Areas ECT* and U. Trento	Trento, Italy	Alessandro Roggero	Daniele Binosi
Instituto Superior Técnico (of the University of Lisbon)	Lisbon, Portugal	Joao Seixas	Yasser Omar (pending)
Laboratoire de physique des deux infinis Irène Joliot-Curie (IJCLab), Paris-Saclay University	Orsay, France	Denis Lacroix	
Universidad Complutense de Madrid	Madrid, Spain	Felipe J. Llanes Estrada	Pia Zurita
Universidad de Granada	Granada, Spain	María Gómez Rocha	Juan Carlos Criado, Lorenzo Luis Salcedo

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If a WP goes forward, open for signups

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