

Hauptseminar II
Quantum Information Processing:
Principles and physical platforms

WS 2022/23

Michael Fleischhauer

Goals of the seminar:

- Learn how to **inform** yourself about a specific research subject from original literature
- Learn how to **prepare** a presentation on the subject
- Practice to give a **talk** and answer questions in the subsequent discussion

Rules:

- Active participation in all seminar talks; in person (unless in quarantine)
- Preparation of talk from given literature & own literature search
- Presentation of scientific talk (35 – 45 min) (english preferred)
- Subsequent scientific discussion (15 – 30 min)
- Oral & written feedback about presentation (15 min)

1. Inform yourself about the subject

- Start reading given material approx. 4 weeks before presentation !
- Additional sources or if no material given:
 - Review articles / thesis are a good starting point
 - Wikipedia good for more general subjects; beware: can be biased if topic is more specialized
 - Google scholar; web of Science; Scopus
- Discuss / ask supervisor or colleagues

- The more prepared you are the more confident you'll be !
- Always know much more than you actually talk about!



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Artikel Diskussion

Lesen

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Quelltext bearbeiten

Versionsgeschichte

Wikipedia durchsuchen



Quantencomputer

Ein **Quantenprozessor** bzw. **Quantencomputer** ist ein **Prozessor**, der die Gesetze der **Quantenmechanik** nutzt. Im Unterschied zum klassischen **Computer** arbeitet er nicht auf der Basis **elektrischer**, sondern quantenmechanischer Zustände. Hierbei sind erstens das **Superpositionsprinzip** (d. h. die quantenmechanische **Kohärenz**, analog zu den Kohärenzeffekten, siehe z. B. **Holographie**, in der sonst inkohärenten **Optik**) und zweitens die **Quantenverschränkung** von Bedeutung.

Theoretische Studien zeigen, dass unter Ausnutzung dieser Effekte bestimmte Probleme der Informatik, z. B. die Suche in extrem großen **Datenbanken** (siehe **Grover-Algorithmus**) und die **Faktorisierung** großer Zahlen (siehe **Shor-Algorithmus**) effizienter gelöst werden können als mit klassischen Computern. Dies würde es ermöglichen, die Berechnungszeit für viele mathematische und physikalische Problemstellungen deutlich zu verringern.

Der Quantencomputer war lange ein überwiegend theoretisches Konzept. Es gab verschiedene Vorschläge, wie ein Quantencomputer realisiert werden könnte, in kleinem Maßstab wurden einige dieser Konzepte im Labor erprobt und Quantencomputer mit wenigen **Qubits** realisiert. Der Rekord lag im November 2021 bei 127 Qubits für den Prozessor.^[1] Neben der Anzahl der Qubits ist aber auch zum Beispiel eine geringe Fehlerquote beim Rechnen und Auslesen wichtig und wie lange die Zustände in den Qubits fehlerfrei aufrechterhalten werden können.

Seit 2018 investieren viele Regierungen und Forschungsorganisationen sowie große Computer- und Technologiefirmen weltweit in die Entwicklung von Quantencomputern, die von vielen als eine der entstehenden **Schlüsseltechnologien** des 21. Jahrhunderts angesehen werden.^{[2][3][4]}

Inhaltsverzeichnis [Verbergen]

- 1 Mögliche Anwendungsgebiete
- 2 Technologie

Google Scholar

quantum computer



Artikel

Ungefähr 169.000 Ergebnisse (0,09 Sek.)

Beliebige Zeit

Seit 2022

Seit 2021

Seit 2018

Zeitraum wählen...

Nach Relevanz
sortieren

Nach Datum sortieren

Beliebige Sprache

Seiten auf Deutsch

Alle Typen

Übersichtsarbeiten

Alert erstellen

The universe as quantum computer

S Lloyd - *A Computable Universe: Understanding and exploring ...*, 2013 - World Scientific

... giant **computer**, and if so, just what kind of **computer** it is. I will show that the universe can be regarded as a giant **quantum computer**. ... In particular, the model shows that the the **quantum** ...

☆ Speichern 99 Zitieren Zitiert von: 104 Ähnliche Artikel Alle 14 Versionen

[PDF] arxiv.org

[HTML] Architecture for a large-scale ion-trap quantum computer

D Kielpinski, C Monroe, DJ Wineland - *Nature*, 2002 - nature.com

... communication to link a number of small ion-trap **quantum** systems. Developing the ... **quantum computer**, based on **techniques** already demonstrated for manipulating small **quantum** ...

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[HTML] nature.com

Full View

Quantum machine learning with D-wave quantum computer

F Hu, BN Wang, N Wang, C Wang - *Quantum Engineering*, 2019 - Wiley Online Library

... principle and **quantum** computing models of the **quantum computer**. ... to **quantum** spin models and the QA-based **quantum** ... the **quantum** annealer and further analyzes the prospects of ...

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[PDF] wiley.com

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Year ▲

- ☐ 2023 (8) ▶
- ☐ 2022 (2,229) ▶
- ☐ 2021 (2,745) ▶
- ☐ 2020 (2,635) ▶

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	Document title	Authors	Year	Source	Cited by
☐ 1	Quantum entanglement Open Access	Horodecki, R., Horodecki, P., Horodecki, M., Horodecki, K.	2009	Reviews of Modern Physics 81(2), pp. 865-942	5927
	View abstract View at Publisher Related documents				
☐ 2	Quantum Phase Transitions (Book) Open Access	Sachdev, S.	2011	Quantum Phase Transitions 9780521514682, pp. 1-501	5699
	View abstract View at Publisher Related documents				
☐ 3	Computable measure of entanglement Open Access	Vidal, G., Werner, R.F.	2002	Physical Review A - Atomic, Molecular, and Optical Physics 65(3),032314, pp. 1-11	3276
	View abstract View at Publisher Related documents				

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Search v0.5.6 released 2020-02-24 Feedback?

quantum AND computer

Abstract

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Next

1. arXiv:2210.02455 [pdf, other] hep-ph hep-lat nucl-th

Form factor and model dependence in neutrino-nucleus cross section predictions

Authors: Daniel Simons, Noah Steinberg, Alessandro Lovato, Yannick Meurice, Noemi Rocco, Michael Wagman

Abstract: ...the nuclear many-body problem and in the determination of the single- and few-nucleon quantities taken as input by many-body methods. To quantify both types of uncertainty, we compute flux-averaged double-differential cross sections using the Green's function Monte Carlo and spectral function methods as well as different parameterizations of the nucleon...

More

Submitted 5 October, 2022; originally announced October 2022.

Comments: 20 pages, 10 figures

Report number: FERMILAB-PUB-22-745-T

2. arXiv:2210.03077 [pdf, other] cond-mat.mes-hall

Bayesian autotuning of Hubbard model quantum simulators

Authors: Ludmila Szulakowska, Jun Dai

Abstract: Spins in gated semiconductor quantum dots (QDs) are a promising platform for Hubbard model simulation inaccessible to... More

Submitted 6 October, 2022; originally announced October 2022.

Comments: 11 pages, 9 figures

2. Prepare your presentation

step 1: identify your audience

step 2: determine how much time you have

step 3: identify the main points you want to convey
(2-3 main points in a 20 – 30 min talk)

step 4: create an outline of your talk

step 5: prepare slides (and backup slides)

step 6: practice, practice, practice !!

2. Prepare your presentation

Organizing a 30 min talk ?

no unique recipe (depends on what type: short / long talk; colloquium)

I. Background & Introduction

- Title slide
- Outline slide (can be skipped in short talk)
- Overview slide (if appropriate) *why is research important ?*
- 1-2 Background slides (if appropriate) *provides background for non-experts*

II. Main body of talk

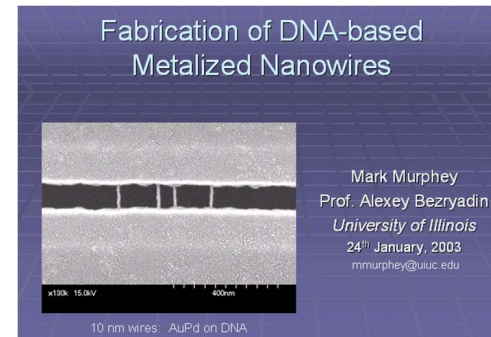
III. Summary

- Summary of key points (2-4 for 20 – 30 min talk)
- Acknowledgement *sources; people involved; funding sources*

The title slide and outline prepares the audience to listen and shows organization of talk

Title slide

Your names and affiliations
Paper citation (for JC)
Venue and date
Attention-getting graphic



Outline or overview of presentation

Prepares the audience to listen
Provides a logical structure for your talk
Provides motivation and context
Summarizes key points (limit to two or three for a 20- to 30-minute talk)

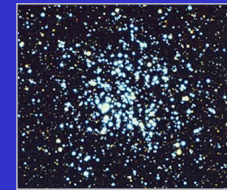


5

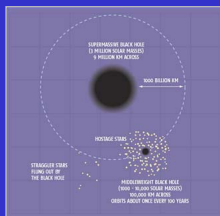
Overview



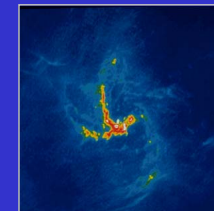
Black holes and star clusters



The galactic center



Intermediate-mass black hole kinematics



Here, we have a **VISUAL** and **WRITTEN** outline and it's not too long !

The “body” of your presentation is the intellectual content of your talk

**Problem statement,
motivation**

~1–2 slides

Previous work

~1-2 slides

Methods

~1–3 slides

Key Results

~5–6 slides

What's this all about?

- **Quark Gluon Plasma (QGP)**
 - hypothesized state of deconfined quarks and gluons
 - expected in the early universe, big-bang stage



– this represents a phase change

– like “melting” a nucleus

pp vs A-A collisions

hard-scattered particles vs soft-scattered particles

cone of hadrons

gluon radiation

hadron distribution softened, broadened?

Energy loss: increased medium-induced gluon radiation

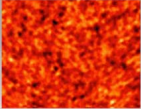
High p_T

- Hard-scattering occurs at earliest times during a high-energy nuclear collision
 - well before QGP is expected to form (equilibrate)
- These “fast” scatterers will experience the strongly interacting medium created in the collision.
- They will lose energy in the hot, dense medium (by *gluon bremsstrahlung*) and their outgoing energy distribution will be modified downward
- Net effect, depletion in yield of high p_T particles compared to p-p case
- The game is then to make the comparison



Provide a “summary” slide

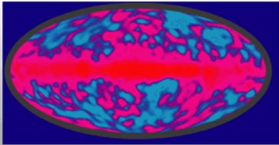
Recap key results and conclusions
Reiterate main critiques (for JC)



Summary

- Non-Gaussianity in the CMB tells about creation of the initial density perturbations in the universe.
- The probability distribution of the nonlinear parameter in our model gives drastically improved constraints on non-Gaussianity.

Next: generalize our method to smaller scale fluctuations and apply to COBE and MAP data



Contact: Michael Schneider mdschnei@uiuc.edu

This slide will probably stay on the screen during the question period and will thus get the longest audience exposure—make it count!



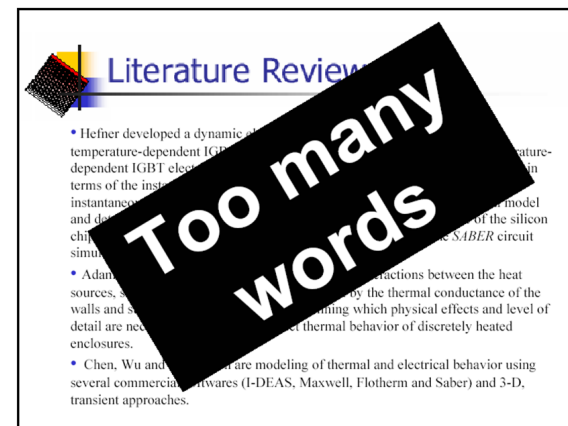
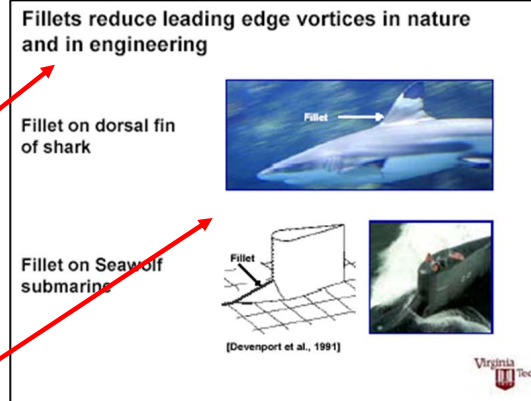
Tips for preparing slides

Have only 1 idea per slide

Use the header to state the main idea of the slide, and use the body of the slide to support that idea

Use well-labeled graphs and figures to illustrate your key points this makes the slide more real and interesting to the audience

Avoid too much text



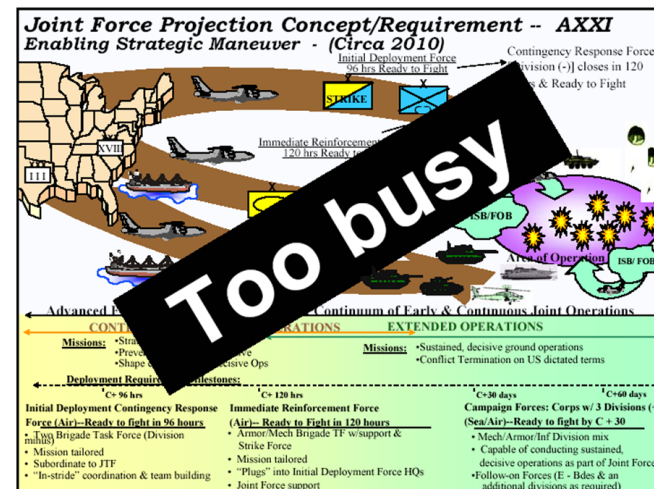
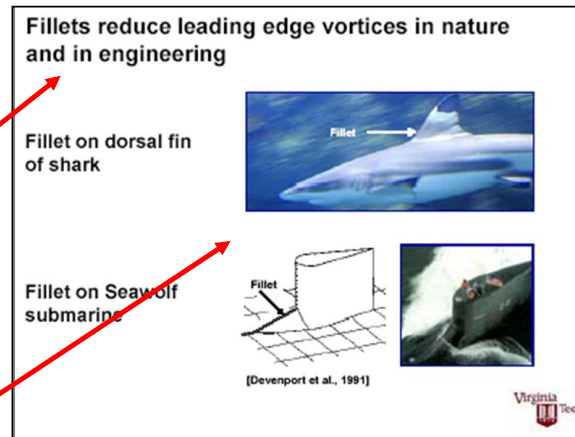
Tips for preparing slides

Have only 1 idea per slide

Use the header to state the main idea of the slide, and use the body of the slide to support that idea

Use well-labeled graphs and figures to illustrate your key points this makes the slide more real and interesting to the audience

or too many distracting images

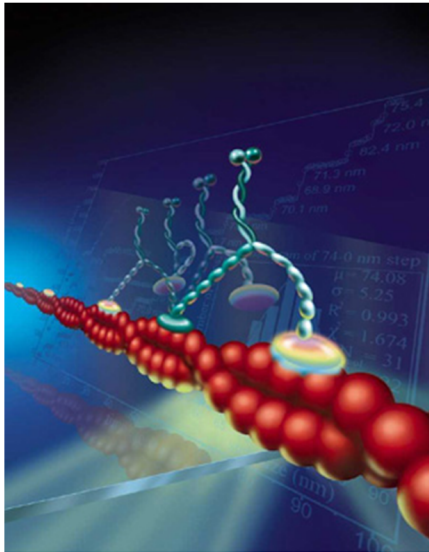


Tips for preparing slides

Use figures to illustrate your key points

Figures:

- enliven slides
- promote audience interest
- provide supporting evidence for key points
- help explain complex ideas and relationships quickly
- show how things work, etc.



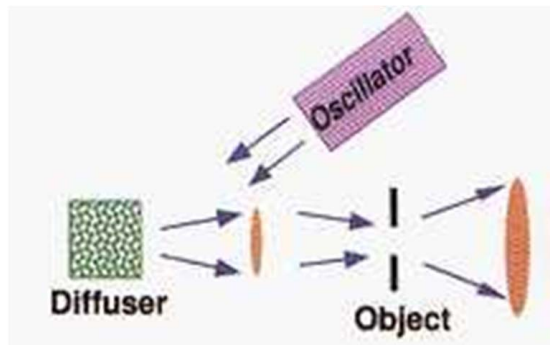
Myosin “walking” on actin
Courtesy of P. Selvin



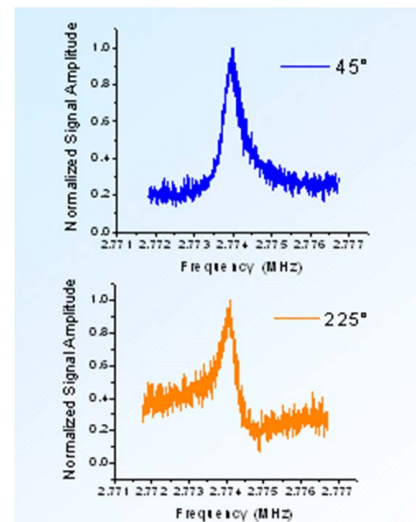
Tips for preparing slides

Label all elements in a figure

- Point out important features
- Label both axes of graphs and show units
- Provide a brief caption
- Give credit to source



The Nike laser system
uses discharge pre-
amplifiers.
(Courtesy US Navy)



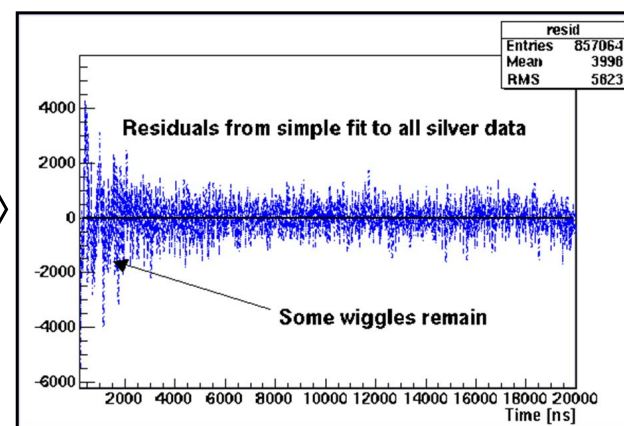
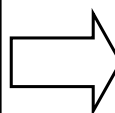
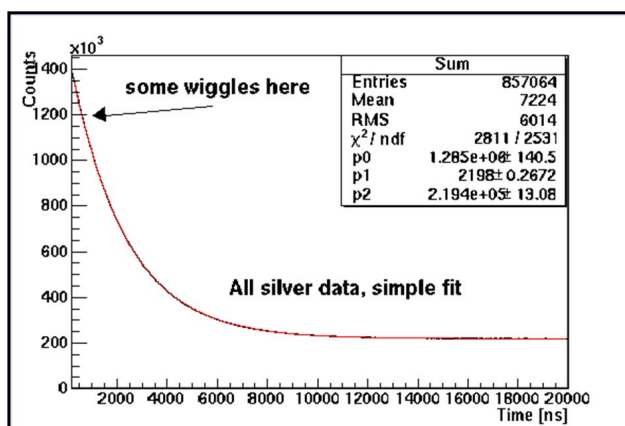
Sample normalized
signals from the two-
beam optical drive.
(Courtesy C. Michael)



Tips for preparing slides

Presenting data is your most important and challenging task

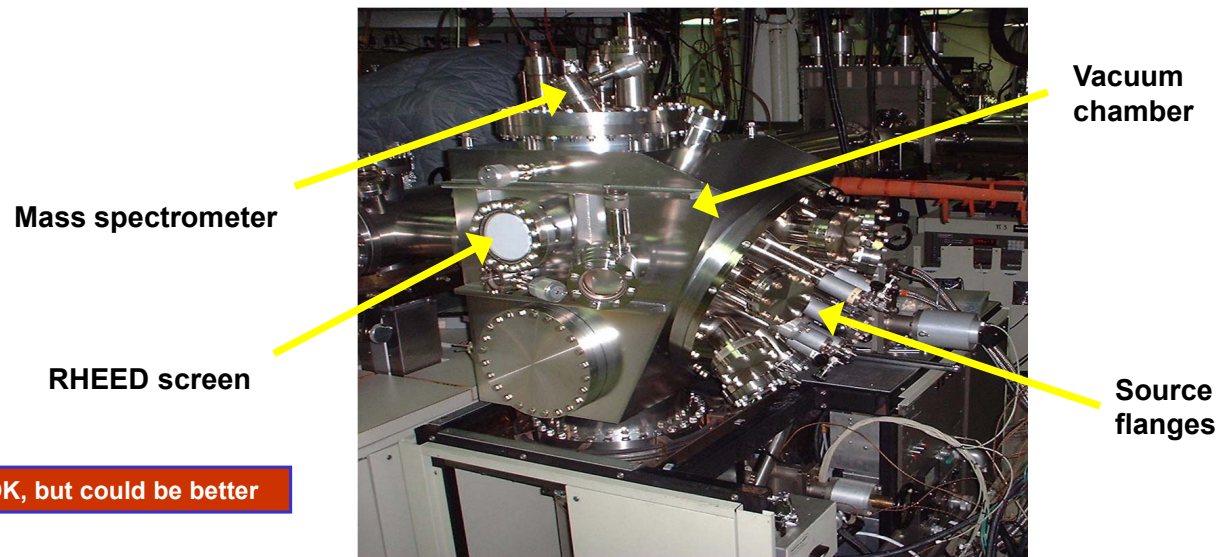
- Avoid copying a graph from a formal article – they have a different style, **e.g., labels are too small**
- Use color and make lines thick, labels legible
- Label axes and annotate important points with arrows and add words
- Use tables sparingly – if used highlight important parts



Tips for preparing slides

Show the equipment **IF** it helps as part of your proof – **but sparingly**, not just because you love it

- **Photographs** give scale and reality – but add labels
- **Schematics** provide concept
- **Diagrams** strip away unnecessary details
- **ALL OF THESE** can be useful in combination



Tips for preparing slides

Use equations sparingly

Use equations only when necessary

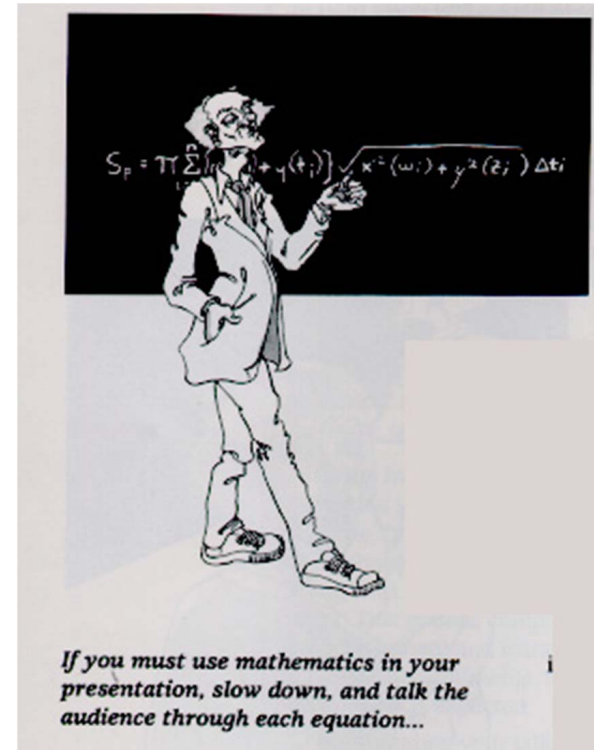
If you use equations

Slow down

Talk through step by step

Explain relevance

Combine with a picture that illustrates the physical principle involved



Tips for preparing slides

Remember, your goal is to convey your ideas, so avoid distracting text and effects!

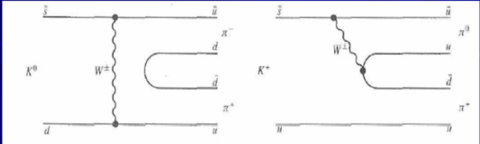
Don't overuse PowerPoint animations and sounds!

Make sure there is good contrast between text and background

Use simple (or no) backgrounds on slides

CP

- Parity invariance fails, combine it with charge conjugation to create a new invariant
- Converts the right-handed anti-neutrino into a left-handed neutrino- exactly what we observe in nature
- Neutral kaon experiment



The diagrams show the decay of neutral and charged kaons. On the left, a K^0 (quarks d and $\bar{s}$) decays via a W^0 boson into π^+ and π^- . On the right, a K^+ (quarks u and $\bar{s}$) decays via a W^+ boson into π^0 and π^+ . The diagrams illustrate the quark-level interactions and the resulting meson decays.



Tips for preparing slides

Eschew weird fonts

Don't use *calligraphy*
or serif fonts

USE THE SAME FONT
THROUGHOUT THE TALK

Make all text at least 20 pt

Tips for preparing slides

Use “normal” colors

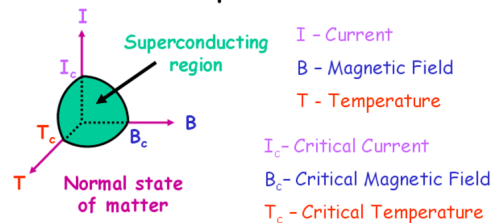
DON'T use red/green or red/blue as contrasting colors

Make sure colors look the way you expect using an LCD projector!

Avoid neon colors and pastels

Don't use many random colors; people expect color to *mean* something

Superconductivity is an electronic state of matter that exists below certain currents, magnetic fields, and temperatures.



Strive for easy reading

Strive for easy reading

Strive for easy reading



27

3. Tips for giving a good talk

Maintain eye contact with audience

Don't stare at screen or monitor

Do not read your talk!

Avoid nervous mannerisms

Pacing, bobbing, waving arms, jingling coins

Use laser pointer or stick directed at screen

Don't point directly at overhead on projector

Don't block the screen

Train yourself to speak slowly and distinctly—practice!

Avoid “fillers”: “uh”, “like”, “um”, “okay”

Be enthusiastic!

If you don't act excited by your results,
don't expect the audience to be!



3. Tips for giving a good talk

Don't show any material on slides (e.g., figures, equations, text, etc.) you can't explain!!

Rehearse how you'll end your talk

Don't end with "Well, I guess
that's it "

Don't just stop and let the committee guess that you're
done

Thank the audience!

Focus on communicating not performing

(humor is good but don't overdo it)

Keep it simple

Prepare key phrases

(it is o.k. to write out some important statements first)

3. Tips for giving a good talk

Rehearse Your Talk!

A few days before

Practice in front of friends
and check timing
Rehearse likely questions
Solicit feedback about
logic and clarity
Revise (*shorten*)

The night before

Go over one more time
Put all materials *in order*
(number your slides!)



Prof. Per Ahlberg delivering the Presentation Speech for the 2001 Nobel Prize in Chemistry at the Stockholm Concert Hall.

4. Tips for question & answers session

Handling questions is an essential part of giving a talk

As part of preparing your talk, try to anticipate questions you might get

In each slide, try to identify what the weak points are, what questions you might ask, etc.

Be prepared to repeat simple derivations of equations or estimates presented on your slides

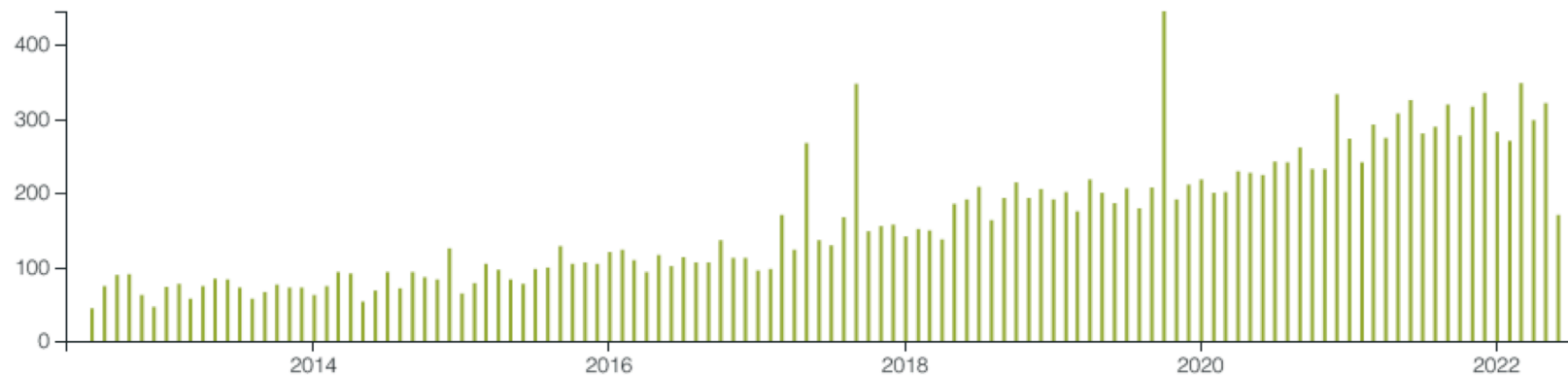
If you don't know the answer?

Say "That's an excellent question. I'm not sure; I'll have to look into it" or "Let's talk about it afterward"

Why ? „Quantum Information Processing“

Publications & Venture Capital Investments

Publications over time

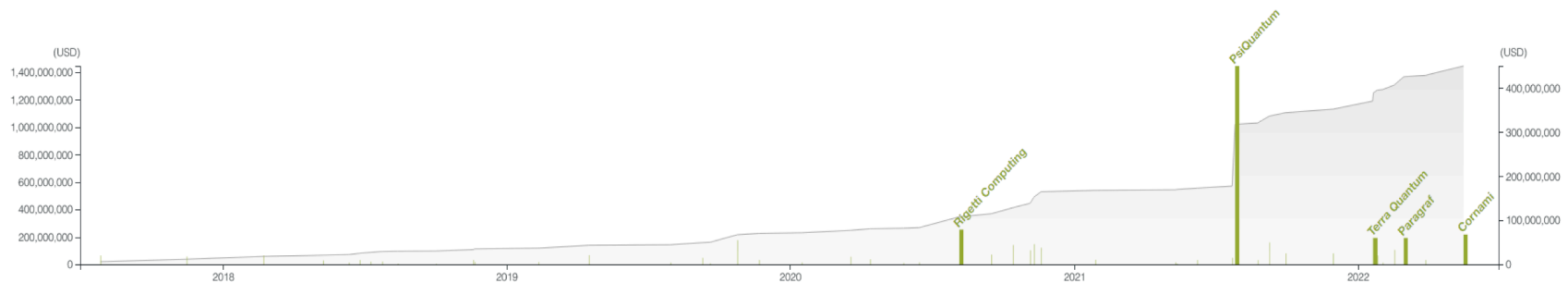


Venture Capital



48 funding events from the past 5 years

Running Total Top Funding Events



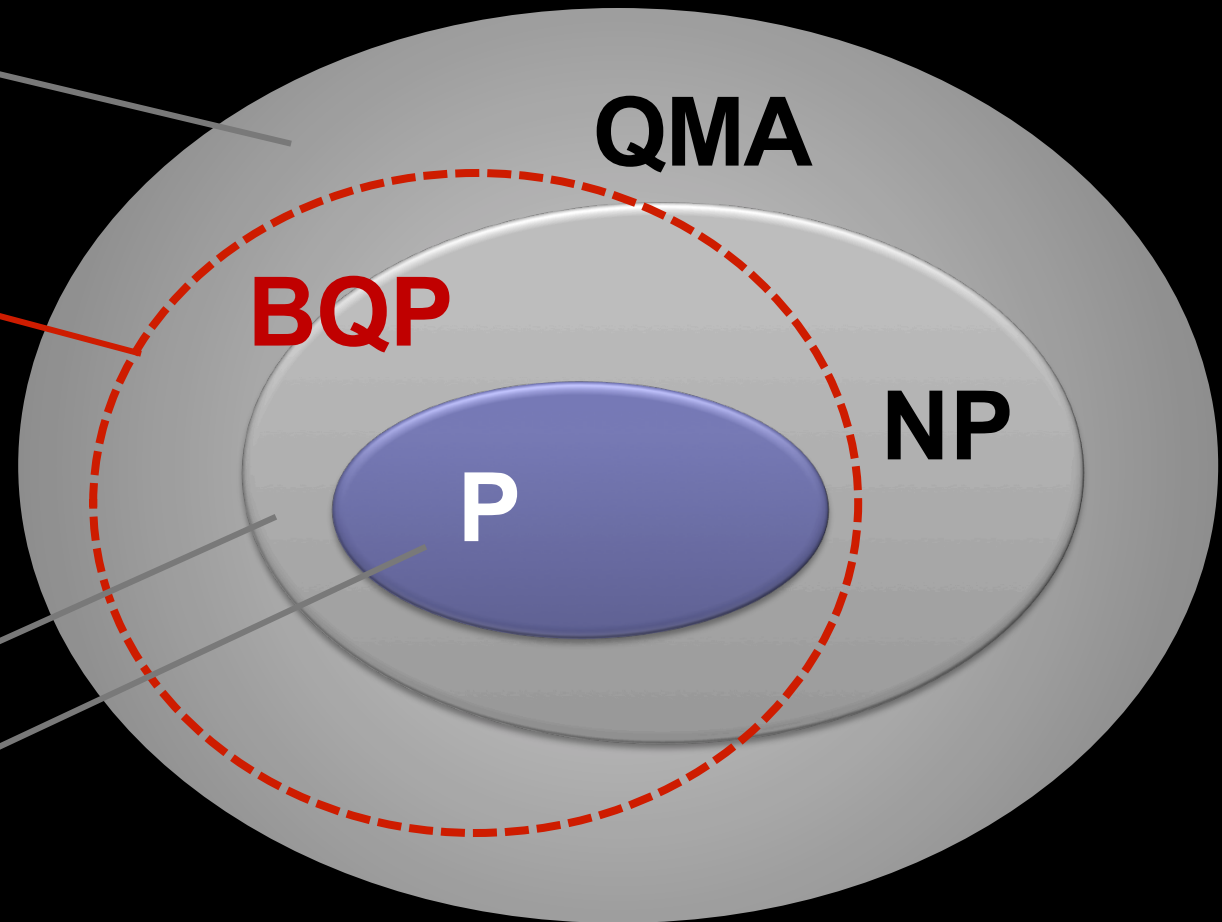
Mathematical problems:

verifiable with Quantum
computer

solvable* with Quantum
computer:

verifiable with classical
computer

solvable* with classcal
computer



Deutsch-Josza algorithm



valid

invalid



front

back

front

back

Deutsch-Josza algorithm

$$f : \begin{array}{cc} \{0, 1\} & \longrightarrow & \{0, 1\} \\ \text{front} \quad \text{back} & & \text{head} \quad \text{tail} \end{array}$$

$$f(0) = 0 \quad f(0) = 1$$

$$f(1) = 0 \quad f(1) = 1$$

constant (invalid)

$$f(0) = 0 \quad f(0) = 1$$

$$f(1) = 1 \quad f(1) = 0$$

balanced (valid)

To find out if f constant or balanced
two inquiries needed!

Deutsch-Josza algorithm

$$|0\rangle|1\rangle \longrightarrow (|0\rangle + |1\rangle)(|0\rangle - |1\rangle)$$

f encoded in unitary transfo

$$U_f : |x\rangle|y\rangle \longrightarrow |x\rangle|y \oplus f(x)\rangle$$

$$U_f |x\rangle (|0\rangle + |1\rangle) = \begin{cases} |x\rangle (|0\rangle + |1\rangle) & \text{constant} \\ -|x\rangle (|0\rangle - |1\rangle) & \text{balanced} \end{cases}$$

A single inquiry sufficient!

Topics for talks

Basics & fundamental experiments

- Bell inequalities: *quantum correlations are stronger than classical one's*
- Quantum teleportation: *how to transport an unknown quantum state from A to B*
- Quantum cryptography: *how to use peculiarities of quantum mechanics to create secure keys?*

Topics for talks

Quantum computing principles

- Network quantum computer: *quantum bits and gates* (M. Fleischhauer)
- Measurement-based quantum computation: *how to replace gate operations by measurements on massively entangled states*

Topics for talks

Physical platforms for quantum computing

- Ion-trap quantum computers
- Neutral atoms in strongly coupling cavities
- Rydberg atoms & Rydberg polaritons
- Superconducting qubits
- Topological qubits (external lecture)

Topics for talks

Physical platforms for quantum networks

- Photon exchange between strongly coupled cavities
- Quantum memories for light based on atomic ensemble
- Duan-Lukin-Cirac-Zoller quantum repeater

