# Vorstellung der Lehre am Atominstitut

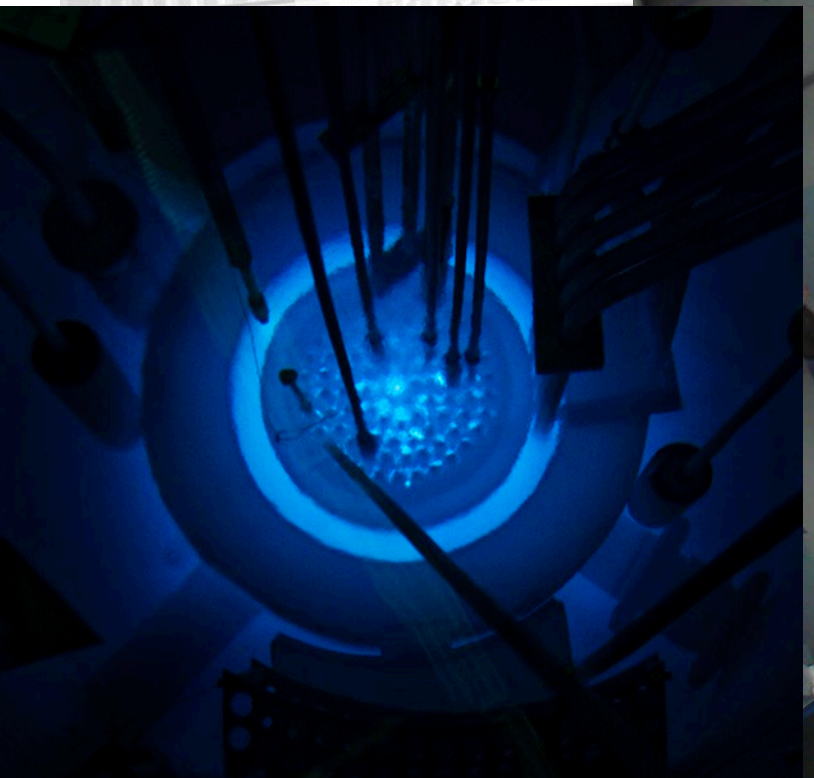
# 2023S

~13 Forschungsgruppen
~150 Mitarbeiter
~100 Studenten

HEPHY

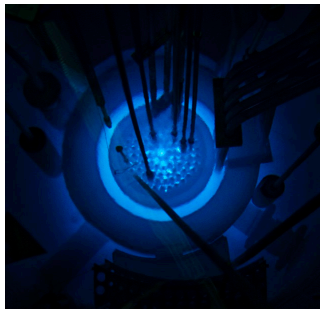
ATOMINSTITUT

# Wissenschaft
# Ausbildung
# Expertise

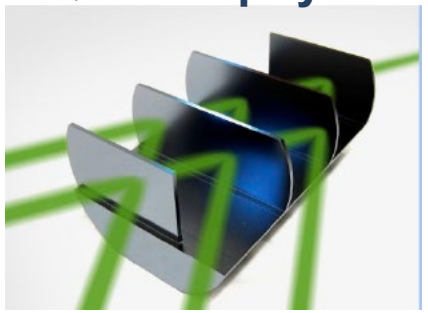


TRIGA Center Atominstitut

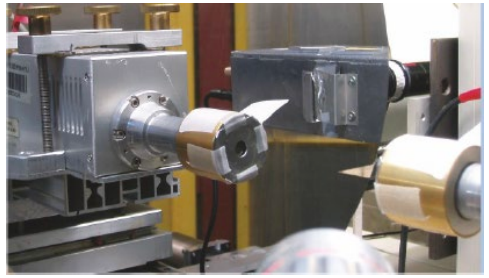
TRIGA Center



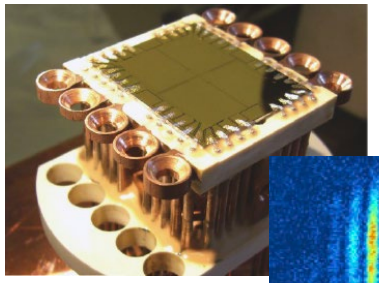
Neutronen- & Quantenphysik

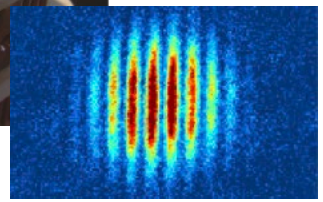


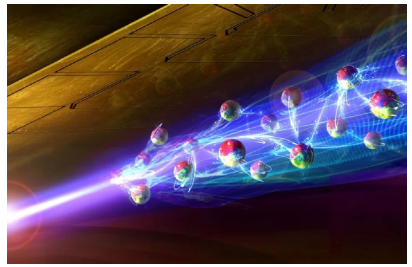
Strahlenphysik



Atomphysik & Quantenoptik

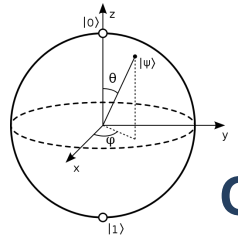


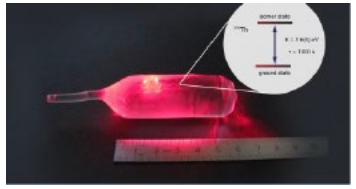




Atominterferometrie

ATOMINSTITUT

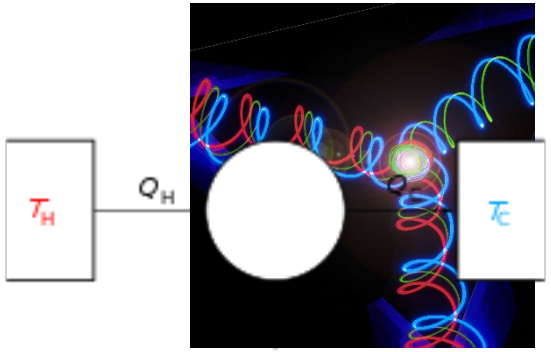




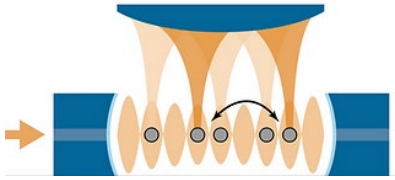
Quantenmetrologie

Kern- & Teilchenphysik

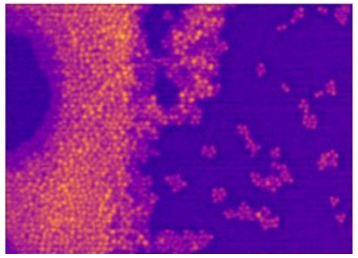
Tieftemperaturphysik & Supraleitung




QUanten Information & Thermodynamik



Experimentelle Quanteninformation



Quantenoptik & Sensorik

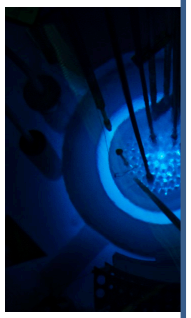
Neutronen-
interferometrie

Strahlenphysik
& Radiochemie

Ultrakalte Gase

Quantensimulation

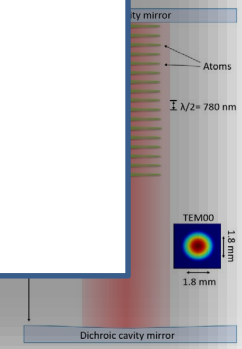
Reaktor-
phys

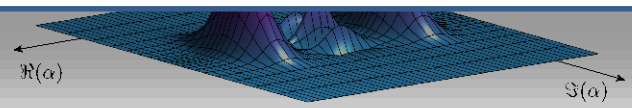


Dunkle
& Kosm

- **Vorlesungen**
- **Praktika, Seminare**
- **Projekt- und Masterarbeiten**

en-
logie




Tieftemperaturphysik
& Supraleitung

Quanteninformation
& Quantenthermodynamik

Quantenoptik & Cavity QED

# Nach der Vorbesprechung ...

# Fragen und Antworten bei Kaffee & Kuchen !

# Kern- und Teilchenphysik

M. Benedikt, M. Faber, A. Hirtl H. Leeb,

F. Reindl, E. Renner und J. Schieck

assoziierte Vortragende des Instituts für Hochenergiephysik (HEPHY) der ÖAW

T. Bergauer, M. Jeitler, R. Schöfbeck, Ch. Schwanda, C. Wulz

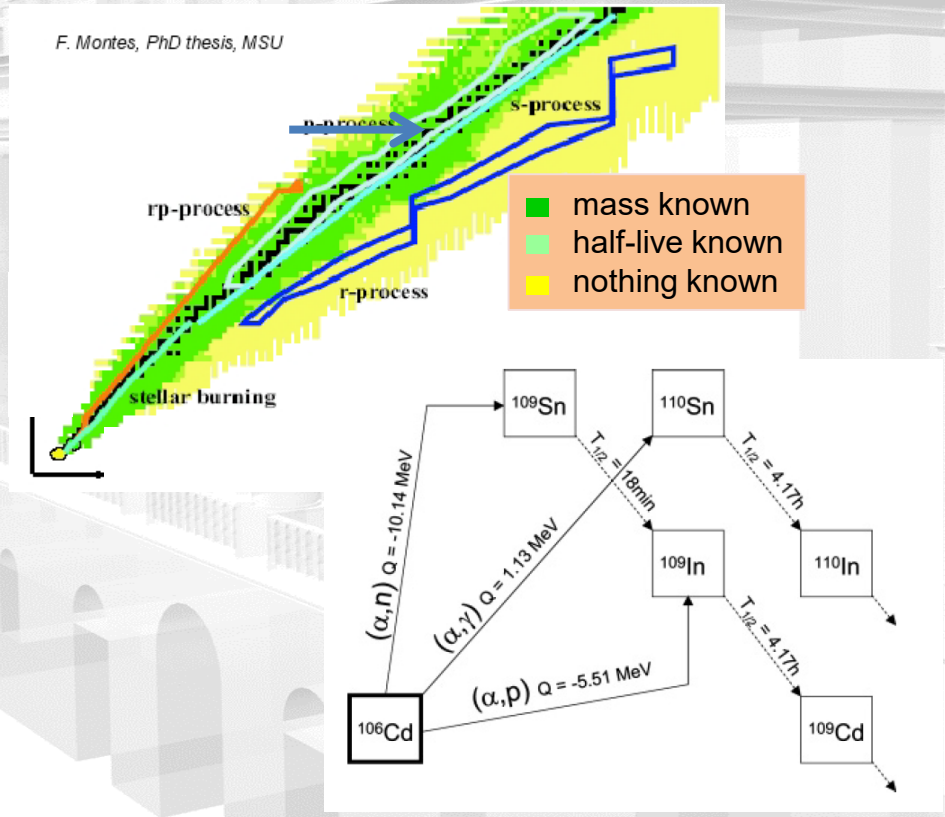
und des Stefan-Meyer-Instituts (SMI) der ÖAW

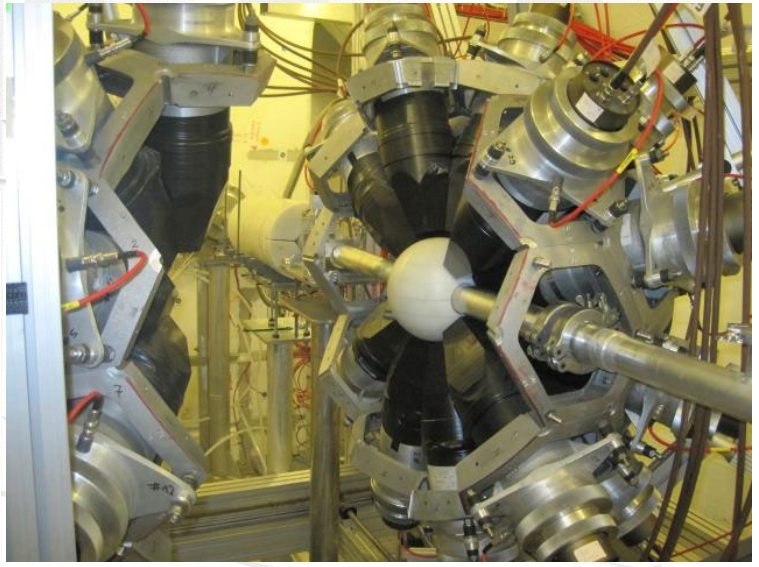
J. Marton

# Kernphysik und Nukleare Astrophysik

- Beschreibung von Kernreaktionen an den Grenzen der Stabilität, relevant für Astrophysik und nukleare Technologien
- Verbindung von Reaktionstheorie mit modernen Kernstrukturtheorien

H. Leeb



4π Calorimeter at nTOF@CERN

# Feldtheorien und Hadronenphysik

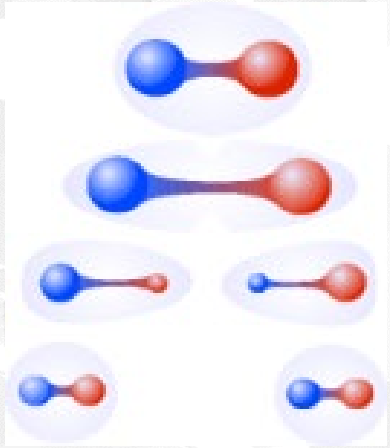
Hadronenphysik

- Beschreibung exotischer Atome und Verständnis der Annihilation
- chirale Feldtheorie

Feldtheorien

- Verständnis der QCD bei niedrigen q-Werten (z.B. Confinement)
- Gittereichtheorien, Solitonmodell

M. Faber



Quark-Antiquark Wechselwirkung

Flußschlauch zwischen Quark-Antiquark aus QCD Gittereichrechnungen



# Experimentelle Teilchenphysik

## Institut für Hochenergiephysik, OeAW

- Verständnis des Standardmodells, Higgs-Teilchen,CP-Verletzung, Suche nach neuer Physik, Suche nach Dunkler Materie, Neutrinophysik
- Entwicklung von Detektoren
- Experimente am LHC@CERN, BELLE@KEK
- Suche nach dunkler Materie CRESST@LNGS

**Schieck** gemeinsam mit (HEPHY) Fabjan, Jeitler, Krammer, Reindl, Schöfbeck, Schwanda, Wulz

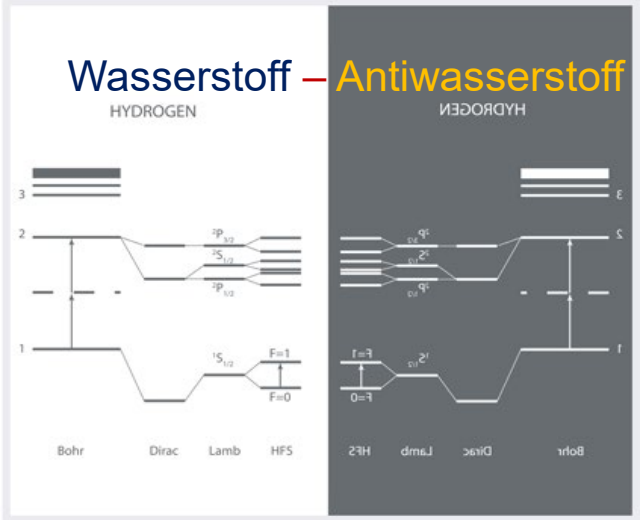
CMS Detektor

## Experimentelle Hadronenphysik

Stefan Meyer Institut, OeAW

- Starke Wechselwirkung, Antimaterie-Materie-Symmetrie,
- Experimente: ASACUSA@CERN, FAIR , DAPHNE

Marton (SMI)




Quelle: oeaw.ac.at/smi/research/

# Wahlpflichtvorlesungen, Kern-Teilchenphysik 1

- **(AKT II,** Schieck & Abele 142.092
  Di & Mi 1.3.2023 14:15 – 15:45 HS6 FH)
- **Energieversorgung**, Leeb 142.084
  Vorbesprechung: Di 14.3.2023 17:00 – 19:00 Hörsaal AI - TPH
- **Physik am LHC**, Jeitler 142.A52
  Einführung in die Physik des LHC Beschleunigers – Higgs u. SUSY
  Vorbesprechung : Di 28.2.2023 17:00 – Online
- **Quantenchromodynamik II**, Faber 142.923
  Einführung in die Phänomene und Theorie der starken Wechselwirkung
  Di 7.3.2024 12:00-14:00 - Sem.R. DB gelb 05 B
- **Selected Experiments of Particle Physics, Schieck & Abele** 141.243
  Einführung in fundamentale Experimente der Teilchenphysik
  Vorbesprechung Mo. 13.3.2023 14:00 – Hörsaal AI - TPH

# Wahlpflichtvorlesungen, Kern-Teilchenphysik 2

- **Techniken der Signalerfassung u. Auswertun,** Bergauer und Hirtl
  141.A88

  Vorbesprechung am Do 9.3.2023, 11:00h – 13:00h Sem.R. DB gelb 05 A
  Vorbesprechung Di 11.10.2022 9:30 – Institut für Hochenergiephysik
- **Einführung in die Modelle der Elementarteilchenphysik II**, Eberl
  141.B02

  Es werden dazu auch Übungen angeboten 141.B01
  Vorbesprechung Fr 10.3.2023 14:00 – 17:00h Sem.R. DB gelb 07

# Projektarbeiten, Bachelorarbeiten

| | | |
|---|---|---|
| • PA Starke Wechselwirkung (Faber, Markum) | faber@kph.tuwien.ac.at | 142.045 |
| • PA Subatomare Physik (Faber, Marton) | faber@kph.tuwien.ac.at<br>johann.marton@oeaw.ac.at | 142.088 |
| • PA Experimentelle Teilchenphysik<br>(Schieck, Schwanda, Krammer, Jeitler,<br>Reindl, Schöfbeck, Wulz) | krammer@oeaw.ac.at<br>schoefbeck@oeaw.ac.at<br>claudia.wulz@cern.ch | 142.039 |
| • PA Methoden der Teilchenphysik<br>(Schieck, Schwanda, Krammer,<br>Reindl, Schoefbeck, Jeitler, Wulz) | schwanda@oeaw.ac.at<br>jeitler@oeaw.ac.at<br>schieck@oeaw.ac.at<br>florian.reindl@oeaw.ac.at | 141.A45 |
| • PA Nukleare Astrophysik (Leeb, Benedikt, Renner) | leeb@kph.tuwien.ac.at<br>michael.benedikt@cern.ch | 141.A21 |
| • PA Kernphysik (Leeb, Benedikt, Renner) | elisabeth.renner@tuwien.ac.at | 141.A22 |

Unter Anleitung durchgeführte wissenschaftliche Arbeiten an aktuellen Forschungsprojekten;
Dauer: 4 – 6 Wochen Vollzeit;
Abschluss: wissenschaftliches Ergebnis sowie schriftliche Dokumentation (Protokoll);
**Beginn:** Nach Vereinbarung, Kontakt mit Betreuer bzw. Betreuerin der Projektarbeit.

TECHNISCHE UNIVERSITÄT WIEN

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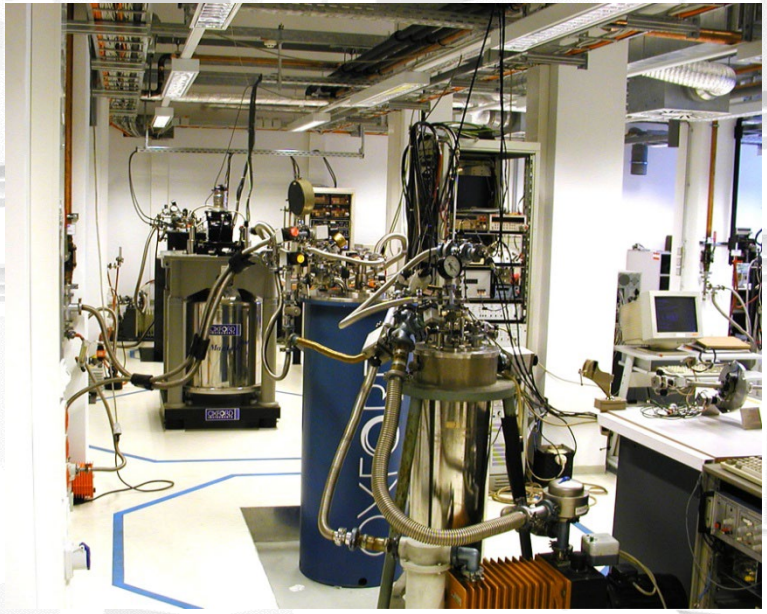
# Tieftemperaturphysik
# Supraleitung

M. Eisterer, F. Sauerzopf, H. Weber

# Unsere Themenschwerpunkte

- **Magnetische Eigenschaften und Stromtransport in Supraleitern**
- Neue Materialien, Hochtemperatursupraleiter
- Flusslinienverankerung, Granularität
- Anwendungsorientierte Materialforschung
- **Fusionsrelevante Materialien, Strahlungsresistenz**
- Supraleiter für Magnetspulen



# Unsere Geräte

- **Magnetsysteme mit Transport- und Magnetisierungsmessungen**
- **Hallsonden-Scanner**
- **Tieftemperatur-Tunnelmikroskop**

- **Hochtemperatursupraleiter**

Michael Eisterer, 141.457
Beginn: 8. März 2023, 16:00, SEM DB gelb 05 B

- **SQUIDs - Grundlagen und Anwendungen**

Franz Sauerzopf, 141.222
Beginn: nach Vereinbarung

- **Superconductivity Seminar**

Michael Eisterer, 141.388 (in Englisch)
Beginn: 13. März 2023, 15:00, ATI Bibliothek

- **Praktikum aus Tieftemperaturphysik**

Michael Eisterer, 141.823
Vorbesprechung: 7. März 2023, 14:00, FH HS1
Blockveranstaltung nach Vereinbarung

- **Diplom- und Projektarbeiten**

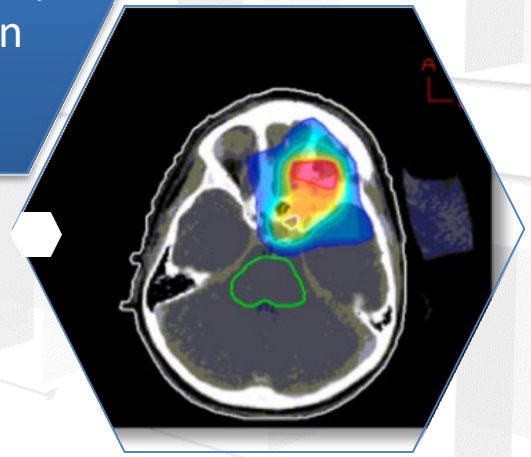
M. Eisterer, H. Weber, 141.B23
Nach Vereinbarung

# Strahlenphysik

Strahlenphysik: Leitung Christina Streli

**Röntgenphysik**

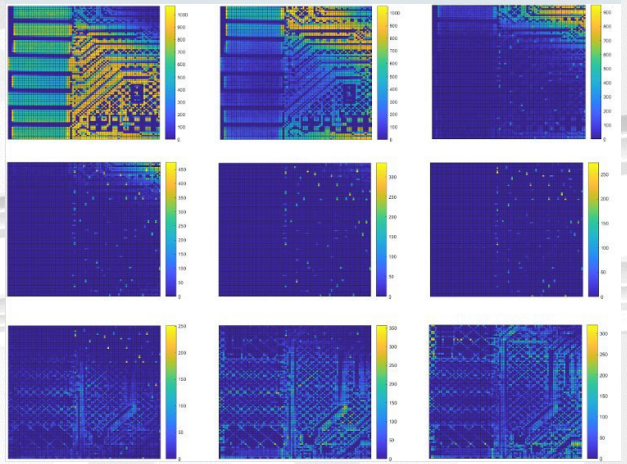
Medizinische Strahlenphysik, MedAustron



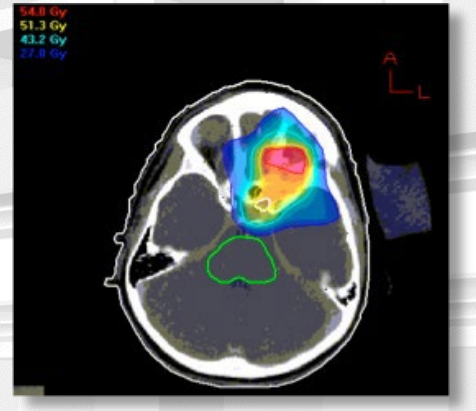
- ## Materialcharakterisierung
  - Charakterisierung von Implantaten in Silizium-Wafern
  - Charakterisierung ultradünner Schichten im Nanometer-bereich auf Silizium-Wafern
  - Spurenelemente im menschlichen Gewebe
  - Waferoberflächenanalytik

- ## Umweltanalytik
  - Chemisches Fingerprinting von geologischem Material
  - Nachweis von Blei im Trinkwasser
  - Spurenelementanalyse von Aerosolen in Luft

- Methodenentwicklung
  - 3D  Element Imaging
  - Tiefenprofilanalytik im Nanometerbereich
  - Entwicklung von Spektrometer für spezielle Aufgabenstellungen

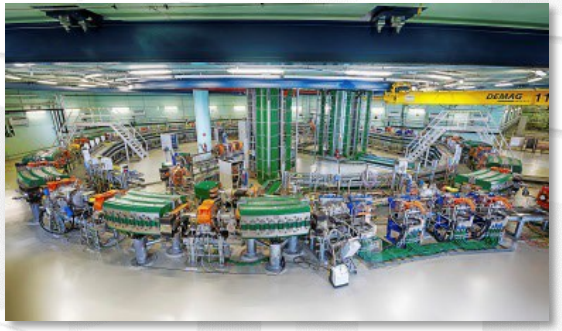


- Medizinische Strahlenphysik
  - Diagnostik
  - Nuklearmedizin
  - Strahlentherapie




- MedAustron

  Internationales Tumortherapie- und Forschungszentrum mit Protonen und Kohlenstoffionen
  - Experimentelles Programm zur
    - Dosismessung und zum Linearen Energietransfer (LET) in menschenähnlichen Phantomen
    - Bildgebung mittels Ionen – Protonen CT



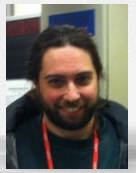
# Strahlenphysik – gemeinsam mit XRC und KTP



Strahlung vielseitig nutzen,
den verantwortungsvollen Umgang lehren!


C. Streli


K. Poljanc


D. Ingerle (XRC)


A. Hirtl (KTP)


K.Hradil (XRC)

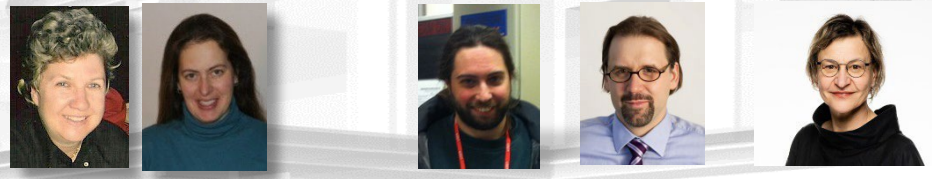
## VORLESUNGEN IM SOMMERSEMESTER 2023

| | | |
|---|---|---|
| 141.405 | VO | Strahlenphysik (Streli, Poljanc, Hirtl, Renner) |
| 141.A40 | VO | Strahlenphysikalische Methoden in der Medizin (Poljanc) |
| 141.B07 | VO | Einführung in die medizinphysikalischen Grundlagen der Ionentherapie (Hirtl) |
| 141.211 | VO | X-ray analytical methods (Streli) |
| 141.A41 | VU | Metrologie (Maringer) |
| 141.A73 | VO | mitdenken.erlaubt@tuwien.ac.at (Poljanc, Maringer, Gebeshuber, Renner) |

## LABOR- UND PRAKTISCHE ÜBUNGEN IM SOMMERSEMESTER 2022

| | | |
|---|---|---|
| 141.115 | PR | Practical Course in X-Ray Analytical Methods (Streli, Wobrauschek) |
| 141.A84 | LU | Praktische Übungen aus Strahlenphysik (Streli, Wobrauschek, Hradil) |

Strahlung vielseitig nutzen,
den verantwortungsvollen Umgang lehren!



C. Streli

## SEMINARE IM SOMMERSEMESTER 2023

| | | |
|---|---|---|
| 141.905 | SE | Strahlenphysikalische Anwendungen in Technik und Medizin (Streli, Aiginger, Poljanc, Hirtl, Renner) |
| 141.A54 | SP | Science TU You – Wissenschaftskommunikation in der Praxis (Poljanc, et al.) |

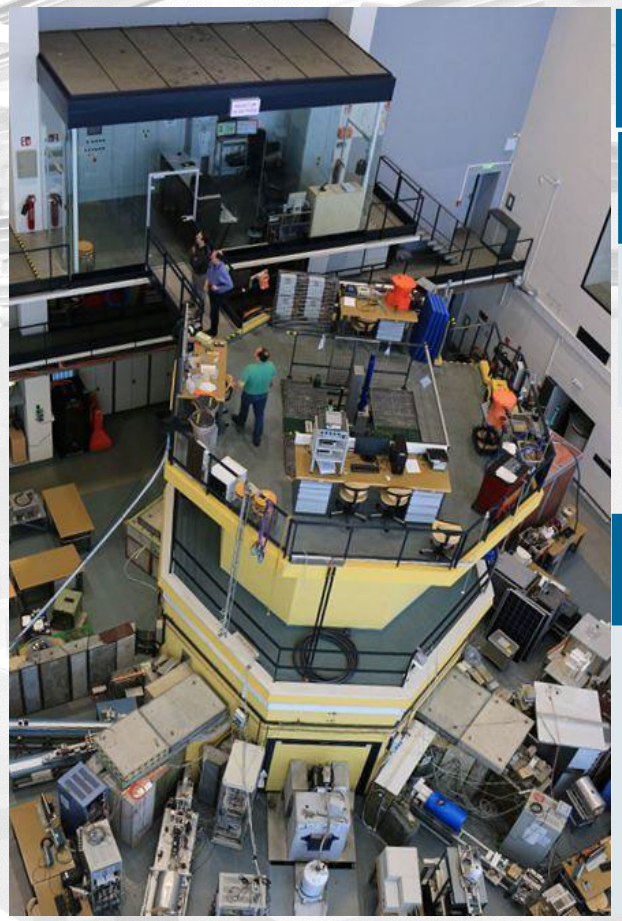
## PROJEKT- UND BACHELORARBEITEN IM SOMMERSEMESTER 2023

| | | |
|---|---|---|
| 134.191 | PR | Wahlpflicht-Projekt: Medizinische Physik und Bildgebung |
| 141.018 | PR | Projektarbeit Strahlenschutz und Dosimetrie |
| 141.079 | PR | Projektarbeit Angewandte Strahlenphysik |
| 141.110 | PR | Projektarbeit Elektronen- und Röntgenphysik |
| 141.153 | PR | Projektarbeit Röntgenanalytik |
| 141.A72 | PR | Projektarbeit Metrologie |

# TRIGA Center

M. Villa, H. Böck, R. Bergmann
J. Sterba, J. Welch,
A. Musilek, D. Hainz, M. Veit-Öller

## Das TRIGA Center Atominstitut ist ein Zentrum unter dem Vizerektorat für Forschung und Innovation



**Leitung & Bewilligungsinhaber**
**Musilek**

| Reaktor-Betriebsleitung | Strahlenschutz | Nukleare Sicherheit | Security |
|---|---|---|---|
| Leitung: Villa<br>Stv.: Bergmann | Leitung: Hainz<br>Stv.: Musilek<br><br>Veit-Öller | Leitung: Sterba<br>Stv.: Welch | Leitung: Sterba<br>Stv.: Villa<br><br>Veit-Öller |

**TRIGA* Reaktor**

Leitung: Villa

Bergmann

*Operateure:*
Stummer
Trunner

**CLIP**
**Radiochemie**

Leitung: Sterba

Denk
Welch

*Labor:*
Foster
Nemetz

Reaktor – CLIP - Strahlenschutz

* Training, Research, Isotope Produtcion, General Atomic
** Center for Labelling and Isotope Production

# TRIGA Reaktor



- Projektarbeiten
  - 141.080 Projektarbeit Reaktortechnik (8.0)
- Seminare
  - 141.114 Seminar aus Reaktorsicherheit (2.0)
- Vorlesungen
  - 141.032 Nuclear Engineering I (2.0)
  - 141.658 Nuclear Engineering II (2.0)
- Laborübungen
  - 141.A79 Praktische Übungen aus Reaktorinstrumentierung (3.0)

- Vortragende und Betreuer:

Mario Villa

Helmuth Böck

Robert Bergmann

Reaktor – CLIP - Strahlenschutz

# Center for Labelling and Isotope Production

- Projektarbeiten
  - 141.167 Projektarbeit Radiochemie (8.0)
- Vorlesungen
  - 141.295 Radiochemie I (2.0)
  - 141.724 Isotopentechnik (2.0)
- Laborübungen
  - 141.A81 Radiochemisches Praktikum (4.0)

- Vortragende und Betreuer:

Reaktor – CLIP - Strahlenschutz

Johannes H. Sterba

Jan Welch

# Strahlenschutz



- Projektarbeiten
  - 141.018 Projektarbeit Strahlenschutz und Dosimetrie (8.0)
  - 141.079 Projektarbeit Angewandte Strahlenphysik (8.0)
- Laborübungen
  - 141.A82 Strahlenschutzpraktikum (4.0)
- Vortragende und Betreuer:

Andreas Musilek

Dieter Hainz

Robert Bergmann

Monika Veit-Öller

TECHNISCHE UNIVERSITÄT WIEN

# Wir freuen uns auf Ihre Teilnahme!

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Reaktor – CLIP - Strahlenschutz

# Neutronen- und Quantenphysik

G. Badurek, Y. Hasegawa, E. Jericha,
C. Käding, B. Koch, M. Pitschmann, I. Pradler, R. Sedmik, S. Sponar,
M. Suda, J. Summhammer, M. Zawisky, H. Abele

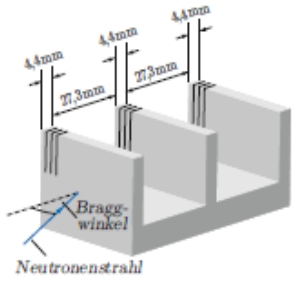


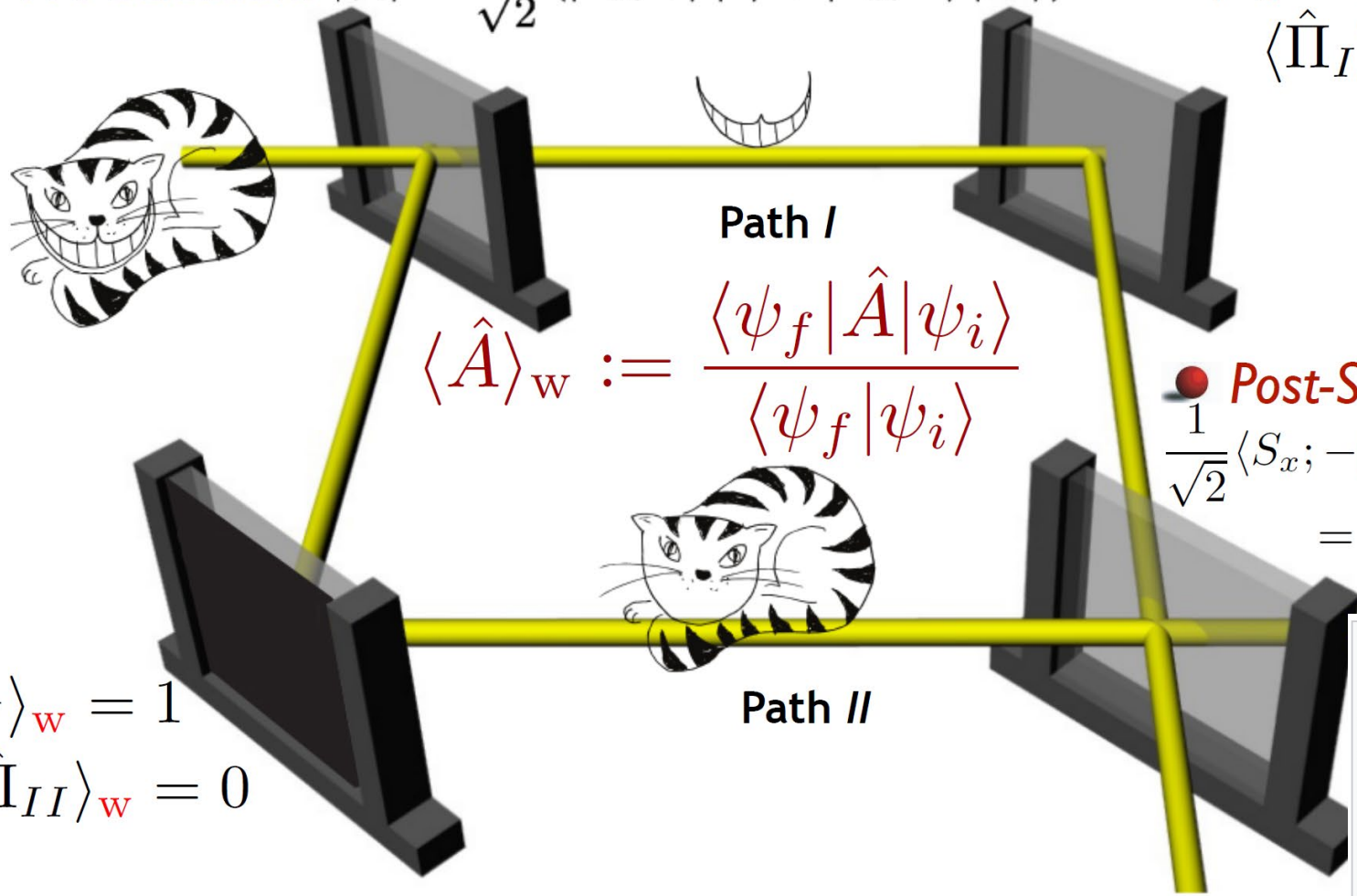

**Abbildung 3.12** Perfektkristall-Interferometer für Neutronen

# Quantum Cheshire Cat



- **Pre-Selection:** $|\psi_i\rangle = \frac{1}{\sqrt{2}}\left(|S_x;+\rangle\,|I\rangle + |S_x;-\rangle\,|II\rangle\right)$

$$\langle \hat{\sigma}_z^{\mathrm{S}} \hat{\Pi}_I \rangle_{\mathrm{w}} = 1$$
$$\langle \hat{\Pi}_I \rangle_{\mathrm{w}} = 0$$




$$\langle \hat{A} \rangle_{\mathrm{w}} := \frac{\langle \psi_f | \hat{A} | \psi_i \rangle}{\langle \psi_f | \psi_i \rangle}$$

- **Post-Selection:**

$$\frac{1}{\sqrt{2}}\langle S_x;-|\left(\langle I| + \langle II|\right) = \langle \psi_f|$$

$$\langle \hat{\Pi}_{II} \rangle_{\mathrm{w}} = 1$$
$$\langle \hat{\sigma}_z^{\mathrm{S}} \hat{\Pi}_{II} \rangle_{\mathrm{w}} = 0$$

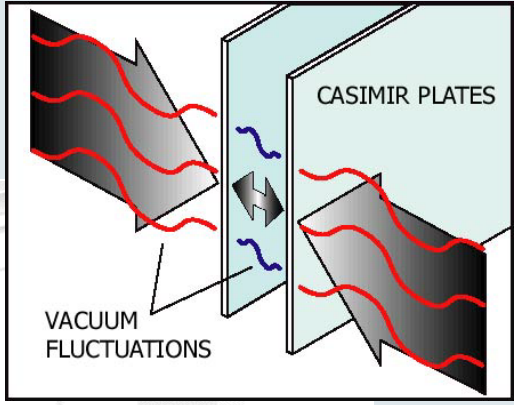
Y. Aharonov, et al,. *New J. Phys.***15** (2013) 113018, Figure courtesy of Leon

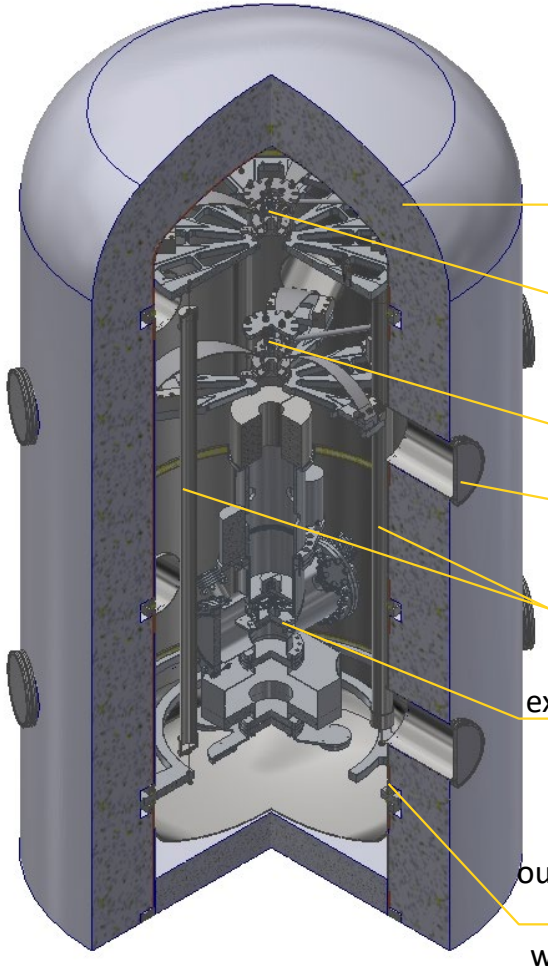
Die *Cheshire Cat*

## Research: Y. Hasegawa, S. Sponar et al.

# The quantum vacuum

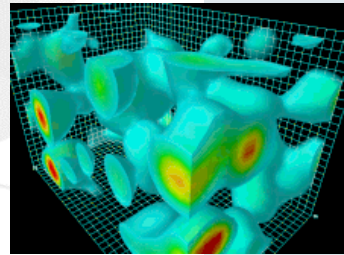
$$U(\nu,T) = \left(1/2 + \frac{1}{e^{h\nu/kT}-1}\right) h\nu$$



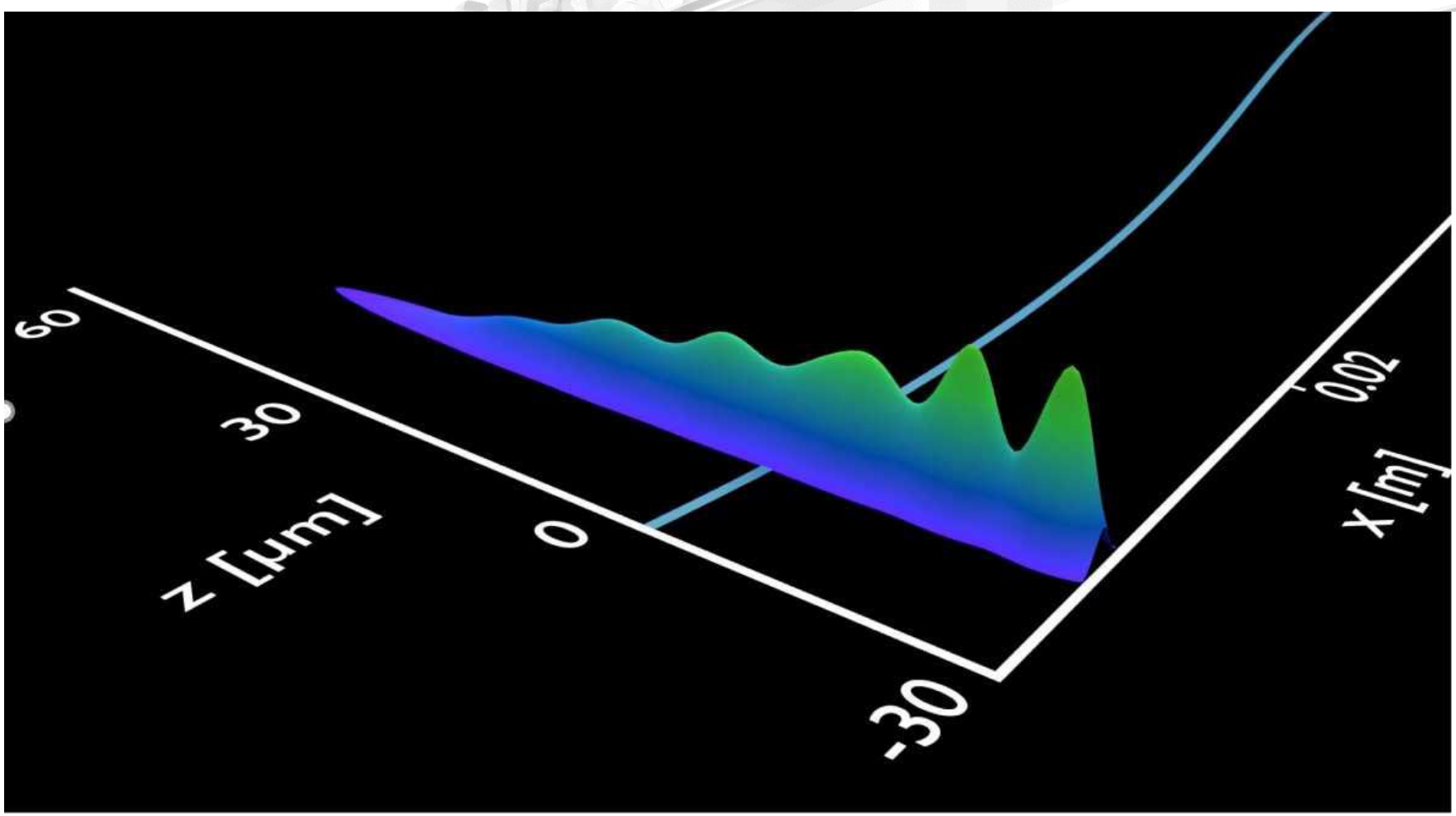

- Quantum Theory: ∞
- QM + Cutoff **$10^{93}$kg/m$^3$**
- Special Relativity **Zero**
- Cosmology **6 x $10^{-27}$ kg/m$^3$**

- Vacuum = potential Energy (GR)
  + vacuum fluctuations
  + cosmological constant
  **~ Zero**



Research: René Sedmik et al.

# The cosmological constant – dark energy

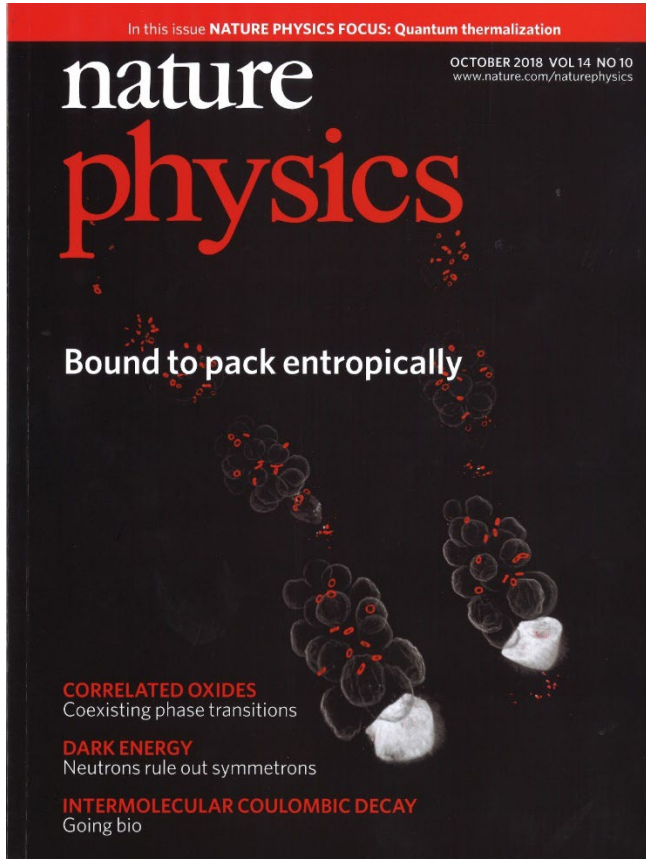



**Gravity Resonance Spectrocopy**
- most precise measuring technique
- rely on frequency measurements
- Transitions between energy states

**dark enery field provoke energy shifts**

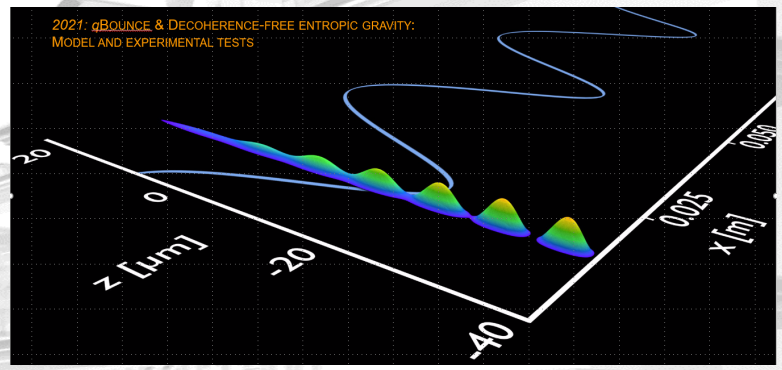
**Neutrons rule out Dark Energy**
**Symmetrons**

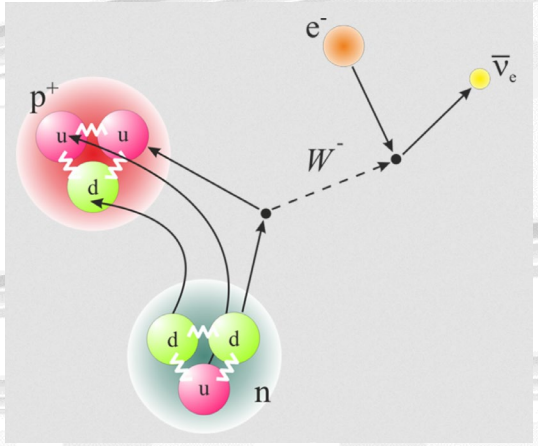
**non-Riemann Gravity**
**entropic force**




*q*BOUNCE: Research: René Sedmik et al.

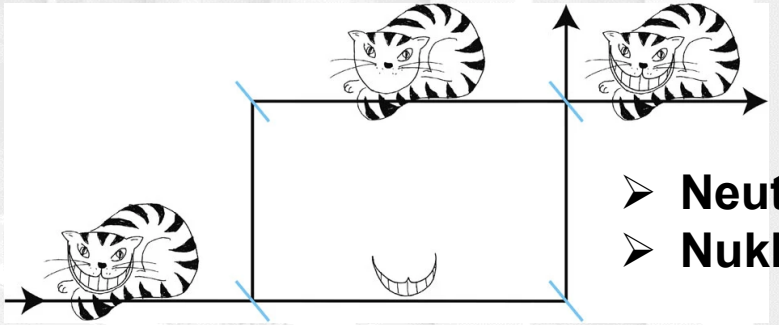
# Projektarbeiten / Bachelorarbeiten:



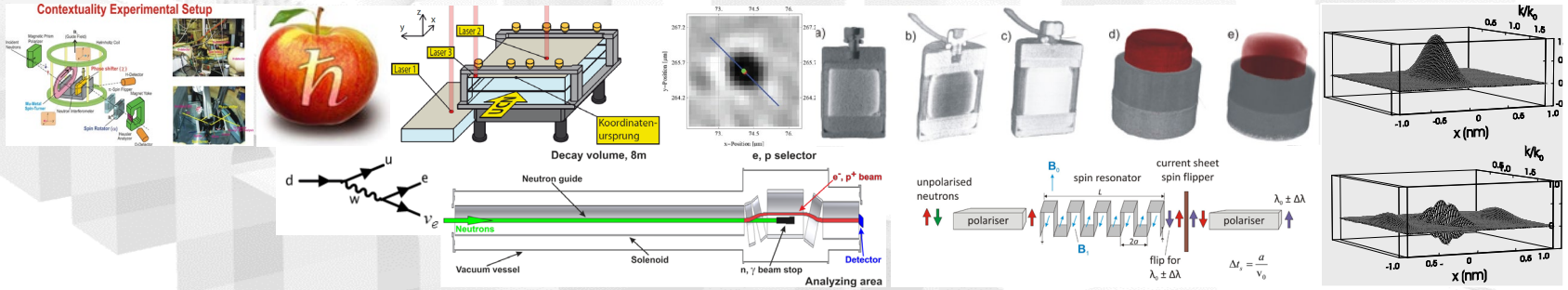




- Gravitation und Quantenmechanik
- Neutronenphysik

- Schwache Wechselwirkung
- Experimentelle Hadronenphysik

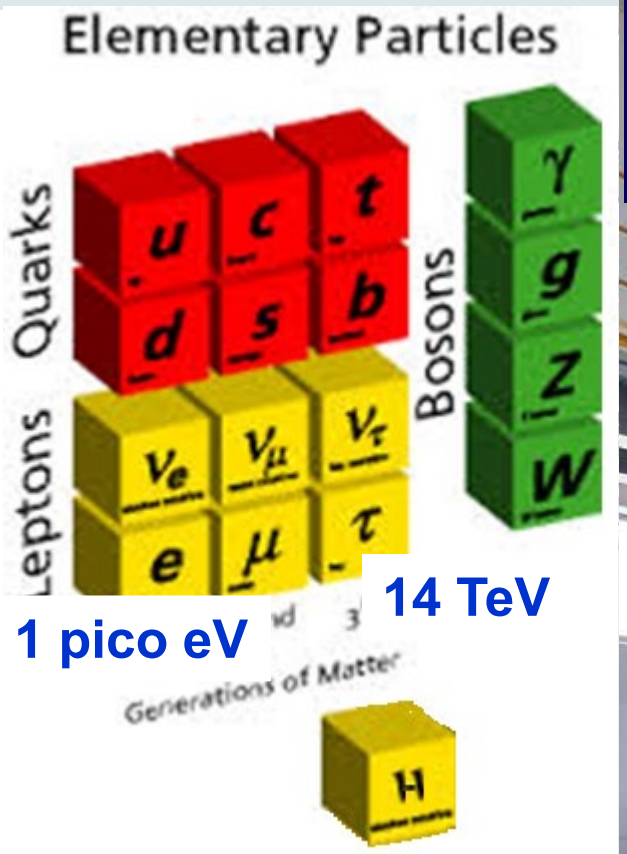


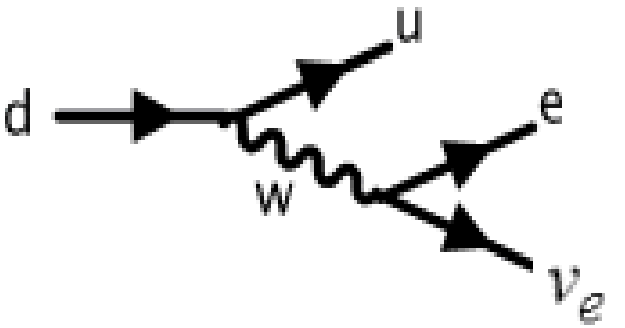
- Neutronenoptik
- Nukleare Festkörperphysik



# Neutron Beta Decay & High Precision Experiments with PERC

## Reserach: I. Pradler, E. Jericha et al.




Spokesperson: B. Maerkisch, TU München,Time & Project Manager: E. Jericha, TU Wien

Neutronen- und Quantenphysik


# Vorlesungen I:

142.086 **Atom-, Kern- und Teilchenphysik I + Ü** — M. Pitschmann, S. Manz
FH HS 6 / Mo 09:00 – 11:00 / Beginn 06.03

142.089 **Übung** Beginn 16.03. — S. Erne
DA grün 03 B / Do 09:00 – 11:00 // DC rot 07 / Do 11:00 - 13:00

142.092 **Atom-, Kern- und Teilchenphysik II + Ü** — Abele, Schieck
FH HS 6 / Di, Mi 14:00 – 16:00 / Beginn 01.03.

142.093 **Übung** Beginn 08.03. — Zawisky, Abele
SEM DA grün 02 A / Mi 11:00 – 12:00 — Schieck, Sedmik

141.243 **Selected Experiments of Atomic, Nuclear and Particle Physics** — Abele, Schieck
ATI HS / Mo 14:00 – 17:00 / Beginn 13.03.

142.440 **Gravitation and Cosmology II** — Abele, Pitschmann, Käding
ATI SEM ZE 01 / Do 11:00 – 13:00 / Beginn 02.03.

142.440 **Biological and Medical Applications of Nuclear Physics II** — Badurek
entfällt im Sommersemester 2023 !!

# Vorlesungen II:

141.236 **Fundamental Physics with Polarized Neutrons** Hasegawa

Vorbesprechung Di 07.03. 10:30 – 11:00, ATI SEM

141.242 **Neutronen- und Röntgendiffraktometrie** Jericha

Vorbesprechung Do 09.03., 12:00, Zoom

141.158 **Neutronenoptik und Tomographie** Zawisky

Vorbesprechung Fr 05.05., 12:00 – 13:00, ATI Aula

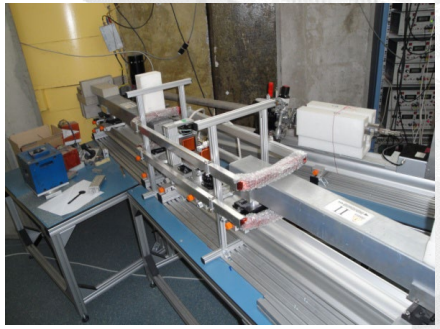
101.989 **Quanten-Interferometrie im Phasenraum I** Suda
141.123 ATI SEM ZE 03 / Di 10:00 – 11:30 / Beginn 07.03.

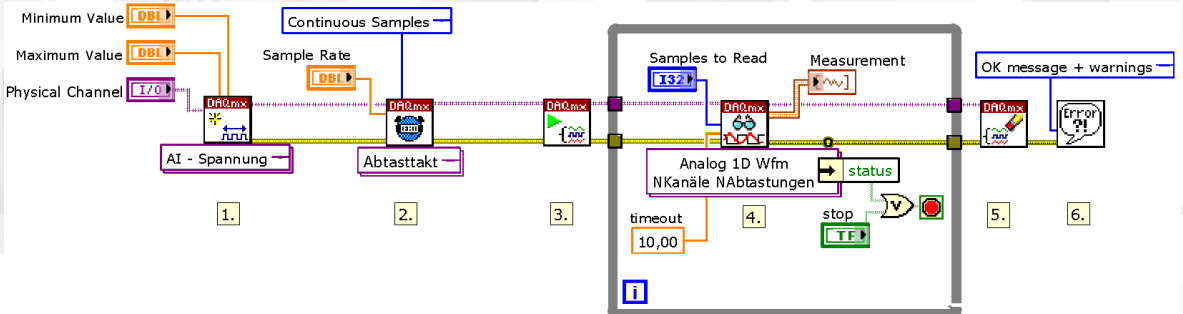
# Praktika:

141.A78 **Praktikum aus Neutronenphysik,**
Abele, Hasegawa, Jericha, Sponar, Zawisky
Vorbesprechung Do 09.03., 12:00, Zoom,
Praktikum nach den Möglichkeiten in 2023S

141.A76 **Graphical Programming and Experiment Control**
Jericha
Vorbesprechung Do 09.03., 12:30, Zoom
Praktikum 04.-17.05. 10:00 – 17:00

141.A86 **Quantenphysik** Haslinger *et al.*






# Seminare:

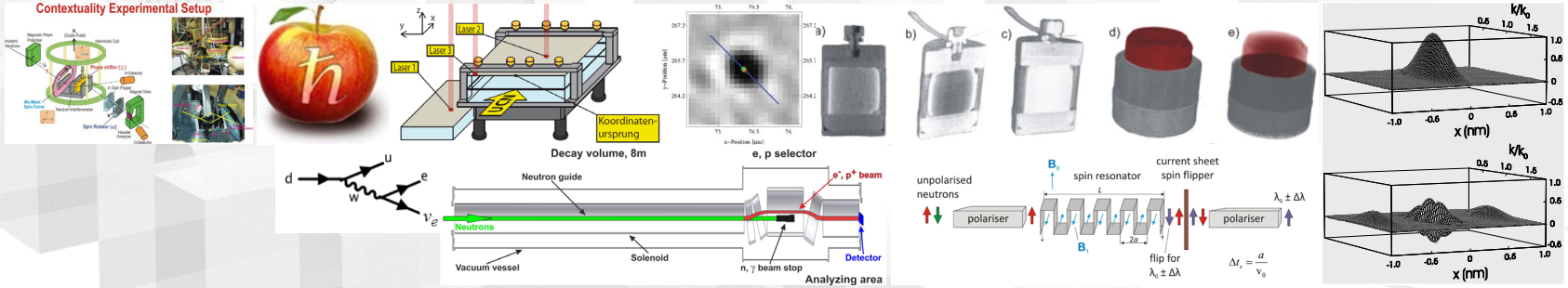
141.543 **Neutronen- und Festkörperphysik**
Fr 10:00-12:00 / Beginn 03.03. / ATI HS

141.B11 **Advances in Quantum Science and Quantum Technology**
Mi 16:00-18:00 / Beginn 01.03. / ATI HS

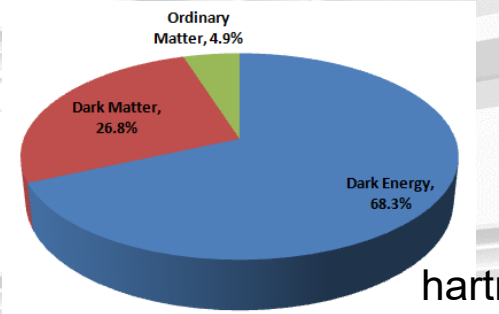
**Frühstücksseminar der Neutronengruppe**
ATI Essraum / Do 09:30 – 10:30 / Beginn 09.03.

# Projektarbeiten / Bachelorarbeiten:

| | | |
|---|---|---|
| 141.A95 | **Projektarbeit Gravitation und Quantenmechanik** | Abele, Sedmik |
| 141.A96 | **Projektarbeit Schwacher Wechselwirkung** | Abele, Jericha |
| 142.025 | **Projektarbeit Nukleare Festkörperphysik** | Jericha, Badurek |
| 142.026 | **Projektarbeit Experimentelle Hadronenphysik** | Jericha, Abele, Zawisky |
| 141.102 | **Projektarbeit Neutronenphysik** | Abele, Hasegawa, Zawisky, Suda |
| 142.025 | **Projektarbeit Neutronenoptik** | Hasegawa, Sponar |

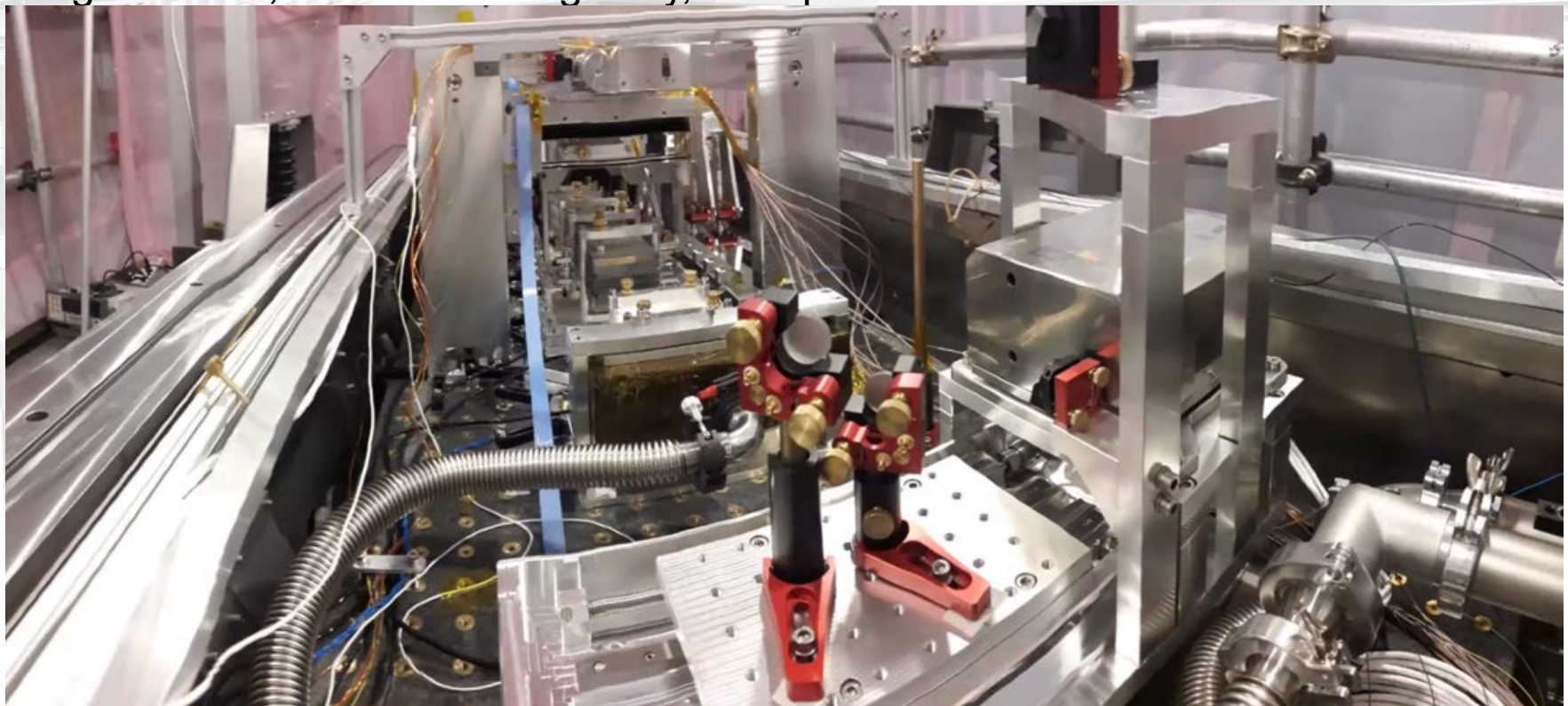


## PA / BA Gravitation & Quantenmechanik: *q*BOUNCE ILL, Grenoble + Vienna




- Quantum states in the gravitational potential
- Potential to probe Dark Energy theories with *q*BOUNCE
- Preparation of a neutron‘s charge measurement
- Instrument control in the submicron regime
- Origine of gravitation, non-Riemann gravity, entropic force

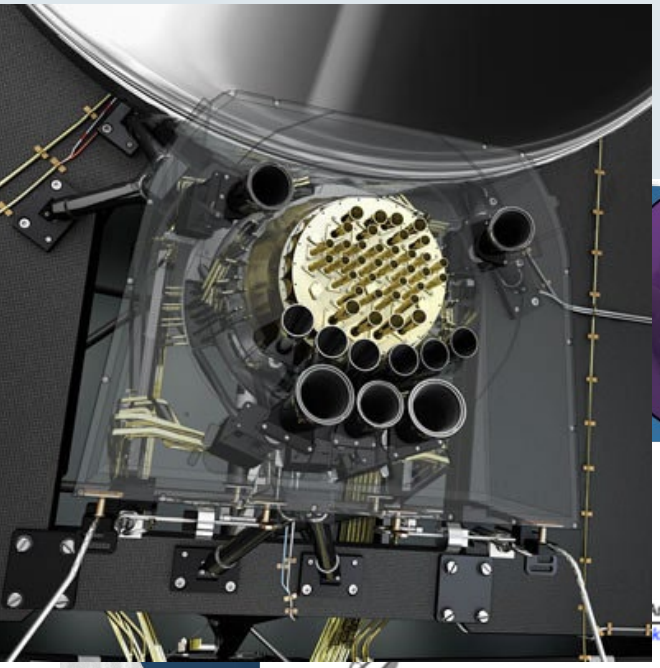
hartmut.abele@tuwien.ac.at

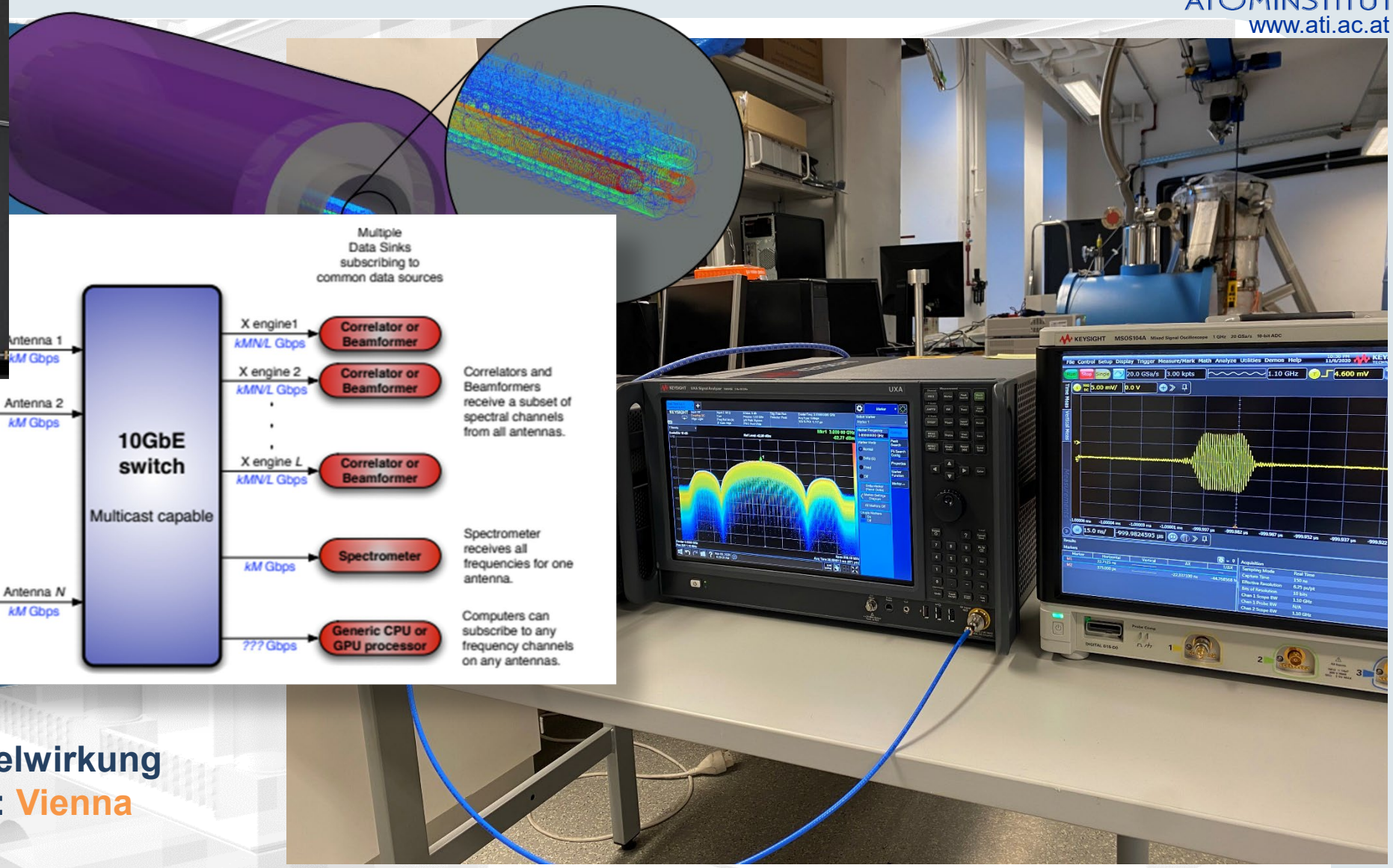



hartmut.abele@tuwien.ac.at

# Munich: Neutron Beta Decay & High Precision Experiments, PERC

Spokesperson: B. Maerkisch, TU München, Time & Project Manager: E. Jericha, TU Wien







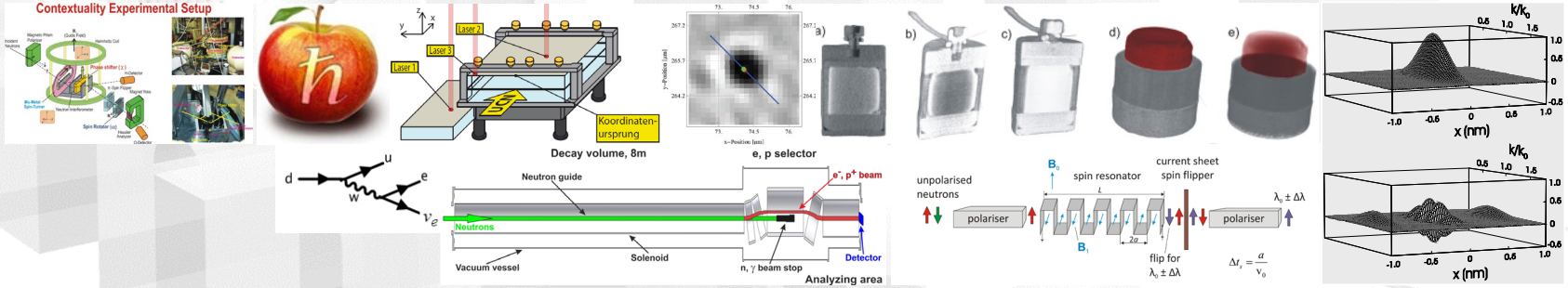

## PA / BA Schwache Wechselwirkung
## Betazerfall der Neutronen: Vienna

*beta decay*
*CREScent: measurement of the cyclotron radiation of electrons*

hartmut.abele@tuwien.ac.at
erwin.jericha@tuwien.ac.at

# Projektarbeiten / Bachelorarbeiten:

| | | |
|---|---|---|
| 141.A95 | **Projektarbeit Gravitation und Quantenmechanik** | Abele, Sedmik |
| 141.A96 | **Projektarbeit Schwacher Wechselwirkung** | Abele, Jericha |
| 142.025 | **Projektarbeit Nukleare Festkörperphysik** | Jericha, Badurek |
| 142.026 | **Projektarbeit Experimentelle Hadronenphysik** | Jericha, Abele, Zawisky |
| 141.102 | **Projektarbeit Neutronenphysik** | Abele, Hasegawa, Zawisky, Suda |
| 142.025 | **Projektarbeit Neutronenoptik** | Hasegawa, Sponar |



TECHNISCHE UNIVERSITÄT WIEN

ATOMINSTITUT
www.ati.ac.at

# Quantum Science & Quantum Technology

| | |
|---|---|
| Atominterferometrie | Ph. Haslinger |
| Atom- und Quantenphysik | J. Schmiedmayer |
| Experimentelle Quanteninformation | J. Leonard |
| Festkörperquantenoptik und Nanophotonik | S. Skoff |
| Quanteninformation & Thermodynamik | M. Huber |
| Quantenmetrologie | T. Schumm |

**VCQ - Vienna Center for Quantum Science & Technology**
**www.vcq.at**

# Quantum S&T – Lectures

## Series of lectures in a 4-semester curriculum

| | | | |
|---|---|---|---|
| • **Quantum Optics** I & II<br>S. Manz, J. Leonard | 141.A10<br>141.A11 | WS 2023<br>SS 2024 |
| • **Quantum Technology** I & II<br>P. Haslinger, J. Leonard, J. Schmiedmayer | 141.A16<br>141.A17 | WS 2024<br>SS 2023 |
| • **Atoms - Light - Matter Waves**<br>J. Schmiedmayer, P. Haslinger | 141.212 | WS 2023 |
| • **Macroscopic Quantum Systems**<br>J. Schmiedmayer, Ph. Haslinger, S. Erne et al. ….. | 141.231 | SS 2023 (continued) |
| • **Quantum Information Theory** I & II<br>M. Huber | 141.B09<br>141.A11 | WS 2023<br>SS 2024 |
| • **Quantum Thermodynamics** I & II<br>M. Huber | 141.B22 | WS 2022/23<br>SS 2023 |

## Seminars (every semester):

- **Advances in Quantum Science and Quantum Technology**
  141.B11, Wednesdays 16:15, Atominstitut, Stadionallee 2

  **students & postdocs**

- **Neutron, Solid-State and Quantum Physics**
  141.543, Fridays 10:00, Atominstitut, Stadionallee 2

- **VCQ Colloquium: Complex Quantum Systems**
  141.271, Mondays 18:00 @ FreihausHS3, announced at www.vcq.at

  **external speakers**

# Quantum S&T – Lab experience



4-Semester Curriculum

## Hands-on Lab experience:

- **Praktikum: Quantum Physics** 4 ECTS **141.A86**
  Haslinger, Sponar, Manz, Schachinger, Schumm, Schmiedmayer, Abele, Schneider

  Lab course where you can experience first hand the basic phenomena of Quantum Physics.
  Brand-new setups, one afternoon each, small teams (2-3)
  **Sign up for labs by mail to:** barbara.stros@tuwien.ac.at

- **Projektarbeiten** (also bachelor projects) 10 ECTS

  Experience real lab research, about 6 weeks full time, small teams (1-3)
  **Contact the supervisor** for planning (at least 1 month in advance)
  - **Quantum Optics** (Bayer-Skoff, Haslinger, Leonard) **141.095**
  - **Nanophotonics** (Bayer-Skoff, Schumm) **141.A13**
  - **Atomuhren und Quantenmetrologie** (Schumm) **141.A27**
  - **Ultracold Atoms and Spectroscopy** (Schmiedmayer, Schumm, Haslinger) **141.214**
  - **Quantum Technology** (Schmiedmayer, Rabl, Leonard) **141.A15**

TECHNISCHE UNIVERSITÄT WIEN

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# QUantum Information &Thermodynamics

Marcus Huber & the
QUIT Physics group

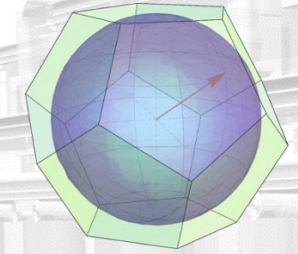
Start
FWF Der Wissenschaftsfonds.
erc
ESQ Discovery
VCQ Vienna Center for Quantum Science and Technology

TECHNISCHE UNIVERSITÄT WIEN

# Quantum Information Theory

ATOMINSTITUT
www.ati.ac.at

## Quantum information in high dimensions



- Bloch representation & entropy characterisation
- Entanglement in high-dimensional systems
- Multipartite and beyond LOCC entanglement
- Device independent characterisation

- High-dimensional protocols
- Quantum communication beyond QKD
- Modeling realistic channels
- Multipartite key distribution

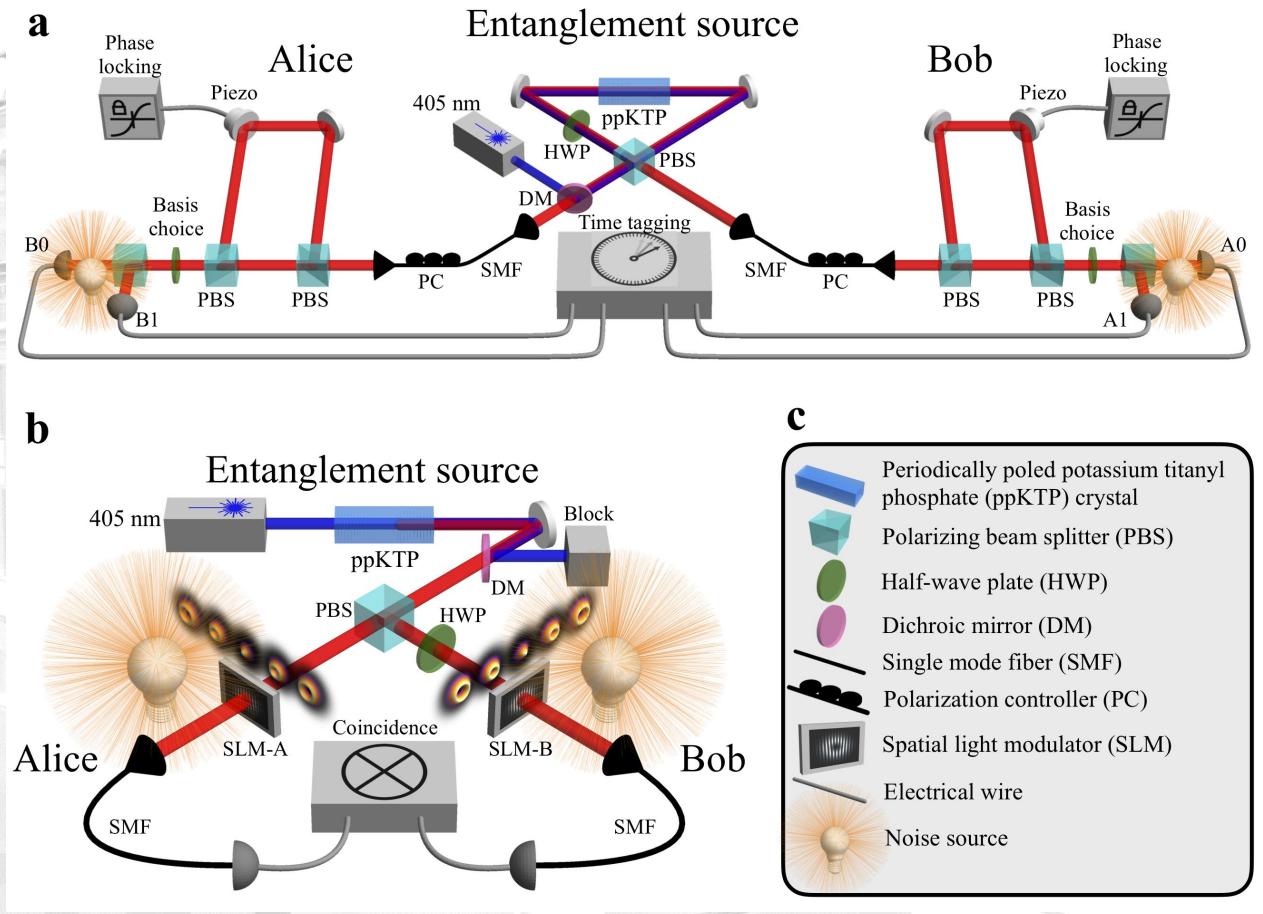
## Quantum cryptography

# Quantum Photonics



High-dimensions: how many bits per photon?

- Energy-time entangled photons




Channels

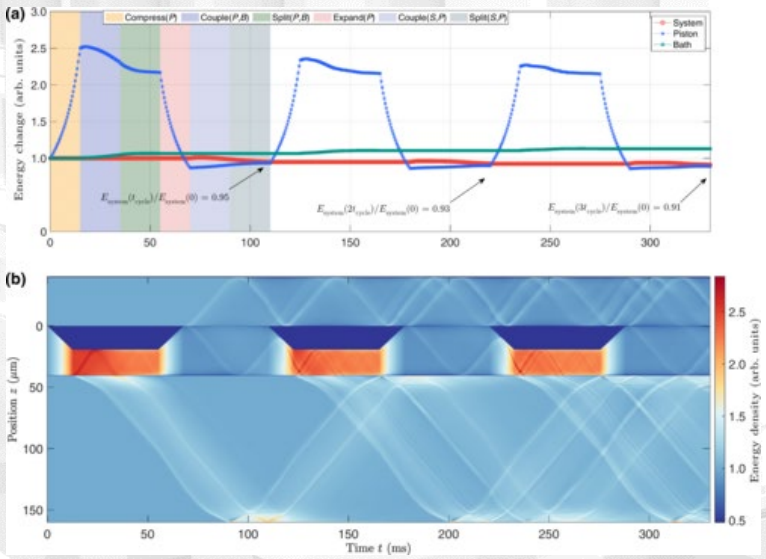
- Free space
- Multicore fibres

- Spatial modes of light: entanglement and measurements

# Quantum Thermodynamics

Funamental Thermodynamics

- Foundation of physics: Ultimate limits to knowledge & acquisition of information
- Thermodynamic protocols: Cooling on a quantum computer & limits to correlations
- Entropy and the arrow of time
- Thermodynamics & Complexity




Applied Thermodynamics

- Modeling realistic thermal machines (open quantum systems & many-body theory)
- Quantum Field Thermal Machine (with Jörg Schmiedmayer)

# Quantum Foundations



Emergence of Physics at different scales and philosophy of science

Micro-state

Macro-state

Coarse graining $C(\alpha_0) = \mathrm{A}_0$

$\alpha_0 = 0111000100110000 1 \ldots$ → $\mathrm{A}_0 = 011110011001 \ldots$

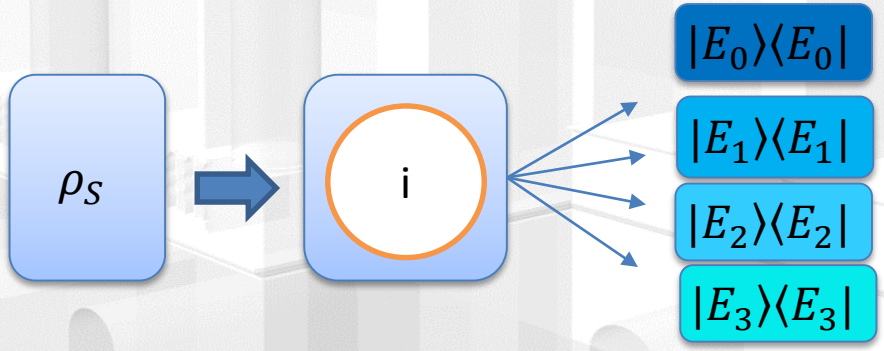
Program: $\mathrm{P}(\alpha_0, t) = \alpha_t$

Program: $\mathrm{E}(A_0, t) = A_t$

Coarse graining $C(\alpha_t) = \mathrm{A}_t$

$\alpha_t = 0101001100100000 1 \ldots$ → $\mathrm{A}_t = 011110011001 \ldots$

The quantum measurement problem: thermodynamic foundation?



# Experimental Quantum Information

Julian Léonard

**www.quantuminfo.com**

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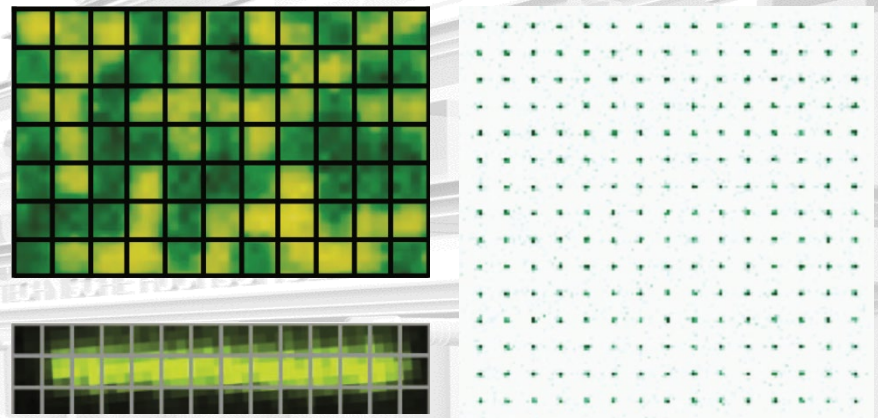
VCQ Vienna Center for Quantum Science and Technology

# Quantum Information: Research

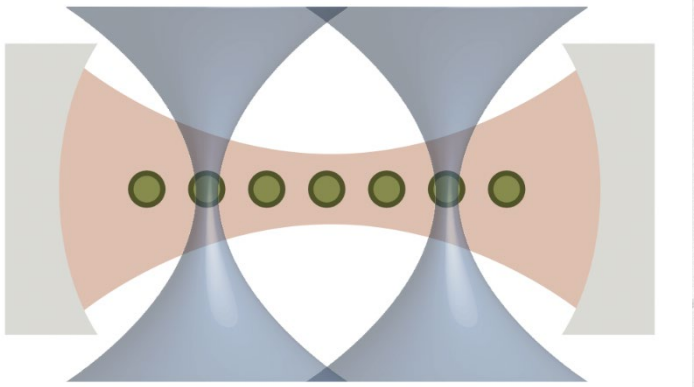


## Building quantum systems atom by atom



**Neutral atoms: a leading platform for quantum simulation/computation**

- Perfect isolation
- Unmatched size & scalability
- Accessible length- and time scales
- Single-qubit control & readout



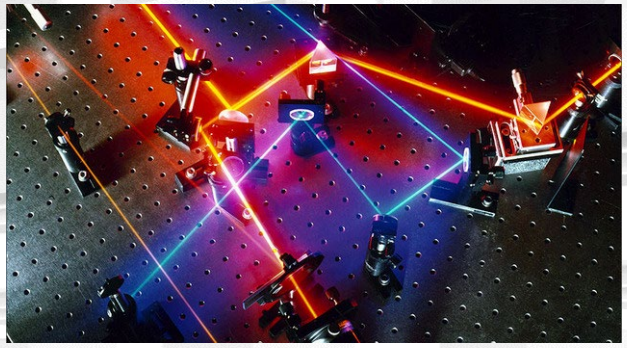
**Build a next-generation quantum processor:**

- Quantum gas microscopy
- Optical tweezers
- Strong light-matter coupling
- Non-local entanglement

## Student projects: Projekt-/Masterarbeiten

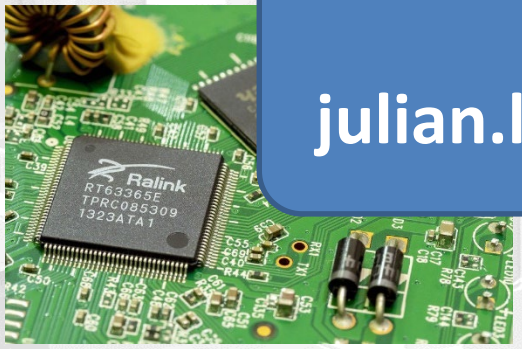
**Various topics, e.g.:**

Beam shaping, design of high-NA optical systems (e.g. Zemax)

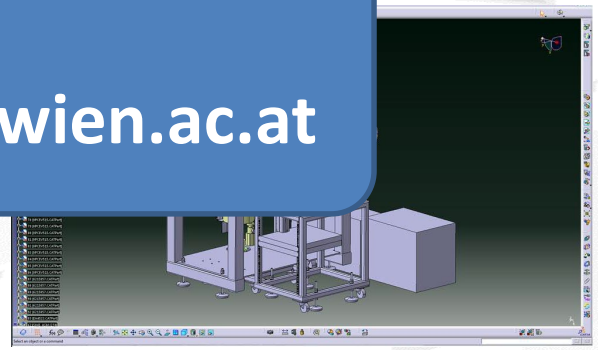


Laser systems: atomic spectroscopy, optical frequency locks, beam shaping

**Contact:**
**julian.leonard@tuwien.ac.at**




Development and prototyping of PCBs (e.g. Altium, with electronics workshop)



Mechanical design and prototyping (CAD, mechanical workshop)

# Solid-State Quantum Optics and Nanophotonics

Sarah Skoff

**www.skofflab.com**

FWF Der Wissenschaftsfonds.

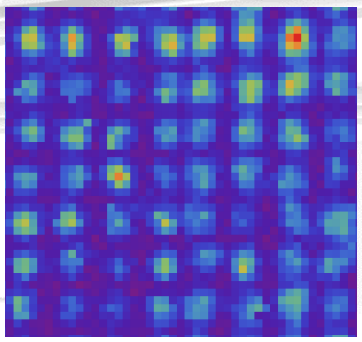
VCQ Vienna Center for Quantum Science and Technology

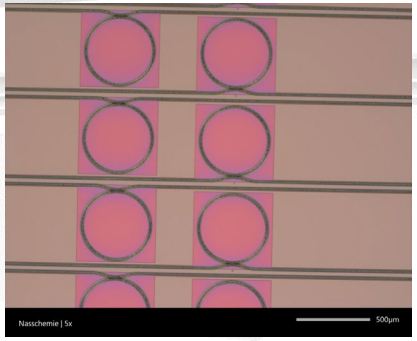
# Solid-State Quantum Optics and Nanophotonics Research



## New quantum technologies based on quantum emitters in solid-state materials ( e.g. 2D materials) and nanophotonics

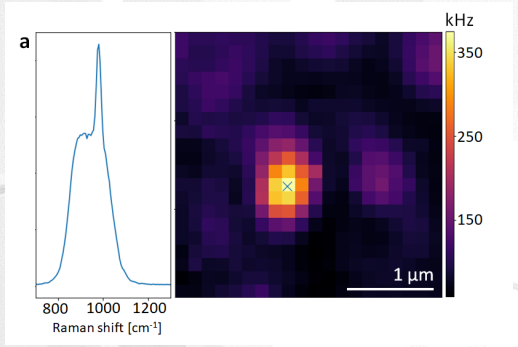
- Implementing **strong light-matter interactions** on the level of **single photons** and **single quantum emitters**
- Developing new technologies **for photonic quantum networks**

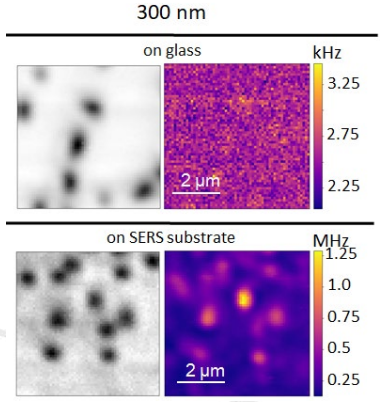




## Nanophotonic platforms for precision sensing

- **Detection and spectroscopy** of nanoparticles**,** in particular **nanoplastic** via **nanophotonic platforms**, such as **plasmonic** substrates.



# Solid-State Quantum Optics and Nanophotonics

## Teaching

### Bachelor-, Project- and Masterprojects (141.095, 141.A13):

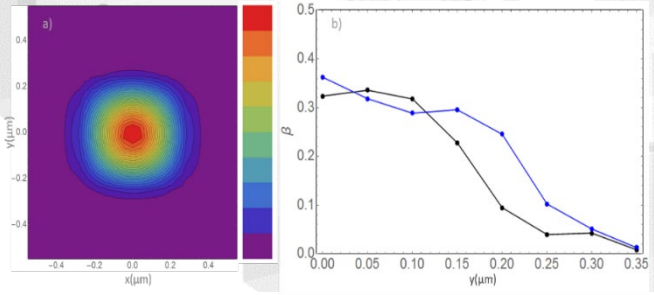
**(available again from WS2024 onwards)**

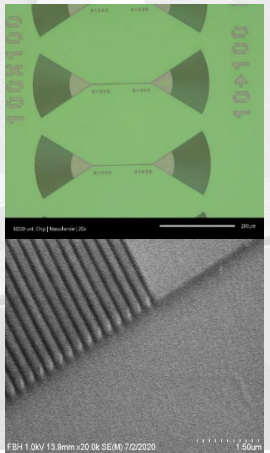
Please contact:
**sarah.skoff@tuwien.ac.at**

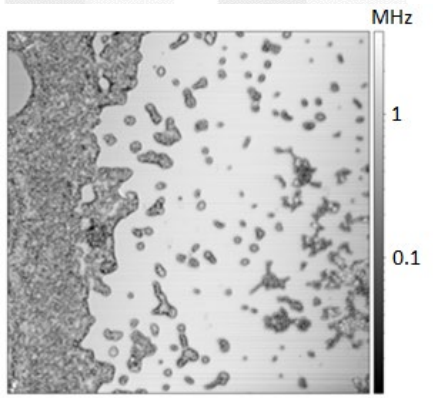
- **Participation in current research projects in the lab**
- Topics: quantum emitters in hexagonal boron nitride, detection of nanoplastic, …

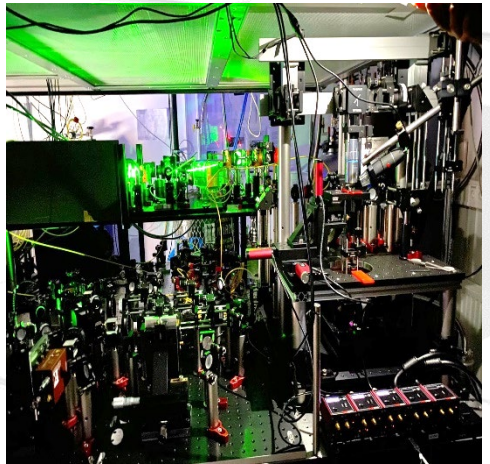
- **Smaller self-contained projects on nanophotonics and spectroscopy**

  Topics: simulation of nanophotonic components (FDTD), characterisation of waveguide structures, homebuilt diode lasers, laser locks,…





AQUnet
Austrian Quantum Fiber Network

AQUclock
Austrian Quantum Clock

# Quantum-Metrology

Thorsten Schumm

Kjeld Beeks, Georgy. Kazakov,
Stephanie Manz, Martin Pimon,
Enikoe Seres, Josef Seres,
Tomas Sikorsky

VCQ
Vienna Center for Quantum Science and Technology

erc

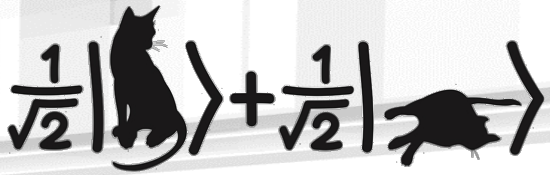
FFG
Promoting Innovation.

Funded by the Austria Research Promotion Agency

# Group research focus

## Precision measurements based on quantum effects:

- „superposition-based“ quantum sensors

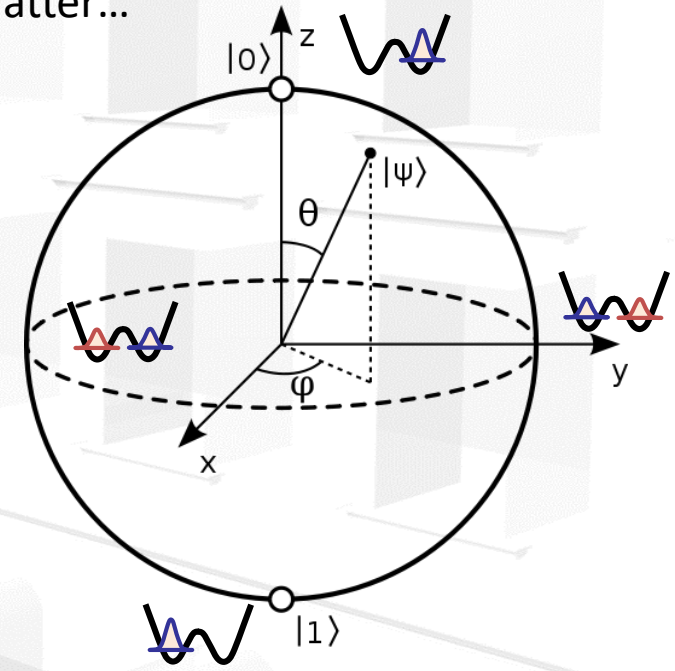



## „Internal“ state superpositions

- atomic clocks (MW, optical, UV...?)
- applications in navigation, communication, geodesy…
- fundamental research: interaction constants, dark matter…
- **research project:** a nuclear clock with Thorium-229

## „External“ state superpositions

- de-localized wave functions of matter
- matter wave interferometry
- measurements of tilt, rotation, accelleration
- fundamental research: quantum-classical boundary
- **research project:** Caesium-BEC-interferometer



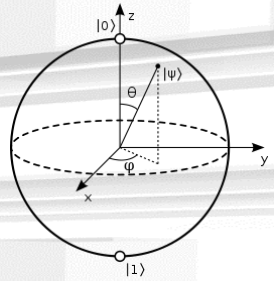
# Teaching

## Lectures

**141.A71 Mesurement Technologies I  Thursday 8:15-10:00 Hörsaal Atominstitut**

**start 2.3.2023**

- Basics concepts of measuring, statistics, errors, fitting, noise
- Basic physical units, SI, present and future implementations
- Emphasis on quantum metrology: atom gravimeters, atomic clocks,…

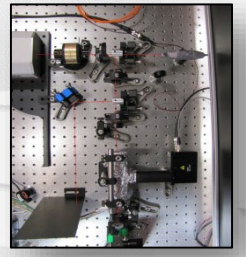



## Projektarbeiten (also suited for bachelor projects)

**141.A27 Atomic clocks and  quantum metrology**

book early!

- hands on projects embedded into research group
- topics: lasers, spectroscopy, experimental control, programming…



**contact:** Thorsten.Schumm@tuwien.ac.at

## Praktikum

**141.A12 Fundamental experiments on quantum physics**

book early!

- nuclear magnetic resonance (NMR)
- single versus two-photon interference
- Einstein-Podolski-Rosen / Bell experiment
- neutron interferometry at TRIGA reactor

**contact:** barbara.stros@ati.ac.at

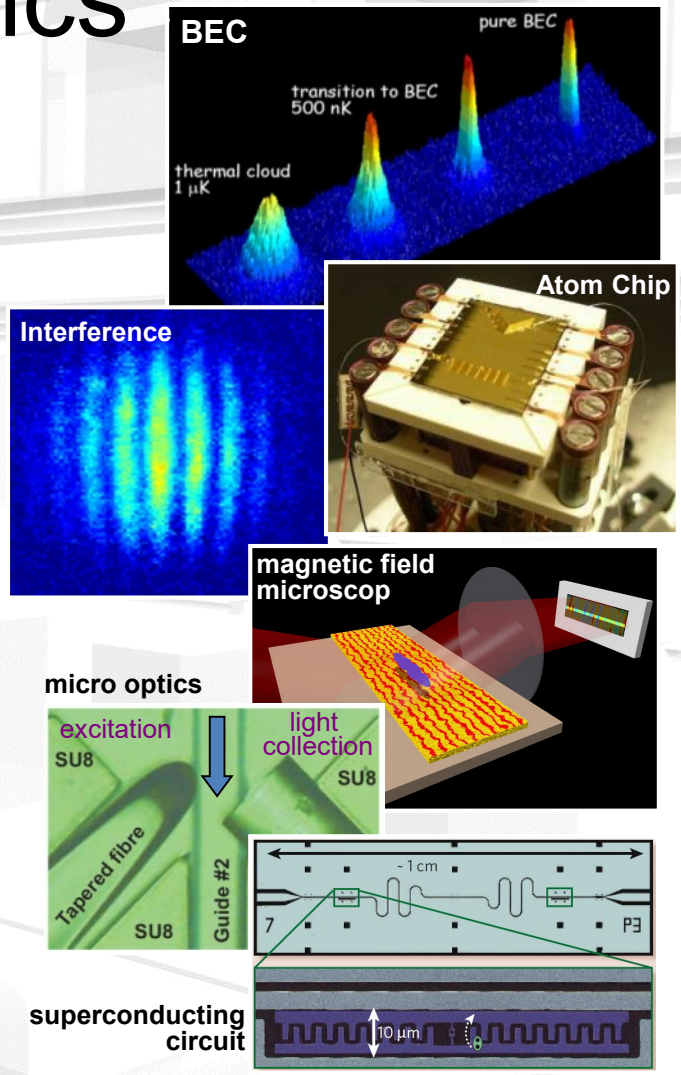
# Atom- und Quantenphysik

I. Mazets, M. Prüfer, S. Erne
J. Schmiedmayer

WITTGENSTEIN
CoQuS ComplexQuantumSystems
FWF Der Wissenschaftsfonds.
erc
SEVENTH FRAMEWORK PROGRAMME
VCQ Vienna Center for Quantum Science and Technology

# Understanding and Implementing Quantum Physics

- fundamental research
  - quantum degenerate Bose and Fermi gases
  - coherence and de-coherence
  - quantum simulations
  - quantum field theories in the Lab
  - connecting quantum systems
- applications in devices
  - Quantum memory
  - Quantum repeater
- technologies
  - lasers, optics
  - imaging and image processing
  - super conductivity and cryogenic technology
  - experimental control and active feedback
  - nano fabrication and micro optics



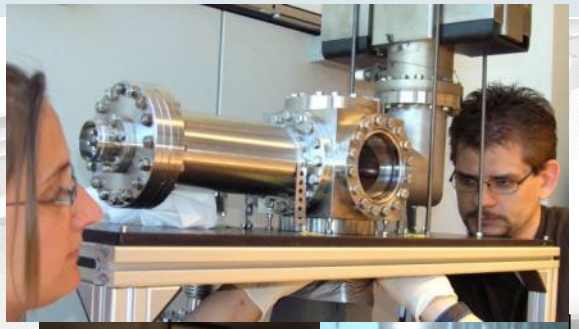
TECHNISCHE UNIVERSITÄT WIEN

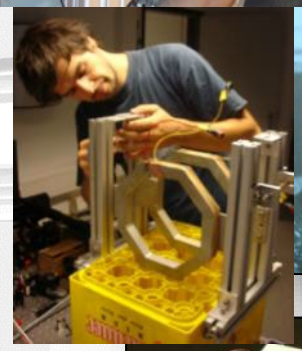
# Atom- und Quantenphysik

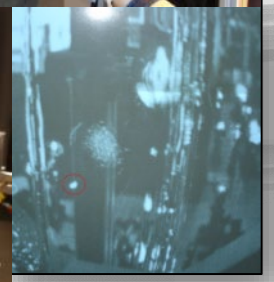
ATOMINSTITUT
www.ati.ac.at

## Projektarbeit 141.214: Ultracold Atoms and Spectroscopy

10 ECTS points, located at ATI







A laser cooling setup built up exclusively by students

gain hands-on experience on...

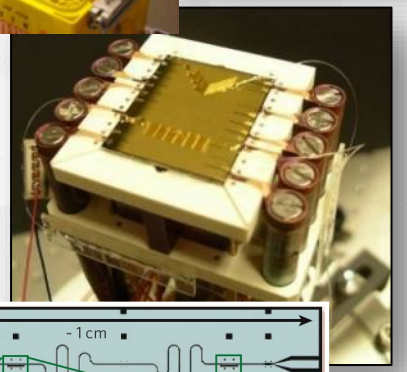
laser physics, high-resolution spectroscopy, feedback and frequency stabilisation, acousto-optics, polarization vacuum technology, laser cooling and trapping, digital imaging and image analysis

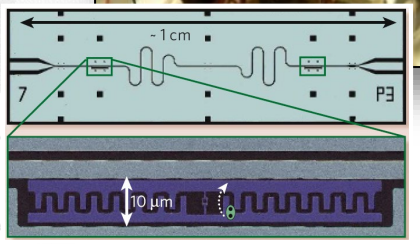
**format:** teams of 1-2, successive bottom-up segments, 4 weeks full time, fully WIKI based documentation (see homepage for info),

**contact:** schmiedmayer@atomchip.org

## Projektarbeit 141.A15: Quantum Technology

10 ECTS points, located at ATI






merging microfabrication with optics and superconducting quantum circuits

gain hands-on experience on...

Nano fabrication, micro optics, single photon optics and detectors, micro wave engineering, micro wave resonators, cryogenics, superconductivity, quantum electronics

**contact:** schmiedmayer@atomchip.org

**Können auch als Bachelorarbeit angerechnet werden !**

# Atom- und Quantenphysik



## Lecture:

- **Macroscopic Quantum Systems** **141.231 SS 2023** (continued)

  J. Schmiedmayer, Ph. Haslinger, S. Erne et al. …..

Introduction into the physics of quantum degenerate ultra cold matter.

Topics will include: BEC, degenerate Fermi gas, low dimensional systems,
quantum simulation, quantum field theory in the lab,
learning the physics from data, verification of quantum models etc …

The lecture will be a continuation of the series started last semester.
for newcomers: extra introduction refreshing essentials of atomic physics and atom-light interaction

**location:** **Atominstitut** (Stadionallee 2),
**language:** English
**format:** 3 Blocks: 2 afternoons for lectures and 1 afternoon for student talks
dates and times will be arranged flexible.
**First Lecture:** ??
**extra introduction:** or fixed by email
**Exam**: 72 hour home exam. All tools except other people are allowed
Short term-paper on a recent scientific publication
Write a report (max 4 pages).
Short discussion on the term paper to determine the grade.

CoQuS
ComplexQuantumSystems

TECHNISCHE UNIVERSITÄT WIEN

ATOMINSTITUT
www.ati.ac.at

AQUTEM

FFG

# Atom-Interferometrie

**(Quantum Electron Optics)**

Philipp Haslinger

**www.haslingerlab.com**

Start

FWF Der Wissenschaftsfonds.

*ESQ Discovery*

VCQ Vienna Center for Quantum Science and Technology

# VCQ Colloquium

- **VCQ Colloquium: Complex Quantum Systems**

  141.271, Mondays 18:00 @ Freihaus HS3 + drinks&snacks

| | |
|---|---|
| 13.03.2023 | Chris Fewster |
| 24.04.2023 | Marianna Safranova |
| 08.05.2023 | Claus Ropers |
| 22.05.2023 | Darrick Chang |
| 02.06.2023 | Philippe Grangier (special talk, Friday at UNIVIE Lise-Meitner Lecture Hall; exact time tbt) (Zeilinger) |
| 19.06.2023 | Cindy Regal |
| 26.06.2023 | Brigitta Whaley |

www.vcq.at

# Hands-on Lab experience

- **Praktikum: Quantenphysik** 4 ECTS **141.A86**

Haslinger, Sponar, Manz, Schachinger, Schumm, Schmiedmayer, Abele, Schneider

Lab course where you can experience first hand the basic phenomena of Quantum Physics.
Brand-new setups, one afternoon each, small teams
**Sign up for labs by mail to:** barbara.stros@tuwien.ac.at

Please sign up before 13.3.2023

- Verschränkte Photonen / Bell-Ungleichung
- HeNe-Laser
- Kernspinresonanz (NMR)
- Laserspektroskopie von Rubidium
- Topological phases with neutrons (am Reaktor, ATI)
- Interferenz am Doppelspalt mit einzelnen Elektronen (am USTEM)

Electron Microscopy @ USTEM

Neutron Interferometry @ ATI

# Quantum Technology II

- **Quantum Technology II** **141.A16** **SS 2023**

P. Haslinger, J. Leonard, J. Schmiedmayer

Immer Donnerstags um 14 Uhr ECTS: 3.0

**Location:** **Freihaus** Sem.R. DA grün 06A
**Language:** English

**Vortragender Prof. Haslinger:** **9.3., 16.3., 23.3., 20.4.**
Materiewellen: von Elektronen über Atome zu komplexen Molekülen; Materiewellenoptik und Interferometrie, fundamentale Experimente mit Materiewellen, Materiewellensensoren.

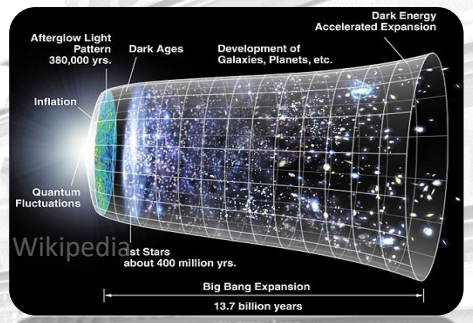
**Vortragender Prof. Leonard:** **27.4., 4.5., 11.5., 25.5.**
Quantum simulation: (a sub-discipline of quantum computing) provides insights into problems from physics or chemistry by assembling and studying an equivalent system from well-controlled building blocks. In this lecture we will review the techniques and important milestones of this thriving field, as well as discuss ongoing progress and future challenges.

**Vortragender Prof. Schmiedmayer:** **(1.6.), 15.6., 22.6., 29.6.**
Hybride Quantum Systems: Connecting different quantum systems in hybrid quantum devices enables to pull their strength to overcome the weaknesses of the individual systems. The lectures will discuss the basic principles and illustrate them in a few prominent examples like the quest for a quantum repeater, a quantum memory or hybrid quantum sensors

# Lattice Atom Interferometry

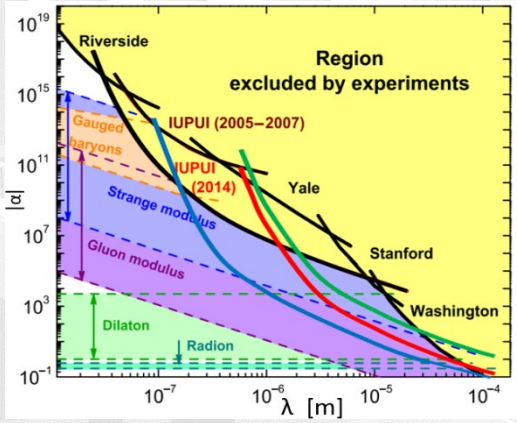
Philipp Haslinger

## The Dark Universe

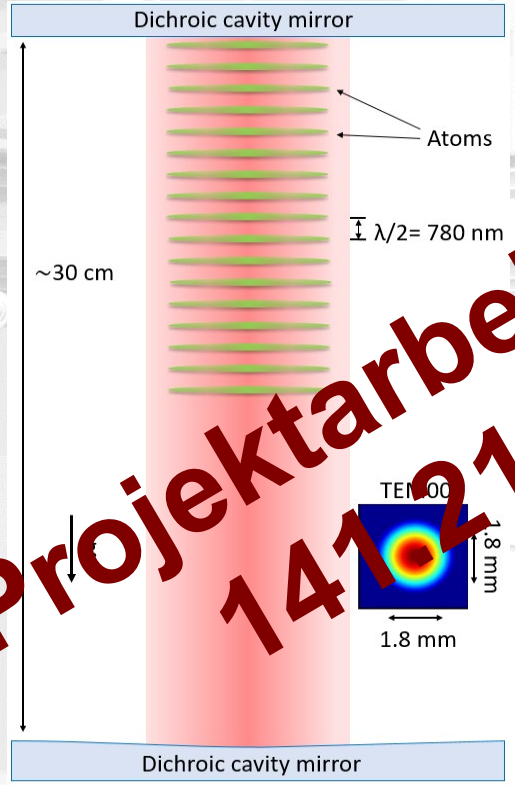



- Discover or rule out many models

## Short Range Forces




- At 10 μm, forces >$10^4$ x gravity possible
- Sense effects beyond the standard model: string theory...



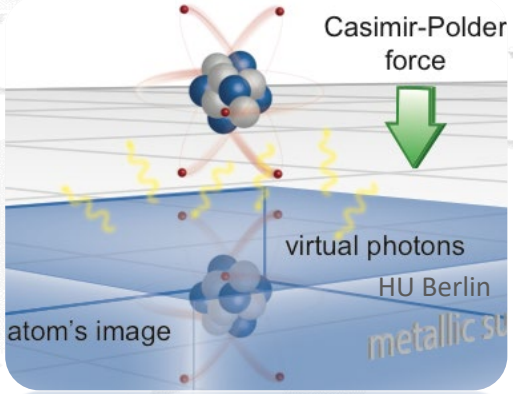

Projektarbeiten 1411214

- Atoms: perfect test-particles
- Ultra long interaction times
- Map pot. energy landscape
- Miniaturized quantum sensor

## Light-Induced Interaction

- Mechanical effects of thermal light
- BEC, Ultracold gasses, astrophysics,...

## Casimir–Polder Interaction




- Interaction from quantum fluctuations
- Temperature & spatial dependence

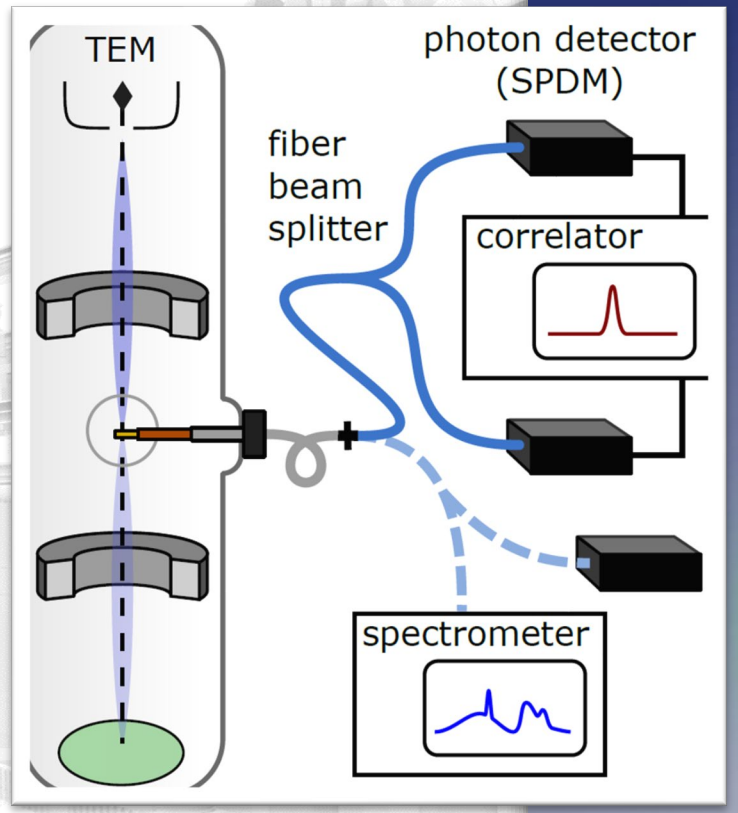
# Ultrafast – Electron Microscopy

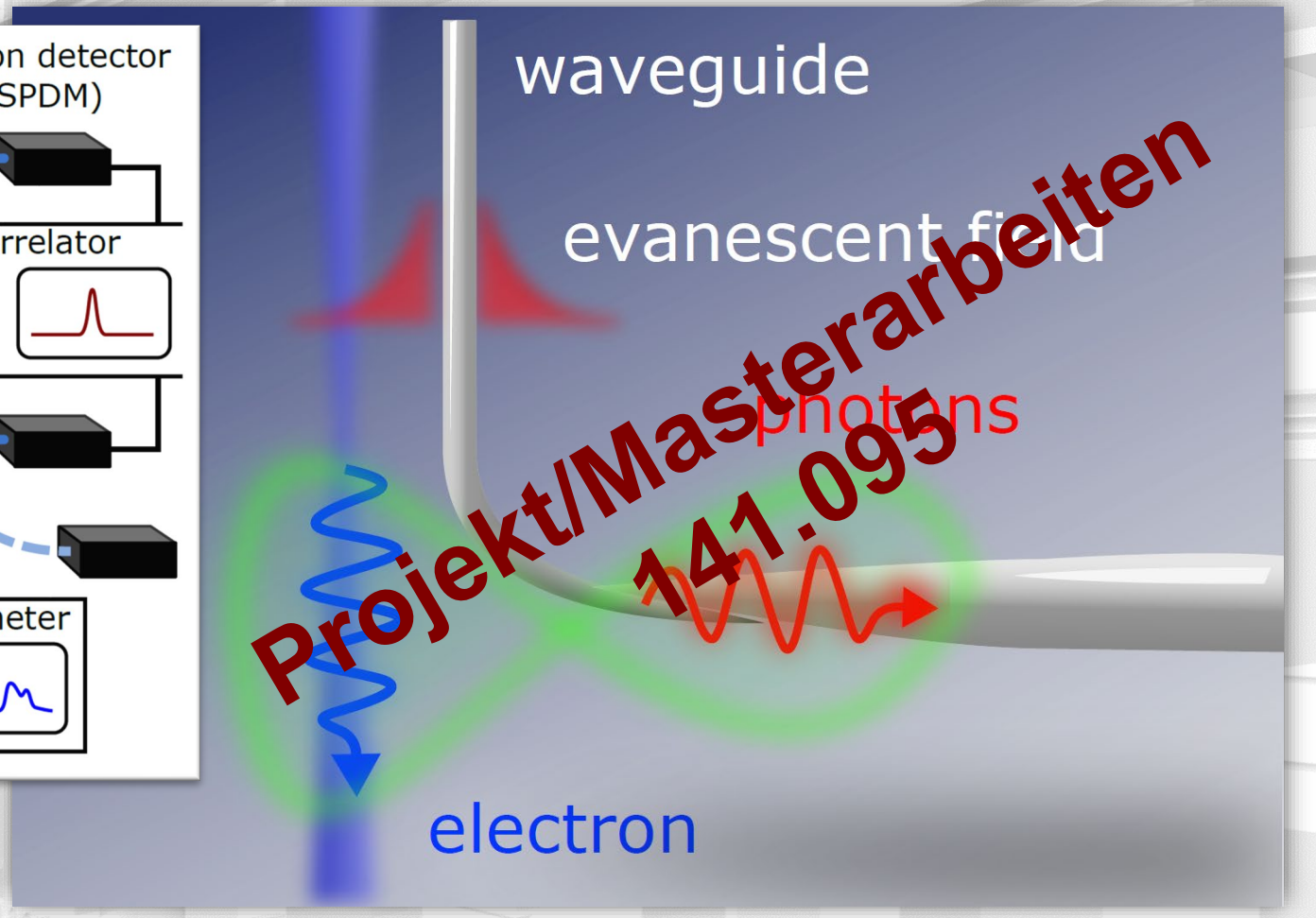

**Projekt/Masterarbeiten**
**141.095**

*Controlling Quantum Systems with Modulated Electron Beams*
D. Rätzel, D. Hartley, O. Schwartz, P. Haslinger
**Physical Review Research** 3, (2), 023247 (2021)

FFG

# Entangled Electron – Photon Pairs in Electron Microscopy



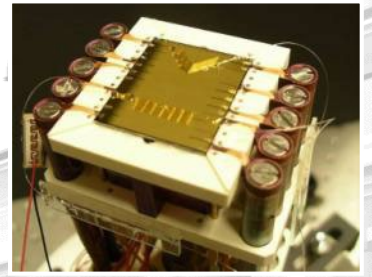



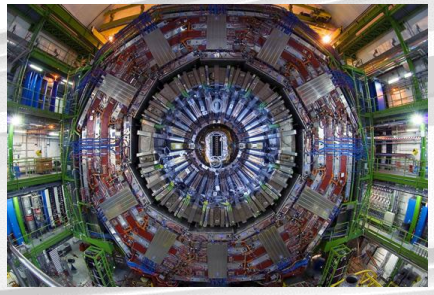
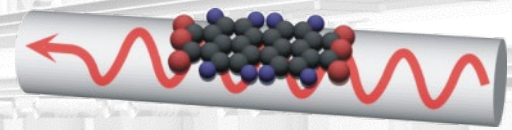

Projekt/Masterarbeiten
141.095

*Discrimination of coherent and incoherent cathodoluminescence using temporal photon correlations*
M. Scheucher, T. Schachinger, T. Spielauer, M. Stöger-Pollach, P. Haslinger
**Ultramicroscopy** 241, 113594 (2022)

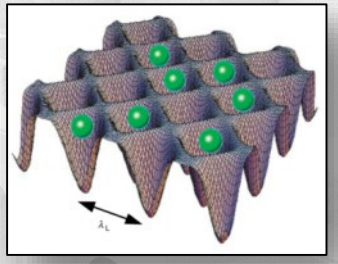
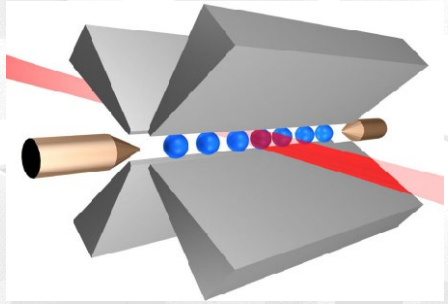
**www.haslingerlab.com**

**philipp.haslinger@tuwien.ac.at**

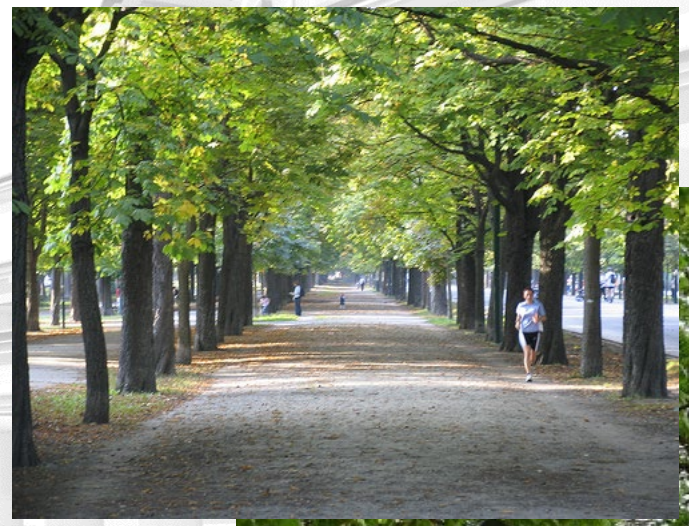


# zum Abschluss


# Beyond Physics @ ATI





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