Fundamental symmetries studied with trapped ultra-cold atoms and ions

- We are a new group at the U. of Manitoba
- establishing a research programme in laser-cooling and trapping of francium at the ISAC radioactive beam facility at TRIUMF, Vancouver
- goal: study electroweak interaction and search for physics beyond the Standard Model by performing very precise laser-spectroscopic experiments

The squared Weinberg-angle, a key observable in electroweak physics, as a function of the interaction energy

Schematic of a magneto-optic trap (MOT) to capture Fr atoms produced in a nuclear reaction at ISAC into a millimeter-sized ball of $10^7$ atoms cooled to 100 micro-Kelvin.

We are looking for graduate students interested in this combination of fundamental physics and table-top laser spectroscopy

contact: Gerald Gwinner, Dept. of Physics, Univ. of Manitoba, (204) 474-9856, gwinner@physics.umanitoba.ca, www.physics.umanitoba.ca/people/faculty/gwinner.html
The TITAN ion trap facility as ISAC

- we collaborate with a group at TRIUMF (J. Dilling et al.) on the realization of an ion trap system mounted on-line at the ISAC radioactive beam facility, which will be unique in the world
- physics goals: measure extremely precisely masses of unstable nuclei, this is very important for astrophysics (nuclear synthesis) and weak interaction experiments

projects:

1. a electron-cooler trap to pre-cool highly-charged ions before injection into the precision trap

2. design of a Penning ion trap to perform measurements of the electron’s bound-state g-factor to test QED and nuclear structure

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EBIT (electron beam ion trap)

the trap:
axially: electron beam space charge

6000 A/cm²
n_e ≈ 10¹³ e⁻/cm³

longitudinally: electrodes

trap potential U_t ≈ 100 V
(U_t × ion charge) ≈ 5000 eV

e⁻-beam

B

40 mm

60 μm
The diagram illustrates a trapping potential with four stages:

- **a)** ions enter trap
- **b)** catching after 1st turn
- **c)** electron cooling
- **d)** resistive cooling

The trapping potential graph is shown with the x-axis labeled as "distance from trap centre (cm)" and the y-axis labeled as "trapping potential."
• modern ‘table-top’ experiments with state-of-the-art laser equipment, student has the opportunity to participate in all aspects

• investigate fundamental physics while getting exposed to hi-tech equipment

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A new test of relativistic time dilation with fast stored ions.

Gerald Gwinner
Saturation spectroscopy

two level system

fixed frequency
laser

\[ \nu_p = \gamma (1 + \beta) \nu \]

PMT

\[ \nu = \gamma (1 - \beta) \nu \]

tunable laser

saturation dip: both lasers in resonance with same velocity group

\[ \nu_p = \gamma (1 + \beta) \nu \]

\[ \nu_a = \gamma (1 - \beta) \nu \]

In special relativity exactly

\[ \nu_a \nu_p = \nu^2 \]

\[ \nu_a \nu_p = \nu^2 (1 - 2\alpha \cdot \beta^2 + ...) \]