Parity violating Berry Phases in an Atomic Beam Spin Echo - Experiment

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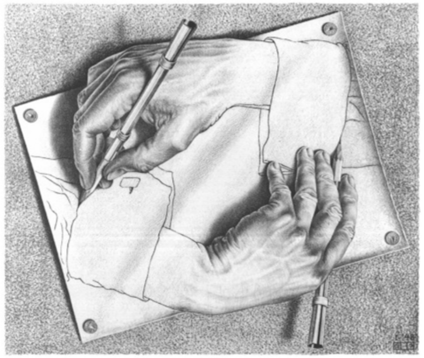
IMPRS-Seminar / 24.4.2012

Outline

- Motivation
- Atomic Beam Spin Echo-Principle & Berry-Phases
- The Experimental Setup
- First Measurements
- Summary & Outlook

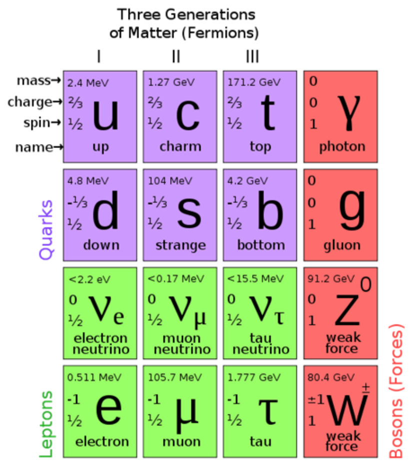
Motivation

Parity Violation

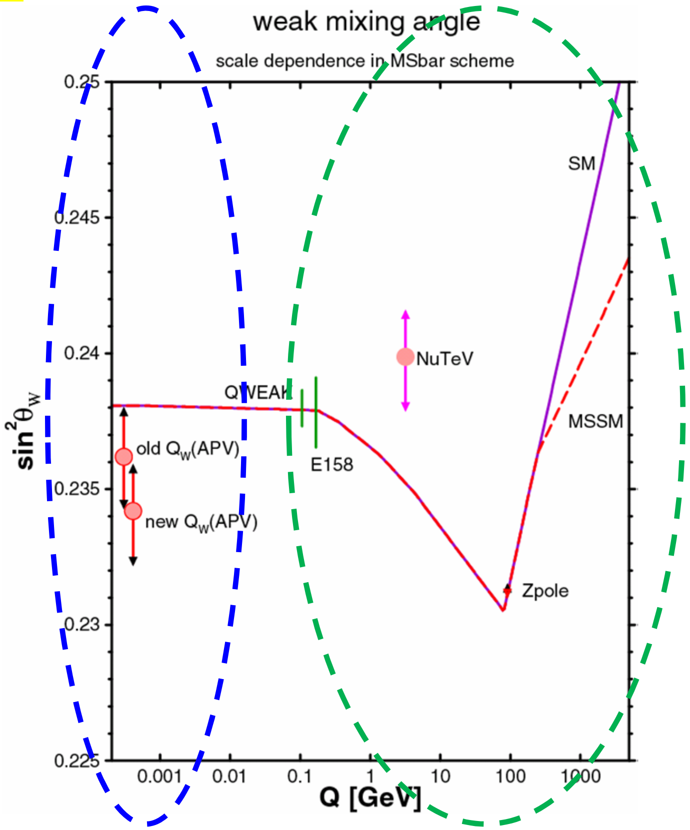


$$P^{-1} H P \neq H$$

Q_W



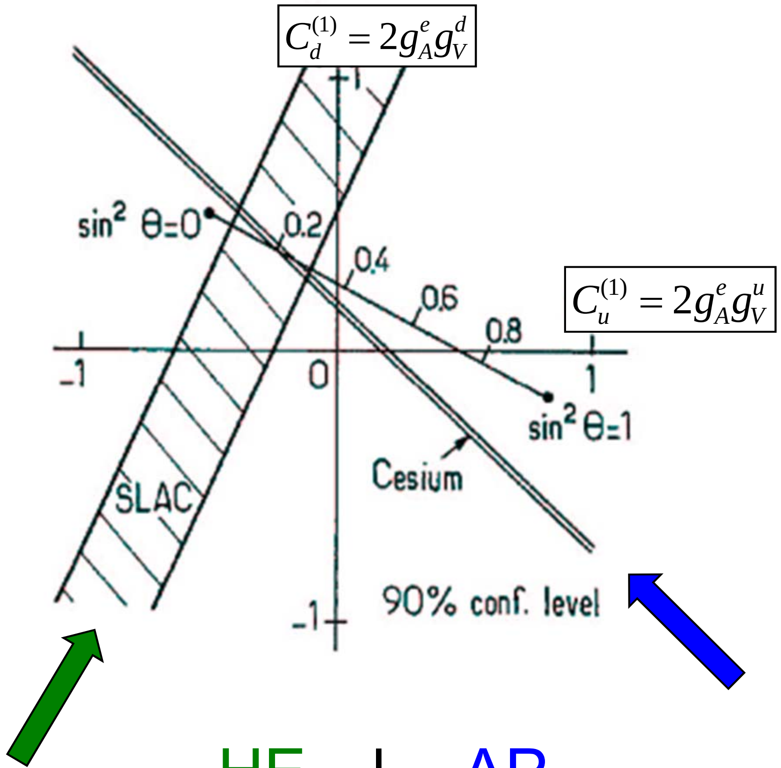
Parity Violation



Atomic Physics

@ Q² ~ 0

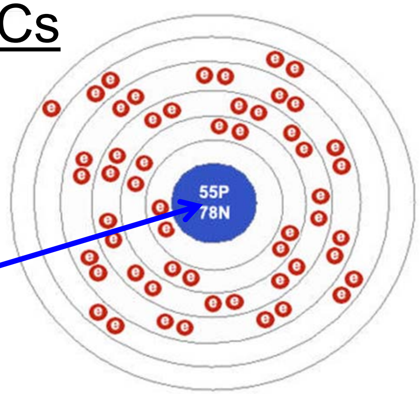
High-Energy Physics



HE ⊥ AP

Parity Violation

Cs

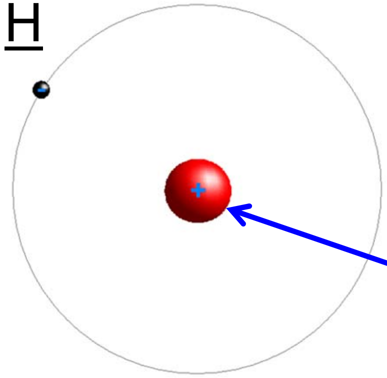


complicated

(133 nucleons)

$Q_w \sim Z^3$

H



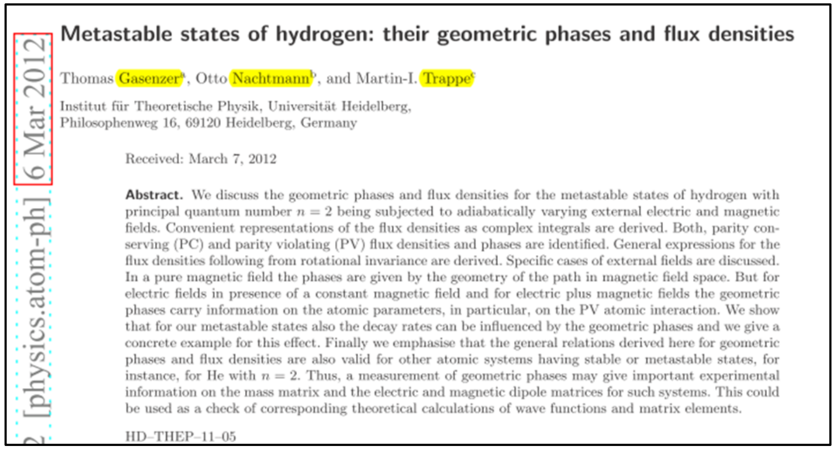
easy structure

$\Delta E_{weak} / \Delta E_{em} < 10^{-6}$

$\Delta E_{weak} / \Delta E_{em} < 10^{-12}$

Parity Violation

P-conserving and P-violating Berry Phases



[physics.atom-ph] 6 Mar 2012

Metastable states of hydrogen: their geometric phases and flux densities

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Abstract. We discuss the geometric phases and flux densities for the metastable states of hydrogen with principal quantum number $n = 2$ being subjected to adiabatically varying external electric and magnetic fields. Convenient representations of the flux densities as complex integrals are derived. Both, parity conserving (PC) and parity violating (PV) flux densities and phases are identified. General expressions for the flux densities following from rotational invariance are derived. Specific cases of external fields are discussed. In a pure magnetic field the phases are given by the geometry of the path in magnetic field space. But for electric fields in presence of a constant magnetic field and for electric plus magnetic fields the geometric phases carry information on the atomic parameters, in particular, on the PV atomic interaction. We show that for our metastable states also the decay rates can be influenced by the geometric phases and we give a concrete example for this effect. Finally we emphasise that the general relations derived here for geometric phases and flux densities are also valid for other atomic systems having stable or metastable states, for instance, for He with $n = 2$. Thus, a measurement of geometric phases may give important experimental information on the mass matrix and the electric and magnetic dipole matrices for such systems. This could be used as a check of corresponding theoretical calculations of wave functions and matrix elements.

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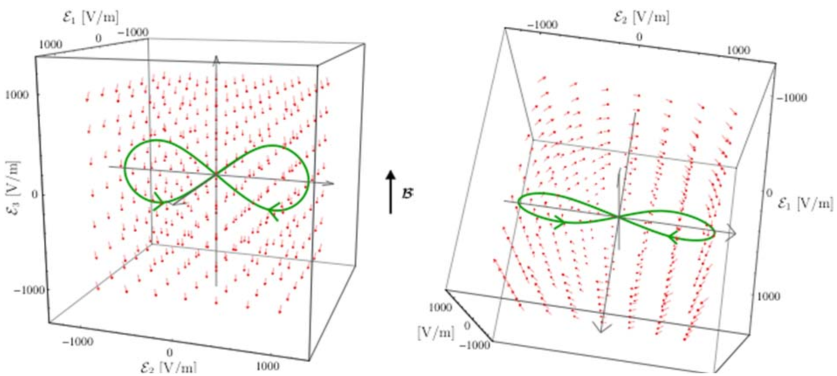
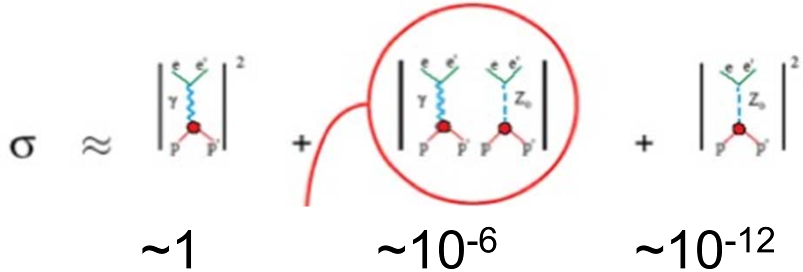


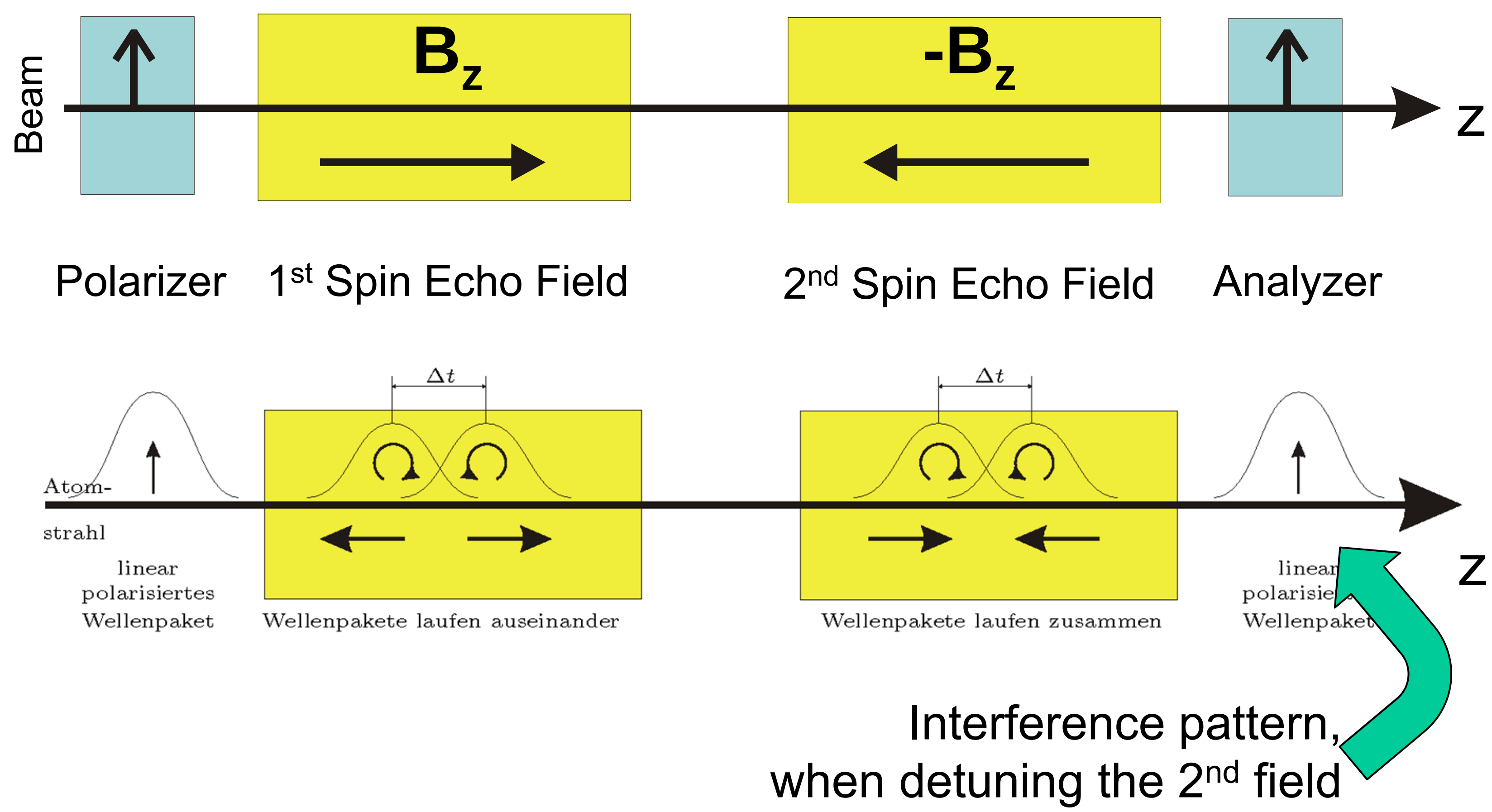
Interferometry



enhancement factor !

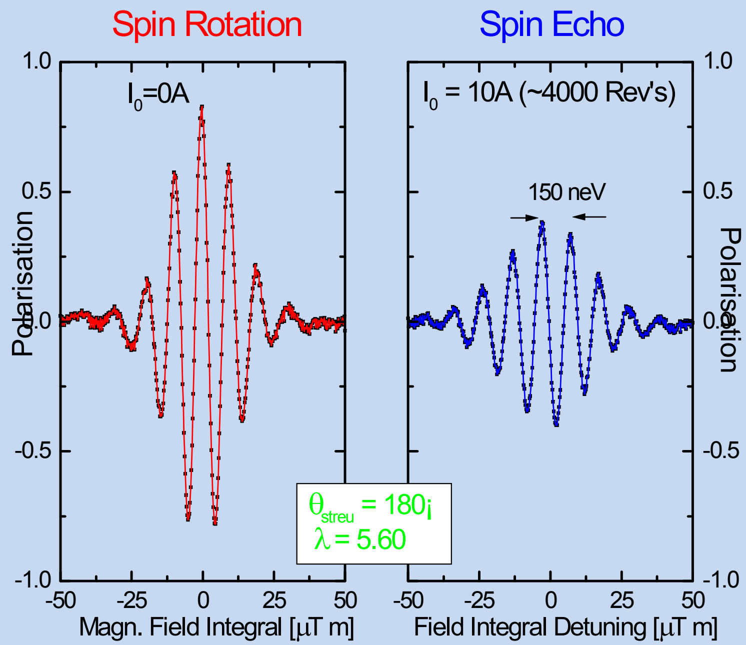
Atomic Beam Spin Echo

The ABSE-Principle



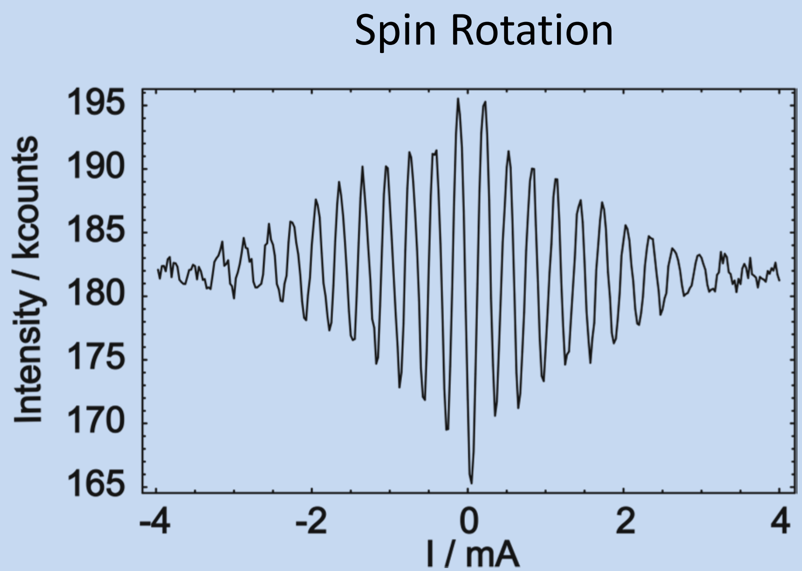
Signal & Resolution

^{3}He data
resolution ≈ 1 neV
(nuclear magnetic moment)



counts or polarization

^{1}H data
resolution ≈ 10 peV
(electron magnetic moment)



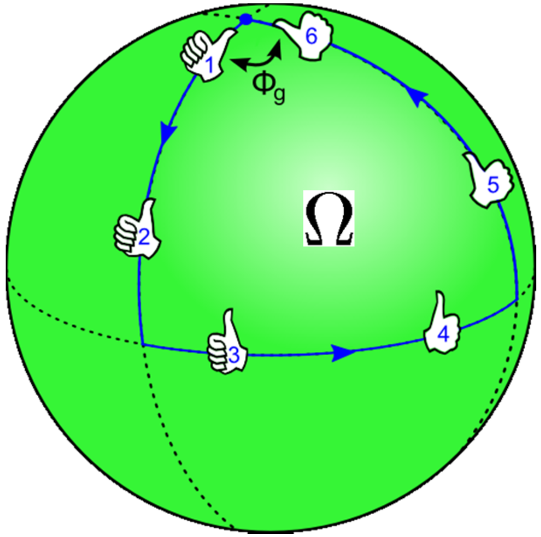
detuning
of B-field

Berry Phase

Berry Phase

<u>Classical Mechanics</u>

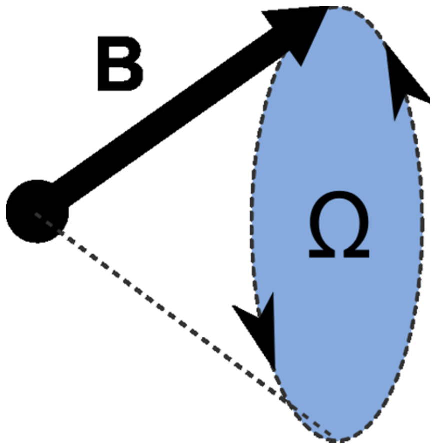
- Parallel Vector Transport
- on Path around exceptional Point



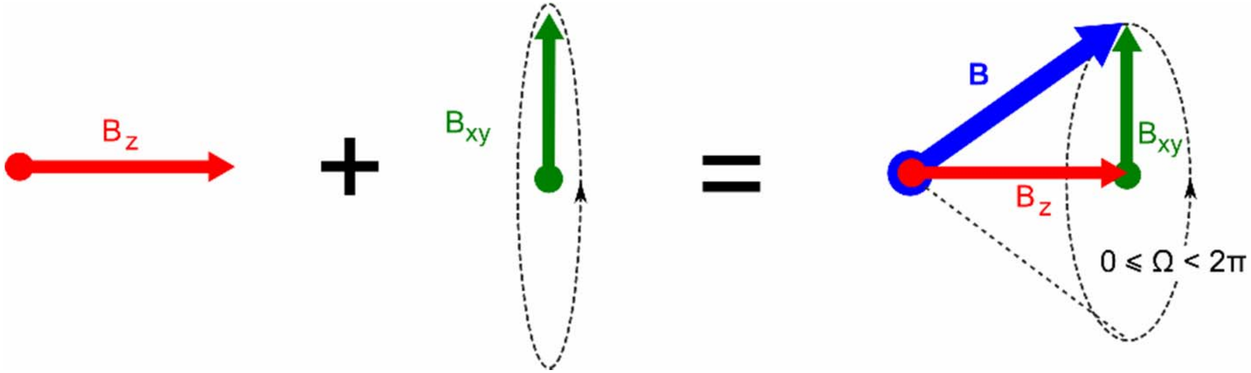
<u>Quantum Mechanics</u>

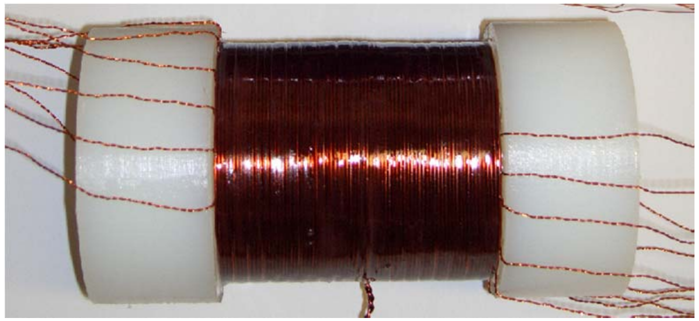
- transport Eigenstate on closed curve in the parameter-space
- Spin in a B-field:

$$\phi_{Berry} = -m \cdot \Omega$$

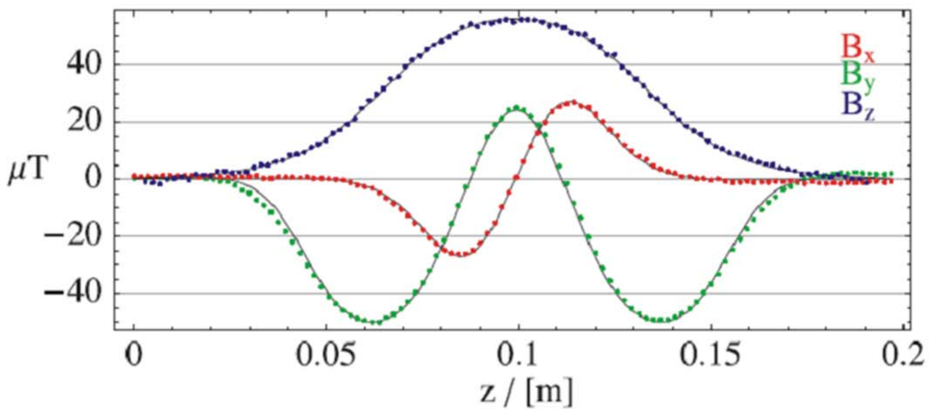


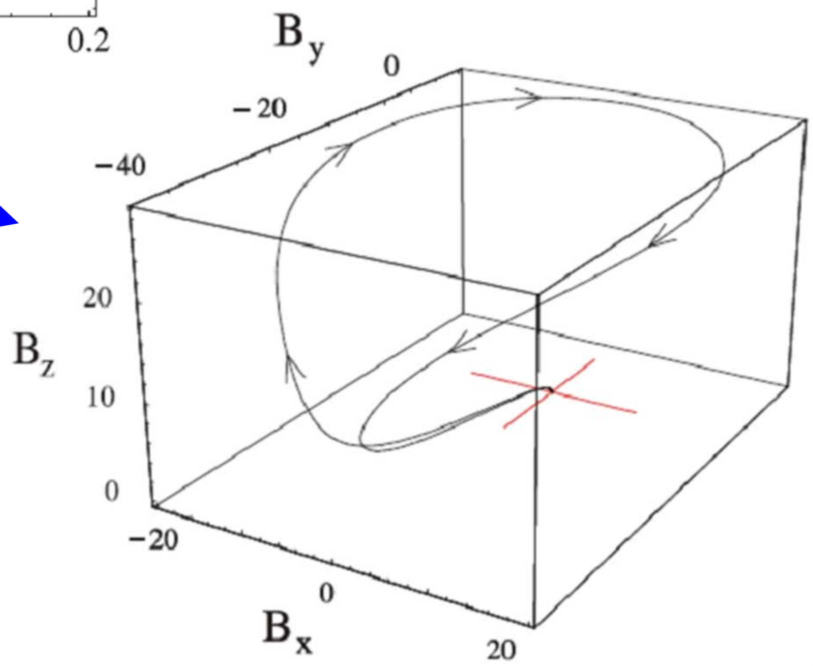
Generation of a Berry-Phase



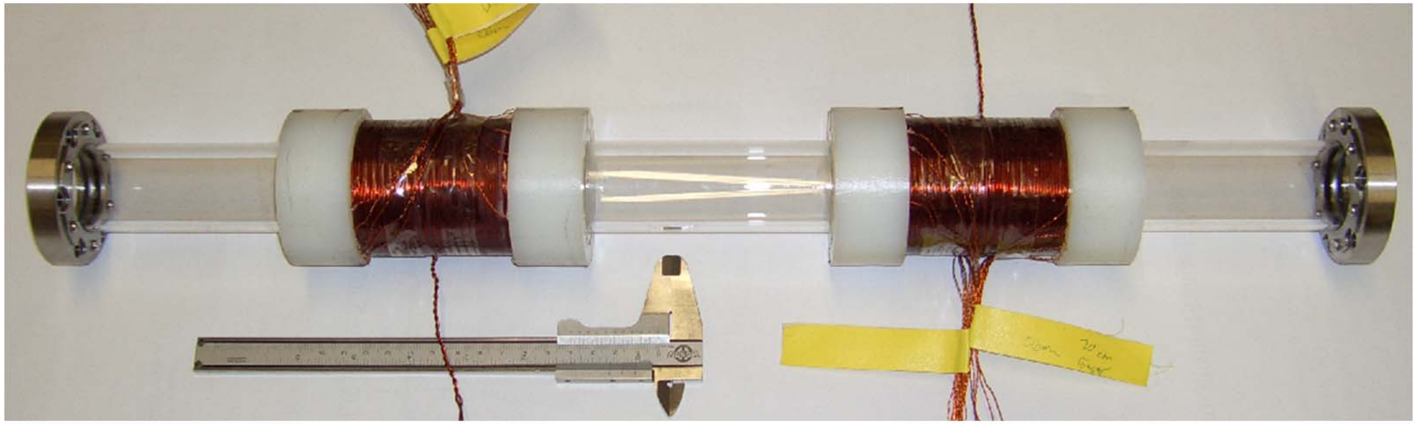


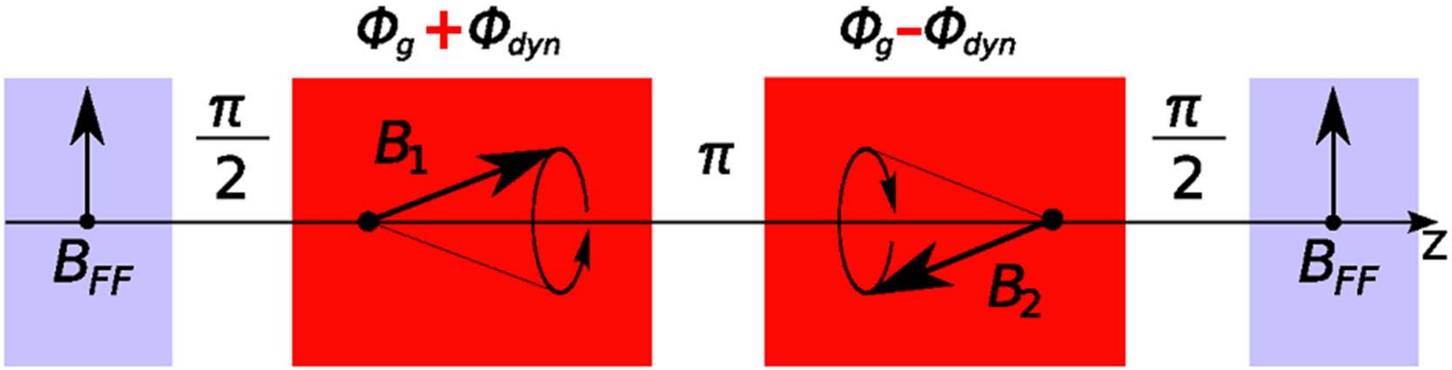
Berry-Coils: Resulting Fields





Berry-Spin-Echo

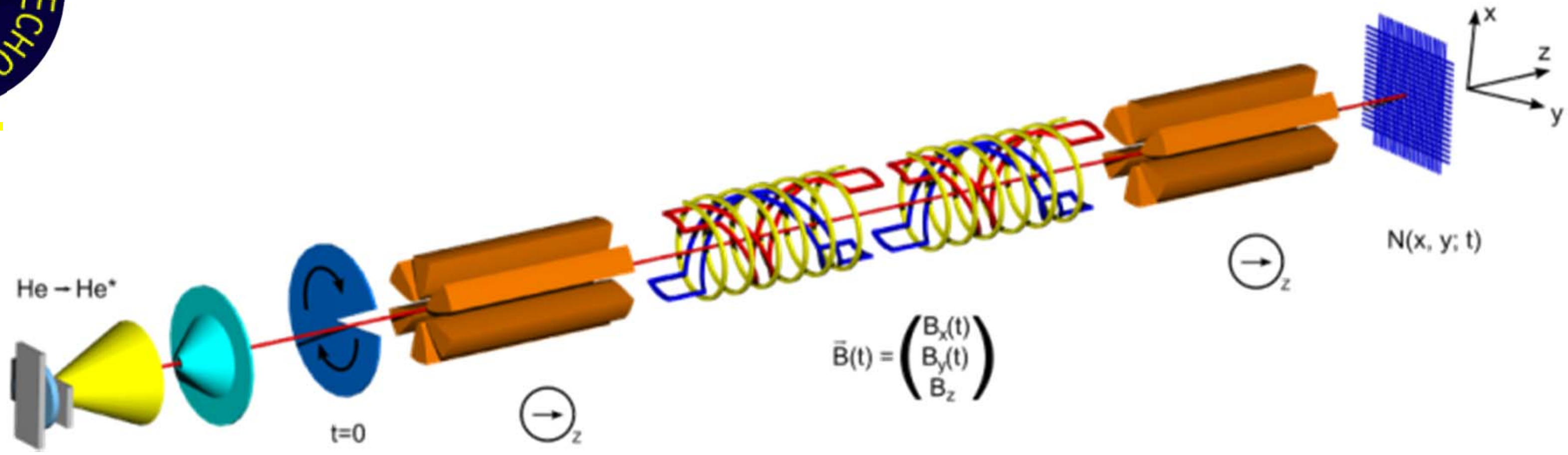


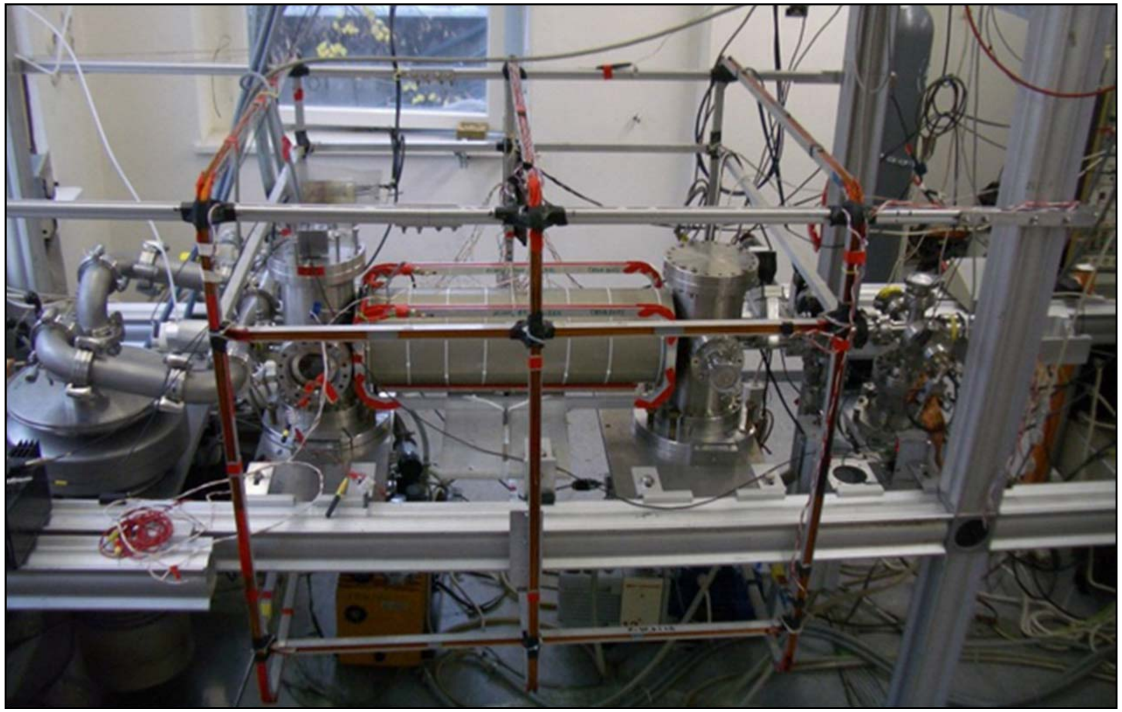


=> Eliminating the dynamic phase

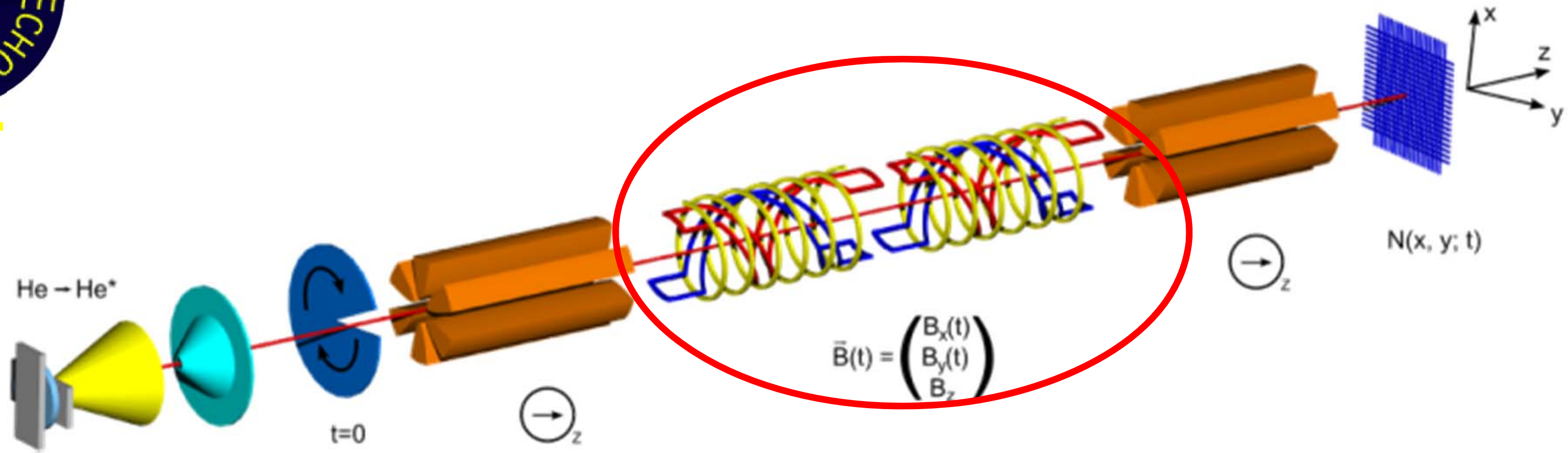
The Experimental Setup

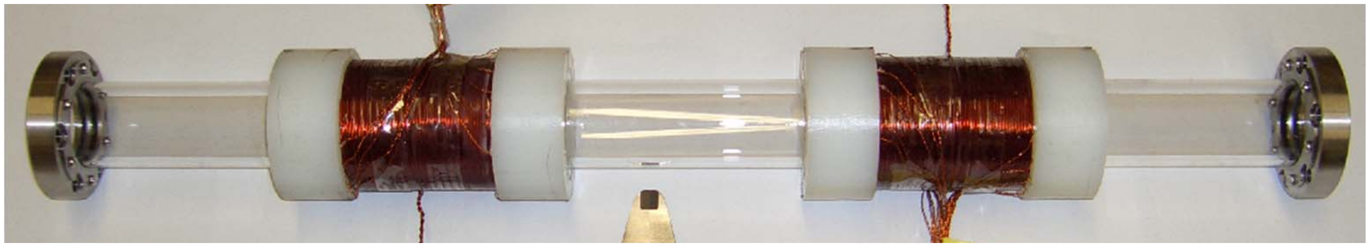
The Experimental Setup



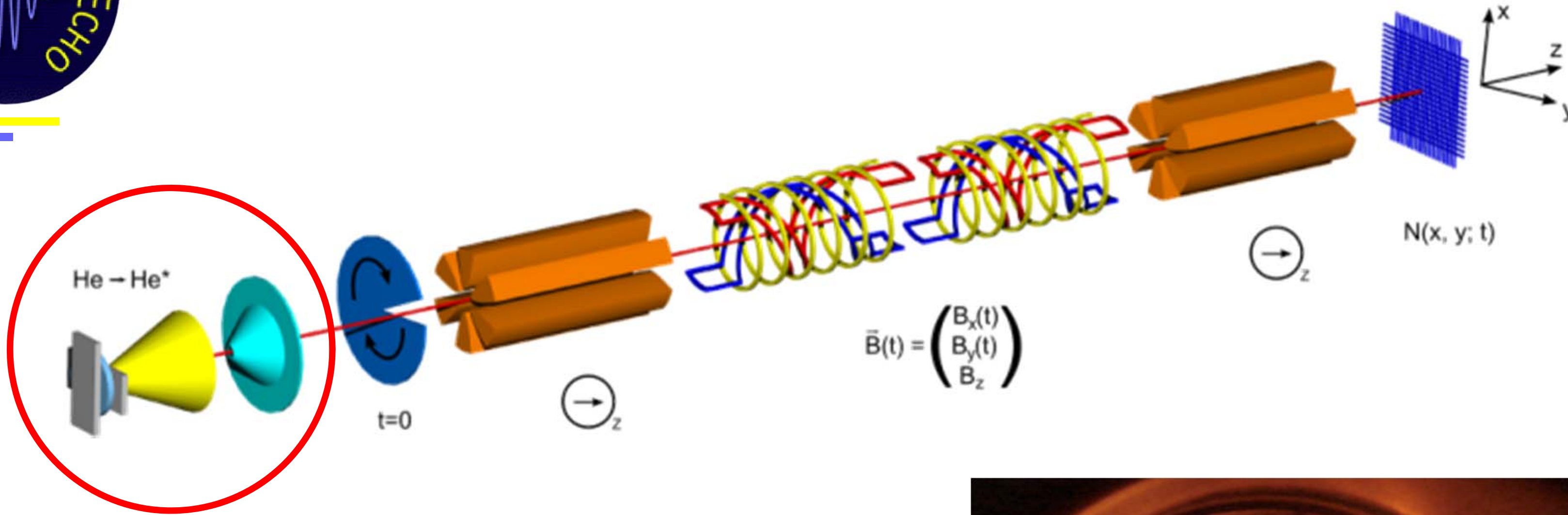


Berry-Spinecho-Tube in the Experiment



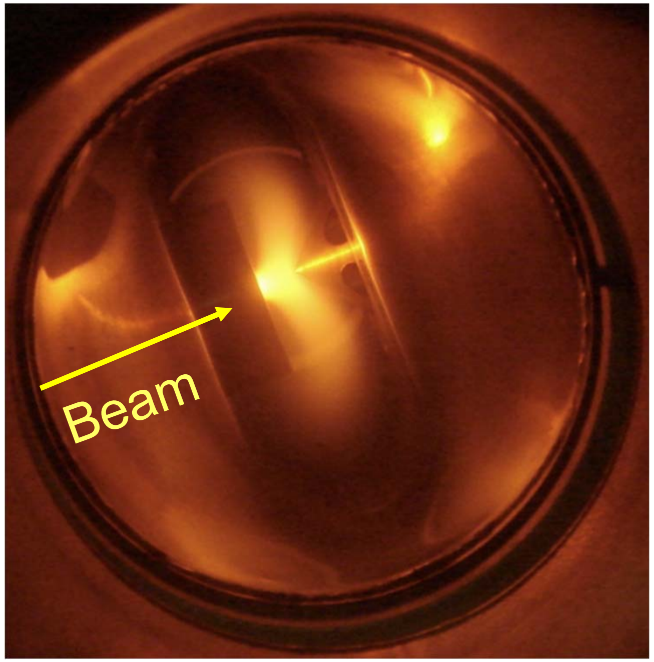


Metastable-Source

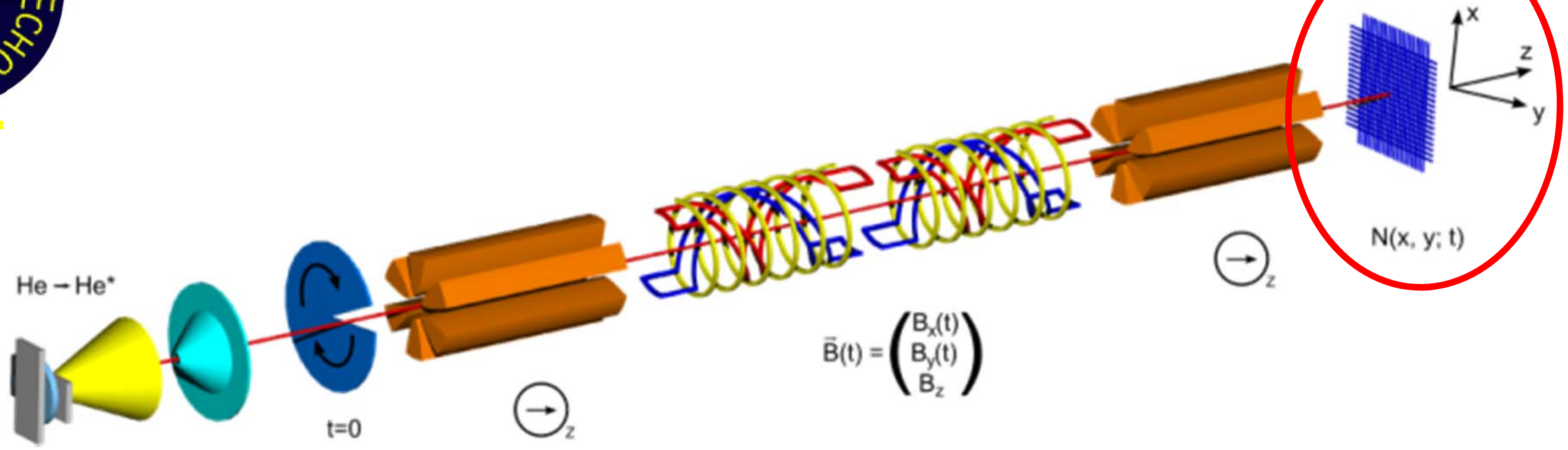


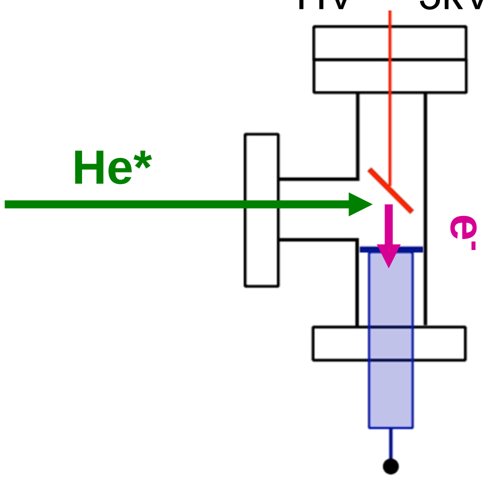
Advantages:

- high inlet pressure
  => high metastable yield
- supersonic expansion
  => cooling atomic beam
  (narrow velocity distribution)



Metastable-Detector

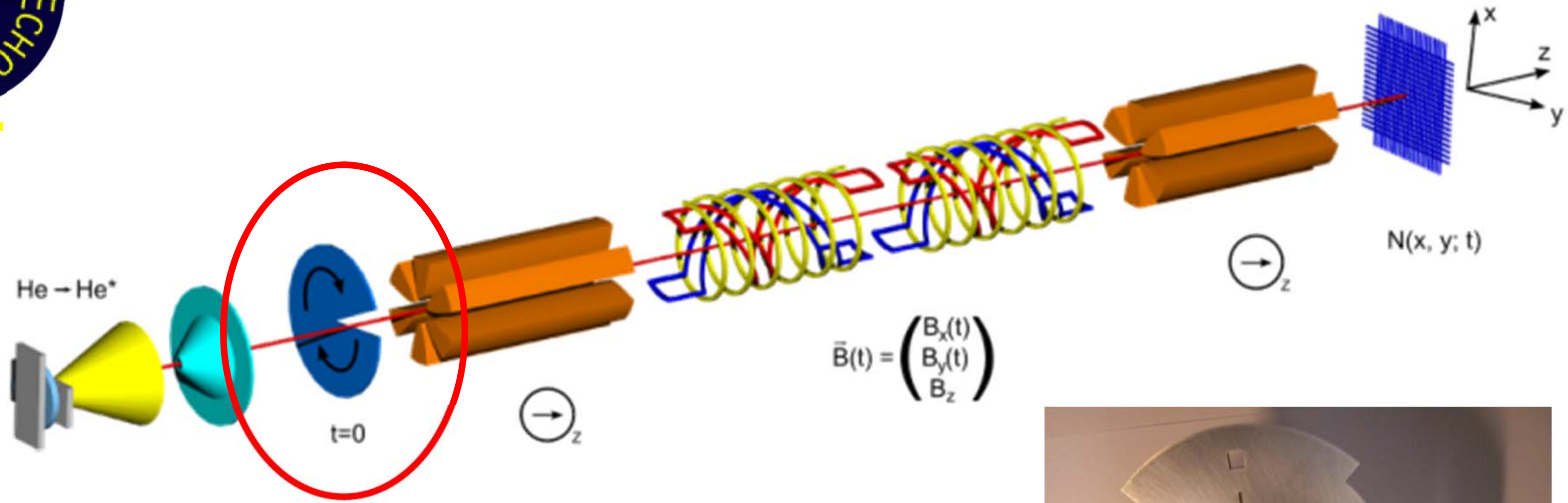




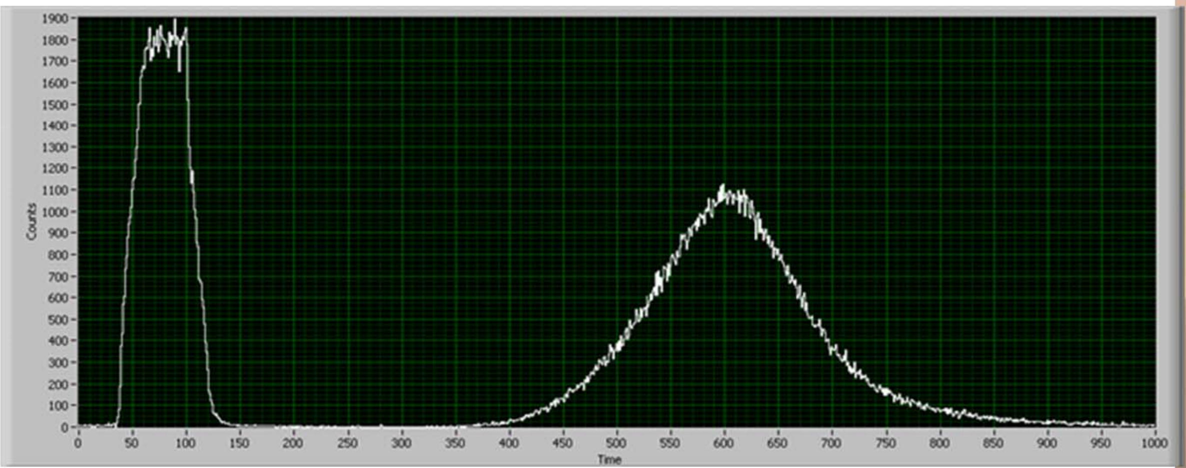
Advantages:

- 100% detection efficiency
- Free of background
  => good S/N
- fast => Time-of-Flight measurement

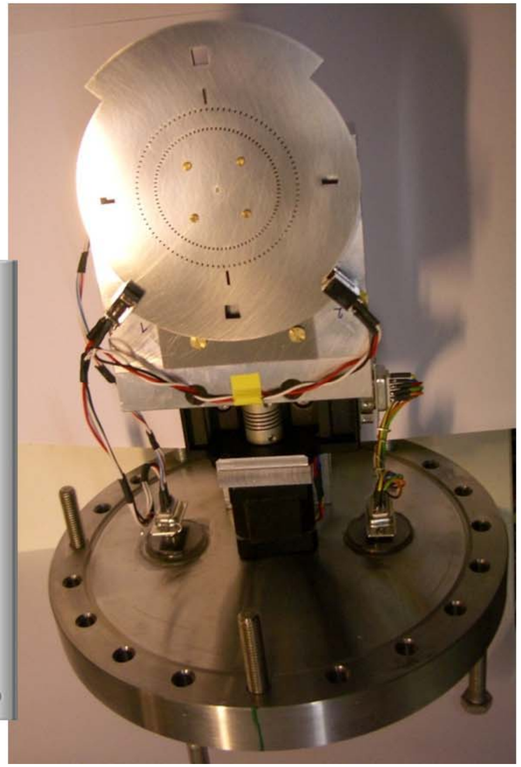
Mechanical Chopper



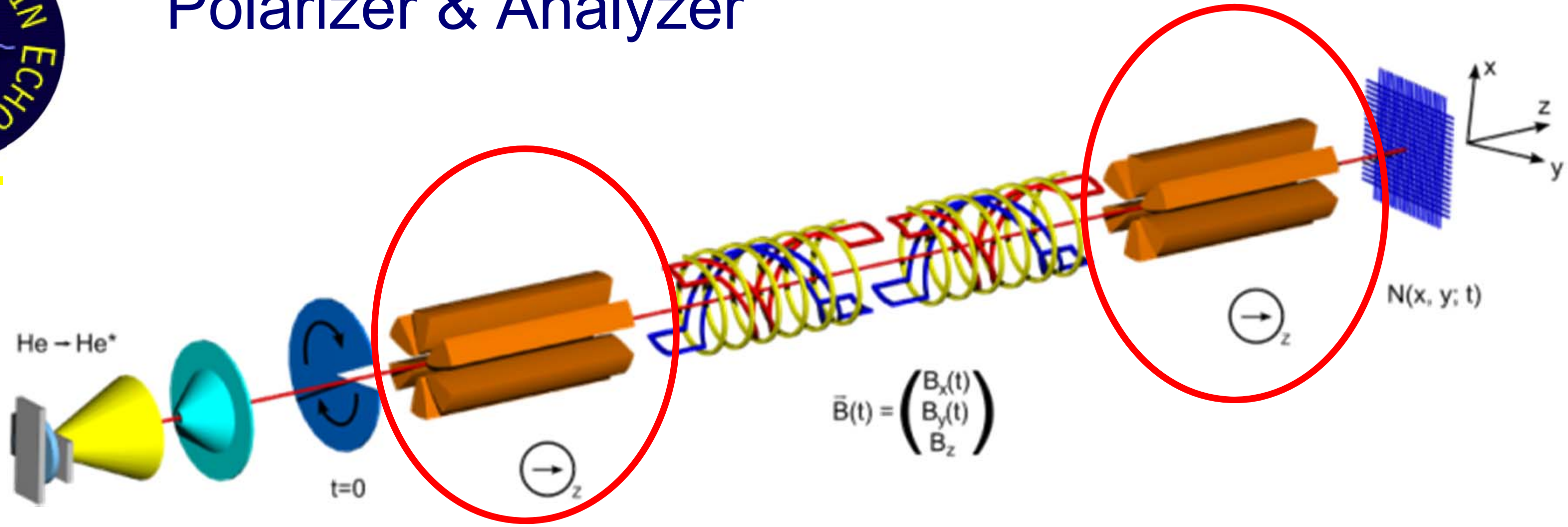
atoms at detector



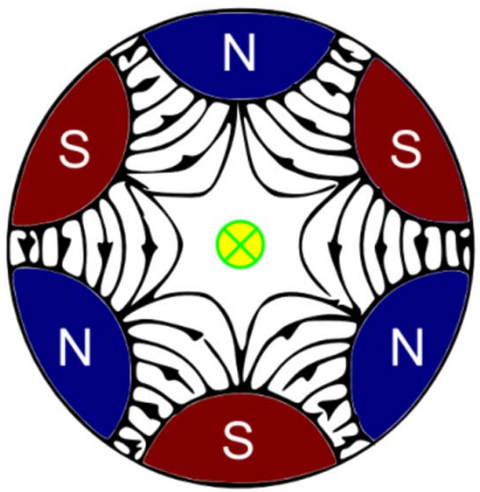
time-of-flight ~ 1 / kin. energy



Polarizer & Analyzer

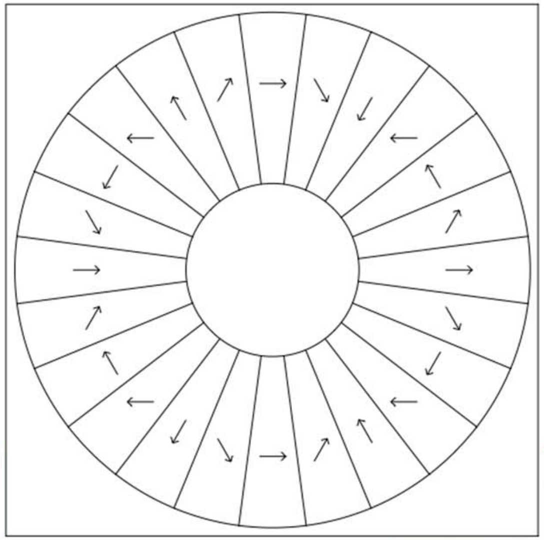


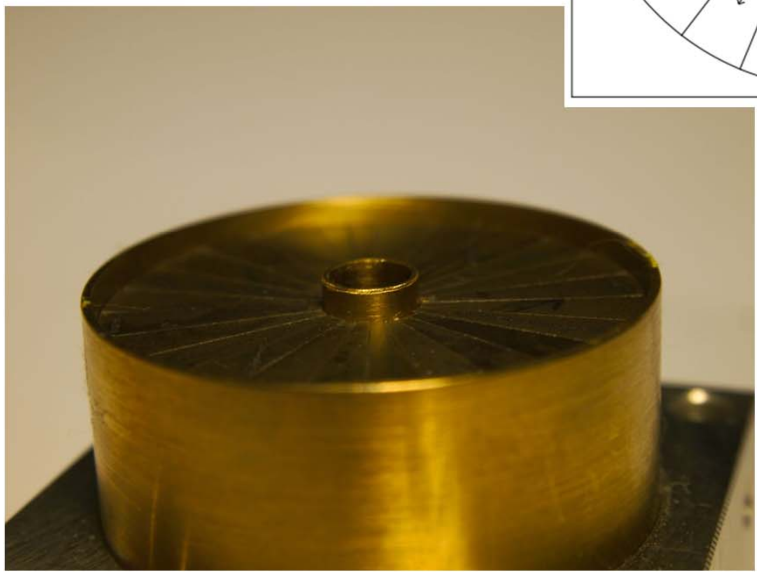
- Sextupole magnet

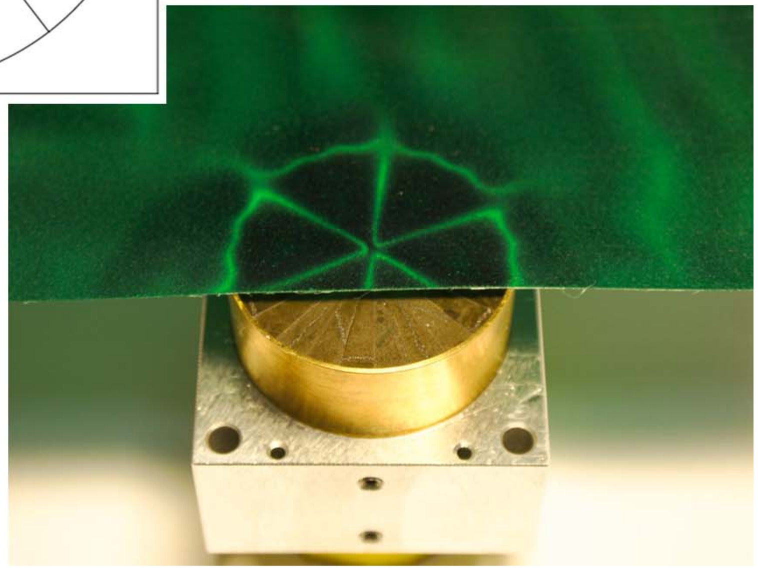


Polarizer & Analyzer

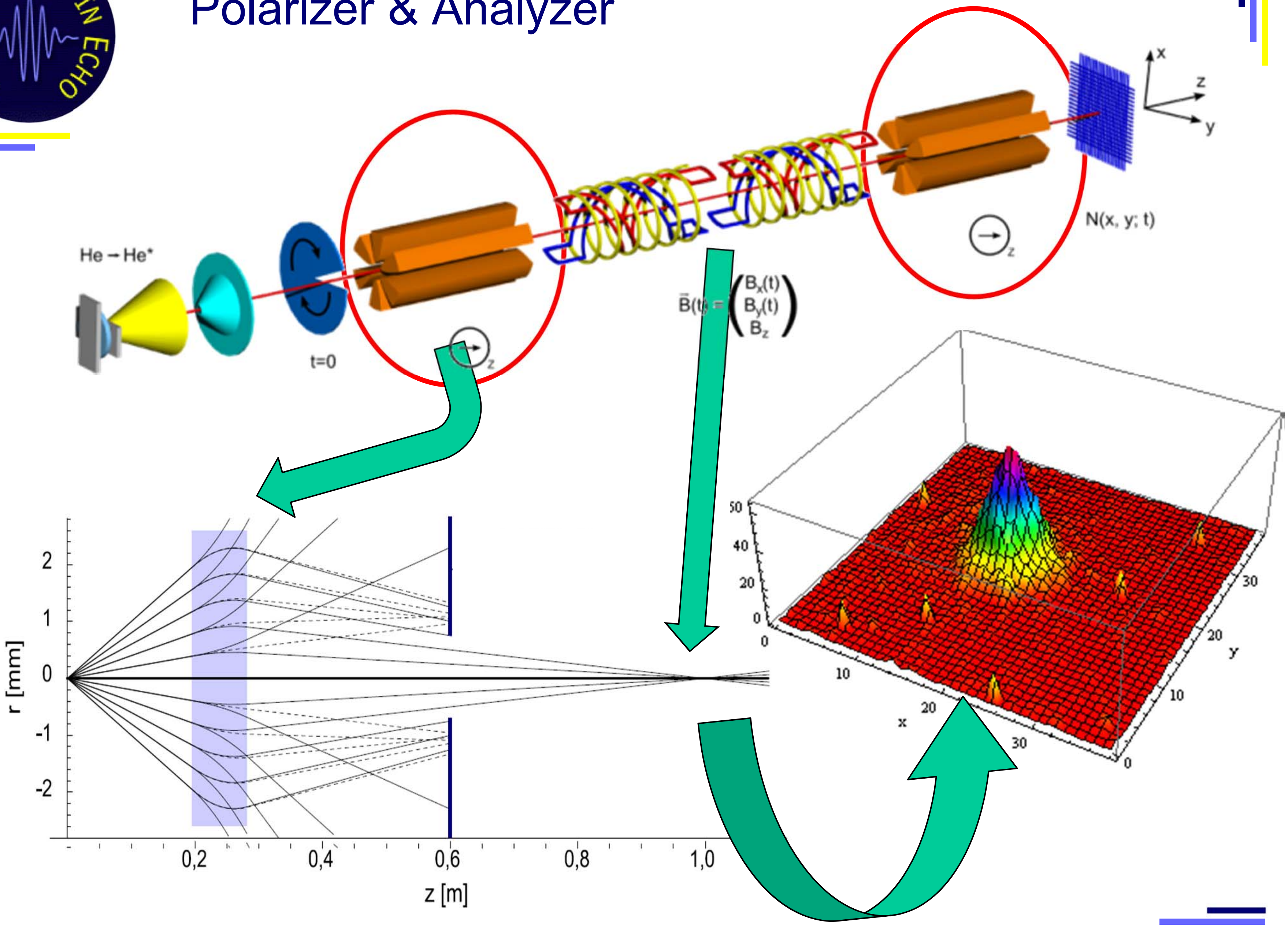
- hexapole consisting of 24 segments







Polarizer & Analyzer



First Measurements

First Measurements

(SLIDES REMOVED)

Summary & Outlook

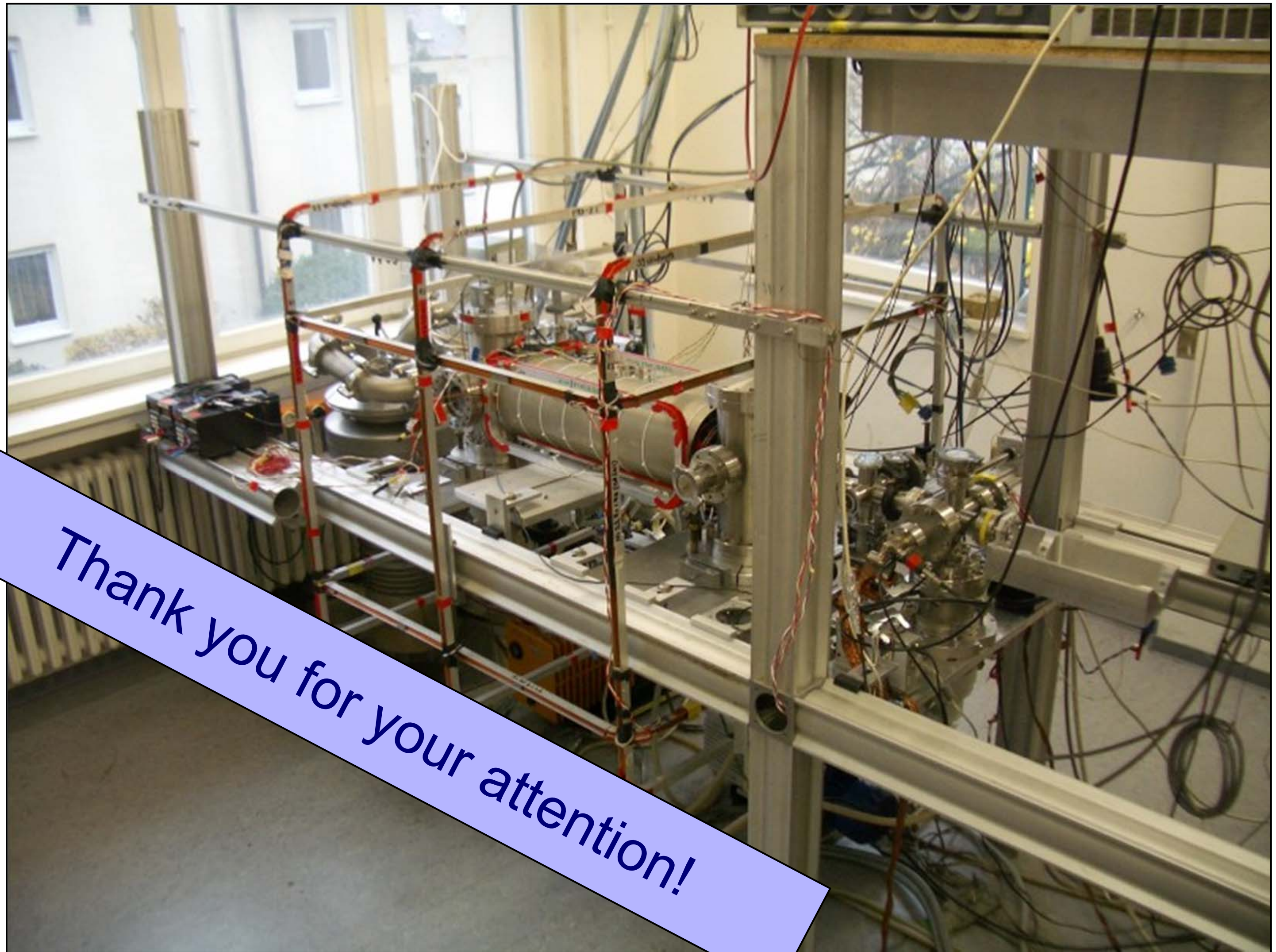
Summary:

- ✓ ABSE & Berry-Phases
  - → APV
- ✓ Running Experimental Setup
  - → first data

Next steps:

- o Detailed analysis of Spin-Rotation-Data
- o Spin-Echo-Measurements (symmetric setup)
  - Change of the polarization direction
  - Improvement of the magnetic shielding

work in progress ...



Thank you for your attention!