Spin Tune Determination at COSY

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Search for Charged Particle EDMs

The **spin precession** in **electric** and **magnetic** fields affected by an **electric dipole moment (EDM)**

Thomas-BMT equation: $\frac{d\vec{S}}{dt} = \vec{\Omega}_s \times \vec{S}$ with $\vec{\Omega}_s = \frac{-q}{m}\left\{ G\vec{B} + \left(\frac{1}{\gamma^2-1} - G\right)\left(\frac{\vec{\beta}\times\vec{E}}{c}\right) + d\,\frac{mc}{q\hbar S}\left(\frac{\vec{E}}{c} + \vec{\beta}\times\vec{B}\right)\right\}$

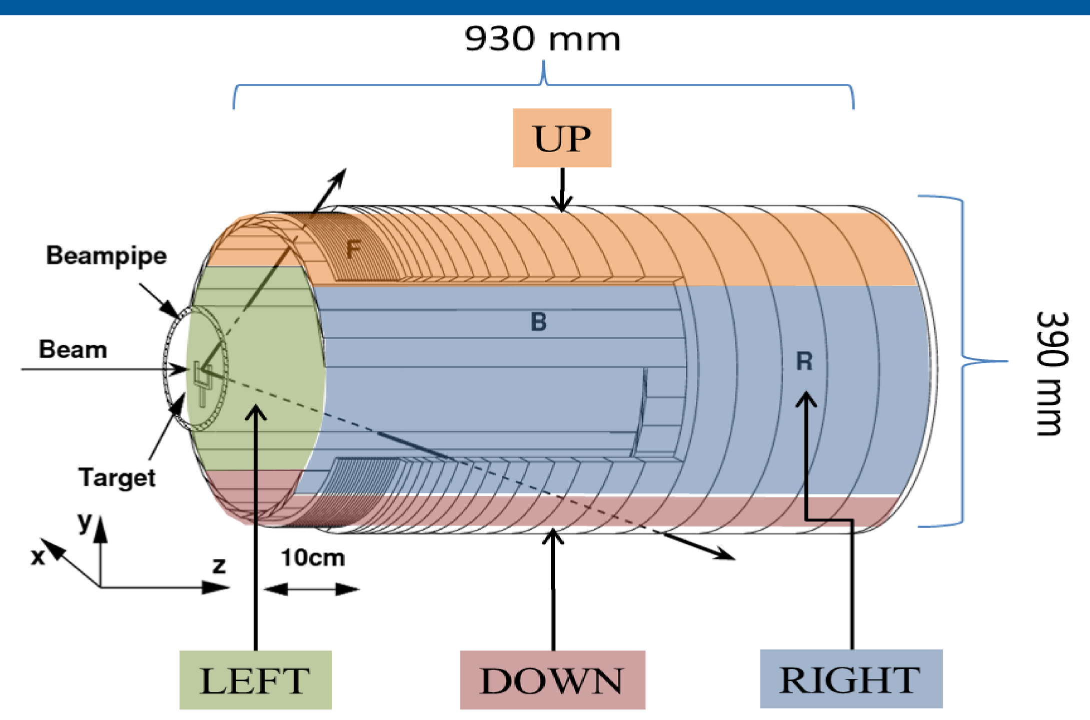
Spin tune measurement sensitive to **EDM:** $\nu_s = \frac{|\vec{\Omega}_s|}{\omega_{rev}} = \frac{\text{spin rotations}}{\text{particle revolutions}}$

Pure magnetic ring (COSY) and **d=0**: $\nu_s = \gamma G \approx -0.1609$ for a $p = 0.97$ GeV/c deuteron beam

New Method to Determine the Spin Tune

Measure up-down asymmetry in polarized deuteron-carbon elastic scattering

Asymmetry: $\mathcal{A}(t) = \frac{N_{up}(t) - N_{down}(t)}{N_{up}(t) + N_{down}(t)} \sim \sin(|\vec{\Omega}_s| t + \varphi_0)$

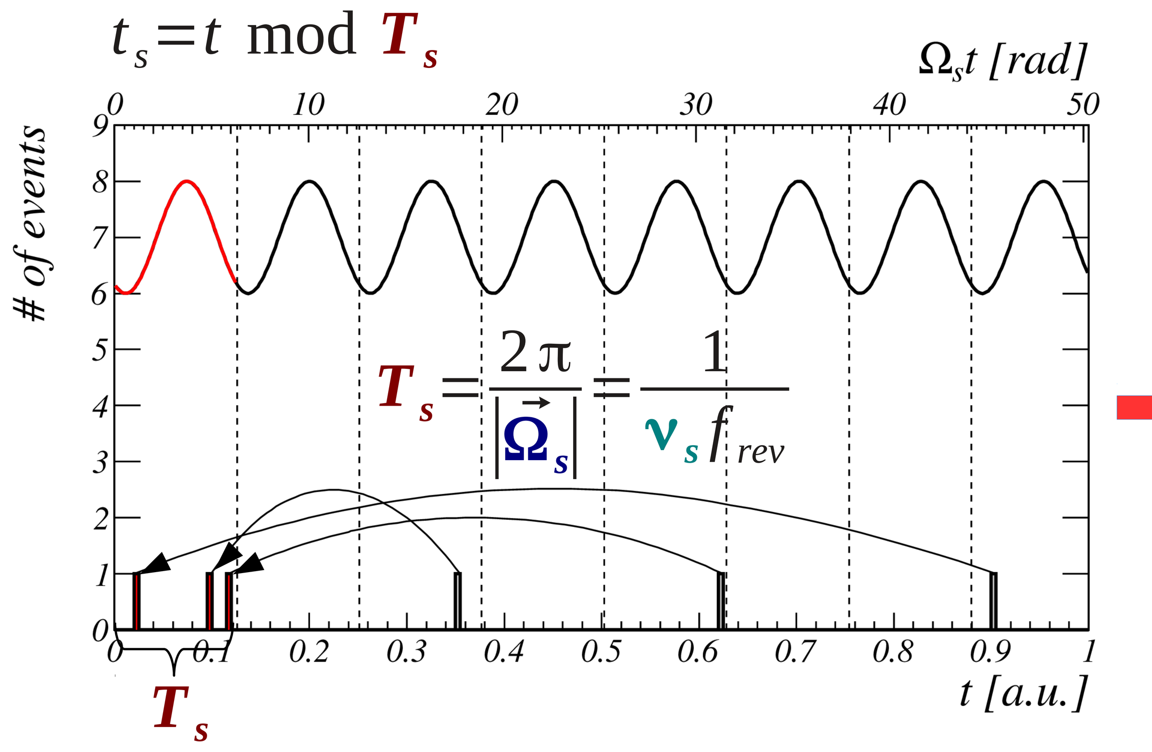


Spin precession ~ 120 kHz >> 5 kHz event rate → no **direct fit possible**

Solution:

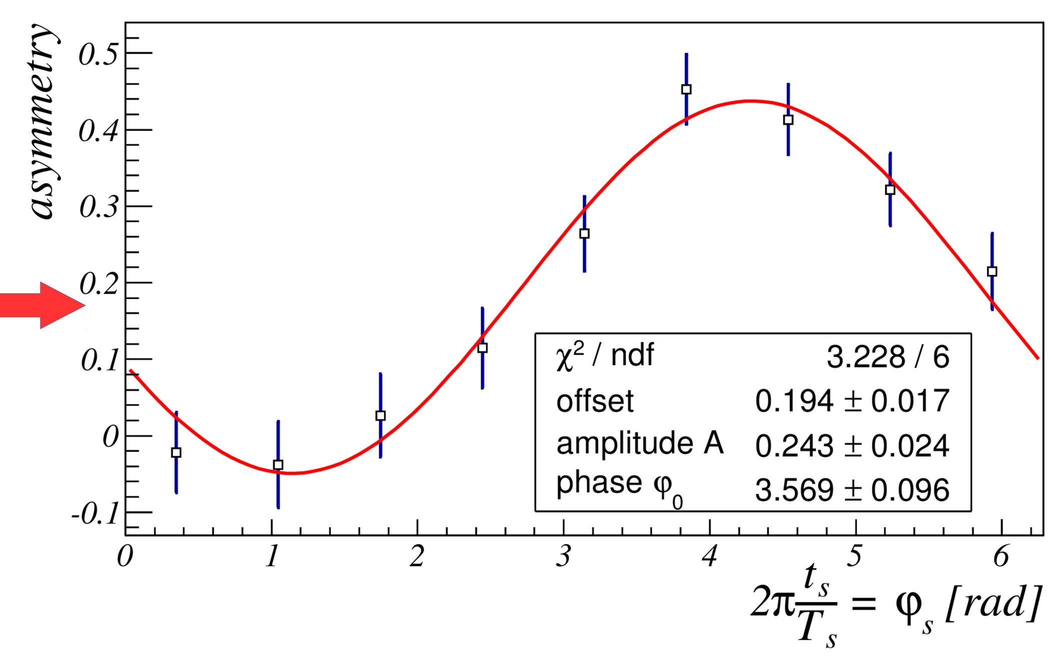
I. Take modulo of event time with a assumed **spin precession period T_s**

$t_s = t \bmod T_s$

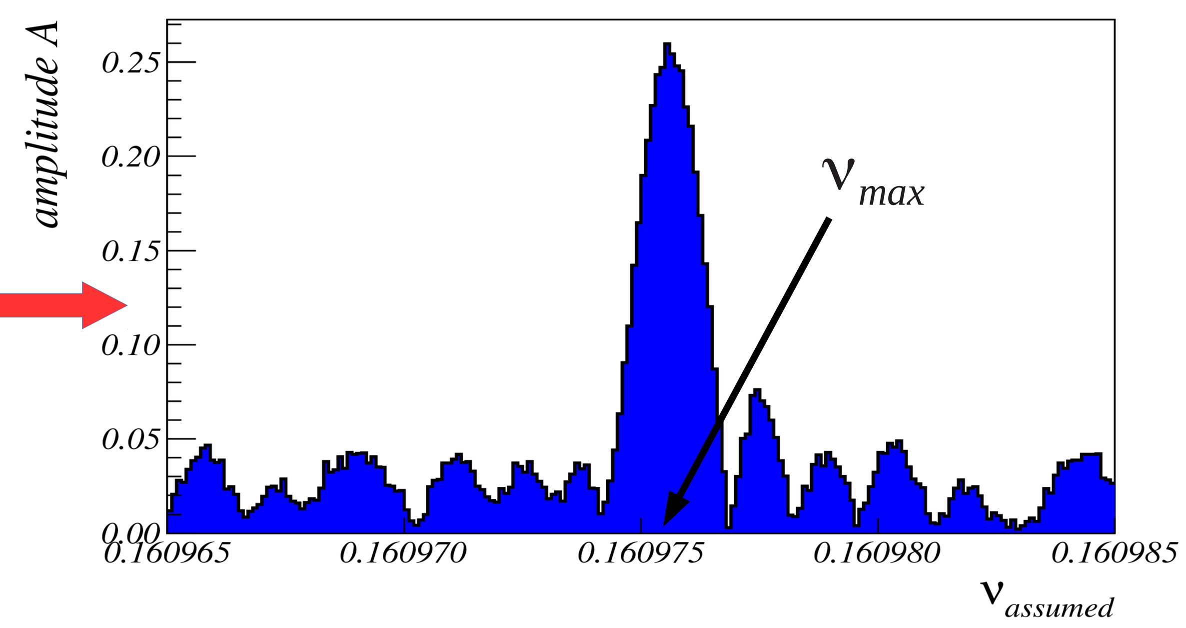


II. Calculate asymmetry for every one second interval and fit a sine

$\mathcal{A}_{fit}(\varphi_s) = A\sin(\varphi_s + \varphi_0) + offset$

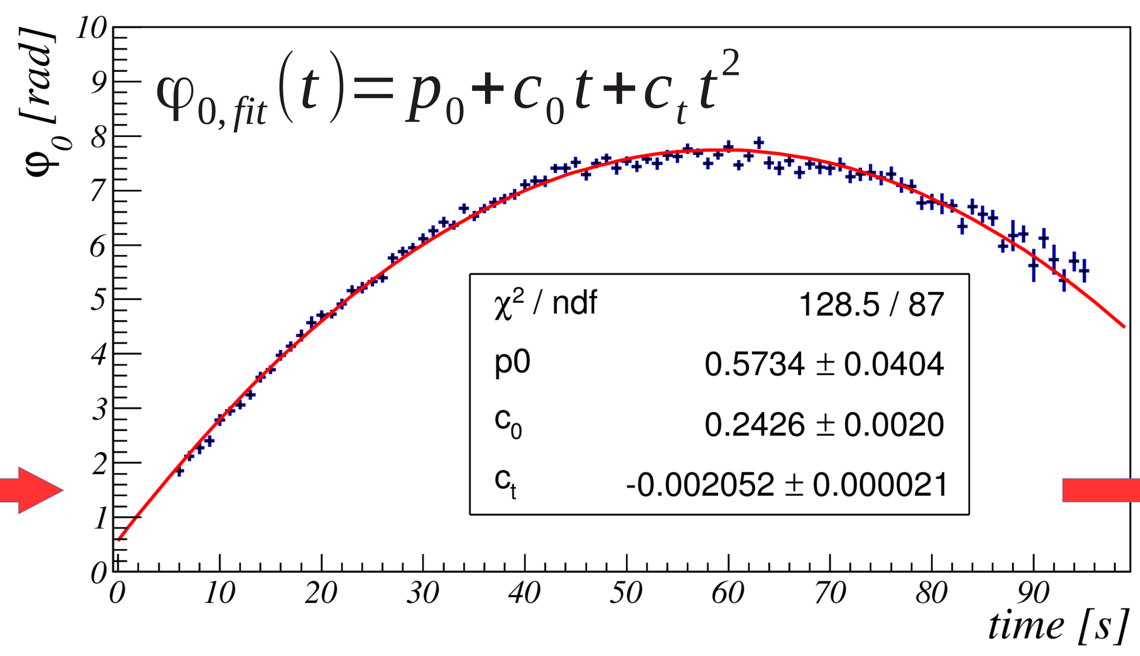


III. Vary the spin tune ν_s and find maximal amplitude



→ **Spin tune precision** from the amplitude scan for one second interval $\approx 10^{-6}$

→ Fix the spin tune for one cycle (100 s) and monitor the phase of the asymmetry fit φ_0



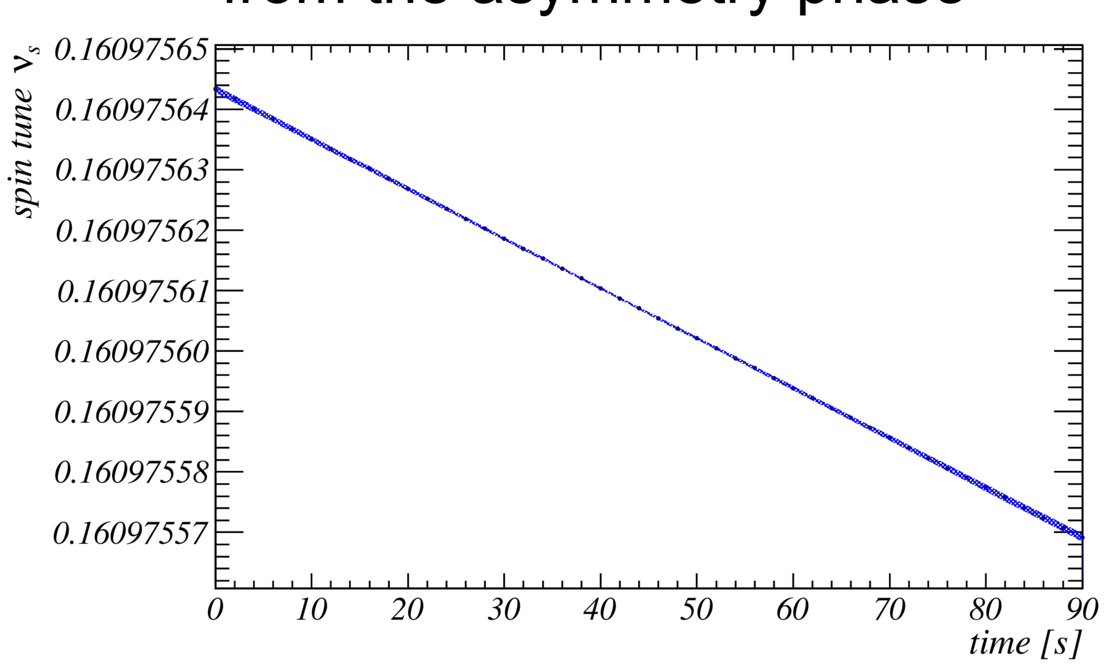
Time depending spin tune:

$$\nu_s(t) = \nu_{max} + \frac{1}{\omega_{rev}}\frac{\partial\varphi_0(t)}{\partial t}$$
$$= \nu_{max} + 2.71\cdot 10^{-7}\,\frac{1}{s}(c_0 + 2c_t\cdot t)$$

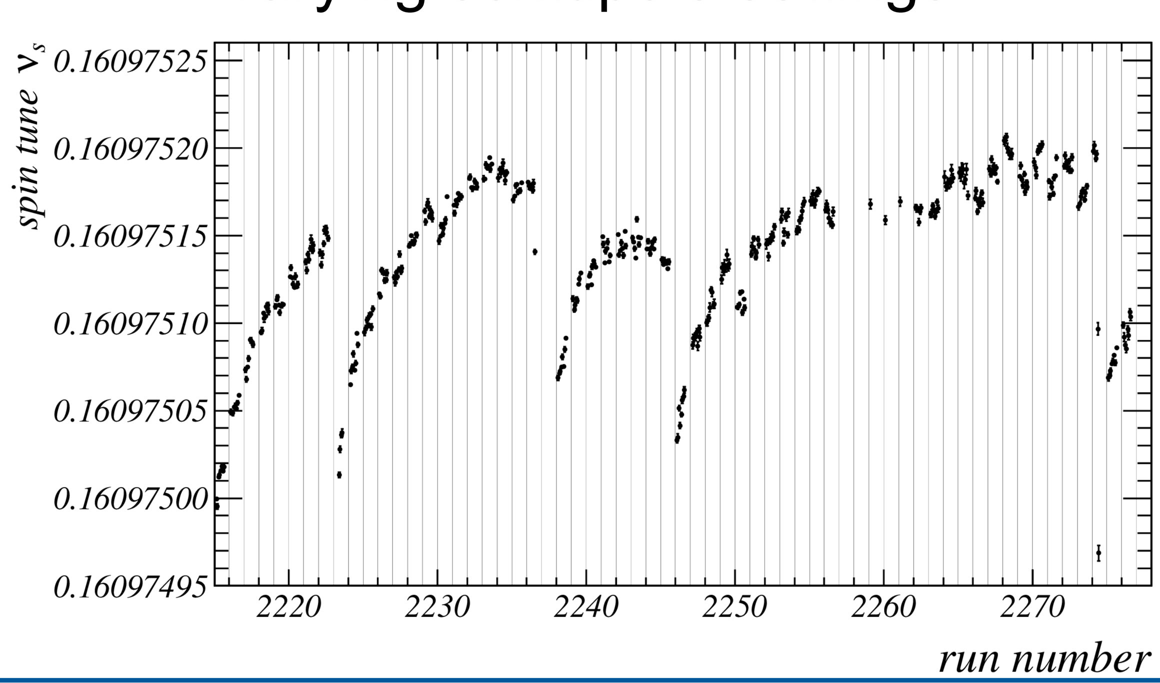
Spin tune precision of 10^{-10} for a 100 s interval

Results

Interpolation of the spin tune from the asymmetry phase



Spin tune for different runs with varying sextupole settings



Conclusion and Questions

The spin tune can determined with a precision of 10^{-10} in 100 s

Why does the spin tune change

I. during one cycle?

II. from cycle to cycle?