Time Stamping, Spin Tune, Feedback

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Outline

- Reminder: time stamping, how, why?
- Spin tune extraction
- Some outlook: online feedback systems
- Requirements for a future DAQ

Aim: Remind everybody to consider these requirements / measurement goals already at the design stage of the polarimeter / DAQ

Experiment

Conditions

- polarized deuteron beam, p = 0.97 GeV/c
  horizontal precession with $f_s \approx 120$ kHz
  event rate ≈ 5000 s^{-1}
  $\nu_s \approx -0.161 \rightarrow$ 6 turns / precession

Detector signals

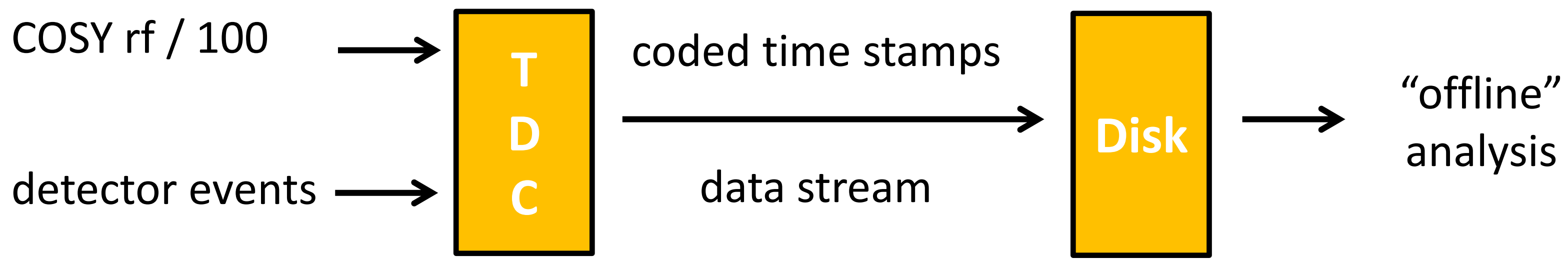
$$N^{up,down} \propto 1 \pm PA \sin(2\pi \cdot f_s t) = 1 \pm PA \sin(2\pi \cdot \upsilon_s \, n_{\text{turns}})$$

P: polarisation, A: analysing power

Primary goal

- follow the polarisation vector and extract polarisation w/o knowing the exact precession frequency (different clocks!)
- example: $\Delta\varphi \leq 1\text{rad}$ after 1s $\rightarrow \Delta f_s \leq 0.3\text{Hz},\ \Delta\nu \ \leq 4 \cdot 10^{-7}$

Measurement



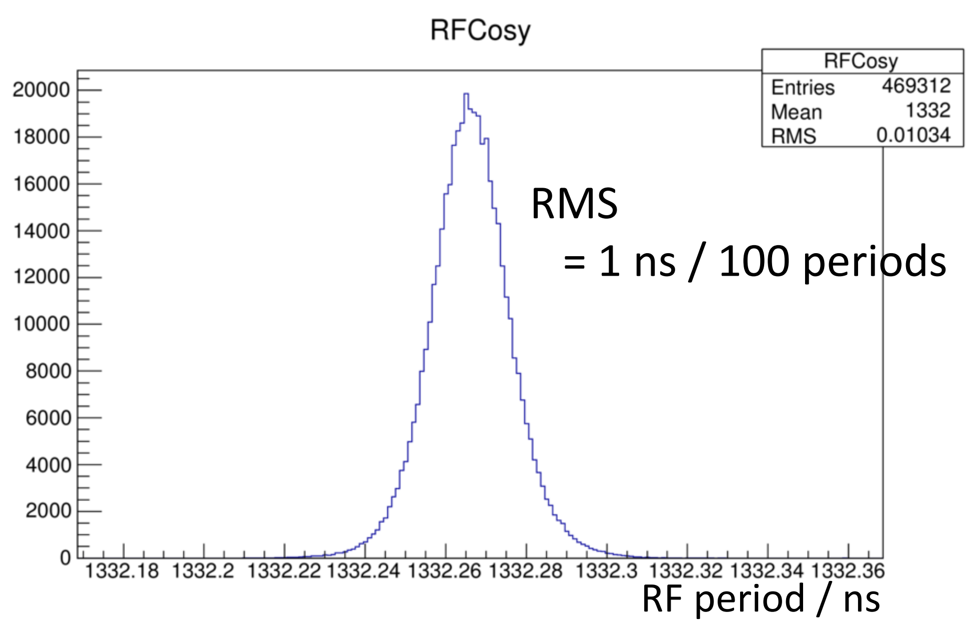
TDC in continous mode, asynchronous readout
overflow every 6.7 s, $\Delta t = 92\ \boldsymbol{ps}$

COSY RF:

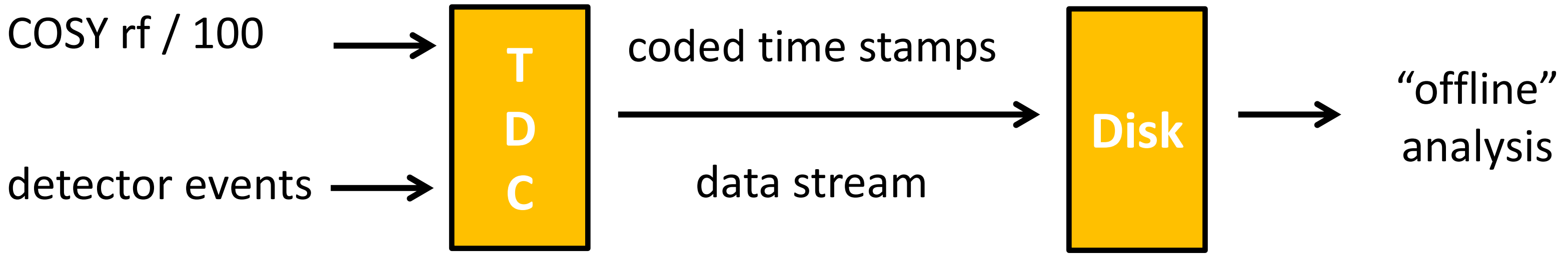
- every 100th signal measured
  → interpolation
- precision in DAQ about 1ns
  per interval (sine wave → discr.)

Detector signals:

- turn number since T_0 via COSY RF
- fractional time:
  distribution within the bunch



Measurement

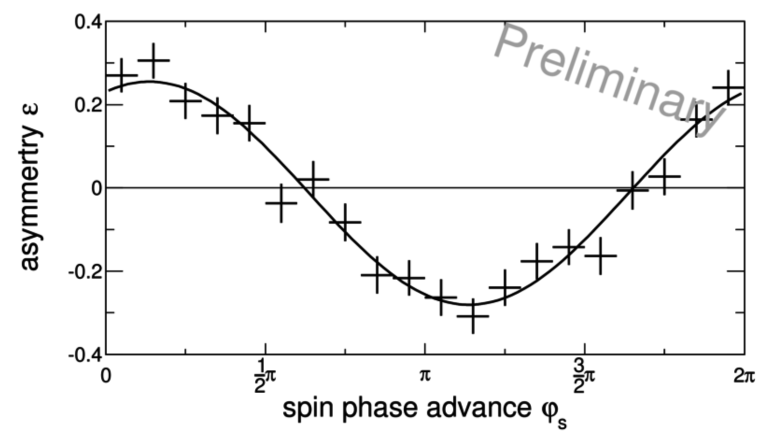


TDC in continous mode, asynchronous readout
overflow every 6.7 s, $\Delta t = 92\ \boldsymbol{ps}$

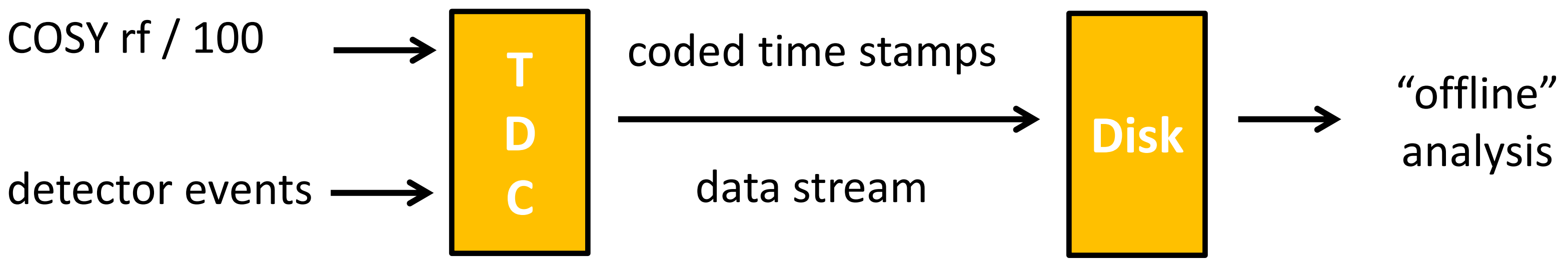
Spin tune:

- timing precision secondary
- counting turns:

$$\varphi_{\text{tot}} = 2\pi\, N_{\text{turn}}\, \nu_s$$
$$\varphi_s = \varphi_{\text{tot}} \bmod 2\pi$$
$$\propto 1 + PA \sin\left(\varphi_s + \Delta\varphi\right)$$



Measurement



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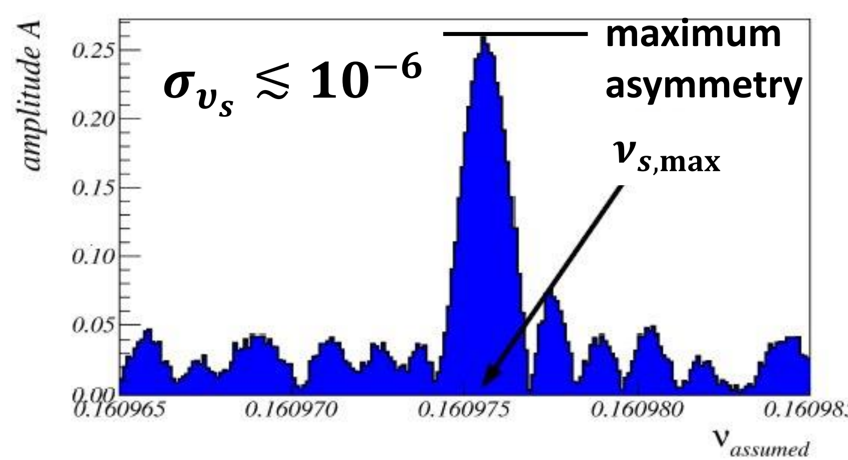
- ν_s not known *a priori*
  $\rightarrow$ scanning ν_s for $\Delta t \approx 1\text{s}$



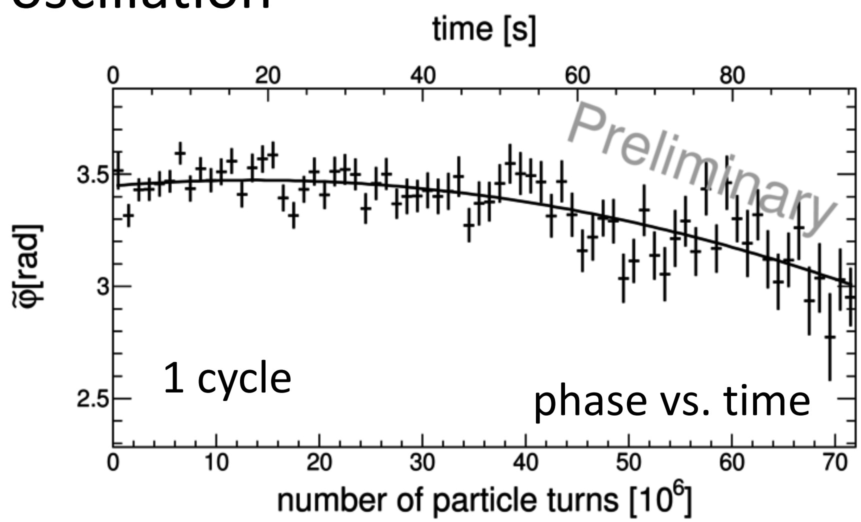
Alternatives: fourier analysis, unbinned likelihood fit

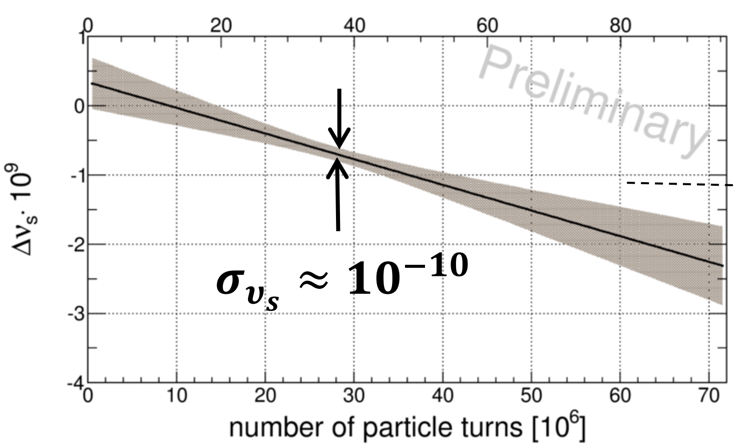
Improvement of σ_{ν_s}

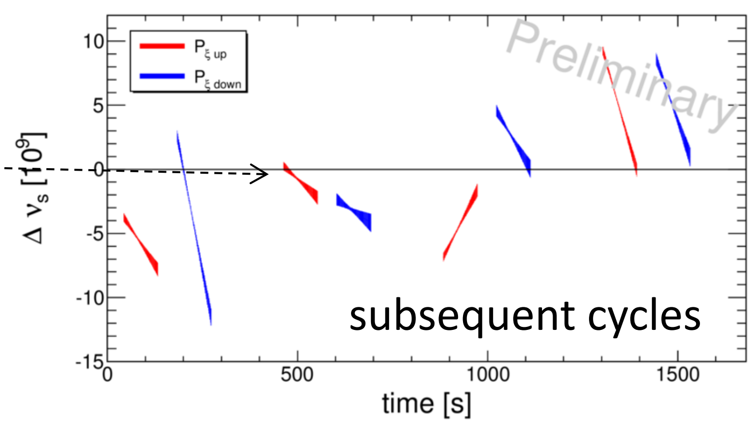
ν_s fixed: monitoring phase of oscillation

first derivative gives deviation from assumed spin tune ν_s

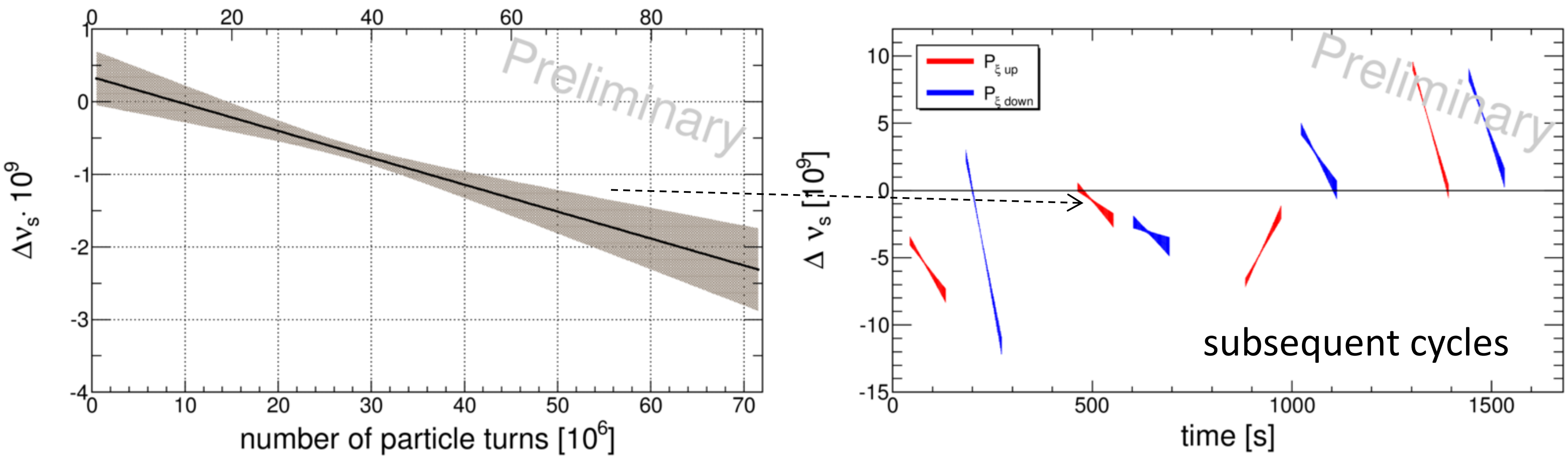
assuming parabolic dependence (linear change in spin tune)







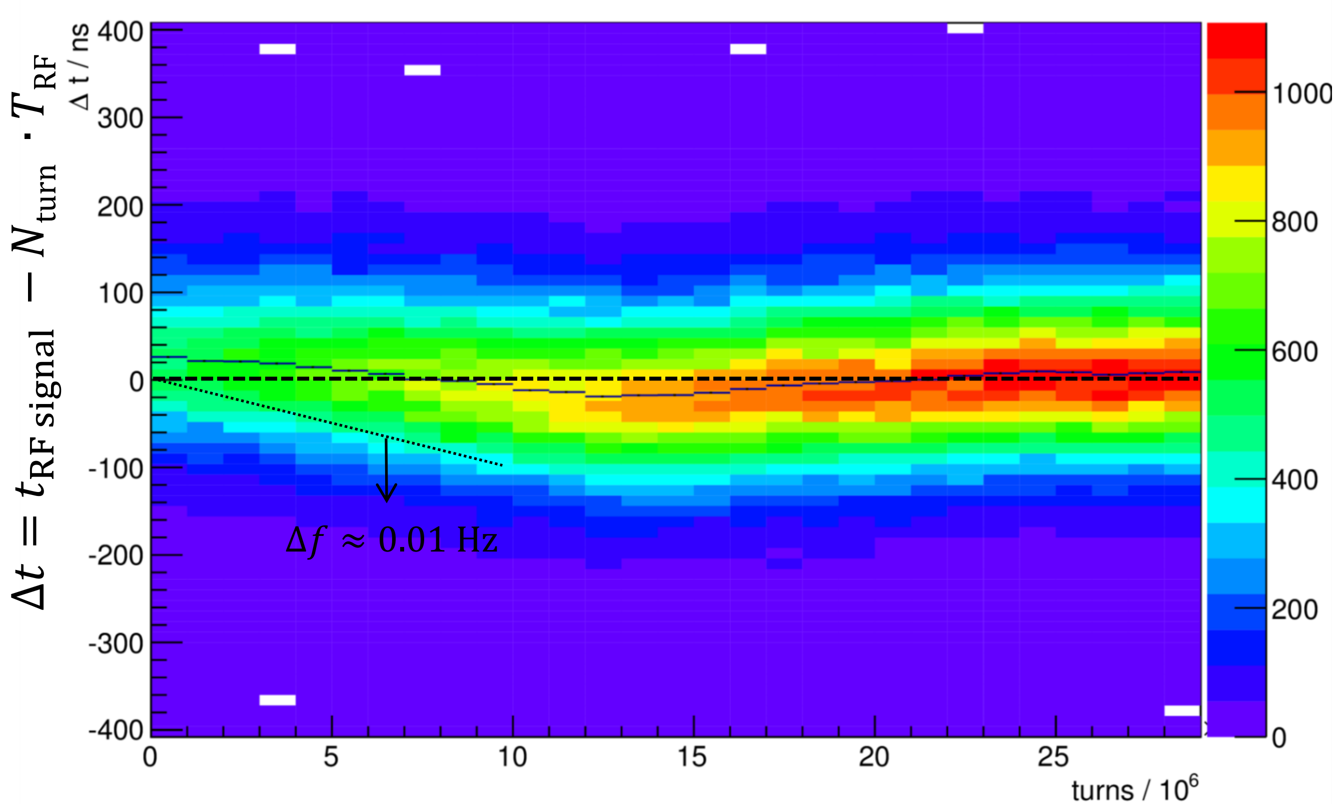
Results: spin tune ν_s



- spin tune ν_s can be determined to $\sigma_{\nu_s} \approx 10^{-8}$ in $\Delta t \approx 2s$
- average $\overline{\nu_s}$ in 1 cycle (≈ 100s) determined to $\sigma_{\nu_s} \approx 10^{-10}$
- one application: study long term stability of the ring
- future application: dedicated online feedback systems

Stability

Origin of spin tune drifts?
Long term stability of RF systems?



After t = 40s: Δt (COSY RF, TDC clock) < 100 ns
For systematic studies: precise clock with excellent long-term stability needed

Feedback systems

- Spin tune / frequency analysis can be done in real time
- Observables:
  - spin tune
  - small changes in spin tune (phase advances)
  - precise, relative measurement of frequencies:
    COSY RF, solenoid RF, Wien filter RF, etc.
  - phase relations: spin tune $\leftrightarrow$ all other oscillators
- Possible objectives:
  - stabilize spin tune by adjusting γ via COSY RF
  - prepare and maintain resonance conditions
    (solenoid, Wien filter, …)
  - maintain phase lock between spin tune and other oscillators

Possible options

- Software only, using data stream from DAQ
  possible issues: decoding, variable latency, influence on DAQ
- FPGA based
  advantage: less timing issues, only counting of periods
  a) integrated in DAQ read-out boards
     possible issues: still relies on DAQ, inter-module communication
  b) stand-alone system
     possible issues: generation of detector (trigger) signals

What to keep in mind for a future DAQ

- Time stamping, offline analysis
  - high precision (UTC) time stamps ($\approx\ 10^{-11}$ in $\tau = 1000s$, state-of-the-art ?, e.g. GPS based) and / or
  - reference oscillator
  - all frequencies (generator, pick up?) in DAQ
- Feedback system
  - online PID, on board / external trigger depending on method
  - frequency generators: freq. and phase smoothly adjustable
- Single, central time base for everything (DAQ, generators) ?