A New ^{3}He polarization for fundamental neutron physics

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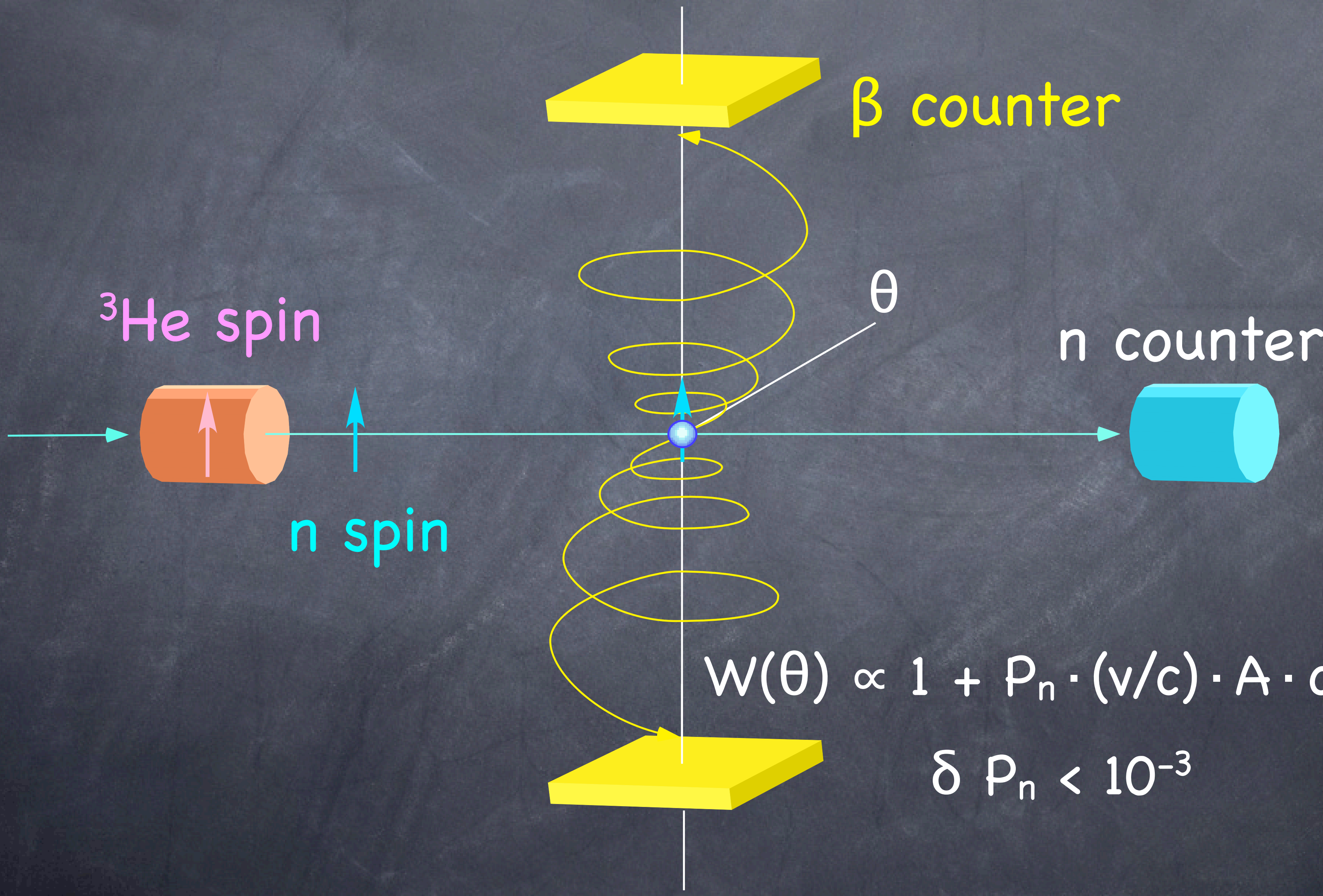
3 New Ramsey resonance

Fundamental Physics

- tests for fundamental symmetries:
  neutron β decay, T violation, PV spin rotation,
  np->dγ asymmetry, and so on.
- precision experiments
- high nuclear polarization with high precision
- high counting statistics
- low background

β decay asymmetry A



$$W(\theta) \propto 1 + P_n \cdot (v/c) \cdot A \cdot \cos\theta$$

$$\delta P_n < 10^{-3}$$

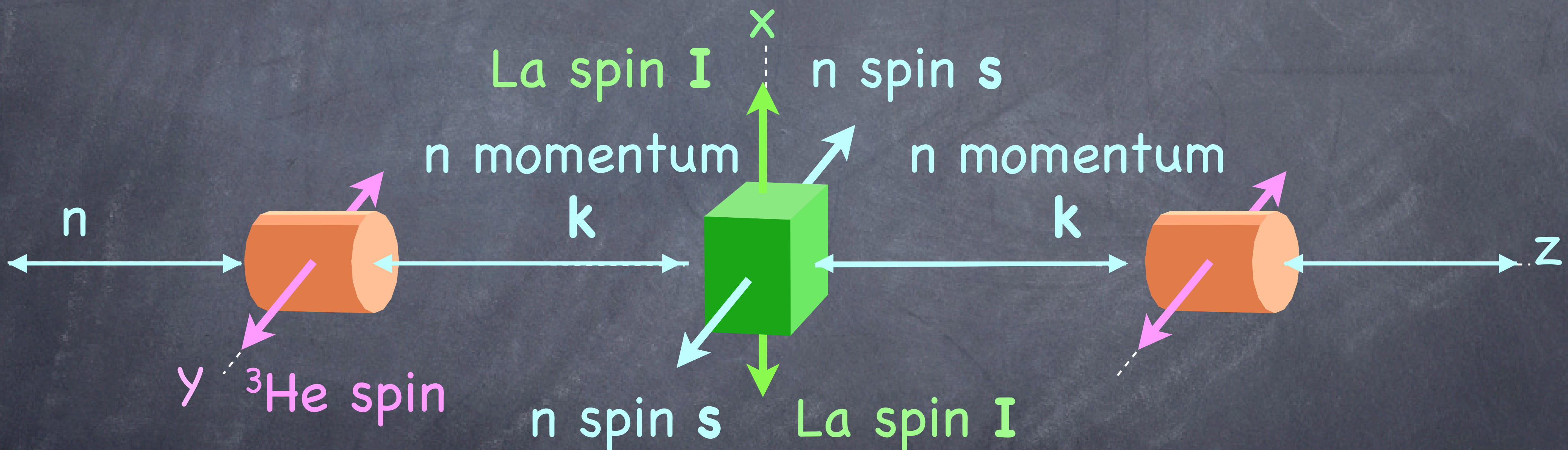
A is crucial for G_A and G_V

- $G_V = V_{ud} G_F$
- V_{ud} from $0^+ \rightarrow 0^+$ nuclear β decay contradicts the CKM unitarity
- Precision asymmetry with 10^{-3} is required

(for ~100 days of beam time at J-PARC)

T violating n transmission

$D\ \mathbf{s}\cdot(\mathbf{k}\times\mathbf{I})$: T-odd



time reversal
spin flip

Baryon asymmetry

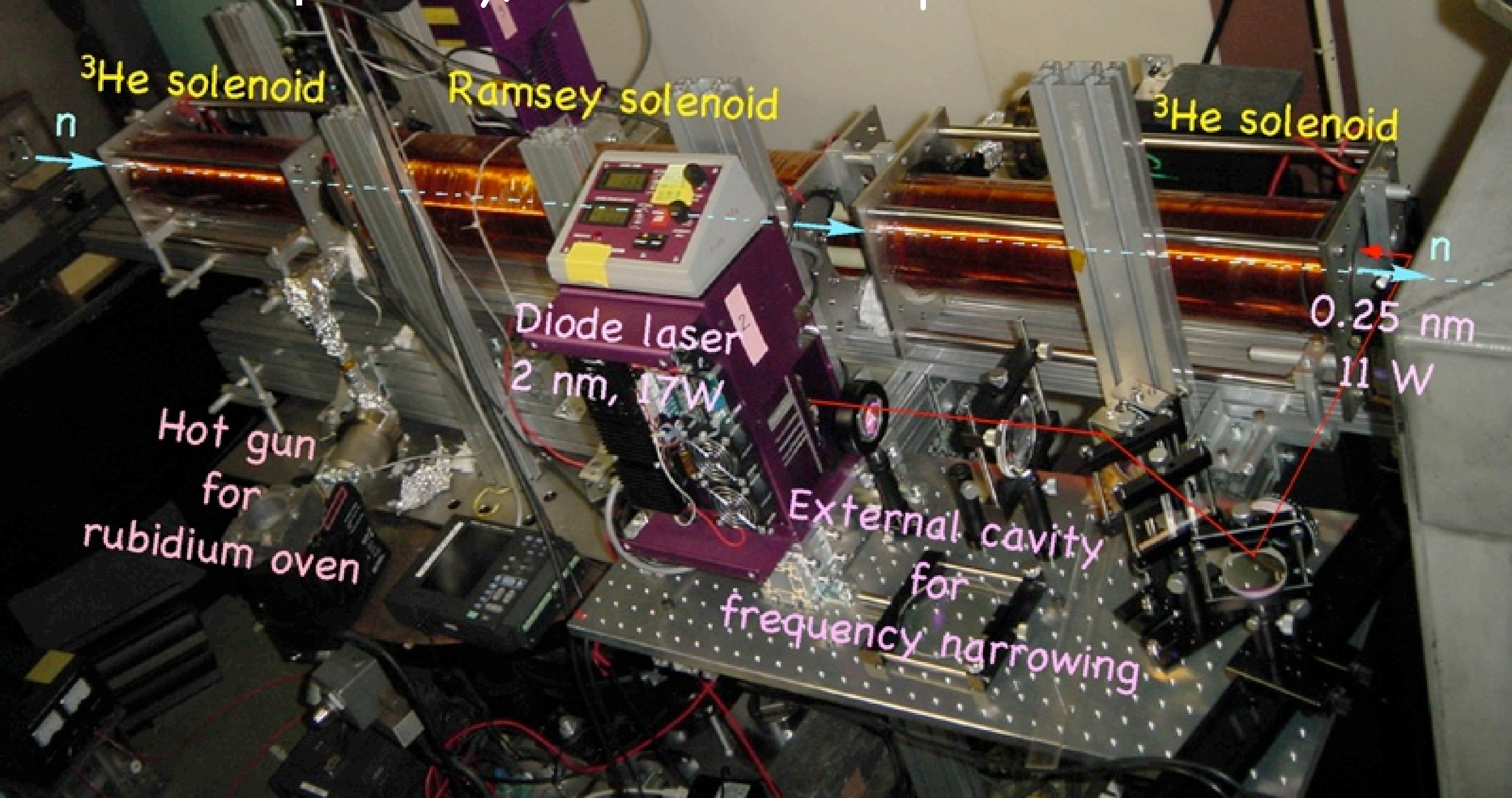
D $\mathbf{s}\cdot(\mathbf{k}\times\mathbf{I})$ is obtained from double asymmetry upon n spin flip and transmission reversal

C $\mathbf{s}\cdot\mathbf{k}$ (P-odd) is already measured

- λ = T-odd/P-odd = 10^{-4} (for ~1 year) →
  - n EDM of 10^{-26}~10^{-27} e·cm Gudkov, Posperov
- Supersymmetry and baryon asymmetry →
  - n EDM of 10^{-26}~10^{-27} e·cm

A new Ramsey resonance

n spin manipulation for the T violation experiment, β decay, and neutron spectrometer



Why ^{3}He polarization ?

Polarized ^{3}He is ideal slow neutron polarizer

- ^{3}He(n, p)t bound state resonance
  - J = 1/2 (n spin) + 1/2 (^{3}He spin) = 1 (parallel)
- $\sigma_\pm = \sigma_0[1- (\pm P_{He})]$, $\sigma_0 \propto 1/v$, v: neutron velocity
  - σ_0 = 5333 b at v = 2200 m/s
  - σ_s = 3.1 b

Spin exchange optical pumping

Compared with meta stability exchange optical pumping

- high pressure polarized ^3He gas
- compact
  - continuous pumping for experiment

Sapphire cell

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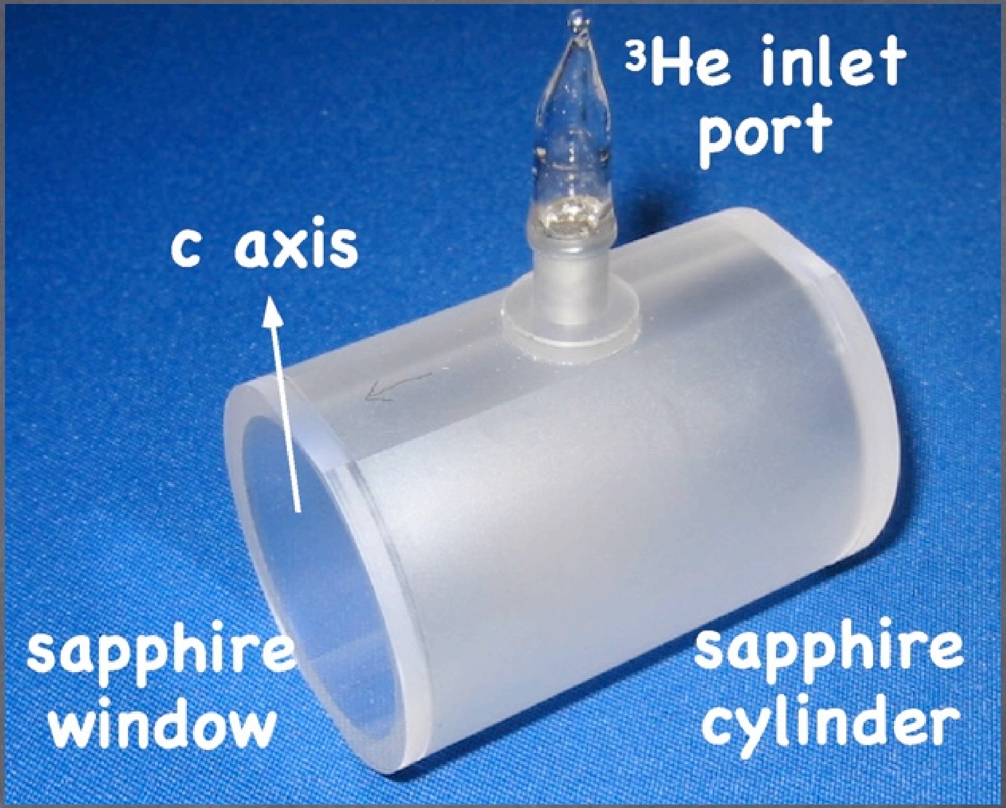
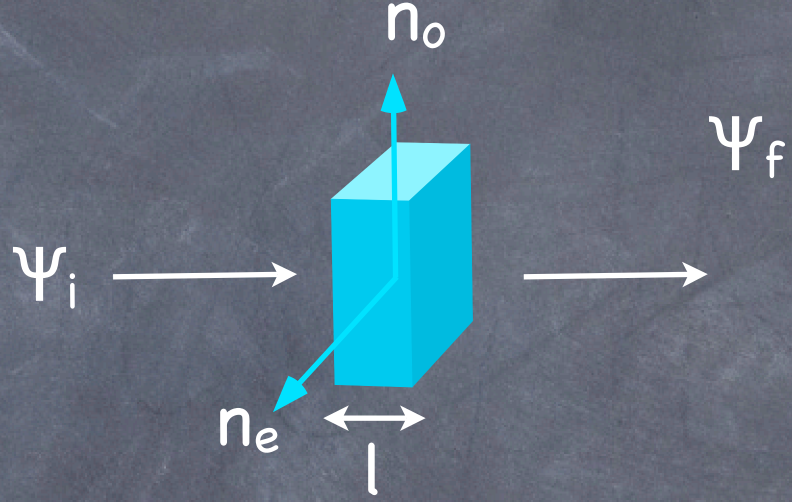


- sapphire is impervious to hot alkali vapor
- very clean
- flat surface to the neutron beam, strong for high pressure
- very low neutron cross section
- birefringence

Phase shift difference at birefringent window



- $\theta = 2\pi\,(n_o - n_e)\, l/\lambda$ is controlled by l
- $P_{pho} = \cos^2(\theta/2) - \sin^2(\theta/2)$
- Ψ_i = R (right handed state)
- $\Psi_f = \cos(\theta/2)\exp[i(\theta/2)]\times R + \sin(\theta/2)\exp[i(\theta/2-\pi/2)]\times L$

Expected polarization

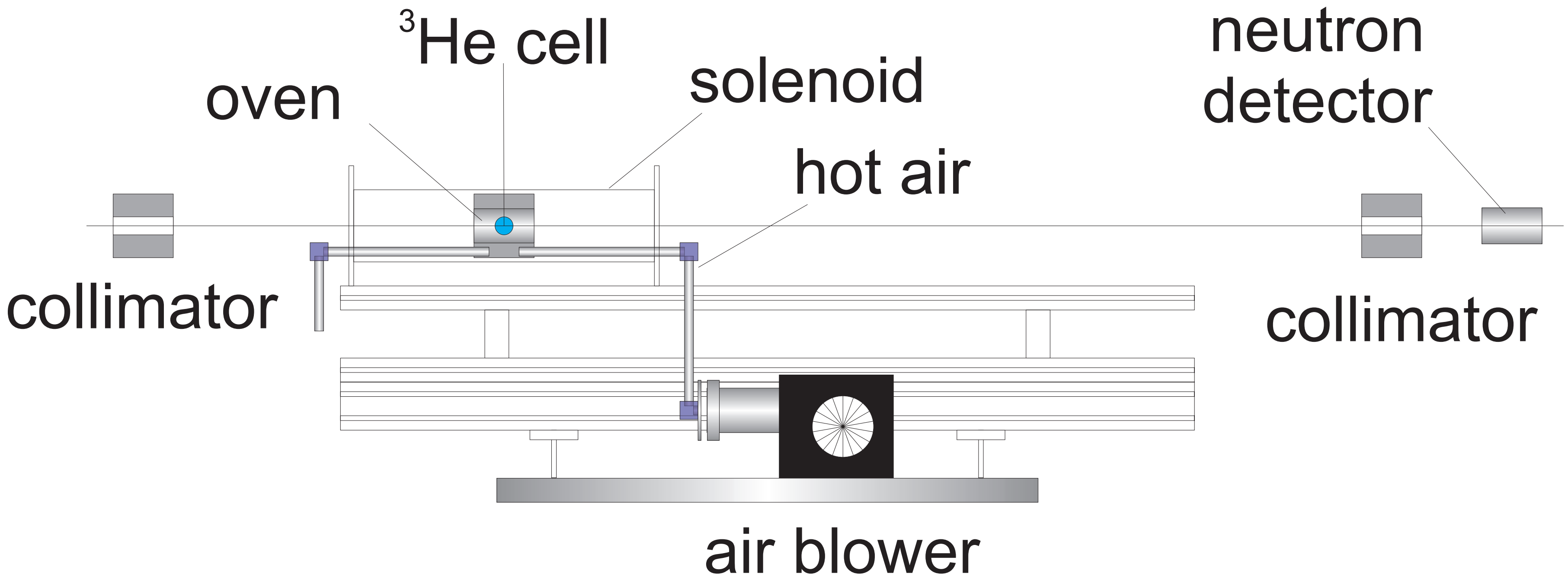
- P_{pho} = 87% at $\theta = 23^o$
- ^{3}He spin relaxation time $1/\gamma$ = 24 h
- if ^{3}He-Rb spin exchange rate $\gamma_{se} = 1/5\ h^{-1}$ at 195^{o}C (Baranga 1998))
  - $\gamma_{se}/(\gamma_{se} + \gamma)$ = 83%
- $P_{He} = P_{Rb}\ \gamma_{se}/(\gamma_{se} + \gamma)$ = 72% assuming $P_{Rb} = P_{pho}$

^{3}He polarization is measured

by n transmission

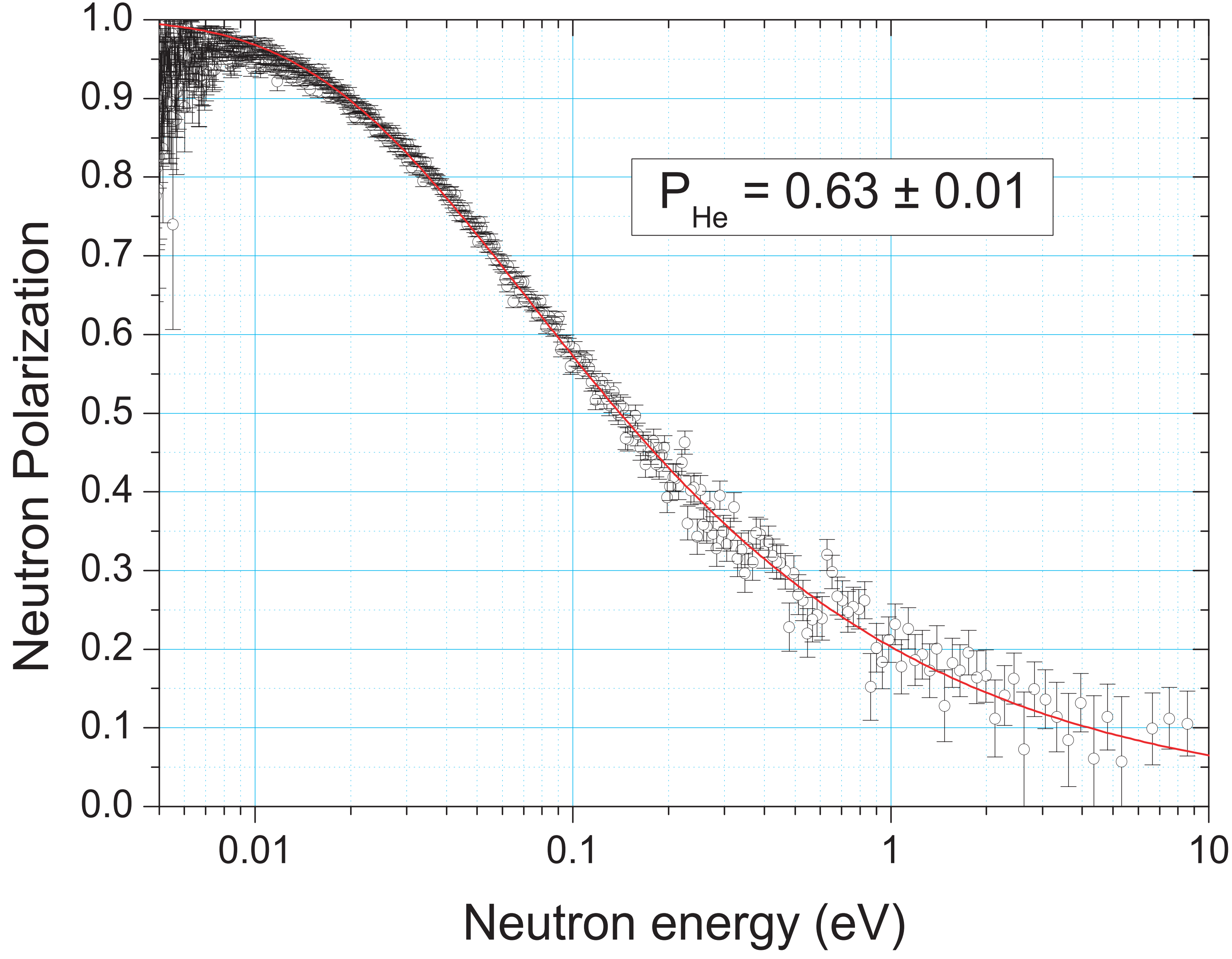
- $T = A \exp(-\sigma_0 N d) \cosh(P_{He} \sigma_0 N d)$
- $T_0 = A \exp(-\sigma_0 N d)$: transmission at $P_{He} = 0$
- A: transmission at $N = 0$ ($\sigma_0 N d = 0$)
- $T/T_0 = \cosh(P_{He} \sigma_0 N d)$ and $T_0/A = \exp(-\sigma_0 N d) \rightarrow P_{He}$
- $P_n = \tanh(P_{He} \sigma_0 N d) \rightarrow P_n = \sqrt{1-(T_0/T)^2}$

Experimental set-up



Result

$\Delta P_n = 10^{-3}$ is possible

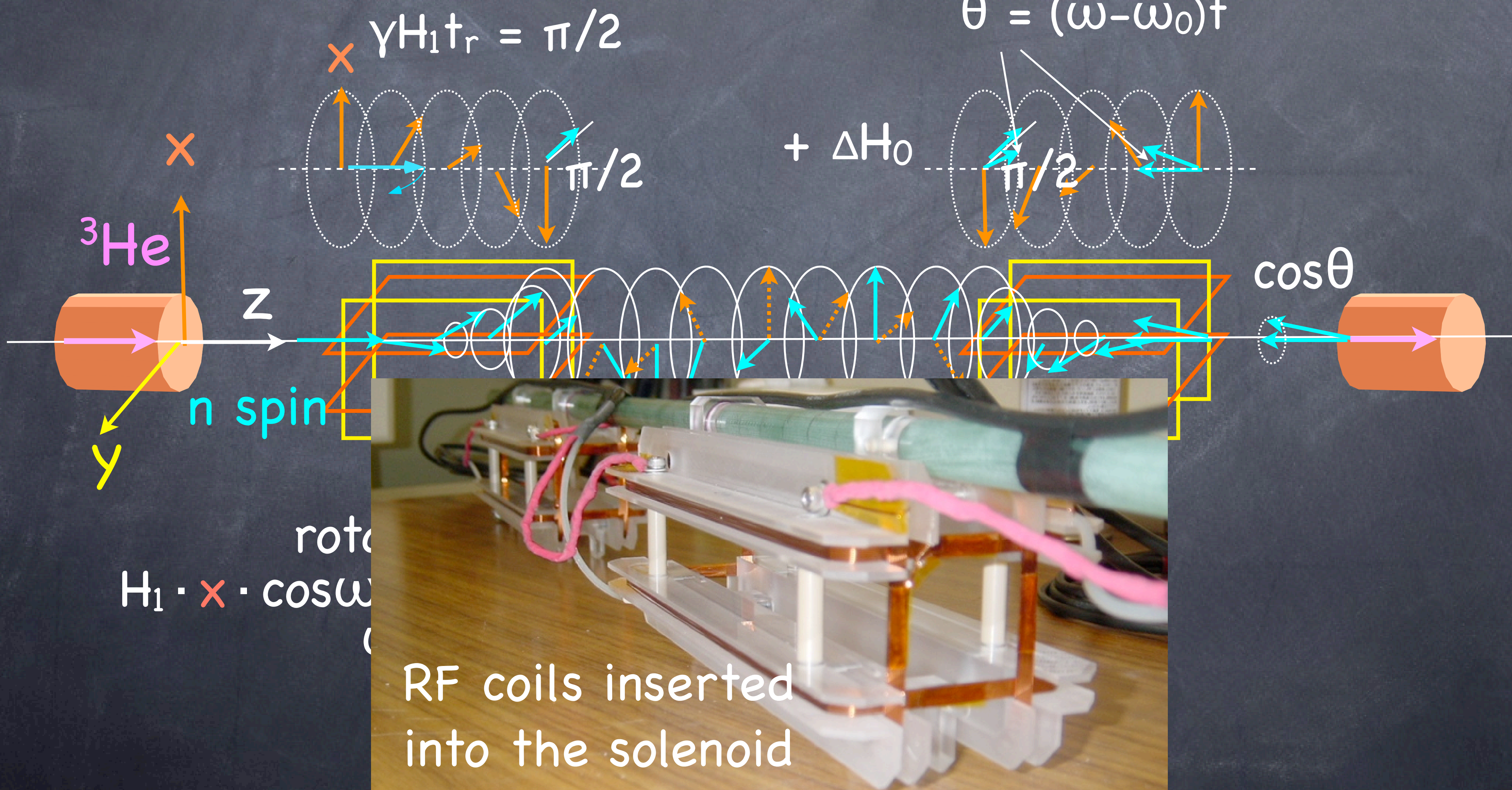


Comparison with expectation

- P_{He} = 63±1% at a pressure of 3.1 atm
- $P_{He} = P_{Rb}\, \gamma_{se}/(\gamma_{se} + \gamma) = 72\%$,
- Low P_{Rb}. The frequency narrowed laser of 11 W is not enough. Rb spin destruction rate is higher than expected because of laser heating.

A new Ramsey resonance

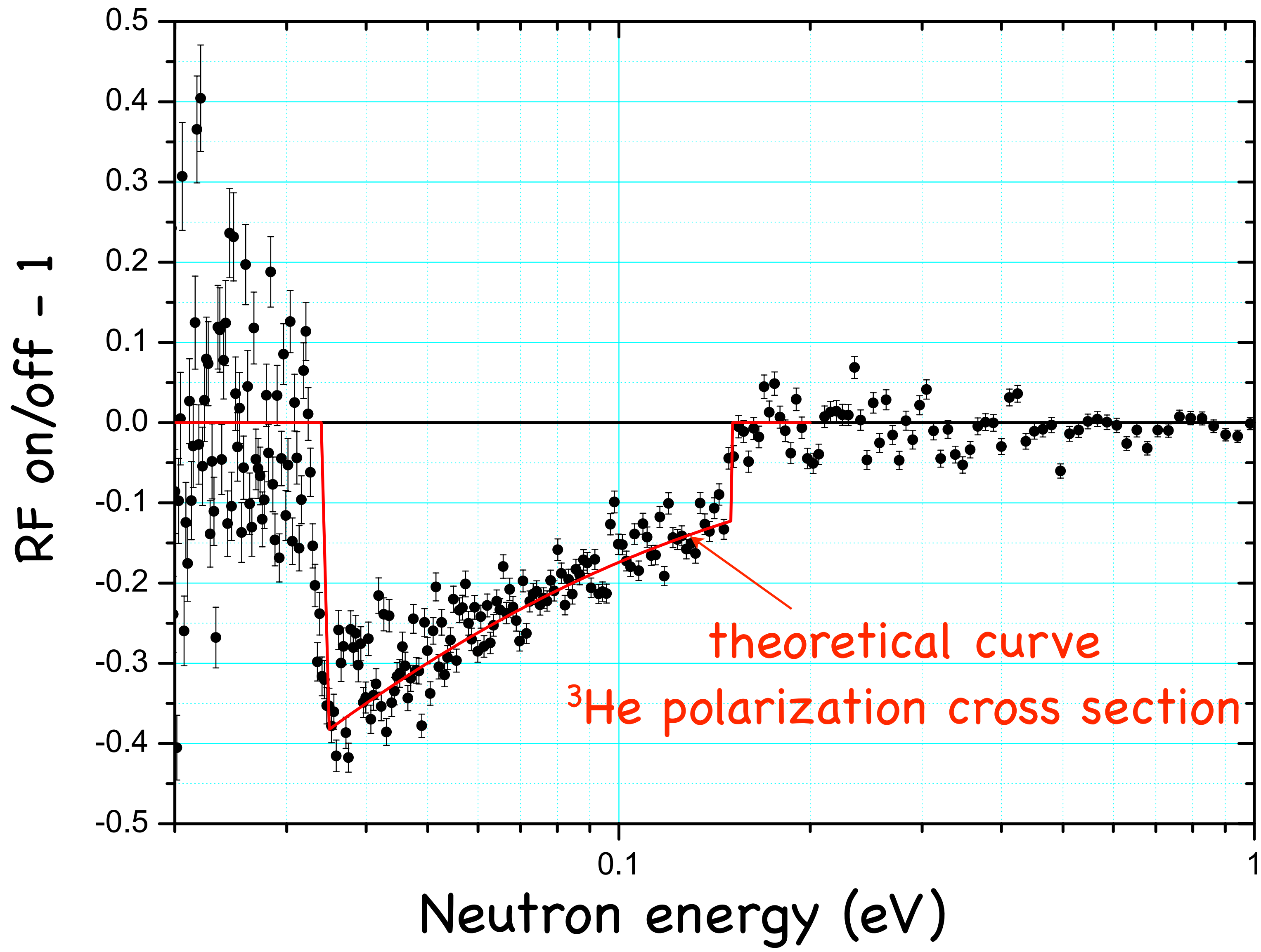
for pulsed neutron spin manipulation



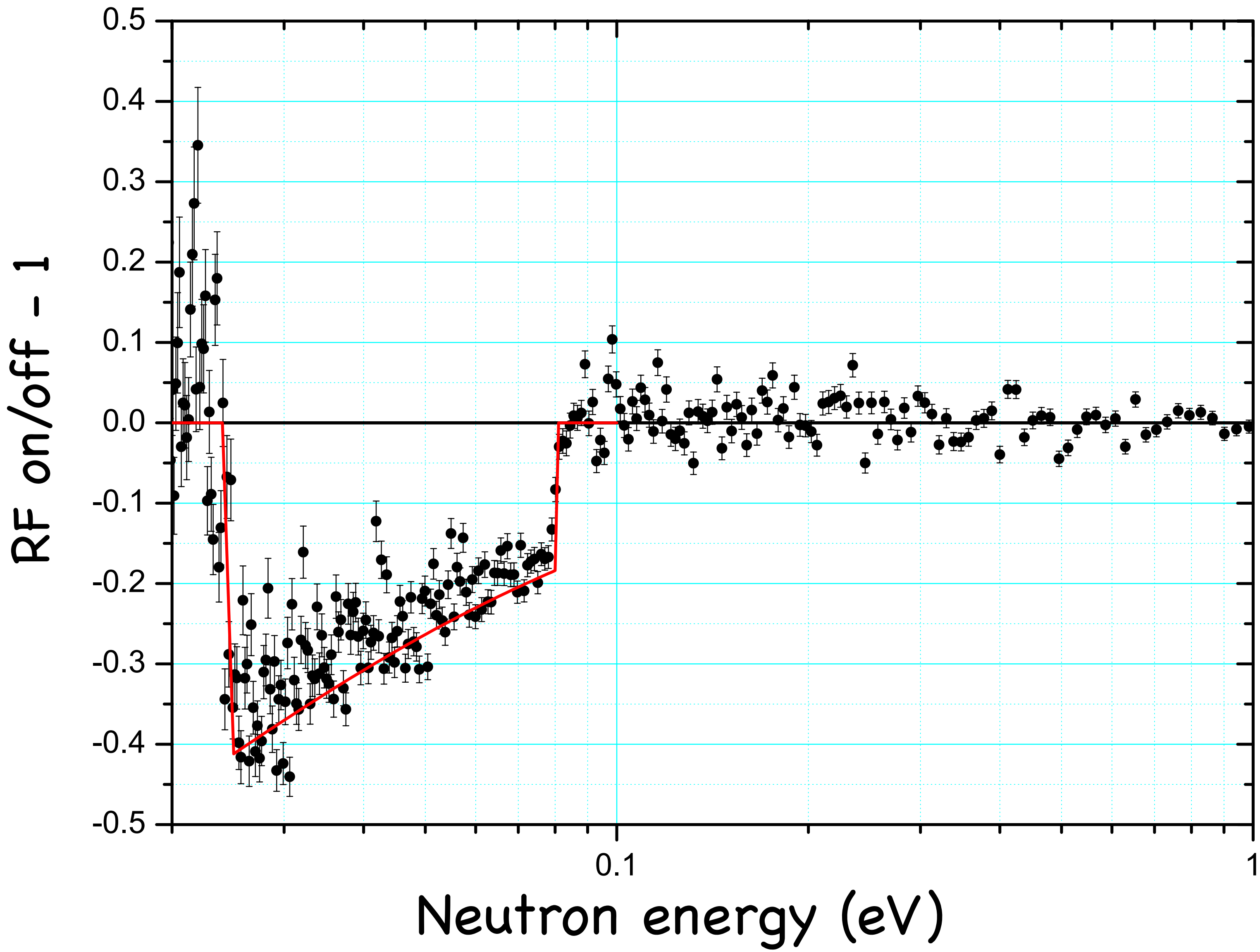
RF coils inserted into the solenoid

Results

θ = 0, π flipper for the T violation and β decay



Timing of RF pulse was changed



RF phase was modulate as a function of n TOF

for T-violation and n spectrometer