Characterisation of the U Shape Spin Analyzer (USSA)

for the n2EDM experiment at PSI

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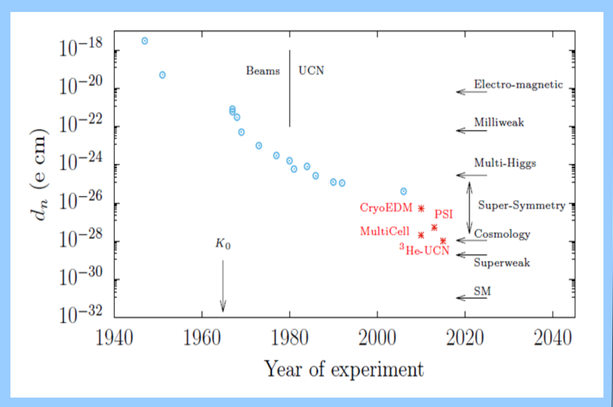
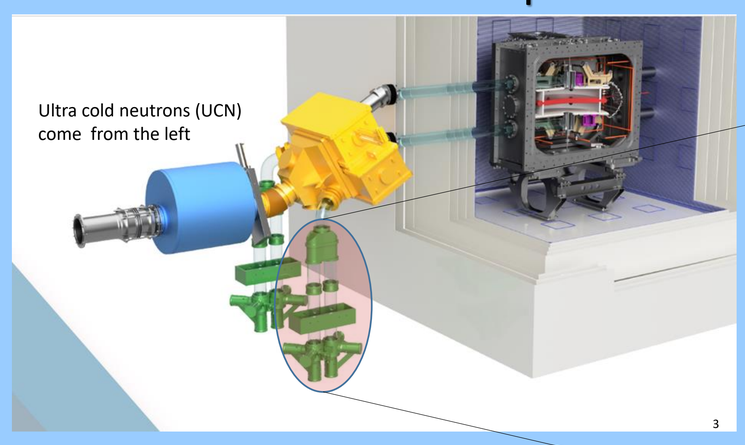
The neutron Electric Dipole Moment

Theoretical motivations

- **Sakharov conditions** [1] **= requirements to explain the matter-antimatter assymetry of the Universe**
  - ✓ Baryon number violation
  - ✓ Interactions out of thermal equilibrium
  - ✓ C and CP violations
- **Neutron EDM (dn) involves CP symmetry violation**
  - ✓ $\widehat{dn} \cdot \hat{\hat{E}} \xrightarrow{CP} - \widehat{dn} \cdot \hat{\hat{E}}$
- **The goal of n2EDM experiment is to obtain a dn limit under 1e^{-27} e.cm !!** [2]

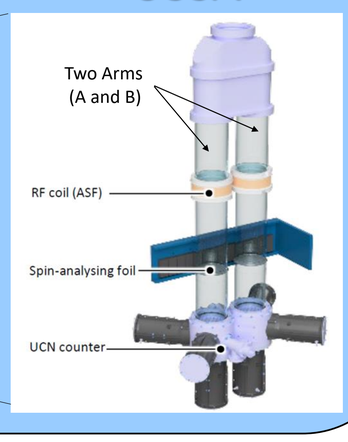


n2EDM experiment at PSI



USSA analyse the neutron polarisation & count UCN

USSA



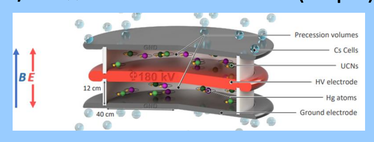
How the measurement works ?

Ramsey method:

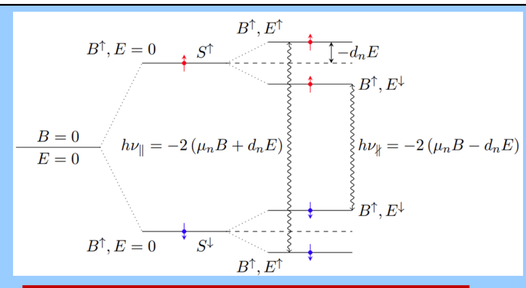
- Neutrons arrives with spin down
- π/2 pulse to obtain free precession (3 min) for all neutrons
- New π/2 pulse to obtain the one of the four working points

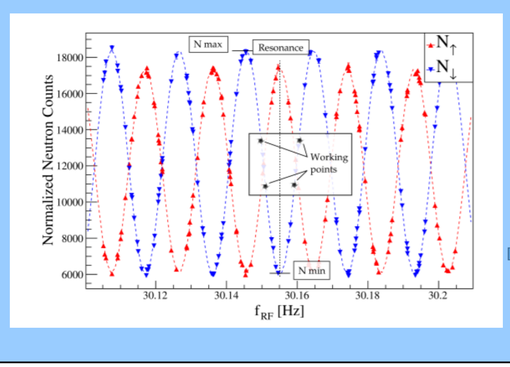
USSA counts the number of UCN as a function of their polarisation

During the free precession, strong electric field is applied 15 kV/cm[2] and weak B field (=1µT)



Induces degenerescences



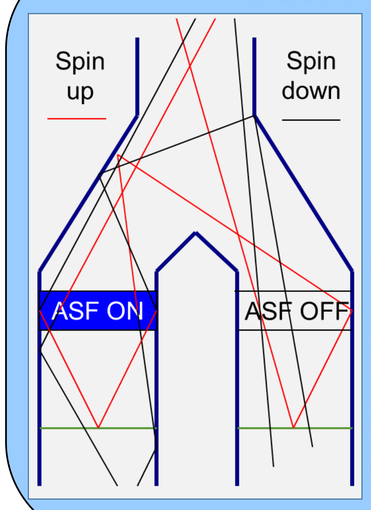


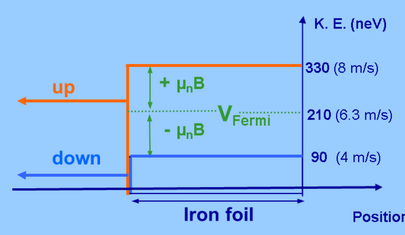
$$dn = \frac{h(\nu_{\parallel} - \nu_{\nparallel})}{4E}$$

$$N_{\uparrow\downarrow} = N_{\uparrow\downarrow}\left(1 \mp \alpha_{\uparrow\downarrow}(T)\cos\left[\frac{fn - fRF}{\Delta\nu}.\pi\right]\right)$$

USSA Characterisation

USSA operating





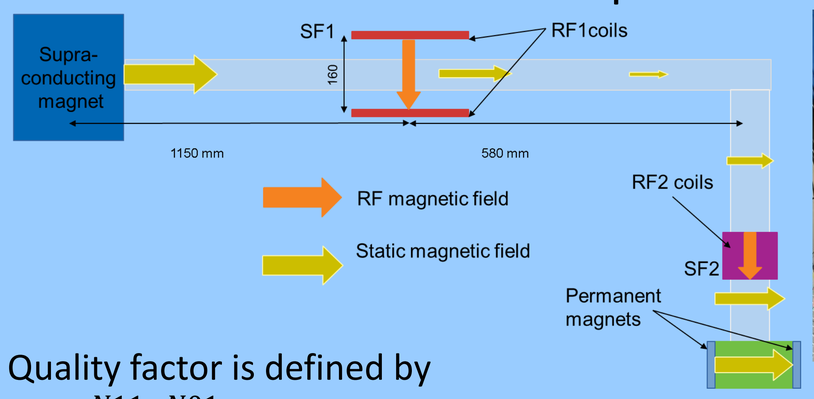
UCN have a kinetic energy lower than 300 neV
The potential « see » by the UCN is: $V(UCN) = V_F(Fe) \pm \mu_n.B$

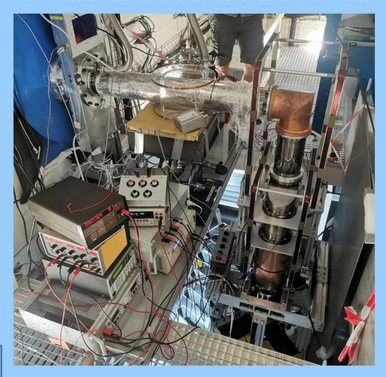
As a conclusion, only neutrons with spin down can across the analysing foil. Otherwise, they bounce and go to the other arm

Adiabatic Spin Flipper (ASF) reverse the spin of all neutron across it

It allows the USSA to analyse the polarisation of the neutrons and count neutrons with spin up in left arm and spin down in right arm

Scheme of the experiment and variables definitions





Analysing power :

$$AP = \frac{N_{ON} - N_{OFF}}{Q.N_{ON} + N_{OFF}}$$

Where:
- P is the polarisation
- N_{ON} number of neutron when SF is ON

Quality factor is defined by

$Q2 = \frac{N11 - N01}{N00 - N10}$ $Q \in [-1;1]$ Q=1 means the SF is perfect

Efficiency $f=(1-\varepsilon)=1-(1-Q)/2$

N11	SF1 ON	SF2 ON	100%
N10	SF1 ON	SF2 OFF	0%
N01	SF1 OFF	SF2 ON	0%
N00	SF1 OFF	SF2 OFF	100%

Detection in perfect case

Results

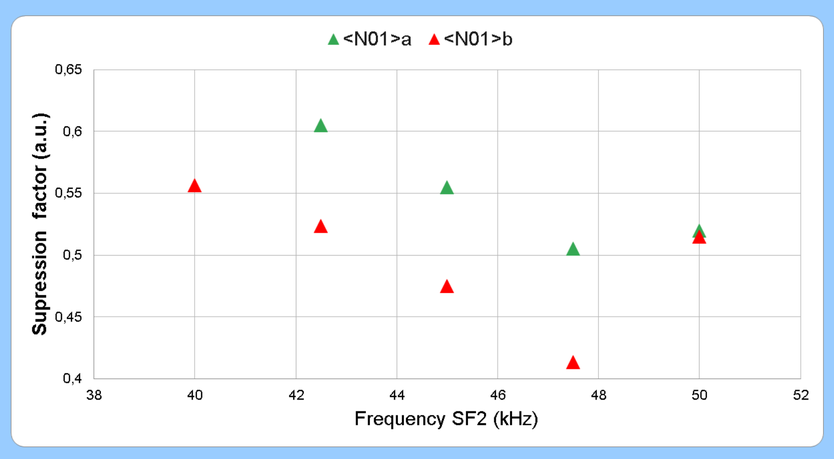


Chart: Suppression factor as a function of the frequency of the SF radiofrequency field.

Frequency: 47.5 kHz

SF efficiency (arm A)= f(A) = 0,985
SF efficiency (arm B)= f(B) = 0,999

Conclusion

Previous experiment

	f (arm B)	f (arm A)	AP
nEDM	0,97	0,97	0,80
n2EDM	0,999	0,985	0,90

Preliminary results show a nice improvement on SF efficiency and analysing power

Supression factor:
Normalised number crossing the analysing foil:
Minimum is reached when the SF is fully operating

References:
- (1) A.D Sakharov. JETP lett., 5 : 24,1967
- (2) N.J. Ayres, G. Ban, L. Bienstman, G. Bison, K. Bodek, et al.. The design of the n2EDM experiment: nEDM Collaboration. *European Physical Journal C: Particles and Fields*, Springer Verlag (Germany), 2021.