Data blinding for the nEDM experiment

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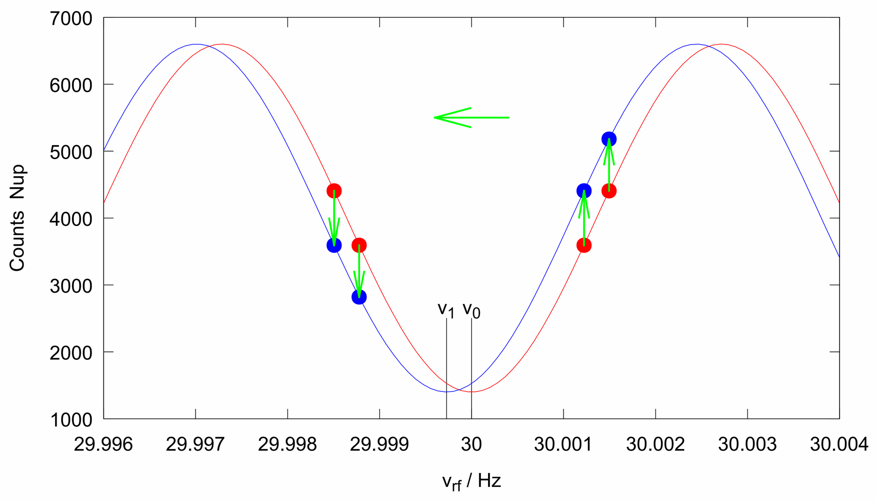
Motivation

Psychological bias towards (or away from) a prior measurement or a theory prediction is an intrinsic threat to any data analysis. While various methods can be used to avoid the bias (e.g. actively not looking at the result), only data blinding is a traceable and thus trustworthy method to circumvent the bias and to convince the external audience that there is not even an accidental psychological bias. Data blinding is nowadays standard in particle physics.

Method of Choice



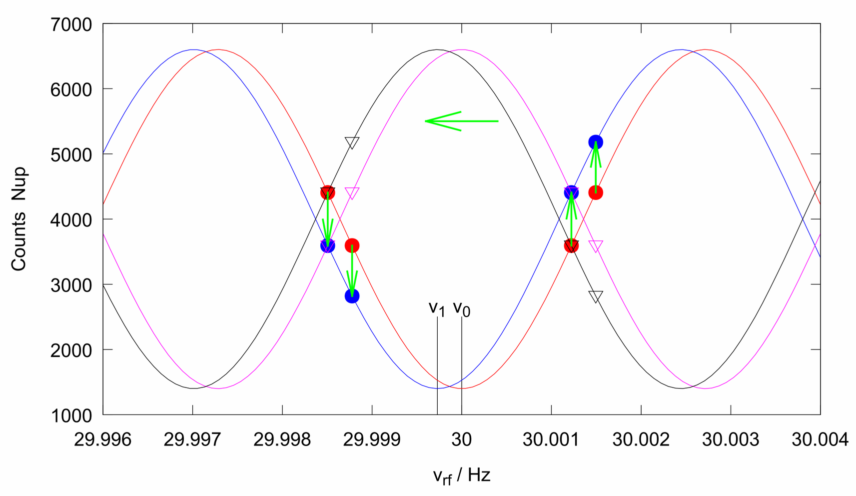
Red line: Real Ramsey pattern
Red dots: Real counts
Blue dots: Blinded counts
Blue line: Pattern fitted to blinded counts

$$\delta N = \left(\frac{d}{d\phi}N\right)\delta\phi$$

$$\delta N = \left(\frac{d}{d\nu_0}N\right)\delta\nu_0 = \left(\frac{d}{d\phi}N\right)\frac{d\phi}{d\nu_0}\delta\nu_0$$

$$\begin{aligned}\delta N_{\uparrow,\downarrow;i} &= \pm\bar{N}_{\uparrow,\downarrow}\alpha\,(\sin\phi_i)\,\delta\phi \\ &= \mp\bar{N}_{\uparrow,\downarrow}\alpha\,(\sin\phi_i)\,\frac{\pi}{\Delta\nu}\frac{2d\cdot E}{h}\end{aligned}$$

$$\delta N_{\uparrow,\downarrow;i} = \mp\bar{N}\frac{\pi\alpha}{\Delta\nu}\frac{d\cdot E}{h}\sin\phi_i$$



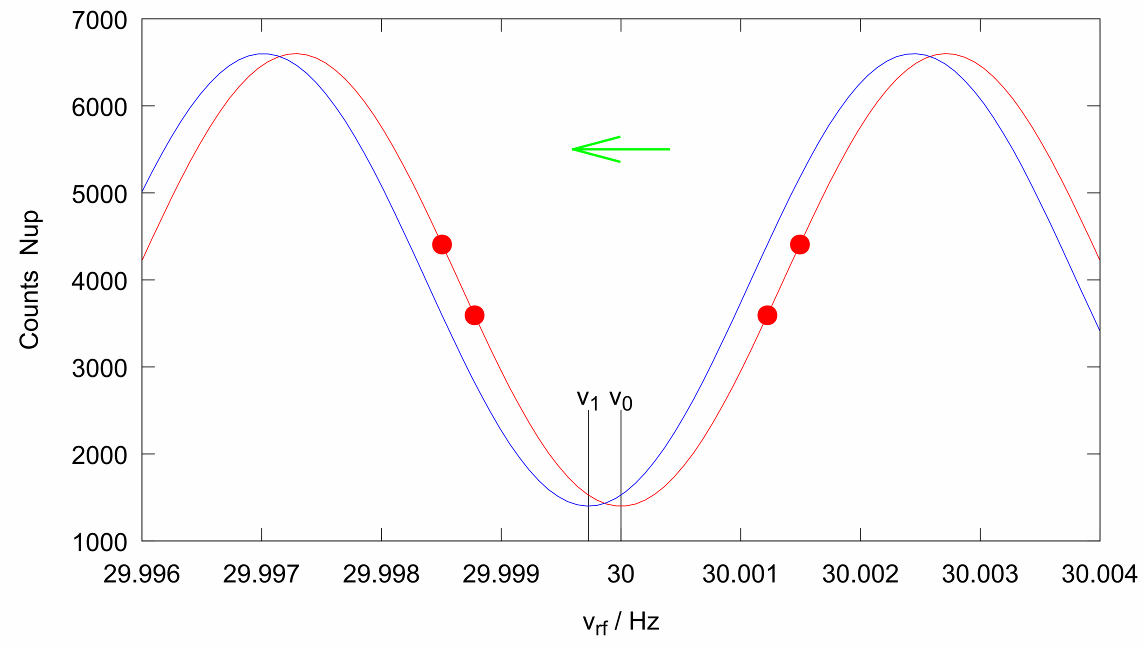
Pink line: Real Ramsey pattern spin down
Pink triangles: Real counts spin down
Black triangles: Blinded counts spin down
Black line: Pattern fitted to blinded counts

Difference between red and blue is always the negative as between pink and black.

Þ Re-declaration of some spin-up to spin-down (or vice versa) is sufficient

$\bar{N} = 8000$, $\alpha = 0.65$, $\sin\phi = 0.99$, $T = 180$ s, $E = 10$ kV/cm $d = 10^{-25}\,e{\cdot}\mathrm{cm} \Rightarrow |\delta N_{\uparrow,\downarrow;i}| \approx 1.44$

Possible Ways to Blind



$$N_{\uparrow,i} = \bar{N}_\uparrow(1-\alpha\cos\phi_i)\,,$$
$$N_{\downarrow,i} = \bar{N}_\downarrow(1+\alpha\cos\phi_i)\,,$$

$$\phi_i = \frac{(\nu_i-\nu_0)}{\Delta\nu}\pi,$$

$$\Delta\nu = \frac{1}{2\,(T+4t/\pi)},$$

$$\delta\nu_0 = 2\vec{d}\cdot\vec{E}/h,$$

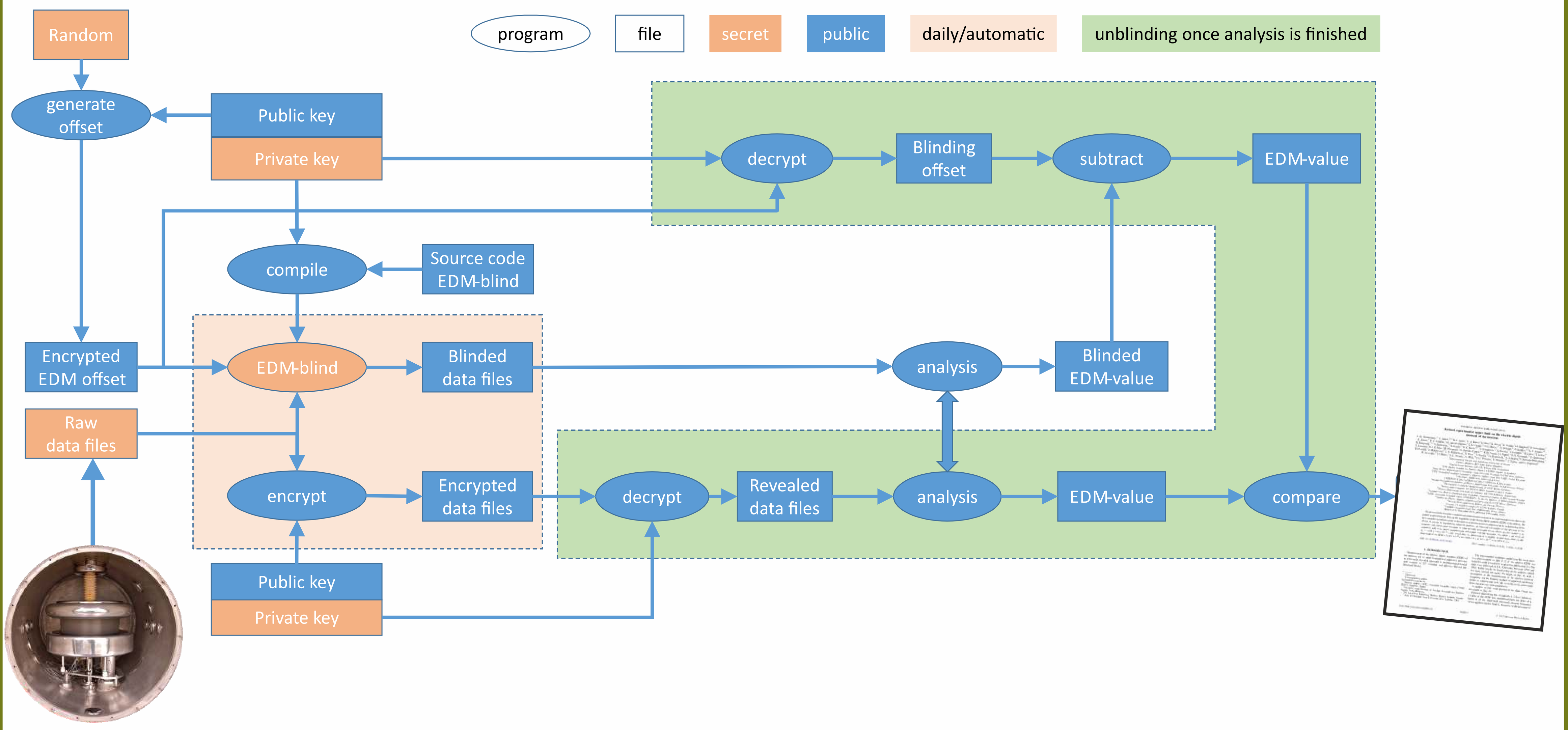
An EDM-signal is a horizontal (frequency) shift of the Ramsey pattern.

- Fake frequency axis (record fake spin-flip frequency).
  - Þ Must also fake magnetometers (otherwise trivial to reveal).
    - Þ Very difficult due to complex magnetometer network.
- Modify frequency-axis (apply different spin-flip frequency).
  - Þ Danger of introducing systematics.
- Fake neutron-counts (record modified number of neutrons).
  - Ü Our method of choice!

Algorithm

After each run (=about once per day):
Do a Ramsey fit to estimate visibility a.
For each cycle of this run:
Use f , N_{up}+N_{down} and a to calculate dN (a rational number).
Add a normal distributed random number (width 2) and round to nearest integer *M*.
Choose *M* neutron events and change their labelling from spin "up" to "down" or vice versa.
Store new file to accessible place.

Blinding and Unblinding



Special Features

Secondary Blinding:
Apply same blinding code twice (with different offset).
Þ A test try for unblinding.
Þ Different blinding offsets for two analysis groups.

Reblinding:
In case a bug in the blinding code is found:
It can be run again (if deviation is small),
without revealing the secret offset!

Ü Need reproducible, true random numbers.
Þ Use random from data files themselves.

Secrecy
Use asymmetric RSA encryption.
Blinding offset encrypted with public key.
Þ Only need to trust one (or a few) persons instead of 50.

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