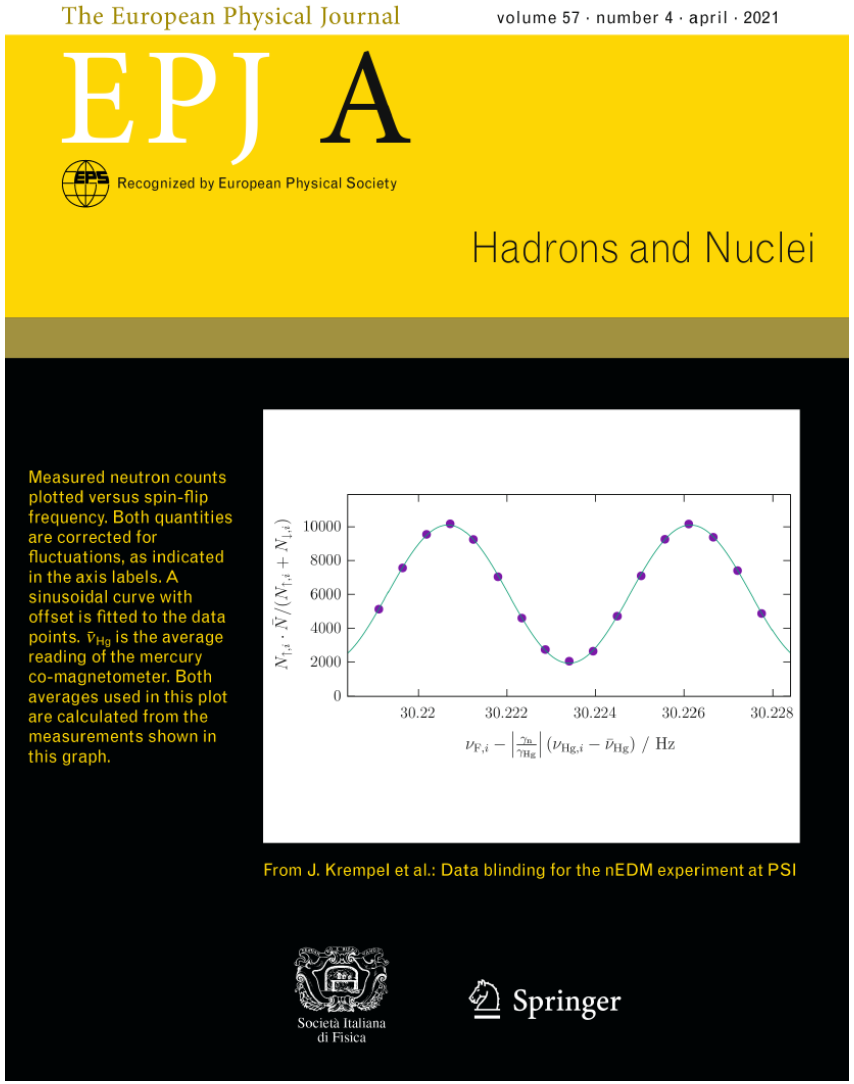
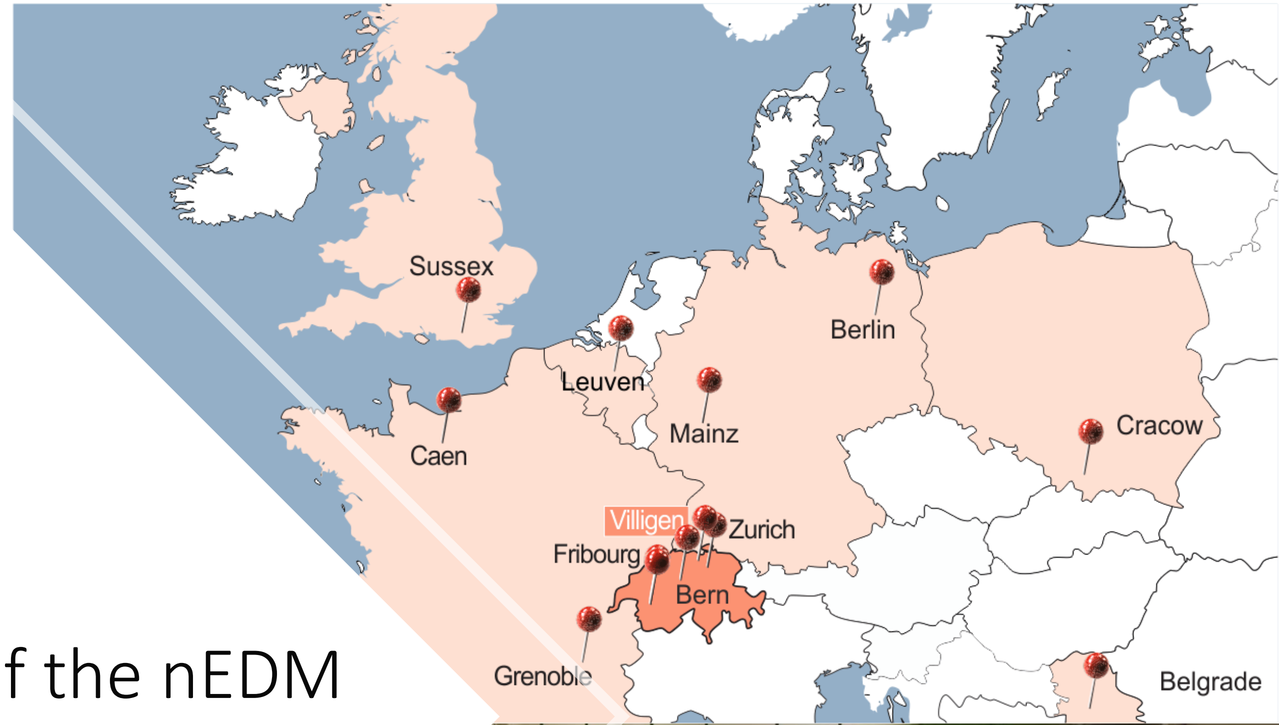
Data blinding: the hidden quest

Nature ***volume 526***, *pages 187–189 (2015)*



On behalf of the nEDM collaboration



A blind analysis

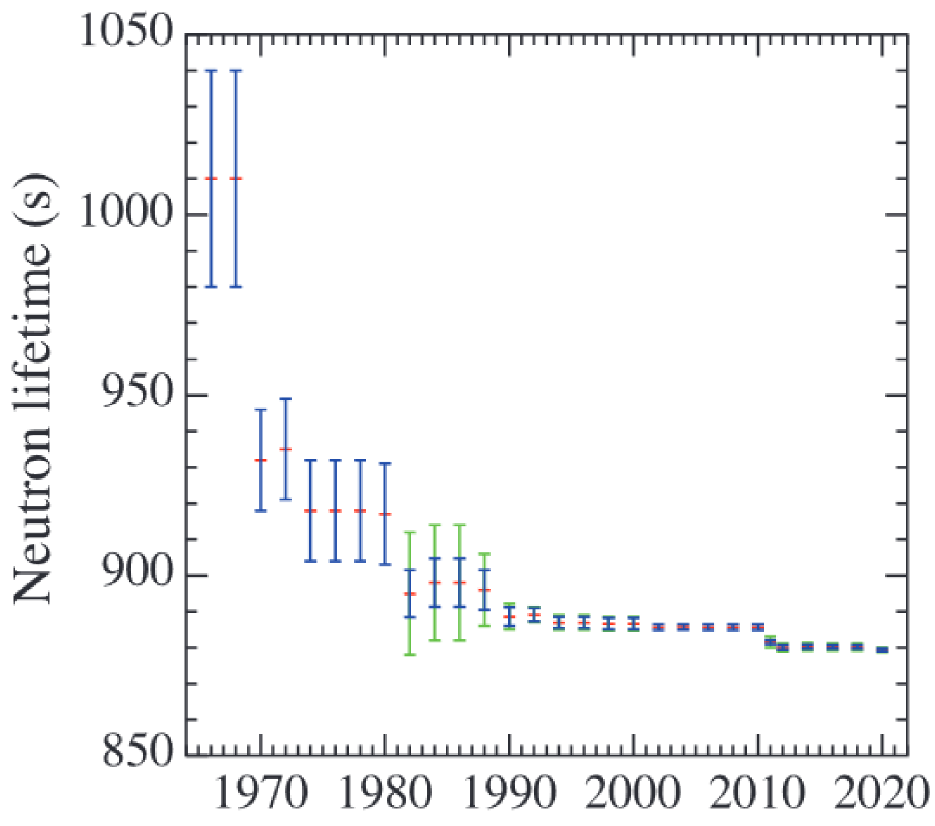
Is a **standard practice** to avoid unconsciously working toward a certain value by:

- checking that the answer makes sense
- giving particular scrutiny to results which contradict established models, previous measurements
- being conservative in our estimates of systematic uncertainties

A blind analysis is a method that hides some aspect of the data or result to prevent experimenter's bias

- hidden signal box, adding or removing Events
- hidden answer (hidden detector parameters, **hidden offset**, divided analysis or data prescaling)

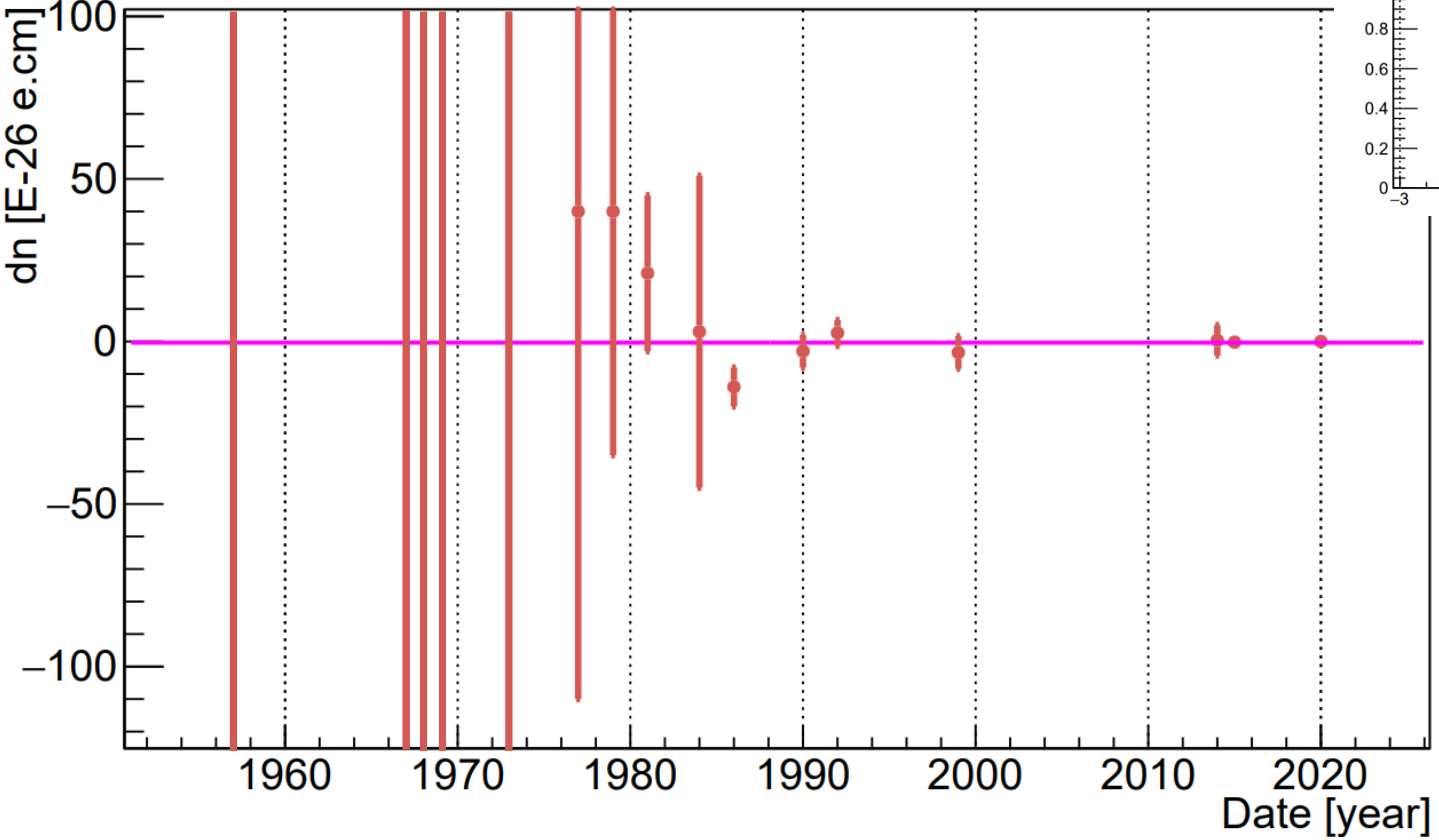
History plots



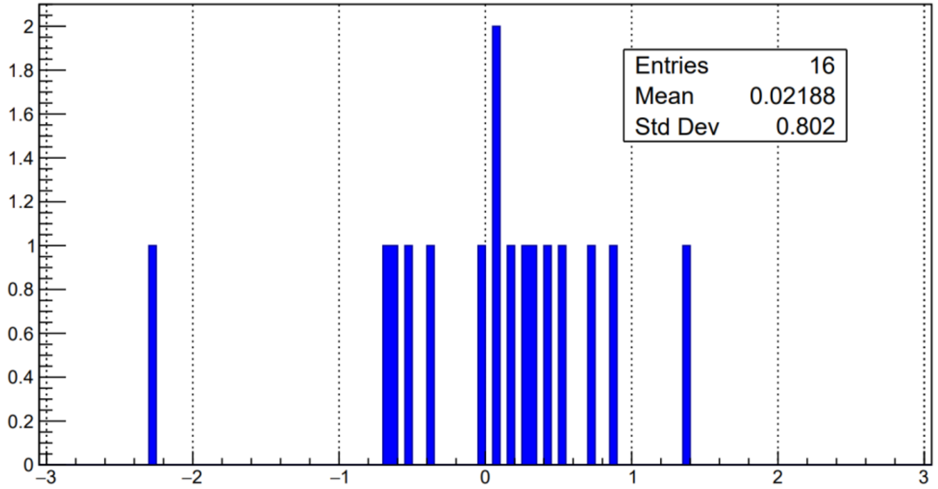
From: https://pdg.lbl.gov/2023/reviews/rpp2022-rev-history-plots.pdf

Often discussed in the context of blinding
Do we have to worry about the history plot for nEDM?

History plots



Fit residuals



Chi2 = 10.3214

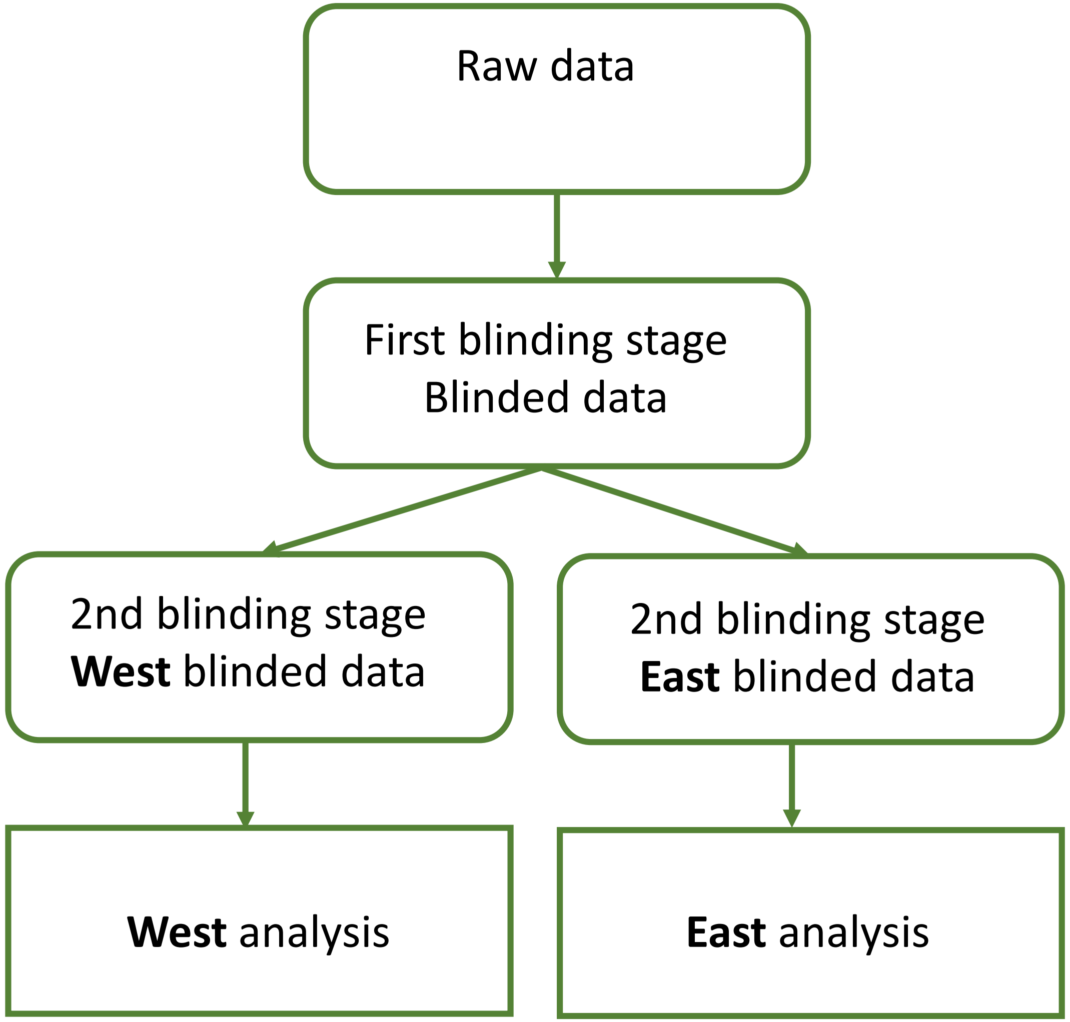
NDf = 15

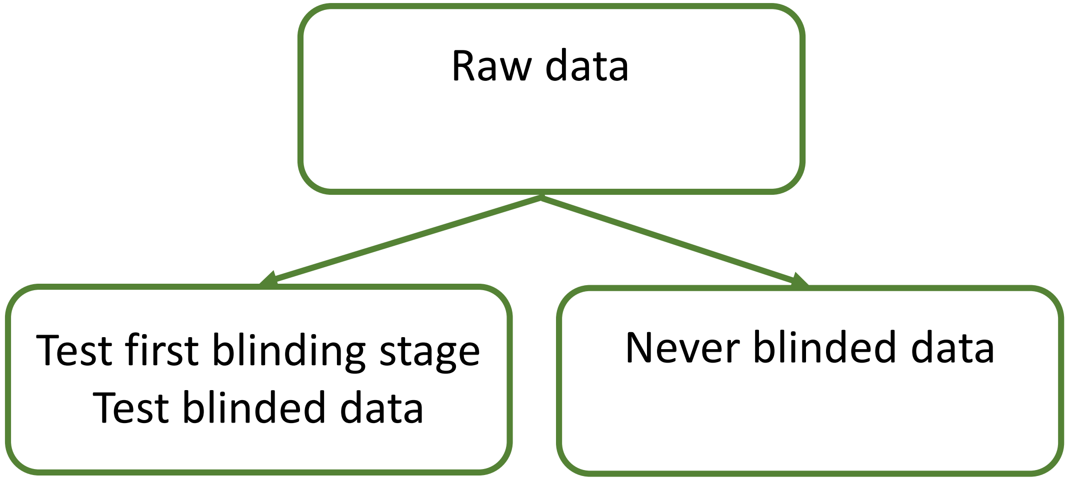
p0 = -0.357157 +/- 0.861726

Perfect Chi2:

Chi2 = 15.0 +/- 5.5

The blind search for the neutron EDM





Additionnal noise:
2×10^{-28} e cm

Sensitivity: 3.2×10^{-26} e cm

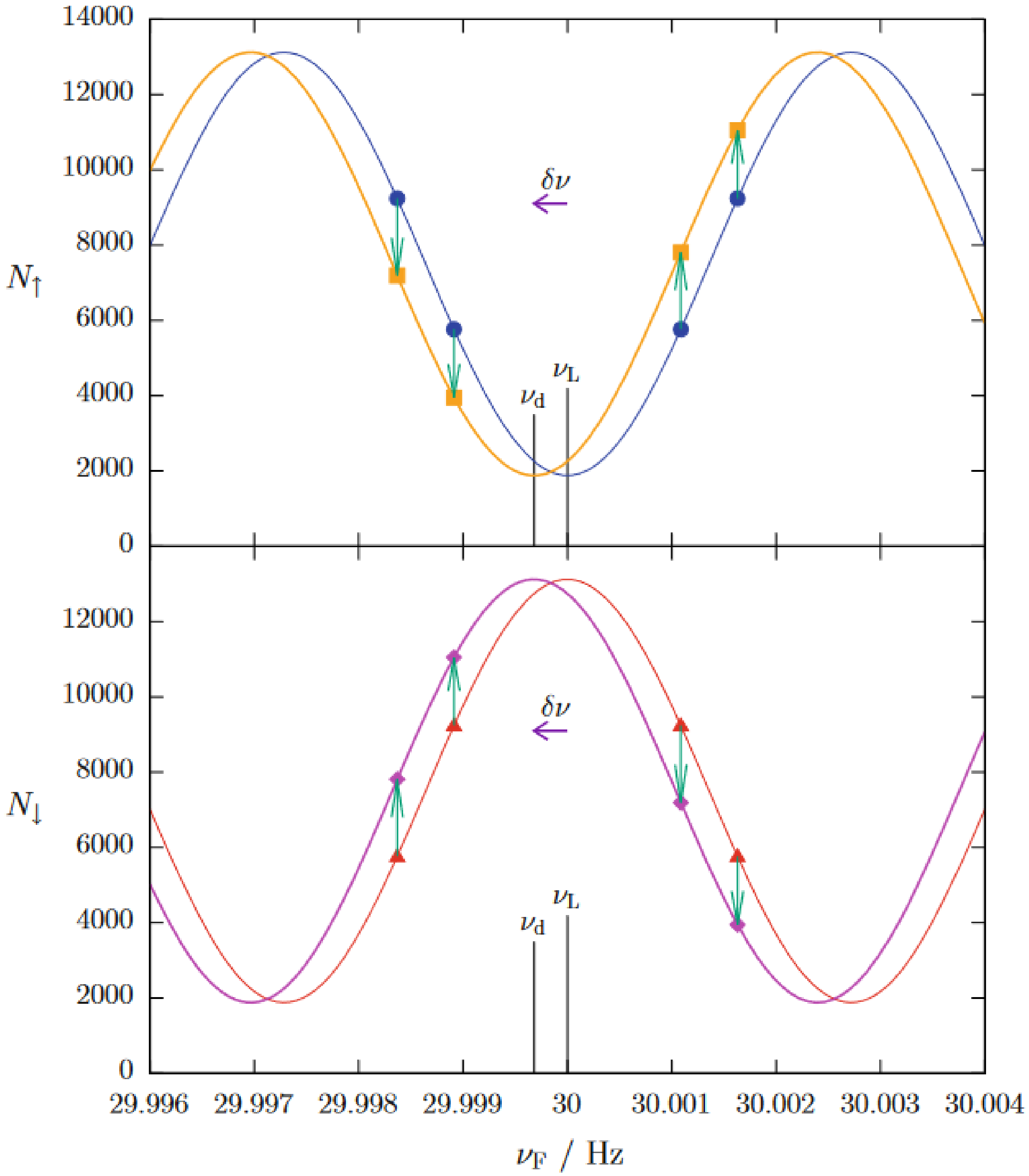
2 independent analysis teams and 2 blinding stages

The blind search for the neutron EDM

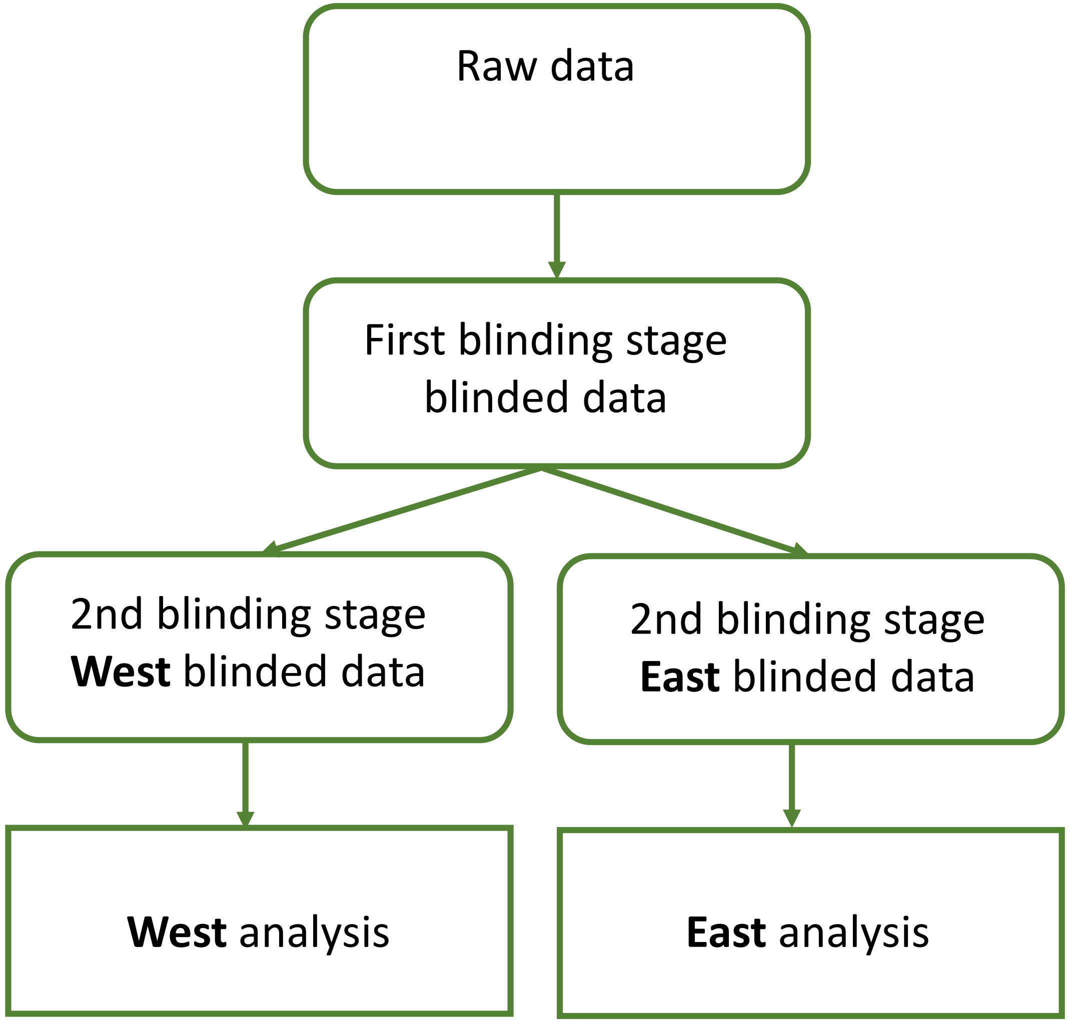
Add an E-dependent offset in the neutron frequency equivalent to an EDM of 1.10^{-25} e.cm
EDM: by moving ~3 neutrons (from up to down or down to up)
n2EDM: by moving ~40 neutrons (from up to down or down to up)

Since the number of neutron is an integer, the rounding creates a noise -> minimized by a random process in rounding.

Same technics can work for n2EDM



The blind search for the neutron EDM

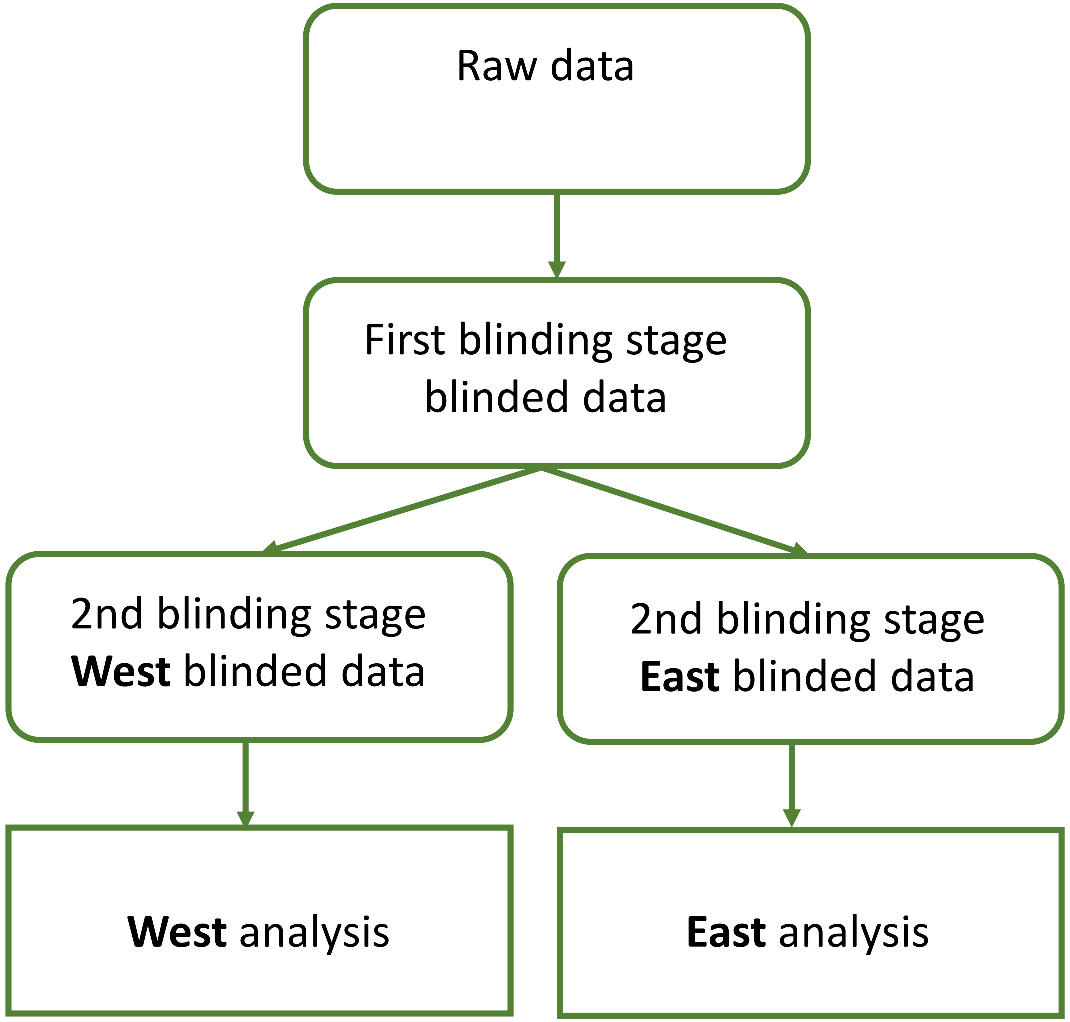


2 independent analysis teams and 2 blinding stages

$d_n = ($ u $\pm$ d $_{at} \pm$ d $_{st})\ 10^{-26} e.\mathrm{cm}$

Analysis task
2011 - 2019

The blind search for the neutron EDM



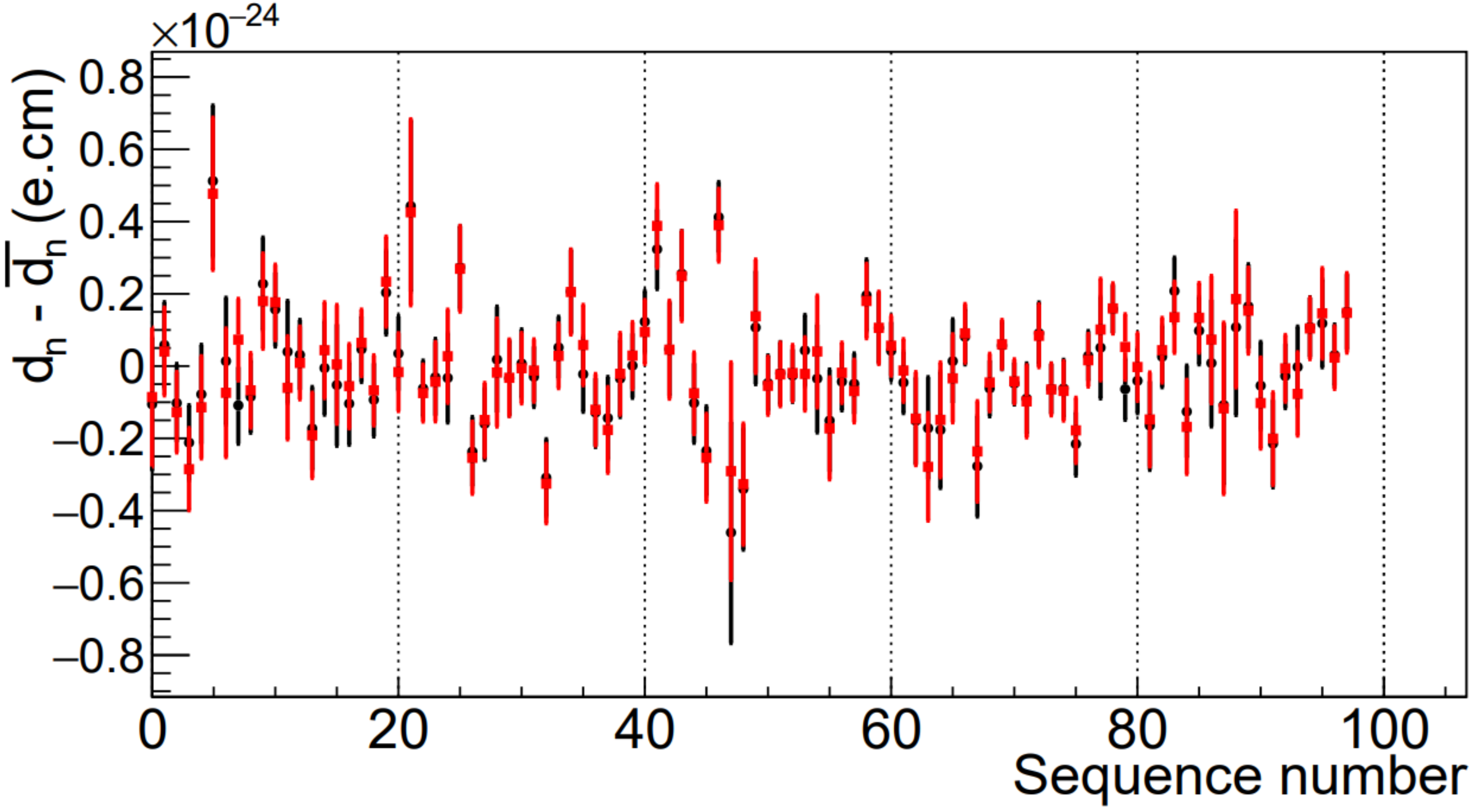
2 independent analysis teams and 2 blinding stages

Analysis comparison
Late 2018

$d_n = (u \pm d_{at} \pm d_{yst}) 10^{-26} e.cm$

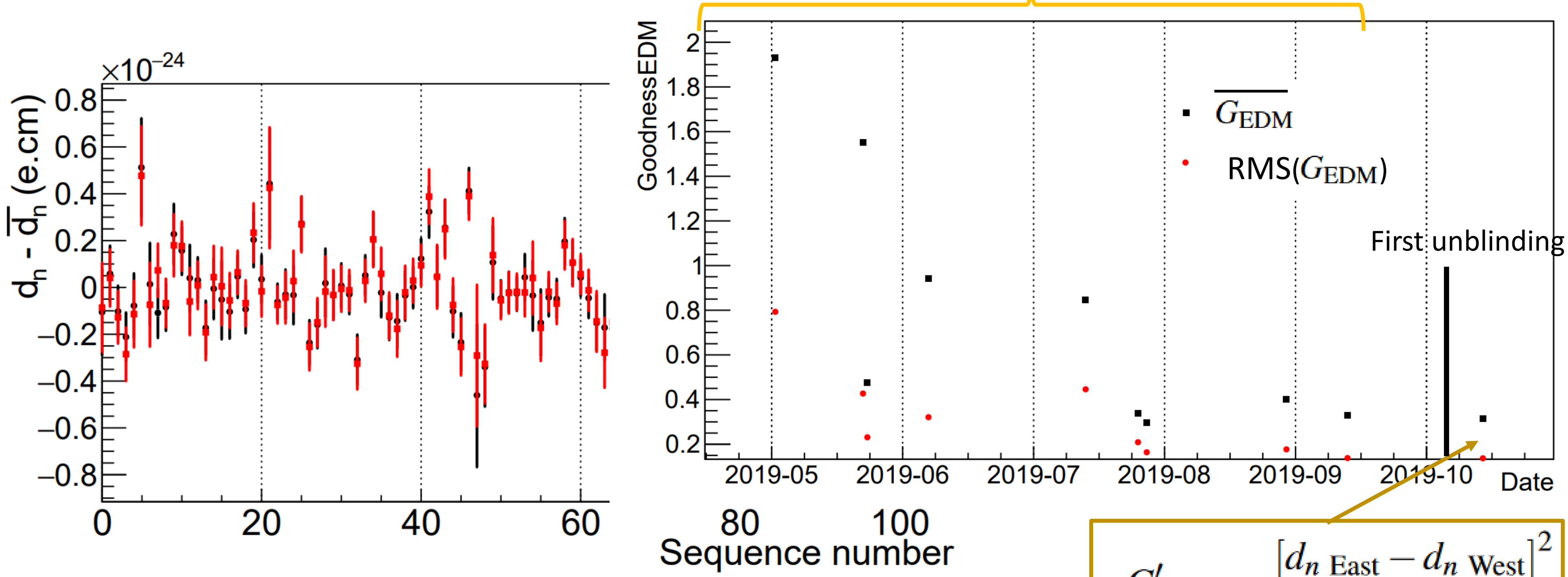
Analysis task
Ongoing since 2011

The blind search for the neutron EDM



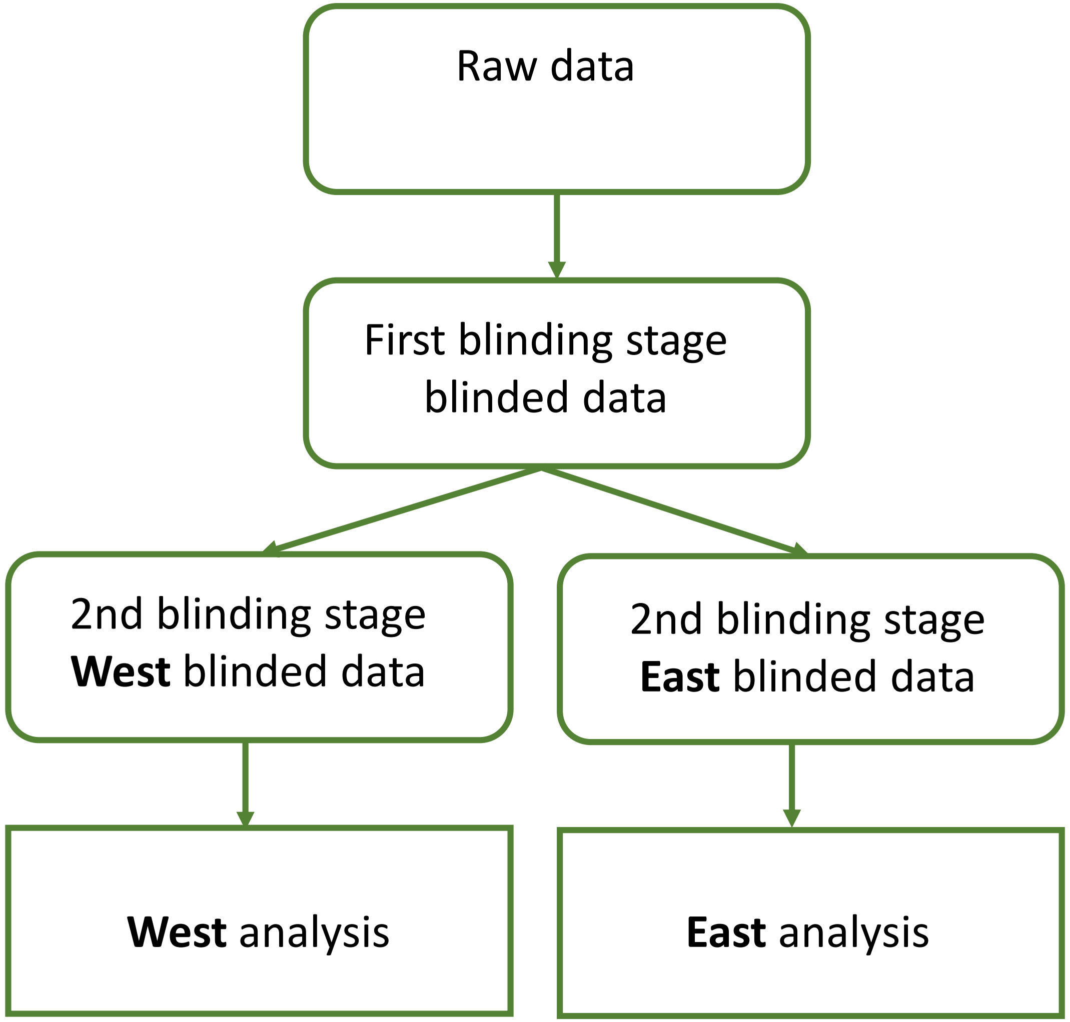
The blind search for the neutron EDM

$$G_{\mathrm{EDM}} = \frac{\left[\left(d_{n\ \mathrm{East}} - \overline{d_{n\ \mathrm{East}}}\right) - \left(d_{n\ \mathrm{West}} - \overline{d_{n\ \mathrm{West}}}\right)\right]^2}{\sigma_{\mathrm{dn,\ East}}\,\sigma_{\mathrm{dn,\ West}}}$$



$$G'_{\mathrm{EDM}} = \frac{\left[d_{n\ \mathrm{East}} - d_{n\ \mathrm{West}}\right]^2}{\sigma_{\mathrm{dn,\ East}}\,\sigma_{\mathrm{dn,\ West}}}$$

The blind search for the neutron EDM



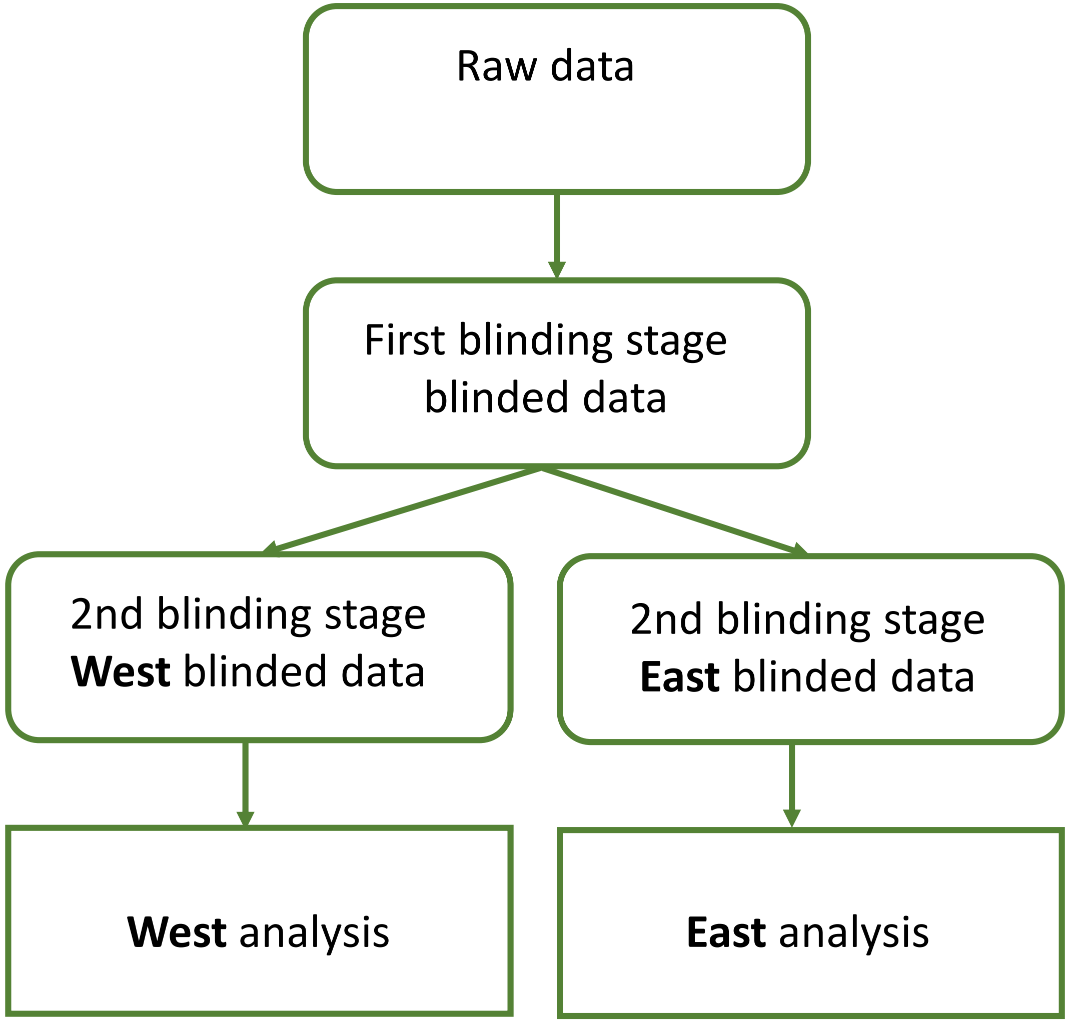
2 independent analysis teams and 2 blinding stages

Analysis comparison
Late 2018

$d_n = (u \pm 1.1_{stat} \pm d_{st})\, 10^{-26} e.\mathrm{cm}$

Analysis task
Ongoing since 2011

The blind search for the neutron EDM



2 independent analysis teams and 2 blinding stages

TABLE I. Summary of systematic effects in 10^{-28} e.cm. The first three effects are treated within the crossing-point fit and are included in $d_{\times}$. The additional effects below that are considered separately.

Effect	Shift	Error
Error on $\langle z \rangle$	...	7
Higher-order gradients $\hat{G}$	69	10
Transverse field correction $\langle B_T^2 \rangle$	0	5
Hg EDM [8]	−0.1	0.1
Local dipole fields	...	4
$v \times E$ UCN net motion	...	2
Quadratic $v \times E$	...	0.1
Uncompensated G drift	...	7.5
Mercury light shift	...	0.4
Inc. scattering ^{199}Hg	...	7
TOTAL	69	18

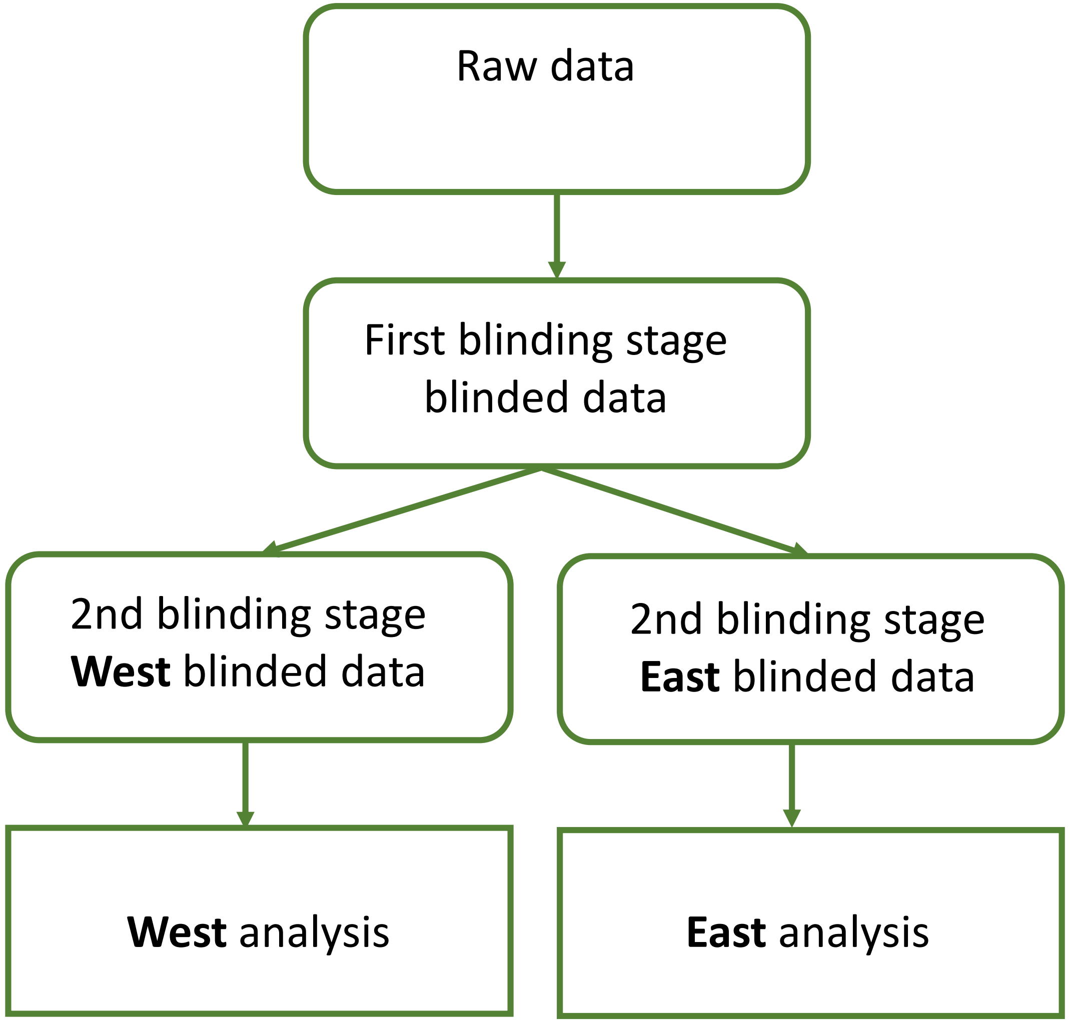
Frozen analysis
+ final systematic error budget
Analysis on single blinded data + first unblinding
+ direct comparison
Oct. the 23rd 2019

Analysis comparison
Late 2018

$$d_n = (\,\mathrm{U} \pm 1.1_{\,stat} \pm 0.2_{\,syst}\,)\ 10^{-26} e.\mathrm{cm}$$

Analysis task
Ongoing since 2011

The blind search for the neutron EDM



2 independent analysis teams and 2 blinding stages

Analysis on raw data + full unblinding
Nov. the 28th 2019

Frozen analysis + final systematic error budget
Analysis on single blinded data + first unblinding
+ direct comparison
Oct. the 23rd 2019

Analysis comparison
Late 2018

$$d_n = (0.0 \pm 1.1_{stat} \pm 0.2_{syst}) 10^{-26} e.\text{cm}$$

Analysis task
Ongoing since 2011

The blind search for the neutron EDM

Pros

Analysis quality

- Large freedom to explore analysis strategies by two teams
- Two completely different analysis
- Analysis choices were not more difficult because of the blinding

Have a result at the highest standards!

Cons

Analysis quality

- Noise in the data

Cost:

- 4% of the data taken at E=0KV for the blinding algorithm
- 2 person years for implementing
- Analysis comparison took 9 months

Merci!

Thanks for your attention

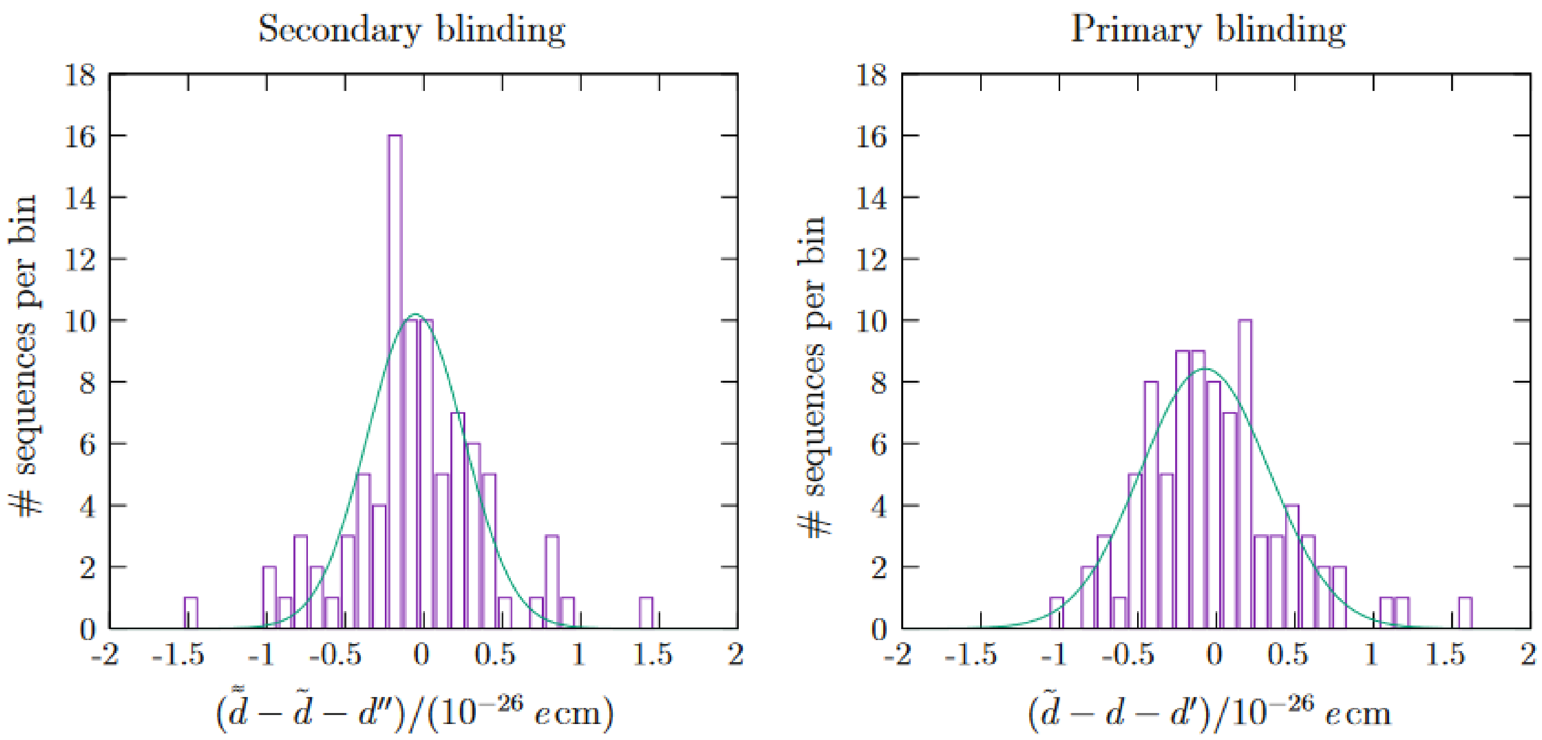
Just in case

nEDM estimator	Western Value	Western χ^2/N_{dof}	Eastern Value	Eastern χ^2/N_{dof}
Doubly blinded $\tilde{\tilde{d}}$	15.39 ± 1.07	90.7/86	3.80 ± 1.11	91.2/86
Singly blinded $\tilde{d}$	5.97 ± 1.07	93.0/86	6.15 ± 1.11	93.2/86
Non-blinded d	-0.02 ± 1.07	92.5/86	0.16 ± 1.11	92.4/86
$\tilde{\tilde{d}} - \tilde{d}$	9.43		−2.35	
Input offset d''	9.48		−2.33	
Difference $\tilde{\tilde{d}} - \tilde{d} - d''$	−0.05		−0.02	
$\tilde{d} - d$	5.99		5.99	
Input offset d'	6.02		6.02	
Difference $\tilde{d} - d - d'$	−0.03		−0.03	

$\tilde{\tilde{d}}$ is the estimator of the doubly blinded data, while $\tilde{d}$ is the estimator of the singly blinded data. The input offset d'' is the value of the secondary blinding offset, which was de-encrypted during the first, relative, unblinding on 23 October 2019. The input offset d' is the value of the primary blinding offset, which was de-encrypted during the second unblinding on 28 November 2019. All analysis results in this table arise only from data taken after 13 September 2015; data prior to this were not blinded with the same offsets and thus cannot be compared. Consequently, the value d listed here differs slightly from the final result [5]. The observed span of χ^2 values of 1.8 corresponds to a change of uncertainty of 1×10^{-28} e cm. The fluctuation in this range – even to smaller values – is within statistical expectation

Just in case

Fig. 5 Difference between results of the analysed blinded and unblinded data sets and the corresponding offsets, shown separately for each of the two blinding steps. The bin width is 10^{-27} $e\,\mathrm{cm}$. Both peaks are centred well within 10^{-27} $e\,\mathrm{cm}$. Only results from the Western analysis using data taken after 13 September 2015 are shown; the Eastern analysis yields similar results



Just in case

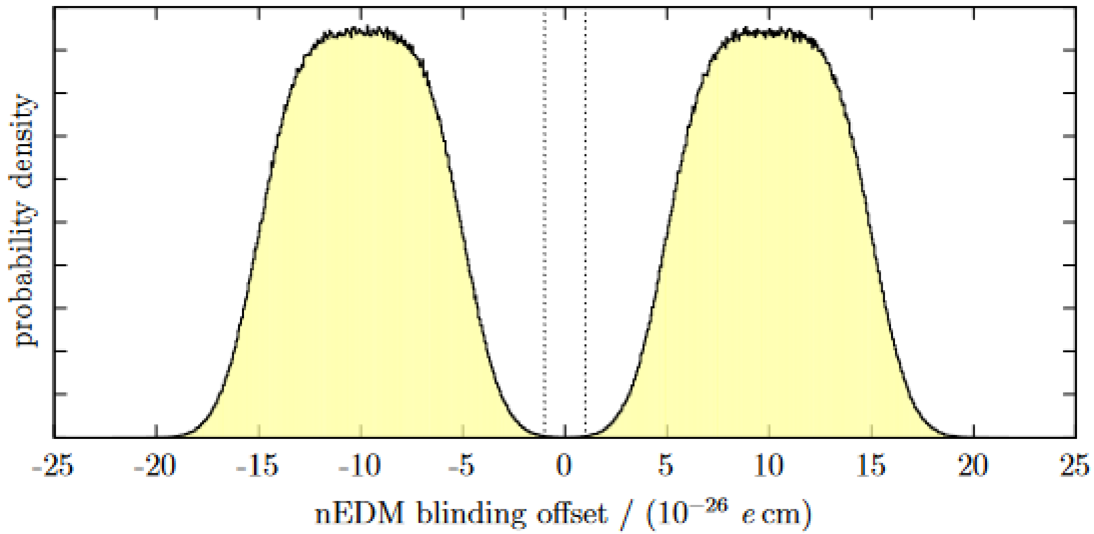


Fig. 3 Probability density function for the choice of the blinding offset created with 10^6 samples. The dashed vertical lines indicate the $\pm 1\sigma$ sensitivity of the data accumulated in 2015 and 2016 assuming a mean value of zero. For psychological reasons, the probability that an offset in this range is selected is kept very small but non-zero (integrated probability $\approx 2 \times 10^{-4}$)