Mercury
Scattering length measurement

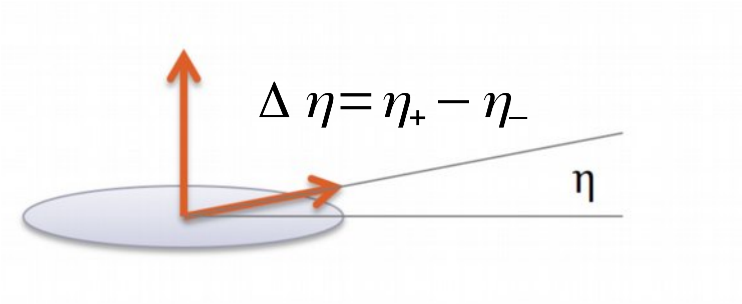
Motivation

Pseudo-magnetic field from **spin** dependent **Strong** interaction

$$B^* = \frac{-4\pi\hbar}{m_n \gamma_n} \rho b_i P \sqrt{\frac{I}{I+1}}$$

- Potential systematic false effect

$$d_n^{false} = \hbar \frac{\gamma_n}{4E} B^* \Delta\eta$$



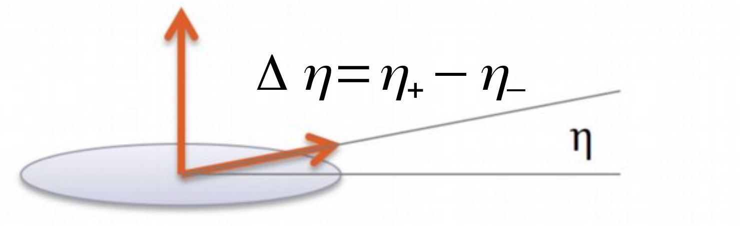
- Calibration measurement for the nEDM apparatus

- Sign of incoherent scattering length

Neutron scattering lengths and cross sections

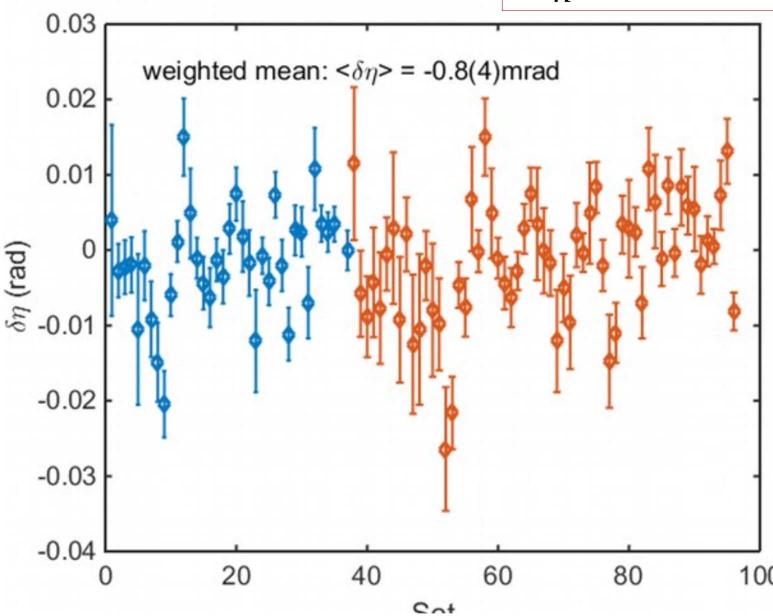
Isotope	conc	Coh b	Inc b	Coh xs	Inc xs	Scatt xs	Abs xs
Hg	---	12.692	---	20.24	6.6	26.8	372.3(4.0)
196Hg	0.2	30.3(1.0)	0	115.(8.)	0	115.(8.)	3080.(180.)
198Hg	10.1	---	0	---	0	---	2
199Hg	17	16.9	(+/-)15.5	36.(2.)	30.(3.)	66.(2.)	2150.(48.)
200Hg	23.1	---	0	---	0	---	<60.
201Hg	13.2	---	---	---	---	---	7.8(2.0)
202Hg	29.6	---	0	---	0	9.828	4.89
204Hg	6.8	---	0	---	0	---	0.43

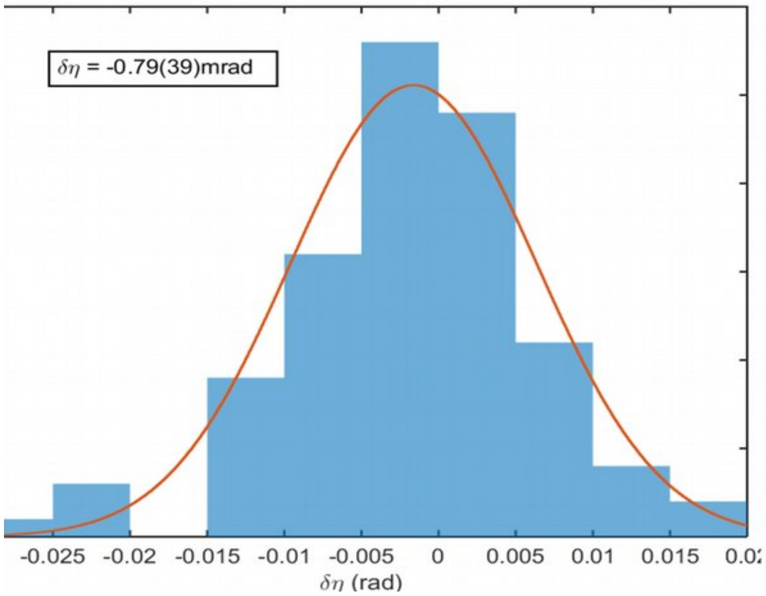
Systematic effect



$$d_n^{false} = \hbar \frac{\gamma_n}{4E} B^* \Delta\eta$$

$$d_n^{false} = \pm 2.1(4.5) 10^{-28} ecm$$





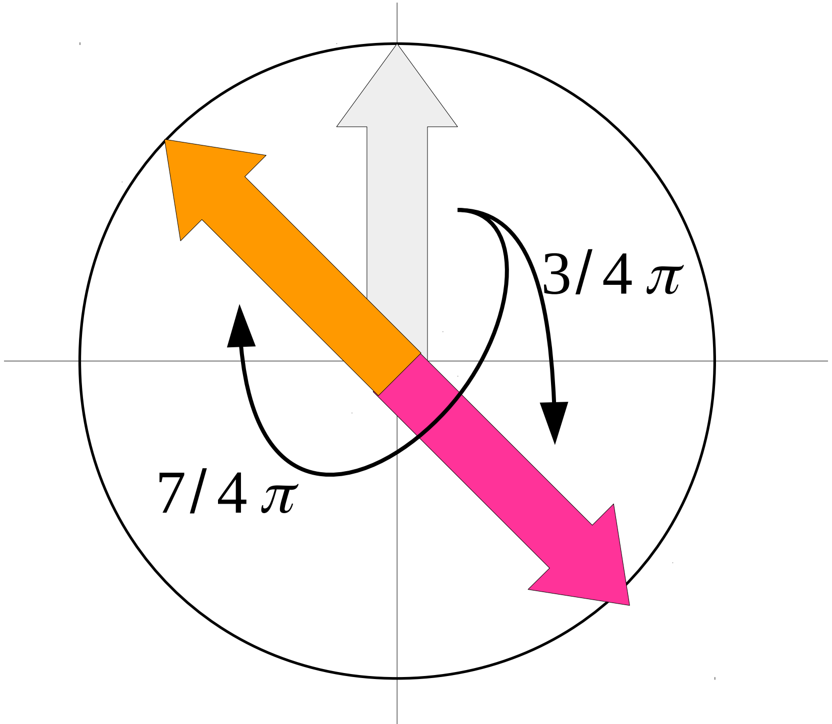
(Phillip's talk Bern)

nedmpsi.atlassian.net/wiki/spaces/schedule/pages/664862743/Hg+incoherent+scattering+length+meeting

b_i measurement

Disadvantage: Reduce Hg-polarisation/effect by factor √2

Advantage: Still able to monitor magnetic field using Hg magnetometer



Batch	Temperature	Hg pulse
1	200°C 225°C	1.5s / 1.5s 1.5s / 1.5s
2	225°C	1.5s / 3.5s
3	225°C	3s / 7s
4	210°C	3s / 7s

Sequence: ABBABAAB

Formula

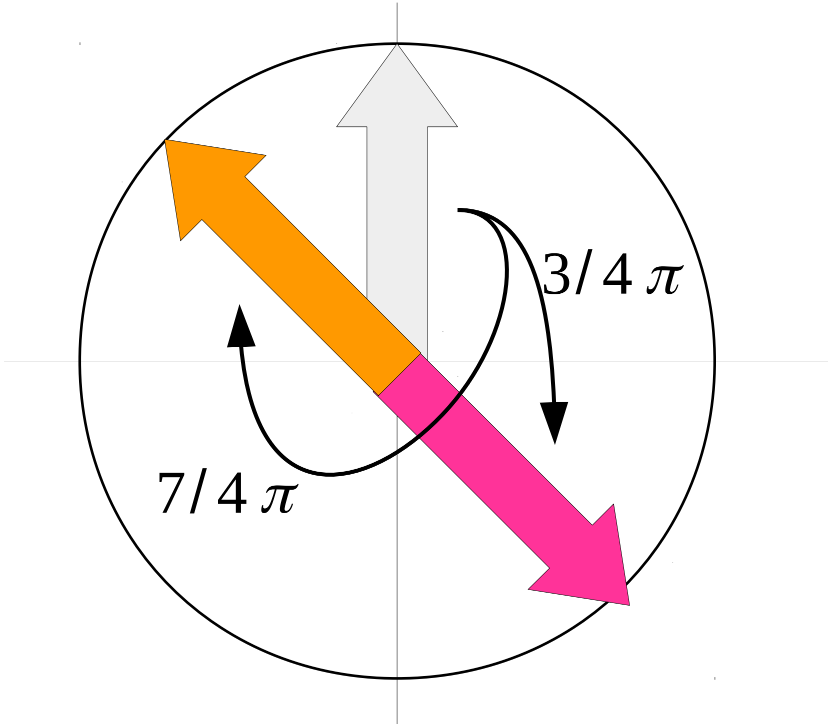
$$\phi* = -\gamma_n B*_{Hg} T$$

&

$$B* = \frac{-4\pi\hbar}{m_n \gamma_n} \rho b_i P \sqrt{\frac{I}{I+1}}$$

$$\ldots = 2.49 \times 10^{-15} \rho b_i P$$

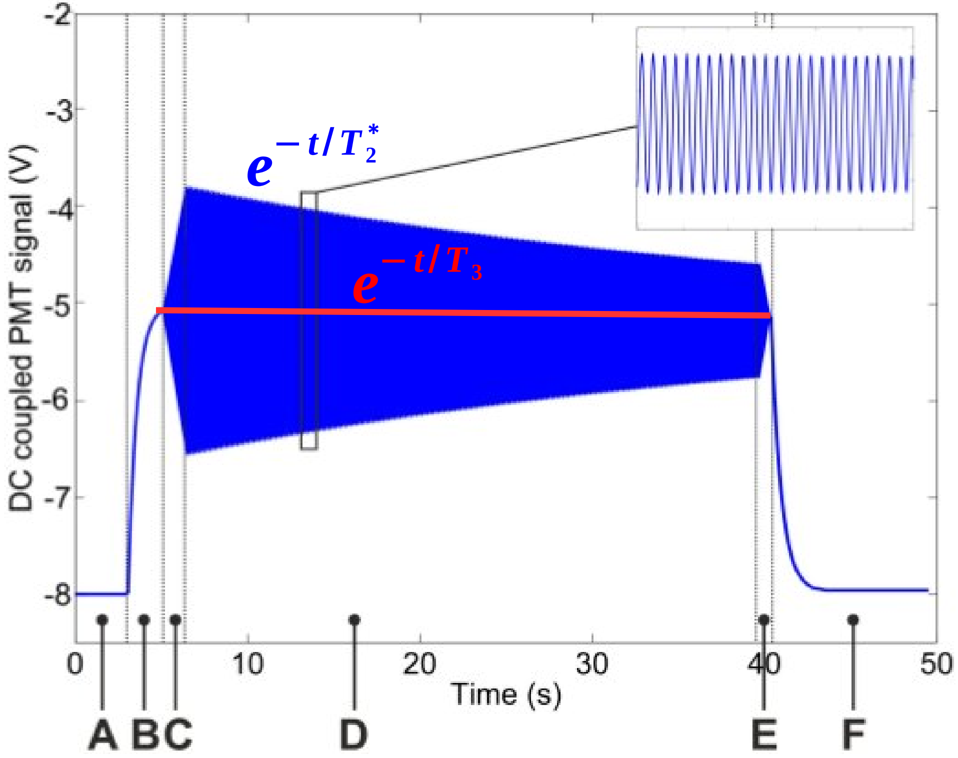
[Tm²]



$$b_i = \frac{-1}{\gamma_n T \times 2.49 \times 10^{-15}} \times \frac{\partial \phi_n}{\partial(\rho_{Hg} P_{Hg})}$$

$(T = 182.5\, s)$

Definition



T : interaction time ~ 182.5s

T_1 : longitudinal depolaristation

T_2 : transversale depolarisation

T_2* : overall depolarisation

~mix of T1 and T_2

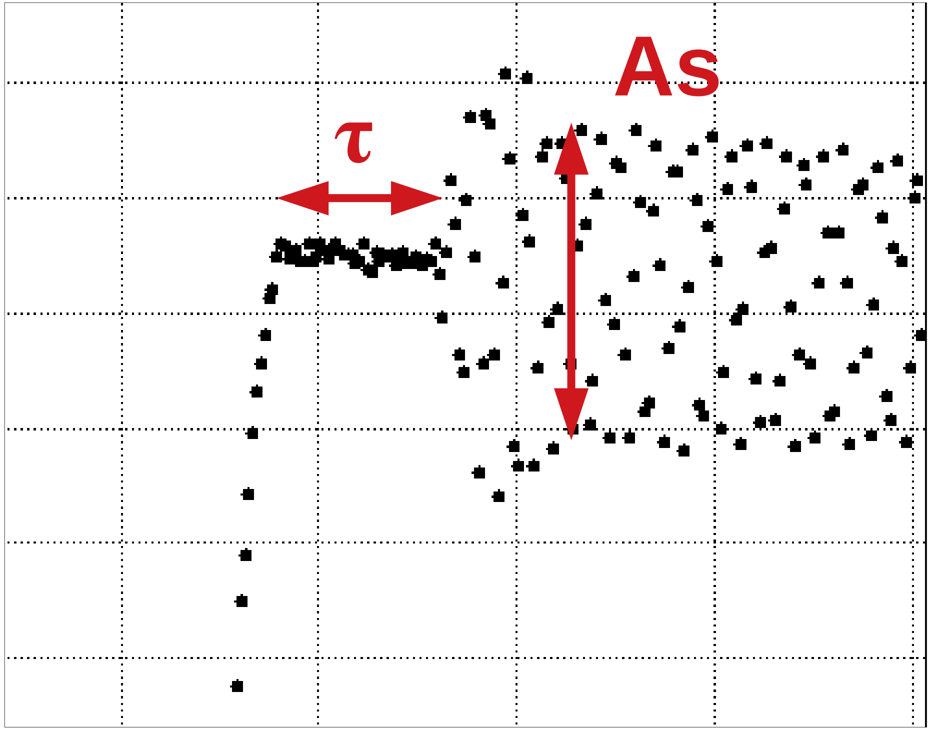
T_3 : leak time

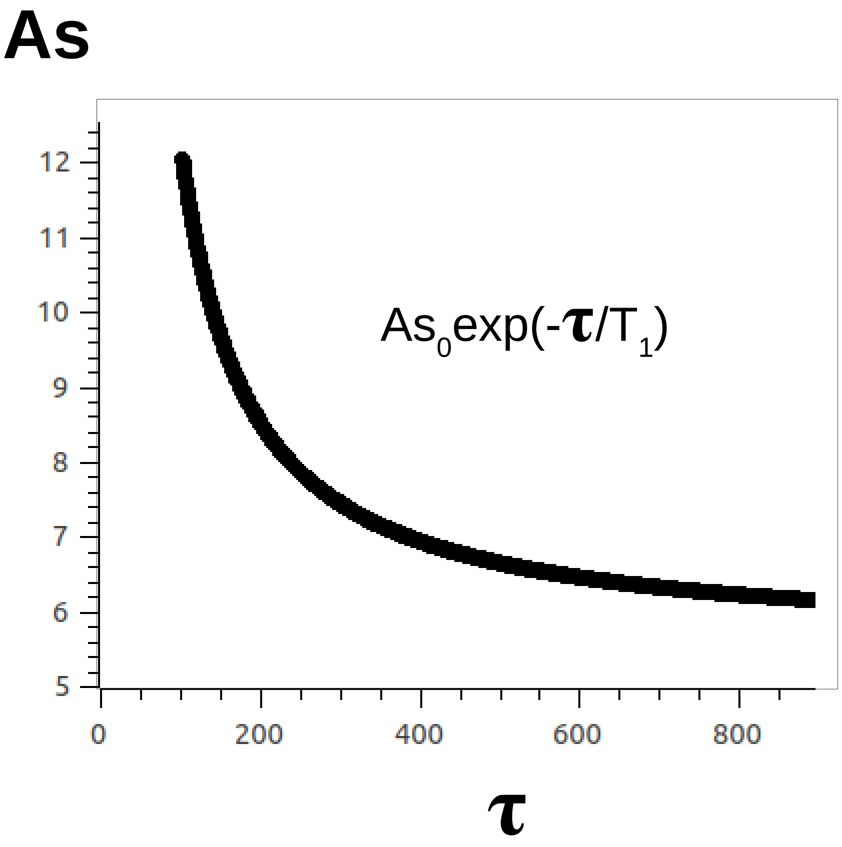
T* : combinaison of T1 and T3

$$1/T^* = 1/T_1 - 1/T_3$$

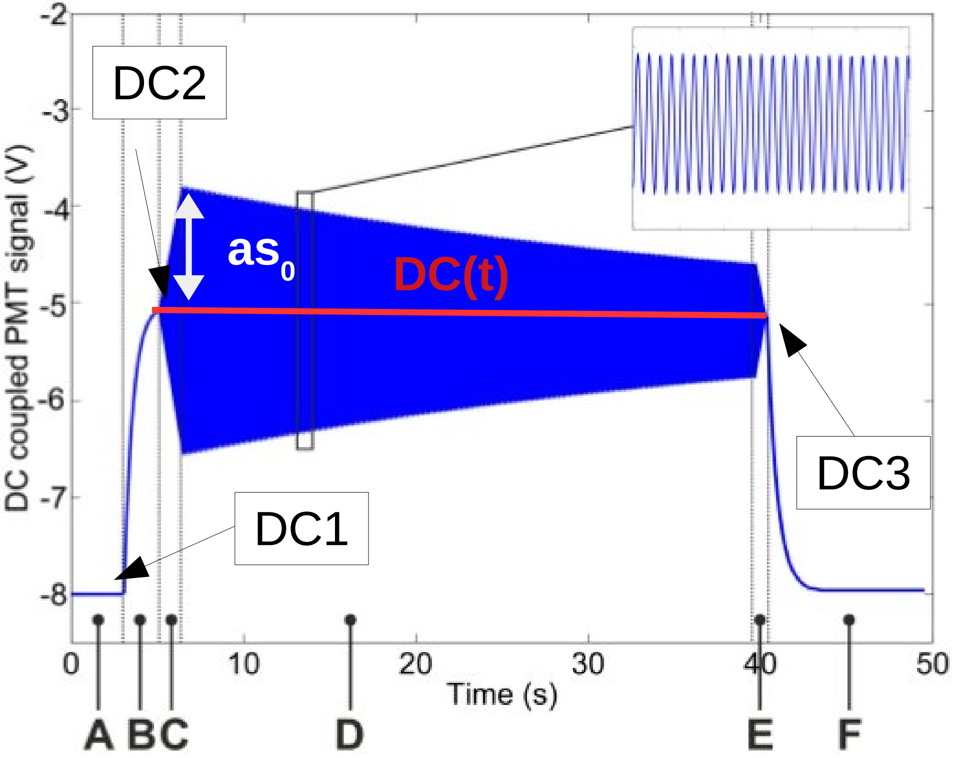
[1] Sybille's thesis

T_1 measurement





Density Polarisation: ρP_{eff}



Generic formula:

$$\sigma \rho P = \frac{1}{L} ash\left(\frac{as}{DC_2}\right) \qquad L = 0.47\, m$$

[1] Sybille's thesis
[2] Stephanie's thesis

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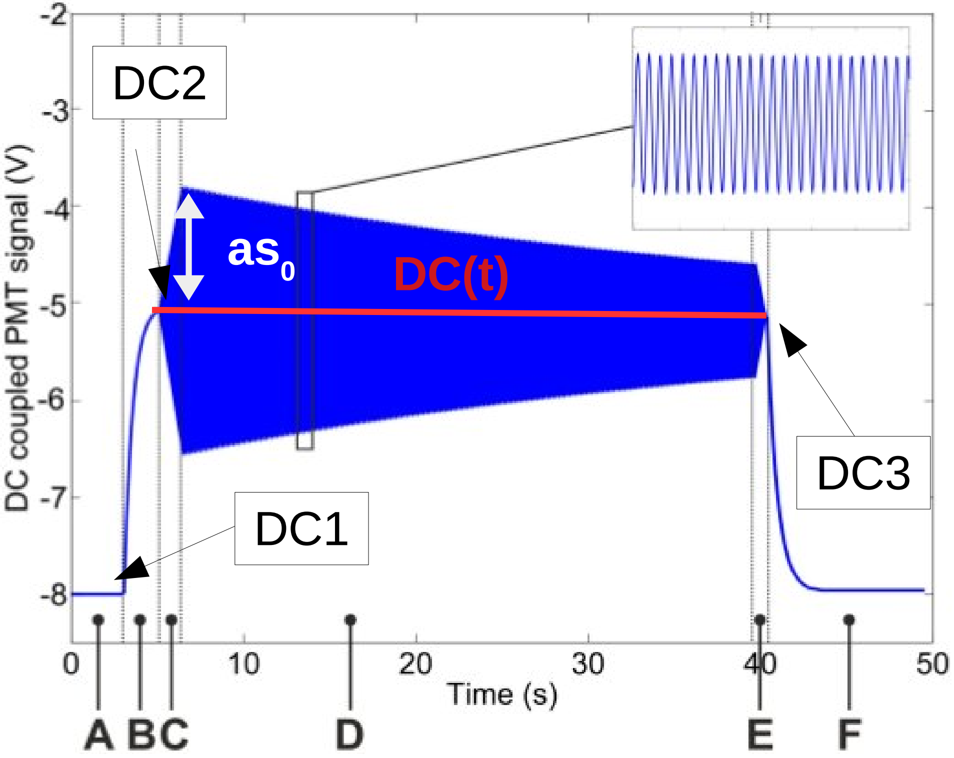

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$$(\sigma \rho P)_{eff} = \frac{1}{LT} \int ash \frac{As(t)}{DC(t)} dt$$

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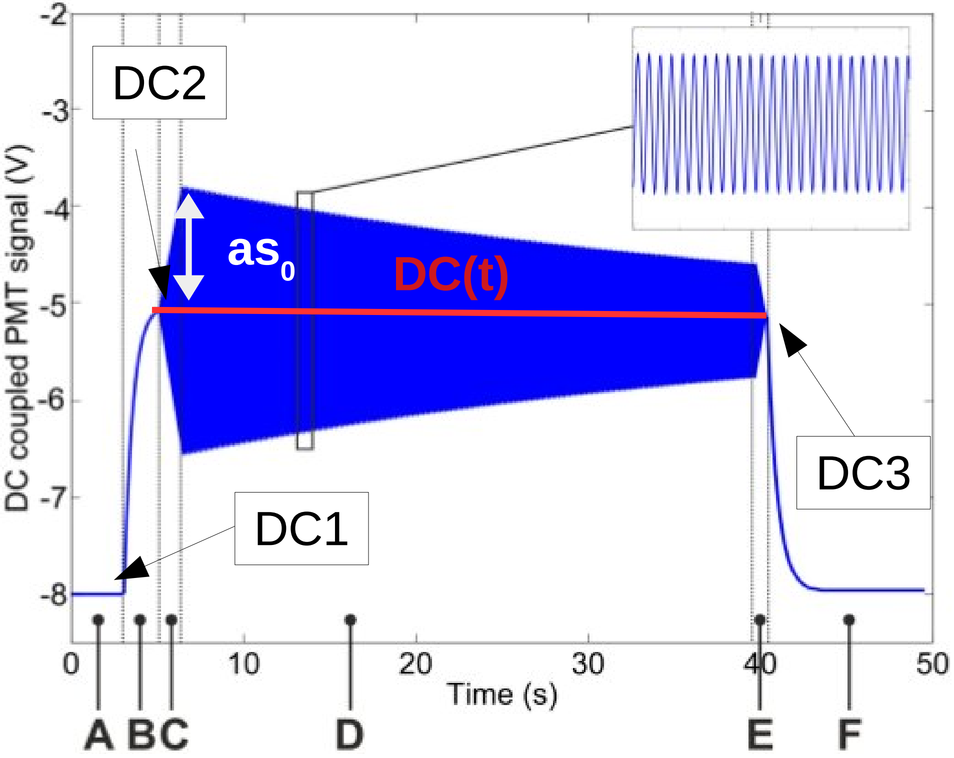

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Assumptions:

$$DC(t) = DC_2 \times e^{-t/T_3} \qquad T_3 = T / \ln\frac{(DC_2 - DC_1)}{(DC_3 - DC_1)}$$

$$T = 182.5\, s$$

$$As(t) = as_0 \times e^{-t/T_1} \qquad T_1 \sim 100\, s$$

$$T^{*-1} = 1/T_1 - 1/T_3$$

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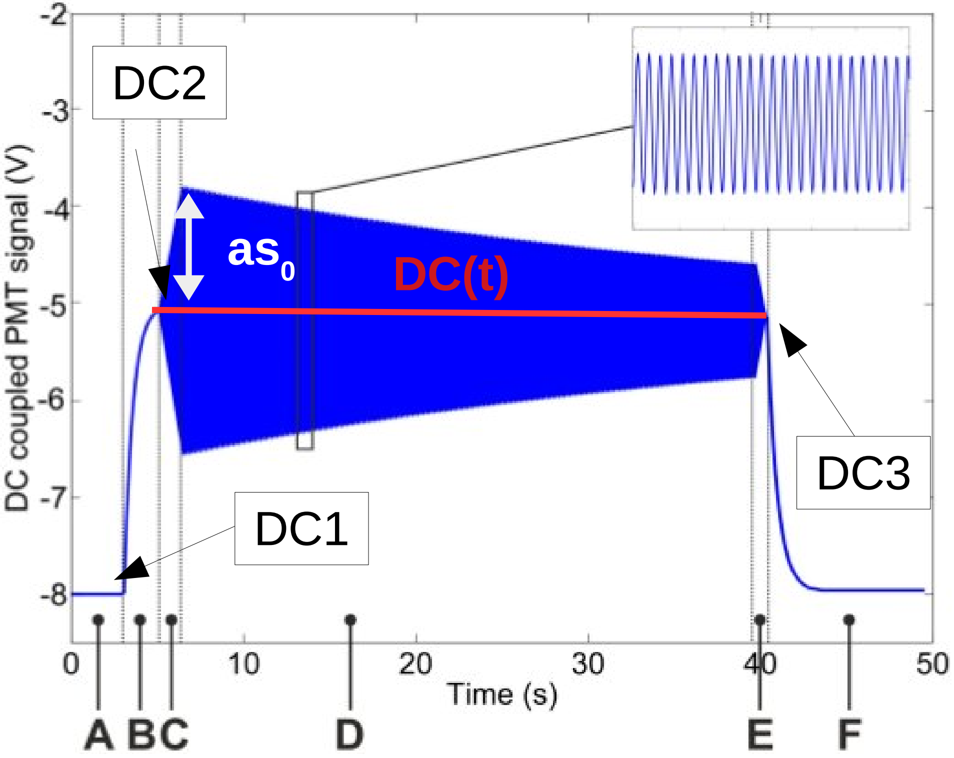

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$$ash(x) \sim x$$

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$$T = 182.5\, s$$

$$T_1 \sim 100\, s$$

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$$(\sigma \rho P)_{eff} \sim \frac{as_0 T^*}{DC_2 L T}\left(1 - e^{-T/T^*}\right)$$

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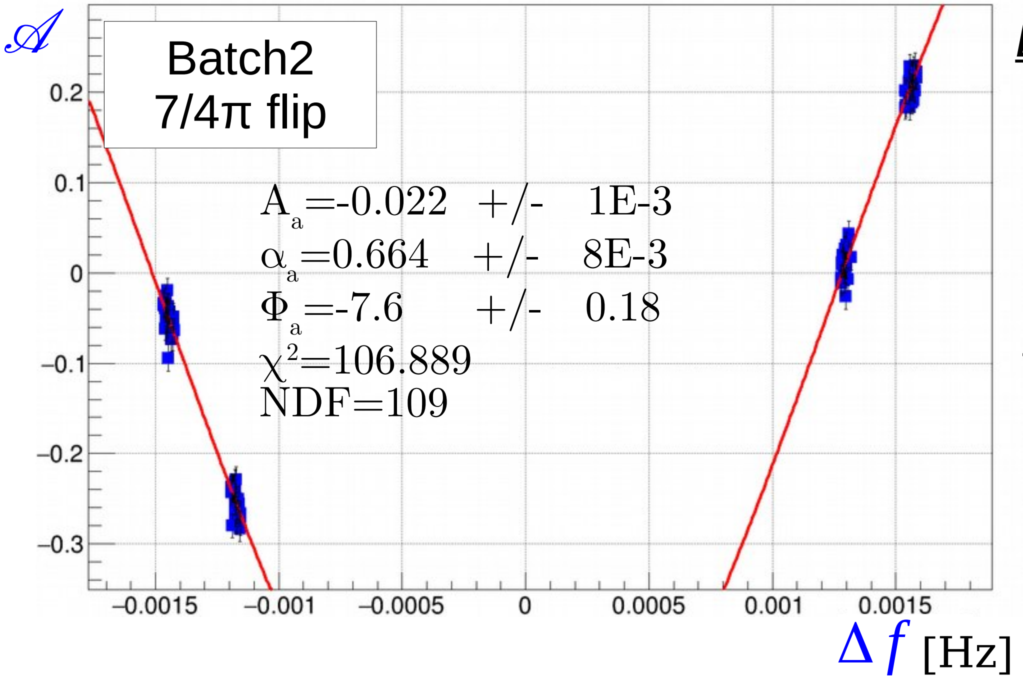
Neutron phase φ_n



Data point:

$$\mathscr{A} = \frac{N_+ - N_-}{N_+ + N_-} \qquad \Delta f = f_{Hg} \left| \frac{\gamma_n}{\gamma_{Hg}} \right| - f_{RF}$$

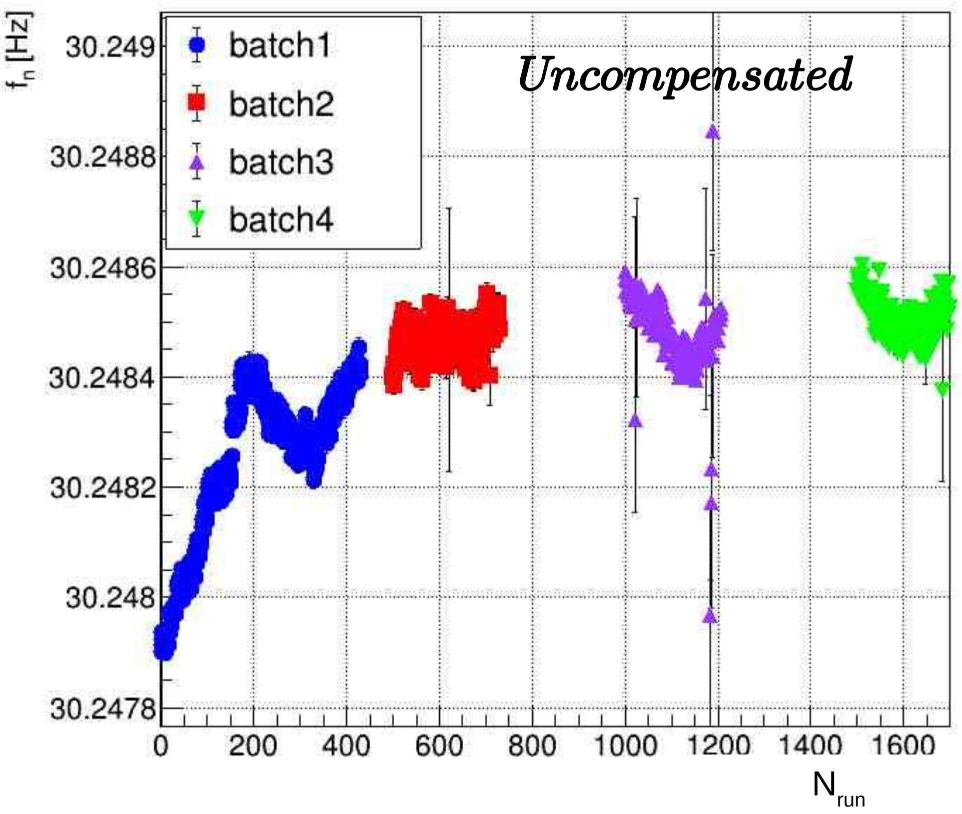
Fit formula:

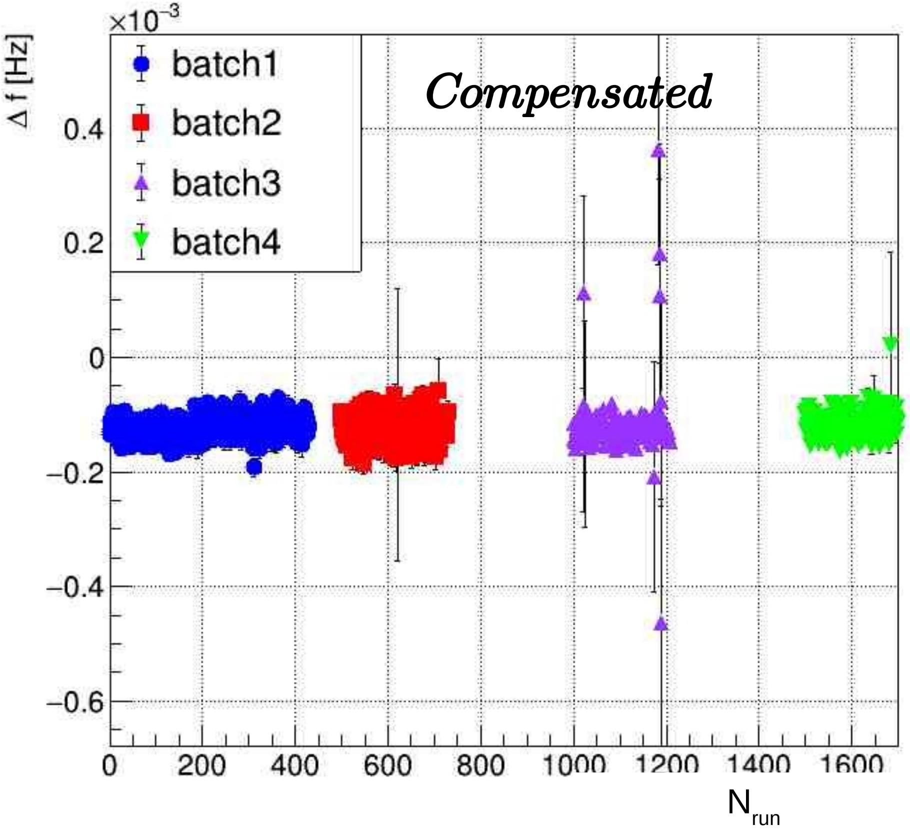
$$\mathscr{A}(\Delta f) = A_a - |\alpha_a| \cos(2\pi T \Delta f - \phi_a)$$

$$T = 182.5\, s$$

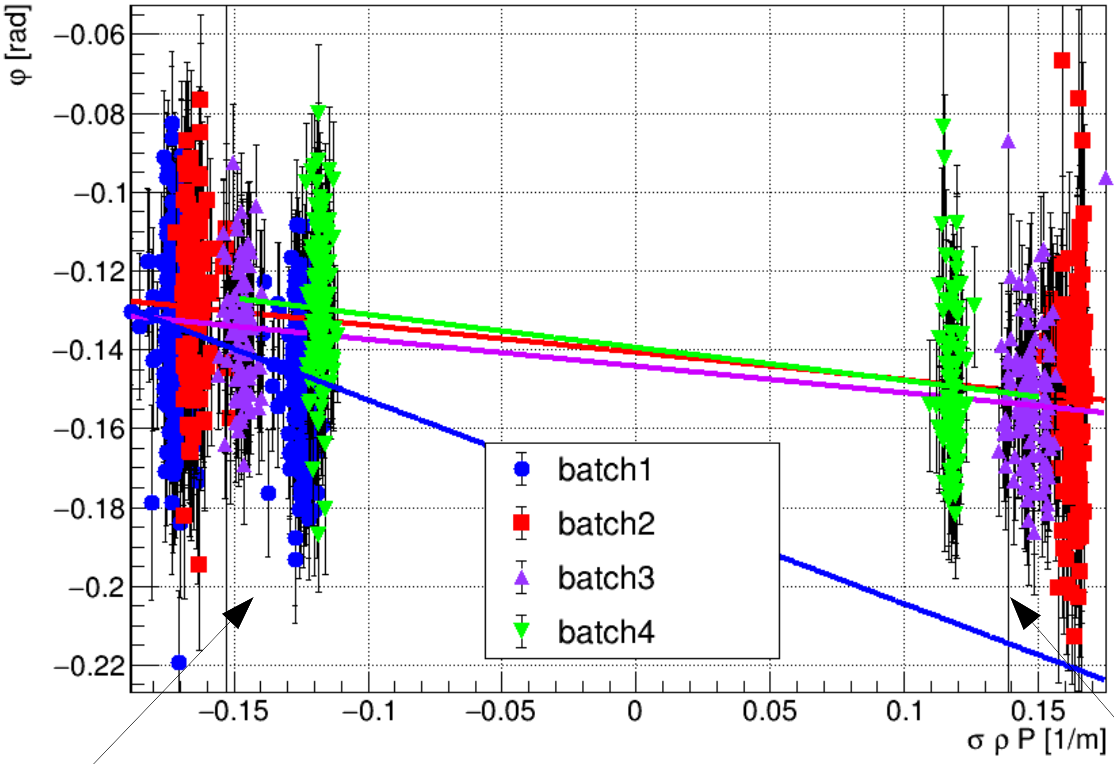
$$\varphi_n(\Delta f) = 2\pi T \Delta f - sgn(\Delta f)\, acos\left(\frac{A_a - \mathscr{A}(\Delta f)}{|\alpha_a|} \right)$$

Mercury compensation





Phase φ_n vs σρP



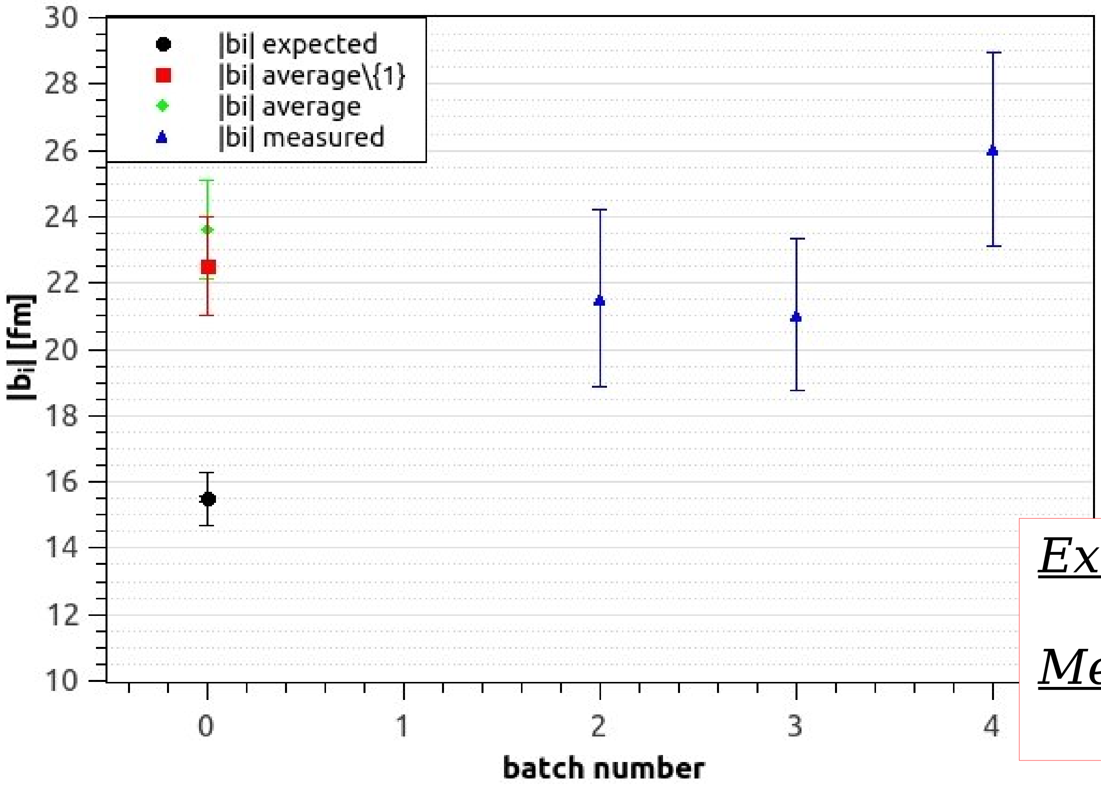
Batch	$\frac{d\varphi}{d\sigma\rho P}$ [rad]	error [rad]
1	-2.59E-1	3.48E-2
2	-6.91E-2	8.60E-3
3	-6.75E-2	7.32E-3
4	-8.35E-2	9.32E-3

(T_1=100s)

3/4 flip

7/4 flip

Results for b_i



$$|bi| = \left| \frac{\frac{d\varphi}{d\sigma\rho P} \times \frac{\sigma}{T}}{\gamma_n \; 2.49\text{E-}15\, Tm^2} \right|$$

σ= 2.6E-17 m^2
T= 182.5 s
T_1= 100 s
γ_n=-1.83247E8

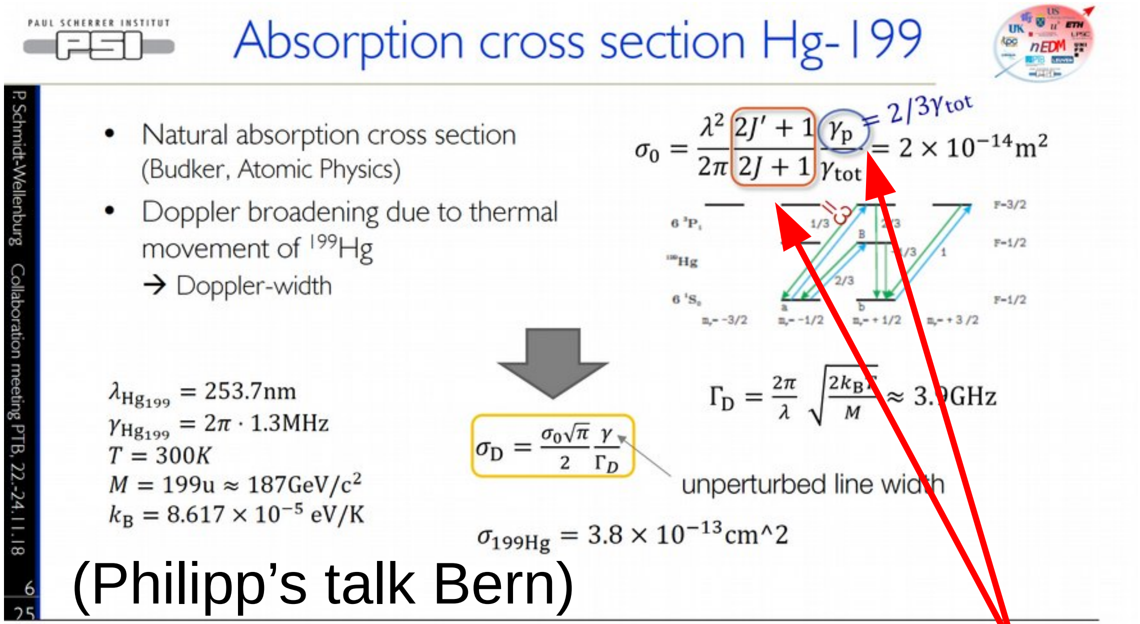
Expected value:

|bi|= 15.5(8) fm

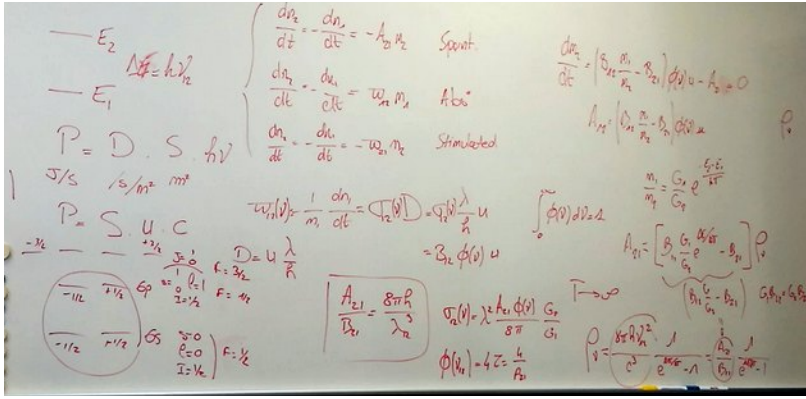
Measured values:

|bi|=22.51 fm +/- 1.49 +/- ….

XS problem



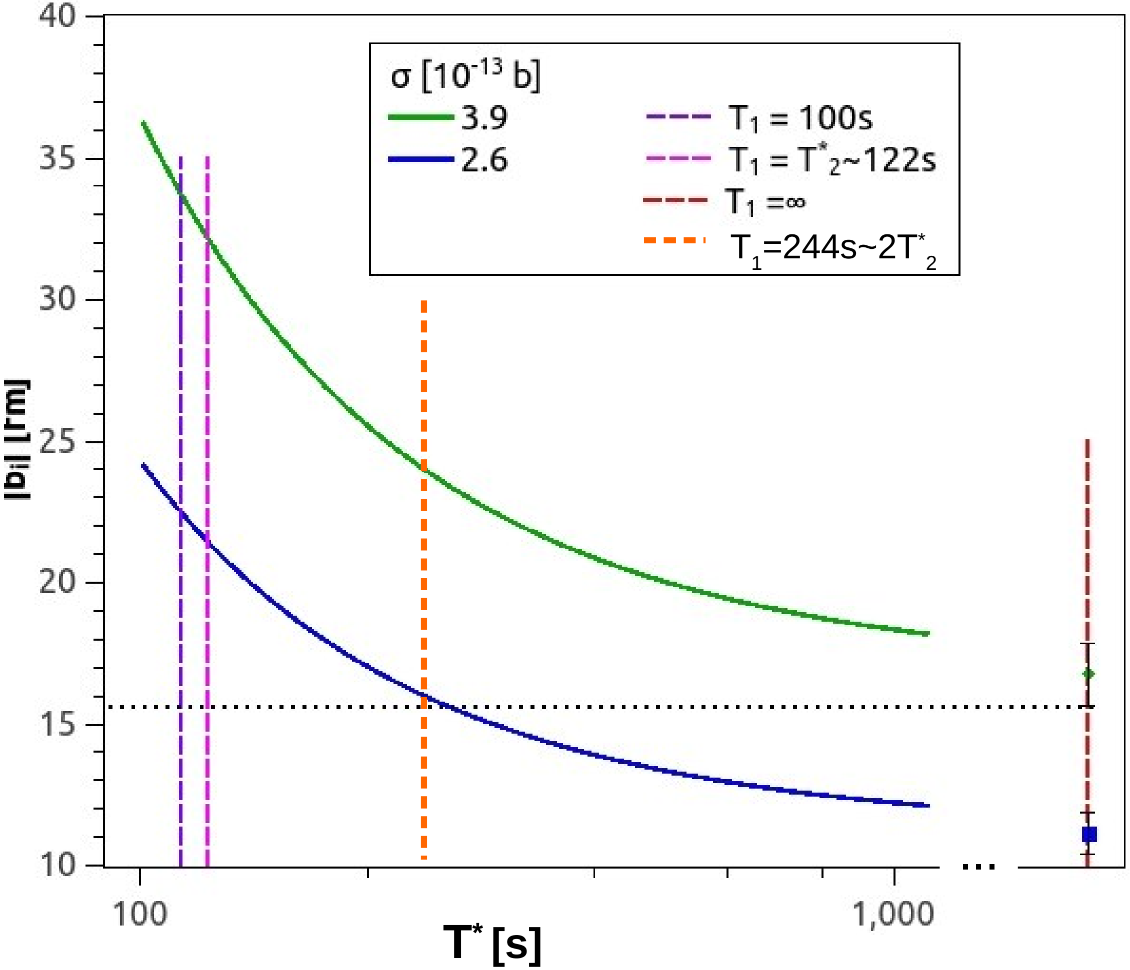
(Philipp’s talk Bern)

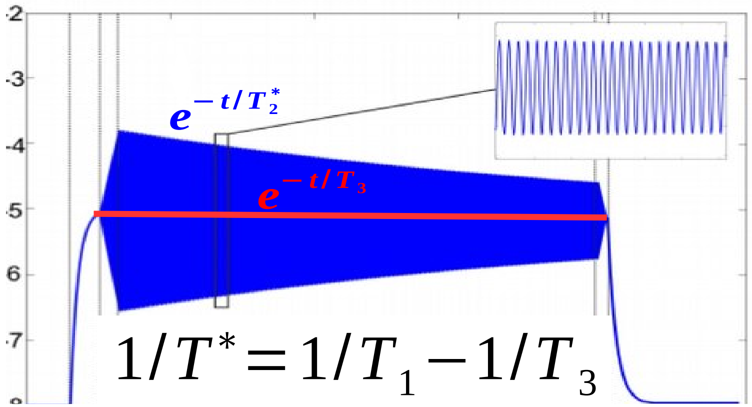


Calculation of the mercury absorption XS
(Arnaud’s talk Bern)

Multiplicative factor not agree upon => call for expert

Results for b_i vs T_1





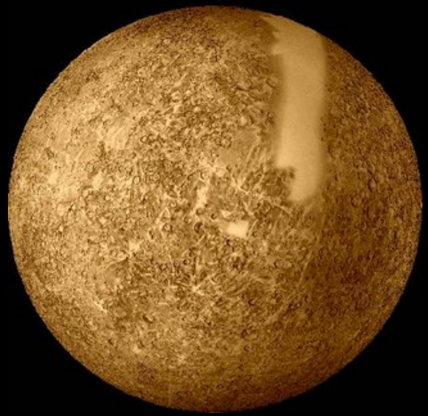
What is T_1?
Measured?

Conclusion

- √ systematic effect evaluated
- √ Non zero measurement
- √ b_i right order of magnitude
  - ? values for T_1
  - ? waiting for σ
- ⊗ sign determination still on going

Caen Collaboration
meeting

questions?



Back up slides

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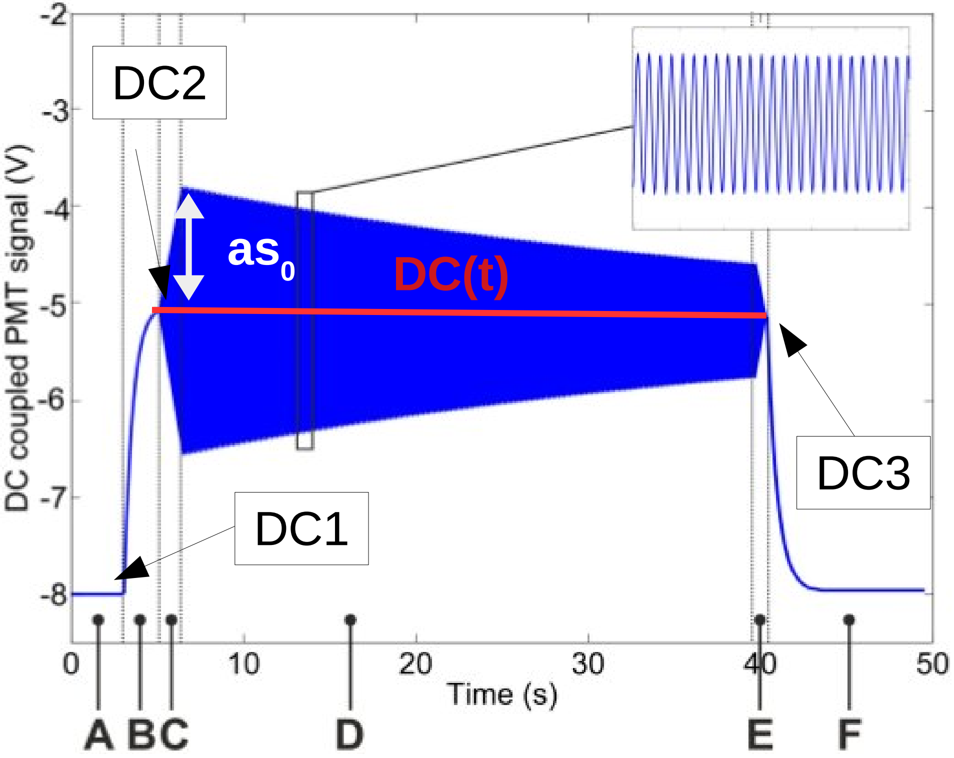

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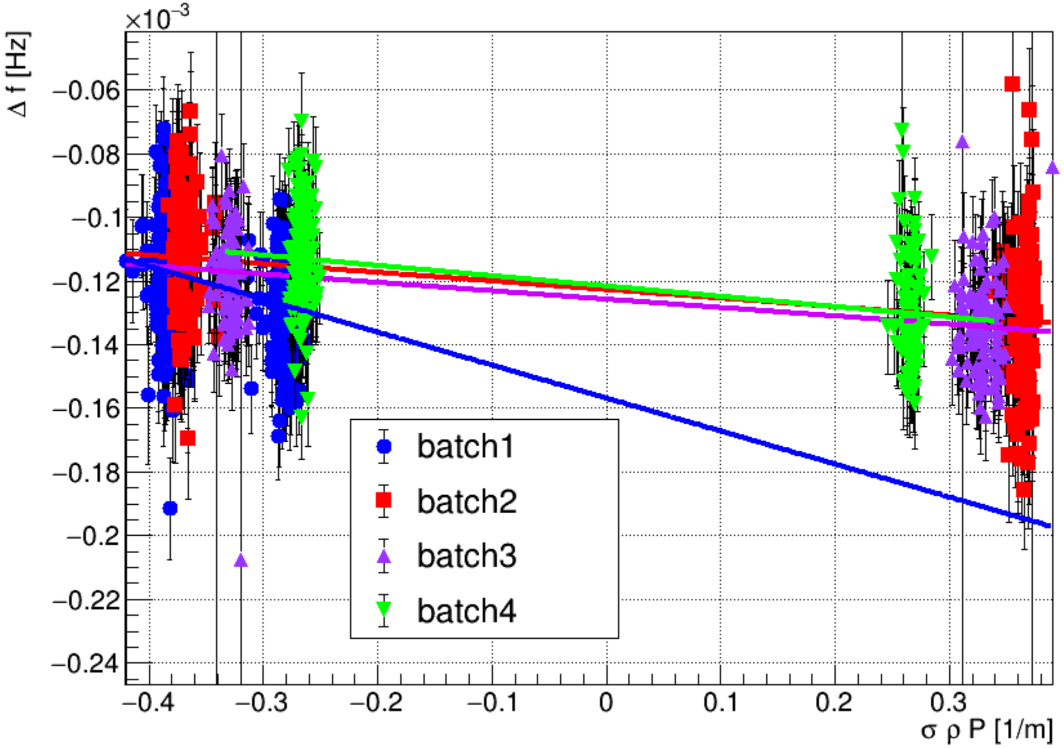
Fit each batch individually



Batch	$\frac{d\,\Delta f}{d\sigma\rho P}$ [mHz]	error [mHz]
1	-2.25E-4	3.03E-5
2	-6.02E-5	7.50E-6
3	-5.88E-5	6.39E-6
4	-7.28E-5	8.13E-6

(T_1=100s)

Data rejection

- fSourceWait_s > 40
- fSourceWait_s < 1
- batch1 1st data point
  (density too far from average value)

< 68 data point rejected over more than 1150

DC_Offset=0 assumption

“The term DC_Offset accounts for light that cannot be absorbed by the Hg atoms in the enriched 199Hg sample. For example, this is light which is emitted by Hg isotopes in the 204Hg bulb different than the ones present in the enriched 199Hg sample. The laser light source tuned to the center of an absorption line closely approximates the ideal condition for which we define DC_Offset= 0 V. “

[1] G.Ban NIMA896(2018)

α and β values

- *“β: Light absorption by isotopes other than 199Hg with modified cross section due to different or missing hyperfine splitting”*

- *“Here the small linewidth of the laser justifies the assumption of α= 1 and parameter β= 1.14 was calculated using the Hg vapor isotopic composition as given in the datasheet of the supplier of the enriched Hg sample.”*

[1] G.Ban NIMA896(2018)