Background investigations for the neutron β-decay spectrometer *a*SPECT

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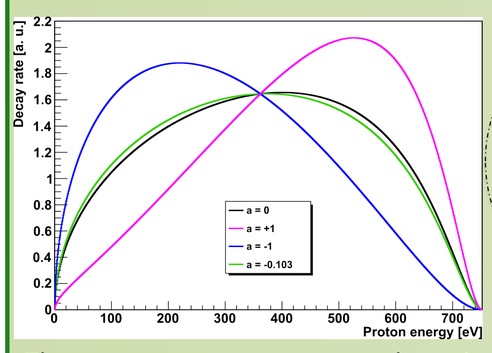
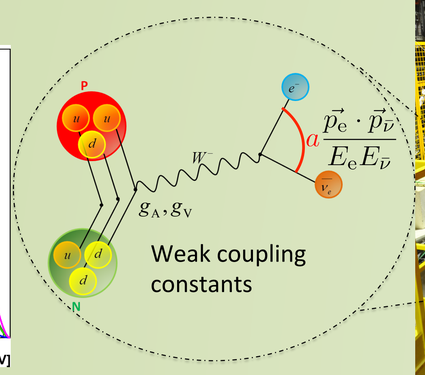
The retardation spectrometer *a*SPECT

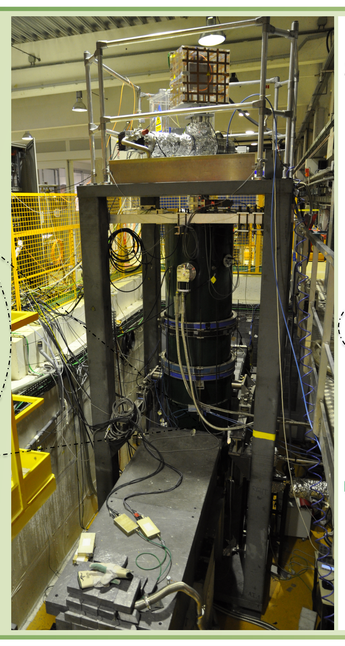
Measurement of the electron-antineutrino angular correlation coefficient ***a*** with unprecedented accuracy, by measuring the proton energy spectrum.

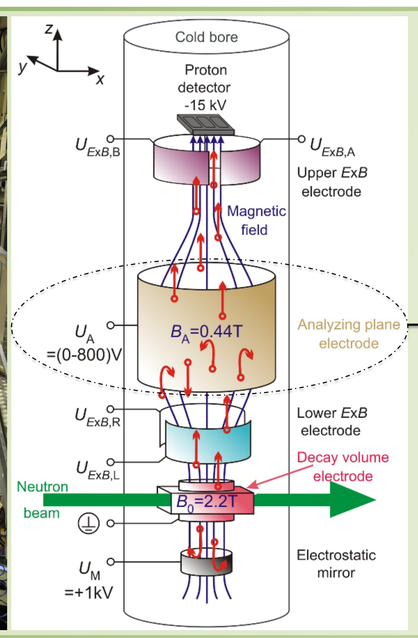




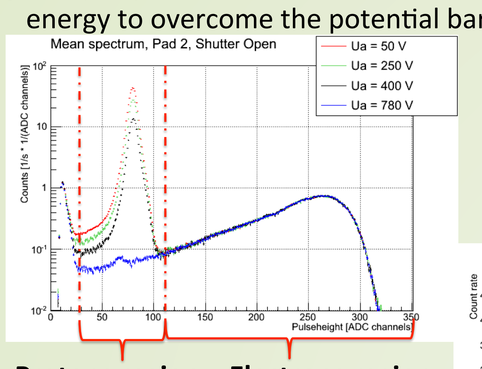
$$a = \frac{1-\lambda^2}{1+3\lambda^2} \qquad \lambda = \frac{g_A}{g_V}$$

The proton energy spectrum shape is tied to the coefficient ***a***.
Endpoint energy for protons: **751 eV**.





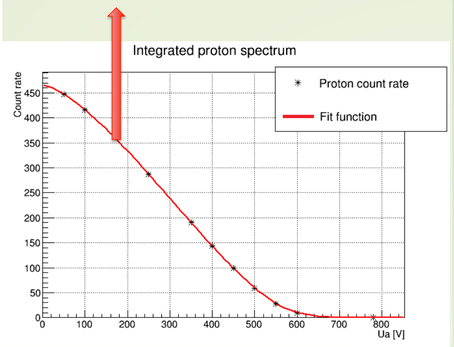
Analyzing Plane (AP) electrode used to select proton with sufficient energy to overcome the potential barrier U_A.



Protons region **Electrons region**

Integration of the proton count rate for each U_A.

Fit function used for the extraction of ***a*** ±Δ***a***

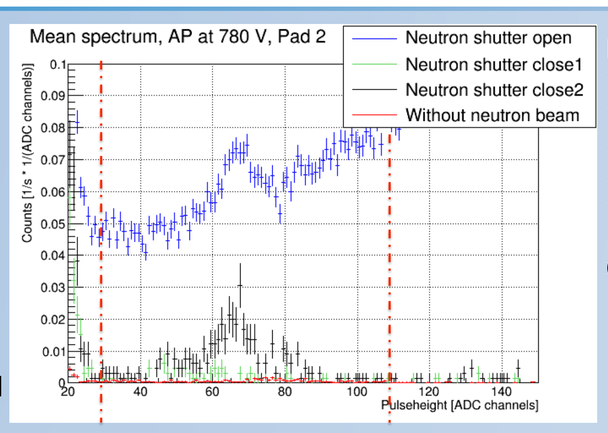


The background status

During beam-time, the background is measured with U_A = **780 V** which blocks all protons from neutron decay.

This background is taken into account as **offset** in the fit function for the integral proton spectrum. This assumes the background to be **independent on U_A**.

Background has to be as low as possible and stable in time.

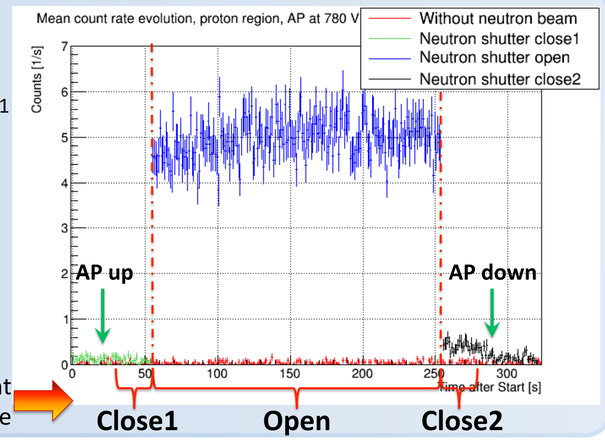


For the same voltage settings:

- Background without external ionizing particles (**red**),
- Background before opening the neutron shutter (**green**), Close1
- Background after closing the neutron shutter (**black**), Close2
- Background with neutron beam, dominated by decay electrons (**blue**), Open

Count rate integrated in the proton region:

→ (5.01 ± 0.03) s^{-1}
→ (0.43 ± 0.03) s^{-1}
→ (0.10 ± 0.01) s^{-1}
→ (0.040 ± 0.002) s^{-1}

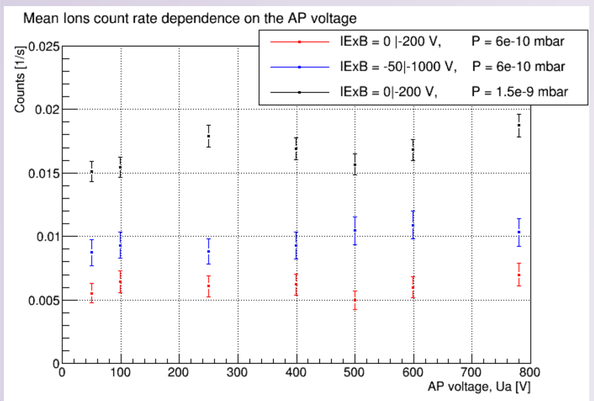


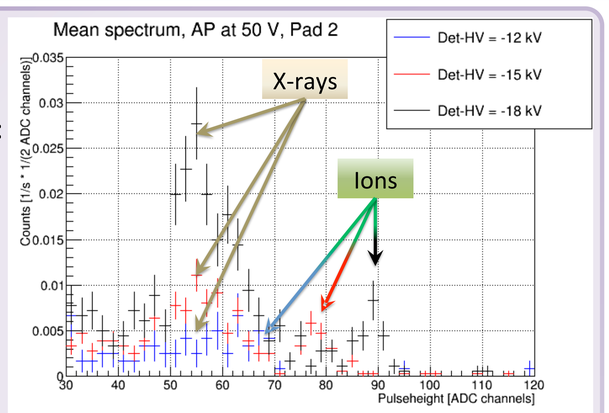
Measurement time sequence → **Close1** **Open** **Close2**

The internal spectrometer background

This background is measured **offline** (without neutron beam).
Identification by variation of the acceleration potential Det-HV:

- **X-rays** influenced in terms of count rate.
- **Ions** mainly influenced in terms of detected energy.



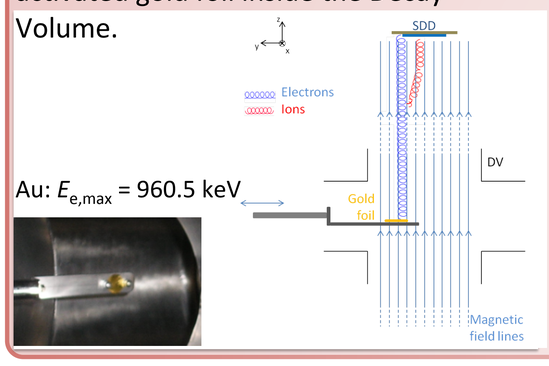


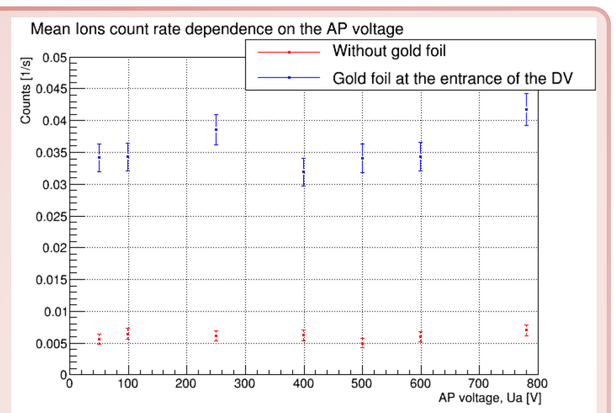
The AP dependence of the ion count rate is **negligible** in the standard configuration.
But it depends on the vacuum conditions (pressure P).

The influence on the coefficient ***a*** accuracy is minimal: this induces a drift on (Δ***a***/***a***) of about $8\cdot10^{-5}$ %.

The ionization by electrons

Ions , from the rest-gas molecules ionization by the decay electrons, can be trapped in the AP, accelerated and detected.
This influence is imitated by placing an activated gold foil inside the Decay Volume.



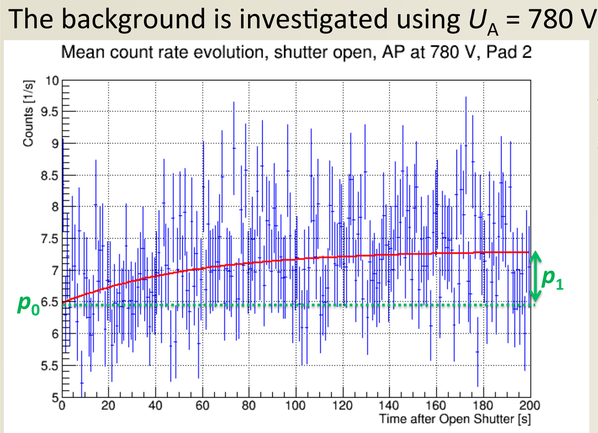


The AP dependence of the ion background slightly **increased** in presence of the gold foil.

It is still influenced by the electrodes setting (low AP-dependence in standard configuration) and the vacuum conditions.

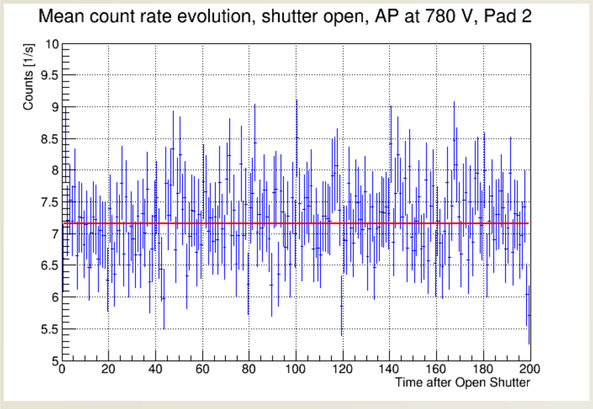
The background in the beam-time

The background is investigated using U_A = 780 V .



Measurement with e15 **symmetric**.

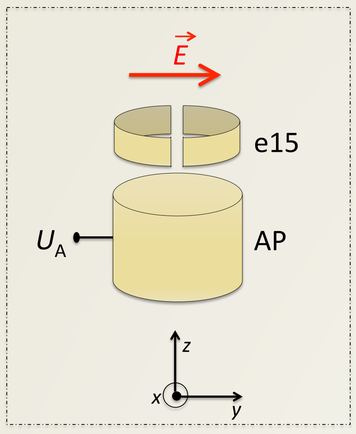
With shutter Open, the count rate shows a time dependence that can be described by an **exponential** function: $f(t) = p_0 + p_1\left(1-e^{-t/\tau}\right)$



Measurement with e15 **asymmetric**.

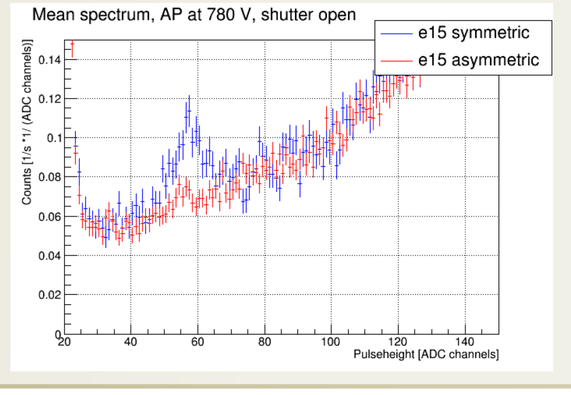
Here, the time dependence of the count rate in the proton region with shutter Open is strongly reduced and can be fit by a **constant**.

In the usual configuration the electrode e15 above the AP is in *symmetric* configuration.



After closing the shutter (*Close2*), the count rate is higher than before opening the shutter (*Close1*): particles trapped in the AP.

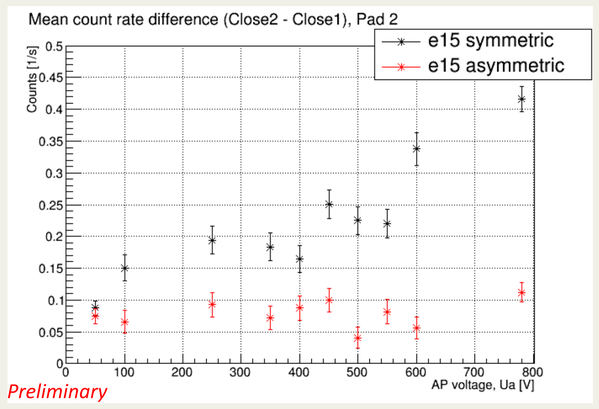
Using e15 in *asymmetric* configuration allows to evacuate these particles due to the created electric field $\vec{E}$ perpendicular to the neutron-beam.



Furthermore, the background after closing the shutter depends on the AP voltage (U_A).

This AP-dependence is large in the case of e15 symmetric, but **not significant in the case of e15 asymmetric.**

In case of AP dependent background, we determine and model the AP dependence from the measurements Close2 → $f_1(U_A)$.

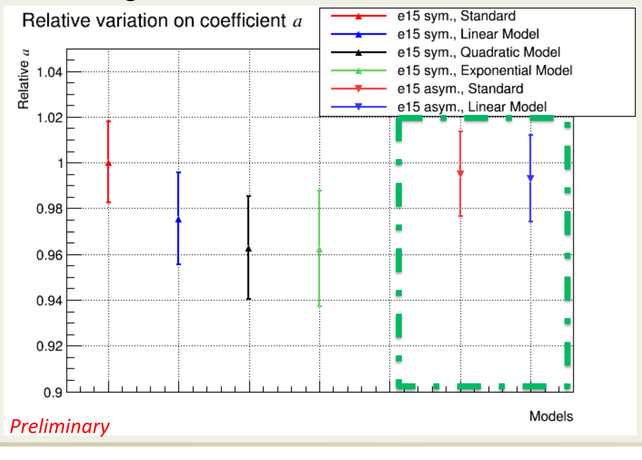


From the measurements Open at U_A=780 V, we quantify the constant and variable background components with beam present → $f(t)$.

$$f(t) = p_0 + \underbrace{p_1\left(1-e^{-t/\tau}\right)}_{\text{Non-constant background}}, \text{ at } U_A = 780\,\text{V}$$

Non-constant background + Close2 = $f_1(U_A)$ → Background to subtract: $p(p_1, U_A)$

This background model is included in the fit function to extract ***a***.



Some tested models:

- Standard: no subtraction.
- Linear Model: linear $f_1(U_A)$.
- Quadratic Model: 2nd degree polynomial.
- Exponential Model: exponential $f_1(U_A)$.

For **asymmetric** e15, the background correction is **negligible**.

Note that the asymmetric configuration for e15 changes also the edge effect.

Conclusions and outlook

- Detailed investigations of the background in the neutron β-decay experiment *a*SPECT have been conducted, both on- and offline neutron beam.
- With optimized electrodes settings, **the background can be strongly reduced**.
- Different **models** will be tested to describe the background and the related systematic error on ***a***.

All presented results are preliminary.

The analysis is ongoing and will be presented in R.M.'s PhD thesis (Université Joseph Fourier, Grenoble, France).