# The KATRIN likelihood function

KATRIN uses the following Poisson likelihood for the campaigns with the shifted analyzing plane (SAP) configuration:

$$-2\log\mathcal{L}_{\mathrm{SAP}} = \sum_{i,k} 2\left(R_{\mathrm{calc},k}(qU_i)\cdot t_i - N_{i,k} + N_{i,k}\cdot\ln\frac{N_{i,k}}{R_{\mathrm{calc},k}(qU_i)\cdot t_i}\right),$$

and the following likelihood for a normal distribution for the campaigns with nominal analyzing plane (NAP):

$$-2\log\mathcal{L}_{\mathrm{NAP}} = \sum_{i}\frac{\left(R_{\mathrm{calc}}(qU_i) - R_{\mathrm{data}}(qU_i)\right)^2}{\sigma_{R,i}^2},$$

where $k$ stands for the patch indices, $R_{\mathrm{calc}}(qU_i)$ are the calculated rates at the $i^{\mathrm{th}}$ high voltage set point, $R_{\mathrm{data}}(qU_i)$ are the corresponding rates, $N_{i,k}$ and $t_i$ are the event counts and the measurement time respectively. $\sigma_{R,i}^2$ is the modified variance accounting for an overdispersion of background rate.

The KATRIN systematic uncertainties are taken as pull terms for the total likelihood:

$$-2\log\mathcal{L}_{\mathrm{sys}} = (\vec{\eta} - \vec{\eta}_{\mathrm{ext}})^T\cdot\Theta_{\mathrm{cov}}^{-1}\cdot(\vec{\eta} - \vec{\eta}_{\mathrm{ext}}),$$

with $\vec{\eta}$ being the nuisance parameters and their calibration measurements $\vec{\eta}_{\mathrm{ext}}$ and covariance matrix $\Theta_{\mathrm{cov}}$.