Group Meeting

26/03/2020

MUPAGE tuning

- Many parameters to vary - https://doi.org/10.1016/j.astropartphys.2005.10.005

- Start with something ‘sensible’ like the flux

3. The multiplicity distribution of muons in bundles vs. depth and zenith angle

The multiplicity distribution of underground muons was experimentally studied with large statistics by the Frejus [21] and the MACRO [22] collaborations. The expected multiplicity distribution for a given primary mass and energy is known to be a negative binomial (NB) distribution. The observed distribution is a convolution of NB distributions, which can be described as a power law. Following the Frejus paper, the function:

$$\Phi(m;h,\theta) = \frac{K(h,\theta)}{m^{v(h,\theta)}} \quad \text{with } v = \frac{v_1}{(1+\Lambda\cdot m)} \tag{2}$$

has been used as parametric formula for the flux of bundles with different number of muons m at a given depth h and zenith angle θ. Here K, v_1 and Λ are free parameters, depending on h and θ. The phase space has been divided in seven values of vertical depth h (from 2.0 down to 5.0 km.w.e. in steps of 0.5 km.w.e.) and nine values of zenith angle θ (from 0° up to 80° in steps of 10°). Histograms have been filled with all the muons (single or in a bundle) reaching a given vertical depth h, and within $\Delta\theta = \pm 1°$ ($\pm 3°$ for the last bin, due to statistics reasons) centred with equation:

$$\Phi(m=1;h,\theta) = K(h,\theta) = K_0(h)\cos\theta\cdot e^{K_1(h)\cdot\sec\theta} \quad (\mathrm{m}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}) \tag{3}$$

At a given zenith angle, the flux decreases with depth and two simple expressions for $K_0(h)$ and $K_1(h)$ have been found (the values of fitted constants are reported in Table 3):

$$K_0(h) = K_{0a}\cdot h^{K_{0b}} \tag{4}$$

$$K_1(h) = K_{1a}\cdot h + K_{1b} \tag{5}$$

3.3. The parameter v

The fraction of multiple muon flux with respect to the single muon flux depends on the parameter v, which, for a given vertical depth h, is a function of $\sec\theta$:

$$v(h,\theta) = v_0(h)\cdot e^{v_1(h)\cdot\sec\theta} \tag{6}$$

For a fixed zenith angle θ, the parameter v increases with increasing vertical depth h as

$$v_0(h) = v_{0a}\cdot h^2 + v_{0b}\cdot h + v_{0c} \tag{7}$$

$$v_1(h) = v_{1a}\cdot e^{v_{1b}\cdot h} \tag{8}$$

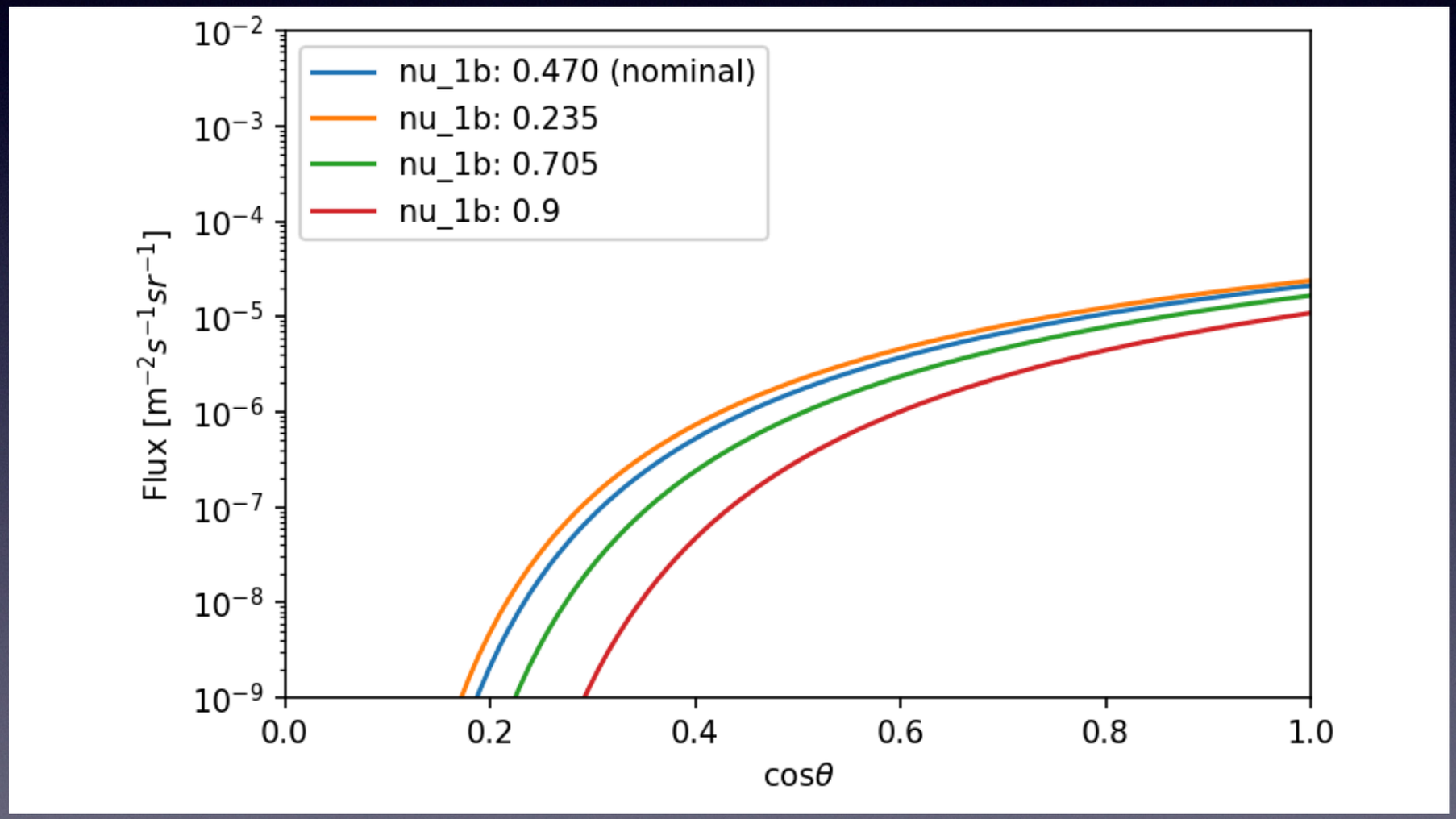
Previously: varied K , only gave a scaling of the distributions

MUPAGE tuning

- All ‘K’ parameters only scale normalisation, shape of distribution does not change.
- ‘v’ is at least a parameter dependent on multiplicity.
- v_{1b} is in an exponent, should affect the shape
- Vary it and run MUPAGE -> JTE -> JRECO_CHAIN and check observables

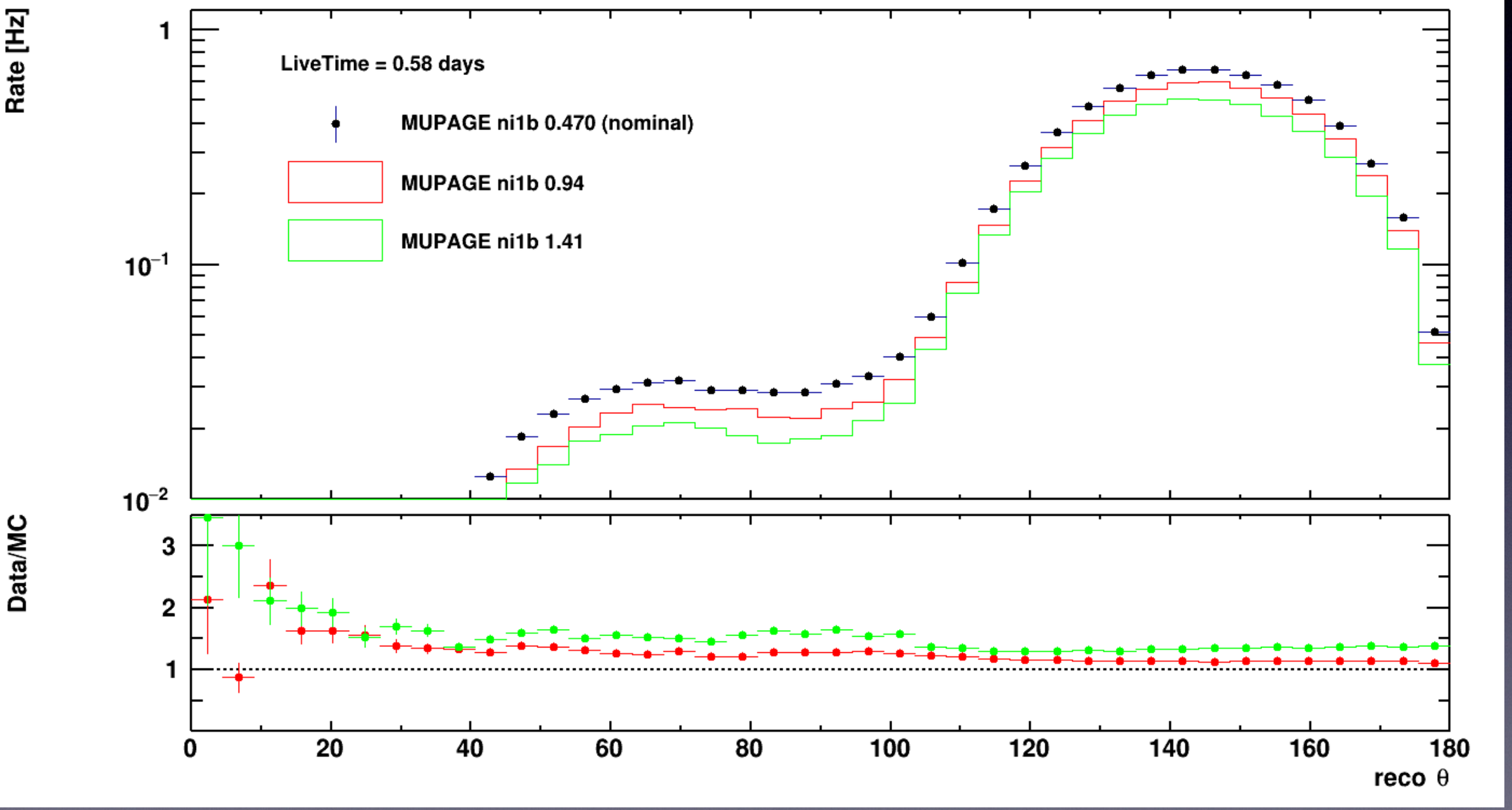
MUPAGE tuning

- Intermezzo: When changing the flux formula (see notebook I made):

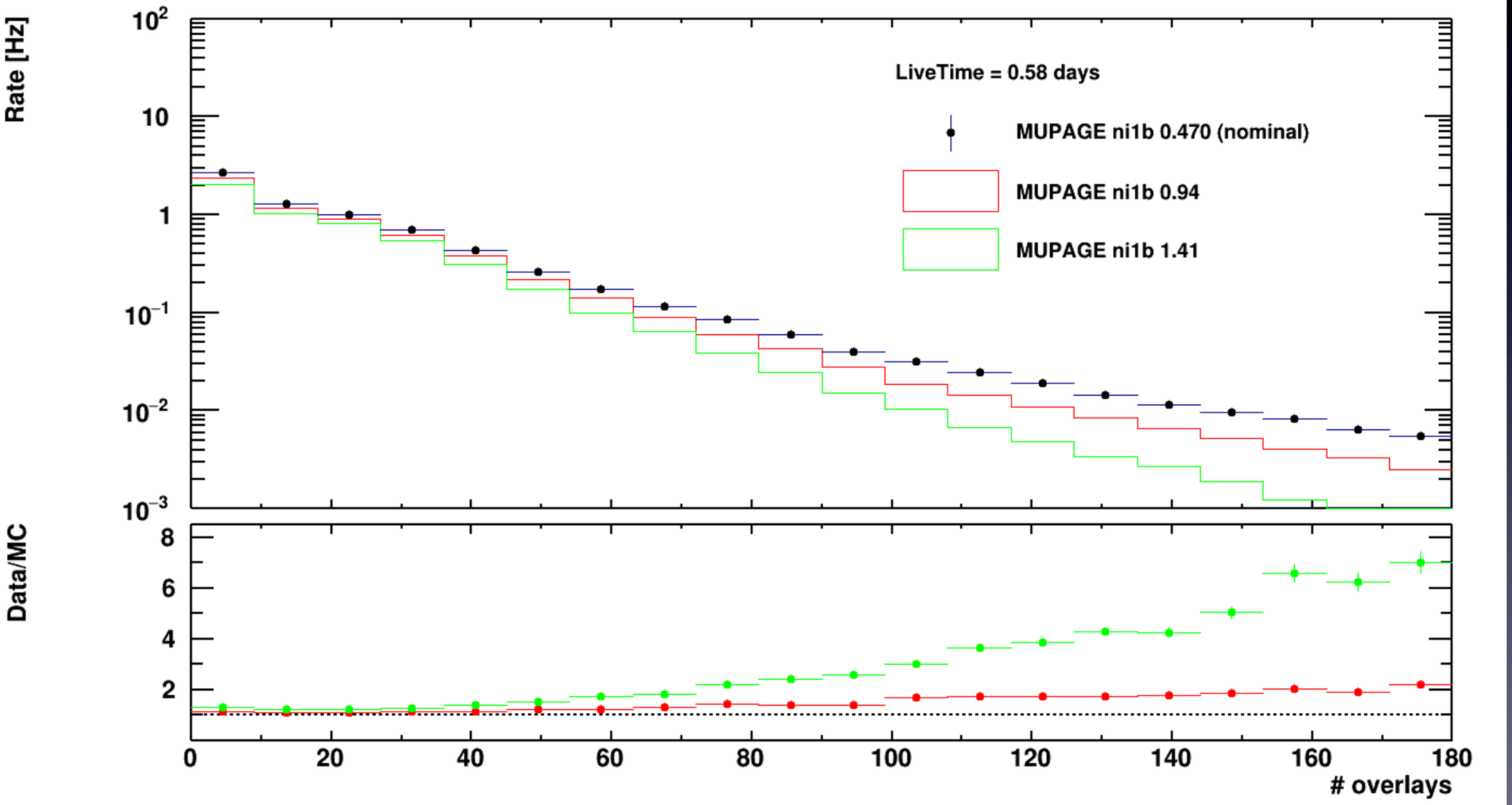


-> vary by x2 and x3

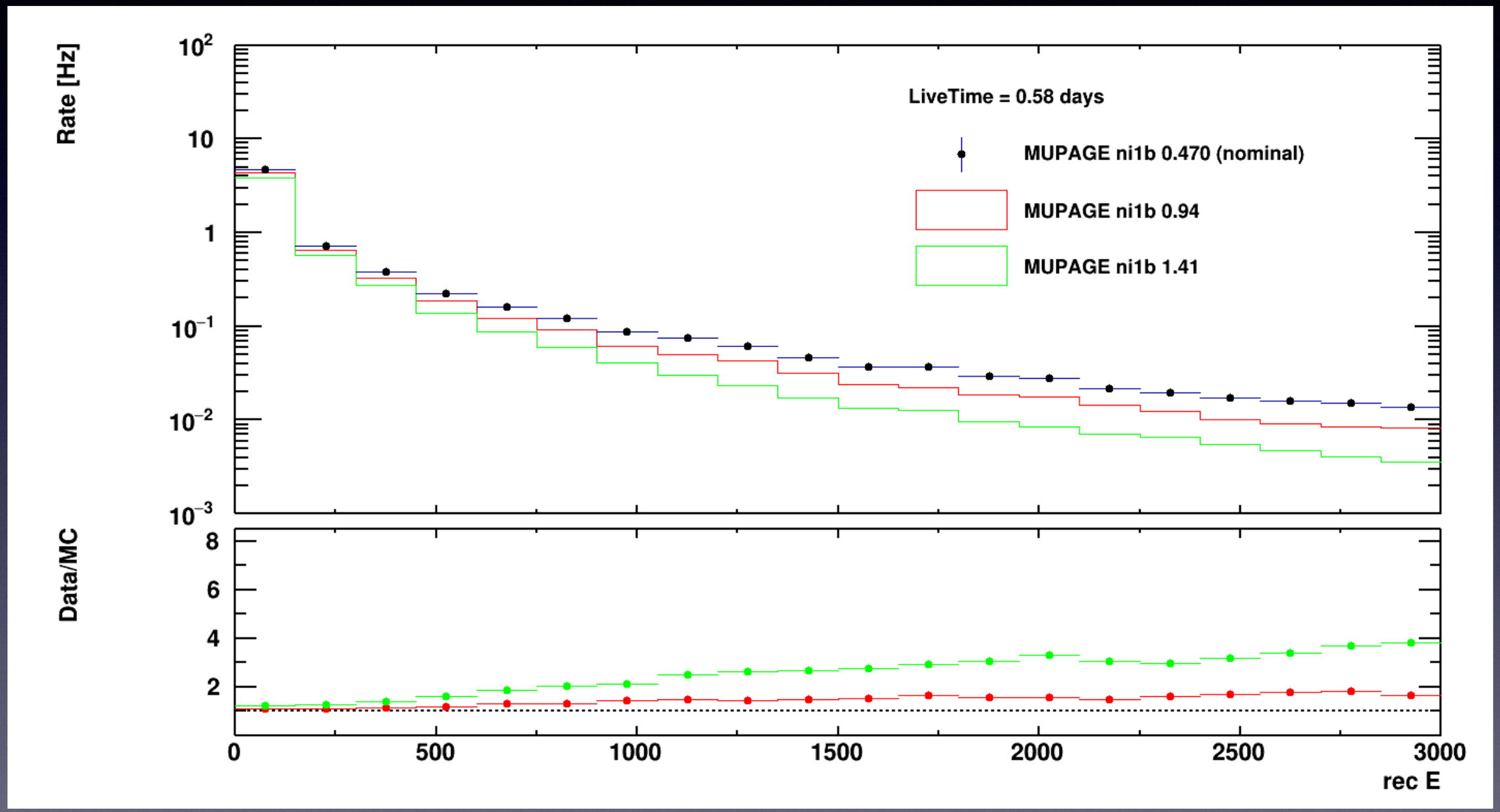
MUPAGE tuning



MUPAGE tuning



MUPAGE tuning



MUPAGE tuning

- Vary more parameters.
- Hint in which parameters to vary from histogram comparisons from Rodrigo?
- Produce MUPAGE generated MC files to match some data files (from ORCA4) and get a ‘data’ curve on those plots.
- Upload notebook to MUPAGE - gitlab