Two slides about the muon method for CTA

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Need to determine as precisely as possible the following numbers:

$$N_{tot}(\theta_c, \rho) = 2\alpha I \varepsilon_\mu \cdot \sin(2\theta_c) \cdot T \cdot R \cdot \int_0^\Phi \sqrt{1 - \left(\frac{\rho}{R}\right)^2 \sin^2\phi} \, d\phi$$

$$\text{with} : \Phi = \begin{cases} \arcsin(R/\rho) & \text{for} : \rho > R \\ \pi/2 & \text{for} : \rho \leq R \end{cases}$$

$$\approx U_0 \cdot \theta_c \cdot E_0(\rho) \cdot T$$

with :

$$U_0 = 2\pi\alpha R I \varepsilon_\mu$$

$$E_0(\rho) = \frac{2}{\pi} \int_0^\Phi \sqrt{1 - \left(\frac{\rho}{R}\right)^2 \sin^2\phi} \, d\phi \quad ,$$

Muon size (p.e.) (<1% possible for unbiased extractors)

local atm. transm. (<< 1% poss

Cherenkov angle (<1% possible)

Impact distance (<0.2m possible, <1% for E_0)

$$\varepsilon_\gamma = \int_{\lambda_1}^{\lambda_2} \psi(\lambda) \cdot \frac{T_\gamma(\lambda)}{\lambda^2} d\lambda \Big/ \int_{\lambda_1}^{\lambda^2} \frac{T_\gamma(\lambda)}{\lambda^2} d\lambda$$

$$= \varepsilon_\mu \cdot C_{\mu-\gamma}$$

$$C_{\mu-\gamma} = \frac{\int_{\lambda_1}^{\lambda_2} \frac{\psi(\lambda)}{\lambda^2} T_\gamma(\lambda) d\lambda}{\int_{\lambda_1}^{\lambda_2} \frac{\psi(\lambda)}{\lambda^2} d\lambda} \cdot \frac{\int_{\lambda_1}^{\lambda^2} \frac{1}{\lambda^2} d\lambda}{\int_{\lambda_1}^{\lambda^2} \frac{T_\gamma(\lambda)}{\lambda^2} d\lambda} \quad ,$$

Spectral correction (from Cherenkov light from muons to gamma-ray showers) 2-3% possible with current designs

Syst. uncertainties

Item	LSTs (%)	MSTs (%)	SSTs (%)	comments
Instrumental part U_0				
Determination of average R	<0.5	<0.5	<0.5	Account for hexagonal mirrors (see Fig. 7).
Shadows	<0.5	<1	??	May require cuts on impact parameter and inclination angle. Still to be assessed by simulations for SSTs.
Reconstr. Cherenkov angle θ_c				
Reconstr. bias from analysis	<0.5	<0.5	<1	Small correction might be necessary, but independent of ring radius (see Fig. 43 and 45).
Ring broadening effects	<0.5	<0.5	<1	Modifies ring radius along muon path (see Fig. 26).
Coma aberration effects	??	0	0	Still to be assessed for LST.
Light modulation due to impact distance E_0	<1	<1	<3	See Eq. 26 and Fig. 14. Still to be verified for SSTs.
Atmospheric transmission T				
Molecular part T_{mol}	<0.2	<0.1	<0.04	See Sect. 8.2.1.1.
Aerosol part T_{aer}	1–3	<2	<1	Exclusion of very bad nights needed, or correction from atmospheric monitoring data, see Sect. 8.2.1.2.
Reconstructed image size N_{tot}				
Trigger biases	1–3	0	<2	See Sect. 8.2.2, 8.1.1.4, 9.3, 9.4 and 9.5. Stereo trigger is assumed for the LST, but can be corrected using mono runs. Checks with different levels of NSB still missing.
Signal extraction biases	0	0	0	Requires un-biased signal extractors (fixed window).
Image selection biases	0	0	<1	See Sect. 8.2.2 and required analysis cuts in Sect. 9.3, 9.4 and 9.5.
Pixel baselines	<0.1	<0.2	<1	See Fig. 10, assumed requirement B-xST-1370.
Non-active pixels	<0.5	<0.5	<0.5	Requiring less than 10 broken pixels on the ring, see Fig. 21.
Translation muon to gamma efficiency $\varepsilon_\mu \to \varepsilon_\gamma$				
Chromaticity of degradation	<2	<2	<1	Need requirements B-xST-1500 and B-xST-1600.
Mis-focused mirrors	??	??	??	Exact magnitude of effects needs MC simulations.
Total	3–5	<3.5	<4.5	Missing items not yet accounted

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