Update on Geant4 muon generator

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Repository for MITO software

- Gitlab MITO group
  - https://baltig.infn.it/mito
  - If you want to contribute, sign in to baltig.infn.it and I will add you to the group
- Gitlab repository for Geant4 based MC simulations:
  - https://baltig.infn.it/mito/muraysimulation
  - Contains software for muon generators, detector simulation, predefined Geant4 useractions, etc. mainly developed by Nicola
- Gitlab repository for the simulation software developed by Massimo and Sandro:
  - https://baltig.infn.it/mito/mimasw

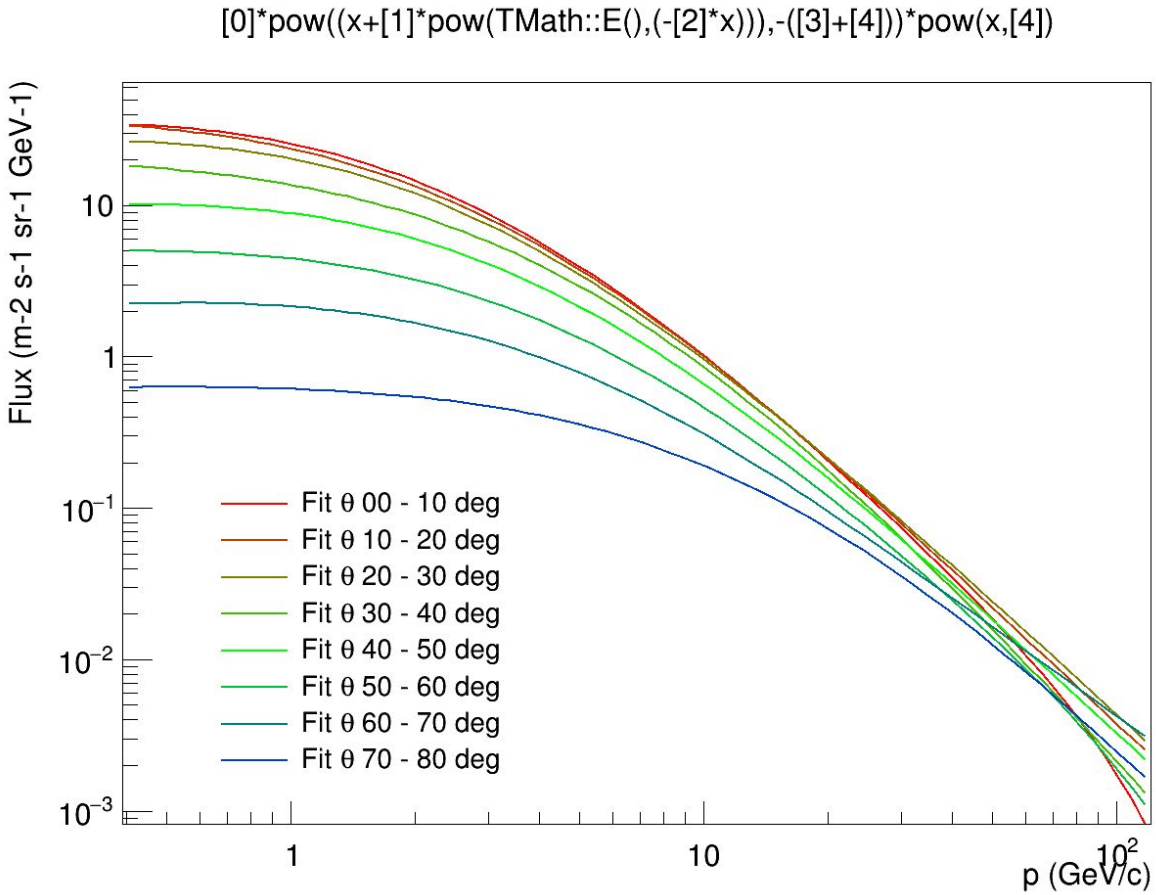
Geant4 muon generator - workflow

- Adamo flux (code):
  - Start from Adamo data and build analytic functions representing the differential flux vs p and θ.
  - Data are represented by 8 analytic functions of diff. flux vs p, one for each θ bin of 10° width (from 0° to 80°).
- Produce text tables (code):
  - Sampling the above functions we build text tables containing the differential flux at fixed p and θ values (more details in the next slides).
- MC generation (code):
  - Tables are converted to 2D histograms (x=p, y=θ, bin content=differential flux).
  - Histograms are sampled using standard ROOT methods.
- Interface to Geant4 (code)

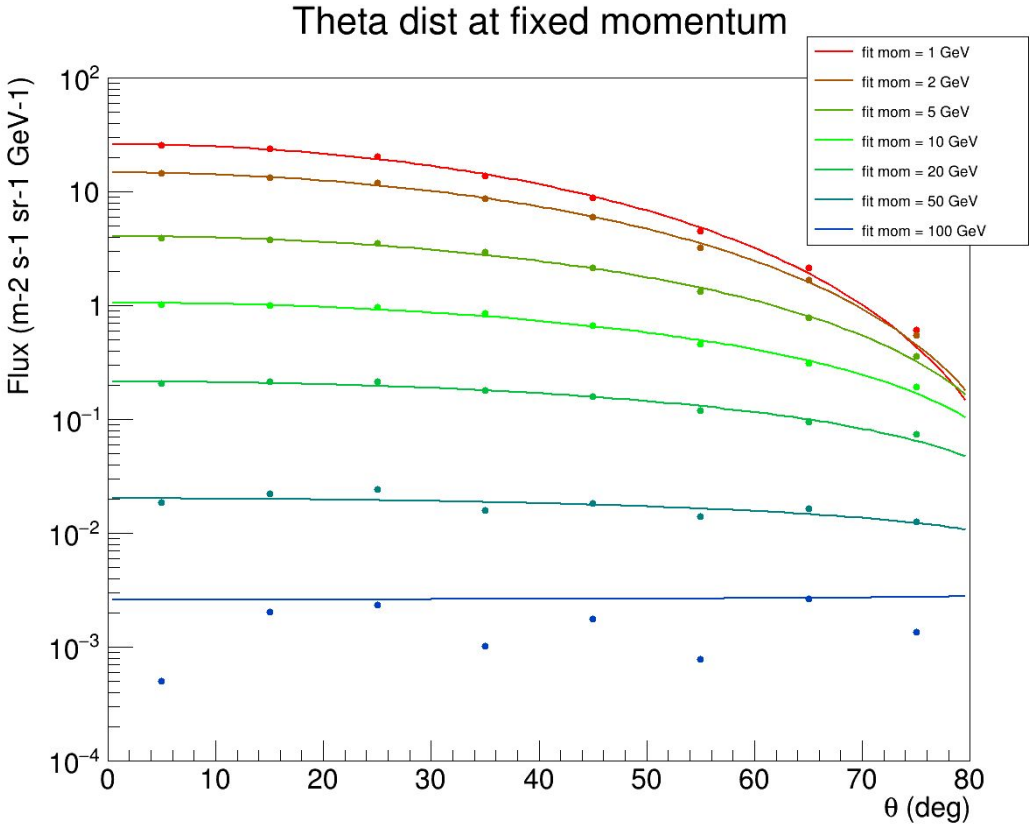
Details on the first steps

- We start from 8 analytic functions of diff. flux vs p:
  - $Flux_{\theta}(p) = A_0 [p + A_1 e^{-A_2 p}]^{-(A_3+A_4)} * p^{A_4}$ for $\theta \in [\theta_i, \theta_j]$
  - NB: different function used by Sandro and Massimo
  - For each θ bin, a different set of parameters A_i (i=0,1,2,3,4) is defined (fixed and hardcoded!).
  - Momentum range: 0.1 - 130 GeV
- In order to get the flux at fixed p and θ:
  - For a given p, extract $Flux_{\theta}$ from the 8 functions above -> 8 fluxes at fixed p and different θ,
  - $Flux_p(\theta) = (Flux_{\theta 0}, Flux_{\theta 1}, ..., Flux_{\theta 7})$
  - Fit with $B_0 (\cos(\theta))^{B1}$ and get the B_0 and B_1 parameters
  - Extract the flux at the desired θ value.

Flux vs p functions



Flux vs θ fits



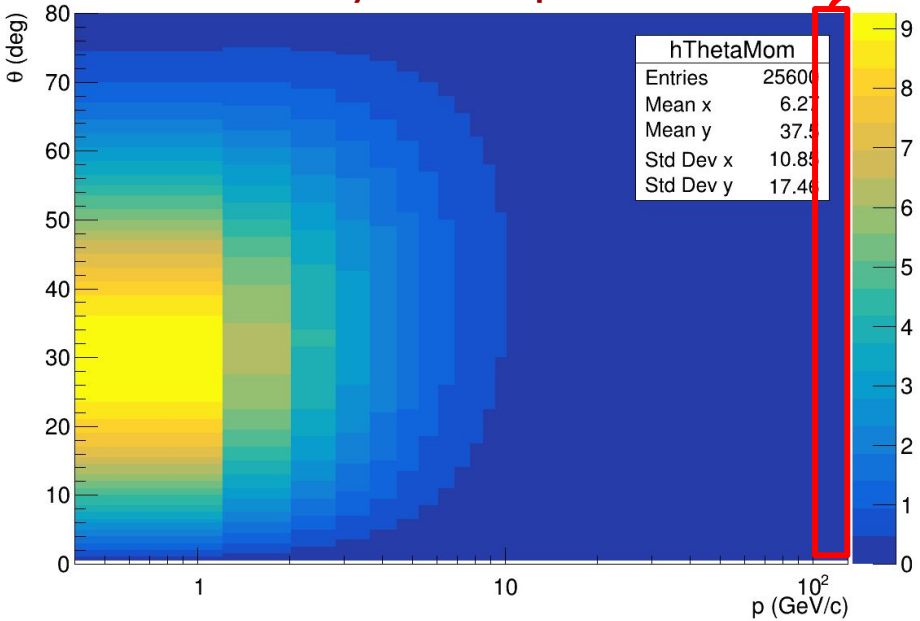
- Fits are not very accurate, especially at high momentum.

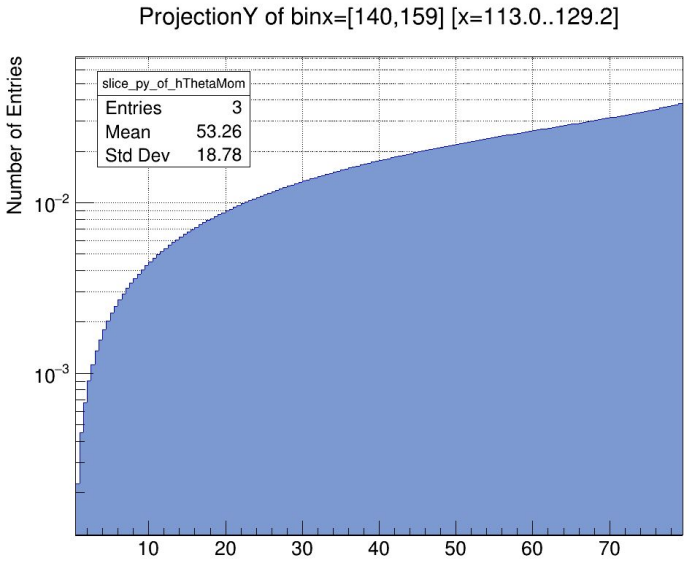
- PROBLEM:
  - No uncertainties are considered in these points(!!!).
  - We should at least propagate the uncertainty from Adamo measurements in order to have a meaningful fit.

2D distributions

- 2D distribution does not show any discontinuity at high p and low θ

Analytic flux vs p and θ



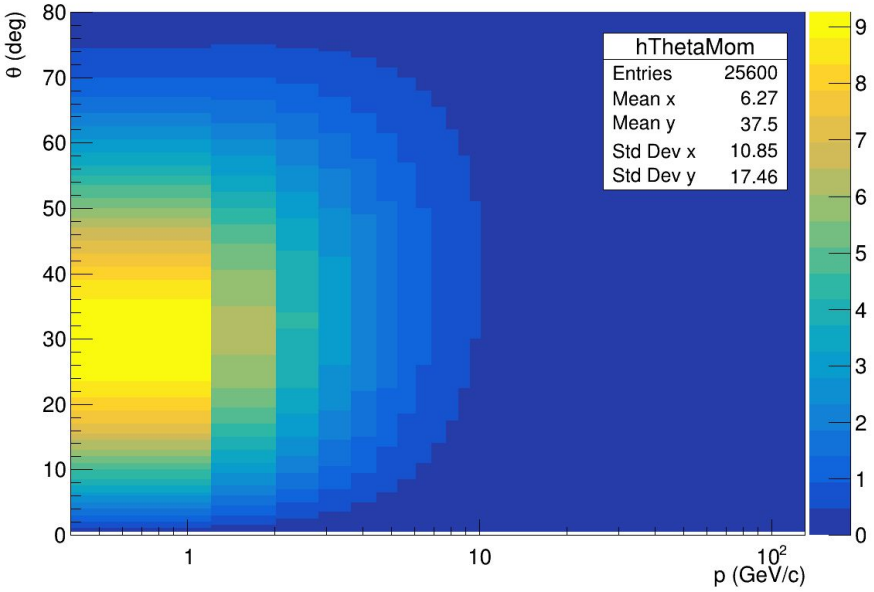


Theta projection for p>110 GeV

Cross check of the MC simulation

- Compare MC simulation with analytic functions:
  - 10M events simulation with Geant4
  - No detector, no material, point-like generation surface
  - Very good agreement with analytic functions (look at Mean and Std Dev!)

Analytic flux vs p and θ



Simulated events vs p and θ