Pileup Study for the Precession Frequency Analysis in Fermilab Muon g-2 Experiment

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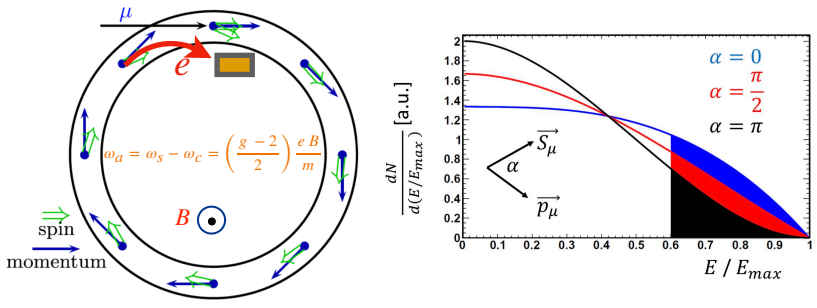
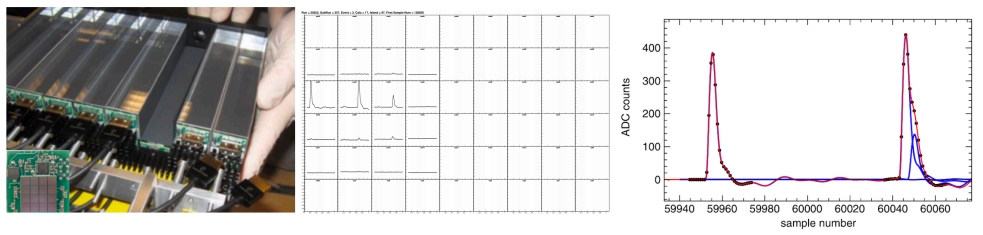
Anomalous spin precession [1,2]



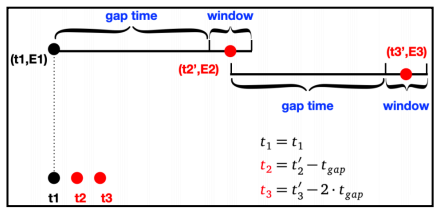
Data reconstruction [2]



Positron hits calorimeter with 6x9 crystals → Digitized waveforms → Pulse fitting → Clustering → One candidate positron

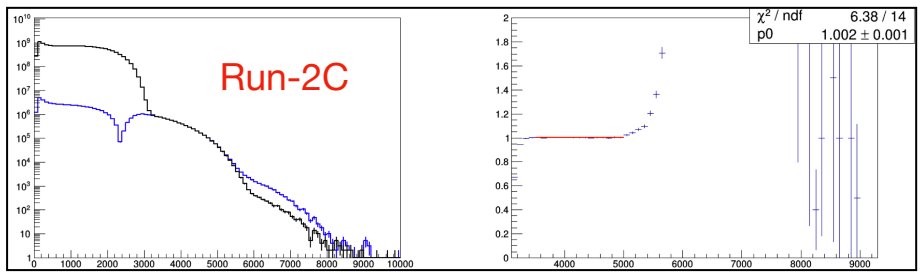
Multipositron pileup [1,2]

- Pileup: when multiple positrons strike a calorimeter sufficiently close in time or space.
- 100 ppb caused by unresolved pileup in Run-1 [2].
- Three data-driven methods:
  1. The empirical method
  2. The probability density function method
  3. The shadow method (applied in our group)



$$PU = D + T + O(\Delta t^3)$$
$$D = D_{12}^{Recon} - D_1^{Recon} - D_2^{Recon}$$
$$T = T_{123}^{Recon} - T_{12}^{Recon} - T_{23}^{Recon} - T_{13}^{Recon} + T_1^{Recon} + T_2^{Recon} + T_3^{Recon}$$

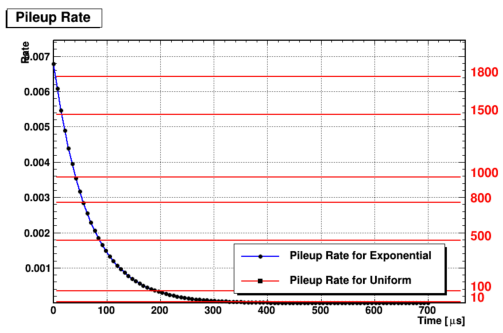
We need to scrutinize our formula when triple pileup becomes significant!



ToyMC pileup simulation

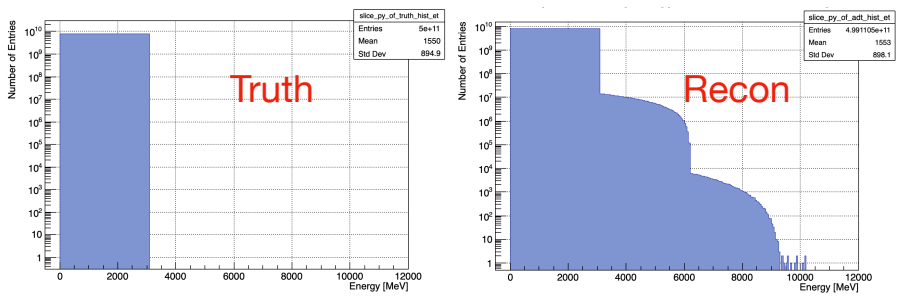
Wrong formula or High-order pileup at early time?

- Uniform time distribution for a fixed pileup rate.
- Different pileup rate by different number of events per fill.



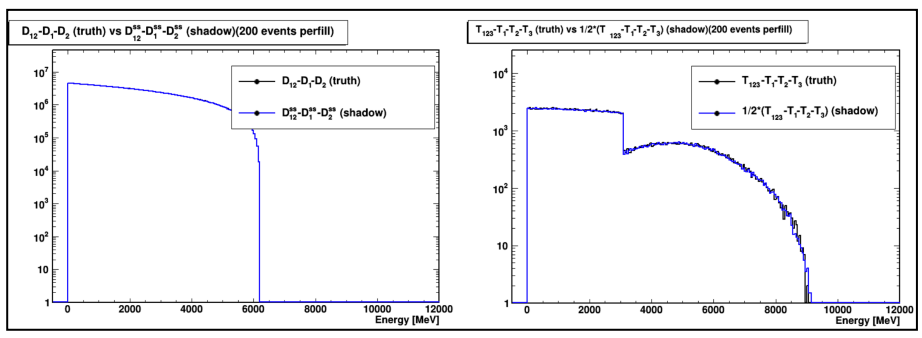
Pileup Simulation

- Truth info of positron: $\rho(E,t) = U(E)(0,\ 3100\ MeV) \times U(t)(0,\ 7e5\ ns)$.
- Pileup identification: when the time interval of any two events is less than 2.5 ns, combine them by adding energy and constructing energy-weighted time.



The shadow method utilizes the Recon to construct Truth with following assumptions:

$$PU = D\left(= D_{12}^{ss} - D_1^{ss} - D_2^{ss}\right) + T\left(= \frac{1}{2}\left(T_{123}^{Recon} - T_1^{Recon} - T_2^{Recon} - T_3^{Recon}\right)\right)$$

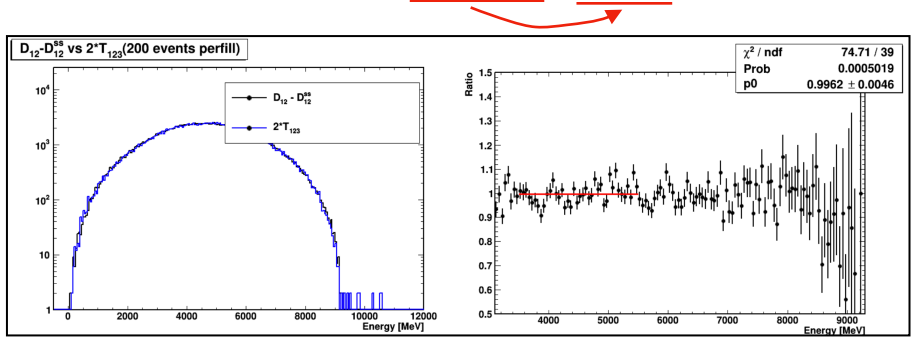


The assumptions are true !

Remove containminations

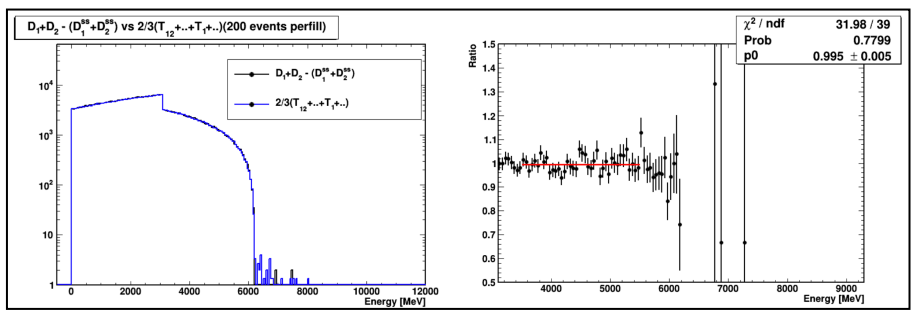
- D_{12}^{Recon}, D_1^{Recon}, D_2^{Recon} have to be corrected.

1. $D_{12}^{Recon} = D_{12}^{ss} + D_{12}^{sd} + D_{12}^{ds}$ $\quad 2 * T_{123}^{Recon}$



Correction works well !

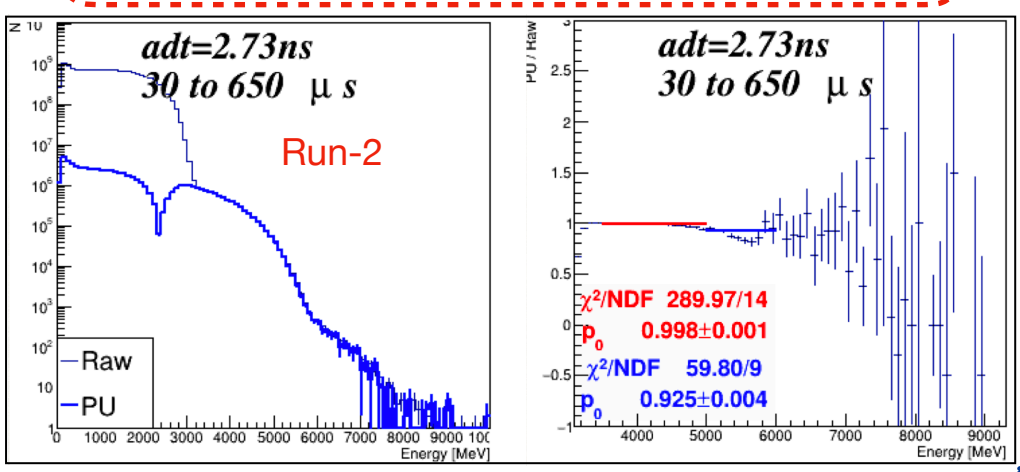
2. $D_1^{Recon} = D_1^{ss} + D_1^{sd} + D_1^{ds}$, $D_2^{Recon} = D_2^{ss} + D_2^{sd} + D_2^{ds}$ $\quad \frac{2}{3}\left(T_1^{Recon} + T_2^{Recon} + T_3^{Recon}\right) + \frac{2}{3}\left(T_{23}^{Recon} + T_{13}^{Recon} + T_{12}^{Recon}\right)$



Correction works well !

New formula and apply to data

$$PU = D + T + O(\Delta t^3)$$
$$D + T = D_{12}^{Recon} - D_1^{Recon} - D_2^{Recon} - \frac{3}{2}T_{123}^{Recon} + \frac{2}{3}\left(T_{12}^{Recon} + T_{23}^{Recon} + T_{13}^{Recon}\right) + \frac{1}{6}\left(T_1^{Recon} + T_2^{Recon} + T_3^{Recon}\right)$$



Reference: [1] B. Abi et al. (Muon g–2 Collaboration) Phys. Rev. Lett. 126, 141801 – Published 7 April 2021
[2] T. Albahri et al. (Muon g–2 Collaboration) Phys. Rev. D 103, 072002 – Published 7 April 2021