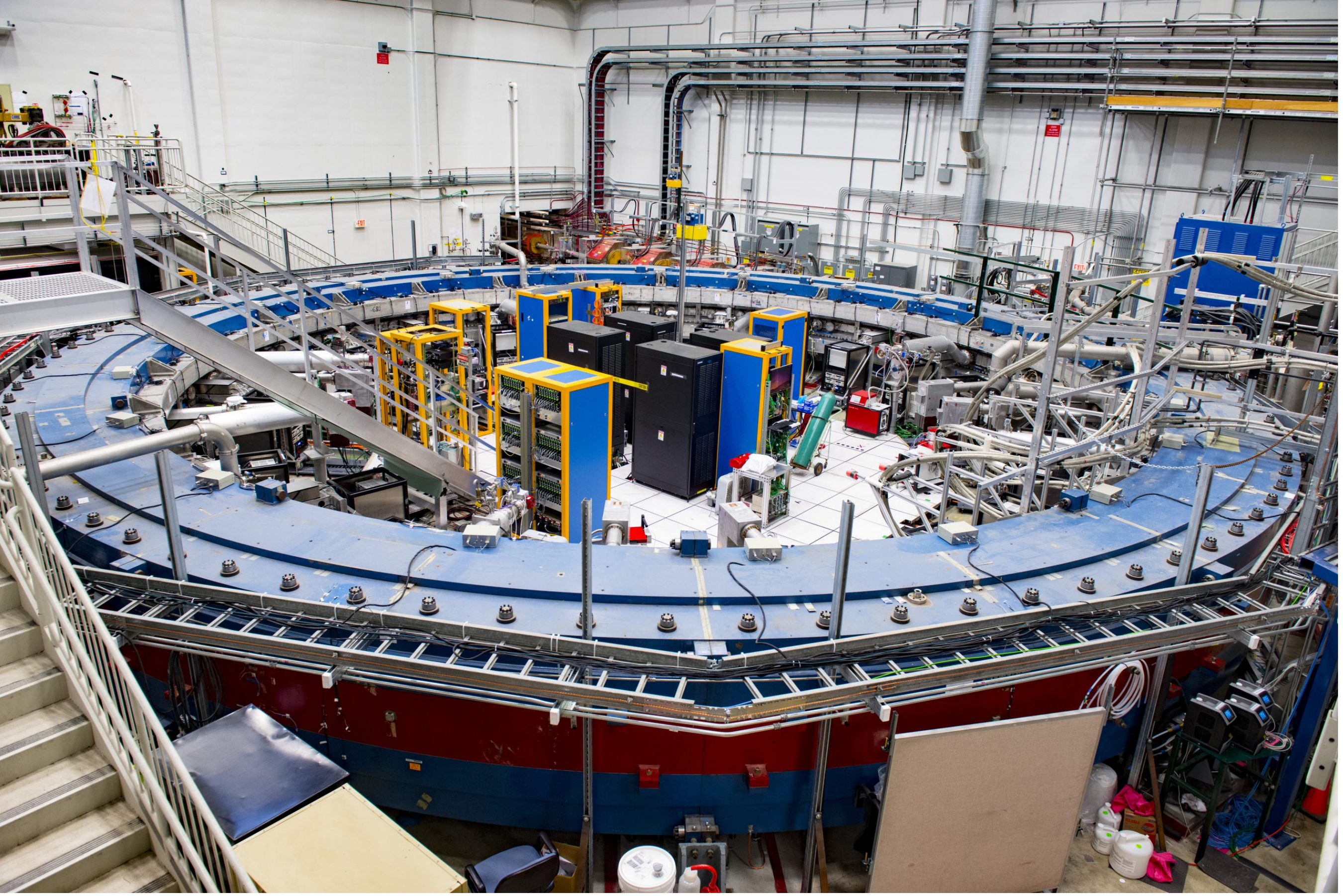


The Energy Calibration System of the muon g-2 experiment at Fermilab

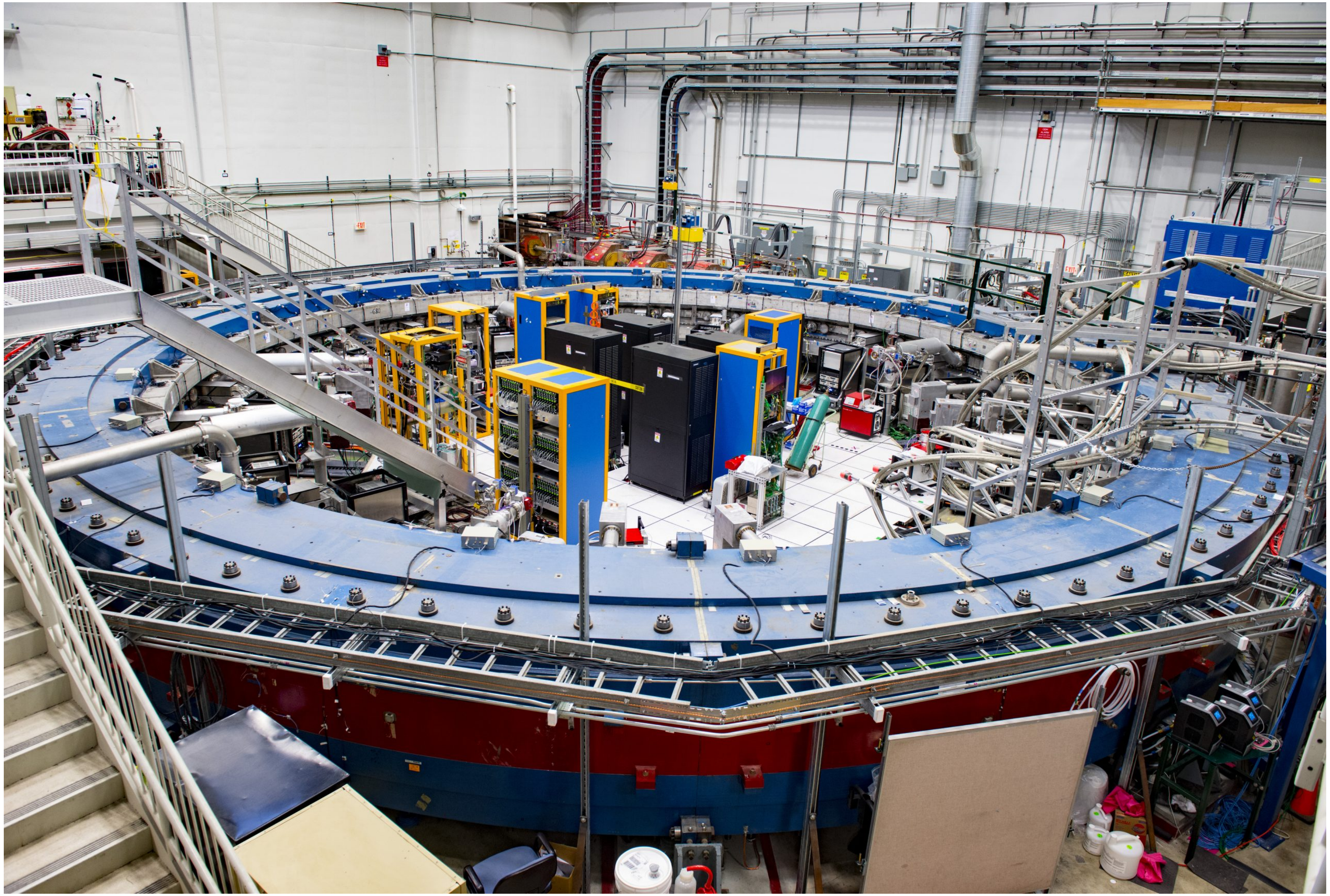
Matteo Sorbara *on behalf of g-2 collaboration*

Società Italiana di Fisica 104^{th} Congress

21^{st} of September 2018

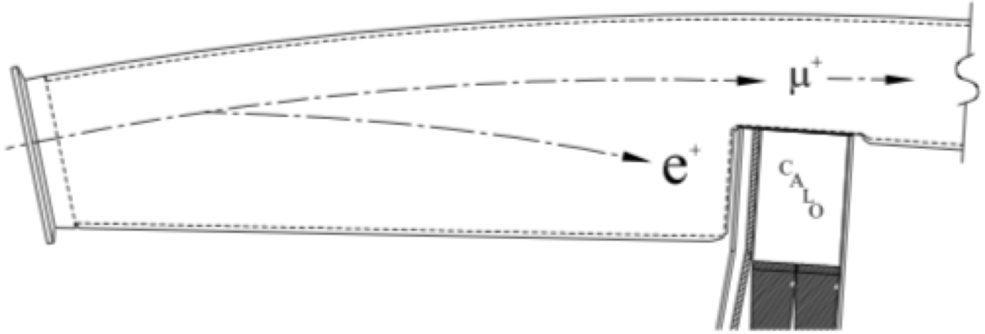
Overview

- The E989 Calorimeter System
- Absolute Energy Calibration
  - Endpoint
  - MIP peaks
- Lost Muons
- Conclusions

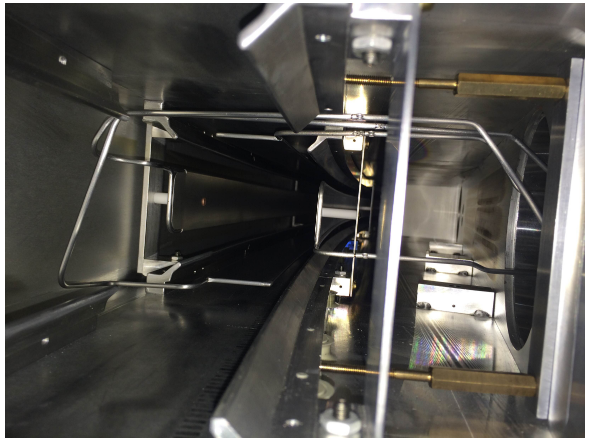


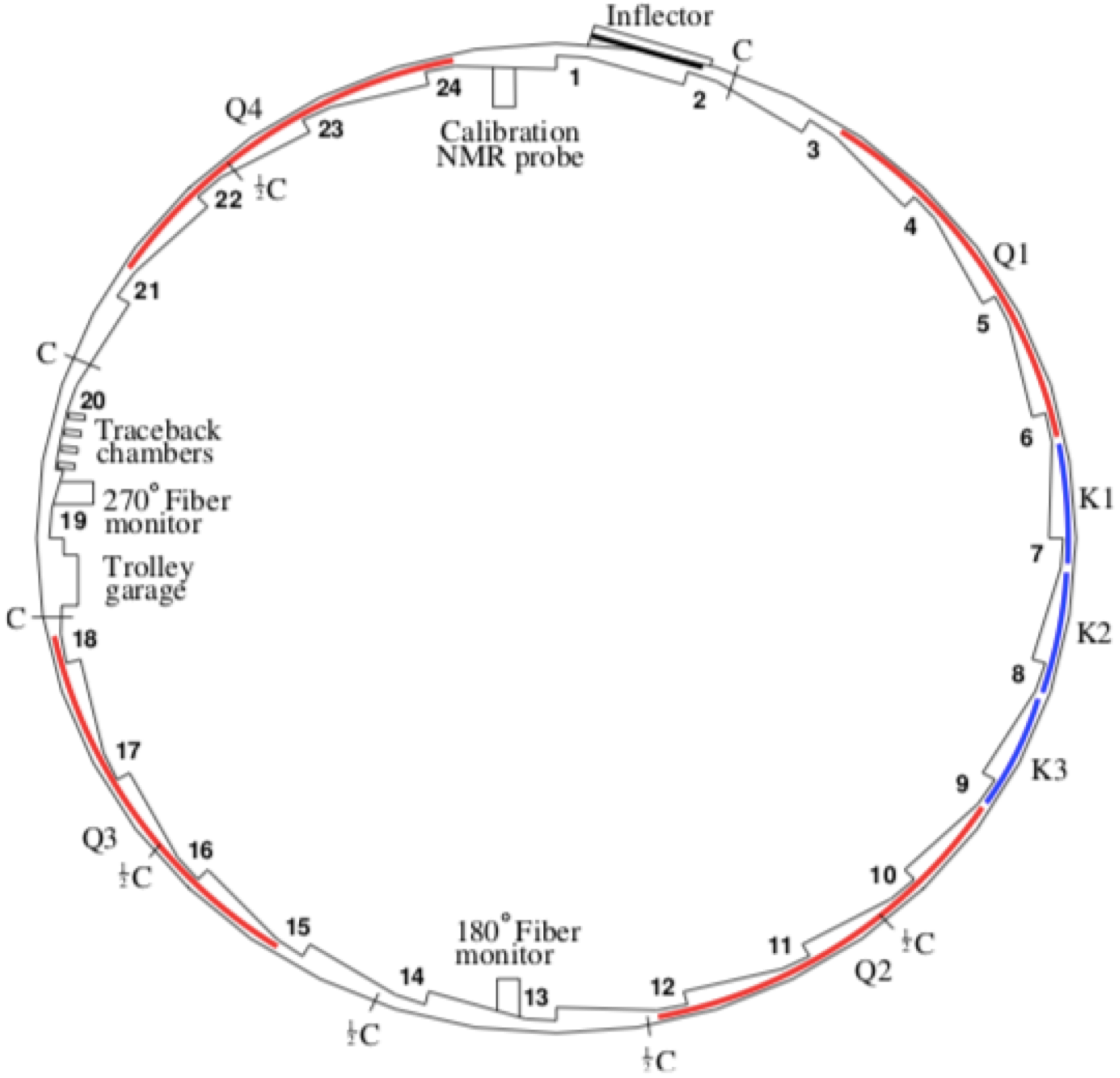
One Ring to rule them all, One Ring to find them, One Ring to bring them all, and in the Darkness blind them. **J. R. R. Tolkjen - Lord Of The Rings**

The Ring



μ+
e+
CALO

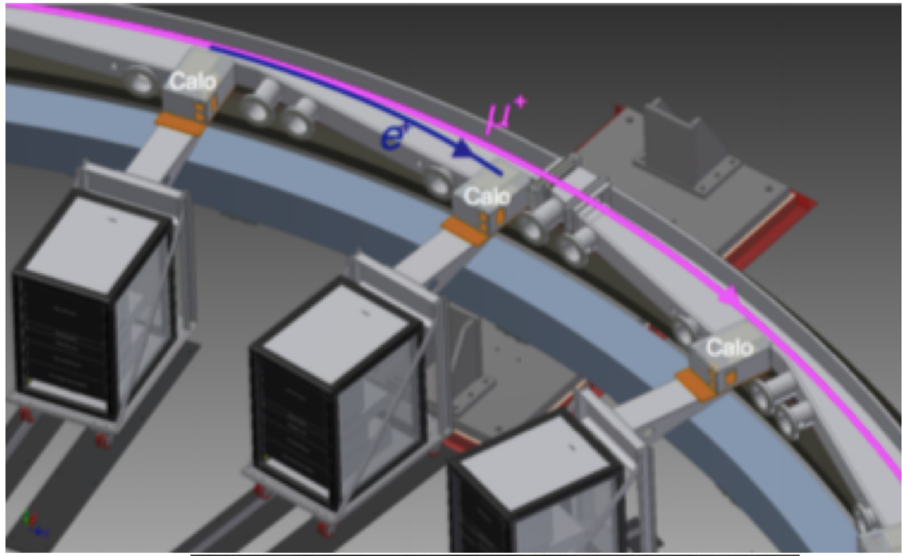


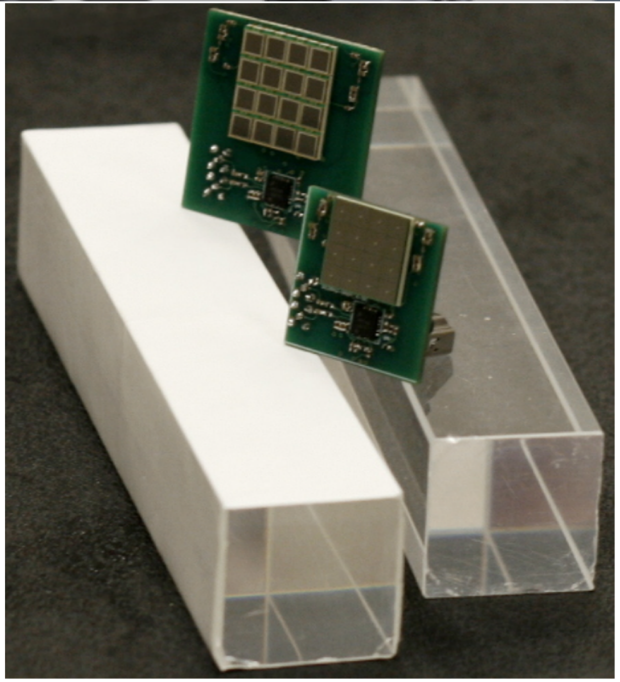


Inflector
C
1
2
24
Calibration
NMR probe
3
Q4
23
22
½C
4
Q1
21
5
C
20
Traceback
chambers
6
270° Fiber
monitor
19
K1
7
Trolley
garage
C
18
K2
8
17
K3
9
Q3
16
½C
10
½C
15
180° Fiber
monitor
11
Q2
14
13
12
½C
½C

The E989 Calorimeter System

- 24 calorimeters along the inner radius of the ring
- Each calorimeter is a 6×9 array of PbF_2 crystals
- Each crystal is $2.5\times2.5\ cm^2$ and $14\ cm$ deep ($= 15\ X_0$)
- Čerenkov crystals >> Fast response >> Less Pile-Up
- Crystals are read by Large Area SiPM



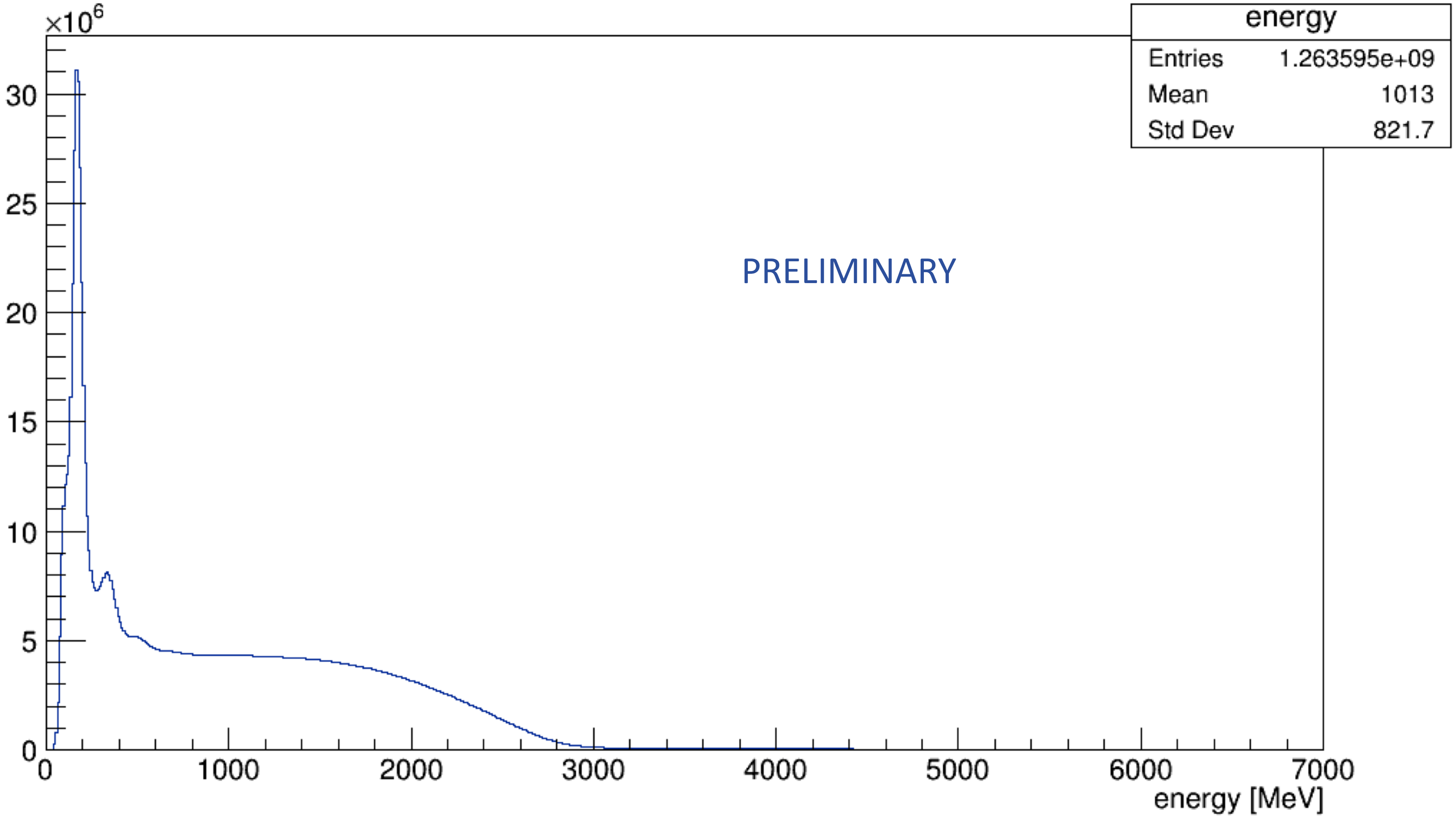


Absolute Energy Calibration

The key point is to use a (reasonably) fixed energy process for the calorimeters' calibration:

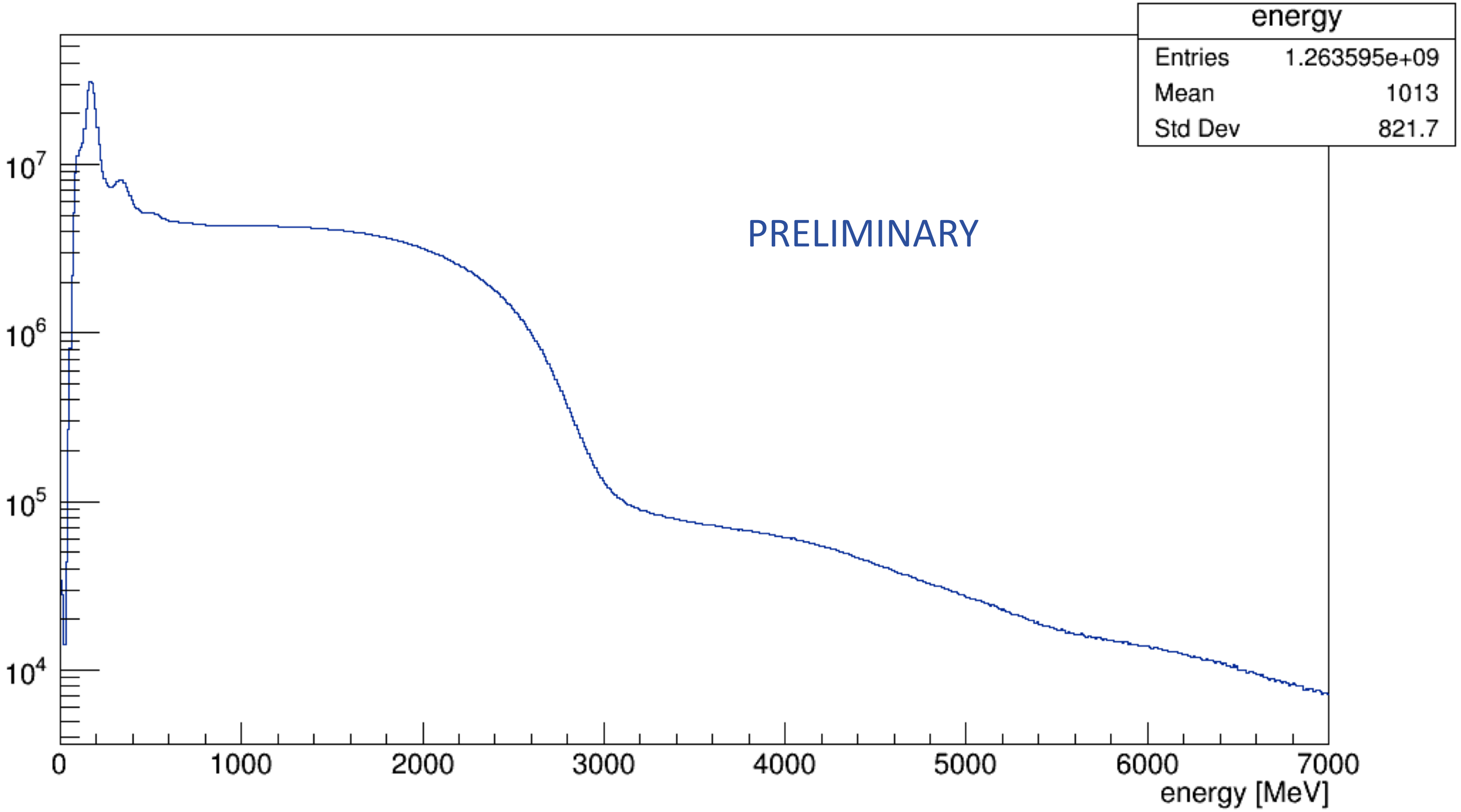
- Endpoint
- MIP Peak

Both are visible in a typical energy spectrum, but…



Absolute Energy Calibration (2)

… Same plot in Log Scale.
The endpoint is affected by pile-up (long tail at $E > 3.1\ GeV$).
The endpoint is also affected by the calorimeter's leakage.
So MIP peak is the process of choice for the absolute energy calibration.



Lost Muons for MIP signal

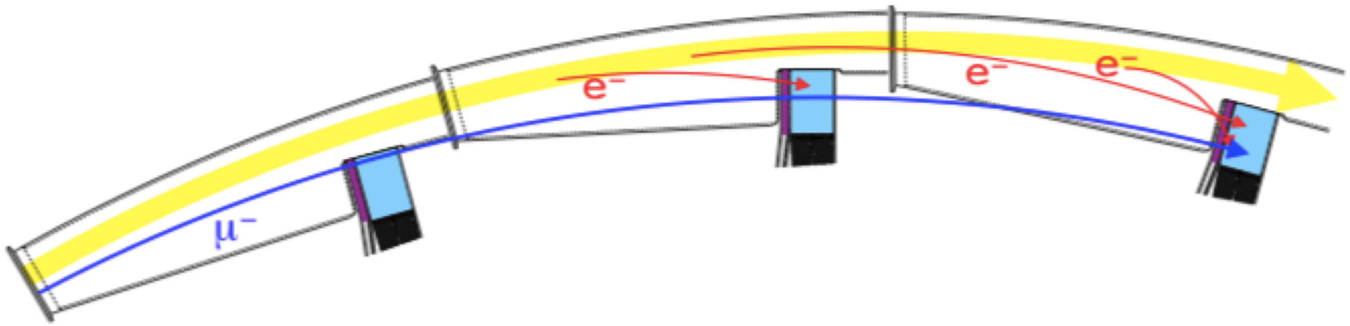
A muon transversing a block of material looses energy due to the ionization process. The Bethe-Bloch formula gives the mean energy deposited by the particle:

$$E_{dep} = \frac{dE}{dx} \cdot \rho x \approx 167\ MeV$$

for 3.1 GeV/c muons in a 14 $cm\ PbF_2$ crystal ($\rho = 7.77 \frac{g}{cm^3}$).

So we expect a peak in the region of $\sim 170\ MeV$ from lost muons that can be used for the energy calibration.

Find Lost Muons



Developed a C++/Root code to look for Double and Triple Coincidences.

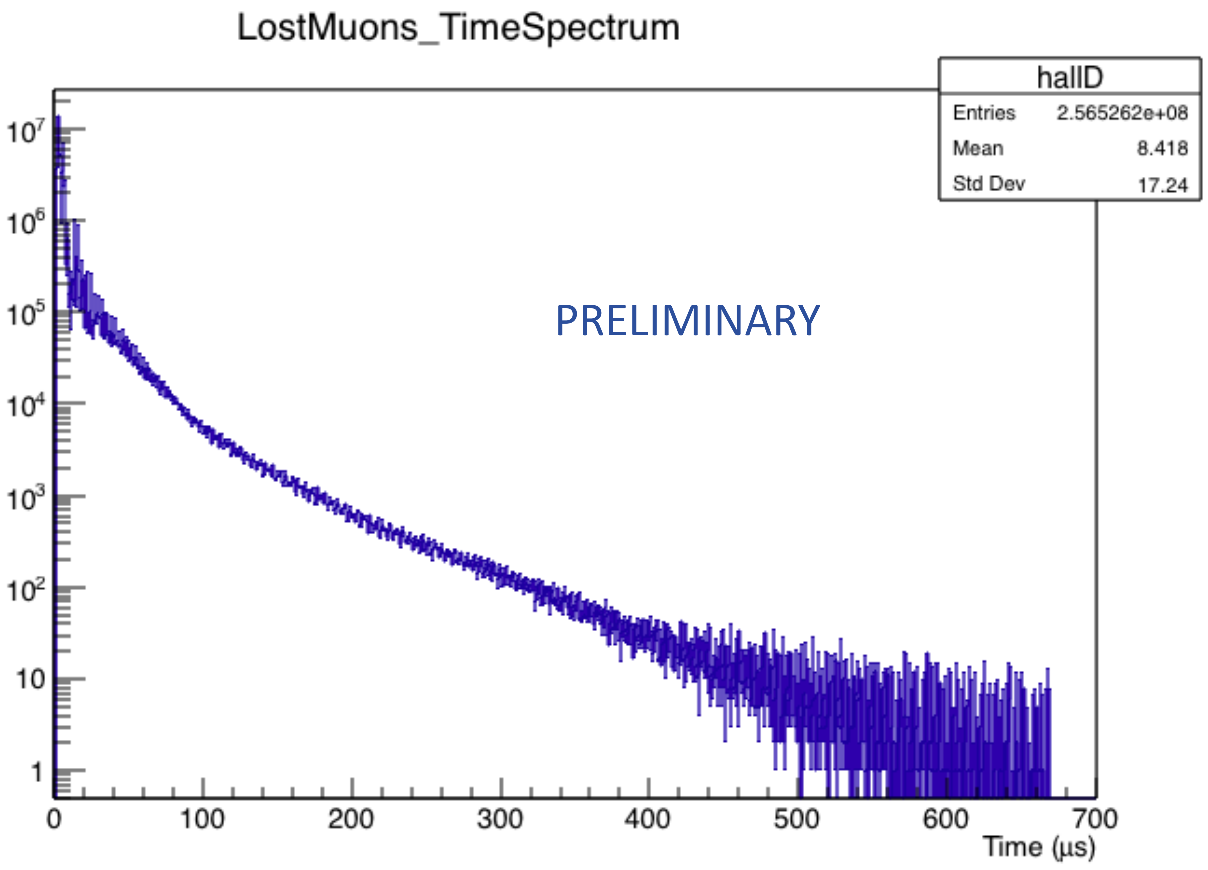
The code looks for:

1. single hit clusters in the n^{th} calorimeter;
2. clusters in the $(n+1)^{th}$ calorimeter within $10ns$ from the first hit;
3. energy difference between the hits $\Delta E < 30\ MeV$;

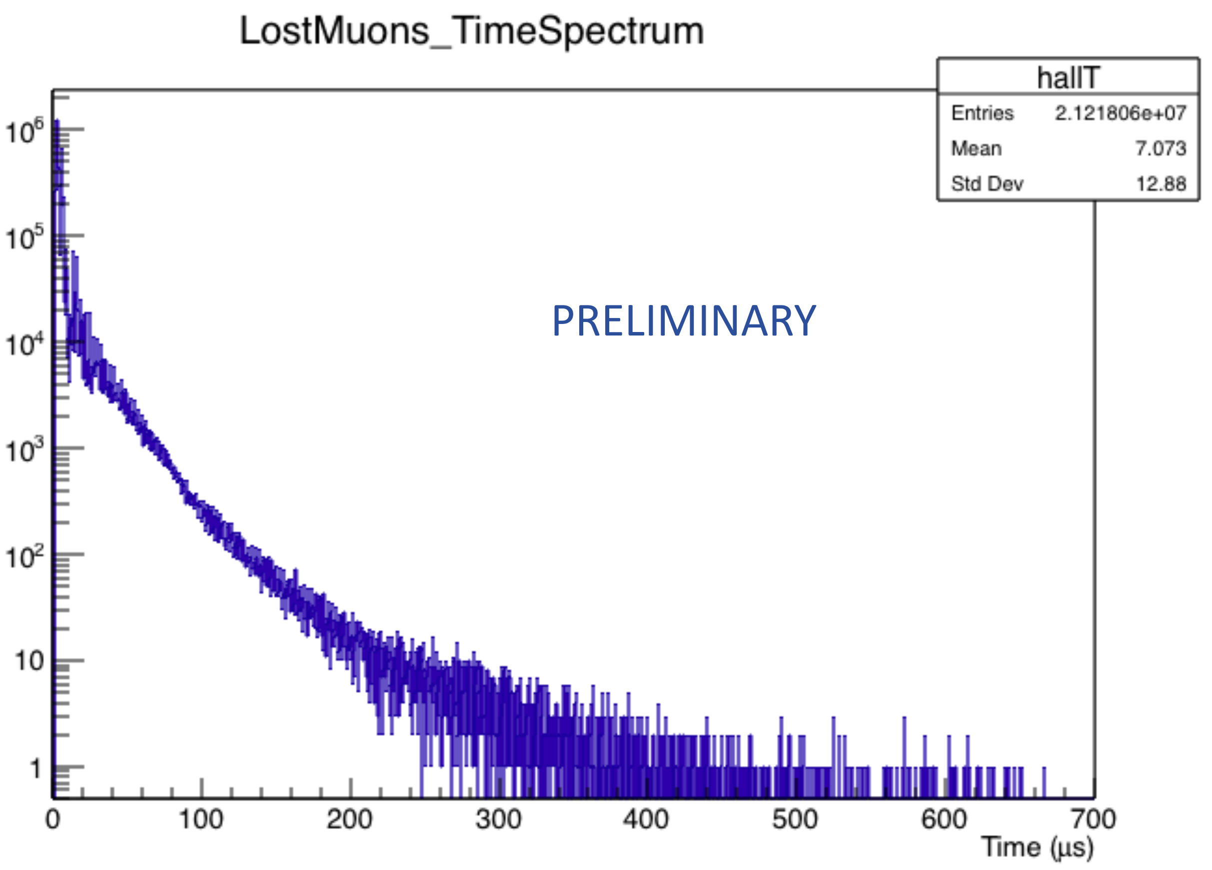
For Triple Coincidences:

4. clusters in the $(n+2)^{th}$ calorimeter within $10ns$ from the first hit and $20ns$ from the second hit.

Time Distribution

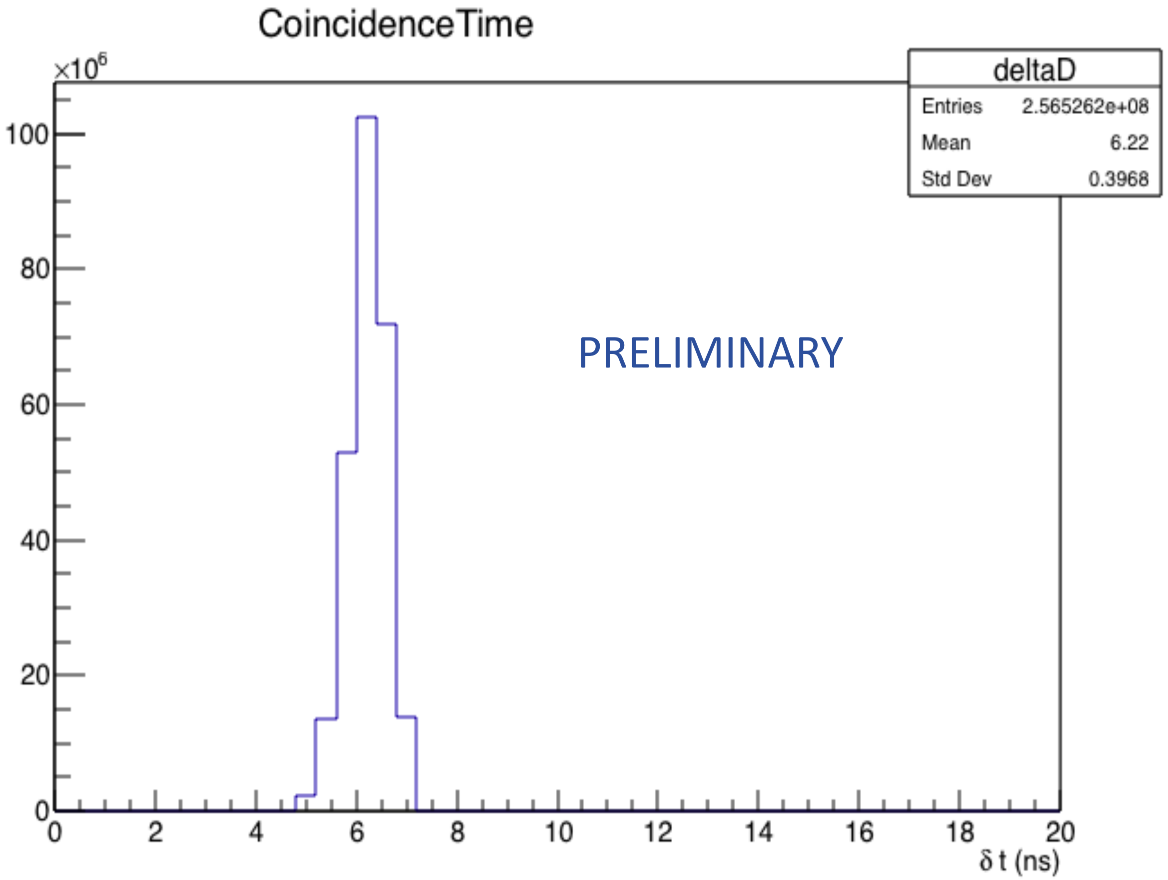


Double Coincidences

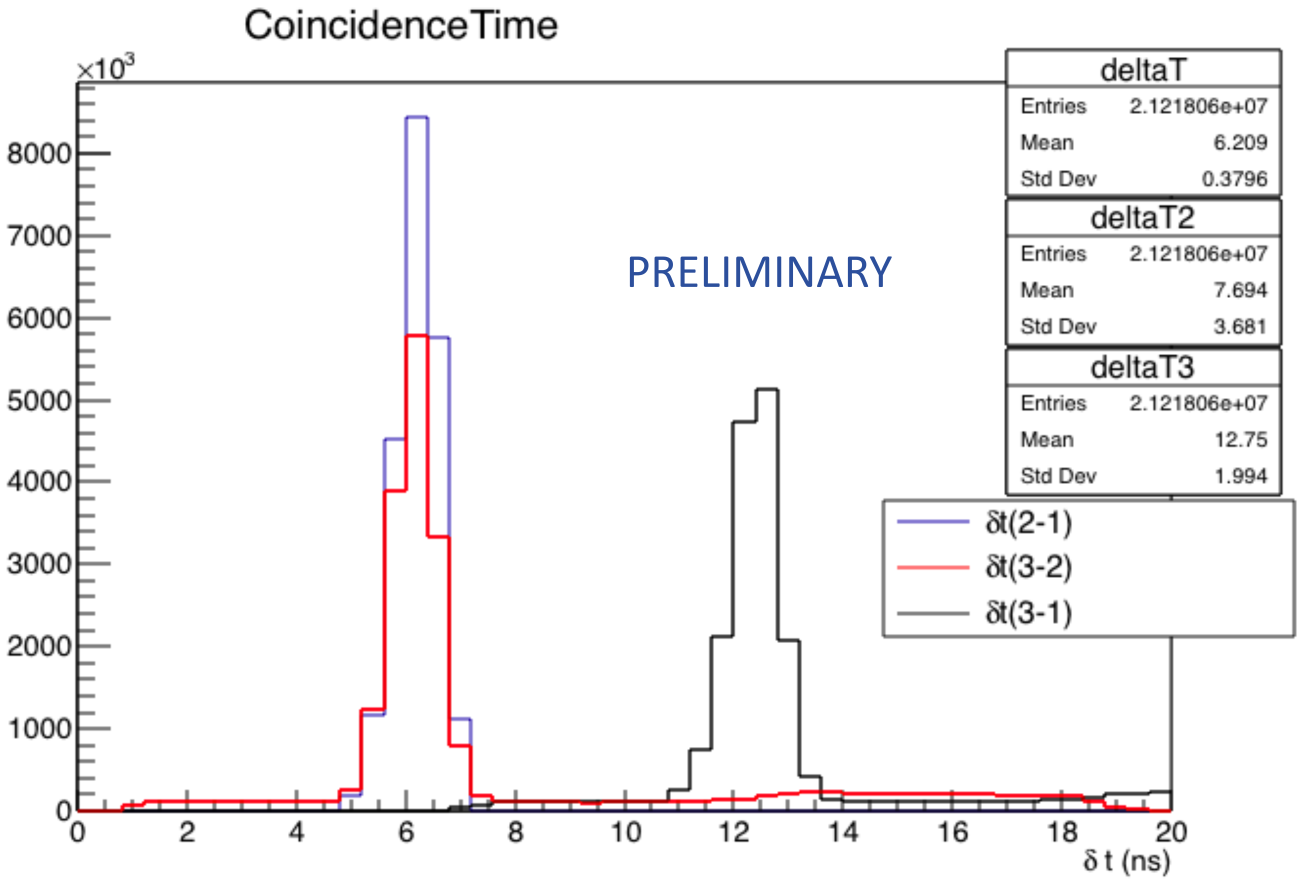


Triple Coincidences

Time Differences

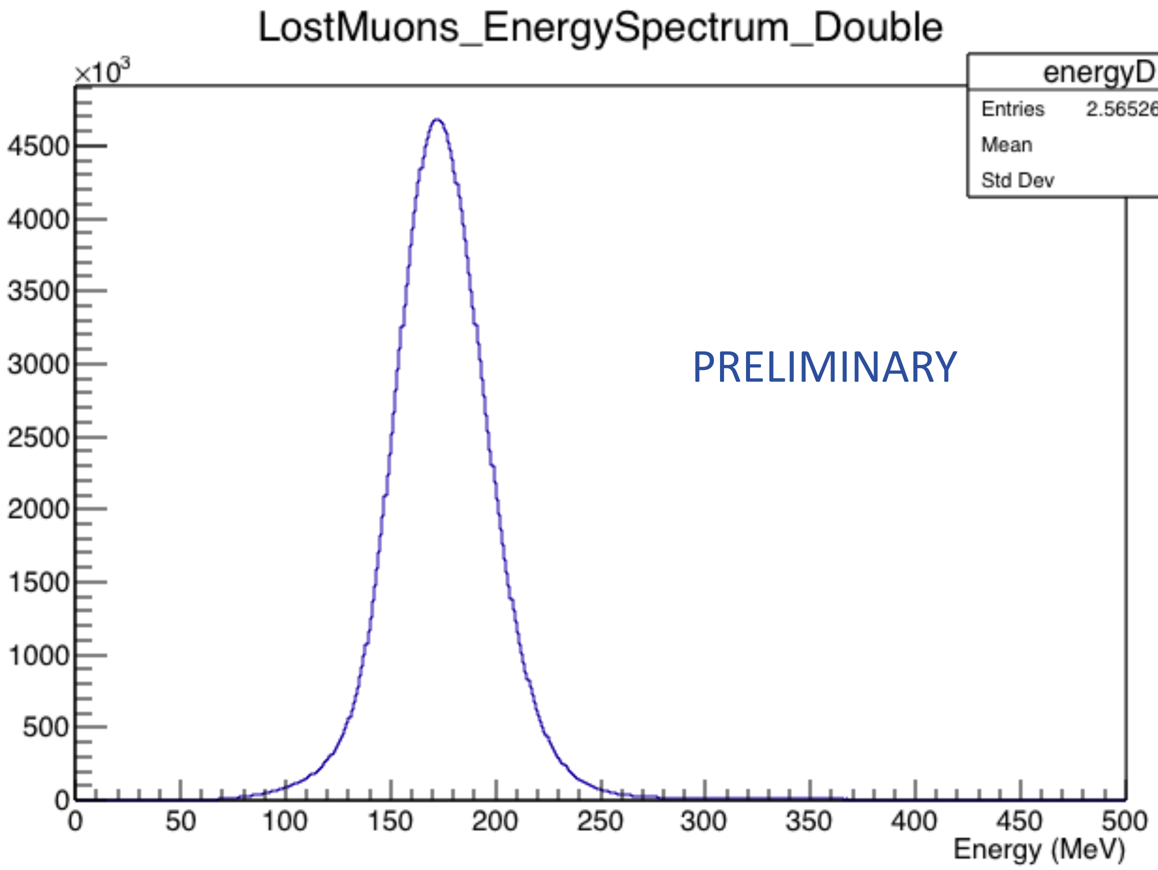


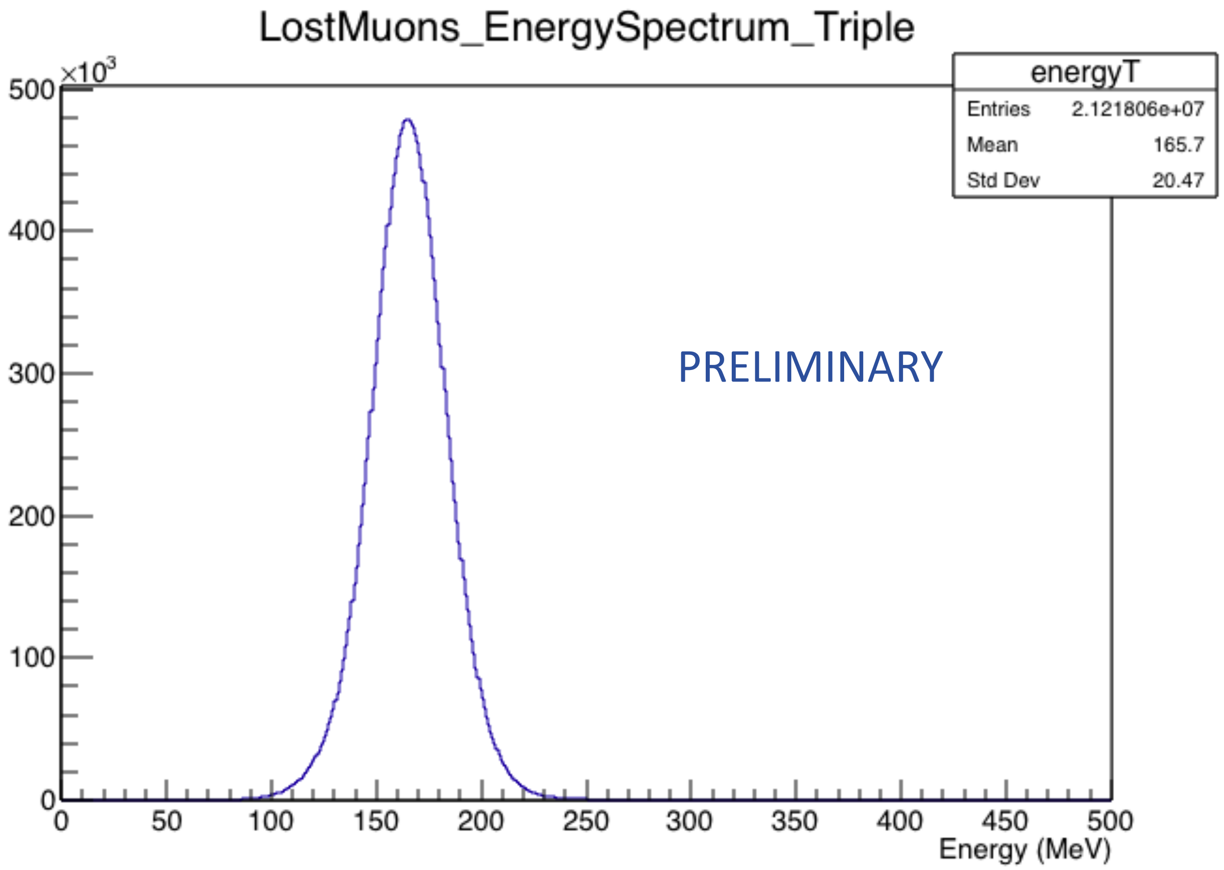
Double Coincidences



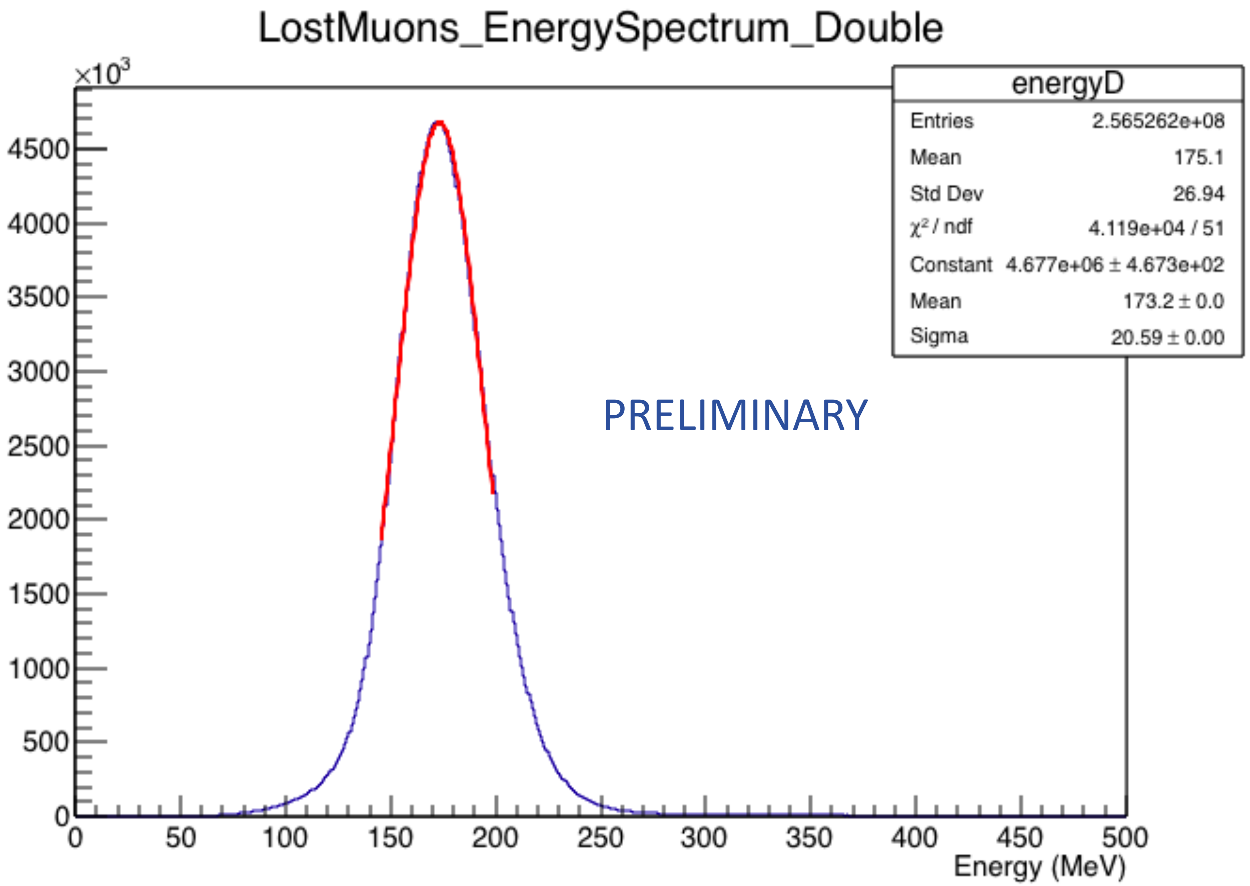
Triple Coincidences

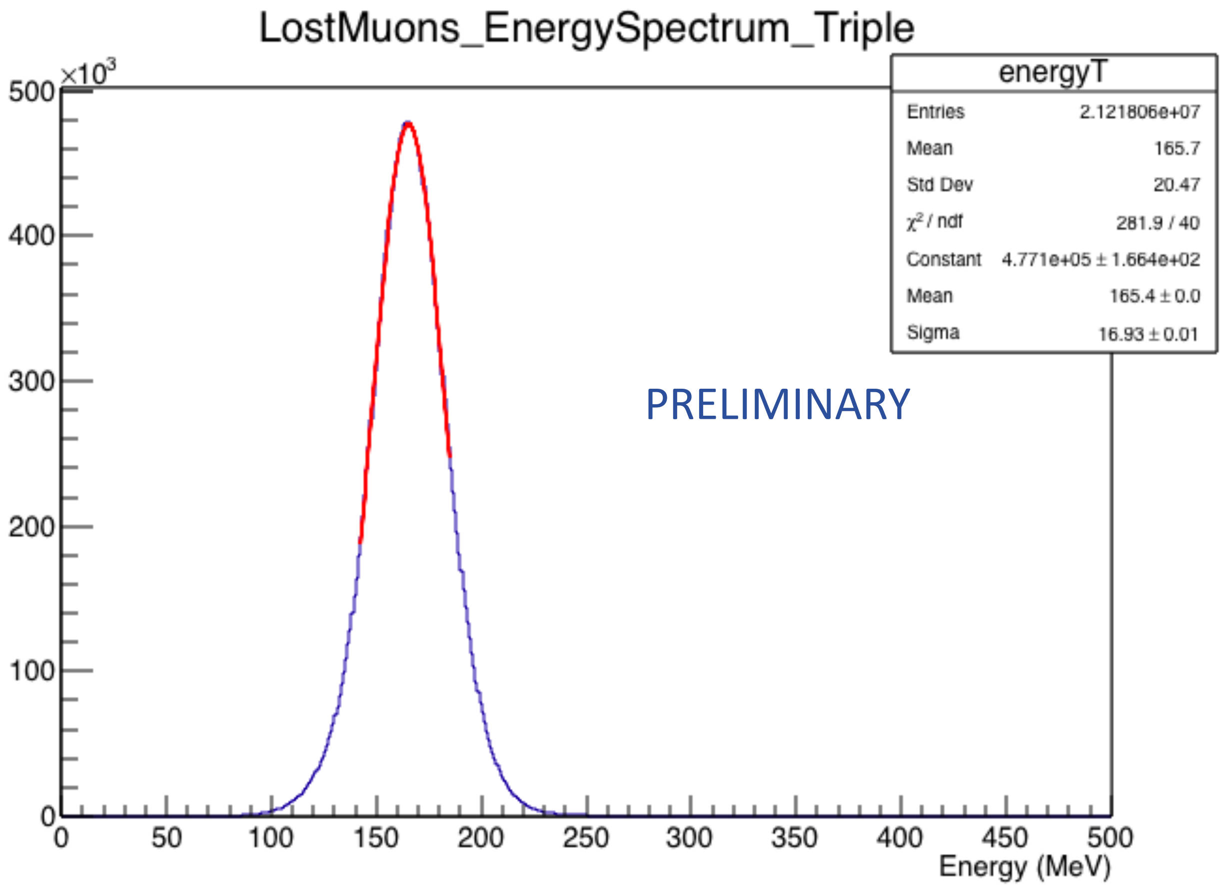
Energy Spectrum



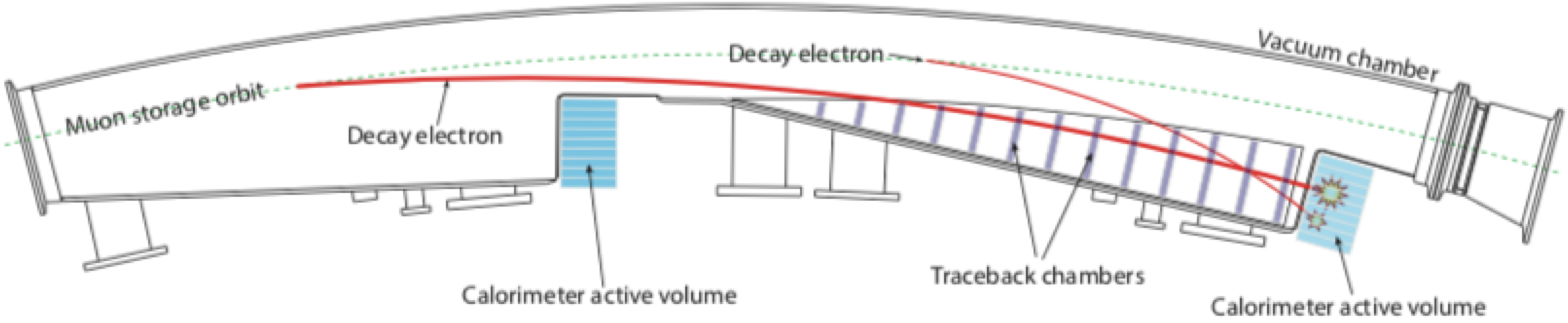


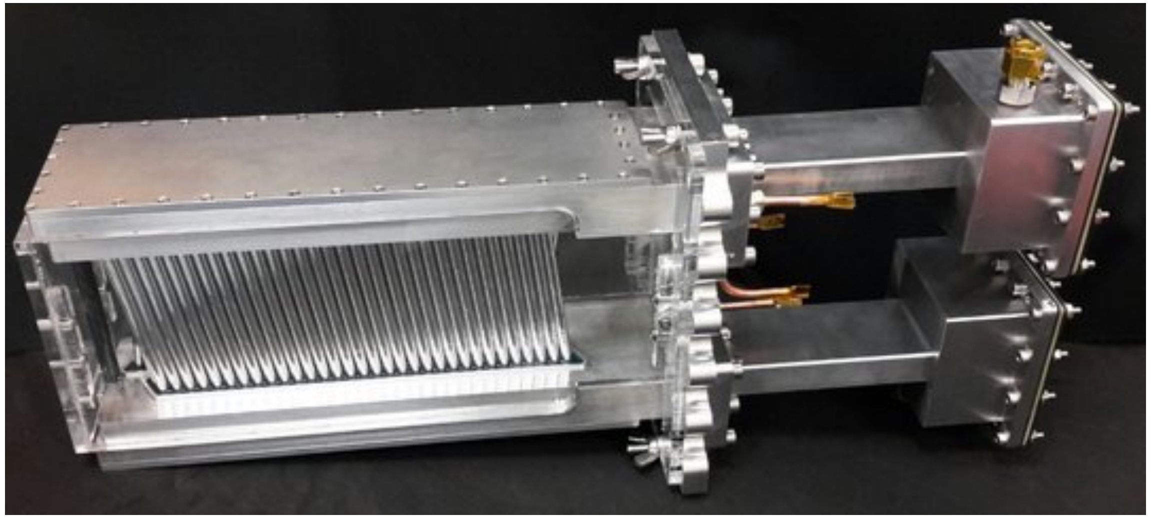
Energy Spectrum





Tracker Detector

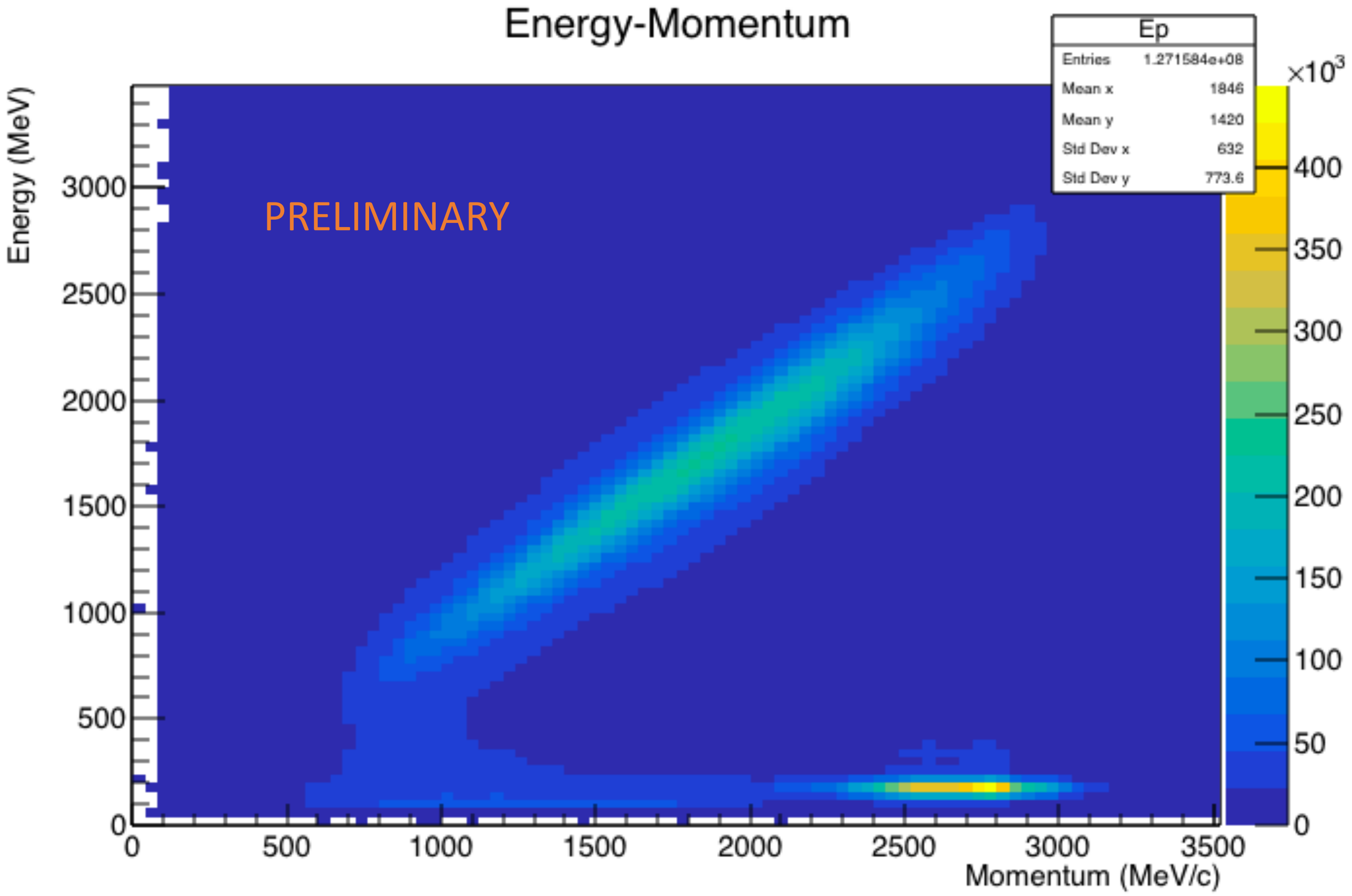




Straw tracker to measure the track of particles.

Can be used to measure the momentum from the curvature of the track → Identify particles

Tracker



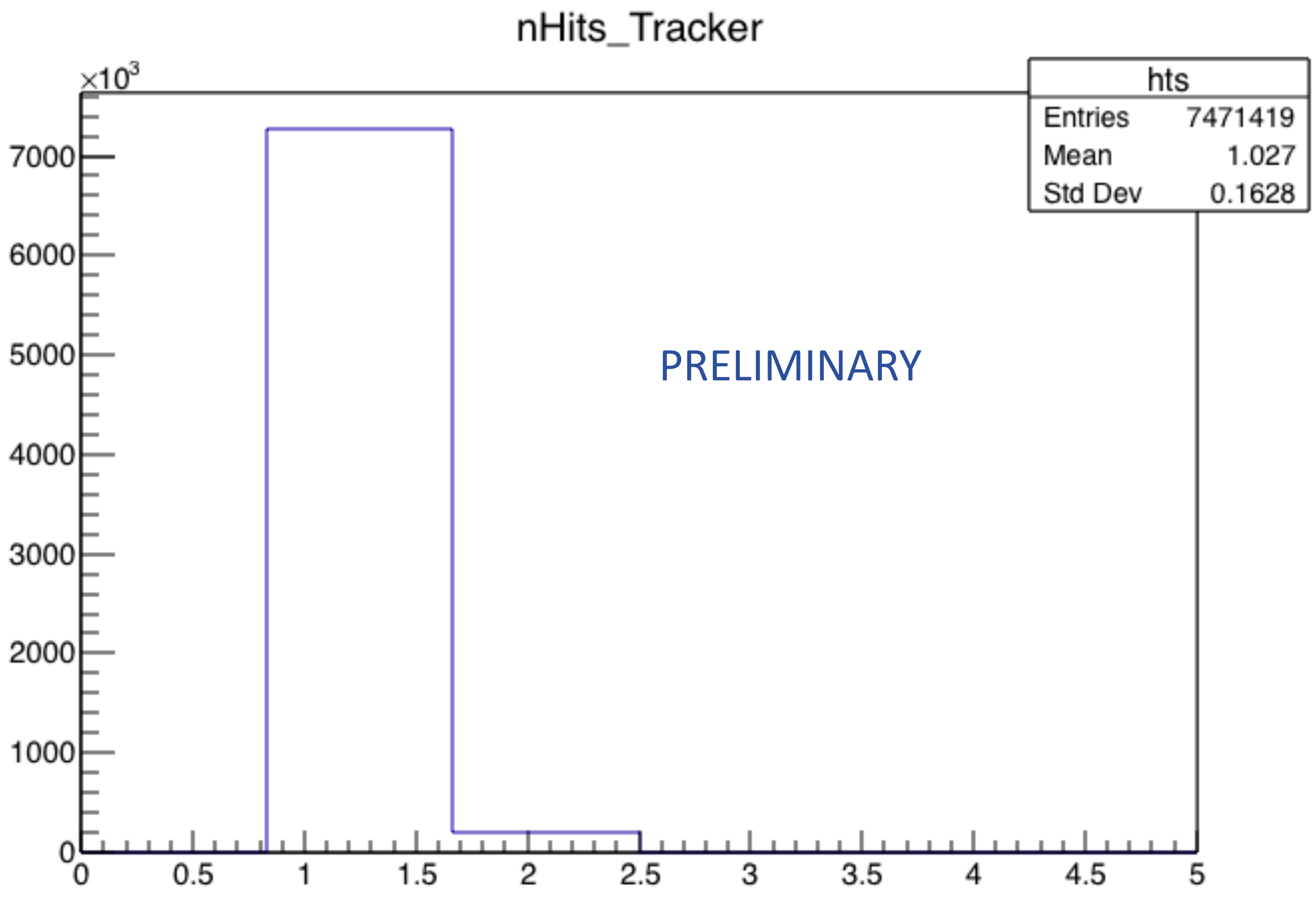
Energy-Momentum plot from the tracker-calorimeter matching.
We can see positrons on the diagonal:

$$m_e \approx 0 \;\rightarrow E \approx pc$$

Muons are in the region with high momentum and small energy deposit.

In this way we can cut on muon events.

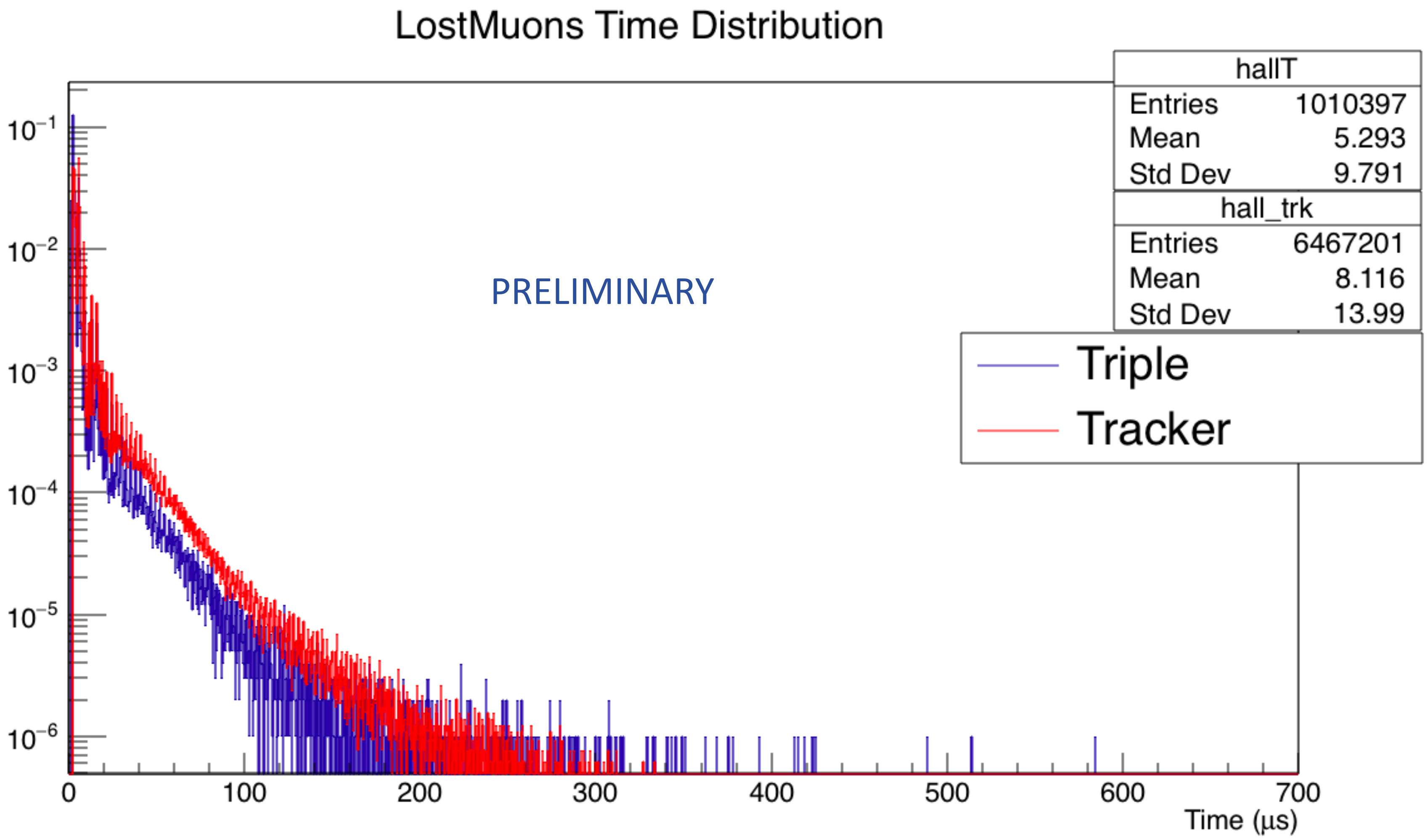
Tracker



Selecting muons with the tracker:
High momentum and small energy loss

The tracker suggest that only a small amount of muons «fire» more than a crystal, so we can use nHit=1 to cut positrons events without loosing statistics on muon events.

Time Distribution - Tracker



The «Triple» curve is calculated with the triple coincidences module.
The «Tracker» one comes from selecting muons with tracker.
Both curves are normalized to their integral.

Conclusions

- The double/triple coincidences works as expected;
- Absolute energy calibration with MIP peak is possible;
- Use the MC to relate the energy spectrum in ADC to the energy of the particles.

Conclusions

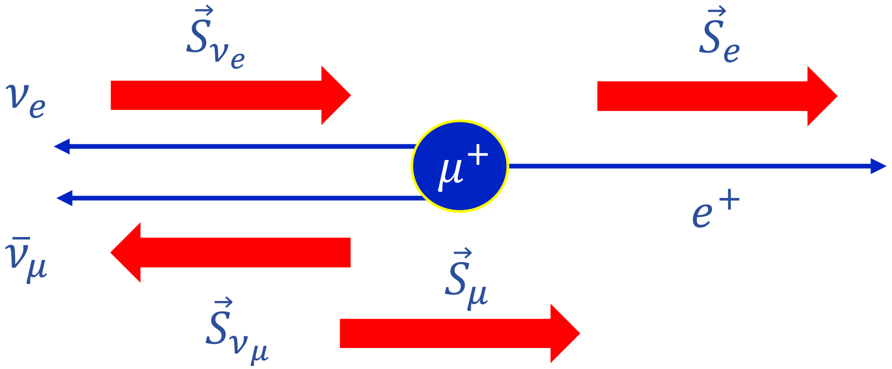
- The double/triple coincidences works
- Absolute energy calibration with MIP peak is possible
- Use the MC to relate the energy spectrum in ADC to the energy of the particles

The journey is just at the beginning…

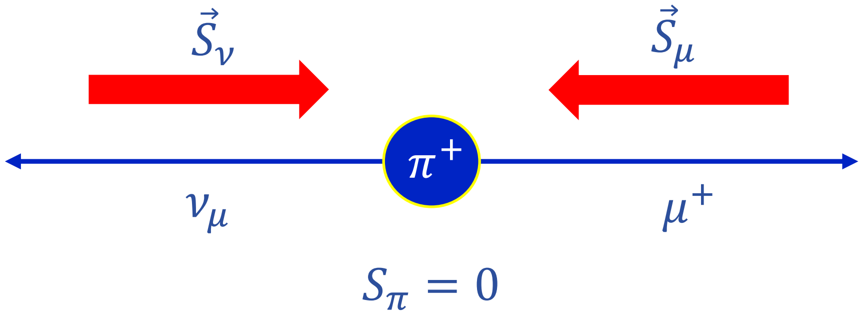
Thank You! Any Question?

Spares

Spin Configuration

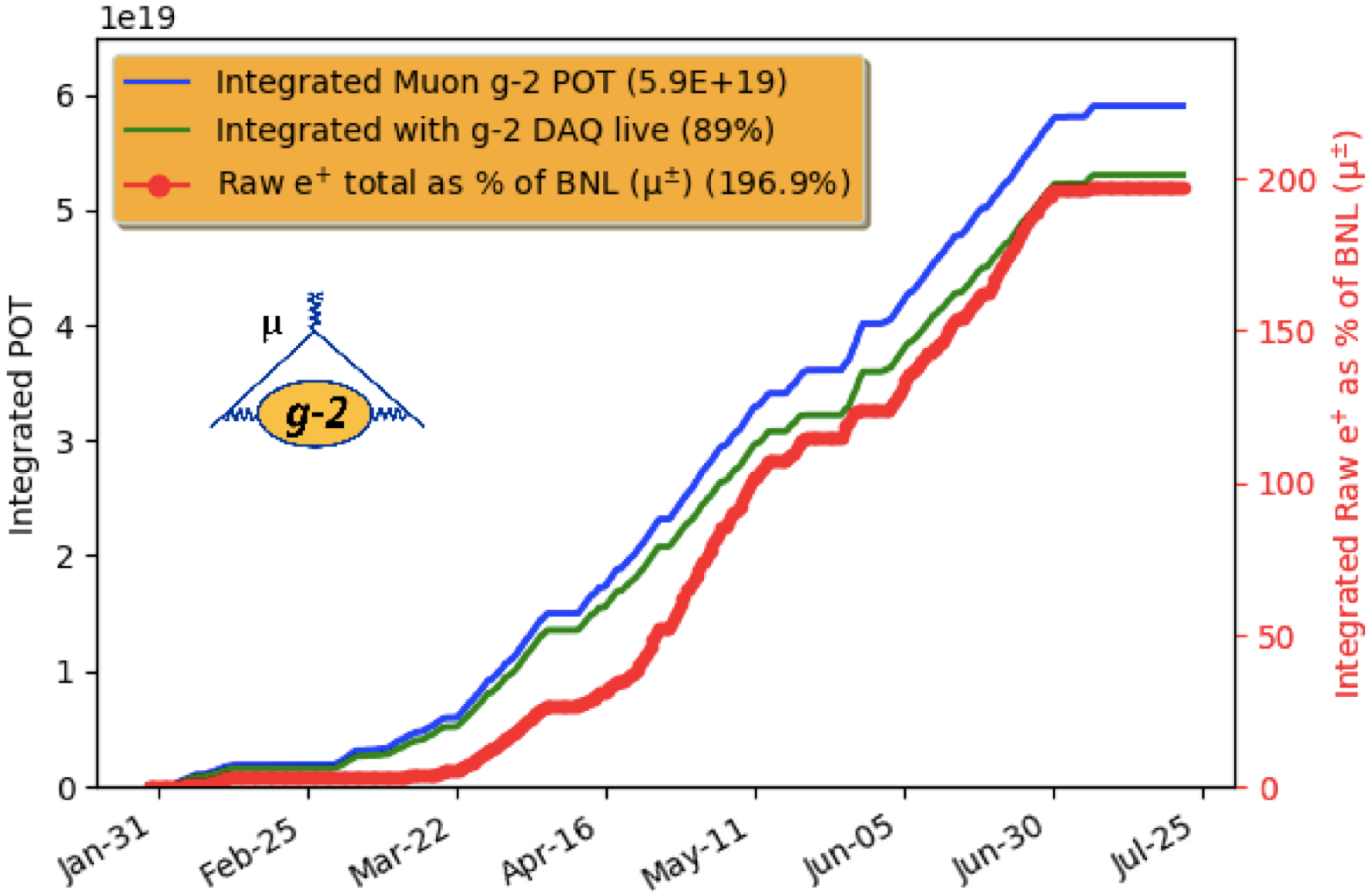


Muon Decay



Pion Decay

Where are we now?

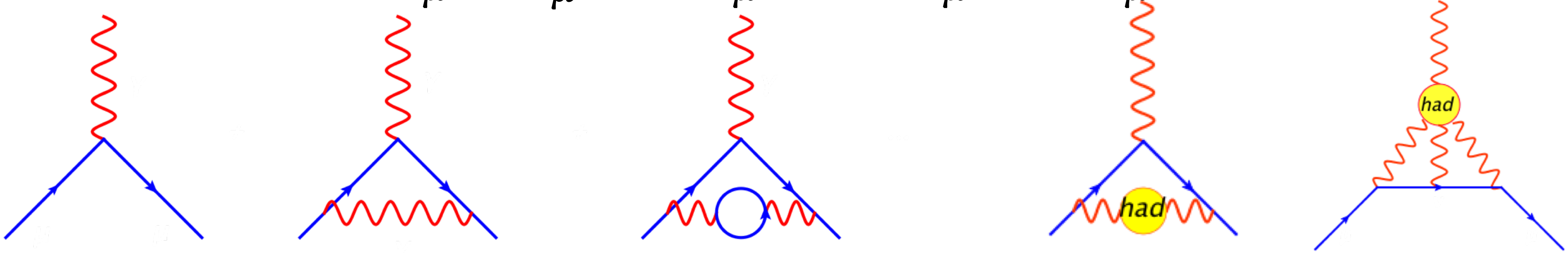


The g-2 value

Dirac Equation naturally predicts the gyromagnetic factor: $g = 2$

Standard Model corrections give contribution to the value. Define $a_\mu = \frac{g-2}{2}$.

$$a_\mu = a_\mu^{QED} + a_\mu^{Weak} + a_\mu^{HVP} + a_\mu^{Hl\times l}$$



A discrepancy of $3 \div 4\ \sigma$ (found in 2001 by BNL, not yet confirmed) can be the evidence of BSM physics contributing to the g-2 value.