Simulations for the PEPS detector

Andrea Parenti and Ioana C. Mariș

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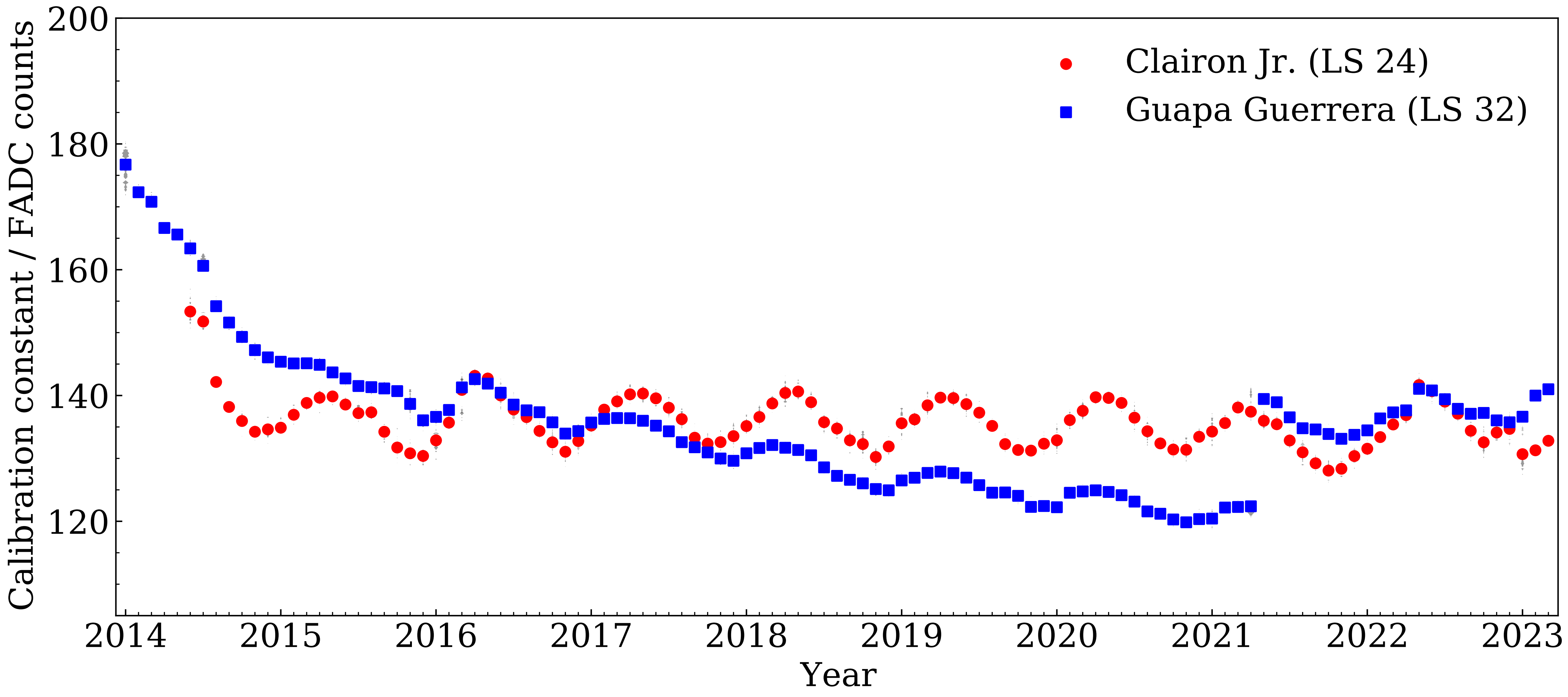
What’s the goal of these simulations?

Two prototype detectors installed in 2014 at the Pierre Auger Observatory.

Standard Auger tank geometry, with addition of an inner layer:

$d = 3.6$ m , $h_{tot} = 1.2$ m; $h_{bottom} = 0.8$ m $h_{top} = 0.4$ m

- Reproduce measured charge histograms with simulations
- Top PMT calibration with muon peak
- Simulate different tank geometries



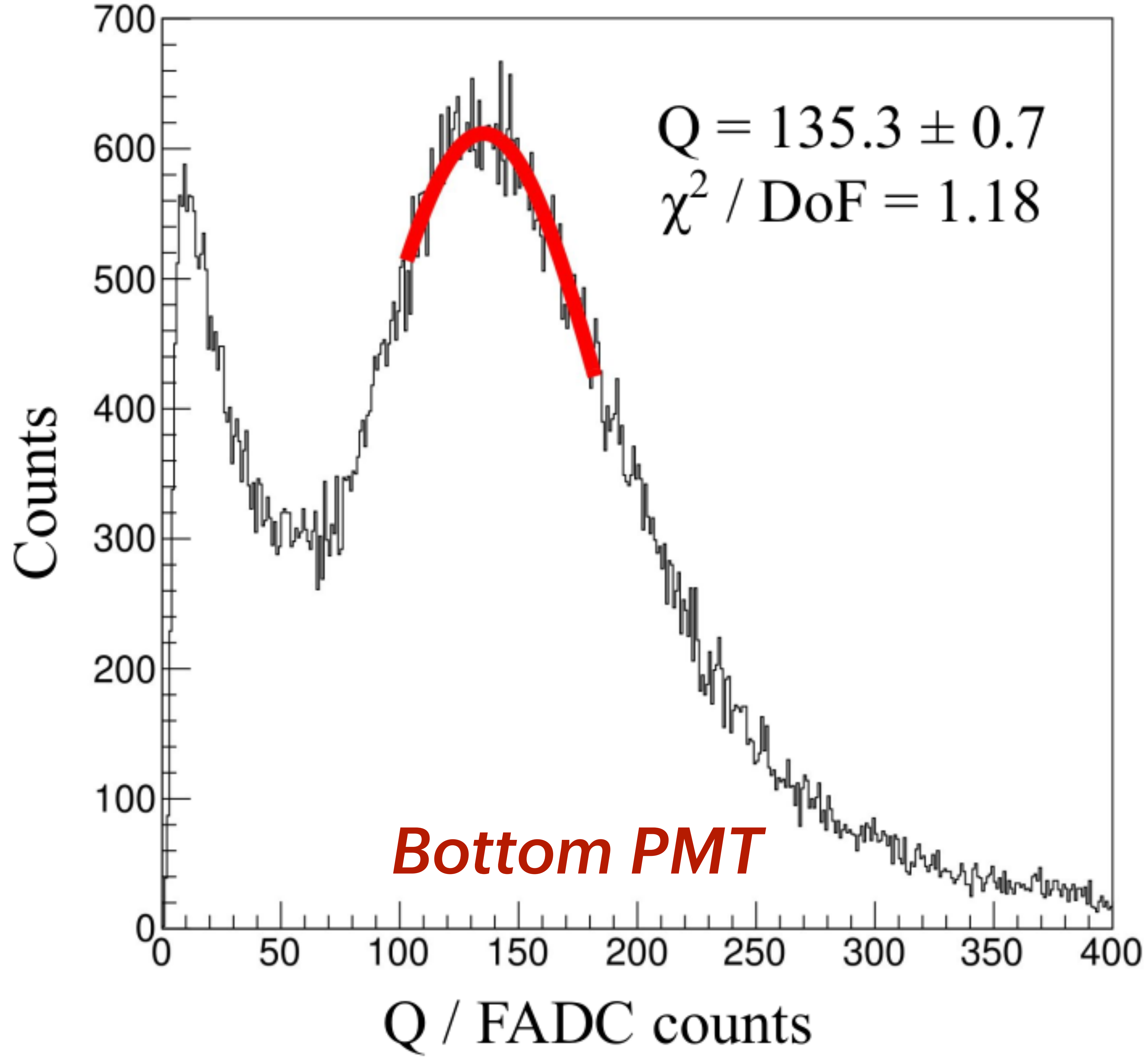
PMT calibration

Signal-over-theshold trigger.

The charge deposited by impinging muons forms a well-distinguished peak.

Its position is used to calibrate the PMT response.

In the top layer the energy deposited by electromagnetic particles and muons is similar. The peak is less distinguishable.



[A. Letessier-Selvon et al.]

[UHECR24 PoS B. Flaggs, I. Mariş]

Simulation set-up

Stand-alone simulation code by Pierre Billoir. Faster that a full GEANT4 simulation.

10^5 particles simulated in ~10 min.

Easy customization.

```
InputFile            allpart.dat
SampleMode           SINGLE
ArrayFile            regular_array
TankProperties       tank_properties_rndm
OutputName           testb
PrintTrace           200
PrintSummary         1
Noutput              5
SampleNRepeat        1
SampleRmin           300.
SampleRmax           2100.
SampleRthin          800.
SampleDeltaR         .01
SampleDeltaAzi       .015
SampleEMWeightFactor 1.
SampleMuWeightFactor 1.
```

SINGLE mode : simulate particles from InputFile on a single tank

SHOWER mode: specify array geometry in ArrayFile and get tank response to a CORSIKA shower from InputFile

Separate file to specify tank geometry, including double lining, number and position of PMTs, optical properties, ...

Simulation set-up

```
Rtank  1.5
Htank  1.3
Zsplit  .8
Npmt    4
Npt_up  3
PMT_X,Y,Z,Rsphere
 1.039   0.600  1.300   0.190
-1.039   0.600  1.300   0.190
 0.000  -1.200  1.300   0.190
 0.000   0.000  0.800   0.190
```

→ Specify tank radius, total height, height of bottom layer, PMT number and position

Simulated processes:

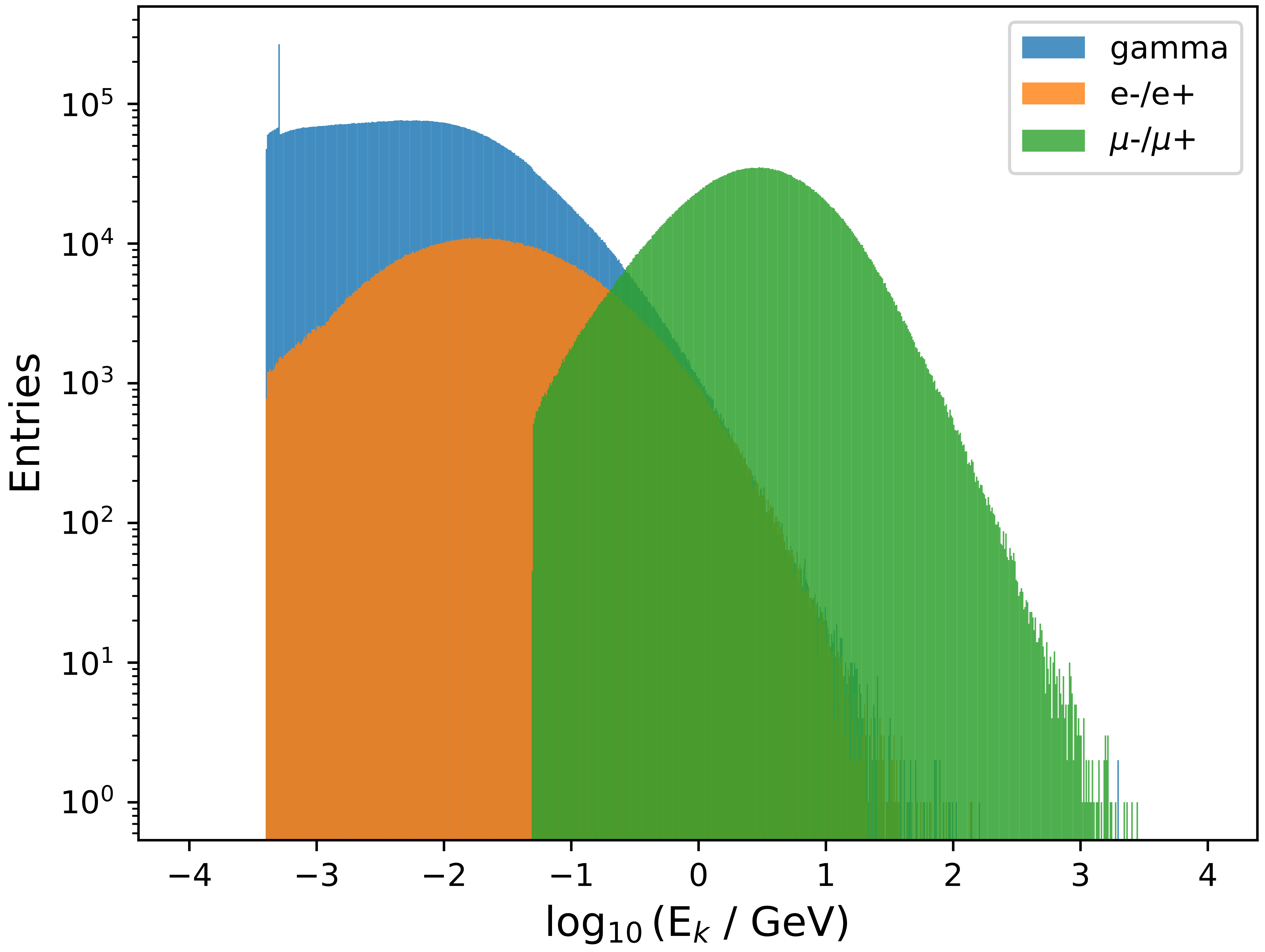
- Muon: ionization energy loss, decay, delta rays
- Electron: ionization energy loss, Bremsstrahlung, multiple scattering
- Gamma ray: Comtpon scattering, pair production

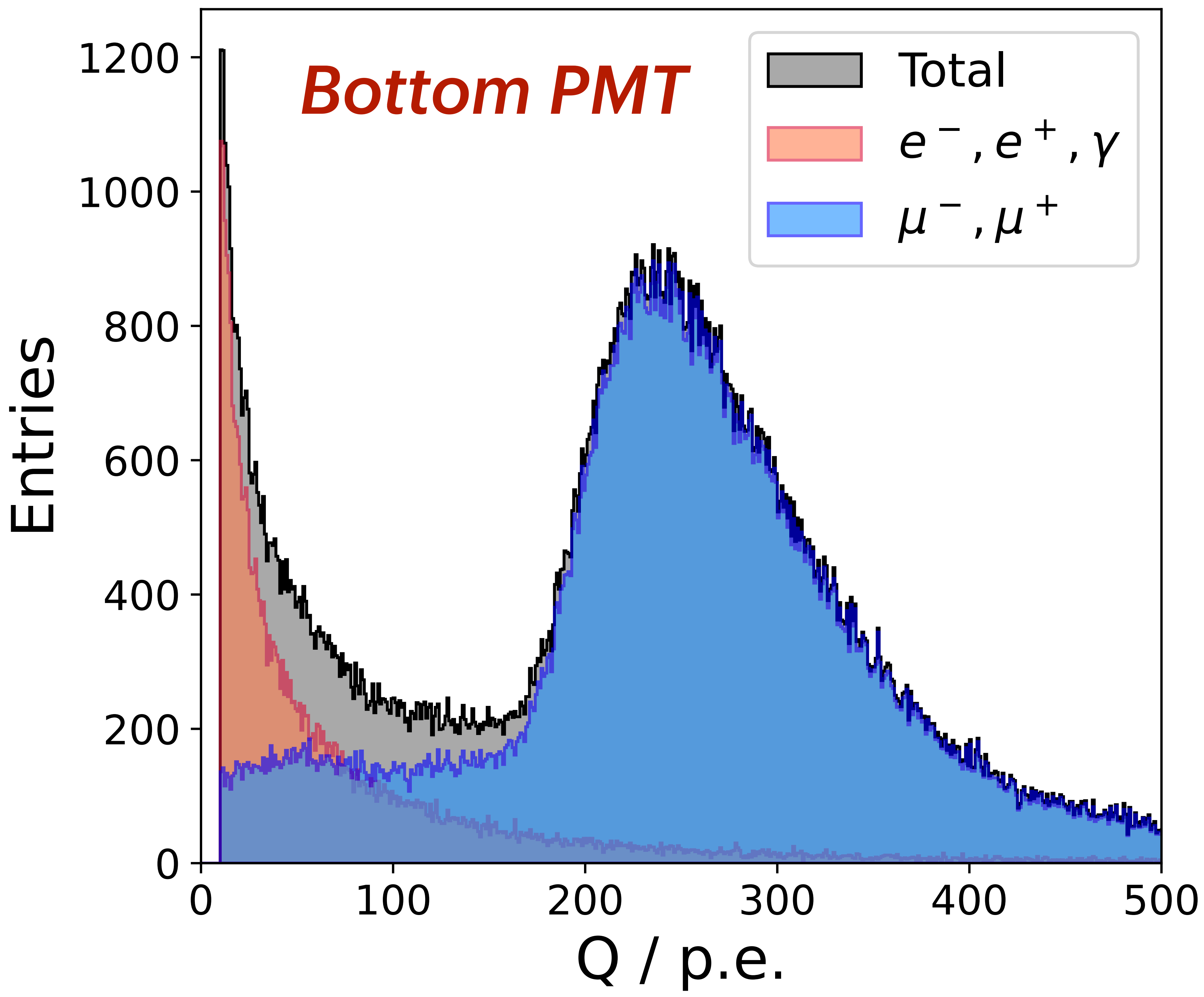
Produce Cherenkov photons for all charged particles above threshold

Reproducing prototype data with simulation

Tank response to secondary particles from low-energy CORSIKA air showers is simulated (10 GV - 10 TV)

The simulation reproduces well the charge histogram in the bottom PMT.

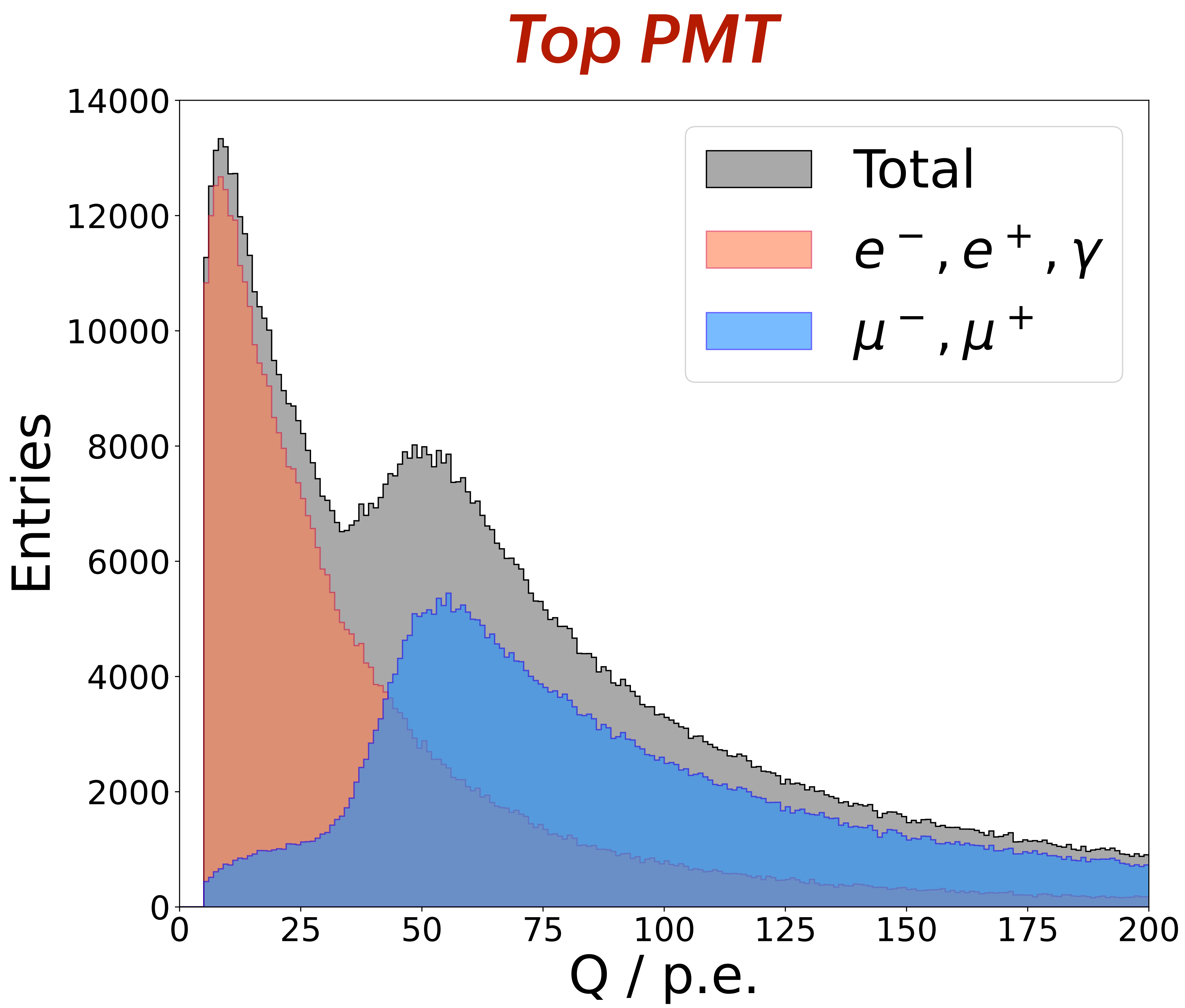


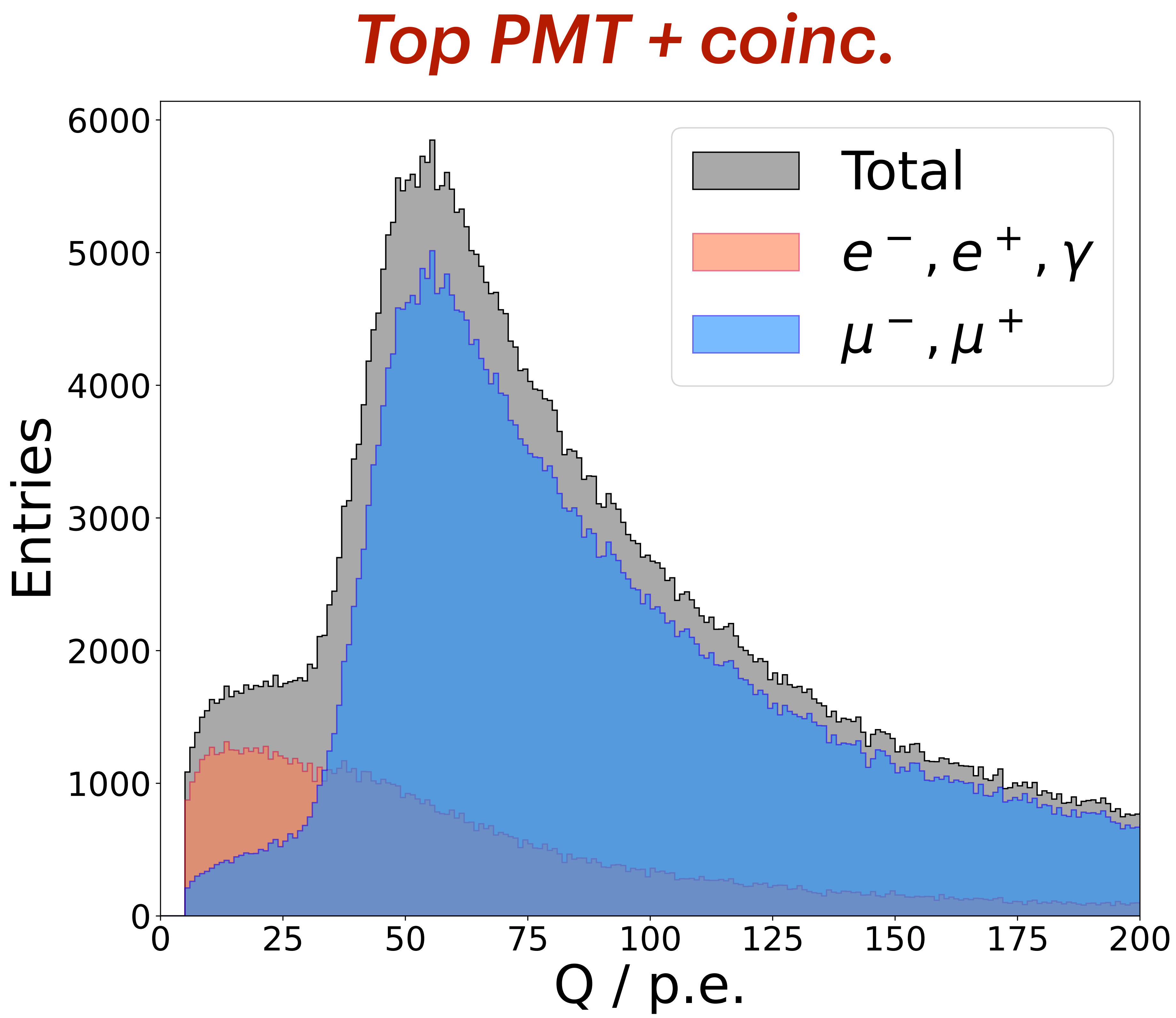


Top PMT calibration with a coincidence request

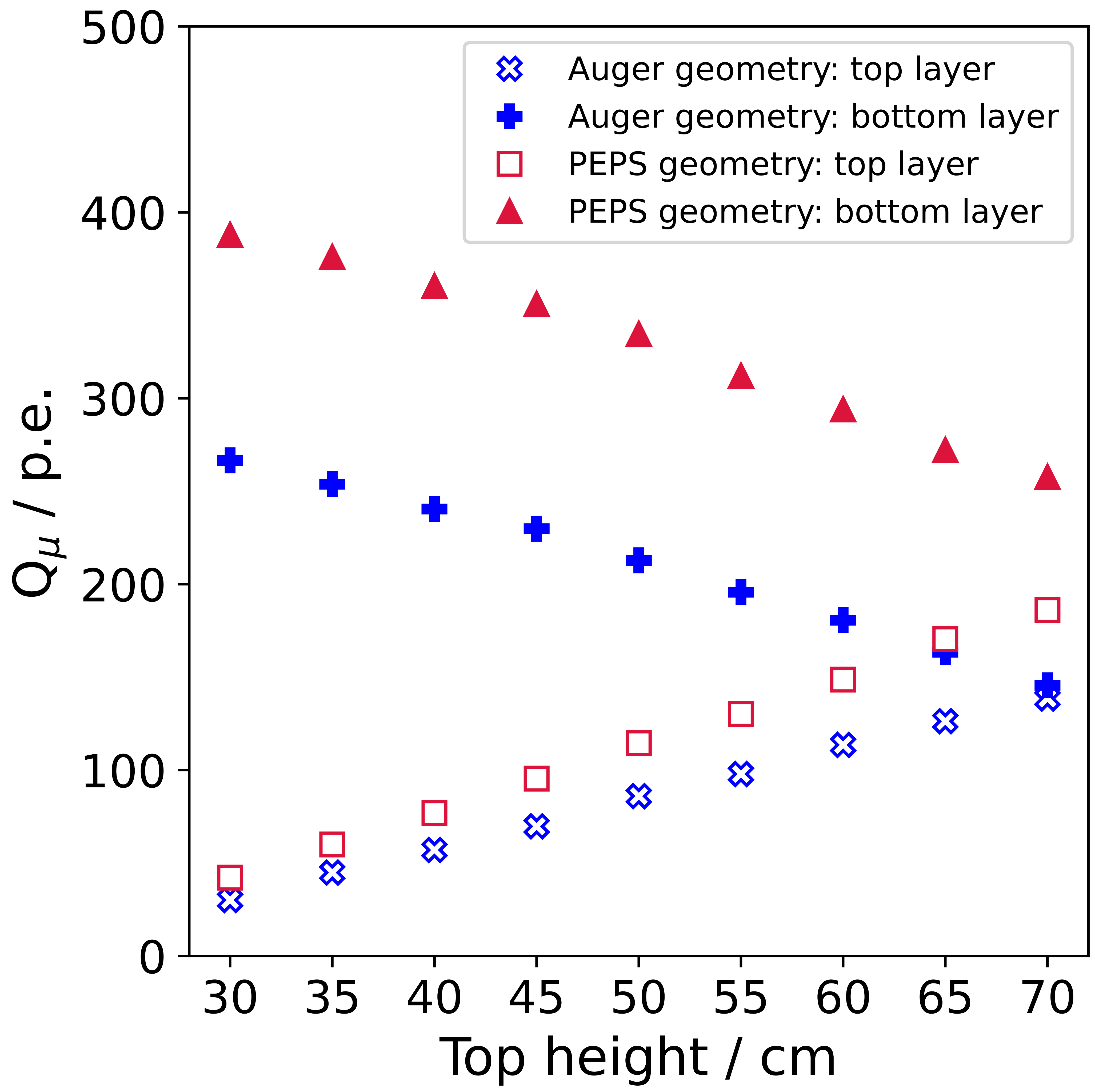
In the top layer, the muon hump is partially hidden by the decreasing e.m. distribution.

The request of a coincidence between top and bottom PMTs (≥ 10 FADC counts) removes the majority of the e.m. contribution.





Testing the PEPS tank size



Reduced diameter for easier transport and increased height of the top layer.

PEPS: d = 3.0 m , h_{bottom} = 0.8 m h_{top} = 0.5 m

Auger: d = 3.6 m , h_{bottom} = 0.8 m h_{top} = 0.4 m

Keeping the total height fixed, different top heights are simulated.

Overall the PEPS geometry leads to a greater measured charge with respect to the Auger tank.

Behavior to be further investigated.

[PoS-ICRC2025-354]

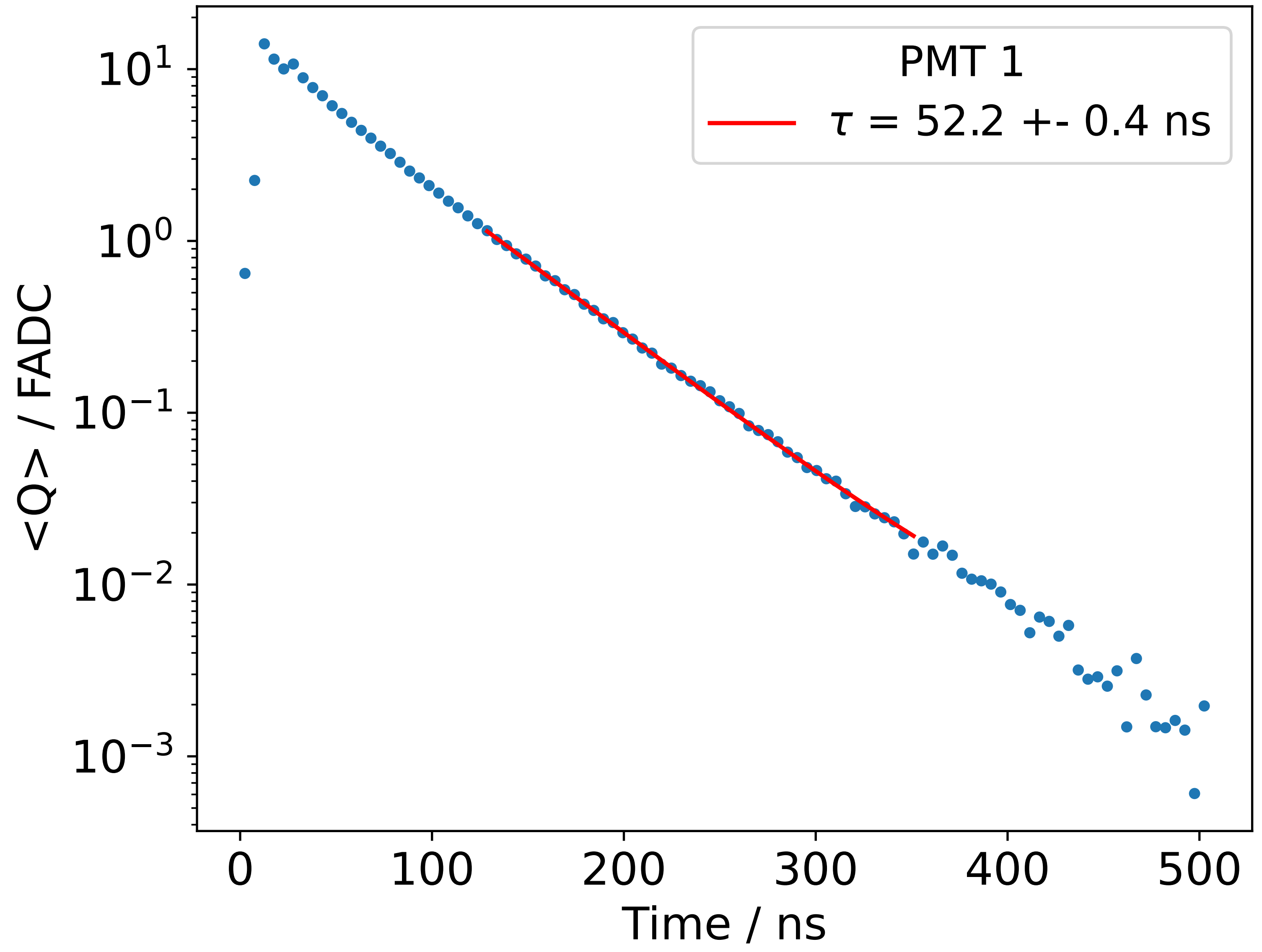
Time response of the tank to muons

The simulation also returns the time trace of the PMT signals.

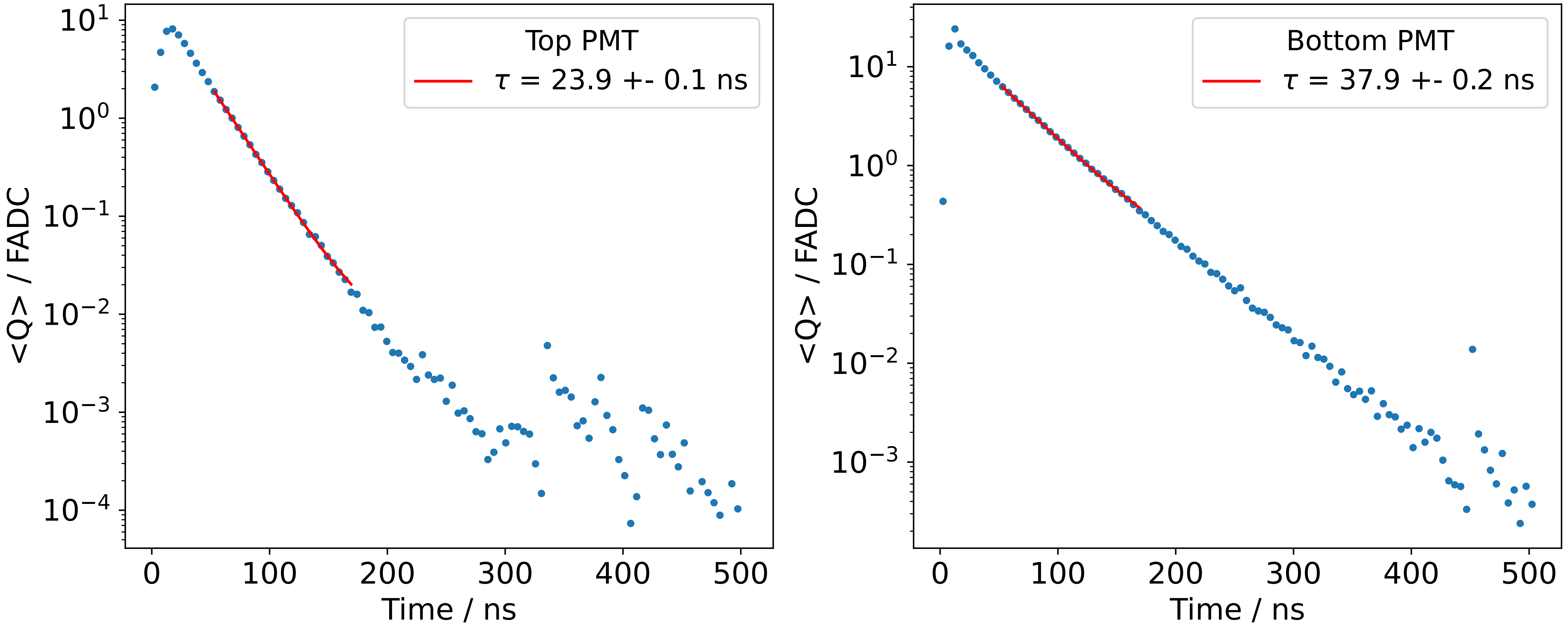
FADC sampling is simulated with a time bin width of 5 ns.

The average time trace is fit with an exponential.

Auger tank (no double layer)



PEPS



Conclusions

- Fast simulation well reproduces results from the prototypes.
- Top PMT calibration can be performed with a coincidence request with the bottom PMT.
- PEPS tank geometry (d = 3.0 m , h_{bottom} = 0.8 m h_{top} = 0.5 m) tested; obtained number of p.e. for muons increases (probably due to lower water absorption).
- Signal time constants for PEPS tank geometry: τ_{top} ~ 24 ns, τ_{bottom} ~ 38 ns.