

7 GeV/c beam events photo detectors response

Dante Totani

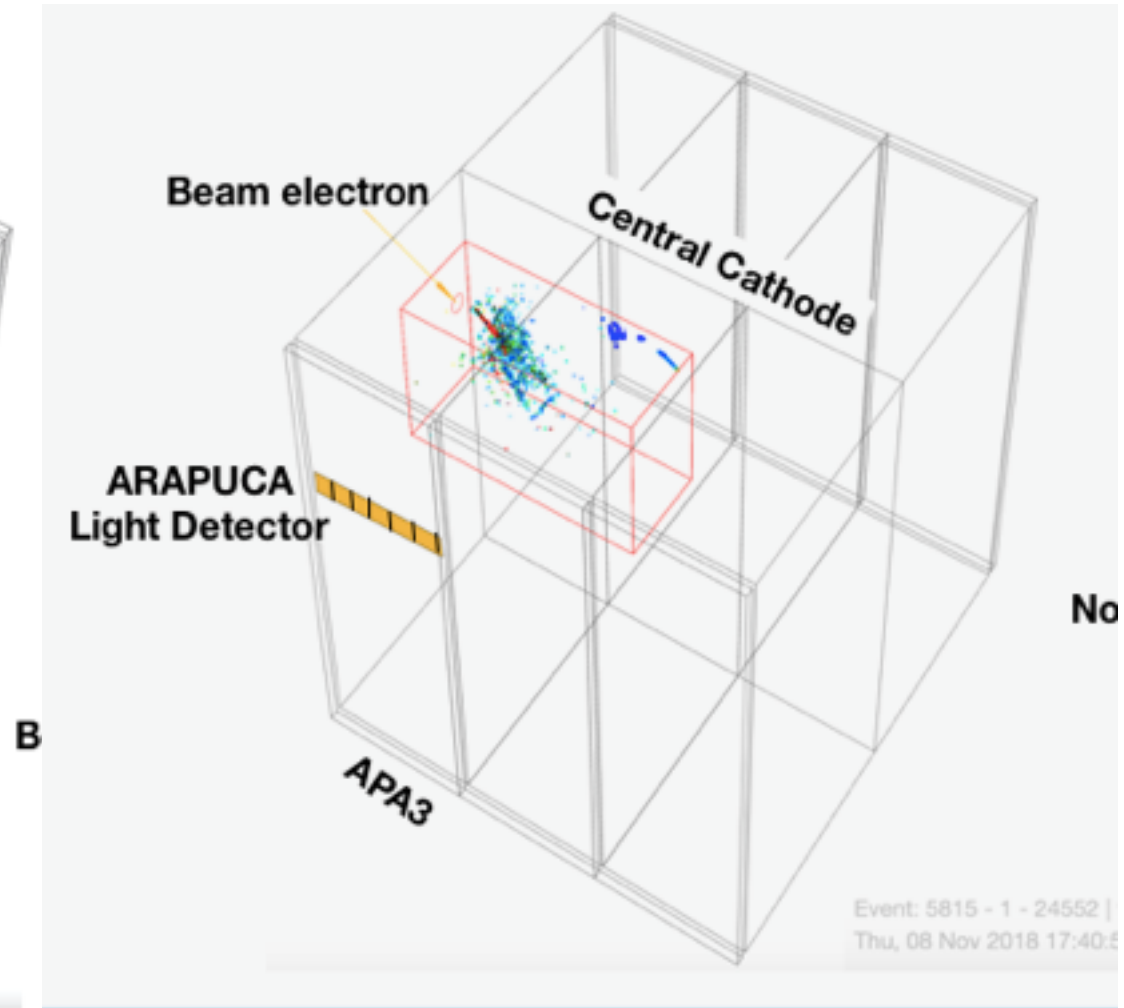
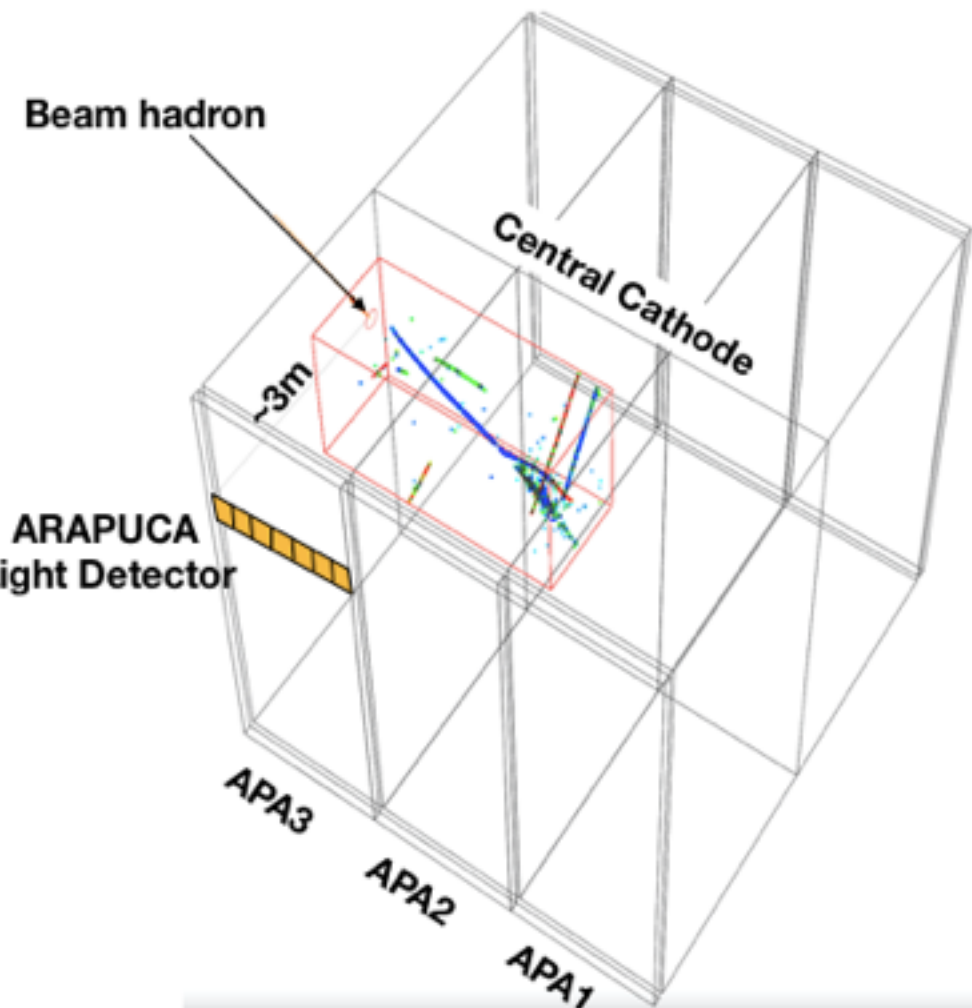
Fermilab - University of L'aquila

ProtoDUNE PDS Meeting
April 11th, 2019

In these slides is shown the Arapuca PD module, and then all the PD modules in the beam side, response to beam events, for Beam momentum of 7GeV/c.

Each kind of particle can be identified and compared to the others.

Hadrons shows common behavior, with some difference from electrons and muons



Particle identification for 7GeV/c

- Cherenkov PID

(HPC=1 LPC=1) -> Electron / Pion

(HPC=1 LPC=0) -> Kaons

(HPC=0 LPC=0) -> Protons

(HPC= High Pressure Cherenkov)

(LPC= Low Pressure Cherenkov)

- Signature from Pandora reconstruction

Shower-like -> Electron

Track-like -> Pion

- Time of Flight

ToF is useless at 7GeV/c

- Photons Spectra

Pions and Kaons spectra shows a second peak, that can be associated to Muons coming from their decay and can be well separated

The whole amount of 7 GeV/c are used in this analysis.

Electrons = 13143

Muons = 8941

Pions = 85878

Kaons = 7027

Protons = 13277

Total Event = 154598

Arapuca Sum Spectra

Spectra shows the photons sum detected by all the Arapuca per selected particles. Photons numbers have been got using the calibration that takes into account after pulses and cross talks.

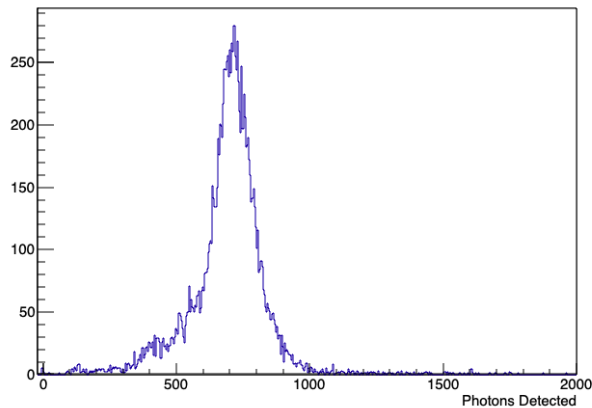
(To convalidate it, a similar calibration is in progress, using the new optimized runs)

Average number of photons per particles:

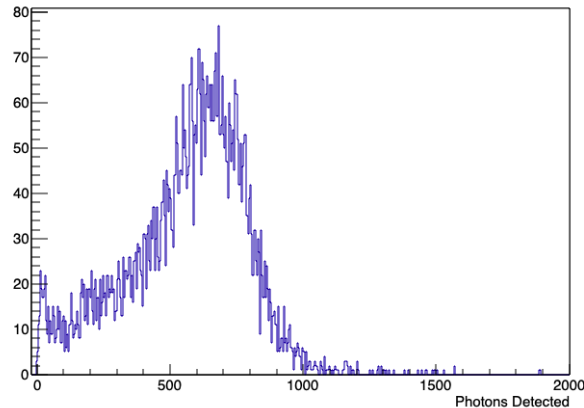
Electros: $\langle N_{ph} \rangle = 693$
Muons: $\langle N_{ph} \rangle = 128$
Pions: $\langle N_{ph} \rangle = 627$
Kaons: $\langle N_{ph} \rangle = 564$
Protons: $\langle N_{ph} \rangle = 534$

Remind: the momentum is fixed, the Kinetic Energy depends on the particle

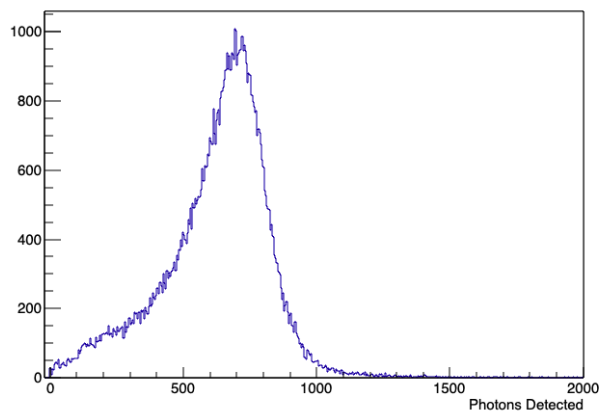
Arapuca Sum spectrum for Electrons of BM = 7 GeV/c



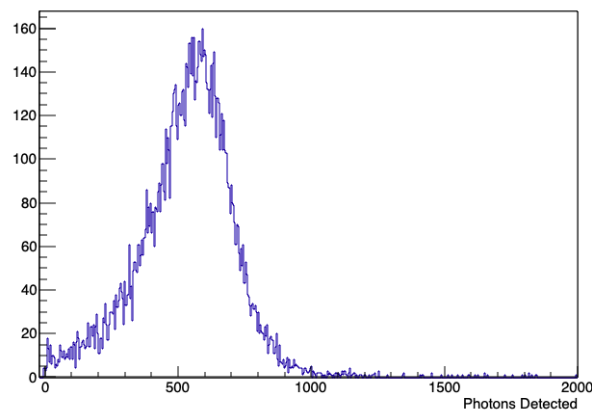
Arapuca Sum spectrum for Kaons of BM = 7 GeV/c



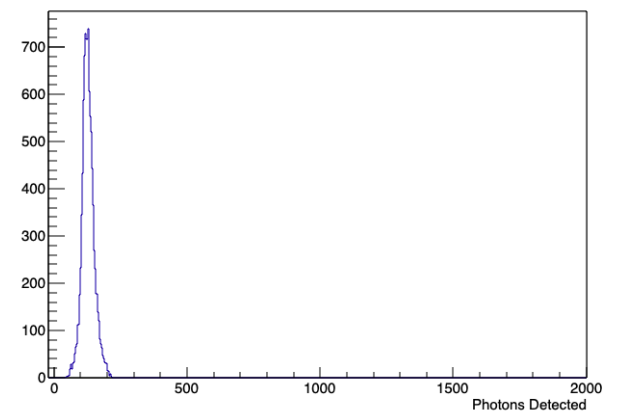
Arapuca Sum spectrum for Pions of BM = 7 GeV/c



Arapuca Sum spectrum for Protons of BM = 7 GeV/c

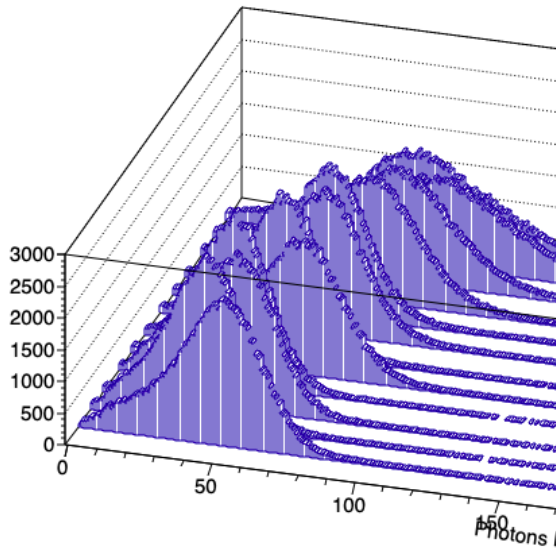


Arapuca Sum spectrum for Muons of BM = 7 GeV/c

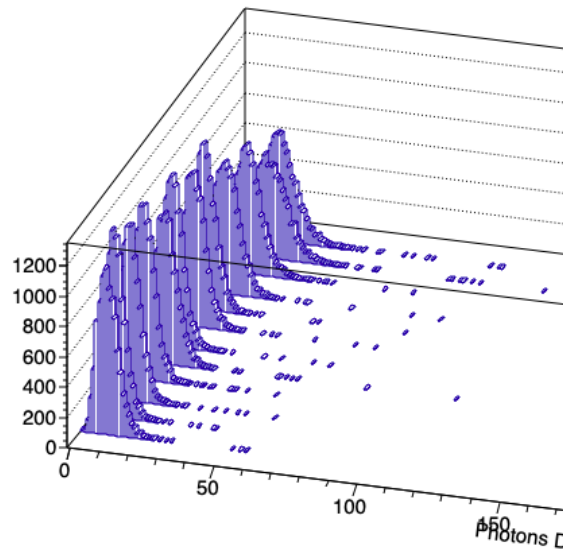


Arapuca Spectra cell by cell

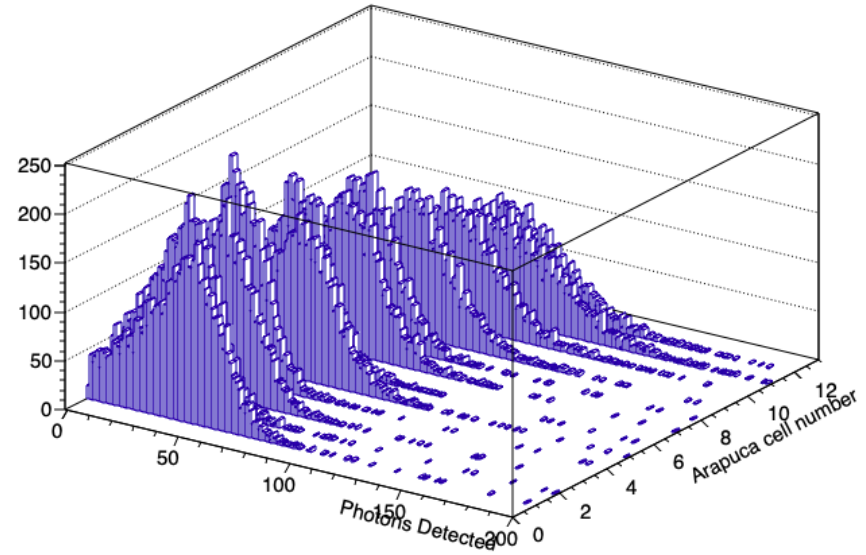
Arapuca single cell spectra for Pions of BM = 7 GeV/c



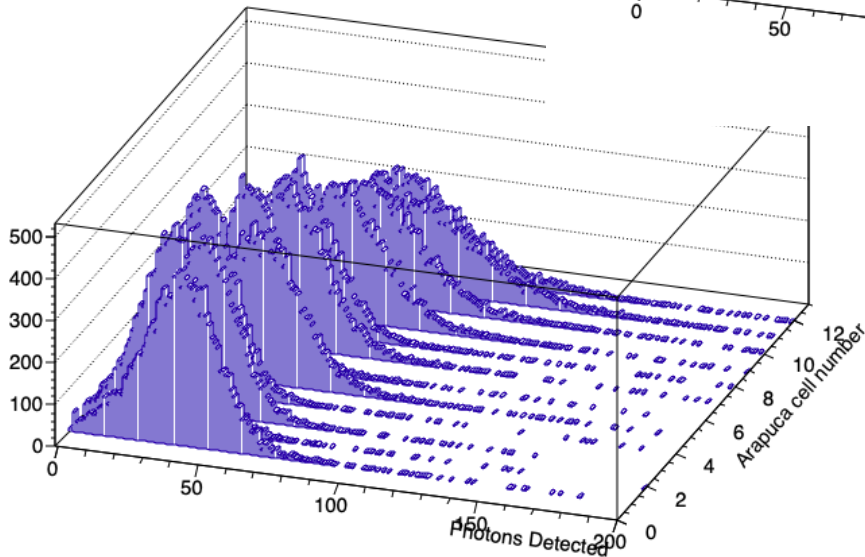
Arapuca single cell spectra for Muons



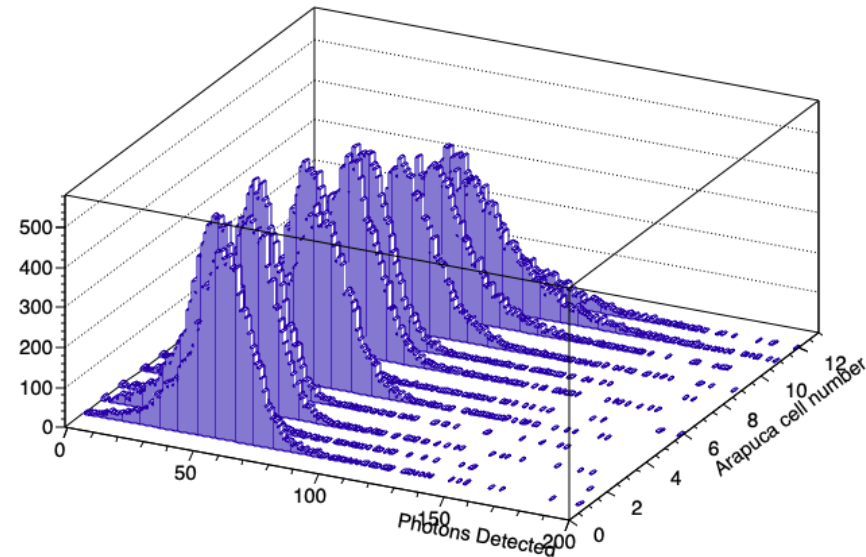
Arapuca single cell spectra for Kaons of BM = 7 GeV/c



Arapuca single cell spectra for Protons



Arapuca single cell spectra for Electrons of BM = 7 GeV/c

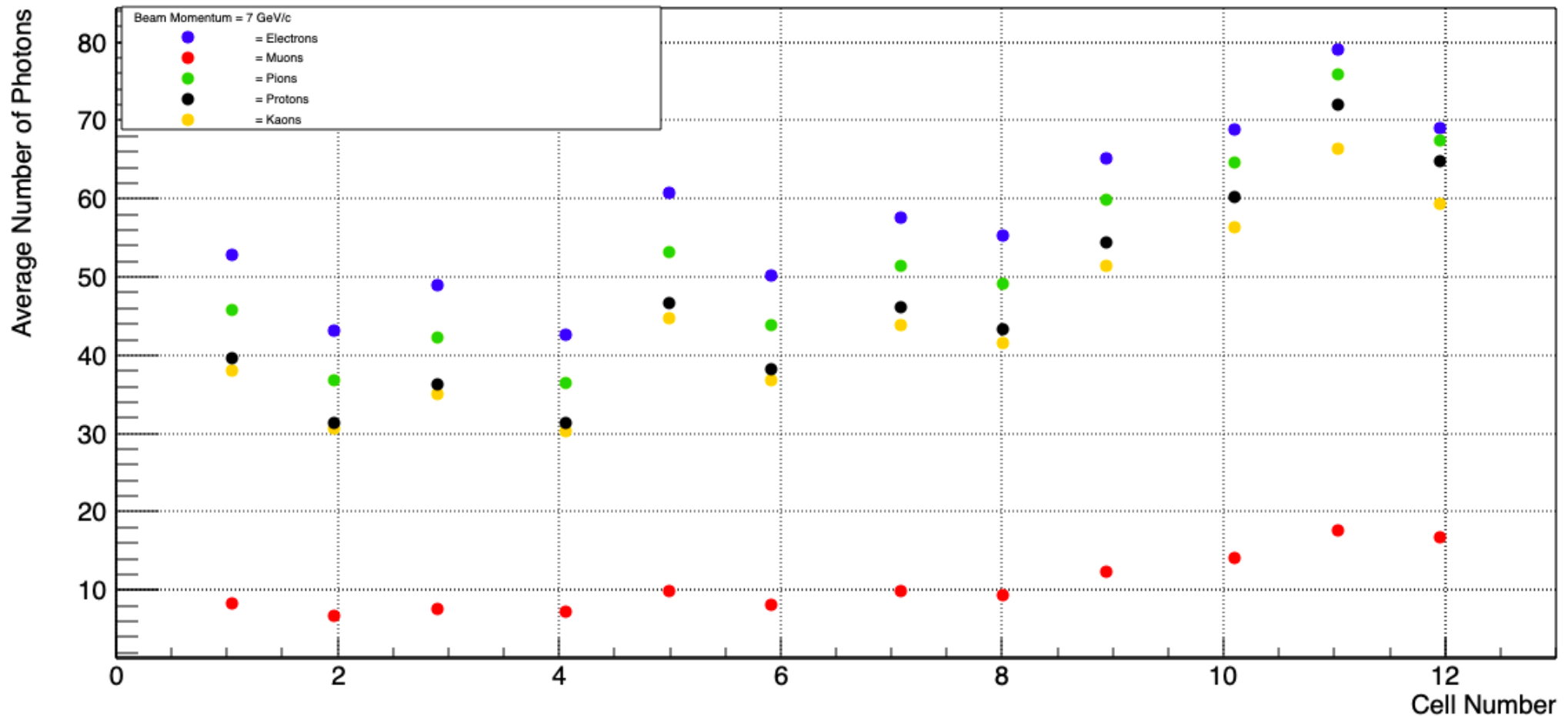


Arapuca $\langle Ph \rangle$ Detected cell by cell

Cell 1 = DAQ channel 132 , Cell 2 = DAQ ch 133 ,

The geometrical position have to be fixed, as well as, what are the channels with two Arapuca connected in parallele and the channels with only one Arapuca

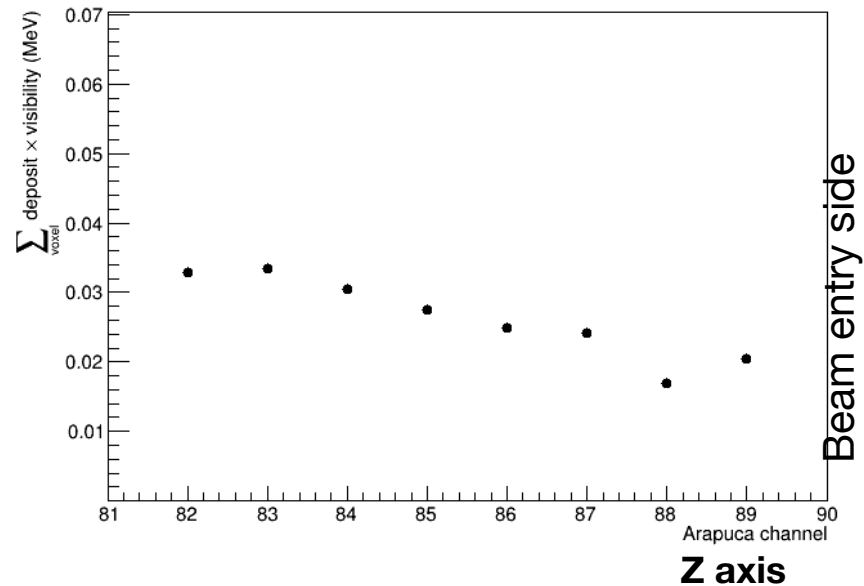
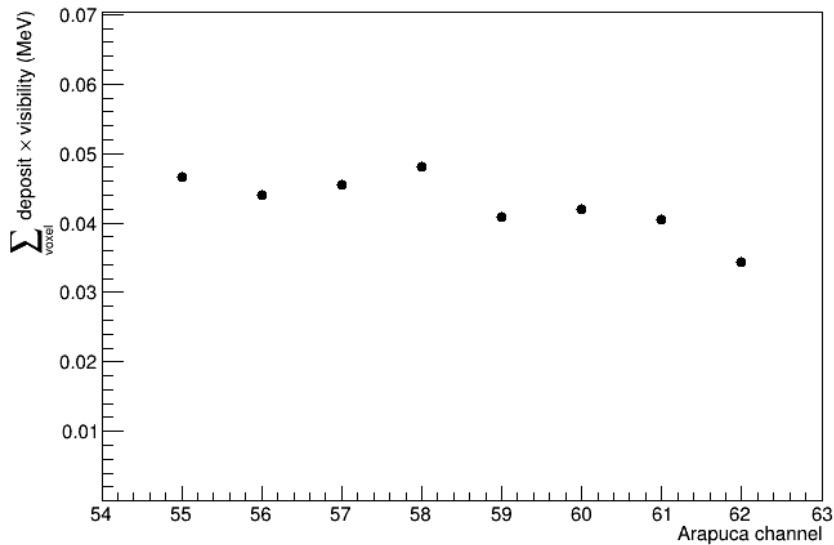
Average number of photons detected by each Arapuca cell per particle



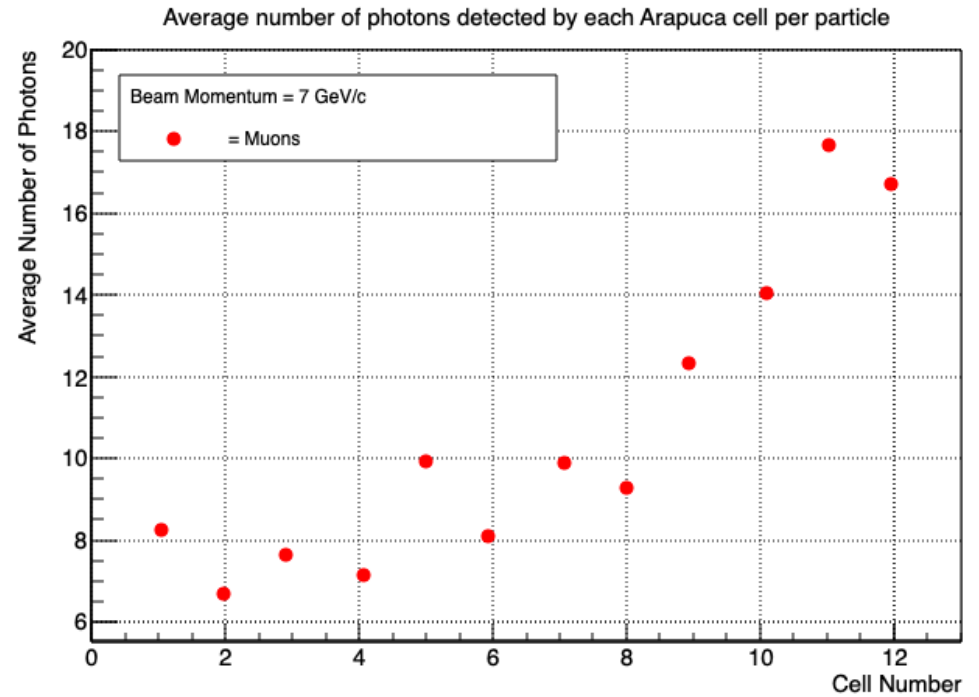
Muons: data & simulation

MC simulation has been made by **Laura Paulucci** and **Franciole Marinho**. The plots below show the fraction of energy deposited normalized the acceptance of each cell. The channel in MC have another labeling and the points are relatives to the Arapuca cells and not to the channels (12 channels for 16 Arapuca).

Simulation



Data



All PD modules - Beam Side response

For this analysis the calibration used is the one got from the PE separation, After Pulses and Cross Talks are not take into account.

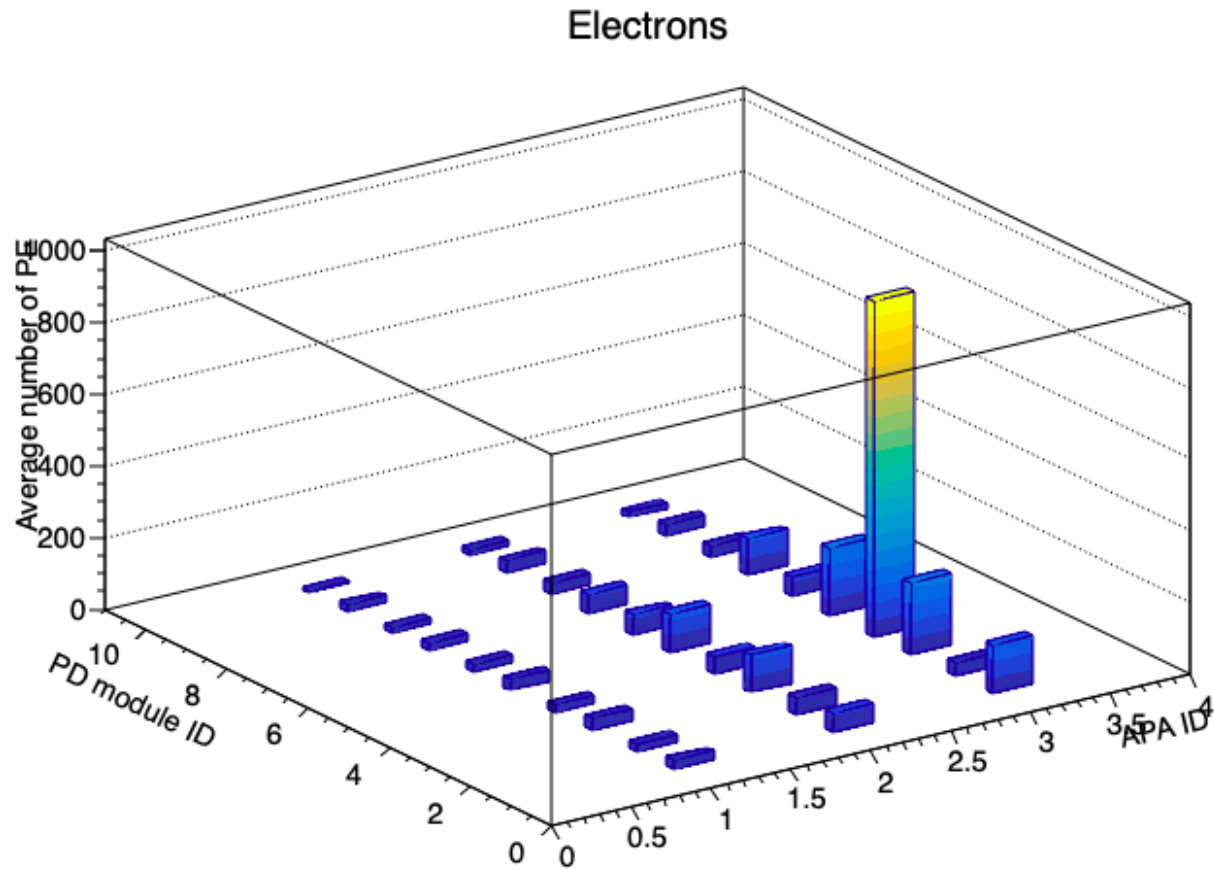
All the numbers are Photo Electrons measured (PE) and not Photons Detected (Ph).
(For MPPCs in Arapuca : PE=1.3 Ph. SensL should have less AP and CT)

Calibration used is the one made by Chris (SensL), Bryan (all the devices) and me (MPPCs in Arapuca). The PD modules with Bars and MPPCs are located all in the No-Beam side.

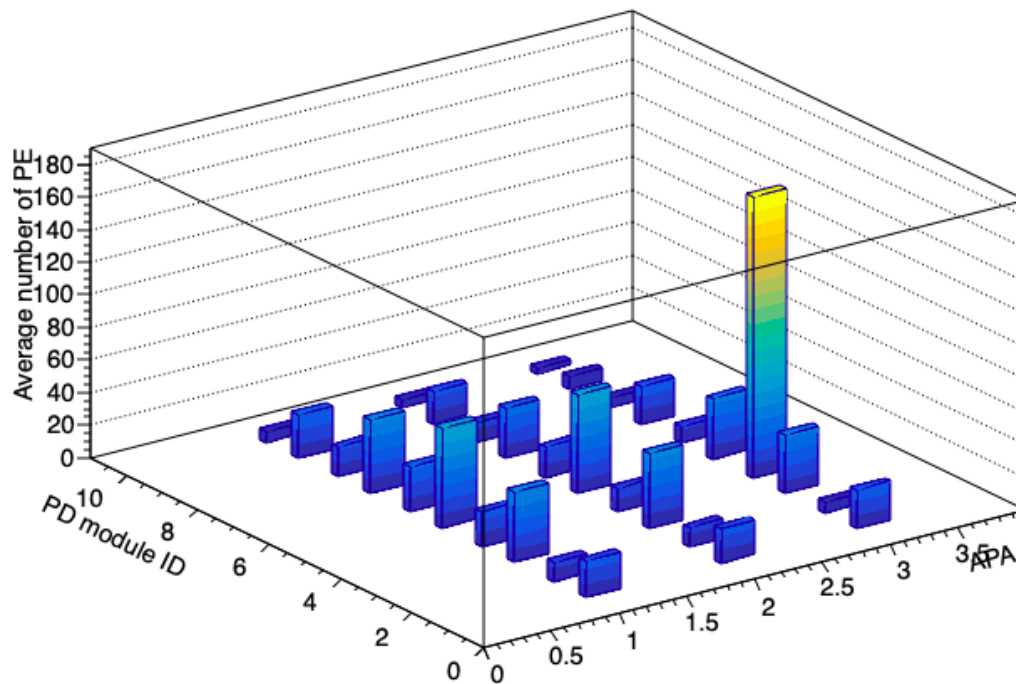
To be noted that:

The Arapuca PD module is composed of 12 channels reading 12 MPPCs each one, in two configurations.

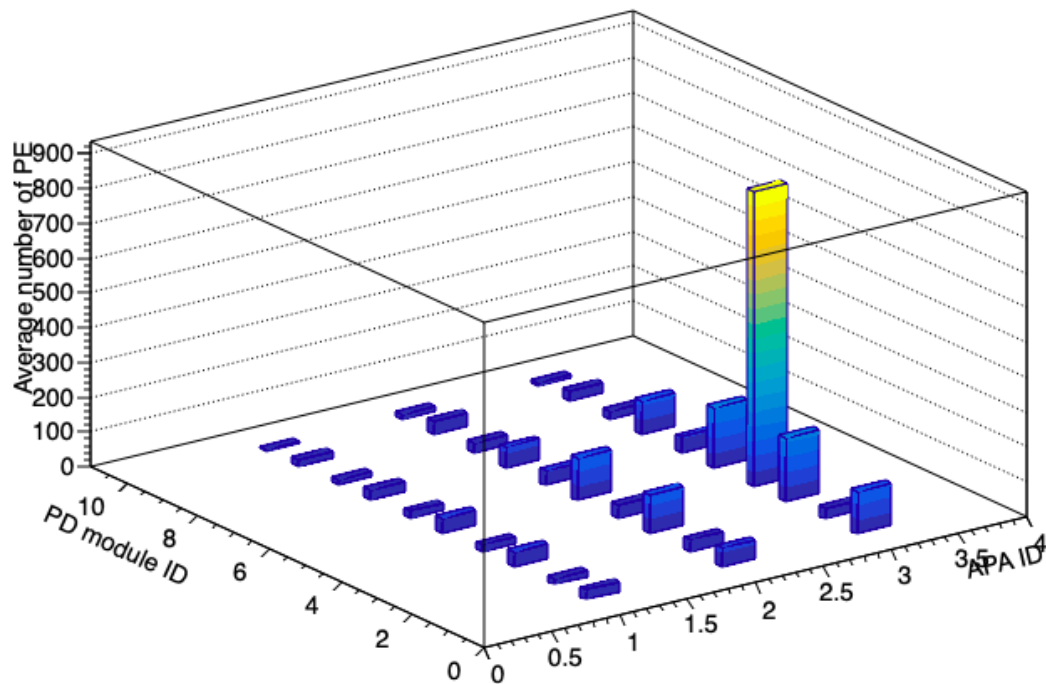
Each bar PD module is composed of 4 channels reading 3 SiPM each one.



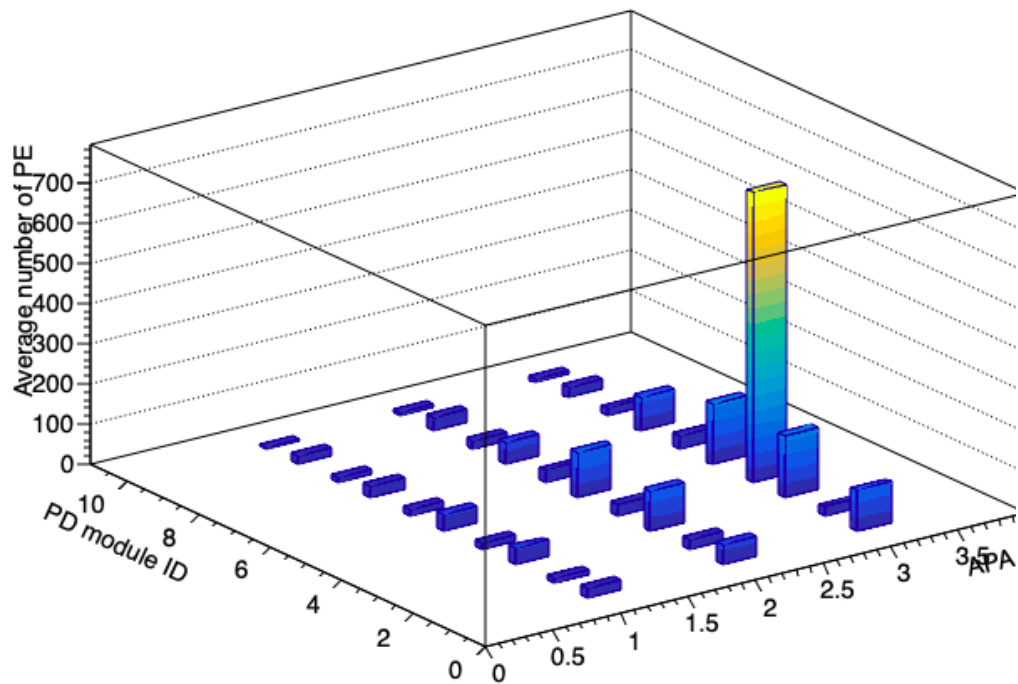
Muons



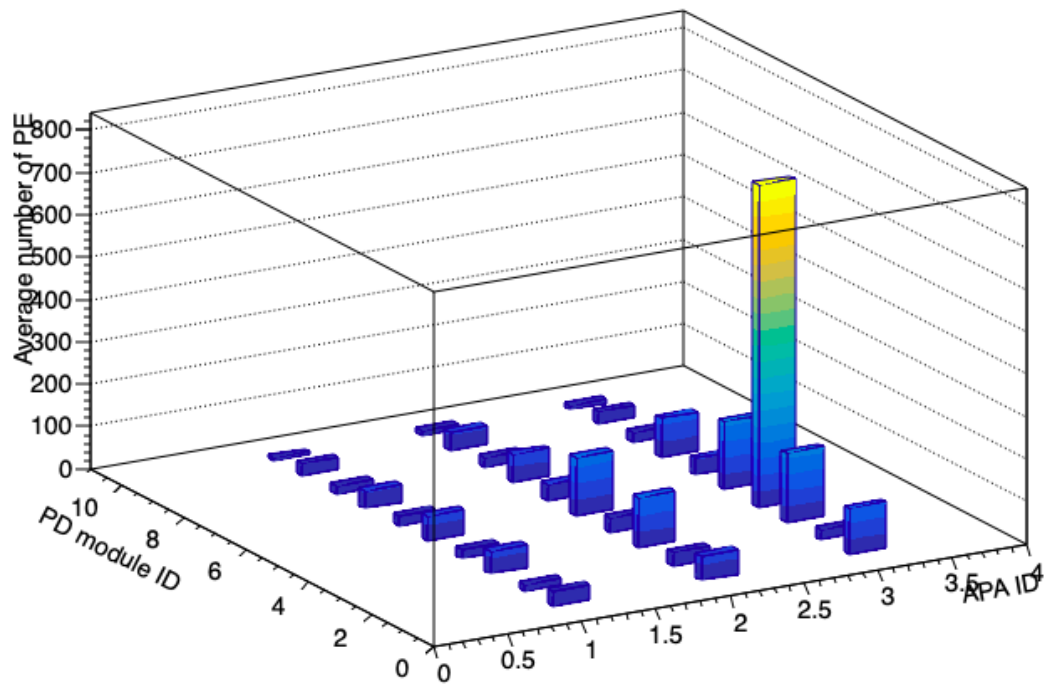
Pions



Protons

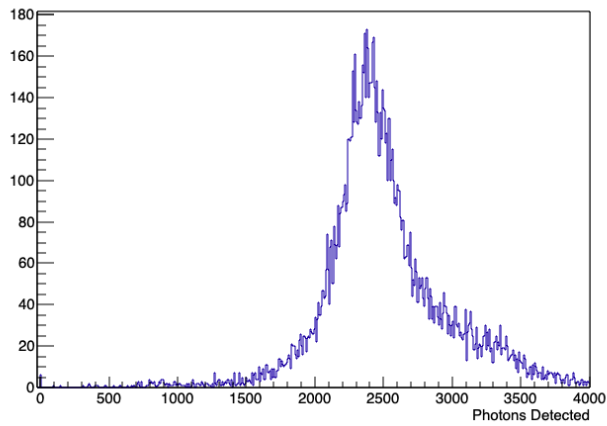


Kaons

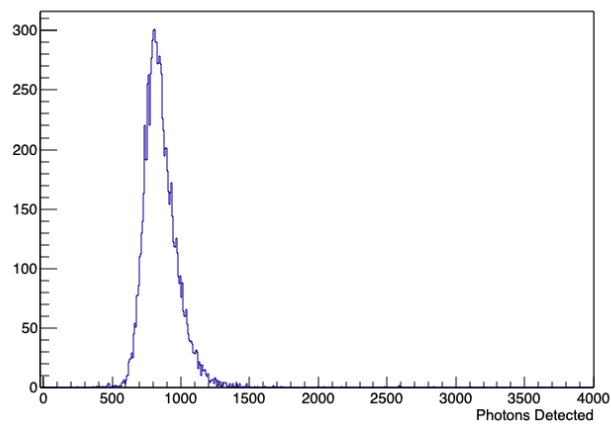


Sum all PD modules - Beam Side spectra

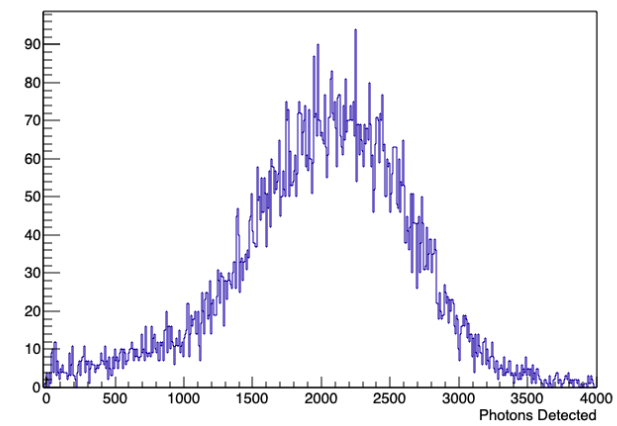
All PD modules Sum spectrum for Electrons of BM = 7 GeV/c



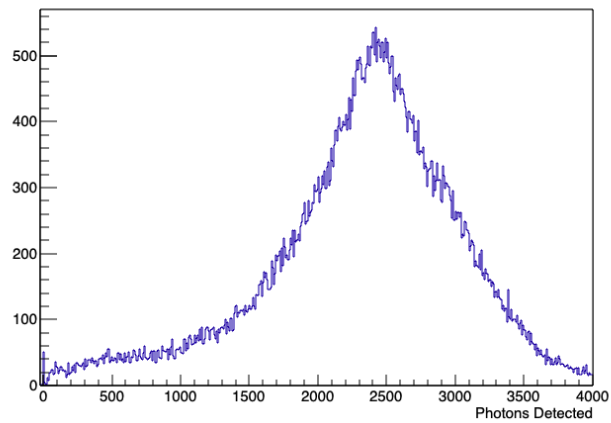
All PD modules Sum spectrum for Muons of BM = 7 GeV/c



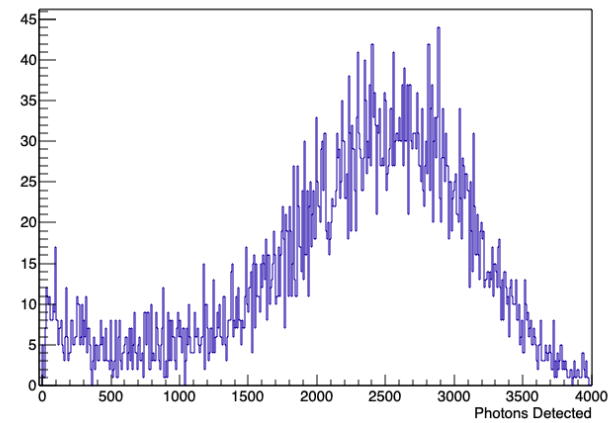
All PD modules Sum spectrum for Protons of BM = 7 GeV/c



All PD modules Sum spectrum for Pions of BM = 7 GeV/c

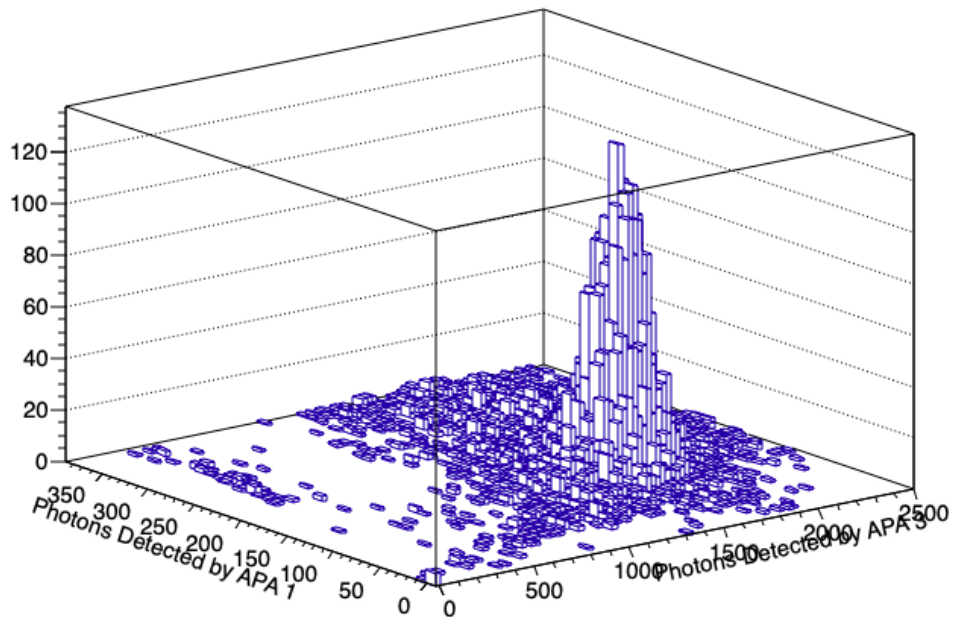


All PD modules Sum spectrum for Kaons of BM = 7 GeV/c

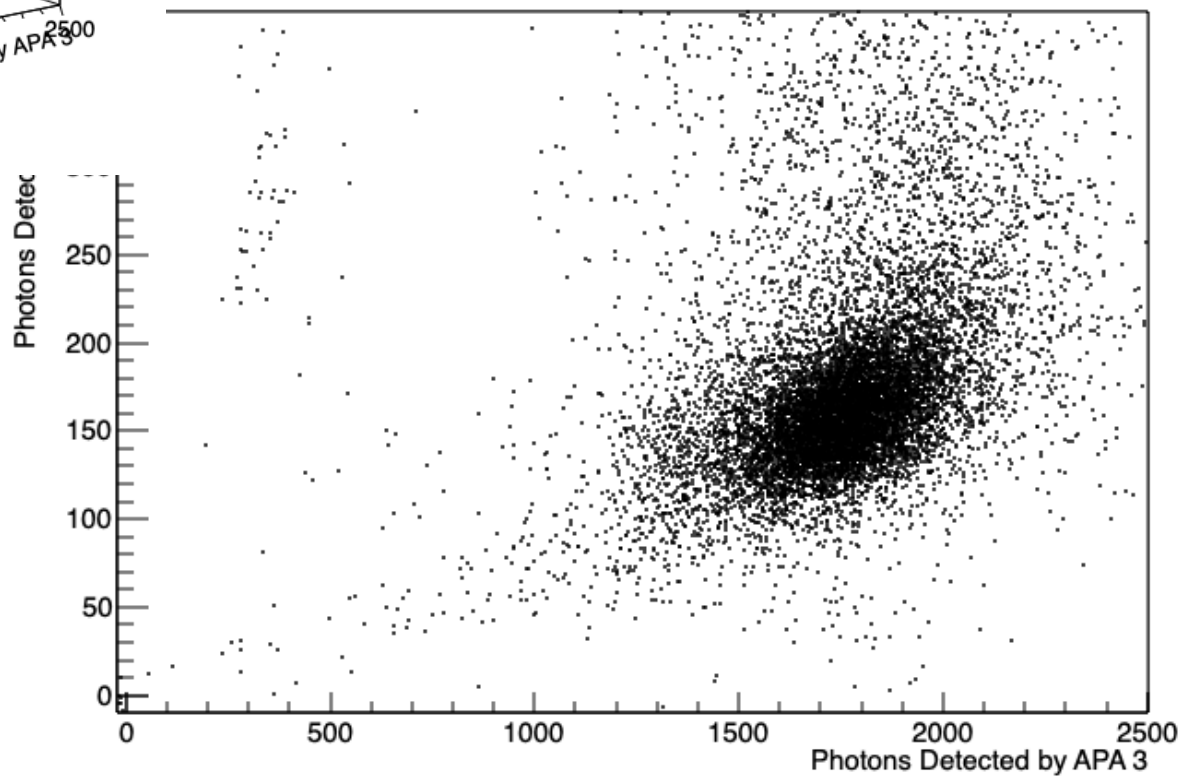


APA 3 vs. APA 1 spectra for Electrons of BM = 7 GeV/c

Electrons

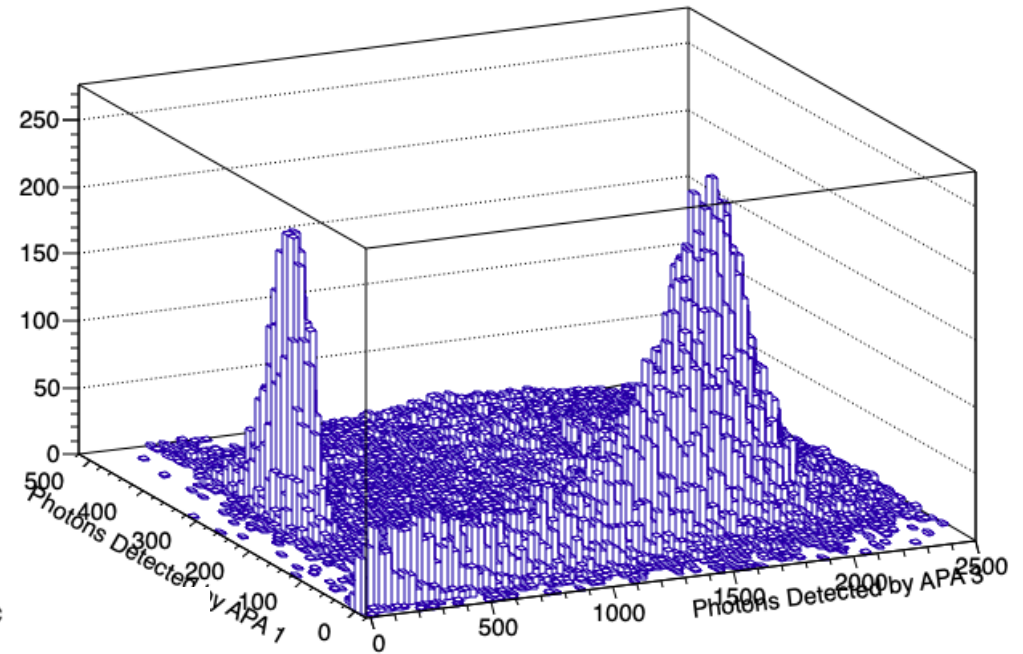


APA 3 vs. APA 1 spectra for Electrons of BM = 7 GeV/c

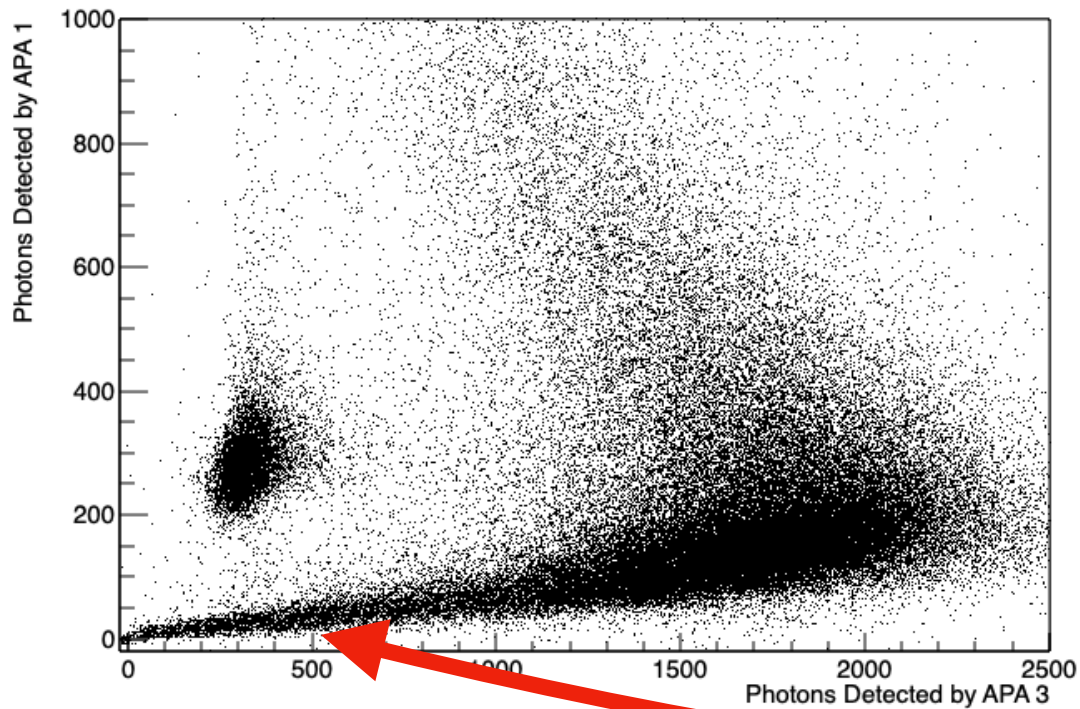


APA 3 vs. APA 1 spectra for Muons and pions of BM = 7 GeV/c

Pions and Muons

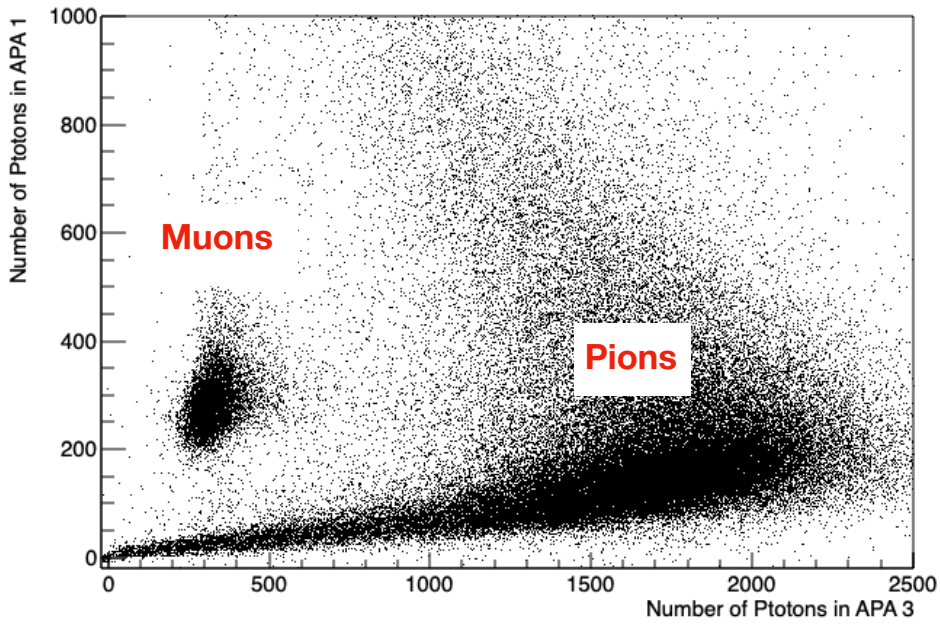


APA 3 vs. APA 1 spectra for Muons and pions of BM = 7 GeV/c

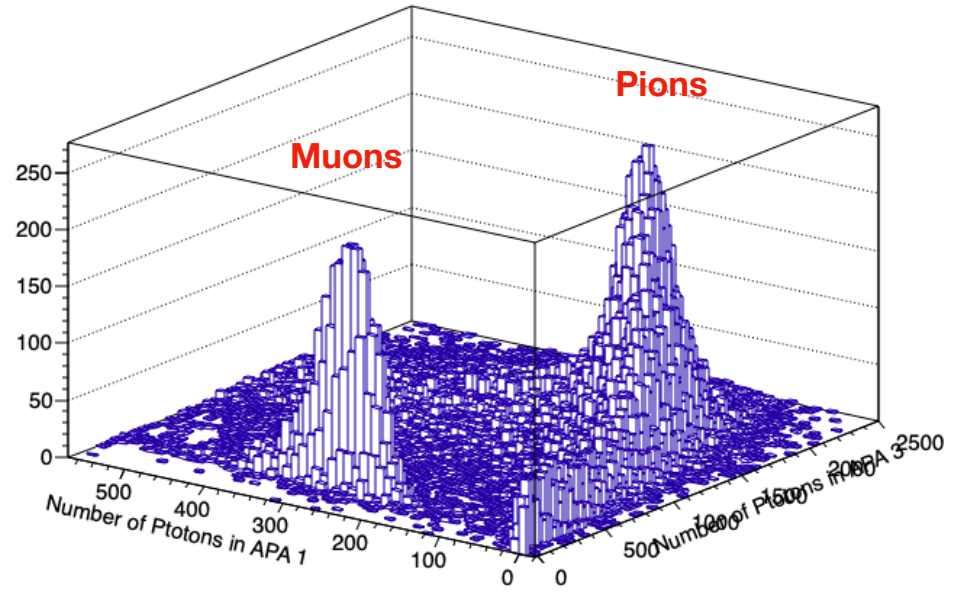


Electrons and Muons are well localized
Pions, Protons and Kaons shows a tail to zero. We are investigating about this behavior

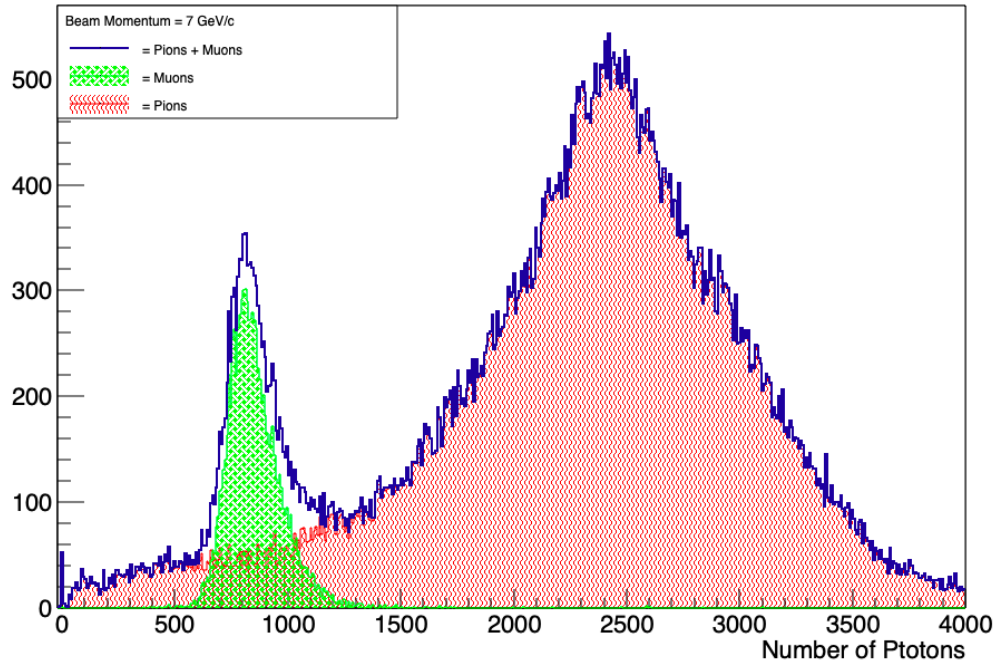
Sum of Ptotons in APA 3 vs Sum of Ptotons in APA 3 for particles selected as Pions + Muons



Sum of Ptotons in APA 3 vs Sum of Ptotons in APA 3 for particles selected as Pions + Muons

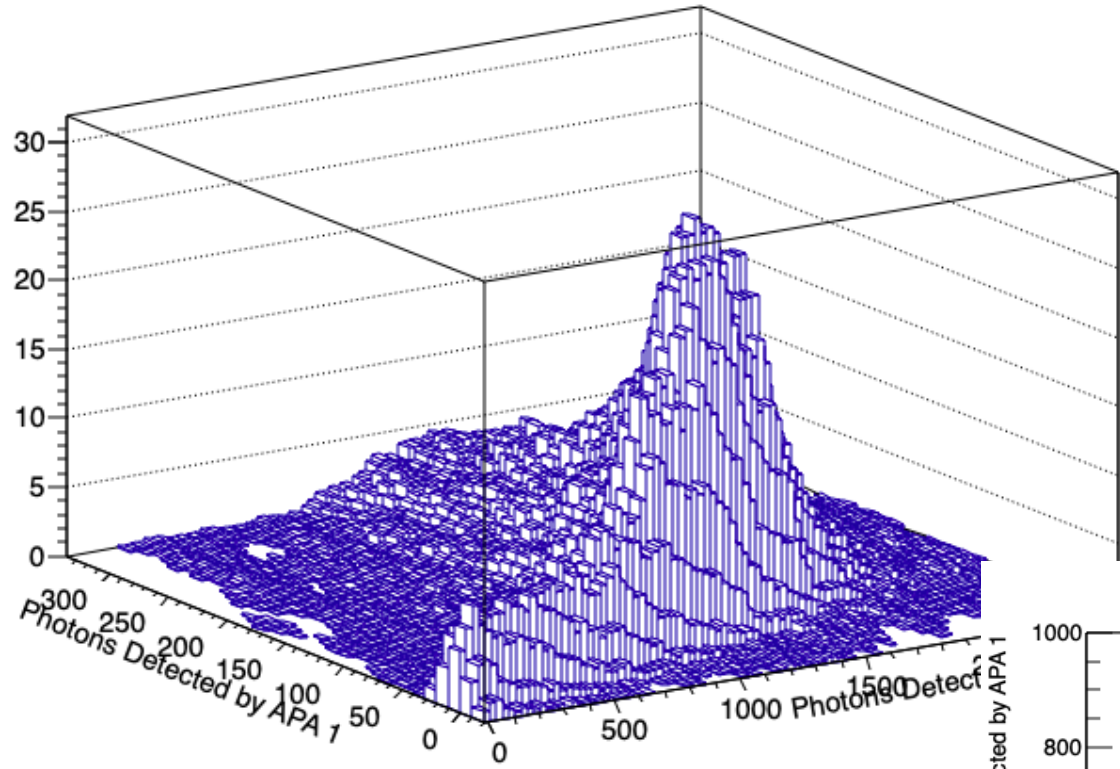


Sum of Photons from all the APAs in the beam side for Pions and Muons

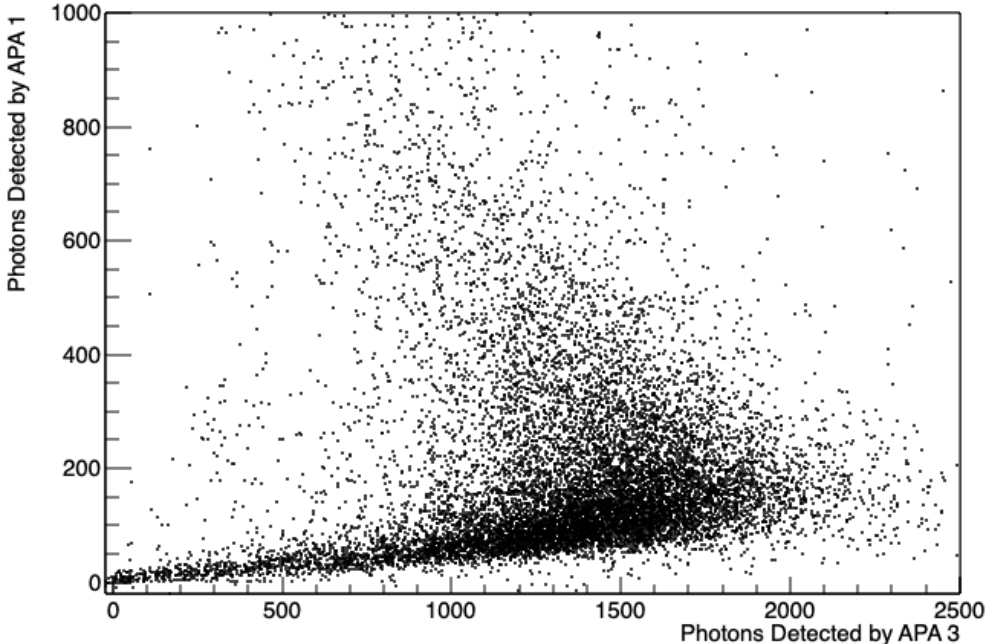


APA 3 vs. APA 1 spectra for Protons of BM = 7 GeV/c

Protons

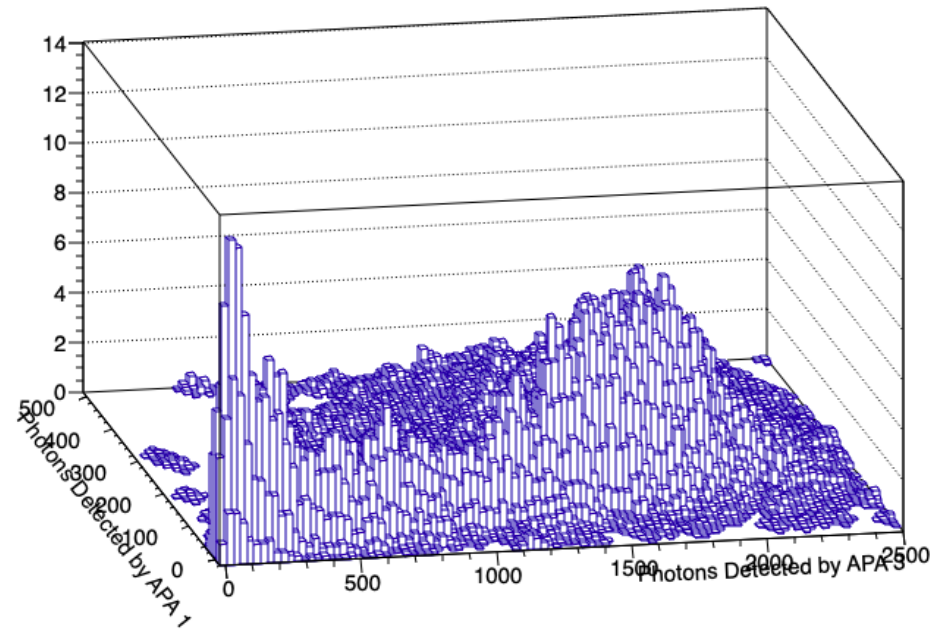


APA 3 vs. APA 1 spectra for Protons of BM = 7 GeV/c

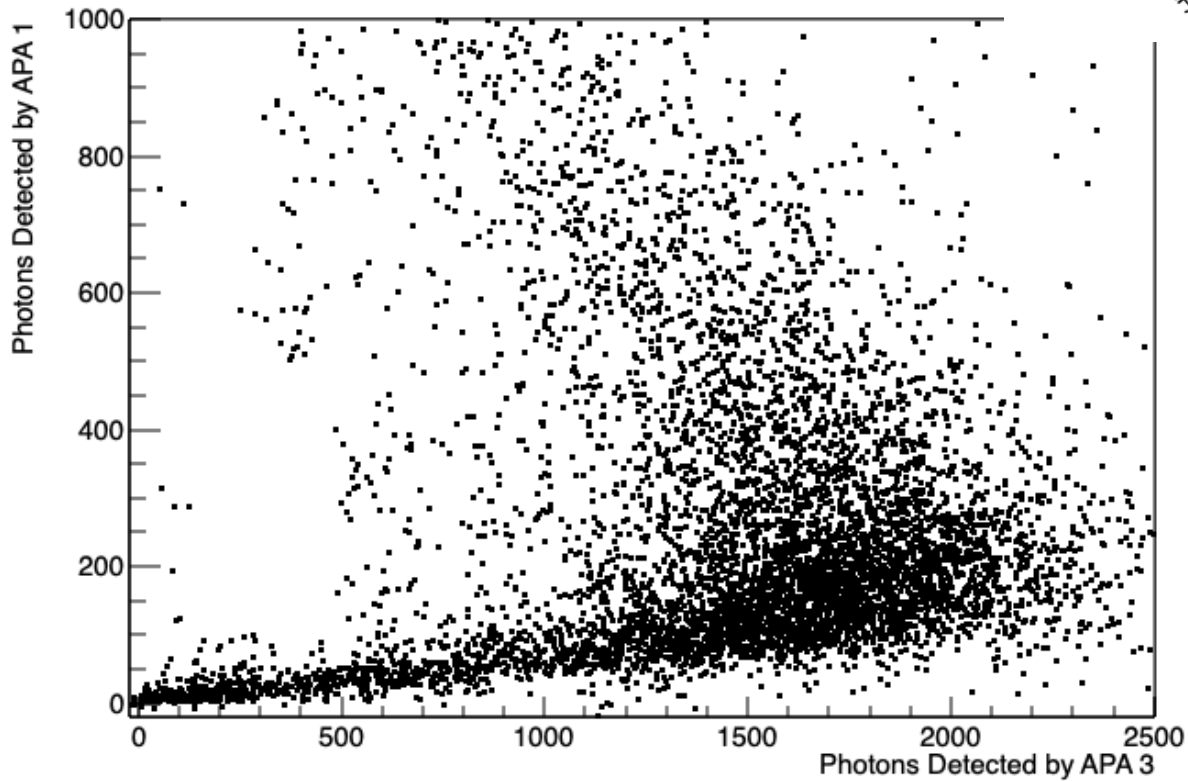


Kaons filtered from Muons

APA 3 vs. APA 1 spectra for Kaons of BM = 7 GeV/c

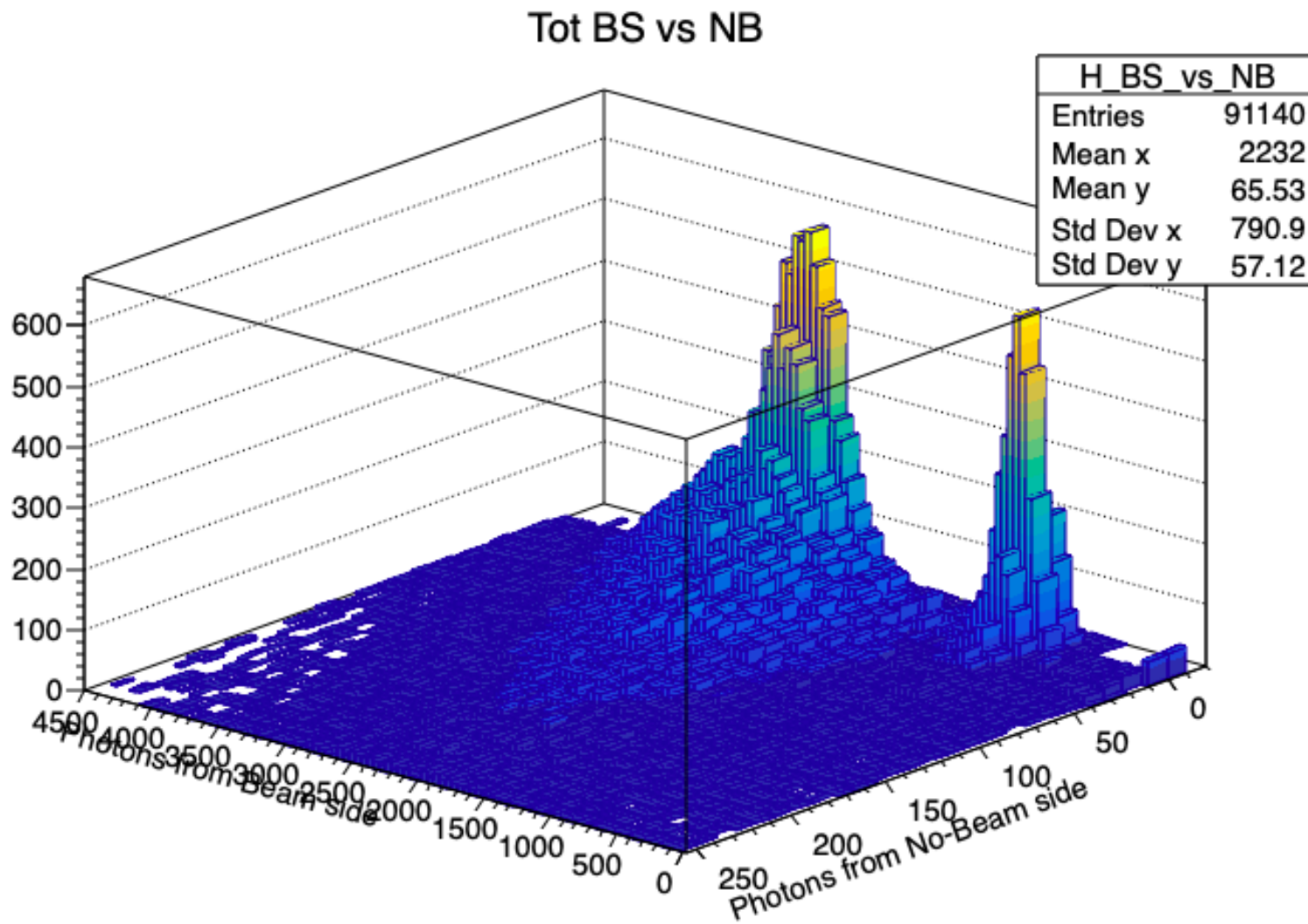


APA 3 vs. APA 1 spectra for Kaons of BM = 7 GeV/c

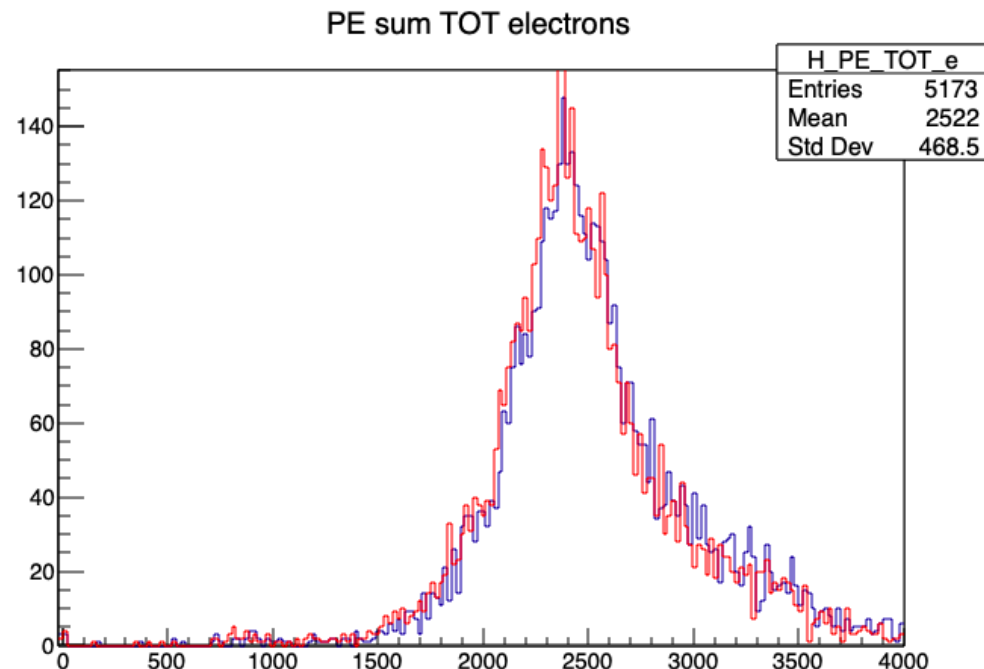
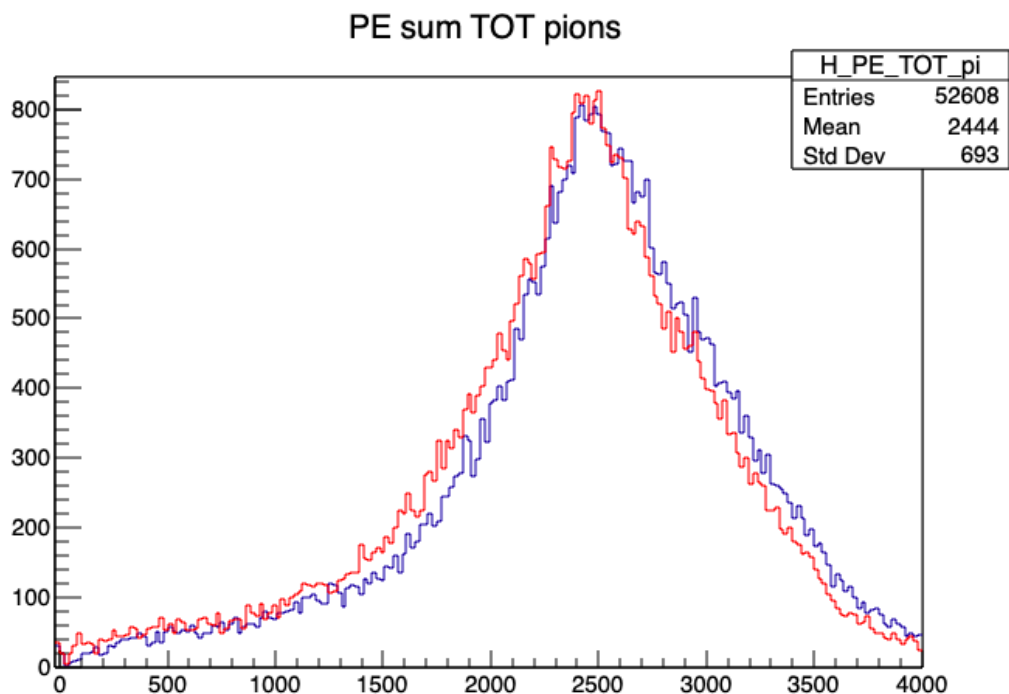


Next step:

investigation about No-Beam side ionization particle escape



Summing all the six APAs.
(in this plots are missing some PD
modules: all APA 4 and four PD
modules in APA 5)



In these plots are reported the
Spectra for sum in APA 1,2,3
And spectra for sum in APA
1,2,3,5,6.
When we add No-Beam side
APAs we can see a shift in the
Pions spectra but not in the
Electrons spectra.

**Some ionizing particles from Hadronic shower cross the cathode,
we are investigating about it**