Preliminary
Bremsstrahlung Yield calculation

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PADME internal Meeting, 30th April 2020

OUTLINE

Aim: *Bremsstrahlung Yield calculations*

Two Ways:

Difference of the occupancy plot PVeto w and w/o target both for MC and DATA

Coincidence PVeto SAC

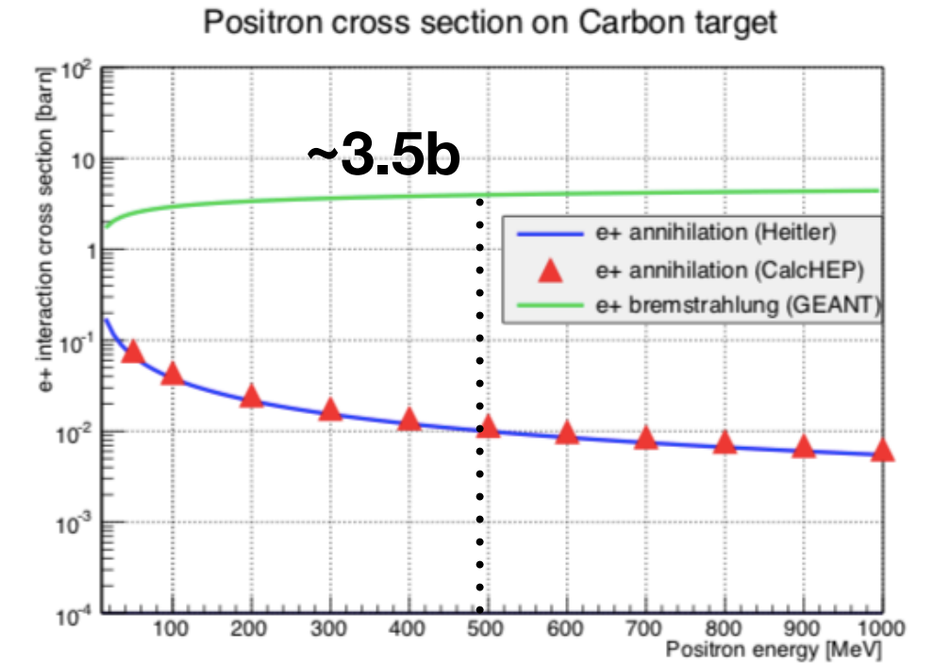
Number of photon emitted from Bremsstrahlung

$$N_\gamma = \frac{d}{X_0}\left[\frac{4}{3}\ln\left(\frac{k_{\max}}{k_{\min}}\right) - \frac{4(k_{\max}-k_{\min})}{3E} + \frac{k_{\max}^2 - k_{\min}^2}{2E^2}\right] .$$

From PDG

kmin, kmax *Energy of the Photon Emitted from a Bremsstrahlung process*

E *energy of the Beam,* ***X_0*** *radiation length,* ***d*** *target thickness*



From Padme proposal

Check of the formula

Energy of emitted photon

1 ≤k ≤ 490 MeV `Cross Section Bremsstrahlung 3.46787e-24cm2 3.46787 barn`

Acceptance Veto cuts *50 ≤ Ee+≤ 440 MeV*

50 ≤ k ≤ 440 MeV `Cross Section Bremsstrahlung 1.04402e-24cm2 1.04402 barn`

(For example from ChId 15 - Ee+ 50 MeV, ChId 90 440 MeV)

$$N\gamma_{TOT} = N_\gamma * N_{POT}$$

for NPOT DATA 9.3 x 10^9 **Nγ expected** 1.71454e+07

PVeto Occupancy Plots for MC and DATA with and w/o target

With target
w/o target

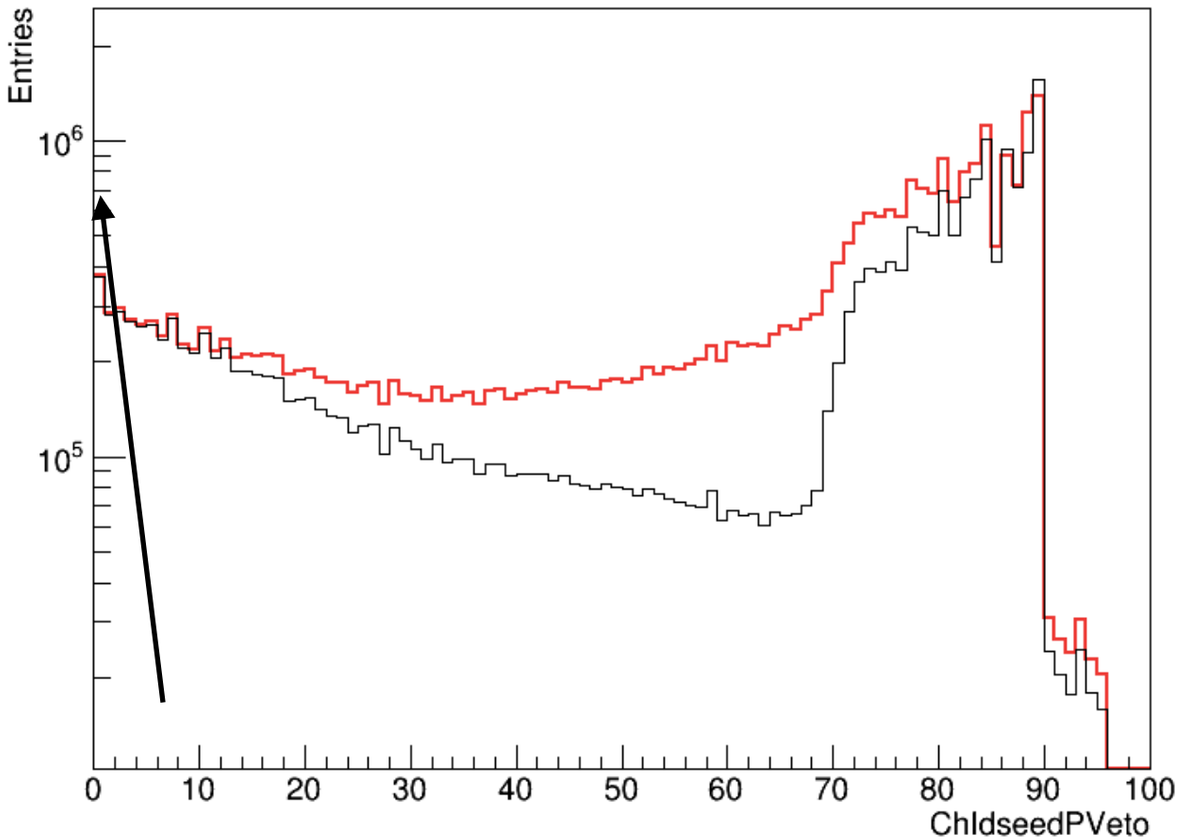
PVetoClusterEnergy >1 MeV

DATA *Golden Run Of July*

MC *MC 23kPOT, 150 ns Bunch Length Veto digi 17 ns sigma 0.4 MeV vetoes*

****MC w/o target means with a target of thickness 0.001 μm***

PVeto_ChId_Clus_DATA

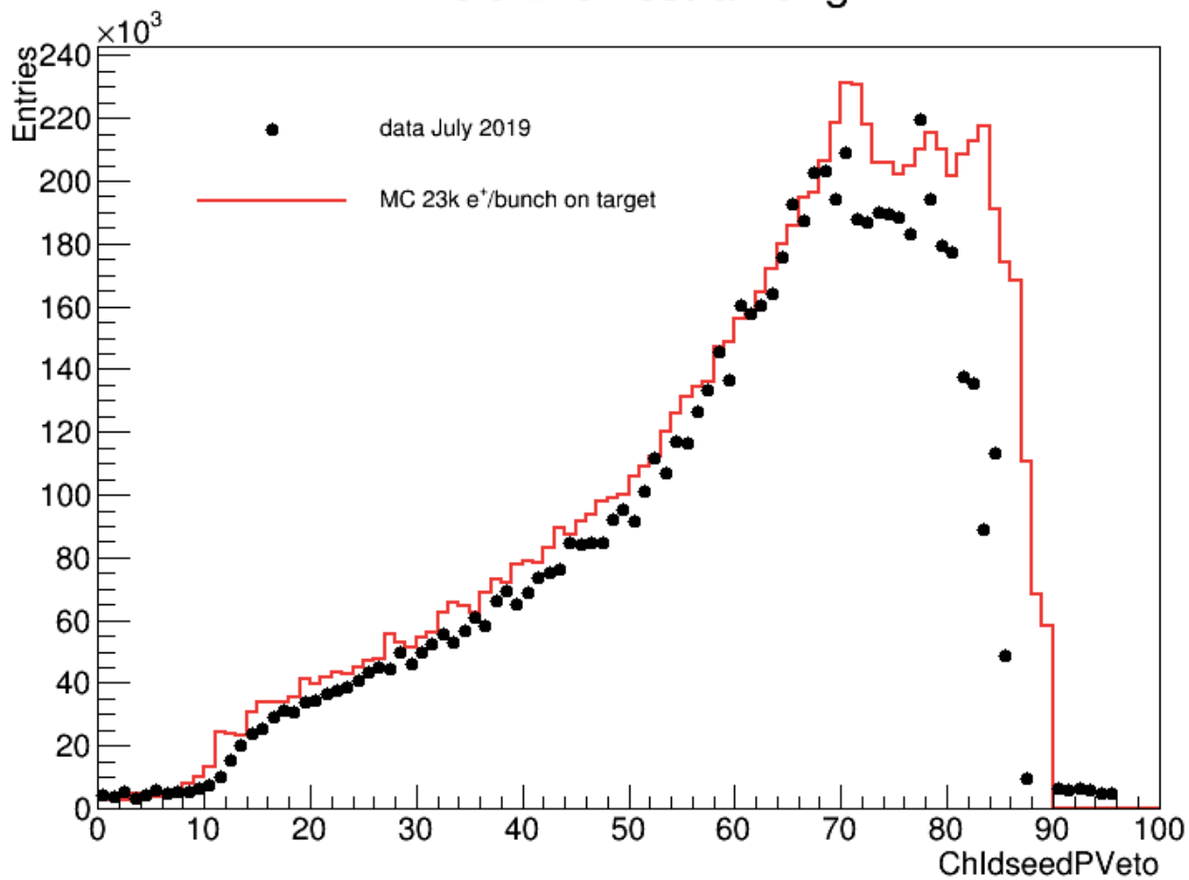


Bin0 as reference?

Same rate with and w/o target as expected

Without Scaling the DATA occupancy plot

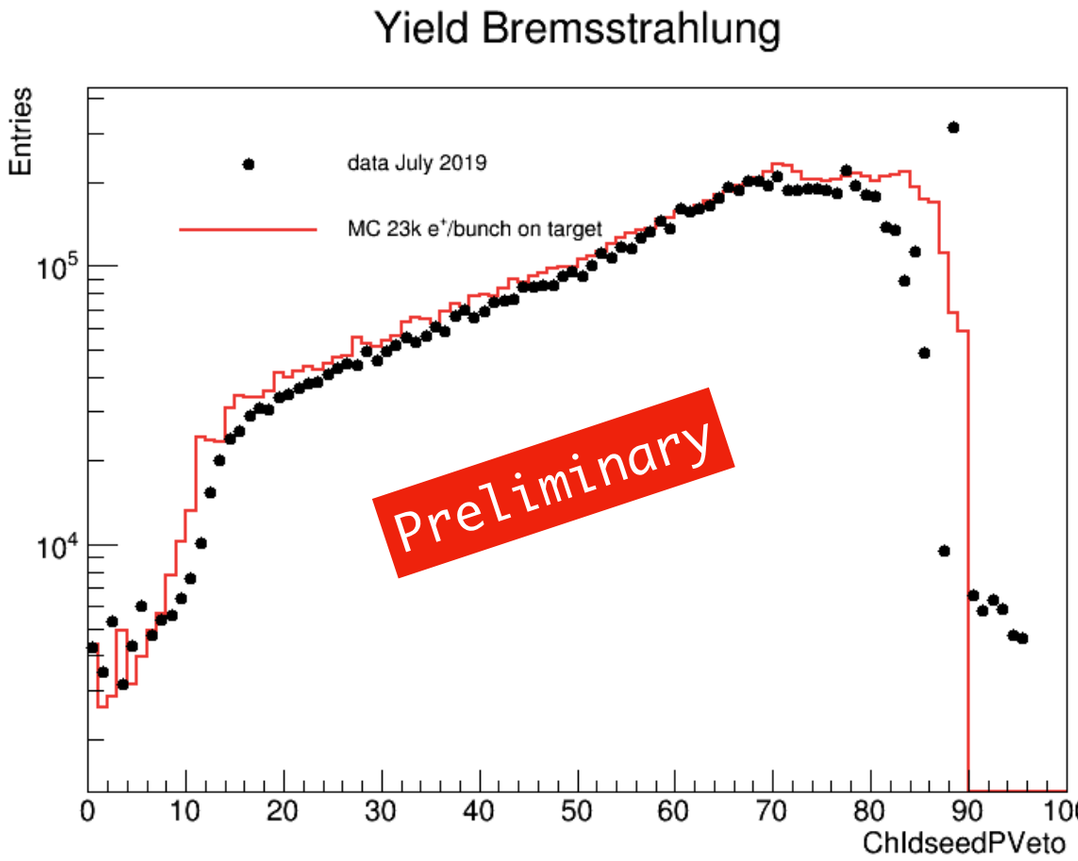
Yield Bremsstrahlung



Same shape for MC and DATA

It seems to be the correct normalisation!

Preliminary calculation of the Bremsstrahlung Yield



10≤ChId≤70

YieldMC 5.65152e+06
YieldDATA 5.24388e+06

*ChId 10-> Ee+ min ~38.5 MeV **
*ChId 70-> Ee+ max ~295 MeV **
Eγmin 195 Eγmax 451

***Ngamm TOT 5.87062e+06** for NPOT 9.3e+09*

60≤ChId≤70

YieldMC xmin 60 xmax 70 2.06341e+06
YieldDATA xmin 60 xmax 70 2.00748e+06

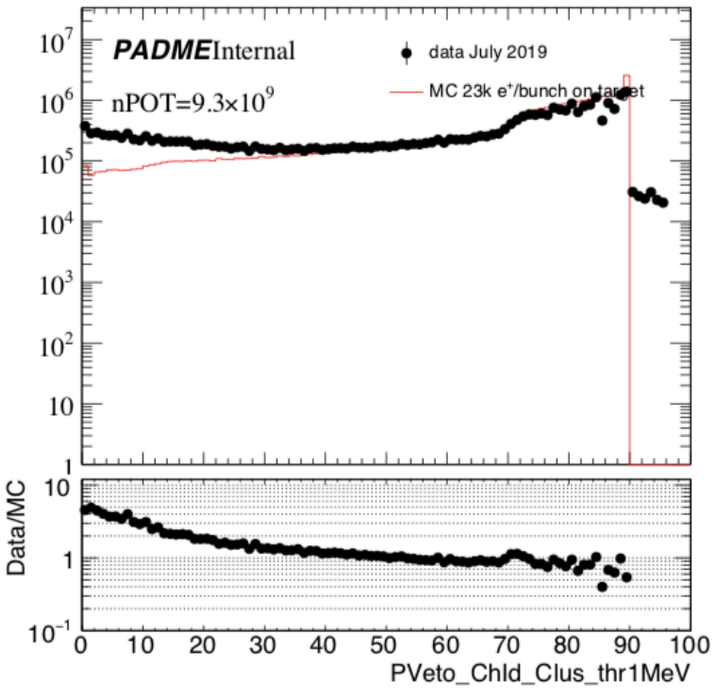
*ChId 60-> Ee+ min ~233 MeV **
*ChId 70-> Ee+ max ~295 MeV **
Eγmin 195 Eγmax 257
***Ngamm TOT 1.97607e+06** for NPOT 9.3e+09*

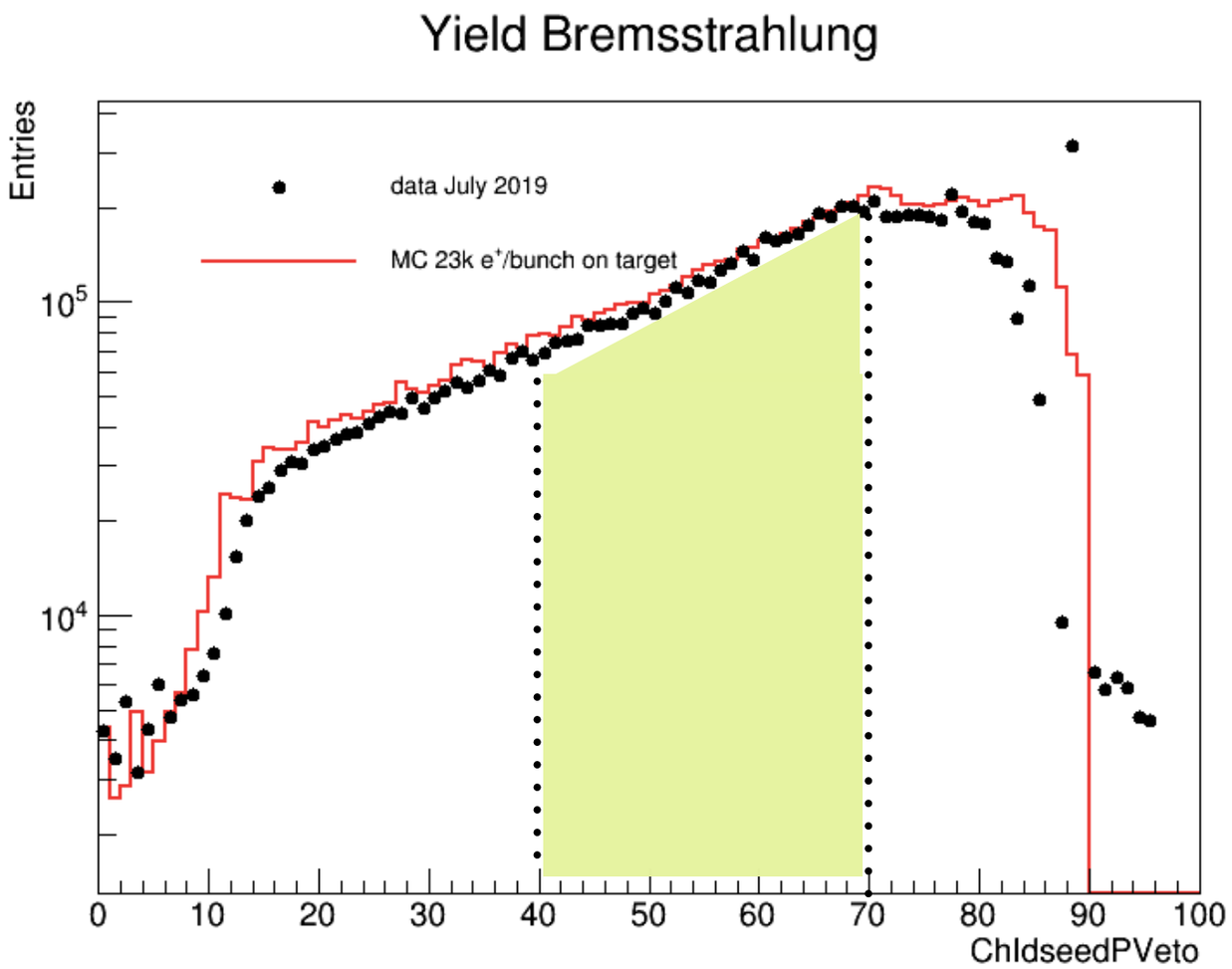
From Preliminary Yield Calculation, MC and DATA yield not so different from the analytic calculation

Integral (binxmin,binxmax)

**from my preliminary calibration of the PVeto momentum VS Z*

Considering the plot of the PVeto occupancy the agreement MC DATA is for 40≤Chld≤70





Ngamma TOT MC 4.22978e+06 NPOTMC 9.3e+09

Integral (binxmin,binxmax)

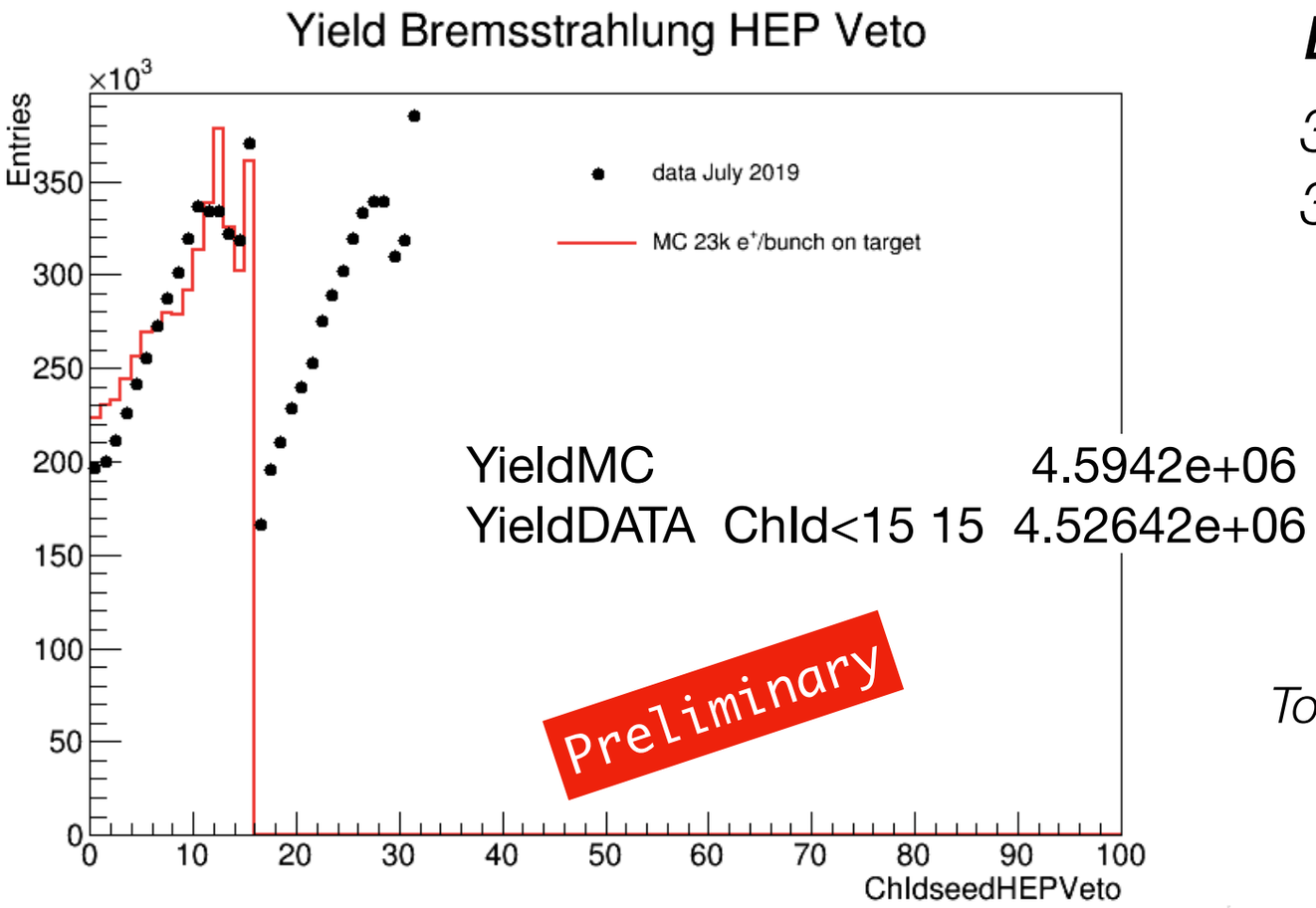
YieldMC xmin 40 xmax 70 4.23264e+06

YieldDATA xmin 40 xmax 70 4.014e+06

Preliminary

Not so different from the analytic calculation, to be checked better

What about HEP Veto Bremsstrahlung yield?



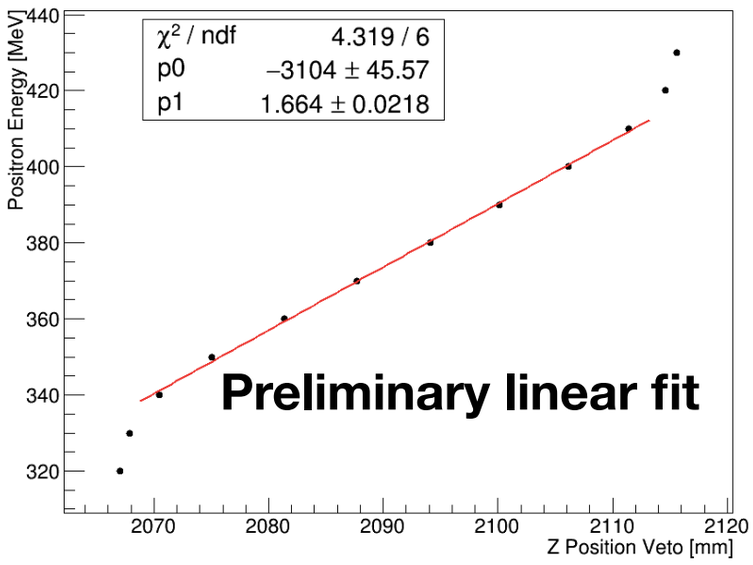
Energy acceptance

340<Ee+<430 MeV Yield 7.8e+06
340<Ee+<420 MeV Yield 6.4e+06

Calculated Yield >Yield MC/DATA

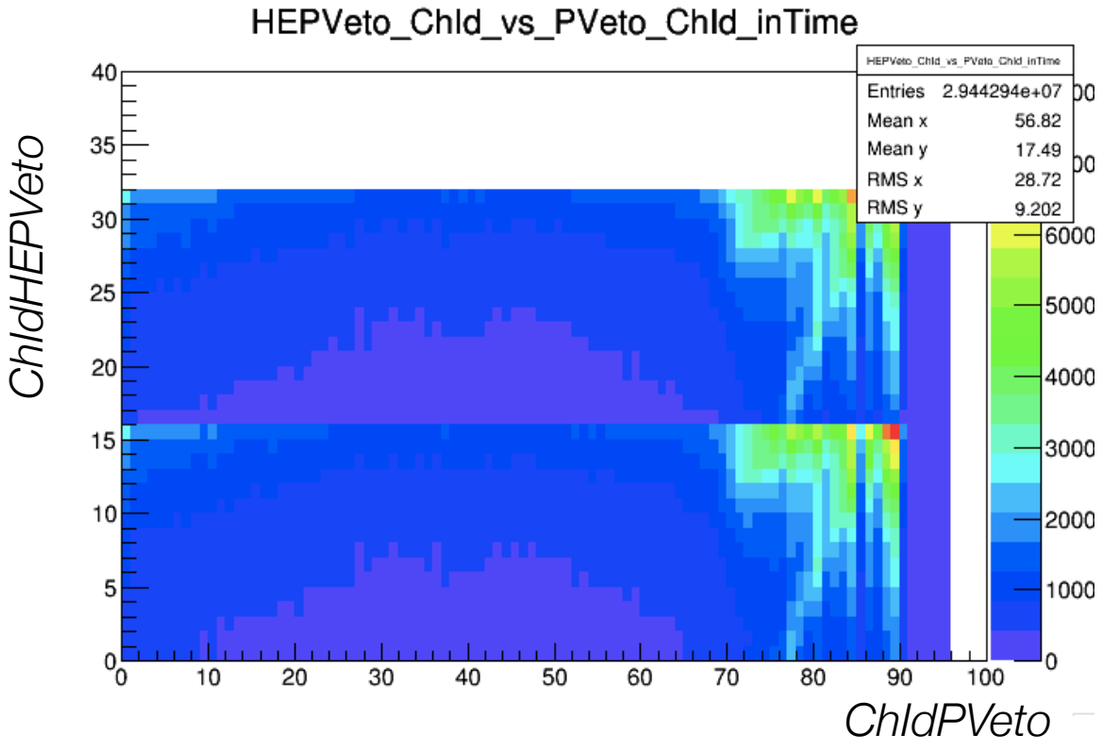
To do: yield up to ChId 12 to avoid higher fingers

A calibration with a single positron was performed for HEP Veto to obtain the energy acceptance

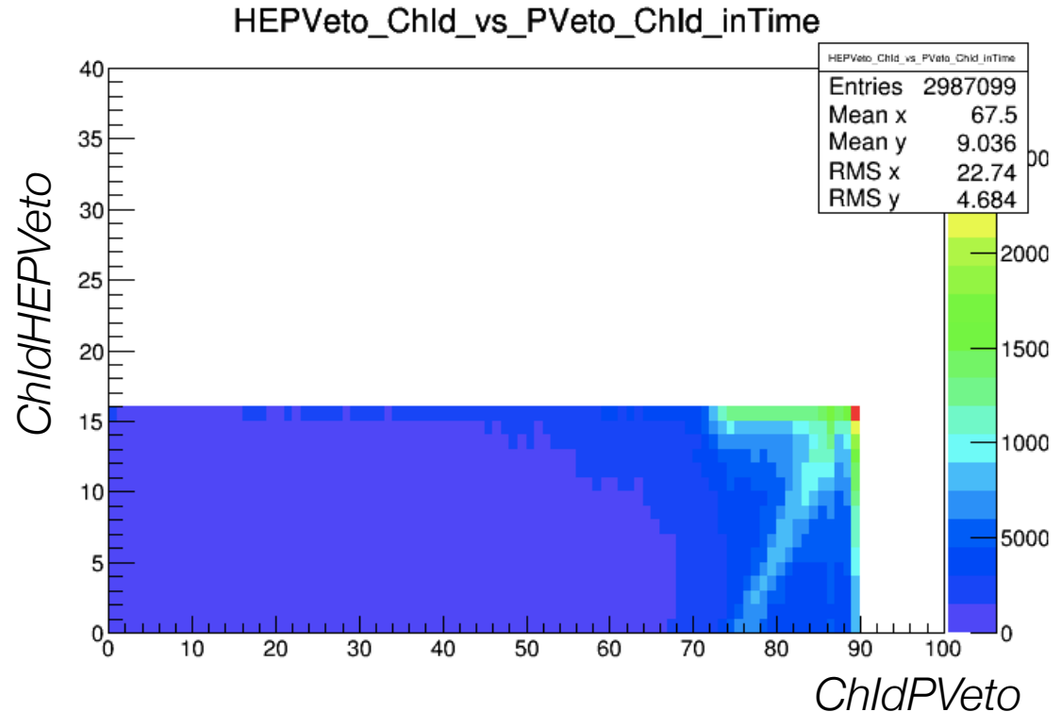


In the linear range
340<Ee+<410 MeV Yield 5.2e+06

HEP Veto and PVeto ChId in time coincidence

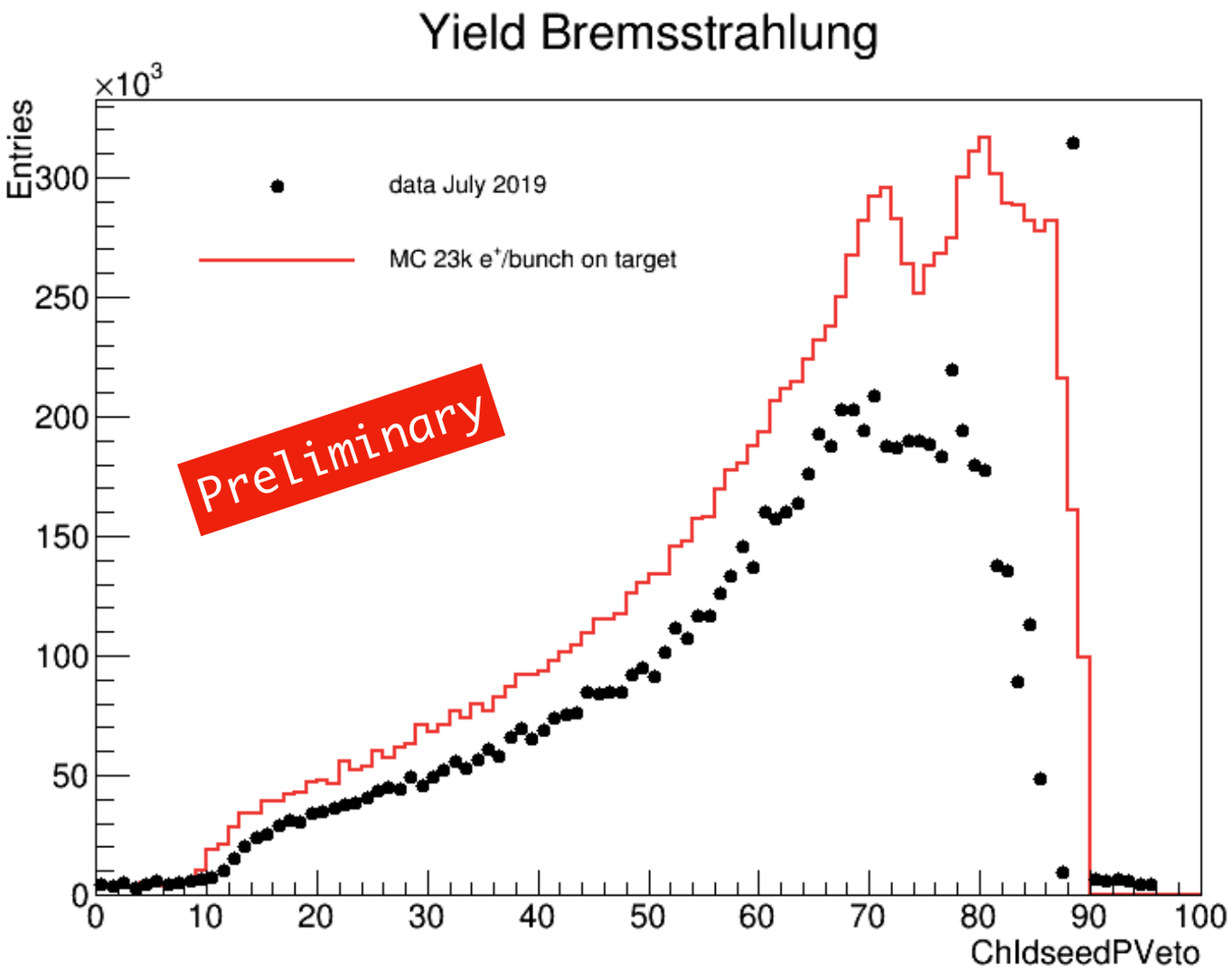


The energy cover could be checked also looking at the correlation between ChId HEP Veto Vs ChId PVeto Plot



Today results..

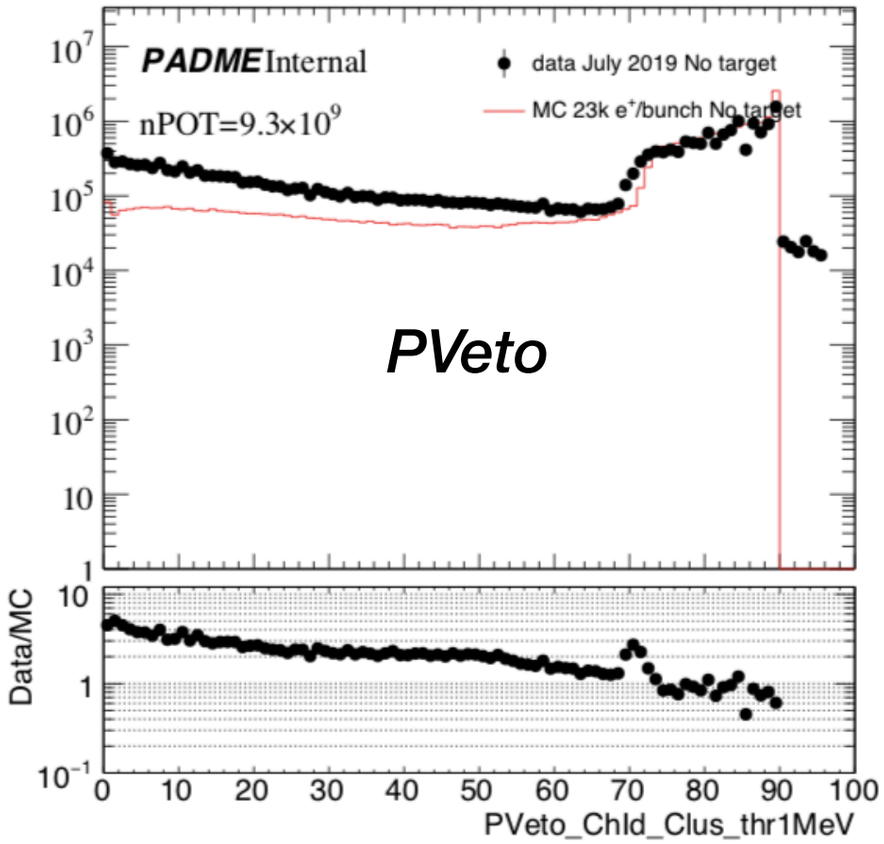
MC moving the PCB

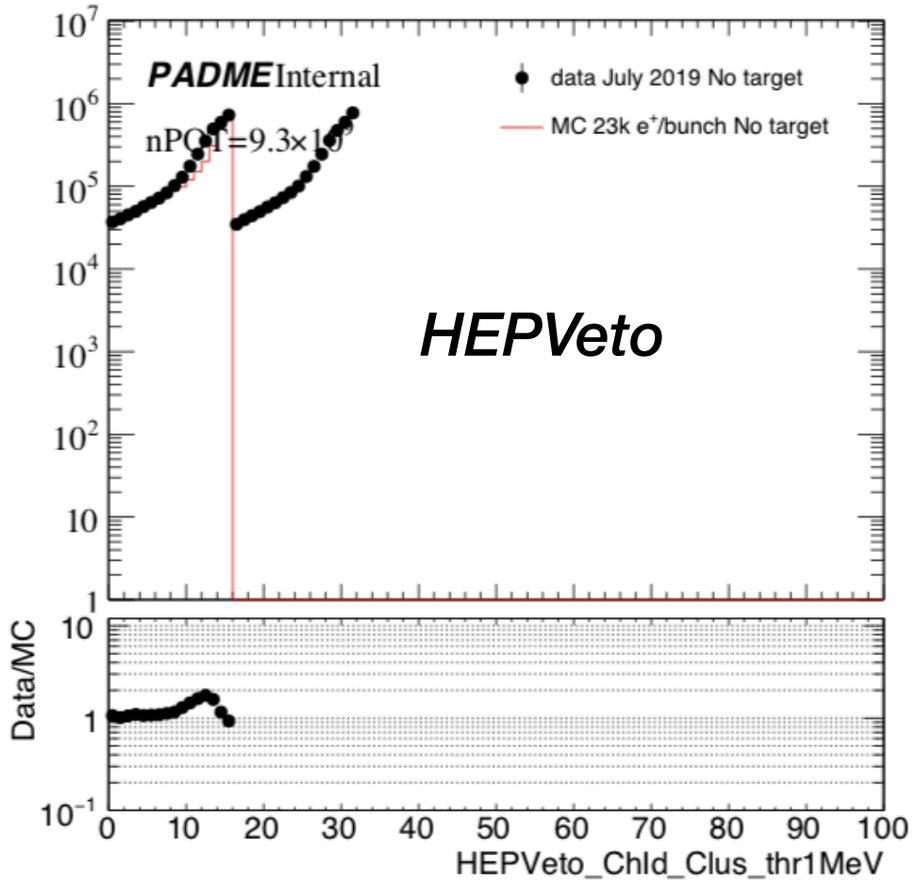


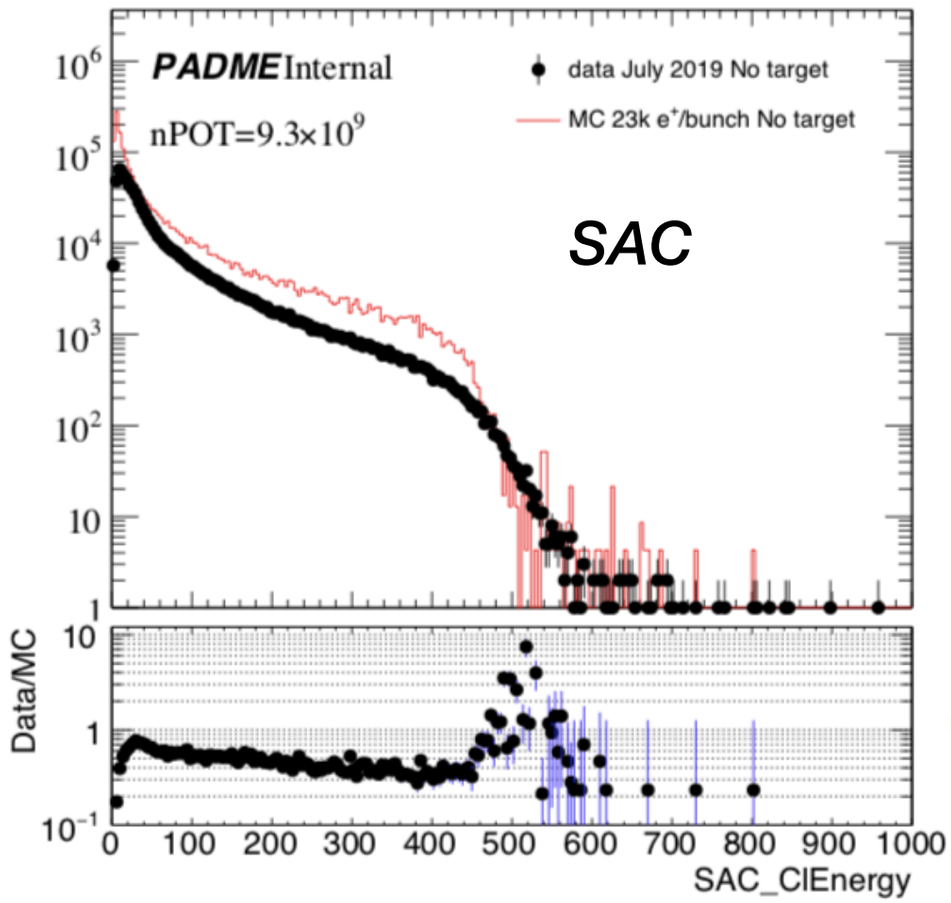
YieldDATA xmin 40 xmax 70 4.014e+06
YieldMC xmin 40 xmax 70 5.31573e+06

MC higher than analytic calculation?

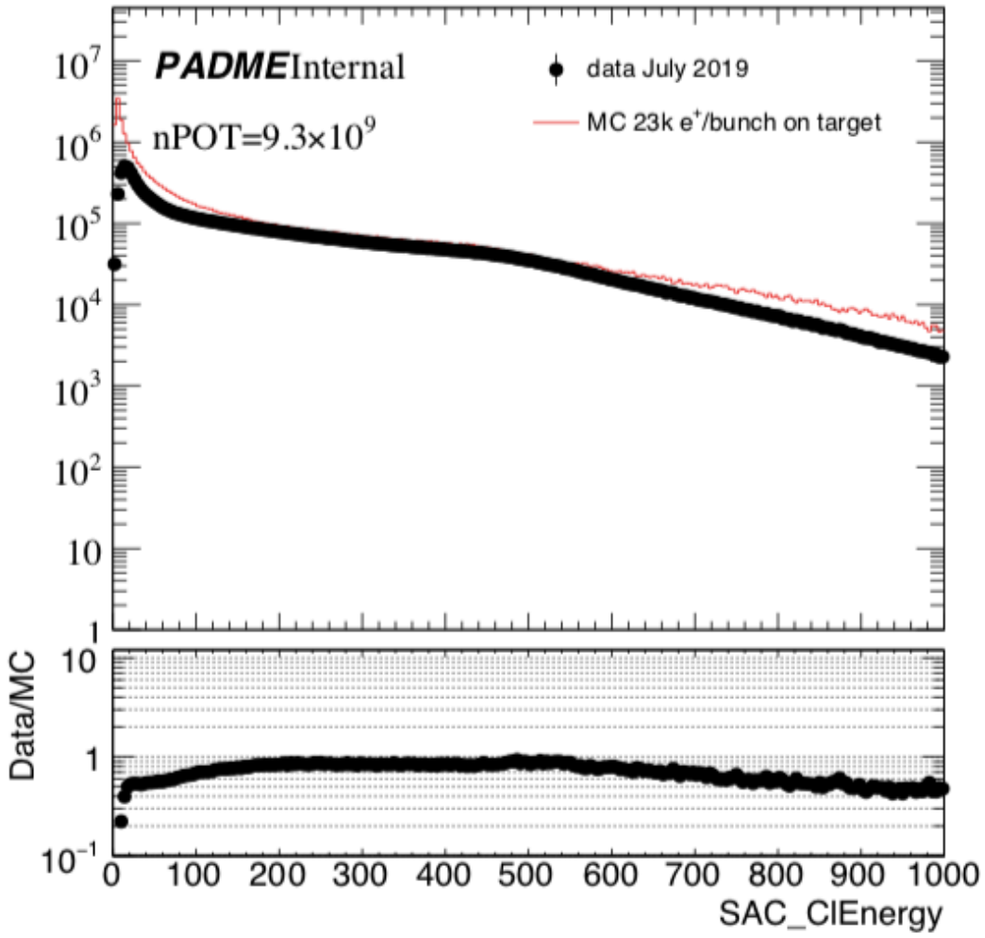
MC DATA NoTarget

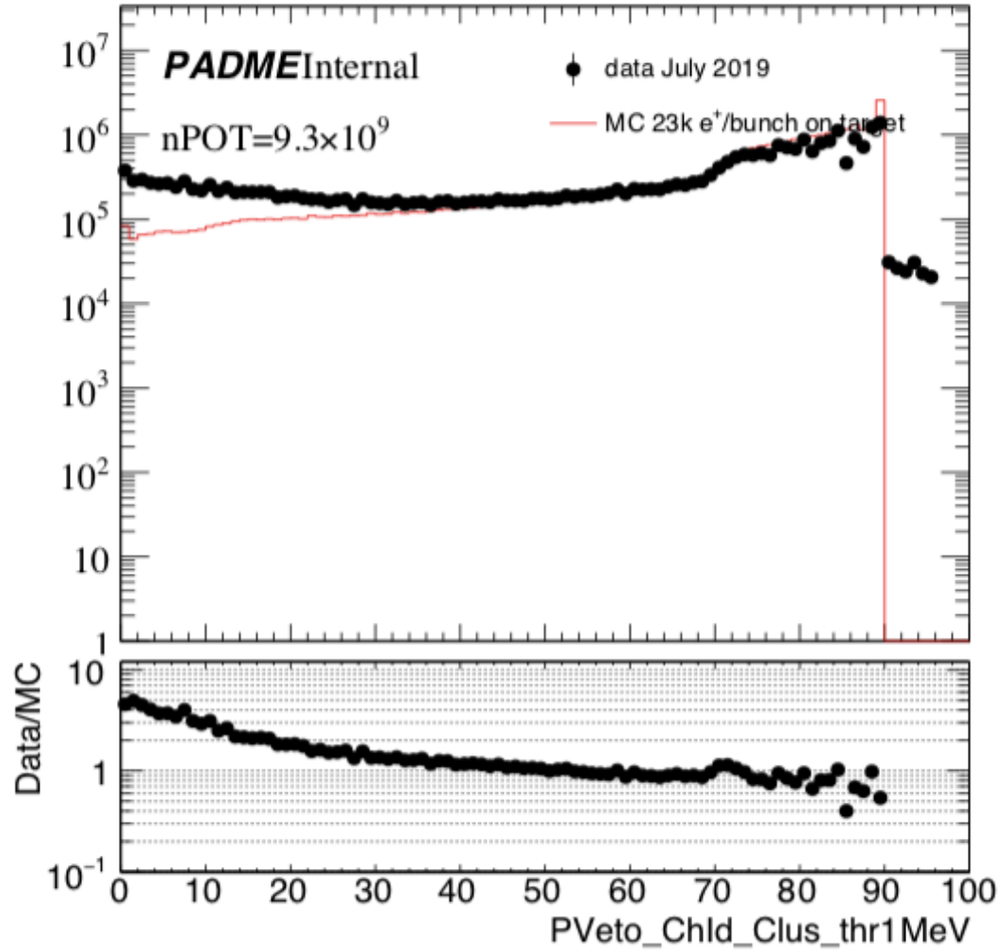


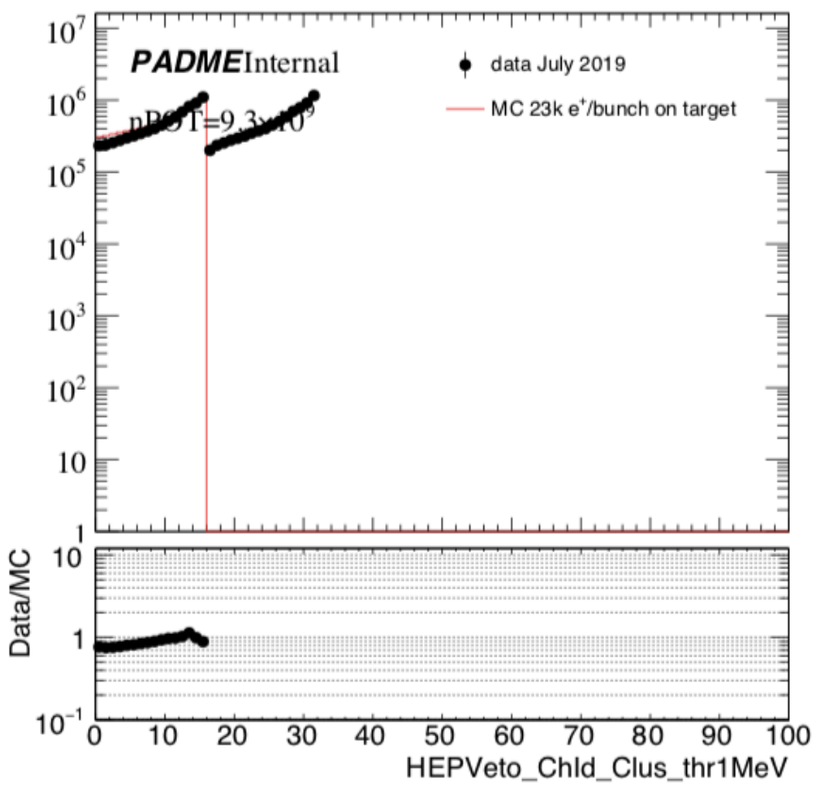


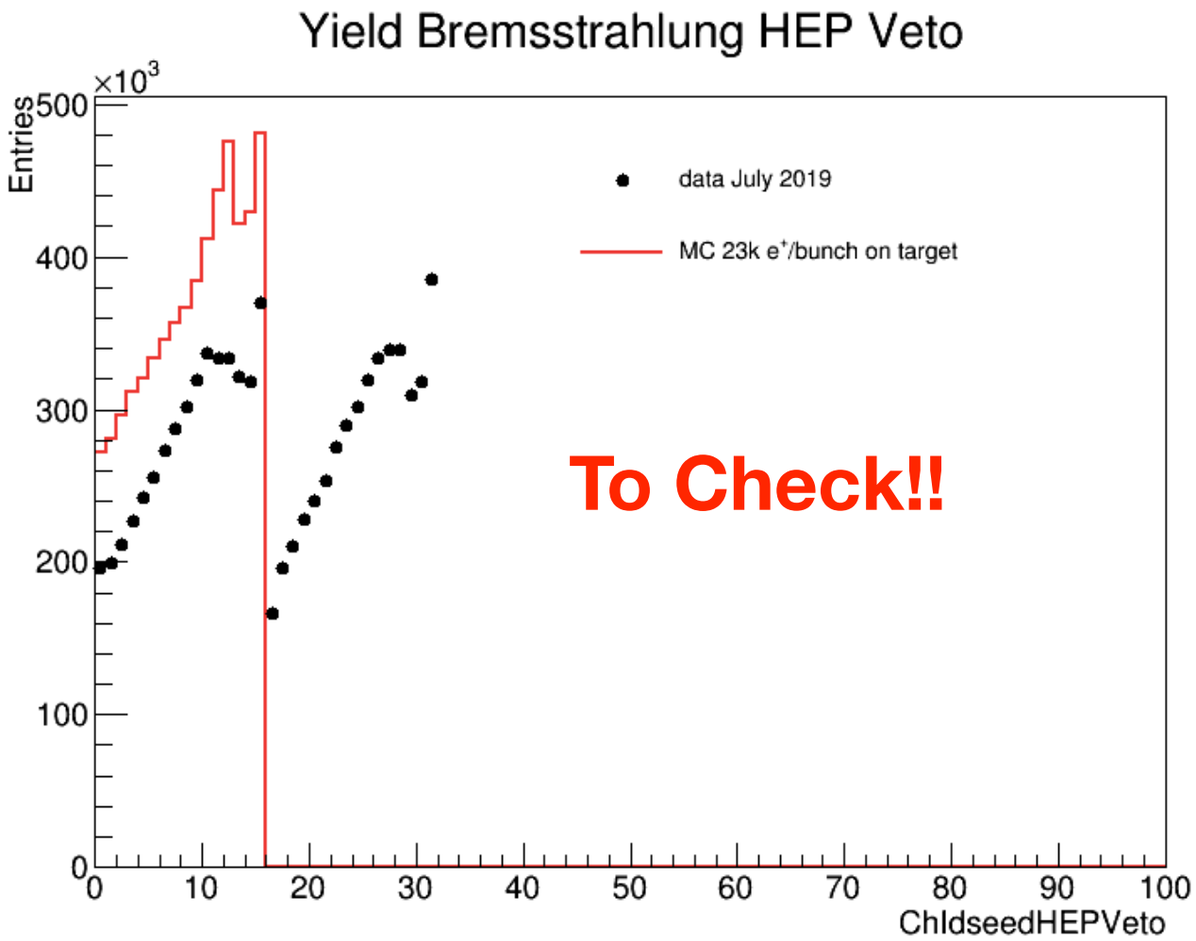


MC DATA Target









YieldMC xmin 0 xmax 15 5.93164e+06

YieldDATA xmin 0 xmax 15 4.52642e+06

Acceptance HEP..
340<Ee+<410 MeV Yield 5.2e+06
340<Ee+<420 MeV Yield 6.4e+06

Considering the time coincidence with SAC, the yield could be extracted in different ways:

- PVeto and SAC clusters in time coincidence (Δt<1ns), taking the SAC energy bin projection of the 2D plot SAC energy VS ChIDSeed PVeto

Not so stable

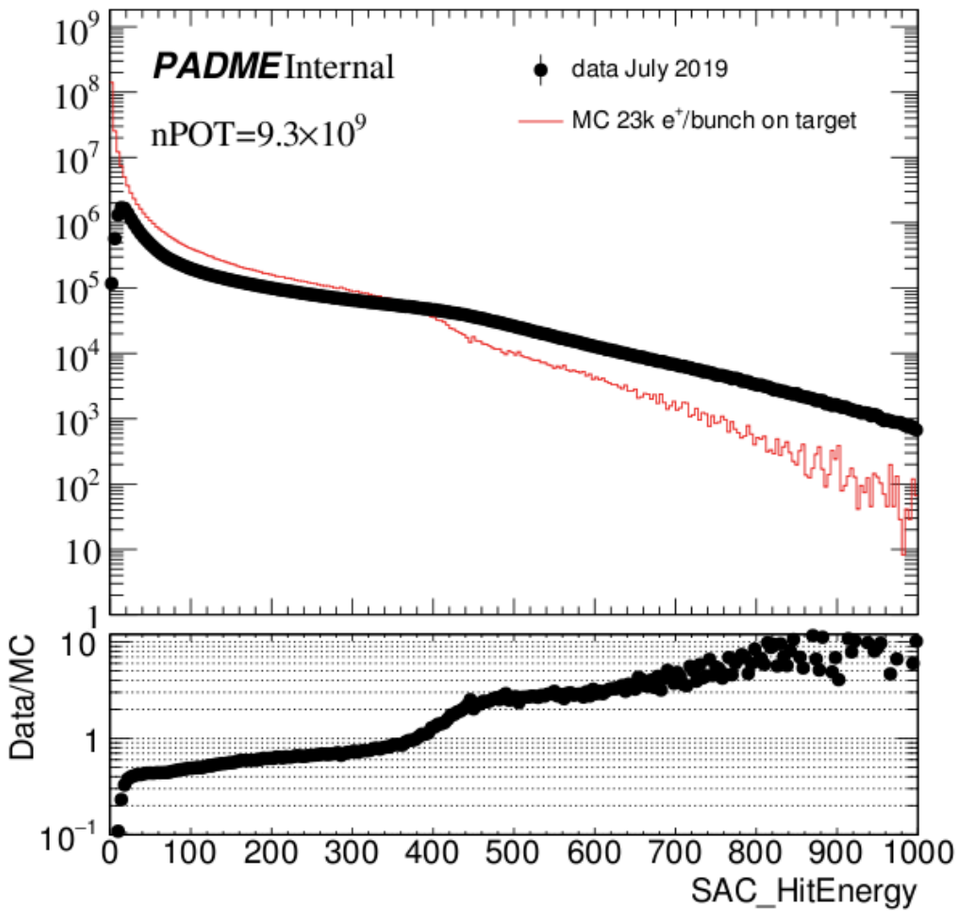
- Considering the spectrum of the sum of the positron & photon (should have a peak at the energy of the beam)

- Considering the plot of the time difference PVeto SAC clusters

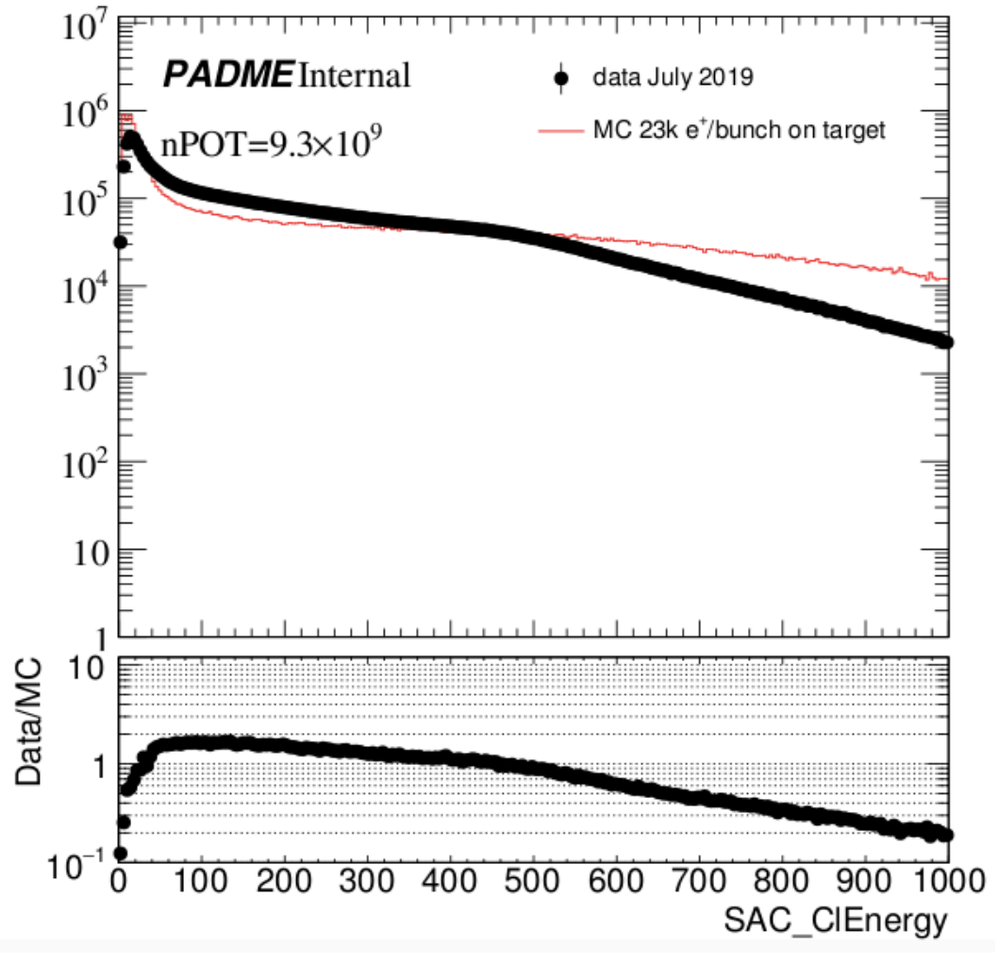
One step back.. Is the MC SAC mimicking the real SAC behaviour?

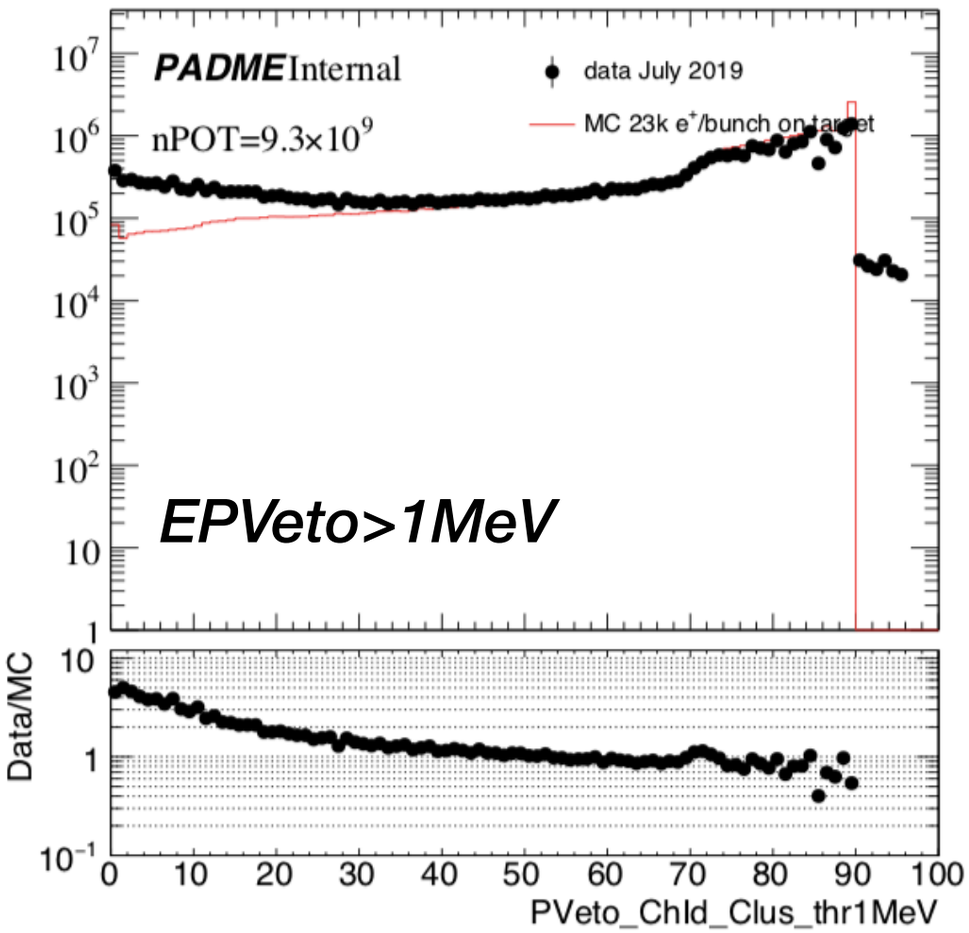
SAC hit and cluster spectra not in agreement

Hit energy

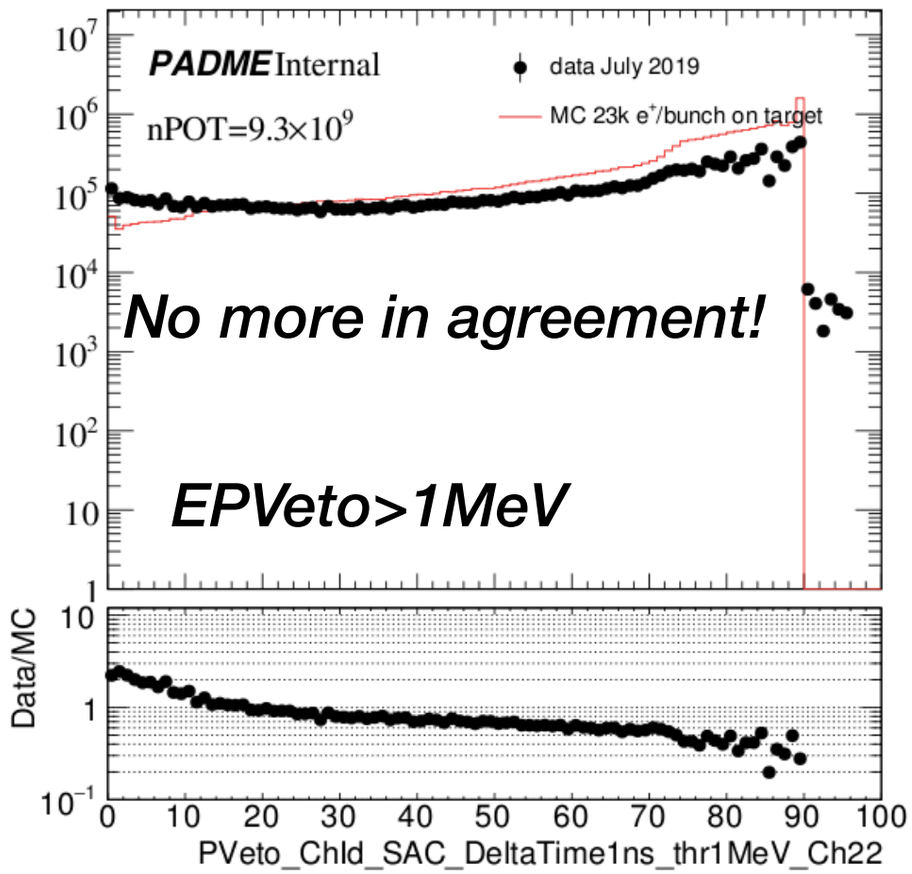


Cluster Energy

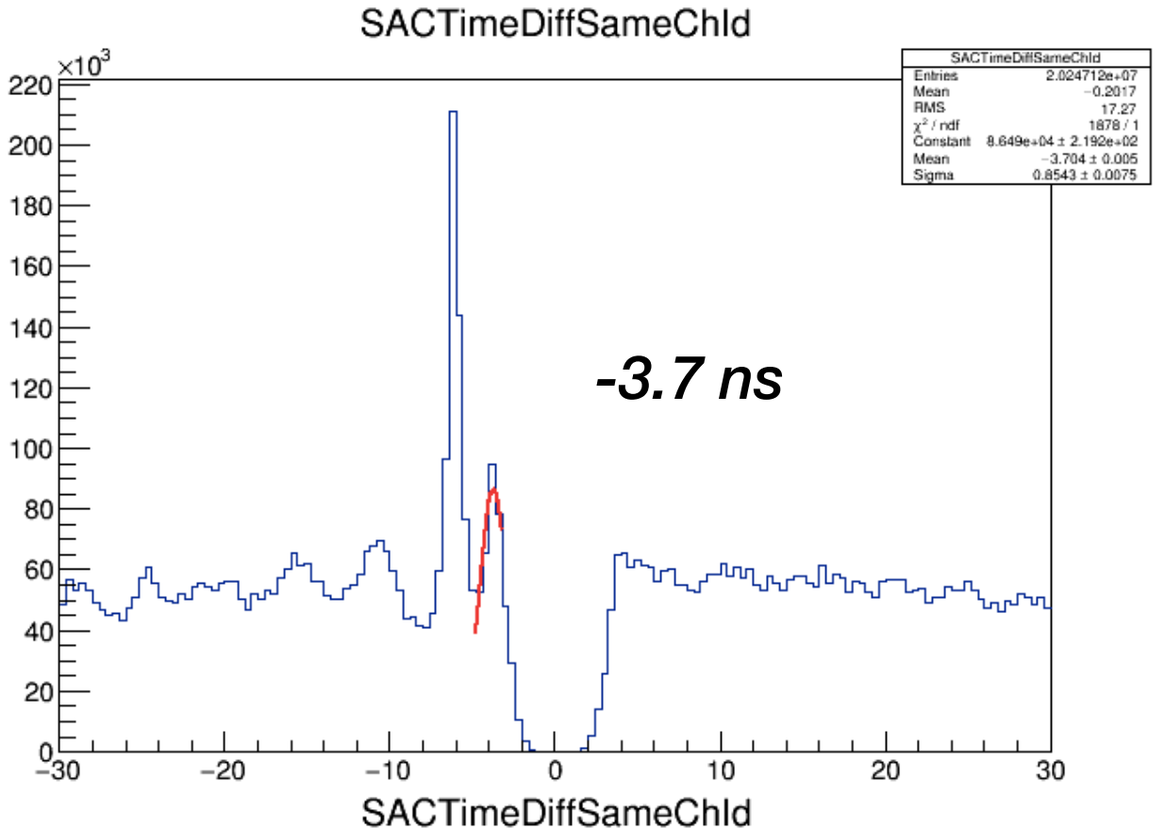




Requiring the coincidence with the central SAC crystal
ChId SAC 22



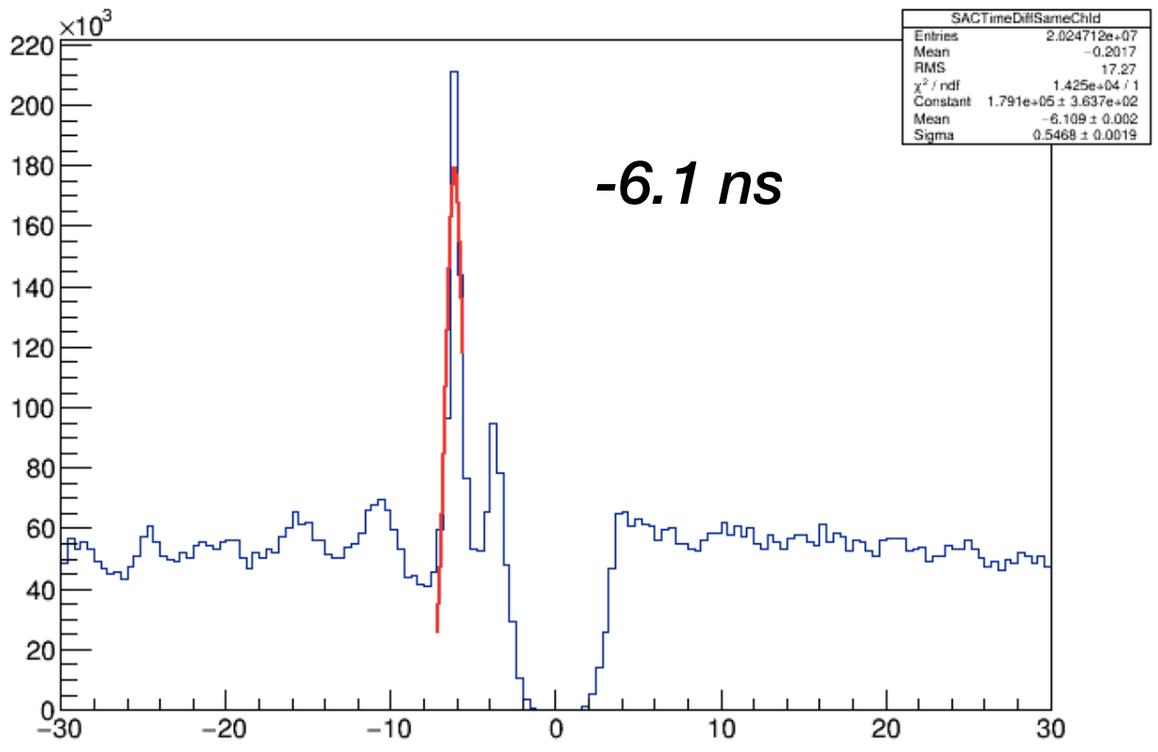
Emulate SAC signal integration time in MC



Default MC

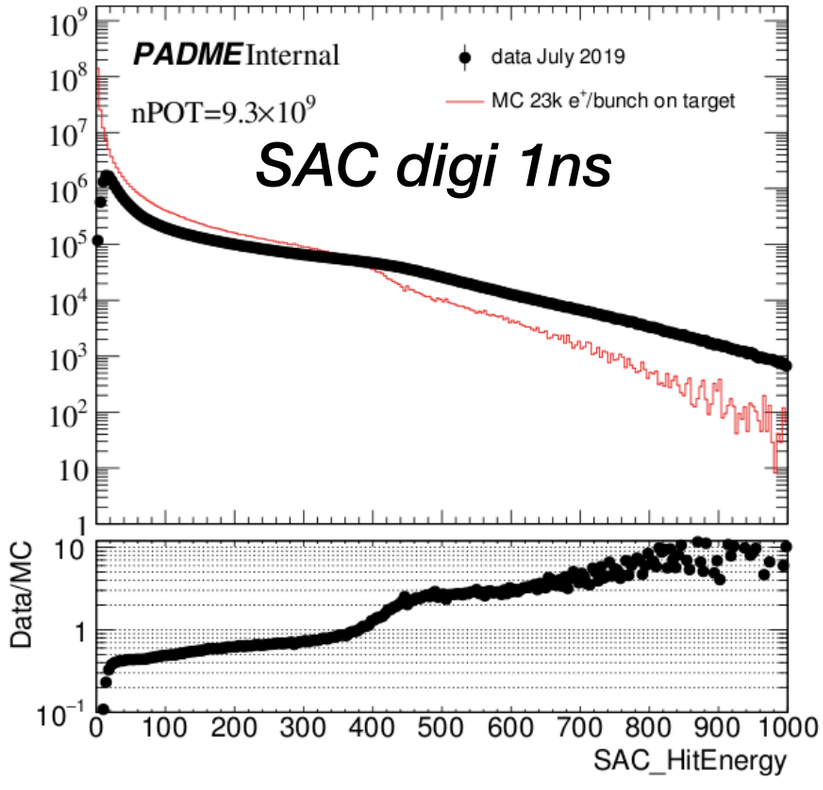
Digi time Window 1ns

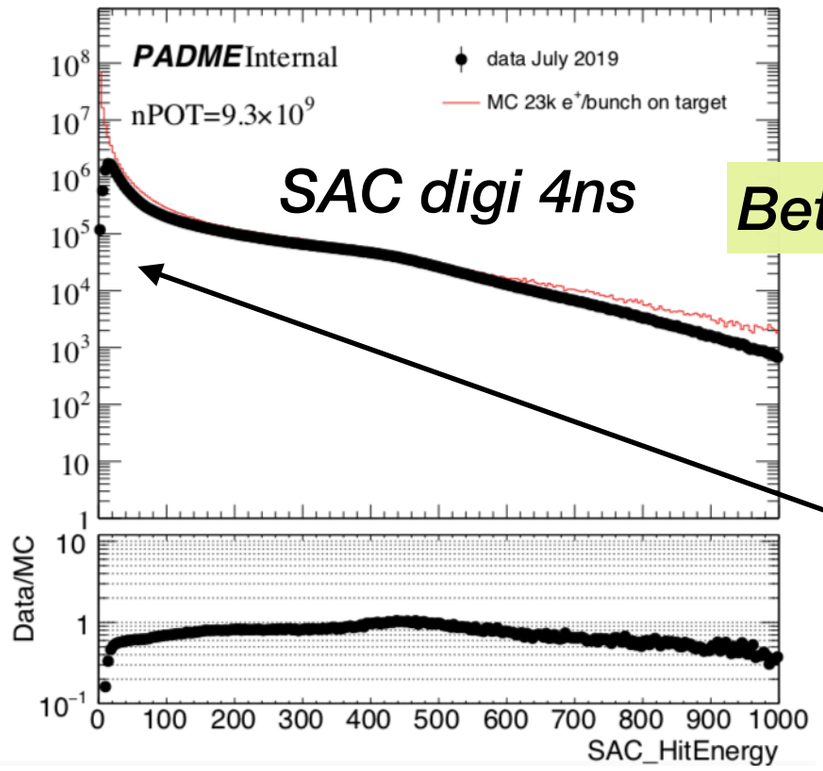
First peak at 4ns chosen



MC with Digi Time Window 4ns

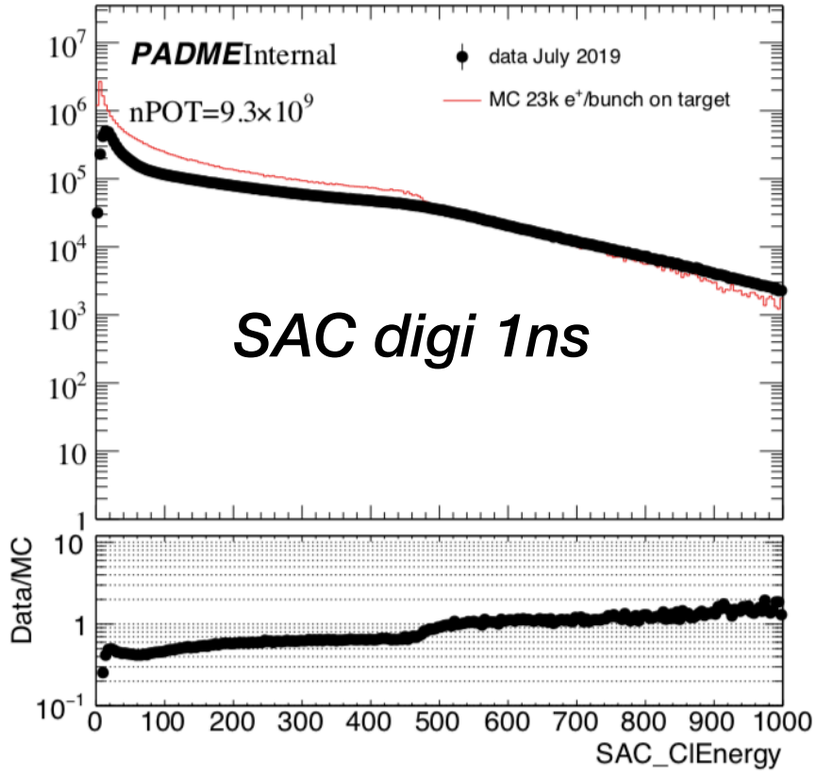
Comparison between DATA MC (SAC dig 1ns and 4ns)

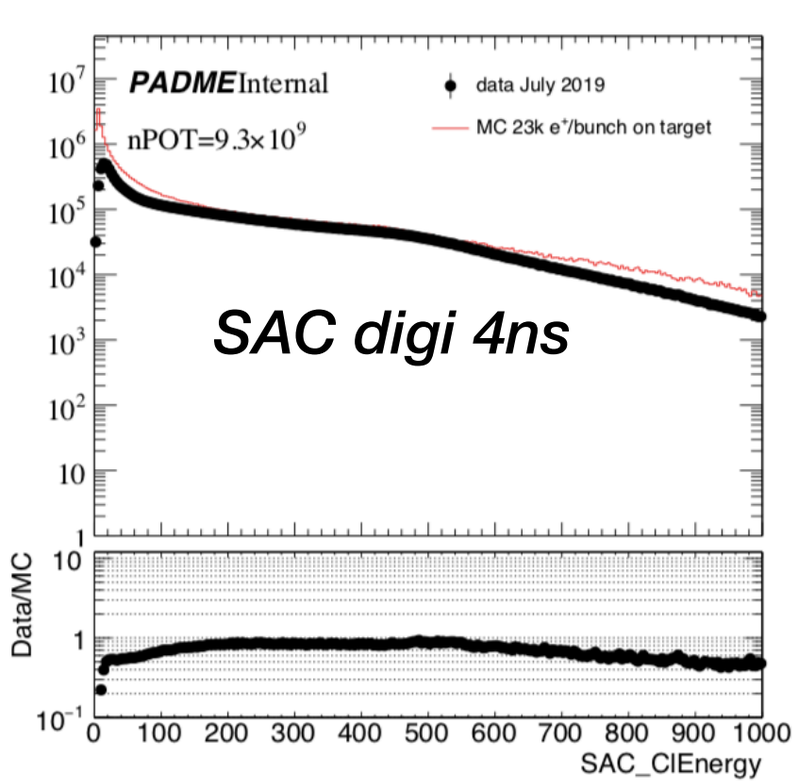




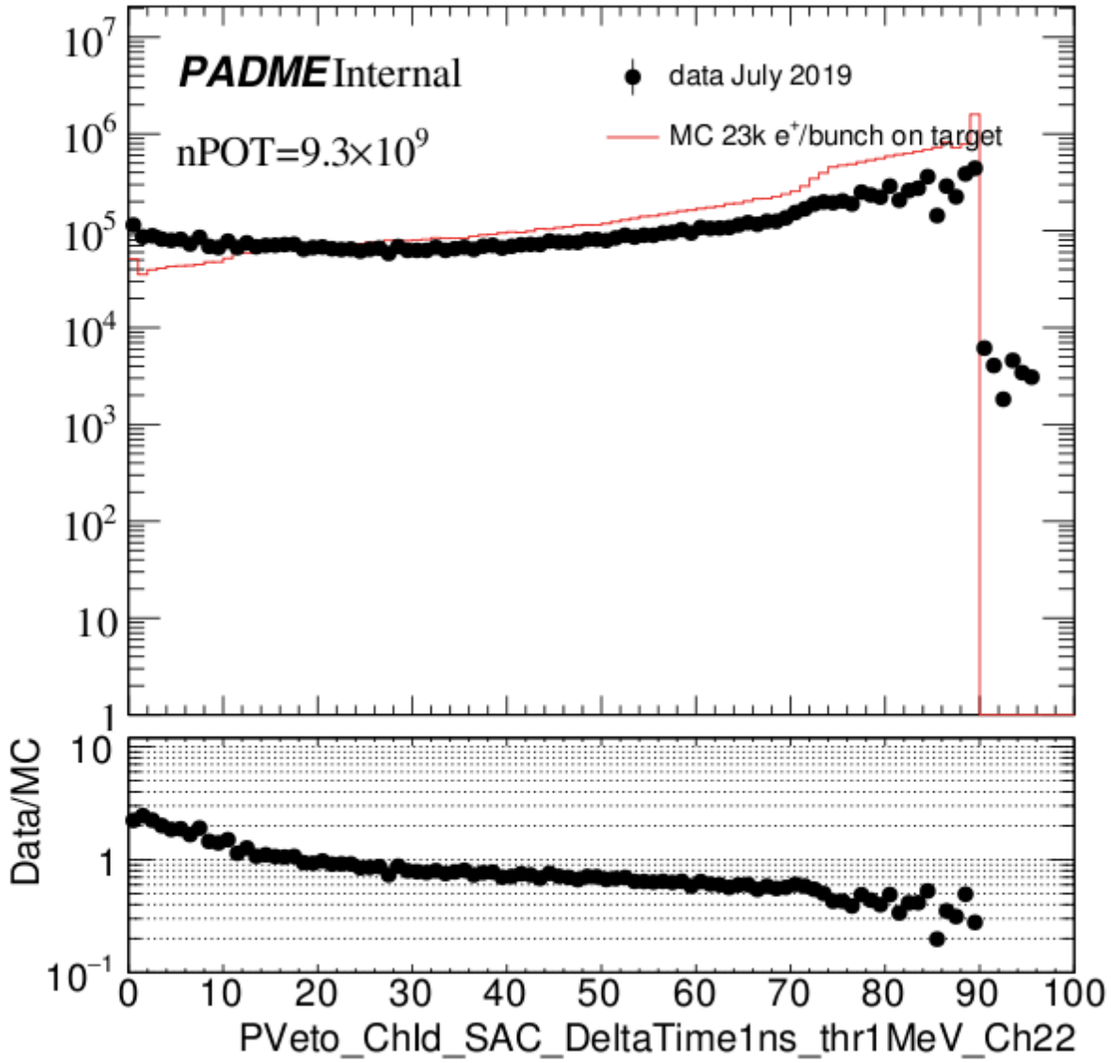
Better agreement

Difference at low energy to thr chosen for the reconstruction, to not overload the reco

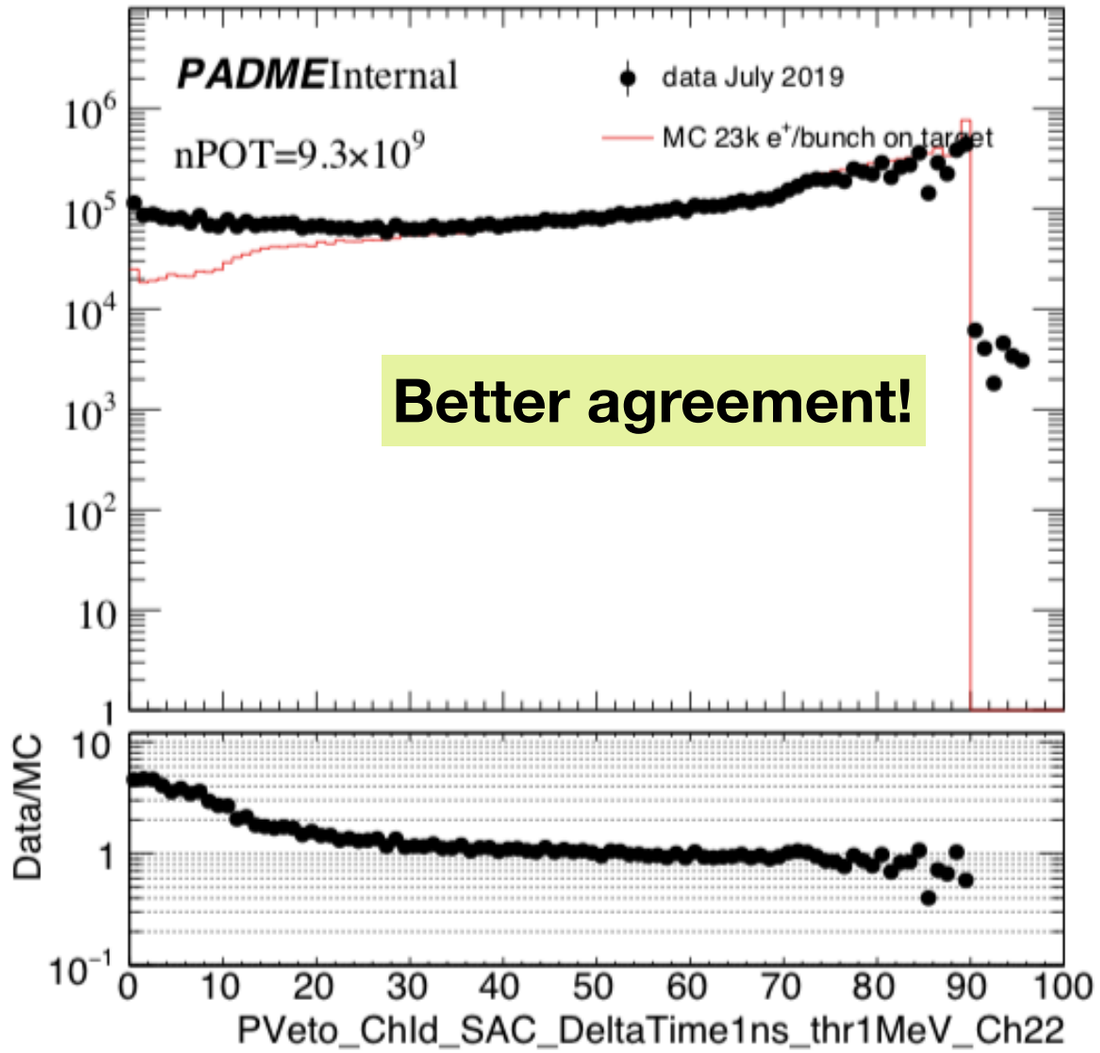




SAC digi 1ns



SAC digi 4ns



The study in the following slides was performed both conoidering the MC prod with SAC digitise 4ns and 1ns

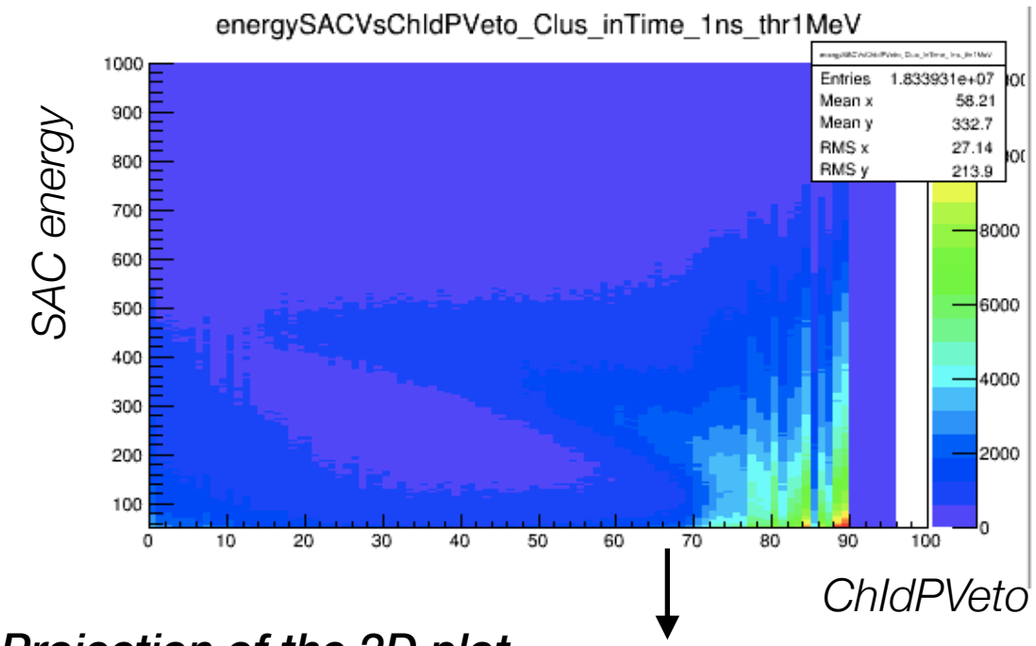
Yield Method I

Yield from time coincidence with SAC

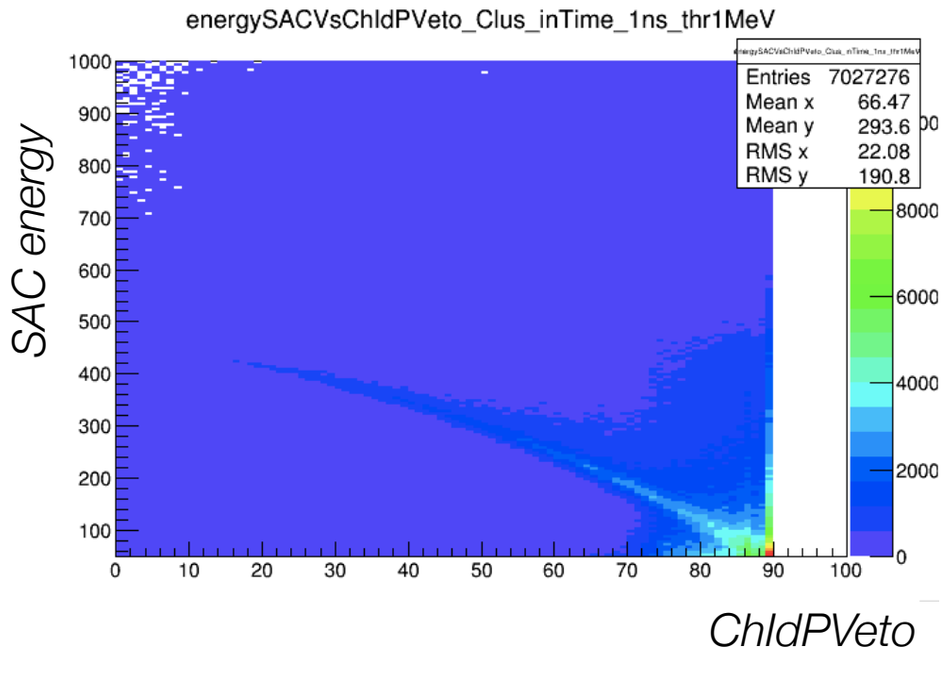
PVeto and SAC clusters in time coincidence (Δt<1ns)

Esac>50MeV

DATA

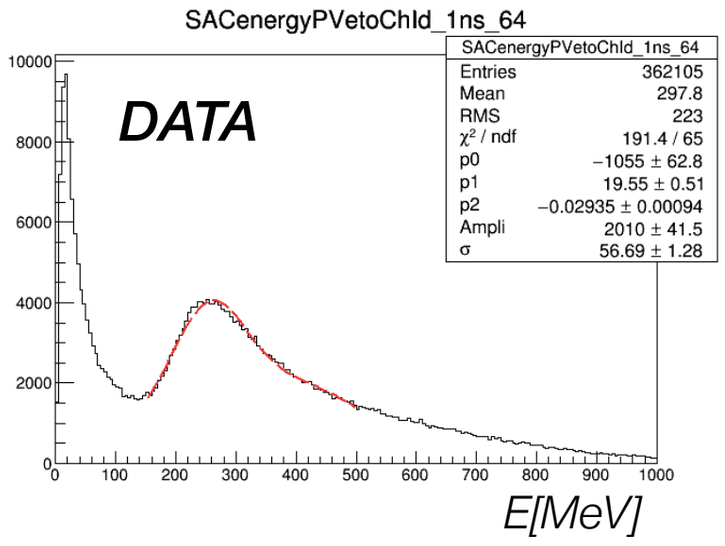


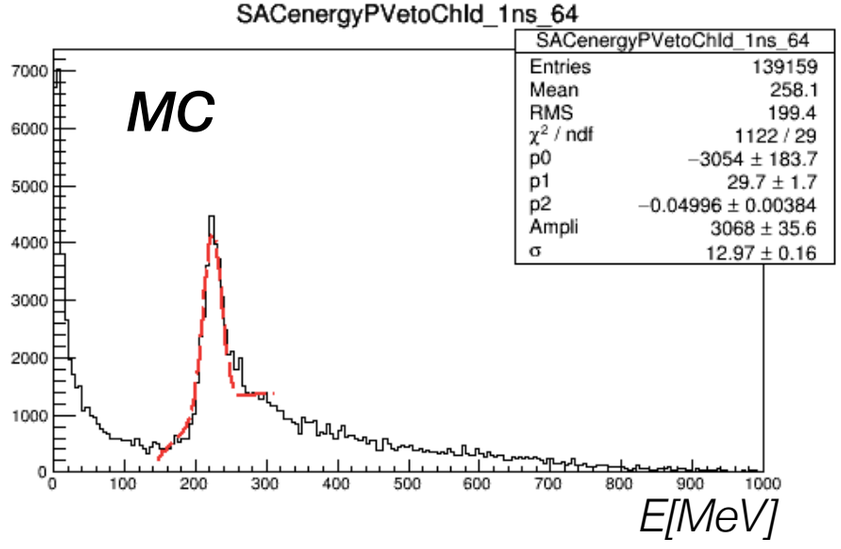
MC



Projection of the 2D plot

SAC energy spectrum for every PVeto ChID





Inaccurate Method

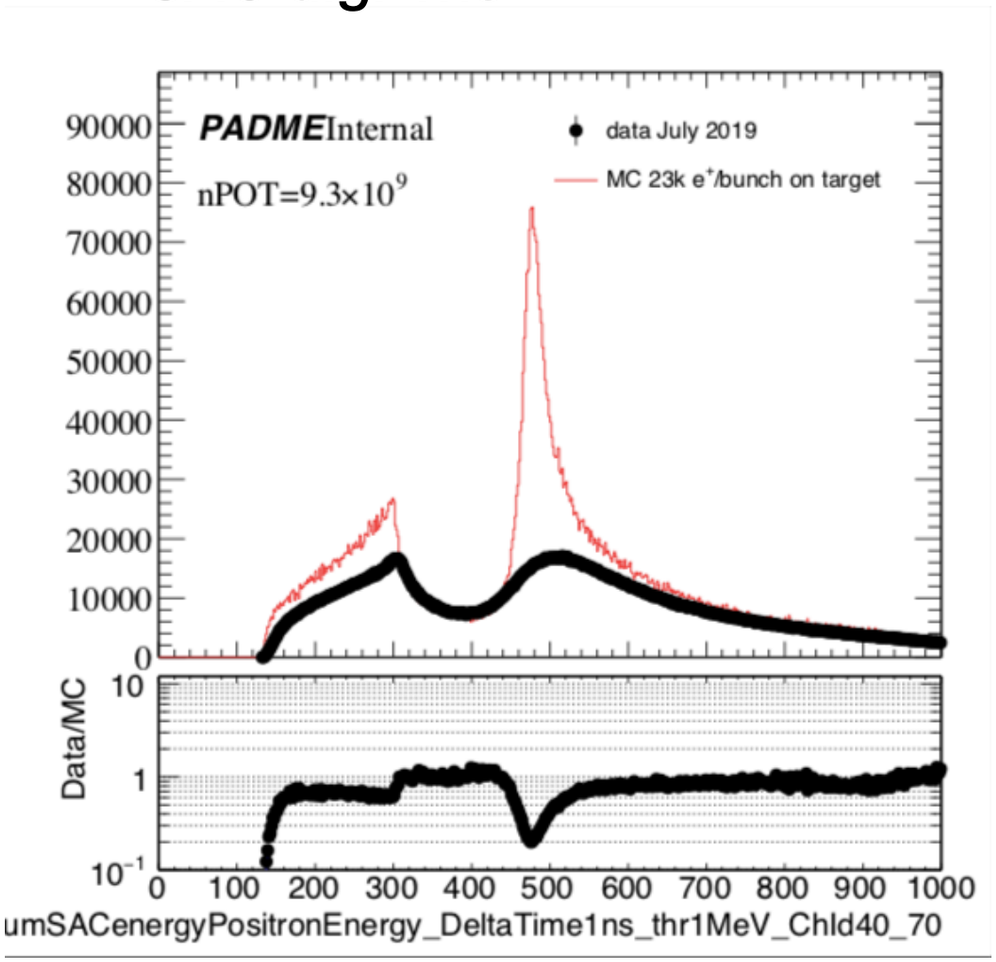
Fit with a combination of function each projection, calculate the area of the gaussian and then sum this yield for all the fingers

Yield Method II

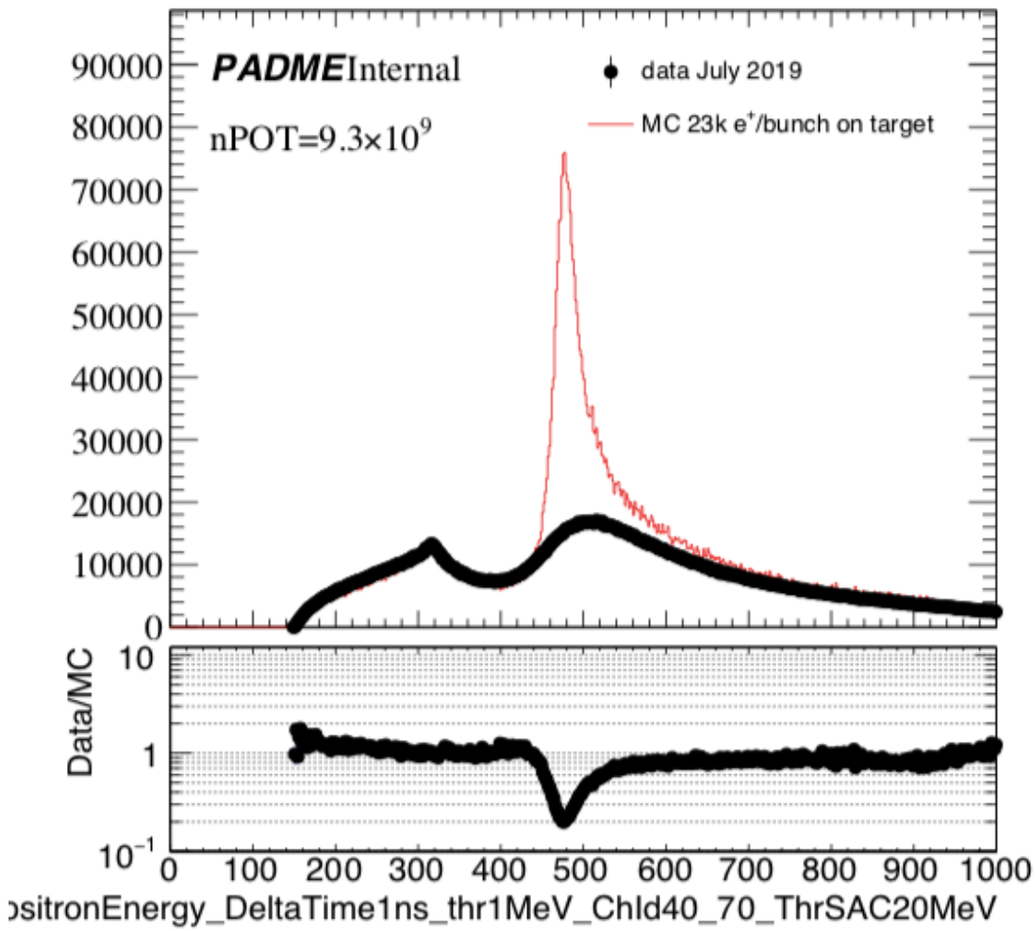
SAC energy + Positron energy in coincidence*

A possibility to obtain the Brem. yield could be taking the signal integral from this plot
In the range of Chld PVeto agreement MC DATA

SAC digi 1ns

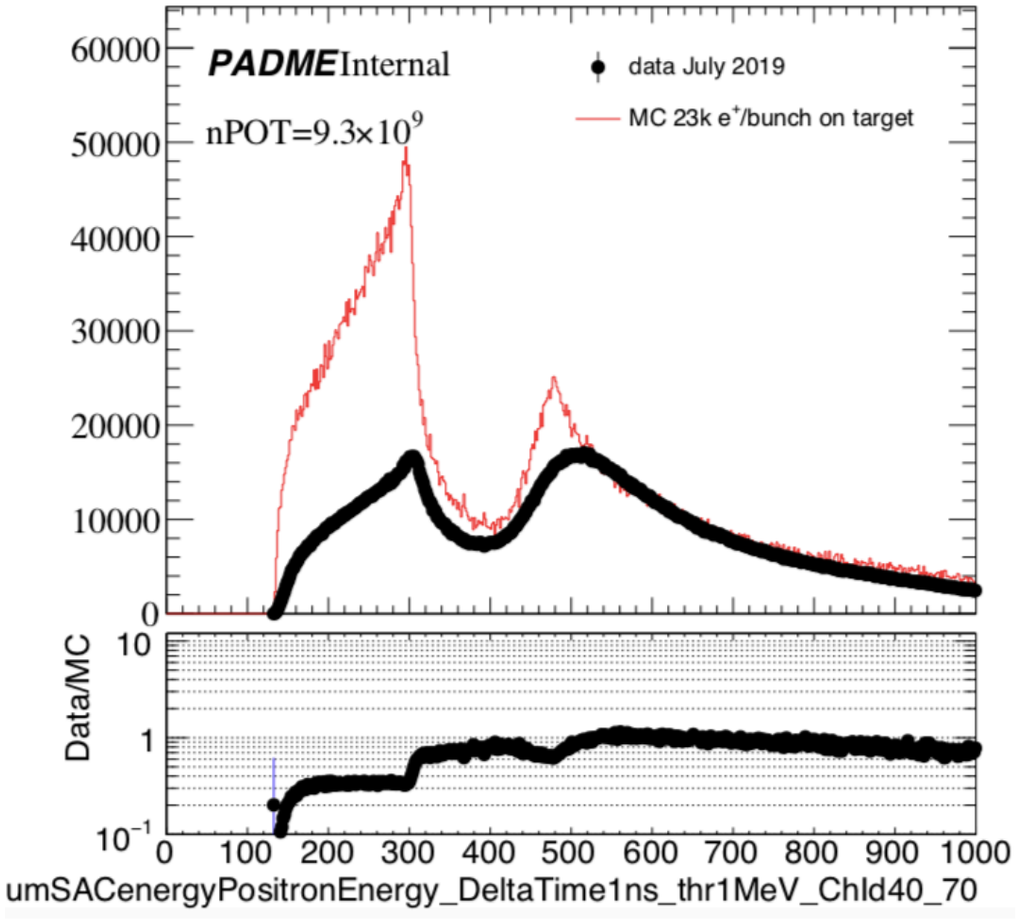


Asking for Esac>20 MeV to avoid the thr effect

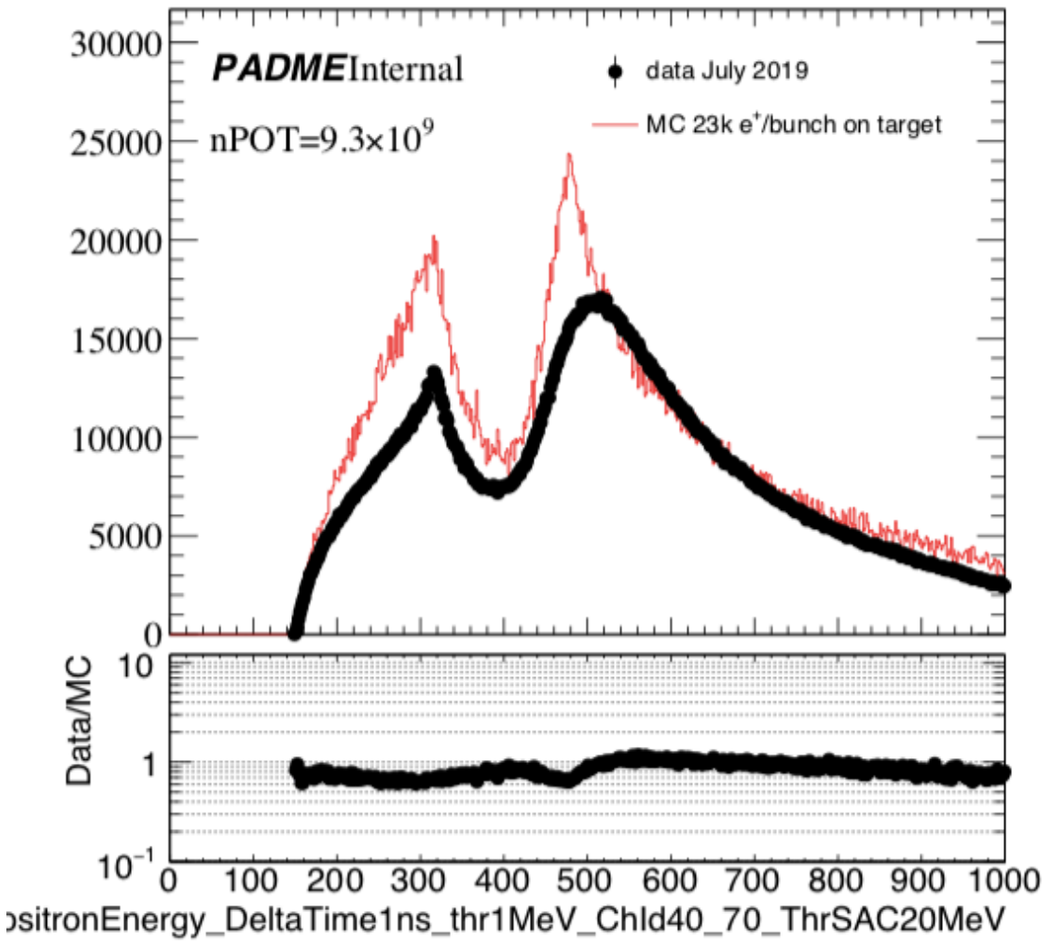


**obtained from Momentum calibration*

SAC digi 4ns



Asking for Esac>20 MeV to avoid the thr effect

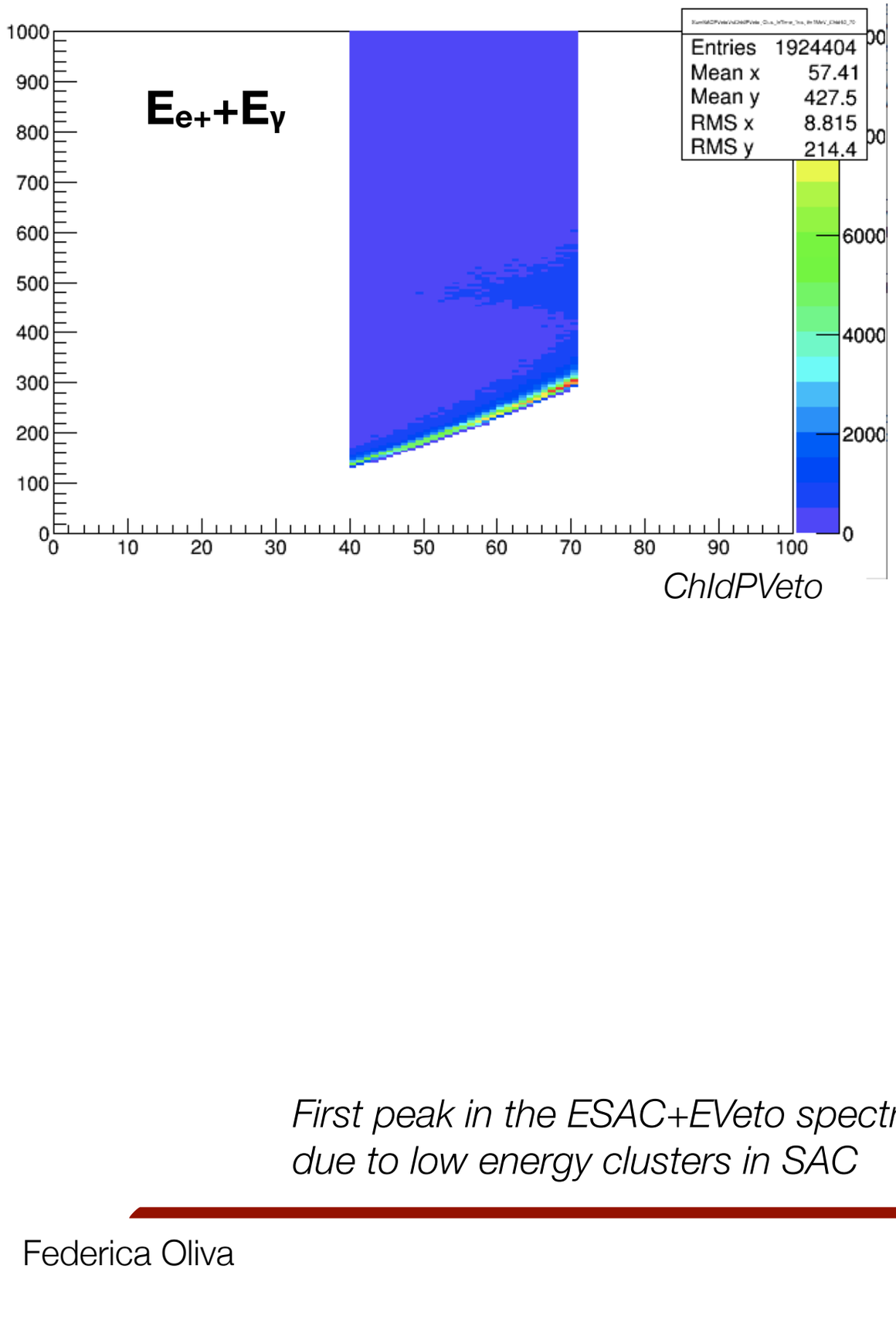


Why a peak at lower energy?

Probably photons in PVeto in coincidence with low energy SAC clusters.
Remember that the energy of the veto cluster is given by the position.

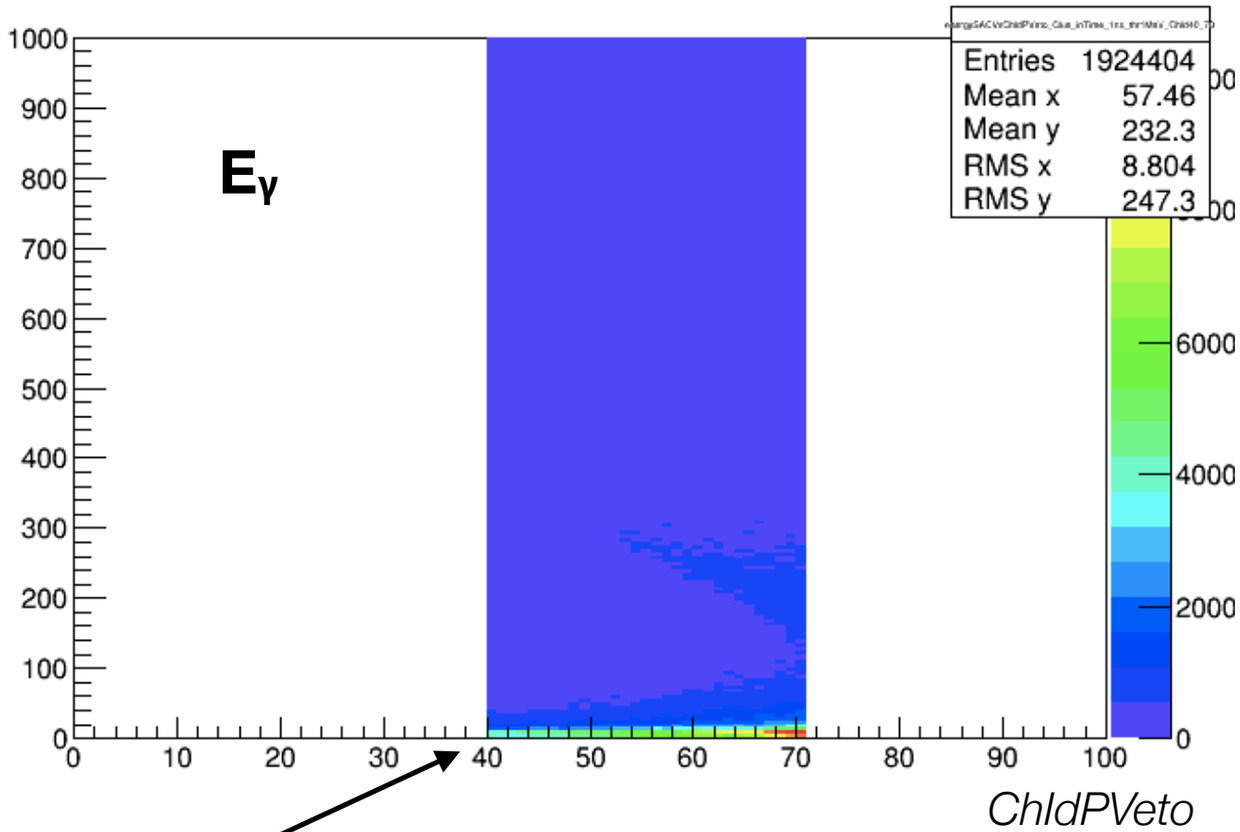
MC digi 4ns

E PVeto cluster + E SAC cluster in coincidence VS ChId Seed PVeto



Δt Cluster SAC/Pveto < 1ns

SAC energy VS PVetoChID

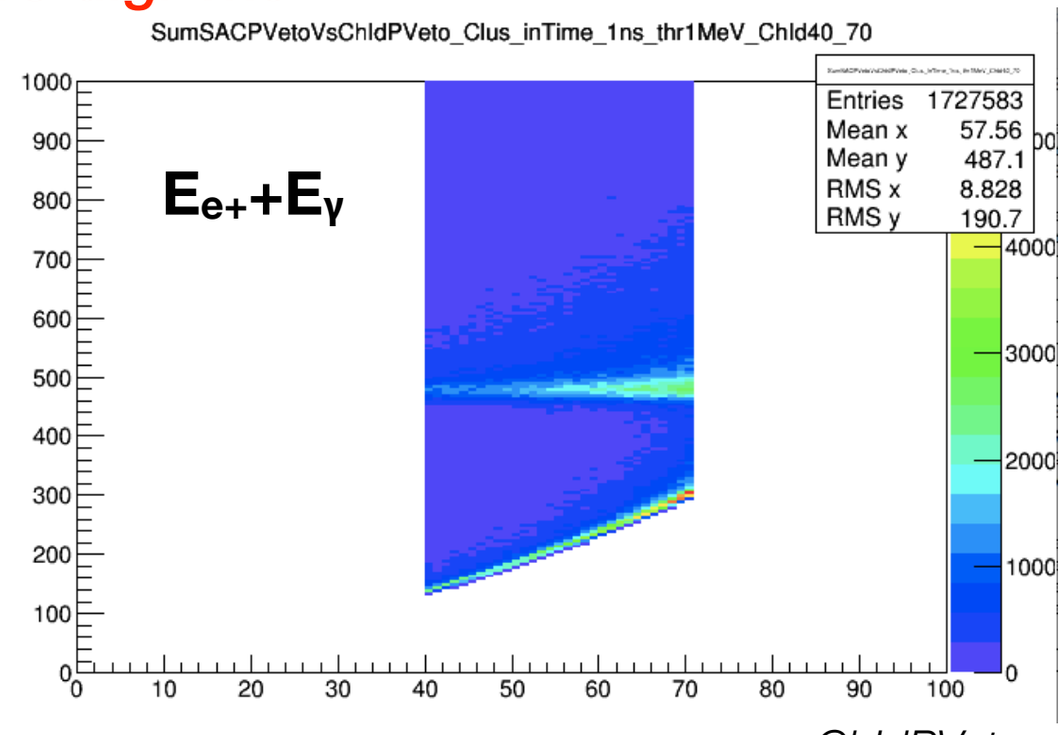


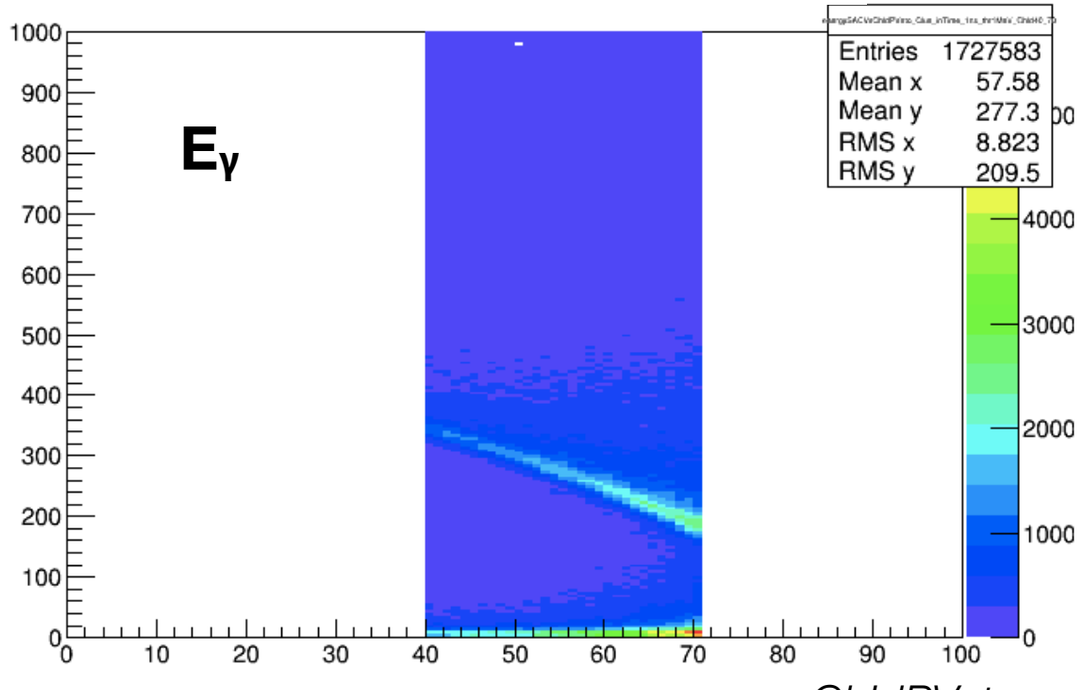
First peak in the ESAC+EVeto spectrum due to low energy clusters in SAC

MC digi 1ns

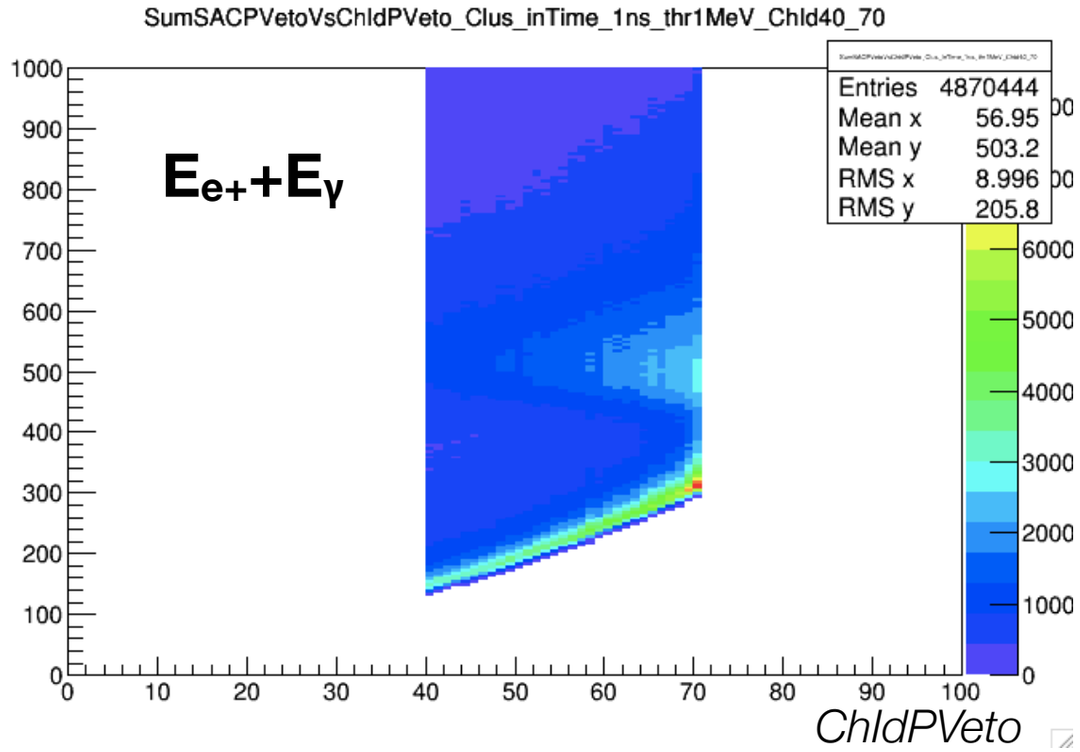
40<PVetoChId<70

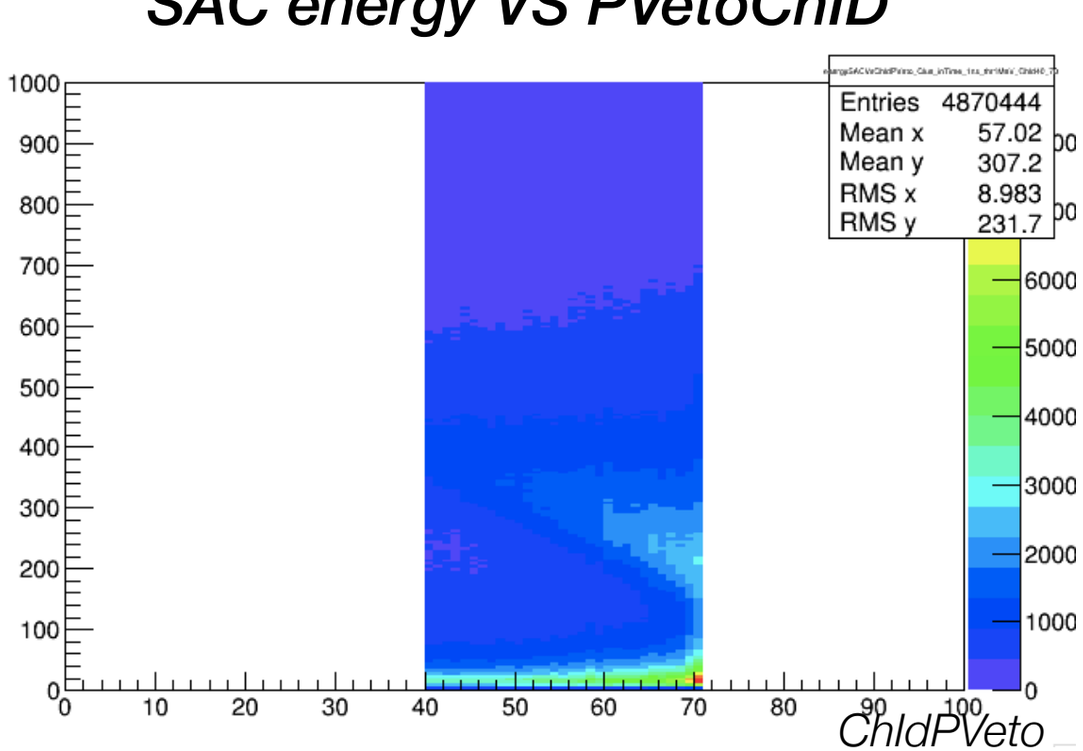
SAC energy VS PVetoChID



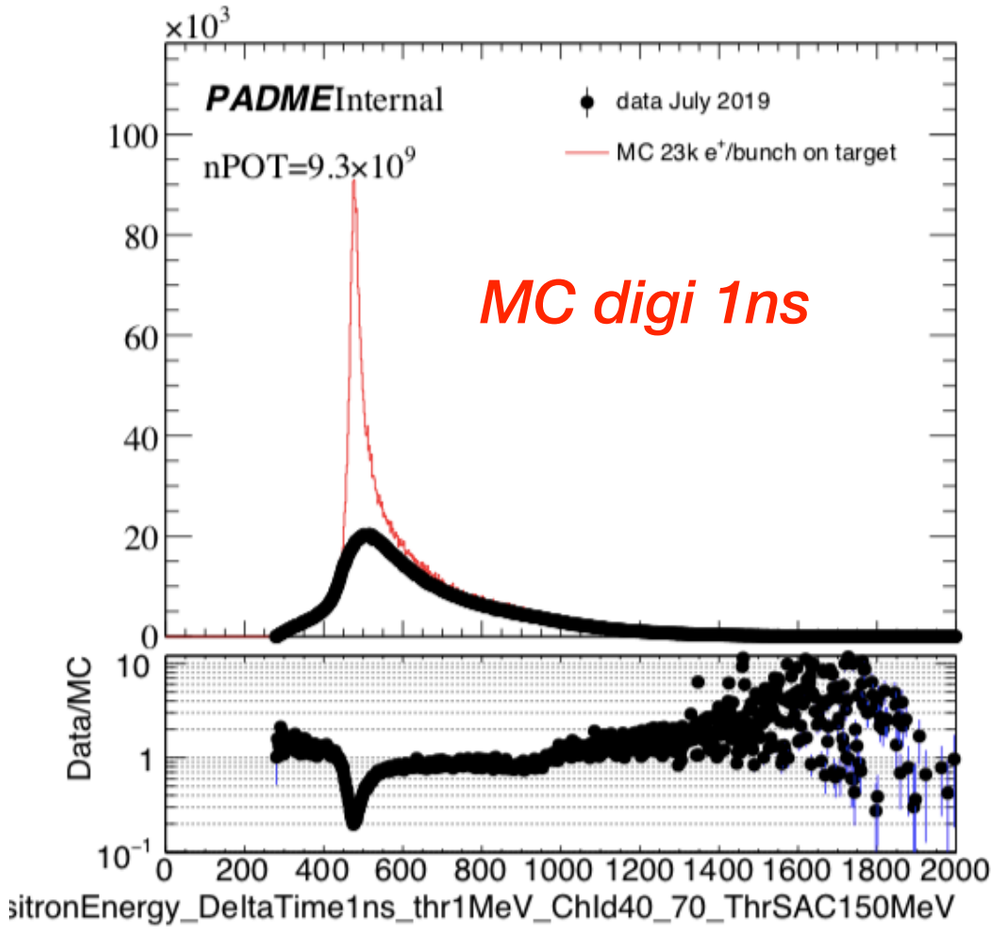


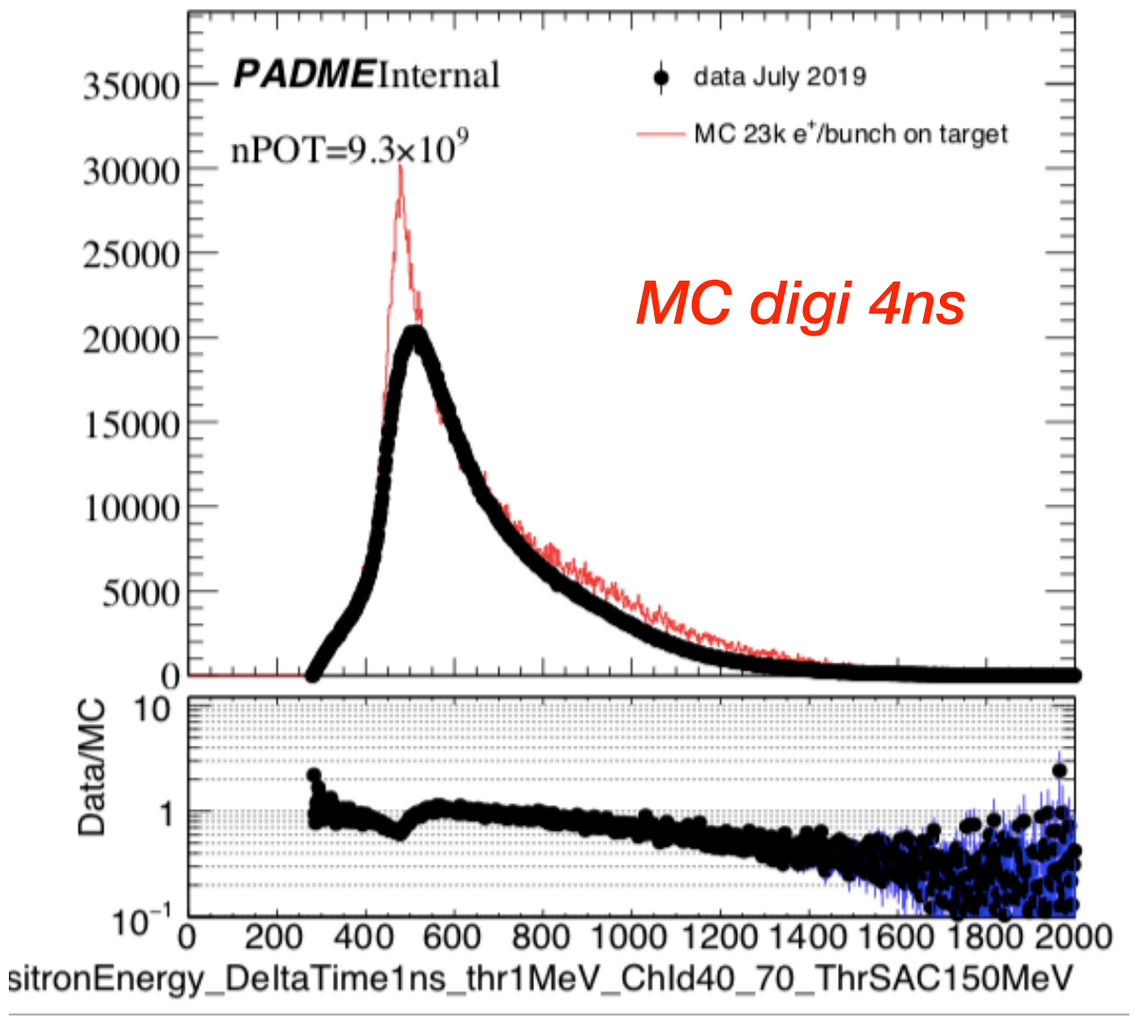
DATA





With an energy threshold for SAC it's possible to select only Bremsstrahlung events candidate

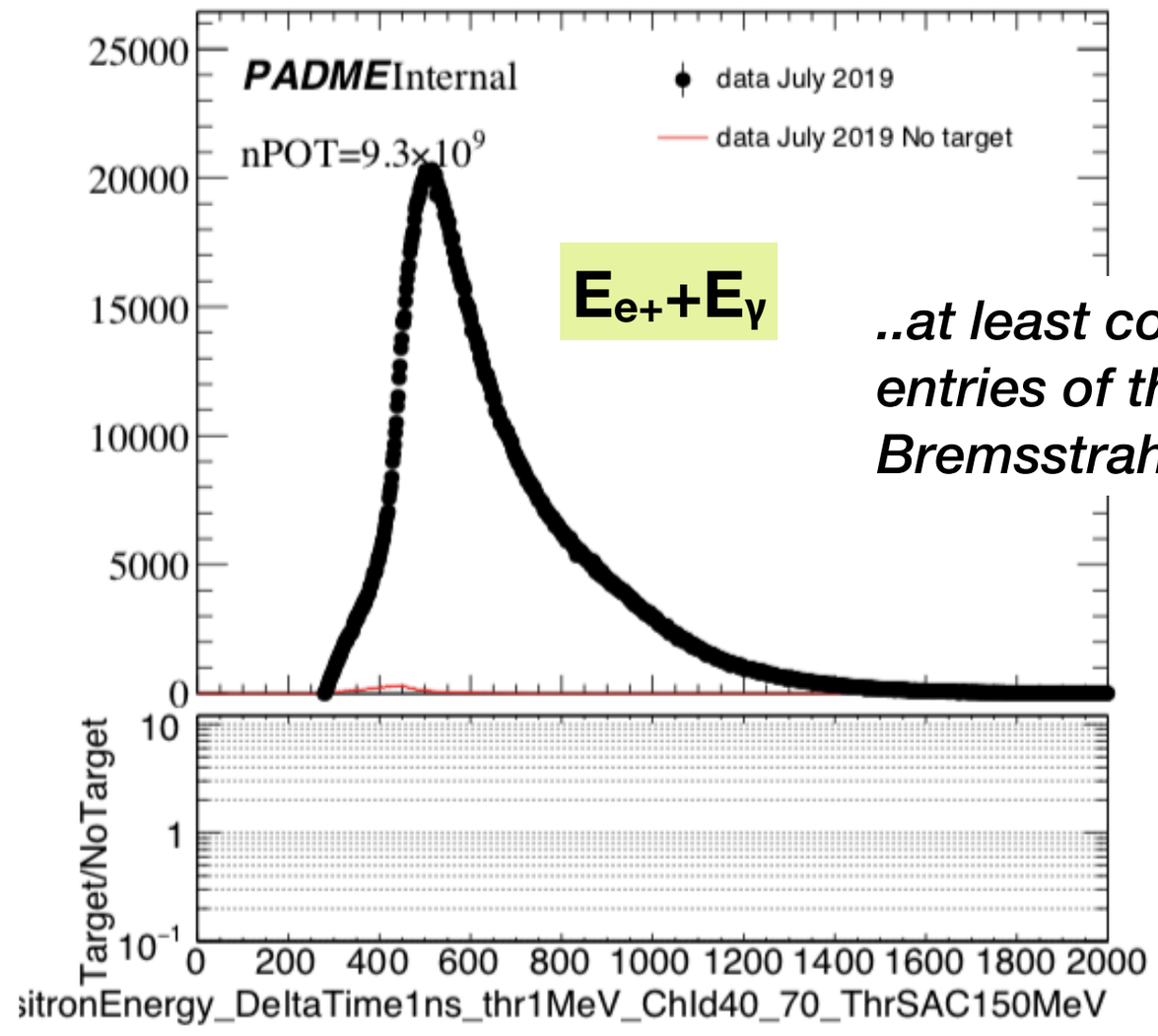




Considering the same plot for DATA with and without the target..

PVeto Chld 40-70
SAC energy>150 MeV

DATA Target/NoTarget



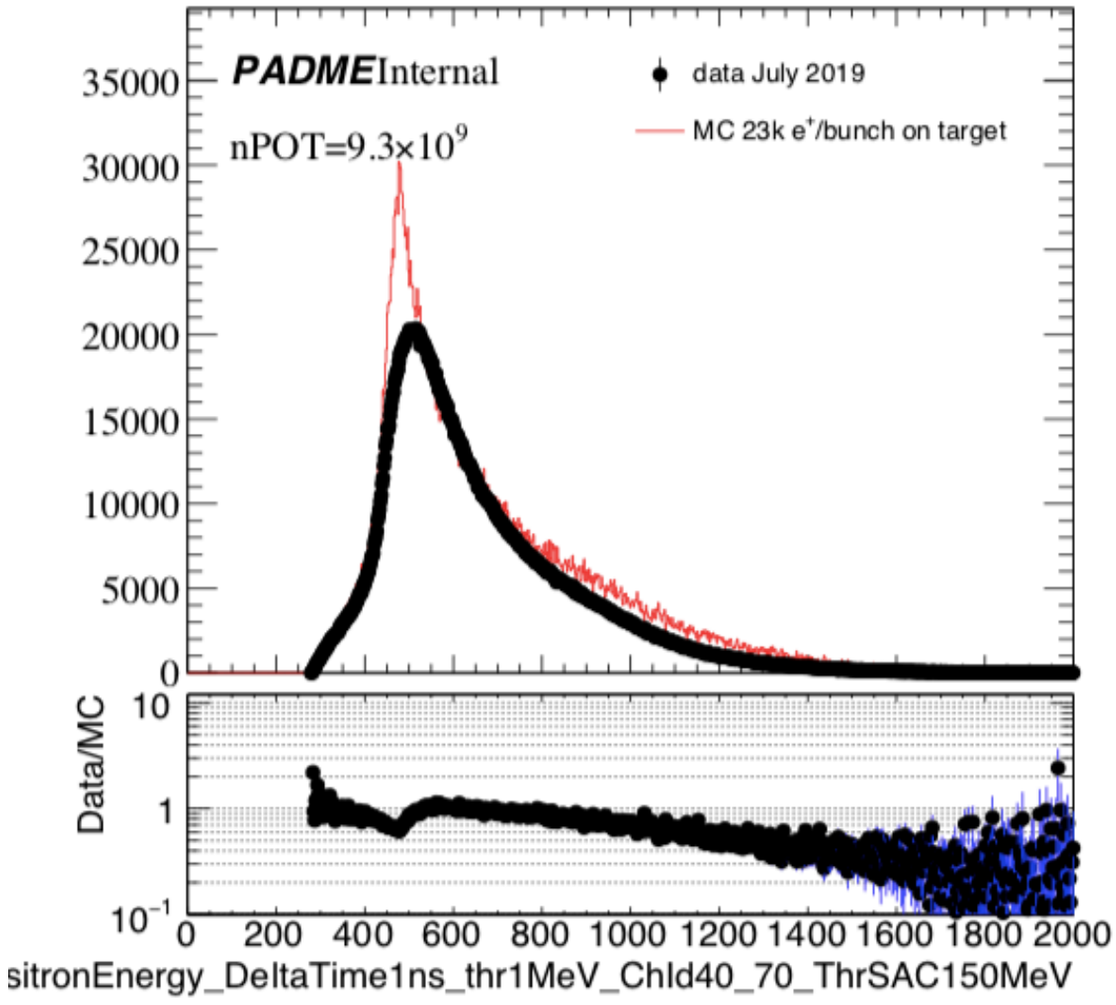
$E_{e+}+E_{\gamma}$

..at least could we say that all the entries of the plots are from Bremsstrahlung process..

Could we calculate the Bremsstrahlung yield considering the entries of this plot?

MC digi SAC 4ns

Photons on SAC expected~ 4.2e+06

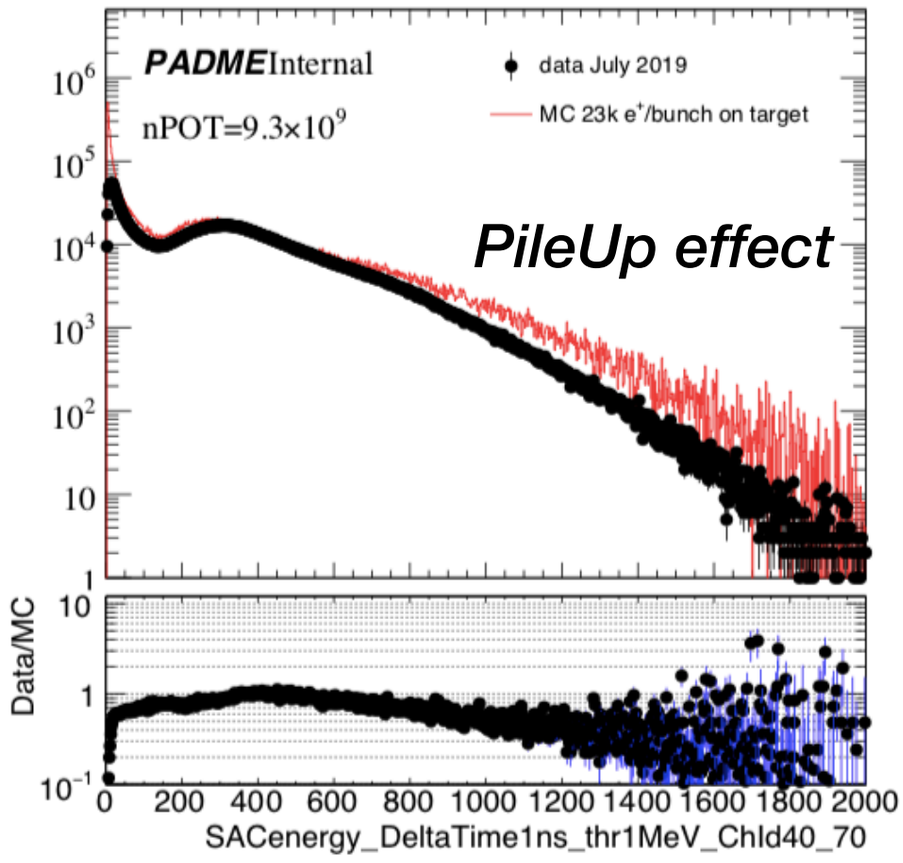


MC Yield

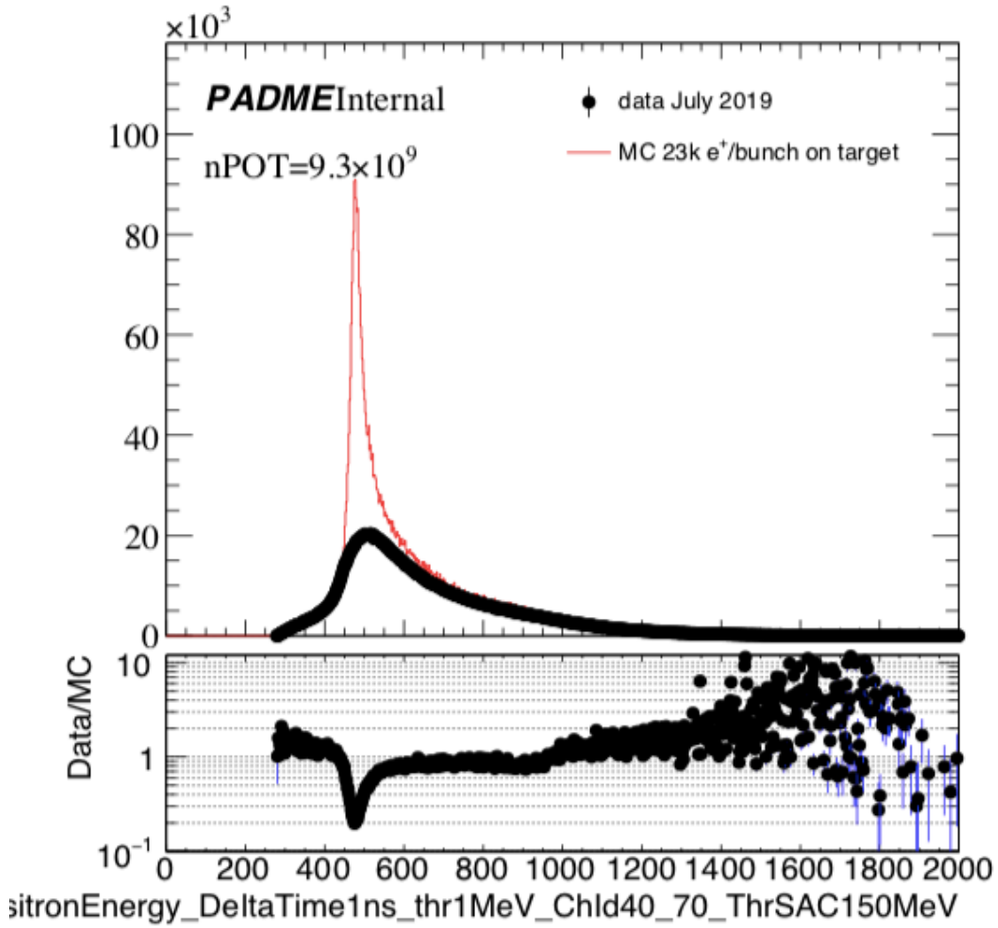
*992880 * Scalefactor = 4.1 M*

DATA Yield

3.39 M

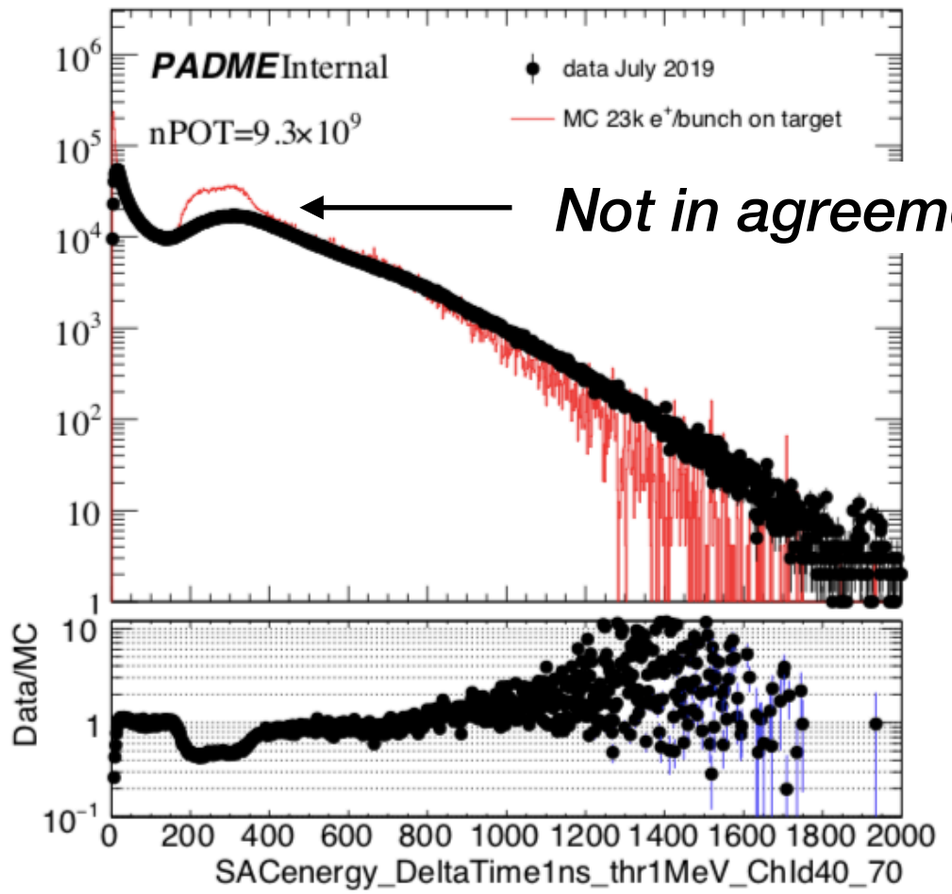


MC digi SAC 1ns



MC Yield

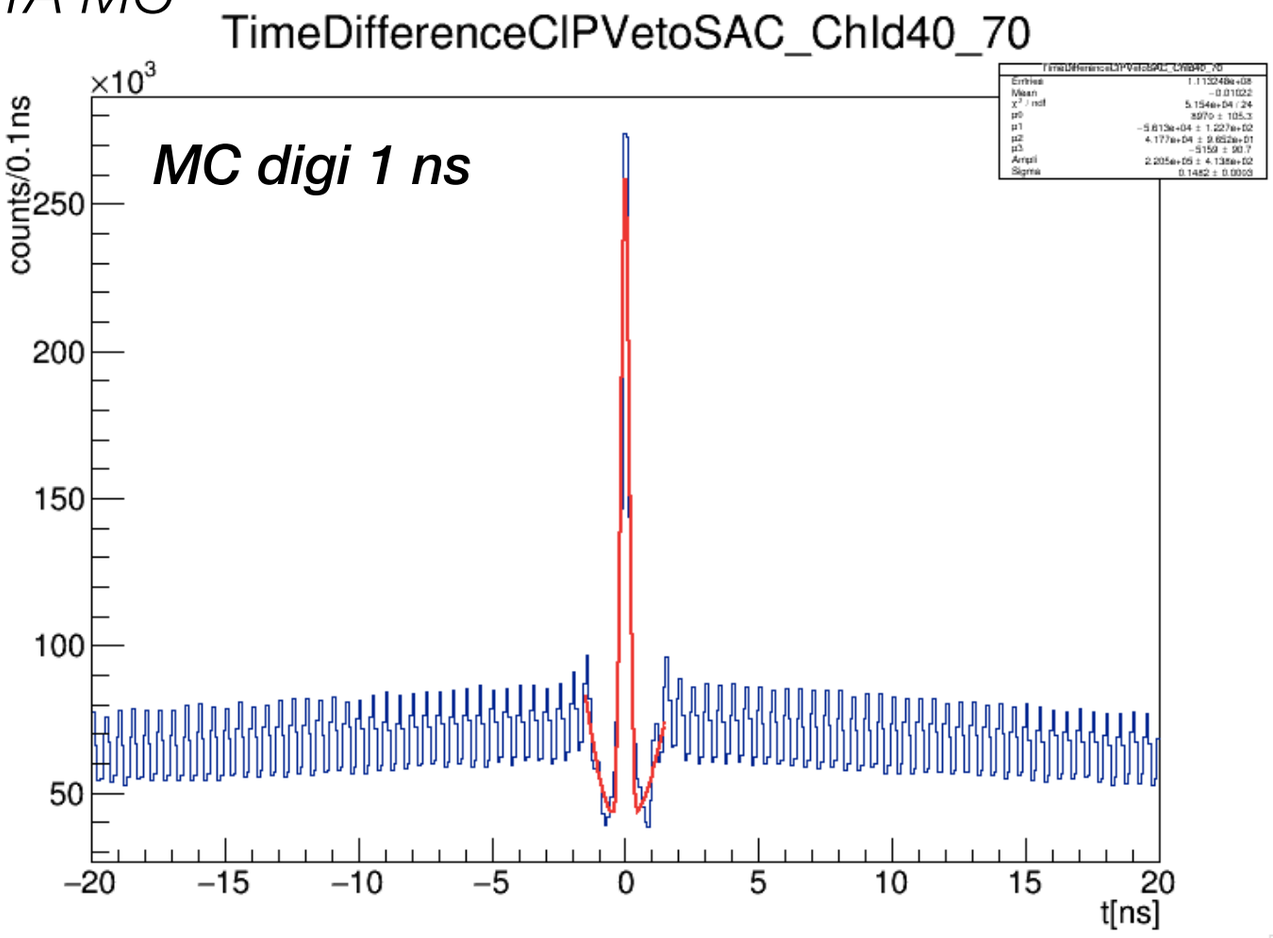
*Entries*Scalefactor ~5e+06*



Not in agreement

Yield Method III

Considering the time difference between SAC and PVeto selecting the PVeto ChId in agreement DATA MC



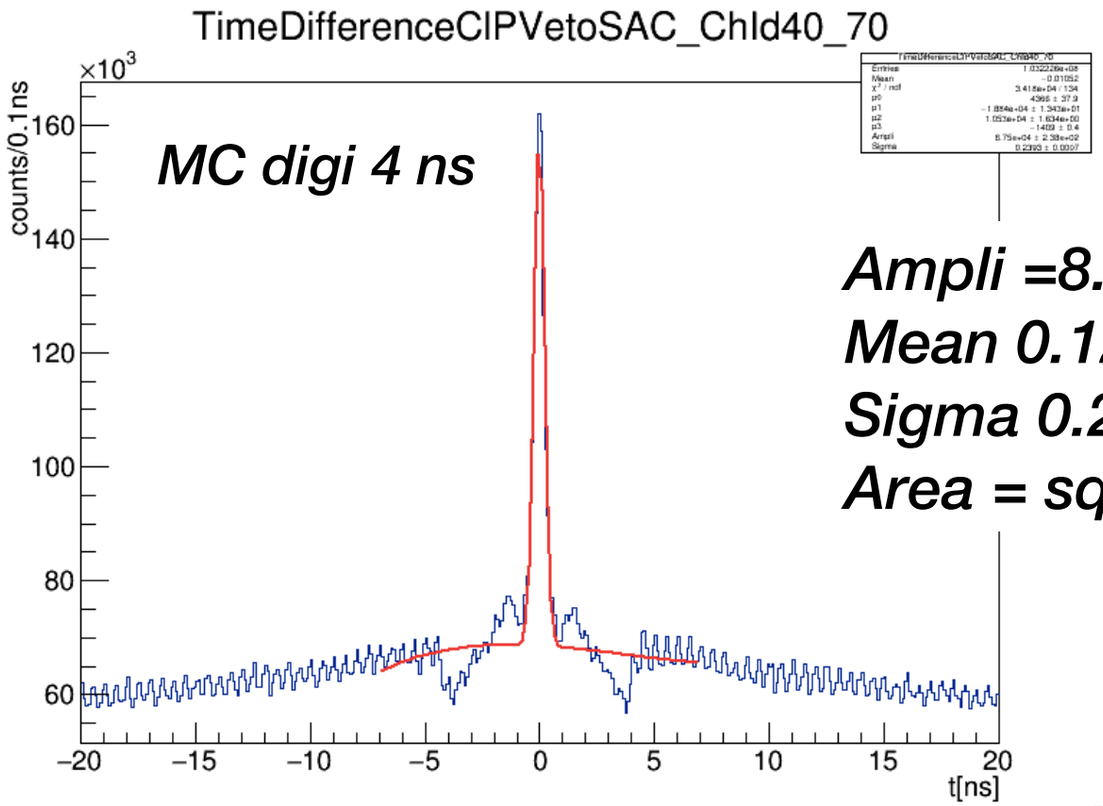
Yield expected from calculations for PVeto ChId 40-70 ~ 4.23 e+06

Preliminary

Ampli =2.2e+05 entries/0.1ns
Mean -0.008 ns
Sigma 0.15 ns
Area = sqrt(2π) Ampli Sigma / BinWidth ~8.2 e+05

AreaScaled~3.4 e+06

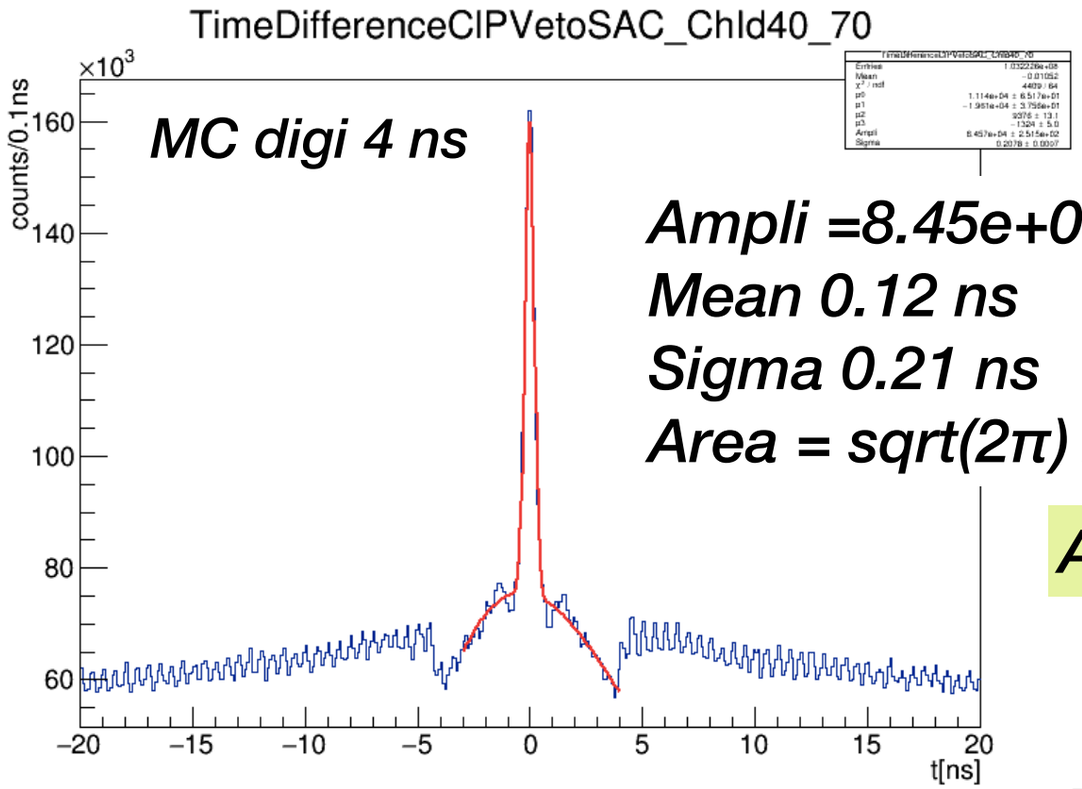
expected ~ 4.23 e+06



Ampli =8.74e+04 entries/0.1ns
Mean 0.12 ns
Sigma 0.24 ns
Area = sqrt(2π) Ampli Sigma / BinWidth ~52 e+04

AreaScaled~2.14 e+06

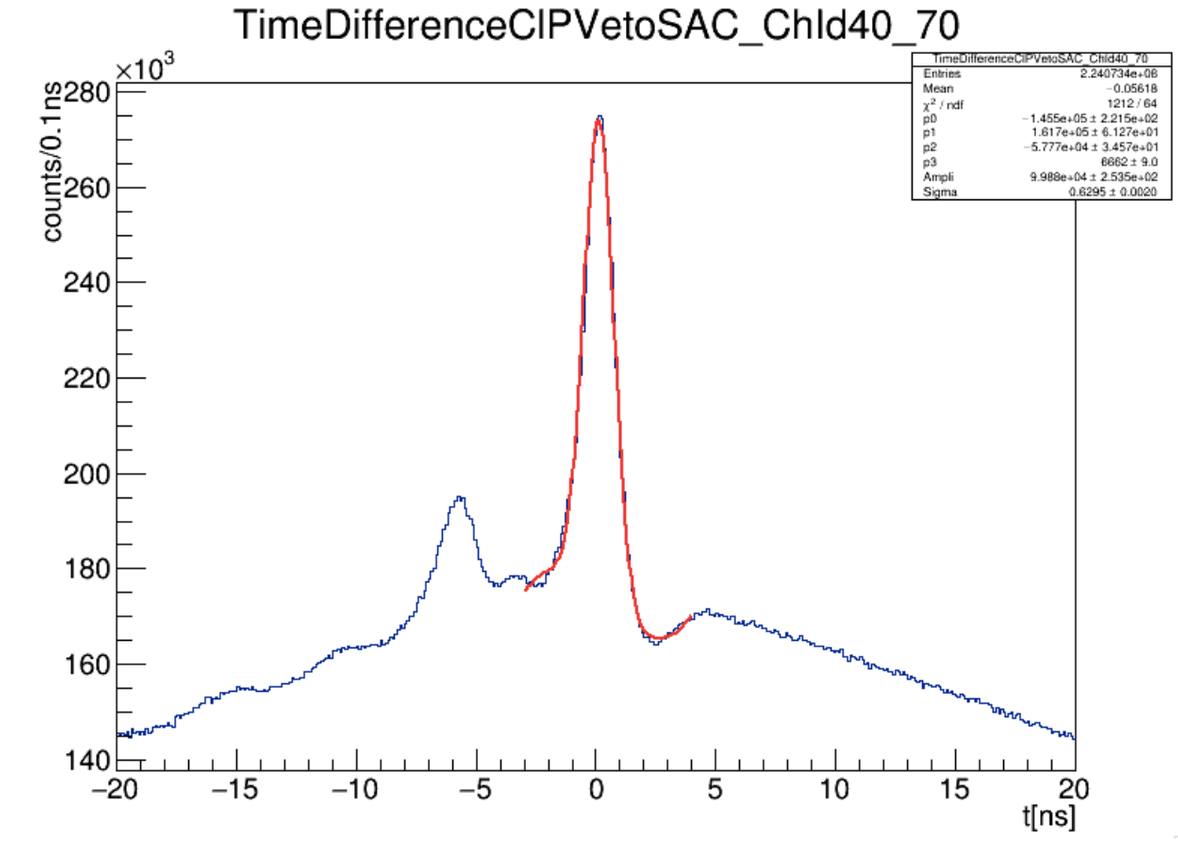
Preliminary



Ampli =8.45e+04 entries/0.1ns
Mean 0.12 ns
Sigma 0.21 ns
Area = sqrt(2π) Ampli Sigma / BinWidth ~44.36 e+04

AreaScaled~1.8 e+06

DATA



expected from
analytic calculation ~ 4.23 e+06

Preliminary

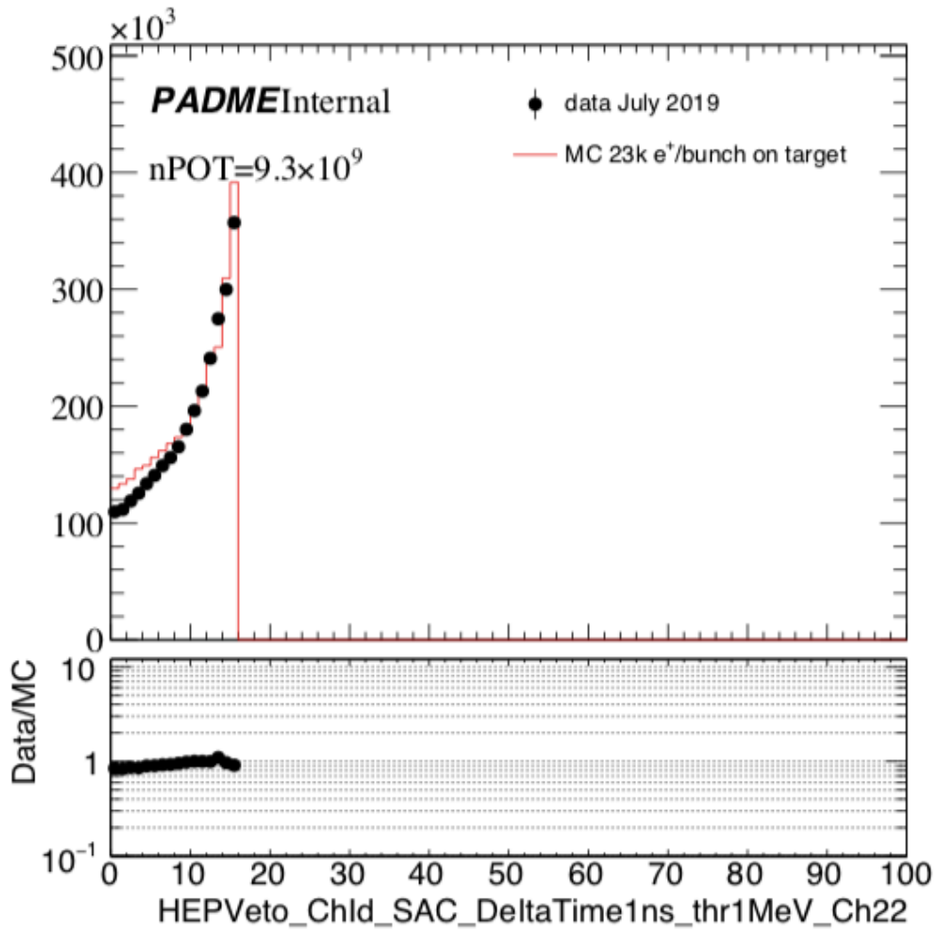
Ampli =9.99e+04 ~10e+05 entries/0.1ns
Mean 0.12 ns
Sigma 0.63 ns
Area = sqrt(2π) Ampli Sigma / BinWidth ~1.6 e+06

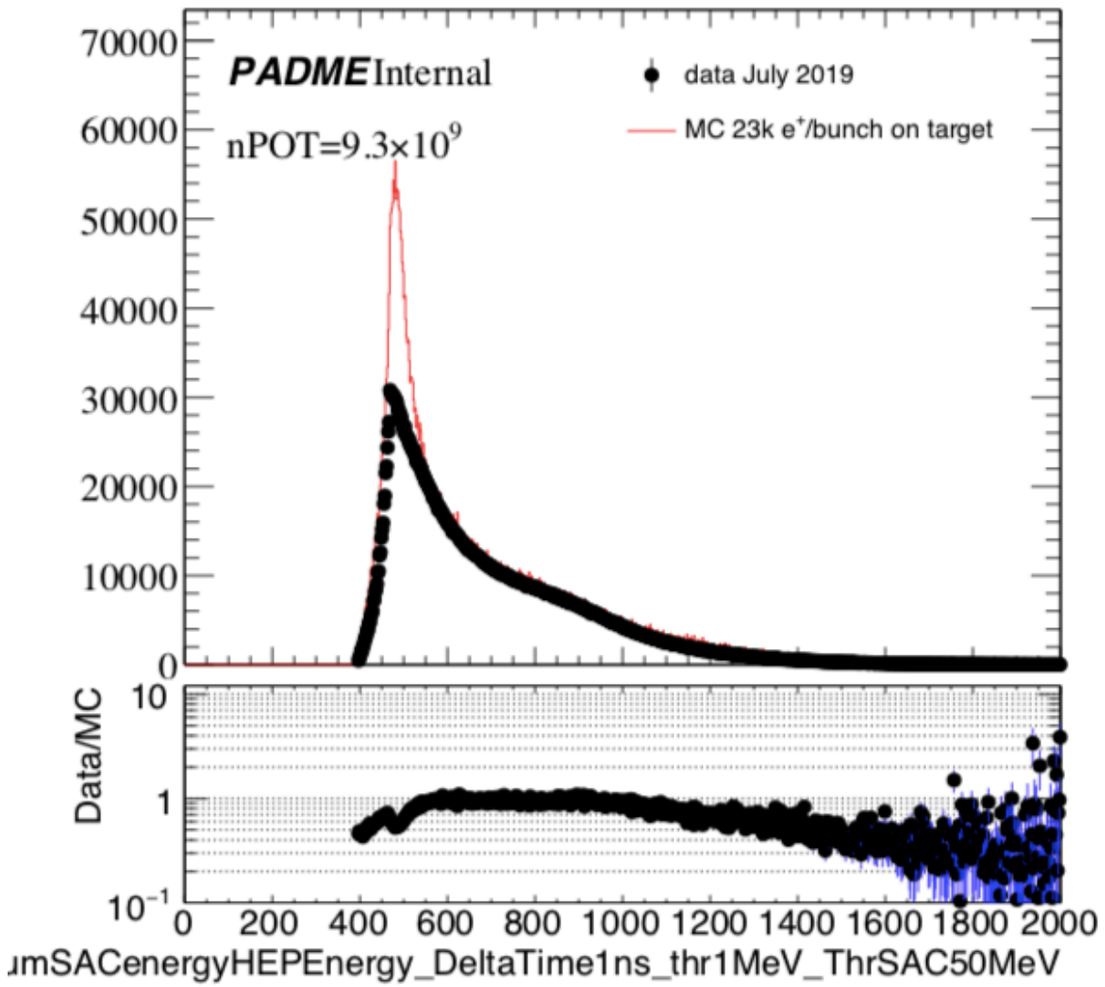
Is it possible to give a first estimation of the efficiency?

SAC Efficiency ~ 40%?

Looking at the HEP Veto..

SAC digi 4ns





Conclusions

The Bremsstrahlung yield can be calculated subtracting the occupancy PVeto plot with and without the target, both for DATA and MC.

From a preliminary calculation, MC and DATA yields are not so different.

To check without PCB

Another way to obtain the yield could be asking for the time coincidence with SAC

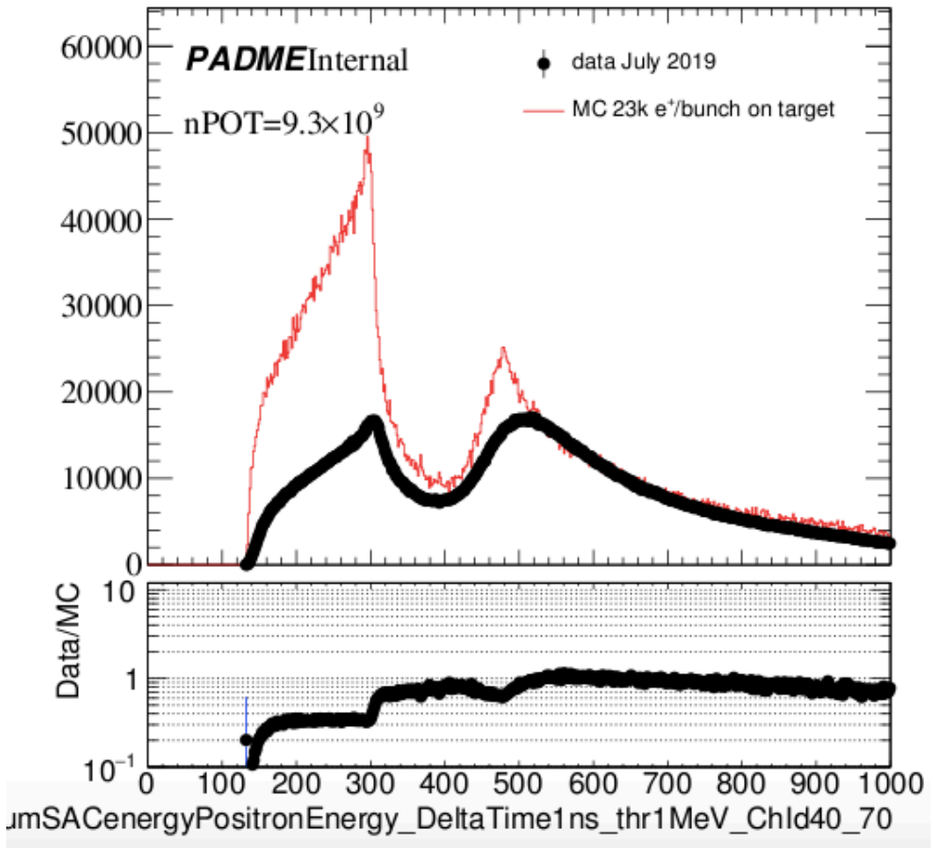
- *Considering the SAC cluster spectrum in coincidence with every ChId of the PVeto*
- *Studying the spectrum of the sum of the positron and the photon in time coincidence*
- *Studying the time difference between SAC and PVeto Clusters in the ChIds range in agremeent of MC DATA*

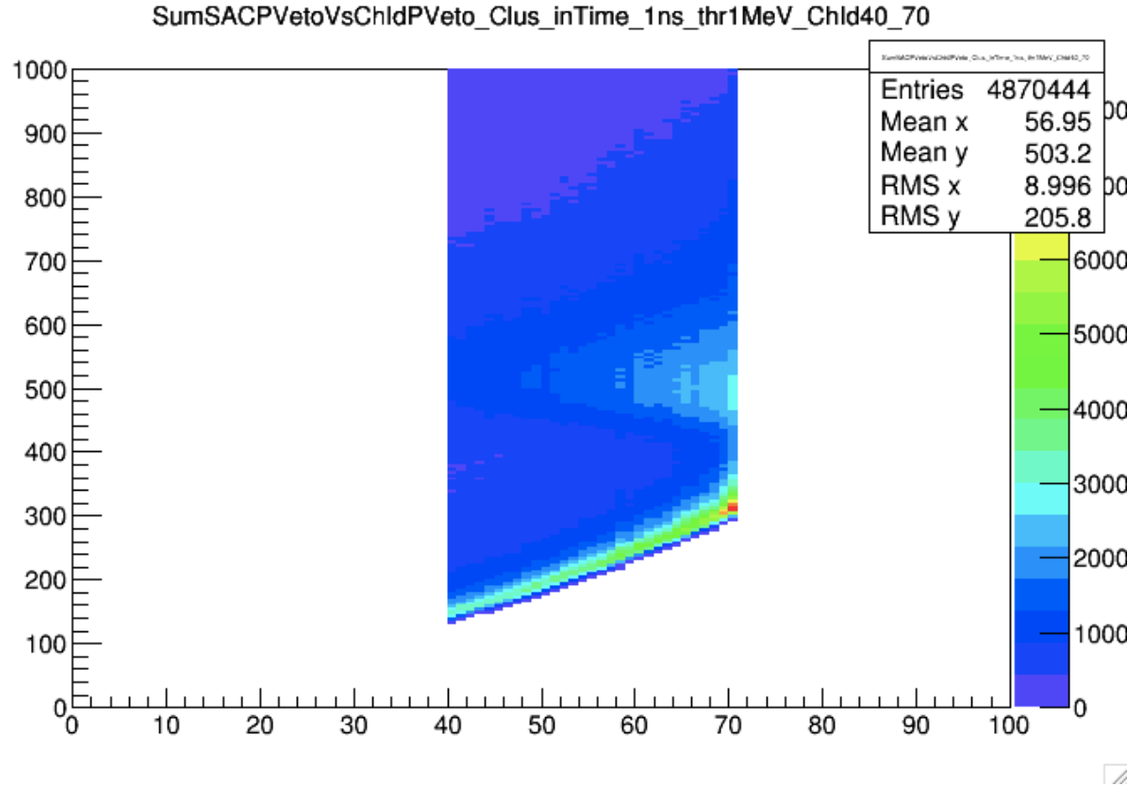
Good tuning MC DATA for SAC needed for this last chance

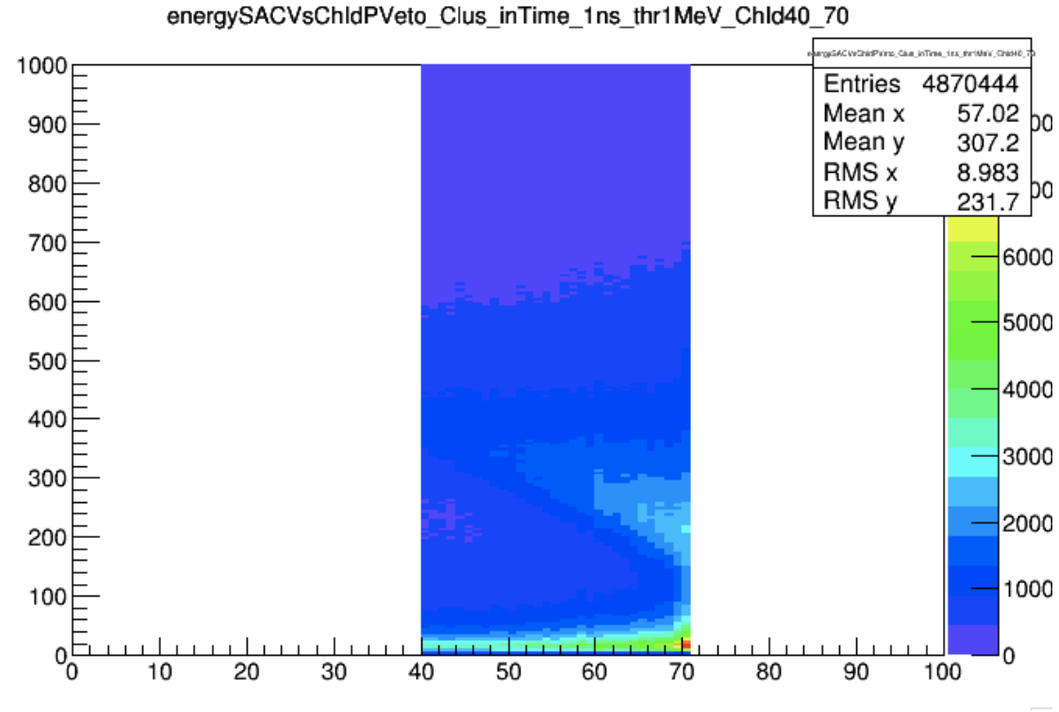
A preliminary study on the integration time for the Sac was also performed, to tune the MC and DATA

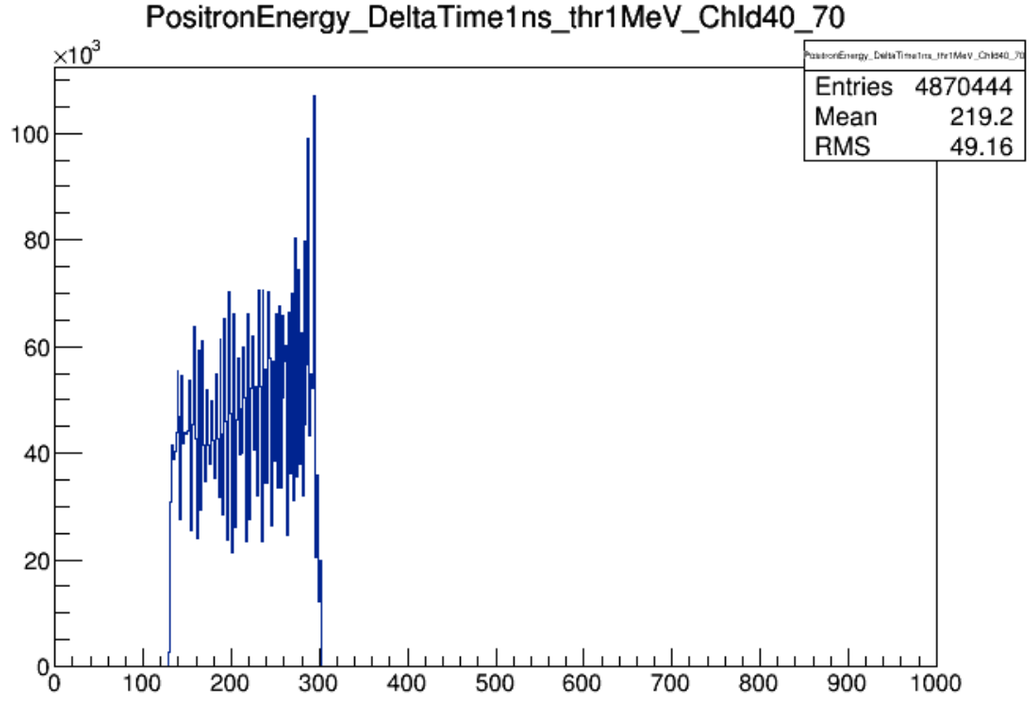
Backup

DATA

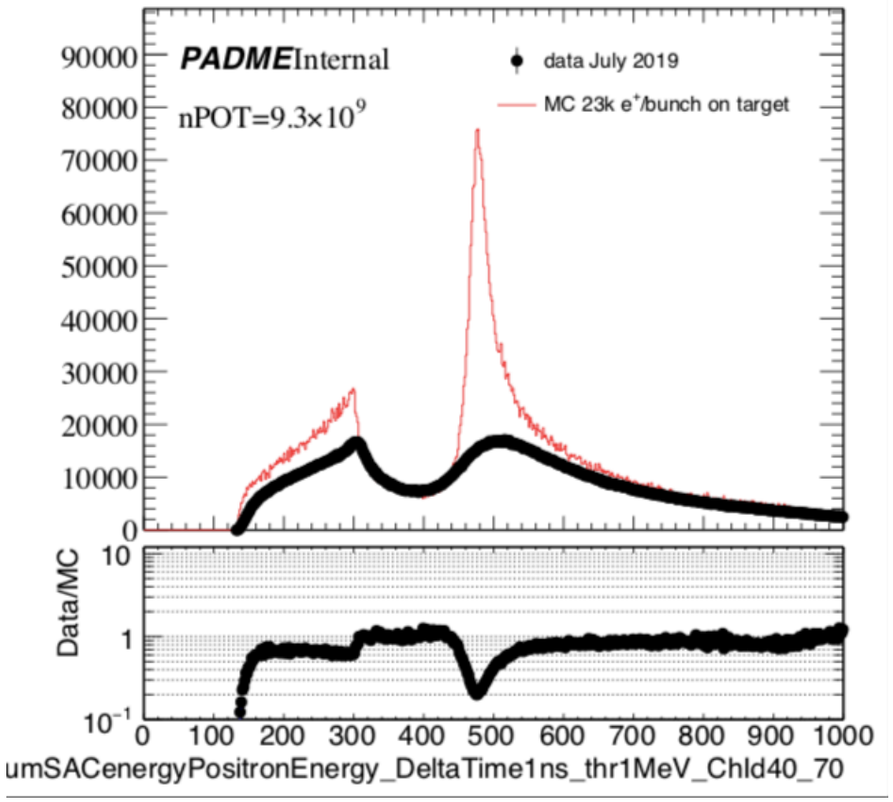

PADMEInternal
data July 2019
MC 23k e+/bunch on target
nPOT=9.3×10^9
Data/MC
umSACenergyPositronEnergy_DeltaTime1ns_thr1MeV_ChId40_70

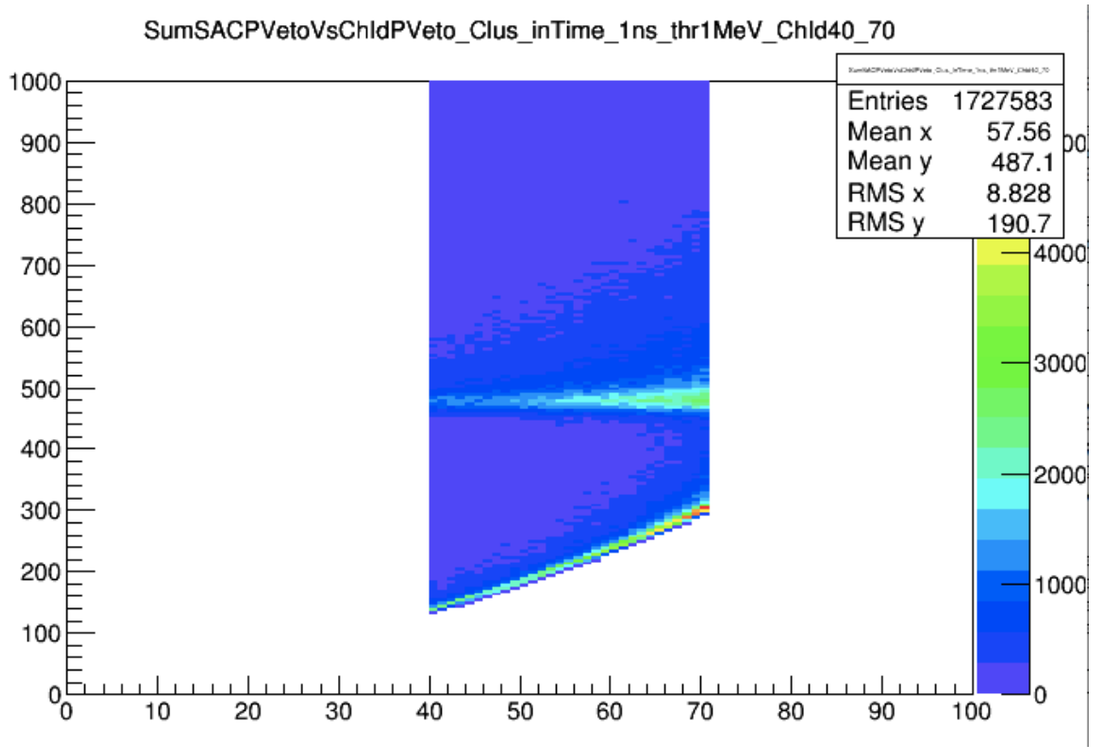

SumSACPVetoVsChIdPVeto_Clus_inTime_1ns_thr1MeV_ChId40_70
Entries 4870444
Mean x 56.95
Mean y 503.2
RMS x 8.996
RMS y 205.8

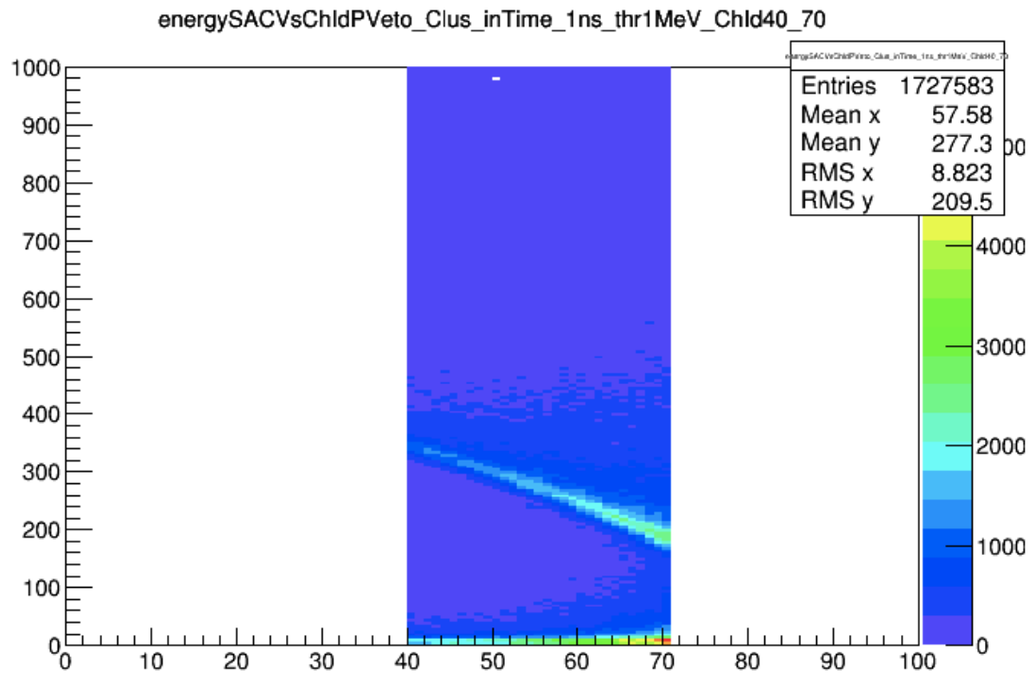

energySACVsChIdPVeto_Clus_inTime_1ns_thr1MeV_ChId40_70
Entries 4870444
Mean x 57.02
Mean y 307.2
RMS x 8.983
RMS y 231.7

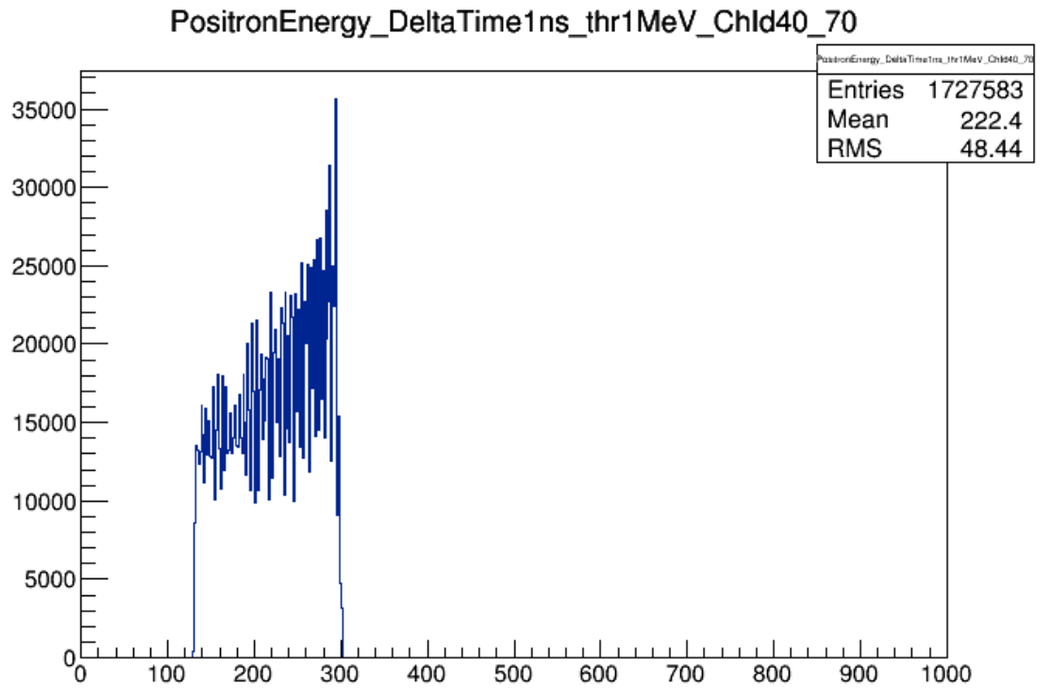

PositronEnergy_DeltaTime1ns_thr1MeV_ChId40_70
Entries 4870444
Mean 219.2
RMS 49.16

MC digi 1ns

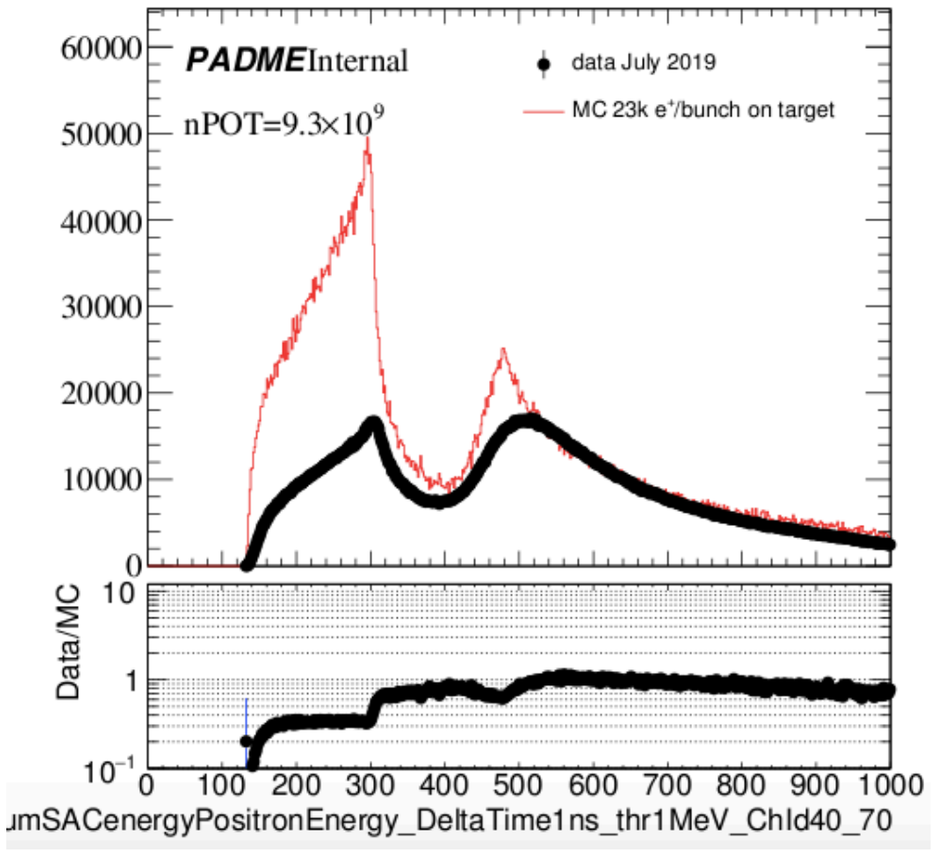

PADMEInternal
data July 2019
nPOT=9.3×10^9
MC 23k e+/bunch on target
Data/MC
umSACenergyPositronEnergy_DeltaTime1ns_thr1MeV_Chld40_70

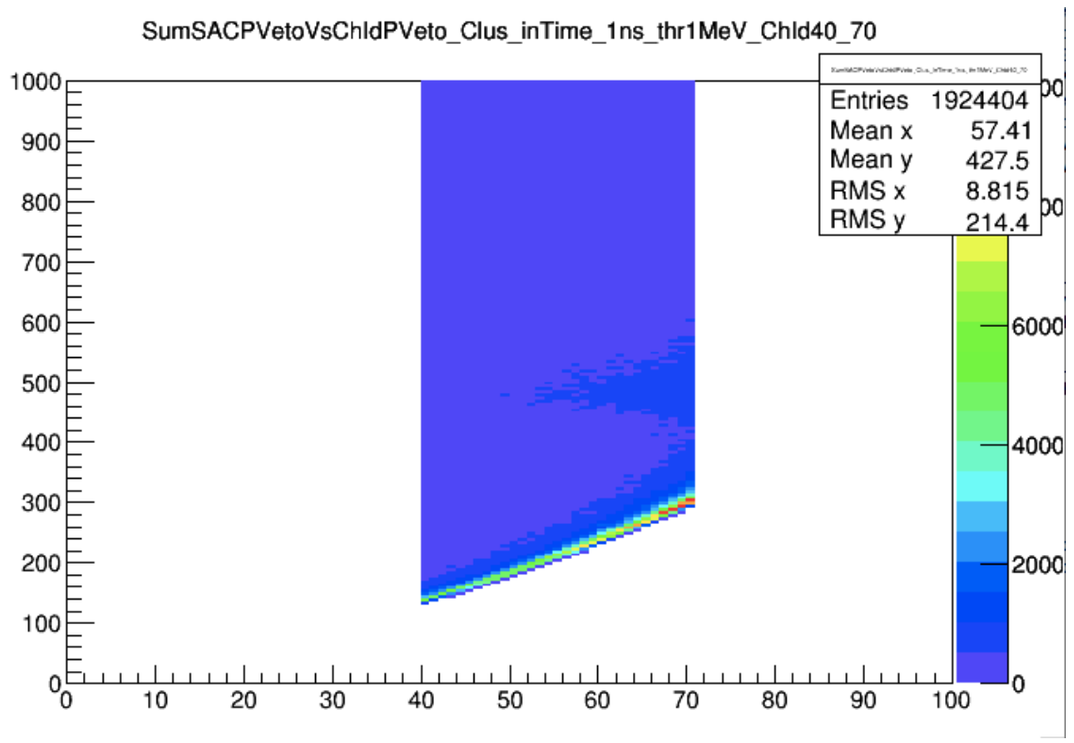

SumSACPVetoVsChIdPVeto_Clus_inTime_1ns_thr1MeV_Chld40_70
Entries 1727583
Mean x 57.56
Mean y 487.1
RMS x 8.828
RMS y 190.7

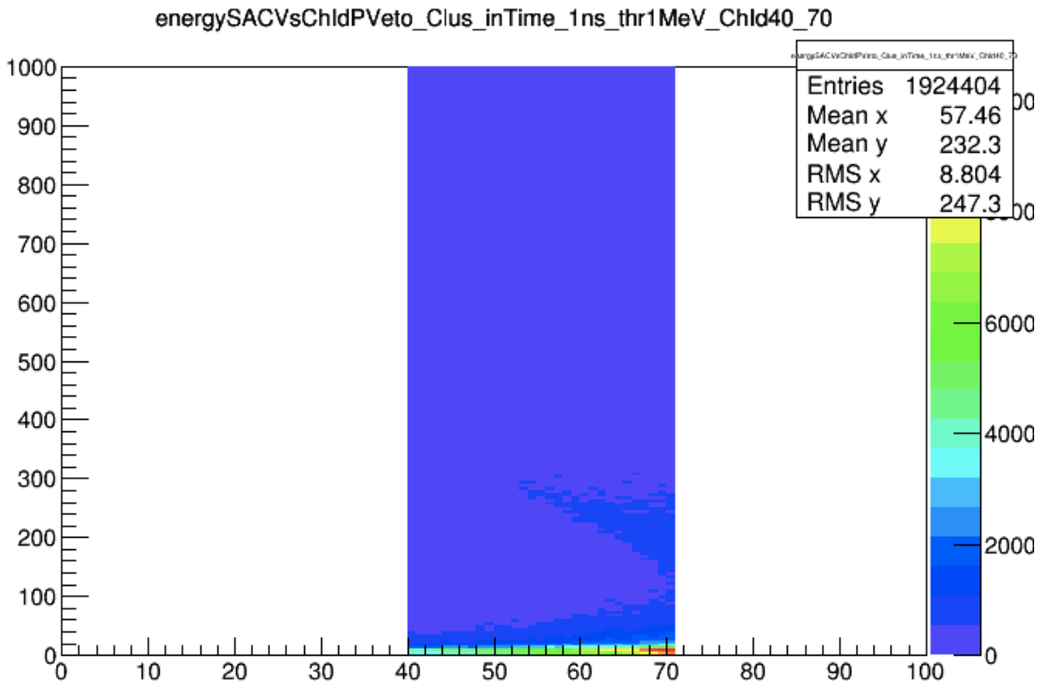

energySACVsChIdPVeto_Clus_inTime_1ns_thr1MeV_Chld40_70
Entries 1727583
Mean x 57.58
Mean y 277.3
RMS x 8.823
RMS y 209.5

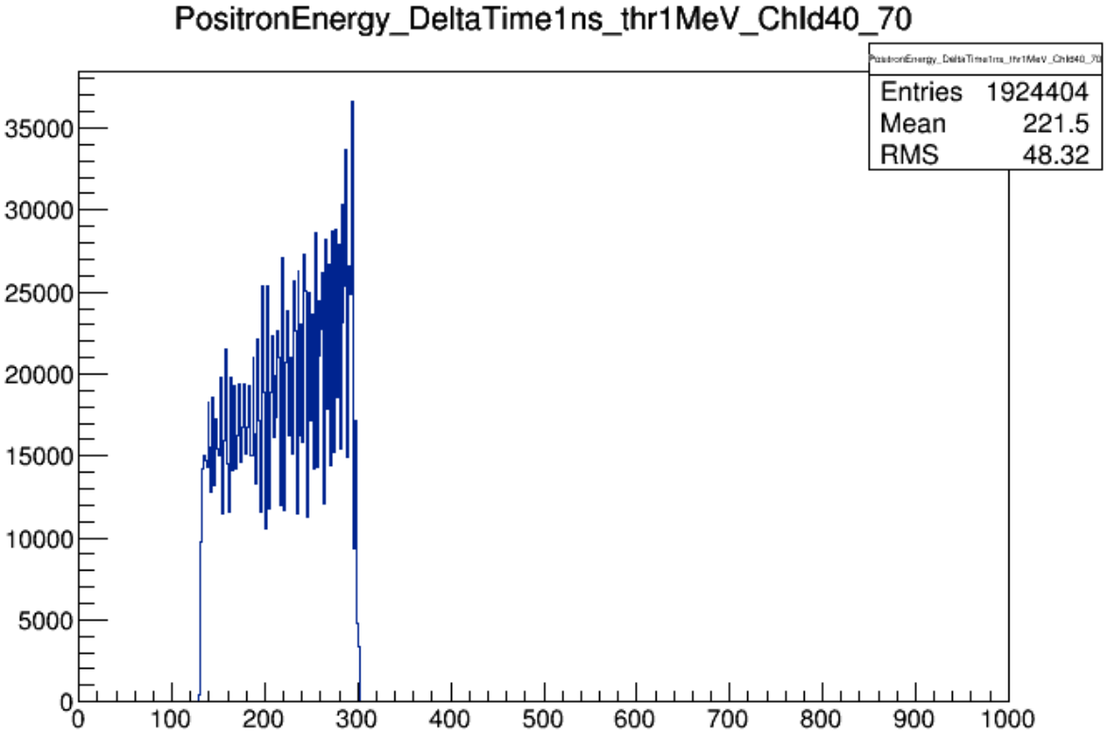

PositronEnergy_DeltaTime1ns_thr1MeV_Chld40_70
Entries 1727583
Mean 222.4
RMS 48.44

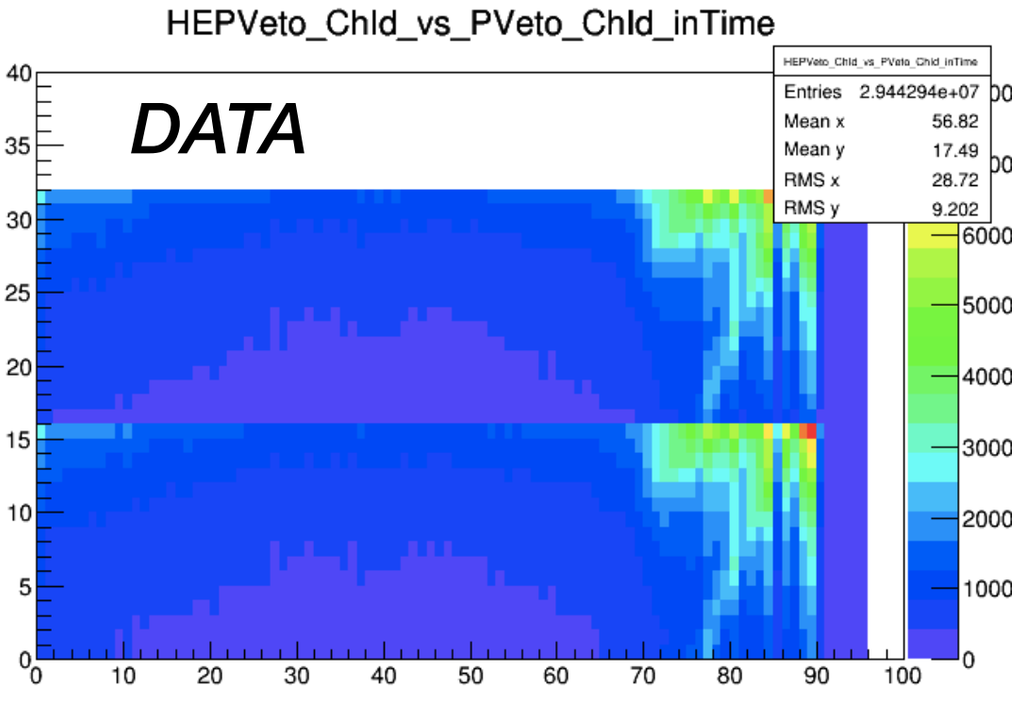
MC digi 4ns

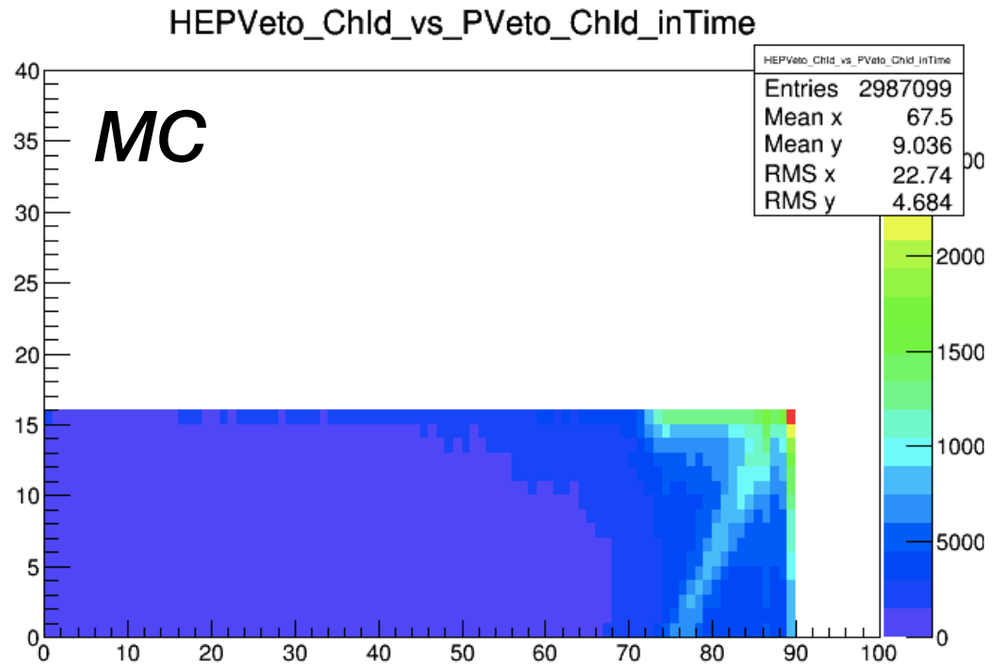

PADMEInternal
data July 2019
MC 23k e+/bunch on target
nPOT=9.3×10^9
Data/MC
umSACenergyPositronEnergy_DeltaTime1ns_thr1MeV_Chld40_70


SumSACPVetoVsChldPVeto_Clus_inTime_1ns_thr1MeV_Chld40_70
Entries 1924404
Mean x 57.41
Mean y 427.5
RMS x 8.815
RMS y 214.4


energySACVsChldPVeto_Clus_inTime_1ns_thr1MeV_Chld40_70
Entries 1924404
Mean x 57.46
Mean y 232.3
RMS x 8.804
RMS y 247.3


PositronEnergy_DeltaTime1ns_thr1MeV_Chld40_70
Entries 1924404
Mean 221.5
RMS 48.32





Correlation with PVeto ChId 73-89

xmin 73 xmax 89 Positron Energy min 314.667 max 432.301 Egamma min 57.6994 Egamma max 175.333

Ngamm TOT MC 9.28307e+06 NPOTMC 9.3e+09

Correlation with PVeto ChId 76-88

xmin 76 xmax 88 Positron Energy min 335.257 max 424.385 Egamma min 65.6153 Egamma max 154.743

Ngamm TOT MC 7.2e+06 NPOTMC 9.3e+09