Bremsstrahlung Studies

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Outline

- The data / MC samples
- The reconstruction software
- The selection
  - The method & its validation
- Summary of the results & Conclusions
- Backup & analysis/results details

The data / MC samples

- ***Data***
  - the highest quality run: (~low beam background)
    - run_0000000_20190724_152634:
    - Primary positron beam
      - E=490 MeV,
      - magnet current I= 211.80 A,
      - ~23000 POT/bunch, bunch length 150 ns

- ***MC***
  - standard GEANT4 SM background sample:
    - 800k background MC events (event=bunch), beam line + BeW simulated (no quadrupoles)
    - E=490 MeV, 20ke+/bunch, bunch length 250 ns

The reconstruction

- ***Current develop*** - stable since ~November- main features:
  - <u>Calibrations</u>:
    - Gabriele P. latest (September) energy calibration of ECal (calibration_4)
    - Clara T. latest SAC energy calibration (calibration_7) & time calibration for all detectors (reference time SAC crystal 22) for data (read from detector-reco conf. files)
    - Gain equalization for all the Veto channels
    - On MC: ***No time alignment channel by channel yet,*** global time shift / detector applies
  - <u>Algorithms for data</u>: may be needed
    - ECal single hit reco: Energy=waveform integral with saturation and signal tail corrections; time=time of max derivative (most often =time of max amplitude)
    - ECal clusters: DTMax 6.ns, DCellMax 3, ThrForSeed(Hit) 20(1) MeV
    - All Vetos hit with TSpectrum (RCfilter disabled, since hit energy [=integral of the filtered waveform] doesn't make physical sense, no Landau stat.)
  - <u>Algorithms for simulation</u>:
    - ECal multi hit reco; ECal clusters: like in data

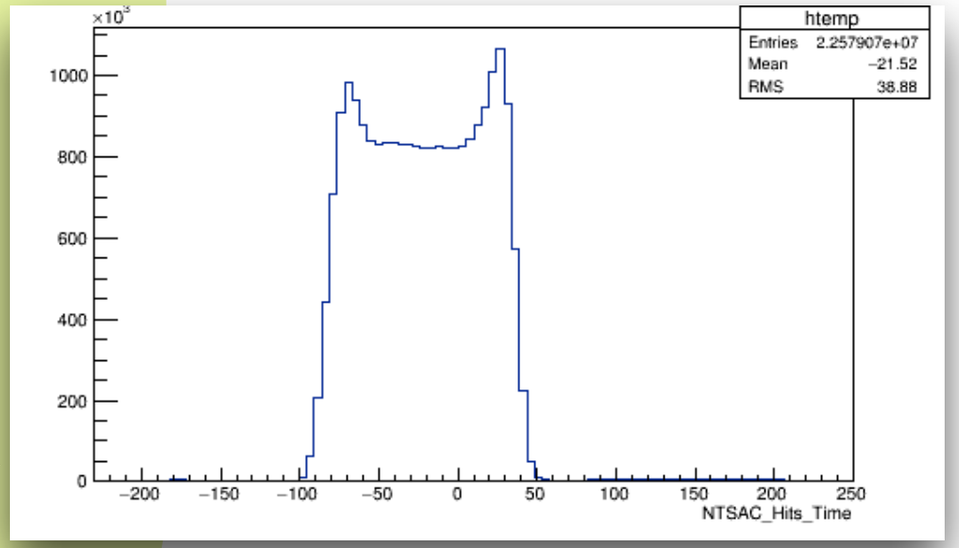
DATA - features details

Reference RUN run_0000000_20190724_152634
N events 476288

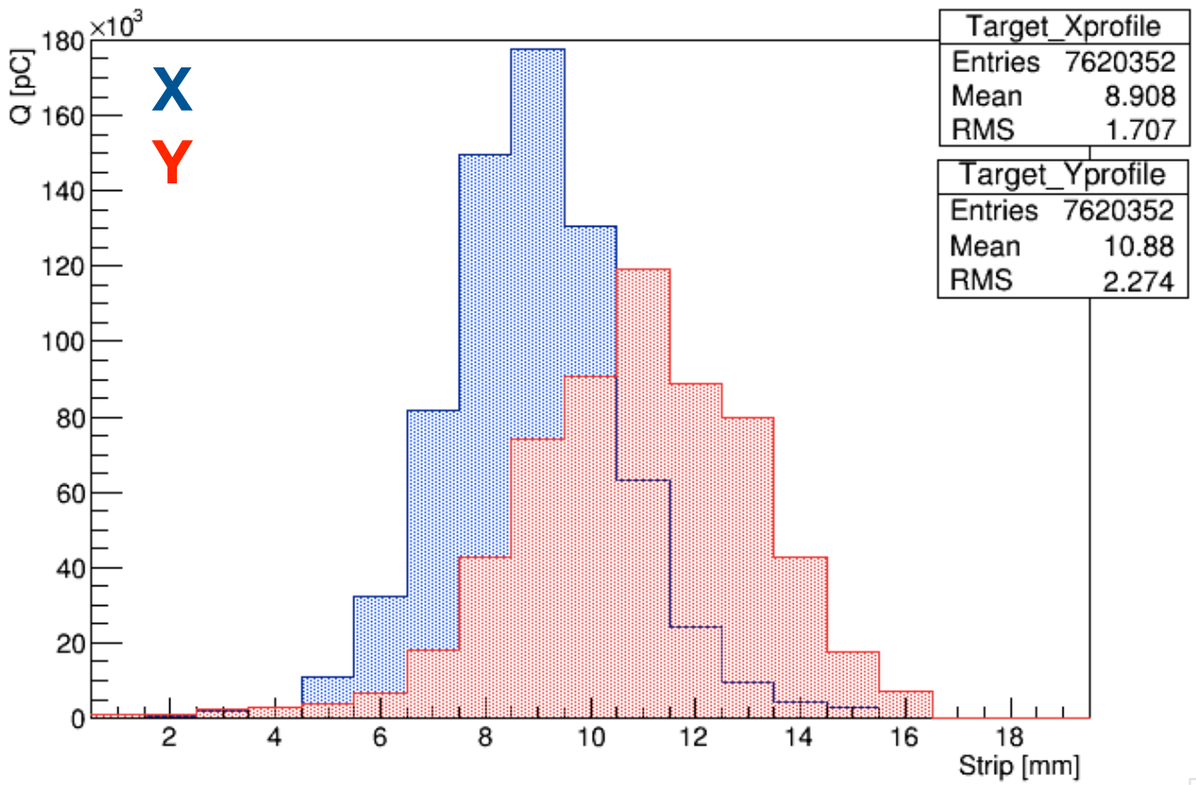
Setup full201907_nozsup

PADME MagnetCurrent 211.80 A, default
Beam energy from DSHTB001 489 MeV
Beam energy from DHSTB02 488 MeV
SAC HV 1100 V
Bunch Length ~ 150 ns

SAC Hits Time



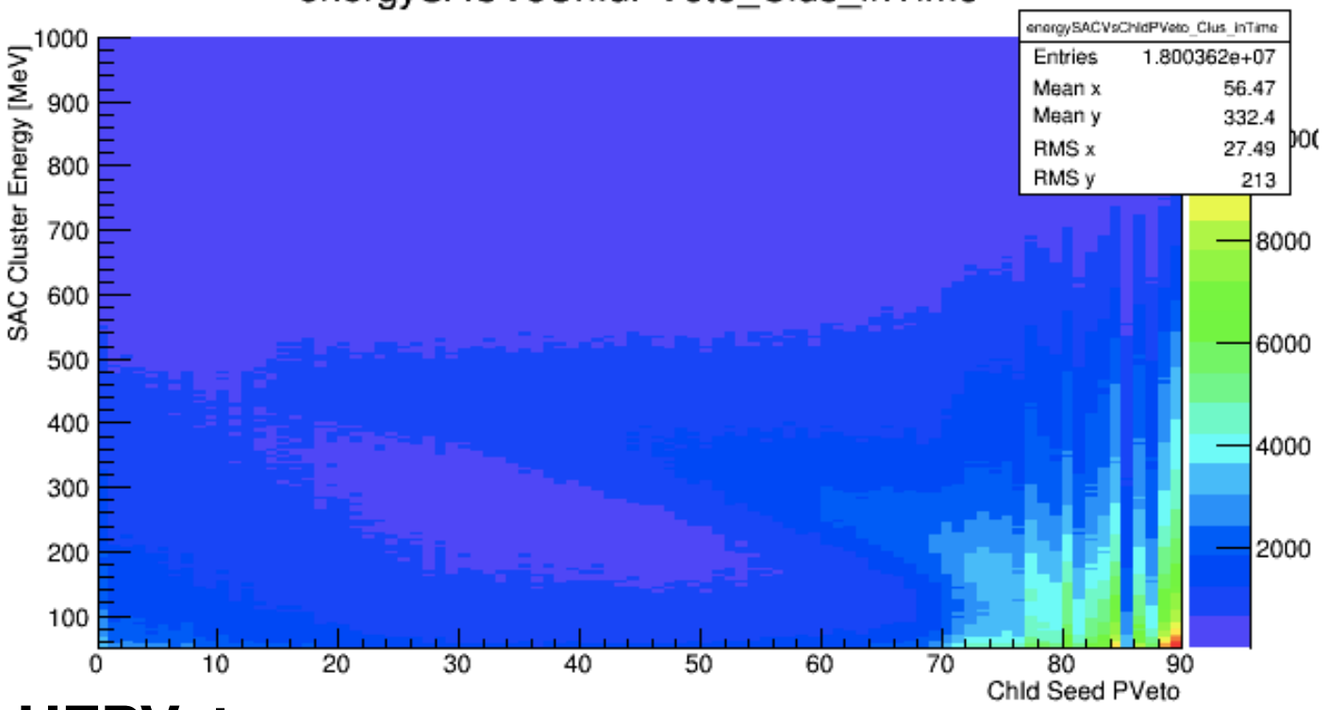
Run cumulative beam profiles from diamond target



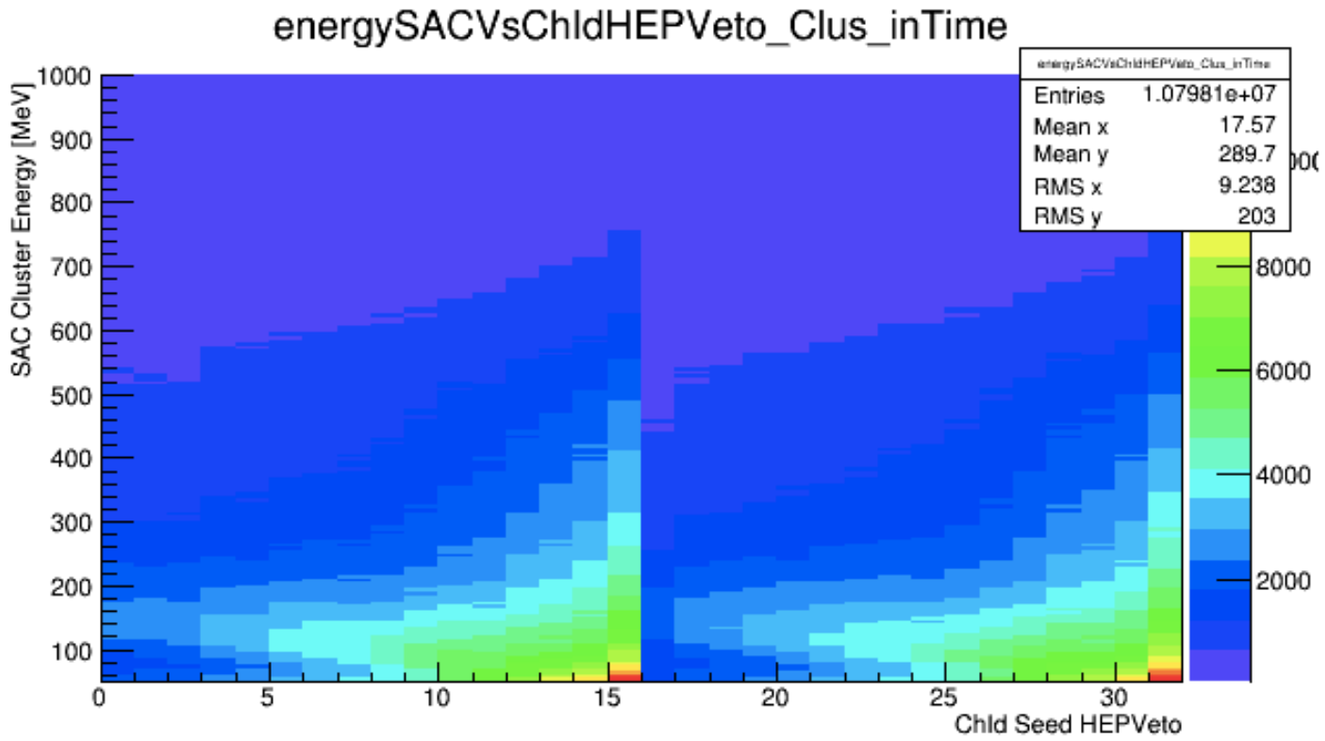
The selection - Bremsstrahlung Identification

Able to see Bremsstrahlung candidate events between SAC and PVeto ✓

PVeto



HEPVeto



Only time coincidence request

$| t_{ClPVeto} - t_{ClSAC} | < 1ns$

Bremsstrahlung Requirements

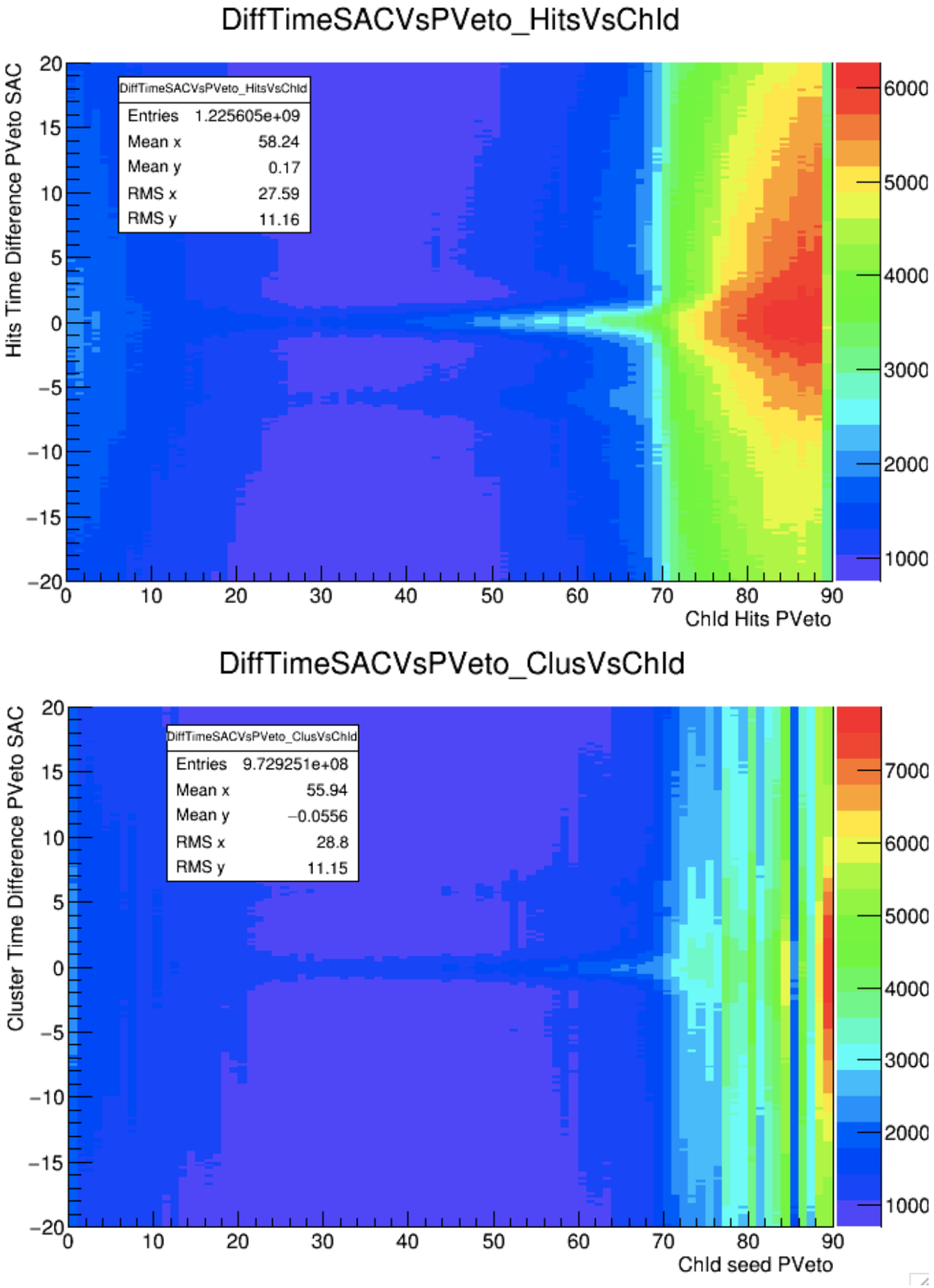
Good time alignment ✓

Gain Channel PVeto Equalization ✓

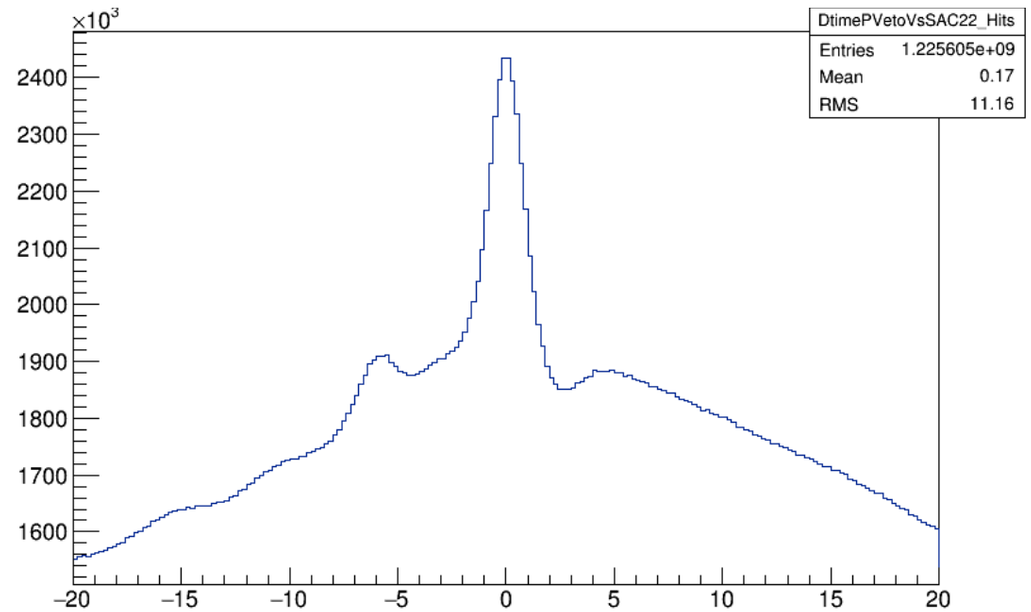
In these plots

$E_{SAC} > 50$ MeV

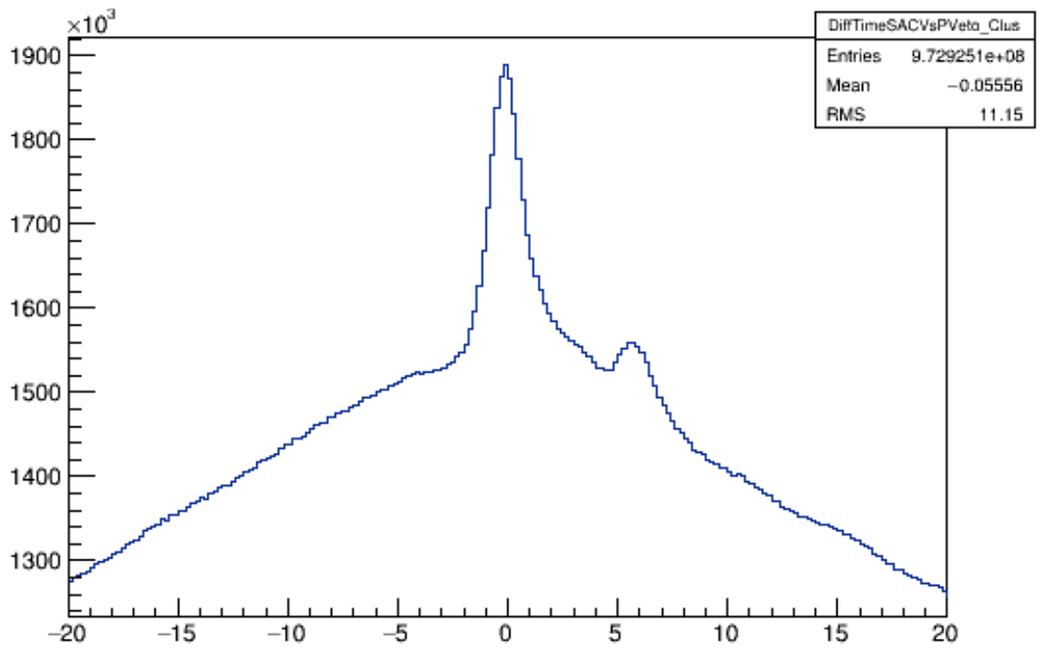
DATA Time Alignment **Time difference between PVeto and SAC central crystal (22)**



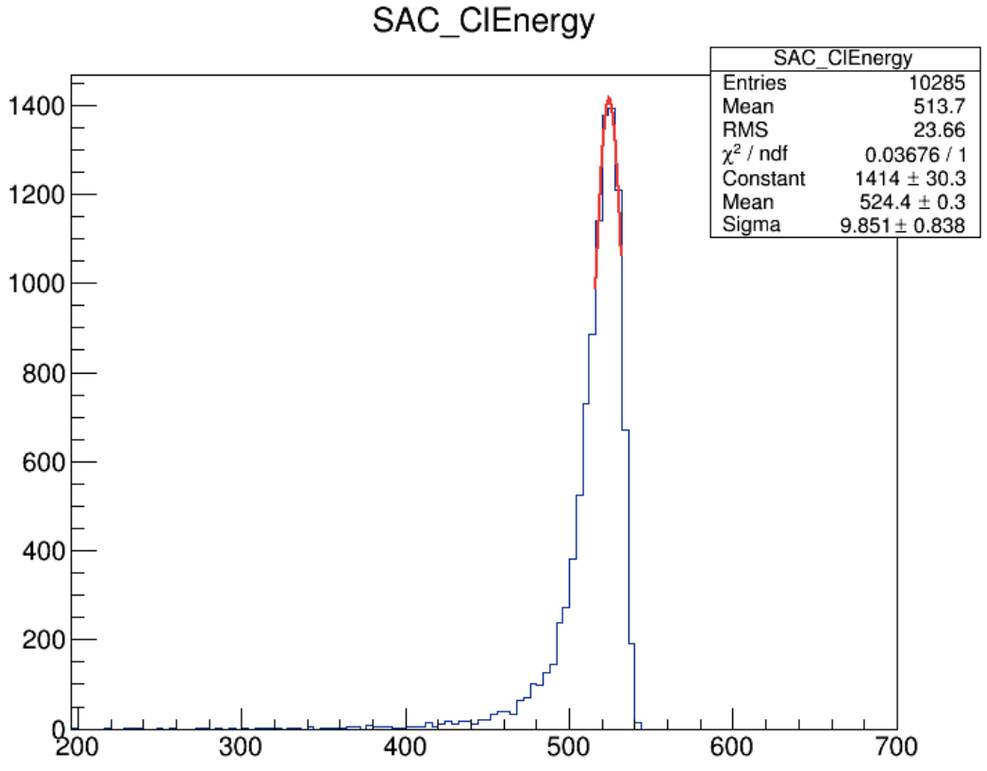
Hit Time difference distribution PVeto SAC22



Cluster Time difference distribution PVeto SAC22



Correction of the SAC MC response



MC production 10k photons on SAC

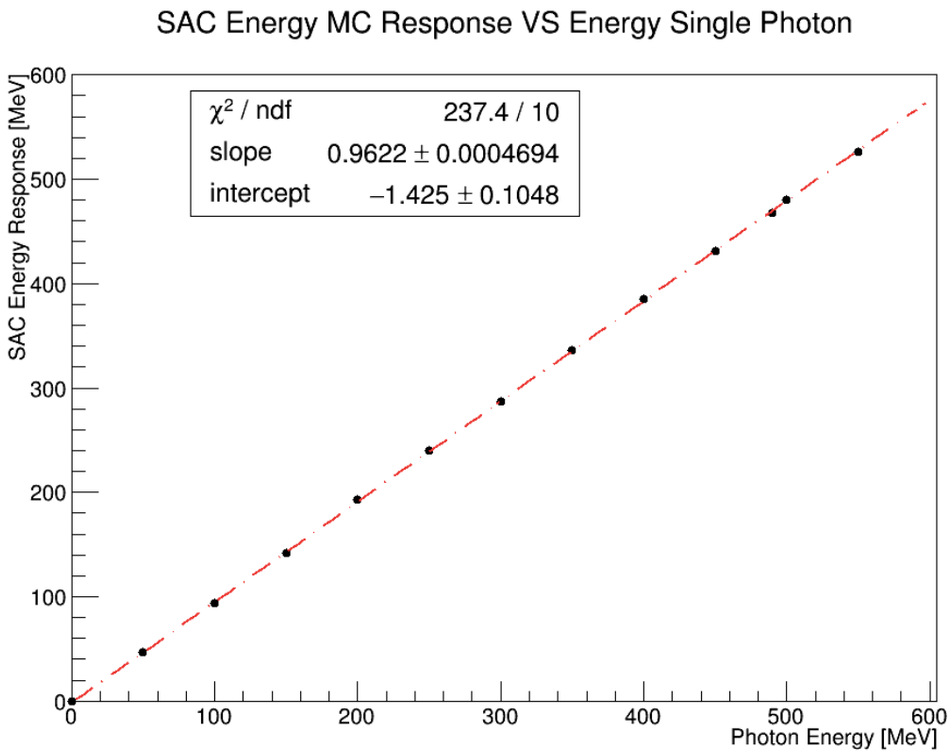
Gaussian Fit Mean (524.4 ± 0.3) MeV

E = 545 MeV

Scale E factor =545/524.4~1.039

All the following studies have been performed both for MC and MC rescaling SAC energy

SAC Linear Response?



SAC Response = PhEn*0.9622 -1.425 MeV

EnScale~1/0.9622 ~1.039

It seems to be linear

Evaluation of a Positron Spectrum

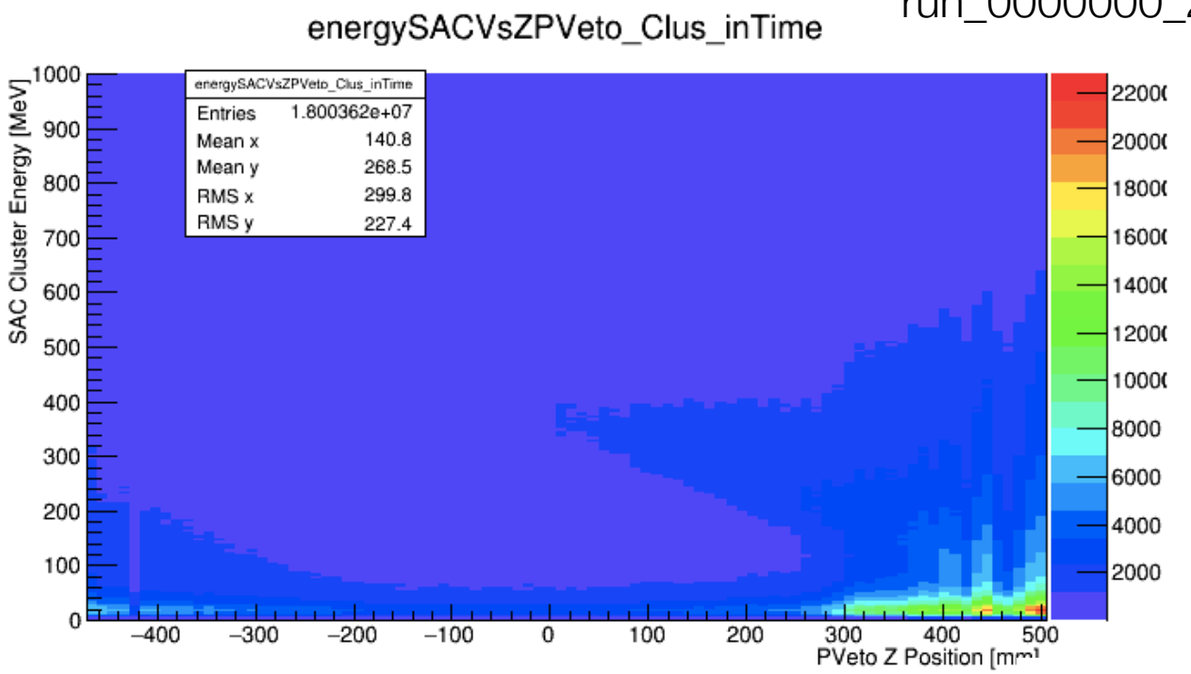
I. Indirect method

Use Bremsstrahlung candidate events to obtain positron spectrum both in MC and DATA

Inconsistency in DATA

run_0000000_20190724_152634

ChId seed Position converted in Z



Requirement for DATA

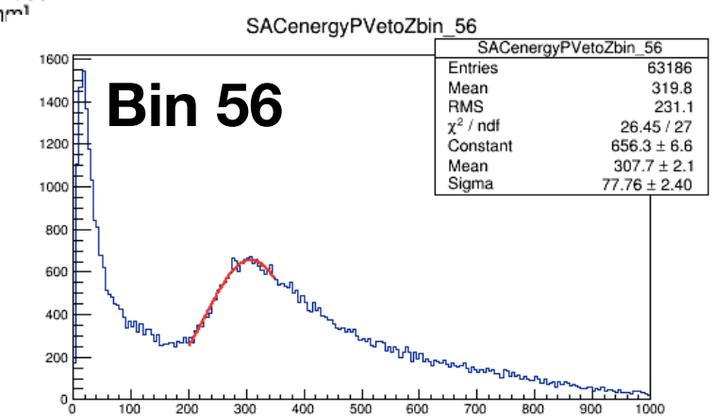
Time Alignment PVeto ✓
Gain Equalization PVeto ✓

(Z Cluster weighted in Energy)

↓

SAC Cluster Energy for each bin

$$E_{e+} = E_{beam} - E_{\gamma SAC}$$



II. Direct Method/Validation

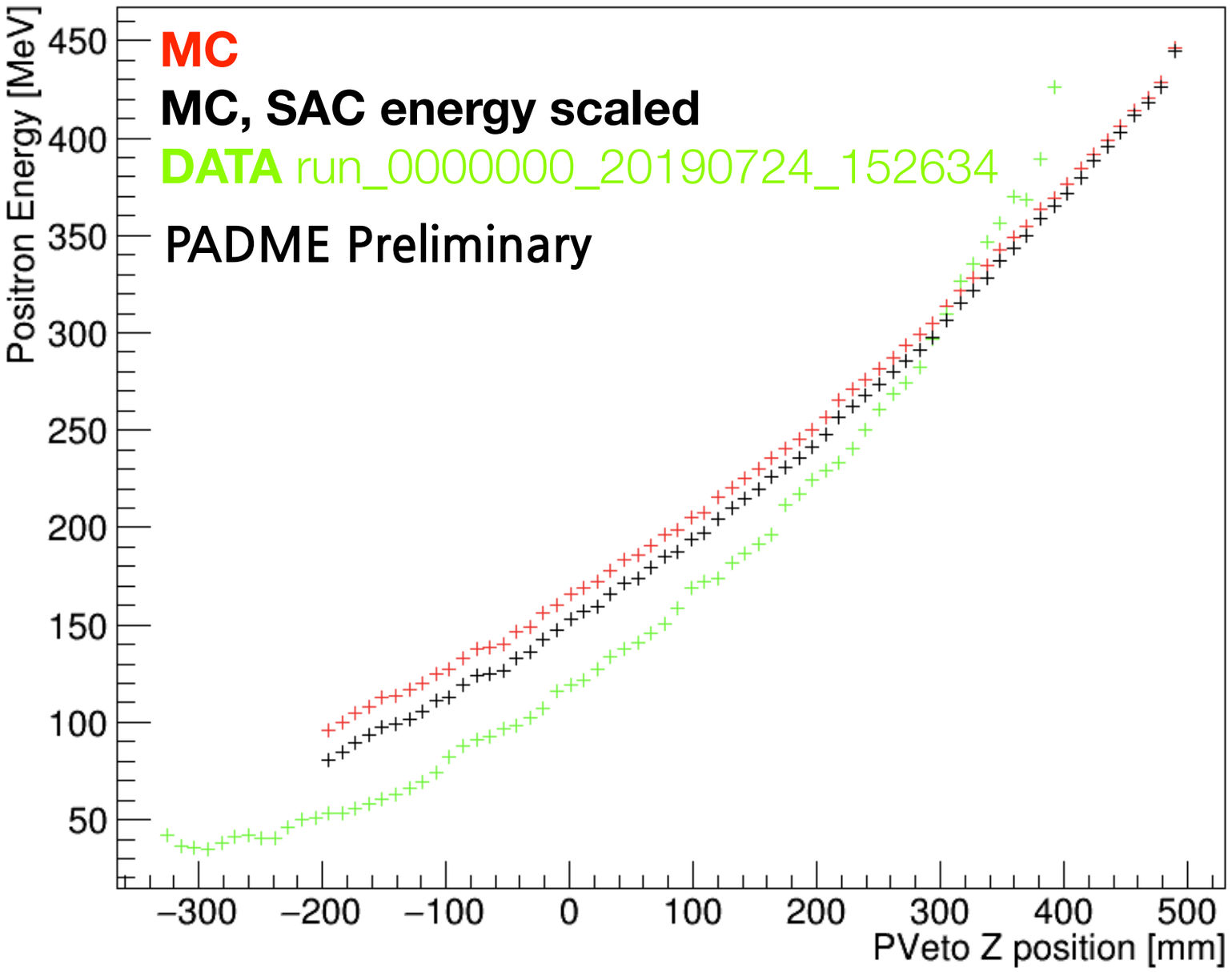
Simulate Single Positron events of different energies to check the Z PVeto hit position

Trusting MC

The best way to obtain the positron spectrum

I. Evaluation of a Positron Spectrum - Indirect Method

Study of the positron energy varying PVeto Z Position



Time coincidence 1 ns

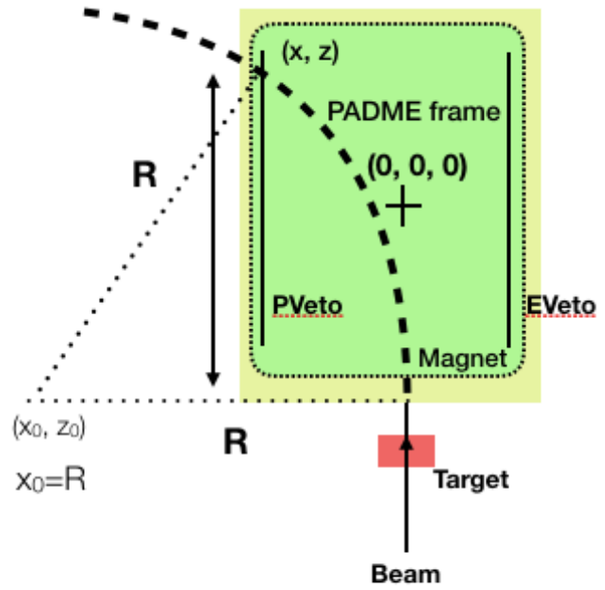
$E_{e+} = E_{beam} - E_{\gamma SAC}$

PVeto Z Cluster position projection

data / MC differences to be understood

Simple fit model: constant B in a rectangular region

details in backup



Why DATA and MC are not in agreement?

Possible explanations..

1. The magnetic field is different from MC and DATA

Magnetic field map in MC reproduces the real conditions ✓

Magnetic Field MC
Scaled with energy, 490 MeV
B = 0.4048 T

From PADME Dipole Calibration

B(gaus)=19.44*x+32.801

DATA taking Primary Beam
I = 211.80 A, B = 0.4150 T

Not so different from MC

2. The position of the fingers of the PVeto is different in DATA and MC or the starting point of the magnetic field is different between DATA and MC

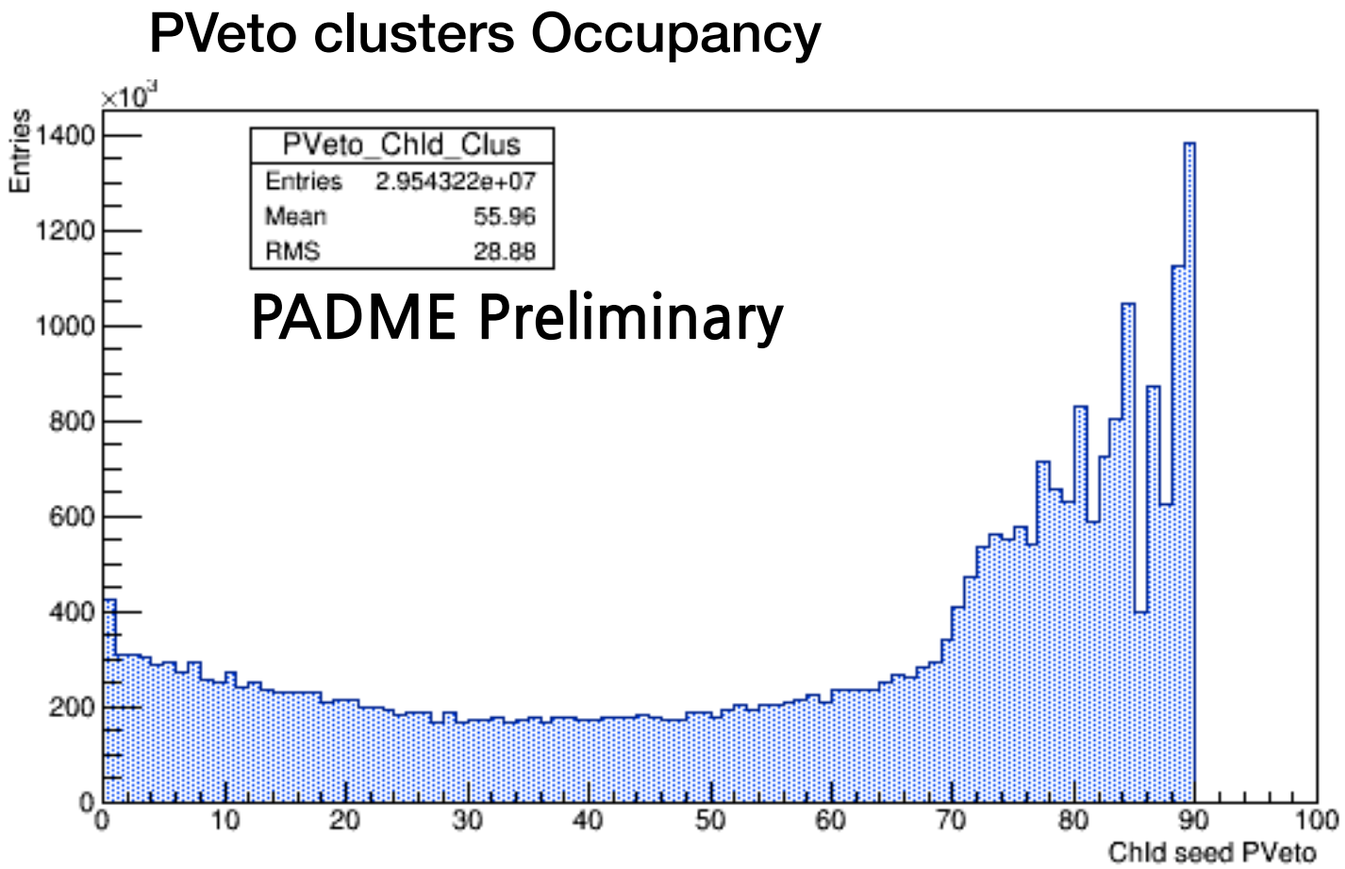
Check between Reco and MC hit of PVeto performed in the following slides

Need to check real measurements

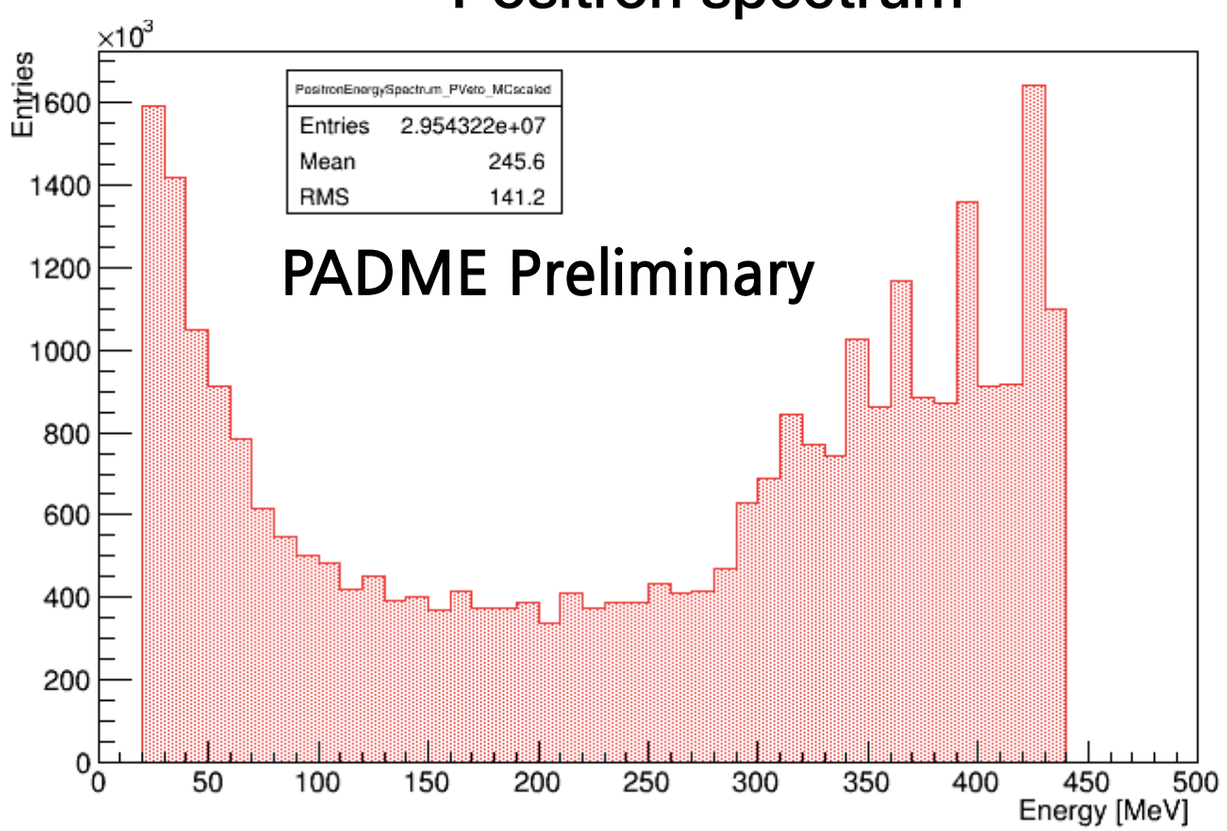
3. SAC energy response is not the same of MC

- addiction component due to pile up in DATA
- SAC Energy Calibration

Possible Positron Spectrum



Positron spectrum obtained from DATA with parameters obtained from **MC SAC scaled**



DATA run_0000000_20190720_125615

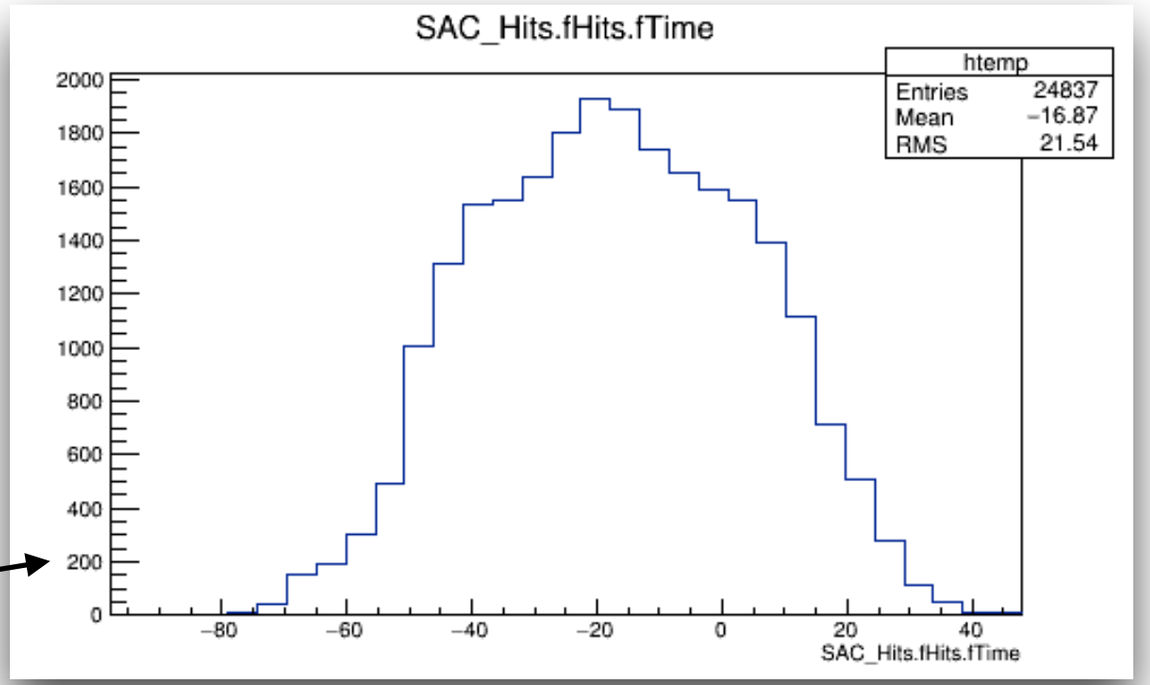
Features

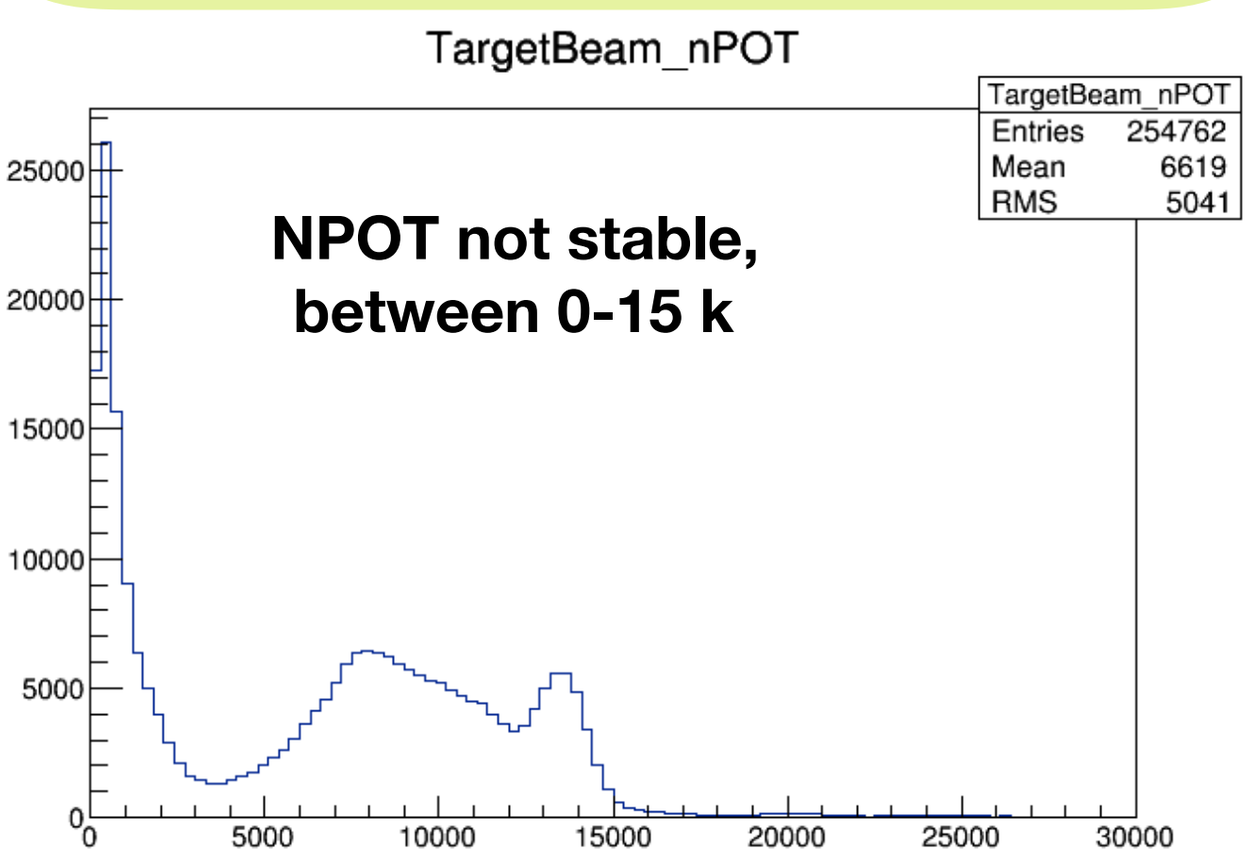
N events 254762

Setup full201907_nozsup

PADME MagnetCurrent 211.80 A, default
Beam energy from DSHTB001 489 MeV
Beam energy from DHSTB02 488 MeV
SAC HV 1100 V
Bunch Length ~ 60 ns

SAC Hits Time

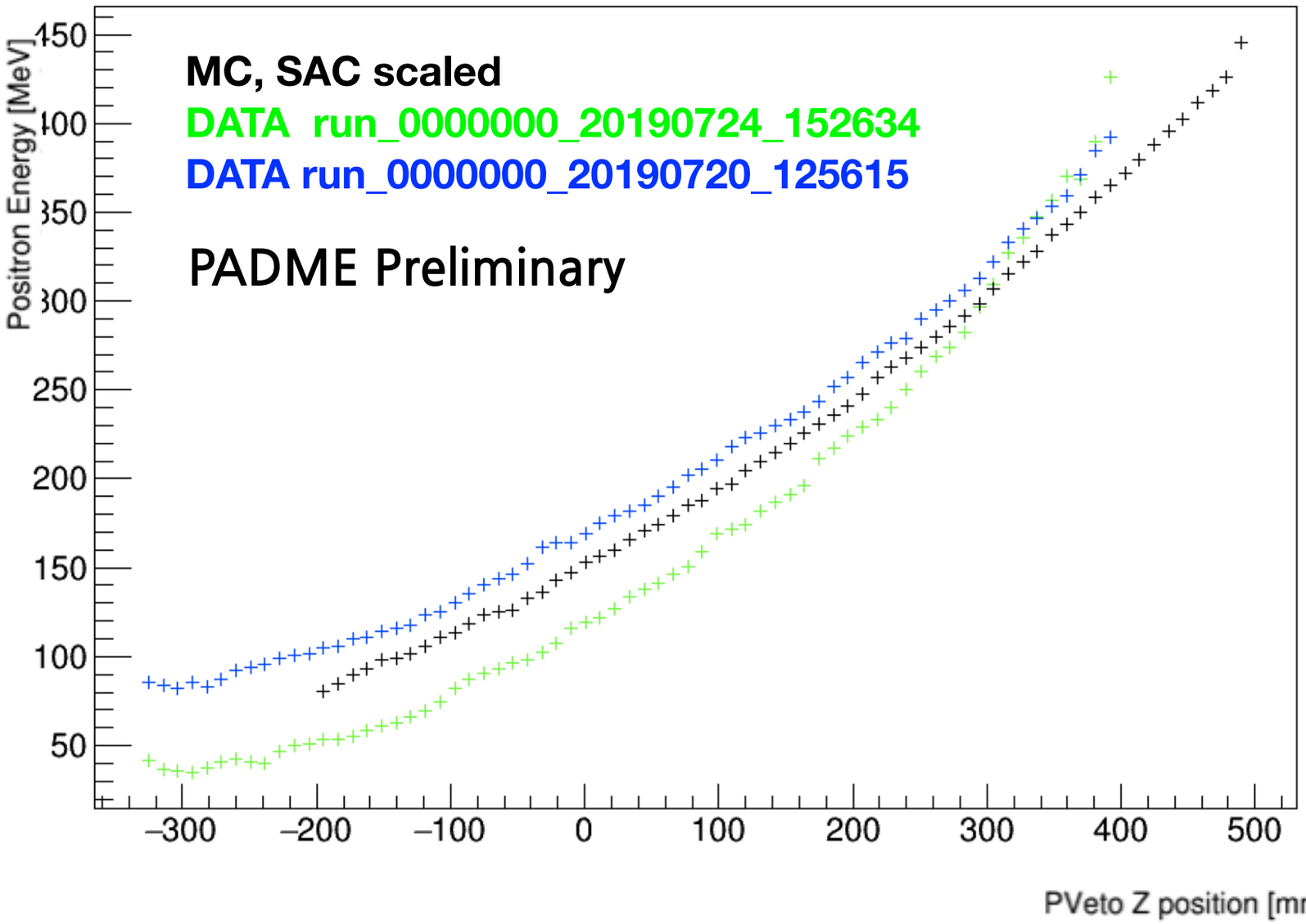




~same POT density of the reference RUN

No selection done on NPOT for the following study

Comparison with DATA run_0000000_20190720_125615



data / MC differences to be understood

+

run to run differences to be understood

II. Evaluation of a Positron Spectrum - Direct Method

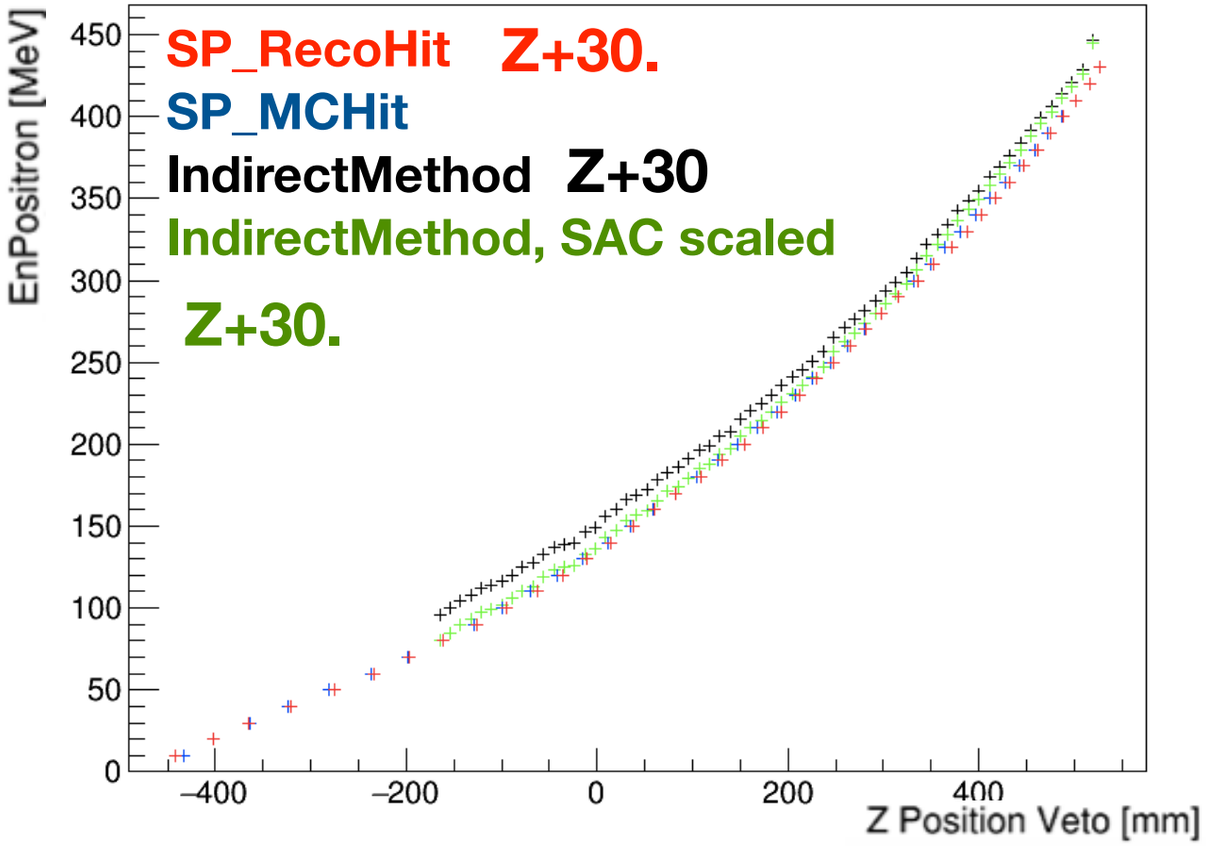
MC Parameters

/Detector/EnableMagneticField
/Detector/SetMagneticFieldValue 0.4048 Tesla
/Detector/DisableStructure Chamber
/beam/position_x 0. cm
/beam/position_y 0. cm
/beam/position_z -103. cm
/beam/momentum from 10 to 490 MeV

5000 events

if we would trust MC geometry, magnetic beam, etc …

Z position of PVeto obtained for Single Positron at different energies, both from MC Hit and Reco Hit, to check possible position mismatch



Shift Reco-MC Hit 30mm

The E_{beam} - E_{SAC} vs Z indirect method to have e+ energy vs Z calibration is successfully validated ✓

SAC simulated in the correct way ✓

Summary of the results & Conclusions

- PADME is able to perform Bremsstrahlung events identification with primary & secondary beam (not shown here) using SAC/PVeto ✓
- the E_{beam} - E_{SAC} vs Z indirect method to have e+ energy vs Z calibration is successfully validated ✓
- DATA/MC differences ✗
- Bremsstrahlung depends on DATA conditions (not able to understand the source yet) ✗

What to do before new DATA taking?

Try to better study Bremsstrahlung with ECAL, from preliminary studies it was not visible requiring time coincidence between PVeto and ECAL

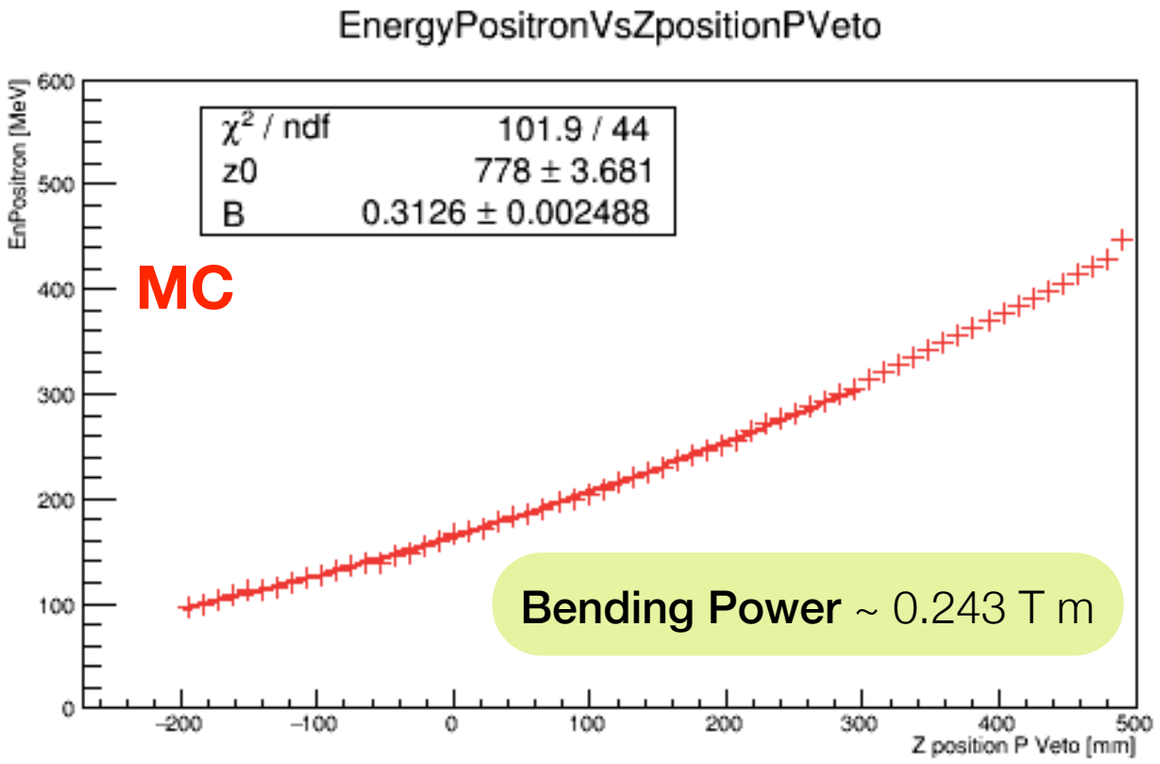
Proposal runs during DATA taking

Perform a new Single Positron calibration for SAC
Scan with Single Positron PVeto varying the energy or the PADME magnet

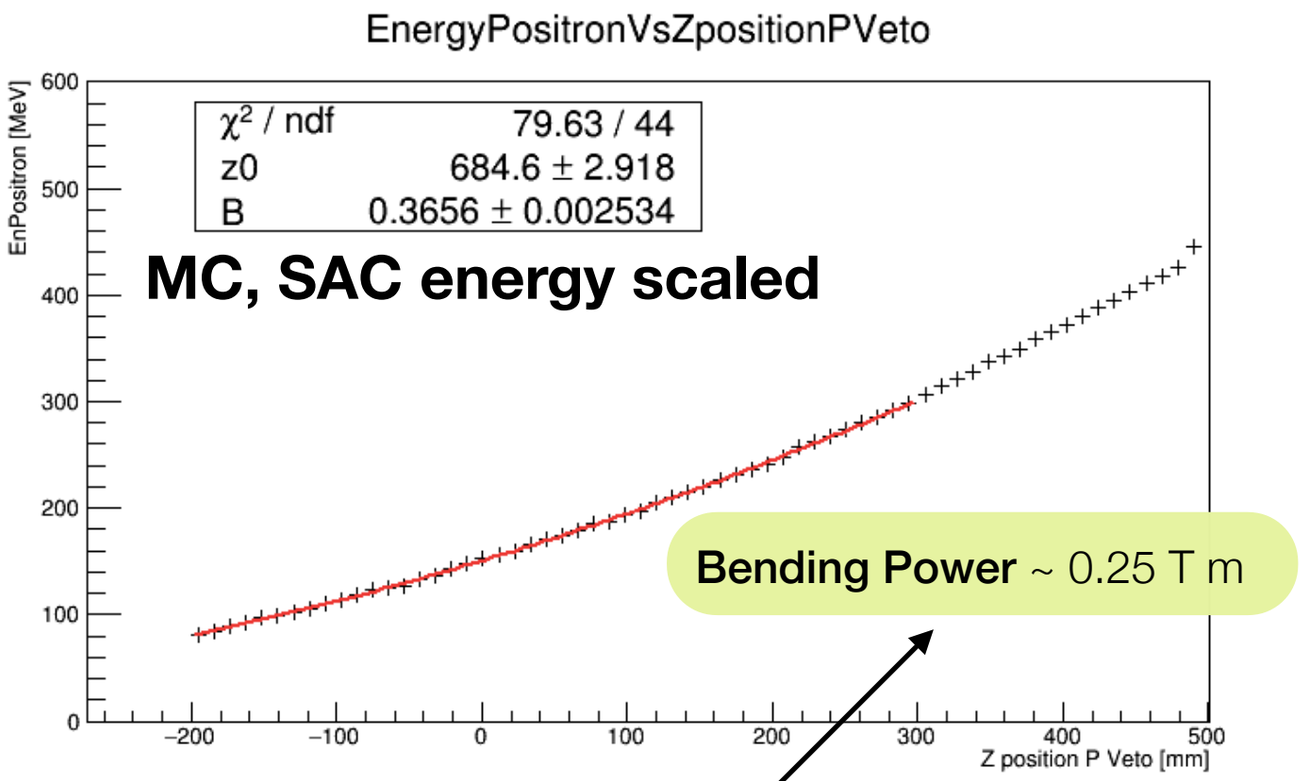
BACKUP SLIDES

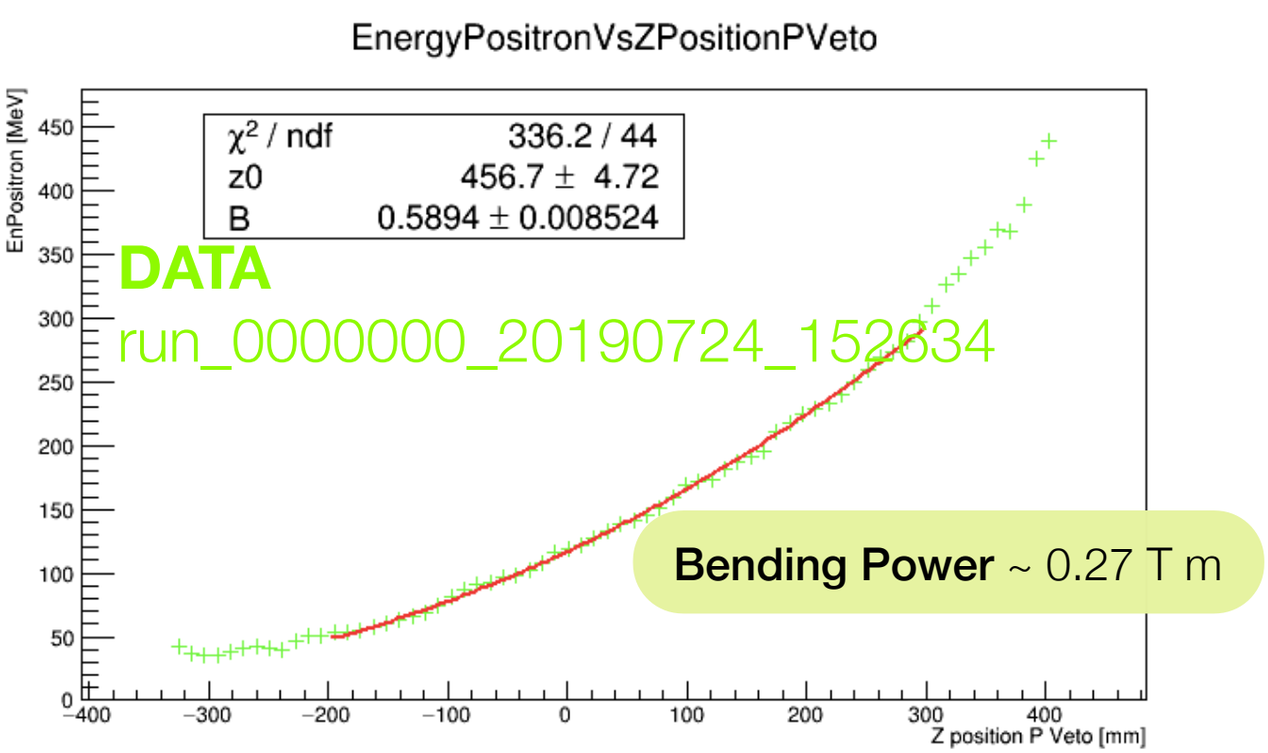
Comparison between Fit parameters

Fit function 2 pars



Fit Range Chosen -200 < Z < 300 mm



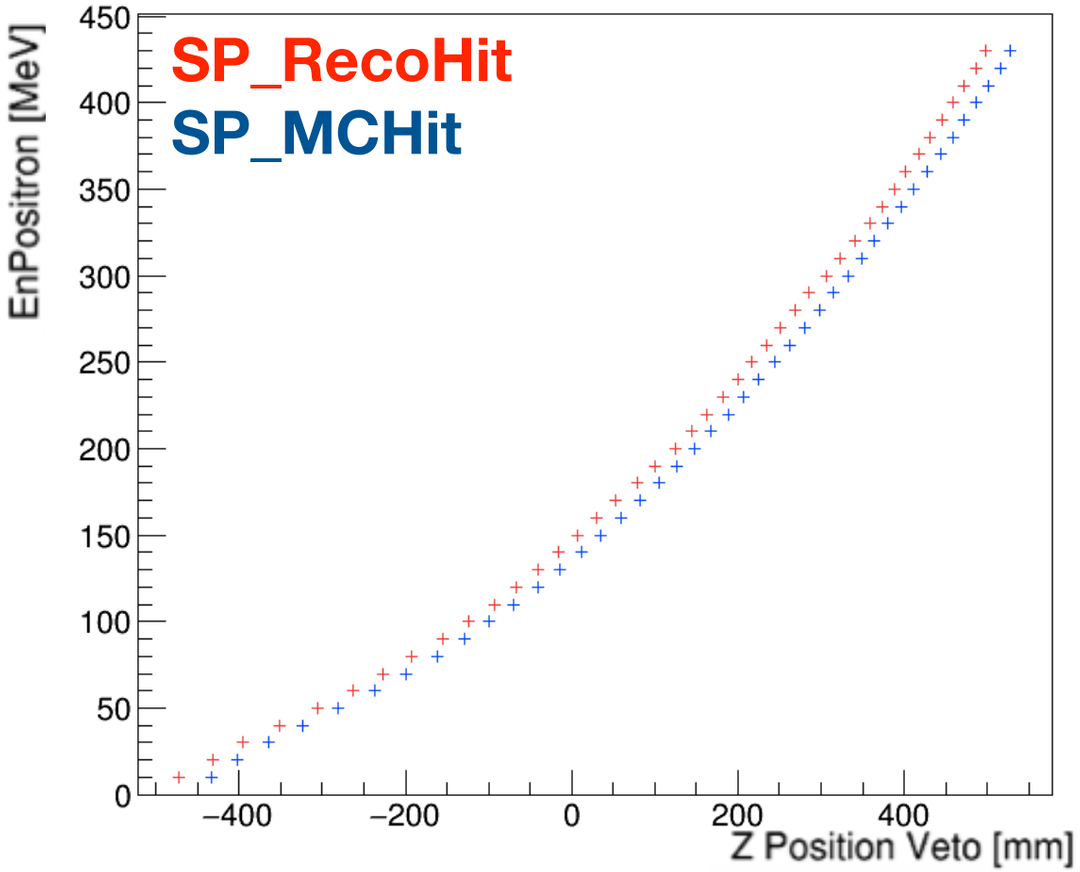


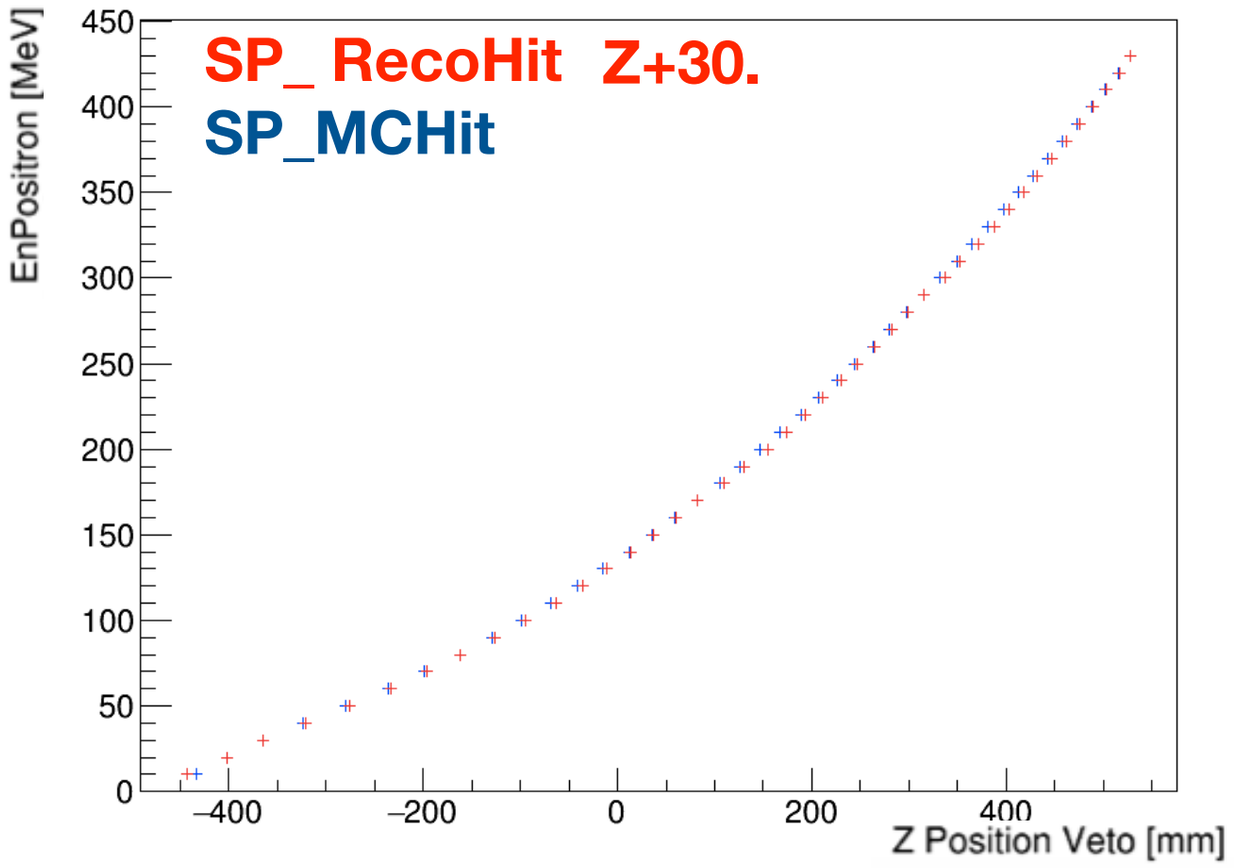
The **bending power** is defined as the field integral ∫Bdl
We can estimate it by:
Bending Power = B * z_0

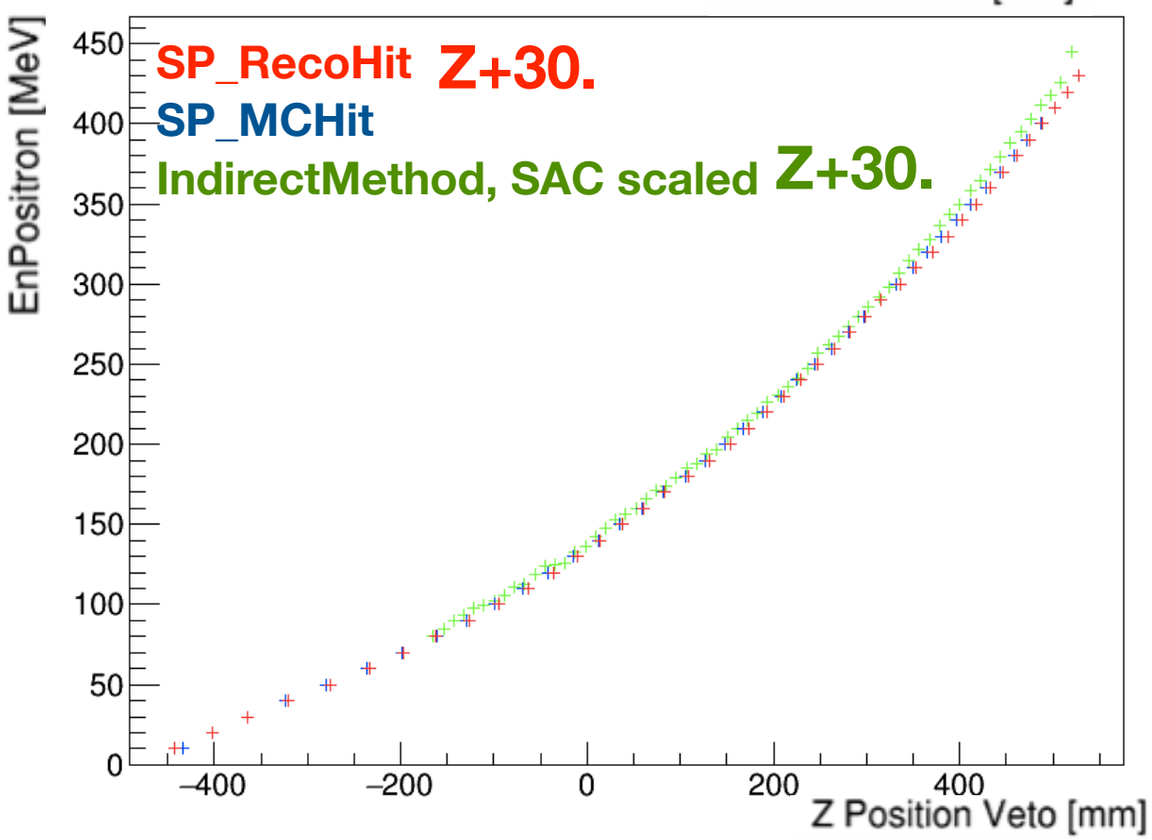
Comparison between DATA and MC

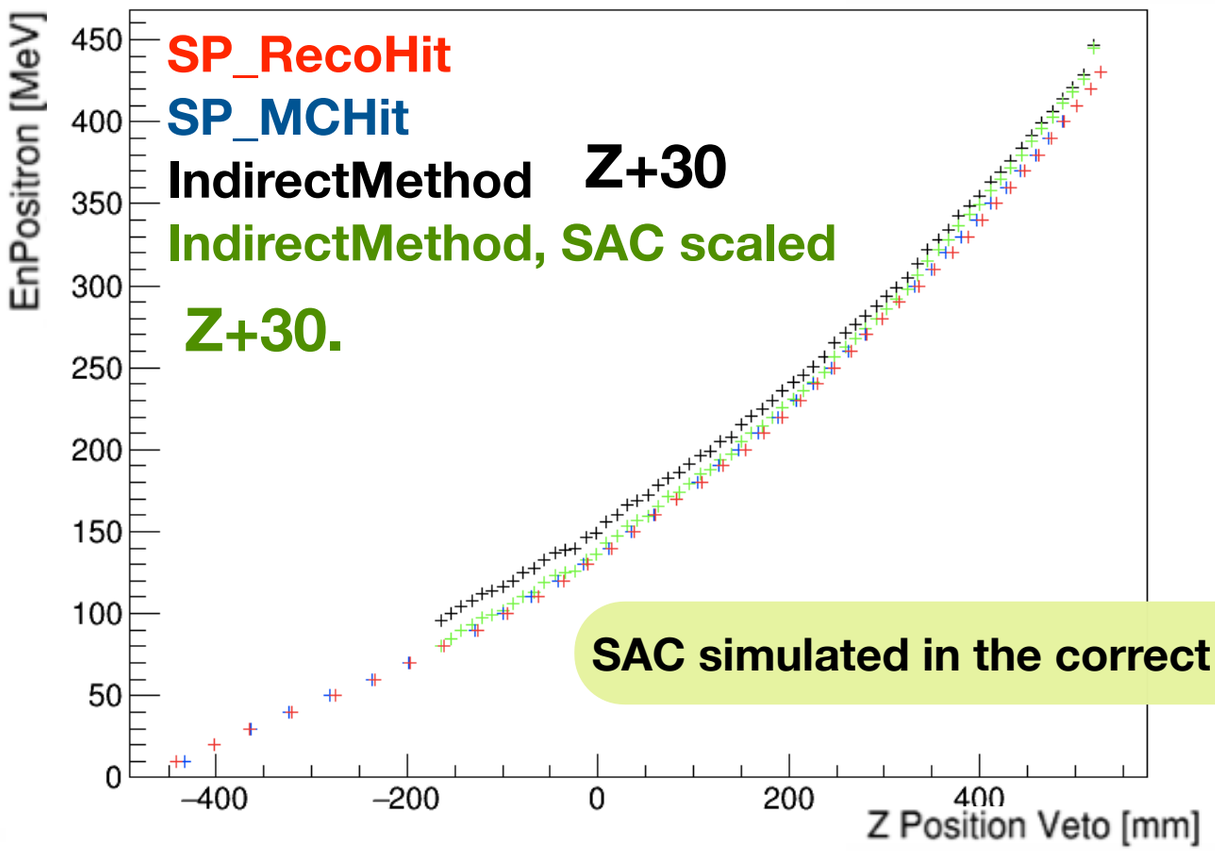
Bending Power similar but..
B and Z_0 not in agreement

Comparison between Single positron MC Hit and Reco Hit



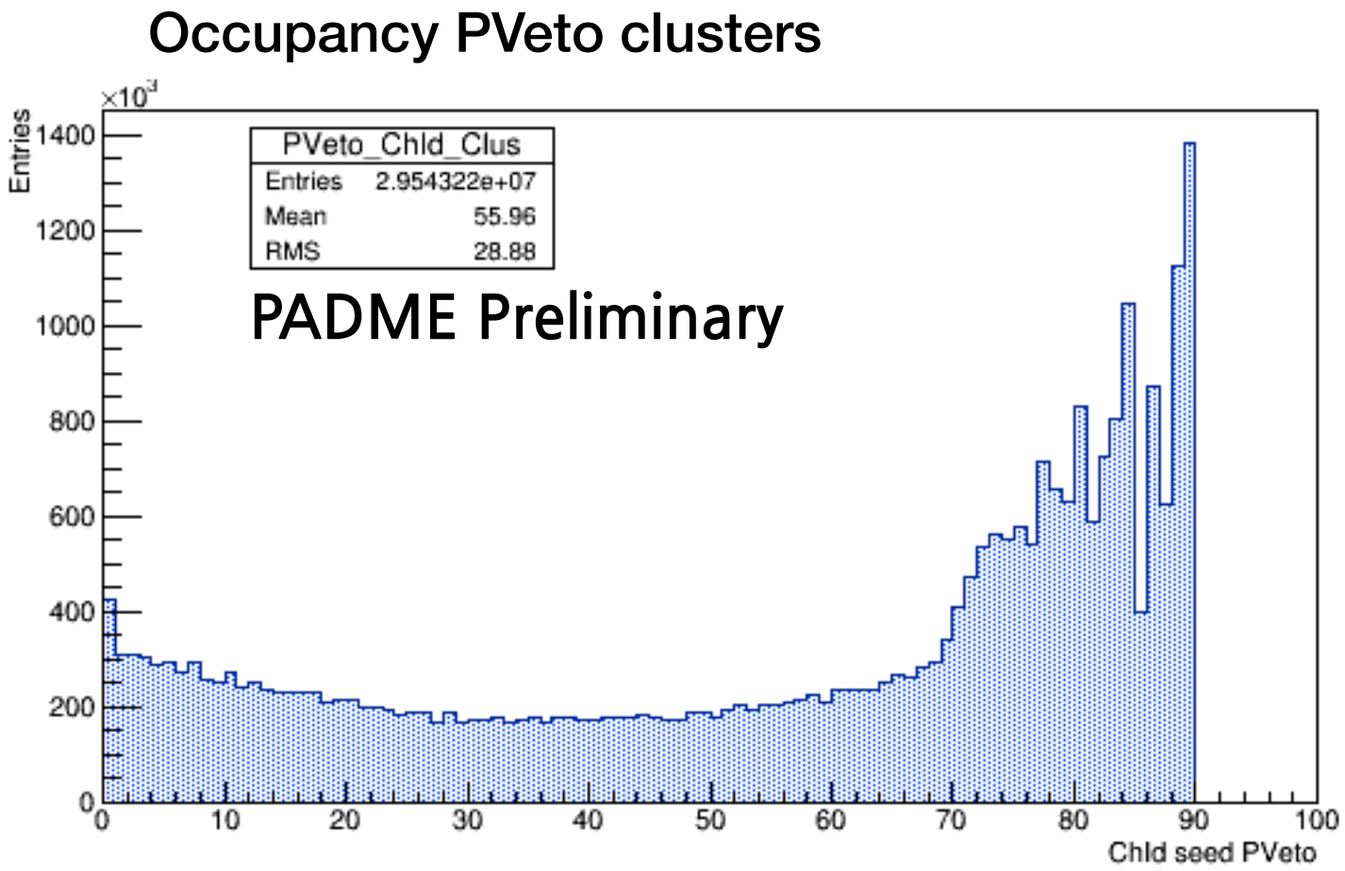






SAC simulated in the correct way

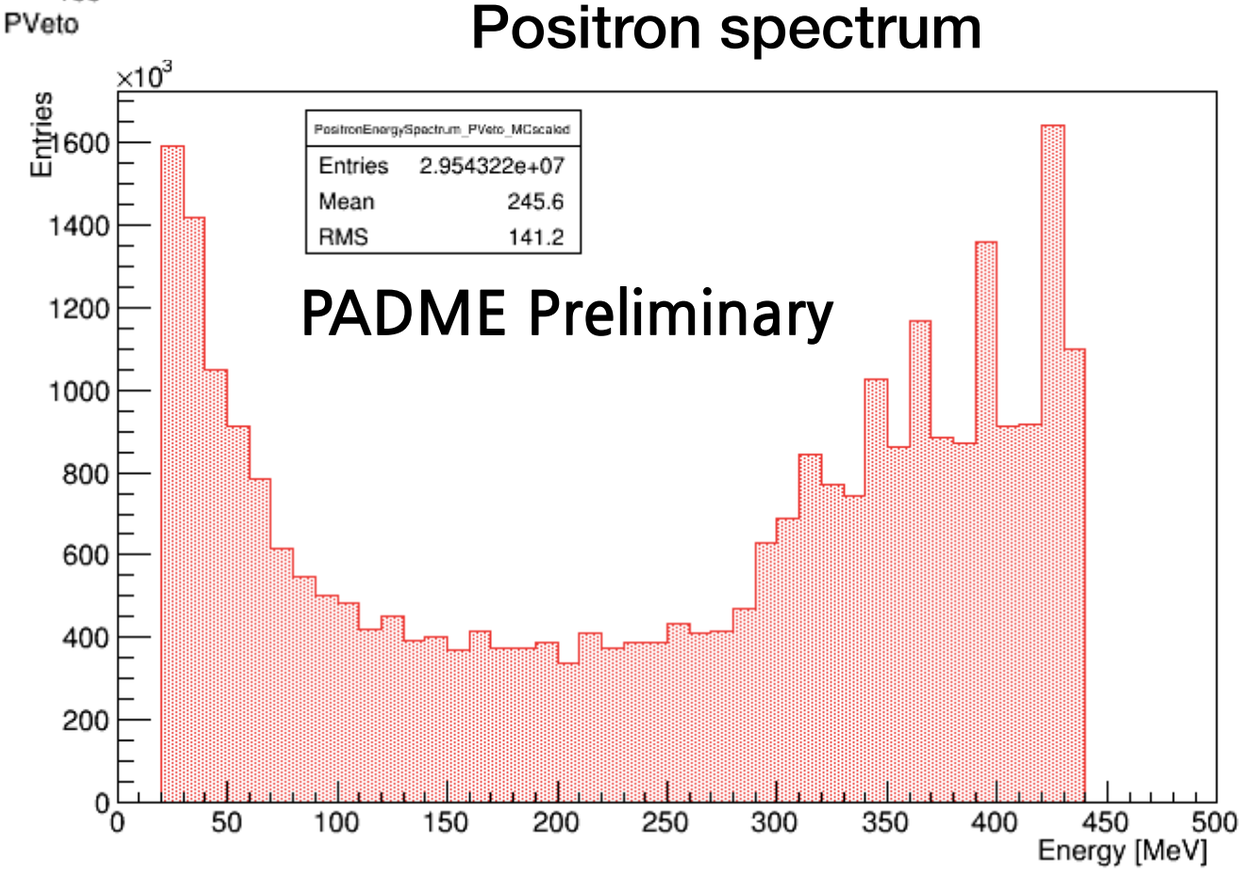
Possible Positron Spectrum



Positron spectrum obtained from DATA with parameters obtained from **MC SAC scaled**

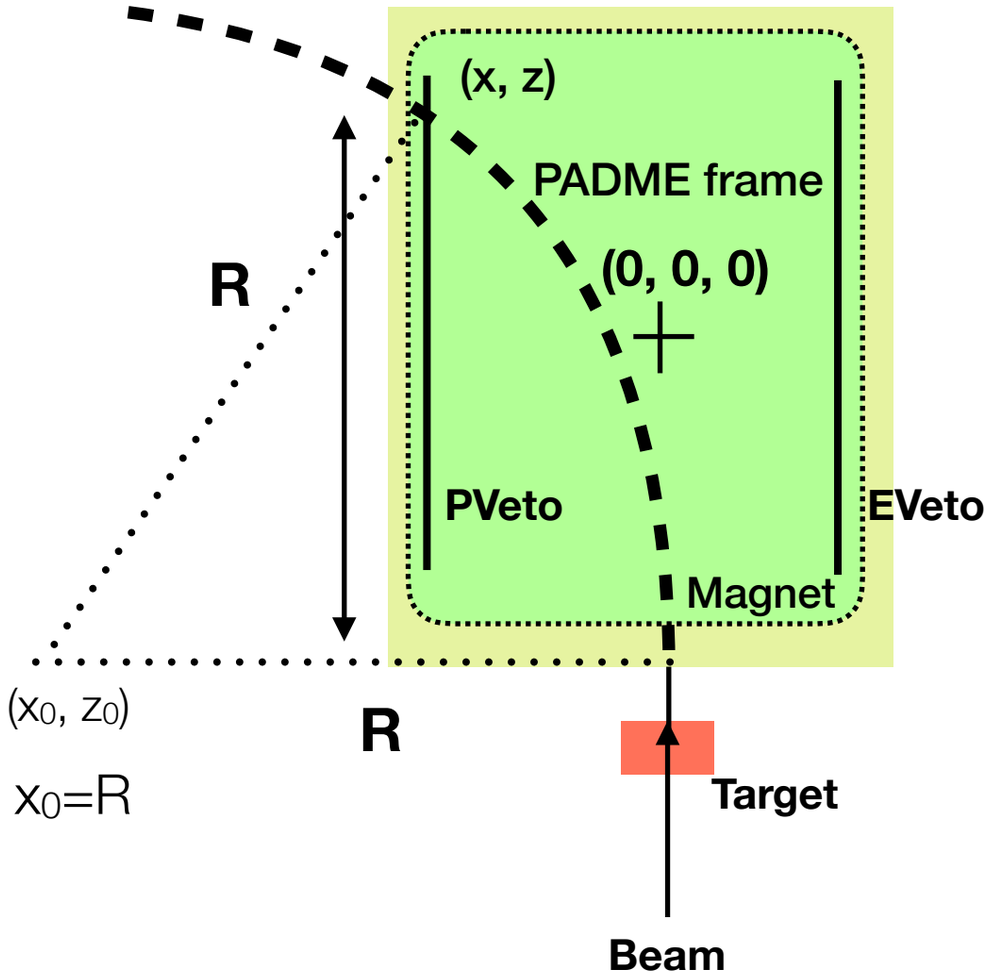
$$E_{e+} = \frac{0.3\ B}{2\ x_{PVeto}} \left[(z_{PVeto} + z_0)^2 + x_{PVeto}^{\ 2} \right]$$

z_0=684.6 mm, B = 0.3656 T



Analytic Fit function

The positron trajectory could be seen as starting straight line, that bends when the magnetic field starts



Starting from the circumference equation..

$$(x-x_0)^2 + (z-z_0)^2 = R^2$$

Knowing that $R = p/0.3B$

It's possible to write:

$$\mathbf{p} = \frac{0.3\,B}{2\,(x+x_0)}\,[\,(z+z_0)^2 + (x+x_0)^2\,]$$

Where..

z_0 starting point of the magnetic field, with a possible component due to a mismatch of the Z PVeto position

(x, z) position PVeto in PADME frame

x_0 potential distance variation from beam

x position PVeto in Reco geometry 182.5 mm

The starting point of the magnetic field could not coincide with half of the length of the magnetic dipole, due to fringe field effect