Bremsstrahlung studies

Isabella Oceano & Lecce group 09/01/2019

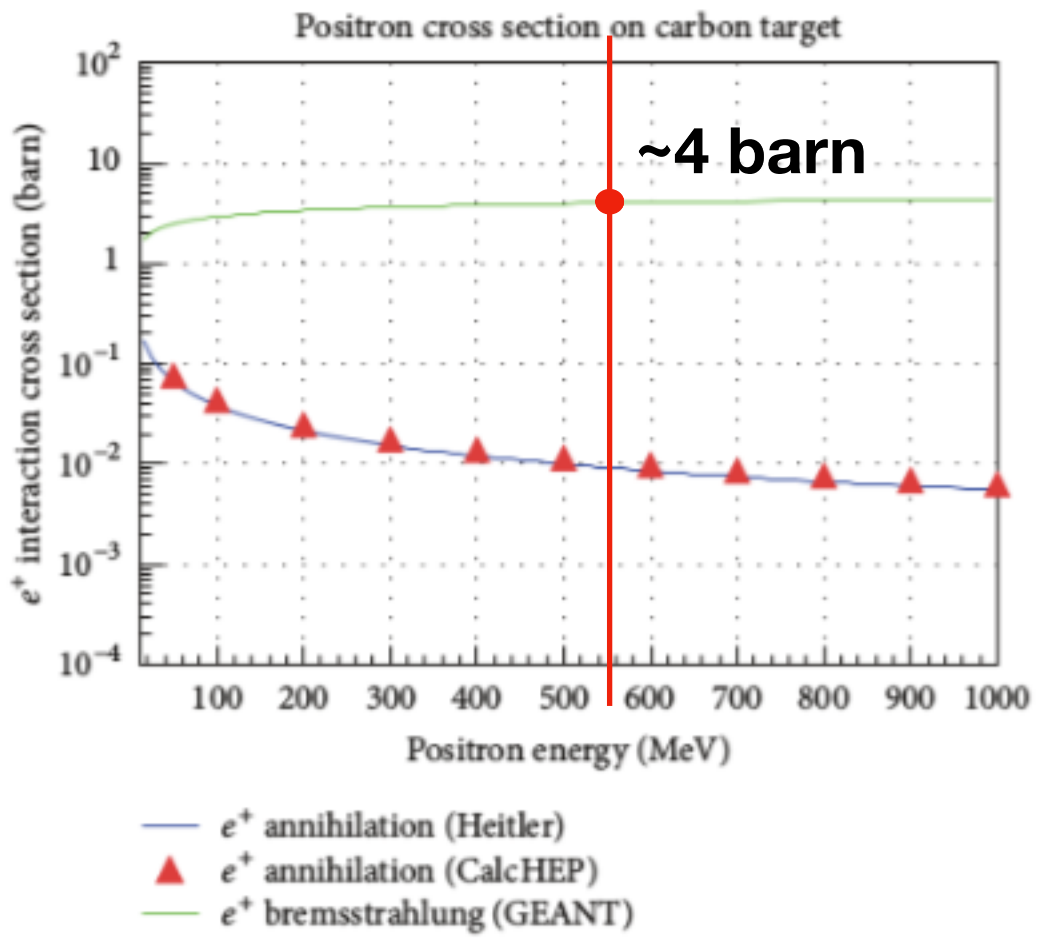
Outline

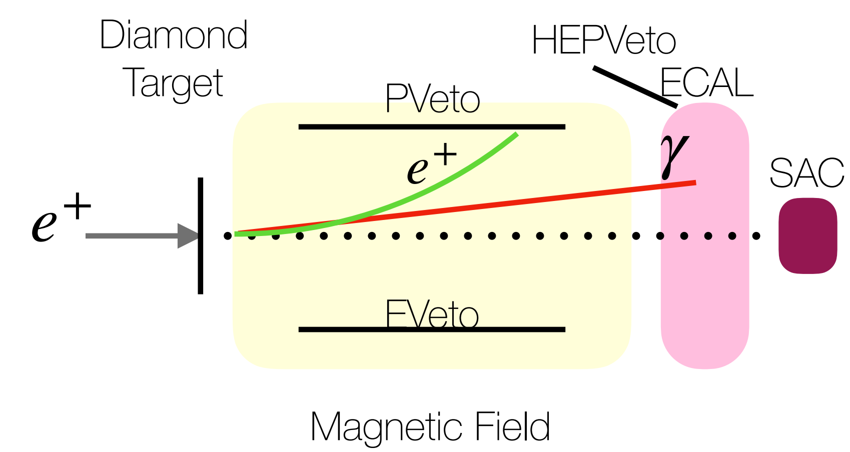
- Bremsstrahlung events:
    - preliminary studies;
    - MC studies.
- Signal + background MC sample:
    - Variables and cuts;
    - Selection efficiency;
    - Missing mass spectrum.
- Raw Data considerations.

Bremsstrahlung Event

$$e^+N \to e^+N\gamma$$

$E > 1$ MeV





$$\sigma(e^+N \to e^+N\gamma) = \frac{N_{int}}{N_{bers} \cdot N_{beam}}$$

$$N_{int} = \sigma(e^+N \to e^+N\gamma)\frac{\rho}{A}N_A \Delta x N_{beam}$$

$N_{int} = 35$ /bunch(5000e$^+$)

$N_{int} = 140$ /bunch(20000e$^+$)

$\rho_{diamond} = 3.5\ \mathrm{g/cm^3}$

$E_{beam} = 550$ MeV

$\Delta x = 100\ \mu$m

...some numbers...

PDG

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

$$N_\gamma = \frac{d}{X_0}(8.41 - 1.33 + 0.5) = \frac{d}{X_0}^{\star} \times 7.58 = d \times 7.58 \times 0.081$$

$K_{max} = 550$ MeV

$K_{min} = 1$ MeV

$E = E_{beam} = 550$ MeV

$$^{\star}\ \frac{1}{X_0} = 4\alpha r_e^2 n_{at}(Z^2[L_{rad} - f(Z)] + ZL'_{rad})$$

$L_{rad} = ln(\frac{184.15}{Z^{1/3}})$ Elastic form factor

$L'_{rad} = ln(\frac{1194}{Z^{2/3}})$ Inelastic form factor

description of the positron scattering with nucleus and electron shells

$f(Z)$ Coulomb correction function

Trascure

$$\frac{1}{X_0} = \frac{4}{137}(2.8 \times 10^{-13}(cm))^2(\frac{\rho}{A}N_A)(6^2 L_{rad} + 6L'_{rad})$$

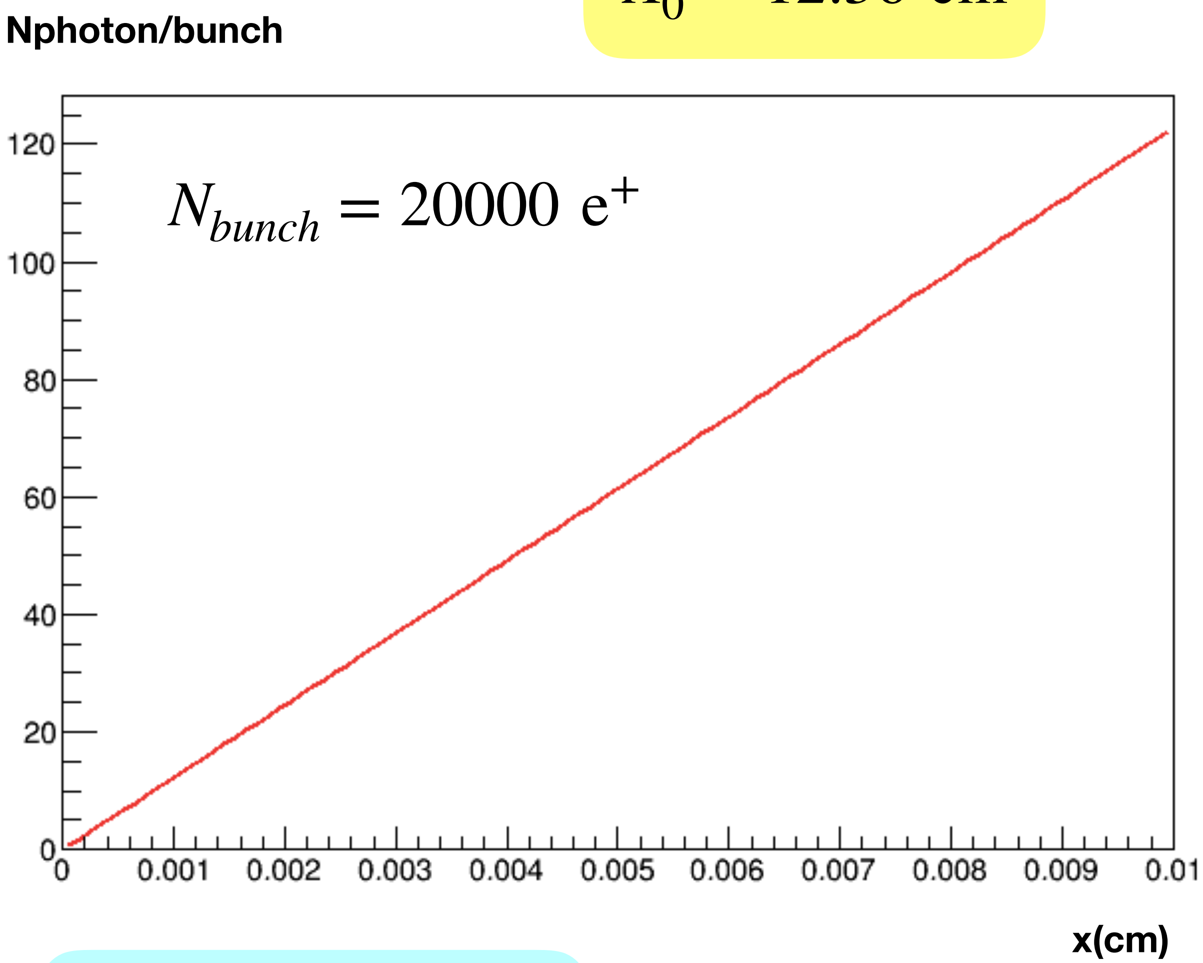
$$\frac{1}{X_0} = \frac{4}{137}(2.8 \times 10^{-13}(cm))^2(3.52 \times 6.02 \times 10^{23}/12)(166 + 35.31) = 0.081 \rightarrow X_0 = 12.36 \text{ cm}$$

PDG: $X_0(diamond) = \frac{42.70 \text{ g/cm}^2}{3.5\text{g/cm}^3} = 12.2$ cm

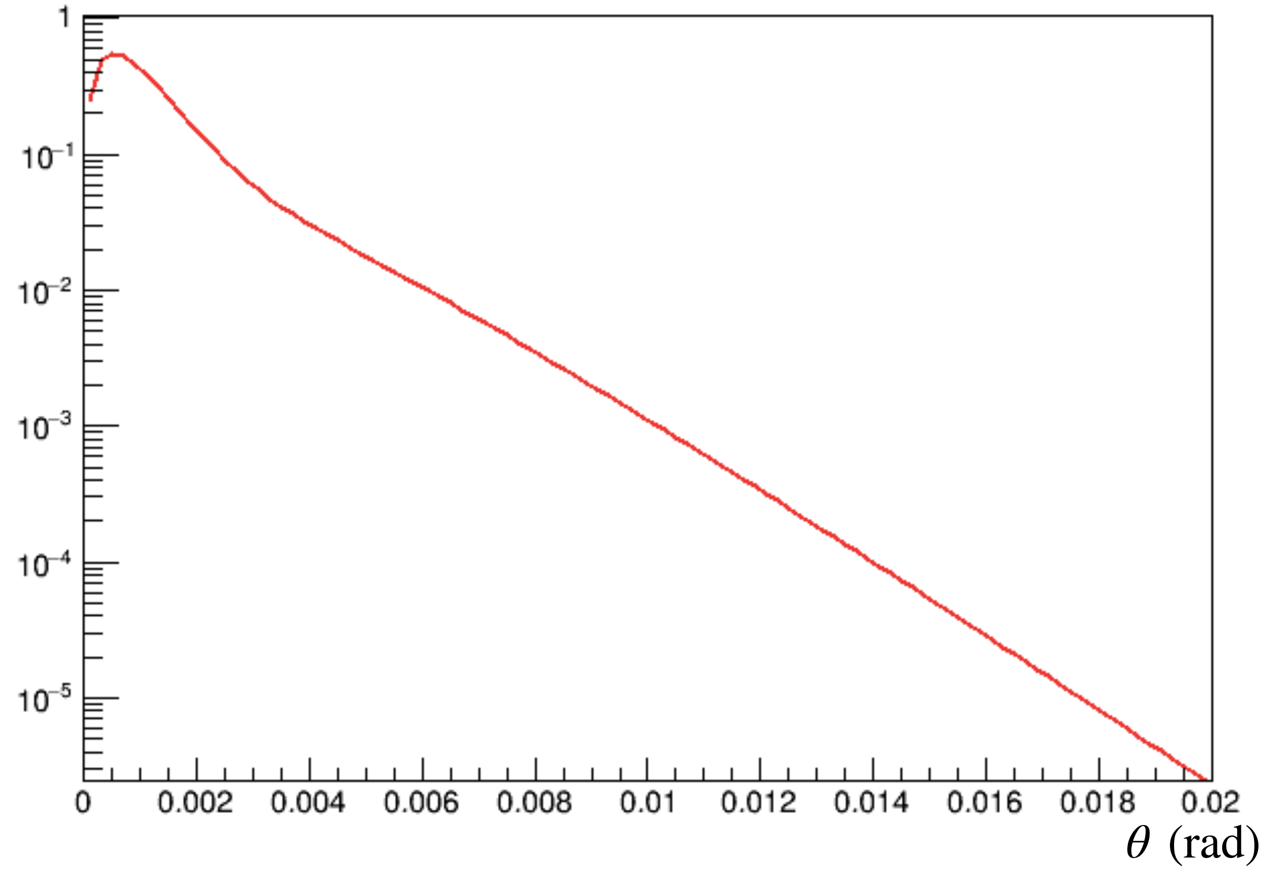
Photons/bunch & angular distribution

$$N_\gamma = \frac{d}{X_0} \times 7.58$$

$X_0 = 12.36$ cm



Photon Angular Distribution *



$N_\gamma \propto ln(E_{max}/E_{min}) \Rightarrow$

$N_\gamma(E_{min} = 10 \text{ MeV}, \text{E}_{\text{min}} = 550 \text{ MeV})$

$N_\gamma(E_{min} = 1 \text{ MeV}, \text{E}_{\text{min}} = 55 \text{ MeV})$

It's the same!

$R_{min}^{ECAL} = 0.017$ rad (5 cm)

$\sim 0.02\,\%$ of photon in ECAL

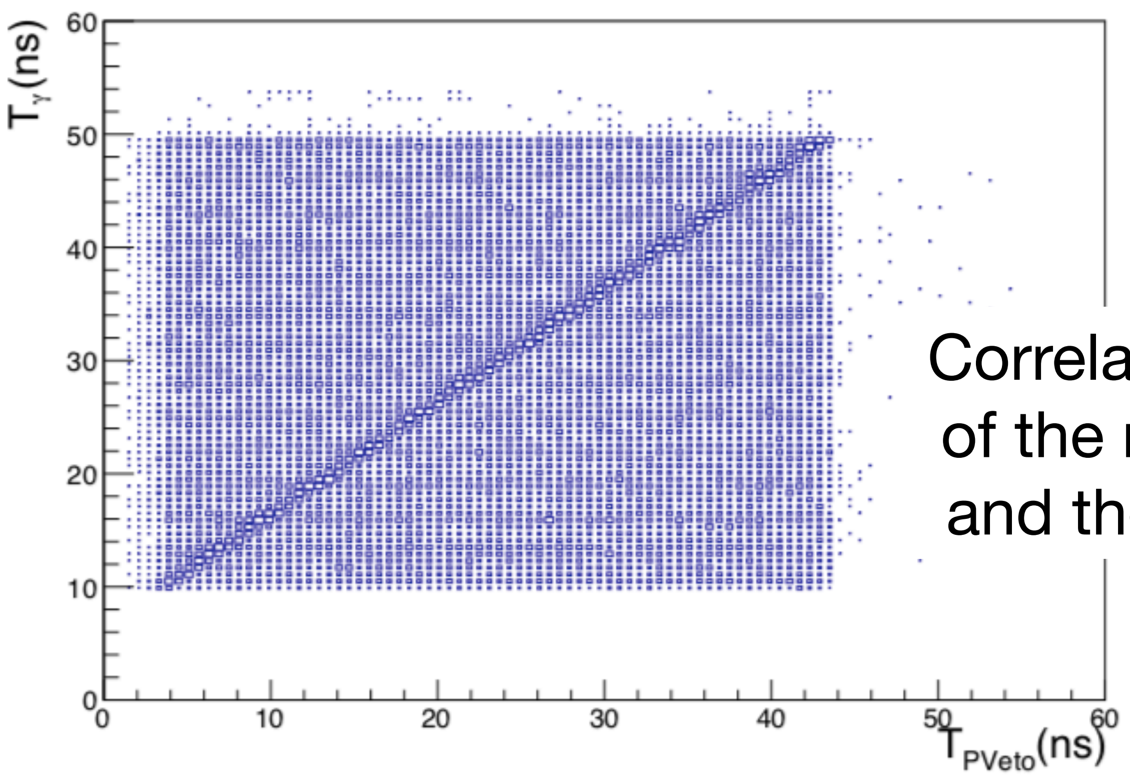
* Y. Tsai. Pair production and bremsstrahlung of charged leptons. *Rev. Mod. Phys.*, 46():815, 1974.

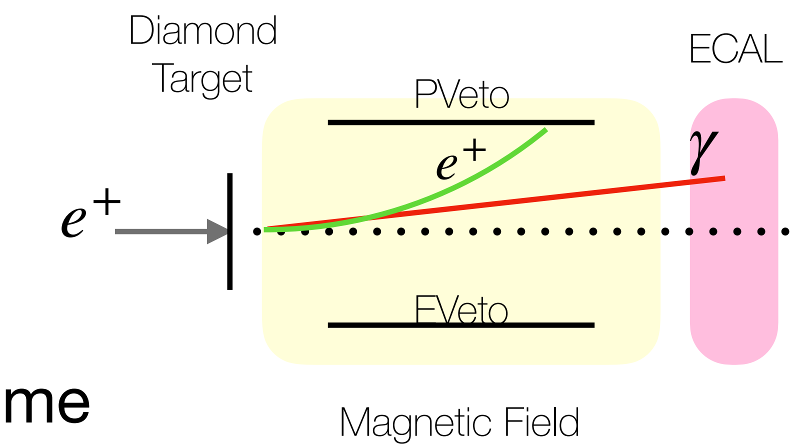
Y. Tsai. Pair production and bremsstrahlung of charged leptons. *Rev. Mod. Phys.*, 49():421, 1977.

Bremsstrahlung signature

MC

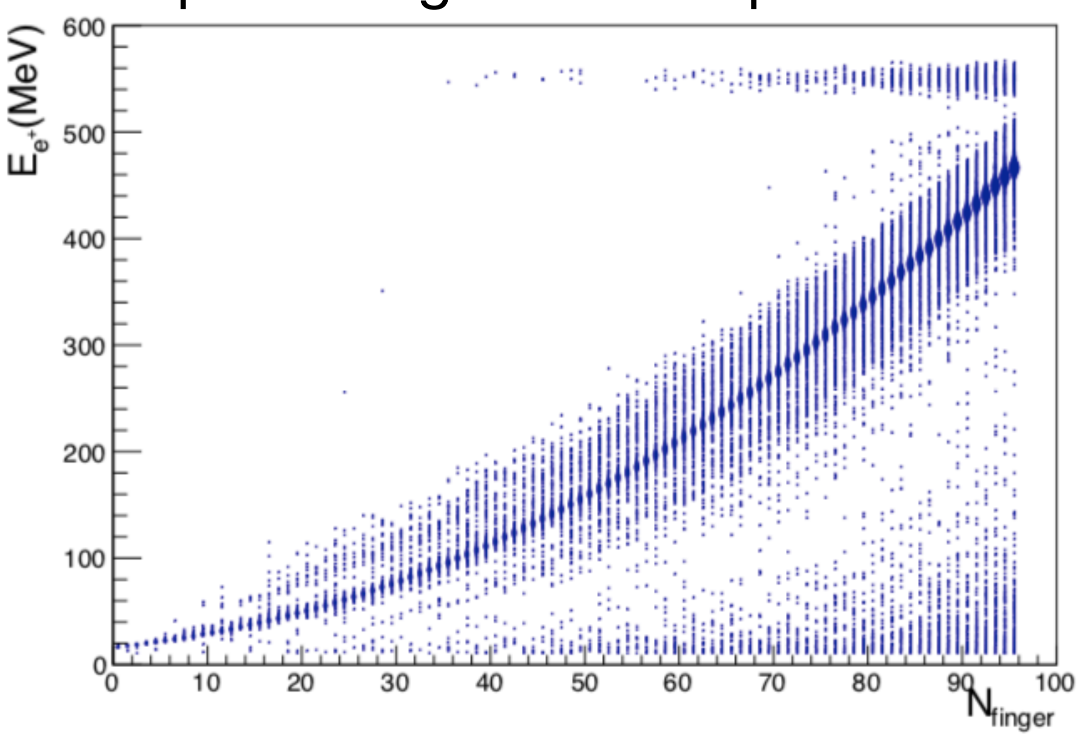
$$e^+N \rightarrow e^+N\gamma$$





Correlation between the time of the reconstructed photon and the time of the positron

Correlation between the number of pVeto finger and the positron energy



To reject bremsstrahlung event we can use:

-Time of hits in the PVeto: we can reconstruct the photon time and compare it with the time of the hit in ECAL (+SAC);

-Finger in PVeto: we can estimate the energy of the positron and compare $E_{e^+}^{estimate} + E_{\gamma}^{reconstruct}$ with the beam energy.

Signal + background MC sample

Variables and cuts

MC

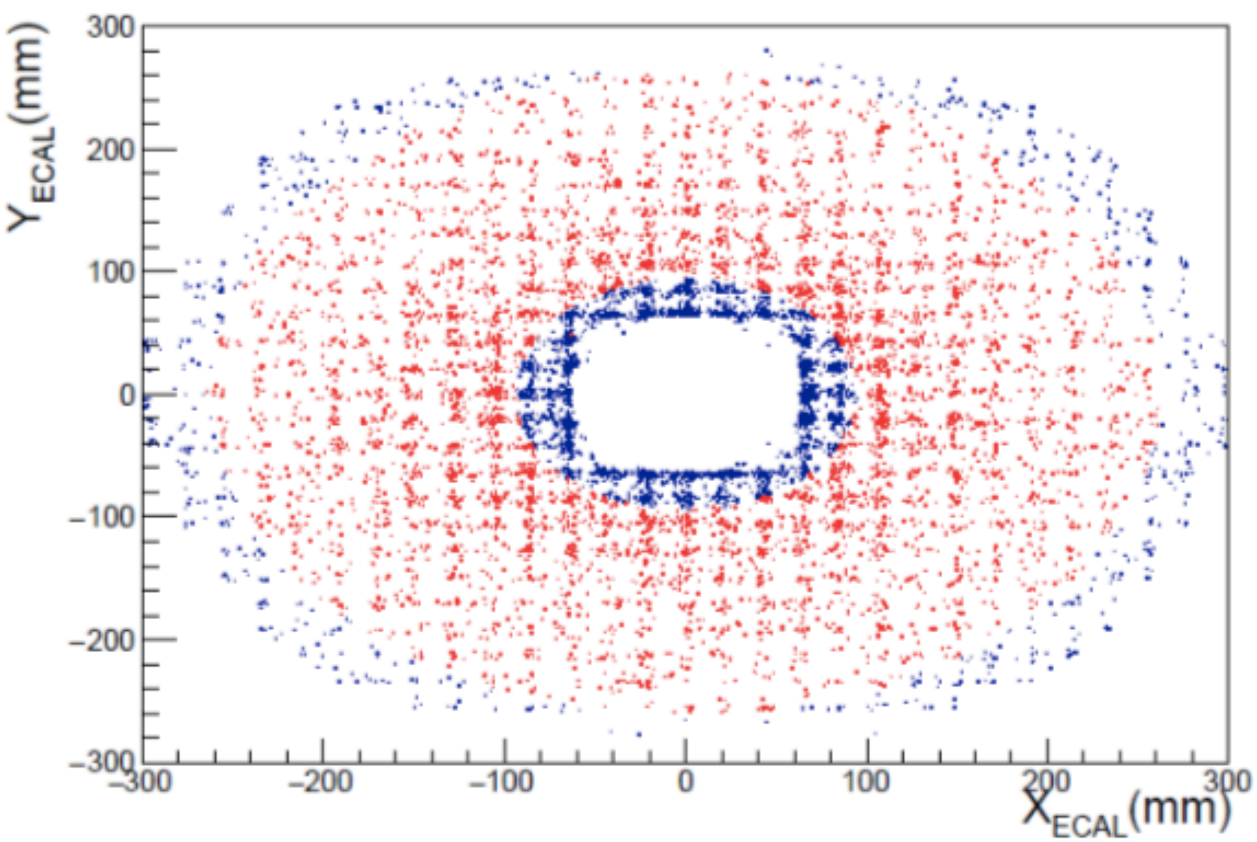
ECAL

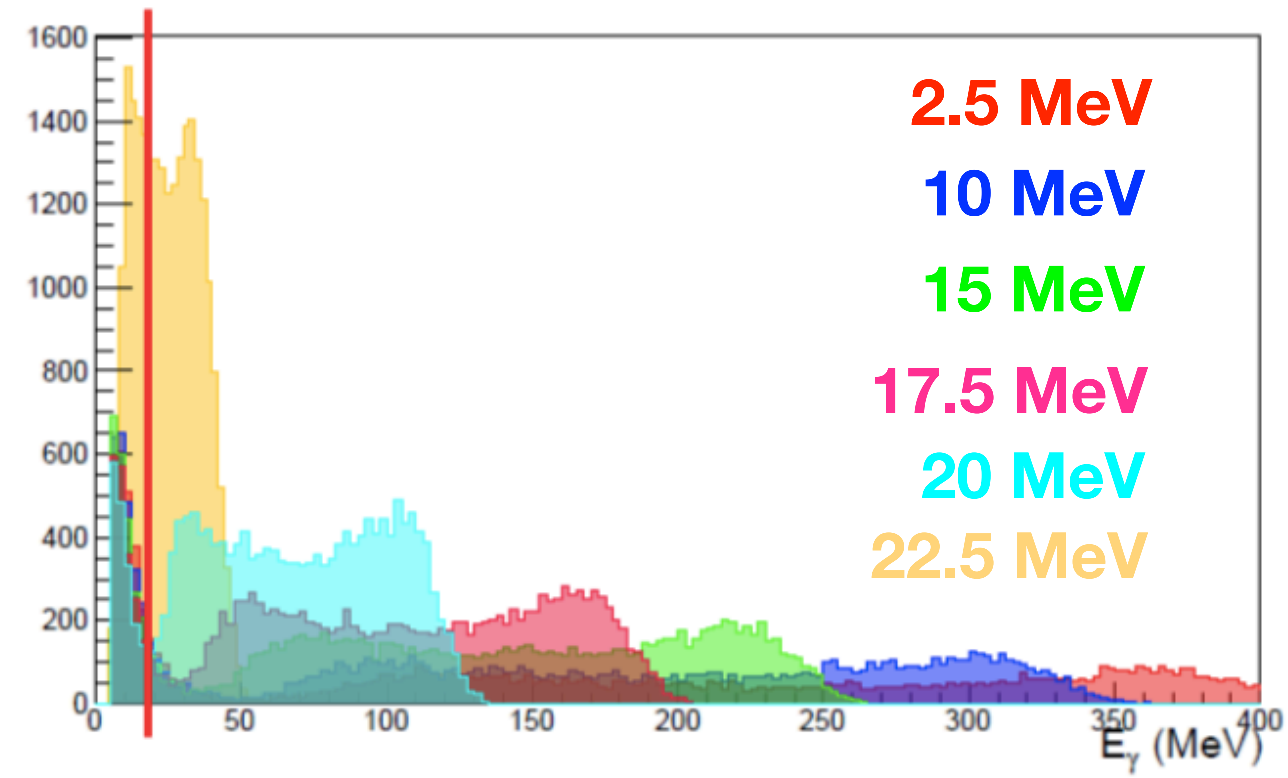
-Set an energy threshold for the photon;

$$E_\gamma > 20\ \text{MeV}$$

-Define a fiducial region;

$$94.5\ \text{mm} < R_\gamma < 262.5\ \text{mm}$$





ECAL (+SAC), PVeto: bremsstrahlung cut

-Require a time coincidence window;

-Add a cut on $E_\gamma + E_{e+}(N_{finger}^{PVeto})$.

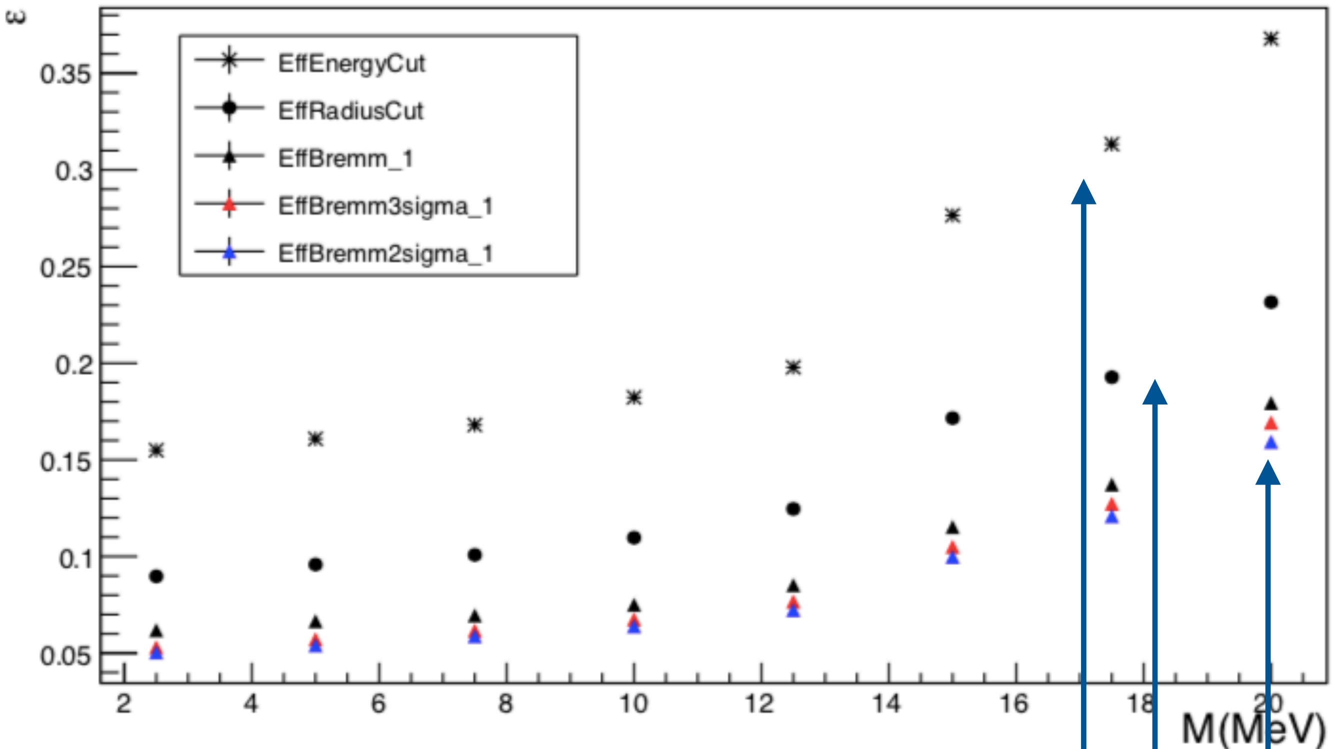
$$|t_\gamma - t_\gamma^{reconstruct}(N_{finger}^{PVeto})| < 2.5\ \text{ns}$$

$$500\ \text{MeV} < E_\gamma + E_{e+}(N_{finger}^{PVeto}) < 650\ \text{MeV}$$

Selection efficiency

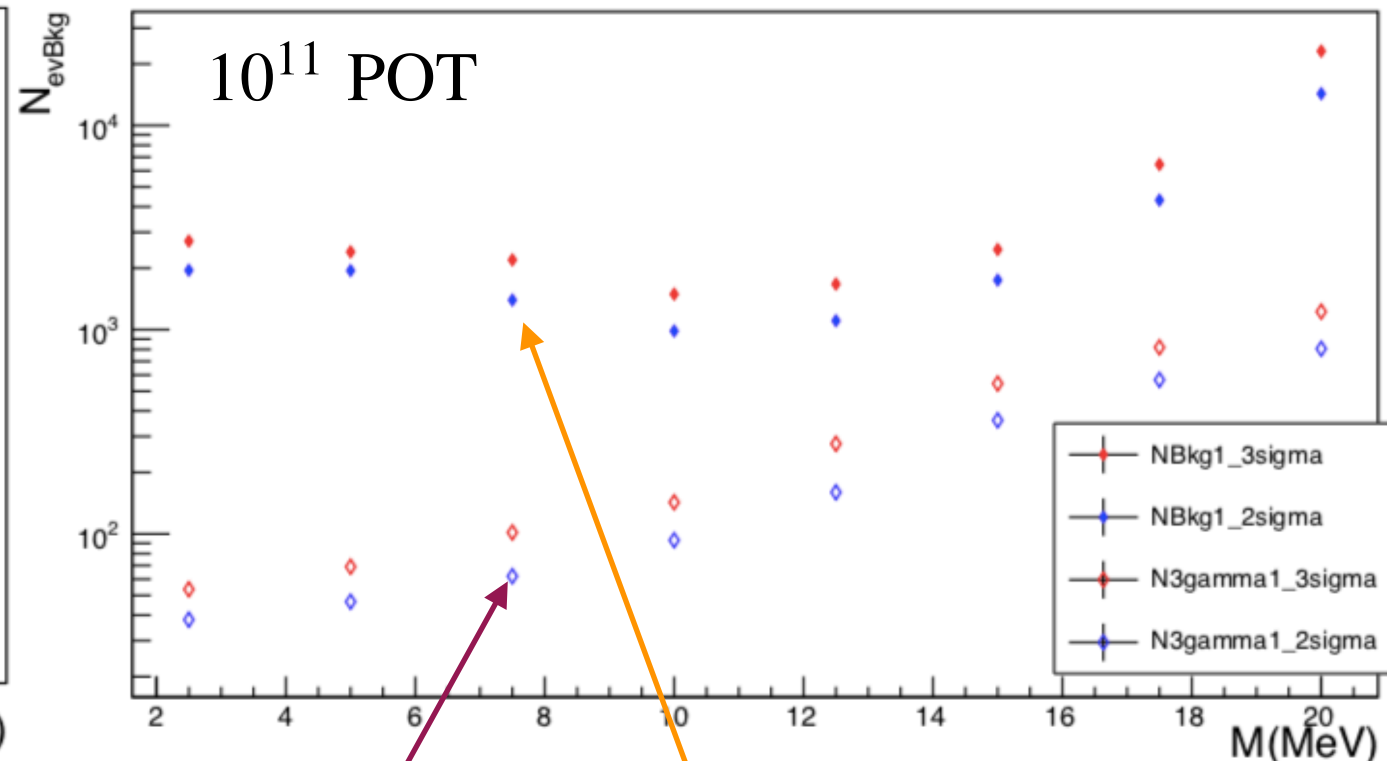
MC

Signal efficiency



Efficiency for different cuts:
- ECAL energy cut;
- ECAL fiducial region cut;
- Bremsstrahlung cut within 3σ and 2σ

Estimated number of background events

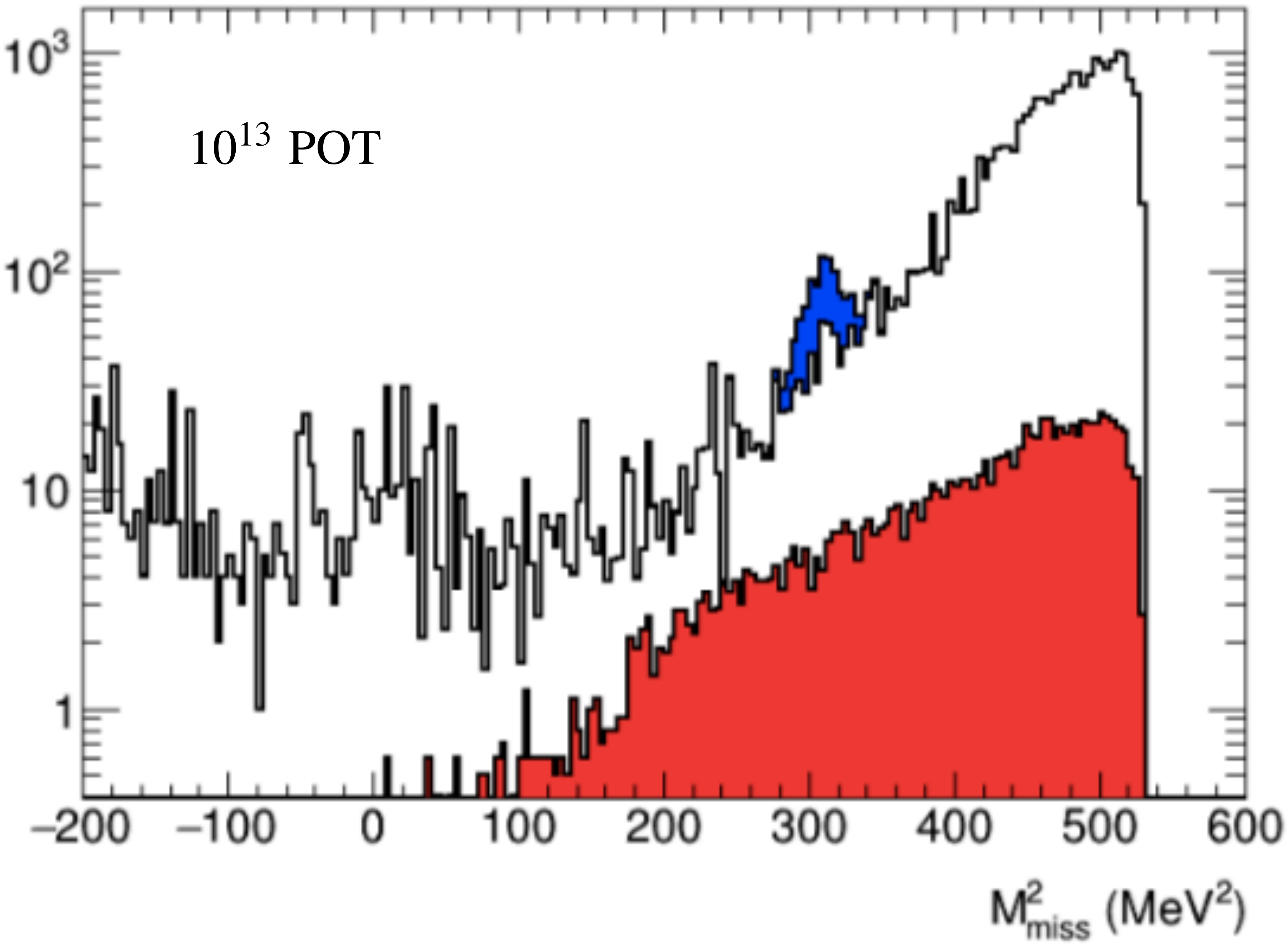


Total background for different mass hypothesis

3γ background for different mass hypothesis

Bremsstrahlung cut within 3σ and 2σ

MC Missing mass spectrum



M=17.5 MeV
(arbitrary normalization)

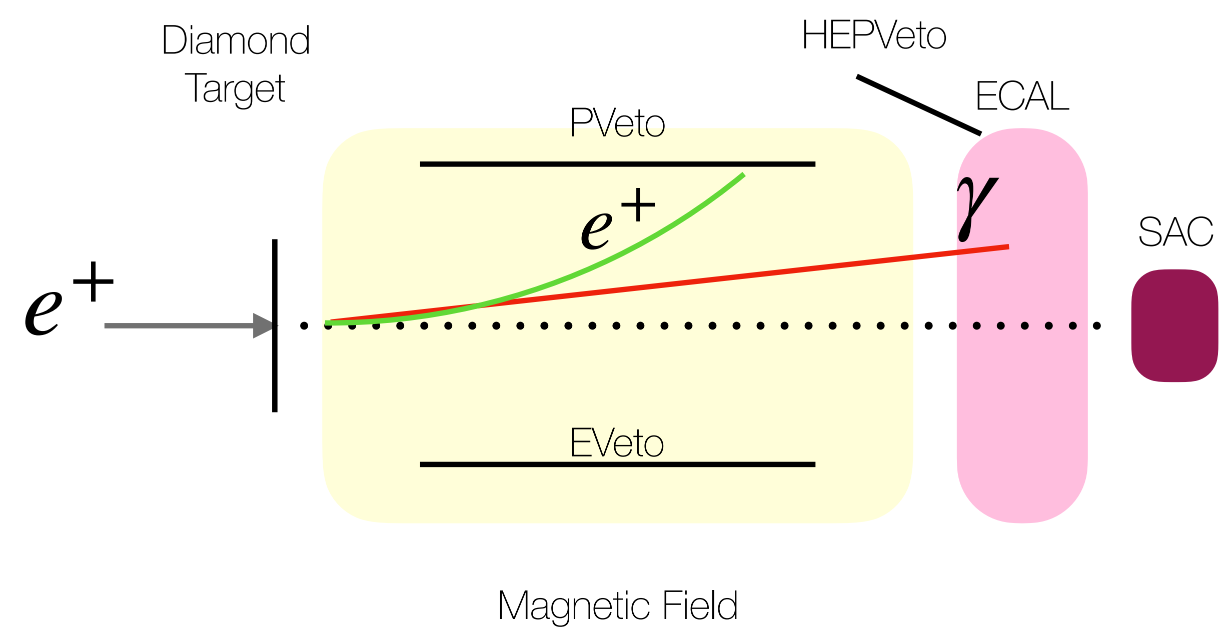
Background $e^+N \rightarrow e^+N\gamma$
$e^+e^- \rightarrow \gamma\gamma$
$e^+e^- \rightarrow \gamma\gamma\gamma$

Background $e^+e^- \rightarrow \gamma\gamma\gamma$

Raw data considerations

Bremsstrahlung Event for Raw Data

$$e^+N \rightarrow e^+N\gamma$$

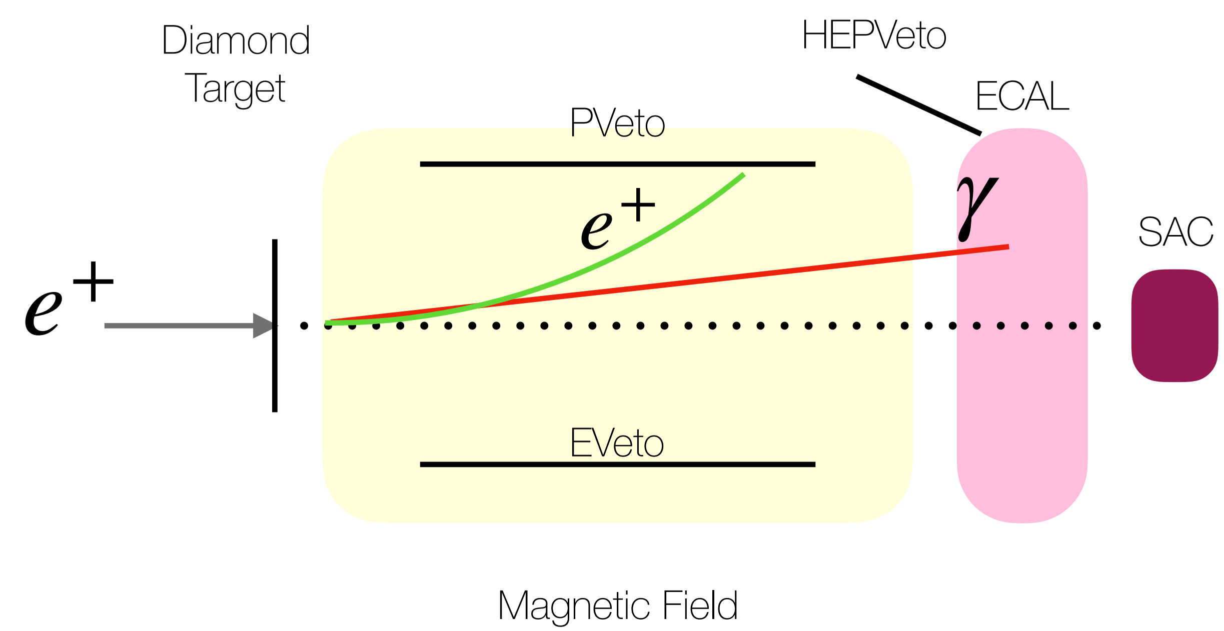


To do list:

- Test the clustering of ECAL and SAC;
- Add the position of the cluster as output;
- Include the clustering algorithm of hits in the PVeto;
- Add the absolute timing system.

Bremsstrahlung Event for Raw Data

$$e^+N \rightarrow e^+N\gamma$$



To do list:

- Test the clustering of ECAL and SAC;
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Grazie per l’attenzione!

Backup slide

Photon Angular Distribution

$$u = \frac{E}{m}\theta$$

(Used in GEANT4)

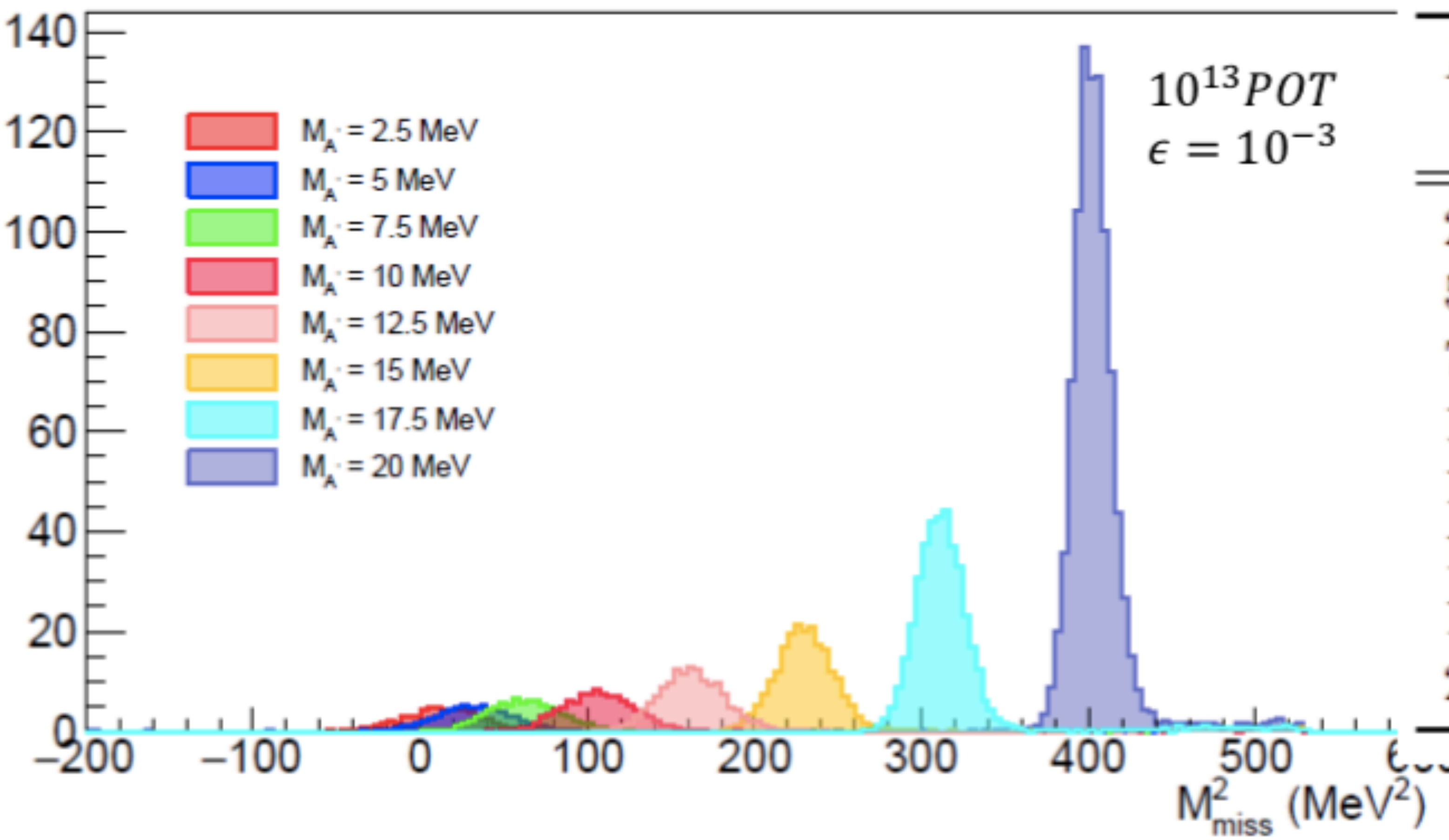
$$f(u) = C(ue^{-au} + due^{-3au})$$

Constants:

$$C = \frac{9a^2}{9+d} \qquad a = 0.625 \qquad d = 27$$

New physics signal

MC



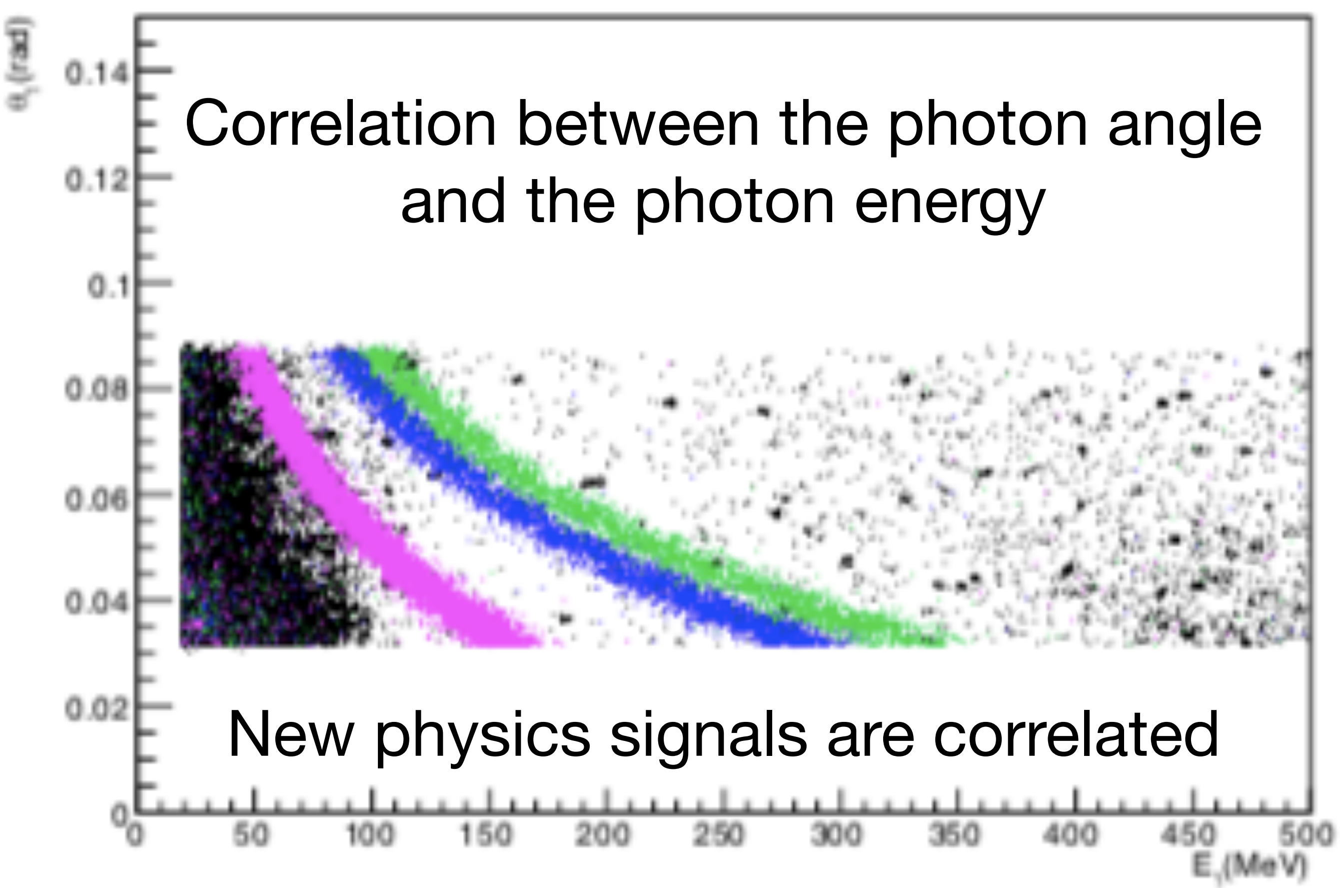
$M_{A'}(MeV)$	δ	$\sigma(e^+e^- \rightarrow A'\gamma)$ nb $(\epsilon = 10^{-3})$
2.5	2.0	31
5.0	2.0	31
7.5	2.0	34
10.0	2.3	37
12.5	3.0	47
15.0	3.8	62
17.5	6.5	91
20.0	10.5	160

Bremsstrahlung Event MC

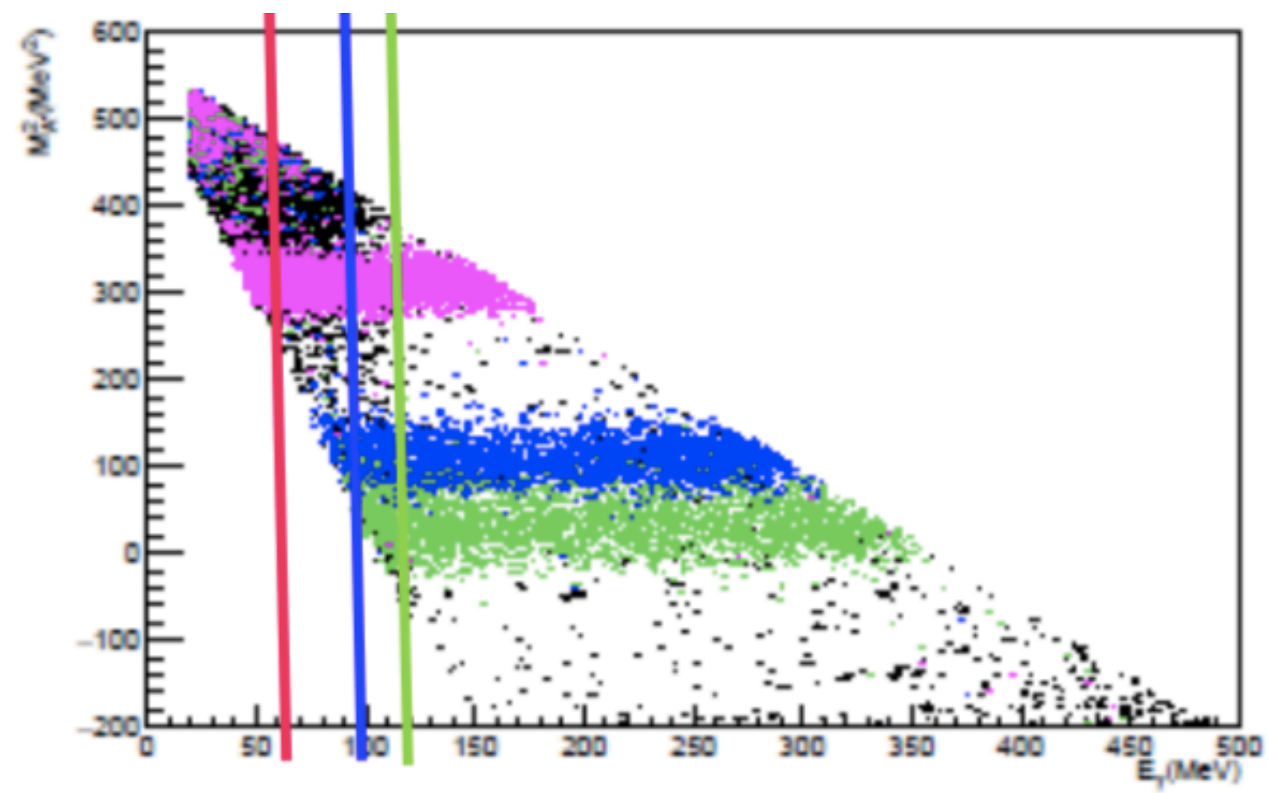
MC

$e^+e^- \to \gamma\gamma$
$e^+N \to e^+N\gamma$

$M_{A'} = 17.5$ MeV
$M_{A'} = 10.0$ MeV
$M_{A'} = 5.0$ MeV



We can try to implement other cuts based on the mass hypothesis



Bremsstrahlung Event

Positron Energy:

$$E(x) = E(0)\exp(-\frac{x}{X_0})$$