Measuring the electron energy: A comparison between two different setups

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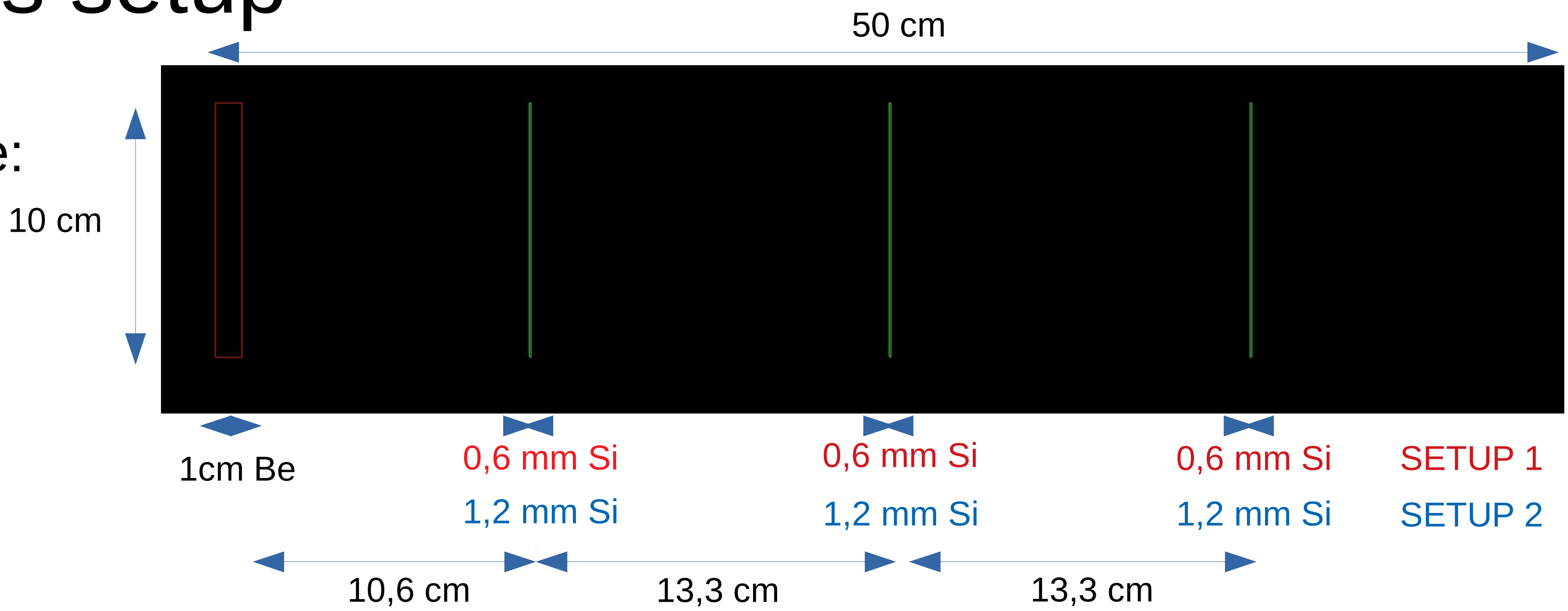
Apparatus setup

Single module:



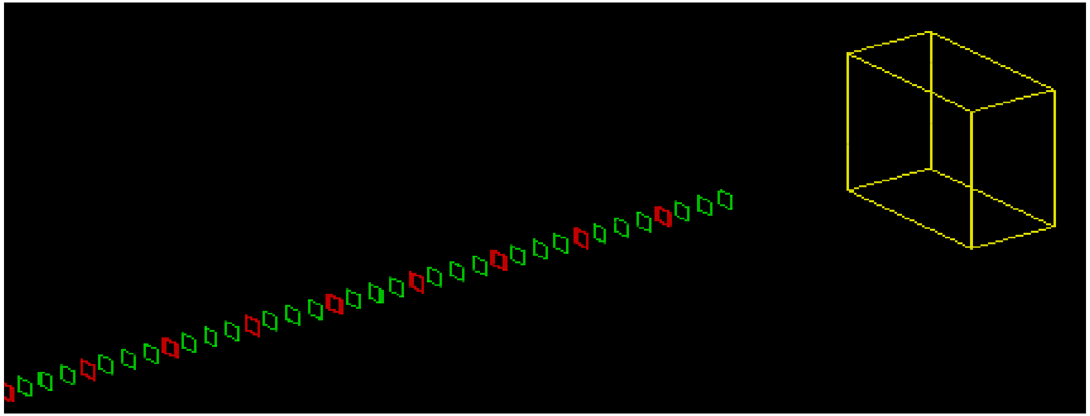
50 modules in total

CsI Calorimeter: 50 cm thickness ~27X_0

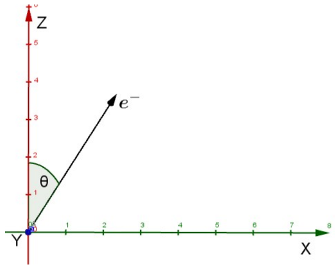
1 m x 1 m

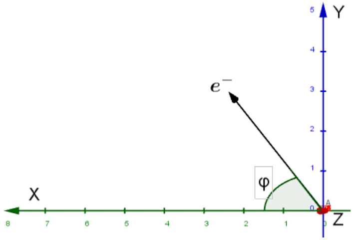
Distance between last Si and CsI calorimeter: 1 m

Only the energy deposit of the e^- in the calorimeter is plotted (the muon is removed)



STEP 1: $\theta_e = 0$ $\varphi_e = 0$, $E_e = 1, 2, 10$ GeV.





SETUP 1

$N_e = 100k$
$N_e\ (E_{cal} > 0) = 98148$ → ~98% of electrons reach the calorimeter

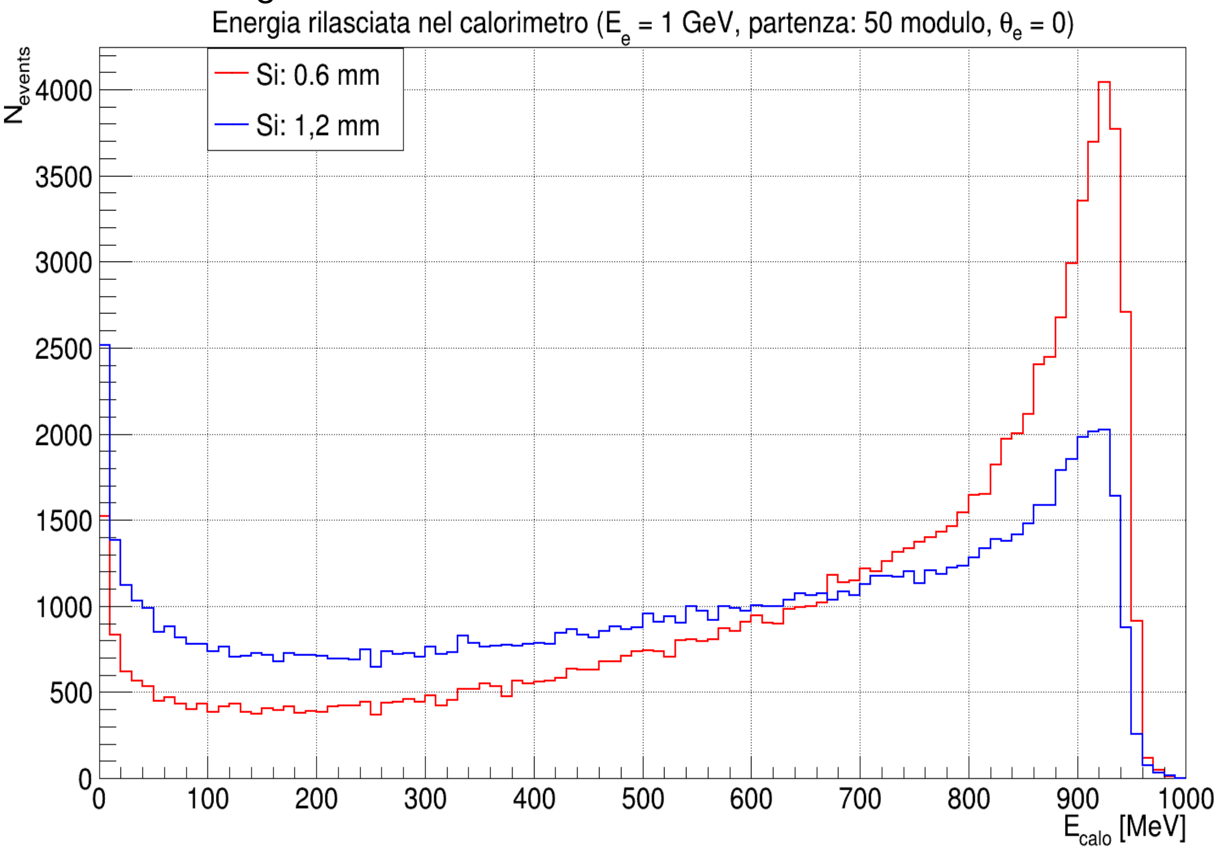
$N_e\ (E_{cal} > 500\ \text{MeV}) = 72146$ → ~72% of electrons reach the calorimeter with >50% their initial energy

SETUP 2

$N_e = 100k$
$N_e\ (E_{cal} > 0) = 97370$ → ~97% of electrons reach the calorimeter

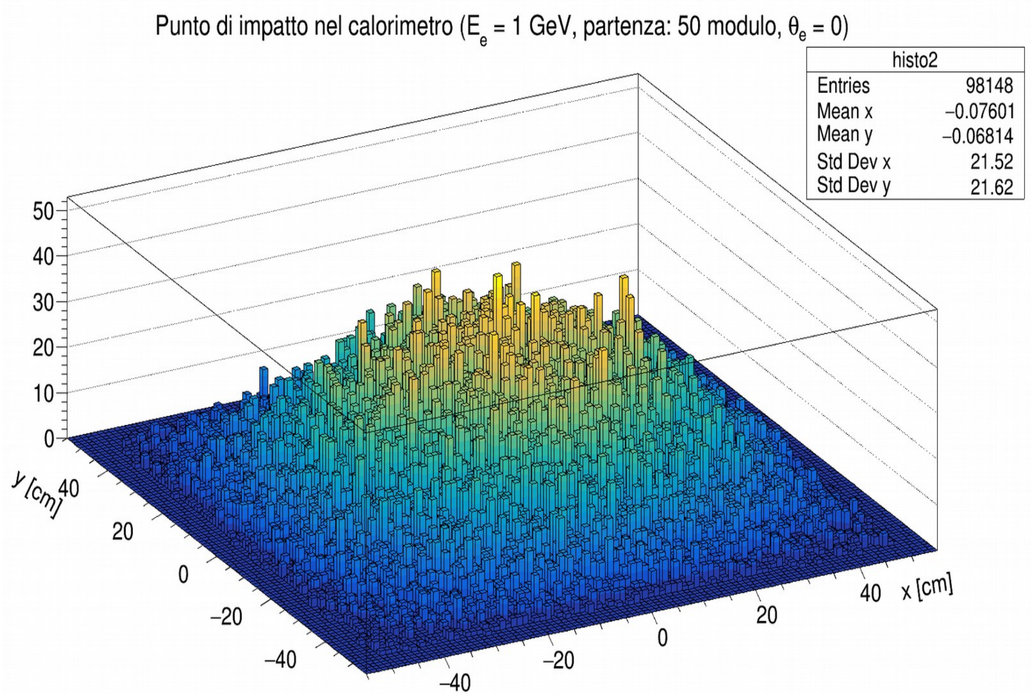
$N_e\ (E_{cal} > 500\ \text{MeV}) = 55856$ → ~56% of electrons reach the calorimeter with >50% of their initial energy

1.a) $E_e = 1$ GeV. Start from 1st module

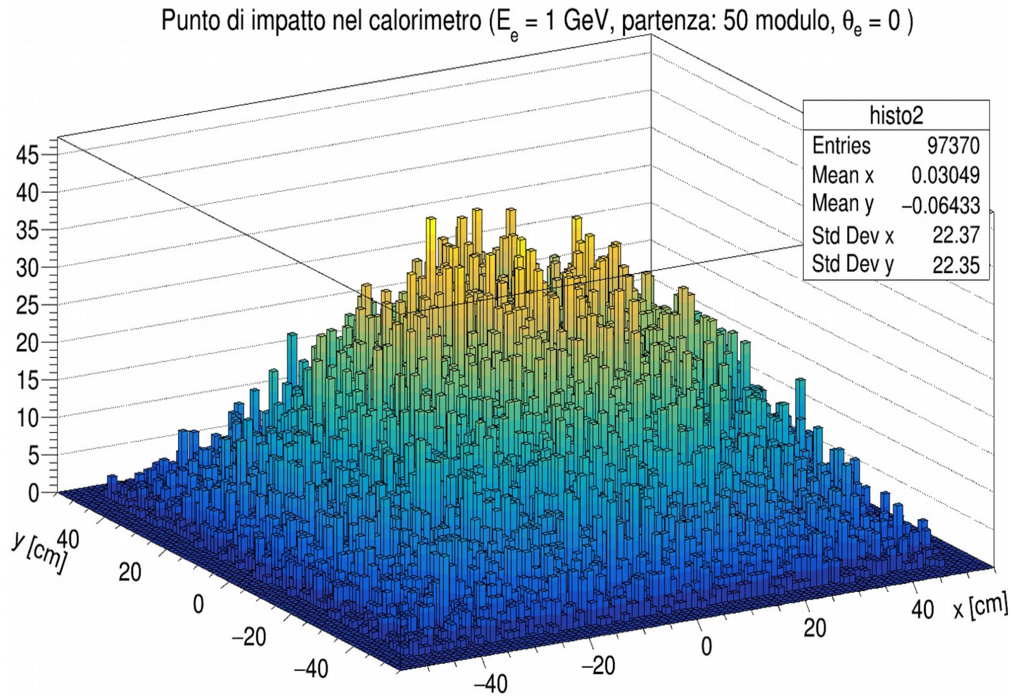


1.a) E_e = 1 GeV. Start from 1st module: Spatial distribution of the hit point on the calorimeter

SETUP 1



SETUP 2



No substantial differences between two setups

SETUP 2 distribution is slightly wider ($\sigma \approx$ 22,4 cm compared to $\sigma \approx$ 21,5 cm of SETUP 1) ➡ Increased MS effect

1.b) E_e = 2 GeV. Start from 1st module

SETUP 1

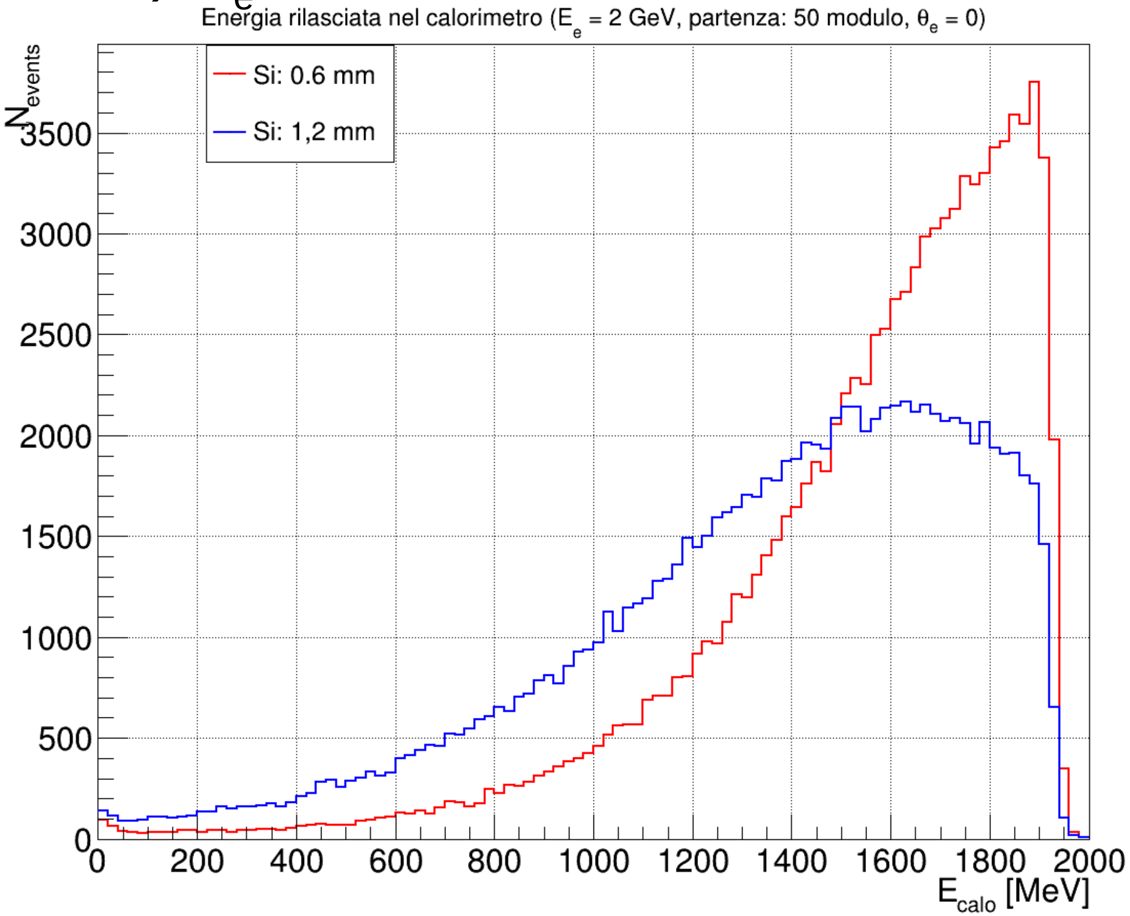
N_e = 100k
N_e (E_{cal}> 0) = 99793 → ~99,8% of electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 93199 → ~93% of electrons reach the calorimeter with >50% their initial energy

SETUP 2

N_e = 100k
N_e (E_{cal}> 0) = 99768 → ~99,8% of electrons reach the calorimeter

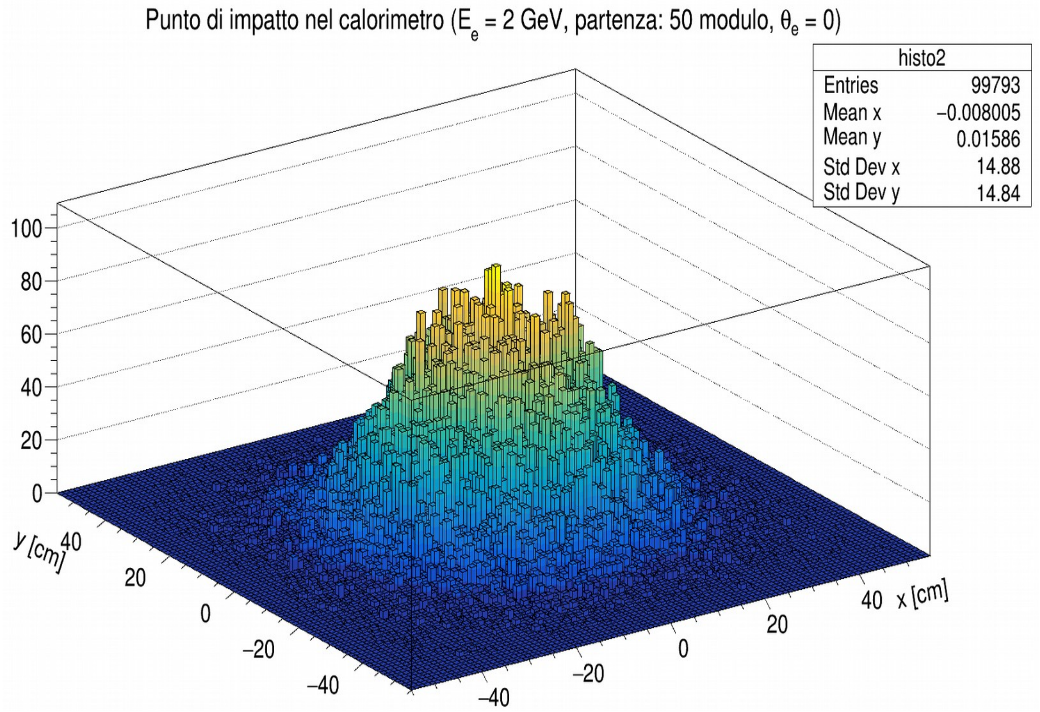
N_e (E_{cal}> 1 GeV) = 81515 → ~81% of electrons reach the calorimeter with >50% of their initial energy



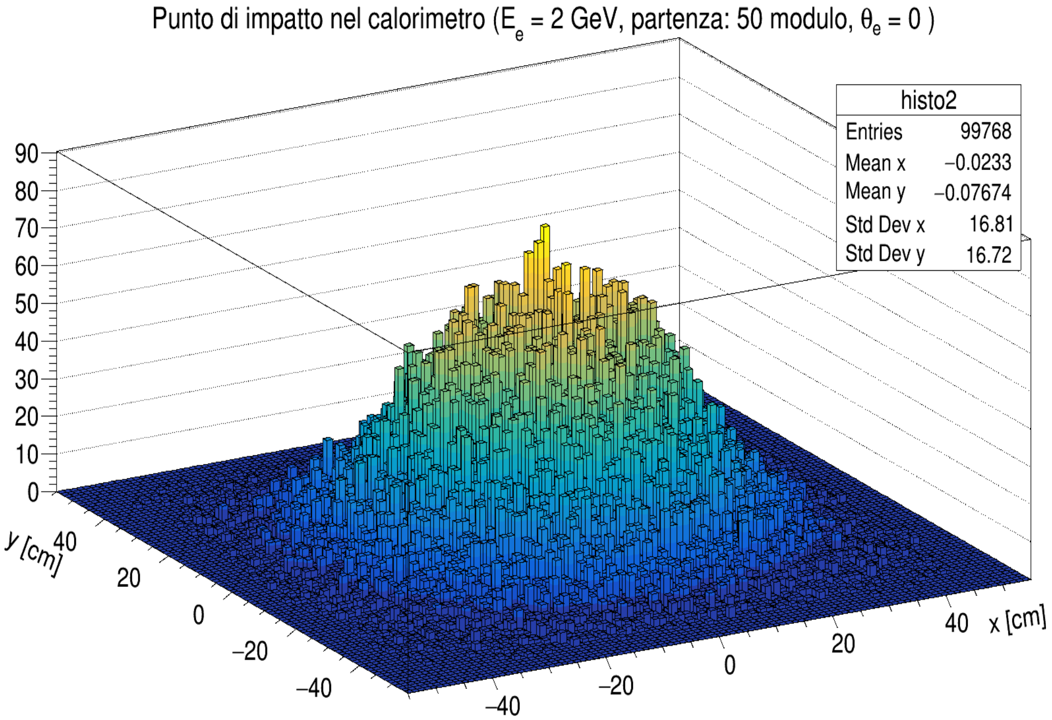
Using SETUP 2 the energy spectrum is much broader, probably because of MS effects, which are increased with respect to SETUP 1

1.b) E_e = 2 GeV. Start from 1st module: Spatial distribution of the hit point on the calorimeter

SETUP 1



SETUP 2



SETUP 2 distribution is slightly wider ($\sigma \approx$ 16,8 cm compared to $\sigma \approx$ 14,8 cm of SETUP 1) ➡ Increased MS effect

1.c) E_e = 10 GeV. Start from 1st module

SETUP 1

N_e = 20k
N_e (E_{cal}> 0) = 20k

All the electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 19998

>99,9% of electrons reach the calorimeter with >50% their initial energy

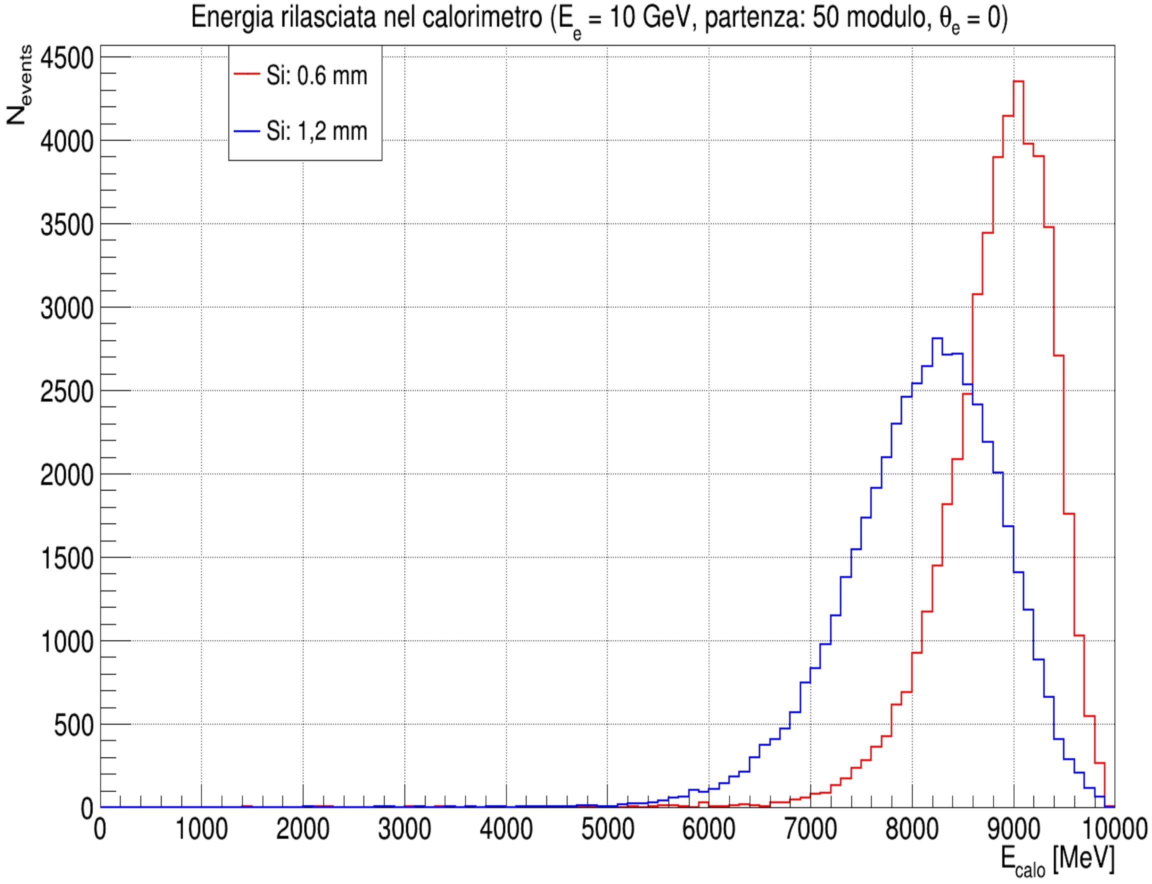
SETUP 2

N_e = 50k
N_e (E_{cal}> 0) = 49998

>99,9% of electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 49988

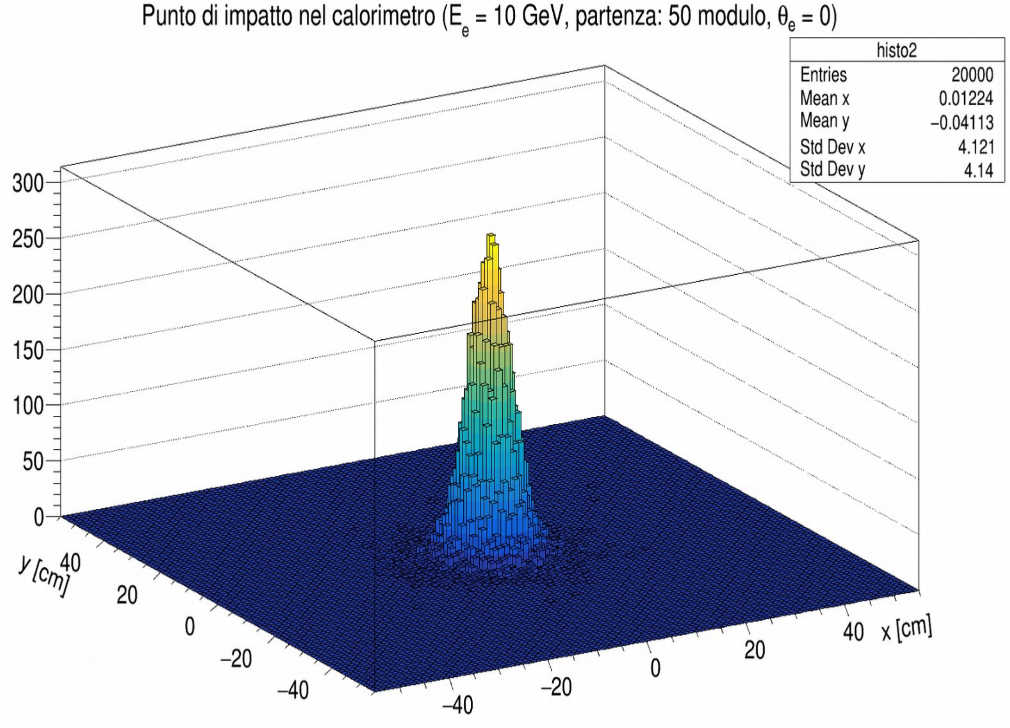
>99,9% of electrons reach the calorimeter with E > 1 GeV



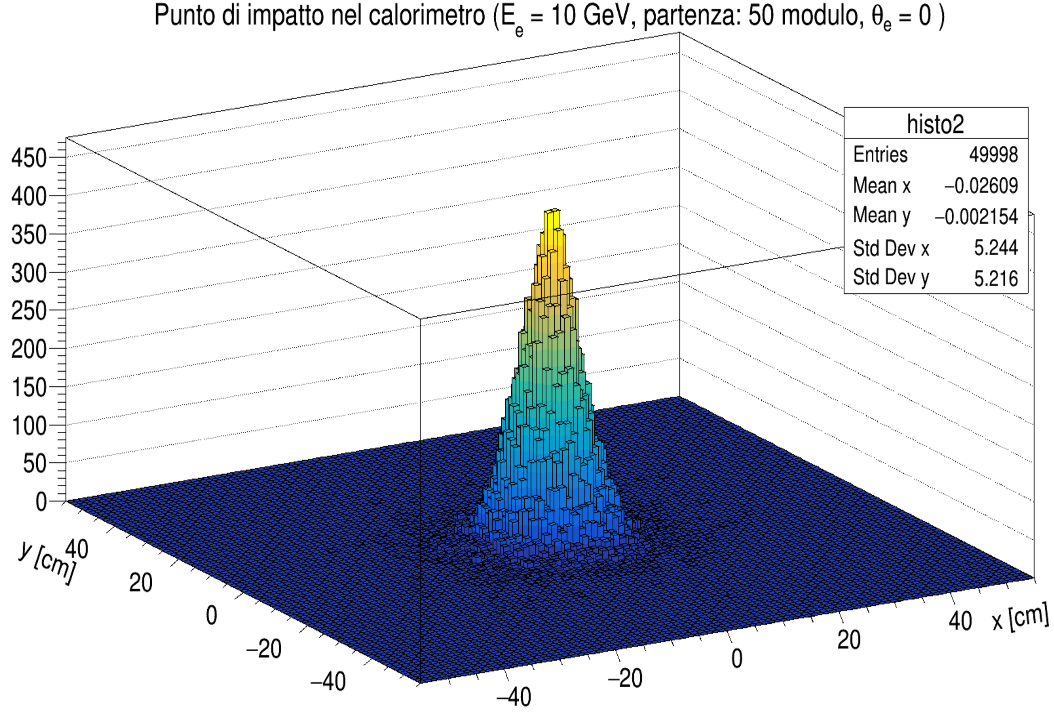
SETUP 2: energy spectrum is much broader and peak is at lower energy with respect to SETUP 1.

1.c) E_e = 10 GeV. Start from 1st module: Spatial distribution of the hit point on the calorimeter

SETUP 1



SETUP 2



SETUP 2 distribution is slightly wider ($\sigma \approx$ 5,2 cm compared to $\sigma \approx$ 4,1 cm of SETUP 1) ➡ Increased MS effect

1.a) E_e = 1 GeV. Start from 25th module

SETUP 1

N_e = 100k
N_e (E_{cal}> 0) = 99855

~99,8% of electrons reach the calorimeter

N_e (E_{cal}> 500 MeV) = 98938

~99% of electrons reach the calorimeter with >50% their initial energy

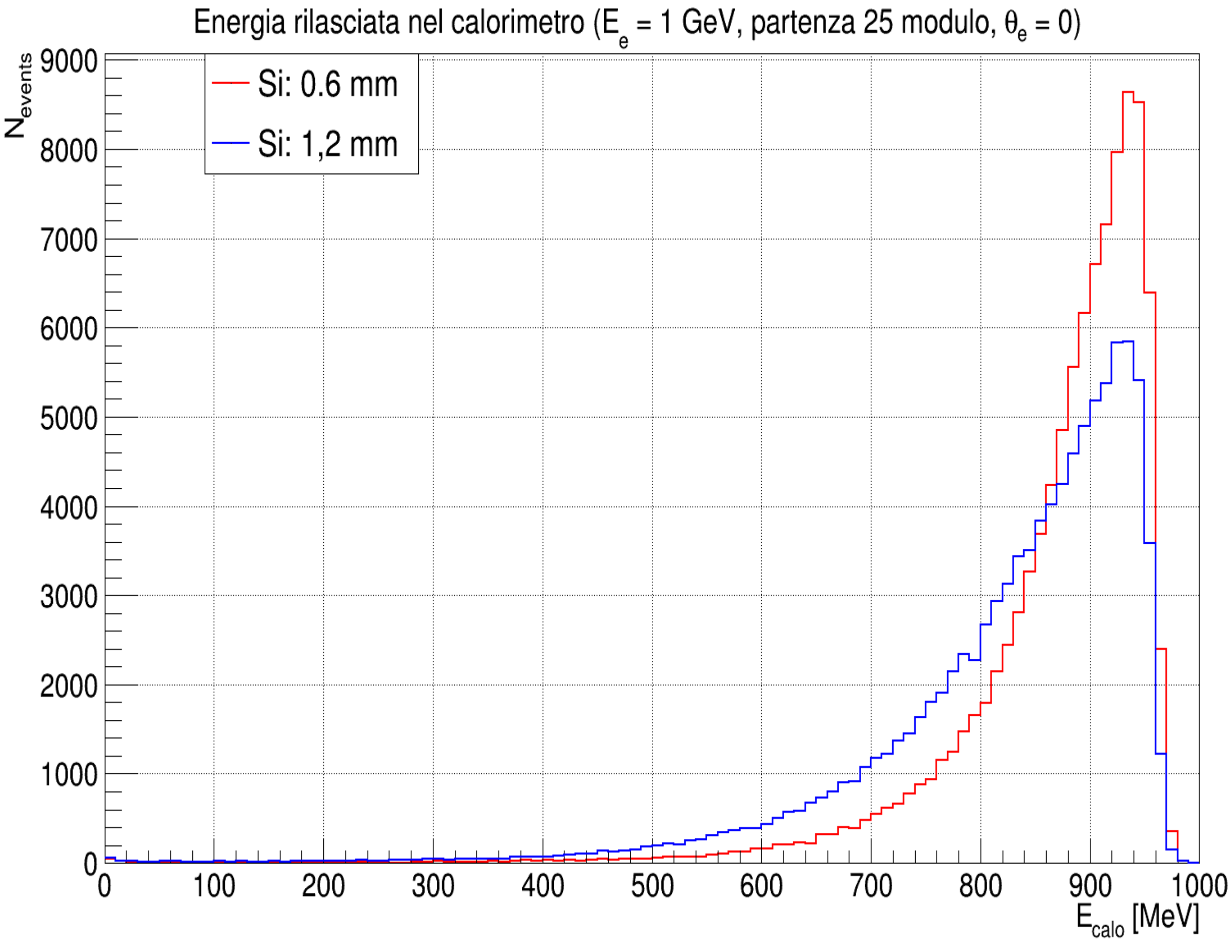
SETUP 2

N_e = 100k
N_e (E_{cal}> 0) = 99827

~99,8% of electrons reach the calorimeter

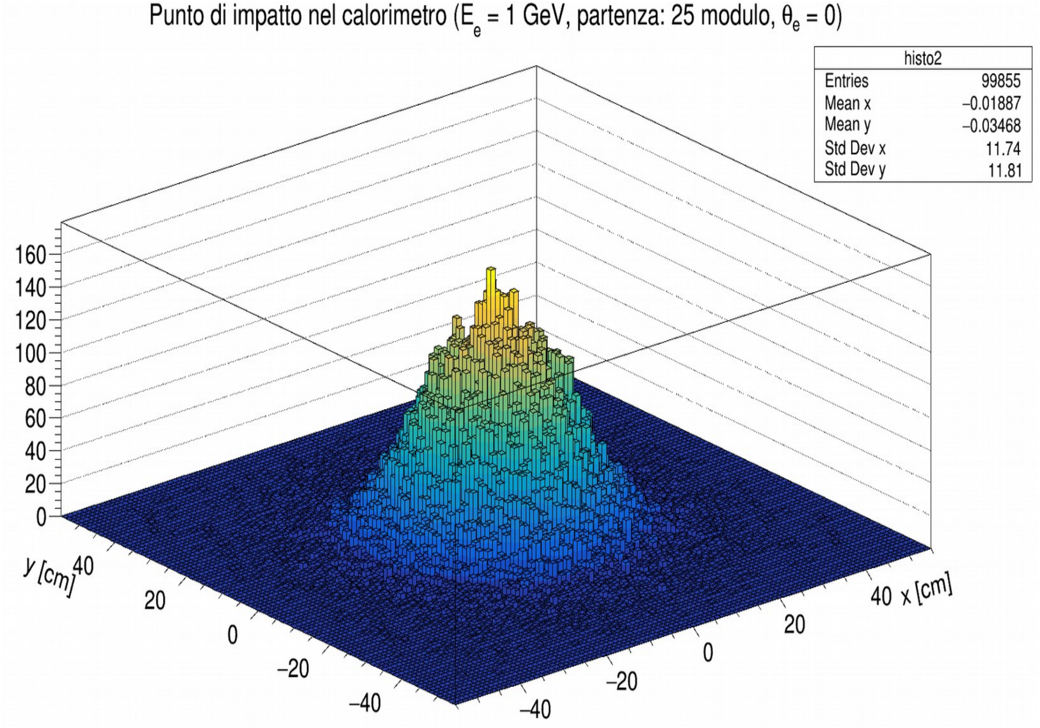
N_e (E_{cal}> 500 MeV) = 97375

~97% of electrons reach the calorimeter with >50% of their initial energy

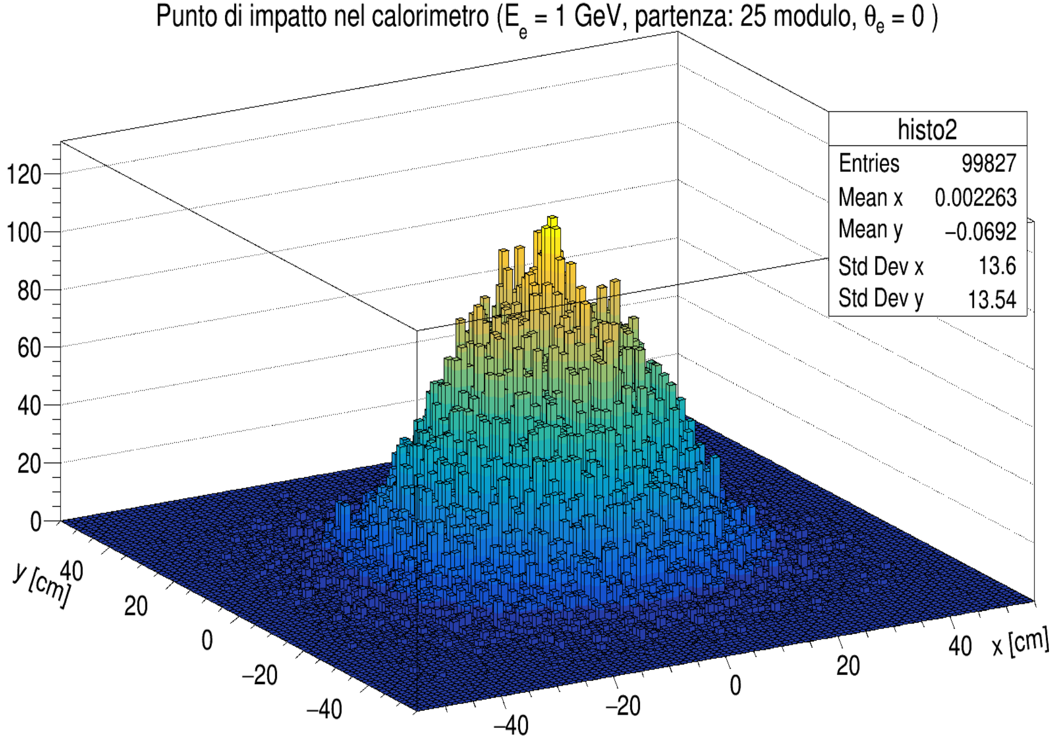


1.a) E_e = 1 GeV. Start from 25th module: Spatial distribution of the hit point on the calorimeter

SETUP 1



SETUP 2



SETUP 2 distribution is slightly wider ($\sigma \approx$ 13,6 cm compared to $\sigma \approx$ 11,8 cm of SETUP 1) ➡ Increased MS effect

1.b) E_e = 2 GeV. Start from 25th module

SETUP 1

N_e = 100k
N_e (E_{cal} > 0) = 99978

>99,9% of electrons reach the calorimeter

N_e (E_{cal} > 1 GeV) = 99815

~99,8% of electrons reach the calorimeter with >50% their initial energy

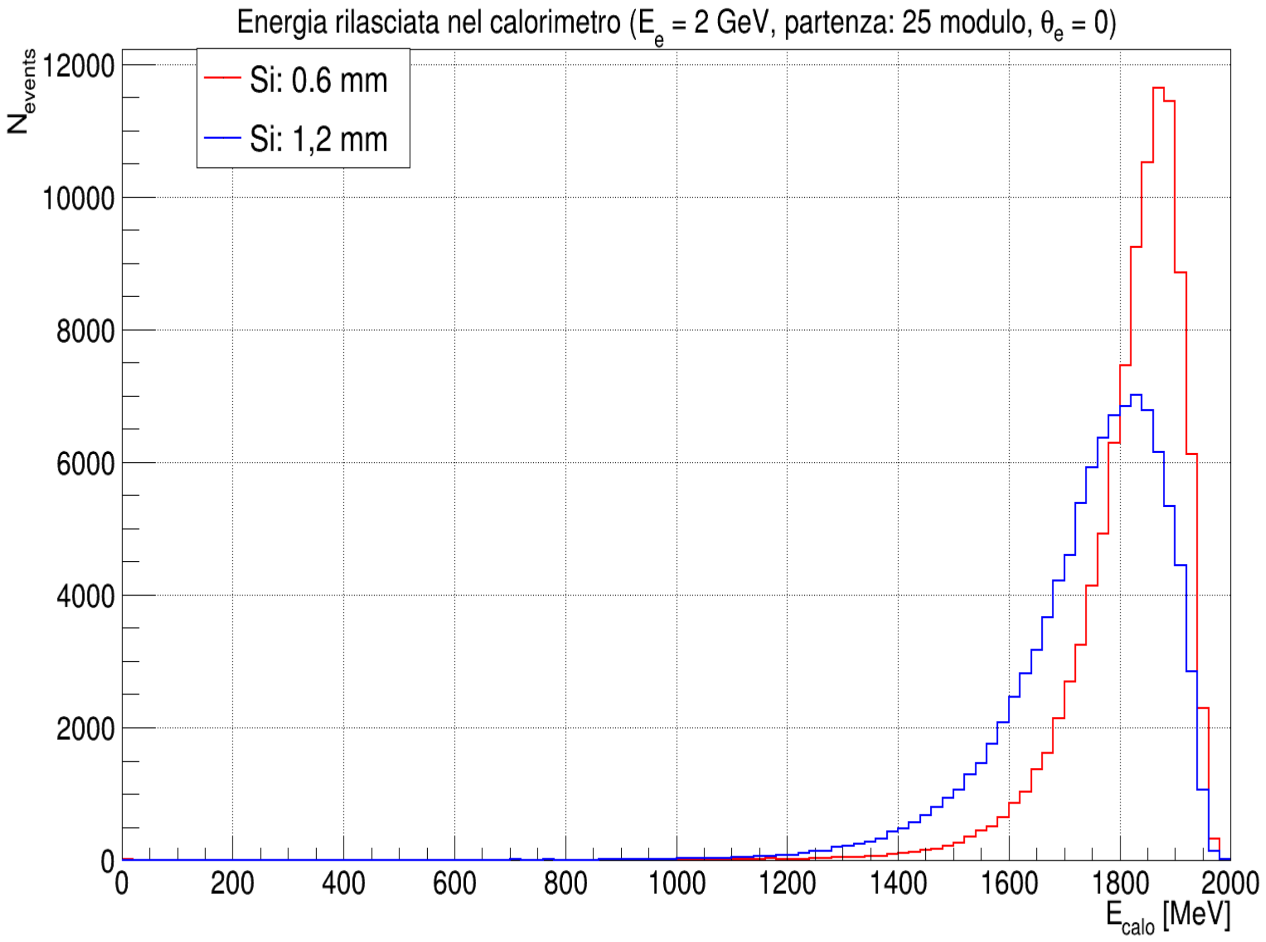
SETUP 2

N_e = 100k
N_e (E_{cal} > 0) = 99982

>99,9% of electrons reach the calorimeter

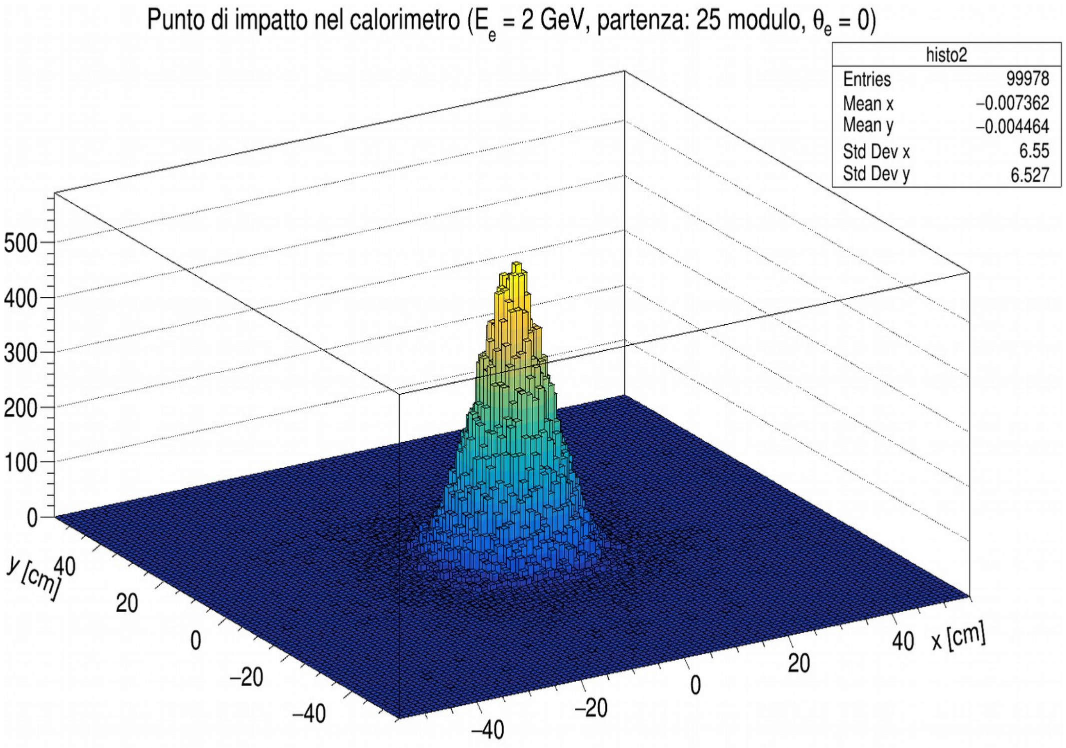
N_e (E_{cal} > 1 GeV) = 99676

~99,7% of electrons reach the calorimeter with >50% of their initial energy

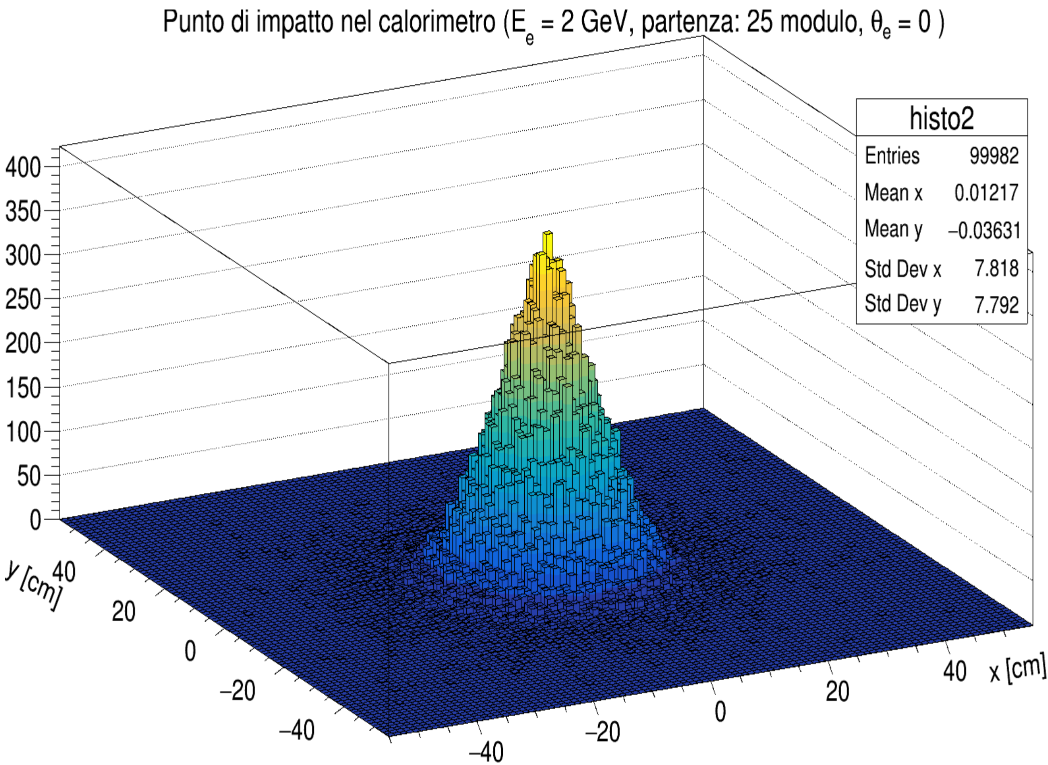


1.b) E_e = 2 GeV. Start from 25th module: Spatial distribution of the hit point on the calorimeter

SETUP 1



SETUP 2



SETUP 2 distribution is slightly wider ($\sigma \approx$ 7,8 cm compared to $\sigma \approx$ 6,5 cm of SETUP 1) ➡ Increased MS effect

1.c) E_e = 10 GeV. Start from 25th module

SETUP 1

N_e = 20k
N_e (E_{cal}> 0) = 20k

All the electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 19999

>99,9% of electrons reach the calorimeter with E > 1 GeV

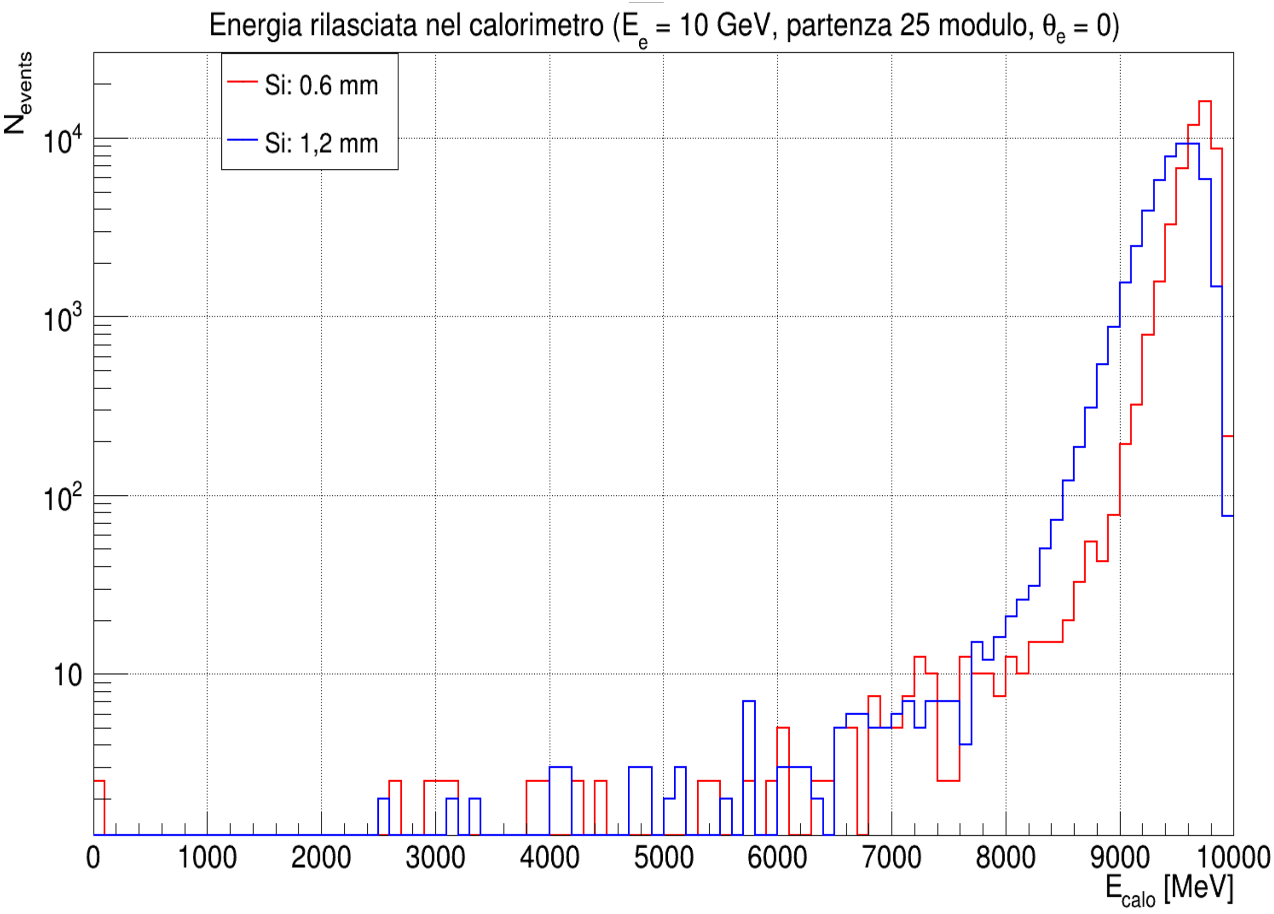
SETUP 2

N_e = 50k
N_e (E_{cal}> 0) = 49998

>99,9% of electrons reach the calorimeter

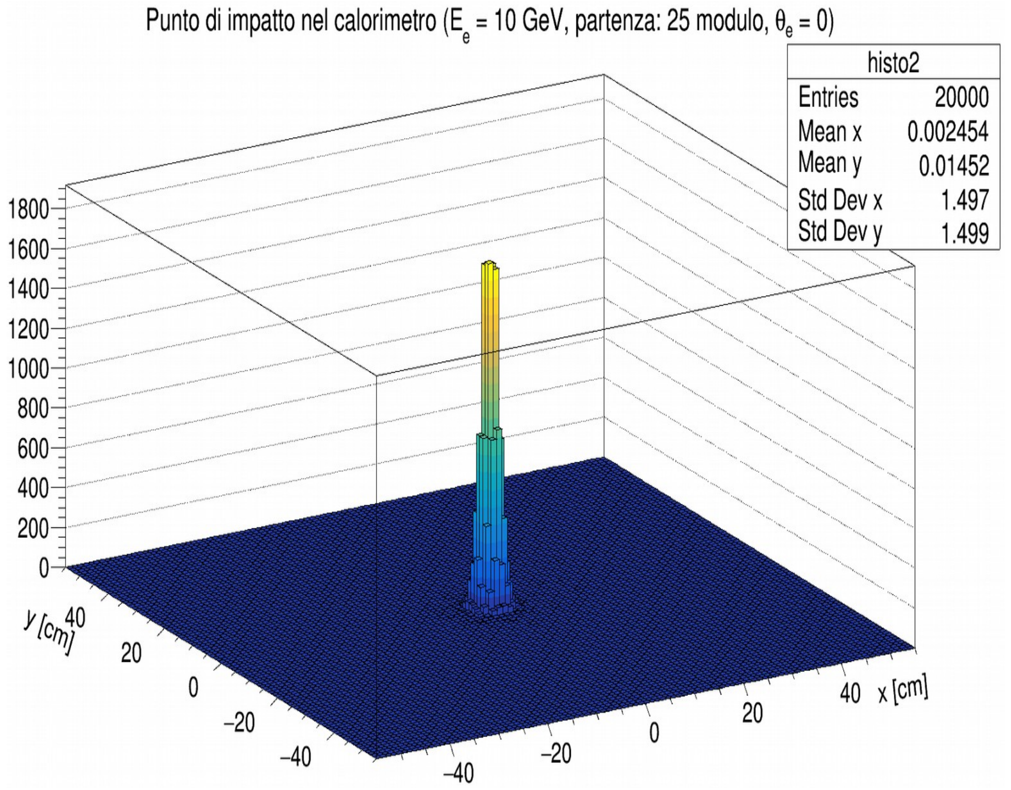
N_e (E_{cal}> 1 GeV) = 49997

>99,9% of electrons reach the calorimeter with E > 1 GeV

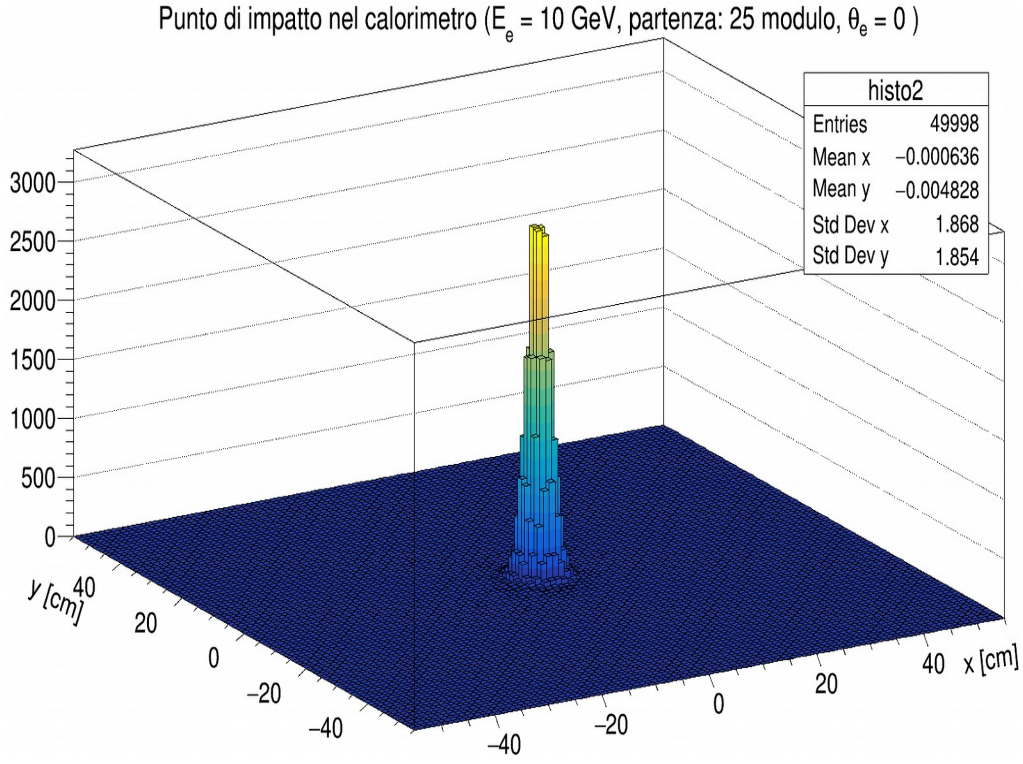


1.c) E_e = 10 GeV. Start from 25th module: Spatial distribution of the hit point on the calorimeter

SETUP 1



SETUP 2



SETUP 2 distribution is slightly wider ($\sigma \approx 1{,}8$ cm compared to $\sigma \approx 1{,}4$ cm of SETUP 1) ➡ Increased MS effect

STEP 2: E_e = 1, 2, 10 GeV, $\theta_e = \theta_e(E_e)$ $\varphi_e = 0$.

2.a) E_e = 1 GeV, θ_e = 31,85 mrad.

Start from 1st module

SETUP 1

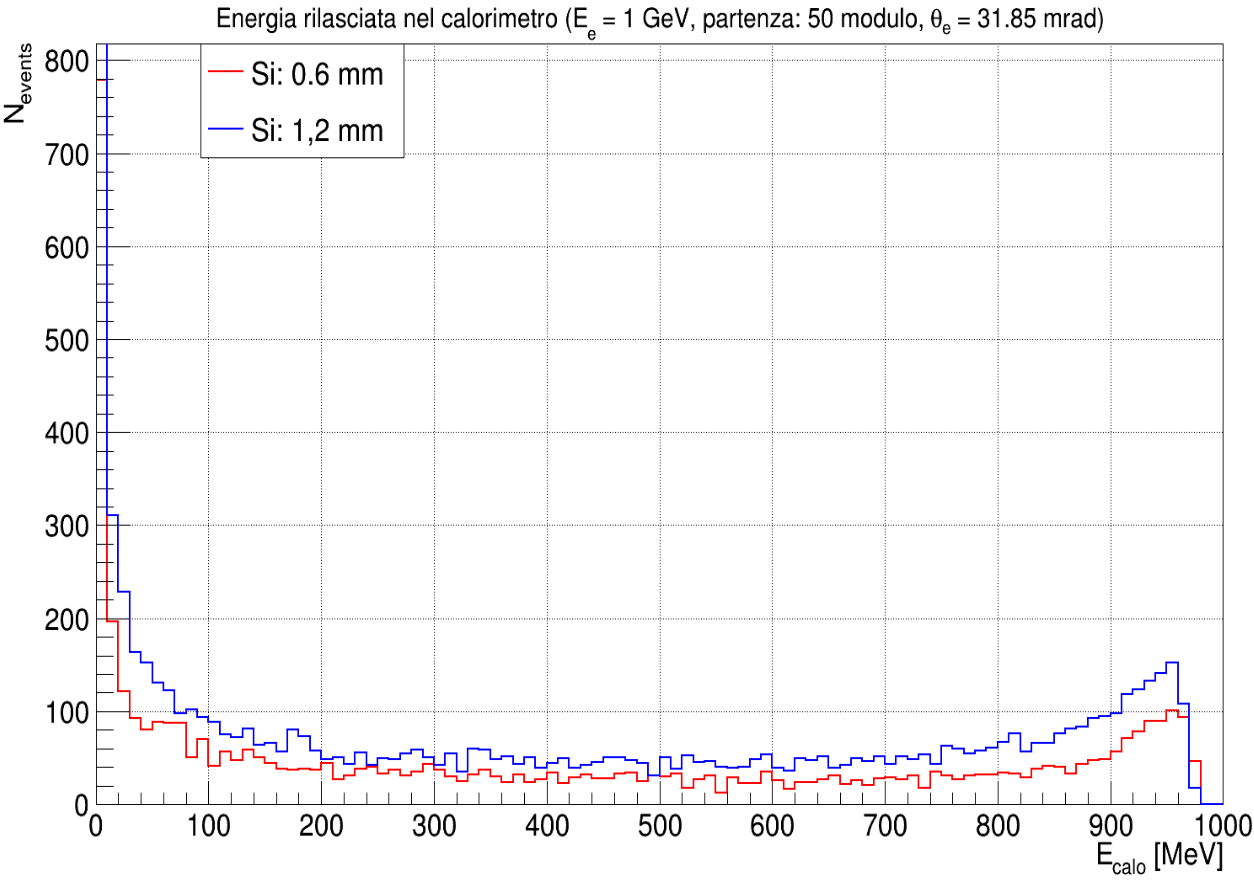
N_e = 100k
N_e (E_{cal}> 0) = 4872 → 4,8% of electrons reach the calorimeter

N_e (E_{cal}> 500 MeV) = 1813 → 1,8% of electrons reach the calorimeter with >50% their initial energy

SETUP 2

N_e = 100k
N_e (E_{cal}> 0) = 7974 → ~8% of electrons reach the calorimeter

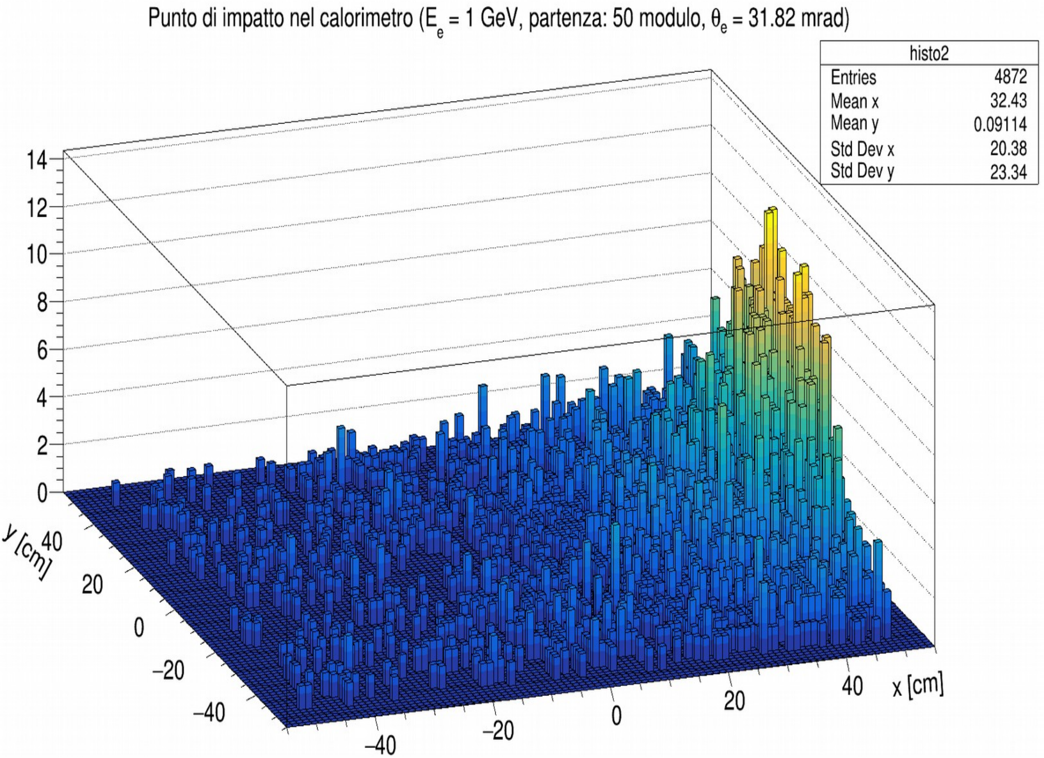
N_e (E_{cal}> 500 MeV) = 3093 → ~3,1% of electrons reach the calorimeter with >50% of their initial energy



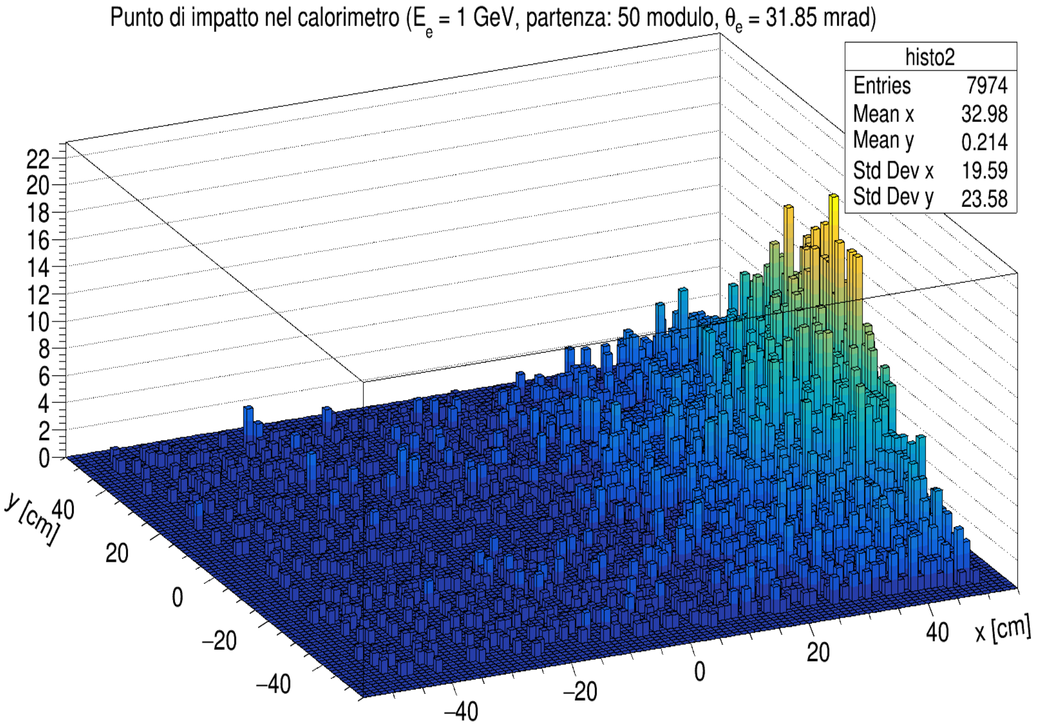
2.a) E_e = 1 GeV, θ_e = 31,85 mrad. Start from 1st module

- After 26 m $x_c \approx$ 80 cm → Out of calorimeter

SETUP 1

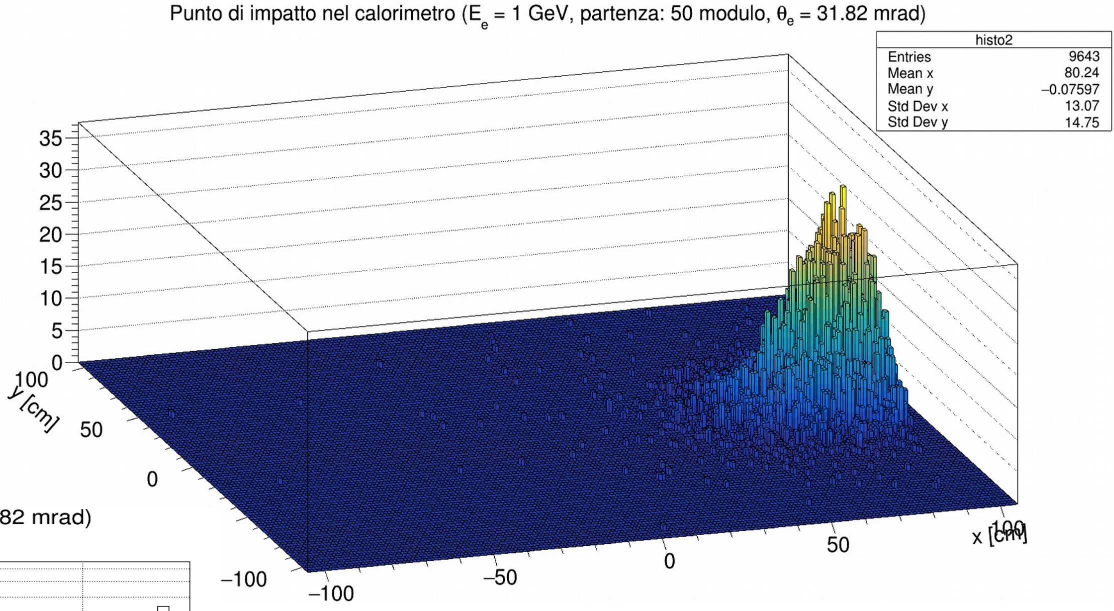


SETUP 2

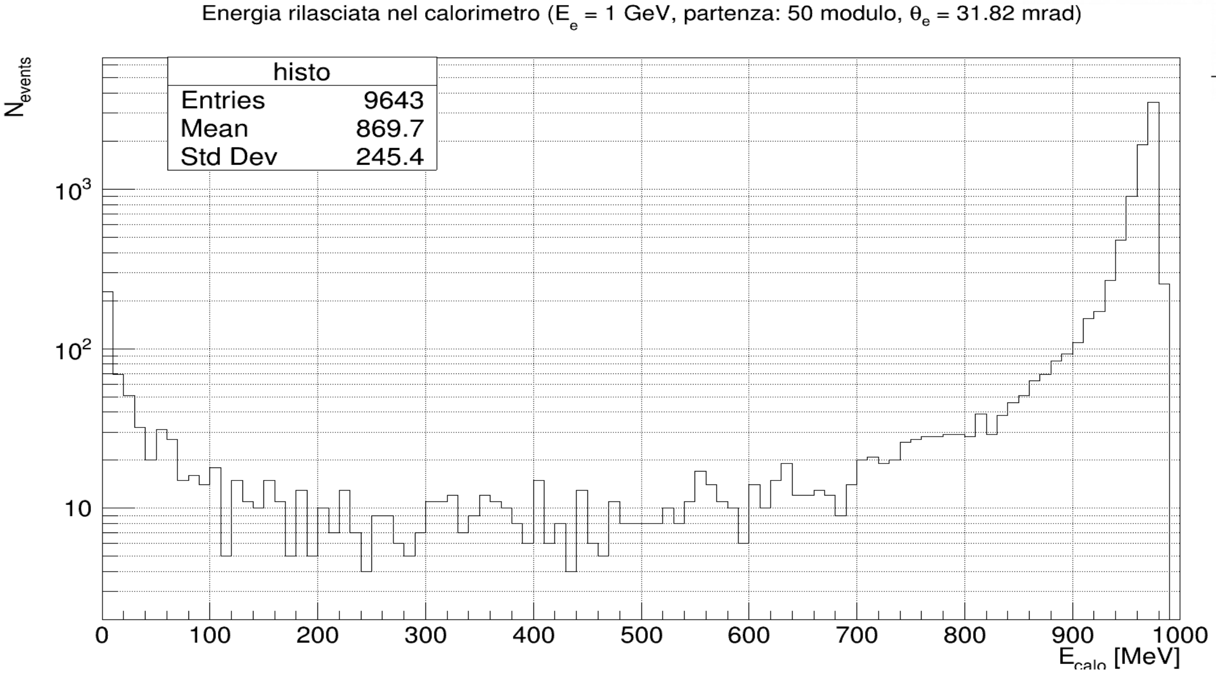


SETUP 2 has more statistics compared to SETUP 1
due to increased MS effect

2.a.1) E_e = 1 GeV, θ_e = 31,82 mrad



With a 2 m x 2 m calorimeter



N_e = 10k

N_e (E_{cal}> 0) = 9643

- 96,4% of events reach the calorimeter

2.b) E_e = 2 GeV, θ_e = 22,44 mrad. Start from 1st module

SETUP 1

N_e = 100k
N_e (E_{cal}> 0) = 26422

26,4% of electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 13609

13,6% of electrons reach the calorimeter with >50% their initial energy

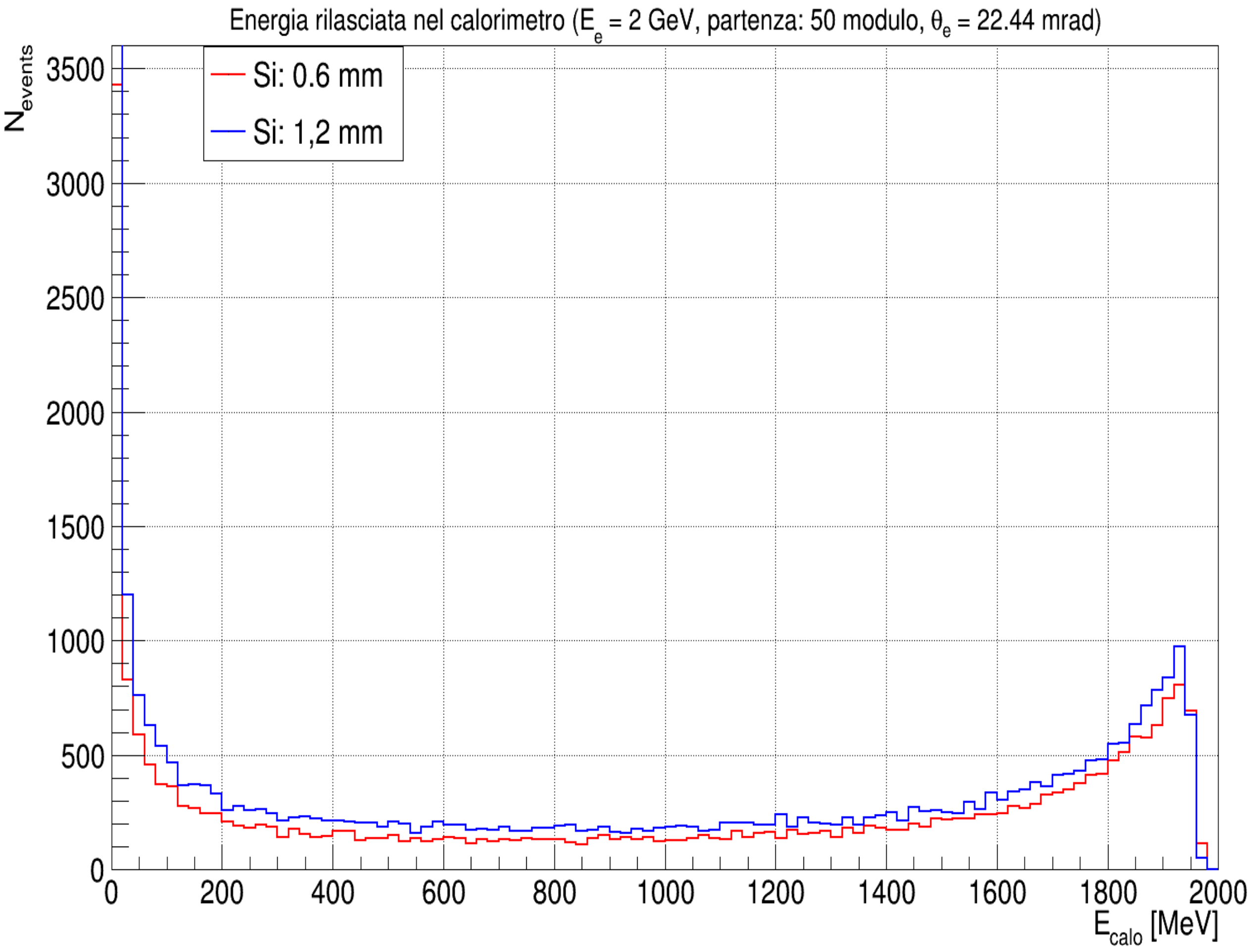
SETUP 2

N_e = 100k
N_e (E_{cal}> 0) = 34121

34,1% of electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 16411

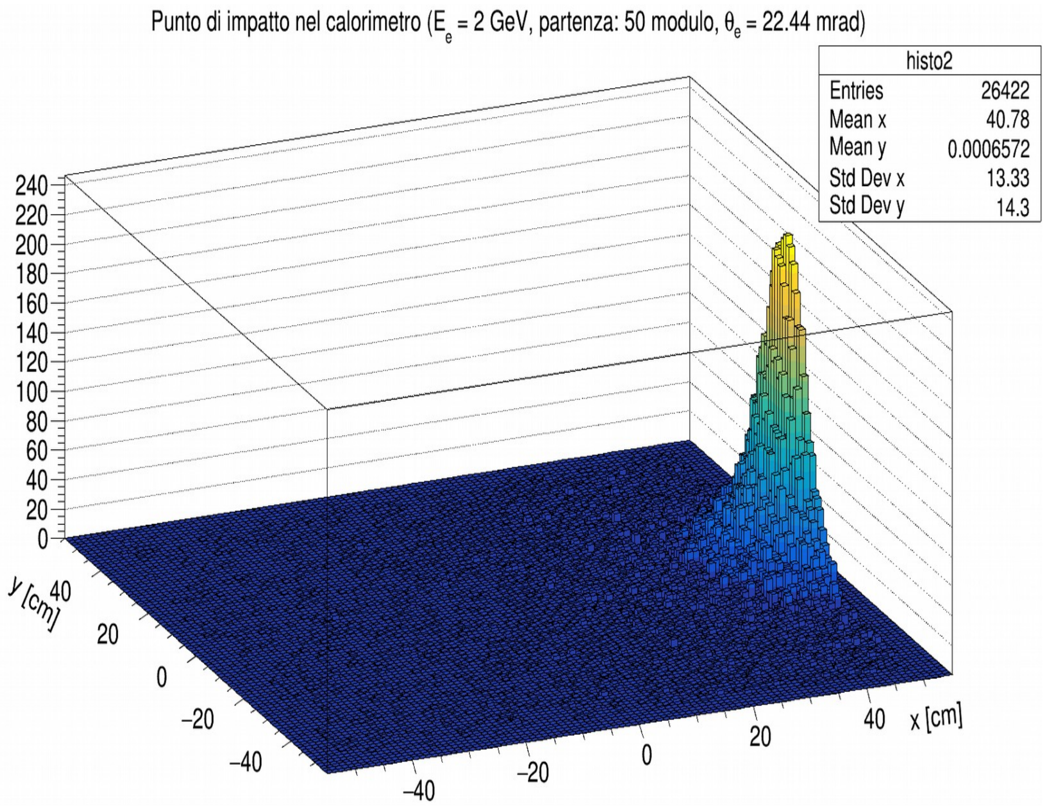
16,4% of electrons reach the calorimeter with >50% of their initial energy



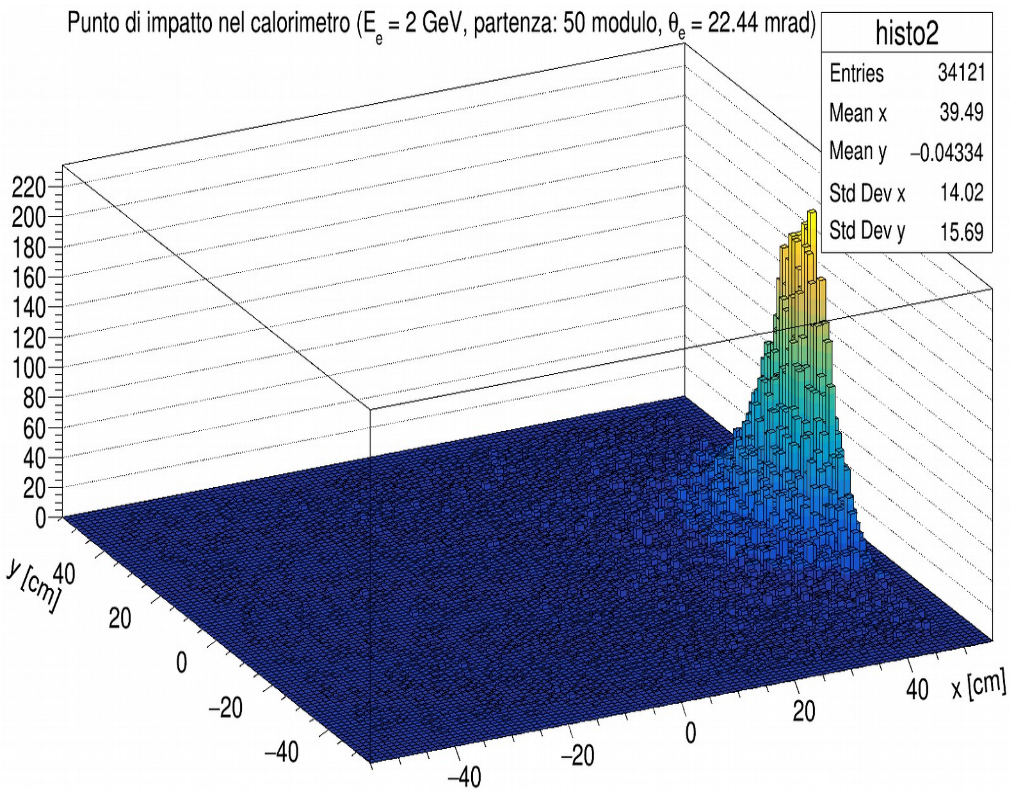
2.b) E_e = 2 GeV, θ_e = 22,44 mrad. Start from 1st module

→ After 26 m $x_c \approx 58$ cm → Out of calorimeter

SETUP 1

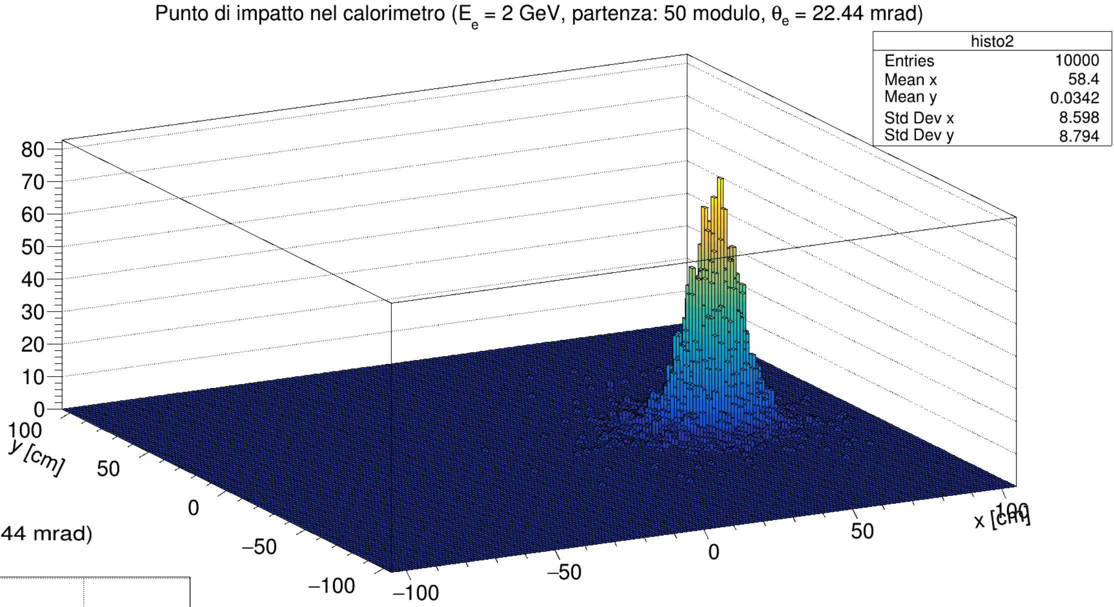


SETUP 2

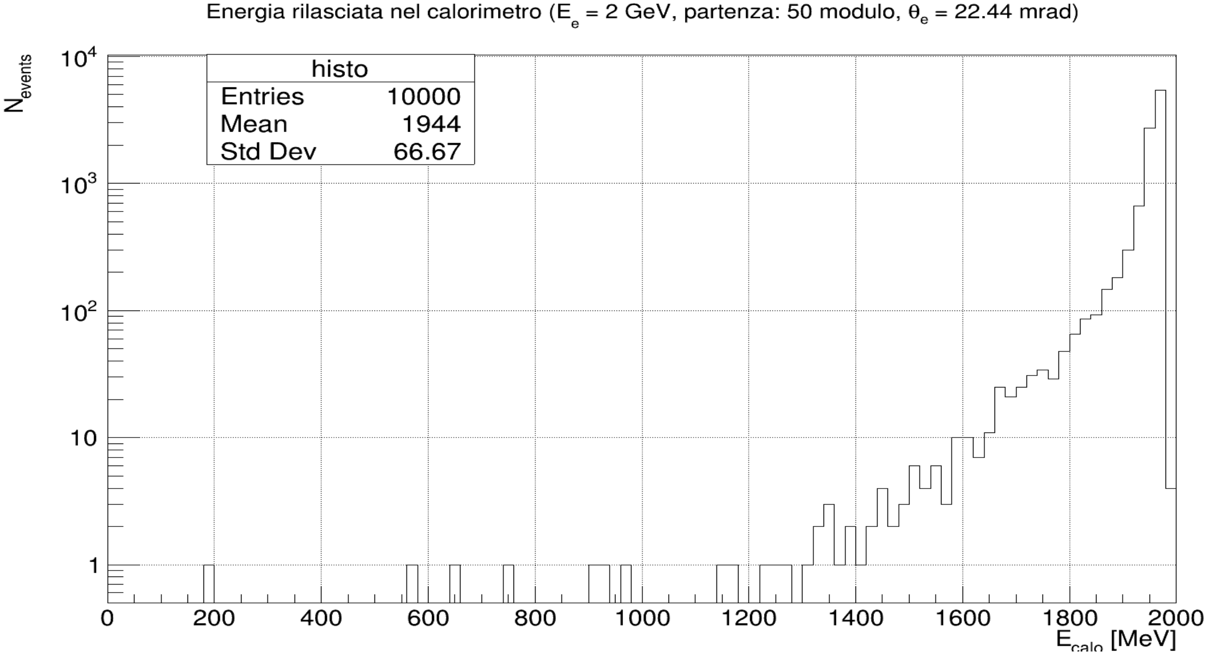


SETUP 2 has more statistics (34,1%) compared to SETUP 1 (26,4%) due to increased MS effect

2.b.1) E_e = 2 GeV, θ_e = 22,44 mrad



With a 2 m x 2 m calorimeter



N_e = 10k

N_e (E_{cal}> 0) = 10k

2.c) E_e = 10 GeV, θ_e = 9,74 mrad. Start from 1st module

SETUP 1

N_e = 20k
N_e (E_{cal}> 0) = 20k

All the electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 19999

>99,9% of electrons reach the calorimeter with E > 1 GeV

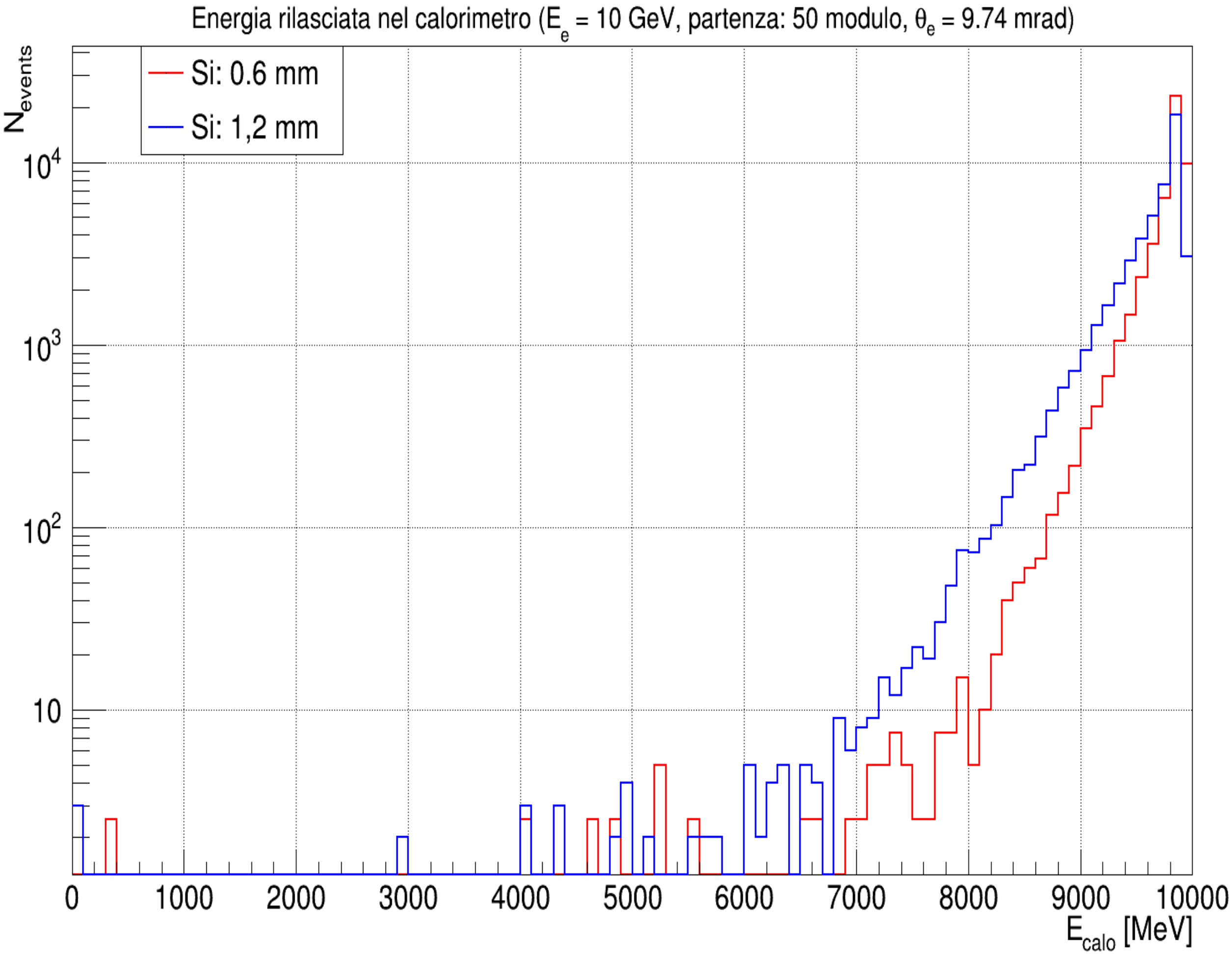
SETUP 2

N_e = 50k
N_e (E_{cal}> 0) = 49999

>99,9% of electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 49996

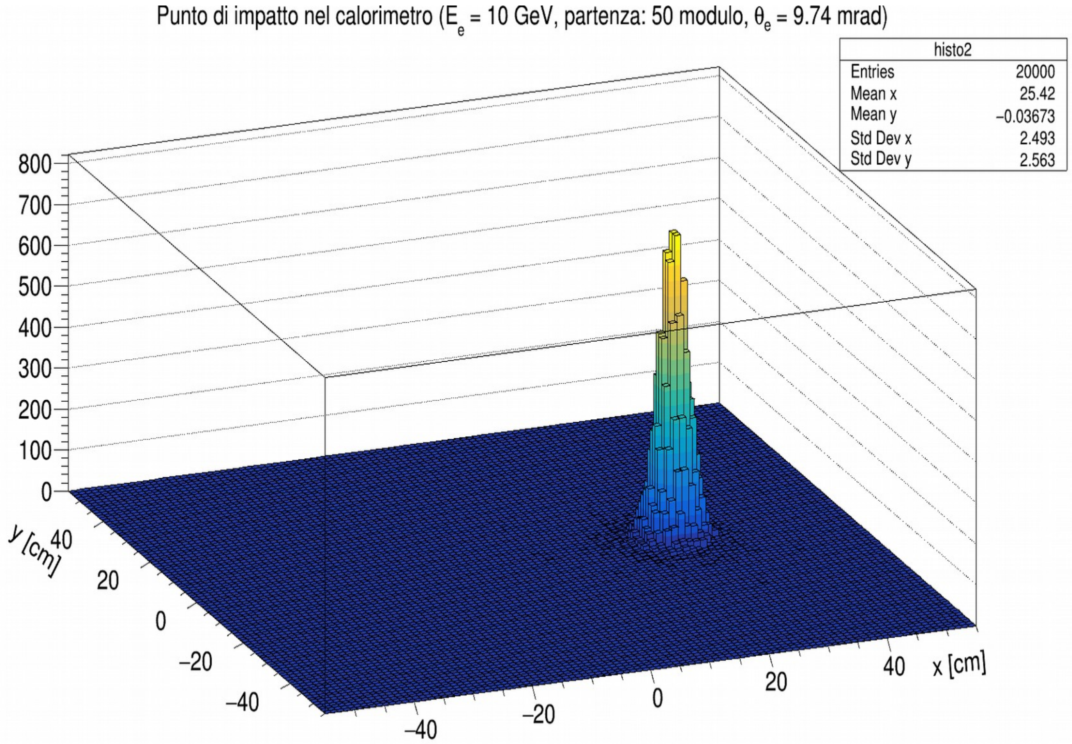
>99,9% of electrons reach the calorimeter with E > 1 GeV



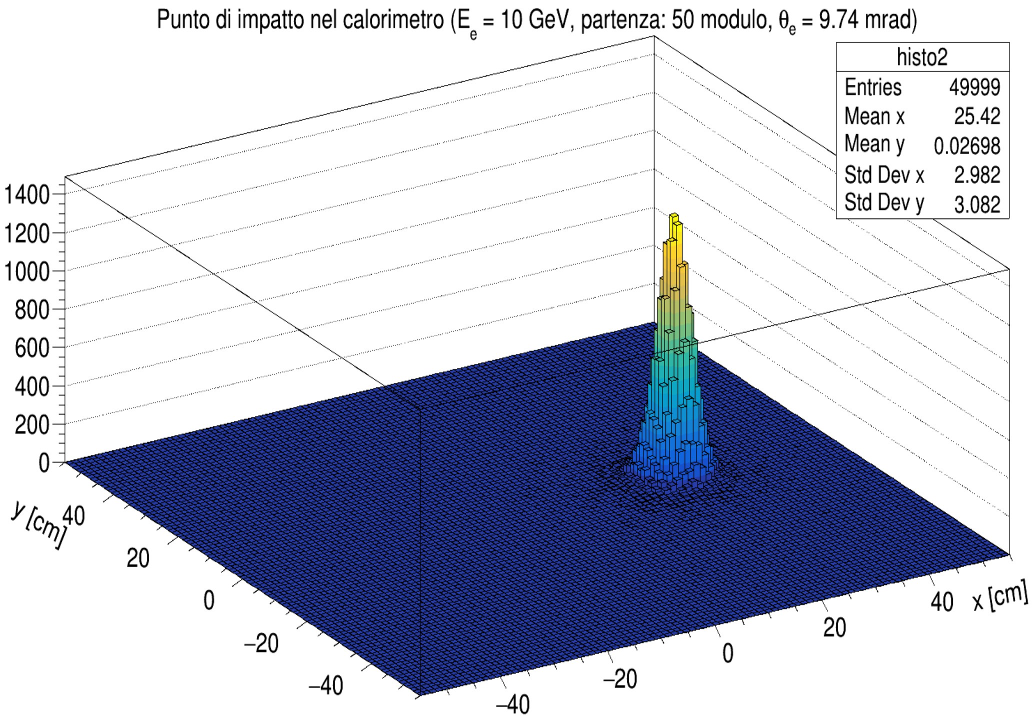
2.c) E_e = 10 GeV, θ_e = 9,74 mrad. Start from 1st module

→ After 26 m $x_c \approx$ 25 cm ⟶ Hits the calorimeter

SETUP 1



SETUP 2



No substantial differences between two setups

SETUP 2 distribution is slightly wider compared to SETUP 1

2.a) E_e = 1 GeV, θ_e = 31,85 mrad. Start from 25th module

SETUP 1

N_e = 100k
N_e (E_{cal}> 0) = 94211

94,2% of electrons reach the calorimeter

N_e (E_{cal}> 500 MeV) = 82708

82,7% of electrons reach the calorimeter with >50% their initial energy

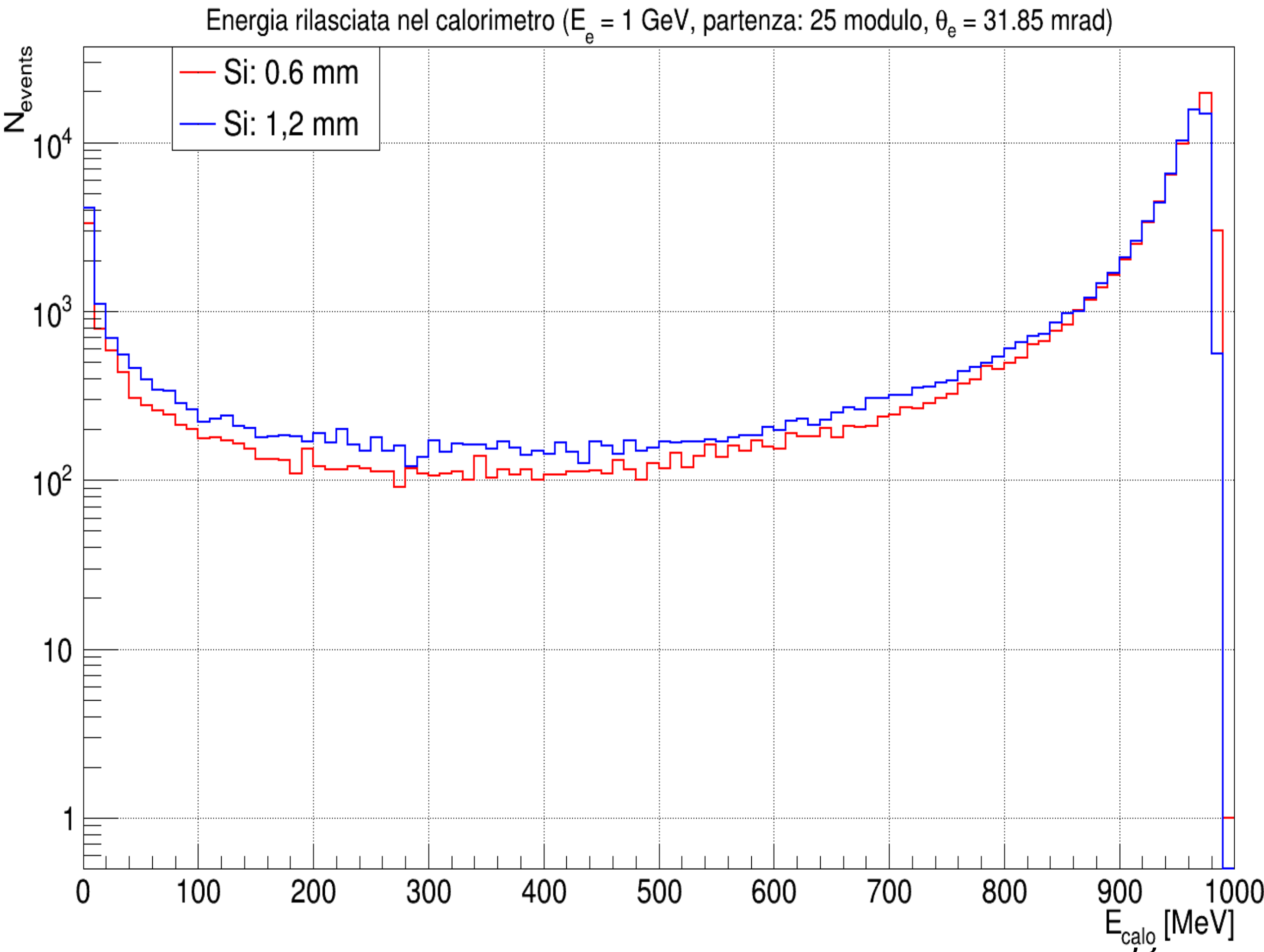
SETUP 2

N_e = 100k
N_e (E_{cal}> 0) = 93636

93,6% of electrons reach the calorimeter

N_e (E_{cal}> 500 MeV) = 78395

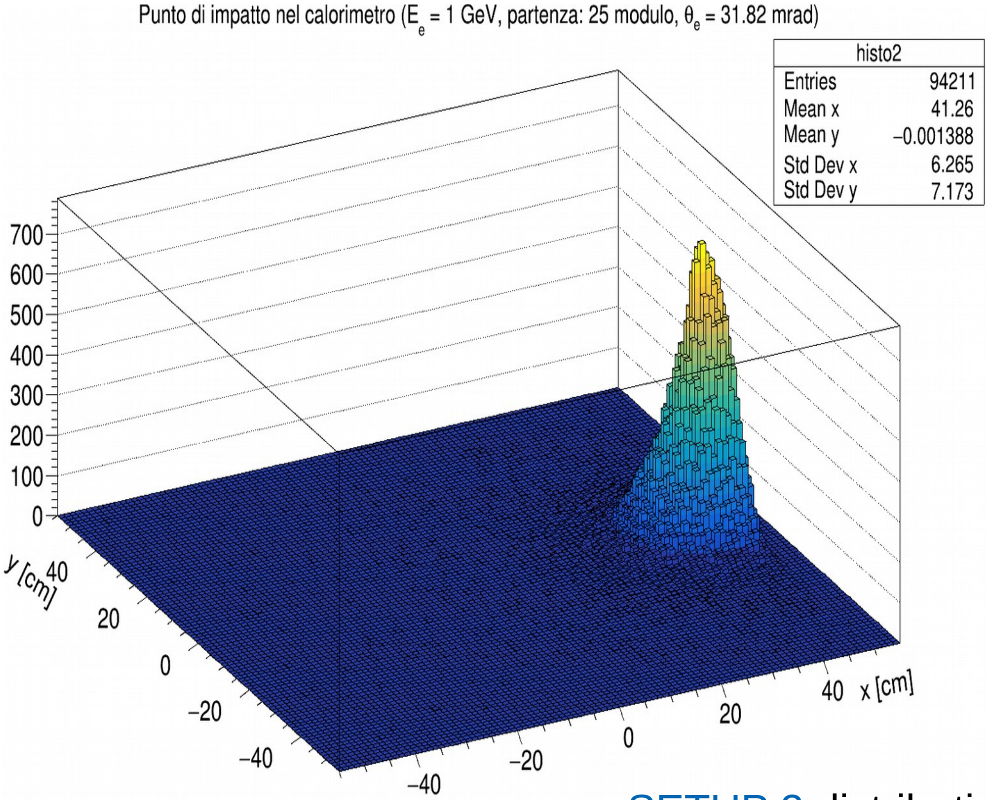
78,4% of electrons reach the calorimeter with >50% of their initial energy



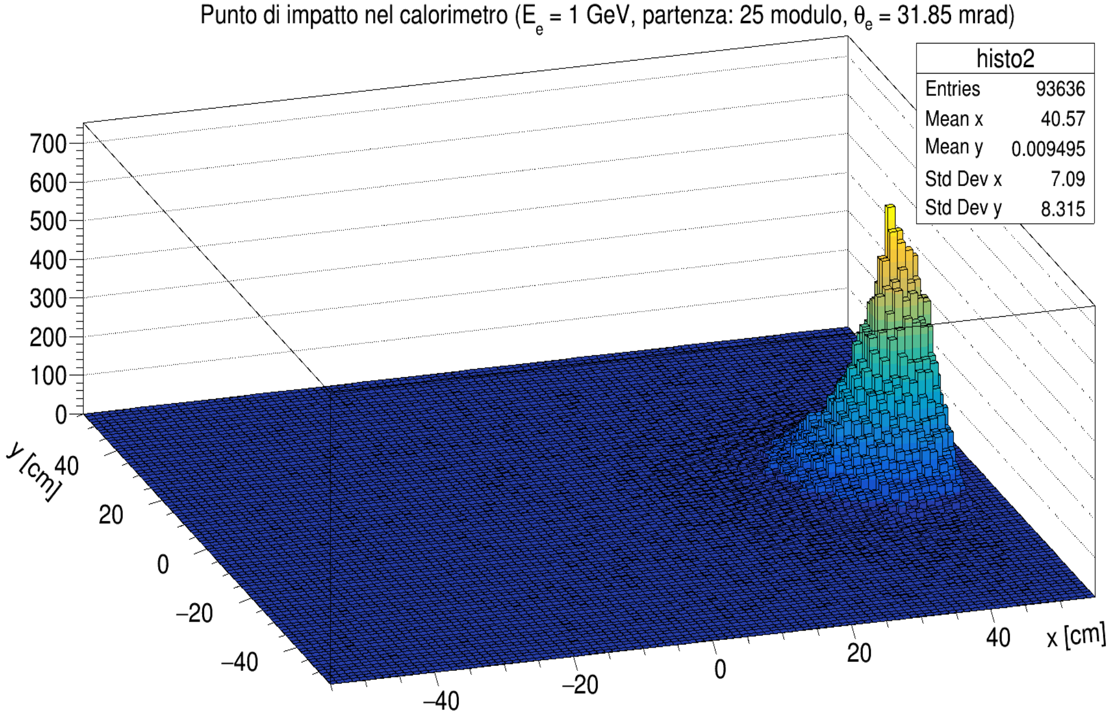
2.a) E_e = 1 GeV, θ_e = 31,85 mrad. Start from 25th module

- After 13,5 m $x_c \approx$ 43 cm → Hits the calorimeter

SETUP 1



SETUP 2



SETUP 2 distribution is slightly wider ($\sigma_x \approx$ 7,1 cm compared to $\sigma_x \approx$ 6,2 cm of SETUP 1)

2.b) E_e = 2 GeV, θ_e = 22,44 mrad. Start from 25th module

SETUP 1

N_e = 100k

N_e (E_{cal}> 0) = 99952

>99,9% of electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 99844

99,8% of electrons reach the calorimeter with >50% their initial energy

SETUP 2

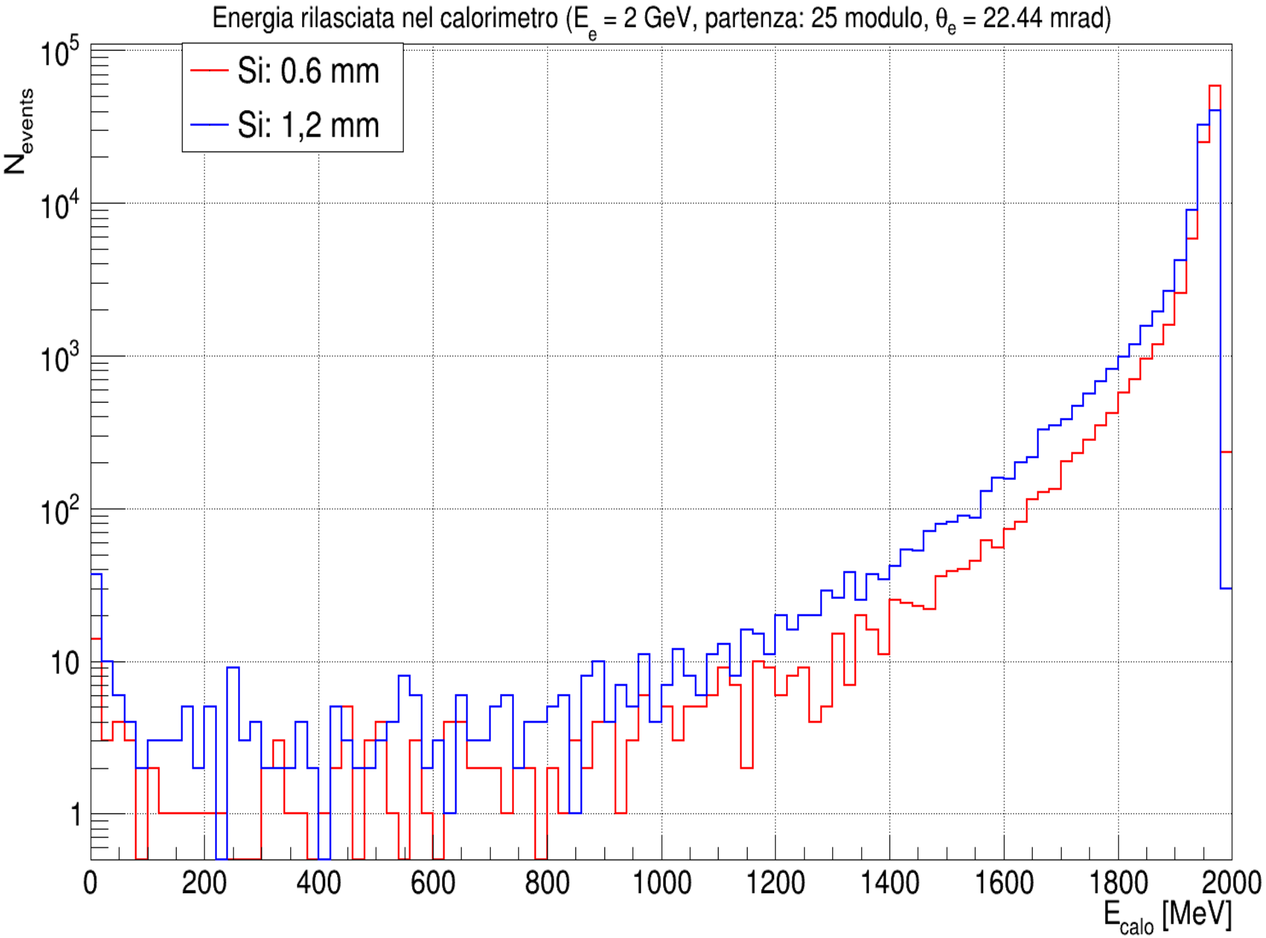
N_e = 100k

N_e (E_{cal}> 0) = 99948

>99,9% of electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 99707

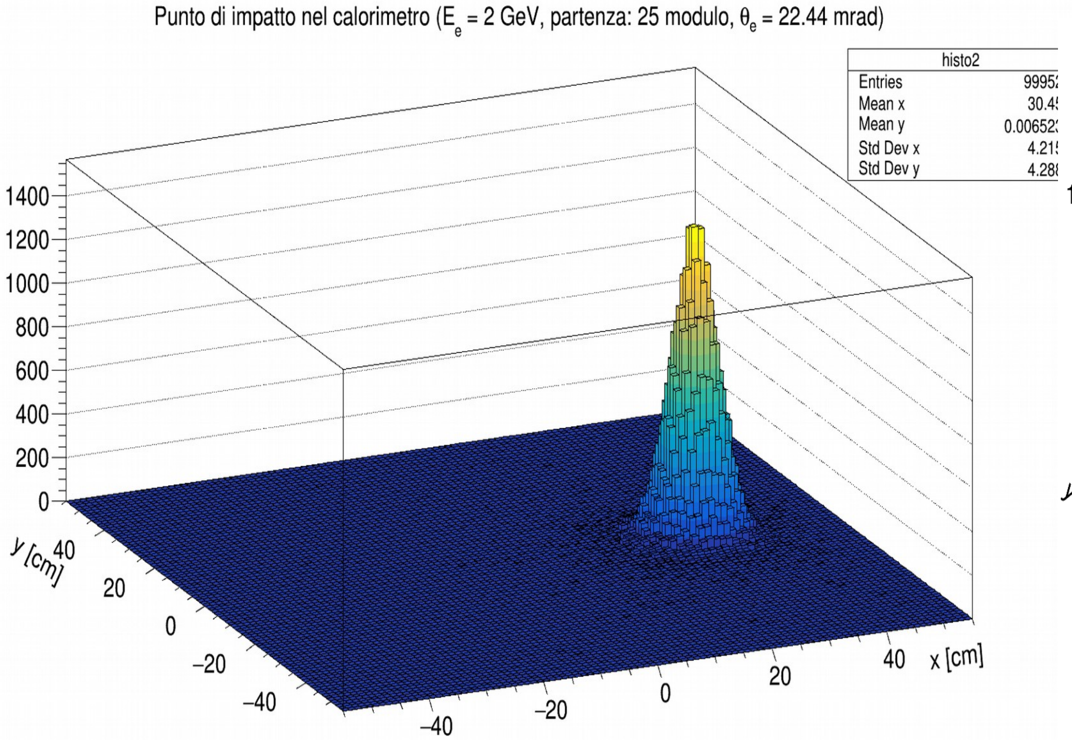
99,7% of electrons reach the calorimeter with >50% of their initial energy



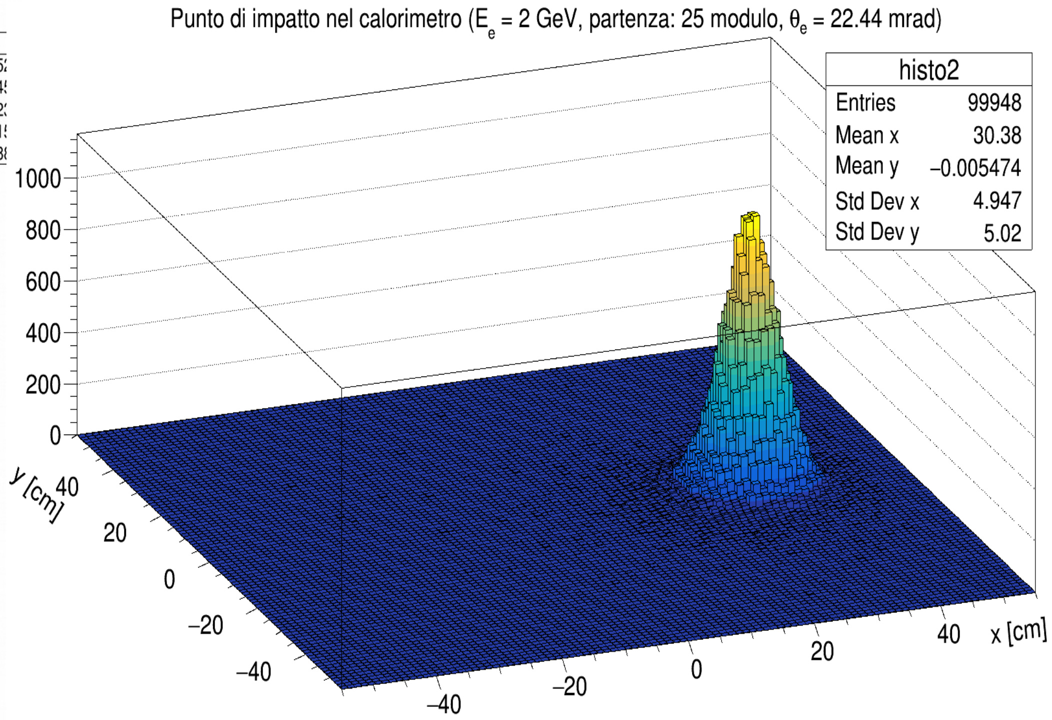
2.b) E_e = 2 GeV, θ_e = 22,44 mrad. Start from 25th module

→ After 13,5 m $x_c \approx$ 30 cm ⟹ Hits the calorimeter

SETUP 1



SETUP 2



No substantial differences between two setups

2.c) E_e = 10 GeV, θ_e = 9,74 mrad. Start from 25th module

SETUP 1

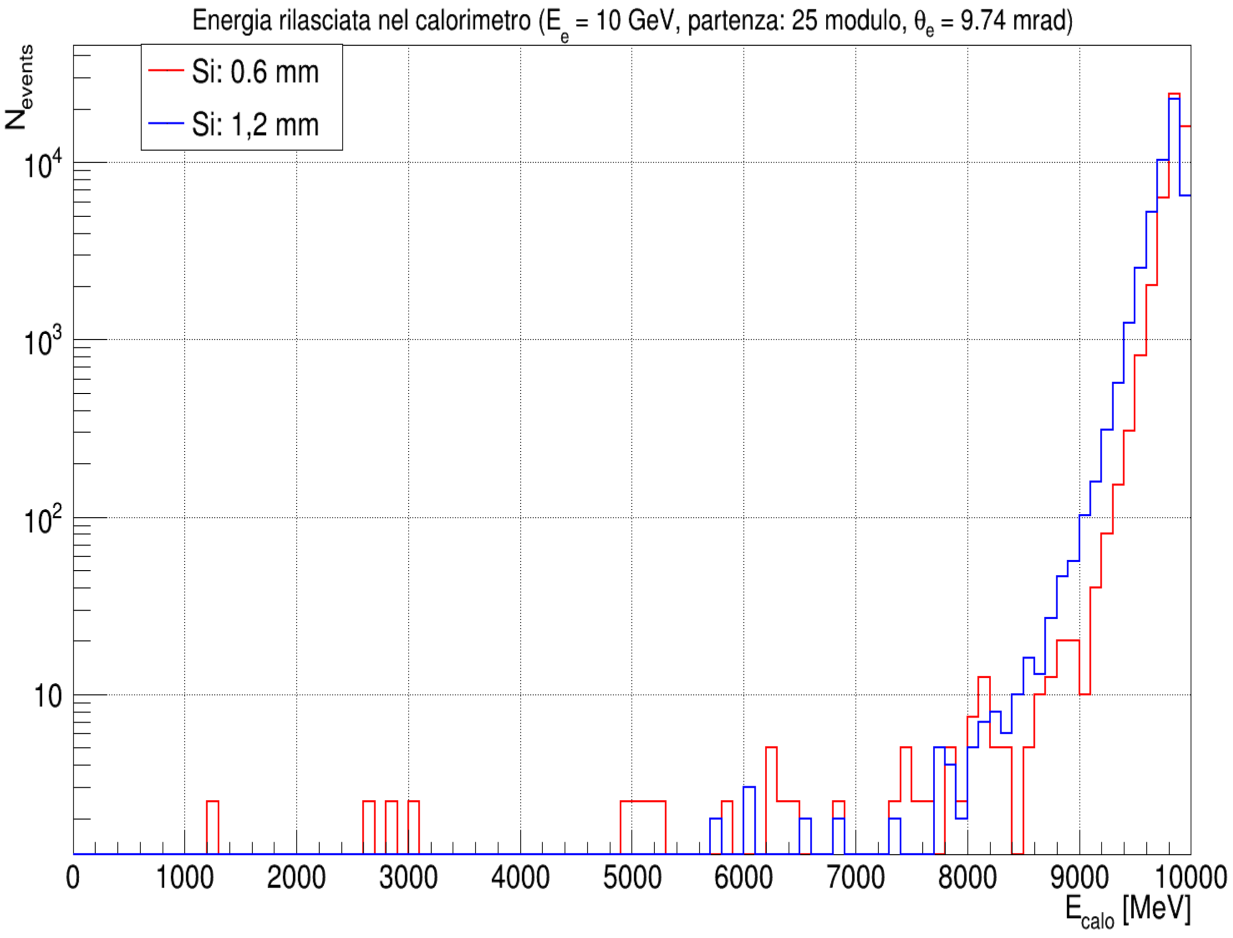
N_e = 20k
N_e (E_{cal}> 0) = 20k → All the electrons reach the calorimeter

N_e (E_{cal}> 1 GeV) = 20k → All the electrons reach the calorimeter with E > 1 GeV

SETUP 2

N_e = 50k
N_e (E_{cal}> 0) = 50k → All the electrons reach the calorimeter

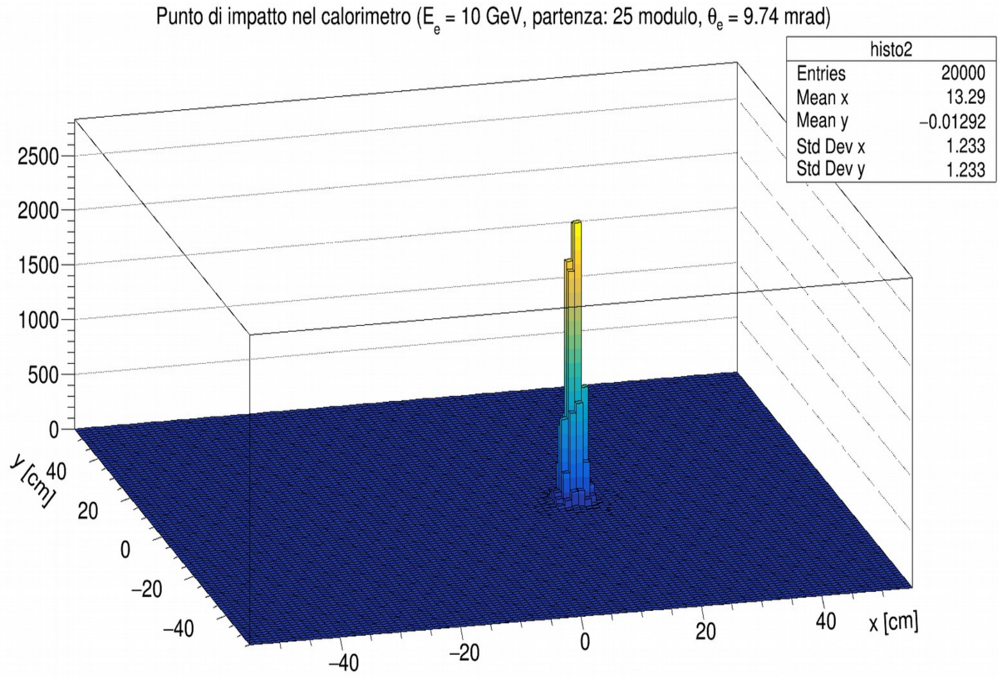
N_e (E_{cal}> 1 GeV) = 49999 → >99,9% of electrons reach the calorimeter with E > 1 GeV



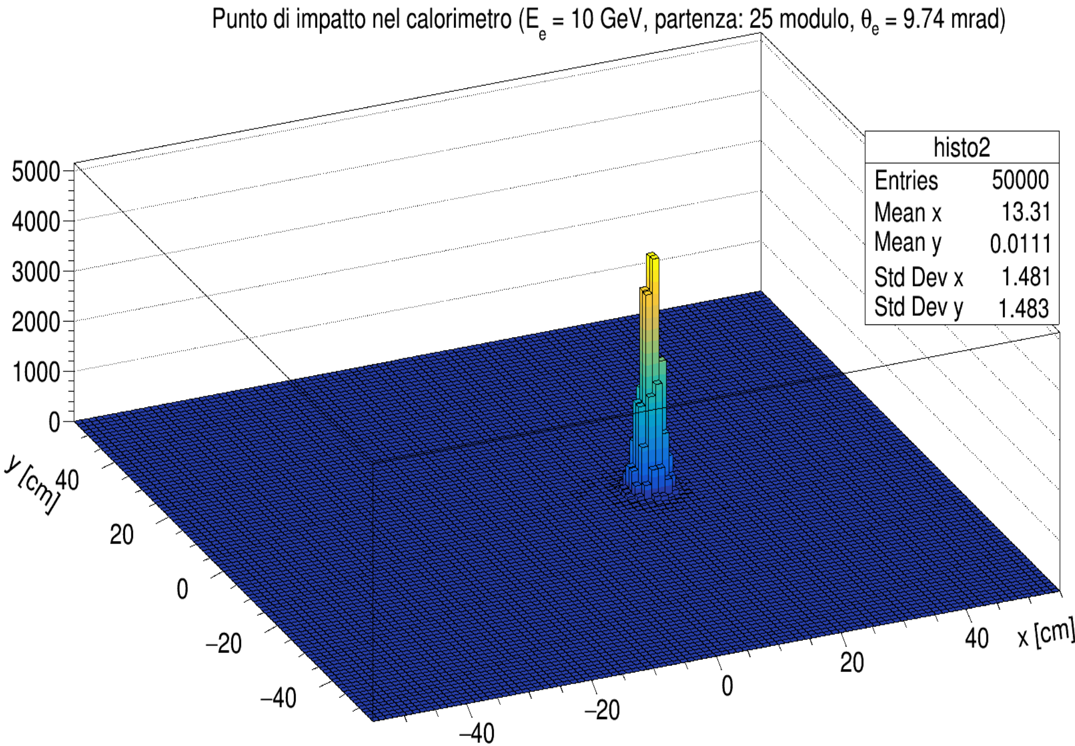
2.c) E_e = 10 GeV, θ_e = 9,74 mrad. Start from 25th module

➔ After 13,5 m $x_c \approx$ 13 cm ➡ Hits the calorimeter

SETUP 1



SETUP 2



SETUP 2 distribution is slightly wider ($\sigma_x \approx$ 1,48 cm compared to $\sigma_x \approx$ 1,23 cm of SETUP 1)

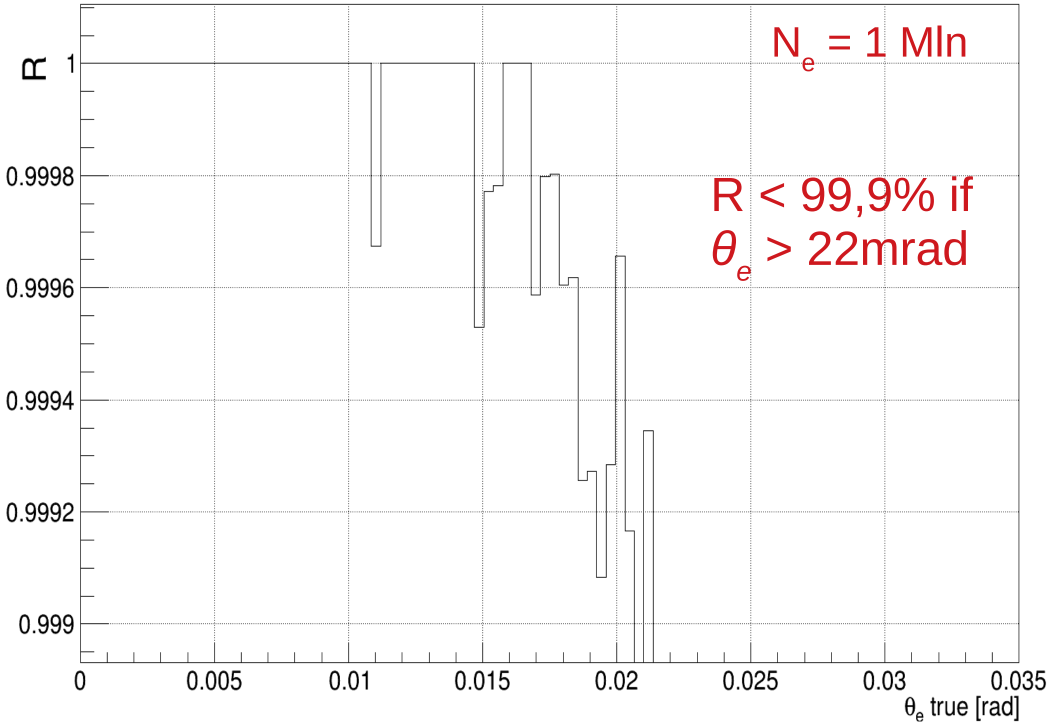
STEP 3: θ_e [0, 35 mrad] generated according to LO distribution.

φ_e generated uniformly between [0, 2π], $E_e = E_e(\theta_e)$

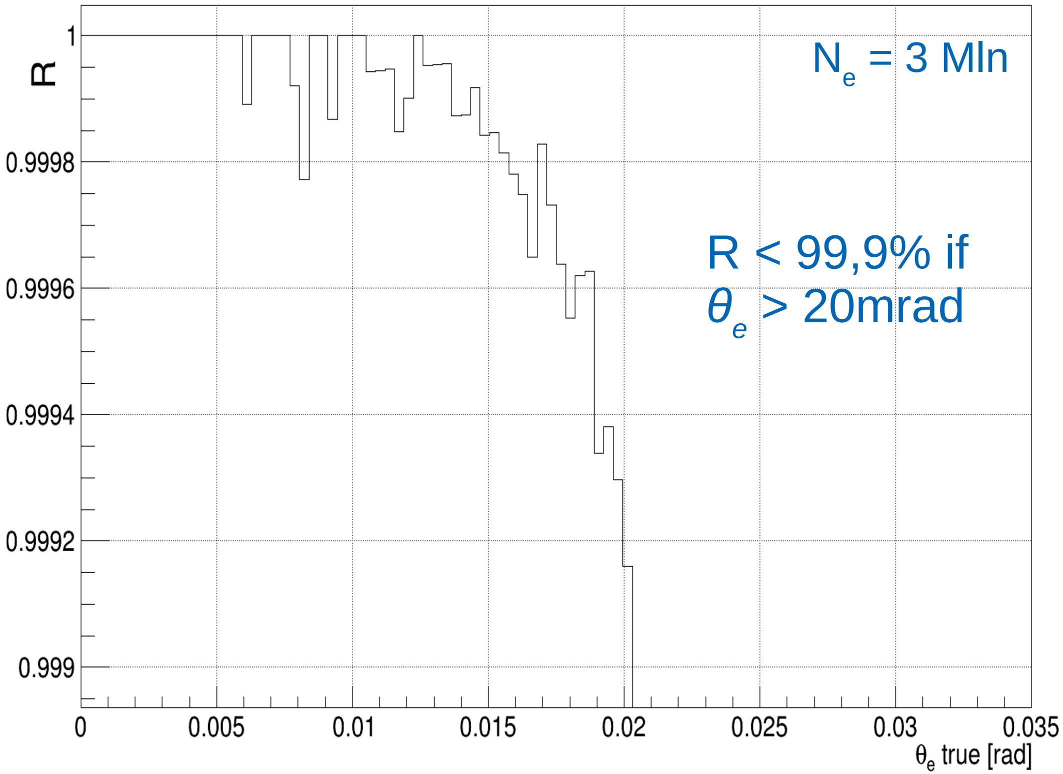
e^- start from 25th module

$$R = \frac{N_e(E_{cal} > 1GeV)}{N_e}$$

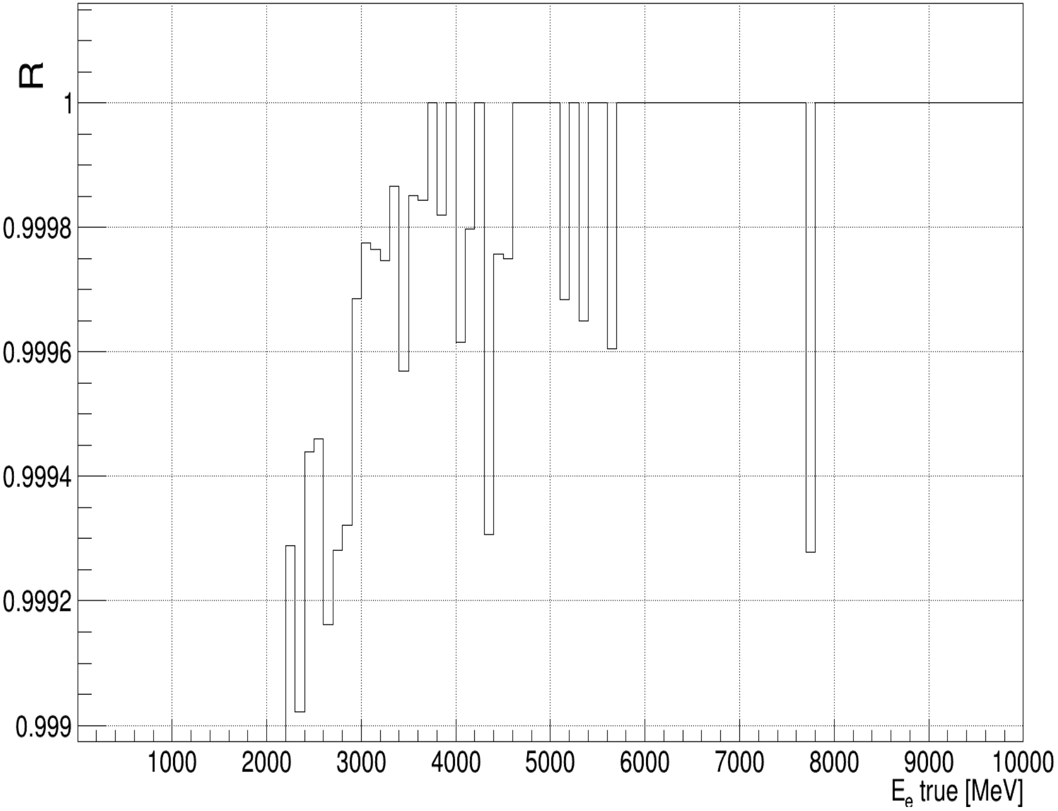
SETUP 1



SETUP 2



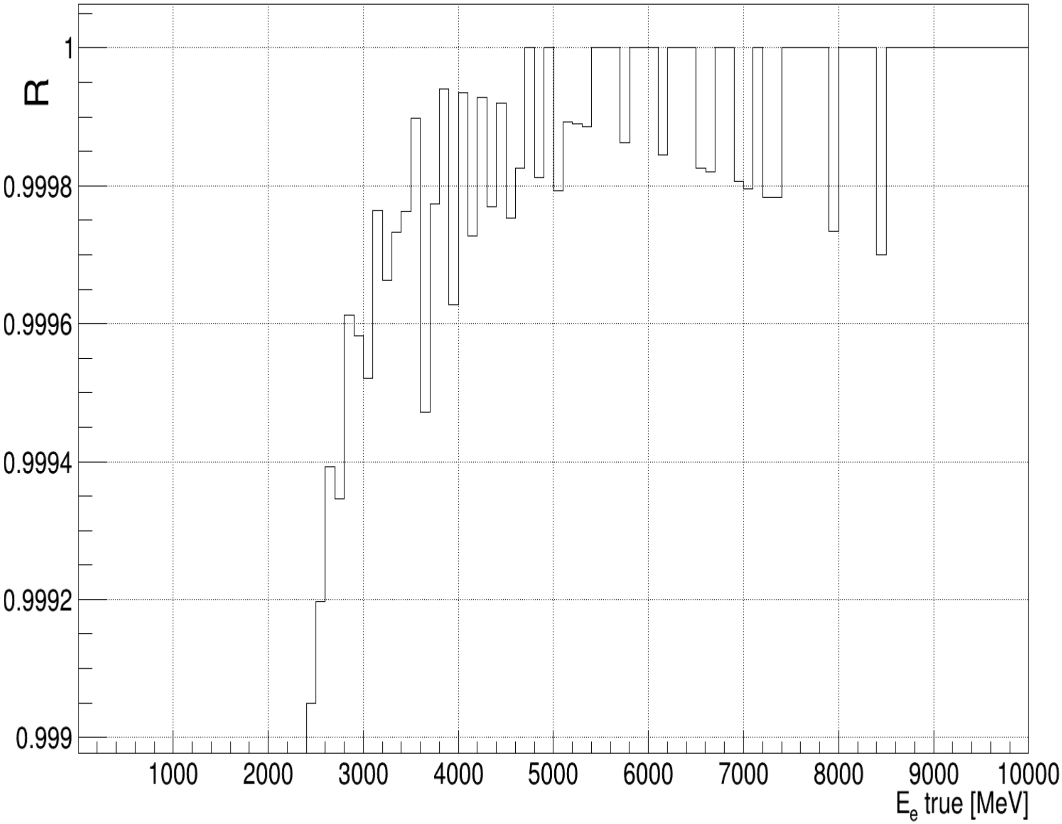
SETUP 1



N_e = 1 Mln

R < 99,9% when E_e < 2,2 GeV

SETUP 2



N_e = 3 Mln

R < 99,9% when E_e < 2,4 GeV

Further developments

- Add scattered muon to the primary vertex
- Measure (using a virtual detector) distance between em shower and muon, in order to determine the calorimeter granularity
- Modify calorimeter setup: from a unique block to a segmeted calorimeter
- Study of energy deposit of e/mu at ~2,5 mrad for PID
- Study the efficiency of the energy cut as a function of the module position
- Use all the information (=likelihood function) to improve energy determination

Conclusions

- Results from STEP 1 ($\theta_e = 0$) show that using SETUP 2 does not change statistics (same amount of electrons hits the calorimeter compared to SETUP 1). However in SETUP 2 energy spectra and spatial distributions are wider than SETUP 1, mainly because of increased MS effects introduced by doubling Si layer thickness. Moreover in SETUP 2 the mean value of calorimeter energy deposit of electrons is lower than SETUP 1, because electrons lose more energy in Si layers.

- Results from STEP 2 ($\theta_e = \theta_e(E_e)$) show that using SETUP 2 increases statistics of electrons with E = 1 – 2 GeV generated at the 1st module by few percent compared to SETUP 1, mainly due to MS which is increased. Energy spectra and spatial distributions are slightly wider than SETUP 1, but this effect is less prononunced with respect to STEP 1, because in STEP 2 electrons are generated with $\theta_e \neq 0$. This means that electrons after few modules don't hit Si layers anymore, so after few modules they are no more subjected to MS.

- A 2 m x 2 m calorimeter is necessary in order to reconstruct the electron energy in range of 1 - 2 GeV when this electrons start from the first module..

- Results from STEP 3 (θe random, $E_e = E_e(\theta_e)$) show that for SETUP 1 applying an energy cut of $E_{cal} > 1$ GeV allows to use the calorimetric measure of the electron energy for 99,9% (or higher) of the events with $E_e > 2{,}2$ GeV ($\theta_e < 22$mrad). For SETUP 2 the same percentage is obtained with $E_e > 2{,}4$ GeV ($\theta_e <$ 20mrad).