Energy Measurement with Compton Backscattering: update

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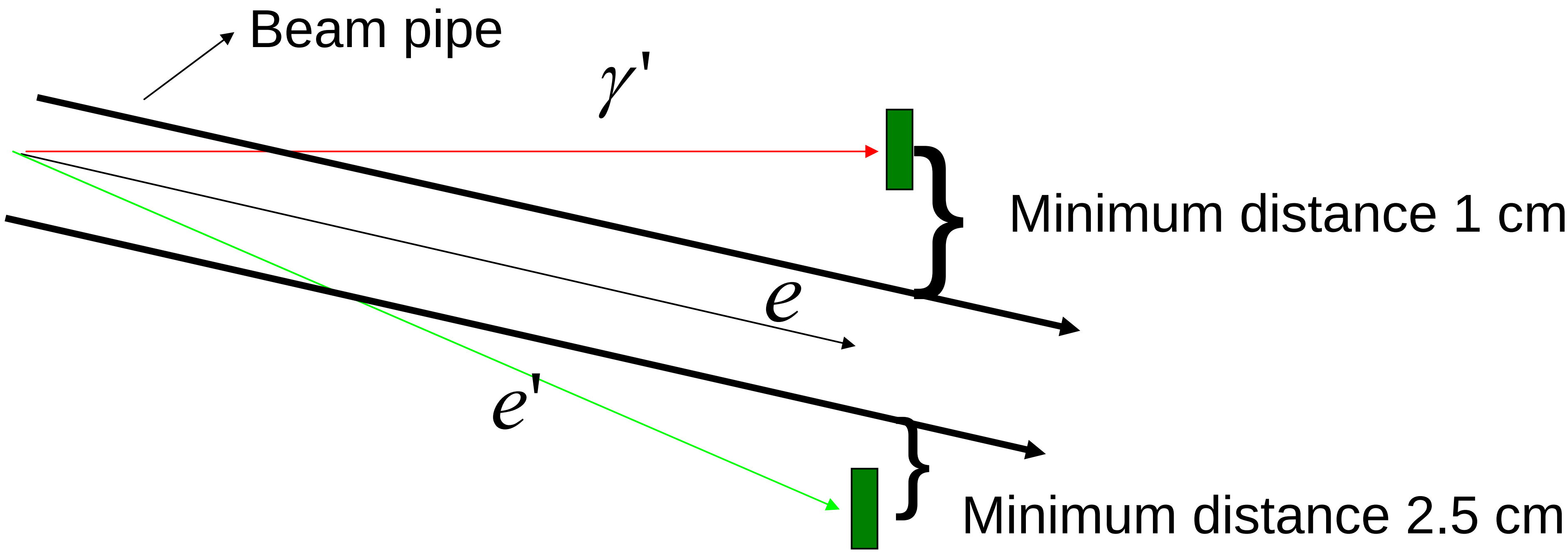
Outline

- Length restriction for our apparatus
- Some remarks on errors
- Possible positions in BDS
- Discussion about advantages and disadvantages
- Conclusion I
- Some words about photons detection
- Conclusion II

Practical Restriction



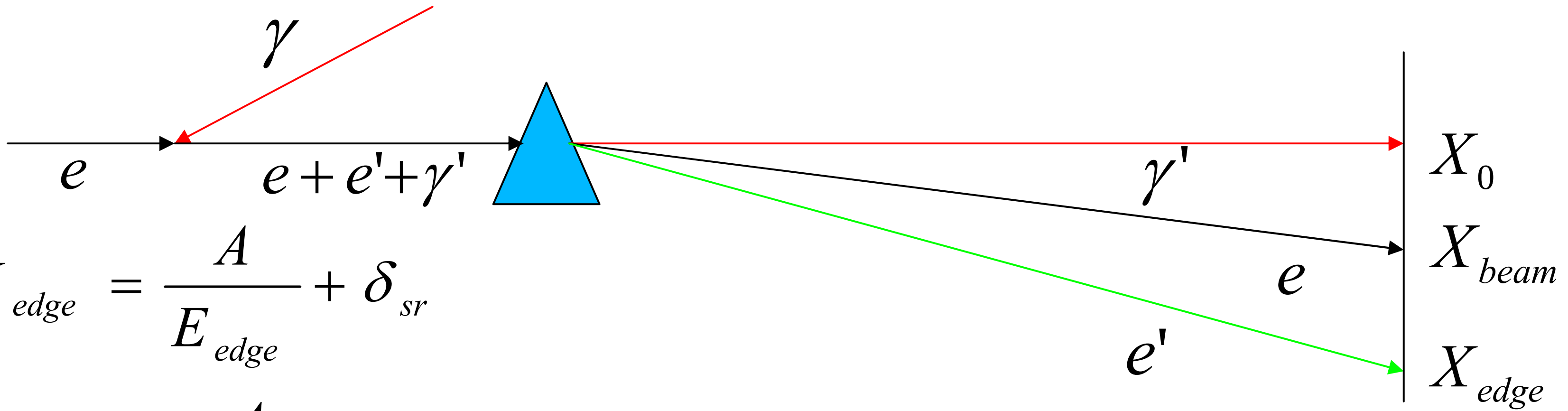
- We have some restrictions on the length L due to practical reasons, for example separation between beam and photons must be at least 20 mm if the beam pipe has a radius of 10 mm.

- If we consider for example BdL = 0.84 T*m the minimum distance L between magnet and detector > 20 m in order to have these conditions satisfied.

Error on Energy Measurement

$$\frac{X_{edge} - X_{beam}}{X_{beam} - X_0 - \delta_{sr}} \propto E_{beam}$$

$$\frac{\Delta E_{beam}}{E_{beam}} = \frac{X_{edge}}{X_{edge} - X_{beam}}\left(\frac{\Delta X_{edge}}{X_{edge}}\right) + \frac{X_{edge}}{X_{edge} - X_{beam}}\left(\frac{\Delta X_{beam}}{X_{beam}}\right) + \frac{\Delta X_0}{X_{beam}} + \frac{\delta_{sr}}{X_{beam}}$$



$$X_{edge} = \frac{A}{E_{edge}} + \delta_{sr}$$

$$X_{beam} = \frac{A}{E_{beam}} + \delta_{sr}$$

$$A = \frac{Bl}{Const}\left(L + \frac{l}{2}\right)$$

Where B is the magnetic field, l is the length of the magnet, L the distance between magnet and detector and δ_{sr} a correttive term due to synchrotron radiation

Error on Energy Measurement

If we assume we can measure the position of the primary beam with a precision of 0.5 micron and the backscattered photons with a precision of 1 micron in the following table is presented the value of the singular term in the formula error in function on some input parameters (considering 10^6 scattered particles, infrared YAG laser and 50 micron beam size in x, BdL=0.84 T*m). The errors are given in PPM (part per milion)

Beam Energy	50 GeV		250 GeV		500 GeV	
Distance L	25 m	50 m	25 m	50 m	25 m	50 m
$\frac{X_{edge}}{X_{edge}-X_{beam}}\left(\frac{\Delta X_{edge}}{X_{edge}}\right)$	63	62	38	38	30	30
$\frac{X_{edge}}{X_{edge}-X_{beam}}\left(\frac{\Delta X_{beam}}{X_{beam}}\right)$	40	20	23	12	21	11
$\frac{\Delta X_{0}}{X_{beam}}$	40	20	40	20	40	20
$\frac{\delta_{sr}}{X_{beam}}$	<10	<10	<10	<10	<10	<10

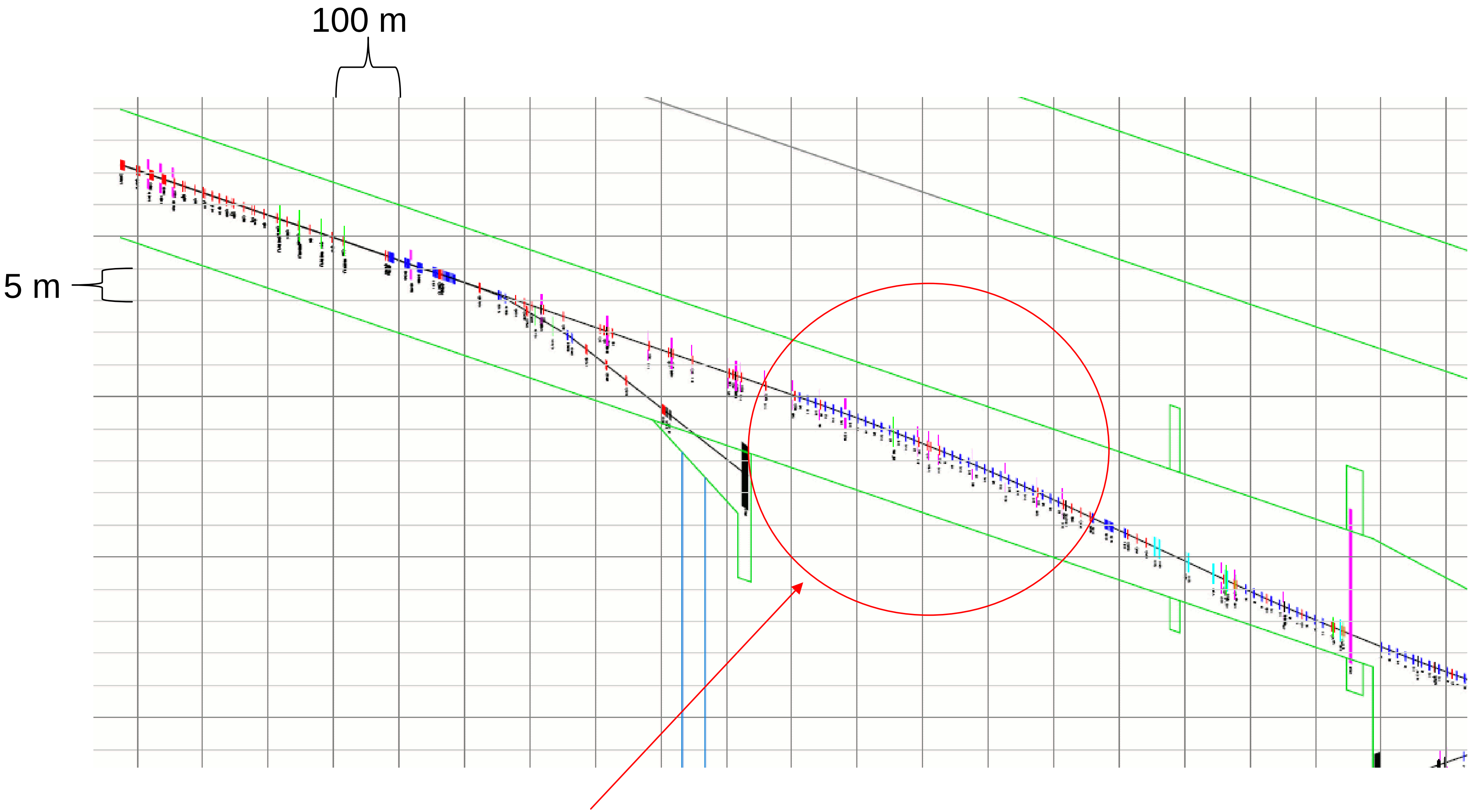
Error on Energy Measurement

- In the range of length 25-50 m we dont have large restriction due to the error on energy measurement.
- The worst case is for 50 GeV beam with a distance magnet-detector of 25 m. In this case we have a relative error of 90 ppm on the beam energy.

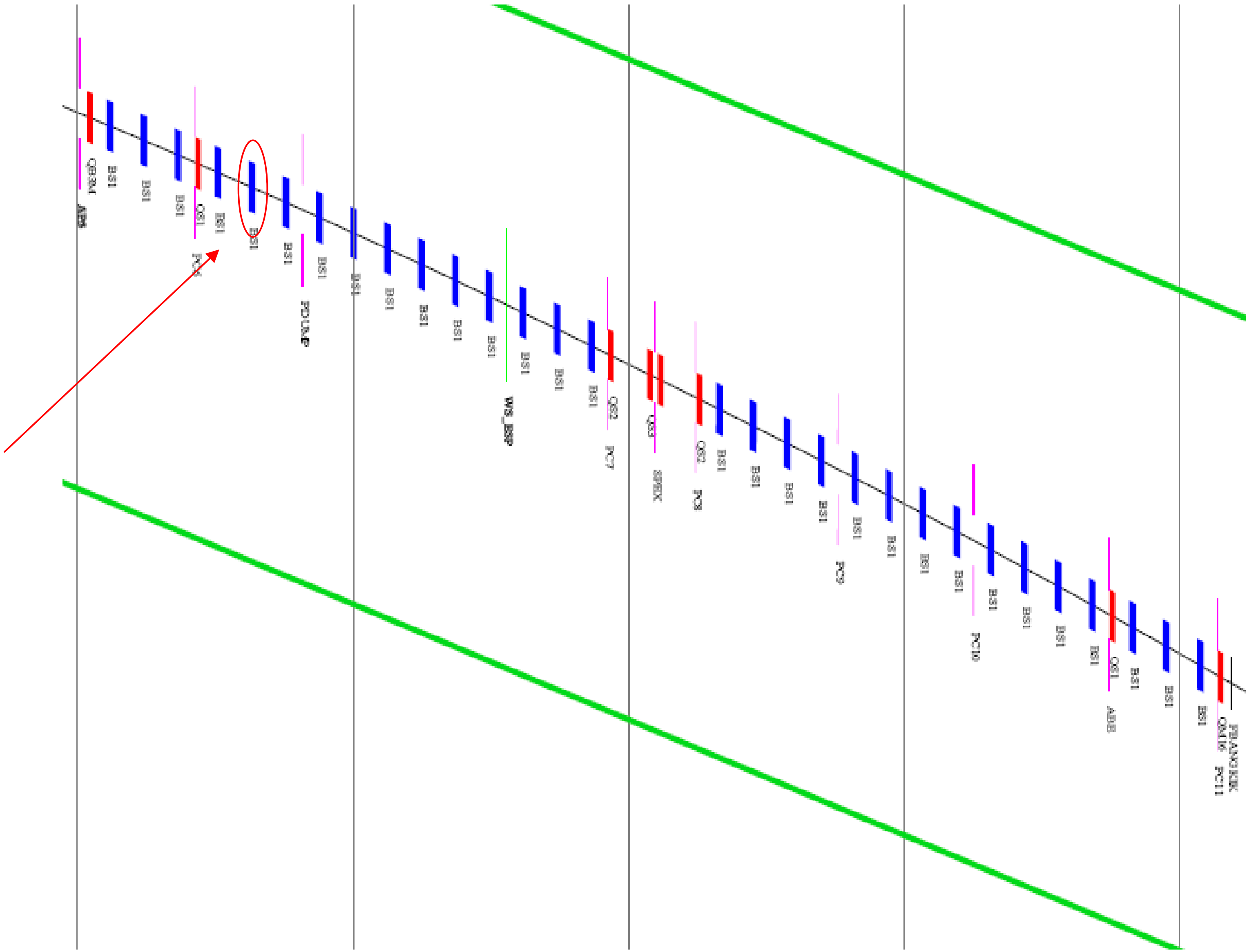
Beam Delivery System

- We want to present some considerations about positioning of our apparatus in the BDS
- Basically we took in consideration 2possibilities:
  - Using an existing chicane (compton polarimeter or energy collimator)
  - Install a new chicane

Energy Collimator



Energy Collimator



Energy Collimator

A chain of long weak magnets (B-field ca 300 G and lengt 2.4 m). In the table the displacement in mm for the unscattered and scattered electrons after each magnet

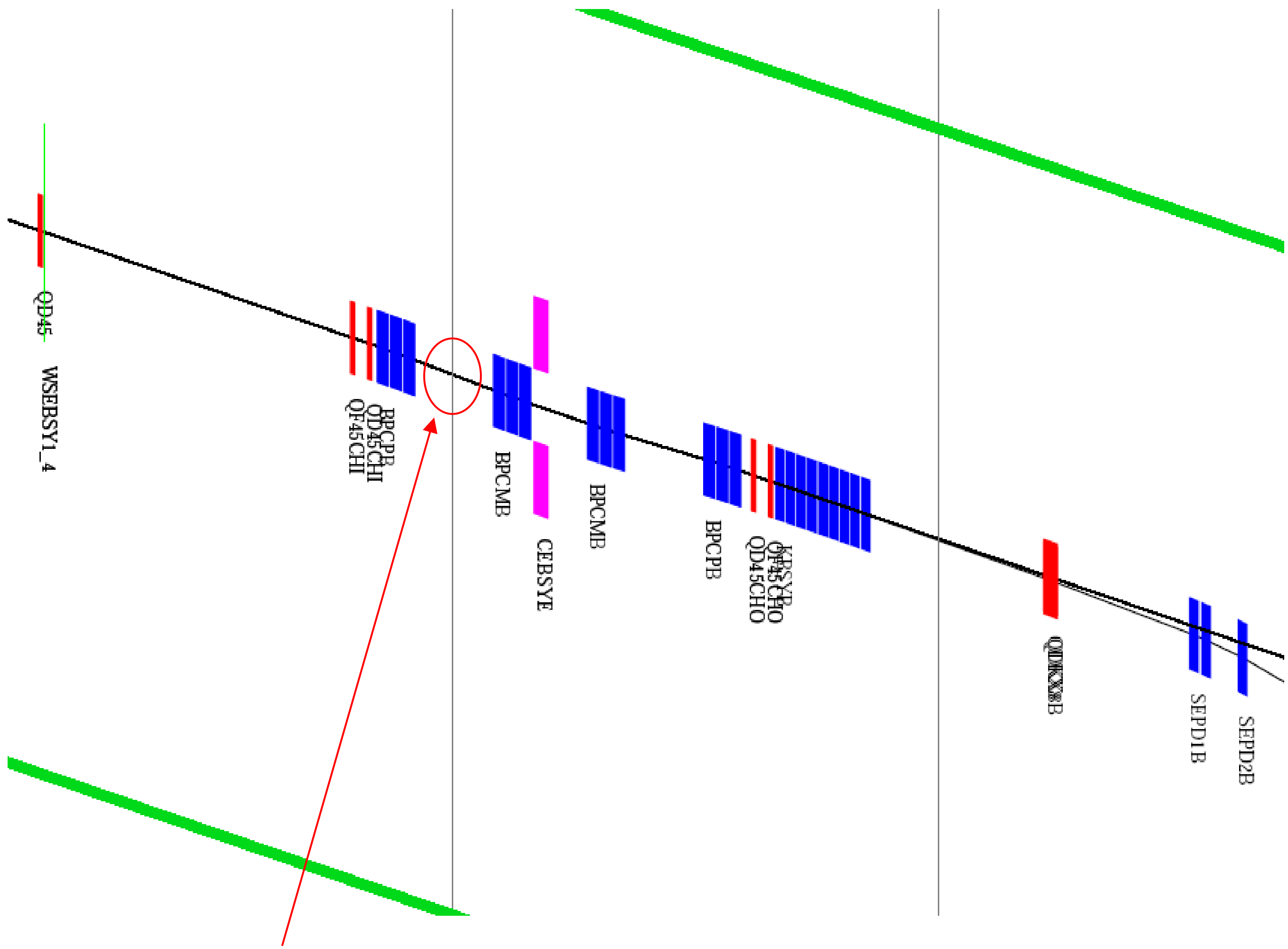
	1 Mag	2 Mag	3 Mag	4 Mag	5 Mag	6 Mag	7 Mag	8 Mag
e unsc	0.1	1.23	3.4	6.6	10.8	16.1	22.4	29.7
e scat	0.55	6.74	18.6	36	59.1	87.9	122	162

Energy Collimator

- It is basically possible to use this chain of dipoles for our spectrometer. In this configuration we must use at least 7 magnets without anything in between in order to have a separation between photons and beam of 20 mm
- Our method requires for scattered and unscattered electrons high uniform B-field inside the gap of the magnet $\left(\frac{B - B_0}{B_0} \approx 10^{-5} \right)$
- In order to reduce background at physics IP it is preferable to install our apparatus at the beginning of the energy collimator
- No additional emittance growth

Comtpon Polarimeter Chicane

Compton Polarimeter Chicane

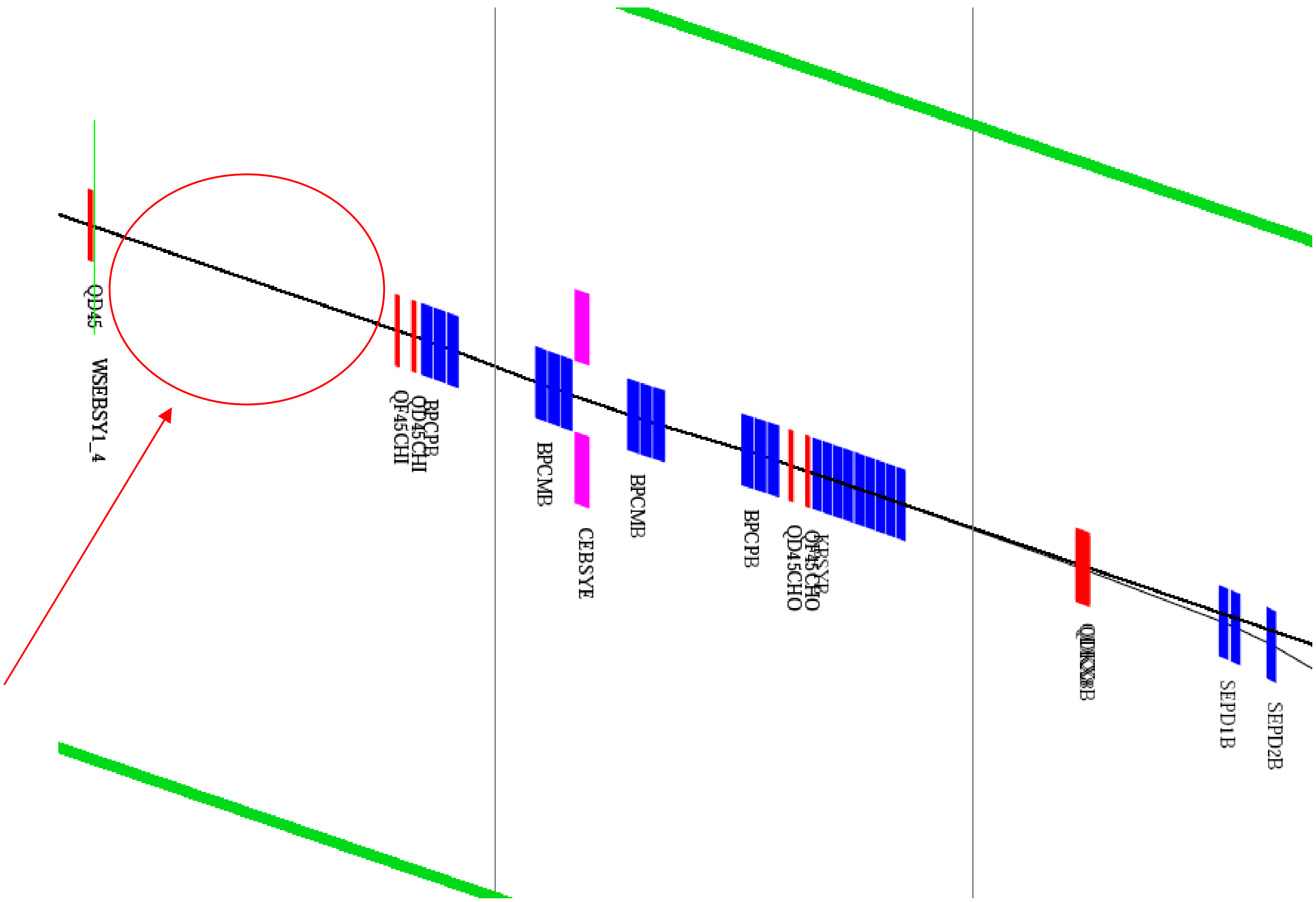


Possible position for our spectrometer

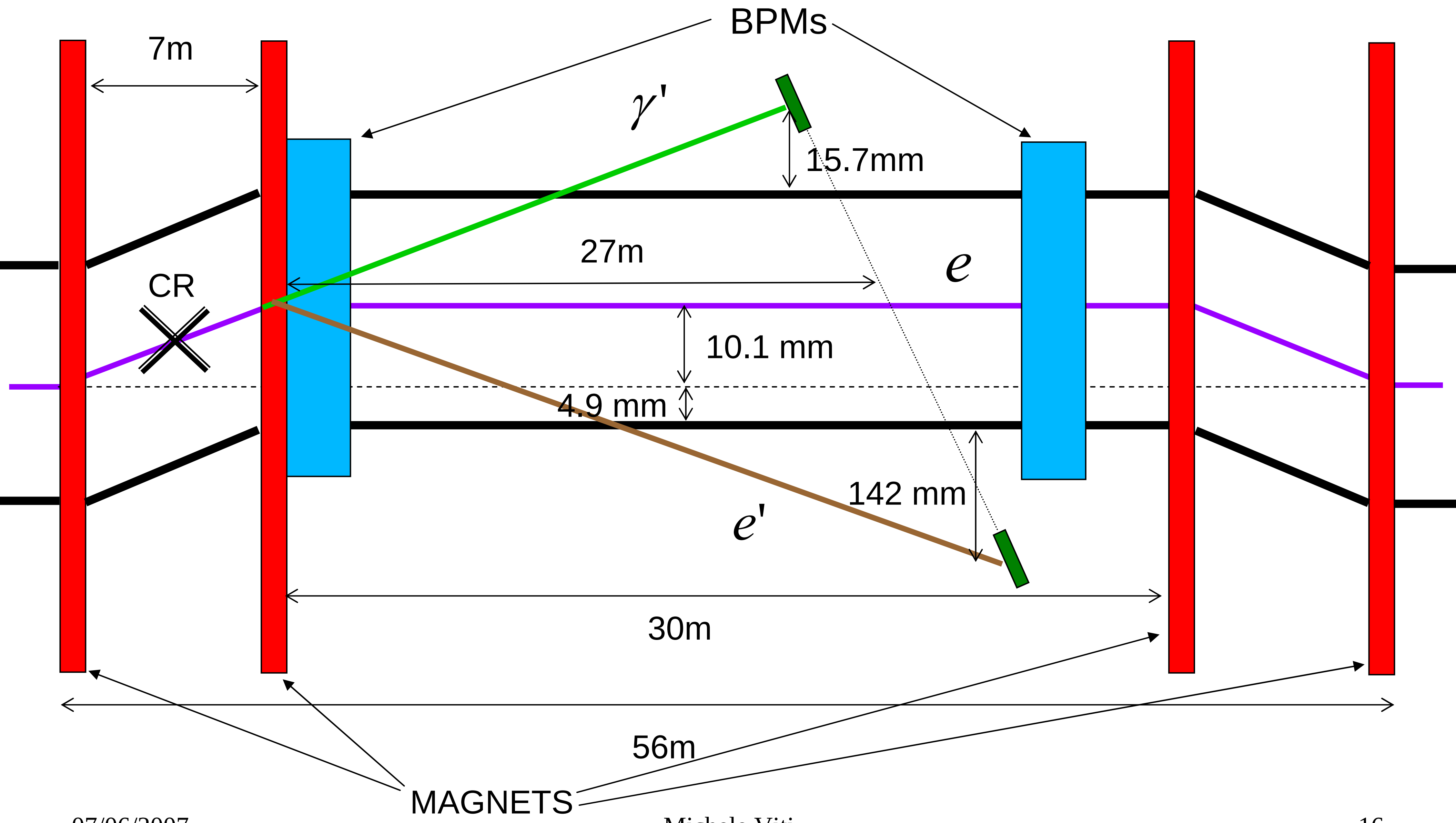
Compton Polarimeter Chicane

- Total Bdl of each magnet 0.699 T*m. Distance between the first and second magnet 16.1 m
- In the case of 250 GeV the offset is around 16.7 mm.
- We need to move upstream the 1st magnet by 10 m (offset around 25.1 mm, 28.4 mm in the central part of the chicane)
- Moreover we need 6 m space between the 1st magnet and the quadrupole QD45CHI (now it is 1 m)
- Refined chicane
- Refined optics needed?
- Problems for Polarimeter to operate with higher offset?

Additional Chicane



Additional Chicane



Additional Chicane

- Possibility to add a new chicane upstream the energy collimator?
- Needed 56 m space (right before the Polarimeter chicane, 63.22 m available).
- 4 magnets 3 m length, $B = \frac{B_0}{E_0} E,\ E_0 = 250\, GeV,\ B_0 = 0.28\, T$
- Maximum emittance growth in case of beam of 500 GeV estimated to be 8% (very roughly estimation)

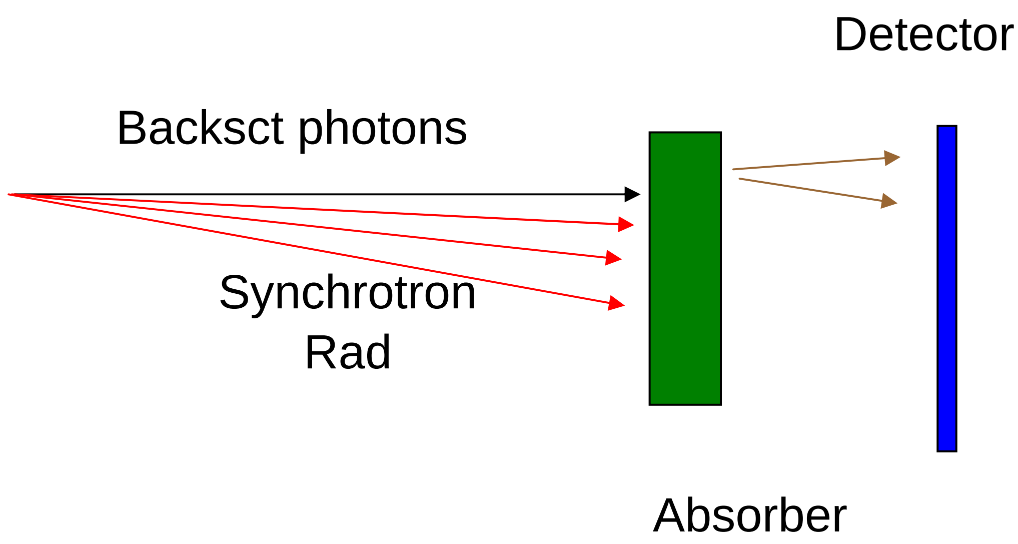
Conclusion

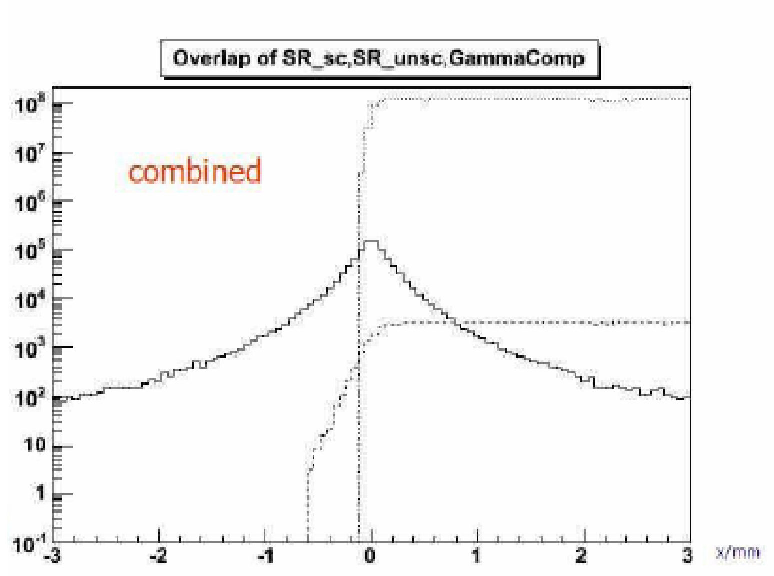
- A setup with a separation between photons and beam >20 mm seems to be fine for our purpose.
- We propose basically 3 options for positioning of our spectrometer:
  - Energy Collimator Chicane
    - Background at IP negligable
    - No emittance growth
    - Large range of high uniformity in the gap of the magnets (~ +/- 10 cm)
  - Compton Polarimeter Chicane
    - No background at IP
    - Smaller range of high uniformity in the gap of the magnets (~ +/- 2 cm)
    - Refined optics and chicane needed
  - New Chicane
    - No Background at IP
    - Negligable emittance growth
    - Smallest range of uniformity for the magnets (~ +/- 1 cm)

Photon Detection

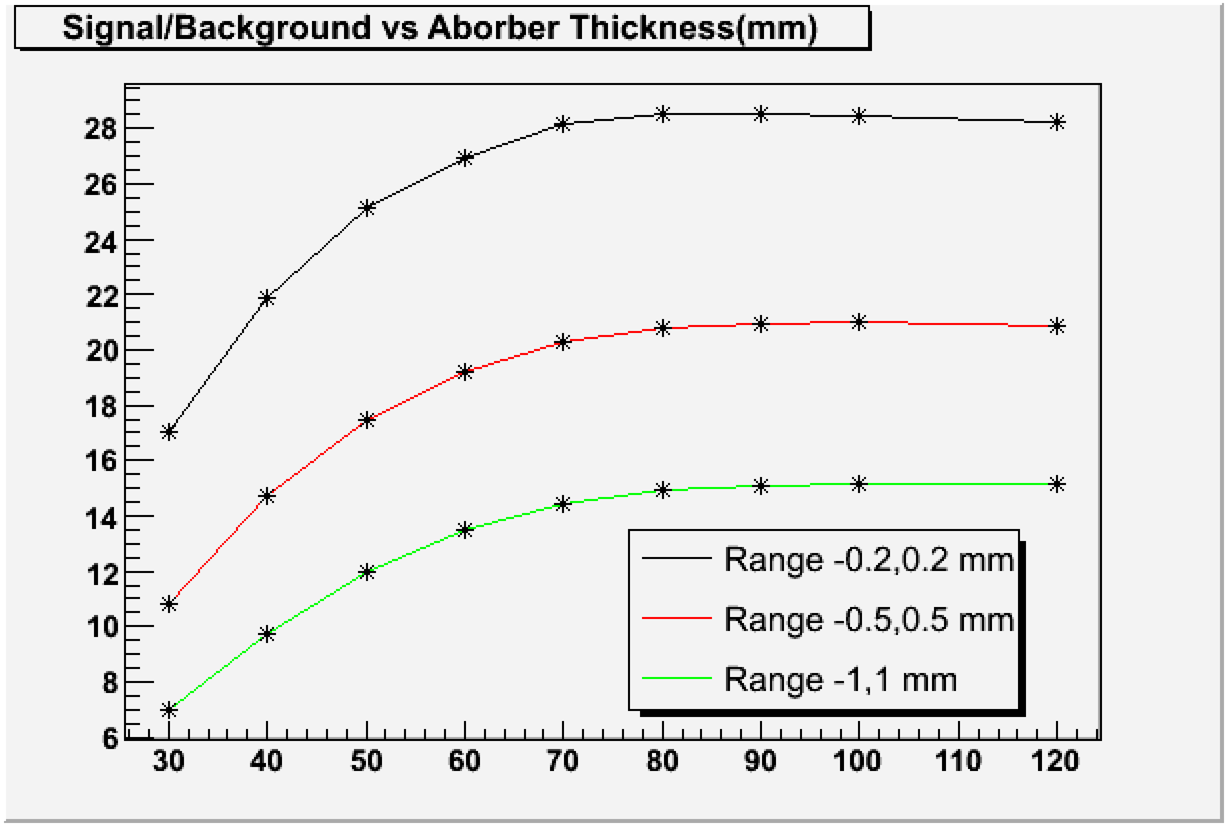
Photon Detection

- Absorber/converter to remove the background and to covert backscattered photons.



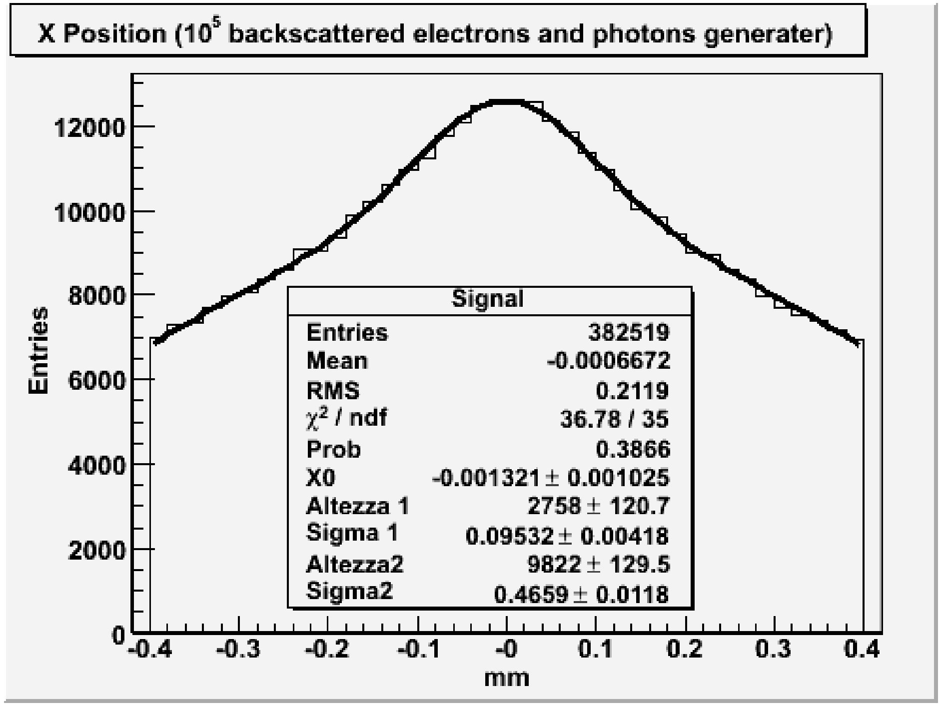


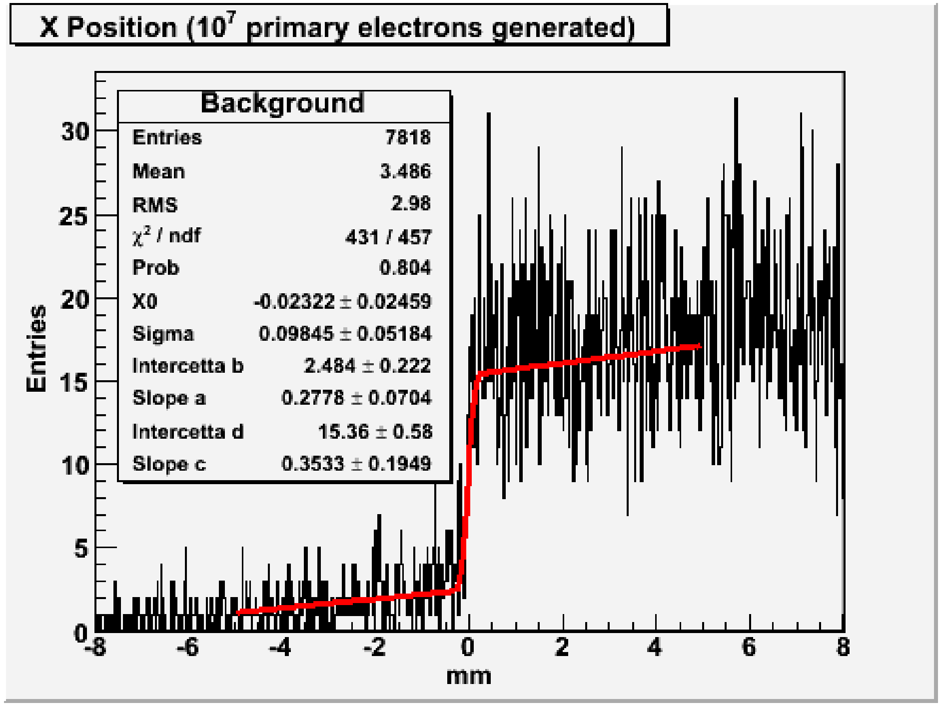
Photon Detection



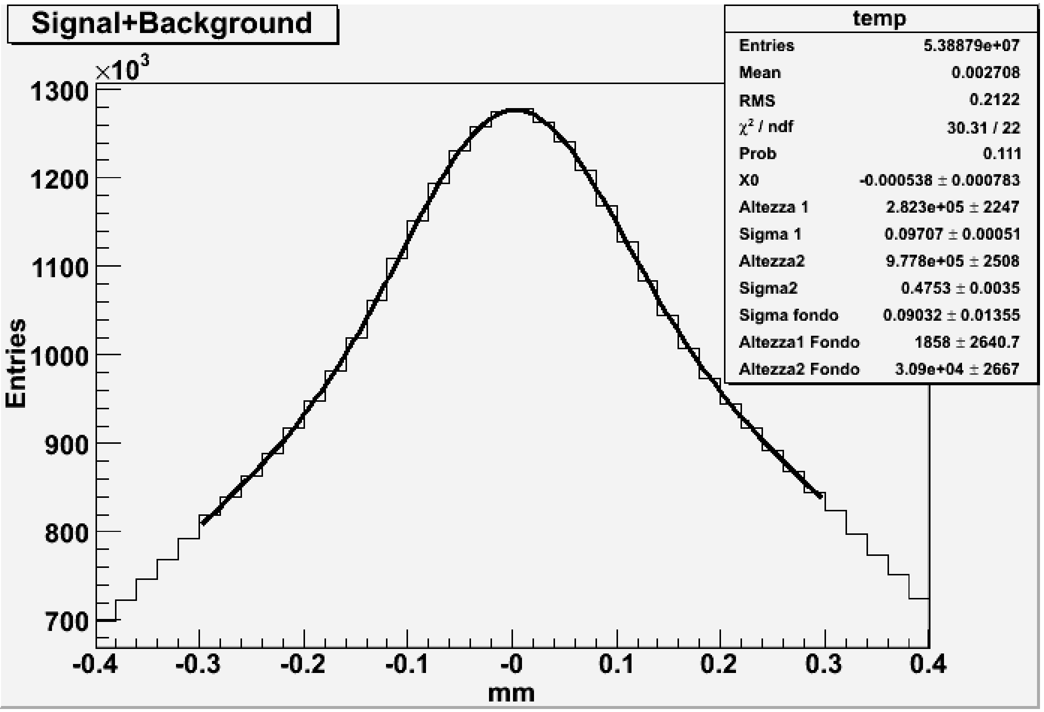
Plot made for lead (1 radiotion length 0.56 cm). Optimum is 60-80 mm (10-14 radiation length)

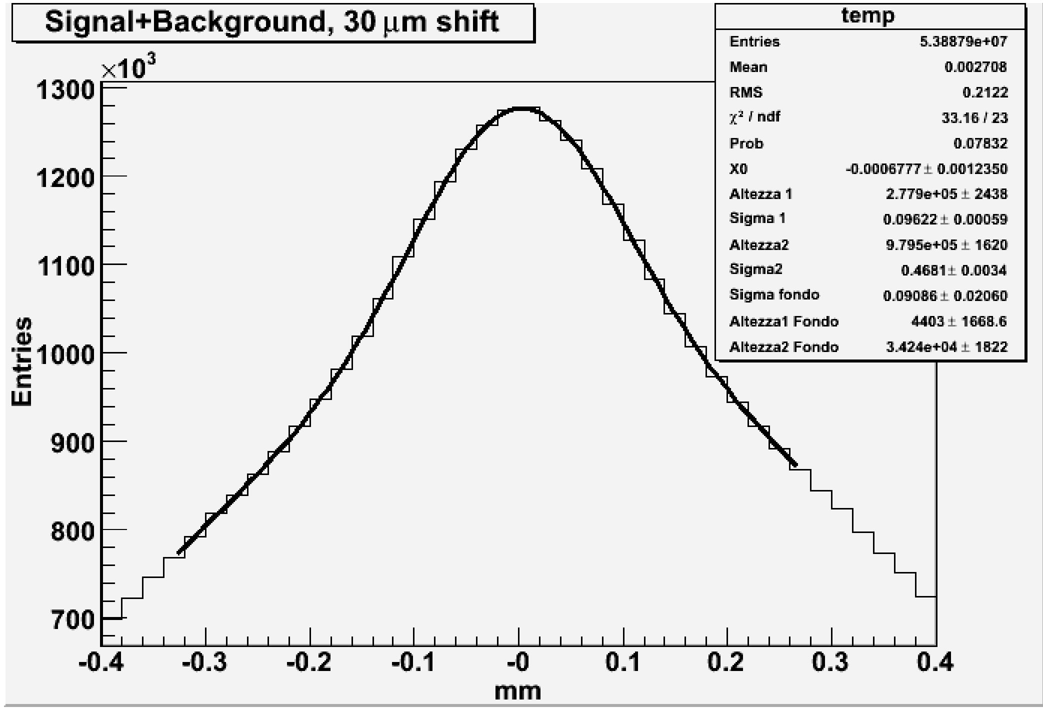
Photon Detection





Photon Detection

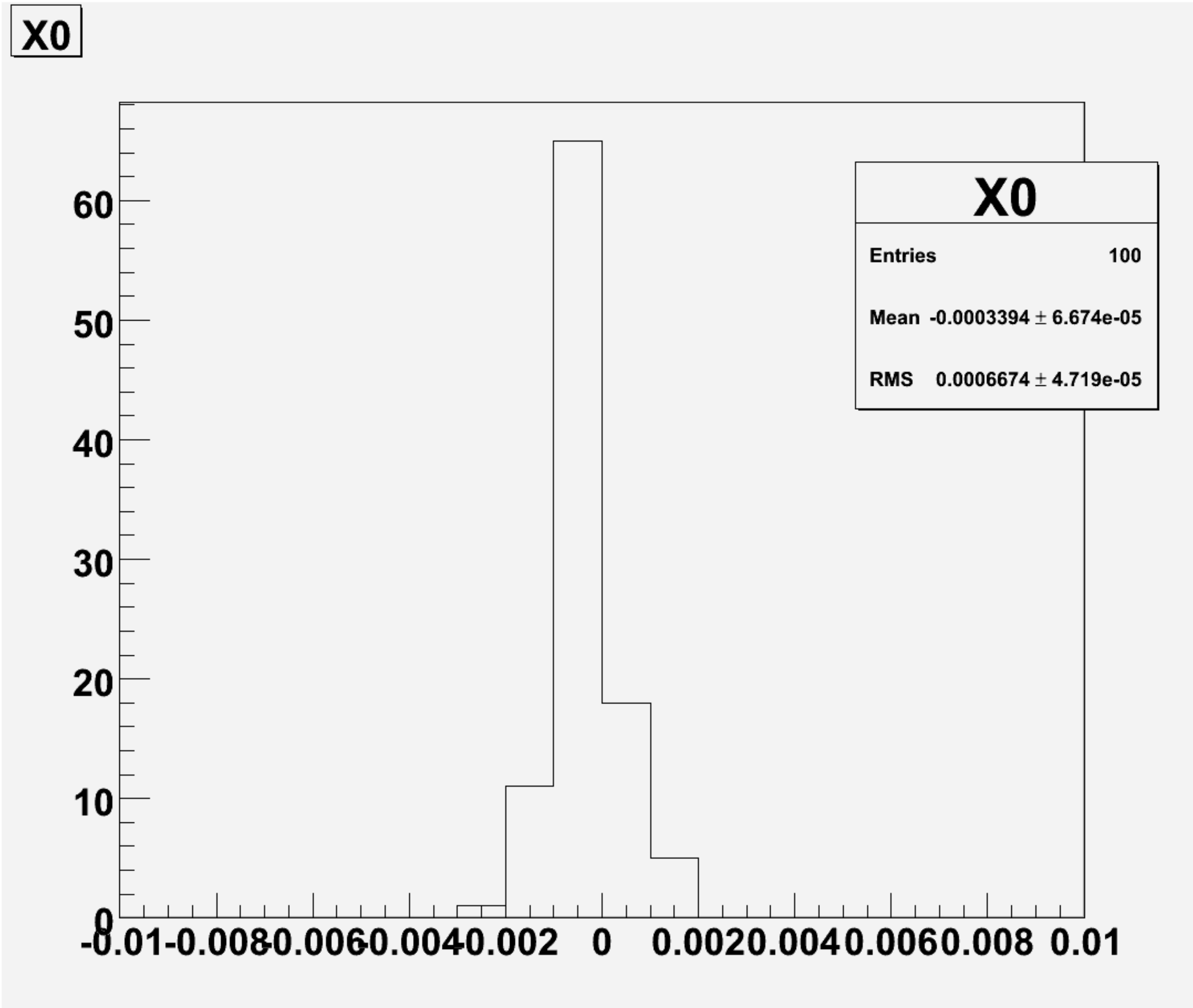




X0 = 0.53 +- 0.78 micron

X0 = 0.67 +- 1.2 micron

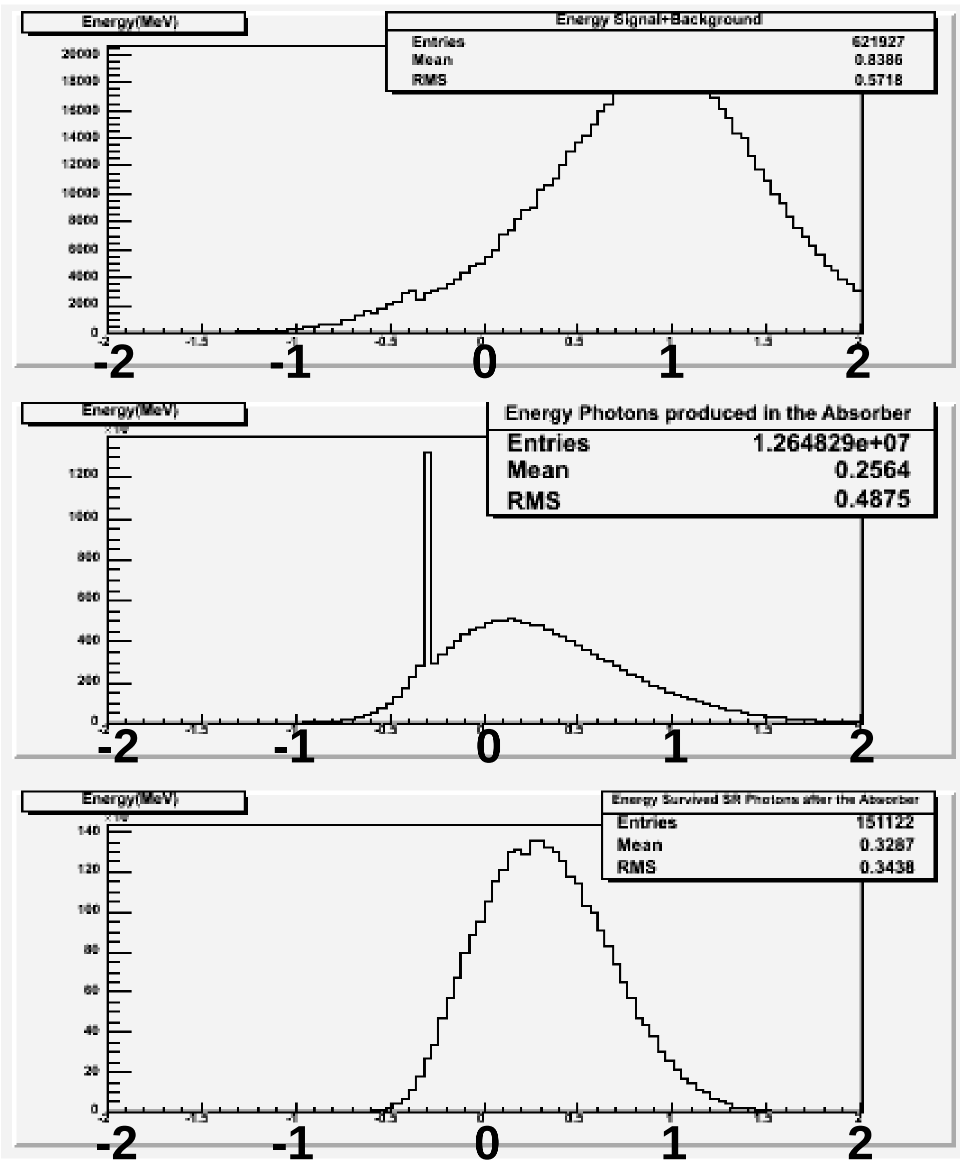
Photon Detection



Mean value = 0.3 +- 0.06 micron

Sigma = 0.66 +- 0.04 micron

Photon Detection



Energy Spectrum for charged particles produced in the absorber (**log(MeV)**)

<u>Mean Value of Energy = 6,8 MeV</u>

<u>Number of particles = 6*10^7</u>

Energy Sepctrum for photons produced in the absorber (**log(MeV)**)

<u>Mean Value of the Energy = 1,8 MeV</u>

<u>Number of photons = 10^9</u>

Energy Spectrum for surviving Synchrotron Rad. Photons after the absorber (**log(MeV)**)

<u>Mean Value of the Energy = 2,13 MeV</u>

<u>Number of photons = 10^7</u>

Conclusion II

- Trough some GEANT4 simulation was studied the possibility to measure the backscattered photon peak with a precision of 1 micron.
- Regarding the statistical accuracy it seems to be fine using an absorber of 10-13 radiation length in order to convert the backsct photons and reduce the background.