Photon flux simulations by GF-CMCC for PoP experiment

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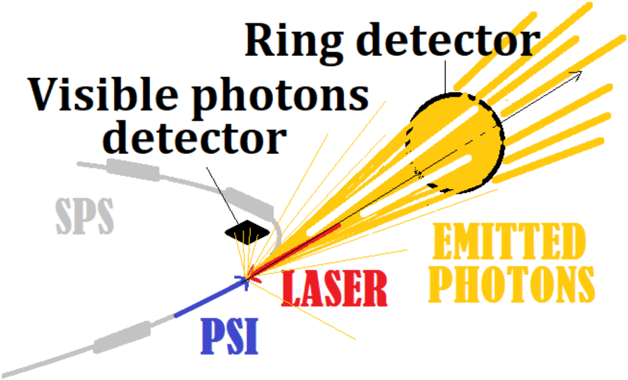
- GF-CMCC to simulate photons emitted by PSI-laser collision for the Proof of Principle experiment at SPS
  - Photon flux downstream and above the interaction point to guide the design of the detection system



INPUT PARAMETERS FOR POP SIMULATIONS

→ PSI beam:

ion: ${}^{207}_{82}\mathrm{Pb}^{79+}$

mass: $M_i = 193.687\,\mathrm{GeV/c^2}$

transition energy and life-time: $\hbar\omega_0 = 230.76\,\mathrm{eV},\ \tau_0 = 74\,\mathrm{ps}$

ion energy and its relative spread: $E_i = 18.68908\,\mathrm{TeV}$, $\sigma_{E_i}/E_i = 3 \cdot 10^{-4}$

relativistic Lorentz factor: $\gamma_i = 96.287$

number of ions per bunch: $N_i = 2 \cdot 10^8$

geometric emittance: $\epsilon_x = \epsilon_y = 2 \cdot 10^{-8}\,\mathrm{m\,rad}$

r.m.s transverse beam size: $\sigma_x = 1.051\,\mathrm{mm}, \sigma_y = 1.171\,\mathrm{mm}$

r.m.s. bunch length $\sigma_z = 12\,\mathrm{cm}$

→ Laser:

Gaussian spatial and time profiles

angle w.r.t. the PSI beam: 2.6°

photon energy and its relative spread: $E_\gamma = 1.196\,\mathrm{eV}$, $\sigma_\omega/\omega = 1.5 \cdot 10^{-4}$

photon wavelength: $\lambda_\gamma = 1037.03\,\mathrm{nm}$

pulse energy: $W_l = 5.1\,\mathrm{mJ}$

r.m.s. transverse beam size at focus: $\sigma_x = \sigma_y = 2\,\mathrm{mm}$

r.m.s. pulse length: $l_l = 1.1092\,\mathrm{mm}$

Simulation modes: laser at resonance or some σ_ω below resonance

- Number of emitted photons per ion per shot, maximum one interaction per ion. Results for laser at resonance and 2 σ_ω below resonance

`GF-CMCC code simulation method`		MC	LUM
N_γ/N_i [%] laser at resonance	without stimulated emission	17.36	17.5
	with stimulated emission	12.1	
N_γ/N_i [%] laser 2 σ_ω below res	without stimulated emission	11.65	11.7
	with stimulated emission	8.25	

- GF-CMCC output for laser at resonance and 2 σ_ω below resonance

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-------------------------------------------------------------------------------
Cross section (Mbarn)         3.3102313989131242
Photons per ion            MC  0.12152549999999999        LUM  0.17557019781144328
Real photons per shot (10^7) MC  2.4305099999999999       LUM   3.5114039562288655
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-------------------------------------------------------------------------------
Cross section (Mbarn)         2.2176744024710850
Photons per ion            MC   8.2598000000000005E-002  LUM  0.11762245191252839
Real photons per shot (10^7) MC  1.6519600000000001       LUM   2.3524490382505676
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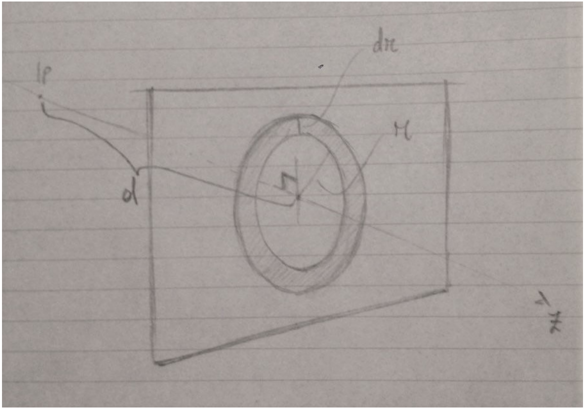
- from now on all the simulations performed with laser 2 σ_ω below resonance (other results obtainable rescaling the flux) and per shot4

SKETCH OF RING DETECTOR

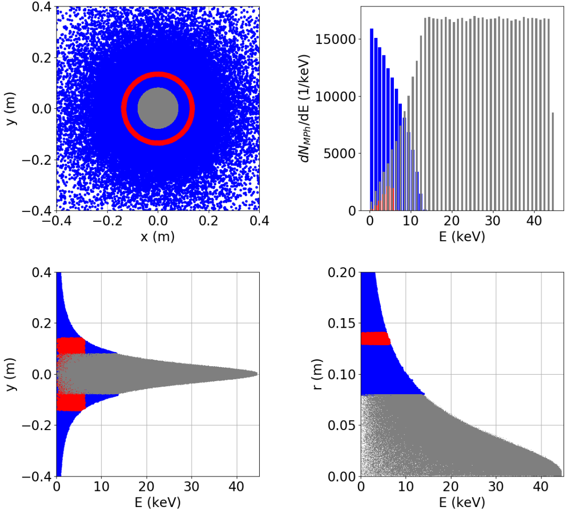
- ring detector out of the beam pipe (8 cm radius) for the photons dacaying in the forward direction



- simulations in the following for $r = 13$ cm, $dr = 1$ cm and $d = 5,\ 7,\ 9$ m
- calculation of real number of photons and total energy in the ring: since the emission is isotropic in the azimutal angle, it is possible to obtain the quantities in a sector of the ring by simply dividing the total

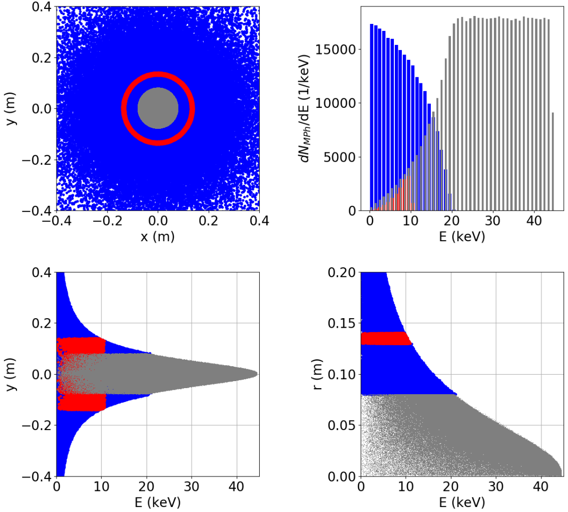
RING DETECTOR

Flat screen perpendicular to z axis (of propagation) @ 5 m from IP
Real ph at 0.0795 < r < 4 m (in blue): 2560260.000
Real ph 0.13 m < r < 0.14 m (in red): 141340.000
Total ph energy at 0 < r < 0.0795 (in grey): 319652.853 MeV
Total ph energy at 0.0795 < r < 4 m (in blue): 12398.738 MeV
Total ph energy 0.13 m < r < 0.14 m (in red): 576.263 MeV

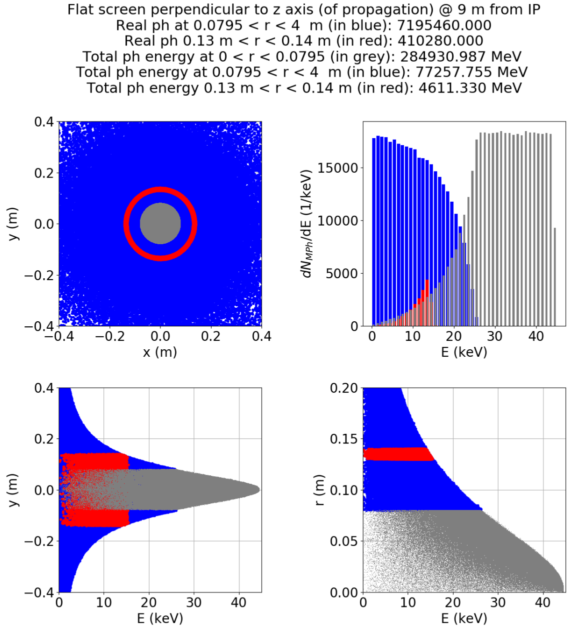


RING DETECTOR

Flat screen perpendicular to z axis (of propagation) @ 7 m from IP
Real ph at 0.0795 < r < 4 m (in blue): 4899940.000
Real ph 0.13 m < r < 0.14 m (in red): 273020.000
Total ph energy at 0 < r < 0.0795 (in grey): 314793.292 MeV
Total ph energy at 0.0795 < r < 4 m (in blue): 38953.651 MeV
Total ph energy 0.13 m < r < 0.14 m (in red): 2043.405 MeV



RING DETECTOR



RING DETECTOR

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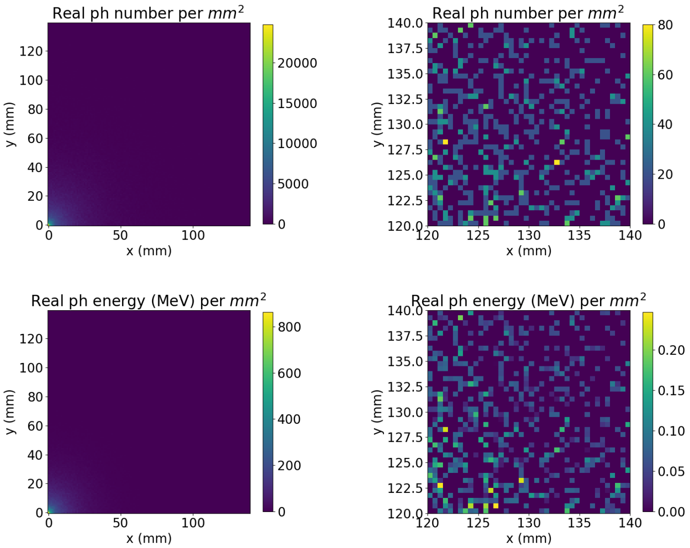

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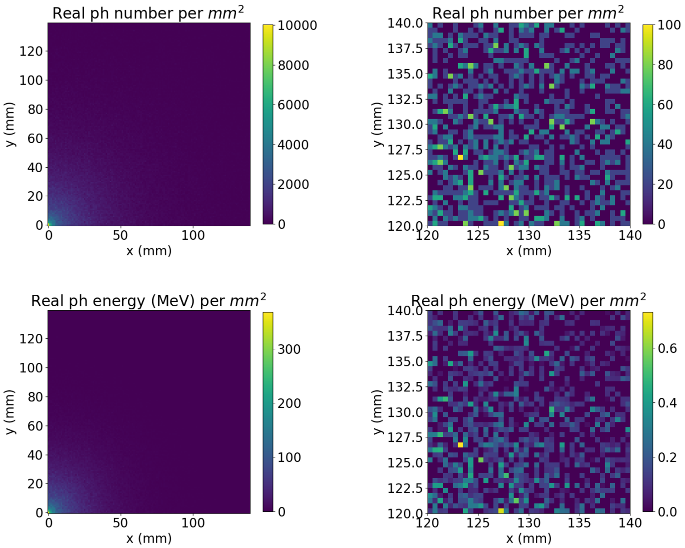
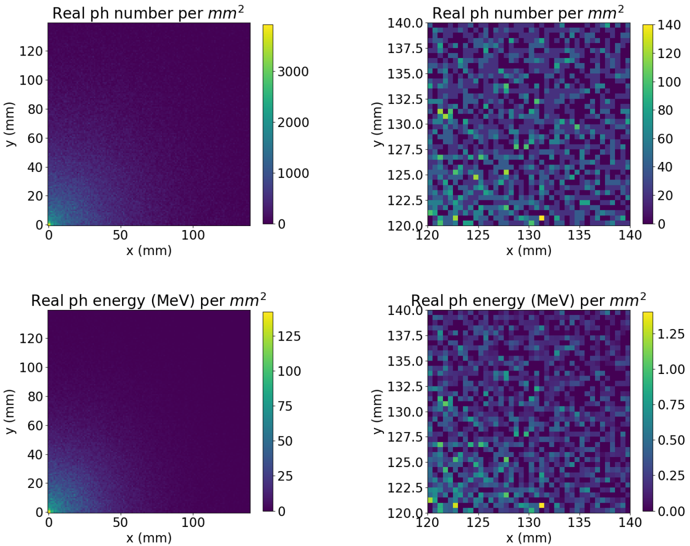


RING DETECTOR

Flat screen perpendicular to z axis (of propagation) @ 9 m from IP



RING DETECTOR

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Real ph at 0.0795 < r < 4 m (in blue): 2560260.000
Real ph 0.13 m < r < 0.14 m (in red): 141340.000
Total ph energy at 0 < r < 0.0795 (in grey): 319652.853 MeV
Total ph energy at 0.0795 < r < 4 m (in blue): 12398.738 MeV
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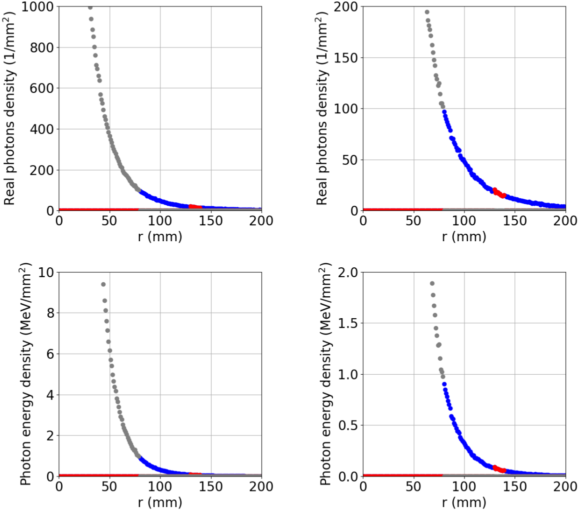

RING DETECTOR

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Real ph at 0.0795 < r < 4 m (in blue): 4899940.000
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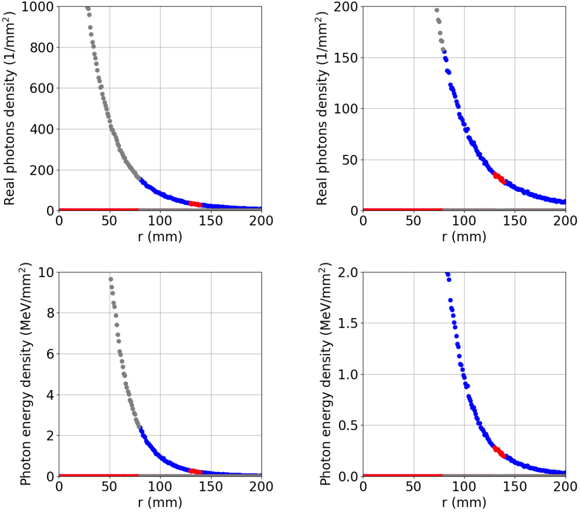
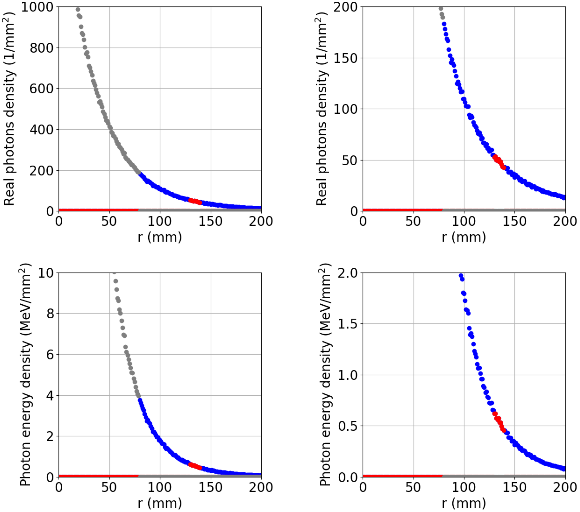


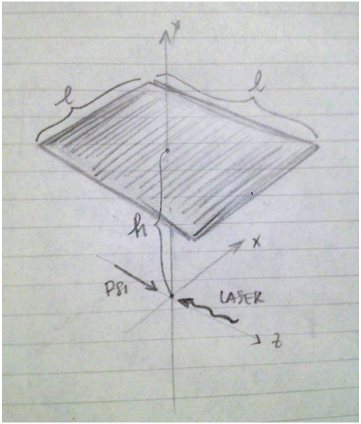
RING DETECTOR

Flat screen perpendicular to z axis (of propagation) @ 9 m from IP
Real ph at 0.0795 < r < 4 m (in blue): 7195460.000
Real ph 0.13 m < r < 0.14 m (in red): 410280.000
Total ph energy at 0 < r < 0.0795 (in grey): 284930.987 MeV
Total ph energy at 0.0795 < r < 4 m (in blue): 77257.755 MeV
Total ph energy 0.13 m < r < 0.14 m (in red): 4611.330 MeV



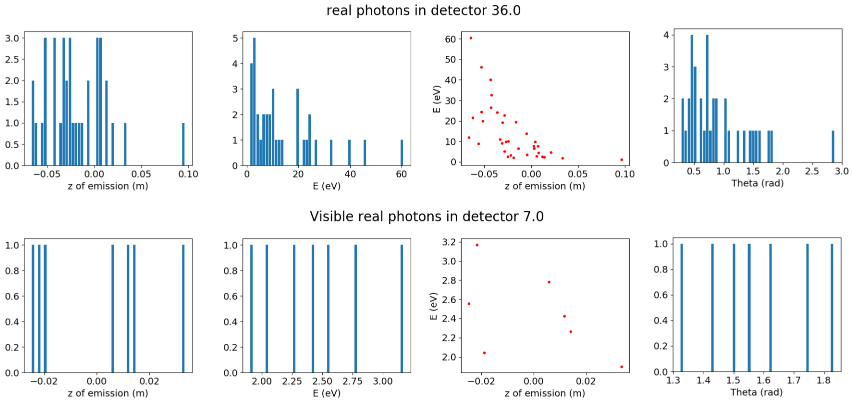
DETECTOR ABOVE THE INTERACTION POINT

- detector above the IP to detect visible photons (energy between 1.7 and 3.2 eV), shape: square



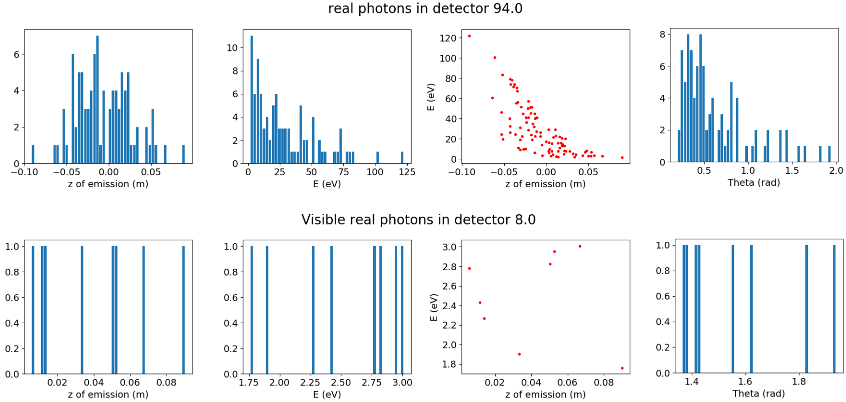
- simulations in the following for $h = 3$ cm and $l = 8$ cm
- optimization on the position in z to obtain the highest number of visible photons (zT is the z coordinate of the center of the target)

ZT=0 CM



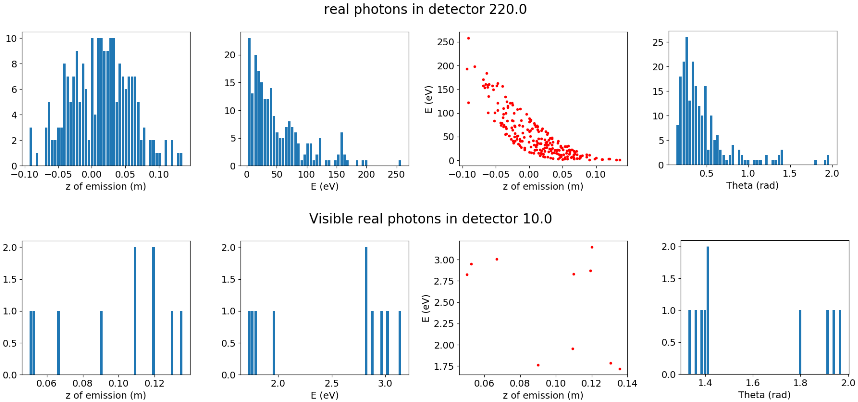
real photons in detector 36.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)
Visible real photons in detector 7.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)

zT=4 cm



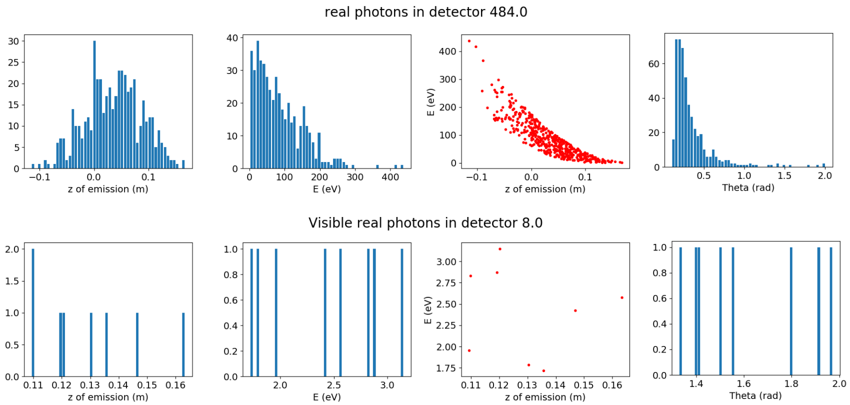
real photons in detector 94.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)
Visible real photons in detector 8.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)

ZT=9 CM

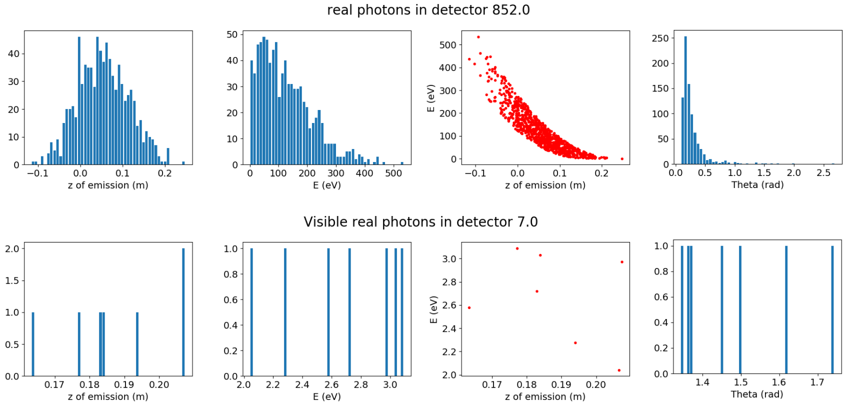


real photons in detector 220.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)
Visible real photons in detector 10.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)

zt=14 cm

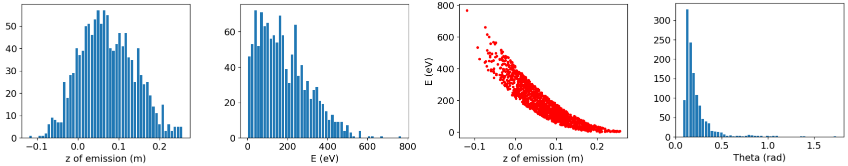

real photons in detector 484.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)
Visible real photons in detector 8.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)

ZT=19 CM

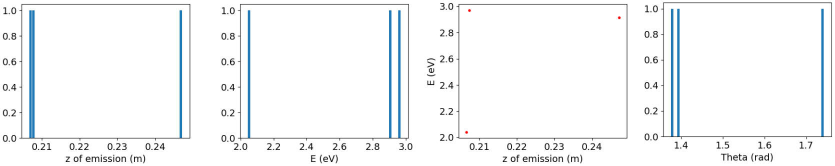

real photons in detector 852.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)
Visible real photons in detector 7.0
z of emission (m)
E (eV)
E (eV)
z of emission (m)
Theta (rad)

zt=24 cm

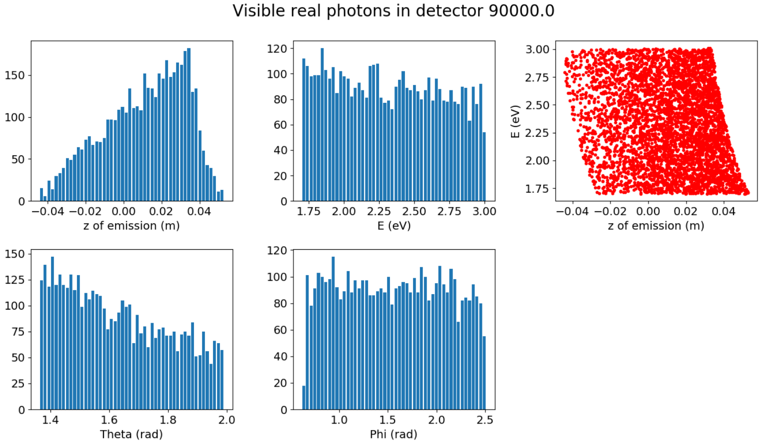
real photons in detector 1239.0



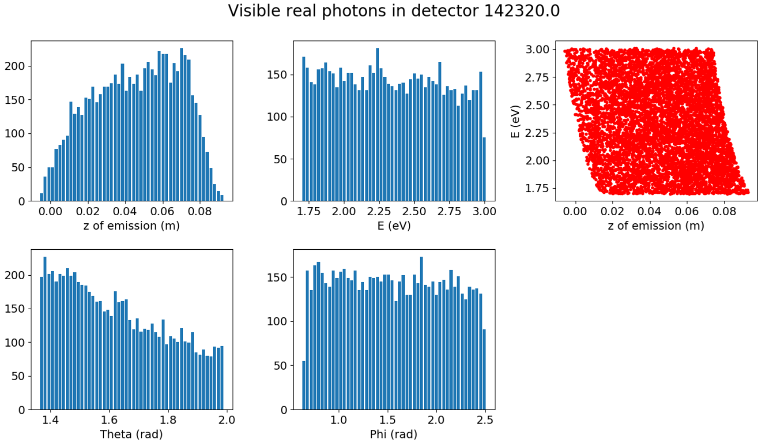
Visible real photons in detector 3.0



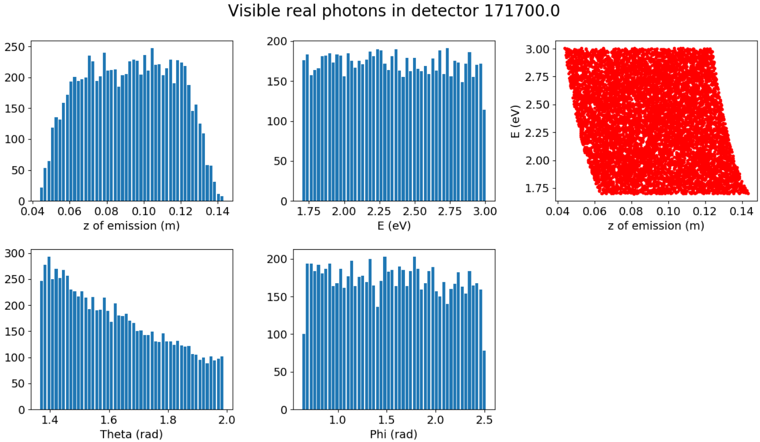
zT=0 cm oversampled



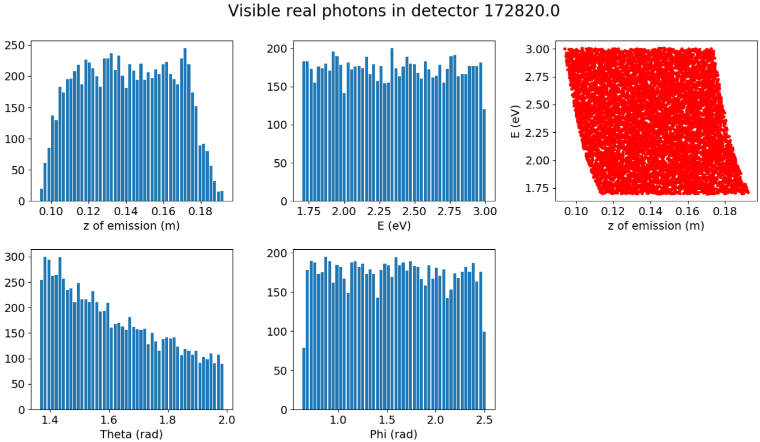
zT=4 cm oversampled



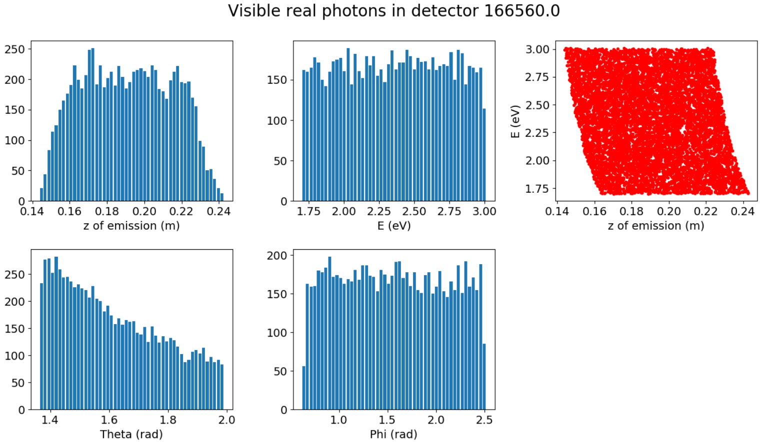
ZT=9 CM OVERSAMPLED



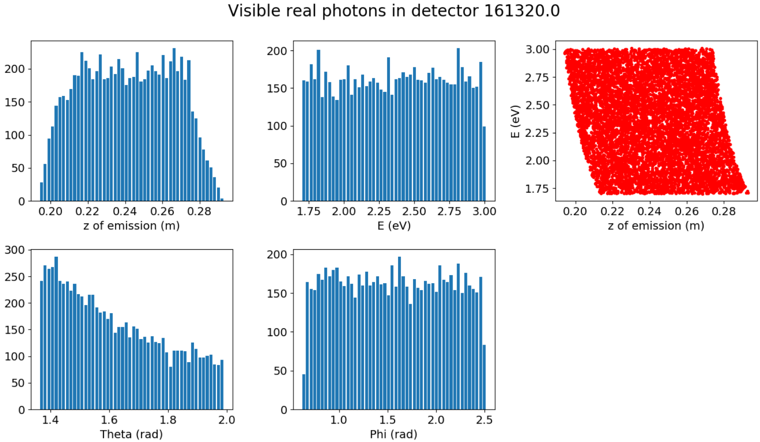
ZT=14 CM OVERSAMPLED



ZT=19 CM OVERSAMPLED



zT=24 cm oversampled



CONCLUSIONS

- First considerations about possible detectors design can be done based on this analysis of the emitted photons' flux. Some specific examples have been considered and it is very easy now to produce similar simulations with different parameters

- Ring detector: different positions donwstream the IP have been considered, the choice depends on the kind of detector

- Visible photons detector: the maximization of the visible photons flux occurs when the center of the square is around 10-12 cm downstream the IP.
All the photons in the square have been considered (not only the visible ones)

Thank you for your attention!

- E. G. Bessonov, *Fundamentals of gamma-Ray Light Sources (Gamma-Factory) based on backward resonance scattering of laser beam photons by cold relativistic ion beams*
- E. G. Bessonov, *Light sources based on relativistic ion beams*, Nucl. Instr. Meth. Phys. Res. B 309 (2013) 92–94
- M. W. Krasny, *The Gamma Factory proposal for CERN*, arxiv:1511.07794 (2015)
- M. W. Krasny *et al.*, *The CERN Gamma Factory initiative: an ultra-high intensity gamma source* in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, BC, Canada, WEYGBD3 (2018)
- C. Curatolo, W. Placzek, L. Serafini, and M. W. Krasny, *New simulation programs for partially stripped ions - laser light collisions* in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, BC, Canada, THPMF076 (2018)