FORWARD PHOTONS

Borysova Maryna (KINR)

11/03/19

LUXE weekly meeting



LAYOUT FOR FDS OF THE LUXE EXPERIMENT

Photons produced at IP1 proceed down their own beamline through the converter foil and the tracking spectrometer



HICS DIFFERENTIAL TRANSITION PROBABILITY VS RADIATED PHOTON ENERGY per initial particle per 100 fs 800 nm laser. 17.5 GeV initial electrons, 0.9*Pi crossing angle

data produced of HICS/IPW/circularly polarized with Mathematica by Anthony Hartin 4/2/2019



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ABSOLUTE NUMBER OF PHOTONS

multiply the rate by the mass of the electron in eV, by 510998, then we will get differential transition rate per electron per 100 fs.

multiply it by the number of electrons in the bunch (6.25e+09) and by the laser pulse duration (t=35 fs) (t/ 100fs)



The transverse structure of the laser field is not taken into account in the data (and xi is Gauss max) and it is assumed that the laser field is uniform in transverse direction and it is essentially the same for all electrons

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ξ	1e 100 fs	1e 35 fs (1BX)	Νγ	
0.5	6.82	2.39	1.49255E+10	
1	24.08	8.43	5.26758E+10	
1.5	46.55	16.29	1.01825E+11	
2	69.75	24.41	1.52579E+11	

The transverse structure of the laser field is not taken into account in the data (and xi is Gauss max) and it is assumed that the laser field is uniform in transverse direction and it is essentially the same for all electrons

ABSOLUTE NUMBER OF PHOTONS W/ ENERGY CUT

multiply the rate by the mass of the electron in eV, by 510998, then we will get differential transition rate per electron per 100 fs.

multiply it by the number of electrons in the bunch (6.25e+09) and by the laser pulse duration (t=35 fs) (t/ 100fs)

ξ	Νγ	Nγ, Εγ>6.0 Gev	Nγ, Eγ>4.0 Gev	Nγ, Eγ>3.0 Gev	Nγ, Eγ>2.0 Gev
0.5	1.49255E+10	4.94882E+08			
1	5.26758E+10	3.16064E+09	1.00437E+10		
1.5	1.01825E+11	7.71401E+09		3.09275E+10	
2	1.52579E+11	9.25216E+09			6.44808E+10

The transverse structure of the laser field is not taken into account in the data (and xi is Gauss max) and it is assumed that the laser field is uniform in transverse direction and it is essentially the same for all electrons

NUMBER OF PHOTONS W/ ENERGY CUT



TUNGSTEN WIRE AS A TARGET



Tungsten wolfram fine wire 0.01mm 0.02mm 0.03mm 0.04mm 0.05mm 0.1mm 0.15mm 0.2mm 0.3mm 0.4mm 0.5mm 1mm for scopes and transits

0.03mm X 2m

0.15mm X 2m

O 20

0.04mm X 2m

0.2mm X 2m

1mm X 2m

WHAT'S DONE & WHAT'S NEXT

- estimated the absolute number of forward photons w/ cuts
- almost implemented the use Bethe-Heitler class from Geant4 for differential cross-section calculations, with corrections and extended for various effects (the screening, the pair creation in the field of atomic electrons, correction to the Born approximation, the LPM suppression mechanism, etc.) test if we could fit and find other parameters describing the process: target material (Z).



TOTAL X-SECTION

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XCOM: Photon Cross Sections Database (The National Institute of Standards and Technology (NIST))

A web database which can be used to calculate photon cross sections for scattering, photoelectric absorption and pair production, as well as total attenuation coefficients, for any element, compound or mixture ($Z \le 100$), at energies from 1 keV to 100 GeV.

G4BetheHeitlerModel from Geant4

total cross section per atom in GEANT4

 $E_{\gamma} =$ incident gamma energy, and $X = \ln(E_{\gamma}/m_ec^2)$ The total cross-section has been parameterised as :

$$\sigma(Z, E_{\gamma}) = Z(Z+1) \left[F_1(X) + F_2(X) Z + \frac{F_3(X)}{Z} \right]$$

with :

$$F_1(X) = a_0 + a_1 X + a_2 X^2 + a_3 X^3 + a_4 X^4 + a_5 X^5$$

$$F_2(X) = b_0 + b_1 X + b_2 X^2 + b_3 X^3 + b_4 X^4 + b_5 X^5$$

$$F_3(X) = c_0 + c_1 X + c_2 X^2 + c_3 X^3 + c_4 X^4 + c_5 X^5$$

The parameters a_i, b_i, c_i were fitted to the data [hubb80]. This parameterisation describes the data in the range :

$$\frac{1 \le Z \le 100}{E_{\gamma} \in [1.5 \text{ MeV}, 100 \text{ GeV}]} \quad \begin{cases} \Delta \sigma \\ \sigma \end{cases} \le 5\% \text{ with a mean value of } \approx 2.2\% \end{cases}$$





FITTED THICKNESS



Thickness, cm	p[7] from the fit, cm	p[7] from the fit, cm
3.5* 10 -3	2.55* 10 ⁻³	3.2* 10 -3
5* 10 ⁻³	5.17* 10 ⁻³	4.6* 10 -3
10-2	0.7* 10-2	0.9* 10-2
2* 10 -2	1.8* 10-2	1.8* 10-2
5* 10 ⁻²	5.67* 10 ⁻²	5.01* 10 ⁻²

TESTING: COMPTON-LIKE

Ee = ∫ σ(Eγ, Ee)g(Eγ)dEγ



$\int \sigma(E\gamma, Ee)g(E\gamma, p1, p2)dE\gamma$

fitting allows finding the parameters quite well :

EXT	PARAMETER		APPROXIMATE	STEP	FIRST
N0.	NAME	VALUE	ERROR	SIZE	DERIVATIVE
1	p0	0.00000e+00	fixed		
2	p1	8.10443e+05	7.55173e+03	4.54179e-07	8.91191e-01
3	p2	5.08073e+00	6.97488e-04	6.53706e-04	1.39541e-01
4	р3	0.00000e+00	fixed		
5	p4	5.78148e+03	1.25645e+02	4.35657e-07	-2.81589e-01
6	p5	7.43076e+00	2.04060e-02	2.03632e-02	-4.17430e-02
7	p6	6.14838e+01	1.53063e+01	2.48844e-05	-8.82892e-03
8	p7	5.01104e-02	4.66919e-04	3.40724e-07	3.39522e+00

PHOTON SPECTRA FROM GEANT4 10E8 PHOTONS





ELECTRON SPECTRA: 35 UM VS 300 UM



GAMMA AND ELECTRON SPECTRA FOR XI=0.5



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GAMMA AND ELECTRON SPECTRA FOR XI=2.0



POSITRON SPECTRA VS TARGET THICKNESS IN GEANT4

Positron spectra vs target thickness



TESTING: COMPTON-LIKE

Ee = ∫ σ(Eγ, Ee)g(Eγ)dEγ



$\int \sigma(E\gamma, Ee)g(E\gamma, p1, p2)dE\gamma$

r .			r .		and the second se							
FCN=	145.218	FROM	HESSE	STATU	S=0K			56	CALLS	120	7 TOTAL	
			EDM=4.	92239e	-08	STRATE	GY=	1	ER	ROR MATRIX	ACCURATE	
EXT	PARAMET	ER						STE	Р	FIRST		
N0.	NAME		VALUE		ERR0	R		SIZ	E	DERIVATIV	E	
1	p0		1.85584e	+05	3.1335	7e+04	7.	8917	6e-07	-3.96577e	-02	
2	p1		9.96061e	+05	9.5041	3e+05	2.	4517	5e-06	1.51142e	-03	
3	p2		5.03997e	+00	3.5816	4e-03	2.	9715	9e-07	-1.51967e	-01	
4	p3		0.00000e	+00	fixe	d						
5	p4		1.04141e	+04	1.8448	5e+03	з.	3030	6e-06	1.00640e	-02	
6	p5		7.55555e	+00	9.8704	1e-02	7.	6813	1e-03	-5.14074e	-04	
7	p6		2.78794e	+02	2.5097	3e+02	1.	6056	4e-05	7.45705e	-05	
8	p7		2.31367e	-03	3.8460	6e-04	з.	6725	5e-07	-2.59769e	+00	
(Int_	t) 0					20						

TOTAL X-SECTION

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LAYOUT FOR THE E-144 EXPERIMENT

Photons produced at IP1 proceed down their own beamline through the converter foil and the tracking spectrometer





CCD image sensors: pixel size 22.5*22.5 um

e-/e+ tracks were reconstructed using the 3 back planes of CCD's. All triplets of points from the back CCD planes of a given arm were tested to see if they fit a line intercepting a region near the center of the spectrometer magnet. This set of candidate tracks included many "fake" tracks from thermal noise, and combinatoric background of points from different particles.

No attempt was made to use the CCDs in the front plane of the spectrometer in this mode, since the high number of hits led to significant ambiguity in the projection from the back planes to the front.

THE CLASSICAL BETHE-HEITLER PAIR SPECTRUM

The classical Bethe-Heitler formula is currently used: H.Bethe, W.Heitler, Proc.Roy.Soc.A146 (34)83

$$\Phi (\mathbf{E}_0) d\mathbf{E}_0 = \frac{\mathbf{Z}^2}{137} \left(\frac{e^2}{mc^2} \right)^2 4 \frac{\mathbf{E}_{0+}^2 \mathbf{E}_{+}^2 + \frac{2}{3} \mathbf{E}_0 \mathbf{E}_{+}}{(h\nu)^3} d\mathbf{E}_0 \left(\log \frac{2\mathbf{E}_0 \mathbf{E}_{+}}{h\nu mc^2} - \frac{1}{2} \right).$$

energies involved are large compared with mc²



The idea - to check if any photon spectrum could be restored if we have the classical BH distribution and characteristic shapes of photon spectrum **TESTING: EXPONENTIAL**



$\int \sigma(E\gamma, Ee)g(E\gamma, p1, p2)dE\gamma$

fitting allows finding the parameters with high precision

****	******	*******	***********		
Minimizer is	s Minuit	/ Migrad			
Chi2		=	8.52694e-11		
NDf		=	98		
Edm		=	1.70646e-10		
NCalls		=	167		
pØ		=	105	+/-	1.72634e-07
p1		=	0.3	+/-	1.73966e-10

TESTING: COMPTON-LIKE



$\int \sigma(E\gamma, Ee)g(E\gamma, p1, p2)dE\gamma$

fitting allows finding the parameters quite well :

*******	**	******	ck	******	*****		
Minimizer	is	Minuit	/	Migrad	Improved		
Chi2				=	5.92197e-07		
NDf				=	97		
Edm				=	1.27179e-06		
NCalls				=	342		
p0				=	1.9899	+/-	0.00109921
p1				=	1.99569	+/-	0.000468708
p2				=	7.99435	+/-	0.000639219
A.A							

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PHOTON SPECTRA VS LASER INTENSITIES

plot from Anthony



TOTAL X-SECTION

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$$\frac{1 \le Z \le 100}{E_{\gamma} \in [1.5 \text{ MeV}, 100 \text{ GeV}]} \quad \left\} \quad \frac{\Delta \sigma}{\sigma} \le 5\% \text{ with a mean value of} \approx 2.2\%$$





FORWARD PHOTONS IN GEANT4



TESTING: COMPTON-LIKE Ee= $\int \sigma(E\gamma, Ee)g(E\gamma)dE\gamma$



$\int \sigma(E\gamma, Ee)g(E\gamma, p1, p2)dE\gamma$

fitting allows finding the parameters quite well :

FCN=1309.19 FROM	HESSE STAT	TUS=0K	39 CALLS	442 T0TAL
	EDM=9.77144	le-09 STRATE	GY= 1 ERROR	MATRIX ACCURATE
EXT PARAMETER			STEP	FIRST
NO. NAME	VALUE	ERROR	SIZE DER	IVATIVE
1 p0	0.00000e+00	fixed		
2 p1	3.71863e-05	1.18274e-07	7.47299e-08 -9.	55179e+00
3 p2	5.00872e+00	2.75457e-03	2.31805e-06 2.	53148e-02
4 p3	0.00000e+00	fixed		
5 p4	1.02419e-07	7.39607e-09	7.48765e-08** at	limit **
6 p5	7.38500e+00	8.55688e-02	1.42343e-05 -1.	88485e-03
7 p6	2.16581e-09	1.14383e-09	3.41734e-06 8.	55195e-03

TESTING: COMPTON-LIKE



******	***	******			
Minimizer is Minuit / Migra	ad]	Improved			
Chi2 =	=	6.09809e-07			
NDf =	=	96			
Edm =	=	1.21973e-06			
NCalls =	=	404			
p0 =	=	1.20003e-08	+/-	6.73267e-14	
p1 =	=	2.50003	+/-	5.02686e-06	
p2 =	=	1.00002e-08	+/-	5.23111e-14	
p3 =	=	0			(fixed)
p4 =	=	9.99282e-11	+/-	1.04159e-14	