Polarisation in Compton Sources

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- Main output parameters
  - yield (current) of positrons,
  - polarisation degree
- determined with
  1. spectra of laser photons and electrons which scatter off the photons
  2. preselection (collimation) of gammas
  3. thickness of conversion target
  4. material of conversion target
  5. postselection – selection of subspectra of polarised positrons.

A priori reduction of number of parameters

- Two parameters from the list considered as given
  1. max energy of gammas limited by available lasers and energy of electrons, etc.;
  4. material of the target (considered as a given).
- Remaining 3 parameters (3D space)
  2. preselection (collimation)
  3. thickness of conversion target
  5. postselection – selection of subspectra of polarised positrons

Analytical Model

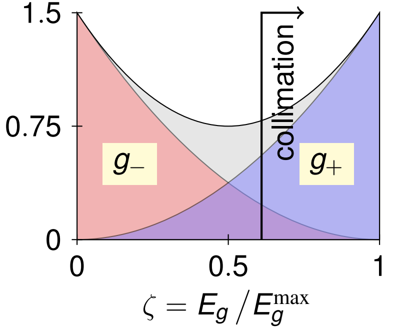
Make things as simple as possible, but not simpler (Albert Einstein)

- Positron output the target is the result of subsequent transformations of the laser photon.
- The gamma and positron ensembles composed from full–polarized subensembles.

Transformations described by:

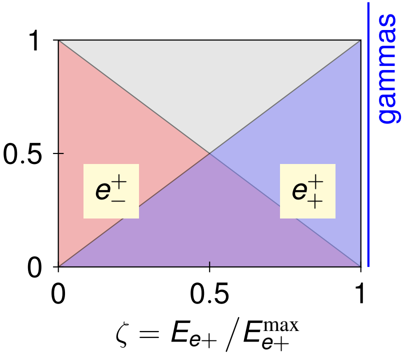
1. Laser photons $\to$ gammas: impulse response (Green's function)
2. Preselection: discards gammas with energies lower than E_{pre}
3. Gamma $\to$ positron conversion: impulse response
4. Positron spectra evolution on the way to the target output: impulse response
5. Postselection discards e+ with energies lower than E_{post}

‘Acceleration’ of Laser Photons and Preselection
(Preselection = Collimation of gammas)



Dirac’s delta distribution of the laser photons split and transformed into two subdistributions.

- Scattered off gammas nonpolarised in average.
- Preselection makes them polarised and reduces power load into the target.



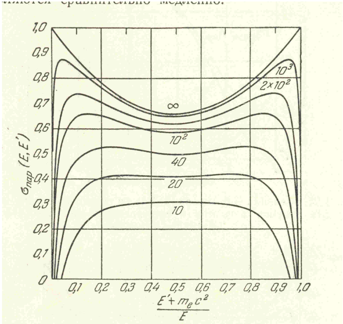
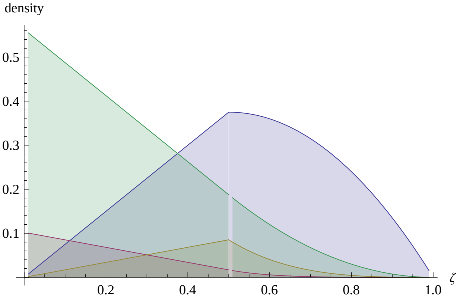


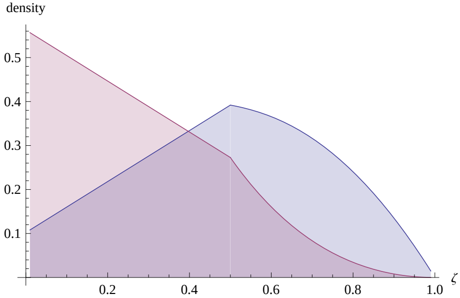
Рис. 1.23. Дифференциальное сечение образования пар в свинце в зависимости от энергии частиц пары для различных энергий налетающих γ-квантов в естественных единицах.

Each gamma produces two subensembles of positrons.

Convolution of two spectra of positrons with two spectra of gammas results in four subensembles of positrons. (Normalization: per gamma = scattered off laser photon.)



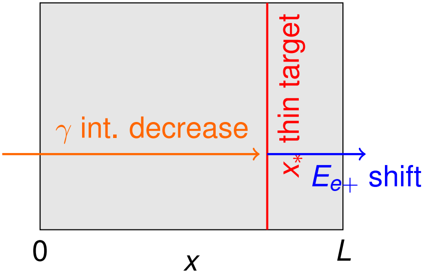
Four spectra for preselection 0.5



Positive and negative cumulated spectra for preselection 0.5

Zero total polarisation of positrons for any preselection

Thick–Target Transformations



- Intensity of gammas decreases exponentially from front-end of target:

$$N_{\mathrm{g}}(x) = N_{\mathrm{g}}(0)\exp(-\kappa x)$$

- Energy of positrons decreases linearly on pass to output surface:

$$D_{\mathrm{out}}(E) = D_x(E + \lambda(L - x))$$

with L the target thickness.

Results of Model Study

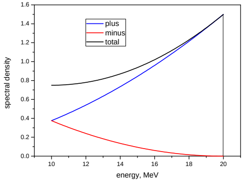
- Polarisation and yield of positrons are determined by the postselection E_{pos}
- Preselection has no effect on the polarisation and yield if $E_{\mathrm{pre}} \leq E_{\mathrm{pos}}$ (but reduces power load into the target)
- For given
  - maximum energy of gammas
  - material of the conversion target
  - energy of postselection (which determines the polarisation)

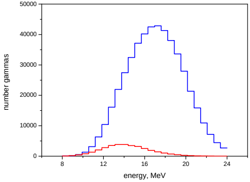
  there exists an optimal thickness of the target which maximize the yield.

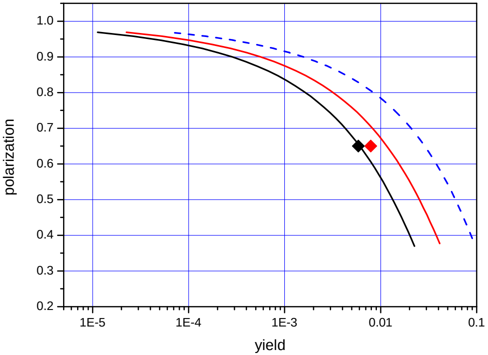
Validation of the Model

Andreas Schalicke, Andriy Ushakov, Sabine Riemann

Input: Spectra from simulations: $E_{\text{gamma}}^{\text{max}} = 20\,\text{MeV}$, Ti and W







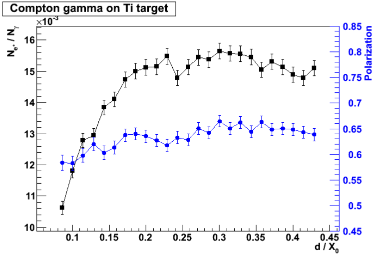
Input spectra

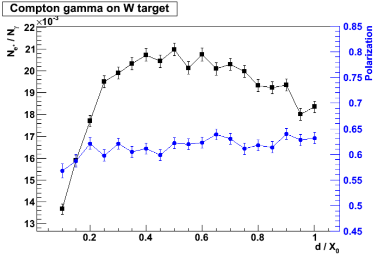
Envelopes for Ti and W targets + results of simulations

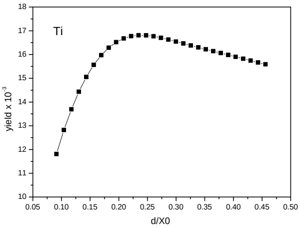
Validation of the Model. More Detail

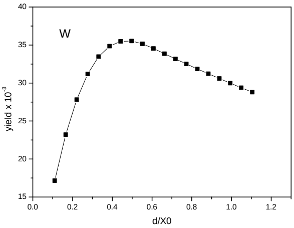
Andreas Schalicke, Andriy Ushakov, Sabine Riemann

Dependence on the target thickness, Ti and W





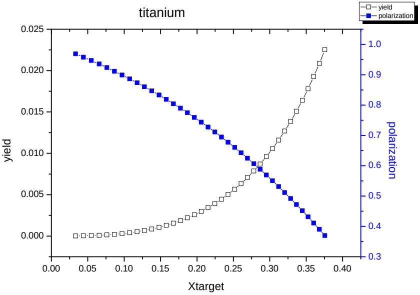


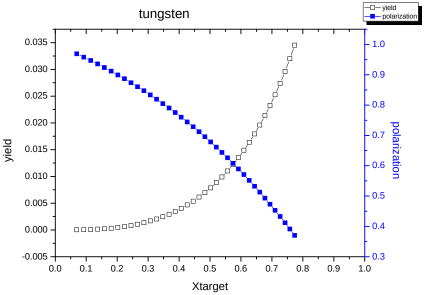


Remarks on the Model

- Model seemed not very physical at lower end of the energy range, but the sources intended to work at higher energy cutoff, $E_{\mathrm{post}} \geq 1/2$
- Estimations show decrease of attainable high polarisation because of wider real gamma spectrum as compared with model's: e.g. at $E_{\mathrm{post}} = 0.75$, tungsten, yield = 0.12% polarisation decreases from 0.85 to 0.76 due to electron bunch energy spread 5%.

Higher the polarisation thinner the target, smaller the yield





Summary and Outlook

- Polarisation degree of about 0.7–0.8 attainable at yield ≈ 0.001
- Higher the polarisation:
  - lower the yield
  - higher the quality of positron beam (energy spread, emittance)
  - thinner the conversion target, lower the power load
- High polarisation requires electron bunches with small energy spread

Study to do

- Validate the model at high E_{post}
- Consider ways to decrease positron's energy loss in the conversion target (the rod target?)