Optimal $\gamma \to e^+$ Conversion Target for Compton Sources

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Thanks to: V. Lapko, N. Shulga, S. Riemann, A. Schaelicke,
and the entire PosiPol collaboration

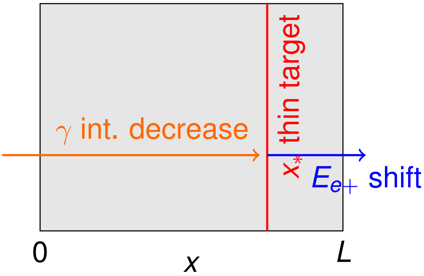
NSC KIPT, Ukraine

ALCPG11, Eugene, 21/03/2011

Outline

Fates of Gammas and Positrons

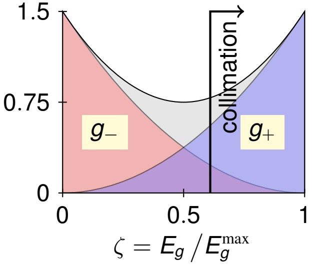
L target thickness, κ positron production, λ positron losses

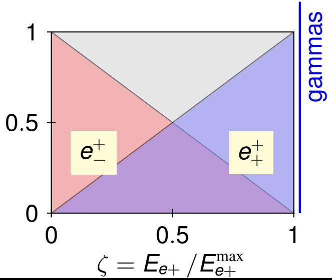


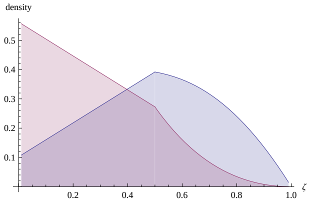
- Balance of gammas
  - $\exp(-\kappa L)$ gammas pass through target
  - $1 - \exp(-\kappa L)$ gammas convert into positron–electron pairs
- Balance of positrons
  - Total production $1 - \exp(-\kappa L)$
  - $(1 + \lambda/\kappa)\,[1 - \exp(-\kappa L)] - \lambda L$ escape from target
  - Fraction with $E_{\mathrm{ac}} \le E \le E_{\mathrm{max}}$ accepted

For each spectrum of gammas, the target material (κ, λ), and theshold accepted positrons energy E_{ac} there exists the optimal target thickness with maximal yield of positrons

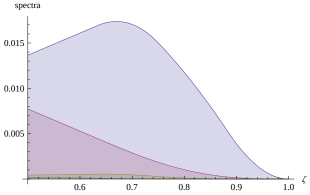
Transformation of Laser Photons into Positrons







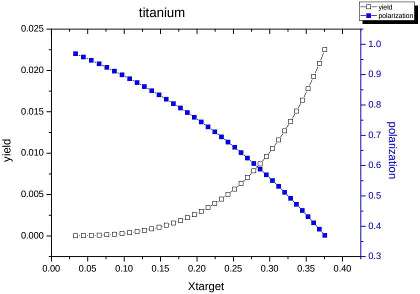
Source spectra for preselection 0.5

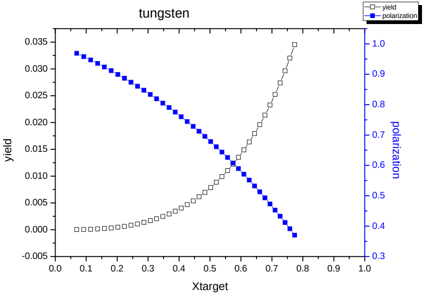


Thick–target spectra for preselection 0.75

Optimal Target Thickness

Higher the polarization thinner the target, smaller the yield

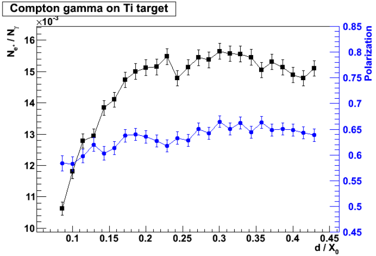


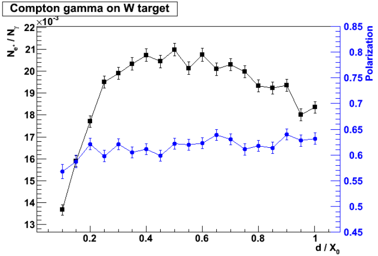


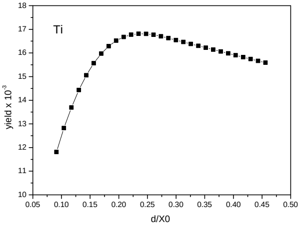
Compton spectra, $E_\gamma^{\max} = 20\,\mathrm{MeV}$

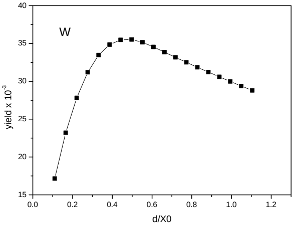
Validation of the Model (A. Schalicke, S. Riemann)

Dependence on the target thickness, Ti and W

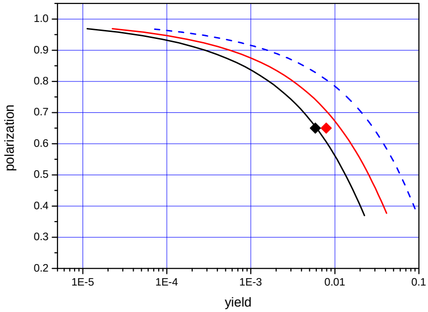








Maximal yield and polarization



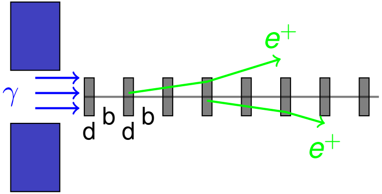
Envelopes for Ti and W targets (optimal thickness)

Dash curve: a rod target

- Polarization degree up to 0.7–0.8 attainable at yield $\geq$ 0.001 per scattered laser photon
- Higher the polarization:
  - lower the yield
  - higher the quality of positron beam (smaller energy spread, emittance)
  - thinner the conversion target, lower the power load
- High–Z material more effective (T. Omori, 2007)

Rod Conversion Target

Idea: V.Lapko, N.Shulga (2007): *positrons path shorter than gammas*



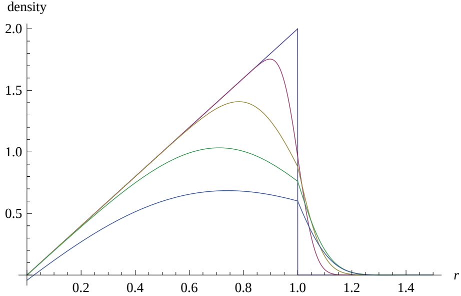
b, d – *spacing and disk thickness (in units of disk radius)*

- Path length of positrons much shorter than of gammas
- Increased yield of positrons due to reduced losses
- Decreased target heat load
- Longer target (in rad. length) may be employed

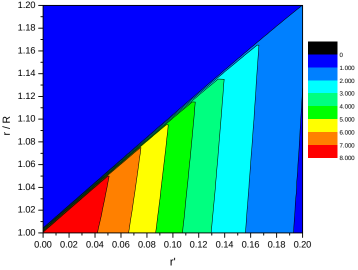
Density and Emittance

Disk spacing $b = 1$, initial angular spread $r'_0 = 0.1$)

Cylindrical coordinate frame



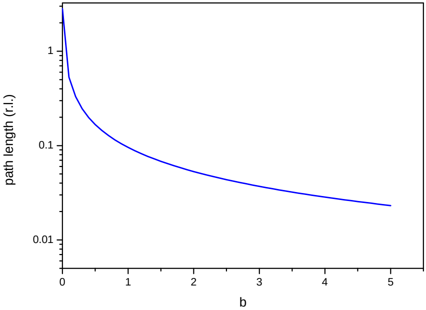
Density profile after source and consecutive scattering disks



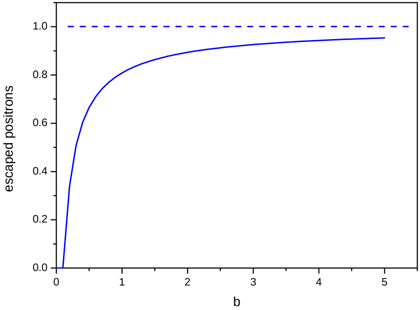
Halo distribution over the radial phase plane after first disk

Stretching of Rod

$E_{\rm positron} = 15\,\text{MeV}$, $r = 1$ r.l., $d = 0.01$ r.l.



Path length of escaped e^+ vs. spacing



Ratio of escaped e^+ vs. spacing

Scaling (not accounted for energy decrease): $b\sqrt{\langle r'^2\rangle} \sim b\sqrt{d}/\gamma$ (d in r.l. units) – increase in energy of positrons is compensated with increase of disk spacing.

A Rod Conversion Target – Example

$E_{\gamma}^{(\max)} = 20\,\text{MeV}\ , \quad E_{\text{pos}} = (10\dots20)\,\text{MeV}$

- Rod parameters
  - material: tungsten
  - total thickness: 3 r.l. (flat target opt. 0.52 r.l.)
  - radius: 1 r.l. (3.3 mm)
  - disk thickness: 0.01 r.l. (33 μm)
  - spacing: $b = 0.3, 1$ (length 1 m, 3 m)
- Positrons
  - produced per scattered gamma: 0.26
  - produced per income gamma: 0.52
  - escaped per scattered: 0.07,0.13 for $b = 0.3, 1$ resp (comp. 0.01 for flat target)
  - instant emittance (source): $\approx 10\,\mu$m rad ($b = 1$)
  - polarization: 0.6

Optimal Flat Target

Compton sources

- Optimal target thickness scaled as $E_{\max}$ of gammas
- Polarization degree of positrons determined by postselection
- Higher the polarization:
  - thinner the optimal target
  - smaller the positron intensity
  - higher the positron beam quality – smaller emittance and energy spread

Polarization degree up to 0.7–0.8 attainable at yield $\geq$ 0.001 per scattered laser photon in Compton sources

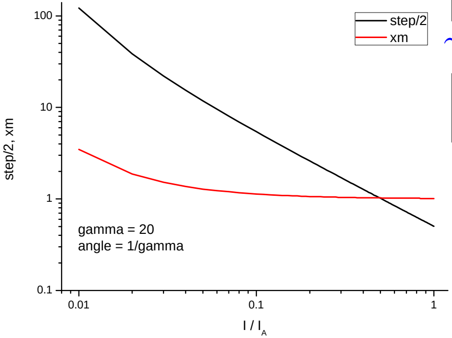
Rod Target

- The rod converter is more effective than the optimal target
- It has no optimal integral thickness and length:
  the longer the more effective
- Dimensions of the sliced rod depend of the experimental setup
- Collection of positrons is of prime importance

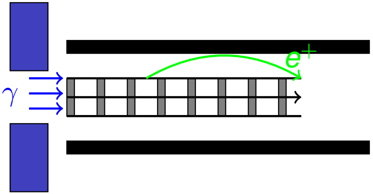
The rod convertor might be applied in the sources other than Comptons: conventional, hybrid, ...

Collection of Positrons

Option – current along rod *(imitation of "lithium lens")*



Max off–axis deviation and half-step vs. current ($I_A = 17\,\text{kA}$)



- Trajectory of positron determined by
  - rod current, and emitting angle
  - energy of positrons,
  - and emitting angle.
- Trajectory of positron scaled as rod radius

Thank You

Thank you for your attention and patience