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A Laser Cavity for Polarised Positron Production?[1]

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Abstract

Polarised positrons can be efficiently produced by pair production from polarised photons, where the photons might stem from Compton scattering of a polarised laser off a high energy electron beam. In this talk some ideas are presented how this may be done in a cost efficient way using a high finesse laser cavity and an electron storage ring.

[1]Talk presented at the positron polarisation workshop Darebury, April 2005

A Laser Cavity for Polarised Positron Production?

Klaus Mönig

(With help from J. Urakawa and others)

Introduction

Up to now two ideas to produce polarised positrons

1. helical undulator in the high energy beam
2. Compton scattering of a low energy electron beam with a CO_2 laser

Both schemes produce polarised photons which are converted into polarised positrons in a thin target

Advantage undulator

- seems technically easier
- small power cost

Advantage Compton scattering

- independent of electron arm
- no additional energy spread

Basics Compton scattering

Basic variable (scaled squared $e\gamma$ cms energy)

$$x = \frac{4E_0\omega_0}{m^2c^4}\cos^2\frac{\alpha}{2} \simeq 0.019\left[\frac{E_0}{\mathrm{GeV}}\right]\left[\frac{\mu m}{\lambda}\right]$$

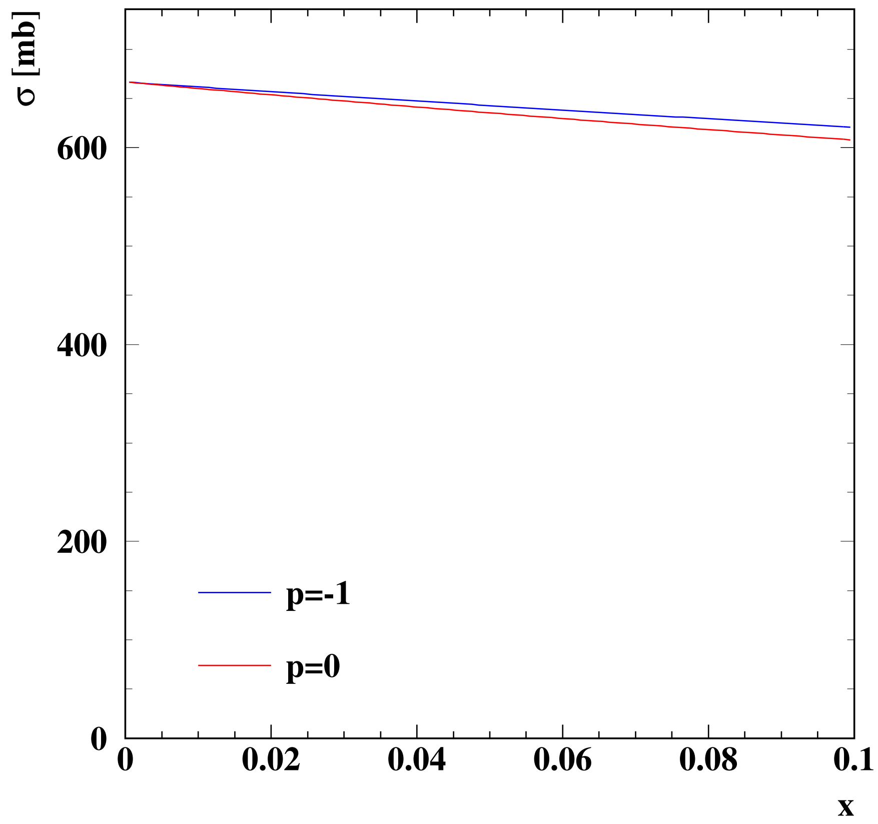
Maximum scattered photon energy $E_\gamma < x/(x+1)E_b$

Relevant range for positron polarisation:

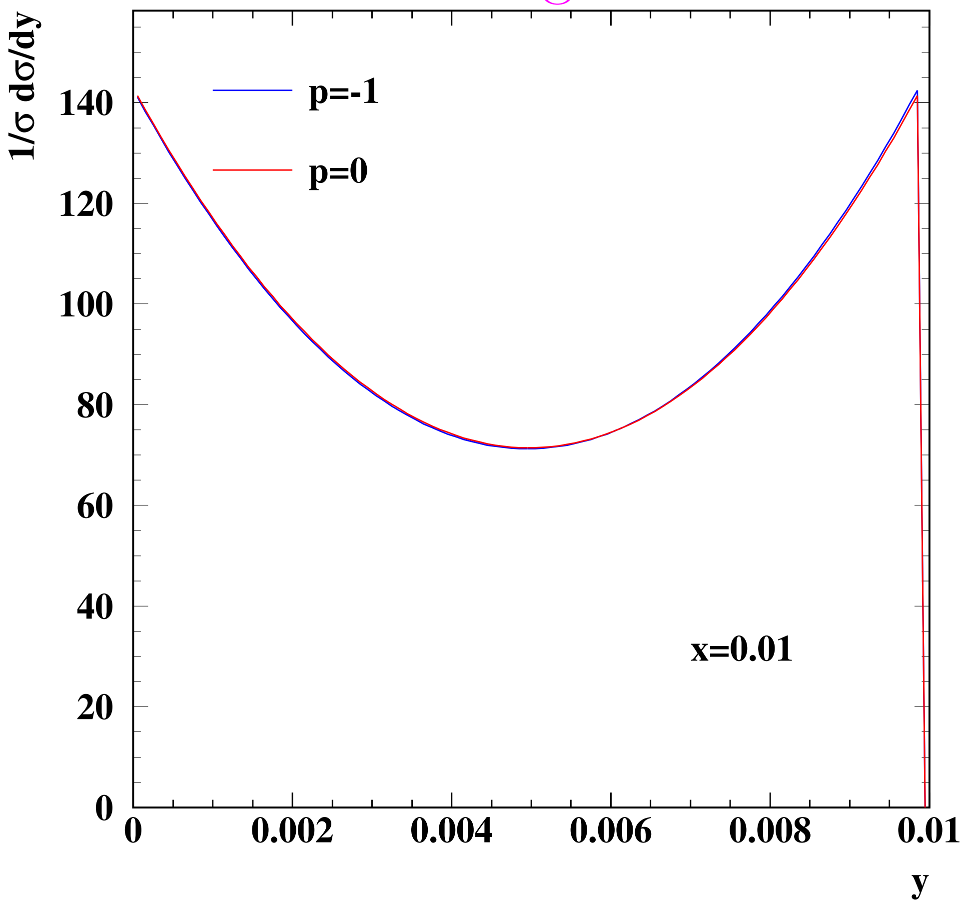
$$x = \mathcal{O}(0.01)$$

Cross section depends on product $\mathcal{P}_e\lambda_\gamma$

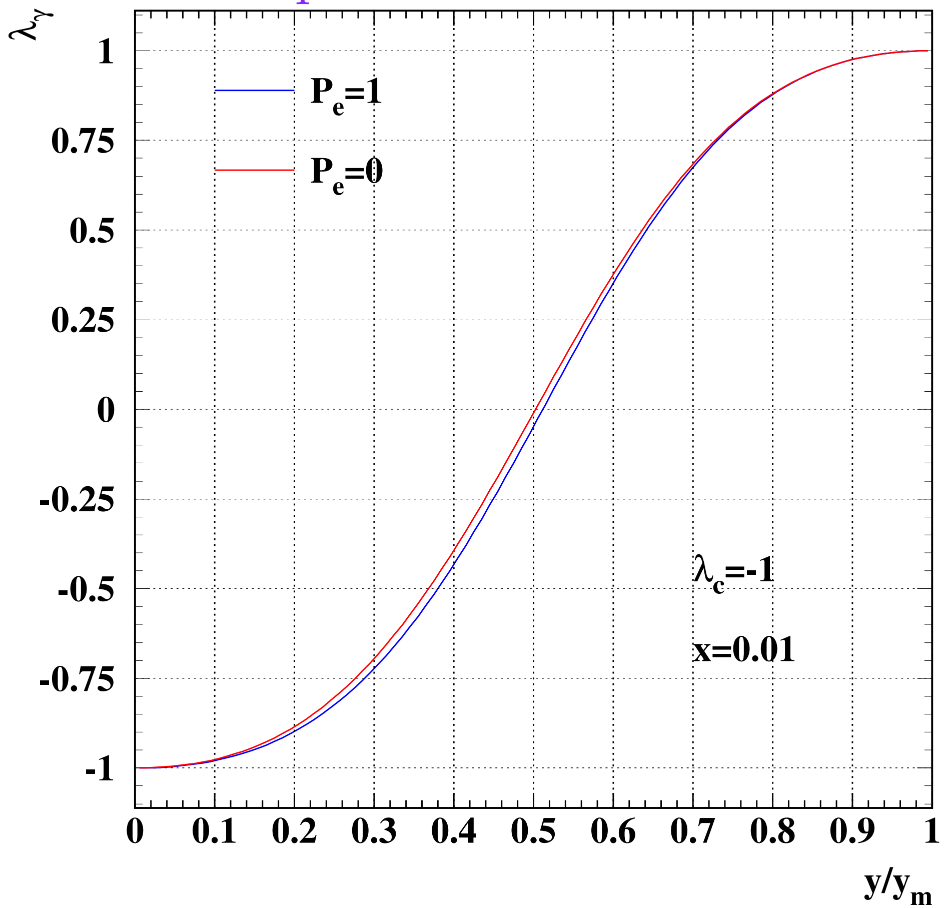
In the relevant range little dependence on x and polarisation



Photon energy peaked at high and low energies



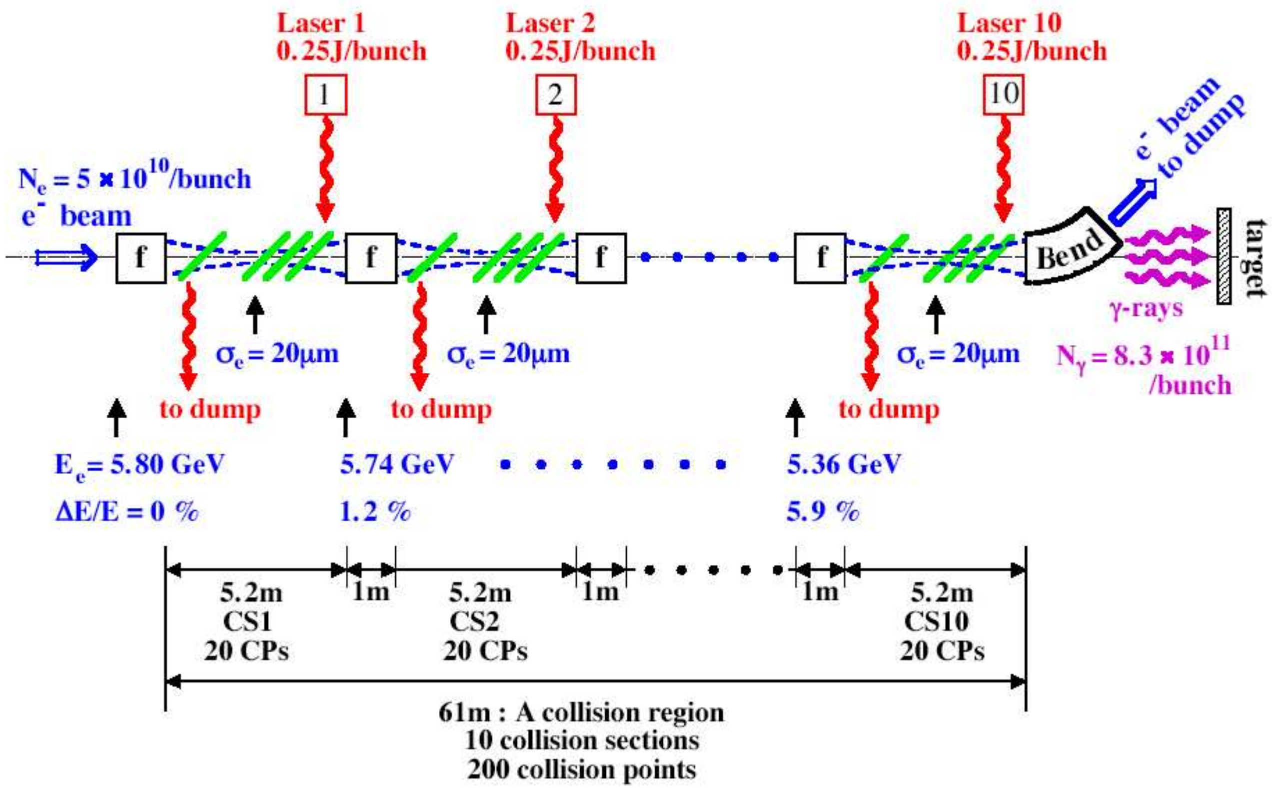
Photon polarisation large for polarised laser



- Selection of high photon energies results in high polarisation
- This polarisation is transfered to the positron in the pair-production if high energy positrons are selected

The Japanese concept

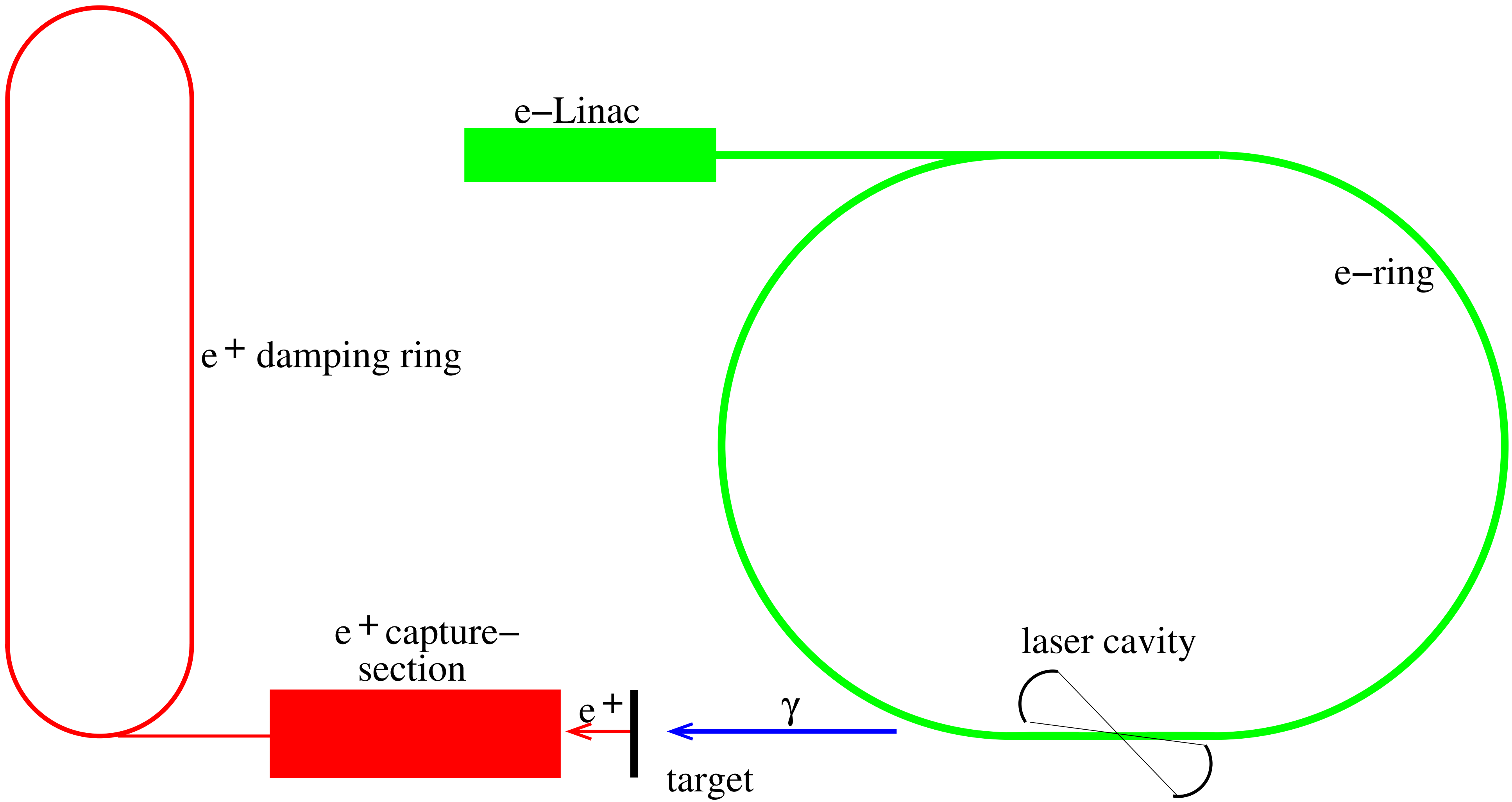
- electron beam with $E_b = 5.8\,\text{GeV}$ from a linac
- CO_2 laser ($\lambda = 10.6\mu\text{m}$) ➟ $x = 0.01$, $E_\gamma < 50\,\text{MeV}$
- need about 70 γs/high energy positron
- realised with 10 lasers and 20 conversion points each



Improved Compton concept?

- In the damping ring the e^+ are stored with a much smaller distance than the ILC bunch spacing
  (Assume 3 ns as proposed by KEK study)
  $\Rightarrow$ can use this bunch spacing for positron production
- Propose to store the electrons in a storage ring with this bunch spacing
- Collide them in one (or few) points with a laser cavity
  - Use Nd:Yag or similar laser ($\lambda = 1.06\mu$m)
  - 10 times smaller luminosity than CO_2 laser for same parameters
  - however much easier to build a cavity and smaller spotsizes possible
  - at KEK a prototype with 5μm spotsize and 3° crossing angle will be built (J. Urakawa)

The oncept for positron generation



A possible storage ring (J. Urakawa)

1.38GeV Electron Storage Ring with full coupling operation:

- emittance $\epsilon = 0.3 \cdot 10^{-9}$ m
- bunch length 3 mm,
- 714 MHz RF acceleration
- two 50 m straight line for γ-generation and beam injection/extraction
- $25 \times 10\mu\text{m}^2$ beam sizes at IPs
- 200 bunches/train $\times$ 2 trains = 400 bunches/ring
- bunch spacing = 2.8 ns, train gap = 60 ns
- total: $199 \times 2.8\,\text{ns} \times 2 + 120\,\text{ns} = 1234.4\,\text{ns} \Rightarrow$ circumference ≈ 370 m
- Bunch charge 3.0 nC, Total circulating charge=1200 nC, Current 1.78 A.

Laser cavity:

- pulse energy 0.1 J
- waist $10 \times 10\mu\text{m}^2$
- pulse length 0.9 mm
- crossing angle 5°

- Maximum energy loss of e^-: 2.5%, should be ok
- Electron conversion probability $\sim 0.2\%$/crossing
- Time between trains $\sim 200\,\mathrm{ms}$
  $\Rightarrow$ assume I can collect positrons for $\sim 100\,\mathrm{ms}$
- Generate $1.3 \cdot 10^{15}$ photons in this time
- With an efficiency $\gamma \rightarrow$ captured e^+ of 1/70 (Omori et al.) need $3.9 \cdot 10^{15}$ photons per ILC train
- This requires 3 laser cavities
- Some further optimisation still possible

Problems with this scheme

How long can we keep the scattered electrons in the ring?

- The bandwidth allows for one maximum or two "average" scatters
- How many turns do we need until the electron energy is recovered?
- Can we use dispersion effects to protect the low energy electrons?
- We need a low emittance gun to fill the electron storage ring

Can we fill the positron damping ring in this mode?

- The positron emittance at the damping ring entrance is very large
- There might not be enough phase space available to fill the positrons on top of the existing bunch
- Can we use some pre-cooling?

What about radiation damage on mirrors?

- Radiation on mirror $0.05\,\mathrm{J/cm^2}$ per pulse and per Joule pulse energy for mirror distance of 1 m from IP
- For a single pulse this is far below the critical value of $2.5\,\mathrm{J/cm^2}$ for 2 ps laser pulses
- However I don't know about data for high repetition rates

Conclusions

- The ILC time structure seems well suited for a polarised positron source using Compton scattering and a laser cavity
- However some important problems still need to be solved
- We need the help of accelerator physicists to progress

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