ERL as High Intensity Mono-Energetic Gamma-Ray Sources

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U.S. DEPARTMENT OF ENERGY
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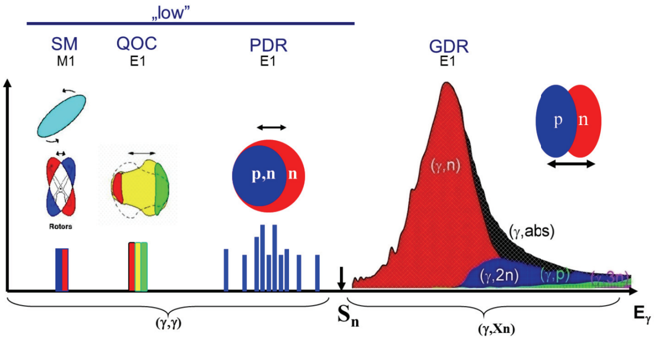
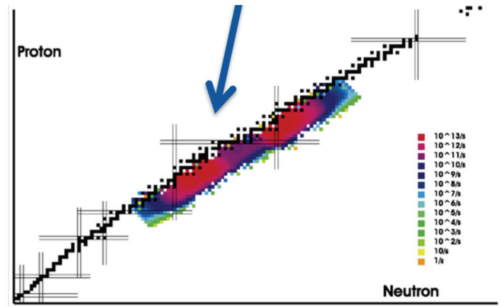
SLAC NATIONAL ACCELERATOR LABORATORY

Motivation for a Compton based source



Photofission of 238U was proposed by W. T. Diamond High energy (Chalk River) in 1999 as an alternative production method for RIB.

Smaller range & depth of products, with emphasis on neutron rich species.



~100eV or 10nm, semiconductor industry, ~kW or 10^{20} photons/sec

~10keV, Compact synchrotron source, ~10^{9}-10^{12}/shot

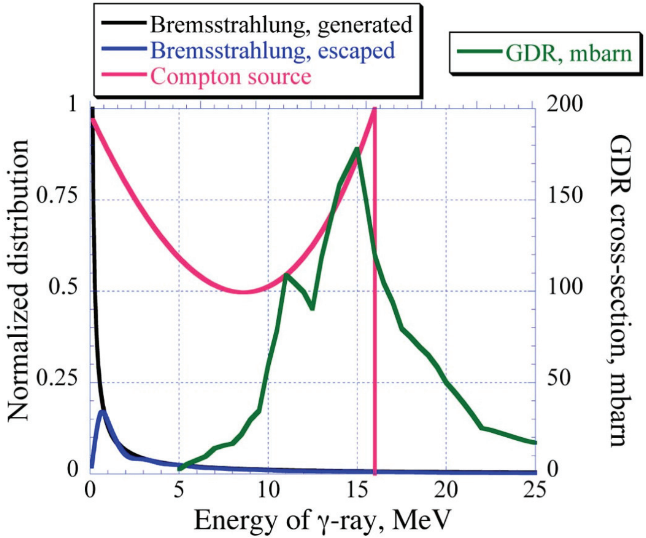
~1MeV, Security applications ~10^{12}/s

~15MeV,Isotope production, Nuclear physics ~$10^{14\text{-}16}$/s

~30-60 MeV Intense polarized positron source ~10^{16}/s

~150 MeV, Pion production ~10^{14}/s

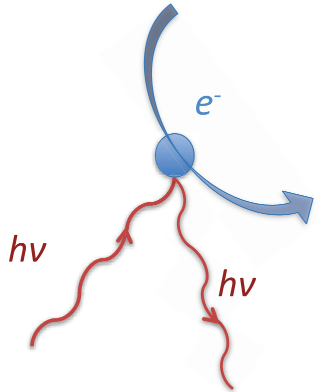
Energy distribution for resulting gamma beam



Normalized distribution go gamma photons as a function of their energy for Bremsstrahlung γ-ray source driven by a 45-MeV electron linac (for a 4-mm-thick 238U target), and Compton γ-ray source with a maximum energy of 16 MeV.

Thomson Scattering

Thomson scattering is the ***elastic*** scattering of electromagnetic radiation by a free charged particle, as described by classical electromagnetism.

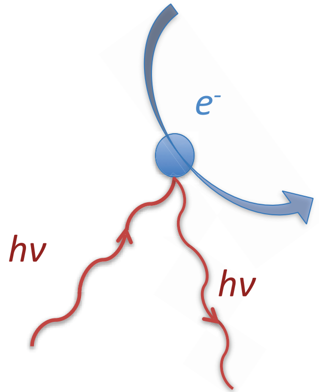


The particle kinetic energy and photon frequency are the same before and after the scattering.

This limit is valid as long as the photon energy is much less than the mass energy of the particle: $h\nu \ll mc^2$.

Compton Scattering (electron recoil)

Compton scattering is an **inelastic** scattering of a photon by a free charged particle, usually an electron. Photon (which may be an X-ray or gamma ray photon) looses energy , called the Compton effect.



Inverse Compton scattering results in a charged particle transferring part of its energy to a photon.

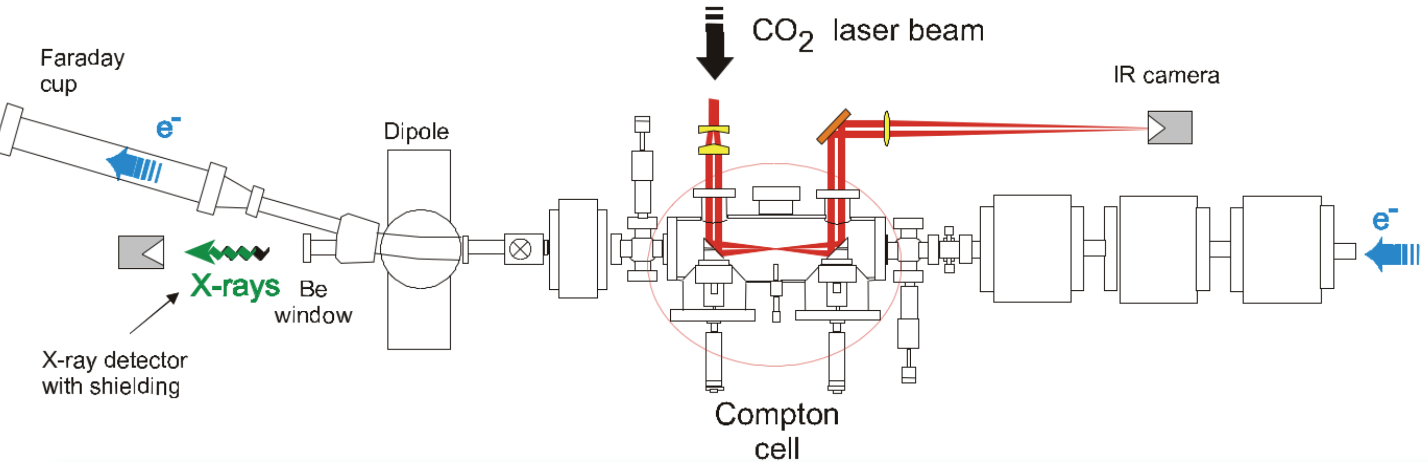
Inverse Compton Scattering

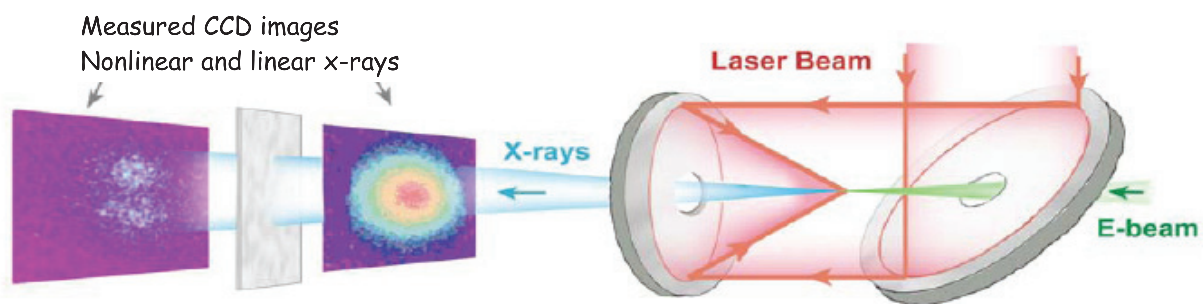
This process converts a low-energy photon to a higher energy photon by a factor of $4\gamma^2$ by scattering of a relativistic particle.

Energy gain by the photon is the opposite of the energy loss suffered during a Compton scattering event.

This name is misleading because the process is not the inverse of Compton or Thomson scattering, but is rather ordinary Compton or Thomson scattering viewed in a frame in which the electron is highly relativistic.

Layout of the ICS at BNL





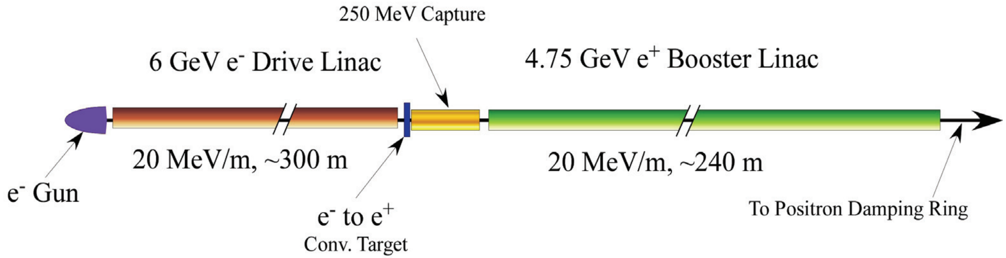
Options for the electron beam source

Efficiency of beam power conversion is proportional to γ/λ and can approach ~30% for optimized pulsed linac at 4 GeV (polarized e+ source)

Pulsed S-band:	120Hz, 300 pulses per beam, 3nC, 100µA, 20 MeV-4 GeV Beam power 2-400 kW, Power efficiency ~30% (CLIC)
SRF:	LCLS-II : 4GeV, 250pC, 1MHz, 250 µA, 1 MW, ~50% TRIUMF: 50MeV, 1.3GHz, 10mA, 0.5 MW, ~50%
Synchrotron:	~100MHz, ~1 GeV, 1A (Beam life time limits gamma beam)
ERL:	~10MHz - 1GHz, ~100mA, 20MeV-10GeV, Up to 1 GW ~95%

Polarized Positrons Source for ILC

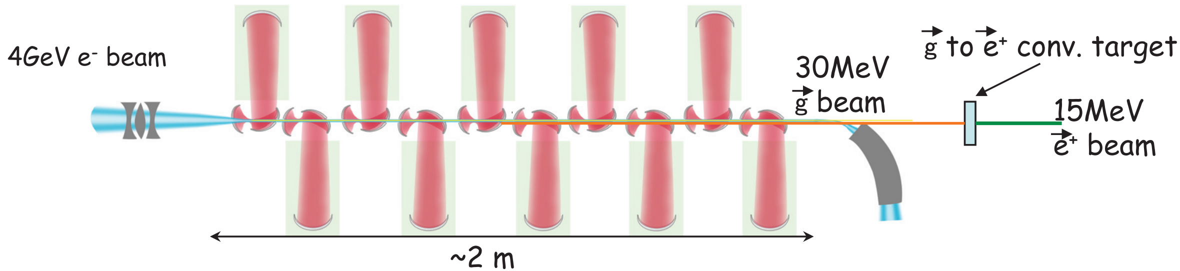
Conventional Non-Polarized Positrons:



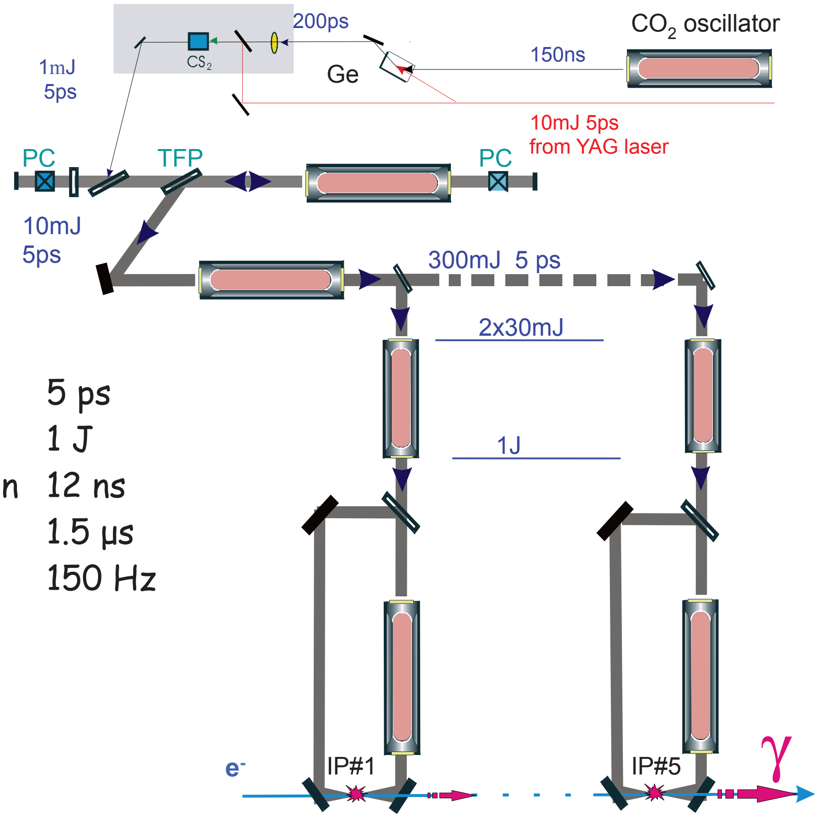
In the proposal

polarized γ-ray beam is generated in the Compton back scattering inside optical cavity of CO2 laser beam and ~4 GeV e-beam produced by linac.

The required intensities of polarized positrons are obtained due to 5 to 10 times increase of the e-beam charge (compared to non polarized case) and 5 to 10 CO2 laser system IPs.

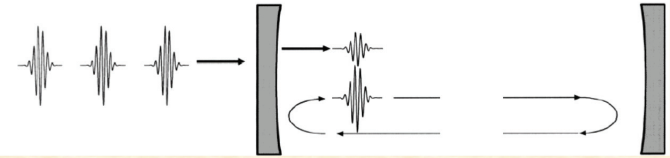


CO_2 laser system

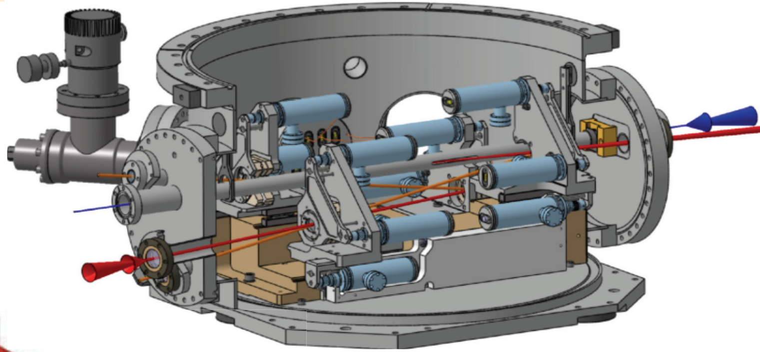


pulse length	5 ps
energy per pulse	1 J
period inside pulse train	12 ns
total train duration	1.5 μs
train repetition rate	150 Hz

Laser enhancement cavity

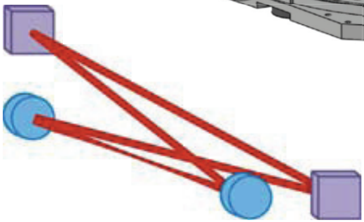


MightyLaser collaboration LAL
(CNRS and Université de Paris-Sud)



- A 4-mirrors non planar cavity is used to stack laser pulses.
- Length: 1.68m => f=178.5MHz (fATF/2)
- A non-planar geometry ensures that the laser pulses are polarised circularly.

3D (or twisted) 4M ring cavity:
stable and no astigmatism



Best power during run at ATF2 40kW locked , 0.4-1MW is foreseen

Conclusion

- ERL offer unique tool for power-efficient generation of intense beams over wide range of energies.

- Naturally solves “melting” of the conversion target at extremely high power

- Needs further development of laser enchantment cavities