High intensity gamma source for … positrons (LeHC)

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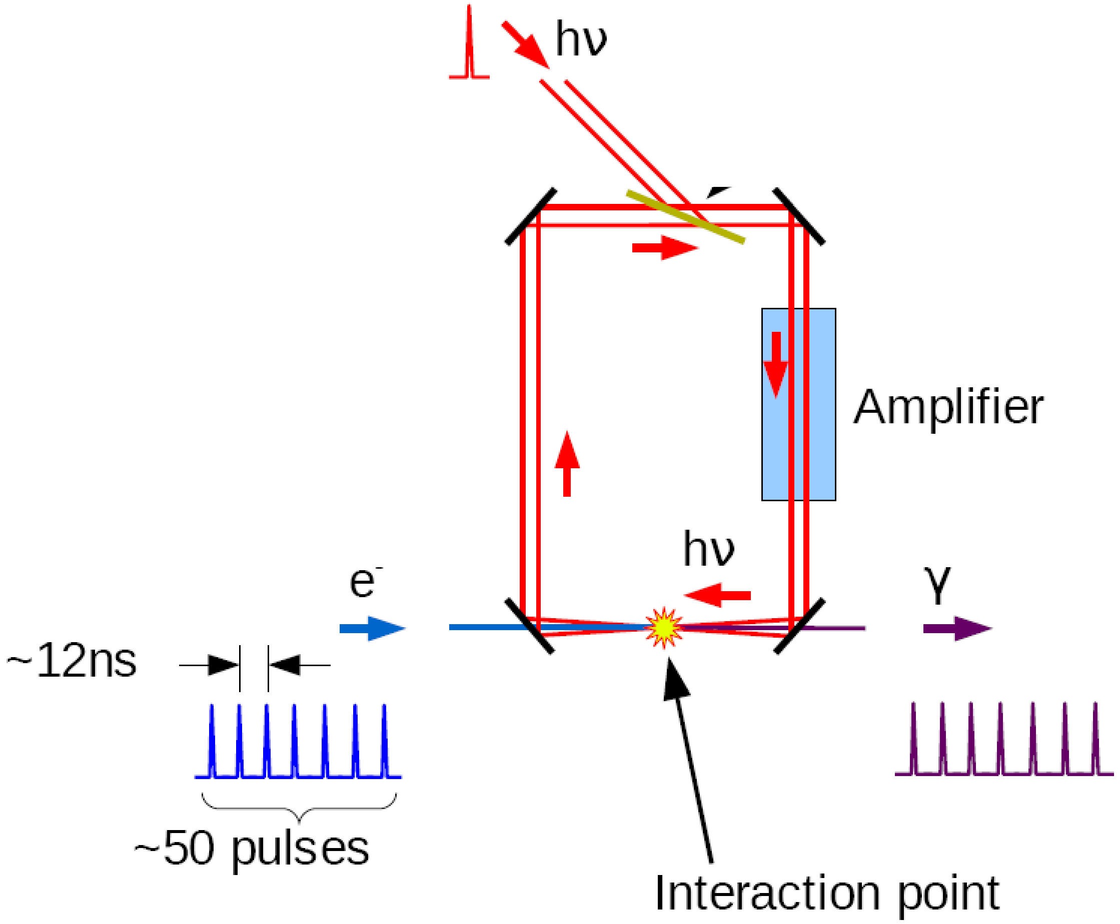
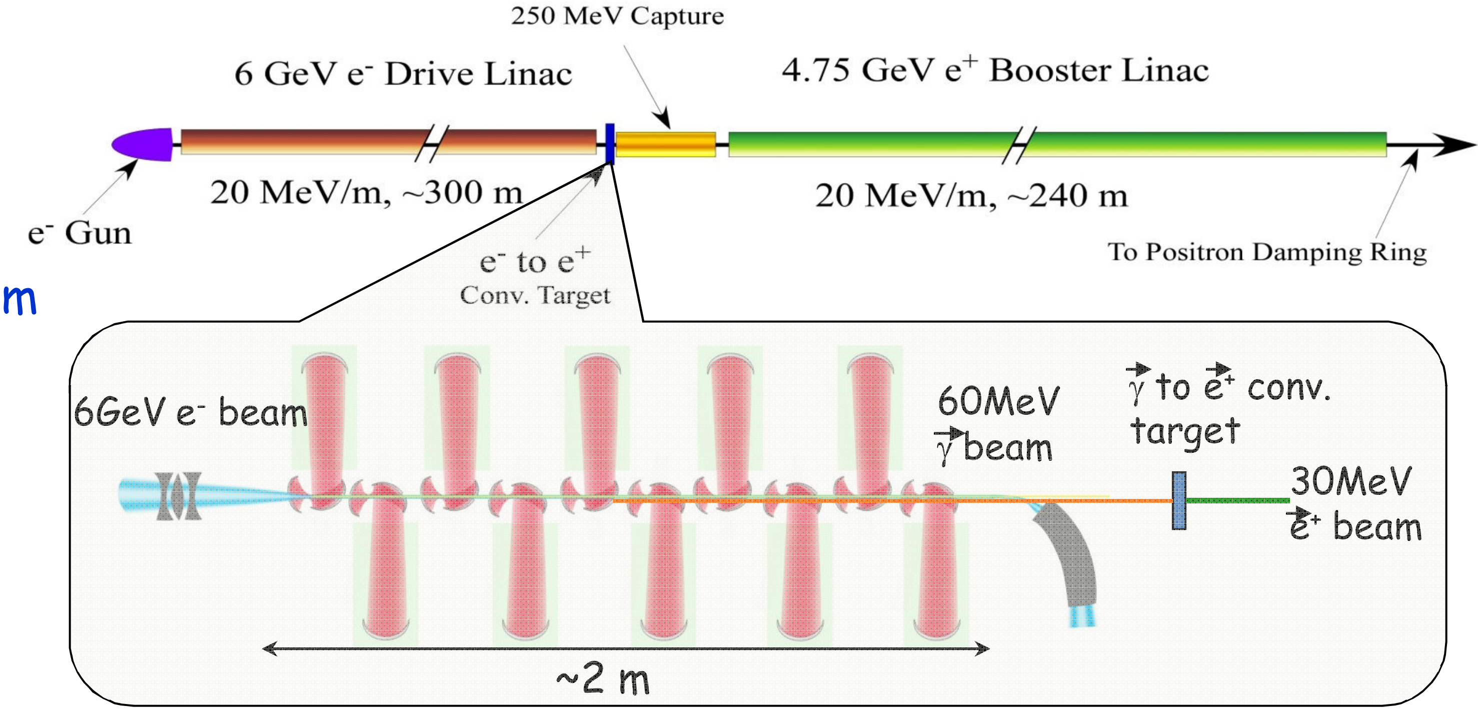
Concept of the Multi-kHz gamma source



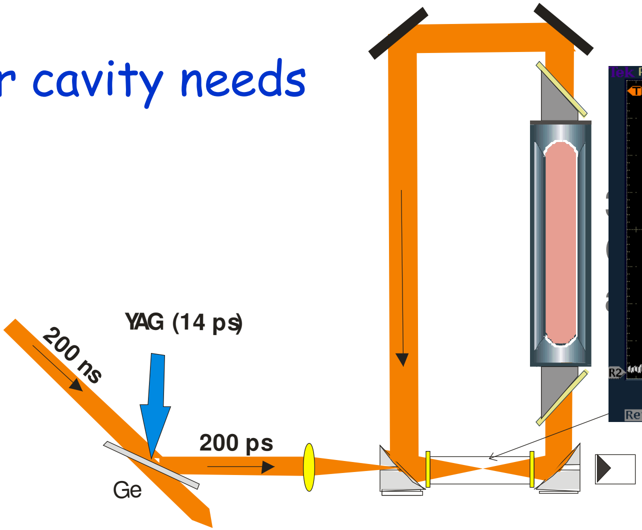
Polarized Positrons Source for ILC, CLIC, Super B

Conventional Non-Polarized Positrons:

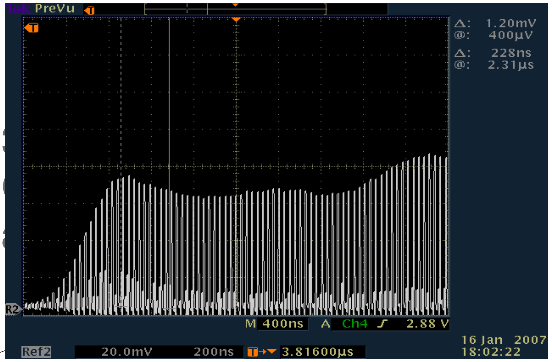


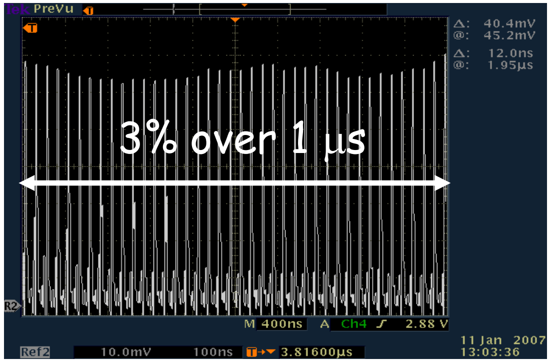
Polarized γ-ray beam is generated in the Compton back scattering inside optical cavity of CO2 laser beam and 6 GeV e-beam produced by linac.

Laser cavity needs R&D.



First tests of the laser cavity:





Simulations

Input: 5 ps, 10 μJ

Active medium: 30 cm

Gas:

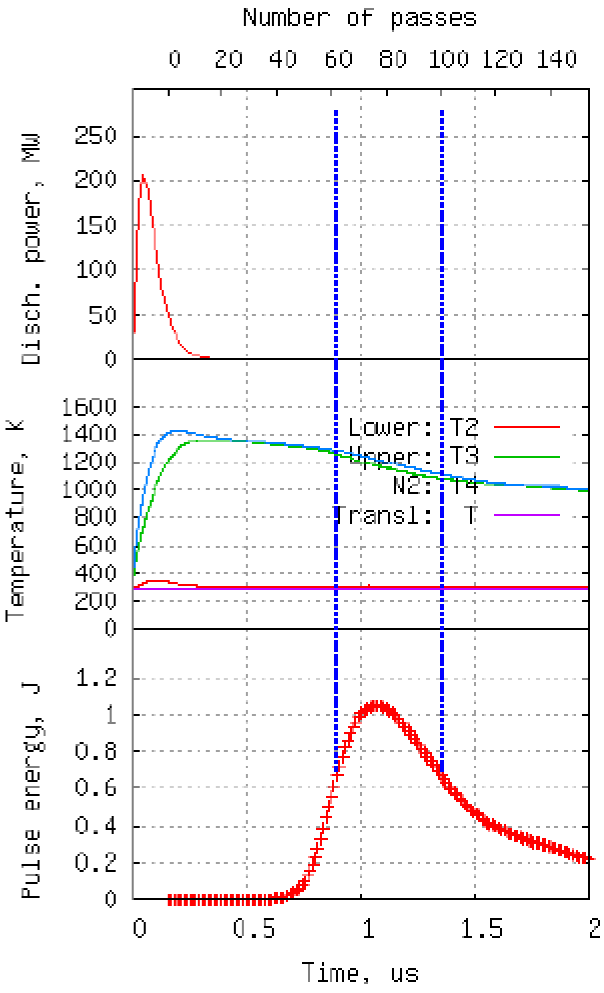
0.6:0.6:8.8 atm
(CO_2:N_2:He)

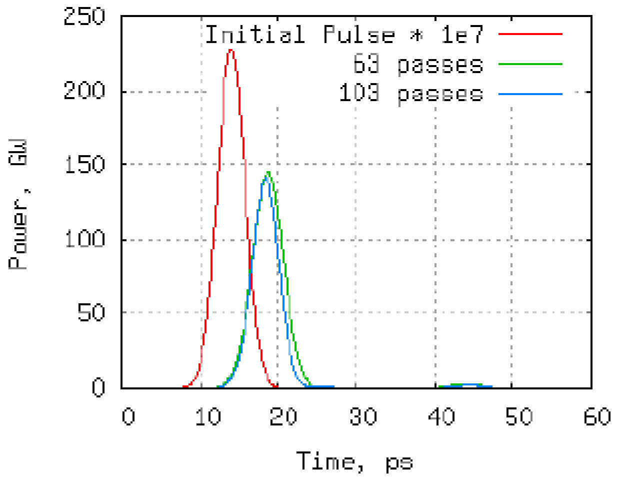
CO_2 isotopes:

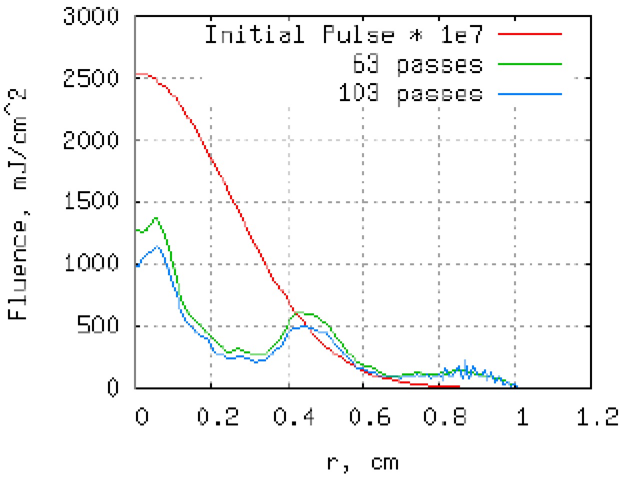
0.15:0.3:0.15 atm
(CO_2^{16} : $CO^{16}O^{18}$: CO_2^{18})

Injection: 1% reflector

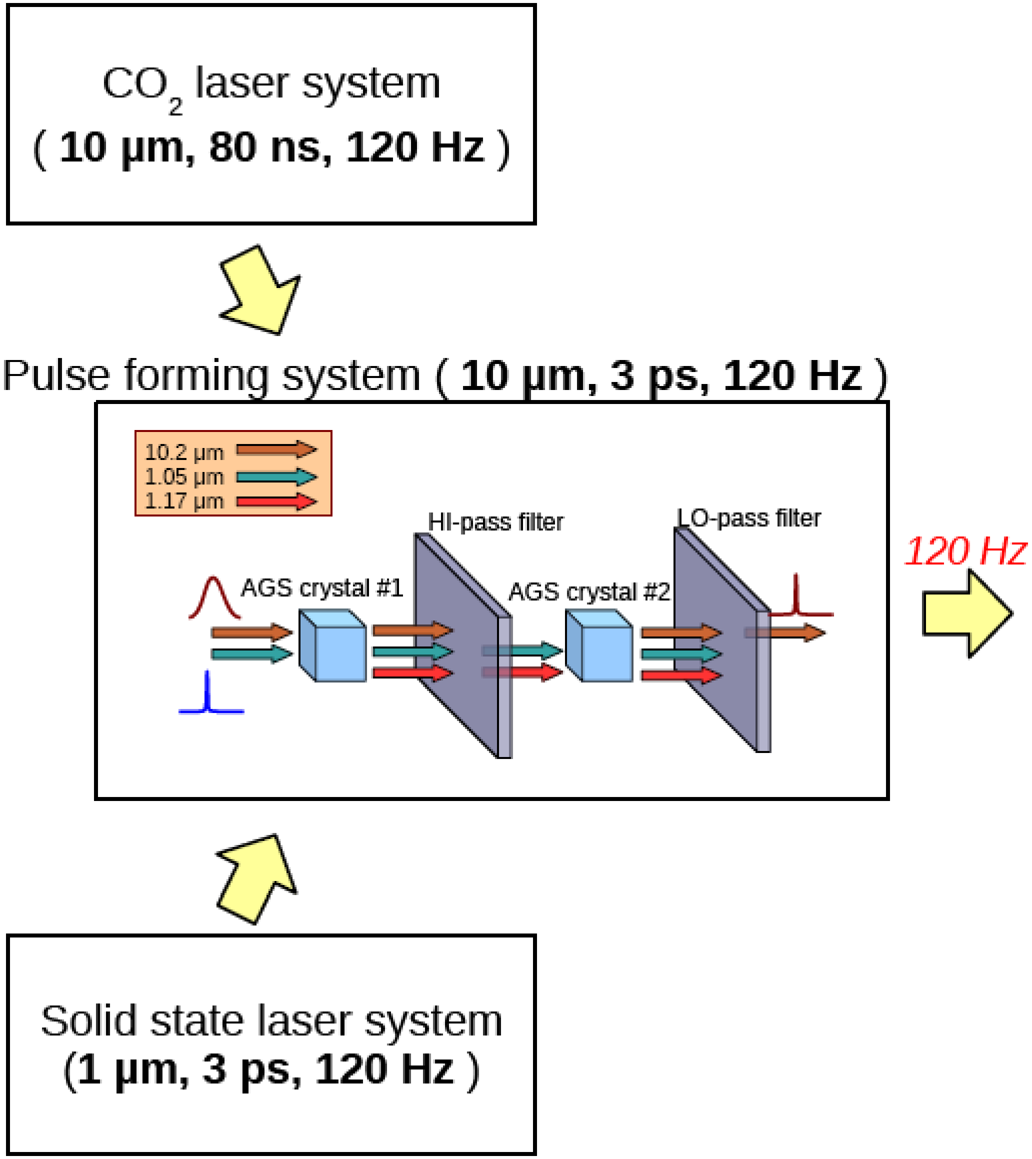
Optical losses: 5% / pass







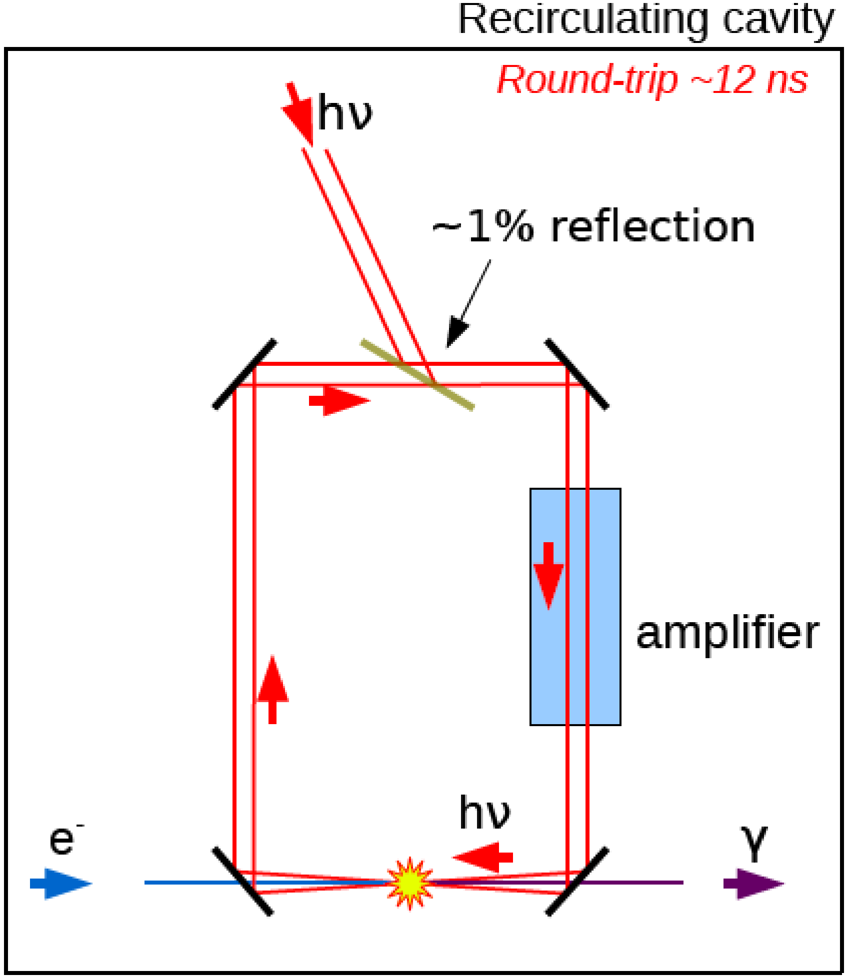
Laser system



CO$_2$ laser system
(**10 μm, 80 ns, 120 Hz**)

Pulse forming system (**10 μm, 3 ps, 120 Hz**)

Solid state laser system
(**1 μm, 3 ps, 120 Hz**)



Recirculating cavity

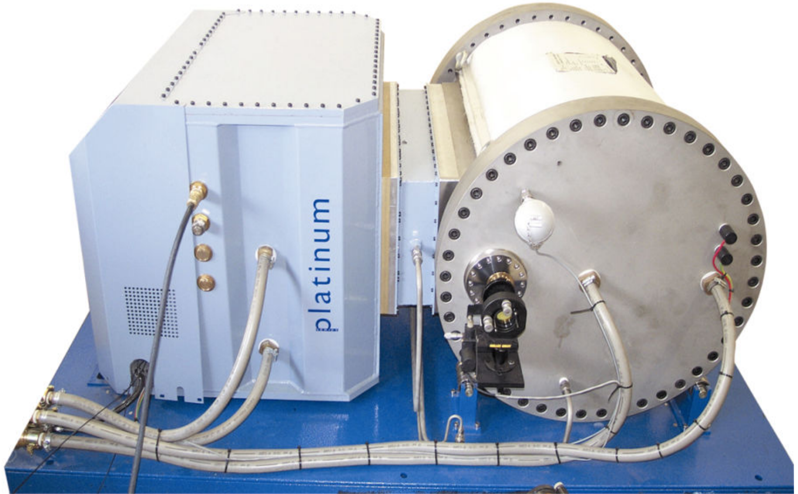
Round-trip ~12 ns

Realistic goal:
Trains: 25~50 pulses @ 120 Hz
(effective repetition rate: 3~6 kHz)
Pulse energy: 0.5~1.0 J
Pulse duration: 3~5 ps (fwhm)

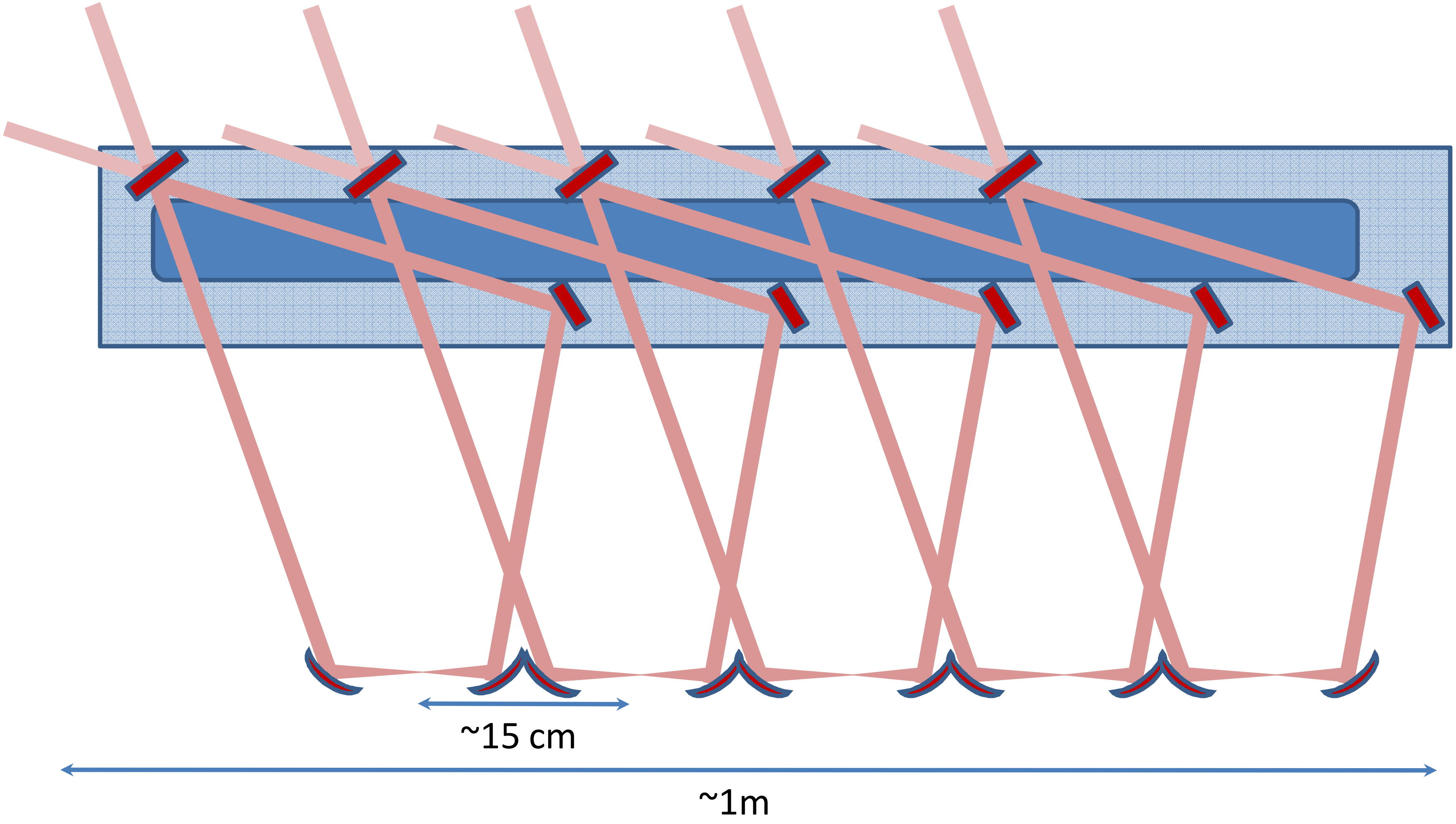
Lasers from SDI

http://www.lightmachinery.com/SDI-CO2-lasers.html

	WH20	WH100	WH350	WH500
Wavelength		9 – 11μm, Line Tunable		
Continuous Repetition Rate	20 Hz	100 Hz	350 Hz	500 Hz
Pulse Energy		1.5 J		
Mode Type		Multimode		
Optional:	TEMoo, custom beam shapes, SLM			
Beam Size		13 x 13 mm^2		
Average Power	30 W	150 W	525 W	750 W
Power Stability		< 7 %		



Possible configuration with 5 IPs and 1 laser amplifier



Choice of parameters

- Train of 50 bunches is generated at 300Hz and will form ~3000 bunches x 5Hz of ILC beam.
- ~6-24 ns bunch spacing can be selected.
- High power/10 atm. (picoseconds beam) CO2 lasers are commercially available at up to 500Hz.
- ~30-40 μm laser focus is set by practical considerations of electron and laser beams focusing and requires ~5 ps long pulses (hour glass effect).
- Nonlinear effects in Compton back scattering limit laser energy at ~1J
- Train of ~5 nC electron bunches are required to produce 1 nC of polarized positrons per bunch.
- ~1 γ-ray per 1 electron per laser IP, 10 IPs (each electron emits 10 γ)
- Conversion efficiency of gammas into captured polarized positrons is simulated at ~2%.

Emittances E_e=6GeV $L_{t\arg et} \square 0.4X0$

- Emittance of the positron beam at the target exit $\varepsilon_N \square \gamma_{e+}\sigma\sigma'$;
- Acquired angular spread $\sigma'_{e+} \square \frac{1}{\sqrt{2}}\frac{14MeV}{E_{e+}}\sqrt{\frac{L_{t\arg et}}{X_0}} \approx 12/\gamma_{e+} \approx 0.14$
- Beam size
  - Gamma beam divergence $\sigma_{\gamma d} \approx \frac{1}{2\gamma_{e-}}\frac{L_{IR}}{\sqrt{2}} \approx \frac{1}{2\cdot 12\,000}\frac{2m}{\sqrt{2}} \approx 60\mu m$
  - Scattering in the target $\sigma_{e+sc} \approx \frac{\sqrt{2}}{3}\sigma'_{e+}L_{t\arg et} \approx \frac{\sqrt{2}}{3}0.14\,1.2mm \approx 80\mu m$
  - e$^-$ beam size on target $\sigma_{\gamma e-} \approx \sqrt{\frac{\varepsilon_{Ne-}}{\gamma_{e-}}\beta_{e-}} \approx \sqrt{\frac{10\mu m}{12\,000}10cm} \approx 10\mu m$

$$\varepsilon_{N\,sc} \sim 1mm \quad and \quad \varepsilon_{N\,\gamma d} \sim 0.7mm$$

- Longitudinal emittance

$$\varepsilon_{\square N} \approx \Delta\gamma_{e+}\sigma_{\tau e-} = \frac{120-60}{4}30\mu m = 450\mu m$$

Emittances E_e=12GeV $L_{target} \square 0.1X0$

- Emittance of the positron beam at the target exit $\varepsilon_N \square \gamma_{e+}\sigma\sigma'$;
- Acquired angular spread $\sigma'_{e+} \square \frac{1}{\sqrt{2}}\frac{14MeV}{E_{e+}}\sqrt{\frac{L_{target}}{X_0}} \approx 6/\gamma_{e+} \approx 0.017$
- Beam size
  - Gamma beam divergence $\sigma_{\gamma d} \approx \frac{1}{2\gamma_{e-}}\frac{L_{IR}}{\sqrt{2}} \approx \frac{1}{2\cdot 24000}\frac{2m}{\sqrt{2}} \approx 28\mu m$
  - Scattering in the target $\sigma_{e+sc} \approx \frac{\sqrt{2}}{3}\sigma'_{e+}L_{target} \approx \frac{\sqrt{2}}{3}0.017\ 0.3mm \approx 2\mu m$
  - e$^-$ beam size on target $\sigma_{\gamma e-} \approx \sqrt{\frac{\varepsilon_{Ne-}}{\gamma_{e-}}\beta_{e-}} \approx \sqrt{\frac{10\mu m}{24000}10cm} \approx 10\mu m$

$$\varepsilon_{N\,sc} \sim 12\mu m, \quad \varepsilon_{N\,\gamma d} \sim 160\mu m \quad and \quad \varepsilon_{N\,e-} \sim 40\mu m$$

- Longitudinal emittance

$$\varepsilon_{\square N} \approx \Delta\gamma_{e+}\sigma_{\tau e-} = \frac{480-240}{4}20\mu m \approx 1.5\mu m$$

Conclusion

- Linac-Compton source based on CO2 laser cavity can be direct upgrade of the non-polarized source. Would require drive linac RF power increase and ~2-3 meters long Compton interaction region with ~10 laser IPs.
- Laser cavity is the only uncertain point of the scheme. Demonstrated at ~10% power on existing hardware. Purchase of adequate amplifier is not funded.
- Pulsed drive linac, conversion and capture components 300Hz for 1μs makes it more efficient and very close to conventional technologies.
- High efficiency of the Linac-Compton source (high energy of gammas and clean spectrum) allows for a much simpler design of the target
- Transverse emittance is dominated by scattering in the target. Improvement possible by using shorter target and higher drive beam energy to improve conversion efficiency and reduce scattering.