Linac e+ source for ILC, CLIC, SuperB, …

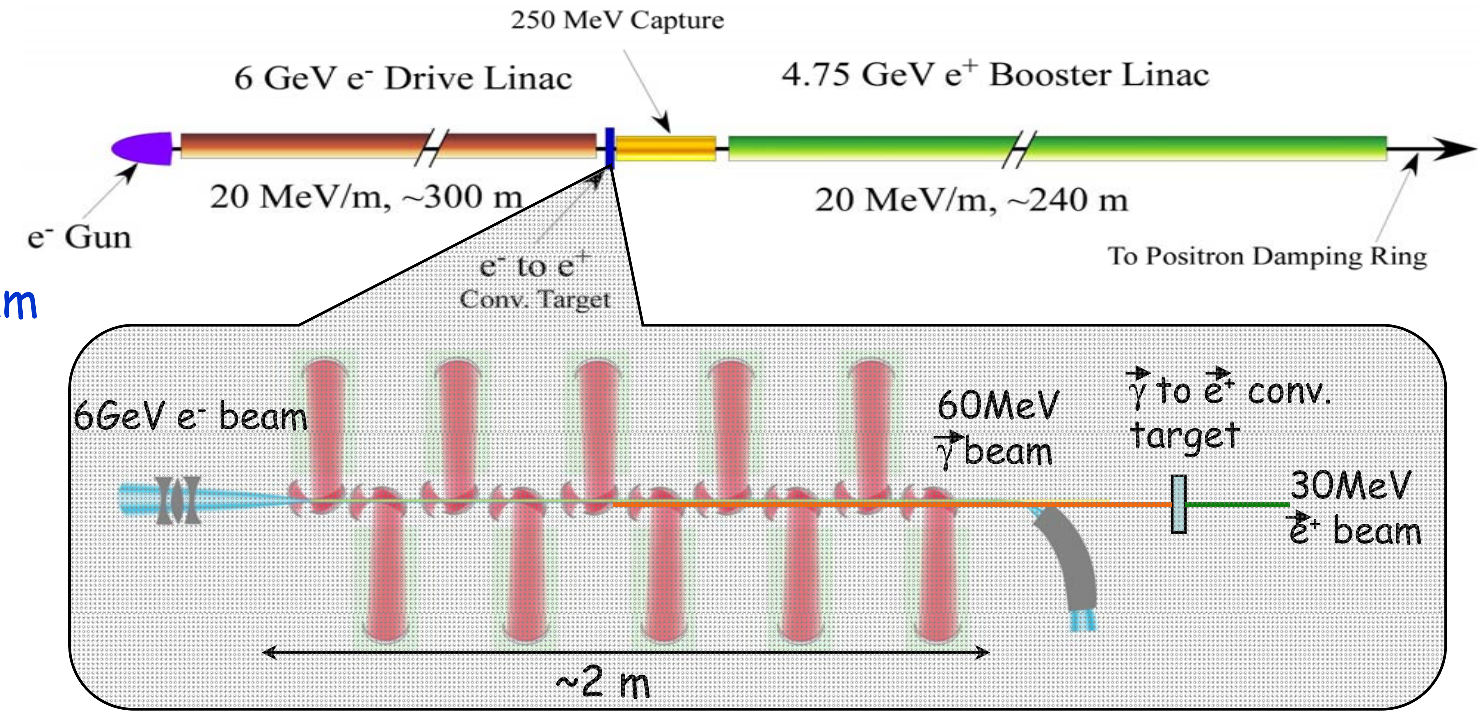
Vitaly Yakimenko, Igor Pogorelsky

November 17, 2008

BNL

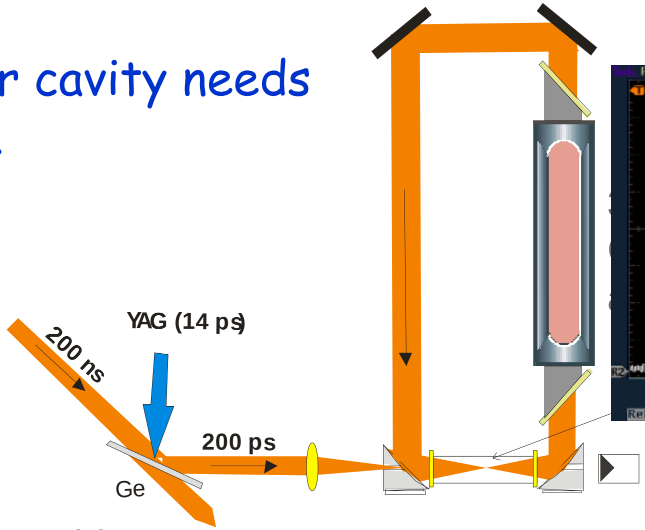
Polarized Positrons Source for ILC, CLIC, Super B

Conventional Non-Polarized Positrons:

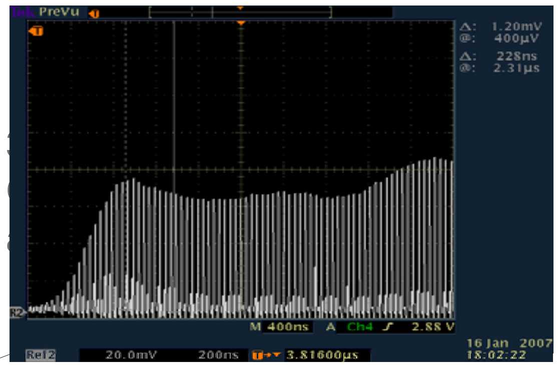


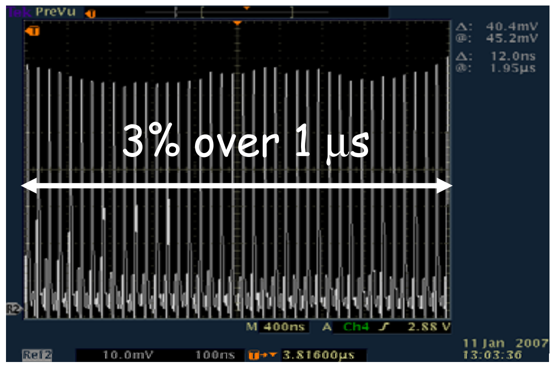
Polarized γ-ray beam is generated in the Compton back scattering inside optical cavity of CO2 laser beam and 6 GeV e-beam produced by linac.

Laser cavity needs R&D.



First tests of the laser cavity:





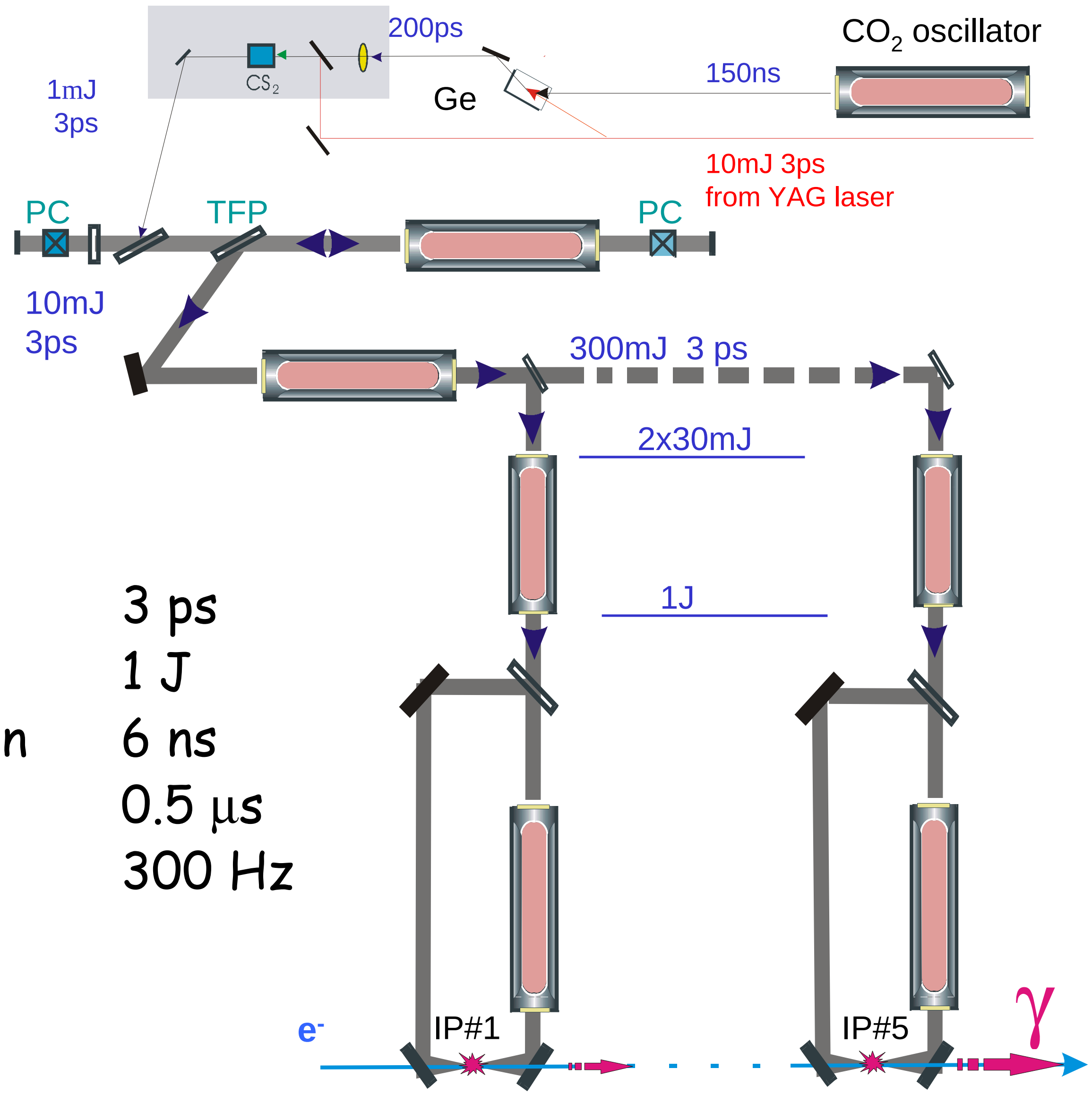
Choice of parameters

- Short bunch trains of ~50 bunches are required for target to survive in any scheme.
- Train of 50 bunches is generated at 300Hz and will form ~3000 bunches x 5Hz of ILC beam.
- ~300ns bunch spacing in the main linac will be changed in the dumping ring in any design. (300ns x 3000bunches requires 150km dumping ring) ~6 ns or 12 ns spacing can be selected.
- High power/10 atm. (picoseconds beam) CO2 lasers are commercially available at up to 500Hz.
- ~40 μm laser focus is set by practical considerations of electron and laser beams focusing and requires ~5-10 ps long pulses (hour glass effect).
- Nonlinear effects in Compton back scattering limit laser energy at ~1J
- Train of ~10 nC electron bunches are required to produce 2 nC of polarized gammas 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% (γ-beam has energy range of 30-60 MeV).
- Stacking is not needed but can be accommodated (~5-10 in horizontal or longitudinal phase space) to relax parameters

Linac Compton Source (LCS): Numbers

Drive e- beam energy/charge	6 GeV / 10nC
Drive e- bunch format	50 bunches / 50Hz
RMS bunch length (laser & e^- beams)	3 ps
γ beam peak energy	60 MeV
Number of laser IPs	10
Total $N\gamma/Ne^-$ yield (in all IPs)	10
$Ne^+/N\gamma$ capture	2%
Ne^+/Ne^- yield / Total e^+ yield	0.2 / 2nC
# of stacking	No stacking

CO_2 laser system



- pulse length (RMS) 3 ps
- energy per pulse 1 J
- period inside pulse train 6 ns
- total train duration 0.5 μs
- train repetition rate 300 Hz

γ beam size on the target

- **W**iggler **S**ource **WS** (150GeV, 200m wiggler):

$$\sigma_r \approx \frac{L_w}{2\gamma}+\frac{L_d}{\gamma}=\frac{200m}{2\cdot 3\cdot 10^5}+\frac{50..500m}{3\cdot 10^5}=0.3mm+0.2..1.6mm$$

  - Low capture efficiency, no angular filtering (high K case) increases required γ intensity 100x => Long drift is needed to make big enough spot at the target, very difficult target

- **C**ompton **L**inac **S**ource **CLS**(6GeV, 10IPs, 0.3m each)

$$\sigma_r \approx \frac{L_{IPs}}{2\gamma}+\frac{L_d}{\gamma}=\frac{3m}{2\cdot 1.2\cdot 10^4}+\frac{3..10m}{1.2\cdot 10^4}=0.12mm+0.25..1mm$$

- **C**ompton **R**ing **S**ource **CRS** (1.2GeV, 5IP, 5m each)

$$\sigma_r \approx \frac{L_{IPs}}{2\gamma}+\frac{L_d}{\gamma}=\frac{25m}{2\cdot 2.5\cdot 10^3}+\frac{3..10m}{2.5\cdot 10^3}=3mm+1.5..4mm$$

Emittance of the positron beam is limited by the gamma beam spot size on the target

Conclusions on Emittance

- **Transverse emittance**
  - WS: emittance is ~4 times higher than in CLS due to lower energy of positrons (scattering in the target)
  - CRS: emitannceis ~15 times higher than in CLS due to larger γ beam size on the target and lower energy of positrons
- Low emittance in CLS allows for 100% capture efficiency of useful positrons and can be further used to
  - to make thicker (more efficient target),
  - 5-10x stacking in horizontal plain

- **Longitudinal emittance** can be similar in all schemes.
  - WS: Difficult to manage nonlinear correlation due to slippage.
  - CRS: Compression/decompression around IP is needed to make shorten electron bunches is needed
  - CLS: No issues in CLS.

Why 100% acceptance of produced positrons (top 50% of the energy) is expected in Compton-Linac Source?

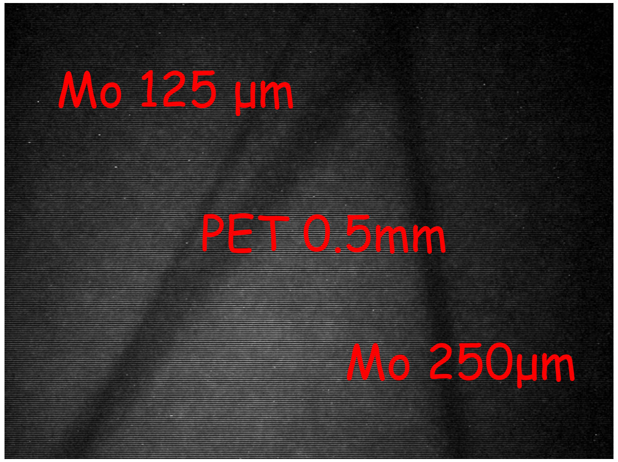
- Interaction region is short
- Target is close to the Compton source
- High γ-energy is possible
- Small spot size on the target and high energy of positrons lead to small emittance.
- Pulsed Optical matching and capture linac.

- **More efficient (W) target can be used with simpler (stationary) design**

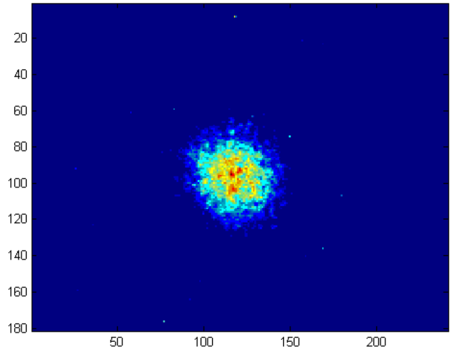
X ray source at ATF is in use

- ~10^8 x rays/pulse delivered to experiment at ATF up to 10keV (will be ~10^9 up to 14keV)
- Experiment on investigation of Compton based source started at ATF:

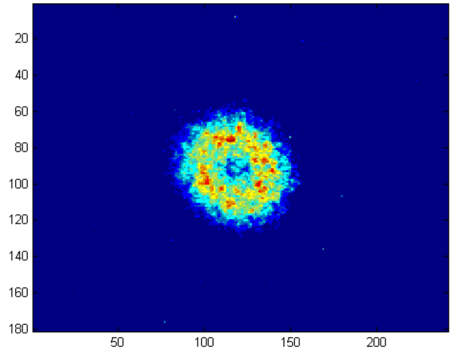
Spatial resolution test:



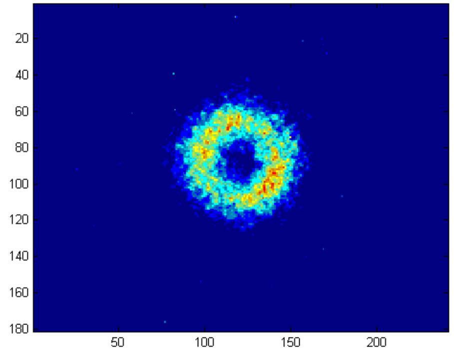
Bandwidth test:
(K-edge scanning, iron foil)



64 MeV



65 MeV



66 MeV

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 correct amplifier is not funded.
- Pulsed drive linac, conversion and capture components 300Hz for 300ns makes it more efficient and very close to conventional technologies.
- High efficiency of the Linac-Compton source allows for a much simpler design of the target
- This scheme will be also optimal for CLIC and SuperB polarized positron sources.