Compton based Polarized Positrons Source for ILC

S.Roychowdhury

On behalf of

V.Yakimenko[1], D.Cline[2] ,I.V.Pogorelsky[1],V.N.Litvinenko[1]

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1.BrookhavenNationaLaboratory,NY,USA

2.University Of California at LosAngeles,CA,USA

3.Duke University,NC,USA

Outline

- Review
  - Requirements (positron beam)for International Linear Collider
  - Proposal by Omori,et al
- ATF(BNL,NY) proposal
  - Introduce the proposal
  - Discuss parameter choice
  - Ring vs. Linac and stacking vs.no-stacking
- Laser System
- Experiment
  - ATF,BNL
  - KEK,Japan
- Conclusions

ILC Source Requirements

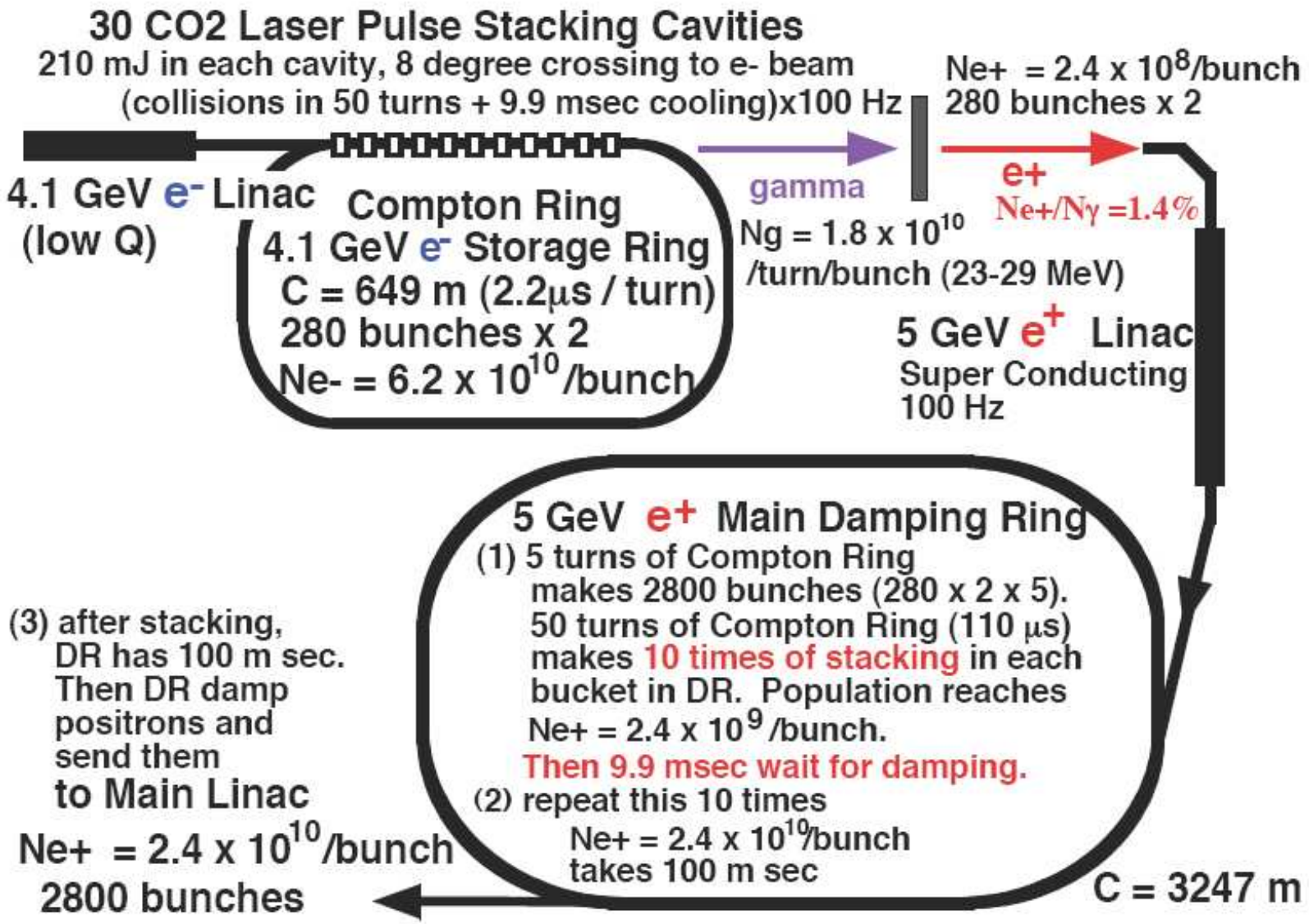
Parameter	Symbol	Value	Unit
Positrons per bunch	n_p	$2\text{x}10^{10}$	e^+
Bunches per pulse	N_b	2820	
Bunch Spacing*	t_b	~300	ns
Pulse rep. rate	f_{rep}	5	Hz
Energy	E_0	5	GeV
Positron Polarization**	P_p	~60	%

*Length of bunch train=2820x300(ns)=0.85ms~250km

**Conversion/capture efficiency for polarized gamma ⟷ polarized e^+

60% ⟷ 1.5%

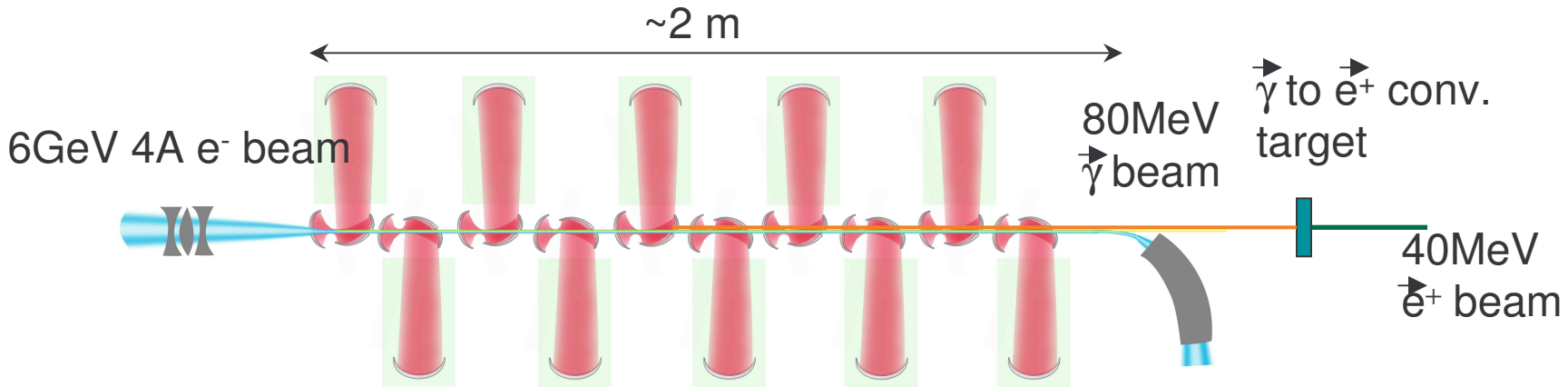
Polarized Positron Production
Compton Ring Scheme: CO_2 Version (Omori, et al.)



Polarized Positrons Source (PPS for ILC)

ATF,BNL Proposal

- Polarized Gamma Ray Generated By
  - • Compton scattering inside optical cavity of CO_2 laser *with*
  - •6 GeV electron beam produced by Linac
  - •Expected Efficiency $N\gamma/Ne^- \sim 10$
- Polarized Positron Beam Generated By
  - •Scattering 80 MeV γ ray on a thin target
  - •Capture Efficiency $Ne^+ / N\gamma \sim 1.5\%$



Merits of the Proposal

- Required intensities of polarized positrons obtained because
  - e-beam charge is sufficiently high(10 times compared to conventional non polarized source)
  - complex CO_2 laser system
- L-band type photo injector and linac for acceleration
  - No R&D required
- Laser system
  - commercially available lasers
  - R&D for the new mode of operation (described later)

Choice of Parameters

$$N_{\vec{\gamma}} = \frac{N_e N_{\vec{\varphi}}}{S} \sigma_C$$

Ne # of electrons, N_ϕ # of laser photons
Nγ # of gamma rays, S area of interacting beams
σ_c Compton cross section

- To produce 10^{12} positrons per bunch ⟷ ~10 nc electron bunches
- Pulse train structure(2820) is set by main linac.
- Bunch spacing(~300 ns) is to be changed in the damping ring(any design)
  - ~3ns spacing matches inversion life time of laser (3ns*2820=8.5microsec)
- Laser Energy limited to ~1J
  - Non linear effects in Compton scattering
- Laser Focus @40μm
  - Practical consideration of e and laser beam focusing
  - 5 ps long laser
- Reducing charge in bunches(positron stacking) leads to
  - increase in average laser power
- Gamma beam size is smaller(compared to other designs)
  - compact design of Compton backscattering region
- Conversion Efficiency (polarized gamma to captured polarized positron)
  - assumed ~1.5%
  - subject to optimization

Polarized Gamma Beam Generation Summary

Parameter	Symbol	Single Shot Injection	Stacking mode	Unit
Rep rate	f_{rep}	5	150	*Hz*
e^- per bunch	n_p	8×10^{10}	8×10^{9}	
Bunches per pulse	N_b	2820	2820	
Bunch Spacing	τ_b	3	3	*ns*
Beam current (ave./pulse)	I_{beam}	0.2 / 4	0.6 / 0.4	*mA / A*
Average beam power	P_{beam}	1	3	*MW*
Number of lasers	N_{laser}	15	5	
Laser pulse length	τ_{laser}	5	5	*ps*
Intra cavity energy	E_{laser}	8 x 0.8	8 x 0.8	*J*
Size at focus	σ_{laser}	40	40	μm
Efficiency per laser IP	$N\gamma / Ne^-$	1	1	
Number of γ per bunch	$N\gamma$	1.5×10^{12}	1.5×10^{12}	

Ring Or Linac?

- 6 GeV Compton Ring
  - rms energy spread ~ 2%
    - CO_2 laser interaction with 4MW synchrotron radiation.
  - Dificult ring design
  - Very difficult laser design
    - high repition rate
    - high average power
    - cavity stacking
- Aperture Requirements of Ring Design
  - small angle Compton back scattering
    - less efficient

- Linac Design
  - Head On Compton back scattering

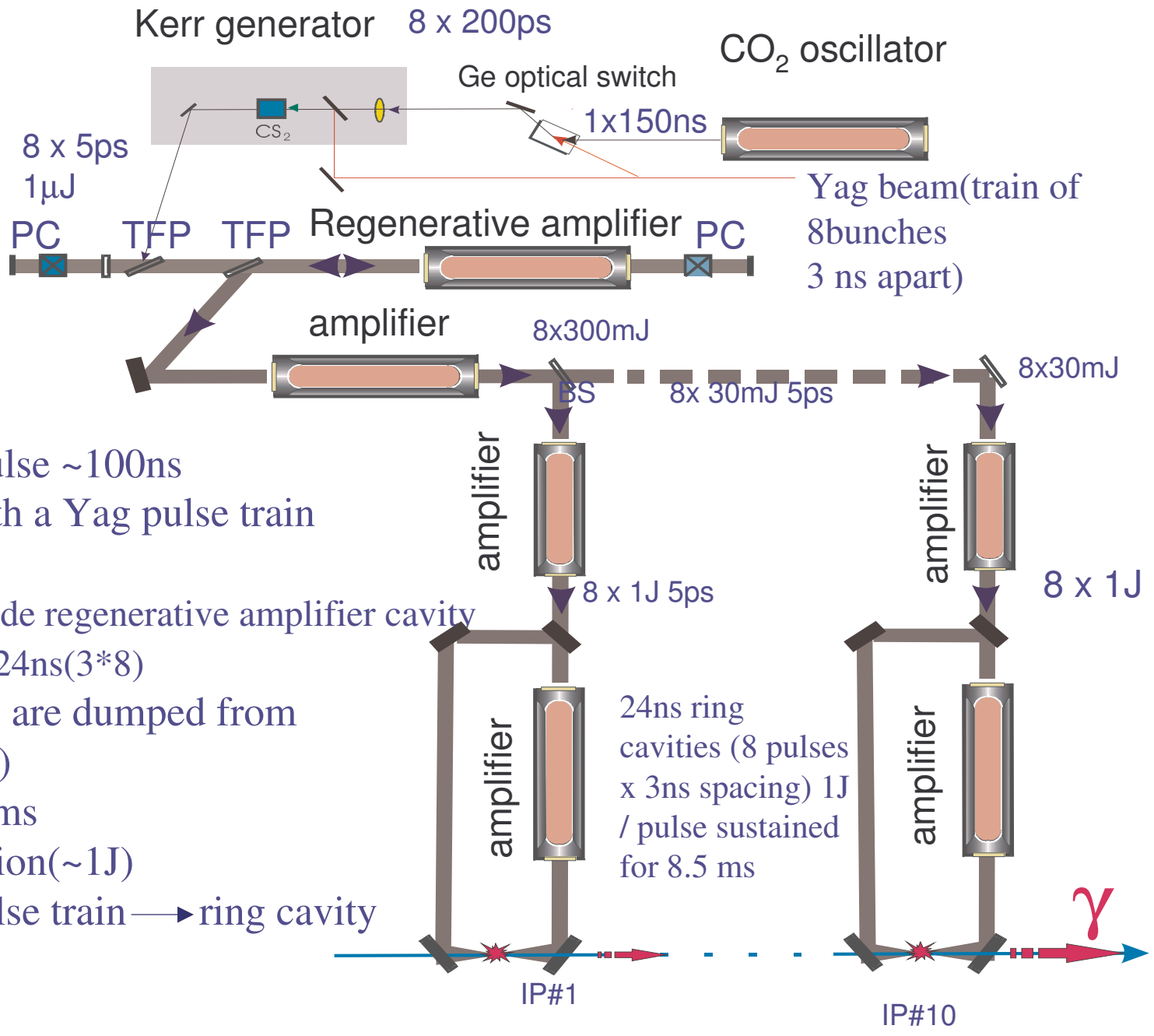
Stacking or No Stacking?

- No Stacking
  - High current in macro-pulse(~ 4 A)
    - short accelerator sections,
    - more klystrons
    - longer linac

- Stacking
  - High repitition
    - average beam power inc
    - 3MW for 150Hz.
  - Linac
    - SuperConducting
    - NormalConducting

•Simpler damping ring and laser system at 5Hz for the scheme without accumulation may offset linac complexity.

Laser System



1. CO_2 oscillator pulse ~100ns
   Sliced with a Yag pulse train
2. CO_2 laser train
   seeded inside regenerative amplifier cavity
   round trip 24ns(3*8)
3. Amplified pulses are dumped from cavity(pockels cell)
4. Split into 10 beams
5. After Amplification(~1J)
   each 8 pulse train ⟶ ring cavity

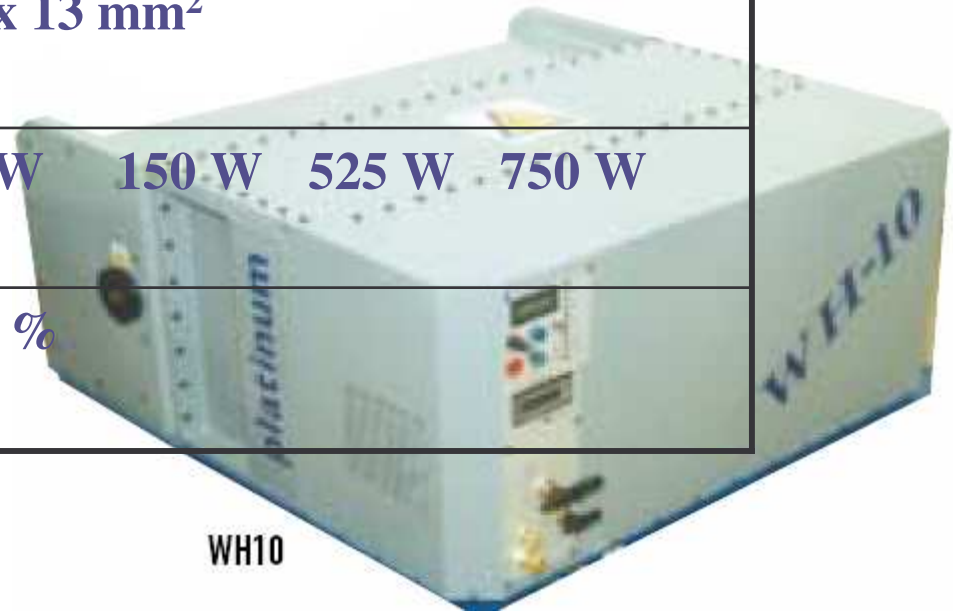
Status Of Laser System For Polarized Positron Source

- ✓Optical slicing and amplification
  - •demonstrated at ATF
  - •routine for user experiments*
- ✓CO_2 oscillator and amplifier
  - •commercially available from SDI
  - •rep rate up to 500Hz
- ❖Final Intra-cavity amplifiers
  - •average power 10-20 Kw(150Hz)
  - • Needs R&D
- ❖Optical elements
  - •need to withstand high intra-cavity power
  - •to be addressed by industry

Laser From SDI

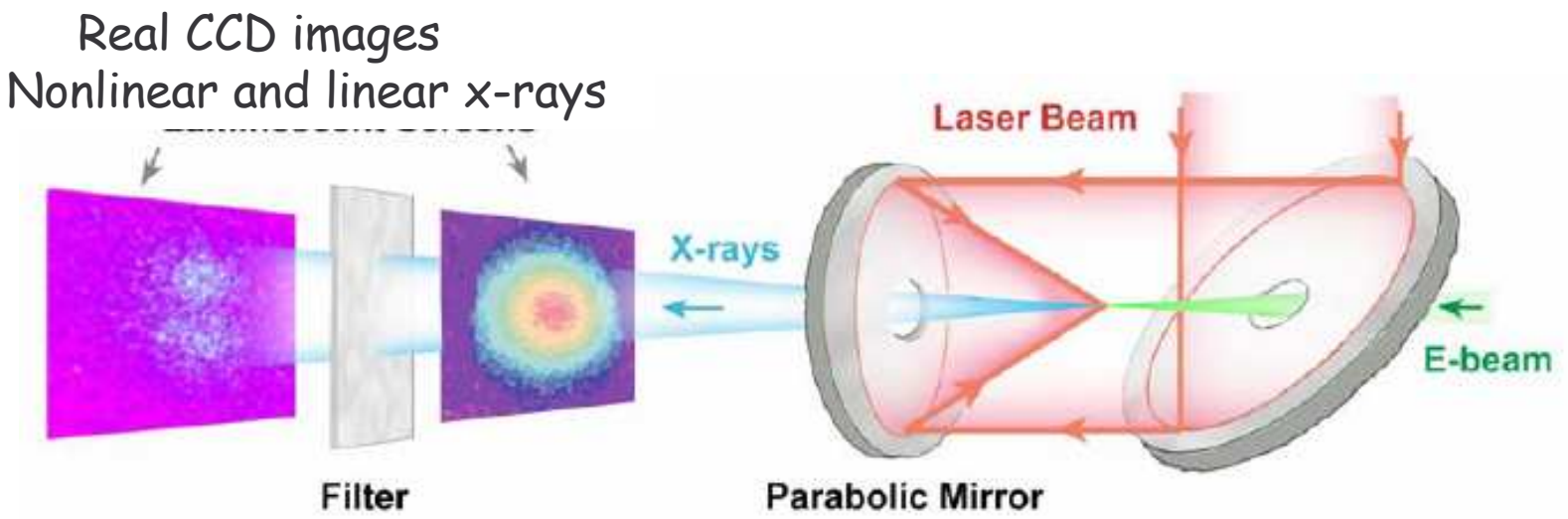
http://www.lightmachinery.com/SDI-CO2-lasers.html

Wavelength (continous)	**9 – 11µm, Line Tunable**
Repetition Rate	**20 Hz 100 Hz 350 Hz 500 Hz**
Pulse Energy	**1.5 J**
Mode Type optional	**Multimode** **TEMoo, custom beam shapes, SLM**
Beam Size	**13 x 13 mm²**
Average Power	**30 W 150 W 525 W 750 W**
Power Stability	**< 7 %**



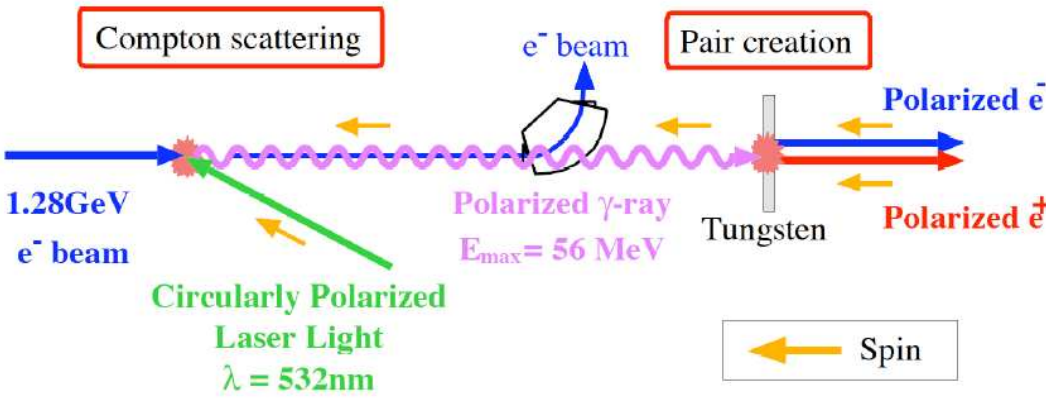
Compton Experiment at ATF,Brookhaven (record number of X-rays with 10 μm laser)

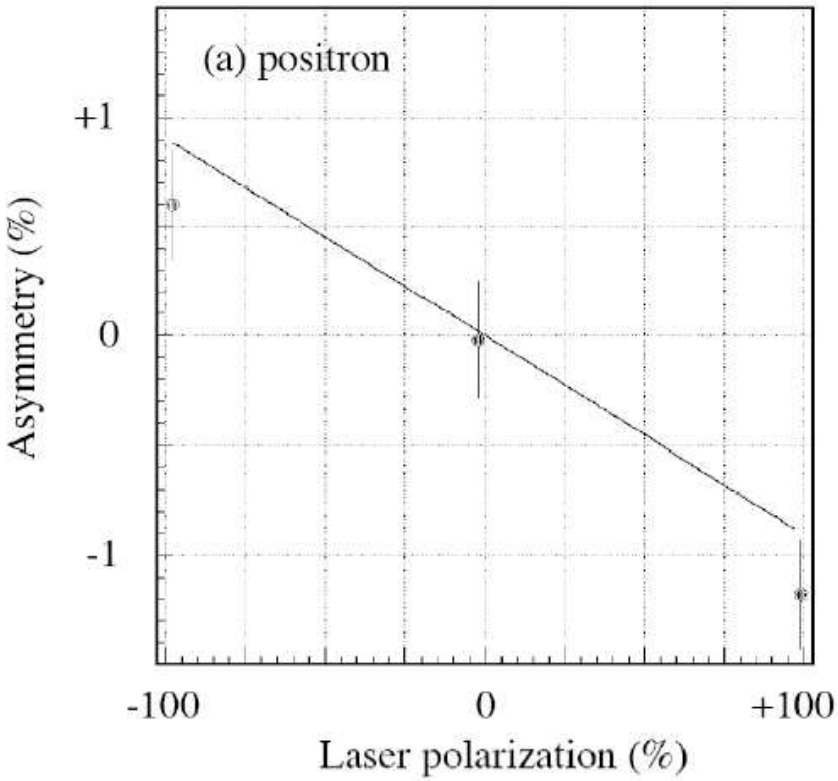
- X rays generated > ~10^8 PR ST 2000
- N_x/N_e ~0.1
- Interaction point with high power laser focus of ~30μm was tested.
- Nonlinear limit (more then one laser photon scattered from electron) was verified. **PRL 2005.**



Compton Experiment at KEK ATF (polarized positrons with 532 nm laser)

- Demonstrated beam of 10^6 polarized γ-rays (PRL 91/16, 2003)
- Demonstrated 10^4 positron beam with 79% polarization level (KEK Preprint 2005-56, PRL 2005)





Conclusion

- We propose a Polarized Positron Source.
  - based on Compton back scattering inside optical cavity of CO_2 laser beam and 6 GeV e-beam produced by linac.
- The proposal utilizes commercially available units for laser and accelerator systems.
- The proposal requires high power picosecond CO2 laser mode of operation developed at ATF
- 3 year laser R&D is needed to verify laser operation in the non standard regime.