Alternative Source Design

A.Variola on behalf of M.Kuriki
EDR KOM Meeting
Daresbury 8-10 October 2007

- Basic Idea : Have a Compton effect based polarized positron source

- Advantages :

-Independent system
-Easy polarization flip @ 5Hz + non polarized (linear laser polarization).
-Higher polarization possible (>70%)
-Not disturbing the main beam
-Operability of the positron arm (especially low energy operation)
-Not considerable target heat problem (slow e^+ production even Linac scheme)
-Wide Applications in many fields
-If ring/ERL can be shared with gamma factory
-depending on the schemes and on choices, part of the Compton driver can be integrated in the e^- Linac

-Cost: to be assessed

- Compton for the polarised source
- Conventional or keep alive => some new ideas

Compton scheme

- At present we are working in three different directions : black box for the drive beam for the Compton production

1)Linac => Advantages : gamma produced in one shot. No stacking
2)Ring => Advantages: Required AMD section in respect to ERL
3)ERL => High possible gamma flux. If multiple stacking possible extremely high polarization.

- 10 interaction point ERL – Ring
- 5 interactions point Linac
- AMD + 5GeV Linac injector

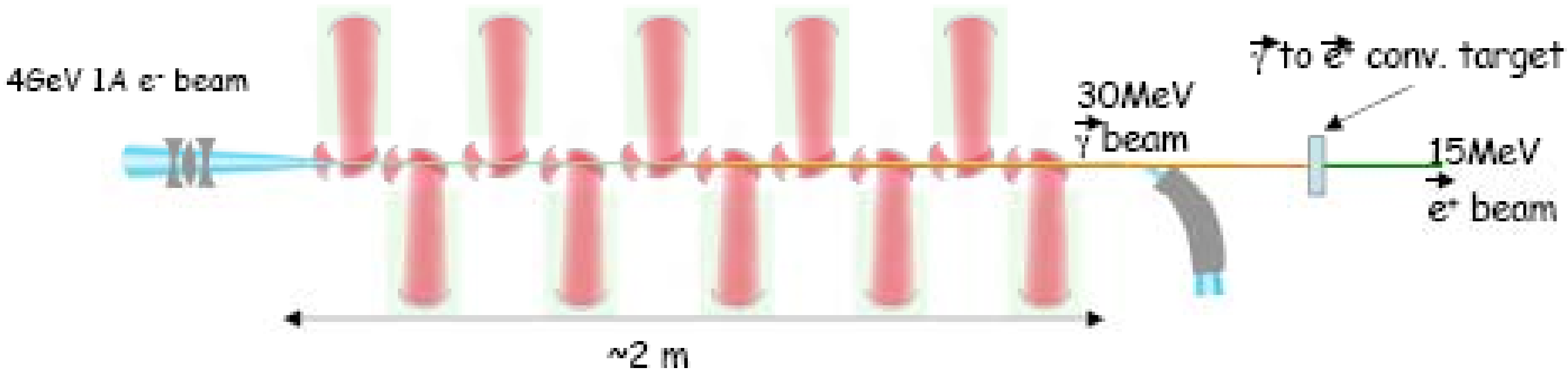
(easy Linac, performant Ring, Difficult ERL)

Global Characteristics

- 1-2 GeV driver, Linac 4-5 GeV
- Stacking Linac=No, Ring~100, ERL~200-1000
- Linac 10 nC, Ring 10-15 nC, ERL 0,15-1,5 nC
- Polarisation varying from 30% to more than 70%
- Capture from 0.6 to 4 % (captured positrons/gammas)
- In ERL it is possible to diaphragm and reduce the injection phase space for stacking

Linac Scheme

- Polarized γ-ray beam is generated in the Compton back scattering inside optical cavity of CO_2 laser beam and 4 GeV e-beam produced by linac.
  - 4GeV 15nC e- beam with 12 ns spacing.
  - 10 CPs, which stores 10 J CO_2 laser pulse repeated by 83 Mhz cycle.
- 5E+11 γ-ray -> 2E+10 e+ (2% conversion)
- 1.2μs pulse, which contains 100 bunches, are repeated by 150 Hz to generated 3000 bunches within 200ms.
- No stacking in DR



By V. Yakimenko and Pogorersky

LINAC SCHEME (from Posipol 2007)

- The conversion efficiency of the polarized γ-photons into polarized positrons is expected to be about 2%, optimized for the 60% level of the beam's polarization.

- Therefore, every positron requires, as precursors, 50 γ-photons.

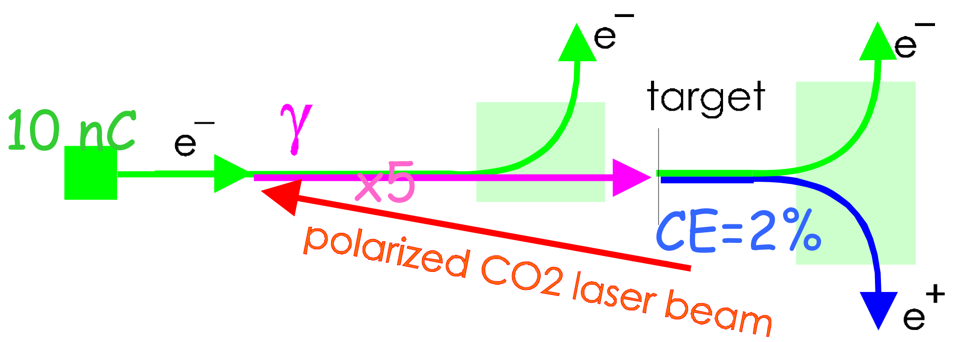
- We propose to accumulate this γ-flux via Compton scattering at 5 consecutive IPs. In each one, a 4-GeV *e*-beam, which fits the collider beam's format but carries a tenfold higher charge per a bunch (10 nC), undergoes a head-on collision with a CO_2-laser pulse that produces one γ-photon per electron.

- The normalized emittance is expected to be 5÷10 μm.

- The focusing system for the *e*-beam would need to generate one with a beta-function of 1 m in the waist that would entail beam sizes of σ=25÷35 μm in the middle, and 35÷50 μm at the ends of the ~2-meter-long total interaction region that extends over five IPs.

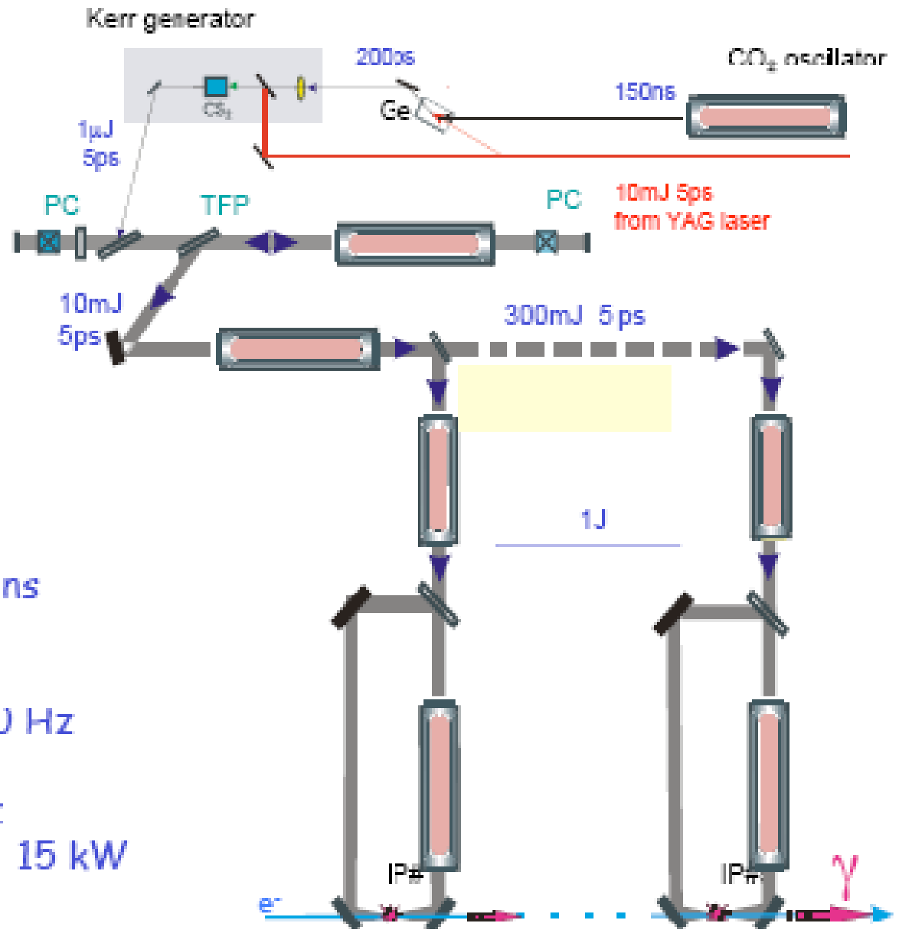
- A 4-GeV *e*-beam divergence will be five times smaller than $1/\gamma$ and, therefore, will not lower the achievable polarization level.

- Simultaneously, a CO_2 laser spot size with $\sigma \equiv 0.5 w_O$ = 35 μm can be realized as was demonstrated experimentally.



CE – conversion efficiency

CO_2 Laser system for ILC



intra-cavity pulse circulation :

- pulse length 5 ps
- energy per pulse 1 J
- period inside pulse train12 ns
- total train duration 1.2 µs
- pulses/train 100
- train repetition rate 150 Hz

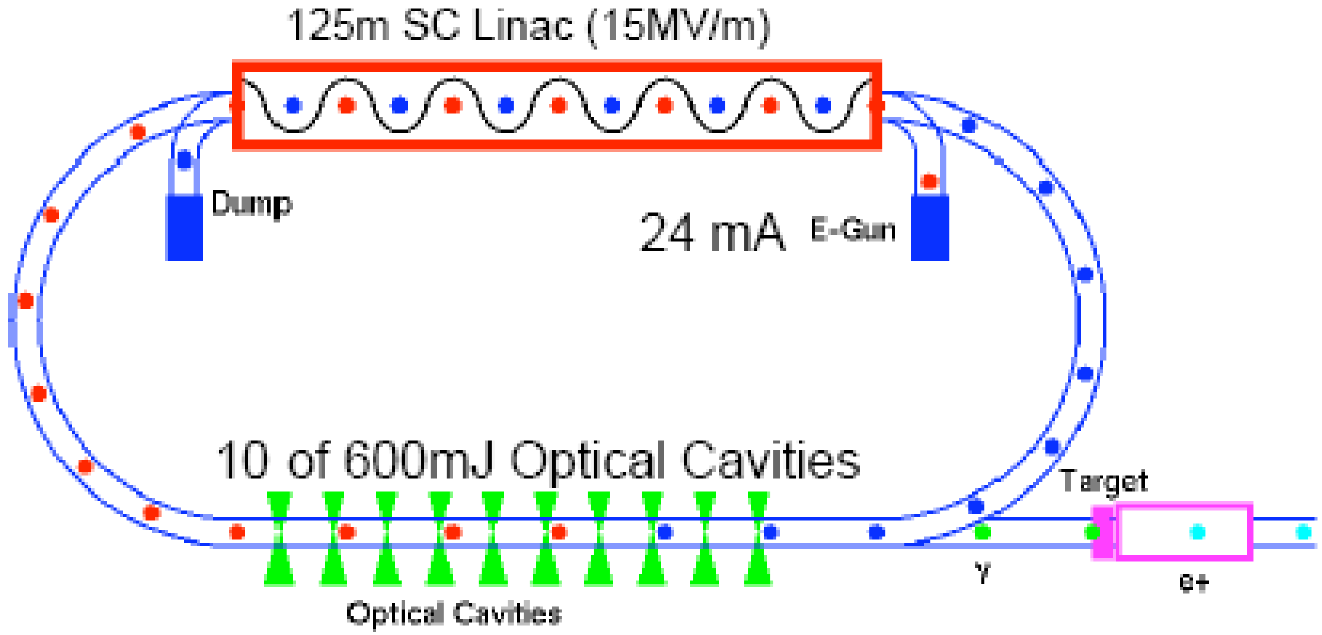
- *Cumulative rep. rate15 kHz*
- *Cumulative average power 15 kW*

Compton Ring (parameters example)

	E = 1.070 GeV		E = 1.300 GeV	
Parameter	**With chic.**	**Without chic.**	**With chic.**	**Without chic.**
Gamma's energy, MeV	10 – 20	10 – 20	15 – 30	15 – 30
Circumference, m	800	1280	1200	1920
Energy acceptance, %	7	5.5	7	5.5
Laser flash energy, J	2	2	2	2
Laser waist (RMS), μ	15	15	15	15
Laser pulse length (RMS), mm	0.5	0.5	0.5	0.5
RF voltage, MV	2×40	20	2×50	30
Bunch length, mm	4 – 6	4 – 6	4 – 6	4 – 6
Bunch charge, nC	2	2	2	2
Bunch spacing, cm	48	48	48	48
Stored current, A	1.25	1.25	1.25	1.25
Energy losses (SR + wigglers), keV	700	700	1000	1000
Particles losses per sec., %	< 20	< 20	< 20	< 20
Positron number per sec.	1.05×10^{14}	1.05×10^{14}	1.05×10^{14}	1.05×10^{14}

ERL example

ERL scheme = Linac scheme + Ring scheme



- Both advantages (high yield + high repetition) are compatible in ERL solution.
  - 0.64 nC 1.3 GeV bunches x 10 of 600 mJ laser, repeated by 40.8MHz -> 6.4E+9 γ-rays -> 2E+7 e+.
  - Continuous stacking the e+ bunches on a same bucket in DR during 100ms, the final intensity is 2E+10 e+.

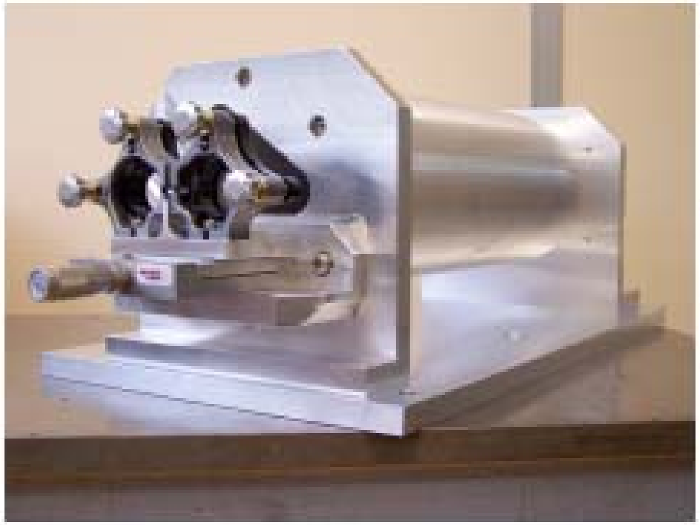
ERL

	ERL Parmeters			
Energie (GeV)	**1 / 2**			
Cadence	**40 - 160** MHz			
Charge (nC)	**0.2**		**1**	
Durée du paquet (fs rms)	**500 - 600**			
Courant moyen	**10-100** mA			
Courant crête (kA)	Total	Slice	Total	Slice
	0.2	**0.2**	**1**	**1**
Emittance (mm mrad)	**2**	**1**	**6**	**5**
Dispersion en énergie (rms)	**0.1** %	**0.04** %	**0.2** %	**0.08** %

Cavity @ 0.6 Joule
1.5 nC => 1.2 10exp9 gamma
10 interaction points 10exp10
= 200 stackings

With the ERL we have at least
1 order of magnitude more positrons
But how to fit them in the ILC
scheme?

Prototype Cavities

4-mirror cavity (LAL)	2-mirror cavity (Hiroshima/KEK)
	
high enhancement very small spot size complicated control	moderate enhancement small spot size simple control

Results already obtained: 20 μm waist in 4 mirror cavity (diag.limited)
1.2 exp 3 gain @ 1 ps in confocal cavity
(world record)

- Areas of risk, weakness, inconsistencies

- Lasers : ERL/Ring => Fiber+FP cavity, LINAC=>CO2+regenerating cavity. Proof of principle @ very high power
- ERL capture warm sections (cavity + sources)
- ERL CW stacking (high charge low frep)
- Ring => beam lifetime, Operation with compressed/crabbed beam
- Ring => Phase stability under Compton regime
- Ring => Stacking procedure
- Linac => Electron Source for the Compton Driver
- Linac => Numbers of IP (beam optics when $\gamma/e^-=1$)

What we need to do
(or demonstrate)

- Ring and ERL: Stacking simulations => captured emittance big. Need solution for stacking.
- Ring & ERL : Proof of Principle experiment. Generation of gammas on ring and ERL.
- Ring & ERL : Laser + FP cavities R&D (at least 200W in 10Exp4 cavity in beam – Lock a 4 mirror cavity @ high finesse)
- ERL : semi-CW capture section. Design Cavity CW, prototype and look for power source @ 1.3 Ghz
- ERL radiation loss study (safety)
- Ring : Assess the ring lifetime at the nominal current
- Ring : Experiment on beam stability under Compton regime
- Ring : Simulations and Exp : Short bunch operation / Crabbed bunch operation
- LINAC : Gun @ 10 nC, 5 ps (I. Ben Zvi)
- LINAC : Prototype the CO_2 laser with the cavity (parabolic+hole)
- LINAC : Study the CO_2 Ampli
- LINAC : Regenerative ring Cavity
- Everybody : simulations (and experiment) of the multiple collision point taking into account the energy spread generated by the Compton collisions
- Everybody : Costing.
- Everybody : Choose a final scheme