CLIC ERL based positrons source with a Compton multiple IPs line.

I. Chaikovska, O. Dadoun, F. Poirier, A. Variola
LAL, Université - Paris Sud XI, IN2P3/CNRS, Orsay, France
R. Chehab, IPNL IN2P3, Villeurbanne, France

IWLC2010, CERN
October 21, 2010

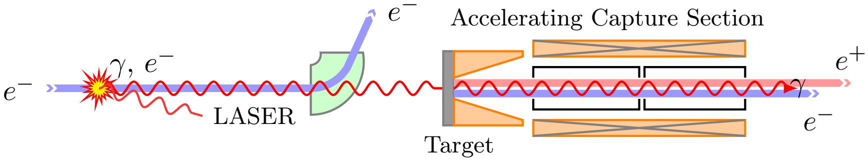
Outline

1. Compton polarized positron sources
2. High energy photons production
3. Positrons production
4. Positrons capture and primary acceleration
5. Summary

General scheme

Compton scheme

Compton backscattering of laser light off an electron beam – method to produce circularly polarized high energy photons.



Why Compton scheme?

Why Compton scheme?

- Method to obtain polarized positrons
- Low energy operation, independent from the main linac...

still some difficulties

- Photons: optical cavity (high power and high quality LASER).
- e^+ stacking and damping.
- Electrons: three proposals – Ring-based, ERL-based, Linac-based Compton scheme.

ERL solution

- No bunch degradation for each collision
- At present, main limitation – weak charge per bunch. Thus, repetition frequency and then stacking efficiency are the main parameters.

Why Compton scheme?

Why Compton scheme?

- Method to obtain polarized positrons
- Low energy operation, independent from the main linac...

still some difficulties

- Photons: optical cavity (high power and high quality LASER).
- e^+ stacking and damping.
- Electrons: three proposals – Ring-based, ERL-based, Linac-based Compton scheme.

ERL solution

- No bunch degradation for each collision
- At present, main limitation – weak charge per bunch. Thus, repetition frequency and then stacking efficiency are the main parameters.

Why Compton scheme?

Why Compton scheme?

- Method to obtain polarized positrons
- Low energy operation, independent from the main linac...

still some difficulties

- Photons: optical cavity (high power and high quality LASER).
- e^+ stacking and damping.
- Electrons: three proposals – Ring-based, ERL-based, Linac-based Compton scheme.

ERL solution

- No bunch degradation for each collision
- At present, main limitation – weak charge per bunch. Thus, repetition frequency and then stacking efficiency are the main parameters.

Why Compton scheme?

Why Compton scheme?

- Method to obtain polarized positrons
- Low energy operation, independent from the main linac...

still some difficulties

- Photons: optical cavity (high power and high quality LASER).
- e^+ stacking and damping.
- Electrons: three proposals – Ring-based, ERL-based, Linac-based Compton scheme.

ERL solution

- No bunch degradation for each collision
- At present, main limitation – weak charge per bunch. Thus, repetition frequency and then stacking efficiency are the main parameters.

Why Compton scheme?

Why Compton scheme?

- Method to obtain polarized positrons
- Low energy operation, independent from the main linac...

still some difficulties

- Photons: optical cavity (high power and high quality LASER).
- e^+ stacking and damping.
- Electrons: three proposals – Ring-based, ERL-based, Linac-based Compton scheme.

ERL solution

- No bunch degradation for each collision
- At present, main limitation – weak charge per bunch. Thus, repetition frequency and then stacking efficiency are the main parameters.

Why Compton scheme?

Why Compton scheme?

- Method to obtain polarized positrons
- Low energy operation, independent from the main linac...

still some difficulties

- Photons: optical cavity (high power and high quality LASER).
- e^+ stacking and damping.
- Electrons: three proposals – Ring-based, ERL-based, Linac-based Compton scheme.

ERL solution

- No bunch degradation for each collision
- At present, main limitation – weak charge per bunch. Thus, repetition frequency and then stacking efficiency are the main parameters.

Why Compton scheme?

Why Compton scheme?

- Method to obtain polarized positrons
- Low energy operation, independent from the main linac...

still some difficulties

- Photons: optical cavity (high power and high quality LASER).
- e^+ stacking and damping.
- Electrons: three proposals – Ring-based, ERL-based, Linac-based Compton scheme.

ERL solution

- No bunch degradation for each collision
- At present, main limitation – weak charge per bunch. Thus, repetition frequency and then stacking efficiency are the main parameters.

Why Compton scheme?

Why Compton scheme?

- Method to obtain polarized positrons
- Low energy operation, independent from the main linac...

still some difficulties

- Photons: optical cavity (high power and high quality LASER).
- e^+ stacking and damping.
- Electrons: three proposals – Ring-based, ERL-based, Linac-based Compton scheme.

ERL solution

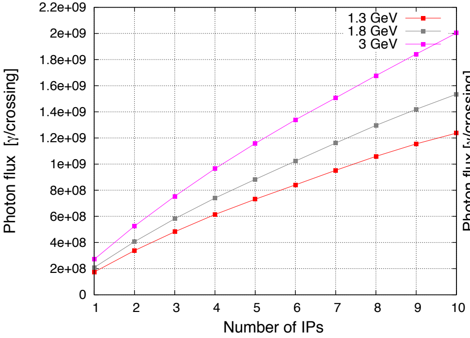
- No bunch degradation for each collision
- At present, main limitation – weak charge per bunch. Thus, repetition frequency and then stacking efficiency are the main parameters.

Compton IP parameters

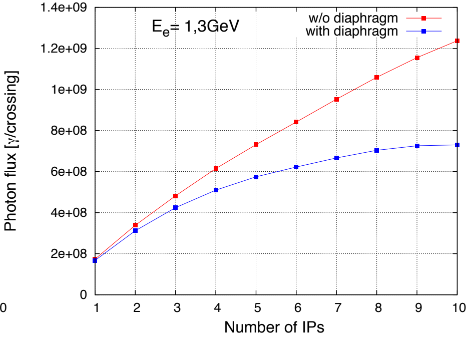
Description	Value	Value	Value
e^- beam energy [GeV]	1.3	1.8	3.0
Electron bunch charge [nC]	1.6	1.6	1.6
e^- bunch length [ps]	2	2	2
IP $\beta_{x,y}$ [m/rad]	0.16	0.16	0.16
Emittance $(\gamma\epsilon_x, \gamma\epsilon_y)$ [μm rad]	5	5	5
LASER type	Fiber	Fiber	Fiber
LASER photon energy [eV]	1.17	1.17	1.17
LASER beam waist radius (ω_0) [μm]	10	10	10
RMS hor./vert. beam size (σ) [μm]	18	15	12
LASER pulse energy [J]	0.1	0.1	0.1
Crossing angle	2°	2°	2°
LASER pulse length [ps]	5	5	5
Photon beam peak energy [MeV]	29.5	56	152.5

Photons flux with multiple IPs line.
10 IPs with 2 crossing LASERs.

Total photon flux



Photon flux after a diaphragm



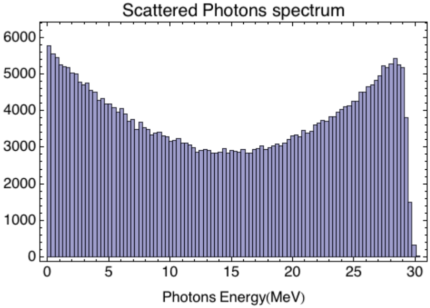
Description of the parameters. Photons production.

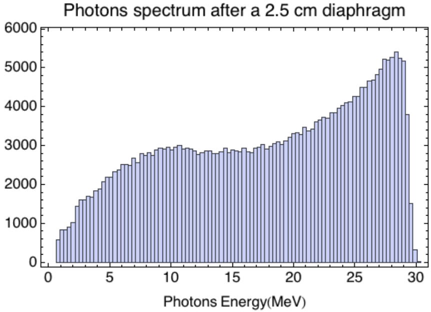
E_e=1.3 GeV, E_{ph}=1.17eV @ last IP

2 LASERs, 5IPs, $\langle E_\gamma \rangle$=14.7 MeV, Polarization= 0

E_e=1.3 GeV, E_{ph}=1.17eV @ diaphragm

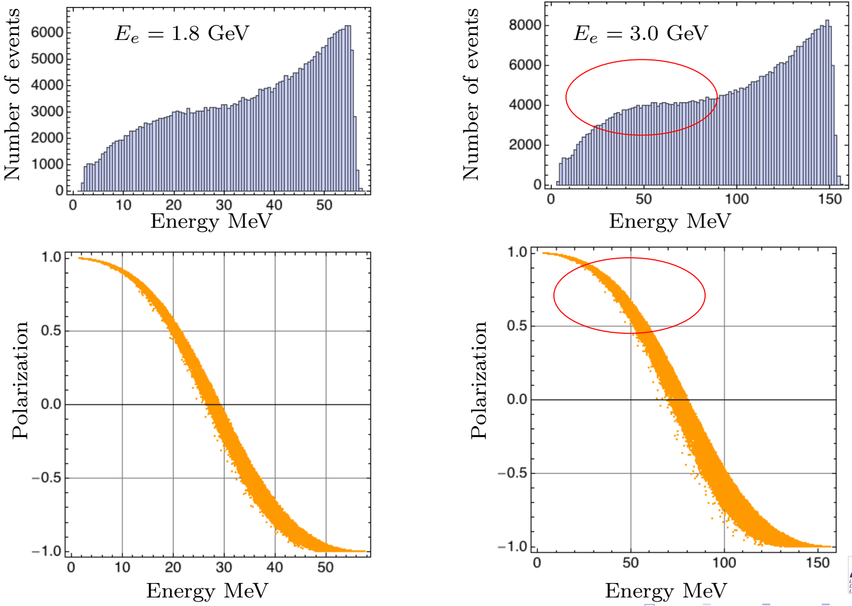
2 LASERs, 5IPs, $\langle E_\gamma \rangle$=17.7 MeV, Polarization= 23%





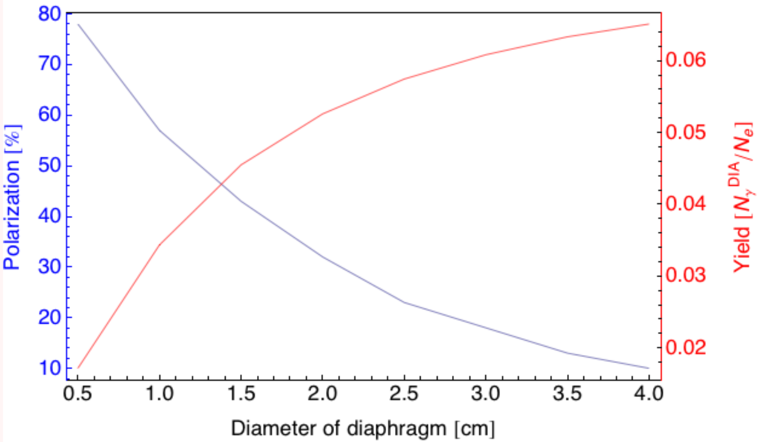
Polarization selection

$\gamma \Rightarrow \theta(Diaphragm) \Rightarrow E \Rightarrow Polarization$


$E_e = 1.8$ GeV
Number of events
Energy MeV
$E_e = 3.0$ GeV
Number of events
Energy MeV
Polarization
Energy MeV
Polarization
Energy MeV

Polarization. Yield. Diaphragm effect.

Gamma's polarization and yield vs. diaphragm size



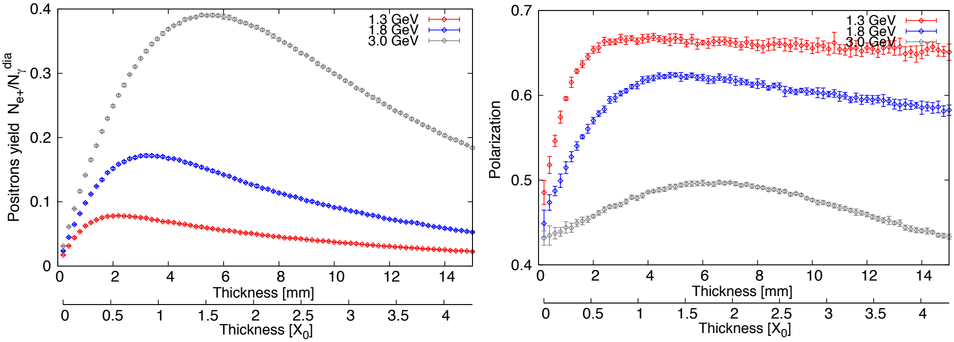
Photons production. Summary.

Electrons energy [GeV]	1.3	1.8	3.0
Maximum photons energy [MeV]	29.5	56	152.5
Mean photons energy [MeV]	14.7	27.8	75.7
Aperture (⊘) after 5m of drift [mm]	25	15	10
Mean photons energy after apert [MeV]	17.7	35	93.4
Mean photons polarization	23 %	30%	25 %
Diaphragm efficiency($N_\gamma^{dia}/N_\gamma^{tot}$)	0.79	0.73	0.75
Compton source efficiency(N_γ^{tot}/N_{e^-})	0.07	0.09	0.12
Compton source yield(N_γ^{dia}/N_{e^-})	0.06	0.06	0.09

Parameters of positrons production

Description	Value	Value	Value
Photons beam peak energy [MeV]	29.5	56	152.5
Mean photons energy [MeV]	14.7	27.8	75.7
Mean photons energy after aperture [MeV]	17.7	35	93.4
Target material	W	W	W
W density (near r.t.) [g/cm^3]	19.25	19.25	19.25
Tungsten radiation length (X_0) [g/cm^2]	8	8	8
Target thickness [mm]	2.2	3.2	5.2
Target size [cm]	2.5	2.5	2.5

Target thickness optimization



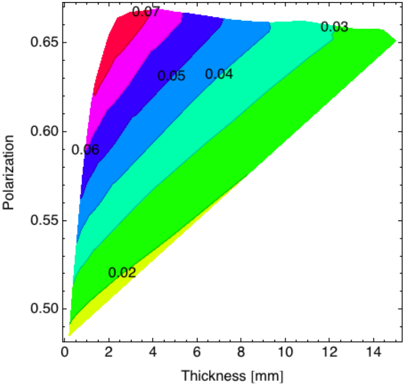
Target thickness optimization I

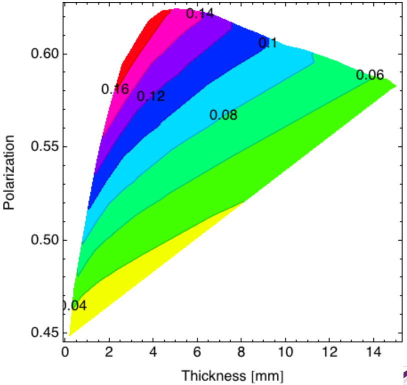
Results of optimization

For the 1.3 GeV → 2.2 mm

Results of optimization

For the 1.8 GeV → 3.2 mm

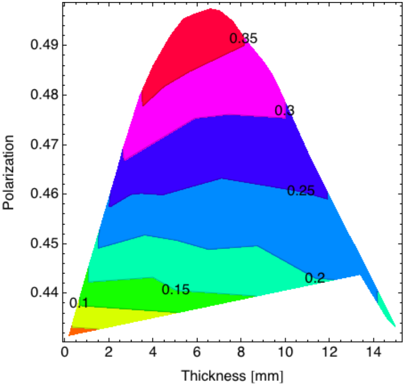




Target thickness optimization II

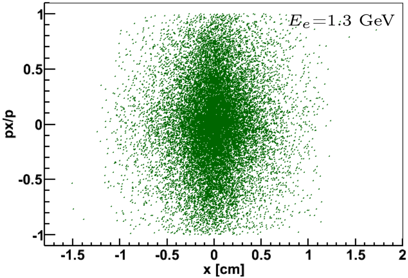
Results of optimization

For the 3.0 GeV → 5.2 mm



Transverse phase space distribution at the target

Large divergence and high emittance positrons beam

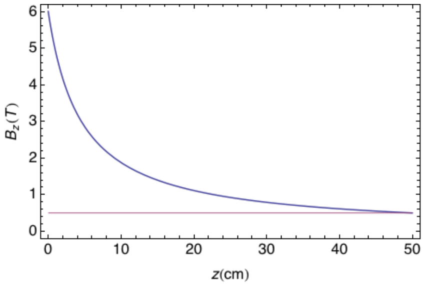


The positron accelerating and capture section (ACS)

- Adiabatic Matching Device (AMD)
  Large angles and small beam dimensions should be transformed to fit accelerator acceptance.
- Accelerating section:
  positron pre-accelerator embedded in a solenoidal field (several RF accelerating structures)

  Concept: collect and accelerate positrons up to 200 MeV

Matching device. AMD.



Positron capture optics (AMD)

Magnetic field varies along z- direction as $B(z) = \frac{B_0}{1+\alpha z}$

Condition for an adiabatic field variation $\frac{P}{eB^2}\frac{dB}{dz} \ll 1$ should be fulfilled.

Initial field $B_0 = 6$ T

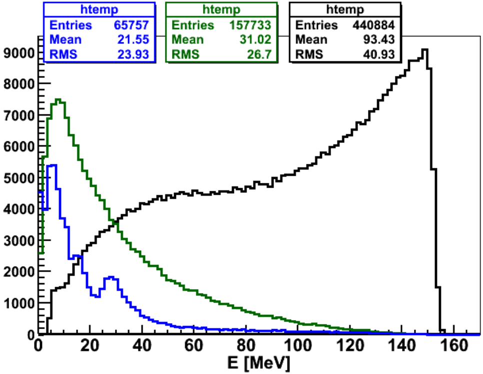
Taper parameter $\alpha = 0.22\ cm^{-1}$

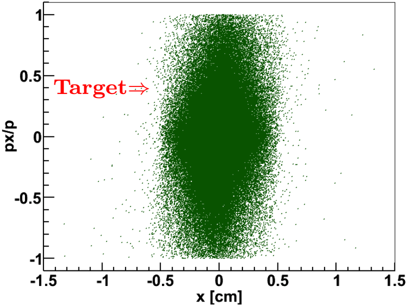
Aperture radius $a = 2$ cm

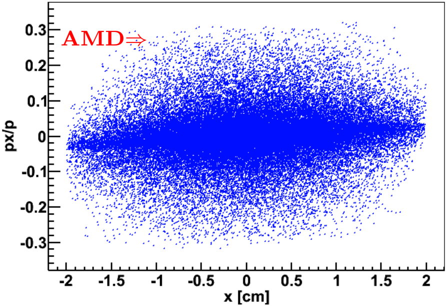
Electrons energy [GeV]	3.0
Positrons production yield $(N_{e+}/N_{\gamma}^{dia})$	0.36
Accepted positrons yield at the AMD $(N_{e+}^{acc}/N_{\gamma}^{dia})$	0.15
AMD capture efficiency $(N_{e+}^{acc}/N_{e+}^{targ})$	0.42
Compton source accepted efficiency(N_{e+}^{acc}/N_{e-})	0.013

Energy spectra. E_e=3.0 GeV

Impinging gammas, positrons @ target and positrons @ exit of AMD.







Accelerating capture section (ACS)

ACS around 20 m long inside 0.5 T solenoidal magnetic field

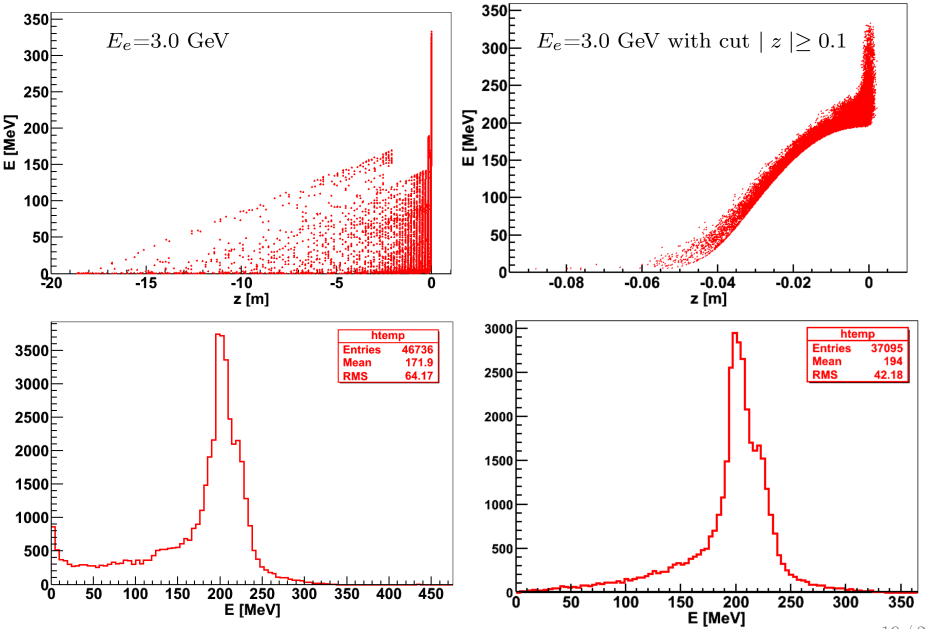
2 GHz TW tanks of 4,36 m long each, 85 cells set up one tank

Aperture radius $a = 2$ cm

4 tanks are used to accelerate e^+ up to 200MeV

Same lattice and tank phase are used for each case, i.e. further lattice optimisation and adaptation is possible. *See the talk of F. Poirier*

Electrons energy [GeV]	1.3	1.8	3.0
Positrons production yield $(N_{e+}/N_{\gamma}^{dia})$	0.07	0.16	0.36
ACS efficiency $(N_{e+}^{\sim 200MeV}/N_{e+}^{targ})$	0.39	0.36	0.29
Compton source efficiency$(N_{e+}^{\sim 200MeV}/N_{e-})$	0.0016	0.004	0.01


E_e=3.0 GeV
E [MeV]
z [m]
E_e=3.0 GeV with cut $|z| \geq 0.1$
E [MeV]
z [m]
htemp
Entries 46736
Mean 171.9
RMS 64.17
E [MeV]
htemp
Entries 37095
Mean 194
RMS 42.18
E [MeV]

Positron production and capture. Summary.

The choice of the capture and primary accelerating system depends on:

1. expected positron yield
2. allowed energy dispersion

Electrons energy `[GeV]`	1.3	1.8	3.0
Mean photons energy after aperture `[MeV]`	17.7	35	93.4
Mean photons polarization	23 %	30%	25 %
Positrons production yield (N_{e+}/N_{γ}^{dia})	0.07	0.16	0.36
Mean positrons polarization	40 %	34%	22 %
Positrons production efficiency(N_{e+}/N_{γ}^{tot})	0.06	0.12	0.27
Compton source production efficiency(N_{e+}/N_{e-})	0.004	0.01	0.03
ACS efficiency ($N_{e+}^{\sim 200 MeV}/N_{e+}^{targ}$)	0.39	0.36	0.29
Compton source efficiency($N_{e+}^{\sim 200 MeV}/N_{e-}$)	0.002	0.004	0.01

- CLIC: $7.6 \times 10^9\ e^+$/bunch, CSE at 3.0 GeV: 1% – $1 \times 10^8\ e^+$/bunch $\Longrightarrow$ 76 injections