$\gamma - \gamma$ option (for CLIC and advanced collider concepts)

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MOTIVATION

$\gamma - \gamma$ colliders become natural way to explote the full capacity of $e^- e^+$ collider

- Important Physics Case (unique?)
- Reduced extra cost investment
- Best suited for single-pass machines
- 3 colliders in 1 machine
- No need of e^+ beam
- Polarized beams
- Reduced background
- Collaboration with the laser community

$\gamma - \gamma$ Collider

Photon Collider History

First idea photon-photon collisions is about 75 years old

$\Rightarrow$ lacking of a source of high energy photons

First photon collider proposed at the first workshop on physics at linear collider VLEPP (Novosibirsk,Dec.1980)

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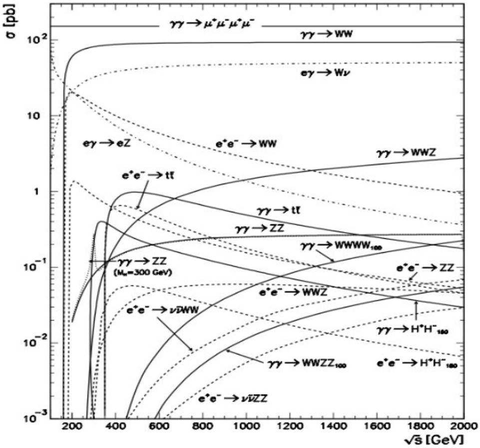
†Figure taken from V. Telnov presentation at the Photon beam workshop, Padova, November 27, 2017

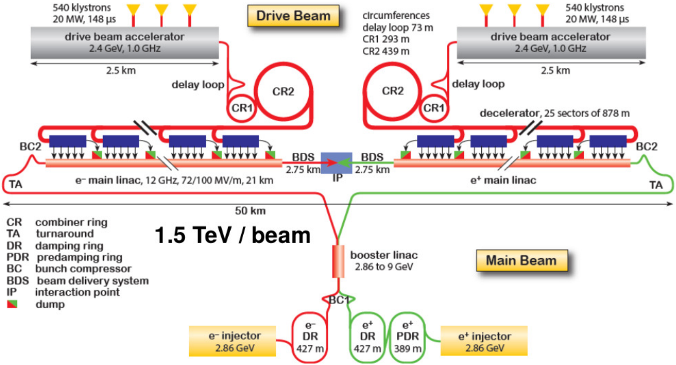
Physics Case

- Higher cross-sections
- Polarization of γ's
- CP-violation†
- λ_{hhh}
- ...?



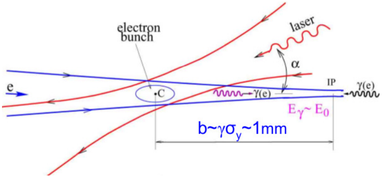
† *M. Velasco, "Physics at Photon Colliders", ICFA Mini-workshop on Future $\gamma\gamma$ Collider, Beijing, China, 2017*

$\gamma\gamma$ Collider Scheme (à la CLIC)

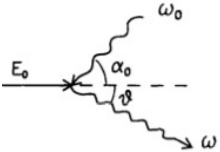


- Lasers
- MDI
- γ's Dumps

(Not easy at all)



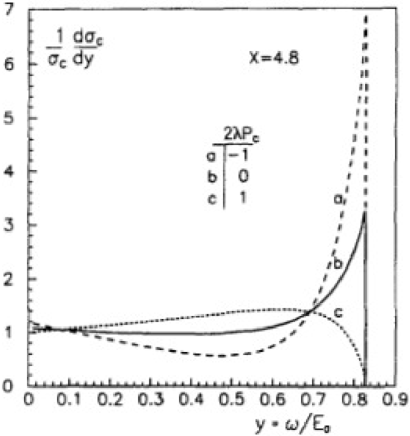
γ Generation



$\omega_m = \frac{X}{X+1} E_0$

$X \approx \frac{4E_0\omega_0}{m^2c^4} \leq 4.8$

- Energy spectra depends on
- e^- helicity
- Laser Pol.



$\sigma_c = \sigma_c^{\text{np}} + 2\lambda_e P_c \sigma_1$
σ_c^{np} and σ_1 depend on X

CLIC Parameters

Parameter choices are determined by beam dynamics studies;

- Q, σ_z and bunch spacing are limited by wakefield in the ML
- ϵ_x is mainly determined by the DR as a function of Q
- ϵ_y is given by the DR, RTML, ML and BDS
- σ_y^* is determined by FFS
- σ_x^* has two sources for the lower limit
  - FFS
  - beamstrahlung effect $\Rightarrow$ Q,$\mathcal{L}$-spectrum

Thinking forward to $\gamma\gamma$-collider:

(what can be done that we have not (couldn't) done)

- Only clear parameter which could be further pushed is σ_x^*
  What is then the limitation from FFS?
- Other machine parameters may be optimized
  - Different parameters choice may provide an overall $\mathcal{L}$ gain, despite compromising one of the mentioned variables

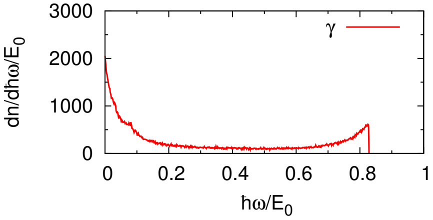
CLIC FFS Parameters

Luminosity	**Unit**	**3 TeV**
Total ($\mathcal{L}$)	[$10^{34} cm^{-2} s^{-1}$]	5.9
High ($\mathcal{L}_{\mathrm{high}}$)	[$10^{34} cm^{-2} s^{-1}$]	2.0
IP beam size ($\sigma^*_{x/y}$)	[nm]	45/1.0
IP betas ($\beta^*_{x/y}$)	[mm]	10/0.07
Emittance ($\gamma\epsilon_{x/y}$)	[nm]	660/20
Energy spread ($\Delta p/p$)	[%]	0.3
Bunch Charge (Q)	[10^9 e^-]	3.7
Bunch length (σ_z)	[μm]	44
# Bunches / train		312
Chromaticity (ξ_y)		50000
$\mathrm{L}_{\mathrm{QD0-IP}}$	[m]	3.5

e^- *to* γ Conversion

Assumed values for hard photons generation :

- $d = 1$ mm (dist. from laser to IP)
- $\rho = \frac{d}{\gamma\sigma_y^*} = 1$
- $k = 1$ (conversion efficiency)
- max E_γ=1243 GeV ($X = 4.83$)
- $\lambda_e = 80\%$ (electron helicity)
- P_γ= -1 (laser polarisation)

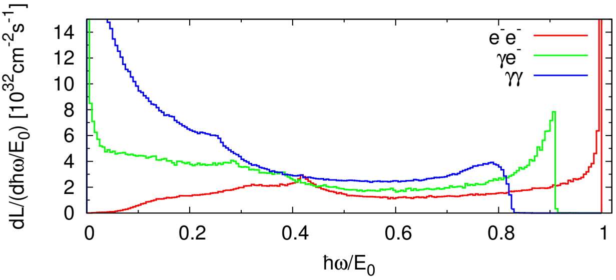


e^--beam and γ-beam parameters after conversion (*linear regime*)

Parameter	**Unit**	e^-	γ
IP beam size ($\sigma^*_{x/y}$)	[nm]	45/1.8	77/77
Energy spread ($\Delta p/p$)	[%]	65	96

$\mathcal{L}$-Spectra

Luminosity	Unit	$e^- e^-$	$e^- \gamma$	$\gamma\gamma$
Total ($\mathcal{L}$)	$[10^{34} cm^{-2} s^{-1}]$	0.6	0.5	0.5
High ($\mathcal{L}_{\rm high}{}^\dagger$)	$[10^{34} cm^{-2} s^{-1}]$	0.5	0.4	0.3



† above $0.6 \cdot E_0$

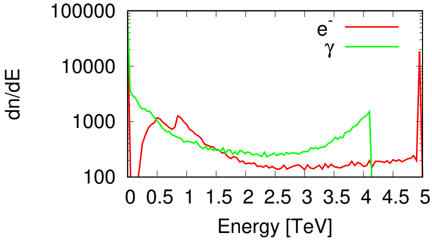
10 TeV FFS Parameters

Luminosity	Unit	10 TeV
Total ($\mathcal{L}$)	$[10^{34} cm^{-2} s^{-1}]$	-
High ($\mathcal{L}_{\rm high}$)	$[10^{34} cm^{-2} s^{-1}]$	-
IP beam size ($\sigma^*_{x/y}$)	[nm]	25/0.5
IP betas ($\beta^*_{x/y}$)	[mm]	10/0.07
Emittance ($\gamma\epsilon_{x/y}$)	[nm]	328/11
Energy spread ($\Delta p/p$)	[%]	0.3
Bunch Charge (Q)	$[10^9\ e^-]$	(3.7)
Bunch length (σ_z)	$[\mu m]$	(44)
# Bunches / train		(312)
Chromaticity (ξ_y)		50000
$L_{\rm QD0-IP}$	[m]	3.5

e^- *to* γ Conversion

Assumed values for hard photons generation :

- $d = 1$ mm (dist. from laser to IP)
- $\rho = \frac{d}{\gamma\sigma_y^*} = 1$
- $k = 1$ (conversion efficiency)
- max E_γ=4142 GeV ($X = 4.83$)
- $\lambda_e = 80\%$ (electron helicity)
- P_γ= -1 (laser polarisation)

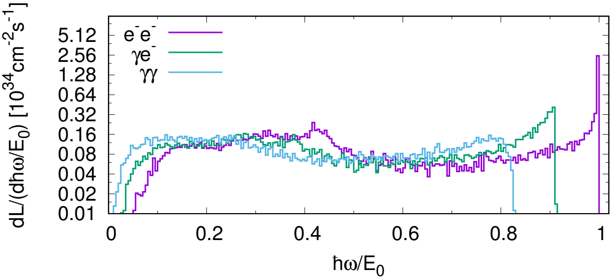


e^--beam and γ-beam parameters after conversion (*linear regime*)

Parameter	**Unit**	e^-	γ
IP beam size ($\sigma^*_{x/y}$)	[nm]	15/0.7	16/36
Energy spread ($\Delta p/p$)	[%]	135	170

$\mathcal{L}$-Spectra

Luminosity	**Unit**	$e^- e^-$	$e^- \gamma$	$\gamma\gamma$
Total ($\mathcal{L}$)	$[10^{34} cm^{-2} s^{-1}]$	1.4	1.2	1.1
High ($\mathcal{L}_{\text{high}}$ †)	$[10^{34} cm^{-2} s^{-1}]$	1.2	1.0	0.8



† above $0.6 \cdot E_0$

CONCLUSIONS

Summary

Luminosity	**Unit**	3 TeV	10 TeV
Total ($\mathcal{L}$)	$[10^{34} cm^{-2} s^{-1}]$	0.5	1.1
High ($\mathcal{L}_{\mathrm{high}}$)	$[10^{34} cm^{-2} s^{-1}]$	0.3	0.8

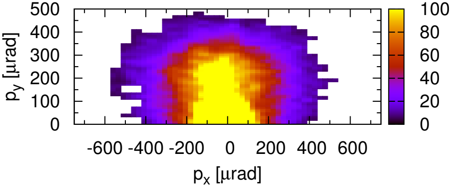
- Attractive $\gamma\gamma$ luminosities as of *March 2018* for the 3 TeV and 10 TeV considered cases
  - although significantly below $10^{36} cm^{-2} s^{-1}$
- Further improvement can be achieved by optimizing laser and IP spot sizes parameters
  - Understanding limitations of FFS on σ_x^* (common interest in the acc, community)
- $e^- \Rightarrow \gamma$ done assuming linear regime

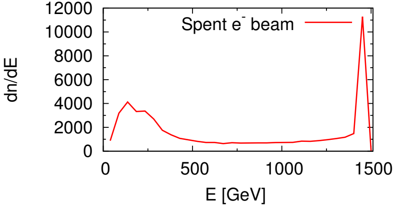
EXTRA SLIDES

Spent e^- beams

Criteria for hitting the BeamCal:

- polar angle $\theta \geq 10\ mrad$
- transverse momentum $p_T \geq 20\ MeV$





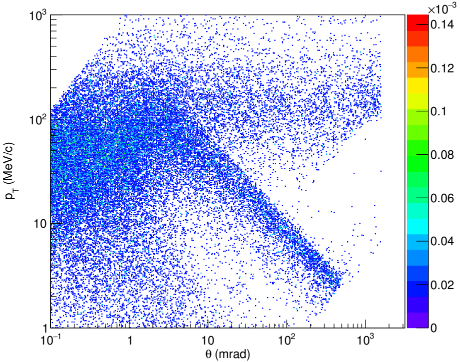
e^- captured by detector 0%

Dissipated Power : 0 W

Incoherent Pairs

Criteria for hitting the BeamCal:

- polar angle $\theta \geq 10$ *mrad*
- transverse momentum $p_T \geq 20$ *MeV*



Pairs captured by detector 26%

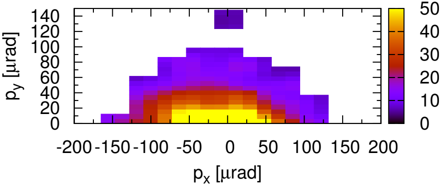
Dissipated Power : 60 W

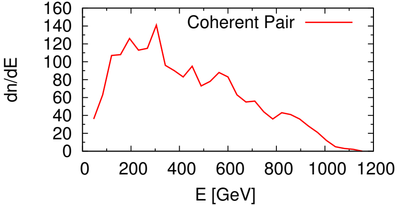
Pairs created y scattered photons and laser are not simulated

Coherent Pairs

Criteria for hitting the BeamCal:

- polar angle $\theta \geq 10\ mrad$
- transverse momentum $p_T \geq 20\ MeV$



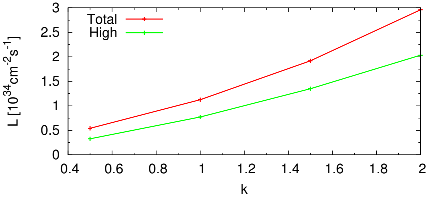


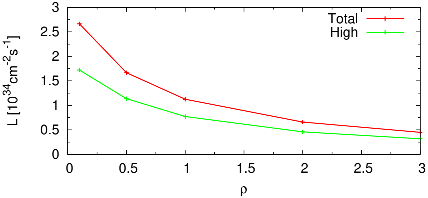
Pairs captured by detector 0%

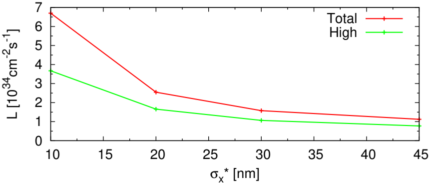
Dissipated Power : 0 W

Parameters Scan

Scan of k, ρ and σ_x^*







Reducing σ_x^* a factor 2 might be possible

Laser Considerations

e^--beam Parameters

- E_0=380 (3000) GeV
- $f_{\rm rep}$ = 50 Hz
- n_b = 352 (312)
- Bunch length = 70 (44) μm

Lasers concerns:

- Pulse length
- Non-linearity (ξ)
- Average power

Parameter	Unit	380	3000
Wavelength	μm	0.747	5.9
x (pairs threshold)		4.83	4.83
Photon Energy	eV	1.66	0.21
Power ($n_\gamma = 10^{19}$)	kW	46	5.2