CLIC e$^-$ and e$^+$ sources and ILC/CLIC common studies

L. Rinolfi

On behalf of the ILC/CLIC e$^+$ working group

Preliminary overview

The CLIC e- / e+ sources study considers 3 configurations:

1) Base Line configuration:

The study is based on 3 TeV (c.m.) with polarized e^- and unpolarized e^+.

2) Compton configuration:

The study is based on 3 TeV (c.m.) with polarized e^- and polarized e^+.

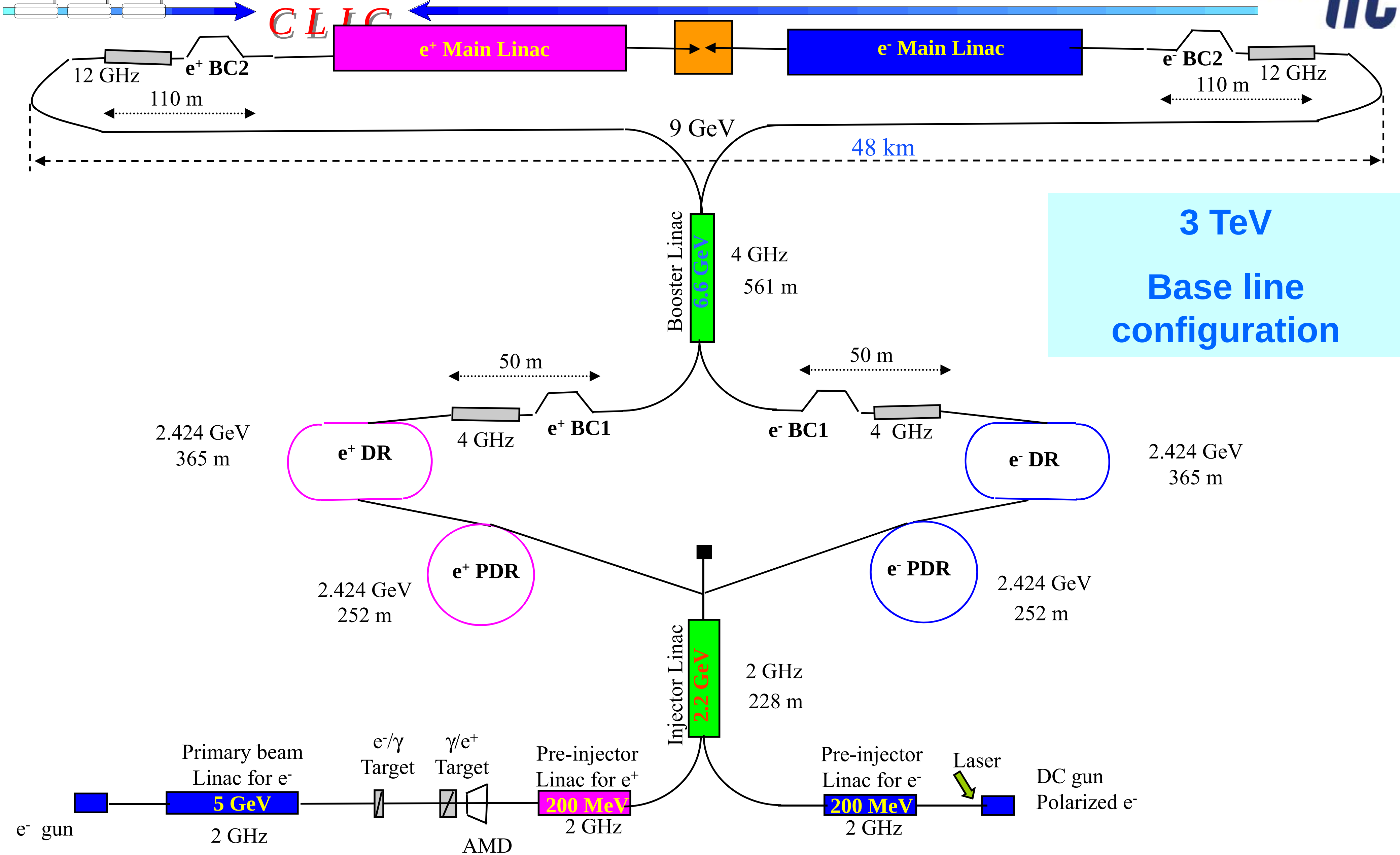
The undulator is an alternative option for polarized e^+.

3) Low energy configuration:

The study is based on 500 GeV (c.m.) but with a double charge per bunch:

=> strong impacts on the e^- / e^+ sources.

The CLIC Injector complex in 2008



3 TeV

Base line configuration

Target parameters for the Main Beams

At the entrance of the Main Linac for e^- and e^+

		NLC (1 TeV)	CLIC 2008 (0.5 TeV)	CLIC 2008 (3 TeV)	ILC (0.5 TeV)
E	GeV	8	9	9	15
N	10^9	7.5	6.8 - 7	3.72 - 4	20
n_b	-	190	354	312	2625
Δt_b	ns	1.4	0.5	0.5 (6 RF periods)	369
t_{pulse}	ns	266	177	156	968925
$\varepsilon_{x,y}$	nm, nm	3300, 30	2400, 10	600, 10	8400, 24
σ_z	µm	90-140	72	43 - 45	300
σ_E	%	0.68 (3.2 % FW)	2	1.5 - 2	1.5
f_{rep}	Hz	120	50	50	5
P	kW	219	180	90	630

CLIC e^- Beam Source Parameters

Parameter	Symbol	CLIC
Number Electrons per microbunch	N_e	6×10^9
Number of microbunches	n_b	312
Width of microbunch	t_b	~ 100 ps
Time between microbunches	Δt_b	500.2 ps
Microbunch rep rate	f_b	1999 MHz
Width of macropulse	T_B	156 ns
Macropulse repetition rate	f_{rep}	50 Hz
Charge per micropulse	C_b	0.96 nC
Charge per macropulse	C_B	300 nC
Average current from gun ($C_B \times f_{rep}$)	I_{ave}	15 uA
Average current macropulse (C_B / T_B)	I_B	1.9 A
Duty Factor w/in macropulse (100ps/500ps)	DF	0.2
Peak current of micropulse (I_B / DF)	I_{peak}	9.6 A

If spot radius = 1 cm

=> challenge for an cathode/anode optics with uniform focusing properties

=> Current density
$J = 3 \text{ A/cm}^2$

For 500 GeV option

=> I peak ≈ 20 A
=> Current density
$J \approx 6 \text{ A/cm}^2$

ILC and CLIC e$^-$ sources

M. Poelker / JLAB F. Zhou / SLAC

Parameters	ILC	CLIC
Electrons/microbunch	~3E10	6E9
Number of microbunches	2625	312
Width of Microbunch	**1 ns**	**~100 ps**
Time between microbunches	**~360 ns**	**500.2 ps**
Width of Macropulse	**1 ms**	**156 ns**
Macropulse repetition rate	5 Hz	50 Hz
Charge per macropulse	**~12600 nC**	**300 nC**
Average current from gun	63 μA	15 μA
Peak current of microbunch	4.8 A	9.6 A
Current density (1 cm radius)	**1.5 A/cm^2**	**3 A/cm^2**
Polarization	**>80%**	**>80%**

Summary

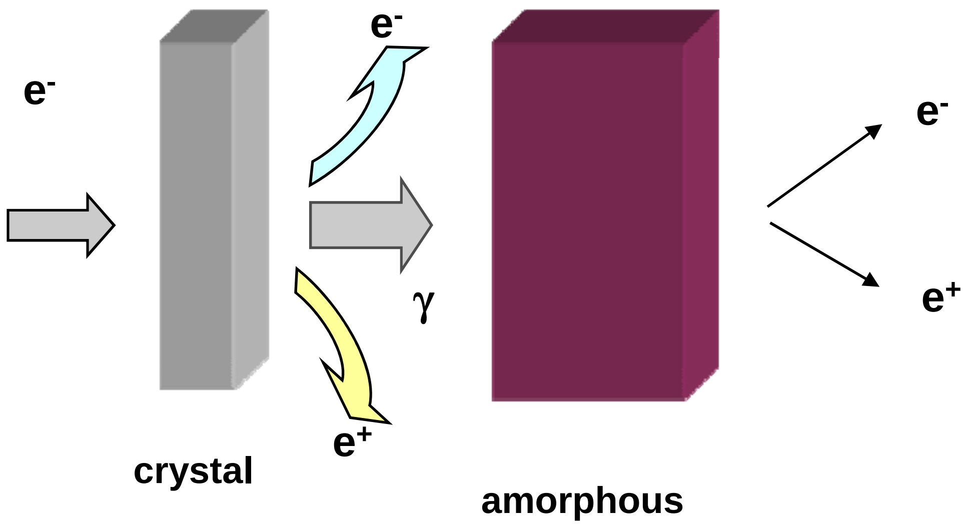
- 0.3% QE
- QE lifetime measured is 120-150 hrs.
- 84% of polarization
- **SLAC has an unique diagnostic to characterize polarized photo-cathodes.**

Unpolarized e^+ source by channelling

Proposal adopted by CLIC :

A e^- beam impinges on the crystal:
- **energy of 5 GeV**
- **beam size of 2.5 mm**

- A crystal e+ source :
  - - a 1.4 mm thick W crystal oriented along <111> axis
  - - a 10 mm thick W amorphous disk



- **Charged particles are swept off after the crystal:only γ (> 2MeV) impinge on the amorphous target.**

Expected yield: 0.92 e^+ / e^-

@ 200 MeV

- **The distance between the 2 targets is 2 meters.**

A similar proposal could be applied to ILC (see R. Chehab and T. Omori talks)

This CLIC study is performed within a CERN/LAL collaboration

e^+ by channeling from hybrid targets

CLIC

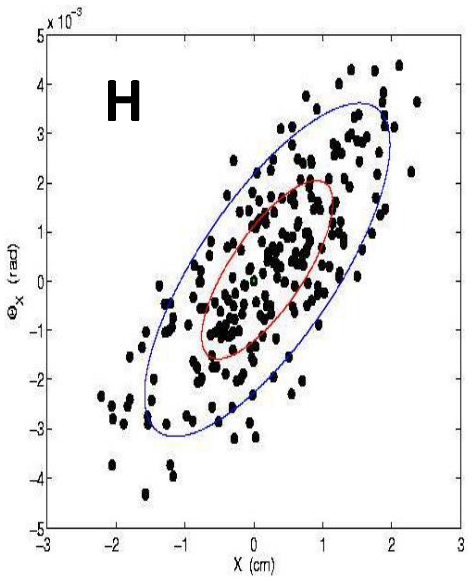
Parameter	Unit	CLIC
Primary e^- Beam		
Energy	GeV	5
N e^- /bunch	10^9	7.5
N bunches / pulse	-	312
N e^- / pulse	10^{12}	2.34
Pulse length	ns	156
Repetition frequency	Hz	50
Beam power	kW	94
Linac frequency	GHz	2
Beam radius (rms)	mm	2.5
Bunch length (rms)	mm	0.3

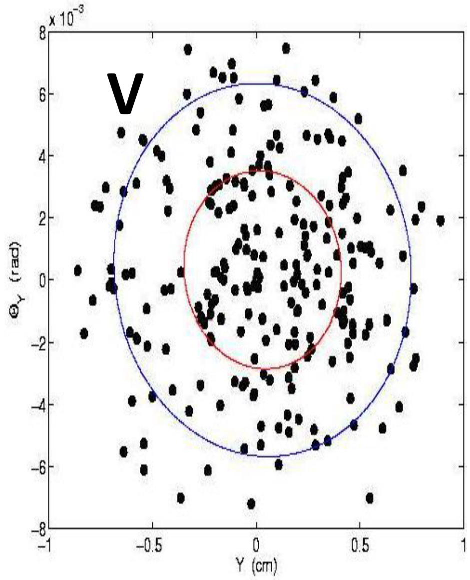
Parameter	Unit		
Target		Crystal	Amorph.
Material		W	W
Length	mm	1.4	10
Beam power deposited	kW	0.2	7.5
Deposited P / Beam Power	%	0.2	8
Energy lost per volume	10^9 GeV/mm^3	0.8	1.9
Peak Energy Deposition Density (PEDD)	J/g	6.8	15.5

Experimental limit found at SLAC: PEDD = 35 J/g => We have a factor 2 as safety margin

At 500 GeV, charge is doubled => Increase spot size, increase 2m space or double target stations ?

- TRANSVERSE EMITTANCES AT END OF CLIC PRE-INJECTOR ($\sigma^- = 2.5$ mm)



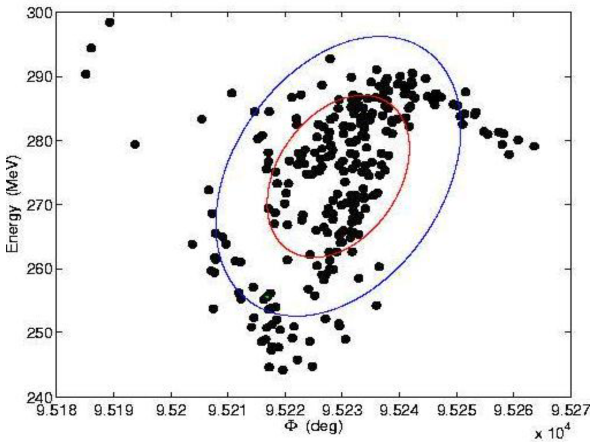


Blue: 80 %
Red: rms

$\varepsilon_x = \varepsilon_y = 17\pi$ mm.mrad

$\gamma\varepsilon_x = \gamma\varepsilon_y = 6650\ \pi$ mm.mrad

- LONGITUDINAL EMITTANCE AT END OF CLIC PRE-INJECTOR @ 200 MeV

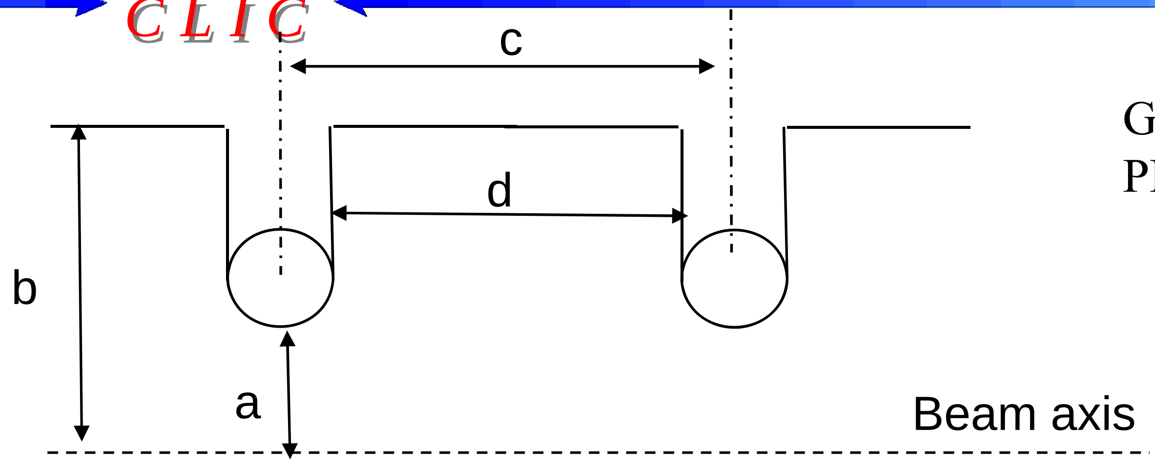


Blue: 80 %

Red: rms
ε_z = 13.6 cm.MeV = 136000 eV.m

R. Chehab, A. Variola, A. Vivoli, V.M.Strakhovenko

Scaling from NLC (S-band) structures



Geometry needed for PLACET simulations

	Units	2 GHz	2.856 GHz	4 GHz
a	mm	22	15.4	11
b	mm	64.3	45	32
c	mm	50	35	25
d	mm	42.8	30	21
G (unloaded)	MV/m	17	25	36
G (loaded) 1.3 A	MV/m	15	22	30
L	m	4	4	3
		CLIC Injector	NLC structure	CLIC Booster

Injector Linac output parameters

Pre-Damping ring input

Parameter	Unit	e^-	e^+
Energy (E)	GeV	2.424	2.424
No. of particles/bunch (N)	10^9	4.4	6.4
Bunch length (rms) (σ_z)	mm	1	5
Energy Spread (rms) (σ_E)	%	0.1	2.7 (*)
Horizontal emittance ($\gamma\varepsilon_x$)	mm. mrad	100	9300
Vertical emittance ($\gamma\varepsilon_y$)	mm. mrad	100	9300

rms values

(*) Simulations have been performed with a bunch compressor at the entrance of the Injector Linac which brings the bunch length from 5 mm down to 2mm:

=> The rms energy spread, at 2.4 GeV, is just below 1% (see CLIC Note 737)

CLIC Pre-Damping Ring for the Base line

F. Antoniou, Y. Papaphilippou / CERN

PARAMETER	PDR
Eenergy [GeV]	2.424
Circumference [m]	252
Number of particles / bunch [10^9]	4.4
Number of trains	1
FWHH momentum spread [%] accepted at injection	3 % (~ 1.3 % rms) (*)
Hor. /ver. / lon./ damping times [ms]	2.5 / 2.5 / 1.2 (**)
Repetition rate [ms]	20
RF frequency [GHz]	2

(*) The rms momentum spread at injection could be reduced (~ 1%) by implementing either a bunch compressor at the entrance of the injector Linac (see previous slide) or an harmonic cavity which smooth the longitudinal distribution.

(**) With 6 damping times the injected normalized emittances are reduced from:

$\gamma\varepsilon$ = 9300 mm.mrad down to $\gamma\varepsilon$ = 18 mm.mrad

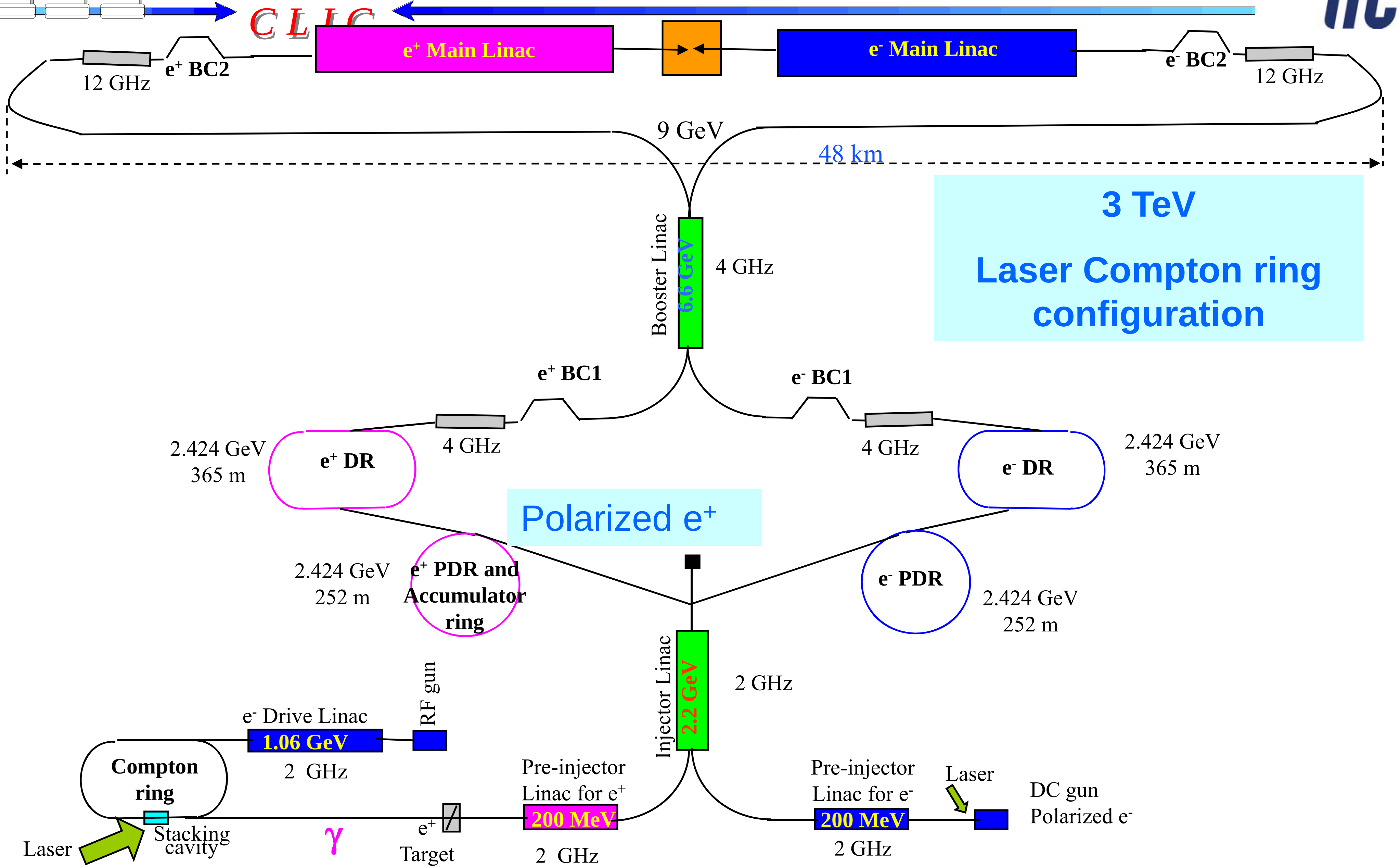
Compton polarized positron source

- Compton schemes are very attractive for the polarized positron sources. For CLIC they present many advantages

BUT:

- Need of strong R&D on lasers and optical cavities
- Careful optimization of the interaction point
- Design of the Compton ring

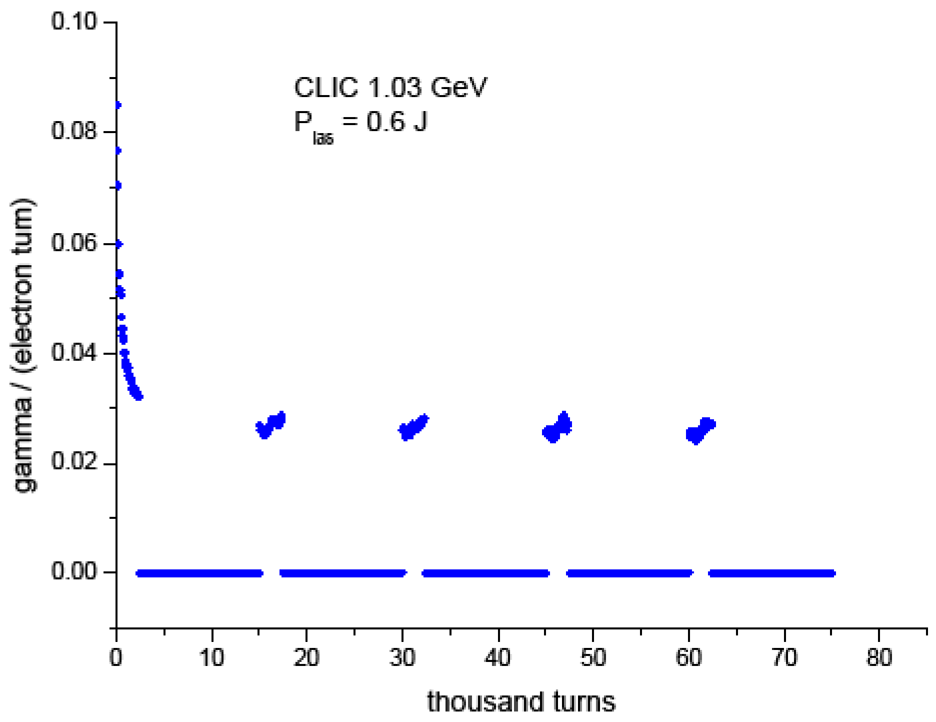
The CLIC Injector complex (Compton ring)

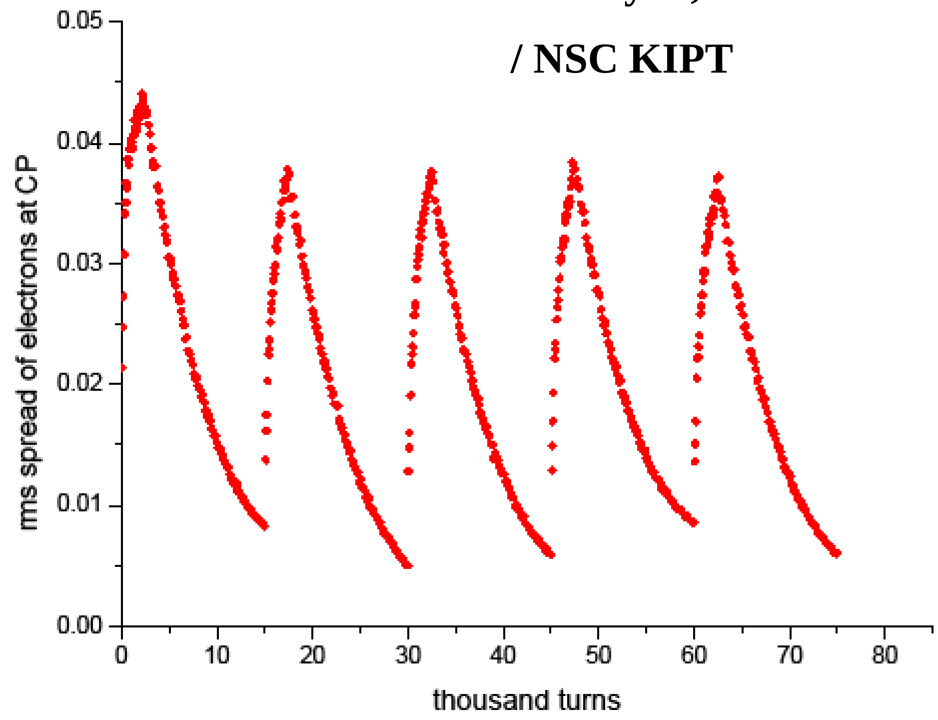


Compton ring design

E. Bulyak, P.Gladkikh

/ NSC KIPT





Number of e- = 312 x 6.2 x 10^{10} = 1.93 x10^{13} in the ring

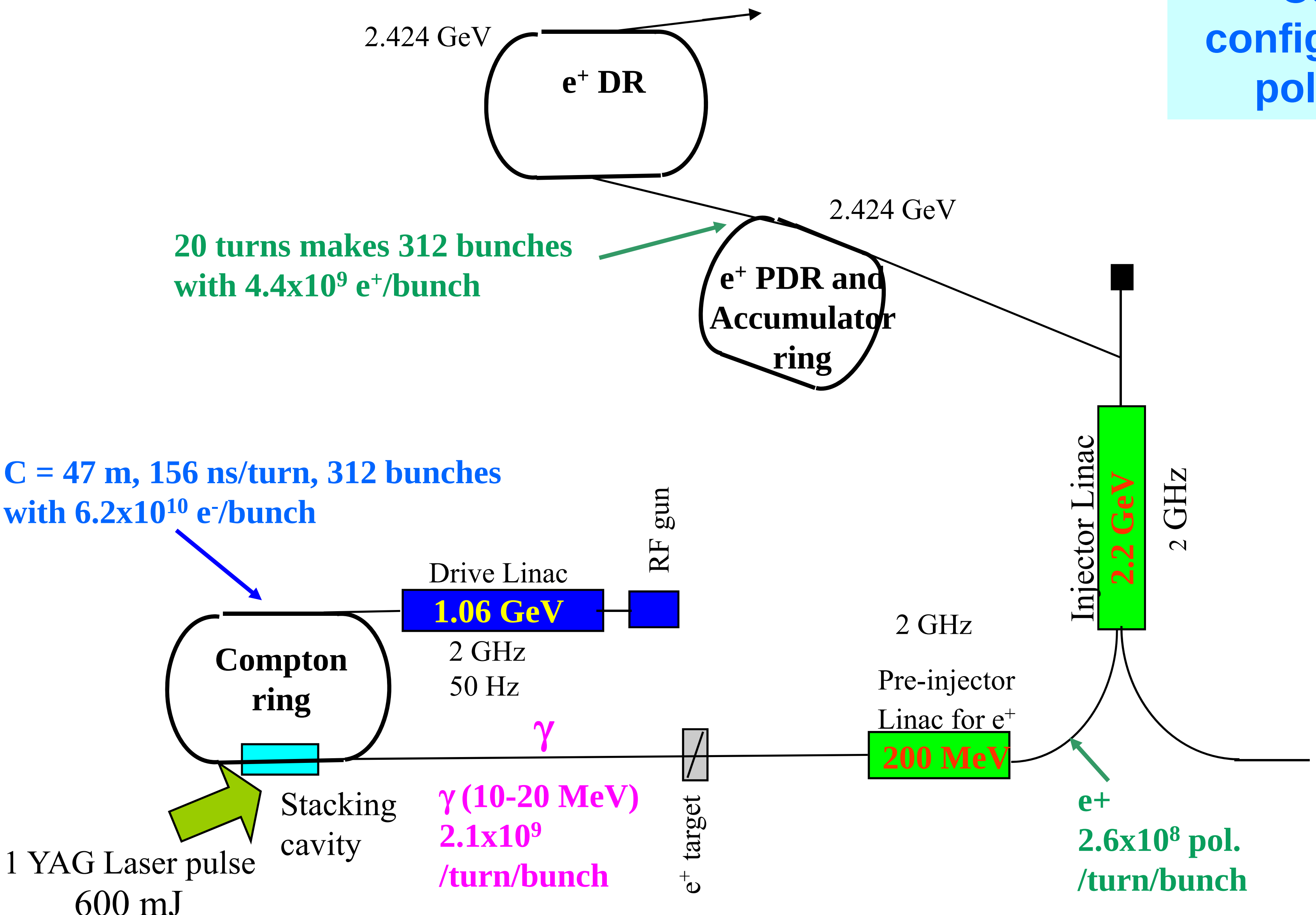
1 cycle = 15 000 turns = > T = 156 ns x 15 000 = 2.3 ms

Laser on during 2500 turns

Photon yield = 85 photons / e-

CLIC Compton scheme

Compton configuration for polarized e+



CLIC PDR for e^+ stacking (Requested values)

F. Zimmermann / CERN

parameter	value*	"Compton-PDR"
#bunches / train	312	
bunch spacing	0.5 ns	
final bunch charge	4.5×10^{9}	
circumference	251.6 m	
RF frequency	2 GHz	
harmonic number	1677	
RF Voltage	2 MV	**16.2 MV**
1st order momentum compaction	8.98×10^{-5}	
2nd order momentum compaction	0.058	**3×10^{-4}**
beam energy	2.424 GeV	
longitudinal damping time	1.25 ms	**0.5 ms**
equilibrium momentum spread	0.095%	**~0.12%**
equilibrium bunch length	0.786 mm	**~0.47 mm**

CLIC Compton scheme challenges

Current in the Compton ring (≈ 20 A)

Design of the Compton ring (with a double chicane)

Energy of laser

Optical stacking cavity

Design of the interaction point

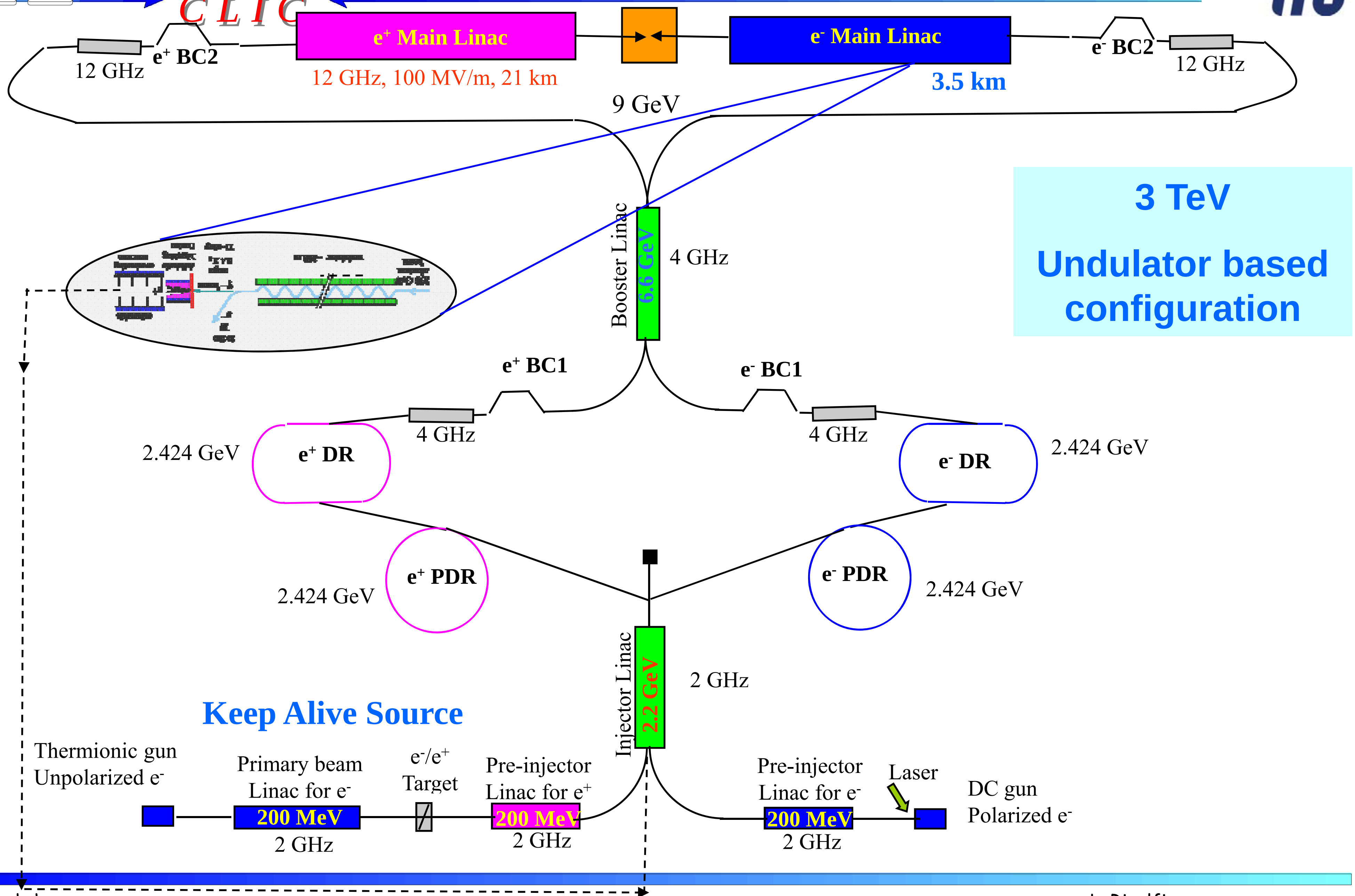
Repetition rate of Pre-Injector Linac and Injector Linac

Injection efficiency into the PDR

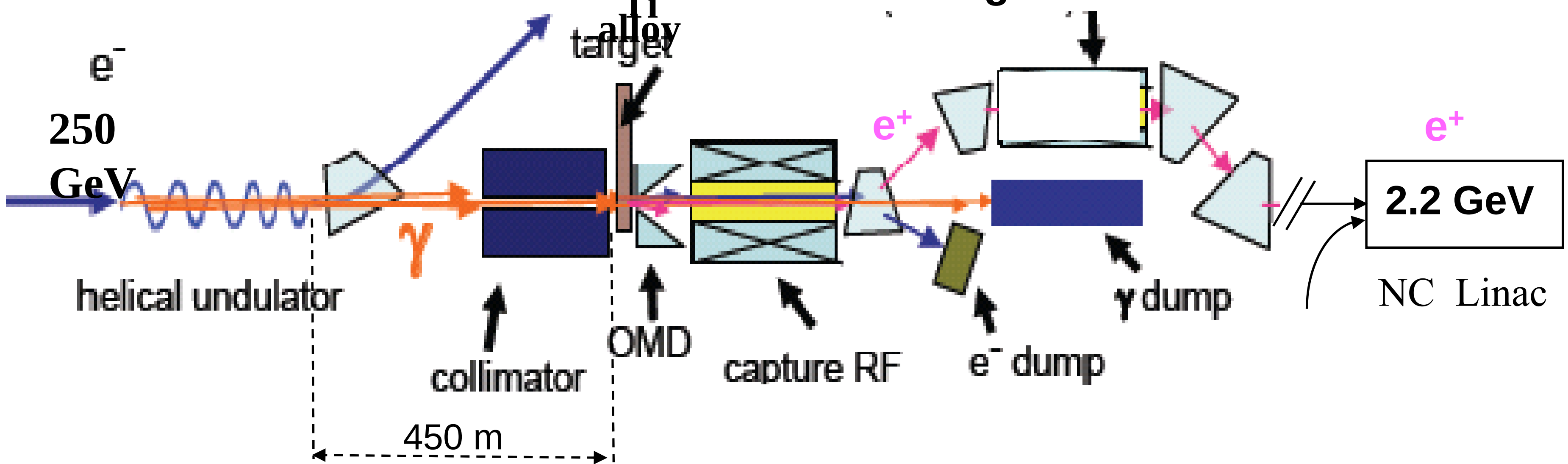
PDR parameters (momentum compaction, RF voltage, damping times, dynamic acceptance,…)

Stacking efficiency

The CLIC Injector complex (Undulator)



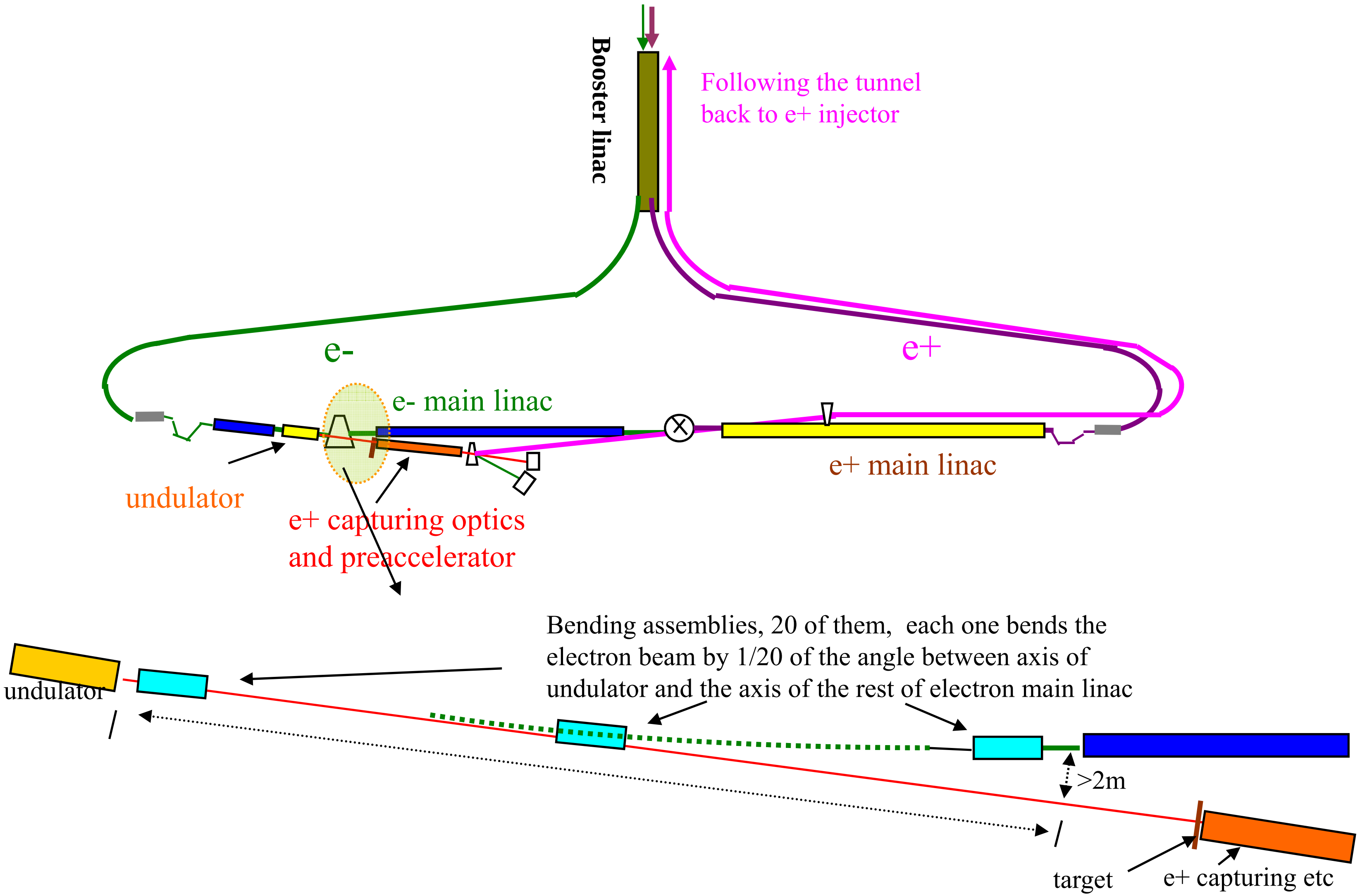
Possible layout and parameters for CLIC e^+



Undulator	Pre-Injector Linac	Injector Linac
K = 0.75	G = 12 MV/m	G = 17 MV/m
λu = 1.5 cm	E = 200 MeV	E = 2.424 GeV
L = 100 m	f_{RF} = ~~1.5 GHz~~ 2 GHz	f_{RF} = ~~1.5 GHz~~ 2 GHz
	B = 0.5 T	f_{rep} = 50 Hz

A possible CLIC complex layout with undulator based e+ source

W. Gai, W. Liu / ANL

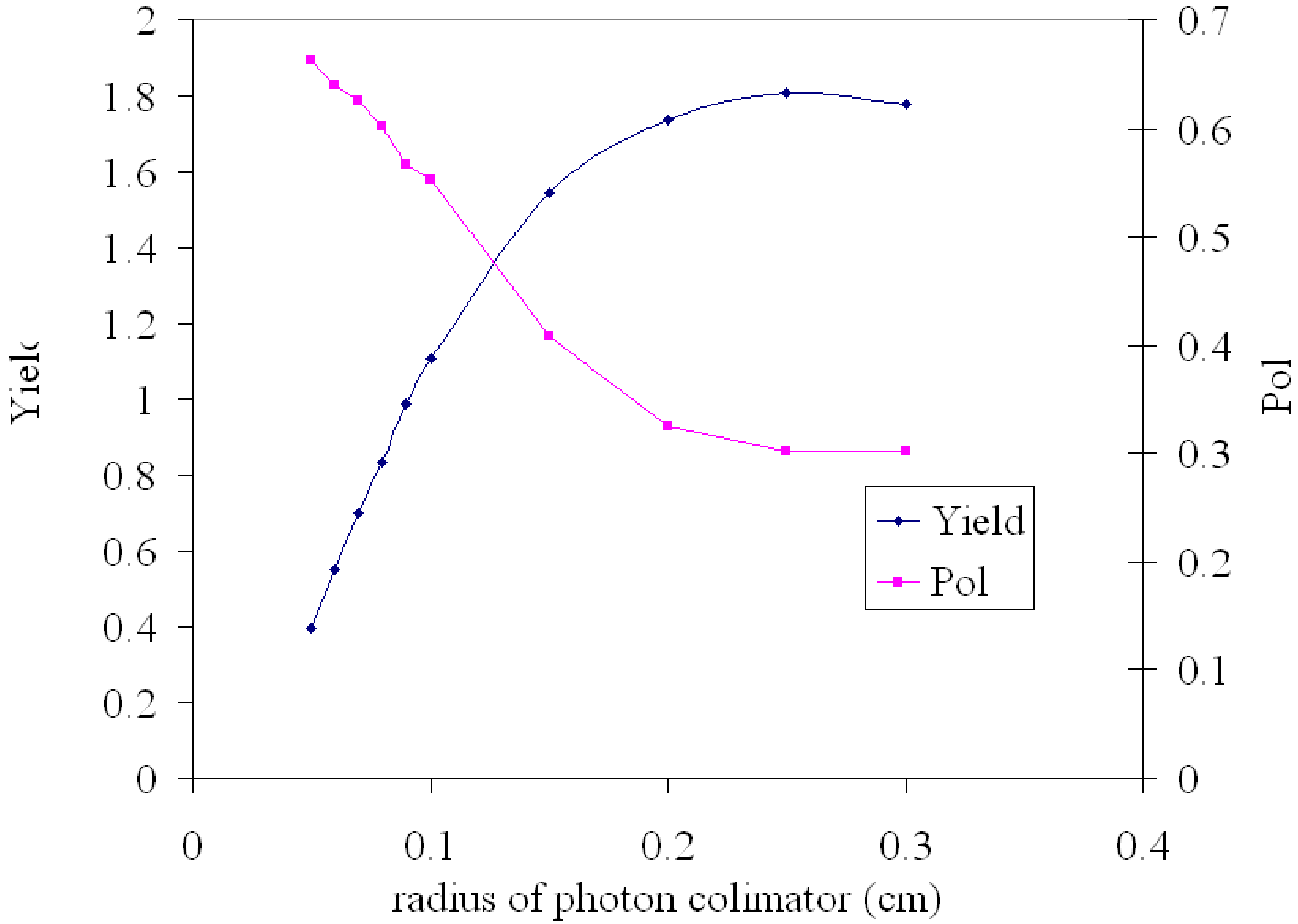


Numerical Simulation

- Drive e- beam energy: 250GeV
- Undulator K: 0.75
- Undulator period: 1.5cm
- Length of undulator: 100m
- Drift to target: 450m
- Accelerator gradient and focusing: 12MV/m to 50MV/m for beam energy <250MeV, 0.5T background solenoid field focusing; for 250MeV to 2.4GeV, 25MV/m with discrete FODO set.
- OMD: Non immersed
- Photon collimator: None
- Target material: 0.4 rl Titanium, immersed and non-immersed
- Yield is calculated as Ne+ captured / Ne- in drive beam.
- Positron capture is calculated by numerical cut using damping ring acceptance window: +/-7.5 degrees of RF(1.3GHz), $\varepsilon x+\varepsilon y < 0.09\ \pi$.m.rad, 1% energy spread with beam energy ~2.4GeV

Yield and polarization

W. Gai, W. Liu /ANL, J. Sheppard/SLAC



Proposed CLIC Studies at CI

I. Bailey, J. Clarke / CI

- Undulator-based source
  - Develop Geant4 model of collimator, target, capture optics, and capture rf assembly.
  - Optimise parameters (e.g. undulator position) wrt yield, polarisation and cost. (Coordination needed with ANL).
  - Consider timing constraints issues and upgrade paths.
  - Consider electron beam quality issues.
  - Consider optimal target technology (thermal load, shock waves, activation).
- Compton source
  - Extend Geant4 model to Compton source. (Coordinate with LAL)
  - Stacking simulations? Desirable, but effort not yet identified.
- Lithium lens capture optics
  - Evaluate suitability for Undulator and Compton schemes at CLIC. (Wide coordination needed.)
- Electron source
  - Tracking studies. (Coordinate with JLAB)

POSIPOL workshops

"POSItons POLarisés"

A important topic of the workshop is the polarized positron source by laser Compton back-scattering schemes in the framework of ILC and CLIC projects. Attention is also paid to a comparison between the Compton and the Undulator baseline scheme. Conventional positron sources with various target material, such as metal, liquid metal, and crystal, for the linear colliders is also a topics of the workshop.

The meeting focus on the development and coordination of the R&D programs under way and the need for a costing of the different solutions.

POSIPOL 2006	CERN	http://posipol2006.web.cern.ch/Posipol2006/
POSIPOL 2007	Orsay	http://events.lal.in2p3.fr/conferences/Posipol07/
POSIPOL 2008	Hiroshima	http://home.hiroshima-u.ac.jp/posipol/
POSIPOL 2009	Lyon	

Collaborations for the CLIC/ILC sources

1) Polarized electron from DC gun:	JLAB (USA)	**Formal agreement**
	SLAC (USA)	**Informal agreement => will be discussed during this workshop**
2) Unpolarized e^+ from channeling:	LAL (France)	**Formal agreement**
3) Polarized e^+ from Compton ring:	LAL (France)	**Formal agreement**
	NSC KIPT (Kharkov)	**Informal agreement**
	KEK (Japan)	**Informal agreement**
4) Polarized e^+ from Undulator:	Cockcroft Institute (UK)	**Formal agreement**
	ANL (USA)	**Informal agreement** => **request for a formal agreement has been made.**
	SLAC (USA)	**Informal agreement => will be discussed during this workshop**

ILC/CLIC sources activities (1)

1) Polarized electron from DC gun:

JLAB (USA) **Contributions to the CLIC workshop. More exchanges are foreseen**

SLAC (USA) **Discussions during this workshop should emphasize the collaboration**

2) Unpolarized e+ from channeling:

LAL (France) **Simulations with hybrid targets have been started. Contributions from IPNL (France) and BINP are already important. 10 deliverables for a period of 2 years (October 2010) have been described. See: https://edms.cern.ch/document/971601/1**

3) Polarized e+ from Compton ring:

LAL (France) **24 man-months have been allocated to start studies on Compton source**

NSC KIPT (Kharkov) **Simulations for the design of a Compton ring are on going**

KEK (Japan) **A Webex meeting (coordinated by T. Omori) is taking place once a month between ANL, BNL, CERN, CI, Hiroshima Uni., IPNL, KEK, KIPT, LAL .**

Optical/stacking cavity (4 mirrors) will be installed on ATF next Summer.

ILC/CLIC sources activities (2)

4) Polarized e+ from Undulator:

Cockcroft Institute (UK) **24 man-months and 9 deliverables have been identified to start studies on Undulator and Compton schemes, Lithium lens and e- source for a period of 2 years (July 2010). Between 2010 and 2012, additional studies are also envisaged to consolidate the CDR work. A MoU has been written. See: https://edms.cern.ch/document/977364/**
More detailed will be discussed during this workshop

ANL (USA) **Simulations have been already performed and were presented at the ILC e^+ workshop in Argonne and at the CLIC 08 workshop at CERN**
Following the request made by ANL, a draft for a formal agreement is in preparation and will be discussed during this workshop

SLAC (USA) **Has already contributed to the ANL studies mentioned above**
More collaboration will be discussed during this workshop

Two new ILC/CLIC working groups approved

E. Paterson / SLAC

Joint ILC/CLIC R&D Areas

- ILC-CLIC working groups formed in 2008. Goal is to optimize use of resources in areas of common or overlapping interests.

  - Civil Engineering and Conventional Facilities (CFS): Claude Hauviller/CERN, John Osborne/CERN, Vic Kuchler (FNAL)
  - Beam Delivery Systems and Machine Detector Interface: D.Schulte/CERN, Brett Parker (BNL), Andrei Seryi (SLAC),, Emmanuel Tsesmelis/CERN
  - Detectors: L.Linssen/CERN, Francois Richard/LAL, Dieter.Schlatter/CERN, Sakue Yamada/KEK
  - Beam Dynamics: A.Latina/FNAL), Kiyoshi Kubo (KEK), D.Schulte/CERN, Nick Walker (DESY)
  - Cost & Schedule: John Carwardine (ANL), Katy Foraz/CERN, Peter Garbincius (FNAL), Tetsuo Shidara (KEK), Sylvain Weisz/CERN

Project progress reports given at workshops such as CLIC08 14-17 Oct,08 and ILC08 15-20 Nov,08
Two new groups are being added, E+ sources, Damping Rings

Oct 30, 2008
9th ICFA Seminar

Global Design Effort

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The two new

co-conveners:

ILC: J. Clarke

CLIC: L. Rinolfi

have more work to do !

Conclusion

1) Many and challenging common issues for ILC and CLIC sources.

2) Polarized e^+ sources still require a lot of studies and R&D .

3) Several international collaborations have been set-up or are being set-up with important expected results.

4) The new ILC/CLIC working group "e^+ sources" would start fruitful collaboration after this ILC08 workshop.

Acknowledgments

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Kharkov Institute (Ukraine):	E. Bulyak, P. Gladikh
LAL (France):	A. Variola
SLAC (USA):	J. Sheppard, F. Zhou
Uppsala Univ. (Sweden):	A. Ferrari