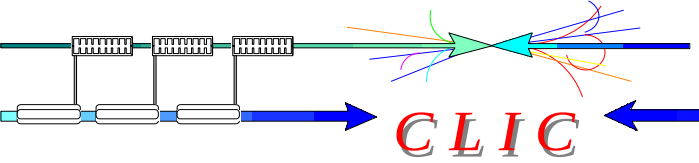
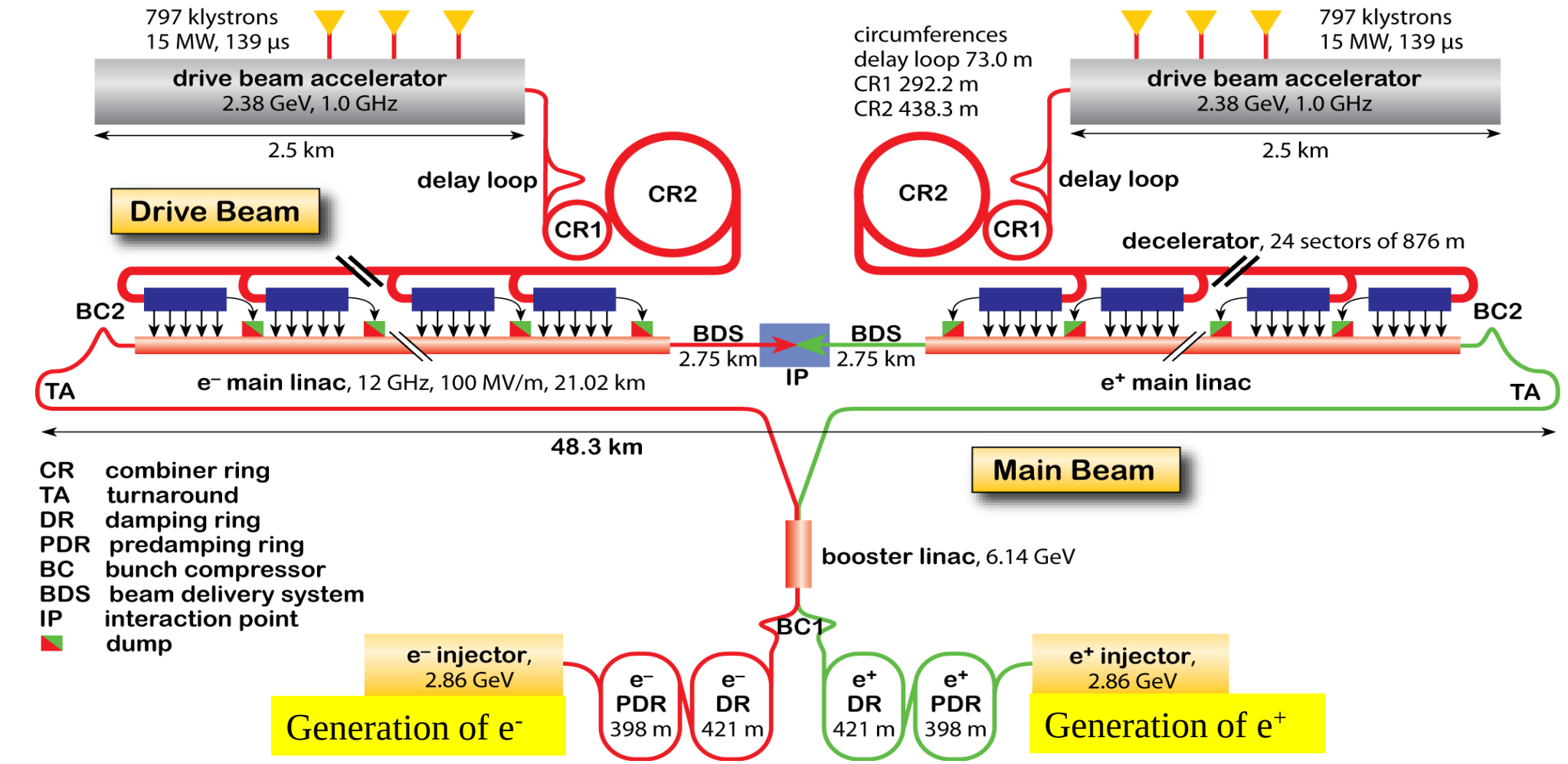


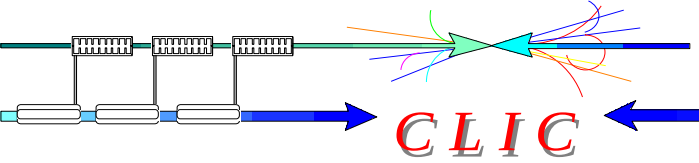
CLIC e^- and e^+ sources overview

Louis Rinolfi

for the CLIC Sources collaboration

General CLIC layout for 3 TeV





CLIC Main Beam generation

CLIC Main Beams generation (values at entrance of the Pre Damping Ring):

1) Study for baseline configuration: 3 TeV (cm):

Polarized electrons ($5x10^9$ e^-/bunch)
Unpolarized positrons ($7x10^9$ e^+/bunch)

2) Study for 500 GeV (cm):

Polarized electrons ($10x10^9$ e^-/bunch)
Unpolarized positrons ($14x10^9$ e^+/bunch)

3) Study for polarized positron at 3 TeV:

"The CLIC positron source based on Compton schemes" by L. Rinolfi et al., PAC09

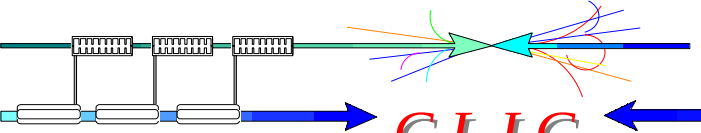
"Beam dynamics in Compton storage rings with laser cooling" by E. Bulyak et al., IPAC2010

"An undulator based polarized positron source for CLIC" by W. Liu et al., IPAC2010

4) Study for 1 TeV < E < 3 TeV:

See D. Schulte talk at this workshop and "CLIC energy scan" by D. Schulte et al., IPAC2010

CLIC Main Beam Injector Complex



e+ Main Linac
IP
e- Main Linac
12 GHz
e+ BC2
12 GHz, 100 MV/m, 21 km
e- BC2
12 GHz
9 GeV
48 km

IP = Interaction Point
SR= Spin Rotator
BC = Bunch Compressor
DR= Damping Ring
PDR= Pre-Damping Ring
AMD= Adiabatic Matching Device

3 TeV

Base line configuration 2010

Booster Linac 6.14 GeV
2 GHz
SR
2.86 GeV
e+ DR
2 GHz
e+ BC1
e- BC1
2 GHz
e- DR
2.86 GeV

unpolarized e+

polarized e-

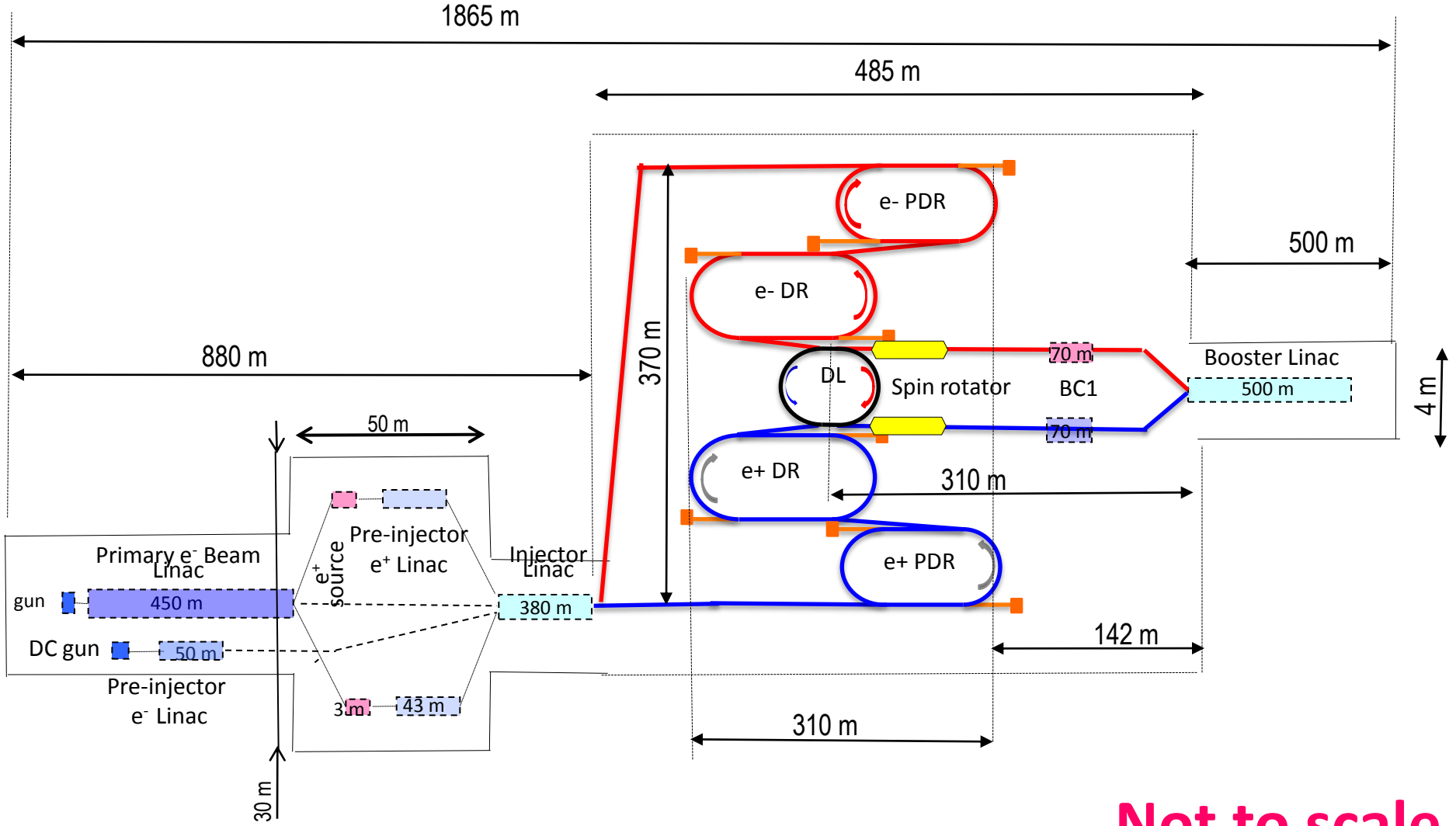
e+ PDR
2.86 GeV
SR
e- PDR
2.86 GeV

Injector Linac 2.66 GeV
2 GHz

Thermionic e- gun
Primary e- Beam Linac 5 GeV
Bunching system
2 GHz
e-/γ Target
γ/e+ Target
AMD
Pre-injector e+ Linac 200 MeV
2 GHz
BC0
Pre-injector e- Linac 200 MeV
2 GHz
Laser
Bunching system
DC gun Polarized e-

Footprint CLIC Main Beam Injector complex

with double e^+ target stations and with the transfer lines including spin rotator

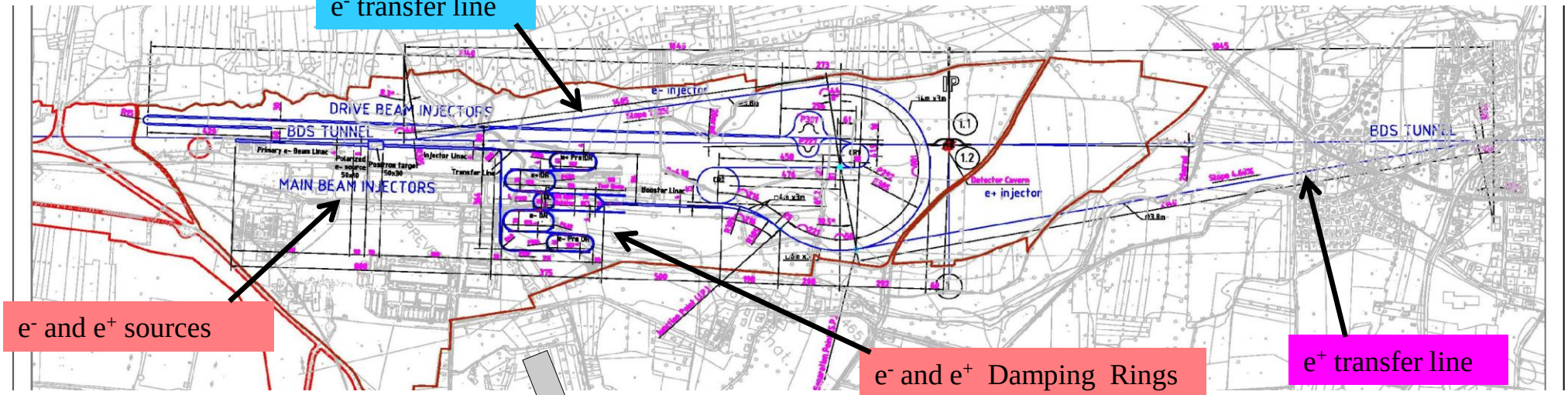


Not to scale

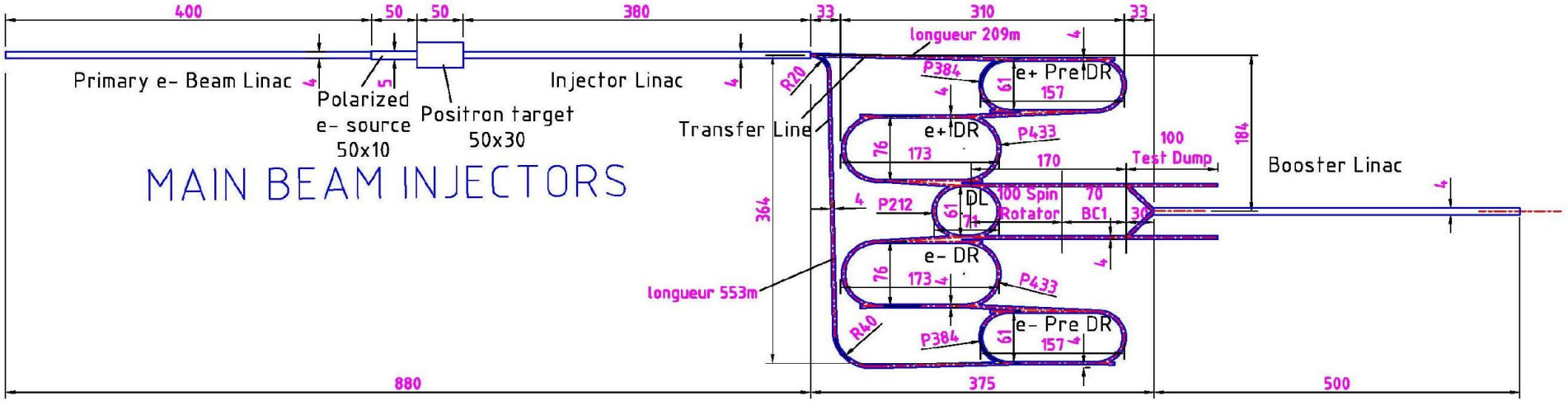
CLIC Main Beam Injector complex

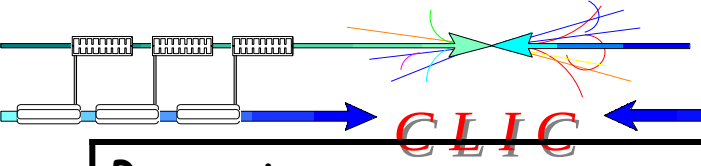
with real dimensions on the CERN site

J. Osborne and N. Baddams



Zoom



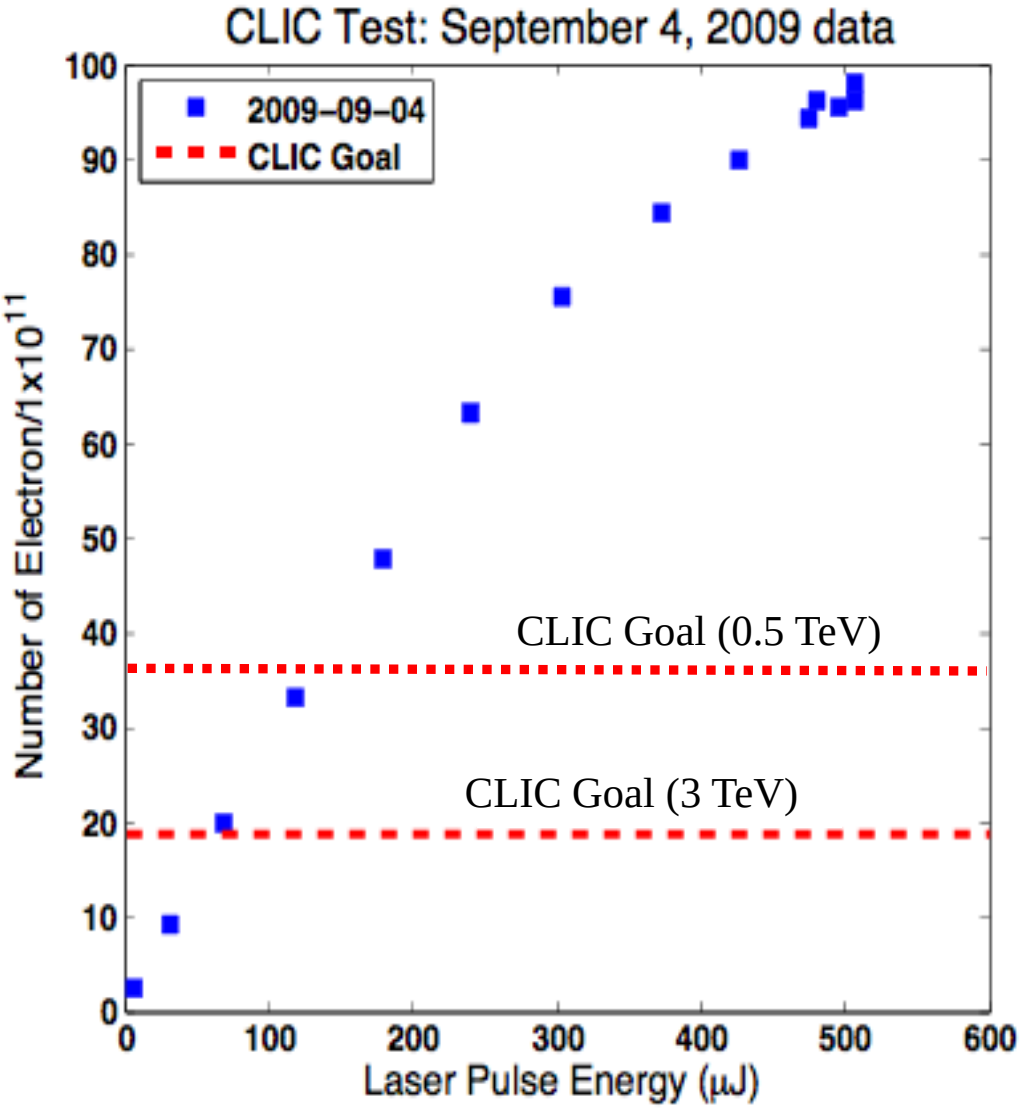


Polarized e⁻ sources parameters

Parameters	ILC (RDR)	CLIC (0.5 TeV)	CLIC (3 TeV)
Electrons/microbunch	3×10^{10}	1×10^{10}	0.6×10^{10}
Charge / microbunch	4.8 nC	1.6 nC	1 nC
Number of microbunches	2625	354	312
Total charge per pulse	79×10^{12}	3.5×10^{12}	1.9×10^{12}
Width of Microbunch	1 ns	~ 0.1 ns	~ 0.1 ns
Time between microbunches	360 ns	0.5002 ns	0.5002 ns
Width of Macropulse	~ 1 ms	177 ns	156 ns
Macropulse repetition rate	5 Hz	50 Hz	50 Hz
Charge per macropulse	12600 nC	566 nC	300 nC
Average current from gun	63 μA	28 μA	15 μA
Average current in macropulse	0.013	3.2	1.9
Peak current of microbunch	4.8 A	16 A	9.6 A
Current density (1 cm radius)	1.5 A/cm^2	5 A/cm^2	3 A/cm^2
Polarization	>80%	>80%	>80%

Polarized e- produced at SLAC

A.Brachmann and J. Sheppard



Pulse length = 160 ns

The total charge produced is a:

factor 3 above the CLIC requirement for 0.5 TeV

factor 5 above the CLIC requirements for 3 TeV

QE ~ 0.7 %

The measured polarization is ~ 82 %

(at low charge)

DC gun, laser and pre-injector

See M. Poelker talk

DC gun high voltage:

1) Reduce space-charge-induced emittance growth

2) Maintain smaller transverse beam dimensions and short bunch length

But the big issue:
Field emission => HV breakdown => photocathode damages => destruction

Laser:

See M. Petrarca talk

1) Simultaneous required parameters (frequency, energy, pulse length, stability, …)

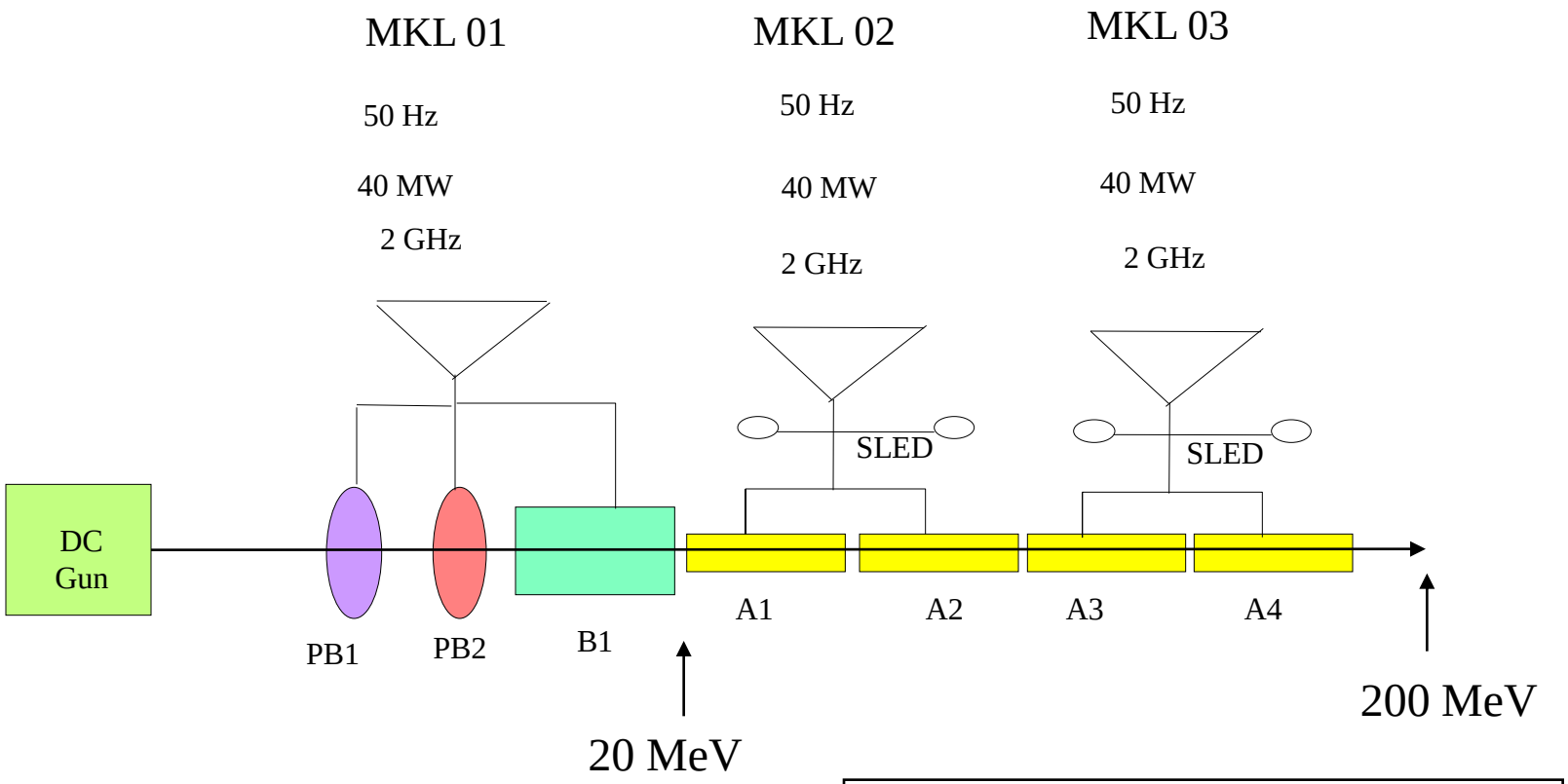
2) Option for a 2 GHz laser

Pre-Injector Linac at 200 MeV:

1) Preliminary simulations done up to 19 MeV *See F. Zhou et al. in CLIC Note 813*

2) Simulations for capture and acceleration up to 200 MeV remains to be done

CLIC Pre-Injector e⁻ Linac



Accelerating cavities:

- Number of cavities: N = 4
- Length: L = 3 m
- Aperture radius: r = 20 mm
- Energy Gain: ΔE = 45 MeV
- Accelerat. gradient: E_z = 15 MV/m
- Frequency: f = 2 GHz

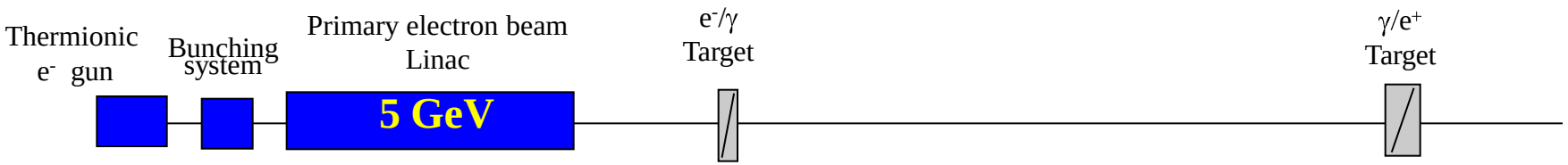
Flux of e^+

	SLC (California)	CLIC (3 TeV)	CLIC (0.5 TeV)	ILC (RDR)	LHeC (CERN)
Energy	1.19 GeV	2.86 GeV	2.86 GeV	5 GeV	100 GeV
e^+/ bunch (at IP)	40 x 10^9	3.7x10^9	7.4x10^9	20 x 10^9	15x10^9
e^+/ bunch (before PDR or DR injection)	50 x 10^9	7x10^9	14x10^9	30 x 10^9	15x10^9
Bunches / macropulse	1	312	354	2625	20833
Macropulse Repet. Rate (Hz)	120	50	50	5	10
e^+ / second x 10^{14}	0.06	1.1	2.5	3.9	31

x 42

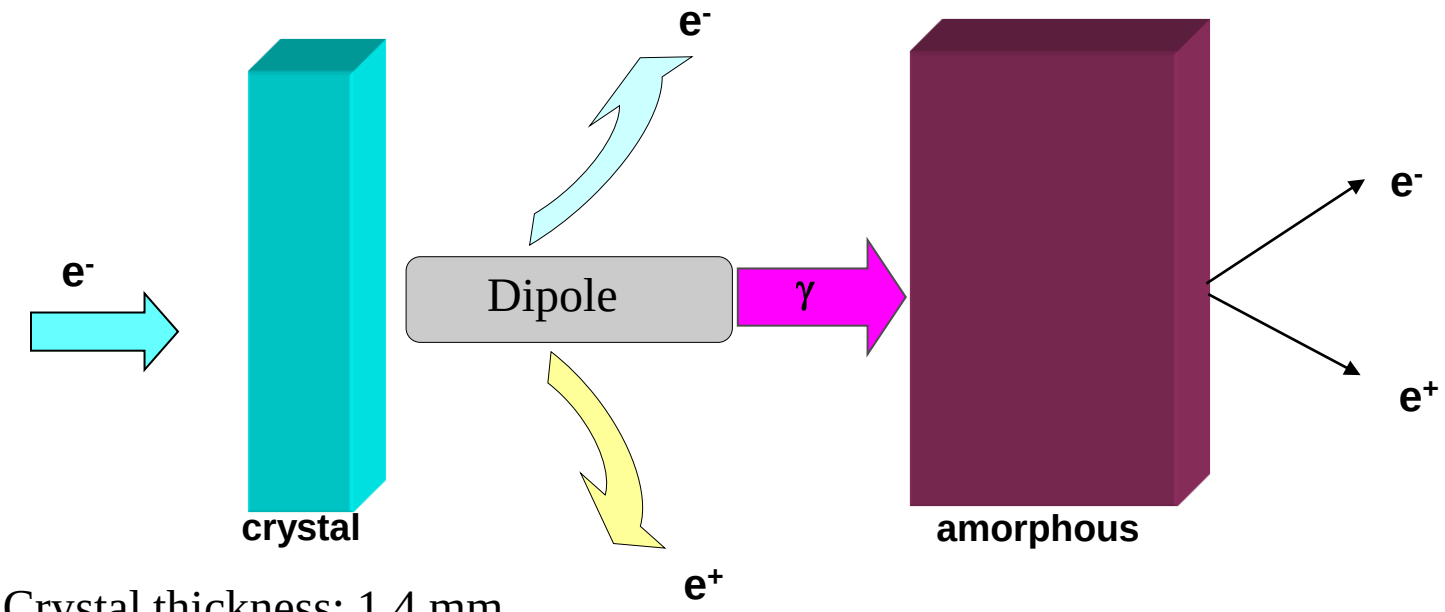
CLIC hybrid targets

e^+ source parameters for the baseline



2.34 10^{12} e^-/train
(previous simulations)

3.1 10^{12} e^-/train
(present value)



Crystal thickness: 1.4 mm

Oriented along the <111> axis

Distance (crystal-amorphous) d = 2 m

O. Dadoun et al., CLIC Note 808

Amorphous thickness e =10 mm

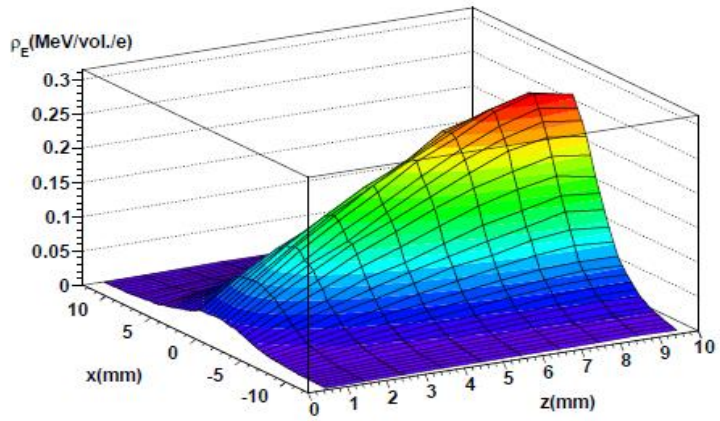
Comparison for PEDD

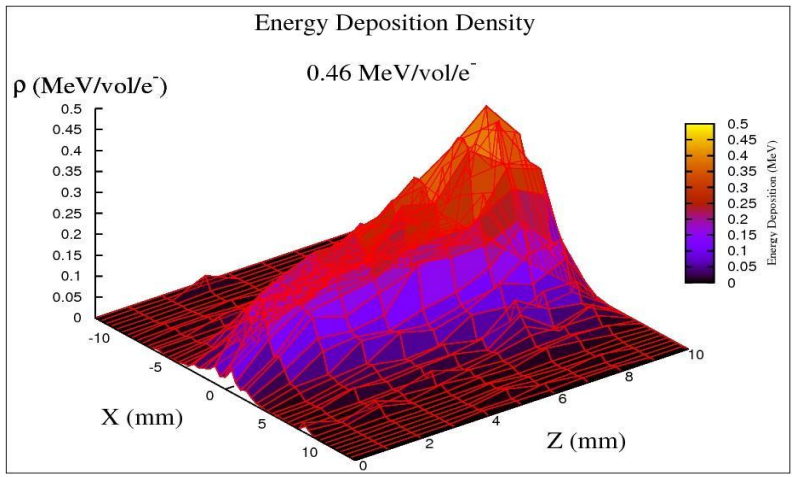
PEDD = Peak Energy Deposition Density

1 GeV/cm^3 = 8.3x10^{-12} J/g for W

Train of 312 bunches = 2.34x10^{12} e$^-$

σ (e- spot) = 2.5 mm





Strakhovenko code

Mesh volume = 0.094 mm^3

(ring shape)

PEDD = 0.040 MeV / vol / e$^-$

PEDD = 0.427 GeV/cm^3/e$^-$

PEDD = 15.5 J/g

GEANT4 results:

Mesh volume = 0.25 mm^3

(parallelepiped shape)

PEDD = 0.285 MeV / vol / e$^-$

PEDD = 1.14 GeV/cm^3/e$^-$

PEDD = 22.14 J/g

FLUKA results:

Mesh volume = 0.25 mm^3

(parallelepiped shape)

PEDD = 0.46 MeV / vol / e$^-$

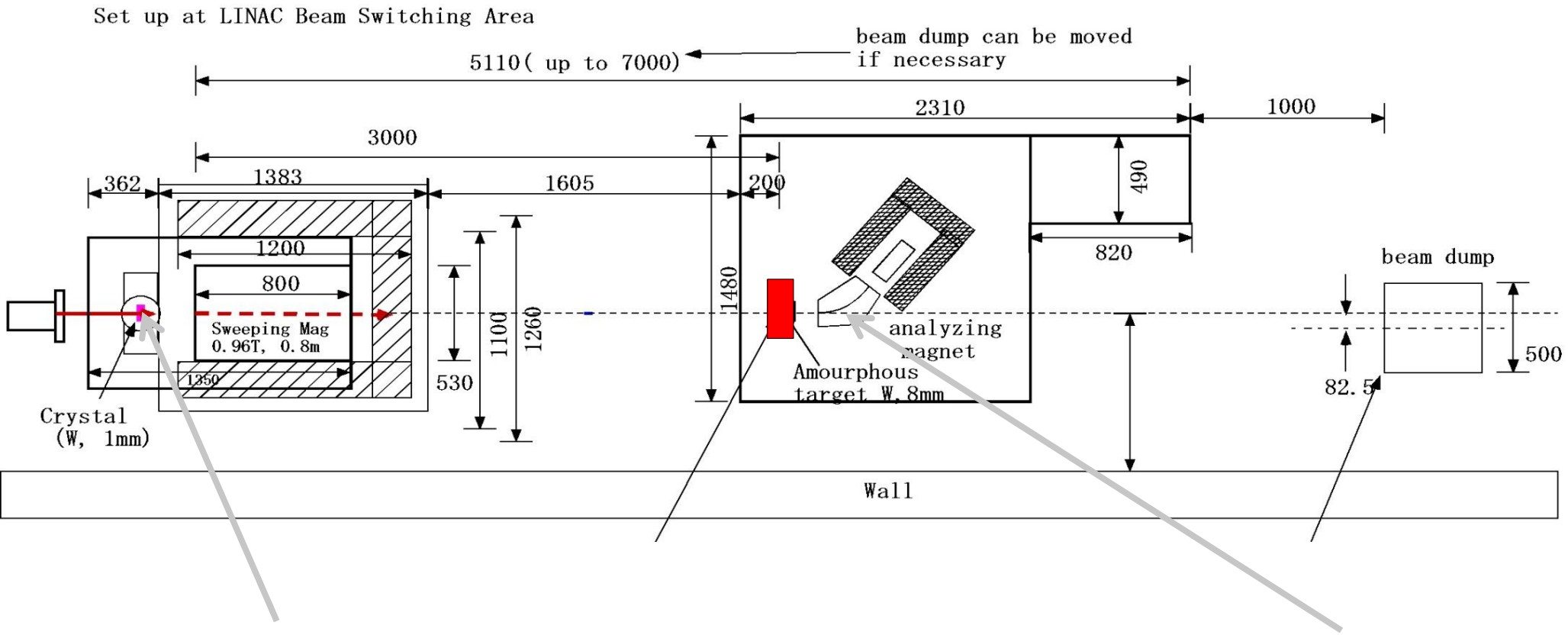
PEDD = 1.83 GeV/cm^3/e$^-$

PEDD = 35.5 J/g

Not a good agreement for photons impinging an amorphous target

KEKB experiments with hybrid targets

See T. Takahashi talk

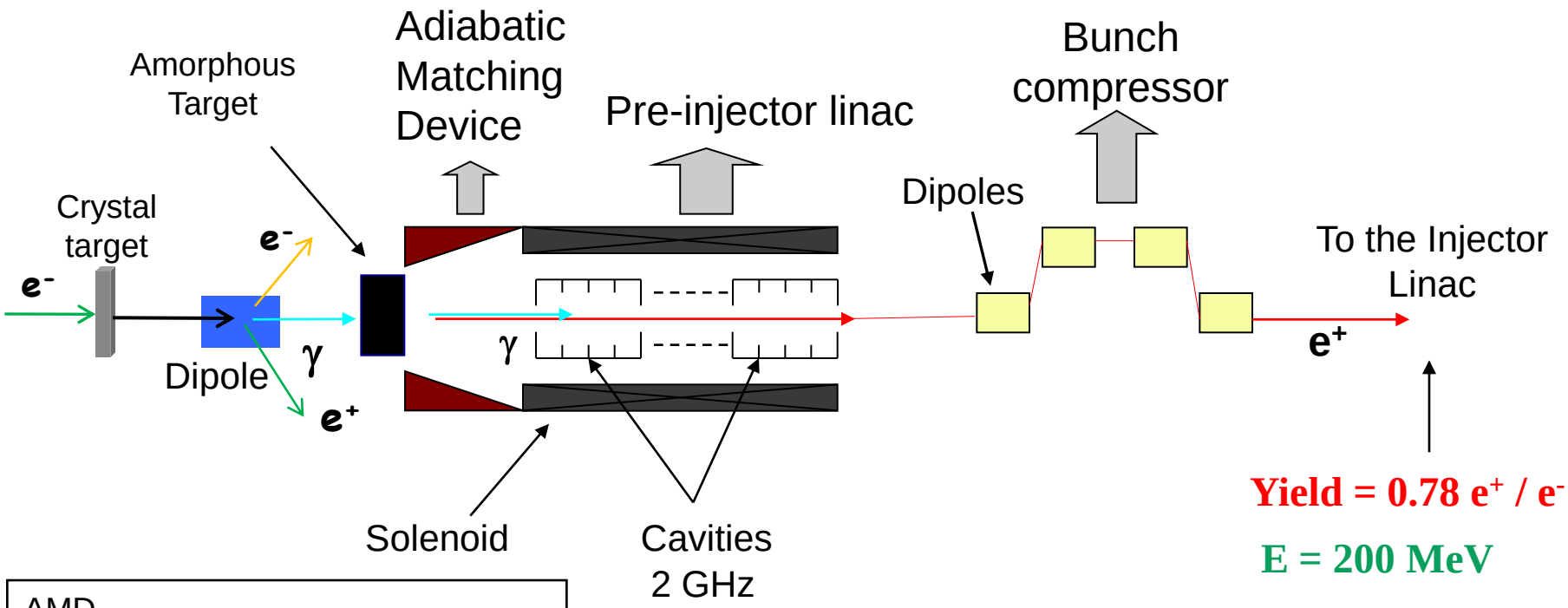


8GeV e-

Analyzing magnet
5 ~ 30MeV

CLIC Pre-Injector e+ Linac

See F. Poirier, C. Xu talks



AMD

- Length : L = 20 cm
- Magnetic Filed: B = 6 - 0.5 T
- Final Aperture: r = 2 cm

SOLENOID

- Length : L = 41.3 m
- Magnetic Filed: B = 0.5 T

Accelerating cavities:

- Number of cavities: N = 21
- Length: L = 1.8 m
- Aperture radius: r = 20 mm
- Energy Gain: ΔE = 9 MeV
- Average Gradient: E_z (r=0) = 5 MV/m
- Frequency: f = 2 GHz

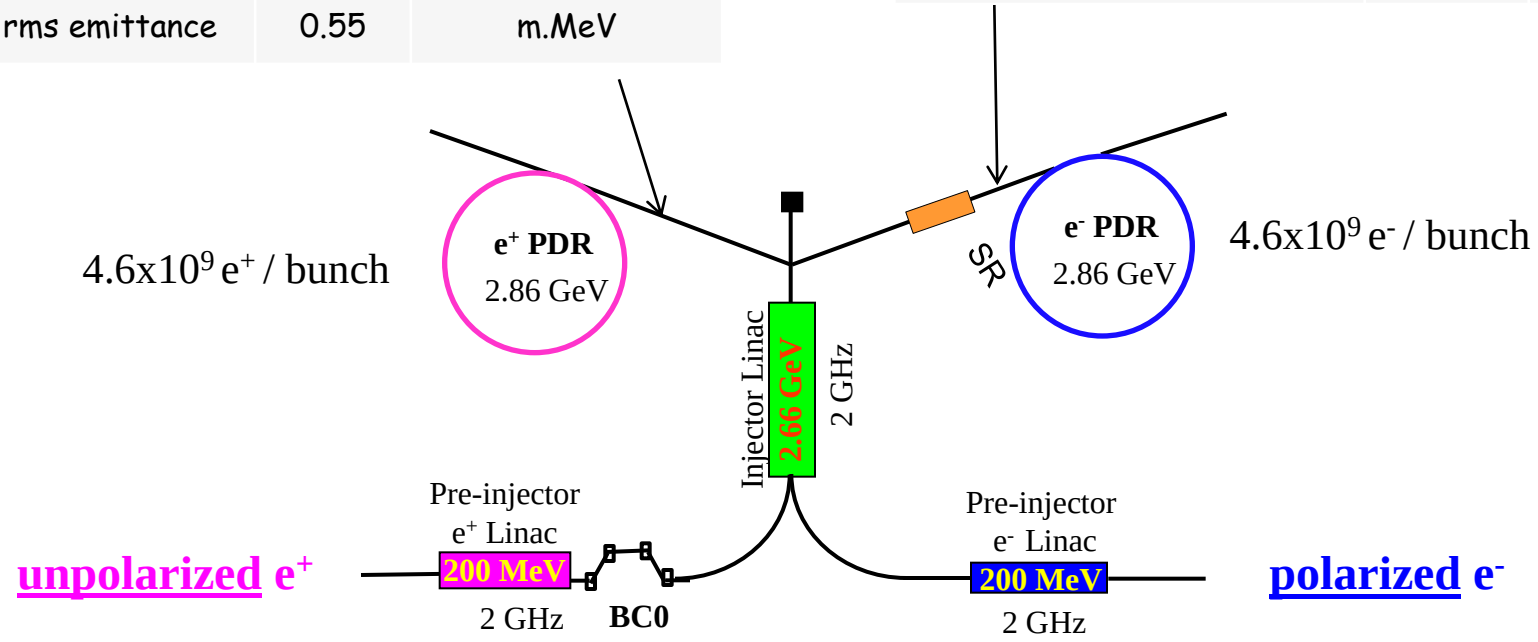
CLIC Injector e^-/e^+ Linac

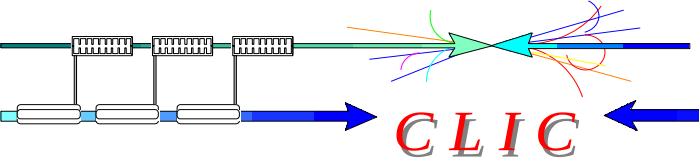
at PDR injection

See A. Vivoli talk

Simulations		
Energy	2.86	GeV
Positron yield (e^+/e^-)	0.7	
Charge	7×10^9	e^+/bunch
Normalized rms emittances	8000	mm.mrad
Energy spread (rms)	4.5	%
Bunch length (rms)	5.4	mm
Longitudinal rms emittance	0.55	m.MeV

Estimations		
Energy	2.86	GeV
Charge	5×10^9	e^-/bunch
Normalized rms emittances	100	mm.mrad
Energy spread (rms)	0.5	%
Bunch length (rms)	4	mm
Longitudinal rms emittance	4×10^{-4}	m.MeV





Polarized e^-/e^+ beams

Polarized e^- :

For the generation	=> See J. Sheppard talk
For polarization measurements	=> See S. Riemann talk
For spin rotators	=> See A. Latina talk

Polarized e^+ :

For justification	=> See G. Moortgat-Pick and S. Riemann
Generation has been demonstrated	=> See Compton results at KEK
	=> See E-166 experiment at SLAC
For polarization issues	=> See W. Gai talk
For the risks	=> See M. Kuriki talk
Some technological issues (flux concentrator)	=> See T. Kamitani and T. Piggott talks

BUT a complete solution is not yet demonstrated for the requested flux of ILC and CLIC

CLIC polarized e+ beam studies

CERN acknowledges strongly the following collaborations:

Compton ring: KEK - NSC/KIPT/Karkhov

See T. Omori and E. Bulyak talks

ERL: KEK - LAL

See T. Omori and I. Chaikovska talks

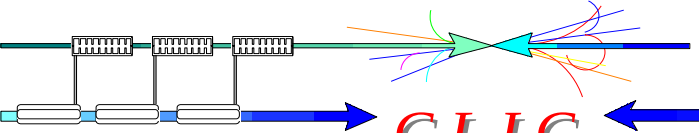
Compton Linac: BNL

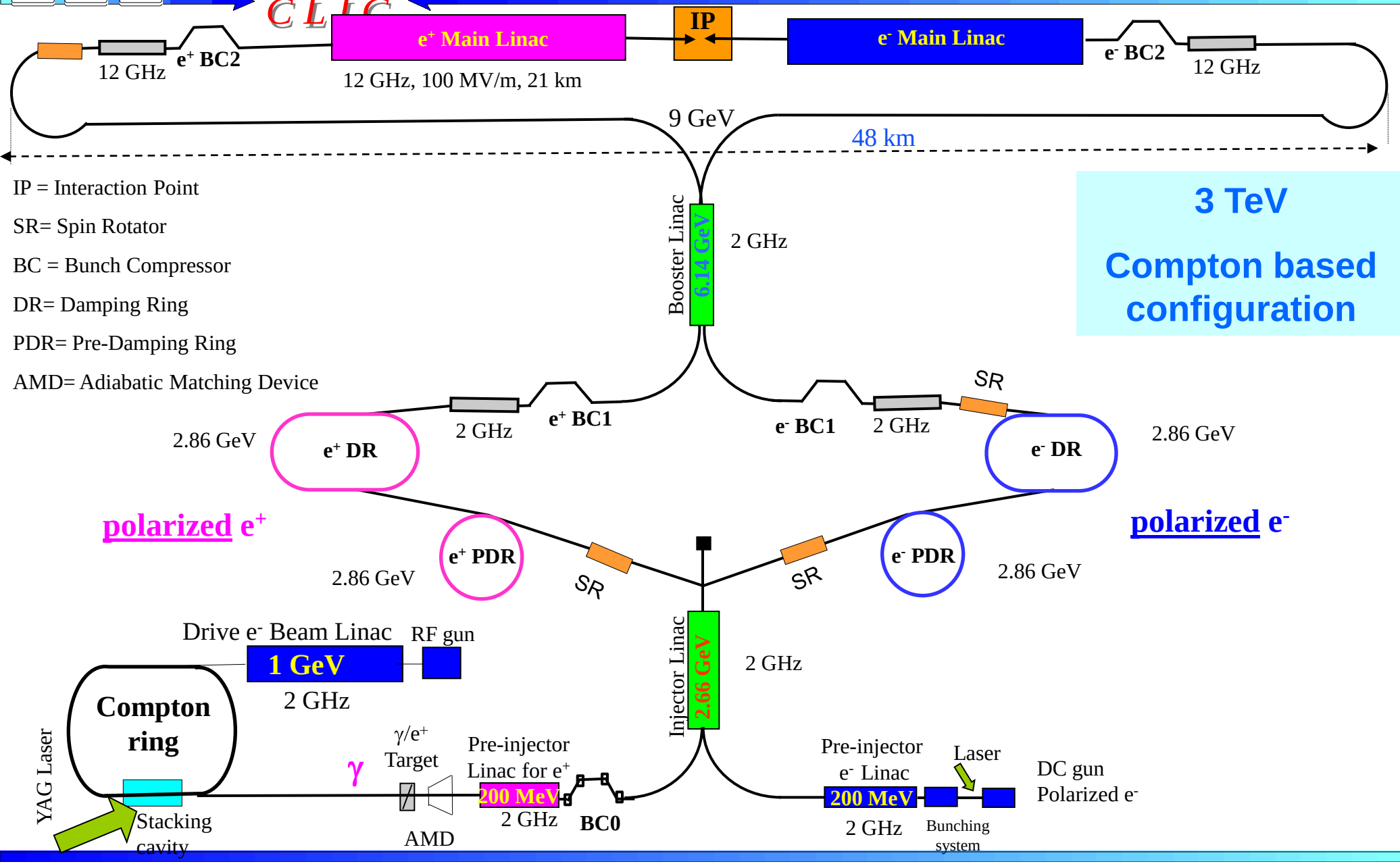
See V. Yakimenko talk

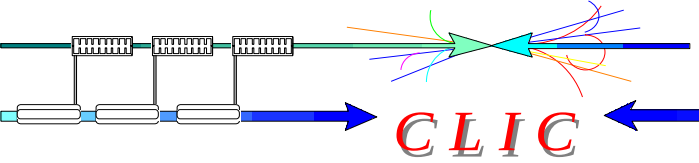
Undulator: ANL - DESY - Cockcroft Institute

See W. Gai , S. Riemann, I. Bailey and J. Clarke talks

CLIC Main Beam Injector Complex







Compton ring as e+ source

Compton ring is very attractive for the CLIC polarized positron sources:

1) no modification in the Main Linac
2) no modification of the Main Beam Injector complex apart to install a new ring
3) could work in parallel with the existing conventional hybrid targets

BUT it needs:

- a Compton ring design (high beam current, double chicane, high RF voltage,…) *See E. Bulyak talk*
- a strong R&D on laser (laser energy, laser pattern,…) *See J. Urakawa talk*
- a careful optimization of the optical cavity and IP (beam size, stability,…) *See F. Zomer talk*
- a high stacking efficiency *See F. Zimmermann talk*
- a new design of the Pre-Damping (momentum compaction, RF voltage, damping times, dynamic aperture,…)

…… or avoid stacking in the Pre Damping Ring

Study for a CLIC Compton Ring

with double chicane and a small stacking ring

E. Bulyak and P. Gladkikh

Compton Ring:

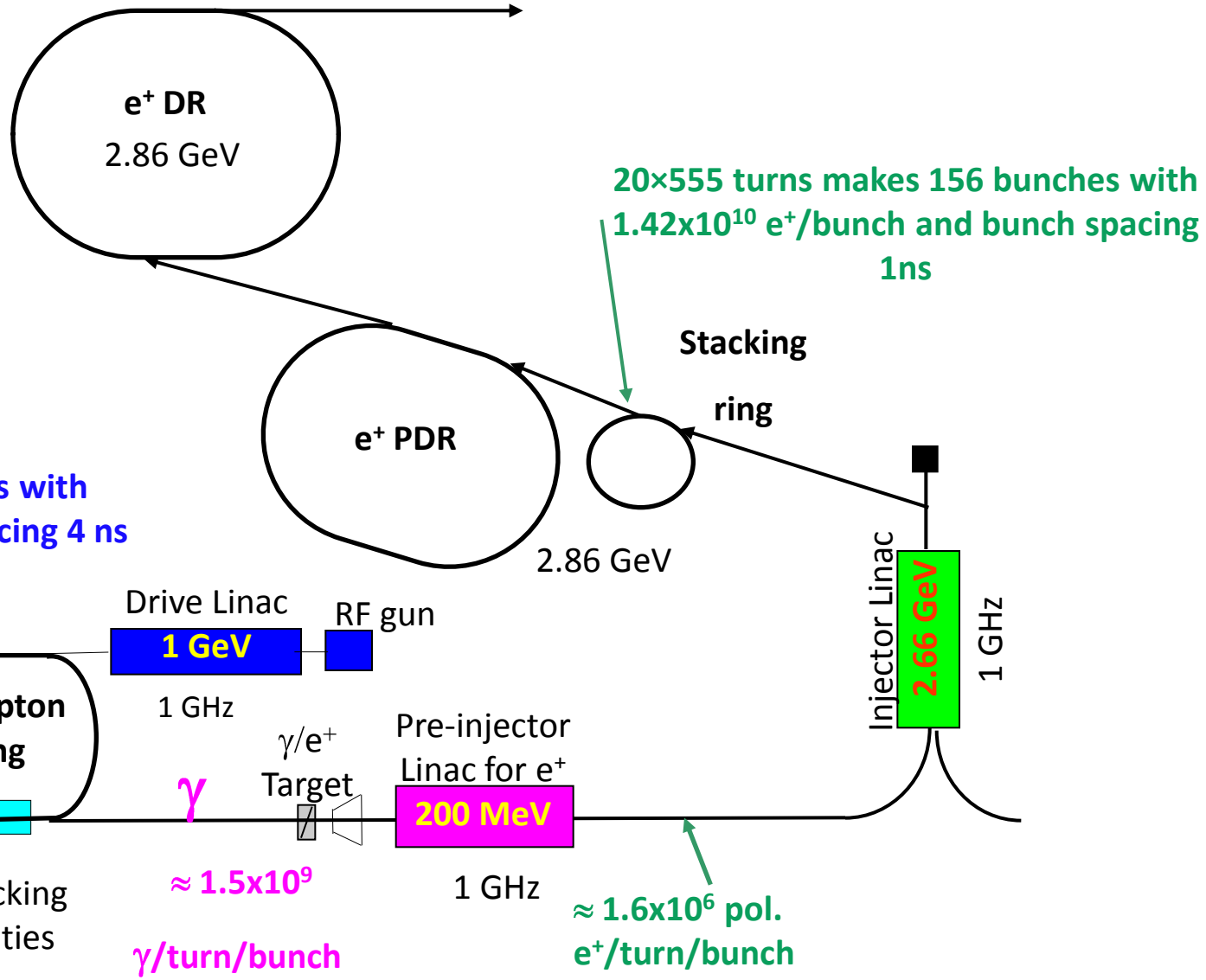
E = 1.06 GeV

C = 270 m

$\mathbf{V}_{RF}$ = 2×200 MV

$\mathbf{f}_{RF}$ = 1 GHz

β_{CP} = 0.05 m



Laser pulse:

ε = 1.164 eV

r = 5 μm

l = 0.9 mm

$\mathbf{W}_{las}$=500 mJ

Optical cavity

using Compton backscattering for ILC and CLIC as source of photons for polarized e^+

See T. Omori and F. Zomer talks

Collaboration CELIA, LAL, LMA, KEK, Hiroshima University

Goal: provide a stable resonator with circularly polarized mode and very high stacked power of photons

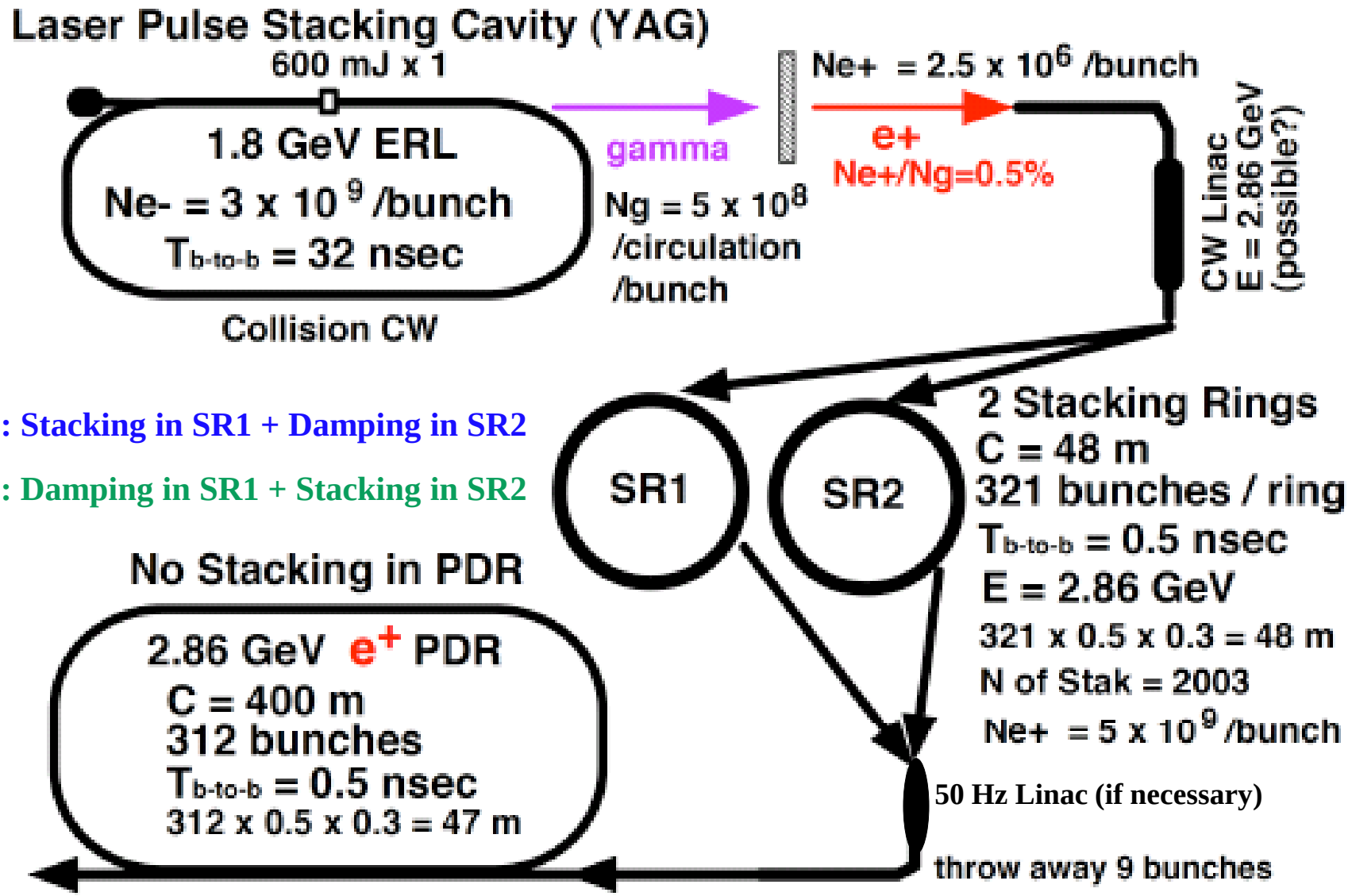
Installed on ATF at KEK in August 2010

First results presented at IWLC 2010

ERL as e+ source

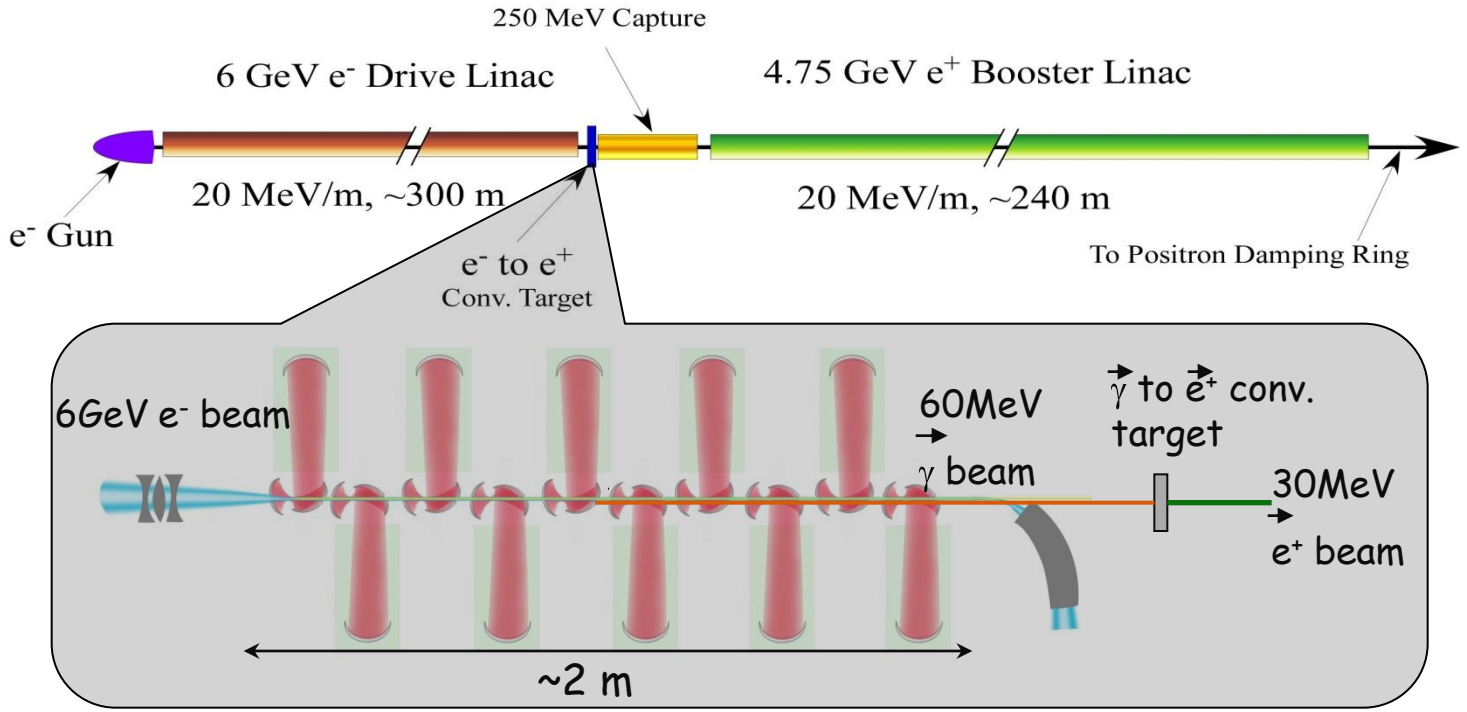
and two small stacking ring

T. Omori and L.R.



Compton linac as e+ source

See V. Yakimenko talk



Polarized γ-ray beam is generated in the Compton back scattering inside optical cavity of CO2 laser beam and 6 GeV e-beam produced by linac.

Undulator as e+ source

See I. Bailey talk

e- Main Linac | IP | e+ Main Linac

e- BC2 | e+ BC2

IP = Interaction Point

SR= Spin Rotator

BC = Bunch Compressor

DR= Damping Ring

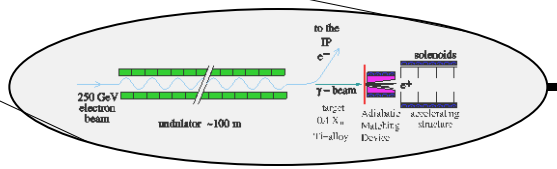
PDR= Pre-Damping Ring

AMD= Adiabatic Matching Device

3 TeV

Undulator based configuration

Booster Linac 6.14 GeV



e+ BC1 | e- BC1 | SR

e+ DR | e- DR

polarized e+ | polarized e-

e+ PDR | e- PDR

2.86 GeV | 2.86 GeV

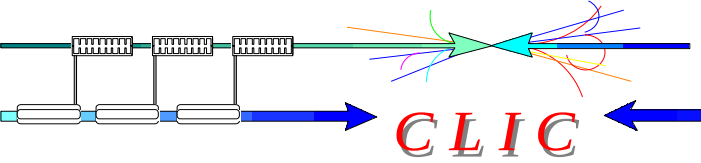
SR

Injector Linac 2.66 GeV

2 GHz

Auxiliary source

Thermionic e- gun | Primary e- Beam Linac 200 MeV | e-/e+ Target | AMD | Pre-injector e+ Linac 200 MeV | BC0 | Pre-injector e- Linac 200 MeV | DC gun Polarized e-



Summary for CLIC

1) The polarized e^- source is based on current technology. The charge (for 0.5 and 3 TeV) has been generated, at SLAC, from a DC gun. Nevertheless a complete experimental and operational test stand is highly recommended.

2) The unpolarized e^+ source is based on hybrid targets, using channeling. Nevertheless further studies are required regarding the simulations (with GEANT4, EGS4, FLUKA,…) of the Peak Energy Deposition Density which is a big issue related to the target breakdown.

3) Experimental tests are mandatory. The KEKB results will be an important step forward in the behavior of the targets.

4) The polarized e^+ source is presently based on Compton Ring. Nevertheless other options are deeply investigated in collaboration with many institutes. A very strong R&D program, regarding several issues, is absolutely requested before promising polarized e^+ to the Physics.

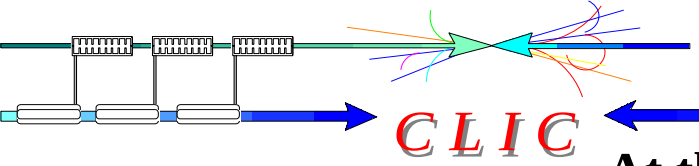
Acknowledgements

Thank you for contributions and discussions:

X. Artru, N. Baddams, I. Bailey, A. Brachmann, E. Bulyak, I. Chaikovska, R. Chehab, J. Clarke, M. Csatari, O. Dadoun, S. Doebert, E. Eroglu, V. Fedosseev, W. Gai, P. Gladkikh, T. Kamitani, M. Kuriki, A. Latina, W. Liu, G. Moortgat-Pick, T. Omori, J. Osborne, M. Petrarca, M. Poelker, I. Pogorelsky, F. Poirier, S. Riemann, D. Schulte, J. Sheppard, V. Strakhovenko, T. Suwada, T. Takahashi, J. Urakawa, A. Variola, A. Vivoli, C. Xu, V. Yakimenko, L. Zang, F. Zhou, F. Zimmermann, F. Zomer.

15 Institutes: ANL, BNL, BINP, CERN, Cockcroft Institute, DESY, Hiroshima University, IHEP, IPNL, JLAB, KEK, LAL, NSC-KIPT, SLAC, Uludag University

SPARES

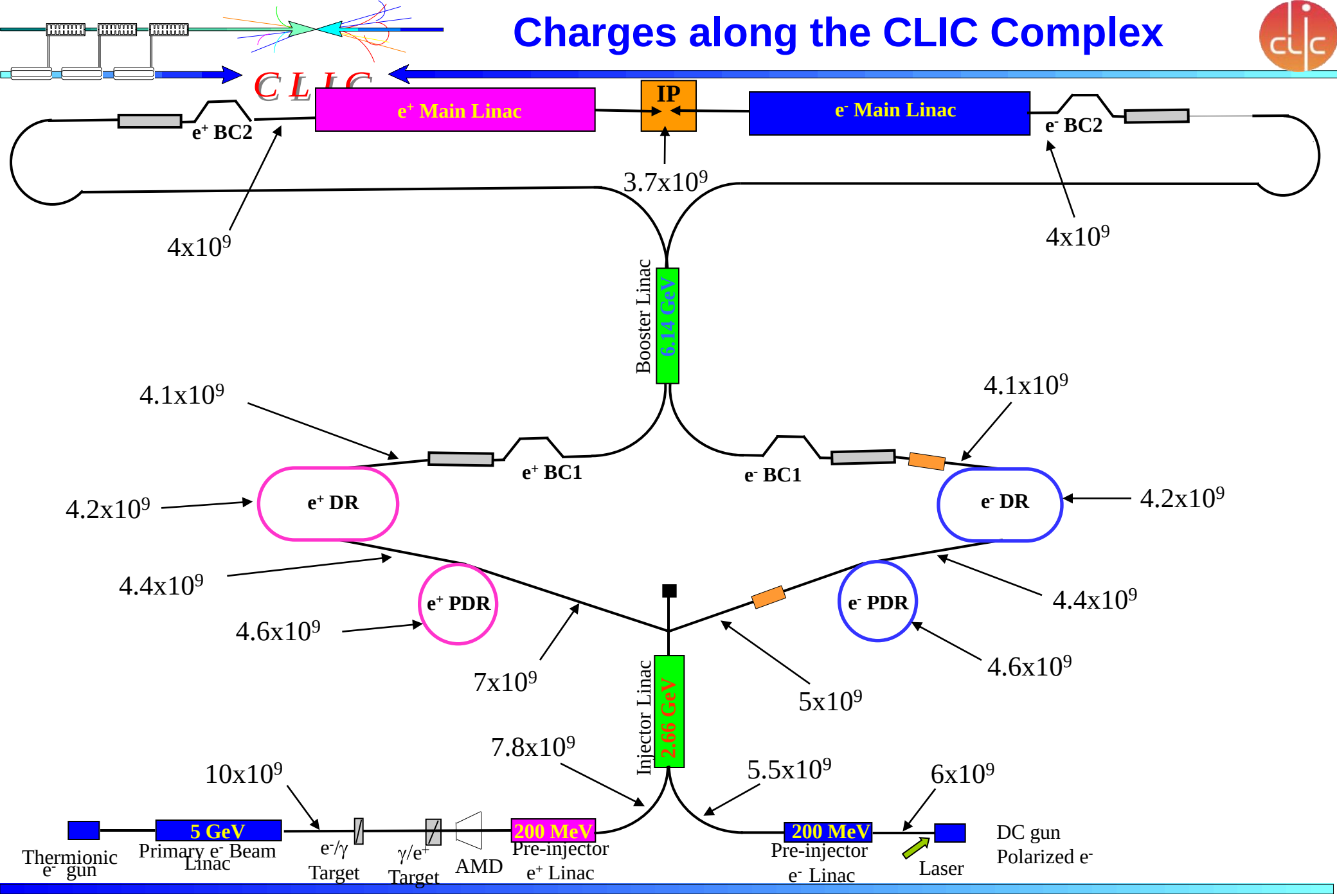


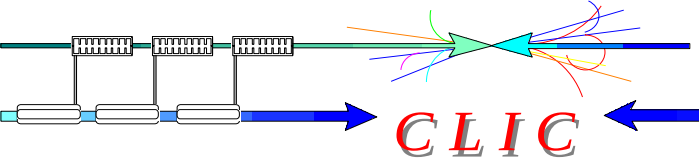
CLIC Main Beam parameters

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

		NLC (1 TeV)	CLIC 2009 (3 TeV)	CLIC 2009 (0.5 TeV)	ILC RDR (0.5 TeV)	ILC SB2009 (0.5 TeV)
E	GeV	8	9	9	15	15
N	10^9	7.5	4	7	20	20
n_b	-	190	312	354	2625	1312
Δt_b	ns	1.4	0.5	0.5	369	740
t_{pulse}	ns	266	156	177	968925	484462
$\varepsilon_{x,y}$	nm, nm	3300,30	600, 10	2000, 10	8400, 24	8400, 24
σ_z	μm	90-140	44	70	300	300
σ_E	%	0.68	1.6	1.6	1.5	1.5
f_{rep}	Hz	120	50	50	5	5
P	kW	219	90	180	630	315

Charges along the CLIC Complex





Yield and charge of e^+ beam for 3 TeV

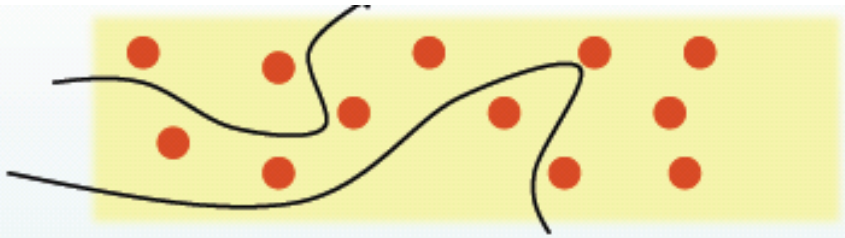
along the CLIC Main Beam Injector Complex,

Values along the Main Beam Injector Complex	Yield e^+ / e^-	# of e^+ per bunch	# of e^+ per pulse	Total charge (nC)	Current (A)
At Interaction Point (1.5 TeV)	0.37	3.72×10^9	1.16×10^{12}	185	1.19
Entrance Main Linac (9 GeV)	0.40	4×10^9	1.25×10^{12}	200	1.2
Entrance of the RTML (2.8 GeV)	0.41	4.1×10^9	1.3×10^{12}	204	1.3
Captured into PDR (2.8 GeV)	0.46	4.6×10^9	1.4×10^{12}	225	1.4
Entrance of PDR (2.8 GeV)	0.70	7×10^9	2.2×10^{12}	349	2.2
Entrance of Injector Linac (200 MeV)	0.78	7.8×10^9	2.4×10^{12}	389	2.5
Primary electron beam (5 GeV)		10.1×10^9	3.1×10^{12}	499	3.2

Channeling of charged particles

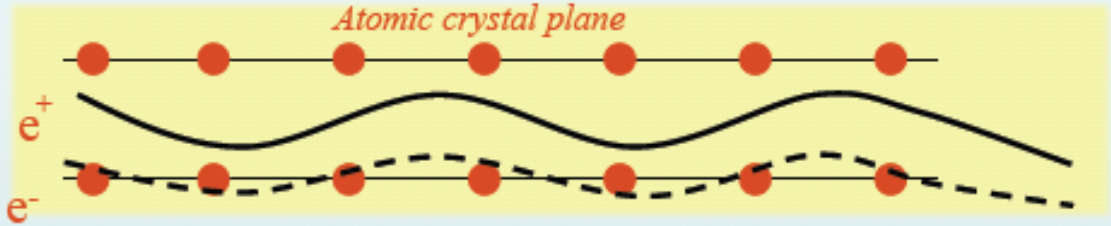
S. Dabagov

@ Amorphous:

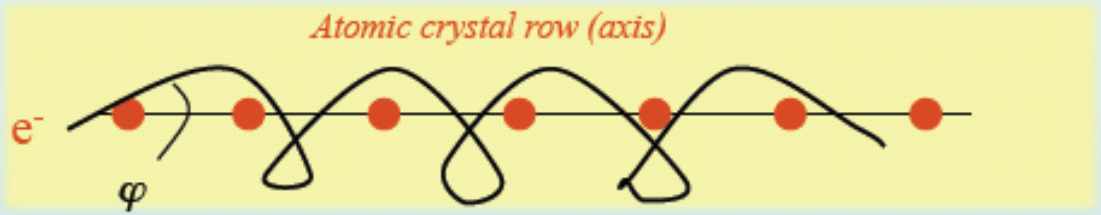


@ Channeling:

planar channeling



axial channeling



$\varphi << 1 \quad (\varphi < \varphi_L \sim \sqrt{U/E})$ - *the Lindhard angle is the critical angle for the channeling*

POSIPOL short history

POSITONS POLARISÉS

(in French)

April 2006

POSIPOL is a series of workshops dealing with the physics aspects, the design issues, and the open questions concerning polarized positron sources in the framework of the ILC and CLIC projects. POSIPOL 2010 was the fifth workshop following:

POSIPOL 2006 at CERN	**Chair: L. Rinolfi**
POSIPOL 2007 at LAL-Orsay	**Chair: A. Variola**
POSIPOL 2008 at Hiroshima	**Chair: M. Kuriki**
POSIPOL 2009 at IPNL-Lyon	**Chair: R. Chehab**
POSIPOL 2010 at KEK	**Chair: T. Omori**
POSIPOL 2011 at IHEP	**Chair: J. Gao**
POSIPOL 2012 at DESY	**Chair: S. Riemann**

"ILC/CLIC e^+ generation" working group

Set-up at University of Illinois Chicago - UIC during ILC08 workshop: 15th - 20th November 2008

ILC convener: J. Clarke (Daresbury)

The Cockcroft Institute of Accelerator Science and Technology

CLIC convener: L. Rinolfi (CERN)

Monthly regular Webex meetings, called "ILC/CLIC e^+ studies" managed by T. Omori / KEK

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