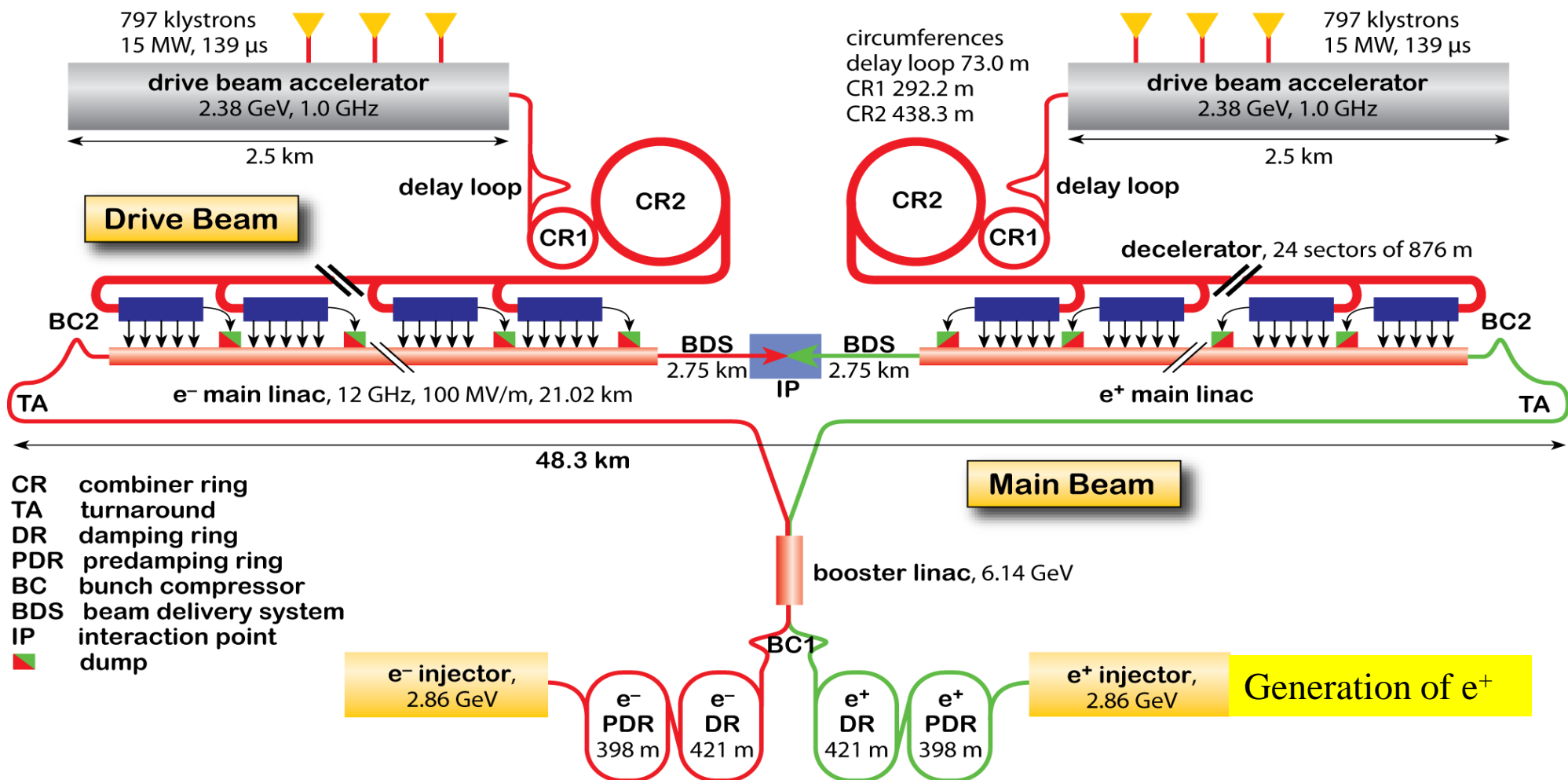


Positron Source using Channelling for the CLIC baseline study

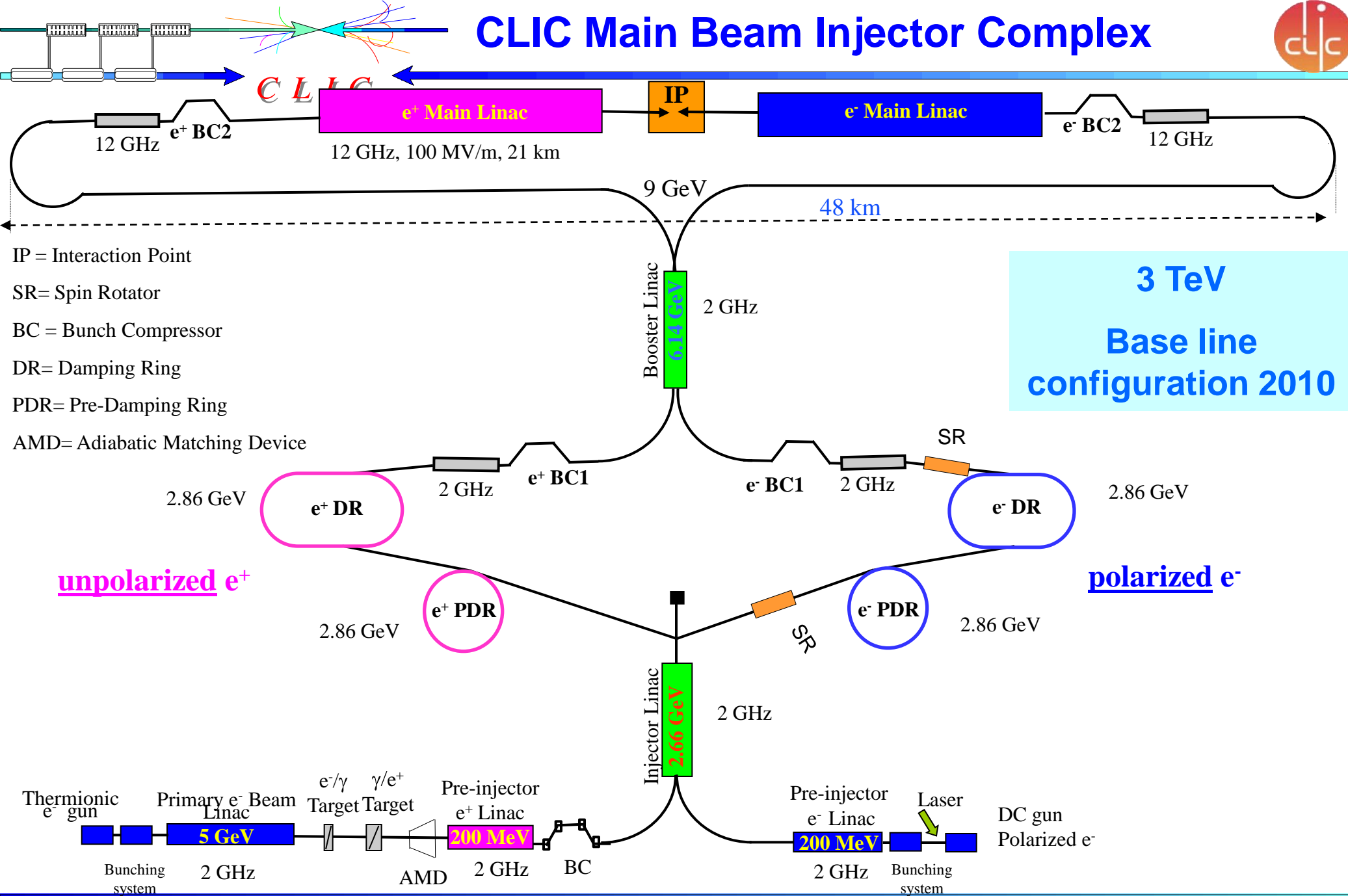
Louis Rinolfi

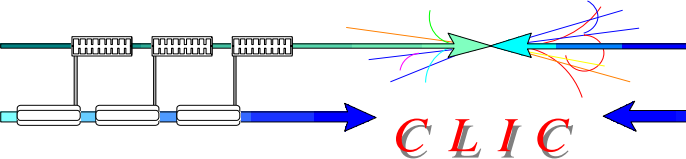
for the CLIC Sources collaboration

General CLIC layout for 3 TeV



CLIC Main Beam Injector Complex



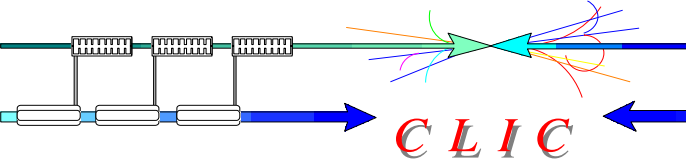


Yield and charge of e^+ beam for 3 TeV



Yield and charge along the 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



1) Baseline 3 TeV: (unpolarized e⁺)

7×10^9 e⁺/bunch (at injection of the Pre-Damping Ring) Pulse of 156 ns long with 312 bunches

2) Study for 500 GeV: (unpolarized e⁺)

14×10^9 e⁺/bunch Pulse of 177 ns long with 354 bunches

3) Polarized positron for 3 TeV:

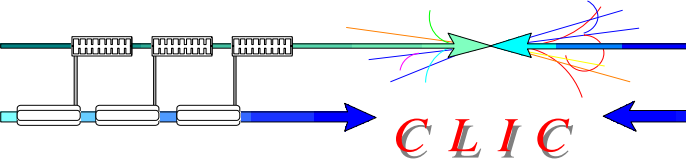
See “The CLIC positron source based on Compton schemes” by L. Rinolfi et al., PAC09

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

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

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

See “CLIC energy scan” by D. Schulte et al., IPAC2010



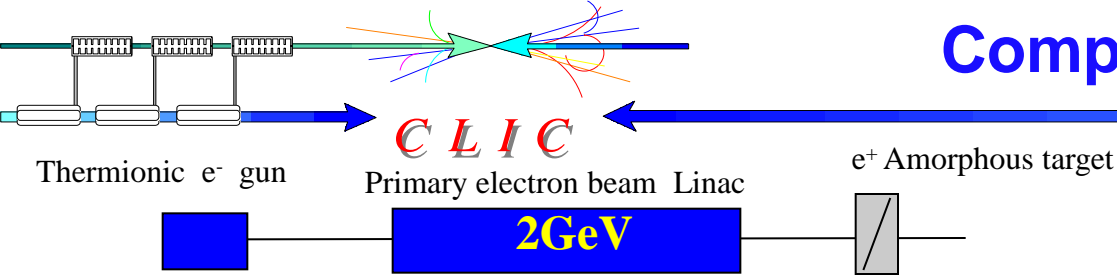
Flux of e^+



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

x 42

Comparison for PEDD



PEDD = Peak Energy Deposition Density

Amorphous W target (CLIC Note 465):

Electron beam energy: 2 GeV

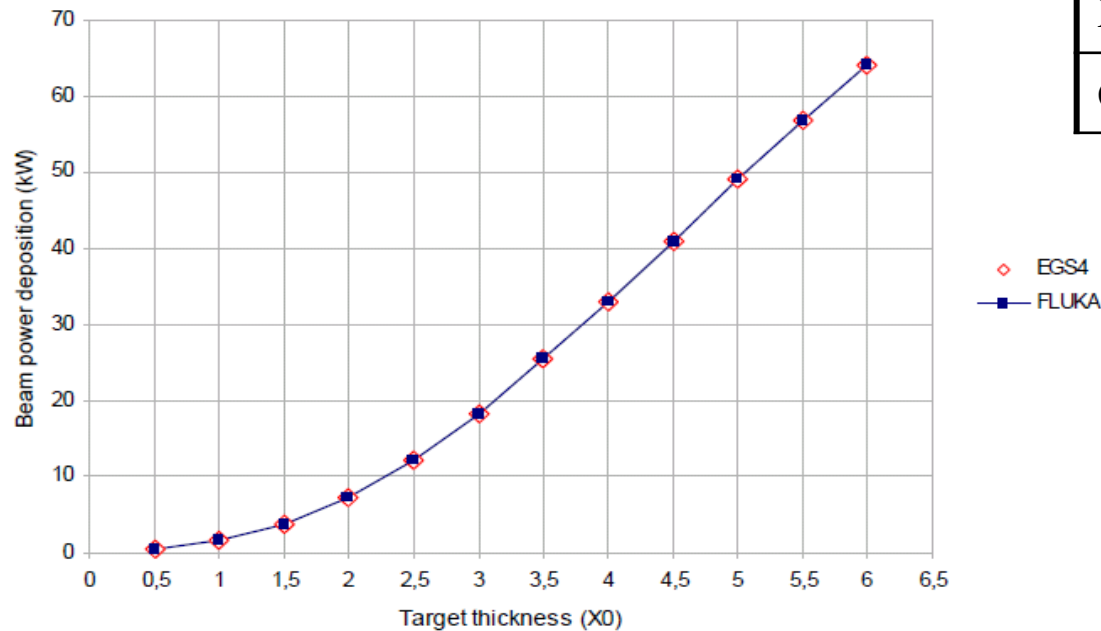
Spot radius (rms): 1.6 mm

Charge: 2×10^{12} e^- /pulse

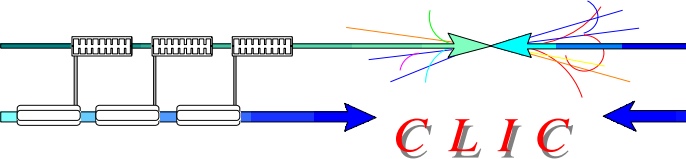
Repetition frequency: 200 Hz

Codes	Peak energy deposition per e^- (MeV)	Total for 2×10^{12} e^- (GeV/mm ³)
EGS4	1.30	0.64×10^{10}
FLUKA	1.35	0.66×10^{10}
GEANT4	1.15	0.56×10^{10}

Mesh volume = 0.425 mm^3



Very good agreement for e^- impinging an amorphous target

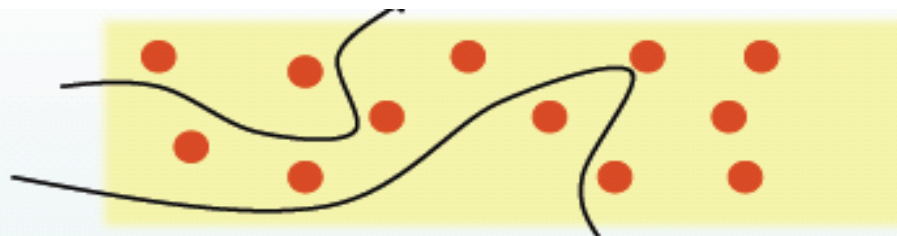


Channeling of charged particles



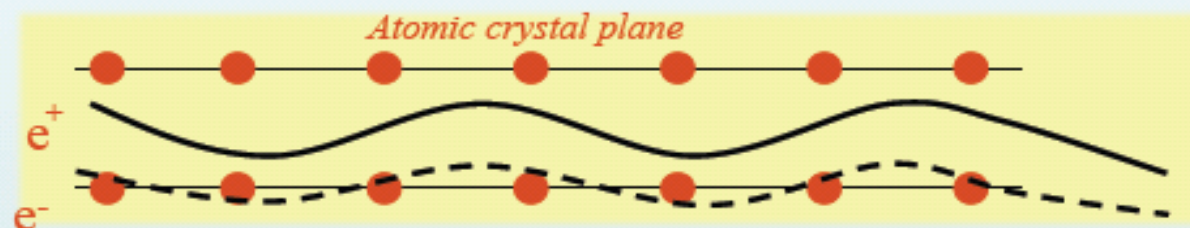
S. Dabagov

@ Amorphous:

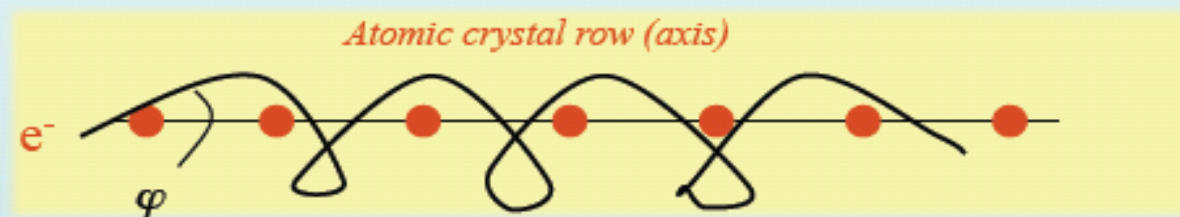


@ Channeling:

planar channeling



axial channeling

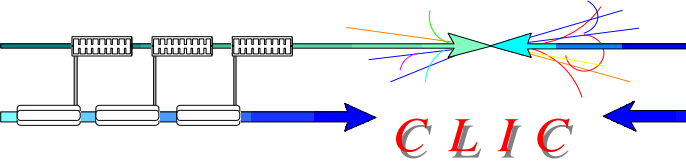


$\varphi \ll 1$ ($\varphi < \varphi_L \sim \sqrt{U/E}$) - the Lindhard angle is the critical angle for the channeling

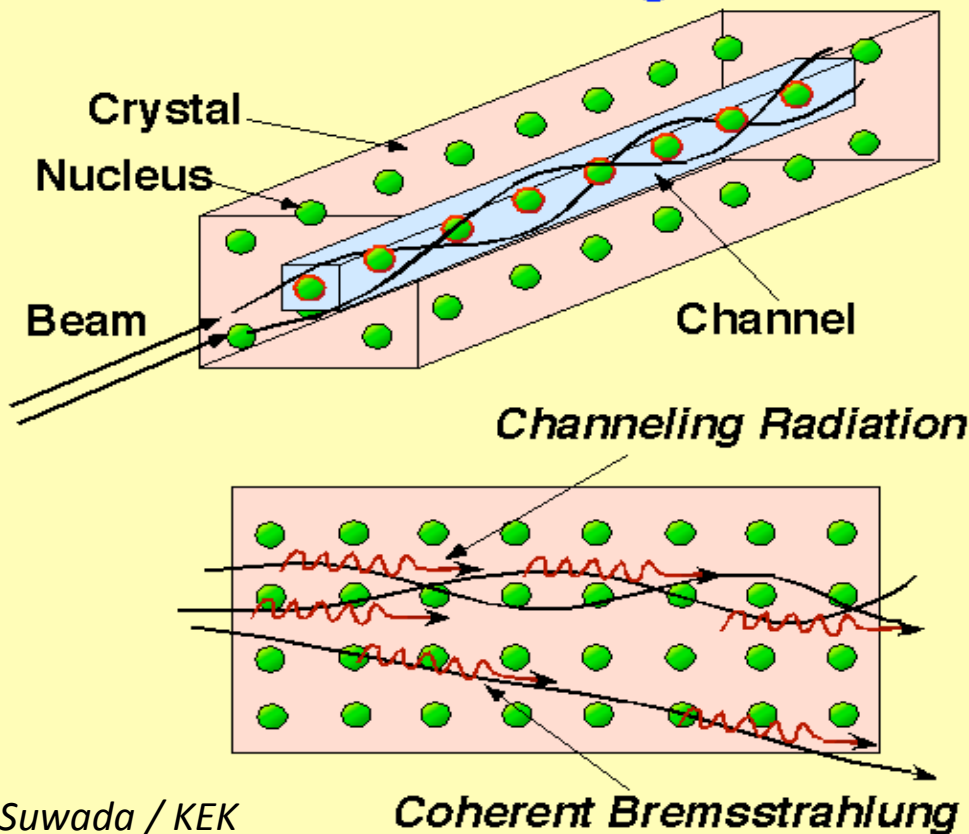
U = potential (on axis)

φ = incidence angle

Channeling process

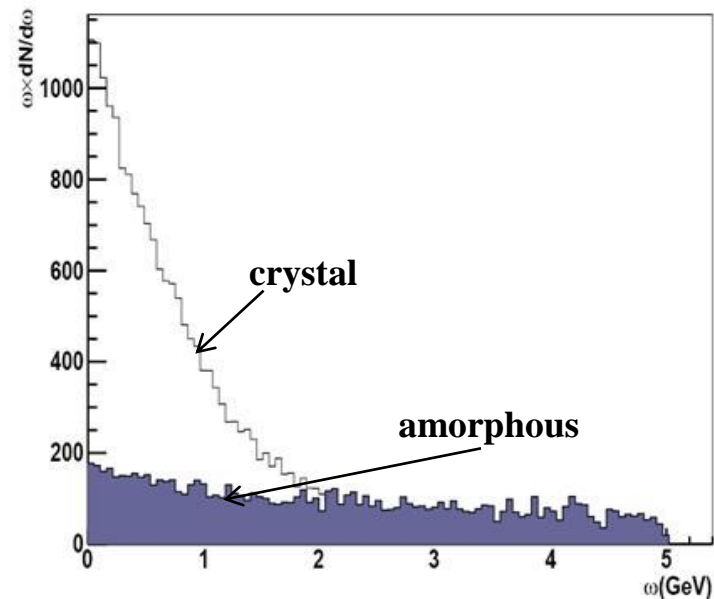


Physical processes for channeling radiation and coherent bremsstrahlung



For W and for $E > 1$ GeV, channeling radiation becomes larger than bremsstrahlung

Higher E , higher channeling effects



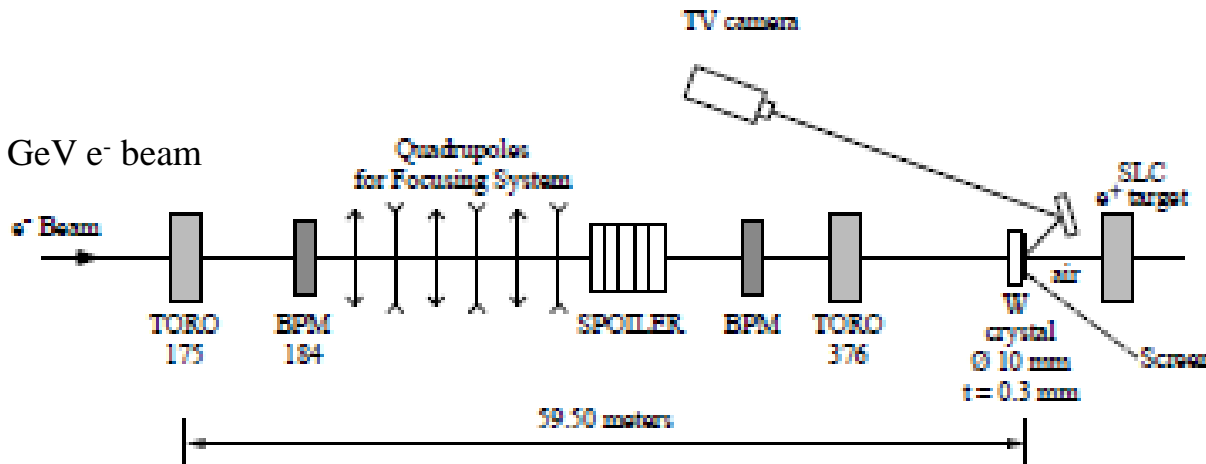
More soft photons with channeling

SLAC test on crystal target in 1995-1996

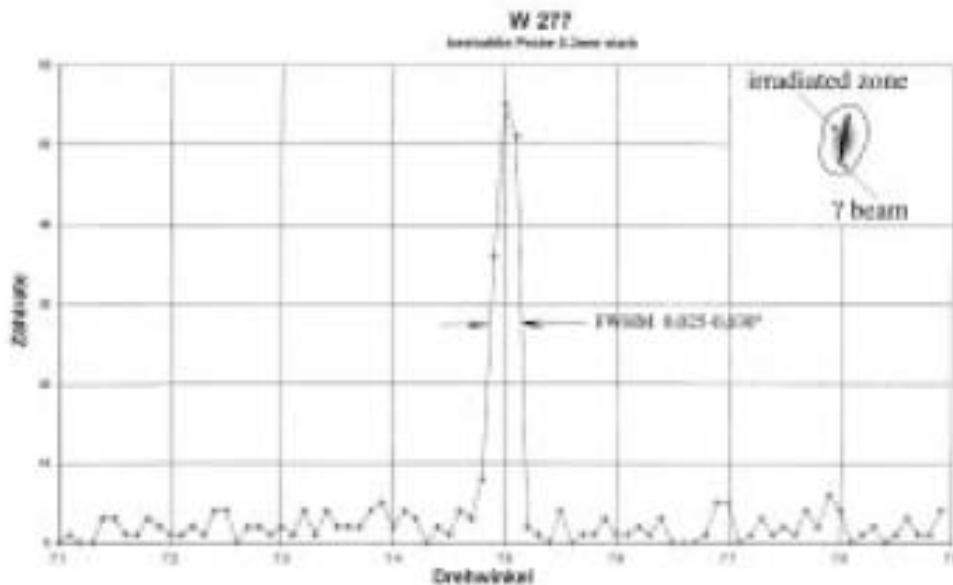


A. Kulikov - L. R.

30 GeV e^- beam



Integrated e^- flux: $2 \times 10^{18} \text{ e}^-/\text{mm}^2$



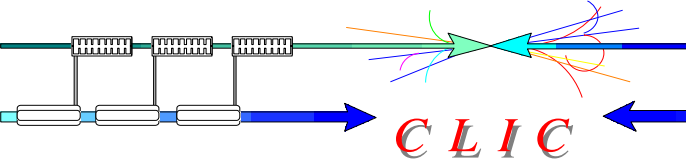
Gamma diffractometry

Mosaic spread remains unchanged after irradiation: (0.4 mrad FWHM)

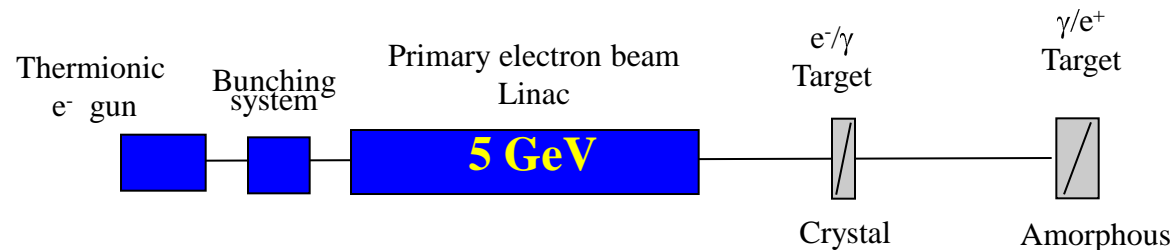
Very encouraging result for crystal target

X. Artru et al. “Radiation-damage study of a monocrystalline tungsten positron converter”, presented by R. Chehab at EPAC1998,

CERN-PS-98-017-LP ; CLIC-Note-369 ; LAL-RT-98-02



Primary Electron Beam Linac



Parameter for 3 TeV	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
Beam radius (rms)	mm	2.5
Bunch length (rms)	mm	0.3

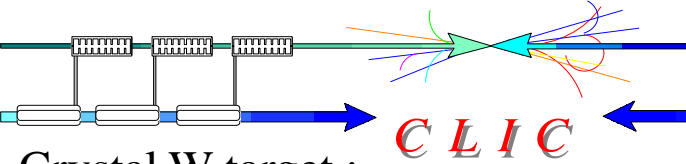
Electron beam parameters on the crystal target

October 2009

With an yield of 1 e^+/e^- (at 200 MeV) , the charge is 7.5×10^9 e^- /bunch on the target.

Parameters used for
BINP/CERN/IPNL/LAL simulations

Photon spectrum



Crystal W target :

Electron beam energy: 5 GeV

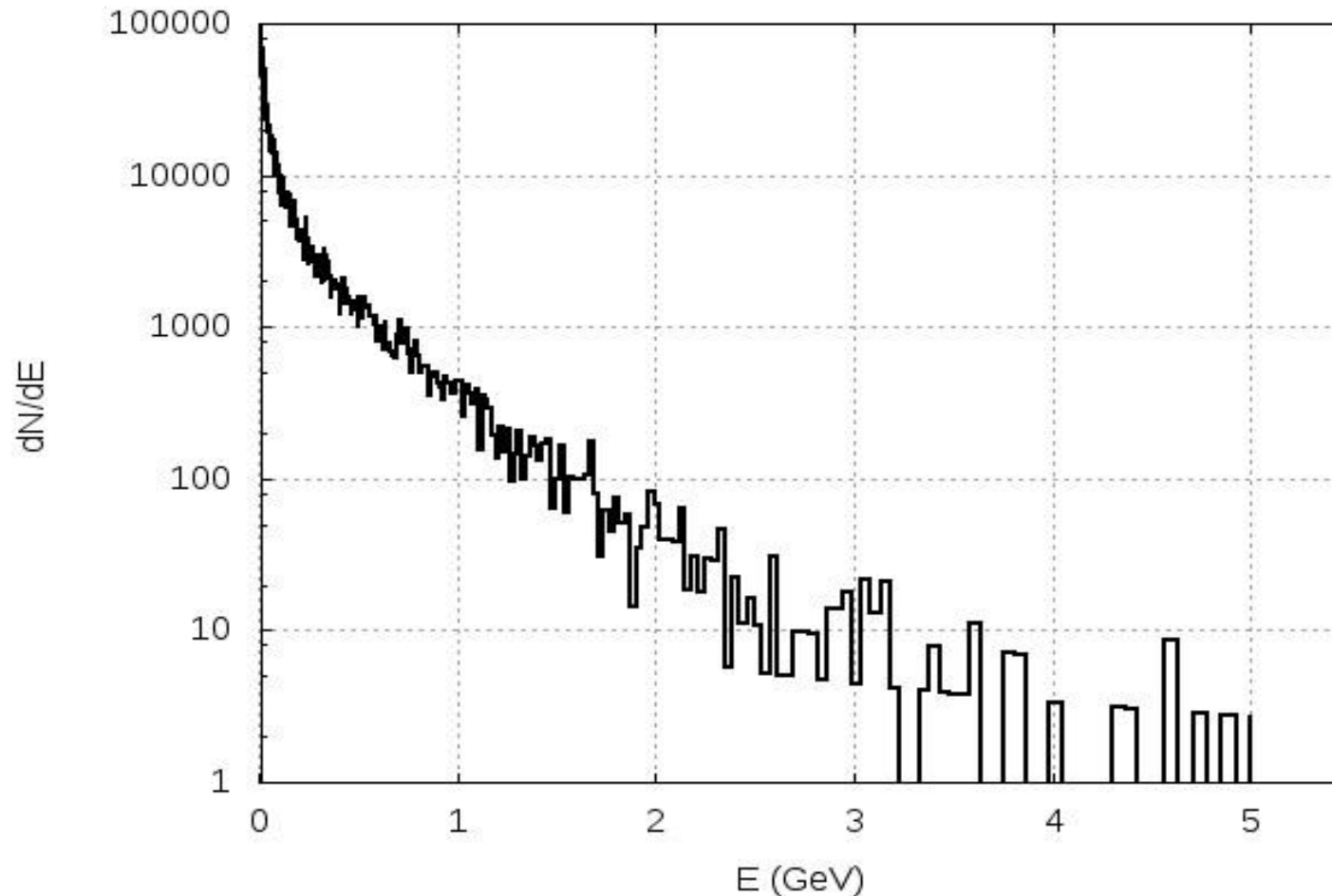
Charge: 2.34×10^{12} e⁻/pulse

Spot radius: 2.5 mm (rms)

at crystal target exit

V. Strakhovenko/BINP

Photon Energy Distribution



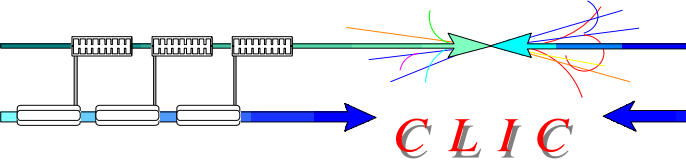
Simulations with
6000 electrons

Channeling:
20 photons / e⁻

Photon evolution

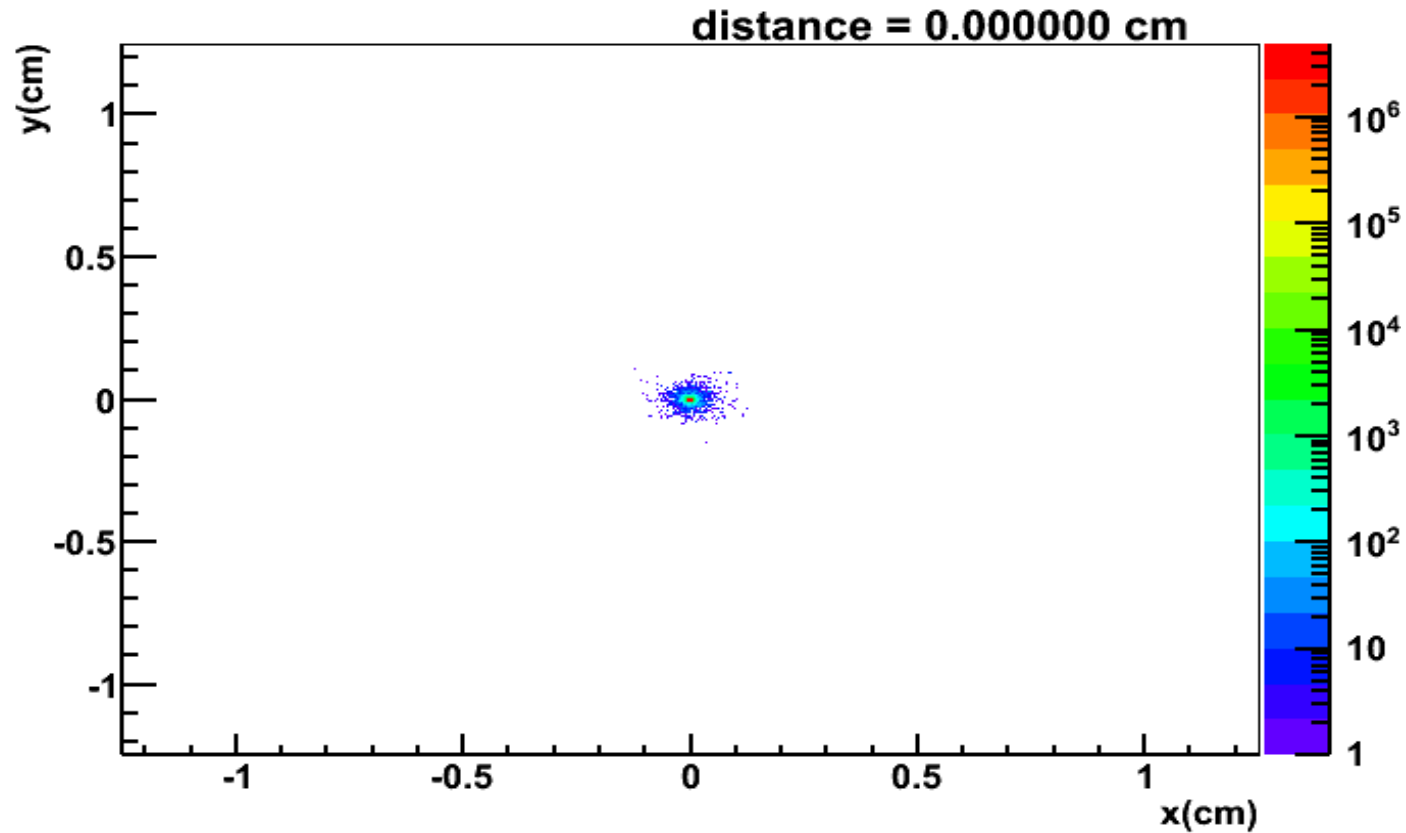


O. Dadoun /LAL

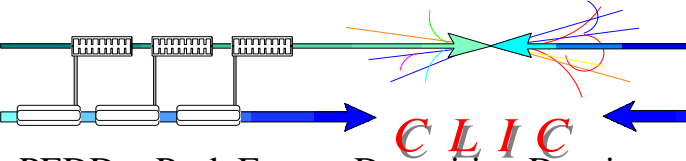


CLIC

From crystal target exit to amorphous target input



Comparison for PEDD

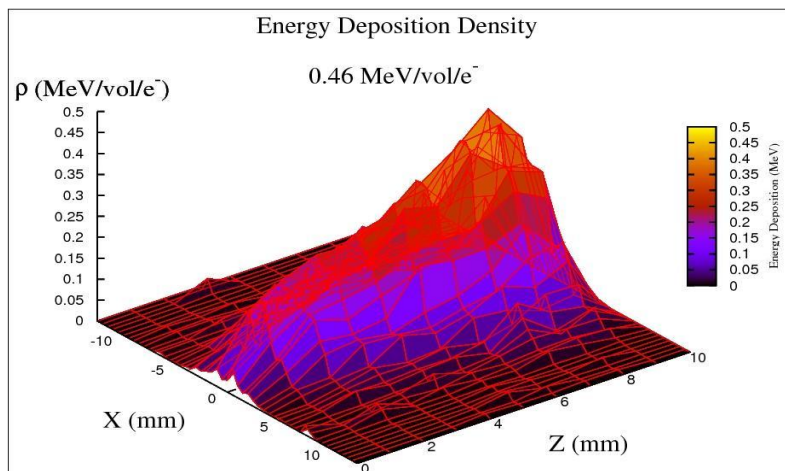
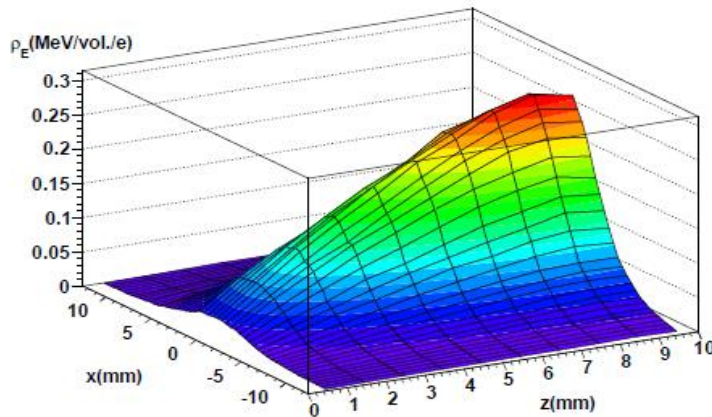


PEDD = Peak Energy Deposition Density

$1 \text{ GeV/cm}^3 = 8.3 \times 10^{-12} \text{ J/g for W}$

Train of 312 bunches = $2.34 \times 10^{12} \text{ e}^- \sigma$

(e- spot) = 2.5 mm



Strakhovenko code

Mesh volume = 0.094 mm^3

(ring shape)

PEDD = $0.040 \text{ MeV / vol / e}^-$

PEDD = $0.427 \text{ GeV/cm}^3/\text{e}^-$

PEDD = 15.5 J/g

GEANT4 results: *O. Dadoun*

Mesh volume = 0.25 mm^3

(parallelepiped shape)

PEDD = $0.285 \text{ MeV / vol / e}^-$

PEDD = $1.14 \text{ GeV/cm}^3/\text{e}^-$

PEDD = 22.14 J/g

FLUKA results: *E. Eroglu, A. Ferrari*

Mesh volume = 0.25 mm^3

(parallelepiped shape)

PEDD = $0.46 \text{ MeV / vol / e}^-$

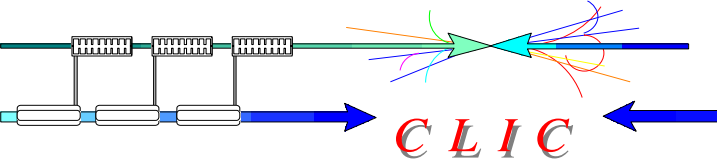
PEDD = $1.83 \text{ GeV/cm}^3/\text{e}^-$

PEDD = 35.5 J/g

**Not a good agreement for photons
impinging an amorphous target**

Investigations are ongoing

Choice for CLIC targets



GEANT 4 simulations

CLIC Note 808

Thickness
amorphous
target

Distance crystal
- amorphous
target

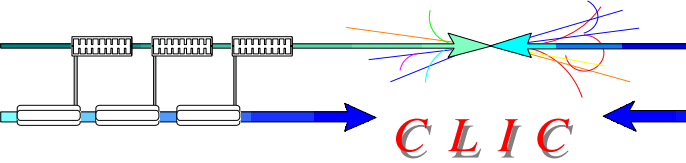
e^+/e^-

Power
deposited in
amorphous
target

e(cm)	d(m)	Yield	P(kW)	Pedd (GeV/cm ³ /e ⁻)	Pedd(J/g/train)
0.6	1.5	1.83	3.90	0.95	18.45
0.6	2.0	1.76	3.85	0.83	16.12
0.6	2.5	1.70	3.70	0.71	13.80
0.6	3.0	1.66	3.65	0.64	12.43
0.8	1.5	2.00	6.70	1.17	22.72
0.8	2.0	1.91	6.55	1.00	19.42
0.8	2.5	1.87	6.40	0.87	16.90
0.8	3.0	1.81	6.20	0.78	15.15
1.0	1.5	2.01	10.05	1.37	26.60
1.0	2.0	1.97	9.80	1.14	22.14
1.0	2.5	1.91	9.60	1.00	19.42
1.0	3.0	1.83	9.25	0.89	17.29
1.2	1.5	2.04	13.70	1.41	27.38
1.2	2.0	1.95	13.45	1.25	24.27
1.2	2.5	1.92	13.05	1.05	20.40
1.2	3.0	1.86	12.65	0.96	18.65

Today
choice

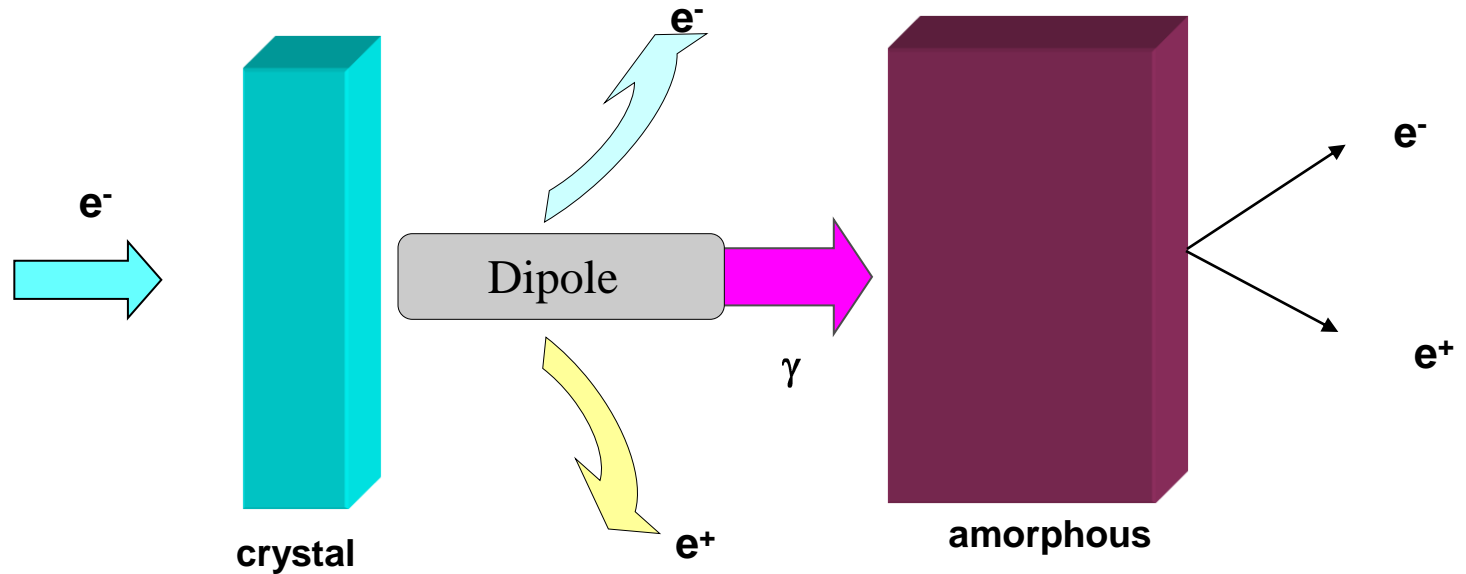
Parameters for CLIC hybrid targets



Primary electron
beam Linac

5 GeV

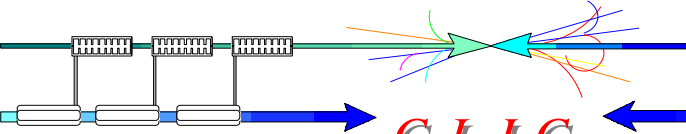
$3.1 \cdot 10^{12} \text{ e}^-/\text{train}$



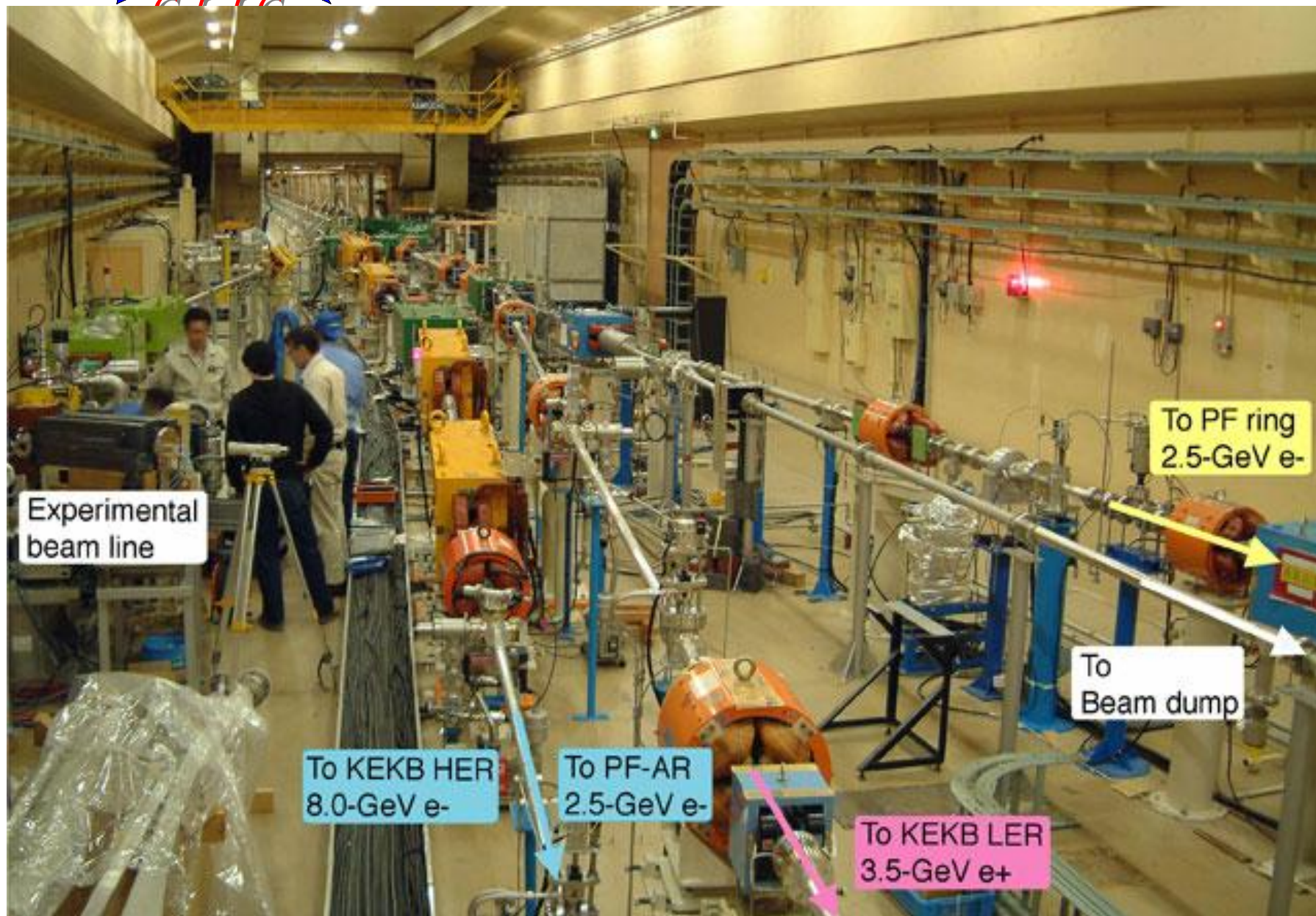
Crystal thickness: 1.4 mm
Oriented along the $\langle 111 \rangle$ axis

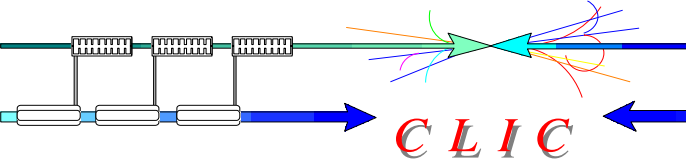
Distance (crystal-amorphous) $d = 2 \text{ m}$

Amorphous thickness $e = 10 \text{ mm}$



Linac switching area at KEKB



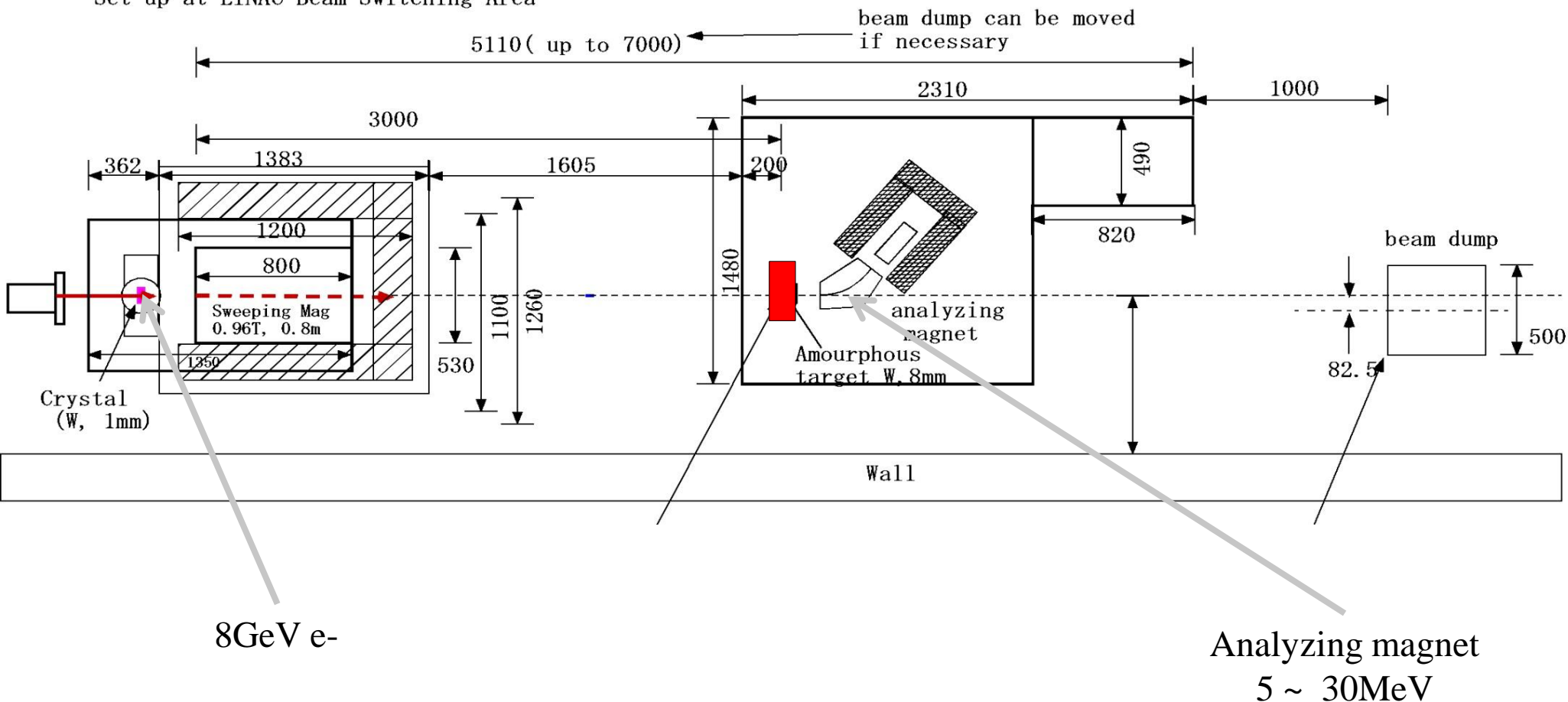


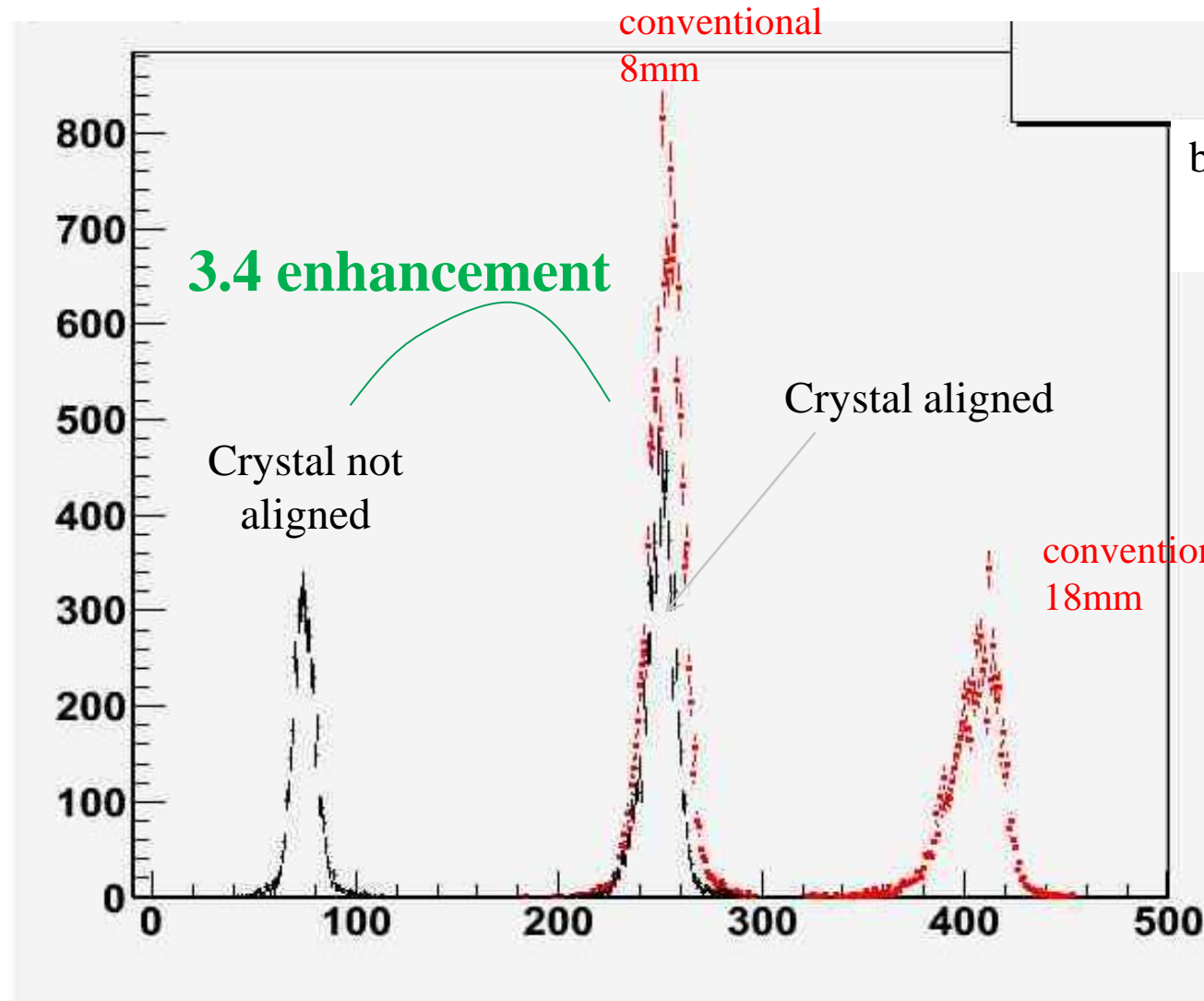
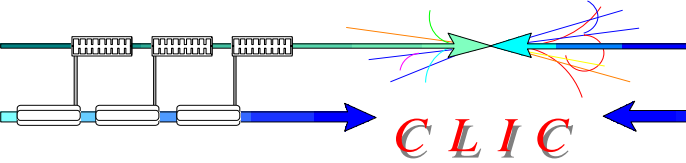
Setup at KEK Linac



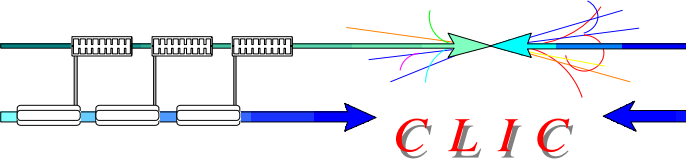
T. Takahashi / Hiroshima Uni. / KEK

Set up at LINAC Beam Switching Area





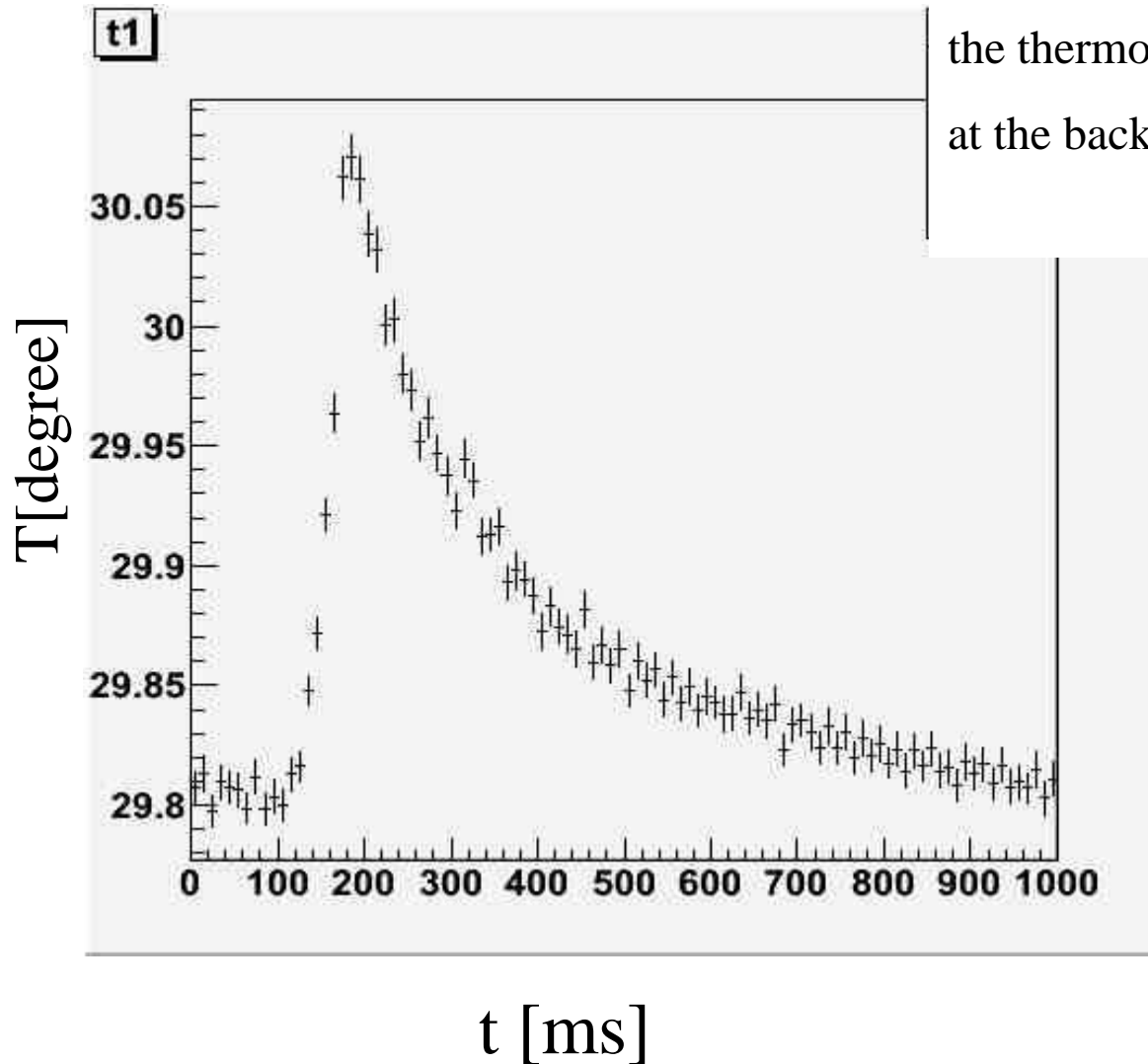
e^+ yield (ADC counts)



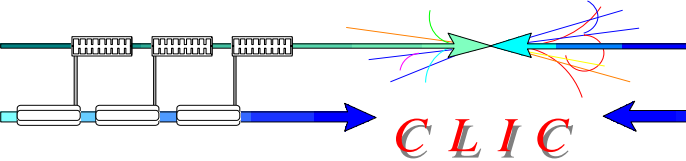
Temperature rise by 1 bunch



temperature measured with
the thermo-couple attached
at the back end of the amorphous target



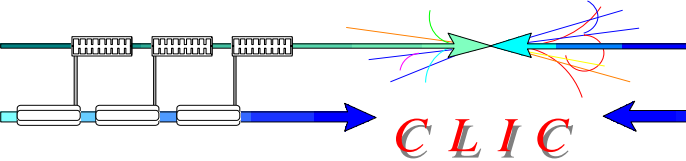
rapid rise by bunch injection and
and slow decrease by thermal
diffusion in the target was
clearly observed



Summary



- 1) The CLIC positron source for the 3 TeV is based on **hybrid targets**, using channeling but producing unpolarized e^+ .
- 2) Further studies are required regarding the **simulations** (with GEANT4, EGS4, FLUKA,...) of the Peak Energy Deposition Density which could be a big issue related to the target breakdown.
- 3) Experimental tests are mandatory. The KEKB results will be important step forward in the behavior of the targets.



Thank you for contributions and discussions:

X. Artru, R. Chehab, S. Dabagov, O. Dadoun, E. Eroglu, A. Ferrari, T. Kamitani, T. Omori, E. Pilicer, F. Poirier, V. Strakhovenko, T. Suwada, T. Takahashi, A. Variola, A. Vivoli