Positron Source using Channelling for the Baseline of the CLIC study

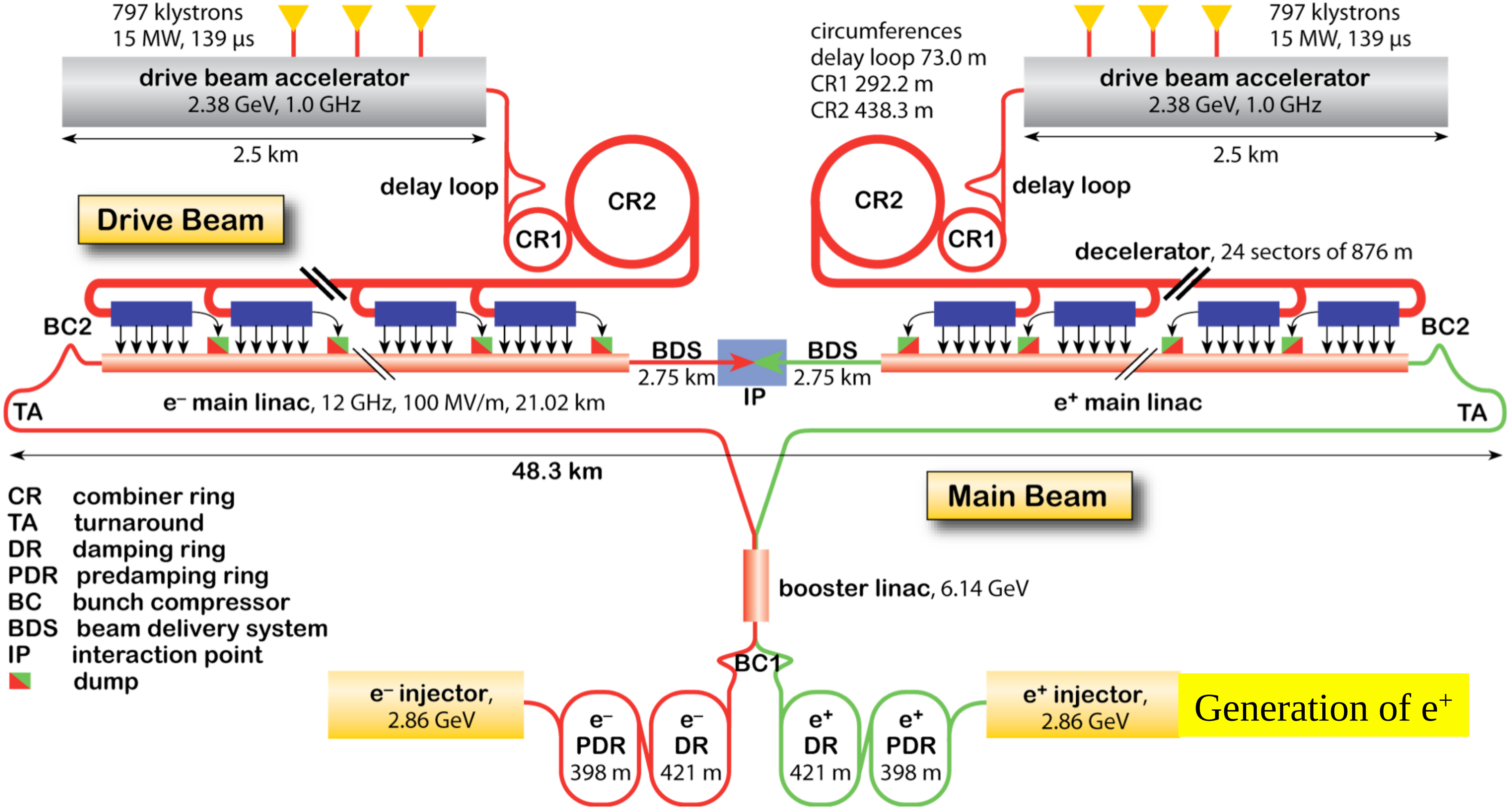
Louis Rinolfi

With contributions from:

X. Artru[2], R. Chehab[2], O. Dadoun[3], E. Eroglu[4], K. Furukawa[5], T. Kamitani[5], F. Poirier[3], T. Omori[5], M. Satoh[5], T. Sigumara[5], V. Strakhovenko[6], T. Suwada[5], T. Takahashi[7], K. Uemori[5], J. Urakawa[5], A. Variola[3], A. Vivoli[1], C. Xu[3]

1, CERN, Geneva, Switzerland
2, IPNL, Université Lyon-1, Lyon, France
3, LAL, Université Paris-Sud, Orsay
4, Uludag University, Turkey
5, KEK, Tsukuba, Japan
6, BINP, Novosibirsk, Russia
7, Hiroshima University, Japan

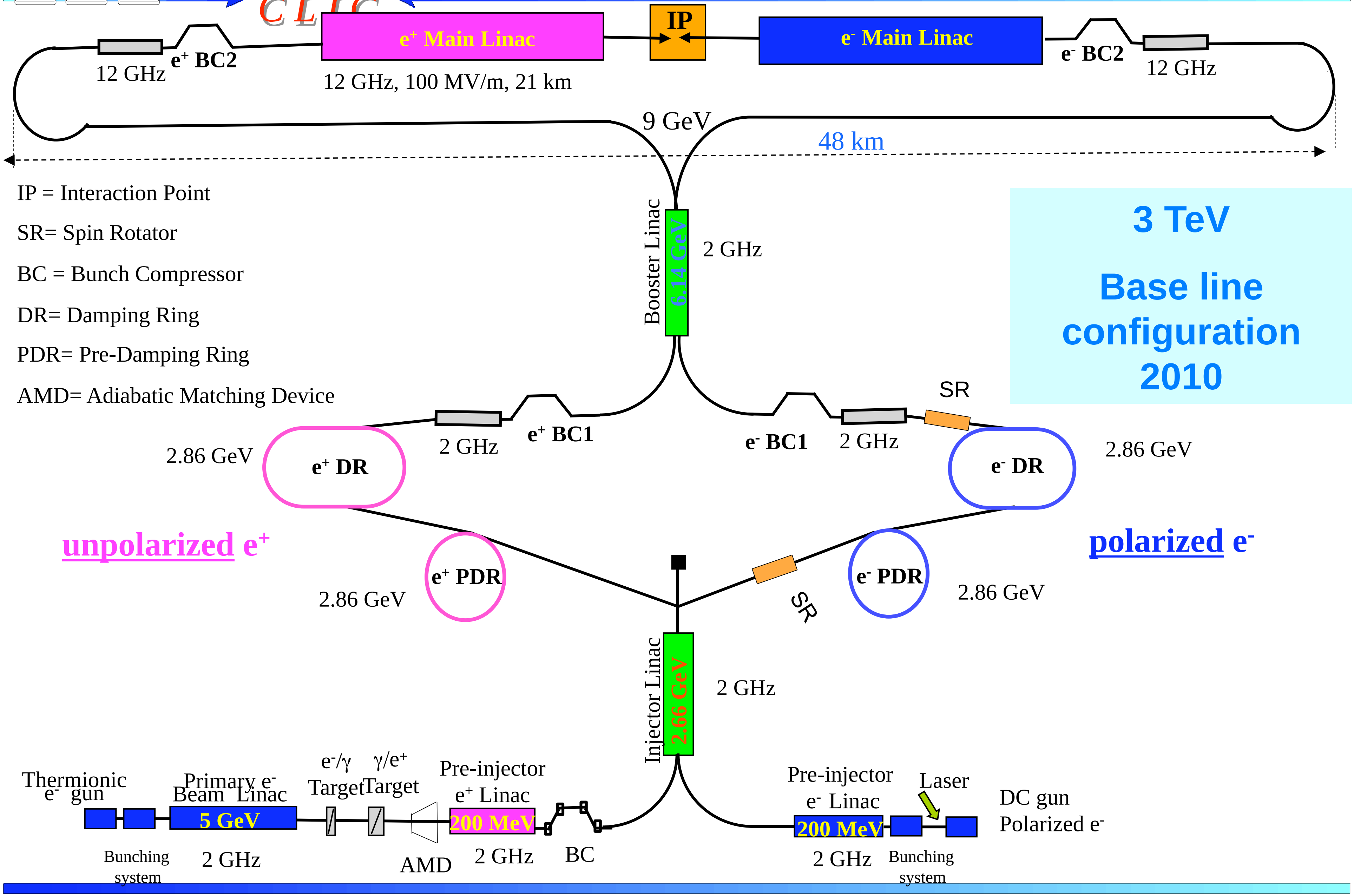
General CLIC layout for 3 TeV



CR	combiner ring
TA	turnaround
DR	damping ring
PDR	predamping ring
BC	bunch compressor
BDS	beam delivery system
IP	interaction point
🟥	dump

Generation of e^+

CLIC Main Beam Injector Complex



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

CLIC

Yield and charge of e^+ beam for 3 TeV

Based on the latest simulations, the yield and the charge have been revised 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	$1.\ 25 \times 10^{12}$	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

CLIC e$^+$ studies

1) Baseline 3 TeV (center of mass):

$7x10^9$ e$^+$/bunch   Pulse of 156 ns long with 312 bunches

2) Study for 500 GeV (center of mass):

$14\ x10^9$ 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, CLIC Note 788

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:

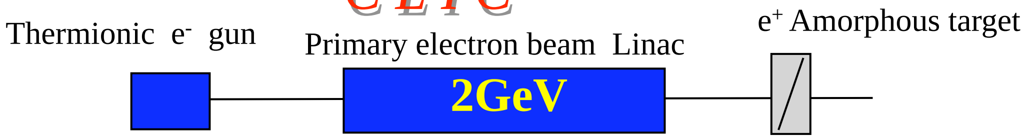
See “CLIC energy scan” by D. Schulte et al., IPAC2010

Flux of e^+

	SLC (California)	CLIC (3 TeV)	CLIC (0.5 TeV)	ILC (RDR)	LHeC (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 DR injection	50 x 10^9	7x10^9	14x10^9	30 x 10^9	15x10^9
Bunches / macropulse	1	312	354	2625	20833
Macropulse Repetition Rate	120	50	50	5	10
e^+ / second x 10^{14}	**0.06**	**1.1**	**2.5**	**3.9**	**31**

≈ x 20

Comparison for PEDD



PEDD = Peak Energy Deposition Density

Amorphous W target (CLIC Note 465):

Electron beam energy: 2 GeV

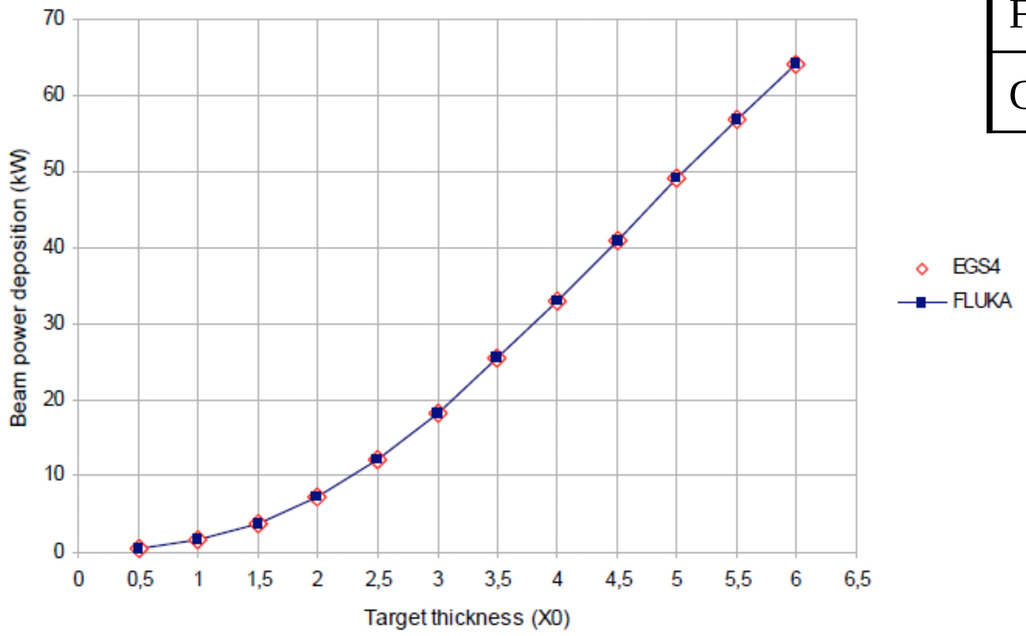
Spot radius (rms): 1.6 mm

Charge: 2x10^{12} e$^-$/pulse

Repetition frequency: 200 Hz

Codes	Peak energy deposition per e$^-$ (MeV)	Total for 2x10^{12} e$^-$ (GeV/mm^3)
EGS4	1.30	0.64x10^{10}
FLUKA	1.35	0.66x10^{10}
GEANT4	1.15	0.56x10^{10}

Mesh volume = 0.425 mm^3

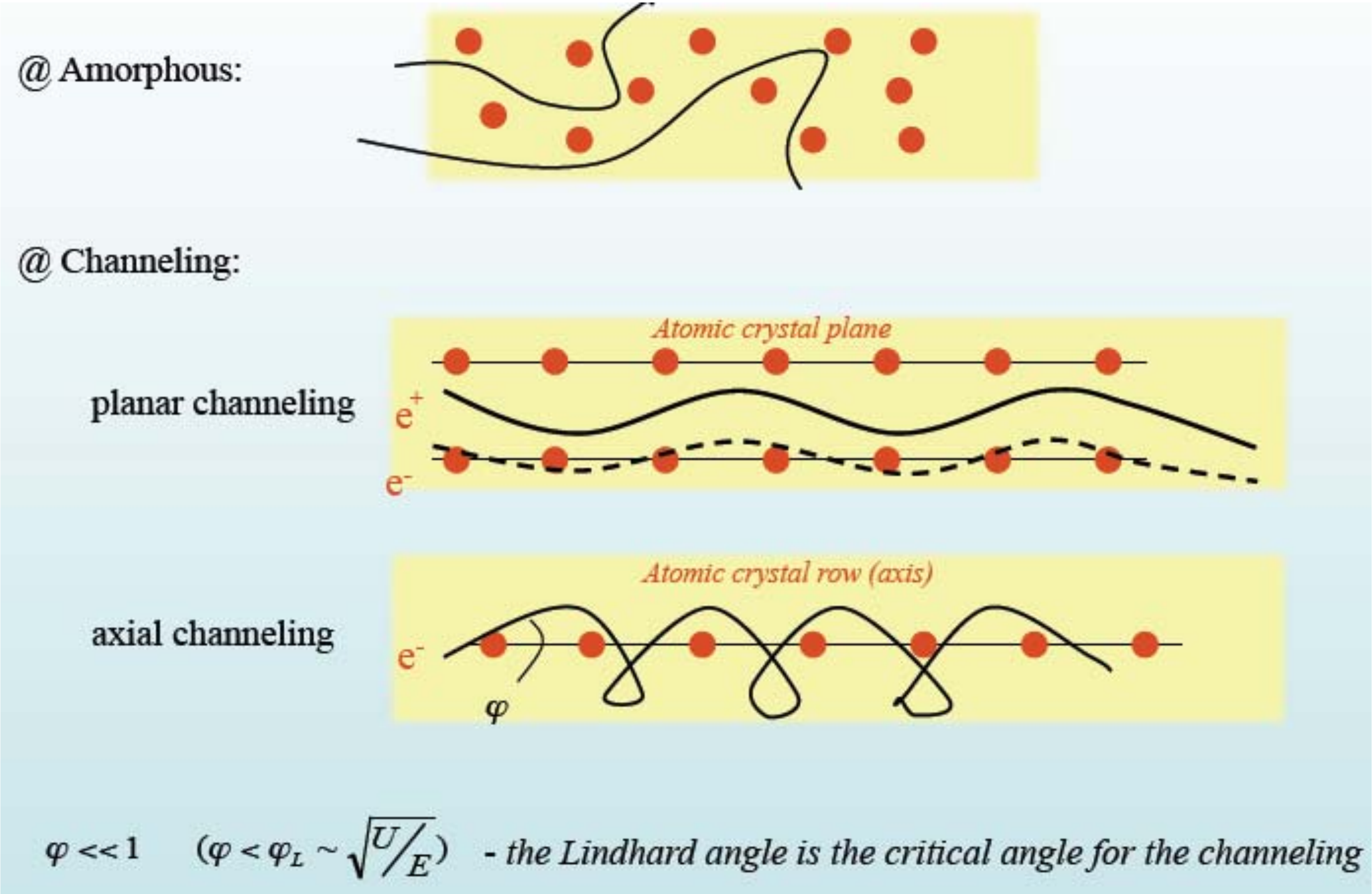


Very good agreement for e$^-$ impinging an amorphous target

But issues with target breakdown

Channeling of charged particles

S. Dabagov



@ Amorphous:

@ Channeling:

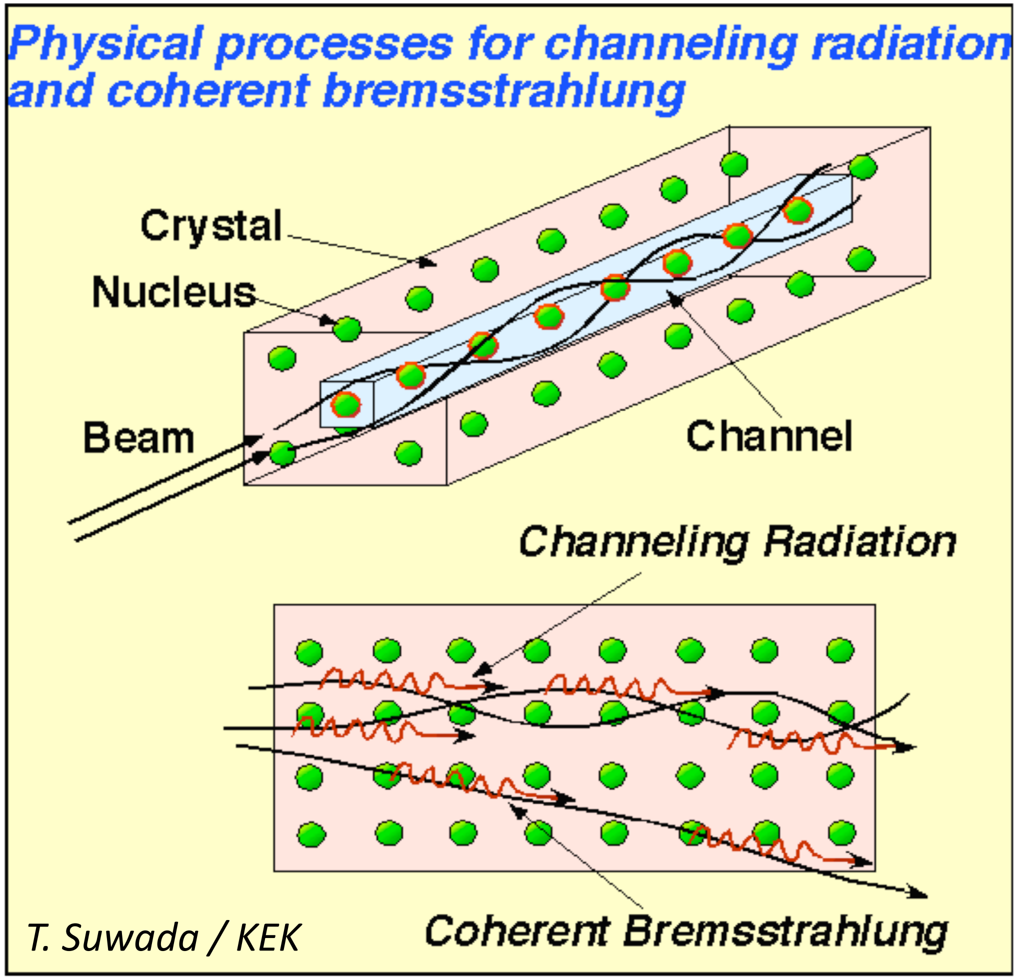
planar channeling

axial channeling

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

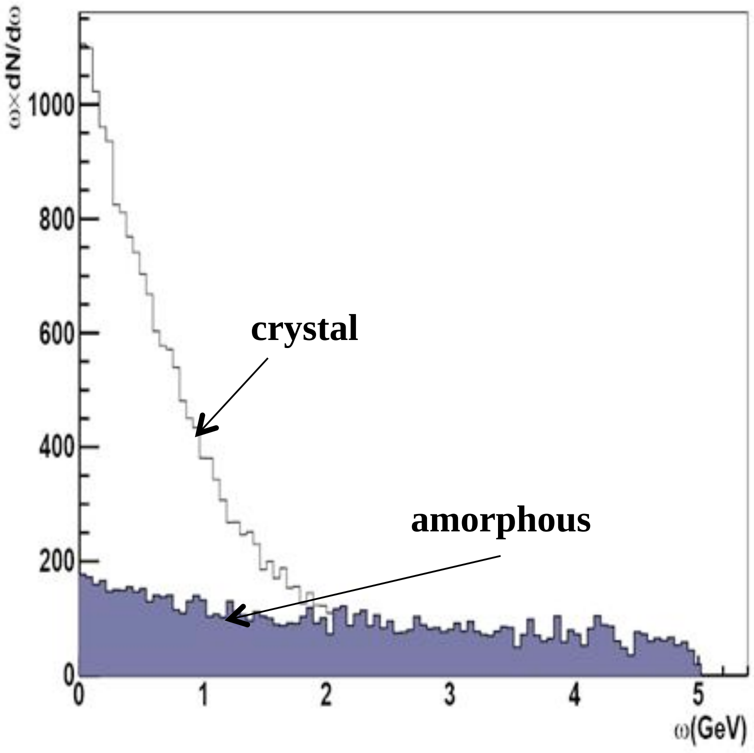
U = potential (on axis) and φ = incidence angle

Energy for channeling in W targets



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

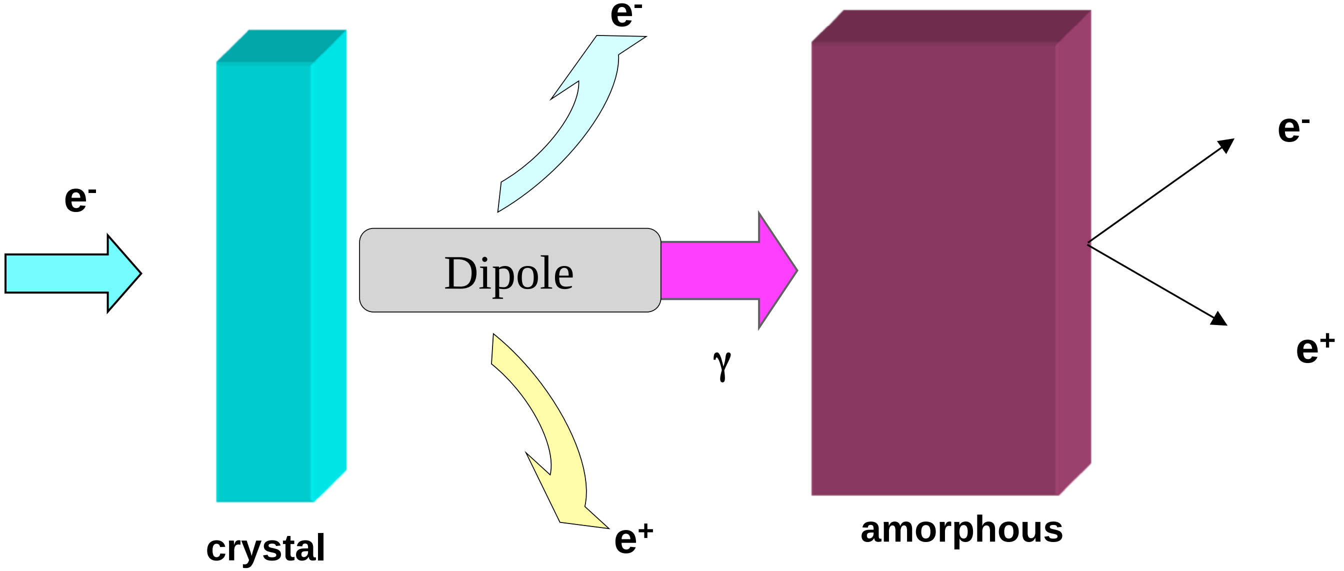
Higher E, higher channeling effects



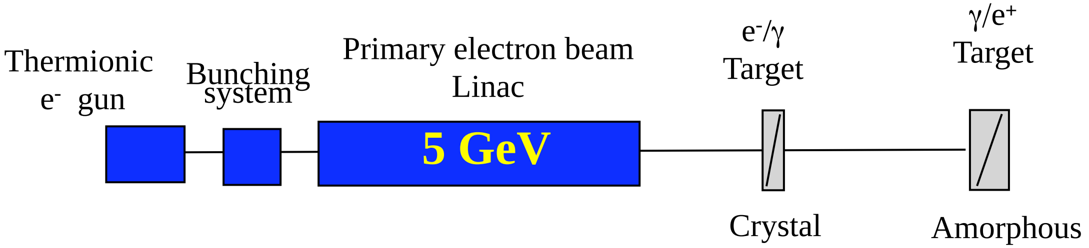
More soft photons with channeling

Concept of hybrid targets

R. Chehab, V. Strakhovenko, A. Variola



Primary Electron Beam Linac



Thermionic e^- gun

Bunching system

Primary electron beam Linac

5 GeV

e^-/γ Target

Crystal

γ/e^+ Target

Amorphous

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 x10^9 e^-/bunch on the target.

Parameters used for BINP/CERN/ IPNL/LAL simulations

Photon spectrum

at crystal target exit

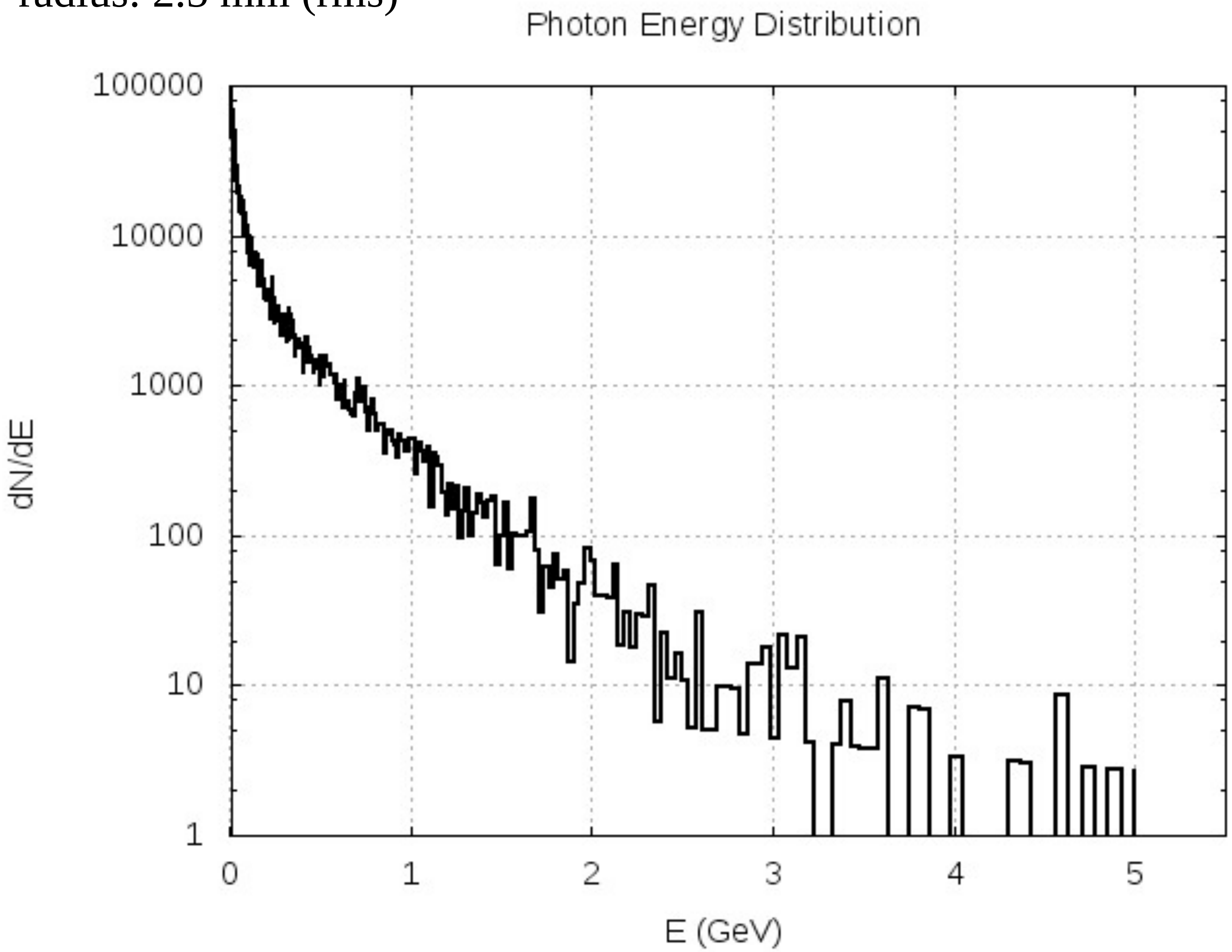
V. Strakhovenko /BINP

Crystal W target :

Electron beam energy: 5 GeV

Charge: 2.34 x10^{12} e^{-}/pulse

Spot radius: 2.5 mm (rms)



Simulations
6000 electrons

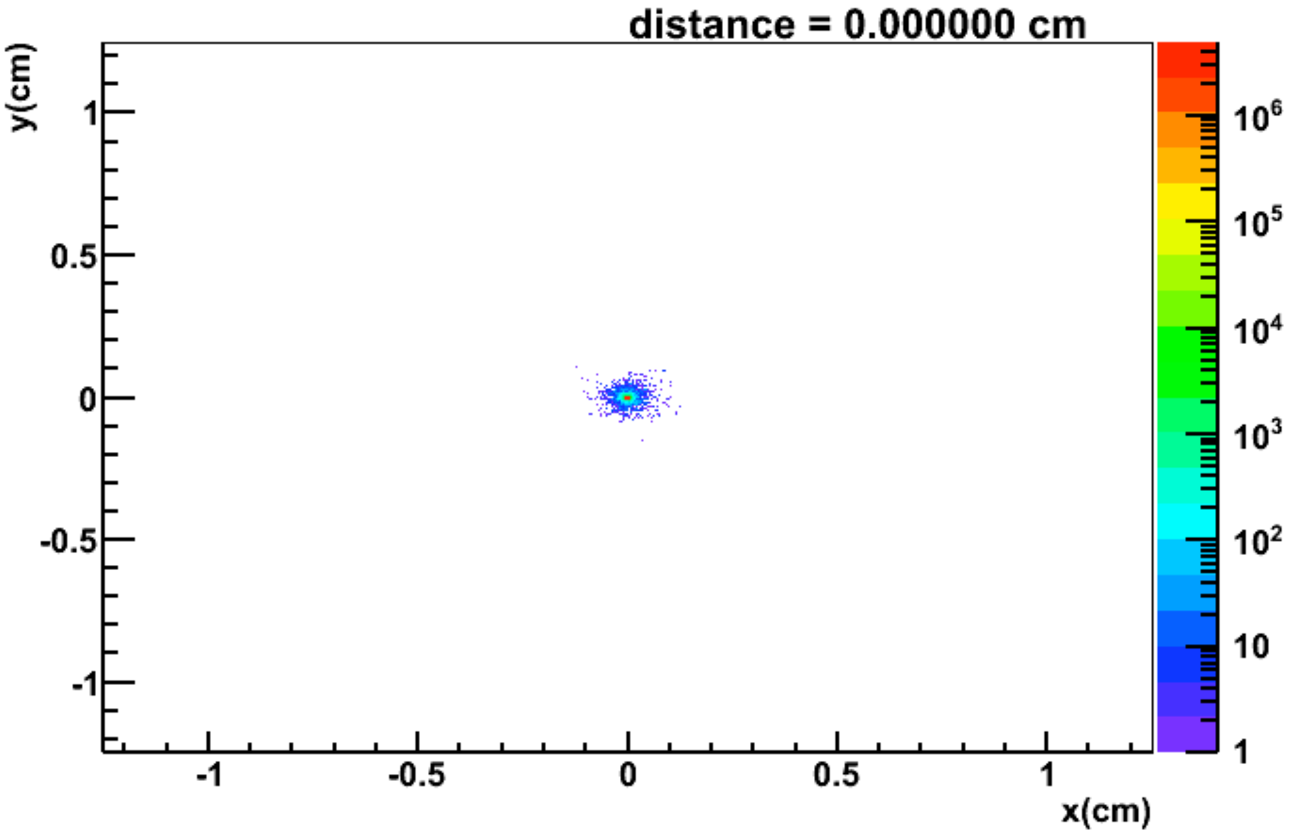
Channeling:

20 photons / e-

Photon evolution

O. Dadoun /LAL

From crystal target exit to amorphous target input



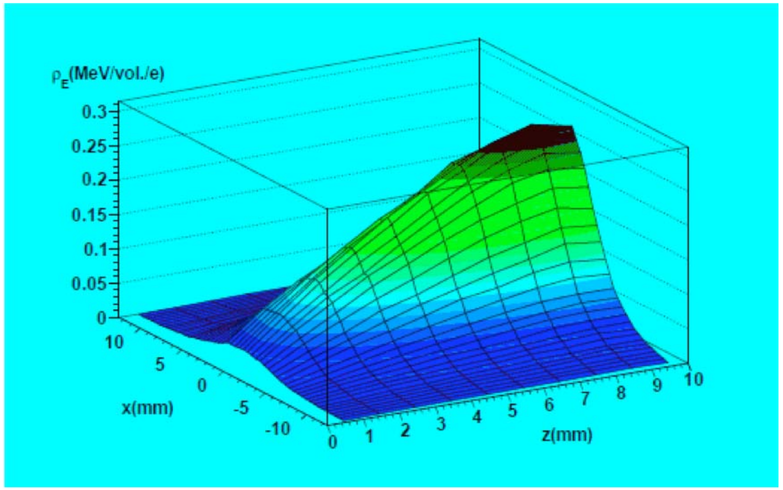
PEDD comparison for amorphous

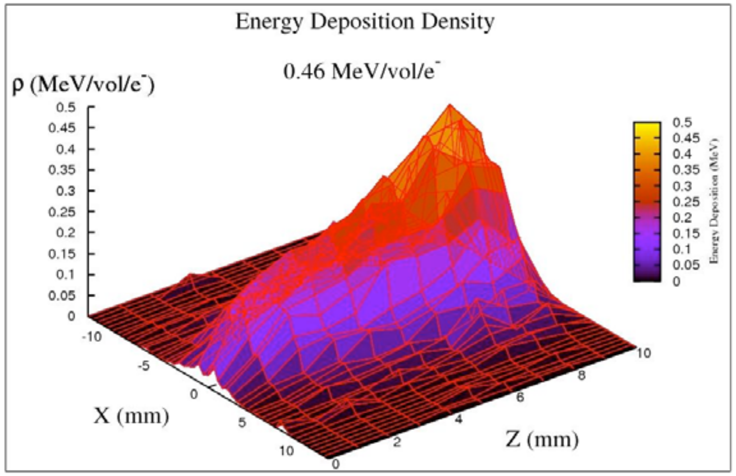
PEDD = Peak Energy Deposition Density

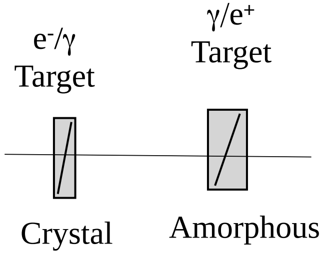
1 GeV/cm^3 = 8.3x10^{-12} J/g for W

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: *(O. Dadoun)*

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:*(E. Eroglu)*

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 very agreement for channeling photons impinging an amorphous target !!!

PEDD study for CLIC targets

GEANT 4 simulations

CLIC Note 808

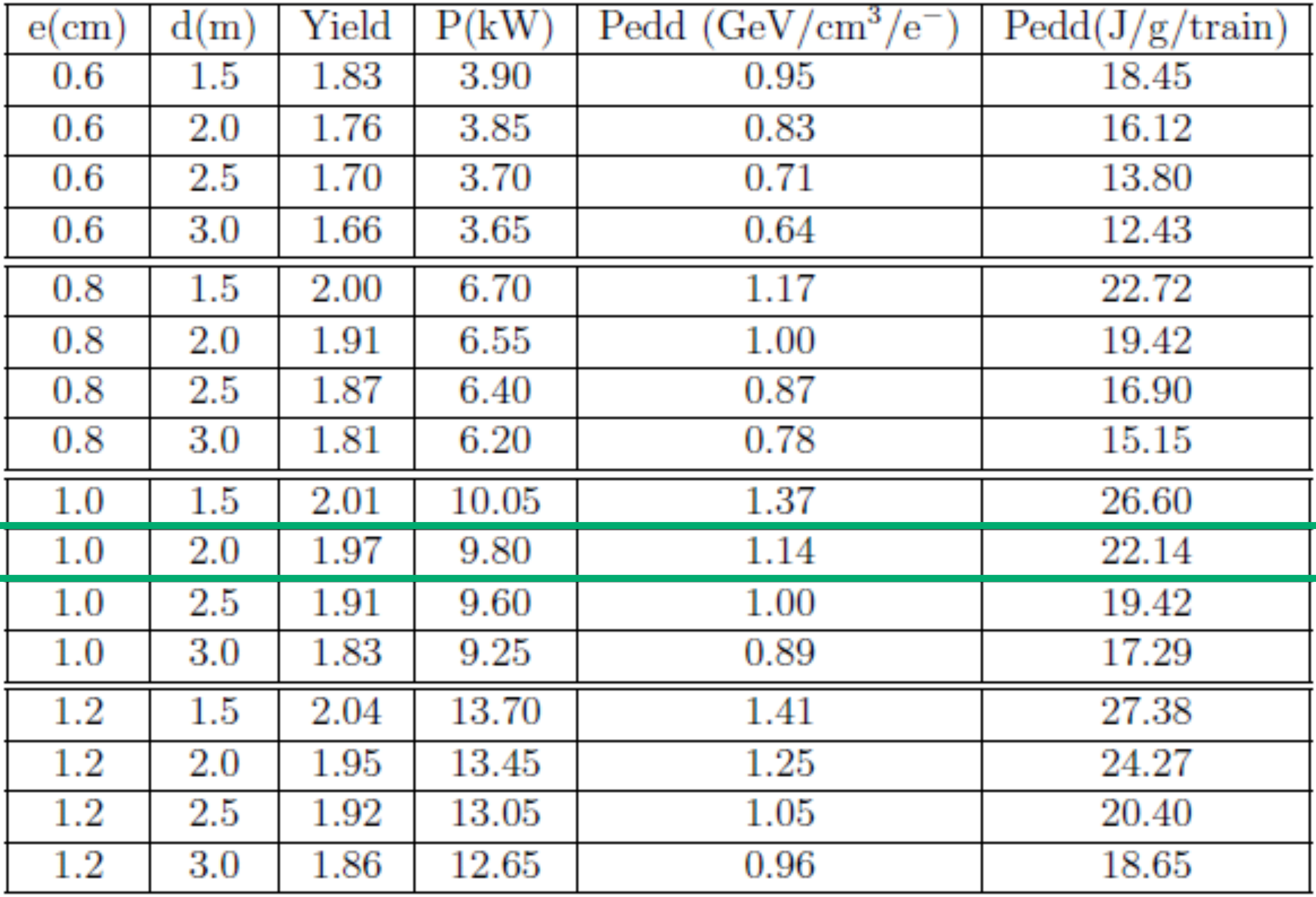
Thickness amorphous target

Distance crystal - amorphous target

e^+/e^-

Power deposited in amorphous target

Today choice



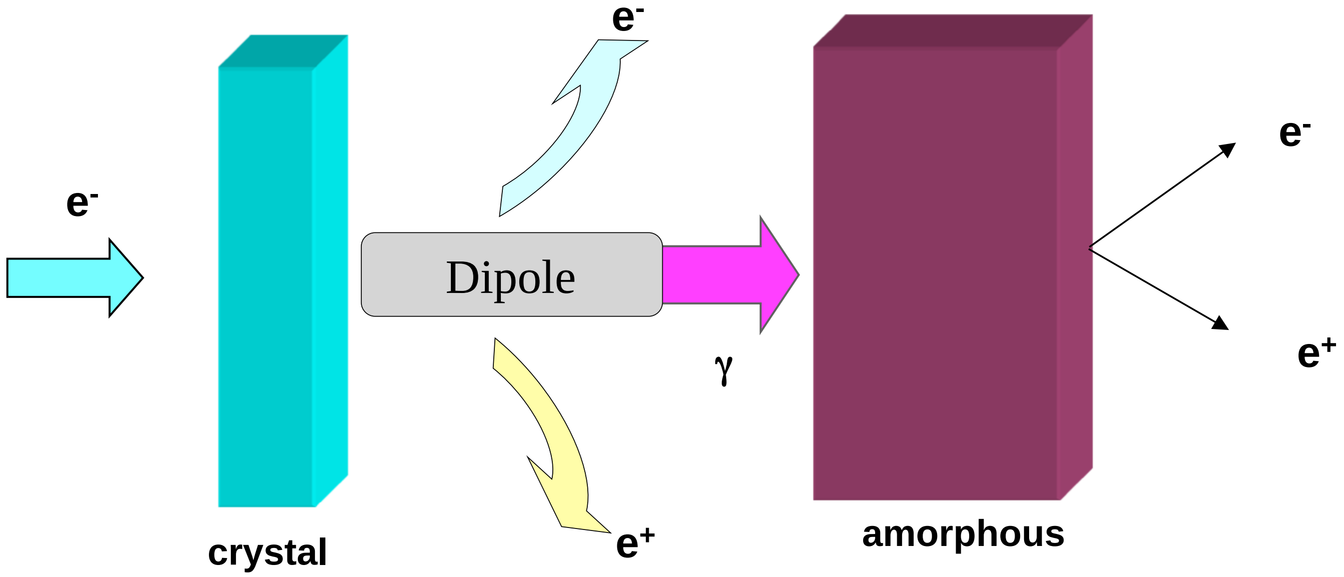
e(cm)	d(m)	Yield	P(kW)	Pedd (GeV/cm^3/e$^-$)	Pedd(J/g/train)
0.6	1.5	1.83	3.90	0.95	18.45
0.6	2.0	1.76	3.85	0.83	16.12
0.6	2.5	1.70	3.70	0.71	13.80
0.6	3.0	1.66	3.65	0.64	12.43
0.8	1.5	2.00	6.70	1.17	22.72
0.8	2.0	1.91	6.55	1.00	19.42
0.8	2.5	1.87	6.40	0.87	16.90
0.8	3.0	1.81	6.20	0.78	15.15
1.0	1.5	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

Parameters for CLIC hybrid targets

Primary electron
beam Linac

5 GeV

2.34 10^{12} e^-/train



Crystal thickness: 1.4 mm
Oriented along the <111> axis

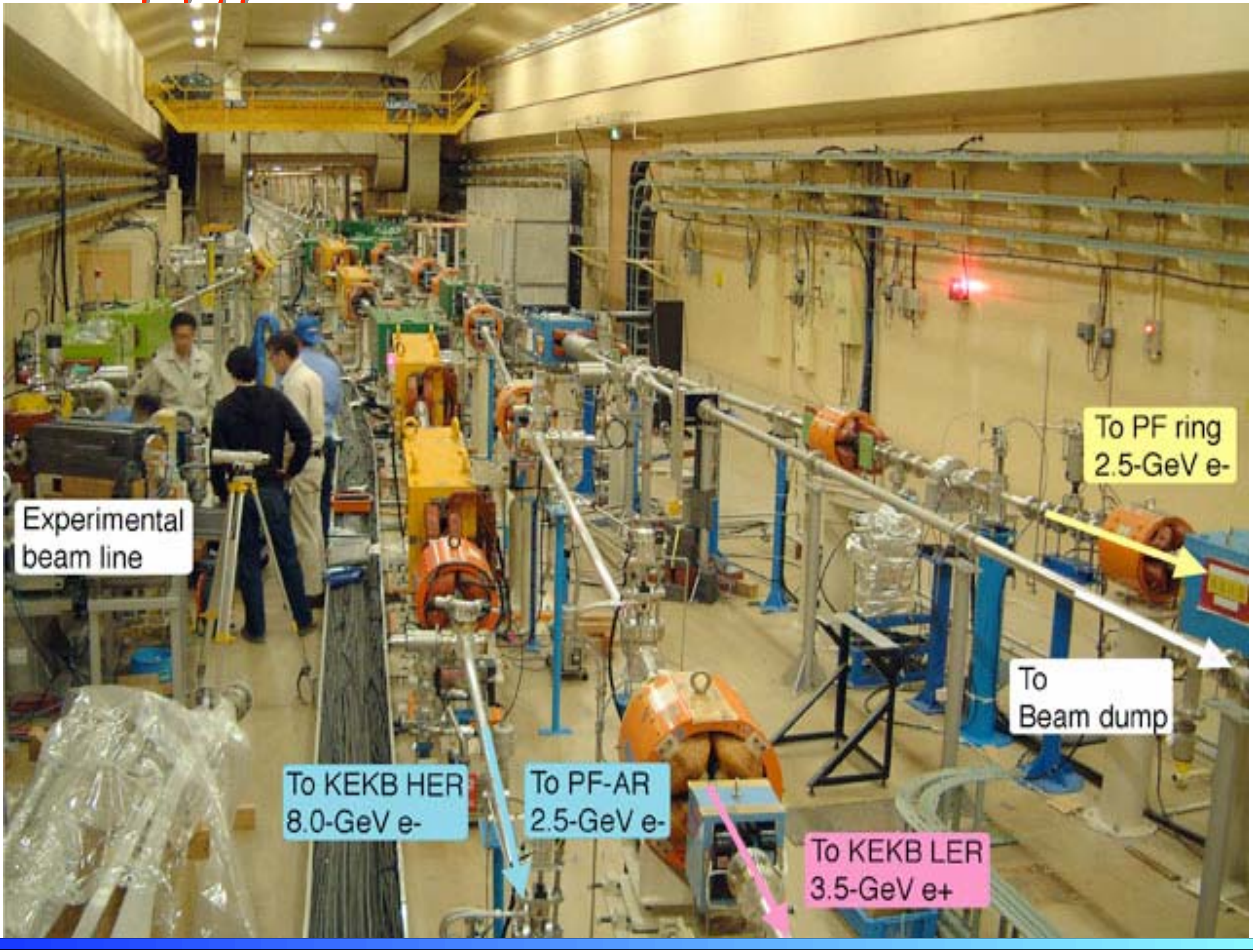
Optimized for 5 GeV
X. Artru et al., NIM 266 (2008) 3868

Distance (crystal-amorphous)
d = 2 m

Optimized for CLIC
O. Dadoun et al., CLIC Note 808

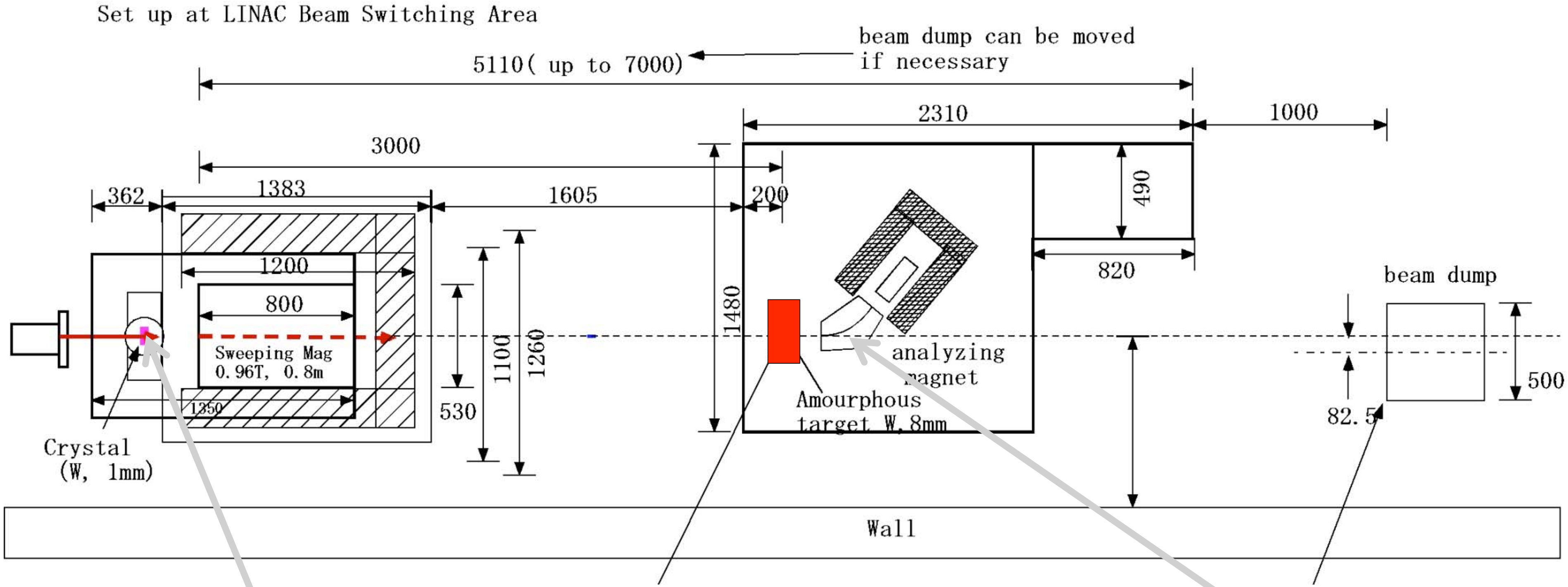
Amorphous thickness
e =10 mm

Linac switching area at KEKB



Setup at KEKB for tests

T. Takahashi / Hiroshima Uni. / KEK

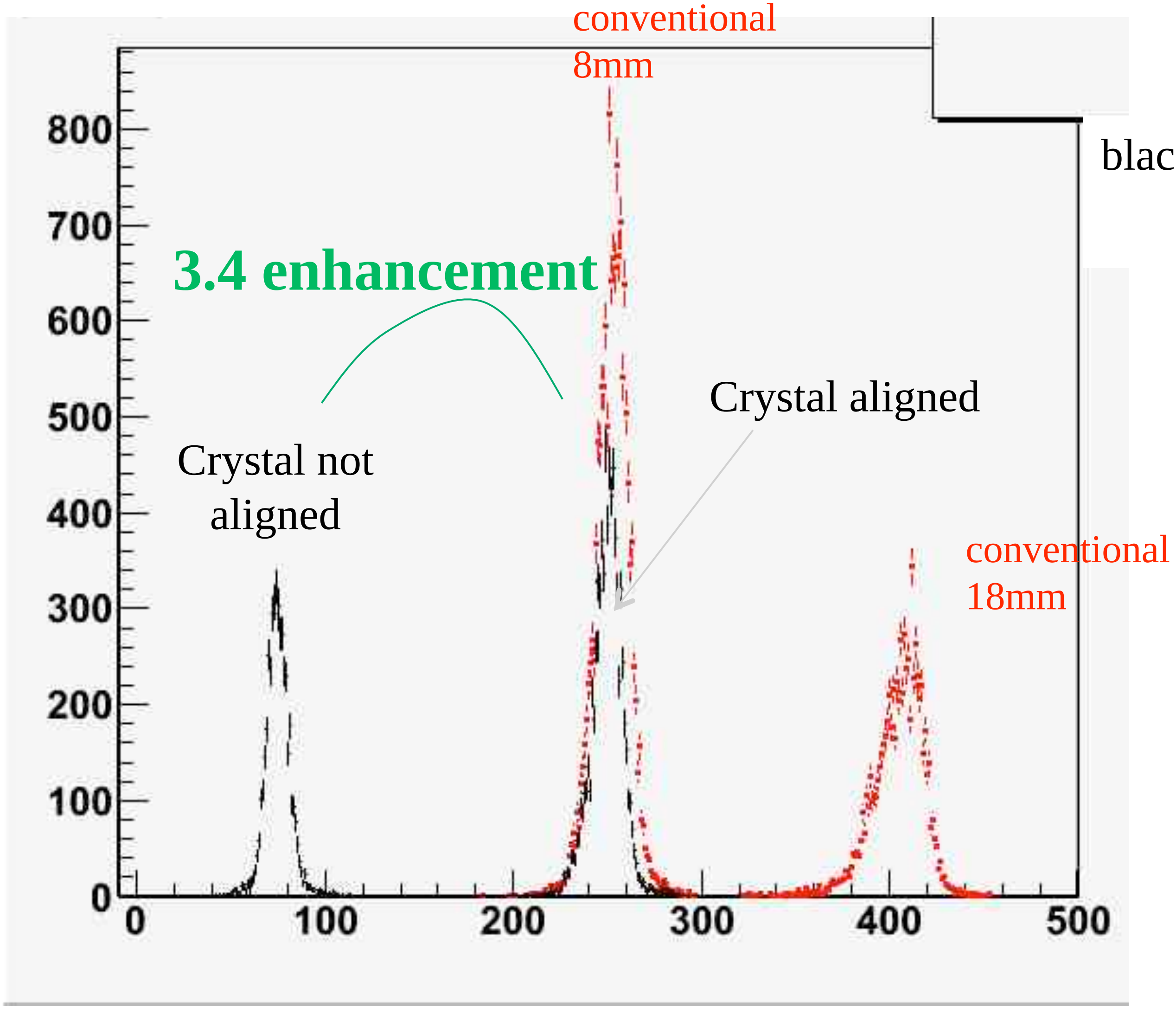


8GeV e-

Analyzing magnet
5 ~ 30MeV

Preliminary results for e^+ at 20 MeV

T. Takahashi / Hiroshima Uni. / KEK



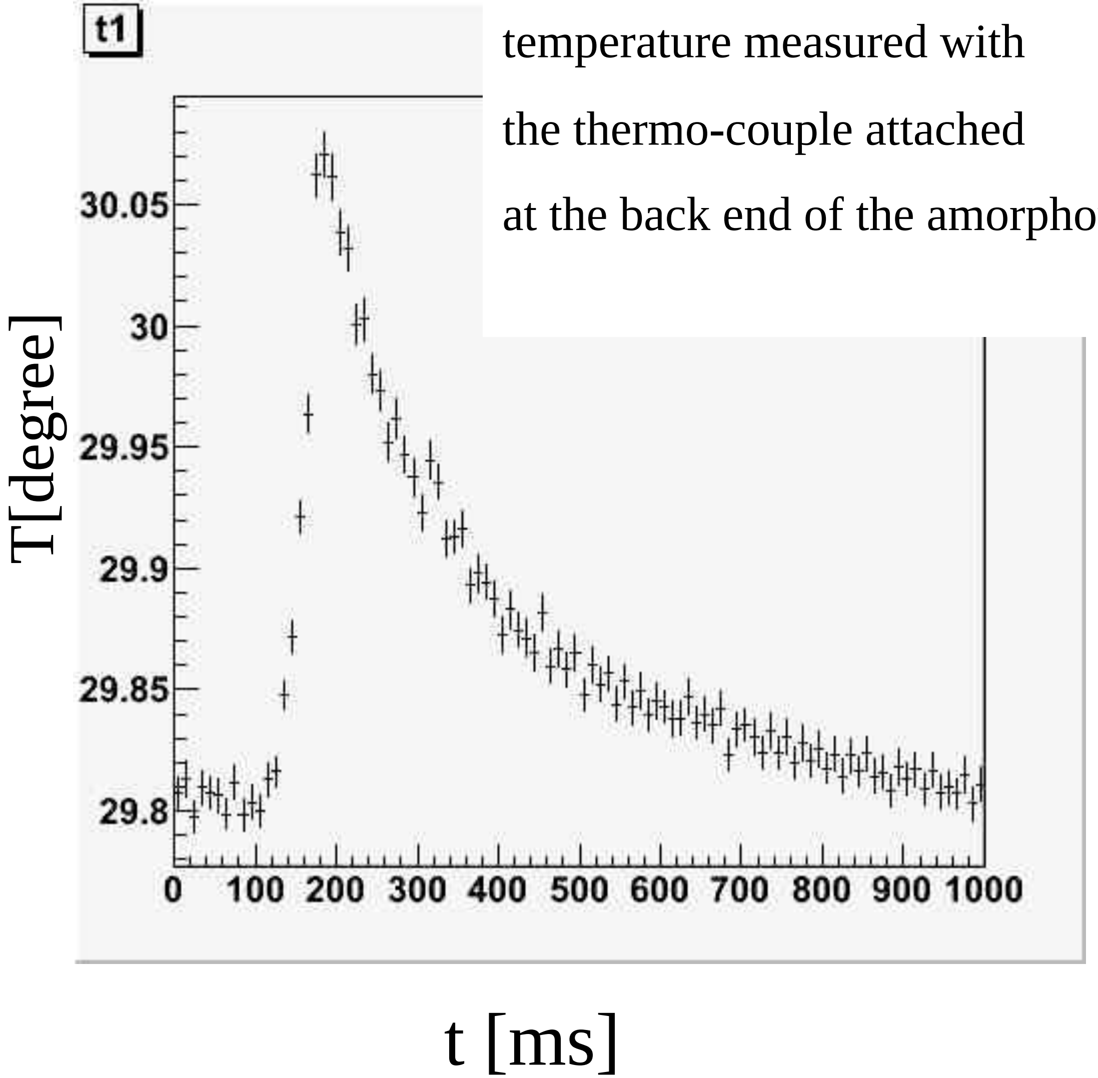
black: 1mm W crystal

+ 8mm W amorphous

e^+ yield (ADC counts)

Temperature rise by 1 bunch

T. Takahashi / Hiroshima Uni. / KEK



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) **Channeling process** allows an important enhancement factor in production of soft photons for e^+ source.

2) The CLIC positron source for unpolarized e^+ is based on the concept of hybrid targets, using channeling.

3) Further studies are required regarding the simulations (with GEANT4, EGS4, FLUKA, particular codes) of the Peak Energy Deposition Density which is a big issue related to the target breakdown.

4) Experimental tests are mandatory. The KEKB results will be a major step forward in the behavior of the targets.