Injectors and Damping Rings working group summary

Y. Papaphilippou (replacing S. Guiducci), L. Rinolfi

A brief overview of the 2 days:

Number of talks: 26

A common session of 3 talks with "Instrumentation" and "Tests Facilities" working groups

Attendance: ≈ 25 to 30 persons in general for each session

26 speakers coming from 11 laboratories and universities:
ANKA (D), ANL, BINP, CERN, Cockcroft Institute, FNAL, IPNL (Lyon), KEK, PSI, Lancaster University, LNF (Frascati),

Preliminary overview

The CLIC Main Beams Injector Complex has 3 studies corresponding to 3 configurations:

1) Base Line configuration:

The study is based on 3 TeV (c.m.) with unpolarized e^+ source and with ultra low emittances for the Damping Rings.

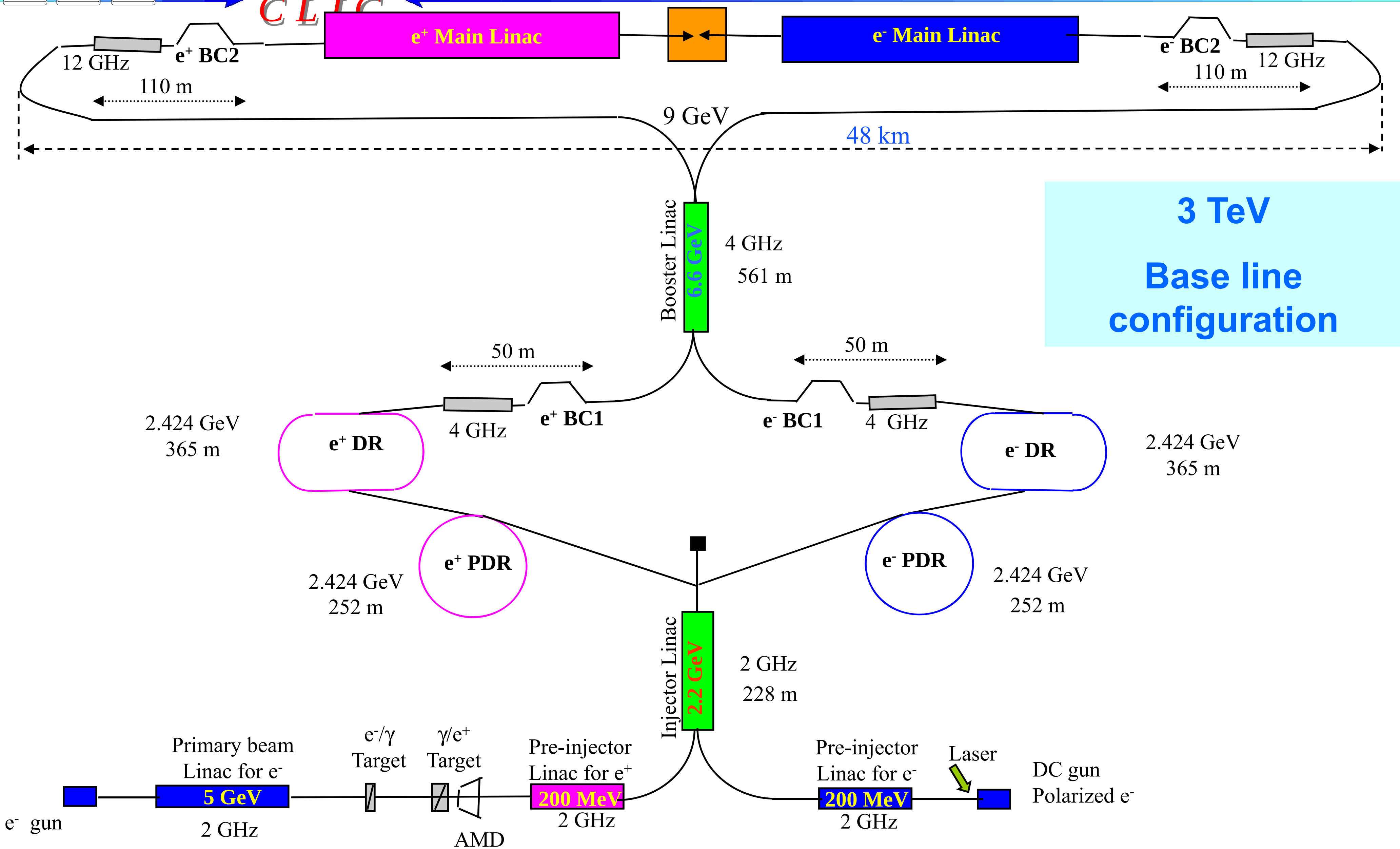
2) Compton configuration:

The study is based on 3 TeV (c.m.) with polarized e^+ source. The undulator option is considered as an alternative.

3) Low energy configuration:

The study is based on 500 GeV (c.m.) with relaxed beam parameters for the Damping Rings but with a double charge per bunch for the lepton sources.

The CLIC Injector complex in 2008



CLIC Main beam parameters

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	7	3.72 - 4	20
n_b	-	190	312	312	2625
Δt_b	ns	1.4	0.5	0.5 (6 RF periods)	369
t_{pulse}	ns	266	156	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 polarized e^- source

M. Poelker / JLAB   F. Zhou / SLAC

From JLAB and SLAC experience:

- Photocathode material (Strained GaAs…) => Polarization > 80 %
- Photo-cathodes preparation techniques => High QE
- High voltage and high field gradient => No field emission
- Ultrahigh vacuum requirements => range of 10^{-11} Torr

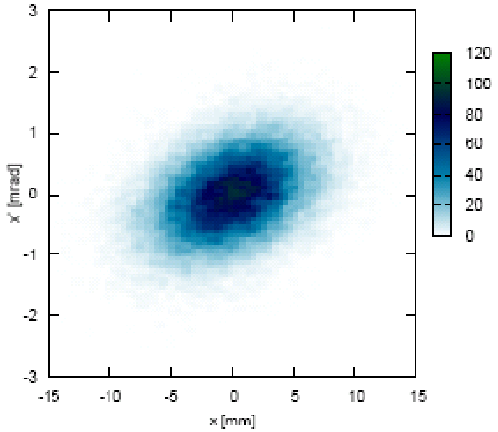
CLIC challenges:

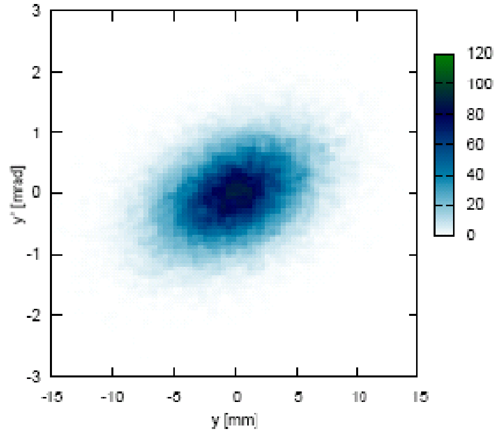
- High bunch charge and high peak current => Space charge and surface charge limits
- Drive laser
- For 500 GeV option, the gun could be a critical issue if the charge is doubled

Beam dynamics simulations in Linacs and TL

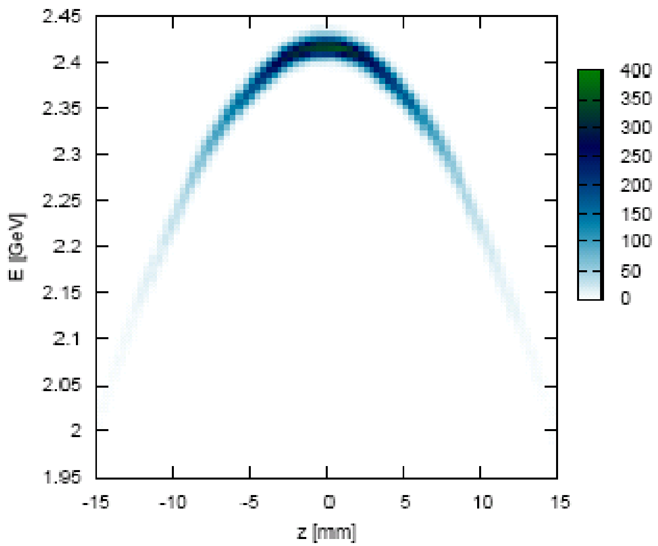
A. Latina / CERN

Transverse





Longitudinal

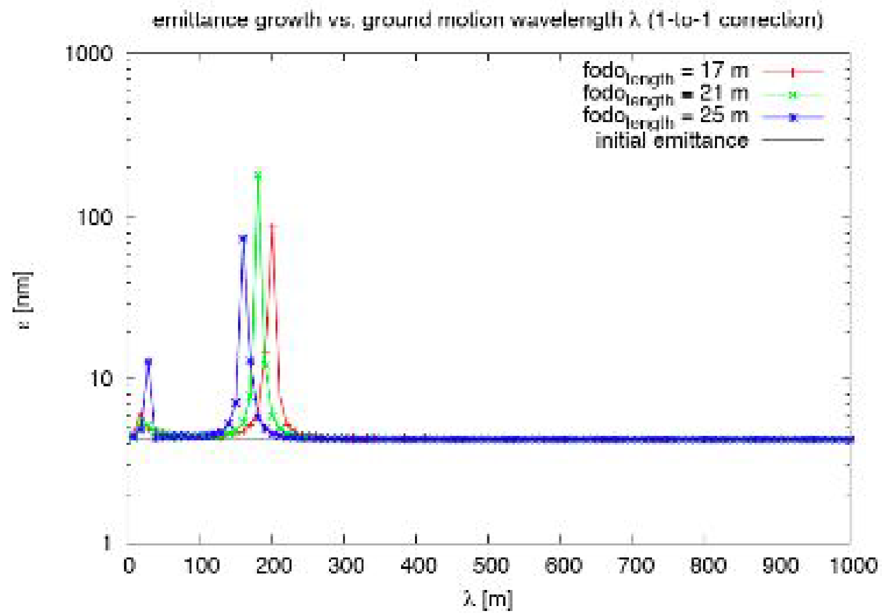


Injector Linac output

Bunch length (rms) = 5 mm

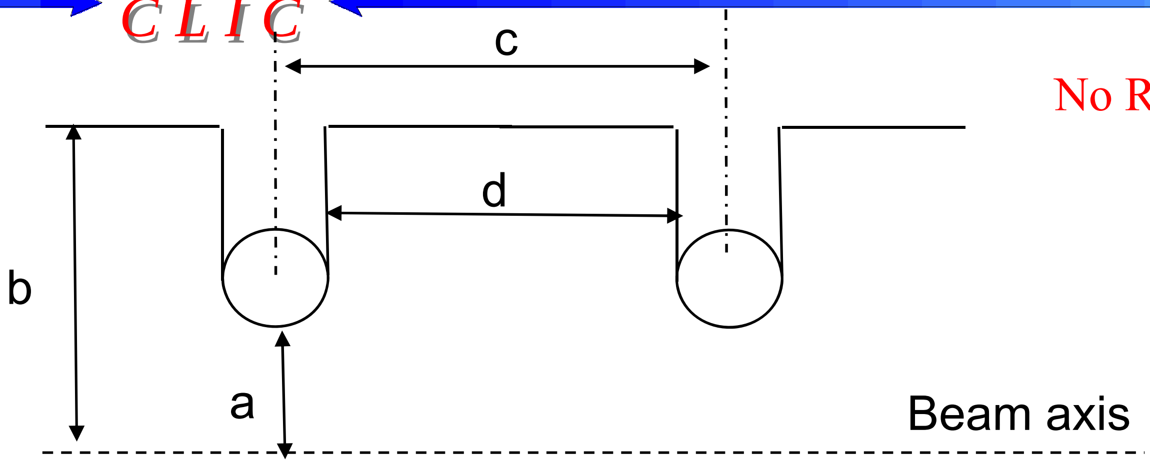
Energy spread (rms) = 65 MeV

21 km Transfer Line with different FODO optics



Effects of long range wake fields remains to be studied for the Booster Linac

Unusual RF frequencies



No RF power sources available for these frequencies

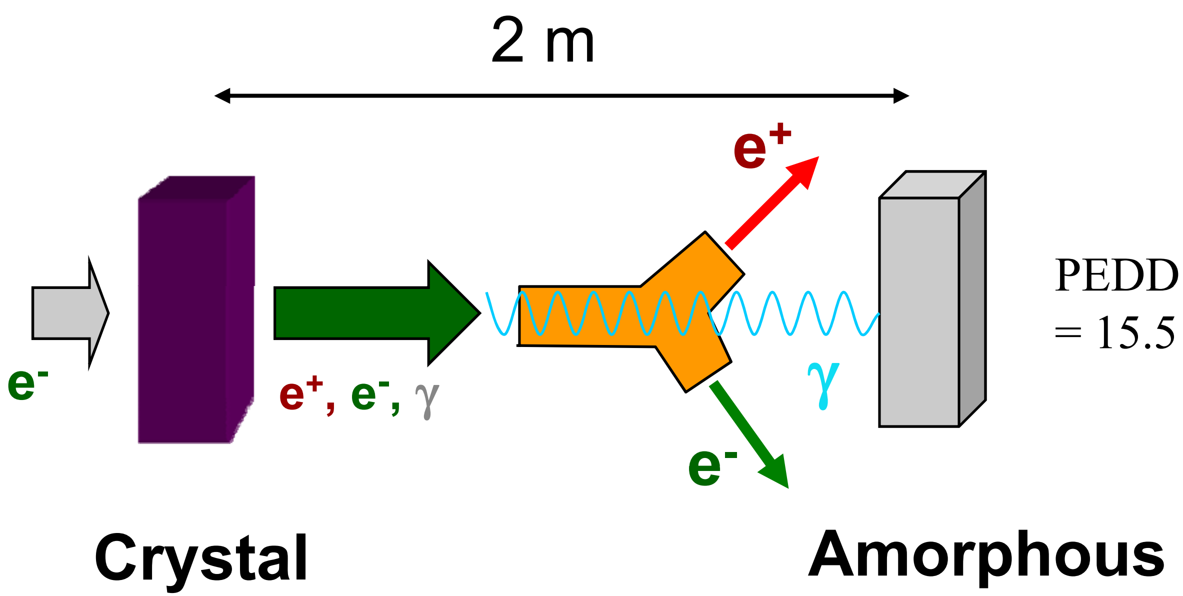
	Units	2 GHz	2.856 GHz	4 GHz
a	mm	22	15.4	11
b	mm	64.3	45	32
c	mm	50	35	25
d	mm	42.8	30	21
G (unloaded)	MV/m	17	25	36
G (loaded) 1.3 A	MV/m	15	22	30
L	m	4	4	3

CLIC Injector | NLC structure | CLIC Booster

R. Chehab / IPNL Lyon

PRELIMINARY CONCLUSIONS for 3 TeV

- The hybrid positron source provides the needed yield for CLIC. A yield >1 e^+/e^- is reachable using only photons coming from the crystal
- The Peak Energy Density Deposition remains under the critical value of 35 J/g (for W) both for the thin crystal and the thick amorphous target.

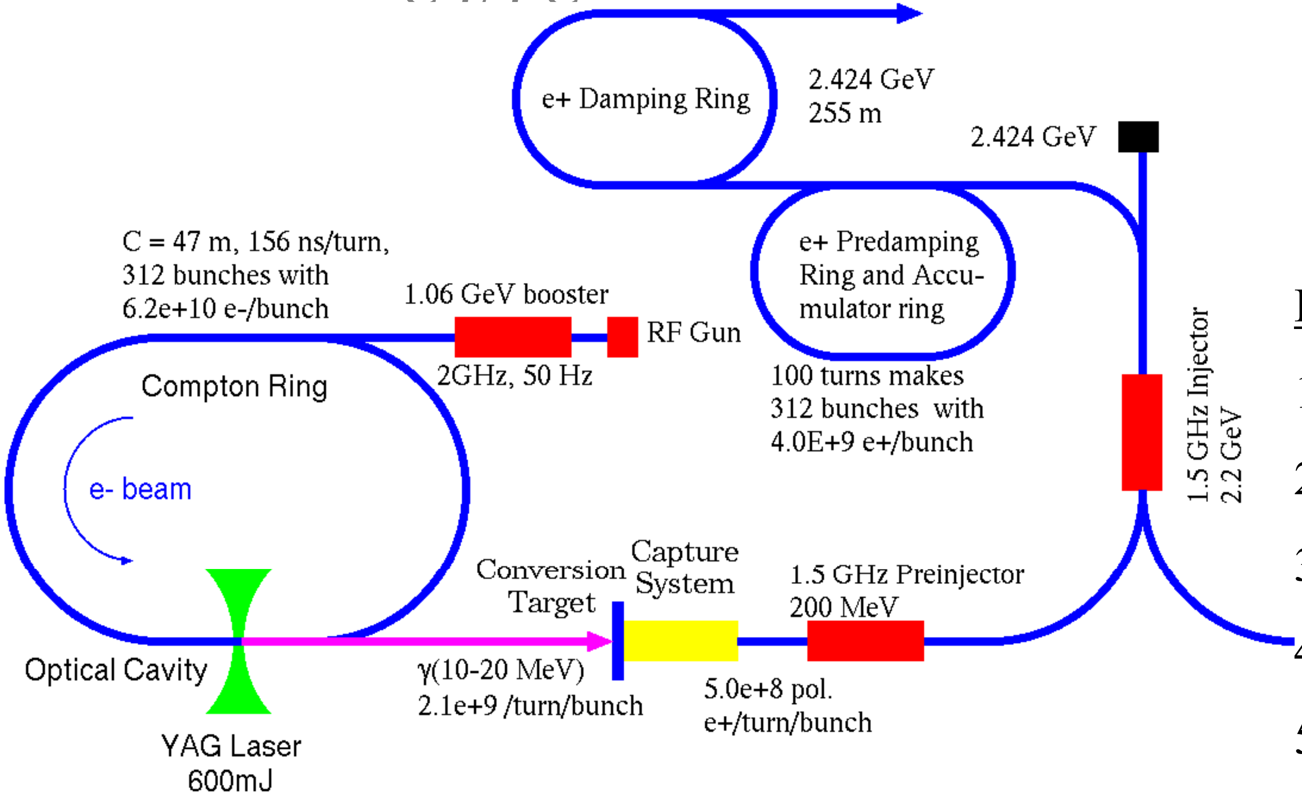


PEDD calculated = 15.5 J/g

At 500 GeV, charge is doubled => Study if a double target stations could be avoided ??

CLIC Compton Scheme

J. Urukawa / KEK



ILC/CLIC common issues on Compton:

1) Number of e^- (beam stability)
2) Optical cavity
3) High quality and high power laser
4) Choice of ERL parameters
5) Energy compression before (P)DR
6) Short Damping Time for (P)DR
7) e^+ stacking

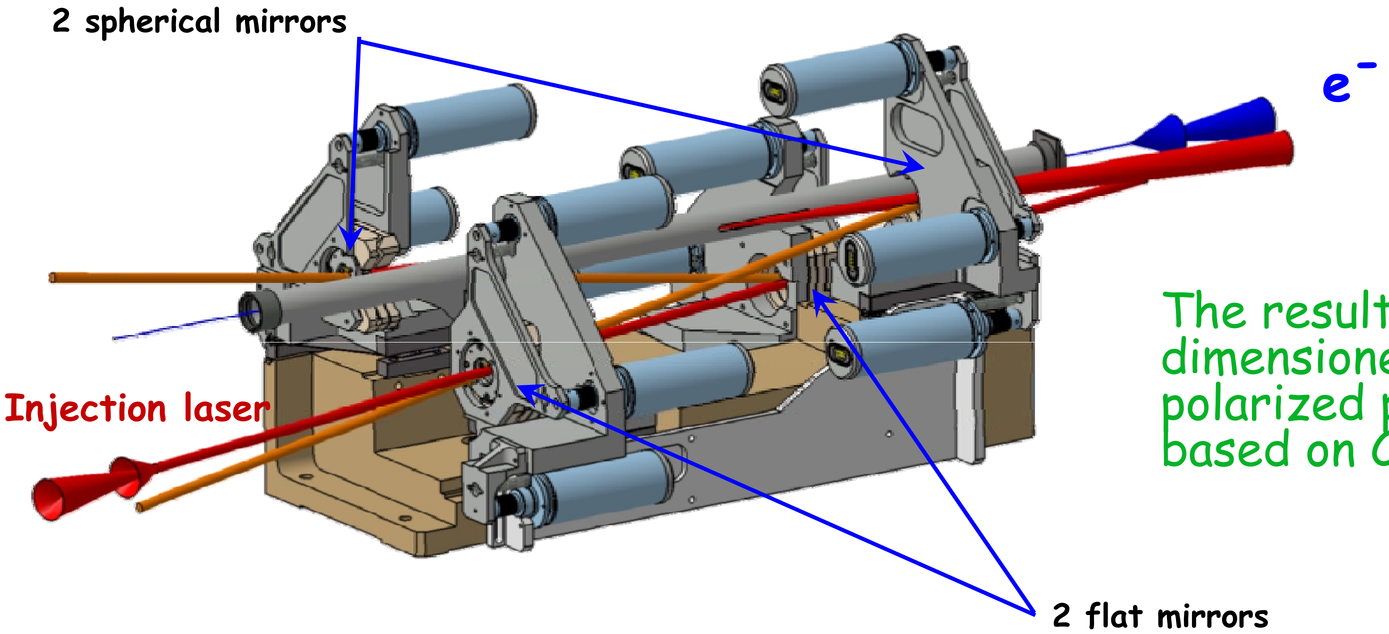
Collaboration on Positron Generation strongly supported by CLIC and ILC managements (J.P. Delahaye@PosiPol08)

Optical cavity R&D at LAL

A. Variola / LAL

GOAL => store the maximum power with a very short pulse for Compton
At low power, LAL results: i) finesse = 30000;
ii) waists of the order of few tenths of microns;
iii) studied the best 4 mirrors cavity configurations due to the polarization effects on modes.

Install the system @ ATF KEK

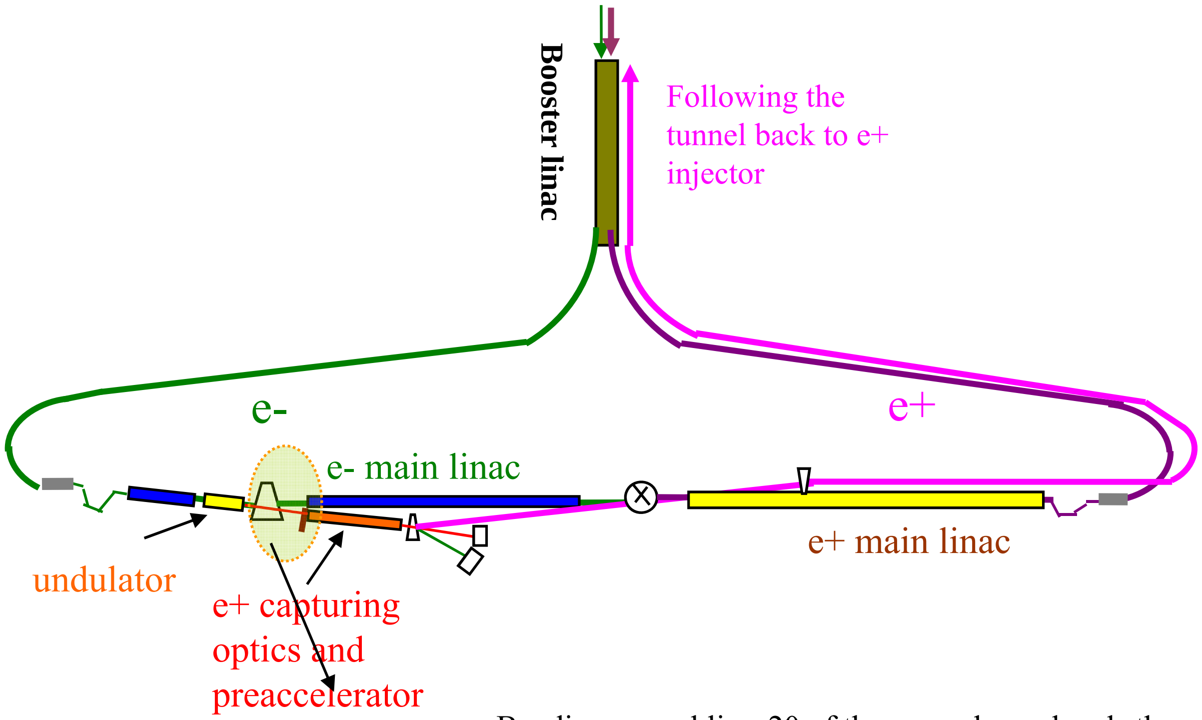


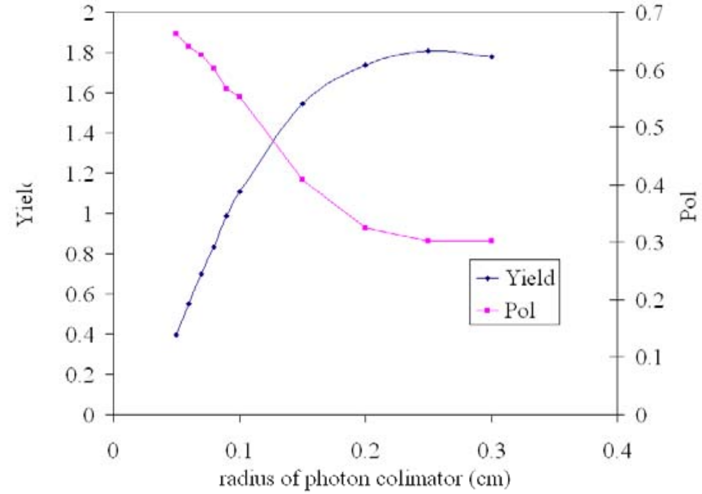
The results will be rescaled and dimensioned for the proposal of the polarized positron source for the CLIC based on Compton scattering

A possible CLIC layout with undulator based e^+ source

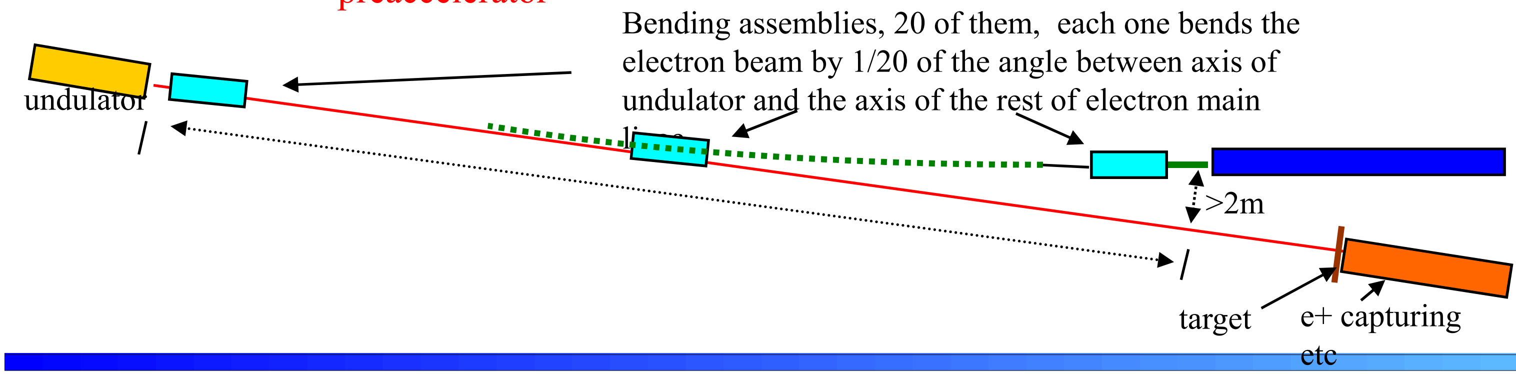
CLIC

W. Gai / ANL



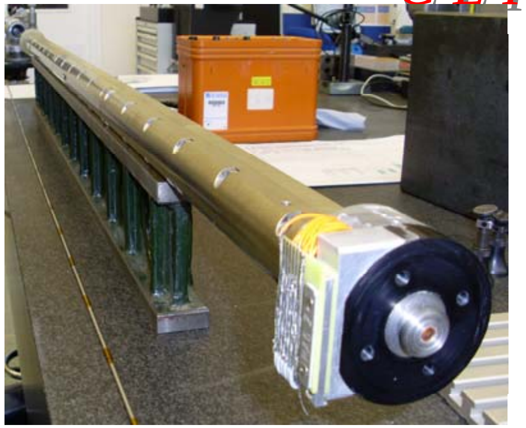


Simulations shows that the undulator will not dilute the emittance of the e- beam.



CLIC undulator option for polarized e^+

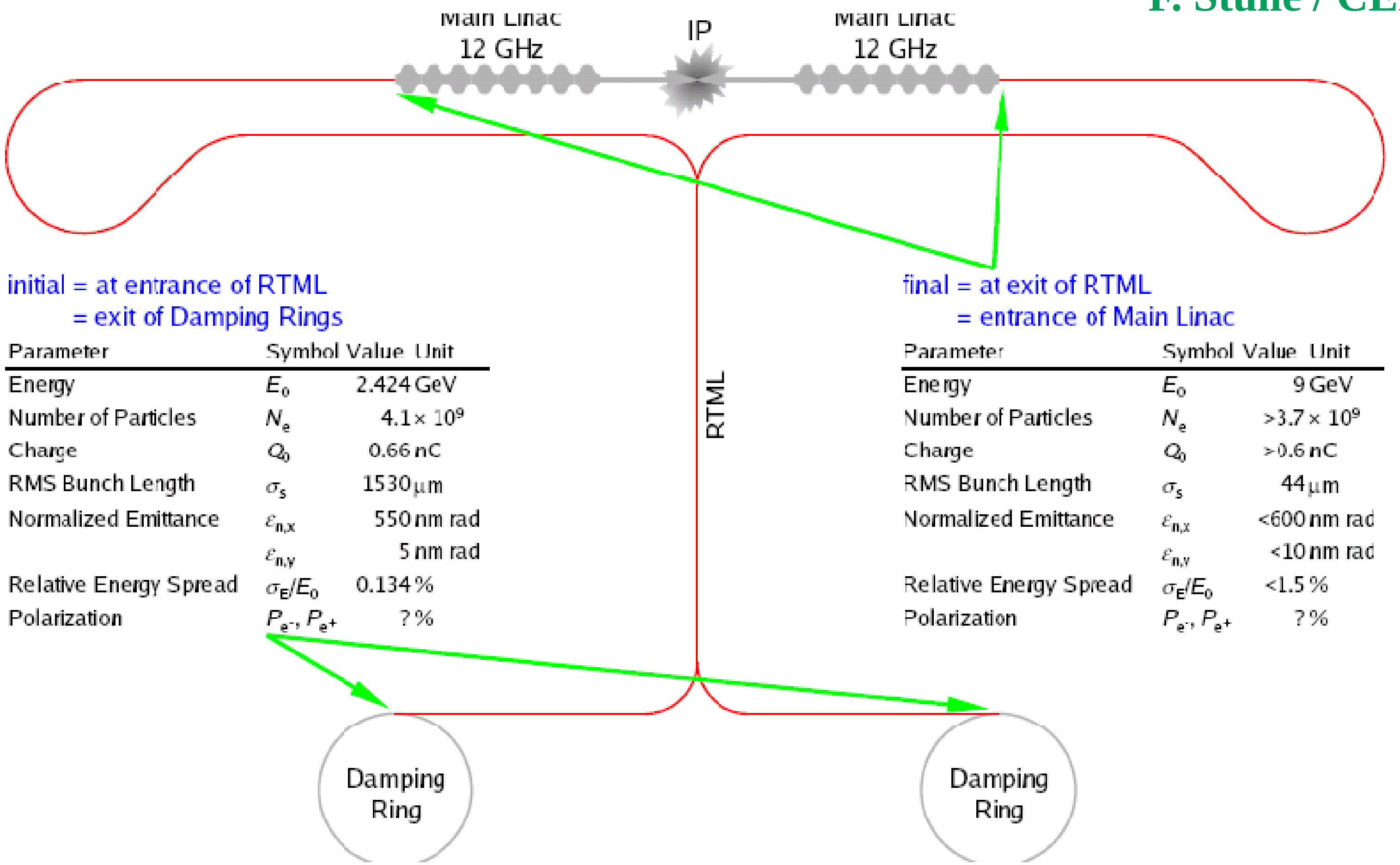
I. Bailey / CI



- Positron polarisation is highly desirable
  - Not necessarily only reason to choose undulator
- Polarisation has to be “designed-in” globally.
- Undulator-based positron source technology in mature state.
- Overall impact on machine operation needs to be re-evaluated for CLIC (c.f. ILC)
- Much scope for optimisation studies
  - Coordination required

Challenges to transport beam from DR to ML

F. Stulle / CERN



initial = at entrance of RTML
= exit of Damping Rings

Parameter	Symbol	Value	Unit
Energy	E_0	2.424	GeV
Number of Particles	N_e	4.1×10^9	
Charge	Q_0	0.66	nC
RMS Bunch Length	σ_s	1530	μm
Normalized Emittance	$\varepsilon_{n,x}$	550	nm rad
	$\varepsilon_{n,y}$	5	nm rad
Relative Energy Spread	σ_E/E_0	0.134	%
Polarization	P_{e^-}, P_{e^+}	?	%

final = at exit of RTML
= entrance of Main Linac

Parameter	Symbol	Value	Unit
Energy	E_0	9	GeV
Number of Particles	N_e	$>3.7 \times 10^9$	
Charge	Q_0	>0.6	nC
RMS Bunch Length	σ_s	44	μm
Normalized Emittance	$\varepsilon_{n,x}$	<600	nm rad
	$\varepsilon_{n,y}$	<10	nm rad
Relative Energy Spread	σ_E/E_0	<1.5	%
Polarization	P_{e^-}, P_{e^+}	?	%

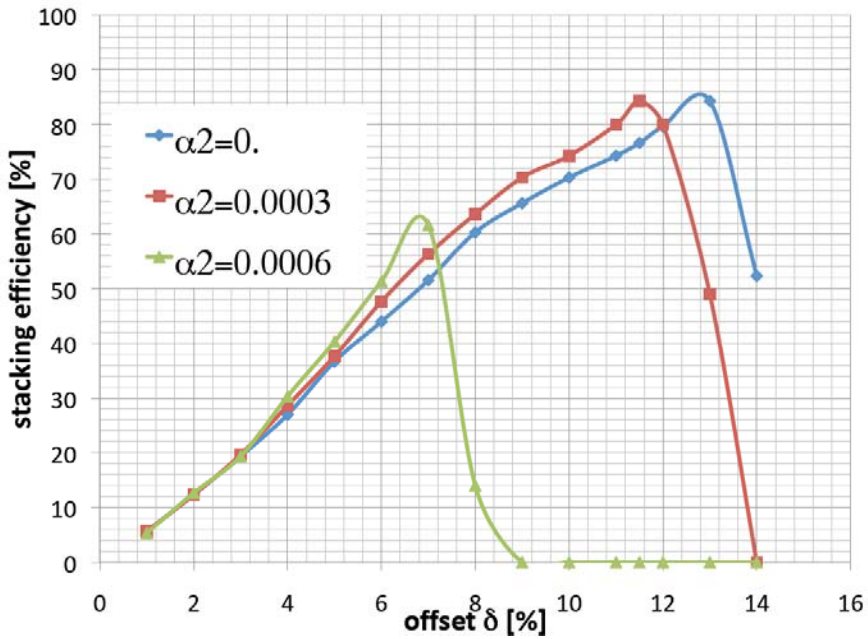
Misalignments, Magnetic field errors, wake fields, RF voltage and phase, synchrotron radiations, beam-gas interaction,…

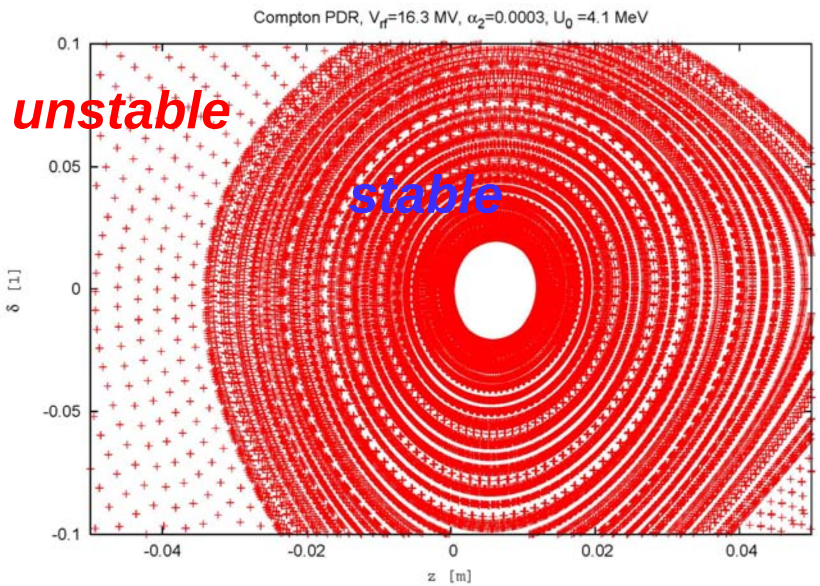
The RTML is not a passive beam transport but an active beam tuning element

Stacking of polarized e+ into the PDR

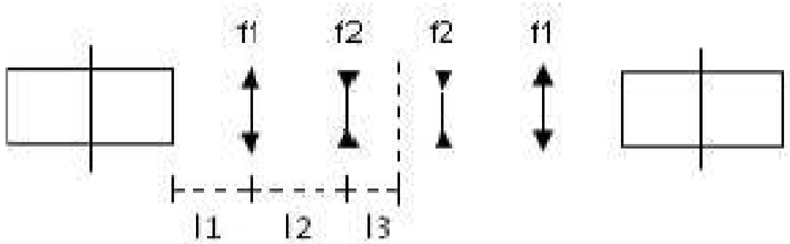
F. Zimmermann / CERN

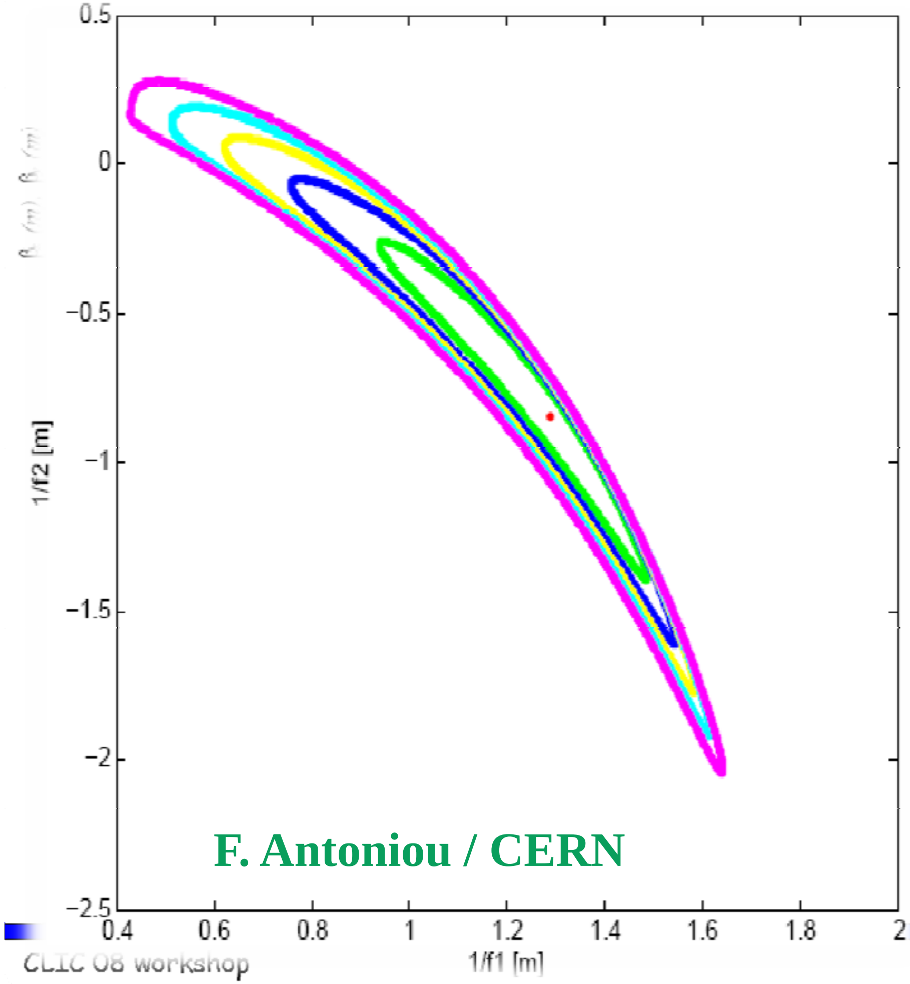
- CLIC Compton source using ERL or CR
- e+ emittance preservation after capture
- CLIC PDR parameters should have a **low** a_2 (4×10^{-4}) and **high** V_{RF} (~16MV)
- 95% efficiency can be achieved with off-momentum off-phase injection
- Needs **10% of momentum acceptance** in PDR (off momentum DA)
- quite some flexibility (# optical cavities vs. e- bunch charge) but a few **challenges** for PDR design



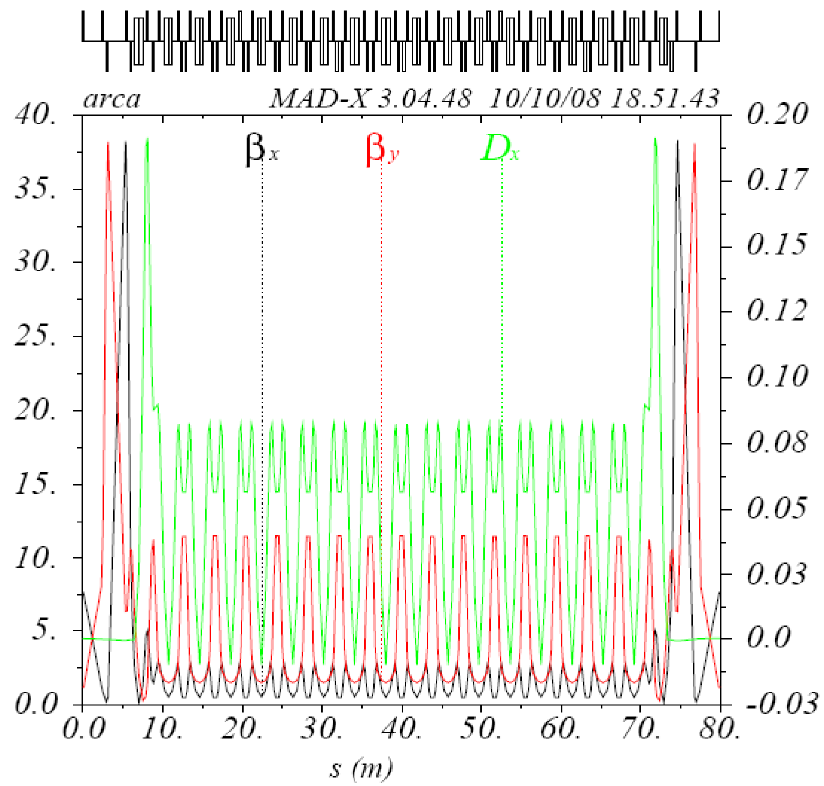


Analytical solution for TME cells





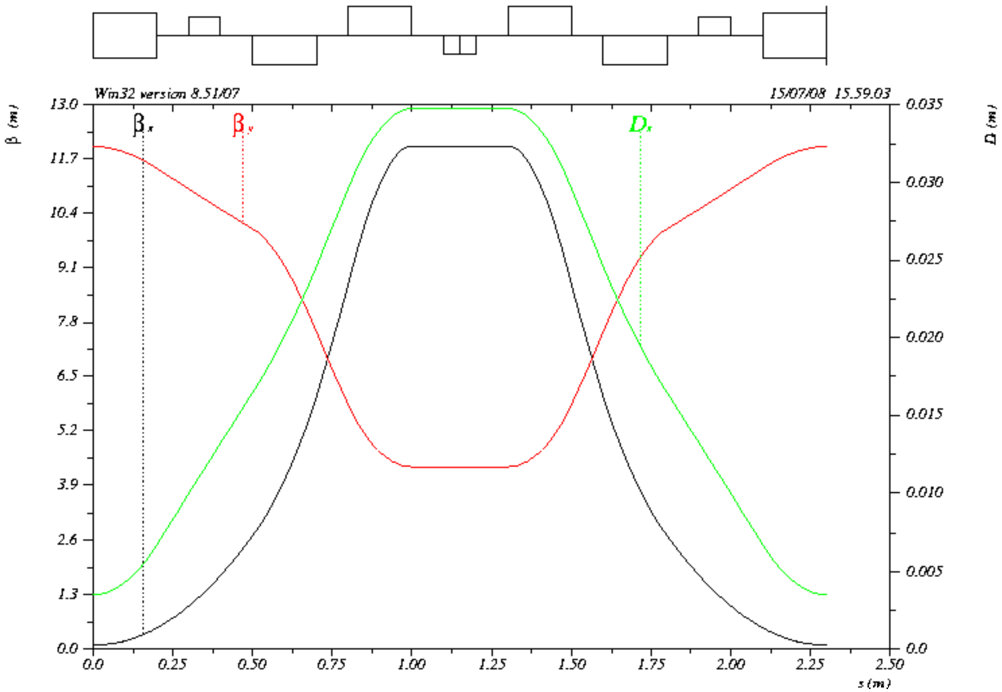
- For general TME cells the focal lengths (under thin lens approximation) can be written as a function of the drifts and the transverse emittance
- Enables optimization of any type of optics parameter
- Guide to design optimal CLIC (P)DRs
- Example: optics design of PDR



New arc cells optics for the Damping rings

K. Zolotarev / BINP

P. Raimondi / LNF

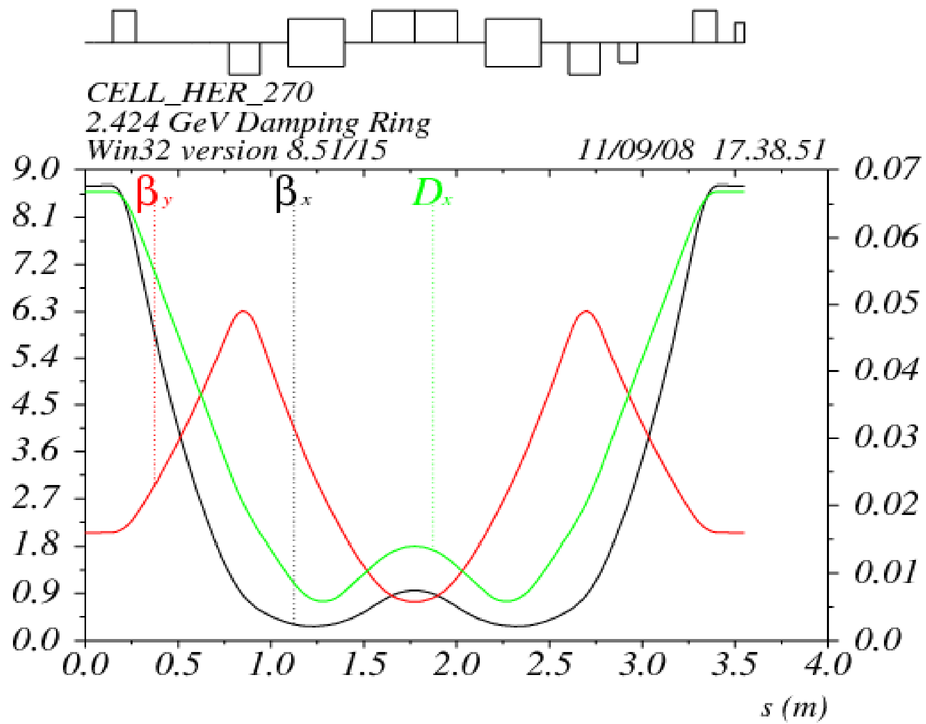


New arc cell design

- Increasing space between magnets, reducing magnet strengths to realistic levels
- Reducing chromaticity, increasing DA
- Even if equilibrium emittance is increased (0current), => IBS dominated emittance stays constant!
- Dipoles have quadrupole gradient (as in ATF!).

Alternative cell based on SUPERB lattice

- Using 2 dipoles per cell with a focusing quadrupole in the middle
- Good optics properties
- To be evaluated for performance when IBS is included



Nb3Sn Wiggler Design

R. Maccaferri / CERN

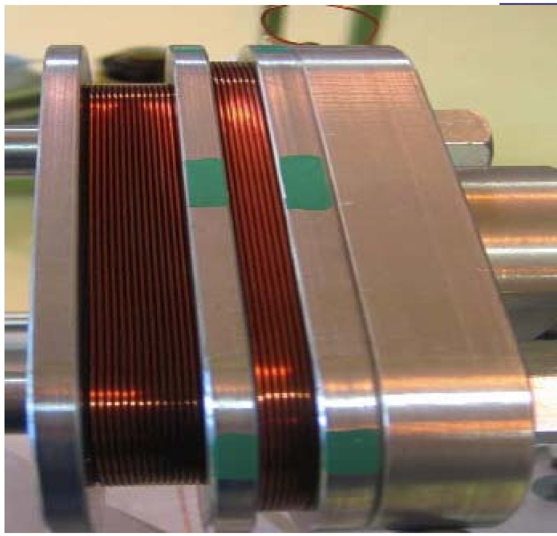
P. Peiffer / ANKA

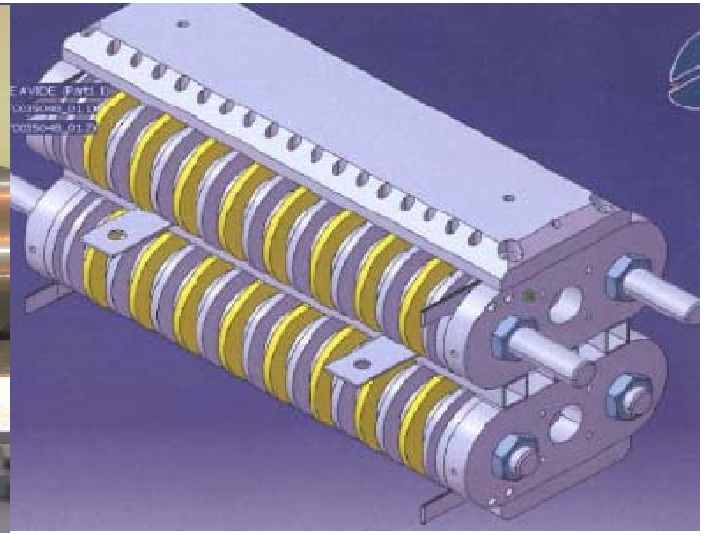
Two models (2.8T, 40mm period)

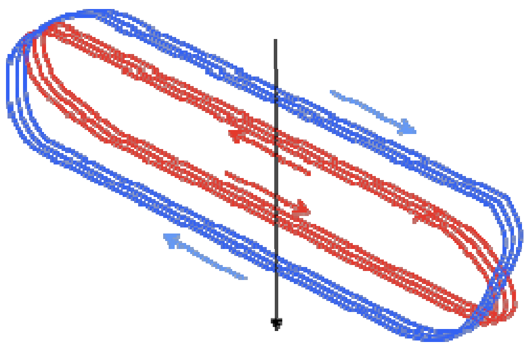
- Vertical racetrack (WR)
- Double helix (WH), can reach 3.2T with Holmium pole tips

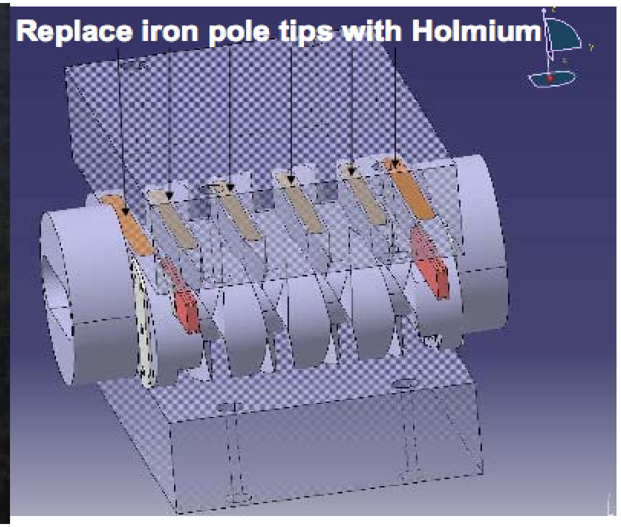
Apart from higher field Nb3Sn can sustain higher heat load (10W/m) than NbTi (1W/m)

Between 2009-2010, two short prototypes will be built, tested at CERN and magnetically measured at ANKA





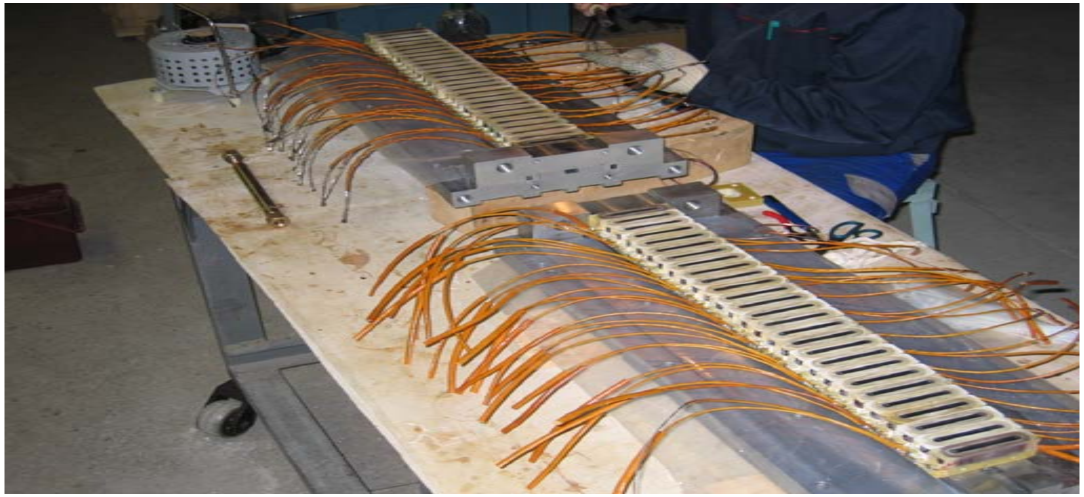




NbTi Wiggler Design

P. Vobbly / BINP

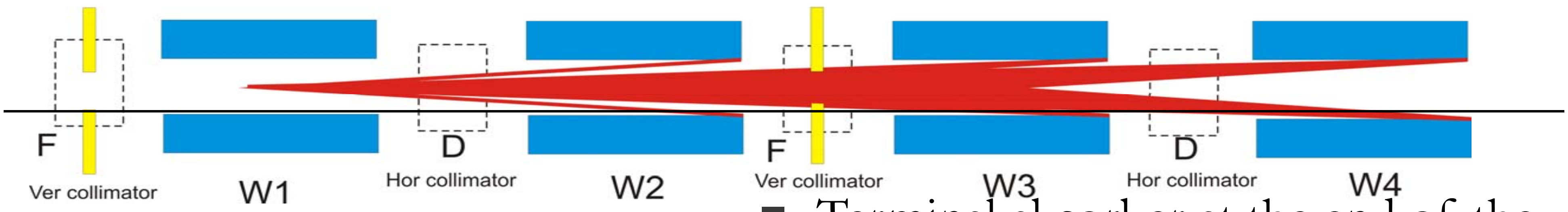
- Present design uses NbTi wet wire in separate poles clamped together (2.5T, 5cm period)
- Performance tests by the end of the year on short prototype
- Magnetic tolerances needed to refine design (e.g. taken from PETRA III wiggler)
- Alternative design allows using Nb3Sn dry wire substantially reducing time and cost



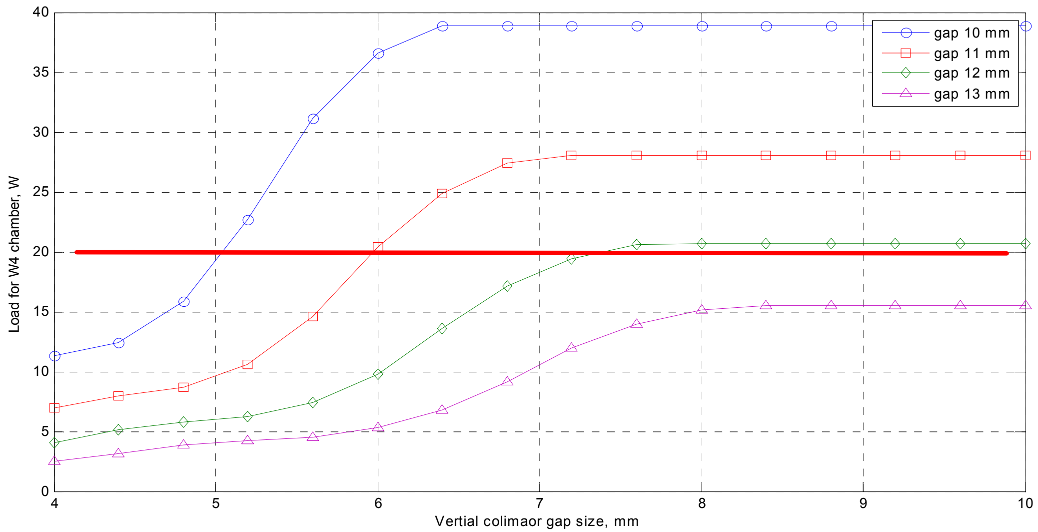
Radiation absorption scheme

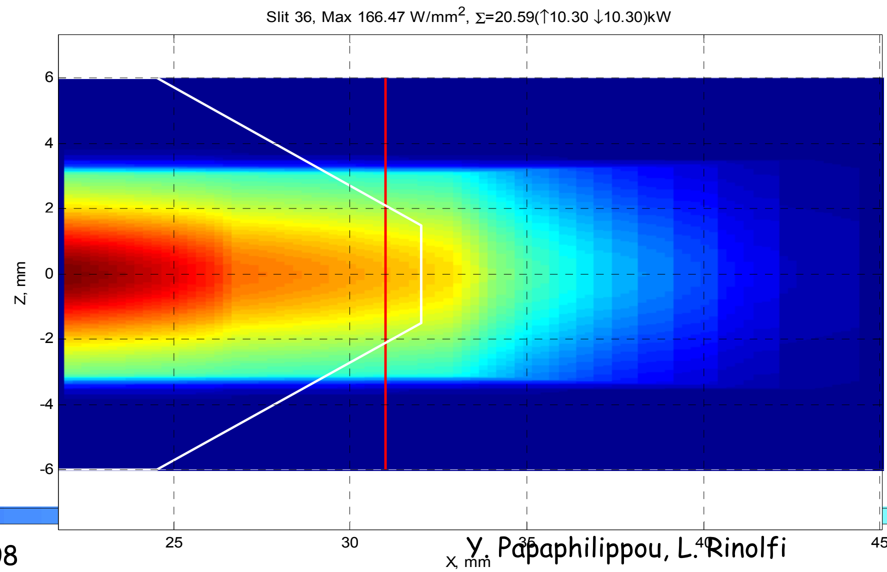
K. Zolotarev / BINP

A 4-wigglers scheme



- Gap of 13mm for NbTi wiggler and 20mm for Nb3Sn design (1W/m) or 13mm (10W/m)
- Terminal absorber at the end of the straight section
- 3D radiation distribution to be used for e-cloud built up
- Impedance estimation



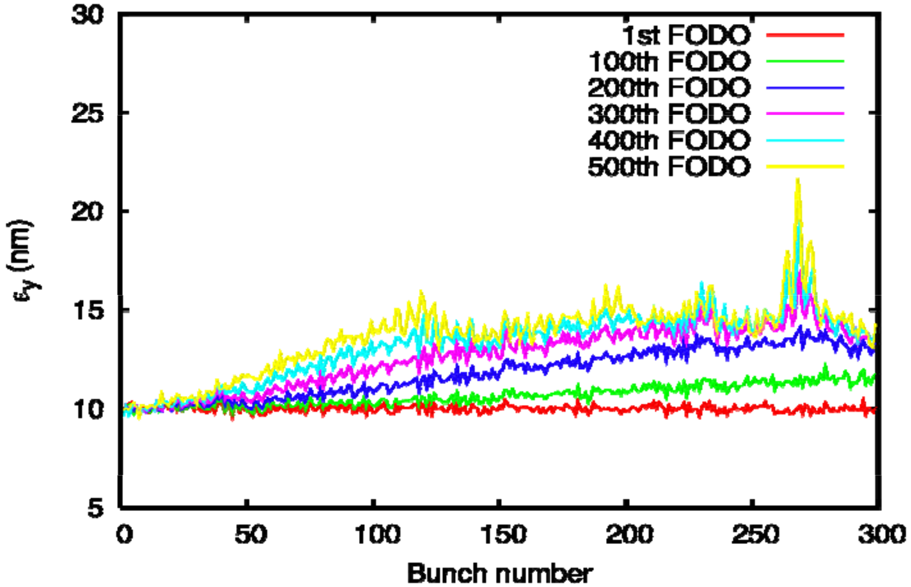


Collective effects in the Injector Complex

G. Rumolo / CERN

- The electron cloud in the e^+ DR impose limits in PEY (99.9% of synchrotron radiation absorbed in the wigglers) and SEY (below 1.3) and can be cured with special **chamber coatings**
- Fast ion instability in :
  - In e^- DR, molecules with A>13 will be trapped (constrains vacuum pressure to around 0.1nTorr)
  - Simulation with ***FASTION*** show fast instability in the transfer line (constrains vacuum pressure again to 0.1nTorr)
- Other collective effects in DR
  - Space charge (large vertical tune spread of 0.188 and 10% emittance growth)
  - Single bunch instabilities avoided with smooth impedance design and resistive wall coupled bunch can be controlled with feedback

Chambers	PEY	SEY	ρ [10^{12} e^-/m^3]
Dipole	0.000576	1.3	0.04
		1.8	2
	0.0576	1.3	7
		1.8	40
Wiggler	0.00109	1.3	0.6
	0.109	1.3	45
		1.5	70
		1.8	80



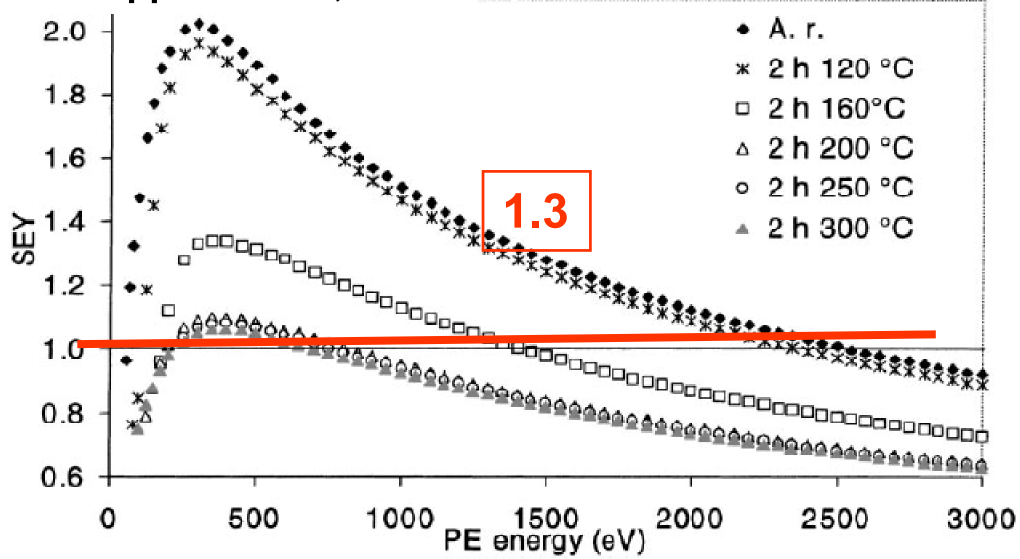
Surface Treatment for e- Cloud Mitigation

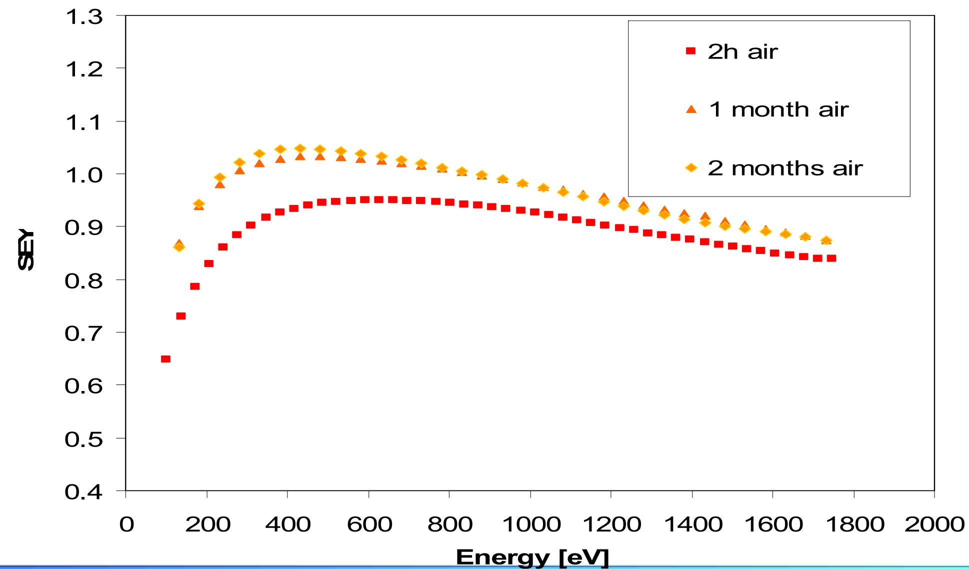
M. Taborelli / CERN

Bakeable system
-NEG gives SEY<1.3 for baking @ > 180C
-the evolution after many venting cycles should be studied
-NEG provides pumping
-it is also conceivable to develop a coating with lower activation T

Non-bakeable system
- a-C coating provides SEY< 1 (2h air exposure), SEY<1.3 (1week air exposure)
-after 2 months exposure in the SPS vacuum or 15 days air exposure no increase of e-cloud activity
-pumpdown curves can be as good as for stainless steel (measurements in progress in lab and ESRF)
-no particles and peel-off
-to be characterized for impedance and PEY

Henrist et al. Appl.Surf.Sci,2001



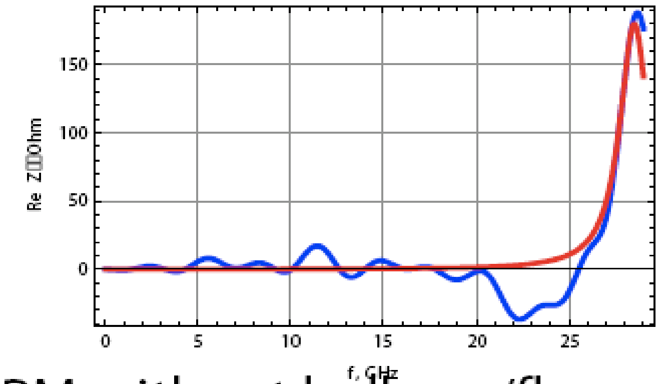


BPMs impedance in ILC DR

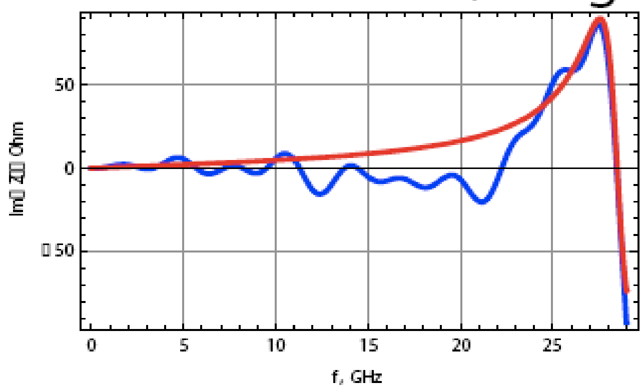
M. Korostelev / CI

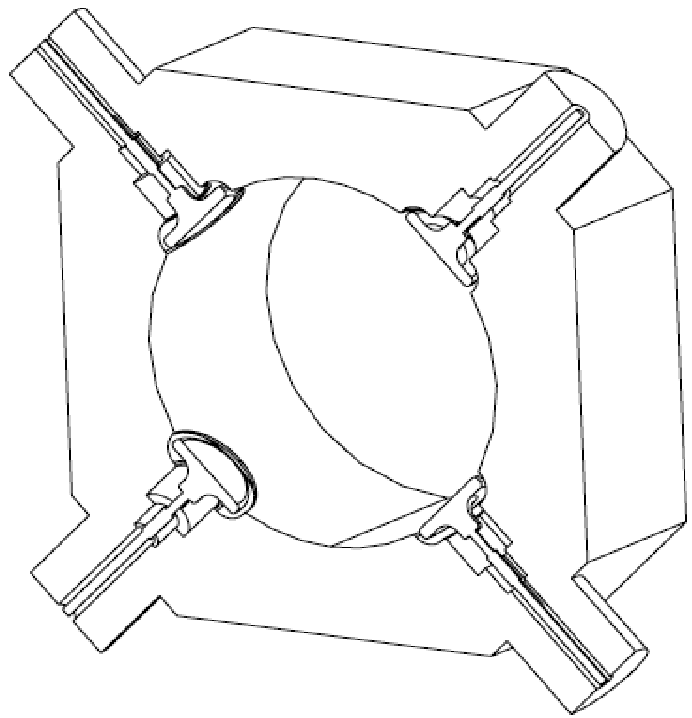
- The Keil-Schnell-Boussard criterion gives an instability threshold of around 170 mW for ILC DR
- Calculated effective impedance from 690 BPMs of around 70 mW;

Rs=180 [Ohm], fr=28.5 [Ghz], Q =15



BPM without bellows/flanges





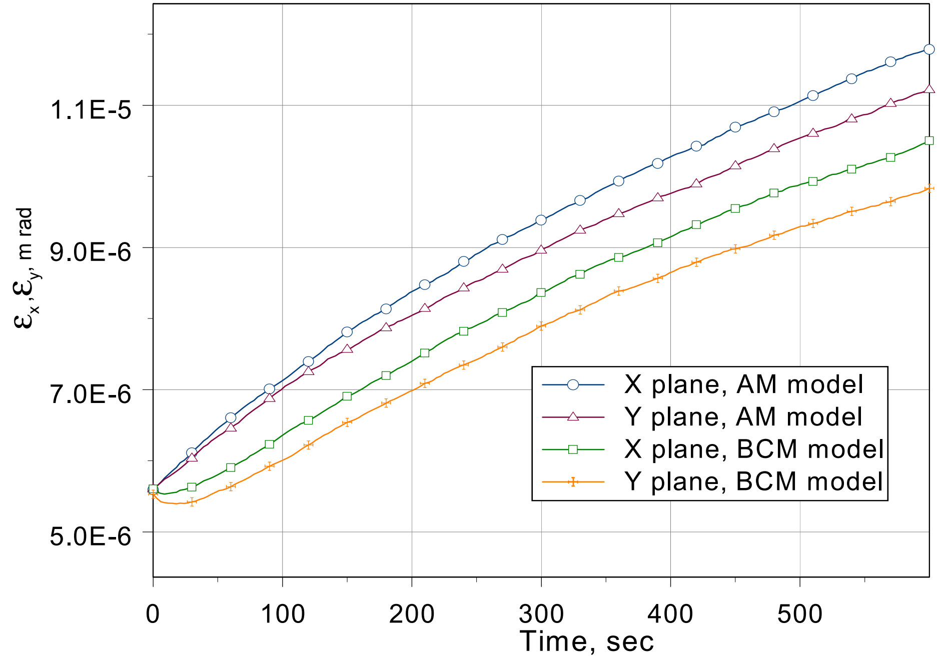
Perturbative approach for analytical computation of wake-fields from moving charge in a circular pipe with planar curvature

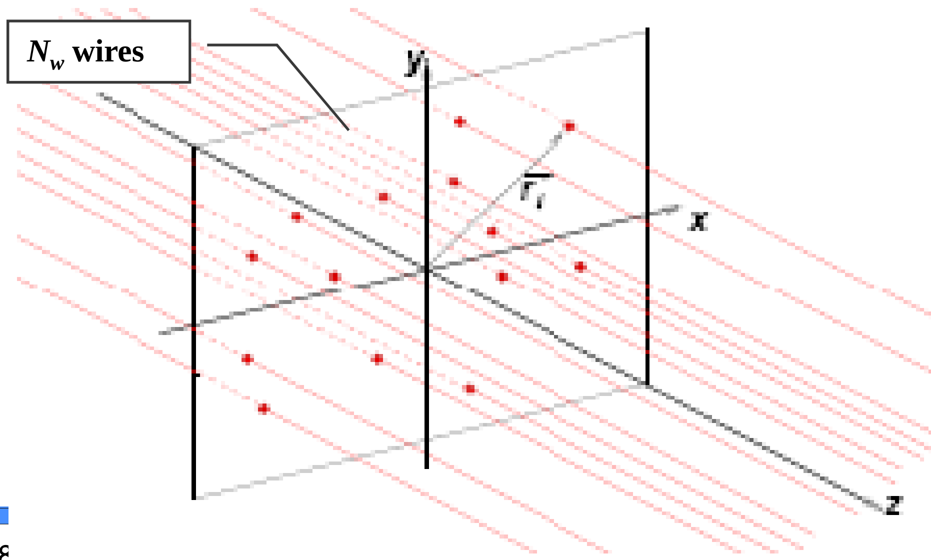
R. Tucker / Lancaster

Intrabeam scattering

M. Martini / CERN

- IBS effect evaluated through semi analytical approach (modified Piwinski or Bjorken-Mtingwa formalism)
  - Derive analytically the optics parameters for reaching minimum IBS dominated emittance in selected lattices (FODO, TME,…)
- Numerical or analytical approach for effect of strong IBS producing non-Gaussian tails including radiation damping is missing
  - Codes for non-Gaussian beams exist (e.g. MOCAC) but not all effects included
  - Use of stochastic diffusion equation approach may be an alternative (presently used for coasting beams)





CLIC DR RF system

A. Grudiev / CERN

1) Main issues:

- Frequency: 2 GHz
- Highest peak and average power
- Very strong beam loading transient effects (beam power of ~5 MW during 156 ns, no beam power during the other 1060 ns)
- Small stored energy at 2 GHz
- High energy loss per turn at relatively low voltage results in big sin $\varphi_s = 0.95$ (any examples of operation ?)
- Wake-fields
- Pulsed heating related problem (fatigue, …)

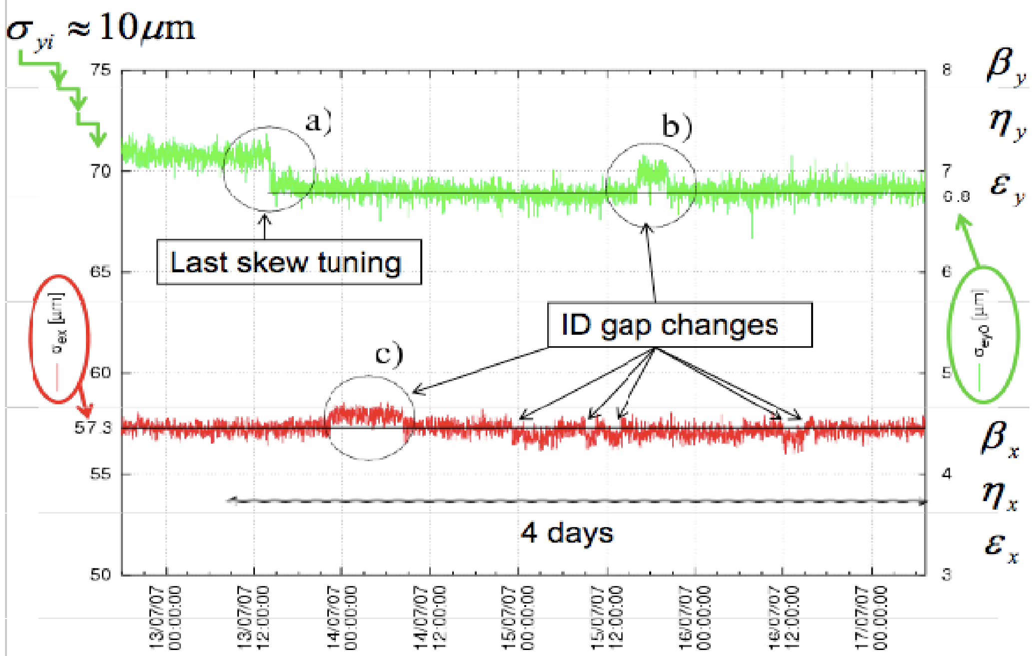
2) Recommendations:

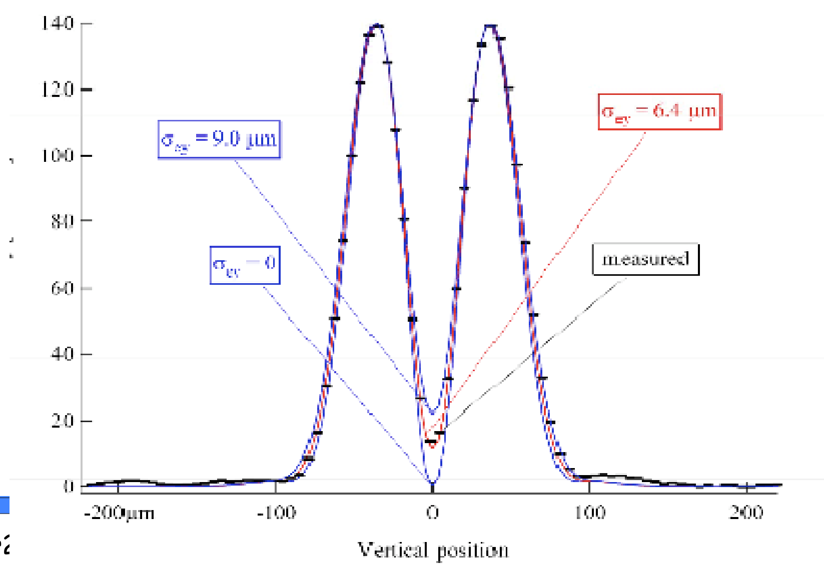
- Reduce energy loss per turn and/or increase RF voltage
- Consider 1GHz frequency (RF system becomes conventional, RF power reduced, but delay loop for recombination is necessary and emittance budget is tight)

Coupling correction and low emittance measurement in SLS

A. Andersson / Lund

1) Achieved 3pm vertical emittance
2) Aggressive program for reaching absolute limit (0.55 pm)
   - Correction of residual dispersion (3mm) induced by sextupole misalignments with skew quads in dispersive regions
3) Beam size measurements using π polarization method
   - Beam image formed by vertically polarized visible-UV synchrotron radiation
   - Beam sizes of a few **microns** can be measured
   - Integration time of a 100-turns limited by response of CCD camera

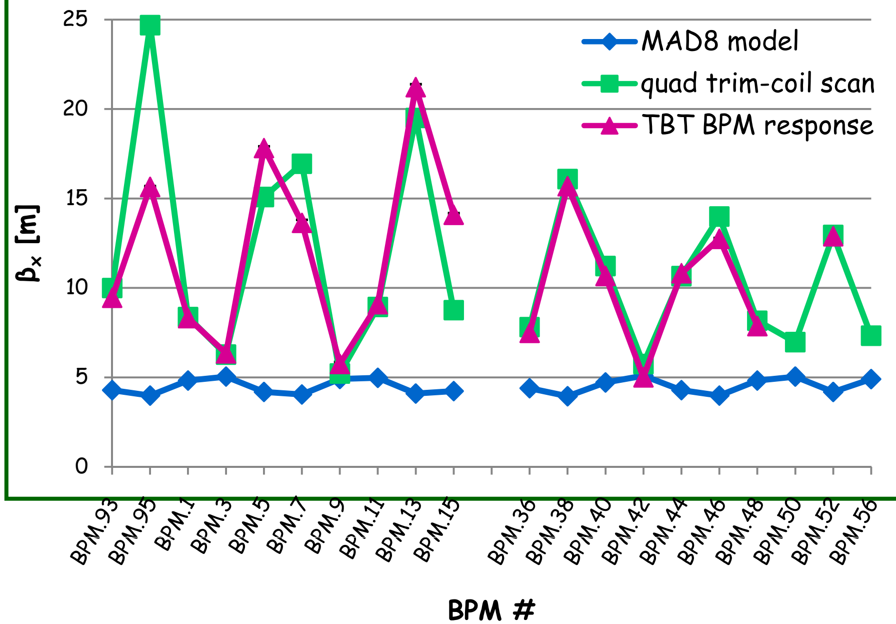




High resolution BPMs for DR

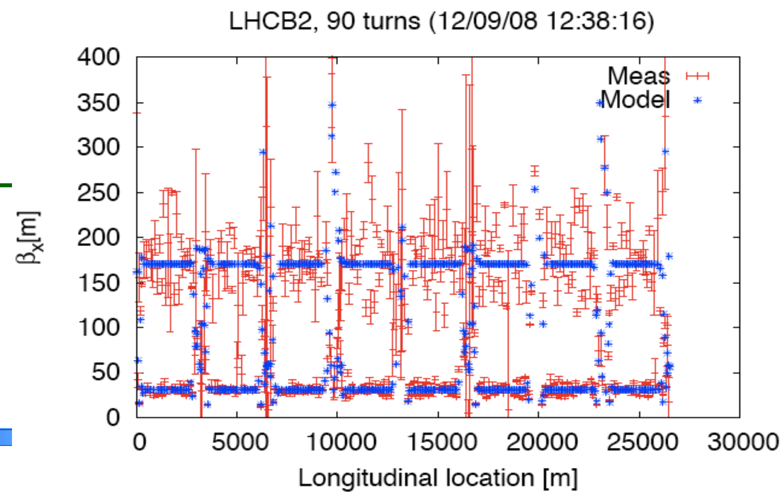
M. Wendt / FNAL

- A DR BPM read-out system with high resolution in TBT (few µm), and narrowband mode (<200 nm) has been implemented in ATF
- 20-out-of 96 ATF DR BPMs have been upgraded, more will follow in FY09/10



R. Tomas/ CERN

- TBT BPM data provides all linear and non-linear information on beam dynamics
- Mature and precise algorithms developed in many accelerators
- First promising tests in ATF2 using only 4 BPMs (in the future take advantage of new many TBT system
- DIAMOND proved non-linear correction using these techniques!



CLIC/ILC DR common issues

S. Guiducci / LNF

- Intense interaction between ILC/CLIC in the community working on the DR crucial issues: ultra low emittance and e-cloud mitigation.
- Common WEBX collaboration meetings already organized for CESRTA, ILC and CLIC DR (inscribe yourself in the mailing list)
- It is very important to strengthen the collaboration and include also other beam dynamics and technical aspects.

	ILC	CLIC
Energy (GeV)	5	2.4
Circumference (m)	6476	365
Bunch number	2700 - 5400	312
N particles/bunch	2×10^{10}	3.7×10^{9}
Damping time τ_x (ms)	21	1.5
Emittance $\gamma\varepsilon_x$ (nm)	4200	381
Emittance $\gamma\varepsilon_x$ (nm)	20	4.1
Momentum compaction	$(1.3 - 2.8) \times 10^{-4}$	0.80^{-4}
Energy loss/turn (MeV)	8.7	3.9
Energy spread	1.3×10^{-3}	1.4×10^{-3}
Bunch length (mm)	9.0 - 6.0	1.53
RF Voltage (MV)	17 - 32	4.1
RF frequency (MHz)	650	2000

Studies &challenges for CLIC Injector Complex

1) Polarized electron source
2) Unpolarized e^+ source based on channeling with hybrid targets (double charge)
3) Capture and acceleration of e^+ at 200 MeV
4) Optimize the preliminary Pre Damping Rings design
5) Review of optics design of the Damping Rings (Dynamic aperture, low emittance tuning,…)
6) IBS effects on beam performance
7) Design of superconducting wigglers
8) Collective effects (e- cloud, FBII, impedances,…)
9) Design the short and long transfer lines optics
10) Design the Compton ring for polarized e^+ (optical cavity, laser system,…)
11) Stacking process into the PDR (+ impacts on pre-injector and injectors linacs)
12) Alternative option based on undulator scheme
13) Polarization studies (measurements, spin rotators, depolarization effects,…)
14) Beam diagnostics (resolution, accuracy, precision,…)
15) Cost estimate (Power consumption, Civil engineering,…)
16) …

Conclusion

1) Enormous progress have been made for the CLIC Main Beam Injector Complex since the last CLIC workshop

2) Two new ILC/CLIC working groups are in place for:

i) Damping Rings

ii) e^+ sources

3) The CLIC Main Beam Injector Complex is considered as a classical ensemble based on conventional technology which should provide the requested beam parameters at the entrance of the Main Linacs (easily):

BUT

a) For the Base Line configuration, crucial studies remain to be performed.

b) For polarized e^+, an intense R&D is necessary.

c) For the 500 GeV option, requesting a double charge per bunch, intense studies are necessary to confirm the feasibility (at lower cost).