Emittance measurement (ILC & CLIC)

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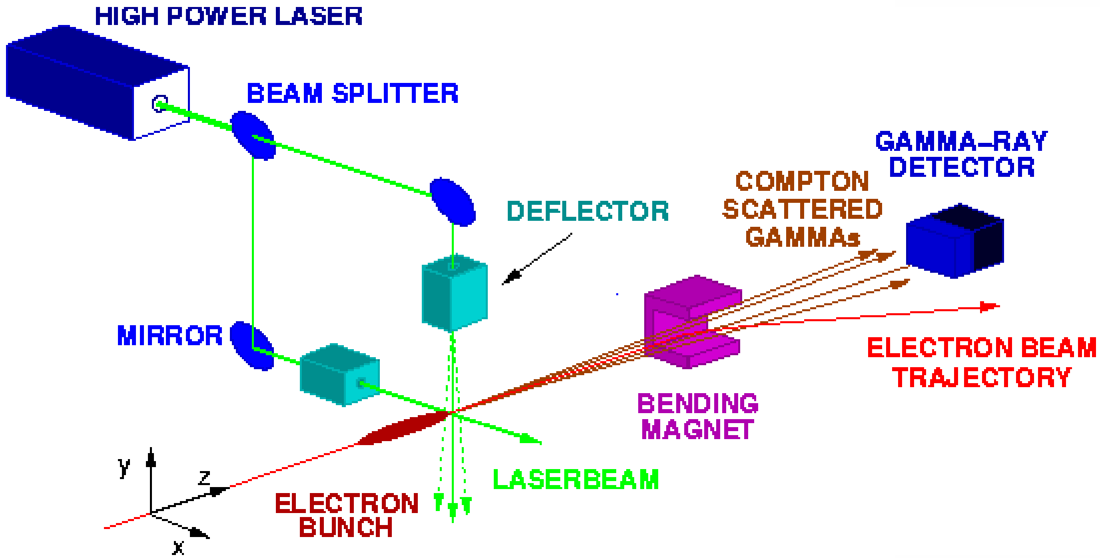
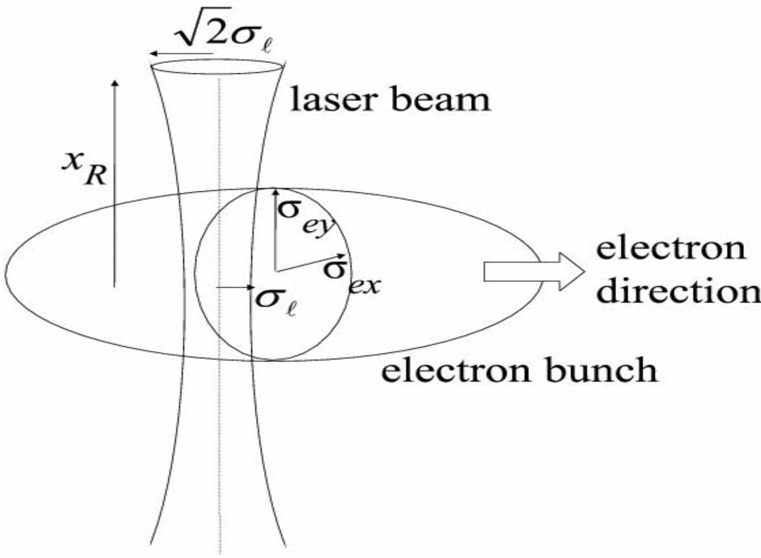
ILC parameters

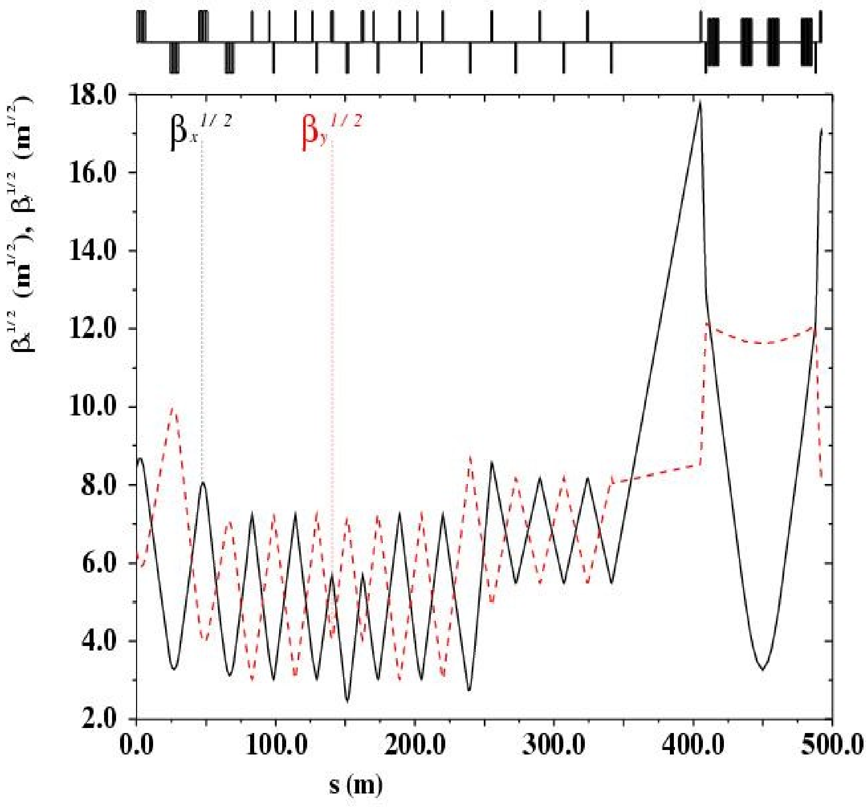
Beam energy	E	250(500)	GeV
Normalised horizontal emittance	$\gamma\epsilon_x$	10^{-5}	m rad
Normalised vertical emittance	$\gamma\epsilon_y$	$4 \cdot 10^{-8}$	m rad
Train repetition rate	f	5	Hz
Number of bunches per train	N_{train}	2625	
Inter-bunch spacing		369	ns
Bunch length	L_b	300	μm
Number of electrons per bunch	N_e	2	$\times 10^{10}$

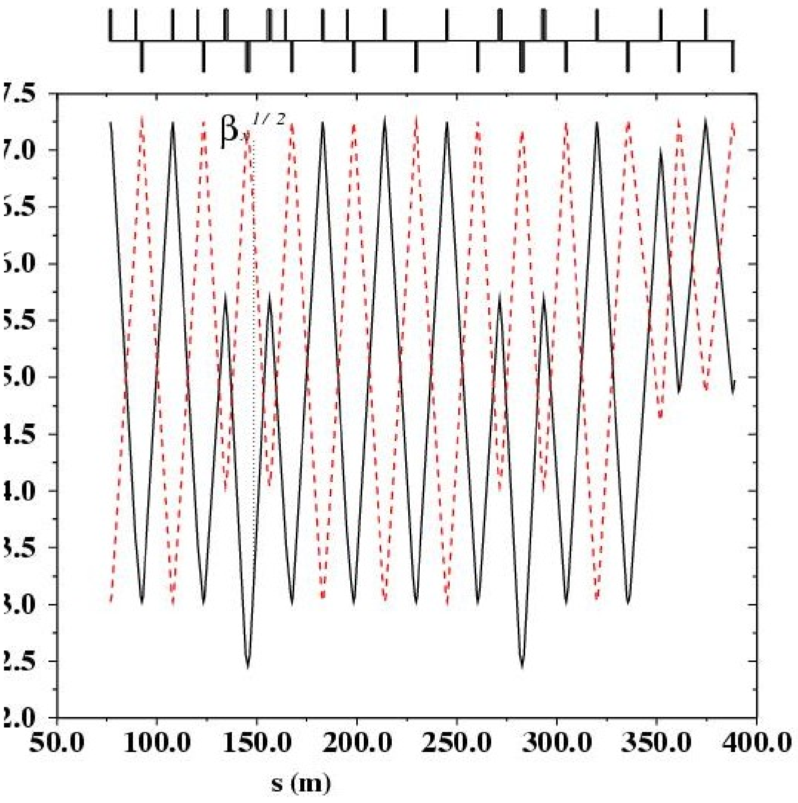
Overview

- Laser wires will be used to measure beam sizes
- Only post-linac diagnostics section considered so far
- Options - 2d (only projected emittance measured) and 4d (full beam matrix measured)
- For details see a paper submitted to prstab

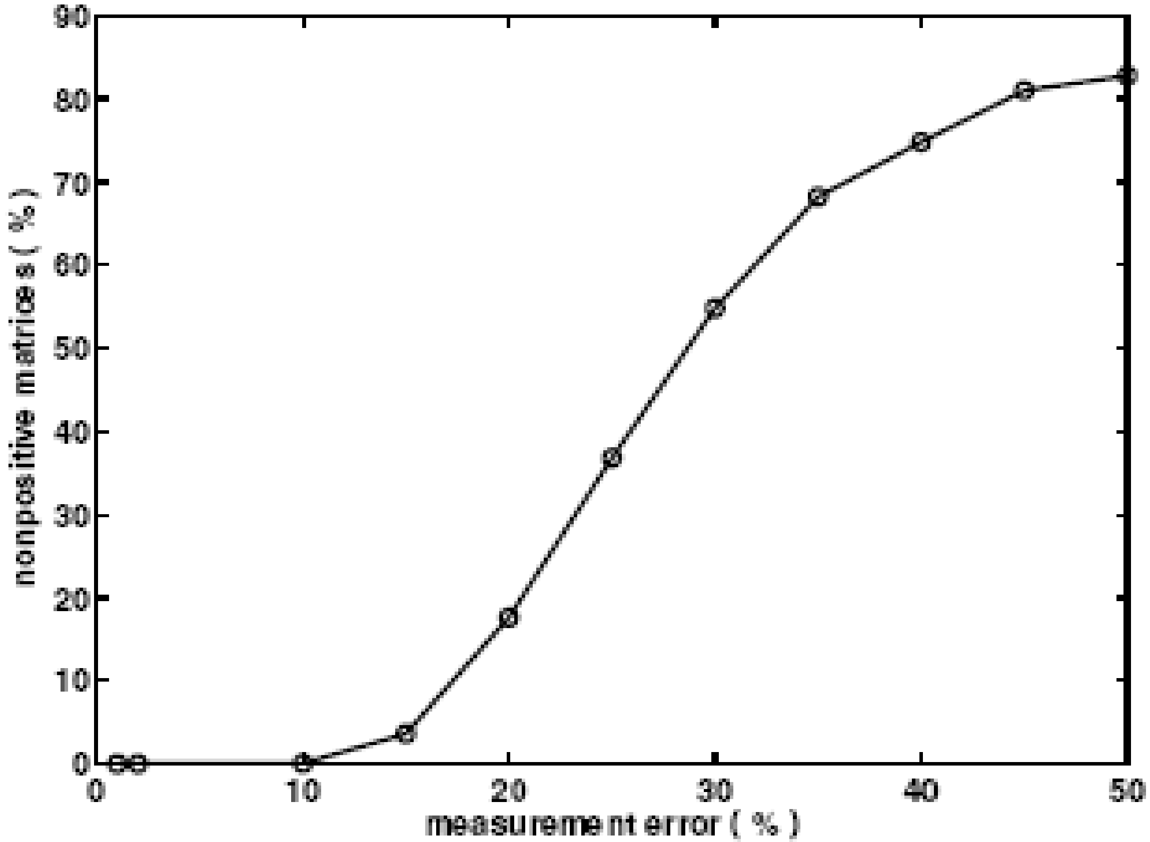




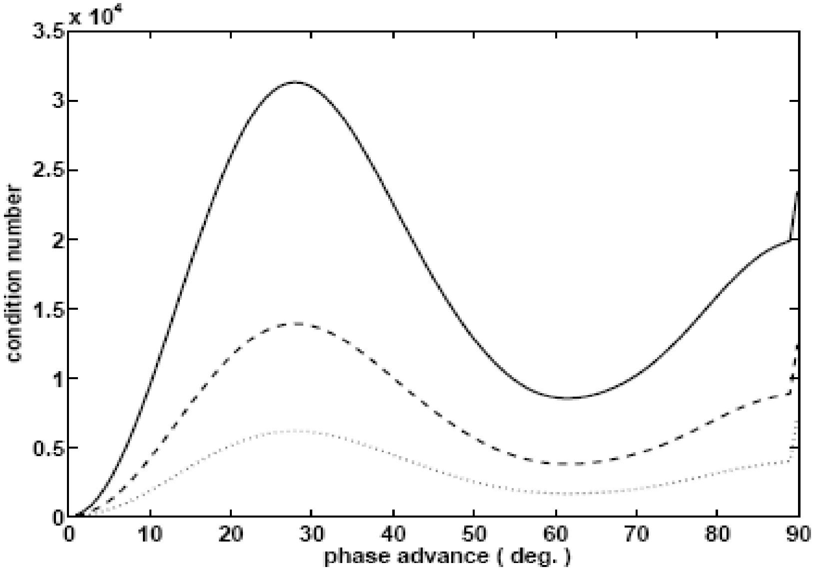


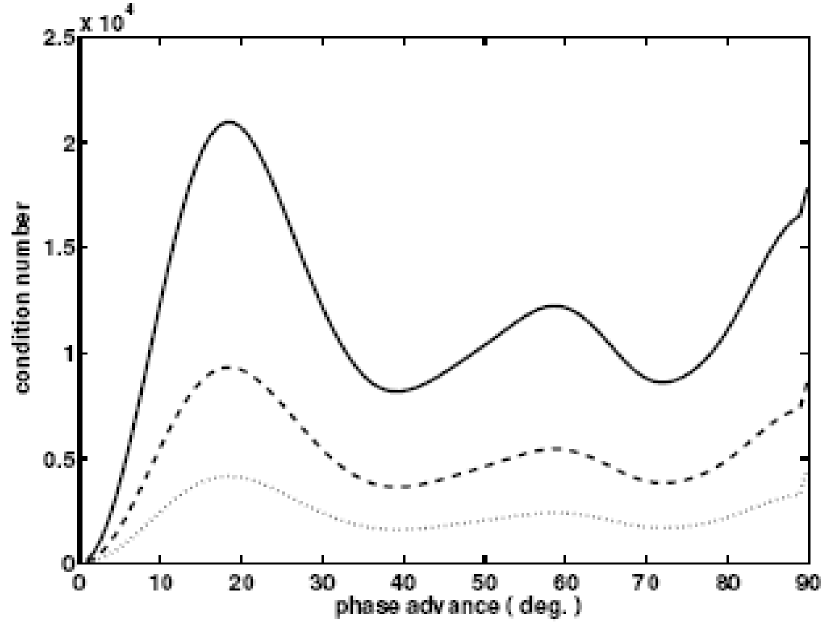


'2d' and '4d' optics for emittance diagnostics section of ILC

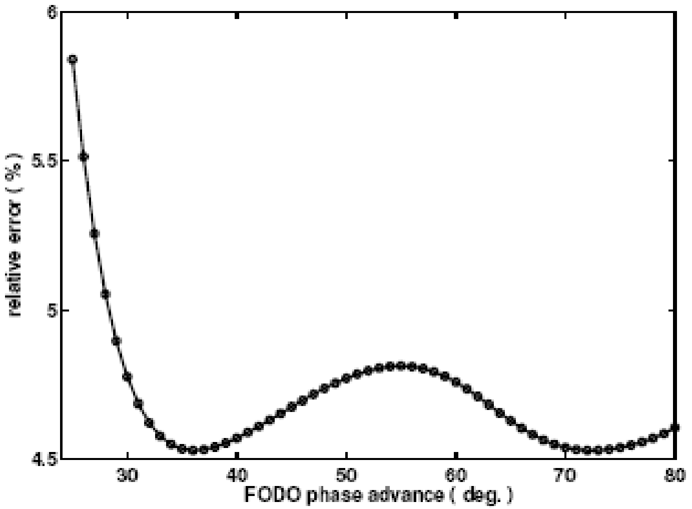


For '2d' measurement emittance reconstruction precision no problem – usual beam matrix fit via least squares ok
For '4d' number of non-positive beam matrices grows fast – Cholesky decomposition with sigma-matrix factorization can be used to improve performance



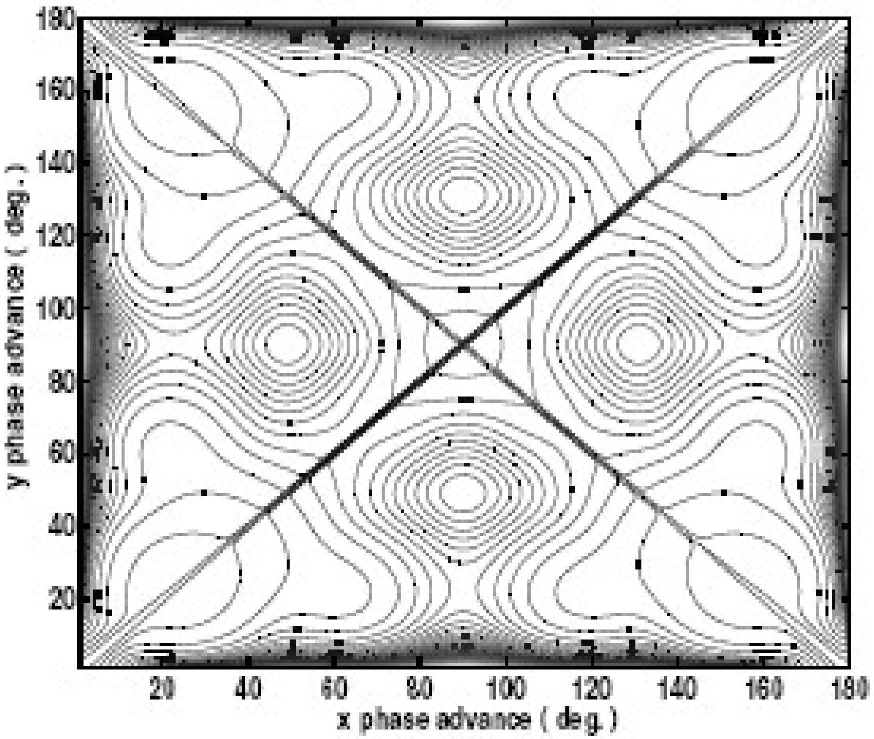


FODO lattice with 5 wire scanners

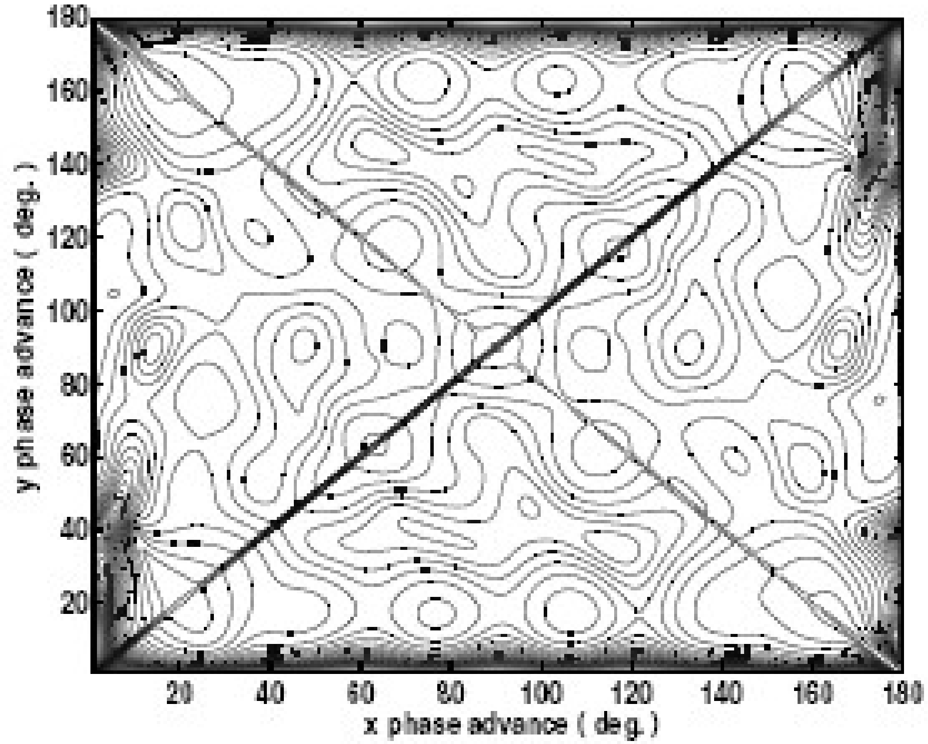


FODO lattice with 4 wire scanners

Condition number of matrix in the fit problem can be used as an optimization criterion for lattice design



FODO lattice with 4 wire scanners



FODO lattice with 5 wire scanners

Condition number can be used for optimization of '4d' optics. With 6 wire stations and more best optics choice obscure

Laser parameters (for more details see G. Blair, this workshop and the paper)

	Symbol	σ_y	σ_u	σ_x
Value (μm)	σ_e	1	1.41	10
Laser Wavelength (nm)	λ	532 (266)	532 (266)	532
Optics f-number	$f_{\#}$	1.5	1.5	1.5
Optics focal length (mm)	F	15	15	70
Pointing Stability ($\times 10^{-3}$)	E_{point}	2.2	1.1	0.5
Beam Jitter ($\times 10^{-3}$)	E_{jitter}	5.0	3.5	0.5
Fit statistics ($\times 10^{-3}$)	E_{stat}	4.3 (4.5)	3.4 (4.2)	4.8
Laser spot-size ($\times 10^{-3}$)	E_{M^2}	10.9 (2.7)	5.4 (1.4)	0.1
Normalisation ($\times 10^{-3}$)	E_{ξ}	0.9 (0.6)	0.7 (0.5)	0.4
Total Error ($\times 10^{-3}$)	$\delta\sigma/\sigma$	13.0 (7.6)	7.5 (5.8)	4.9

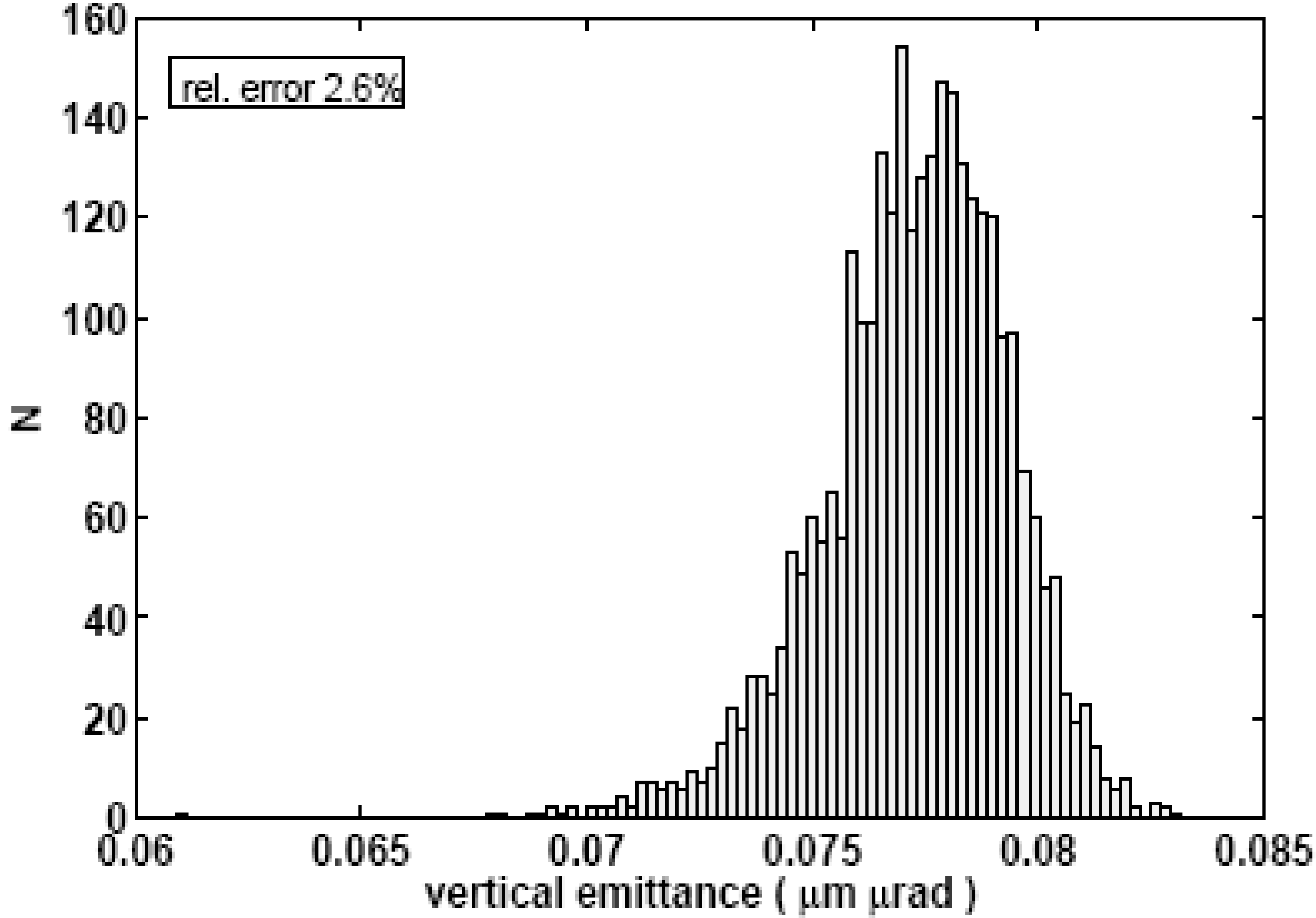
TABLE V: *Requirements on laser-system for intra-train laser-wire scans at the ILC, with reference to the equation that sets the goal value. Note, an extra factor of 2 has been applied to allow a 50% loss of power due to light transport between the laser and the laser-wire IP, which may involve distances of several hundred metres in the ILC*

Parameter	Symbol	Goal Value	Eqn.
Wavelength	λ	≤ 532 nm	(23)
Mode Quality	M^2	≤ 1.3	(23)
Peak Power	P_ℓ	≥ 20 MW	(18)
Average Power	P_ℓ^{av}	≥ 0.5 W	(44)
Pulse Length	T_ℓ	≥ 2 ps	(39)
Trigger Stability	τ_ℓ	≤ 0.3 ps	(39)
Pointing Stability	ψ_ℓ	≤ 10 μrad	(30)

TABLE VI: *The relevant measurables for emittance measurement under the approximation* $\sigma_{xy} \simeq 0$ *for a set of electron beam sizes of interest at the ILC for the given beam energies* E_b. *The quoted precisions for* $\frac{\delta\langle xy\rangle}{\langle xy\rangle}$ *are those obtainable if each of the dimensions* σ_x, σ_y, *and* σ_u *can be measured to 1%. The corresponding precisions for* $\frac{\delta\sigma_x^2}{\sigma_x^2}$ *and* $\frac{\delta\sigma_y^2}{\sigma_y^2}$ *are then both 2%.*

E_b	σ_x	σ_y	ϕ	σ_u	σ_v	precision $(\mu\text{m})^2$		
GeV	μm	μm	deg	μm	μm	$\delta(\sigma_x^2)$	$\delta(\sigma_y^2)$	$\delta\langle xy\rangle$
500	9	1.4	81.2	1.95	8.89	1.62	0.04	0.30
500	15	1.4	84.7	1.97	14.9	4.5	0.039	0.51
250	14	2	81.8	2.8	13.8	3.92	0.08	0.68
250	20	1.8	84.8	2.53	19.9	8.0	0.06	0.88

A typical distribution of emittance measurements



Summary and plans

• ILC – 1-5% emittance measurement can be achieved (see paper)
• For CLIC – more challenging but in principal similar
• Plan N1 – evaluate performance for CLIC parameters (in progress)
• Plan N2 - look at using the emittance measurement for luminosity tuning (almost in progress)