Summary & Discussion
Low emittance design and tuning

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- Common challenges and questions
- Nonlinear dynamics:
  Tools and measurements
- Vertical emittance: common issues

Common challenges

	PDR	DR (CLIC)	DR (ILC)	LS	PF (superB)
Horizontal acceptance	10 mm mrad?	\	10 mm mrad	10 mm mrad	3 mm mrad
in sigma		\	140	300	30
Vertical acceptance	10 mm mrad?	\	10 mm mrad	1 mm mrad	0.2 mm mrad
in sigma		\	2200	300	140
Energy acceptance	3%	<1%	<1%	3..5%	>1%
Current	low	< 0.5 A	0.5 A	~0.5 A	2..3 A
Lifetime	\	\	\	10 hrs	~10 min
Horizontal emittance	~10 nm ?	0.1 nm	0.5 nm	0.1 nm	<3 nm
Vertical emittance	~30 pm ?	0.5 pm	2.0 pm	~10 pm	<10 pm
Energy spread	0.10%	0.10%	0.15%	0.10%	0.10%
Energy	3 GeV	3 GeV	5 GeV	3..6 GeV	3..8 GeV

Injection schemes:	accumulation / septum ⇔ on-axis
Emittance minimization:	arc cells (MBA ⇔ TME ⇔ LGB) ⇔ damping wigglers
Methodology (interplay):	lattice design (linear ⇔ nonlinear) ⇔ collective effects

Nonlinear dynamics

- Code comparison: lessons learned ?
- Catalog of standard measurements
  (taken from Louis Emery / Riccardo Bartolini list)

Energy (spin depolarisation)
Momentum compaction
Dispersion
Natural chromaticity
Nonlinear dispersion
Detuning with momentum
Detuning with amplitude

Apertures (on/off momentum and engineering apertures)
Lifetime
Frequency Maps (x –z and x –dp/p)
Resonance driving terms
Chromatic phase advance
Effect of IDs

  $\Rightarrow$ Possible collaborations ?
- Genetic algorithms....
  – simultaneous linear/nonlinear optimization
- Integrated lattice & collective effect design

Vertical emittance: common issues

- Requirements
  - natural limit (iso-mag.)
  - LS and PF goals: few pm
  - DR: ~ 0.5 pm (CLIC), 2 pm (ILC)

$$\varepsilon_y \approx 0.2\,pm \left\langle \beta_y \right\rangle_{MAG} \Big/ \rho$$

- Measurements
  - pinhole with point-spread functions (Diamond)
  - visual polarized light (SLS)
  - 100 keV profile monitors (ESRF)
- Tuning algorithms
  - optics correction using LOCO
  - optics corrections based on turn by turn data
  - skew quadrupole schemes
  - girder alignment and sextupole centering
- Drifts and long term stability
  - orbit (and other) feedback

Table taken from: Riccardo Bartoloni / Opening session:

"state of the art": lattices with coupling 0.1% and $\varepsilon_y < 5$ pm,

	Model emittance	Measured emittance	β-beating (rms)	Coupling* ($\varepsilon_y/\varepsilon_x$)	Vertical emittance
ALS	6.7 nm	6.7 nm	0.5 %	0.1%	4-7 pm
APS	2.5 nm	2.5 nm	1 %	0.8%	20 pm
ASP	10 nm	10 nm	1 %	0.01%	1 pm
CLS	18 nm	17-19 nm	4.2%	0.2%	36 pm
Diamond	2.74 nm	2.7-2.8 nm	0.4 %	0.08%	2.2 pm
ESRF	4 nm	4 nm	1%	0.25%	10 pm
SLS	5.6 nm	5.4-7 nm	4.5% H; 1.3% V	0.05%	2.8 pm
SOLEIL	3.73 nm	3.70-3.75 nm	0.3 %	0.1%	4 pm
SPEAR3	9.8 nm	9.8 nm	< 1%	0.05%	5 pm
SPring8	3.4 nm	3.2-3.6 nm	1.9% H; 1.5% V	0.2%	6.4 pm