For Draft List of Standard Errors

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What is “standard” errors and for what?

Standard error should be:

- Tolerable, from beam dynamics
- Reasonable, from engineering

Let us (beam dynamics group) make draft list first.

- Tolerance, if we estimated.
- Assumed (commonly used) errors in simulations.
- Can we do this now?
  - Fill tables. (remove ?-marks)
  - Assign people to items which cannot be filled now. ???

- Ask if they are reasonable from engineering point of view (or cost ?)

“Standard” Alignment Error in RTML and ML

Error	Cold Sections	RTML Warm	BDS Warm
Quad Offset	300 μm	150 μm	200 μm
Quad roll	300 μrad	300 μrad	300 μrad
RF Cavity Offset	300 μm	---	---
RF Cavity Pitch	200 μrad	---	---
BPM Offset (initial)	300 μm	200 μm	30? μm (wrt magnet)
Cryomoduloe Offset	200 μm	---	---
Cryomodule Pitch	20 μrad	---	---
Bend offset	---	300 μm	200 μm
Bend Roll	---	300 μrad	300 μrad

Reference for Main Linac:

e.g. by R.Ranjan, report in GDE meeting Vancouver, 2006

Nominal Misalignment tolerances

Tolerance	Vertical (y) plane
BPM Offset w.r.t. Cryomodule	300 μm
Quad offset w.r.t. Cryomodule	300 μm
Quad Rotation w.r.t. Cryomodule	300 μrad
Cavity Offset w.r.t. Cryomodule	300 μm
Cryostat Offset w.r.t. Survey Line	200 μm
Cavity Pitch w.r.t. Cryomodule	300 μrad
Cryostat Pitch w.r.t. Survey Line	20 μrad
BPM Resolution	1.0 μm

Reference for RTML

by J. Smith, report in LET Workshop at SLAC, 2007

Survey Alignment

Our old canonical set, should consider more realistic misalignments...
Survey people would prefer we use cold specs for all components.

Error	Cold Sections	Warm Sections	With Respect To...
Quad Offset	300 µm	150 µm	Cryostat
Quad Tilt	300 µrad	300 µrad	Cryostat
Quad strength	0.25%	0.25%	Design Value
BPM Offset BPM-Quad Shunting	300 µm 20 µm?	200 µm 7 µm	Cryostat/Survey Quadrupole
BPM Resolution	1 µm	1 µm	True Orbit
Bend tilt	300 µm	300 µm	Survey Line
Bend Strength	0.5%	0.5%	
RF Cavity Offset	300 µm	n/a	Cryostat
RF Cavity Pitch	200 µrad	n/a	Cryostat
Cryostat Offset	200 µm	n/a	Survey Line
Cryostatic Pitch	20 µrad	n/a	Survey Line

Refence for RF error: RDR

TABLE 3.9-1
Summary of tolerances for phase and amplitude control. These tolerances limit the average luminosity loss to <2% and limit the increase in RMS center-of-mass energy spread to <10% of the nominal energy spread.

Location	Phase (degree)		Amplitude (%)		limitation
	correlated	uncorr.	correlated	uncorr.	
Bunch Compressor	0.24	0.48	0.5	1.6	timing stability at IP (luminosity)
Main Linac	0.35	5.6	0.07	1.05	energy stability $\leq 0.1\%$

of the vector sum must be calibrated to an accuracy on the order of 1% for amplitude and 1.0° for phase. The phases of crab cavities in the beam delivery system must be stabilized to better than 0.015°. Table 3.9-1 gives an overview of the regulation requirements of the Main Linac and RTML bunch compressor.

Reference for BDS

Error set in BDS simulatio, By Glen White, LET WS at SLAC, 2007

Quad, Sext, Oct x/y transverse alignment	200 um
Quad, Sext, Oct x/y roll alignment	300 urad
Initial BPM-magnet field center alignment	30 um
dB/B for Quad, Sext, Octs	1e-4
Mover resolution (x & y)	50 nm
BPM resolutions (Quads)	1 um
BPM resolutions (Sexts, Octs)	100 nm
Power supply resolution	14 - bit
FCMS (Final CryoModule System): Assembly alignment	200 um / 300urad
FCMS: Relative internal magnet alignment	10um / 100 urad
FCMS: BPM-magnet initial alignment (i.e. BPM-FCMS Sext field centers)	30 um
FCMS: Oct – Sext co-wound field center relative offsets and rotations	10um / 100urad
Corrector magnet field stability (x & y)	0.1 %
Luminosity (pairs measurement or x/y IP sigma measurements)	1%

“Standard” Magnet Strength fixed Error

	Cold Sections	RTML Warm	BDS
Quad	0.25%	0.25%	1 E-4
Bend Strength	---	0.25%	1E-4
Corrector	?	?	?
Sext.	---	---	1E-4
Oct.	---	---	1E-4

It is not clear what determines these tolerances.

Mechanical fast movement (vibration)

	Cold Sections	RTML Warm	BDS Warm
Quad, Sext.	100 nm	30 nm ?	30 nm ?

Tolerance will be determined by orbit change at IP.
Also should be looked:
RTML: emittance dilution in the turn-around (note that it is before the feed-forward)
ML: Orbit change at linac end (assuming post linac orbit feedback or not ?)
BDS: ???

“Standard” Magnet Strength Stability Requirement
Magnet to magnet independent, random

	Cold Sections	RTML Warm	BDS Warm
Quad	1E-4	1E-5 ?	1E-5
Bend Strength	---	1E-5 ?	1E-5 ?
Corrector	5E-4	1E-3 ?	1E-3
Sext.	---	---	1E-5
Oct.	---	---	1E-5

Tolerance will be determined by orbit change at IP.
Also should be looked:
RTML: emittance dilution in the turn-around (note that it is before the feed-forward)
ML: Orbit change at linac end (assuming post linac orbit feedback or not ?)
BDS:

Appendix: Main Linac Quad vibration and Quad, corrector strength jitter

Orbit angle change by vibration δx
$\sim K1 * \delta x$

Orbit angle change by strength jitter of quad $\delta B/B$
$\sim K1 * \Delta x * \delta B/B$
(Δx: beam offset at quad ~ quad misalignment)
→ Tolerance of $\delta B/B$ ~ Tolerance of $\delta x / \Delta x$
~ 100 nm / 300 um ~ 3E-4

Orbit angle change by strength jitter of vertical corrector $\delta B/B$
$\sim \theta * \delta B/B$
(θ: Kick angle ~ angle following the earth curvature ~ 6 urad
or angle for correcting misalignment ~ Δx / 40 m ~ 7.5 urad)
→ Tolerance of $\delta B/B$ ~ Tolerance of $K1 * \delta x / \theta$
~ 0.04 m^{-1} * 100 nm / 7.5 urad ~ 5E-4

“Standard” RF dynamic errors

	Amplitude	Phase
BC Correlated	0.5%	0.24 deg.
Uncorelated	1.6%	0.48 deg.
ML Correlated	0.07%	0.35 deg
Uncorelated	1.05%	5.6 deg
Crab e+e- Relative		0.015 deg

from RDR

Corelated :same for all klystrons
Uncorelated : klystron to klystron independent, random

What determines the tolerance?
BC: Timing at IP
ML: Energy jitter at the end.
Crab: Horizontal offset at IP

Beam energy error in Main Linac

What determines the energy error?

A) Calculate energy from cavity voltages?

→ RF cavity voltage error

B) Measure energy using dipole correctors and BPM?

→ Strength error of corrector magnet and BPM scale error

What is affected by the energy error?

- Response to correctors can be calibrated.
  - Ratio, corrector strength / beam energy is relevant ?

“Standard” error of beam monitors

	Cold Sections	RTML Warm	BDS
BPM Resolution	1 μm	1 μm	0.1 μm
BPM Scale error	2%	2% ?	2% ?
Beam size monitor resolution	1 μm ?		
Luminosity monitor	---		1%

“Standard” Survey Line Error

Error	Step length = L1	Step length = L2	
Random angle / step			
Random offset / step			
Systematic angle (common for all steps)			
Systematic offset (common for all steps)			
Initial angle			
Offset of Primary References			