Voltage and Harmonic Requirements

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BE-RF-BR

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Contents

Parameter Space

Beam Types

Roughly grouped into “High Brightness”, “High Intensity”, and “Other”

High Brightness	*High Intensity*	*Other*
LHC25	ISOLDE	LHCINDIV
BCMS	MTE	LHCPROBE

Example Beams

LHC25

- Minimise space charge effects at injection
- Large longitudinal emittance at extraction

ISOLDE

- Maximum intensity
- Moderate emittance

LHCINDIV

- Small well controlled longitudinal emittance
- Low intensity

MTE

- High intensity
- Minimise space charge
- Bunch splitting before extraction

"Easy" Beams

LHCINDIV

- Low intensity ∴ no intensity effects
- Low emittance (longitudinal) ∴ no acceptance problem
- Single harmonic ∴ no relative phase requirements
- Might need longitudinal shaving so requires high harmonic (or equivalent)

ISOLDE

- Low energy ∴ lower $\dot{B}$
- Relaxed longitudinal parameters ∴ uncontrolled blow-up more tolerable
- Double harmonic desirable

Not "Easy" Beams

LHC25

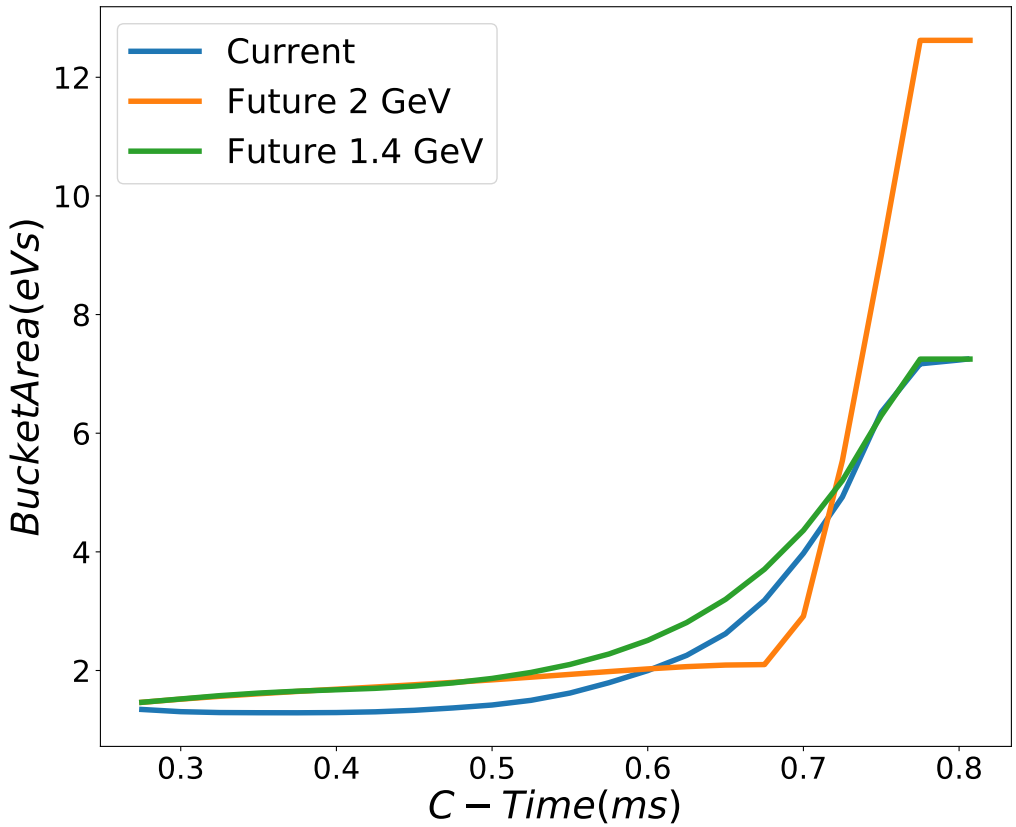
- Moderate intensity ∴ some intensity effects
- Requires longitudinal blow-up ∴ needs high harmonic (or equivalent) and sufficient bucket area
- High brightness ∴ needs double harmonic
- Strict longitudinal requirements

MTE

- High intensity ∴ large intensity effects
- h=2 extraction ∴ needs RF gymnastics and double harmonic
- Minimum ε_V required ∴ better with double harmonic

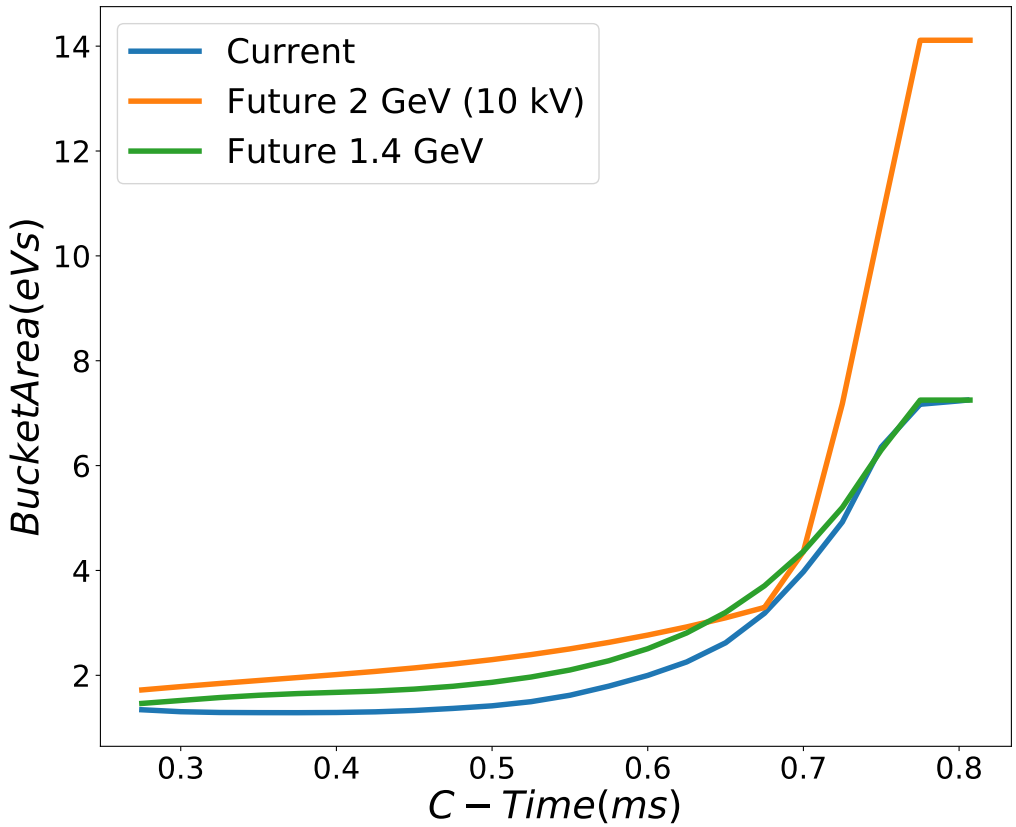
Split Voltage Problem

Acceptance Comparison



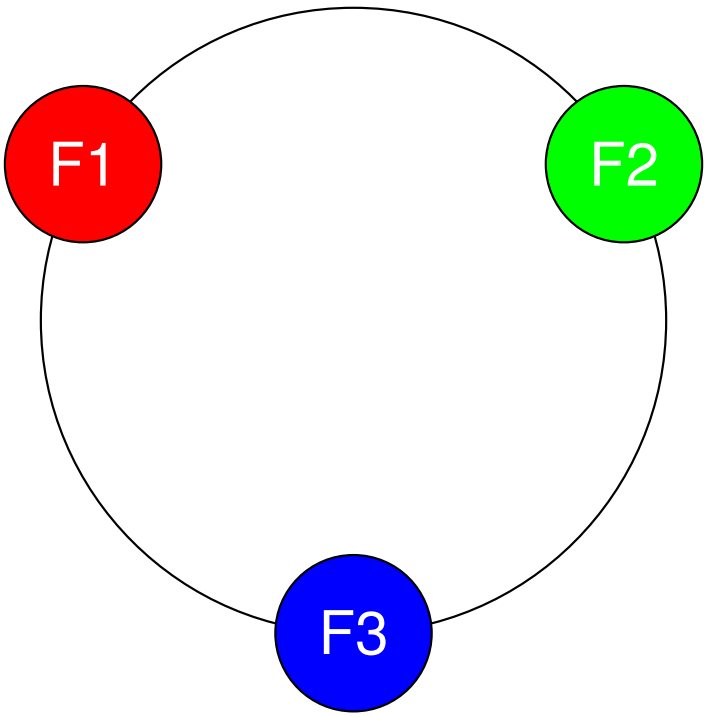
- Future 1.4 GeV “better” than current ramp with 8 kV
- Future 2 GeV low acceptance until nearly C700, ok for INDIV type but might be difficult for gymnastics and blow-up

Acceptance Comparison 2



- 10 kV sufficient to keep 2 GeV cycle bucket area above current level throughout the cycle

Three Finemet cavities



RF phase φ_{RF} in cavity given by:

$\varphi_{RF} = D\omega_{RF} + \varphi_A$

- Dispersion in RF system (D)
- Azimuthal position (φ_A)

Correction can be applied:

$\Delta\varphi_{RF} = \omega_{RF} dt + \Delta\varphi$

- Time delay (dt)
- Phase correction ($\Delta\varphi$)

dt and $\Delta\varphi$ must be known

Taking two cavities and calculate result seen by the beam:

$$V_1 = A_1 sin(\omega t + \varphi_1)$$
$$V_2 = A_2 sin(\omega t + \varphi_2)$$
$$V_3 = A_3 sin(\omega t + \varphi_3) = A_1 sin(\omega t + \varphi_1) + A_2 sin(\omega t + \varphi_2)$$

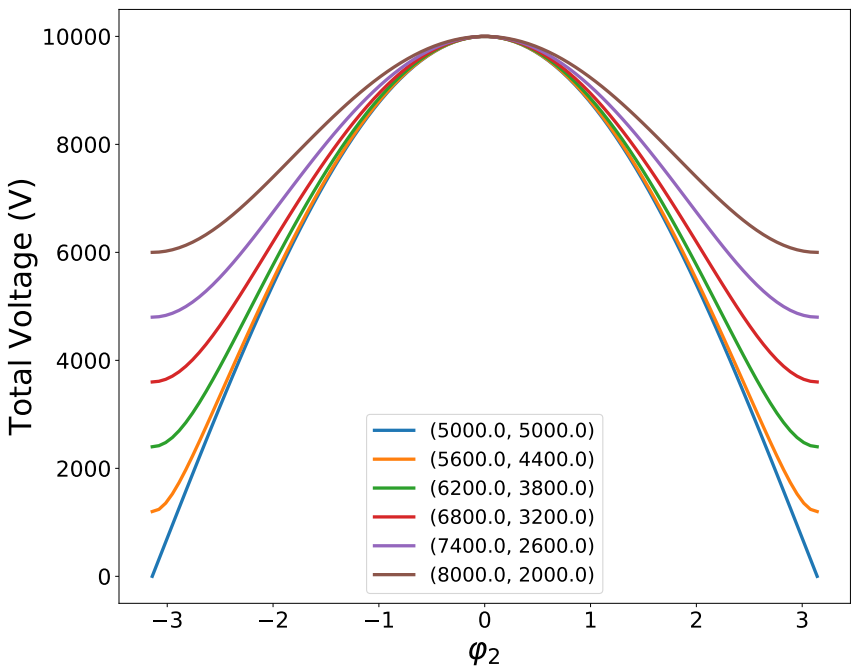
A little jigger pokery (and assuming $\varphi_1 = 0$) and we get:

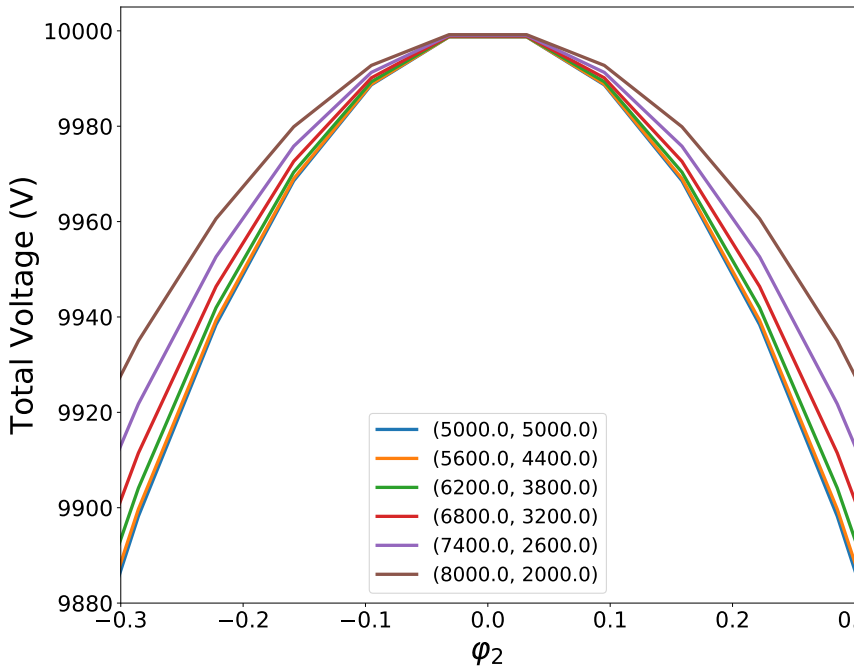
$$A_3 = \left[A_1^2 + A_2^2 + 2A_1 A_2 cos(\varphi_2)\right]^{\frac{1}{2}}$$
$$tan(\varphi_3) = \frac{A_2 sin(\varphi_2)}{A_1 + A_2 cos(\varphi_2)}$$

Also useful to have:

$$\Delta\varphi_s = sin^{-1}\left(\frac{\Delta E}{A_1}\right) - sin^{-1}\left(\frac{\Delta E}{A_3}\right) + \varphi_3$$

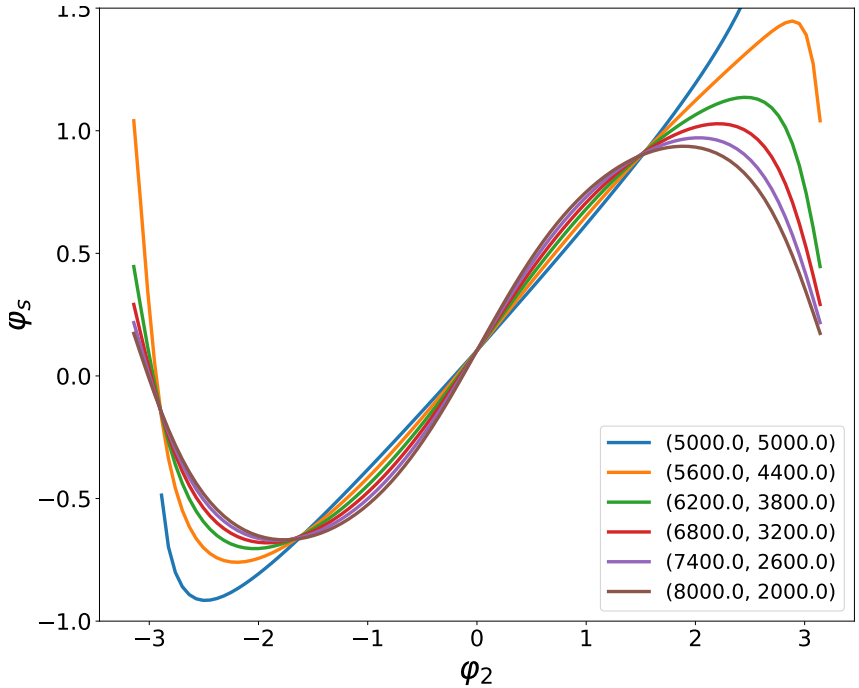
Splitting 10 kV (Amplitude)

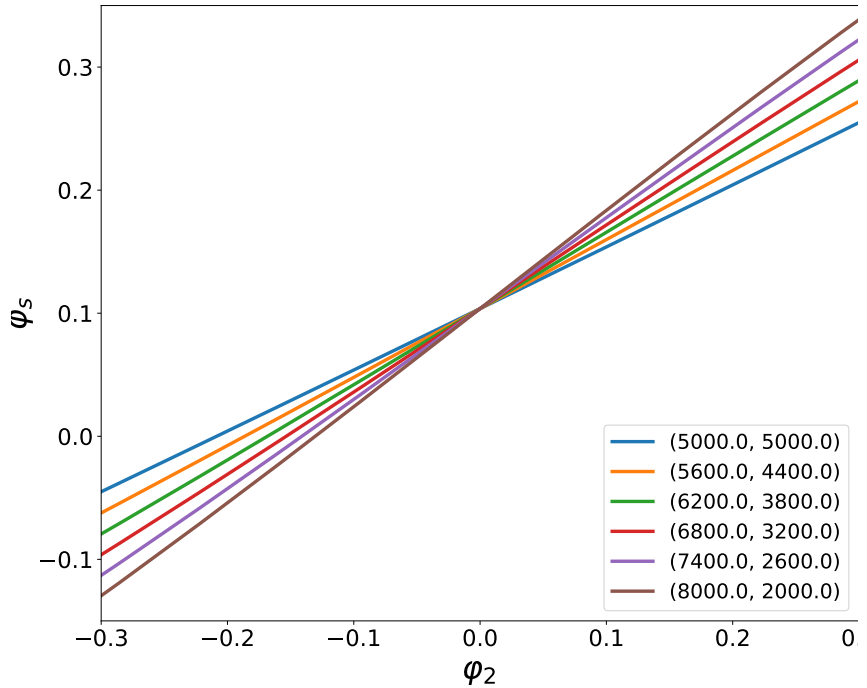




- Assume $\varphi_1 = 0$ (reference cavity), scan φ_2 and split voltge across cavities in different ratios
- 50:50 split and 0.3^c (17 degrees) phase offset beam still sees 9.9 kV (99%)

Splitting 10 kV ($\Delta\varphi_s$)





- Synchronous phase much less forgiving than total voltage
- Operationally almost transparent sensitive beams (e.g. MTE at splitting) would need $h_1 : h_2$ phase function correcting if voltage distribution changed
- "Detailed" work like accurate relative phasing in tomography would require phase offsets re-measuring

Proposed Restart Functionality

Simplest Restart Proposal

F1	F2	F3
Master h=1	Master h=2	Extra h=1 h=8

RESULTING FUNCTIONALITY:

- Capture up to 14 kV (h=1) + 7kV (h=2)
- Use “spare” h=1 voltage for blow-up e.g. 12 kV (h=1) + 2 kV (h=2)
- Splitting possible for MTE type at similar time scale to now

Sparkly Restart Proposal

F1	F2	F3
Master h=1	Master h=2	Master h=3
	h=8	Extra h=1
		Extra h=2

RESULTING FUNCTIONALITY:

- Blow-up in single or double harmonic, enables large h=1 buckets for blow-up
- More h=2 voltage e.g. for capture in h=2
- Third harmonic for bunch flattening at capture