Beam BreakUp at Daresbury

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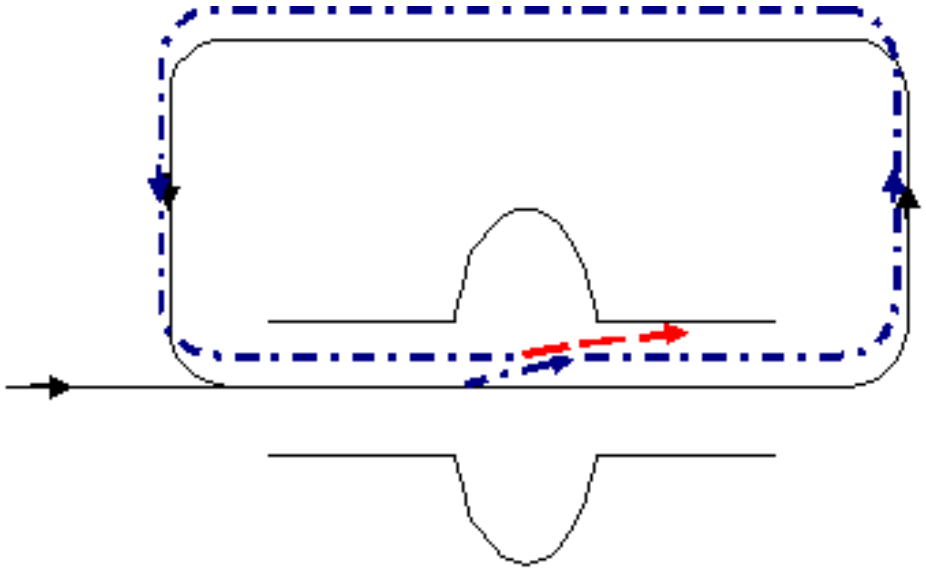
Outline

- The causes of Beam Breakup (BBU)
- Types of BBU
- Why investigate BBU?
- Possible solutions

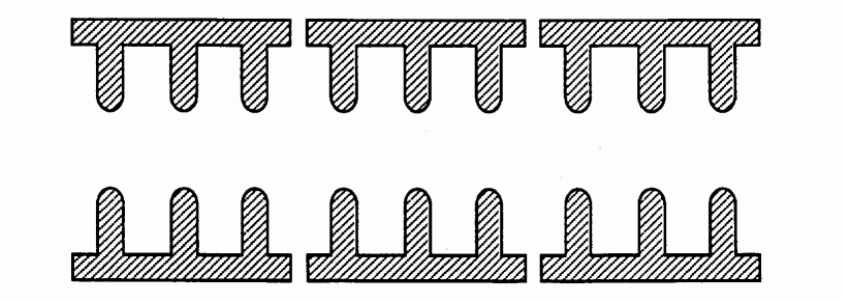
Causes of BBU

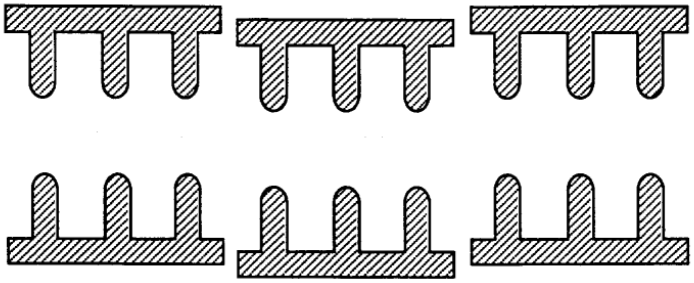


- There are four main causes.
  - Interaction with HOM/wakefield
  - Injection off-axis
  - Cavity or magnet misalignment
  - Noise

Types Of BBU

- Single bunch
  - 'Banana' beams
  - Cured by BNS damping - increased focusing at the tail of the bunch
  - Beam based alignment
- Multipass – Of concern in syncrotrons
- Multibunch – Of concern in linacs





Multibunch

- Transverse and Longitudinal
- Two forms:
  - Regenerative
  - Cumulative
- The beam feeds the HOMs and is kicked by the HOMs of the previous bunch(es)
- In the longitudinal case this can cause displacement and loss of energy
- In the transverse case it can cause beam loss

Multibunch - 2

Regenerative

- Occurs in a single multicell structure
- The cells will have strong electromagnetic coupling between them
- Gradual phase slippage can cause the electrons to be decelerated
- Dilution of phase space

Cumulative

- Occurs in independent cavities uncoupled to each other.
- HOMs are driven by from cavity to cavity by their coupling to the beam
- Each successive bunch gets a larger transverse kick
- Effect is a function of the number of cavities and the number of bunches

Threshold current

$$I_{th} = \frac{-2p_r}{e\left(\frac{R}{Q}\right)_m Q_m k_m R_{ij} \sin(\omega_m t_r)}$$

- This is the highest current at which the beam can remain stable

Why?

- 4GLS will suffer from multibunch BBU
- The threshold current needs to be greater than 100mA
- Methods of achieving this threshold need to be investigated now

Possible solutions

- Design
- Cavity design
- Damping
- Optical
- Beam based feedback

Possible Solutions - Design

- Good beam alignment/limit noise/jitter
- Strong focusing
- Detune the deflecting modes between the cavities – may happen naturally
- Lower fundamental frequency
- Chose accelerating gap that decreases the transit time for deflecting modes
- Decrease bunch charge

Possible Solutions - Cavities

- Work into SC cavity design is being carried out for ILC studies
- Low loss, higher gradients are being investigated

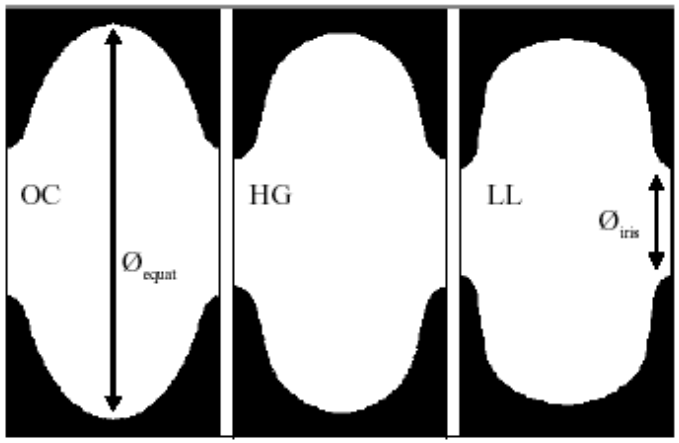


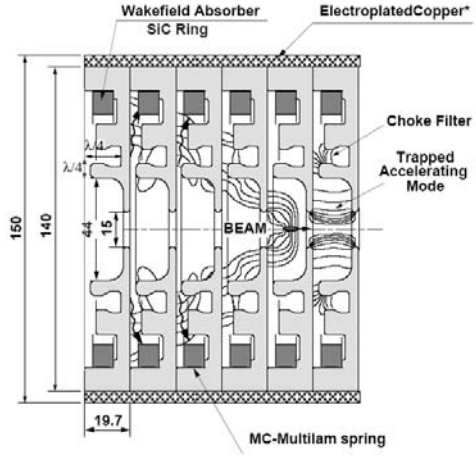
Figure 1: Geometry of three inner cells.

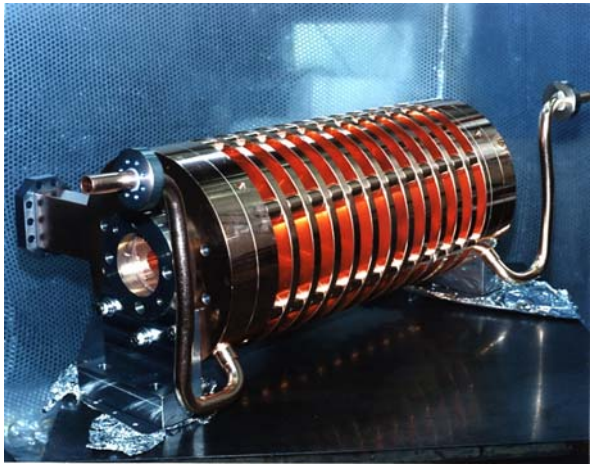
Table 1. Parameters of inner cells

Parameter		OC	HG	LL
$Ø_{equator}$	[mm]	187.0	180.5	174.0
$Ø_{iris}$	[mm]	70.0	61.4	53.0
k_{cc}	[%]	3.29	1.72	1.49
E_{peak}/E_{acc}	[-]	2.56	1.89	2.17
B_{peak}/E_{acc}	[mT/(MV/m)]	4.56	4.26	3.74
R/Q	[Ω]	96.5	111.9	128.8
G	[Ω]	273.8	265.5	280.3
R/Q·G	[Ω²]	26422	29709	36103

Possible Solutions - Choke Cavity

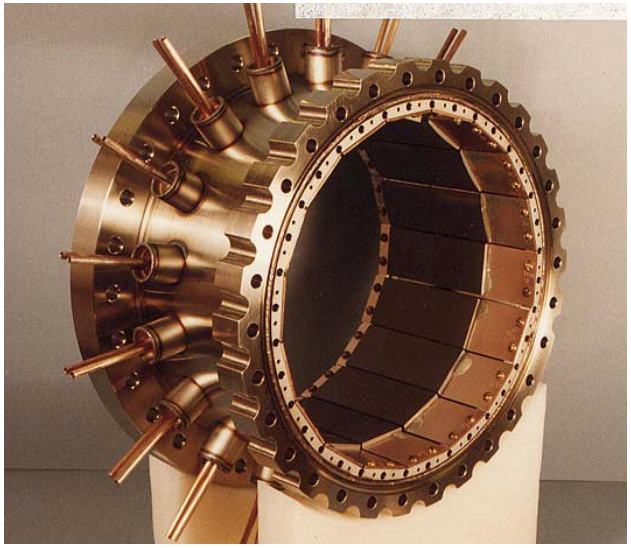
- Virtually HOM Free
- Lowers Q
- Lowers shunt impedance by as much as 25%

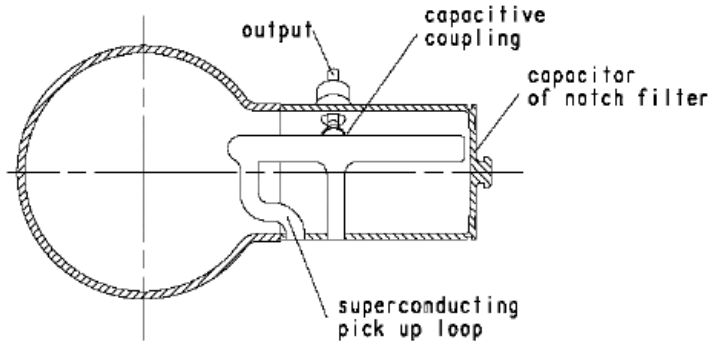




Possible Solutions - Damping

- Damp the deflecting modes
  - Ferrites
  - HOM couplers





Possible Solutions - Optical

- Two schemes, based on beam orientation for the 2nd pass through the linac:
- Reflection (x→y)(y→x)
  - Suppresses BBU completely if HOM are oriented at 0° or 90°
  - Simulations suggest increase in threshold by a factor of 3 for any HOM orientation
- Rotation (x→y)(y→-x)
  - Theoretically suppresses all HOMs
  - Simulations suggest increase in threshold by 2 orders of magnitude

Beam Based Feedback

- Acts as a mode by mode feedback system
- After the 1st/n-1th pass the phase shift and gain of a HOM is measured
- Before entering the linac for the 2nd/nth the beam is passed through a stripline kicker which modulates the beam so that it is damped on its 2nd/nth pass

Summary

- BBU is a problem that can limit the current in light sources
- But it can be suppressed by a combination of cavity design, damping, lattice design and feedback