Beam Loss and Beam Abort Strategies

George R. Neil and the FEL Team
Jefferson Lab
Newport News, Virginia

And thanks to R. Hajima, JAERI, and H. L. Owen, 4GLS, for contributions

ICFA FLS Workshop
Hamburg
May 16, 2006

Beam Losses

The high power produced by ERLs being planned demands careful approaches for dealing with beam loss.

- **Sources:**
  - **Halo**
    - **Beam induced**
    - **Field emission from gun and srf cavities**
    - **Scattered light in photoinjector**
    - **…**
  - **Trips and hardware failures**
  - **Edge of beam**

Halo Summary

- A bit of an issue for us
- Comes more from more from scattered light & various emitters than from exotic effects - i.e., reality hits at currents well below those at which “space charge” matters
- Halo sources – things making low charge bunches that go on to be mishandled by the accelerator
  - Drive laser transport scattering light to nether regions of cathode
  - Drive laser ghost pulses
  - Field emitters on gun surfaces and in SRF cavities
  - Unresolved 2nd order dispersion (T_{166}, T_{266})

  these get longitudinally overfocused and blown out to large momenta

Halo (2002)

"The stuff in the tails that you can't use, can't see, and probably don't know about, but that CAN hurt you, or at least melt something"

- **Beam loss scales with current, beam envelope (beam size and lattice contributions), and with the inverse of aperture**

$$I_{loss} \sim C\, I_{beam}\, \beta / a_{pipe}$$

- **CEBAF & Demo experience suggest $C \sim \frac{1}{2} \times 10^{-7}$, in turn suggesting (limit loss to 0.1 μA) you need $\beta / a_{pipe} \sim$ 20 at 100 mA – or, a 10 cm bore & 1 m envelopes!**

Halo (May 2006)

- See some evidence of halo
  - Localized activation on beam line
  - Steering independent Beam Loss Monitor activity that can be modified by changing quad focusing and/or sextupoles
- Requires real care at wiggler aperture (13 mm)
- Occasionally (> about 7 mA CW) an operational limitation
    - Slow beamline pressure rise ⇒ limited beam loss
    - Can work around by altering phase advance, betatron matching solution
    - Seems to collimate in 1st arc (there's 7 m/20 tons of steel between the linac/backleg!)

"You can't collimate electrons; you can only make them angry"

Beam Losses Criteria

- JLab: Losses must be < 1 uA at any one point in the machine or we trip fast shutdown to avoid beamline burnthrough
- 4GLS ERLP: 15 W uncontrolled single point loss
- KEK/JAERI ERL: determined by radiation view point, cost of radiation shield, radiation noise at X-ray beamline downstream

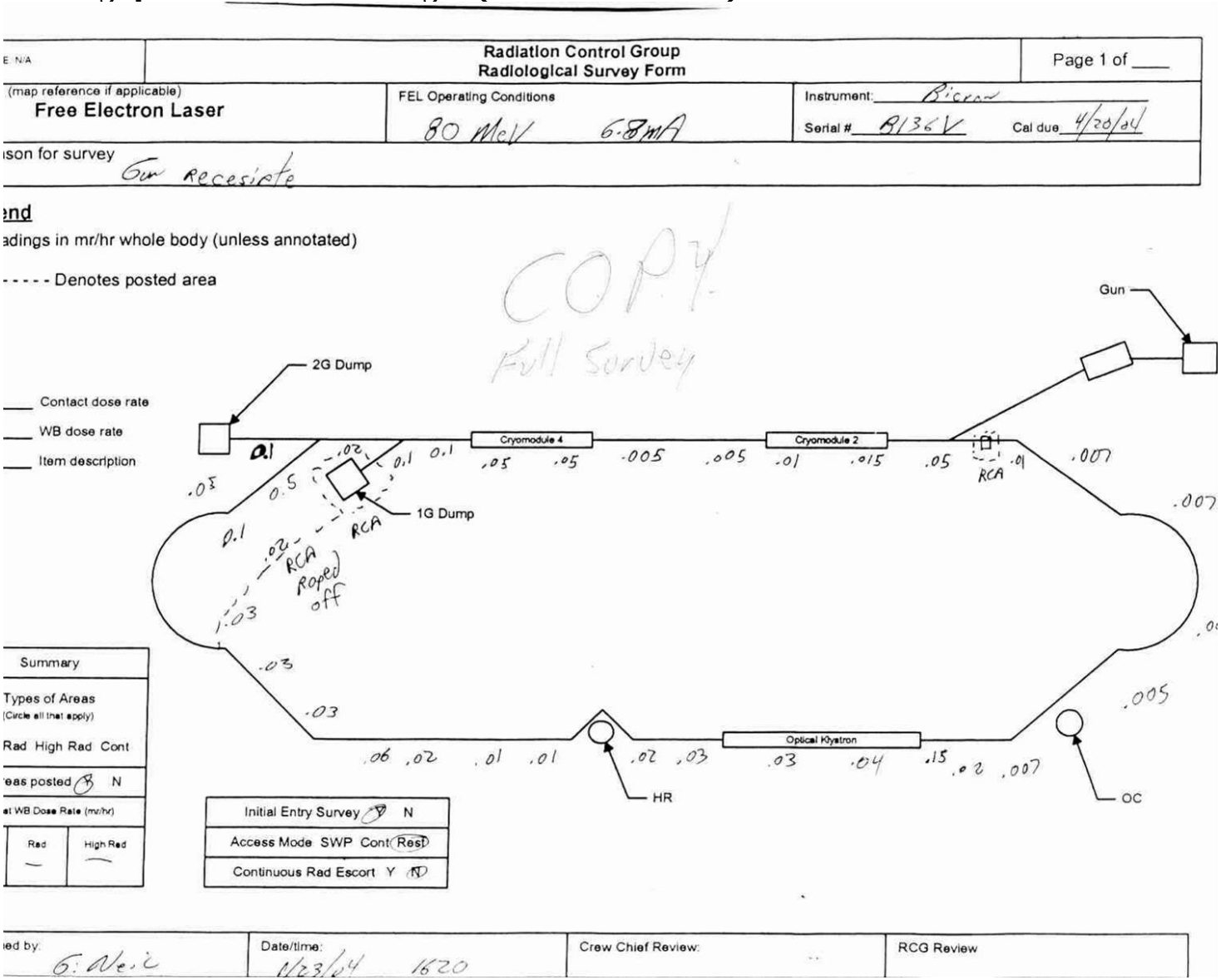
- Energy of lost ERL beam pulse could be >200J (0.1A x 2 us x 1 GeV). This can blow a hole in beamline. Must strive for faster detection and shutdown, beam catchers at key points.
  - Detection time: 100-1000 ns pulse delay and beam fill through linac 500-3000 ns
  - Fast kickers <100 ns. How many? where? Stops?

Beam Shutdown

- JLab uses PM radiation detectors to determine beam loss
  - Current monitors do not have sufficient sensitivity to measure 10^{-4} changes)
  - Trip value is set by deliberately driving 1 uA into beamline at each detector
- On sensing X-rays, a fast shutdown system is triggered:
  - Removes beam permission and shuts fast (0.1 us) E-O shutter on photoinjector drive laser and two (slower: ms) mechanical shutters. (some issues with EO! Bias thermally dependent)
- Slower signals can also be used: vacuum trip levels and thermal sensors at a few key points

- n.b. typically if rf or other system trips off, beam loss occurs at first dispersed location after linac
- also we use fast (ms) valves triggered by cold cathode gauges to protect srf cavities in event of loss of vacuum accident. We HAVE fried beam valves!

Typical Survey (Jan 2004)



Radiation Control Group
Radiological Survey Form

Page 1 of ____

(map reference if applicable)
Free Electron Laser

FEL Operating Conditions
80 MeV 6.8mA

Instrument: Bicron
Serial # 8136V Cal due 4/20/04

Reason for survey Gun Recesiate

End

Readings in mr/hr whole body (unless annotated)

- - - - - Denotes posted area

COPY
Full Survey

____ Contact dose rate
____ WB dose rate
____ Item description

2G Dump
1G Dump
RCA
RCA Roped off
Gun
Cryomodule 4
Cryomodule 2
Optical Klystron
HR
OC

Summary

Types of Areas (Circle all that apply)
Rad High Rad Cont

Areas posted Y N

at WB Dose Rate (mr/hr)

Rad	High Rad
—	—

Initial Entry Survey Y N
Access Mode SWP Cont Rest
Continuous Rad Escort Y N

Surveyed by:	Date/time:	Crew Chief Review:	RCG Review
G. Neil	1/23/04 1620		