An Overview of Top-Up Safety Tracking

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Why Are Light Sources Safe?

- Everyone “knows” that it is safe to operate a light source with shutters open and stored beam. There are good reasons for believing this.
- Photon beamlines of necessity diverge from the design electron beam path. This is accomplished using dipole magnets to bend the electron beam path.
- If a dipole shorts, the field loss is gradual compared to the revolution time of the beam.
  - Gradual loss of field in one or more dipole magnets results in loss of stored beam long before any particles get steered into the photon beamline aperture.
  - This is assured by the presence of beam-limiting apertures and lattice nonlinearities.
- Even if beam was extracted, it is only one pulse and will not produce a dangerous dose.

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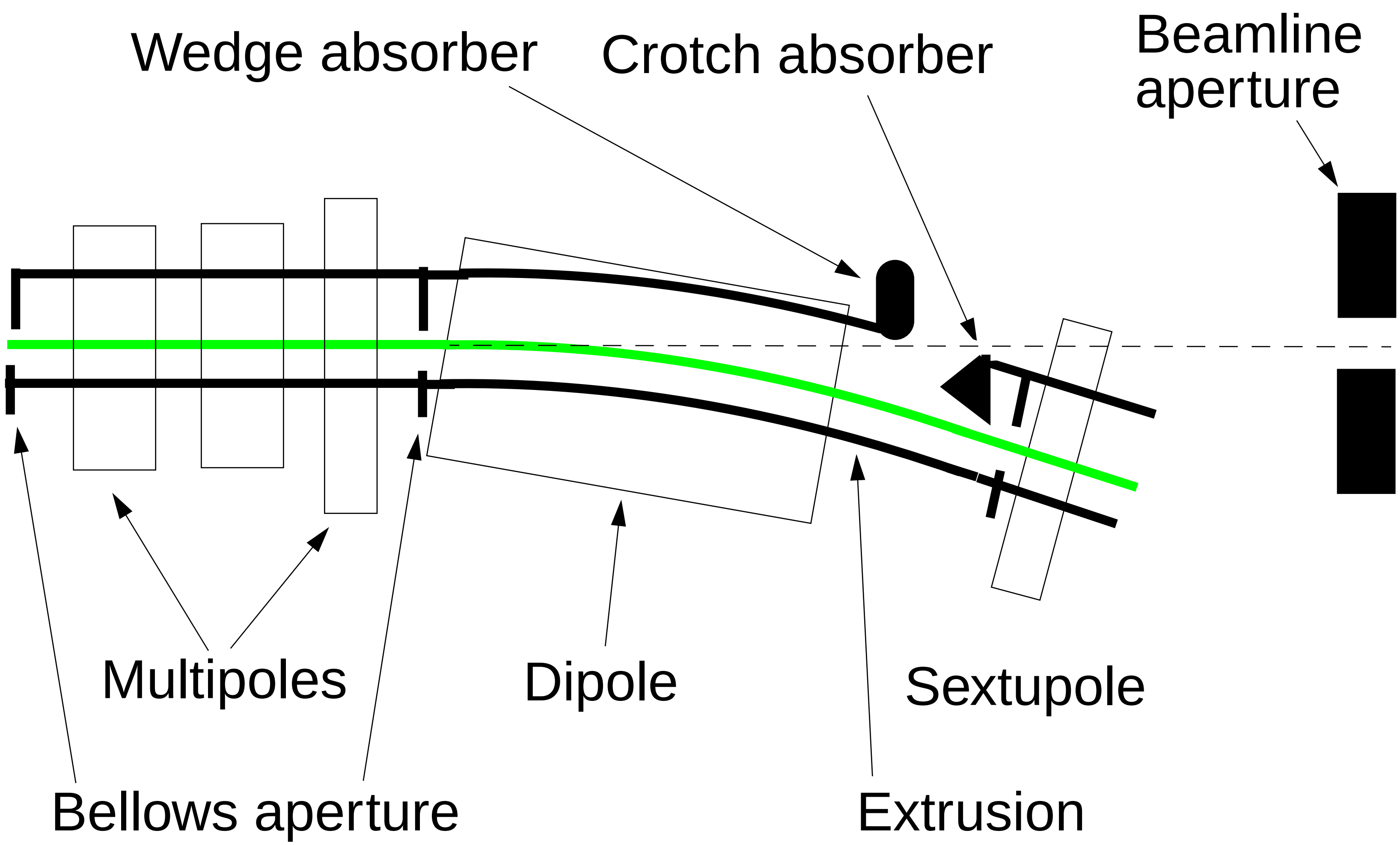
Schematic Geometry of a Beamline



Why Is Top-Up Different?

- In top-up, we add the complication of having injected beam. With this comes new concerns:
  - The injected beam is not on the stored beam orbit.
  - The injected beam needn't survive a full turn in order to exit a photon beamline. Hence, it is less constrained than the stored beam.
  - The injected beam by assumption is "under the influence" of fast pulsed magnets.
  - The injected beam need not have the same energy as the stored beam.
  - Injection provides a potentially continual source of beam, and hence presents a greater potential radiation danger.
- In addition, during injection the stored beam is being kicked by fast pulsed magnets.

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Top-Up Safety Approach

- Assume that the existence of a stored beam precludes extraction of injected beam down a photon beamline.
- Given this, we can ensure top-up safety using redudant stored beam monitors that disable injection whenever there is less than ~20mA stored beam with shutters open.
- Demonstrate the original supposition.
  We did this using particle tracking.

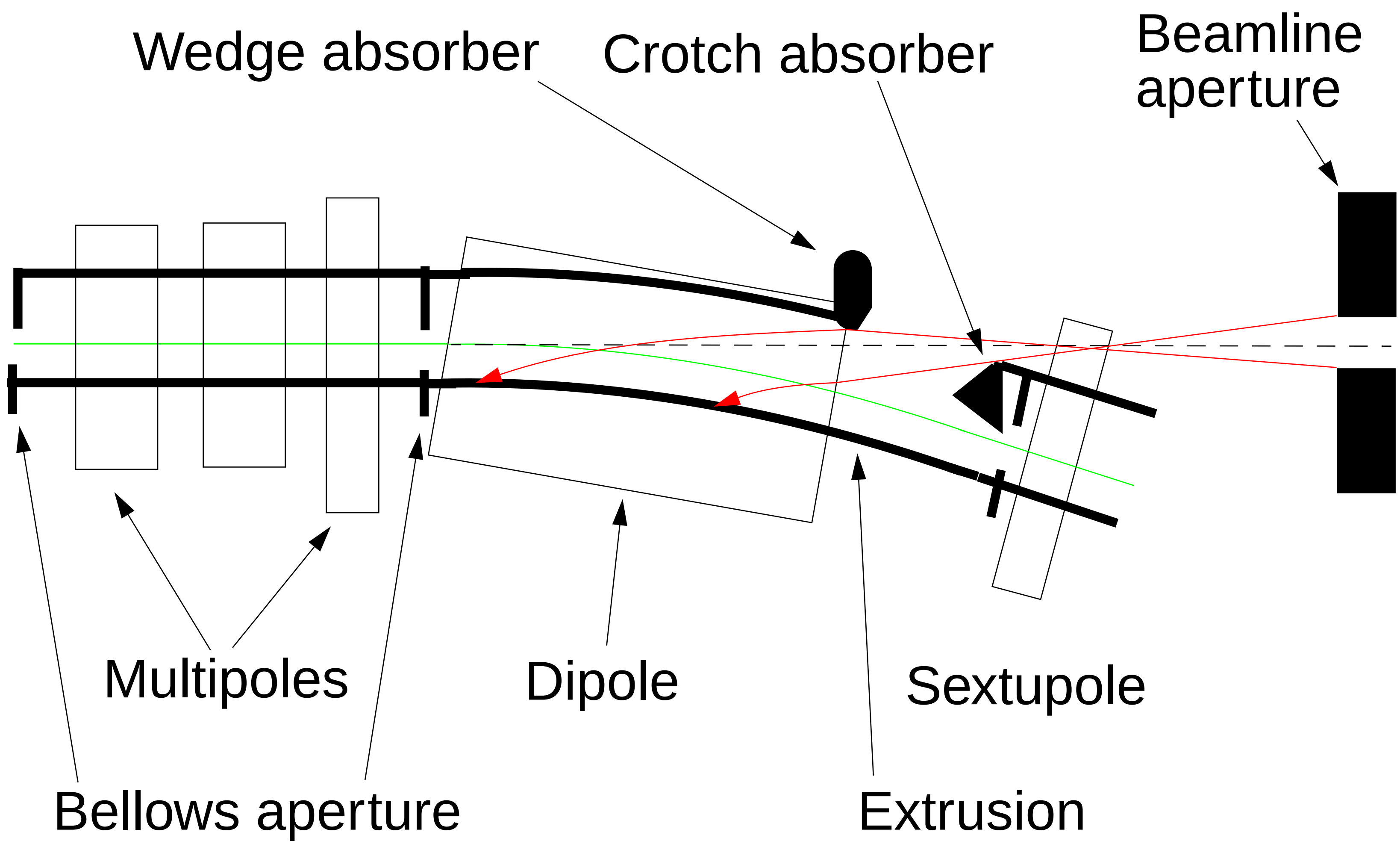
Top-Up Accident Simulations

- A top-up accident is a situation where injected beam exits the storage ring tunnel through a photon beam port while stored beam exists.
- An accident requires, at minimum, a fully- or partially- shorted dipole in a sector with an ID/AM or BM beamline.
- Generally, a simulation scenario is evaluated as follows:
  - Choose a dipole to short.
  - Choose additional failures.
  - Simulate stored beam as a function of the degree of shorting (the Fractional Strength Error or FSE).
  - Simulate extraction of beam down a photon beamline vs FSE.
  - See if there is a gap between the FSE that allows stored beam and the FSE that allows extraction of beam.

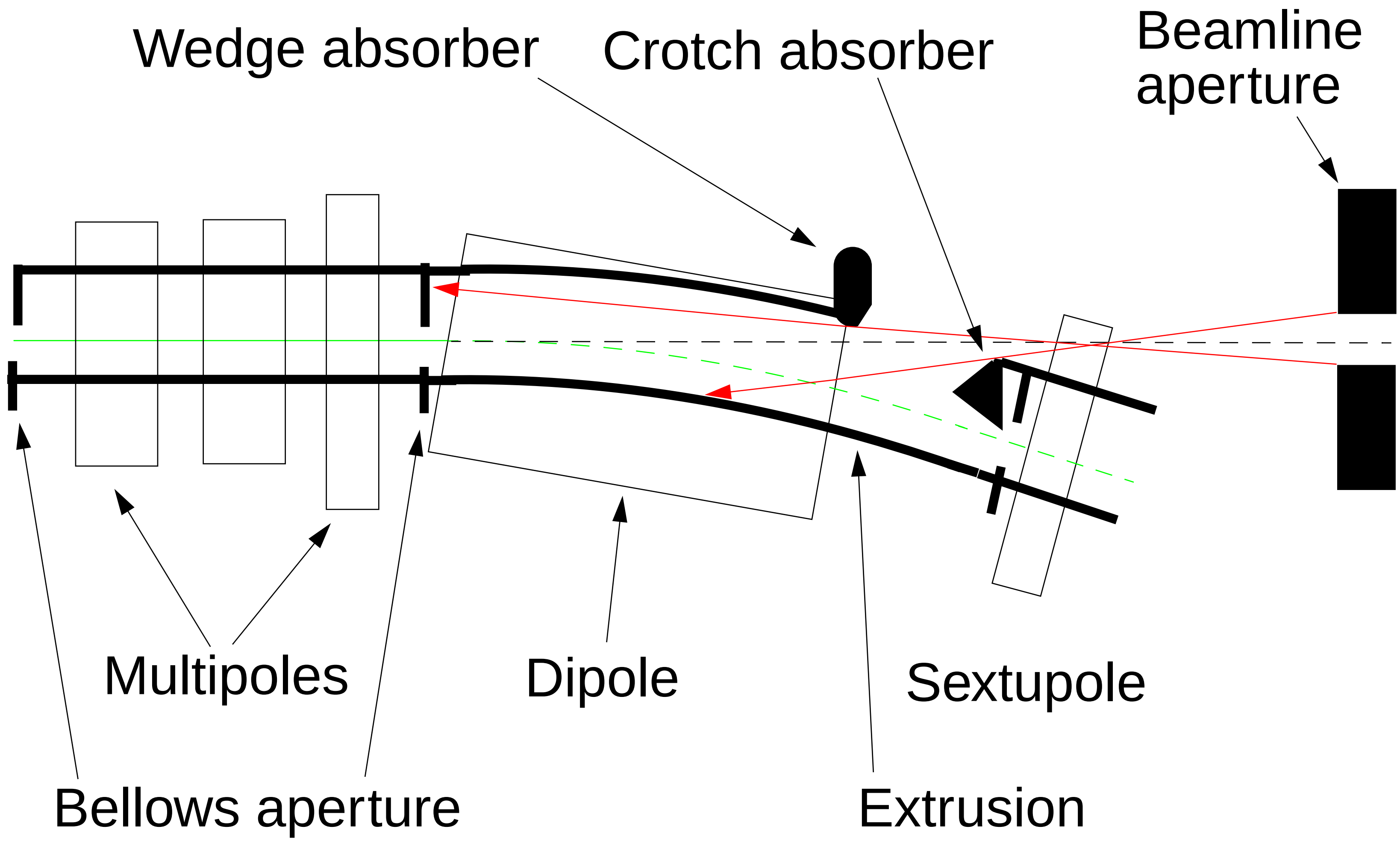
Two Types of Tracking

- For stored beam
  - Compute the closed orbit in the presence of the magnet errors prescribed by the failure scenario.
  - Track a particle on that closed orbit and determine if the particle is lost on any aperture.
- For injected beam
  - Perform backwards tracking of a beam that fills the photon beamline acceptance.
  - Track particles to the beginning of the sector (i.e., the exit of the upstream ID chamber).
  - If no particles exit the sector, then we know that in the simulated conditions no injected beam could exit the beamline.
  - Since we never track to the location of the kicker magnets, there is no need to worry about their influence.

Schematic of Back-Tracking with Dipole On



Schematic of Back-Tracking with Dipole Off



General Assumptions of Accident Scenarios

- A single dipole shorts, fully or partially.
- Other errors in magnet strength occur that "conspire" to make an accident more likely. E.g., quadrupole strength errors or corrector errors.
- We assume the magnet locations are the ideal ones and that all alignment errors can be assigned to the apertures.
- We assume that top-up operation is not performed below 6 GeV.
- These assumptions require specific knowledge of the hardware:
  - Multipole magnet design, polarity, and strength limits.
  - Location, size, and positional tolerance of apertures in the accelerator and photon beamline.

Hardware Assumptions
—Magnets and Power Supplies—

- Quadrupoles
  - Power supply limit is 450 A
  - Original APS design used.
  - Design locations used.
  - All quadrupoles have the design polarity (except in single polarity error scenarios)
- Sextupoles
  - Power supply limit is 250A.
  - Original APS design used.
  - Design locations used.
  - Design polarity used.
- Correctors
  - Power supply limit is 150A.
  - Original APS design is used.
  - Design locations used.

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Hardware Assumptions —Storage Ring Apertures—

- Only horizontal apertures are relevant.
- These apertures are documented in detail elsewhere. The precise values may differ from sector to sector.
- The apertures in question are
  - Extrusion (in all elements outside the ID chamber)
  - Bellows (8 locations)
  - CA2 and CA4 crotch absorbers.
  - EA1, EA3, and EA5 end absorbers.

Hardware Assumptions —Photon Beamlines—

- In general, we use two apertures in each photon beamline.
- These apertures are considered radiologically safe places to dump beam.
- For **standard sectors**, the apertures are
  - AM/ID line (distances from center of ID straight):

    1. Safety shutter: +/-36mm at 22.976m
    2. CA2/WA2 absorbers: +/-22mm at 11.645m

  - BM line (distances from BM line source point):

    1. Lead collimator: +/-61mm at 19.194m
    2. CA4/WA4 absorbers: +/-13mm at 3.634m

Documents Describing Apertures in Detail

- Procedure 3-00051, **Storage Ring Apertures Relevant to Top-Up**, M. Borland
- Procedure 3-00054, **Storage Ring Apertures Relevant to Top-Up for Sector 35**, M. Borland. *Now applicable only to 35ID.*
- **Changes in Storage Ring/Beamline Apertures due to Girder Move in S34/35-XAXSTF**, Om Singh. Covers 33ID, 34BM, 34ID, and 35BM.
- **SR Magnet and Photon Aperture Tolerance Budget for Top-Up Safety**, L. Emery.

Other related documents

- Procedure 3-00050, **Top-Up Tracking Procedure**, M. Borland.
- Procedure 3-00052, **Commissioning Plan for Top-Up Injection**, L. Emery.