Hurricane Isabel's impact on JLab

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Outline

- Introduction of Jefferson Lab
- Basic knowledge of hurricanes
- 2003 Hurricane Isabel's impact on JLab accelerator
- JLab recovery after hurricane Isabel
- Performance of JLab accelerator after the recovery
- Preventive measures
- Other events

Jefferson Lab

- Jefferson Lab is a basic nuclear physics research laboratory operated for the US Department of Energy.

- Jefferson Lab is an electron particle accelerator based on superconducting radiofrequency (SRF) technology.

Jefferson Lab

- Located in Newport News, Virginia, on the east coast of the USA.
- Latitude: 36 deg. N
- Longitude: 76 deg. W.
- Elevation: about 32 feet (9 m) above sea level.

- Hurricane season: June 1 - November 30.

Location of JLab

Aerial View of JLab

Service Buildings


NLO2

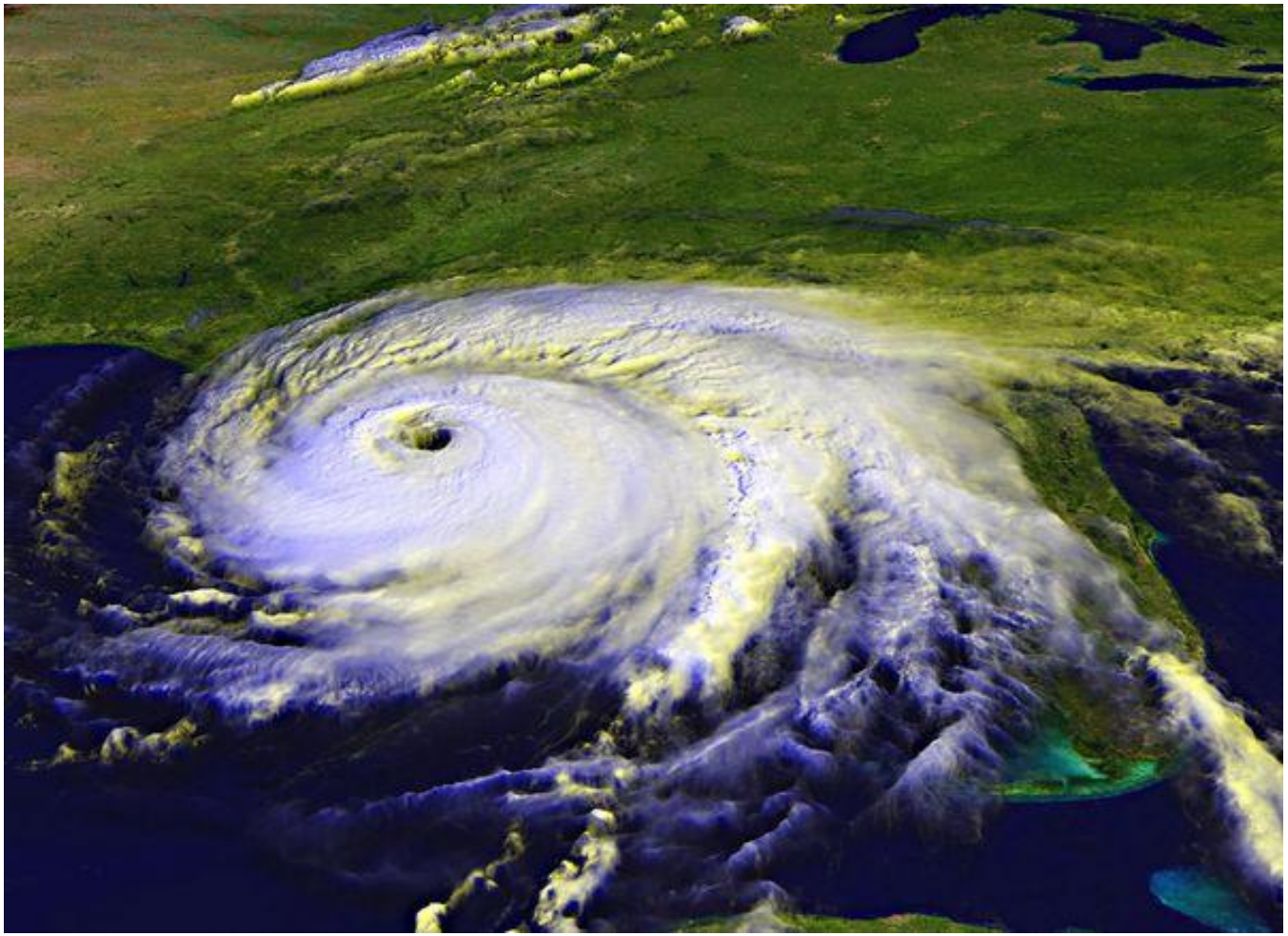
SRF Cavities

- 328 SRF cavities operated at -270 ºC or 2 Kelvin using liquid helium as cryogen.
- Central Helium Liquefier (CHL) runs at all times to maintain the low temperature.
- 65,000 liters of liquid helium needed.
- Cavities' insulating vacuum maintained at ~ e-9 torr.

Hurricanes

Hurricanes are giant, spiraling tropical storms that pack high wind speeds and can unleash more than 9 trillion liters of rain a day. When a hurricane makes landfall it often produces a devastating surge that can reach 20 feet (6 m) high and extend 100 miles (160 km). A hurricane's high winds are also destructive and may spawn tornadoes.

Hurricanes



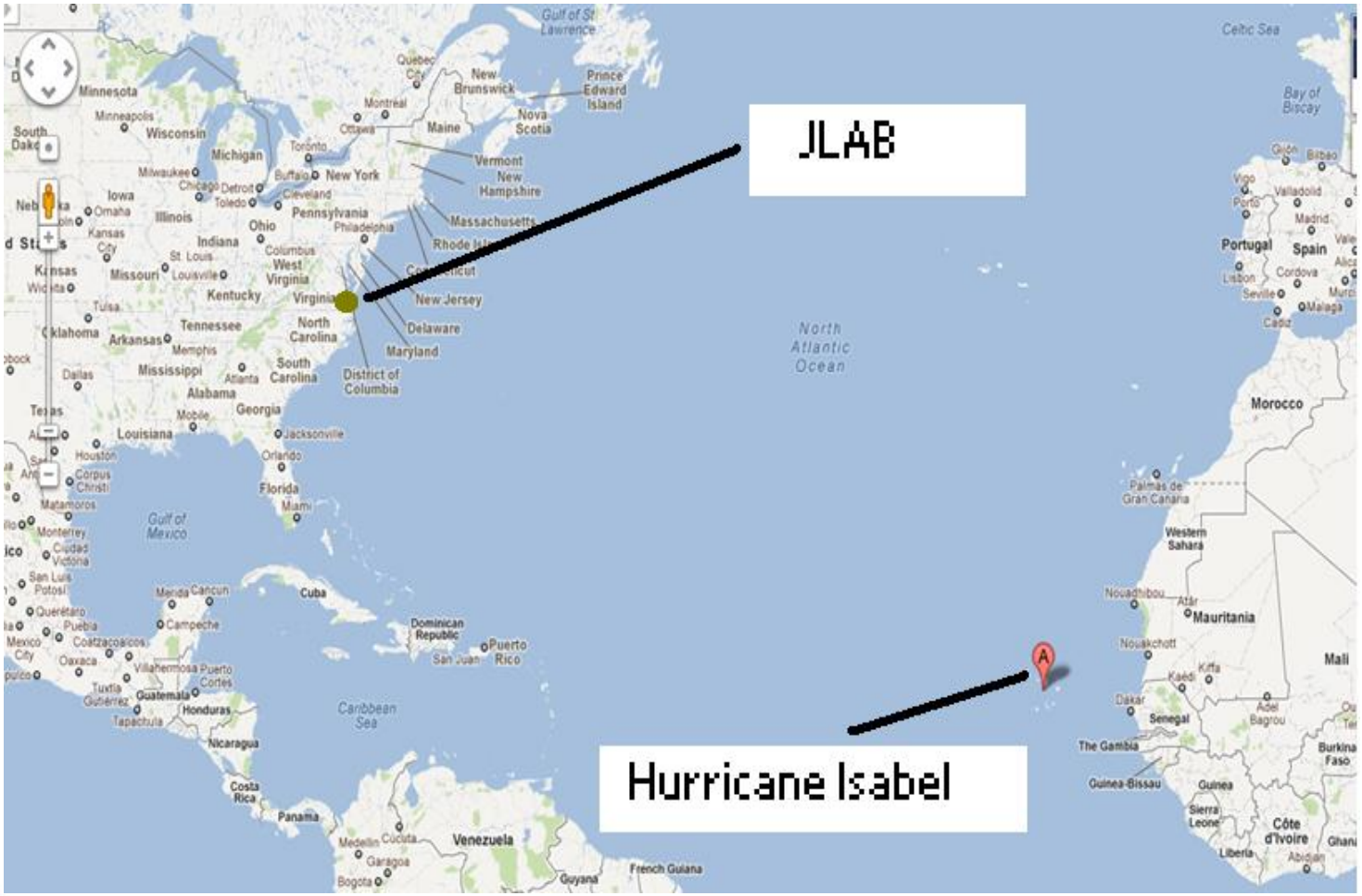
Hurricane Categories

Hurricane	Wind Speed miles per hour	Storm Surge feet	Damage
Category I	74 – 95 (119 - 153 km/h)	1.0 – 5 .0 (0.3 - 1.5 m)	Minimal
Category II	96 - 110 (154 - 177 km/h)	5.3 – 8.0 (1.6 - 2.4 m)	Moderate
Category III	111 - 130 (178 - 209 km/h)	8.1 – 12.0 (2.5 - 3.6 m)	Extensive
Category IV	131 - 156 (210 - 249 km/h)	12.1 – 18.0 (3.7 - 5.4 m)	Extreme
Category V	> 156 (249 km/h)	> 18.0 (5.4 m)	Catastrophic

The 2003 Hurricane Isabel

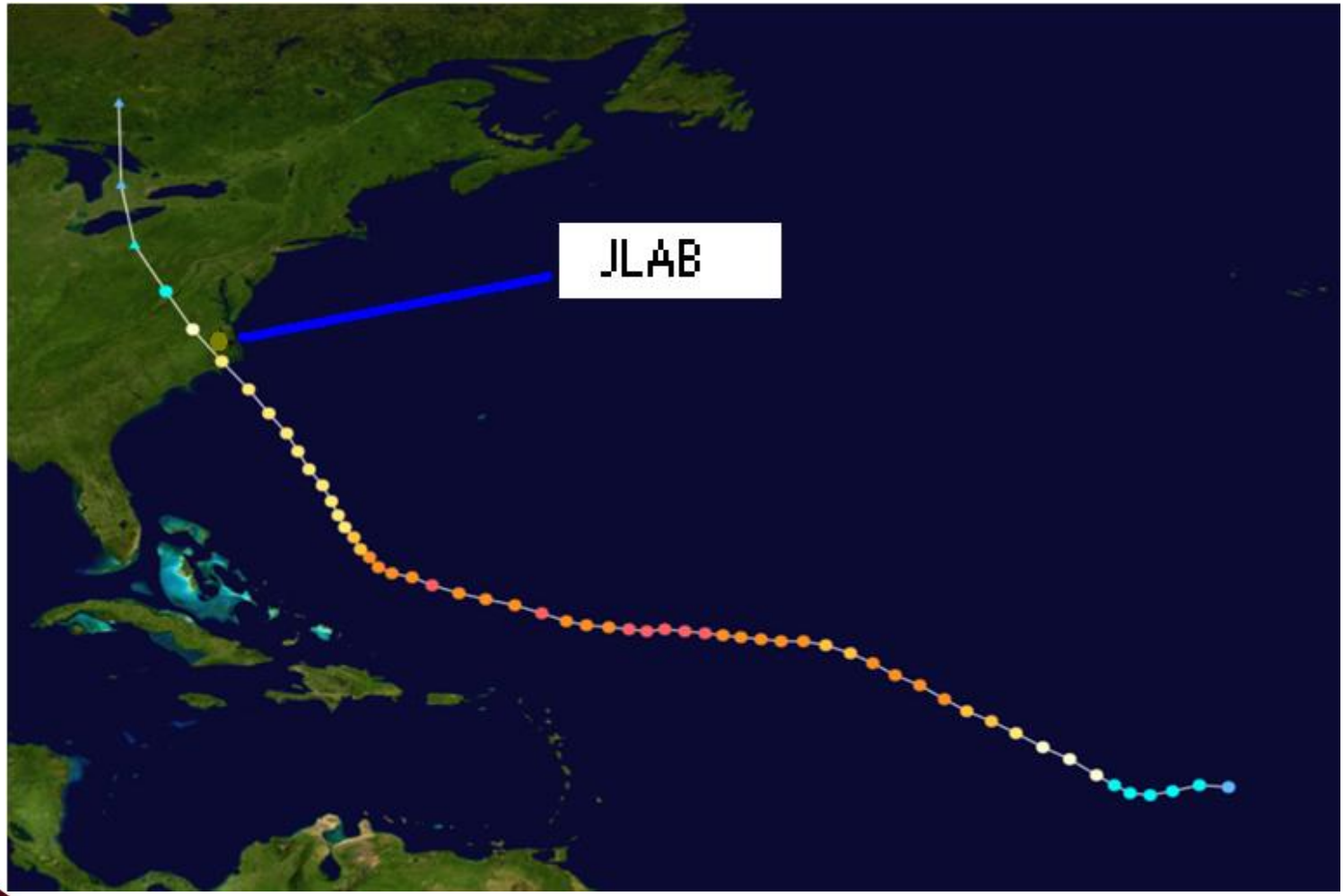
- The costliest and deadliest hurricane in the 2003 Atlantic hurricane season.
- Formed near the Cape Verde Islands from tropical waves on September 6.
- Became a category-5 hurricane five days later.
- Gradually weakened and made landfall on the Outer Banks of North Carolina with wind of 103 mph (165 km/h) on Sept. 18.
- Quickly weakened over land and became a category-1 hurricane as it passed through central Virginia.

Formation of Hurricane Isabel



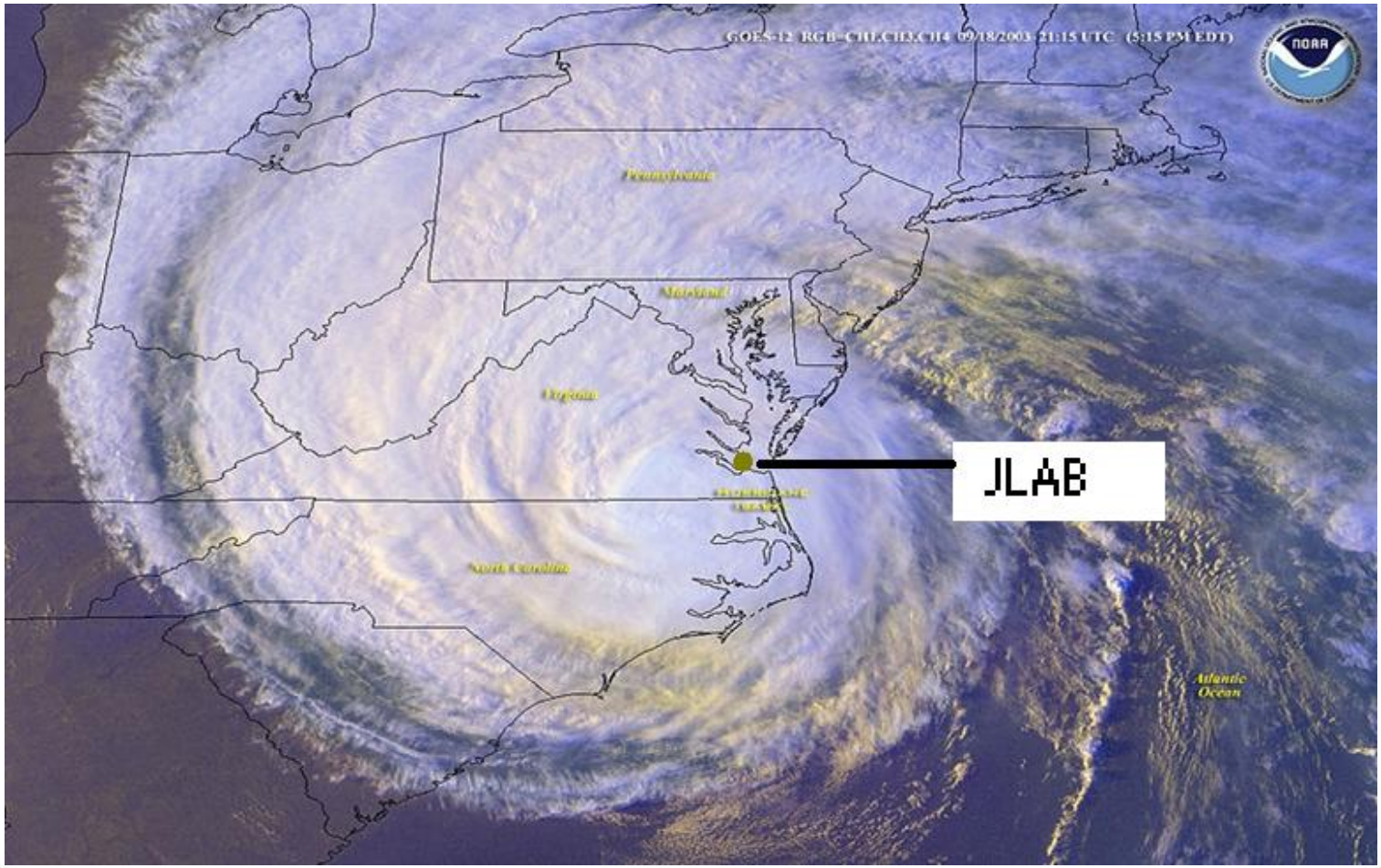
Jefferson Lab

Hurricane Isabel's Path



Isabel Approaching

Landfall of Hurricane Isabel



Isabel's Impact on Community

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Hurricane Isabel's Impact on Virginia

Isabel's strong winds affected 99 counties and cities in Virginia, which downed thousands of trees and left about 1.8 million without power:

Date:	September 18 – 19, 2003
Highest Winds:	75 mph (120 km/h)
Fatalities:	10 direct, 26 indirect
Damage:	$1.85 billion (2003 USD)

JLab Prepared for Isabel

- One week notice of category-5 hurricane Isabel with wind speed of 156 mph (249 km/h) moving toward Virginia/North Carolina coastline.
- Every possible preparation was taken before Jlab was evacuated on Sept. 17, 2003.
- Isabel arrived on Sept. 18 as a category-1 hurricane with wind speed of 75 mph (120 km/h).

Isabel's Impact on JLab

- Minimal direct damage to the infrastructure
- Power outage that lasted about three-and-a-half days.
- Historically, the longest power outage before Isabel was a few hours. Without power the Central Helium Liquefier (CHL) could not run and the SRF insulating vacuum could not be maintained. Therefore, *all 328 SRF cavities warmed up to the ambient temperature and all the liquid helium vented out.*

Initial Response after the Storm

- Our first instinct was to restore the power & the CHL ASAP.
- After some thought, we decided to carry out aggressive preventive maintenance on the electrical substation, the CHL and other sub-systems.

  The substation had not had preventive maintenance for about five years, and the CHL had not been off for an extended period of more than twelve years.
- A detailed recovery schedule was developed.

The Recovery

- Aggressive preventive maintenance was conducted for all accelerator systems.
- Cryomodules were cooled down to 4K, then to 2K
- RF performance was assessed and characterized.
- Two weeks were used to carefully tune and set up the accelerator.
- One week of dedicated physics/accelerator collaborative commissioning was used to prepare for upcoming experiments.

Cryogenic Recovery

- All the O-rings in the helium transfer lines were replaced since they almost reached their life time.

- The insulating vacuum spaces were pumped out to remove the cryo-pumped contaminants that had accumulated over the years.

SRF Recovery

- Warming the cryomodules expands all of the internal components. Opening up one of the internal indium vacuum seals (64 per module) could possibly introduce a helium leak into the cavity beamline vacuum. So each module was examined.

- Overall, 5 out of 328 cavities could not be recovered. Four were because of superfluid leak; one was due to an open probe cable.

SRF Recovery

- Three weeks after the hurricane we started cooling down the cryomodules.

- By the end of October the cavities were brought up to 5MeV/m to look for, and address, vacuum problems in the warm window region.

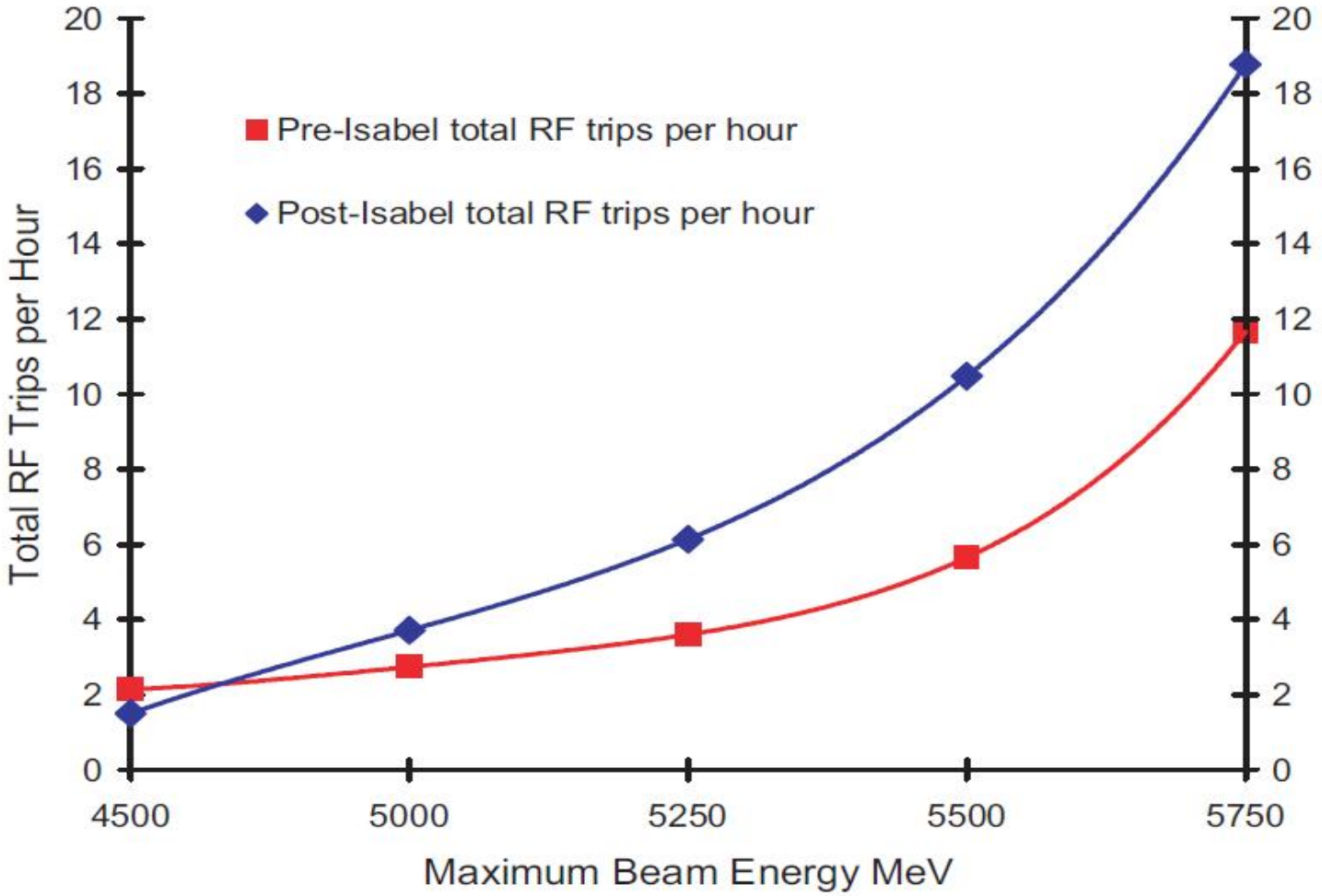
Cavity Trips

There are two windows in the original CEBAF cavities, one at liquid helium temperature and one at room temperature. The cold window tends to arc at high gradients due to charging of the window by electrons created by field emission in the cavity. The RF and beam must be shut off to protect the cavity (a trip). The trip rate depends exponentially on the accelerating gradient, determining the maximum beam energy.

Assessment of SRF

- Deliver 5.5 GeV beam at about 10 RF trips per hour.
- Deliver 5.75 GeV beam at about 20 RF trips per hour.
- We would lose about 10% of the energy if keeping the same level of RF trips.

RF trip rate as a function of beam energy



Recovery Timeline

- Sept. 18, 2003 – Hurricane Isabel

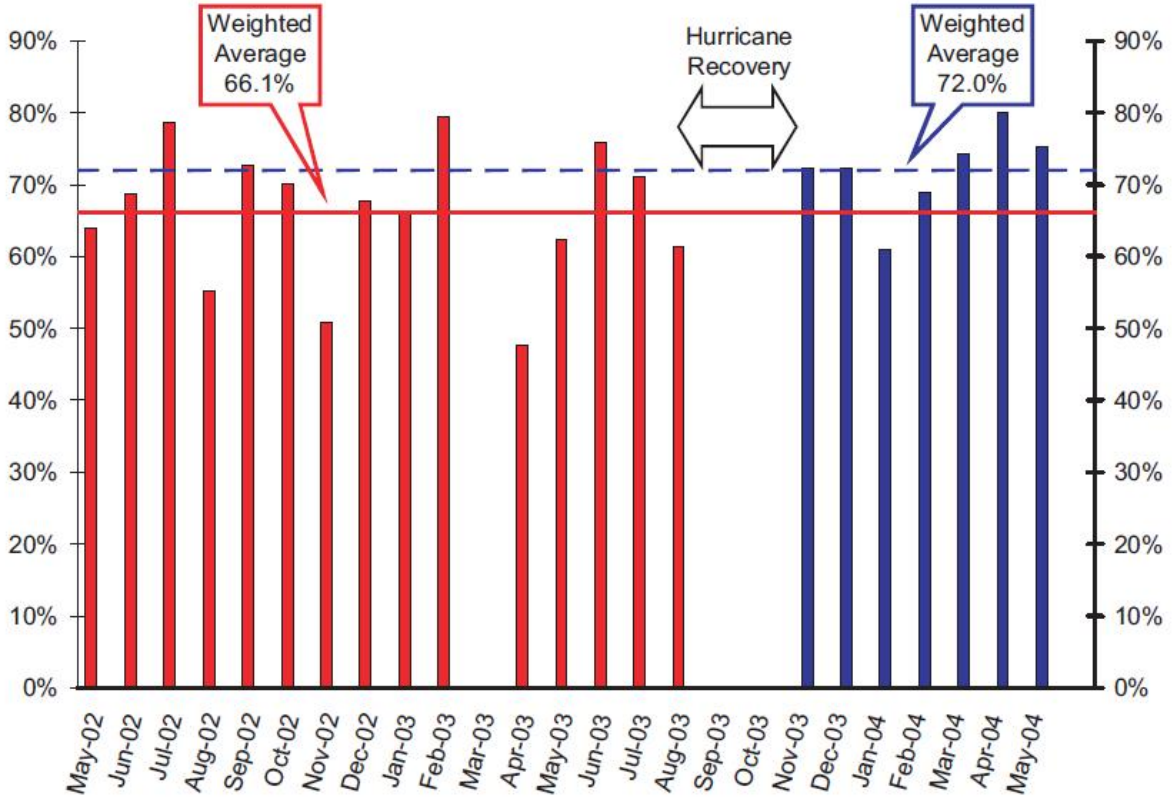
  Little physical damage to Jlab, but power outage for 3.5 days.
- Sept. 22 – Power restored

  ~65,000liters of helium was lost and SRF cavities warmed up.
- Sept. 23 – Employees returned to work. Started preventive maintenance on RF, electrical system, etc.
- Oct. 8 – Cryomodules cooldown started
- Oct. 21 – 2K cooldown complete

Recovery Timeline

- Oct. 23 – Recovery and characterization of RF cavities
- Nov. 10 – Beam in the main machine
- Nov. 11 – Detailed accelerator setup and beam studies started
- Nov. 25 – Beam to all Halls for system checkout
- Dec. 2 – Physics resumed with all of the required beam specifications being met.

Accelerator Availability



Preventive Measures

- Installed 500 kW generator to power the following:
  - Machine Control Center
  - Injector warm region vacuum
  - Cryo controls
  - SRF vacuum power supplies
  - PSS/ODH sensors and alarms
  - Tunnel sump pumps
  - lighting for tunnel and service buildings
- Upgraded the cryo valve actuators, SRF vacuum pump reset/restart.

Other Events

- August 2011: Hurricane Irene
  - Heavy rain and strong wind but little impact on Jlab.
- August 2011: Earthquake
  - Magnitude 5.8, west of Richmond, no damage to CEBAF.
- December 2003: Earthquake
  - Magnitude 4.5, west of Richmond, caused a lot of RF cavities to trip. It took one hour to recover.
- September 1999: Hurricane Floyd
  - More flood than wind; a few hours of power outage.

Summary

- Jlab had little direct physical damage from 2003 Hurricane Isabel.
- JLab SRF was affected due to the power outage but recovered well.
- CEBAF performed well after the recovery from Hurricane Isabel.
- Preventive measures are important means to mitigate the impact caused by disasters like earthquakes, hurricanes, floods, power outages, fires, etc.