

When the Chips Are Down....

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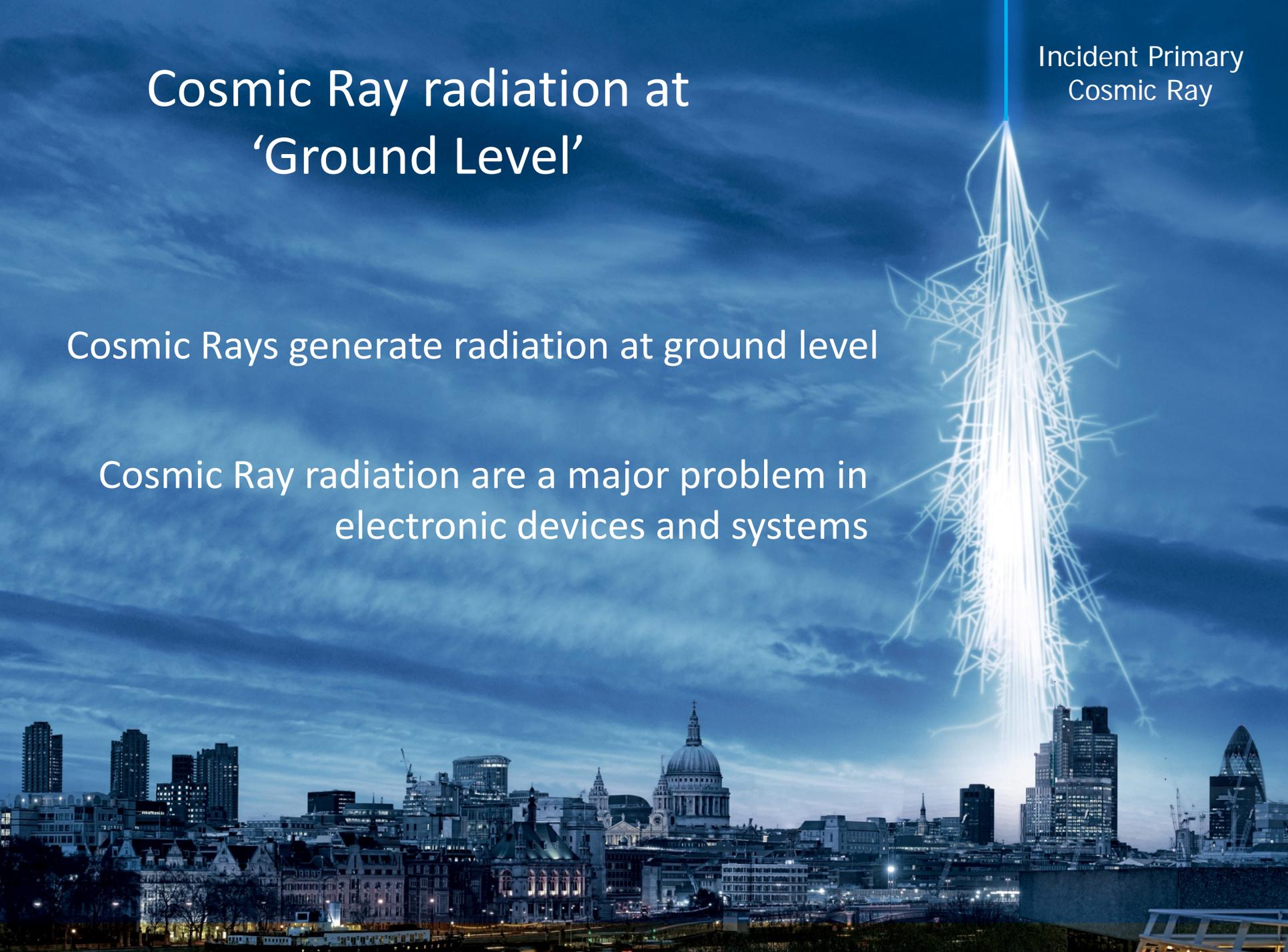
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Cosmic Ray radiation at 'Ground Level'

Incident Primary
Cosmic Ray

Cosmic Rays generate radiation at ground level

Cosmic Ray radiation are a major problem in
electronic devices and systems



***STOP: 0x000000D1 (0x00000000, 0xF73120AE, 0xC0000008, 0xC0000000)

A problem has been detected and Windows has been shut down to prevent damage to your computer

DRIVER_IRQL_NOT_LESS_OR_EQUAL

If this is the first time you've seen this Stop error screen, restart your computer. If this screen appears again, follow these steps:

Check to make sure any new hardware or software is properly installed. If this is a new installation, ask your hardware or software manufacturer for any windows updates you might need.

If problems continue, disable or remove any newly installed hardware or software. Disable BIOS memory options such as caching or shadowing. If you need to use Safe Mode to remove or disable components, restart your computer, press F8 to select Advanced Startup Options, and then select Safe Mode.

*** ABCD.SYS - Address F73120AE base at C0000000, DateStamp 36B072A3

Kernel Debugger Using: COM2 (Port 0x2F8, Baud Rate 19200)

Beginning dump of physical memory

Physical memory dump complete. Contact your system administrator or technical support group.

Schaerbeek, Belgium

May 18th 2003, 22:30



4096 (2^{12}) votes added to an electronic voting machine

4096

“worried about the influence of Martians on these elections... unless the cosmic rays affect our lists in a positive way!”

0 0 0 0 0 1 0 0 0 1 1 0 0 1 1 0 1

7th October 2008 at 04:40:26

Flight Qantas QF72 – Singapore to Perth



news.com.au
NEWS WEBSITE OF THE YEAR
AUSTRALIA

Travel News

'Cosmic rays' may have hit Qantas plane off Australia's northwest coast

By Ben Packham | Herald Sun | November 19, 2009 12:01am

- Two terrifying dives by Qantas Airbus
- Flight attendant, passengers injured
- Cosmic rays from space may be to blame

COSMIC rays may have been responsible for a near disaster involving a Qantas jet off Australia's northwest coast.

Safety investigators have isolated the cause of two terrifying dives by the Airbus A330-303 to an onboard computer.

But the computer itself, fitted to about 900 aircraft worldwide, was found to be in perfect working order. [The Herald Sun reports](#).

A flight attendant and 11 passengers were seriously injured and many others experienced minor injuries in a near-miss on October 8 last year.

An Australian Transport Safety Bureau report into the incident found at least six passengers' seatbelts came unfastened during the event.

The aircraft's nose pitched violently downward twice in rapid succession, diving 650ft and 400ft, throwing unsecured passengers and luggage around the cabin / File

thewest.com.au
crazy sales
ATSB probes 'cosmic ray' Qantas jet plunge

Take the plunge

ave hit Qantas

‘Real-world Incident’



“There were significant logistical difficulties in obtaining access to appropriate test facilities and developing test software and procedures.....”



Soft-Error Impact

- Cell phone with one 4-Mbit, low-power memory with an SER of 1000 FITs per megabit
 - One soft error every 28 years
- High-end router with 10 Gbits of SRAM and an SER of 600 FITs per megabit
 - One error every 170 hours
- Router farm that uses 1 Tbits of same memory
 - One potential networking error interrupting proper operation every 1.7 hours
- Person on an airplane over the Atlantic at 35,000 ft working on a laptop with 256 Mbytes of memory
 - At this altitude, the SER of 600 FITs per megabit becomes 100,000 FITs per megabit
 - One potential error every five hours

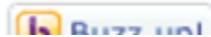
Single-Events (Soft Errors)

- SIA Roadmap has listed soft errors as one of the major reliability issues going forward; data from advanced technology nodes support this conclusion
- Semiconductor companies will need soft error characterization for advanced technologies



Zombie Satellite Causes Astronomical Buzz

by Claudine Zap
18 hours ago

 1,251 Votes

[EE Times:](#)

Cosmic rays damage automotive electronics

 Print |  Email |  Reprints |  RSS |  Digital |  SHARE

EBay: One outage too many



EDTN Network
EE TIMES.COM
THE TECHNOLOGY SITE FOR ENGINEERS AND TECHNICAL MANAGEMENT

TI and RadioScope deliver a £30 design for Eureka-147 DAB

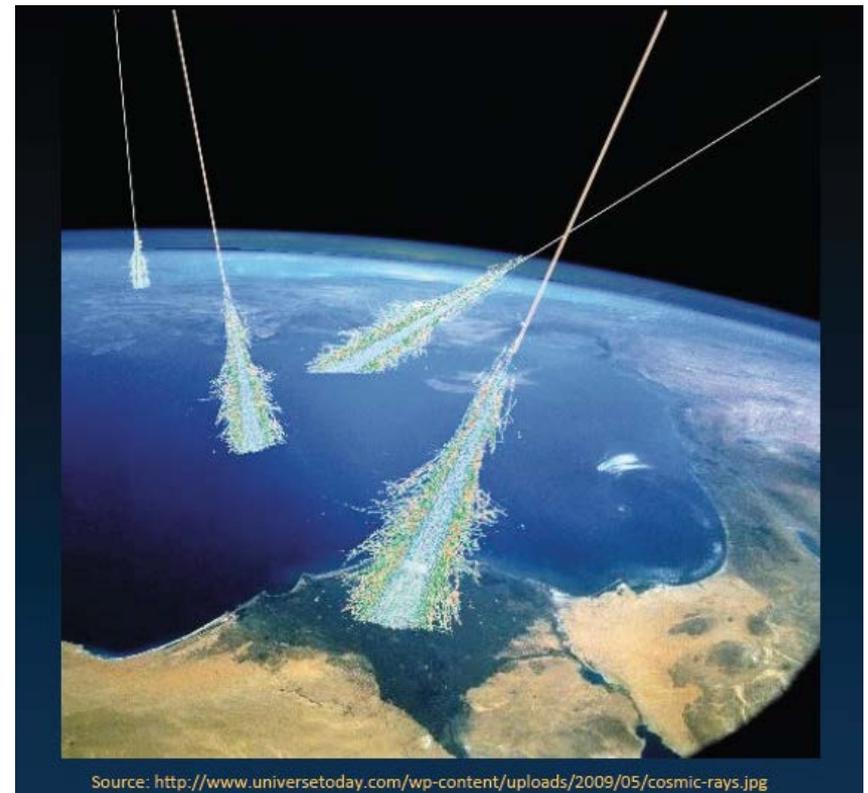
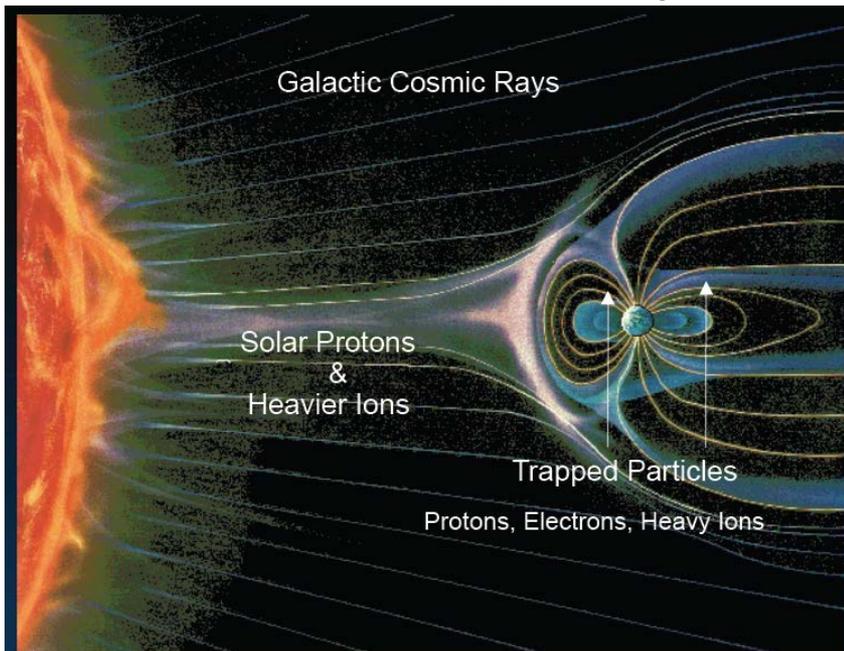
TOP OF THE NEWS

SRAM soft errors cause hard network problems
Networking equipment is growing increasingly susceptible to soft errors — nonrecoverable,

Bank Of American: Network products #1 problem is soft failure

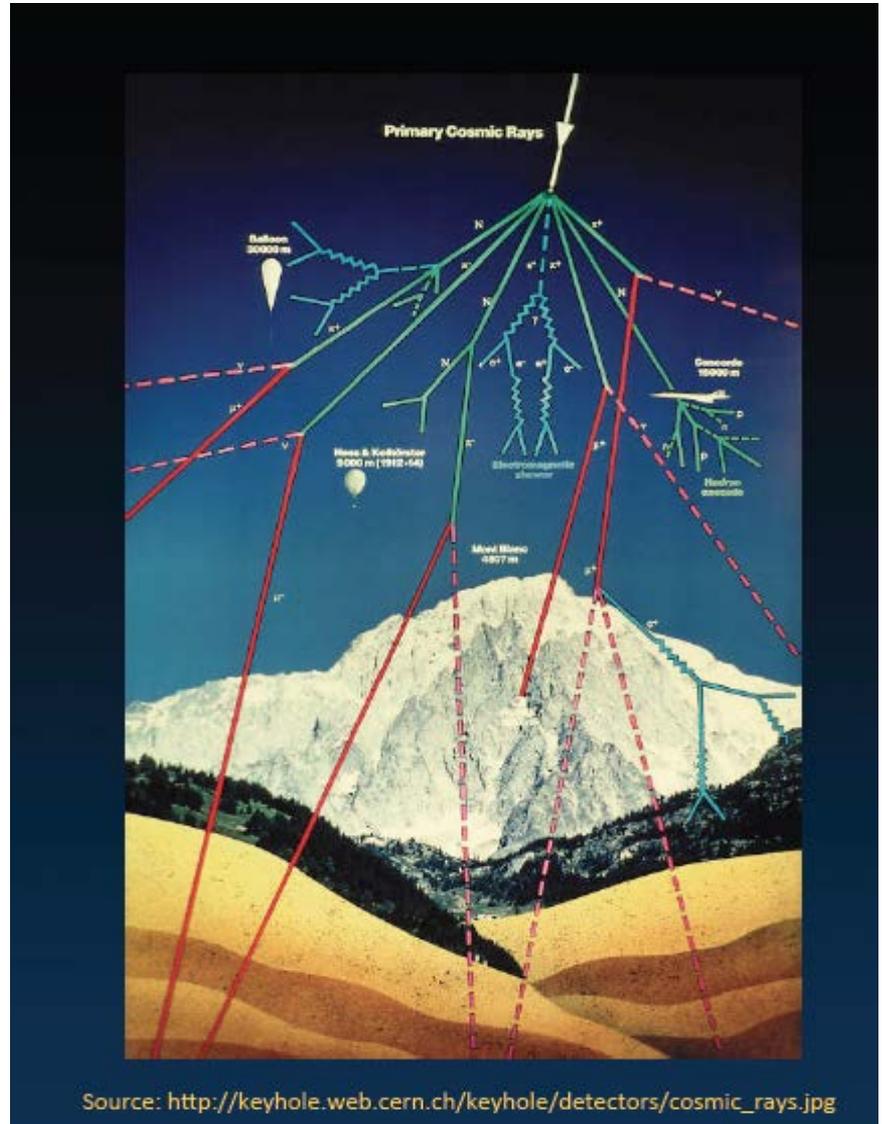
Cosmic Rays

- Natural background radiation is one of the primary sources of soft errors
- Particle sources
 - Cosmic ions from deep space
 - Usually heavy ions
 - Ions from solar activity
 - Protons, heavy ions



Cosmic Rays

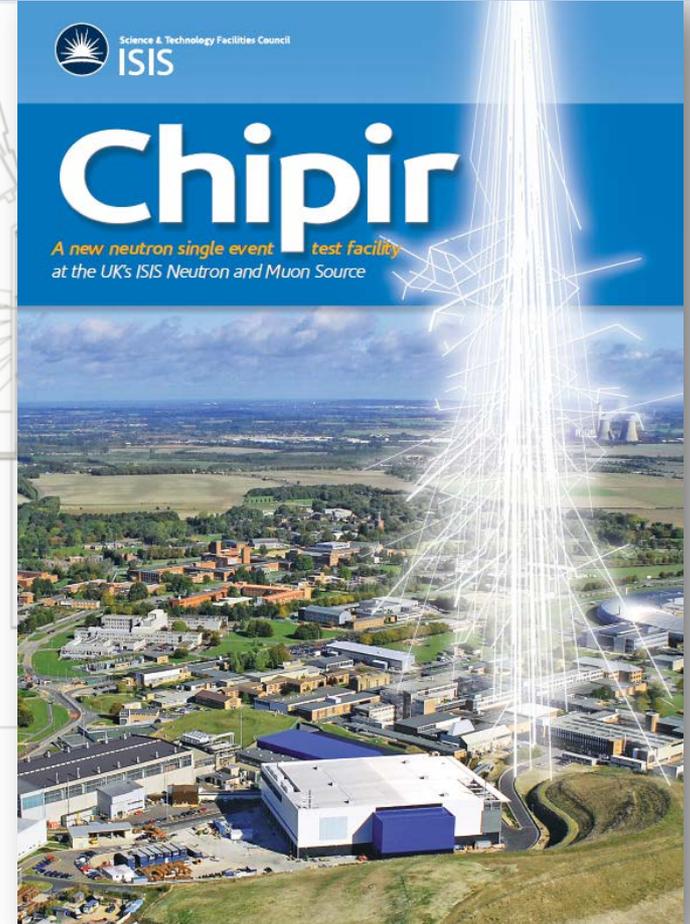
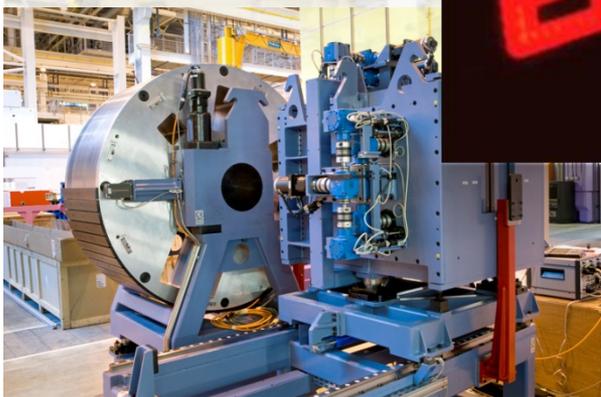
- Cosmic ray showers include neutral particles (neutrons) as well as charged particles (protons, pions, muons, ...)
- Single event upset cross section from neutron interactions dominate terrestrial single events
(eg. $n + \text{Si} \rightarrow \text{Mg} + \alpha$)
- How much will muon particles contribute to overall SER?



CHIPIR @ ISIS



Commissioning

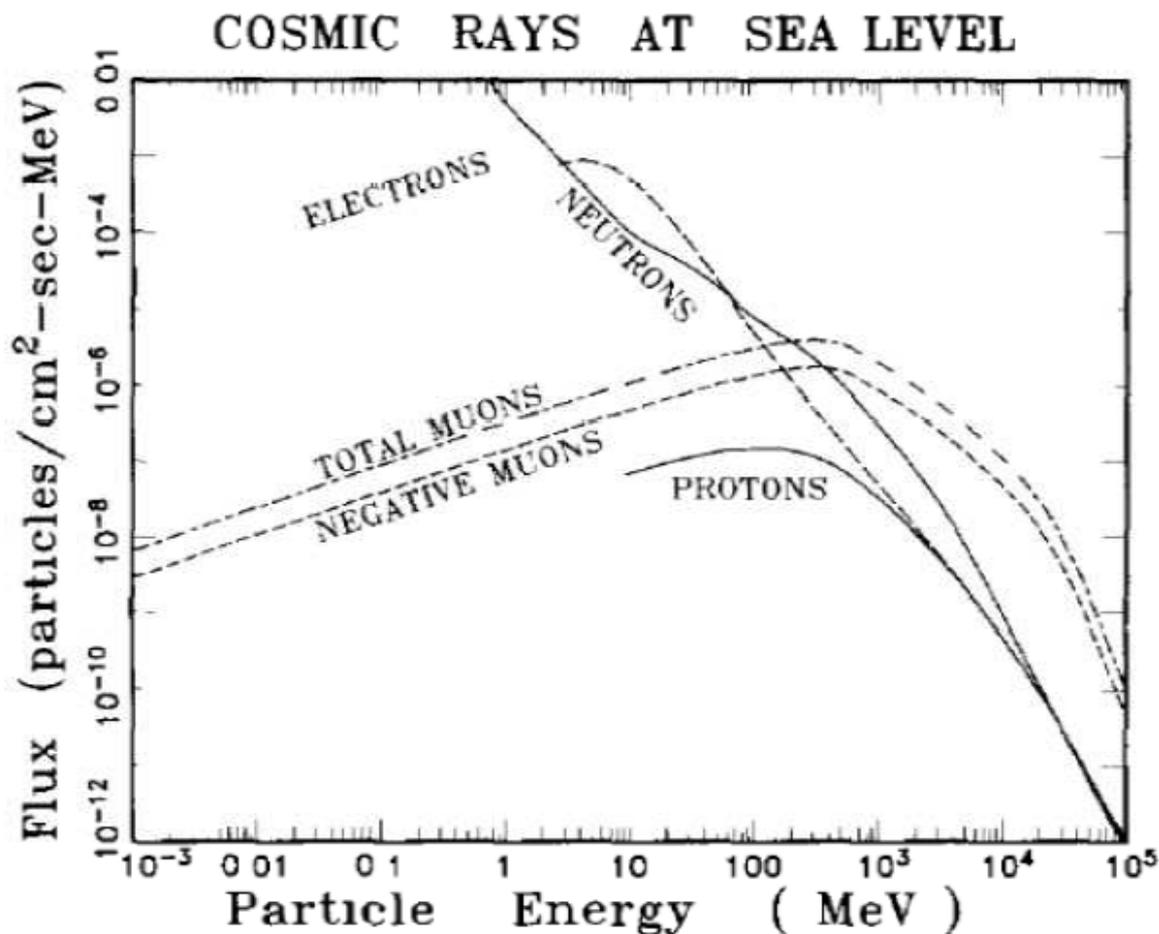


100-1000 million times
more intense

1 hour at ISIS = 100's years in real environment

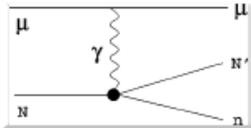
Muon Spectra

- Neutron and Muon spectra in the terrestrial environment are very different

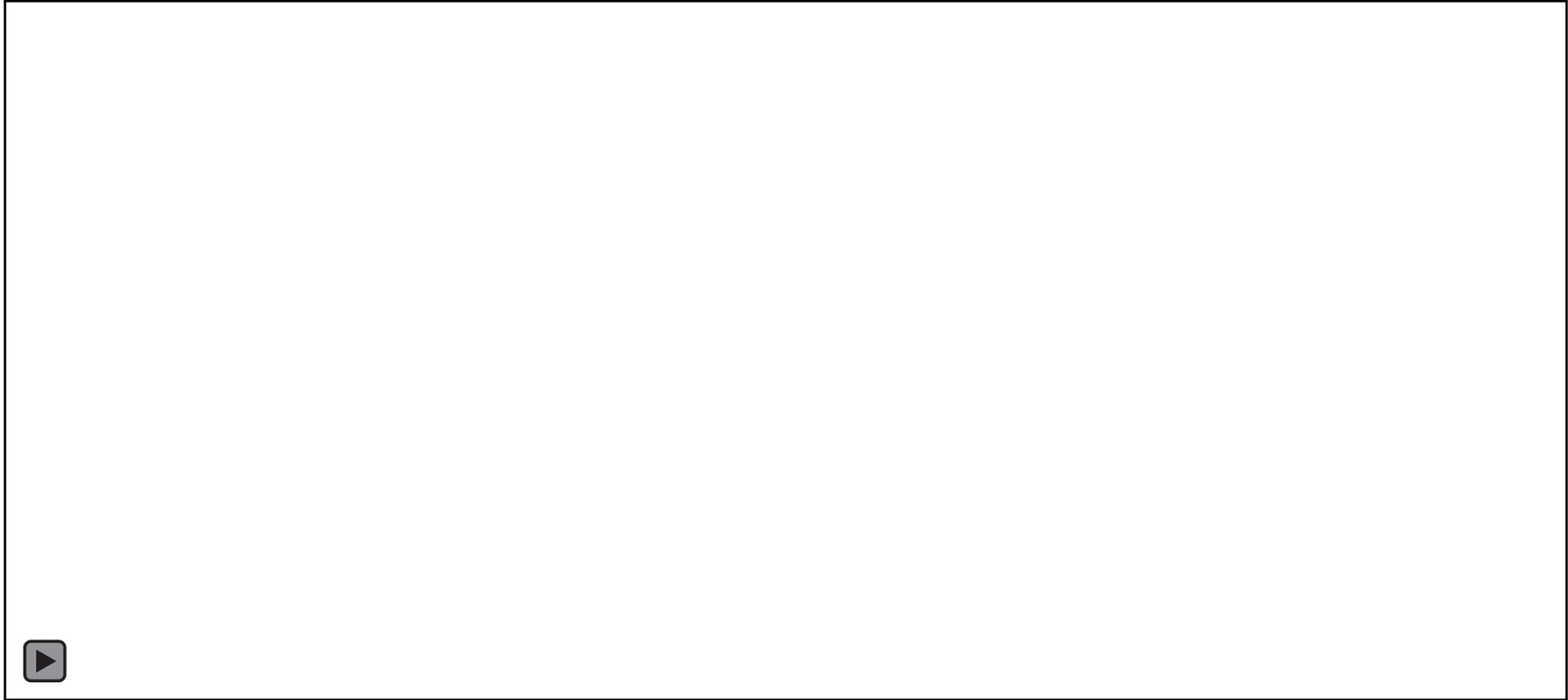


Particle Interactions with Si

- Neutrons may cause an upset through nuclear interactions
- Muons may cause an upset through coulombic reactions

Cosmic-ray induced	Interaction Type	Particle interaction with Silicon
Neutron	Strong	$n + \text{Si} \rightarrow \text{Si recoil nucleus}$ <i>elastic or inelastic scattering</i>
		$n + {}^{28}\text{Si} \rightarrow {}^{25}\text{Mg} + \alpha$ (2.75 MeV threshold) <i>ex. of nuclear reaction</i>
Proton	Electromagnetic & Strong	<i>Direct ionization wake</i>
		$p + \text{Si} \rightarrow \text{Si recoil nucleus}$ <i>elastic or inelastic scattering</i>
Muon	Electromagnetic & Weak	$p + {}^{28}\text{Si} \rightarrow {}^{25}\text{Al} + \alpha$ (7.99 MeV threshold) <i>ex. of nuclear reaction</i>
		<i>Direct ionization wake</i>
		$\mu + \text{Si} \rightarrow \text{energetic Silicon recoil}$ <i>Electromagnetic scattering</i>
		 High energy μ^- / μ^+ “ <i>spallation</i> ” process \rightarrow nuclear disintegration
		$\mu^- + \text{Si}^{28} \rightarrow \text{Al}^{28} + \nu + 100.5 \text{ MeV}$ Low energy μ^- <i>complex capture</i> by Si nucleus

Motion of an ion through Si<110>



-0.08



0

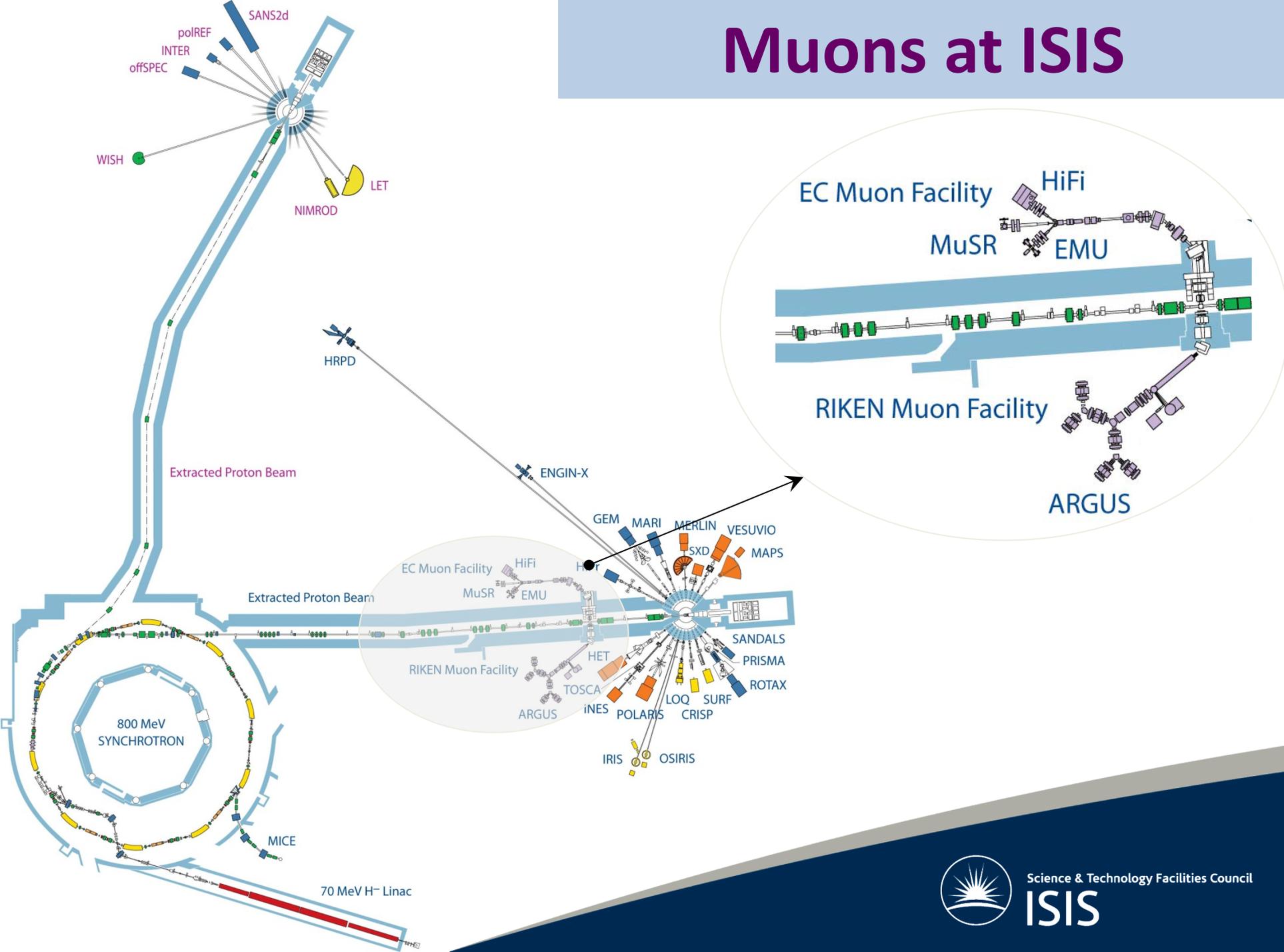
0.08

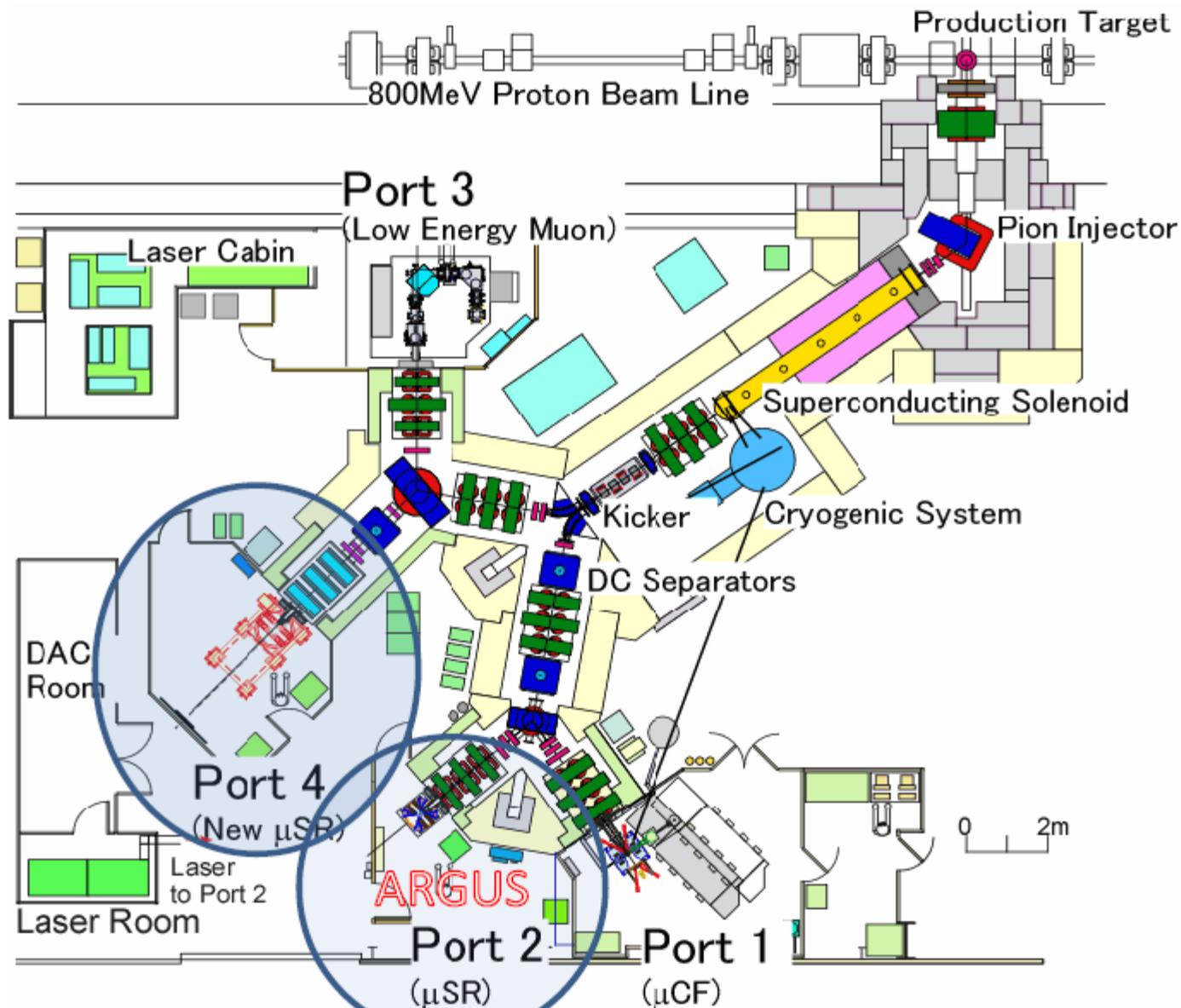
ISIS: UK's Neutron and Muon Source



Rutherford Appleton Lab

Muons at ISIS





The RIKEN-RAL Muon Facility

Meson hall, TRIUMF, Canada

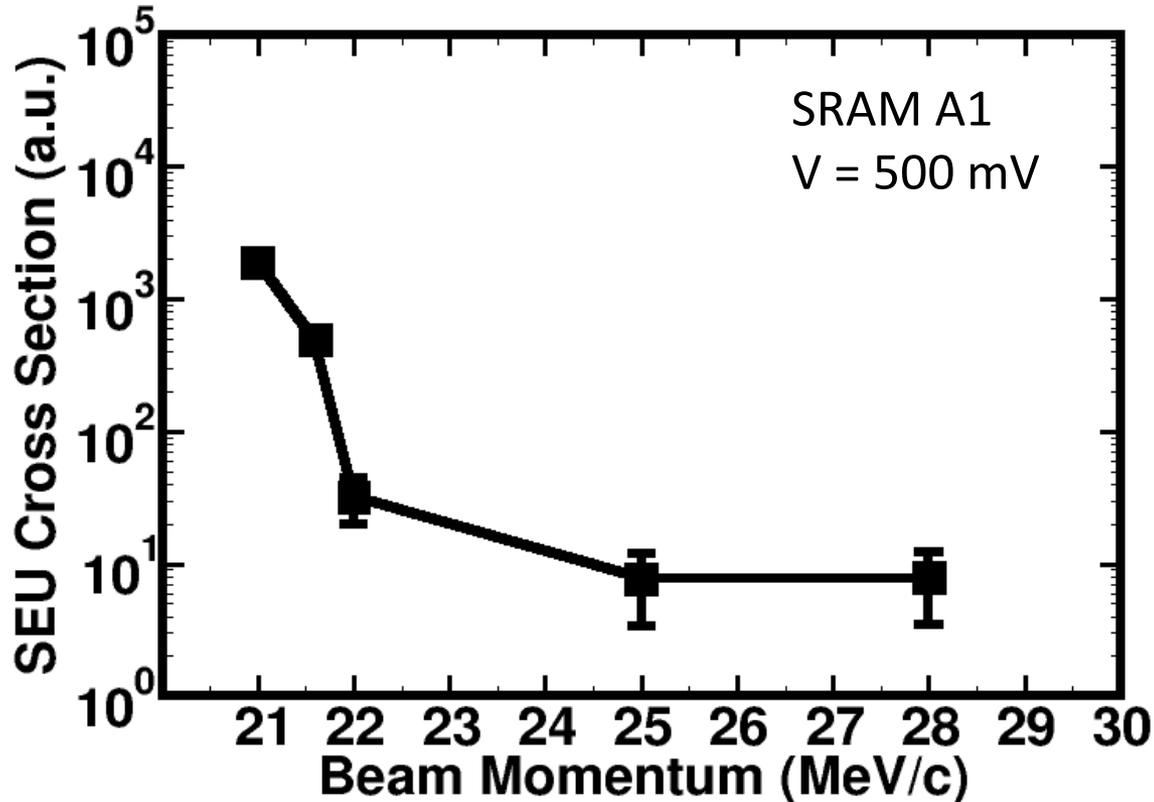


Facilities



- Variable momentum positive muons at TRIUMF and ISIS
RIKEN-RAL
- Lower momenta available through magnetic selection
- Beam further degraded by air and scintillator
- Pulse-height analysis with surface-barrier detector performed to characterize incident beam energy
- Dosimetry determined by positron decays

Depth Dependence

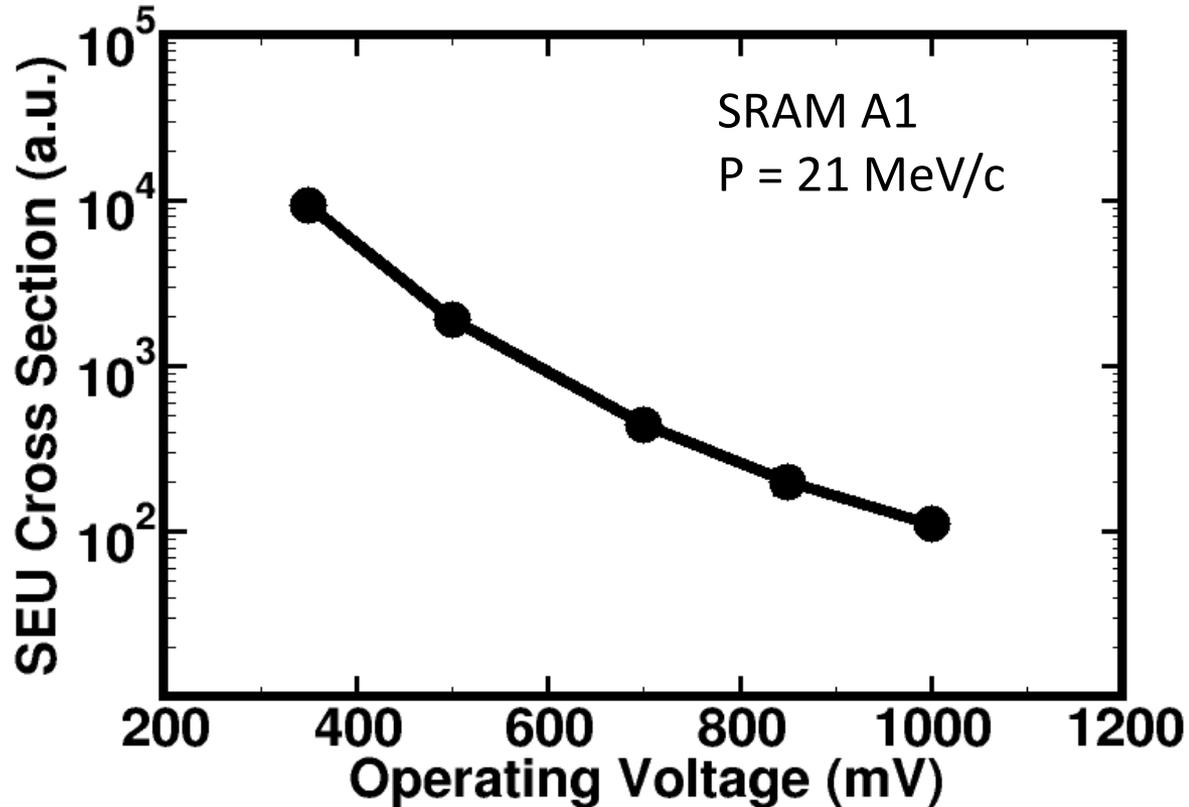


- Exposures at 28 MeV/c (TRIUMF) resulted in countable, but few upsets
- Decreased muon momentum lead to increased number of upsets down to 21 MeV/c

Reduced Bias Operation

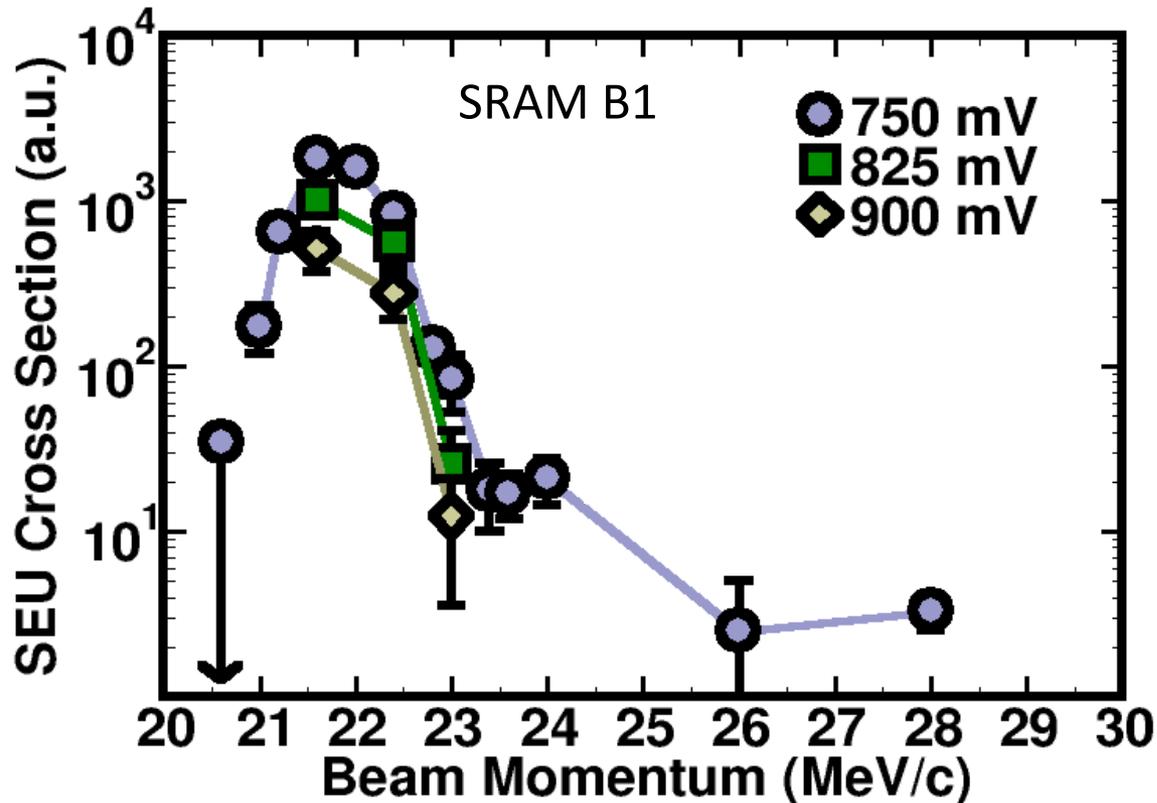
- Metric to assess the relevance for future technology nodes
- Assume that technology scaling can be approximated by decreased critical charge through reduced bias
- 65 nm SRAMs did not show significant numbers of muon-induced upsets at nominal voltage
- 45 nm SRAMs demonstrated strong bias dependence of muon-induced upset probability

Bias Dependence



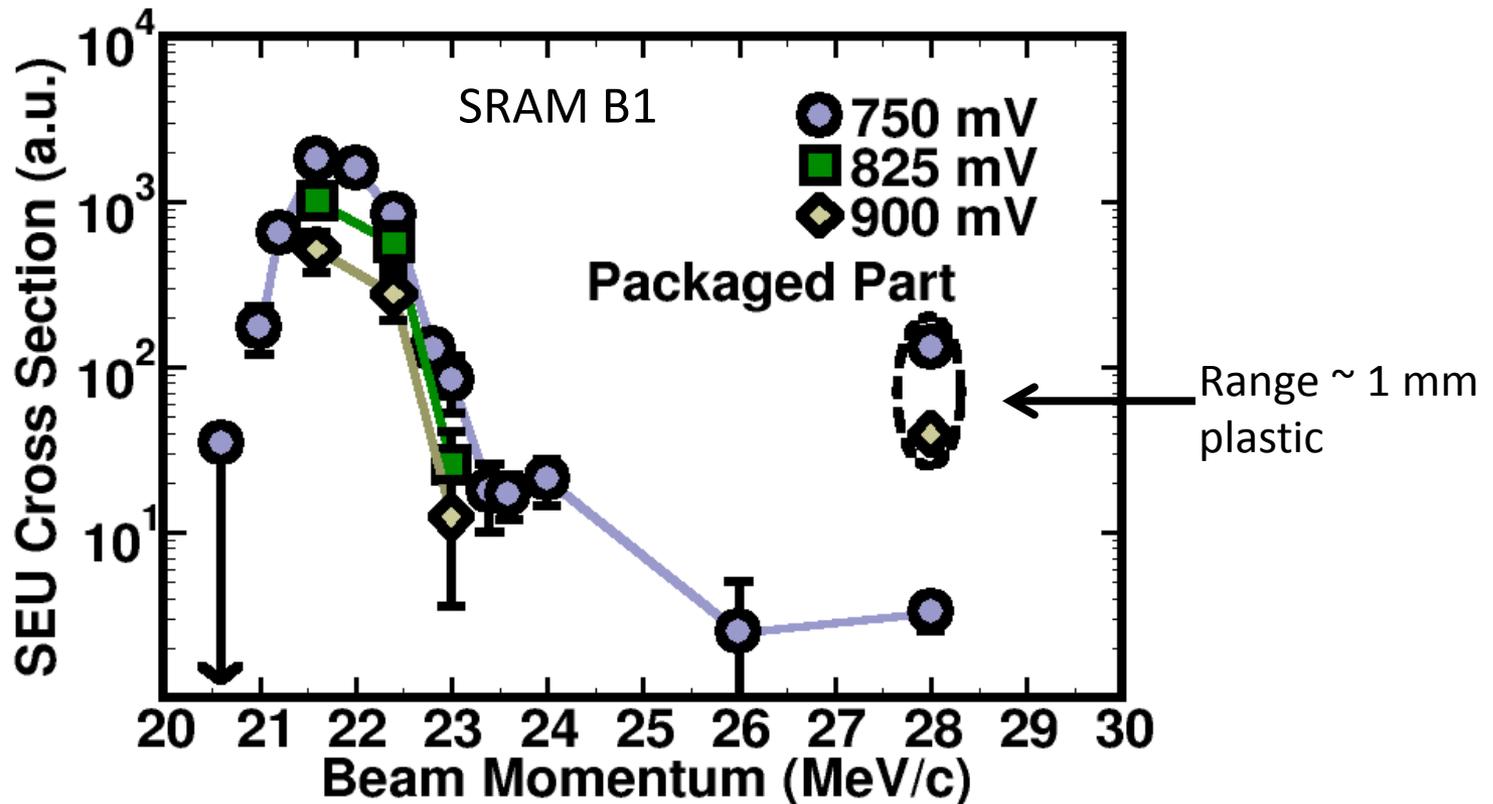
- Exposures at peak SEU cross section (21 MeV/c) conducted over bias
- Cross section increased by two orders of magnitude at lowest bias

Bias Dependence



- Exposures at the highest momentum 28 MeV/c resulted in countable, but relatively few upsets
- At 750 mV, critical charge threshold is reduced and allows muons with slightly higher momentum to upset the cells

Testing Lidded Parts



- The beam was tuned to the highest momentum to penetrate the additional packaging material
- Elevated cross section due to ionization from stopping muons
- Demonstrated potential to test lidded parts

Conclusions

- Muons can causes upsets in electronics
- Industry is taking notice!
- Experiments have shown that the muon-induced single event upset cross section increases due to reduced operating voltage over the range of muon momenta tested
- Reducing the size of the active component increases the error rate