Single Event Effect Microchip Testing
at the Texas A&M University
Cyclotron Institute

Dr. Henry Clark

SEELine Project Manager

http://cyclotron.tamu.edu/ref/

Effects from radiation on Microchips:

SEE – Single Event Effect
Dose – Total Dose from ionizing radiation

Electromagnetic (UV, x-rays, ɣ-rays) – Dose

Electrons – Dose

**Neutrons - Dose**

Light ions (protons, alphas) – Dose, SEE

**Heavy ions (N, O, Ne, Ar, Fe…U) – SEE (mainly), Dose**

SEE definitions:

- **A single event upset (SEU)** is a change of state caused by one single ionizing particle (ions, electrons, photons...) striking a sensitive node in a micro-electronic device.

- **Soft errors** are non-destructive and normally appear as transient pulses in logic or support circuitry, or as bit flips in memory cells or registers.

- **Hard errors** usually result in a high operating current, above device specifications, and must be cleared by a power reset. Burnout errors are so destructive that the device becomes operationally dead.

Example of Hard Error or Gate Rupture of MOSFET device.
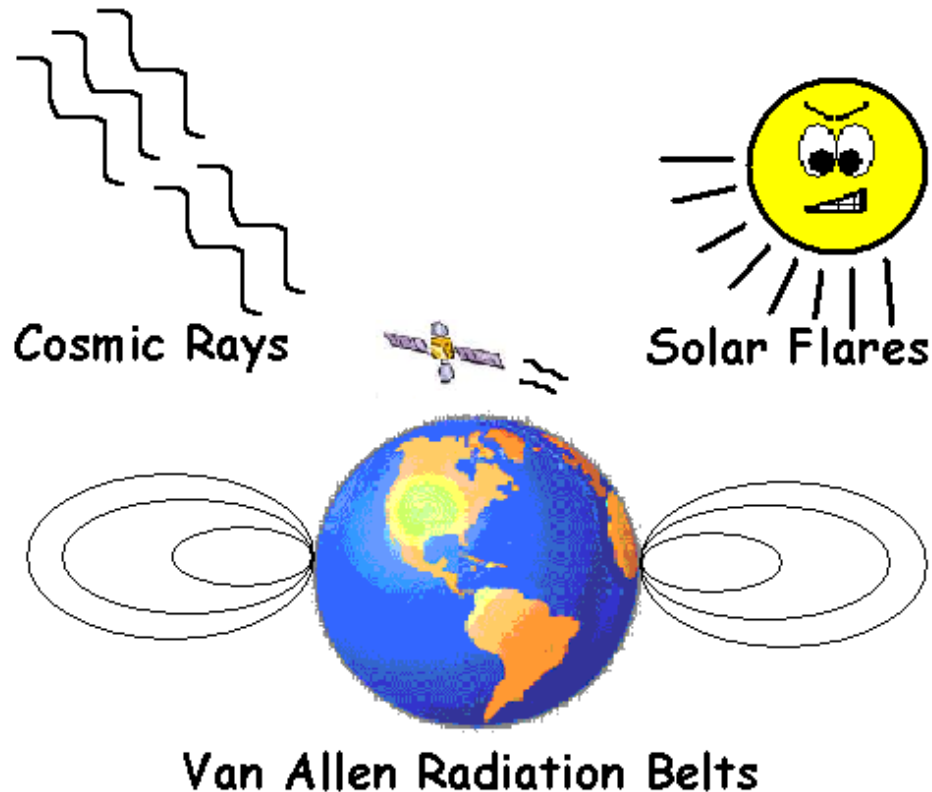
Each particle produces an ionization track
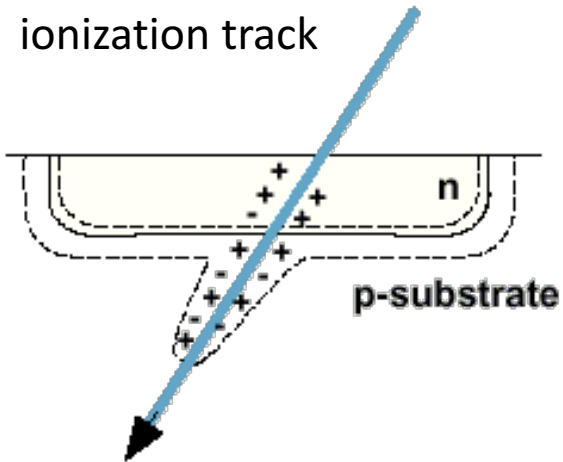
Reroutes the flow of electrons of the device – causing charge and voltage changes
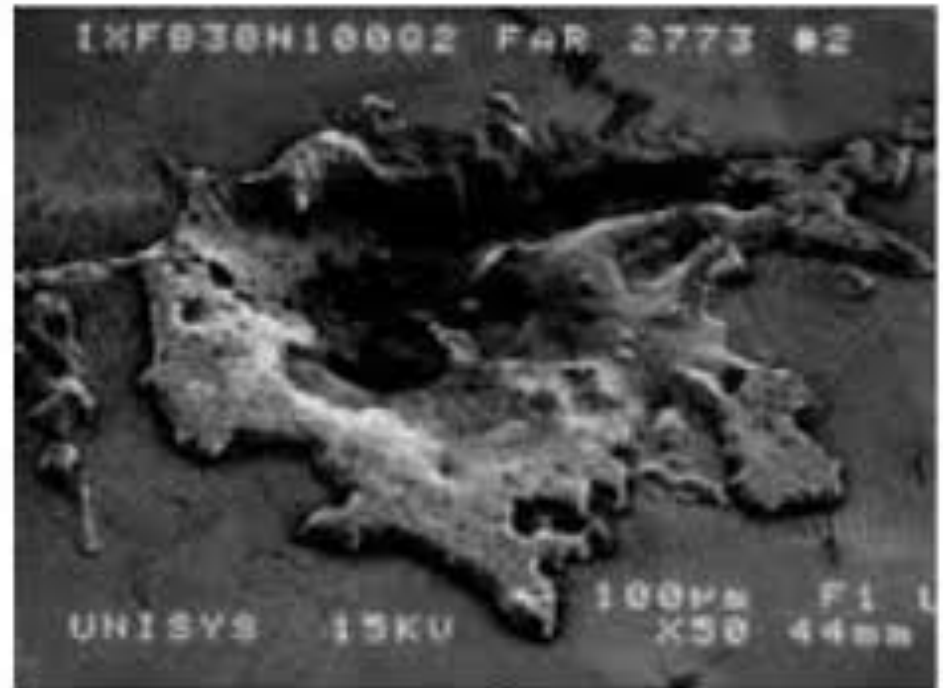
Figure 2: SEM image of failed MOSFET chip

Space Radiation Effects:

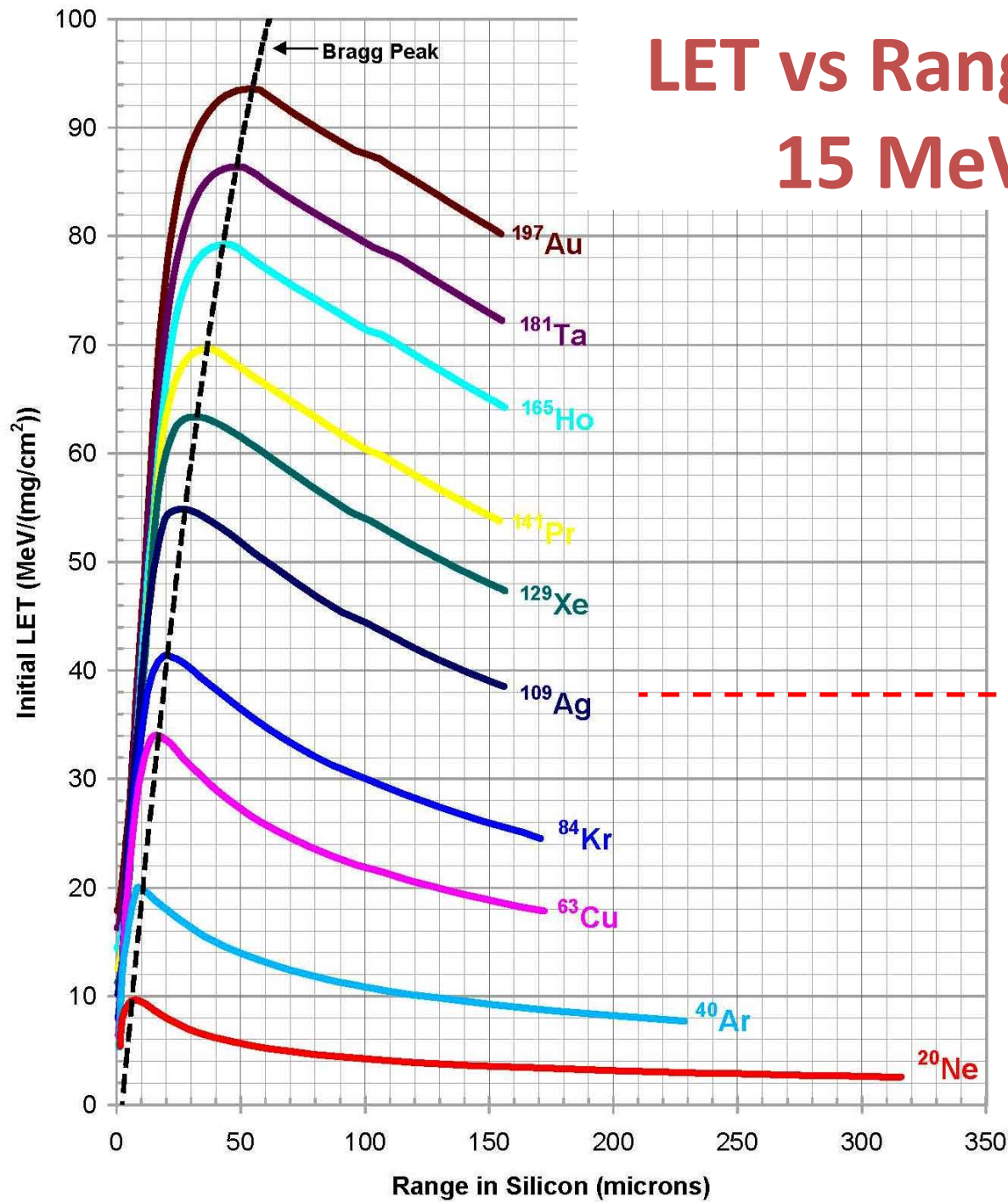- Aerospace computer equipment receives radiation from cosmic rays, solar flares and the Earth's Van Allen radiation Belts - **causing SEUs**.

- Engineers must test the resilience of their computer chips in accelerated beams here on Earth to simulate the effects that will happen in space.

Cosmic Rays

Solar Flares

Van Allen Radiation Belts

Typical SEU "Soft Error" Cross Section
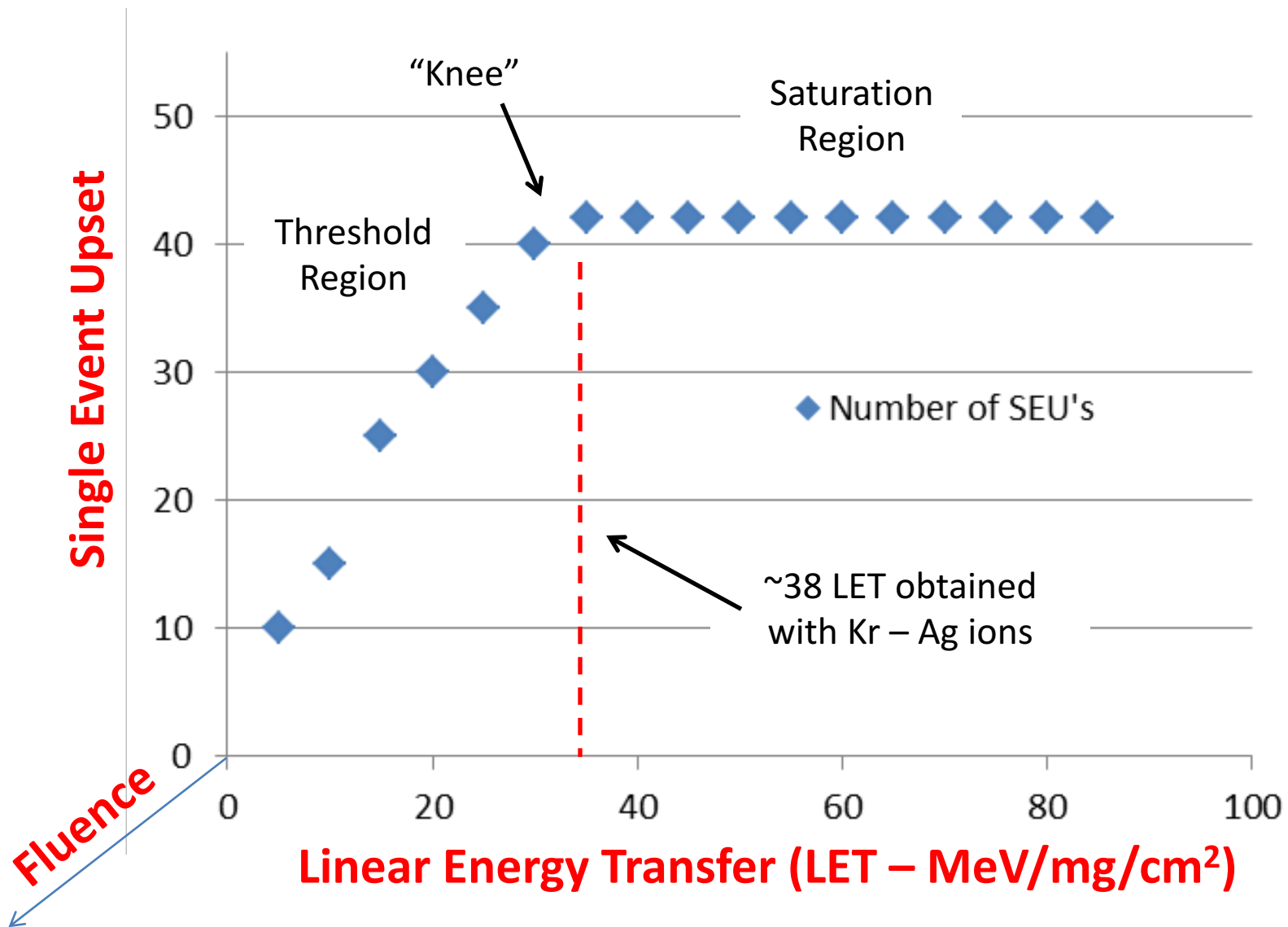
LET vs Range in Silicon 15 MeV/u ions

Two SEU Testing Stations at Texas A&M

Heavy ions – K500 Cyclotron

Protons – K150 Cyclotron

ECR ION SOURCE

K500 CYCLOTRON

RADIOACTIVE ION GUIDE

K500 RADIATION EFFECTS FACILITY 1994, 2000, 2005

BEAM ANALYSIS SYSTEM 1994

CB-ECR SOURCE

H- SOURCE

ECR ION SOURCE

MARS RECOIL SPECTROMETER 1992

Q^3 SPECTROMETER 2012

NIMROD 1999

K150 RADIATION EFFECTS FACILITY 2015

K150 (88") CYCLOTRON

TAPE TRANSPORT & PRECISION DECAY FACILITY 1999

MDM SPECTROMETER 1993, 2000

TEXAS A&M UNIVERSITY
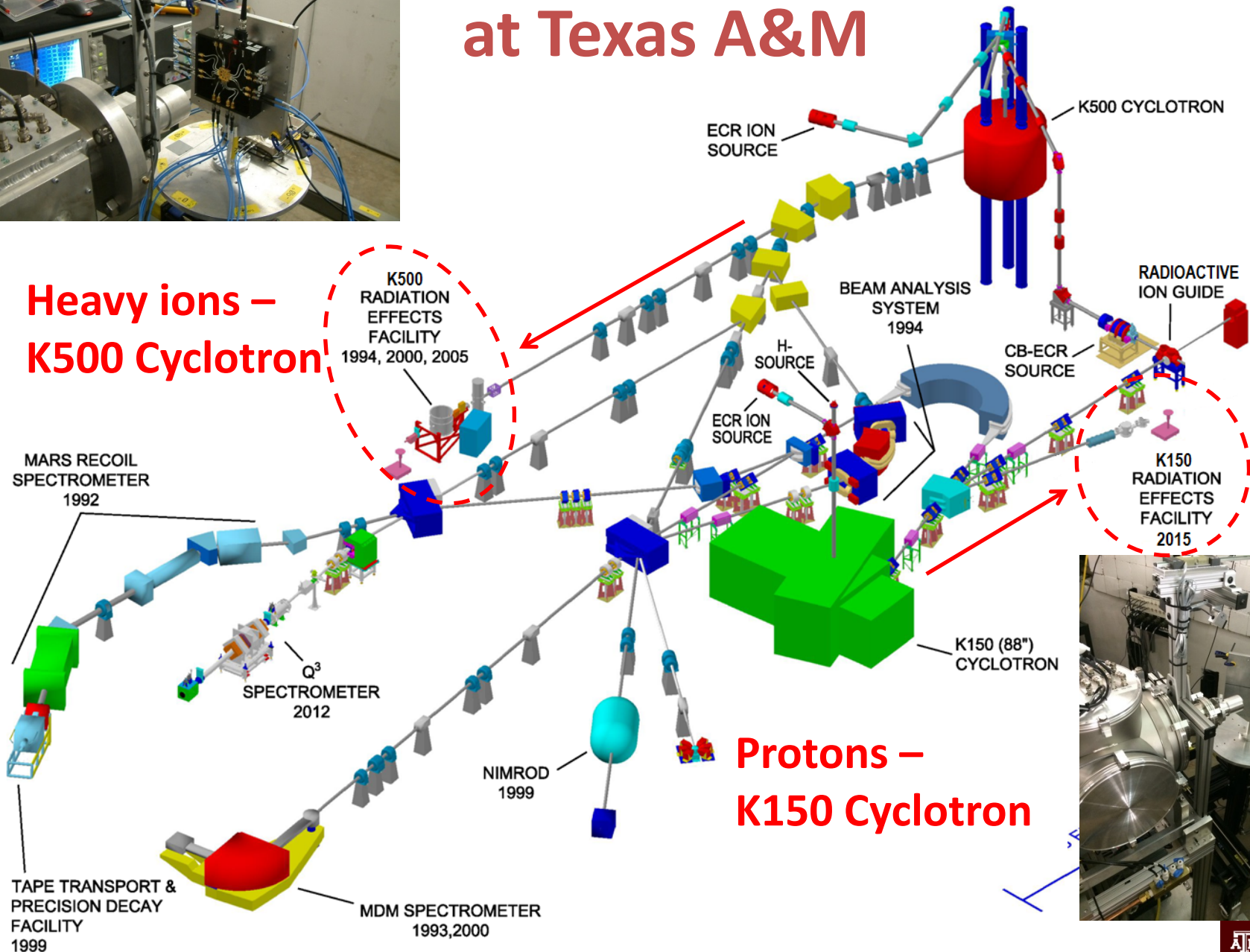
Large & Uniform Beam Spot Technique

Beam spot (intensity) must be uniform up to 3" diameter

Quadrupole Magnets "defocused mode"

~100% uniformity over 2" x, y

K150 SEE Test Line

Initial beam: 3 mm x 8 mrad

X (cm)

Y (cm)

X

Y

Q   Q   BM   Q   Q
          45 deg   F

Distance along beamline (m)

TEXAS A&M UNIVERSITY
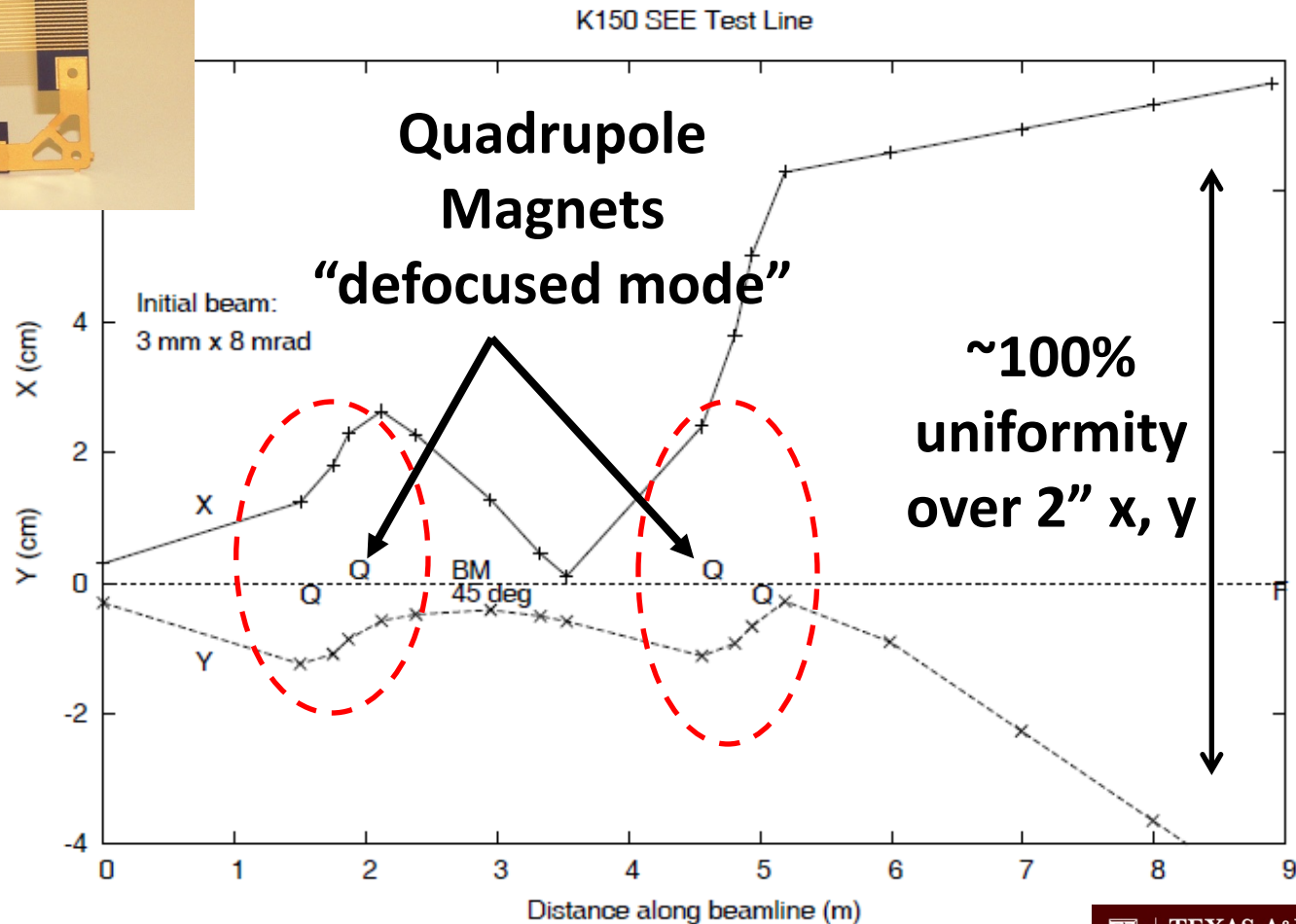
History of SEU Testing at Texas A&M

- **Began in 1995 with 10 MeV/u heavy ions, but with a limited list of beams**

- **Added high energy series (15, 25, 40 & 55 MeV/u) over years 1997-2005 (15 MeV/u is offered from ^{4}He to ^{197}Au)**

- **Offered "in-air" testing in year 2000 - usage hours increased from ~500/yr to ~2500/yr**

- **Usage hours have remained steady at >2500 hours since year 2006**

- **Usage by 1/3 Government/University and 2/3 Commercial agencies has remained consistent**

- **Usage by international agencies continues to increase (France, Japan, Italy, Korea, Singapore, Canada)**

- **In 2015, added K150 proton testing beam line (~1 – 50 MeV)**

SEU Testing Hours at Texas A&M
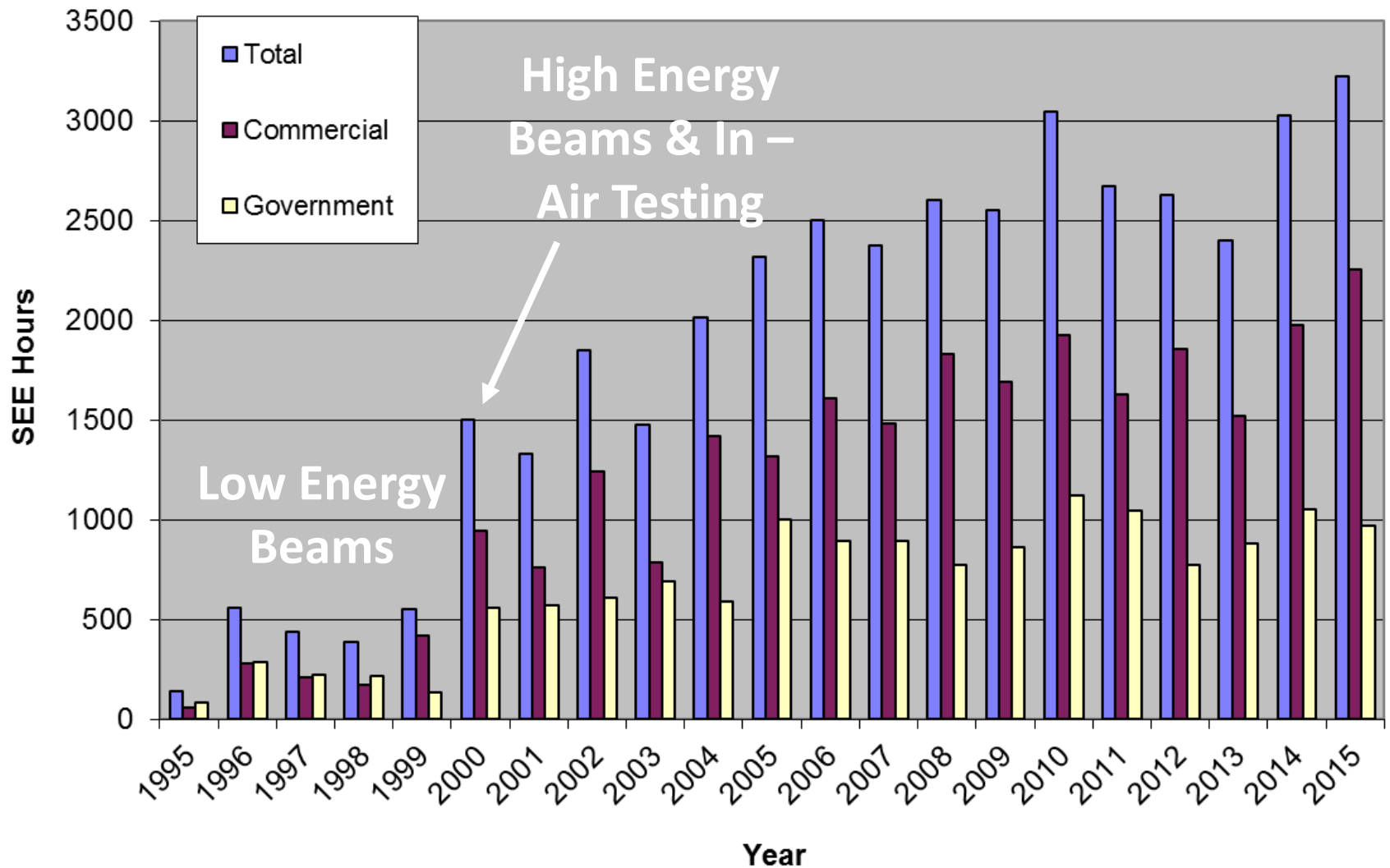
Part Size...
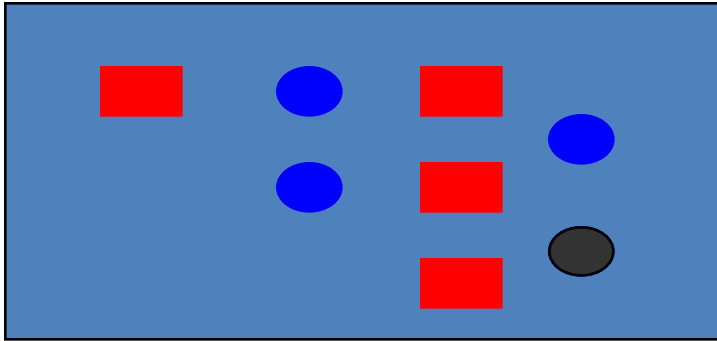
Circuit 20 years
ago – "inches"

Integrated Circuit
Today – "microns"
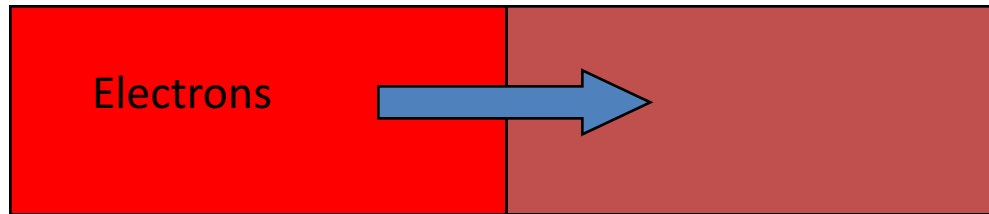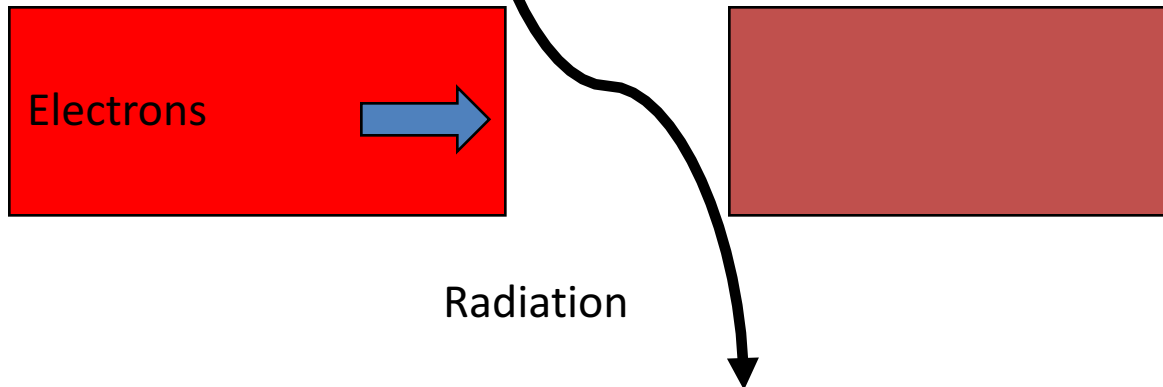
Normal Semiconductor Crystal

Electrons

Electrical Engineering

- -

Physics

"Upset"   Semiconductor Crystal

Electrons

Radiation

Single Event Upset Testing Agencies...

3D Plus	Freebird	Maxwell Engineering	Save Inc
Actel Corporation	Fuji Electric - Japan	McDonnell-Douglas	Scientic
Aeroflex	Full Circle Research	MD Robotics	SEAKR Engineering
Aerospace Corp.	General Dynamics	MDA Corp	SEMICOA
Air Force	Georgia Tech University	Michigan State University - NSCL	Signal Analysis
Airbus - France	GNSS-Norway	Micro RDC	Silicon Space Technologies
AMTEC	Harris Semiconductor	MicroSat - Canada	Silicon Turnkey Solutions
Applied Nanotech	HIREX - France	Microsemi	SOREQ - Israel
ARIA	Honeywell	Millennium Space	Southwest Research Institute
ARQ	Hughes Space Communications	Mitsubishi Heavy Industries	Stapor Research
ASTRUM - Germany	IBM	Montana State University	Star Vision
ATK Mission Research	ICS Radiation	Motorola Corporation	Sun Tronics
ATMEL - France	IMT - Italy	MSEI	T2 Research
BAE Systems	InnoFlight	NASA-Goddard Space Flight Center	Teledyne DALSA
Ball Aerospace	InnoFlight	NASA-Jet Propulsion Laboratory	TAMU Physics Department
Bionetics	Innovative Concepts, Inc.	NASA-Johnson Space Center	Texas Instruments
Blue Line Engineering	INTA	National Semiconductor	Thales Alenia Space - France
Boeing (Seattle)	Intel Corporation	Naval Research Laboratory	TRAD - France
Boeing Satellite Systems	International Rectifier	Naval Surface Warfare Center	United Space Alliance
Broadcom Communications	Intersil Corporation	Northrop Grumman	University of Colorado
CAMBR	IRCOS	Novous Technologies	University of Idaho
CEA - France	IRCOS	OptiComp Corp	University of Maryland
Cisco Systems	ITT Aerospace	Orbital ATK	University of Michigan
Cobham (RAD)	ITT Communications	Peregrine Semiconductor	University of Saskatchewan
Custom Test Sys	JAXA - Japan	Prairie View A&M University	University of Texas - El Paso
Data Devices Inc	JD Instruments	Radiation Assured Devices	Utah State University
Defense Threat Reduction Agency	Johns Hopkins	Radiation Group	Vanderbilt University
DRS Sensors	KAIST - Korea	Raytheon Corporation	VPT Inc
DSO-Singapore	L-3 Communications	RES LLC	White Sands Applied Research Laboratory
EM Photonics	Lockheed Martin	Ryoei - Japan	Woosong University - Korea
Ensign-Bickford	Los Alamos National Laboratory	SAIC	Xilinx Corporation
European Space Agency	Makel Engineering	Sandia National Laboratory	

Possible job opportunity at NASA GSFC…

Hi Henry –

I may be in the market for a physicist/engineer interested in working in our accelerator lab (two Van de Graaffs and one electrostatic machine). We do some single-event testing, though most of the work is dedicated to space physics flight instrument calibration (e.g., measures solar wind, magnetically-trapped particles, etc.) and dielectric charging characterization. Within the facility, we also operate high-energy gamma sources for ionizing dose testing. The accelerator facility is attached to the larger Radiation Effects and Analysis Group.

Anyway, if you know of some good candidates please drop me a note. I can provide more details if requested, though we are at the very early stages, so there is still more to work out.

Many thanks, Jonny

Jonathan Pellish
Code 560, Acting Associate Chief
Electrical Engineering Division
NASA Goddard Space Flight Center

Texas A&M Cyclotron Institute
K500 Operational Hours

	Total Hours	% Total
Science	3,117.00	36%
SEELine	3,295.00	38%
Scheduled Maintenance	1,275.00	15%
Beam Development	838.00	10%
Unscheduled Maintenance	211.00	2%
	8,736.00	100.0%

Annual K500 Operation:
February – December

Scheduled Maintenance:
January

- Science
- SEELine
- Scheduled Maintenance
- Beam Development
- Unscheduled Maintenance

2%
10%
15%
36%
38%
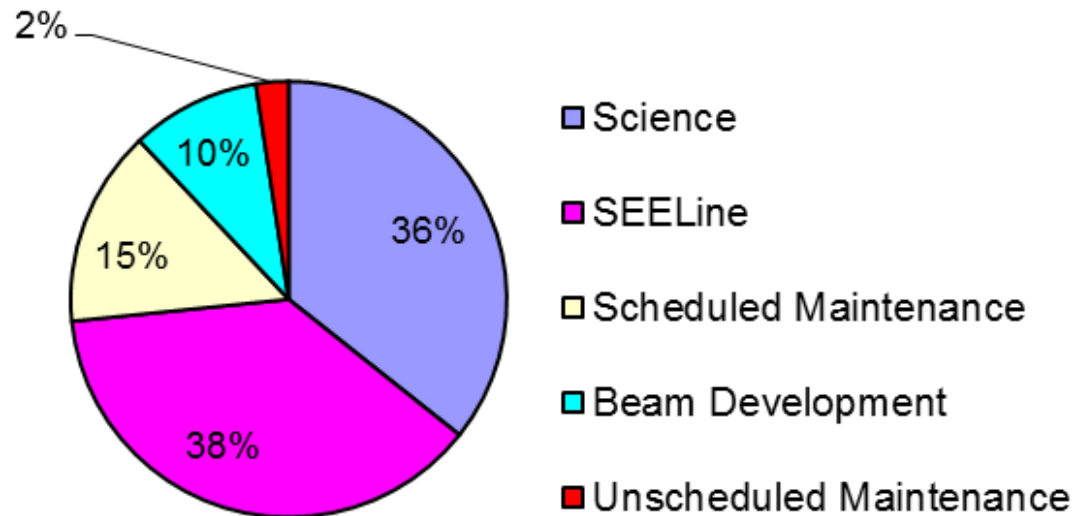
hours	Monday 6-Feb	Tuesday 7-Feb	Wednesday 8-Feb	Thursday 9-Feb	Friday 10-Feb	Saturday 11-Feb	Sunday 12-Feb
000	Shut Down Maintenance						
0800			NASA JPL SEE Line			SJY-FAUST MDM Line	
1600	V	V	V	V	V	V	V
	Monday 13-Feb	Tuesday 14-Feb	Wednesday 15-Feb	Thursday 16-Feb	Friday 17-Feb	Saturday 18-Feb	Sunday 19-Feb
000							V
0800							NASA GSFC SEE Line
1600	V	V	V	V	V	V	V
	Monday 20-Feb	Tuesday 21-Feb	Wednesday 22-Feb	Thursday 23-Feb	Friday 24-Feb	Saturday 25-Feb	Sunday 26-Feb
000							
0800				NASA JSC SEE Line			V
1600	V	V	V	NASA JPL SEE Line	V	V	Lock Mart SEE Line
	Monday 27-Feb	Tuesday 28-Feb	Wednesday 1-Mar	Thursday 2-Mar	Friday 3-Mar	Saturday 4-Mar	Sunday 5-Mar
000							
0800	SJY NIMROD	V	V	Aeroflex SEE Line			
1600	V	Raytheon SEE Line	Lock Mart SEE Line	NAVSEA SEE Line	V	V	V
	Monday 6-Mar	Tuesday 7-Mar	Wednesday 8-Mar	Thursday 9-Mar	Friday 10-Mar	Saturday 11-Mar	Sunday 12-Mar
000			V				
0800	V		NAVSEA		RET-Catania MDM Line		
1600	Maintenance V		SEE Line V	V			
	Monday 13-Mar	Tuesday 14-Mar	Wednesday 15-Mar	Thursday 16-Mar	Friday 17-Mar	Saturday 18-Mar	Sunday 19-Mar
000					V		
0800					RET MARS Line		
1600	V	V	V	V	V	V	V
	Monday 20-Mar	Tuesday 21-Mar	Wednesday 22-Mar	Thursday 23-Mar	Friday 24-Mar	Saturday 25-Mar	Sunday 26-Mar
000	V			V			Beam Development
0800	Boeing Sat Sys SEE Line			Intern Rect SEE Line	V		SJY NIMROD
1600	V	V	V	V	BAE Systems SEE Line	V	V
	Monday 27-Mar	Tuesday 28-Mar	Wednesday 29-Mar	Thursday 30-Mar	Friday 31-Mar	Saturday 1-Apr	Sunday 2-Apr
000					V	Beam Development	Beam Development
0800	Boeing Sat Sys SEE Line	V	V	V	PVAMU SEE Line	NASA JSC SEE Line	
1600	V	Raytheon SEE Line	Lock Mart SEE Line	Beam Development	V	V	V

Typical Beam Schedule:

- 1 – 2 weeks SEU Testing (yellow)

- 1 – 2 weeks of Science Experiments (all other colors)

- Schedule 6 – 8 weeks in advance

Accelerator Physics Group

Dr. Henry Clark

Dr. Don May

Dr. George Kim

Dr. Greg Chubarian

Dr. Gabriel Tabacaru

Dr. Vladimir Horvat

Dr. Brian Roeder

Mr. Bruce Hyman

Mr. Joe Brinkley

Mr. Stephen Gerlt

Visit our website at
http://cyclotron.tamu.edu/ref/

Questions, contracting, scheduling
contact Henry Clark at
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