REU 2013 Career Day
Radiation Effects Testing

Henry L. Clark, Ph D

Accelerator Physicist /

SEE Line Project Manager / Upgrade Project Manager

Cyclotron Institute, Texas A&M University

Education

- 1988 B.S. in Physics, Ohio University
  - Undergraduate thesis/research nuclear physics
- 1993 Ph.D. in Nuclear Physics, Ohio University
  - High Energy Physics at Fermi Nat Lab, Batavia, Ill
  - Summer positions at Los Alamos Nat Lab, Brookhaven Nat Lab
  - Experiments at Indiana U and Oak Ridge Nat Lab

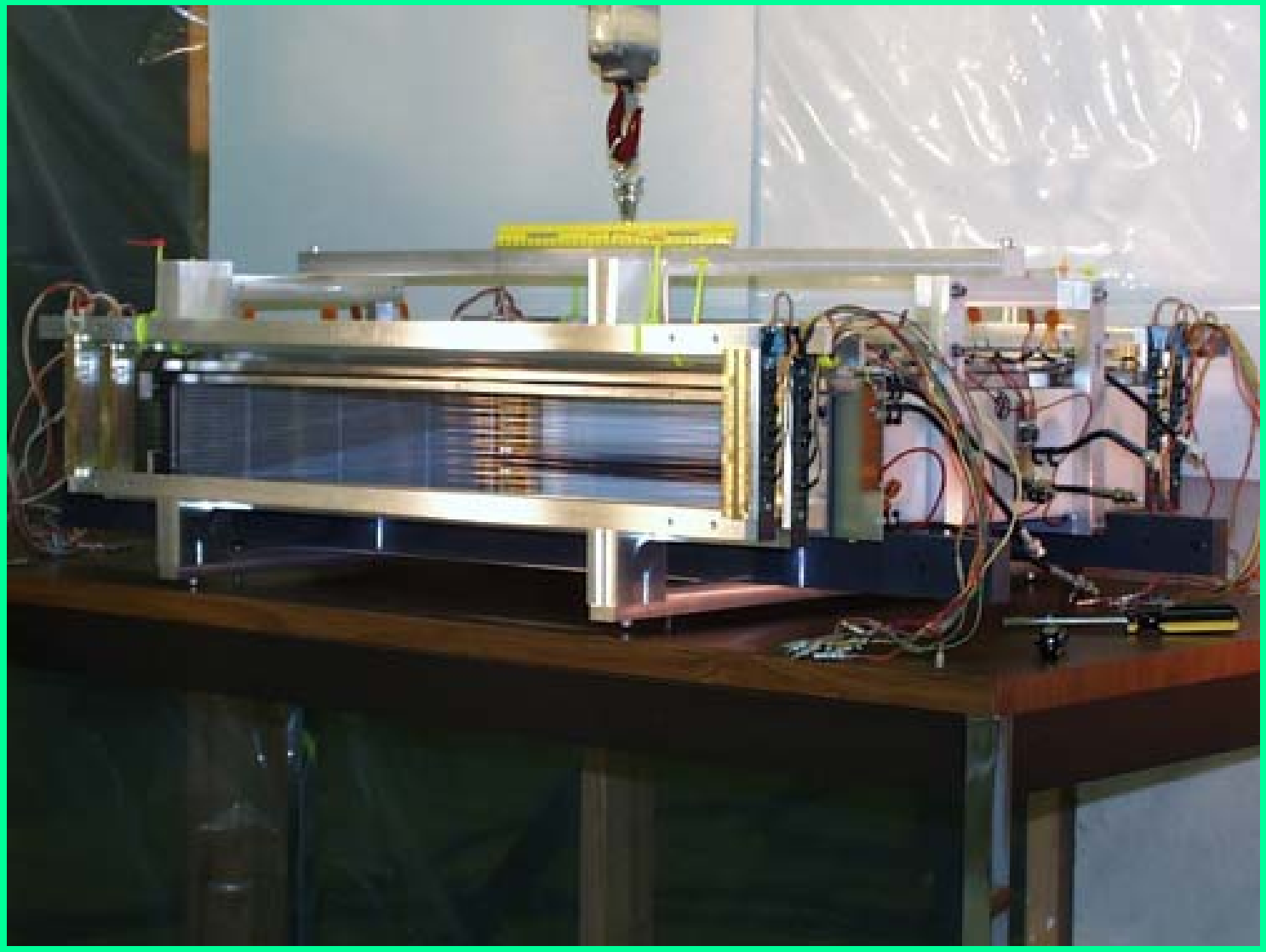
Cyclotron Institute

1993 – 1998:

Research Associate (Dr. Youngblood)

- Giant resonance studies (GMR, ISGDR…)
- Designed and built MDM large focal plane detector
- Over 50 publications in Scientific journals
- Presentations at Conferences and Workshops in USA, Europe and Asia
- Very exciting and rewarding Research project!

MDM Focal Plane Detector

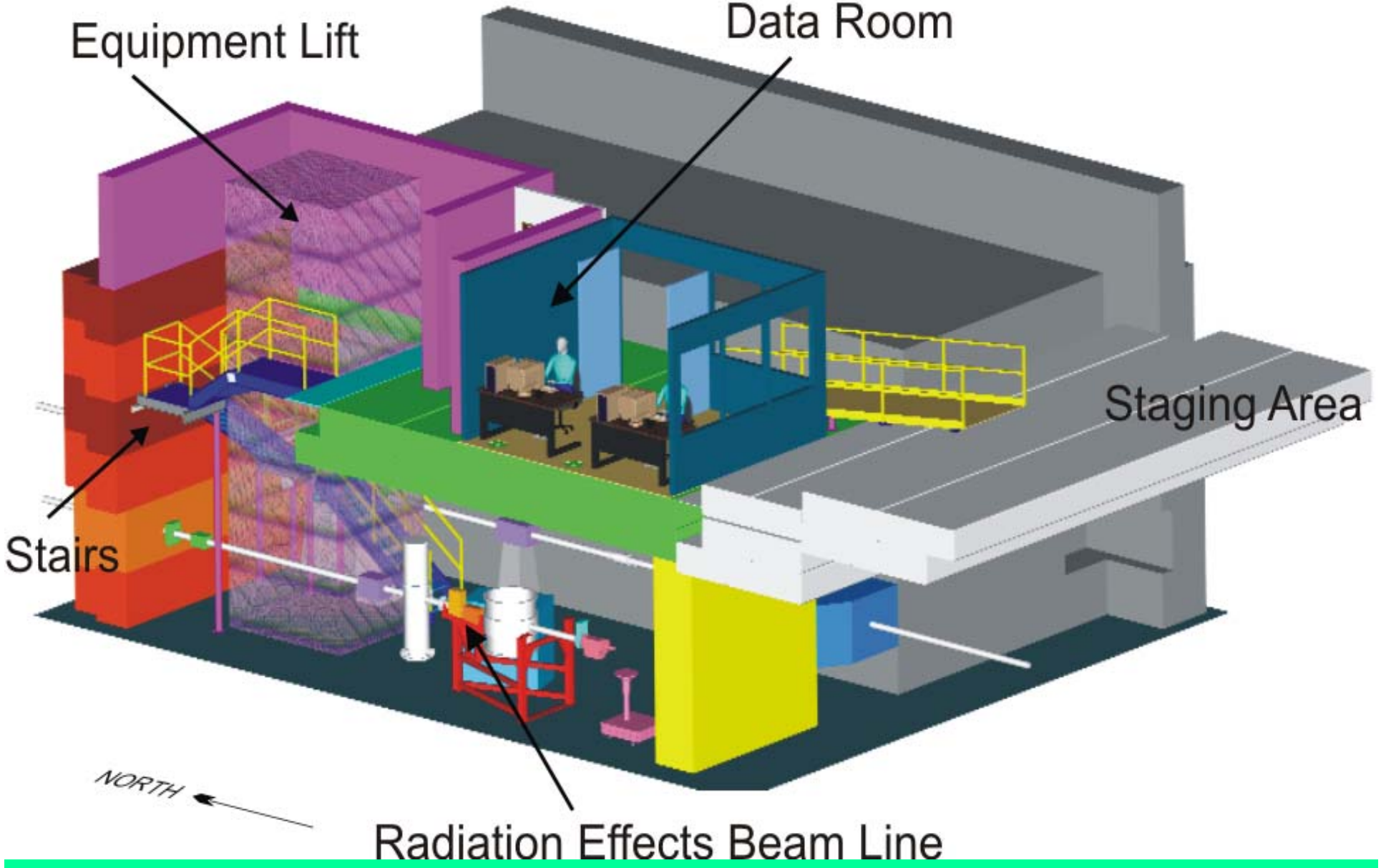


Cyclotron Institute

1998 – Present:

Accelerator Physicist / SEE Line Project

- Upgraded capabilities / Improvements
- Built large customer base
- Manager of the Project (business project!)
- Scheduling – interleaving with Science Programs
- Contracts and Invoicing
- Annual audit with Texas A&M FMO to determine hourly rates for Government and Commercial agencies
- As usage grew over time – added personnel to the Accelerator Physics Group – from 5 to 10 people

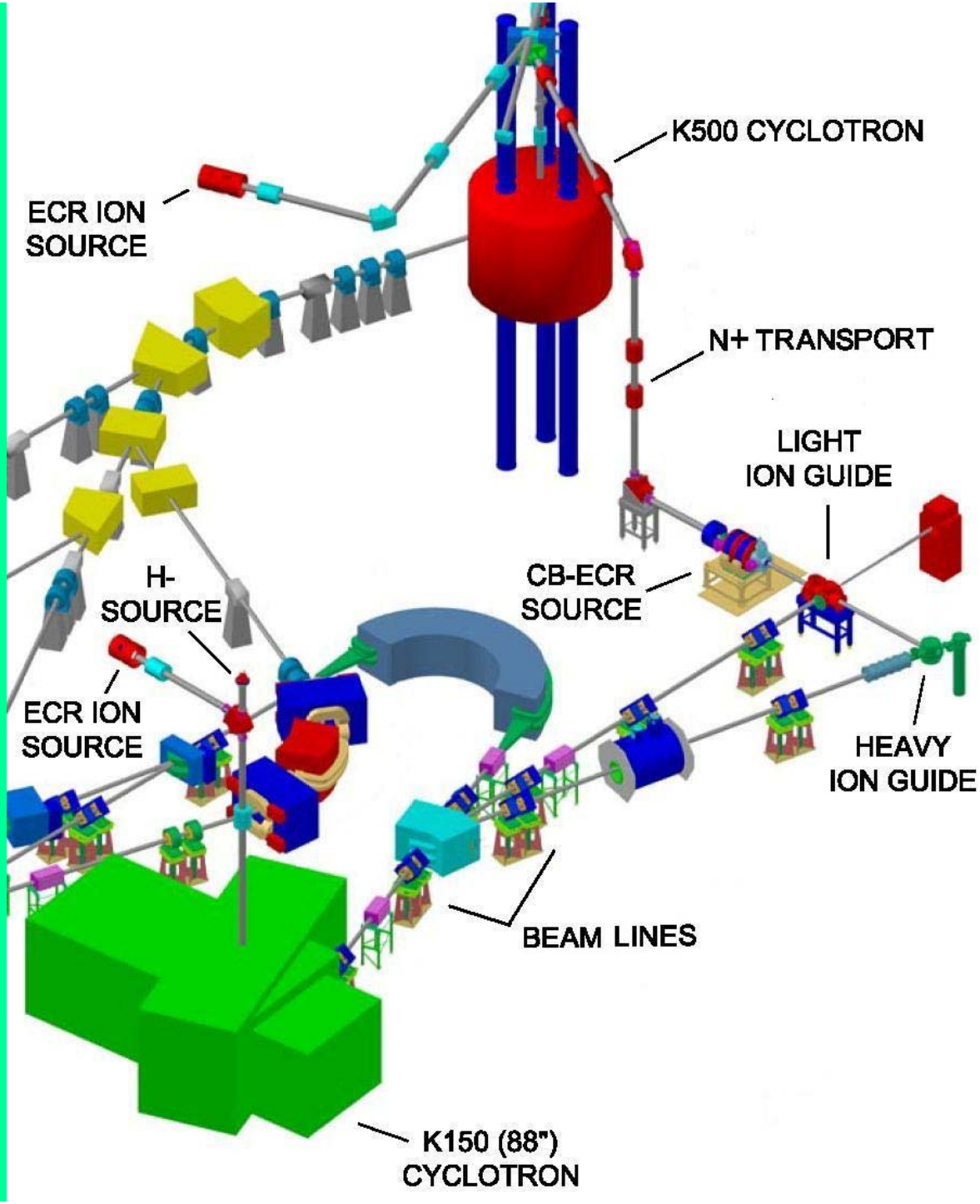

Equipment Lift
Data Room
Staging Area
Stairs
NORTH
Radiation Effects Beam Line

Cyclotron Institute

2005 – Present:

Upgrade Project Manager

- Recommissioning of 88” (K150) cyclotron
- Funding DOE, State, Welch Foundation, SEE Line
- Restoration & utility improvements
- Beam lines to existing K500 experiments
- Ion Guides for reaccelerating radioactive ions
- Liaison with DOE on project status and spending


K500 CYCLOTRON
ECR ION SOURCE
N+ TRANSPORT
LIGHT ION GUIDE
CB-ECR SOURCE
H- SOURCE
ECR ION SOURCE
HEAVY ION GUIDE
BEAM LINES
K150 (88") CYCLOTRON

Texas A&M University Cyclotron Institue SEELine Testing

- Began in 1995 with 10 MeV/u ions, limited list of beams
- Added high energy series (15, 25, 40 & 55 MeV/u) over 1997-2005
- Offered “in-air” testing in 2000 - usage hours increased from ~500/yr to ~2,500/yr
- Usage by 1/3 Government/University and 2/3 Commercial agencies
- Increase in international agencies in the past few years, including France, Japan, Korea and Spain (recent)…

Accelerator Physics Group

Dr. Don May, Dr. George Kim,

Dr. Henry Clark, Dr. Greg Chubarian,

Dr. Gabriel Tabacaru, Dr. Lixin Chen,

Dr. Vladimir Horvat, Dr. Brian Roeder,

Mr. Joe Brinkley and Mr. Bruce Hyman

~100 Testing Agencies

Actel Corporation
Aeroflex Corporation
Aerospace Corporation
Air Force
AMTEC Corporation
ASTRUM - France
ATK Mission Research
BAE Systems
Ball Aerospace
Boeing Corporation
Boeing Research & Technology
Boeing Satellite Systems
Broadcom Communications
CAMBR / University of Idaho
CEA - France
Cisco Systems
Data Device Corporation
Full Circle Research
General Dynamics
Georgia Tech University
Harris Semiconductor
HIREX - France
Honeywell
Hughes Space Communications
IBM Corporation
ICS Radiation
Innovative Concepts, Incorporated
Intel Corporation
International Rectifier
Intersil Corporation
ITT Aerospace
ITT Communications
JD Instruments
Johns Hopkins
Lockheed Martin
Los Alamos National Laboratory
Makel Engineering
Maxwell Engineering
McDonnell-Douglas
MD Robotics
MDA Corporation
Michigan State University-NSCL
Micro RDC
MicroSemi Corporation
Mitsubishi Heavy Industries
Motorola Corporation
NASA Goddard Space Flight Center
NASA Jet Propulsion Laboratory
NASA Johnson Space Center
NASA-Goddard Space Flight Center
National Semiconductor
Naval Research Laboratory
Naval Surface Warfare Center
Northrop Grumman
Novous Technologies
OptiComp Corporation
Peregrine Semiconductor
Prairie View A&M Center For Applied Radiation Research
Radiation Assured Devices
Raytheon Corporation
SAIC
Sandia National Laboratory
Save Incorporated
SEAKR Engineering
Silicon Space Technologies
Silicon Turnkey Solutions
SOREQ - Israel
Southwest Research Institute
Stapor Research
Star Vision
Sun Tronics
Texas Instruments
Thales Alenia-France
TRAD-France
United Space Alliance
University of Colorado
University of Idaho
University of Texas - El Paso
Vanderbilt University
VPT Incorporated
White Sands Army Research Laboratory
Xilinx Corporation

People in Radiation Effects

1/3 – Electrical Engineers

2/3 – Physicists

EE degrees – MS and BS

Physics degrees – MS and BS

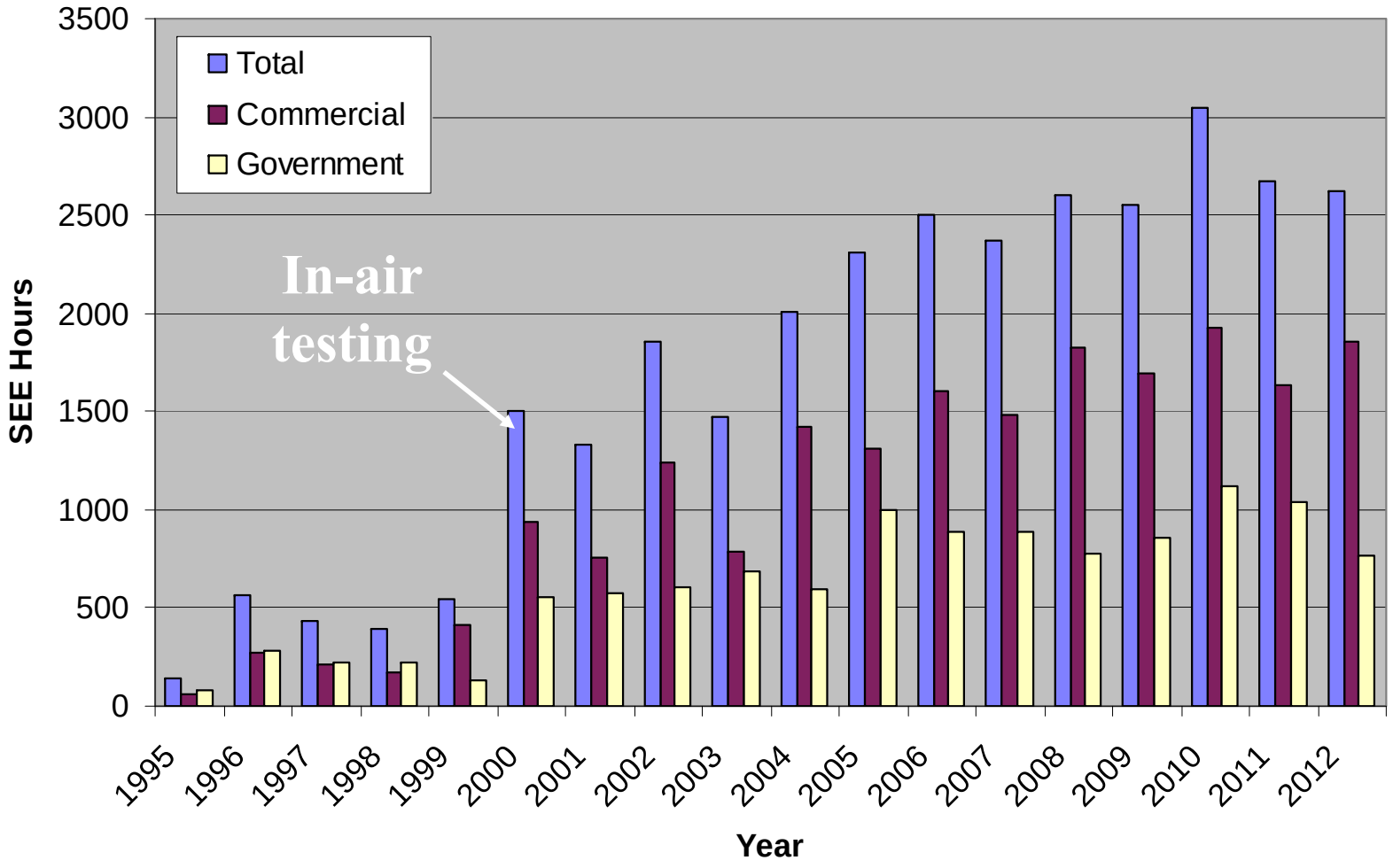
Group Leaders – Ph D

More Information

Nuclear Radiation Effects Conference (NSREC)

www.nsrec.org

Billed Hours / Year



~3,000 Hours of SEE Line

Normal office: 52 weeks/year

x (5 days/week)

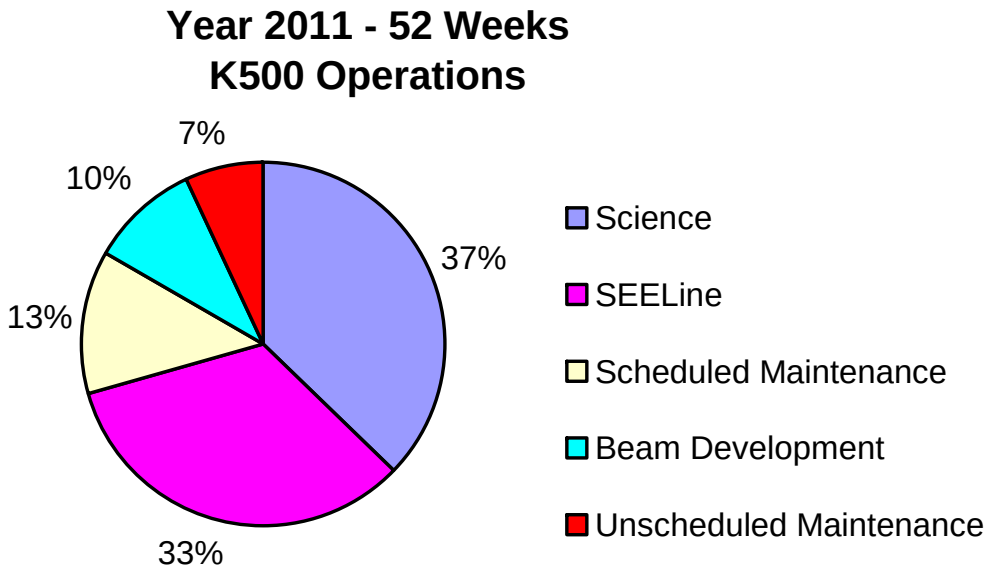
x (8 hours/days)

= 2,080 hours (66%)

Typical hours per year

Year 2011 K500 Analysis
52 Weeks

	Total Hours	% Total
Science	3,240.00	37%
SEELine	2,924.00	33%
Scheduled Maintenance	1,128.00	13%
Beam Development	832.00	10%
Unscheduled Maintenance	612.00	7%
	8,736.00	100.0%



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

Typical Beam Schedule:

1 – 2 weeks Radiation Effects (yellow) then, 1 – 2 weeks of Nuclear Physics (all other colors)

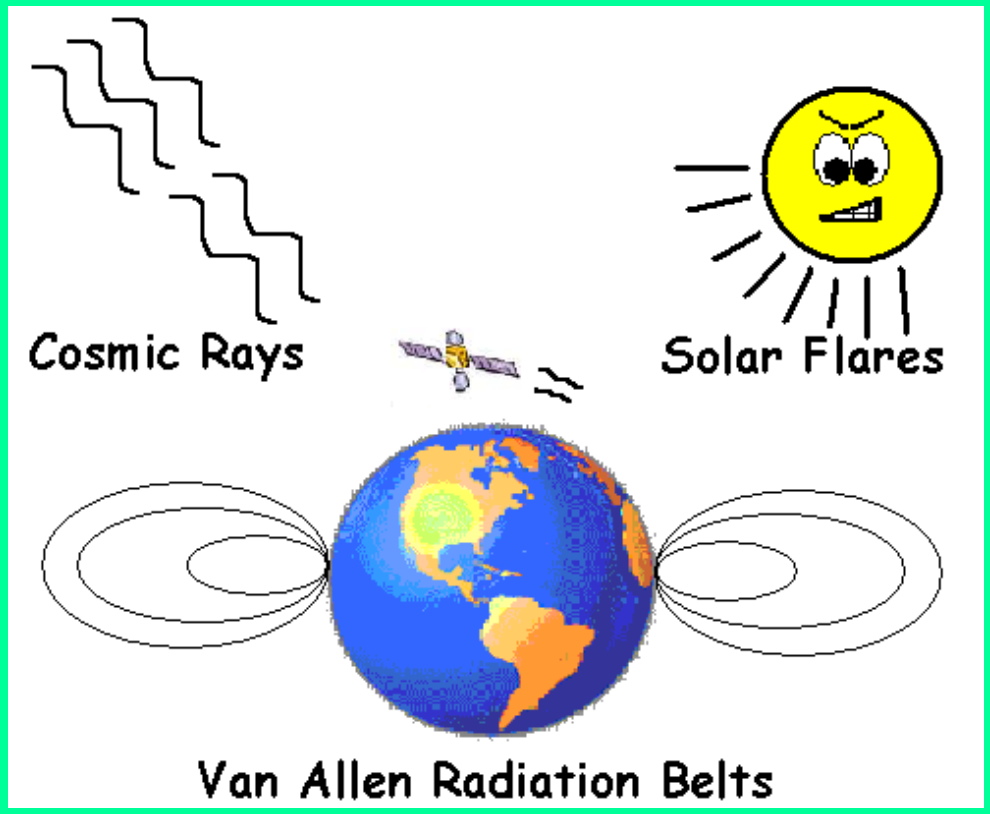
Annual K500 Operation:

February – December

Scheduled Maintenance:

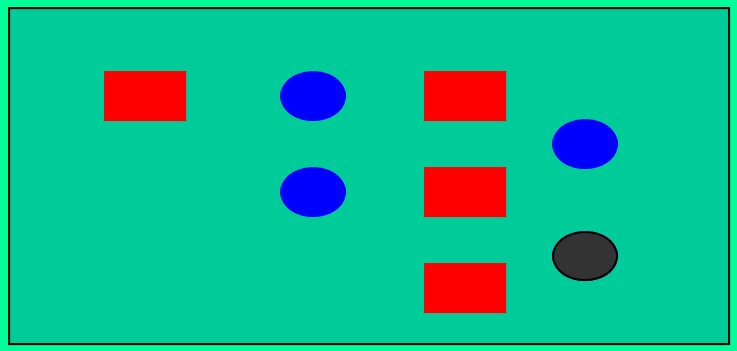
January

Radiation Effects



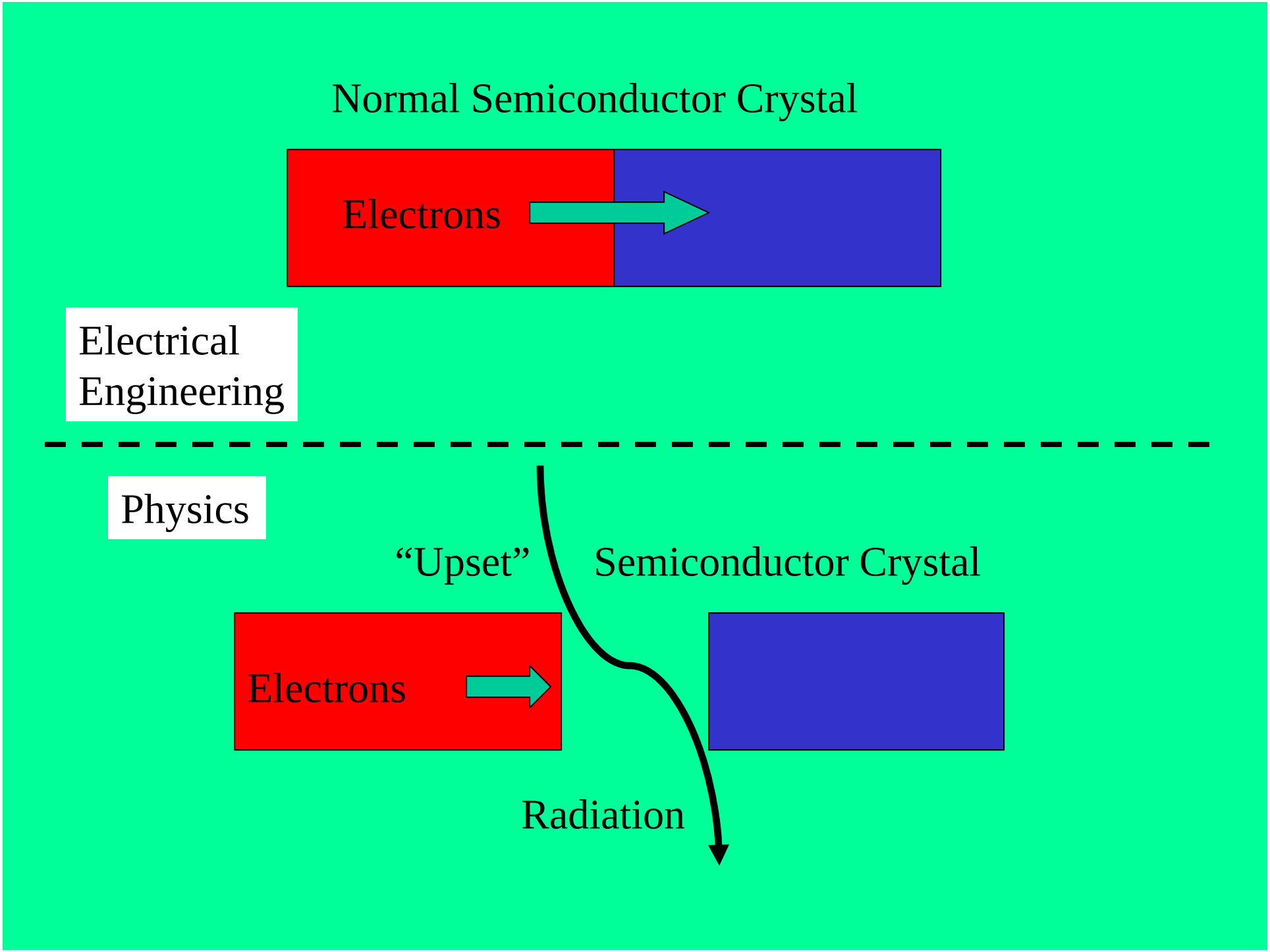
- Aerospace computer equipment receives radiation from cosmic rays, solar flares and the Earth's Van Allen radiation Belts.
- This radiation can harm or destroy space bound materials.

Part Size…



Circuit 20 years ago – “inches”

Integrated Circuit Today – “microns”


Normal Semiconductor Crystal
Electrons
Electrical Engineering
Physics
"Upset"
Semiconductor Crystal
Electrons
Radiation

Various Effects

- Different forms of Radiation:
  - Light ions (protons, alphas),
  - Heavy ions (Ne, Ar, Fe…..Au, U),
  - Neutrons (nuclear reactions with space craft),
  - Electromagnetic (x-rays, gamma-rays)
- Total dose:
  - High intensity light ions and EM radiation
- Single Event Effects (SEE):
  - Heavy ions and light ions

Total Dose Effect

- High intensity light-ions & EM radiation
- Complete failure of device
- Cannot be reset or repaired
- Testing is performed with
  - Protons (40 – 350 MeV), Indiana U, UC Davis, Berkeley Nat Lab, Massachusetts Gen Hosp…
  - Flash x-ray (Boeing-Seattle)
  - Gamma-ray (Co^{60})

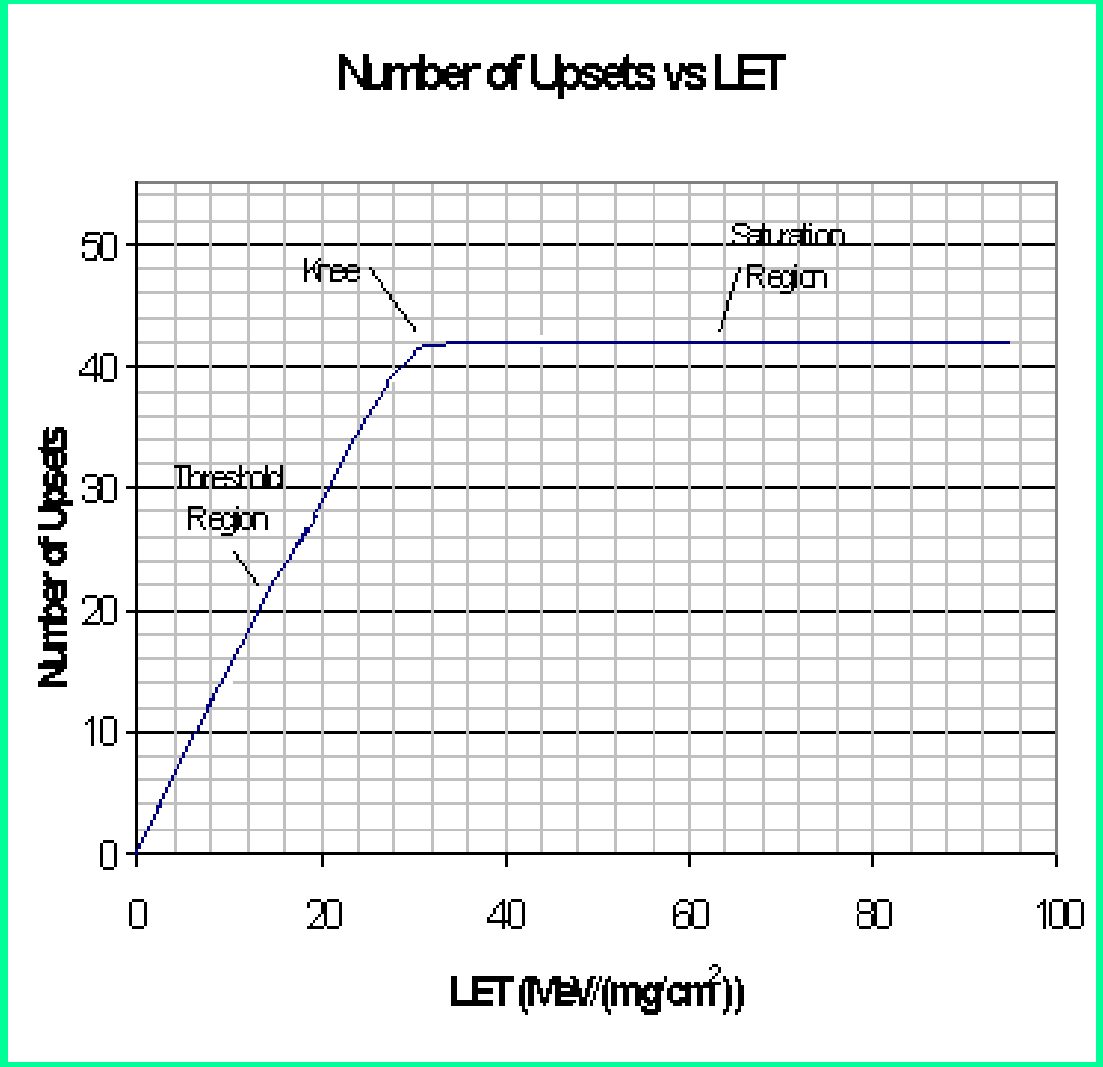
Single Event Effects

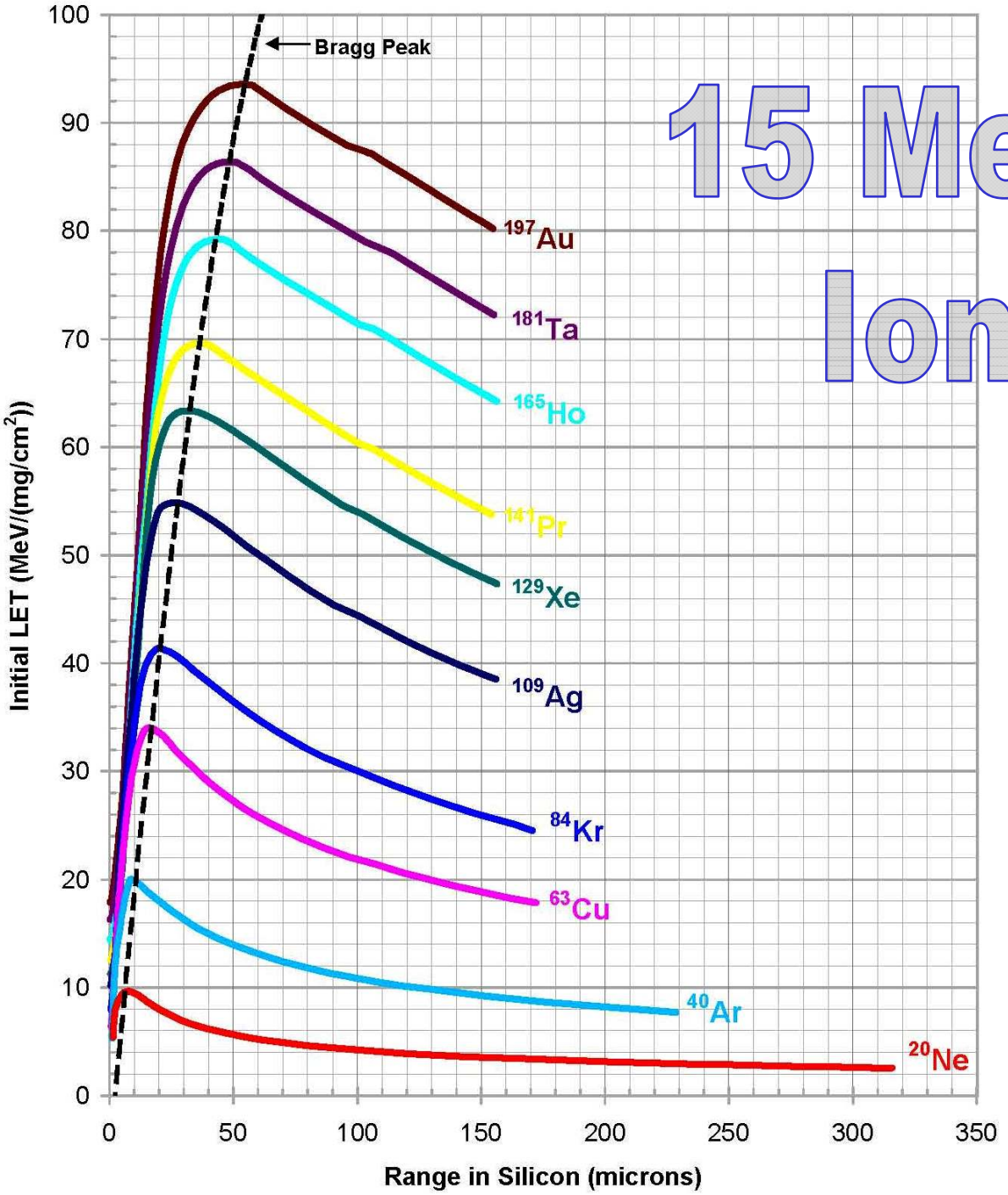
- Low intensity heavy ions (~10s ions/s-cm^2)
- Hard Errors
  - "Burn out" or "Latch up"
  - Cannot be reset or repaired
  - Generally caused by largest heavy-ions, Xe-Au
- Soft Errors
  - "Bit flip" from 1 to 0
  - Instantaneous de-synchronization or data loss
  - Rates measured over wide range of heavy-ions

Radiation Effects

- Particle energy matters!
- Most heavy ions in space: 15-100 MeV/nucleon
  - Test at space energies
  - TAMU K500 Cyclotron (80 MeV/u design limit)
    - 15 MeV/u He,N,Ne,Ar,Cu,Kr,Ag,Xe,Pr,Ho,Ta,Au (Z=2-79)
    - 25 MeV/u He, N, Ne, Ar, Kr, Xe (Z=2-54)
    - 40 MeV/u He, N, Ne, Ar, Kr (Z=2-36)
    - 55 MeV/u O, Ar (Z=8-18)

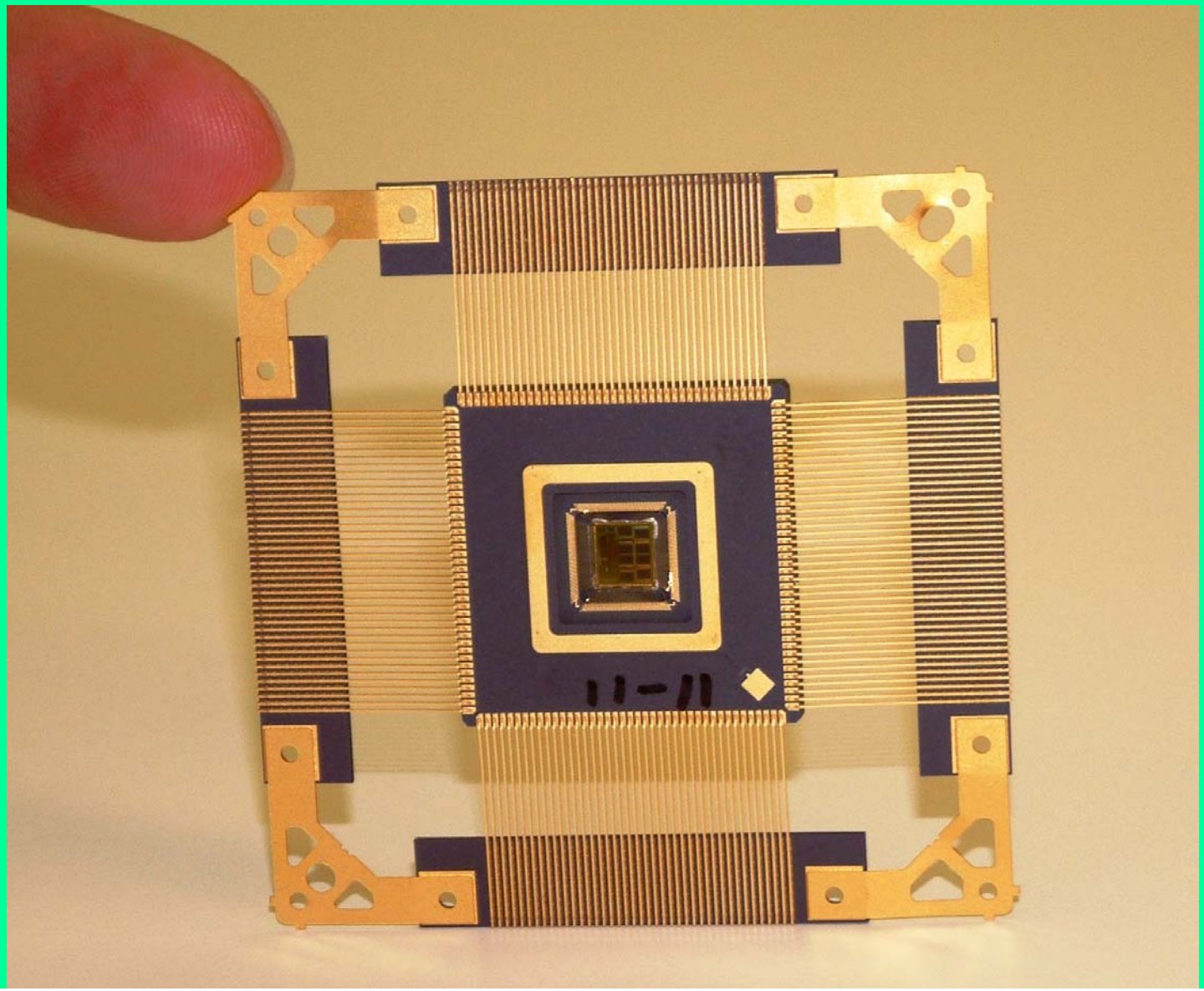
Upset Cross Section



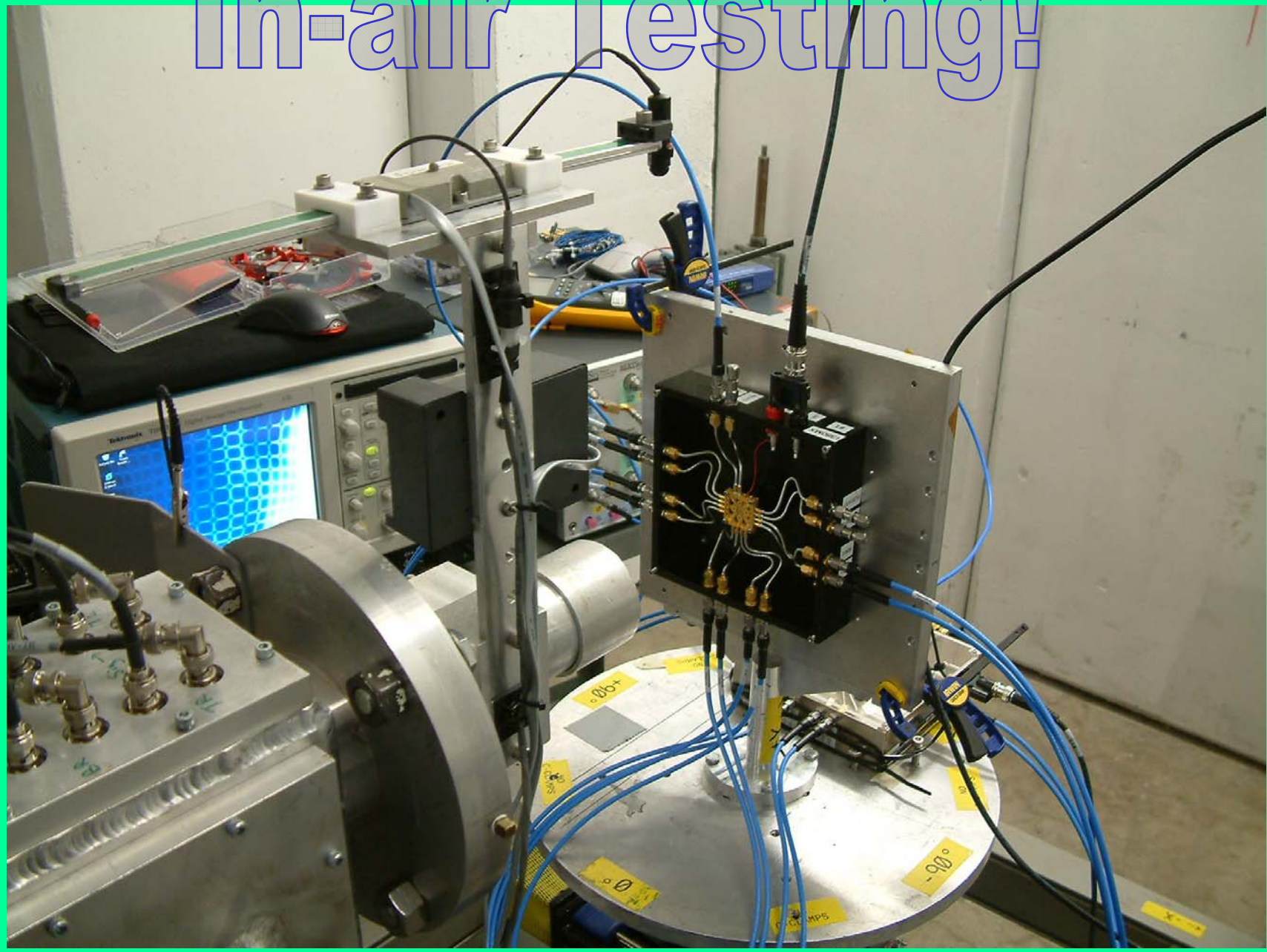

Bragg Peak
197Au
181Ta
165Ho
141Pr
129Xe
109Ag
84Kr
63Cu
40Ar
20Ne
Initial LET (MeV/(mg/cm2))
Range in Silicon (microns)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350

15 MeV/u Ions

Parts must be "Delidded"



In-air Testing!



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TEXAS A&M UNIVERSITY

The Upgrade Project

- **Production of reaccelerated ion beams (RIBs): two cyclotrons – K500 (superconducting) and 88” (K150)**

- **88” (K150) – used as driver for acceleration of high intensity primary beams: proton, heavy ions**

- **K500 – used for reacceleration**

- **Light Ion Guide – used for production of neutron deficient RIBs A(p,xn)B reactions**

- **Heavy Ion Guide – used for both neutron deficient and proton deficient RIBs (deep inelastic and nuclear fragmentation reactions)**

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Scientific program

1. **Nuclear Astrophysics:**
   a. Radioactive beams from K500: Asymptotic Normalization Coefficients method
   b. Intense stable beams from 88” Cyclotron
2. **Nuclear Structure:**
   a. Giant Monopole Resonance and Compressibility: GMR as a nuclear structure effect and compressibility in nuclei with much higher asymmetry
   b. Cluster Structure: radioactive beams and thick target inverse kinematics technique
3. **Fundamental Interactions**: superallowed β-decay measurements
4. **Nuclear Dynamics and Nuclear Thermodynamics**

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Project Management

- Re-commission the existing 88” (K150) cyclotron and install new beam lines
- Construct Light-Ion and Heavy-Ion guides. Produce and transport 1+ radioactive ions
- Charge boost radioactive ions, transport and re-accelerate in the K500 cyclotron

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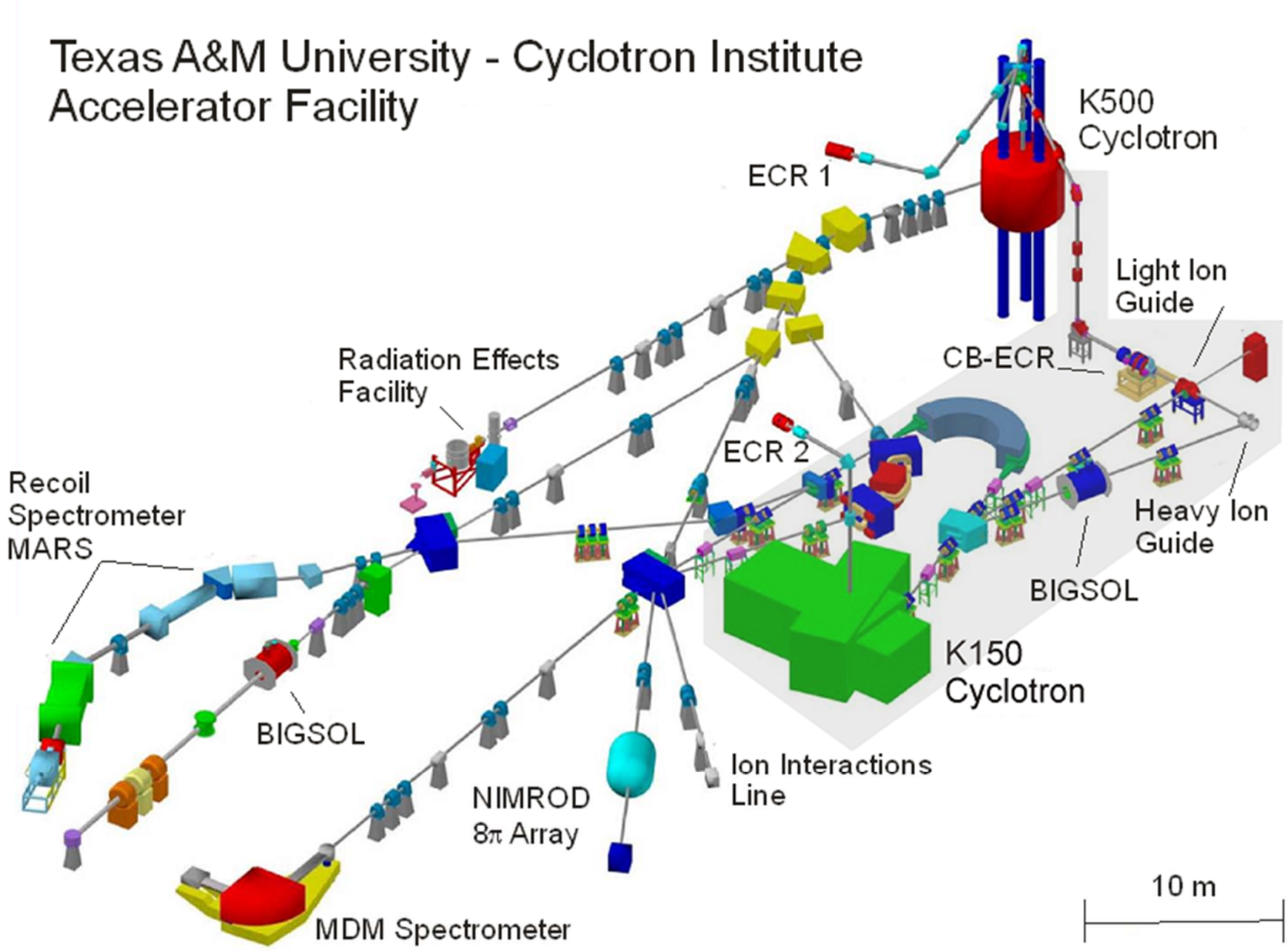
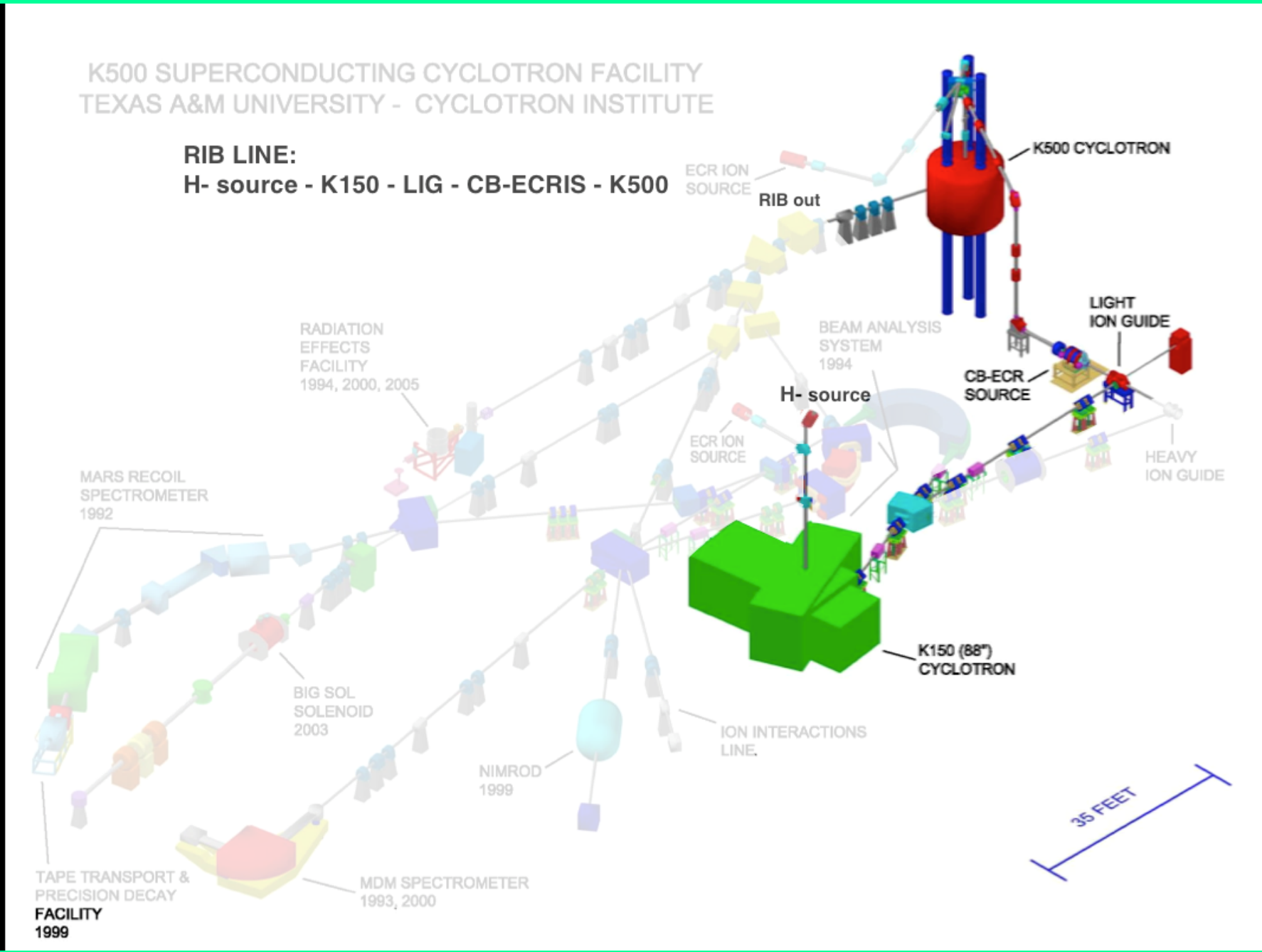
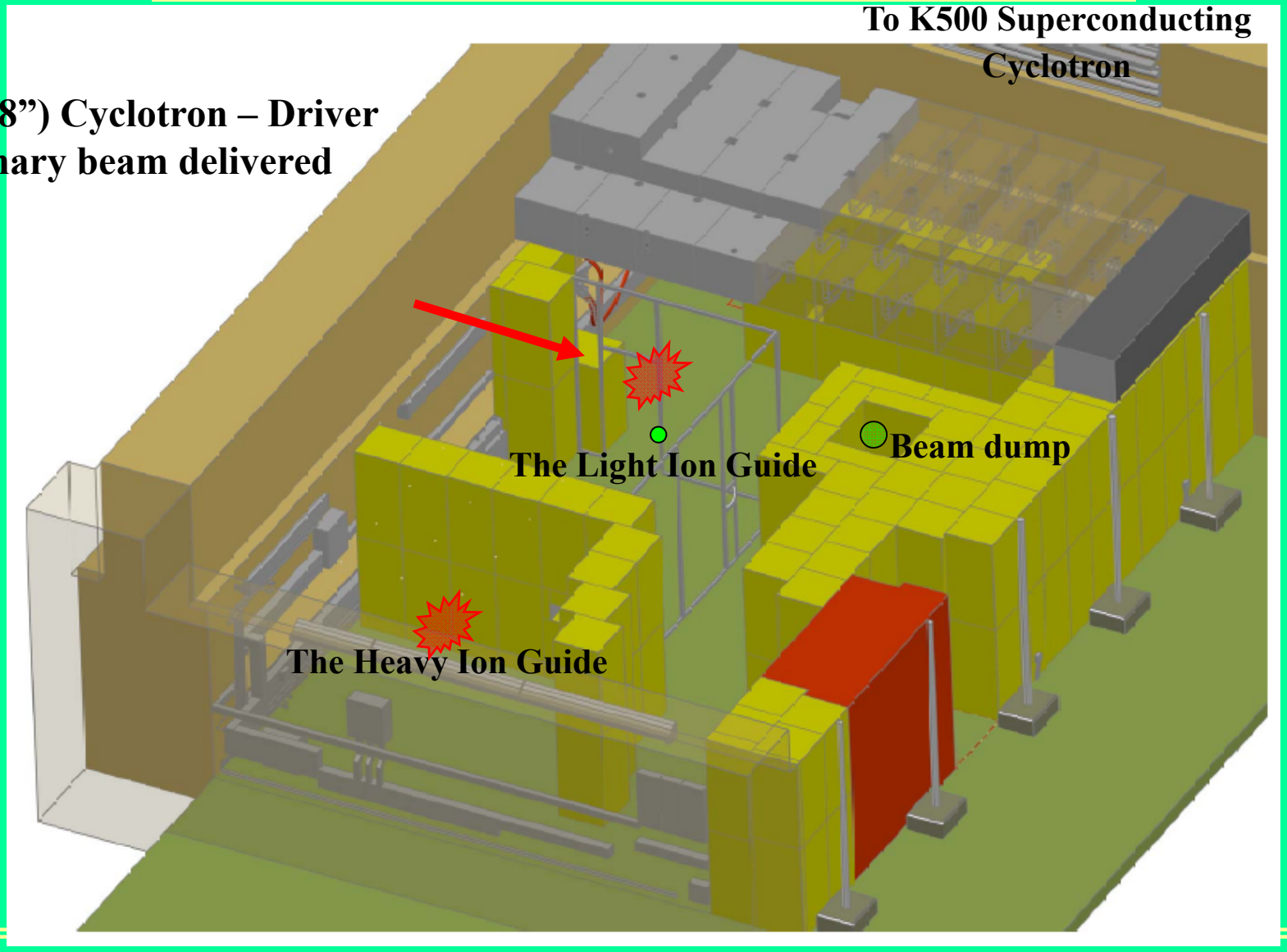
Major Components to Re-commission K150 Cyclotron

- Power supplies main, trim & valley coils
- Radiofrequency (RF) system
- Vacuum System
- Deflector and Inflector
- Reconnect electrical & LCW utilities
- Computer Control System
- ECR and injection line
- Connect beam lines to Ion Guides and K500 experimental areas


Texas A&M University - Cyclotron Institute
Accelerator Facility
K500
Cyclotron
ECR 1
Light Ion
Guide
CB-ECR
Radiation Effects
Facility
ECR 2
Recoil
Spectrometer
MARS
Heavy Ion
Guide
BIGSOL
K150
Cyclotron
BIGSOL
Ion Interactions
Line
NIMROD
8π Array
10 m
MDM Spectrometer


K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE
RIB LINE:
H- source - K150 - LIG - CB-ECRIS - K500
ECR ION SOURCE
RIB out
K500 CYCLOTRON
LIGHT ION GUIDE
RADIATION EFFECTS FACILITY 1994, 2000, 2005
BEAM ANALYSIS SYSTEM 1994
CB-ECR SOURCE
H- source
ECR ION SOURCE
HEAVY ION GUIDE
MARS RECOIL SPECTROMETER 1992
K150 (88") CYCLOTRON
BIG SOL SOLENOID 2003
ION INTERACTIONS LINE.
NIMROD 1999
35 FEET
TAPE TRANSPORT & PRECISION DECAY FACILITY 1999
MDM SPECTROMETER 1993, 2000

Ion Guides Hall



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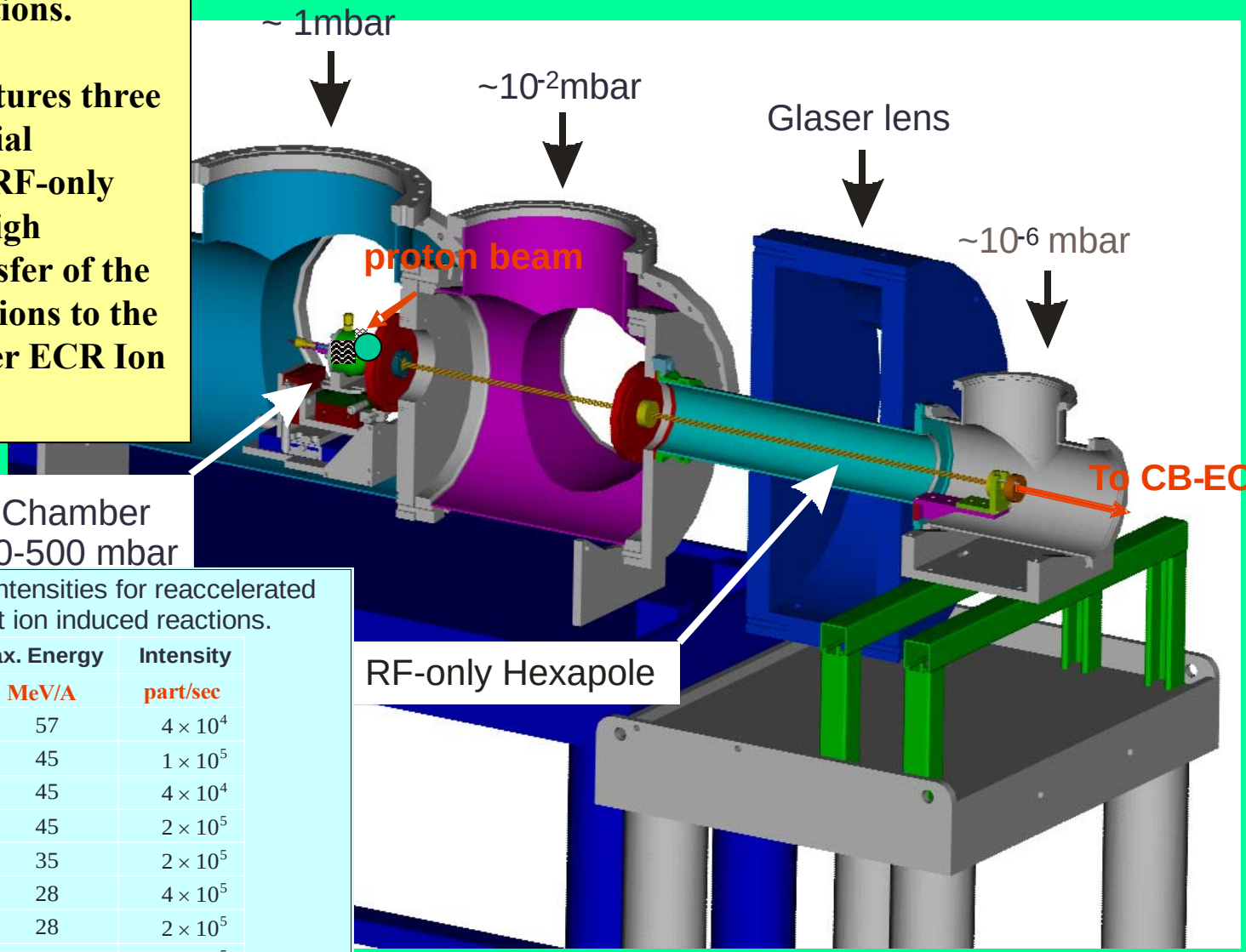
The Light Ion Guide

The Light Ion Guide will be used for production of neutron deficient radioactive ion beams - A(p,xn)B reactions.

The device features three stage differential pumping and RF-only hexapole for high efficiency transfer of the 1^+ radioactive ions to the Charge Breeder ECR Ion Source.



Estimated beam intensities for reaccelerated products of light ion induced reactions.

p,n Product	Max. Energy MeV/A	Intensity part/sec
^{27}Si	57	4×10^4
^{50}Mn	45	1×10^5
^{54}Co	45	4×10^4
^{64}Ga	45	2×10^5
^{92}Tc	35	2×10^5
^{106}In	28	4×10^5
^{108}In	28	2×10^5
^{110}In	26	4×10^5

First RIB: winter 2012

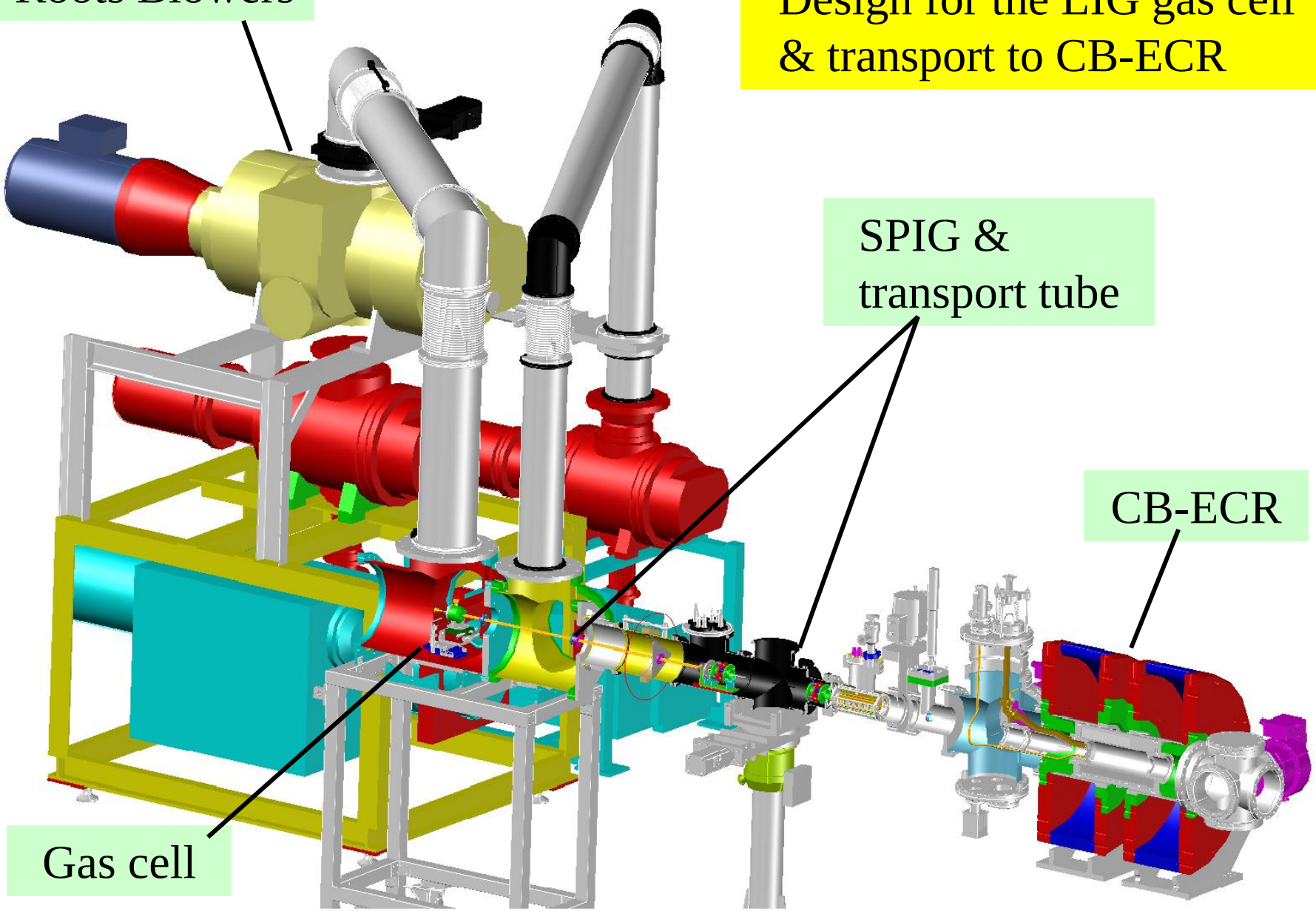
In collaboration with Dr. J. Arje - Jyväsky

Roots Blowers

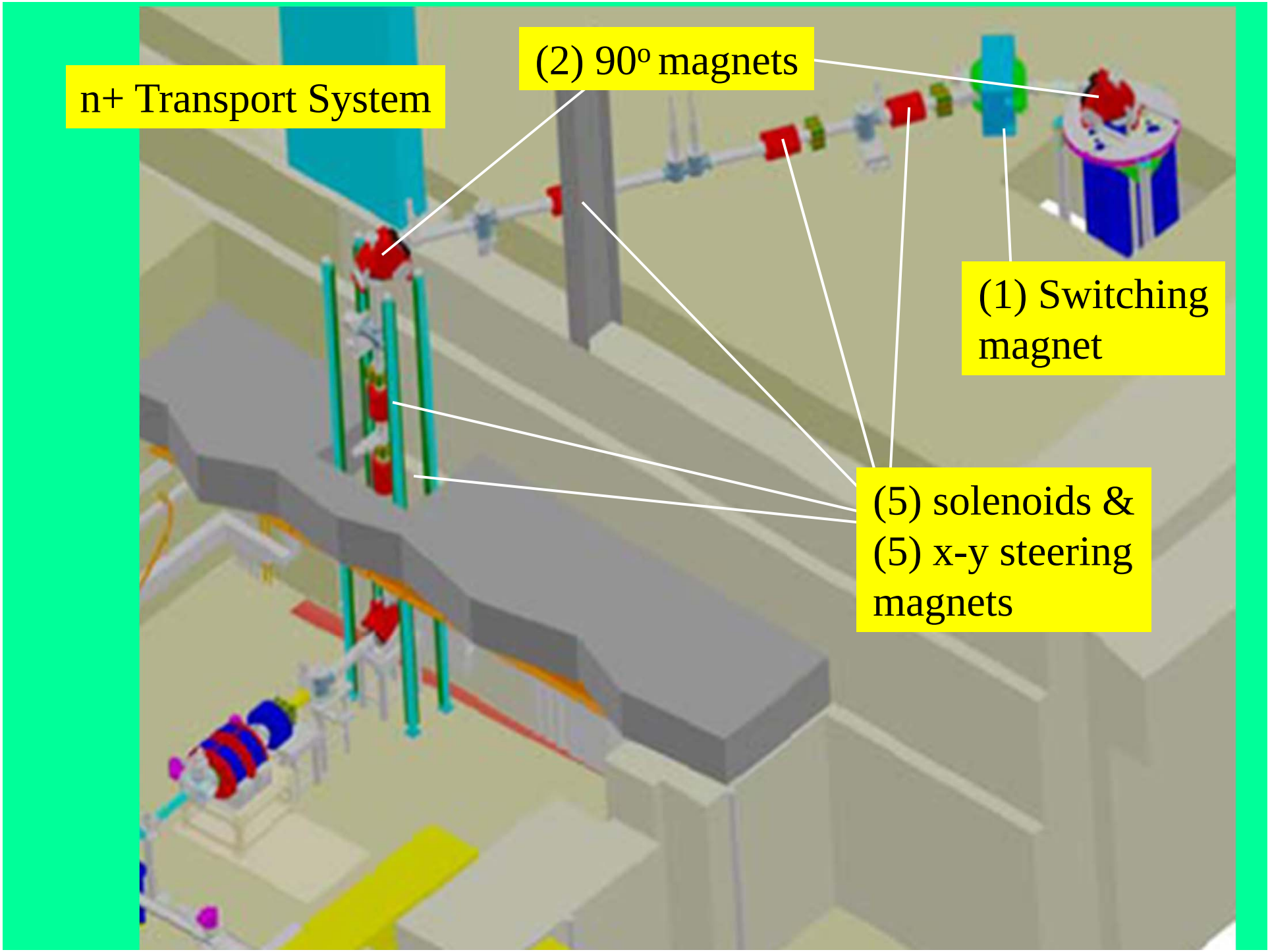
Design for the LIG gas cell & transport to CB-ECR

SPIG & transport tube

CB-ECR



Gas cell


n+ Transport System
(2) 90o magnets
(1) Switching magnet
(5) solenoids &
(5) x-y steering magnets

Thank you!