# The Inaugural SEE Run for the NSCL SEE Test Facility

**NASA *Point of Contact***

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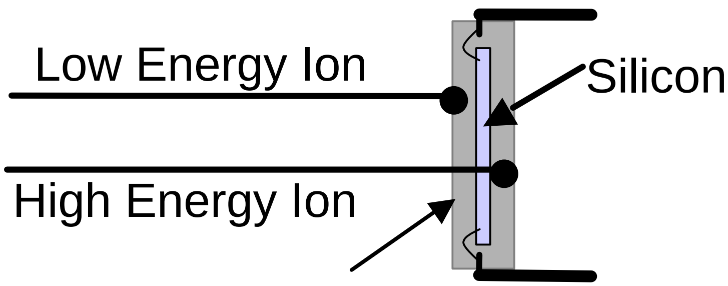
Sponsored by NASA Electronic Parts and Packaging Program
and the Defense Threat Reduction Agency

# Outline

- Motivation for test facility at NSCL
- Summary of the facility development
- Results for the Inaugural run in Feb of 2004
- Limitations of the facility
- Conclusions

# Motivation for NSCL SEETF (2)

Limited penetration depth of ions available at other facilities prohibits SEL/SEU testing of devices that have inactive materials layered over die




| Facility | Ion (Energy) | LET (Si) | Range in Si (?m) | Peak LET |
|---|---|---|---|---|
| NSCL | Xe (3.2 GeV) | 40 | 272 | 69 |
| TAMU | Ar (2 GeV) | 5.9 | 390 | 18 |

Table Assumes ion traverse 1.5 mm plastic

LET given in MeV-cm$^2$/mg

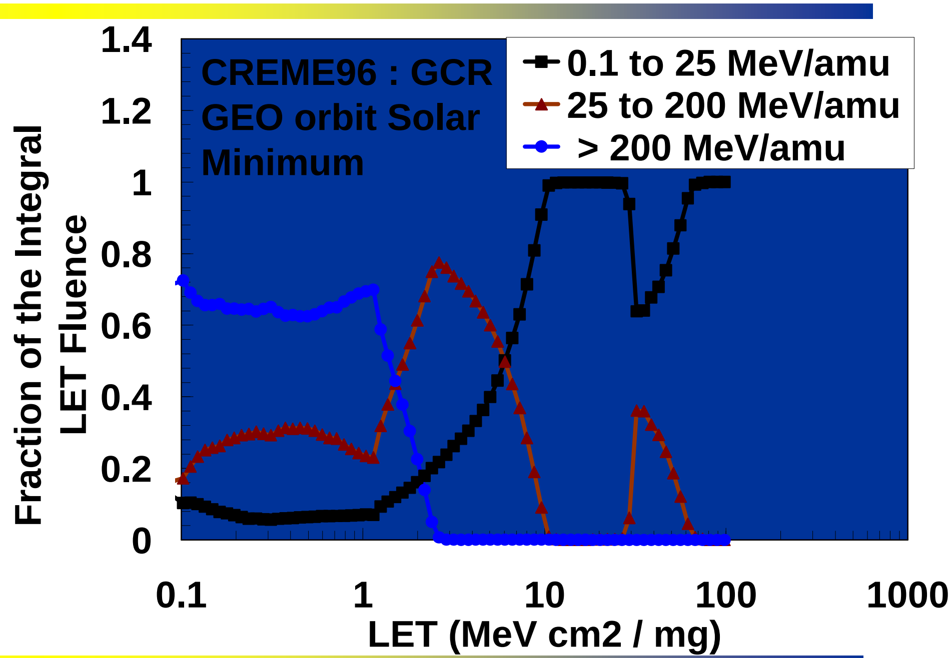
Space heavy ions have LETs < 100 MeV-cm$^2$/mg Space energies range 0.1 to $10^5$ MeV/amu.

Current facilities: most < 25 MeV/amu

SEETF:

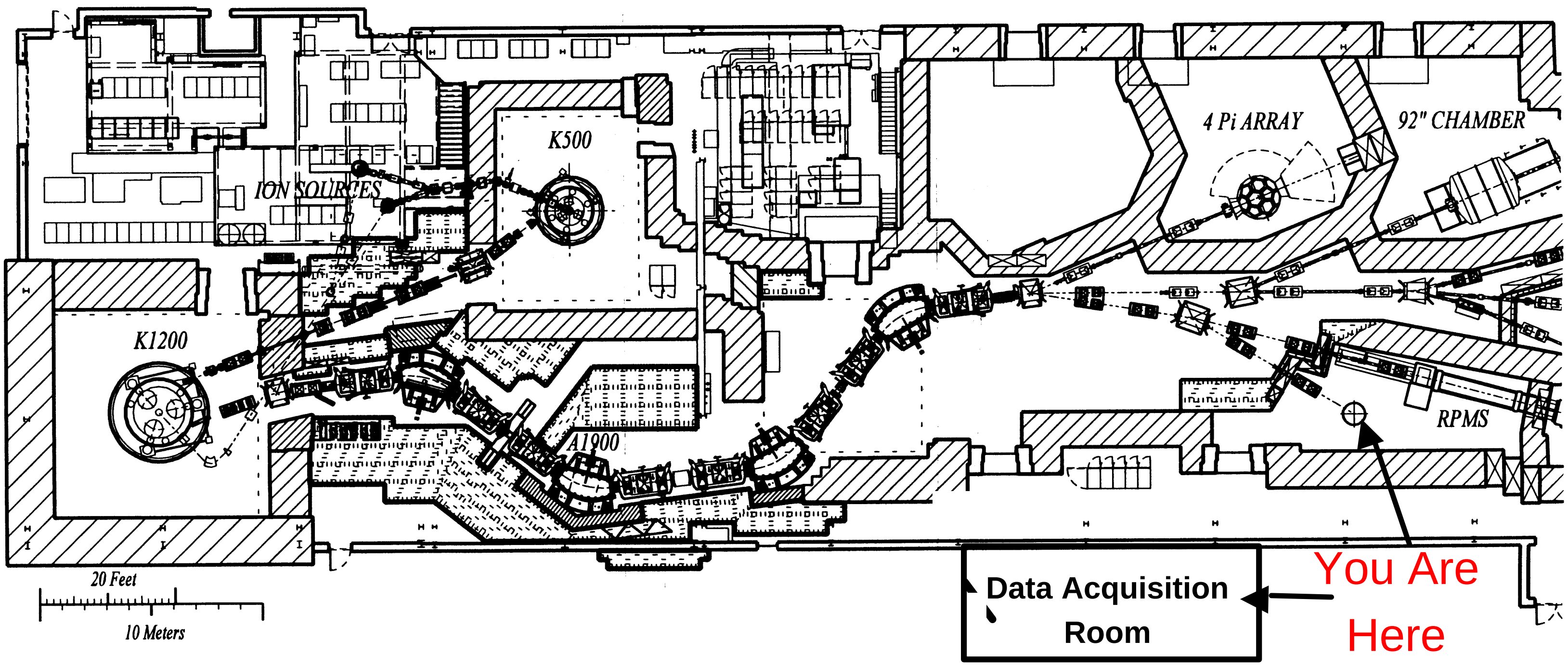
Possible to simulate ~99% of the space environment with LETs >3 Mev-cm$^2$ / mg.

Ability to research device effects in an energy regime that has never be explored.



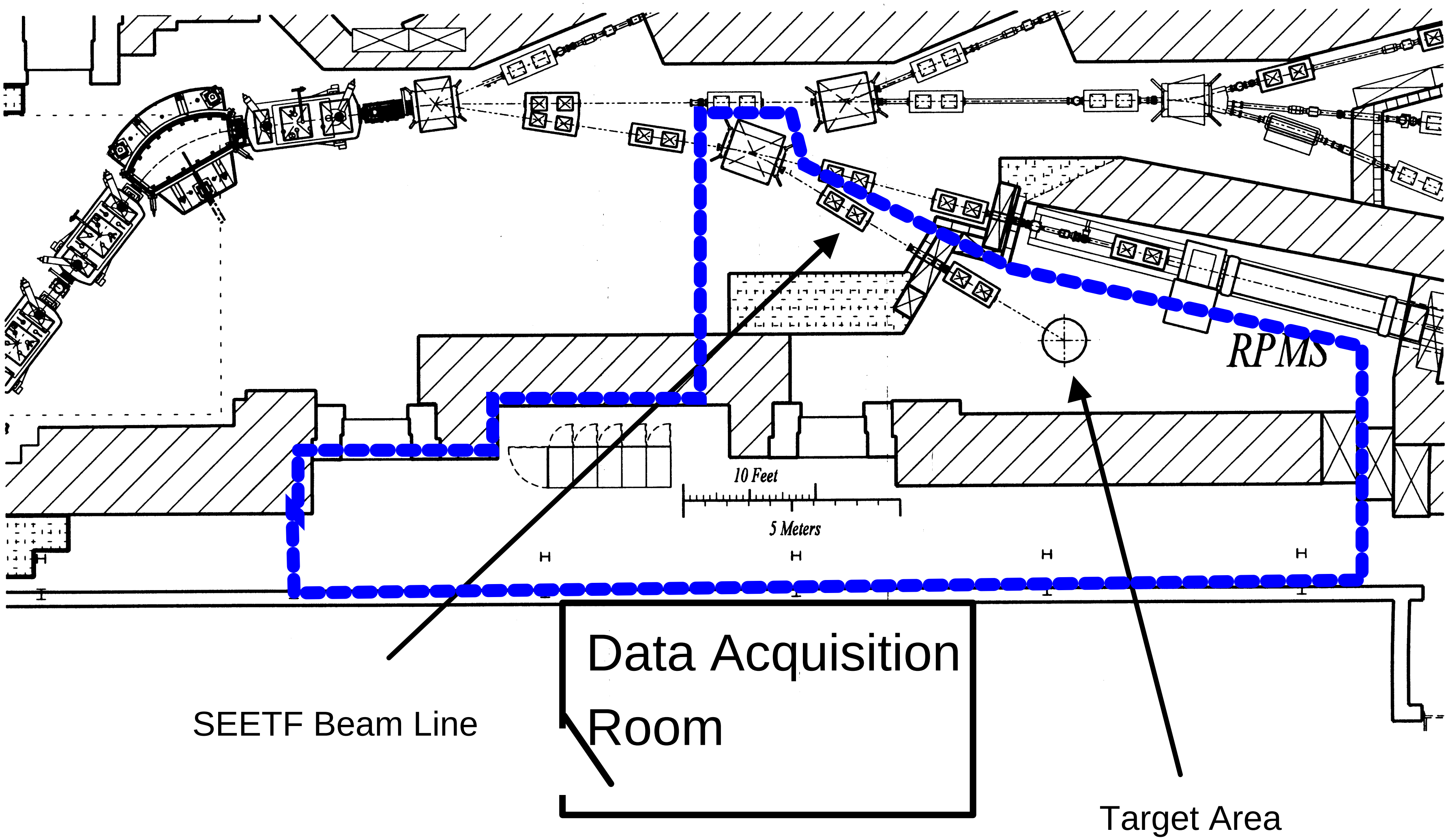
# Recent Upgrade of NSCL

- NSF funded a major upgrade that coupled two existing cyclotrons at NSCL to support basic physics research
  - Capable of energies up to 200 MeV/amu
- NASA and DTRA funded the development of the Single Event Effects Test Facility (SEETF) during this upgrade.



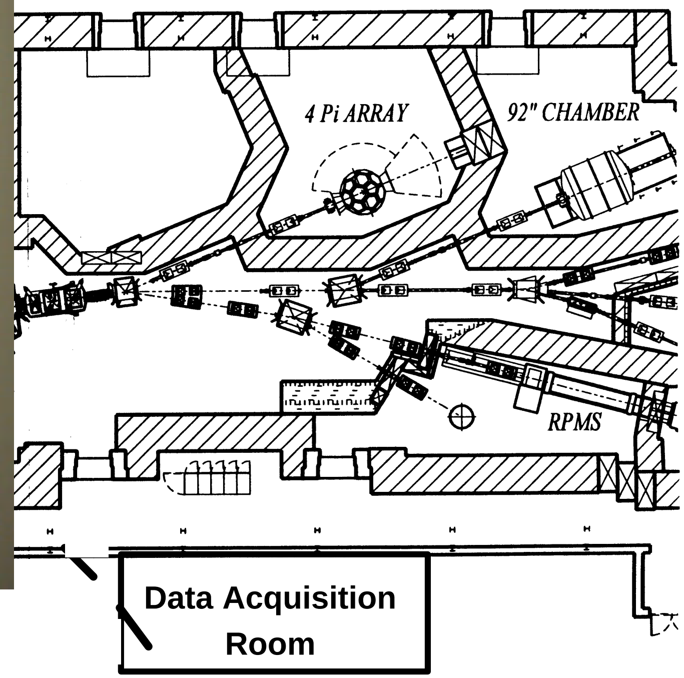

Blue print showing NSCL after upgrade, including SEETF.

# NSCL SEETF


RPMS
10 Feet
5 Meters
Data Acquisition Room
SEETF Beam Line
Target Area

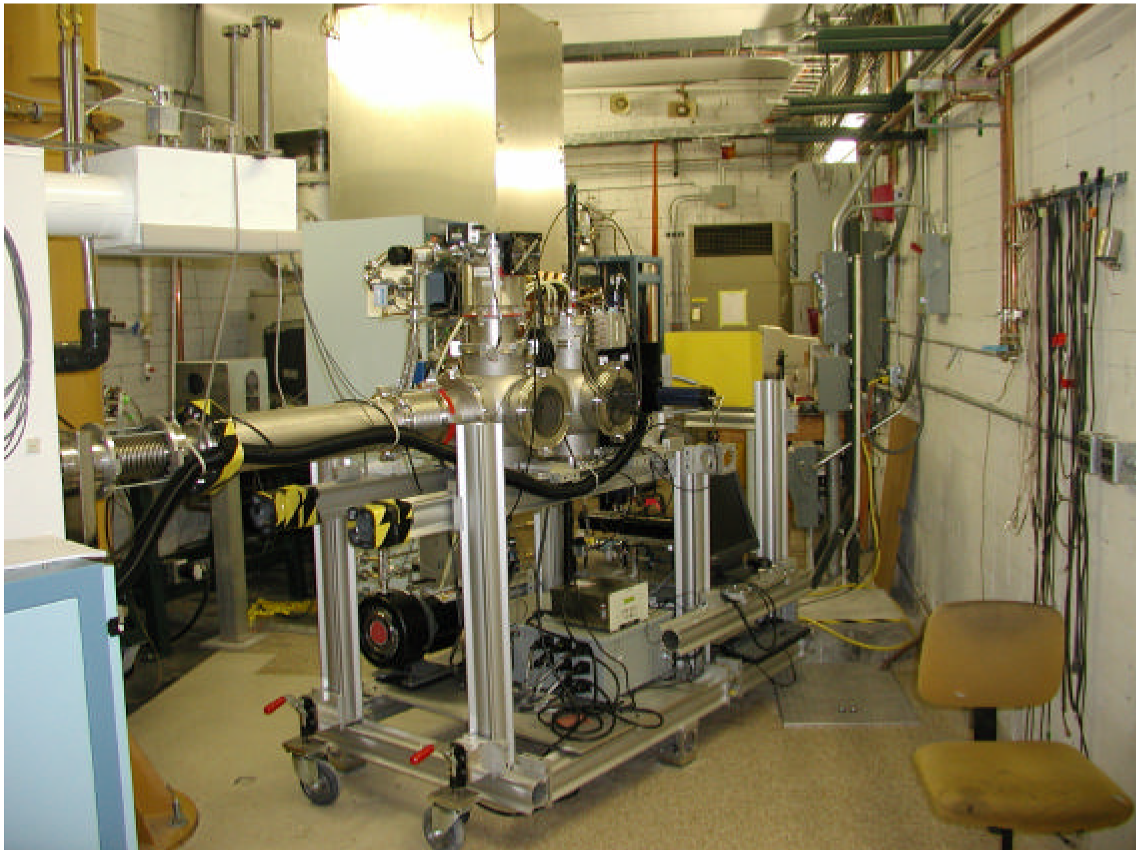
## A few pictures…

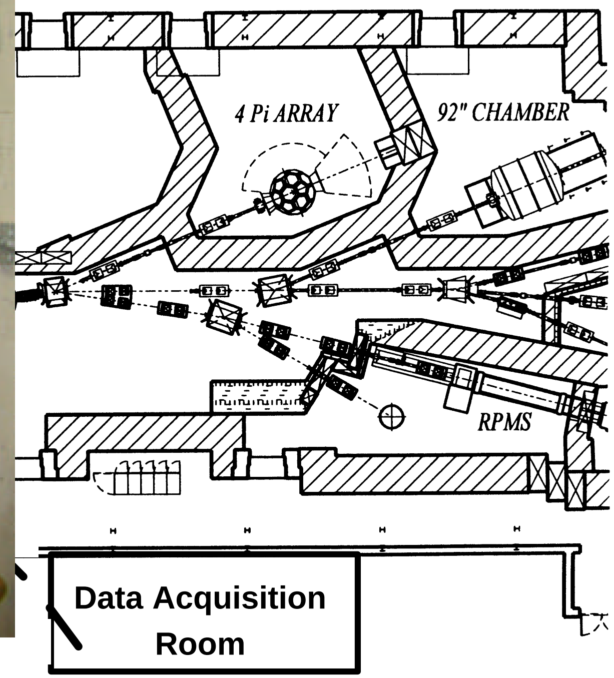
# Inside the Data Room



## A few pictures…

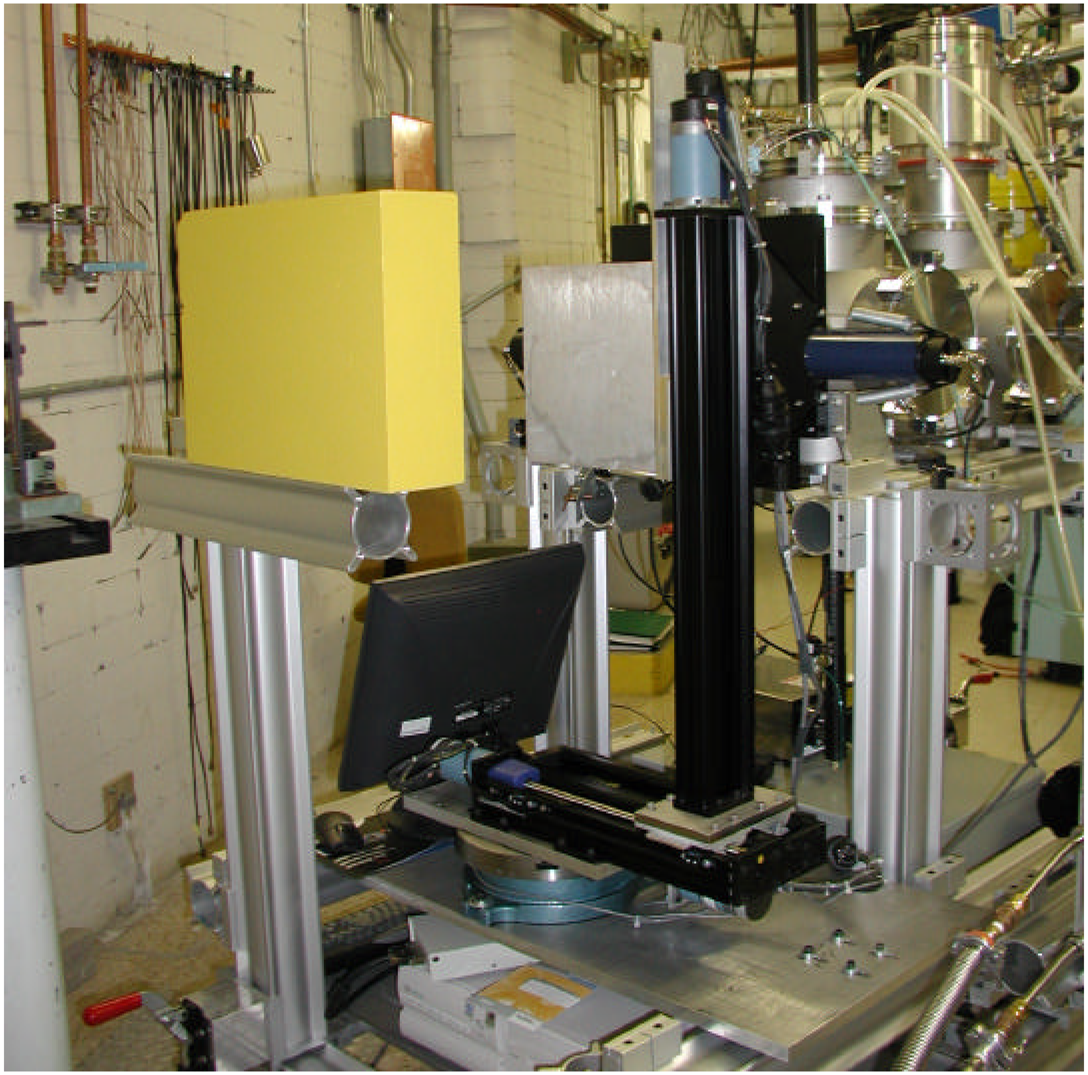
# Inside the Vault



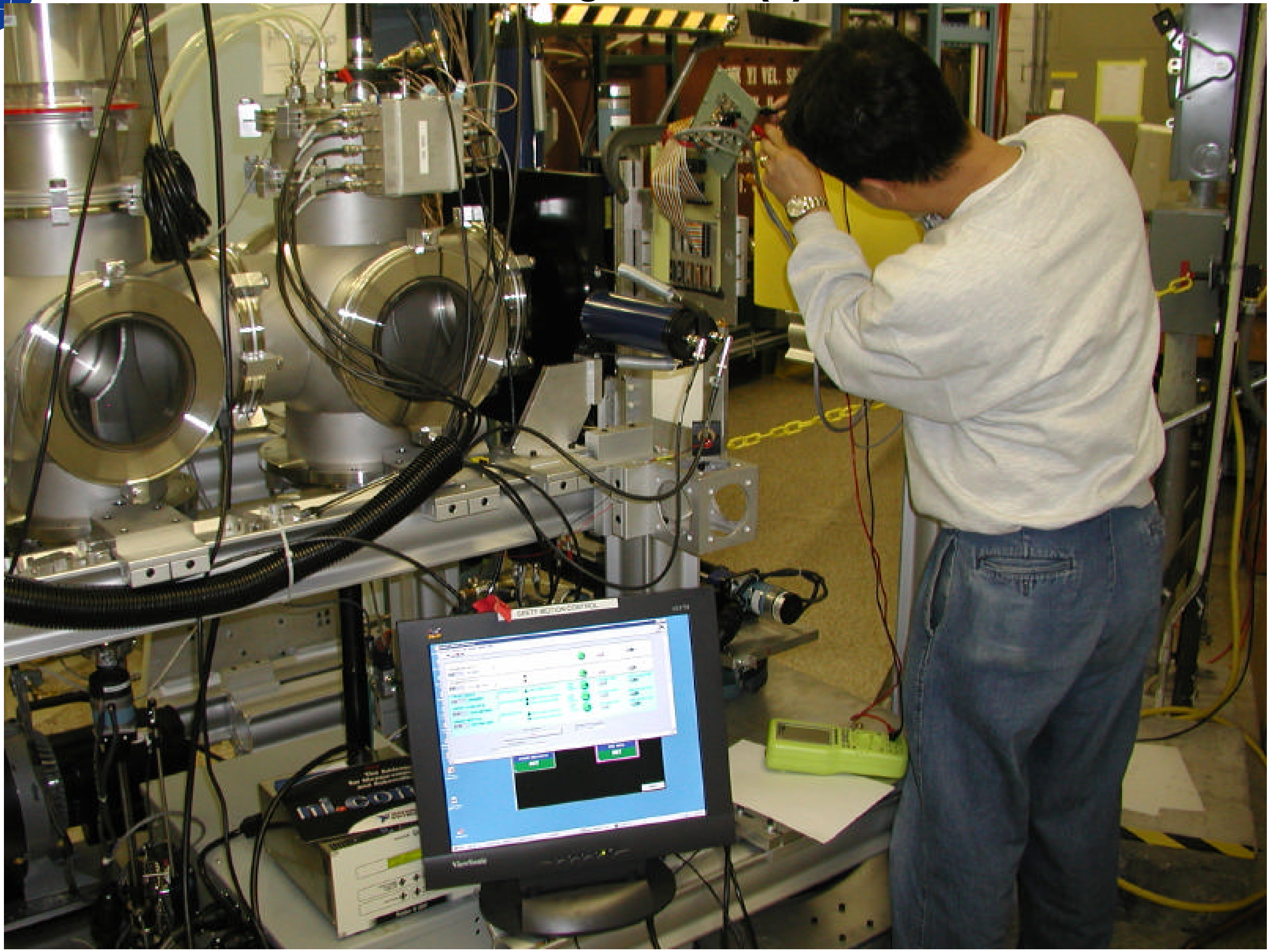



10 Meters

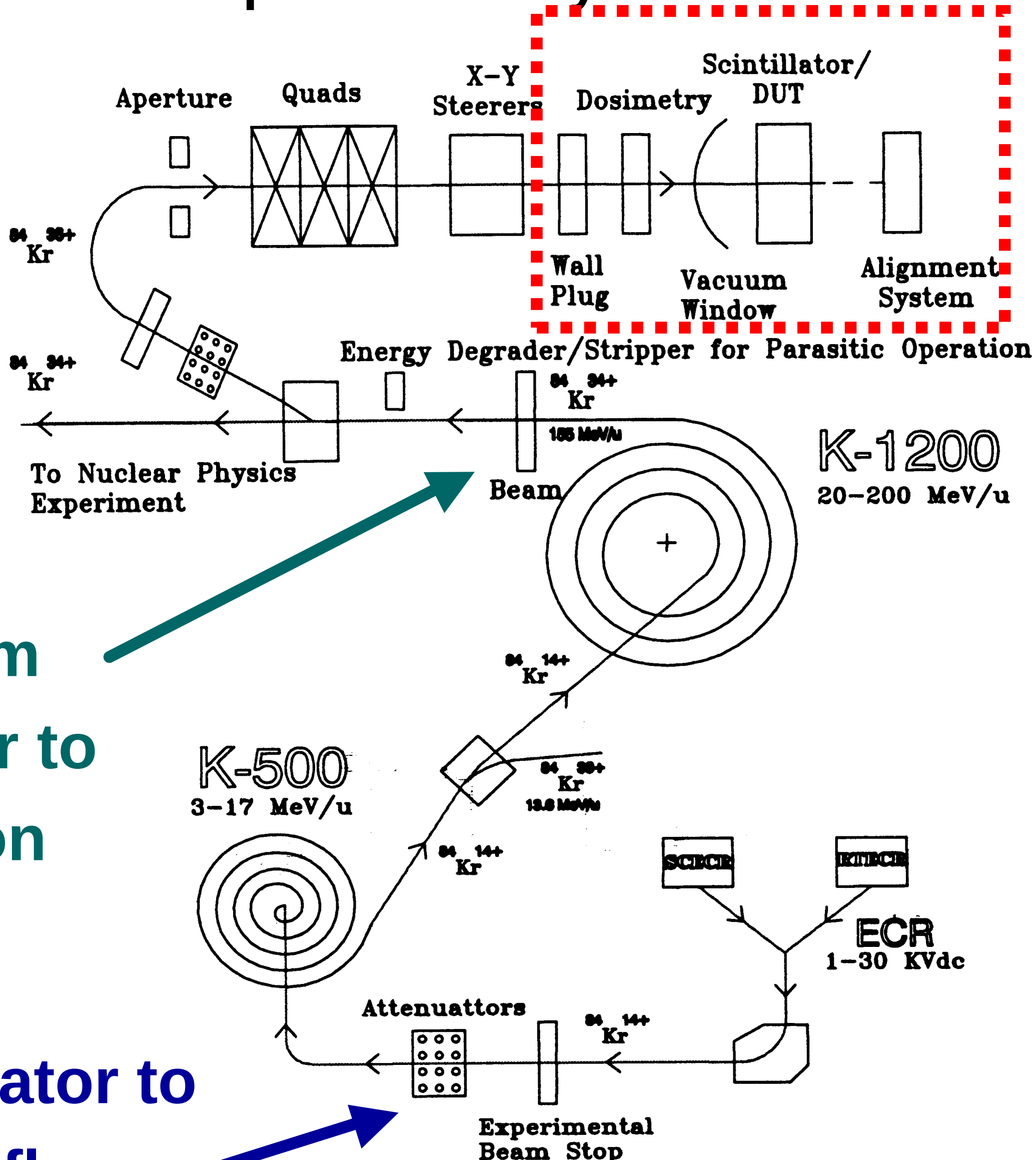
# Target Area (1)



# Target Area (2)



# Ion "path" from Cyclotron to DUT

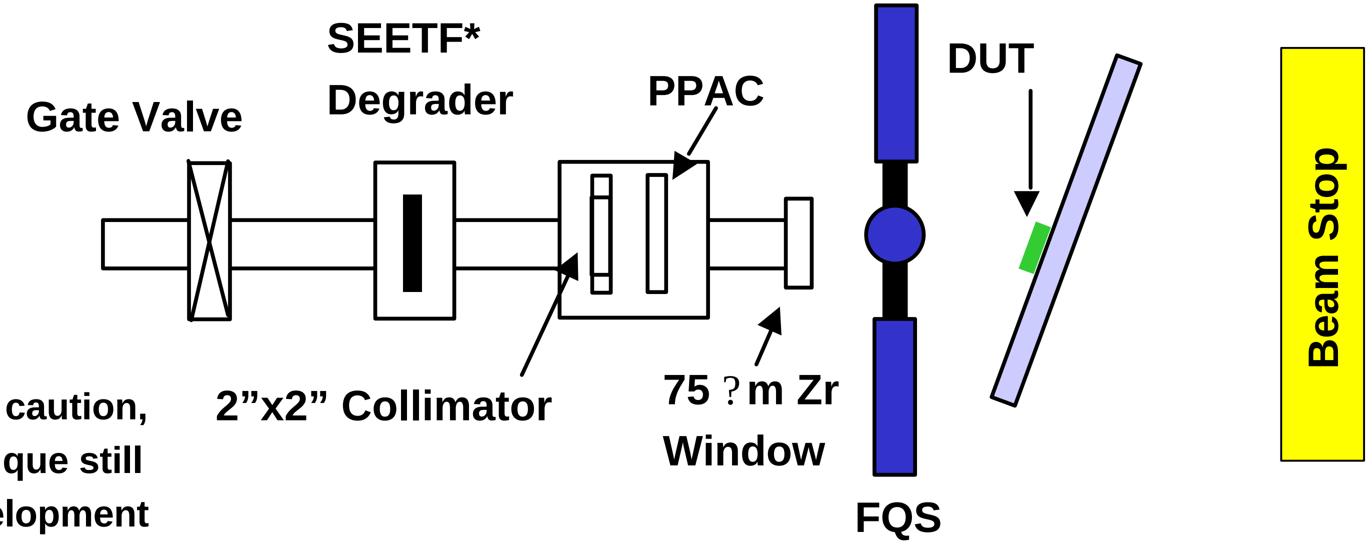



**Detailed view on next Slide**

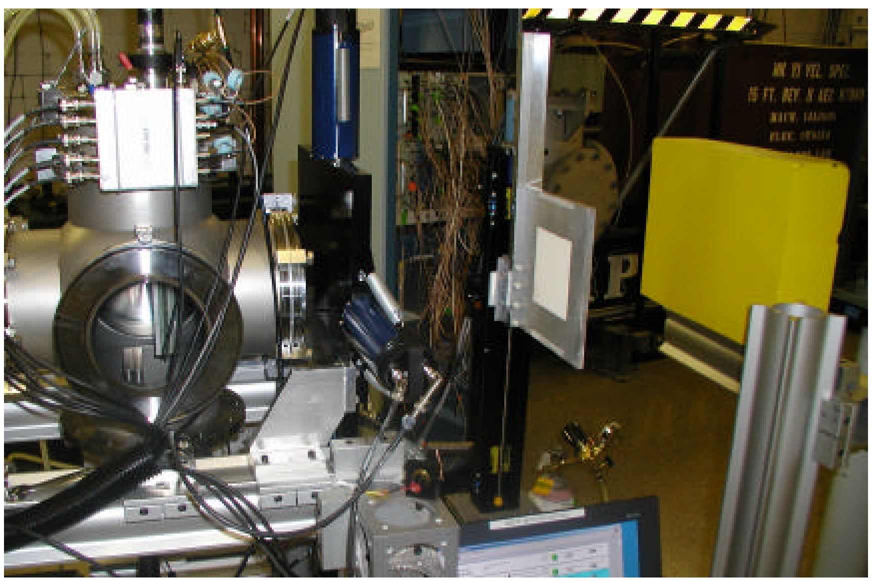
**Upstream degrader to adjust ion energy**

**Attenuator to adjust flux**

# Details of Inside SEETF Vault




* Use with caution, this technique still underdevelopment



Two Dosimeters:

- Parallel Plate Avalanche Counter (PPAC)
  - **detailed uniformity measurement**
  - **limited flux range (<4x10$^2$ p/cm$^2$/s)**
- Four Quadrant Scintillator (FQS)
  - **Divides beam into four quadrants**
  - **Larger flux range (<1x10$^6$ p/cm$^2$/s)**

# SEETF - General Information

- There are two phases to the contract
  - Beam setup phase (***completed***)
  - Beam delivery phase(***we are currently in this phase***)
    - **Inaugural run completed February 2004 (more on this later)**
  - The contract also allows for future upgrades and other support
- SEETF facility scheduling, availability, and operational highlights:
  - Minimum reserve time will be 24 hours for SEE testing, can be combined user time
  - Two modes of accessing ion beam from cyclotron:
    - **SEETF user utilizes ion tune from a long duration physics experiment: 8 hours to tune SEETF beamline**
    - **SEETF user request untuned ion: 24 hours to tune cyclotron and SEETF beamline**
  - Availability of 300-600 hours or up to 10% of the beam time, whichever is less
  - All testing requires NASA support to operate SEETF facility
  - All SEE users should contact Robert Reed at 301-286-2153 (Robert.Reed@nasa.gov) for SEETF access
  - Beam time cost depend on user type (FY04)
    - **US Government $2352.48/hour**
    - **Commercial $2633.69/hour**
    - **SEETF Developers Consortium rates are available (see Ken LaBel for details)**

# Key Requirements for SEETF Ion Beam Characteristics

- Ion energy selection –
  - selectable up to maximum energy available for the selected ion in the coupled-cyclotron mode.
  - achieved by tuning or energy degraders as long as the homogeneity of ion energy is not violated.
- Ion LET –
  - selectable from <2 to >90 MeV*cm²/mg.
  - For a single ion, degraders are used to changing the beam LET in less than 2 hours.
  - Ion Species Ar, Kr, Xe, Au, U between 90 and 200 MeV/amu
- Variable Spot Size: 1-5cm diameter
- Flux Uniformity: <than 10% variability over entire beam area
- Homogeneity in ion species >95%
- Homogeneity in ion energy >90%
- Flux: 1.0 to > $1x10^8$ ions/cm²/sec; switching time <15 mins
- Absolute Dosimetry – exceeding 10% routinely

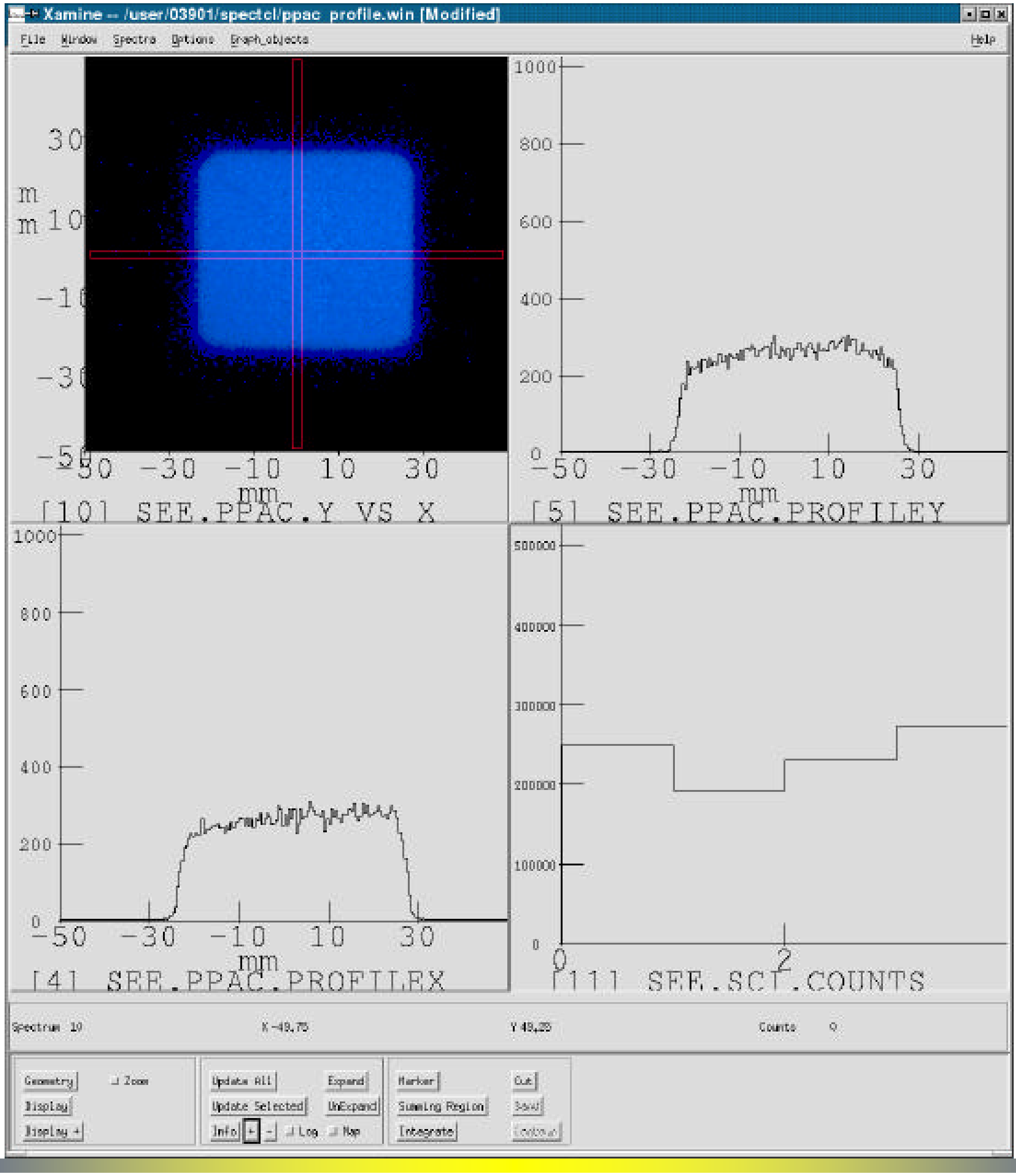
# SEETF Inaugural Run on Feb 24th and 25th 2004

- Possible ions:

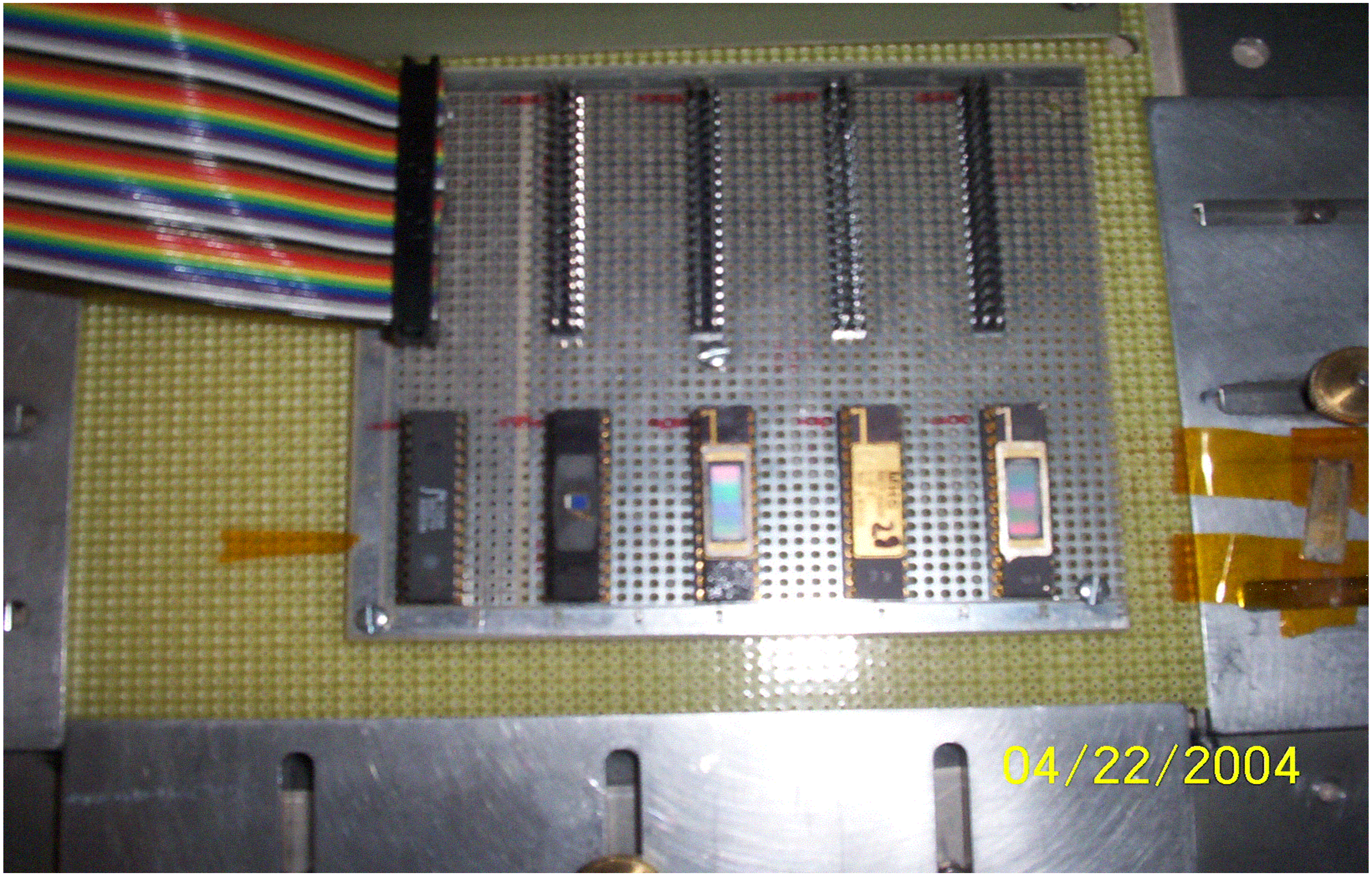
| Ion | Max. Energy (MeV/amu) | LET in Si (MeV-m$^2$/mg) | Range in Si (?m) |
|---|---|---|---|
| Ar-36 | 143 | 1.50 | 8860 |
| Kr-78 | 121 | 6.08 | 4440 |
| Xe-136 | 131 | 14.1 | 3070 |
| Bi-209 | 72 | 42 | 1100 |

- Time required to change from one species to another is less than 24 hours.
- Cyclotron was tuned to Ion was Kr-78 at 140 MeV/amu
  - 121 MeV/amu (LET = 6.3 MeV-cm$^2$/mg)
  - Upstream degrader used to reduce energy to 76 MeV/amu (LET = 8.7)
    - **Changed in 1.7 hours**
- Spot Size: 2”x2”
- Flux Uniformity: <than 15% variability over entire beam area
- Flux: 1x10$^2$ to 1x10$^5$ ions/cm$^2$/sec; switching time < 5 mins
- Devices tested: Matra and IDT 256k SRAM

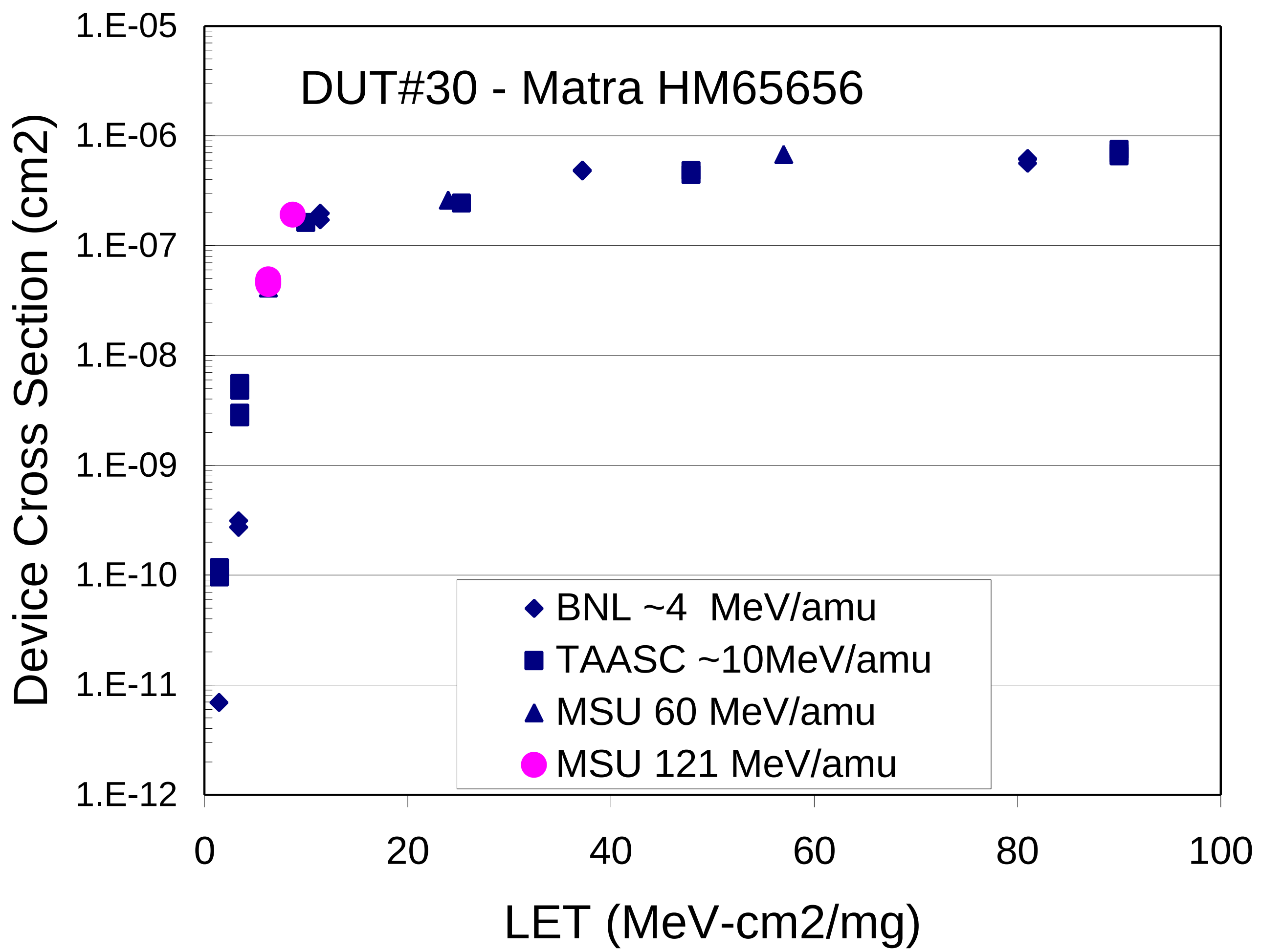
# PPAC and FQS Dosimetry for Kr-78 Ion Beam



# Test Setup



# Matra Data ….


DUT#30 - Matra HM65656
Device Cross Section (cm2)
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
0
20
40
60
80
100
LET (MeV-cm2/mg)
BNL ~4 MeV/amu
TAASC ~10MeV/amu
MSU 60 MeV/amu
MSU 121 MeV/amu

## Degraded Beams (Low Energy)

| Ion | Max. Energy (MeV/amu) | LET in Si (MeV-m$^2$/mg) | Range in Si (?m) | 80% of peak LET in Si | Range in Si |
|---|---|---|---|---|---|
| Ar-36 | 143 | 1.50 | 8860 | 14.6 | 40 |
| Kr-78 | 121 | 6.08 | 4440 | 32 | 85 |
| Xe-136 | 131 | 14.1 | 3070 | 55 | 117 |
| Bi-209 | 72 | 42 | 1100 | 80 | 178 |

- **It is possible to obtain higher LETs by using a energy degraded ion beam**
  - **This can be achieved using upstream degraders, SEETF degraders*, or from device packaging materials or the die itself.**
  - **Decreased range**
  - **Risk of uncertainty in energy (i.e. LET)**
    - **This risk is somewhat mitigated by using upstream degrader**
- **Packaging material can add to this uncertainty. For very low energy beams this will be significant**
- **We have developed a technique for in-situ measurement of LET after the ion has traversed an unknown amount of shielding:**
  - **R.A. Reed, et.al "In Situ Measurement of the Particle Linear Energy Transfer Using the Sensitive Junctions of the Device Under Test," RADECS 2001.**

*** This technique is currently under development**

# Hazards of Degraded Beams

| Part | Packaging | Incident Energy (MeV) | LET @ die surface (MeVcm$_2$/mg) | Average Cross Section (cm$^2$) |
|---|---|---|---|---|
| IDT71256 | Lidded Plastic | 9574 | ?? | 2.01E-3 |
| IDT71256 | Delidded | 9574 | 6.3 | 1.08E-3 |
| IDT71256 | Lidded Plastic | 5953 | ?? | 6.92E-5 |
| IDT71256 | Delidded | 5953 | 8.7 | 5.15E-3 |
| Matra HM65656 | Lidded Hermetic | 9574 | 6.3 | 4.89E-2 |
| Matra HM65656 | Delidded | 9574 | 7.1 | 1.35E-1 |
| Matra HM65656 | Lidded Hermetic | 5953 | 11.7 | 1.61E-2 |
| Matra HM65656 | Delidded | 5953 | 6.3 | 1.25E-2 |

- Degrading beam energy is not without risk
  - IDT part behaves as expected for undegraded beam
  - Degraded beam shows evidence of ranging out even for 1.25 mm plastic lid

# Comment and Conclusions

- NSCL's SEETF is fully functional high energy irradiation facility capable of delivering ion beams with:
  - Energies between 50 and 200 MeV/amu
  - LETs in Si between 1.5 and 42 MeV-cm$^2$ / mg
  - Range in Si between 8.9 and 1.1 mm
  - Limited energy degrading is possible to achieve higher LETs
  - Improvements are need so that low energy, longer range, higher LET ions can be used
- Increase low energy testing capability by:
  - Add capability to change angle of down stream degrader relative to ion path to add fine resolution energy tuning
  - Add motion control parallel to ion beam to reduce air gap
  - Develop ion energy measurement for low energy ion beams (<50 MeV/amu)