The CRÈME Tools on the Internet

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Acknowledgements:

- NASA MSFC: Advanced Avionics and Processor Systems (AAPS), formerly RHESE
- The Geant4 collaboration, especially Makoto Asai, Dennis Wright and Vladimir Ivantchenko
- DTRA Basic Research and Radiation Hardened Microelectronics Programs
- NASA GSFC: NASA Electronic Parts and Packaging (NEPP) Program
- LANL and TRIUMF, for collaborative work

What is the Crème site?

- Omnibus web site for modeling of energy deposition in materials due to heavy particle radiation
- Provides access to:
  - Legacy Creme-86 and Creme-96 RPP models
  - New, Geant4-based Crème-MC Monte-Carlo radiation transport in multilayer stacks
  - Secure and simple management of files on site
  - Plotting and download of data from all simulations

Site Feature Status

Feature	Status
CREME96 Modules	Public
Updated GCR Model	Public
Multiplanar Stack	Beta
MC Sensitive Volumes	Beta
CREME86	Alpha
Lunar Neutron Albedo Model	Alpha
Probabilistic Solar Proton Models	Development
HZETRN Radiation Transport	Development
Radiation Transport Through Spacecraft	Development
Revised Geomagnetic Cutoff Model	Development

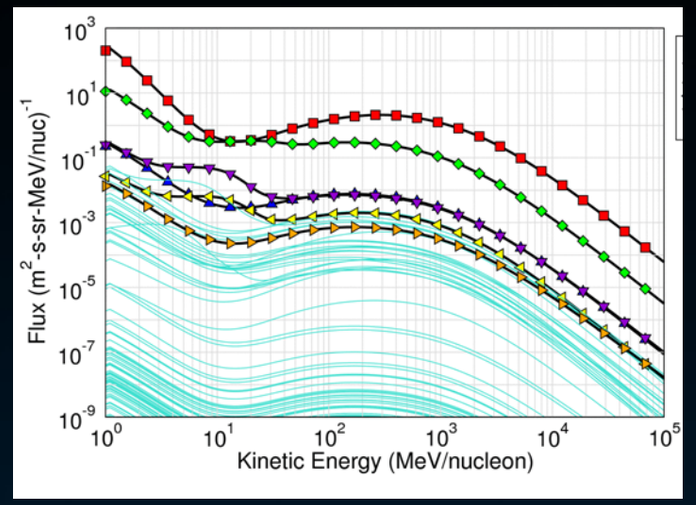
- Naval Research Laboratory was shut down CREME96 on July 19, 2010
- Users should register with CRÈME: https://creme.isde.vanderbilt.edu
- Public release scheduled for November 2010
- Normal Registration does not provide access to MC tools... email a request to be a beta user

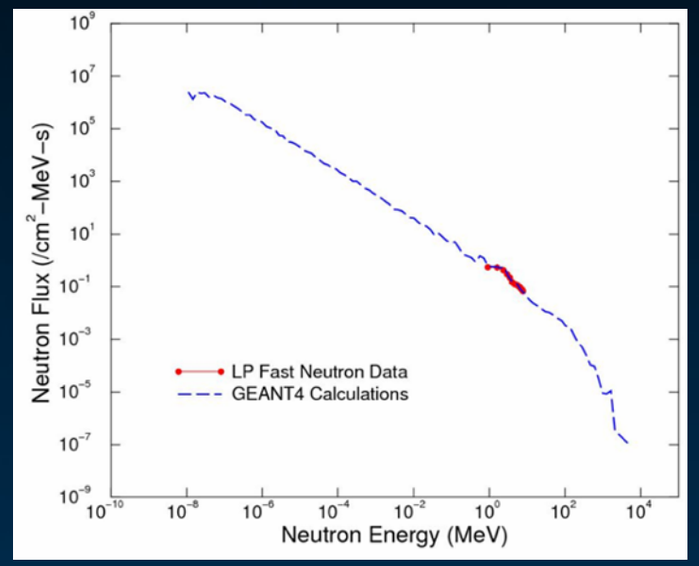
Why is Crème-MC important or useful?

- For simple geometries, provides highly detailed particle transport and energy deposition
- Allows Creme-96 GCR, trapped proton and geomagnetic transmission models to generate particle fluxes to transport with Geant4
- Has multiple-device coincidence capability built in
- Has weighted-sensitive-volumes built in to account for partial charge collection from regions distant from device center
- Includes CEM03 and LAQGSM nuclear models for high-fidelity breakup of heavy nuclei at cosmic-ray energies

Radiation Environments

- Legacy models
  - CREME86 and CREME96
- Updated Galactic Cosmic Ray model (ISO 15390:2004)
- Lunar Neutron Albedo model (Adams, 2007)
- Probabilistic Solar Proton Models
  - Worst-Case Peak Flux Spectra
    - ESP model for protons (Xapsos et al., 1998)
    - Extend to heavy ions
- Worst-Case Event Fluence Spectra
  - ESP model for protons (Xapsos et al. 1999)
  - Extend to heavy ions
- Worst-Case Cumulative Mission Spectra
  - Psychic model extended to include heavy ions (Xapsos et al., 2007)

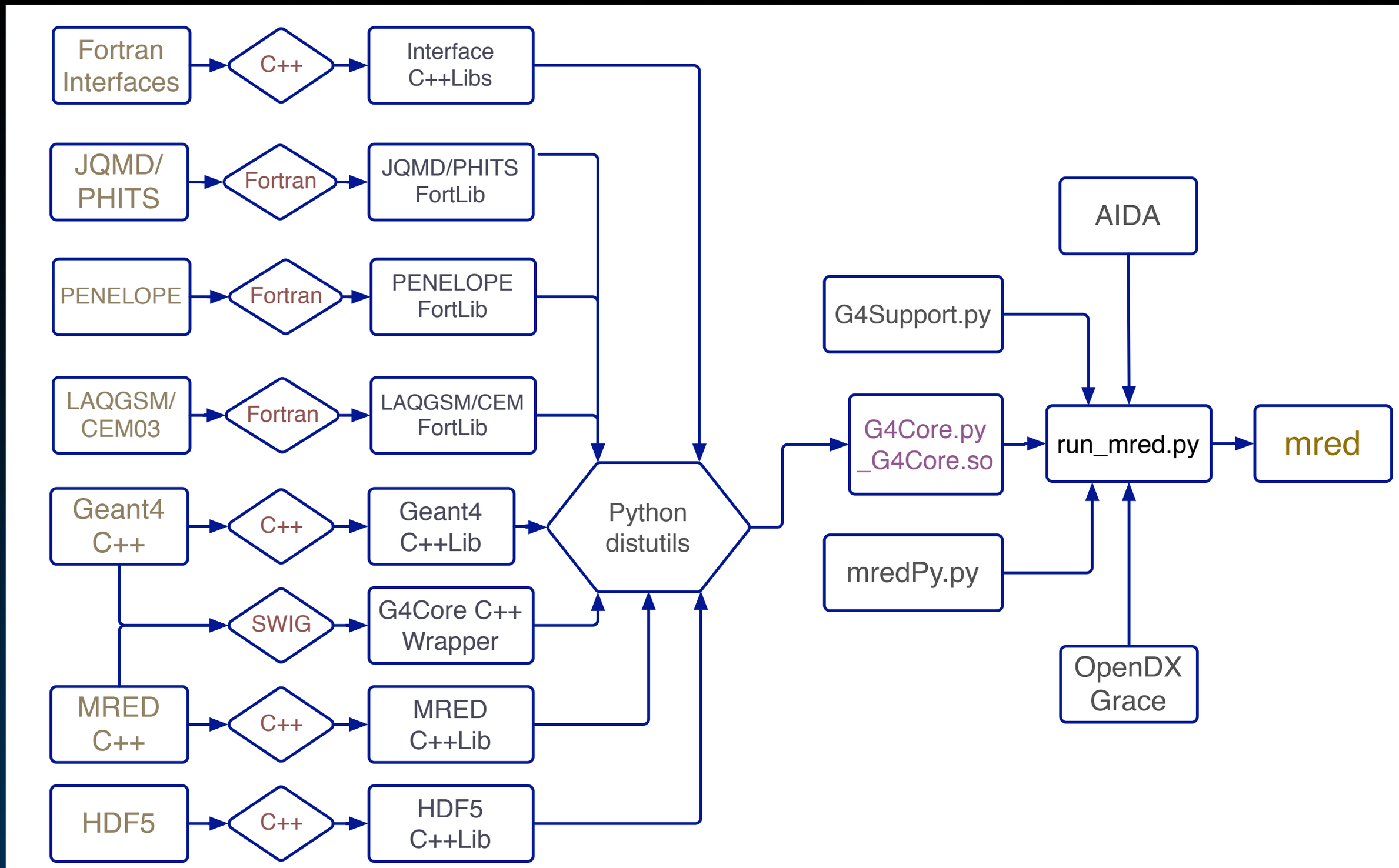




Crème-MC technology

- Web site is controlled via Plone to provide secure environment and file management
- Using much custom Python glue code, site produces a set of files which are digested by Vanderbilt MRED code
- MRED is a python-wrapped Geant4 application optimized for small (semiconductor-scale) geometries

MRED Architecture



Extended nuclear physics codes

- Heavy-ion driven nuclear fragmentation drives many important types of microelectronic events
- National labs, etc., have very detailed nuclear physics models, mostly written in FORTRAN, which can provide high fidelity reactions.
- Need to be able to use these codes in our framework
  - These codes are not designed to be executed inside the framework of other codes. They are stand-alone.
  - Common heritage of codes means many COMMON blocks and variables have same names

Tool for importing FORTRAN codes

- Automated Python script collects and rearranges code and renames structures to avoid conflicts
  - All separate files collected into a single big file
  - Main code body moved into FORTRAN ‘module’
  - BLOCK DATA statements collected and moved to end, renamed with unique names e.g.
    BLOCK DATA constants -> BLOCK DATA constants_cem
  - COMMON blocks renamed with unique names e.g.
    COMMON reaction -> COMMON reaction_cem
- c++ & python interface generated
- Automated procedure guarantees 2 things:
  - low probability of bugs introduced via typos
  - updates in master code easily reincorporated
- This is a unique tool -- no one else has this machinery

Sample rearranged code

```
      module cem03
      private
      contains
      subroutine cem03event

      common / adbf_cem /
     *     amf, rom, tjsp, nhump
      common / ajsbar_cem /
     *   ainit, zinit, eb(30,70,100), egs(30,70,100)
      ...
      end subroutine

      end module cem03
```

subroutines and functions collected inside ‘module’

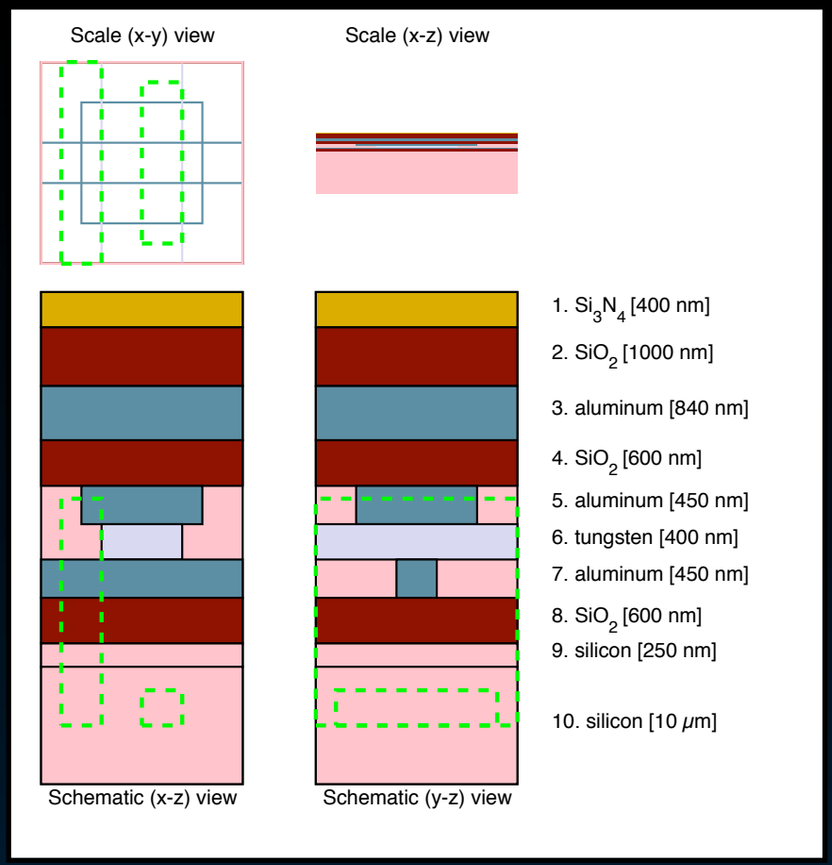
```
      block data bd1_cem

      common / coefa_cem /
     *   ankj(4,4,29)
      common / coefbc_cem /
     *  bnkj(4,4,8), ckj(3,8)
c  j = 17; pi- + p --> pi0 n or pi+ + n --> pi0 + p Charge exchange
c           scattering; Tlab <= 0.08 GeV:
      data ((ankj(n,k,17),n=1,4),k=1,4) /
     & 1.4988d-1 ,  2.8753d+0 , -5.3078d+0 ,  6.2233d+0 ,
     &-5.9558d+0 , -1.6203d+2 ,  4.3079d+2 , -6.2548d+2 ,
     & 1.2875d+2 ,  3.1402d+3 , -7.9189d+3 ,  1.0983d+4 ,
     &-8.5161d+2 , -1.8780d+4 ,  4.4607d+4 , -5.8790d+4 /

      end block data
```

BLOCK DATA not allowed in module, automatically moved to end

Conceptual framework of Crème-MC



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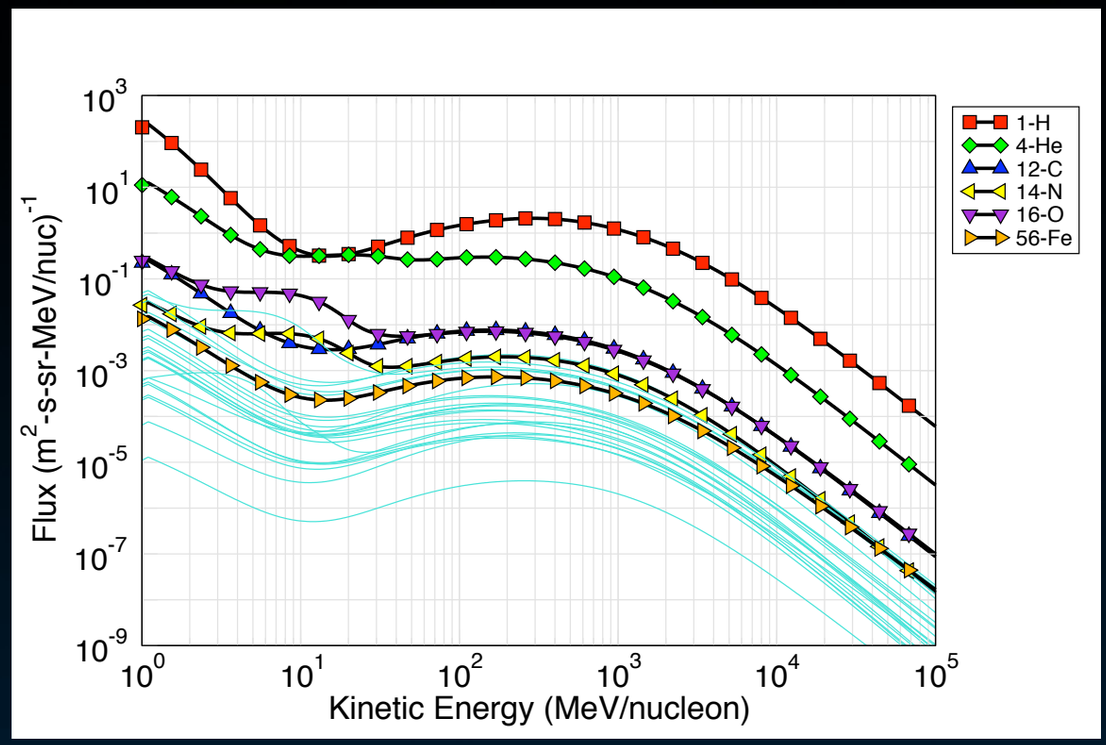

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Device Parameters

Name: dev1 **Ecrit:** .01

xmin	ymin	zmin	xmax	ymax	zmax	alpha	Use ellipsoid?
-20	-25	-2	-10	25	5	1	

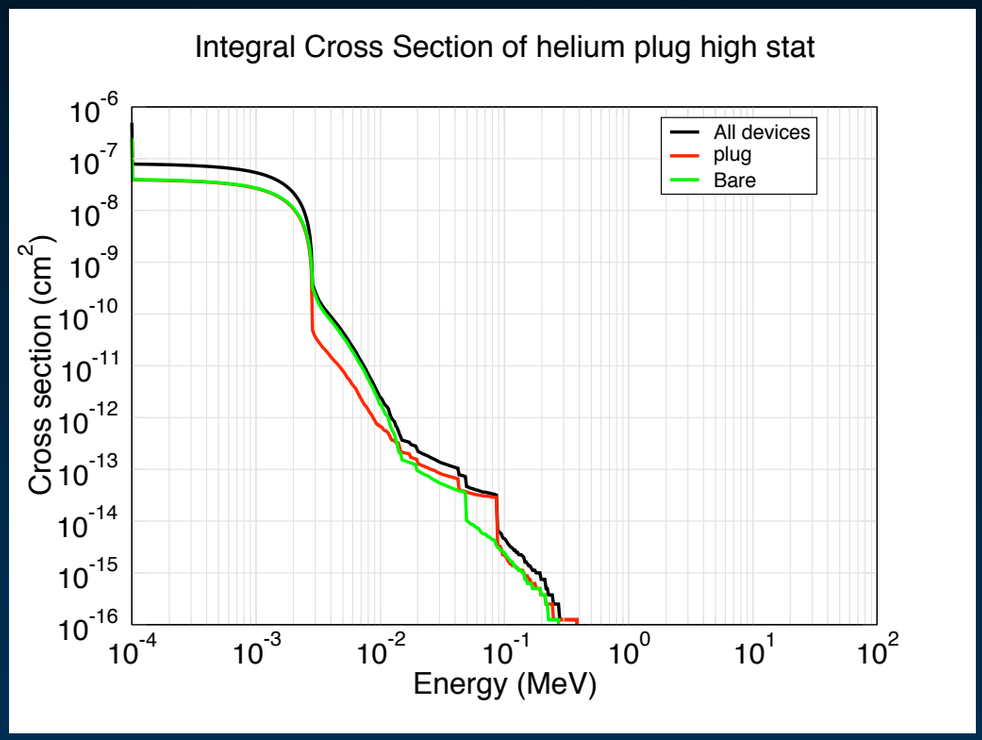
add volume

Device Parameters

Name: dev2 **Ecrit:** .01

xmin	ymin	zmin	xmax	ymax	zmax	alpha	Use ellipsoid?
0	-20	2	10	20	5	1	

add volume

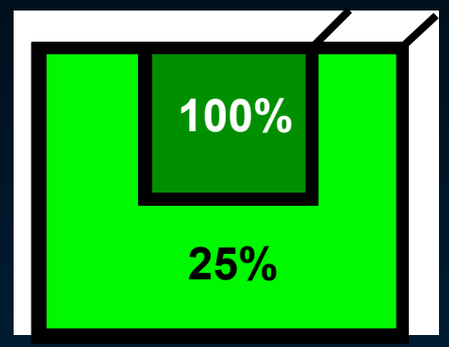


Capabilities

- Create stacks with arbitrary number of layers of materials commonly found in electronics
- Create either monochromatic beam or ‘space environment’ as radiation source
- Define multiple ‘devices’, each consisting of a set of RPPs or ellipsoids with specified collection weight
- Manage range cuts for either
  - high detail of delta ray tracking (LET mode)
  - lower detail, to allow very large numbers of incident ions (nuclear reaction mode)
- Produce histograms of energy deposition and of integral cross section
- Compute coincidence rates between devices

Sensitive Volumes

- Weighted sensitive volumes relate spatial ionizing energy deposition with charge collected at a circuit node
- Volumes may be rectangular parallelepipeds or ellipsoids
  - Each have a location within the multilayer stack, size, and efficiency
  - Volumes may overlap or be disjoint



Device Parameters

Name: NMOS **Ecrit:** 0

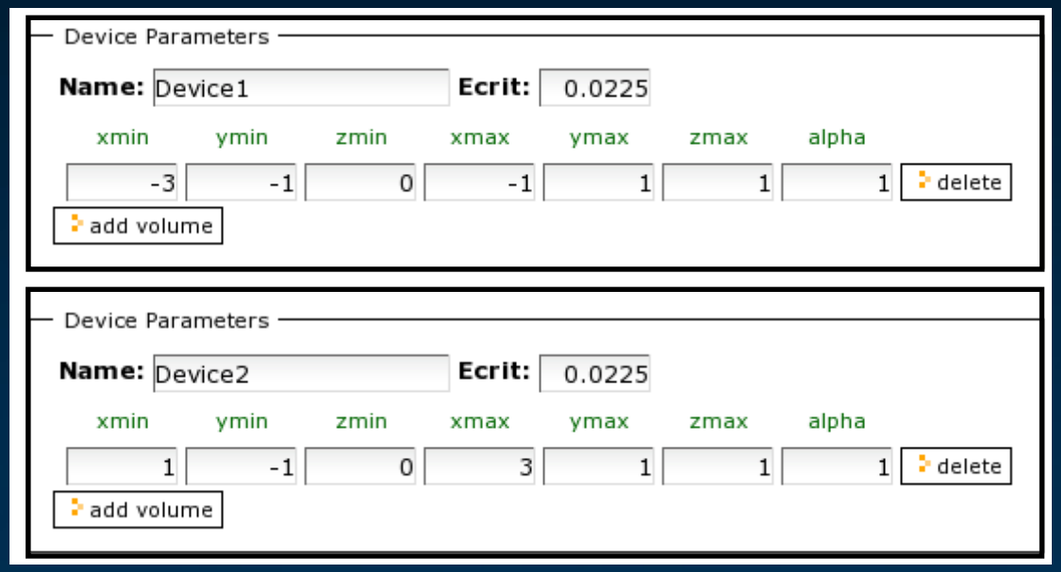
xmin	ymin	zmin	xmax	ymax	zmax	alpha	
-0.5	-0.5	0	0.5	0.5	0.5	0.75	delete
-1	-1	0	1	1	1	0.25	delete

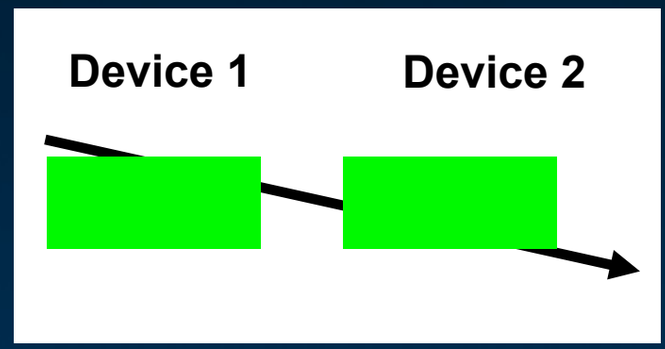
add volume

$$\mathbf{E_w} = \sum_{\mathbf{k=1}}^{\mathbf{N}} \mathbf{a_k E_{dep,k}}$$

Multiple Device Models

- Represent class of failures requiring multiple circuit nodes to collect charge
- Multiple cell upsets, DICE latches, etc
- Sensitive volume models are specified for each device and given upset threshold
- Cross sections and SEU rates are provided based on frequency of events meeting coincidence requirement





Extended Services From ISDE

- Website is backed by the electronics expertise of ISDE
  - Largest university-based microelectronics radiation group worldwide (?)
  - Can provide expertise in setting up model systems, running simulations, and interpreting results
  - Problems which are beyond capabilities of the web interface can be migrated to full MRED sims, with almost unlimited flexibility via Python interface.
  - Maintain close working relation with G4 collaboration, especially SLAC group and EM physics.
- ISDE can coordinate full accelerator-based tests to validate calculations

The Institute for Space and Defense Electronics (ISDE)
The Radiation Effects and Reliability (RER) Group
Vanderbilt University, Nashville, TN

VANDERBILT ISDE & RER

World's largest university-based radiation effects program

Radiation Effects Research (RER) Group

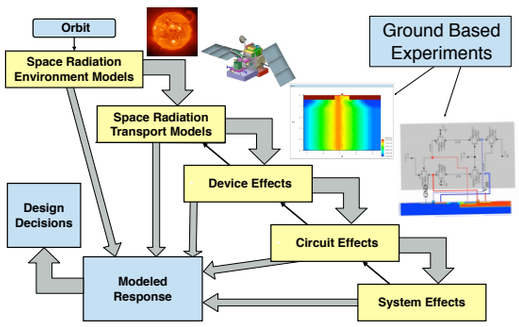
- 9 faculty with decades of radfx experience
- 30 graduate students
- A few undergraduate students
- Open access
- Hundreds of technical publications
- Basic research and support of ISDE engineering tasks
- Training ground for rad-effects engineers

Institute for Space and Defense Electronics (ISDE)

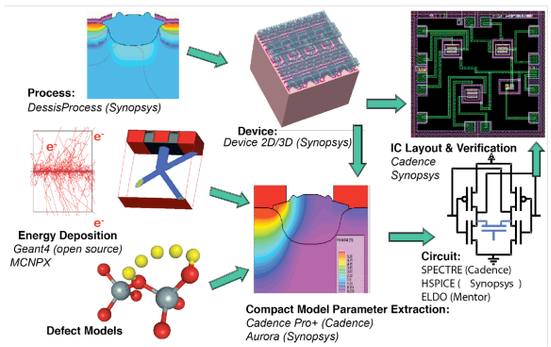
- **15 full time engineers**
- **2 support staff**
- **Limited access, ITAR compliant, IP protection**
- **Document control, milestone tracking, structured management**
- **Task driven support of specific radiation effects engineering needs in government and industry, both large and small**

- **Faculty fellows with extensive expertise in radiation-effects**
- **Vanderbilt Beowulf supercomputing cluster and ISDE mini cluster**
- **Custom software codes**
- **EDA tools from multiple commercial vendors**
- **Multi-million $ aggregate annual funding**
- **Test and characterization capabilities and partnerships**

ISDE & RER Capabilities

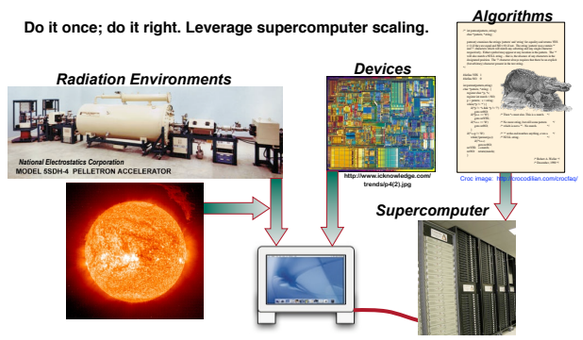


ANALYSIS & SIMULATION

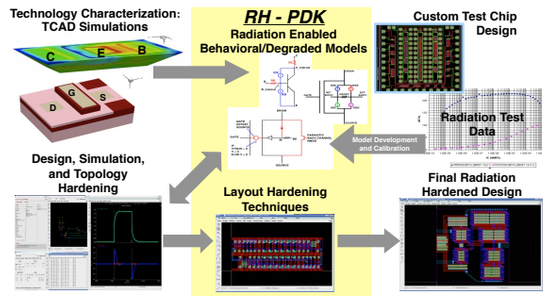


Supercomputer-Based Radiation-Effects Analysis

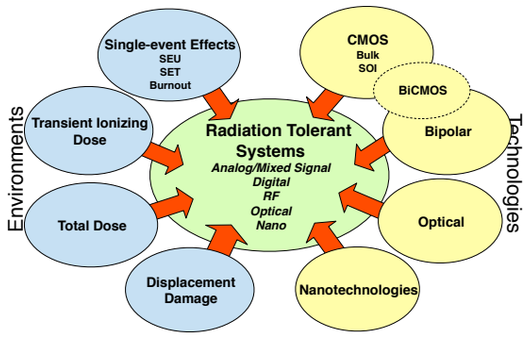
Do it once; do it right. Leverage supercomputer scaling.



DESIGN SUPPORT



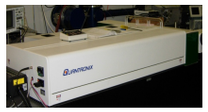
- **Rad-aware compact modeling: IC's & discretes**
- **Process modeling with radiation effects**
- **Test chip design**
- **RHBD systems design & training**
- **Software tool development & automation**



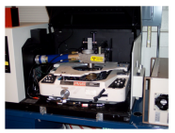
RADIATION TESTING

- **Test and characterization capabilities**
  - **Total Ionizing Dose**
  - **Single Event Effects**
  - **Displacement Damage**
- **Extensive set of characterization hardware**

Laser Testing

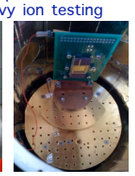


ARACOR



High Speed Probe Station

Custom cold temperature dewar for in-situ heavy ion testing



In addition to in-house test capabilities, ISDE has extensive experience working with outside radiation test facilities

- **ISDE has access to a suite of radiation sources and a fully equipped parts analysis laboratory**

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