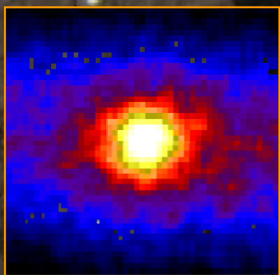
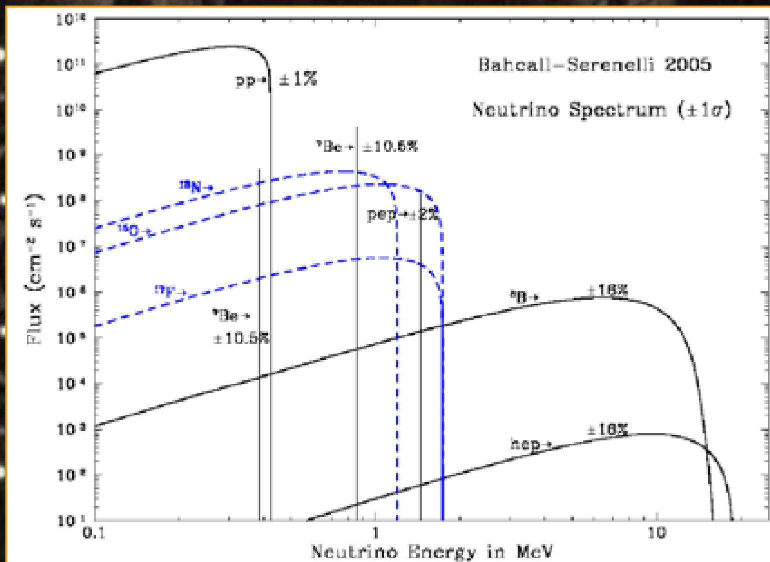
DIANA

Dakota Ion Accelerator for Nuclear Astrophysics

- Science
- Project
- Equipment
- Status

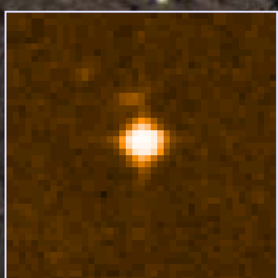
Scientific Questions

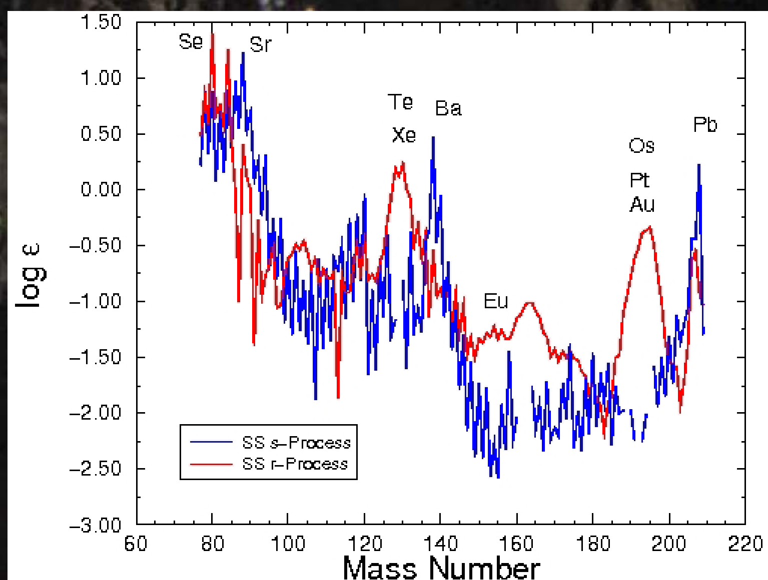




Stellar Neutrino Sources

in the sun & massive stars

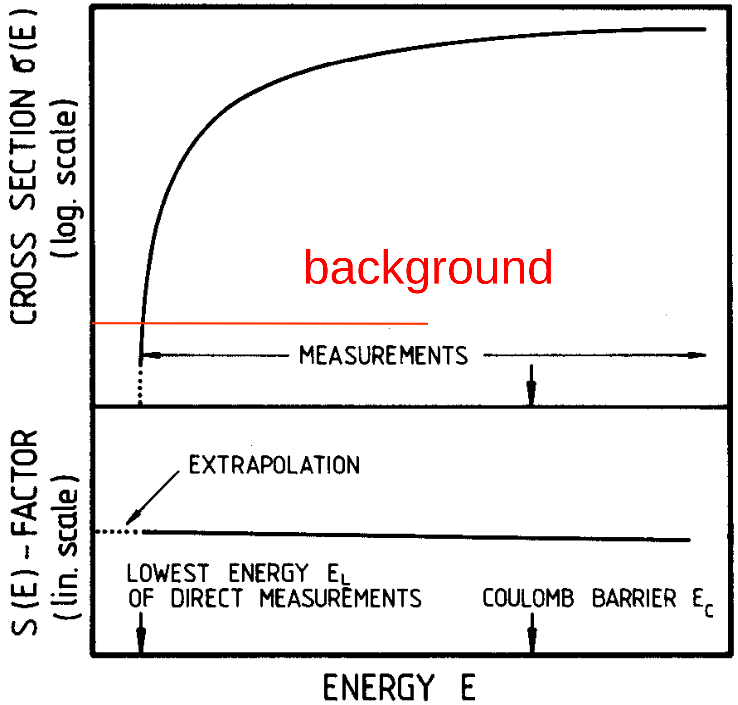


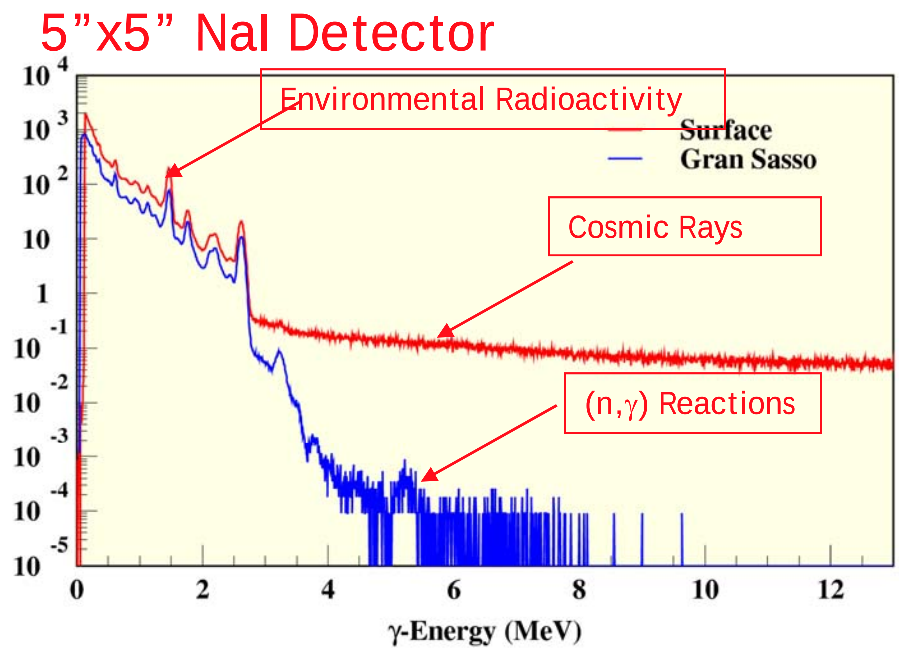


Origin of the Elements

In early & present Universe

Why going underground?

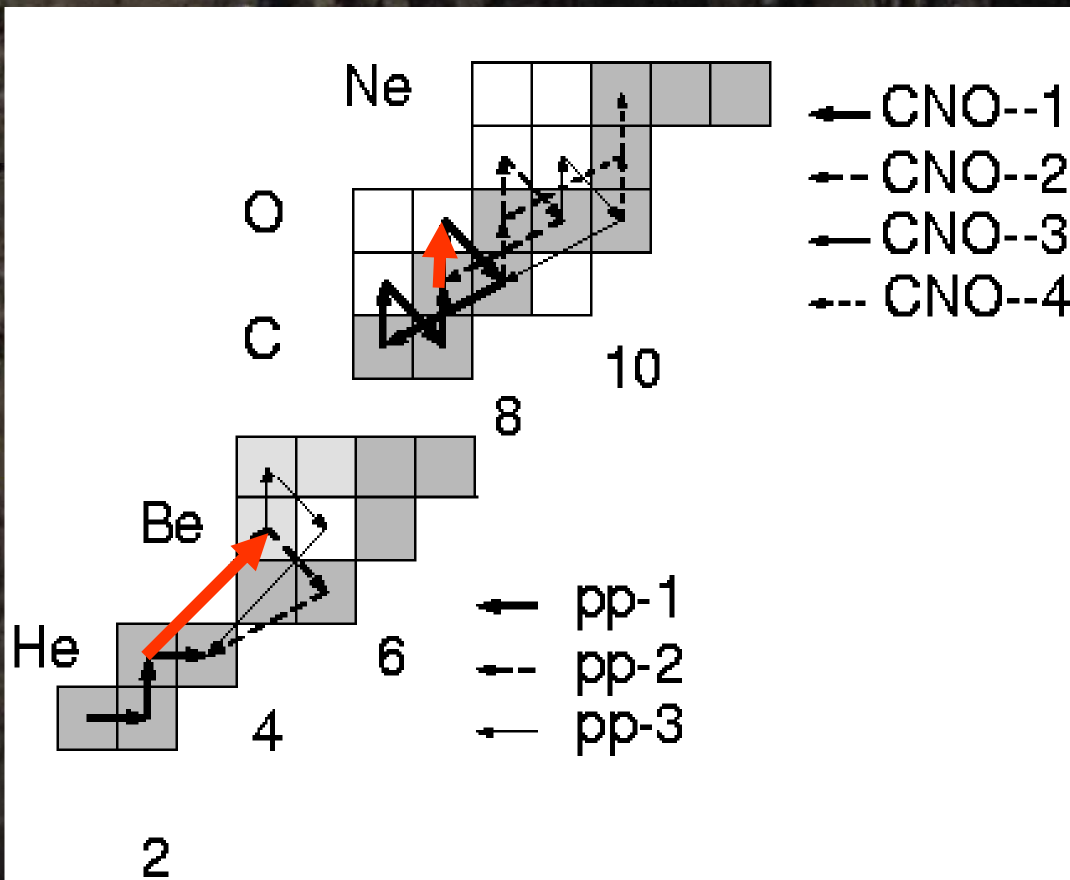




For low Q-value reaction: Passive shielding (Pb) is more effective when the muon flux is reduced

Slide from Alberto Lemut, LUNA collaboration

Neutrino production & solar metallicity



Two critical reactions

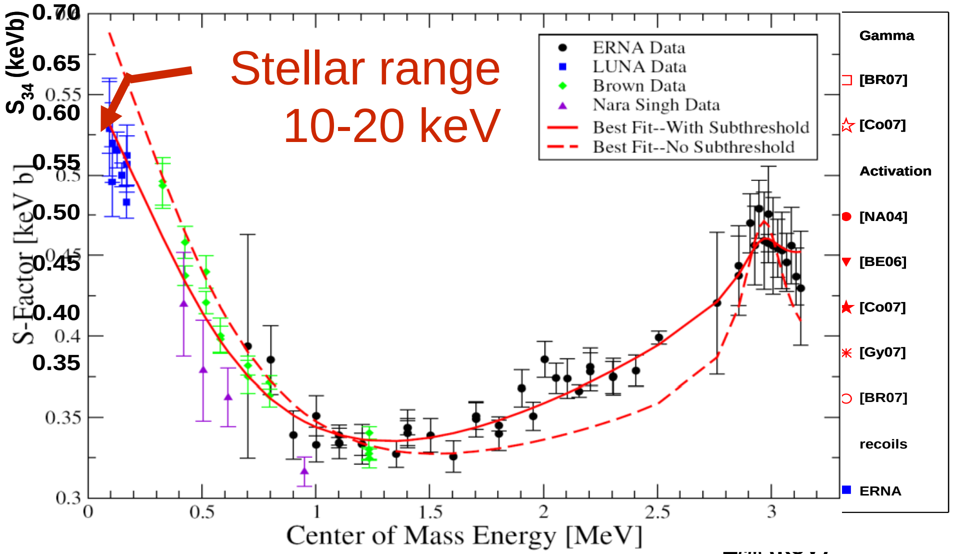
pp-chains: $^{3}He(\alpha,\gamma)^{7}Be$

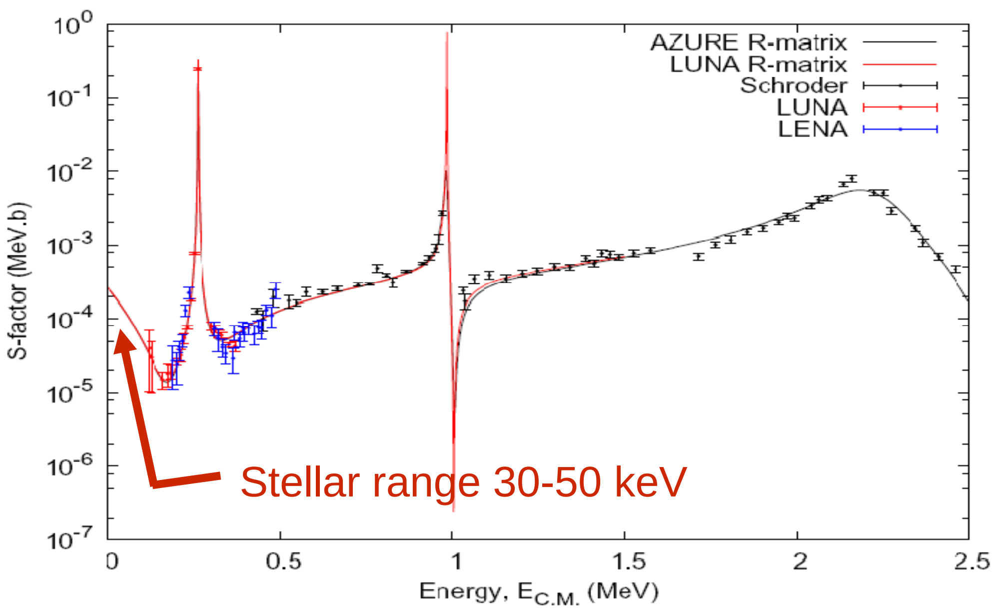
CNO-cycles: $^{14}N(p,\gamma)^{15}O$

Pioneering work at LUNA
New technology necessary for further improvement

Measurement of nuclear reactions at (near) stellar energies with 5%-10% accuracy

$^{3}He(\alpha,\gamma)^{7}Be$ and $^{14}N(p,\gamma)^{15}O$

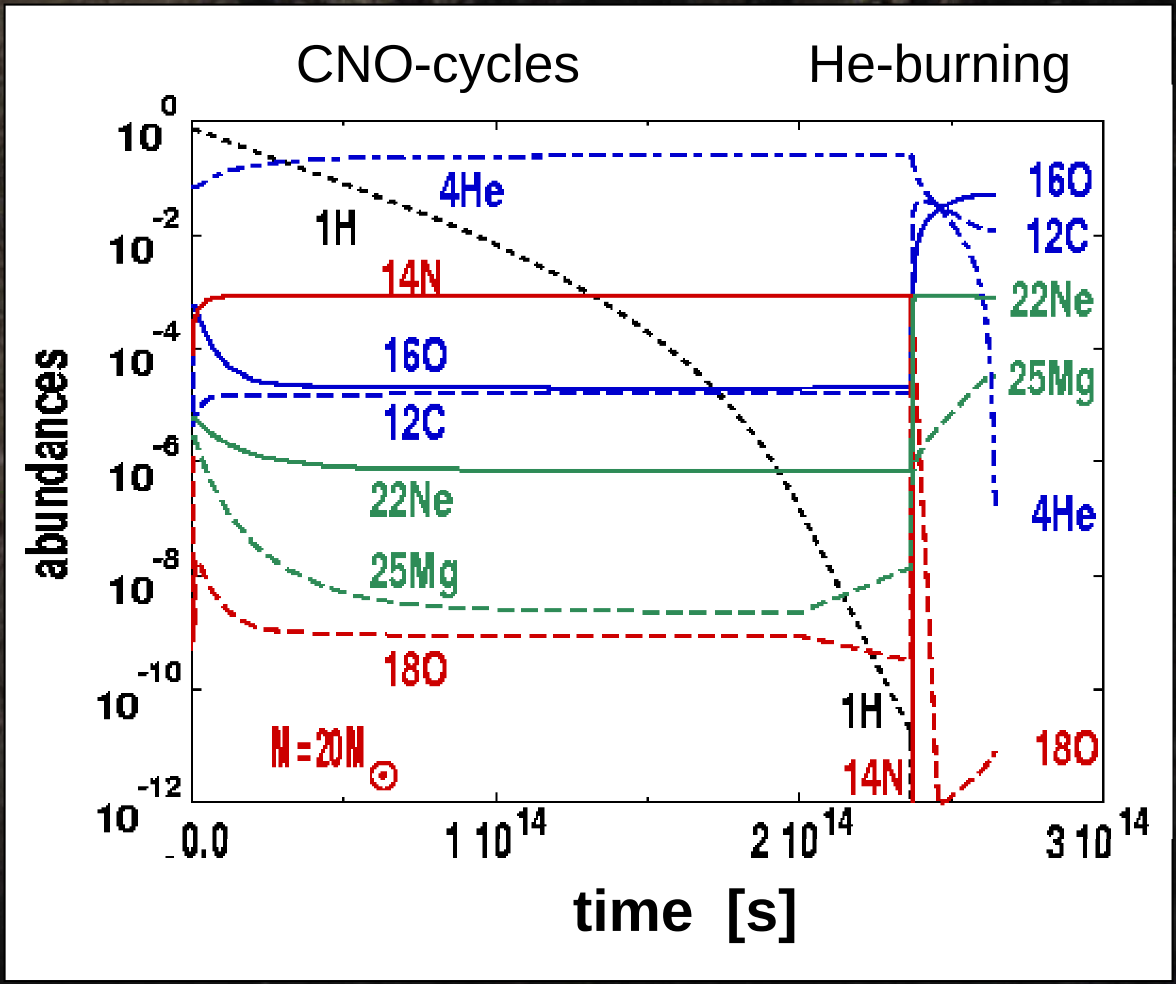




LUNA experiments are close to stellar energy range, theory based extrapolations suffer from model uncertainties.

New generation accelerators with high beam intensity in a background free environment are necessary to reach the stellar energy range.

Neutron Sources



How strong is $^{22}Ne(\alpha,n)$?

$^{25}Mg(\alpha,n)$

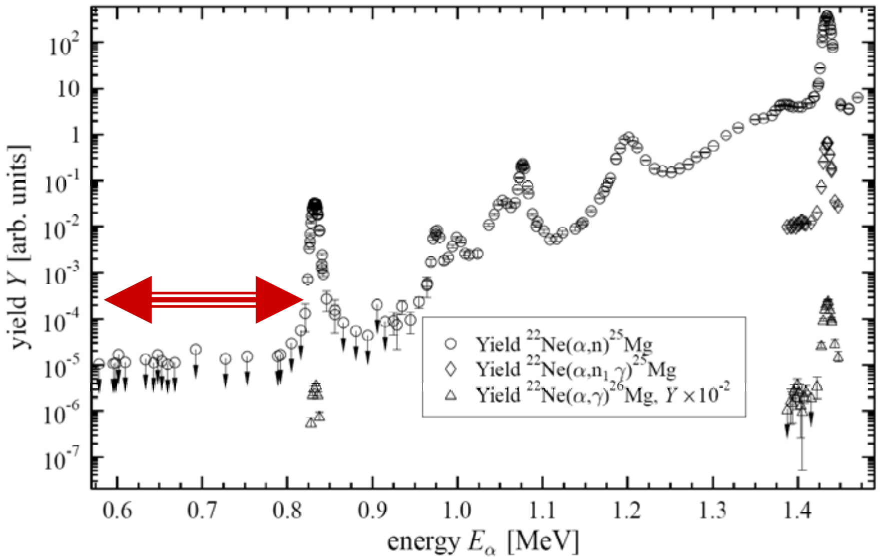
….

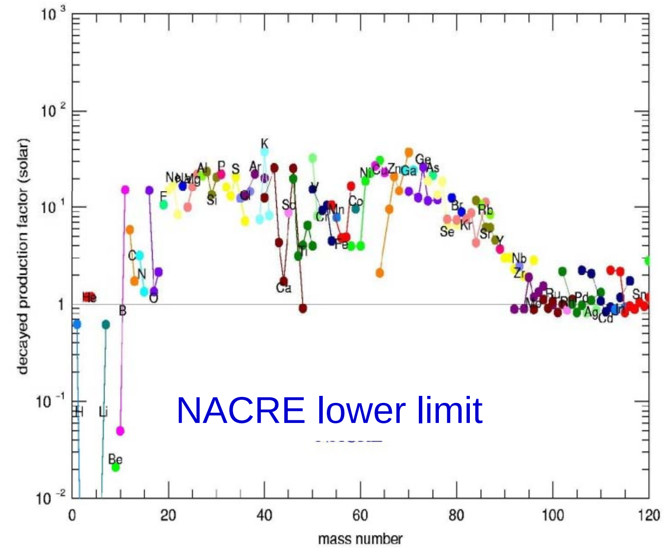
…

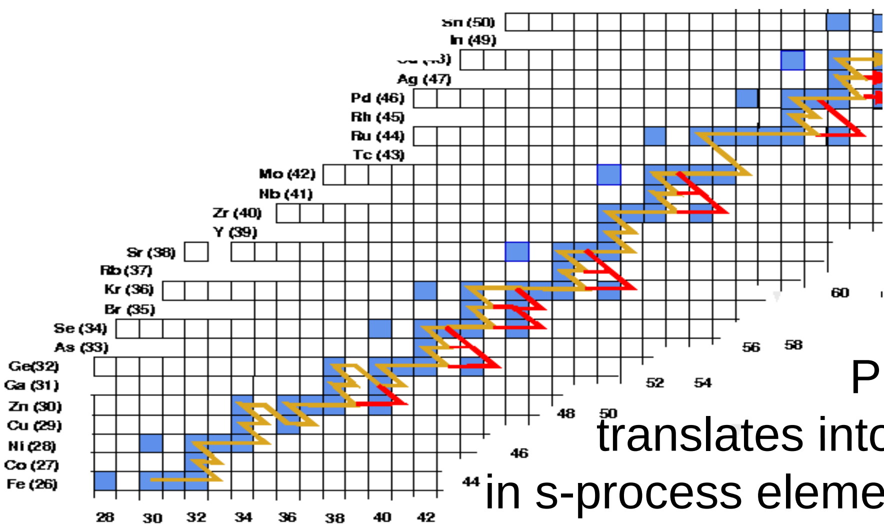
..

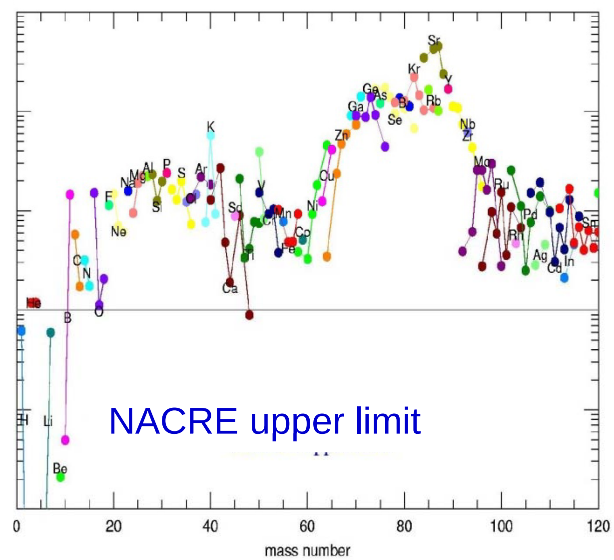
.

The impact of neutron production







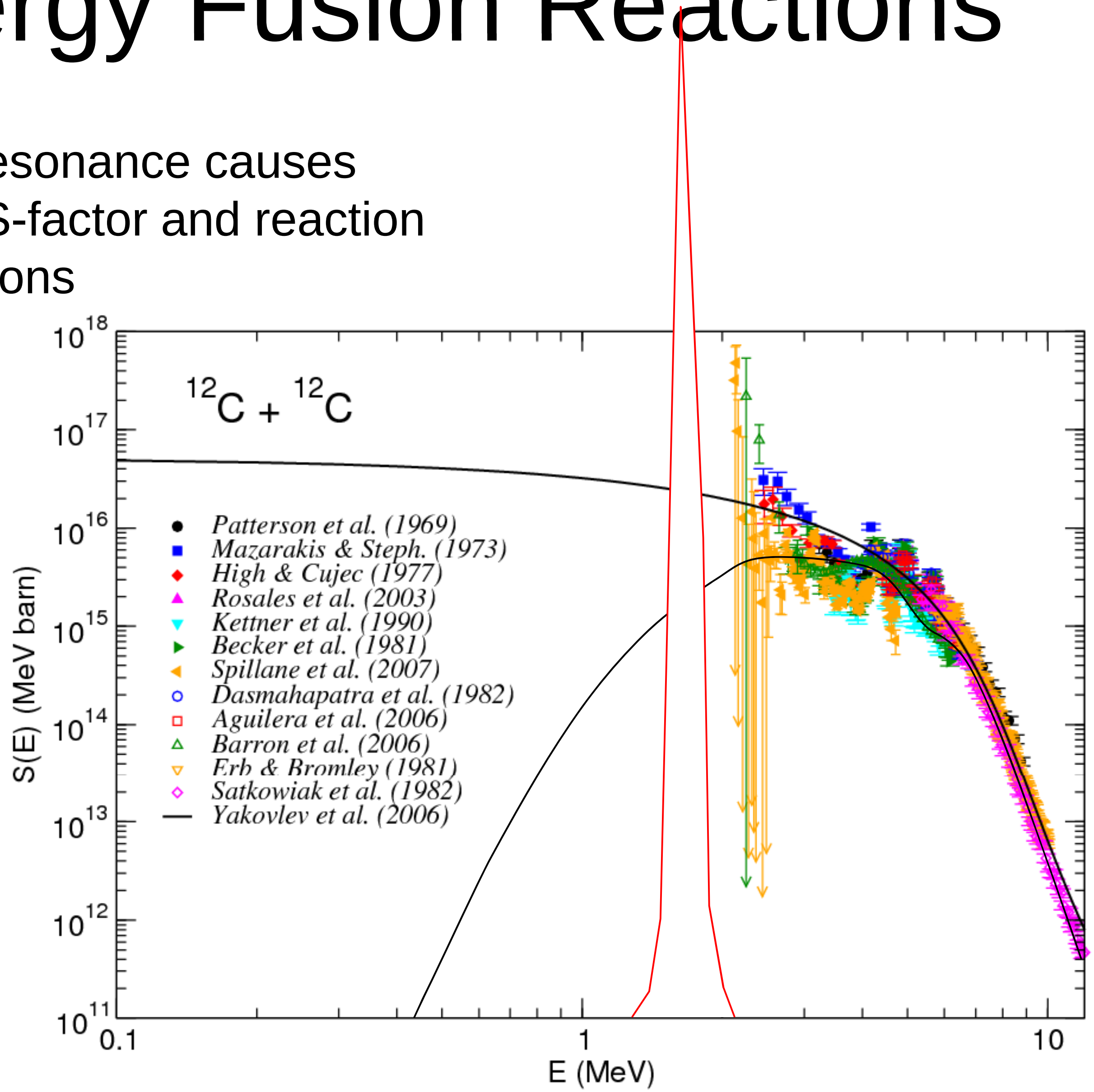


Present uncertainty translates into large uncertainty in s-process element production with broad consequences for explosive scenarios of nucleosynthesis such as p-process and r-processs

Low Energy Fusion Reactions

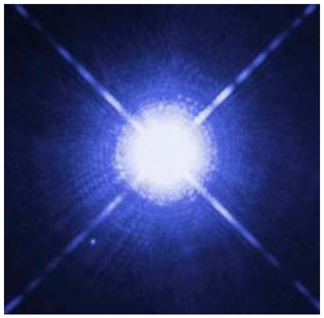
Strong, molecular $^{12}C+^{12}C$ resonance causes enormous enhancement of S-factor and reaction rate at stellar burning conditions

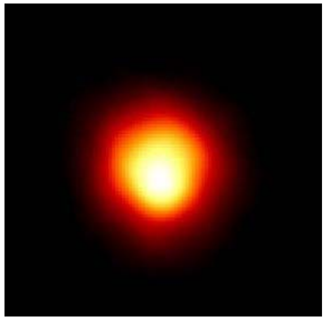
- standard potential model
- low energy resonances

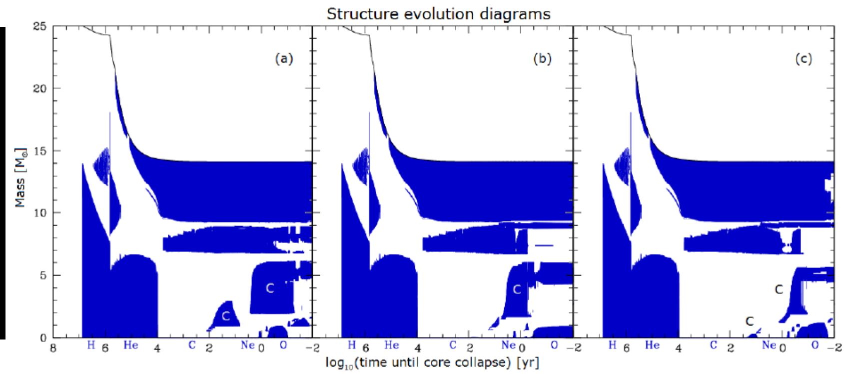


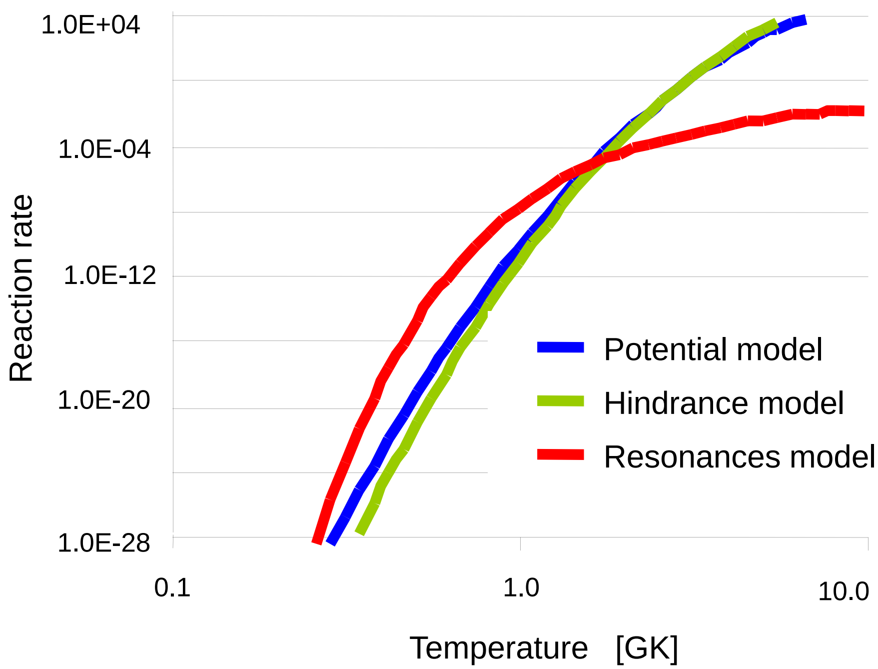
Caughlan & Fowler ADND 1988
Gasques et al. PRC 2005
Spillane et al. PRL 2007
Zickefoose et al. Capri 2009

The consequences for stars

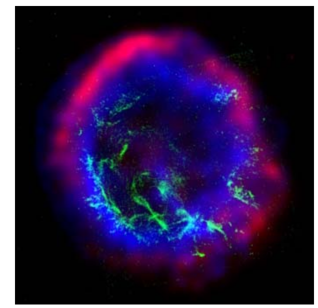


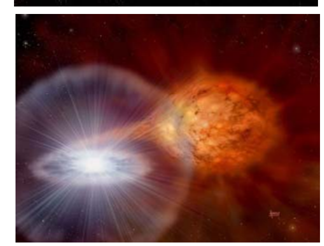






- ❑ Change of time scale for carbon burning phase
- ❑ Change of internal structure of pre-SN stars
- ❑ Decrease for ignition conditions for type Ia SN
- ❑ Explanation for fusion triggered superbursts

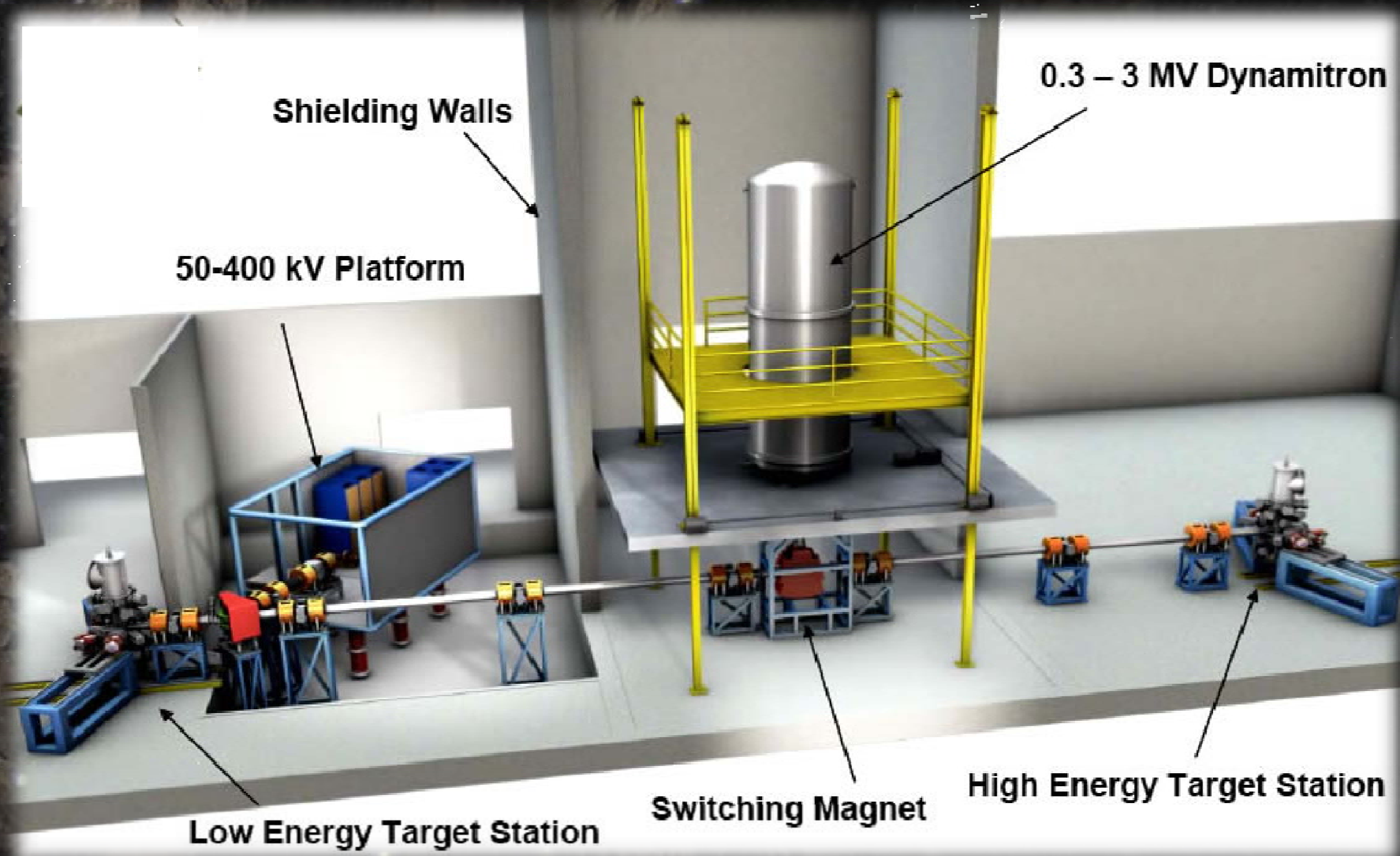




Project Design & Development

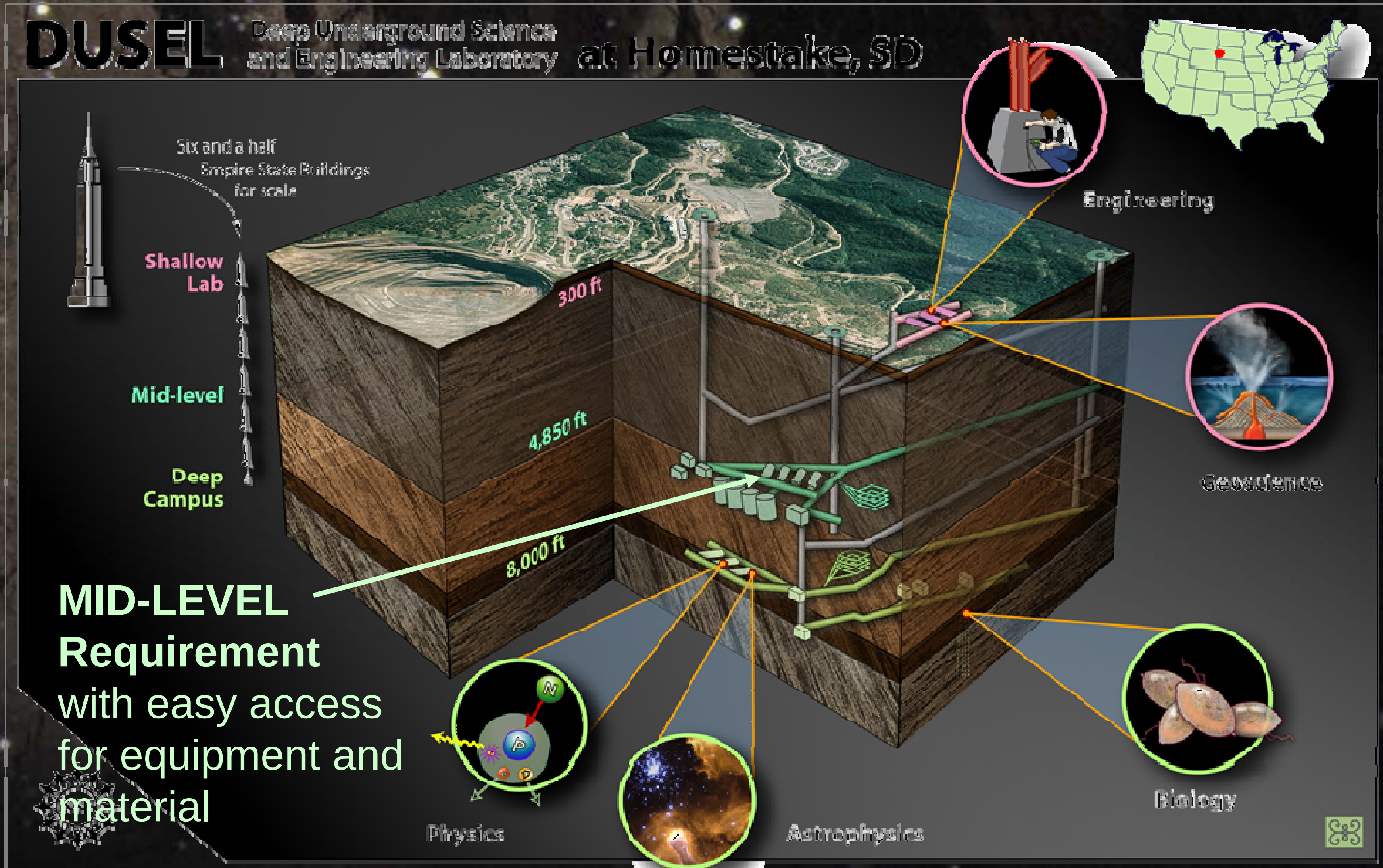
- low energy accelerator with high proton/alpha beam intensity
- medium energy accelerator for alpha and heavy ion beams
- gas target and solid target production facilities
- detector design for active background rejection
  & event identification
- passive shielding for room background rejection
  & beam induced background shielding

Laboratory Lay-Out



Approx. Cave Dimensions:
Length: 45 m
Width: 20 m
Max. Height: 20 m

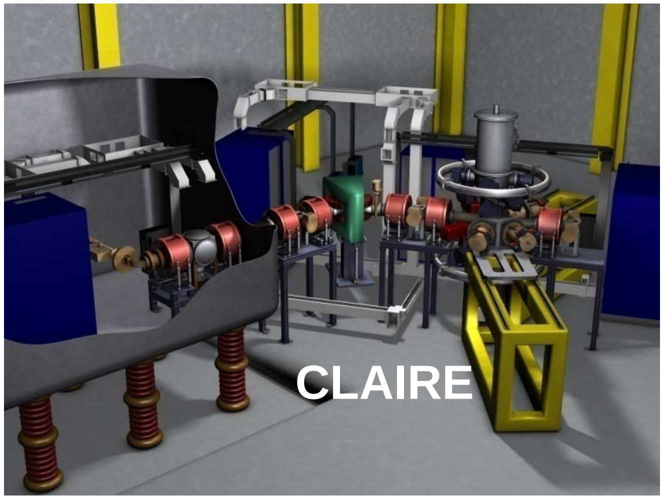
Location & Depth Requirements



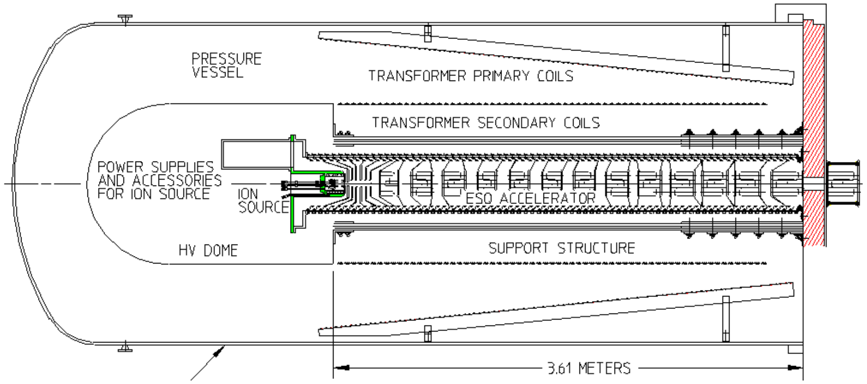
MID-LEVEL Requirement with easy access for equipment and material

DIANA - Accelerator & Ion Source

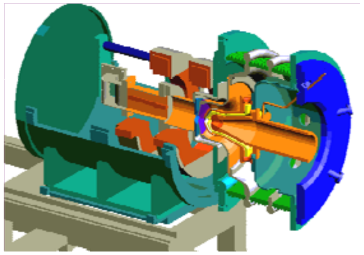
1. A compact, high intensity low energy (50keV - 400keV) accelerator under development
   - CLAIRE (High current DC accelerator)

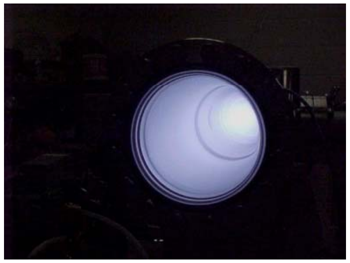


2. A versatile high intensity heavy ion accelerator for medium energies (.3 to 3MeV) in planning
   - Dynamitron type with ECR source

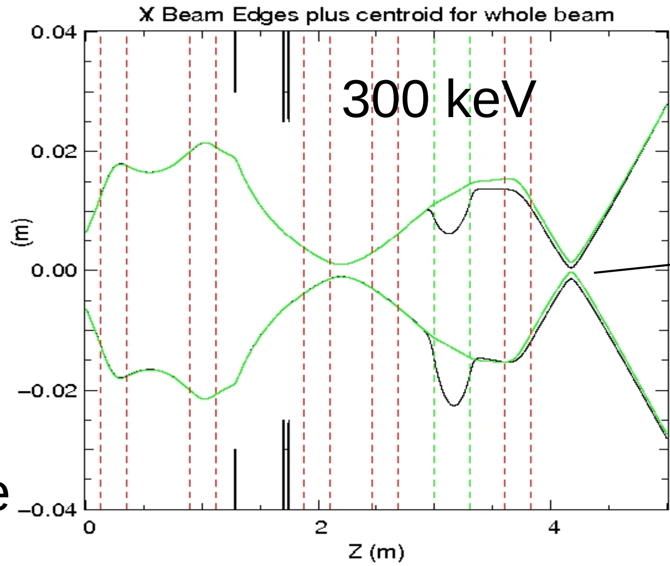


3. Ion sources for both accelerators
   - high intensity 1+ ECR (up to 100mA)
   - Medium intensity n+ ECR (.5mA)

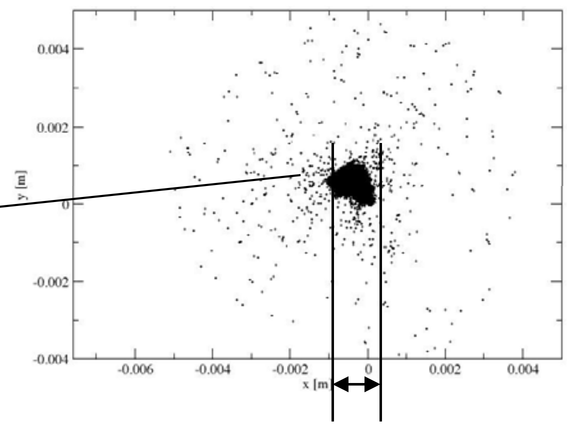




Beam Optics Simulations

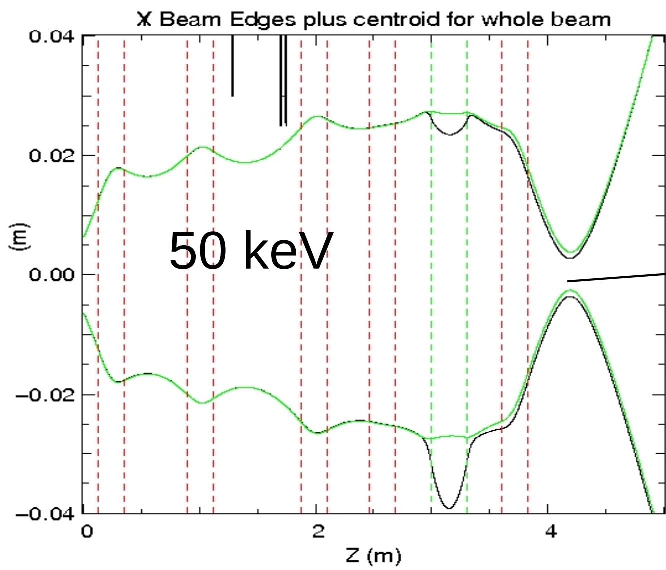


target

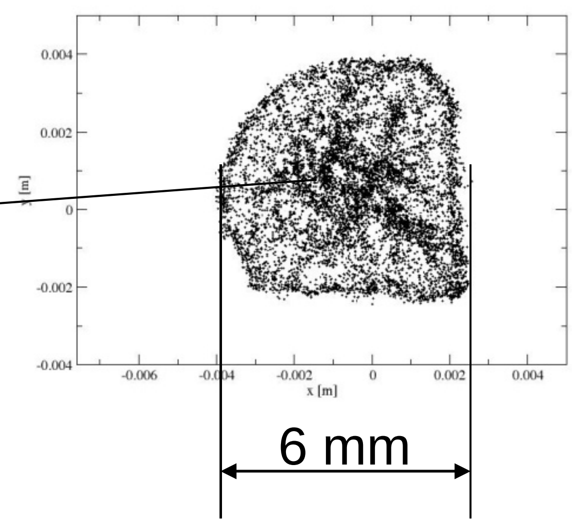


ion source
and beam
extraction

needs interfacing
with the gas jet
target geometry



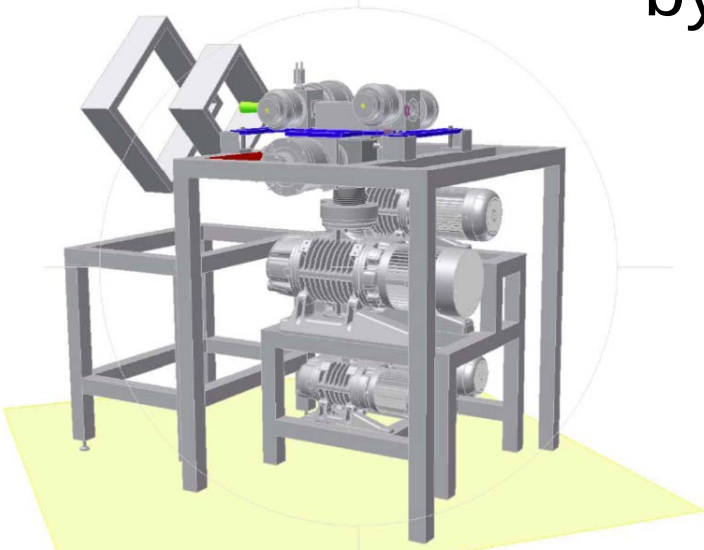
target



solenoids

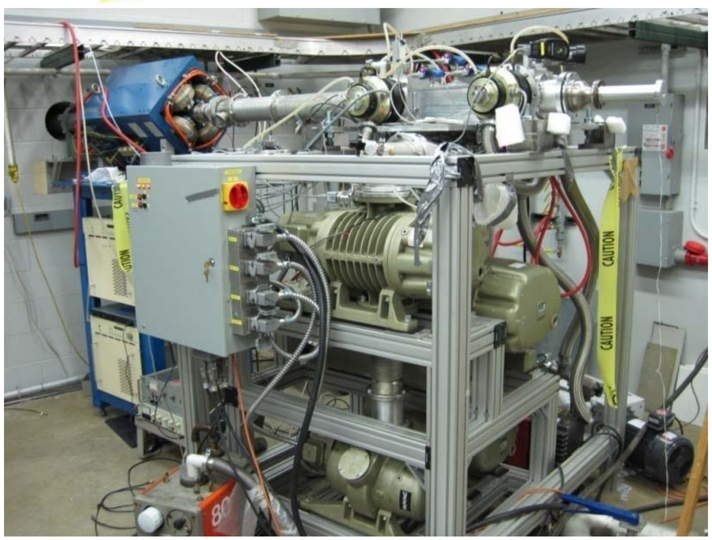
Equipment Development

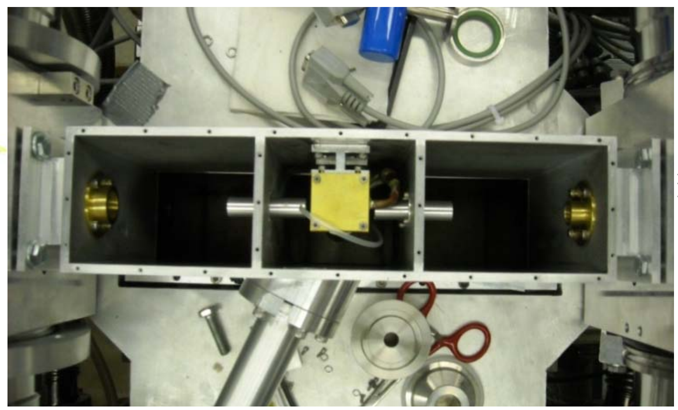
by university consortium

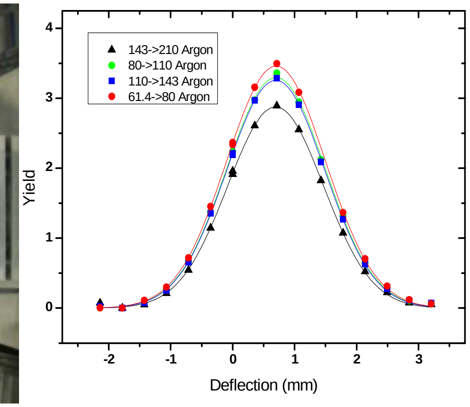


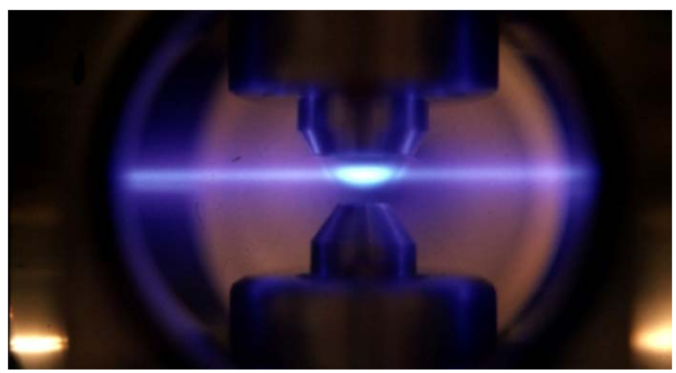
- Target systems
- Detector arrays
- Shielding

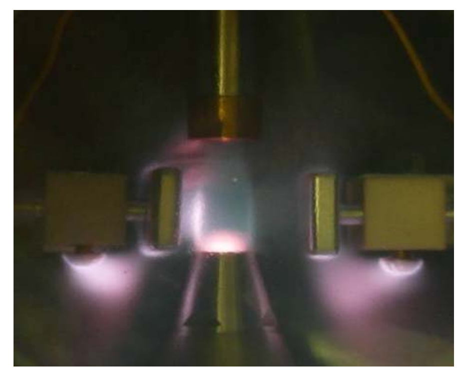
Jet Gas Target System



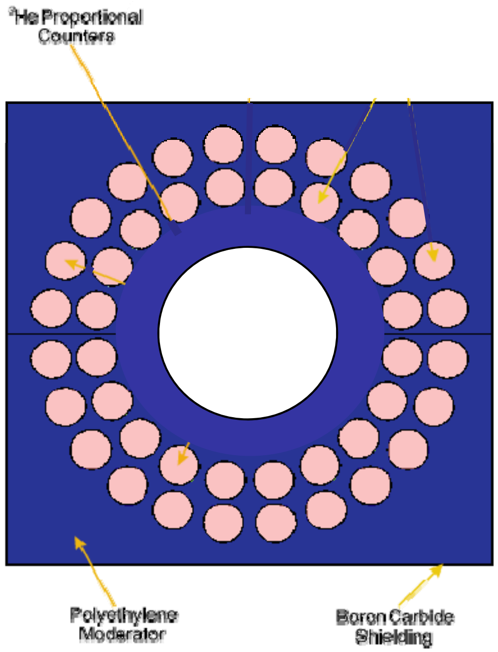


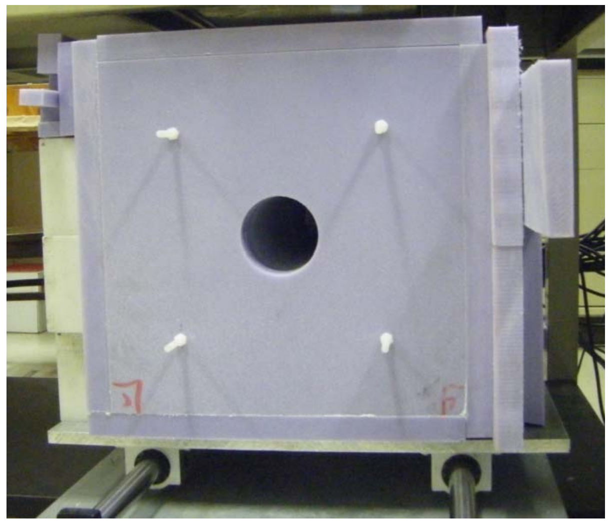




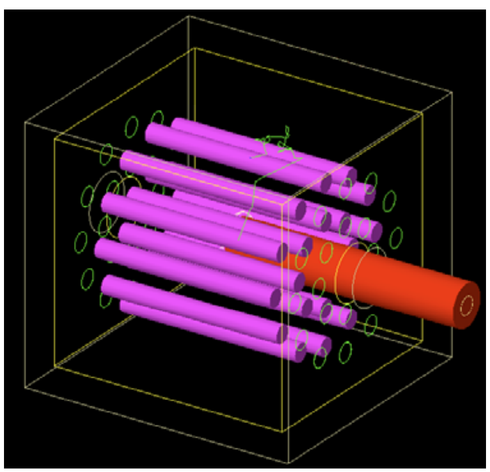


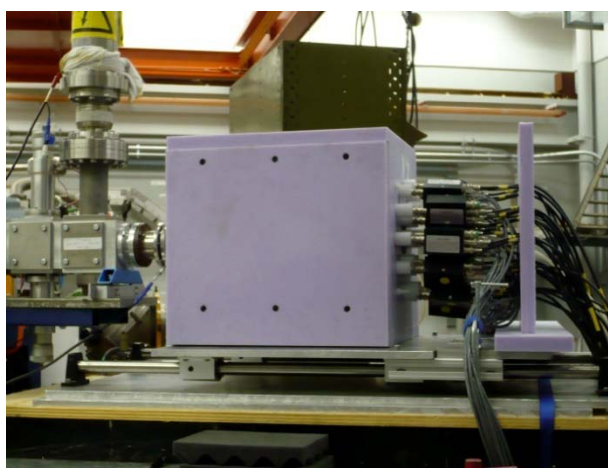
Neutron Detectors



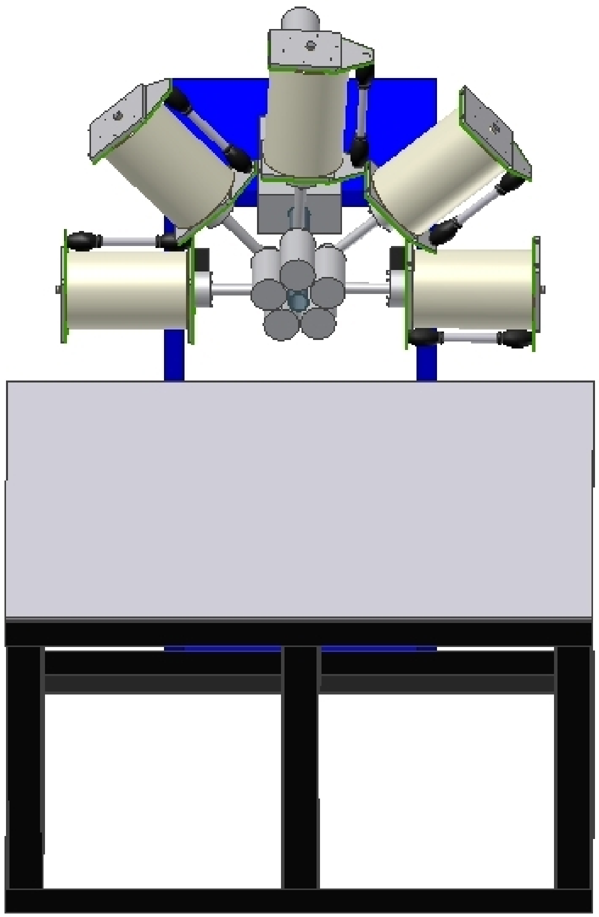


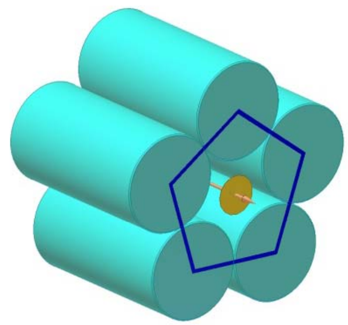
- Test design completed with ^{3}He tubes on loan.
- Several ^{18}O,^{26}Mg(α,n) reactions measured for general performance and internal background test!
- Underground detector tests planned for DUSEL and WIPP environment!



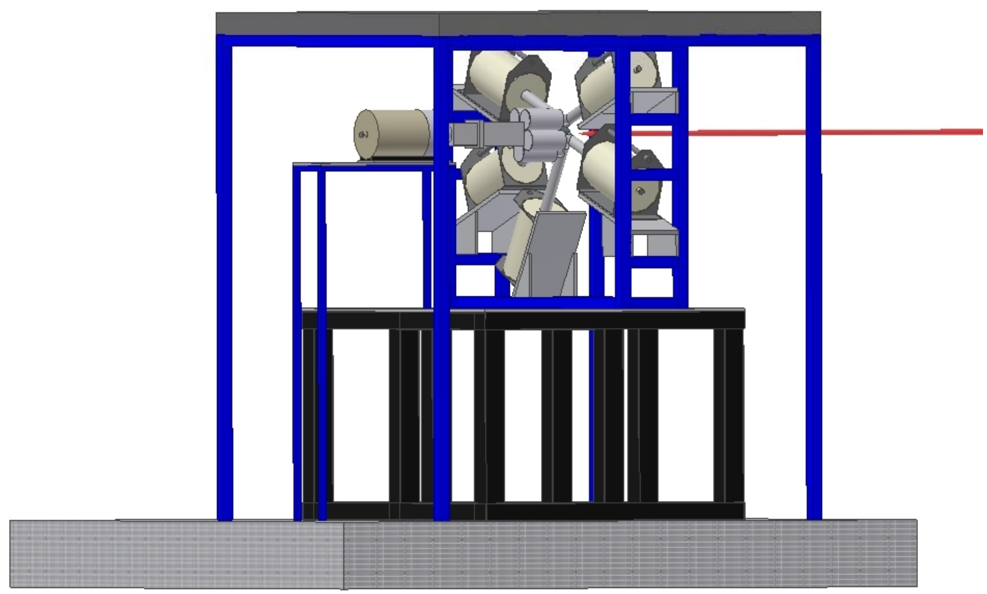


Gamma Detectors

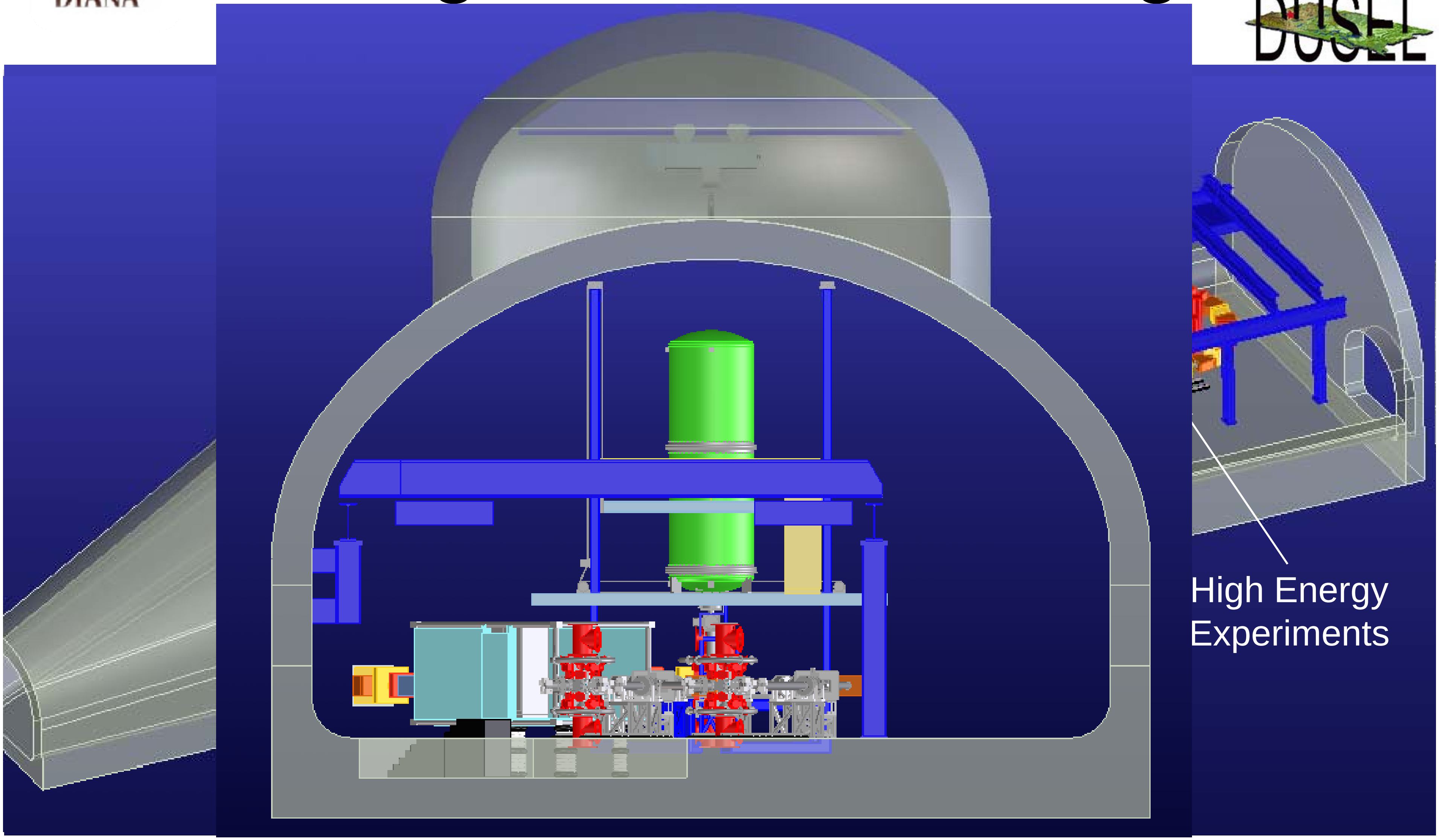




MC simulations of design for optimizing the segmentation of Ge crystals



Underground Vault Design



Accelerator Lab Module 20m x 12m x 50 m

DIANA

Space

One Standard Experimental Cavities of 50x20x15m^3 are currently envisioned for the **4850 ft** level.

- Low energy accelerator: CLAIRE: 10x8x5m^3
- High Energy Accelerator: 30x20x5m^3, space for SF_6 (if needed)
- Experimental hall: 20x15x5 m^3 with additional space of 5x10x3 m^3 for housing the necessary power supply units for magnetic and electric beam optics systems.
- Control area, Counting area: 8x8x3 m^3
- Power supplies: 5x10x3m^3
- SF6 storage, Cooling water, Cryogenic equipment/cryogenics 10x10x5 m^3.

Above ground areas

- Machine shop area
- Above ground office space and counting areas
- Laboratory space for general use (experiment preparation, detector testing and target preparation)

Infrastructure for Accelerator and Experimental halls

- Overhead crane systems for transporting and positioning heavy equipment
- De-ionized cooling water
- Air conditioning
- Electrical power requirements 200kW (CLAIRE)
- Electrical power requirements, Medium Energy Accelerator (TBA, Engineering and R&D item)

Auxiliary Equipment

- windowless re-circulating gas target (gas jet and gas cell)
- evaporator and target laboratory (a serious shortcoming at LUNA)
- a Ge-NaI or Ge-BGO detector array
- Segmented Ge or Ge strip detectors,
- a number of Si strip detector systems
- heavy ion recoil separator

DIANA

DIANA S-4 PROJECT

Project Director
Michael Wiescher
Institute for Structure and Nuclear Astrophysics
University of Notre Dame

Project Management
Matthaeus Leitner
Engineering Division
Lawrence Berkeley National Laboratory

TARGET STATION DESIGN

Principal Investigator
Michael Wiescher
Institute for Structure and Nuclear Astrophysics
University of Notre Dame

Gas Jet Development
Target Station Physics Design
Magnet Optics and Design
Neutron Detectors

1 Post Doc
1 Staff Scientist

DIAGNOSTICS DEVELOPMENT

Principal Investigator
Christian Iliadis
Nuclear Astrophysics Group
University of North Carolina

Detector Development

1 Post Doc

ACCELERATOR AND FACILITY DESIGN

Principal Investigator
Daniela Leitner
Nuclear Science Division
Lawrence Berkeley National Laboratory

Low-Energy Accelerator Design
High-Energy Accelerator Design
Ion Optics
Facility Integration
Target Station Mechanical Design
Project Management

1 Post Doc
0.2 FTE Staff Scientist
0.8 FTE Mechanical Engineer
0.5 FTE Electrical Engineer
0.1 FTE Project Management
0.05 FTE Cost Estimator

SHIELDING DEVELOPMENT

Principal Investigator
Michael Famiano
Physics Department
Western Michigan University

Shielding Development

0.15 Scientist

__D__akota __I__on __A__ccelerators for __N__uclear __A__strophysics is a collaboration between the following institutions:

UNIVERSITY OF NOTRE DAME
THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL
BERKELEY LAB — ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

The DIANA Team