DEEP SCIENCE WITH SMALL ACCELERATORS

What are the science questions?

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Low Energy Accelerator Community at DUSEL

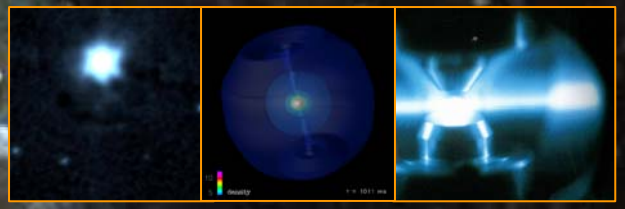
Lawrence Berkeley Laboratory
Colorado School of Mines
Louisiana State University
University of North Carolina
University of Notre Dame
Ohio University
University of Washington
Western Michigan University
Yale University

ATOMKI, Debrecen, Hungary
Ruhruniversität Bochum, Germany
HH-NIPNE, DFN-TANDEM, Romania
INFN Geneva, Italy
INFN Gran Sasso, Italy
Universita Frederico II Napoli, Italy
Universität Wien, Austria
University of Edinburgh, UK

Nuclear Astrophysics

Nuclear Processes as Engine of Stellar Evolution and Trigger of Stellar Explosion

Observers, Modelers, Experimenters



Stable Beam Experiments
Neutron Beam Experiments
Radioactive Beam Experiments
Weak Interaction & Neutrino Experiments

- Development of S4 proposal
- Identification of Scientific Goals
- Collaboration Structure
- Infrastructure Requirements
- Identification of Technical Needs
- Collaboration Tasks & Work Distribution
- Cost Assessment for Full Proposal

Successful experiments have demonstrated considerable discovery potential for low energy reaction measurements

$^{14}N(p,\gamma)^{15}O$

$^{22}Ne(\alpha,n)^{25}Mg$

$^{12}C(^{12}C,\alpha)^{20}Ne$

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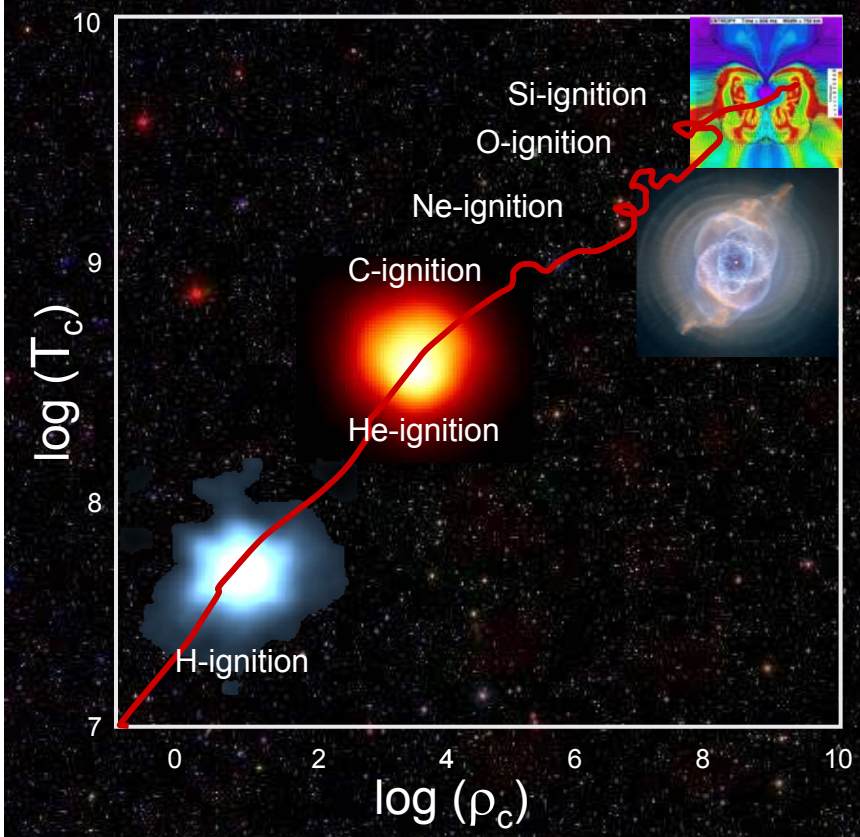
Nuclear burning & stellar evolution



Hydrogen Burning

$^{3}He(\alpha,\gamma)^{7}Be$
$^{3}He(^{3}He,2p)^{4}He$
$^{7}Be(p,\gamma)^{8}B$

$^{12}C(p,\gamma)^{13}N$
$^{14}N(p,\gamma)^{15}O$
$^{15}N(p,\gamma),(p,\alpha)^{16}O,^{12}C$

$^{17}O(p,\gamma),(p,\alpha)^{18}F,^{14}N$
$^{18}O(p,\gamma),(p,\alpha)^{19}F,^{15}N$
$^{19}F(p,\gamma),(p,\alpha)^{20}Ne,^{16}O$

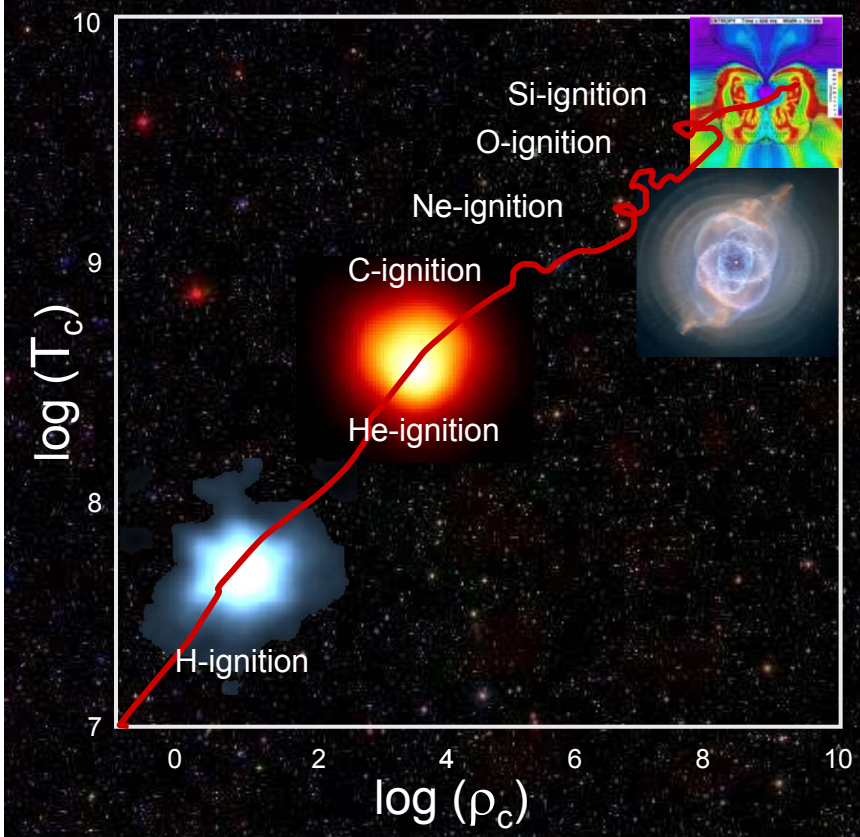
Critical reactions for:

- energy generation,
- time scale
- nucleosynthesis

Choice should be guided, by

- Scientific relevance
- Experimental suitability
- Alternative opportunities

Nuclear burning & stellar evolution



Critical reactions for:

- energy generation,
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Helium Burning

$^{12}C(\alpha,\gamma)^{16}O$
$^{16}O(\alpha,\gamma)^{20}Ne$
$^{20}Ne(\alpha,\gamma)^{24}Mg$

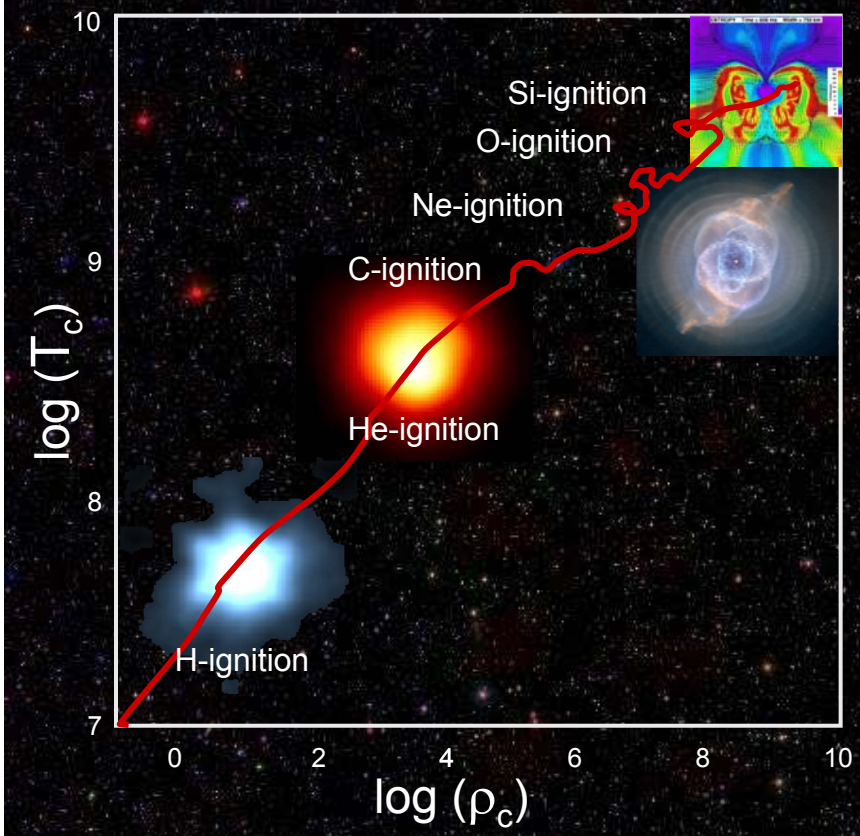
$^{18}O(\alpha,\gamma)^{22}Ne$
$^{22}Ne(\alpha,\gamma)^{26}Mg$
$^{24}Mg(\alpha,\gamma)^{28}Si$

$^{13}C(\alpha,n)^{16}O$
$^{22}Ne(\alpha,n)^{25}Mg$
$^{25}Mg(\alpha,n)^{28}Si$
$^{26}Mg(\alpha,n)^{29}Si$

Choice should be guided, by

- Scientific relevance
- Experimental suitability
- Alternative opportunities

Nuclear burning & stellar evolution



Heavy Ion Burning

$^{12}C+^{12}C$
$^{12}C+^{16}O$
$^{16}O+^{16}O$

$^{17}O(\alpha,n)^{20}Ne$
$^{28}Si(\alpha,\gamma)^{32}S$
...
..
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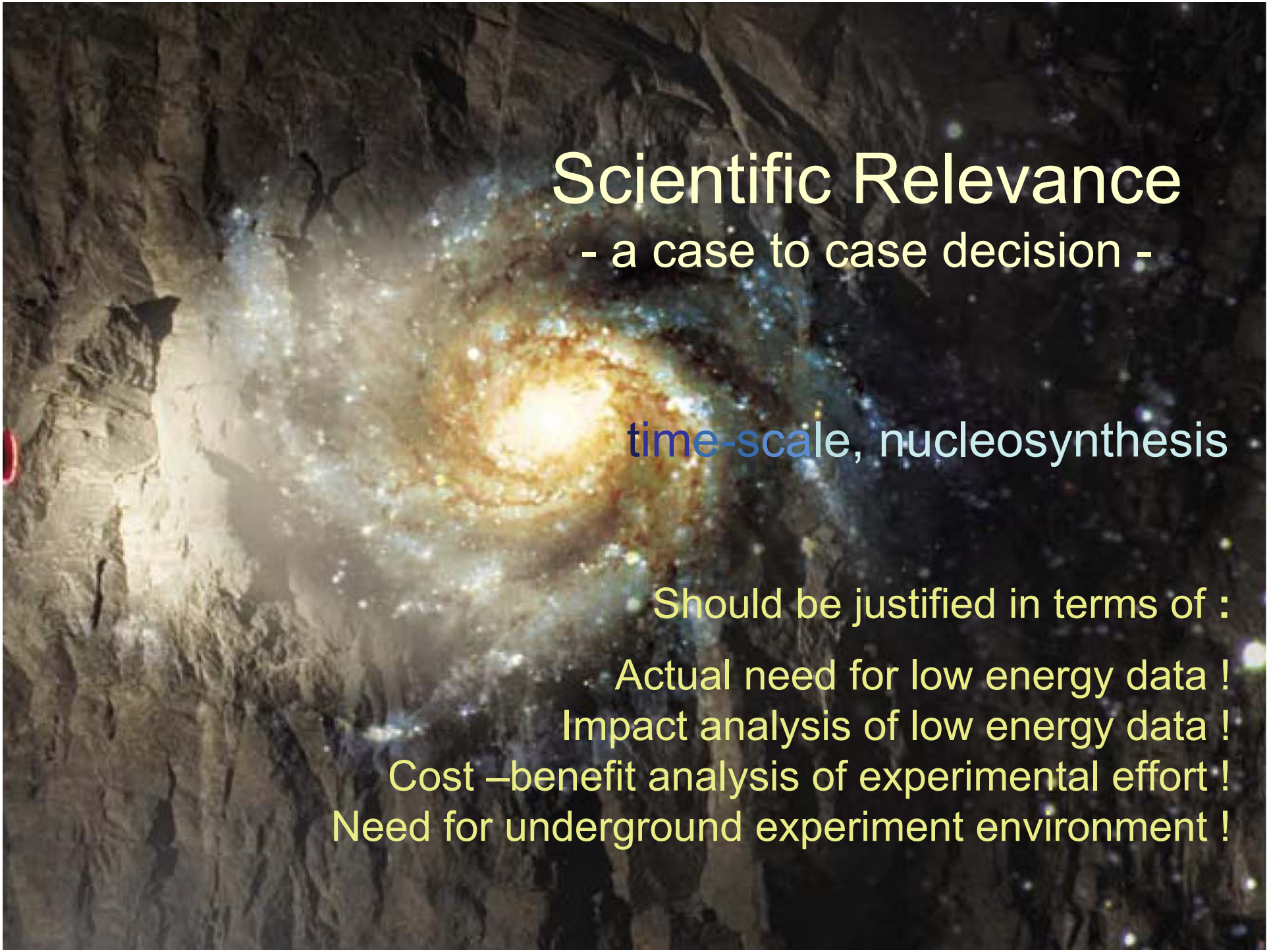
Critical reactions for:
- energy generation,
- time scale
- nucleosynthesis

Choice should be guided, by
- Scientific relevance
- Experimental suitability
- Alternative opportunities



Scientific Relevance

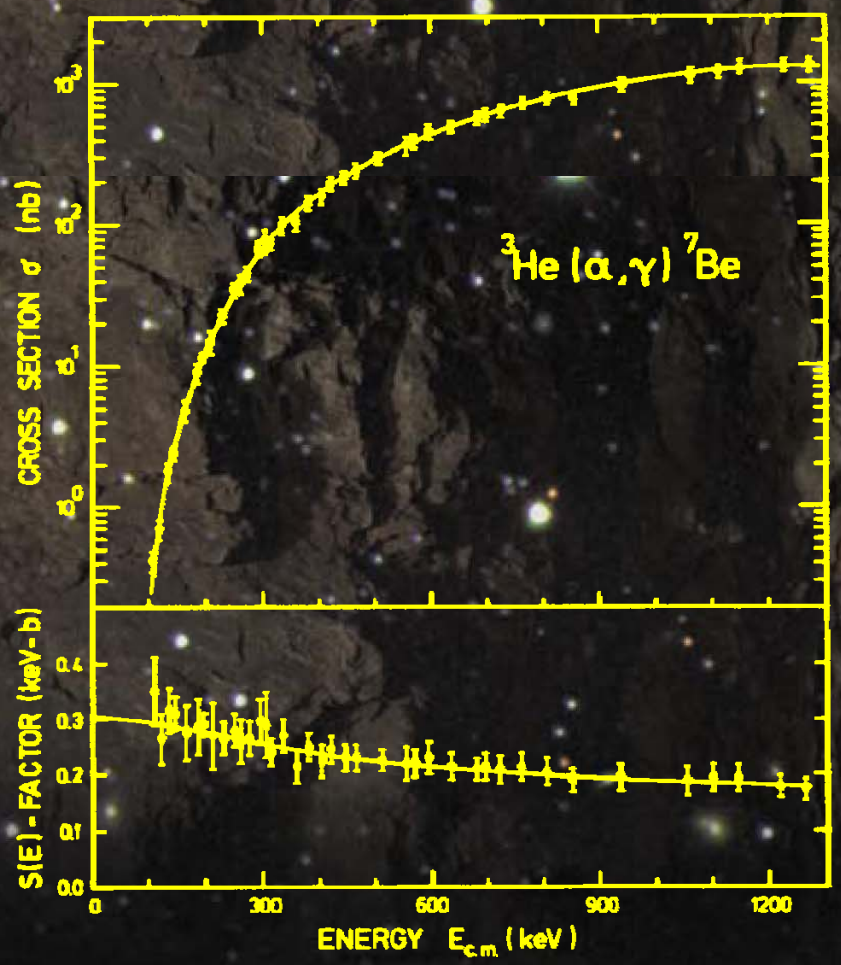
- a case to case decision -

time-scale, nucleosynthesis

Should be justified in terms of :

Actual need for low energy data !
Impact analysis of low energy data !
Cost –benefit analysis of experimental effort !
Need for underground experiment environment !

We know the problem ...



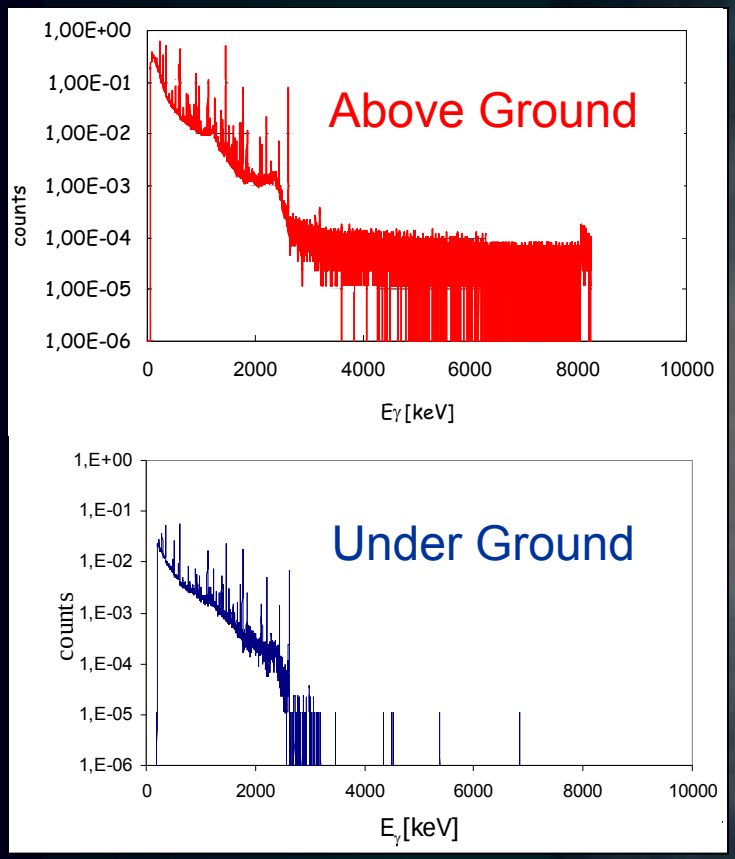
$$S(E) = \sigma(E) \cdot E \cdot e^{(E_G/E)^{1/2}}$$

Low Energy Problem:

- Reaction Yield (cross section)
- Energy Calibration (S-factor)
- Background Yield
  - Cosmic Ray Induced Background
  - Natural Background
  - Beam Induced Background

Cosmic Ray induced Background

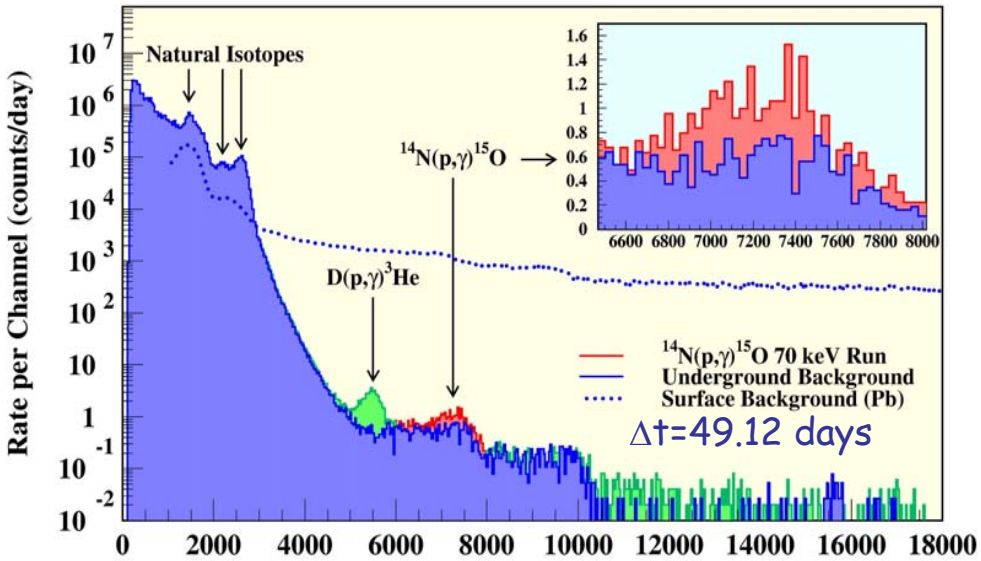
dominates energy range >3.0 MeV

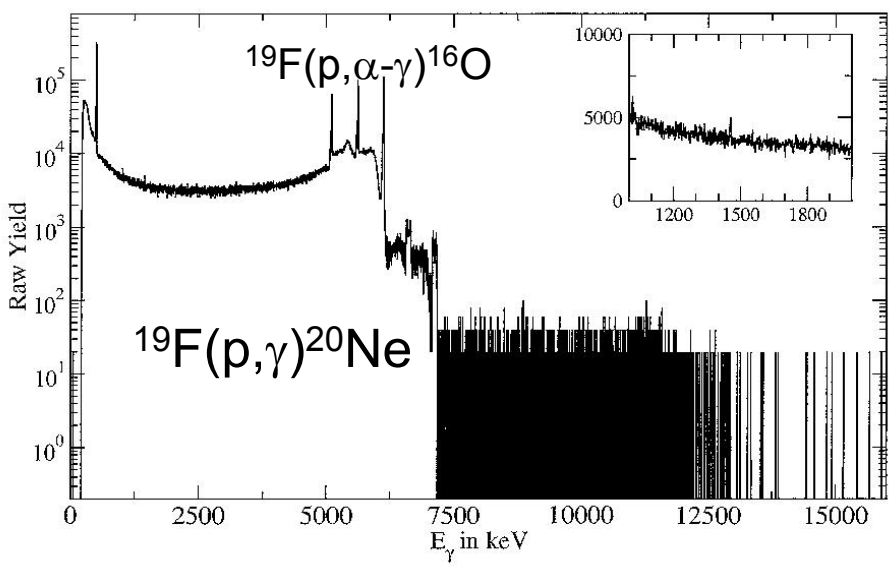


10^{-6} reduction of Cosmic Rays
by moving under ground, but ...

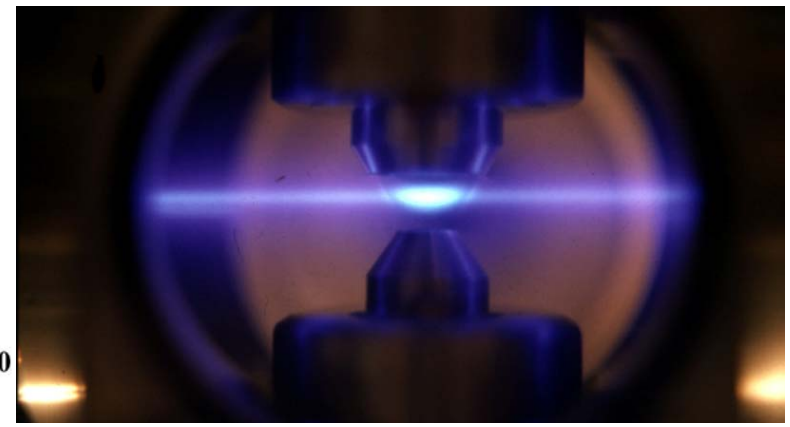
Natural Background for E<3.0 MeV !
Low Q-value reactions are handicapped

Beam Induced Background

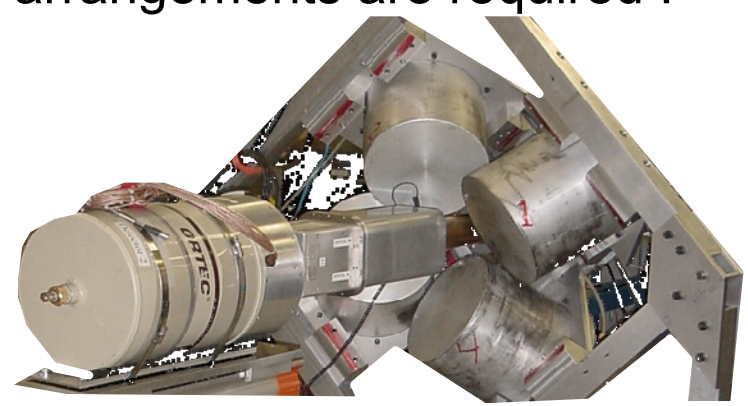




- Low Z target impurities,
- Reaction impurities

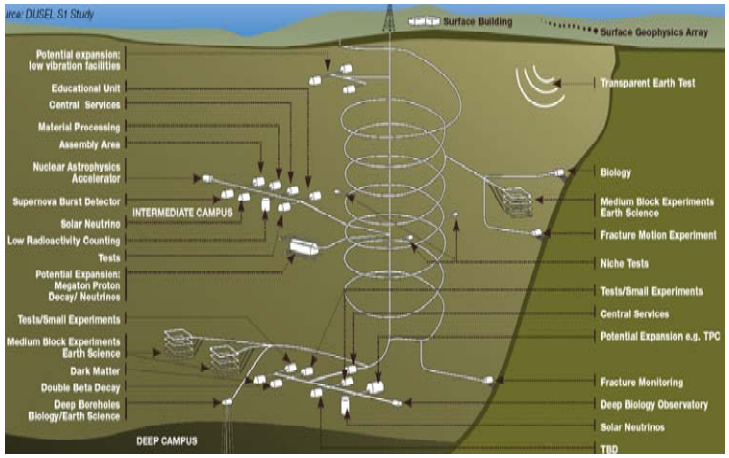
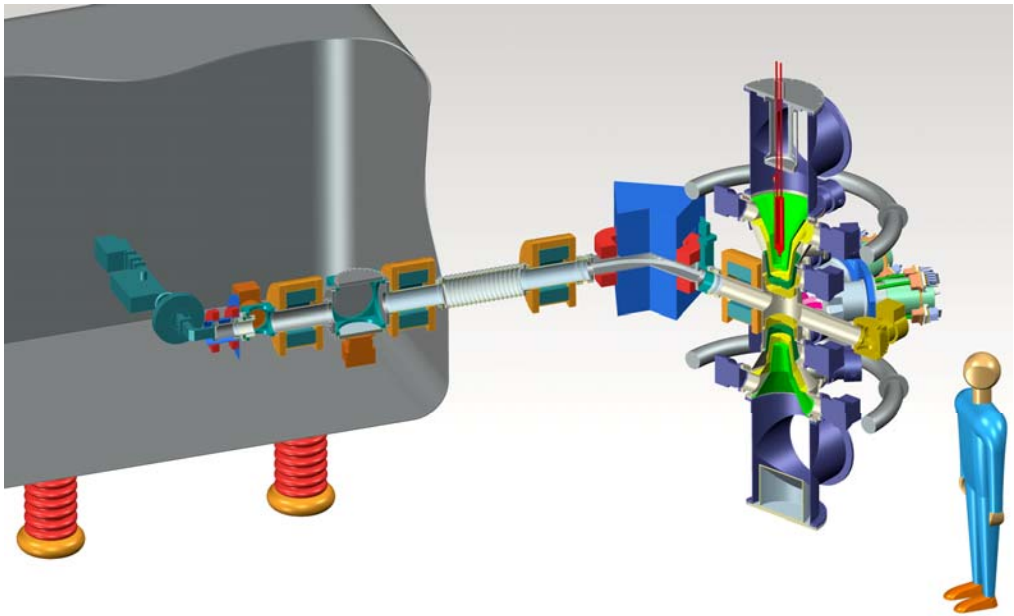


Special detector designs or arrangements are required !



To be discussed: ALNA

Accelerator Laboratory for Nuclear Astrophysics



- The science of ALNA: Lucio Gialanella
- The MREFC Process: Matthias Leitner
- International Plans: Christina Bordenau
- Accelerator Needs & Design: Paul Vetter
- Infrastructure Needs: Jose Alonso (tbc)
- Experimental Needs: H. Costantini, G. Imbriani
- Detector & Target Developments: tba
- Collaboration Organization