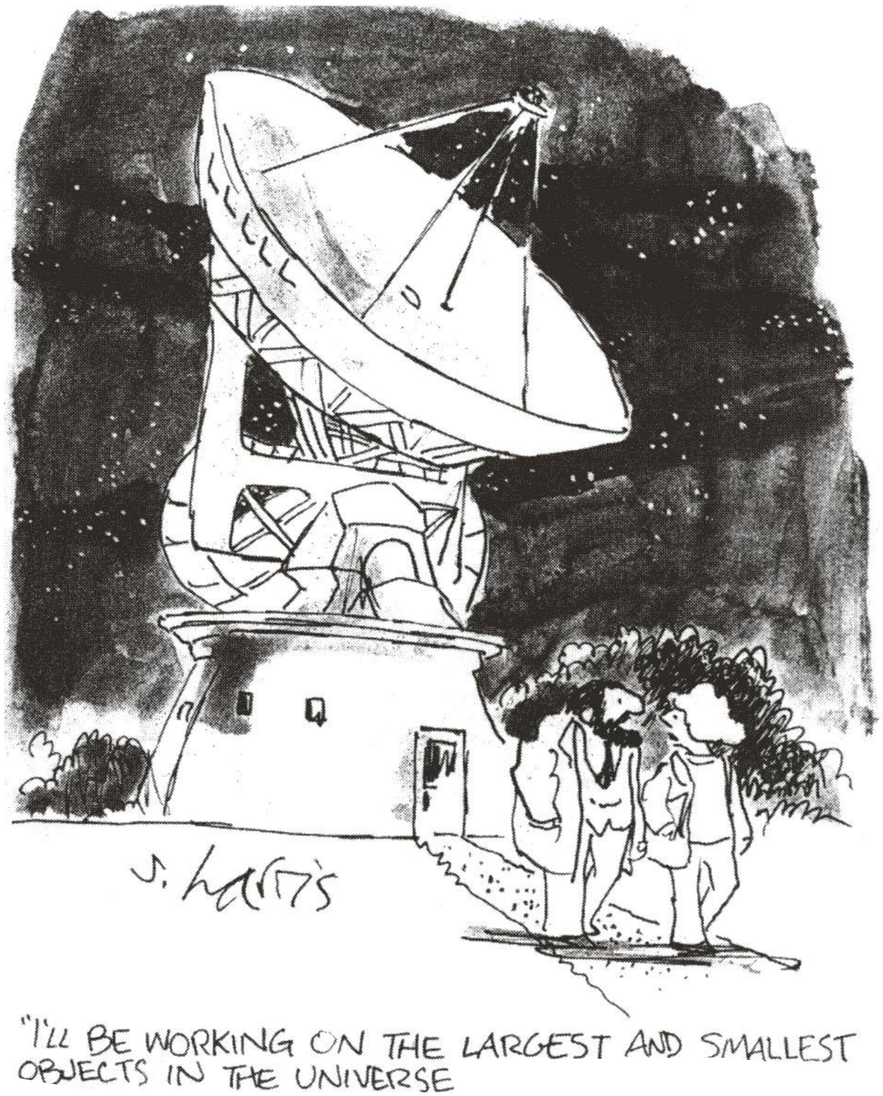
Perspectives on Nuclear Astrophysics
d the role of DUSEL



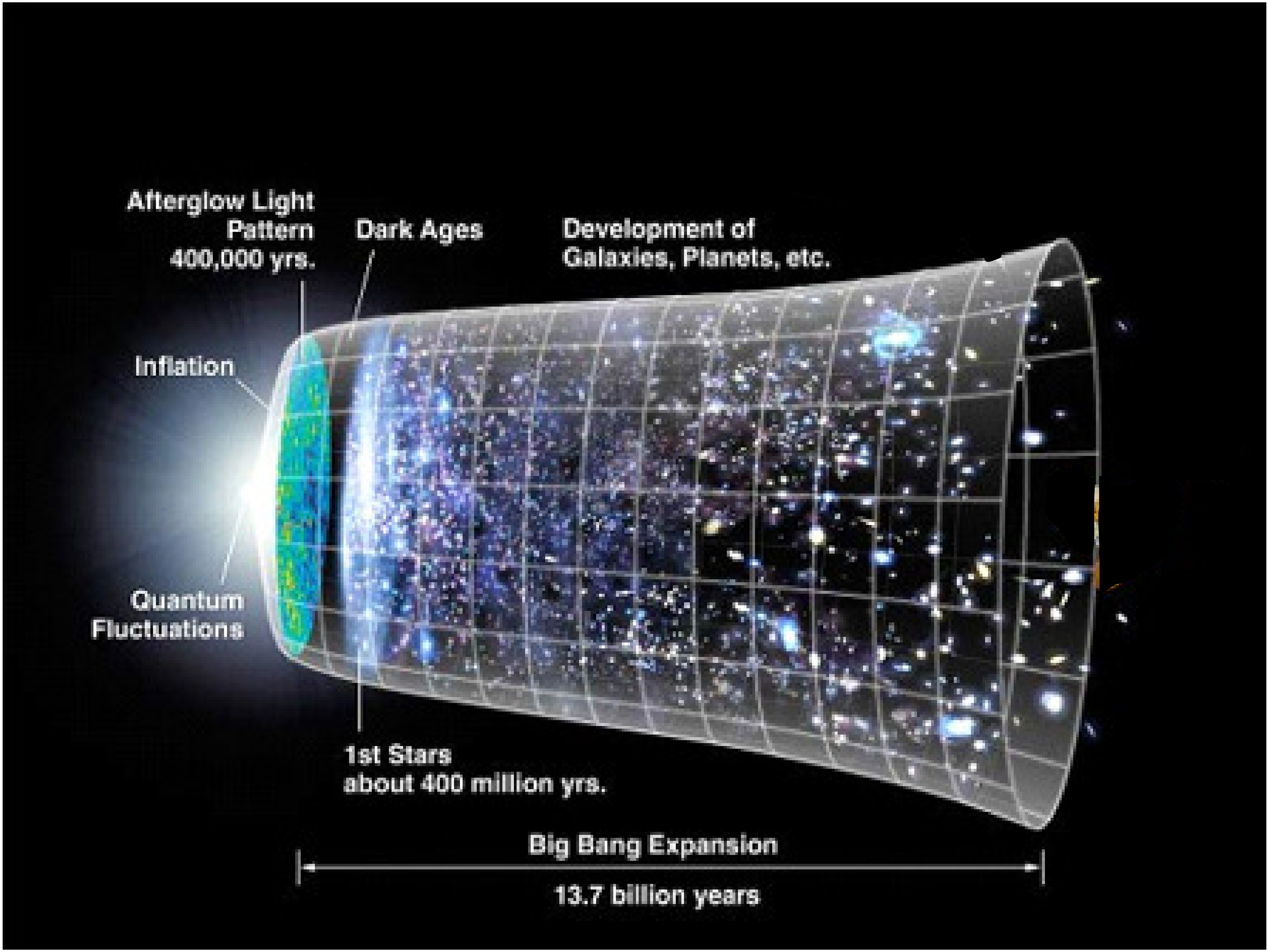
Nuclear Astrophysics is a broad field that needs facilities from 1keV-100GeV

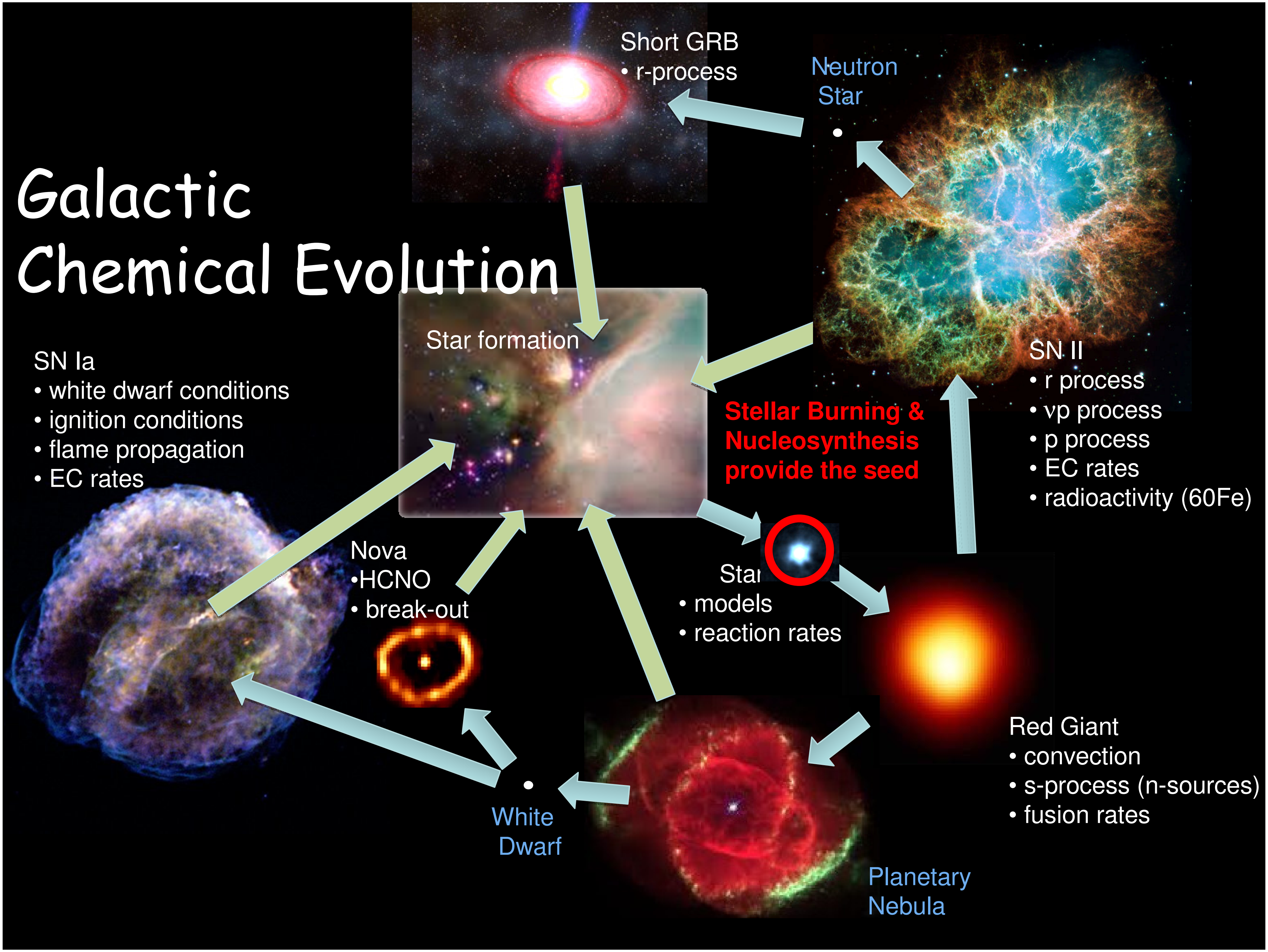
A low energy accelerator DIANA a DUSEL is a unique instrument for probing key questions for the field

Michael Wiescher

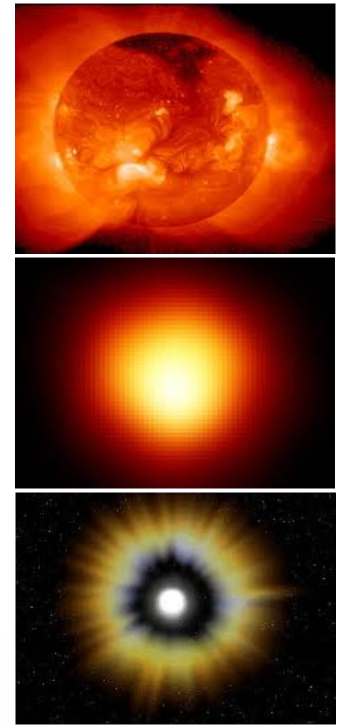
Joint Institute of Nuclear Astrophysics
University of Notre Dame

- Nucleosynthesis sites
- Stellar nucleosynthesis
- Experimental challenges
- DIANA at DUSEL

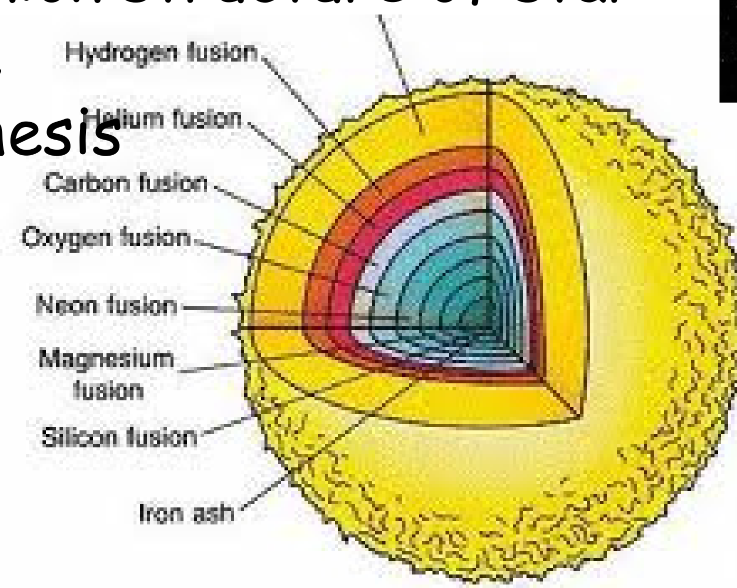

Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years


Galactic Chemical Evolution
Short GRB
• r-process
Neutron Star
Star formation
SN Ia
• white dwarf conditions
• ignition conditions
• flame propagation
• EC rates
SN II
• r process
• νp process
• p process
• EC rates
• radioactivity (60Fe)
Stellar Burning & Nucleosynthesis provide the seed
Nova
•HCNO
• break-out
Star
• models
• reaction rates
Red Giant
• convection
• s-process (n-sources)
• fusion rates
White Dwarf
Planetary Nebula

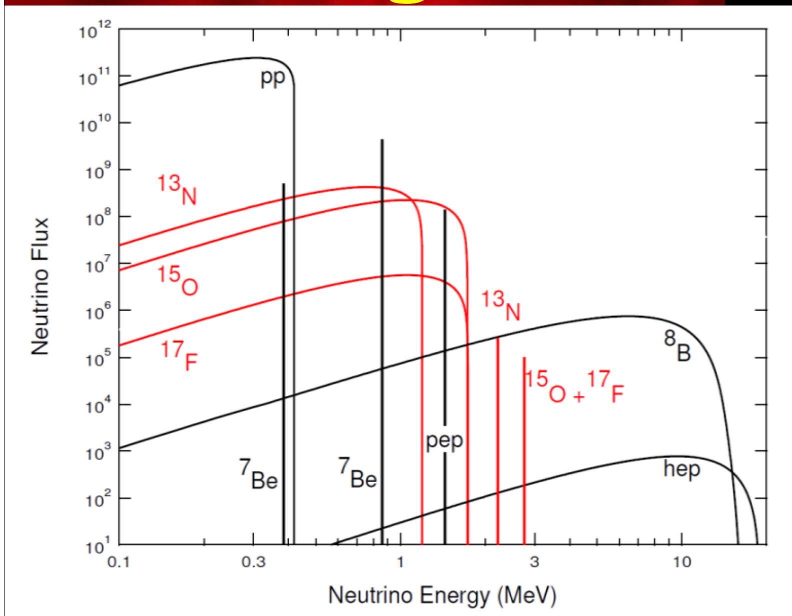
Origin of seed and fuel

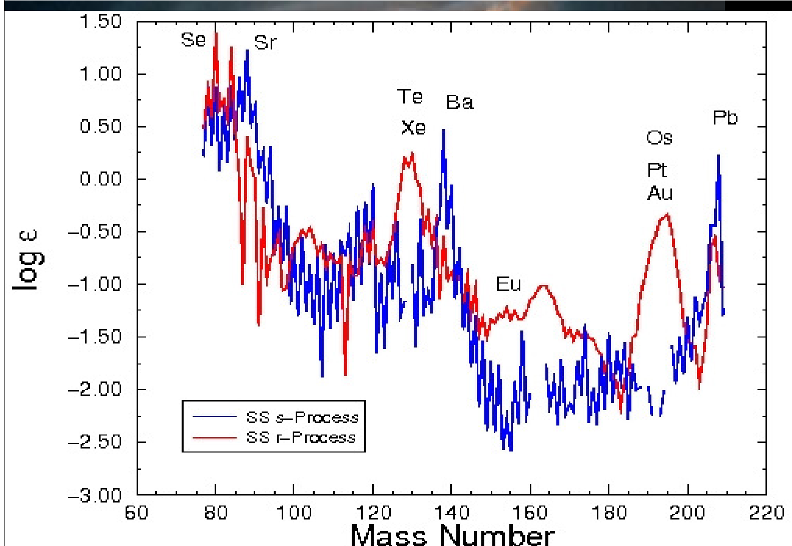


- Hydrogen Burning: ^{4}He, ^{14}N
- Helium Burning: ^{12}C, ^{16}O, ^{22}Ne, n, s-nuclei
- Carbon Burning: ^{16}O, ^{20}Ne, ^{24}Mg ... s-nuclei
- Ne-, O-, Si-Burning: onion structure of star
  seed for core collapse
  supernova nucleosynthesis



New signatures from stellar interiors





Solar neutrino problem (pp-neutrino observations) triggered neutrino physics!

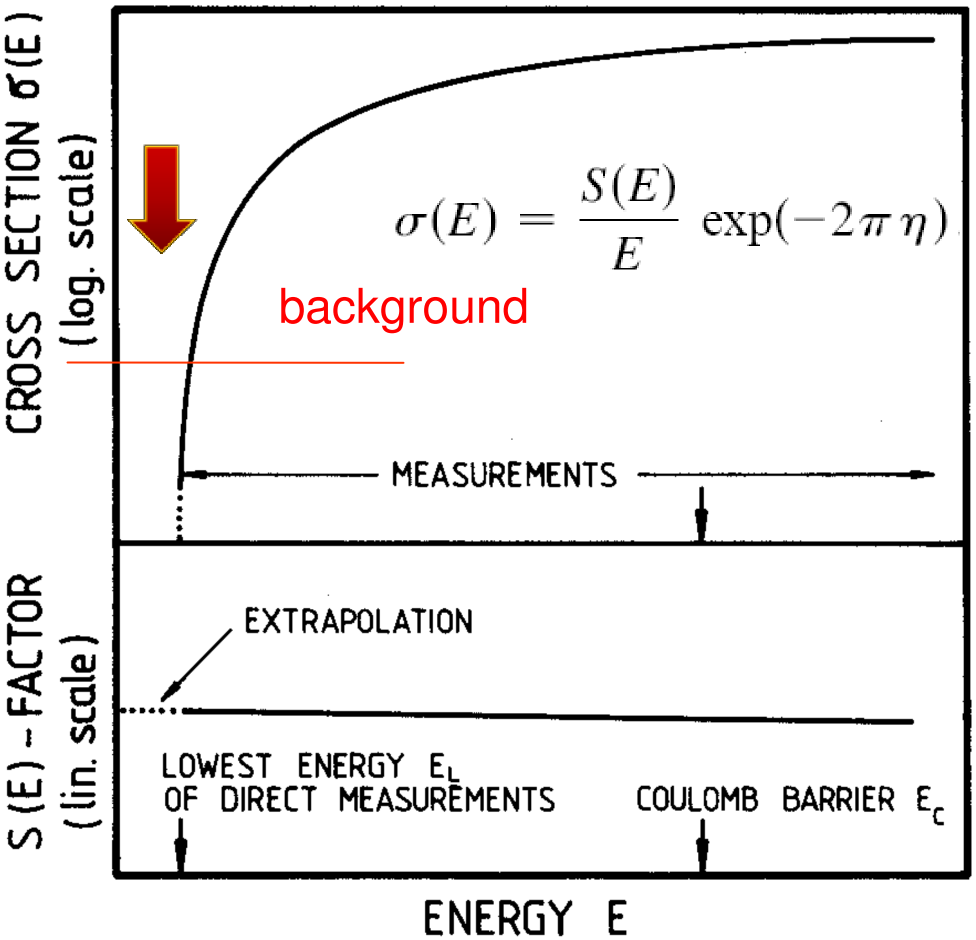
CNO neutrinos scale with solar core metallicity!

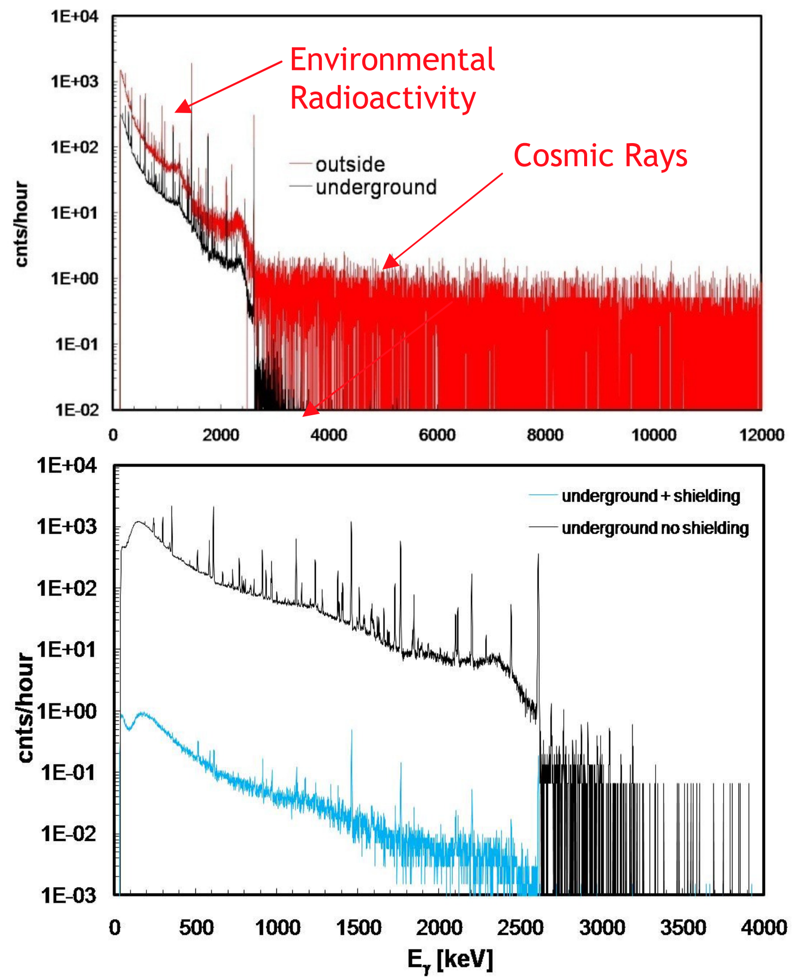
SN neutrinos scale core collapse

Isotopic abundances from Cosmo-Chemistry provide:

- Measure for neutron flux,
- Temperature & density
- Convective conditions
- Shock front environment

Why go underground?

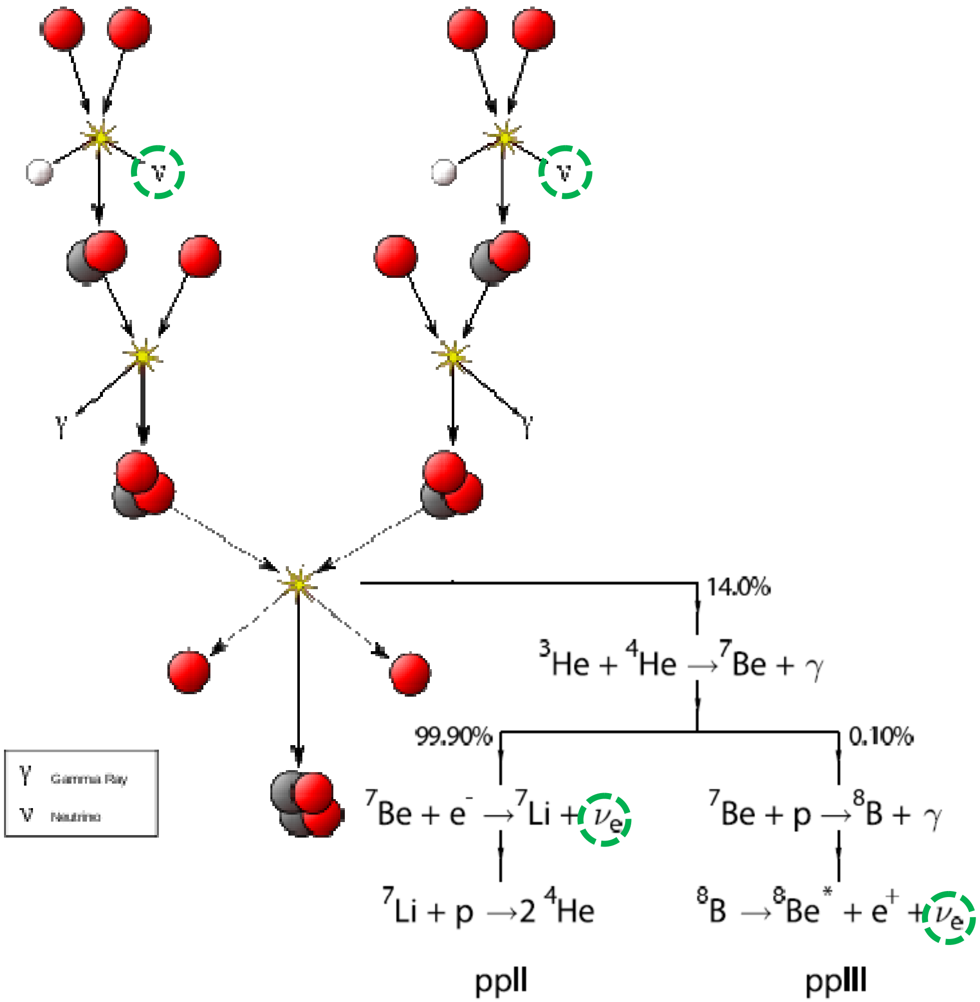


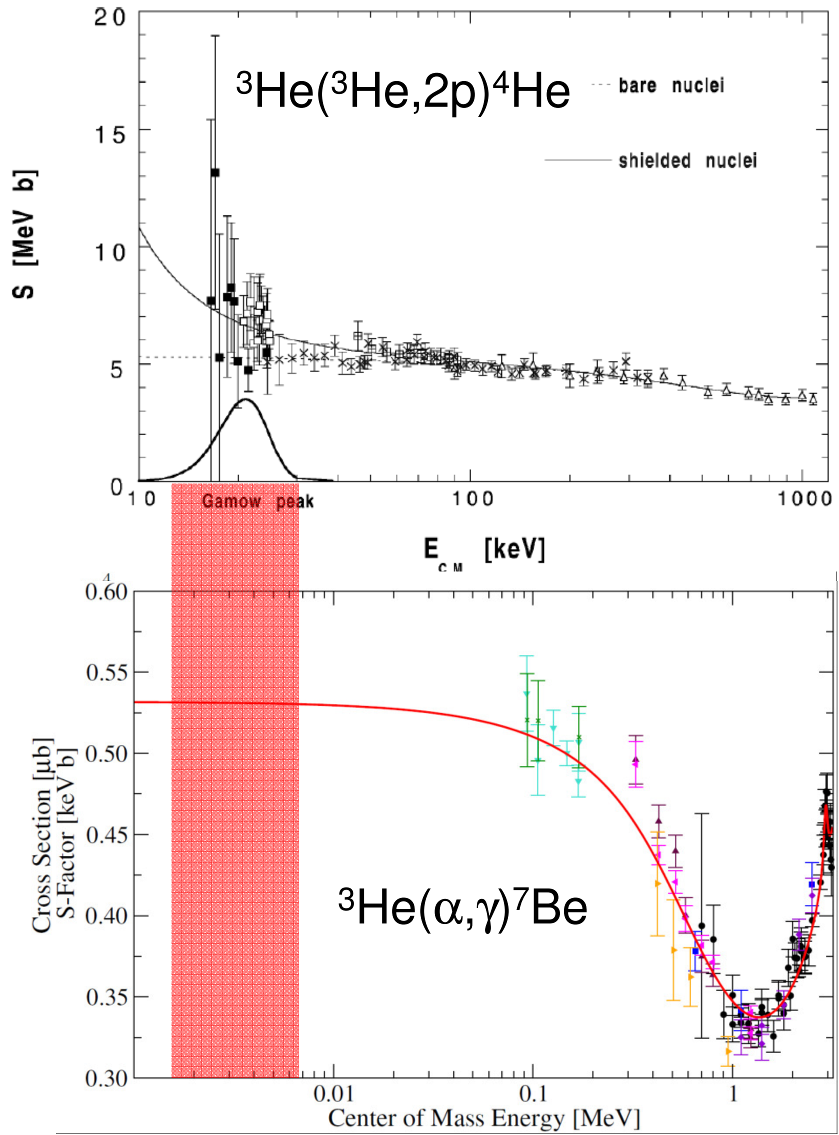


$$N_A\langle\sigma v\rangle = \sqrt{\frac{8}{\pi\cdot\mu}}\cdot(kT)^{-3/2}\cdot\int_0^\infty E\cdot\sigma(E)\cdot\exp\left(-\frac{E}{kT}\right)dE$$

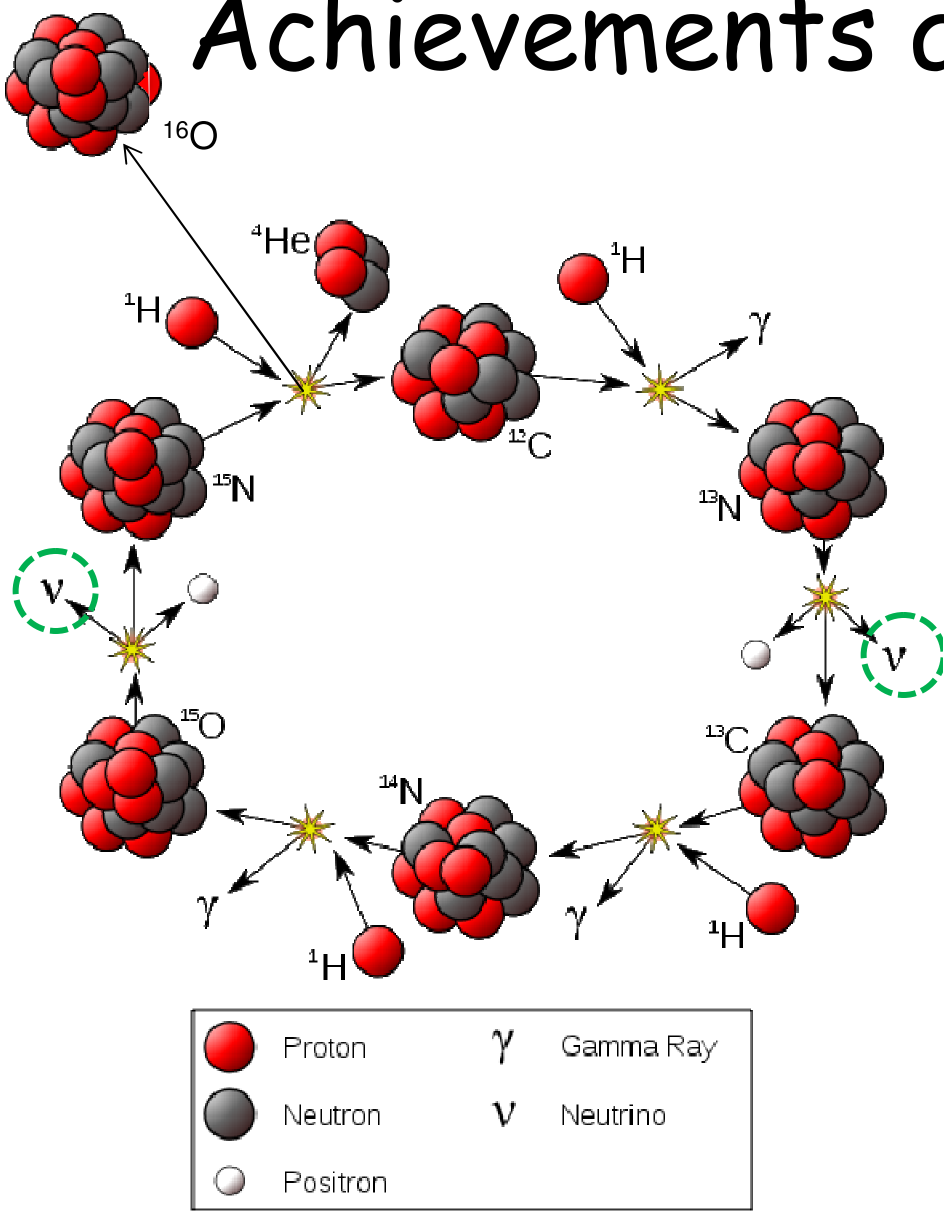

A first attempt of underground
accelerator

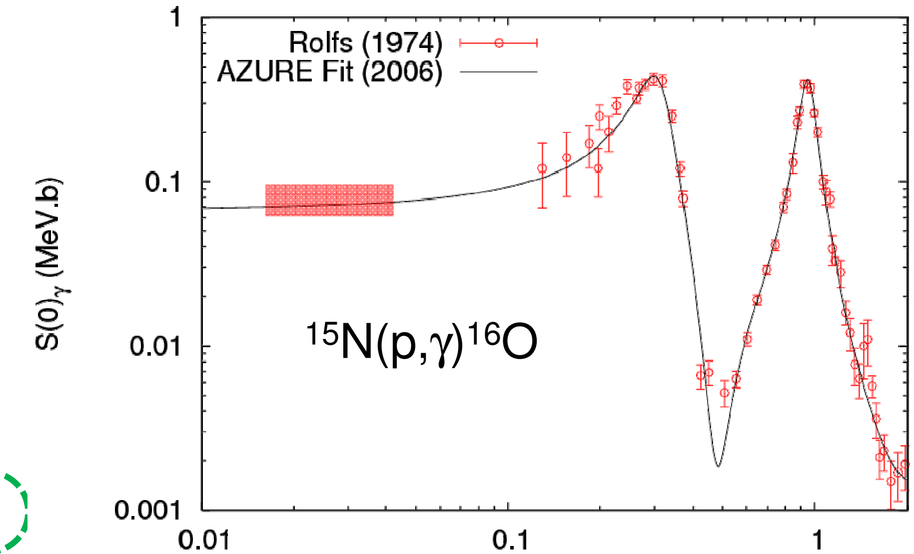
Achievements and Challenges

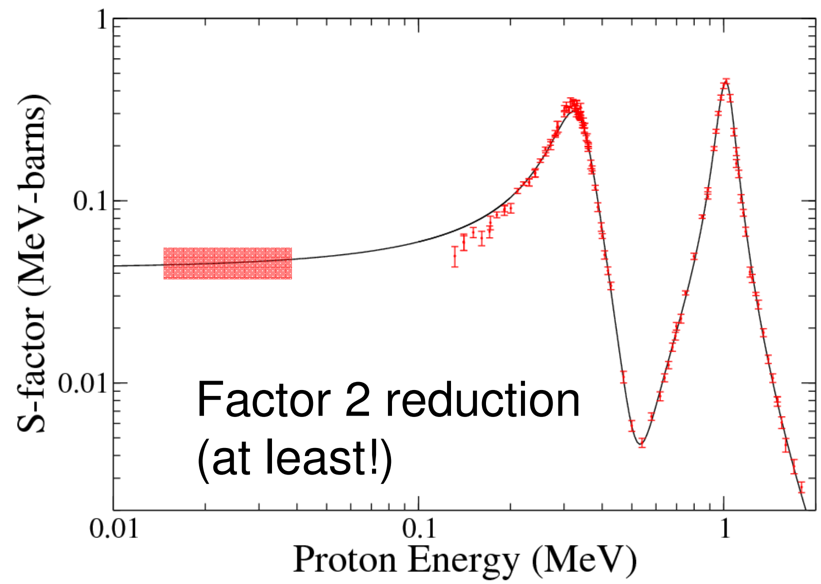




Achievements and Uncertainties

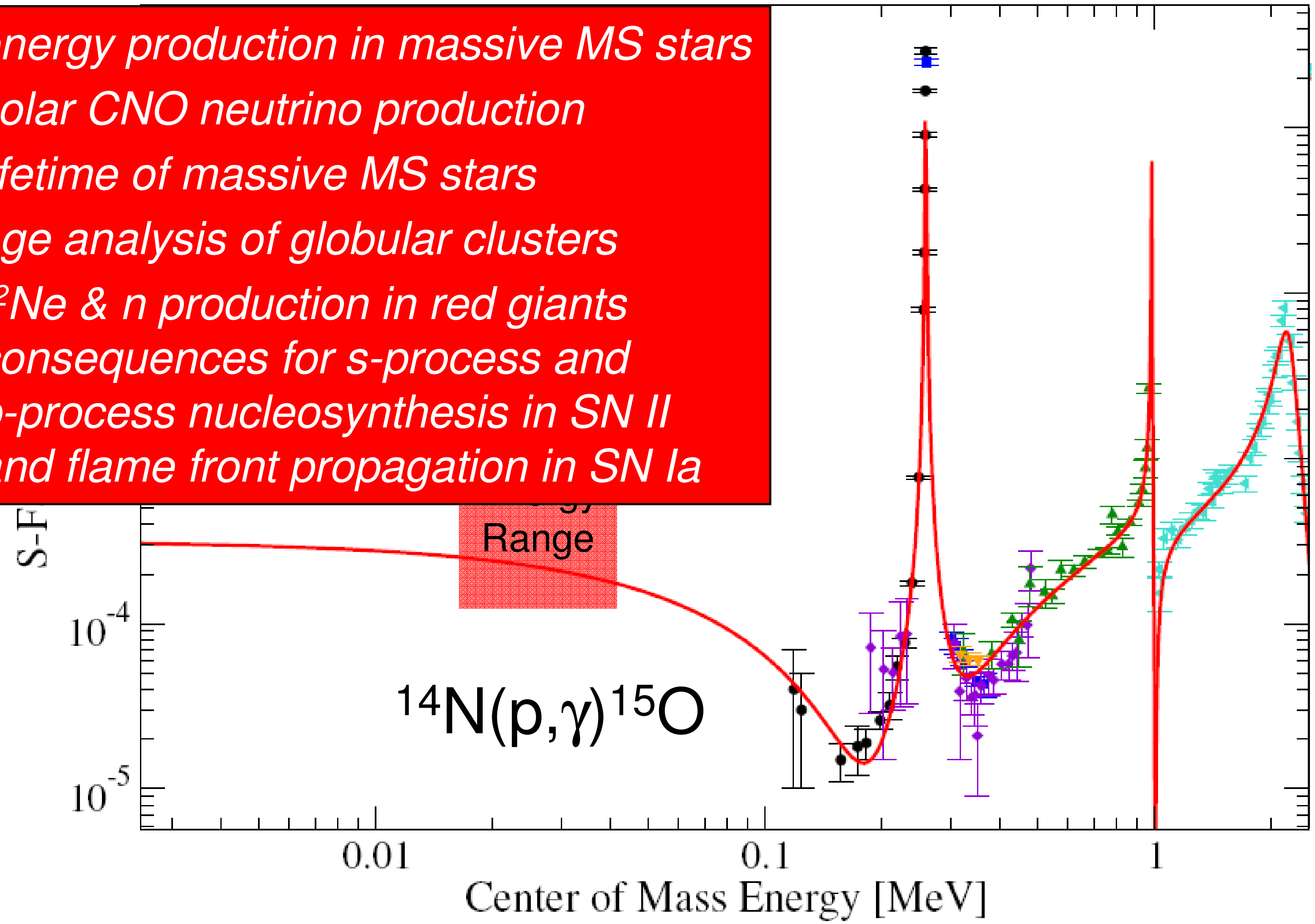




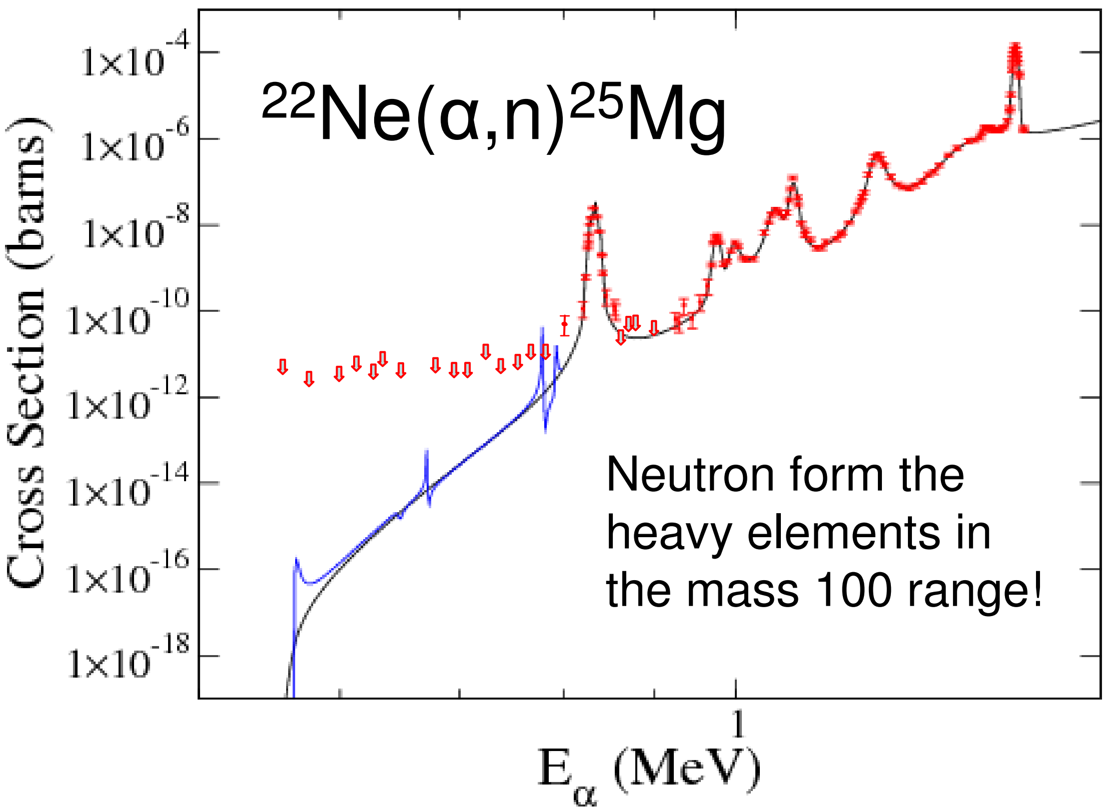


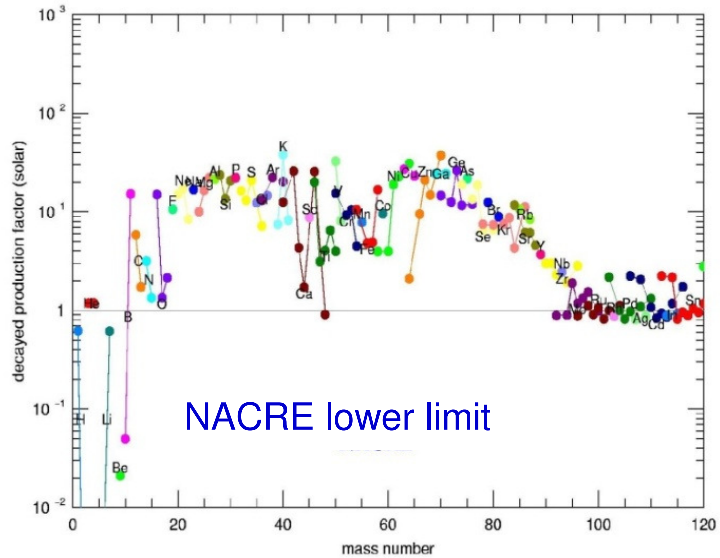
Achievements and Limitations

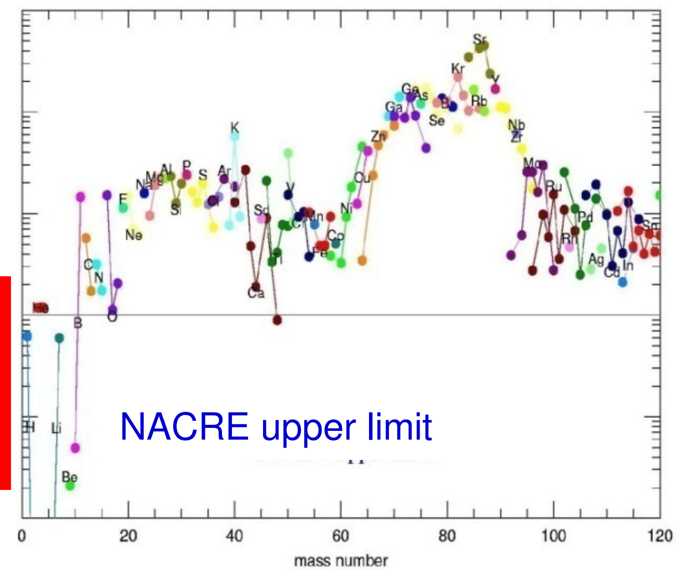
- *energy production in massive MS stars*
- *solar CNO neutrino production*
- *lifetime of massive MS stars*
- *age analysis of globular clusters*
- *^{22}Ne & n production in red giants consequences for s-process and p-process nucleosynthesis in SN II and flame front propagation in SN Ia*



Nucleosynthesis in He Burning



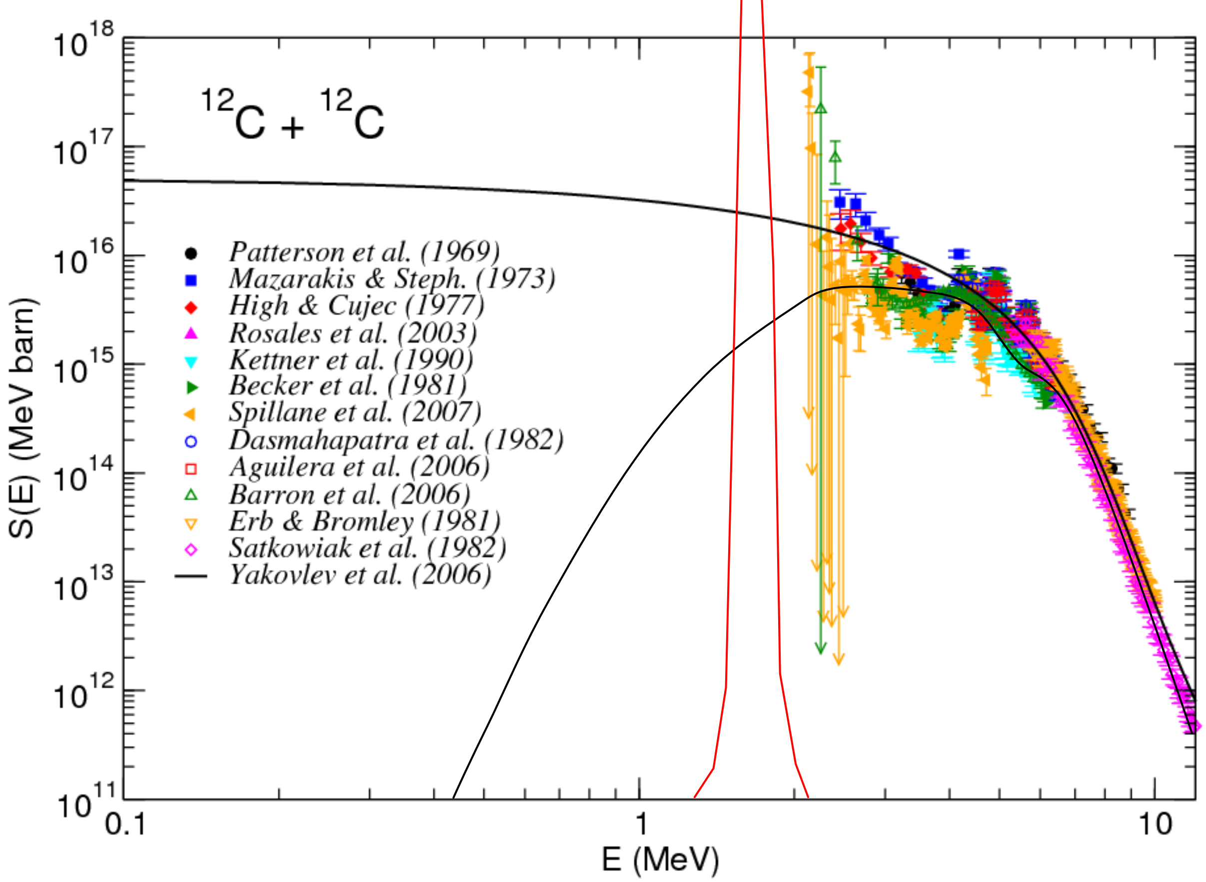


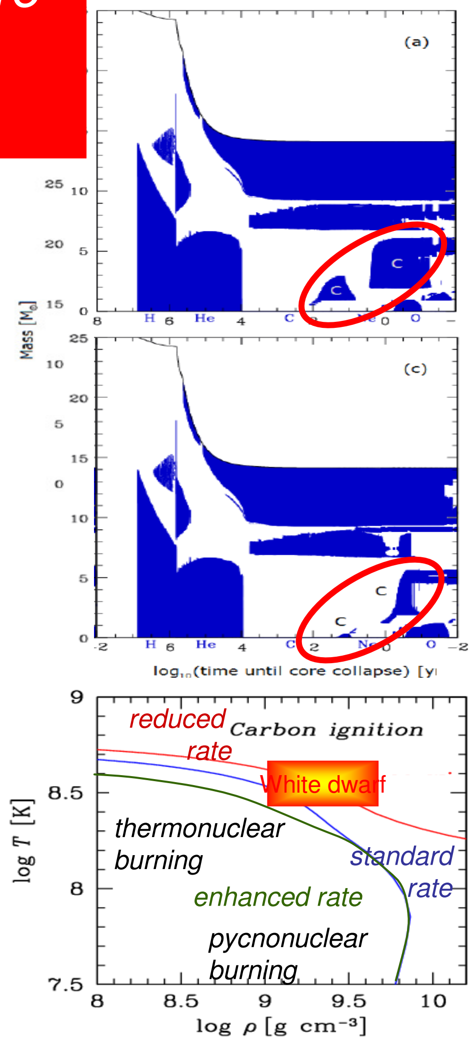


Nucleosynthesis in Red Giant Stars
p-process in core collapse supernovae
Type Ia supernovae → Flame Front Propagation

Low Energy Fusion Reactions

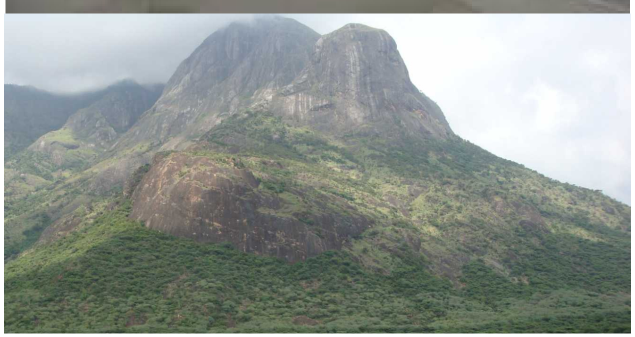
Late stellar evolution → disappearance of onion structure
Type Ia supernovae → ignition conditions
Superbursts → explosive carbon burning



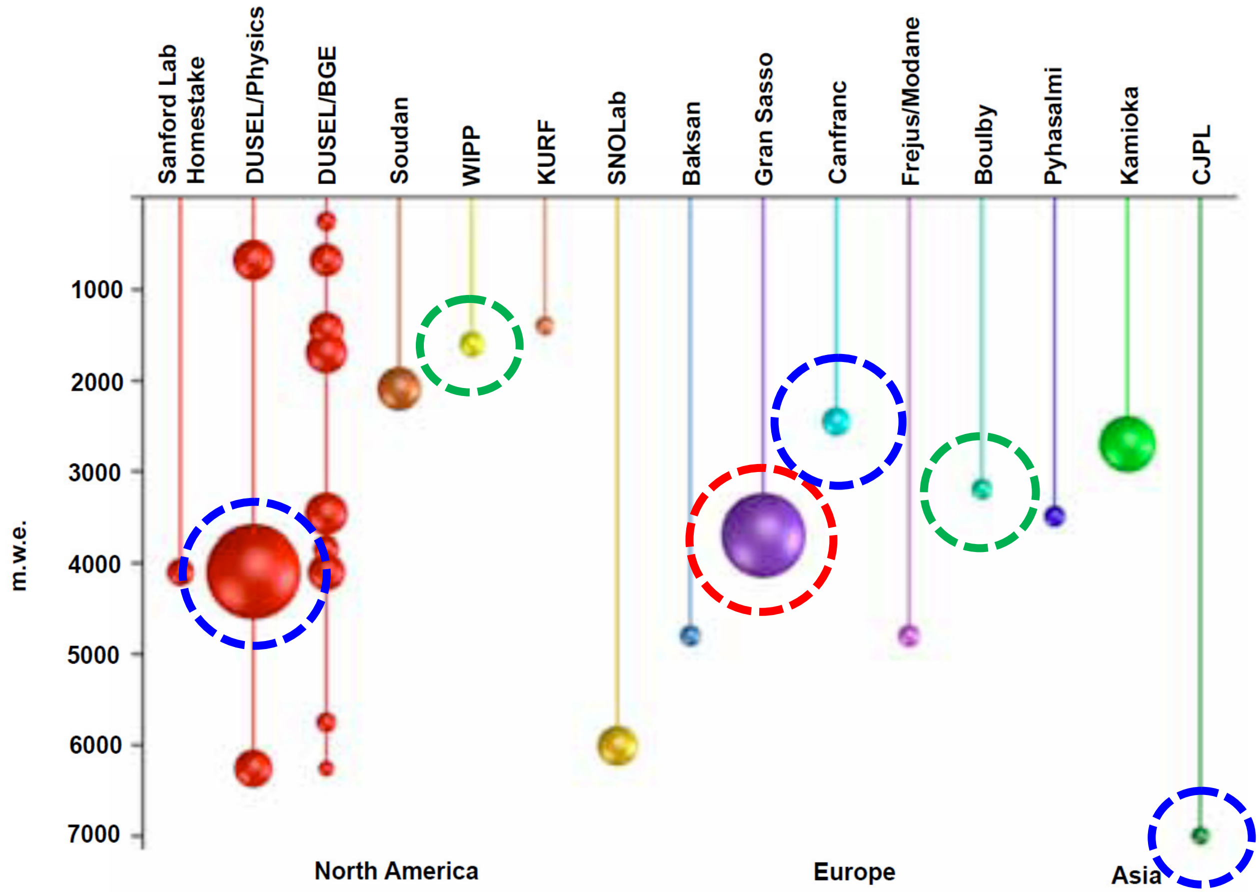


The International Situation



in the underground accelerator business

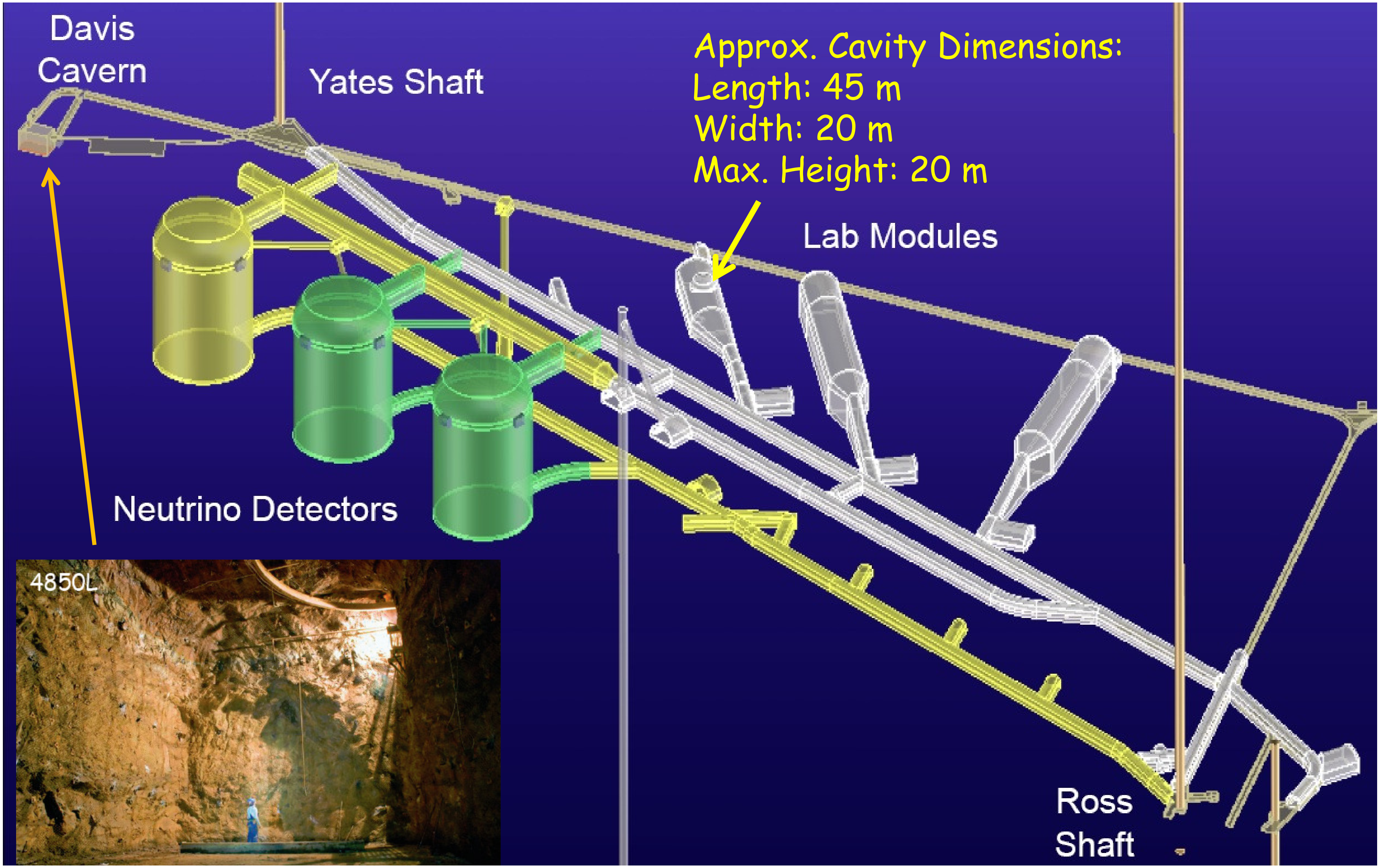


New accelerator projects:
Felsenkeller, Dresden, Germany
FRENA at INO, Saha Institute, India

Why DIANA

- Wide energy range for covering all stellar burning phases, not just hydrogen burning
- High beam currents to extend measurements towards lower energies
- High density target with high power capabilities (confined gas jet & solid targets) to enhance luminosity
- Advanced detector design for active background rejection & event identification

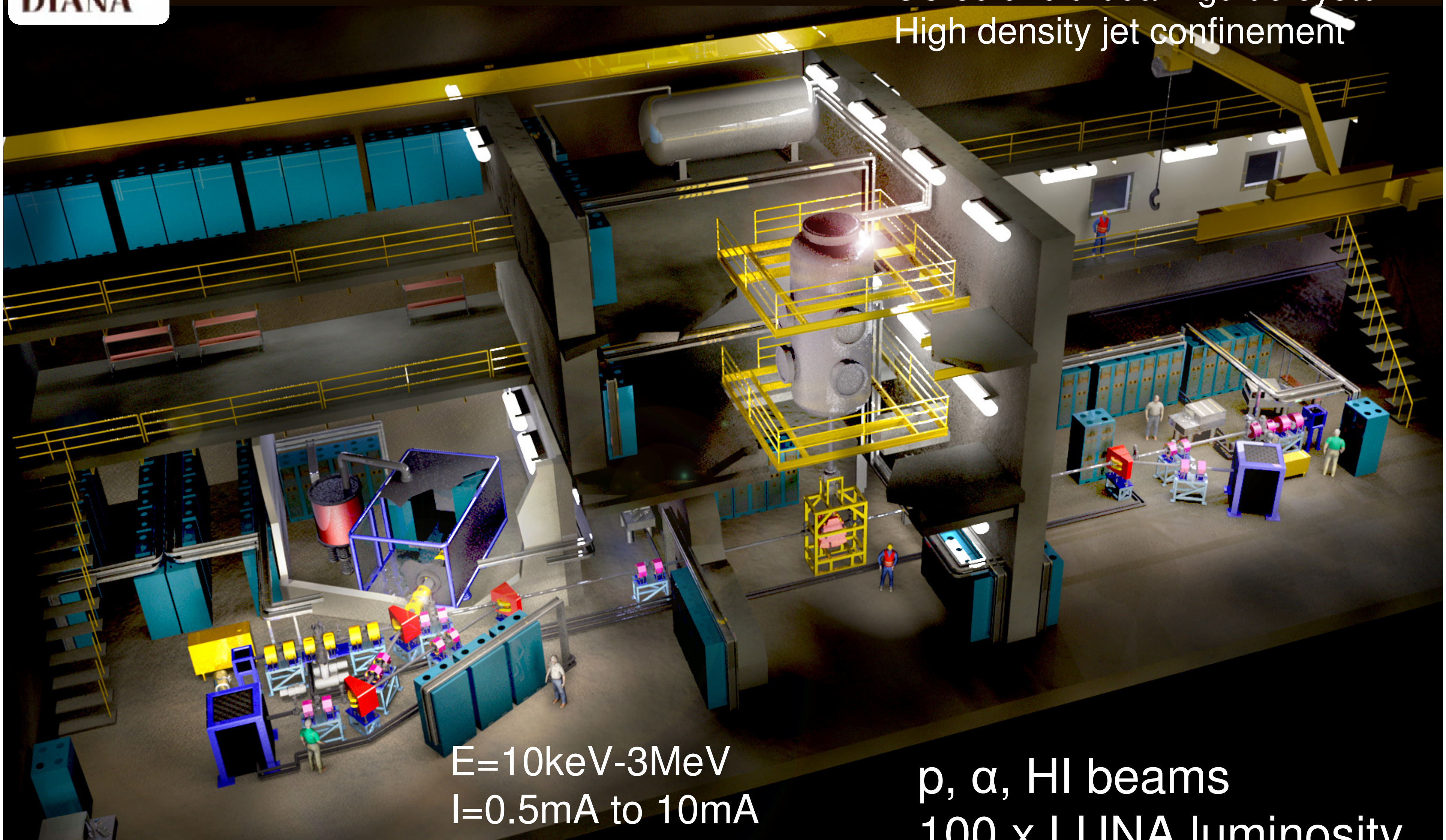
Proposed location in DUSEL



DIANA design

Technical achievements:

New acceleration tube design
SC solenoid beam guide system
High density jet confinement

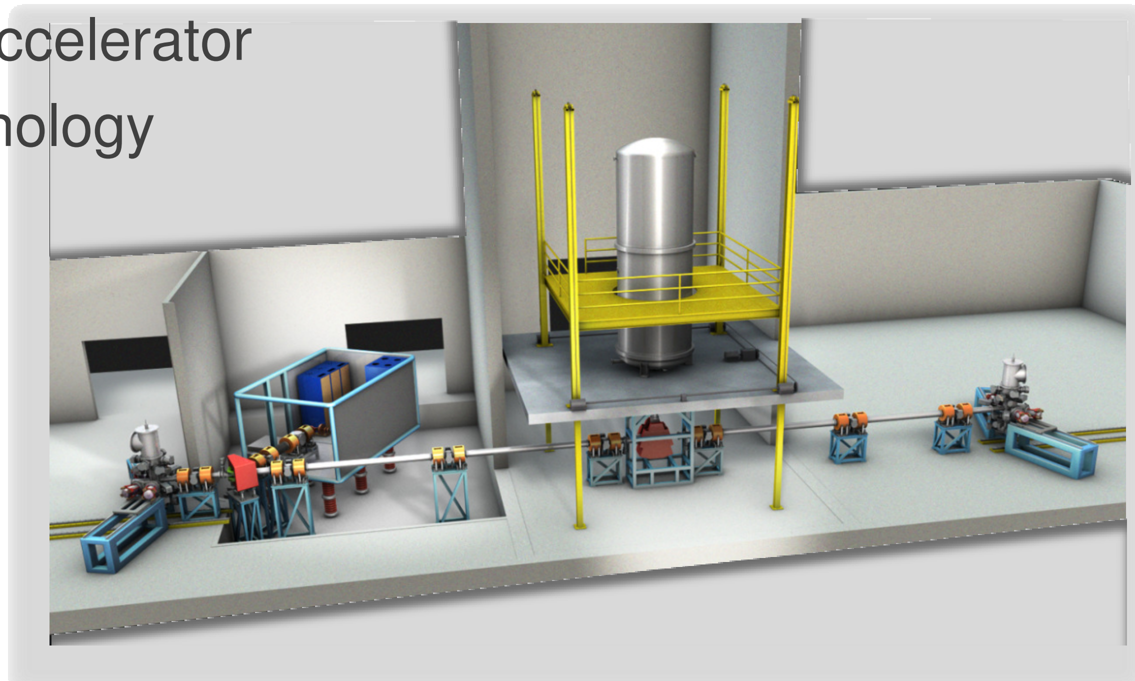


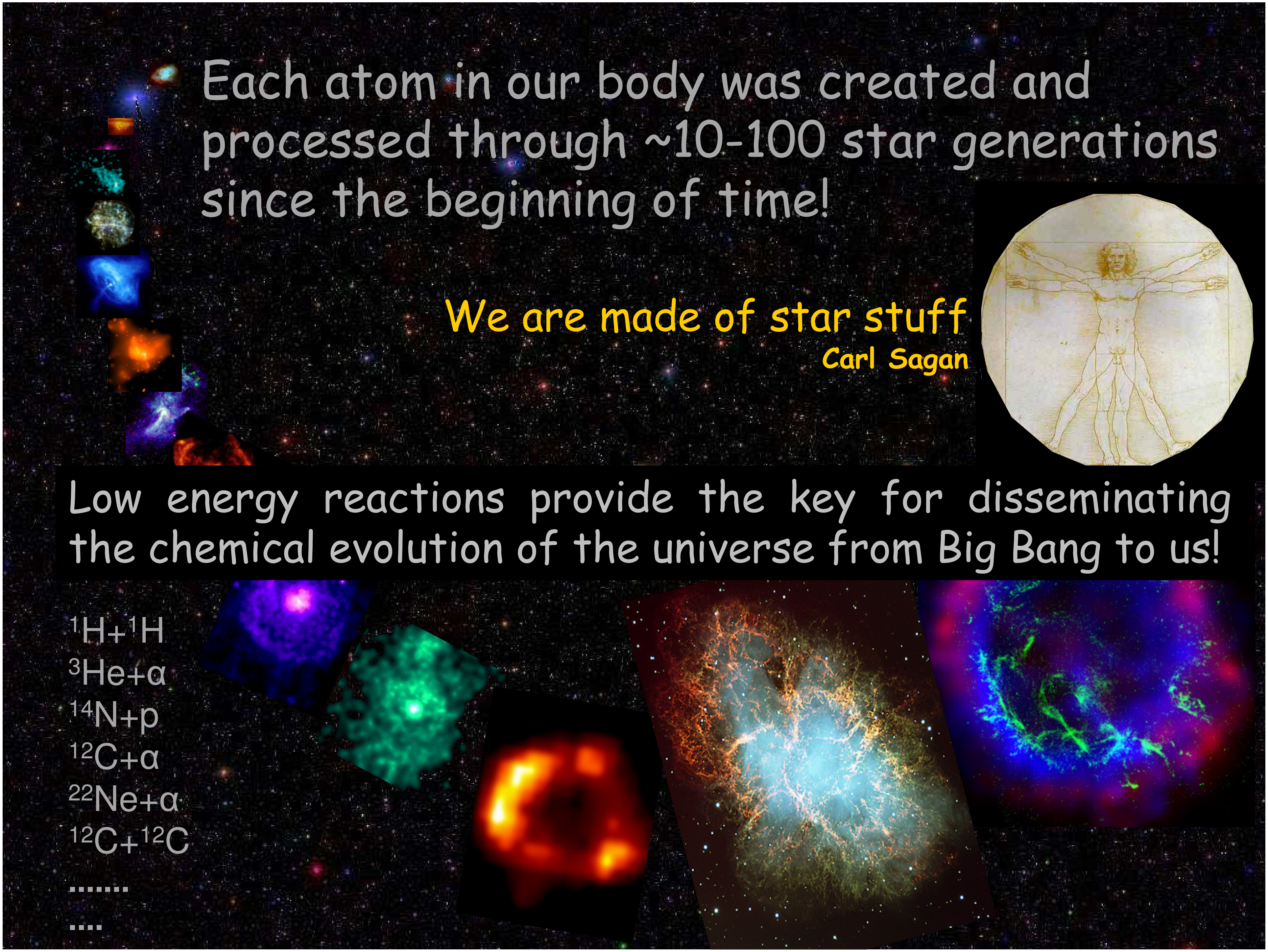
E=10keV-3MeV
I=0.5mA to 10mA
$\rho=10^{19}$prt/cm^2

p, α, HI beams
100 x LUNA luminosity

Facility Status

- Unique experimental facility, will ensure US leadership in this area
- Growing international interest & collaboration (invited talks at NIC2010 & INPC2010, 3 review papers in 2010)
- Technical progress is in accelerator beam optics and jet technology
- DIANA will be ready for installation in 2017 (as soon as Lab module becomes available)




Each atom in our body was created and processed through ~10-100 star generations since the beginning of time!
We are made of star stuff
Carl Sagan
Low energy reactions provide the key for disseminating the chemical evolution of the universe from Big Bang to us!
$^{1}H+^{1}H$
$^{3}He+\alpha$
$^{14}N+p$
$^{12}C+\alpha$
$^{22}Ne+\alpha$
$^{12}C+^{12}C$
....
....