White paper

Draft has been started by
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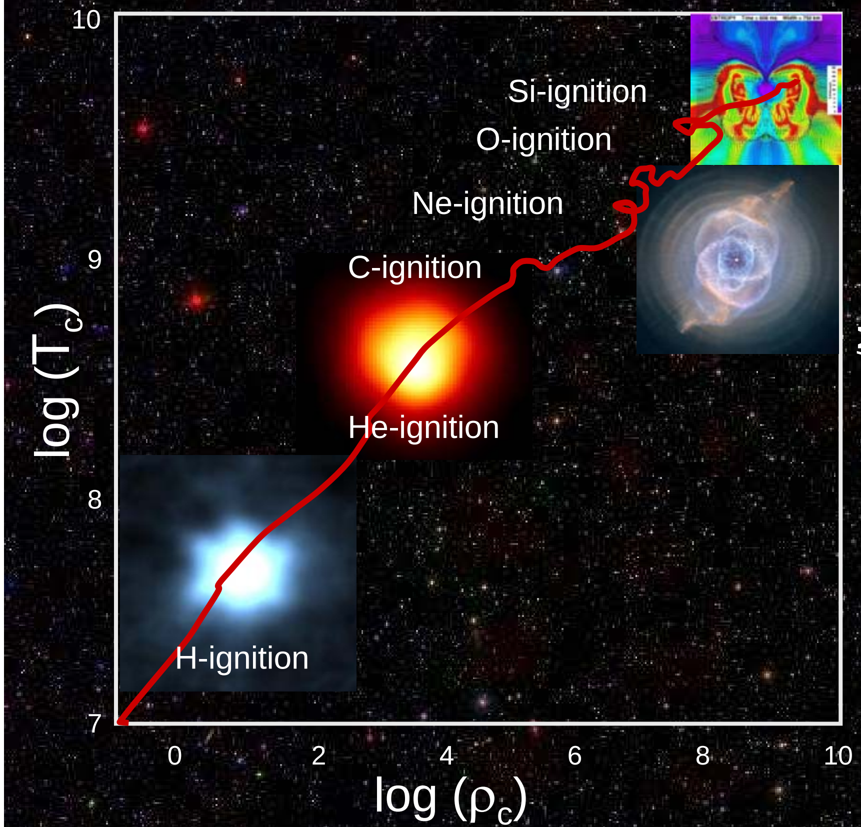
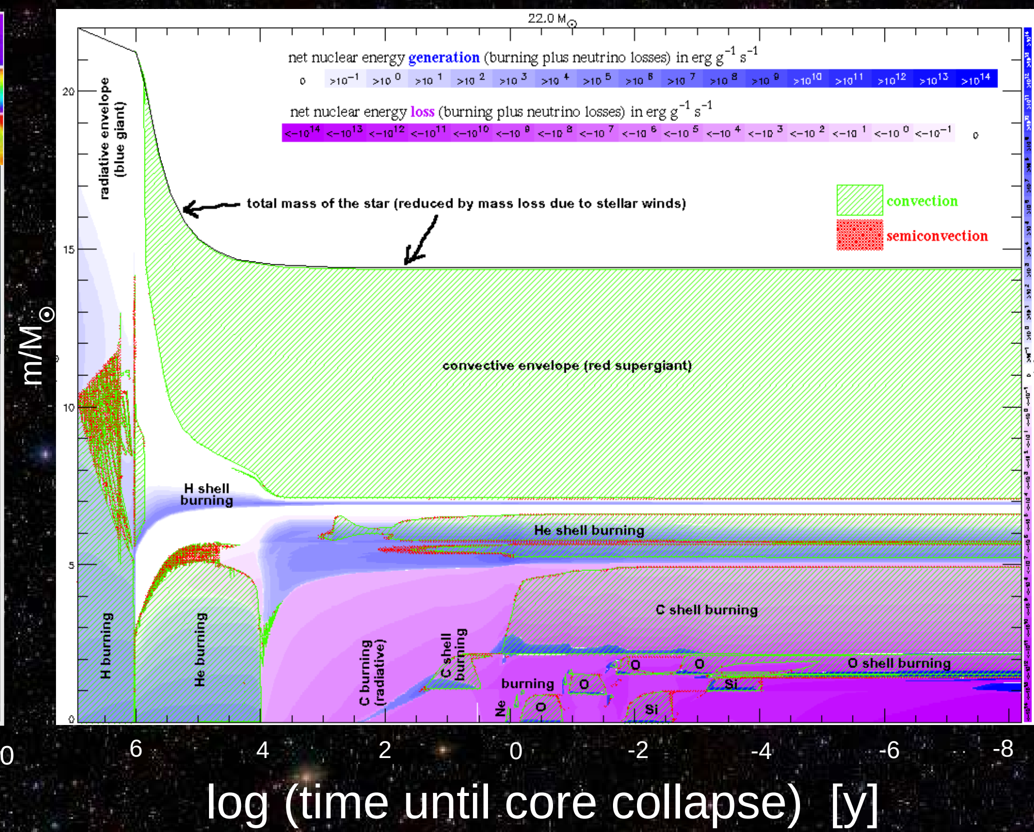
More input through the discussions on Saturday and Sunday
Need broad community input

Science Case
Nuclear burning & stellar evolution





Each burning phase is determined by nuclear reactions in terms of

- energy generation,
- time scale
- nucleosynthesis

Preliminary Conclusions

The underground accelerator will be complementary to astrophysics accelerator experiments above ground and must be embedded in the total effort of the community.

2 opportunities

1. **High intensity low energy beams**
   Physics: Studying the pp chain, with energies below 100 keV, probes the main energy balance in low-mass (sun-like) stars, probes of stellar structure and evolution, galactic evolution…

   "LUNA" List

   - 15N(p,g)16O, d(a,g)6Li, 3He(a,g)7Be, 17O(p,a)(p,g), 18O(p,a)(p,g), 23Na(p,a)(p,g)
   - H-burning : pp-chains, CNO cycles, NeNa cycle, MgAl cycle
     - CLAIRE would be a powerful instrument

2. **Heavy ion accelerator** 3MeV terminal + ECR higher intensities than currently available

- Unique, potentially more scientific impact in combination with these are cross section that face major technical challenges above ground;

  Physics: evolution of massive stars, galactic nucleosynthesis, etc.

  - He- burning, here the most important - besides 12C(a,g) - are the stellar neutron sources 13C(a,n) and 22Ne(a,n)
    - Development of the MeV accelerator and ion sources with intense high charge state beams are critical

Experimental Areas and Detectors and Equipment

To take full advantage of the underground, low cosmic ray background environment, careful attention must be given to detector materials and to shielding against ambient (room, cavity wall) backgrounds in the experiment hall cavity.

- windowless re-circulating gas target (gas jet and gas cell), solid target, target preparation, vacuum components, gas handling components,
- a Ge-NaI detector array
- a number of Si strip detector systems
- Segmented Ge, or Ge strip detectors, novel detection schemes (e.g. LXe TPC)
- Heavy ion recoil separator (stage 2)

R&D Needs and Issues

- High efficiency tracking detector

- Experiment concepts, design the layout, detector, high purity target (feasibility study, experts, homework assignments) need to be developed
  - Shielding (how is the laboratory built, what are the materials used in those modules)
  - Background from concrete and other construction material?
  - Are there background spectrum available from the Homestake mine?
    - Collaborative effort to measure the various background levels
- 2 beam lines for solid targets and gas target
- Maintenance and further development costs of detectors
- Synergies with other experiments
  - Recommendation: DUSEL planning should put a infrastructure in place that fosters cross communications between other physics disciplines, astrophysics has a lot of common interest with other physics detectors.
  - How can we take advantage of detector developments and maintenance done for other experiments

Background, some Notes

- Background components include environmental radiation (detector activity and room background), beam transport system, reactions on target impurities and cosmic-rays.
- The background needs to be addressed in the white paper in terms of justifying to place an experiment underground.
- Experiences from the LUNA facility show that every reaction needs to be addressed in terms of background sources and reduction.

- Room background
  - A need to invest in target and detector technologies even if the experiment is underground.
- Beam induced background is a major concern for many reaction, cross section measurements in inverse kinematics provide one solution, high purity targets are essential
- The He-burning reactions are very important and a major motivation for the facility. Doing them in forward kinematics is complicated by a beam-induced neutron background
- Neutron Background
  - How to address the concerns of other experiments
  - address this issue (the neutrino experiments may make the whole issue moot).

How to arrive at realistic cost estimates

What R&D is needed? Roadmap (rough order magnitude time/cost)

Accelerator R&D

- **Community Consensus was a 3MeV Dynamitron accelerator would be the most desirable accelerator with compact ECR ion source (R&D proposal ?)**

- 1 MeV/u Accelerator; Design study must be conducted before the accelerator option can be decided. Accelerator specifications and requirements must be developed by the community . (3-4 people, 6-12 months).
  - What intensity at which energy?
  - What final energy ?
  - What energy resolution is necessary?
  - Ion beams
- CLAIRE: Accelerator R&D has been started; a detail project and preliminary cost estimate exists, complementary machine for low energy direct kinematics pp chain reactions and CNO cycle

Infrastructure ALNA white paper is a good start

- **Depth**
  - **4850 ft is sufficient**
  - **Different depth area to address background to other experiments**
- **Space**
  - **$50x20x15m^3$**
- **Above ground areas**
- **Infrastructure for Accelerator and Experimental halls**
- **Auxiliary Equipment**

Education and Outreach

- Accelerator facilities are great opportunities in terms of tours for the public at various levels. There is plenty of hardware to see.., the basic aspects of the experimental facility can be easily conveyed to the public.
  - Cosmic rays
  - Radioactivity
  - Detector physics
- Undergraduate outreach: Measure background spectra could be an undergraduate outreach program and very valuable
- Design and construction of the facilities offers various aspects of outreach possibilities (e.g. CLAIRE project has hosted so far 4 undergraduates, 1 graduate student, 1 post doc)
- Astrophysics experiments could offer a great opportunity for local and small universities to participate
- However complex, high precision experiments may not translate well to extensive outreach efforts on a lower level, and require rather high-level student participation (i.e. high-school students would find relatively few opportunities).