Summary of the A4 and A5 Working Groups

Mr. Robertson, your mission, should you choose to accept, is to attend and summarize the sessions on:

A4: Dark Matter

Organizers: Dan Akerib, Rick Gaitskell

A5: Accelerator (nuclear astrophysics)

Organizers: Daniela Leitner, Art Champagne, Michael Wiescher

The sessions are being held in parallel. If you are caught or captured, the Secretary will disavow all knowledge,…
This tape will self-destruct in 5 seconds.

Hamish Robertson
DUSEL: Washington, DC 11/4/07

Goals for S4

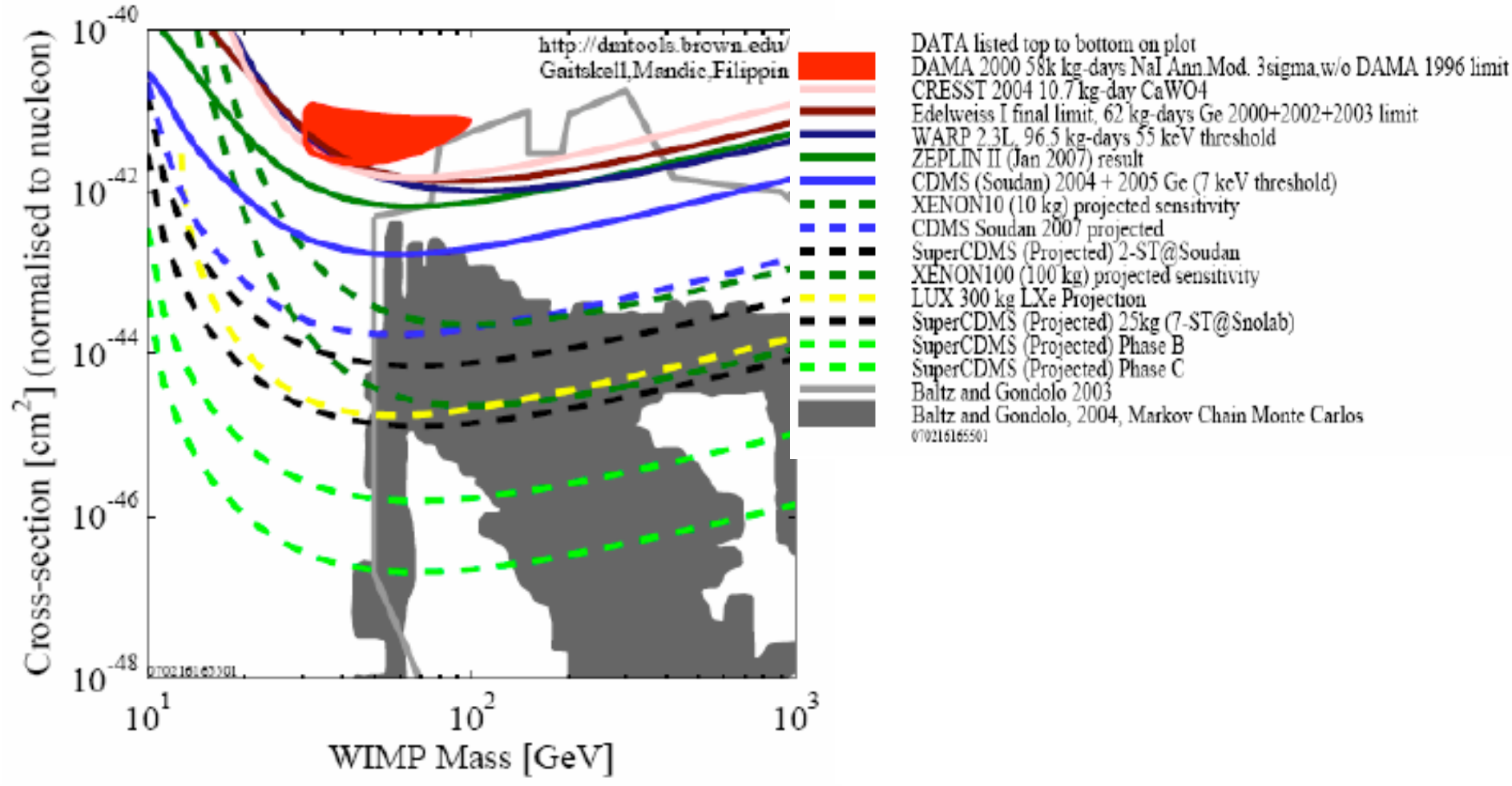
What NSF needs:

1. Strong MREFC package by 3/09
2. Complete facility engineering design, project books (S3)
3. Initial suite of experiments, project books (S4)

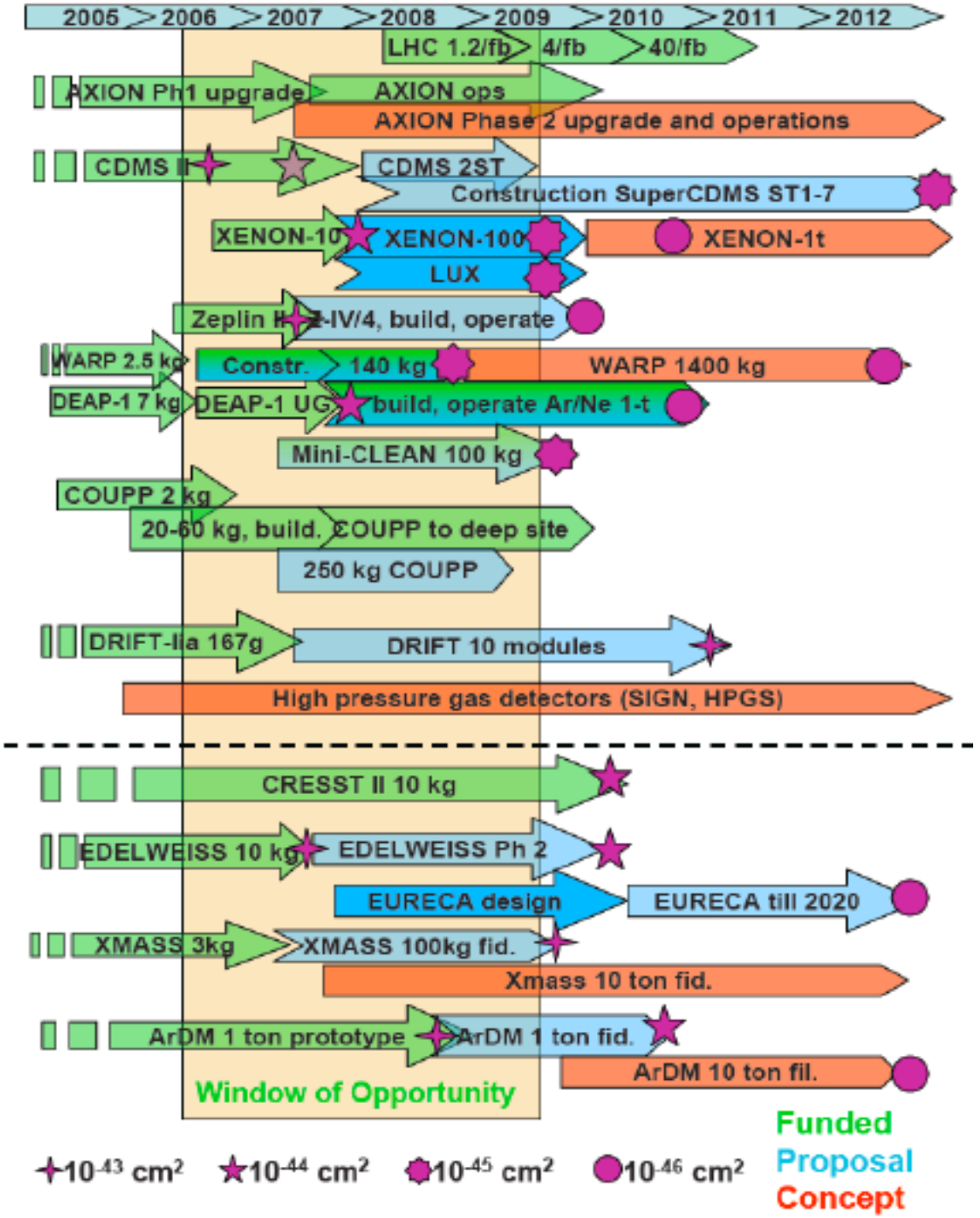
Experiments?

1. What experiments?
2. “initial suite” candidates, later phases and experiments, experiments that will not be in DUSEL.
3. R&D done? If not, what remains?
4. What resources are needed to produce project books?
5. How does DOE program affect this?

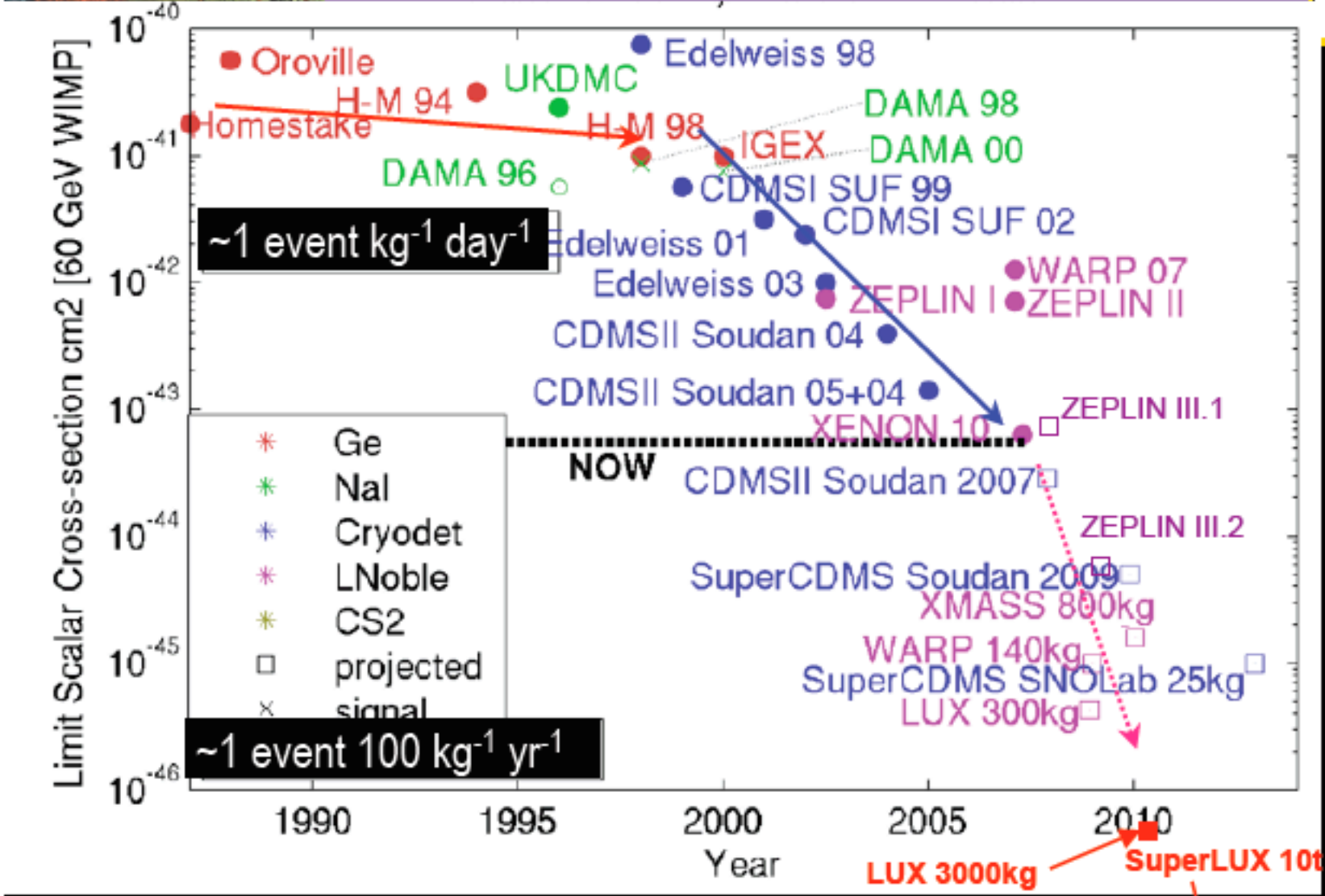
Dark Matter


http://dmtools.brown.edu/
Gaitskell,Mandic,Filippin
Cross-section [cm^2] (normalised to nucleon)
10^{-40}
10^{-42}
10^{-44}
10^{-46}
10^{-48}
10^1
10^2
10^3
WIMP Mass [GeV]
DATA listed top to bottom on plot
DAMA 2000 58k kg-days NaI Ann.Mod. 3sigma,w/o DAMA 1996 limit
CRESST 2004 10.7 kg-day CaWO4
Edelweiss I final limit, 62 kg-days Ge 2000+2002+2003 limit
WARP 2.3L, 96.5 kg-days 55 keV threshold
ZEPLIN II (Jan 2007) result
CDMS (Soudan) 2004 + 2005 Ge (7 keV threshold)
XENON10 (10 kg) projected sensitivity
CDMS Soudan 2007 projected
SuperCDMS (Projected) 2-ST@Soudan
XENON100 (100 kg) projected sensitivity
LUX 300 kg LXe Projection
SuperCDMS (Projected) 25kg (7-ST@Snolab)
SuperCDMS (Projected) Phase B
SuperCDMS (Projected) Phase C
Baltz and Gondolo 2003
Baltz and Gondolo, 2004, Markov Chain Monte Carlos
070216165501

DMSAG Summary GANTT (S.R. Elliott)



DM Direct Search Progress Over Time



Plot updated from that in: R J Gaitskell, Ann. Rev. Nucl. and Part. Sci. 54 (2004) 315-359

All masses are Gross kg.

A4 WG Summary 11/03

- Strong emphasis on discovery potential, DM is "Flagship Science"
- Current Sensitivity of DM experiments σ_{SI} ~10^{-43} cm^2
- Experiments for DUSEL ISE 2012-> will be below 10^{-45} cm^2. The dm field is moving rapidly, so this ISE is generation after *next* phase.
- This will require minimum fiducial mass for ISE experiments of ~1 tonne, expect 1-10 tonne fiducial
- This level of sensitivity may be a challenge for some technologies
- There may already be signal, either in earlier dm experiment, or LHC

A4 WG Summary 11/03

- Write a strong plan to address science case broadly
  - search and discovery mode
  - Multiple detectors to confirm discovery rapidly, address any concern over systematics
  - Strategy to scan both SD/SI couplings to cover parameter space
  - Large detectors to investigate to 10^{-46} (multi-tonne)
- Exploitation (post discovery) phase
  - Large Detectors (Scale up by 10-30 fold on discovery instrument)
  - Multiple targets to determine WIMP mass and couplings (SI A^2, SD-p, SD-n)
  - Directional -- R&D still necessary to cost/scale once cross section known.

A4 WG Conclusion 11/03

- Conclusion: multiple targets chosen from
  - F, Ar, Xe, Ge, Ne, I
  - TDR(PDR)-level descriptions could be written in 6 months for some of the technologies. Significant challenge, need to leave options open to extent possible within MREFC project plan.
  - However some readout methods are still subject of R&D
- Multipurpose experiments
  - DBD and pp neutrino seems possible with 10-tonne detectors
  - important not to compromise primary goal
- Contrarian view (not as popular) would be that we need to focus on a much more limited number of very large detectors.
  - particularly important if still in signal search mode

Underground Accelerator (A5)

The science case:

Cosmic backgrounds are significant for reactions near Gamow peak.

LUNA has actually done it for $^{2}H(p,\gamma)^{3}He$ and $^{14}N(p,\gamma)^{15}O$

Some tough cases: $^{3}He(^{4}He,\gamma)^{7}Be$, $^{12}C(^{4}He,\gamma)^{16}O$, $^{12}C(^{12}C,\gamma)^{24}Mg$, $^{13}C(^{4}He,n)^{16}O$, $^{22}Ne(^{4}He,n)^{25}Mg$ very important (solar, He burning, hot CNO, s-process).

Can sometimes be done on surface: $^{3}He(^{3}He,2p)^{4}He$, Caltech, LENA

Not so clear hot CNO, etc., need the low backgrounds. But they don't hurt, and a facility focused on this kind of measurement will help.

The Collaboration:

___ scientists.

JINA project, in collaboration with LBNL for accelerator technology.

Present support? LBNL LDRD? JINA NSF block grant(s)?

Needed for preconceptual PED

Underground Accelerator (A5)

The technology:

1. Like LUNA at first, but more current. 50-400 keV, up to 100 mA(!) DC. CLAIRE project at LBNL ready for PED.

2. Inverse kinematics machine: RFQ or DC? Tradeoffs of current, energy available. Need up to 1 MeV/u.

3. Portfolio of multi-element gamma and particle detectors, and a recoil separator (e.g. DRAGON at TRIUMF). Neutron detector array? Gas target.

The infrastructure needed:

~4000 mwe, total area 1200 m^2

CLAIRE: 10x8x5 m^3

HE machine: 30x20x5 m^3

Expt hall: 20x15x5 m^3

Utilities: 5x10x5 m^3

Counting Room: 8x8x5 m^3

SF_6, cooling water, cryogenics: 10x10x5 m^3

Background reduction at LUNA

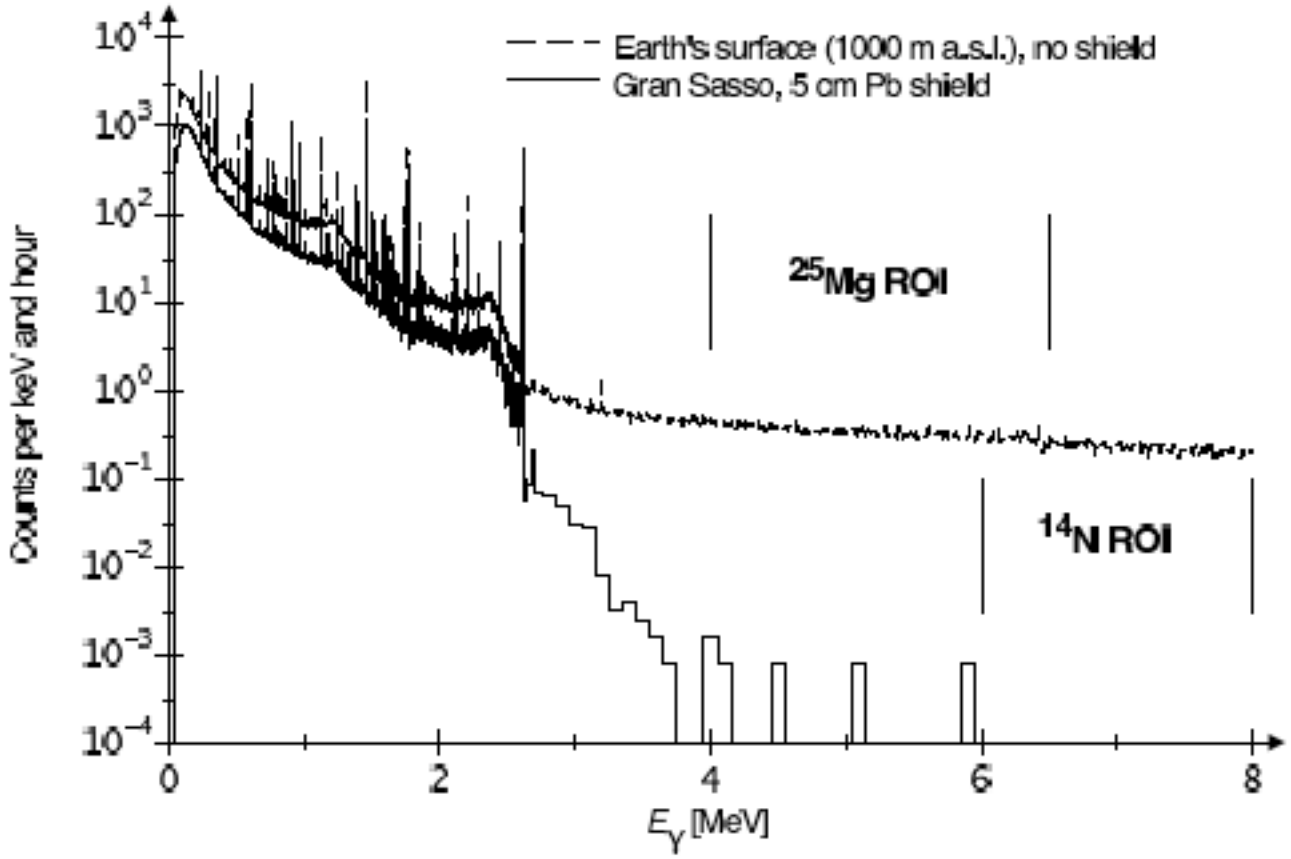


Fig. 2. Laboratory γ background as seen with the germanium detector of setup A at the earth's surface (1000 m above sea level) and inside the Gran Sasso underground facility.

Bemmerer et al., nucl-ex/0502007

ALNA - Accelerator Laboratory for Nuclear Astrophysics Underground

(http://www.deepscience.org/TechnicalDocuments/Final/ualna_final.pdf)

Two accelerator based experimental areas

- A compact, high intensity low energy accelerator for forward kinematics reactions (complementary or expanding on LUNA activities, need priority list of experiments)
  - CLAIRE
  - High current DC accelerator
- A high intensity heavy ion accelerator for inverse kinematic reaction and low energy fusion reactions (need to develop a priority list of reactions that benefit from going underground)
  - RFQ LINAC
  - Pelletron, Tandem
  - Dynamitron, Singletron

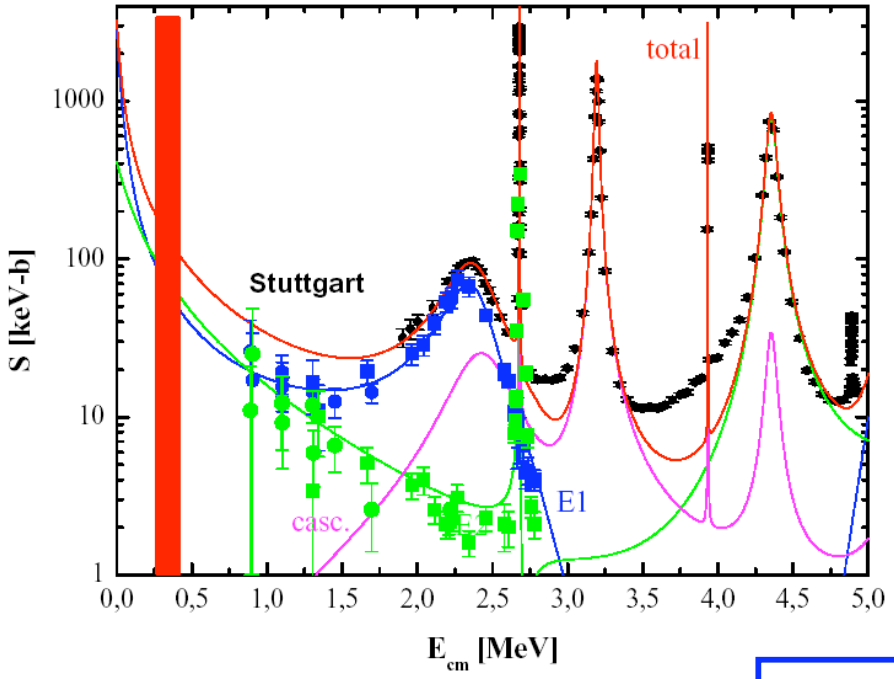
•The energy range of both accelerators combined should ideally cover beam energies from as low as 50keV up to 1 MeV/u for ion masses up to Mg

•The two accelerators should have an overlap in energy range for comparison between experiments over a common energy.

$^{12}C(\alpha,\gamma)^{16}O$

The reaction that all nuclear astrophysicists want to know…

- Determines the amount of oxygen and carbon, "Life" element creation, timescales, dispersion
- Determines isotopic abundances in progenitors of Type 2 Supernovae
- Type Ia Supernova, central carbon burning of C/O white dwarf



- Unfortunately has a very difficult complex resonance structure, interfering broad resonances causes difficulties in the reliability of low energy extrapolation.
- Needs to be measured over a wider energy range
- Target impurities cause beam induced background

Another key reaction: $^{12}C(^{12}C,\gamma)^{24}Mg$

A5 WG Conclusions

- Converging to a consensus, if wider community agrees
- Unique chance to resolve 40-year-old major problems in astrophysics: $^{12}C(\alpha,\gamma)$ and $^{12}C(^{12}C,\gamma)$. (But, field not static…)
  Plus a host of other measurements that LUNA, LENA will also be tackling.
- ~ 3 MV hi-current DC machine, terminal ECR source, 10+ pmA of beam, gas target. Magnetic beam analyzer. Low-bkg detectors. Recoil separator not required at first.
- This may be the MOST unified and ready community.
- Perfect for Early Implementation Suite: PDR could be developed fairly quickly, and 4850 is the right level.

Problems

- No clearly defined process
- Short time to MREFC PDR (3/2009)
- Long time to ISE (2014?)
- Evolving technology, competition, physics
- “Insufficiently ambitious” plan (long baseline, megadetector, at fringe, not central)

Solutions (Enough whining already!)

- MANY clearly defined processes!
  - Present NSF, DOE support via regular channels
  - SUSEL Early Implementation
  - S4 - $15M over 3 years for DUSEL related research
  - MREFC ISE and funding. $250 M over ~5+ years
  - DOE HEP, NP capital projects. Increasing free energy by 2014.
- Short time to MREFC PDR (3/2009)
  - Need clear program, but experiment evolution will be "permitted"
  - Help NSF get this launched
- Long time to ISE (2014?)
  - The time will pass like you won't believe
- Evolving technology, competition, physics
  - Not a bad thing. Just be sure we're driving it.
- "Insufficiently ambitious" plan (long baseline, megadetector, at fringe, not central)
  - Be prepared for success of θ_{13} measurements