DUSEL AARM Collaboration Meeting at Minneapolis – February 25-26

DIANA – Simulation Requirements

Talk Outline:

- DIANA Goals (very very briefly).
- Example of LNGS Background
- Detectors & Shielding
- Simulation Needs
- Additional Simulation Needs

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Stellar Reaction Rate

- Today it is well known that stars are powered by nuclear reactions.
- They determine the origin of elements in the cosmos, stellar evolution and dynamic, etc.
- Many reactions ask for High Precision data.

Stars in Hydrostatic and Thermal Equilibrium (Spherical Symmetry)

FRANEC, Stellar Evolution Code (A. Chieffi, M. Limongi, and O. Straniero, Astrophys. J. 502 (1998) 737)

Mechanical Equilibrium:

$$\frac{dP}{dr} = -G\frac{M(r)\rho(r)}{r^2} \qquad \rho(r) = \sum_i m_i \rho_i(r) \qquad M(r) = \int_0^r \rho(r) 4\pi r^2 dr$$

Energy Transportation:

$$\frac{dT}{dr} = -GM(r)\rho(r)\frac{T(r)}{P(r)}\frac{d\log T}{d\log P}$$

$$\boxed{\sigma(E)}$$

Energy Generation Rate:

$$\frac{dL}{dr} = (\epsilon_N + \epsilon_G + \epsilon_\nu)\, 4\pi r^2 \qquad \epsilon_N = \sum_{ijkl} \frac{\rho_i \rho_j}{1+\delta_{ij}} < \sigma v >_{ij\to kl} Q_{ij\to kl}$$

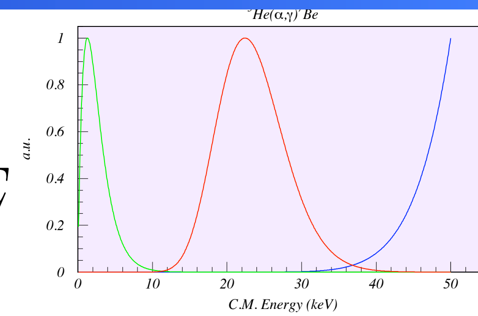
Elemental/Isotopic Evolution (one eq. per each isotope, no 3-body reactions):

$$\frac{d\rho_i}{dt} = \underbrace{\sum_{jkl} \frac{\rho_j \rho_k}{1+\delta_{jk}} < \sigma v >_{jk\to il}}_{\text{Production Rate}} - \underbrace{\sum_{jkl} \frac{\rho_i \rho_j}{1+\delta_{ij}} < \sigma v >_{ij\to kl}}_{\text{Destruction Rate}} + \underbrace{\sum_{j\neq i} \frac{\rho_j}{\tau_{j\to i}}}_{\text{Dec. Prod. R.}} - \underbrace{\sum_{j\neq i} \frac{\rho_i}{\tau_{i\to j}}}_{\text{Dec. Destr. R.}}$$

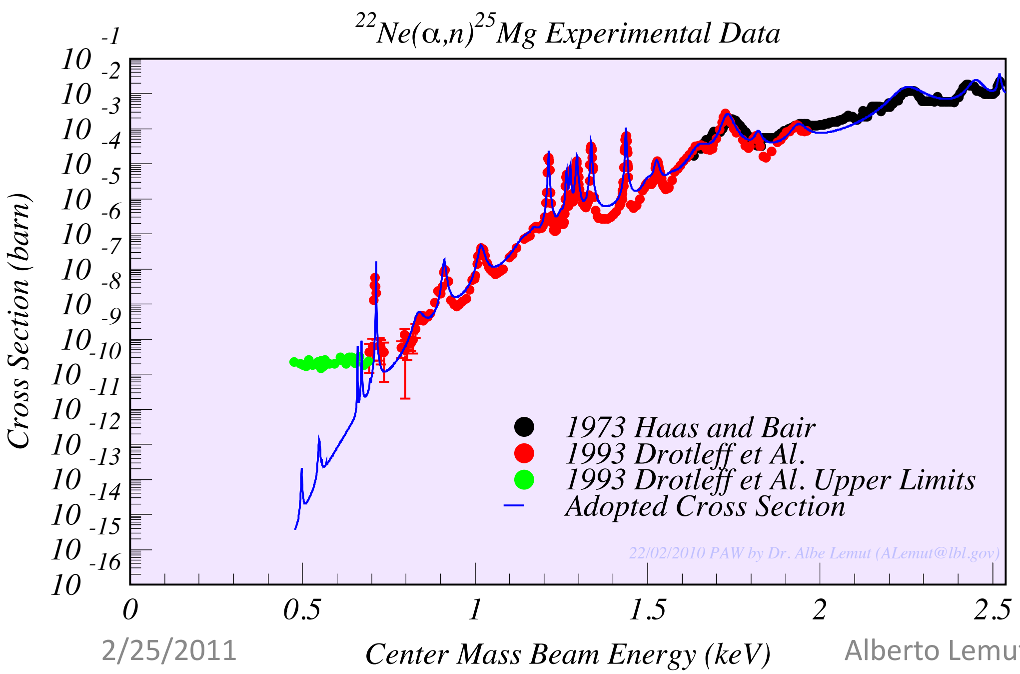
DIANA Goals

Maxwell-Boltzmann Averaged Cross Section:

$$< \sigma v > (T) = \sqrt{\frac{8}{\pi\mu(k_B T)^3}} \int_0^\infty \sigma(E) E e^{-E/(k_B T)} dE$$



DIANA Goals:
(Small) Cross Section Measurements of Astrophysically Relevant Nuclear Reactions.



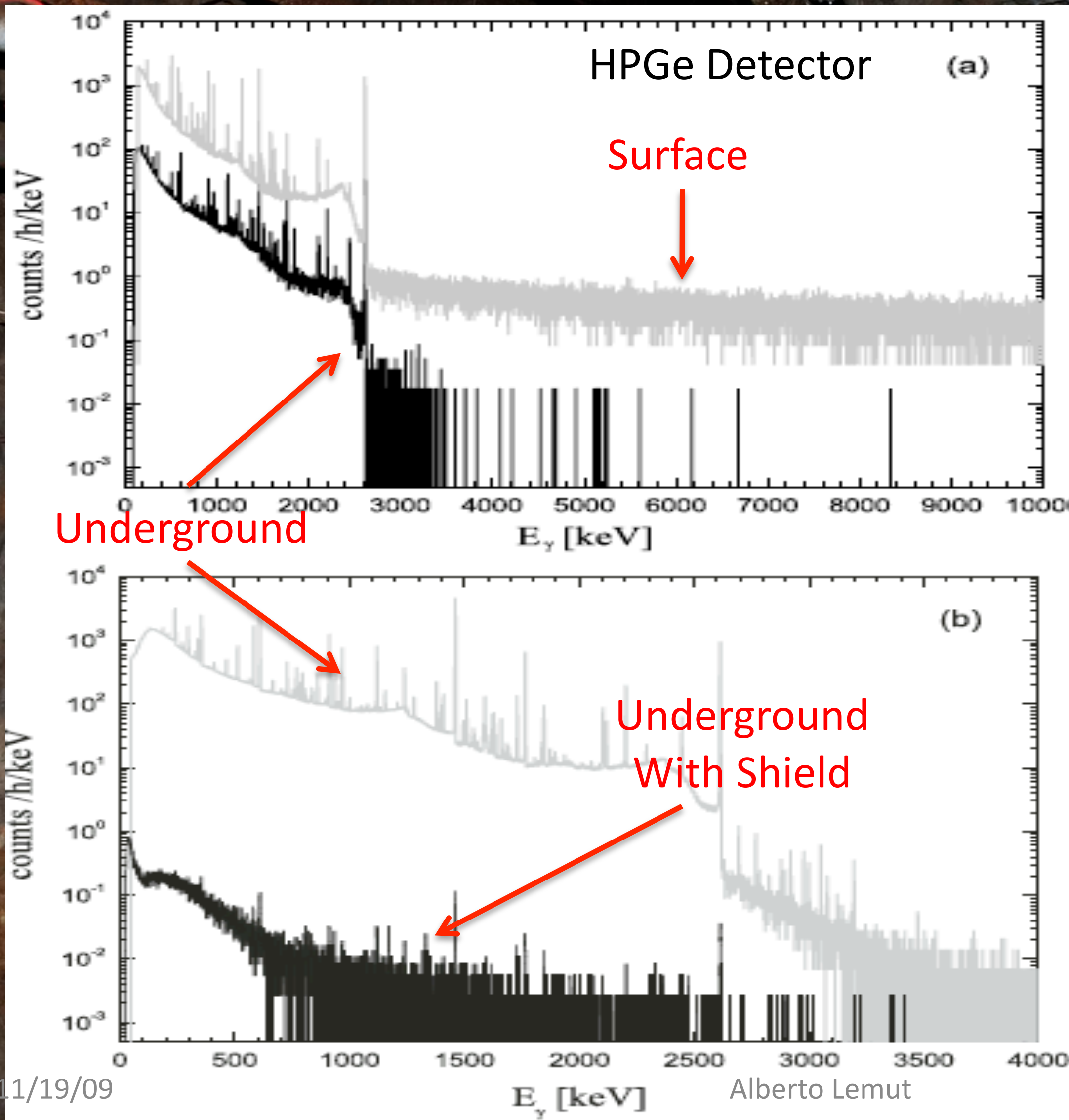
Very Small Cross Sections:

$$\sigma(E) = \frac{1}{E} e^{-\left(2\pi \frac{Z_T Z_P e^2}{\hbar} \sqrt{\frac{\mu}{2E}}\right)} S(E)$$

Low Laboratory Counting Rates:
1 counts/month – 1 counts/day.

DIANA Is a Low Counting Facility
for Nuclear Reactions Experiments!

LNGS Background



H. Costantini et. Al., Rep. Prog. Phys. **72 (2009) 086301**

Background reduction at the LUNA facility in the Gran Sasso National Laboratory

1400 m deep (= 3100 meter of flat overburden water equivalent shielding)

Muon flux is reduced by 6 orders of magnitude

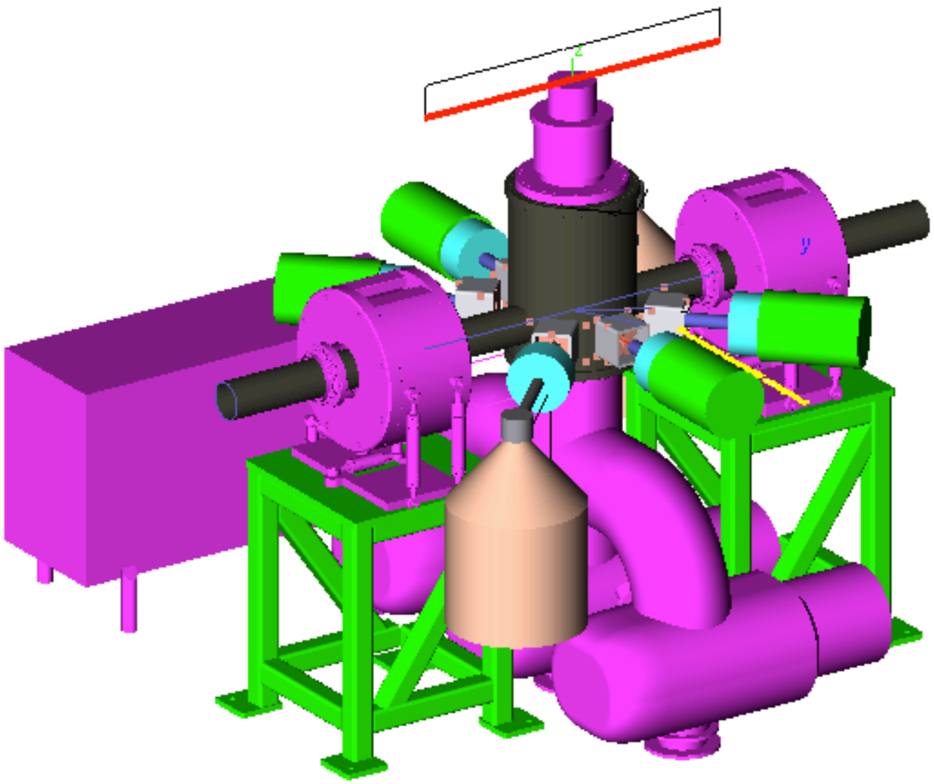
Neutron flux is reduced by 3 order of magnitude

Clear advantage for high Q-value reactions.

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

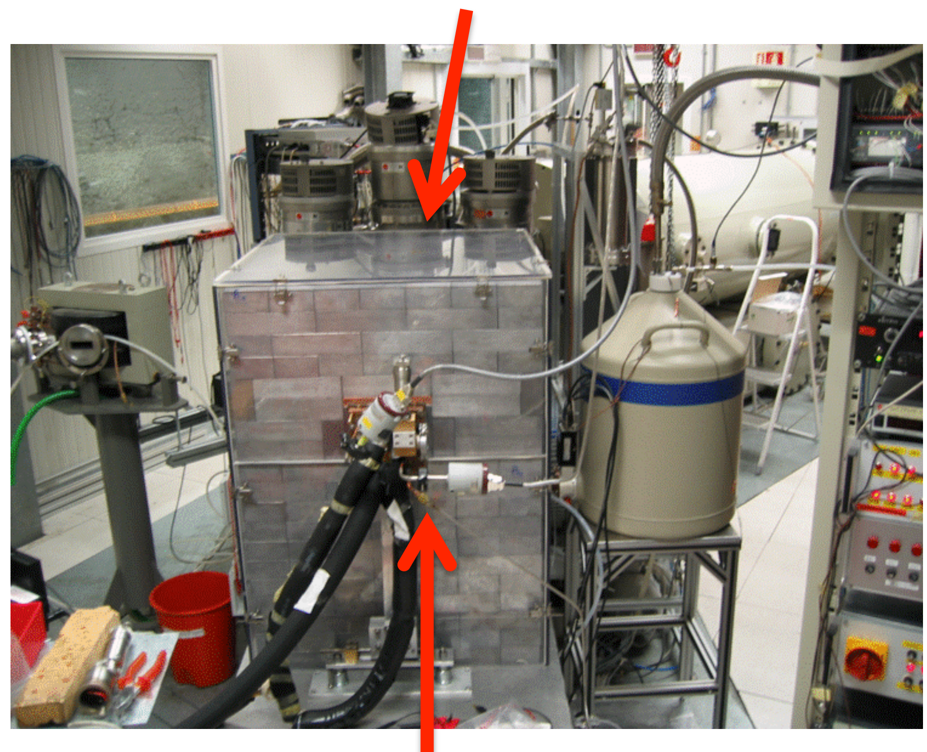
DIANA Detectors & Shielding

The Characterization of the Underground Radiogenic (neutron and gamma) Background is very important for the Shielding and Detector Design



High Purity, Ultra Low Activity Materials

Radon Box Flushed with High Purity Nitrogen



Oxygen Free Copper Inside to Shield Detectors

Picture from LUNA $^{3}He(\alpha,\gamma)^{7}Be$ Setup at LNGS

DIANA Simulation Needs

- DIANA will need to size the shield thickness (copper and lead layers): for this task realistic simulation of the underground neutron and gamma (low energy) radiation is required.
- Critical are the calculations of the Jet-Gas-Target Shield ”Bottom Hole”.
- For both these tasks an accurate knowledge of the (low energy) gamma and neutron energy, position and angular spectra are required.

- DIANA will need to determine minimum Isotopic “Contaminations” requirements into passive shielding and materials. For this task “simulation techniques” developed for the radiogenic background simulation may be “borrowed”.
- DIANA will need to determine also the maximum Rn activity tolerable inside the shielding, and thus in the surrounding environment (up to now LNGS was assumed while DUSEL are dramatically higher).

Note:

- No special Very Low Energy gamma packages are required.
- High Precision Neutron Models, including the thermal ones are required.

DIANA Cavity Shielding

DIANA Detectors Shielding Summary:

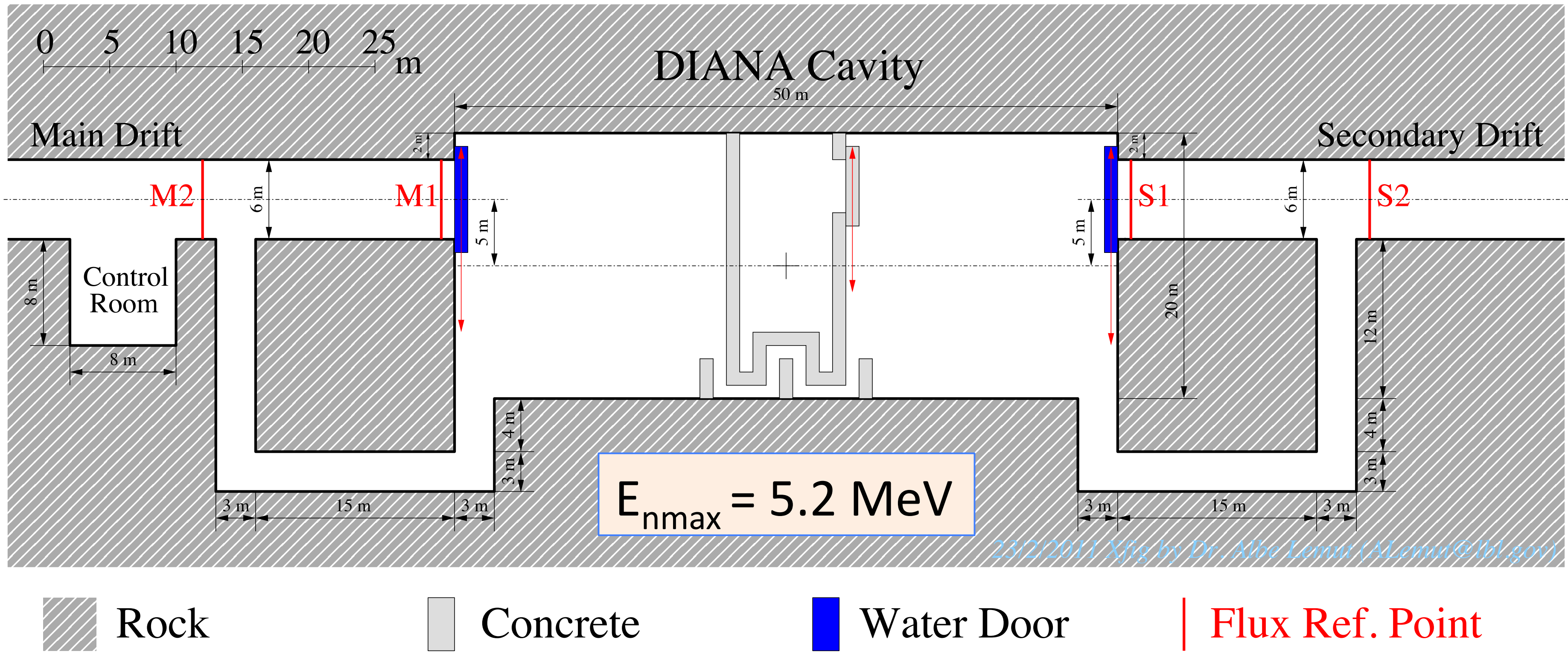
- **The environmental radiation (Rn included)** will be the major source of background into DIANA detectors. It will be shielded by high radio-purity materials like lead, copper and polyethylene.
- **Beam dump, slits and aperture radiation emission** occurring in high energy and high beam current intensity runs, can be shielded simply with lead and polyethylene shield.

Other DUSEL Experiments:

- **DUSEL rock shielding**: experimental cavities will be separated by at least **40 m of rock**, which effectively shields any **BEAM INDUCED GAMMA OR NEUTRON FIELDS TO NEGLIGIBLE LEVELS**.
- However if neutron production occur, scattering can happen in the entrance drifts, and need to be studied and eventually mitigated.
- For this purpose, the DIANA Collaboration carried out a detailed study of Cavity entrances shield.

DIANA Cavity Shielding

Modified Cavity Layout Proposed to DUSEL Project



The Cavity entrances shielding has been designed such that any beam induced radiation outside (at M2 and S2) will be **BELOW THE NATURAL RADIATION LEVELS** of DUSEL (Φ_n = (2.3 ± 0.8) × 10^{-6} n/(cm^2 s), Φ_γ = (0.32 ± 0.10) γ/(cm^2 s), after D. Mei *et Al.*, Astropart. Phys, Vol. 34 (2010) 33 - 39).

DIANA Additional Simulation Needs

Operational Note:

1) 3×3 m^2 egress mazes will grant continuous safe personnel access to the cavity, for detector/target operation (low radiation field).
2) During accelerator operations water doors will stay closed.
3) During beam tuning access will not be allowed.
4) In addition, radiation monitors will be installed inside the cavity, and will shut down accelerators if radiation exceeds defined threshold.

DIANA Additional Simulation Needs:

- DIANA is cross checking the initial simulation results obtained with Geant4, using MNCP.
- DIANA is willing to cross check these results also with a the proposed simulation code (if feasible) to show DIANA won't have any impact on the other experiments installed in DUSEL.

Additional Note:

- The DIANA proposed entrances maze design and water doors is based on the same design concept of the internal one and concrete walls. DIANA wants to cross check the internal mazes and walls design too.

The DIANA Team

DIANA

@ DUSEL Workshop

Thank You for Your Patience!!!

Albe

Thursday, October 1st 2009, Lead SD

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