A solar neutrino space craft detector

Holger Meyer for the NuSOL collaboration

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Outline

- Why detect neutrinos in space?
  - Rate – to the sun
  - Backgrounds – away from Earth
- How to get started
  - NASA Technology Readiness Levels
- The NuSOL project
  - Simulations, hardware, orbits,...

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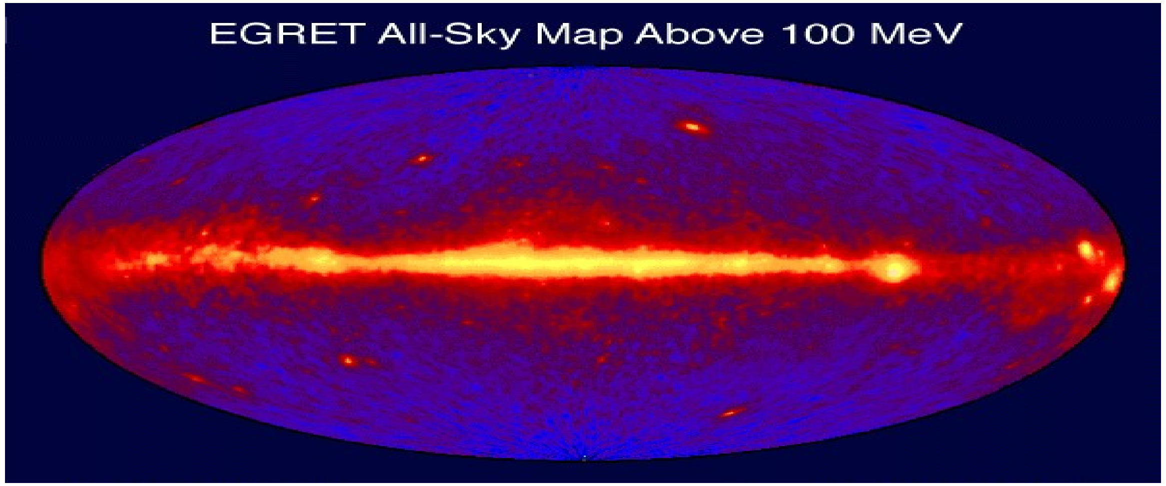
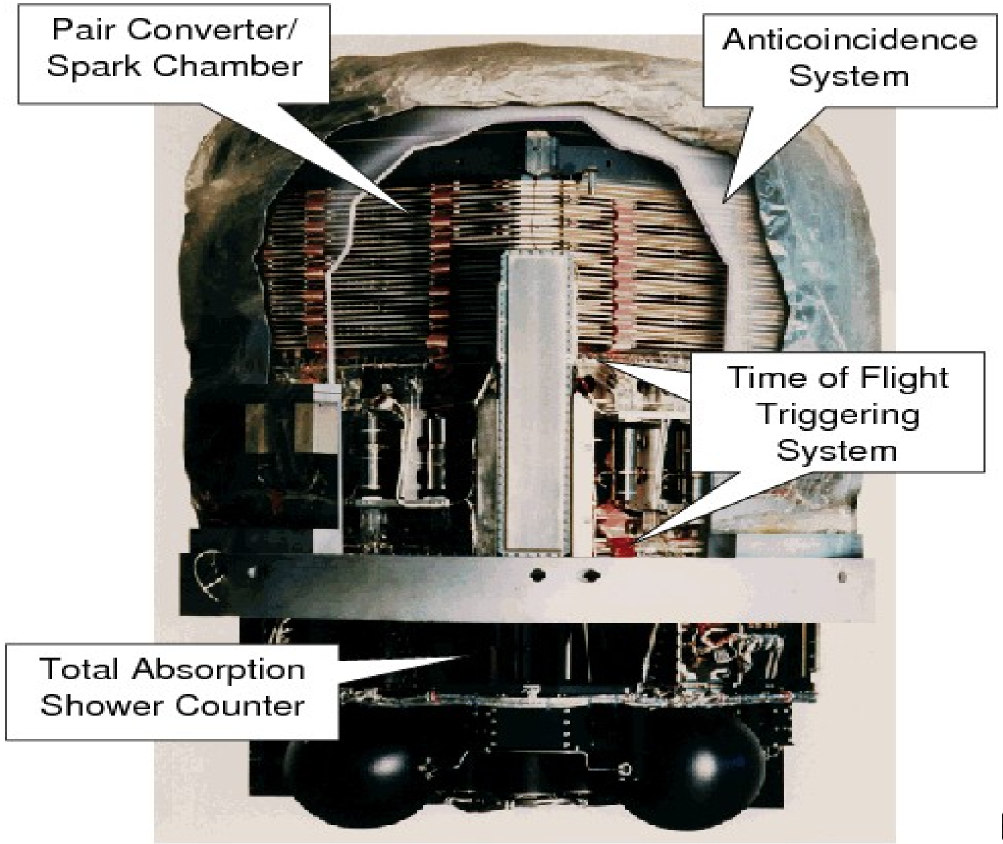
Physics motivation

- Detection from space has been very successful in the past.
  - Hubble Space Telescope vs. ground based optical telescopes
  - EGRET, a small spark-chamber spacecraft launched in 1992, let us view the sky in gamma-rays. Now: Fermi satellite





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Physics motivation

- But wait, neutrinos propagate through the atmosphere just fine
  - No atmospheric distortions like light, interactions like gamma rays
  - We are already looking at solar neutrinos with ground based neutrino detectors
- 1 A.U = 215.03 r_{sun}
  - Get close to the sun and the rate will increase, e.g. 10,000 fold at ~3 r_{sun}
  - Parker solar probe will get to ~10 r_{sun}, Russian probe will get to ~5 r_{sun}
  - A small neutrino detector will get the same rate as kton scale detectors on Earth.
  - Every neutrino is a solar neutrino, no backgrounds from atmospheric neutrinos, geo-neutrinos, ...

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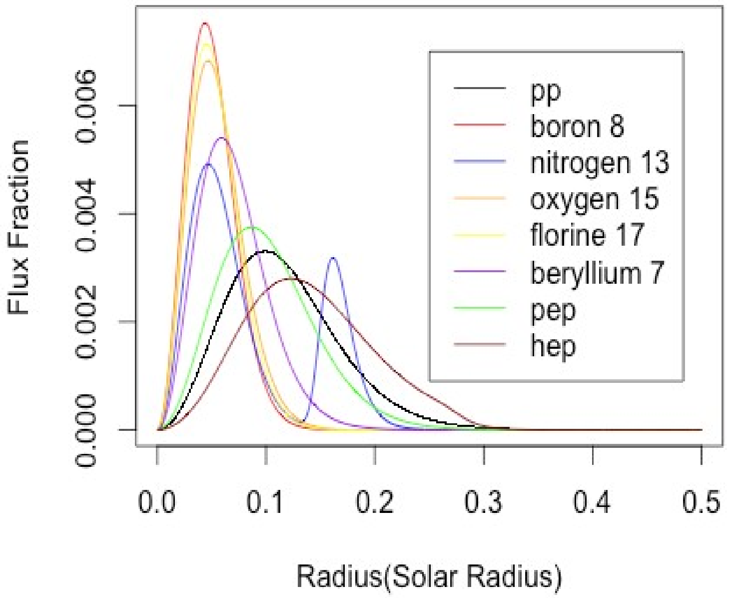
Physics motivation

- Image the fusion core of the sun
  - Look from outside the ecliptic plane
  - But orbits are challenging. Want to spend as much time close to the sun as possible.



- Neutrino physics complementary to what can be done on Earth
  - coherence length at 10 MeV is 2.44×10^{7} km = 35 r_{sun}
- Many other studies are possible

NASA Technology Readiness Levels

- DOE has Critical Decision (CD-0 to CD-4) steps
- NASA has TRL 1 to TRL 9
  - One take-away: If it is not well proven on Earth then it won't fly.
- The first neutrino detector in space won't be a LAr-TPC.
  - … just like EGRET was old technology at the time of launch.
- The first neutrino detection (Cowan&Reines) used the coincidence of a prompt signal (positron annihilation gamma rays) and a delayed signal (neutron capture on cadmium)

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NuSOL – A neutrino solar orbiting laboratory

- Collaboration:
  M. Christl, NASA MSFC
  S. Turyshev, NASA JPL
  R. McTaggart, South Dakota State University
  N. Solomey, H. Meyer, A. Dutta, C. Gimar, A. Nelsen, J. Folkerts, J. Novak, T. Nolan, Wichita State University
- Funded through NIAC phase 1, NIAC phase 2 grants
- Concept: doped liquid scintillator

^{69}Ga + ν into e- ^{69}Ge m1 or m2	^{69}Ge m1 decays X-ray	5 us	86 keV
	^{69}Ge m2 decay gamma	2.8 us	397 keV
^{71}Ga + ν into e- ^{71}Ge m1	^{71}Ge m1 decay gama	20 ms	175 keV

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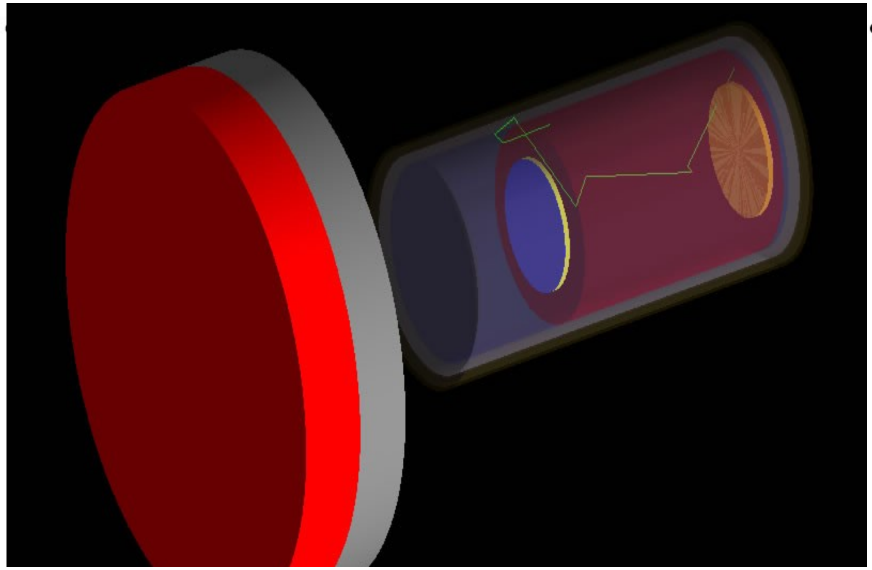
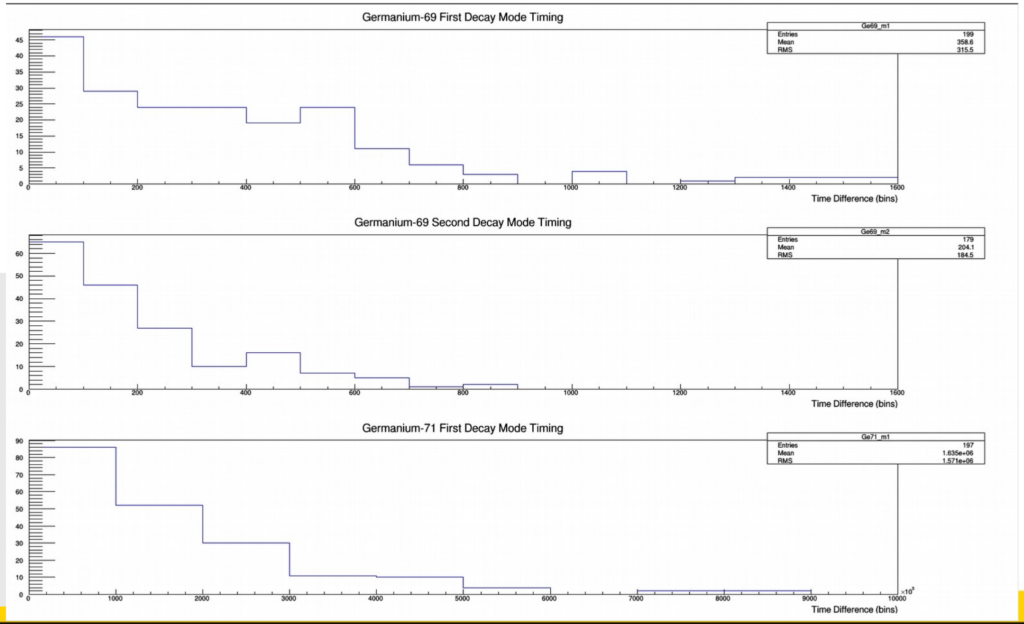
NuSOL – A neutrino solar orbiting laboratory



- Cylindrical scintillator vessel read out on each endcap
- Inside a charged particle veto
- Behind a heat shield

- No full detector readout simulation yet, but we get the excited state lifetimes back.



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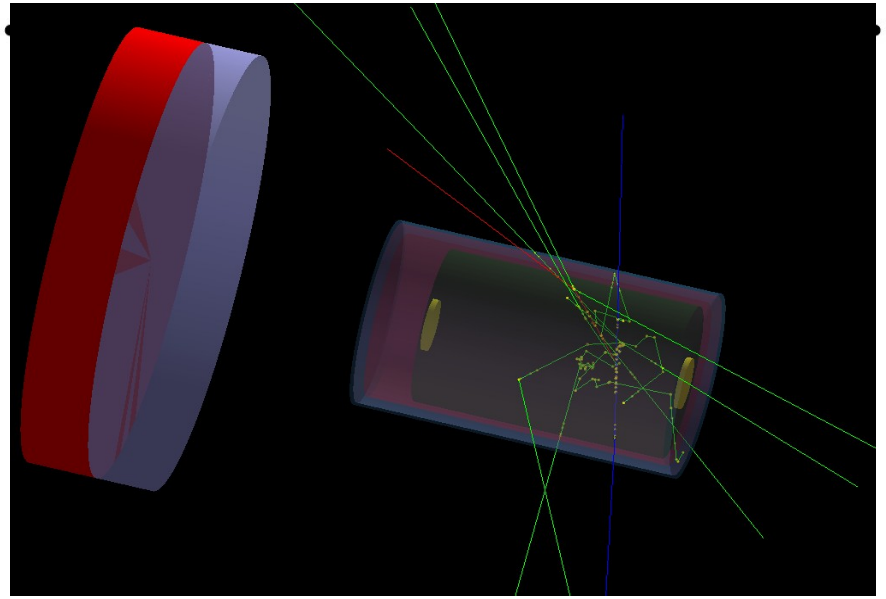
Simulation of Ga Neutrinos Interaction and Backgrounds with Geant 4

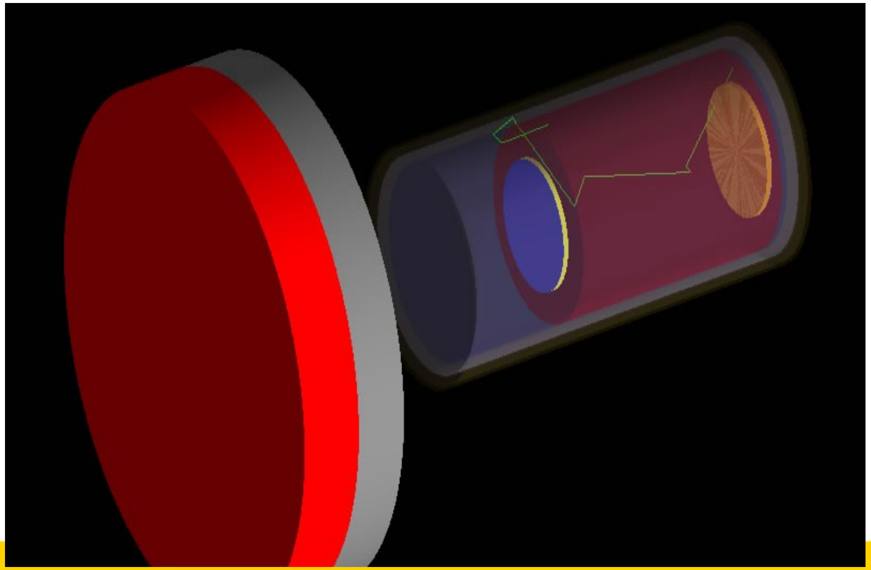
Cosmic Ray

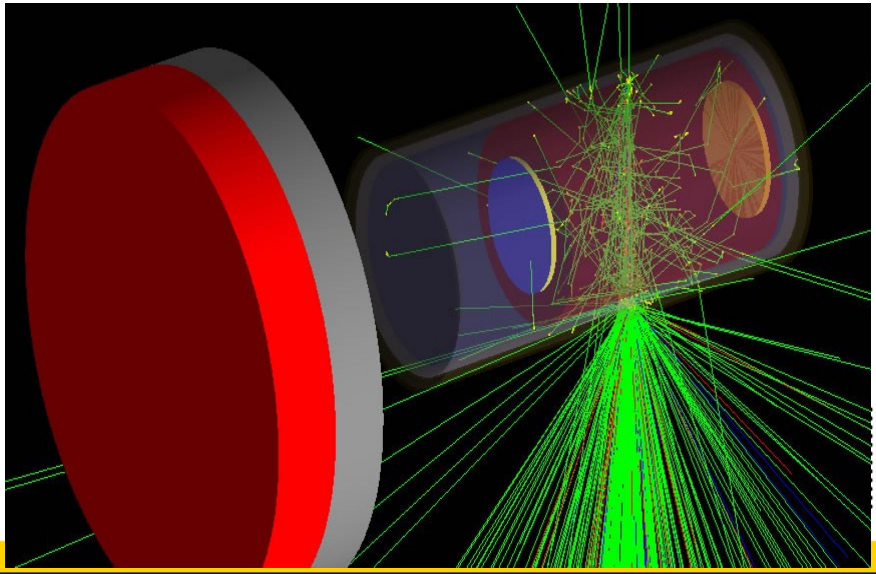
Gamma Ray

Neutrino Event

ν Ga into e- Ge emits delayed γ







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NuSOL timeline

- We have shown with simulations in a NASA Innovation Advanced Concept Phase-1 grant 2018-2019 that the technique can work, over coming the backgrounds and pulling out a neutrino signal.
- We are starting a 2-year NIAC Phase-2 grant 2019-2021 that aims to build a prototype and test it on Earth with cosmic rays, gamma sources and flight design studies.

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NuSOL Detector studies

- How much Ga?
  - Light attenuation length at high dopant concentrations? Does not need to be long when the detector is small.
    - Setting up measurements as part of NIAC phase II
  - Fall out of suspension? In zero G? But what about the launch?
- Design of heat shield
  - Need to also shield EM showers from the sun.
- Veto surrounding doped scintillator, electronics, integration.

Thank you!

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Abstract

The NuSOL collaboration pursues the physics motivation and detector development for a neutrino detector in space. I will briefly present some of the physics motivation for detecting solar neutrinos at a distance of just a few solar radii from the sun. The environment close to the sun provides very different backgrounds from those present on Earth. I will also discuss some detector design considerations and initial simulations of a detector concept. The detector obviously needs to be much smaller than typical neutrino detectors on Earth. This is compensated for in the expected event rate by the increase in neutrino flux as the detector gets close to the sun. The smaller detector allows more freedom in design. For example dopants to scintillator in large Earth based neutrino detectors are limited by their availability and cost. The smaller detector volume of a neutrino detector space craft makes feasible higher concentrations of dopants or doping with elements that are not common enough to be used as dopants in kilo-ton scale detectors. On the other hand the space environment and launch provide challenges an Earth based detector does not encounter.

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