Simulation of the charging process of the LISA test masses due to solar particles.

5th International Lisa Symposium

14 July 2004

Helios Vocca

INFN Pg

Solar Energetic Particles (SEPs)

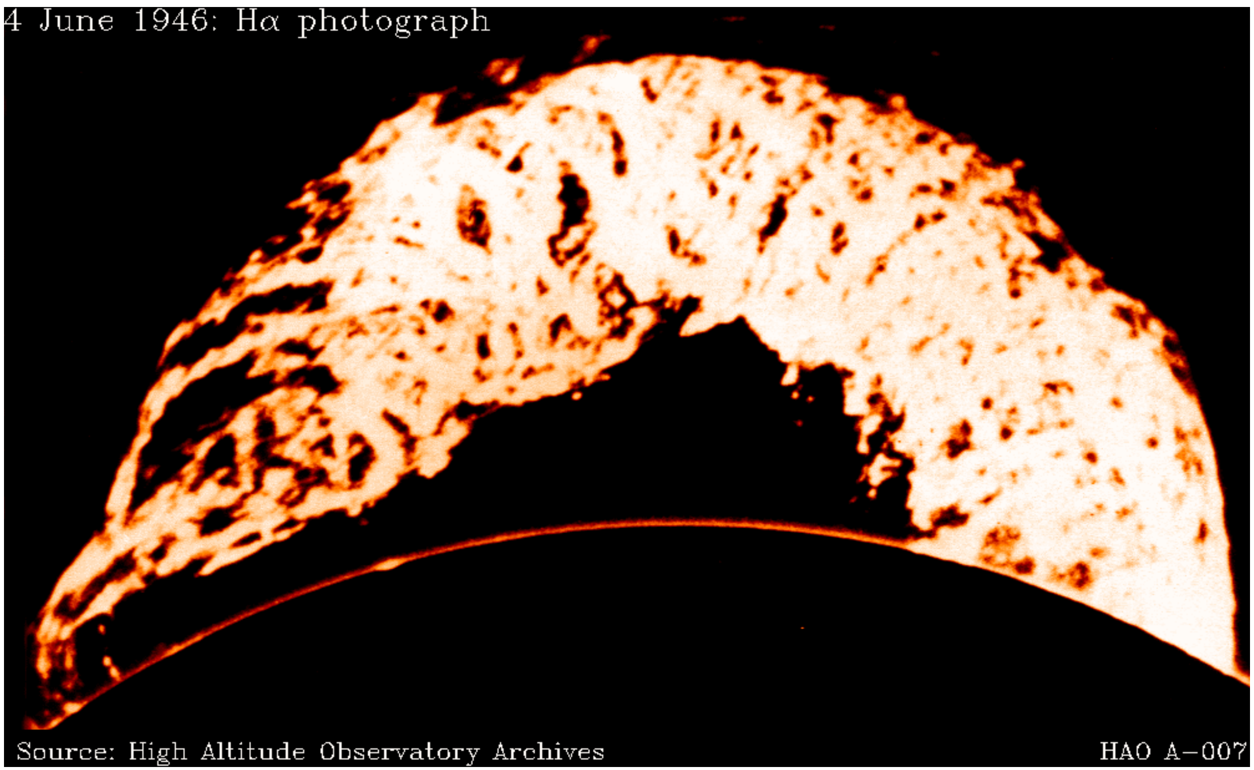
SEPs are particles above 1 MeV emitted by the Sun.
They are mainly divided in two types of events: **Impulsive** and **Gradual**

	Impulsive	**Gradual**
Particles	*Electron-rich*	*Proton-rich*
3He/4He	*~1*	*~0.0005*
Fe/O	*~1*	*~0.1*
H/He	*~10*	*~100*
QFe	*~20*	*~14*
Duration	*Hours*	*Days*
Longitude Cone	*<30 deg*	*~180 deg*
Radio Type	*III, V (II)*	*II, IV*
X-rays	*Impulsive*	*Gradual*
Coronagraph	-	*CME (96%)*
Solar Wind	-	*IP Shock*
Events/year	*~1000*	*~10*

Reames, D V 1996, Energetic Particles from Solar Flares and Coronal Mass Ejections, in High Energy Solar Physics, Eds. R Ramaty, N Mandzhavidze, X-M Hua, *AIP Conf. Proc. 374, p35*.

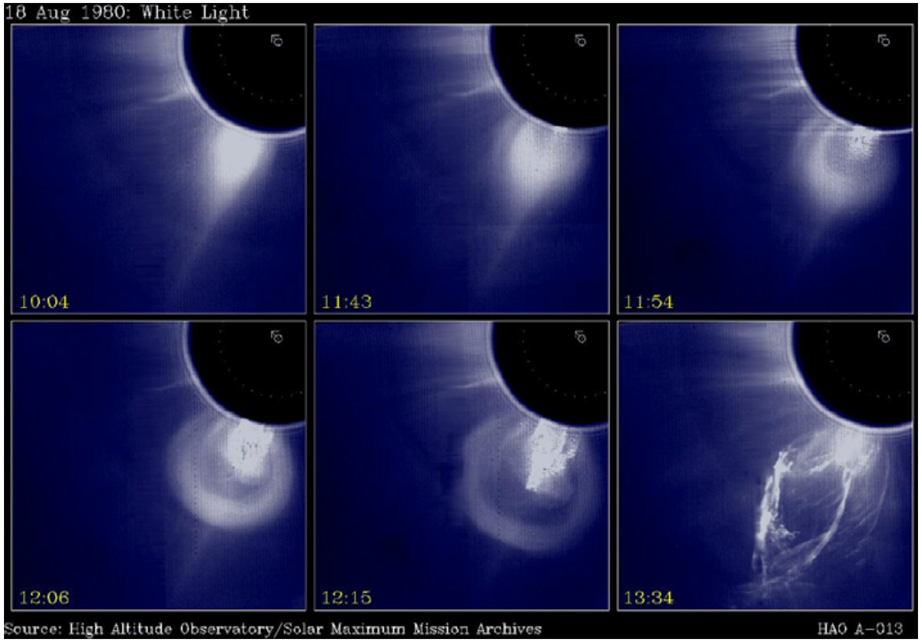
Gradual Events

Solar energetic particles (SEPs) in gradual events are accelerated at a shock driven by a coronal mass ejection (CME) moving through the corona into the interplanetary medium.



CME-driven shocks produce most of the large particle events at 1 AU and can accelerate protons up to 20 GeV.

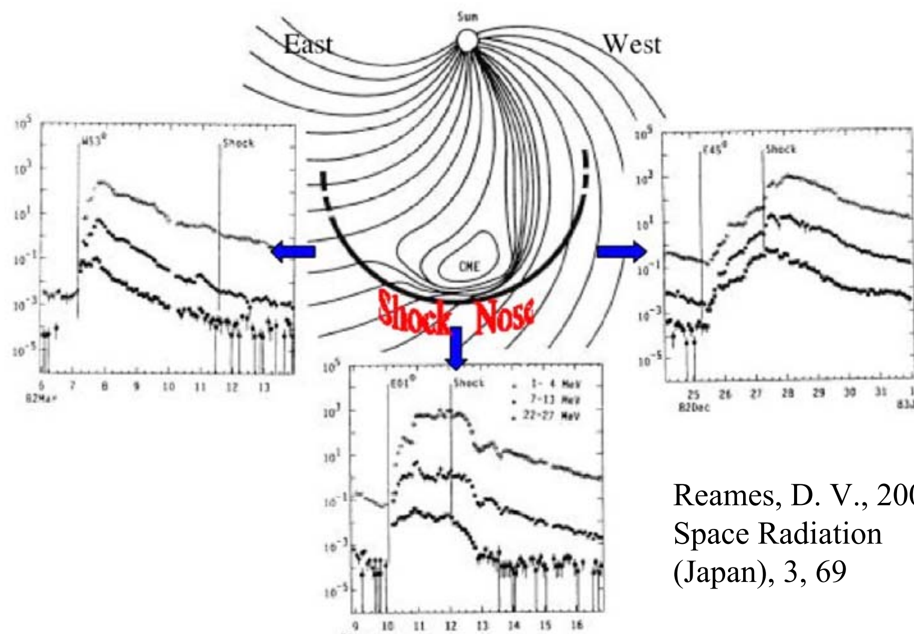
In large events the shock has been directly observed by spacecraft near 1 AU that are separated in longitude by 160°.



CME propagation

The high fluence active sun period is of 7 years, from 2 years before the solar maximum year to 4 years after.
The propagation time (between event and appearance of protons at the spacecraft) is a strong function of the longitude of the solar event.
The time of the onset corresponds to the time at which the shock intercepts the magnetic field lines to the spacecraft

The spiral interplanetary magnetic field generates an asymmetry in the intensity-time profiles of SEP. In particular, events originating in the western hemisphere of the Sun are more likely to produce SEPs able to reach the Earth with respect to those in the eastern hemisphere.
Protons can arrive from magnetically well-connected sites in tens of minutes.
For particles in the GeV range, the most effective longitude is close to 60°W.



Reames, D. V., 2002, Space Radiation (Japan), 3, 69

LISA spacecraft characteristics

- Distance from the Sun

  $0.9933 \div 1.0133$ AU

- Latitude off the ecliptic

  $0.7^{o} \div 1.0^{o}$

- Longitude difference with respect to Earth

  $19^{o} \div 21^{o}$

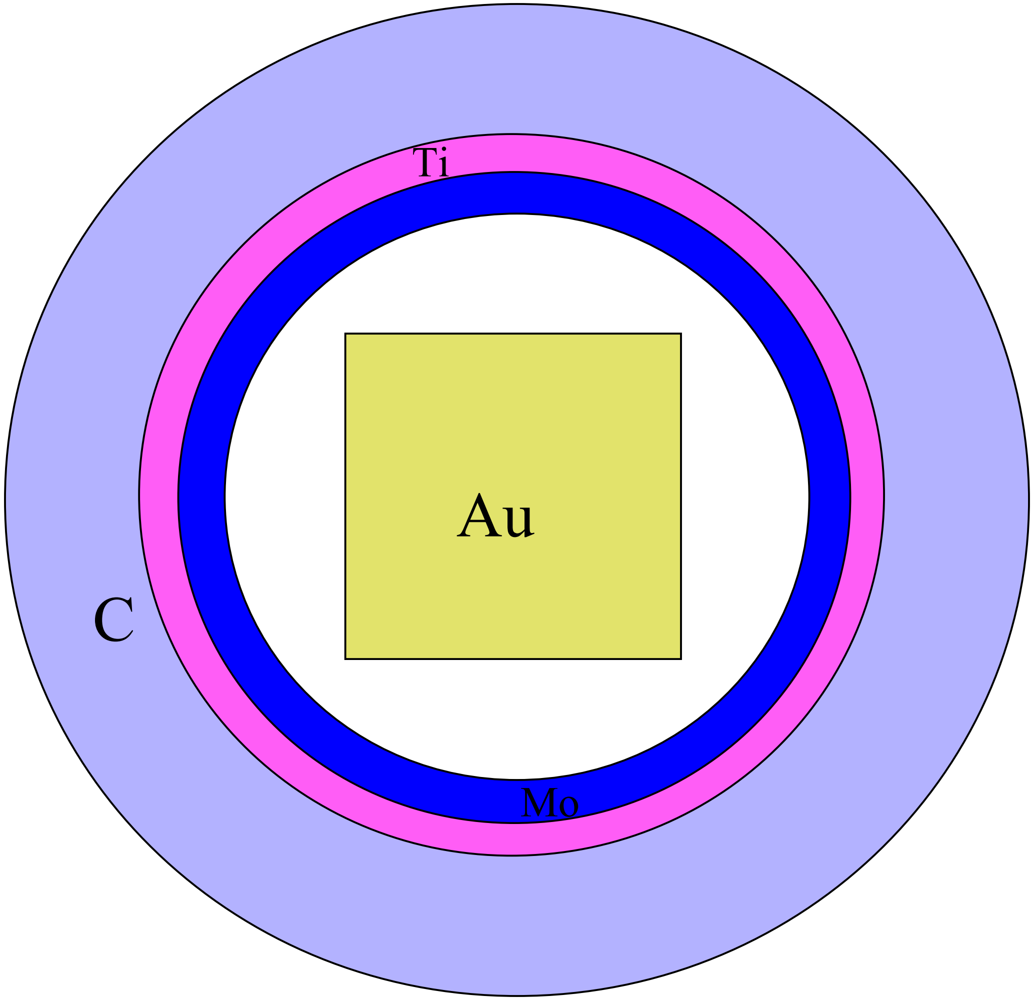
SEPs on LISA

- The *shock nose* of a typical gradual event takes about two days to reach Earth or LISA, half a day to cover the distance Earth-Lisa and about one hour to go through the three LISA detectors
- Gradual event can cause a series of signals of frequency below a few units 10^{-4} Hz

Fluka particle transport

	Secondary particles	Primary particles
Charged hadrons	*1 keV ÷ 20 TeV*	*100 keV ÷ 20 TeV*
Neutrons	*Thermal ÷ 20 TeV*	*Thermal ÷ 20 TeV*
Muons	*1 keV ÷ 1 PeV*	*100 keV ÷ 1 PeV*
Electrons (low-Z)	*1 keV ÷ 1 PeV*	*70 keV ÷ 1 PeV*
(high-Z)	*1 keV ÷ 1 PeV*	*150 keV ÷ 100 TeV*
Photons	*1 keV ÷ 1 PeV*	*7 keV ÷ 1 PeV*

Simulation scheme

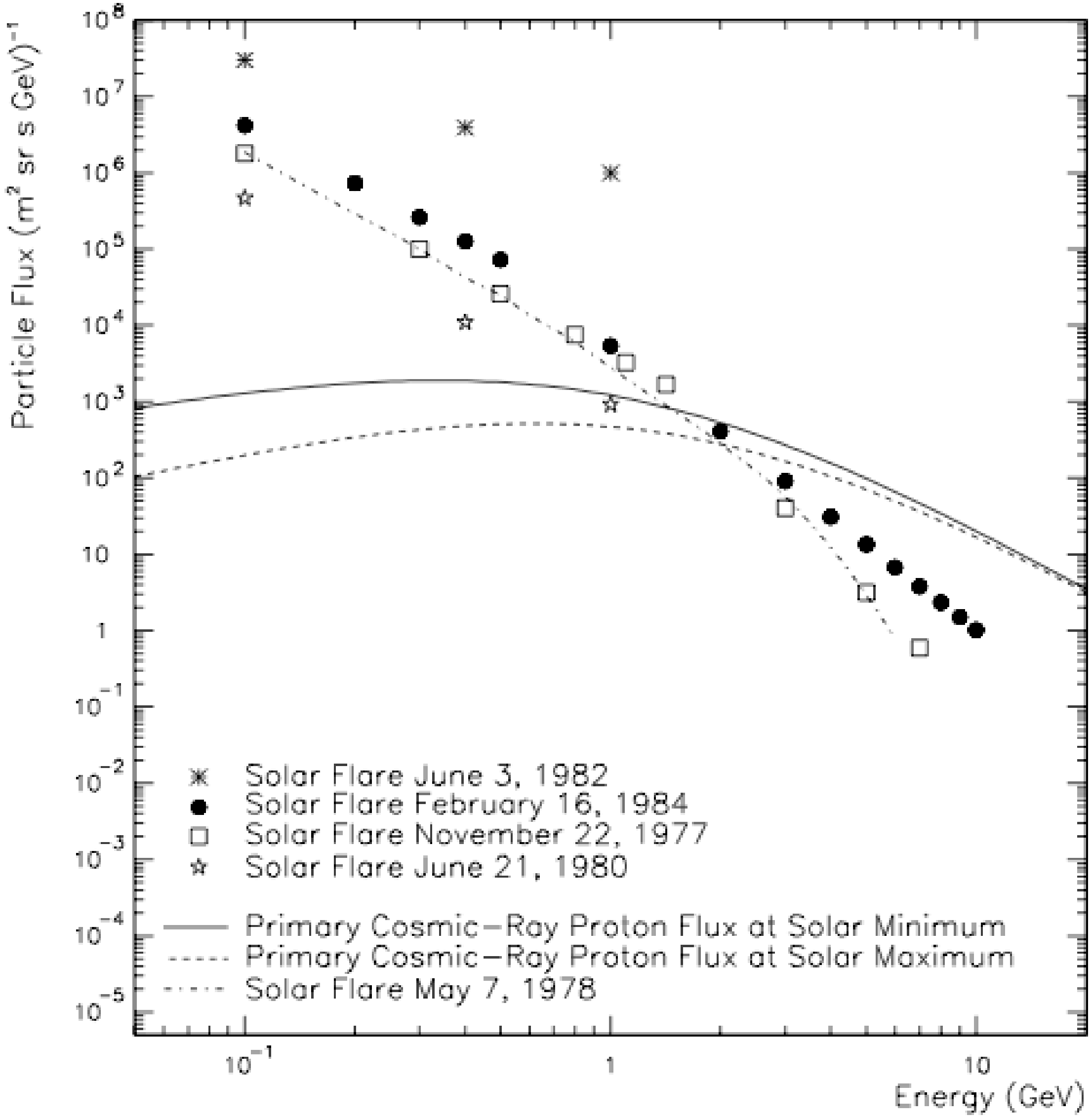


- Shape: cube
- Side: 4.6 cm
- Material: gold
- Thickness : 88.9 g/cm^2

Simulation materials

	Density *(g/cm^3)*	**Thickness** *(cm)*	**Grammage** *(g/cm^2)*
Carbon	*2.1*	*2.0*	*4.2*
Titanium	*4.54*	*0.5*	*2.3*
Molybdenum	*10.28*	*0.6*	*6.2*
Gold	*19.32*	*4.6*	*88.9*

Proton fluxes



Proton results:

Source	Charge rate (e^+/s)	Effective charge rate (e/s)
GCR at solar maximum	*15*	*110*
GCR at solar minimum	*42*	*150*
Gradual Event 1	*173*	*206*
Gradual Event 2	*2090*	*2120*
Gradual Event 3	*3460*	*3480*
Gradual Event 4	*4385*	*4395*
Gradual Event 5	*4570*	*4575*
Solar Flare peak flux	*10700*	*10720*

LISA acceleration noise spectral density

$$S^{1/2}(\omega) = 0.8 \times 10^{-15} \frac{m}{s^2\sqrt{Hz}} \left(\frac{4mm}{gap}\right)\left(\frac{V_{dc}}{10mV}\right)\left(\frac{\lambda_{eff}}{300s^{-1}}\right)^{1/2}\left(\frac{0.1mHz}{f}\right)$$ *

Required acceleration noise limit
for random charge:

$9.4 \cdot 10^{-16}$ ($m\ s^{-2}\ Hz^{-1/2}$)
[total: $3 \cdot 10^{-15}$]

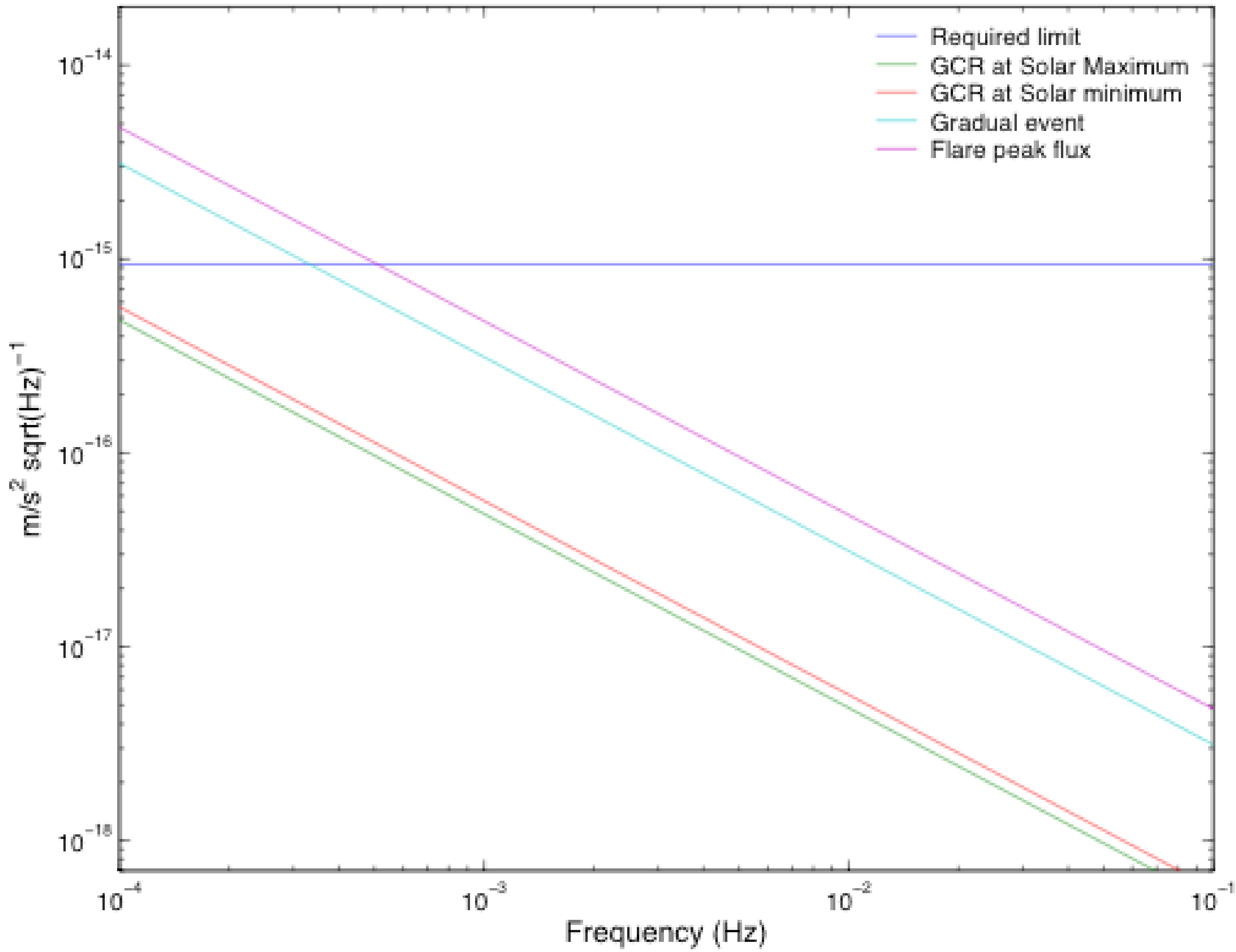
($10^{-4} \div 10^{-1}$ Hz)

* See Rita Dolesi's talk

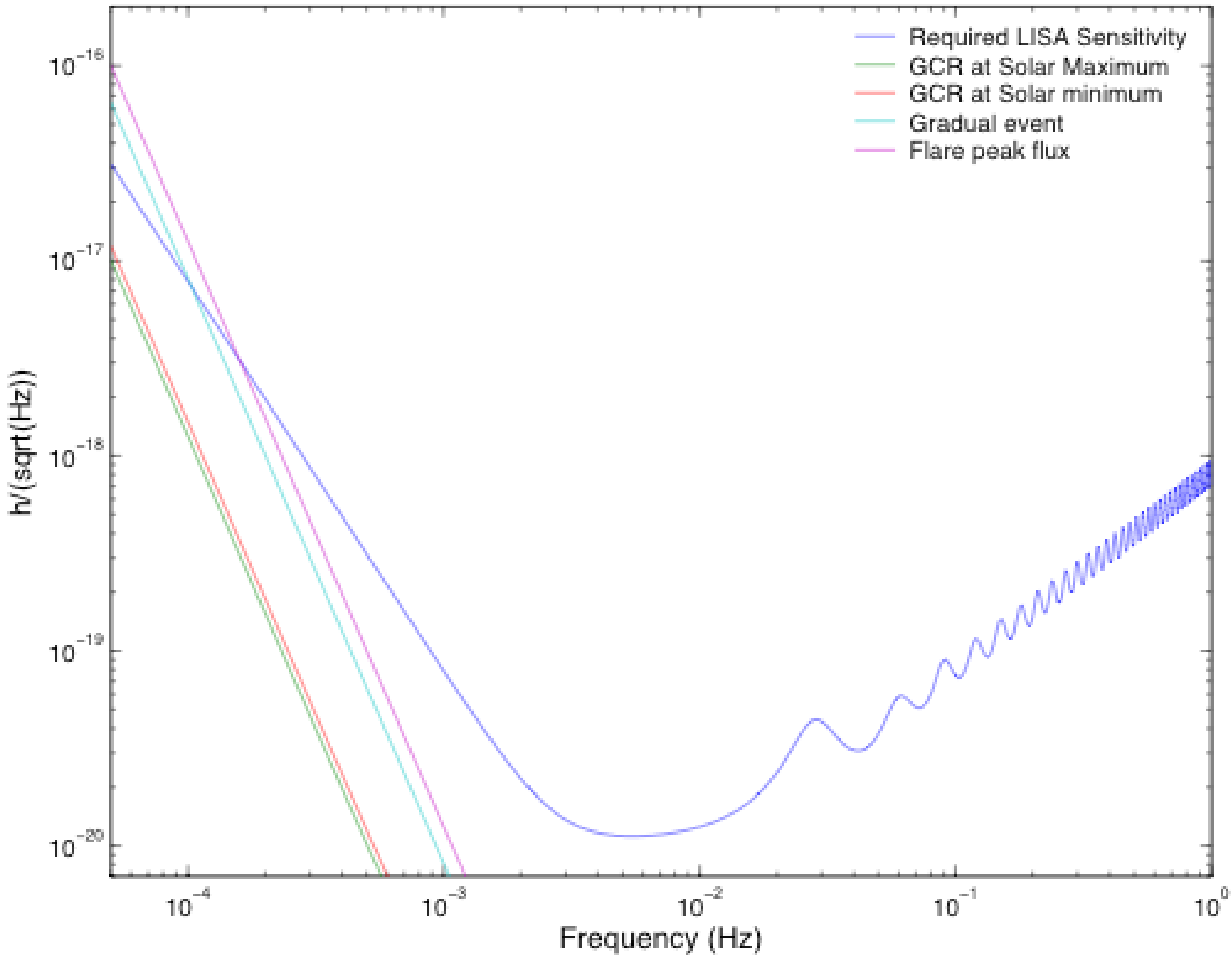
LISA acceleration noise spectral density

Source	Effective charge rate *(e/s)*	Acceleration noise spectral density @ 0.1mHz *($m\ s^{-2}\ Hz^{-1/2}$)*
GCR at solar maximum	*110*	$0.48 \cdot 10^{-15}$
GCR at solar minimum	*150*	$0.57 \cdot 10^{-15}$
Gradual Event 1	*206*	$0.66 \cdot 10^{-15}$
Gradual Event 2	*2120*	$2.1 \cdot 10^{-15}$
Gradual Event 3	*3480*	$2.7 \cdot 10^{-15}$
Gradual Event 4	*4395*	$3.1 \cdot 10^{-15}$
Gradual Event 5	*4575*	$3.1 \cdot 10^{-15}$
Solar Flare peak flux	*10720*	$4.8 \cdot 10^{-15}$

Acceleration noise spectral density

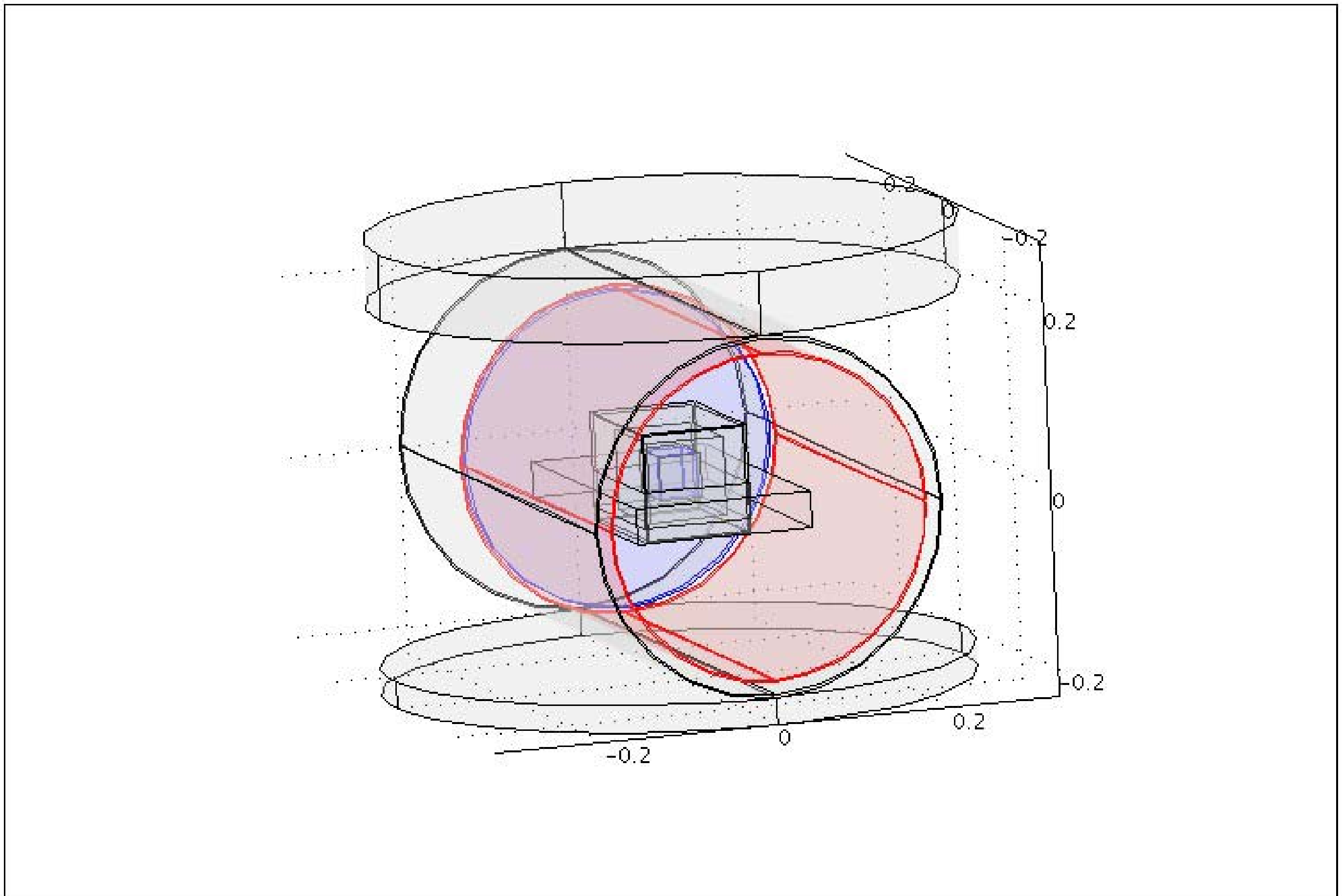


LISA sensitivity



Next step

- The new geometry has been inserted
- No data available until now



Conclusions

- The LISA test mass charging process is studied with the Fluka Monte Carlo program;
- Preliminary geometry results are available at the present moment for protons and solar flares;
- The charge rate due to GCR and solar protons have been determined;
- Simulations of a much complex geometry are in progress.