Imperial College London

Test Mass Charging on LISA Pathfinder

(and particle spectrum variations)

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Talk outline

- LISA Pathfinder test mass charging simulation geometry and results
- Charging effects of gravitational compensation masses
- Galactic cosmic ray fluctuations
- Particle monitor for LISA Pathfinder

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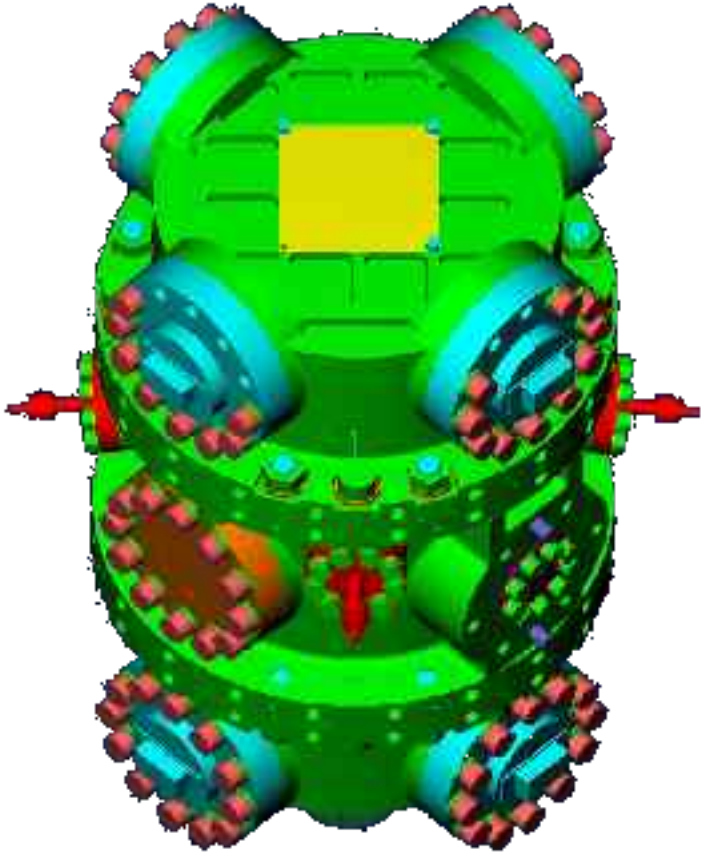
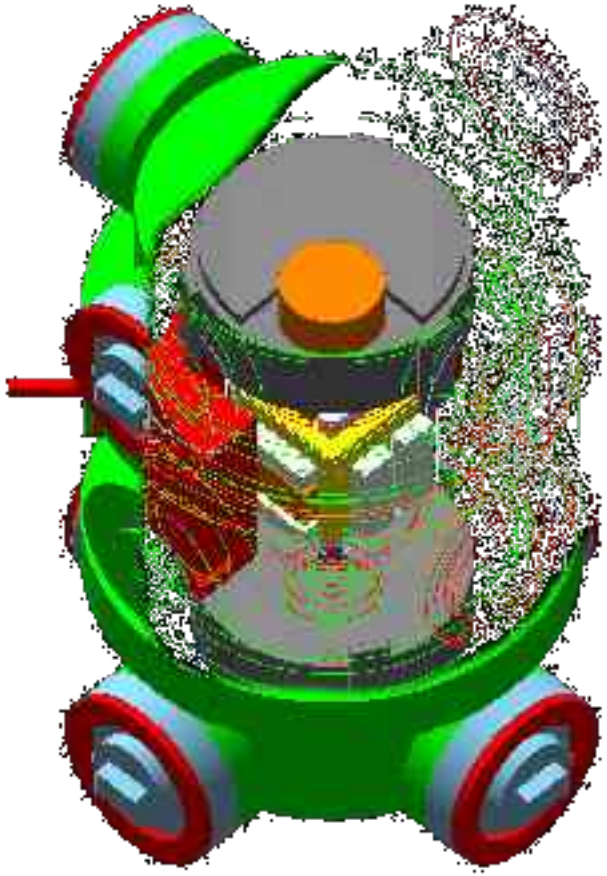
LISA Pathfinder charging simulations

- Simulations in Geant4 identical to LISA
  - Physics models
  - Radiation environment
  - Solar minimum and maximum conditions
- Geometry
  - ~400 implemented volumes
  - ~80% of total s/c mass

Inertial Sensor

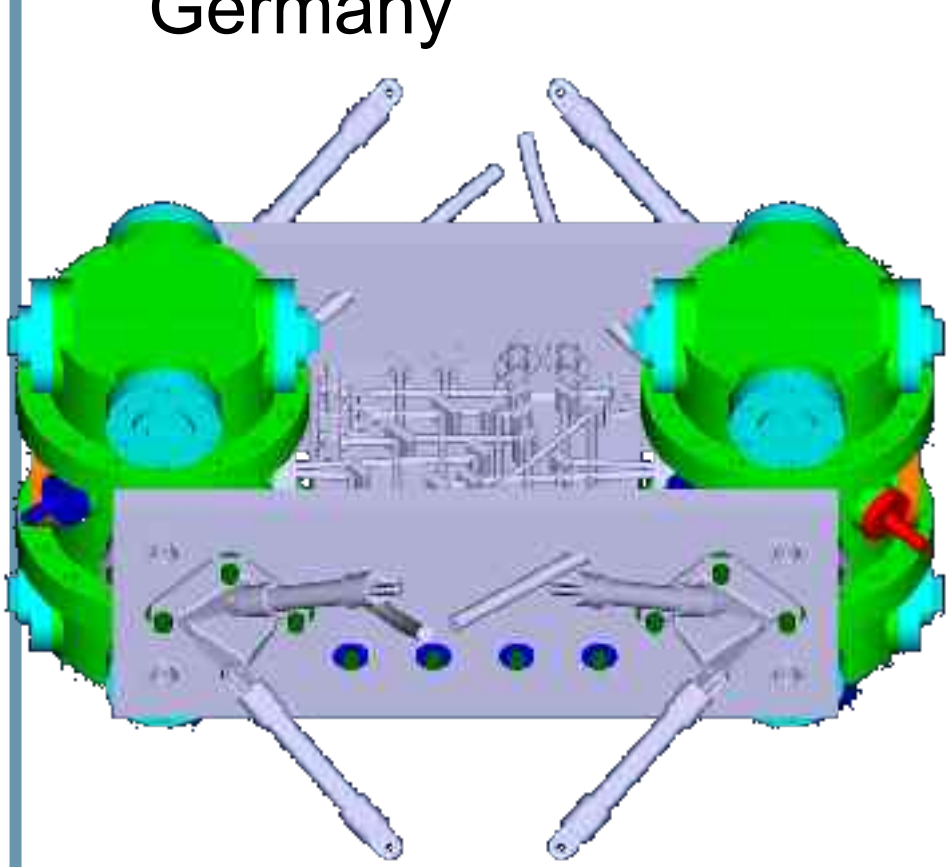
- Based on model from CGS

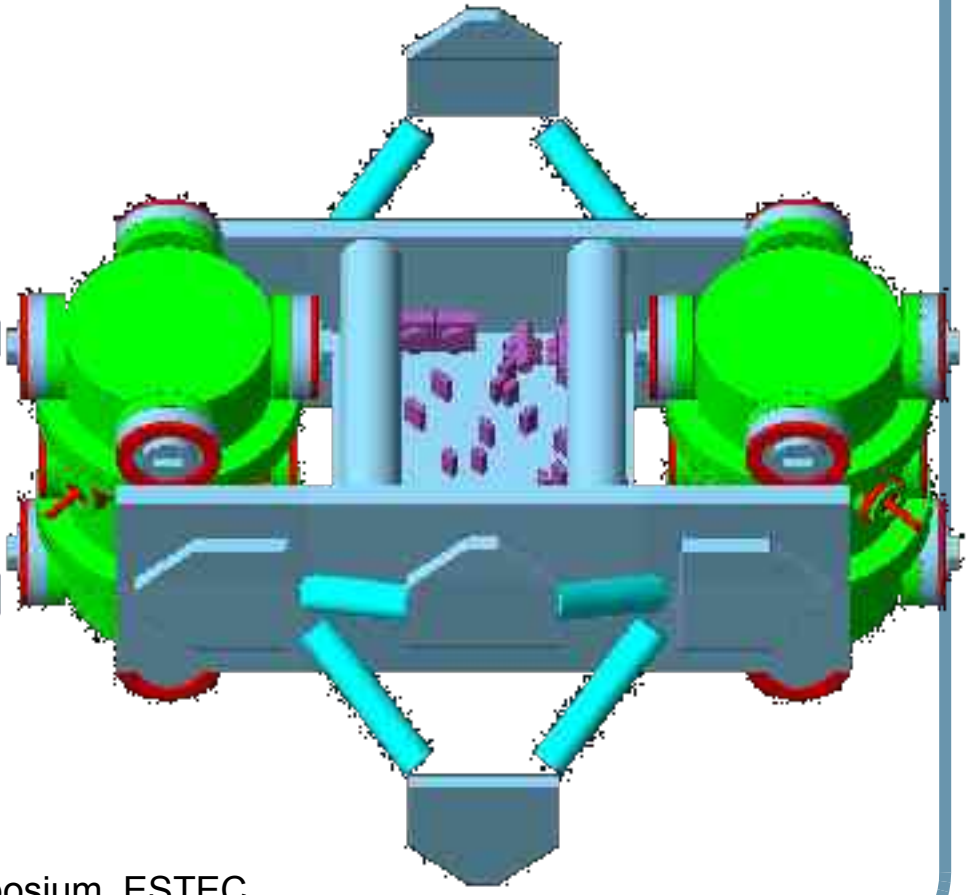




LTP

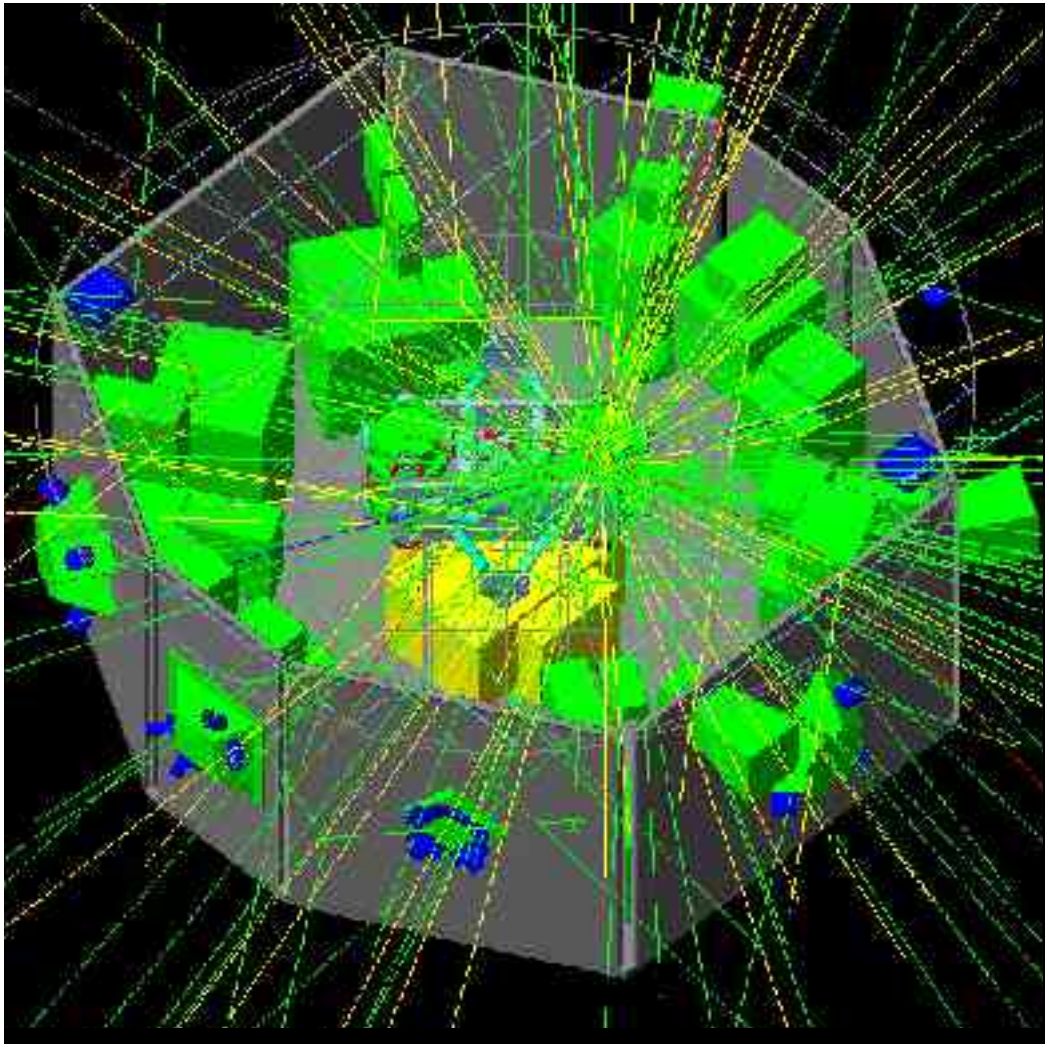
- Based on CAD model from EADS Astrium, Germany





Spacecraft

- Model from EADS Astrium UK
- Components outside LTP inc DRS modelled as black box of correct mass and size



Charging results

primary particle	solar activity	GCR flux Φ, /s/cm²	GCR flux Φ, %	timeline N_0 ($x10^6$)	timeline CPU, days	timeline T, s	timeline N_0/N_Q
protons		4.29	92.0	142.6	143	235	2096
He-4	min	0.315	6.8	22.0	22	491	958
He-3		0.0591	1.3	33.1	33	3958	1010
Total		**4.66**	**100**	**197.6**	**198**	**–**	**398**
protons		1.89	91.9	59.4	59	222	1758
He-4	max	0.142	6.9	8.8	9	440	798
He-3		0.0236	1.1	31.8	32	9524	874
Total		**2.06**	**100**	**99.9**	**100**	**–**	**337**

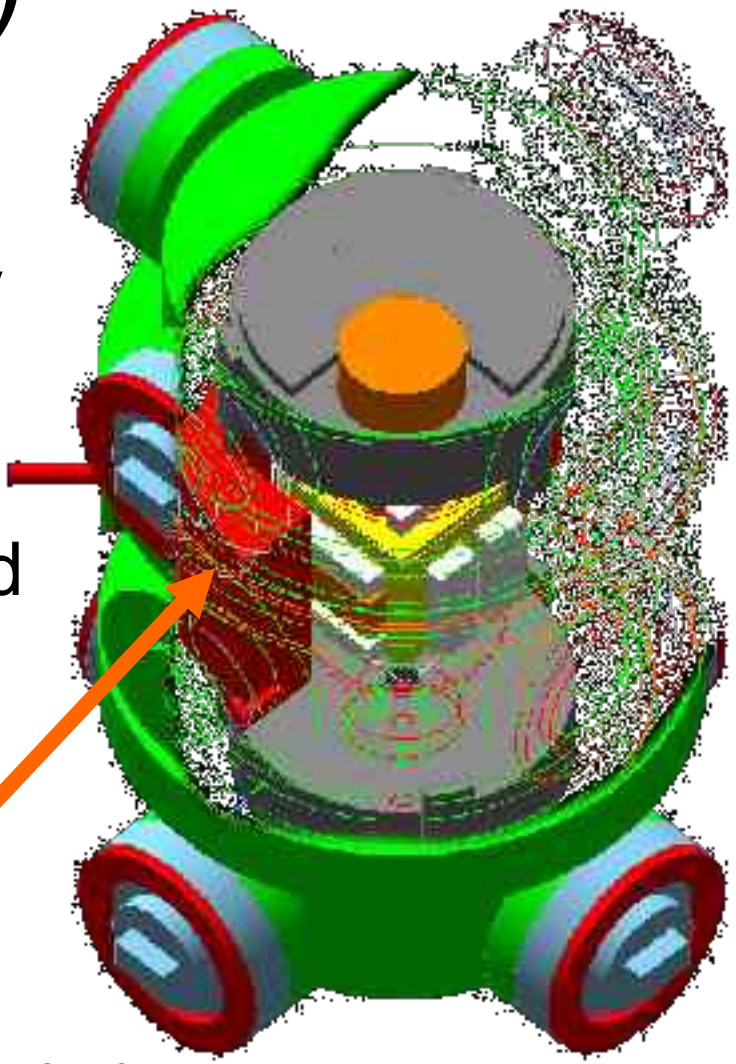
- Simulations run at CERN LSF cluster
- ~1 CPU Year
- 2×200s timelines

- Solar minimum 88+e/s 35e/s/√Hz
- Solar maximum 43+e/s 28e/s/√Hz
- Subject to low energy effects

primary particle	solar activity	TM 0 R, e/s	TM 0 σ_M, e/s	TM 0 S_R,e/s/√Hz	TM 1 R, e/s	TM 1 σ_M, e/s	TM 1 S_R,e/s/√Hz
protons		71.7	1.4	31.3	68.9	1.4	30.3
He-4	min	14.2	0.5	15.5	13.7	0.5	15.2
He-3		2.22	0.06	5.6	2.06	0.06	5.5
Total		**88.1**	**1.5**	**35.4**	**84.7**	**1.5**	**34.3**
protons		33.5	1.1	24.1	34.8	1.2	25.1
He-4	max	7.1	0.4	12.7	7.2	0.4	12.1
He-3		0.85	0.03	4.2	0.85	0.03	4.1
Total		**41.4**	**1.2**	**27.6**	**42.9**	**1.3**	**8.2**

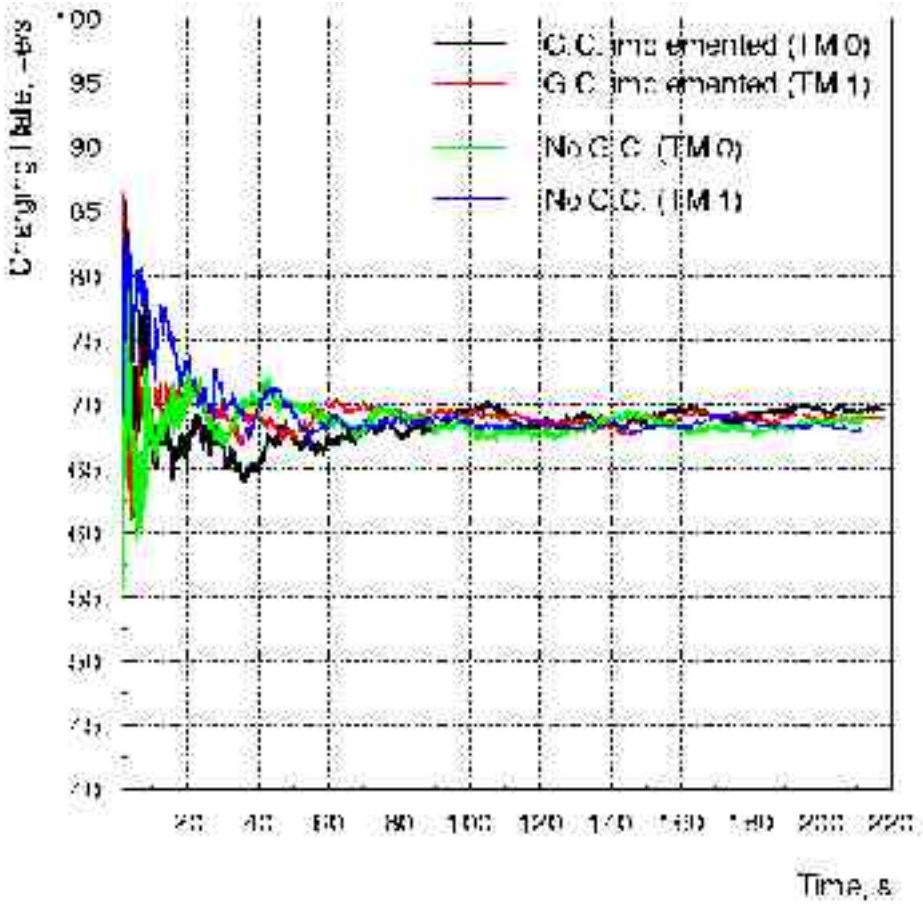
Gravitational compensation (GC)

- Gravitational compensation necessitates positioning of large amounts of mass very close to the TM, (within the vacuum enclosure)
- Potential to cause increased charging through hadronic showers.
- Mass definition from M. Armano, Trento



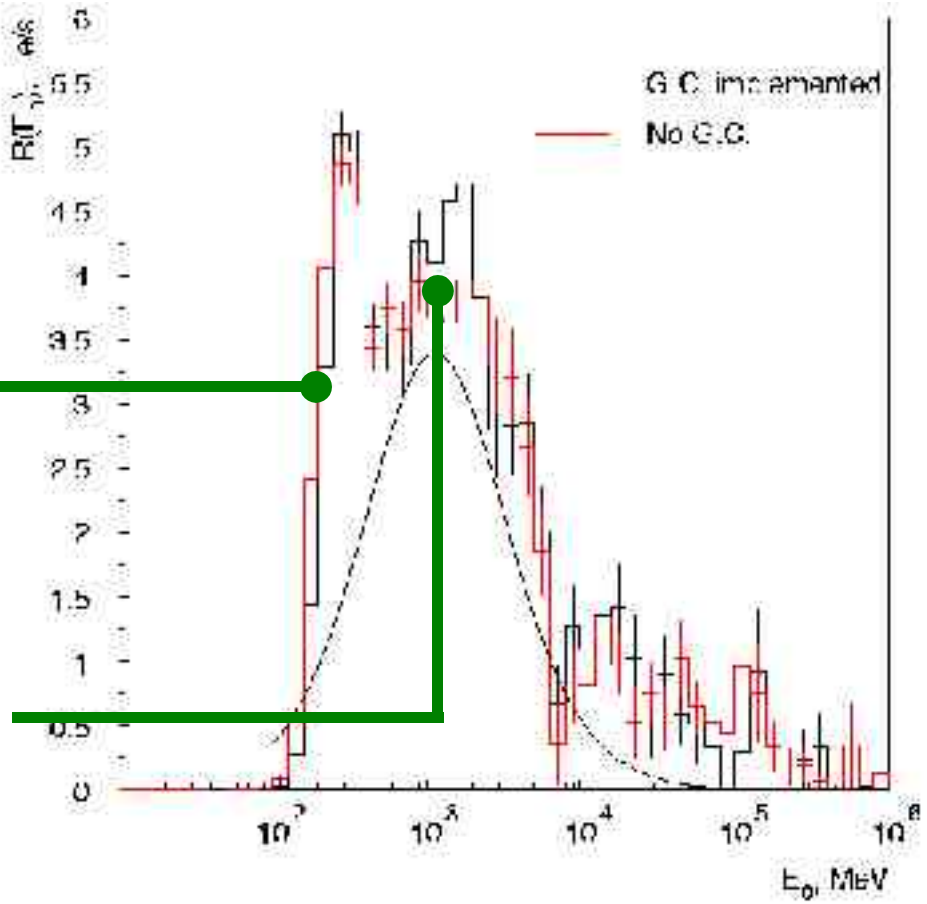
Simulations

- GCR protons solar minimum with and without GC masses
- Charging rates remain the same within errors ~70+e/s



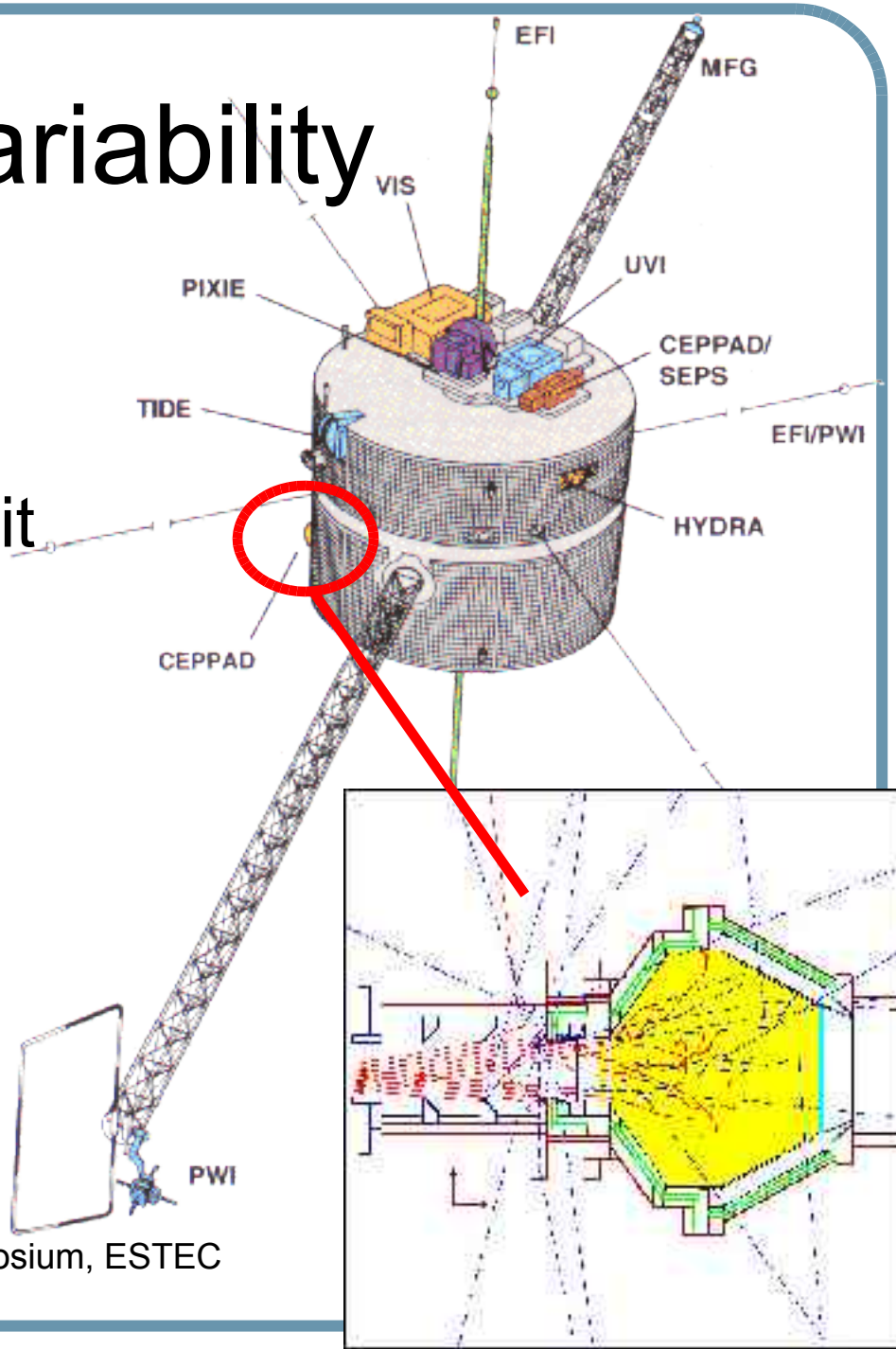
Simulations

- Charging spectra do differ
  - Fewer low energy protons ~100MeV reach the TM – stopped in the GC masses
  - Increased charging from ~1GeV primaries caused by hadronic showering in the GC



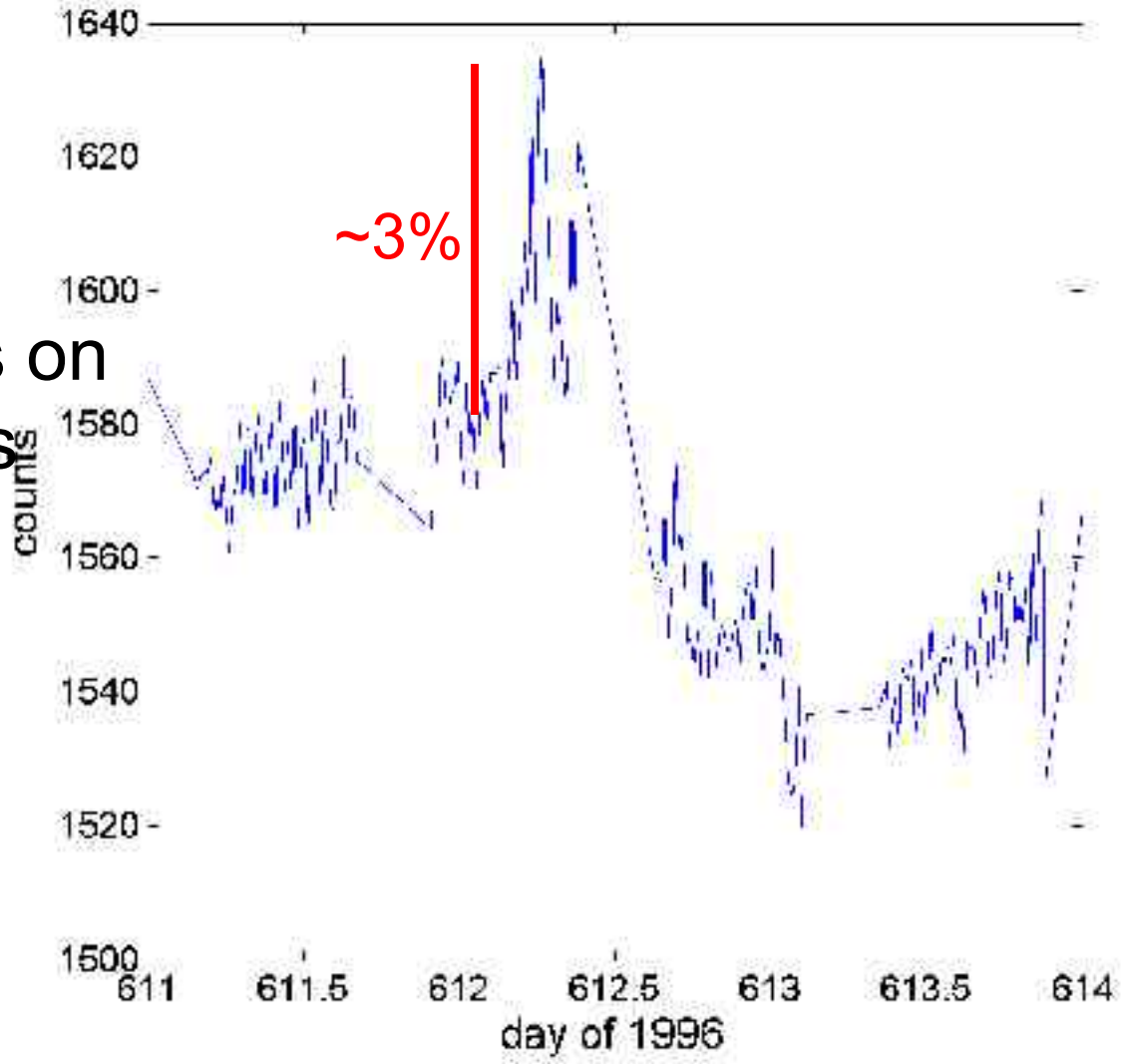
GCR Variability

- Data from POLAR spacecraft
- Highly elliptical earth orbit
- HIST instrument sensitive to high energy cosmic rays
  - Large scintillator
  - High count rates
  - Good time resolution
  - No spectral information



Data

- Count rate tracks solar variation
- Smaller variations on shorter timescales
- Even some variation <1 day
- Need to be sure this is not solar activity



Future work

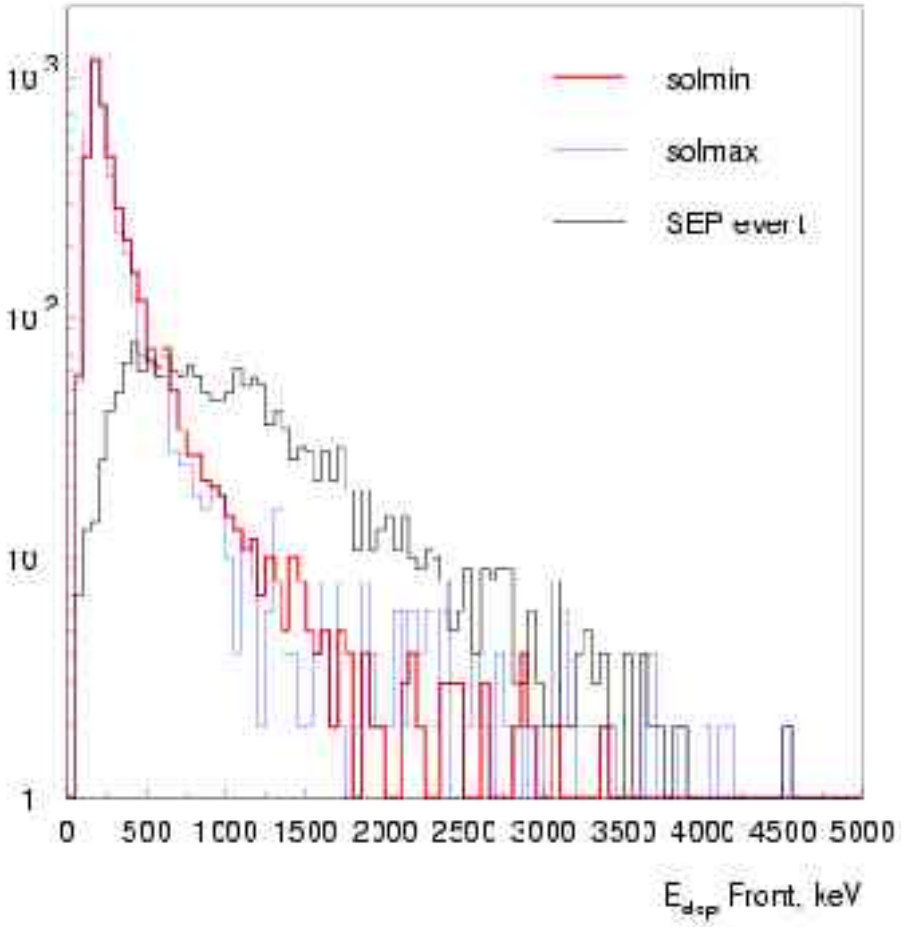
- Analyse and check higher resolution data
- Quantify noise and/or signals in the LISA bandwidth due to charging fluctuations
- Look for correlations with interplanetary magnetic field

Particle monitor

- Short term fluctuations of GCR flux and SEP events may cause disturbances that could mimic a GW signal in the LISA bandwidth
- Led us to recommend strongly that a particle monitor be on board LISA Pathfinder
- Remove spurious signals caused by flux variability
- Geant4 simulations have led us to identify several requirements as input for IEEC Barcelona collaboration design

Particle monitor

- Recommendations for:
  - Detector layout
  - Count rates
  - Energy sensitivity
  - Spectral sensitivity
- Work in progress



Summary

- Test mass charging rate for LISA Pathfinder is 88+e/s at solar minimum with shot noise 35e/s/√Hz (43+e/s & 28e/s/√Hz at solar maximum)
- Gravitational compensation masses as currently defined do not adversely affect the charging rate
- Galactic cosmic rays show low frequency variations which could lead to disturbances in the LISA bandwidth
- A particle monitor is under development to help mitigate the risks posed to science data by GCR variability and SEP events