Radiations on Gaia

Native and irradiated Charge Transfer Inefficiency characterization

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All the space you need

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Radiations on Gaia

- The impact on science data
- The radiation test bench
- Test results
- Modelling & calibration
- Conclusion

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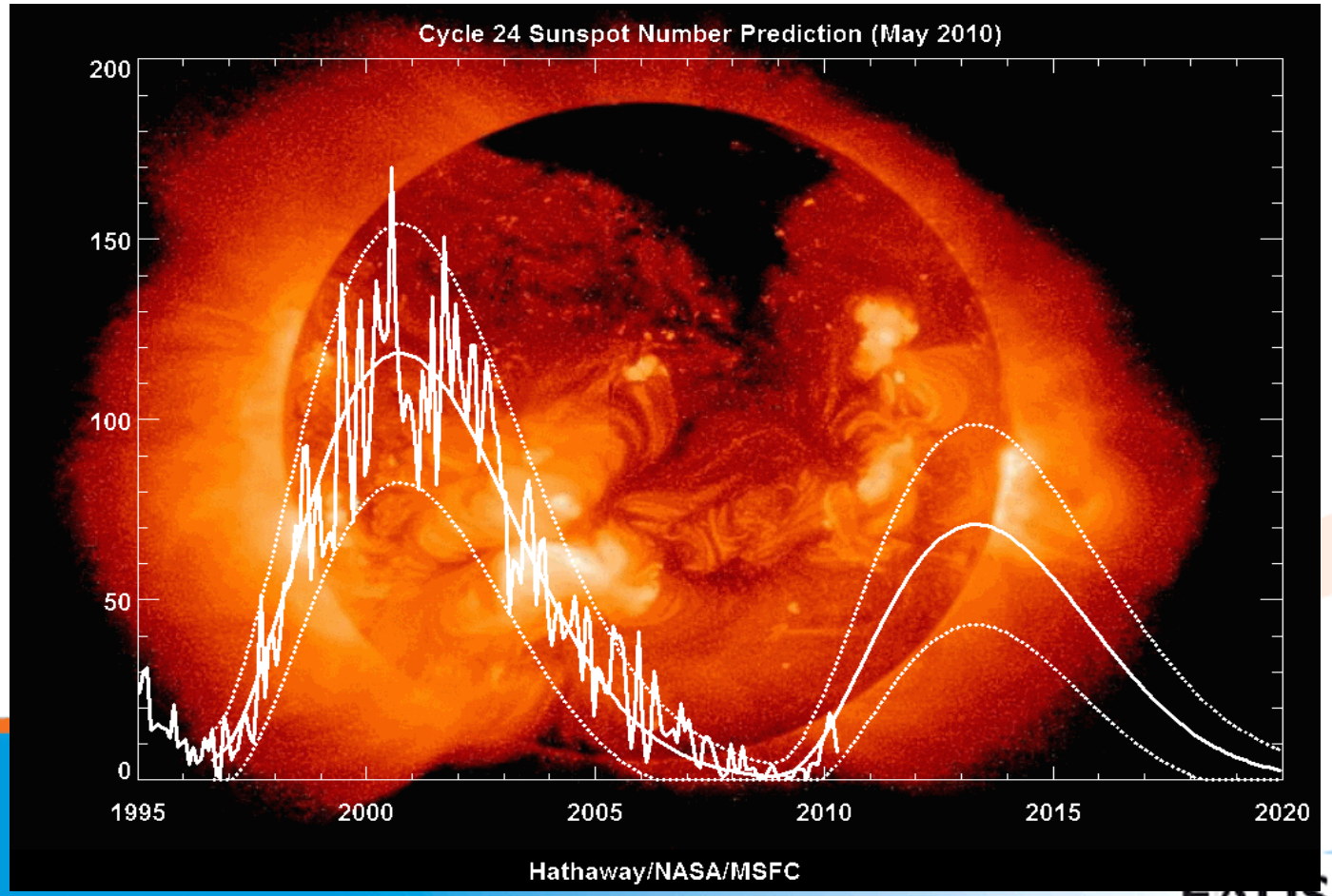
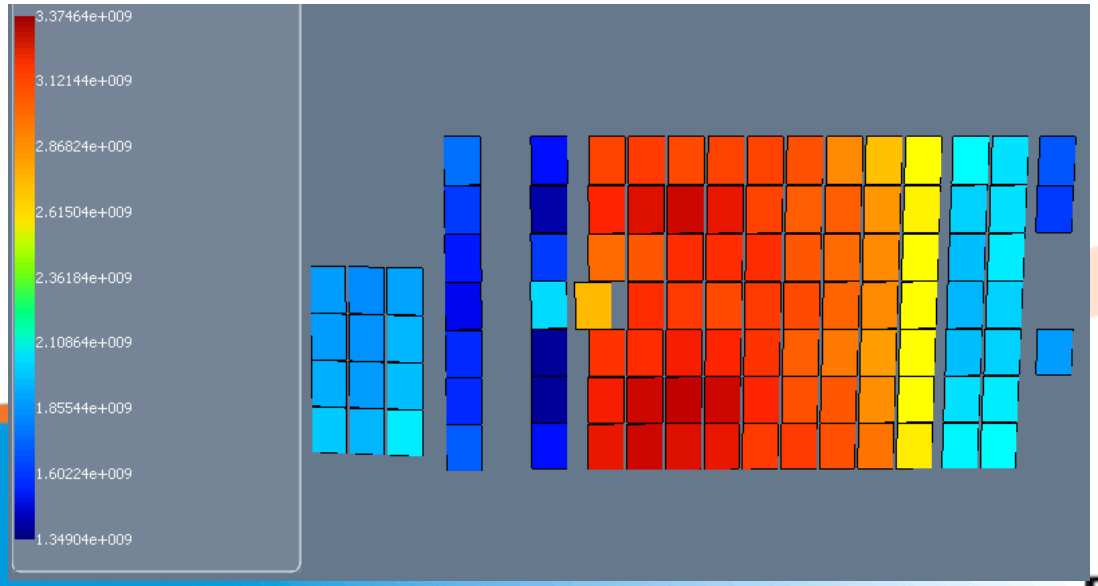
The impact on science data

- The environment



The impact on science data

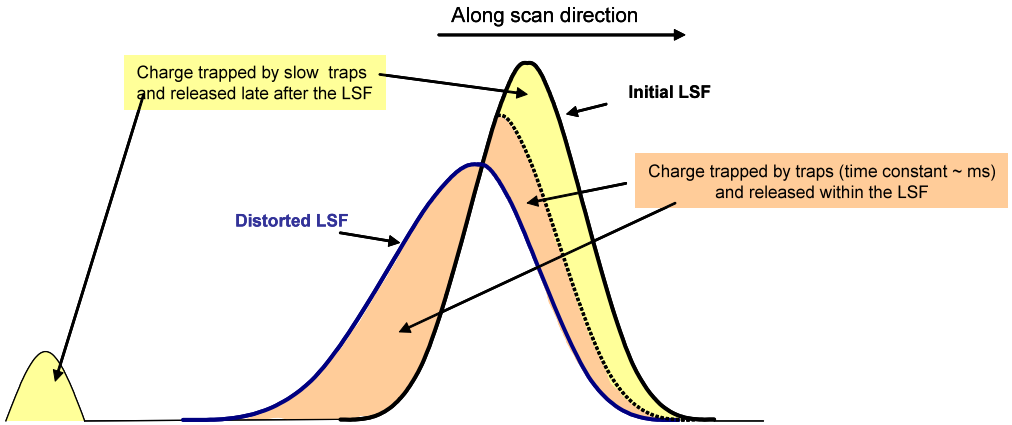
- The environment
  - The solar activity is minimal today, but…
  - Current estimations predict that the new cycle will have its maximum during the Gaia mission
  - The associated particles flux (mainly solar protons) will damage the CCDs and corrupt the science data



Simulated particle flux in part/cm² at end of mission

The impact on science data

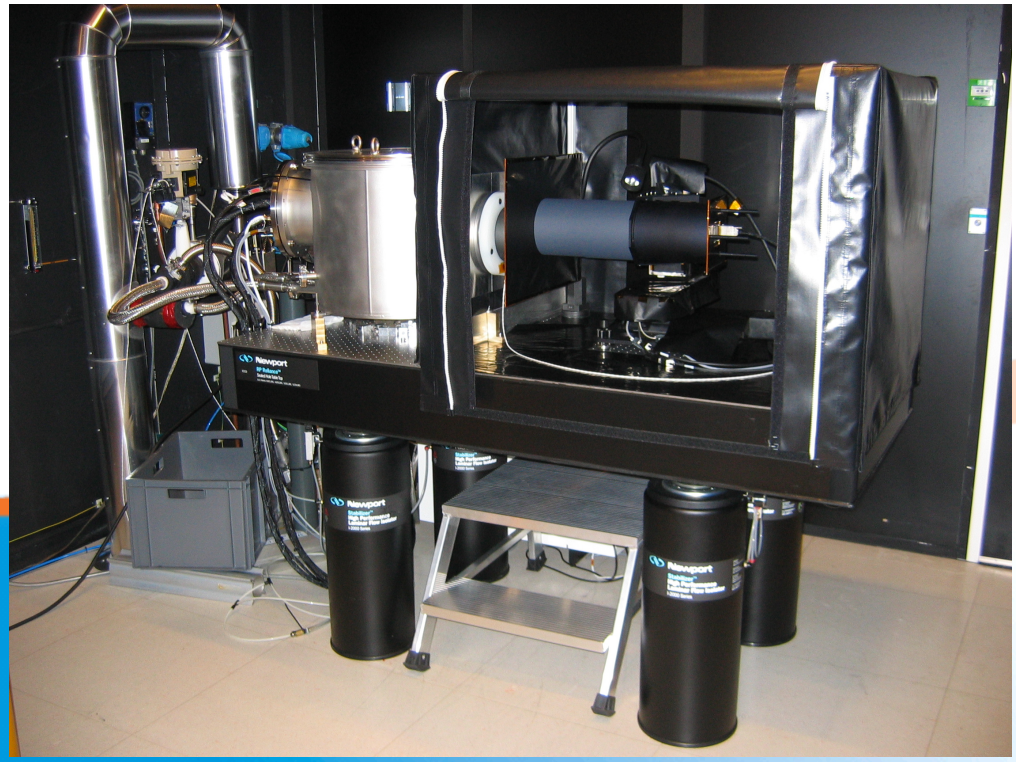
- The raw data gets corrupted
  - Degradation of the signal to noise ratio
  - Distortion of the signal during the TDI transfer



- Impacts needing quantitative characterization
  - Centroiding & magnitude bias in astrometry
  - Radial velocity bias in RVS
  - Spectral mixing in photometry and RVS

The radiation test bench

- Internal tests from 2004
- New test bench developed from 2008 under ESA funding
- Objective: to characterize the radiations effects on representative Gaia CCDs



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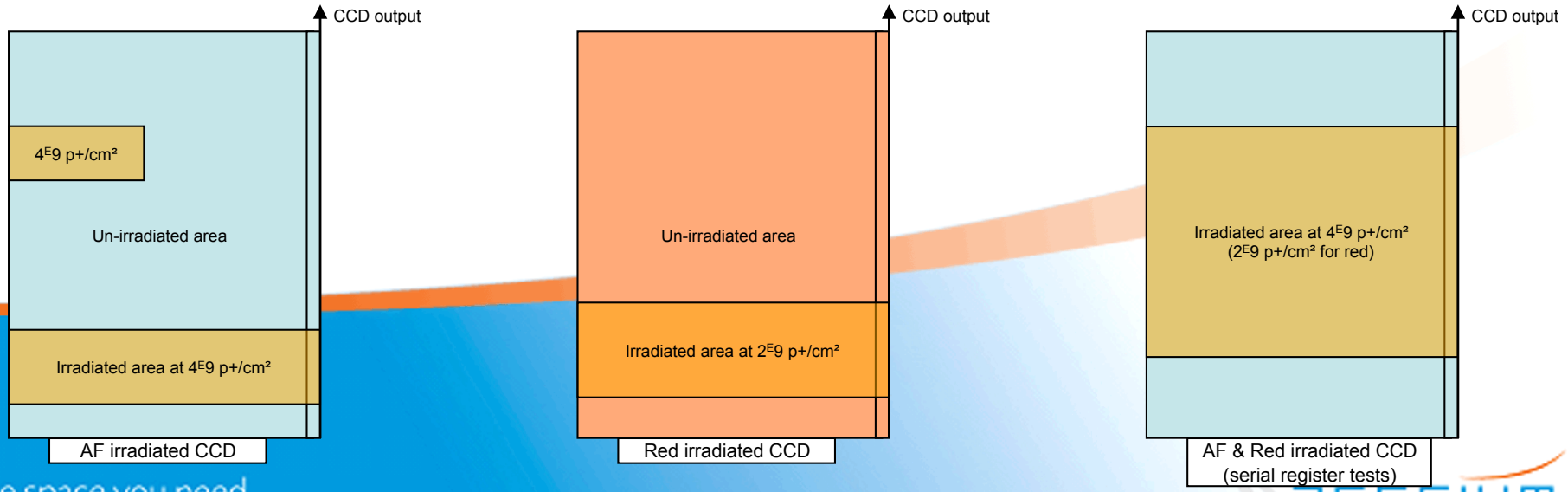
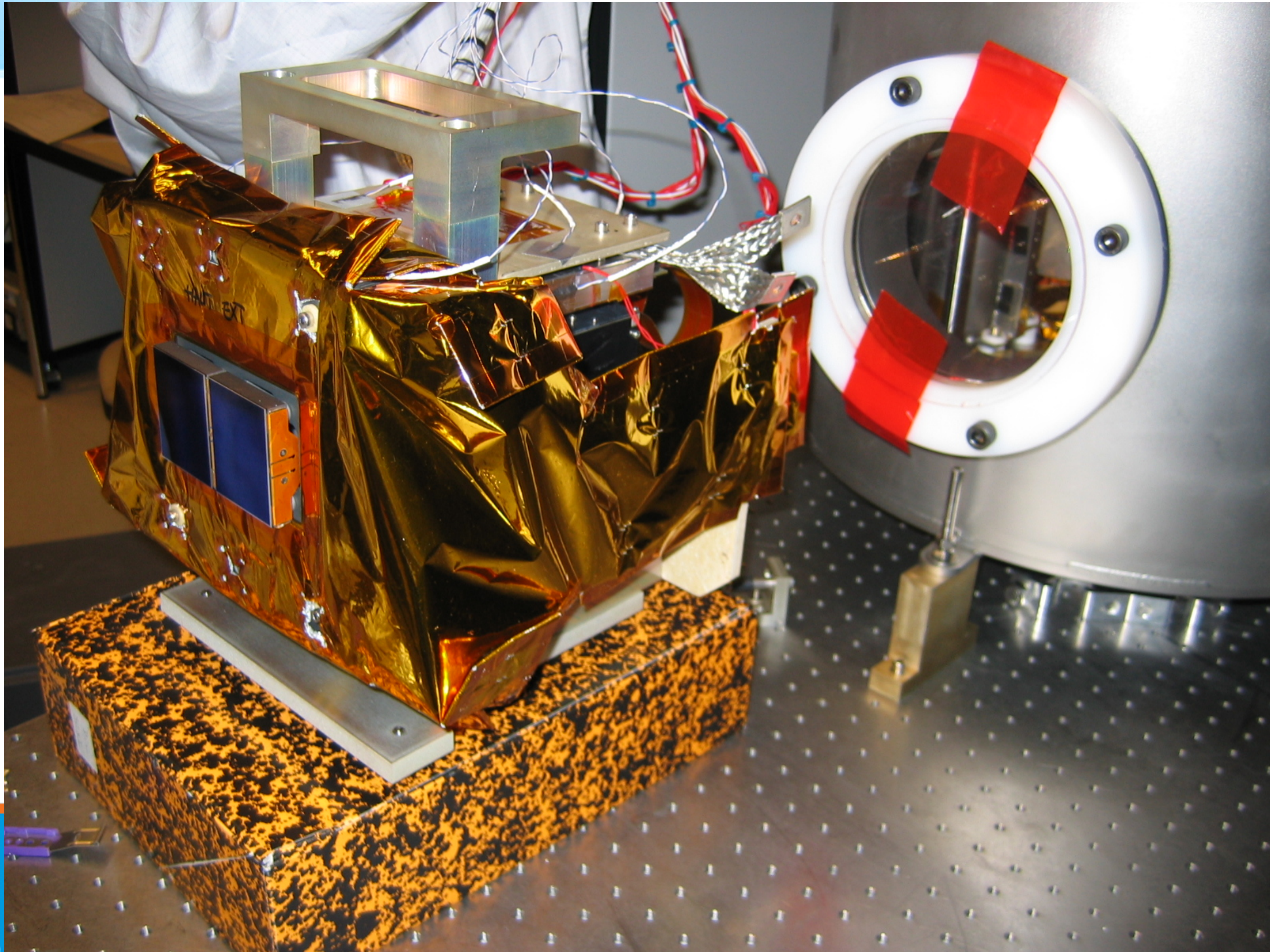
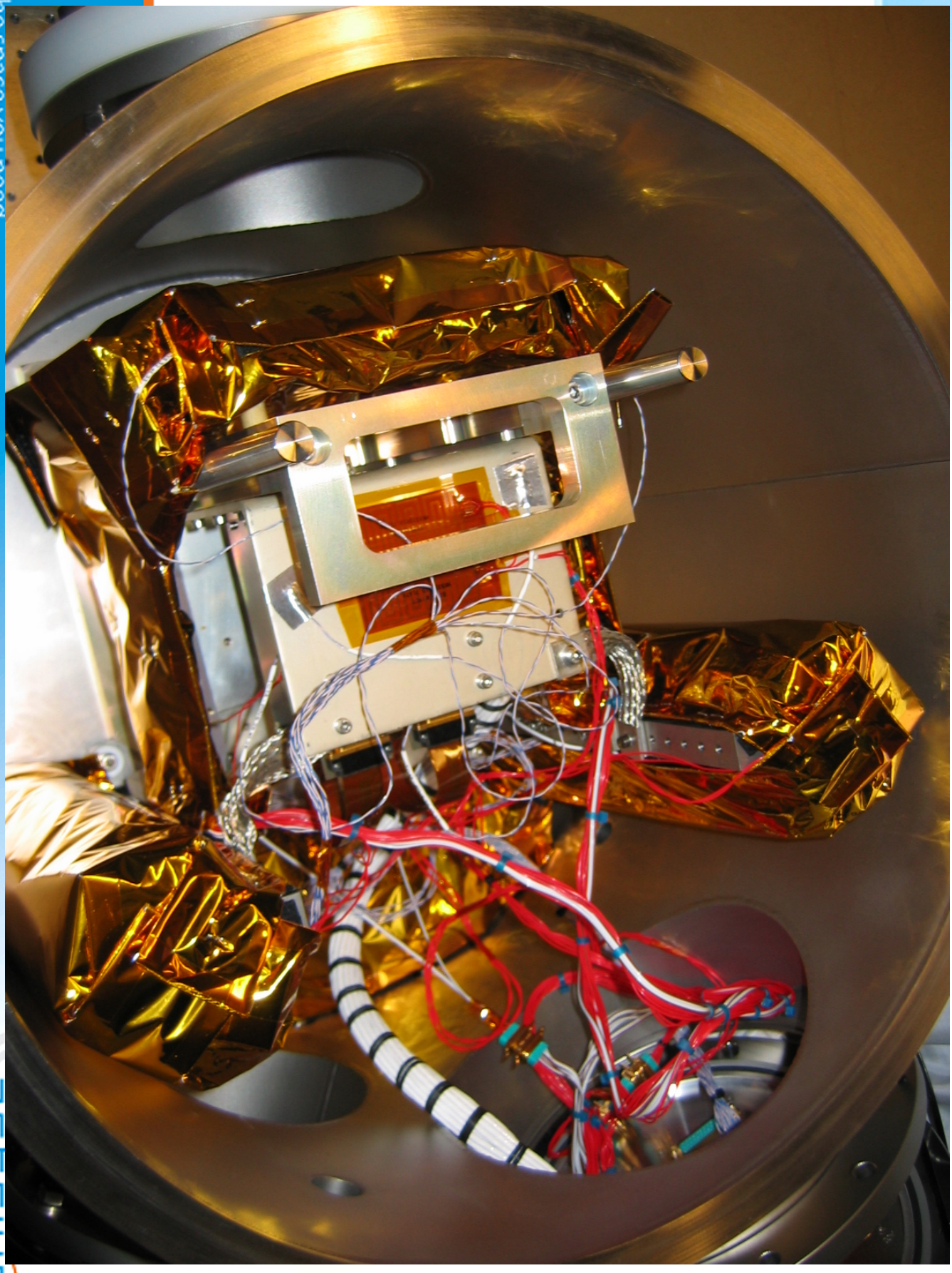
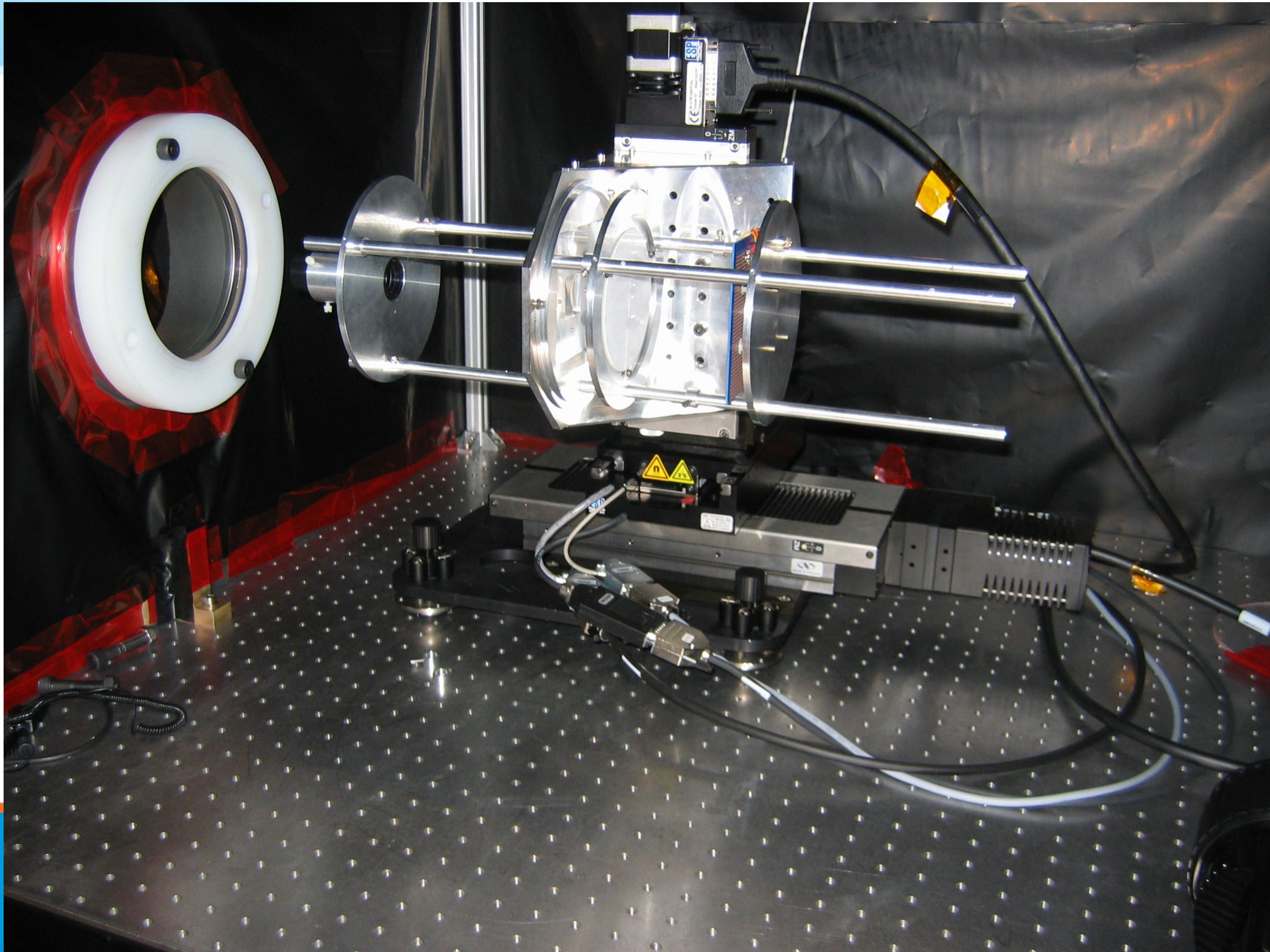
The radiation test bench

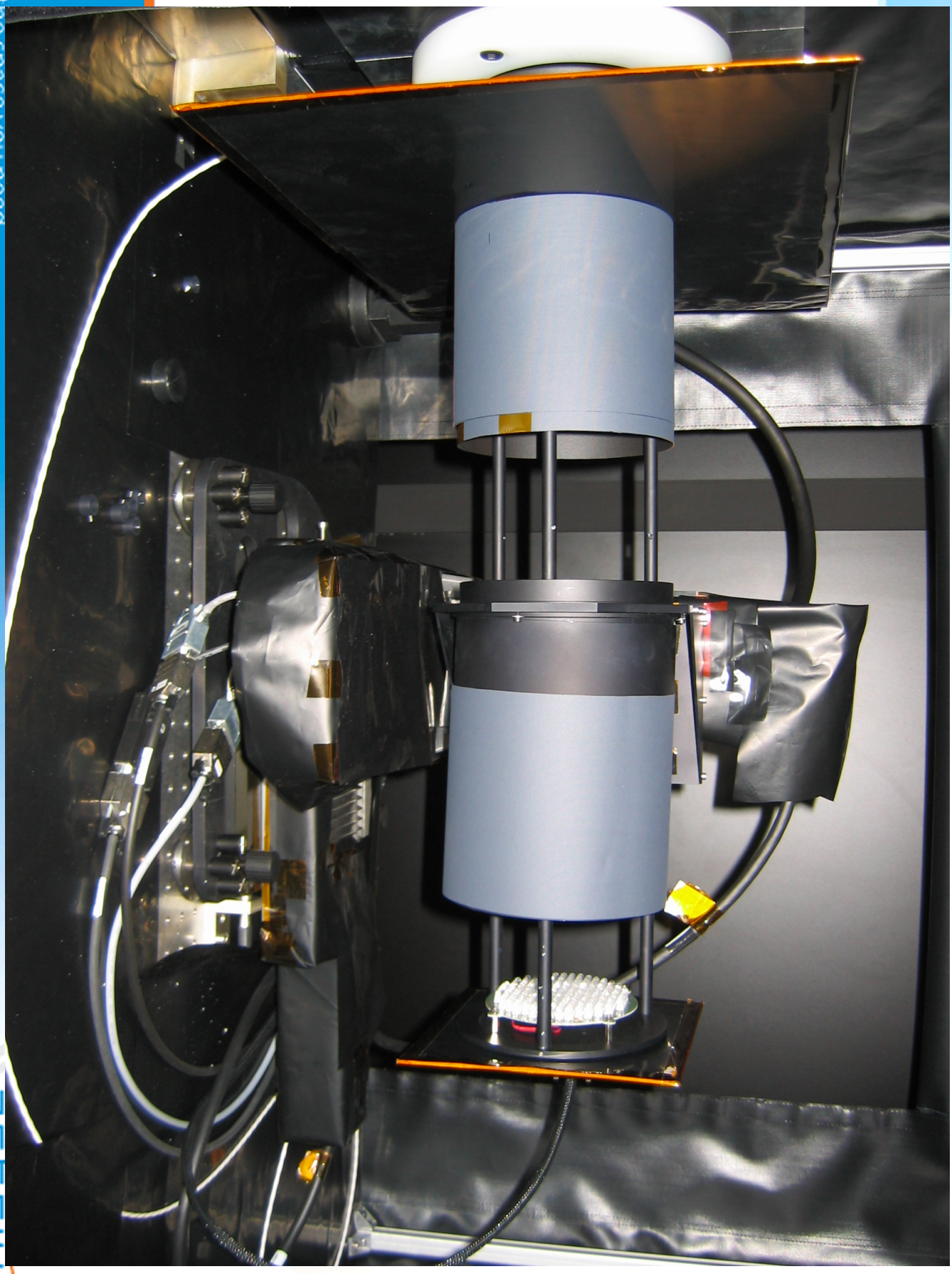
- Main components
  - LN_2 cooling tank and irradiated CCDs
  - Driving electronics (Crisa PEM)
  - Optical masks
  - Optical source (mask & diffuse optical background)
  - Translation baseplate and mechanisms (for TDI motion + all axis)

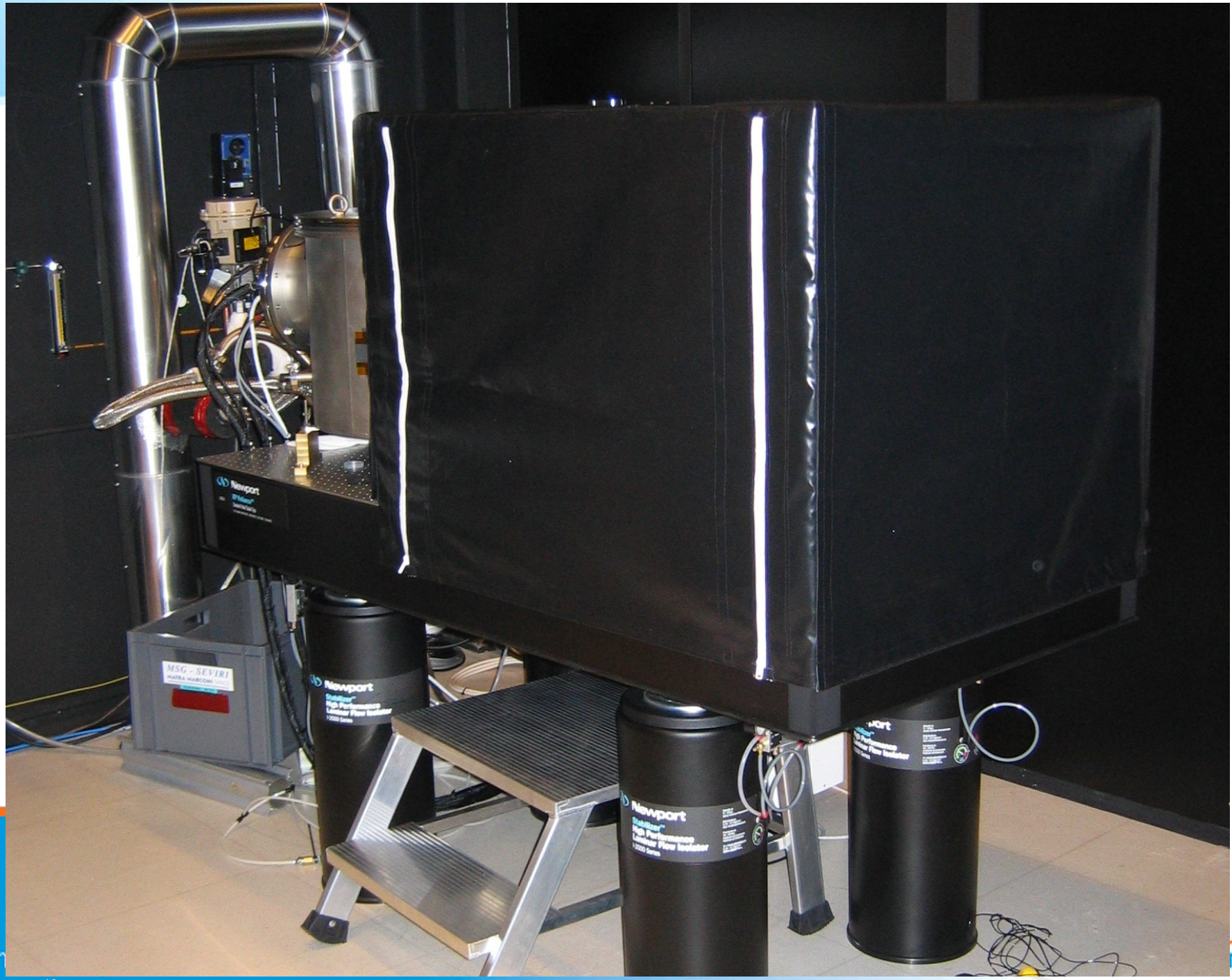






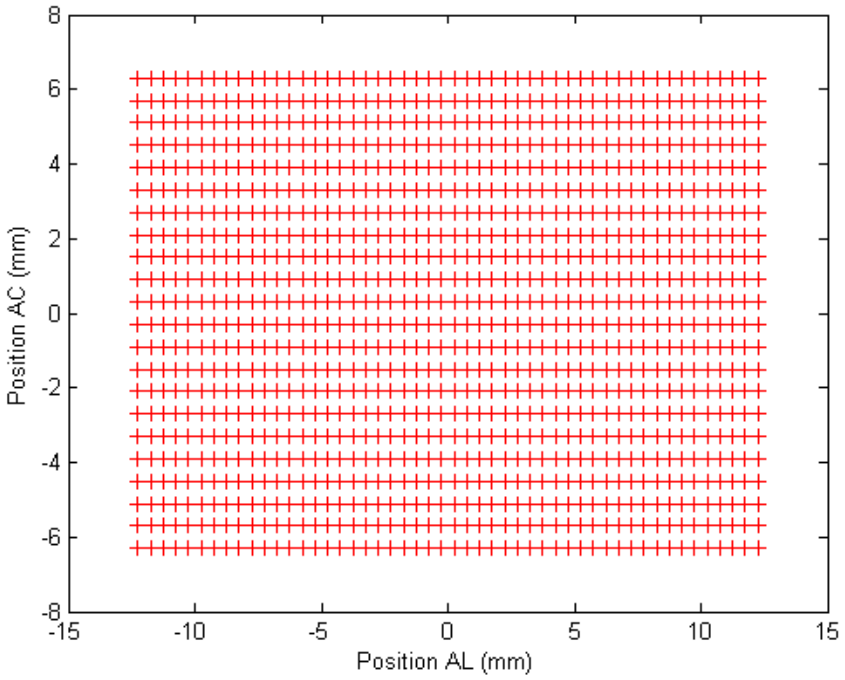


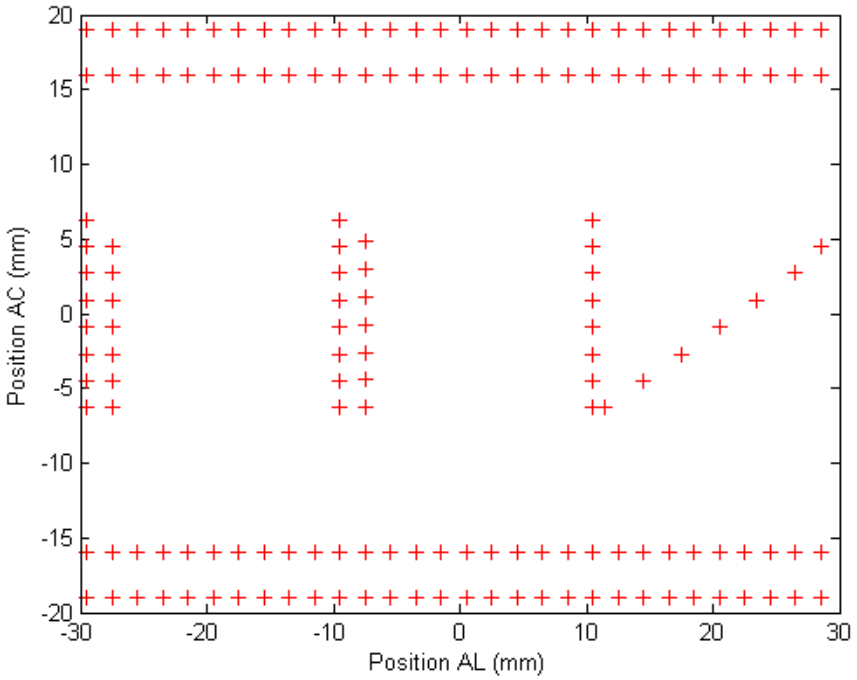




The radiation test bench

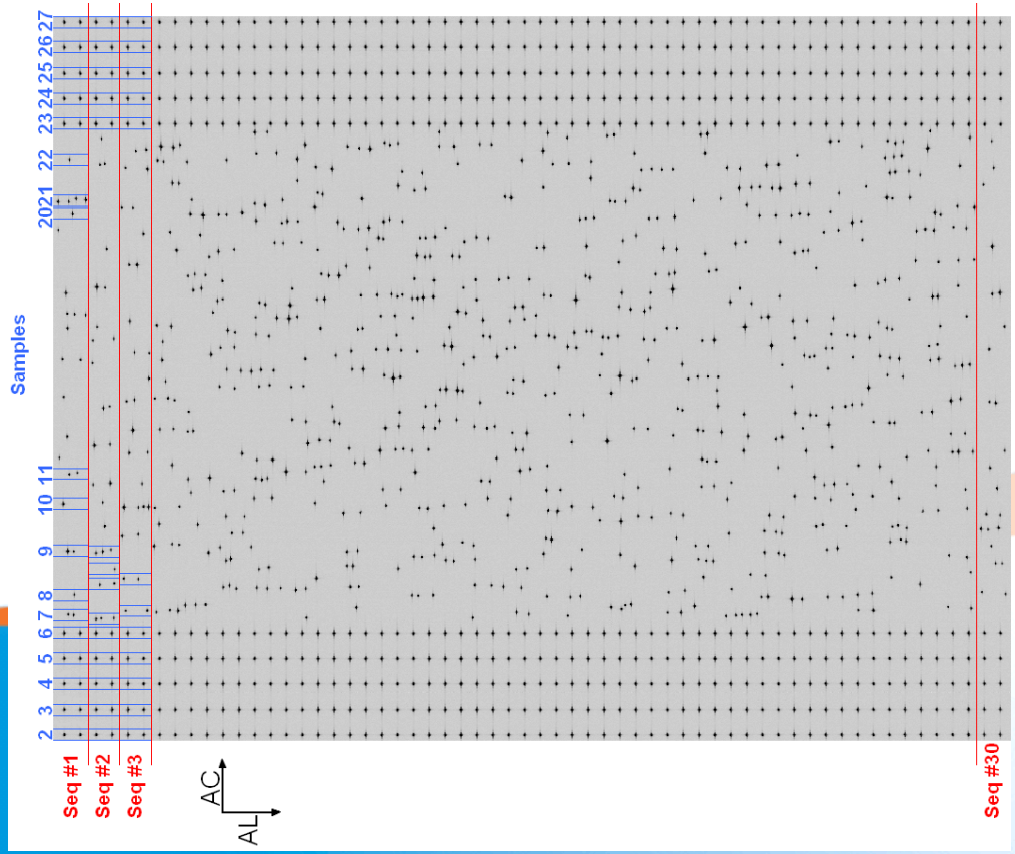
- Optical masks
  - Representative stimuli for AF, XP, & RVS
- Academic configurations:





The radiation test bench

- Optical masks
  - Representative stimuli for AF, XP, & RVS
- Sky-like configuration:



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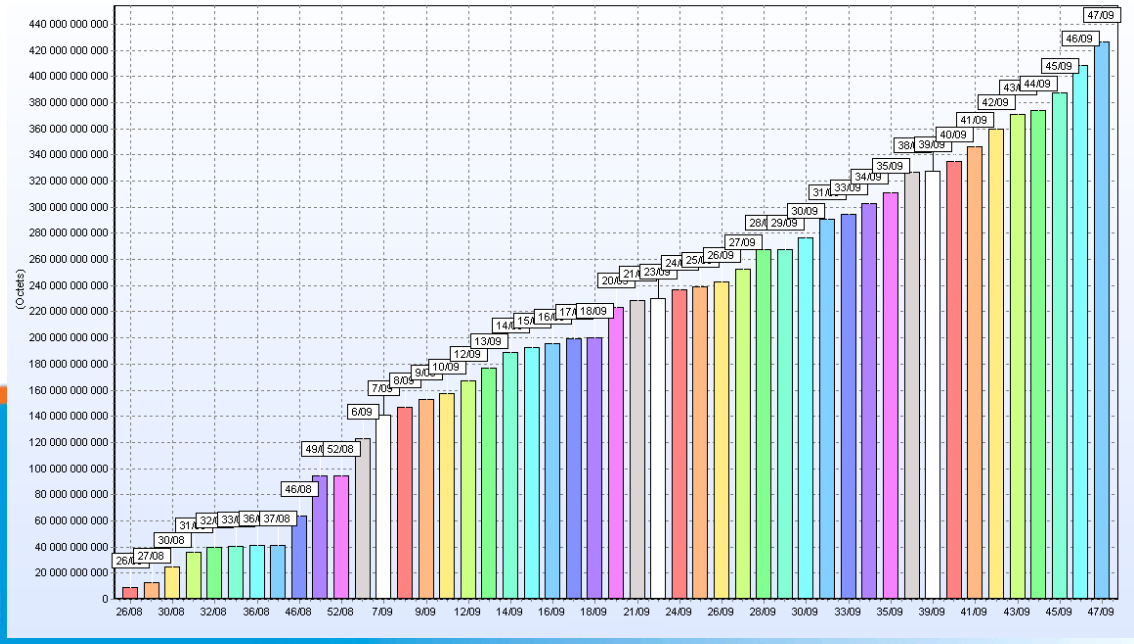
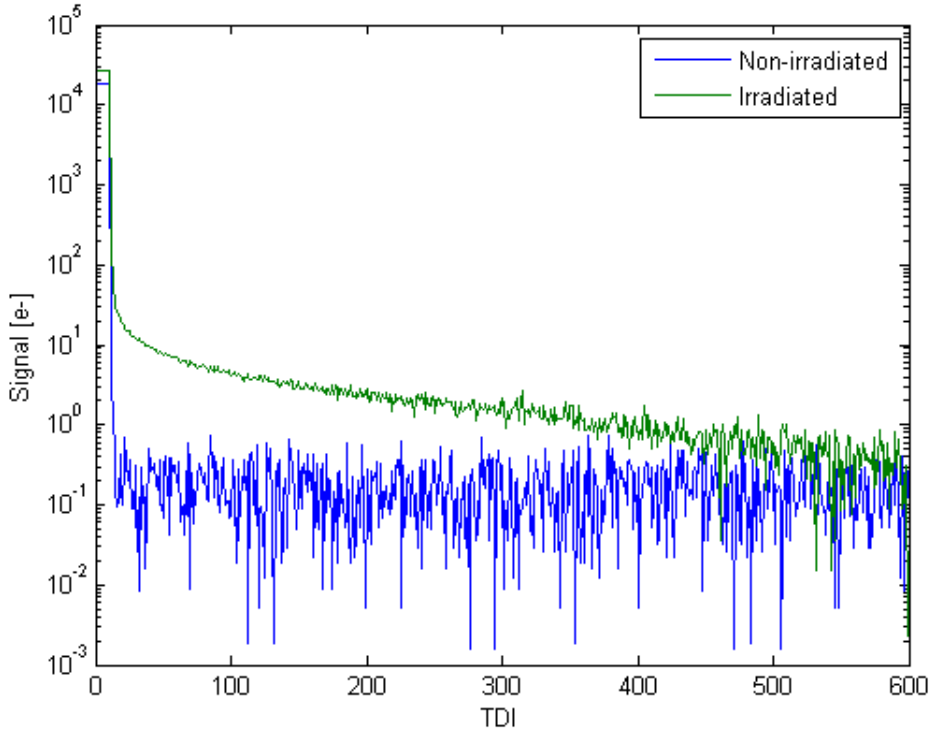
The radiation test bench

- A few figures
  - 2 years of almost continuous operation
  - 400 Gigabytes of raw data
  - Thousands of line of code
  - Thousands of liters of liquid nitrogen
  - >200.000 transits



Test results

- Charge injection
  - Used to “fill” the traps induced by the radiations
  - Resets the history of the CCD and limits the radiation effects
  - Charge trail used to estimate the characteristics of the traps

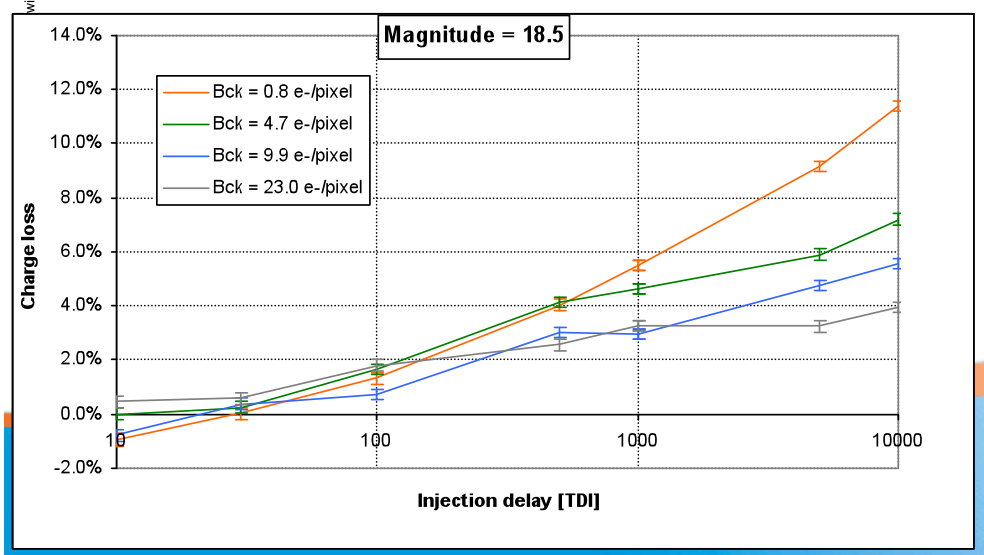


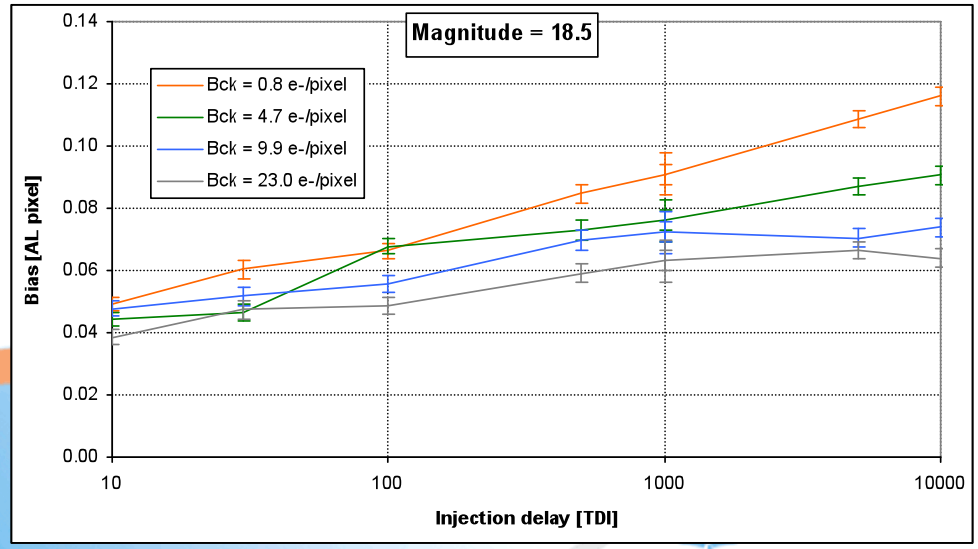
Typical flight configuration:

- Level = 20 ke-/pixel
- Period = 1 sec
- Duration = 4 TDI

Test results

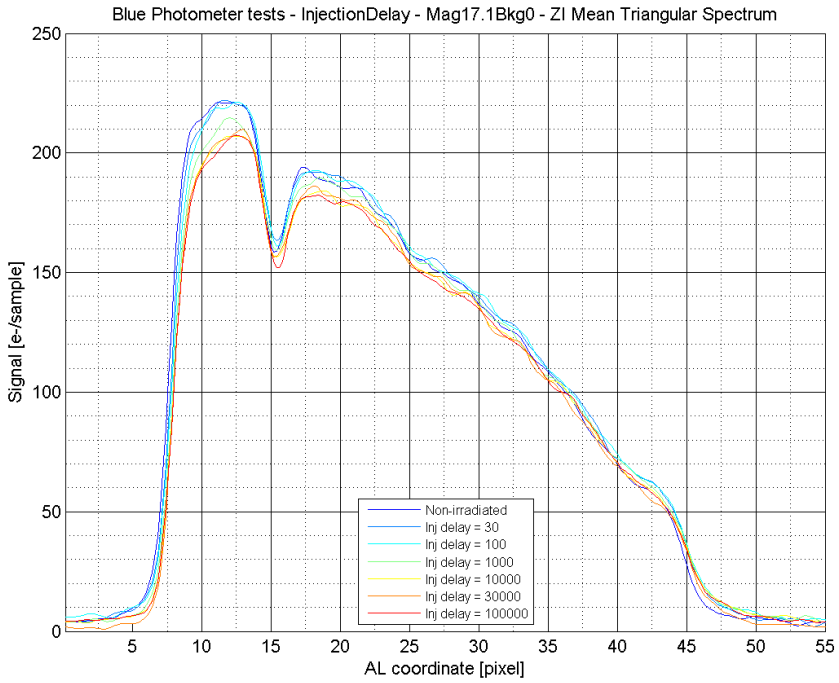
- Line spread function
  - Strong variability of the radiations effects
  - Bias & charge loss depend on the magnitude, injection delay, background
  - Centroiding bias up to 0.2 AL pixels for the faintest stars

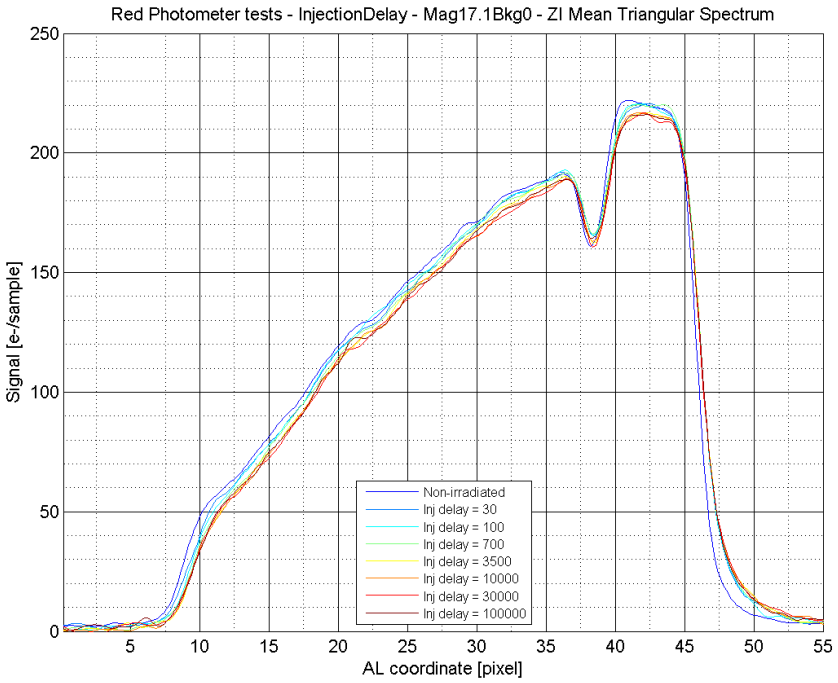




Test results

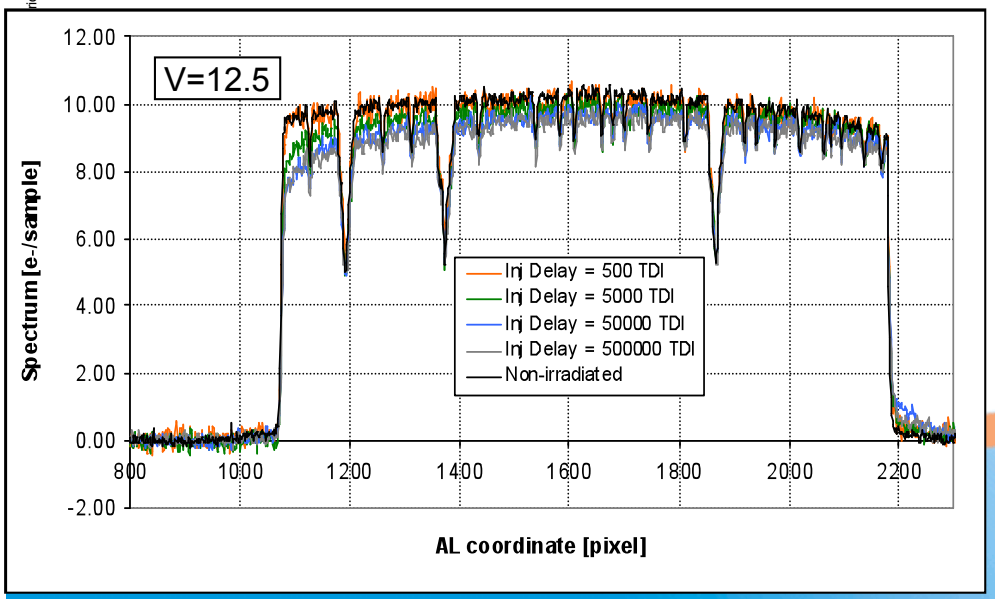
- BP & RP spectra
  - Charge loss of a few percent (<10%) to be expected in flight
  - Spectral mixing: charges transferred from one band to another

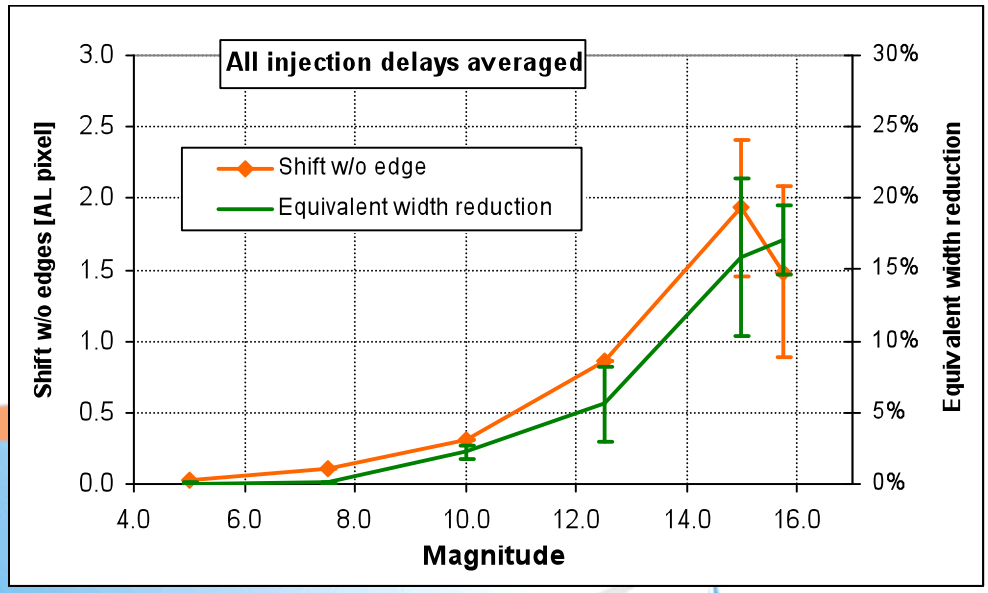




Test results

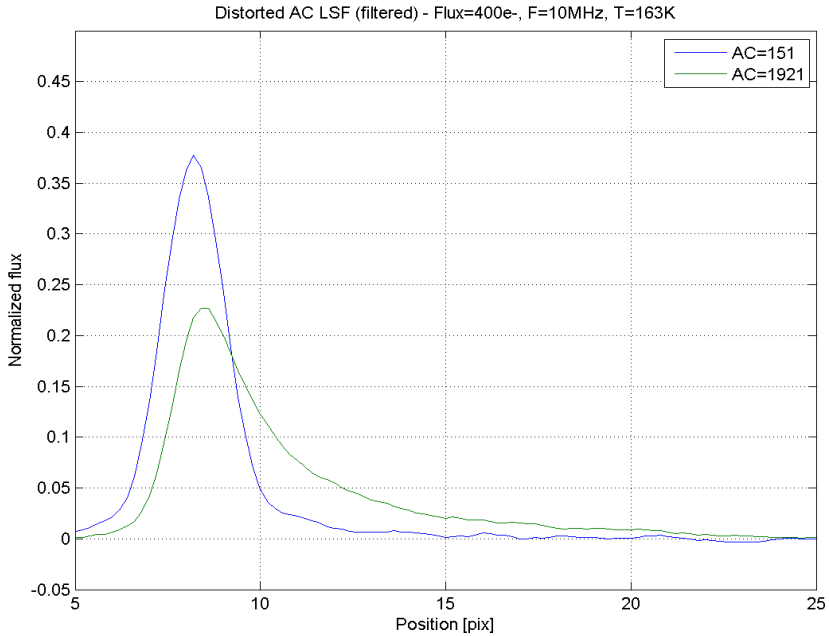
- RVS spectrum
  - Degradation of the signal to noise ratio
  - Spectral lines filled up to ~20% at V=15.75
  - Induced radial velocity bias up to ~20 km/s
  - Charge injection not used in flight for RVS





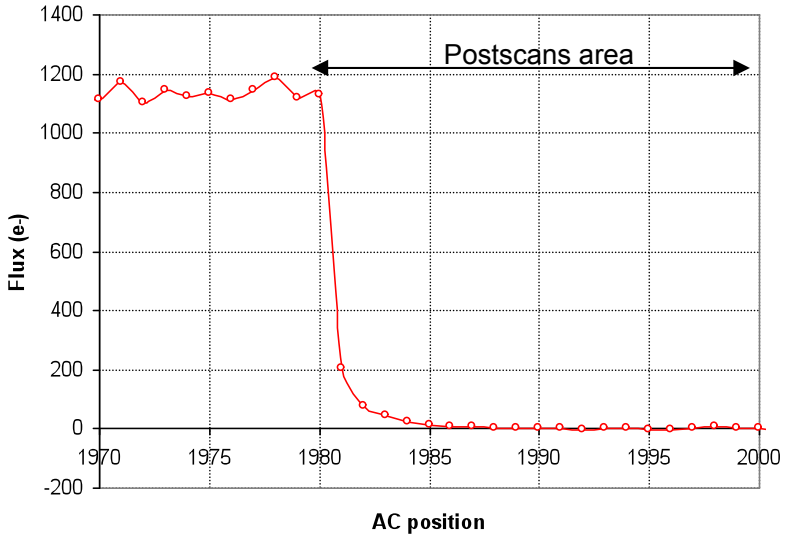
Test results

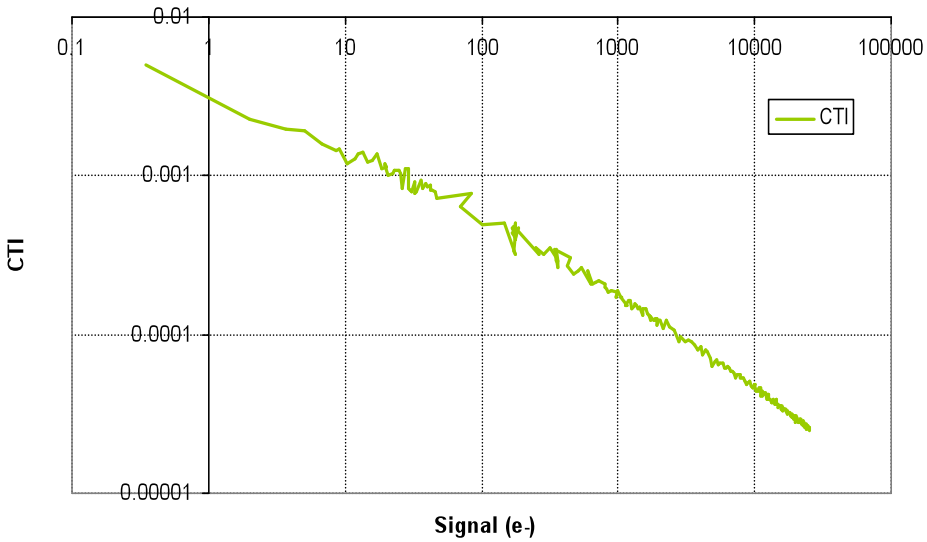
- Native (un-irradiated) CTI
  - Very low in the AL direction
  - Much higher in the AC direction (serial register)
    Main cause: very fast pixel flushing at 10 MHz
  - Generates additional charge loss: flux lost outside the AC bounds of the window



Test results

- Serial register CTI: measurement technique
  - Flatfield illumination of the CCD
  - Acquisition & summation of the charges trailed in the postscans (postscans = un-illuminated virtual pixels at the end of image zone)
  - CTI is function of the illumination level





Test results

- Optimal temperature
  - FPA design temperature: 163K
  - Image zone radiation effects are higher when T_{CCD} increases
  - But: serial register transfer improves
  - 163K ~ optimal setting for the mission

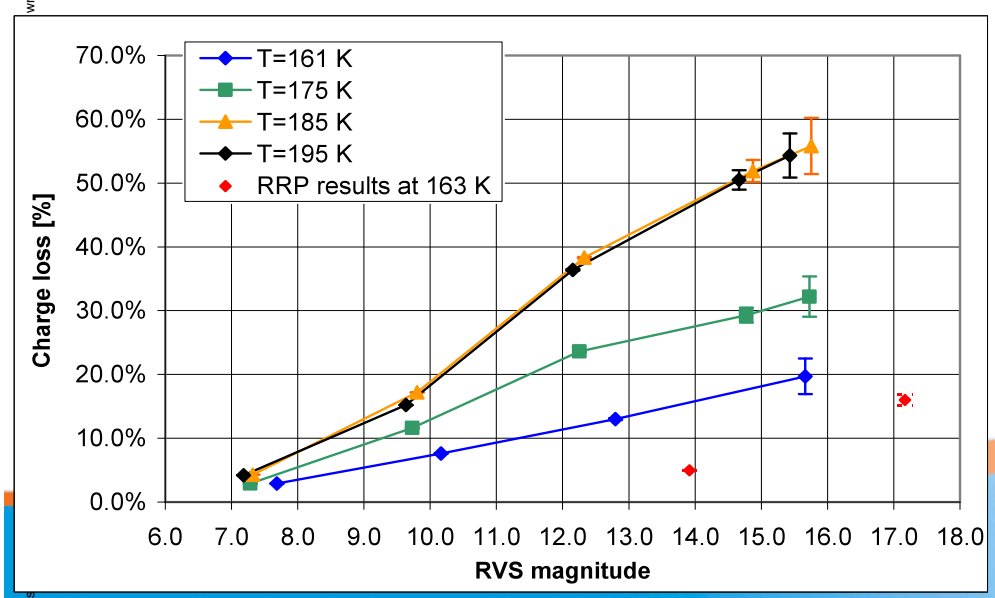
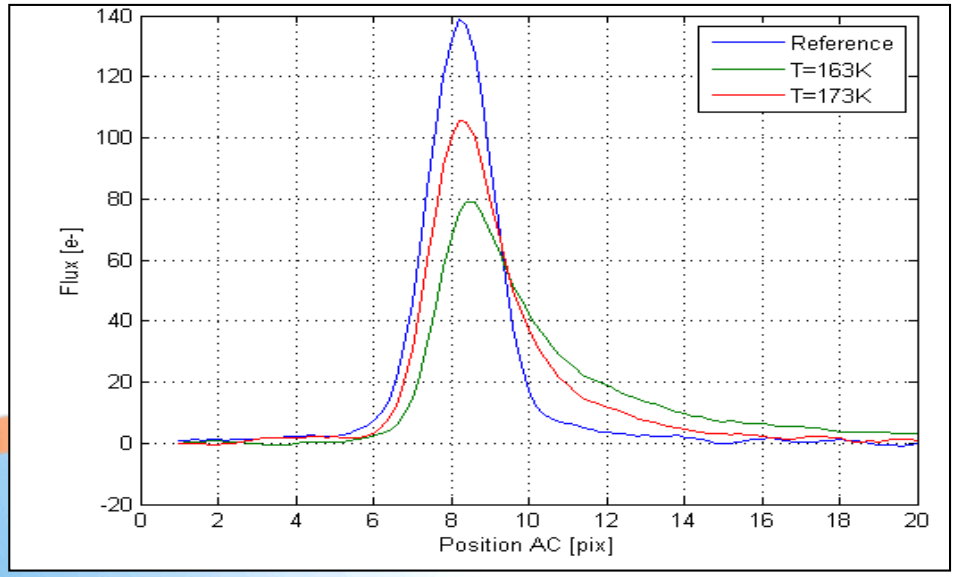


Image zone – RVS radiation charge loss



Serial register – AC LSF distortion

Modelling & calibration

- Objectives of these tests
  - Characterize of the radiation effects
  - Provide input data for the demonstration that on-ground calibration is feasible

- Activity carried out by the Radiation Calibration Working Group:
  - ESA project
  - EADS Astrium
  - DPAC scientists from the different CU
  - ELSA PhDs !

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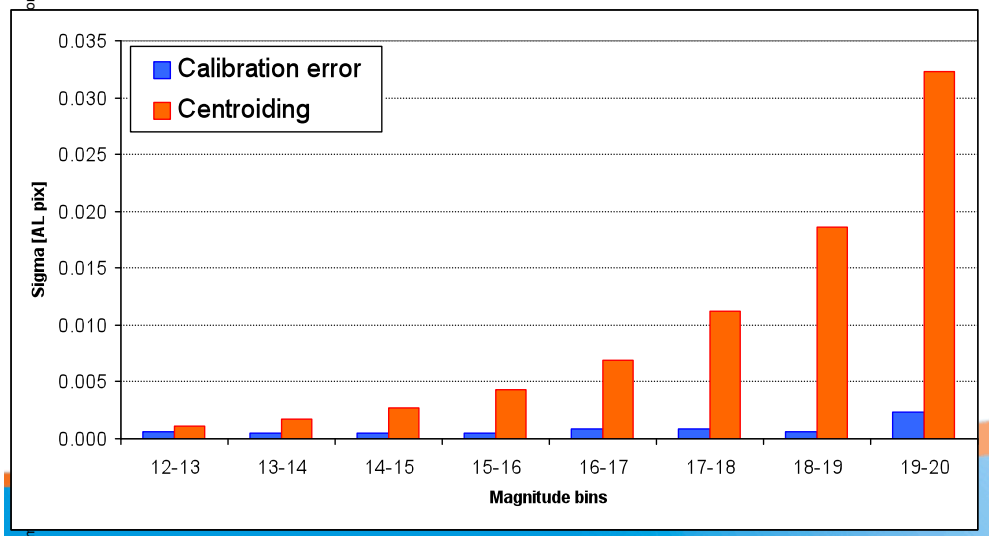
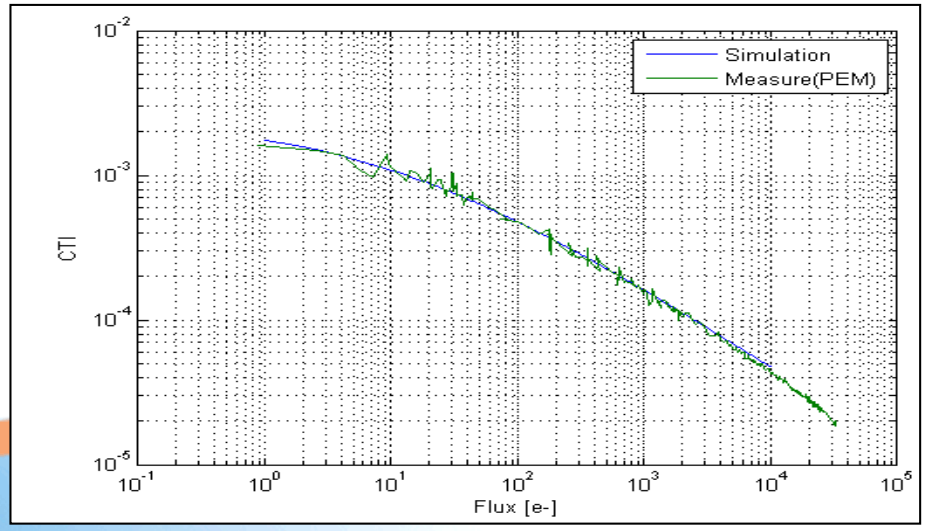
Modelling & calibration

- Several physical or empirical models have been developed:
  - Charge Distortion Model (CDM01, 02, 03)
  - Pixel modelling (volume occupied by the charges)
  - $Bias \propto \sum \alpha_{ij} G^i \log(ID)^j$
- Good agreement with the test data:



Astrometric calibration errors



CDM02 fitting of serial register data

Conclusion

- Tests are still on-going: radiation campaign #4
  - Irradiated serial register tests
  - Persistency tests
  - RVS tests in LR mode
- Thanks to the work already done, we've reached a better understanding of the radiations, and their impact on Gaia
- There is now more confidence in the radiation calibration process, and its limited impact on the performances
  - Ex: calibration errors <15% on the astrometric budget

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