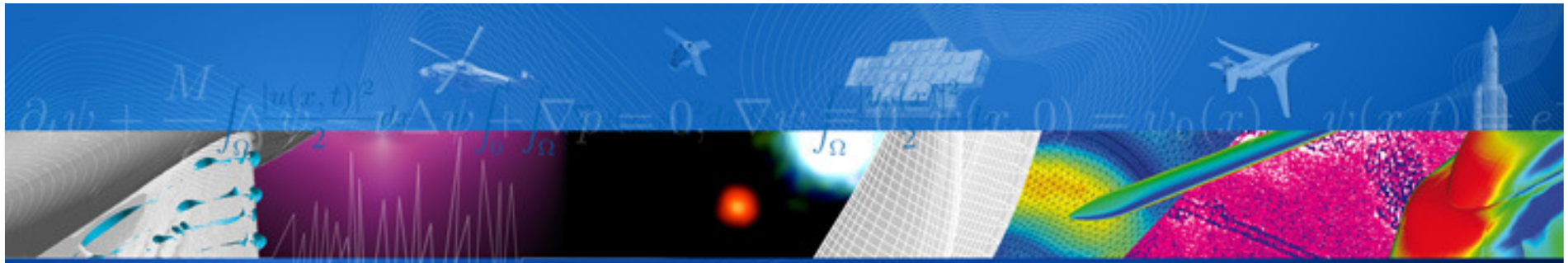

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Image Sensor Dark Current Non Uniformity modeling using GEANT 4

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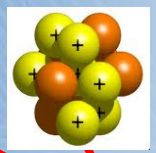
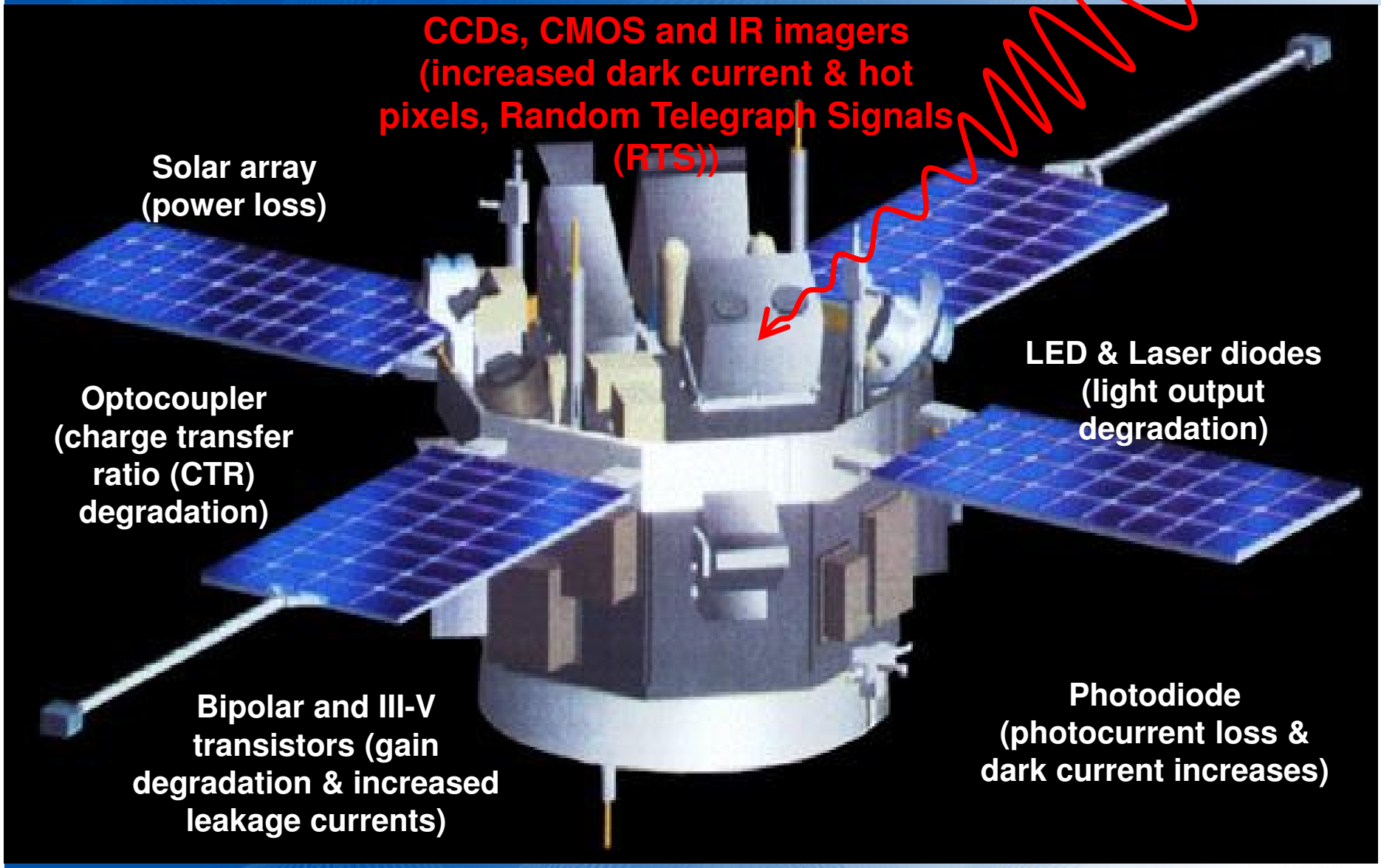
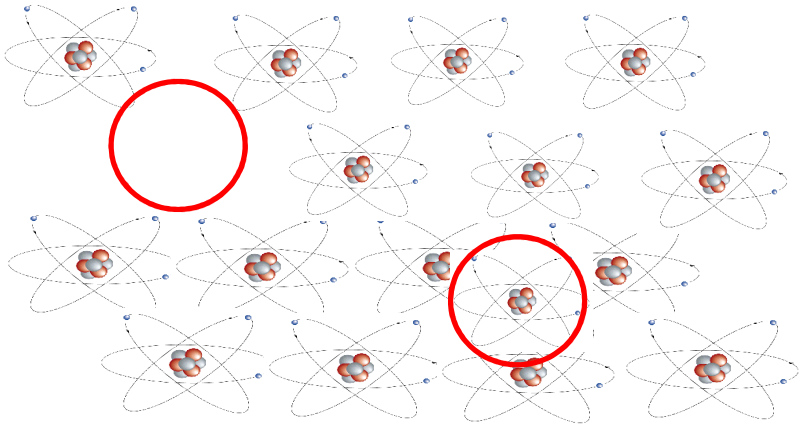
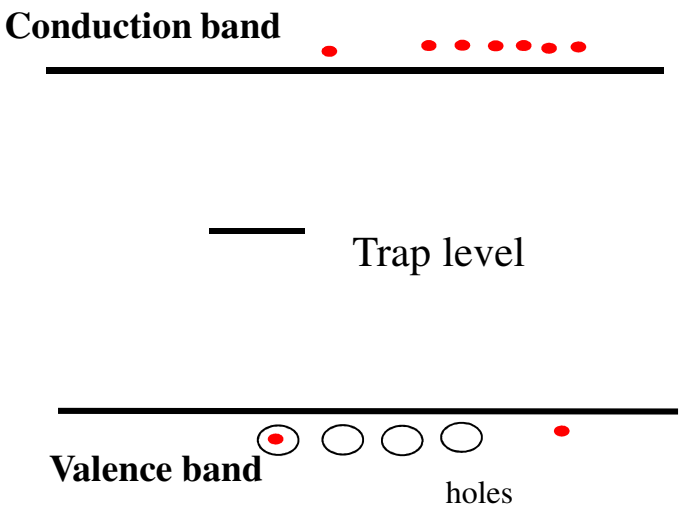
Deffects in semiconductor



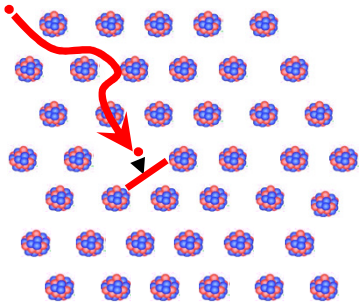


Deffects in semiconductors : Carrier transport degradation

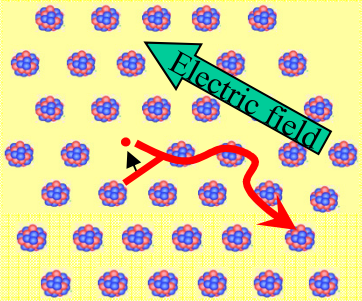




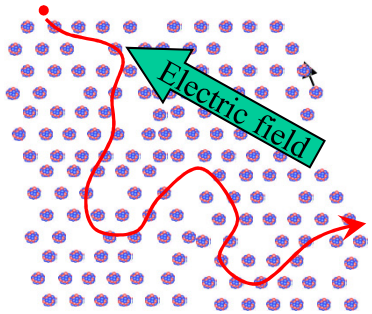
Recombination



Generation

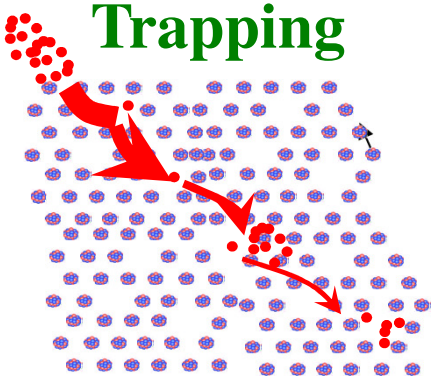


Scattering



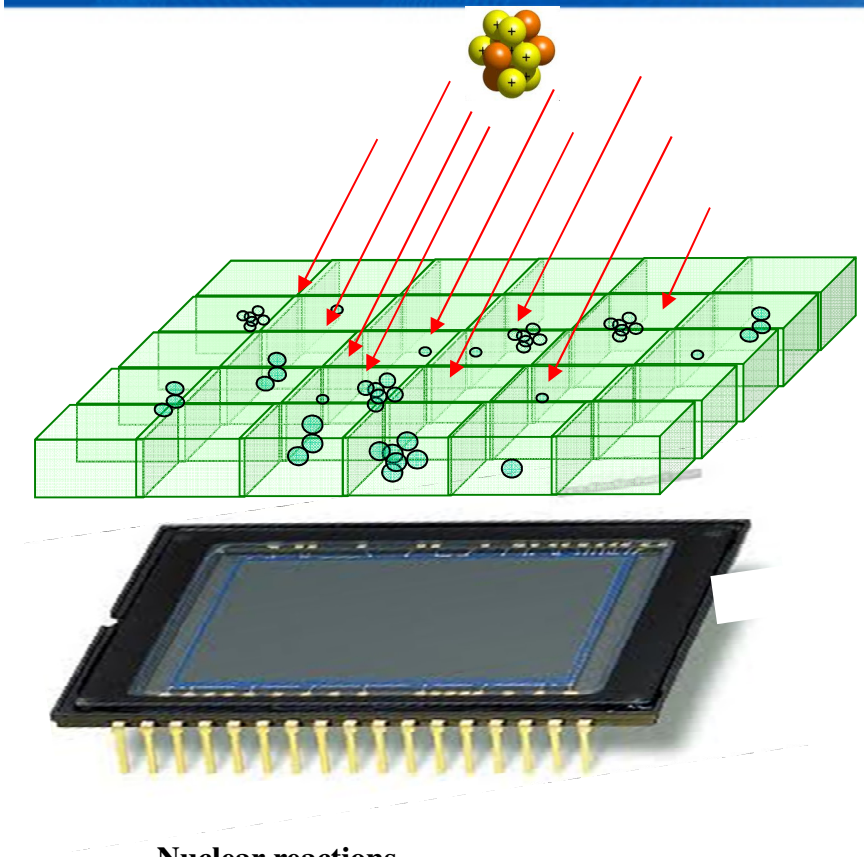
Mobility reduction

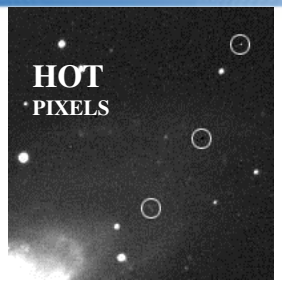
Trapping

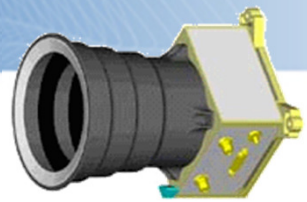


Conductivity reduction

Image sensors degradation

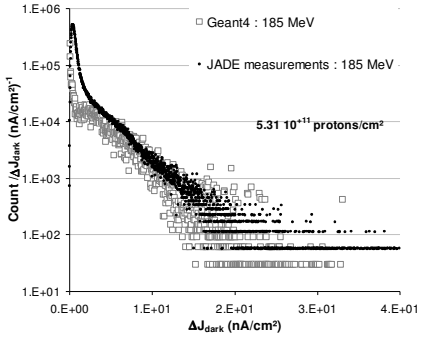






Hot pixels critical
For star trackers

Dark signal Distribution



Non uniform increase in dark current

Nuclear reactions

↓

Damage cascade

↓

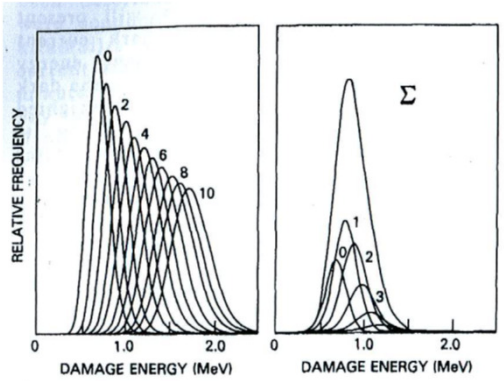
Dark current

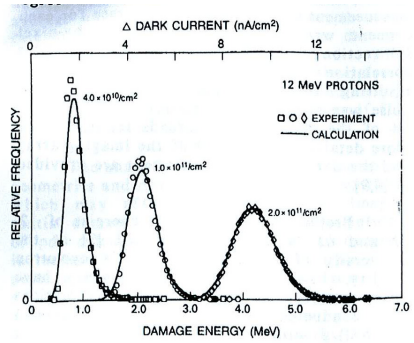
→

Different number of nuclear reactions initiated in each pixel (Poisson's Law)

Different recoil nuclei
Initiating different damage cascade

Existing modelling approach



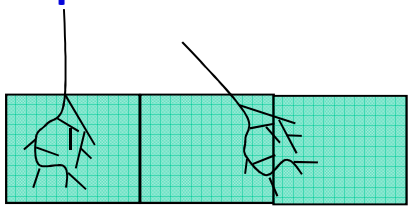


Analytical approach

•(P.W. Marshall, C. J. Dale, E. A. Burke, IEEE Trans. Nucl. Sci., Dec. 1990.)

- Gaussian or Gamma shape are assumed recoil damage distribution
- Parameterised using average Damage energy (NIEL) and variance

- Nuclear inelastic reactions roughly simulated
  - Many recoil nuclei with different mass (different range) can be produced
- Border Crossing effect is neglected
  - The damage is suposed to be confined in the pixel



- Supposed to work for pixels greater than ~10 µm side
- What about pixels of a few µm ?

Geant 4

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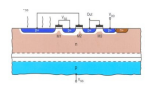
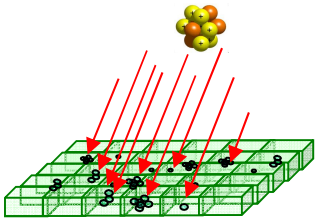
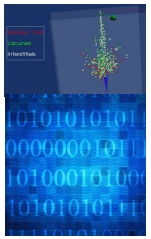
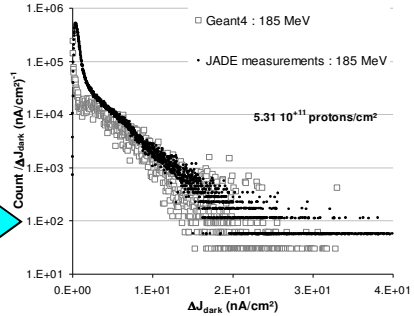
Geant 4 DSNU Modelling









Pixel design

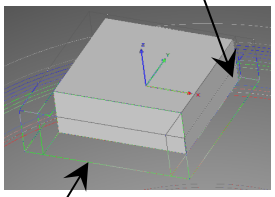
Geant4 modelling

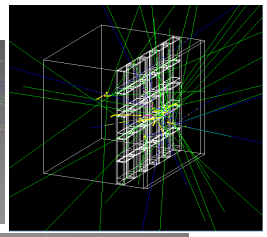
Damage pixel databank

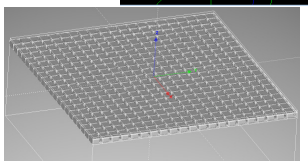
DSNU modelling

FASTRAD GDML

Depleted zone
=
sensitive detector







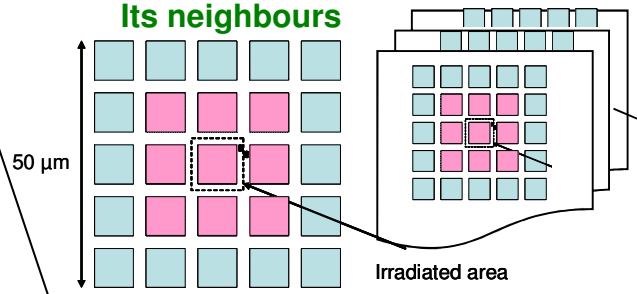
Dead zones
+ substrate
+ upper layers

G4Binary
- nuclear reaction model

G4screenedNuclearRecoil
- Coulombic damage of cascade

G4XWrapperProcess
- Cross section Biasing

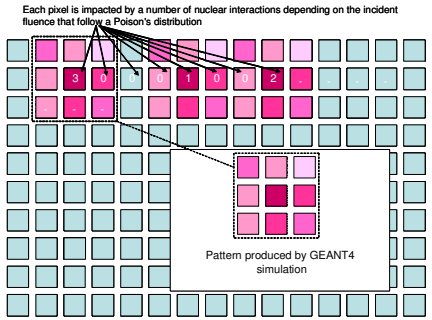
Central pixel irradiation
Storage :
number of displacements
in
the impacted pixel
+
Its neighbours



- Atomic displacements

Typicaly 10 000 nuclear reactions

Number of nuclear reactions randomly selected
In a Poison distribution
For each reaction the damage in the irradiated pixel + its neigbours is randomly selected in the Precalculated dataset



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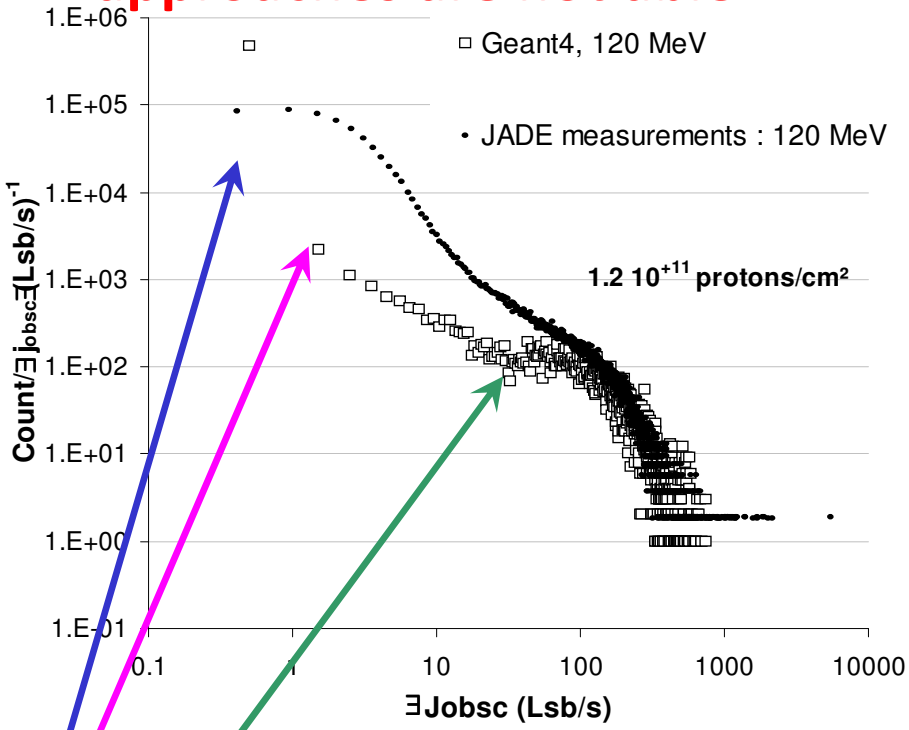
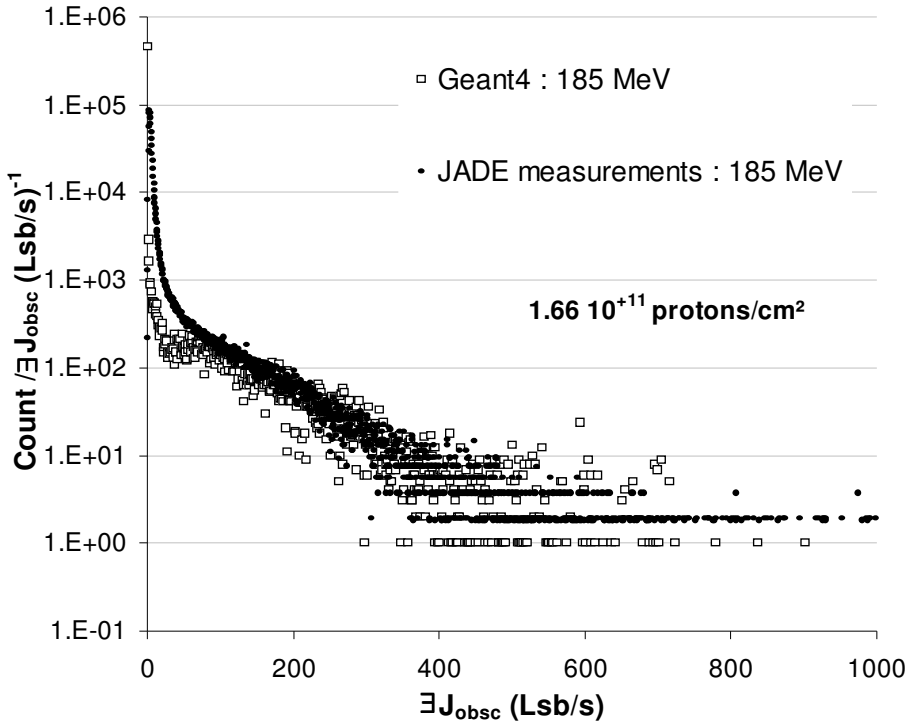
DSNU : Comparison with E2V JADE measurements

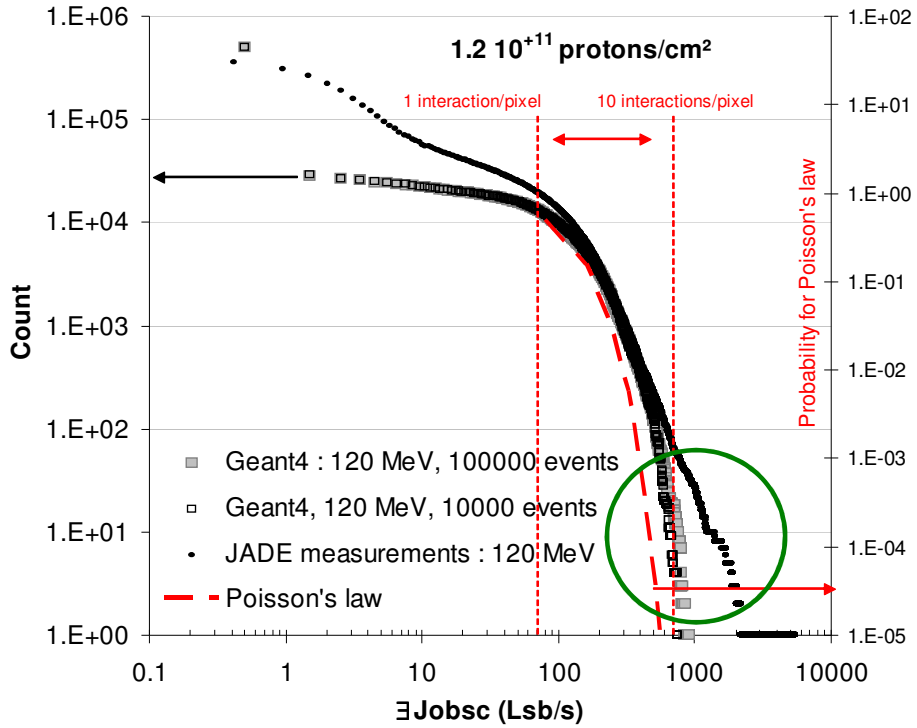
- **Good predictions**
- **High accuracy that evidences "abnormal" events that standard approaches are not able**





- **Discrepancy due partly to coulombian scattering**
- **Discrepancy partly due to nuclear elastic events**
- **Ionizing dose**

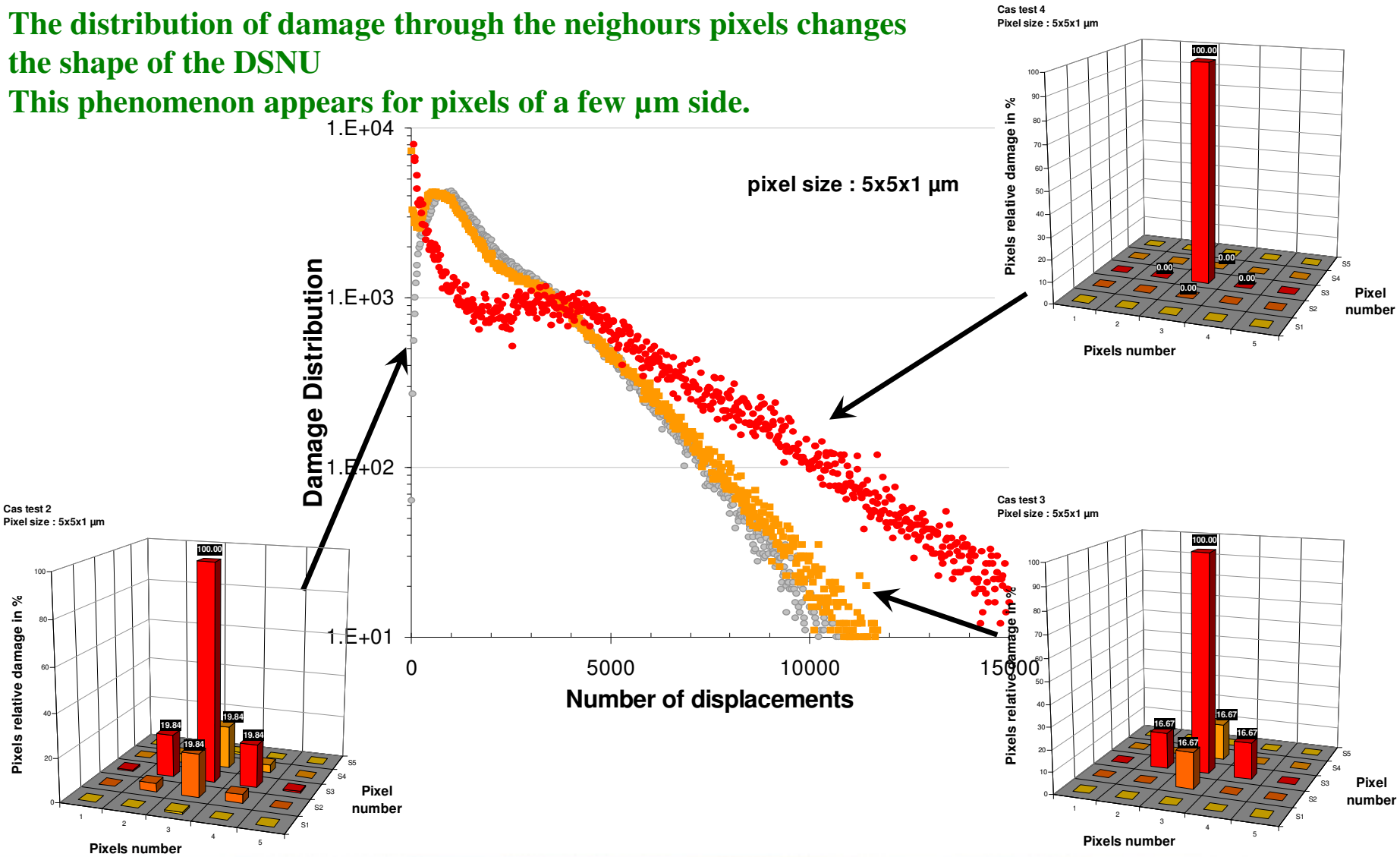
DSNU : Enhancement effect



- **Evidences of "abnormal" events**
- **Enhancement phenomena**

Border Crossing effect analysis

The distribution of damage through the neighours pixels changes the shape of the DSNU
This phenomenon appears for pixels of a few µm side.



Conclusions and perspectives

- Original 3D Monte Carlo approach for DSNU prediction
- Very good predictions knowing only the size of the pixels
- Border crossing evidence for small pixels (few µm side)
- Improvement of the model in progress
  - Nuclear elastic scattering
  - Coulombic scattering

Potential SPENVIS application for image sensor degradation prediction ?!