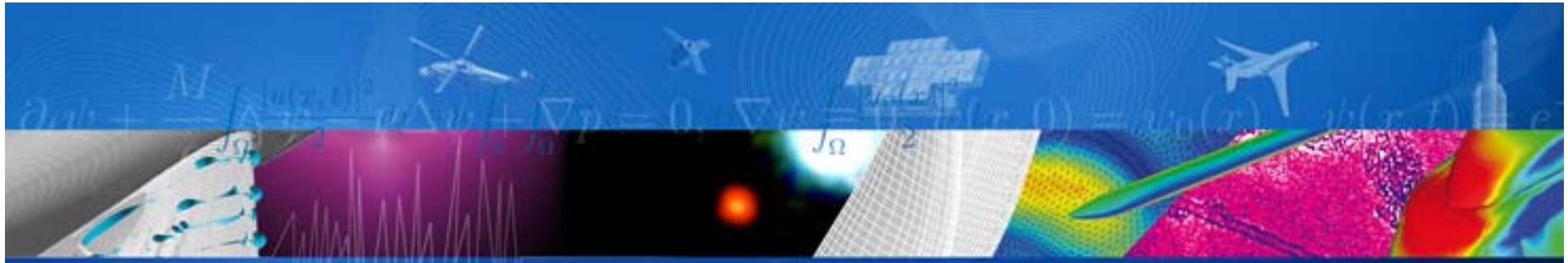

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Displacement Damage Defect : Improving NIEL scaling

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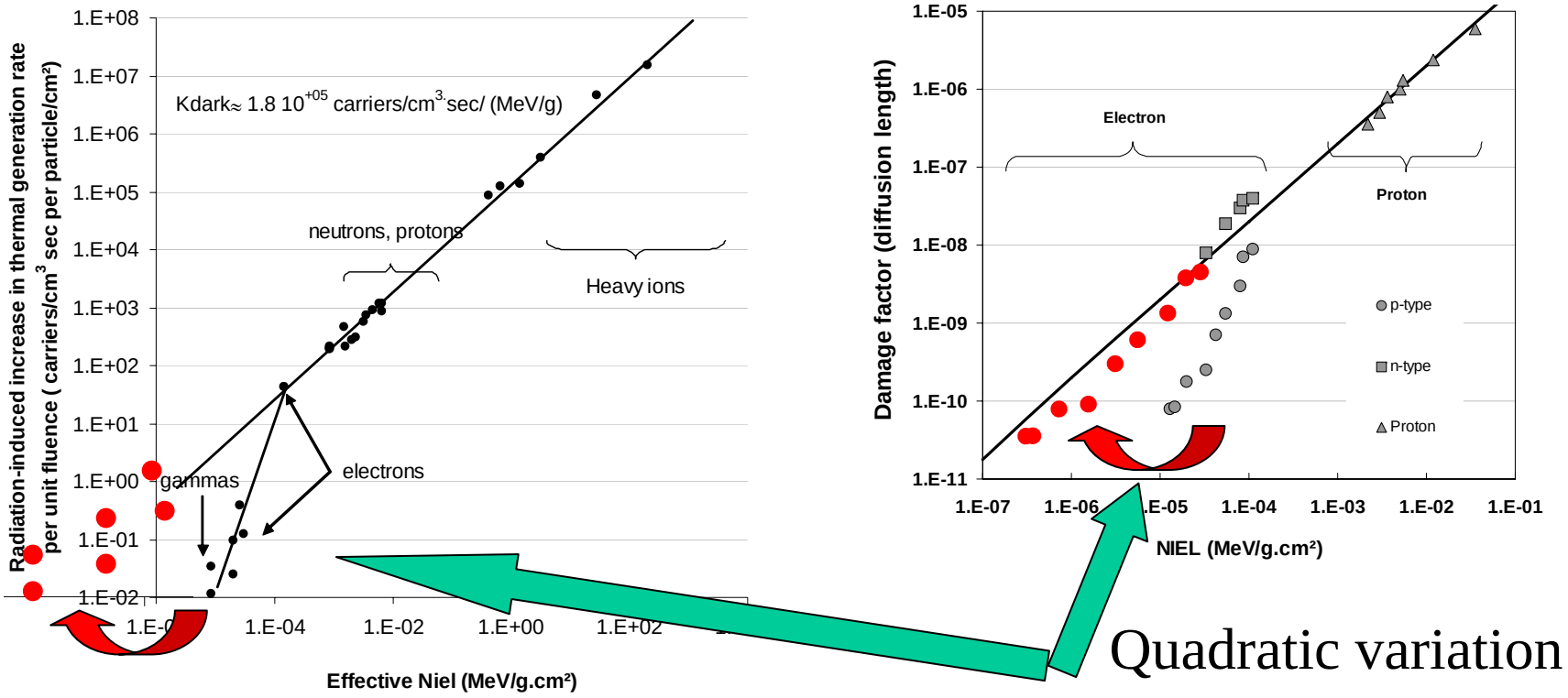
Introduction : NIEL scaling

- NIEL fails sometimes to predict degradation rate due to displacement damages



J. R. Srour, J. W. Palko " A framework for understanding displacement damage mechanisms in irradiated silicon devices," IEEE Trans. Nucl. Sci., vol. NS-53, no6, December 2006.
G. P. Summers, E. A. Burke, P. Shapiro, S. Messenger, R.J. Walters , IEEE Trans. Nucl. Sci.., vol. 40, No. 6, pp. 1372-1379, December 1993.

C. Inguimbert, P. Arnolda, T. Nuns, G. Rolland IEEE Trans. Nucl. Sci., vol. NS-57, no4, 2010

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Goal

- Improving Displacement Damage degradation prediction
  - Improving NIEL
  - Improving Monte Carlo transport codes

} **BCA hypothesis**

Incorporating for displacement analysis the "improved BCA" method in a GEANT 4 application

Outline

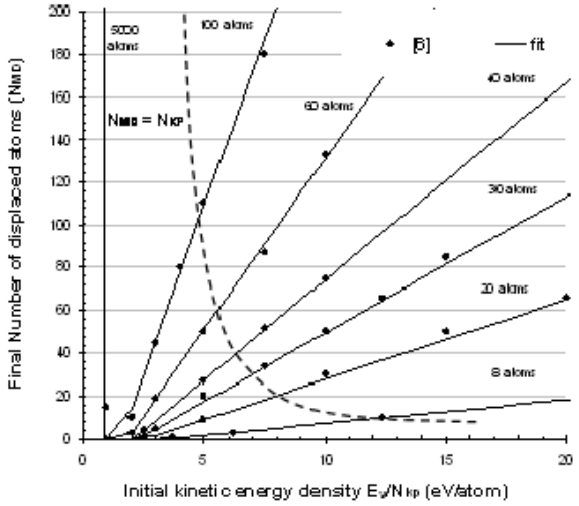
- Introduction
- NIEL improvement for **silicon**
  - Principle of the calculation
  - Comparison with measured defects introduction rates
- Conclusion
- Outlook

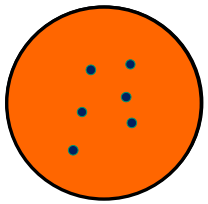
Amorphous pockets

- Competition between melting and diffusion of energy processes
- Importance of deposited energy density Santos & al. [5, 6]
- Collective motion that allows displacement damages generation below the traditional threshold (T_d ~21 eV in Si)

BCA

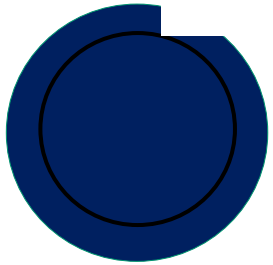
$$Number\ of\ displacements = 0.4\frac{G(E)}{T_d}$$





1eV/atom

2eV/atom



5eV/atom

Size initial moving atoms

Size final pocket

[5] I. Santos, L. Marques, P. Lourdes, " Modeling of damage generation mechanisms in silicon at energies below the displacement threshold, " Physical Review B 74, 174115 (2006).

[6] I. Santos, L. Marques, P. Lourdes, P. Lopez, " Molecular dynamics study of damage genertation mechanisms in silicon at the low energy regime, " Electron Devices, 2007 Spanish Conference on, pp. 37-40, 02 February 2007.

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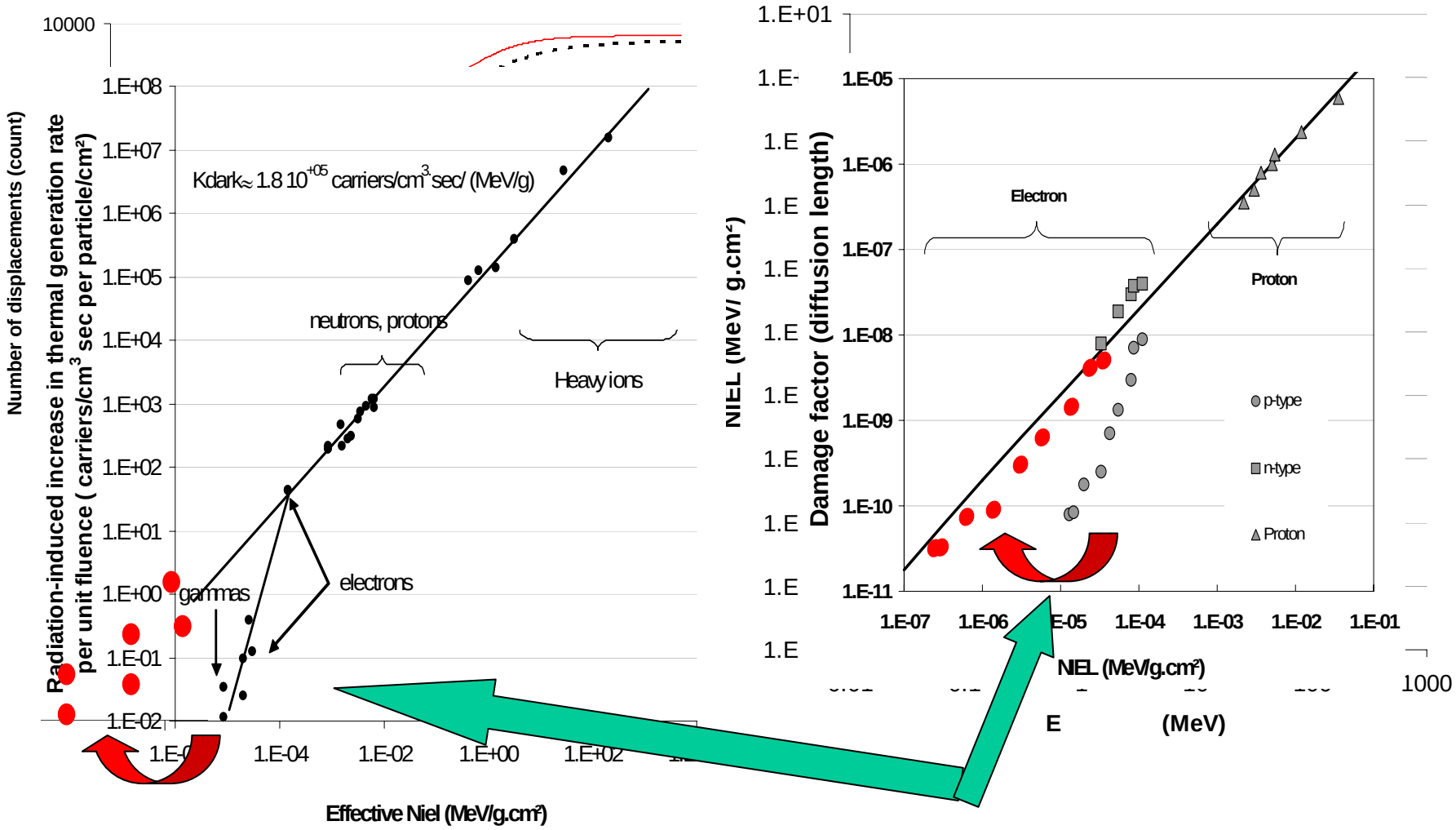
Amorphous pockets



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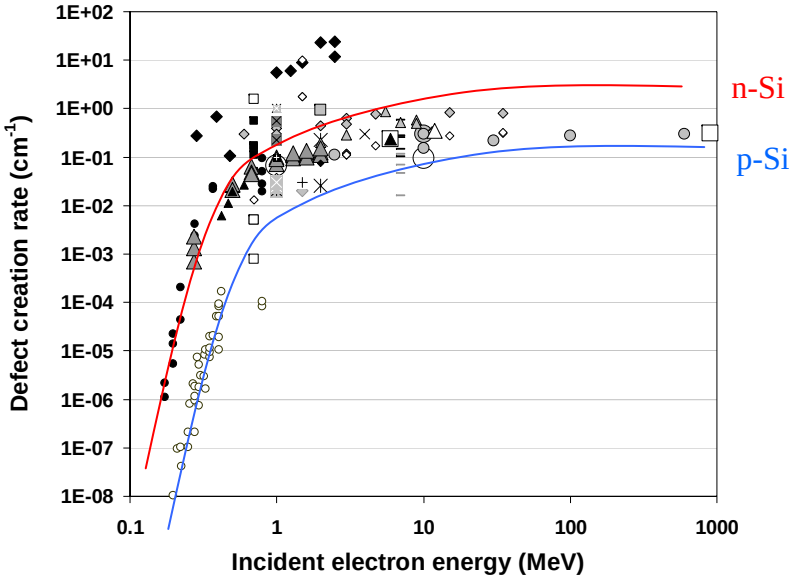
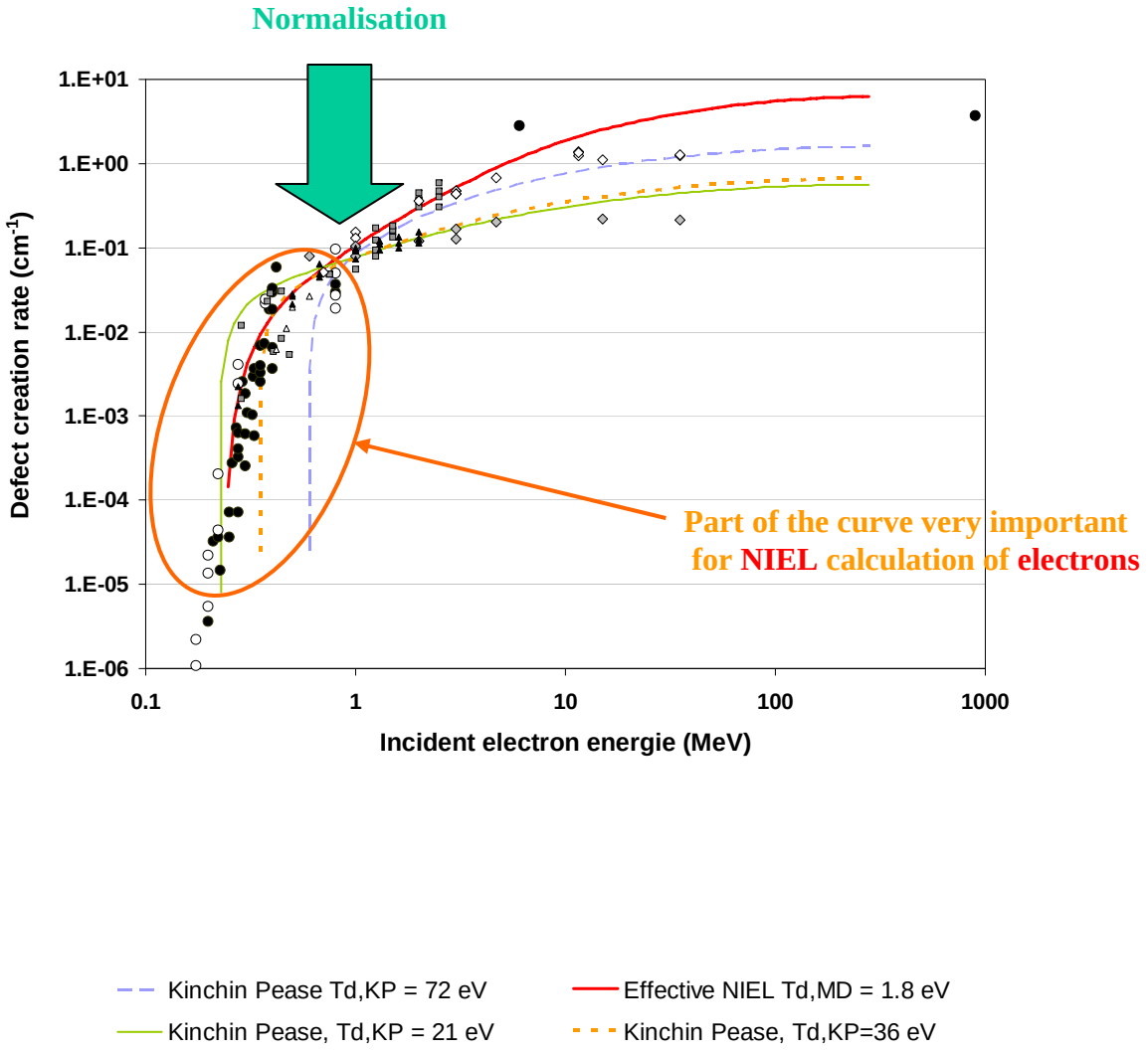
Bibliographic data : defects introduction rates for electrons in silicon



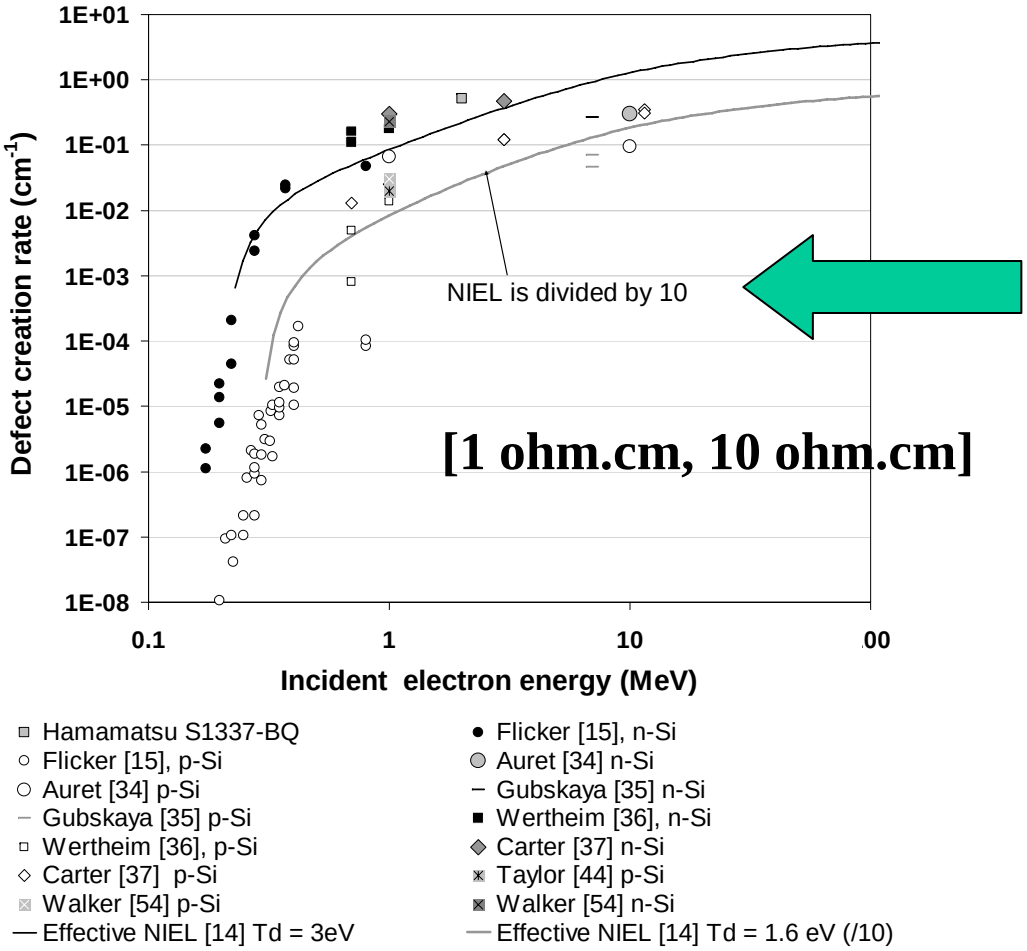
- Hamamatsu S1337 n-type
- Flicker [15], n-Si
- Auret [34] n-Si
- Gubskaya [35], p-Si
- Wertheim [36], n-Si
- Carter [37] n-Si
- Hönniger [38], n-Si
- McKeighen [39] n-Si
- Wada [41]n-Si
- Nubile [43] p-Si
- Kimerling [45] p-Si
- Hemment [47] n-Si
- Londos [49] n-Si
- Zhalko-Titarenko [52] n-Si
- Walker [54] p -Si
- Fuochi [55] n-Si
- Flicker [15], p-Si
- Krinicky [17] n-Si
- Auret [34] p-Si
- Gubskaya[35], n-Si
- Wertheim [36], p-Si
- Carter [37] p-Si
- McKeighen [39] p-Si
- Trauwaert [40] p-Si
- Lugakov [42] n-Si
- Taylor [44]p-Si
- Makhkamov [46] n-Si
- Rai-Choudury [48] n-Si
- Bleka [50],[51] n-Si
- Khan [53] p-Si
- Walker [54] n-Si
- Hazdra [56] n-Si

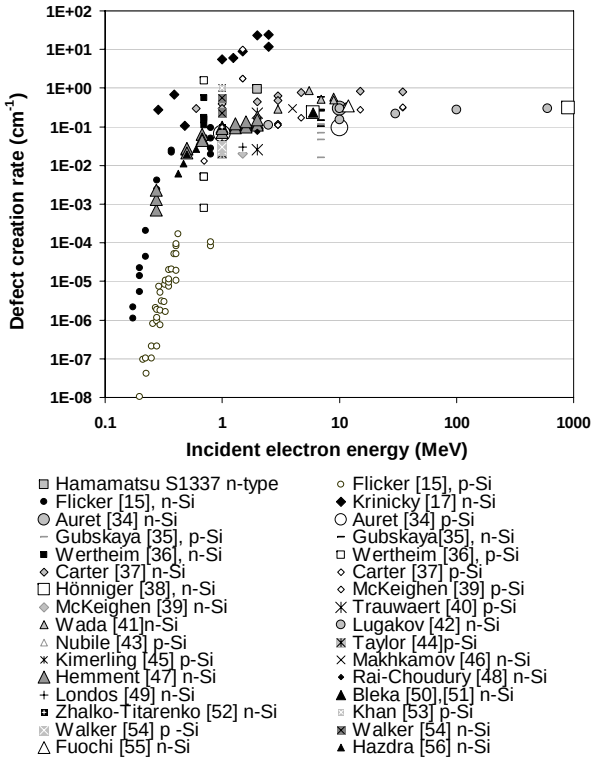
M. J. Beck, L. Tsetseris, M. Caussanel, R. D. Schrimpf, D. M. Fleetwood, and S. T. Plantelides, "Atomic scale Mechanisms for low-NIEL dopant-type dependent damage in Si, " IEEE Trans. Nucl. Sci., vol. NS-53, no6, pp. 1372-1379, December 2006.

New NIEL calculation

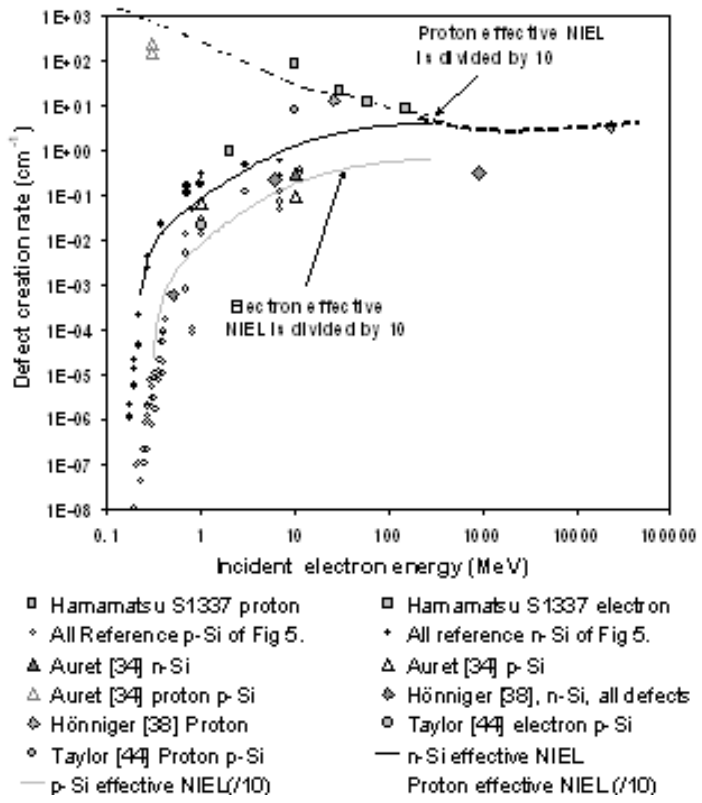


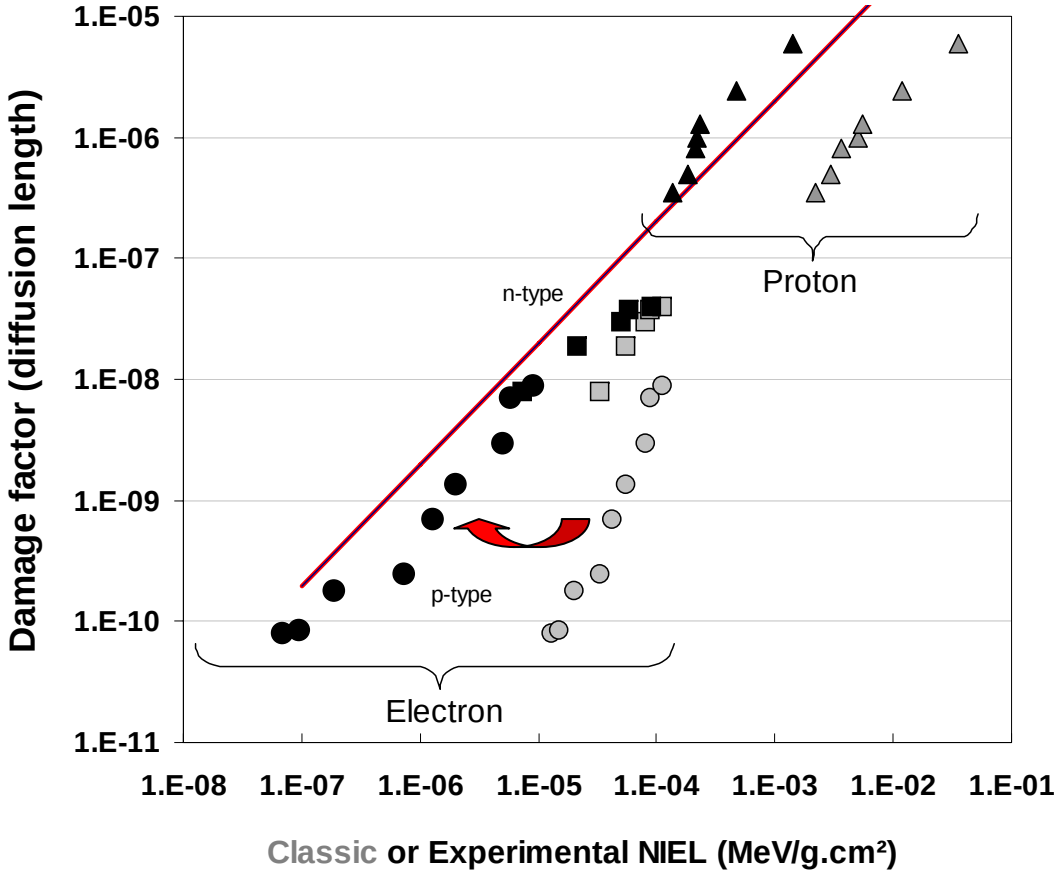
Defect introduction rate : comparison with experiments





Scaling degradation rate





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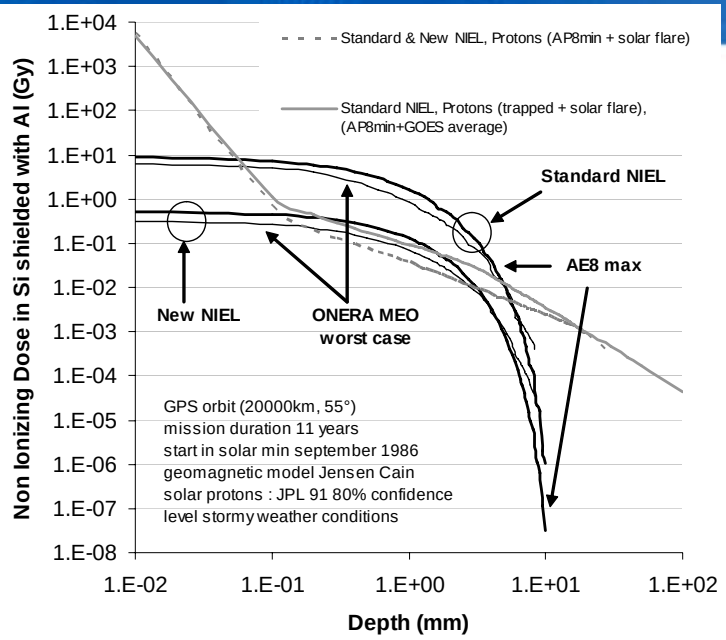
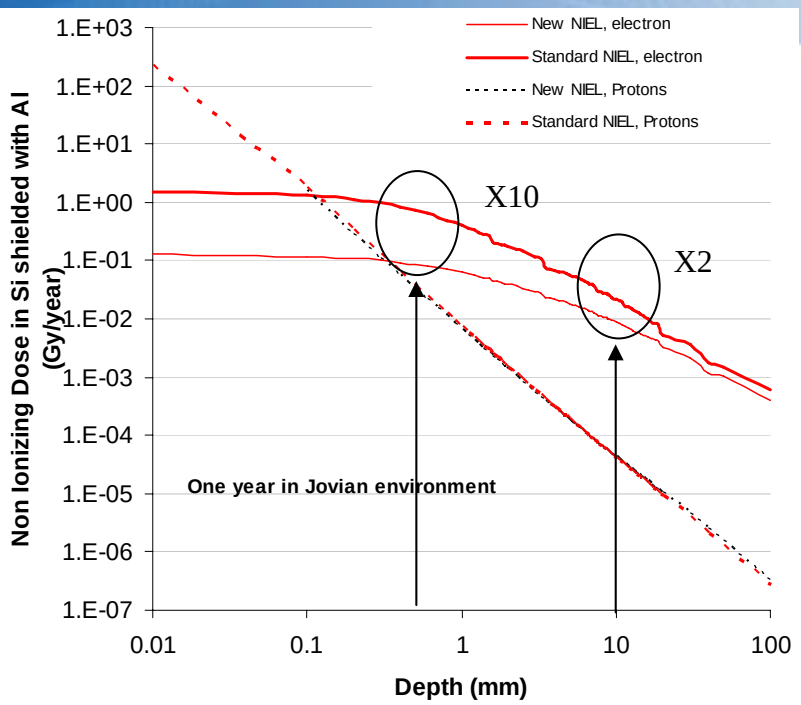
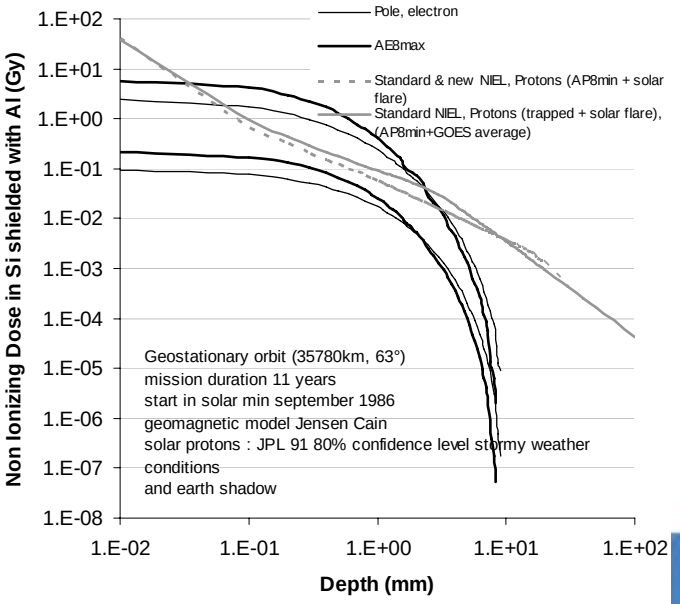
Displacement Damage Dose profile







Electron constraint reduced between a factor 2 and a factor 10

Conclusion

Demonstrated for silicon

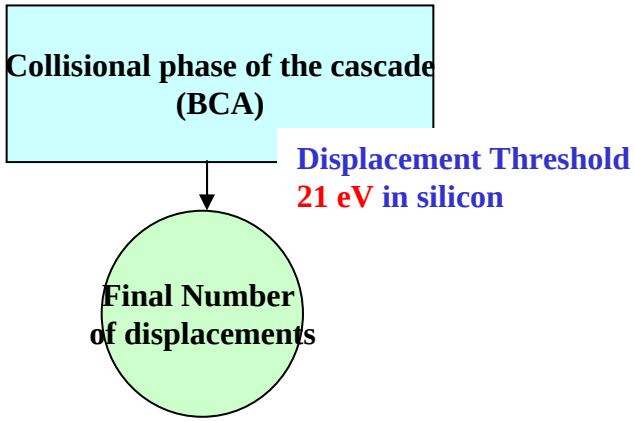
- Non linear effects, for low energy PKAs, (amorphous pockets)
- MD simulation are used to calculate a new energy partition function for Silicon and new NIEL (Electrons)
- Mixing calculation and defect introduction rate measurements leads to a better degradation prediction

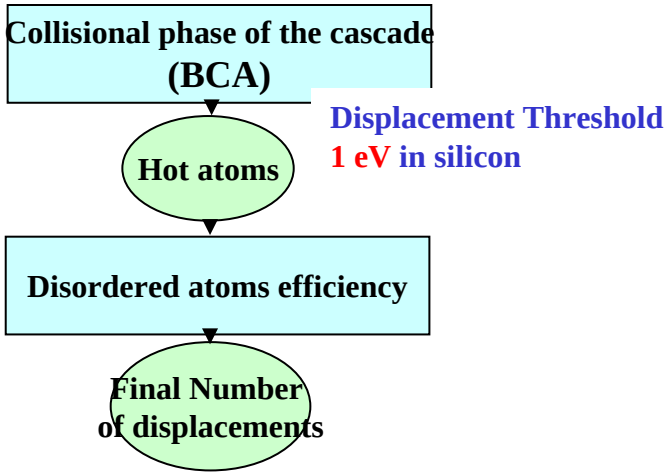
Otlook : Improved BCA approach

Improving NIEL scaling method

Extending MD simulations for other materials (GaAs, InP, ...)
In order to define a new energy partition function and new NIELs tables

- **Monte Carlo (GEANT 4) implementation**





Perspectives : GEANT4 User Interface

- Incorporating the Improved BCA approach within a GEANT 4 user Interface
- Our own G4 interface demonstrator
  - Based on Input/Output file library