# Optimization of Monte Carlo codes PENELOPE 2006 and PENFAST by parallelization and reduction variance implementation

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# OPTIMIZATION OF MONTE CARLO CODES PENELOPE 2006 AND PENFAST BY PARALLELIZATION AND REDUCTION VARIANCE IMPLEMENTATION

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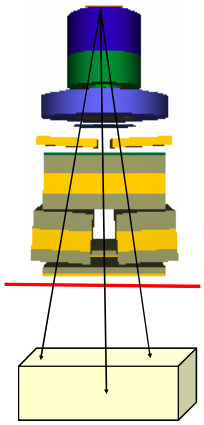
## CONTEX AND OBJECTIVES

- **Conventional TPS** are **fast** but **not enough accurate** in presence of heterogeneities
- Introduction of **MC** methods allows **better accuracy.**
- Recently, a **fast MC dose calculation** code, named **PENFAST** has been developed by Salvat et al (2008). PENFAST is an optimized version of the MC PENELOPE code, adapted to CT **voxelized geometries.**
- Reduction of calculation time thanks to two methods :
  - Introduction of **variance reduction techniques** in PENELOPE 2006
  - **Parallelization** of Monte Carlo codes using MPI (Message Passing Interface) or equivalent

## MATERIALS AND METHODS

- **MC calculations are split into two parts**



**Step 1**
Detailed simulation of the particle transport through the accelerator head

**PENELOPE**

**Phase space**

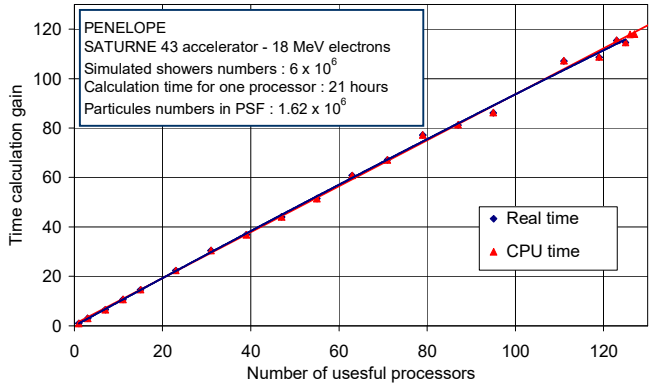
**Step 2**
Simulation of the three-dimensional dose distribution in a voxelised phantom

**PENFAST**

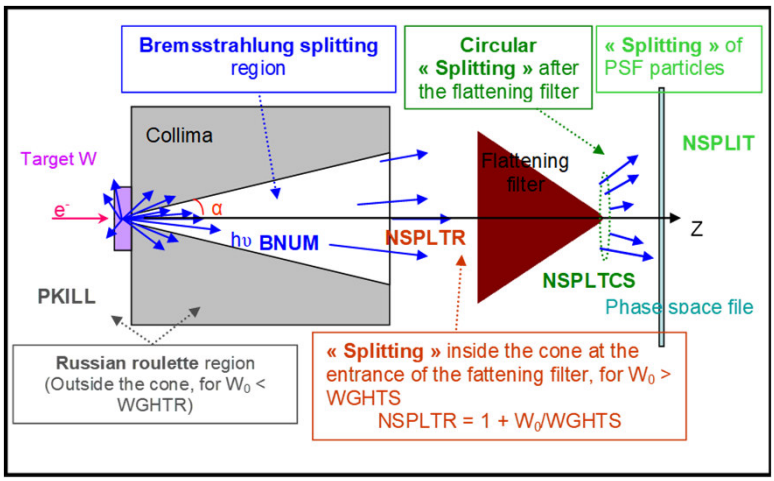
## PARALLELIZATION OF MONTE CARLO CODES

**Parallelization of PENELOPE 2006 and PENFAST codes**

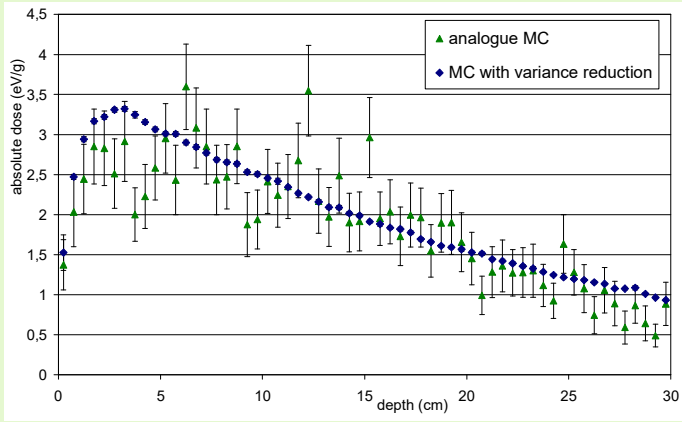
- Achieved using MPI – Message Passing Interface – version mpich2 1.0.6
- Implemented in fortran 77, excepted for the random generator and PSF management
- Generator RP Brent : period of $10^{1230}$
- A processor master in charge of PSF read/write operations and $N_P$ -1 slaves dedicated to the Monte Carlo calculation

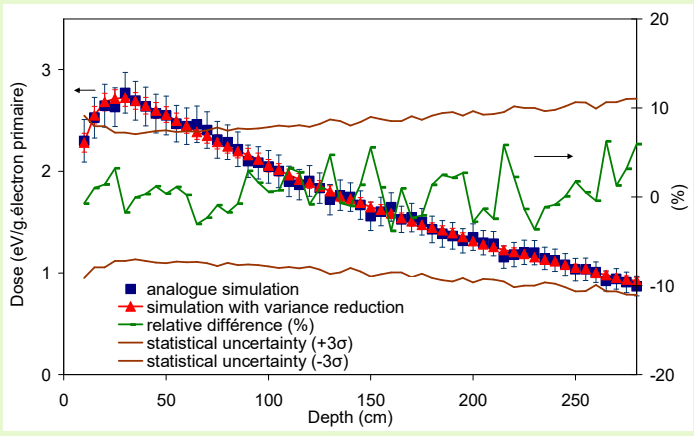



## VARIANCE REDUCTION TECHNIQUES




The implemented methods increase the simulation efficiency by a **factor greater than 100** compared with the analogue simulation.




## CONCLUSIONS

- Monte Carlo methods lead to decrease uncertainties in dose calculation but are too time expensive
- Thanks to implementation of variance reduction techniques in the PENELOPE 2006 code, simulation time is reduced by a factor greater than 100 with unbiaised results
- The use of variance reduction coupled with parallelization allow to achieve the reasonable computation time (10 min) with the required uncertainty (2 %)