New Computing solutions and their impact on scientific algorithms

ET Project – WG4 Meeting
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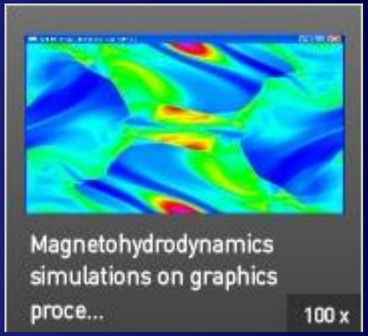
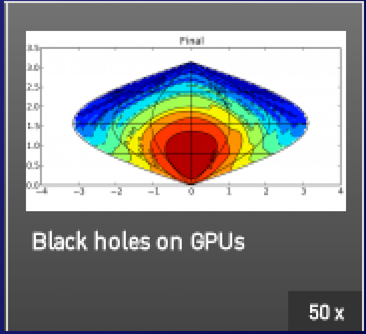
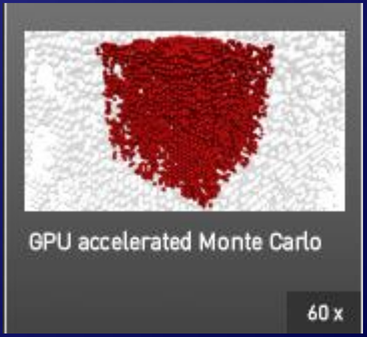
Thirst of computing power

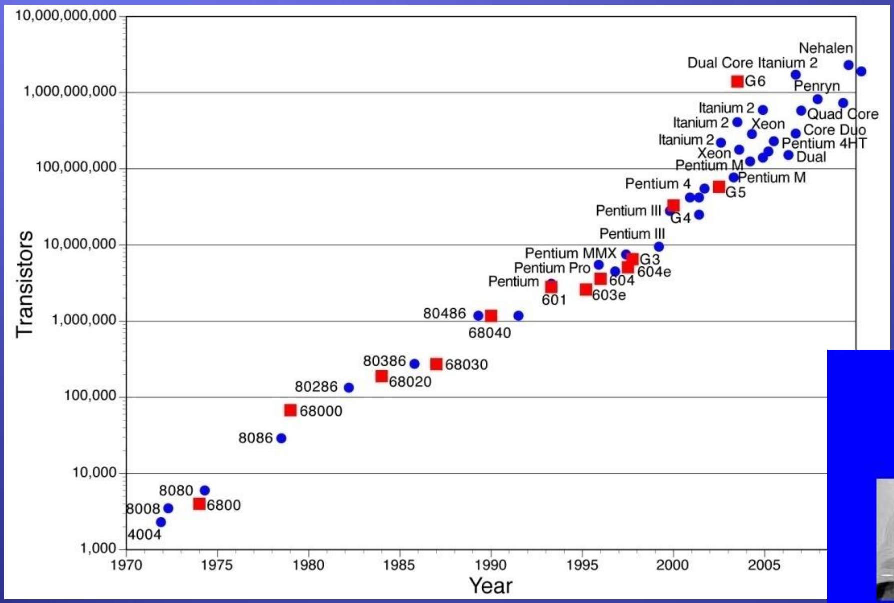
- All Science fields require even more computing power, and GPU computing starts to be a reliable solution.
  - Signal processing
    - Signal generation
    - Signal detection
    - FFT
  - Algebraic operations
  - Monte Carlo simulations
  - Black Hole (NR) simulation
  - Molecular Simulation
  - Object / pattern classification recognition
  - Stochastic Differential Equation
  - Financial Market
  - Many ..many others..



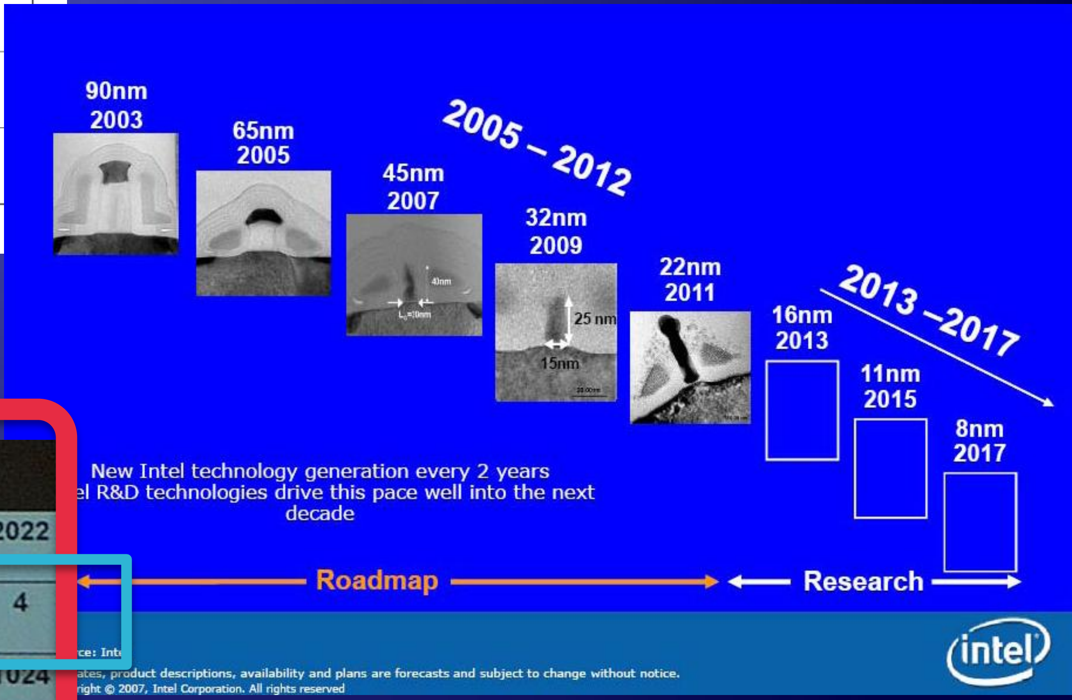




Technological outlook:



Is the Moore's Law close to its limit?



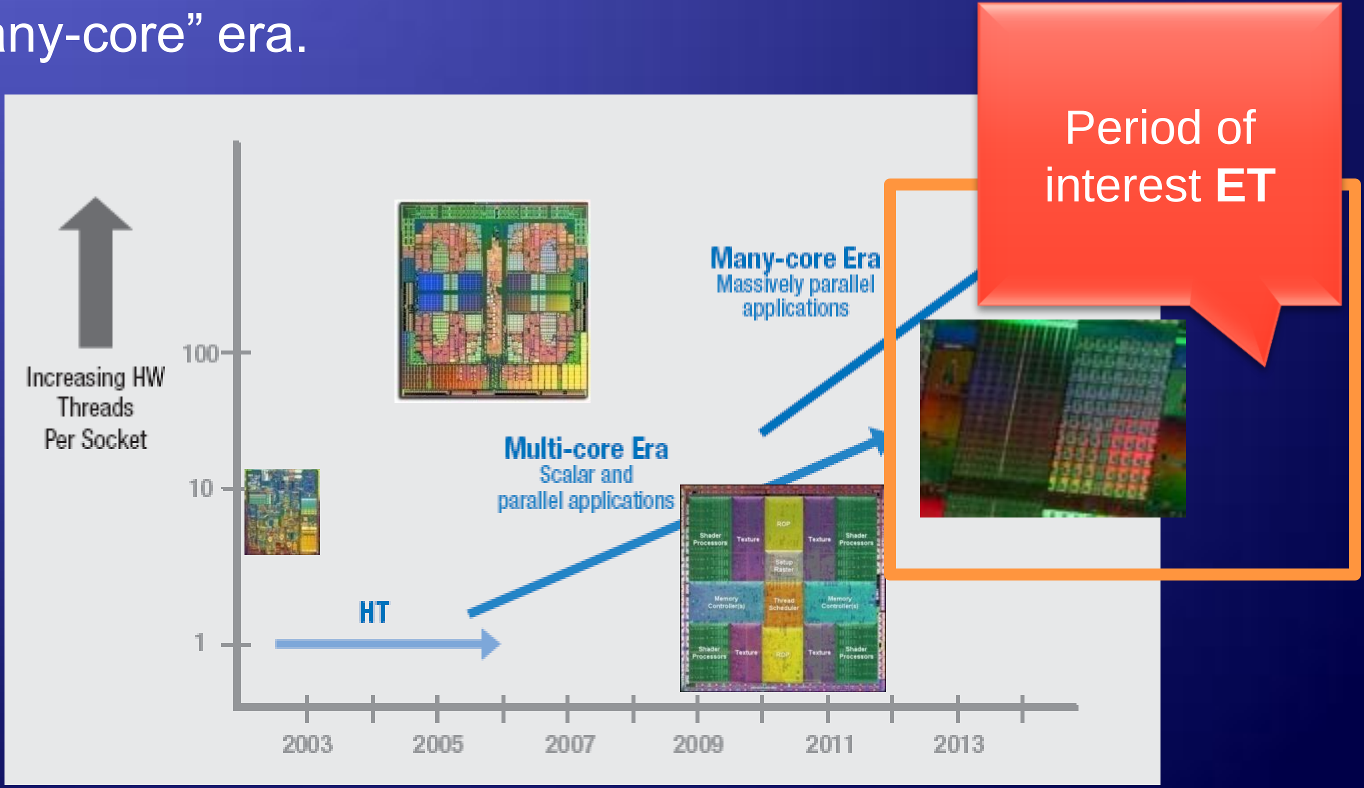
Technology Outlook

High Volume Manufacturing	2008	2010	2012	2014	2016	2018	2020	2022
Technology Node (nm)	45	32	22	16	11	8	6	4
Integration Capacity (BT)	8	16	32	64	128	256	512	1024

Intel ref.

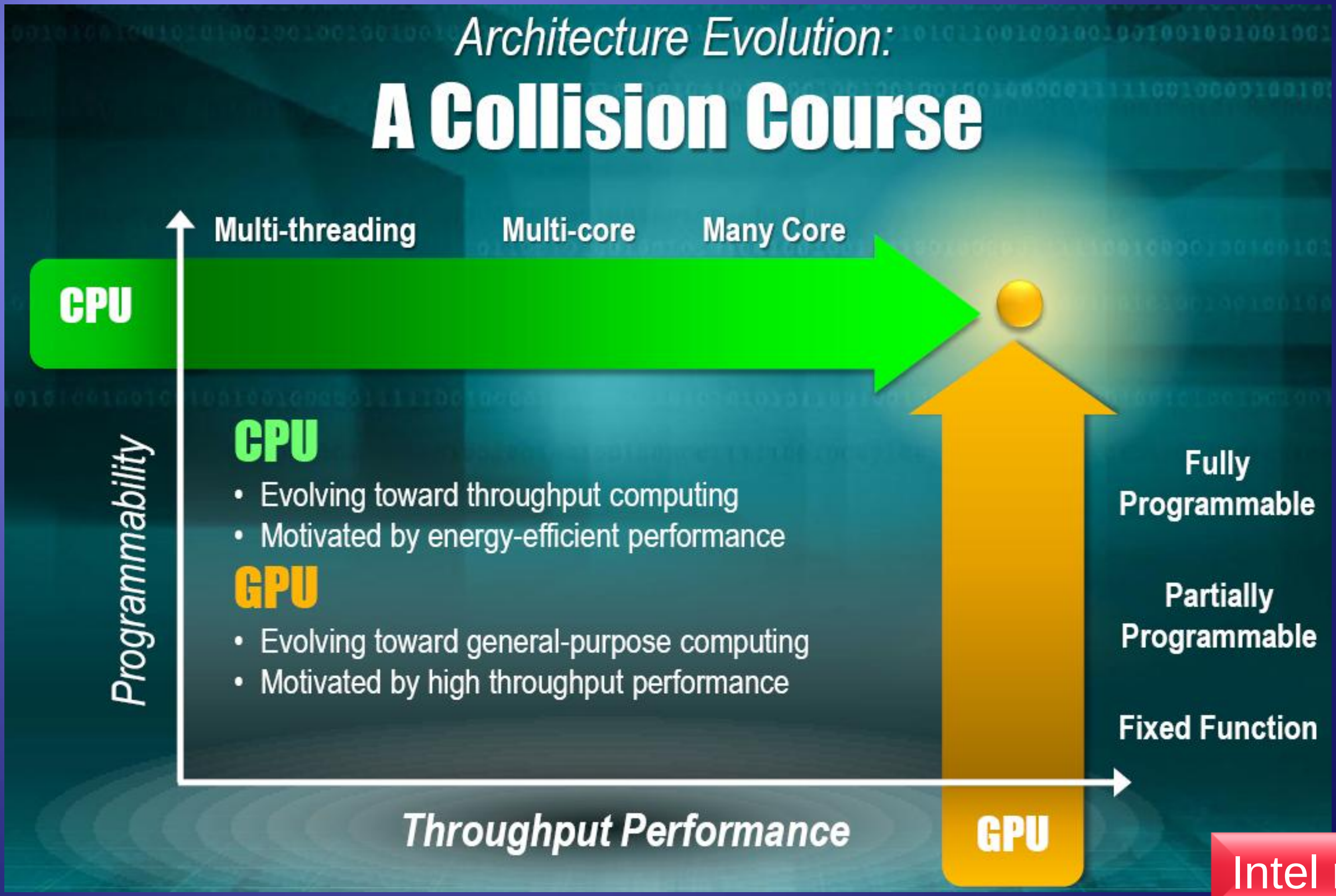
Technological outlook:

- Most important chip semiconductor maker are working in order to limit the problems due to integration scale reduction.
- In the last 10 years processor architectures are changed a lot, introducing parallelization at several architectural levels.
- That evolutive process will continue in a deeper way, moving to the so called “many-core” era.



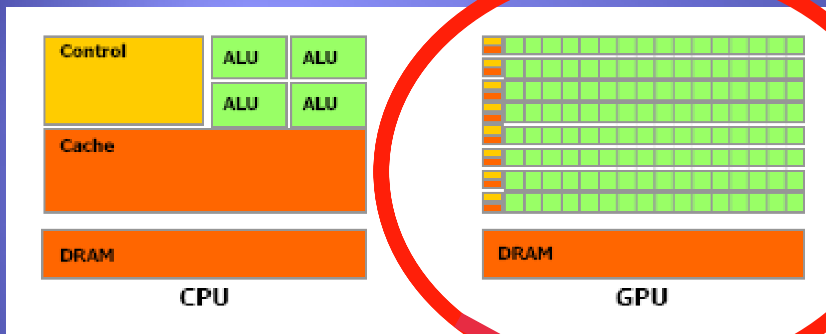
Intel ref.

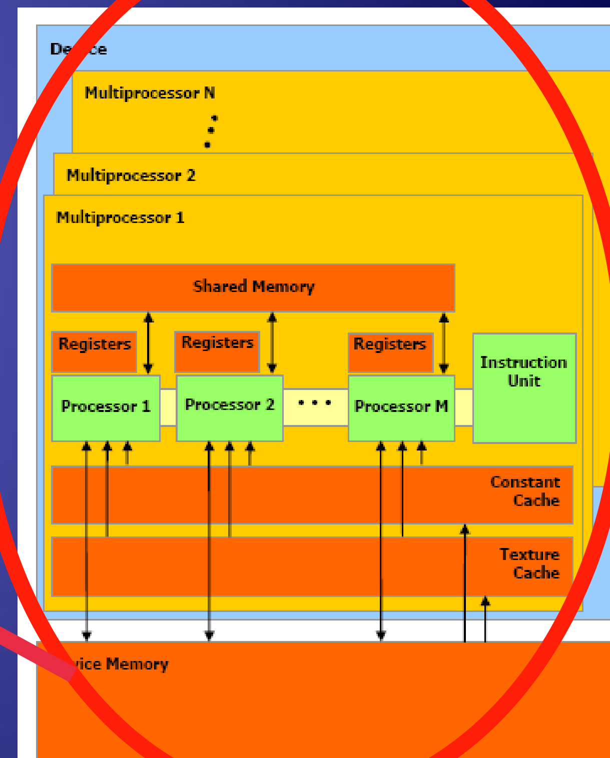
Architecture Evolution:



Intel ref.

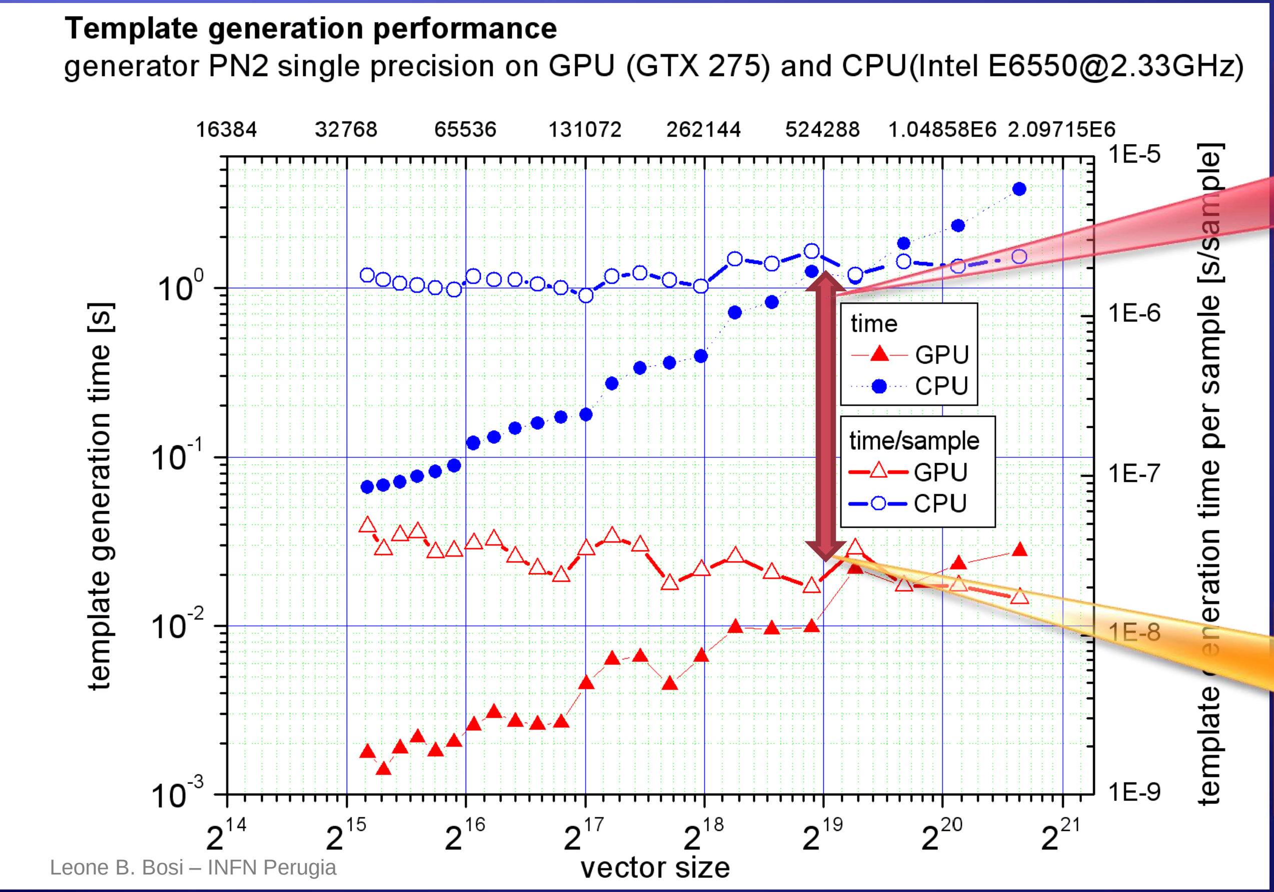
CPU – GPU (NVIDIA) architectural model comparison





- CPU
  - Optimized for low-latency access to cached data sets
  - Control logic for out-of-order and speculative execution
- GPU
  - Optimized for data-parallel, throughput computation
  - Architecture tolerant of memory latency
  - More transistors dedicated to computation

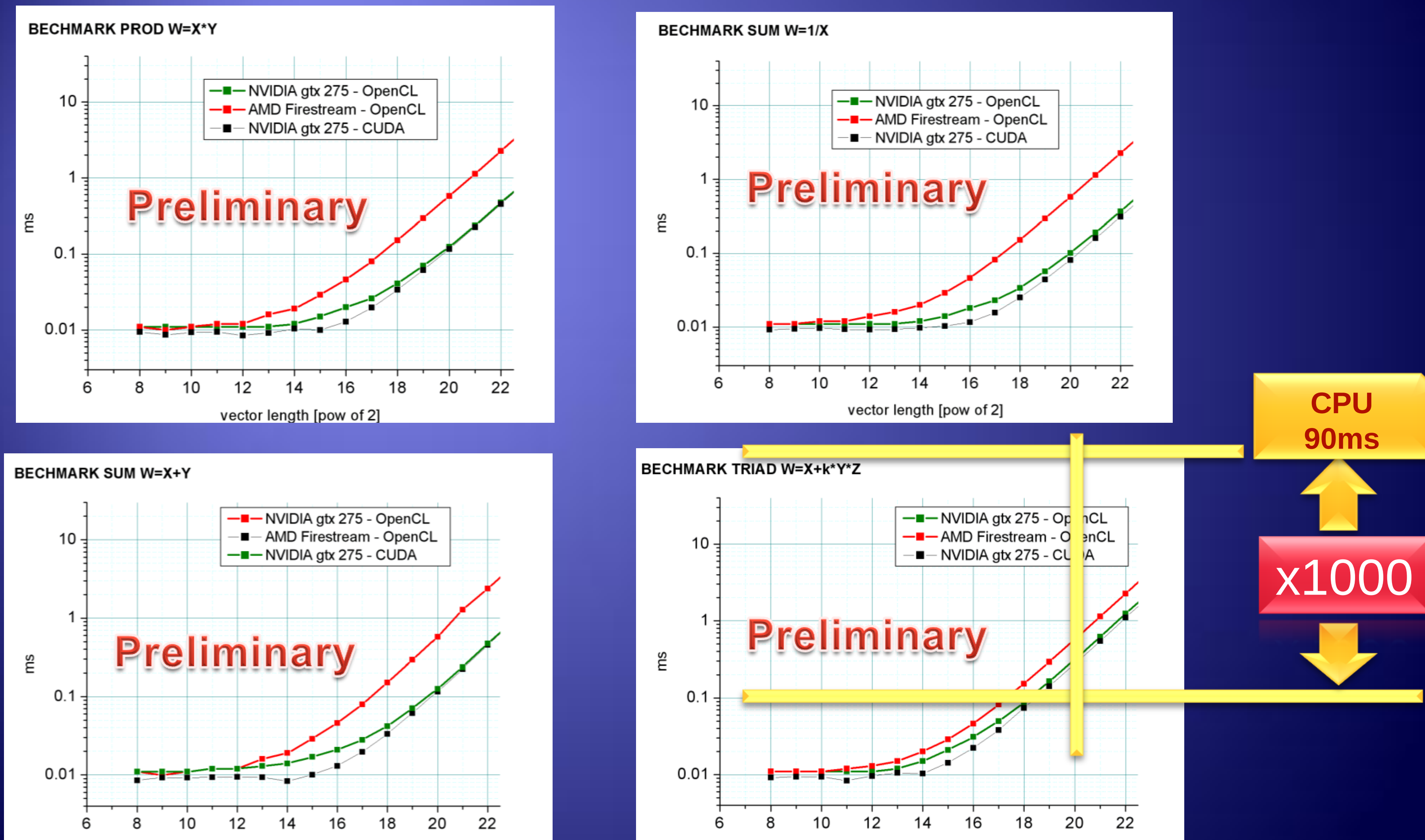
Signals generation: CB PN2 example



gain = X100

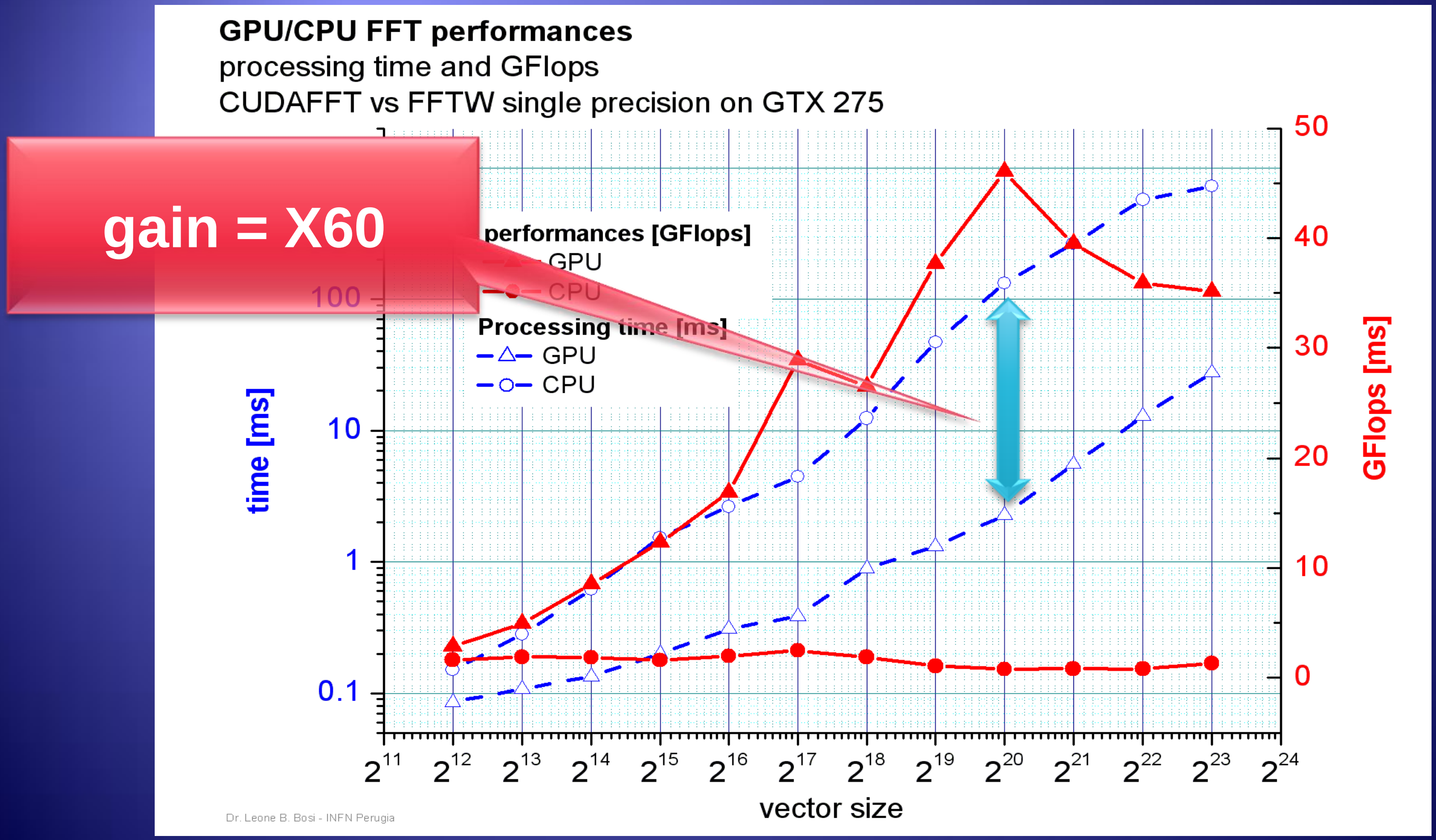
2-3 10^{-8} s/sample

Vector Operations:
Add-Mul-Inv-Triad

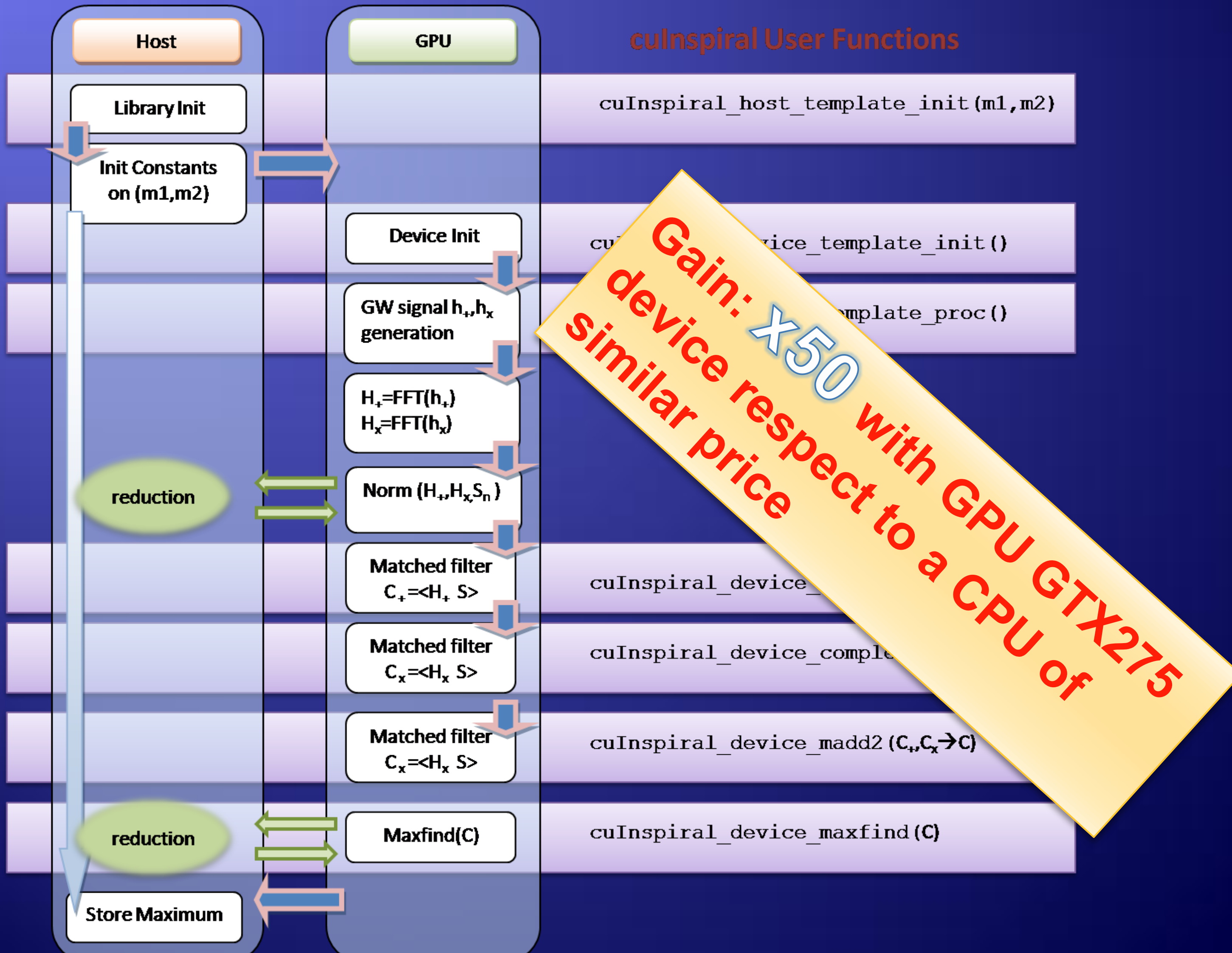


Results of MaGGO experiment. (NVIDIA GTX 275 vs ATI FireStream 9270)

Fast Fourier Transform (FFT):
CUDAFFT vs FFTW



CB pipeline speed up:
cuInspiral GW detection pipeline



CW Analysis speed up estimation:

Targeted

- Time-domain methods based on resampling
  - **X100**
- Heterodyne procedure (Abbott et al. PRL 94181103, 2005)
  - **X100**
- Frequency domain methods, based on likelihood maximization
  - **X 50**
- Frequency domain methods based on Analytical Signal
  - **X 40**

Blind search

- Hough transform
  - **X 40**
- Radon Transform
  - **X 10-20**

Preliminary

Simulations speed up estimation

Numerical Relativity:

- There are some interesting results about Numerical relativity.
- e.g. GPU has been used in the Cactus Computational Toolkit (CCT), used to solve Albert Einstein's field equations
  - http://www.ksc.re.kr/kcnr/nrg2009/baiotti-Whisky-Cactus.pdf
  - http://www.cct.lsu.edu/CCT-TR/CCT-TR-2008-1
- The speed up is of the order of **X50**

Optics:

- Ray-tracing **X200**
- Modal Analysis **X50**

Preliminary

Simulations speed up estimations:

Monte Carlo and
Random Numbers Generator **X50-250**

Magnetodynamic **X100**

Nbody simulation: **X80**

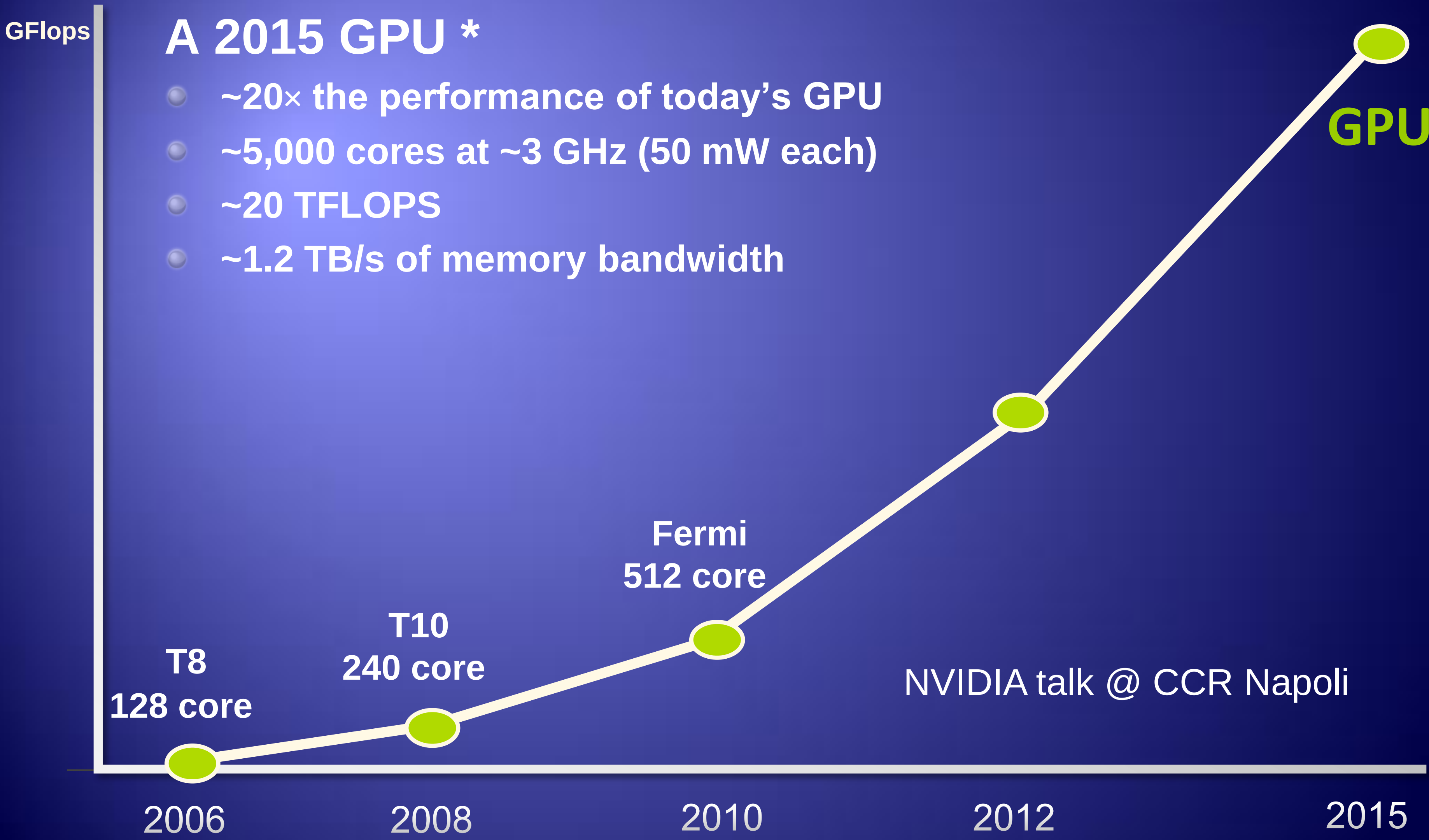
BLAS **>X4**

Preliminary

GPU next 5 year..

A 2015 GPU *

- ~20× the performance of today's GPU
- ~5,000 cores at ~3 GHz (50 mW each)
- ~20 TFLOPS
- ~1.2 TB/s of memory bandwidth



NVIDIA talk @ CCR Napoli

* This is a sketch of a what a GPU in 2015 might look like; it does not reflect any actual product plans.

GPU next 10 year..

- *If we make the hypothesis that CPU manufacturers follow the many-core direction*
- *If we use the actual GPU performances speed-up as reference*
- *We can try to simulate the available speed up for the algorithms previously introduced.*
- *Using the Moore's Law we can consider a conservative factor* **X100** *for 2020*
- *Using this information we can roughly predict the speed up respect actual CPU*

.. Speed up factor for 2020

Algorithm/Procedure	Speed up
Signal Generation	**X10000**
FFT	**X5000**
CB pipeline/Chi2	**X500**
CW Analysis Targeted	**X4000 - X10000**
CW Analysis Blind	**X1000 - X4000**
Numerical Relativity	**X5000**
Optics Ray tracing/Modal Analysis	**X20000 / X5000**
Monte Carlo / Random Number	**X5000 – X25000**
Magneto dynamic	**X10000**

Preliminary

Which ET Physics we can do or it is precluded with these numbers?