

# Computazione e Fisica

ovvero:

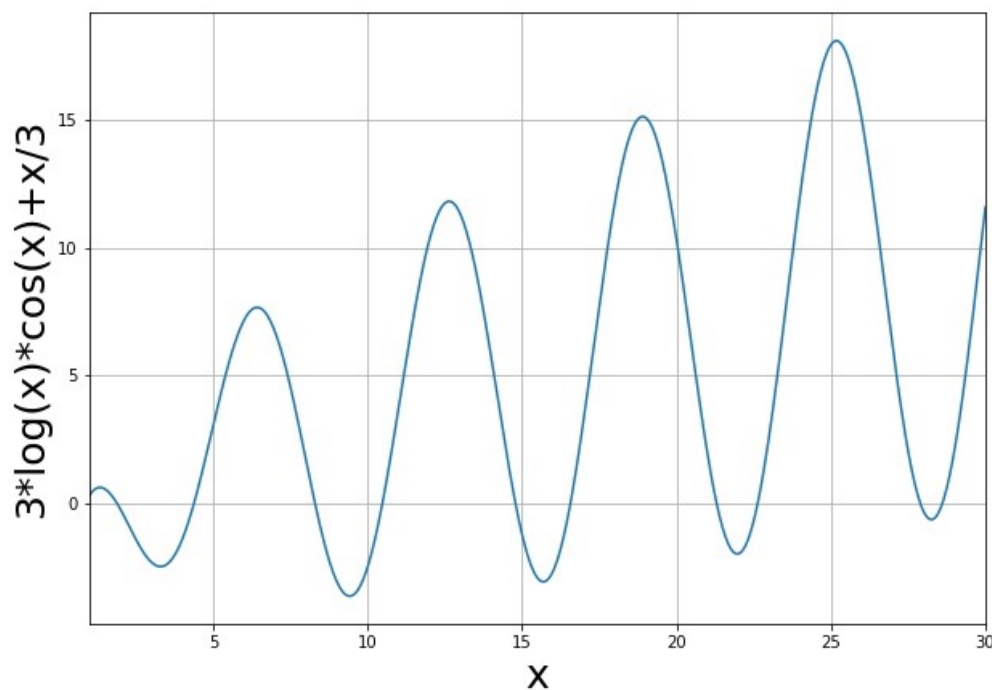
perchè Tecniche Informatiche  
al primo semestre del primo anno?

<http://www.to.infn.it/~maina/> → AA 2024/25:TIF

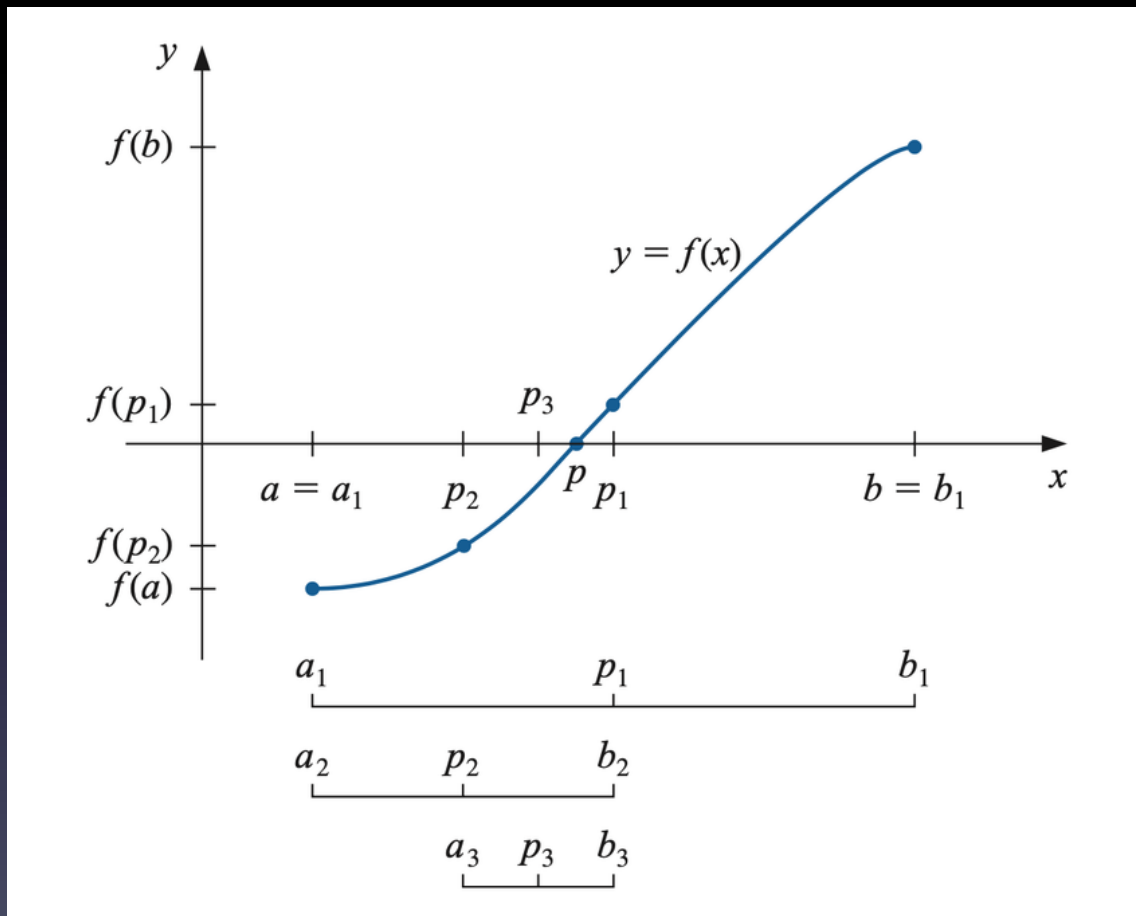
# Problemi semplici non risolvibili analiticamente

$$a_n x^n + a_{n-1} x^{n-1} + \dots + a_1 x + a_0 = 0$$

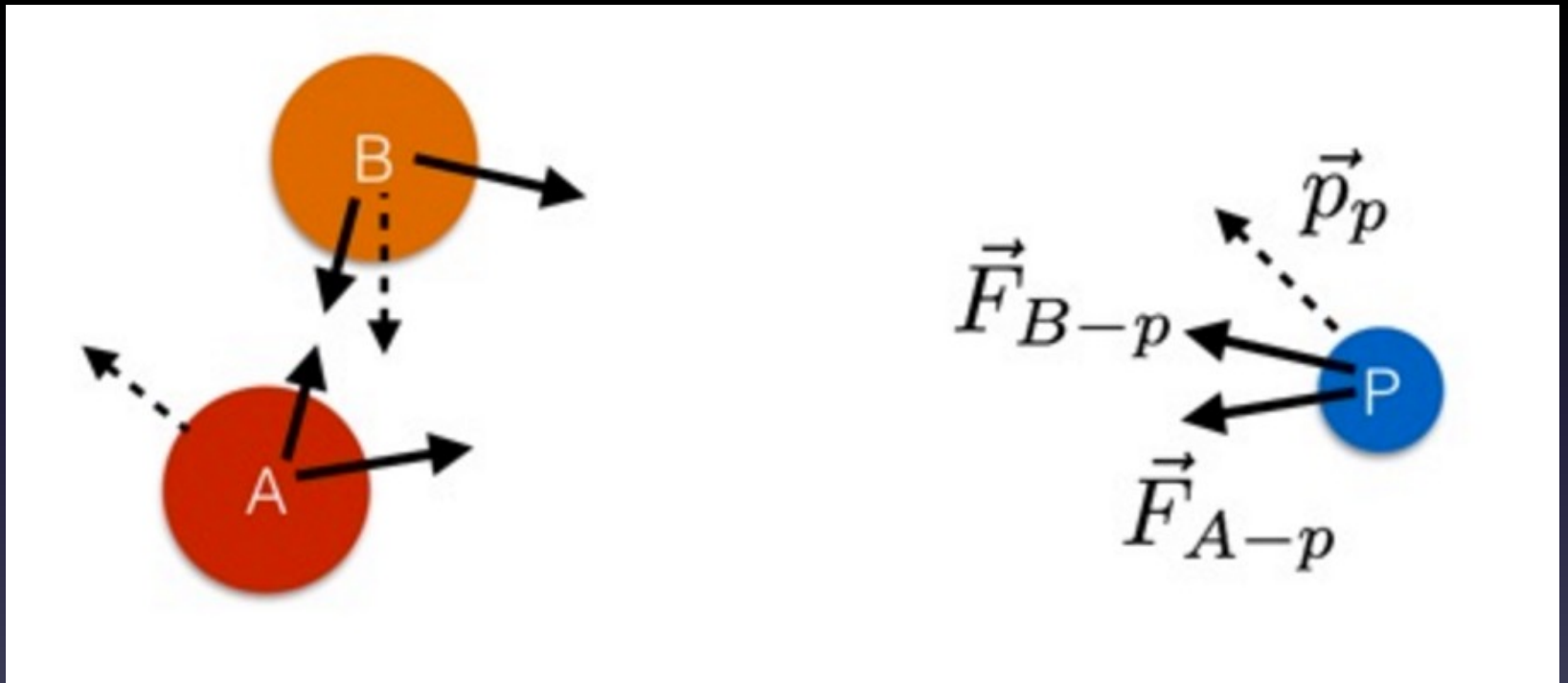
$$n > 4$$



# Trovare numericamente una radice di una funzione

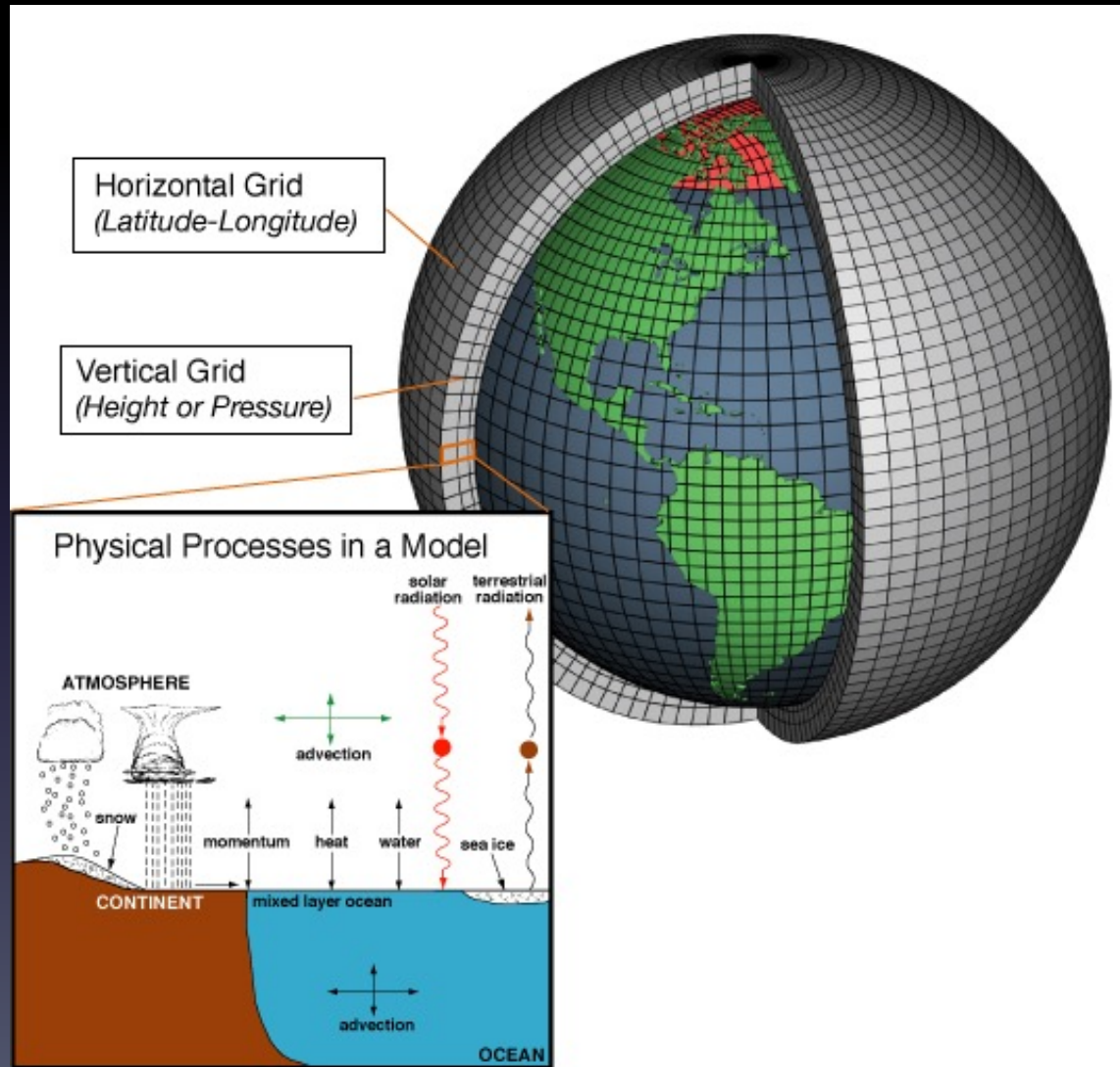


3 masse gravitanti: le forze sono note.  
Non sappiamo calcolare il moto.



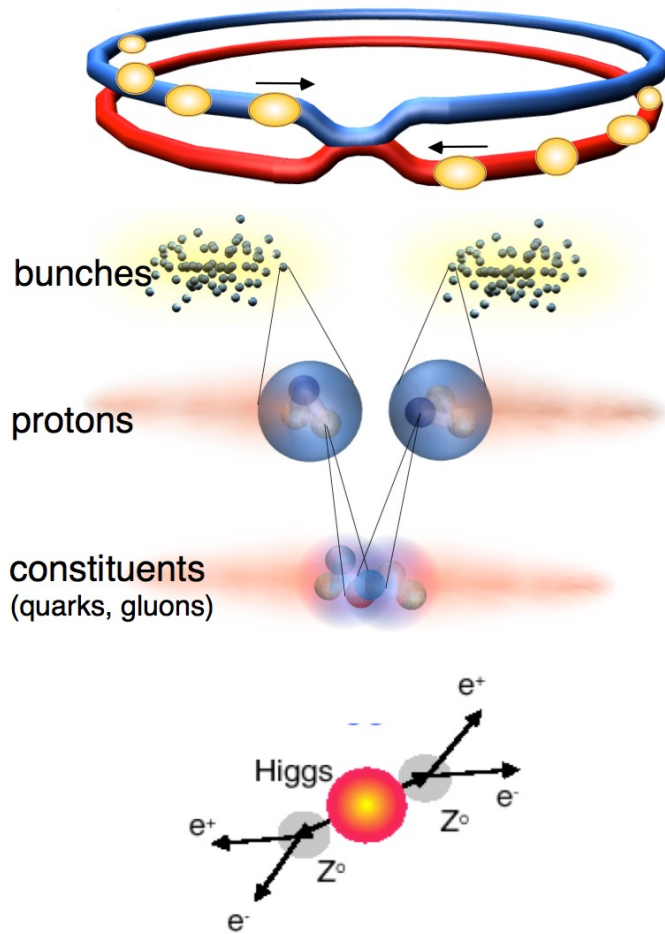
# Problemi complessi

## Dinamica dell'atmosfera



# Un esperimento al CERN

## proton collisions at LHC

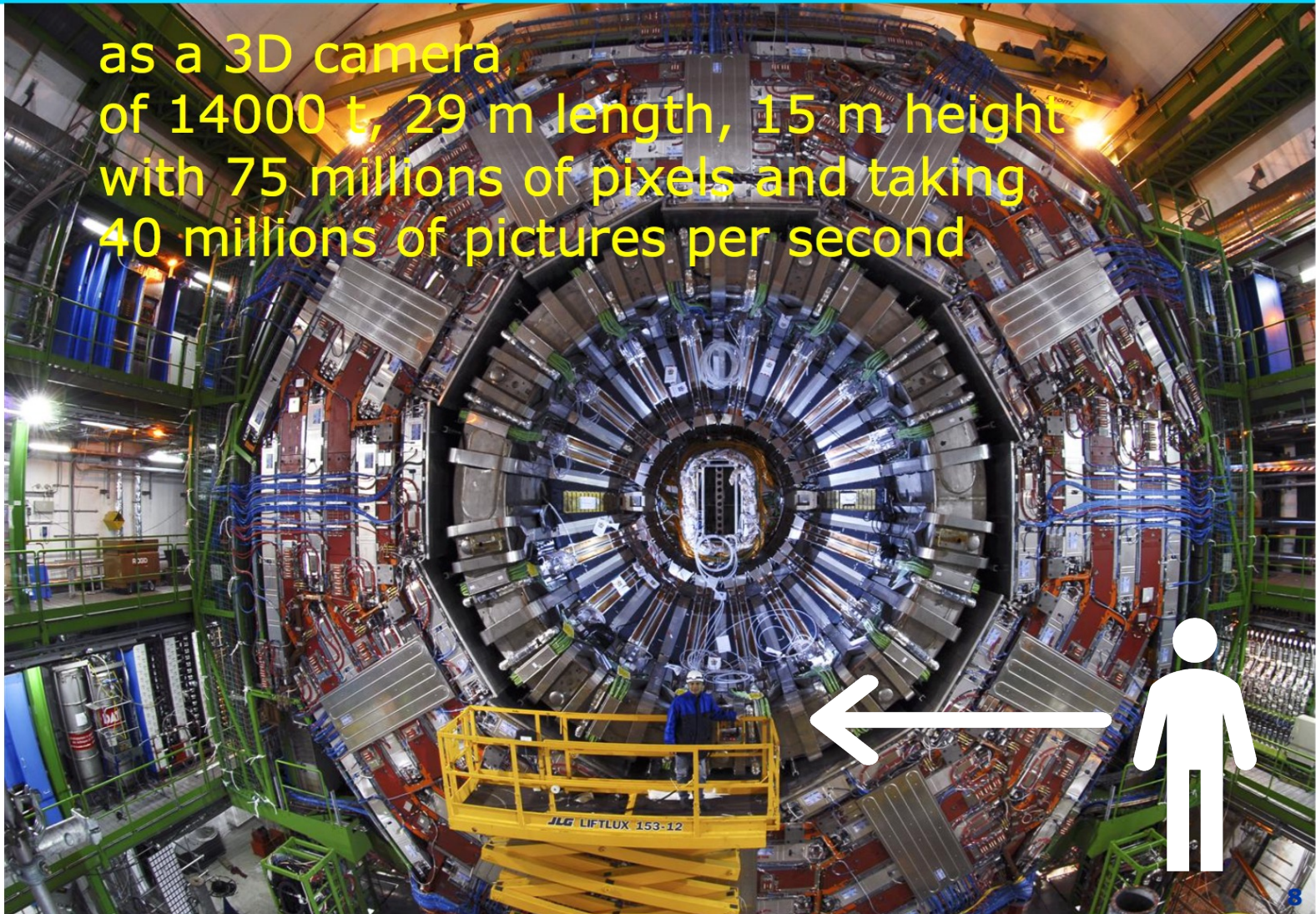


- 2800 bunches of protons
- energy of each proton : 6.5 TeV
- 100 billions protons / bunch
- beam crossing rate: 40 MHz
- in the experiments at each crossing:
  - ~ 20-50 proton-proton collisions
  - ~ 1500 particles produced
- 1 billion interactions / second
- impossible to record everything !
- a Higgs boson to find within 5 billions of collisions...



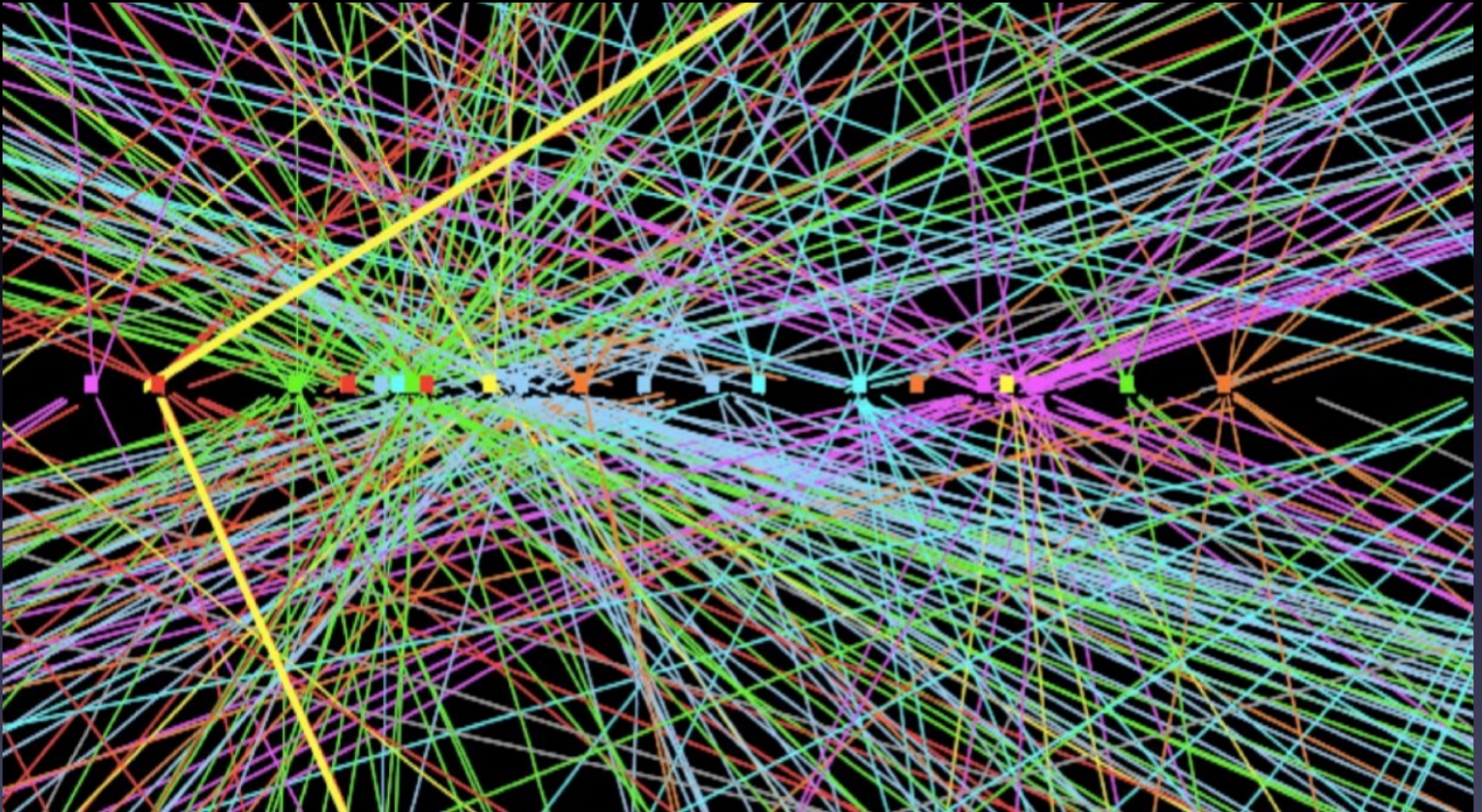
## the CMS detector

as a 3D camera  
of 14000 t, 29 m length, 15 m height  
with 75 millions of pixels and taking  
40 millions of pictures per second

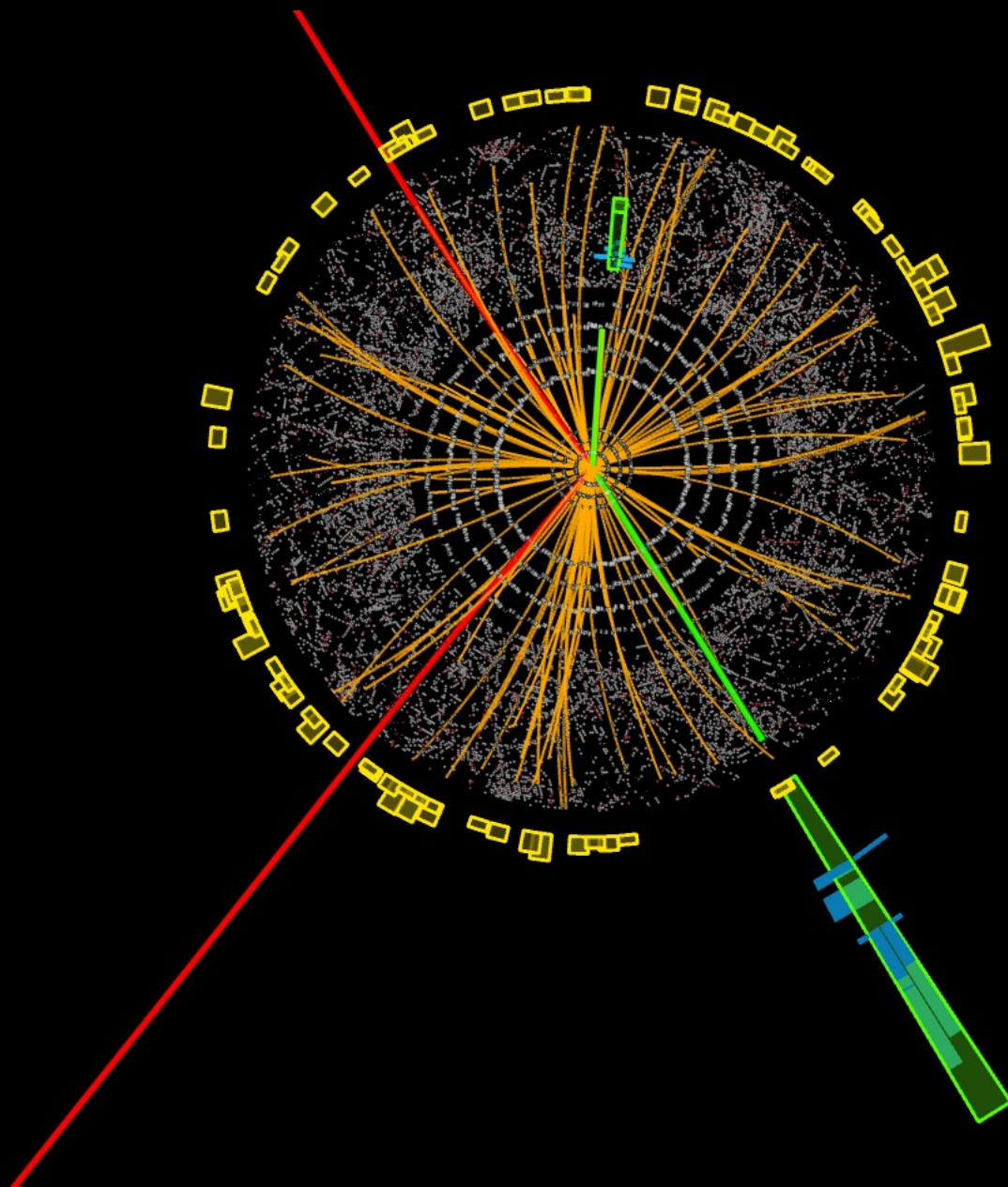




Un evento:  $\sim 20$  urti, ogni traccia una particella

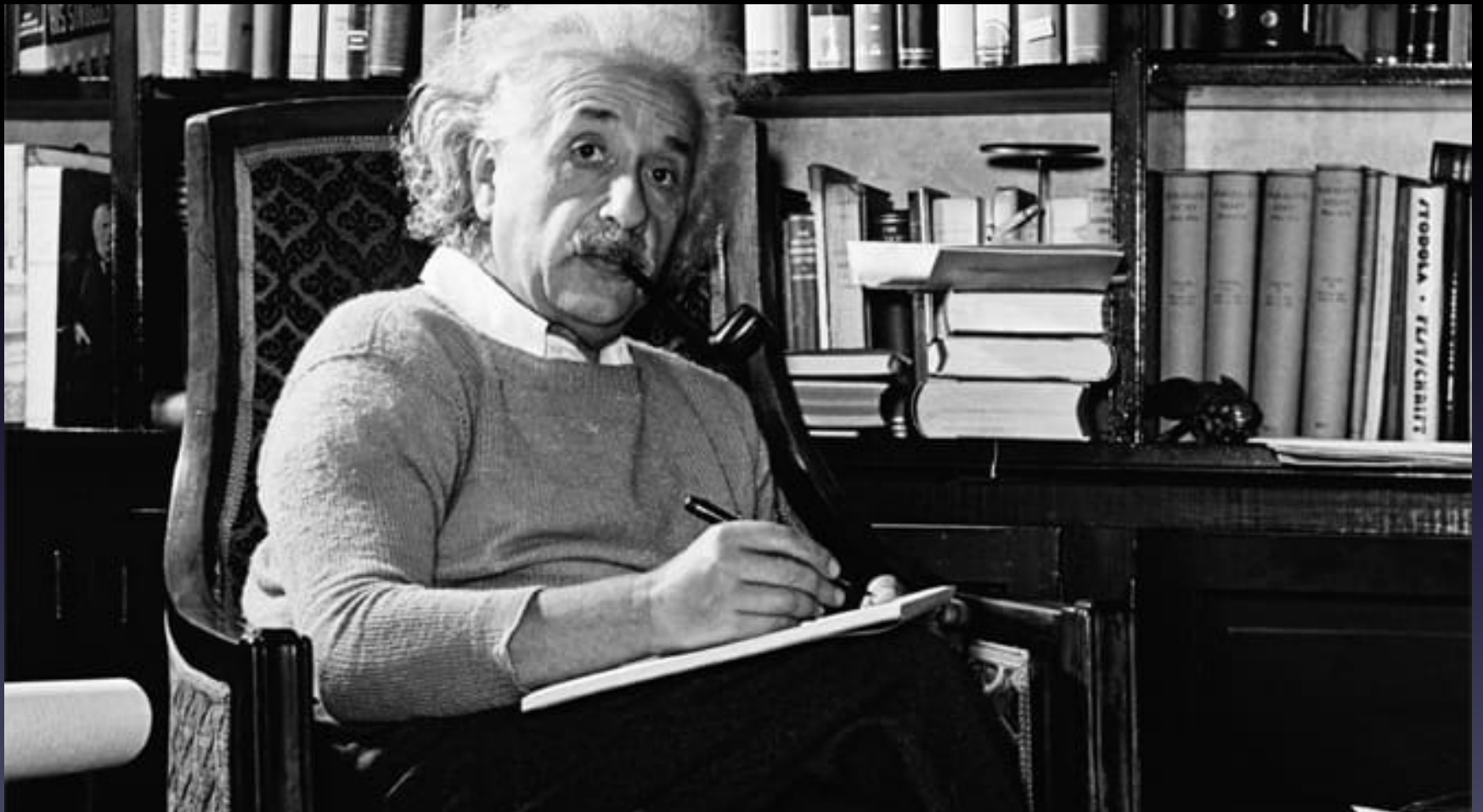






Run: 205113  
Event: 12611816  
Date: 2012-06-18  
Time: 11:07:47 CEST

Farò il teorico, come Einstein...




## Two-Loop Master Integrals for $\gamma^* \rightarrow 3$ Jets: The planar topologies

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Agosto 2000



$$= \left( \frac{S_\epsilon}{16\pi^2} \right)^2 \frac{(-s_{123})^{-2\epsilon}}{s_{12} + s_{13}} \sum_{i=-1}^3 \frac{f_{5.1,i} \left( \frac{s_{13}}{s_{123}}, \frac{s_{23}}{s_{123}} \right)}{\epsilon^i} + \mathcal{O}(\epsilon^2), \quad (4.20)$$

with:

$$f_{5.1,3}(y, z) = 0, \quad (4.21)$$

$$f_{5.1,2}(y, z) = -H(0; z), \quad (4.22)$$

$$f_{5.1,1}(y, z) = +H(0; y)H(0; z) - 2H(0; z) + 2H(0, 0; z) + H(1, 0; z) + \frac{\pi^2}{6}, \quad (4.23)$$

$$\begin{aligned} f_{5.1,0}(y, z) = & +2H(0; y)H(0; z) - 2H(0; y)H(1, 0; z) - 4H(0; z) - H(0; z)H(1 - z, 0; y) \\ & - 2H(0, 0; y)H(0; z) + 4H(0, 0; z) - 2H(0, 0; z)H(0; y) - 4H(0, 0, 0; z) - H(0, 1, 0; y) \\ & - 2H(0, 1, 0; z) + 2H(1, 0; z) - H(1, 0; z)H(1 - z; y) - 2H(1, 0, 0; z) - 2H(1, 1, 0; z) \\ & - H(1 - z, 1, 0; y) + \frac{\pi^2}{6} [ +2 - 2H(0; y) - 3H(0; z) - 2H(1; z) - H(1 - z; y) ], \end{aligned} \quad (4.24)$$

$$\begin{aligned} f_{5.1,-1}(y, z) = & +4H(0; y)H(0; z) - 4H(0; y)H(1, 0; z) + 4H(0; y)H(1, 0, 0; z) + 4H(0; y)H(1, 1, 0; z) \\ & - 8H(0; z) - 2H(0; z)H(1 - z, 0; y) + 2H(0; z)H(1 - z, 0, 0; y) \\ & + H(0; z)H(1 - z, 1 - z, 0; y) - 4H(0, 0; y)H(0; z) + 4H(0, 0; y)H(0, 0; z) \\ & + 4H(0, 0; y)H(1, 0; z) + 8H(0, 0; z) - 4H(0, 0; z)H(0; y) + 2H(0, 0; z)H(1 - z, 0; y) \\ & + 4H(0, 0, 0; y)H(0; z) - 8H(0, 0, 0; z) + 4H(0, 0, 0; z)H(0; y) + 8H(0, 0, 0, 0; z) \\ & + 2H(0, 0, 1, 0; y) + 4H(0, 0, 1, 0; z) - 2H(0, 1, 0; y) - 4H(0, 1, 0; z) \\ & + 4H(0, 1, 0; z)H(0; y) + 2H(0, 1, 0; z)H(1 - z; y) + 2H(0, 1, 0, 0; y) + 4H(0, 1, 0, 0; z) \end{aligned}$$

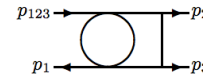


Per arrivare a queste  
formule  
sono stati necessari  
mesi di tempo  
macchina

$$\begin{aligned}
& -H(0, 1, 1, 0; y) + 4H(0, 1, 1, 0; z) + 2H(0, 1 - z; y)H(1, 0; z) \\
& + 2H(0, 1 - z, 0; y)H(0; z) + 2H(0, 1 - z, 1, 0; y) + 4H(1, 0; z) - 2H(1, 0; z)H(1 - z; y) \\
& + 2H(1, 0; z)H(1 - z, 0; y) + H(1, 0; z)H(1 - z, 1 - z; y) - 4H(1, 0, 0; z) \\
& + 2H(1, 0, 0; z)H(1 - z; y) + 4H(1, 0, 0, 0; z) + 4H(1, 0, 1, 0; z) - 4H(1, 1, 0; z) \\
& + 2H(1, 1, 0; z)H(1 - z; y) + 4H(1, 1, 0, 0; z) + 4H(1, 1, 1, 0; z) + H(1 - z, 0, 1, 0; y) \\
& - 2H(1 - z, 1, 0; y) + 2H(1 - z, 1, 0, 0; y) - H(1 - z, 1, 1, 0; y) + H(1 - z, 1 - z, 1, 0; y) \\
& + \frac{7\pi^4}{90} + 5\zeta_3 H(0; z) \\
& + \frac{\pi^2}{6} \left[ + 4 - 4H(0; y) + 4H(0; y)H(0; z) + 4H(0; y)H(1; z) - 6H(0; z) \right. \\
& + H(0; z)H(1 - z; y) + 4H(0, 0; y) + 6H(0, 0; z) - H(0, 1; y) \\
& + 2H(0, 1 - z; y) - 4H(1; z) + 2H(1; z)H(1 - z; y) + 4H(1, \\
& \left. - 2H(1 - z; y) + 2H(1 - z, 0; y) - H(1 - z, 1; y) + H(1 - z
\end{aligned}$$

Ognuno degli  $H(\dots)$  è  
una funzione da  
valutare  
numericamente

$$\begin{aligned}
& -2H(1 - z, 0, 1, 0; y) + 2H(1 - z, 1, 0; y) - 2H(1 - z, 1, 0, 0; y) \\
& - H(1 - z, 1 - z, 1, 0; y) + \frac{37\pi^4}{360} + \zeta_3 [10 - 6H(0; y) - 5H(0; z) - H(1; z) - H(1 - z; y)] \\
& + \frac{\pi^2}{6} \left[ + 2H(0; y) - H(0; y)H(0; z) - H(0; y)H(1; z) - H(0; z)H(1 - z; y) \right. \\
& - 2H(0, 0; y) - H(0, 1; z) - 2H(0, 1 - z; y) + 2H(1; z) \\
& \left. - H(1, 0; z) + 2H(1 - z; y) - H(1 - z, 0; y) - H(1 - z, 1 - z; y) \right] .
\end{aligned} \tag{4.31}$$



$$= \left( \frac{S_\epsilon}{16\pi^2} \right)^2 \frac{(-s_{123})^{-2\epsilon}}{s_{23}} \sum_{i=-1}^3 \frac{f_{5,2,i} \left( \frac{s_{13}}{s_{123}}, \frac{s_{23}}{s_{123}} \right)}{\epsilon^i} + \mathcal{O}(\epsilon^2), \tag{4.26}$$

with:

$$f_{5,2,3}(y, z) = -1, \tag{4.27}$$

$$f_{5,2,2}(y, z) = -2 + H(0; y) + H(0; z), \tag{4.28}$$

$$f_{5,2,1}(y, z) = -4 + 2H(0; y) - H(0; y)H(0; z) + 2H(0; z) - 2H(0, 0; y) - H(0, 0; z) - H(1, 0; y), \tag{4.29}$$

$$\begin{aligned}
f_{5,2,0}(y, z) = & -8 + 4H(0; y) - 2H(0; y)H(0; z) + H(0; y)H(1, 0; z) + 4H(0; z) + H(0; z)H(1 - z, 0; y) \\
& - 4H(0, 0; y) + 2H(0, 0; y)H(0; z) - 2H(0, 0; z) + H(0, 0; z)H(0; y) + 4H(0, 0, 0; y) \\
& + H(0, 0, 0; z) + 2H(0, 1, 0; y) - 2H(1, 0; y) + H(1, 0; z)H(1 - z; y) + 2H(1, 0, 0; y) \\
& + H(1, 1, 0; z) + H(1 - z, 1, 0; y) + 5\zeta_3 + \frac{\pi^2}{6} [ + H(0; y) + H(1; z) + H(1 - z; y) ] ,
\end{aligned} \tag{4.30}$$

$$\begin{aligned}
f_{5,2,-1}(y, z) = & -16 + 8H(0; y) - 4H(0; y)H(0; z) + 2H(0; y)H(1, 0; z) - H(0; y)H(1, 0, 0; z) \\
& - H(0; y)H(1, 1, 0; z) + 8H(0; z) + 2H(0; z)H(1 - z, 0; y) - 2H(0; z)H(1 - z, 0, 0; y) \\
& - H(0; z)H(1 - z, 1 - z, 0; y) - 8H(0, 0; y) + 4H(0, 0; y)H(0; z) - 2H(0, 0; y)H(0, 0; z) \\
& - 2H(0, 0; y)H(1, 0; z) - 4H(0, 0; z) + 2H(0, 0; z)H(0; y) - H(0, 0; z)H(1 - z, 0; y) \\
& + 8H(0, 0, 0; y) - 4H(0, 0, 0; y)H(0; z) + 2H(0, 0, 0; z) - H(0, 0, 0; z)H(0; y) \\
& - 8H(0, 0, 0, 0; y) - H(0, 0, 0, 0; z) - 4H(0, 0, 1, 0; y) + 4H(0, 1, 0; y) \\
& - H(0, 1, 0; z)H(0; y) - H(0, 1, 0; z)H(1 - z; y) - 4H(0, 1, 0, 0; y) - H(0, 1, 1, 0; z) \\
& - 2H(0, 1 - z; y)H(1, 0; z) - 2H(0, 1 - z, 0; y)H(0; z) - 2H(0, 1 - z, 1, 0; y) \\
& - 4H(1, 0; y) + 2H(1, 0; z)H(1 - z; y) - H(1, 0; z)H(1 - z, 0; y) \\
& - H(1, 0; z)H(1 - z, 1 - z; y) + 4H(1, 0, 0; y) - H(1, 0, 0; z)H(1 - z; y) \\
& - 4H(1, 0, 0, 0; y) - H(1, 0, 1, 0; z) + 2H(1, 1, 0; z) - H(1, 1, 0, 0; z)
\end{aligned}$$

Risolvere numericamente un problema richiede  
la capacità di spezzarlo in parti più semplici,  
di individuare i passi per ottenere la risposta,  
di controllare la correttezza di ogni passo

Non vi laureerete senza imparare a programmare

**Cominciamo subito**

<http://www.to.infn.it/~maina/>