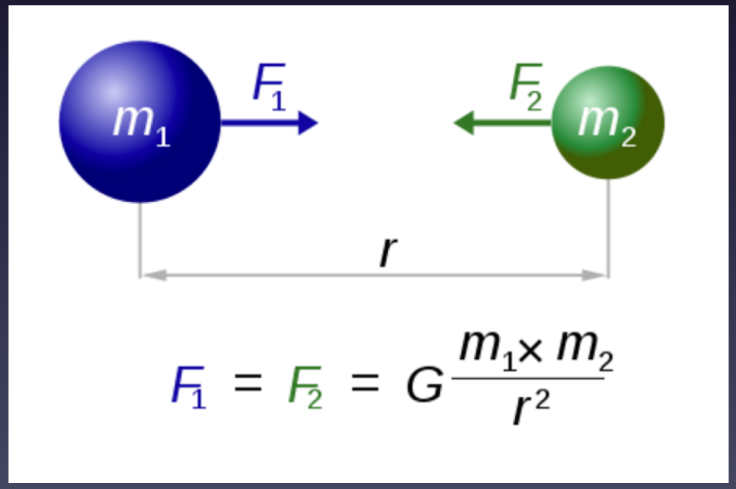
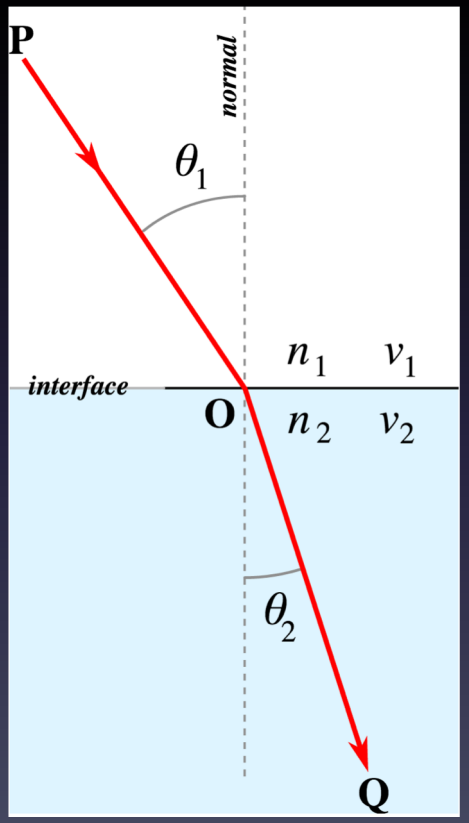
Computers e Fisica

- Fisica è descrivere la realtà in formule
- Predizione
- Verifica/Esperimento



$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

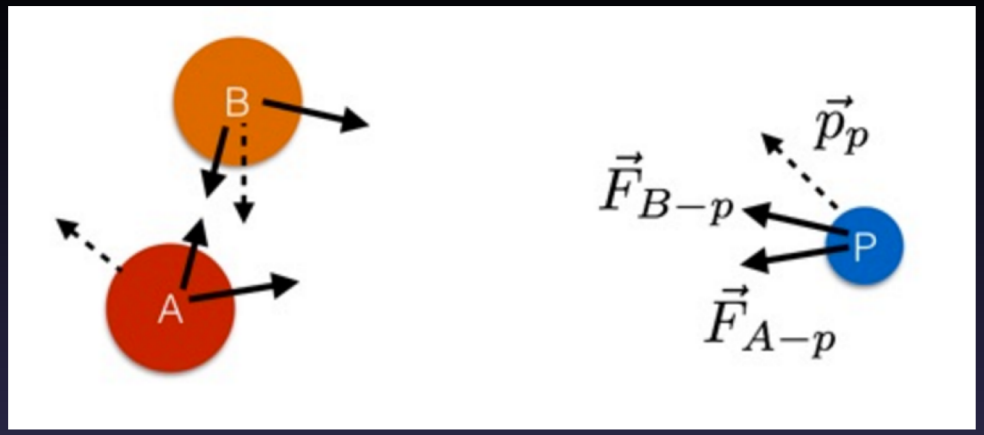


Problemi semplici non risolvibili "analiticamente"

- Eq. algebrica di grado n >4

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

- Il problema di 3 masse gravitanti



- Integrale "innocuo" non esprimibile in funzioni elementari

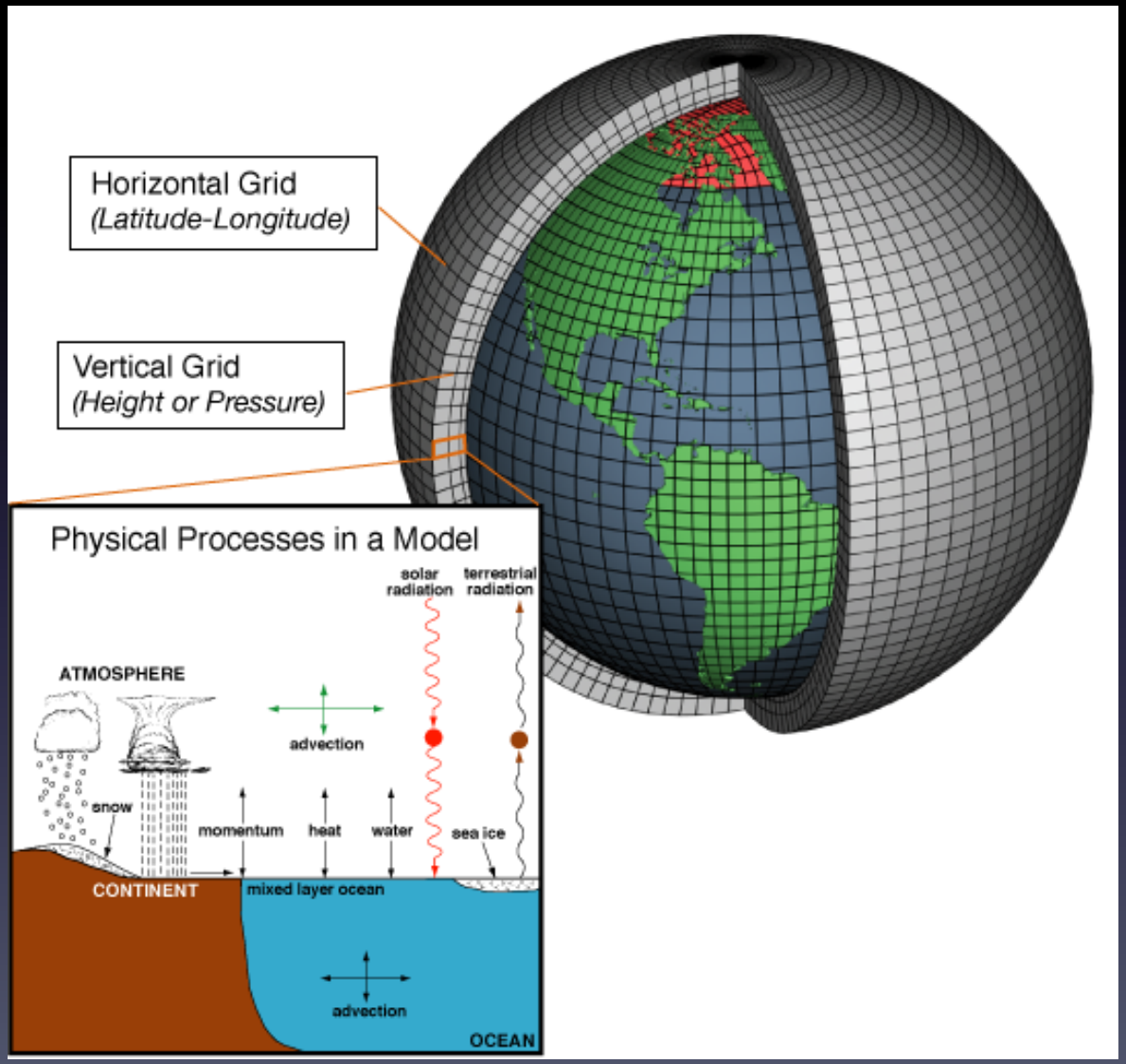
$$\mathrm{Li}_2(z) = -\int_0^z \frac{\ln(1-u)}{u}\,\mathrm{d}u,\ z \in \mathbb{C} \setminus [1,\infty)$$

$$\mathrm{Li}_2(z) = \sum_{k=1}^{\infty} \frac{z^k}{k^2}.$$

$|z| < 1$

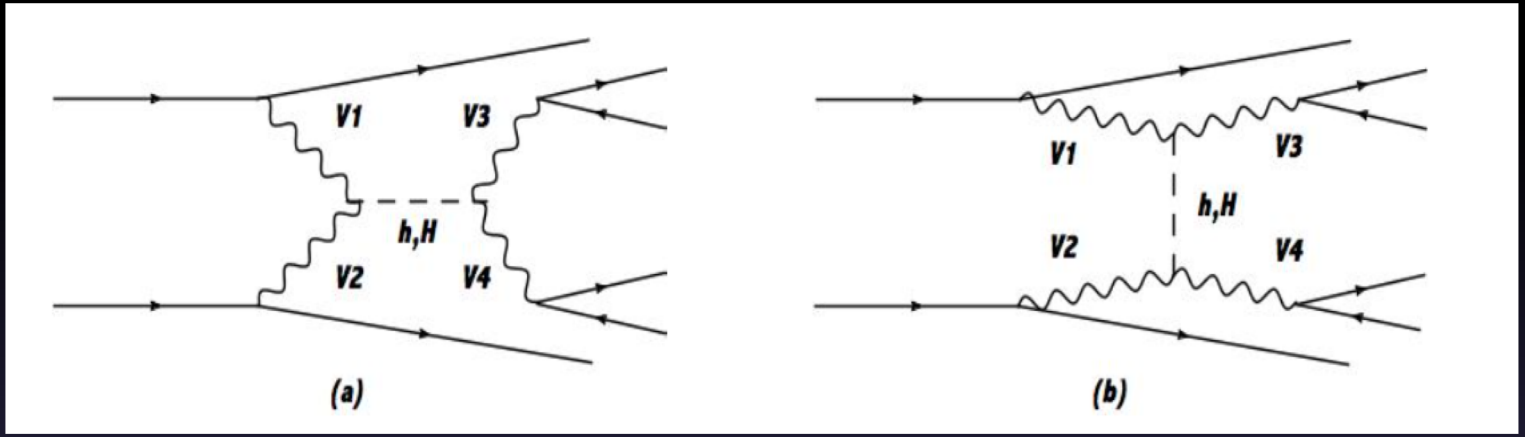
Problemi troppo complessi da risolvere analiticamente

- Dinamica atmosfera



Problemi troppo complessi da risolvere analiticamente

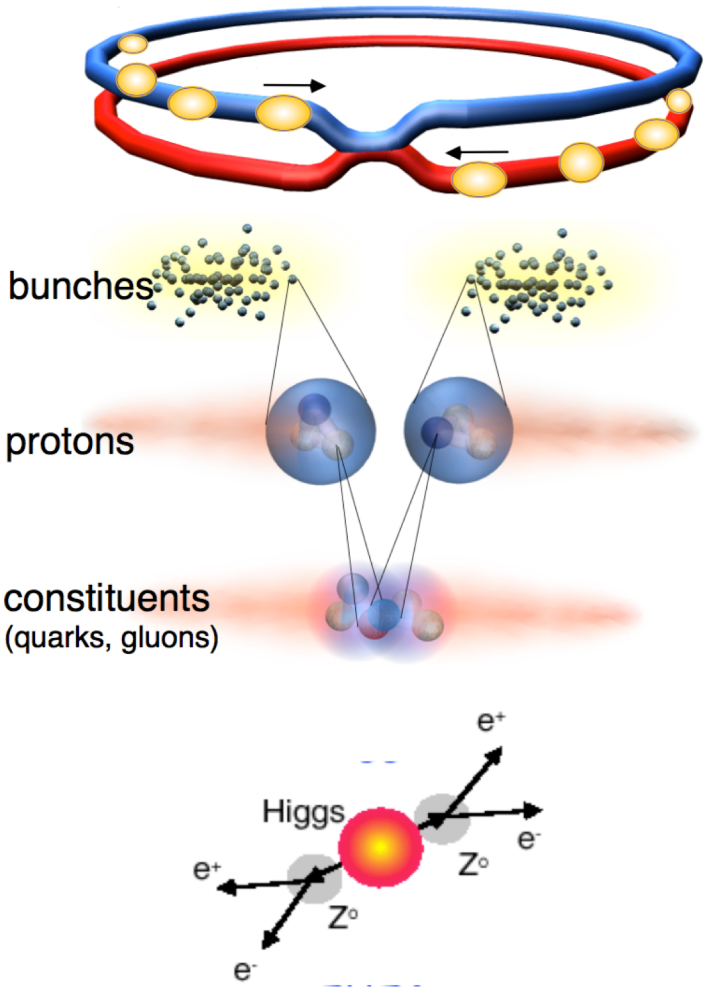
- Urto fra particelle elementari $2 \to n$



Richiede come minimo :

- Centinaia di termini
- Integrazione su $3n-4$ variabili

proton collisions at LHC



- 2800 bunches of protons
- energy of each proton : 6.5 TeV
- 100 billions protons / bunch
- beam crossing rate: 40 MHz

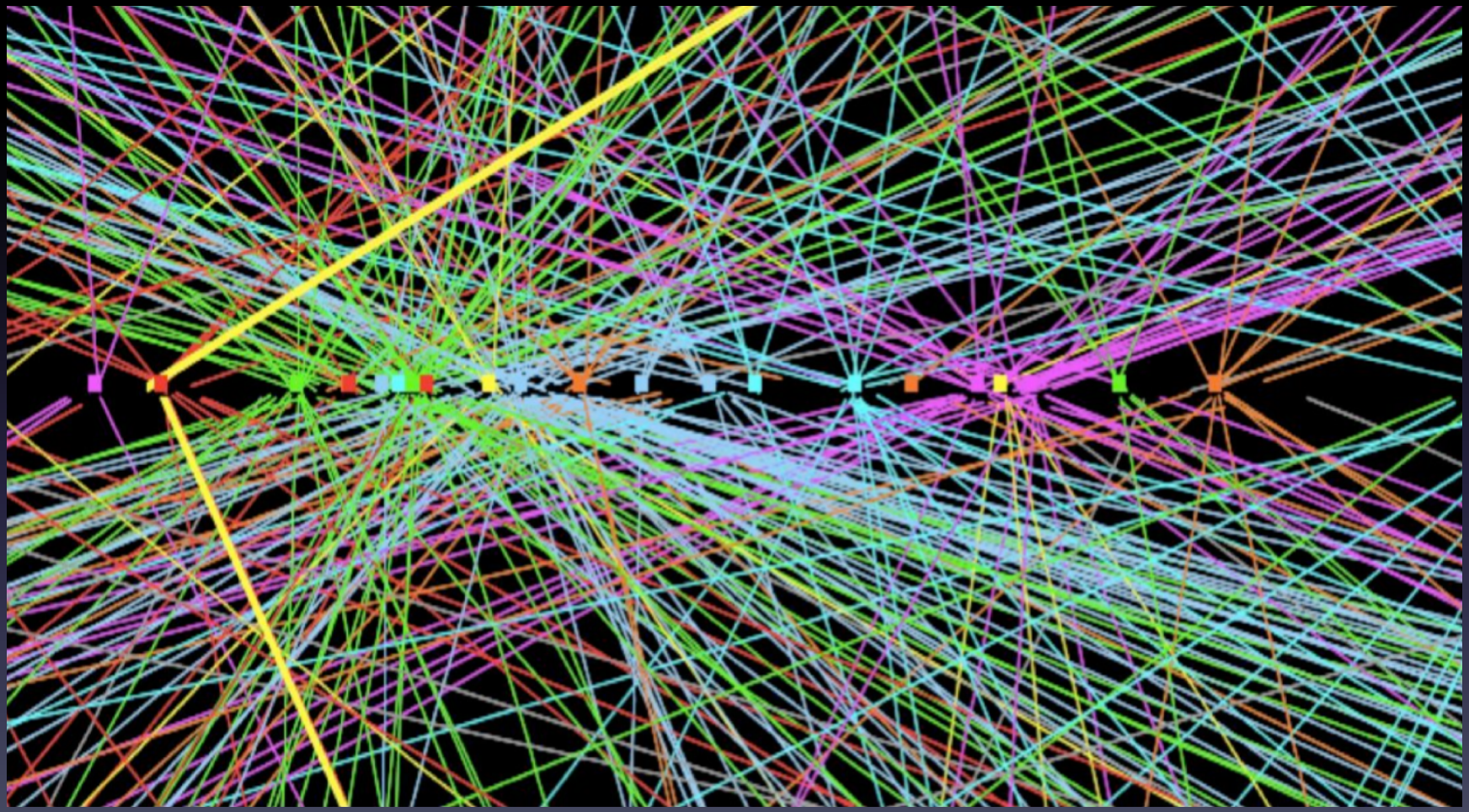
- in the experiments at each crossing:
  ~ 20-50 proton-proton collisions
  ~ 1500 particles produced

- 1 billion interactions / second

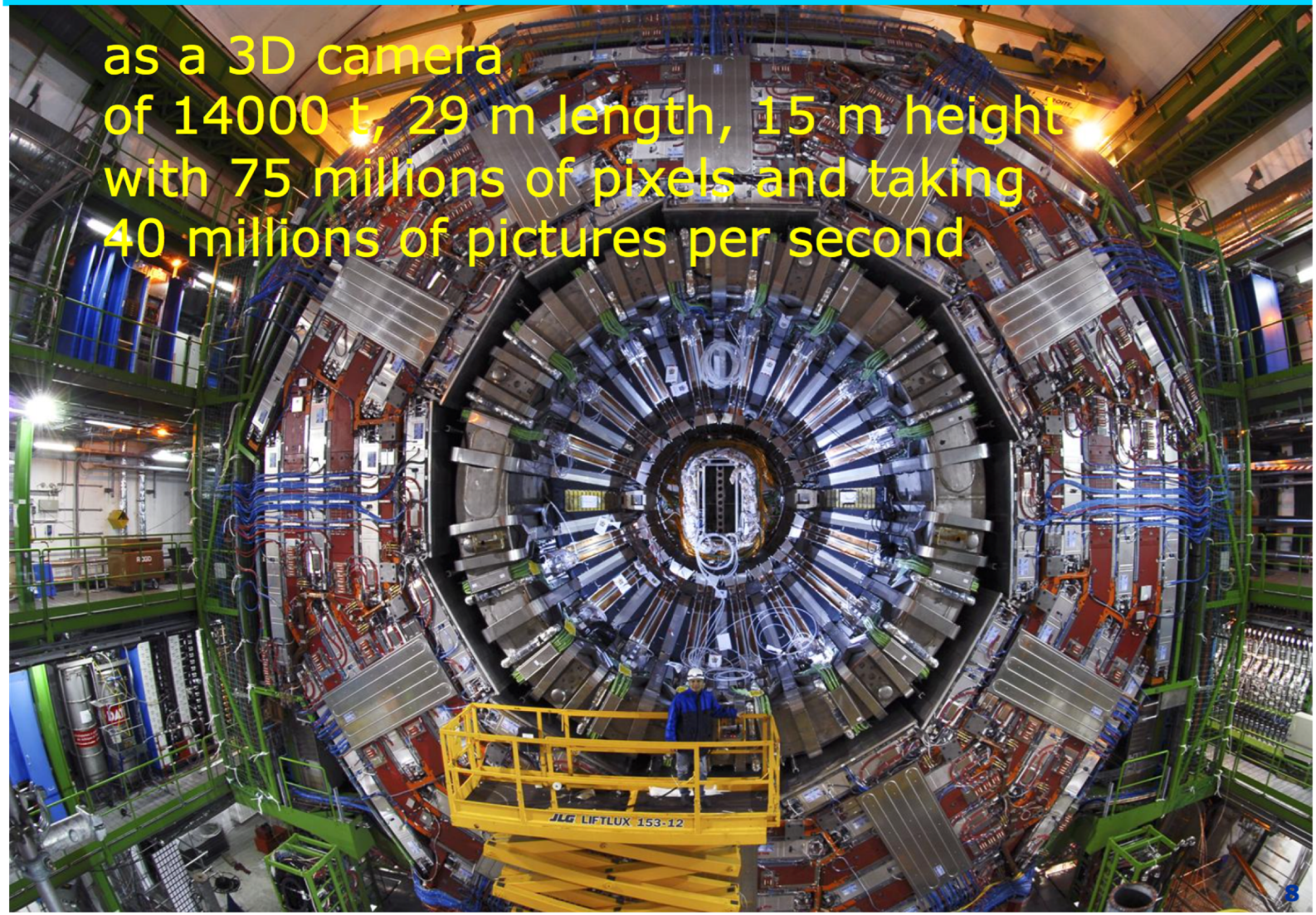
- impossible to record everything !

- a Higgs boson to find within 5 billions of collisions…

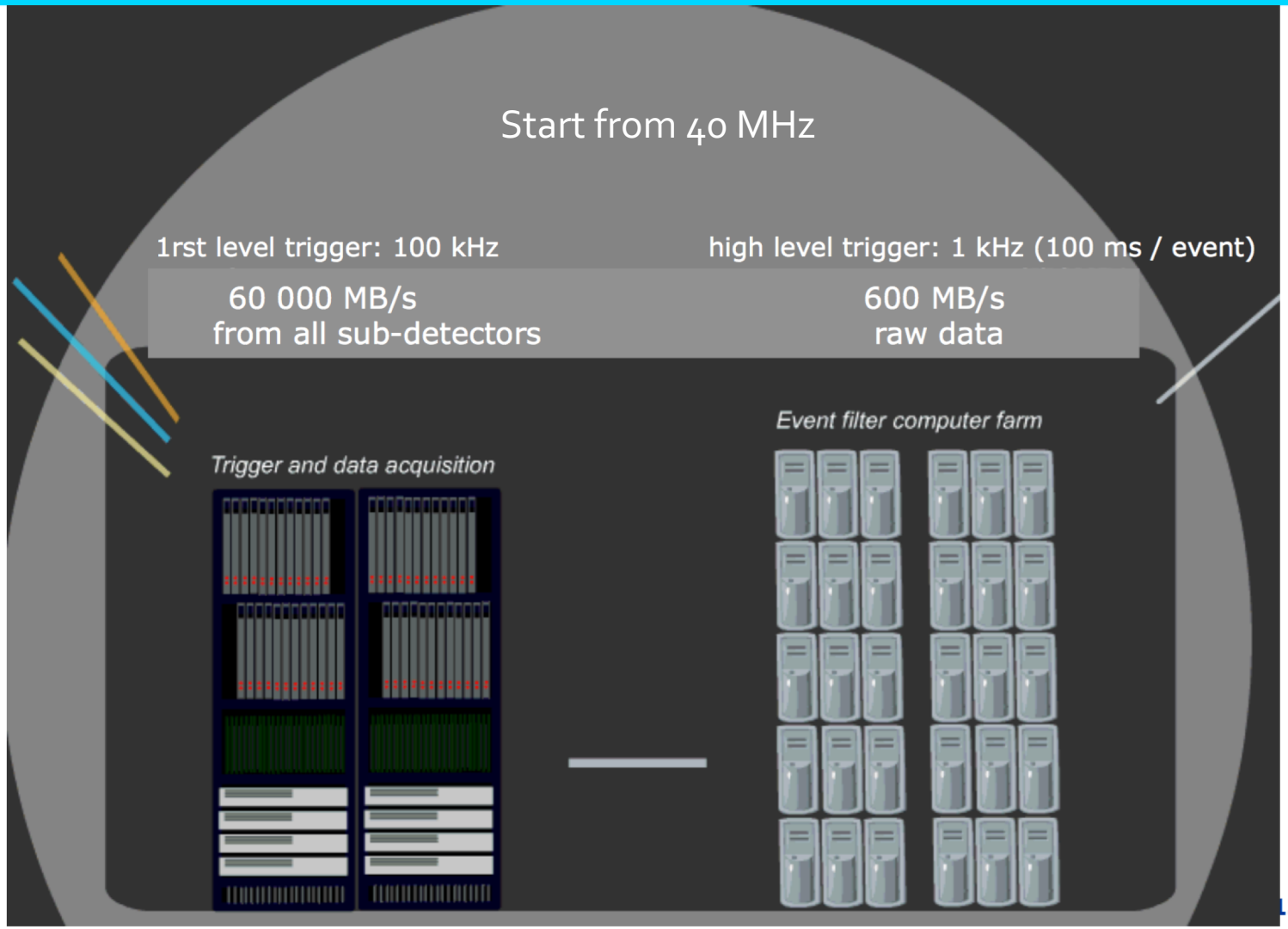
Un evento



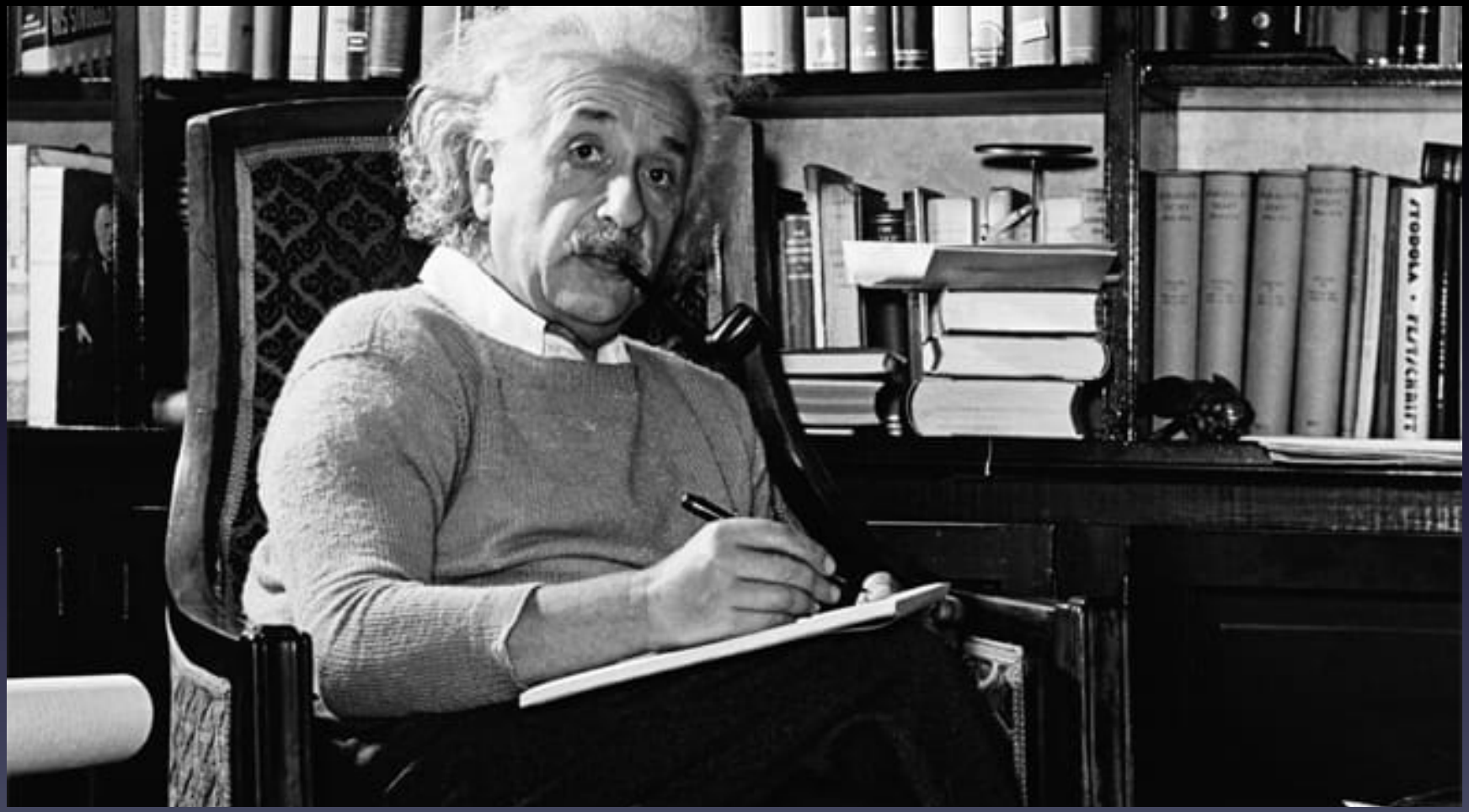
the CMS detector



trigger and data acquisition



Farò il teorico, come Einstein…



TTP00–20
hep-ph/0008287
August 2000

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

T. Gehrmann[a] and E. Remiddi[b]

[a] *Institut für Theoretische Teilchenphysik, Universität Karlsruhe, D-76128 Karlsruhe, Germany*

[b] *Dipartimento di Fisica, Università di Bologna and INFN, Sezione di Bologna, I-40126 Bologna, Italy*

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

with:

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

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

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

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

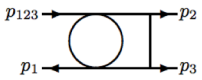
$$\begin{aligned} f_{5.1,-1}(y,z) = {} & +4H(0;y)H(0;z) - 4H(0;y)H(1,0;z) + 4H(0;y)H(1,0,0;z) + 4H(0;y)H(1,1,0;z) \\ & -8H(0;z) - 2H(0;z)H(1-z,0;y) + 2H(0;z)H(1-z,0,0;y) \\ & +H(0;z)H(1-z,1-z,0;y) - 4H(0,0;y)H(0;z) + 4H(0,0;y)H(0,0;z) \\ & +4H(0,0;y)H(1,0;z) + 8H(0,0;z) - 4H(0,0;z)H(0;y) + 2H(0,0;z)H(1-z,0;y)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

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

Per arrivare a queste formule sono stati necessari mesi di calcoli impossibili con carta e penna

Ognuno degli H(…) è una funzione complicata da valutare numericamente

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



$$
= \left(\frac{S_\epsilon}{16\pi^2}\right)^2 \frac{(-s_{123})^{-2\epsilon}}{s_{23}} \sum_{i=-1}^{3} \frac{f_{5.2,i}\left(\frac{s_{13}}{s_{123}},\frac{s_{23}}{s_{123}}\right)}{\epsilon^i} + \mathcal{O}(\epsilon^2), \qquad (4.26)
$$

with:

$$
\begin{aligned}
f_{5.2,3}(y,z) &= -1\,, && (4.27)\\
f_{5.2,2}(y,z) &= -2+H(0;y)+H(0;z)\,, && (4.28)\\
f_{5.2,1}(y,z) &= -4+2H(0;y)-H(0;y)H(0;z)+2H(0;z)-2H(0,0;y)-H(0,0;z)-H(1,0;y)\,, && (4.29)\\
f_{5.2,0}(y,z) &= -8+4H(0;y)-2H(0;y)H(0;z)+H(0;y)H(1,0;z)+4H(0;z)+H(0;z)H(1-z,0;y)\\
&\quad -4H(0,0;y)+2H(0,0;y)H(0;z)-2H(0,0;z)+H(0,0;z)H(0;y)+4H(0,0,0;y)\\
&\quad +H(0,0,0;z)+2H(0,1,0;y)-2H(1,0;y)+H(1,0;z)H(1-z;y)+2H(1,0,0;y)\\
&\quad +H(1,1,0;z)+H(1-z,1,0;y)+5\zeta_3+\frac{\pi^2}{6}\left[+H(0;y)+H(1;z)+H(1-z;y)\right]\,, && (4.30)\\
f_{5.2,-1}(y,z) &= -16+8H(0;y)-4H(0;y)H(0;z)+2H(0;y)H(1,0;z)-H(0;y)H(1,0,0;z)\\
&\quad -H(0;y)H(1,1,0;z)+8H(0;z)+2H(0;z)H(1-z,0;y)-2H(0;z)H(1-z,0,0;y)\\
&\quad -H(0;z)H(1-z,1-z,0;y)-8H(0,0;y)+4H(0,0;y)H(0;z)-2H(0,0;y)H(0,0;z)\\
&\quad -2H(0,0;y)H(1,0;z)-4H(0,0;z)+2H(0,0;z)H(0;y)-H(0,0;z)H(1-z,0;y)\\
&\quad +8H(0,0,0;y)-4H(0,0,0;y)H(0;z)+2H(0,0,0;z)-H(0,0,0;z)H(0;y)\\
&\quad -8H(0,0,0,0;y)-H(0,0,0,0;z)-4H(0,0,1,0;y)+4H(0,1,0;y)\\
&\quad -H(0,1,0;z)H(0;y)-H(0,1,0;z)H(1-z;y)-4H(0,1,0,0;y)-H(0,1,1,0;z)\\
&\quad -2H(0,1-z;y)H(1,0;z)-2H(0,1-z,0;y)H(0;z)-2H(0,1-z,1,0;y)\\
&\quad -4H(1,0;y)+2H(1,0;z)H(1-z;y)-H(1,0;z)H(1-z,0;y)\\
&\quad -H(1,0;z)H(1-z,1-z;y)+4H(1,0,0;y)-H(1,0,0;z)H(1-z;y)\\
&\quad -4H(1,0,0,0;y)-H(1,0,1,0;z)+2H(1,1,0;z)-H(1,1,0,0;z)
\end{aligned}
$$

- Non vi laureerete senza imparare a programmare. Probabilmente in modi e linguaggi diversi.
- Tanto vale cominciare subito.

Buon Lavoro