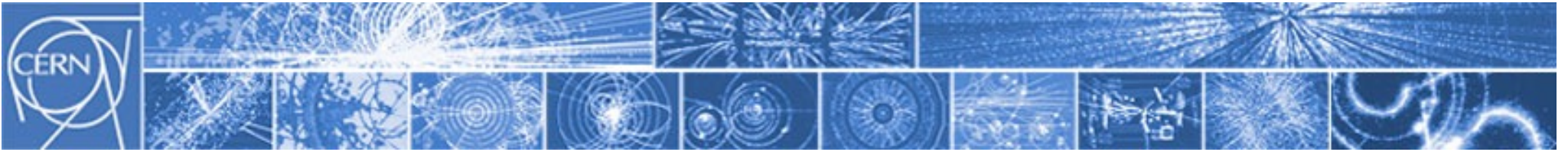


I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p}$

(semirigoroso)

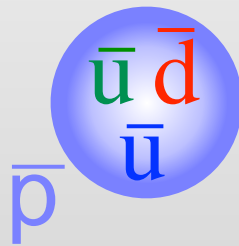
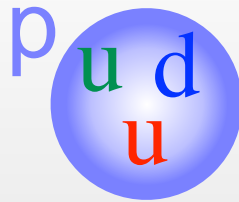


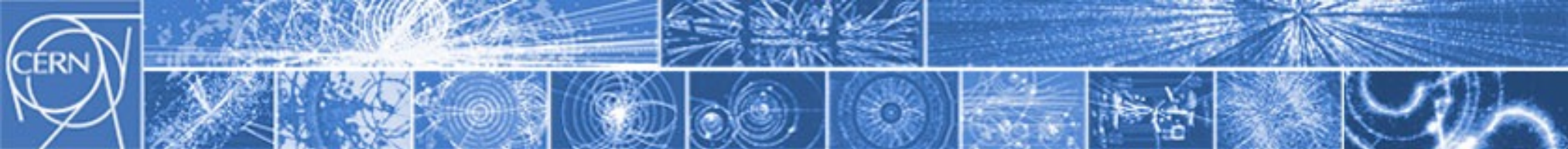
I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p}$

(semirigoroso)

TeVatron
2 TeV

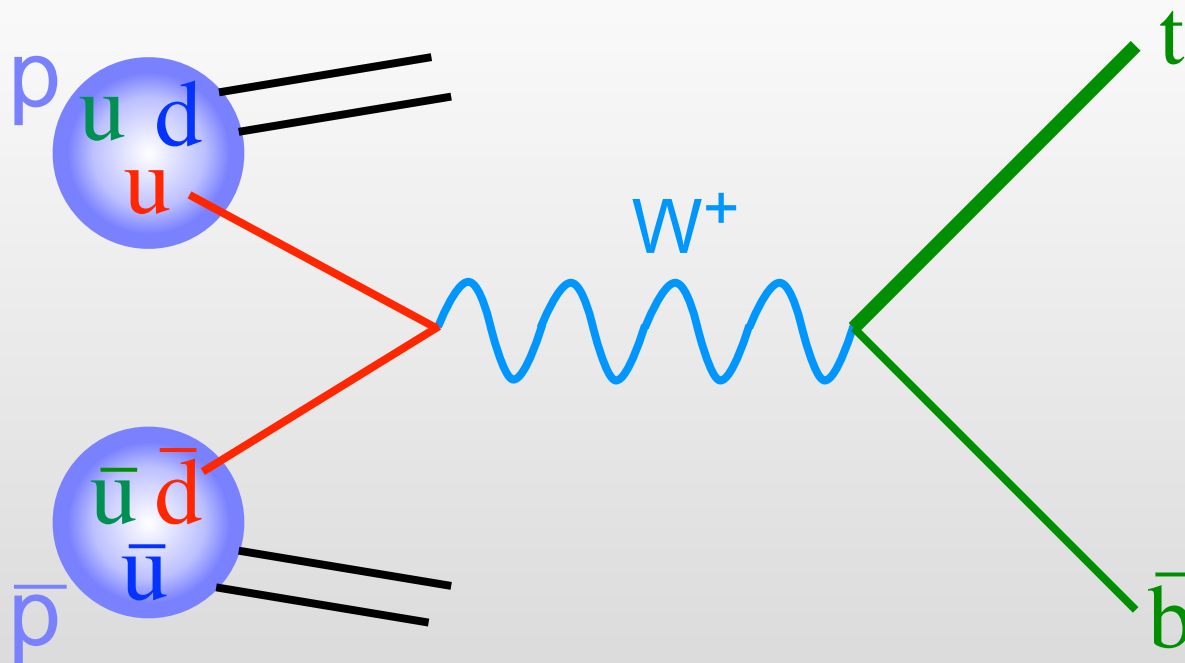




I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p} \rightarrow$ produzione di quark top
(semirigoroso)

TeVatron
2 TeV



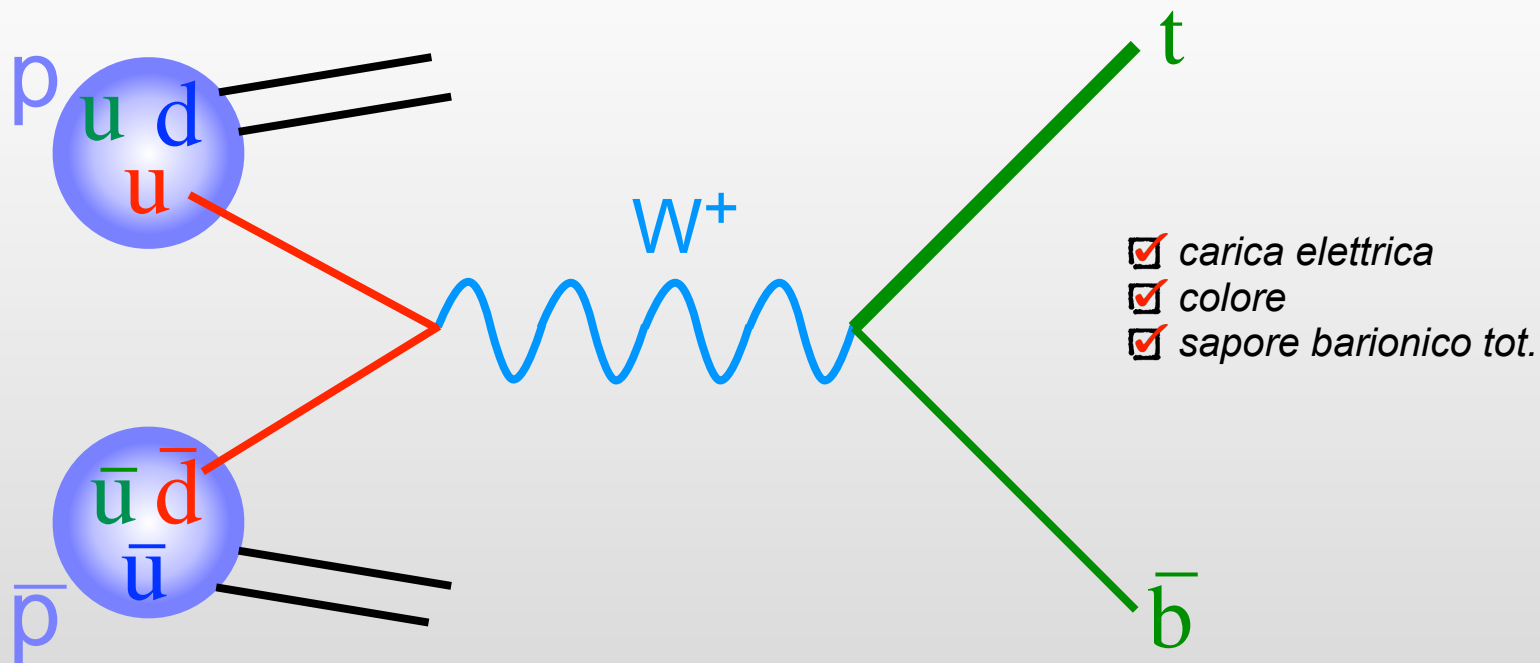
Nota: non è il canale più efficace per produrre un top quark al Tevatron, ma vabbè.



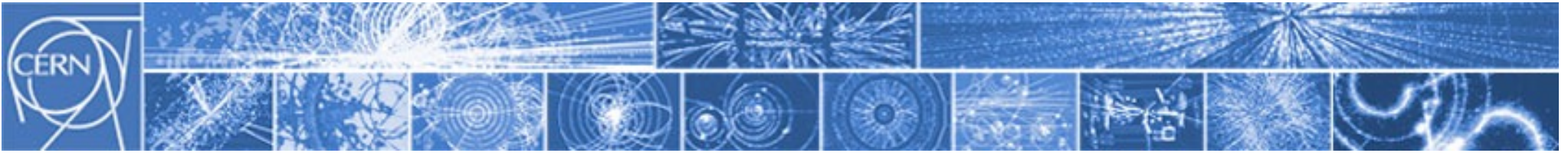
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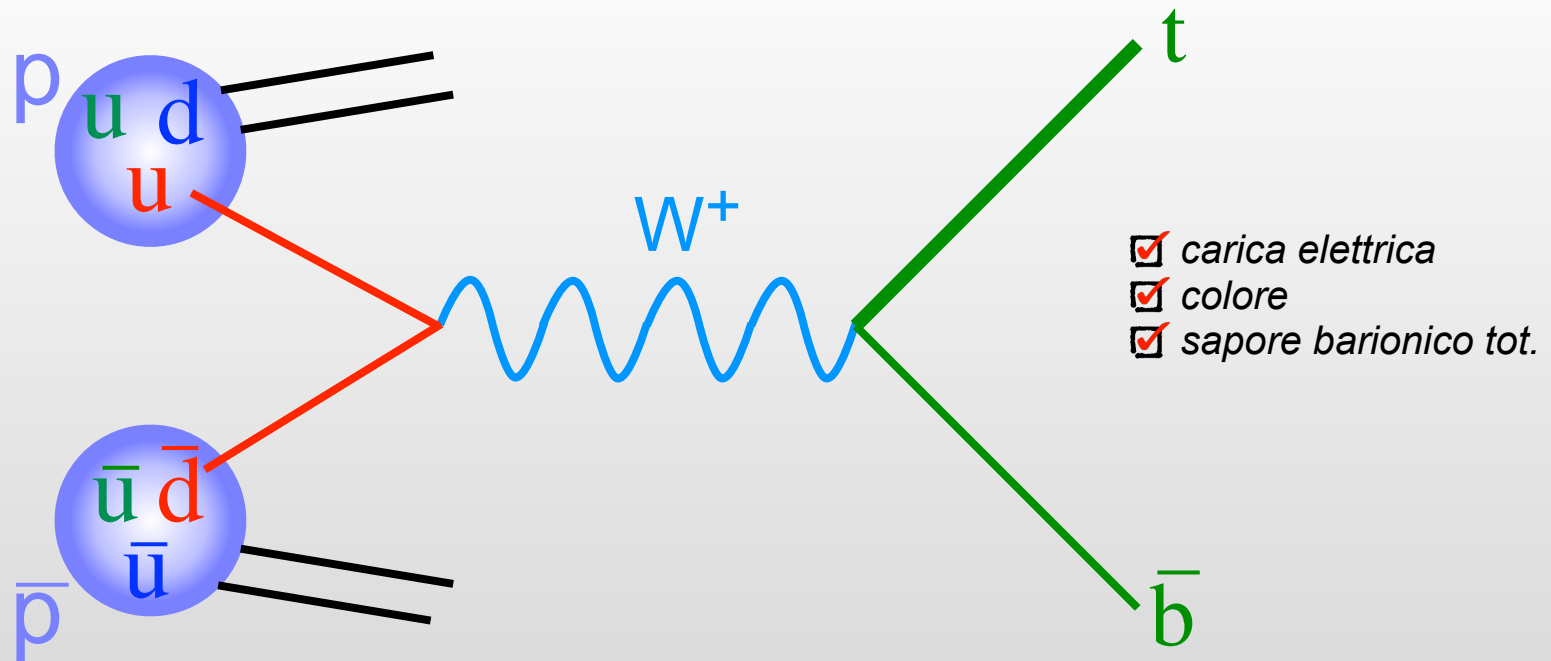
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I diagrammi di Feynman al lavoro

Esempio 2: collisione $p\bar{p} \rightarrow$ produzione di quark top
(semirigoroso)

TeVatron
2 TeV



Ogni q porta una frazione del momento del p : serve una grande energia.

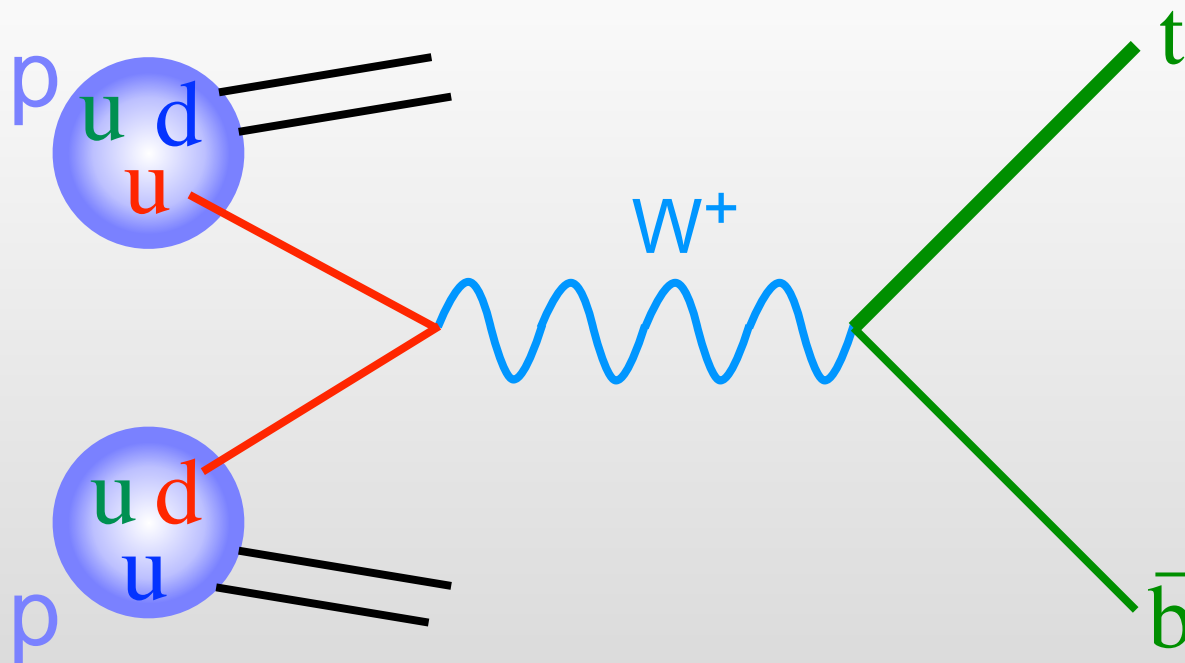
Magari scopriremo così una nuova particella pesante (un *nuovo 'quark'*?).

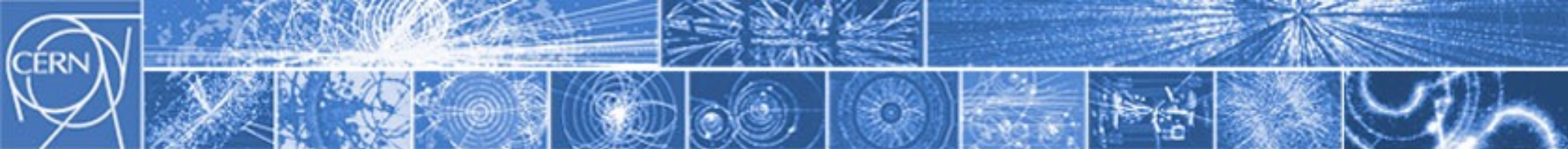


I diagrammi di Feynman al lavoro

Esempio 2b: collisione $pp \rightarrow$ produzione di quark top
(semirigoroso)

LHC
'14 TeV'



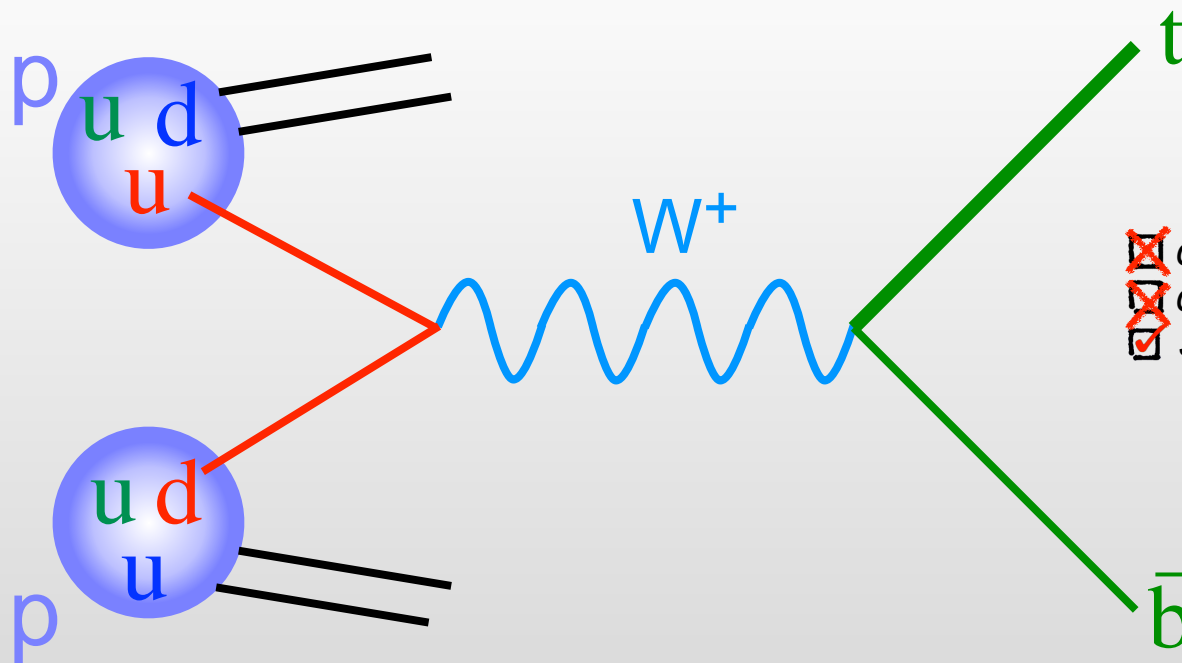


I diagrammi di Feynman al lavoro

Esempio 2b: collisione $pp \rightarrow$ produzione di quark top

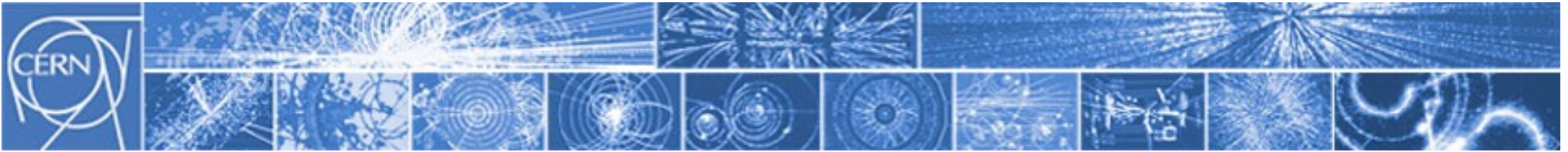
(semirigoroso)

LHC
'14 TeV'



- carica elettrica
- colore
- sapore barionico tot.



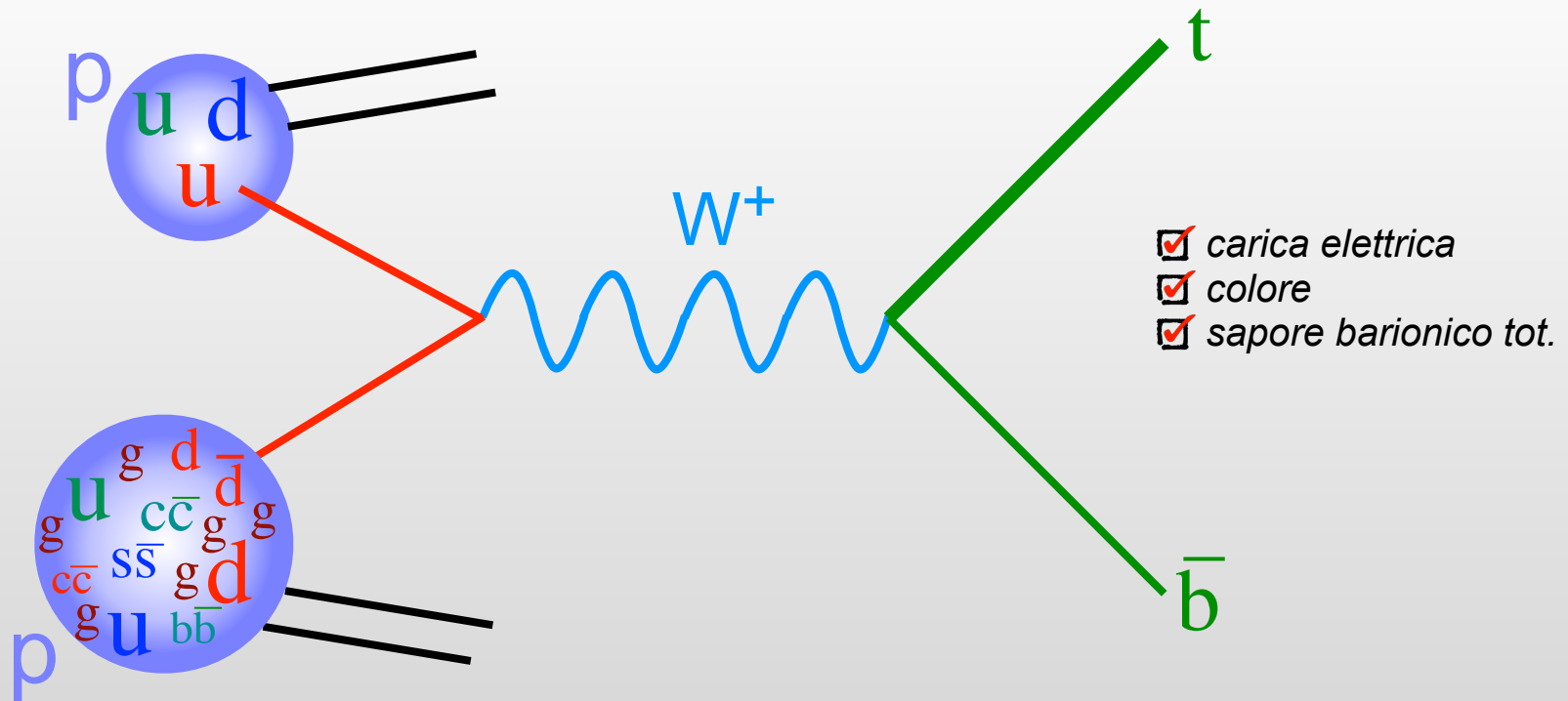


I diagrammi di Feynman al lavoro

Esempio 2b: collisione pp → produzione di quark top

(semirigoroso)

LHC
'14 TeV'



Un protone 'contiene' *quarks*, *antiquarks* di tutti i sapori (del *mare*, vs *valenza*), e *gluoni*, secondo una certa *distribuzione di probabilità*, funzione dell'energia.

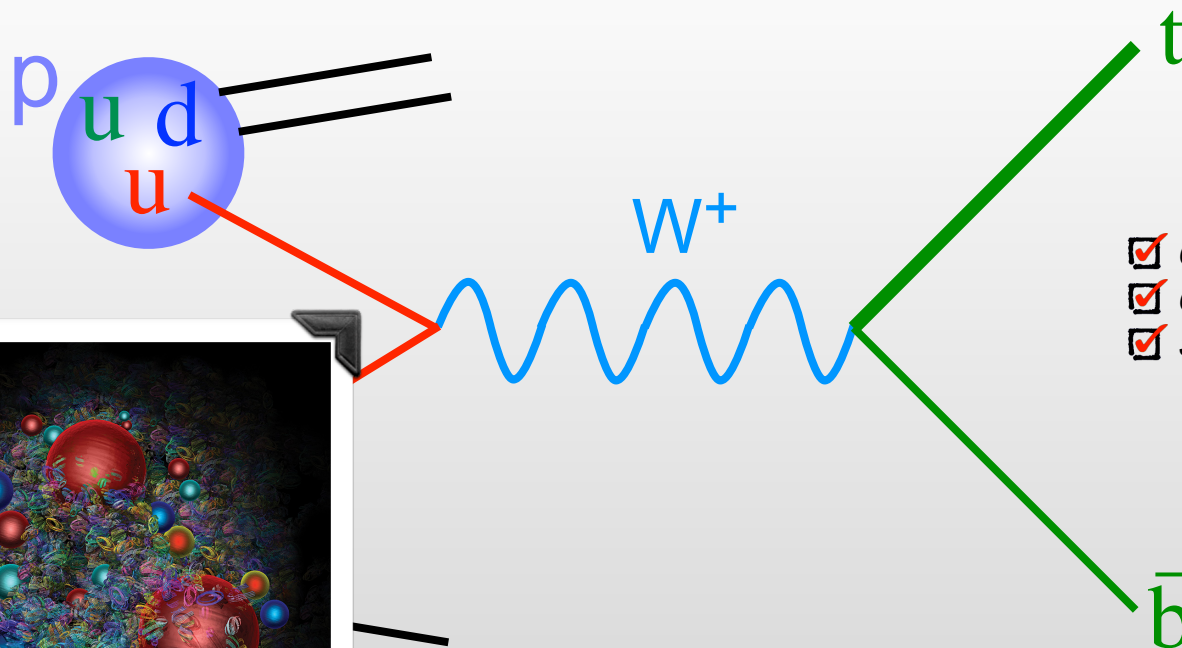


I diagrammi di Feynman al lavoro

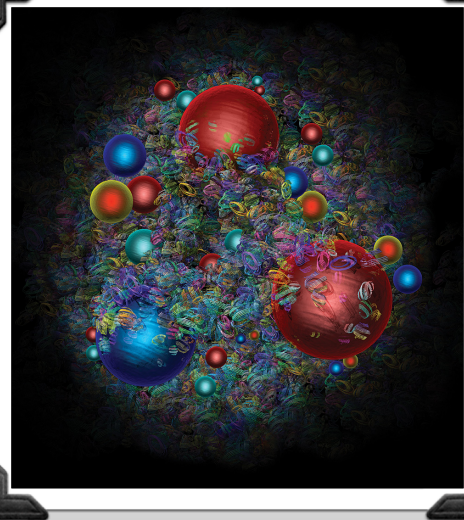
Esempio 2b: collisione pp → produzione di quark top

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LHC
‘14 TeV’

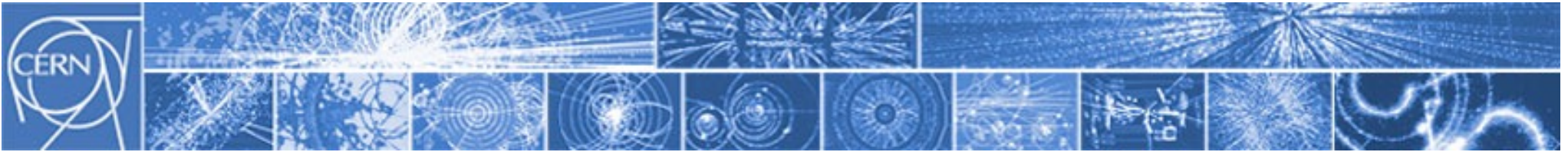


- carica elettrica
- colore
- sapore barionico tot.



Un protone, antiquarks di tutti i sapori (del mare, vs valenza),
e gluoni, distribuzione di probabilità, funzione dell'energia.

An artist's impression of the mayhem of quarks and gluons inside the proton.
Credit: D Dominguez/CERN.

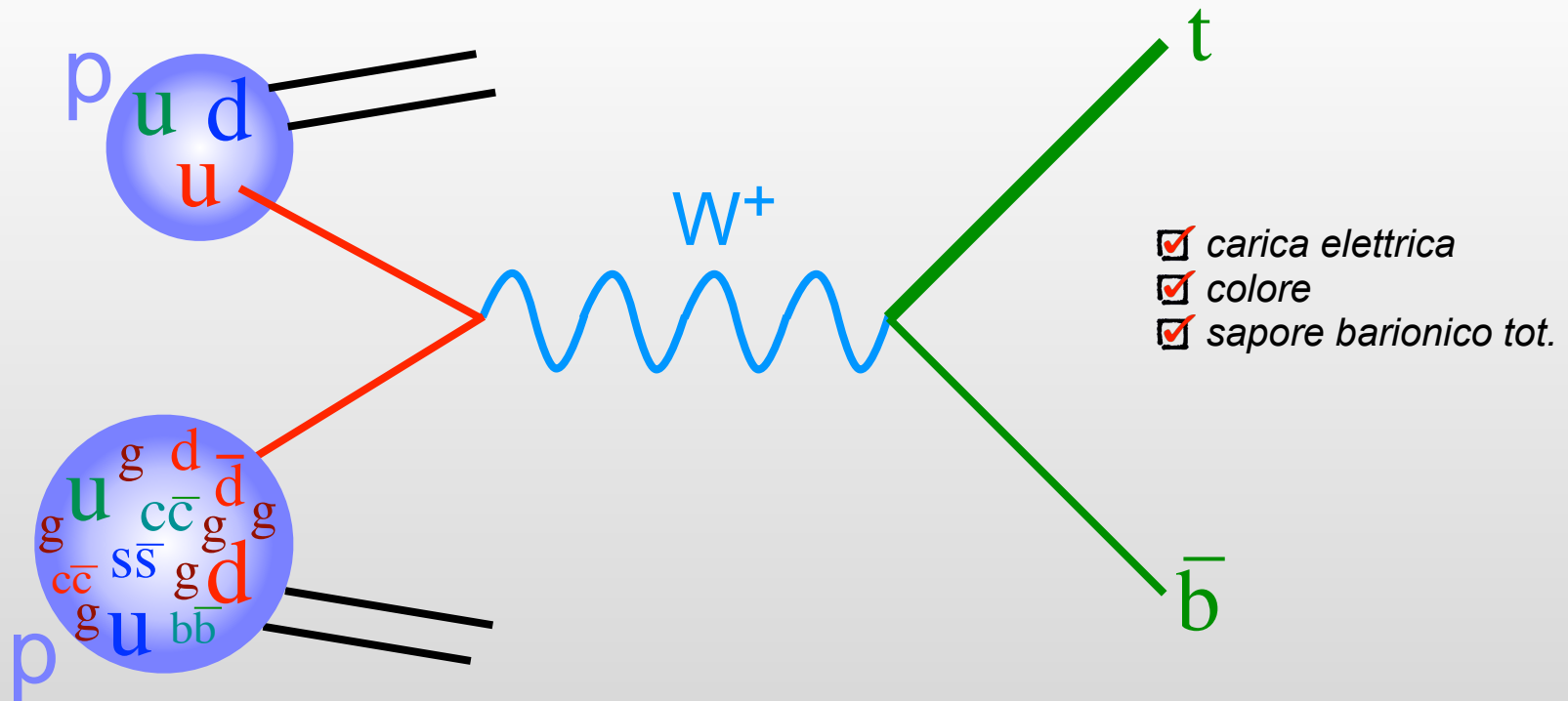


I diagrammi di Feynman al lavoro

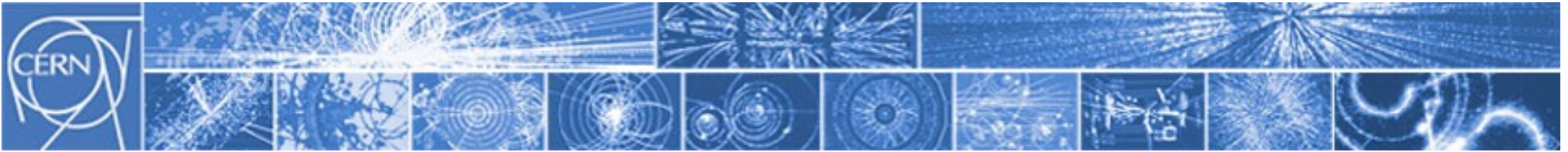
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LHC
'14 TeV'



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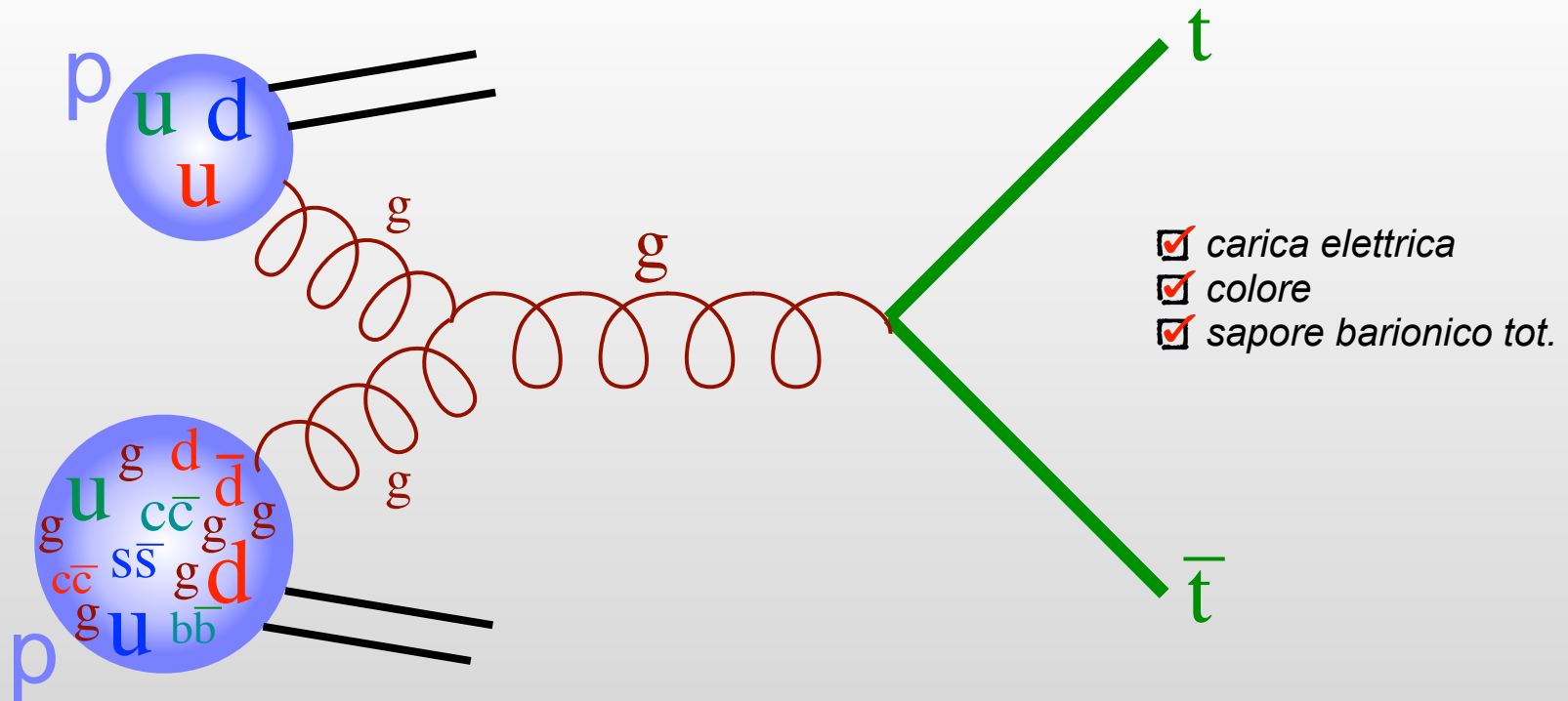


I diagrammi di Feynman al lavoro

Esempio 2b: collisione pp → produzione di quark top

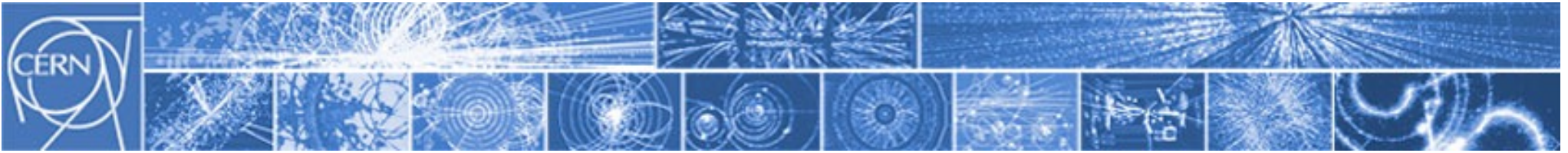
(semirigoroso)

LHC
'14 TeV'



Un protone 'contiene' *quarks*, *antiquarks* di tutti i sapori (del *mare*, vs *valenza*), e *gluoni*, secondo una certa *distribuzione di probabilità*, funzione dell'energia.

By the way, ecco uno dei canali più efficaci per produrre un top quark a LHC.

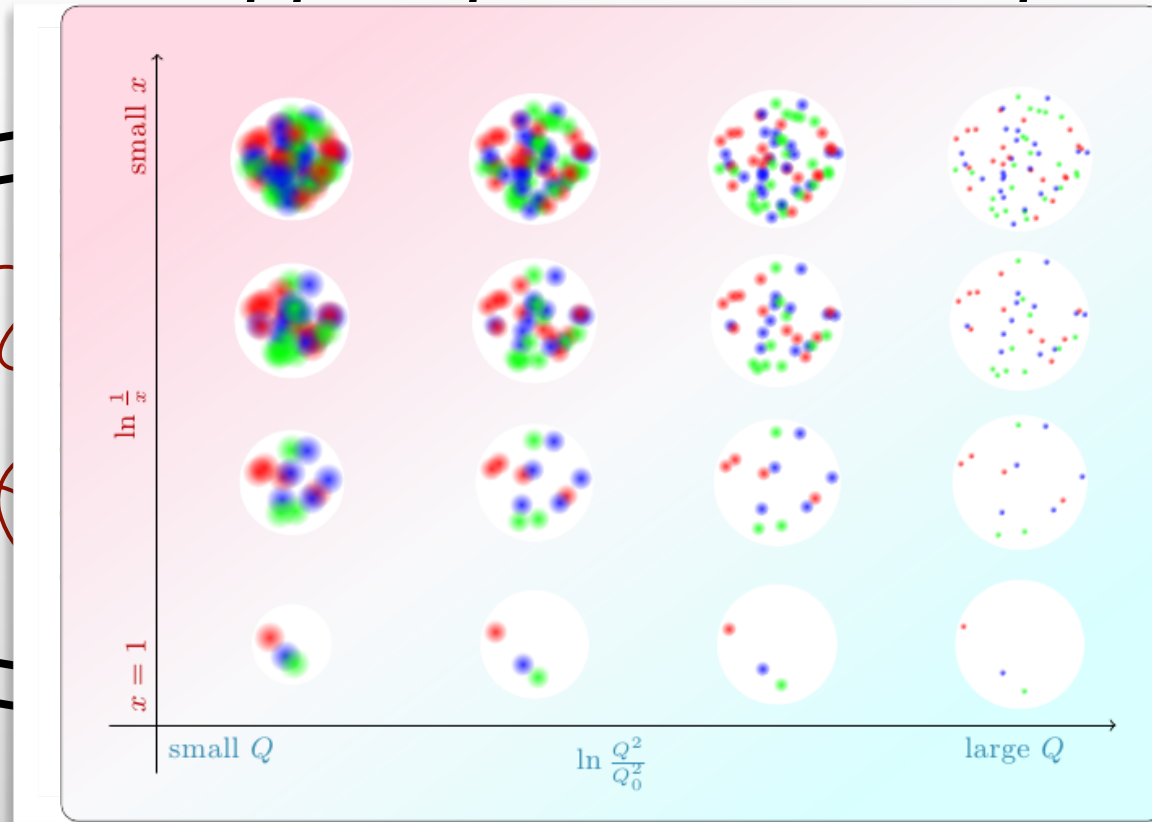
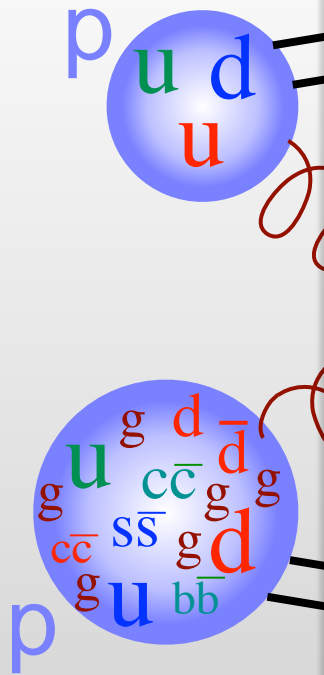


I diagrammi di Feynman al lavoro

Esempio 2b: collisione pp → produzione di quark top

(semirigoroso)

LHC
'14 TeV'



Credit: David Zaslavsky
Also: JCLab 2022

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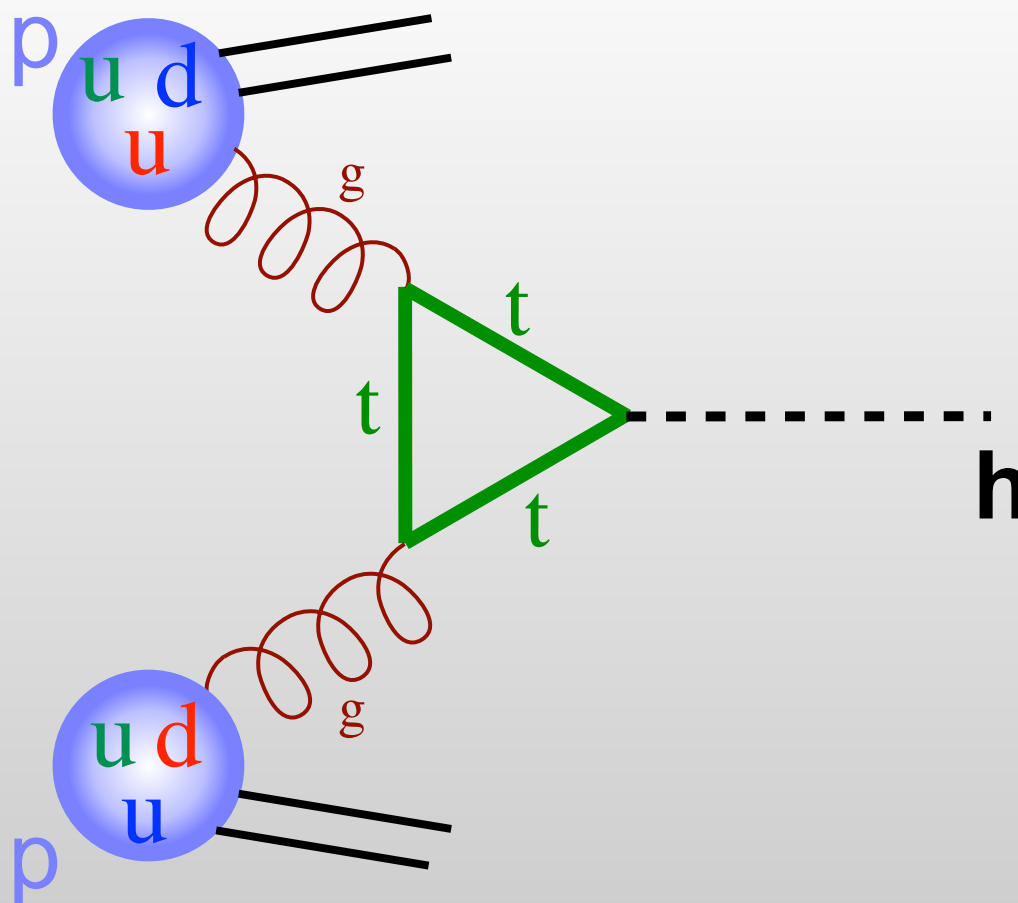


I diagrammi di Feynman al lavoro

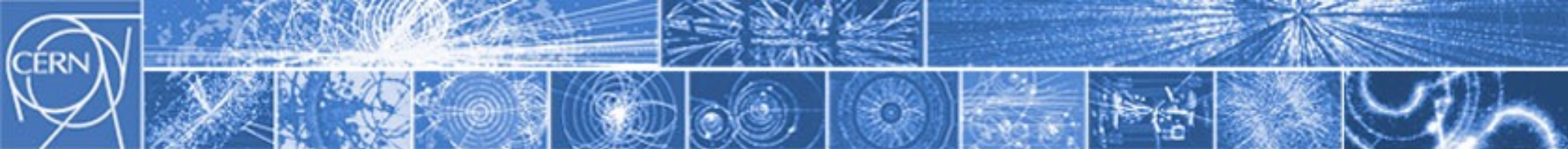
Esempio 3: collisione $pp \rightarrow$ produzione di higgs

(semirigoroso)

LHC
'14 TeV'



- carica elettrica*
- colore*
- sapore barionico tot.*

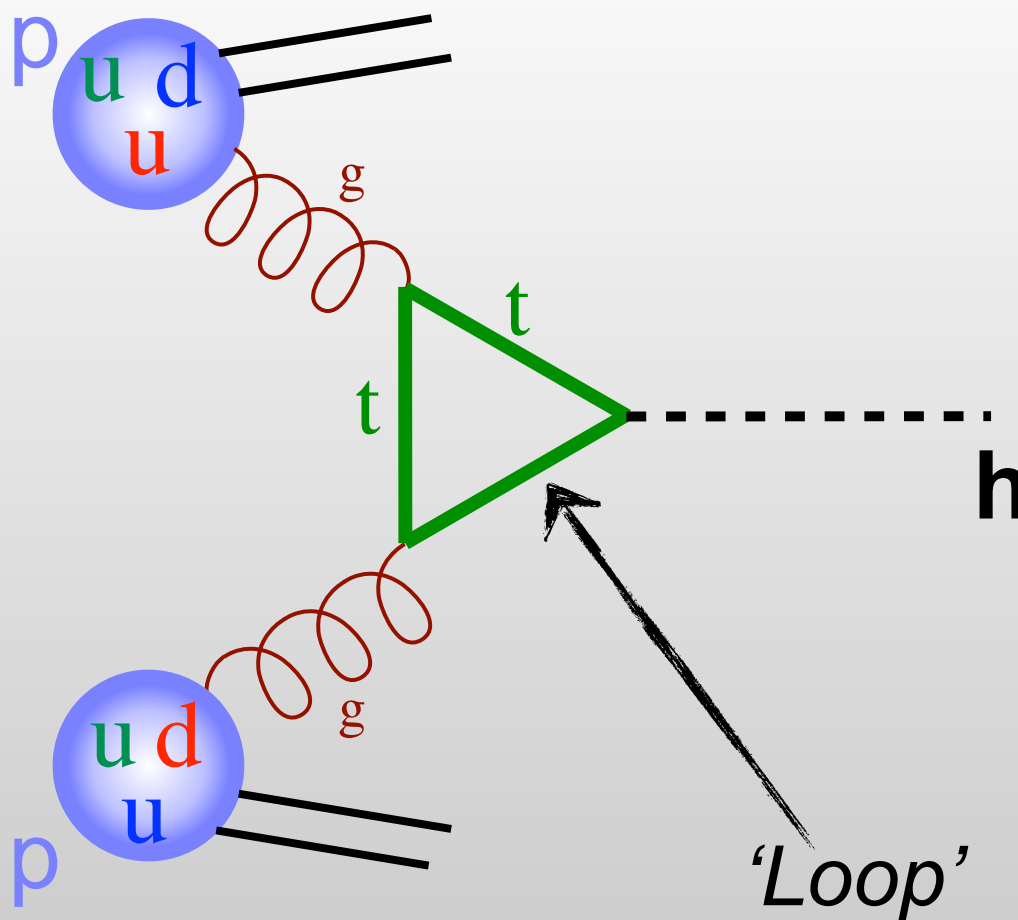


I diagrammi di Feynman al lavoro

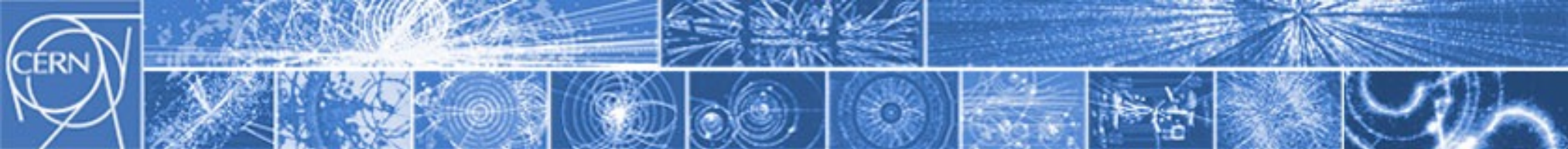
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LHC
'14 TeV'



- carica elettrica
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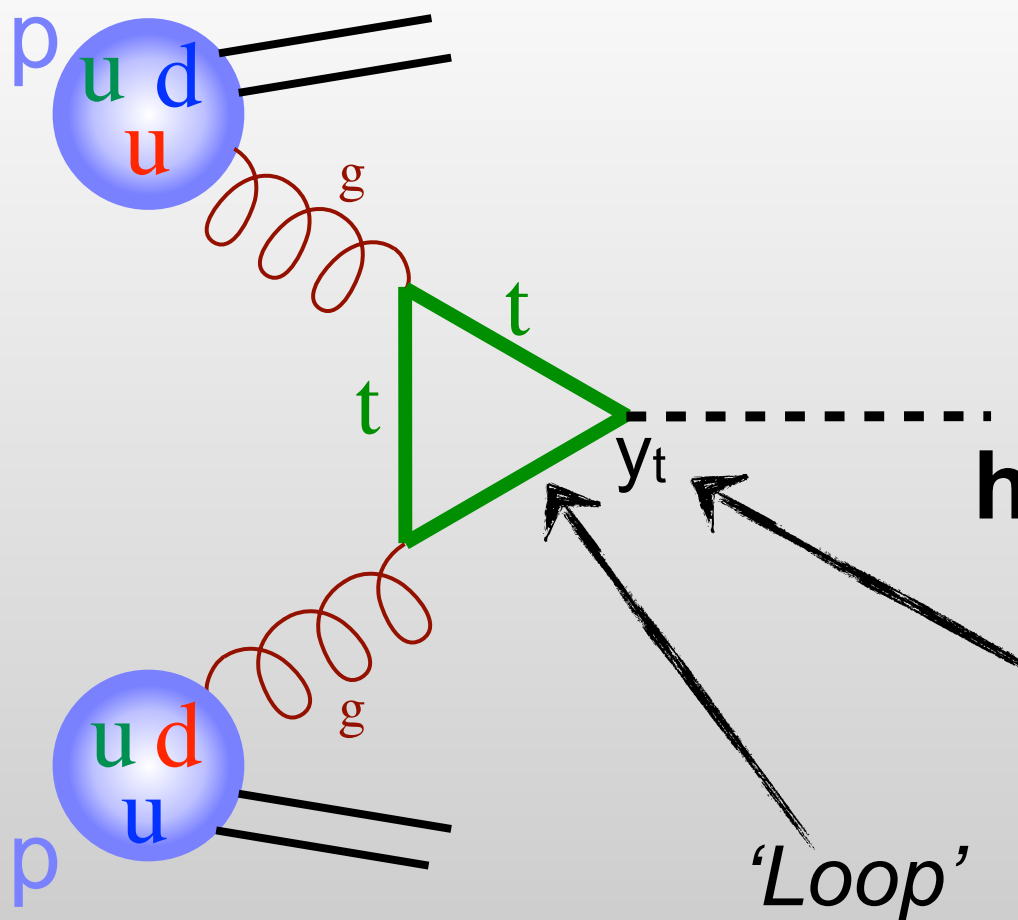


I diagrammi di Feynman al lavoro

Esempio 3: collisione $pp \rightarrow$ produzione di higgs

(semirigoroso)

LHC
'14 TeV'



- carica elettrica
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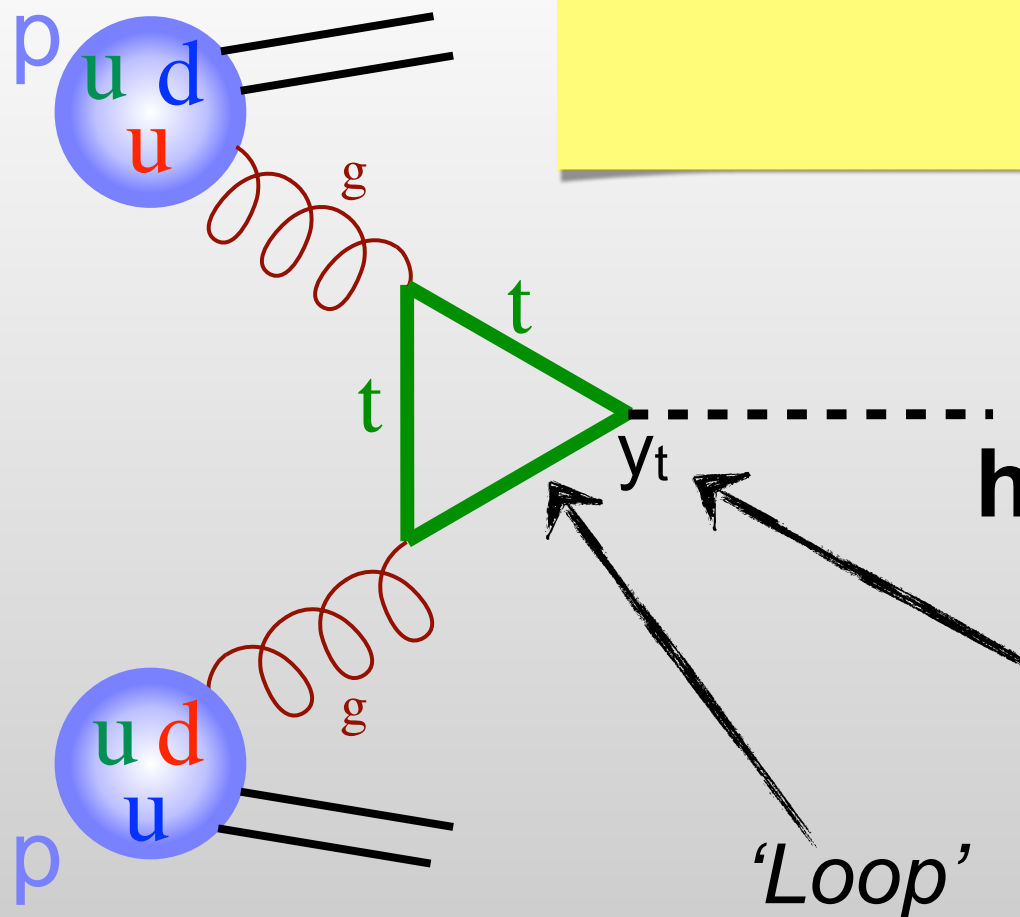
I diagrammi di Feynman al lavoro

Esempio 3: collisione $pp \rightarrow$ produzione di higgs

(semirigoroso)

Q: Ma quindi alla fin fine si può fare un po' tutto?

LHC
'14 TeV'



- carica elettrica
- colore
- sapore barionico tot.

'accoppiamento'

'Loop'



I diagrammi di Feynman al lavoro

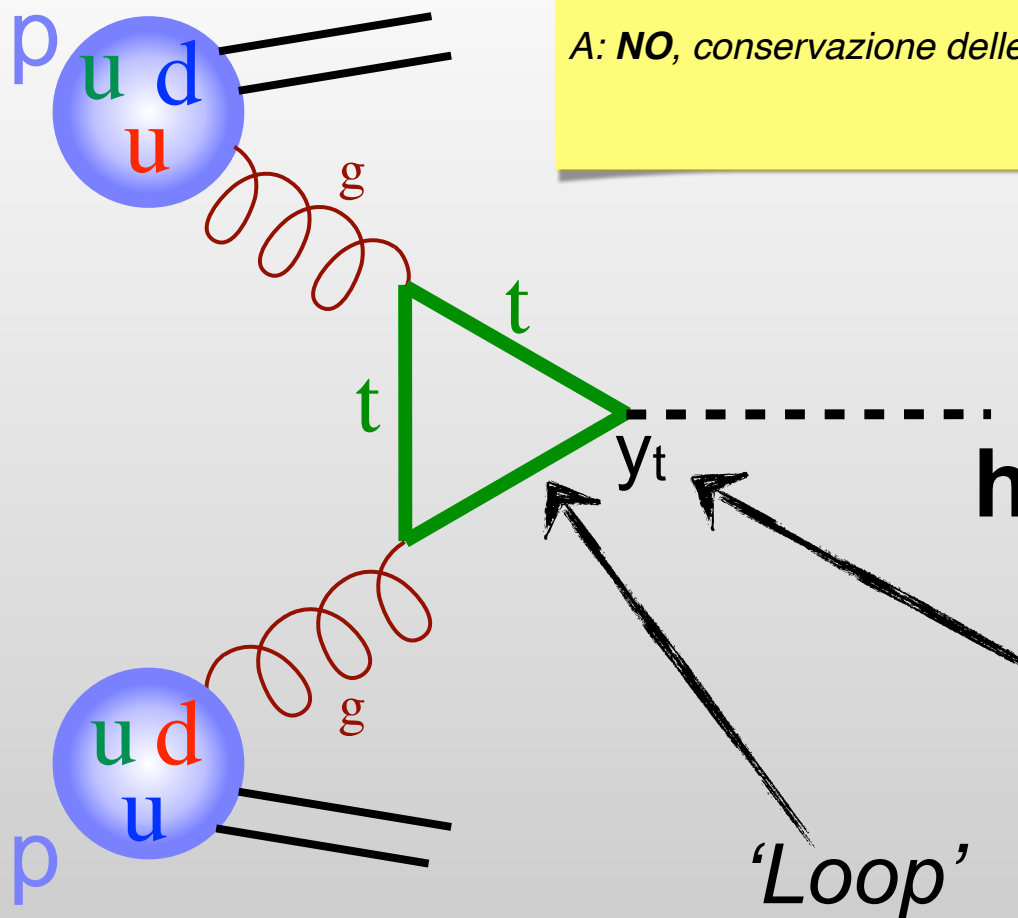
Esempio 3: collisione $pp \rightarrow$ produzione di higgs

(semirigoroso)

Q: Ma quindi alla fin fine si può fare un po' tutto?

A: **NO**, conservazione delle cariche...

LHC
'14 TeV'



- carica elettrica
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I diagrammi di Feynman al lavoro

Esempio 3: collisione $pp \rightarrow$ produzione di higgs

(semirigoroso)

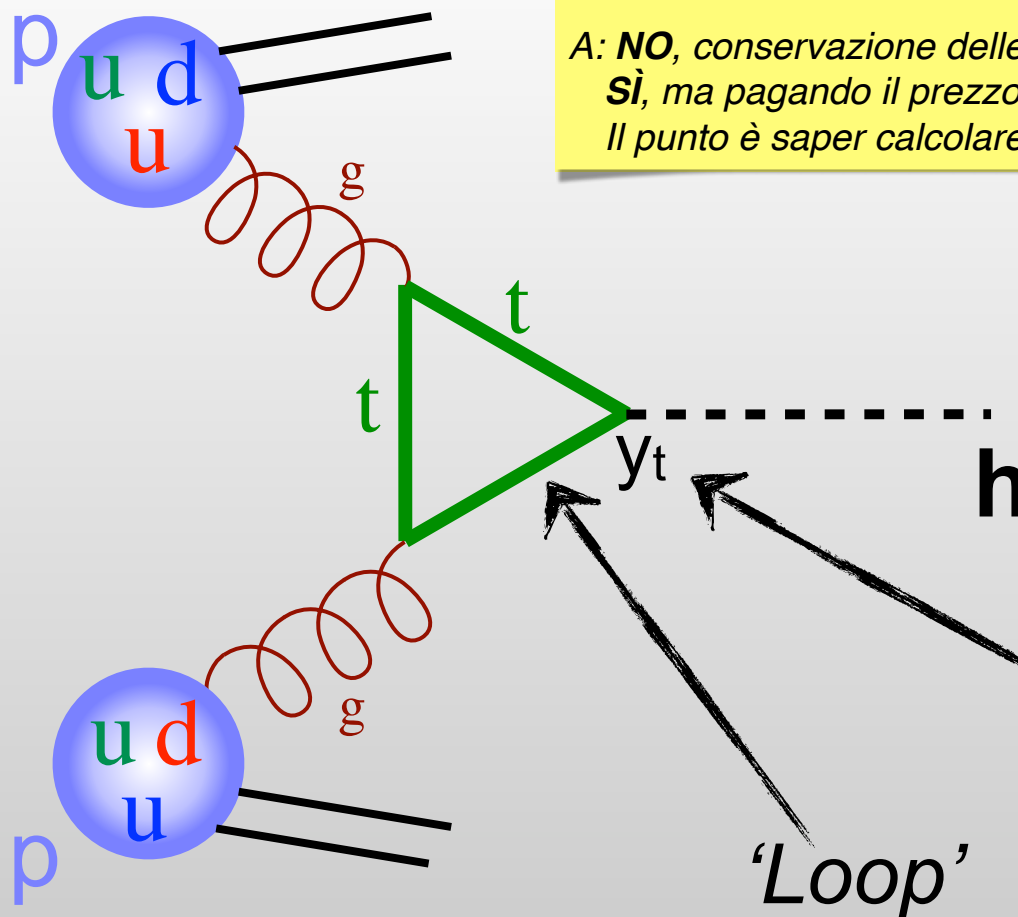
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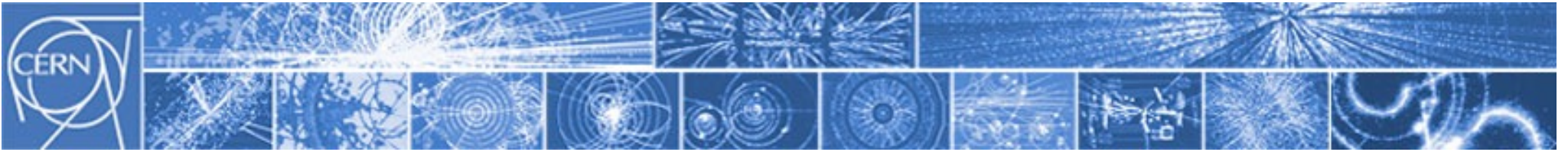
Sì, ma pagando il prezzo della rarità (processo 'soppresso'...)

Il punto è saper calcolare i vari processi.

LHC
'14 TeV'



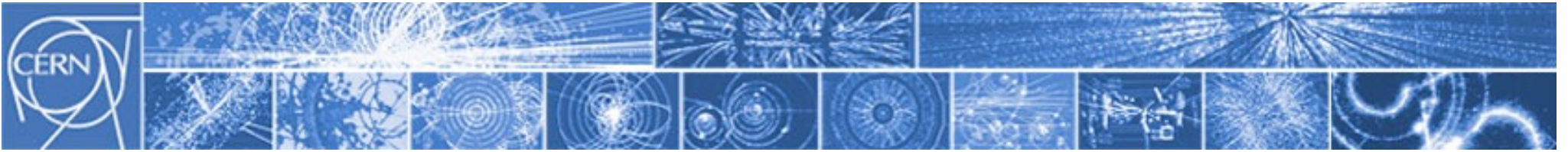
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I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

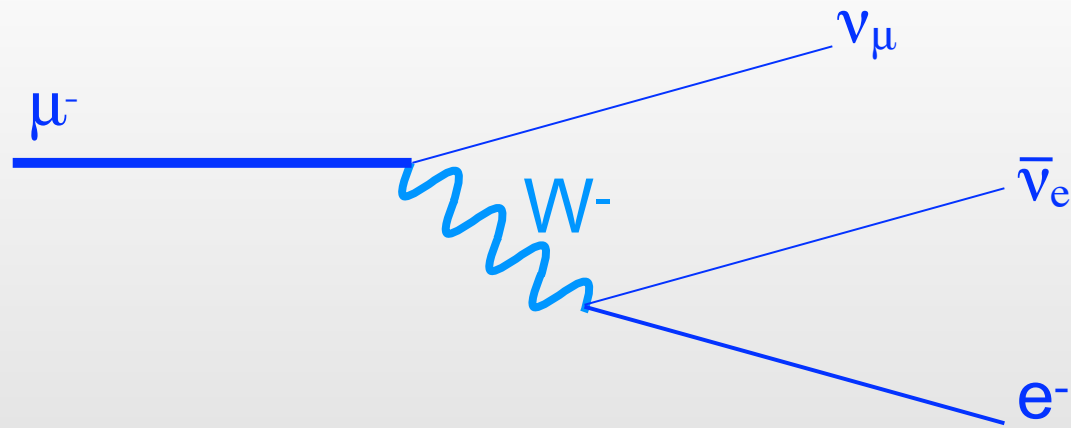
(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)

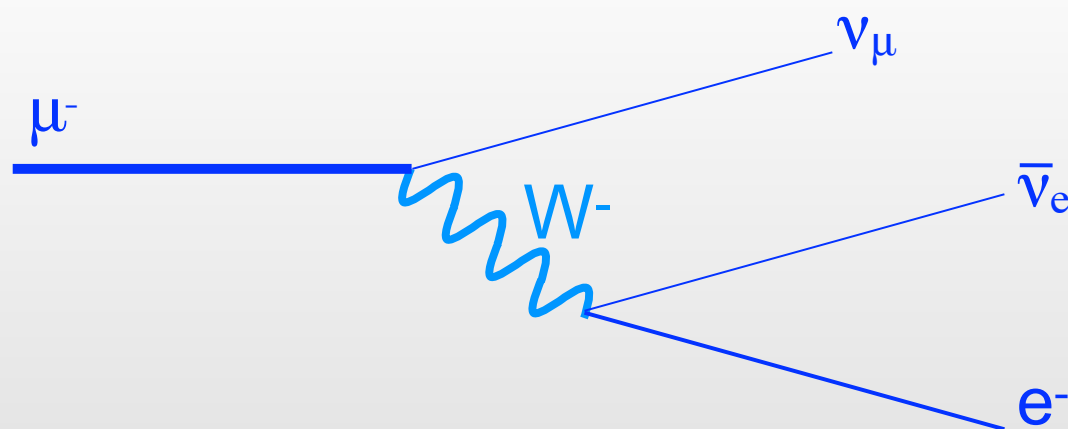




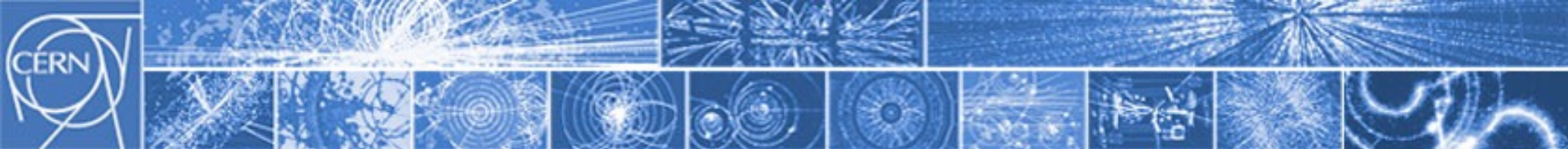
I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

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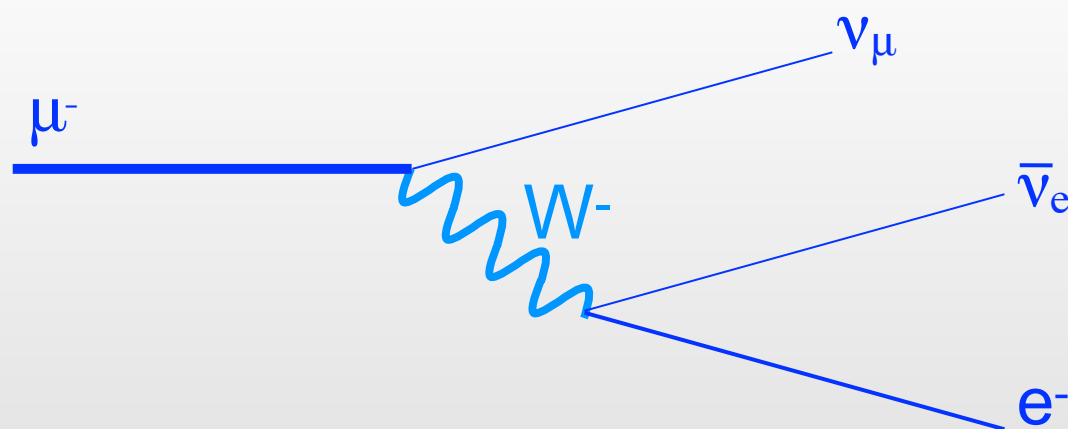
$$\mathcal{L} \simeq -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{\Psi} \not{D} \Psi + y_{ij} \Psi_i \Psi_j \phi + |D_\mu \phi|^2 - V(\phi)$$



I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



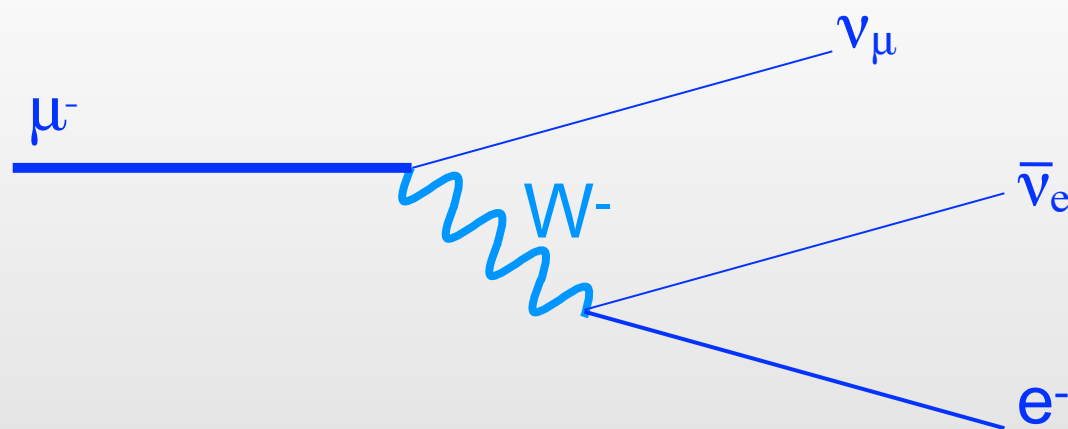
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I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



$$\mathcal{L} \simeq -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

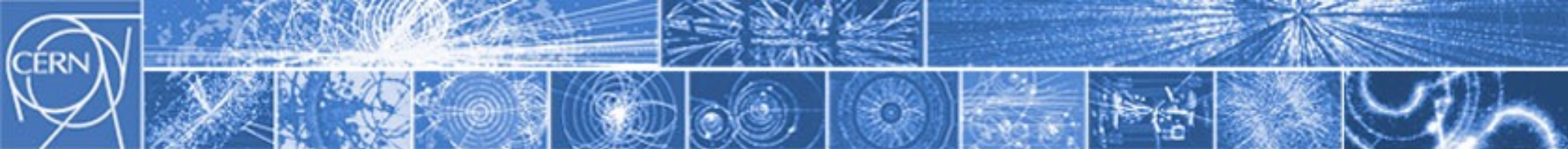
$$+i\bar{\Psi} \not{D} \Psi$$

$$+y_{ij} \Psi_i \Psi_j \phi$$

$$+|D_\mu \phi|^2 - V(\phi)$$

$$\Psi = \begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix}_L = \begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix} \frac{1 - \gamma_5}{2}$$

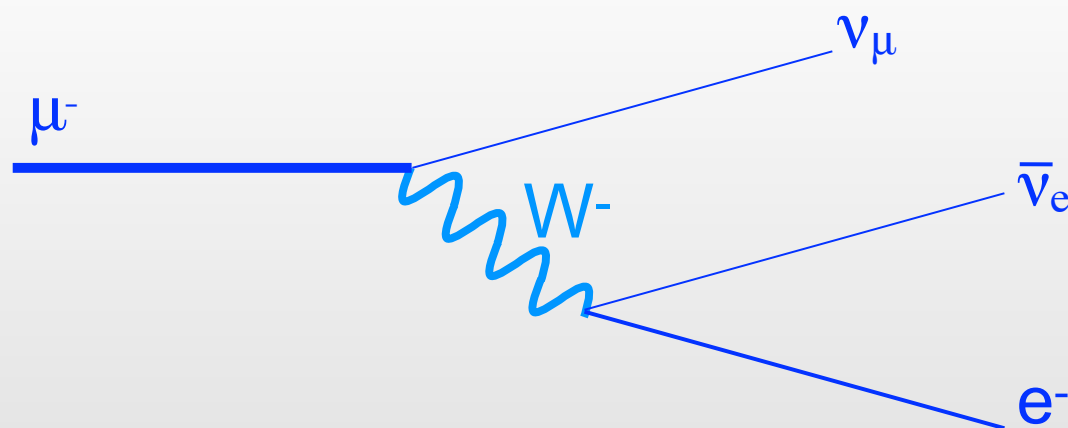
$$\not{D} = \gamma D \supset \gamma \left(-i \frac{g}{\sqrt{2}} W^- \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix} \right)$$



I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

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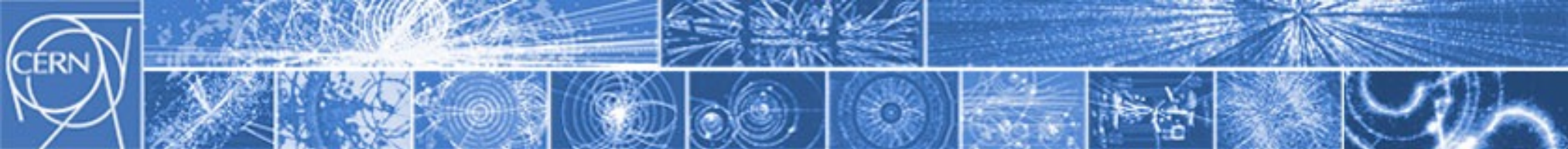
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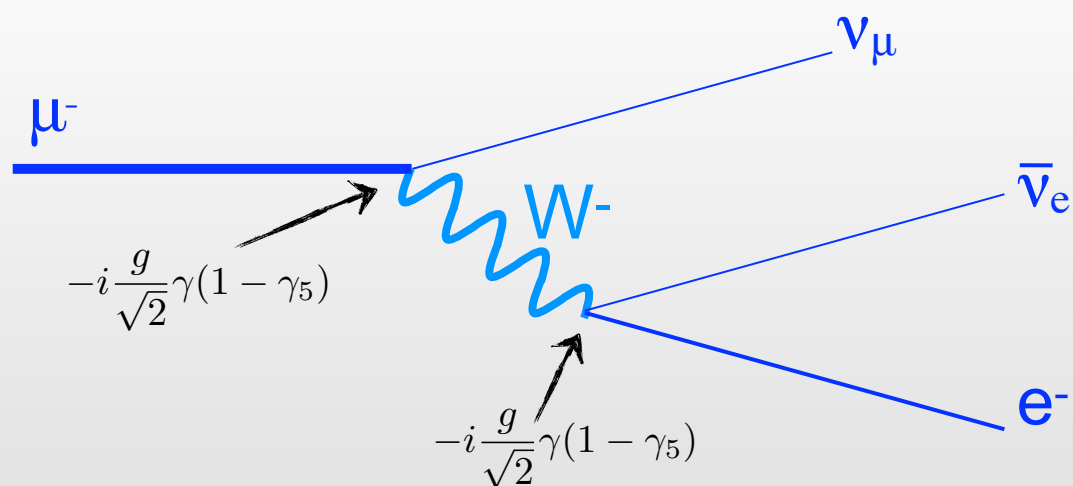
$$\simeq \nu_\mu \left(-i \frac{g}{\sqrt{2}} \right) \gamma (1 - \gamma_5) W^- \mu$$



I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



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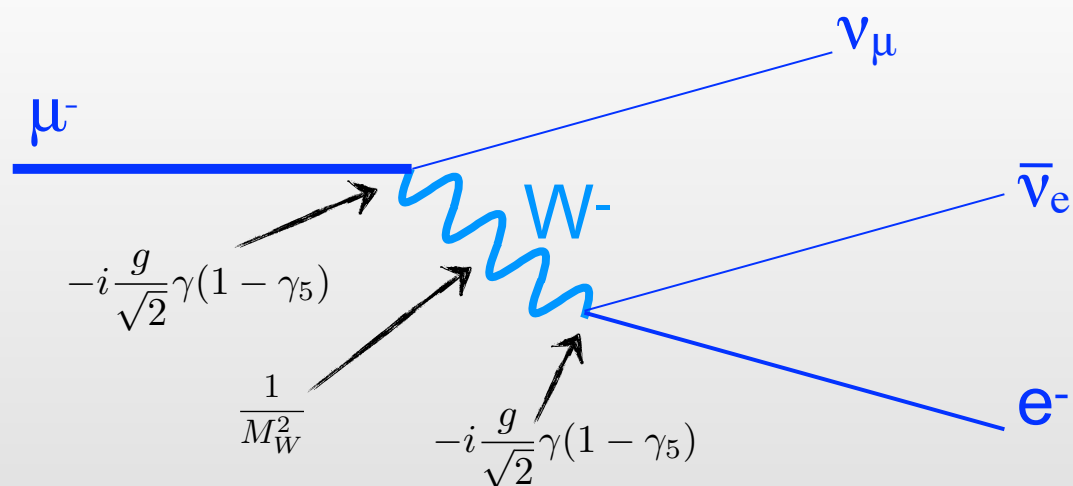
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I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



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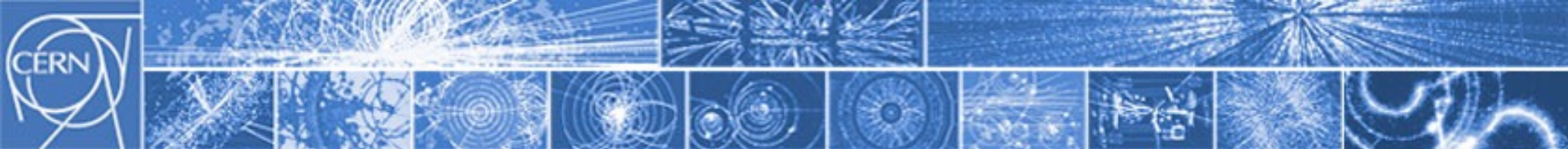
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$$\not{D} = \gamma D \supset \gamma \left(-i \frac{g}{\sqrt{2}} W^- \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix} \right)$$

$$\text{[light blue box]} \simeq \nu_\mu \left(-i \frac{g}{\sqrt{2}} \right) \gamma(1 - \gamma_5) W^- \mu$$

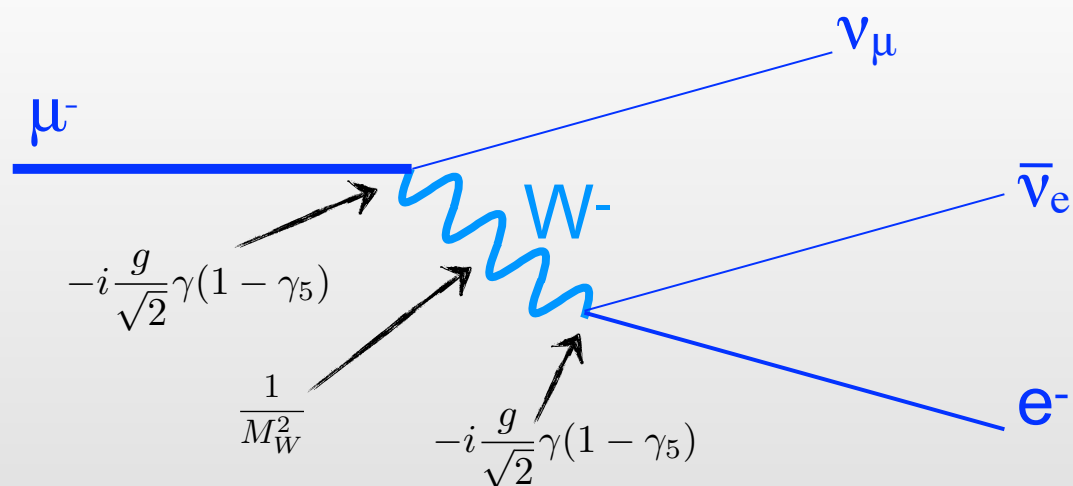
$$\text{[blue wavy line]} \propto \frac{1}{M_W^2 - p^2} \rightarrow \frac{1}{M_W^2}$$



I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



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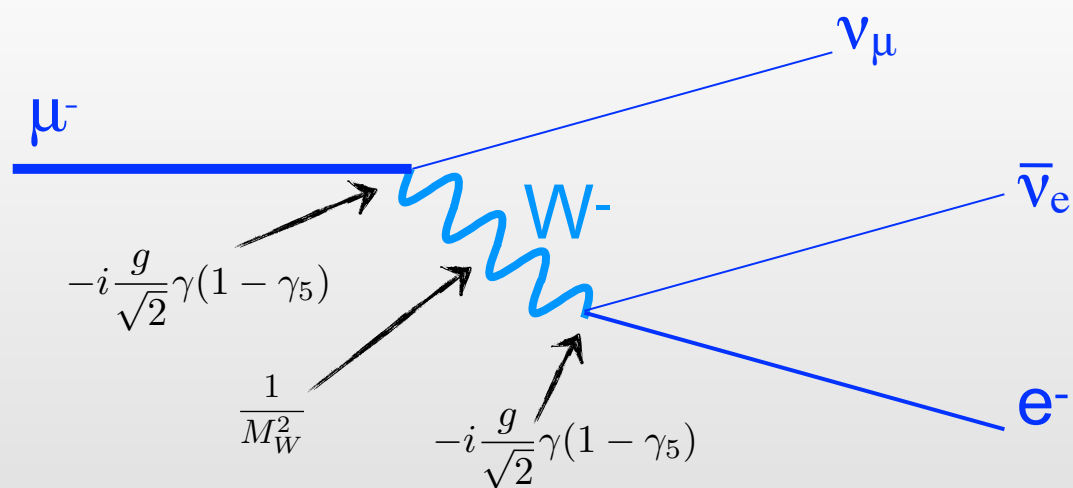
ampiezza: $|\mathcal{M}| \propto \frac{g^2}{2} [\nu_\mu \gamma(1 - \gamma_5) \mu] \frac{1}{M_W^2} [e \gamma(1 - \gamma_5) \nu_e]$



I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



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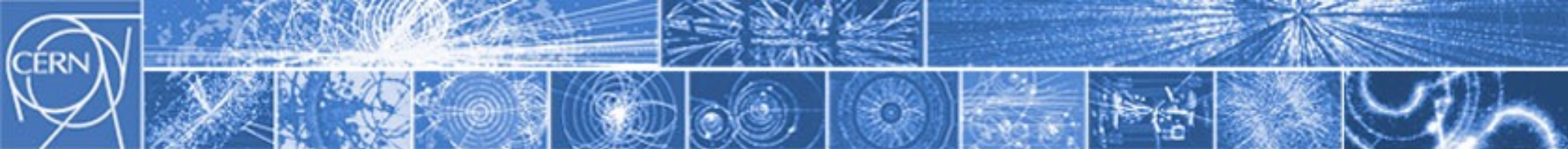
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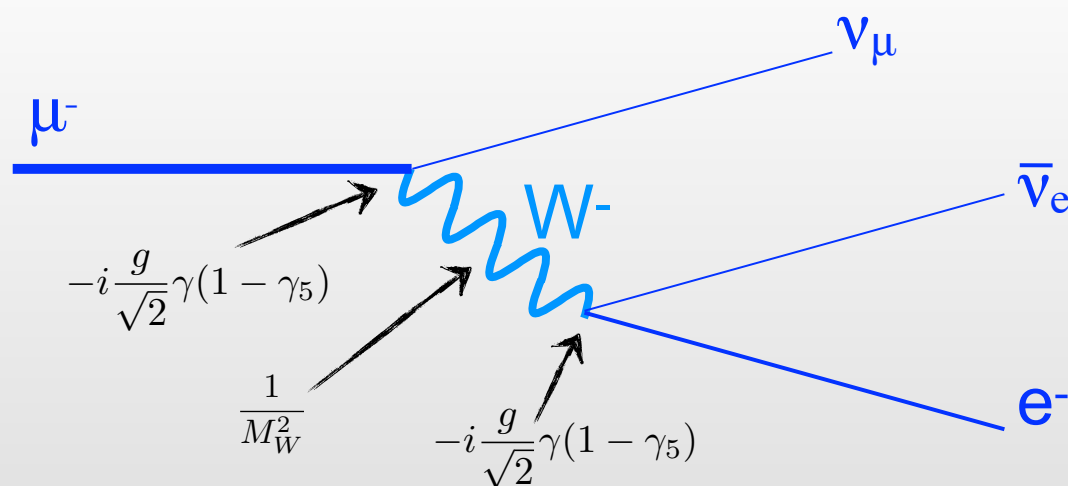
tasso di decadimento: $\Gamma \propto |\mathcal{M}|^2$



I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



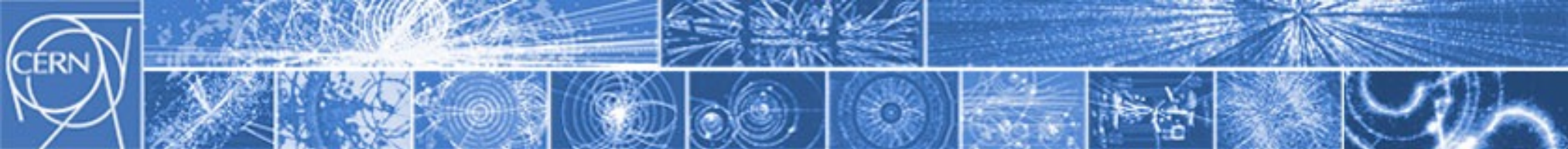
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ampiezza: $|\mathcal{M}| \propto \frac{g^2}{2} [\nu_\mu \gamma(1 - \gamma_5) \mu] \frac{1}{M_W^2} [e \gamma(1 - \gamma_5) \nu_e]$

“...dopo una serie di facili passaggi, si può facilmente dimostrare che...”

$$G_F = \frac{\sqrt{2} g^2}{8 M_W^2}$$

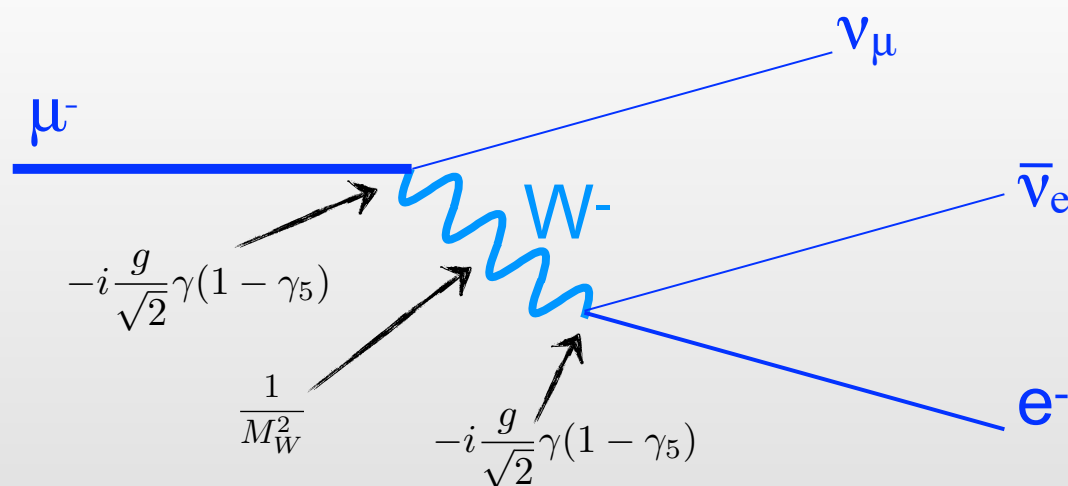
tasso di decadimento: $\Gamma = \frac{1}{192 \pi^3} G_F^2 m_\mu^5$



I diagrammi di Feynman al lavoro

Esempio 4: decadimento del muone

(piuttosto rigoroso: ma per i dettagli ci vorrebbe un intero corso di QFT!)



$$\mathcal{L} \simeq -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{\Psi} \not{D} \Psi + y_{ij} \Psi_i \Psi_j \phi + |D_\mu \phi|^2 - V(\phi)$$

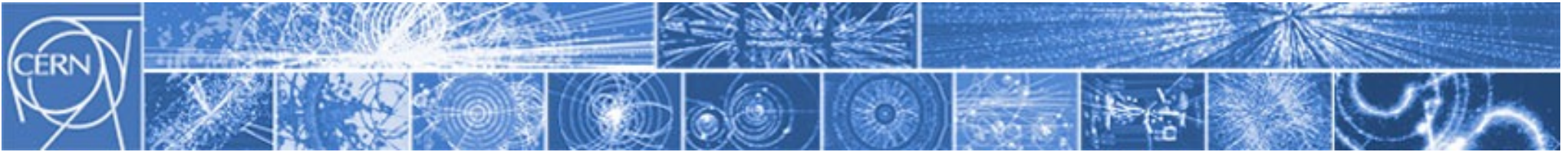
ampiezza: $|\mathcal{M}| \propto \frac{g^2}{2} [\nu_\mu \gamma(1 - \gamma_5) \mu] \frac{1}{M_W^2} [e \gamma(1 - \gamma_5) \nu_e]$

“...dopo una serie di facili passaggi, si può facilmente dimostrare che...”

$$G_F = \frac{\sqrt{2} g^2}{8 M_W^2}$$

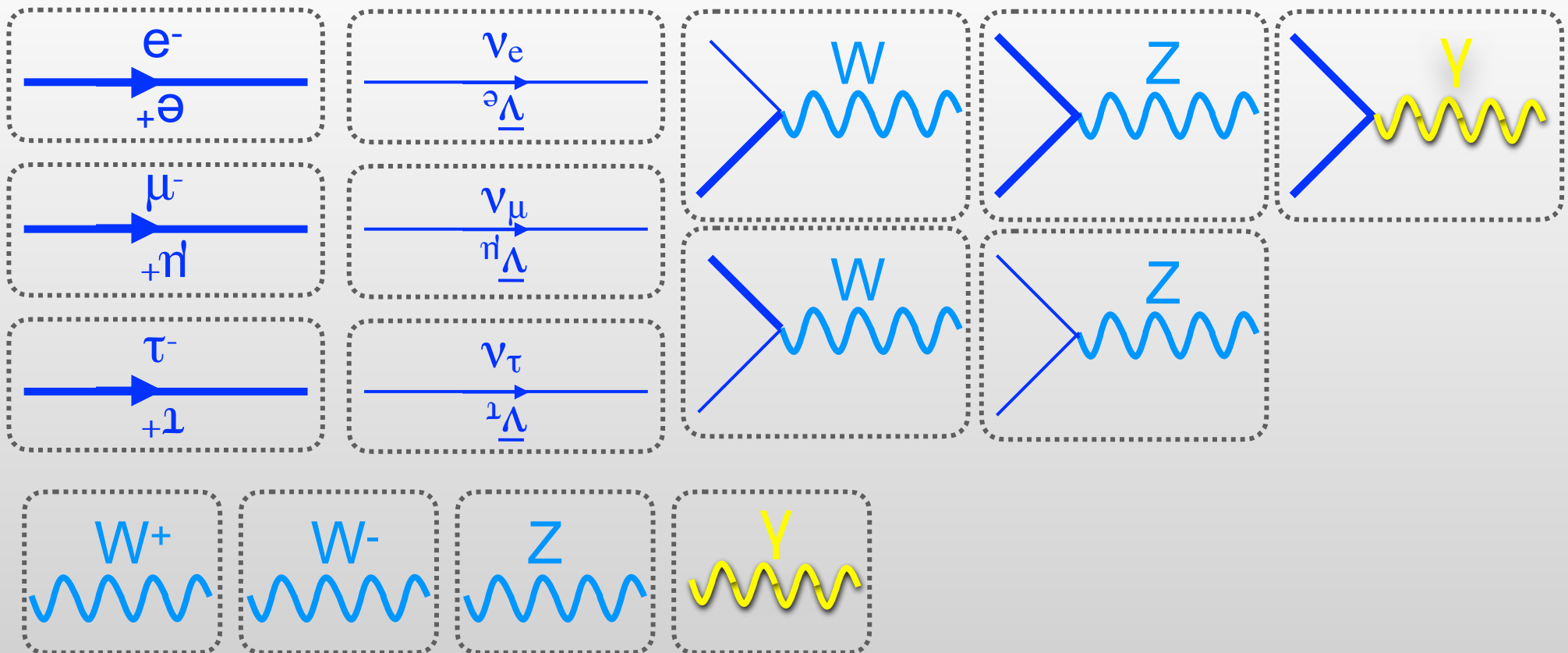
tasso di decadimento: $\Gamma = \frac{1}{192 \pi^3} G_F^2 m_\mu^5$

vita media: $\tau = 1/\Gamma = (2.1969811 \pm 0.0000022) \times 10^{-6}$ secondi



I diagrammi di Feynman al lavoro: gioco del domino *(un'idea di presentazione/masterclass?)*

EW Feynman rules



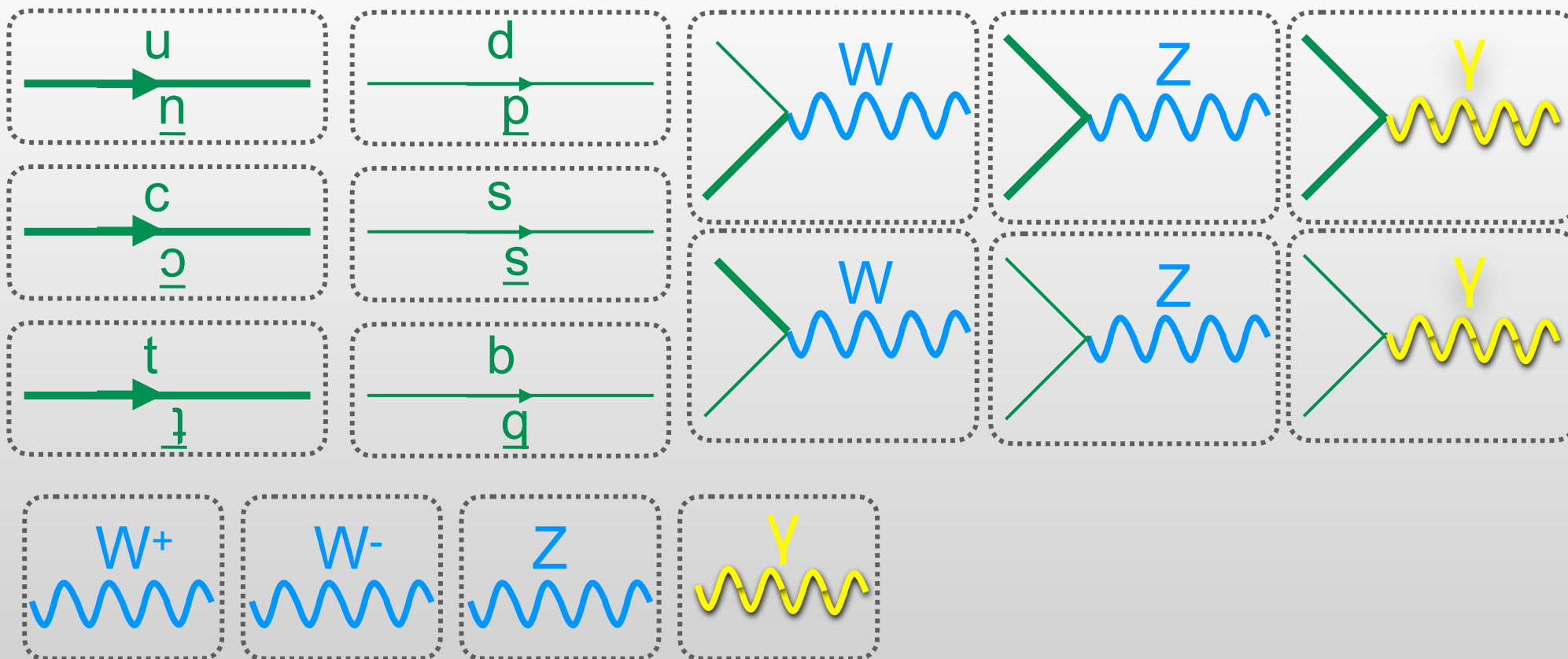
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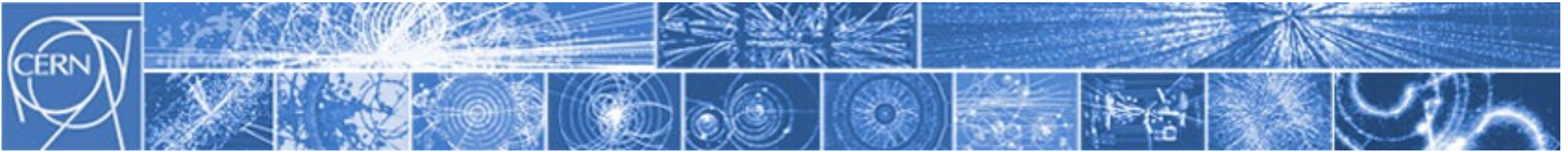
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EW Feynman rules



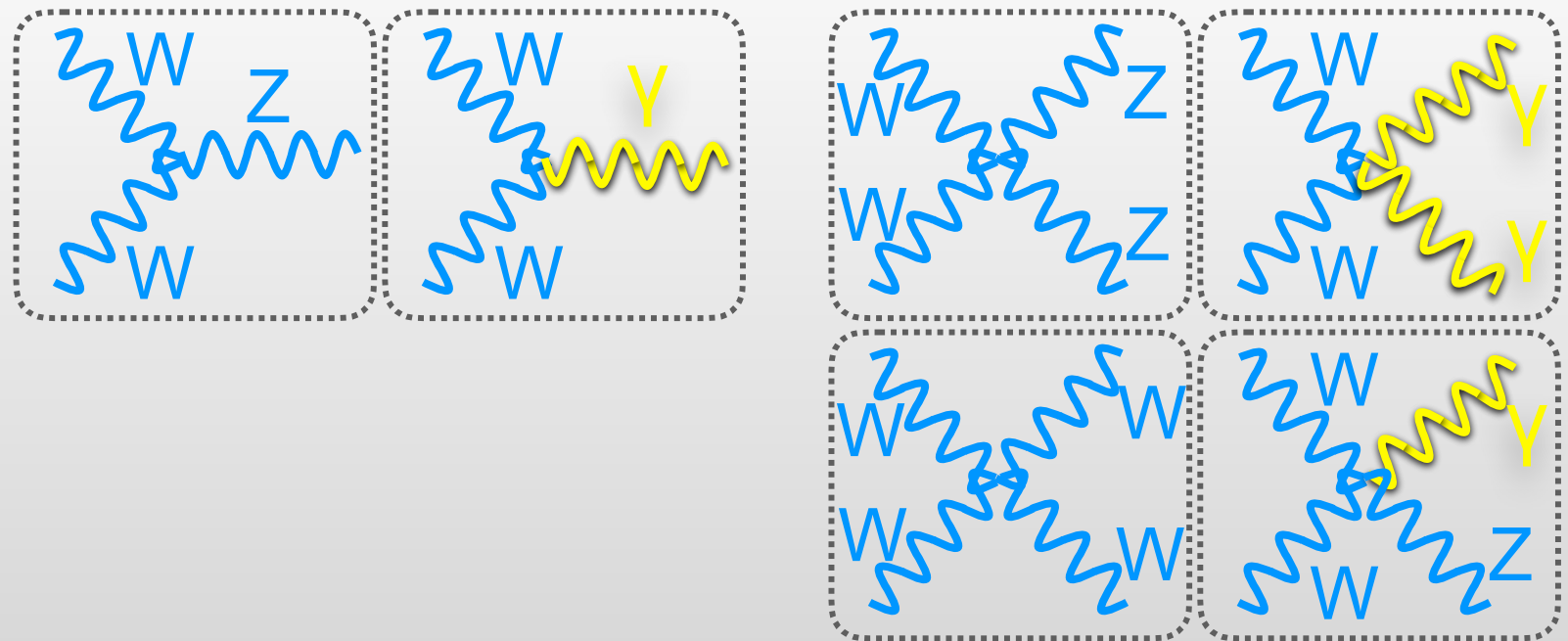
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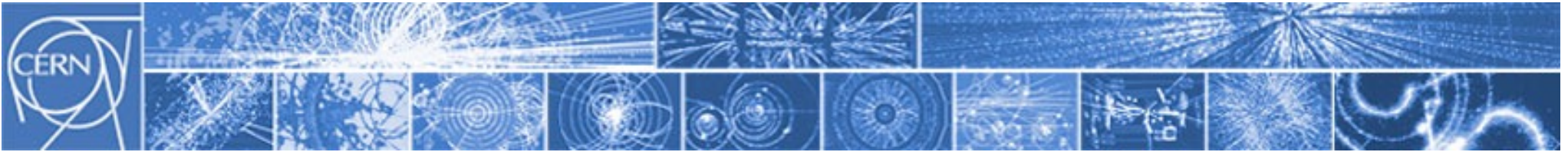
I diagrammi di Feynman al lavoro: *gioco del domino* (un'idea di presentazione/masterclass?)

EW Feynman: triple and quartic gauge interactions



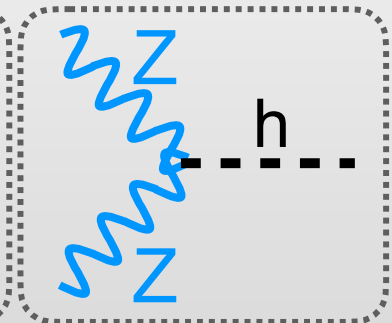
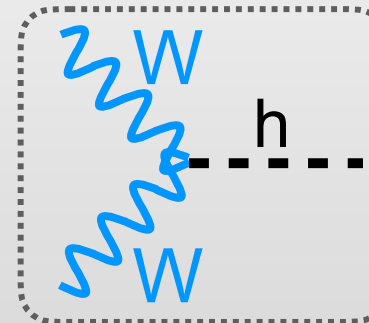
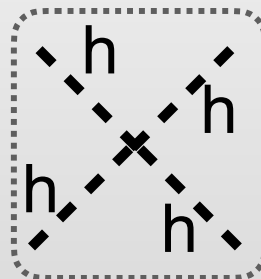
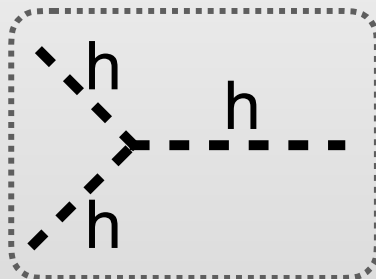
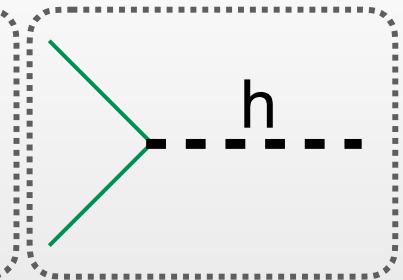
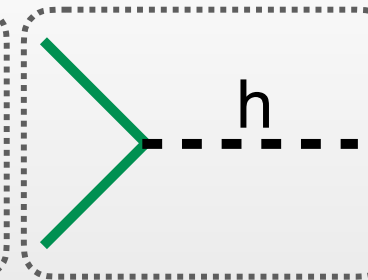
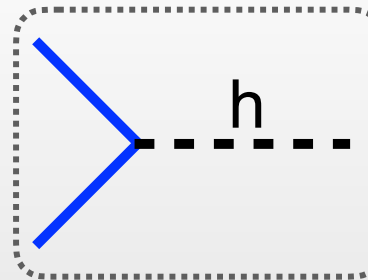
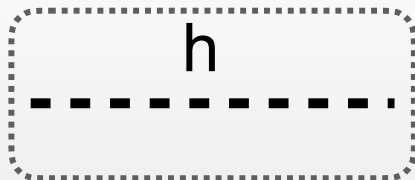
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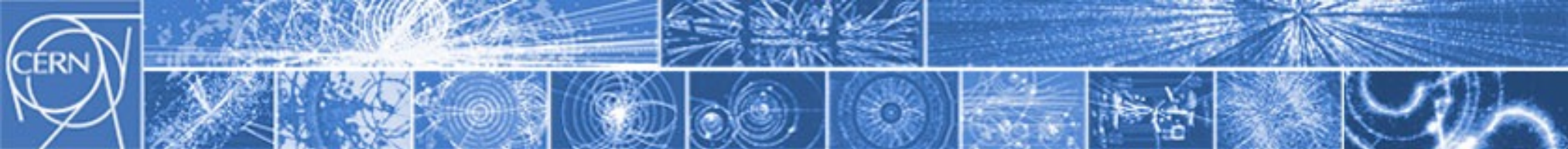
I diagrammi di Feynman al lavoro: *gioco del domino* (un'idea di presentazione/masterclass?)

Feynman rules higgs sector



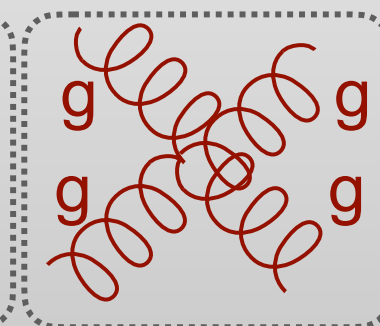
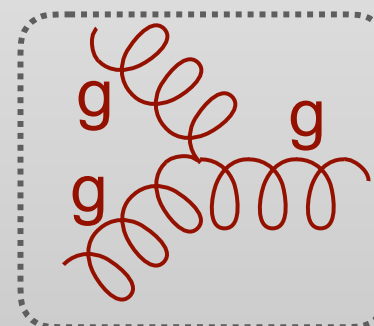
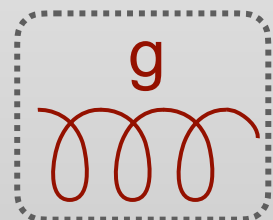
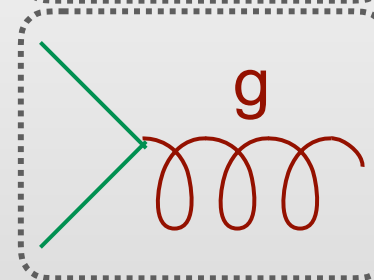
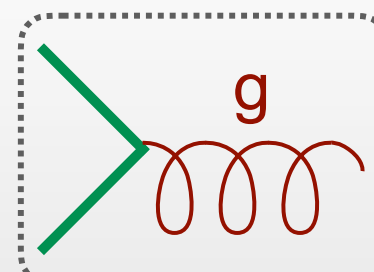
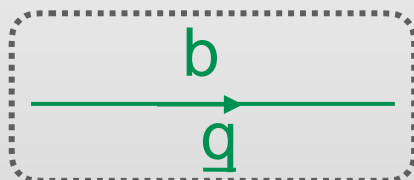
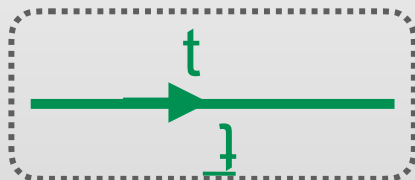
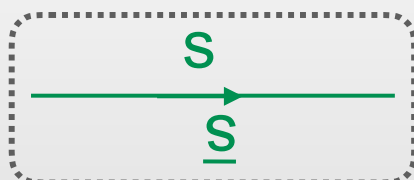
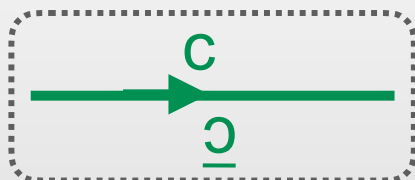
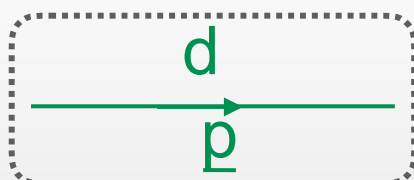
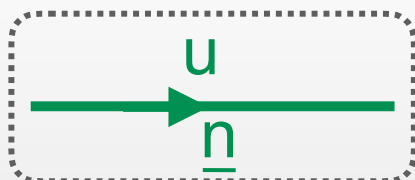
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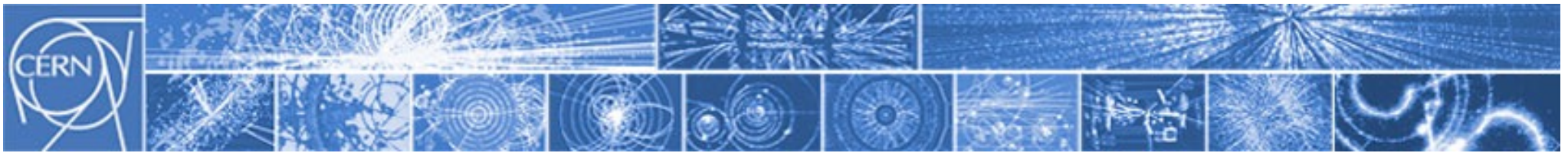
I diagrammi di Feynman al lavoro: *gioco del domino* (un'idea di presentazione/masterclass?)

QCD Feynman rules



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I diagrammi di Feynman al lavoro: *FeynGame* (un'idea di presentazione/masterclass?)

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FeynGame

R.V. Harlander, S.Y. Klein, M. Lipp

(Submitted on 28 Feb 2020)

A java-based graphical tool for drawing Feynman diagrams is presented. It differs from similar existing tools in various respects. For example, it is based on models, consisting of particles (lines) and (optionally) vertices, each of which can be given their individual properties (line style, color, arrows, label, etc.). The diagrams can be exported in any standard image format, or as PDF. Aside from its plain graphical aspect, the goal of FeynGame is also educative, as it can check a Feynman diagrams validity. This provides the basis to play games with diagrams, for example. Here we describe on such game where a given set of initial and final states must be connected through a Feynman diagram within a given interaction model.

Comments: 26 pages, several figures and screenshots. FeynGame is available from [this https URL](https://arxiv.org/abs/2003.00896)

Subjects: **Physics Education (physics.ed-ph)**; High Energy Physics – Phenomenology (hep-ph)

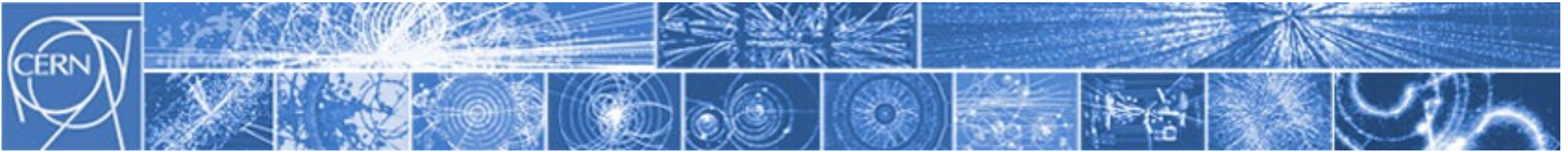
Report number: TTK-20-04

Cite as: [arXiv:2003.00896](https://arxiv.org/abs/2003.00896) [physics.ed-ph]

(or [arXiv:2003.00896v1](https://arxiv.org/abs/2003.00896v1) [physics.ed-ph] for this version)

<https://arxiv.org/abs/2003.00896>

<https://gitlab.com/feyngame/FeynGame>



I diagrammi di Feynman al lavoro: *FeynGame* (un'idea di presentazione/masterclass?)

The screenshot displays two windows from a Java application. The left window is a terminal titled 'out -- java -jar FeynGame.jar game.model -- 122x39'. It shows the output of a build process, including file sizes and compression ratios for various resources and JavaFX classes. Below the terminal output is a large green 'FeynGame' logo and copyright information for 2019, listing Robert Harlander, Sven Yannick Klein, and Maximilian Lipp. The right window is titled 'FeynGame v1.0.0' and shows a graphical interface with a grid background. A Feynman diagram is displayed, featuring two vertices connected by a red wavy line (representing a photon or gluon). Each vertex has two black lines with arrows pointing away from it, representing fermions. A toolbar at the bottom of the right window contains icons for adding a vertex (+), a fermion line (t), a gluon line (g), a photon line (y), a Higgs boson line (H), a fermion vertex (black dot), a fermion vertex (red dot), a cross vertex (Cross), and a star (Star).

<https://arxiv.org/abs/2003.00896>

<https://gitlab.com/feyngame/FeynGame>