

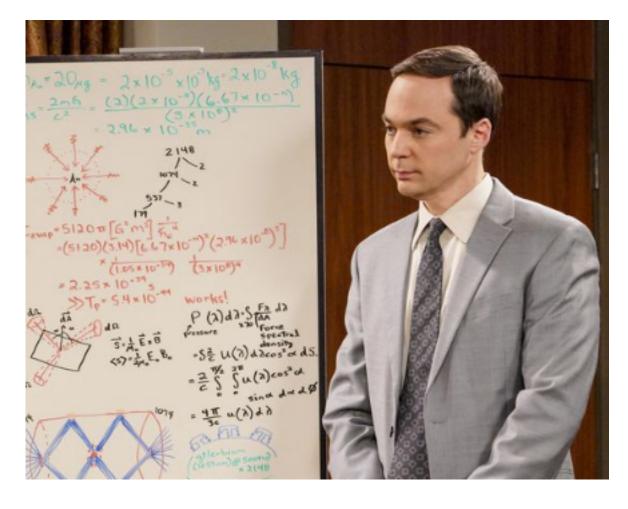
Andrea Coccaro - 2 Febbraio 2021



## Chi sono?









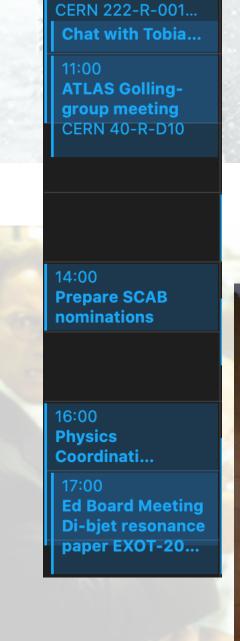


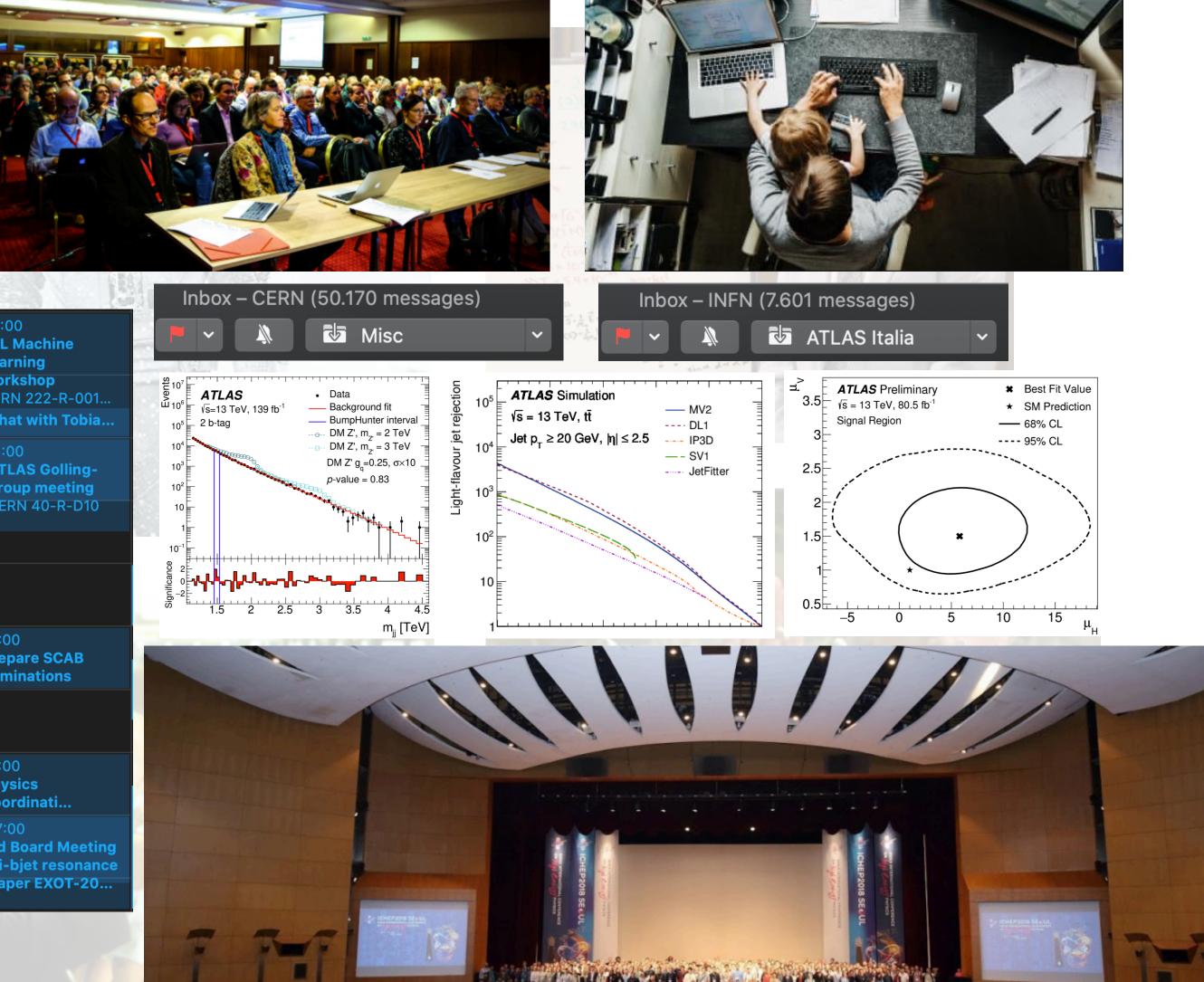


< 2020  $\geq$  2020

Fisico sperimentale delle particelle 2007-2010 | PhD | Genova 2010-2011 | Post-doc | Genova 2012-2014 | Post-doc | Washington 2015-2016 | Post-doc | Ginevra 2017- Ricercatore INFN Genova







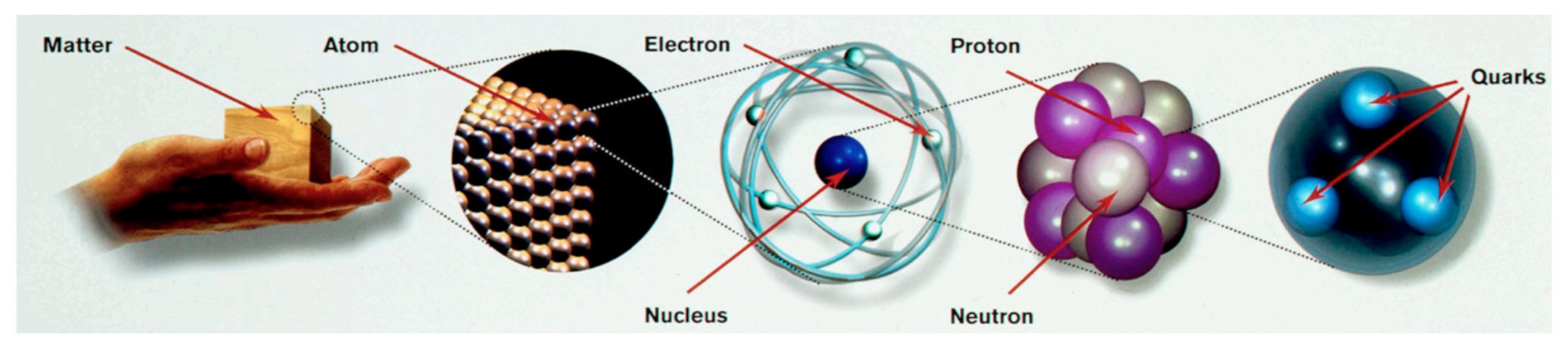
## La danza della scienza

1 Osservazione di un fenomeno tramite esperimento

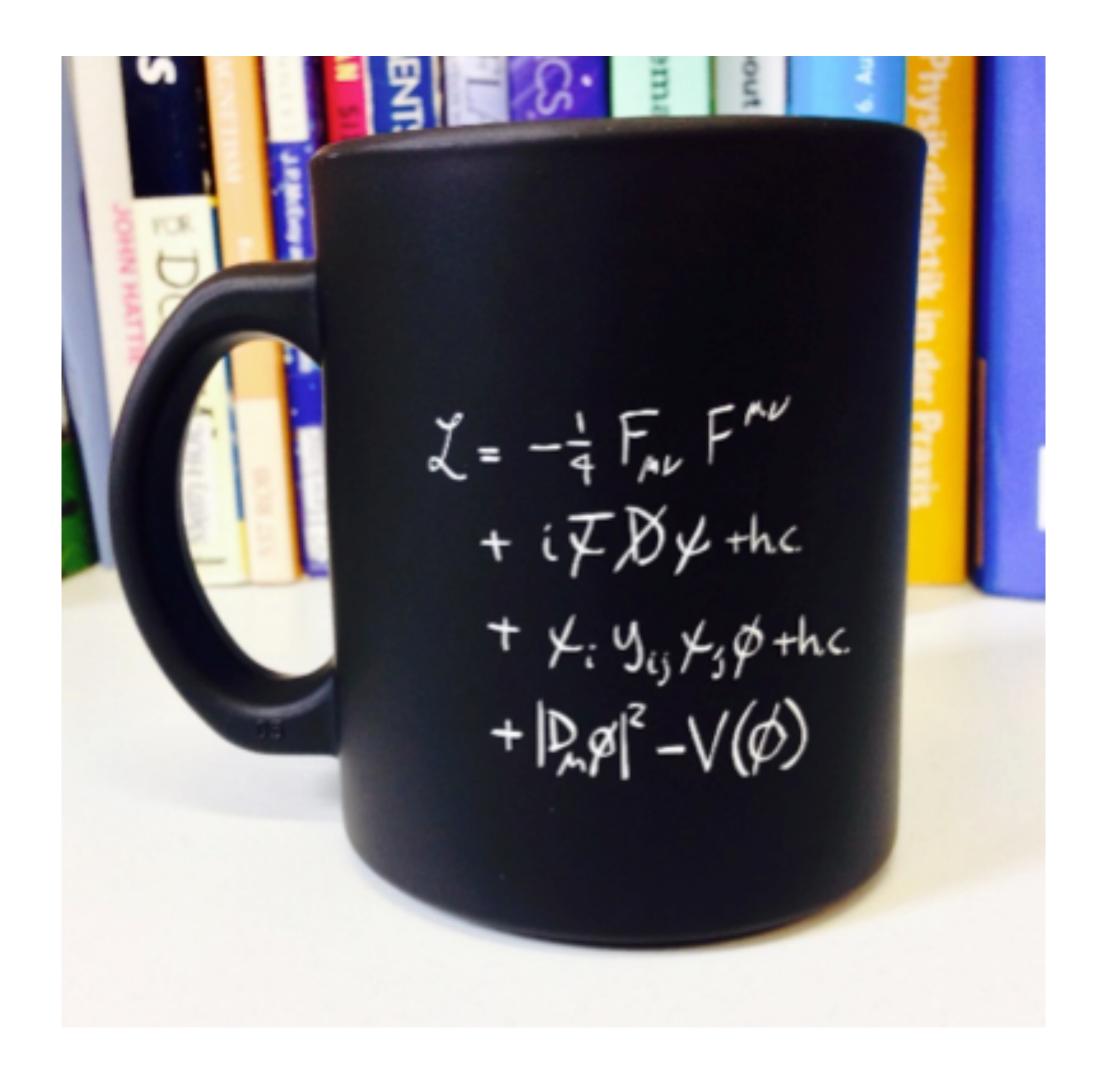
2 | Formulazione di una teoria per spiegare il fenomeno

3 | Potere predittivo della teoria per un nuovo fenomeno

4 Nuovo esperimento per verificare la predizione della teoria



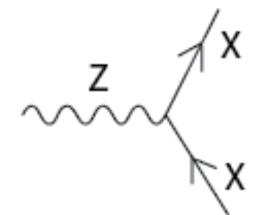
## Il Modello Standard



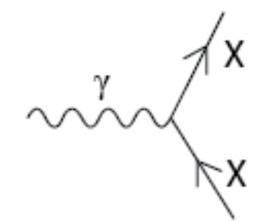
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\mathcal{L}_{SM} = -\frac{1}{2}\partial_{\nu}g^{a}_{\mu}\partial_{\nu}g^{a}_{\mu} - g_{s}f^{abc}\partial_{\mu}g^{a}_{\nu}g^{b}_{\mu}g^{c}_{\nu} - \frac{1}{4}g^{2}_{s}f^{abc}f^{ade}g^{b}_{\mu}g^{c}_{\nu}g^{d}_{\mu}g^{e}_{\nu} - \partial_{\nu}W^{+}_{\mu}\partial_{\nu}W^{-}_{\mu} -
                                                                                        M^2 W_{\mu}^+ W_{\mu}^- - \tfrac{1}{2} \partial_{\nu} Z_{\mu}^0 \partial_{\nu} Z_{\mu}^0 - \tfrac{1}{2c_{c}^2} M^2 Z_{\mu}^0 Z_{\mu}^0 - \tfrac{1}{2} \partial_{\mu} A_{\nu} \partial_{\mu} A_{\nu} - igc_w (\partial_{\nu} Z_{\mu}^0 (W_{\mu}^+ W_{\nu}^- - W_{\mu}^- W_{\mu}^- - W_{\mu}^- - W_{\mu}^- - W_{\mu}^- W_{\mu}^- - W_{\mu}^- W_{\mu}^- - W_{\mu}^- W_{\mu}^- - W_{\mu}^- - W_{\mu}^- W_{\mu}^- - W_{\mu}^- W_{\mu}^- - W_{\mu}^- - W_{\mu}^- - W_{\mu}^- - W_{\mu}^- W_{\mu}^- - W_{\mu}^-
                                                                                                                                             W_{\nu}^{+}W_{\mu}^{-}) - Z_{\nu}^{0}(W_{\mu}^{+}\partial_{\nu}W_{\mu}^{-} - W_{\mu}^{-}\partial_{\nu}W_{\mu}^{+}) + Z_{\mu}^{0}(W_{\nu}^{+}\partial_{\nu}W_{\mu}^{-} - W_{\nu}^{-}\partial_{\nu}W_{\mu}^{+})) -
                                                                   igs_w(\partial_{\nu}A_{\mu}(W_{\mu}^+W_{\nu}^- - W_{\nu}^+W_{\mu}^-) - A_{\nu}(W_{\mu}^+\partial_{\nu}W_{\mu}^- - W_{\mu}^-\partial_{\nu}W_{\mu}^+) + A_{\mu}(W_{\nu}^+\partial_{\nu}W_{\mu}^- - W_{\mu}^-\partial_{\nu}W_{\mu}^+) + A_{\mu}(W_{\nu}^+\partial_{\nu}W_{\mu}^- - W_{\mu}^-\partial_{\nu}W_{\mu}^-)
                                                                                 W_{\nu}^{-}\partial_{\nu}W_{\mu}^{+})) - \frac{1}{2}g^{2}W_{\mu}^{+}W_{\nu}^{-}W_{\nu}^{+}W_{\nu}^{-} + \frac{1}{2}g^{2}W_{\mu}^{+}W_{\nu}^{-}W_{\mu}^{+}W_{\nu}^{-} + g^{2}c_{w}^{2}(Z_{\mu}^{0}W_{\mu}^{+}Z_{\nu}^{0}W_{\nu}^{-} - Q_{\mu}^{2}W_{\mu}^{-}W_{\nu}^{-}))
                                                                          Z_{\mu}^{0}Z_{\mu}^{0}W_{\nu}^{+}W_{\nu}^{-}) + g^{2}s_{w}^{2}(A_{\mu}W_{\mu}^{+}A_{\nu}W_{\nu}^{-} - A_{\mu}A_{\mu}W_{\nu}^{+}W_{\nu}^{-}) + g^{2}s_{w}c_{w}(A_{\mu}Z_{\nu}^{0}(W_{\mu}^{+}W_{\nu}^{-} - A_{\mu}A_{\mu}W_{\nu}^{-}W_{\nu}^{-}) + g^{2}s_{w}c_{w}(A_{\mu}Z_{\nu}^{0}(W_{\mu}^{+}W_{\nu}^{-}) + g^{2}s_{w}c_{w}(A_{\mu}Z_{\nu}^{0}(W_{\mu}^{+}W_{
                                                           W_{\nu}^{+}W_{\mu}^{-}) - 2A_{\mu}Z_{\mu}^{0}W_{\nu}^{+}W_{\nu}^{-}) - \frac{1}{2}\partial_{\mu}H\partial_{\mu}H - 2M^{2}\alpha_{h}H^{2} - \partial_{\mu}\phi^{+}\partial_{\mu}\phi^{-} - \frac{1}{2}\partial_{\mu}\phi^{0}\partial_{\mu}\phi^{0} - \frac
                                                                                                                                                                                                                                                                                                                                    \beta_h \left( \frac{2M^2}{g^2} + \frac{2M}{g}H + \frac{1}{2}(H^2 + \phi^0\phi^0 + 2\phi^+\phi^-) \right) + \frac{2M^4}{g^2}\alpha_h - \frac{1}{2}(H^2 + \phi^0\phi^0 + 2\phi^+\phi^-) + \frac{2M^4}{g^2}\alpha_h - \frac{1}{2}(H^2 + \phi^0\phi^0 + 2\phi^-\phi^-) + \frac{2M^4}{g^2}\alpha_h - \frac{2M^4}{g^2}\alpha_h -
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            q\alpha_{b}M(H^{3}+H\phi^{0}\phi^{0}+2H\phi^{+}\phi^{-})-
                                                                                                                                                    \tfrac{1}{8}g^2\alpha_h\left(H^4+(\phi^0)^4+4(\phi^+\phi^-)^2+4(\phi^0)^2\phi^+\phi^-+4H^2\phi^+\phi^-+2(\phi^0)^2H^2\right)-
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             gMW_{\mu}^{+}W_{\mu}^{-}H - \frac{1}{2}g\frac{M}{c_{\nu\nu}^{2}}Z_{\mu}^{0}Z_{\mu}^{0}H -
                                                                                                                                                                                                                                                                                                        \frac{1}{2}ig\left(W_{\mu}^{+}(\phi^{0}\partial_{\mu}\phi^{-}-\phi^{-}\partial_{\mu}\phi^{0})-W_{\mu}^{-}(\phi^{0}\partial_{\mu}\phi^{+}-\phi^{+}\partial_{\mu}\phi^{0})\right)+
                   \frac{1}{2}g\left(W_{\mu}^{+}(H\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{+} - \phi^{+}\partial_{\mu}H)\right) + \frac{1}{2}g\frac{1}{c_{w}}(Z_{\mu}^{0}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{+} - \phi^{+}\partial_{\mu}H)) + \frac{1}{2}g\frac{1}{c_{w}}(Z_{\mu}^{0}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + \frac{1}{2}g\frac{1}{c_{w}}(Z_{\mu}^{0}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + \frac{1}{2}g\frac{1}{c_{w}}(Z_{\mu}^{0}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + \frac{1}{2}g\frac{1}{c_{w}}(Z_{\mu}^{0}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_{\mu}H)) + W_{\mu}^{-}(H\partial_{\mu}\phi^{0} - \phi^{0}\partial_
      M\left(\frac{1}{c_{w}}Z_{\mu}^{0}\partial_{\mu}\phi^{0}+W_{\mu}^{+}\partial_{\mu}\phi^{-}+W_{\mu}^{-}\partial_{\mu}\phi^{+}\right)-ig\frac{s_{w}^{2}}{c_{w}}MZ_{\mu}^{0}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{+})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W_{\mu}^{+}\phi^{-}-W_{\mu}^{-}\phi^{-})+igs_{w}MA_{\mu}(W
                                                                                                                                         W_{\mu}^{-}\phi^{+}) - ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) + igs_{w}A_{\mu}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) - ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) + igs_{w}A_{\mu}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) - ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) + igs_{w}A_{\mu}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) - ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) + igs_{w}A_{\mu}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) - ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) + igs_{w}A_{\mu}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) - ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) + igs_{w}A_{\mu}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) - ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) + igs_{w}A_{\mu}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) - ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{+}) + ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{+}\partial_{\mu}\phi^{-} - \phi^{-}\partial_{\mu}\phi^{-}) + ig \frac{1-2c_{w}^{2}}{2c_{w}} Z_{\mu}^{0}(\phi^{-}\phi^{-}\phi
                                     \frac{1}{4}g^2W_{\mu}^+W_{\mu}^- \left(H^2 + (\phi^0)^2 + 2\phi^+\phi^-\right) - \frac{1}{8}g^2\frac{1}{c_w^2}Z_{\mu}^0Z_{\mu}^0 \left(H^2 + (\phi^0)^2 + 2(2s_w^2 - 1)^2\phi^+\phi^-\right) - \frac{1}{8}g^2W_{\mu}^+W_{\mu}^- \left(H^2 + (\phi^0)^2 + 2\phi^+\phi^-\right) - \frac{1}{8}g^2W_{\mu}^-W_{\mu}^- \left(H^2 + (\phi^0)^2 + 2\phi^-\phi^-\right) - \frac{1}{8}g^2W_{\mu}^-W_{\mu}^- \left(H^2 + (\phi^0)^2 + 2\phi^-\phi^-\right) - \frac{1}{8}g^2W_{\mu}^- \left
                          \frac{1}{2}g^2 \frac{s_w^2}{c_w} Z_\mu^0 \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) - \frac{1}{2}ig^2 \frac{s_w^2}{c_w} Z_\mu^0 H(W_\mu^+ \phi^- - W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^+) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^0 (W_\mu^+ \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^- \phi^-) + \frac{1}{2}g^2 s_w A_\mu^- \phi^- (W_\mu^- \phi^- + W_\mu^
                                                                                                                                                                         W_{\mu}^{-}\phi^{+}) + \frac{1}{2}ig^{2}s_{w}A_{\mu}H(W_{\mu}^{+}\phi^{-} - W_{\mu}^{-}\phi^{+}) - g^{2}\frac{s_{w}}{c_{w}}(2c_{w}^{2} - 1)Z_{\mu}^{0}A_{\mu}\phi^{+}\phi^{-} - Q_{\mu}^{-}\phi^{+})
                                    g^2 s_w^2 A_\mu A_\mu \phi^+ \phi^- + \frac{1}{2} i g_s \, \lambda_{ij}^a (\bar{q}_i^\sigma \gamma^\mu q_j^\sigma) g_\mu^a - \bar{e}^\lambda (\gamma \partial + m_e^\lambda) e^\lambda - \bar{\nu}^\lambda (\gamma \partial + m_\nu^\lambda) \nu^\lambda - \bar{u}_j^\lambda (\gamma \partial + m_\nu^\lambda) 
                                                                                                               m_u^{\lambda})u_j^{\lambda} - \bar{d}_j^{\lambda}(\gamma \partial + m_d^{\lambda})d_j^{\lambda} + igs_w A_{\mu} \left( -(\bar{e}^{\lambda}\gamma^{\mu}e^{\lambda}) + \frac{2}{3}(\bar{u}_j^{\lambda}\gamma^{\mu}u_j^{\lambda}) - \frac{1}{3}(\bar{d}_j^{\lambda}\gamma^{\mu}d_j^{\lambda}) \right) +
                                                                                      \frac{ig}{4c...} Z_{\mu}^{0} \{ (\bar{\nu}^{\lambda} \gamma^{\mu} (1 + \gamma^{5}) \nu^{\lambda}) + (\bar{e}^{\lambda} \gamma^{\mu} (4s_{w}^{2} - 1 - \gamma^{5}) e^{\lambda}) + (\bar{d}_{j}^{\lambda} \gamma^{\mu} (\frac{4}{3}s_{w}^{2} - 1 - \gamma^{5}) d_{j}^{\lambda}) + (\bar{e}^{\lambda} \gamma^{\mu} (4s_{w}^{2} - 1 - \gamma^{5}) e^{\lambda}) + (\bar{d}_{j}^{\lambda} \gamma^{\mu} (\frac{4}{3}s_{w}^{2} - 1 - \gamma^{5}) d_{j}^{\lambda}) + (\bar{e}^{\lambda} \gamma^{\mu} (1 + \gamma^{5}) \nu^{\lambda}) + (\bar{e}^{\lambda} \gamma^{\mu} (4s_{w}^{2} - 1 - \gamma^{5}) e^{\lambda}) + (\bar{d}_{j}^{\lambda} \gamma^{\mu} (\frac{4}{3}s_{w}^{2} - 1 - \gamma^{5}) d_{j}^{\lambda}) + (\bar{e}^{\lambda} \gamma^{\mu} (1 + \gamma^{5}) \nu^{\lambda}) + (\bar{e}^{\lambda} \gamma
      (\bar{u}_{j}^{\lambda}\gamma^{\mu}(1 - \frac{8}{3}s_{w}^{2} + \gamma^{5})u_{j}^{\lambda})\} + \frac{ig}{2\sqrt{2}}W_{\mu}^{+}((\bar{\nu}^{\lambda}\gamma^{\mu}(1 + \gamma^{5})U^{lep}_{\lambda\kappa}e^{\kappa}) + (\bar{u}_{j}^{\lambda}\gamma^{\mu}(1 + \gamma^{5})C_{\lambda\kappa}d_{j}^{\kappa})) +
                                                                                                                                                                                                                                                                                          \frac{ig}{2\sqrt{2}}W_{\mu}^{-}\left((\bar{e}^{\kappa}U^{lep}_{\kappa\lambda}^{\dagger}\gamma^{\mu}(1+\gamma^{5})\nu^{\lambda})+(\bar{d}_{j}^{\kappa}C_{\kappa\lambda}^{\dagger}\gamma^{\mu}(1+\gamma^{5})u_{j}^{\lambda})\right)+
                                                                                                                                                                                                                                           \frac{ig}{2M\sqrt{2}}\phi^{+}\left(-m_{e}^{\kappa}(\bar{\nu}^{\lambda}U^{lep}_{\lambda\kappa}(1-\gamma^{5})e^{\kappa})+m_{\nu}^{\lambda}(\bar{\nu}^{\lambda}U^{lep}_{\lambda\kappa}(1+\gamma^{5})e^{\kappa}\right)+
                                                                                        \frac{ig}{2M\sqrt{2}}\phi^{-}\left(m_{e}^{\lambda}(\bar{e}^{\lambda}U^{lep}_{\lambda\kappa}^{\dagger}(1+\gamma^{5})\nu^{\kappa})-m_{\nu}^{\kappa}(\bar{e}^{\lambda}U^{lep}_{\lambda\kappa}^{\dagger}(1-\gamma^{5})\nu^{\kappa}\right)-\frac{g}{2}\frac{m_{\nu}^{\lambda}}{M}H(\bar{\nu}^{\lambda}\nu^{\lambda})-\frac{g}{2}\frac{m_{\nu}^{\lambda}}{M}H(\bar{\nu}^{\lambda}\nu^{\lambda})
                                                                                                                                  \frac{g}{2} \frac{m_e^{\lambda}}{M} H(\bar{e}^{\lambda} e^{\lambda}) + \frac{ig}{2} \frac{m_{\nu}^{\lambda}}{M} \phi^0(\bar{\nu}^{\lambda} \gamma^5 \nu^{\lambda}) - \frac{ig}{2} \frac{m_e^{\lambda}}{M} \phi^0(\bar{e}^{\lambda} \gamma^5 e^{\lambda}) - \frac{1}{4} \bar{\nu}_{\lambda} M_{\lambda \kappa}^R (1 - \gamma_5) \hat{\nu}_{\kappa} -
                                                           \frac{1}{4} \overline{\nu_{\lambda} M_{\lambda\kappa}^{R} (1 - \gamma_{5}) \hat{\nu}_{\kappa}} + \frac{ig}{2M\sqrt{2}} \phi^{+} \left( -m_{d}^{\kappa} (\bar{u}_{j}^{\lambda} C_{\lambda\kappa} (1 - \gamma^{5}) d_{j}^{\kappa}) + m_{u}^{\lambda} (\bar{u}_{j}^{\lambda} C_{\lambda\kappa} (1 + \gamma^{5}) d_{j}^{\kappa}) + m_{u}^{\lambda} (\bar{u}_{j}^{\lambda} C_{\lambda\kappa} (1 + \gamma^{5}) d_{j}^{\kappa}) + m_{u}^{\lambda} (\bar{u}_{j}^{\lambda} C_{\lambda\kappa} (1 + \gamma^{5}) d_{j}^{\kappa}) \right) + m_{u}^{\lambda} (\bar{u}_{j}^{\lambda} C_{\lambda\kappa} (1 + \gamma^{5}) d_{j}^{\kappa}) + m_{u}^{\lambda} (\bar{u}_{j}^{\lambda} C_{\lambda\kappa} (1 + \gamma^{5}) d_{j}^{\lambda}) + m_{u}^{\lambda} (\bar{u}_{j}^{\lambda} C_{\lambda\kappa} (1 + \gamma^{5}) d_{j}^{\lambda}) + m_{u}^
                                                                                                                                \frac{ig}{2M\sqrt{2}}\phi^{-}\left(m_d^{\lambda}(\bar{d}_j^{\lambda}C_{\lambda\kappa}^{\dagger}(1+\gamma^5)u_j^{\kappa})-m_u^{\kappa}(\bar{d}_j^{\lambda}C_{\lambda\kappa}^{\dagger}(1-\gamma^5)u_j^{\kappa}\right)-\frac{g}{2}\frac{m_u^{\lambda}}{M}H(\bar{u}_j^{\lambda}u_j^{\lambda})-
                                                \frac{g}{2} \frac{m_d^\lambda}{M} H(\bar{d}_j^\lambda d_j^\lambda) + \frac{ig}{2} \frac{m_u^\lambda}{M} \phi^0(\bar{u}_j^\lambda \gamma^5 u_j^\lambda) - \frac{ig}{2} \frac{m_d^\lambda}{M} \phi^0(\bar{d}_j^\lambda \gamma^5 d_j^\lambda) + \bar{G}^a \partial^2 G^a + g_s f^{abc} \partial_\mu \bar{G}^a G^b g_\mu^c +
      \bar{X}^{+}(\partial^{2}-M^{2})X^{+}+\bar{X}^{-}(\partial^{2}-M^{2})X^{-}+\bar{X}^{0}(\partial^{2}-\frac{M^{2}}{c_{w}^{2}})X^{0}+\bar{Y}\partial^{2}Y+igc_{w}W_{\mu}^{+}(\partial_{\mu}\bar{X}^{0}X^{-}-M^{2})X^{0}+\bar{X}^{0}(\partial^{2}-M^{2})X^{0}+\bar{X}^{0}(\partial^{2}-M^{2})X^{0}+\bar{Y}\partial^{2}Y+igc_{w}W_{\mu}^{+}(\partial_{\mu}\bar{X}^{0}X^{-}-M^{2})X^{0}+\bar{X}^{0}(\partial^{2}-M^{2})X
                                                                                                                                                                                                                                                  \partial_{\mu}\bar{X}^{+}X^{0})+igs_{w}W_{\mu}^{+}(\partial_{\mu}\bar{Y}X^{-}-\partial_{\mu}\bar{X}^{+}\bar{Y})+igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}-igc_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}X^{0}))
                                                                                                                                                                                                                                                         \partial_{\mu}\bar{X}^{0}X^{+})+igs_{w}W_{\mu}^{-}(\partial_{\mu}\bar{X}^{-}Y - \partial_{\mu}\bar{Y}X^{+}) + igc_{w}Z_{\mu}^{0}(\partial_{\mu}\bar{X}^{+}X^{+} - \partial_{\mu}\bar{Y}X^{+})
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      \partial_{\mu}\bar{X}^{-}X^{-})+igs_{w}A_{\mu}(\partial_{\mu}\bar{X}^{+}X^{+}-
\partial_{\mu}\bar{X}^{-}X^{-}) - \frac{1}{2}gM\left(\bar{X}^{+}X^{+}H + \bar{X}^{-}X^{-}H + \frac{1}{c_{w}^{2}}\bar{X}^{0}X^{0}H\right) + \frac{1-2c_{w}^{2}}{2c_{w}}igM\left(\bar{X}^{+}X^{0}\phi^{+} - \bar{X}^{-}X^{0}\phi^{-}\right) + \frac{1}{c_{w}^{2}}igM\left(\bar{X}^{+}X^{0}\phi^{+} - \bar{X}^{-}X^{0}\phi^{-}\right) + \frac{1}{c_{w}^{2}}
                                                                                                                                                                                                           \frac{1}{2c_w}igM(\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-) + igMs_w(\bar{X}^0X^-\phi^+ - \bar{X}^0X^-\phi^-) + igMs_w(\bar{X}^0X^-\phi^+ - \bar{X}^0X^-\phi^-) + igMs_w(\bar{X}^0X^-\phi^-) + igMs_w(
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      \frac{1}{2}igM\left(\bar{X}^{+}X^{+}\phi^{0}-\bar{X}^{-}X^{-}\phi^{0}\right).
```

# I diagrammi di Feynman

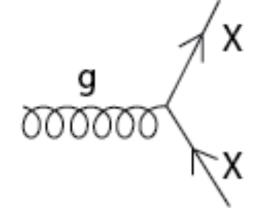
Standard Model Interactions (Forces Mediated by Gauge Bosons)



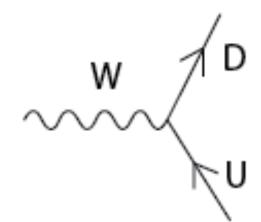
X is any fermion in the Standard Model.



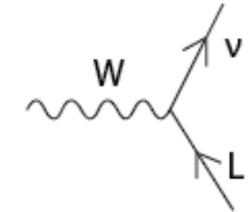
X is electrically charged.



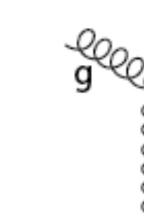
X is any quark.

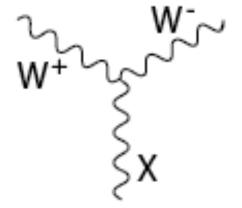


U is a up-type quark; D is a down-type quark.

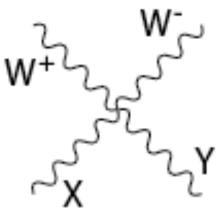


L is a lepton and v is the corresponding neutrino.

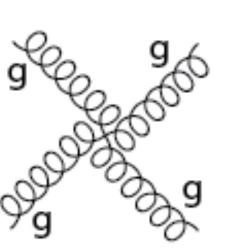


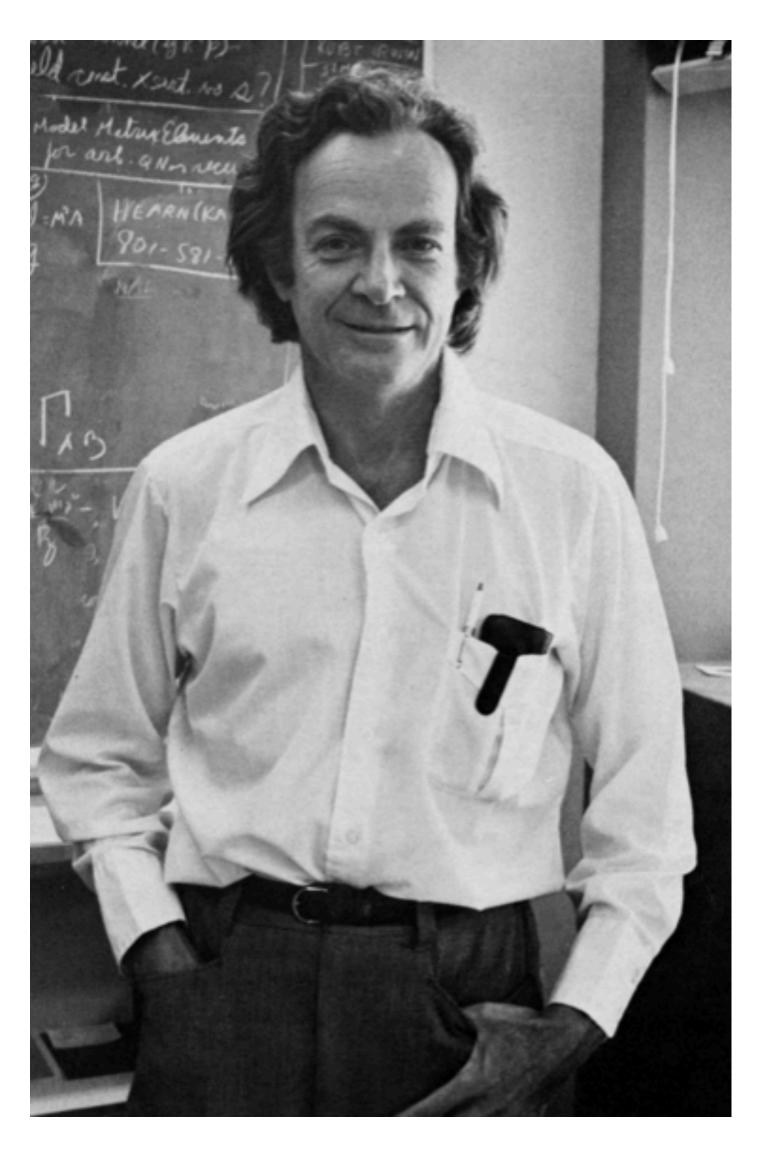


X is a photon or Z-boson.



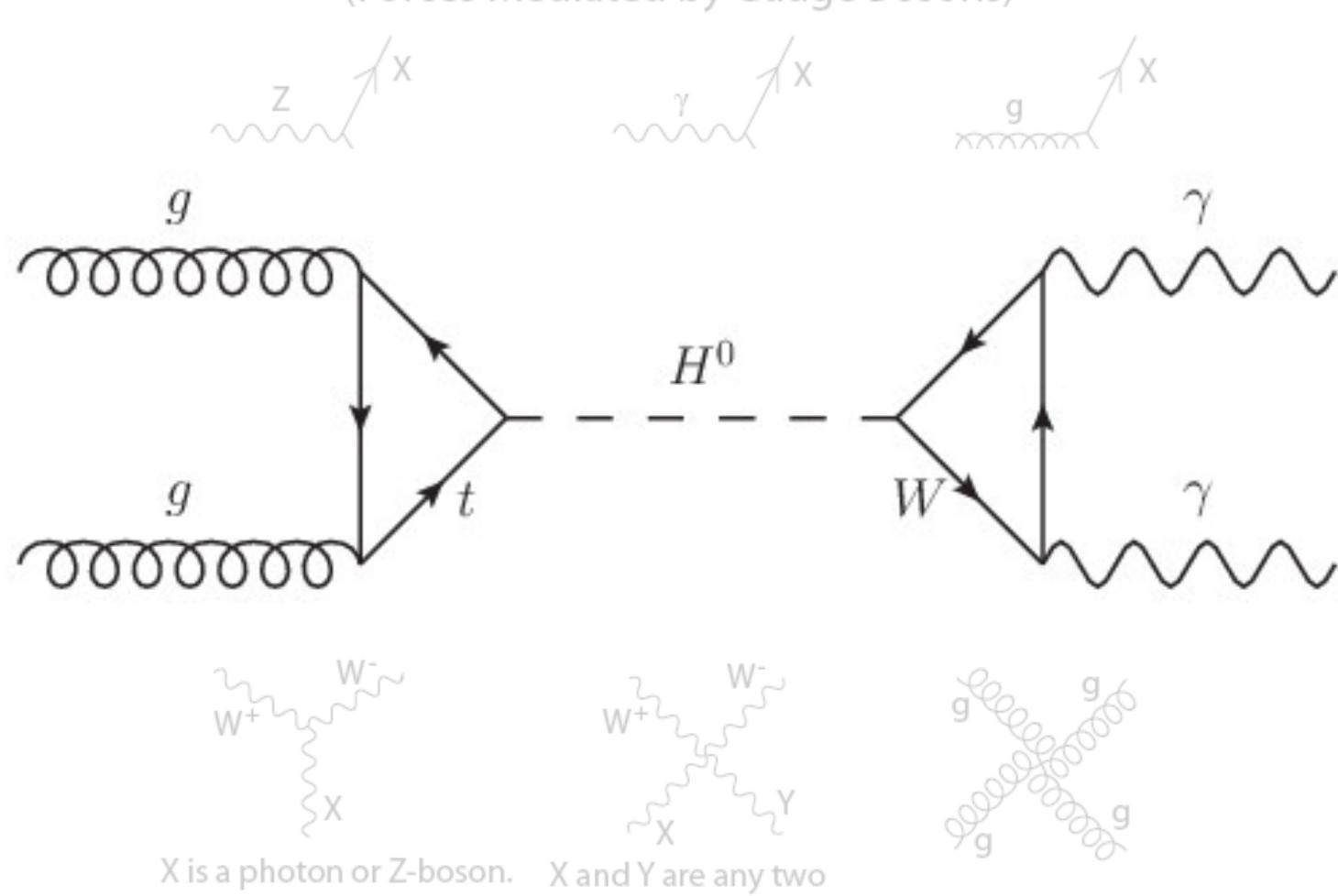
X and Y are any two electroweak bosons such that charge is conserved.





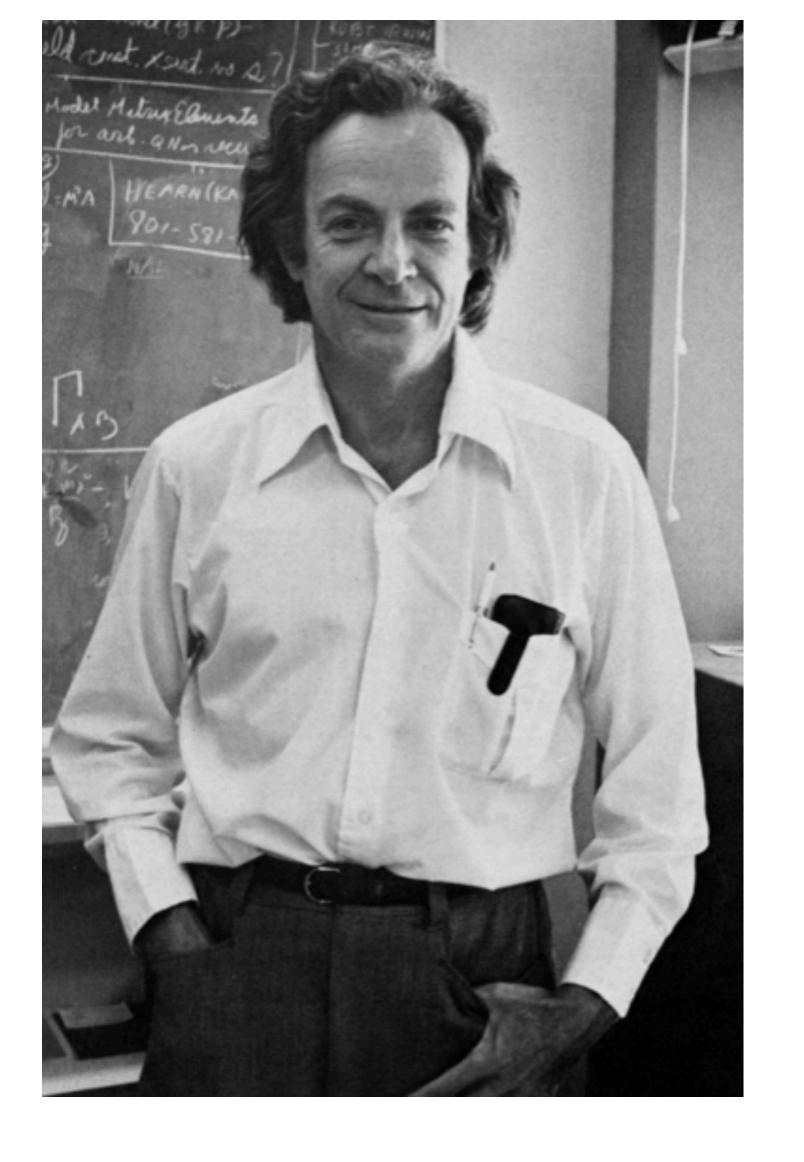
# I diagrammi di Feynman

Standard Model Interactions (Forces Mediated by Gauge Bosons)



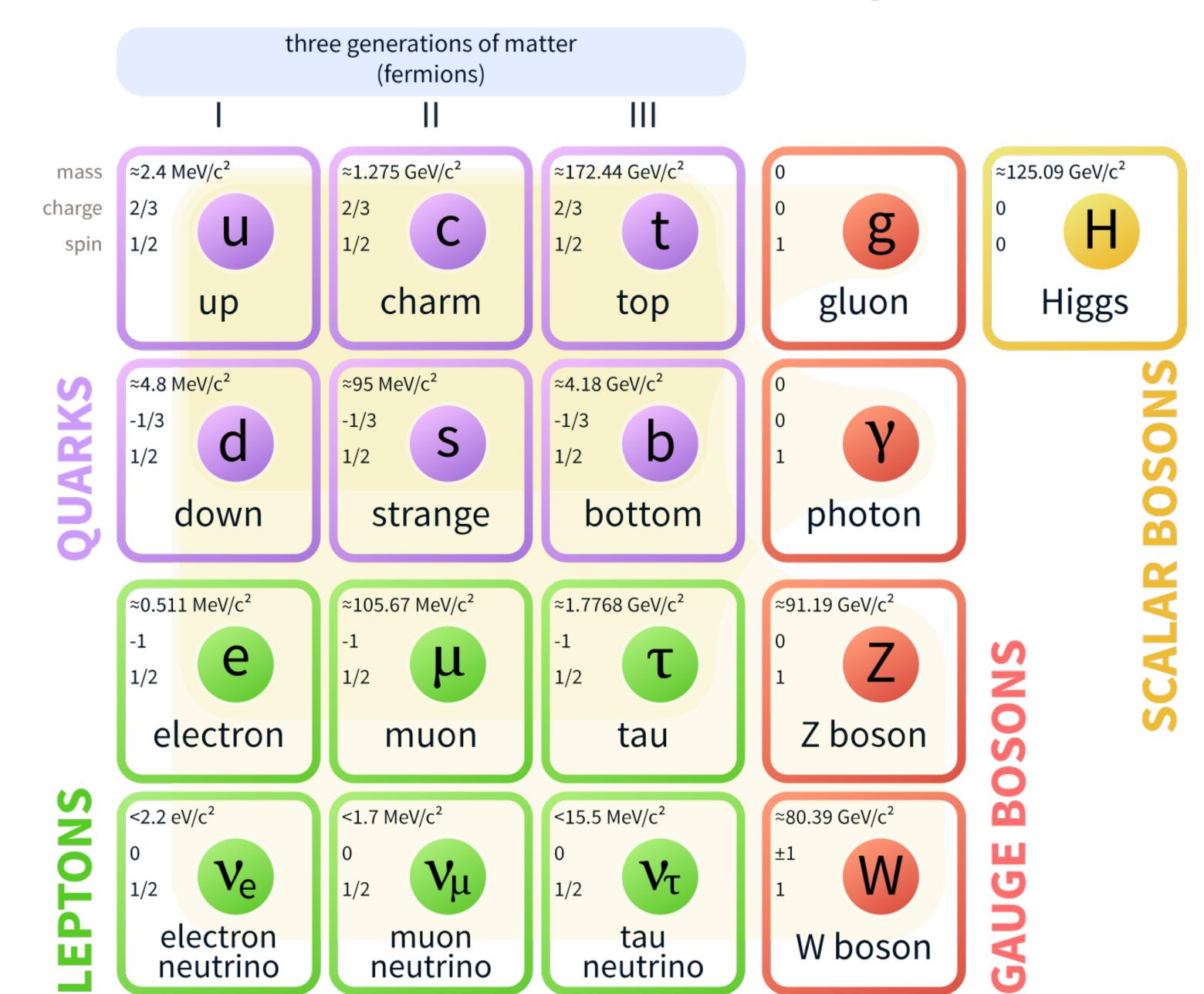
electroweak bosons such

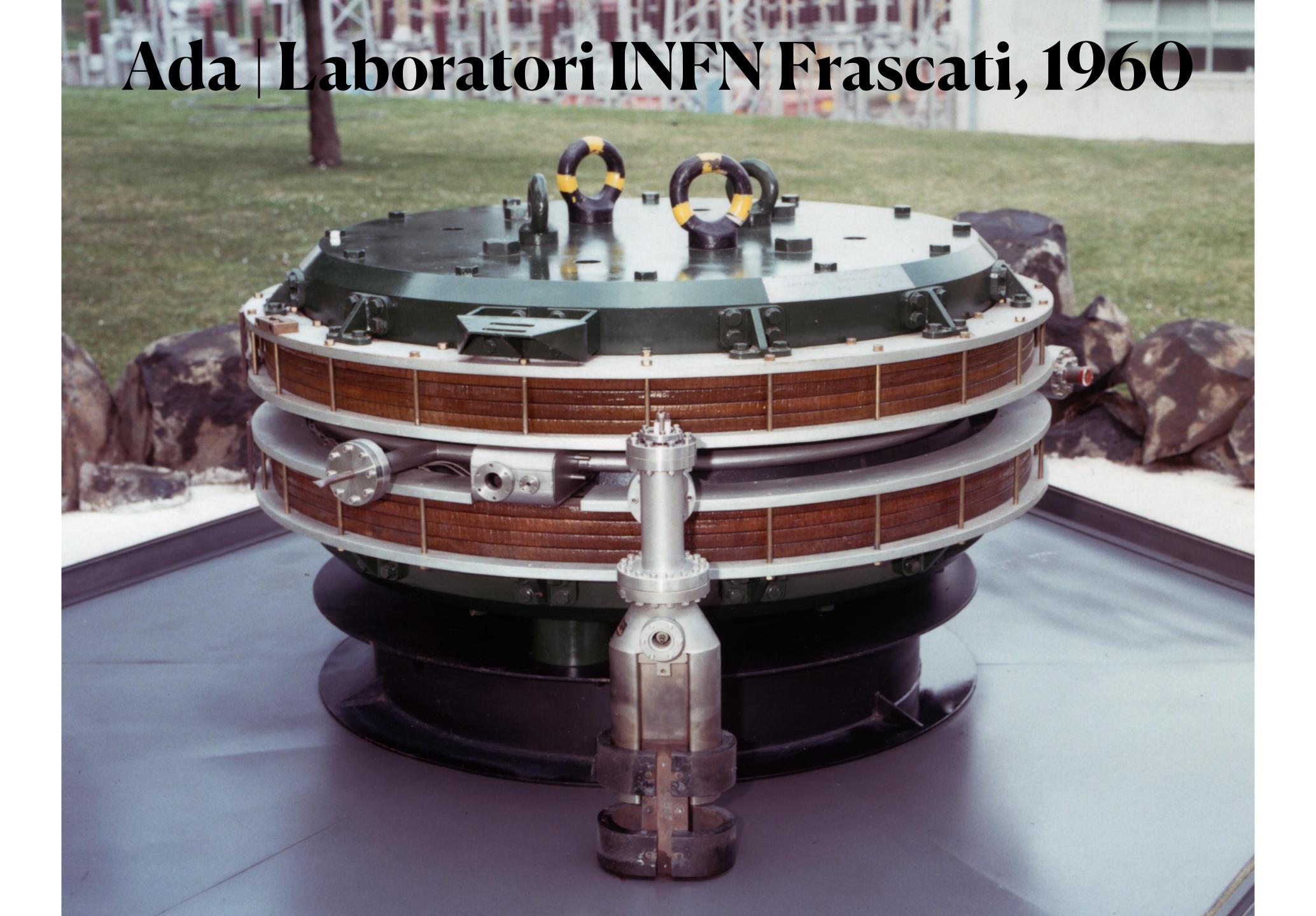
that charge is conserved.



Physics is like sex: sure, it may give some practical results, but that's not why we do it.

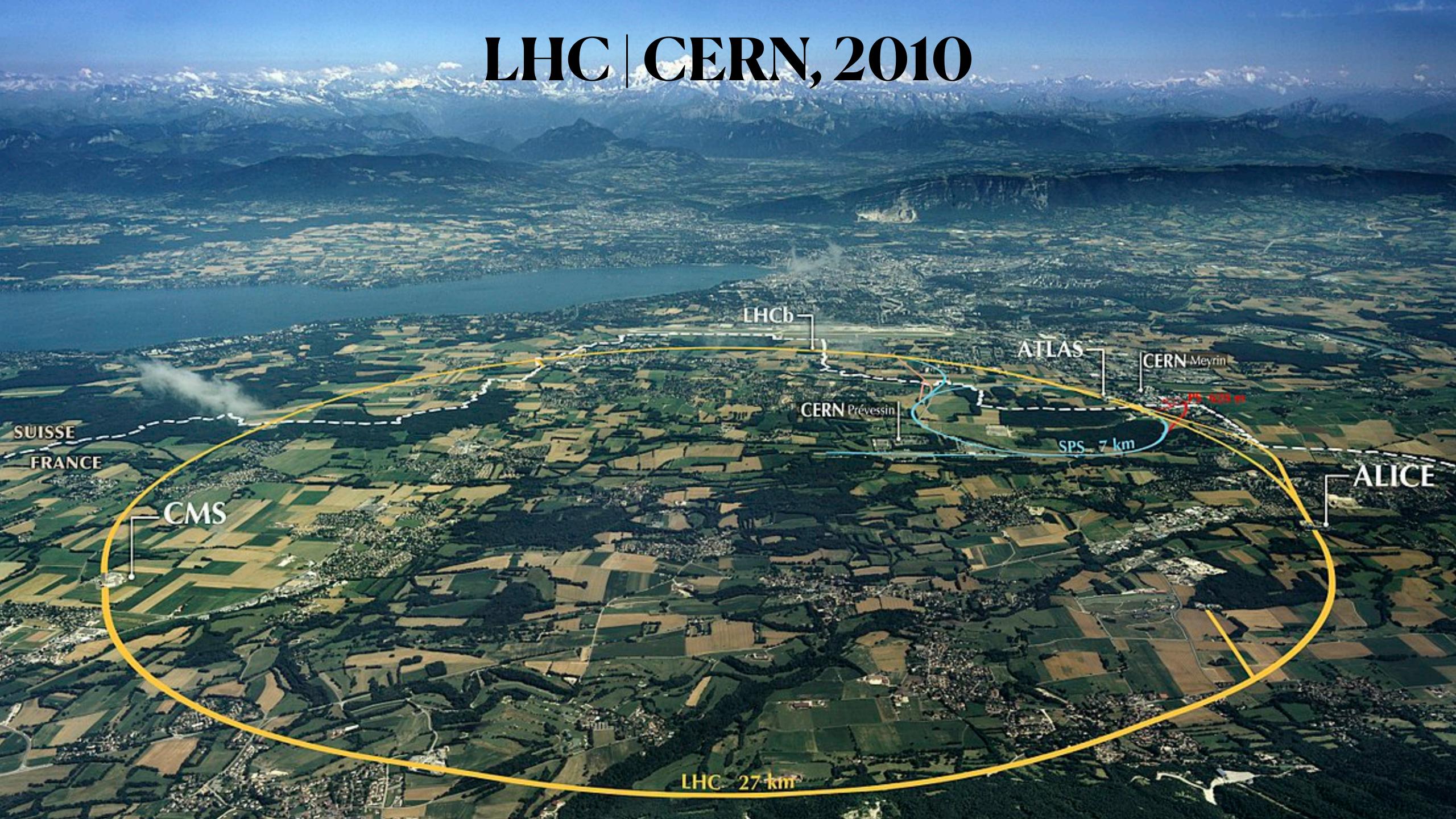
### **Standard Model of Elementary Particles**





"... abbiamo rivolto la nostra attenzione alla creazione di questo nuovo ente internazionale, un laboratorio o un istituto dove sia possibile effettuare ricerca scientifica al di là del quadro nazionale dei vari stati membri ... un ente dotato di risorse maggiori di quelle disponibili ai laboratori nazionali che possa quindi farsi carico di compiti le cui dimensioni e la cui natura siano tali che i singoli Stati non possano svolgerli da soli."

L. De Broglie (1949)



#### Distribution of All CERN Users by Nationality on 27 January 2020

#### MEMBER STATES

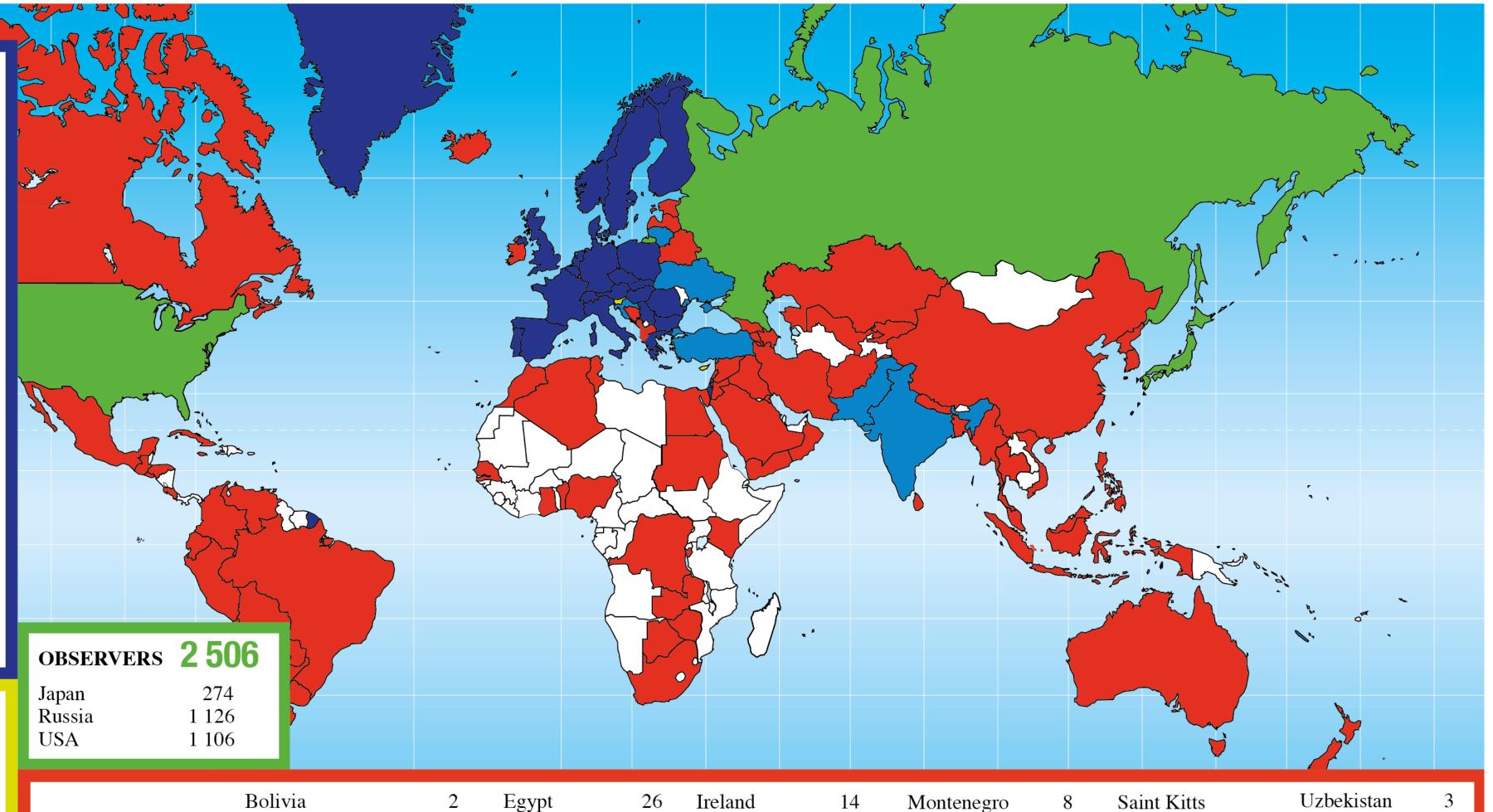
 -	
	ъ

	145
Austria	95
Belgium	113
Bulgaria	71
Czech Republic	216
Denmark	52
Finland	72
France	778
Germany	1 177
Greece	216
Hungary	77
Israel	59
Italy	1 856
Netherlands	170
Norway	59
Poland	311
Portugal	94
Romania	144
Serbia	49
Slovakia	128
Spain	405
Sweden	74
Switzerland	204
United Kingdom	729

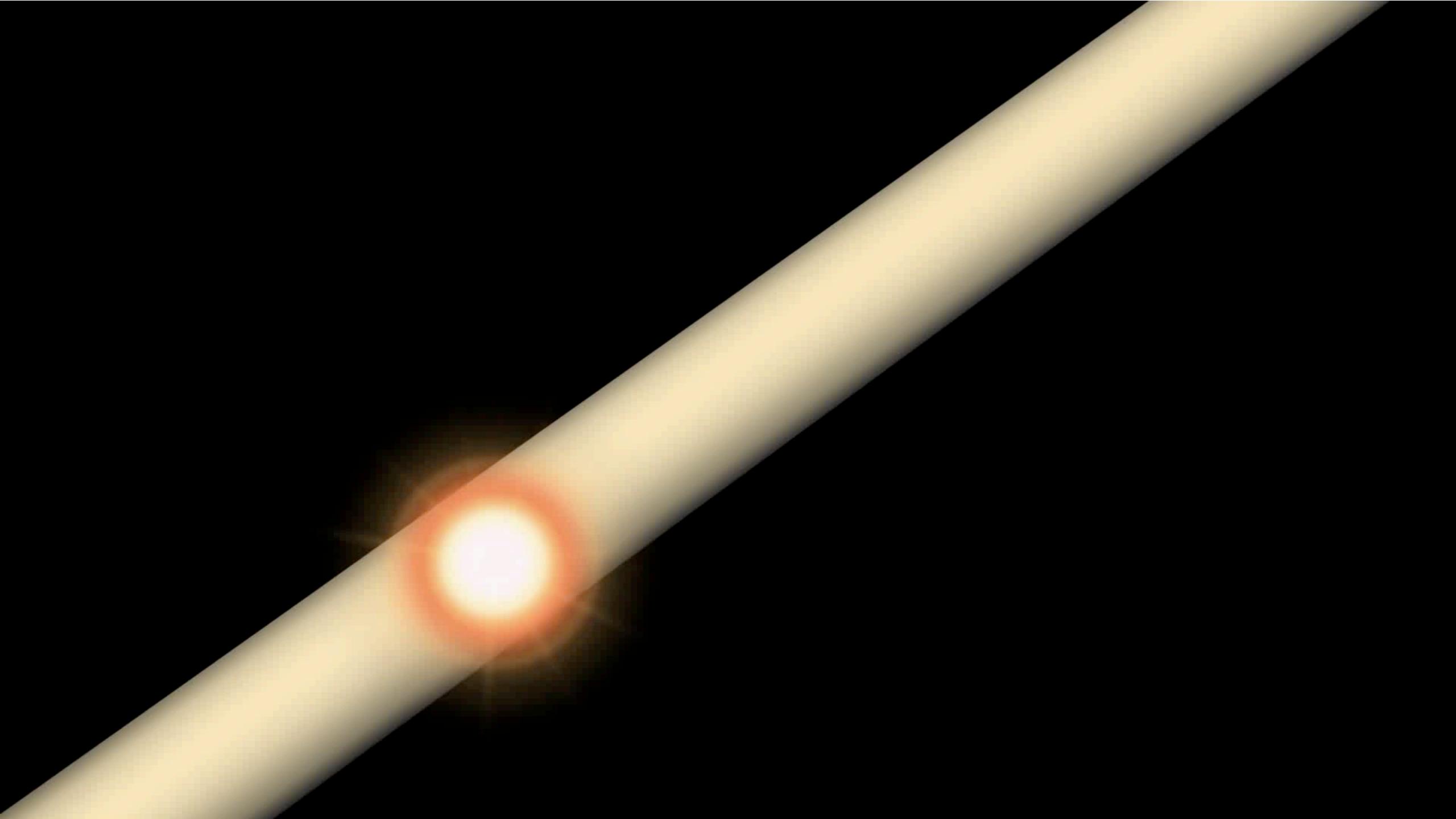
# ASSOCIATE MEMBERS IN THE PRE-STAGE TO MEMBERSHIP

Cyprus	21
Slovenia	33

ASSOCIATE MEMBERS	770
Croatia	47
India	367
Lithuania	31
Pakistan	63
Turkey	162
Ukraine	100

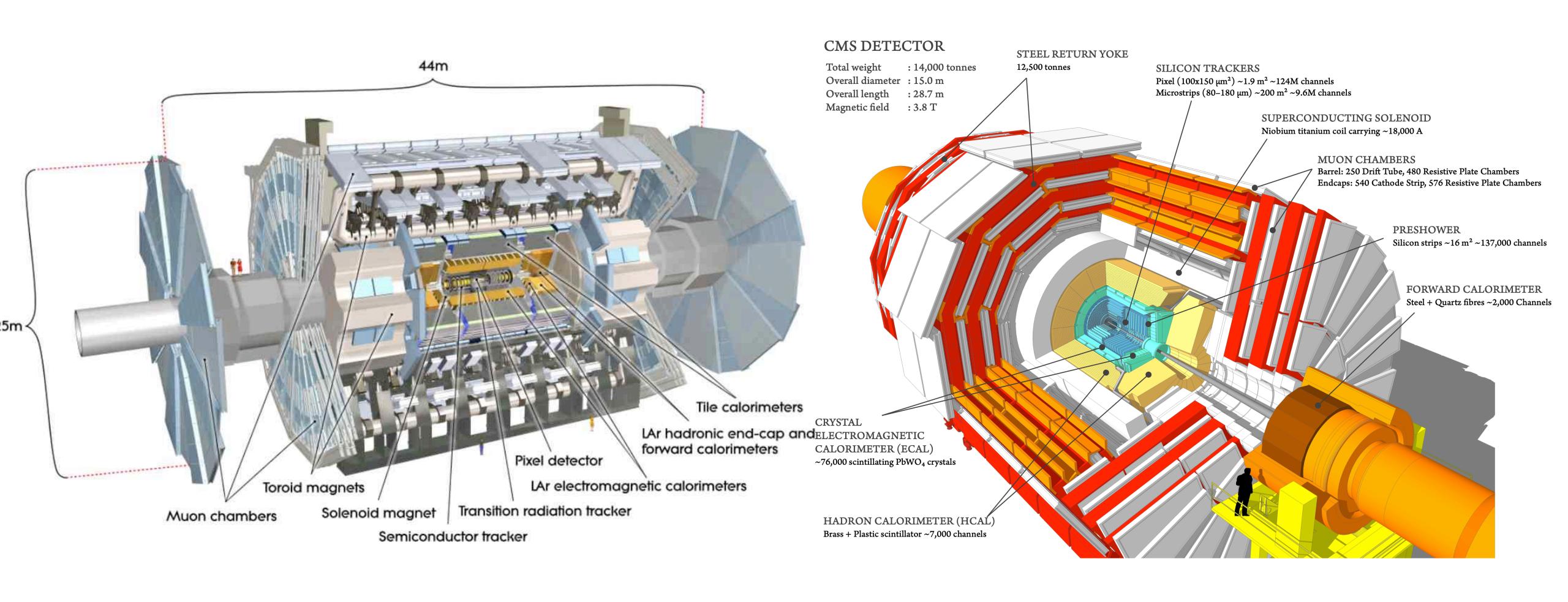


		Bolivia	2	Egypt	26	Ireland	14	Montenegro	8	Saint Kitts		Uzbekistan	3
OTHERS		Bosnia & Herz	egovina 2	El Salvador	1	Jamaica	1	Morocco	26	and Nevis	1	Venezuela	10
		Bostwana	1	Estonia	16	Jordan	2	Myanmar	1	Saudi Arabia	2	Viet Nam	10
Albania	4	Brazil	121	Georgia	54	Kazakhstan	12	Nepal	8	Senegal	1	Yemen	1
Algeria	8	Burundi	1	Ghana	1	Kenya	1	New Zealand	6	Singapore	4	Zambia	1
Argentina	22	Canada	155	Gibraltar	1	Korea	161	Nigeria	2	South Africa	54	Zimbabwe	1
Armenia	18	Chile	21	Guatemala	1	Kyrgyzstan	1	North Korea	3	Sri Lanka	6		
Australia	28	China	569	Hong Kong	1	Latvia	4	North Macedonia	. 2	Sudan	2		
Azerbaijan	7	Colombia	35	Honduras	1	Lebanon	23	Oman	1	Syria	2		
Bahrain	3	Congo	1	Iceland	5	Luxembourg	3	Palestine	7	Taiwan	47		
Bangladesh	5	Costa Rica	1	Indonesia	11	Malaysia	19	Paraguay	1	Thailand	24		
Belarus	49	Cuba	16	Iran	46	Malta	5	Peru	6	Tunisia	5	4 (	000
Benin	1	Ecuador	11	Iraq	1	Mexico	80	Philippines	4	Uruguay	1	<u> </u>	822

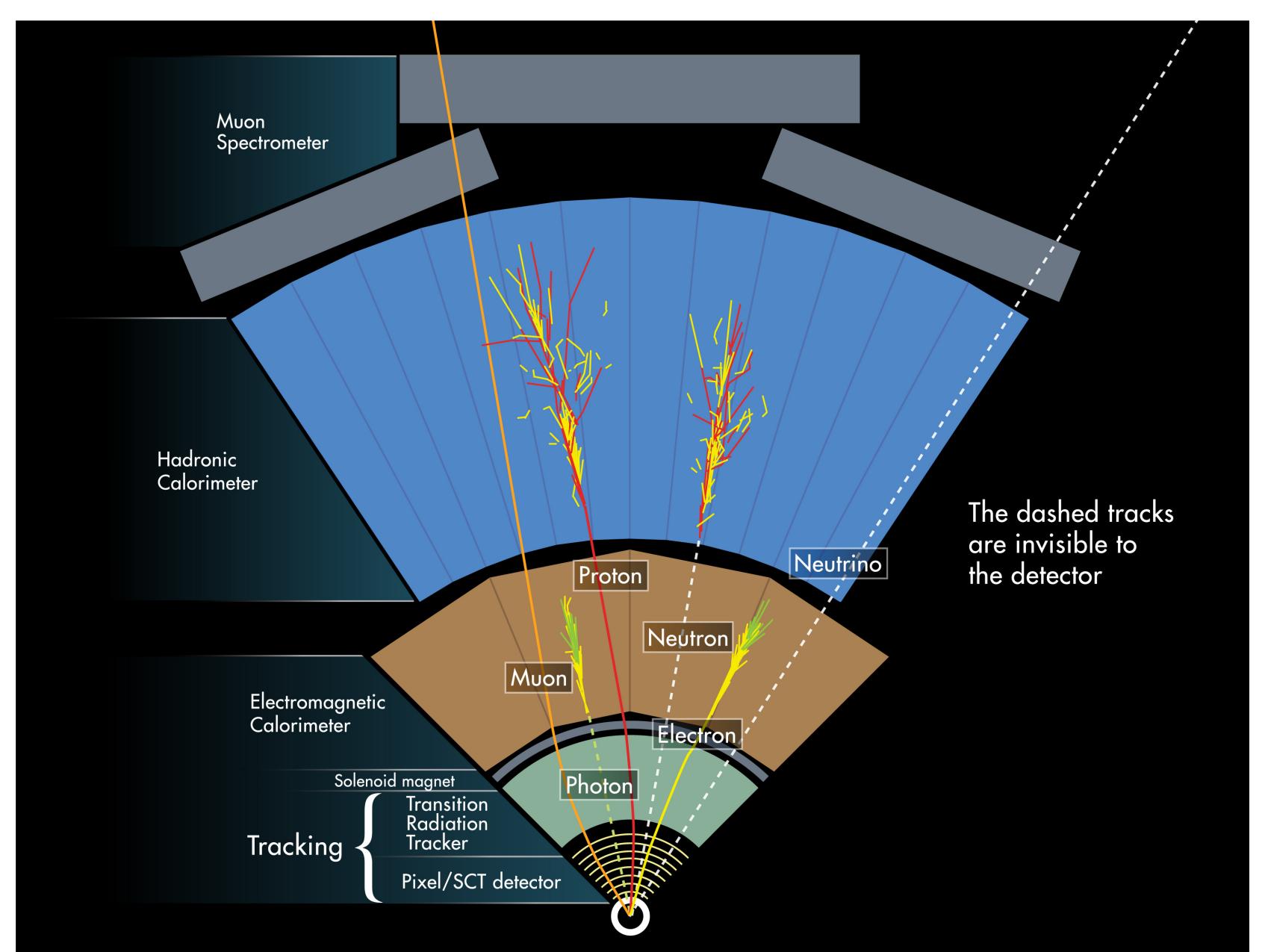


## ATLAS CMS

#### A Toroidal Lhc Apparatus | Compact Muon Solenoid

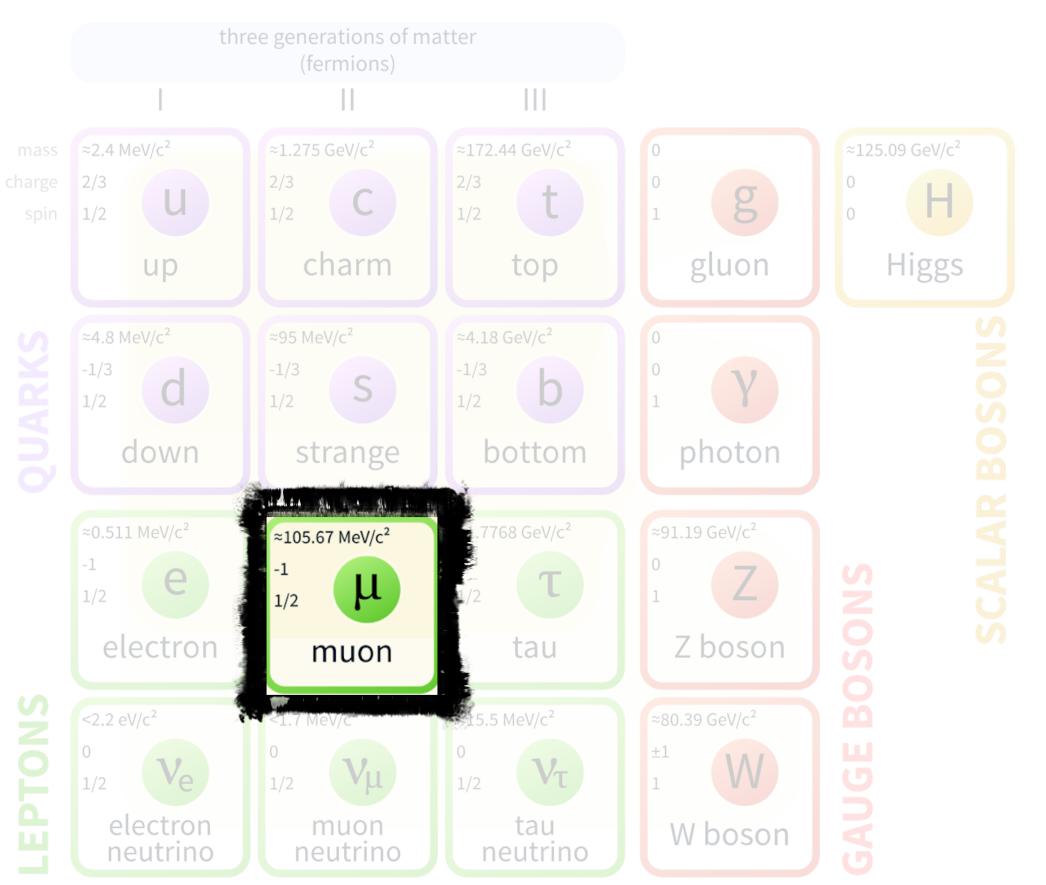


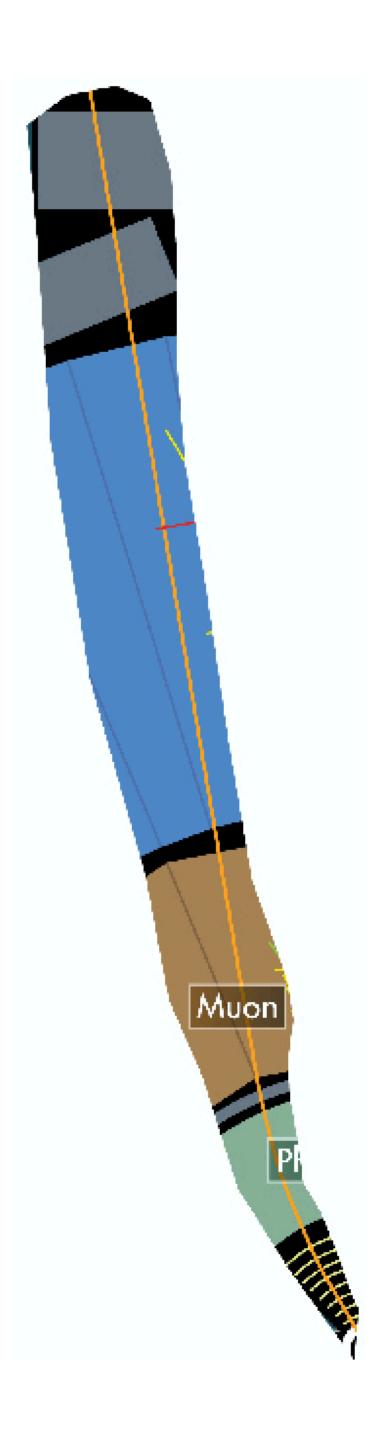
# La firma di (poche) particelle



## Muone

#### **Standard Model of Elementary Particles**





$$J=rac{1}{2}$$

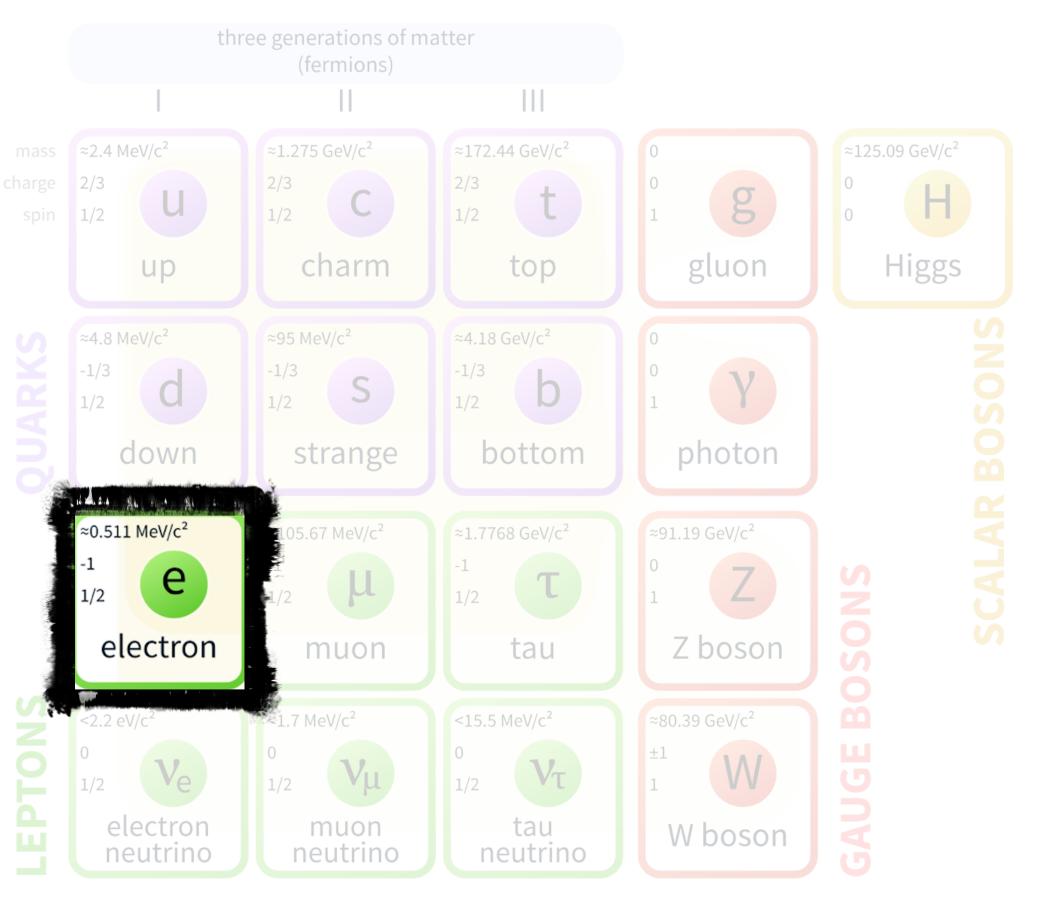
Mass  $m=0.1134289257\pm0.0000000025$  u Mass  $m=105.6583745\pm0.0000024$  MeV Mean life  $\tau=(2.1969811\pm0.0000022)\times10^{-6}$  s  $\tau_{\mu^+}/\tau_{\mu^-}=1.00002\pm0.00008$   $c\tau=658.6384$  m Magnetic moment anomaly  $(g-2)/2=(11659209\pm6)\times10^{-10}$   $(g_{\mu^+}-g_{\mu^-})$  /  $g_{\rm average}=(-0.11\pm0.12)\times10^{-8}$  Electric dipole moment  $d=(-0.1\pm0.9)\times10^{-19}$  e cm

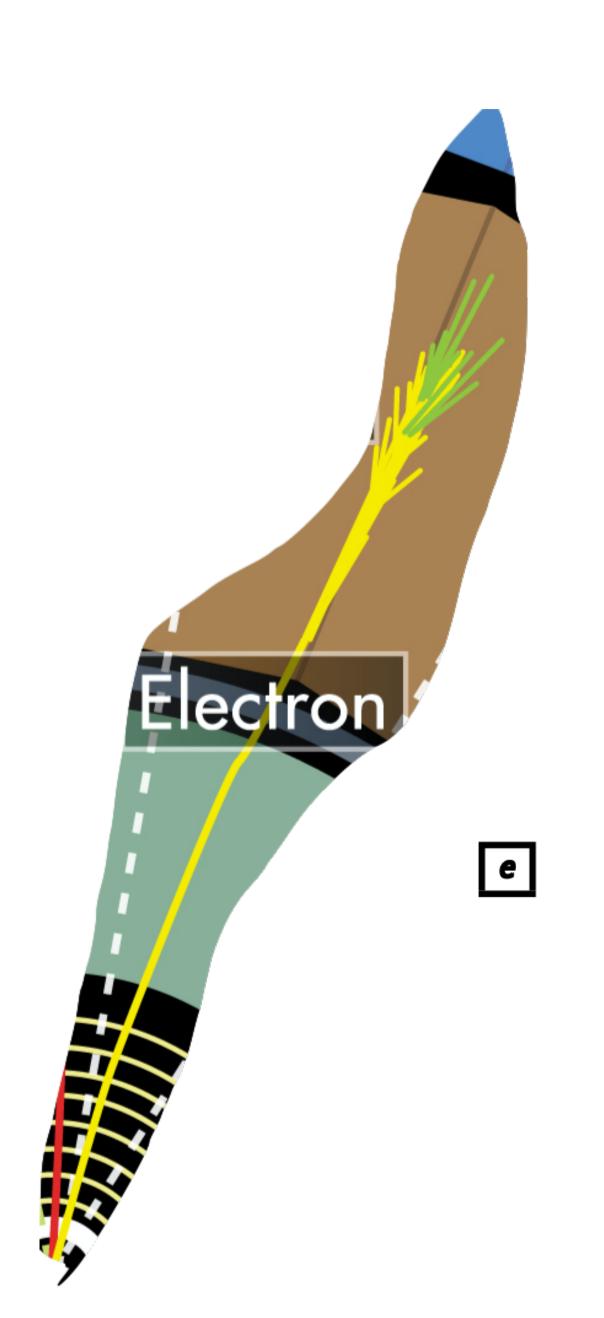
#### Decay parameters [b]

$$\rho = 0.74979 \pm 0.00026$$
 $\eta = 0.057 \pm 0.034$ 
 $\delta = 0.75047 \pm 0.00034$ 
 $\xi P_{\mu} = 1.0009^{+0.0016}_{-0.0007} [c]$ 
 $\xi P_{\mu} \delta / \rho = 1.0018^{+0.0016}_{-0.0007} [c]$ 
 $\xi' = 1.00 \pm 0.04$ 
 $\xi'' = 0.98 \pm 0.04$ 
 $\alpha / A = (0 \pm 4) \times 10^{-3}$ 
 $\alpha' / A = (-10 \pm 20) \times 10^{-3}$ 
 $\beta / A = (4 \pm 6) \times 10^{-3}$ 
 $\beta' / A = (2 \pm 7) \times 10^{-3}$ 
 $\overline{\eta} = 0.02 \pm 0.08$ 

## Elettrone

#### **Standard Model of Elementary Particles**



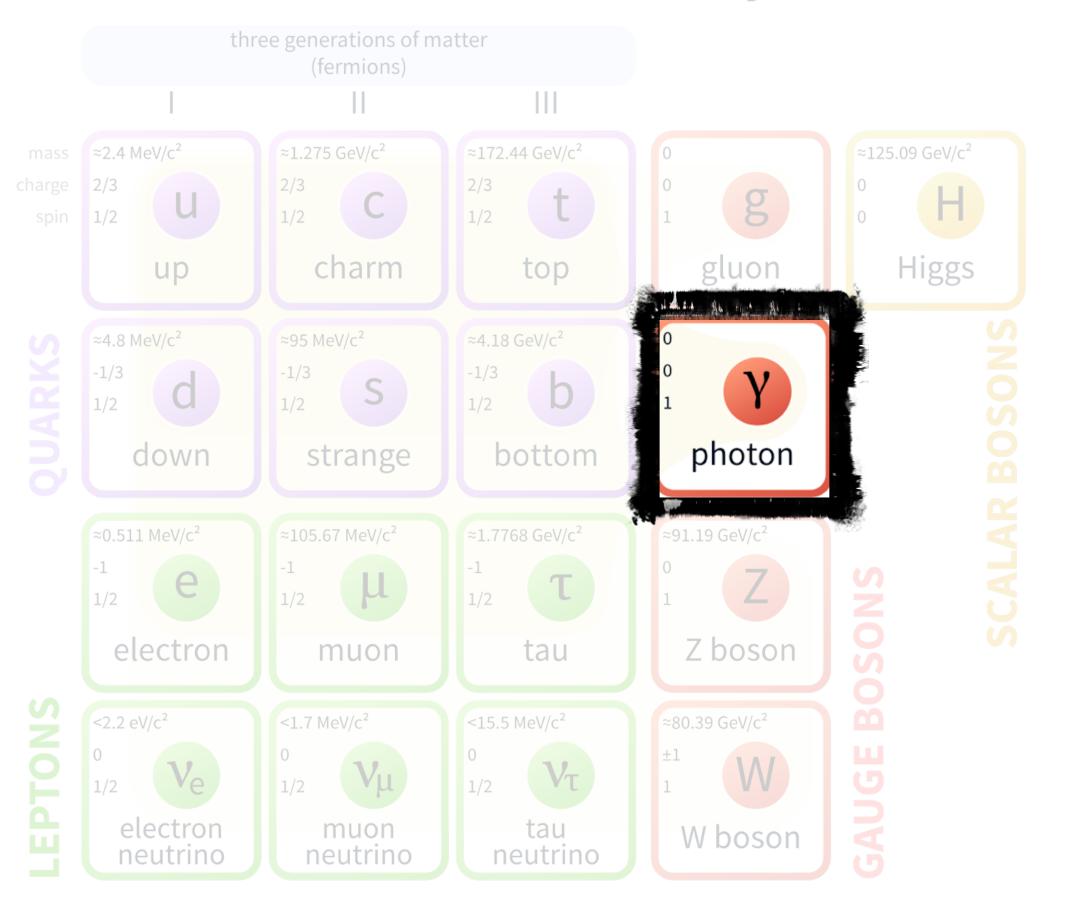


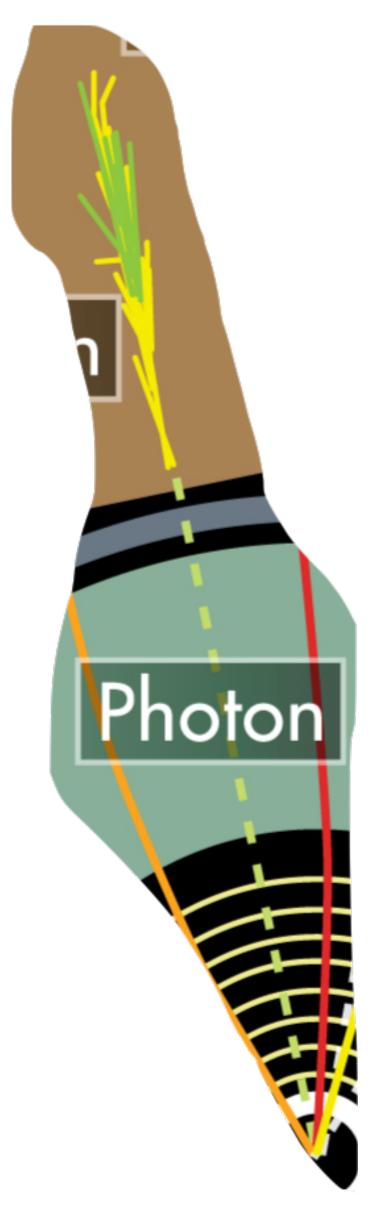
$$J=\frac{1}{2}$$

Mass  $m=(548.579909070\pm0.000000016)\times 10^{-6}$  u Mass  $m=0.5109989461\pm0.0000000031$  MeV  $|m_{e^+}-m_{e^-}|/m<8\times 10^{-9},$  CL =90%  $|q_{e^+}+q_{e^-}|/e<4\times 10^{-8}$  Magnetic moment anomaly  $(g-2)/2=(1159.65218091\pm0.00000026)\times 10^{-6}$  ( $g_{e^+}-g_{e^-}$ ) /  $g_{\rm average}=(-0.5\pm2.1)\times 10^{-12}$  Electric dipole moment  $d<0.87\times 10^{-28}$  e cm, CL =90% Mean life  $\tau>6.6\times 10^{28}$  yr, CL =90% [a]

## Fotone

#### **Standard Model of Elementary Particles**







$$I(J^{PC}) = 0.1(1^{-})$$

#### $\gamma$ MASS

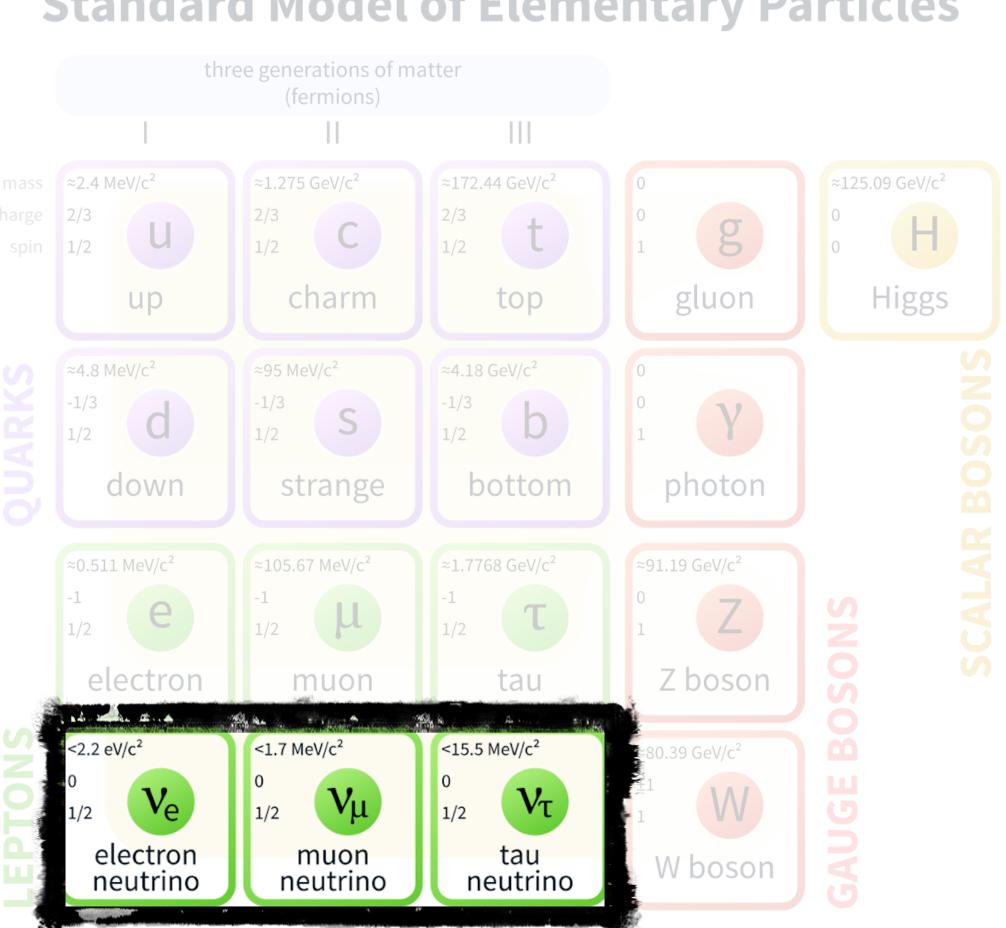
Results prior to 2008 are critiqued in GOLDHABER 10. All experimental results published prior to 2005 are summarized in detail by TU 05.

The following conversions are useful: 1 eV =  $1.783 \times 10^{-33}$  g =  $1.957 \times 10^{-6}$   $m_e$ ;  $\chi_C = (1.973 \times 10^{-7} \text{ m}) \times (1 \text{ eV}/m_\gamma)$ .

<i>VALUE</i> (eV)	<u>CL%</u>	DOCUMENT ID		COMMENT
$<1 \times 10^{-18}$		<sup>1</sup> RYUTOV	07	MHD of solar wind
<ul> <li>● ● We do not use</li> </ul>	the follow	ving data for avera	iges, f	its, limits, etc. ● ●
$< 2.2 \times 10^{-14}$		<sup>2</sup> BONETTI	17	Fast Radio Bursts, FRB 121102
$< 1.8 \times 10^{-14}$		<sup>3</sup> BONETTI	16	Fast Radio Bursts, FRB 150418
$< 1.9 \times 10^{-15}$		<sup>4</sup> RETINO	16	Ampere's Law in solar wind
$< 2.3 \times 10^{-9}$	95	<sup>5</sup> EGOROV	14	Lensed quasar position
		<sup>6</sup> ACCIOLY		Anomalous magn. mom.
$< 1 \times 10^{-26}$		<sup>7</sup> ADELBERGER	R 07A	Proca galactic field

## Neutrino

#### **Standard Model of Elementary Particles**





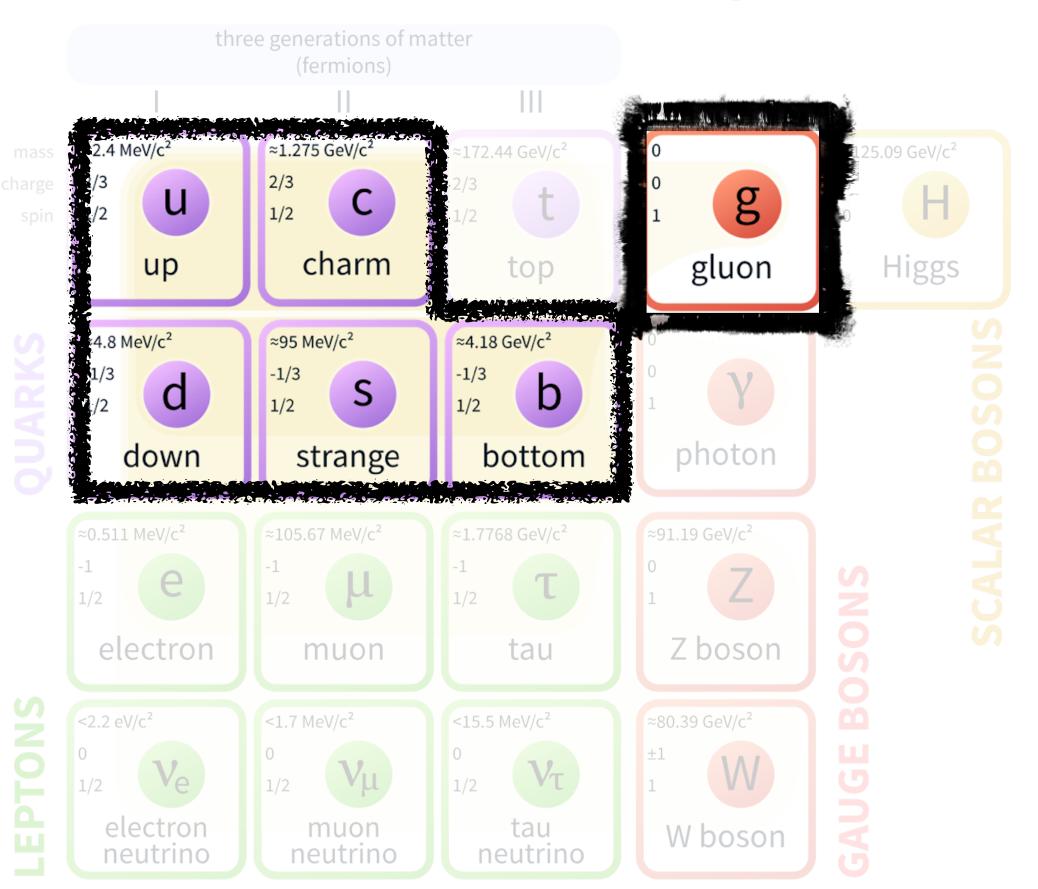
Neutrino

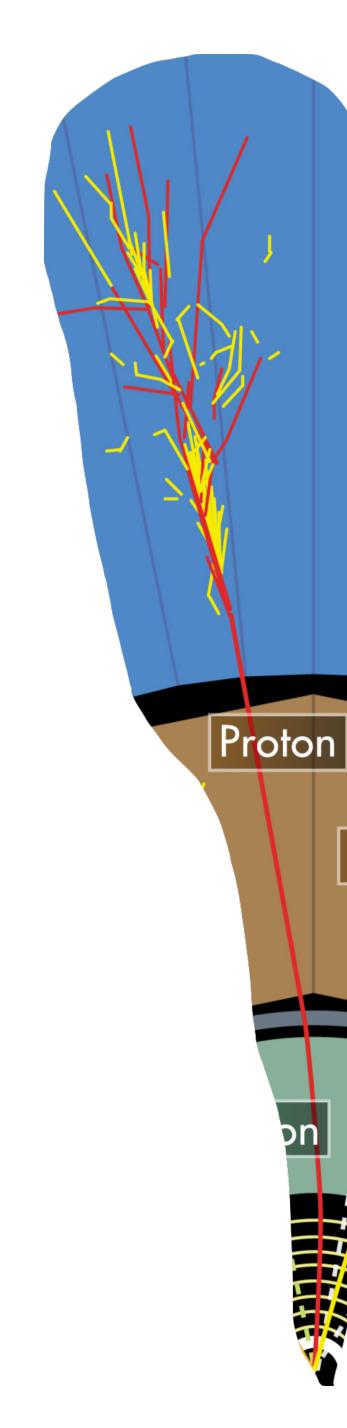
Those limits given below are for the square root of  $m_{
u_e}^{2({
m eff})} \equiv \sum_i |{
m U}_{ei}|^2$  $m_{\nu_i}^2$ . Limits that come from the kinematics of  ${}^3{\rm H}\beta^-\overline{\nu}$  decay are the square roots of the limits for  $m_{\nu_e}^{2({\rm eff})}$ . Obtained from the measurements reported in the Listings for " $\overline{\nu}$  Mass Squared," below.

VALUE (eV)	<u>CL%_</u>	DOCUMENT ID		<u>TECN</u>	COMMENT
< 2 OUR EVALUATI	ON				
< 2.05	95	<sup>1</sup> ASEEV	11	SPEC	$^3$ H $\beta$ decay
< 2.3	95	<sup>2</sup> KRAUS	05	SPEC	$^3$ H $\beta$ decay
<ul><li>● ● We do not use the</li></ul>	following	data for averages	, fits,	limits, e	tc. • • •
< 5.8	95	<sup>3</sup> PAGLIAROLI	10	ASTR	SN1987A
<21.7	90	<sup>4</sup> ARNABOLDI	03A	BOLO	$^{187}$ Re $eta$ -decay
< 5.7	95	<sup>5</sup> LOREDO	02	ASTR	SN1987A
< 2.5	95	<sup>6</sup> LOBASHEV	99		,
< 2.8	95	<sup>7</sup> WEINHEIMER	99	SPEC	, ,
< 4.35	95	<sup>8</sup> BELESEV	95	SPEC	$^3$ H $\beta$ decay
<12.4	95	<sup>9</sup> CHING	95	SPEC	
<92	95	<sup>10</sup> HIDDEMANN	95	SPEC	$^3$ H $\beta$ decay
$^{+32}_{15}$		HIDDEMANN	95	SPEC	$^3$ H $\beta$ decay

## "Jet"

#### **Standard Model of Elementary Particles**





$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 
$$m_u = 2.16^{+0.49}_{-0.26} \text{ MeV} \qquad \text{Charge} = \frac{2}{3} \ e \quad I_z = +\frac{1}{2}$$
 
$$m_u/m_d = 0.47^{+0.06}_{-0.07}$$

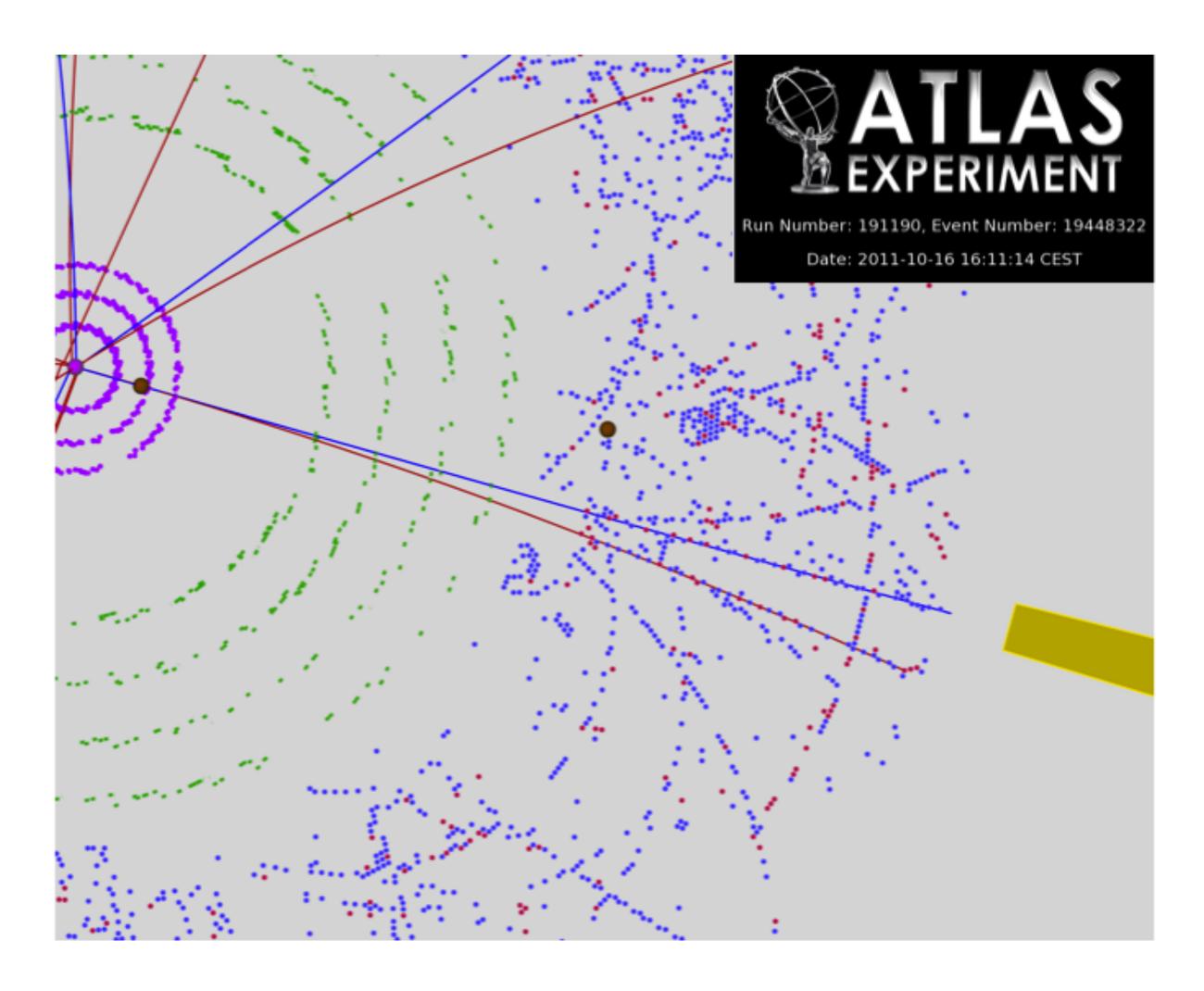
$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 
$$m_d = 4.67^{+0.48}_{-0.17} \text{ MeV} \qquad \text{Charge} = -\frac{1}{3} \ e \qquad I_z = -\frac{1}{2}$$
 
$$m_s/m_d = 17\text{--}22$$
 
$$\overline{m} = (m_u + m_d)/2 = 3.45^{+0.55}_{-0.15} \text{ MeV}$$

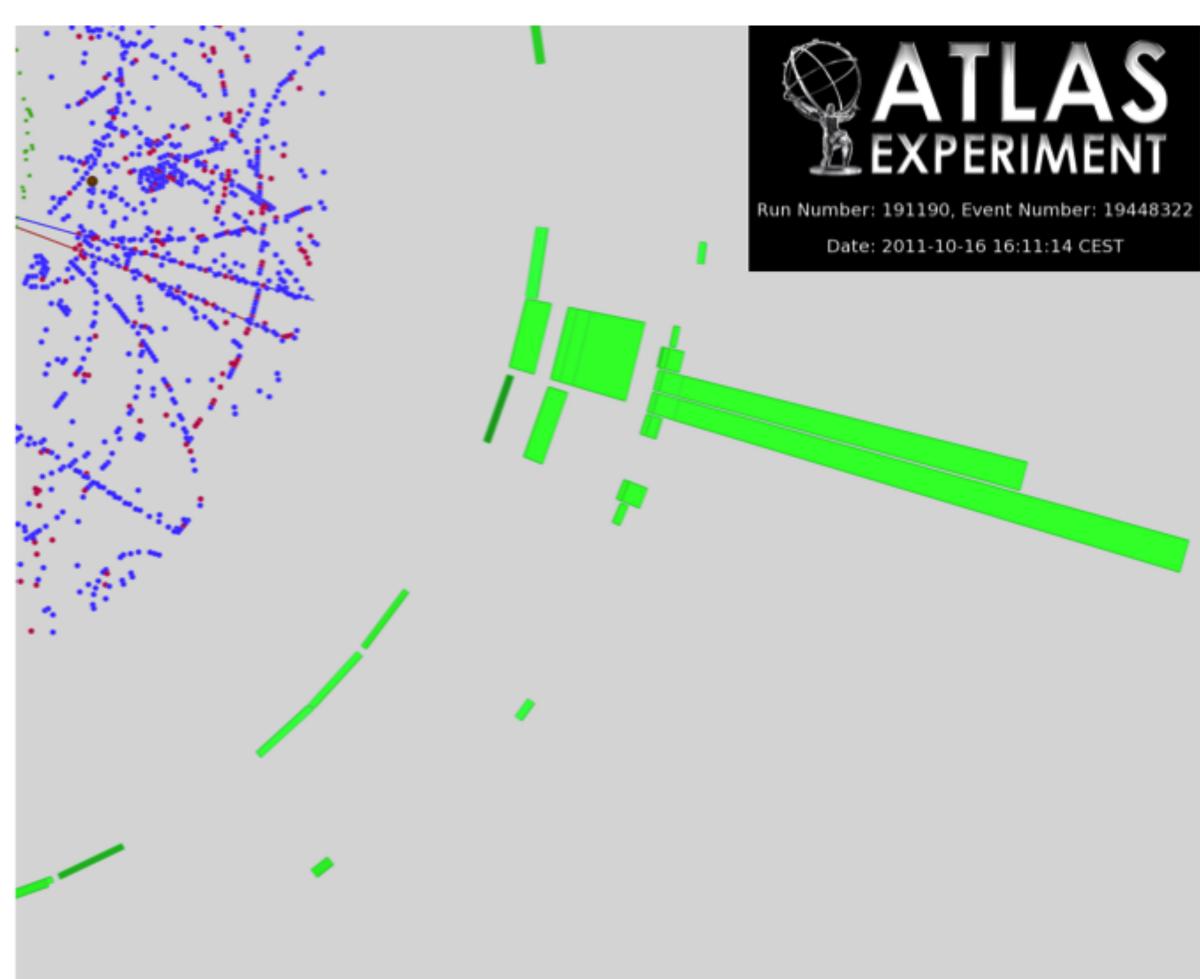
$$I(J^P)=0(rac{1}{2}^+)$$
  $m_s=93^{+11}_{-5}~{
m MeV}~{
m Charge}=-rac{1}{3}~e~{
m Strangeness}=-1$   $m_s~/~((m_u+m_d)/2)=27.3^{+0.7}_{-1.3}$ 

$$I(J^P) = 0(\frac{1}{2}^+)$$
  $m_c = 1.27 \pm 0.02 \; \text{GeV} \qquad \text{Charge} = \frac{2}{3} \; e \quad \text{Charm} = +1$   $m_c/m_s = 11.72 \pm 0.25$   $m_b/m_c = 4.577 \pm 0.008$   $m_b-m_c = 3.45 \pm 0.05 \; \text{GeV}$ 

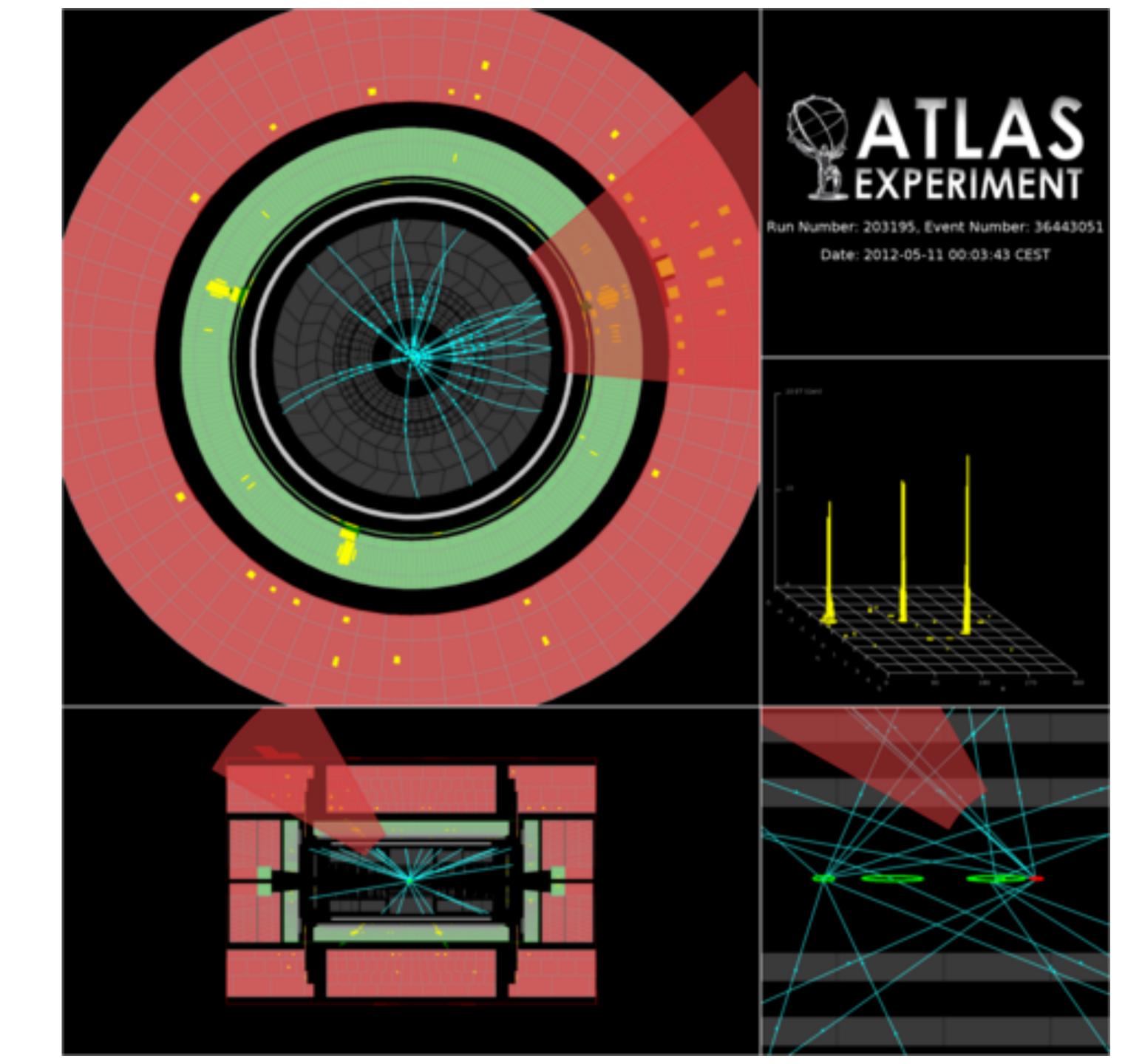
$$I(J^P) = 0(rac{1}{2}^+)$$
  $m_b = 4.18^{+0.03}_{-0.02} \; ext{GeV} \; \; \; \; ext{Charge} = -rac{1}{3} \; e \; \; ext{Bottom} = -1$ 

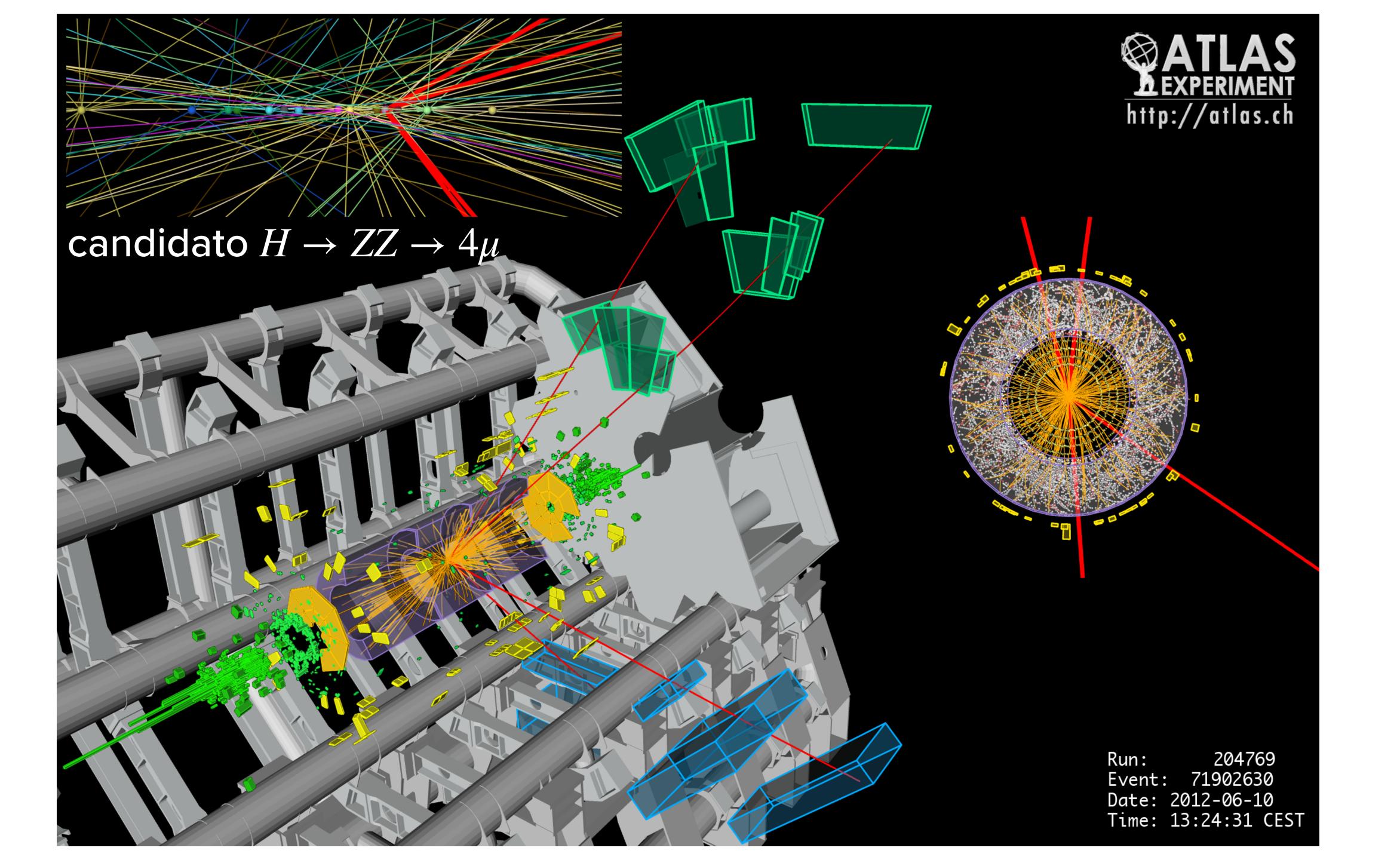
## Conversione di un fotone in elettroni

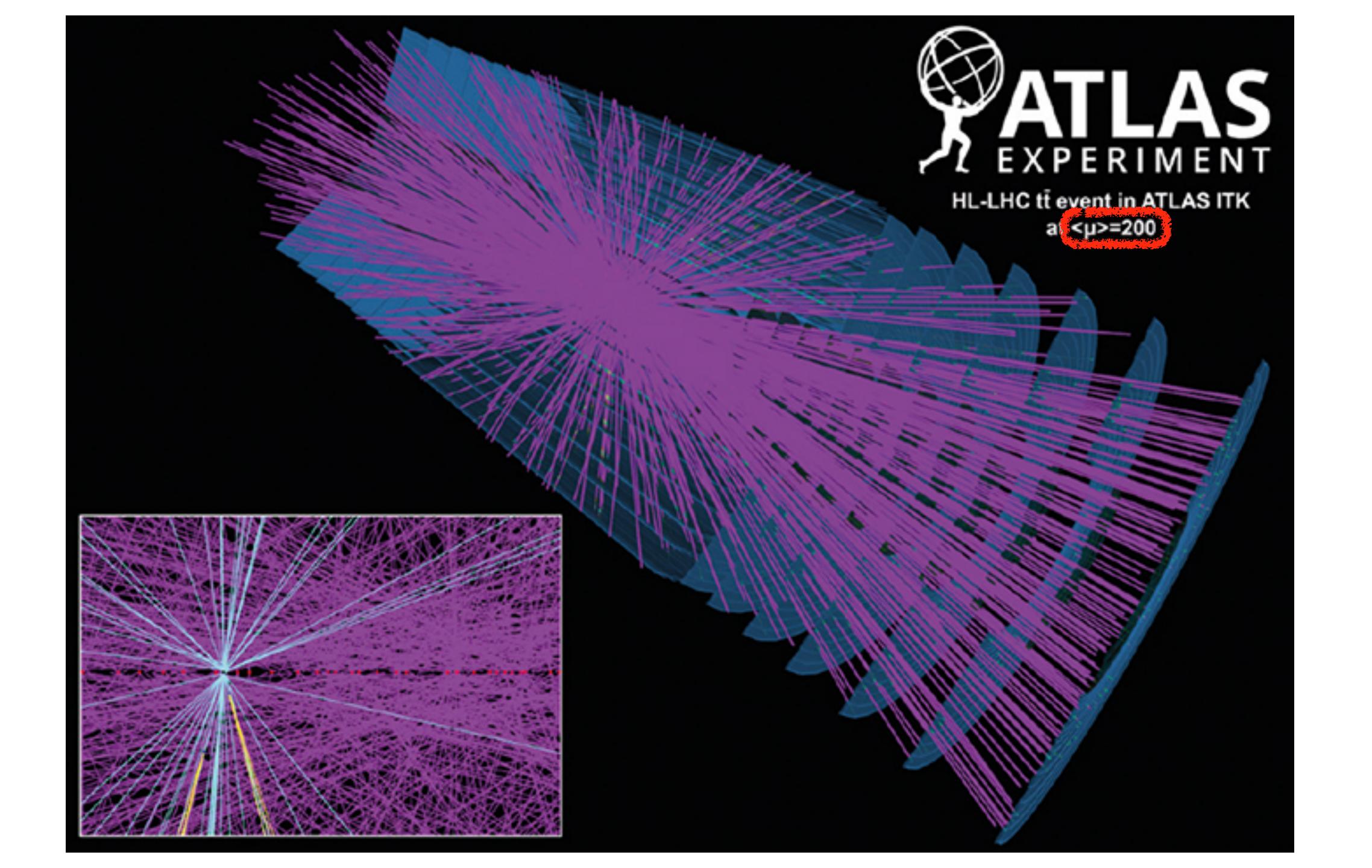




# Coppia di fotoni e jet





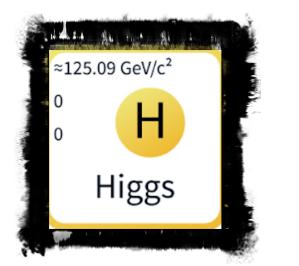


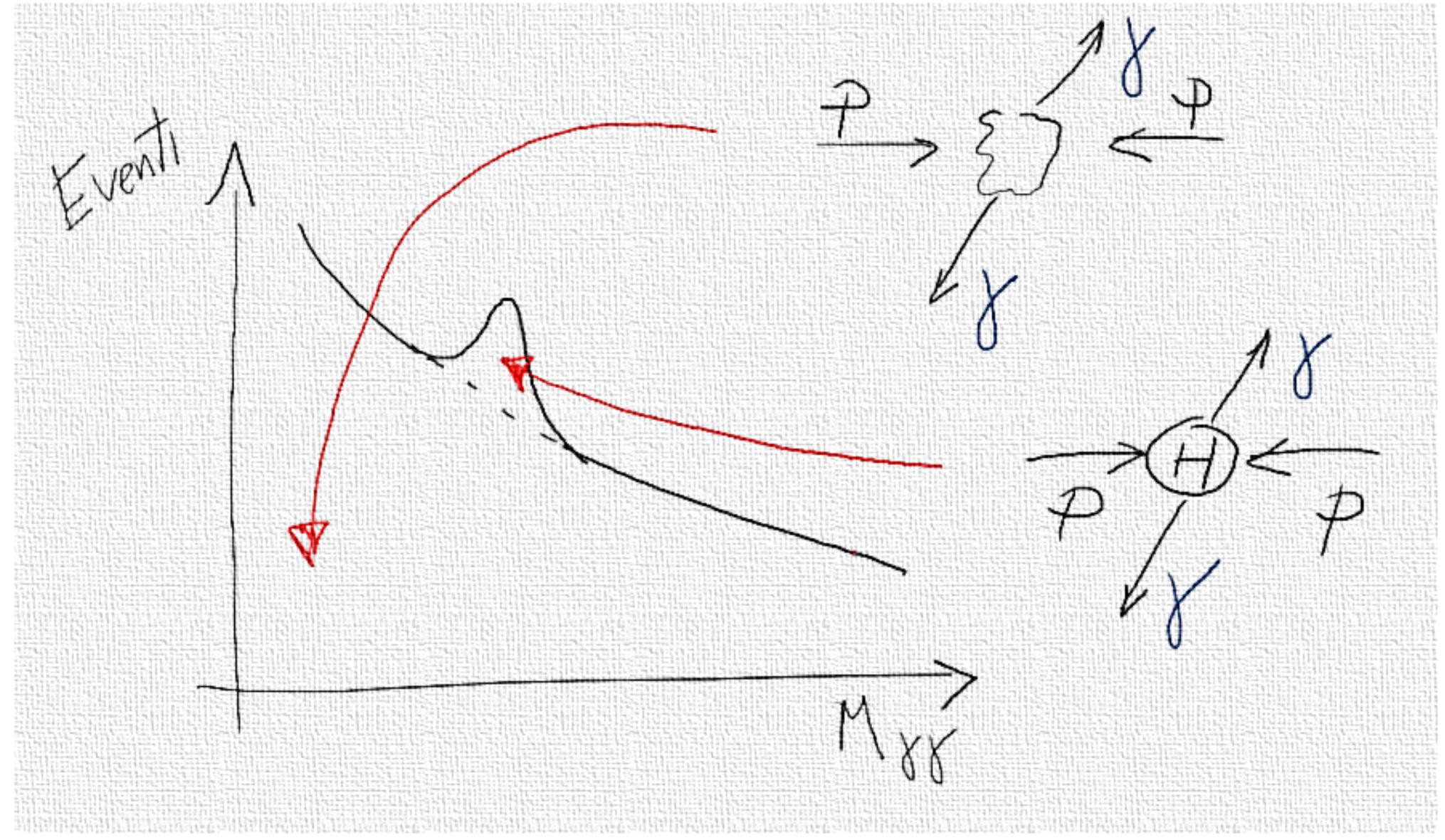
#### **Standard Model of Elementary Particles**





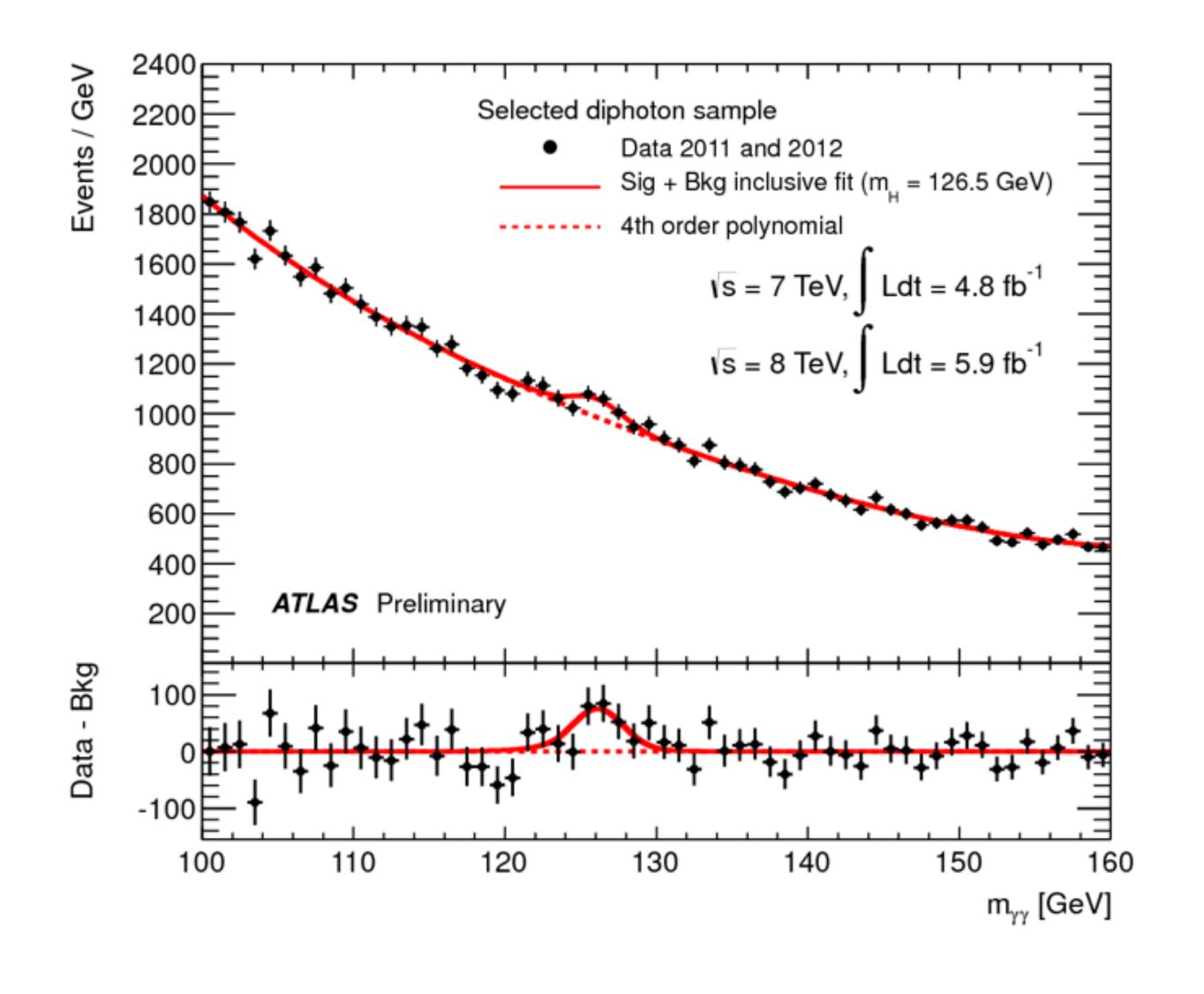
$$\tau_{\rm H} \sim 1.6 \cdot 10^{-22} \, {\rm s}$$
 $(\tau_{\mu} \sim 2.2 \cdot 10^{-6} \, {\rm s})$ 

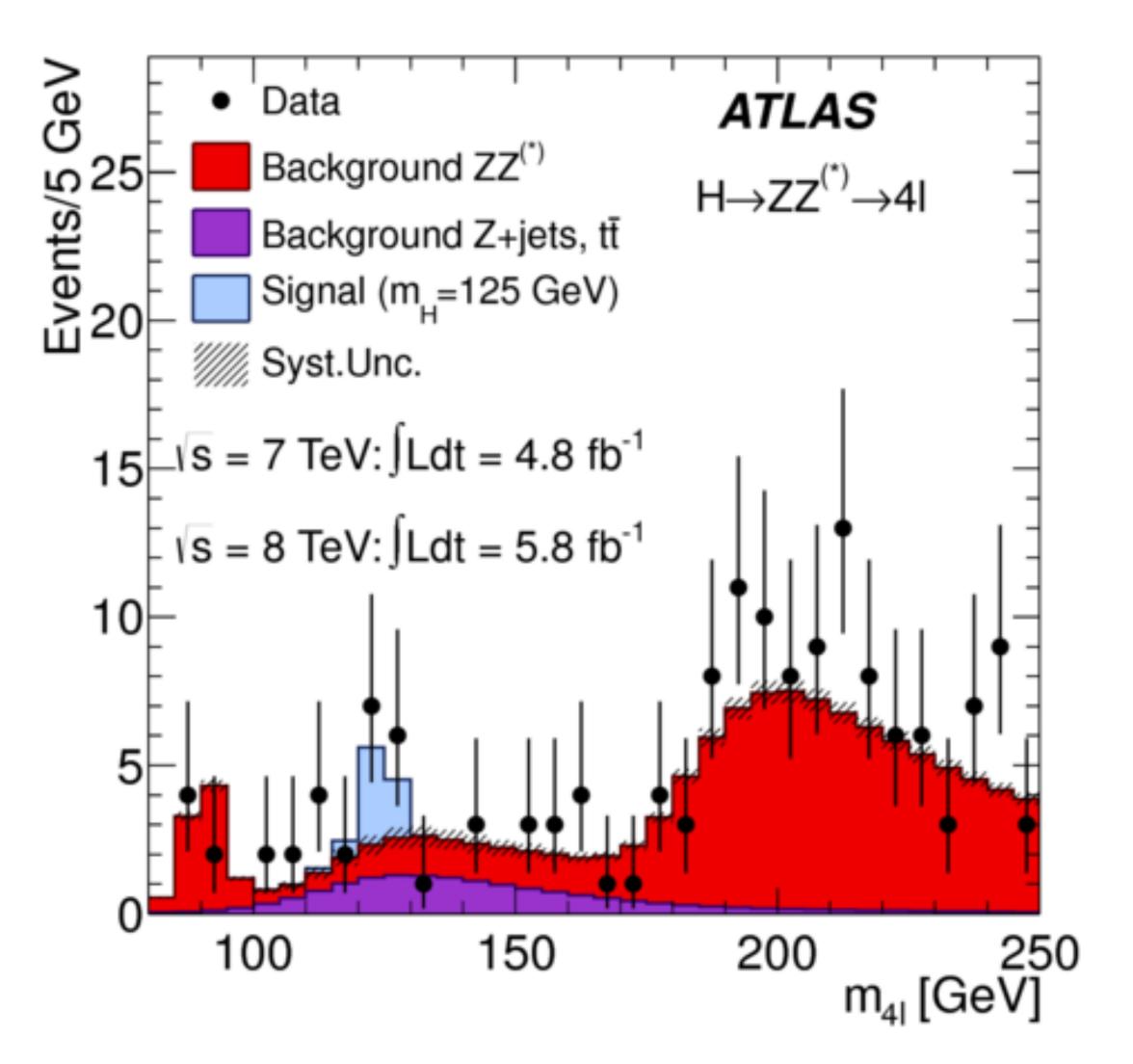






# La scoperta del bosone di Higgs







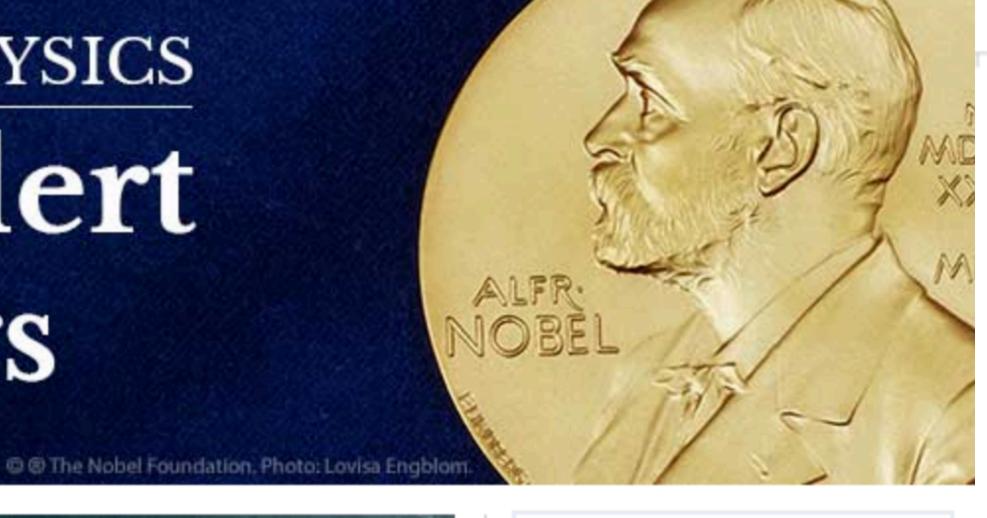
# La scoperta del bosone di Higgs

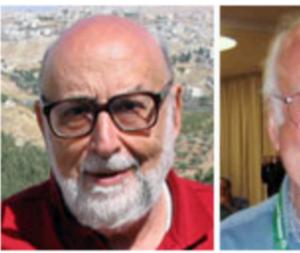
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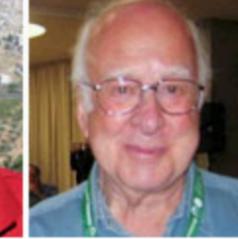
100

#### 2013 NOBEL PRIZE IN PHYSICS

# François Englert Peter W. Higgs



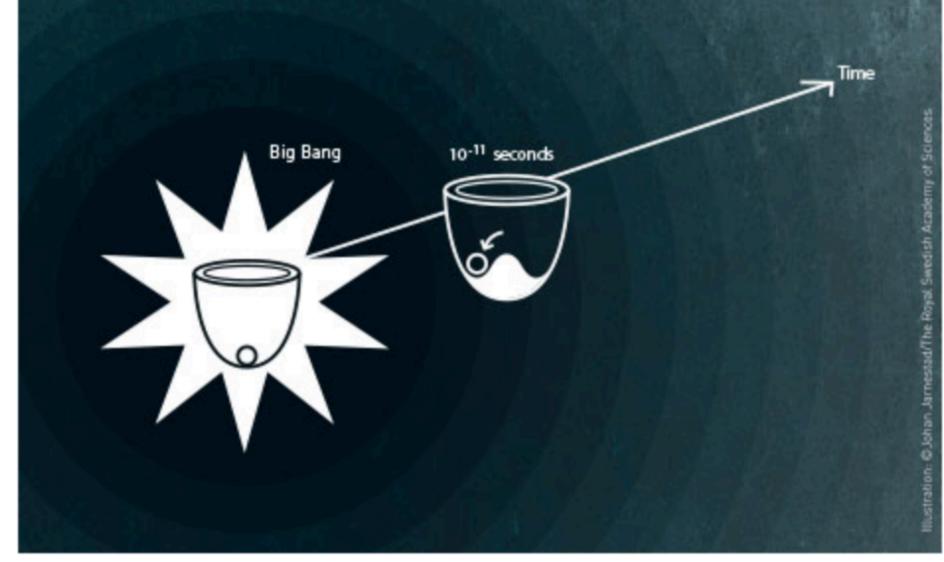




F. Englert and P. Higgs Photo: Wikimedia Commons

# 2013 Nobel Prize in Physics

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs "for the



#### Announcements of the 2013 Nobel Prizes

Physiology or Medicine:

Announced Monday 7 October

#### Physics:

Tuesday 8 October, 11:45 a.m. CET

at the earliest

#### Chemistry:

Wednesday 9 October, 11:45 a.m.

CET at the earliest

Literature:

250 GeV]

## Concludendo

