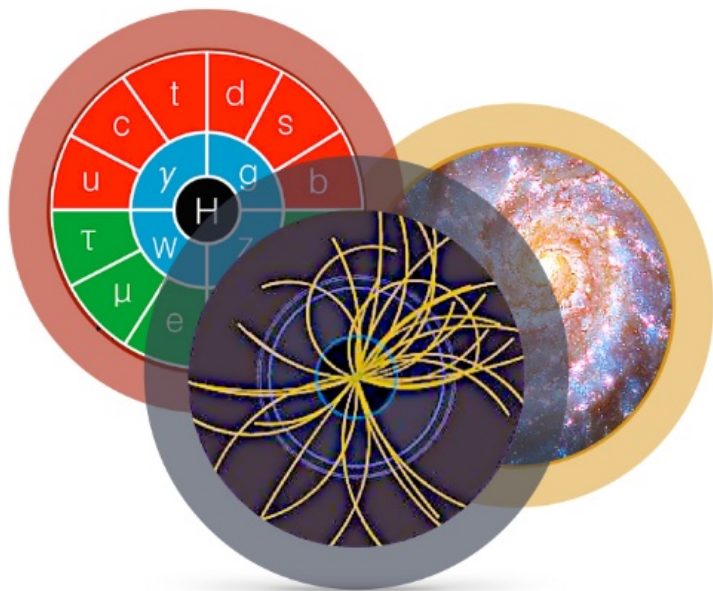




LHCPHENO: Física de partículas en el LHC y las factorías de sabor





Personnel



Name	Position
Antonio Pich Zardoya	CU
Francisco Campanario Pallas	RyC
Otto Eberhardt	IP
Claudius Krause	IP
Ioannis Papavassiliou	TU
Jorge Portolés Ibáñez	CT
Germán V. Rodrigo García	IC
Ignasi Rosell Escribà	C
William J. Torres Bobadilla (Feb 2017)	IP
Gauhar Abbas	IP
César Ayala	IP
Roger J. Hernández Pinto	IP
Germán F.R. Sborlini	IP
Lei Wang	IP
Gabriel López Castro	PS

PhD Candidates

Félix Driencourt-Mangin
 Javier Fuentes Martín
 Héctor Gisbert Mullor
 Víctor Ilisie (**PhD 2016**)
 Andrea Lami (**PhD 2016**)
 Clara Murgui Gálvez
 Ana Peñuelas Martínez
 Antonio Rodríguez Sánchez
 Joaquín Santos Blasco
 Mehran Zahiri Abyaneh

Master Students

Madeleine Adrien
 David Bellés Agut
 Javier Castellano
 Victor Miralles Aznar
 José Llanes Jurado

CU: Catedrático de Universidad UVEG; TU: Profesor Titular UVEG;
 IC: Investigador Científico CSIC; CT: Científico Titular CSIC; RyC: Investigador Ramón y
 Cajal; IP: Investigador Postdoctoral; C: Colaborador; PS: Profesor Sabático



Funding



European Union
European Regional
Development Fund



- **FPA2014-53631-C2-1-P:** Particle Physics at the LHC and Flavour Factories (MINECO) coordinated with U. Huelva
- **PROMETEU/2013/007:** Physics at the LHC: search for new interactions in the high-energy frontier (GVA)
- **PhD Candidates** supported by FPU, FPI, Grisolia (GVA), La Caixa and Atracció de Talent (UVEG)



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- Hosted four **Marie Skłodowska-Curie** fellows recently
- Coordinated two European networks: FLAVIANET and LHCPHENONET
- Participate in evaluation committees of the **European Agencies ERCEA and REA**





Research lines:

- **FLAVOUR AND HIGGS BOSON PHENOMENOLOGY AT THE LHC AND THE PHYSICS OF THE FLAVOUR FACTORIES**
- **PRECISION COLLIDER PHENOMENOLOGY AT THE LHC AND FUTURE COLLIDERS**
- **NON-PERTURBATIVE QCD FROM LATTICE, SCHWINGER-DYSON EQUATIONS AND EFFECTIVE FIELD THEORY**



SU(5) Grand Unified Theory

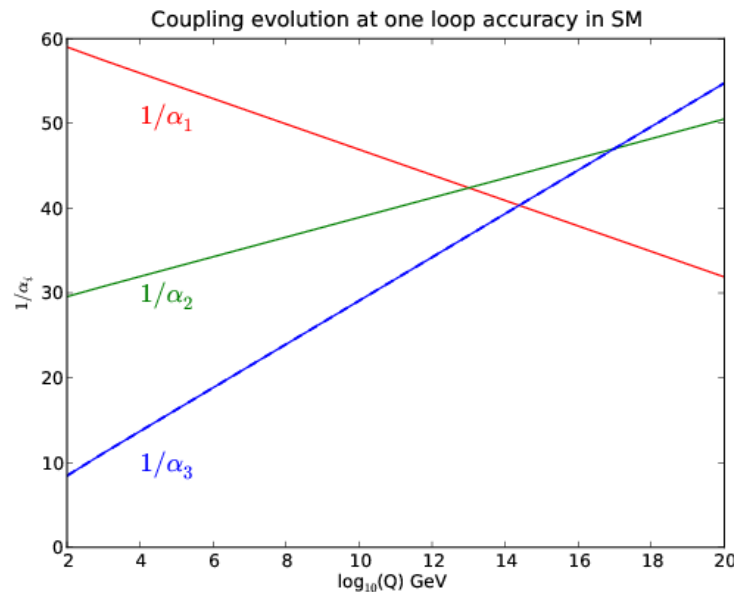
Clara Murgui

Georgie-Glashow (GG): matter assignment $\mathbf{5}, \mathbf{10}$ Higgs bosons $5_H, 24_H$

$$G_{SM} = SU(3) \otimes SU(2) \otimes U(1) \in SU(5)$$

Why is the GG model ruled out?

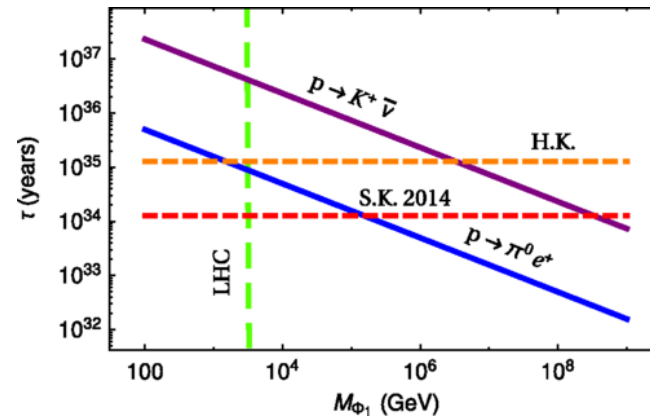
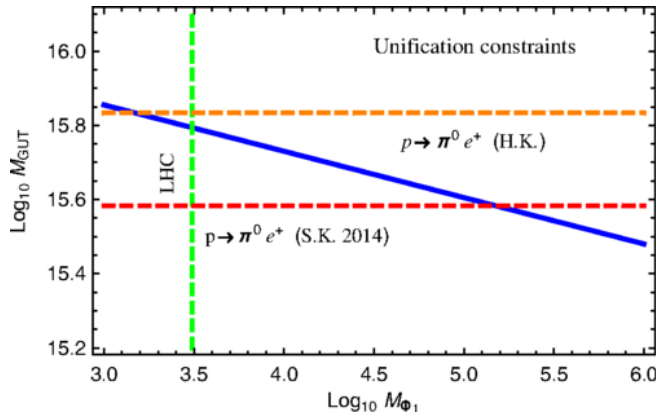
- (i) The unification of gauge couplings in disagreement with the experiments.
- (ii) $M_e = M_d^T$ at the GUT scale in disagreement with the experiments.
- (iii) $M_\nu = 0$





SU(5) Grand Unified Theory

Clara Murgui



Simple realistic extension: Minimal Renormalizable SU(5)

$SU(5)_{\text{GG}} + 45_H + 10_H$ **P. Fileviez Perez, C. Murgui, Phys. Rev. D94 (2016) 7, 075014**

- 45_H → corrects (i) by the splitting of
 - ⇒ Predicts a “light” (3.5-5 TeV) **colored octet** ! $\phi \sim (8, 2, 1/2) \in 45_H$
- corrects (ii) by $H_2 \sim (1, 2, 1/2) \in 45_H$
- 10_H → corrects (iii) by giving mass to the neutrinos through the Zee mechanism

$$\Rightarrow M_\nu = \lambda M_e^{\text{diag}} \left(c_e M_e^{\text{diag}} + 3c_d D_c M_d^{\text{diag}} V_{CKM}^T \right) + \text{transpose} \quad \delta^+ \sim (1, 1, 1) \in 10_H$$



Left-Right symmetric Model

Clara Murgui

$$SU(3) \otimes SU(2)_R \otimes SU(2)_L \otimes U(1)_{B-L} \xrightarrow{H_R} G_{SM} \xrightarrow{\Phi} U(1)_Q$$

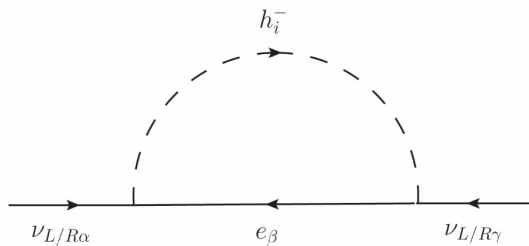
Simplest LR model predicts **Dirac neutrinos**

G. Senjanovic and R. N. Mohapatra, Phys. Rev. D 12 (1975) 1502

Simple **extension with Majorana neutrinos**: Simplest LR + $\delta^+ \sim (1, 1, 1)$

P. Fileviez Pérez, C. Murgui, S. Ohmer, Phys. Rev. D94 (2016) 5, 051701

⇒ Predicts **light sterile neutrinos** through the Zee mechanism.



$$(M_\nu^L)^{\alpha\gamma} = \frac{1}{4\pi^2} \lambda_L^{\alpha\beta} m_{e\beta} \sum_i \text{Log} \left(\frac{M_{h_i}^2}{m_{e\beta}^2} \right) V_{5i} \left[(Y_3^\dagger)^{\beta\gamma} V_{2i}^* - (Y_4^\dagger)^{\beta\gamma} V_{1i}^* \right] + \alpha \leftrightarrow \gamma,$$

$$(M_\nu^R)^{\alpha\gamma} = \frac{1}{4\pi^2} \lambda_R^{\alpha\beta} m_{e\beta} \sum_i \text{Log} \left(\frac{M_{h_i}^2}{m_{e\beta}^2} \right) V_{5i} \left[(Y_3)^{\beta\gamma} V_{1i}^* - (Y_4)^{\beta\gamma} V_{2i}^* \right] + \alpha \leftrightarrow \gamma$$

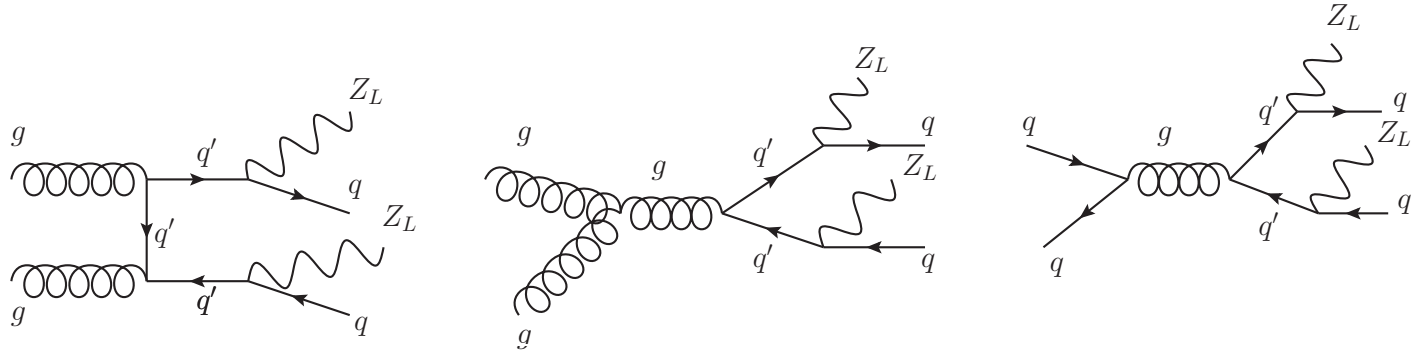
⇒ Predicts **LNV** processes (δ^+)

- Drell-Yan process: $pp \rightarrow \gamma, Z, Z' \rightarrow \delta^+ \delta^- \rightarrow e_i^+ e_j^- E_T^{miss}$,
- $e_j \rightarrow e_i \gamma$, $e_j \rightarrow e_i$ conversion.



Left-Right-Right-Left symmetry

Gauhar Abbas, arXiv:1605.02497 and arXiv:1609.02899



- Left and right handed fermions are kept in the fundamental representation of the gauge groups $SU(2)_L$ and $SU(2)_R$.
- To restore parity, there are mirror gauge symmetries $SU(2)_{R'}$ and $SU(2)_{L'}$. Thus, coupling constants of $SU(2)_L$ and $SU(2)_R$ are completely independent.
- Scalar sector is optimised. There is no VEV having unnaturally small value. There is **no fine-tuning for neutrino masses** and W_R . Mirror gauge sector at 10^9 GeV.
- In **low scale LRRL models**, scalar sector is pretty simple, optimised and a few scalar particles. Furthermore, mirror fermions and mirror gauge sector could be simultaneously at TeV scale which is impossible in any other model. (accepted PRD)
- Yields an explanation for neutrino masses whether they are Dirac or Majorana. Fine-tuning of the SM Higgs mass postponed up to a sufficiently high scale.
- Rich and interesting phenomenological possibilities for future investigations.



Two-Higgs Doublet Model

O. Eberhardt, H. Gisbert, V. Ilisie, A. Peñuelas, A. Pich

Adding a **second Higgs doublet**



$$\Phi_1 = \begin{bmatrix} G^+ \\ \frac{1}{\sqrt{2}}(v + S_1 + iG^0) \end{bmatrix}, \quad \Phi_2 = \begin{bmatrix} H^+ \\ \frac{1}{\sqrt{2}}(S_2 + iS_3) \end{bmatrix}$$

3 Goldstone bosons
+
3 neutral Higgses
+
1 charged Higgs

FCNC at tree level (very constrained phenomenologically)

$$\mathcal{L}_Y = -\frac{\sqrt{2}}{v} \left(\bar{\mathbf{Q}}'_L (\mathbf{M}'_d \Phi_1 + \mathbf{Y}'_d \Phi_2) \mathbf{d}'_R - \bar{\mathbf{Q}}'_L (\mathbf{M}'_u \tilde{\Phi}_1 + \mathbf{Y}'_u \tilde{\Phi}_2) \mathbf{u}'_R - \bar{\mathbf{L}}'_L (\mathbf{M}'_l \Phi_1 + \mathbf{Y}'_l \Phi_2) \mathbf{l}'_R + \text{h.c.} \right)$$

New CP-violation sources

+
Family universality
+
No FCNC at tree level

$$\mathbf{Y}'_a = \zeta_a^{(*)} \mathbf{M}'_a$$

Alignment in Flavour space

Aligned Two-Higgs Doublet Model (A2HDM)

$$\mathcal{L}_Y = -\frac{\sqrt{2}}{v} H^+ \left\{ \bar{u}(x) [\zeta_d V \mathbf{M}_d \mathcal{P}_R - \zeta_u \mathbf{M}_u^\dagger V \mathcal{P}_L] d(x) + \zeta_l \bar{\nu}(x) \mathbf{M}_l \mathcal{P}_R l(x) \right\} - \frac{1}{v} \sum_{\varphi_i, f} y_f^{\varphi_i} \varphi_i^0 [\bar{f}(x) \mathbf{M}_f \mathcal{P}_R f(x)] + \text{h.c.}$$

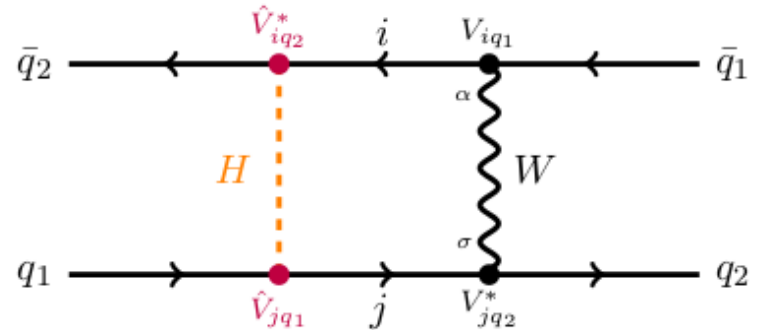


Constraints from Neutral Meson Mixing

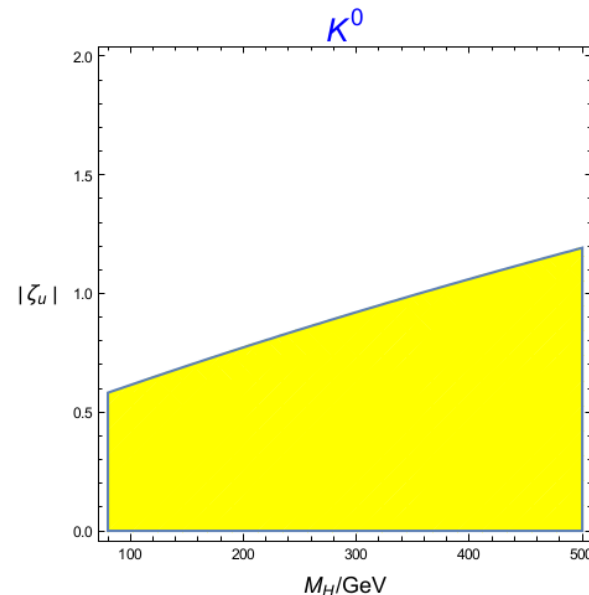
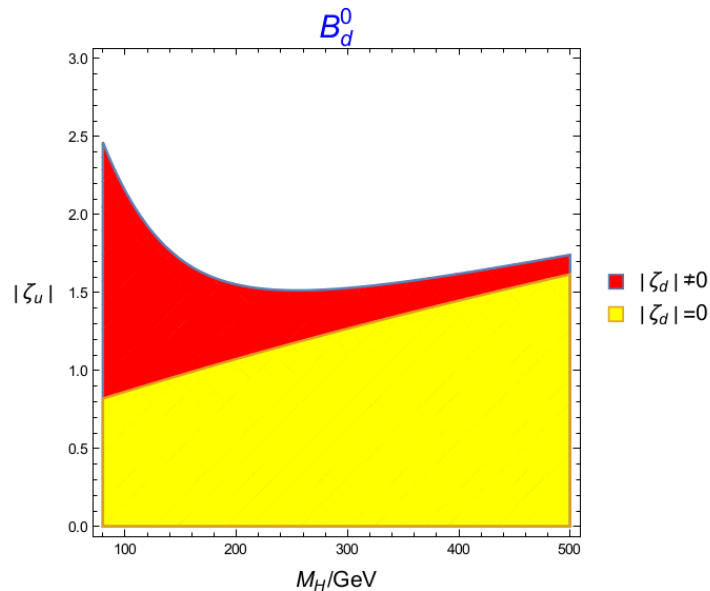
Hector Gisbert

One-loop computation of the short-distance **Wilson coefficients at NLO**

$$\mathcal{H}_{\text{eff}}^{\Delta F=2} = \frac{G_F^2 M_W^2}{16\pi^2} \sum_{ijk} \lambda_i \lambda_j C_k^{ij}(\mu) \mathcal{O}_k \Rightarrow$$



Experimental observables: $\Delta m_{B_{s,d}}, \epsilon_K \longrightarrow$ Constraints on ζ_q





Beyond the Standard Model fits

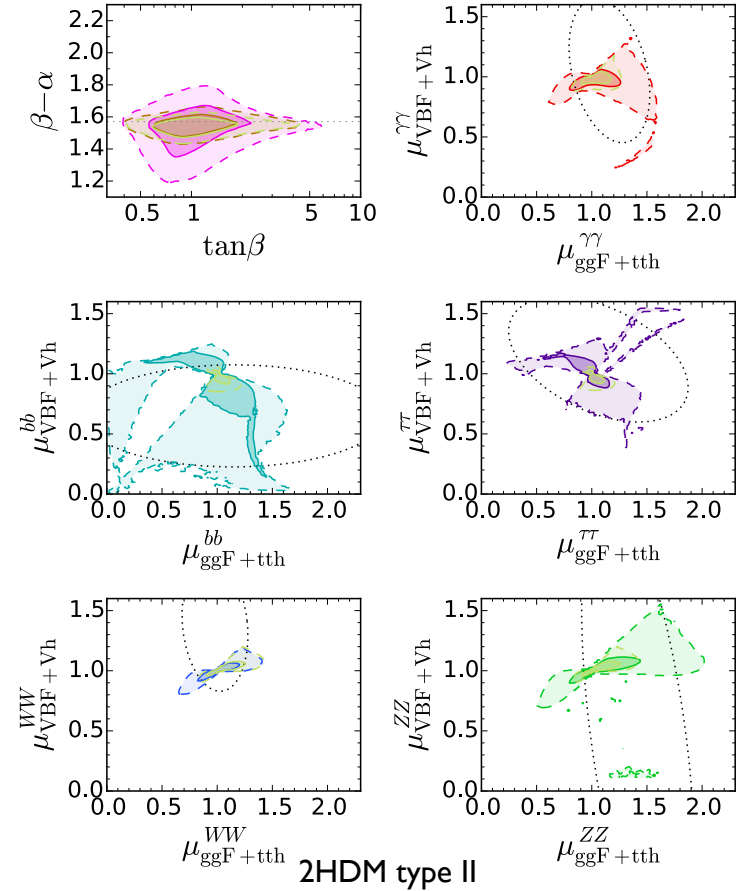
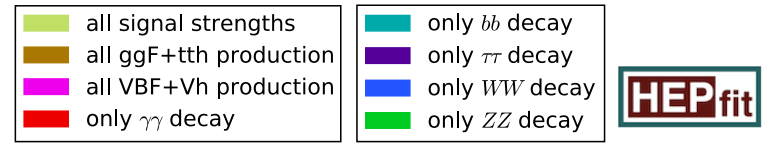
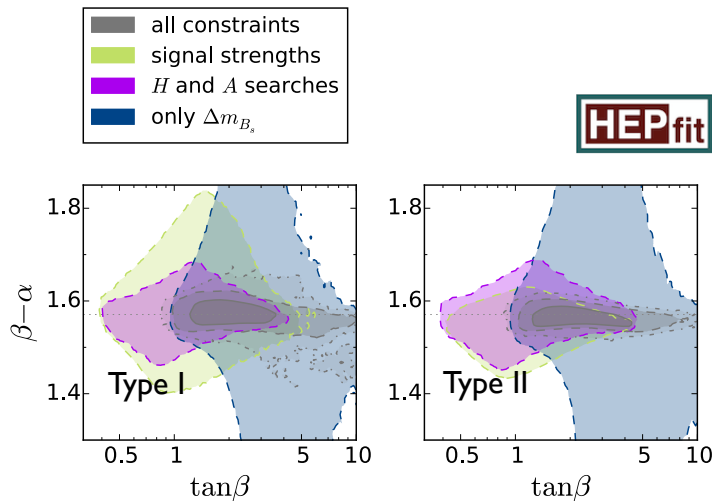
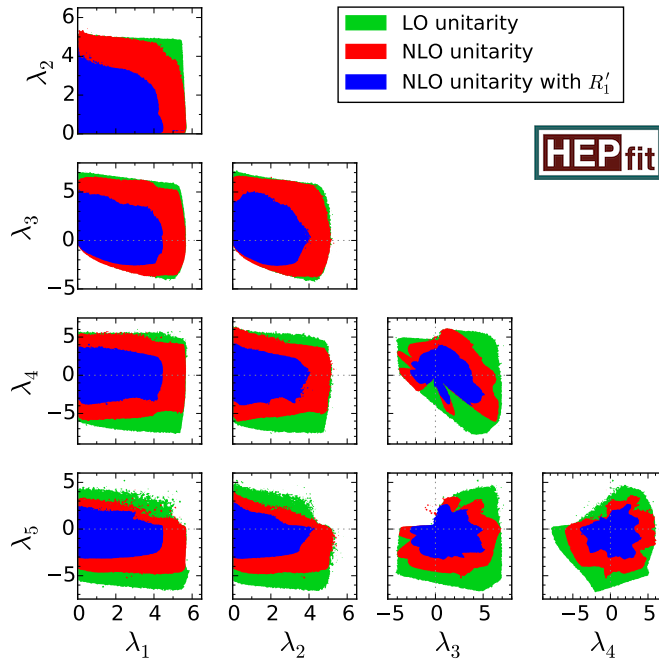
Otto Eberhardt (S8a)

- Two-Higgs-Doublet models
- Georgi-Machacek model
- Left-Right symmetric models
- Supersymmetric models
- Effective field theories

Implementation into
the multi-purpose
code **HEPfit**

<http://hepfit.roma1.infn.it>

It includes many observables from **flavour**,
Higgs and **electroweak** precision physics
in the SM and in a couple of BSM models.

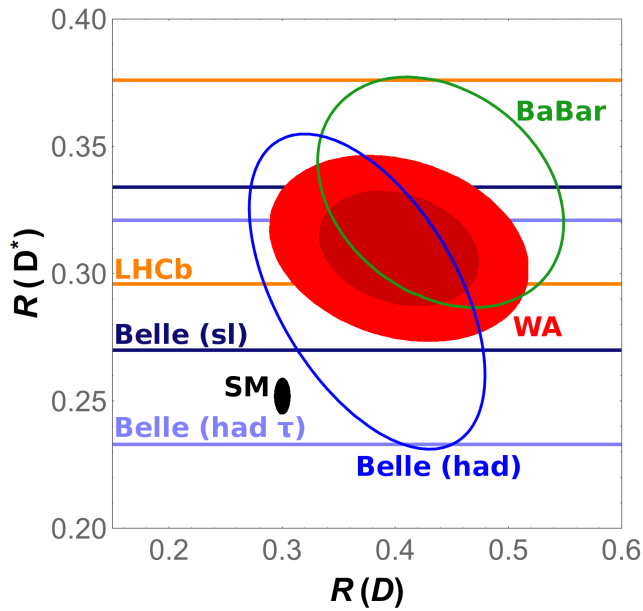


(for details see JHEP 1611 (2016) 026)



Constraints on extra scalars from B decays

A. Celis, M. Jung, X.-Q. Li, A. Pich, 1612.07757

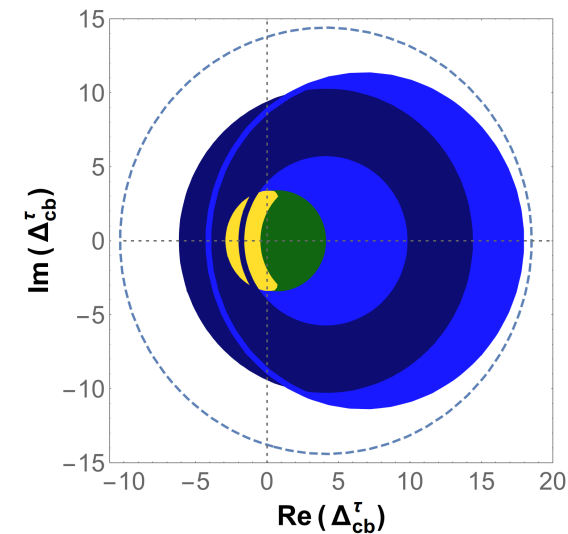
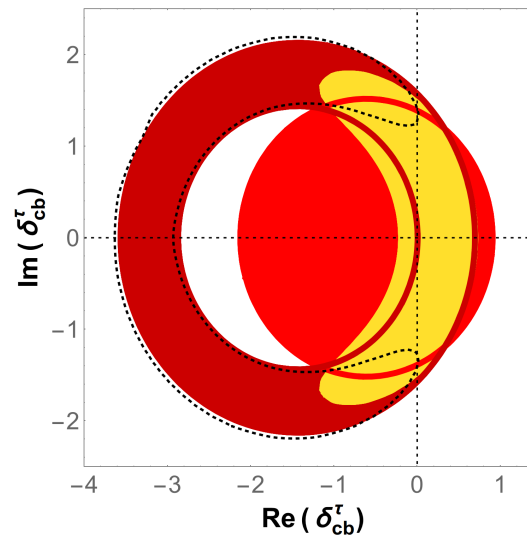


4 σ discrepancy

$$R(D^{(*)}) = \frac{\text{Br}(B \rightarrow D^{(*)} \tau \nu)}{\text{Br}(B \rightarrow D^{(*)} \ell \nu)}$$

$$\mathcal{L}_{\text{eff}} = -\frac{4G_F V_{quqd}}{\sqrt{2}} \left[\bar{q}_u (g_L^{quqd\ell} \mathcal{P}_L + g_R^{quqd\ell} \mathcal{P}_R) q_d \right] [\bar{\ell} \mathcal{P}_L \nu_\ell]$$

$$\delta_{cb}^\ell \equiv \frac{(g_L^{cb\ell} + g_R^{cb\ell})(m_B - m_D)^2}{m_\ell (\bar{m}_b - \bar{m}_c)}, \quad \Delta_{cb}^\ell \equiv \frac{(g_L^{cb\ell} - g_R^{cb\ell})m_B^2}{m_\ell (\bar{m}_b + \bar{m}_c)}$$



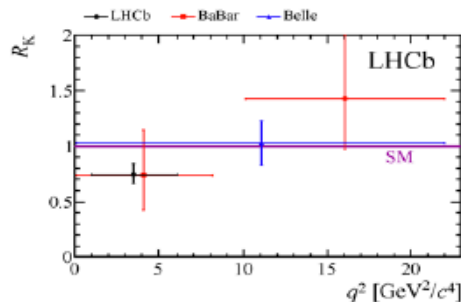


Flavor anomalies: Lepton non-universality in B decays

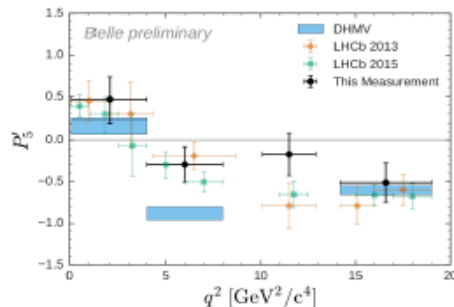
J. Fuentes-Martín

Explaining the anomalies from an extended gauge sector:

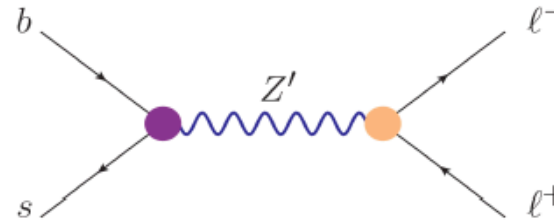
$$R_K = \frac{\text{Br}(B \rightarrow K \mu^+ \mu^-)}{\text{Br}(B \rightarrow K e^+ e^-)}$$



$$B \rightarrow K^* \ell^+ \ell^-$$



Above 4 σ tension with the SM prediction



- A **minimal U(1)'** explanation of the anomalies

Alejandro Celis, Javier Fuentes-Martín, Martin Jung, Hugo Serôdio, Physical Review D 92 (2015) 1, 015007

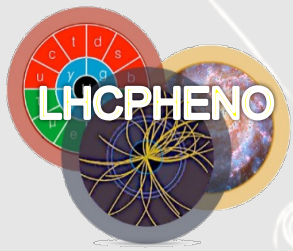
- Possible connection with the SM flavor puzzle: **Flavor anomalies from dynamical Yukawas**

Andreas Crivellin, Javier Fuentes-Martín, Admir Greljo, Gino Isidori, Physics Letters B 766 (2016) 77-85

- **Simultaneous explanation of the $b \rightarrow s \ell^+ \ell^-$ and $R(D^{(*)})$ anomalies** from an $SU(2)$ gauge extension

Sofiane M. Boucenna, Alejandro Celis, Javier Fuentes-Martín, Avelino Vicente, Javier Virto; Physics Letters B 760 (2016) 214-219; JHEP 1612 (2016) 059

New data expected soon ($R_{K^*}, R_\phi, B \rightarrow K^* e^+ e^-, \dots$): **uncover new model building directions, interplay with other problems of the SM and with other NP searches**

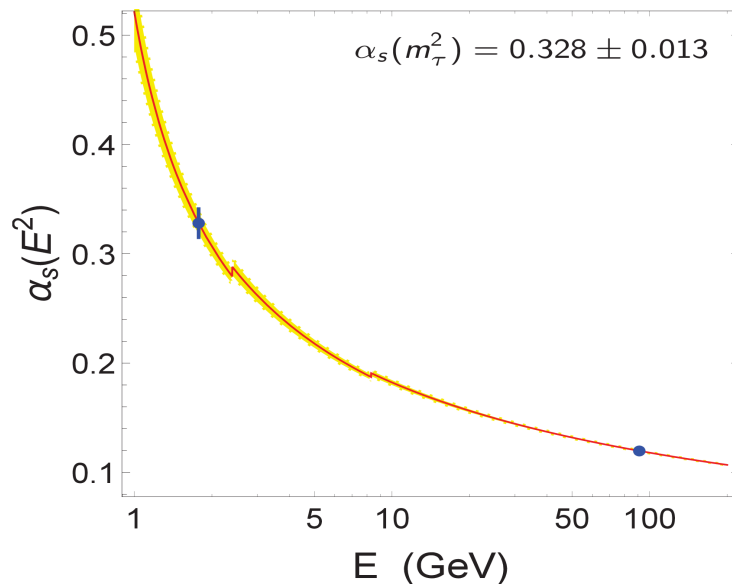


QCD tests from tau decays

Asymptotic Freedom

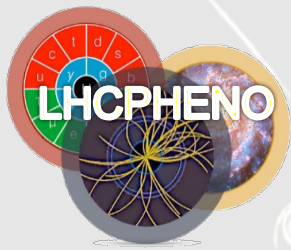
A. Rodríguez-Sánchez, A. Pich, PRD 94 (2016) 034027

$$\alpha_s(M_Z^2) = 0.1197 \pm 0.0015$$



$$\alpha_s(M_Z^2)|_\tau - \alpha_s(M_Z^2)|_Z = 0.0001 \pm 0.0015_\tau \pm 0.0030_Z$$

- Updated spectral functions from ALEPH [arXiv:1312.1501](https://arxiv.org/abs/1312.1501)
- Includes detailed analysis of **duality violation** effects

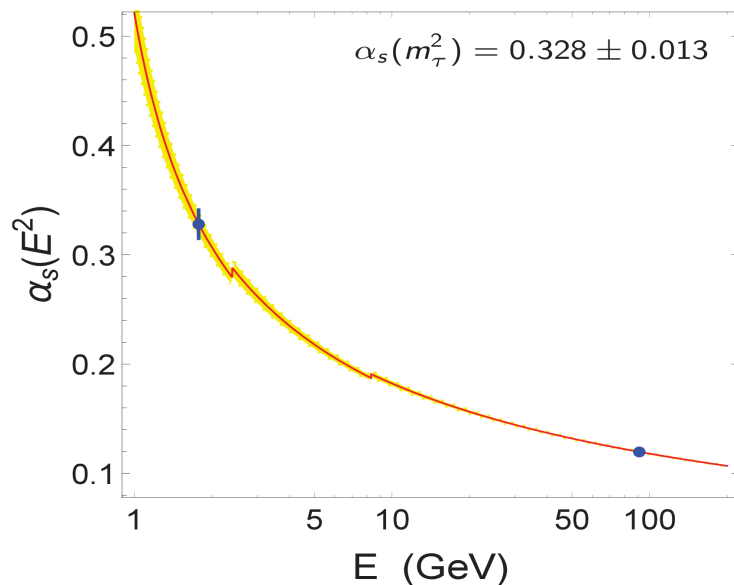


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A. Rodríguez-Sánchez, A. Pich, PRD 94 (2016) 034027

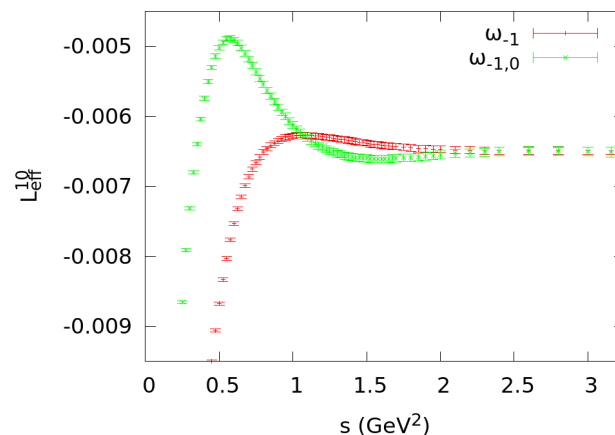
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Chiral Symmetry

M. González-Alonso, A. Rodríguez-Sánchez, A. Pich, PRD 94 (2016) 014017



- ChPT couplings**

$$L_{10}^r(M_\rho) = -(4.1 \pm 0.4) \cdot 10^{-3}$$

$$C_{87}^r(M_\rho) = (5.10 \pm 0.22) \cdot 10^{-3} \text{ GeV}^{-2}$$

- V-A Vacuum condensates**

$$\mathcal{O}_6 = (-3.6^{+1.0}_{-0.9}) \cdot 10^{-3} \text{ GeV}^6$$

$$\mathcal{O}_8 = (-1.0 \pm 0.5) \cdot 10^{-2} \text{ GeV}^8$$



Electroweak Effective Theory

J. Fuentes-Martín, C. Krause, A. Pich, J. Portolés, I. Rosell,
P. Ruiz-Femenía, J. Santos, J.J. Sanz-Cillero

Energy Scale

Fields

Effective Theory

$\Lambda_{\text{NP}} \sim \text{TeV}$

S_n, P_n, V_n, A_n, F_n

H, W, Z, γ, g

τ, μ, e, ν_i

t, b, c, s, d, u

Underlying Dynamics

..... Energy Gap



M_W

H, W, Z, γ, g

τ, μ, e, ν_i

t, b, c, s, d, u

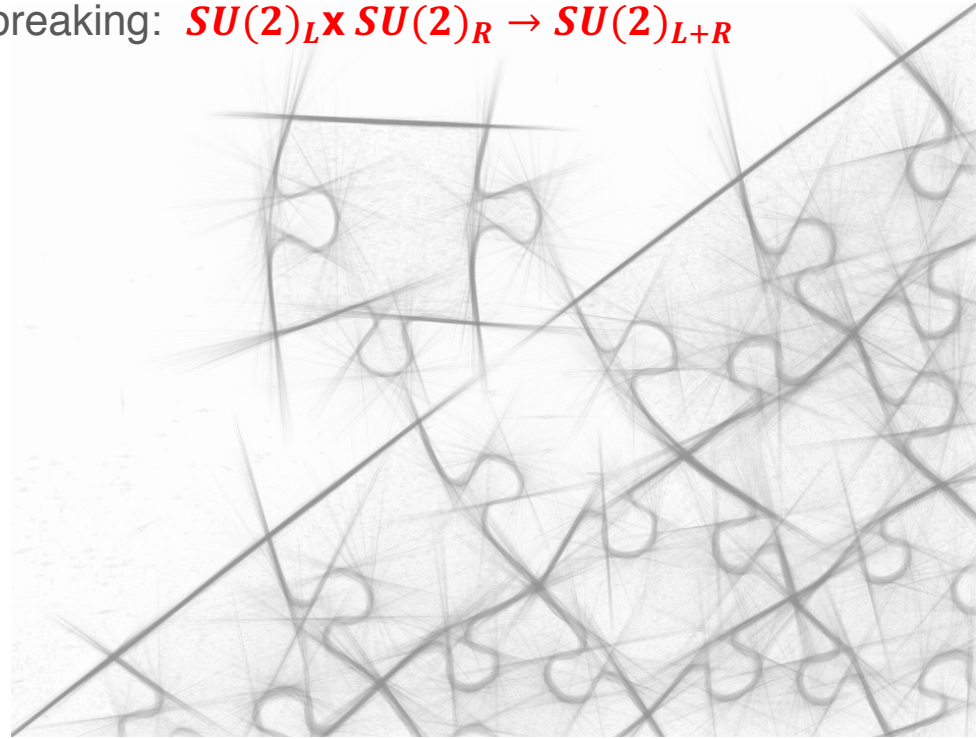
Standard Model



Fingerprints of Heavy Scales in ElectroWeak Effective Lagrangians

A. Pich, I. Rosell, J. Santos, J.J. Sanz-Cillero, arXiv:1609.06659 & PRD 93 (2016) 055041
now incorporating C. Krause

- There is a **gap** between the SM and heavier states: **EFTs are a good framework to search for new physics**
- We consider **SM particles** and **symmetries** and a full set of colourless $J^{PC} = 0^\pm, 1^\pm$ heavy resonances, invariant under $SU(2)_{L+R}$ and organised with a **well-defined power counting**
- The only assumption is chiral symmetry breaking: $SU(2)_L \times SU(2)_R \rightarrow SU(2)_{L+R}$





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- The only assumption is chiral symmetry breaking: $SU(2)_L \times SU(2)_R \rightarrow SU(2)_{L+R}$
- Once the heavy states are integrated out, we obtain their **predictions** in the **Low Energy couplings Constants (LECs)**, which can be **tested experimentally**
- Spin-1 resonances allow different resonance representations (specifically Proca and antisymmetric formalism). We prove that the **predictions are the same** (and so the theory) and establish when each formalism is more convenient
- Predictions for LECs improve when some UV conditions are assumed
- **Ongoing projects:**
 - 1.- Incorporate **color** to the model
 - 2.- Add **flavour**: promote fermions to 3 families



Effective Field Theories at one loop

J. Fuentes-Martín, J. Portolés, P. Ruíz-Femenía

EFTs offer a model-independent tool for the description of heavy New Physics:

- Recent and ongoing efforts to extend EFT analyses at NLO

See for instance CERN Yellow Report 4; Henning, Lu, Murayama, arXiv:1604.01019;
Ellis, Quevillon, Lu, Zhang Phys.Lett. B762 (2016) 166-176; Zhang, arXiv:1610.00710

- Loop corrections to the EFT also important for flavor physics

e.g. Feruglio, Paradisi, Patteri, Phys.Rev.Lett 118 (2017); Pruna, Signer, JHEP 1410 (2014) 014

We developed a method to construct the full 1-loop EFT of arbitrary BSM models:

Javier Fuentes-Martín, Jorge Portolés, Pedro Ruiz-Femenía, JHEP 1609 (2016) 156

- We extract the one-loop Wilson coefficients from the hard momentum region in the path integral

$$\int d^d x \mathcal{L}_{\text{EFT}}^{\text{1loop}} = S_H^{\text{hard}}$$

- **Complete calculation with important simplifications w.r.t other recently proposed approaches**

Currently applying this method to determine **the full one-loop EFT of a general 2HDM in the decoupling limit and its phenomenological implications**



Precision Phenomenology

F. Driencourt-Mangin, F. Campanario, R. J. Hernández-Pinto,
G.F.R. Sborlini, W. Torres, G. Rodrigo

- **No clear signal of new physics** at the LHC
- New physics should appear as a gentle deviation from the SM
- LHC events characterized by complex multi-particle final-states



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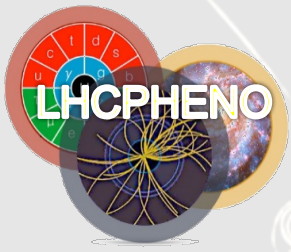


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New perturbative methods



Loop-Tree duality

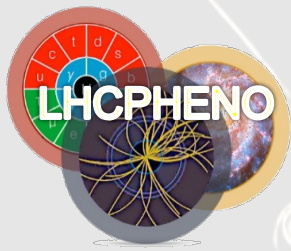
F. Driencourt-Mangin, R. J. Hernández-Pinto, G.F.R. Sborlini, G. Rodrigo,
JHEP 1608 (2016) 160 and JHEP 1610 (2016) 162

Emitting particles with zero energy $\neq$ zero emission

Parallel particles look like one single particle

QFT extrapolated to infinite energy in loop corrections





Loop-Tree duality

F. Driencourt-Mangin, R. J. Hernández-Pinto, G.F.R. Sborlini, G. Rodrigo,
JHEP 1608 (2016) 160 and JHEP 1610 (2016) 162

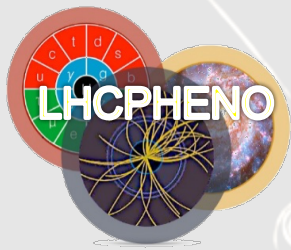
Emitting particles with zero energy $\neq$ zero emission

Parallel particles look like one single particle

QFT extrapolated to infinite energy in loop corrections

DREG

- Modify the space-time dimensions to $d=4-2\epsilon$
- Singularities manifest **after** integration as **$1/\epsilon$ poles**
- Real and virtual contributions are considered **separately**



Loop-Tree duality

F. Driencourt-Mangin, R. J. Hernández-Pinto, G.F.R. Sborlini, G. Rodrigo,
JHEP 1608 (2016) 160 and JHEP 1610 (2016) 162

Emitting particles with zero energy $\neq$ zero emission

Parallel particles look like one single particle

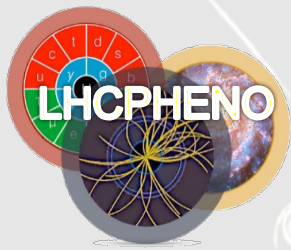
QFT extrapolated to infinite energy in loop corrections

DREG

- Modify the space-time dimensions to $d=4-2\epsilon$
- Singularities manifest **after** integration as $1/\epsilon$ **poles**
- Real and virtual contributions are considered **separately**

LTD / FDU

- Computations made in **$d=4$ space-time** dimensions by using a suitable momentum mapping
- Singularities are killed **before** integration: summation over degenerate states at integrand level
- Real and virtual contributions are considered **simultaneously**: efficient Monte Carlo implementation



Loop-Tree duality

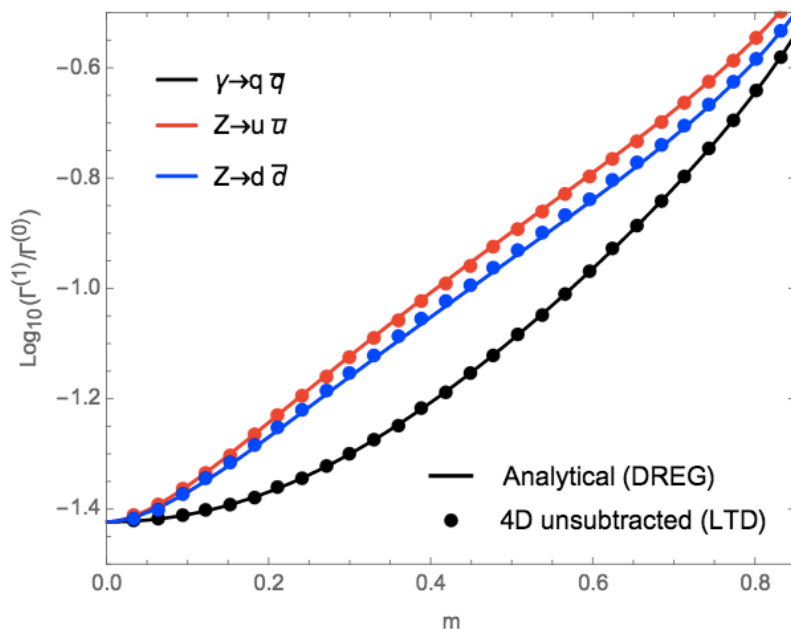
F. Driencourt-Mangin, R. J. Hernández-Pinto, G.F.R. Sborlini, G. Rodrigo,
JHEP 1608 (2016) 160 and JHEP 1610 (2016) 162

Emitting particles with zero energy $\neq$ zero emission

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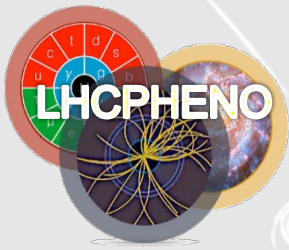
QFT extrapolated to infinite energy in loop corrections

Smooth massless limit



LTD / FDU

- Computations made in **d=4 space-time** dimensions by using a suitable momentum mapping
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- Real and virtual contributions are considered **simultaneously**: efficient Monte Carlo implementation



Loop-Tree duality

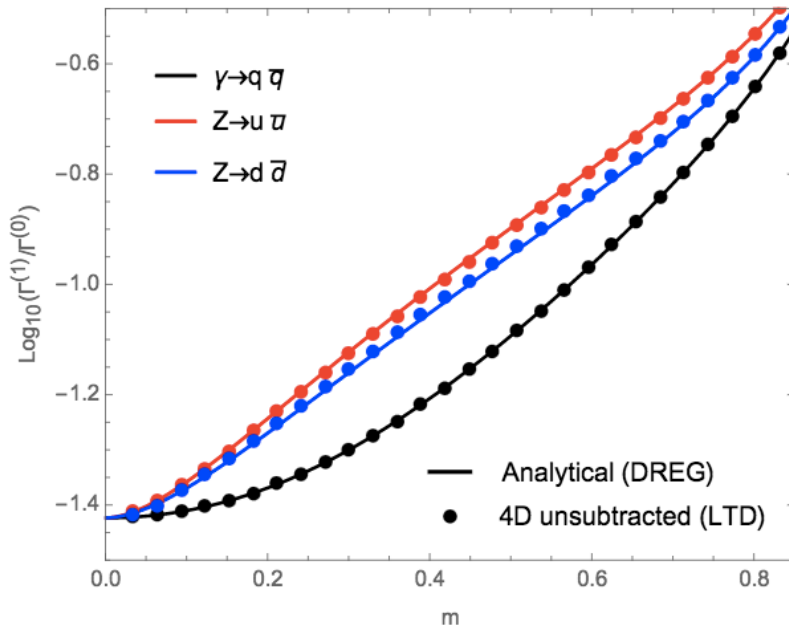
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Emitting particles with zero energy $\neq$ zero emission

Parallel particles look like one single particle

QFT extrapolated to infinite energy in loop corrections

Smooth massless limit



Forthcoming applications

- Very compact expressions with **EW gauge bosons**: gauge cancellations explicit
- Easier **asymptotic expansions** / EFT
- Fully differential predictions at NNLO
- Scattering amplitudes with **gravitons** in combination with Color-Kinematics duality (CKD)



Nota de prensa

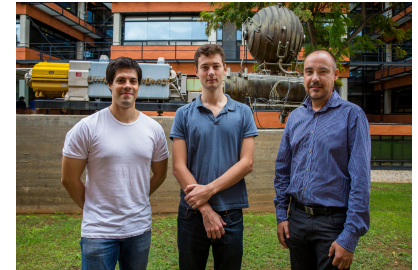
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Thanks to Isidoro

Valencia, 5 de octubre de 2016

Un equipo de investigadores del IFIC resuelve el problema de las dimensiones del espacio-tiempo en las teorías aplicadas al LHC

- Los resultados se presentaron a principios del mes de agosto en la mayor conferencia de física de partículas del mundo, ICHEP 2016 de Chicago, y se han publicado en *Journal of High Energy Physics*





Nota de prensa

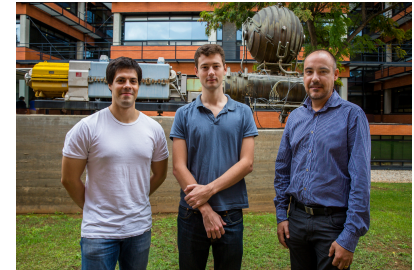
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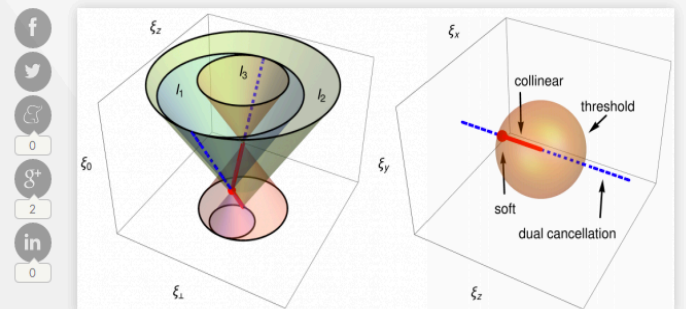


NAUKAS

La Ciencia de la Mula Francis

Hacia un nuevo método de regularización más allá de la regularización dimensional

1 Comentario



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from research organizations

Researchers solve the problem of the dimensions of space-time in theories relating to the Large Hadron Collider

Date: October 21, 2016

Source: Asociación RUVID

Summary: Researchers propose an approach to the experimental data generated by the Large Hadron Collider that solves the infinity problem without breaching the four dimensions of space-time.



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El Confidencial

LAS PROVINCIAS

laRazón

LA VANGUARDIA

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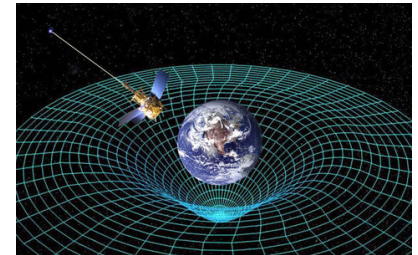
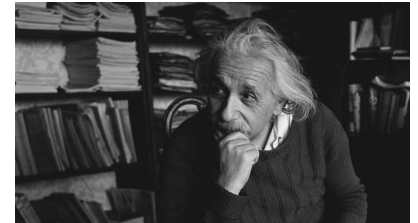
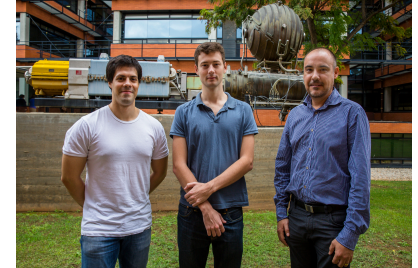
UN EQUIPO DEL INSTITUTO DE FÍSICA CORPUSCULAR

Físicos españoles resuelven el problema de los infinitos en las 4 dimensiones de Einstein

El método resuelve uno de los problemas principales a los que se enfrentan los físicos de partículas a la hora de trasladar la teoría al experimento

Un nuevo método permite mantener las dimensiones espacio-tiempo de Einstein

Un grupo de investigadores del Instituto de Física Corpuscular, ha desarrollado un nuevo método que redefine la teoría evitando la aparición de infinitos, y que permite por tanto mantener la teoría en las cuatro dimensiones habituales del espacio-tiempo.





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La Hora
LO QUE NECESITAS SABER

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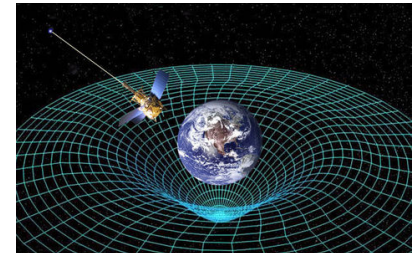
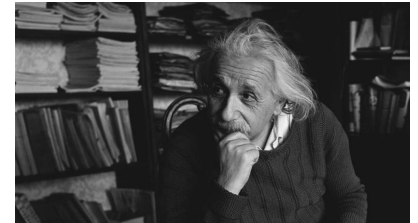
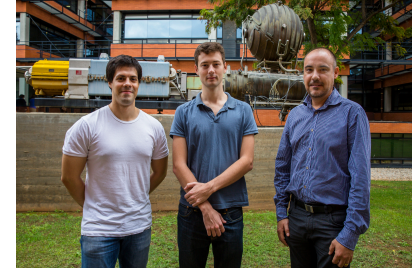
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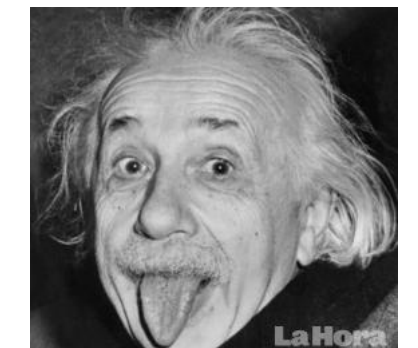
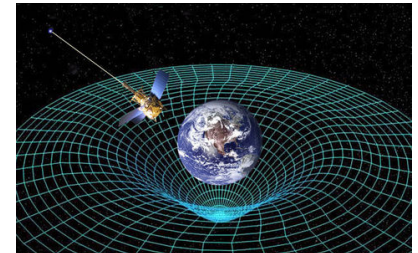
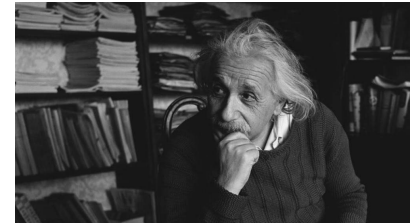
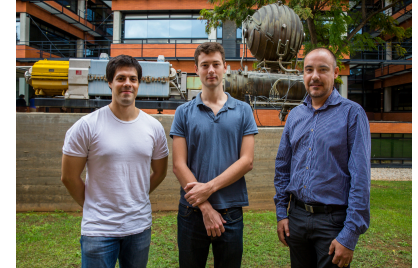
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CIENCIA Y TECNOLOGÍA

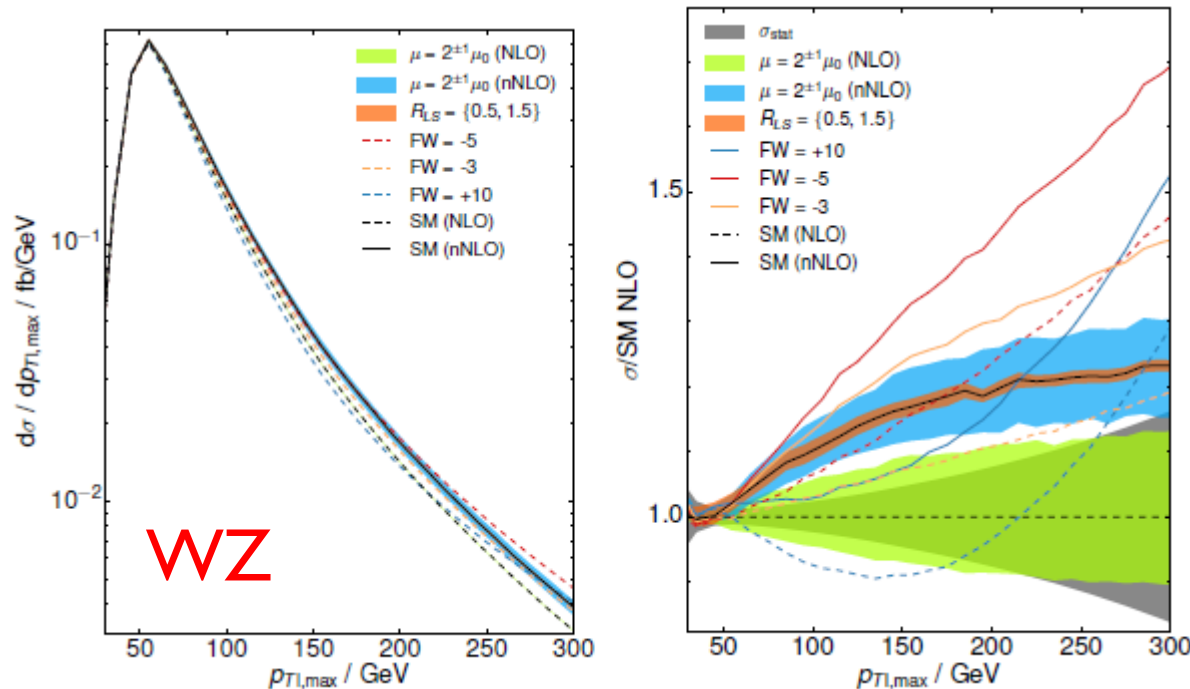
Método resuelve teorías de Einstein





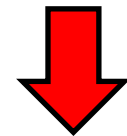
VV@LHC beyond NLO and searches of Anomalous Couplings

Francisco Campanario, Robin Roth, Sebastian Sapeta and Dieter Zeppenfeld: arXiv:1612.03577



NNLO corrections

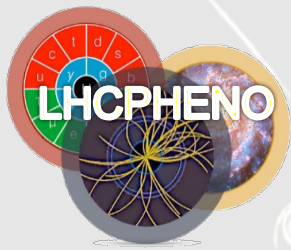
- Large
- Can **fake** Anomalous coupling effects



Need to be included

Future:

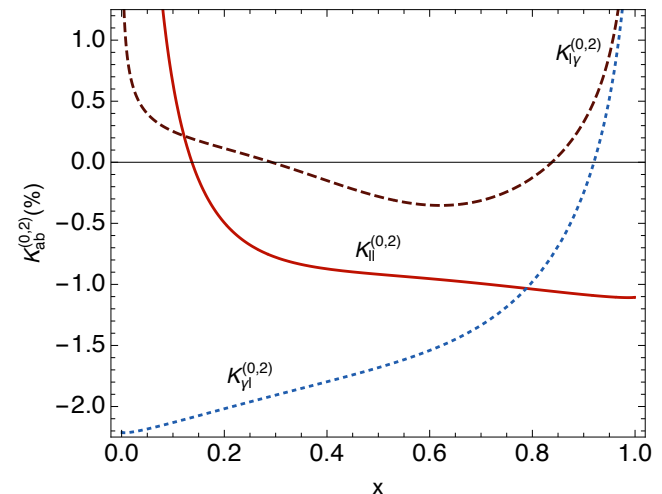
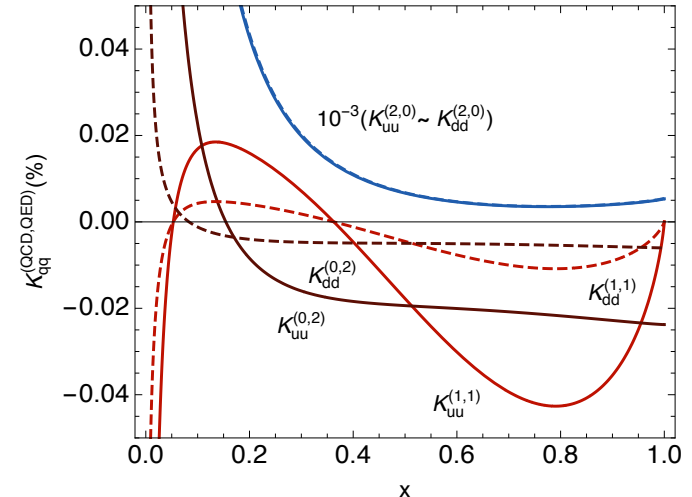
NNLO effects in VVV and anomalous coupling searches



EW contributions to PDF's evolution

D. De Florian, G.F.R. Sborlini, G. Rodrigo, EPJC76 (2016) 282 and JHEP 10 (2016) 056

- EW effects competing with QCD with the current LHC precision data $\alpha_S^2 \approx \alpha$
- Mixed QCD-QED and two-loop QED contributions to **Altarelli-Parisi splitting functions** calculated for the **first time**
- They govern PDF evolution, and necessary to control IR behaviour / proof factorisation for physical observables
- Abelianisation algorithm from pure QCD
- Besides photon's PDF, **new leptonic densities** that mix with partonic densities through DGLAG evolution
- Extended DGLAP equations



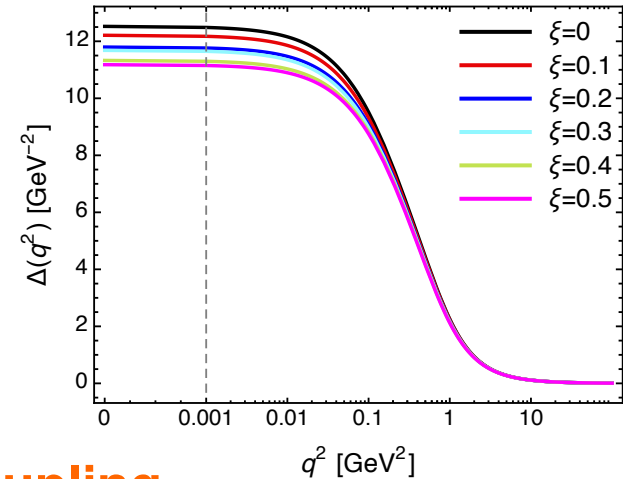


Schwinger mechanism in linear covariant gauges

A.C. Aguilar, D. Binosi, J. Papavassiliou, arXiv:1611.02096

Gluon mass generating mechanism in the context of the linear covariant gauges. Schwinger mechanism in pure Yang-Mills theories hinges crucially on the inclusion of massless bound-state excitations in the fundamental nonperturbative vertices of the theory. The dynamical formation of such excitations is controlled by a homogeneous linear Bethe-Salpeter equation, whose nontrivial solutions have been studied only in the Landau gauge. The form of this integral equation is derived for general values of the gauge-fixing parameter, under a number of simplifying assumptions.

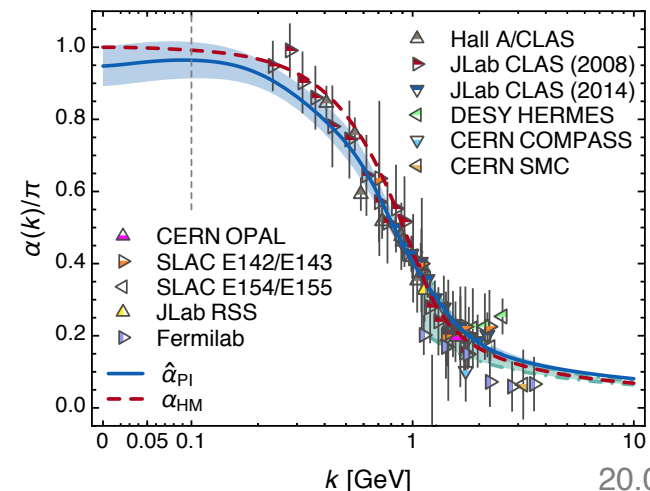
Gluon propagators for various values of the gauge-fixing parameter

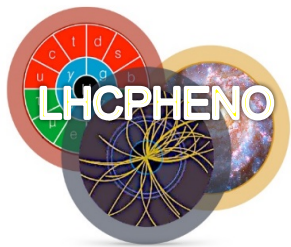


Process-independent strong running coupling

D. Binosi, C. Mezrag, J. Papavassiliou, C. D. Roberts, J. Rodriguez-Quintero, arXiv:1612.04835

Understanding the infrared behaviour of QCD, phenomenological based on data, and via quantum field equations in the continuum. Process-independent running-coupling, an **effective charge** analogue to the Gell-Mann--Low effective coupling in QED. The result is almost identical to the process-dependent effective charge defined via the Bjorken sum rule, which provides one of the most basic constraints on our knowledge of nucleon spin structure. This reveals the Bjorken sum to be a near direct means by which to gain empirical insight into QCD's Gell-Mann--Low effective charge

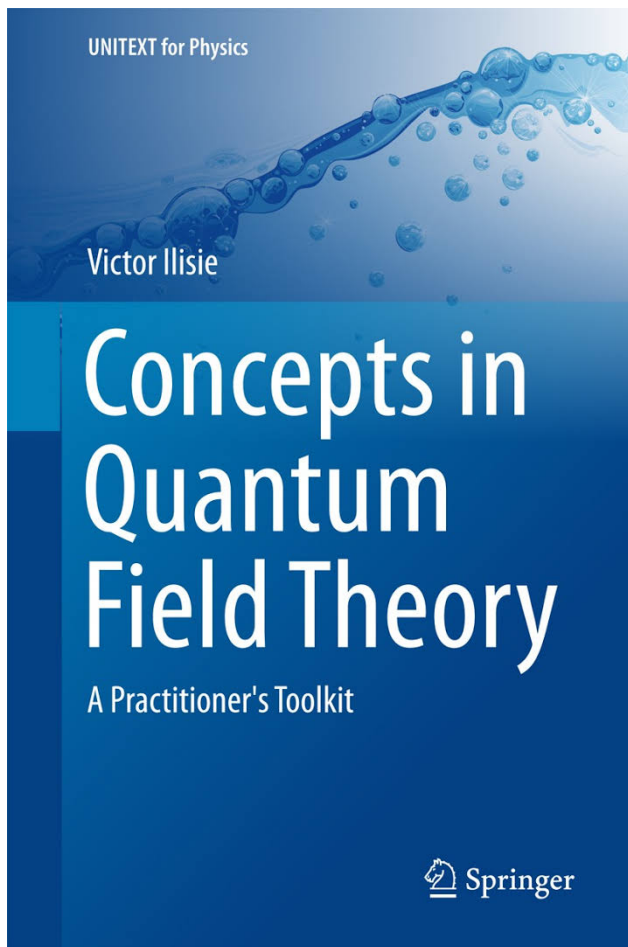




Victor Ilisie

Concepts in Quantum Field Theory

A Practitioner's Toolkit



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TAE 2016 | Taller Altas Energías

International School of
High Energy Physics
4 - 17 September
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Cosmology and Dark Matter: Subir Sarkar (U. Oxford)
Detectors: Mar Capeans (CERN)
Field Theory and the Standard Model: José Ignacio Illana (U. Granada)
Flavour Physics: Zoltan Ligeti (U. Berkeley)
Future Prospects: Teresa Rodrigo (IFCA, Santander)
Heavy Ion Physics: Jorge Casalderrey (ICCUB, Barcelona)
LHC Physics: Daniel Froidevaux (CERN)
LHCb Physics: Arantza Oyanguren (IFIC, Valencia)
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Finaliza una nueva edición del TAE con éxito de participación

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Se cierra hoy en el Centro de Ciencias de Benasque Pedro Pascual la edición del Taller de Altas Energías (TAE) más numerosa de los últimos años. Medio centenar de estudiantes de máster y doctorado ha recibido dos semanas de formación en los temas más punteros de la física de partículas, astropartículas y cosmología.



- 50 estudiantes de máster y primeros años de doctorado
- 34% de los participantes procedente de universidades no españolas





Summary

- **Very broad spectrum of research interests:** from model building to precision phenomenology, from innovative perturbative and effective field theories to non-perturbative methods, from the low energy/high-intensity frontier to the high-energy frontier
- **Good position to have an impact in the physics programme of the LHC and flavour factories, and a leading role at National and European level**
- **Very committed in outreach and public engagement activities**
- **Innovation activities through European networks with leading scientific software companies**

