

The LHCb-Pisa Group

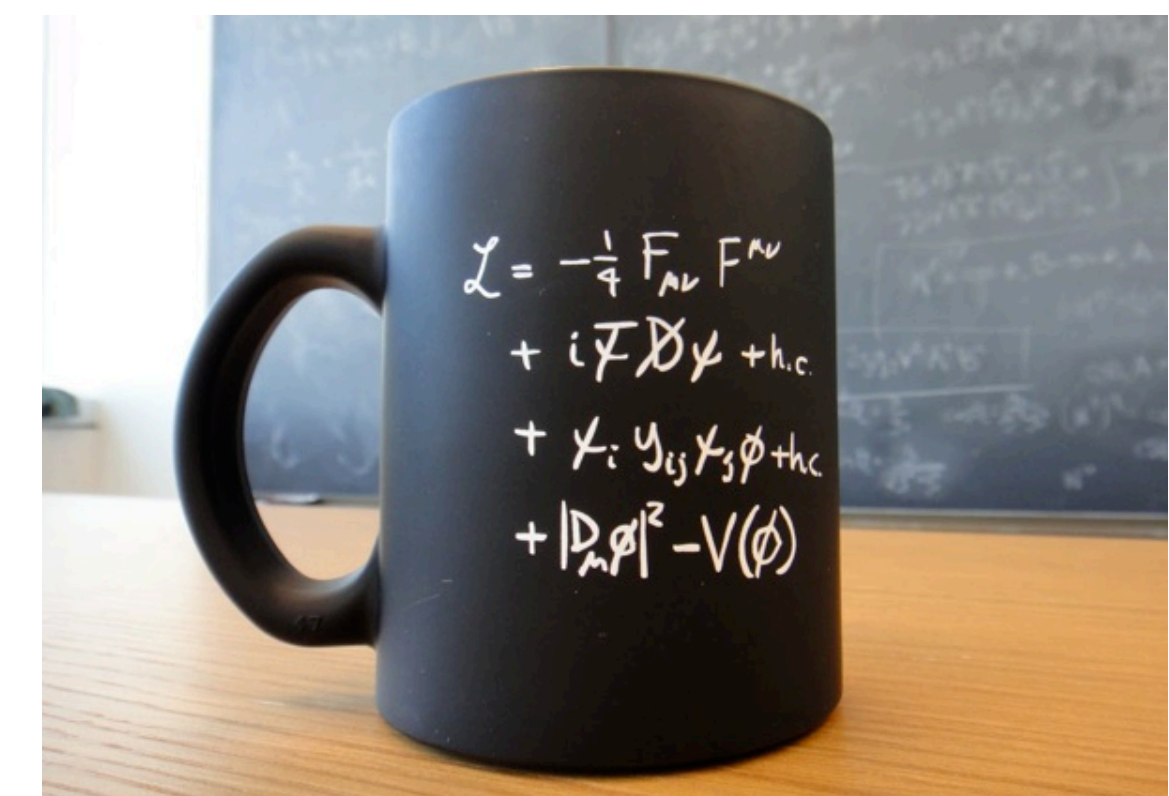
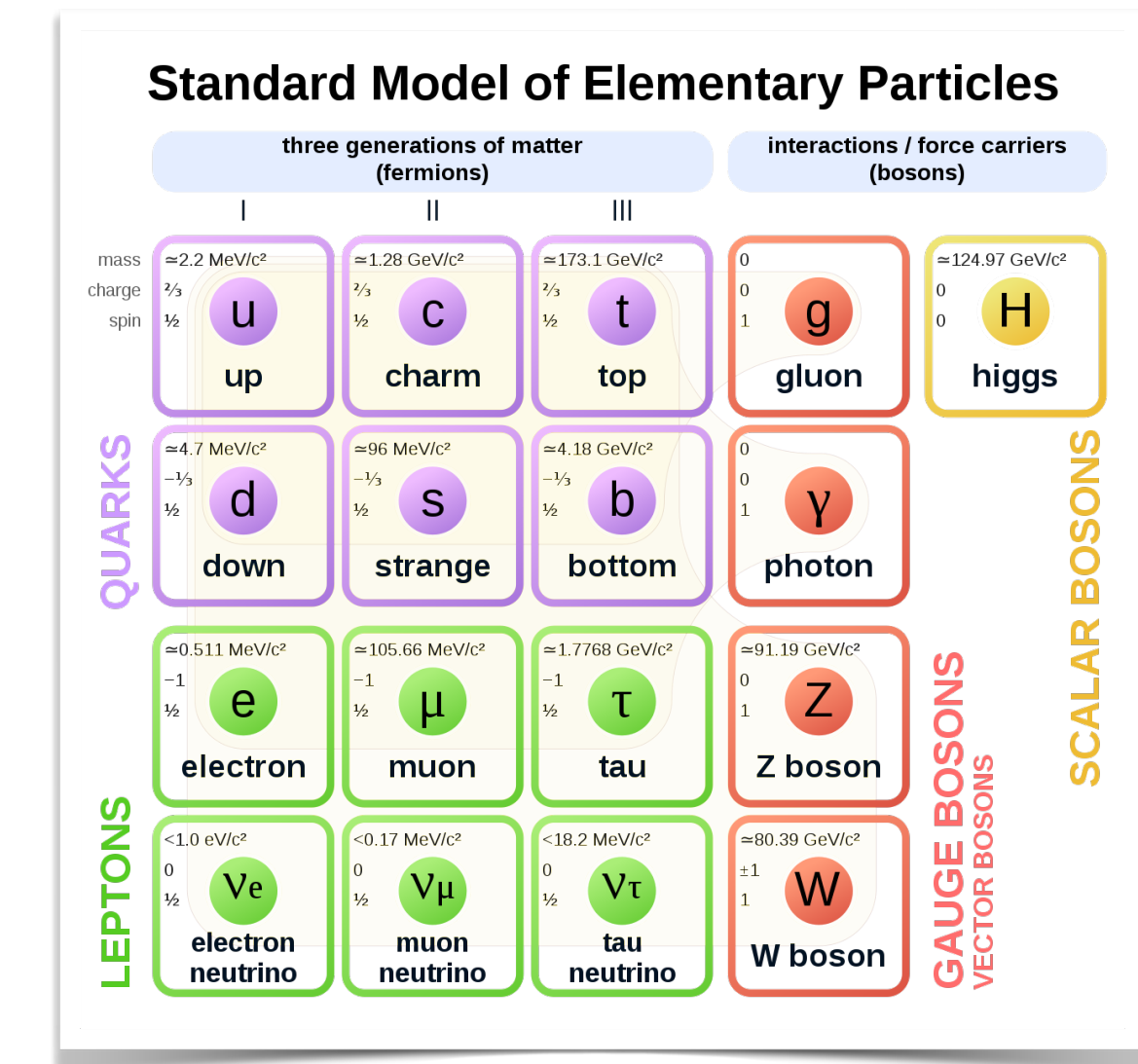
Michael J. Morello (SNS and INFN-Pisa)

May 26th, 2026



The Standard Model

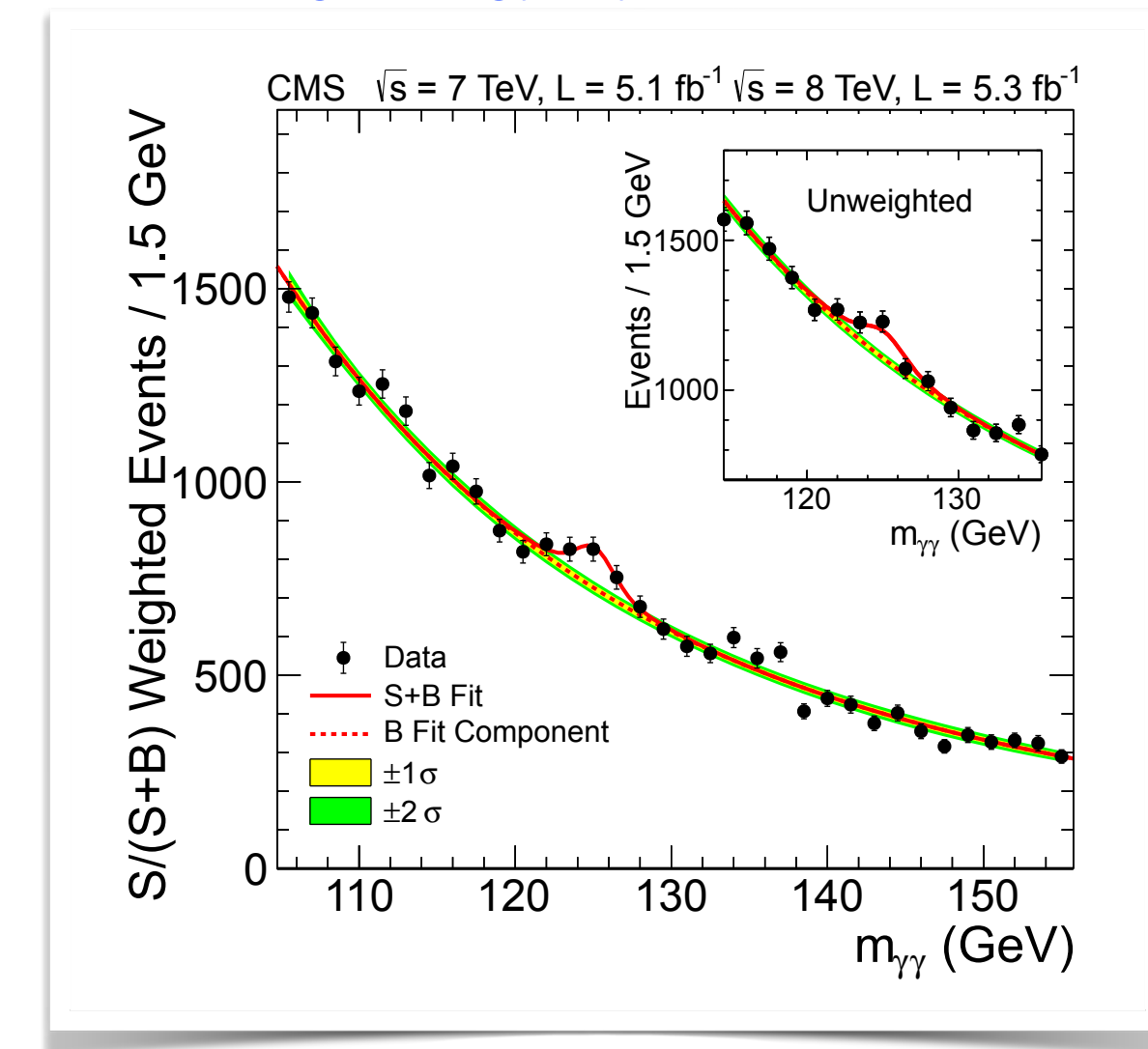
- Elementary particles include the fundamental fermions (quarks, leptons, anti-quarks, and anti-leptons), which generally are "matter particles" and "antimatter particles".
- As well as the fundamental bosons (gauge bosons and the Higgs boson), which generally are "force particles" that mediate interactions among fermions: **strong, weak and electro-magnetic interactions.**
- SM proved to be successful and extremely predictive. However, something beyond that must exist...
- Since ever, HEP aims at improving our 'limited' knowledge of [fundamental physics phenomena](#), hopefully revealing deeper and more complex dynamics beyond our current understanding of Nature.



Energy vs intensity

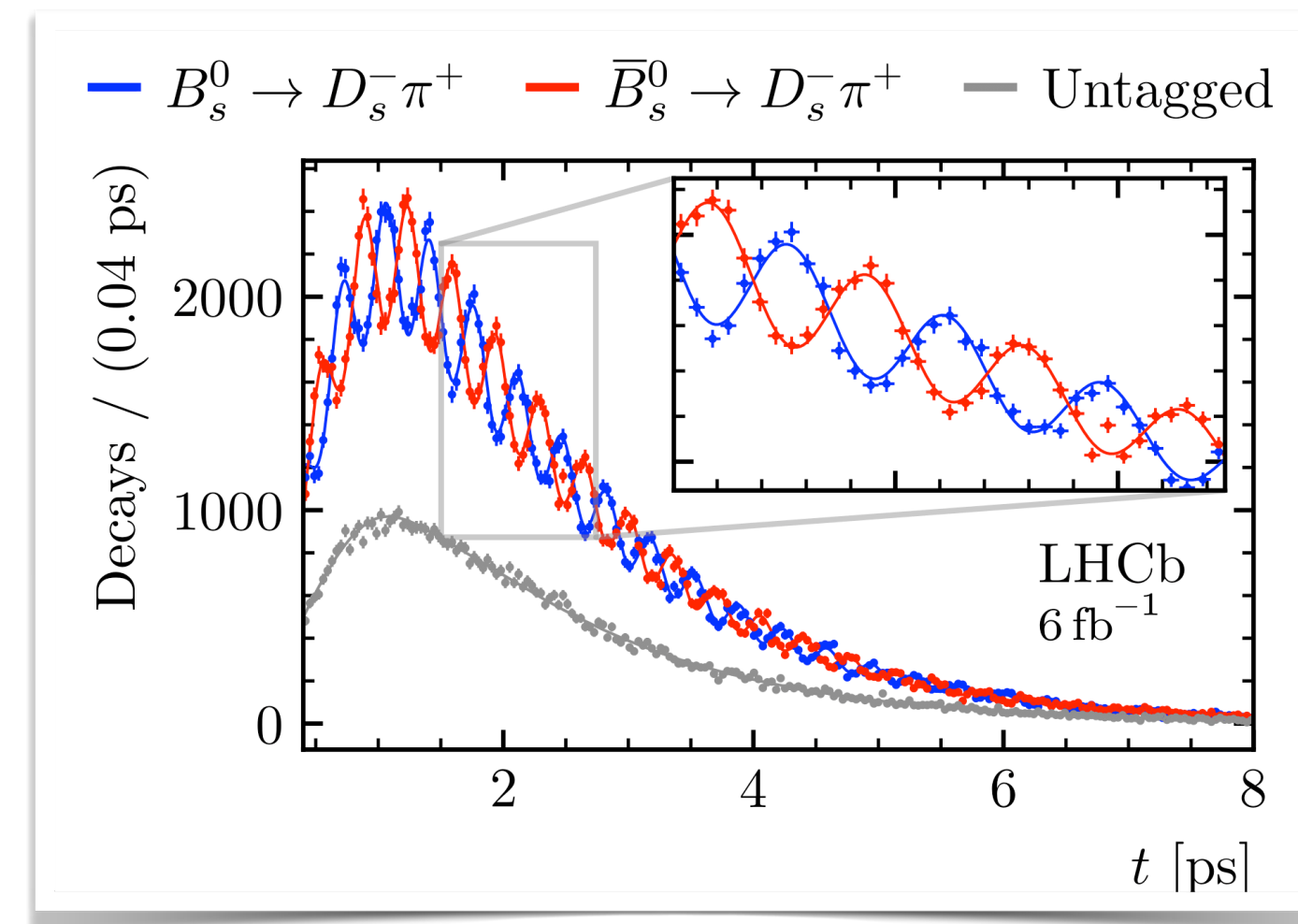
- Energy frontier (**direct search**)
 - Direct access to new particles at higher mass, produced in high energy collisions.
 - ATLAS, CMS at LHC (future experiments).
- Intensity frontier (**indirect search**)
 - Study processes that are suppressed or even forbidden in the SM.
 - Precision measurement of observables that are very well predicted in the SM.
 - LHCb at LHC, Belle2 at Super-KEKB and their Future Upgrades.

Discovery of Higgs Boson in 2012 from ATLAS and CMS
[J. High Energy Phys. 06 \(2013\) 081](#)



2013
Higgs&Englert

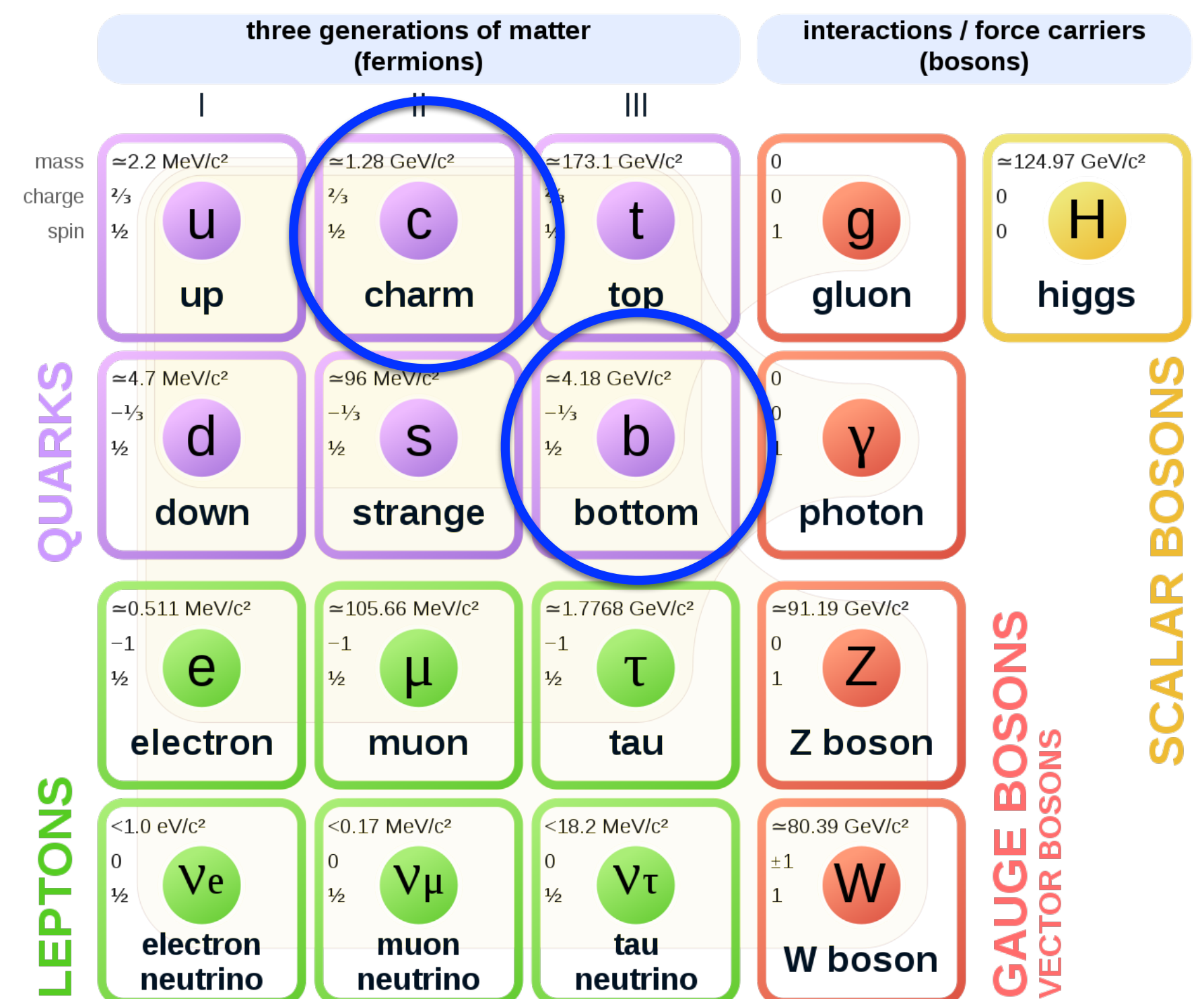
Precise measurement of oscillations frequency
[Nature Physics volume 18, pages 1–5 \(2022\)](#)



Heavy Flavour Physics

- Within the Standard Model of particle physics, there are six “flavours” of quark.
- Hadrons containing charm (c) or beauty (b) quarks or antiquarks are known as “heavy flavoured” particles.
 - $B^0(\bar{b}d)$, $B_s^0(\bar{b}s)$, $D^0(c\bar{d})$,
- The heaviest flavoured particle, the **top quark**, is not usually included with discussions of “heavy flavour physics”. Different dynamics and experimental challenges.

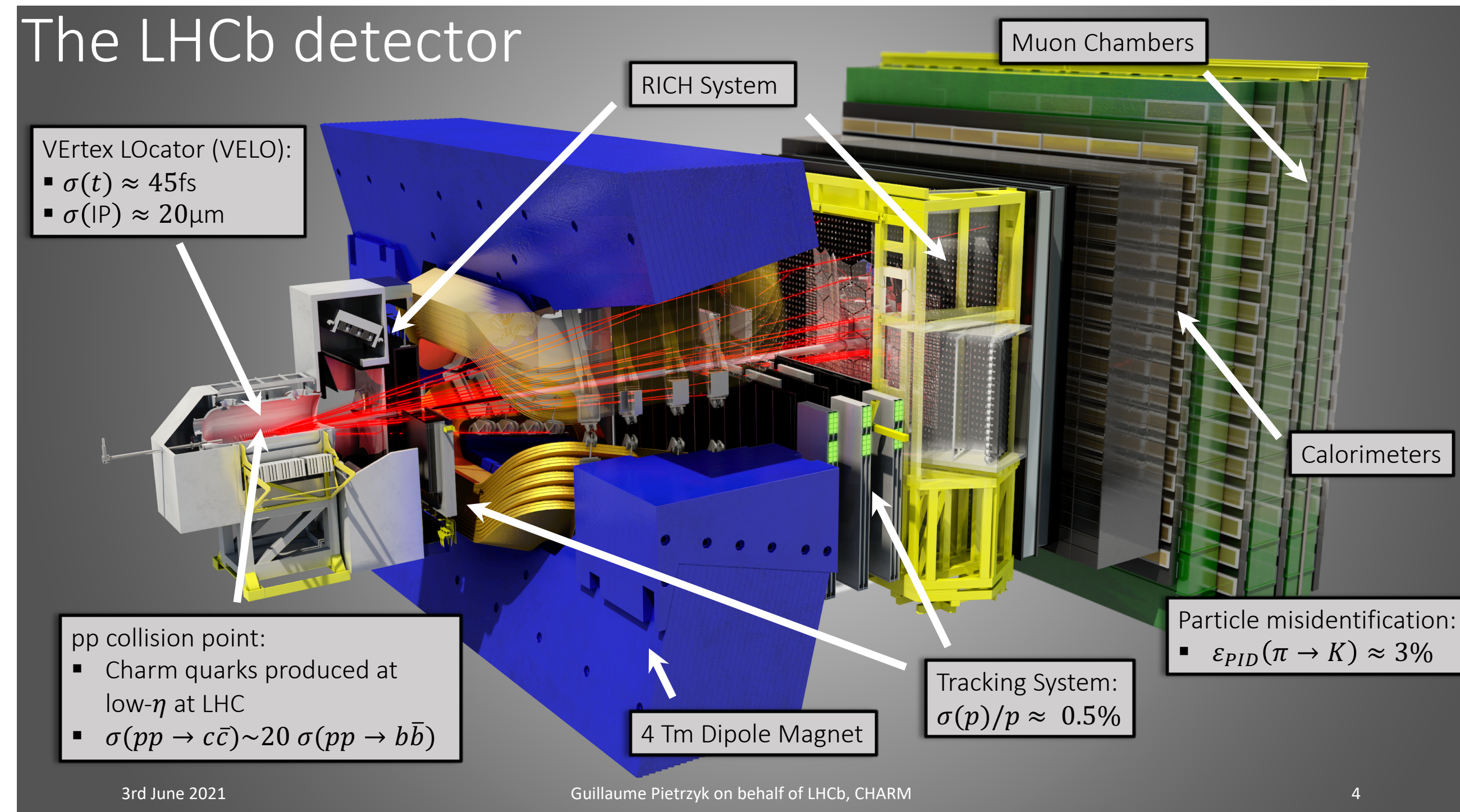
Standard Model of Elementary Particles



Heavy Flavour Physics (II)

- Measurements of the **properties of heavy flavoured hadrons (masses, lifetime, productions, etc)** – including those of states that had not previously been observed – provide tests of the theory of the strong interaction, quantum chromodynamics (QCD), in a regime where it is not well understood.
- **Phenomena involving heavy flavors, such as mixing and rare decays, are mediated by loop processes involving virtual particles (i.e. Flavour Changing Neutral Currents), and are sensitive to possible non-Standard Model physics at high scales.** In fact, precision measurements in the quark sector can be sensitive to new particles with masses much higher than the reach of the LHC collisions.
- Possibility to learn more about the origin of the asymmetry between matter and antimatter in the Universe. **Violation of the combined CP symmetry**, that is symmetry under inversion of parity (P) and of all internal quantum numbers (charge conjugation, C) is a prerequisite for the evolution of an asymmetric Universe.

The LHCb experiment

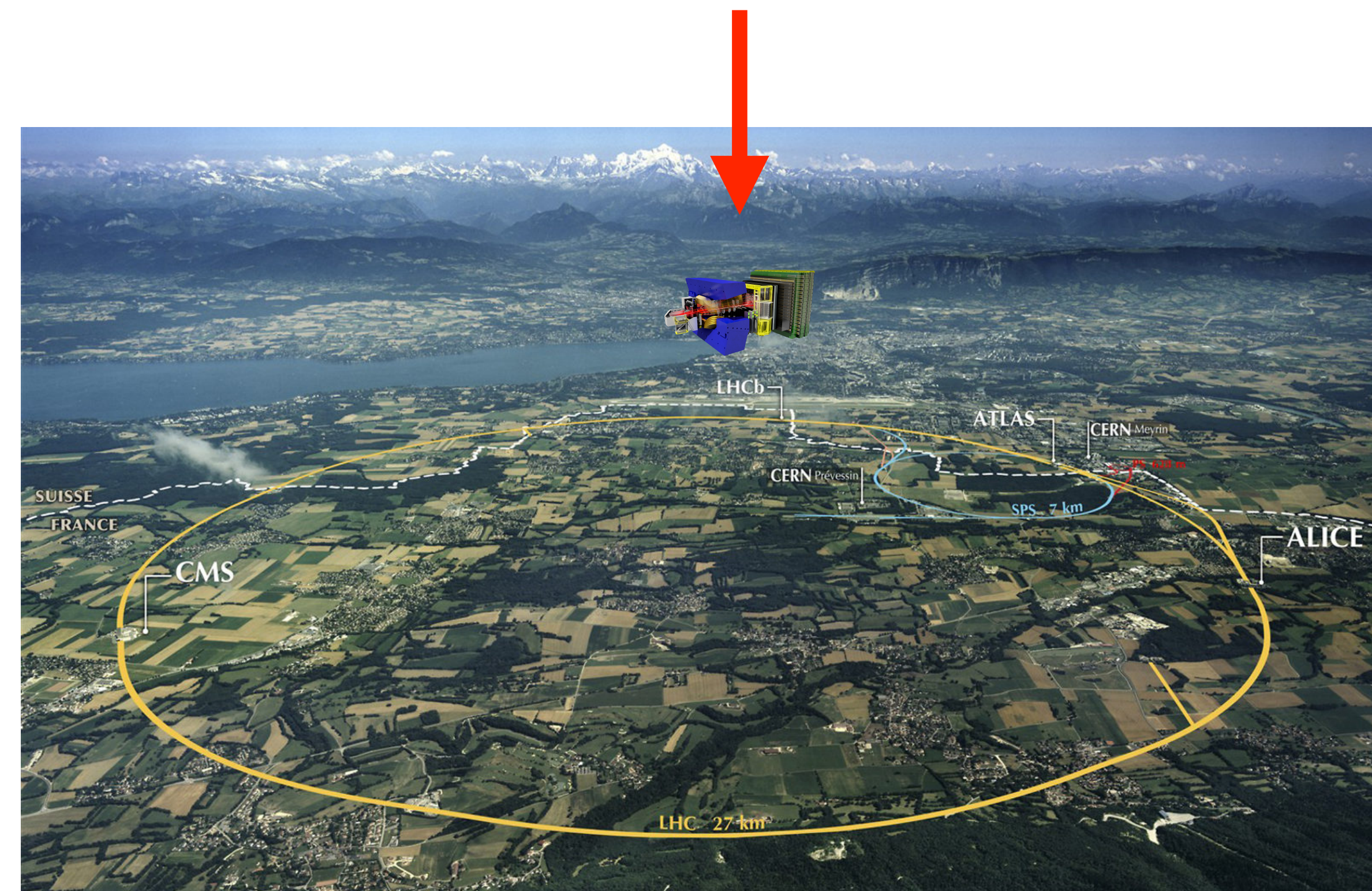


Built for Heavy Flavour Physics at hadron collisions
Excellent tracking and particle identification capabilities
~1300 people from 100 institutes from 22 countries around the world

LHC as a charm and beauty factory

- The Large Hadron Collider produces the largest number of $b\bar{b}$ and $c\bar{c}$ pairs ever. Huge potential in Heavy Flavour Physics.
 - $\approx 10^{13}$ $b\bar{b}$ per year (x20 for $c\bar{c}$)
- The LHCb experiment designed to fully exploit such an abundant production (high precision regime and well suited to search for rare processes).
- However, large quantities of other particles are produced, and (and) production represents only a fraction (of order $10^{-3} - 10^{-2}$) of the total. BRs of interesting processes are very small (of order $10^{-4} - 10^{-10}$ and below).
- **A huge experimental challenge. Need an “excellent detector” and a “fast and intelligent DAQ and trigger system”.**

We are here!!!



The LHCb-Pisa group

<https://web.infn.it/LHCb-PI/>



- Founded in 2012 by three scientists (including myself newly hired by the SNS) from the CDF experiment, which pioneered Heavy Flavour Physics at hadrons collisions.
- After ~14 years the group is very healthy, with a similar size of other historical groups at INFN-Pisa.
- Leadership and important contributions:
 - **Data analysis** (Charm Physics and Rare decays).
 - **DAQ and Trigger** in "Real Time Analysis" Project.
 - **Fast simulation** of the LHCb detector.
- INFN funds and supports the group each year. SNS has a leading role in many areas.

	Members	Institution	Role	
1	Barbieri Matteo	UniPi	under	
2	Bedeschi Franco	INFN	Staff	
3	Butera Erich Vito	SNS	PhD	
4	Celestino Irene	SNS	PhD	
5	Cordova Giulio	SNS	PhD	
6	Fantechi Riccardo	INFN	Staff	
7	Graverini Elena	UniPi	Staff	
8	Lazzari Federico	UniPi	Post-doc	
9	Lusiani Alberto	SNS	Staff	
10	Morello Michael J	SNS	Staff	
11	Paciolla Francesco	UniSi	PhD	
12	Passaro Daniele	SNS	PhD	
13	Punzi Giovanni (TL)	UniPi	Staff	
14	Rainini Sabrina	UniPi	under	
15	Rama Matteo	INFN	Staff	
16	Riccardi Domenico	SNS	PhD	
17	Terzuoli Francesco	UniSi	Post-doc	
18	Xu Ao	SNS	Post-doc	

Present and former SNS people



Former

- Pietro Marino (PhD student, 2014-2017) → Post-doc at [EPFL](#) (Lausanne) → Senior Data Scientist at [PhAST](#) → Senior Quantitative Researcher at [Signal](#) (Zurich)
- Riccardo Cenci (Post-doc, 2014-2016) → Firmware/Software Electronic Design Engineer at [UMBRIA AEROSPACE SYSTEMS S.p.A.](#) (Perugia)
- Simone Stracka (Post-doc, 2013-2014) → RTDa UniPi → INFN Staff researcher.
- Tommaso Pajero (PhD-student, 2016-2019) → Post-doc at [Oxford University](#) → Research Fellow at CERN → LD at CERN.
- Giacomo Vitali (Post-doc, 2018) → Senior Researcher at [LINKS Foundation](#) (Torino).
- Giovanni Bassi (PhD-student, 2018-2022) → Post-doc at SNS → Embedded System Developer and FPGA design at [Knowledge Resources GmbH](#) (Basel)
- Roberto Ribatti (PhD-student, 2019-2023) → Post-doc at [EPFL](#) (Lausanne)
- Nico Kleijne (PhD-student, 2021-2025) → Secondary school physics teacher (Mathematics and Physics)
- Lorenzo Pica (PhD-student 2019-2023 and Post-doc) - post-doc now

Present

- Ao Xu (post-doc) - CPV in charmed baryons and RETINA-DWT.
- Domenico Riccardi (PhD-student at 4 year) - Search for lepton flavor violating $\tau \rightarrow \phi \mu$ decays
- Daniele Passaro (PhD-student at 4 year) - FPGA-based 2D VELO Clustering at 30MHz and RETINA-DWT.
- Cordova Giulio (PhD-student at 2 year) - Monitoring of beam line in real-time with FPGAs.
- Irene Celestino (PhD student at 2 year) - High precision CPV measurements and RETINA-DWT co-processor.
- Erich V. Butera (PhD student, 2 year) - Measurement of direct CPV in $D^0 \rightarrow K_S^0 K_S^0$ decays and FPGA reconstruction with FPGA.

Many others not listed here from UniPi, UniSi, and INFN-Pisa.

Thank you for attention