



Coordination of the Particle Physics Group IPhU Days 2021



Aoife Bharucha+
Lorenzo Feligioni
CPT / CPPM



Introduction to particle physics@IPhU

Searching for a better understanding of the Standard Model (SM) and probing physics beyond the SM (BSM).



Direct (as predicted by models such as SUSY, composite Higgs, etc.,)

Dark Matter
(the search for the particle constituting 75% of the Universe)

Indirect
(deviations in precise SM measurements could reveal new physics at higher scale)

Direct searches@IPhU

Georges Aad, Marlon Barbero, Yann Coadou, Cristinel Diaconu, Arnaud Duperrin, Lorenzo Feligioni, Emmanuel Monnier, Guy Steve Muanza, Elemer Nagy, Elisabeth Petit, Alexandre Rozanov, Thomas Strebler, Mossadek Talby, Sylvain Tisserant, Laurent Vacavant

Direct searches for new phenomena and measurements relating to Higgs couplings are at the core of the **ATLAS-CPPM** group physics program, these will benefit from:

- ❖ Expected increase in the LHC's luminosity
- ❖ Upgrades of the ATLAS detector and subsequent improvement in its performance.
- ❖ Interplay with the CPT and IFAC-UM theory groups. In the CPT there is expertise in the construction of strongly-coupled models in collaboration with experts from IFAC-UM, and making predictions for the LHC, and in first principles calculations of nucleon and parton distributions.

Indirect searches@IPhU

Is there New Physics hiding in.....

heavy-flavour, rare-decay anomalies reported by Babar, Belle and LHCb?

- ❖ The **Belle-CPPM** and the **LHCb-CPPM** groups are heavily involved in measuring rare B and tau decays and in testing lepton universality. Tensions in these sectors will be extensively investigated thanks to the LHC and SuperKEKB data-taking program as well as the upgraded detectors.
- ❖ The **CPT** and **CPPM** groups work together closely, focusing on global analyses of measurements, on studies of precise predictions of sensitive rare decay observables within the SM and on investigations of BSM extensions responsible for possible deviations.

present and forthcoming precision measurements of the muon ($g-2$)?

- ❖ Expertise in lattice quantum chromodynamics (QCD), in the phenomenology of the muon ($g-2$), in perturbation theory and in the building of extensions to the SM, the **CPT** and **IFAC-UM** teams
- ❖ This will provide the theory needed to determine whether the new ($g-2$) measurements, at Fermilab and J-PARC, are consistent with SM expectations and, if not, the theory to interpret these results in terms of new, fundamental physics.

Dark Matter: an overview@IPhU

(see also IPhU astro-particles group)

- ❖ **DM model building, new generation mechanisms:** Work is ongoing on constructing models of Dark Matter (DM) and axion-like particles and new DM generation mechanisms at the **CPT**.
Aoife Bharucha, Sophie Mutzel, Felix Bruemmer
- ❖ **Direct detection and novel “desktop” experiments:** Groups recently been founded at the **CPPM** on the exciting DarkSide and MadMax experiments, further work at the **CPT** on the quark content of nuclei results in improved bounds on the DM models
Isabelle Wingerter-Seez, José Busto, Pascal Pralavorio, Fabrice Hubaut, Julien Laval, Laurent Lellouch, Emmanuel Nezri
- ❖ **Searches at colliders:** The **CPPM** ATLAS is also working on DM searches via missing ET signatures.
Steve Muanza et al
- ❖ **Indirect searches:** There is ongoing work at the **CPPM** on the CTA and Km3net experiments, relying on work done at **LAM** on the modelling of DM in the universe.
Vincent Bertin, Jose Busto, Paschal Coyle, Damien Dornic, Eric Kajfasz, Mathieu Perrin-Terrin, Heide Costantini, Jean-Pierre Ernenwein

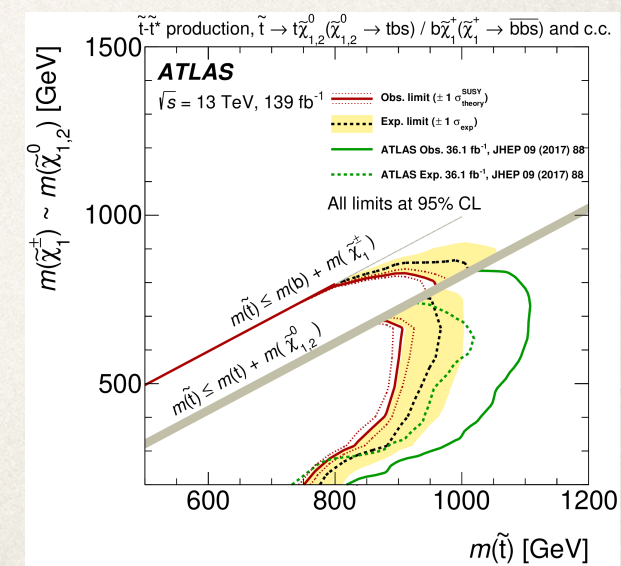
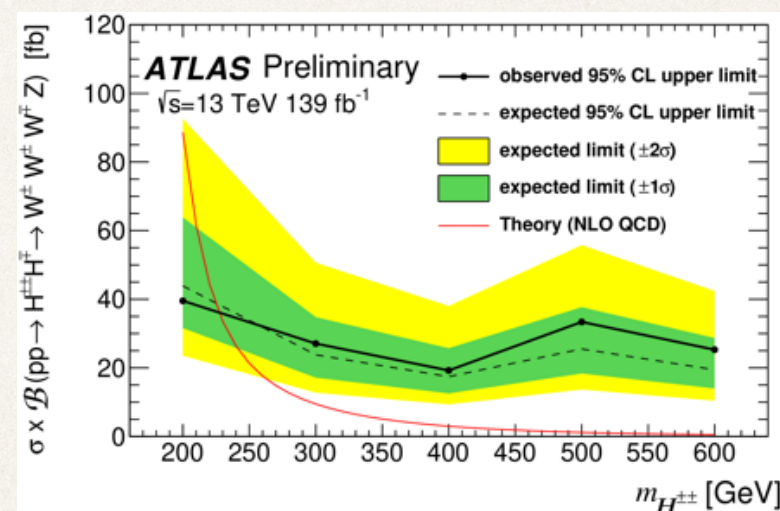
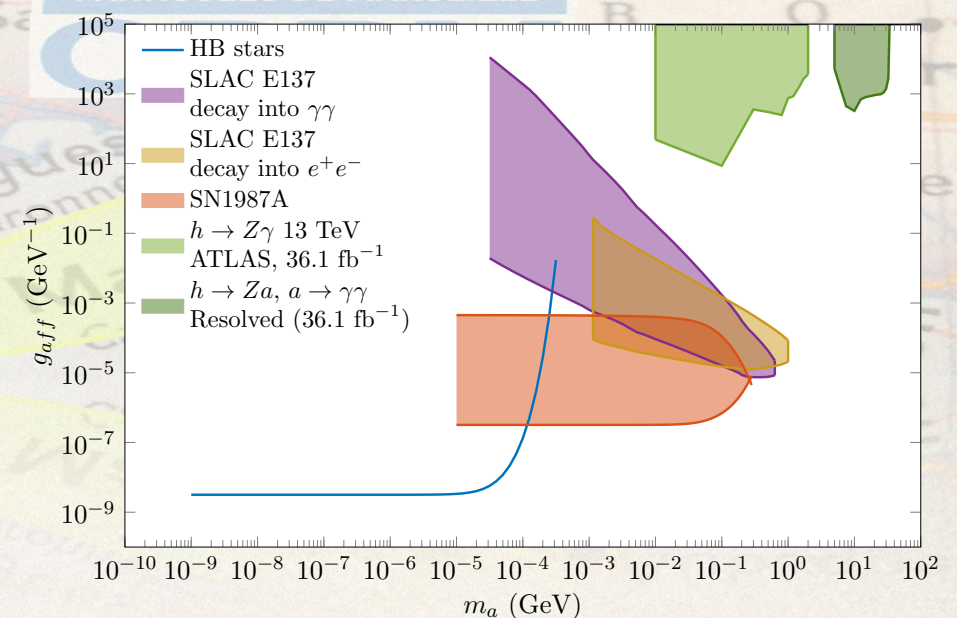
Ongoing projects@IPhU

- ❖ Semileptonic measurements with excited D mesons at LHCb, e.g. $R(D^{**})$ - IPhU PhD funding (Anton Poluetkov, Olivier Leroy, Aoife Bharucha, Jérôme Charles)
See talk by Anton Poluetkov later this afternoon!
- ❖ BSM Physics at the Terascale - IPhU funding
See talk by Lorenzo Feligioni later this afternoon!
 - Dark Matter Models (Felix Brümmer, Aoife Bharucha)
 - Type II Seesaw Models (Gilbert Moutaka Emmanuel Monnier, Ana Dumitriu)
 - Supersymmetry (Gilbert Moutaka, Steve Muanza, Lorenzo Feligioni)
 - Natural electroweak symmetry breaking with a composite Higgs (Marc Knecht, Michele Frigerio, Jean-Loic Kneur)
 - Analysis of Run 3 data and preparation to the HL-LHC phase (Fundamental is the involvement in ATLAS upgrade (calorimeter, pixel, trigger), ANR collaborative presented for the 2021 call (CPPM-L2C))
(M. Talby, L. Feligioni, M. Frigerio, G. Moutaka, E. Petit, F. Bruemmer)

BSM Physics at Terascale

Aoife Bharucha, Felix Brümmer, Ana Dumitriu, Lorenzo Feligioni, Michele Frigerio, Marc Knecht, Jean-Loic Kneur, Emmanuel Monnier, Gilbert Moultaika and Steve Muanza

- ❖ Collaborative experimental (ATLAS-CPPM) theoretical (CPT,L2C,LUPM) project
- ❖ phenomenology work addressing dynamical explanation of EWSB, particle physics solution dark matter problem, explanation of neutrino masses.
- ❖ From model building to interpretation of ATLAS results
- ❖ Novel data analysis data focused on unexplored signatures
- ❖ Two new ATLAS results appeared in 2020, from original ideas developed within the collaboration



See talk by Lorenzo Feligioni later this afternoon!

Direct search for WIMP dark matter

Proposal for a new 4-year project btw experimentalists and theorists across 3 IPHU science working groups gathering **4 labs**. Request: **25 k€** over the 4 years and **one PhD grant** starting 2021

Goal : Prepare at best the search for WIMP dark matter with the first data of DarkSide-20k expt [Gran Sasso, It.] in 2024. This expt will explore the most favored region of phase space for masses between 1 GeV and 100 TeV

IPHU science working group(s) involved:

Astroparticle and HE Universe ☒ Galaxies and Cosmology ☒ Particle Physics ☒
Quantum Field Theory and Quantum Gravity ☐

Project title: **Direct search for WIMP dark matter**

Project time frame:

Start date: **01/01/2021**

duration (months): **48**

Project coordination:

Coordinator's name: **Pascal Pralavorio**

Lab/team: **CPPM/Matière Noire** email: pralavor@c ppm.in2p3.fr

tel: **04 91 82 72 69**

List of other teams involved:

Lab/team: **CPPM/Matière Noire**

Team project leader: **Fabrice Hubaut**

Lab/team: **LAM/GECO**

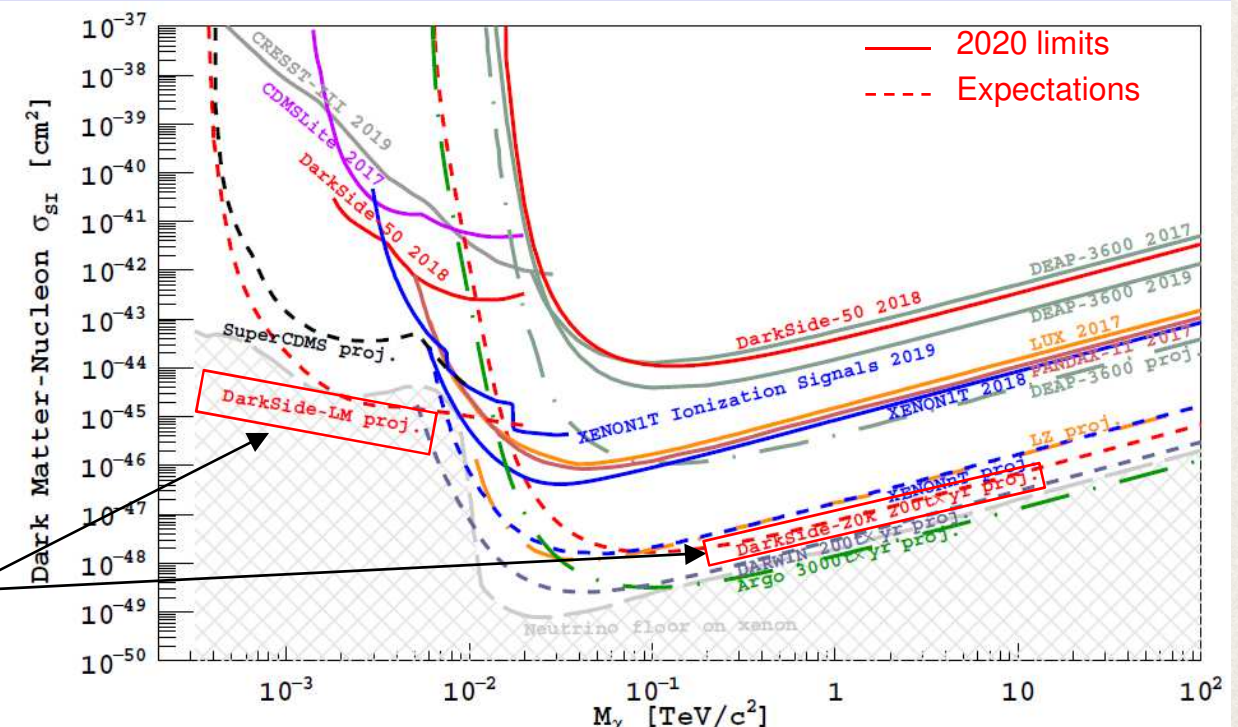
Team project leader: **Emmanuel Nezri**

Lab/team: **CPT/PP**

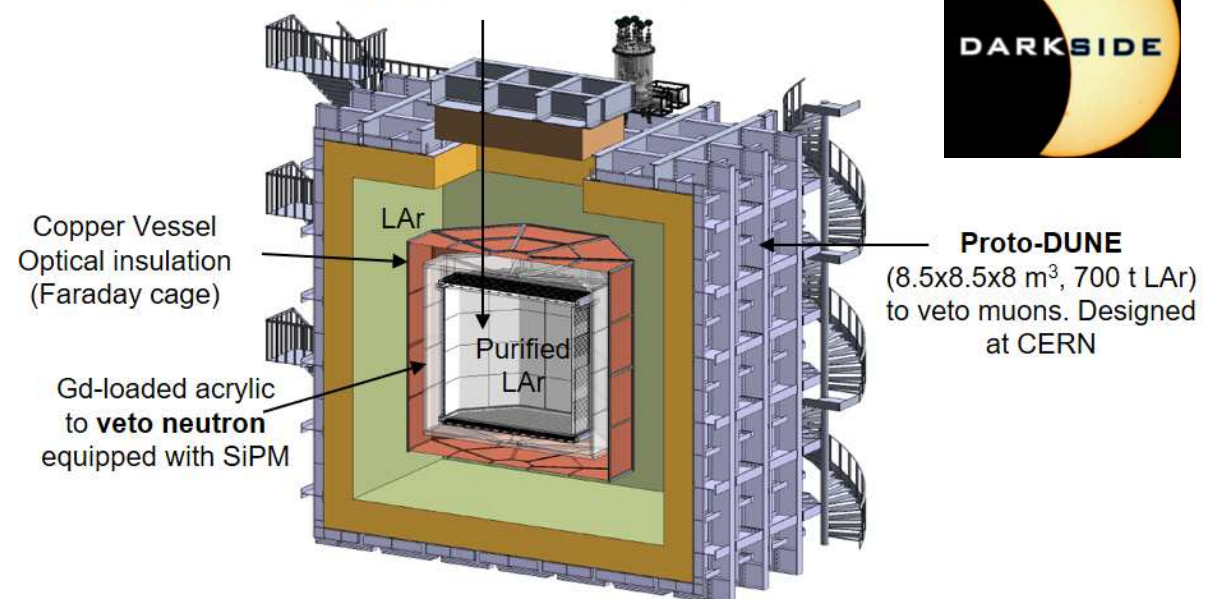
Team project leader: **Laurent Lellouch**

Lab/team: **LUMP/IFAC**

Team project leader: **Julien Laval**



Acrylic TPC (3.5x3.5x3.5 m³, 50t purified LAr)
read by 8300 PDMs (~200k SiPM)



Submitted 18-Dec 2020

New IPhU project:

Test of Lepton Flavor Universality using $B^0 \rightarrow D^{*-} \tau^+ \nu_\tau$

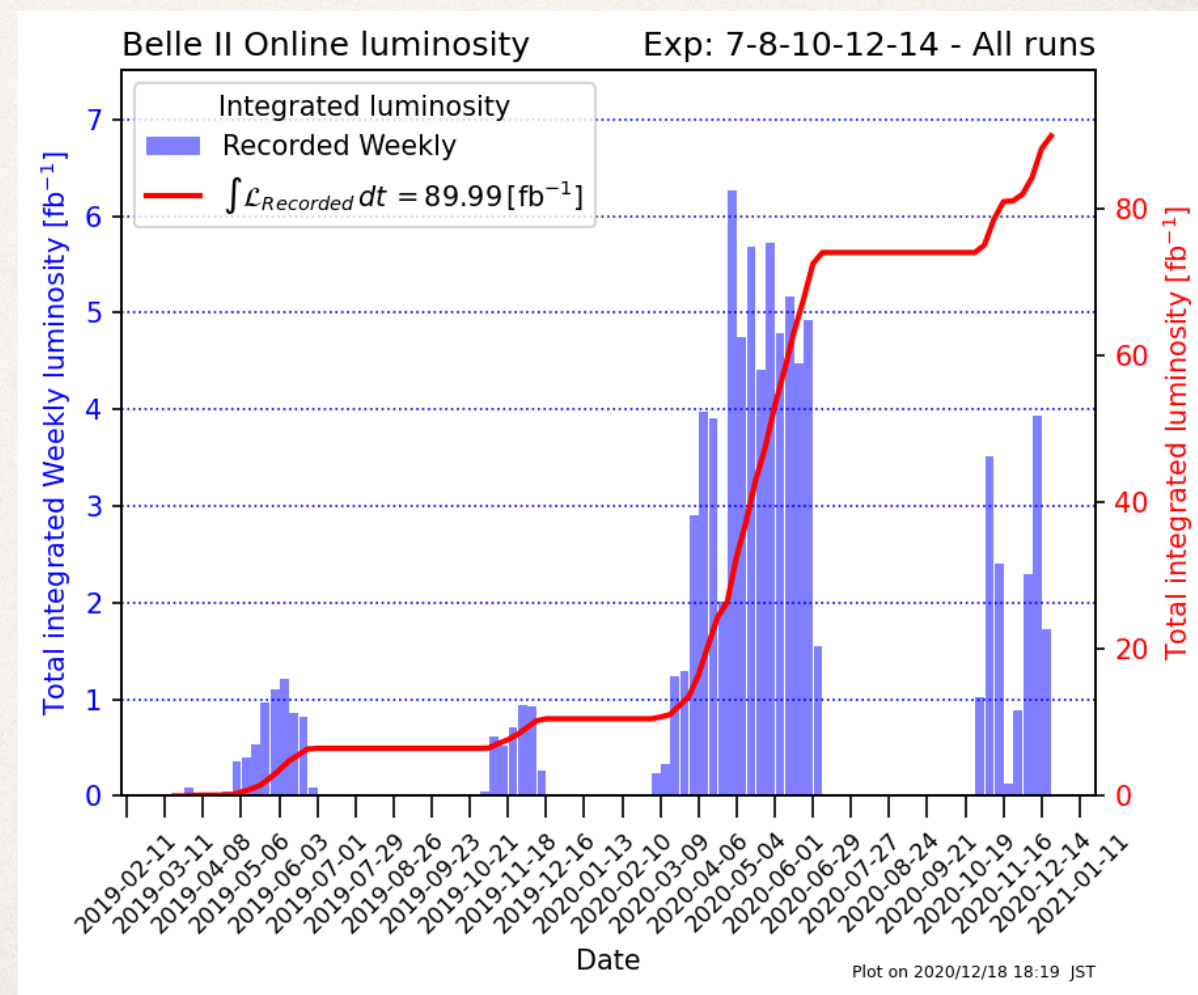
- $R(D^{(*)}) = \frac{\mathcal{B}(B^0 \rightarrow D^{(*)} \tau \nu_\tau)}{\mathcal{B}(B^0 \rightarrow D^{(*)} \ell \nu_\ell)}, \quad \ell = \mu, e$
- 8 measurements by three experiments using different analysis techniques: ALL $R(D^*)$, $R(D)$ and $R(J/\psi)$ measurements lie ABOVE the SM expectations.
- Combined tension with the SM is 3.8σ : one of the most intriguing anomalies in HEP nowadays!
- Published LHCb analysis used only 2011-2012 data so far!
- There is the chance to clarify the situation within IPhU in the next 3 years: need a PhD student to finalize the very complex LHCb analysis and extend the CPPM-CPT collaboration:
 - Full 2011–2018 LHCb dataset used for the first time
 - Improved analysis using a combined $R(D^*)$ and $R(D)$ fit
 - Precious CPPM-CPT collaboration to make sure SM theoretical predictions are under control, parametrize the SM and NP contributions and interpret the results in term of constraints on NP (A. Bharucha, J. Charles).
- This project is complementary and different to the already existing one lead by Anton Poluektov (Amplitude analysis and CPV in $B \rightarrow D^{**} \tau \nu$)

Belle II activities@CPPM

Justine Serrano
(Güney Polat, Laura
Zani, Robin
Leboucher)

Main activity regards physics analysis with searches for LFV tau decays, in particular $\tau \rightarrow l h h'$. Searches for $B \rightarrow \tau$ LFV decays to be started in 2021.

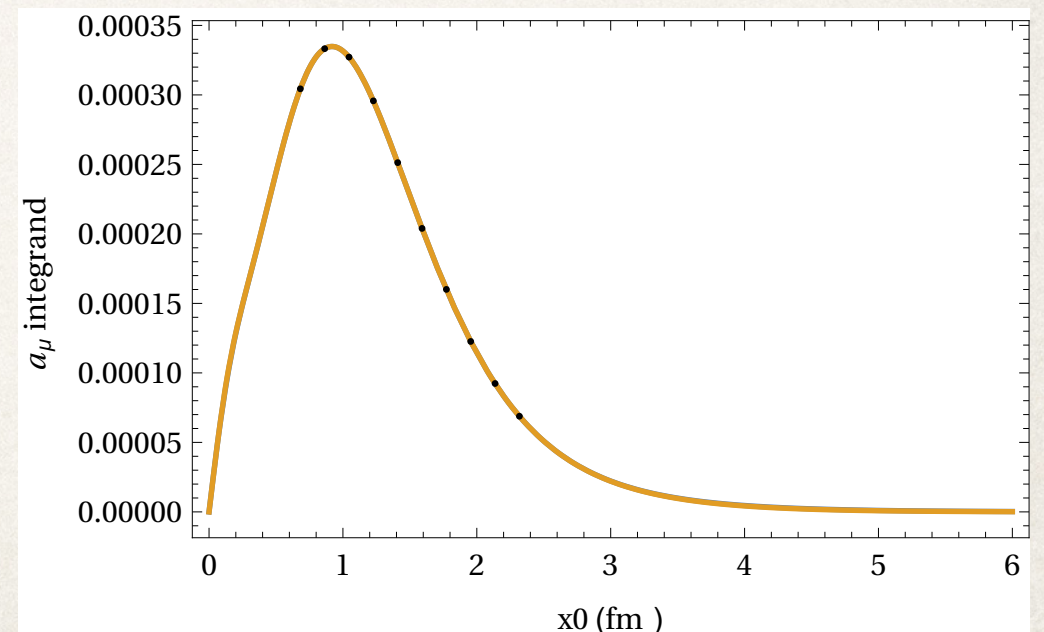
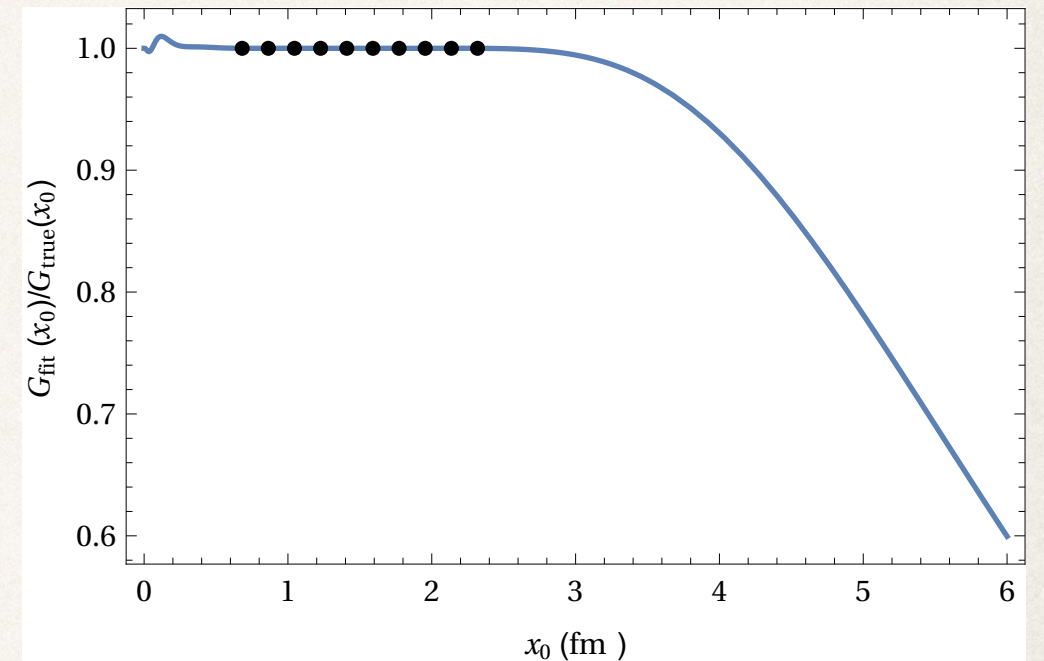
- ❖ Performance: Measurement of tracking efficiencies using $\tau^+\tau^-$ events (shown at ICHEP)
- ❖ Detector: Participation to the Silicon Vertex Detector offline software (study of the cluster position resolution). We are also joining the effort towards an upgrade of the vertex detector to be installed in 2026.
- ❖ Participation in data taking: various shifts (SVD, control room, data production), Calibration manager



$(g-2)_\mu$ phenomenology @CPT

Jérôme Charles, Eduardo Raphael and David Greynat

- ❖ Reconstruction of spectral functions and hadronic correlators, based on analyticity and asymptotic properties, from LQCD calculations extrapolated to the full physical range.
- ❖ Ratio of the reconstructed (blue) to the true (black) LQCD hadronic correlator that is relevant for $g-2$
- ❖ Same approach for the a_μ integrand itself



Particle Physics@IPhU: Timeline

- ❖ 2/3/2020: Initial Meeting of the IPhU Particle Physics working group
- ❖ 11/5/2020: 1st Topical Discussion Session - Axions and ALPs (including seminar by Fatih Ertas)
- ❖ 2/11/2020: Webinar - A physicist's view on pandemic dynamics, Giacomo Cacciapaglia
- ❖ 1/2/2021: 2nd Topical Discussion Session - Low mass resonances at the LHC (including seminars by Ennio Salvioni of CERN and Caterina Doglioni of ATLAS)

We're looking forward to a rich programme of collaborations and activities in 2021!