

# Quelques nouvelles récentes

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# Été comme hiver

# Les "confs"

- En physique des particules, conférences d'hiver (Moriond) et d'été (ICHEP, Lepton-Photon, EPS-HEP)



- ICHEP: conf. internationale, organisée sous l'égide de l'International Union of Pure and Applied Physics, tous les 2 ans, dans un endroit différent (Amérique, Asie, Europe)
- Cette année du 6 au 13 juillet, à Bologne (Italie)
- ~ 1500 personnes du monde entier, sur place (1200) et en ligne (300)
- Autant pour les présentations, calibrées, que pour les discussions, informelles, aux pauses (rumeurs...)

# D'autres occasions de rencontres

- réunions satellites de grandes conférences  
*avant et après les conférences*
- conférences thématiques et workshops spécialisés  
*par ex, en septembre à Orsay: Higgs Hunting*
- écoles (d'été, d'hiver et autres)  
*CERN summer school, Les Houches, Cargèse...*
- séminaires et visites dans d'autres laboratoires  
*en permanence !*



# Les trois premiers jours d'ICHEP2022

- Sessions parallèles (12 sessions, 15-20 min sur sujet spécifique)
  - Près de 900 interventions !
  - Une séance de (300 !) posters avec vin et fromage



Higgs Physics Neutrino Physics  
ge Beyond the Standard Model Top

quark and Electroweak Physics

Quark and Lepton Flavour

*Physics Strong interactions and*

Hadron Physics Heavy Ions

Astroparticle Physics and

Cosmology Dark Matter Formal

Theory Accelerator Physics

Present Detectors Detectors

future facilities Computing and

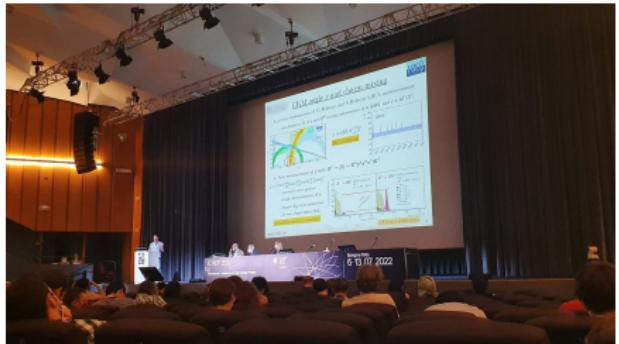
Data handling Education and

Outreach Equality, Diversity and

Inclusion Technology and

## *Industrial Applications*

# En images





## ICHEP 2022 Newsletter - Day 1 (07/07/2022) Highlights from Parallel Sessions



### Beyond the Standard Model

Day 1 of the Beyond-the-Standard Model (BSM) sessions covered both the state-of-the-art phenomenological ideas, new constraints on a variety of models, new results and projections from past and future experiments that will probe BSM physics (from future colliders). The first session had a lot of variety, from new BSM models that could address existing anomalies, to future collider prospects and dark sector searches. There was also an exciting update on the hunt for the X17 boson at MEGII. The X17 boson or "Atomic anomaly" has generated some excitement in the field, and we look forward to future results in this area. Dark photon explanations featured in several talks in the second session, including PADME and NAG4. This session had a great coverage of non-LHC experiments targeting dark sector models and milli-charged particles. New theoretical calculations for calculating "portal

effective field theories" were also presented. The first significant excess that showed up at the conference was... the "excess" of presentations related to leptoquarks in the first afternoon session: this indeed testify the renewed interest in the field after the recent hints of flavor violation. However, there was an interesting breadth of topics from TeV scale phenomenology to the possible impact on proton decay. SUSY theoretical developments and experimental searches from ATLAS and CMS have been presented showing no discrepancies and thus setting more stringent limits on parameters of the supersymmetric particles. In a nutshell: the first day of ICHEP demonstrated both the quality and breadth of work going on in the experimental and theoretical community related to BSM physics. There was lively discussion and we look forward to the rest of the conference.

### Higgs Physics

The Higgs Physics session is in the light of the 10 years' anniversary of the Higgs boson and the restart of the third data taking period of the LHC with stable beams at a record-breaking proton-proton center-of-mass energy of 13.6 TeV. Speakers from both the ATLAS and CMS collaborations showed new results with unprecedented precision. The inclusive and gluon-fusion-production cross sections in the bosonic final states are now measured to a precision of 10% or better, while the vector-boson-fusion production mode has now been observed with more than 5 standard deviations in several individual channels. Differential cross-section measurements, both using fiducial definitions and production-mode specific categories ("Simplified Template Cross Sections") have been newly performed in several channels by both collaborations, reaching unprecedented precision and comparing with various prediction, as well as performing interpretations in Effective Field Theories and other models. Both collaborations zoom in on the coupling of the Higgs boson to the charm quark, with an observed precision on the charge coupling modifier  $\kappa$  from direct VH,  $H \rightarrow c\bar{c}$  ( $V = W$  or  $Z$ ) and  $H \rightarrow b\bar{b}$  ( $V = W$  or  $Z$ ) channels. CMS reported a measurement of a transverse momentum of the Higgs boson from the same channel with VH,  $H \rightarrow b\bar{b}$  and with a measurement of the Higgs boson transverse momentum using the  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ^*$  ( $E_T = e + \mu$ ) channels obtaining  $-2.47 < \kappa < 2.53$  at 95% confidence level (ATLAS).

CP-odd contributions to Higgs-boson interactions with fermions in the Yukawa couplings can in principle happen at leading order. Both ATLAS and CMS presented impressive results probing the top-Higgs and Higgs-tau couplings. ATLAS presented a new VVH CP analysis using the VBF  $H \rightarrow \gamma\gamma$  channel.

ATLAS presented a brand new Higgs-boson mass measurement in the  $H \rightarrow ZZ^* \rightarrow 4E$  channel using the full LHC dataset obtaining 124.94 GeV with a total uncertainty of 180 MeV, of which only 30 MeV is from systematic sources.

Both ATLAS and CMS highlighted their brand new combined Higgs-boson analyses using the full LHC Run-2 dataset. The precision on the total signal strength (i.e. the observed rate over SM-LHC prediction) achieves now a total uncertainty of 6%, the Higgs-boson couplings modifiers are obtained with precisions between about 6% and 25%, and 95% confidence level upper limits on invisible decays of the Higgs boson as good as 13% are measured, where 8% were expected (ATLAS).

Experiments highlighted special techniques and methods to perform the sophisticated analyses. Amongst these are multivariate analyses that perform a many-dimensional interpolation between different matrix elements or parton showers for systematic control, embedding heavy-flavor jets or taus into  $Z \rightarrow ee$  events, special techniques for highly boosted jets originating from an  $H \rightarrow b\bar{b}$  or  $cc$  event, and other.

# Le dimanche

- Digérer les résultats, travailler...
- Des activités “sociales” (tourisme) proposées



# Les trois derniers jours d'ICHEP 2022

- 3 jours de sessions plénieress (exposés plus longs sur un domaine)
- Session "anniversaire" pour les 10 ans du boson de Higgs
- Remise de prix, tables rondes, banquet

ICHEP 2022 (6-July 13, 2022): Timetable - Agenda (Indico)

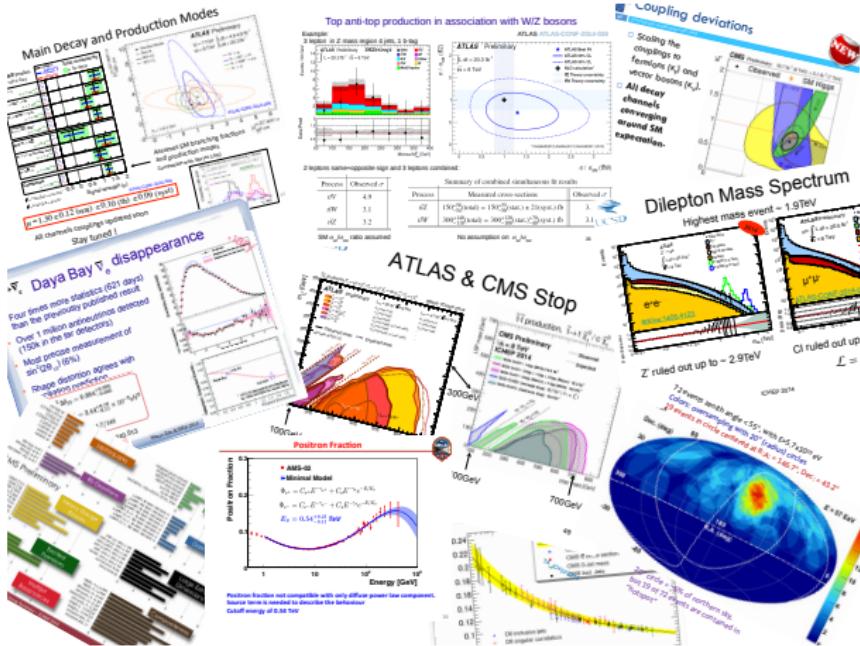
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Tue 12/07

[Go back](#) | [Print](#)

09:00	<b>Electroweak results and precision tests of the Standard Model</b> <i>Europa Auditorium</i>	Jan Kretzschmar 	09:00 - 09:30
	<b>Experimental results of BSM searches</b> <i>Europa Auditorium</i>	Robin Erbacher 	09:30 - 10:00
10:00	<b>New Physics: where do we stand?</b> <i>Europa Auditorium</i>	Veronica Sanz 	10:00 - 10:30
	<b>Coffee break</b> <i>Bologna, Italy</i>		10:30 - 11:00
11:00	<b>The road to the Higgs boson discovery</b> <i>Europa Auditorium</i>	Fabiola Gianotti	11:00 - 11:30
	<b>Higgs results: from the discovery to precision physics</b> <i>Europa Auditorium</i>	Chiara Mariotti 	11:30 - 11:50
12:00	<b>Future perspectives for Higgs physics</b> <i>Europa Auditorium</i>	Sven Heinemeyer 	11:50 - 12:10
	<b>Plenary Sessions: Round table with Lab Directors</b> Antonio Zoccoli, Beate Heinemann, Dmitri Denisov, Fabiola Gianotti, Nigel Smith, Sergei Nagaitsev, Sébastien Descotes-Genon, Yamauchi Masanori, Yifang Wang		
13:00	Moderators: Daniela Bortoletto and Karl Jakobs, Europa Auditorium <b>Lunch</b>		12:10 - 13:10

# De quoi se cultiver...



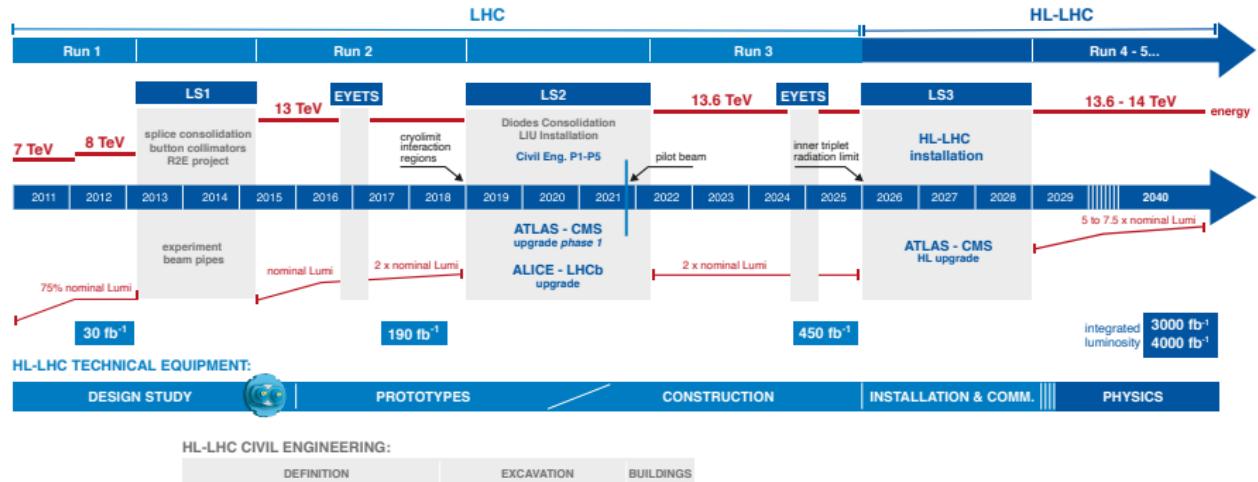
- Beaucoup de transparents
- Des articles paraissent juste après les talks
- Proceedings (comptes-rendus) à écrire dans la foulée

# Pousser les limites

# Le réveil du LHC



## LHC / HL-LHC Plan



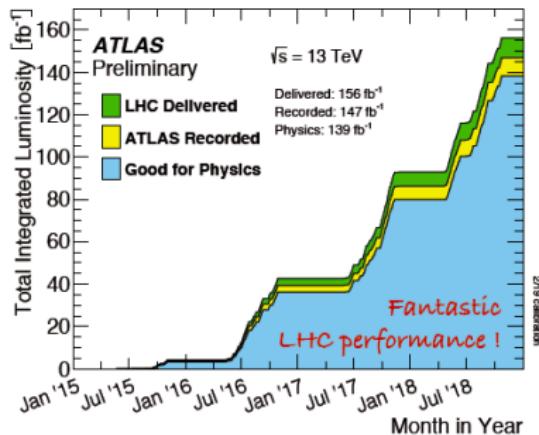
- Alternance de prise de données et d'arrêts (long shutdown)
- Fin du Long Shutdown 2 qui a suivi le run 2
- Upgrade détecteurs et machine, analyse des données du run 2...
- ... et impatience de prendre de nouvelles données

# De plus en plus de données

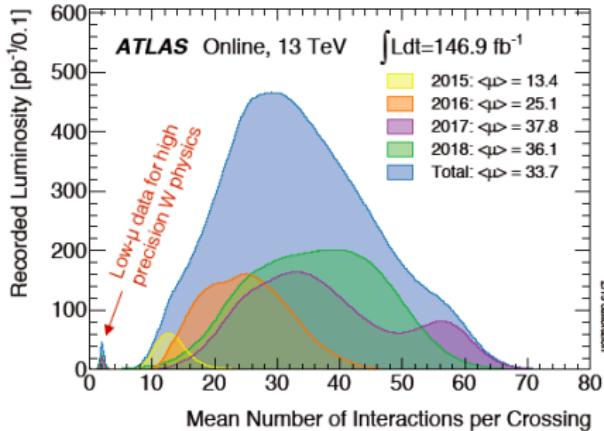
Données du run 2 : 2015-2018 à 13 TeV

## Integrated pp luminosity during Run-2

Also collected 2.3 nb<sup>-1</sup> of 5 TeV Pb-Pb data, and p-Pb & Xe-Xe data



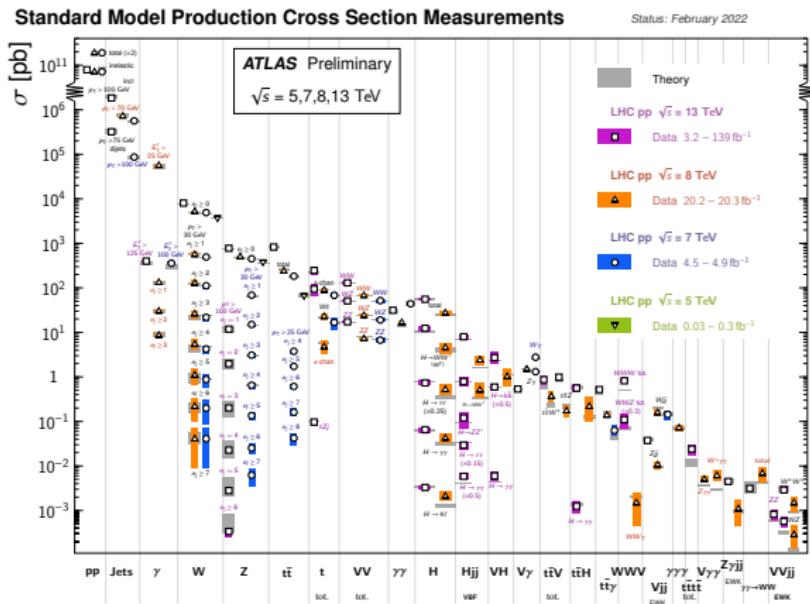
## High-luminosity comes with a challenge



- Tester en détail tout le Modèle Standard (MS)
- en particulier le boson de Higgs
- dans un environnement compliqué (beaucoup de collisions)

# Un excellent accord avec le MS

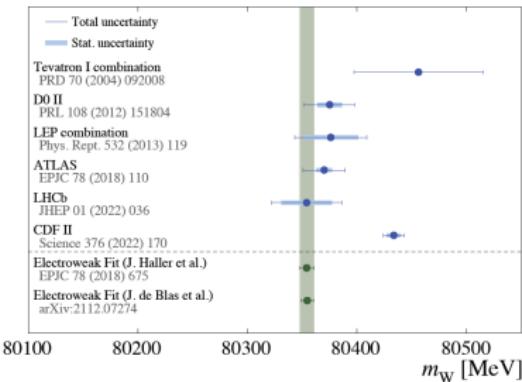
Production de différentes particules (W, Z, top, H) dans collisions pp en excellent accord avec les prédictions du MS (de + en + précises)



large benefit from recent theory developments and computations

# Et une grosse surprise de la part du Tevatron (1)

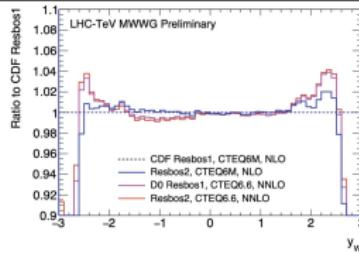
W mass: there is great confusion under heaven, the situation is excellent



CDF (8.8 fb<sup>-1</sup>) [Science 376 (2022) 170]

$$m_W = 80433.5 \pm 6.4 \text{ (stat.)} \pm 6.9 \text{ (sys.) MeV}$$

PDF are a key input, important to understand differences and harmonize PDF+generators before combining the measurements



<https://agenda.infn.it/event/28874/sessions/21485/#20220707>

- Mesure récente de la masse du  $W$  par CDF
- En désaccord avec toutes les autres mesures de la même mass

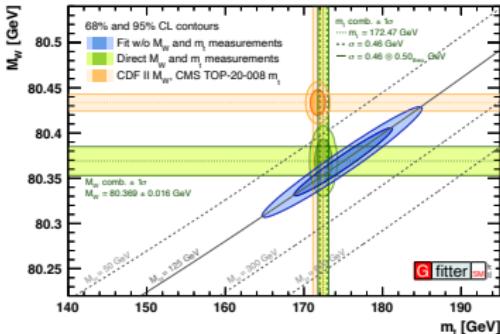
# Et une grosse surprise de la part du Tevatron (2)

## Summary

- SM very consistent using  $M_W$  from LEP+LHC
- Need to resolve tension with CDF II  $M_W$  experimentally
- Looking forward to  $m_t$  and  $M_W$  combinations from Collaborations

We cannot know  
 $M_W$  and  $\sin^2\theta_W^{\text{eff}}$   
precisely enough

(theoretically and experimentally)



G fitter

[www.cern.ch/gfitter](http://www.cern.ch/gfitter)



Roman Kogler

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The Global Electroweak Fit

- En désaccord avec le fit global du secteur électrofaible
- Que se passe-t-il ? (effets hadroniques  $p\bar{p}$  ? Nouvelle physique ?)

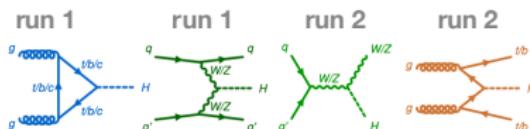
# Le Higgs apparaît et disparaît comme attendu

## Higgs boson coupling measurements

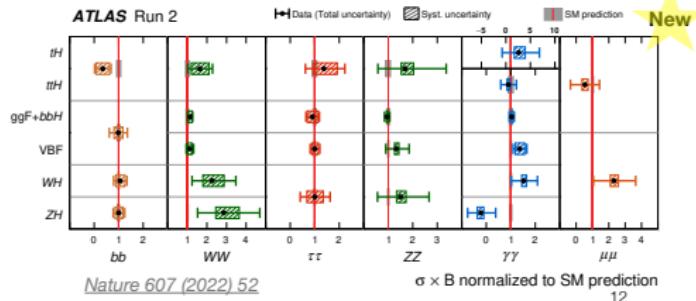
Total cross-section / Standard Model prediction

$$\mu = 1.05 \pm 0.06 = 1.05 \pm 0.03 \text{ (stat.)} \pm 0.03 \text{ (exp.)} \pm 0.04 \text{ (sig. th.)} \pm 0.02 \text{ (bkg. th.)}$$

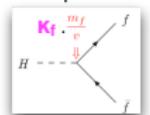
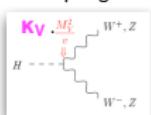
(benefits also from reduced theory uncertainty)



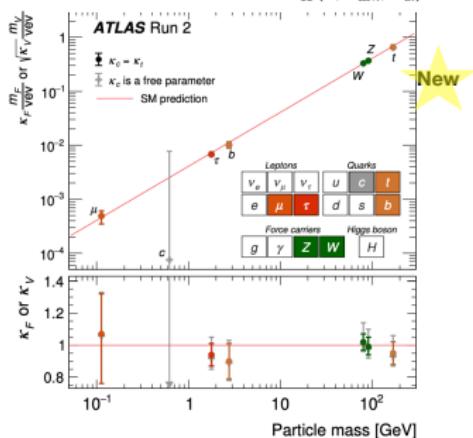
Measurements per production mode \* decay channel:



Coupling modifier interpretation



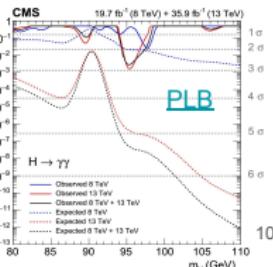
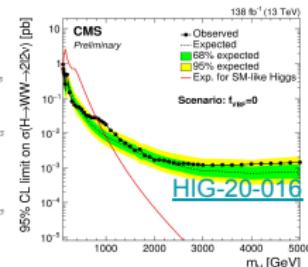
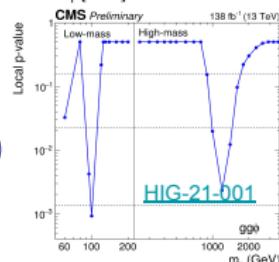
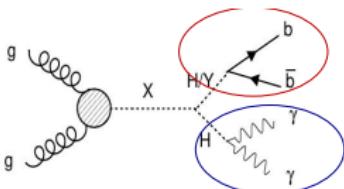
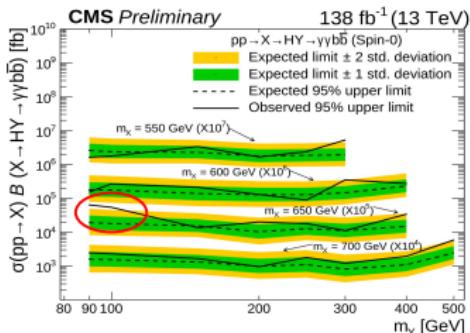
$$\sigma(i \rightarrow H \rightarrow f) = \sigma_i B_f = \frac{\sigma_i(\kappa) \Gamma_f(\kappa)}{\Gamma_H(\kappa, B_{\text{inv}}, B_u)}$$



Pour la suite: produire paires de Higgs pour tester potentiel scalaire

# Mais avec quelques excès inattendus ?

## New physics searches with Higgs



- Modèles avec des bosons de Higgs supplémentaires ?
- Nous verrons ce que les données du Run 3 vont nous apprendre

# Le début du Run 3

## First Stable Beams at 13.6 TeV – 5<sup>th</sup> July



Live from CERN: Join us for the first collisions for physics at 13.6 TeV!

41,634 watching now. Started streaming 65 minutes ago. In April 2022, CERN restarted the Large Hadron Collider (LHC) after more than three years of maintenance and upgrade. [Watch now](#)



Live from CERN: Join us for the first collisions for physics at 13.6 TeV!

38,577 watching now. Started streaming 57 minutes ago. In April 2022, CERN restarted the Large Hadron Collider (LHC) after more than three years of maintenance and upgrade. [Watch now](#)

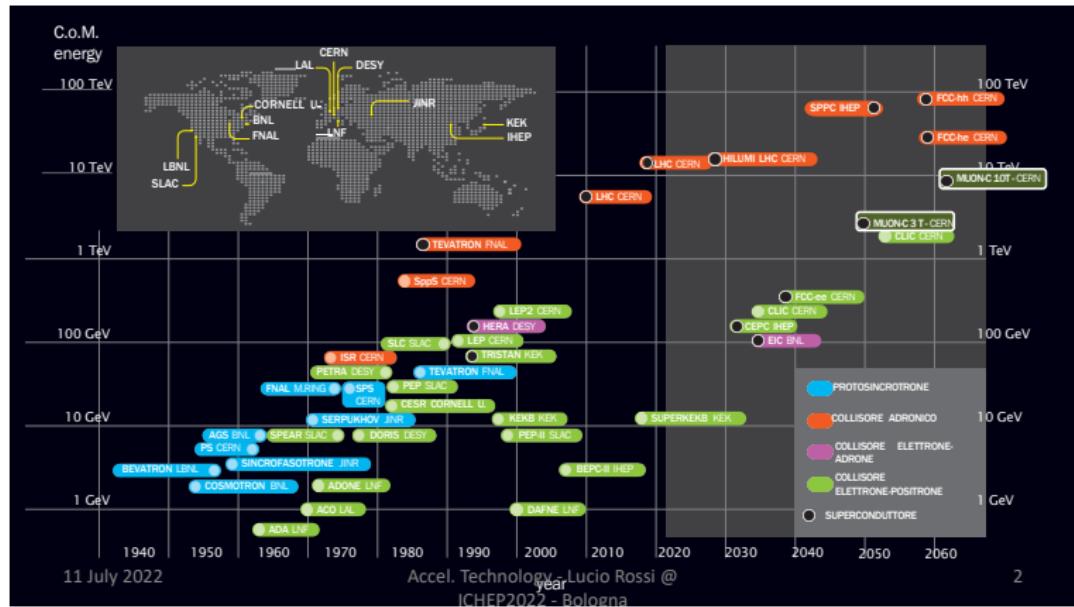


Live from CERN: Join us for the first collisions for physics at 13.6 TeV!

43,620 watching now. Started streaming 56 minutes ago. In April 2022, CERN restarted the Large Hadron Collider (LHC) after more than three years of maintenance and upgrade. [Watch now](#)



# Au-delà (1) ?



Stratégie européenne de la physique des particules mise à jour, avec HiLumi-LHC en 2025+

- $250 \text{ fb}^{-1}/\text{an}$ , entre 150 et 200 événements/croisement
- Upgrade significatif à faire pour la machine et les détecteurs

# Au-delà (2) ?



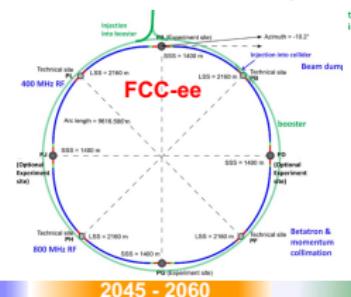
## The FCC integrated program inspired by successful LEP – LHC programs at CERN

comprehensive long-term program maximizing physics opportunities

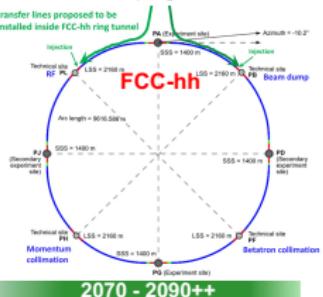
- stage 1: FCC-ee ( $Z$ ,  $W$ ,  $H$ ,  $t\bar{t}$ ) as Higgs factory, electroweak & top factory at highest luminosities
- stage 2: FCC-hh ( $\sim 100$  TeV) as natural continuation at energy frontier, with ion and eh options
- complementary physics
- common civil engineering and technical infrastructures, building on and reusing CERN's existing infrastructure
- FCC integrated project allows seamless continuation of HEP after completion of the HL-LHC program



2020 - 2040



2045 - 2060



2070 - 2090++

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Au-delà,  $e^+e^-$  pour étudier le Higgs et le secteur électrofaible:

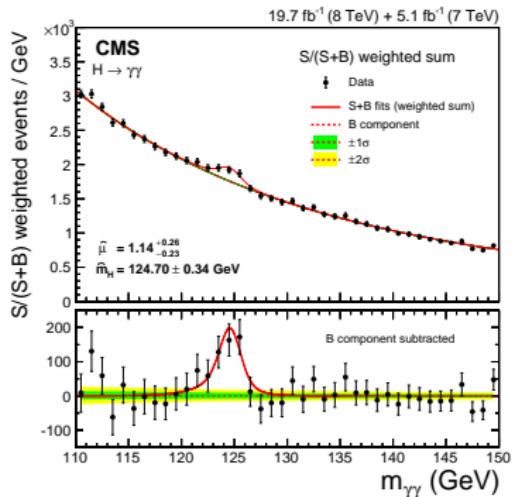
- Collisionneurs linéaires: ILC, CLIC...
- Collisionneurs circulaires: FCC, CEPC

ou une idée nouvelle (collisionneurs à muon, accélérateurs linéaires à récupération d'énergie, accélération laser-plasma...) ?

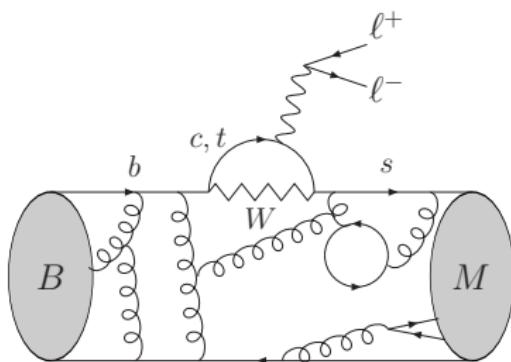
Tous les leptons naissent  
libres et égaux en droits ?  
Pas si sûr !

# Deux chemins complémentaires

Voie relativiste:  $E = mc^2$



Voie quantique:  $\Delta E \Delta t \geq \hbar/2$



Collisions avec assez dénergie  
pour produire directement des  
particules au-delà du MS

Haute énergie

Preuve "directe"

Petites déviations venant  
d'états intermédiaires  
avec des particules lourdes

Haute intensité

Preuve indirecte

# Les désintégrations rares $b \rightarrow s\ell\ell$

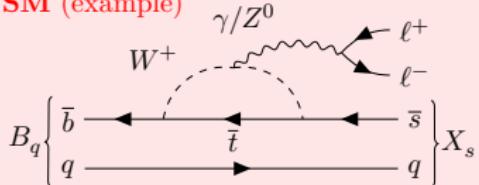


## Motivation

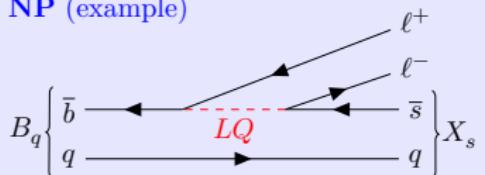


- ▶ Electroweak Penguins (**EWP**) mediate rare  $b \rightarrow s\ell^+\ell^-$  transitions
- ▶ Strongly **suppressed** in the Standard Model of Particle Physics (**SM**)
- ▶ New Physics (NP) may have **significant contribution** to SM amplitudes
- ▶ Intriguing **tensions** w.r.t. the SM, e.g.:
  - Angular analyses, e.g.  
 $B^0 \rightarrow K^{*0} \mu^+ \mu^-$  decays  
[PRL 125 011802 (2020)]
  - Branching fractions, e.g.  
 $B_s^0 \rightarrow \phi \mu^+ \mu^-$  decays  
[PRL 127 151801 (2021)]
- ▶ **EWP decays at LHCb** by Sara Celani

### SM (example)



### NP (example)



FSP LHCb  
Erforschung von  
Universum und Materie

Sebastian Schmitt

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# Les désintégrations rares $b \rightarrow s\ell\ell$



## Flavour Universality Ratios

ICHEP 2022  
BOLOGNA

- SM is Lepton Flavour Universal (**LFU**)
- Test LFU in  $b \rightarrow s\ell^+\ell^-$  transitions using:

$$R_X = \frac{\int_{q_{\min}^2}^{q_{\max}^2} \frac{d\mathcal{B}(B_q \rightarrow X_s \mu^+ \mu^-)}{dq^2} dq^2}{\int_{q_{\min}^2}^{q_{\max}^2} \frac{d\mathcal{B}(B_q \rightarrow X_s e^+ e^-)}{dq^2} dq^2} = 1 \pm \mathcal{O}(1\%)^1$$

- With  $q^2 = m(\ell^+\ell^-)^2$
- Hadronic **uncertainties** cancel in ratio
- ⇒  $R_X$  can be precisely predicted in the SM
- Here  $X_s$ :  $K^+$ ,  $K_S^0$ ,  $K^{*+}$ ,  $pK$ ,  $K^{*0}$

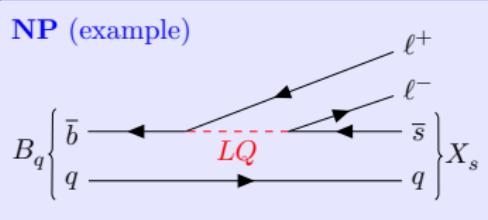
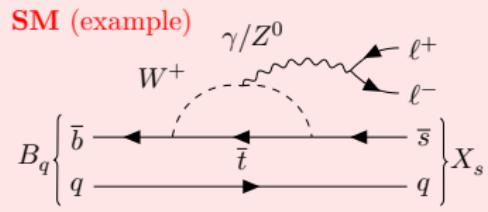
<sup>1</sup>[Eur. Phys. J. C 76, 440 (2016)]



FSP LHCb  
Erforschung von  
Universum und Materie

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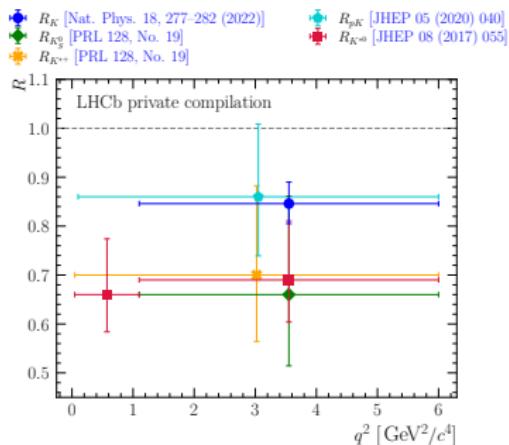
# La violation de l'universalité leptונית



## Summary of Results



- ▶ Brief rundown of the **LFU tests** in  $b \rightarrow s\ell^+\ell^-$ -transitions at LHCb
- ▶ Highlighted **key differences** of electrons at muons at LHCb
- ▶ Discussed analysis **strategy** and **validation**
- ▶ Intriguing tensions with the SM observed
- ▶ Measurements of  $R_{K^{*0}}$ ,  $R_K$ ,  $R_{pK}$ ,  $R_\phi$ ,  $R_{K\pi\pi}$ , and more with full  $9 \text{ fb}^{-1}$  dataset ongoing



Sebastian Schmitt

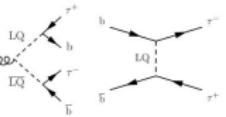
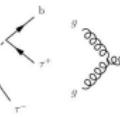
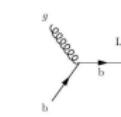
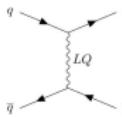
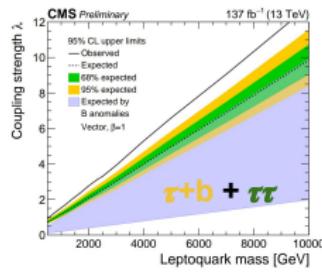
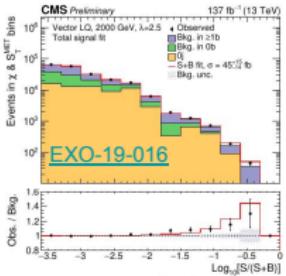
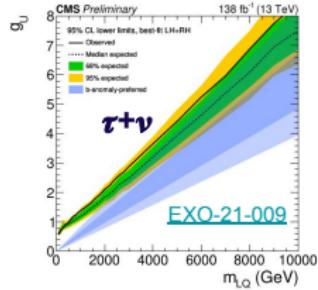
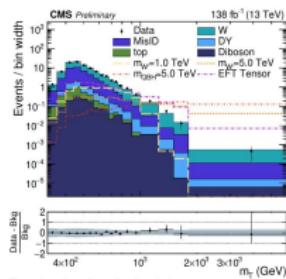
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- Des déviations observées dans  $b \rightarrow s\mu\mu$ , en attente de nouvelles données
- Idem pour  $b \rightarrow c\tau\nu\dots$  pas d'update pour ICHEP !

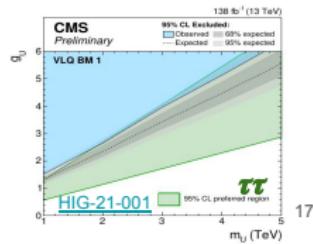
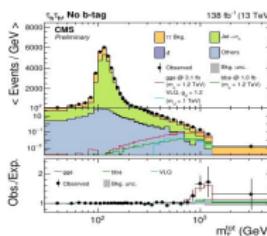
# Quelques excès inattendus...

## Searches related to b-anomalies with $\tau$

New@ICHEP



- Final states with  $\tau+\nu$ ,  $\tau+b$  and  $\tau\tau$  are investigated
- Good probe of models related to b-anomalies (e.g. leptoquark)
- Sensitivity approaching the "preferred" region from b-anomalies in some LQ models
- Some sizeable excess in non-resonant  $\tau\tau$  final state (seen by two different analyses)



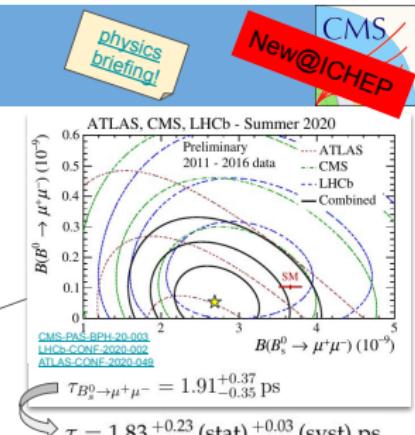
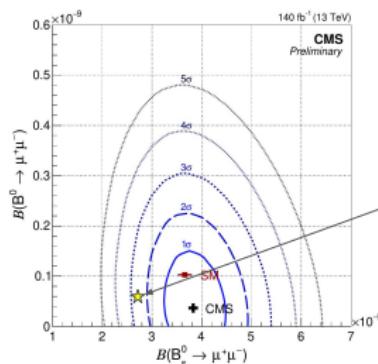
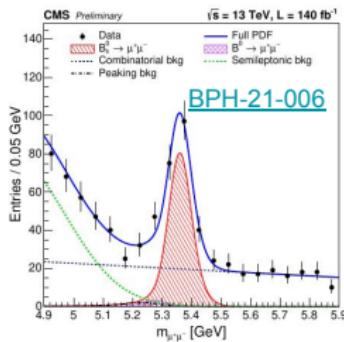
17

- Recherche de leptoquarks, se désintégrant en quark et en leptons
- Pouvant expliquer les déviations actuellement observées pour

# ... ou pas ?

- même si d'un autre côté, CMS a mis à jour  $B_s \rightarrow \mu\mu$
- avec une valeur très proche du Modèle Standard

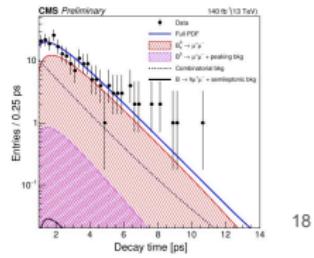
## Full Run 2 result on $B_s \rightarrow \mu\mu$



$$\mathcal{B}(B_s^0 \rightarrow \mu^+ \mu^-) = [3.95^{+0.39}_{-0.37} (\text{stat})^{+0.29}_{-0.24} (\text{syst})] \times 10^{-9}$$

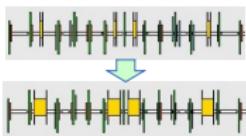
- Updated results with **full Run-2 luminosity**
- Most precise single experiment measurement to date
  - Highly compatible with SM prediction**
- Most precise measurement of lifetime

..if you missed the parallel  
Dedicated CERN  
 Seminar on July 26th

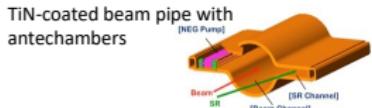


# A l'est, du nouveau

Replace short dipoles  
with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance



## KEKB → SuperKEKB



New superconducting /permanent final focusing quads near the IP



Low emittance positrons to inject

Damping ring

Low emittance gun

Low emittance electrons to inject

Positron source

New positron target / capture section



Add / modify RF systems  
for higher beam current



Jul 16, 2019

F.Forti, Belle II & Flavor

23



- Collisionneur  $e^+$  (4 GeV)  $e^-$  (7 GeV) situé à Tsukuba (Japon)
- Etude intensive des désintégrations du quark  $b$
- 25 pays, 110 institutions, 800 chercheurs

# Belle II entre en action

## Belle II @ SuperKEKB

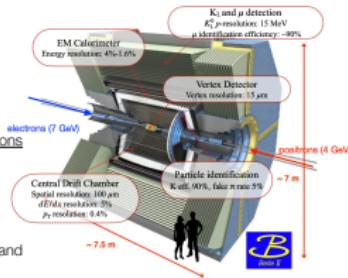
Energy-asymmetric  $e^+e^-$  collisions at 10.58 GeV corresponding to the  $\Upsilon(4S)$ -resonance mass

- $B\bar{B}$  at threshold production: low background
- Collide point-like particles and nearly  $4\pi$  coverage: reconstruct final states with neutrinos or inclusively
- Flavor universal: similar performance for electrons and muons

Belle II in 2019-2022:

- world-record luminosity by SuperKEKB:  $4.7 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- collected  $424 \text{ fb}^{-1}$  of data
- now starting one year stop for vertex detector completion and improved beam pipe

Today's results from  $63 \text{ fb}^{-1}$  and  $190 \text{ fb}^{-1}$



## Summary

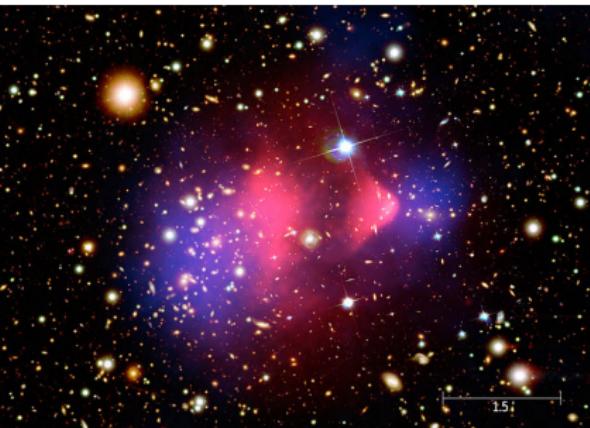
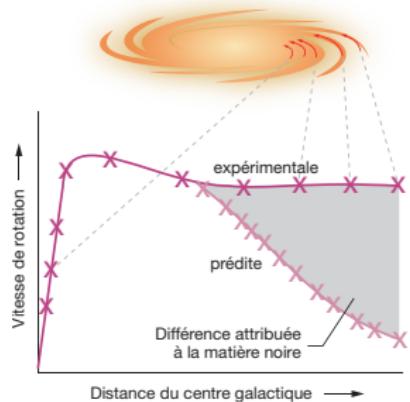
- $b \rightarrow s$  transitions offer powerful probe of the SM and physics beyond
- $b \rightarrow s$  studies are essential portion of the Belle II physics program
  - ▷ unique access to radiative and missing energy modes
- Measurements with  $63 \text{ fb}^{-1}$  and  $190 \text{ fb}^{-1}$  presented:
  - ▷  $B \rightarrow K^* l \bar{l}$  branching fraction;
  - NEW! ▷ Branching fraction, isospin asymmetry, and  $R_K(J/\psi)$  of  $B \rightarrow J/\psi K$  decays;
  - ▷  $B \rightarrow K \nu \bar{\nu}$  branching fraction;
  - ▷  $B \rightarrow K^* \gamma$  branching fraction;
  - NEW! ▷ Partial branching fractions of  $B \rightarrow X_s \gamma$  decay with hadronic tag approach.

Belle II is on track to carry out independent and/or unique searches of NP indications in EW and Rad penguins

- Première série de données accumulées
- Statistique du même ordre de grandeur que Belle
- Arrêt pour augmenter la luminosité
- Déjà des premiers résultats de physique

# Lumière sur la matière noire

# Matière noire et nouvelle physique



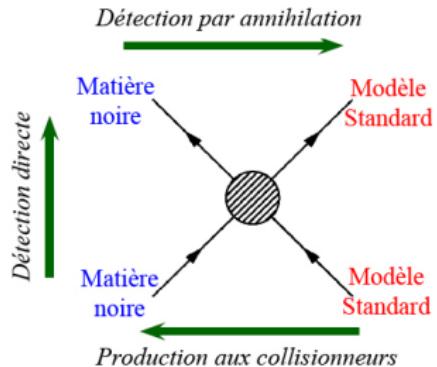
En se basant sur les lois de la gravitation, pas assez de matière visible

- Pour expliquer la dynamique des grandes structures (galaxies...)
- Pour décrire l'évolution de l'Univers  
(ray. de fond cosmologique, nucléosynthèse primordiale)

## Matière "noire"

- lourde, stable, neutre, interagissant peu avec son environnement, hormis par interaction gravitationnelle
- particule nouvelle  $\chi$ , hors du Modèle Standard ?

# Observer la matière noire

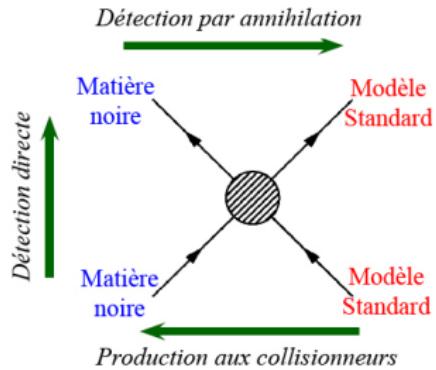


Une coopération entre infiniment petit et infiniment grand

- La produire en accélérateur (si assez “légère”)

Des signaux par le passé, mais tous ont trouvé une explication ou n'ont pas été confirmés

# Observer la matière noire

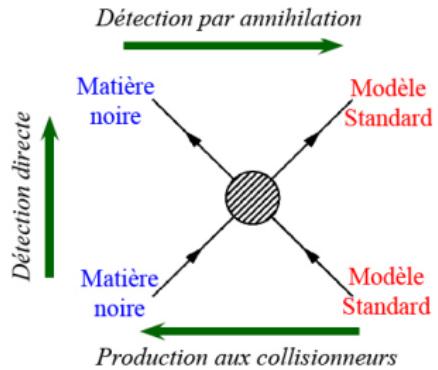


Une coopération entre infiniment petit et infiniment grand

- La produire en accélérateur (si assez “légère”)
- La détecter lors de son passage sur Terre  
⇒ interaction avec noyau, qui recule

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# Observer la matière noire



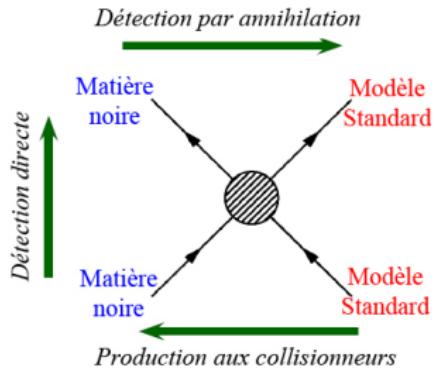
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- Voir son annihilation en observant le ciel
  - ⇒ rayons gamma monochromatiques ( $E_\gamma = M_\chi c^2$ )
  - ⇒ excès de rayons cosmiques de haute énergie

Des signaux par le passé, mais tous ont trouvé une explication ou n'ont pas été confirmés

# Observer la matière noire



Une coopération entre infiniment petit et infiniment grand

- La produire en accélérateur (si assez "légère")
- La détecter lors de son passage sur Terre  
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- Voir son annihilation en observant le ciel
  - ⇒ rayons gamma monochromatiques ( $E_\gamma = M_\chi c^2$ )
  - ⇒ excès de rayons cosmiques de haute énergie
- Détecter sa présence par observations astronomiques
  - ⇒ déformation d'images par lentilles gravitationnelles
  - ⇒ informations cosmologiques (CMB)

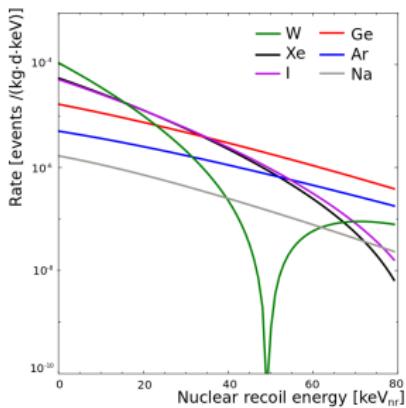
Des signaux par le passé, mais tous ont trouvé une explication ou n'ont pas été confirmés

# Détection directe: quels détecteurs ?

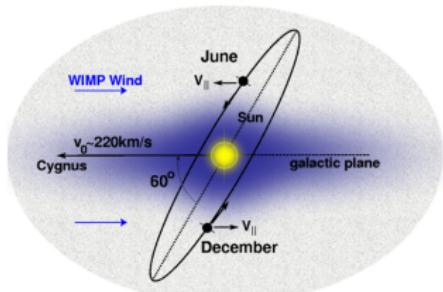
## Detector requirements and signatures

- Large detector mass (grams up to several tonnes)
- Low energy threshold ~ few keV's or sub-keV
- Very low background and/or background discrimination (from  $\gamma$ 's,  $e^-$ 's, neutrons and  $\nu$ 's!)

J. Phys. G: 43 (2016) 1 & arXiv:1509.08767

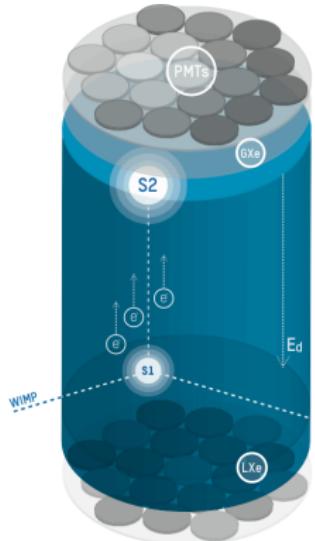


- Other signatures of dark matter
  - Annual modulated rate
  - Directional dependence



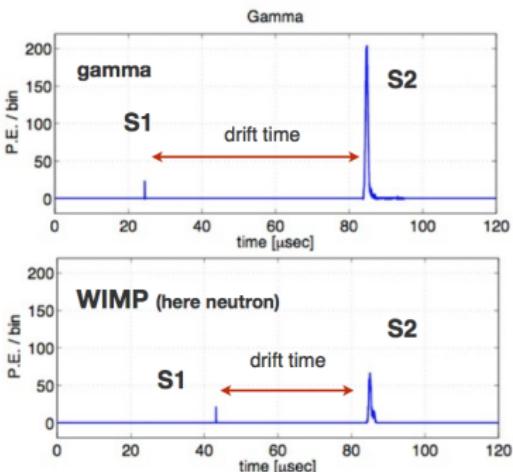
# Détection directe: les détecteurs à gaz noble

## Two phase noble gas TPC



- Position resolution
  - XY from PMT pattern
  - Z from drift time

- Scintillation signal (**S1**)
- Charges drift to the liquid-gas surface
- Proportional signal (**S2**)  
→ Electron- /nuclear recoil discrimination



# Détection directe: les détecteurs actuels

*Current generation: LZ, PandaX-4T and XENONnT*



## LZ:

- **7 T** target mass
- First data released last Thursday!

## PANDAX-4T:

- **4 T** target mass
- First data released in July 2021

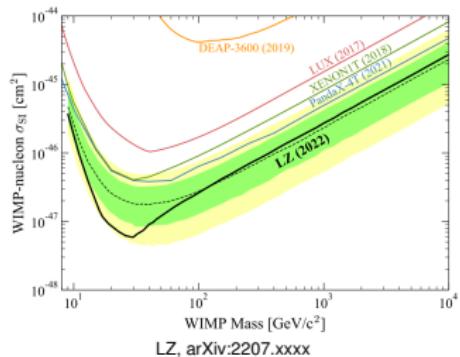
## XENONnT:

- **6 T** target mass
- First data about to be released!

→ A race to measure WIMPs down to  $\sigma \sim 10^{-48} \text{ cm}^2$

# Détection directe : une nouvelle limite !

## LZ results from last Thursday & XLZD

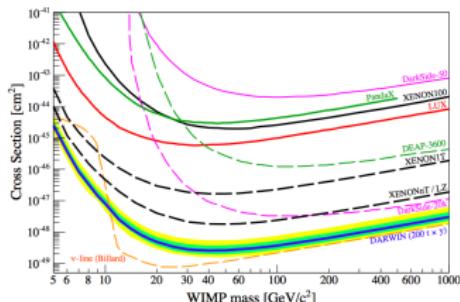


LZ, arXiv:2207.xxxx

- SR1: 5.5 t and 60 days
- Currently best exclusion limit

- XLZD: XENON, LZ and DARWIN together

Common paper with physics case: arXiv:2203.02309



DARWIN, JCAP 1611 (2016) no.11, 017, arXiv:1606.07001



DARWIN, XENON + LUX ZEPLIN meeting in Karlsruhe, July 2022

# Trois neutrinos sur une balançoire

# Neutrinos : où les trouver ?



Neutrinos:  
The Future

Mary Bishai  
Brookhaven  
National  
Laboratory

Overview

$\nu$  Properties

Absolute mass

Majorana or Dirac?

Neutrino interaction  
crosssections

$\nu_{SM}$

Mixing, Oscillations  
and PMNS

$\nu_{\tau}$

$\nu$  in  
Astrophysics  
& Cosmology

Solar Neutrinos

SN  $\nu$

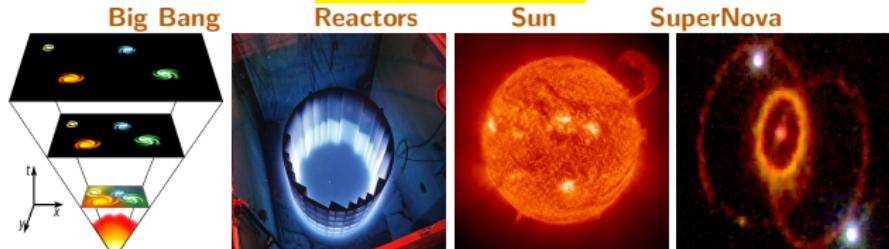
UHE  $\nu$  probes

$\nu$  Applications

Summary

## The Neutrino Experimental Landscape

### Sources of Neutrinos



3 / 63

# Neutrinos : quelles expériences ?



Neutrinos:  
The Future

Mary Bishai  
Brookhaven  
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Laboratory

Overview

$\nu$  Properties

Absolute mass

Majorana or Dirac?

Neutrino interaction  
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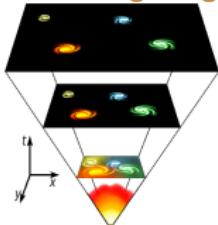
$\nu$  Applications

Summary

## The Neutrino Experimental Landscape

### Examples of Neutrino Experiments ( current, future)

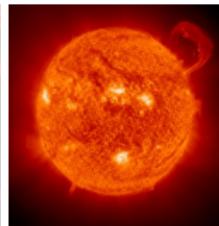
#### Big Bang



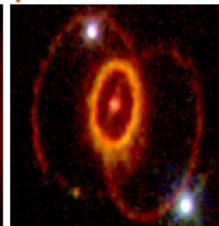
#### Reactors



#### Sun

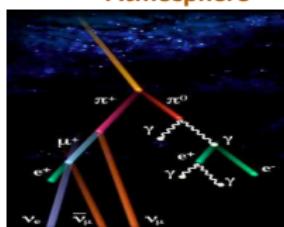


#### SuperNova



#### PTOLEMY

#### Atmosphere



#### Daya Bay JUNO

#### BOREXINO SNO+ / JUNO

#### SuperK-GD DUNE / HK / JUNO

#### Accelerators



#### Extragalactic



#### SuperK / IC-DeepCore

#### HyperK / KM3NeT / ORCA

#### T2K / NoVA

#### T2HK / DUNE / ESS $\nu$ SB

#### IceCUBE

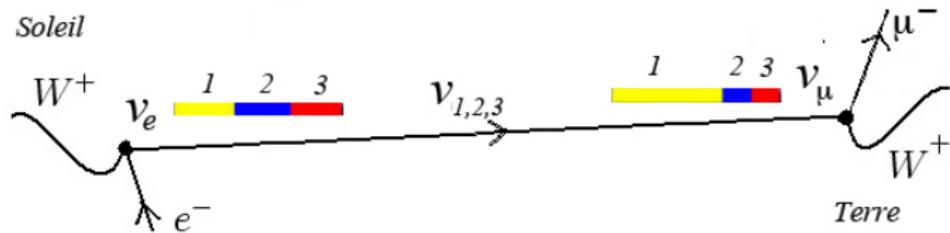
#### IceCUBE-Gen2<sub>4/63</sub>

# Les oscillations de neutrinos

Différence entre états propres de masse  $\nu_{1,2,3}$  et d'interactions  $\nu_{e,\mu,\tau}$

$$\begin{bmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{bmatrix} = \begin{bmatrix} 1 & c_{23} & s_{23} \\ -c_{23} & -s_{23} & c_{23} \end{bmatrix} \begin{bmatrix} c_{13} & e^{-i\delta} s_{13} \\ -e^{i\delta} s_{13} & c_{13} \end{bmatrix} \begin{bmatrix} c_{12} & s_{12} \\ -s_{12} & c_{12} \end{bmatrix} \begin{bmatrix} 1 & e^{i\lambda_2} \\ e^{i\lambda_3} & 1 \end{bmatrix} \begin{bmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{bmatrix}$$

- 3 rotations:  $c_{ij} = \cos \theta_{ij}$ ,  $s_{ij} = \sin \theta_{ij}$
- Asymétrie  $\nu \bar{\nu}$ : phase  $\delta$  (Dirac),  $\lambda_{2,3}$  (Majorana)
- 6 paramètres + 2 différences de masse + 1 échelle absolue
- $\nu_e$  combinaison de 3 états  $\nu_1, \nu_2, \nu_3$ , de masses différentes, se propageant à des vitesses légèrement différentes
- la composition de l'état change sur de longues distances !  
 $|\nu_e\rangle \rightarrow c_e(L)|\nu_e\rangle + c_\mu(L)|\nu_\mu\rangle + c_\tau(L)|\nu_\tau\rangle$  **oscillation de neutrinos**

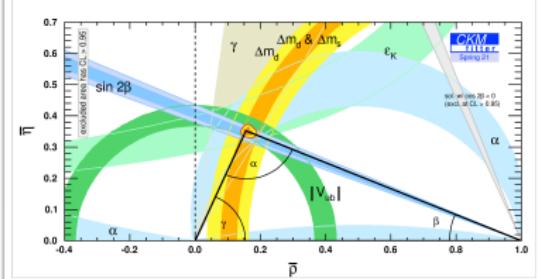


# Neutrinos : bien moins connus que les quarks

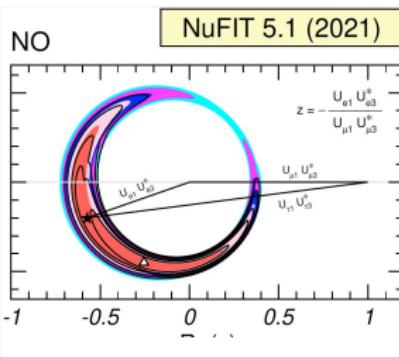
Paramètres de mélange, mais aussi les masses, leur nature (Majorana ou Dirac) . . . pas très bien connus !

## Precision Flavour Physics

### Quarks



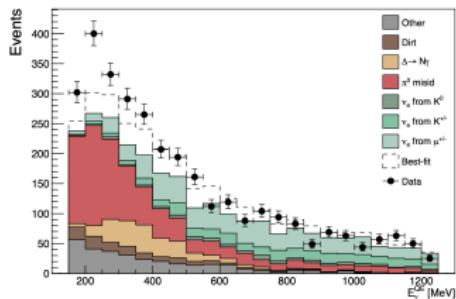
### Leptons



# Neutrinos : MiniBooNE

- MiniBooNe (Fermilab): Détecteur Cerenkov rempli de 800 tonnes d'huile minérale + 1280 photomultiplicateurs
- Excès de  $\nu_e$  apparaissant à partir d'un faisceau de  $\nu_\mu$

## MiniBooNE

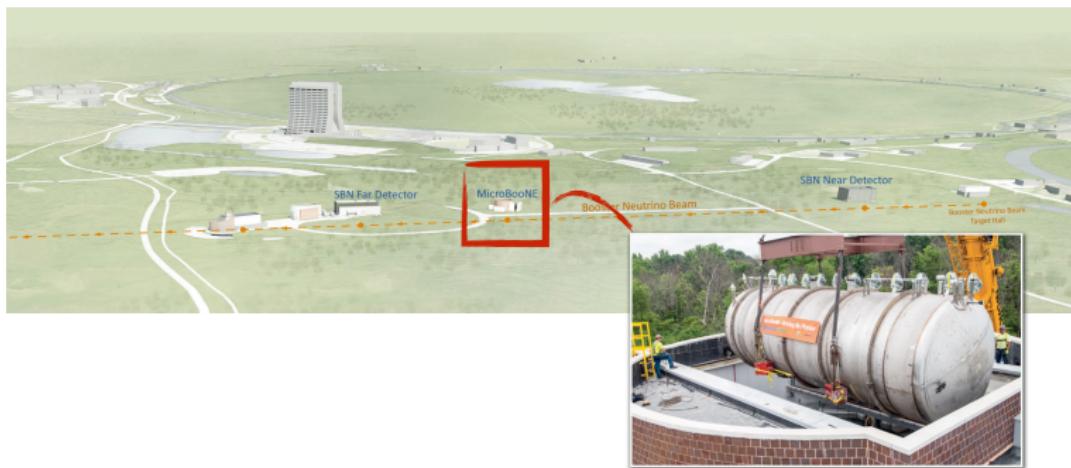


- Unexplained excess of few 100 MeV  $\nu_e$  in  $\nu_\mu$  beam ( $4.8\sigma$ )
- source-detector distance too small for std. oscillations
- But consistent with other anomalies in the  $\nu_e \rightarrow \nu_\mu$  and  $\nu_e \rightarrow \nu_e$  channels

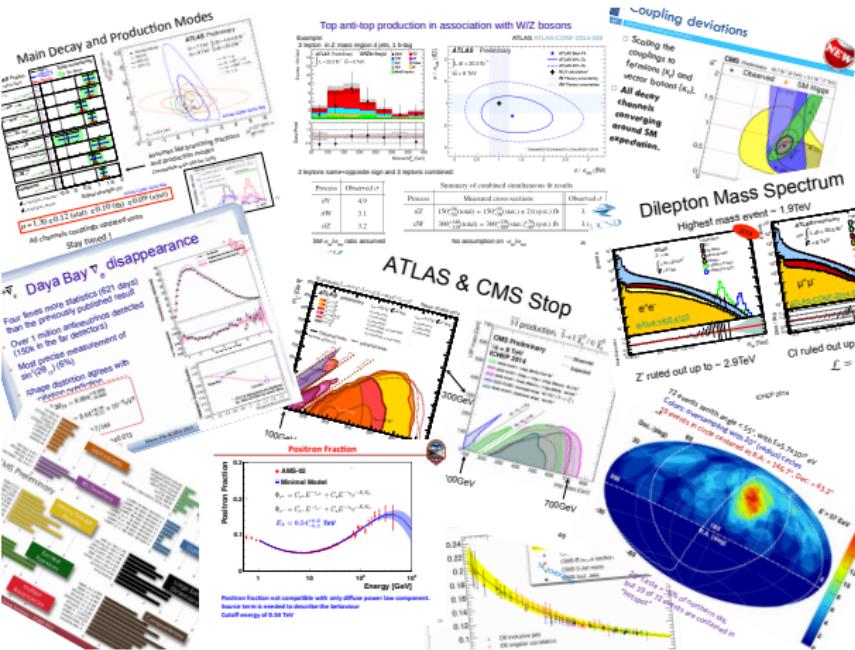
# Neutrinos : MicroBooNE

- Nouvelle expérience Microboone pour tester bruit de fond et flux de  $\nu_e$  : pas d'explication MS de l'excès vu par MiniBooNe
- Neutrinos supplémentaires (“stériles”) : difficile de se mettre d'accord avec les autres données expérimentales

## MicroBooNE



# Et bien plus encore...





ICHEP 2022  
BOLOGNA



ICHEP 2022  
**XLI**

International Conference  
on High Energy Physics  
Bologna (Italy)

6–13 07 2022

À dans un an  
pour Lepton-Photon 2023  
à Melbourne (Australie),  
ou  
pour EPS-HEP 2023,  
à Hambourg (Allemagne)

ou dans deux ans,  
pour ICHEP 2024  
à Prague (Tchéquie) !