Moriond Electroweak 2025

Experimental Summary

Johannes Albrecht (TU Dortmund)

30th of March 2025

Search for physics beyond the SM

Indirect searches for New Physics

- High **energy**:
  "real" new particles can be produced and discovered via their decays
  - Discovery of the Higgs boson at the LHC → completion of the SM
  - **Tested scale : <10TeV**

- High **precision**:
  "virtual" new particles can be seen in quantum loops
  - Higher mass scale reachable (up to **~100TeV**)

**Direct and indirect searches are both needed,
both equally important,
and complement each other**

Search for physics beyond the SM

**Direct and indirect searches are both needed,
both equally important,
and complement each other**

Experimental landscape at MEW25

- LHC
  - Clean and well calibrated dataset of 150/fb, still numerous results from Run-2…
  - Run 3 with a beautiful 2024 is ramping up, results starting to come
  - LHCb's full software trigger opens new roads
- Electron machines also prospering
  - Super KEK-B and Belle II world's highest instantaneous luminosity
  - BESIII shows incredible productivity
- Neutrino experiments
  - Interesting data from long- and short baseline experiments
  - Next generation experiments (Hyper K, Dune, JUNO, Legend, CUPID, nEXO, etc…)
- Dark Matter / Axions
  - New generation Xenon DM searches delivering new results (Xenon nT, Lux Zeppelin, PandaX)
  - Next generation DM experiments in preparation
  - Very strong Axion program evolving (IAXO, MadMax, Haystack and many more)

Moriond Electroweak 2025

MONDAY24/03	TUESDAY25/03	WEDNESDAY26/03	THURSDAY27/03	FRIDAY28/03	SATURDAY29/03
C. Marin Benito	S. Stefkova	N. Ackerman	D. Litim	M. Schmaltz	A. Nigamova
S. Wang	J. Kamenik	A. Menegolli	S. Addepalli	A. Droster	M. Valli
S. Trifinopoulos	R. Manfredi	S. Urrea-González	M. Nardecchia	D. Kaplan	H. Yin
L. Ecklund	M.L. Piscopo	G. Milton	C. Pena	D. Leppla Weber	A. Trautner
S. Robertson	G. Ruggiero	F. Jörg	J. Zupan	V. Domcke	C. Vico
coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break
M. Reboud	G. Karathanasis	C. Englert	P. Ecker	C. Yèche	R. Wang
T. Martinov	J. Kleykamp	C. Pollard	A. Ibarra	M. Drewes	M. Stange
X. Pan	D. Henaff	A. Teixeira	S. Eriksen	A. Chou	G. Boldrini
A, Juettner	T. Tashiro	C. Wang	G. Perez	M. Mühlleitner	D. Camarero
Lunch	Lunch	Lunch	Lunch	Lunch	Lunch
P. Gironella	C. Hill	I. Neutelings	D. Redigolo	R. Hayes	E. Manca
R. Puthumanaillam	I. Esteban	K. Kowalska	C. De Dominicis	R. Chatterjee	T. Robens
M. Escudero	T. Lasserre	M. Montella	A. Ray	V. Miralles	F. Fabbri
A. Scarabotto	P. Decowski	J, Lizana	L. Di Luzio	T. Lenz	D. Pinna
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YSF I M. Hartmann, G. Gaudino, A. Bansal, C. Lemettais, D. Suelmann. L. Paolucci	YSF II H. Birch, E. Lavaut, J.P. Pinheiro, N. Bhuiyan, M.I. Dias Astros, C. Girard-Carilho, R. Faure, A. Langella	YSF III A. Ruggiero, S. Lomte, M. Kuschick, T. Aoki, F. Esser	G. Yu	Moriond discussion	E. Watton
			E. Fernandez Martinez		YSF IV Z. Wolls, D. Minh Hoang. H. Tiblom, E. Muhammad, D. Marckx
			Dinner		

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Part 1: Flavor

Part 2: Neutrinos

Part 3: BSM

Part 4: DM, Axions and Cosmology

Part 5: BEH & SM

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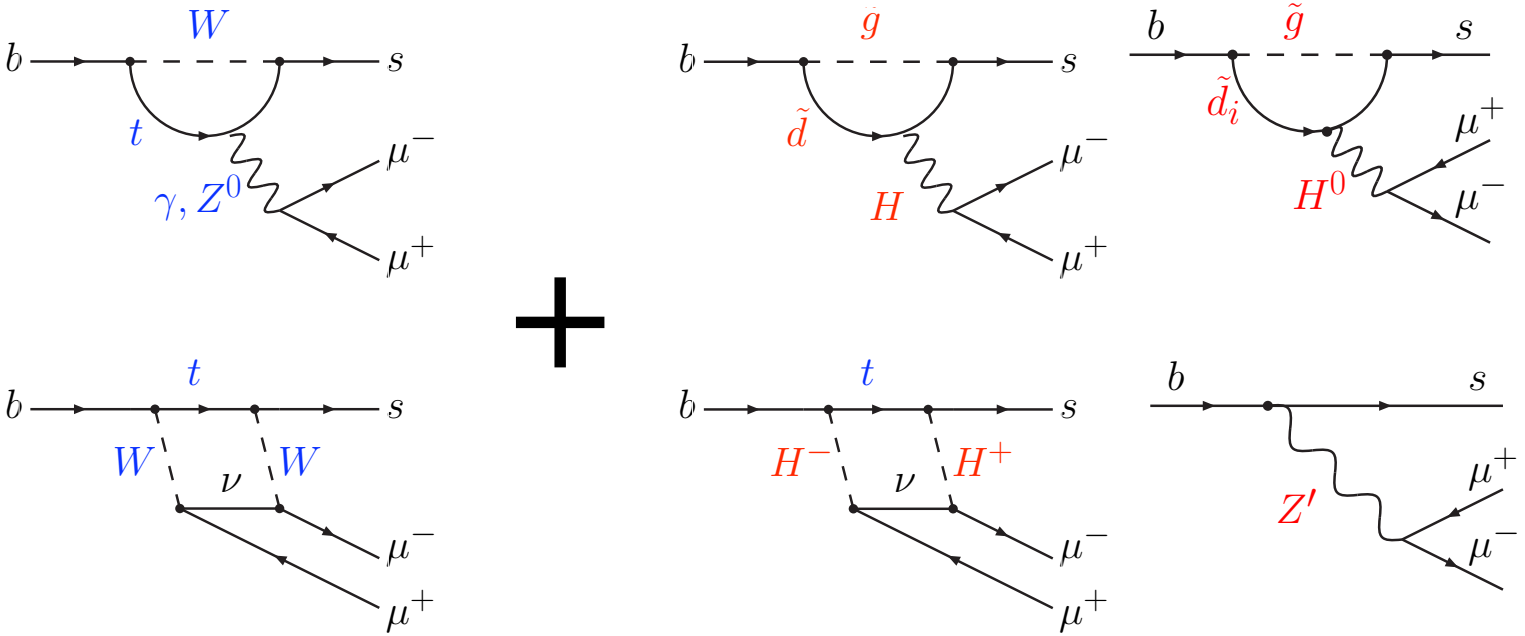
Part 1: Flavor

Searches for New Physics in flavor

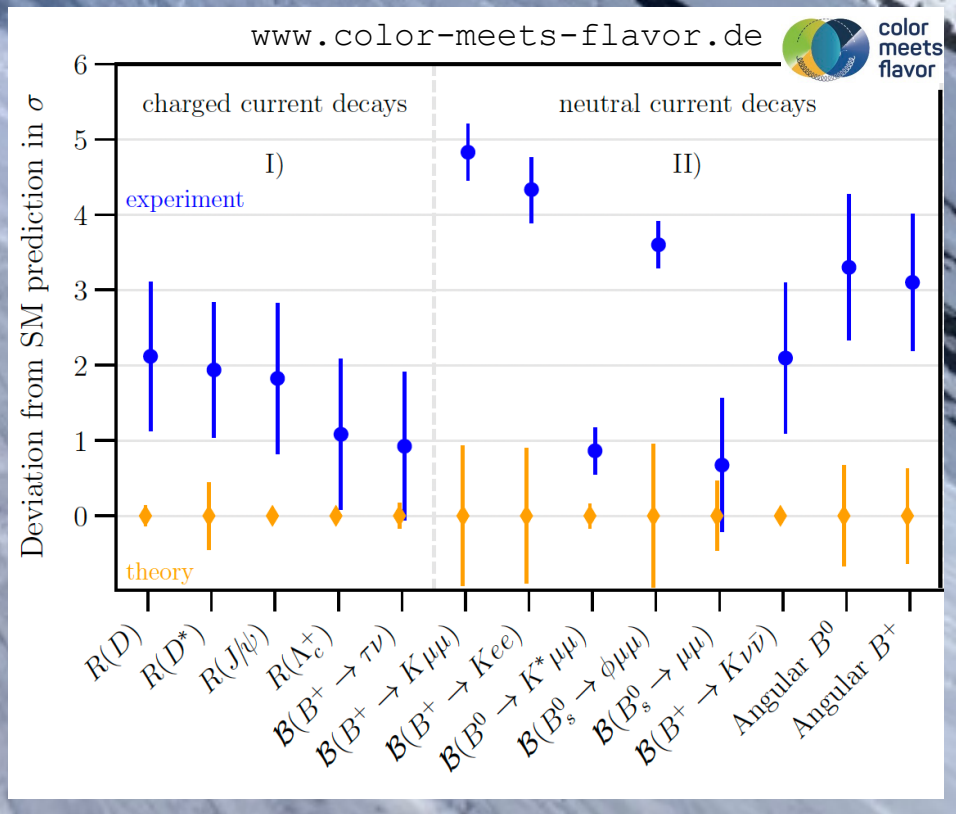
Example: Rare B decays:



- Same principle is repeated in many different systems:
  - Rare beauty, charm, strange
  - CPV in beauty, charm, strange
  - Search for invisibles, DM signatures, ..

Flavor: Isn't flavor a bit complicated? Soo many observables..

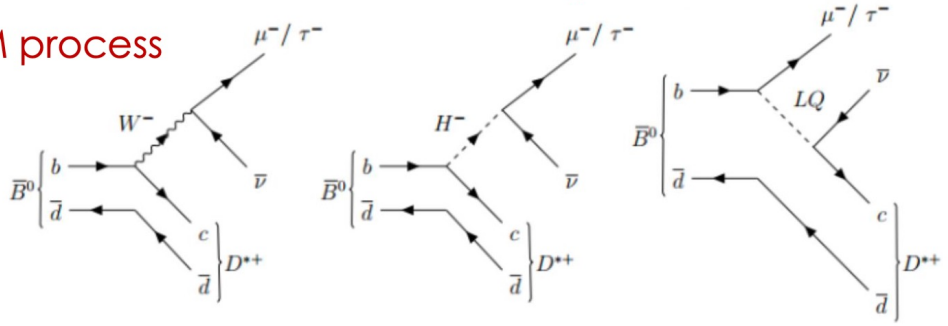
- Flavor physics ?
  a) Charged current decays
     Neutral current decays
     LFV & dark sectors
  b) CPV
  c) Dark sectors



Flavor anomalies: charged current

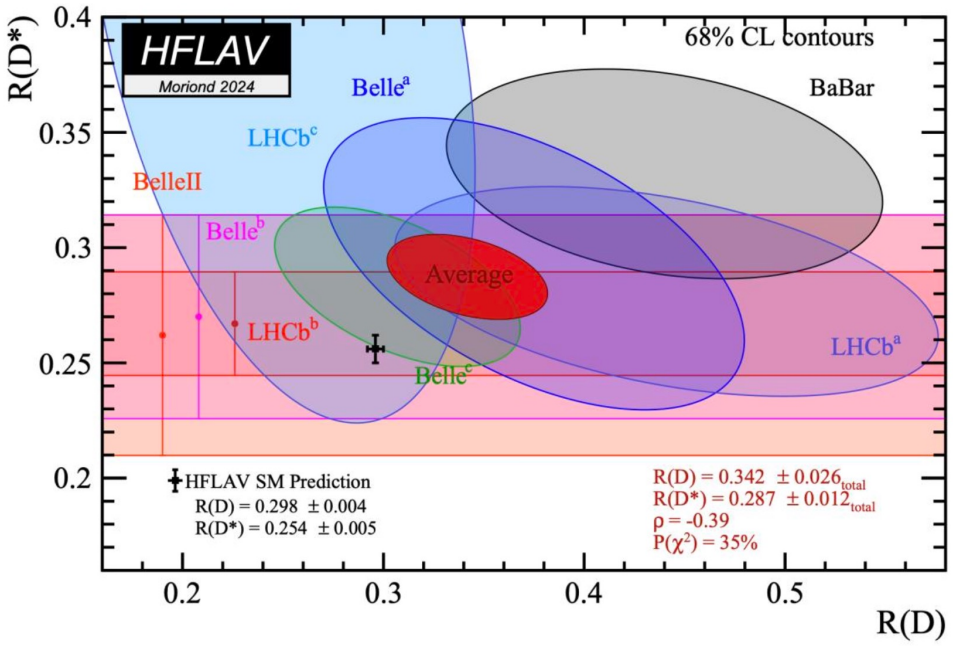
BSM processes

SM process



Lars Eklund	LHCb
Tommy Martinov	Belle 2
Xiang Pan Giovanni Gaudino (YSF)	BESIII Belle 2

- HFLAV average of $R(D^{(*)})$
  - 3.3σ deviation from the SM prediction



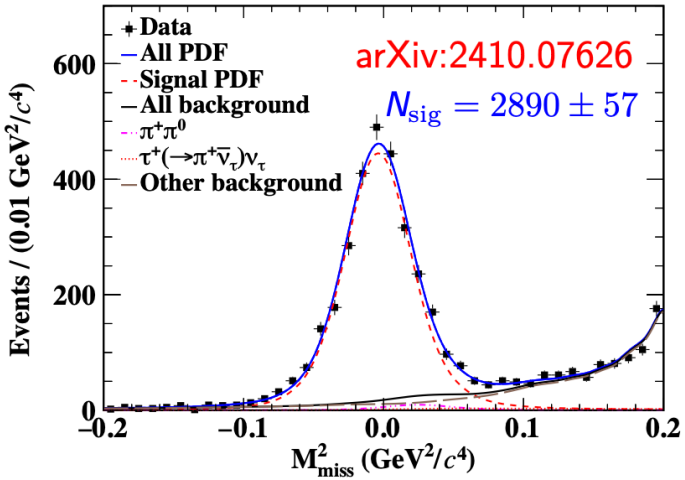
Semileptonic decays

Xiang Pan (BESIII)
Giovanni Gaudino (Belle2)

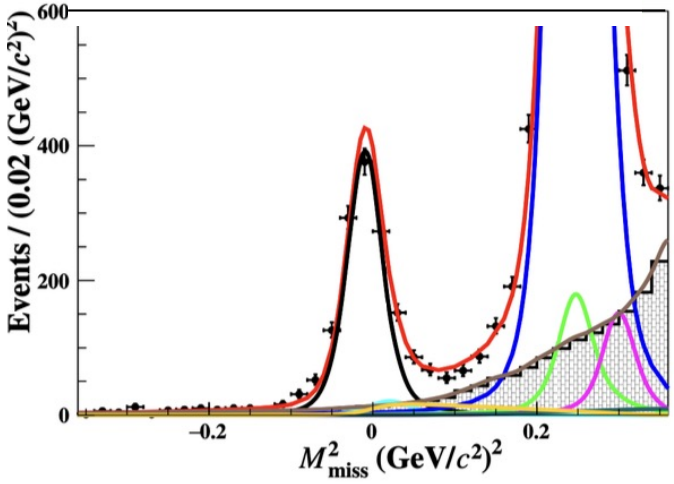
D decays at BESIII

Rich harvest in (semi-) leptonic decays

$BR(D^+ \to \mu^+\nu_\mu)$

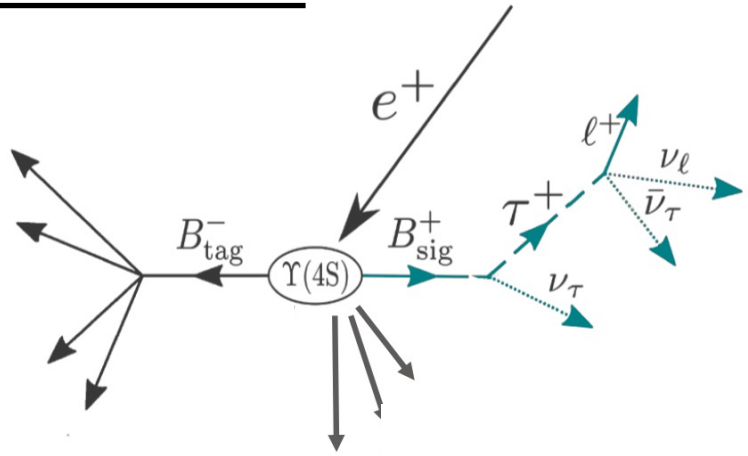


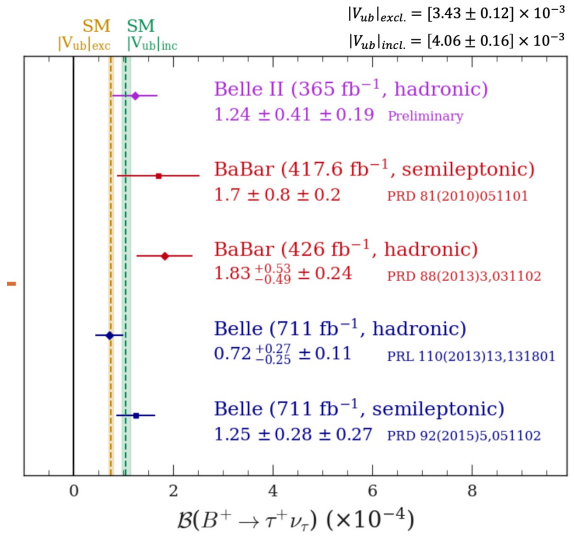
$BR(D^+ \to \tau^+\nu_\tau)$



Leptonic B decays at Belle 2

$BR(B^+ \to \tau^+\nu_\tau)$





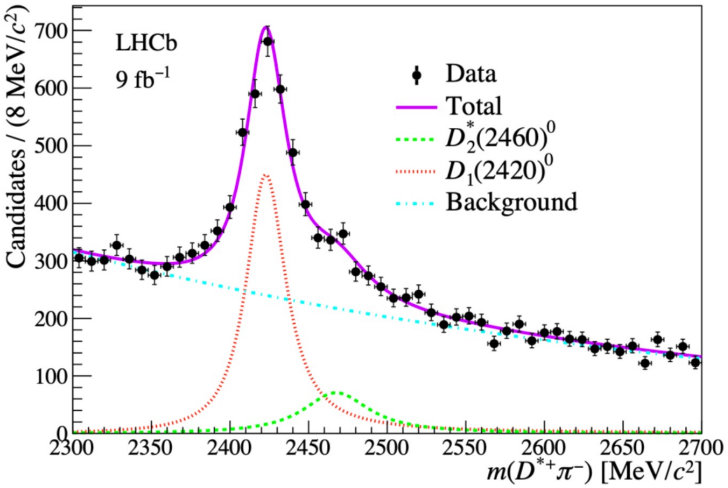
New results from LHCb and Belle 2

Lars Eklund (LHCb)
Tommy Martinov (Belle2)

LHCb: Study of $B^- \to D^{**0}\tau^-\bar{\nu}_\tau$

- Important component in all R_D LFU measurements
- Measurement of BR and LFU

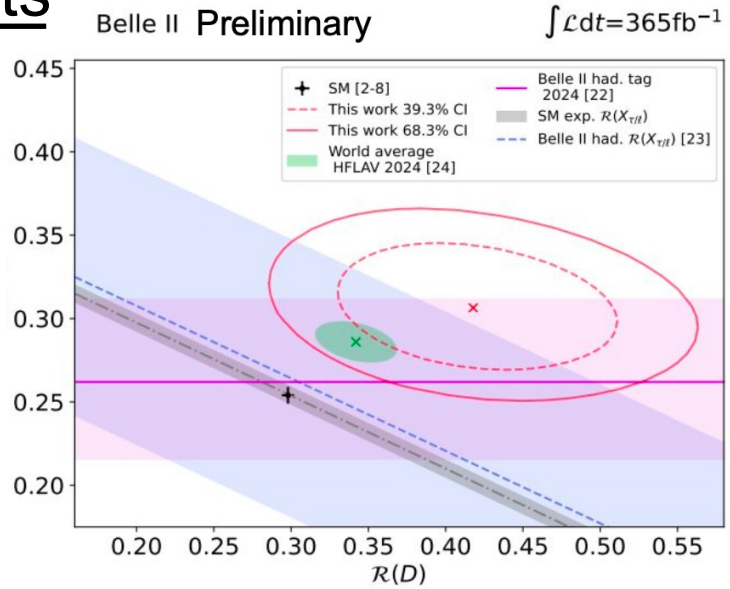
$$R(D^{**0}_{1,2}) = \frac{\mathcal{B}(B^0 \to D^{**0}_{1,2}\tau^-\bar{\nu}_\tau)}{\mathcal{B}(B^0 \to D^{**0}_{1,2}\mu^-\bar{\nu}_\mu)} = 0.13 \pm 0.04$$



Belle 2: Two new semileptonic LFU results

- Determination of Vcb with inclusive tagging
- Test of LFU with semileptonic tagging in R(D) and R(D*)

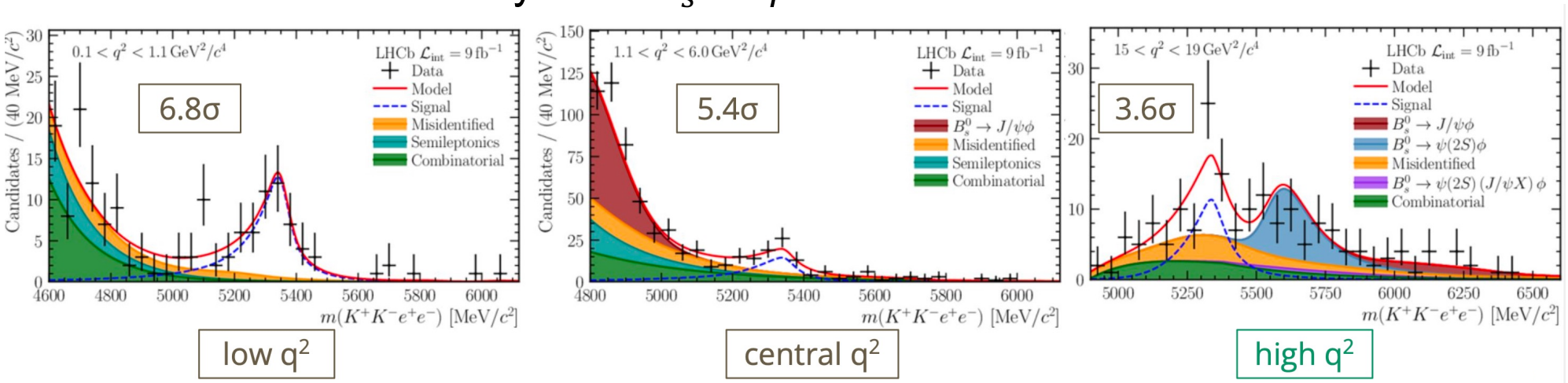
$$\mathcal{R}(D^+) = 0.418 \pm 0.074\ (\text{stat}) \pm 0.051\ (\text{syst})$$
$$\mathcal{R}(D^{*+}) = 0.306 \pm 0.034\ (\text{stat}) \pm 0.018\ (\text{syst})$$



Flavor anomalies: FCNC

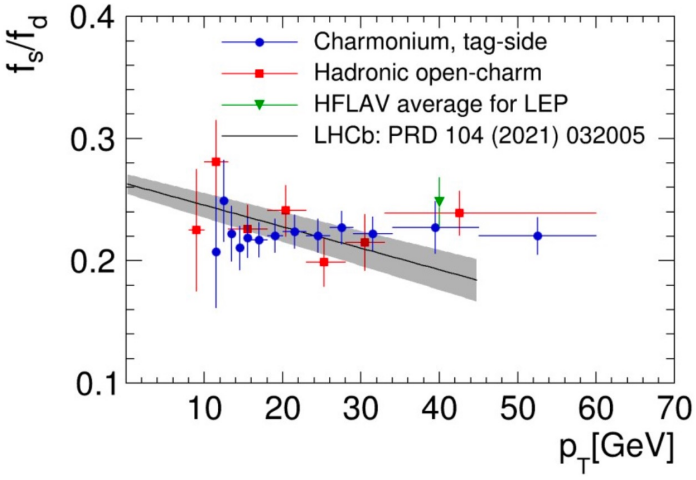
Carla Benito (LHCb)
Marie Hartman (LHCb)
Lorenzo Paolucci (LHCb)

- First LFU test in Bs system: $B_s \to \phi \ell^+ \ell^-$



- LHCb shows angular analyses with electrons: $B^0 \to K^{*0} e^+ e^-$

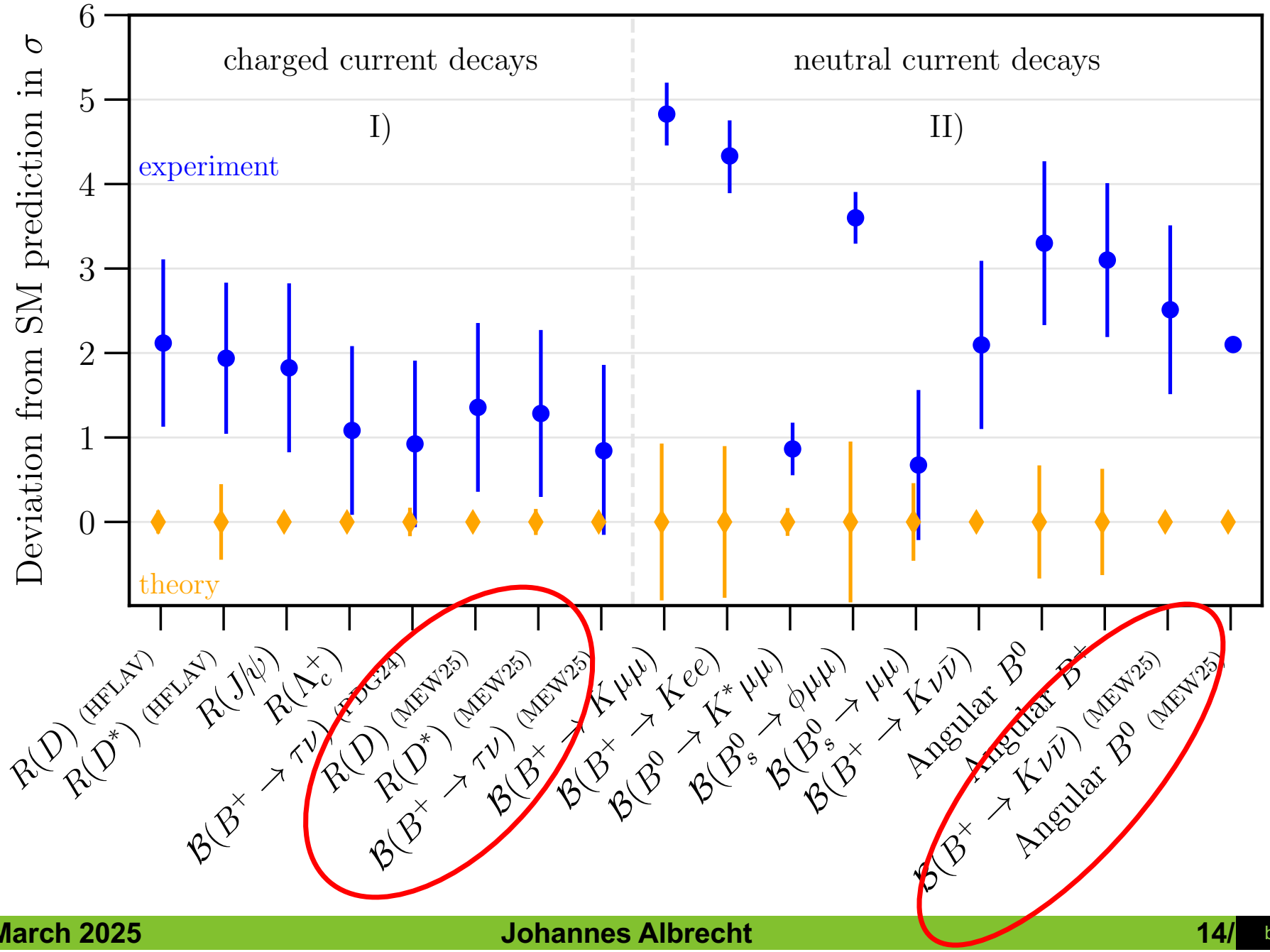
- Production fractions measured by CMS
  - Comaptible with LHCb measurement, but in tension with linear trend
  - Will have an impact on Bs measurement by CMS



Georgios Karathanasis (ATLAS & CMS)

Summary flavor anomalies

www.color-meets-flavor.de



Lepton Flavor Violation

Alessandro Scarabotto	LHCb
Vidya Sagar Vobbilisetti	Belle 2
Clotilde Lemettais (YSF)	Belle 2

Lepton Flavor in charged leptons strictly conserved

.. but in neutral leptons not… cLFV would be a clear BSM signature

The landscape now...

	K^+	K_S^0	K^{*0}	K^{*+}	Experimental sensitivity
$B \to K \tau e$	Belle BaBar	Belle + Belle II	LHCb $O(10^{-6})$	-	$O(10^{-5})$
$B \to K \tau \mu$	Belle LHCb ($B^+ \to K^+ \tau^+ \mu^-$) BaBar	Belle + Belle II	Belle + Belle II LHCb	-	$O(10^{-5})$
$B \to K \tau \tau$	BaBar	-	Belle II Belle LHCb (from unbinned fit of $B^0 \to K^{*0}\mu\mu$) [JHEP09(2024)026]	-	$O(10^{-3})$

Results shown today are either world's best limits or first searches.

CP Violation

Pere Gironella	Belle 2
Resmi Puthumanaillam	LHCb

- LHCb: updates on gamma and new combination

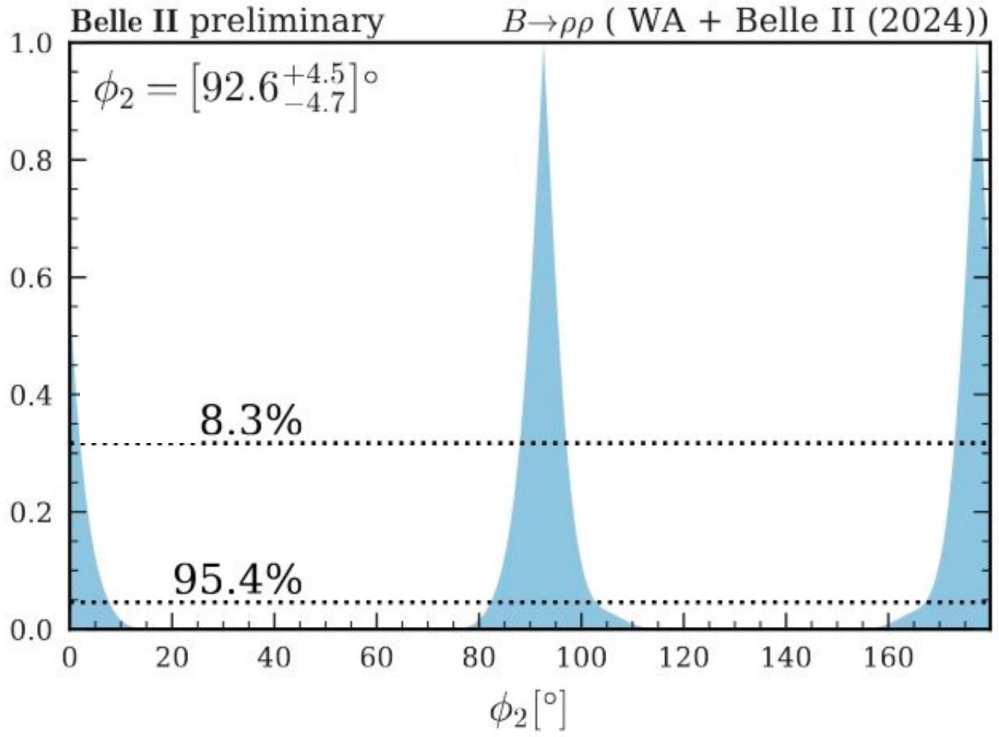
$$\gamma = (64.6 \pm 2.8)^\circ$$

- Belle 2: constraints on alpha (ϕ_2)
  - $B^0 \to \pi^0\pi^0$
  - $B^0 \to \rho^+\rho^-$

Solution compatible with SM:

$$\phi_2 = (92.6^{+4.5}_{-4.7})^\circ$$

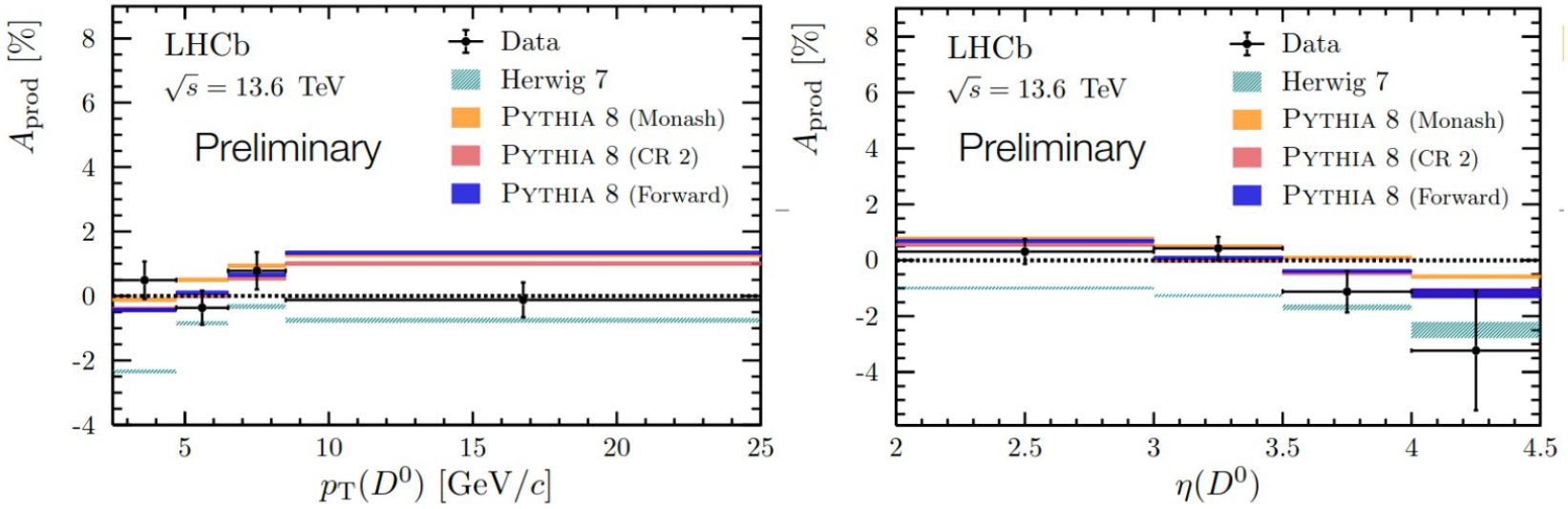
$$\Delta\phi_2 = (2.4^{+3.8}_{-3.7})^\circ$$



Charm physics

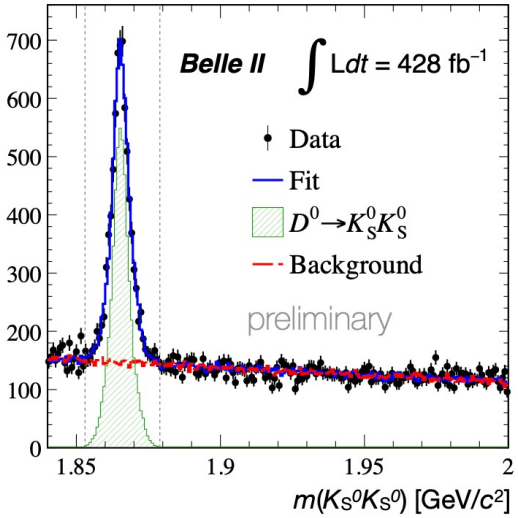
R.Puthumanaillam (LHCb)
Riccardo Manfredi (Belle2)
A. Scarabotto (LHCb)

- LHCb shows its first Run 3 measurement



- Belle 2 shows new very stringent CPV tests
  - $D^0 \to \pi^0\pi^0$
  - $D^0 \to K_s^0 K_s^0$

Method	A_{CP} [%]
D^*-tag [PRD 111, 012015]	$-1.4 \pm 1.3 \pm 0.1$
CFT-tag	$1.3 \pm 2.0 \pm 0.3$
Combination	$\mathbf{-0.6 \pm 1.1 \pm 0.1}$



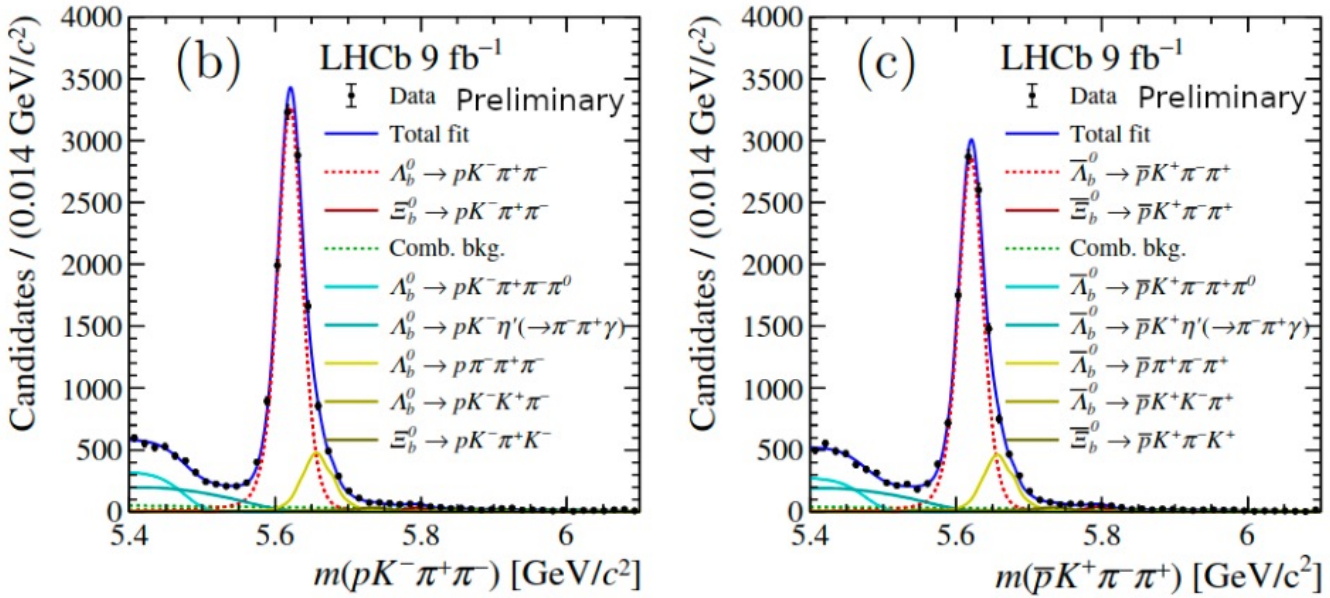
Discovery of CP Violation in Baryons

Resmi Puthumanaillam | LHCb

The *CP* asymmetry in $\Lambda_b \to pK^-\pi^+\pi^-$ decays:

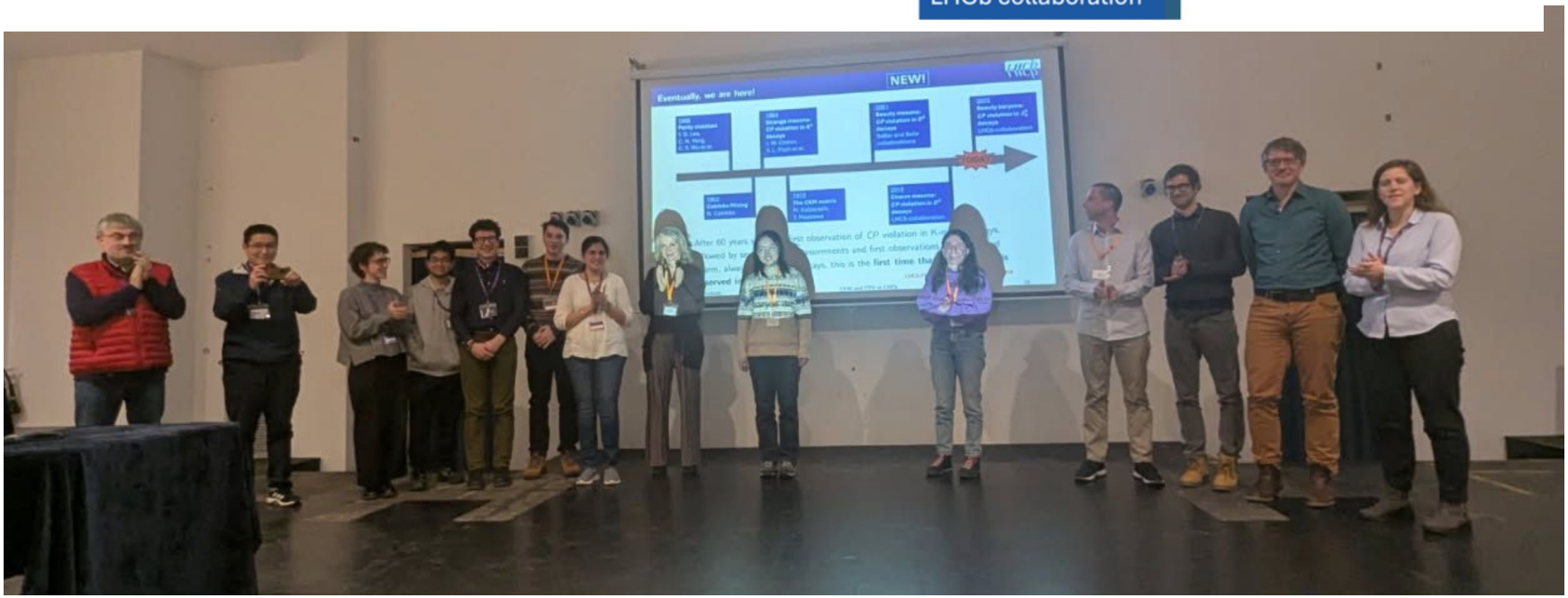
$$A_{CP} = (2.45 \pm 0.46 \pm 0.10)\%$$

First observation of CPV in baryonic decays - difference of **5.2σ** from zero



Discovery of CP Violation in Baryons

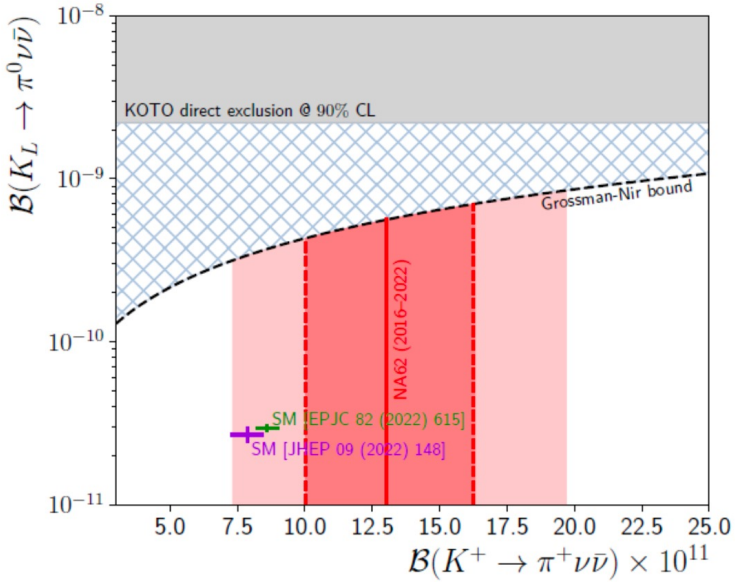
Resmi Puthumanaillam	LHCb



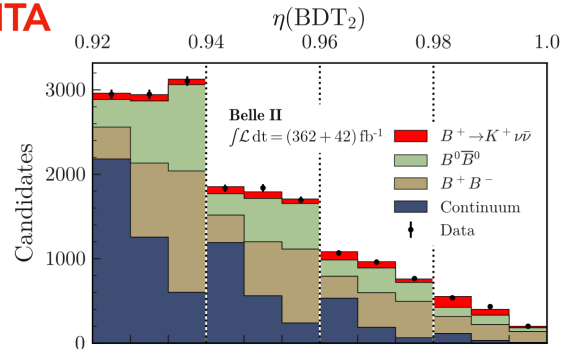
Dark sectors in flavor

Shaojie Wang (BESIII)
Steven Robertson (BaBar)
Sally Stefkova (Belle 2)
Giuseppe Ruggiero (NA62)

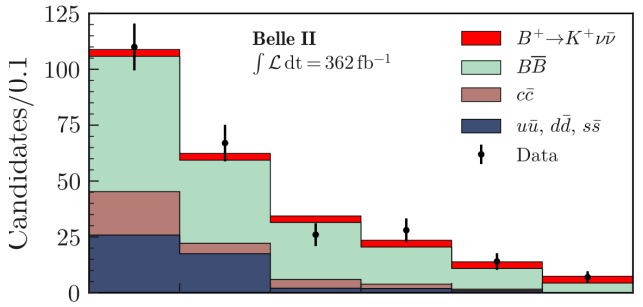
- BaBar constrains B-baryogenesis
  - $B^+ \to \Lambda_c^+ \psi_D$ dark matter search
- BESIII shows immense productivity
  - First limits for invisible K_S decays
  - Many more results, many lepton number violating D decays tested
- Na62 observed rarest meson decay ever
  - $BR(K^+ \to \pi^+ \nu\,\bar{\nu}) = (13.0^{+3.3}_{-3.0}) \times 10^{-11}$
- Belle2 finds first evidence for $B^+ \to K^+ \nu\bar{\nu}$
  - $BR(B^+ \to K^+ \nu\bar{\nu}) = \left(2.3 \pm 0.5(stat)^{+0.5}_{-0.4}(syst)\right) \times 10^{-5}$
  - Consistency with SM: 2.7σ



ITA



HTA



YSF session (MON)

Theory progress on $D^+ \to \pi^+ \ell^+ \ell^-$

Anshika Bansal

24/03/2025

Universität Siegen / TP1 Theoretical Particle Physics / CPPS Center for Particle Physics Siegen

PH

59th Rencontres de Moriond 2024: Electroweak Interactions & Unified Theories
La Thuile, 24th March 2025

$\mathcal{B}(B^+ \to \tau^+ \nu_\tau)$ measurement with the hadronic FEI at Belle II

Giovanni Gaudino*
on behalf of Belle II collaboration

*gaudino@na.infn.it

Belle II

INFN SSM

Rencontres de Moriond

Bivacco Edoardo Camardella – La Thuile

université PARIS-SACLAY · IJCLab · cnrs · erc · CHIARO SCURO · LHCb THCP

Angular Analyses of $B^0 \to K^{*0} e^+ e^-$ decays at LHCb.

59th Rencontres de Moriond – Young Scientist Forum

Marie Hartmann
on behalf of the LHCb collaboration

Rencontres de Moriond

Search for Lepton Flavour Violating $B^0 \to K^{*0} \tau \ell$ decays with the Belle and Belle II experiments

59th Rencontres de Moriond, La Thuile

Clotilde Lemettais
on behalf of the Belle II collaboration

March 24, 2025

amU Aix Marseille Université · CPPM Centre de Physique des Particules de Marseille · Funded by the European Union · erc European Research Council · Belle II

BSM reach of rare charm decays, including the rising star $\Lambda_c \to p\mu^+\mu^-$

Dominik Suelmann
in collaboration with H. Gisbert, G. Hiller
based on arXiv:2410.00115

Supported by the Federal Ministry for Education and Research (BMBF)

TU Dortmund
Department of Physics

24. March 2025
59th Rencontres de Moriond

Rencontres de Moriond

technische universität dortmund

Bundesministerium für Bildung und Forschung

Rencontres de Moriond

credit: @pingmypingon Instagram

LHCb THCP · WARWICK THE UNIVERSITY OF WARWICK

Strange penguins at LHCb

An angular analysis of $B_s^0 \to \phi e^+ e^-$ decays

Lorenzo Paolucci (he/him), on behalf of the LHCb Collaboration

Flavor summary

Beautiful playground for big kids

Situation looks like an academic example for NP discovery
→ pattern of anomalies seems to be consistent (EFT)
Promising next years for flavor physicists

Experimental: situation needs to be clarified, too many 2-3σ
(CMS parked data, LHCb * 4, Belle2, BESIII, ..)
Theoretical: "we tried very hard to show this is SM and failed"
Improved calulations needed, mesons are instable, extended objects, methods for BR calculation needed, lattice progress

Moriond Electroweak 2025

MONDAY24/03	TUESDAY25/03	WEDNESDAY26/03	THURSDAY27/03	FRIDAY28/03	SATURDAY29/03
C. Marin Benito	S. Stefkova	N. Ackerman	D. Litim	M. Schmaltz	A. Nigamova
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coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break
M. Reboud	G. Karathanasis	C. Englert	P. Ecker	C. Yèche	R. Wang
T. Martinov	J. Kleykamp	C. Pollard	A. Ibarra	M. Drewes	M. Stange
X. Pan	D. Henaff	A. Teixeira	S. Eriksen	A. Chou	G. Boldrini
A, Juettner	T. Tashiro	C. Wa…	G. Perez	M. Mühlleitner	D. Camarero
Lunch	Lunch	Lunch	Lunch	Lunch	Lunch
P. Gironella	C. Hill	I. Neutelings	D. Redigolo	R. Hayes	E. Manca
R. Puthumanaillam	I. Esteban	K. Kowalska	C. De Dominicis	R. Chatterjee	T. Robens
M. Escudero	T. Lasserre	M. Montella	A. Ray	V. Miralles	F. Fabbri
A. Scarabotto	P. Decowski	J, Lizana	L. Di Luzio	T. Lenz	D. Pinna
coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break
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Part 2: Neutrinos

Neutrinos: more elusive than the other particles

[David Hénaff]

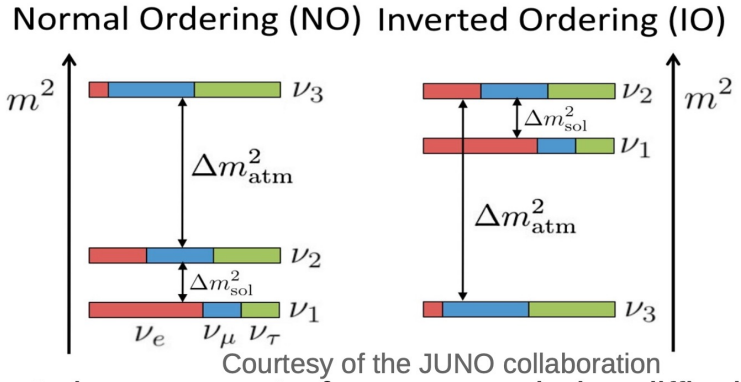
- Compared to flavor, neutrinos are in an exploration phase
- PMNS Matrix beginning to be determined

ν **oscillation:**

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix}}_{\text{Atmospheric}} \underbrace{\begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix}}_{\text{Reactor}} \underbrace{\begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{\text{Solar}} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

$\theta_{23} \approx 45°$	$\theta_{13} \approx 10°$	$\theta_{12} \approx 35°$
Atmospheric exp.	*Reactor*	*Solar exp.*

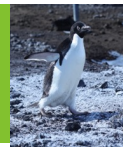
- Many unknowns
  → current research directions
  - Mass hirachy ≡ or ≡
  - Absolute masses
  - CP violation in neutrinos
  - CPV connection to baryogenesis
  - Existence of right-handed or sterile neutrinos
  - Dirac or Majorana Neutrinos
  - Connection between Neutrinos and dark matter ?



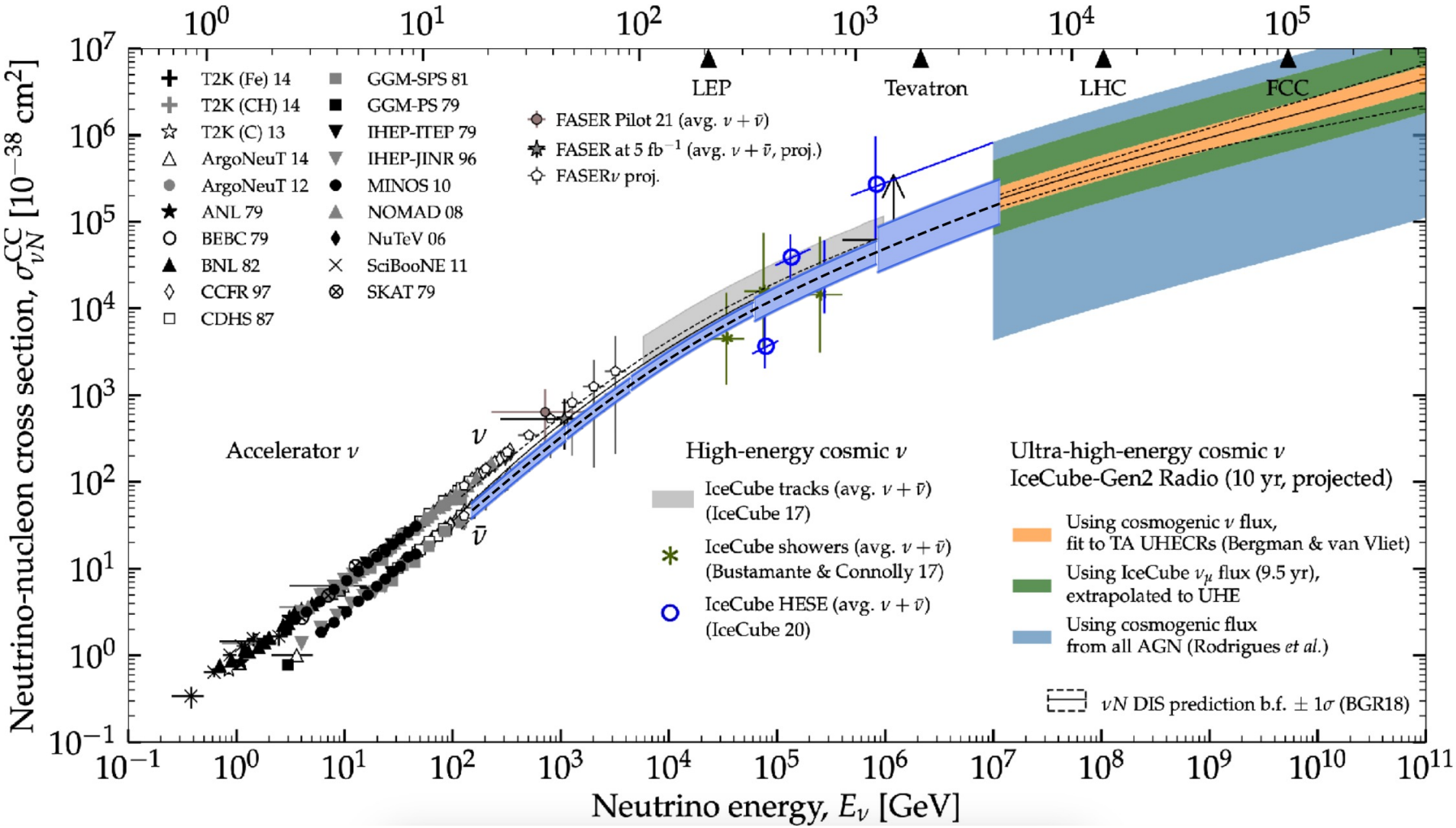
Courtesy of the JUNO collaboration

Only measure Δm^2 → mass ordering difficult

Neutrino cross sections



Colton Hill (IceCube)

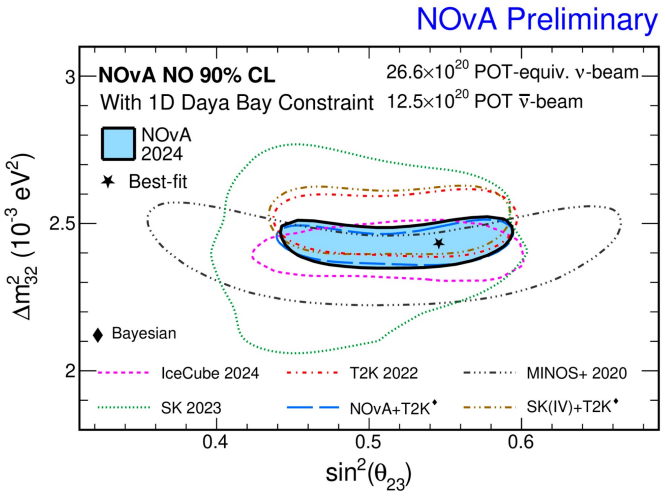


*Disclaimer, this is a simplification from JA to illustrate the idea

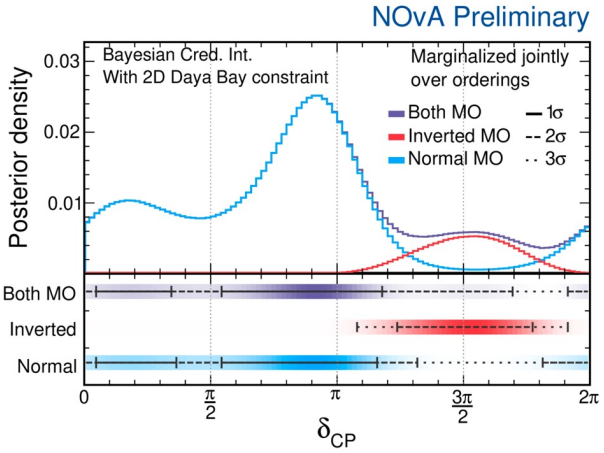
Neutrino Oscillations

Jeffery Kleykamp (Nova)
David Henaff (T2K)
Takuya Tashiro (S.Kamiokande)

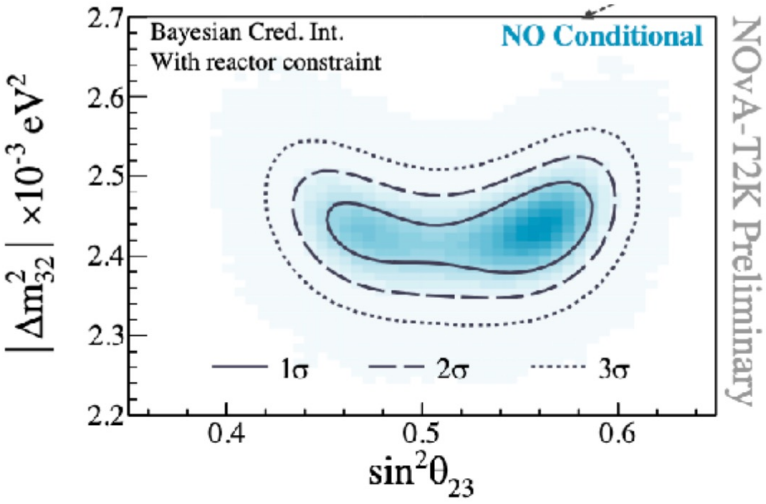
Δm^2_{32} vs $\sin^2\theta_{23}$

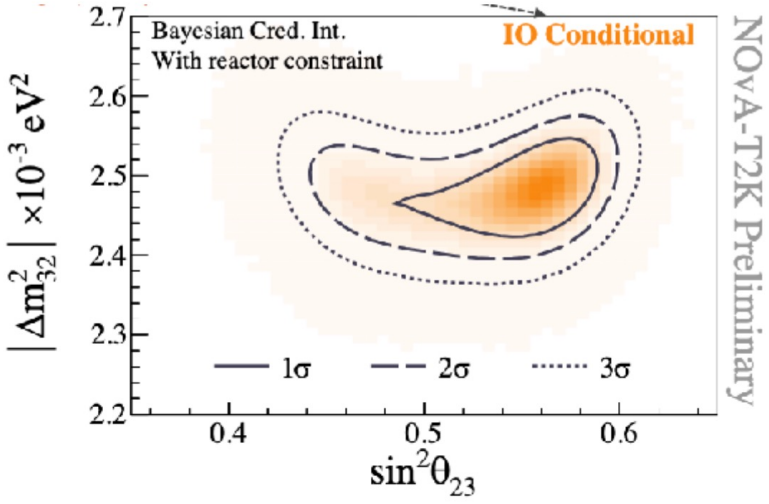


δ_{CP}, Bayesian Analysis



N.O. preferred, but not significant yet



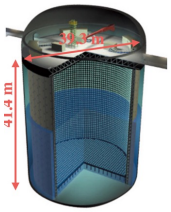


Oscillation analysis:

- CP symmetry is excluded at 90% CL (T2K)
- Mild preference for normal ordering and upper octant for θ_{23}

Neutrino Oscillations

Jeffery Kleykamp (Nova)
David Henaff (T2K)
Takuya Tashiro (S.Kamiokande)

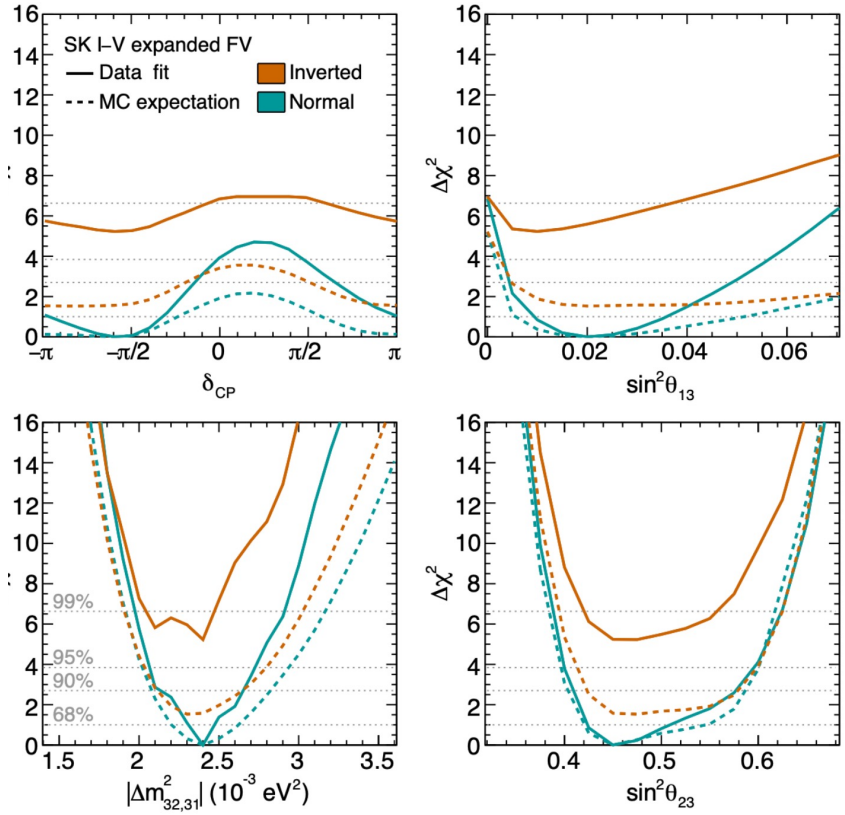


- Super-Kamiokande
- Detailed analysis of the flavor components depending on the zenith angle and energy set strong constraints on the oscillation parameters.
- Normal ordering preferred

Solar neutrinos

$$\sin^2\theta_{12} = 0.307 \pm 0.012$$
$$\Delta m^2_{21} = (7.50^{+0.19}_{-0.18}) \times 10^{-5}$$

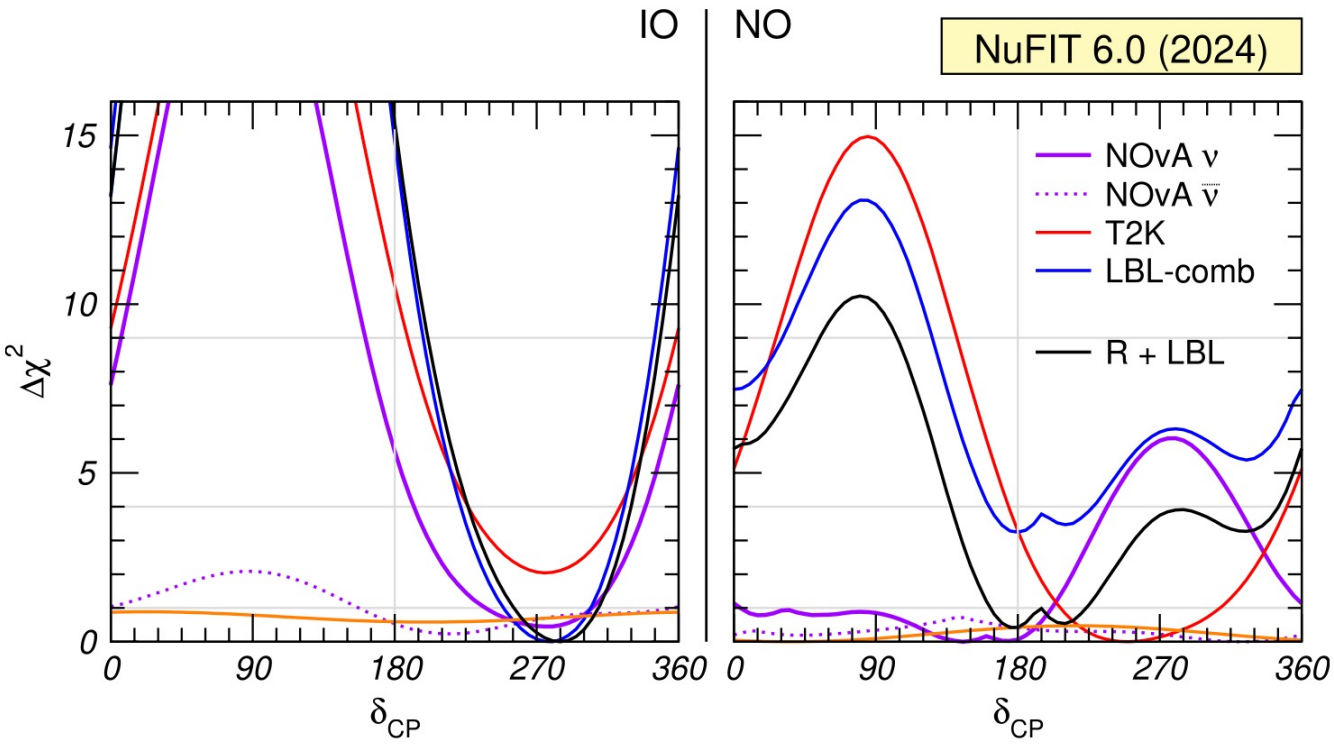
- Combination with KAMLAND



From Phys. Rev. D 109, 072014

Normal or inverted ordering preferred??

Ivan Esteban (TH)

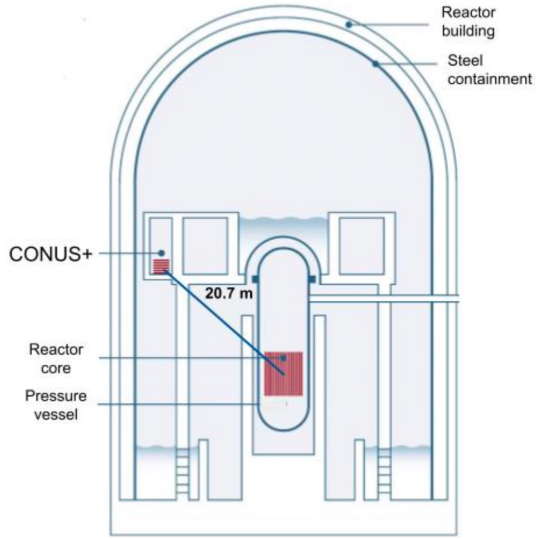


- A reactors + LBL tension in $\Delta m^2_{3\ell}$ *within IO* gives a $\sim 2\sigma$ preference for NO.
- A NOνA + T2K tension in $\delta_{\rm CP}$ *within NO* gives a $\sim 2\sigma$ preference for IO.
- The global analysis is at the *maximal confusion level*, with 1σ–2σ hints not pointing in the same direction,
  - Only after adding IceCube and *Super-K* tables, there is preference for NO.
  - For NO, CP conservation is favored. For IO, maximal CP violation.
  - No clear preference for θ_{23} octant.

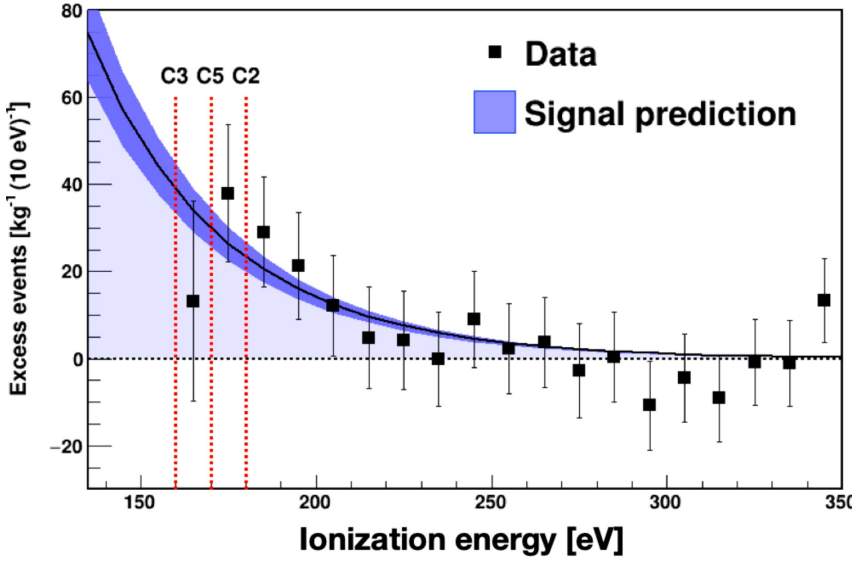
Super-K: $\sim 2\sigma$ rejection of IO. But data is not particularly compatible with NO either

Coherent neutrino scattering

Nicola Ackermann
(CONUS+)



- Start of physics data taking in Nov. 2023
- First evidence of reactor antineutrinos by coherent scattering
  - Rejection of null hypothesis: 3.7σ

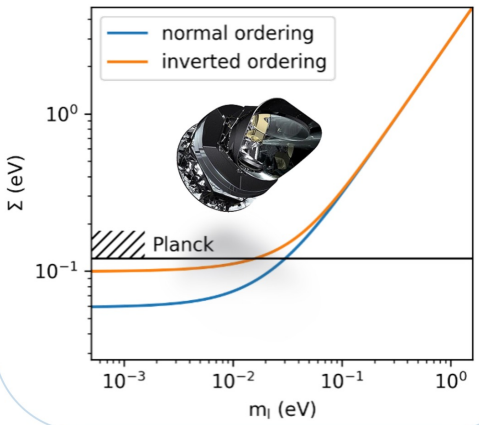


Mass of the neutrino

Thierry Lasserre (Katrin)

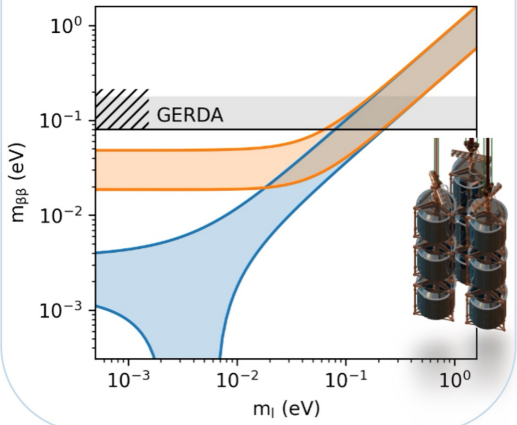
Cosmology

$$\Sigma = \sum_i m_i$$



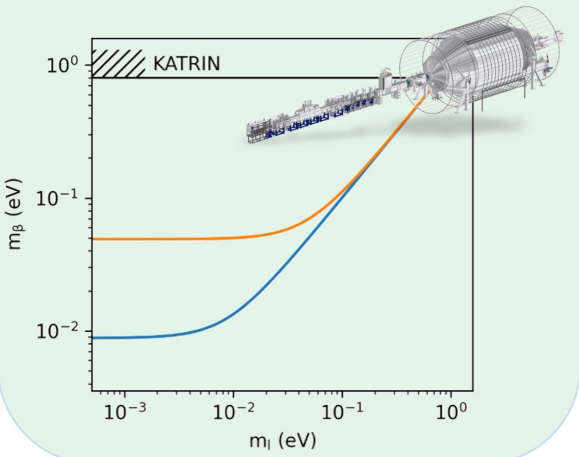
Neutrinoless ßß decay

$$m_{\beta\beta} = \sum_i U_{ei}^2 \cdot m_i$$



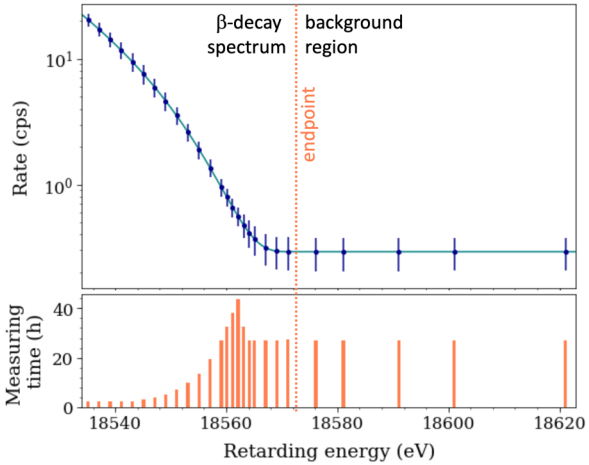
ß-decay kinematics

$$m^2_{\nu/\beta} = \sum_i |U_{ei}|^2 \cdot m_i^2$$



- Katrin measured based on 36 *10^6 e^- (1/6 of planned final dataset)

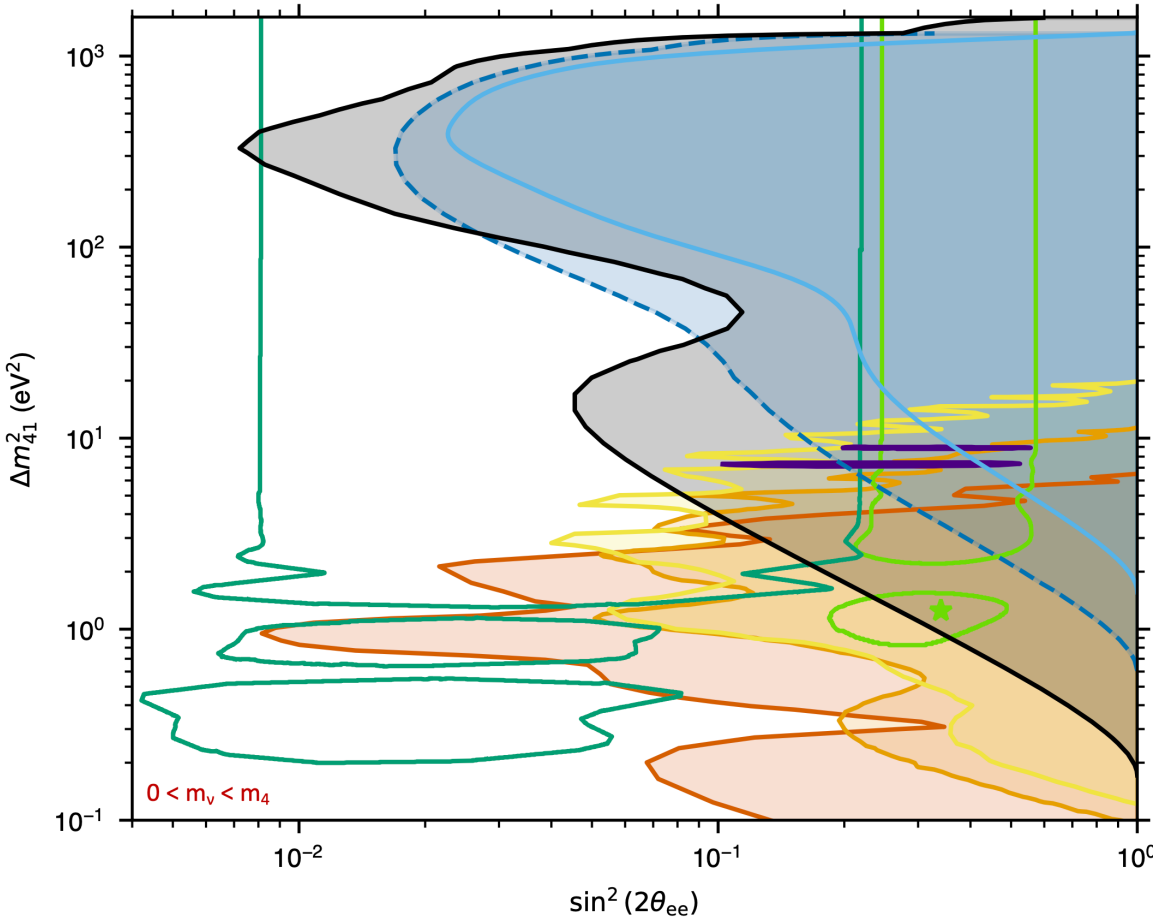
$$m_\nu < 0.45 \text{ eV (90\% CL)}$$

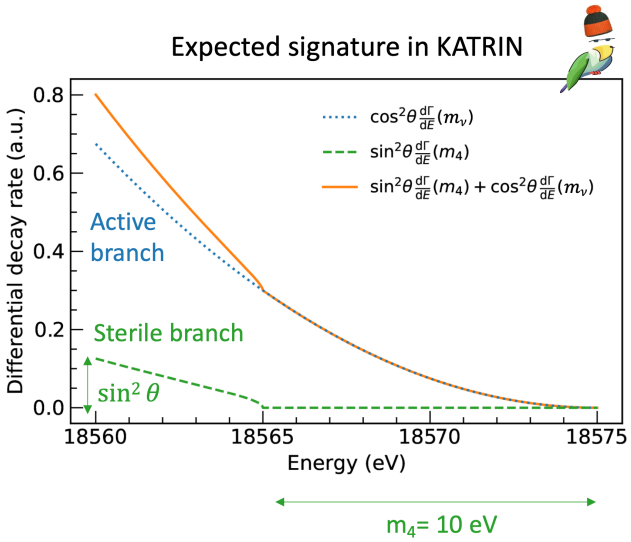


Sterile neutrinos?

Thierry Lasserre: (Katrin)

- Katrin released new result synchronised for Moriond
- Measure distortion of tritium spectrum





new exclusion limit

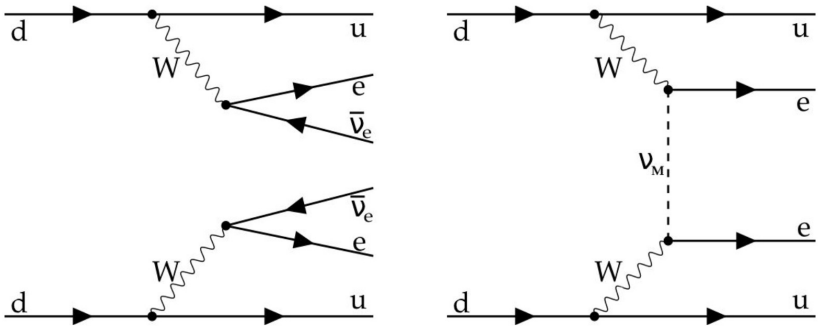
NEW!

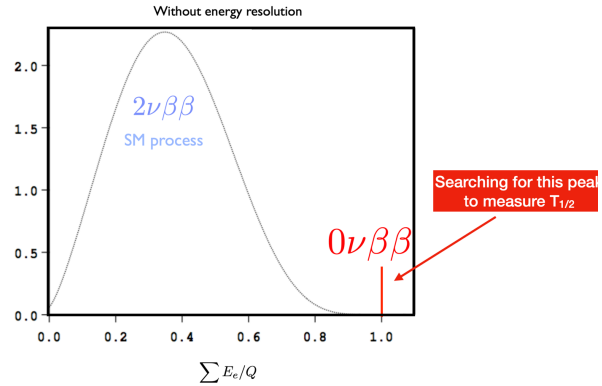
http://arxiv.org/abs/2503.18667

- Complementary to reactor experiments
- Excludes Gallium Anomaly allowed region

Neutrinoless double-beta

Patrick Decowski	Kamland
Valerio D'Andrea	Legend

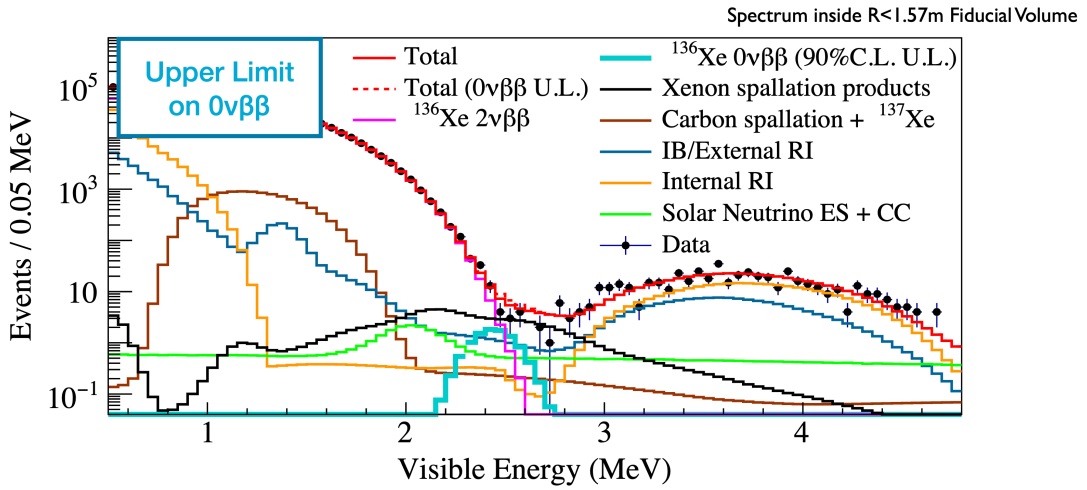




^{136}Xe Kamland-Zen

$T_{1/2} > 3.8 \times 10^{26}$ years

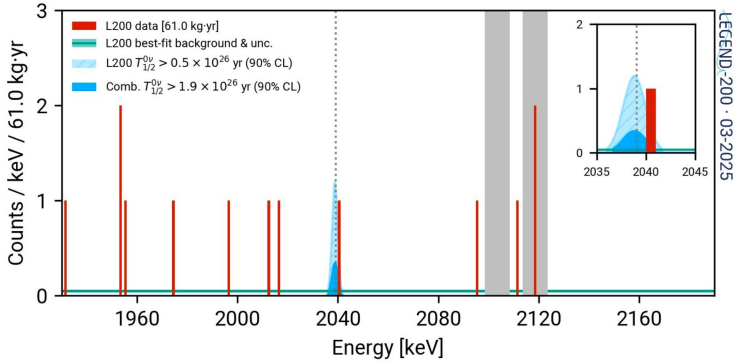
$\langle m_{\beta\beta} \rangle < 28 - 122$ meV



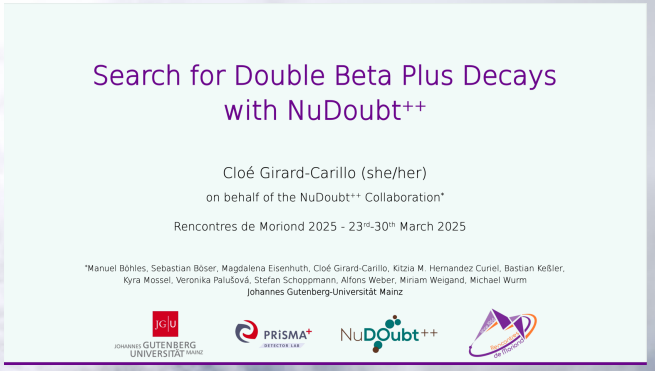
^{76}Ge Legend

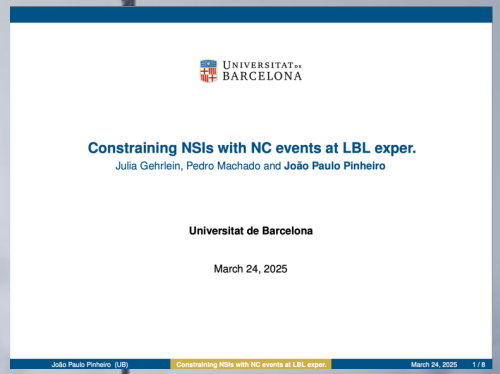
$T_{1/2} > 1.9 \times 10^{26}$ yr @ 90% CL

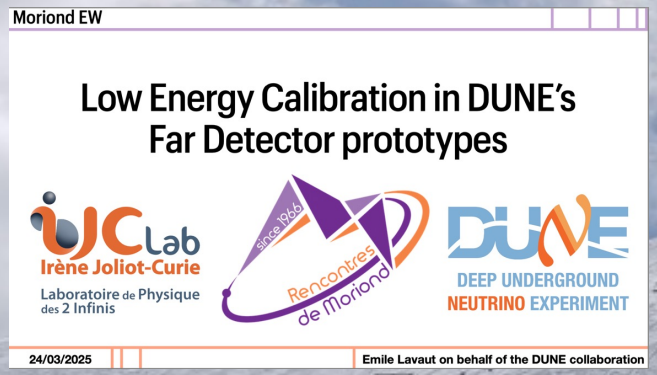
$m_{\beta\beta} < 70–200$ meV

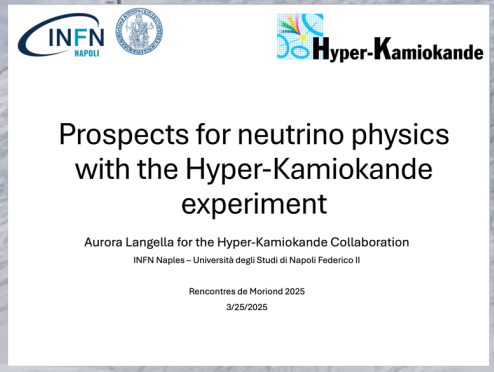


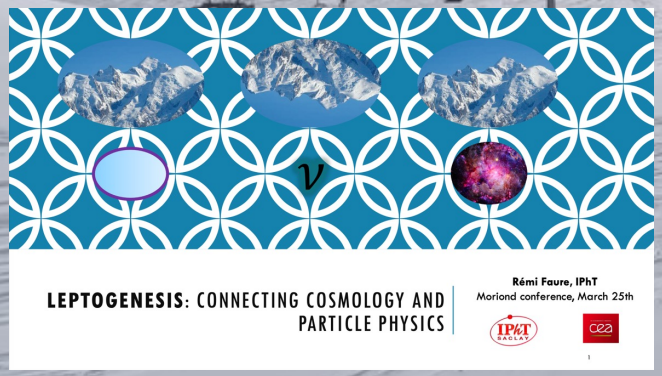
YSF session (TUE)

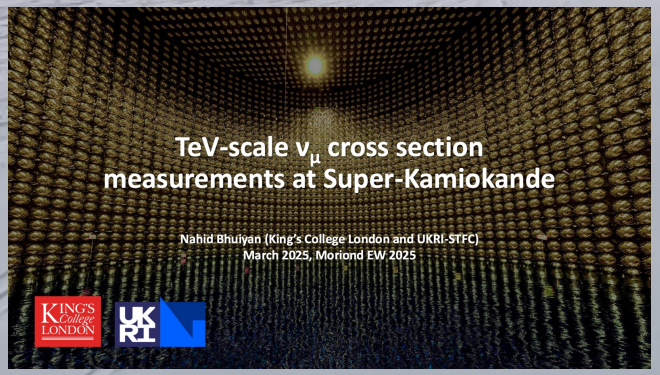








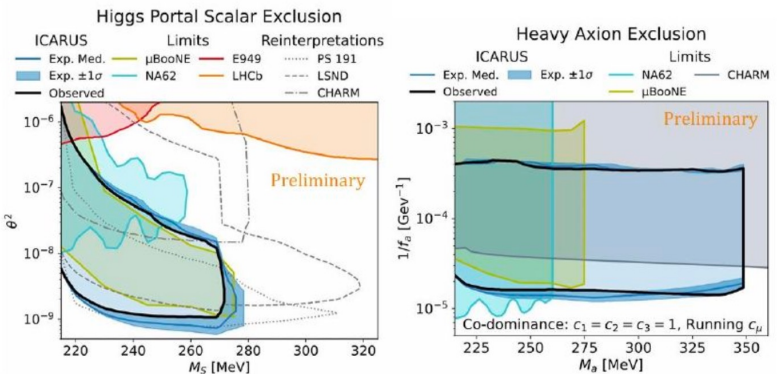




Short baseline neutrino experimetns

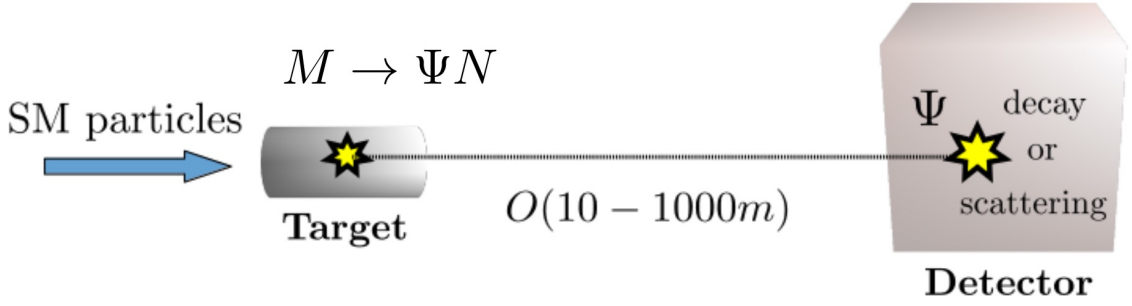
Alessandro Menegolli (ICARUS)
Salvador Urrea González (Proto-DUNE)

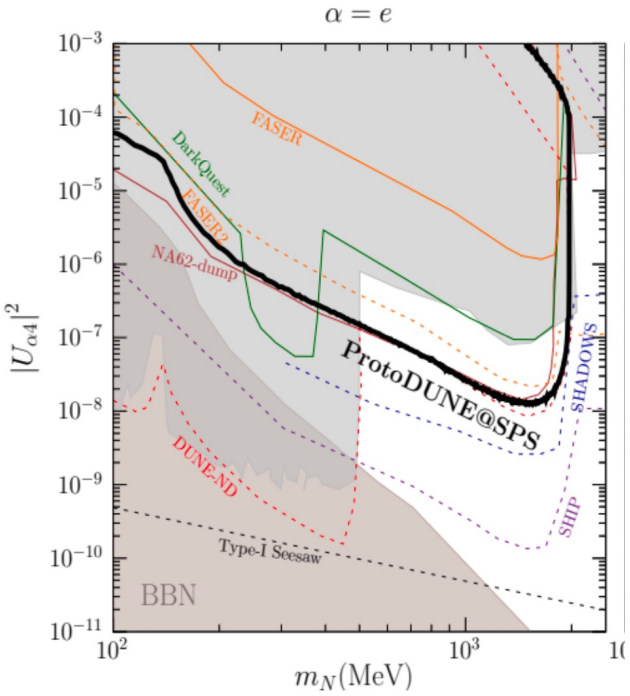
- Short baseline, ICARUS
  - Already intersting results before installation of near detector
  - Higgs Portal Scalar (HPS) → scalar dark sector mixing with Higgs boson
  - Heavy QCD axion (ALP) → Pseudoscalar mixing with pseudoscalar mesons



- ProtoDUNE

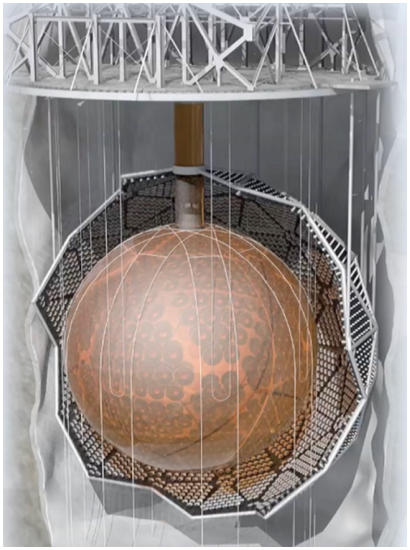
New particles produced in meson decays





SNO+

Gulliver Milton (SNO+)



- SNO+ has a broad physics program
  - Reactor and geo-neutrinos
  - 0nbb
  - Supernova, Solar and exotic neutrinos

- First indications of boron-8 solar neutrinos on C13
  - Significance of 2.4 sigma

- Antineutrino measurement

$$\Delta m^2_{21} = 7.96^{+0.48}_{-0.41} \times 10^{-5} eV^2$$

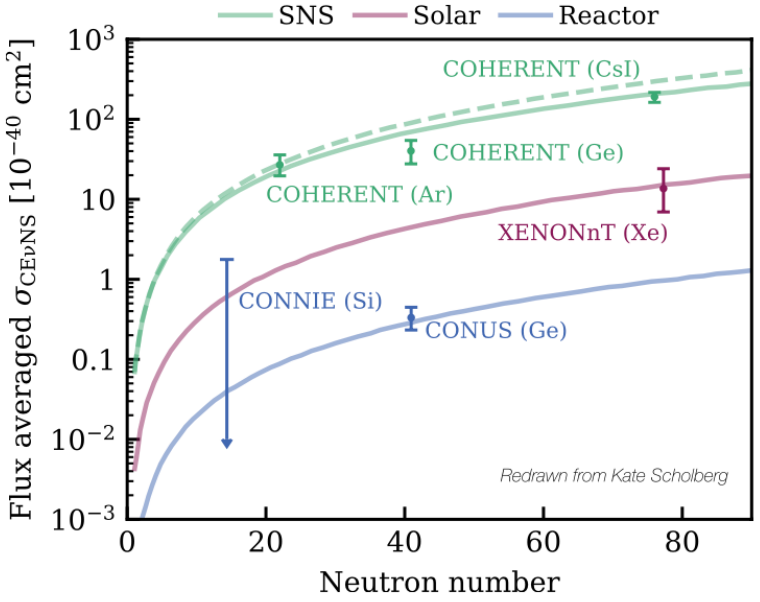
- Data from 2021 – 2023

- Detect CEvNS from 8 B solar neutrinos

Expected events: 38.3 ± 4
— Background: (26.4 ± 1.4)
— Signal: (11.9 ± 4)

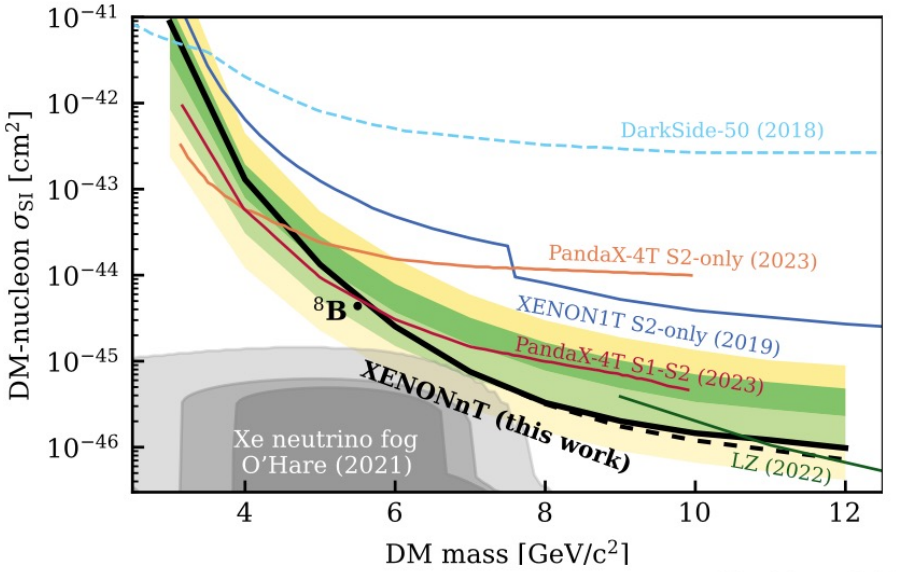
Observed events: 37

bkg only rejected **2.73σ**



5σ in reach within the lifetime of experiment

- XENONnT conducted first dark matter search in the "neutrino fog"



[2409.17868]

Summary neutrinos

- PMNS (2025) may be similar to CKM (1990)
  - We are starting to measure all angles
  - We are starting to understand the CPV phase
  - We are closing in on the mass
  - We are making precision measurements of Δm
  - We are closing parameter space for sterile neutrinos
  - We are starting to see evidence for coherent neutrino scattering

Moriond Electroweak 2025

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Lunch	Lunch	Lunch	Lunch	Lunch	Lunch
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			E. Fernandez Martinez		YSF IV Z. Wolls, D. Minh Hoang. H. Tiblom, E. Muhammad, D. Marckx
			Dinner		

Part 3: BSM

Searches now … and in the coming decades

Evolution of **exclusion** search sensitivity

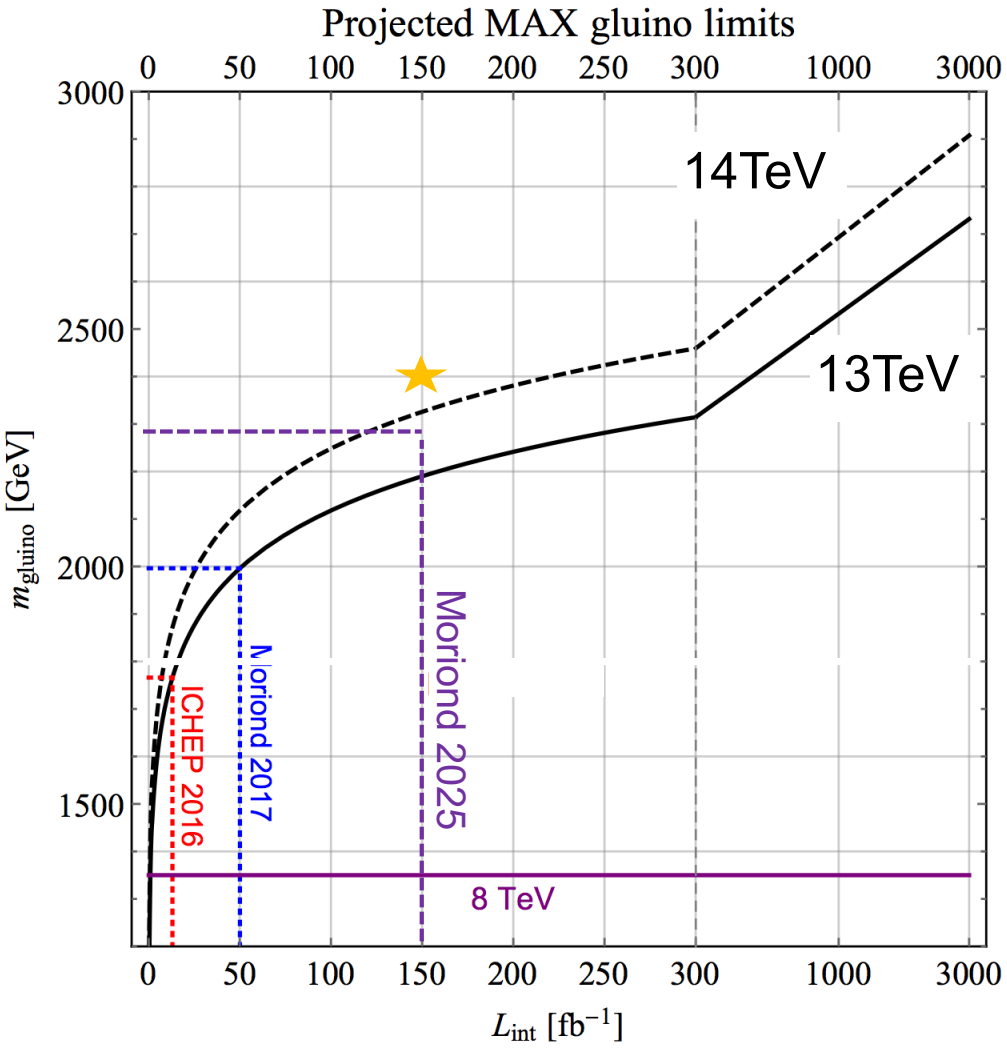


Illustration: Evolution of **exclusion** search sensitivity for generic strongly interacting particle (e.g. **gluino**)
From D. Shih et al. (from G. Salam and A. Weiler)

- Strongly IA particles:
  - Sensitivity increases slowly now
  - Steeper rise with HL-LHC
  - Still room for discoveries! (~2σ can become 5 σ)
- Performance can be improved
  - With new ideas and developments at all levels (reconstruction, ML, ..)
  - Improving precision will be key
- Discoveries will however take longer: doubling time of the luminosity of several years

Direct BSM searches at ATLAS and CMS

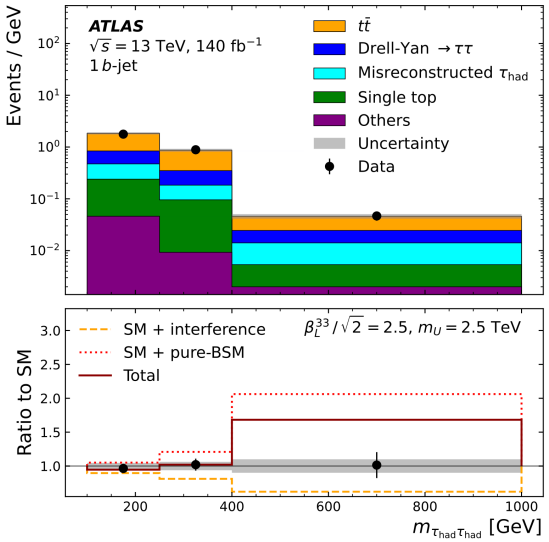
- **Christopher Pollard**: Search for lepton flavour violation and SUSY particles at LHC
- **Christina Wang**: Search for vector like quarks and vector like leptons at LHC
- **Izaak Neutelings**: Search for lepto-quarks at LHC
- **Marco Montella**: Other Exotic Searches at LHC
- **Binbin Dong**: Searches in the top sector at LHC
- **Alessandro Ruggiero (YSF)**: Searching for direct slepton production in moderately compressed mass spectra with the ATLAS detector
- **Shivani Lomte (YSF):** Search for dark matter with mono-Higgs signature
- **Sagar Addepalli** : Searches for displaced signatures at LHC
- **Cristián Ignacio Peña Herrera**: Searches using unconventional signatures or new techniques at LHC

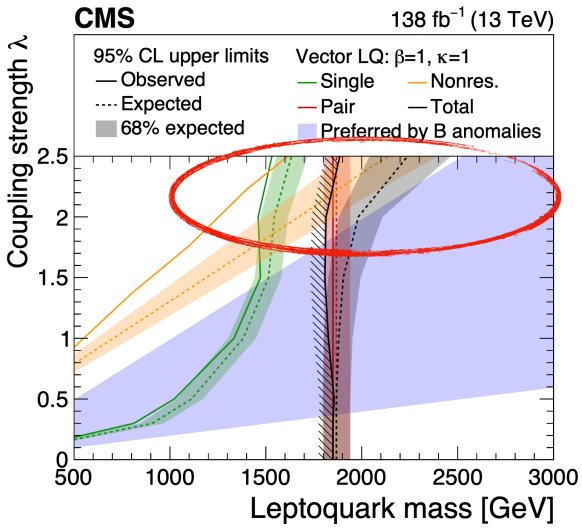
Enormous wealth of results, many new for MEW25
I will only manage to show some illustrative examples here

Example: Non-resonant *t*-channel

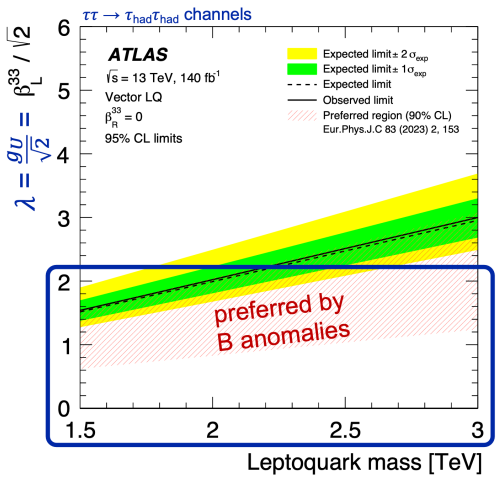
Christopher Pollard
Izaak Neutelings
(ATLAS / CMS)

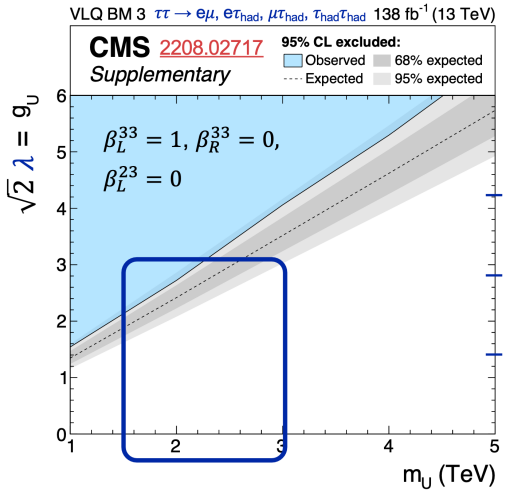
- Non-resonant *t*-channel: bb → $\tau\tau$
  - New ATLAS result
  - CMS sees some anomalies





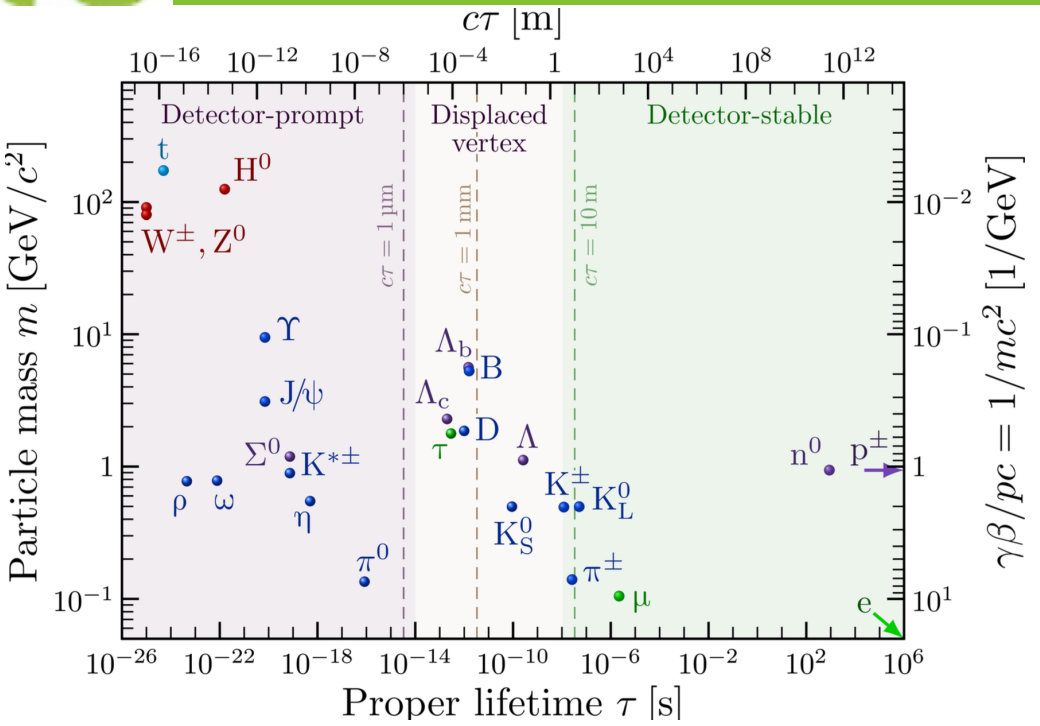
- Results start to explore parameter space preferred by B-anomalies



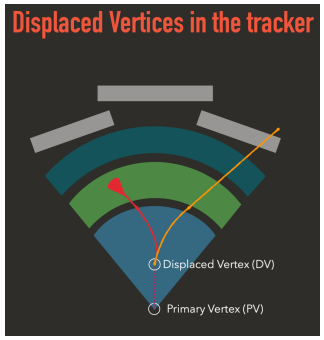


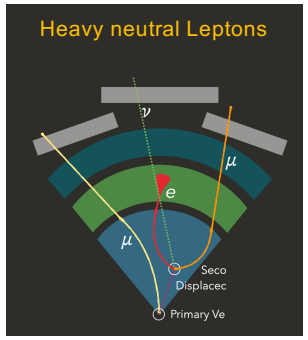
Long lived particles

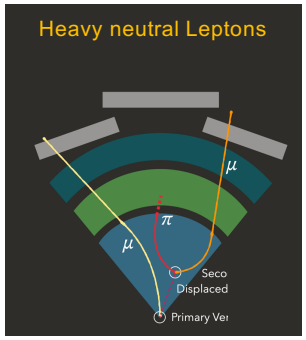
Christina Wang
Sagar Addepalli
(ATLAS / CMS)

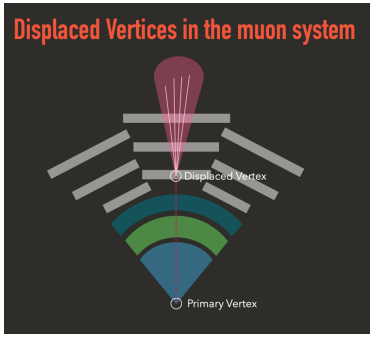


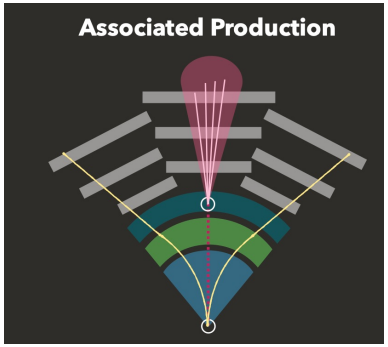
- Long-Lived Particles (LLPs): one of the most promising directions to expand searches
- Searches often need specialized reconstruction and analysis techniques







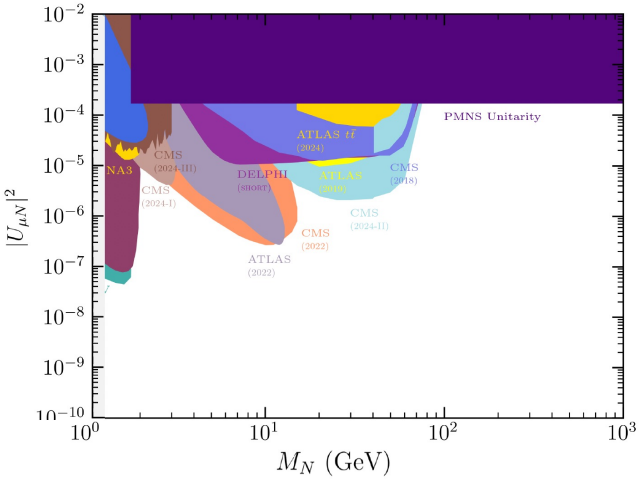


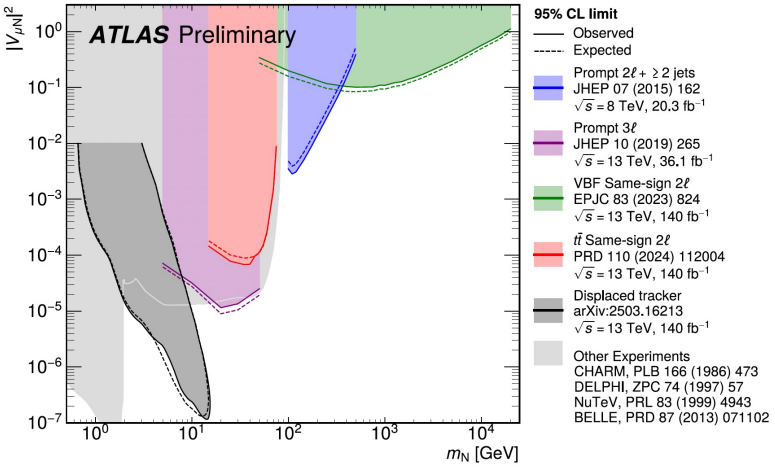


Searches: filling the gaps

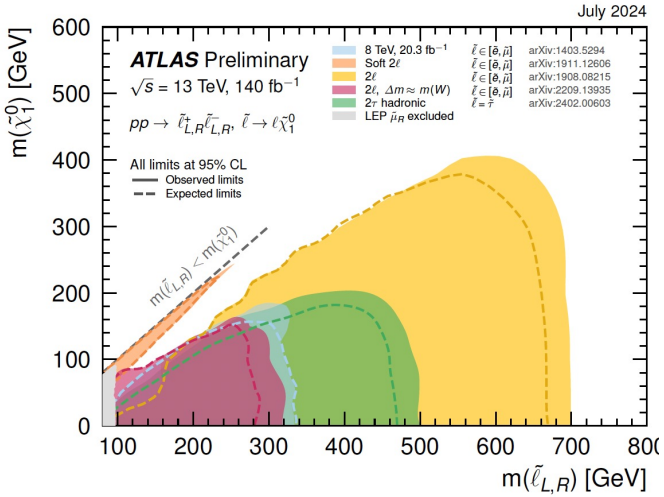
Alessandro Ruggiero
Sagar Addepalli
ATLAS & CMS

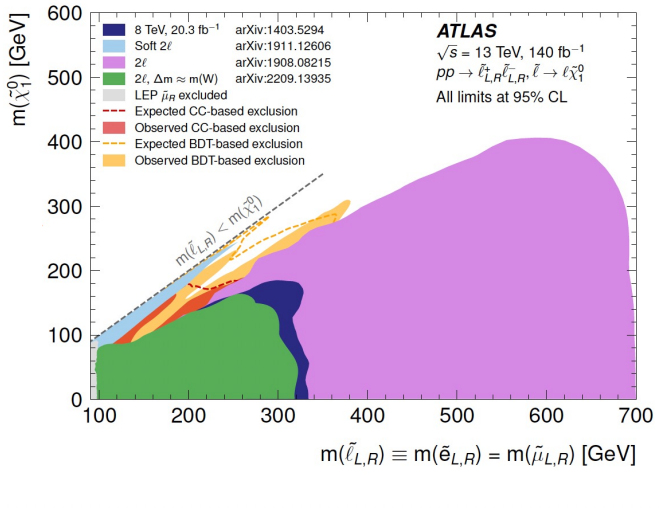
- Heavy Neutral Leptons





- Searches for direct slepton production in the compressed-mass corridor





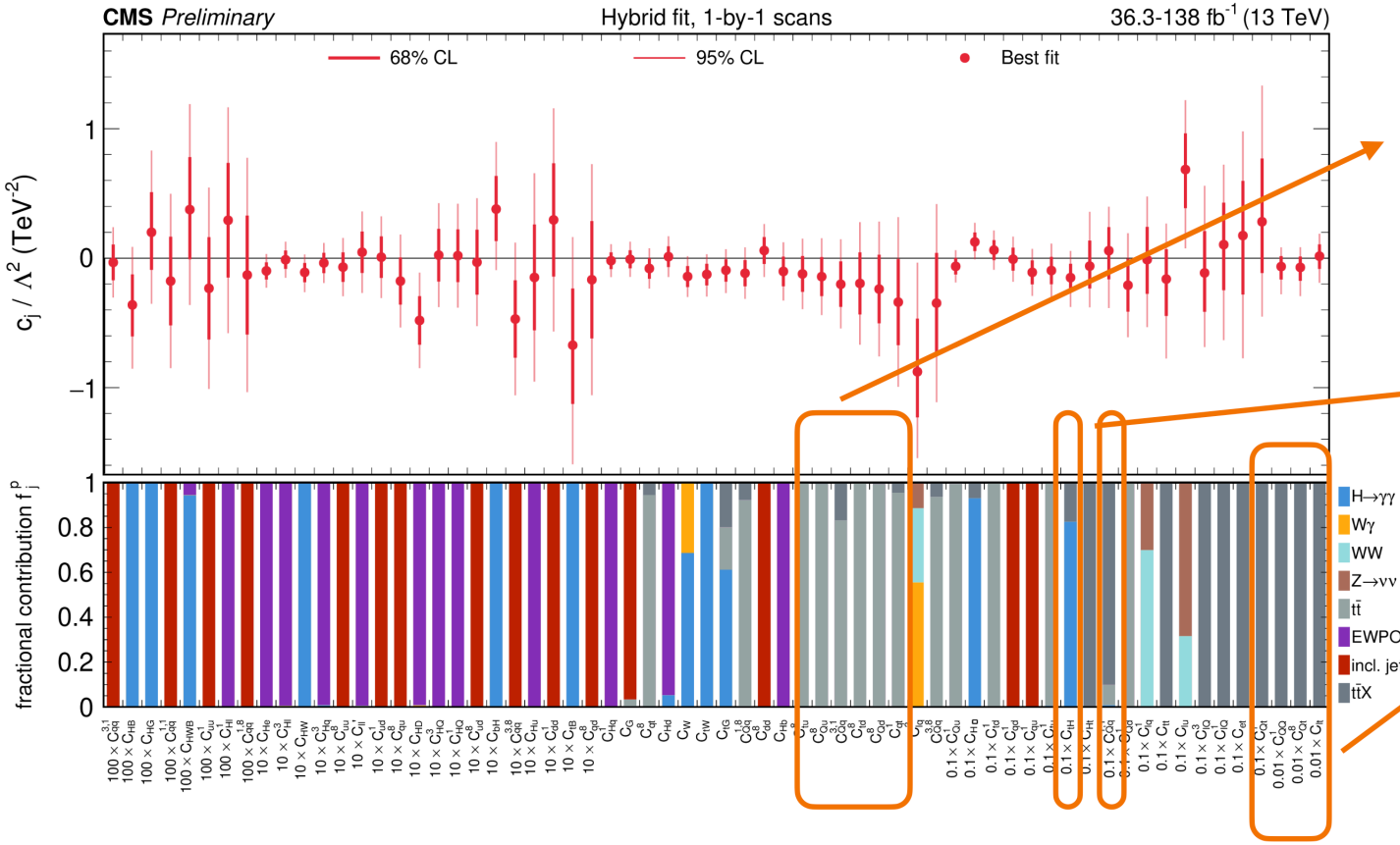
EFT based searches

Binbin Dong
ATLAS & CMS

SM Effective Field Theory (EFT) is a powerful tool to study effects from BSM phase space not directly accessible at the LHC.

$$\mathcal{L}_{\mathrm{EFT}} = \mathcal{L}_{\mathrm{SM}} + \sum_{d,i} \frac{c_i^d}{\Lambda^{d-4}} \mathcal{O}_i^d$$

EFTs induce effects in many channels, ideal framework for combination!



two-heavy-two-light operators constrained from a combination of $t\bar{t}X$ and $t\bar{t}$

Top-Higgs coupling sensitivity increased by combination of $t\bar{t}X$ and $H \to \gamma\gamma$

Sensitivity to 4-heavy operators from $t\bar{t}X$ only

Weakly supervised anomaly detection

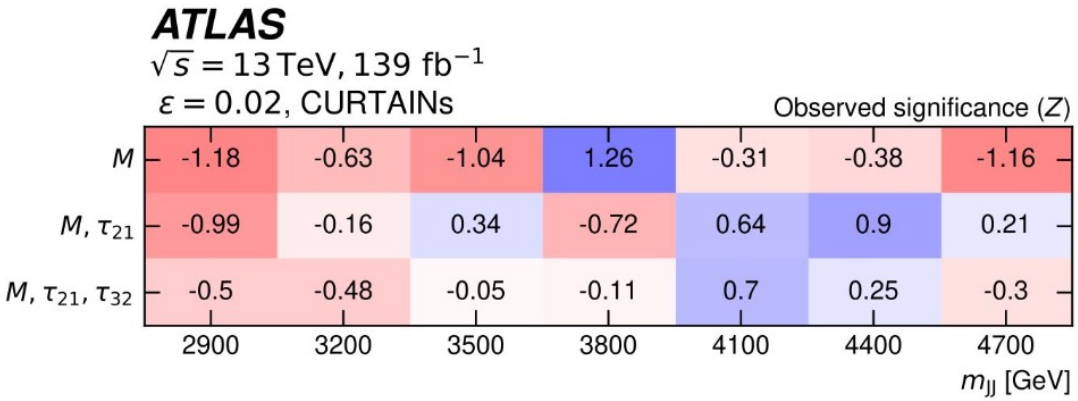
Marco Montella
(ATLAS / CMS)

Target Signature:

- pp → **A → BC**, A, B, C massive BSM resonances
- A, B decaying to SM quarks → Fully hadronic final state
- Adjacent to DiBoson (WW,WZ,ZZ) searches

Model Independent Search:

- ML application to "learn" the underlying distribution of key event features



No statistically significant deviation from the SM

Novel method and strategy, not trivial to digest all details and implications, both internally of experiments and in the community

Measurements driven by new techniques

Cristián Peña
Izaak Neutelings
(ATLAS / CMS)

- Unconventional signatures and new techniques enhance the LHC physics program

- Charm tagging: Pair production: $LQ\ LQ \rightarrow c\ \nu\ c\ \nu$
- Trigger is decisive on physics at LHC
  - ATLAS: Trigger level analysis
  - CMS: data parking / data scouting
- CMS 4 lepton resonance search boosted by merged-electron reconstruction
- Sophisticated techniques for background estimations
  - Extended ABCD
  - ABCDisCoTEC
- Search for dark matter (DM) with a light Z' enabled by narrow and low-hadron-multiplicity object ("pencil-jet")

YSF session (WED)

FACULTY OF MATHEMATICS AND PHYSICS
Charles University

IFIC
INSTITUT DE FÍSICA CORPUSCULAR

Couplings of axion-like particles in linear and chiral EFT realisations

with Maeve Madigan, Alexandre Salas-Bernardez, Veronica Sanz and Maria Ubiali

JHEP 09 (2023) 063 || arxiv:2303.17634
JHEP 10 (2024) 164 || arxiv:2404.08062

Fabian Esser
IPNP
Charles University Prague

Moriond EW
2025
26.03.2025

UNIVERSITY OF OXFORD

Rencontres de Moriond

ATLAS EXPERIMENT

Searches for direct slepton production in the compressed-mass corridor

Moriond Electroweak - 26/3/25

Based on the paper submitted to JHEP: arXiv:2503.17186

Alessandro Ruggiero (alessandro.ruggiero@cern.ch)
On behalf of the ATLAS collaboration

CMS

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

Search for dark matter with mono-Higgs signature

59th Rencontres de Moriond
Electroweak Interactions & Unified Theories
23rd - 30th March, 2025

Shivani Lomte (University of Wisconsin-Madison)
on behalf of CMS Collaboration

Rencontres de Moriond

H DM

Universität Münster

Encoding off-shell effects in top pair production in direct diffusion networks

Anja Butter[1,3], Tomáš Ježo[2], Michael Klasen[2],
Mathias Kuschick[2], Sofia Palacios Schweitzer[1] and Tilman Plehn[1]

1 Institut für Theoretische Physik, Universität Heidelberg, Germany
2 Institut für Theoretische Physik, Universität Münster, Germany
3 LPNHE, Sorbonne Université, Université Paris Cité, CNRS/IN2P3, Paris, France

living.knowledge

MORIOND EW 26.03.2025

Institut für theoretische physik

Searches at 4π

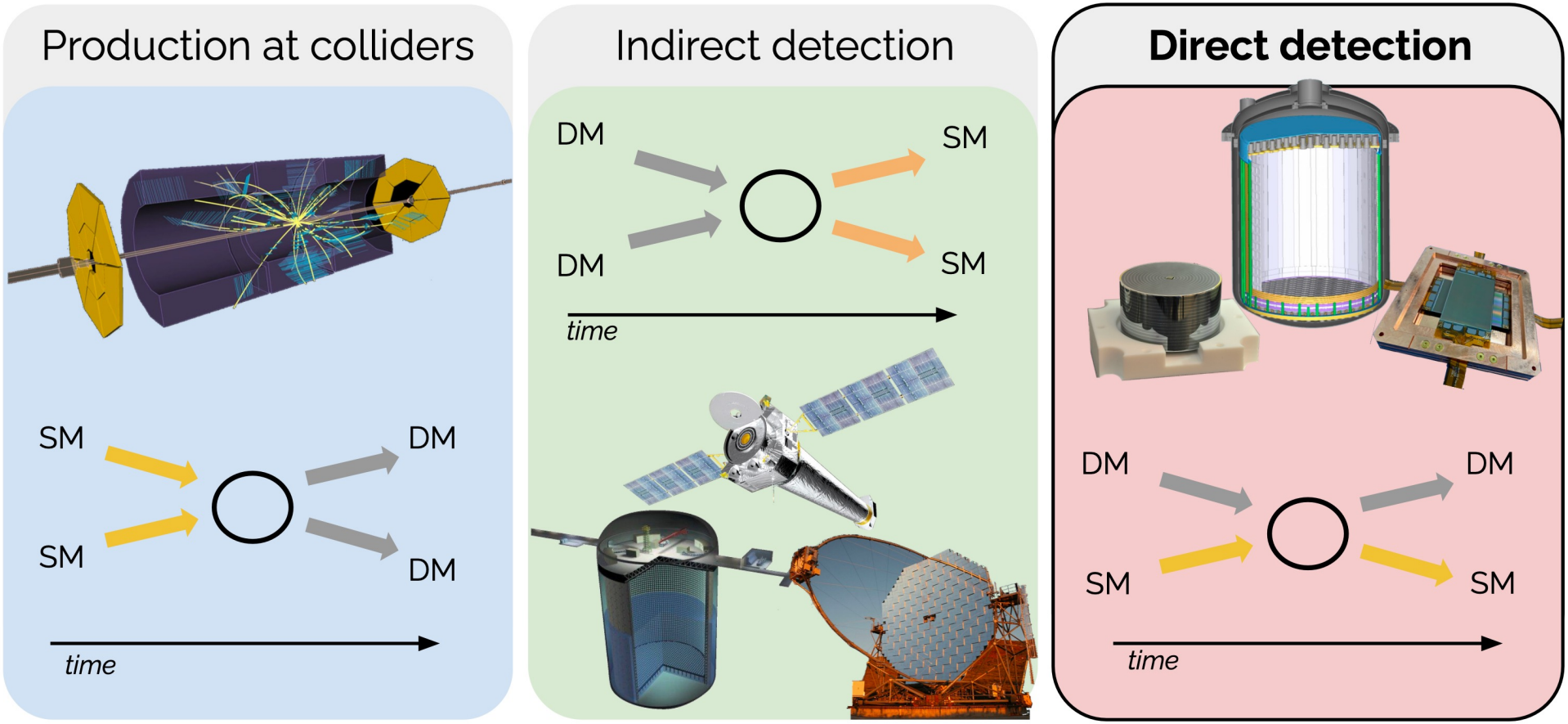
- Main strategy: leave no stone unturned
  - Impressive number of searches, complex analyses
  - Very large number of searches in large variety of topologies and models
  - Increasing number of analysis probing unusual/displaced signatures
  - Take home messages for LHC discovery potential:
    1-2 TeV level for most cases
    up to 5-8 TeV for non-resonant probes
- Special interest in motivated searches
  - E.g. from flavor anomalies
  - Or from excesses seen by other experiments
- Some excesses here and there seen (not yet significant)
  → stay tuned

Moriond Electroweak 2025

Part 4: Dark Matter, Axions and Cosmology

MONDAY24/03	TUESDAY25/03	WEDNESDAY26/03	THURSDAY27/03	FRIDAY28/03	SATURDAY29/03
C. Marin Benito	S. Stefkova	N. Ackerman	D. Litim	M. Schmaltz	A. Nigamova
S. Wang	J. Kamenik	A. Menegolli	S. Addepalli	A. Droster	M. Valli
S. Tri[illegible]opoulos	R. Manfredi	S. Urrea-Gonzalez	M. Nardecchia	D. Kaplan	H. Yin
L. [illegible]cklun	T.L. Pisc[illegible]	G. M[illegible]	C[illegible]ena	D. Leppla Weber	A. Trautner
S. Robertson	G. Ruggiero	F. Jörg	J. Zupan	V. Domcke	C. Vico
coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break
M. Reboud	G. Karathanasis	C. Englert	P. Ecker	C. Yèche	R. Wang
T. Martinov	J. Kleykamp	C. Pollard	A. Ibarra	M. Drewes	M. Stange
X. Pan	[illegible]	[illegible]	S. Eriksen	A. Chou	G. Boldrini
A, Juettner	T. Tashiro	C. Wa[illegible]	G. Perez	M. Mühlleitner	D. Camarero
Lunch	Lunch	Lunch	Lunch	Lunch	Lunch
P. Gironella	C. Hill	I. Neutelings	D. Redigolo	R. Hayes	E. Manca
R. Puthumanaillam	I. Esteban	K. Kowalska	C. De Dominicis	R. Chatterjee	T. Robens
M. Escudero	T. Lasserre	M. Montella	A. Ray	V. Miralles	F. Fabbri
A. Scarabotto	P. Decowski	J, Lizana	L. Di Luzio	T. Lenz	D. Pinna
coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break
V. S. Vobbilisettyi	V. D'Andrea	B. Donmg	R. Durrer	A. Taliercio	B. Fuks
YSF I M. Hartmann, G. Gaudino, A. Bansal, C. Lemettais, D. Suelmann. L. Paolucci	YSF II H. Birch, E. Lavaut, J.P. Pinheiro, N. Bhuiyan, M.I. Dias Astros, C. Girard-Carilho, R. Faure, A. Langella	YSF III A. Ruggiero, S. Lomte, M. Kuschick, T. Aoki, F. Esser	G. Yu E. Fernandez Martinez	Moriond discussion	E. Watton YSF IV Z. Wolls, D. Minh Hoang. H. Tiblom, E. Muhammad, D. Marckx
			Dinner		

How to detect dark matter?

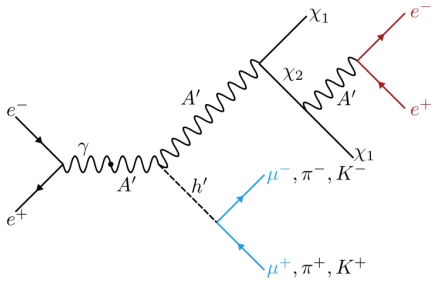


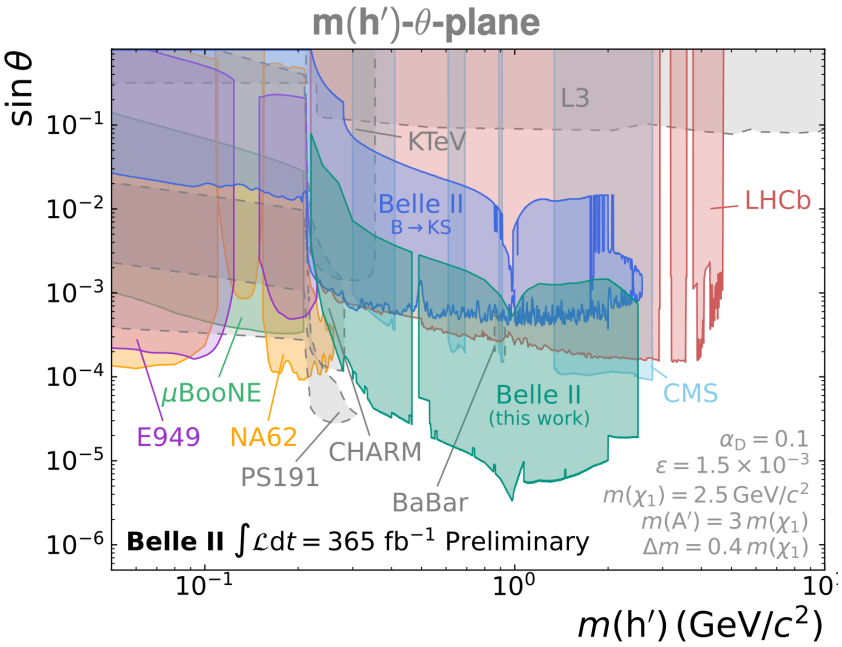
[Claudia De Dominicis]

Dark sector physics at Belle II

Patrick Ecker
(Belle 2)

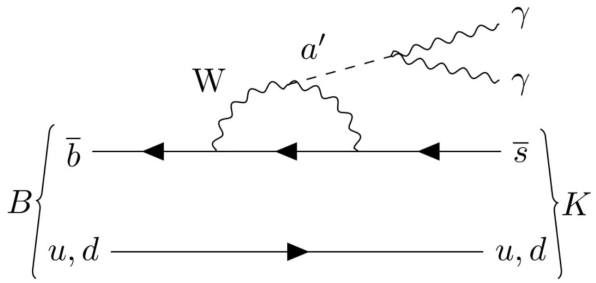
Dark Higgs + Inelastic DM

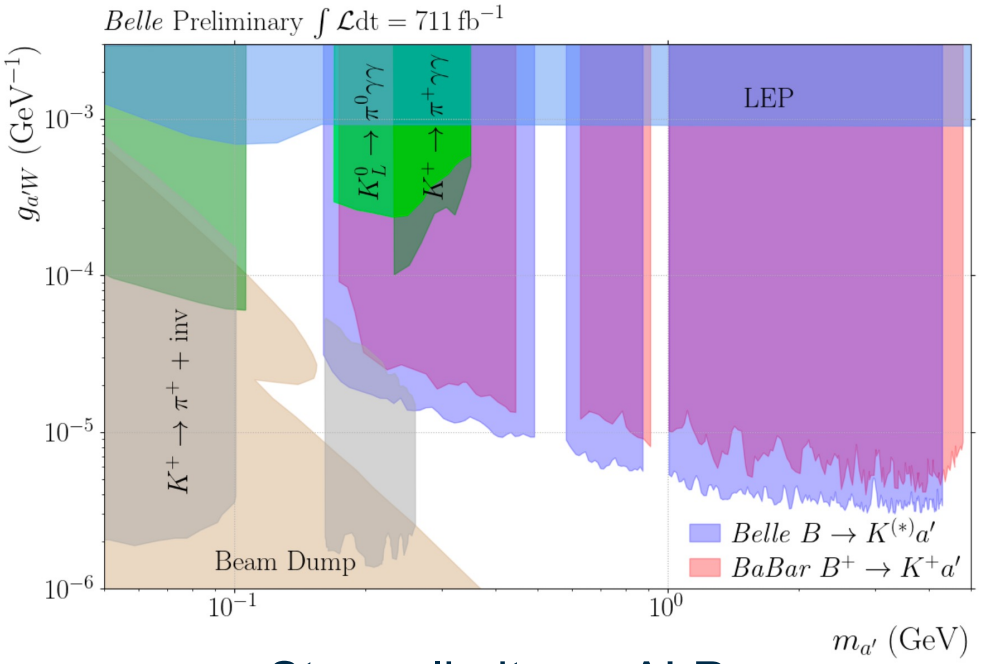




Strong limits, but model dependent

$B \to K^{(*)} a'(\to \gamma\gamma)$



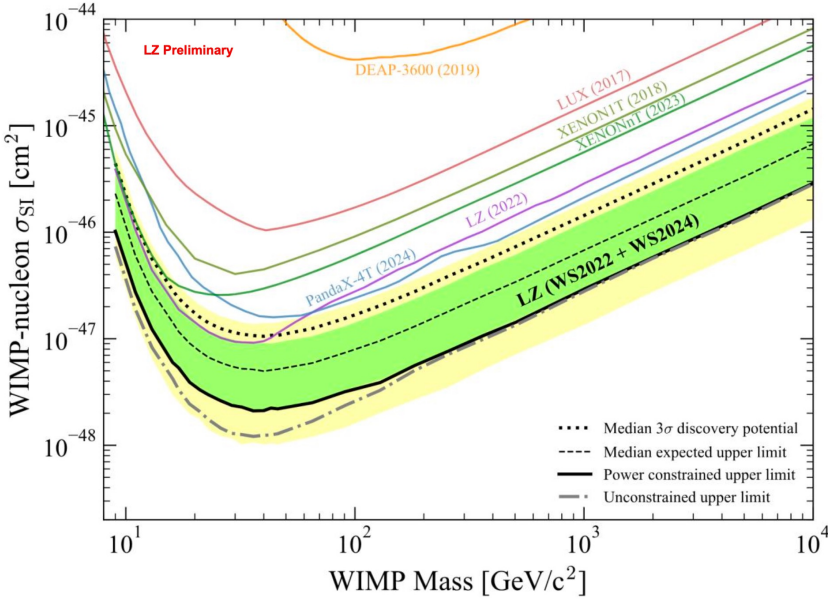


Strong limits on ALPs

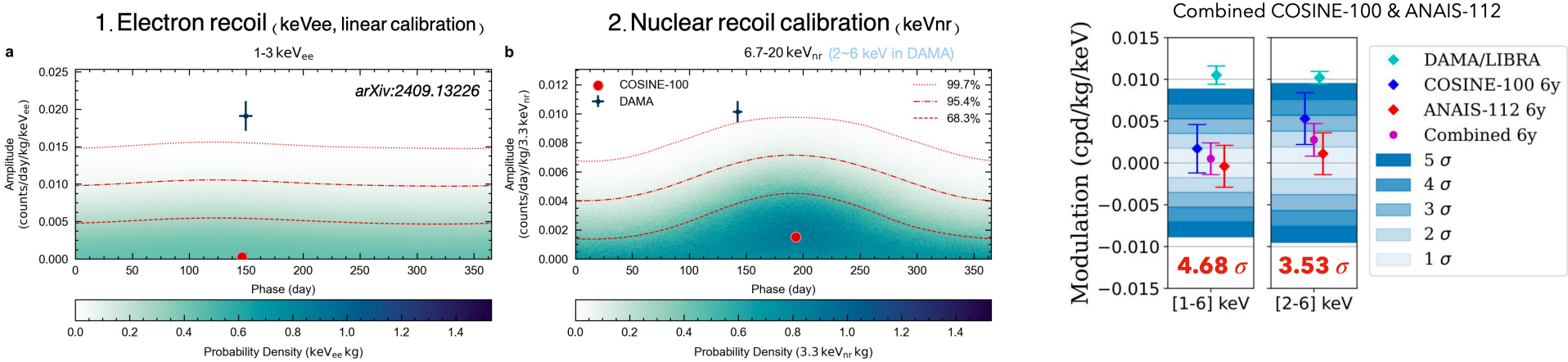
Weakly Interacting Massive Particles

Sam Eriksen. (Lux-Zeppelin)
Gyunho Yu (COSINE-100)

- WIMP direct detection
  - Lus-Zeppelin is the world's most sensitive WIMP direct detection
  - Experiment



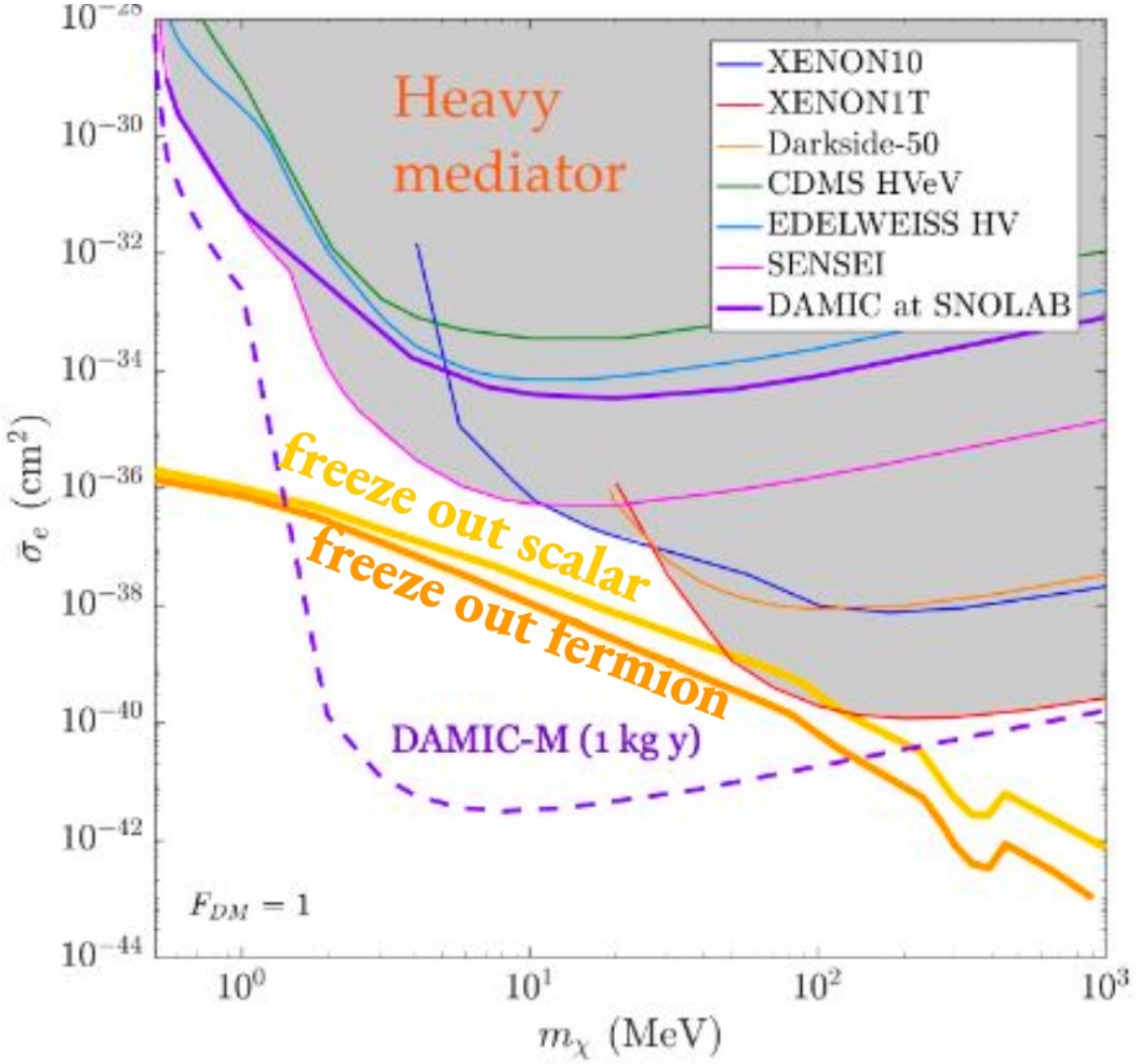
- WIMP Annual modulation

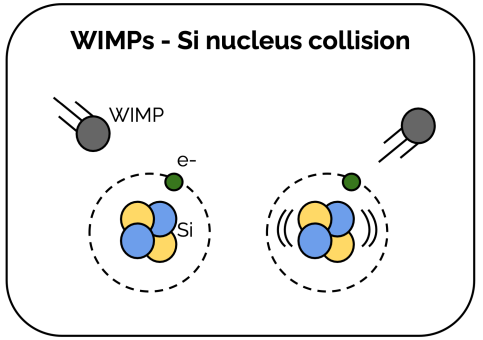


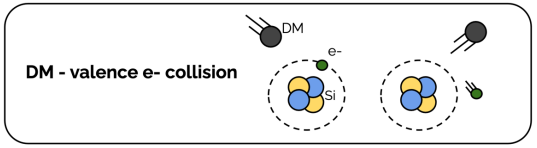
→ no modulation seen, DAMA strongly disfavoured - also with NaI(Tl)

Dark Matter In CCDs: DAMIC-M

Claudia
Dedominicis
(DAMIC-M)







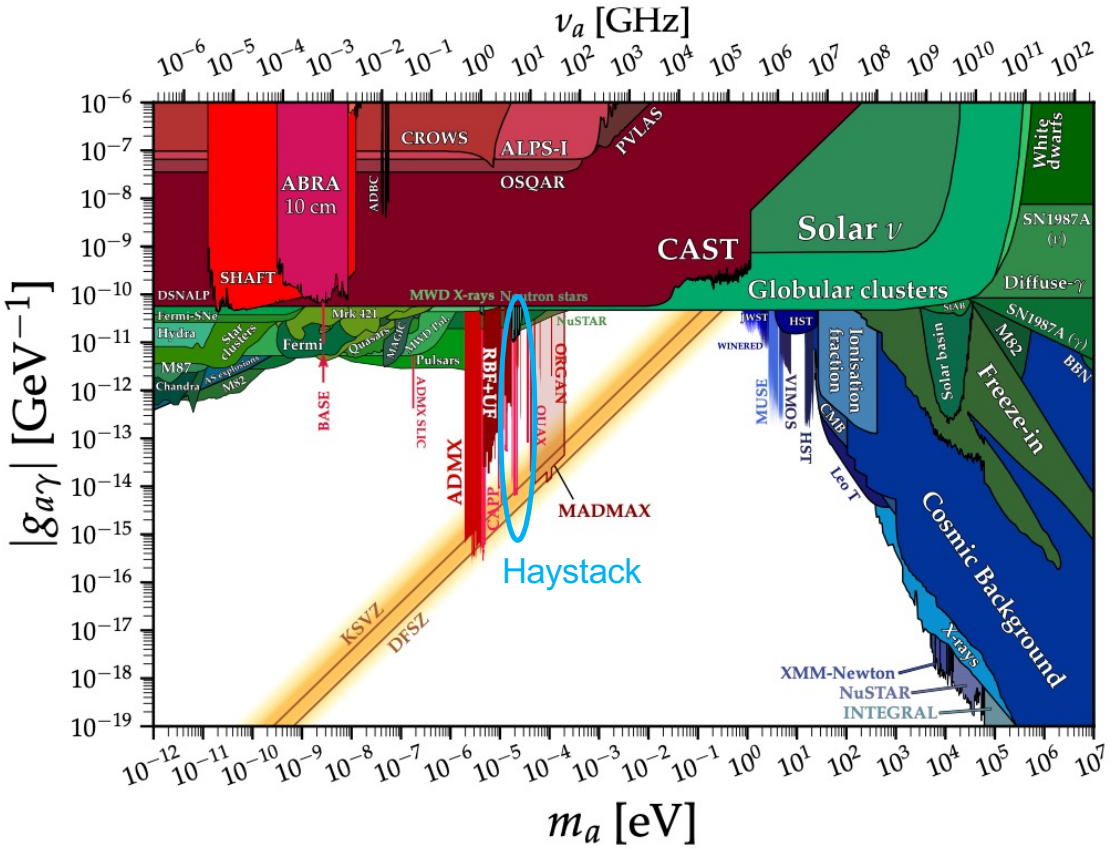
Strong exclusion limits on DM-electron interactions, exclusion of benchmark scenarios

Axion searches

Alex Droster (HAYSTACK)
David Leppla-Weber (MadMAx)

- Haystack
  - HAYSTAC has beaten the Standard Quantum Limit, achieving a scan rate enhancement of 2X.
  - Exciting synergy with quantum sensing

- MadMax
  - Dielectric haloscope looking for ~100μeV axions
  - Axion and dark photon search successfully performed with prototypes → already leading at their mass range

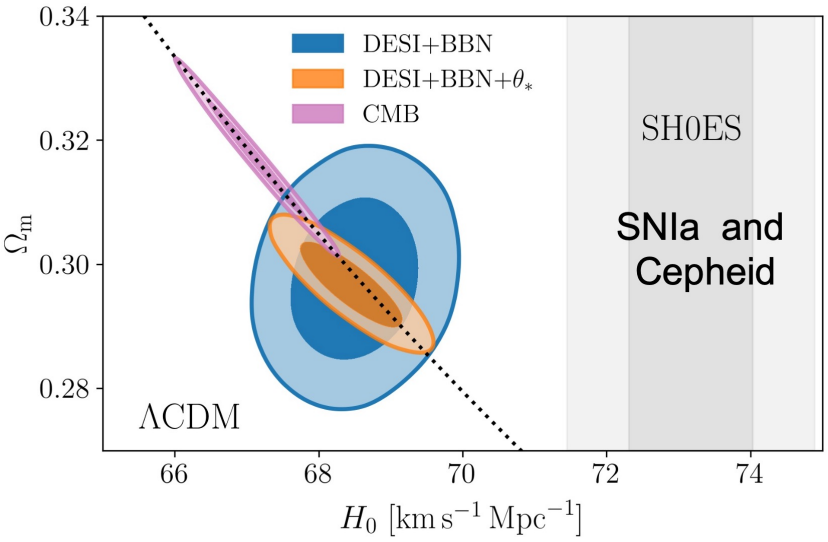


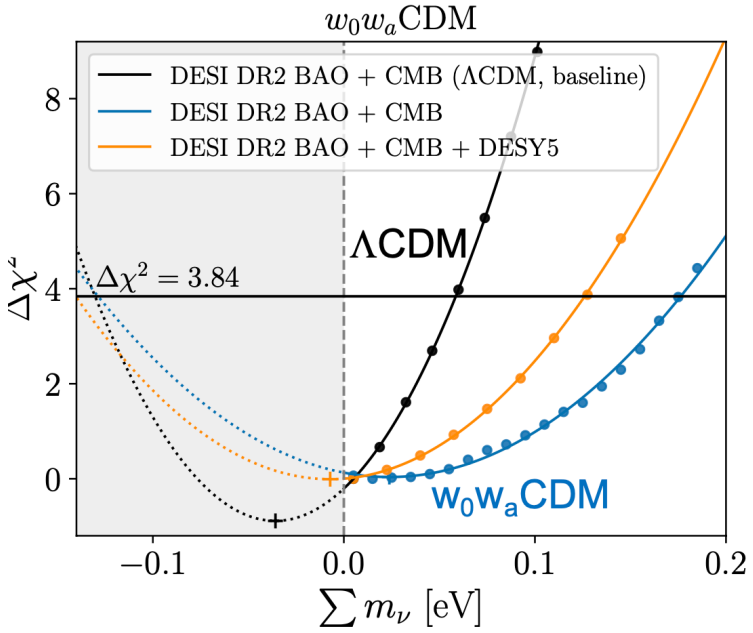
Dark Energy Spectroscopic Instrument

Christophe Yeche (DESI)

- Spectrographic astronomical surveys of distant galaxies
- DESI prefers lower Ω_m than CMB (~2.3σ)
- Indications of time-varying Dark Energy equation of state (2-4σ)
- CMB is sensitive to Σm_ν
  - $\Sigma m_\nu < 64\ mEV$
  - Relaxed model $\Sigma m_\nu < 130\ mEV$

→ This comes very close to region tested in neutrino experiments

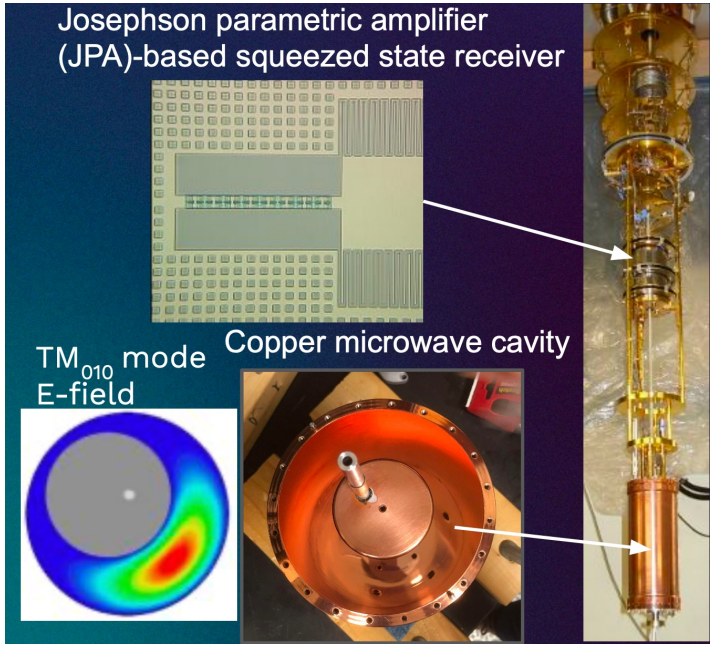




Quantum sensing

Aaron Chou
Alex Droster

- Quantum computing platforms resemble dark matter rexperiments
  - Cannot shield from dark matter, gravitational waves, other weakly-interacting particles.
  - Google quantum processor as a calorimeter



Haystack experiment

Quantum computer safely outside the MRI room

- Quantum sensors/tricks can do a great deal to improve SNR in axion searches, but ultimately, we also have to bring the hammer – larger magnets!

Summary: Dark Matter, Axions and Cosmology

Moriond Electroweak 2025

Part 5: Brout-Englert-Higgs and Standard Model

MONDAY24/03	TUESDAY25/03	WEDNESDAY26/03	THURSDAY27/03	FRIDAY28/03	SATURDAY29/03
C. Marin Benito	S. Stefkova	N. Ackerman	D. Litim	M. Schmaltz	A. Nigamova
S. Wa	J. [illegible]mchik	[illegible]olli	S. Addepalli	A. Droster	M. Valli
S. Trifinopoulos	R. Manfredi	S. Urrea-González	M. Nardecchia	D. Kaplan	H. Yin
L. Ecklund	M.L. Piscopo	G. Milton	C. Pena	D. Leppla Weber	A. Trautner
S. Robertson	[illegible]	F. Jörg	J. Zupan	V. Domcke	C. Vico
coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break
M. [illegible]ord	G. Karathanasis	C. Engel	P. Ecker	C. Yèche	R. Wang
T. Mar[illegible]v	J. Kley[illegible]	C. [illegible]	A. Ibarra	M. Drewes	M. Stange
X. Pan	D. Henaff	A. Teixeira	S. Eriksen	A. Chou	G. Boldrini
A, Juettner	T. Tashiro	C. Wang	G. Perez	M. Mühlleitner	D. Camarero
Lunch	Lunch	Lunch	Lunch	Lunch	Lunch
P. Gironella	C. Hill	I. Neutelings	D. Redigolo	R. Hayes	E. Manca
R. Puthumanaillam	I. Esteban	K. Kowalska	C. De Dominicis	R. Chatterjee	T. Robens
M. Escudero	T. Lasserre	M. Montella	A. Ray	V. Miralles	F. Fabbri
A. Scarabotto	P. Decowski	J, Lizana	L. Di Luzio	T. Lenz	D. Pinna
coffee-break	coffee-break	coffee-break	coffee-break	coffee-break	coffee-break
V. S. Vobbilisettyi	V. D'Andrea	B. Donmg	R. Durrer	A. Taliercio	B. Fuks
YSF I M. Hartmann, G. Gaudino, A. Bansal, C. Lemettais, D. Suelmann. L. Paolucci	YSF II H. Birch, E. Lavaut, J.P. Pinheiro, N. Bhuiyan, M.I. Dias Astros, C. Girard-Carilho, R. Faure, A. Langella	YSF III A. Ruggiero, S. Lomte, M. Kuschick, T. Aoki, F. Esser	G. Yu	Moriond discussion	E. Watton
			E. Fernandez Martinez		YSF IV Z. Wolls, D. Minh Hoang. H. Tiblom, E. Muhammad, D. Marckx
			Dinner		


Clearly, here we see some peaks
Z^0
H^0
$W^{\pm}$
?
?
t

Higgs and Standard Model

- **Robin Hayes:** Latest Higgs inclusive and differential cross section measurements
- **Rajdeep Mohan Chatterjee**: Latest Higgs property measurements
- **Tatjana Lenz**: Search for BSM Higgs
- **Hang Yin:** EW physics and LLPs at LHCb
- **Aliya Nigamova:** Higgs highlights at CMS
- **Angela Taliercio**: DiHiggs searches (HH, XH)
- **Carlos Vico Villalba**: Run 3 standard model cross section measurements
- **Rongkun Wang**: Diboson measurements
- **Max Stange**: ATLAS wildcard (Evidence for longitudinally polarized W bosons in the electroweak production of same-sign W boson pairs in ATLAS)
- **Giacomo Boldrini**: CMS wildcard (New results in multiboson production from CMS)
- **Daniel Camarero Munoz**: Triboson and VBS results
- **Elisabetta Manca**: W mass and related measurements
- **Federica Fabbri**: Top quark properties and mass measurements
- **Deborah Pinna**: t(t)+X cross section measurements
- **Elliot Watton**: ATLAS wildcard (Measurement of the top quark mass using tt events with a high transverse momentum top quark in ATLAS)

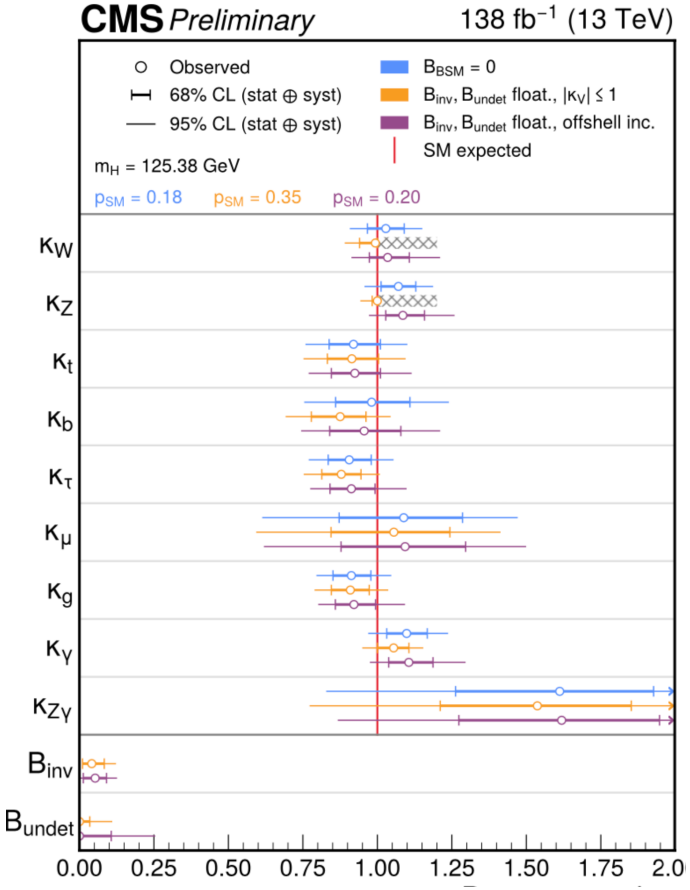
Enormous wealth of results, many new for MEW25

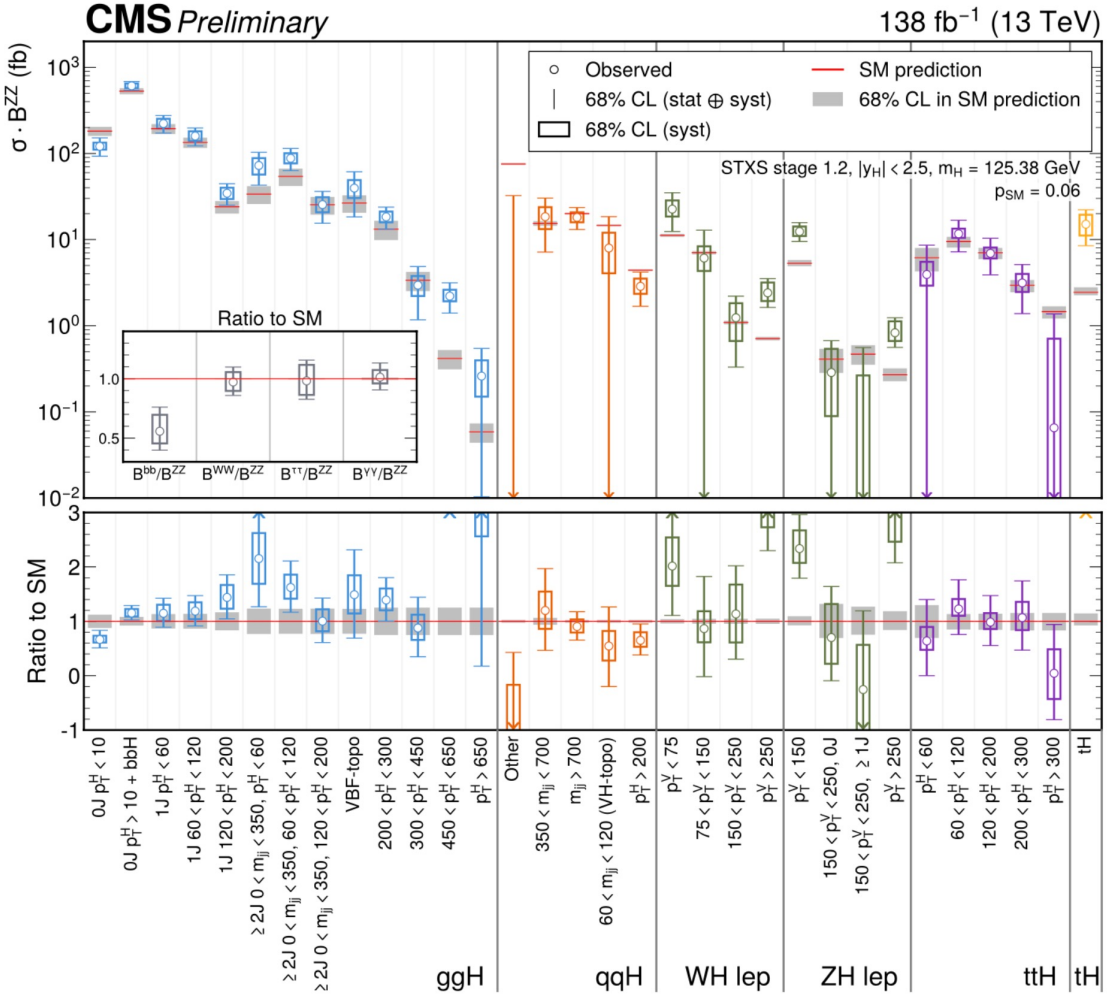
I will only manage to show some illustrative examples here

SM Higgs properties

H-team: ATLAS & CMS
Hayes, Chatterjee, Lenz,
Nigamova, Taliercio

- Precision tests of H^0 production and decays
- New CMS Higgs combination

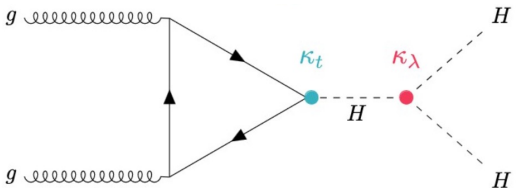


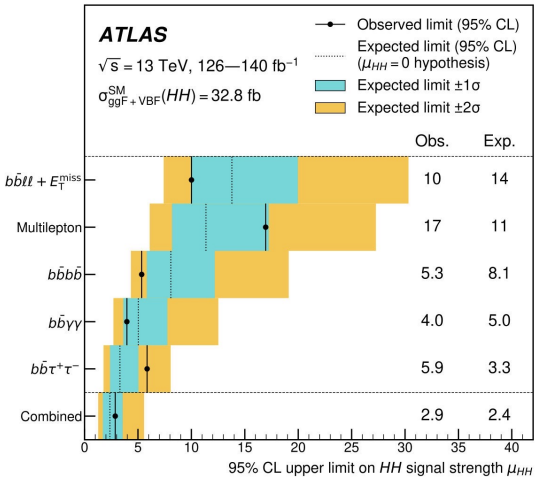


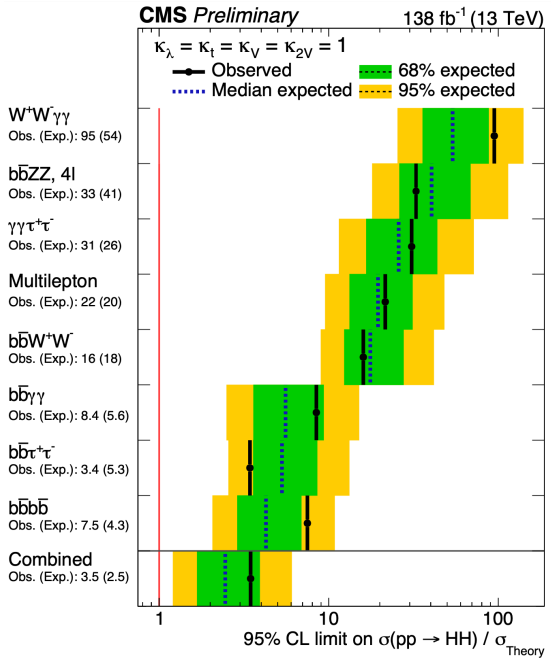
Precision Higgs fingerprint !

Higgs self coupling

H-team: ATLAS & CMS
Hayes, Chatterjee, Lenz,
Nigamova, Taliercio

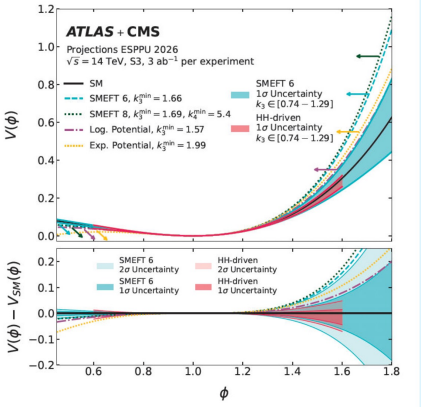






- Limit on HH cross section given
  - Golden channels: $4b, bb\gamma\gamma, bb\tau\tau$
  - Combination of both experiments at about 3 times SM expectation

- Extrapolations to 3/ab presented:
  - ATLAS: 4.5σ, CMS: 4.5σ
  - Combination: 7.6σ discovery (“S3 assumption”)



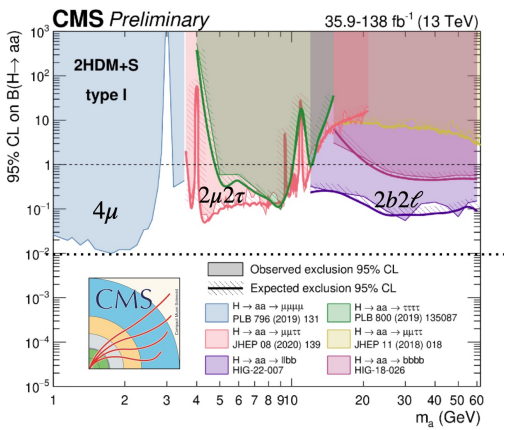
Additional Higgs bosons

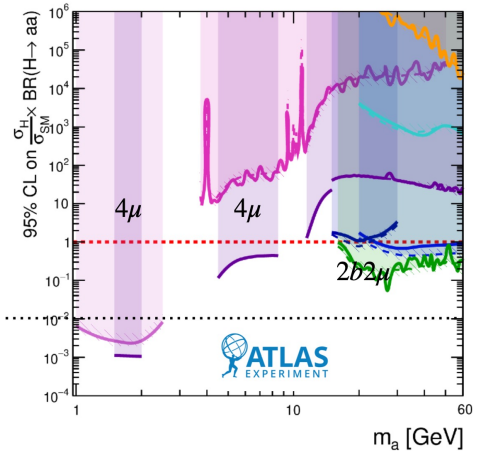
H-team: ATLAS & CMS
Hayes, Chatterjee, Lenz,
Nigamova, Taliercio

Many NP models predict additional Higgs bosons, many searches ..

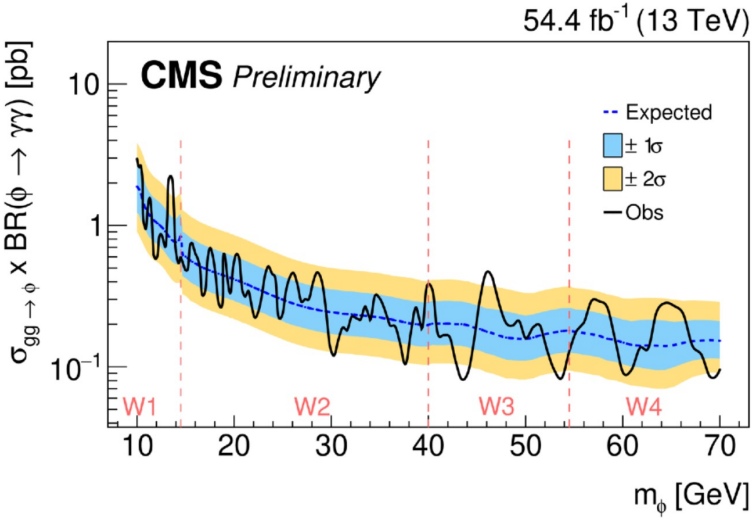
2HDM+S

95% CL on $\frac{\sigma(H)}{\sigma_{SM}} \times \mathcal{B}(H \to aa)$

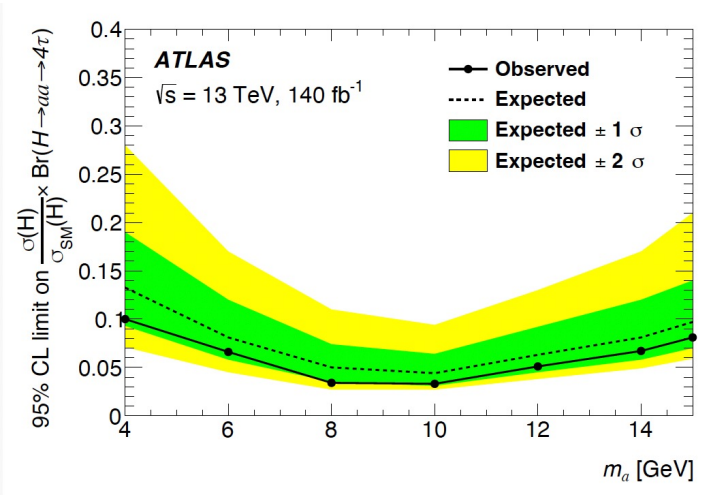




Low mass $H^0 \to \gamma\gamma$



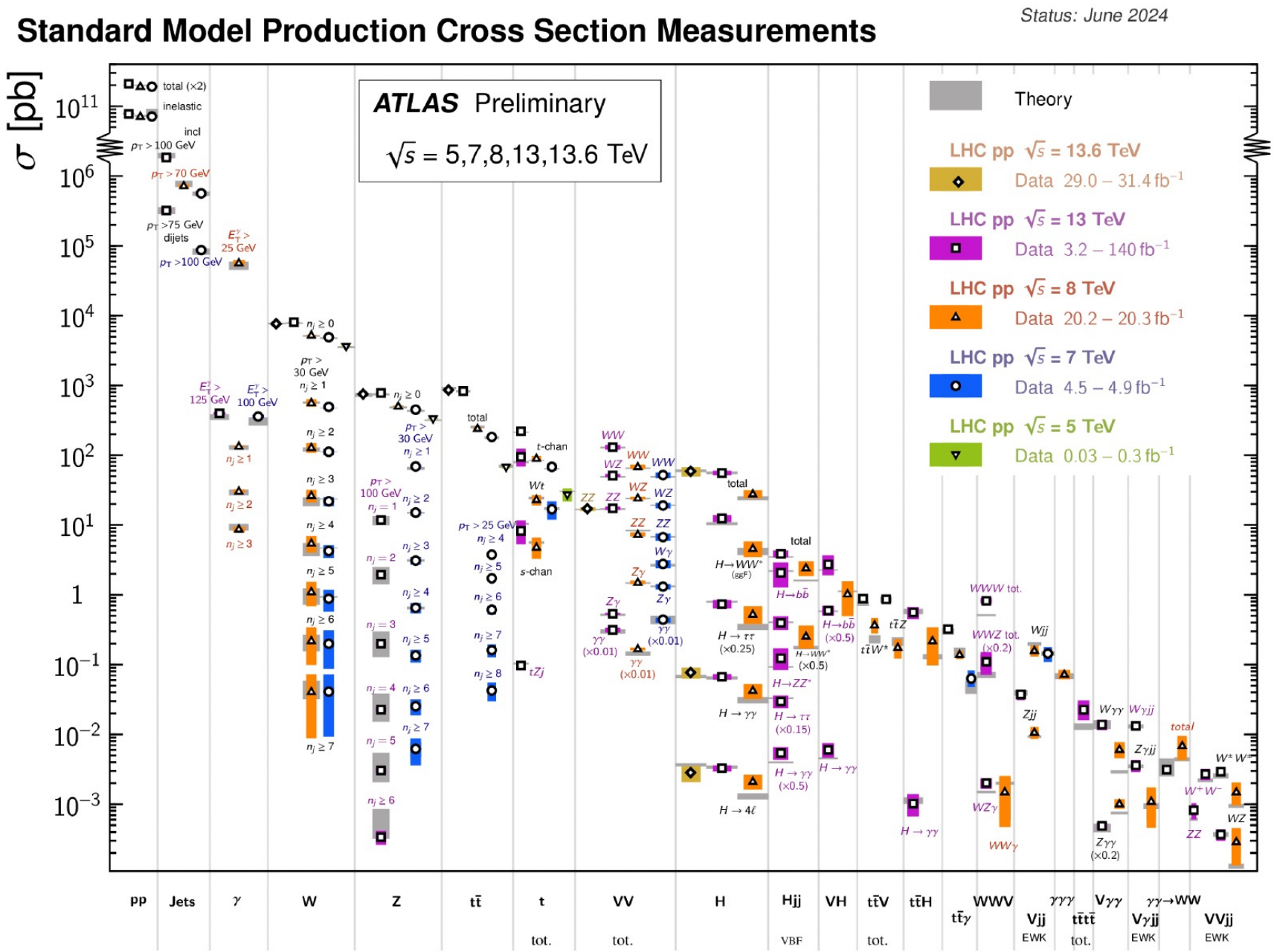
$H^0 \to aa \to 4\tau$



… and many many more channels!

Precision SM test with EW-Bosons

WZ-team: ATLAS & CMS
Wang, Stange, Boldrini,
Munoz, Manca

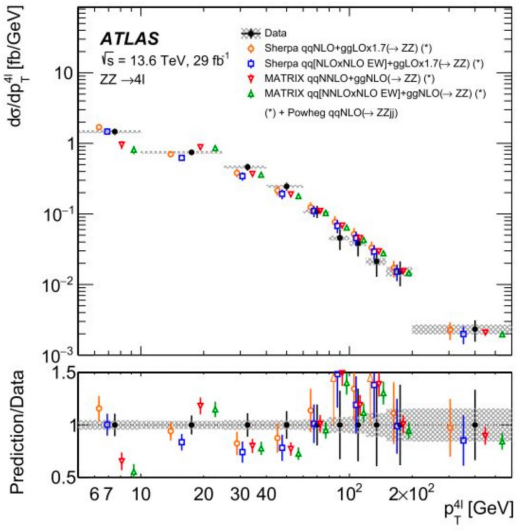


The SM also applies to Run 3

WZ-team: ATLAS & CMS
Wang, Stange, Boldrini, Munoz, Manca

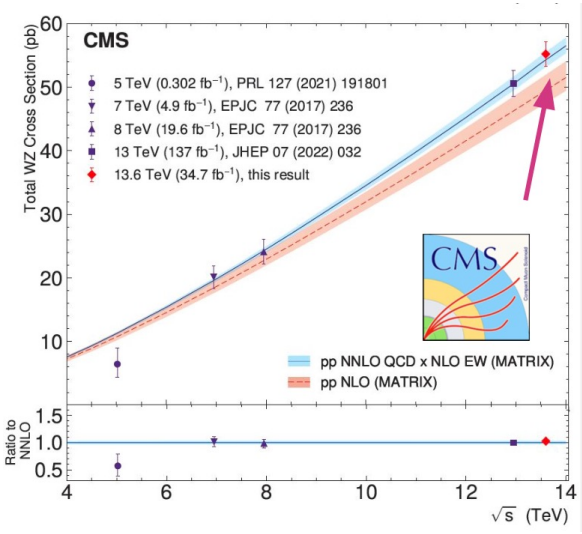
$Z^0Z^0 \to 4\ell$

ATLAS measures ZZ production using Run 3 data and a new slim data format



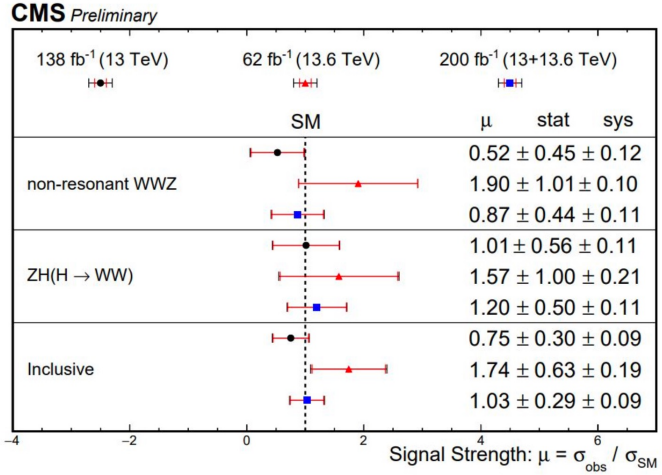
$W^{\pm}Z^0 \to 3\ell + \nu$

The heavyforce carriers at record energy



$W^{\pm}W^{\pm}Z^0 and\ Z^0H^0$

Cross section measurement of WWZ and ZH



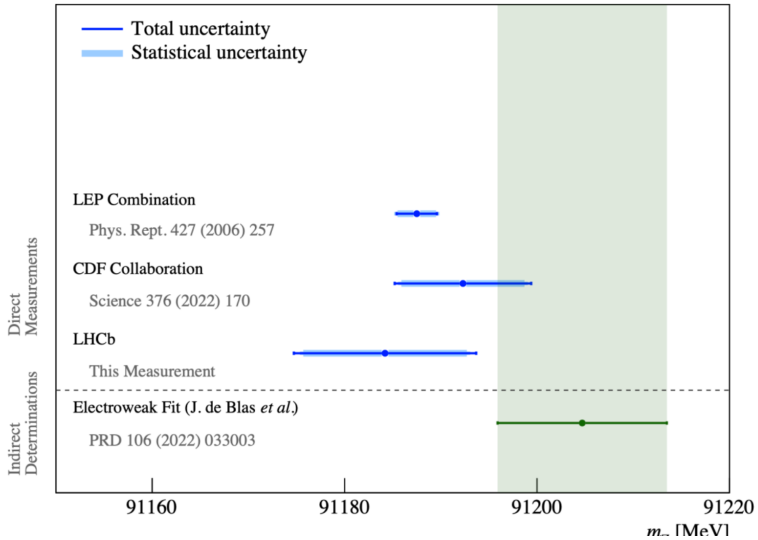
LHC collaborations are targeting the largest ever recorded dataset in HEP

Run 3 should be seen as a marathon race, not a sprint.

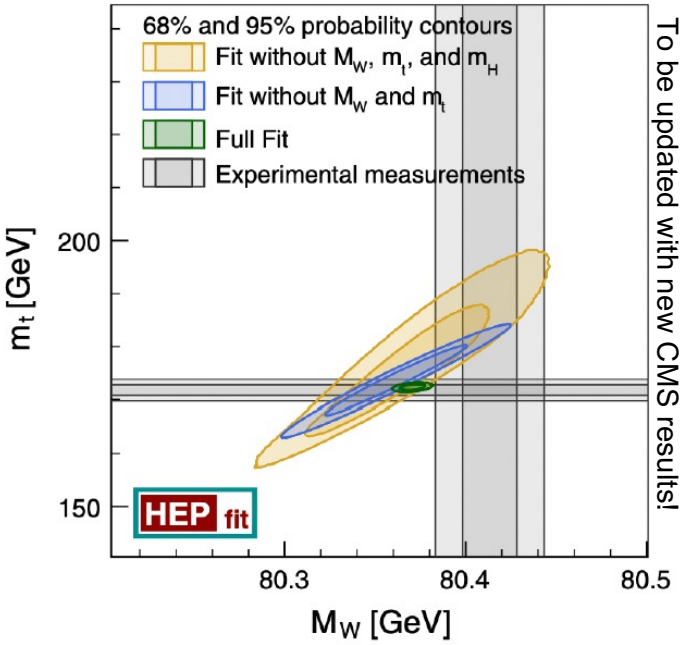
Weak boson mass measurements

WZ-team: ATLAS & CMS
Wang, Stange, Boldrini,
Munoz, Manca
Hang Yin (LHCb)

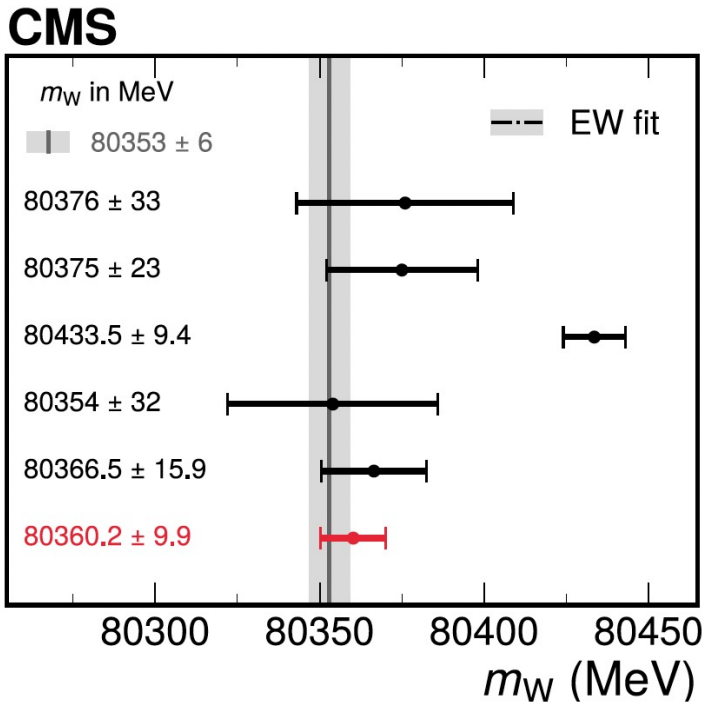
- LHCb measures Z^0 mass with 2016 data
  - First dedicated measurement of m_Z @ LHC
  - Reached the EW fit precision
  - $m_Z = 91184.2 \pm 8.5 \pm 4.3\ MeV$



- m_W measured at LHC

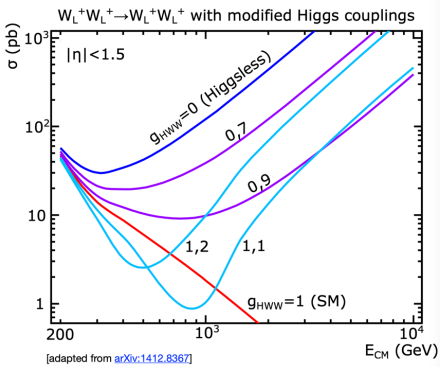


Electroweak fit
Phys. Rev. D 110, 030001
LEP combination
Phys. Rep. 532 (2013) 119
D0
PRL 108 (2012) 151804
CDF
Science 376 (2022) 6589
LHCb
JHEP 01 (2022) 036
ATLAS
Eur. Phys. J. C 84 (2024) 1309
CMS
arXiv:2412.13872, subm. to Nature

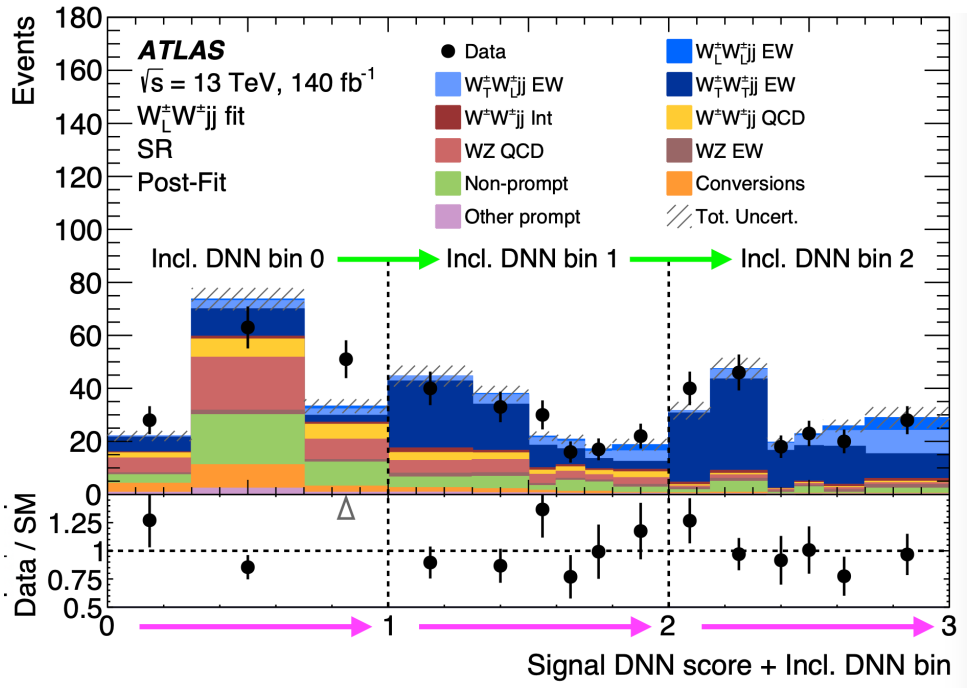


ATLAS Wildcard: W polarization

- Longitudinal $W_L W_L \rightarrow W_L W_L$ violates unitarity without SM Higgs
- Unique probe of electroweak symmetry-breaking

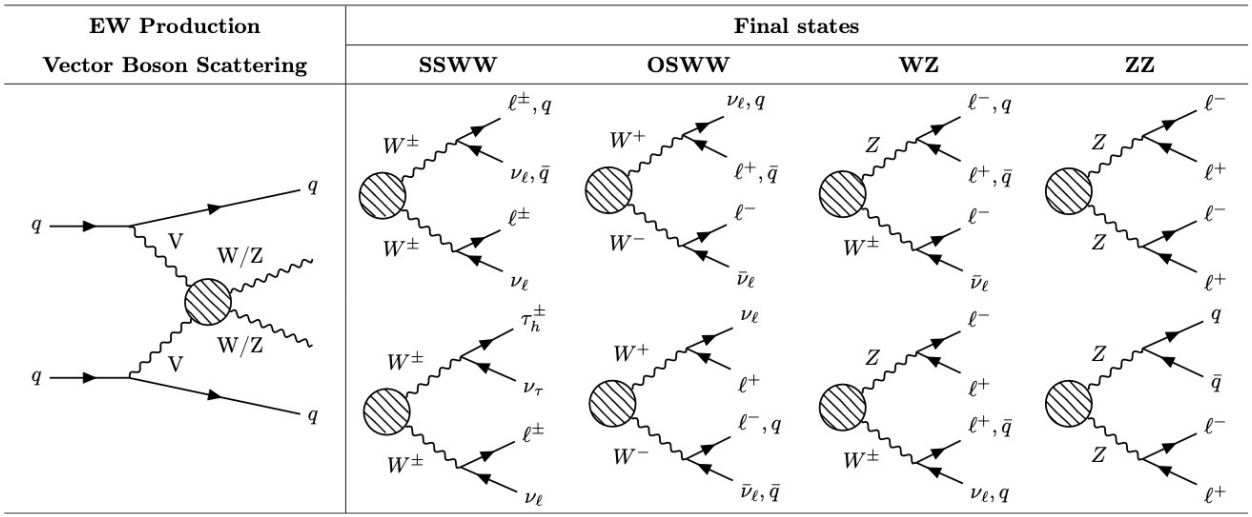


- W polarization states can be distinguished by angular analysis
- First evidence for longitudinal polarization in $W_L W jj$ with 3.3σ
- Limit on $W_L W_L\, jj$ of 0.45fb

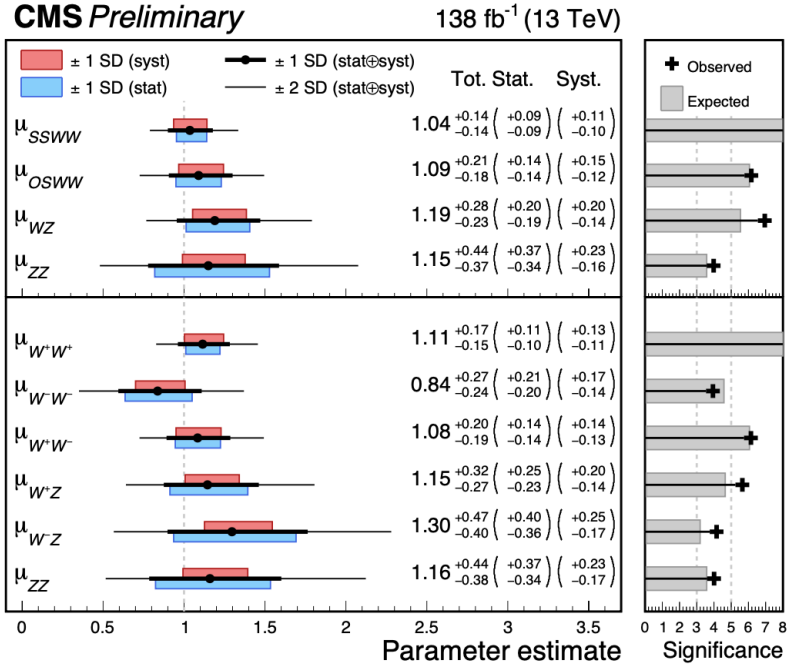


CMS Wildcard: VBS combination

Giacomo Boldrini
(CMS)



- CMS combination of Vector boson scattering data
  - 5-10% improvement on signal strengths. Evidence for all charged parameters
  - First step towards a global interpretation of VBS processes



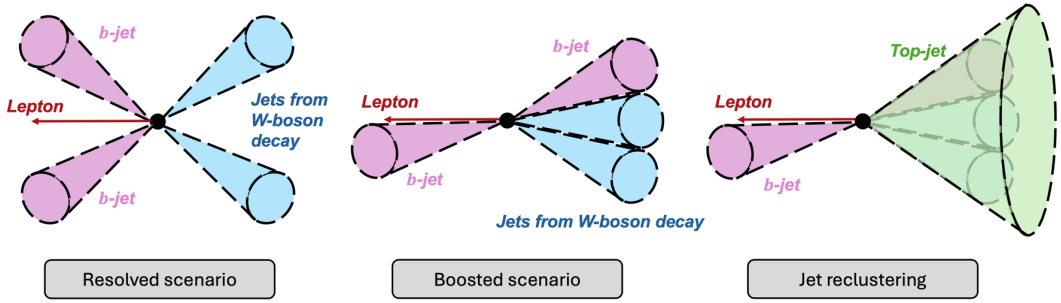
ATLAS wildcard: boosted top mass

top-team: ATLAS & CMS
Fabbri, Pinna, Watton

- Top mass important for via loop diagrams.
- Precision measurements of m_{top} provide information of electroweak parameters

- ATLAS Wildcard: top mass with boosted tops

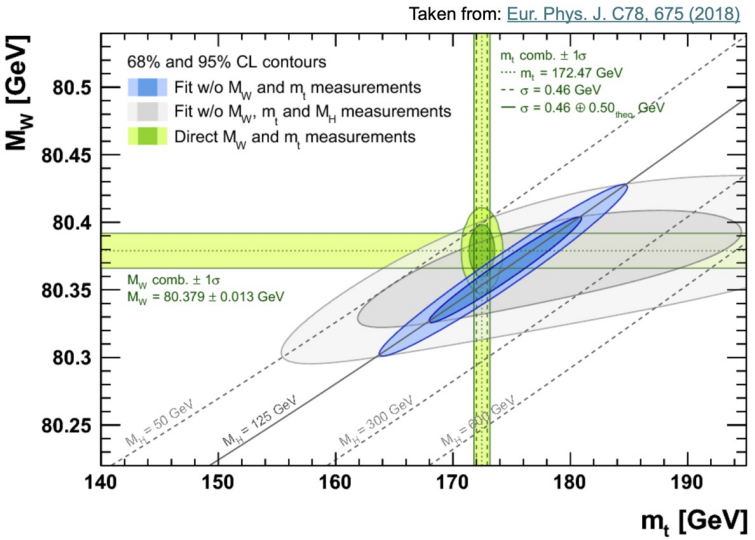
$$t\bar{t} \rightarrow W^+W^-b\bar{b} \rightarrow \ell\nu q\bar{q}'b\bar{b}$$

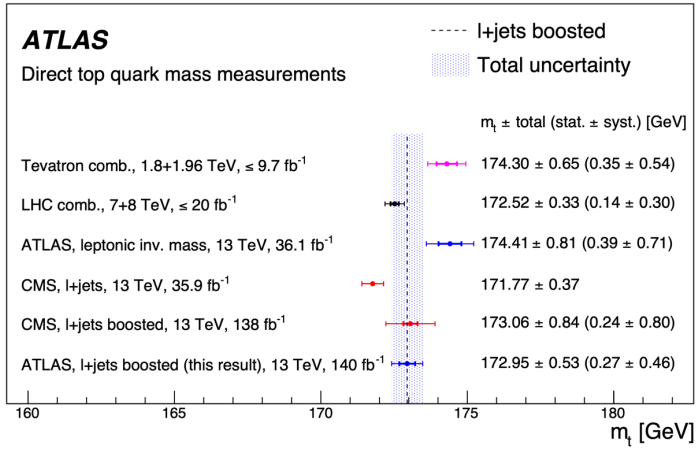


- Reconstruction of boosted signature reduces systematic uncertainty on m_{top}

- Most precise single ATLAS measurement
  $m_t = 172{,}95 \pm 0{,}53\ GeV$

Taken from: Eur. Phys. J. C78, 675 (2018)

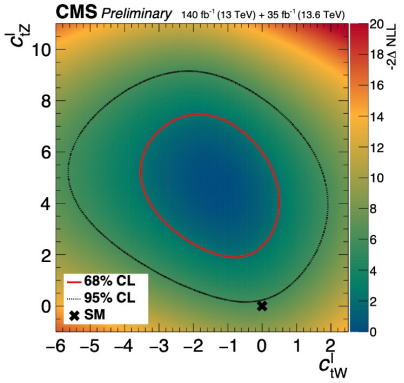




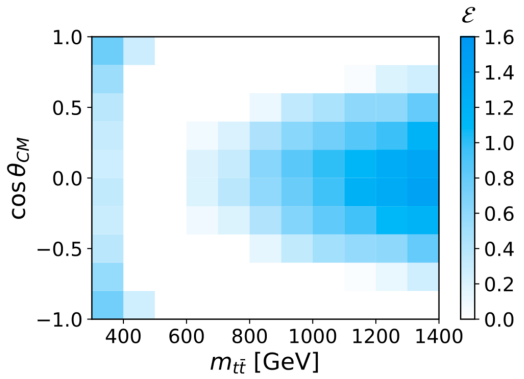
Top-fingerprint: phase and QC

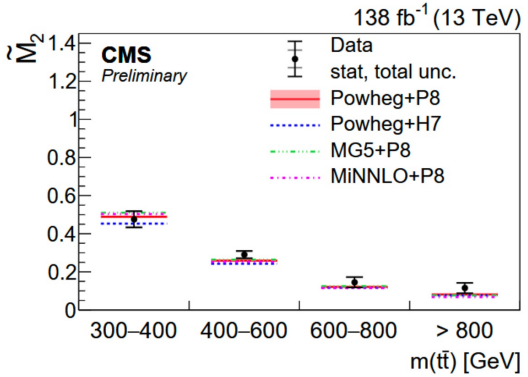
top-team: ATLAS & CMS
Fabbri, Pinna, Watton

- Test for CPV in tt+Z, t+Zq
  - CP-odd observables defined using physics-informed ML
  - Good agreement with SM: slight c^{I}_{tZ} asymmetry



- Top spin densitiy matrix analysis
  - Top-quark decays faster than spin decorrelation time
  - ATLAS and CMS measure entanglement stronger than expected
  - CMS shows first measurement of "quantum character of top-pairs"





YSF session (SAT)

Measurement of the Z boson mass with the LHCb detector

Emir Muhammad, on behalf of the LHCb Collaboration

29 March 2025 / Moriond YSF

European Research Council
Established by the European Commission

Photo by Gilbert Sopakuwa, CC BY-NC-ND 2.0

Flavor hierarchies and quark-lepton unification

Based on Greljo, Thomsen, Tiblom; [2406.02687]

Hector Tiblom

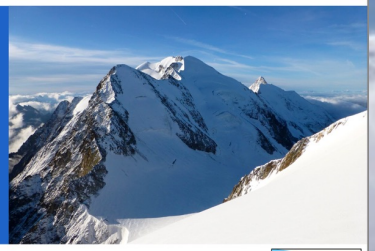
59th Rencontres de Moriond YSF
March 29, 2025

University of Basel

First differential ttW cross section measurement at CMS

David Marckx (Ghent University)
on behalf of the CMS collaboration

29/03/2025
Moriond/EW2025
La Thuile, Italy



GHENT UNIVERSITY

NEW CMS-PAS-TOP-24-003

CMS

Nikhef

CERN-EP-2025-059

The Higgs boson's lifetime measurement via off-shell decays to W-bosons

MoriondEW, 29-03-2025, La Thuile

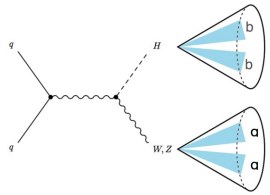
Zef Wolffs,
on behalf of the ATLAS collaboration
Nikhef, University of Amsterdam

University of Amsterdam

ATLAS EXPERIMENT

V(qq)H(bb) in the boosted Higgs channel

CMS-PAS-HIG-24-017



Duc Hoang (dhoang@mit.edu) for the CMS Collaboration

Recontres de Moriond Electroweak 2025

CMS

MIT

H^0, EW Bosons and top: Summary

- Run 2: new results with advanced techniques, NN, etc
- Combinations of Run 2 measurements
  - H + VBS combination shown
- Run 3 is becoming a significant dataset and new results are coming

Thank you

- I am honoured to have been invited to summarize MEW25
- The wealth of information and competence of the speakers was outstanding
- The progress in the field if obvious, but the loose ends are, too
  → great time to be a particle physicist!

It’s a pleasure to hand over to Laura to