WG3 Summary

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DIS2026 BOLOGNA

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In a nutshell

Muon performance

Z+jet

Weak mixing angle

Drell-Yan

Precision Electroweak

W mass

Zγ

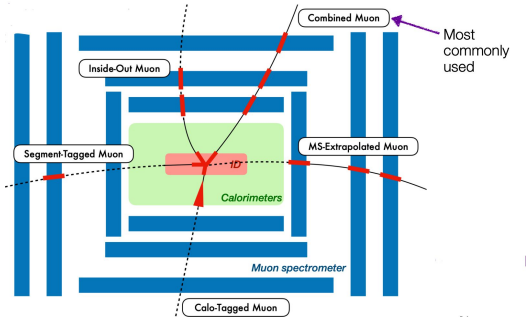
EW correction

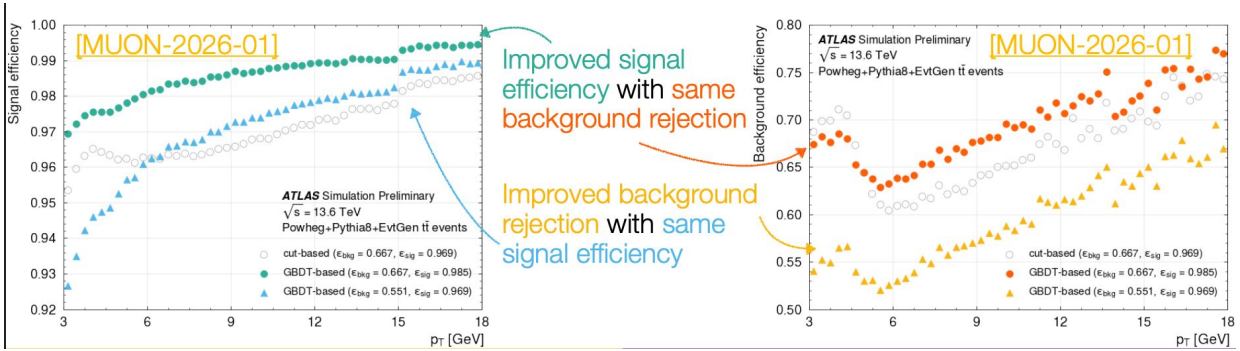
PDF uncertainty

Muon performance with ATLAS in Run 3

- Slides from Volker Austrup

- Good reconstruction performance crucial
- Precise understanding of muons in the detector required to correct for biases in data and simulation
- Machine-learning-based approaches allow further improvements in **identification** efficiency and **background rejection**





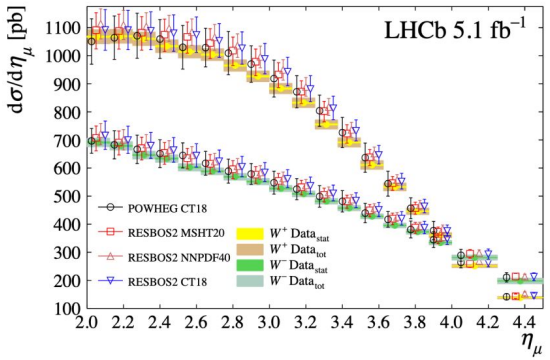
EW measurements at LHCb

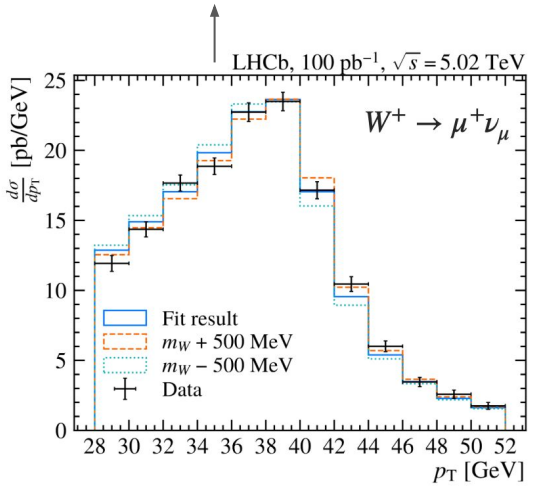
- Slides from Alisha Lightbody

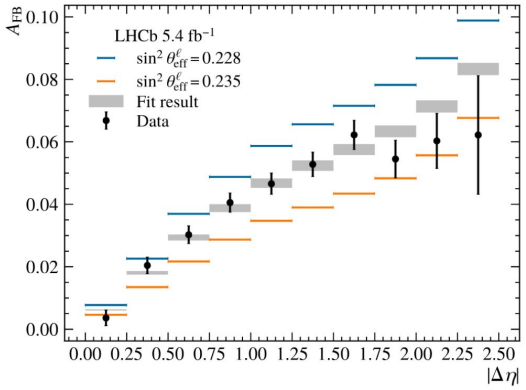
- LHCb plays a key role in EW with its complementary coverage from ATLAS and CMS
- Run3 Low-mass Drell-Yan measurement is ongoing, can go down to 3 GeV

First W mass measurement using unfolded $d\sigma/dp_{\mathrm{T}}$ fit

@13 TeV







$\sigma_{W^+\to\mu^+\nu} = 1754.2 \pm 1.5 \pm 11.9 \pm 35.1$ pb

$\sigma_{W^-\to\mu^-\bar{\nu}} = 1178.1 \pm 1.3 \pm 9.7 \pm 23.6$ pb

$m_W = 80369 \pm 130_{(\mathrm{exp})} \pm 33_{(\mathrm{th})}$ MeV

$\sin^2\theta^l_{\mathrm{eff}} =$

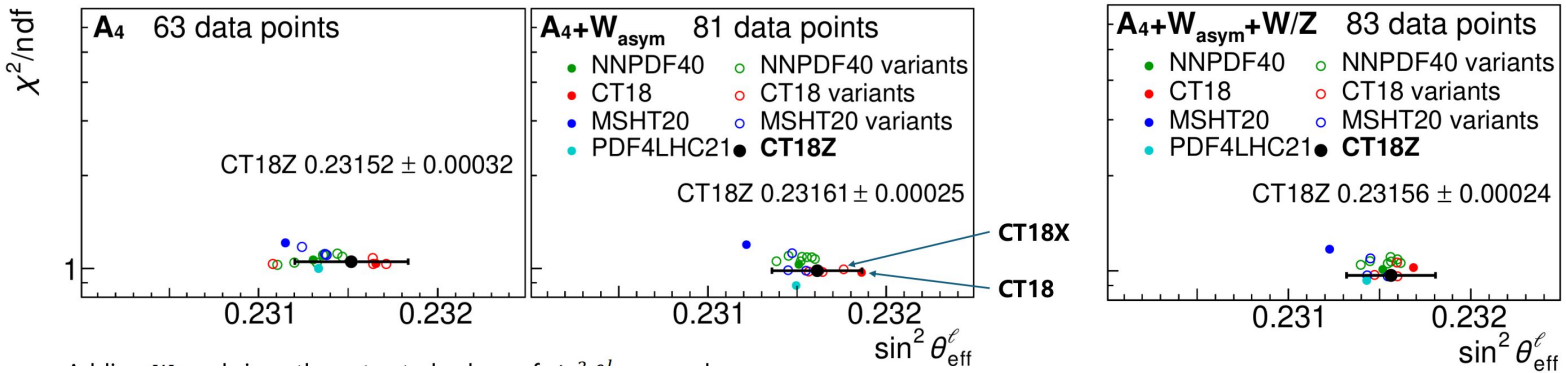
$0.23147 \pm 0.00044_{(\mathrm{stat})} \pm 0.00005_{(\mathrm{syst})} \pm 0.00023_{(\mathrm{th})}$

PDF uncertainty

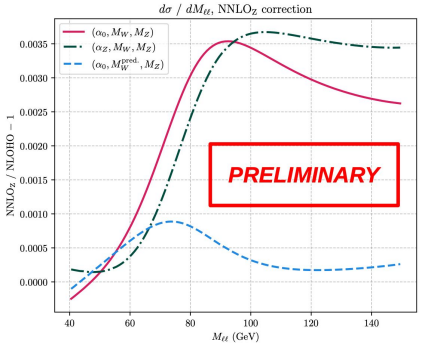
- [Slides from Hyon Ssan Seo]

- CMS 13TeV weak mixing angle result: 0.23152 ± 0.00031 (CT18Z)
  - PDF gives the largest uncertainty: 0.00027
- New analysis: extract weak mixing angle based on A4 measurements of CMS 13 TeV, with additional constraint on PDF from
  - CMS W charge asymmetry: help constrain d/u PDF
  - CMS W/Z cross section ratio for strange quark

$$\sin^2\theta^{l}_{\mathrm{eff}} = 0.23156 \pm 0.00024$$



Electroweak correction



- In the weak mixing angle measurement **different EW input schemes** lead to a spread in theoretical predictions at the order of 10^{-4} (comparable to the level of experimental precision)

- M. Chies: by incorporating higher-order universal fermionic corrections and achieving two-loop weak corrections at the Z resonance (Griffin), the theoretical spread can be reduced to the 10^{-5} level

- S. Devoto: The 2-loop amplitudes are one of the main bottlenecks for Drell-Yan process!
  - the implementation was successful, confirming that the inclusion of **NNLO corrections** significantly reduces the discrepancy between different coupling schemes from **12.7%** at tree-level to just **0.78%**

- Slides from Mauro Chiesa

Large computations ($\mathcal{O}(10^4)$ diagrams);
systematic bookeeping is a priority;
Treatment of γ_5;
how can γ_5 be consistently used in dimensional regularisation?
Additional internal **massive lines**;
*additional scales in the problem (m_Z, m_W, m_H…) bring additional complications, in particular **elliptic integrals**;*
Need for the **complex mass scheme**;
requires to analytically continue the master integrals on the complex plane!

ABISS *Private Mathematica package*

SEASYDE *Public Mathematica package*

- Slides from Simone Devoto

Z+jet and Zγ

B. Duch: performed an exact calculation including the full mass dependence for both electron and quark and identified the leading Coulomb correction, and the framework allows the quark mass to be set to zero

- results can directly used as building blocks for describing electron-quark scattering processes in deep inelastic scattering

- Slides

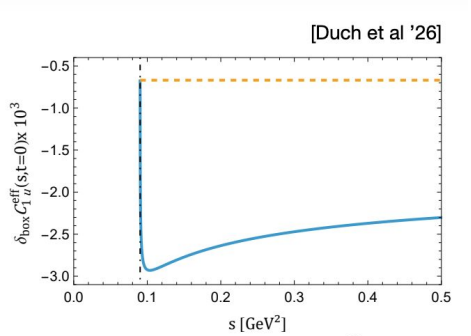
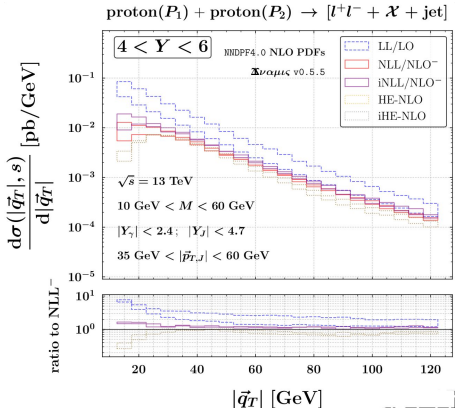


Figure 2: The box-graph corrections $\delta_{box} C_{1u}^{eff}(s, t = 0)$ as a function of the Mandelstam variable s, evaluated at fixed $t = 0$ for a quark mass of $m_q = 0.3$ GeV. The orange dashed lines show the value of $\delta_{box} C_{1u}$ at threshold $(s \to (m_q + m_e)^2)$.

F. Celiberto showed his team utilized the JETHAD-Dynamis framework to effectively match high-energy resummation at NLL accuracy with standard fixed-order NLO calculations

- this approach enables a precise analysis of the angular structure and polarization of the Z boson when it is produced in association with a jet

- Slides



Rare processes

Di-boson

Multiboson

Spin

Polarization

VBS

Tri-boson

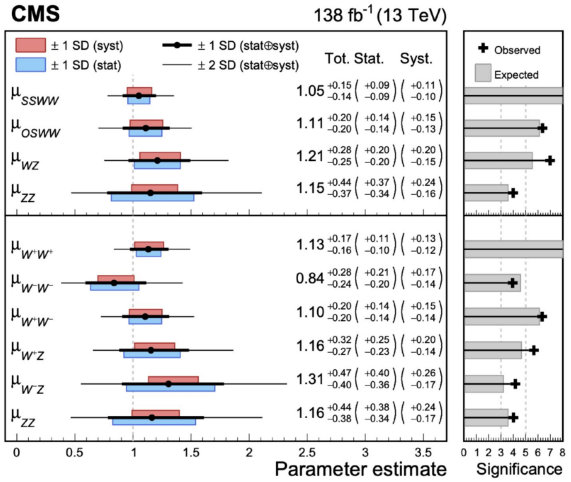
Experiment

Rare processes & polarization information
→ improved BSM sensitivity

CMS

- Slides from Tianyu Mu

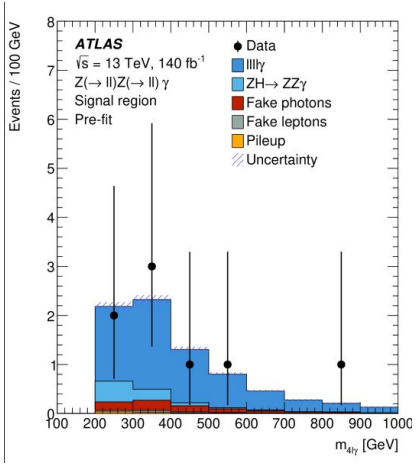
- WW & WZ cross section measurements @ 13.6 TeV
- Zγ measurements & nTGC/SMEFT interpretation
- **First evidence of ZZγ production 3.7(3.0)σ**
- WWZ/ZH @ 13/13.6 TeV
- VBS ZZ (13 TeV), $W^{\pm}W^{\pm}$ & WZ (13.6TeV)
- **VBS Run 2 combination**
  - Input to future combined interpretations



ATLAS

- Slides from Alain Bellerive

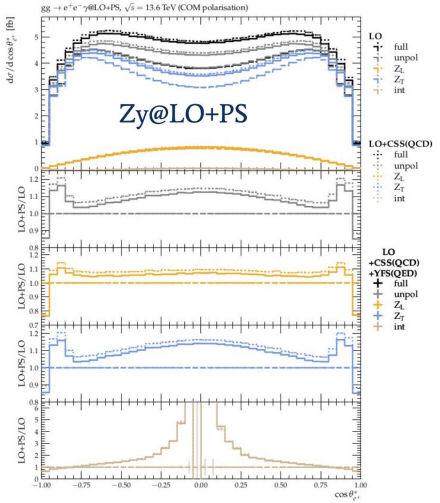
- Differential Wγ measurements & **EFT interpretation**
  - polarization-sensitive observables
- ZZ & ZZjj in ll**νν** channel & EFT interpretation
- **First (ATLAS) 4.6σ evidence of ZZγ production**



Theory: polarisation & more amplitudes

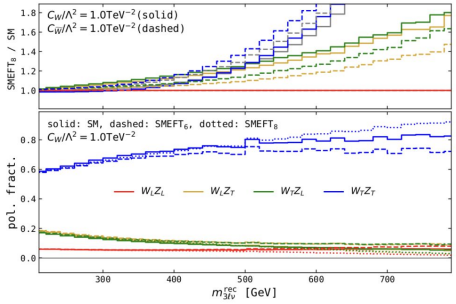
M. Hoppe shows recent developments of **vector boson polarization** modeling with SHERPA, incorporating - Slides

- loop-induced processes @ LO+PS
- full NLO polarized corrections in the NWA scheme
- New physics-motivated ML-observable for polarization measurements



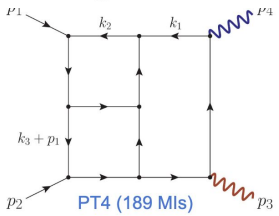
G. Pelliccioli: Charting **the spin structure of WZ events** - Slides

- Polarized templates: implementation NLO fixed order, NLO+PS, and SMEFT
- Enables quantum tomography in diboson final states (Qutrit)
- Develop EFT validity tests based on well defined density matrix



D. Canko reports the computation of all planar three-loop four-point master integrals with two off-shell legs in the leading color approximation, providing essential theoretical components for **diboson production at N3LO QCD**

- Slides



Yukawa coupling

Single top

$|V_{cb}|$

$t\bar{t}$

Mass

Top quark

Toponium

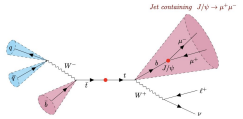
Charge Asymmetry

Rare production

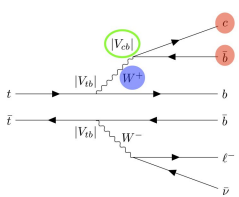
EFT

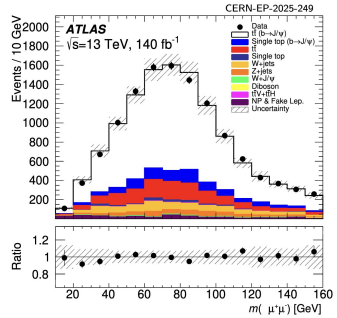
Entanglement

Production & properties



$m_t = 172.17 \pm 0.80(\text{stat}) \pm 0.81(\text{syst}) \pm 1.07(\text{recoil})$ GeV





ATLAS

- Slides from Alberto Pardes

- **Top mass from purely leptonic method using J/$\psi \rightarrow \mu^+\mu^-$ ->** reduced jet systematics
- Top quark pole mass from dileptonic tt̄ + jet events
- First measurement of $|V_{cb}|$ at the weak scale (in t tbar events)
- EFT constraints from angular decay rates in single-top t-channel

$|V_{cb}| = (50^{+11}_{-14}) \times 10^{-3}$

excluding by 5 s.d.

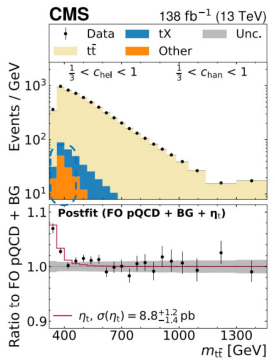
Observed significance: 6.1 σ

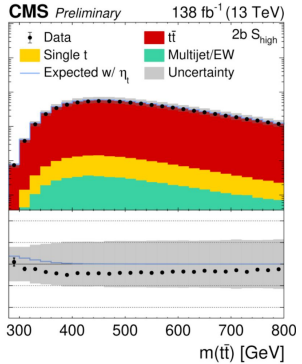
CMS

- Slides from Javier Cuevas

- **t-channel single top @ 5.02 TeV**
  - competitive uncertainties despite tiny luminosity
- tt̄+j Charge Asymmetry, no significant deviation
- Quantum properties of ttbar events
- **Threshold excess: Toponium?**
  - spin correlations crucial to confirm excess
  - significant excess in data at the tt̄ threshold

in both dilepton channel and in the lepton+jets channel



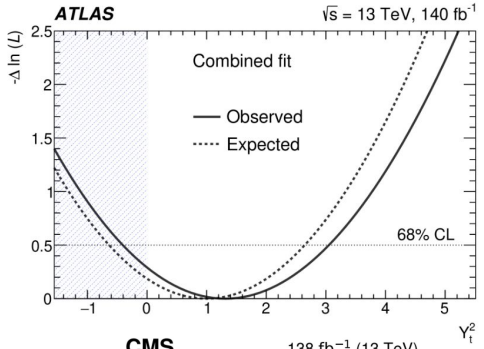


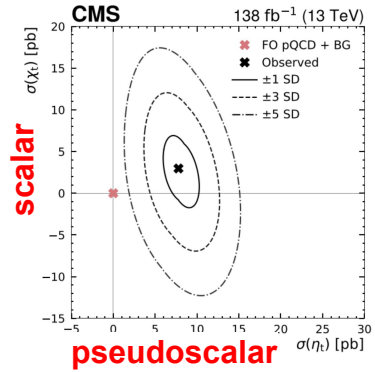
Top pair threshold

ATLAS

- Slides from Nello Bruscino

- Observed **> 5σ excess** at the threshold and behaving like spin-singlet toponium
- Deriving the top **Yukawa coupling constant** from the exchange of virtual Higgs bosons in t tbar events near the threshold region
- Very precise inclusive, fiducial, and differential tt̄ cross section measurements in leptonic observables
- Off-shell: dileptonic & semi-leptonic measurement of WbWb

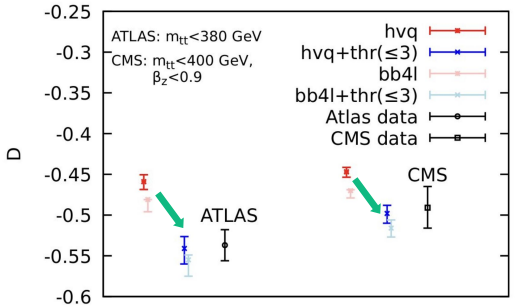




E. Re:

- “Toponium” contribution to cross section arises at N3LO
- **Alleviate tensions by proper inclusion of threshold effects**
- Is it premature to claim observation of pseudoscalar state?

- Slides from Emanuele Re

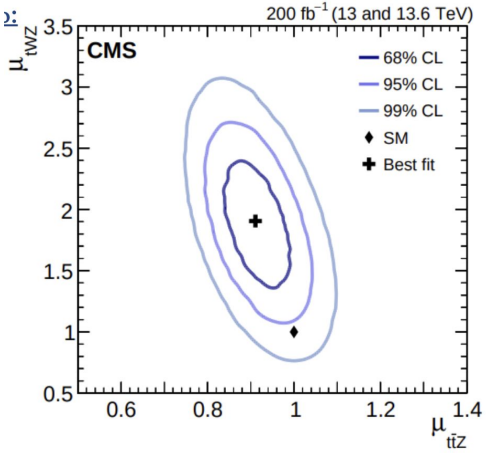


Rare production & EFT interpretations

CMS

- Slides from Victor Rodriguez Lorenzo

- **First observation of tWZ: 5.8(3.5 expected)σ**
- CP violation limits compatible with SM in ttZ/tZq
- ttW differential cross sections within expectations
- Differential ttγ and tqγ results consistent with predictions
- 3 top: σ_{ttt} < 25 fb

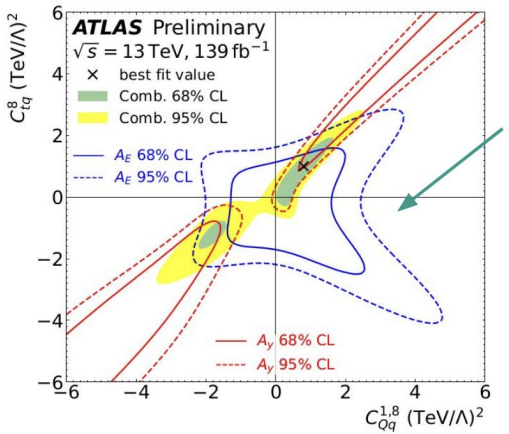


Ever-improving EFT constraints & future inputs to global fits

ATLAS

- Slides from Barbora Eckerova

- High mass ttll & lepton flavour universality analysis, no deviations from the SM or signs of LFU violation
- **First observation of tt$\gamma\gamma$: 5.2σ**
- Search for electroweak ttW+jet & EFT interpretation
- Constraints on EFT via quadruple-differential angular decay rates from t-channel single top
- **Combined EFT interpretation of tt rapidity and energy asymmetry measurements**



State-of-the-art amplitudes & MC studies

M. Pozzoli: - Slides

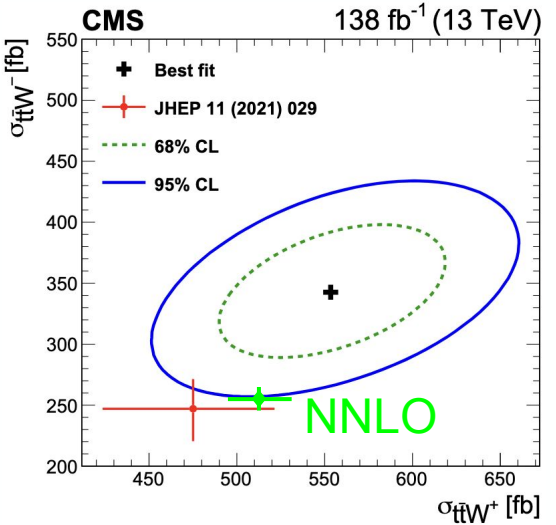
- Long-standing theory/experiment discrepancy on ttW
- Highly anticipated NNLO prediction in leading-color approx.
- Result agrees with previous approximate NNLO predictions
- **Some tension remains…**

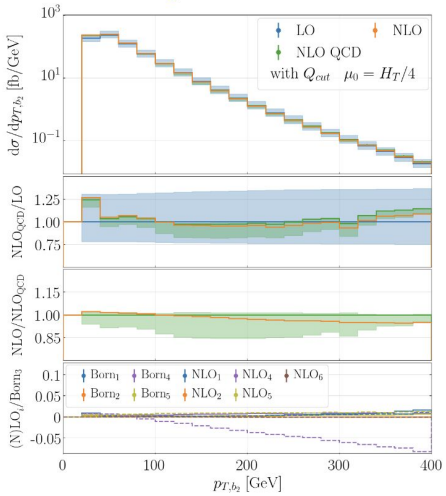
N. Dimitrakopoulos: - Slides

- Provide improved NLO QCD predictions for fully off-shell ttW jet
- MiNLO shows reduced scale uncertainties compared to NLO

M. Alsairafi: the fixed-order NLO and NLO+PS predictions for tttt at the LHC are consistent within theoretical uncertainties, particularly when matrix element corrections are included to better model higher-order effects in top-quark decays - Slides

L. Mans: Complete NLO QCD+EW calculations for off-shell tt production in the semi-leptonic channel, showcasing the interplay between QCD, EW sudakov & photon-induced in differential tails - Slides





Form Factor

Hyperon

LFU

CPV

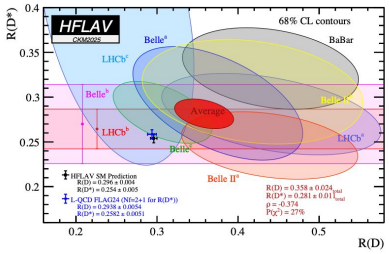
Flavour

Heavy neutral leptons

CKM

Semi-leptonic B-hadron decays

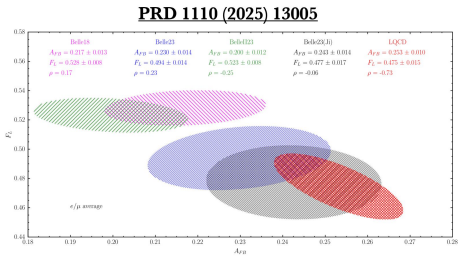
LFU



HFLAV2025

$$\mathcal{R}(D^*) = \frac{\mathcal{B}(B \to D^* \tau^- \bar{\nu}_\tau)}{\mathcal{B}(B \to D^* \mu^- \bar{\nu}_\mu)} \text{ at } 3.6\sigma$$

- Discrepancies when including lattice input in angular observables



LHCb

- Slides from Sofia Zalambani

$$\mathcal{R}(D_{1,2}^{**0}) = \frac{\mathcal{B}(B^- \to D_{1,2}^{**0} \tau^- \bar{\nu}_\tau)}{\mathcal{B}(B^- \to D_{1,2}^{**0} \mu^- \bar{\nu}_\mu)} = 0.13 \pm 0.03(\text{stat}) \pm 0.01(\text{syst}) \pm 0.02(\text{ext})$$

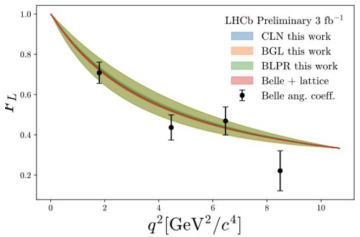
- Compatible with the SM prediction, the deviation of $\mathcal{R}(D^*)$ is not likely to be due to a global underestimation of $B^- \to D_{1,2}^{**0} \tau \bar{\nu}_\tau$

$$\mathscr{R}^{\mu,e} = \frac{\Gamma(\Lambda \to p \mu^- \bar{\nu}_\mu)}{\Gamma(\Lambda \to p e^- \bar{\nu}_e)} = 0.175 \pm 0.012$$ agrees with the SM prediction

- First measurement at LHCb of hadronic FF parameters in $B^0 \to D^{*-} \mu^+ \nu_\mu$

✳ Longitudinal polarization of the D^* meson:

$$F_L = \frac{3J_{1c} - J_{2c}}{3J_{1c} - J_{2c} + 2(3J_{1s} - J_{2s})}$$

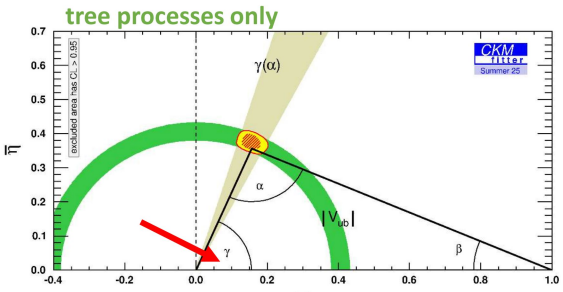


Agree with the BLPR fit to Belle data

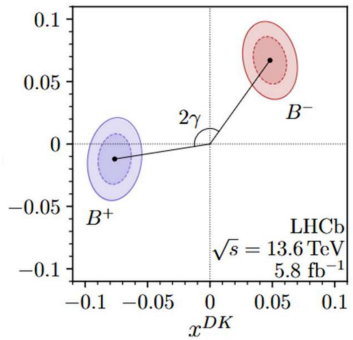
- Slides from Alessandro Bertolin

CKM

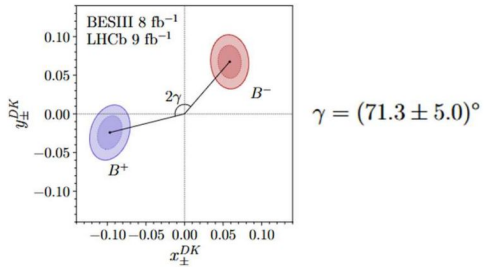
- New measurement are using LHCb Run 3 data, $5.8\ \mathrm{fb}^{-1}$: $B^+ \to Dh^+$ with $D \to K^0_s h^+ h^-$, with $h = \pi/K$



$$\gamma = (68.1 \pm 6.7)^\circ$$



- Simultaneous determination of the associated CP-violating observables and strong-phase parameters,

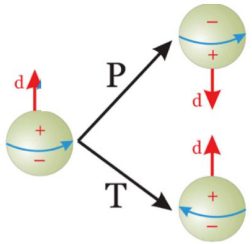


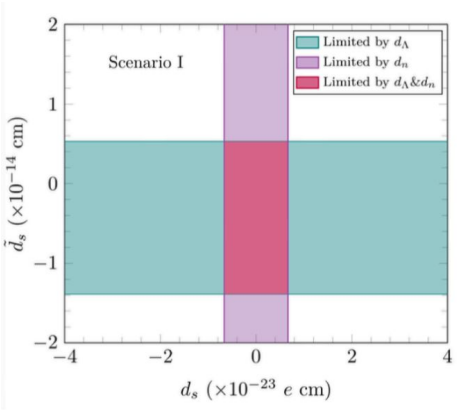
$$\gamma = (71.3 \pm 5.0)^\circ$$

the most precise to date and consistent with previous measurements and world averages

CPV

- Slides from Xuanbo Tong



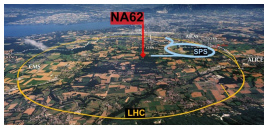


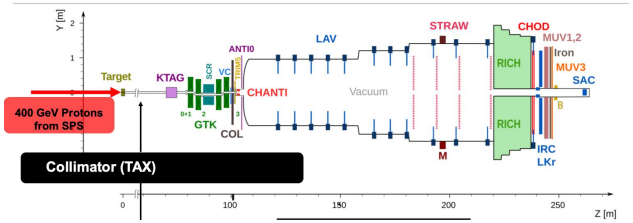
- The electric dipole moments (EDMs) of hyperons, such as Λ hyperon is sensitive to new sources of BSM CP violation
- In the large-Q^2 limit, the Λ hyperon EDM form factor is linked to quark-level EDM and chromo-electric dipole moments
- Numerical evaluations demonstrate that the Λ EDM has a unique sensitivity to the strange quark chromo-electric dipole moments (d_s)
- By incorporating the latest measurement results from BESIII, d_s is constrained within a specific, finite region

$$|\tilde{d}_s| < 1.4\times10^{-14}\text{cm}$$

NA62

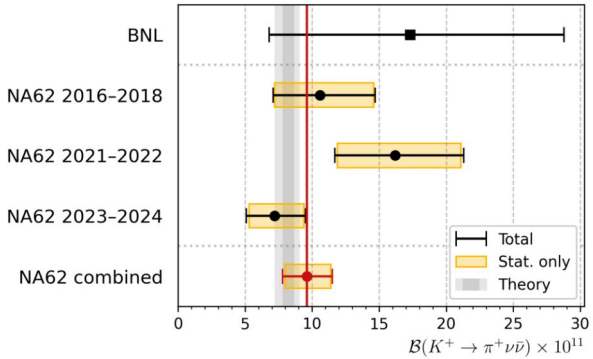
Fixed target experiment, Kaon factory



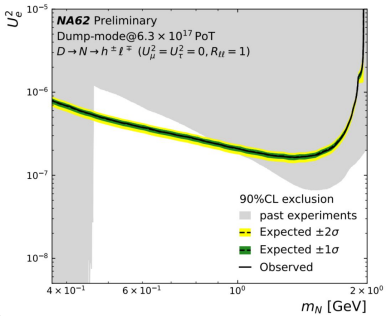


- Slides from Tommaso Spadaro

New result including 2023-24 data
Result compatible with SM



BC6



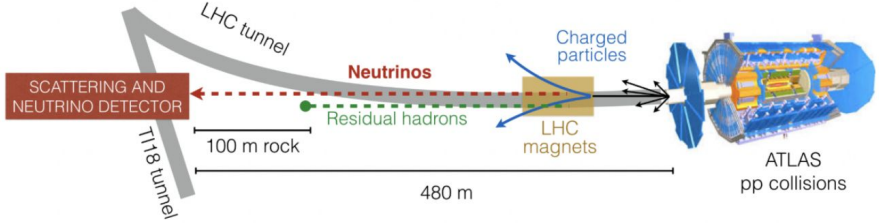
Excluded parameter space at level of $U^2 < 10^{-6}$ for Heavy Neutral Leptons masses in 500-1000 MeV range

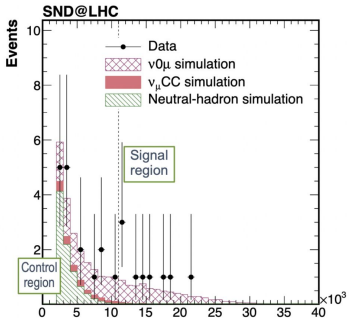
- Slides from Daniel Grewe

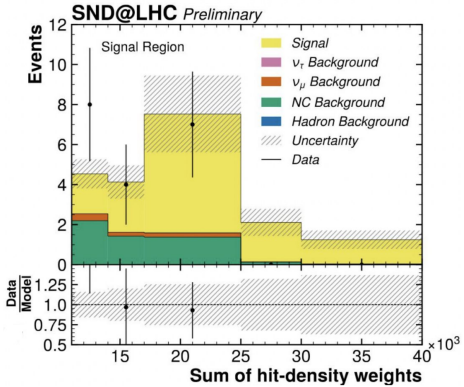
SND

- Slides from Cemal Din

Large neutrino fluxes in forward region from pp collisions







- 31 ν_μ CC interactions are observed with the 2023 data
- Observe non- ν_μ CC neutrino interaction with electronic detectors
- See ~ 3σ ν_e CC

CPV

Mass

Couplings

Decays

Higgs

Anomalous couplings

Higher-order QCD

Cross sections

EW corrections

Width

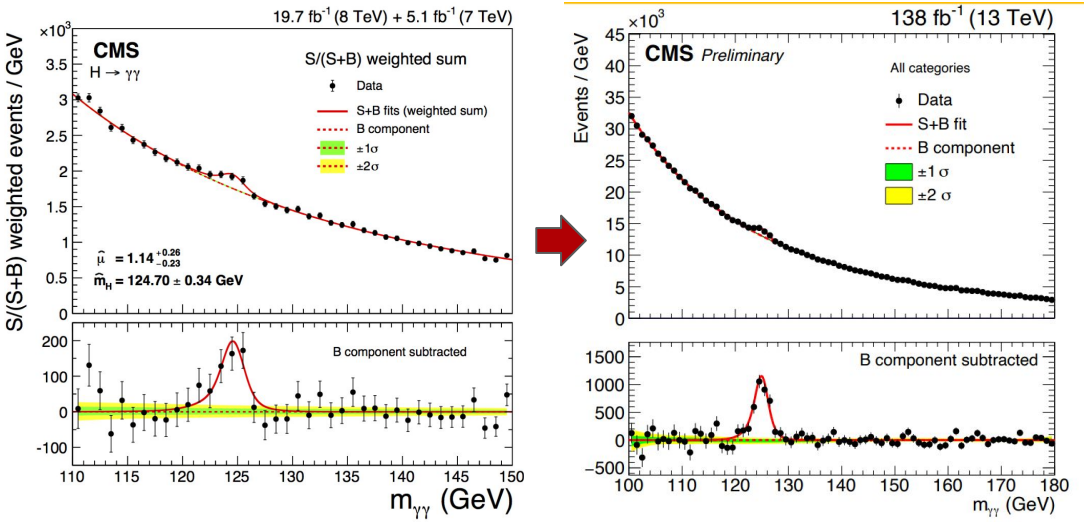
Higgs production in H→ZZ→4l and H→γγ

O. Poncet - Higgs coupling and properties at CMS **<- Check here for all the analyses!**

We came a long way since 2012…

Properties under investigation

- Mass
- Width
- Differential cross sections
- Higgs couplings
- CPV and anomalous couplings



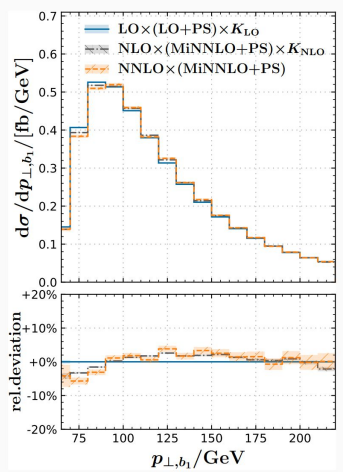
Rare / challenging decays:

- **H → cc:** not yet observed (searched in VH) Phys. Rev. Lett. 131 (2023) 061801
- **H → μμ:** evidence at ~3σ JHEP 01 (2021) 148
- **H → Zγ:** ~1.9σ with Run 2 + Run 3 CMS-PAS-HIG-23-010

Precision predictions for Higgs production

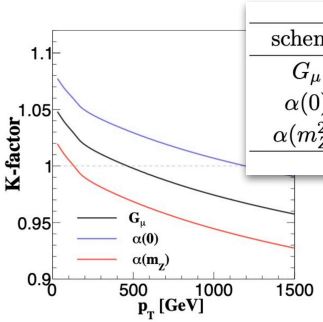
A Behring - [Parton-shower and fixed-order QCD effects in Higgs boson production in weak-boson fusion and its decays to bottom quarks]

- H->bb vs QCD background: challenge to reject background
  -> **Better in WBF kinematics**
- Large perturbative corrections at NNLO: -41% for the fiducial bb setup: **Resummation needed**!
- Solved by adding PS for the bb decay



Haitao Li - [Electroweak corrections to Higgs+jet production]

- Improvements on top of recent NLO QCD predictions
- **O(few %) corrections** at high energies
- **NLO EW corrections reduce the scheme dependence**, improving theoretical reliability



scheme	σ^{LO}[pb]	σ^{NLO-EW}[pb]
G_μ	7.91	8.25
$\alpha(0)$	7.56	8.11
$\alpha(m_Z^2)$	8.04	8.16

SUSY

Long-lived particles

Scalars

Extensions

Leptoquarks

BSM searches

Vector-like quark

Dark sector

Portal

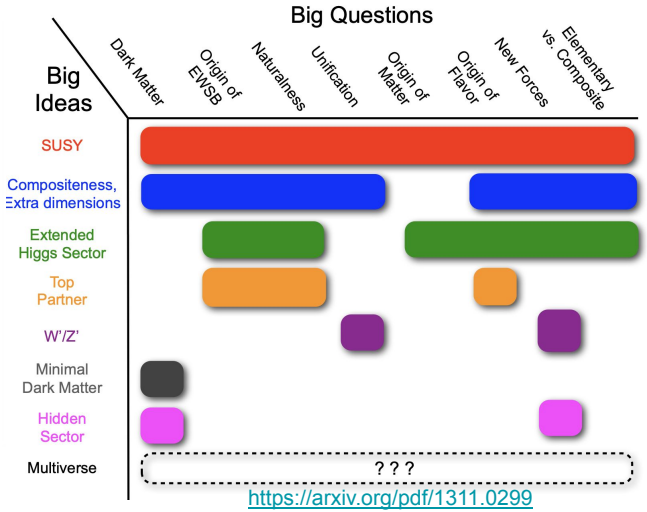
Introduction

Many well-motivated extensions of the SM predict an **extended scalar sector**, introducing additional Higgs bosons or scalar states.

- Two-Higgs-Doublet Models (2HDM)
- Supersymmetry (e.g. MSSM)
- Higgs portal models to dark sectors
- Singlet extensions and hidden valley scenarios

The models often predict **new scalar or pseudoscalar particles** with masses ranging from sub-GeV to the TeV scale, as well as **non-standard Higgs boson decays**, including:

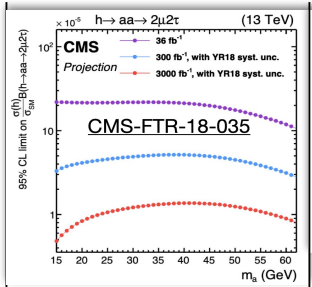
- Exotic decays into long-lived particles
- Decays into invisible or semi-visible final states
- Higgs cascade decays (e.g. $H \to aa \to 4\ell$, 4b/6b, $2\gamma 2\tau$,…)
- Narrow resonances Z' and a Z_D



https://arxiv.org/pdf/1311.0299

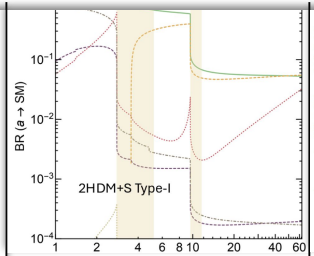
Slide taken from Monica Verducci: ATLAS searches for new scalars & BSM Higgs decays

BSM searches



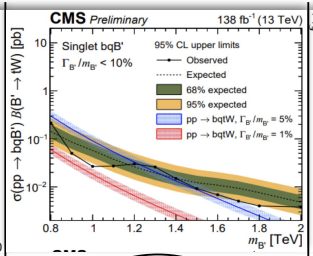
F. Zhang: [Search for rare decay of SM Higgs to light scalars in CMS]

- Higgs decay to two neutral scalars
- Higgs decay to 4τ and 2μ2τ final state
- Searches in final states with boosted μμ and ττ pairs



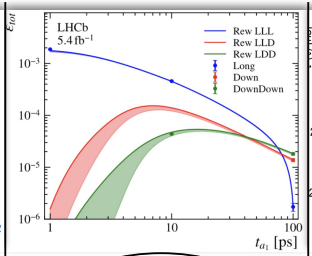
M. Verducci: [ATLAS searches for new scalars & BSM Higgs decays]

- Higgs boson decays in four or six b-quarks
- Higgs decay into four taus
- Higgs decay in two taus and two photons
- Di-muon resonance search



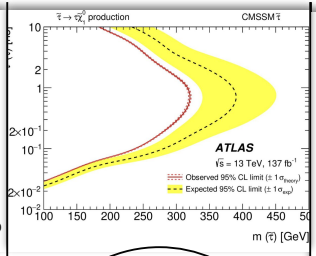
C. D. Fraia: [Searches for heavy and vector-like fermions, and leptoquarks with ATLAS and CMS]

- VLQ searches
- BSM physics in multilepton final states: Anomaly Detection!!
- Leptoquark searches
- Projected HL-LHC sensitivity
- …



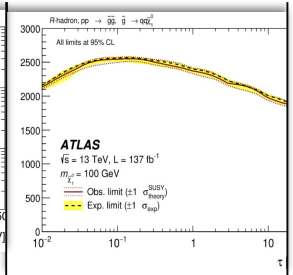
A. Usachov: [Dark sector searches at LHCb]

- Dark photons in di-muon spectrum
- Search for ALPs decaying to photon pairs
- HNLs in b-meson decays
- Search for scalars in multimuon B-meson decays
- Upgraded LHCb expectations!



J. Smith: [Searches for long-lived particles, exotic heavy resonances and dark matter with ATLAS]

- 3- and 4-layer disappearing tracks with an associated low-pT pion
- Displaced vertices and displaced leptons
- Exotic tt resonances
- Quantum black holes

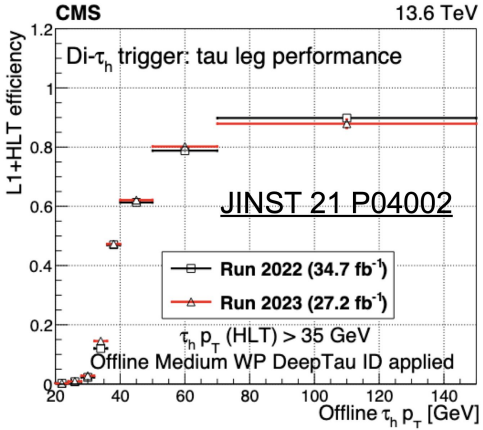


Y. Cai: [Searches for SUSY at ATLAS and CMS]

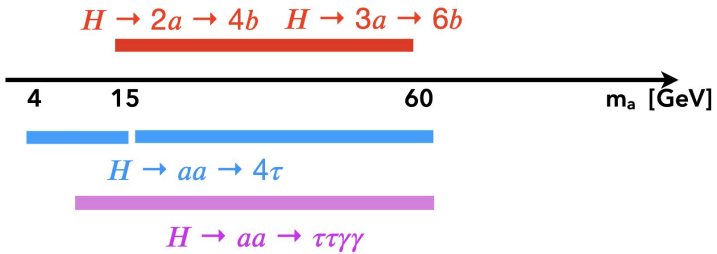
- Stop in OS-2ℓ + MET (ATLAS)
- Long-lived staus (CMS)
- Exotic tt resonances
- EWKinos in γ + jets + MET in GGM (ATLAS)
- RPC-to-RPV Reinterpretation (ATLAS)
- …

ATLAS and CMS searches for SM/ BSM Higgs decays

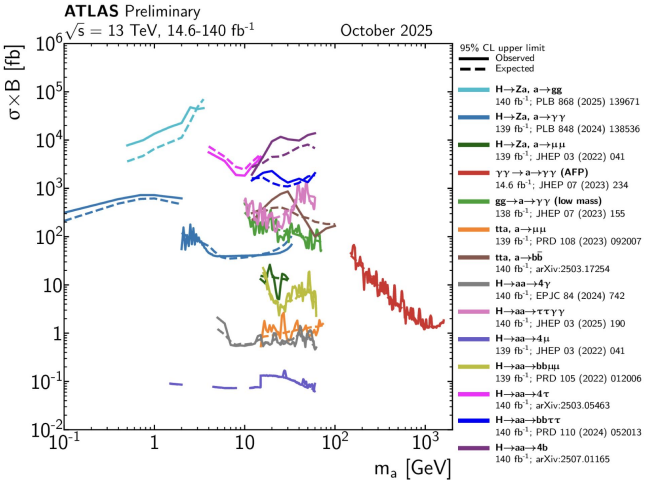
- Feng Zhang: **CMS results on search for rare decay of SM/BSM Higgs to light scalars/pseudo-scalars** with special highlight on searches in final states with boosted μμ and ττ pairs
  - Triggers on single τ_h or double isolated τ_h have been developed and deployed in Run3, despite the requirement of high pT(τ_h)
  - From Run2 to Run3, CMS upgraded “DeepTau” that could discriminate isolated τ_h from background more effectively



- Monica Verducci: **ATLAS Searches for new scalars & BSM Higgs decays**



  - Unfortunately still no significant excess has been observed … but still open place for improvement and new signatures

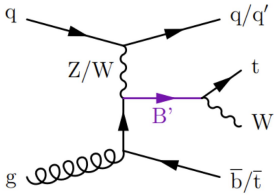


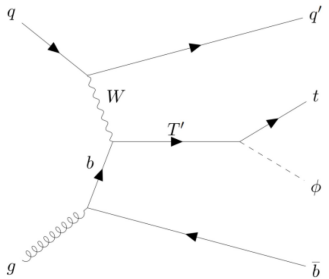
Searches for VLQs and LQs in ATLAS and CMS

Carlo di Fraia: Searches for heavy and vector-like fermions, and leptoquarks with ATLAS and CMS

Vector-like quarks (VLQs)

- Colored spin ½ fermions with a mass of the order of TeV
- Right-handed component also sensitive to weak charged processes
- Do not acquire mass by Yukawa coupling with Higgs field
- Full Run2 CMS dataset





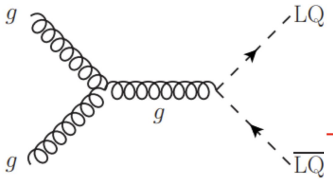
ϕ = a neutral scalar boson (including SM H)

The most stringent limits to date for masses ≥ 1.8 TeV

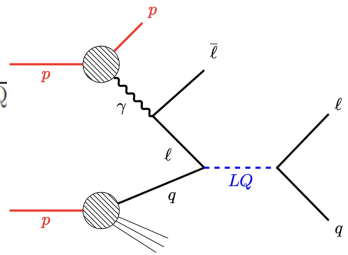
Leptoquarks (LQs)

- Vector (or scalar) colored charged bosons carrying baryon and lepton numbers
- New bosons manifesting connection between quarks and leptons
- Predicted by several SM extensions: GUT, technicolor, compositeness…
- Upper limits at 95% CL on coupling

Full Run-2 CMS dataset

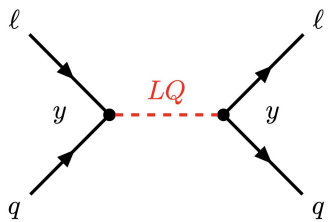


LQ pairs decaying to electrons and quarks



Leptoquarks produced via muon-quark scattering

Full Run-2 + partial Run-3 ATLAS dataset



Highlights resonant production as a complementary probe, extending sensitivity beyond pair-production searches.

Searches for LLPs with ATLAS

James Smith: Searches for long-lived particles, exotic heavy resonances and dark matter with ATLAS
Yuchen Cai: Searches for SUSY at ATLAS and CMS

What are LLPs?

Anything above tracking impact parameter resolution

Most of the particles we produce!

No reason to expect BSM physics is only prompt!

Commonly generated by compressed phase spaces, heavy mediators, weak couplings, e.g. R-Parity-violating decays and more

Extracted from James Smith's talk

Search for events with displaced vertices and displaced muons at 13.6 TeV:

- 2022-2024 dataset, Dedicated displaced muon triggers, improved LRT and DV reconstruction
- No significant excess, Cross-section upper limit of 0.04-0.5 fb at 0.1 ns

Search for DVs for two OS leptons:

- No events are observed in the SRs, consistent with the bkg exp.
- The first x-section upper limits placed on $c\tau$
- Exclusion limits placed on gluino and Higgsino pair production

Search for 3- and 4-layer disappearing tracks with an associated low-pT pion at 13 TeV:

- Small 1.9σ excess, consistent with fluctuations and material scattering
- New world-best limits for pure-winos (670 GeV) and pure-higgsinos (225 GeV), and up to 2.5x lower x-sec limits

Search for LLPs using DVs+MET:

- Novel Fuzzy secondary vertexing (FDV): DVs producing b-hadrons
- No obvious excess
- m(gluino) up to 1.8 to 2.5 TeV, and EWKino up to 350 to 650 GeV, are excluded for a wide range of lifetimes

SUSY searches in ATLAS and CMS

Yuchen Cai: Searches for SUSY at ATLAS and CMS

ATLAS	CMS
Search for $\tilde{q}$ and $\tilde{g}$ in events with τs, jets and MET* (Eur. Phys. J. C 85 (2025) 1437)	*Search for SUSY in events with highly Lorentz-boosted objects* (CMS Physics Analysis Summary)
Search for Higgsinos in compressed mass spectra using low-momentum tracks (2511.20042)	Search for Stop in events with many light-flavor jets and 0, 1, or 2 charged leptons (JHEP 10 (2025) 236)
Search for EWKinos in events with γ + jets + MET (JHEP 04 (2026) 150)	Search for new physics using single-lepton events with high jet and b jet multiplicities (CMS Physics Analysis Summary)
Search for LLP using displaced vertices + OS-2ℓ (2601.05664)	*General search for SUSY in compressed mass spectra scenarios* (Phys. Rev. D 112 (2025) 11, 112023)
Search for LLPs using displaced vertices + muons (2603.01991)	*Search for LLPs using displaced vertices with low-momentum tracks* (2511.08212) (*in backups, probing compressed region using DVs*)
Search for long-lived charginos and Stau using a disappearing track (2603.08315)	*Search for Higgsinos in compressed mass spectra using low-momentum lepton-track pairs* (2511.16394)
Search for LLP using displaced vertices + MET (2603.12051)	*Search for Heavy LLPs with L1 Trigger scouting data** (2601.20063)
Reinterpretation of Run 2 SUSY searches in models with variable RPV coupling strength (2603.15007)	*Search for the long-lived Stau* (2601.17576)
Search for Stop in events with OS-2ℓ + MET* (2603.16191)	*Search for EWKinos in compressed-spectrum scenarios with low-momentum isolated tracks* (2604.25604)

- Analysis in shadow will be presented, mainly focusing on the analyses published this year.
  - Red asterisk* indicates (Run 2 and) partial Run 3 used.
  - Including conventional scenarios, summary efforts, and *unconventional signatures* (*in italics*).

Extracted from Yuchen Cai's talk

Search for Stop in OS-2ℓ + MET (ATLAS):

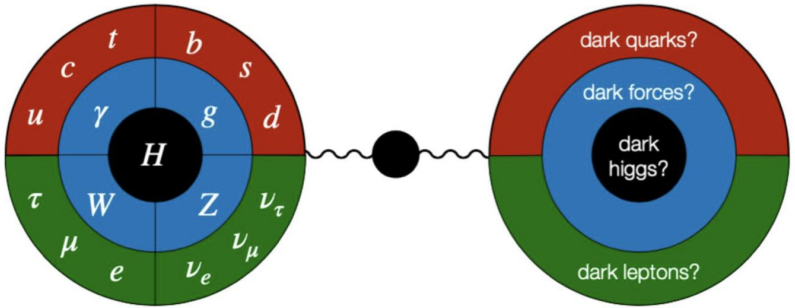
- Stop pair production, direct decay to on-shell top+LSP.
- No significant excess
- Extended Run 2 exclusion limits to 1060 GeV
- Sensitivity extends to compressed region where the NN is not trained for

Search for EWKinos in γ + jets + MET in GGM (ATLAS):

- Electroweakinos pair production
- No significant excess
- Exclusion limits set on masses and branching ratios with γ/Z scenario and γ/h scenario
- highest exclusion reaches up to 1.2 TeV for 100% BR to photons

Dark sector searches at LHCb

Andrii Usachov: Dark sector searches at LHCb



SM Dark sector

- Four portals to connect the Standard Model with the Dark Sector:
  - Vector - Dark Photons
  - Neutrino - Heavy Neutral Leptons (HNLs)
  - Axion-like particles (ALPs)
  - Dark Higgs boson
- LHCb has performed searches for all portals with Run 1 and / or Run 2 data sets, with best sensitivity at low mass

Extracted from Andrii Usachov's talk

Dark photons in di-muon spectrum

HNLs in b-meson decays

Search for ALPs decaying to photon pairs

Search for scalars in multimuon B-meson decays

Upgraded LHCb!

- First **fully neutral search for ALPs in di-photon mode**
- Search for **HNLs in b-decays** - order of magnitude sensitivity improvement compared to previous LHCb search
- Comprehensive search for **scalars in rare B-decays with multiple muons**
- Greatly improved efficiency for dark sector searches in Run 3 with the fully-software based trigger

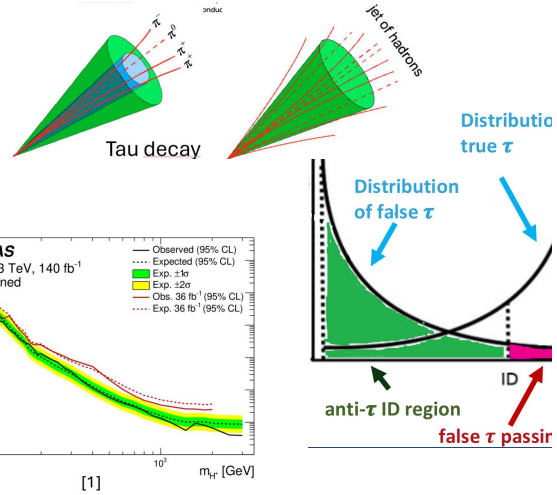
Improved bounds through improved techniques

Monika Juzek - Data-driven estimation of fake τ-lepton background in the H±→τν search with ATLAS Run-II data

τ lepton plays a key role in BSM searches at ATLAS

- powerful probe, **challenging to reconstruct and identify**
- Search for $H^+ \rightarrow \tau\nu$ using Run-II data with Fake Factor method for data-driven estimation of jet → τ misidentification

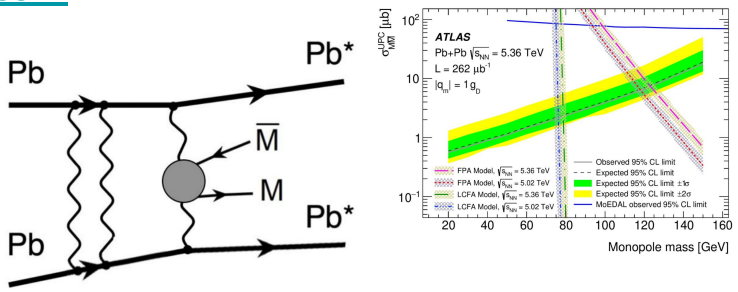
→ Improves analysis sensitivity



Lydia Beresford - Results on photon-photon scattering processes in ultra-peripheral Pb+Pb collisions with ATLAS

LHC as a photon collider:

- Lepton-pair production: ee, $\mu\mu$, $\tau\tau$
  → Limits on tau electro-magnetic moment
- Using PbPb to set **world-leading limits on magnetic monopoles**!

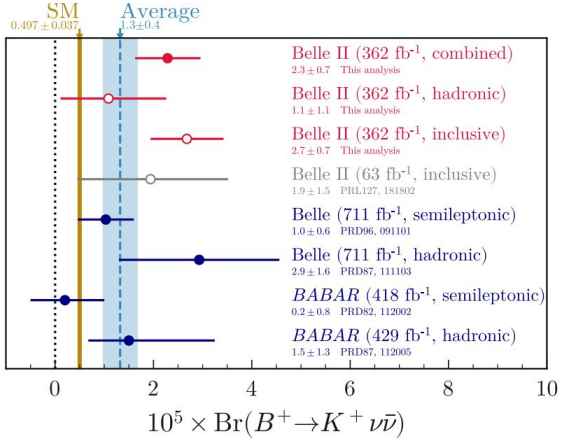


Belle 2 results

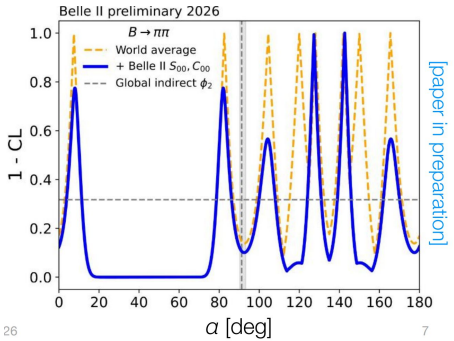
A Di Canto - [Probing Electroweak Interactions and Beyond the Standard Model Physics at Belle II]

Improved precision w.r.t to Belle despite ½ int. lumi

- Established 3.5σ **evidence for rare B+ -> K+ $\nu\nu$ decay** (slightly above SM)
- **world-leading upper limits on LFV in τ decays**
- CPV: **first-ever time-dependent B0 -> π0π0** -> new constraints on the CKM α-angle



$$\mathcal{B}(\tau^- \to e^- \eta) < 9.2 \times 10^{-8}$$
$$\mathcal{B}(\tau^- \to \mu^- \eta) < 4.2 \times 10^{-8}$$



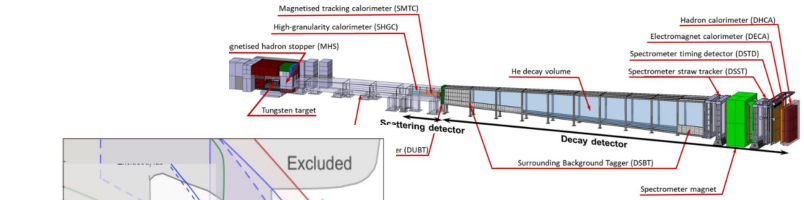
Covering the corners of the phase space

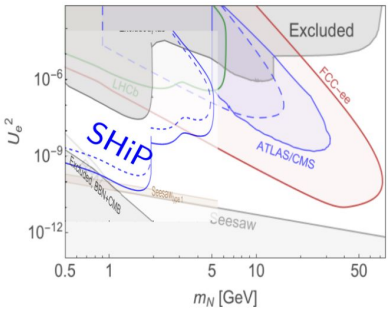
G. Frisella - [The SHiP/NA67 experiment at the ECN3 high-intensity beam facility at the CERN SPS]

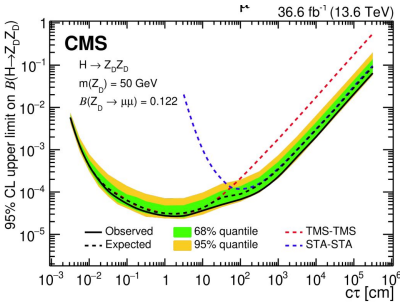
- **Covering phase space inaccessible** for ATLAS/CMS for feebly interacting particles (HNL, Dark Photon, ALPs)
- **Unique sensitivity for tau-neutrino**

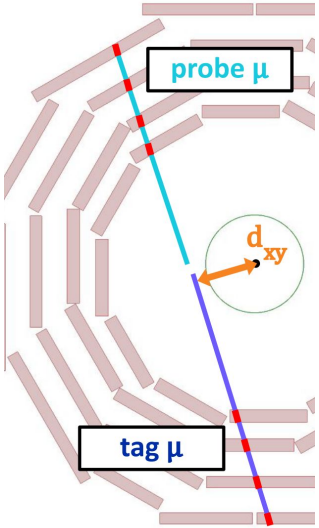
M. Cruciani - [Displaced Muons in CMS: Performance and Applications in LLP Physics]

- Specific algorithms to tag LLPs decaying into muons
- Using reconstruction of **displayed vertices to put limit on LLPs**
- Cosmic muons can be used as tag-and-probe study









Muon-hadron collider at CERN: HET physics

H. Kahnpour - [Perspectives for studies of the HET physics at the muon-hadron collider at CERN]

Combines the clean lepton-hadron initial state of DIS with a multi-TeV centre-of-mass energy, opening a new regime for Higgs, electroweak, top, and BSM studies

QCD & DIS frontier

Multi-TeV μp scattering extends the accessible (x, Q^2) plane well beyond HERA and the EIC/LHeC, strengthening the PDF, small-x, and α_s programme.

Top and rare-top physics

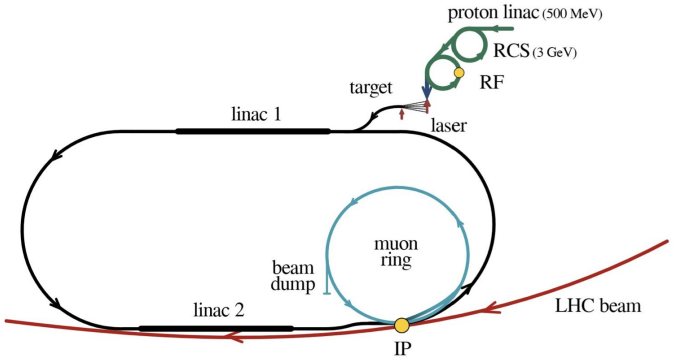
The top sector gives the clearest rate gain: already the 500 GeV LHμC benchmark enhances $t\bar{t}$ production by ~ 32 relative to the 50 GeV LHeC case, motivating precision top and FCNC studies.

Higgs–EW precision

Large CC/NC Higgs samples enable concrete coupling studies; the $h \to b\bar{b}$ benchmark reaches sub-percent sensitivity to g_{hbb}, while EW/SMEFT observables gain a larger high-Q^2 lever arm.

$\gamma\gamma$ and BSM portals

Photon-induced channels provide high-statistics $\tau^+\tau^-$ samples and high-mass $WW, ZZ, t\bar{t}$ probes, while direct μq and μg portals target RPV squarks, color-octet muons, and other muon-coupled BSM states.



Conceptual layout of the proposed LHμC configuration.

Energy scales

Correlation

Wilson coefficient

SMEFT

EFT

HEFT

Global Fit

Linear and quadratic

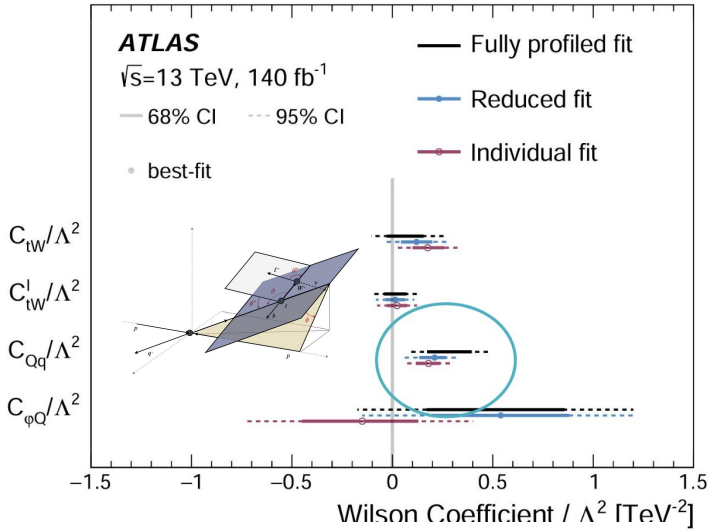
Differential data & global fits

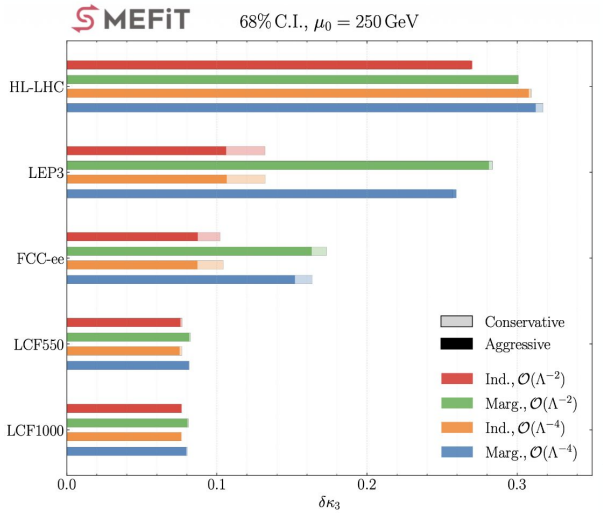
L. Brenner: *EFT measurements in ATLAS*

- HVV interaction: ggF & VBF in $H \to WW^*/\tau^+\tau^-$
  - CP even & odd couplings: different effects on distributions such as $\Delta\varphi_{jj}$
  - Results compatible with the SM
- **Top measurements:** quadruple differential single top decays
  - Dominated by systematics
  - See also A. Prades & B. Eckerova
- Global fits: combined (di-)Higgs, EW, top, DY & EW fit
  - Matching to UV models (Z' & 2HDM)
- EFT fits benefit from combinations (orthogonal analyses)

M. Thomas: *Global fits at future colliders with the SMEFiT framework*

- Comprehensive comparison of New Physics reach of future colliders using the SMEFT framework
  - State of the art analysis for HL-LHC/FCC projections
- EFT validity, impact of theory uncertainties
- **Focus on trilinear Higgs coupling** [arXiv:2604.16596]
- More in paper: Kappa framework, effective couplings, UV models



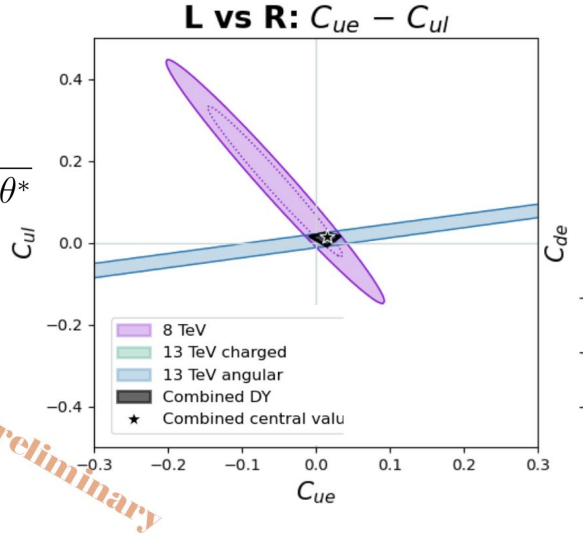


Drell Yan in the SMEFT & PDF interplay

M. Fusi: *The Impact of Drell-Yan Data on Four-Fermion SMEFT Operators*

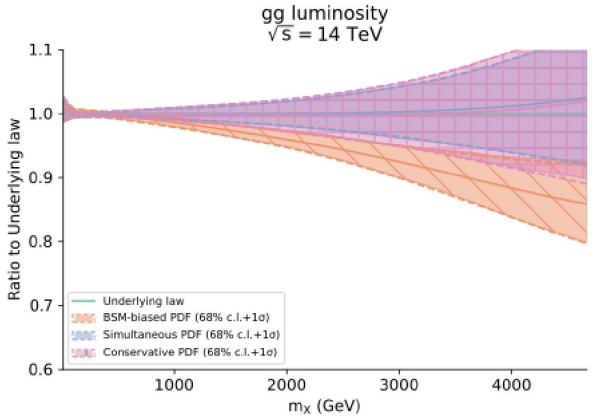
$$\frac{d^3\sigma}{dm_{\ell\ell}\, dy\, d\cos\theta^*}$$

- Multi-differential DY measurements @ 8 & 13 TeV
- Obtained individual and marginalised constraints at interference level
- **Angular & rapidity information breaks flat directions: uu vs dd initiated, L vs R chiralities**
- Multi-TeV sensitivity to BSM
- Eagerly anticipating 13 TeV triple differential data
- Ongoing combination with other data



E. Cole: PDF and BSM interplay in the top and Drell-Yan sector

- Framework for simultaneous fit of PDF & SMEFT
- Signs of new physics can be fitted away in PDF, leading to
  - **BSM `hiding' in the PDFs**
  - **Inaccurate PDF determination**
- Proposals: 'conservative PDFs' or simultaneous fits

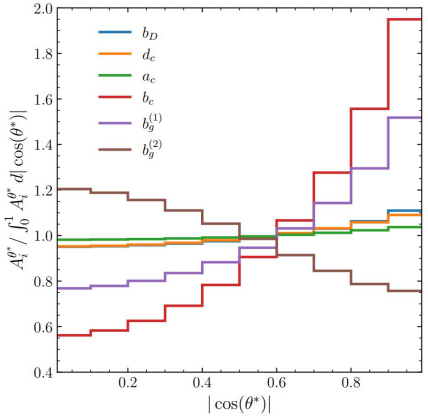


Precision for EFT predictions

K. Schmid - Di-Higgs Production via gluon fusion in HEFT and SMEFT

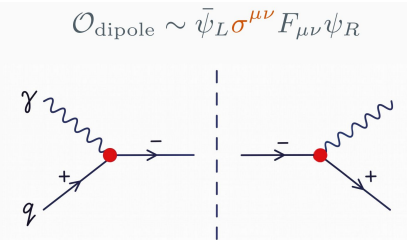
- calculation in **HEFT and dimension-6 SMEFT** including **NLO QCD**
- **di-Higgs phenomenology** in HEFT and dimension-6 SMEFT (linear vs. quadratic truncation)

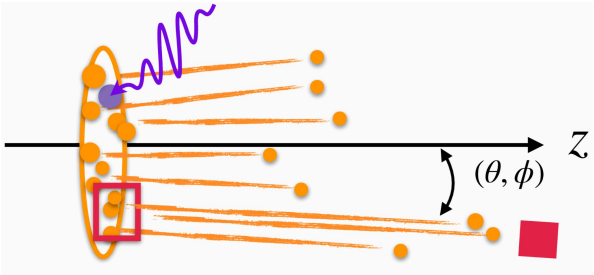
$$
\begin{aligned}
&- a_{\lambda^3}\lambda v h^3 - \frac{y_t v}{\sqrt{2}}\left(a_t\frac{h}{v}+b_t\frac{h^2}{v^2}\right)\bar{t}t + \frac{g_s^2}{16\pi^2}G^a_{\mu\nu}G^{a\mu\nu}\left(a_g\frac{h}{v}+b_g\frac{h^2}{v^2}\right)\\
&+\frac{y_t b_D}{4\pi\Lambda}\frac{1}{v^2}(\partial_\mu h)^2\bar{t}t + \frac{g_s y_t}{4\pi\Lambda}\left(\bar{t}_L\sigma^{\mu\nu}G^a_{\mu\nu}T^a t_R + \text{h.c.}\right)\left(d_c + a_c\frac{h}{v}+b_c\frac{h^2}{v^2}\right)\\
&+\frac{g_s^2 b_g^{(1)}}{16\pi^2\Lambda^2}\frac{h^2}{v^2}(D^\mu G^{a\nu\lambda})(D_\mu G^a_{\nu\lambda}) + \frac{g_s^2 b_g^{(2)}}{16\pi^2\Lambda^2}\frac{h}{v}G^{a\lambda\nu}G^{a\mu}_{\lambda}\frac{1}{v}(\partial_\mu\partial_\nu h)
\end{aligned}
$$



Y. Huang - Probing light-quark dipole operators with nucleon energy correlators

- Resurrect **sensitivity to light-quark dipole operators by Nuclear Energy Correlators** @ EIC





Final remarks

- EW, Higgs and top physics is a staple of precision test of the SM and the search for BSM physics
- In the absence of ‘smoking gun’ signals, precision is the key driver of progress
- Many latest results on EW physics/ Higgs/ top/ BSM shown
- Thanks to the organizers for providing us a platform to share latest results
- Thanks to all the participants for contributing to WG3 sessions!