The 29th International Workshop on Weak Interactions and Neutrinos (WIN2023)

Electroweak Interactions & Higgs Summary

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Disclaimer: very biased summary

5 plenary talks

- Review of EW interactions (theory) +1:
  - **Liantao Wang**, Overview of the future directions of particle physics
- Review of EW interactions (experiment) +1:
  - **Xiaohu Sun**, Experimental overview of EW and BSM physics at CMS and ATLAS
- Highlights +3:
  - **Jiang-Hao Yu**, Effective Field Theories for Weak Interactions and Neutrinos
  - **Yusheng Wu**, Progress in the measurements of the W mass, the Z-boson transverse momentum and alpha_S
  - **Jia Liu**, The progress of Electroweak and Beyond the Standard Model studies at CEPC

24 parallel talks = 12 theo. + 12 expt.

Higgs physics

- Higgs physics + 6:
    - **Qianying Guo**, HVV, Higgs mass, CP
    - **Zhiyuan Li**, Higgs fermion at the CMS experiment
    - **Fengwangdong Zhang**, Search for BSM Higgs at CMS
    - **Lailin Xu**, Searches for new physics in the Higgs sector
    - **Michihisa Takeuchi**, Double aligned two Higgs doublet models at LHC

24 parallel talks = 12 theo. + 12 expt.

Electroweak physics

- Precision measurements (theo.) +4:
  - **Zhe Guan**, Recent di-boson and tri-boson measurements at CMS
  - **Yusheng Wu**, Measurements of electroweak diboson production in association with two jets in ATLAS
  - **Hao Xu**, Measurement of multiboson production in ATLAS
  - **Xiao Wang**, WZ cross section measurements at LHCb
  - **Menglin Xu**, W mass measurements at LHCb

24 parallel talks = 12 theo. + 12 expt.

Electroweak physics

- Precision measurements (theo.) +4:
  - **Rui-Qing Xiao**, LHC and Future High Energy Colliders: Probing the nTGC New Physics
  - **Jiayin Gu**, SMEFT at future lepton colliders
  - **Yiming Liu**, The interplay of EWPO and top interactions in SMEFT fits at Electroweak Interactions
  - **Bin Yan**, Application of the jet charge in electroweak and Higgs physics
- Top quark +2:
  - **Jian Wang**, Precise prediction for the top quark width
  - **Xiaohu Sun**, Top quark mass measurements at CEPC

24 parallel talks = 12 theo. + 12 expt.

New phenomena

- Searches +1:
  - **Oliver Stelzer-Chilton**, Searches for new phenomena with the ATLAS detector
- Supersymmetry +2：
  - **Pengxuan Zhu**, A concise review on some Higgs-related new physics models in light of current experiments
  - **Norimi Yokozaki**, Spontaneous CP violation and supersymmetry
- Dark matter & New light particles +3:
  - **Leila Kalhor**, Light dark matter around 100 GeV from the inert doublet model
  - **Houbing Jiang**, Dark sector and Axion-like particle search at BESIII
  - **Xiaoping Wang**, ALP explanation to the muon (g-2) and its test at future Tera-Z and Higgs factories

24 parallel talks = 12 theo. + 12 expt.

New phenomena

- Electroweak baryogenesis +2:
  - **Huaike Guo**, Electroweak phase transition and barogenesis
  - **Yanda Wu**, Electroweak sphaleron under multiple-step EWPT with the general high dimensional SU(2) multiplet extension to the Standard model

Theoretical review

Liantao Wang

Open questions in the Standard Model

↓

What is the future?

↓

Future experimental probes, and what we can learn from them

The experimental probes

Energy frontier
HL-LHC, Future colliders

Rest of the talk

Cosmological observations
CMB, LSS, Gravitational wave

Table top exp, fixed target, …
Intensity frontier

10 times more data to come at the HL-LHC → What will this data tell us?

Theoretical review

Liantao Wang

A lot of data → Precision; Exotica / (Very) rare phenomena

Precision

In particular: Higgs

Exotica
(Very) rare phenomena

Why focusing on Higgs?

Higgs is simple.

A simple "Mexican hat" potential.

⇒ Electroweak symmetry breaking

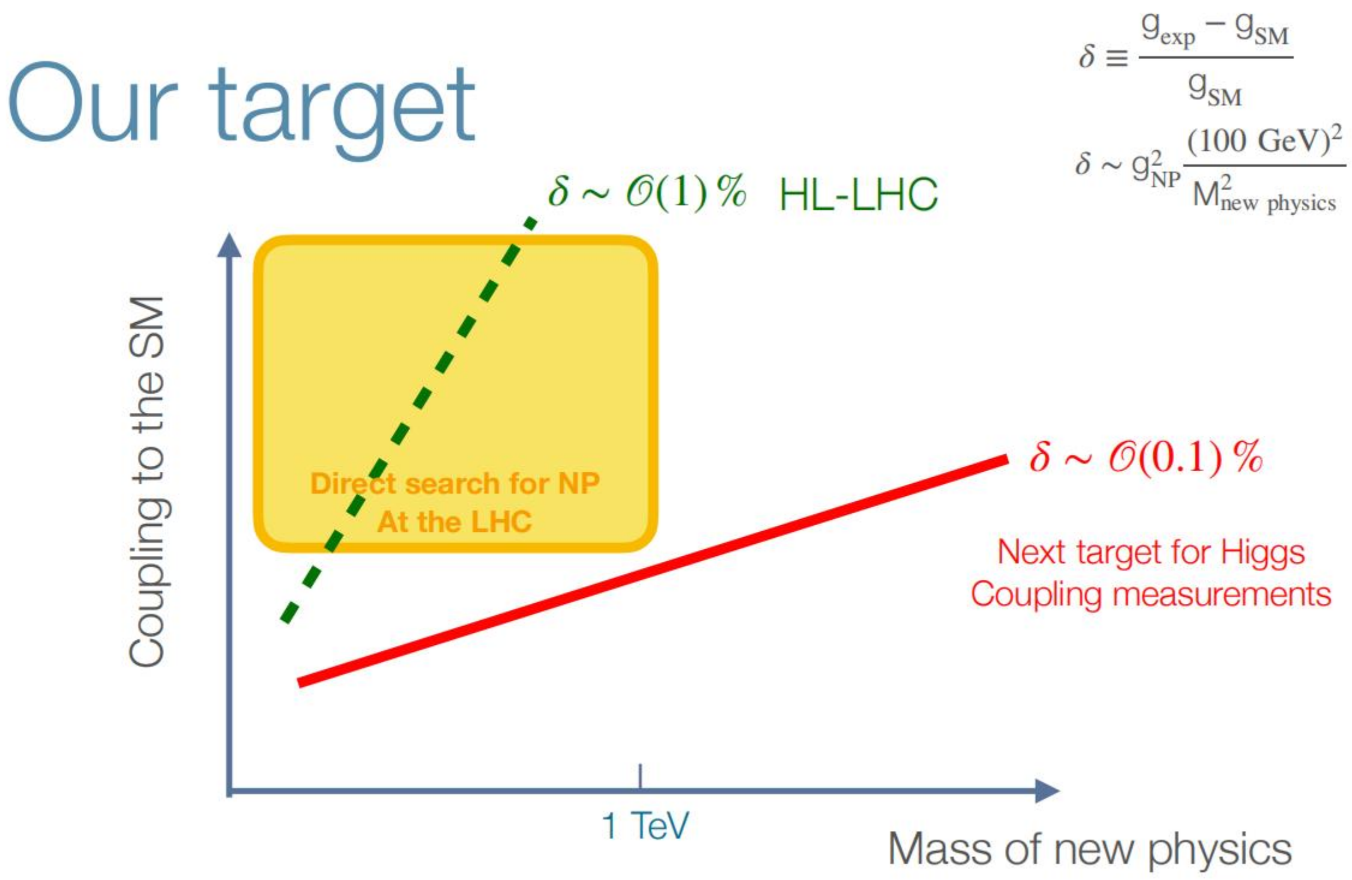
⇒ gives masses of SM particles

Yet, Higgs is confusing.

- Is Higgs boson elementary or composite?
- Are there other Higgs bosons?
- How does Higgs mechanism set the masses of the SM particles?

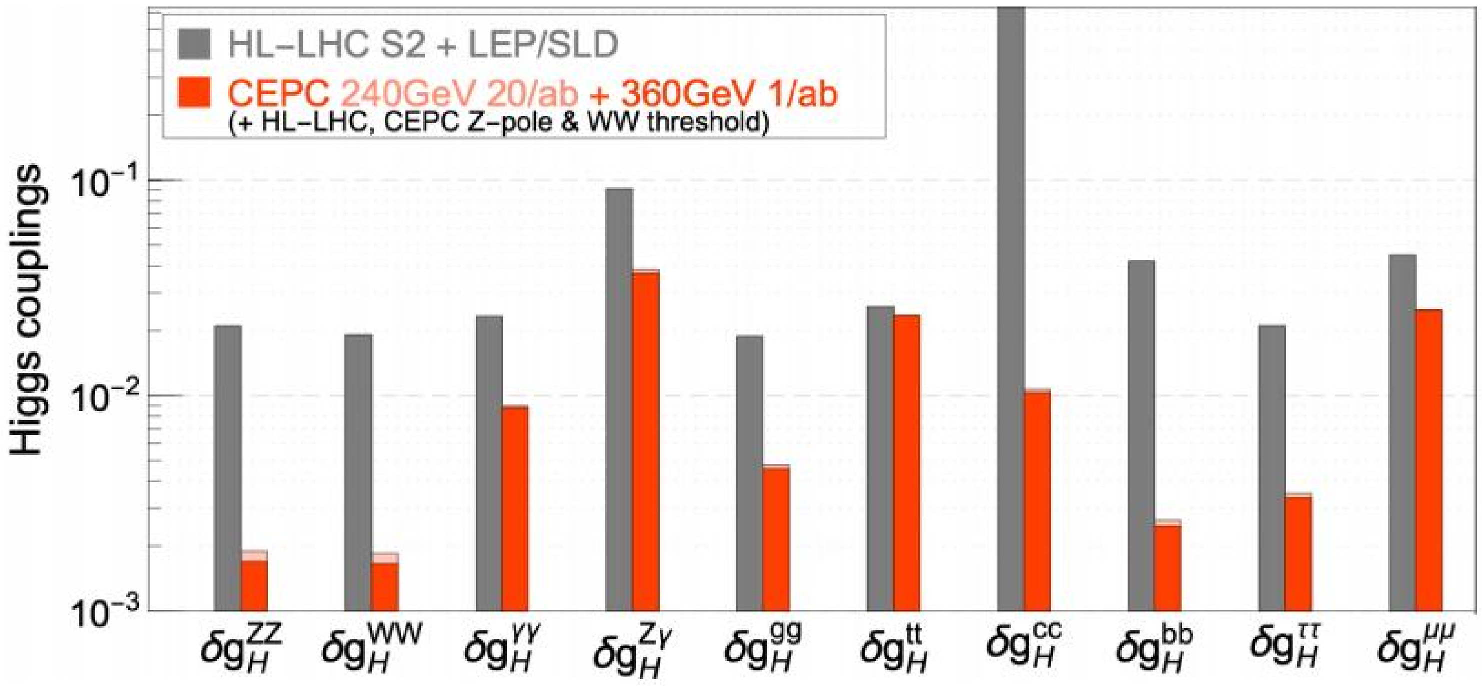
Theoretical review

Liantao Wang



Future colliders are needed

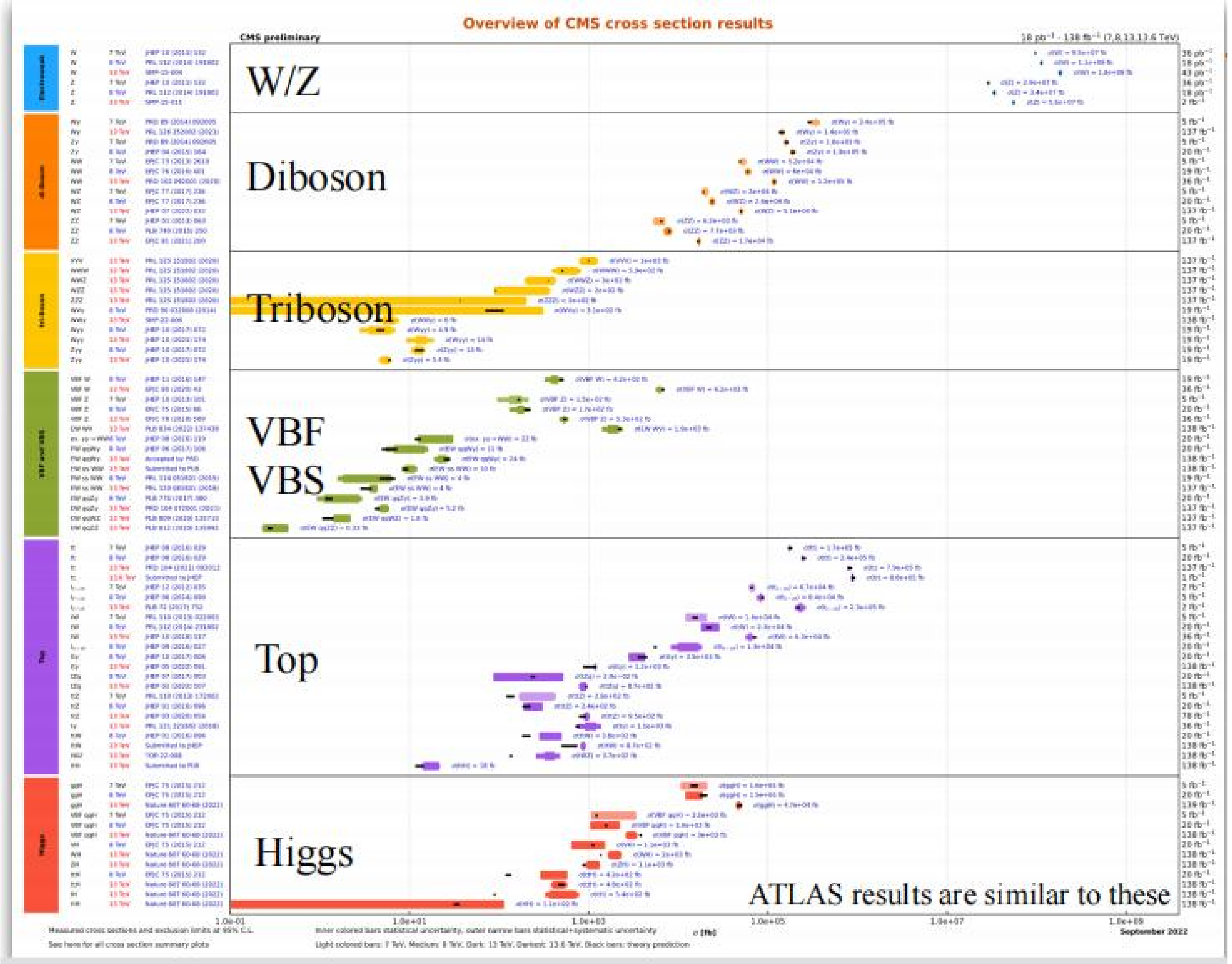
Theoretical review



See Jia Liu’s talk

Experimental review

Xiaohu Sun



- EW W/Z, VBS, multiple bosons
- $t\bar{t}$, single top, mass
- Higgs, rare decays
- And the relevant BSM

Very comprehensive review

My summary borrows a lot from this review

Higgs physics

Higgs measurements

Qianying Guo @CMS

- Higgs Mass: $m_H = 125.38 \pm 0.14\ (\pm 0.11)\ GeV$
- Higgs Width: $\Gamma_H = 3.2^{+2.4}_{-1.7}\ MeV$
- First observed off-shell Higgs production at LHC with 3.6σ
- Limit on HVV anomalous couplings
- First evidence of $\mathrm{H} \rightarrow Z\gamma$ channel with 3.4σ combined with ATLAS and CMS
- All results are consistent, within their uncertainties, with the expectations for the Standard Model H boson

$$\frac{\sigma^{\text{on-shell}}_{gg\to H\to ZZ^*} \sim \dfrac{g^2_{ggH} g^2_{HZZ}}{m_H \Gamma_H}}{\sigma^{\text{off-shell}}_{gg\to H^*\to ZZ} \sim \dfrac{g^2_{ggH} g^2_{HZZ}}{(2m_Z)^2}} \quad \text{ATLAS } \Gamma = 4.6^{+2.6}_{-2.5}\ \text{MeV}$$

Higgs measurements

Qianying Guo @CMS

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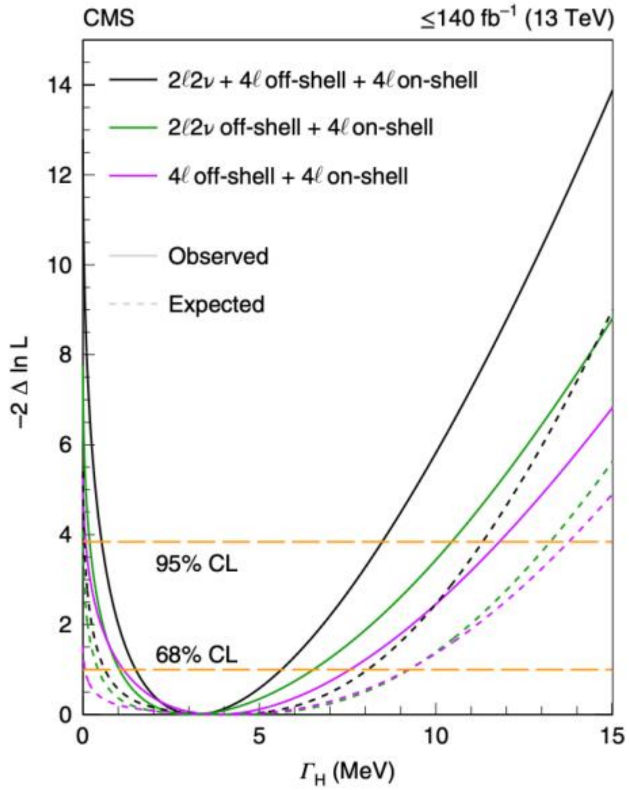

Distributions of ZZ invariant mass observables in off-shell signal regions

$$m_{VV} > 2m_V$$

Higgs measurements

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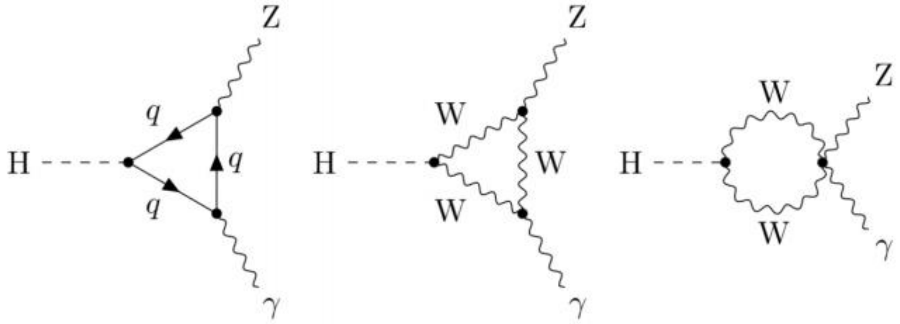
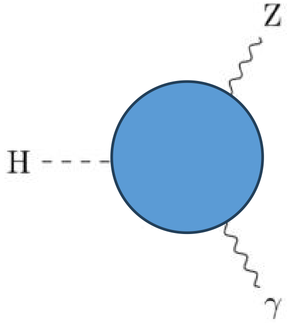
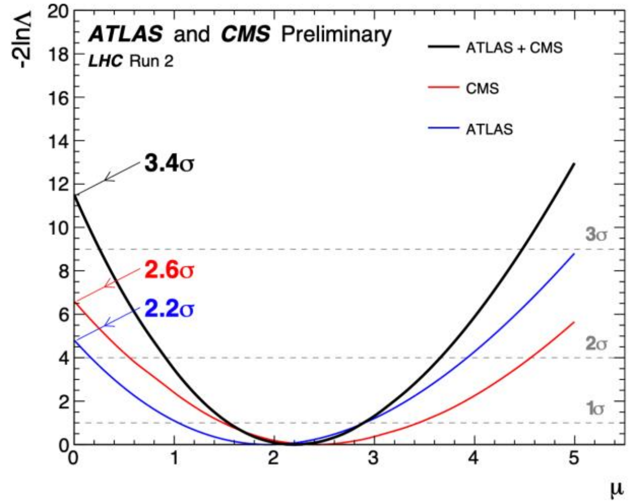
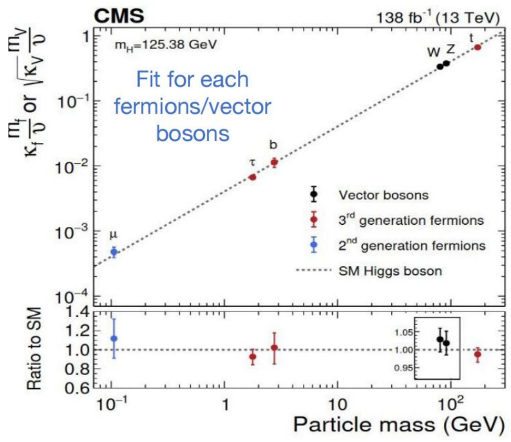




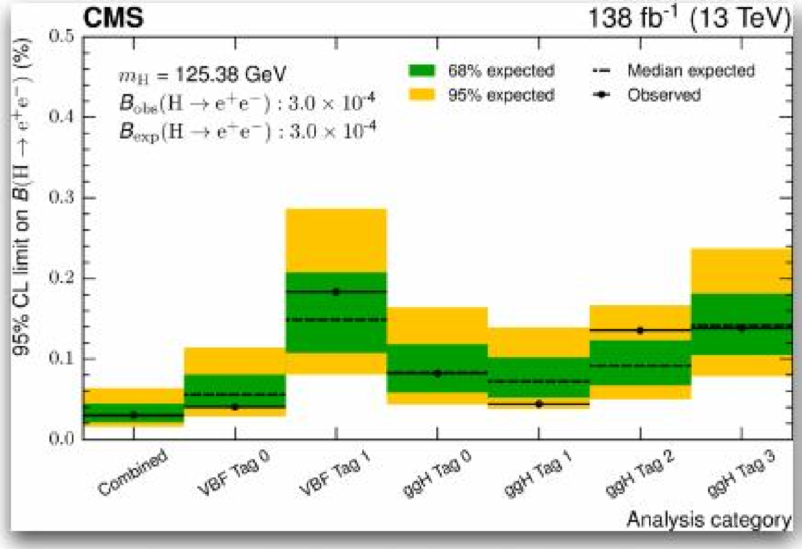
Qianying Guo @CMS

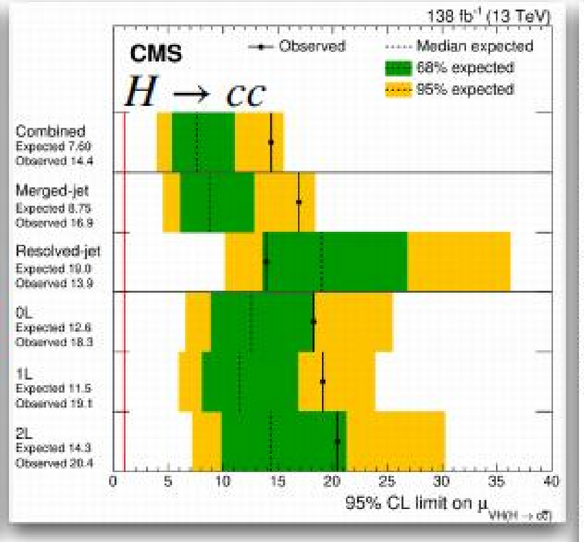


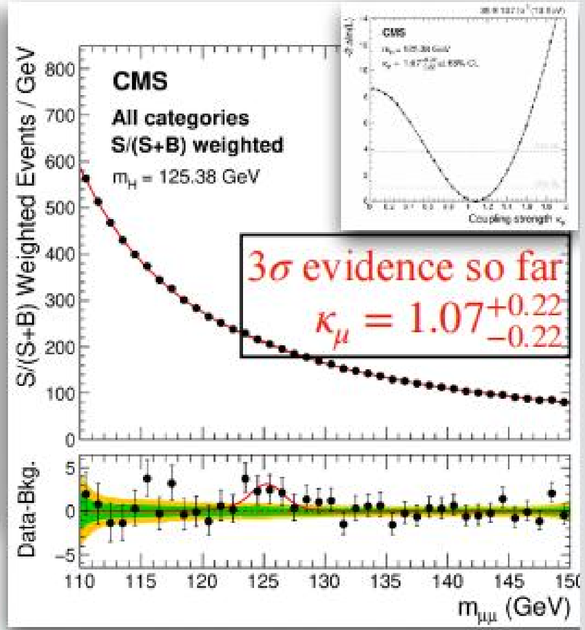
Higgs measurements



- Couplings to lighter fermions in the first and second generations







$BR(H \to ee) < 3.0 \times 10^{-4} (3.0 \times 10^{-4})$ at 95% CL. Accepted by PLB

SM predicts $BR(H \to ee) = 10^{-9}$

$1.1 < |\kappa_c| < 5.5$ $(|\kappa_c| < 3.4)$ at 95% CL. Accepted by PRL

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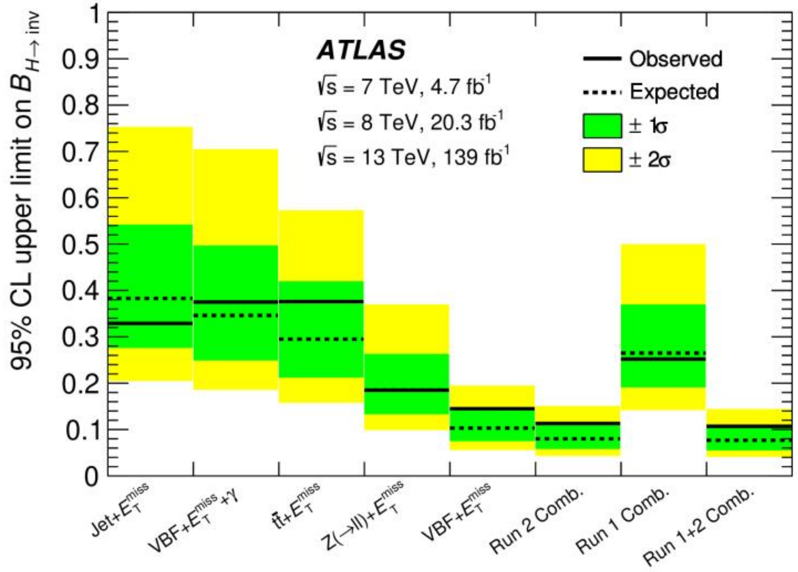
Zhiyuan Li @CMS

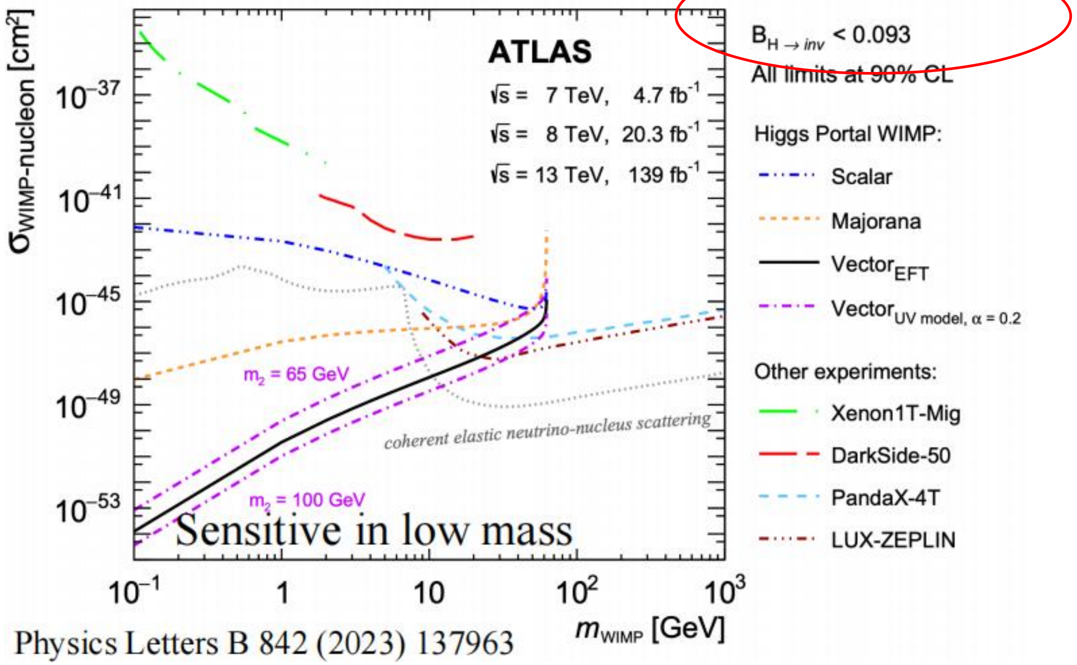
Exotic Higgs decays

- H -> invisible:

95% CL limit for H→ inv
ATLAS: 10.7% (7.7% exp.)
CMS: 15% (8% exp.)



Lailin Xu @ATLAS



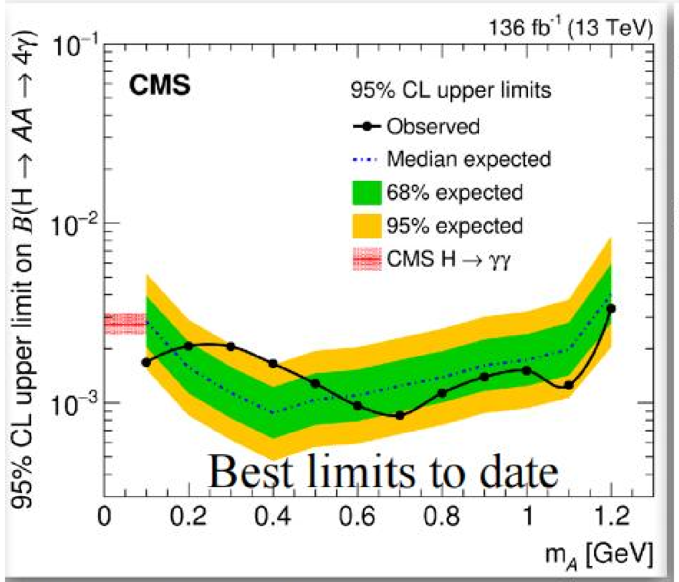
Significant complementarity between LHC and direct detection experiments

Also Fengwangdong Zhang @CMS

Exotic Higgs decays

Xiaohu Sun

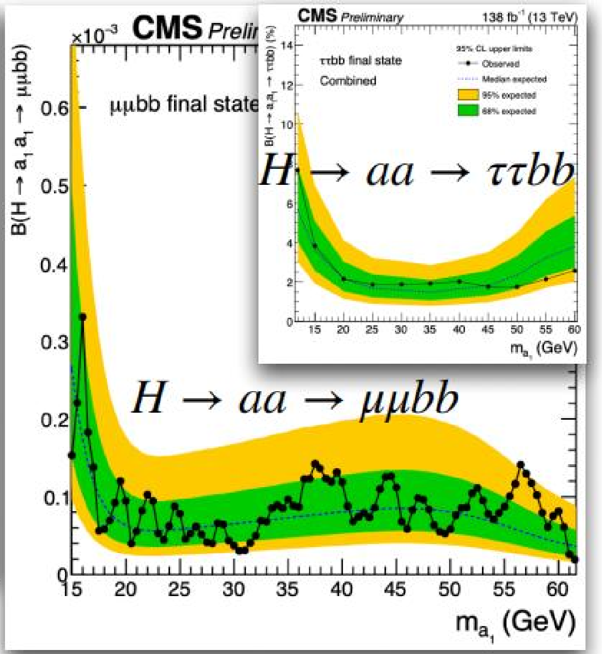
- Higgs to pseudoscalars:



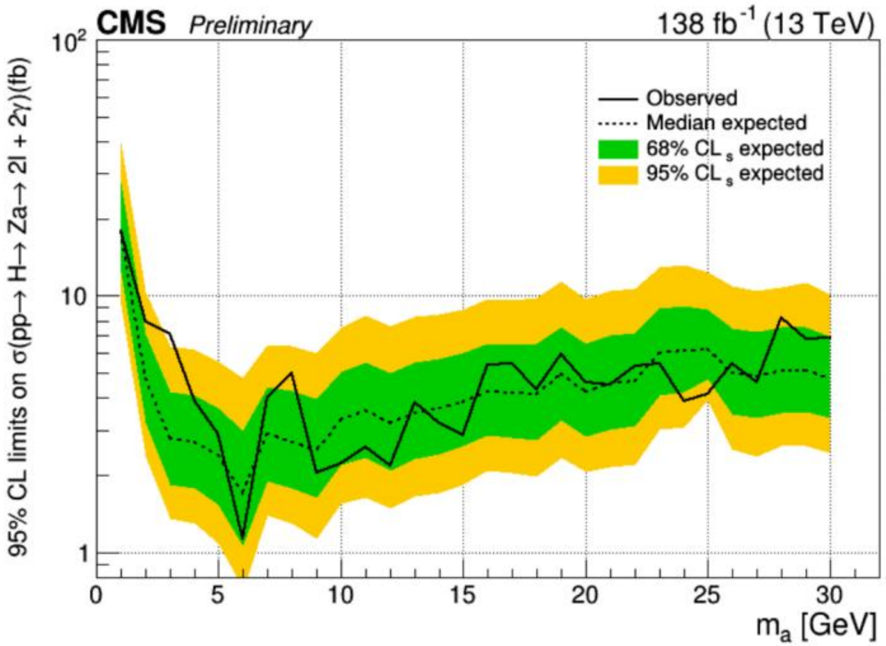
$H \to aa \to 4\gamma$

First merged diphoton topology!

Accepted by PRL

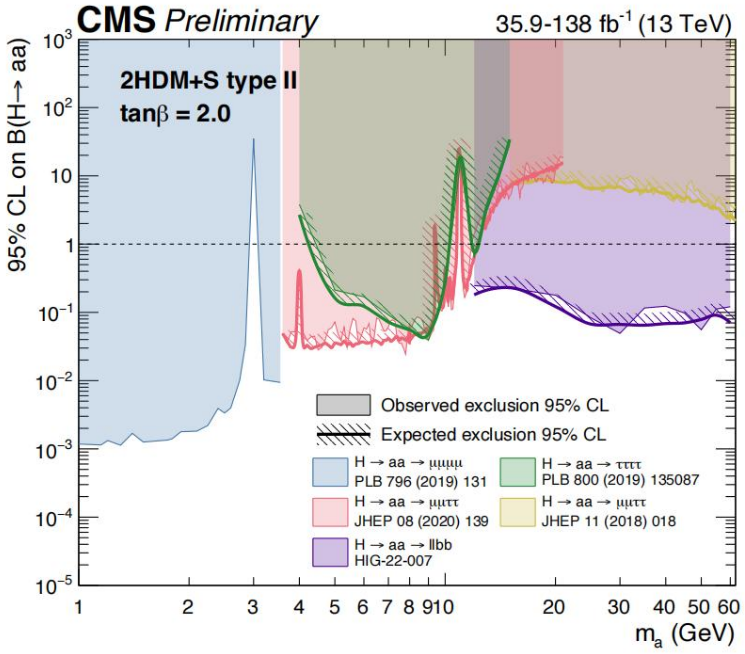


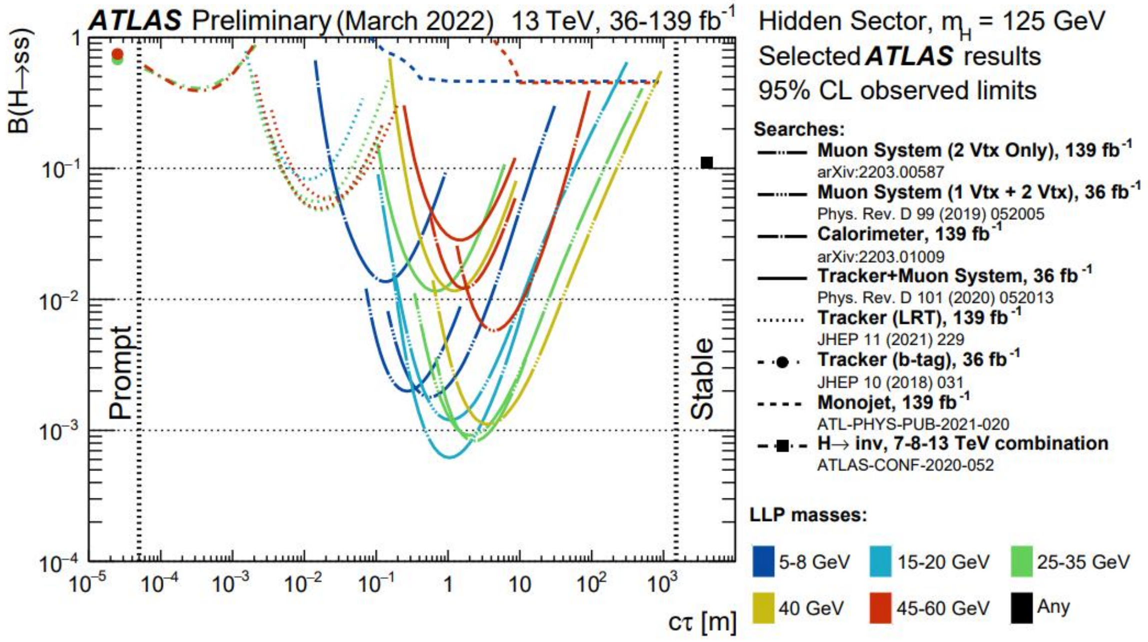
CMS-PAS-HIG-22-007



Exotic Higgs decays

- Higgs to pseudoscalars:





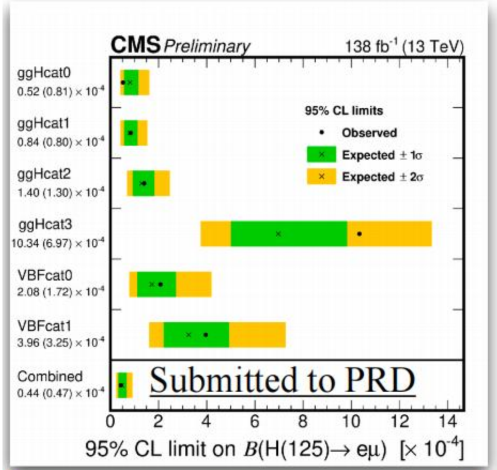
Fengwangdong Zhang @CMS

Oliver Stelzer-Chilton @ATLAS

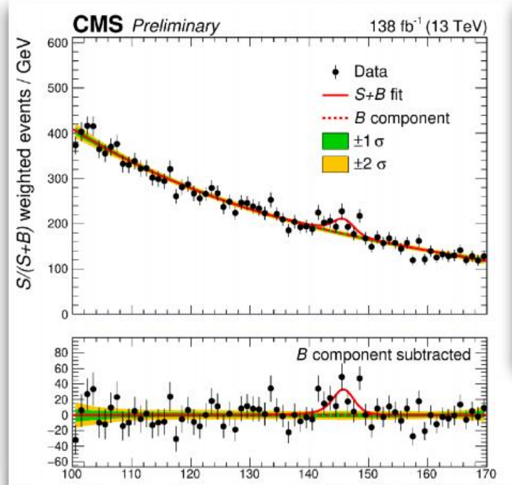
Exotic Higgs decays

Xiaohu Sun

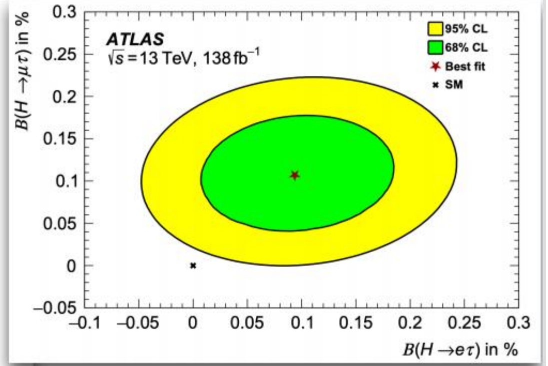
- Higgs decays with lepton flavor violation:
  - CMS searches for $H \to e\mu$ for SM H and scans the mass from 110 to 160 GeV for BSM H
  - ATLAS searches for $H \to e\tau, \mu\tau$ decays



$BR(H \to e\mu) < 4.4\ (4.7) \times 10^{-5}$ at 95% CL



Found small excess of 3.8σ (2.8σ) local (global) at 146 GeV



Simultaneous fit with 2 POIs

BR(H→eτ) < 0.20% (0.12% exp)

BR(H→μτ) < 0.18% (0.09% exp)

2302.05225

Additional "Higgs bosons"

Lailin Xu @ATLAS

Searches	Ref.	Searches	Ref.
Boosted $a \to \gamma\gamma$ $(10\ \text{GeV} < m_X < 70\ \text{GeV})$	arXiv:2211.04172	$t \to H^{\pm}b, H^{\pm} \to cb$	arXiv:2302.11739
Low-mass resonance $X \to \gamma\gamma$ $(66 < m_X < 110$ GeV)	ATLAS-CONF-2023-035	$H^{\pm\pm} \to l^{\pm}l^{\pm}$	arXiv:2211.07505
$tta, a \to \mu\mu$	arXiv:2304.14247	$ttH/A \to tttt$	arXiv:2211.01136
$X \to Z\gamma$	ATLAS-CONF-2023-030	$A \to ZH \to lltt + \nu\nu bb$	ATLAS-CONF-2023-034
$X \to WW$	ATLAS-CONF-2022-066	FCNC $t \to qX, X \to bb$	arXiv:2301.03902

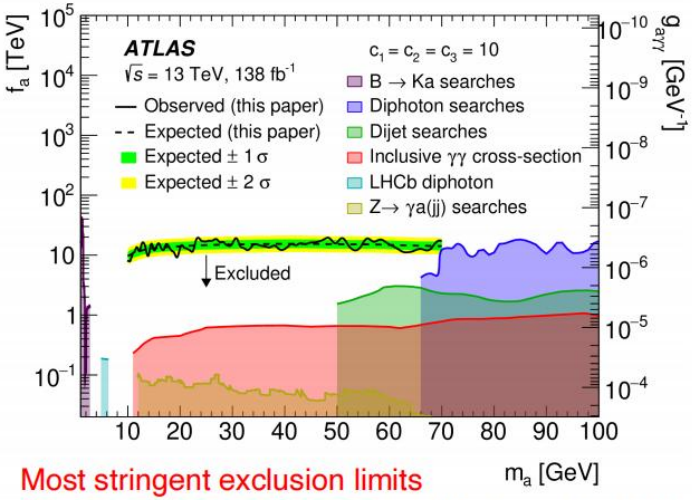
Additional “Higgs bosons”

Lailin Xu @ATLAS

- Boosted a -> γ γ

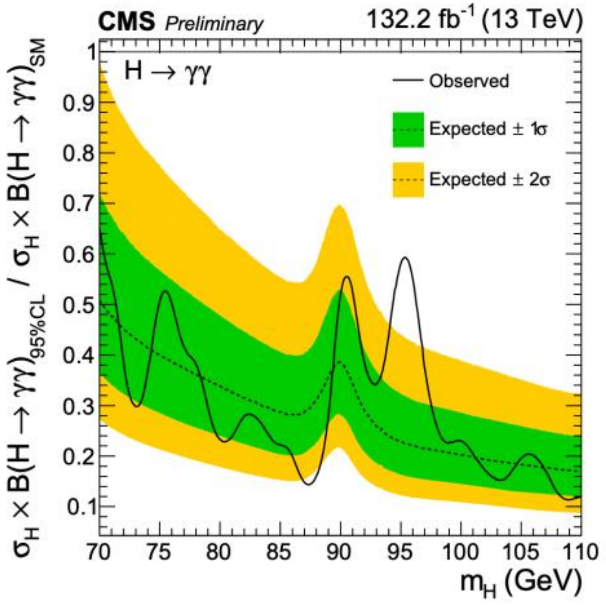
Limits interpreted into the KSVZ-ALP parameter space

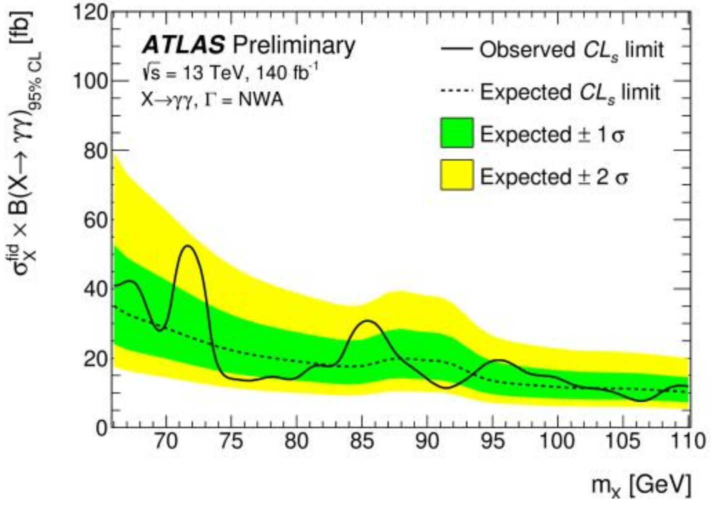
$$\frac{a}{4\pi f_a}\left[\alpha_3 c_3 G^a\tilde{G}^a + \alpha_2 c_2 W^i\tilde{W}^i + \alpha_1 c_1 B\tilde{B}\right] + \frac{1}{2}m_a^2 a^2$$



Most stringent exclusion limits
Covers a longstanding gap in diphoton resonance searches

- Low-mass resonance X -> γ γ



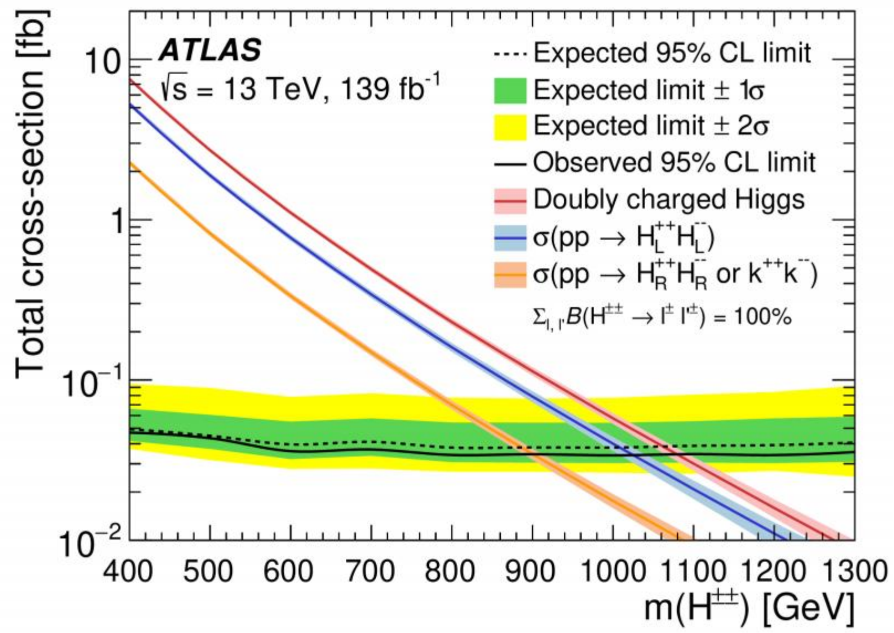


- CMS sees a 2.9σ excess at 95 GeV
- The 95 GeV excess is not confirmed by ATLAS

Additional "Higgs bosons"

Lailin Xu @ATLAS

- $H^{\pm\pm} \rightarrow l^{\pm} l^{\pm}$



$m_{H^{\pm\pm}} < 1080\ (900)$ GeV excluded for the LRSM (Zee-Babu) model

Provides a first direct test of the Zee–Babu model ($k^{++}k^{--}$) at the LHC

Michihisa Takeuchi

Additional "Higgs bosons"

- 125GeV Higgs is SM like → Aligned CPV 2HDM

Aligned CPV 2HDM and EDM

Higgs potential (without Z2 sym.)

$$V = -\mu_1^2|\Phi_1|^2 - \mu_2^2|\Phi_2|^2 - \left\{\mu_3^2(\Phi_1^\dagger\Phi_2) + h.c.\right\} + \frac{1}{2}\lambda_1|\Phi_1|^4 + \frac{1}{2}\lambda_2|\Phi_2|^4 + \lambda_3|\Phi_1|^2|\Phi_2|^2 + \lambda_4|\Phi_2^\dagger\Phi_1|^2 + \left\{\left[\frac{1}{2}\lambda_5(\Phi_1^\dagger\Phi_2) + \lambda_6|\Phi_1|^2 + \lambda_7|\Phi_2|^2\right](\Phi_1^\dagger\Phi_2) + h.c.\right\}$$

(Higgs basis)
[Davidson, Haber, PRD72, 035004 (2005)]

Yukawa couplings

$$\mathcal{L}_{\rm yukawa} = -\bar{Q}_L\frac{\sqrt{2}M_u}{v}(\tilde{\Phi}_1 + \zeta_u\tilde{\Phi}_2)u_R - \bar{Q}_L\frac{\sqrt{2}M_d}{v}(\Phi_1 + \zeta_d\Phi_2)d_R - \bar{L}_L\frac{\sqrt{2}M_e}{v}(\Phi_1 + \zeta_e\Phi_2)e_R + h.c.$$

Higgs basis

$$\Phi_1 = \begin{pmatrix} G^+ \\ \frac{1}{\sqrt{2}}(v + h_1^0 + iG^0)\end{pmatrix}, \quad \Phi_2 = \begin{pmatrix} H^+ \\ \frac{1}{\sqrt{2}}(h_2^0 + ih_3^0)\end{pmatrix}$$

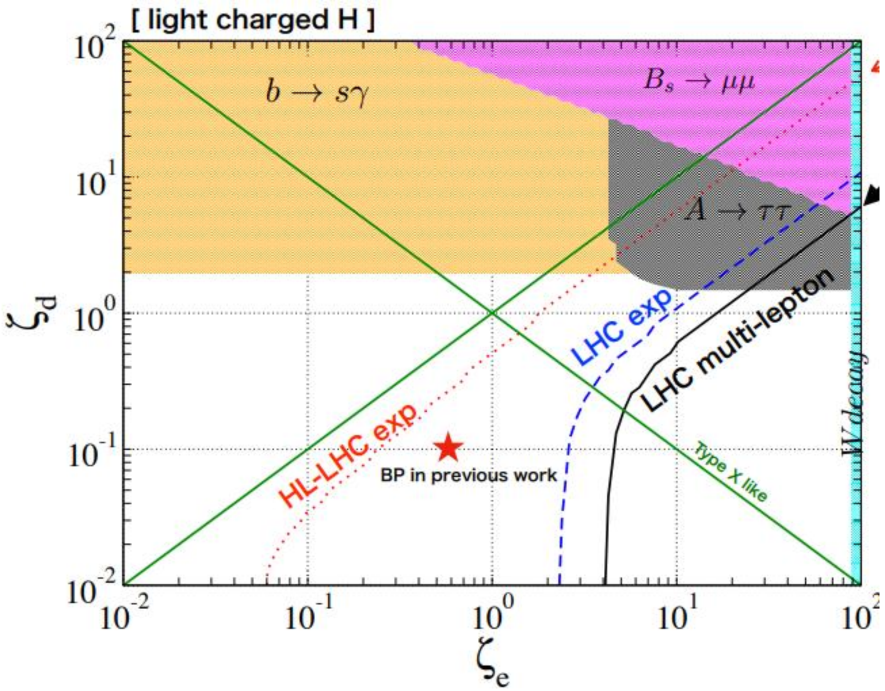
Mass Matrix

$$\mathcal{M}^2 = v^2\begin{pmatrix} \lambda_1 & {\rm Re}[\lambda_6] & -{\rm Im}[\lambda_6] \\ {\rm Re}[\lambda_6] & \frac{M^2}{v^2} + \frac{1}{2}(\lambda_3+\lambda_4+{\rm Re}[\lambda_5]) & -\frac{1}{2}{\rm Im}[\lambda_5] \\ -{\rm Im}[\lambda_6] & -\frac{1}{2}{\rm Im}[\lambda_5] & \frac{M^2}{v^2} + \frac{1}{2}(\lambda_3+\lambda_4-{\rm Re}[\lambda_5])\end{pmatrix}.$$

Pheno-motivated 2 types of alignments assumed:

Higgs alignment $\lambda 6 = 0 (=\mu 3)$ ⇄ No mixing among Higgses 125GeV
Higgs measurements indicate SM like

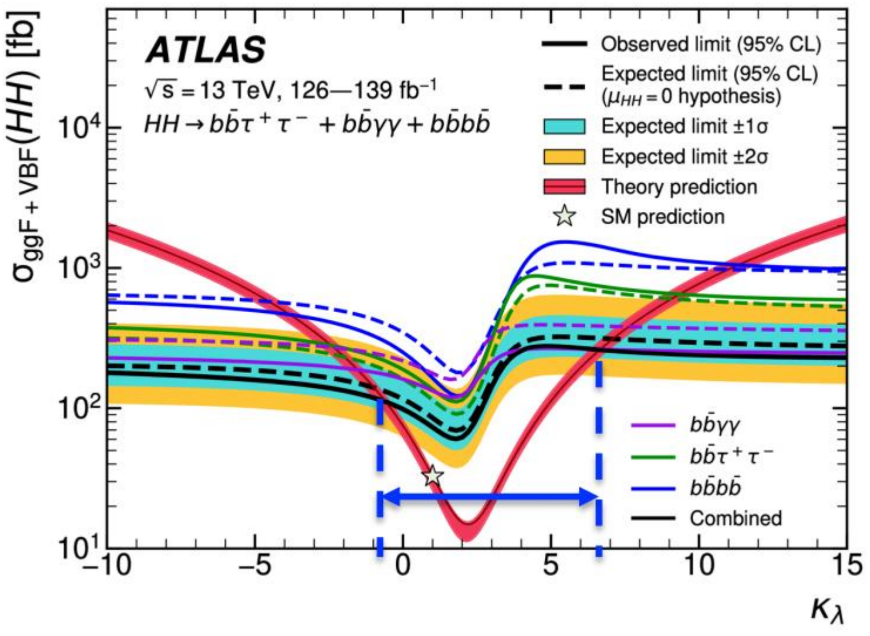
Yukawa alignment to avoid FCNC at tree level
→ 4 complex parameters remain $\zeta_e, \zeta_d, \zeta_u, \lambda_7$



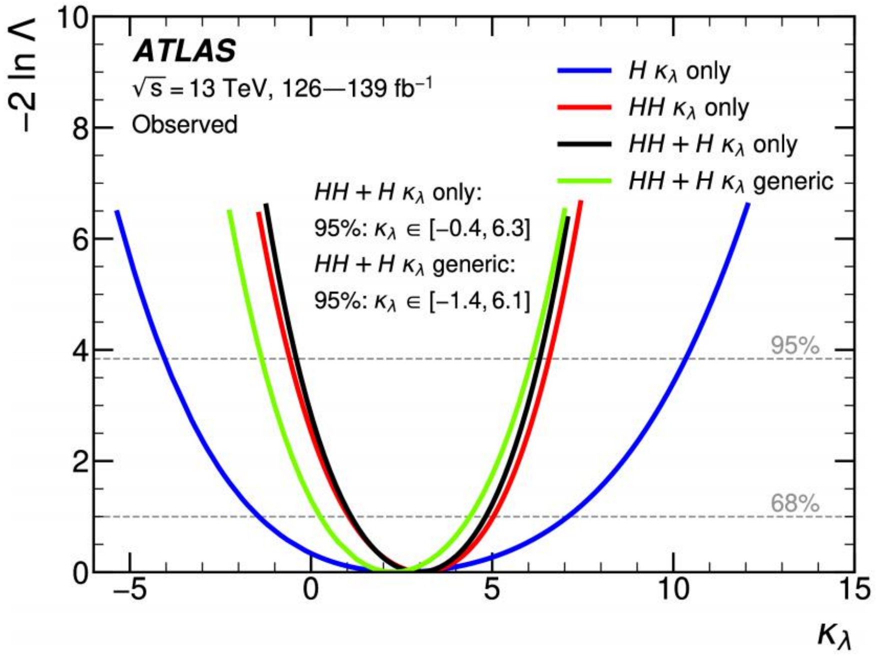
Di-Higgs production

Lailin Xu @ATLAS

- Non-resonant



Also Fengwangdong Zhang @CMS

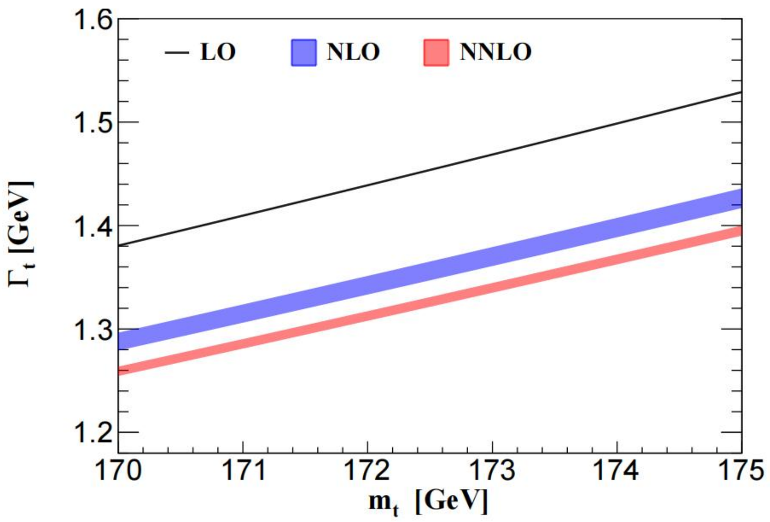


Provides the most stringent constraints on Higgs boson self-interactions to date

Electroweak physics

Top quark

- ttbar production: new early Run3 at 13 TeV results
- Four-top production : Observation at ATLAS with 6.1 (4.3) s.d. and CMS with 5.5 (4.9) s.d
- Top quark width



The full analytical result of top-quark width at NNLO in QCD

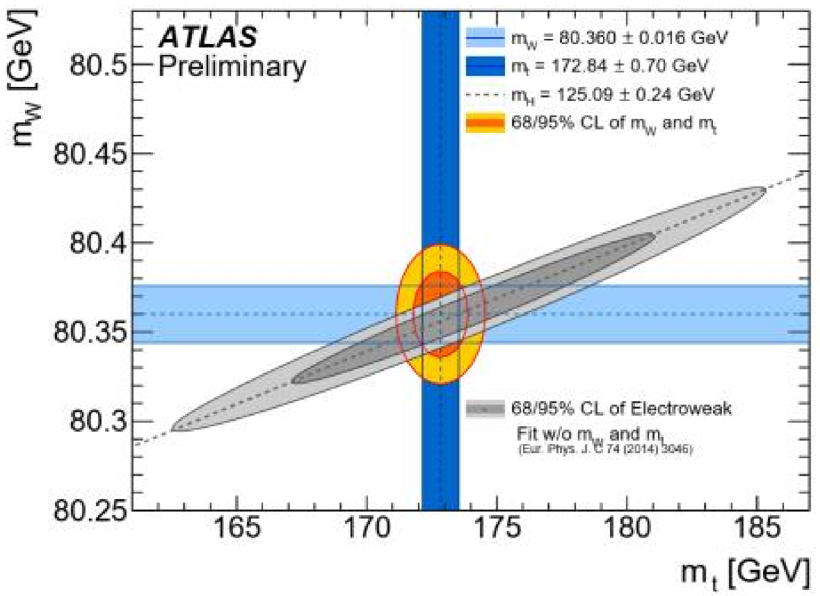
Considering all the possible uncertainties, the uncertainty at NNLO is less than 1%

See Jian Wang's talk

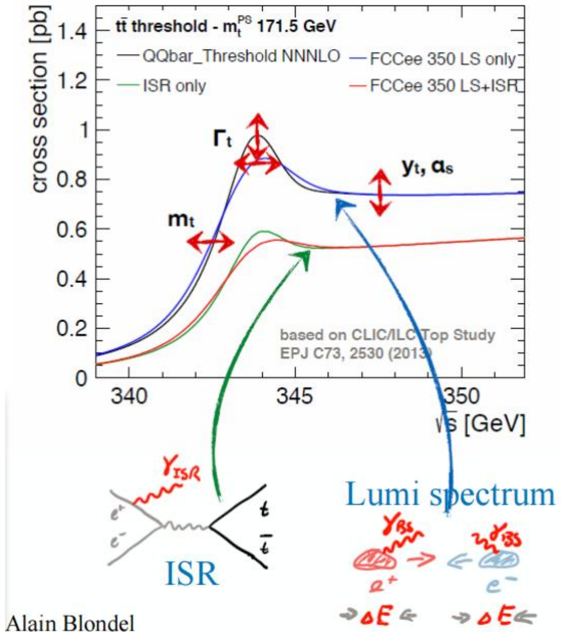
Top quark

Xiaohu Sun @CEPC

- Top quark mass



- The top mass is measured using top reconstruction at hadron colliders
  - Heavily relies on the performance o: MET (the neutrino) and jet energy scale/resolution uncertainties
- CMS Run1 combined uncertainty reached ~500 MeV dominated by systematic uncertainties
- Very difficult to further improve the precision due to dominant systematic uncertainties at hadron colliders



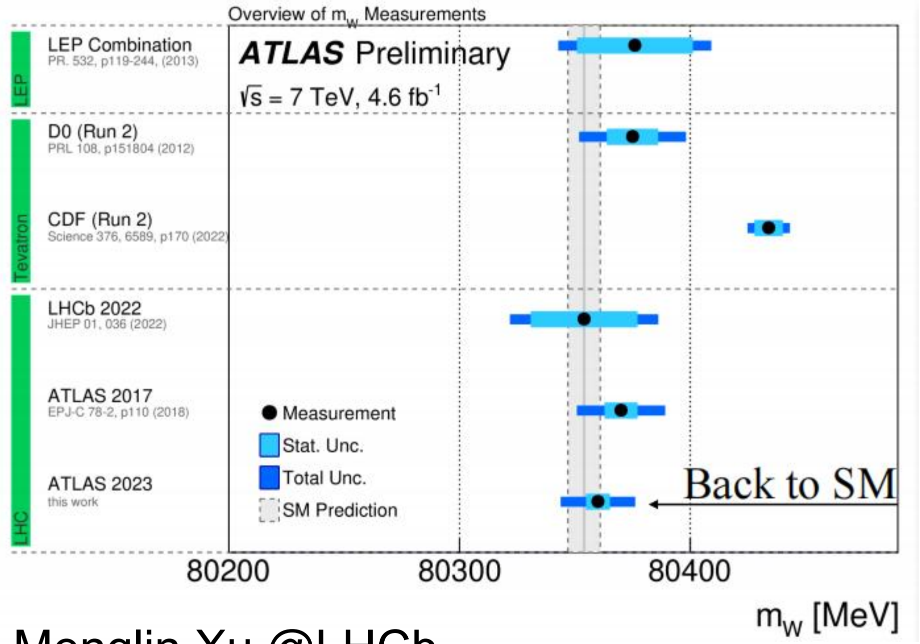
Alain Blondel

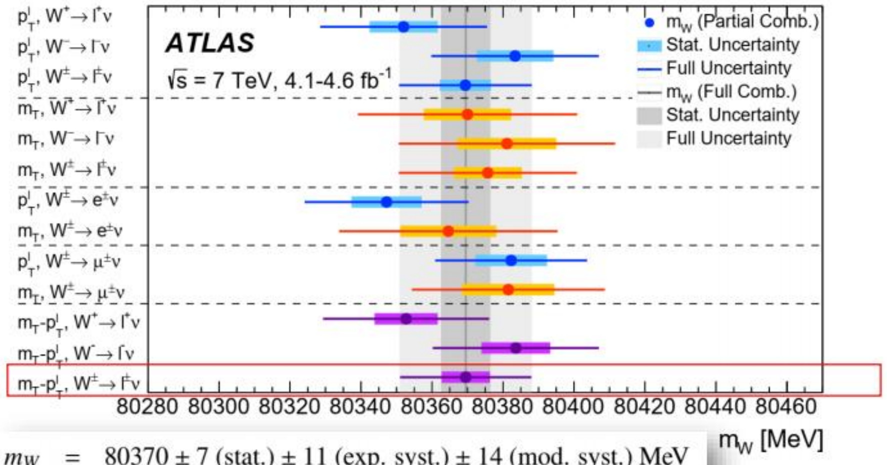
- The total error is 24 MeV (57 MeV) optimistically (conservatively)
- 1 order of magnitude better than the LHC

Precision measurements

Yusheng Wu @ATLAS

- W mass:





$$m_W = 80370 \pm 7\,(\text{stat.}) \pm 11\,(\text{exp. syst.}) \pm 14\,(\text{mod. syst.})\ \text{MeV}$$
$$= 80370 \pm 19\ \text{MeV},$$

$$m_W = 80360 \pm 5(\text{stat.}) \pm 15(\text{syst.}) = 80360 \pm 16\ \text{MeV}$$

See also Menglin Xu @LHCb

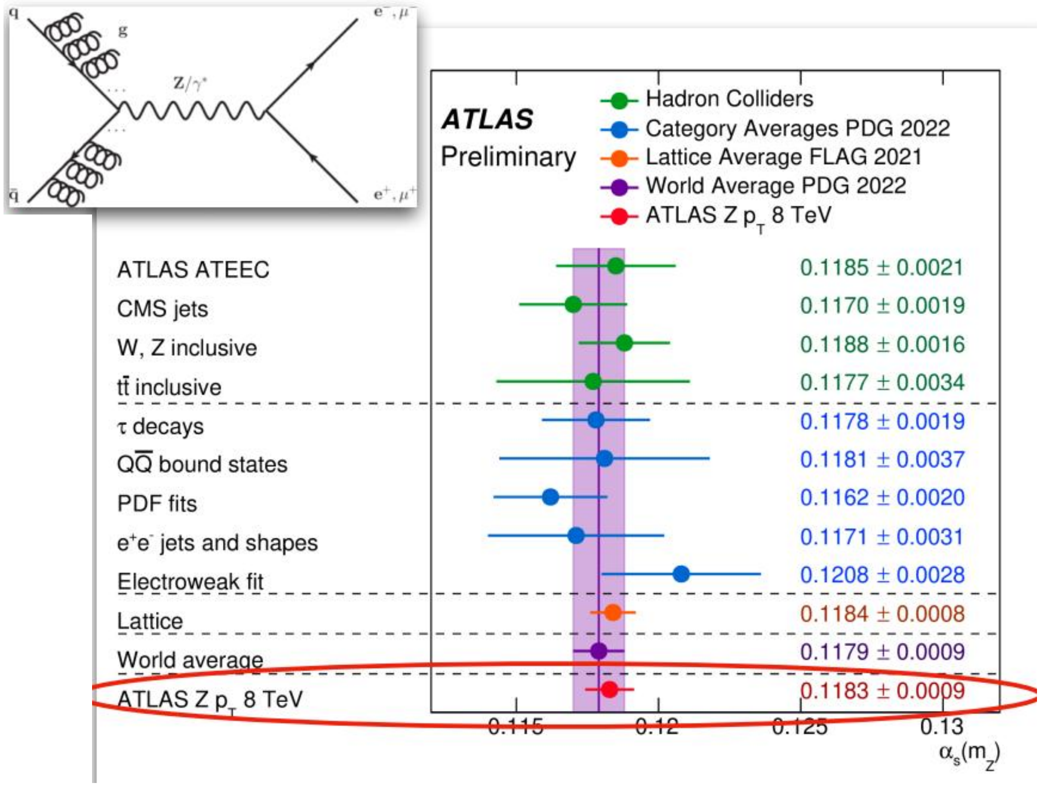
Updated mW measured to have lower mass, and 3 MeV smaller unc.

FUTURE:
more precise, independent measurements from ATLAS, CMS, LHCb will be desired (in view of discrepancies w.r.t. CDF results) ➔ more precise calibrations (with more data), better pT modelling (more precise V pT measurements), better PDF modelling (more relevant PDF measurements at the LHC)

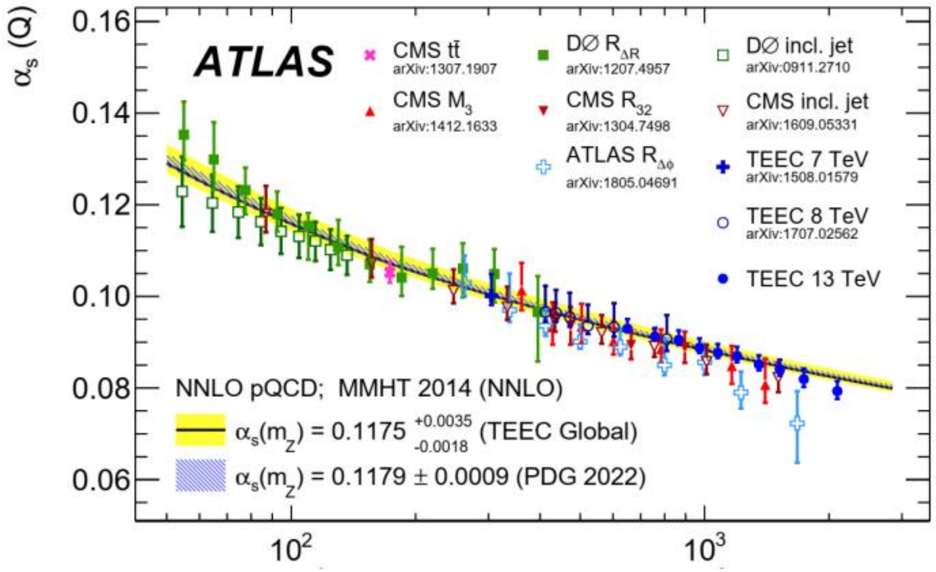
Precision measurements

Yusheng Wu @ATLAS

- *αS*: Most precise measurement by ATLAS, using large-stat Zjets events with ISR



A single best precision measurement so far 0.8% precision in *αS*



Precise ***αs*** determination at TeV scales

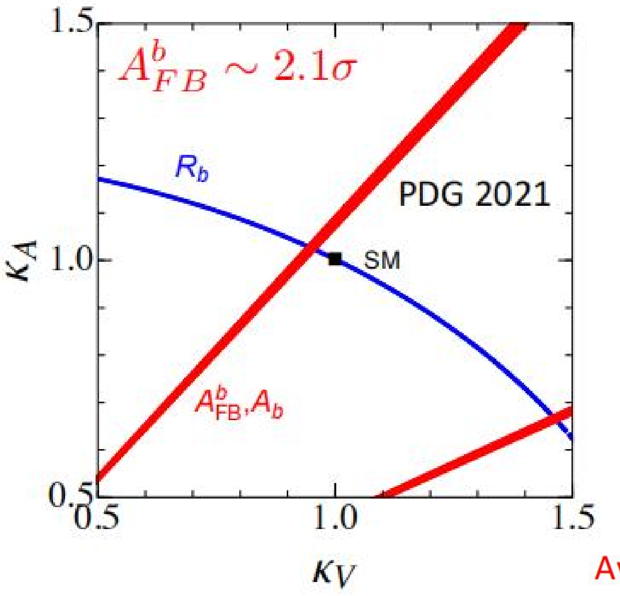
$$\frac{1}{\sigma}\frac{d\Sigma}{d\cos\phi} \equiv \frac{1}{\sigma}\sum_{ij}\int \frac{d\sigma}{dx_{Ti}dx_{Tj}d\cos\phi} x_{Ti}x_{Tj}dx_{Ti}dx_{Tj} = \frac{1}{N}\sum_{A=1}^{N}\sum_{ij}\frac{E_{Ti}^{A}E_{Tj}^{A}}{\left(\sum_k E_{Tk}^{A}\right)^2}\delta(\cos\phi - \cos\varphi_{ij})$$

Precision measurements

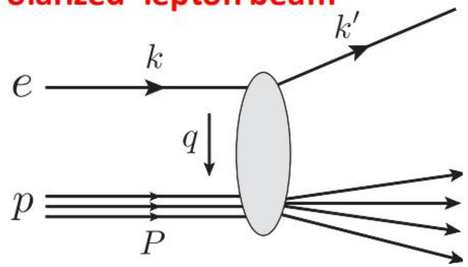
Bin Yan

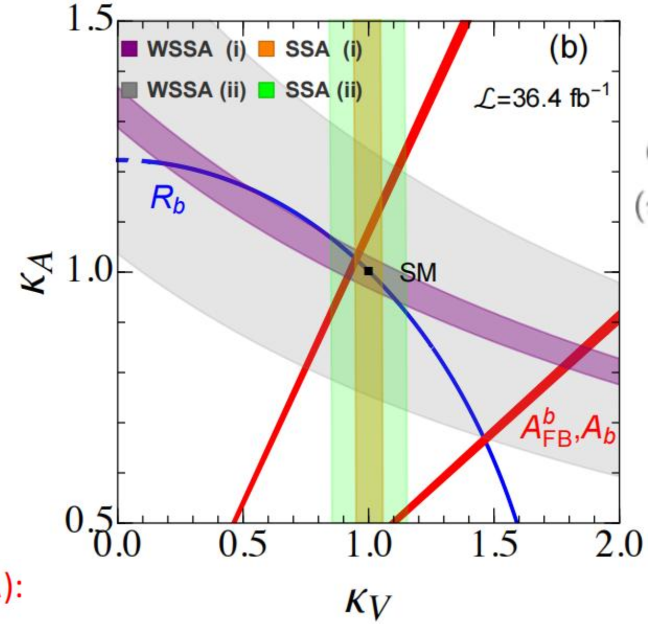
- Zbb coupling

At Electron-Ion Collider



Polarized lepton beam





Average jet charge weighted Single-Spin Asymmetry (WSSA):

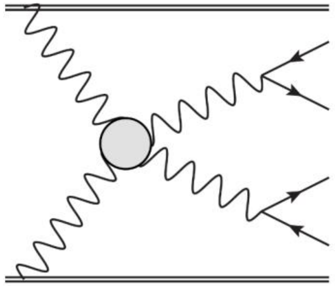
$$A_e^{bQ} = \frac{\sigma^Q_{b,+} - \sigma^Q_{b,-}}{\sigma^Q_{b,+} + \sigma^Q_{b,-}} \qquad \sigma^Q_{b,\pm} = \int dp_T^j \frac{d\sigma^{\rm tot}_{b,\pm}}{dp_T^j} \langle Q_J \rangle_b (p_T^j)$$

$$\langle Q_J \rangle_b (p_T^j) = \sum_{q=u,d,c,s,b} \left[f_J^q(p_T^j, \epsilon_q^b) - f_J^{\bar{q}}(p_T^j, \epsilon_q^b) \right] \langle Q_J^q \rangle_b (p_T^j)$$

Precision measurements

Zhe Guan, Yusheng Wu,
Hao Xu, Xiao Wang

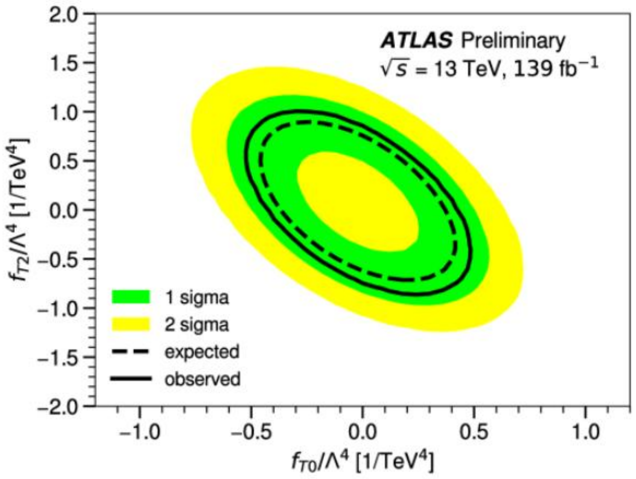
- Diboson production

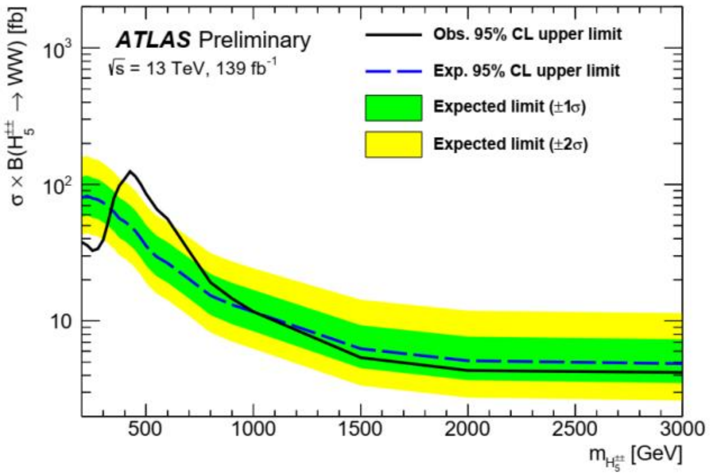


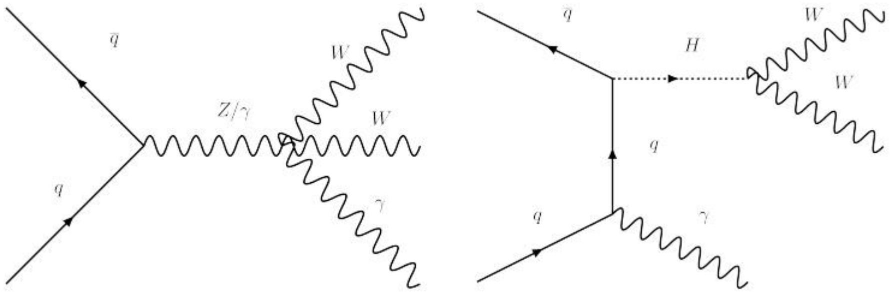
Same-sign EW WWjj

- Triboson production

Observation of WWγ at ATLAS & CMS





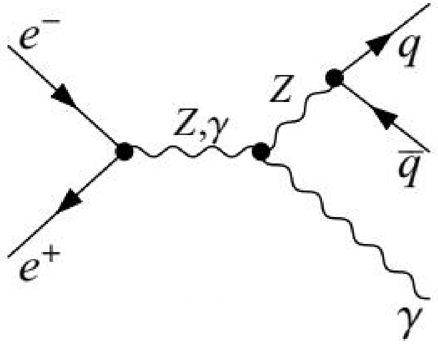


Yukawa couplings limits exp.(obs.)
$\|\kappa_u\| \leq 13000$ (16000)
$\|\kappa_d\| \leq 14000$ (17000)
$\|\kappa_s\| \leq 1300$ (1700)
$\|\kappa_c\| \leq 110(200)$

Precision measurements

Rui-qing Xiao

- Neutral triple-gauge coupling (nTGCs)
  - nTGCs provide unique probe of dimension-8 SMEFT operators
  - New nTGC form factor formalism which match dimension-8 SMEFT is proposed



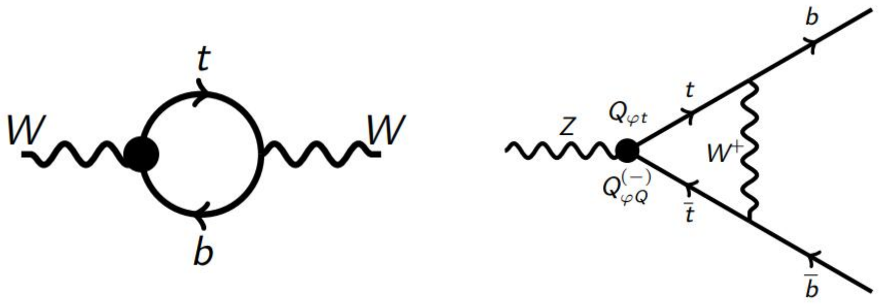
$$\Gamma^{\alpha\beta\mu(8)}_{Z\gamma V^*}(q_1,q_2,q_3) = \frac{e(q_3^2-M_V^2)}{M_Z^2}\left[\left(h_3^V + h_5^V\frac{q_3^2}{M_Z^2}\right)q_{2\nu}\epsilon^{\alpha\beta\mu\nu} + \frac{h_4^V}{M_Z^2}q_2^\alpha q_{3\nu}q_{2\sigma}\epsilon^{\beta\mu\nu\sigma}\right]$$

$$\mathcal{T}[f\bar{f}\to Z_L\gamma] = h_3^V O(E^3) + h_4^V O(E^5) + h_5^V O(E^5) = \Lambda_j^{-4}O(E^3)\,.$$

Precision measurements

Yiming Liu

- SMEFT fits: loop effects



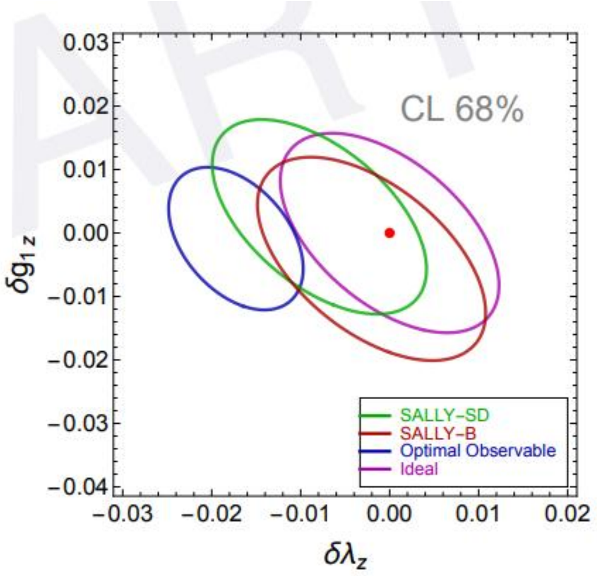
Operator	$C_{\varphi t}$	$C^{(+)}_{\varphi Q}$	$C^{(-)}_{\varphi Q}$	$C_{\varphi tb}$	C_{tW}	C_{tB}	$C_{t\varphi}$
$\mu_{EFT} = 125\text{GeV}$	2.5	1.3	3.2	9.3	0.2	0.07	0.9
$\mu_{EFT} = 1000\text{GeV}$	1.3	0.5	4.3	1.3	0.6	0.08	0.9
Current	2.3	5.1	1.2	5.3	0.06	0.145	3.9
Our results	0.286	0.04	0.336	14.8	0.822	0.592	–

Precision measurements

Jiayin Gu

- SMEFT fits: machine learning

  - **Inverse:** From data / MC samples, how do we know the model parameters?
  - With **Neural Network** we can (in principle) reconstruct $\frac{d\sigma}{d\Omega}$ (or likelihood ratios) from MC samples.

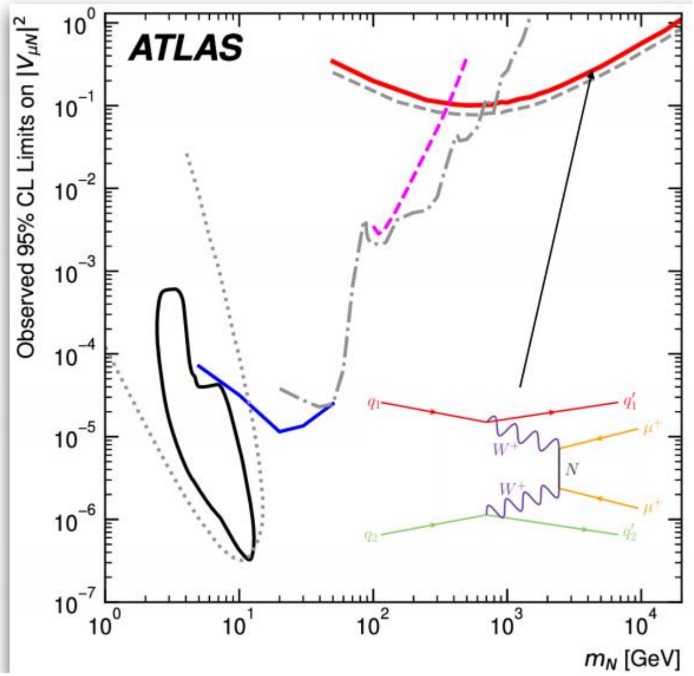


New phenomena

Majorana neutrino

Oliver Stelzer-Chilton @ATLAS

- VBS same-sign WW for Majorana neutrinos

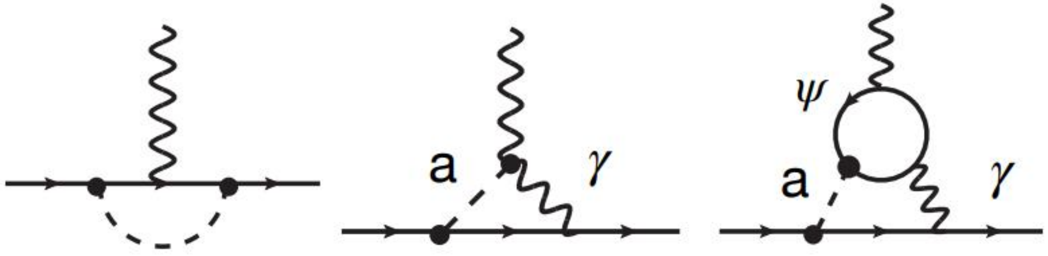


New light particles

Xiao-Ping Wang

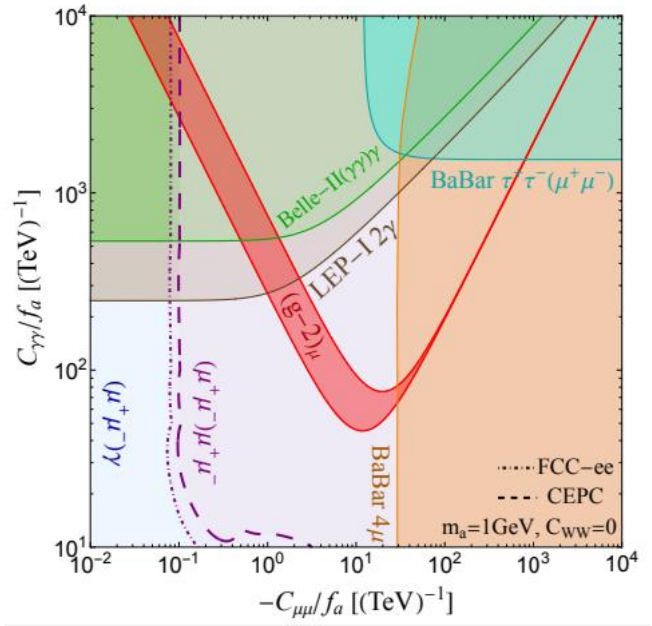
- Axion-like particle

$$\mathscr{L}_{\rm eff}^{\rm D\leq 5} = \sum_f \frac{C_{ff}}{2}\frac{\partial^\mu a}{f_a}\bar{f}\gamma_\mu\gamma_5 f + \frac{\alpha C_{\gamma\gamma}}{4\pi}\frac{a}{f_a}F_{\mu\nu}\tilde{F}^{\mu\nu} + \frac{\alpha C_{\gamma Z}}{2\pi s_w c_w}\frac{a}{f_a}F_{\mu\nu}\tilde{Z}^{\mu\nu} + \frac{\alpha C_{ZZ}}{4\pi s_w^2 c_w^2}\frac{a}{f_a}Z_{\mu\nu}\tilde{Z}^{\mu\nu}$$
$$+\frac{\alpha C_{WW}}{\pi s_w^2}\frac{a}{f_a}\epsilon_{\mu\nu\rho\sigma}\partial^\mu W_+^\nu \partial^\rho W_-^\sigma + \ldots$$



$\Delta a_\mu^{(1)} \propto -\frac{c_{\mu\mu}^2}{16\pi^2}$ $\Delta a_\mu^{(2)} \propto -\frac{c_{\mu\mu}c_{\gamma\gamma}\alpha}{16\pi^3}$ $\Delta a_\mu^{(3)} \propto -\frac{c_{\mu\mu}c_{ii}\alpha}{16\pi^3}$

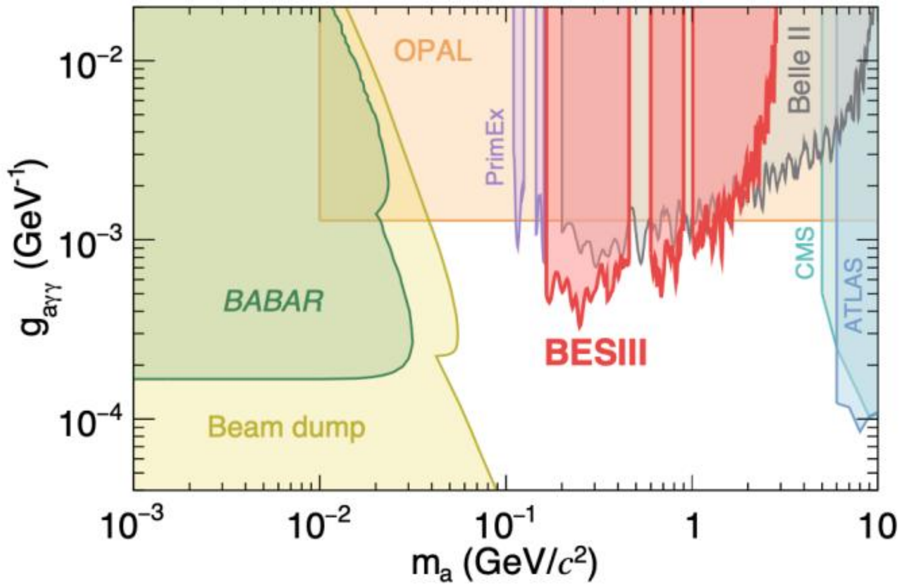
- Different sign for $c_{\mu\mu}$ and $c_{\gamma\gamma}$ is needed



New light particles

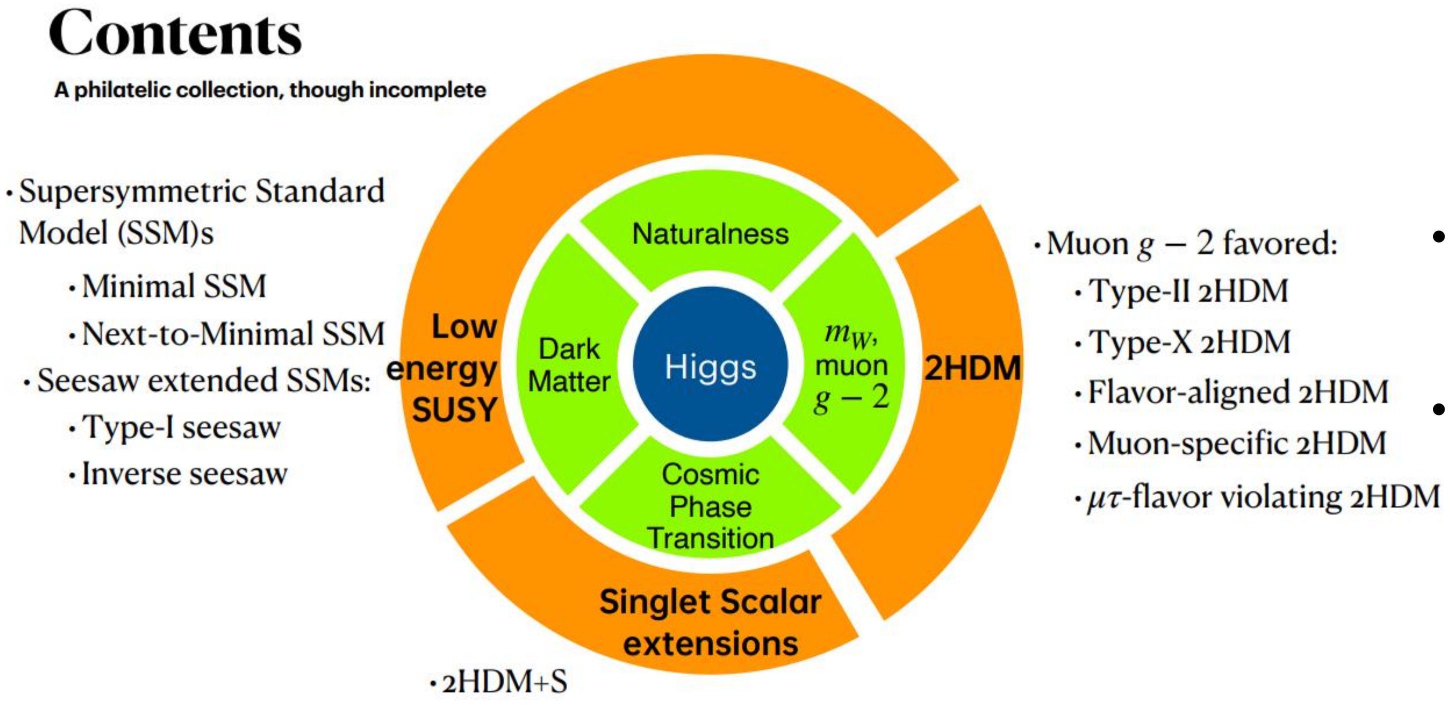
Houbing Jiang @BESIII

- Axion-like particle



$$J/\psi \to \gamma a, a \to \gamma\gamma$$

SUSY



$$\mathcal{L} = \frac{\bar{\theta}}{64\pi^2} \epsilon^{\mu\nu\rho\sigma} G_{\mu\nu} G_{\rho\sigma}$$

- The spontaneous CP violation is alternative way to solve the strong CP problem
- Supersymmetric model of spontaneous CP violation leads to a robust framework

See Pengxuan Zhu's talk

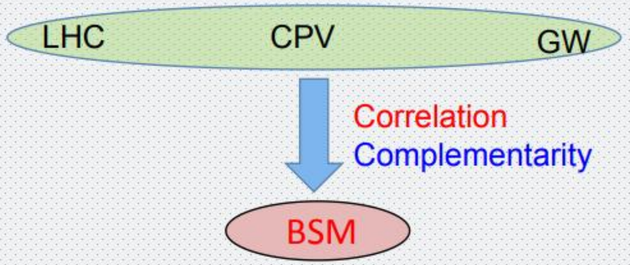
See Norimi Yokozaki's talk

Electroweak baryogenesis

Huaike Guo

- Electroweak phase transition:

- Modified Higgs potential (Higgs physics, GW)
- Extra CP-violation (EDM, LHC)
- B-violation: Sphaleron process (LHC, GW)



See Yanda Wu's talk for sphaleron

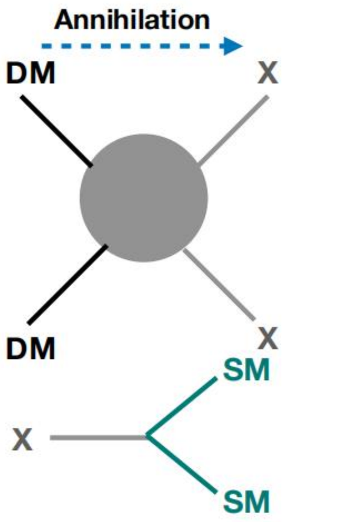
Models	Strong 1[st] order phase transition	GW signal	Cold DM	Dark Radiation and small scale structure
SM charged				
Triplet [20–22]	✓	✓	✓	✗
complex and real Triplet [23] (Georgi-Machacek model)	✓	✓	✓	✗
Multiplet [24]	✓	✓	✓	
2HDM [25–30]	✓	✓		✗
MLRSM [31]	✓	✓	✗	✗
NMSSM [32–36]	✓	✓	✓	✗
SM uncharged				
S_r (xSM) [37–49]	✓	✓	✗	✗
2 S_r's [50]	✓	✓	✓	✗
S_c (cxSM) [49, 51–54]	✓	✓	✓	✗
$U(1)_D$ (no interaction with SM) [55]	✓	✓	✓	✗
$U(1)_D$ (Higgs Portal) [56]	✓	✓	✓	
$U(1)_D$ (Kinetic Mixing) [57]	✓	✓	✓	
Composite SU(7)/SU(6) [58]	✓	✓	✓	
$U(1)_L$ [59]	✓	✓	✓	✗
$SU(2)_D \to$ global $SO(3)$ by a doublet [60–62]			✓	✗
$SU(2)_D \to U(1)_D$ by a triplet [63–65]			✓	✓
$SU(2)_D \to Z_2$ by two triplets [66]			✓	✗
$SU(2)_D \to Z_3$ by a quadruplet [67, 68]			✓	✗
$SU(2)_D \times U(1)_{B-L} \to Z_2 \times Z_2$ by a quintuplet and a S_r [69]			✓	✗
$SU(2)_D$ with two dark Higgs doublets [70]	✓	✓	✗	✗
$SU(3)_D \to Z_2 \times Z_2$ by two triplets [62, 71]			✓	✗
$SU(3)_D$ (dark QCD) (Higgs Portal) [72, 73]	✓	✓	✓	
$G_{SM} \times G_{D,SM} \times Z_2$ [74]	✓	✓	✓	
$G_{SM} \times G_{D,SM} \times G_{D,SM} \cdots$ [75]	✓	✓	✓	
Current work				
$SU(2)_D \to U(1)_D$ (see the text)	✓	✓	✓	✓

Also Leila Kalhor's talk

Dark matter

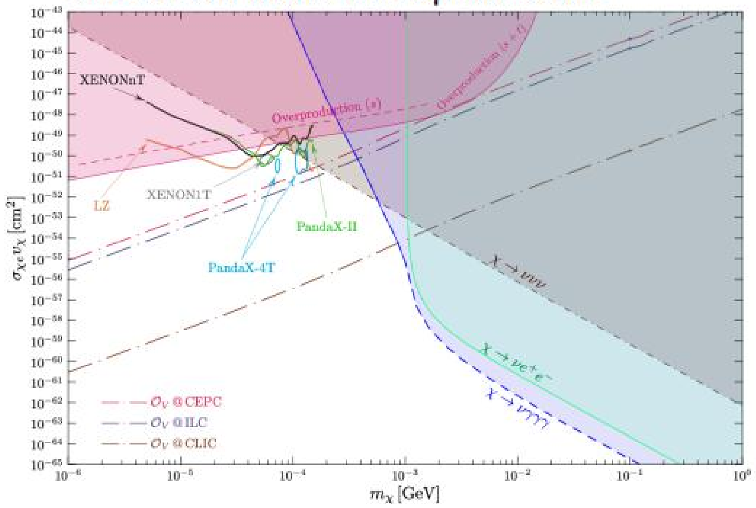
Outline

- CEPC and Dark Sector searches
  - Fermion portal — lepton portal
  - Higgs portal
  - Vector portal
  - EFT models
- Summary



Dark mediator X
with small coupling to SM

- Collider complementary between DM direct and indirect experiments



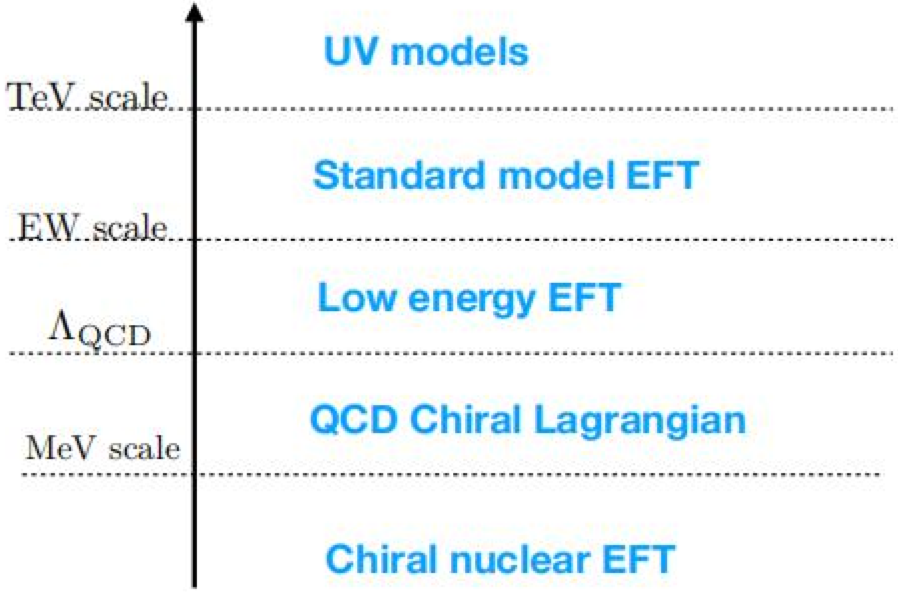
See Jia Liu’s talk

Effective field theory

EFTs for WIN

Jiang-Hao Yu

- The EFT framework provides most general description on weak interactions and neutrinos



Low energy probe of high energy physics

(Intensity frontier)

Construct operator bases in each levels of EFTs using spinor Young tensor

Complete UVs can be explored via Casimir projection

- With the whole EFT framework, we are ready to investigate WIN pheno in a systematic way