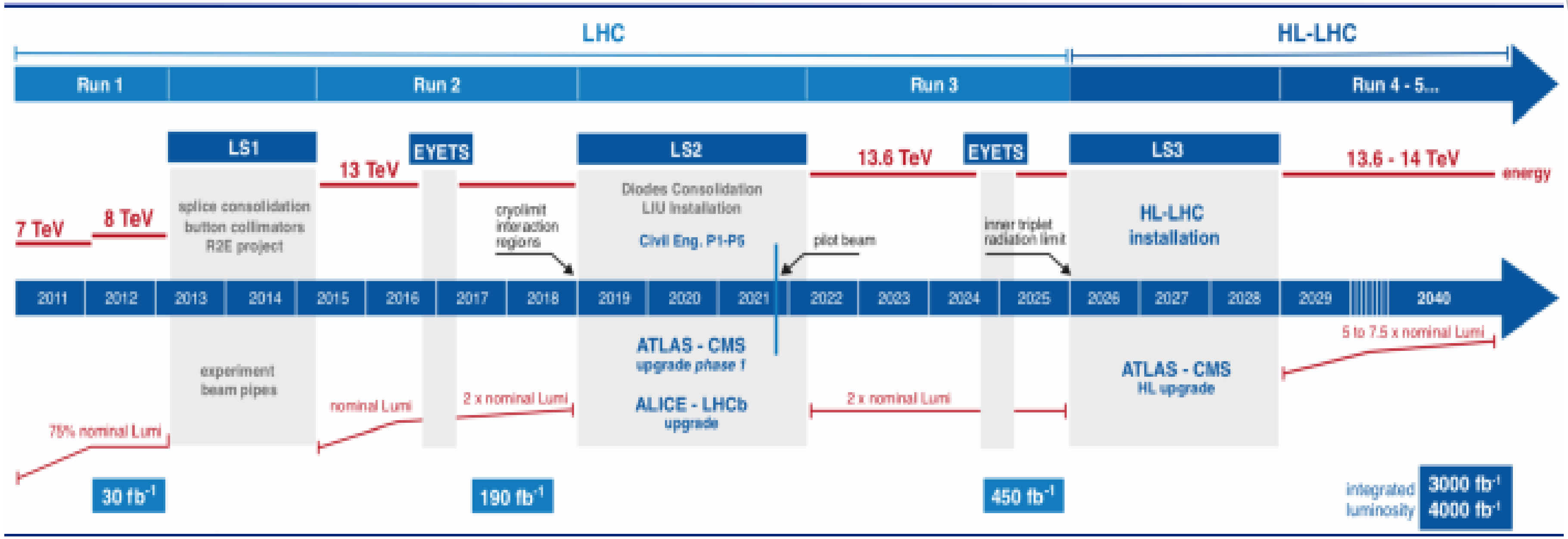
Recent result from ATLAS and CMS experiments

A.Myagkov (IHEP)

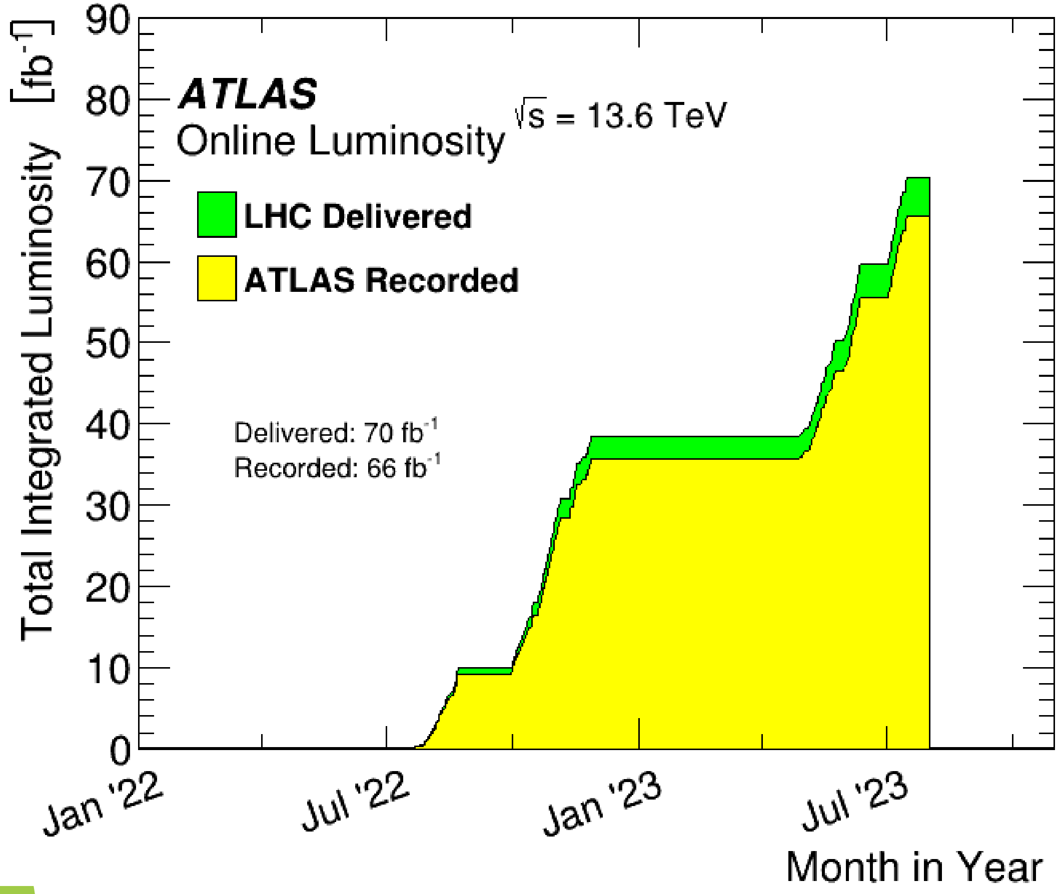
LHC: status and plans

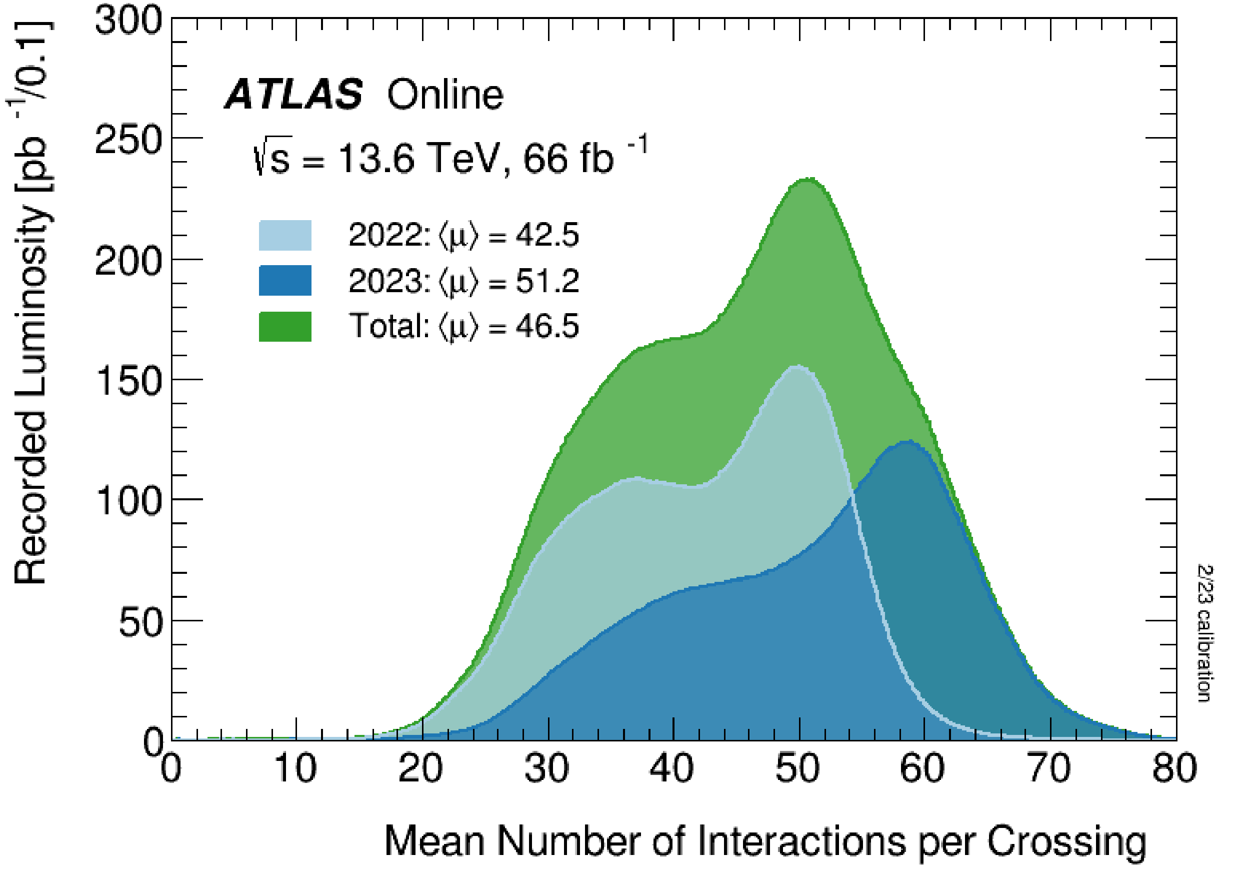


Run 3 6.8 TeV
ATLAS, CMS target 250 /fb
LHCb 25-30 /fb
ALICE 200/pb pp, 7/nb Pb-Pb

Run 4 (HL_LHC) High pileup up to ‹μ›=140-200, high particle multiplicity, plan ~3/ab

Total Integrated Luminosity in Run 3 (13.6 TeV p-p data only)





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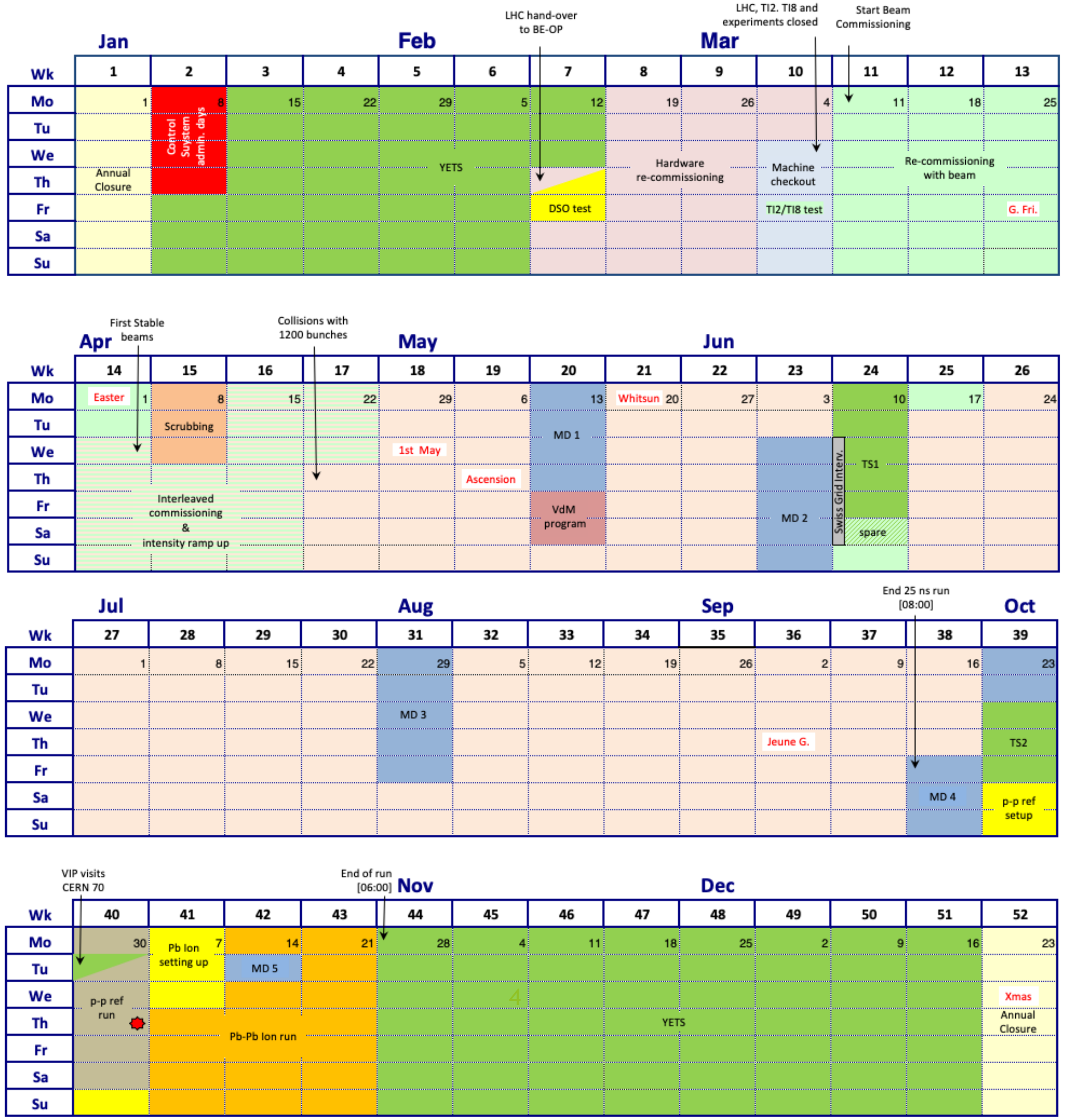
2024 LHC schedule

Activity	#days	%
25 ns physics (>1200 bunches)	**124**	53.7
Special physics runs (incl. setting-up)	**2**	0.9
Pb-Pb ions physics & p-p ref. run	**22.5**	9.7
Beam Commissioning & Intensity ramp-up	42	18.2
Scrubbing	3	1.3
Pb-Pb ions & p-p ref. setting-up	6	2.6
Technical stop	9	3.9
Technical stop recovery	2	0.9
Other scheduled stops	0.5	0.2
Machine Development (incl. floating MDs)	20	8.7
Total:	**231**	**100%**



Closure of LHC and experimental caverns on March 6th 2024

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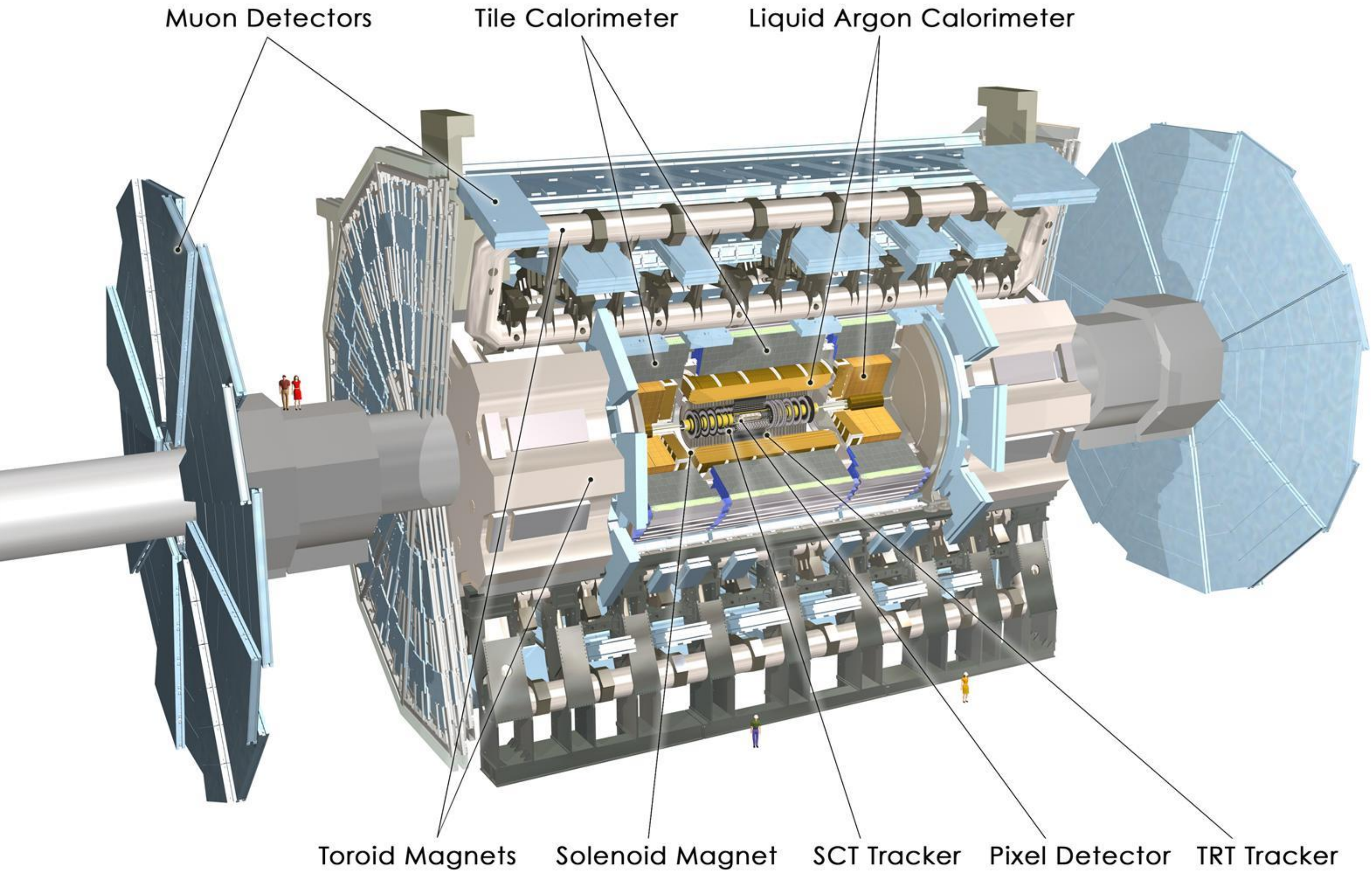
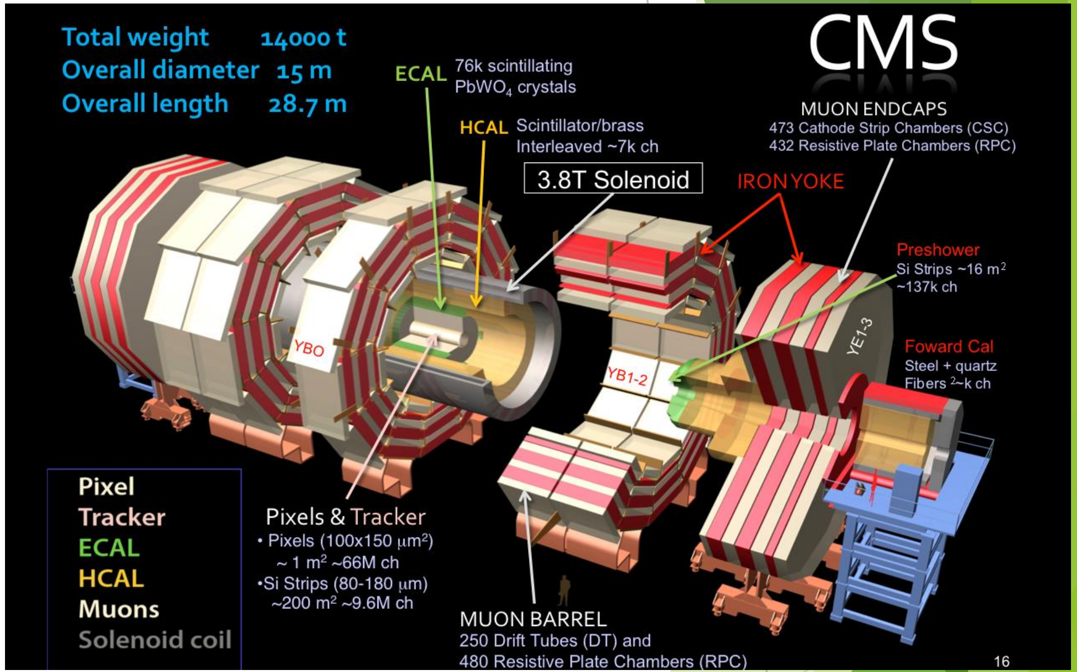
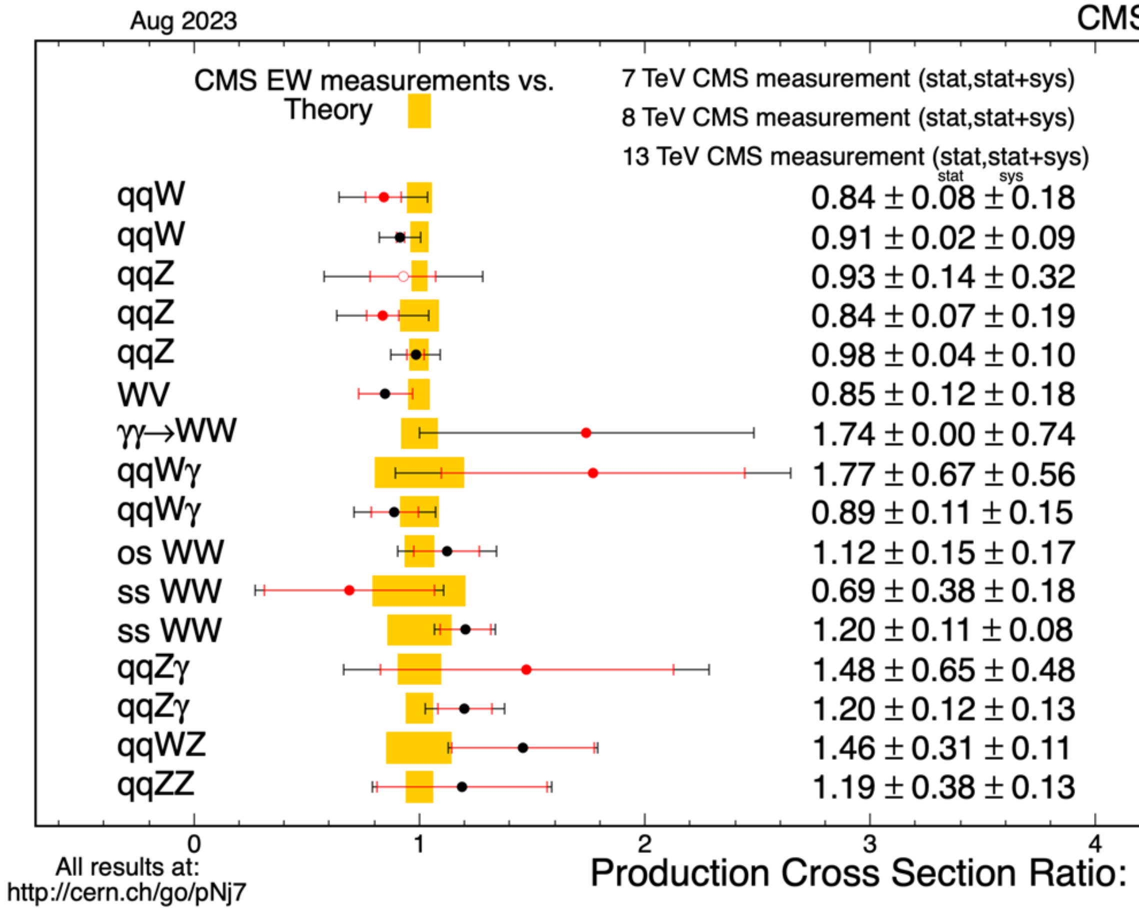
ATLAS and CMS





Ratio of diboson EWK cross-section measurements to theory

Multiboson measurements (diboson and triboson)
- allow new precise tests of SM
- are very sensitive to anomalous couplings (BSM search)
- backgrounds to more rare processes, such as processes involving Higgs boson(s)



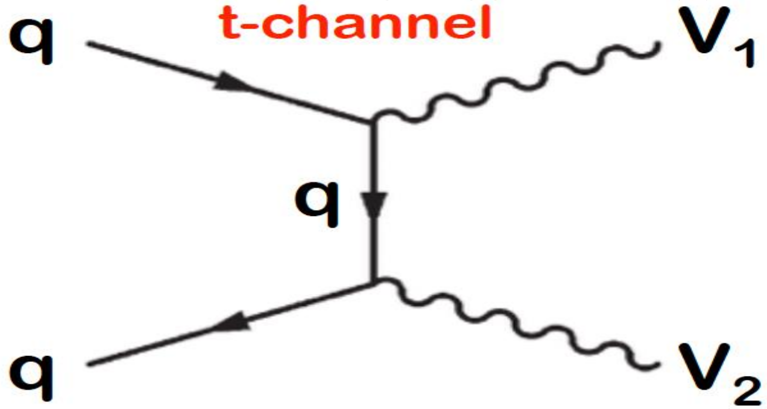
Large number of processes study

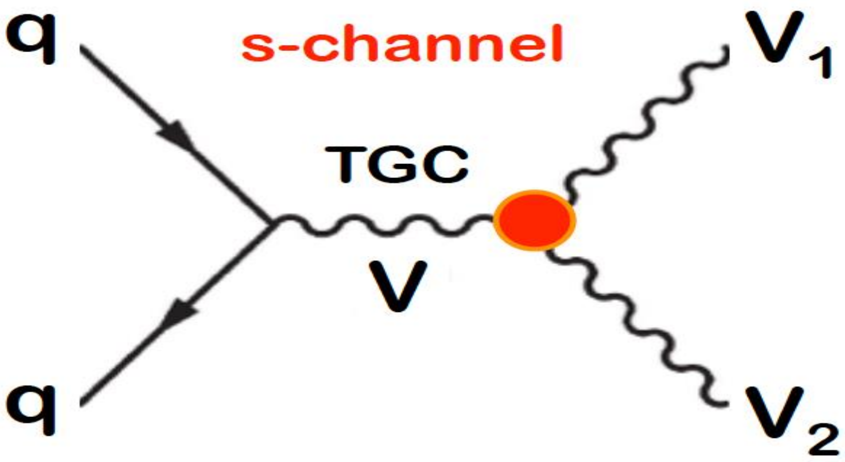
Generally good agreement between experiment and theory

Constraint on anomalous couplings

Multi-Boson Production

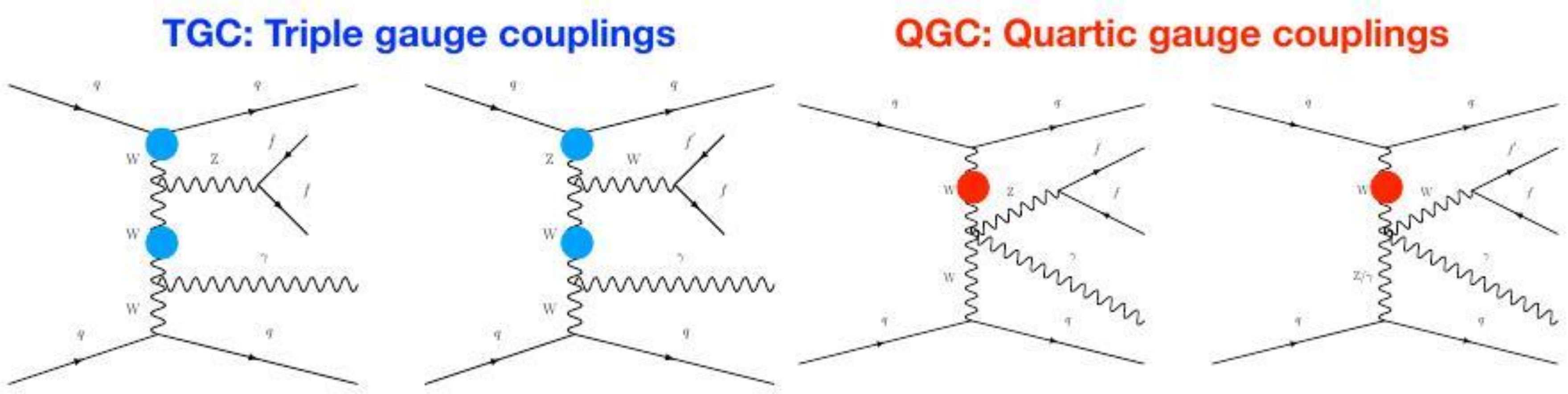
Multiboson measurements (diboson and triboson)
- allow new precise tests of SM
- are very sensitive to anomalous couplings (BSM search)
- are main backgrounds to more rare processes, such as processes involving Higgs boson(s)





Large number of processes study
Generally good agreement between experiment and theory
Constraint on anomalous couplings

TGC,QGC

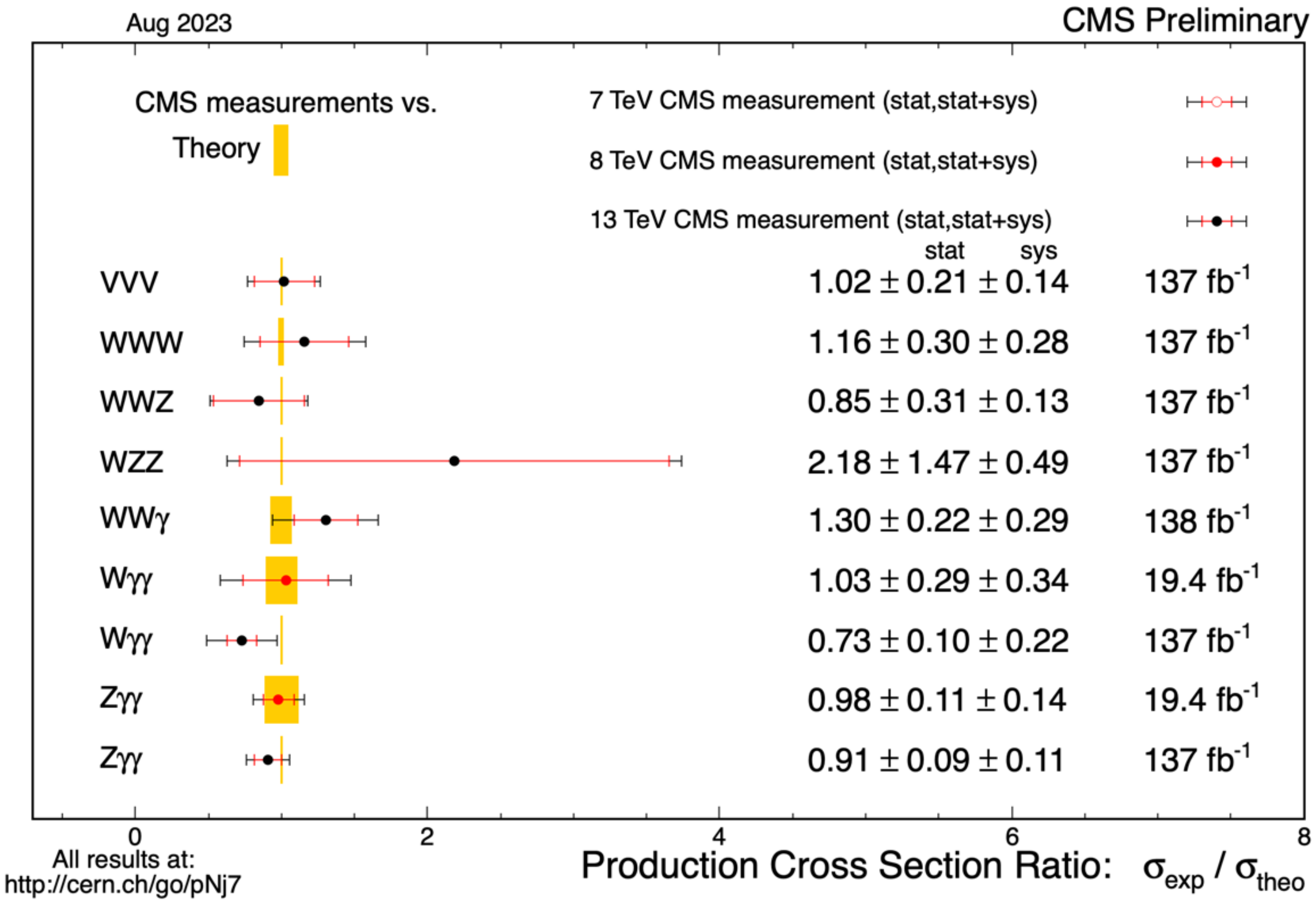


Larger cross sections:
- More precise measurement for SM test
- Possibly accurate differential cross section

Multiboson couplings:
- T(Q)GC: WWZ, WWγ, WWZγ, WWγγ
- BSM TGC: ZZγ, Zγγ
- BSM QGC : ZZγγ, ZZZγ,Zγγγ

BSM Higgs decay by Z → νν

Multi-Boson Production



EFT

Effective field theory (EFT)

- **Modern model independent approach to parameterize BSM effects** (deviations from SM in the measurements) **in the Lagrangian**
- Effective Lagrangian is based on Taylor expansion in local operators with mass dimension >4:

$$\mathscr{L}_{SMEFT} = \mathscr{L}_{SM} + \sum \frac{c_i^{d=6}}{\Lambda^2}\mathcal{O}^{d=6} + \sum \frac{c_i^{d=8}}{\Lambda^4}\mathcal{O}^{d=8} + \ldots$$

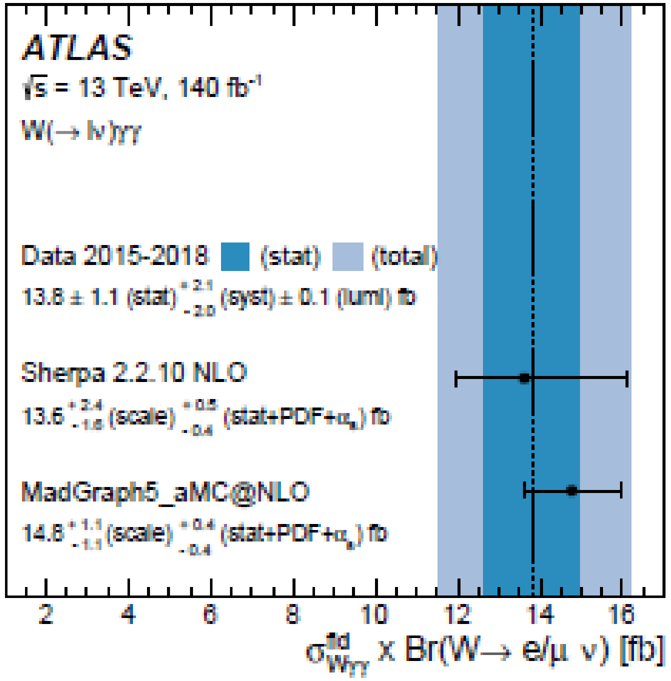
- Operators O are gauge invariant combinations of SM fields; the odd ones violate B-L number

- c_i are the Wilson coefficients, Λ is the new physics scale

- Only c_i/Λ^{d-4} are measurable, they ***can be constrained using data*** → possible **constraints on BSM models**

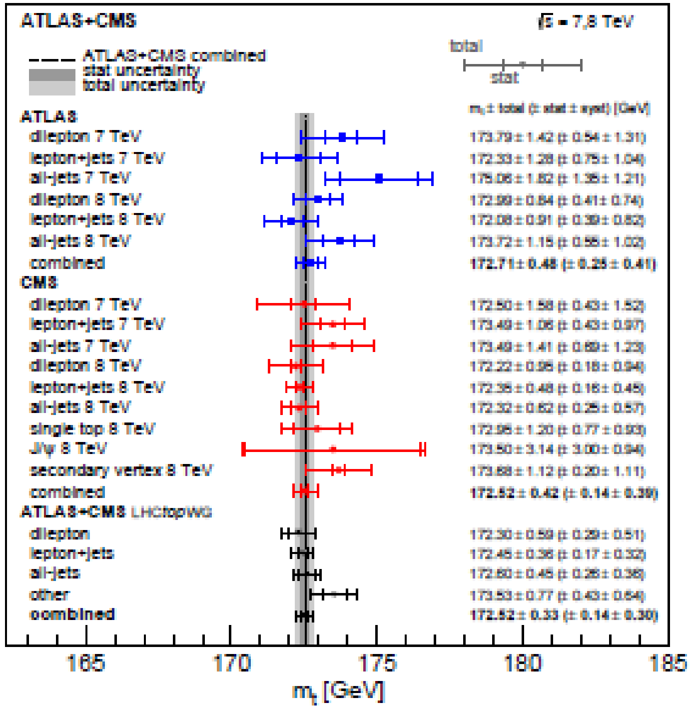
Observation of $W\gamma\gamma$ Phys. Lett. B 848 (2024) 138400

- $\boldsymbol{W\gamma\gamma}$ production in e/μ final states is observed first time with significance of $5.6\boldsymbol{\sigma}$ (observed and expected)
- The measured fiducial cross section for$W(e\nu)\gamma\gamma$
- and$W(\mu\nu)\gamma\gamma$ events is σ(fid)
- = 13.8 ± 1.1(stat) +2.1−2.0(syst) ± 0.1(lumi)\ fb
- in agreement with the SM predictions
- for this process



top mass combination ATLAS and CMS arXiv:2402.08713

- Key SM parameter: Higgs coupling, consistency fits
- Method: Best Linear Unbiased Estimated – BLUE combination of 15 Run-1 measurements
- Datasets (assumed) statistically uncorrelated Challenge: how to correlate systematics between experiments?
- ▸ Classify sources as strongly/partially/un·correlate
- (ρ = 0.85/0.5/0)
- m_t = 172.52 ± 0.14 (stat) ±0.30 (syst) GeV
- Total uncertainty ±0.33 GeV → 0.2%!
- Most precise m_t ever reported by experiments;
- ~same precision as PDG world average!



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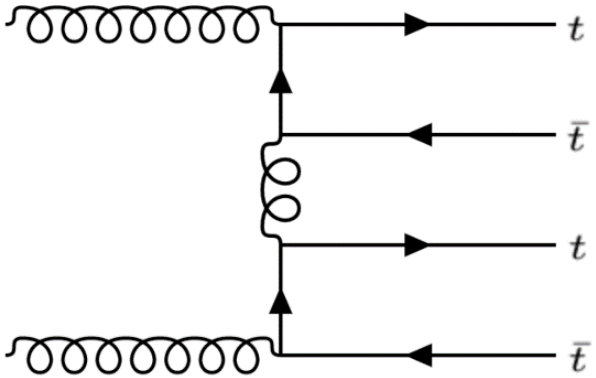
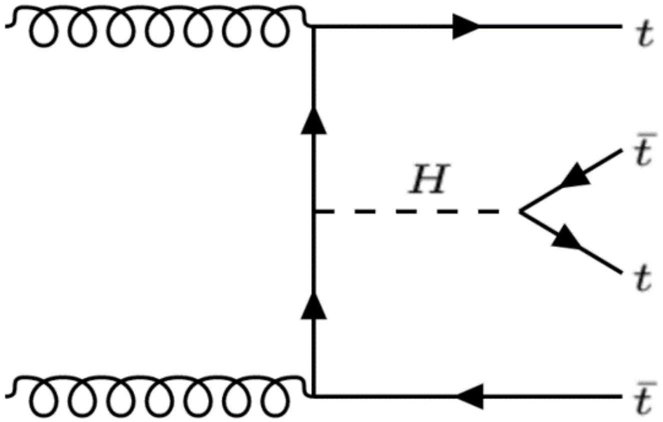
$t\bar{t}t\bar{t}$

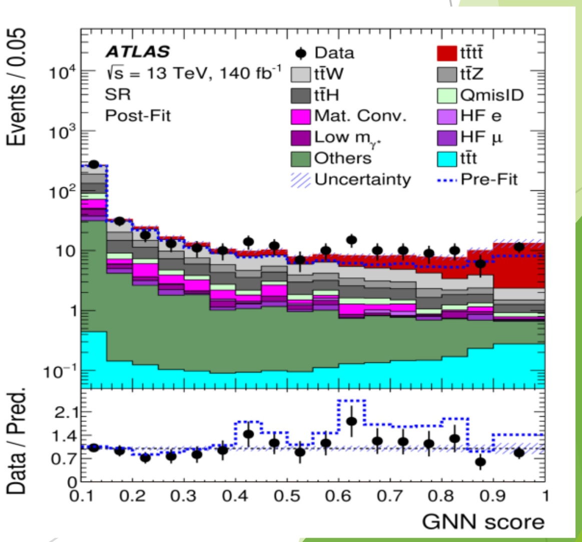
Eur.Phys.J. C83 496(2023)





Rare Standard Model process
Sensitive to the top-quark Yukawa coupling
Can be significantly enhanced in many BSM models

GNN score in signal region



tt̄t̄ signal is observed at 6.1(4.3)σ:

$$\sigma_{t\bar{t}t\bar{t}} = 22.5^{+4.7}_{-4.3}(\text{stat})\,^{+4.6}_{-3.4}(\text{syst})\text{ fb} = 22.5\,^{+6.6}_{-5.5}\text{ fb}$$

SM: σ_{tttt}= 12.0±2.4fb JHEP 02(2018) 031

re-analysis of the Run 2 140 fb−1 dataset at s=13TeV in the 2LSS/3L channels:

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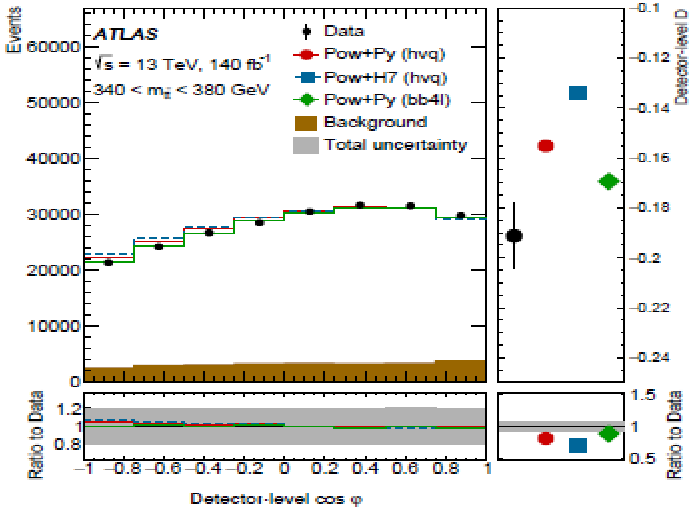
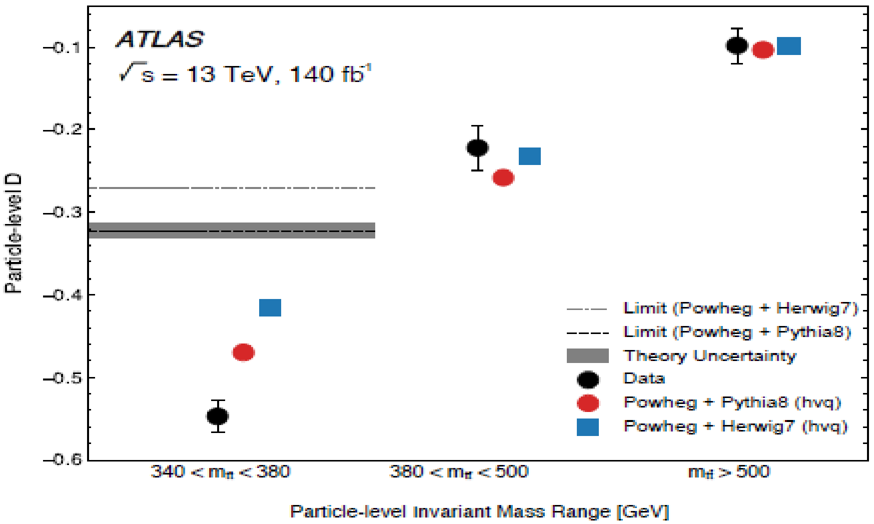
$t\bar{t}$ quantum entanglement

- New lab for observing quantum effects (with relativistic effects)
- Pseudo-bare quark! → entanglement expected in $t\bar{t}$ near threshold
- Angle between charged leptons from top/antitop decay→ entanglement marker D





CMS Focus on low-mass region (345 < mtt < 400 GeV

$$D_{obs} = -0.478 \pm 0.017\,(\text{stat})\,^{+0.018}_{-0.021}\,(\text{syst})$$

$$D_{exp} = -0.465^{+0.016}_{-0.017}\,(\text{stat})\,^{+0.019}_{-0.022}\,(\text{syst})$$

A.Myagkov **NRC KI - IHEP**

Higgs boson

CERN 10 years HIGGS boson discovery

Monday 4 Jul 2022, CERN

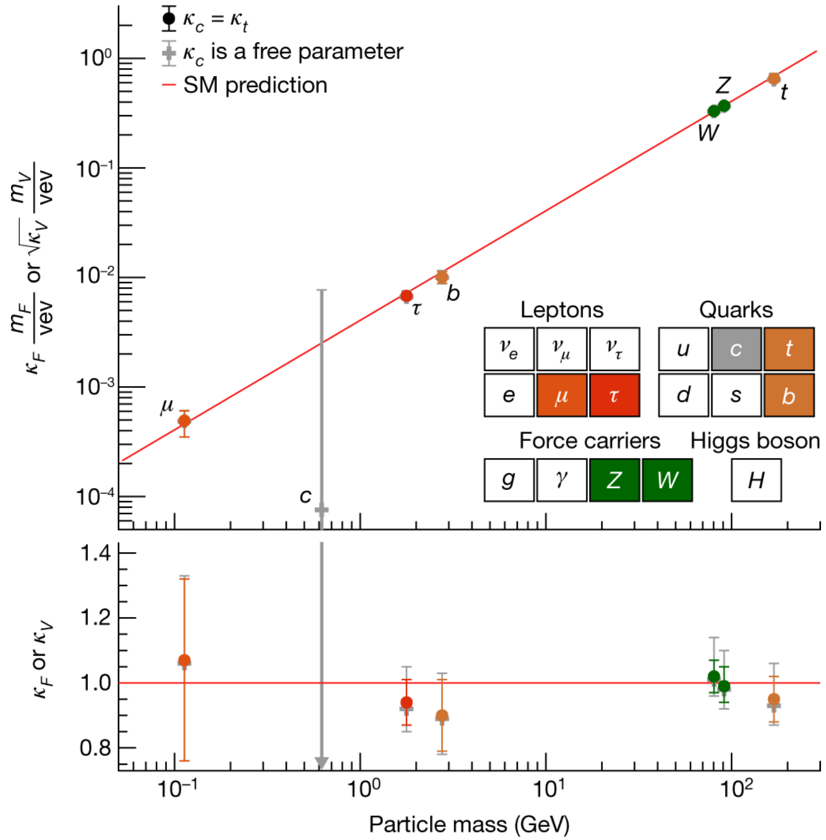
2207.00043 A portrait of the Higgs boson by the CMS experiment ten years after the discovery

Nature volume 607,pages 60-68 (2022)

2207.00092 A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery

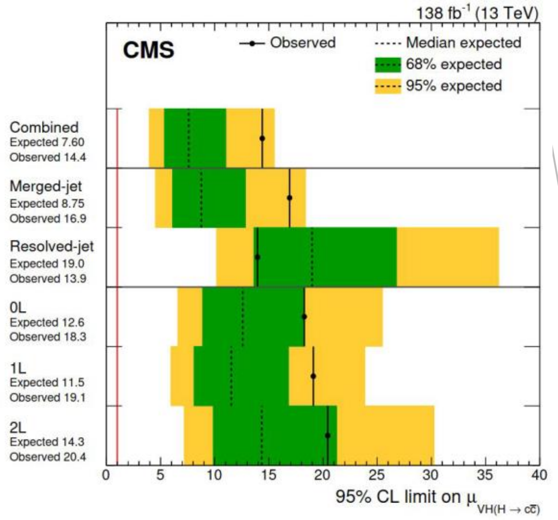
Nature volume 607,pages 52-59 (2022)

Reduced Higgs boson coupling strength modifiers and their uncertainties.



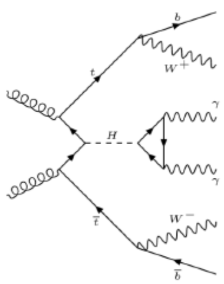
H->2nd Generation (H->ccbar)

PhysRevLett.131.061801

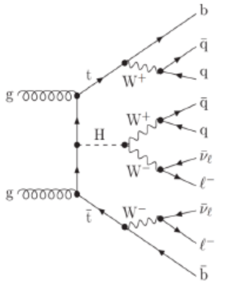


- **CMS**
- $\mu(VZ, Z\to cc) = 1.01^{+0.23}_{-0.21}$
- ○ First observation of Z → cc at a hadron collider
- ○ Observed (expected) significance of 5.7 (5.9) σ
- ● $\sigma(VH) \times BR(H\to cc) < 14\ (7.6^{+3.4}_{-2.3})$ SM at 95% CL
- ● $1.1 < |\kappa_c| < 5.5$ (expected: $|\kappa_c| < 3.4$) at 95% CL
- **ATLAS**
- ● $\mu(VH\to cc) = -9 \pm 10$ (stat.) ± 12 (syst.)
- ○ $\mu(VZ\to cc) = 1.16 \pm 0.32$ (stat.) ± 0.36 (syst.).
- ● Observed (expected) constraint of $|\kappa c| < 8.5$ (12.4) at 95% CL
- ● Ratio κc/κb constrained to less than 4.5 at the 95% CL

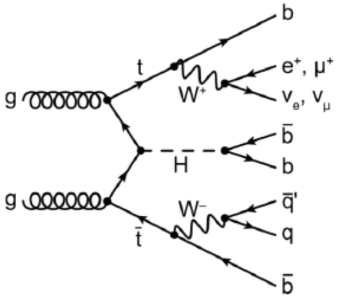
Higgs coupling to top quark



$H \to ZZ^* \to 4\ell$
$H \to \gamma\gamma$

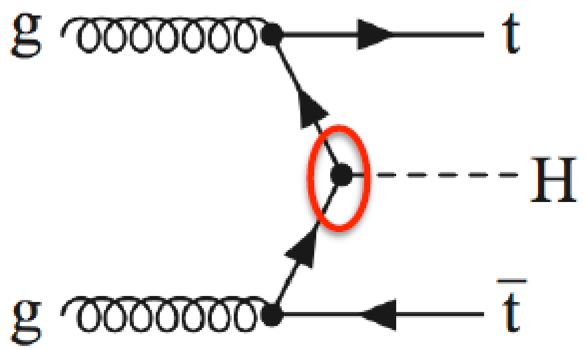


$H \to WW^* \to \ell\nu\ell\nu$
$H \to \tau\tau$
(multi-leptons)



$H \to b\bar{b}$

ttH production



Yukawa coupling proportional to fermion mass → largest couplings to t-quark

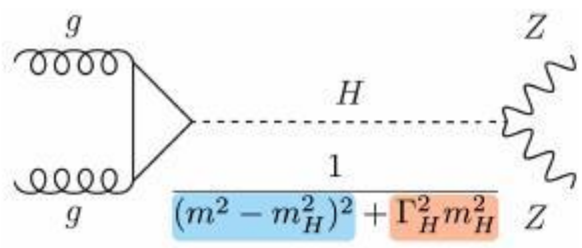
CMS
Run-1+Run-2: **5.2σ** (4.2σ exp.)

PRD 97 (2018) 072003,
PRL 120 (2018) 231801,
PRL 125 (2020) 061802

ATLAS 6.3 (5.1) sig
Higgs boson decays into $b\bar{b}$, WW^*, ττ, γγ, and ZZ^*
Phys. Lett. B 784 (2018) 173

Higgs Boson Width

- Predicted width in SM ΓH: **4.07MeV**
- Direct measurements : measuring Higgs lifetime or on-shell width.
- mass resolution limited by **detector resolution 1-2GeV.**



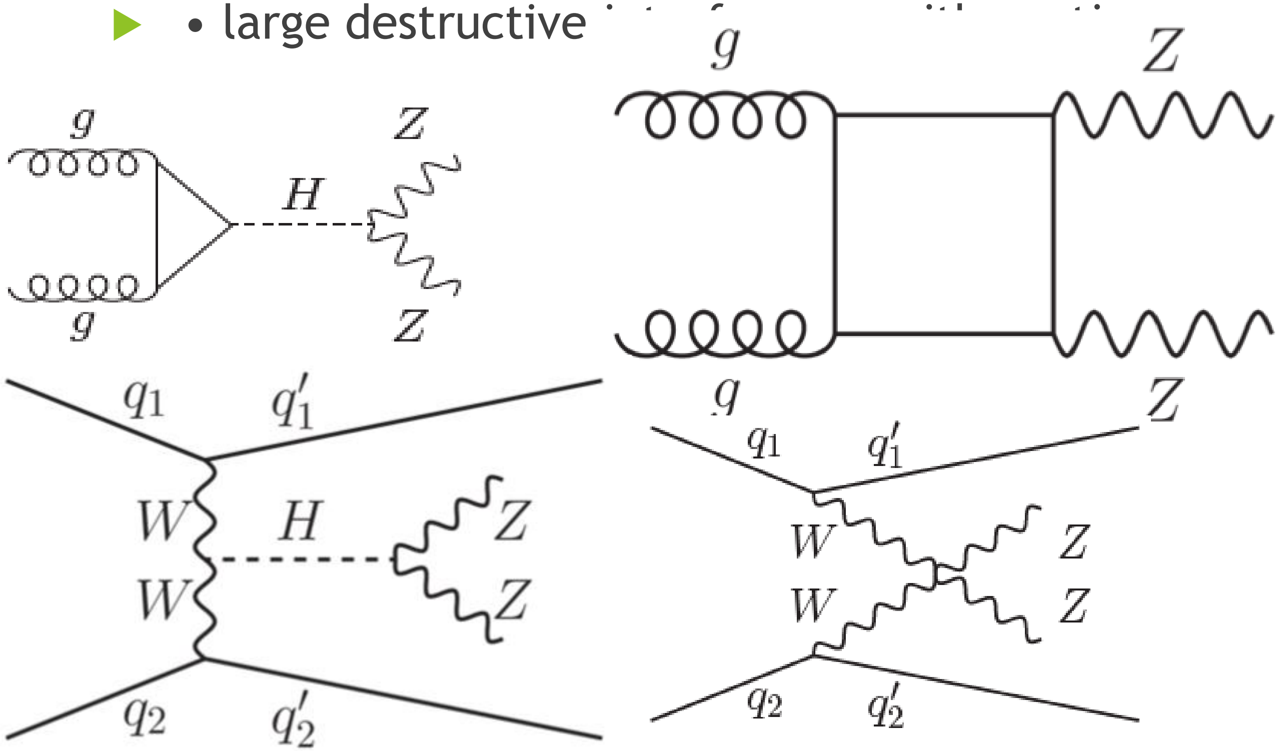
$$\frac{\mu_{\text{off-shell}}}{\mu_{\text{on-shell}}} = \frac{\Gamma}{\Gamma_{SM}}$$

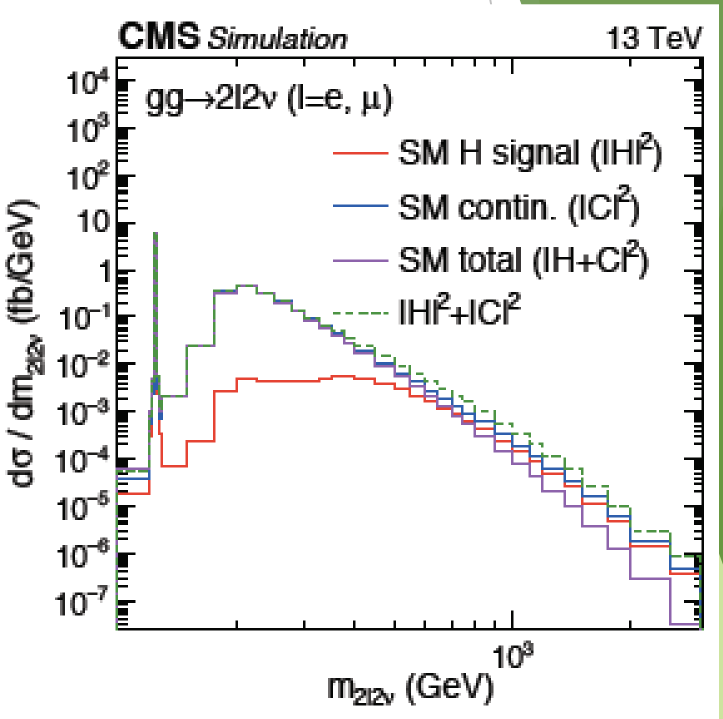
$$\sigma^{\text{on-shell}}_{pp \to H \to VV^*} \sim \frac{g^2_{\text{gluon}} g^2_V}{m_H \Gamma_H} \quad \sigma^{\text{off-shell}}_{pp \to H^* \to VV} \sim \frac{g^2_{\text{gluon}} g^2_V}{m^2_{VV}}$$

- Indirect measurement: measuring the signal strengths in on-shell and off-shell separately, and take their ratio: ZZ is the ideal channel

Off-shell Higgs in ZZ channel and Higgs Boson Width

- Difficulties for probing off-shell Higgs:
- • low production rate: ~10% of total xs
- • large destructive





CMS: Nature Phys. 18(2022)1329

$$\Gamma_H = 3.2^{+2.4}_{-1.7}\,\mathrm{MeV}$$

ATLAS: Physics Letters B 846 (2023 138223

$$\Gamma H = 4.5 + 3.3 - 2.5\ MeV$$

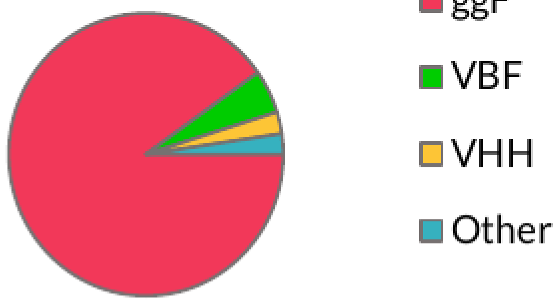
Higgs Pair Production and Decay Modes

gluon-gluon Fusion (ggF)
$\sigma \sim 31.0$ fb — $\sim\kappa_\lambda$

Vector Boson Fusion (VBF)
$\sigma \sim 1.72$ fb — $\sim\kappa_\lambda, \kappa_{2V}$

Vector Boson Associated (VHH)
$\sigma \sim 0.86$ fb — $\sim\kappa_\lambda, \kappa_{2V}$

Cross Section (13 TeV)



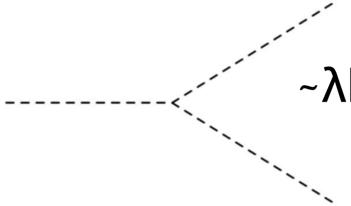
$$\kappa_\lambda = c_{HHH}/c_{HHH}^{SM}$$
$$\kappa_{2V} = c_{VVHH}/c_{VVHH}^{SM}$$

HH Decay Modes

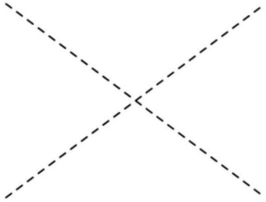
	bb	WW	ττ	ZZ	γγ
bb	34%				
WW	25%	4.6%			
ττ	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
γγ	0.26%	0.10%	0.028%	0.012%	0.0005%

Higgs self interaction

$$V(H) = \frac{1}{2}m_H^2 H^2 + \lambda v H^3 + \frac{1}{4}\lambda H^4$$



~λH^3



~λH^4

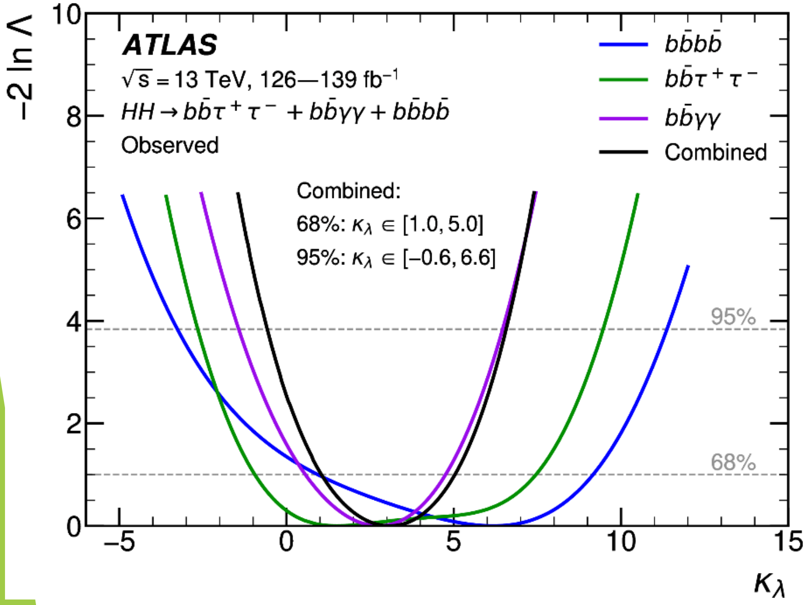
$$\lambda = \frac{m_H^2}{2v^2}$$

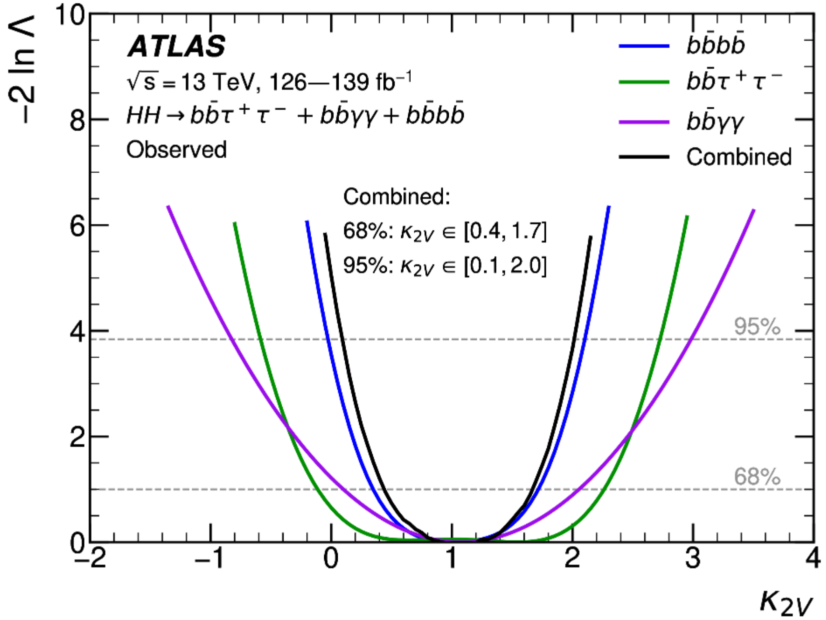
~0.13

The coupling ***λ*** is difficult to measure, because the cross section for HH production, which provides sensitivity to this coupling, is very small

HH Combination

Physics Letters B843(2023)137745





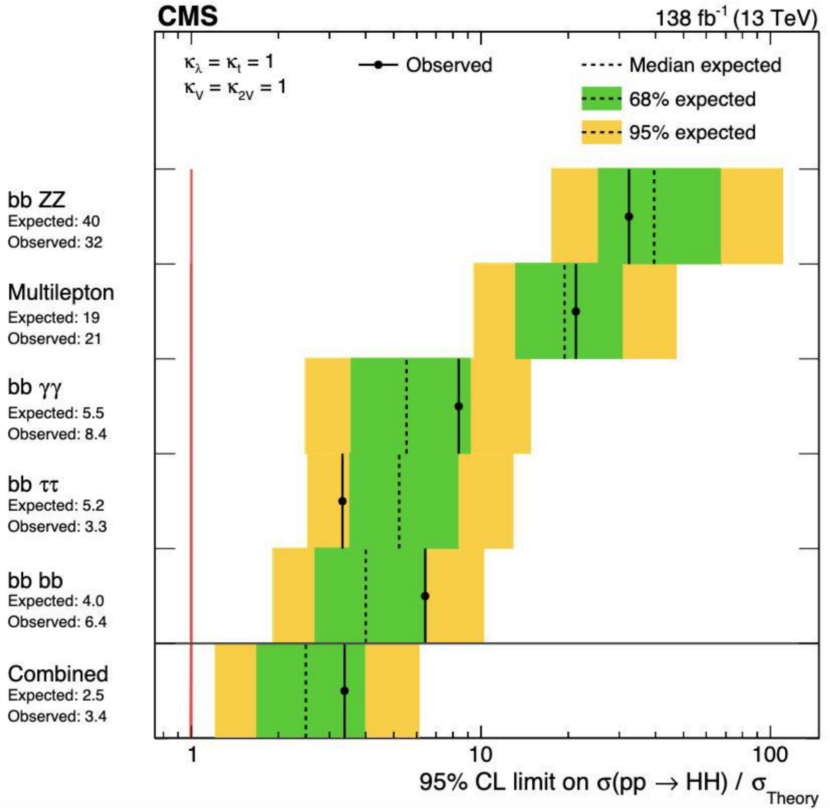
k

-0.6< k_λ <6.6 (95% CL)

0.1< k_2v< 2.0 (95 % CL)

Combined upper-limit SM HH Cross-Section 2.4*Sig_SM (2.9 Exp.)

Combined limit based on previous results

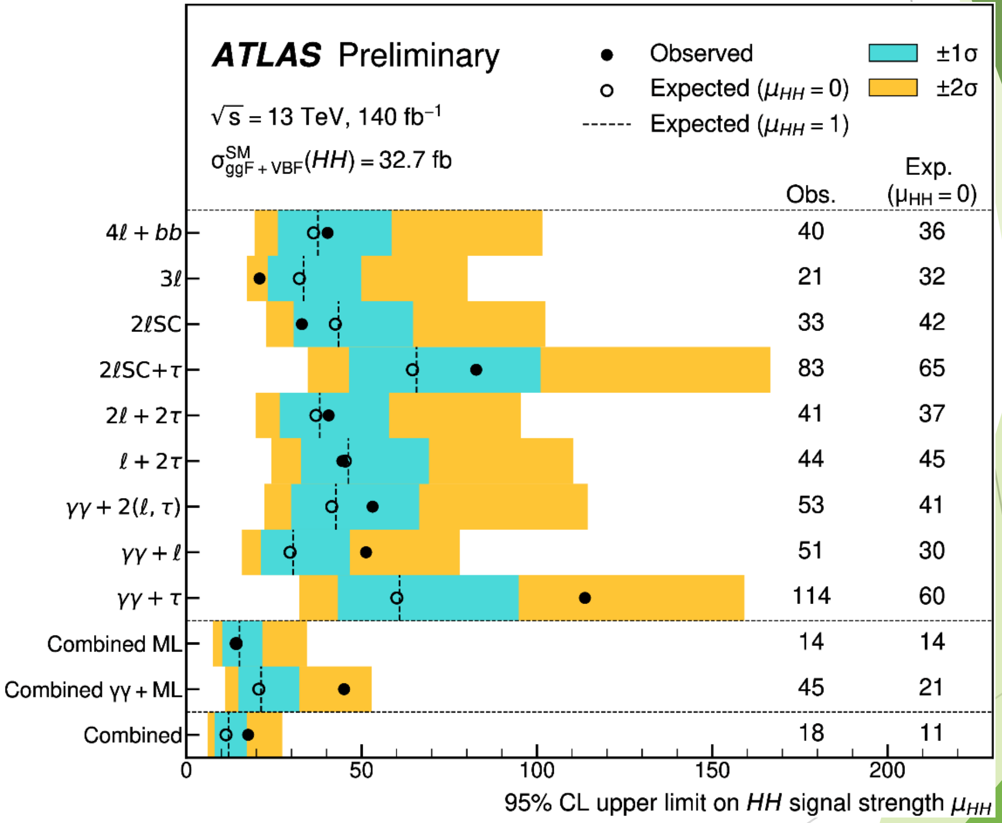


Nature 607 (2022) 60-68

Combined upper limit on ggF+VBF production
σHH < 3.4 (2.5) σHH(SM) based on previous result

NEW ATLAS results: HH ML (ATLAS-CONF-2024-005)

For the first time, ATLAS is analysing data in with a holistic way considering all the H->WW,ZZ,ττ lepton decay modes, in addition with H-> γ γ. No b-jets are expected, except for the HH->bbZZ channel.

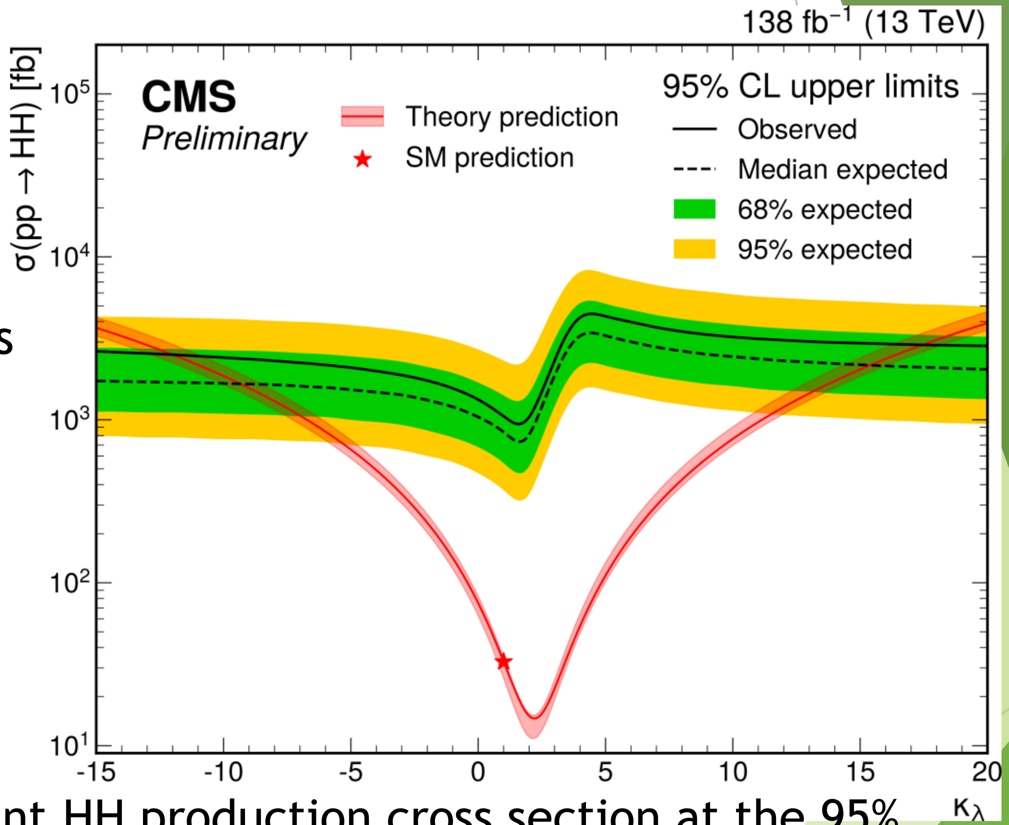


The result is interpreted in terms of limits on the signal strength. Combination yields an observed (expected) limit of 18 (11)

NEW CMS results: X→HH→$\gamma\gamma\tau\tau$ CMS-PAS-HIG-22-012

Despite the very low branching ratio, this channel benefit from the very good di-photon mass resolution and the clean lepton decay from taus.

The result is interpreted in terms of limit on the Cross section, with an observed (expected) limit of 33 (26) times the SM.



Expected and observed upper limits on the nonresonant HH production cross section at the 95% CL, obtained for different values of κ_λ. The green and yellow bands represent the one and two standard deviations for the expected limit, respectively. The theoretical prediction with the uncertainty of the cross section as a function of κ_λ is shown by the red band.

Problems in SM

- Dark Matter in the Universe
- Particle – antiparticle asymmetry in the Universe, numbers!
- CP violation CKM phase – too small efect
- Neutrino masses, mixing, oscillations
- Very small cosmological constant. Very weak gravity interaction
- Muon $(g\text{-}2)\mu$ anomaly (about 3.5 $\sigma \rightarrow$ 4.2 σ BNL)
- B-anomalies (about 4.5 σ)
- CDF W-mass anomaly (about 7 σ)

More Problems in SM

- What is a generation? Why there are only 3 generations?
- How quarks and leptons related to each other, what is a nature

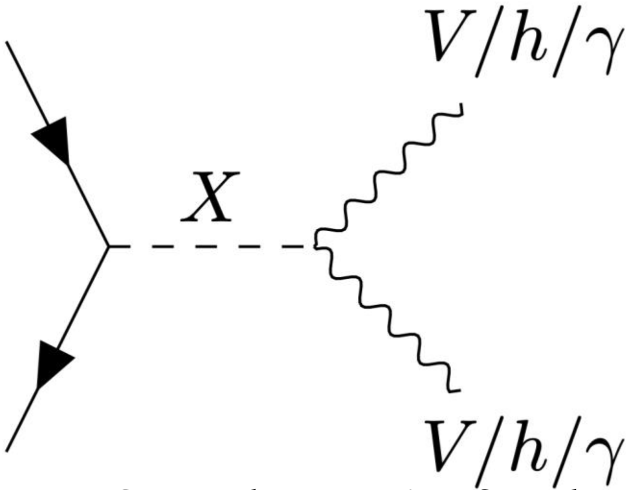
  of quark-lepton analogy?
- What is responsible for gauge symmetries, why charges are quantize?
- Are there additional gauge symmetries?
- What is responsible for a formation of the Higgs potential?
- To which accuracy the CPT symmetry is exact?
- Why gravity is so weak comparing to other interactions?

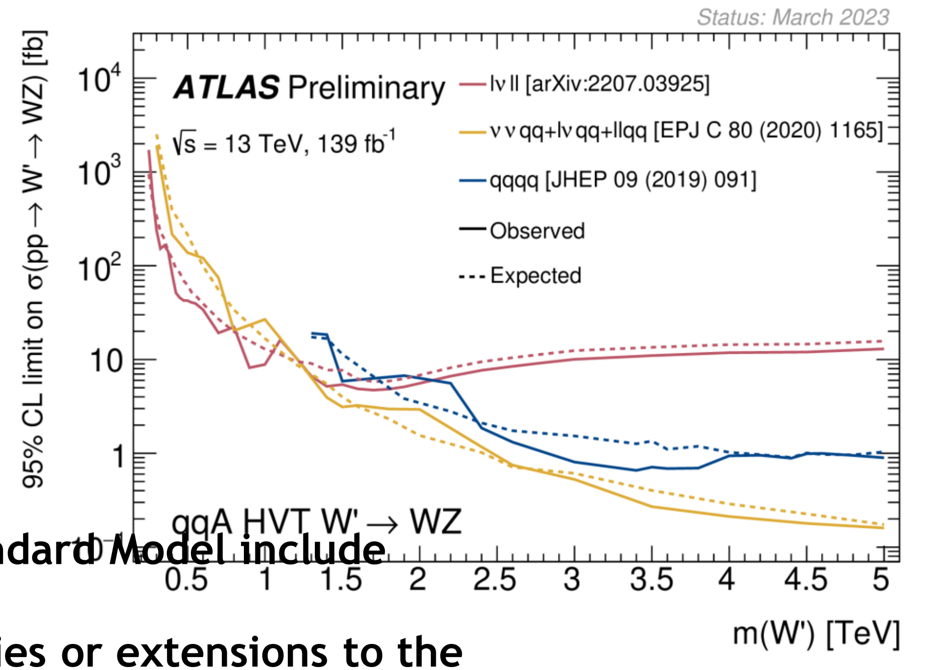
Summary of ATLAS results (EXO+SUSY) from Run 2

- Exploration at the high-energy frontier: ATLAS Run 2 searches investigating the exotic jungle beyond the Standard Model (2403.09292)

The quest to discover supersymmetry at the ATLAS experiment (2403.02455)

Searches for resonances decaying to pairs of heavy bosons





Several scenarios for physics beyond the Standard Model include new par7cles decaying into pairs of bosons

• This can be due to eg. new Gauge symmetries or extensions to the Higgs sector, like the 2-Higgs Doublet Model, Supersymmetry or models introducing spin-2 gravitons.

• ATLAS present limits on 3 benchmark models for these models:

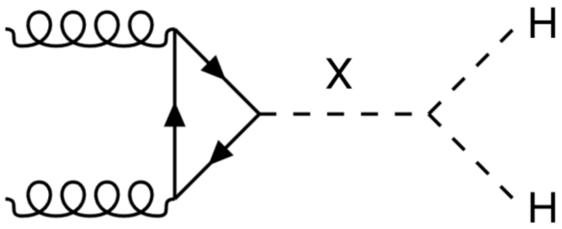
o Neutral Spin-0: Randal-Sundrum Radion (Charged Spin-0: Georgi-Machacek)

o Spin-1: Heavy vector triplet (HVT)

o Spin-2: Randall-Sundrum Graviton

Resonant HH

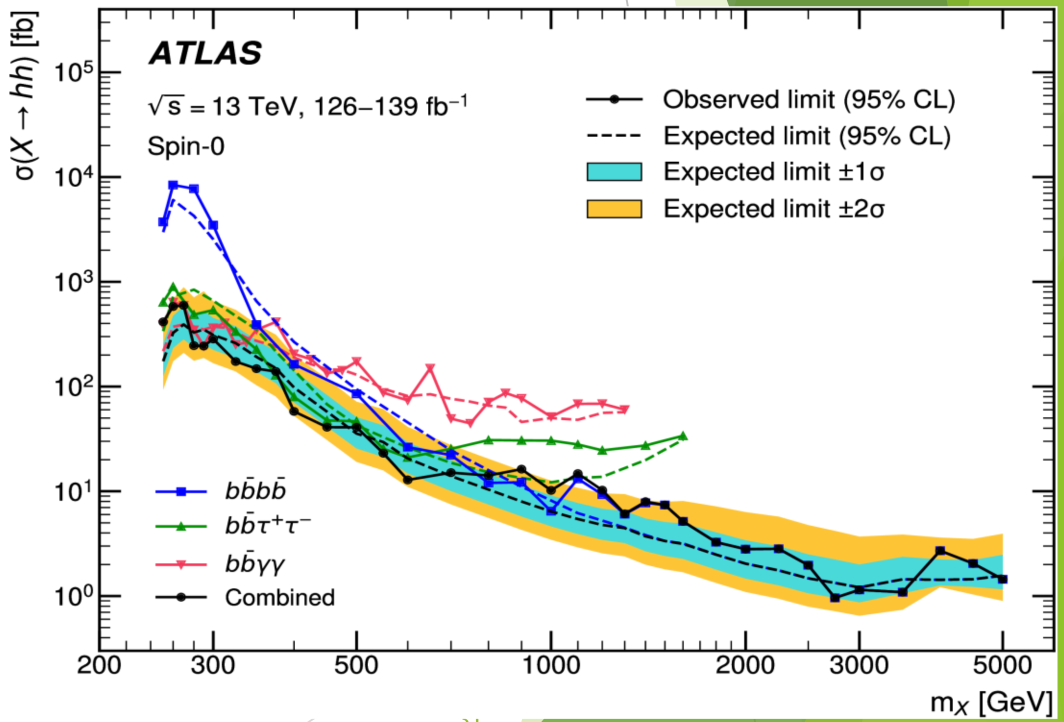
Phys. Rev. D 105 (2022) 092002
JHEP 11 (2020) 163 JHEP 07 (2023) 040
JHEP 07 (2023) 040 JHEP 11 (2020) 163



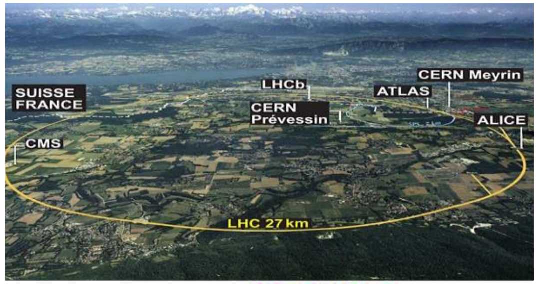
X->HH -> bbbb   X->HH -> bb τ+ τ-   X-> HH->bb γγ

Combined likelihood with inputs from all three HH resonant analyses

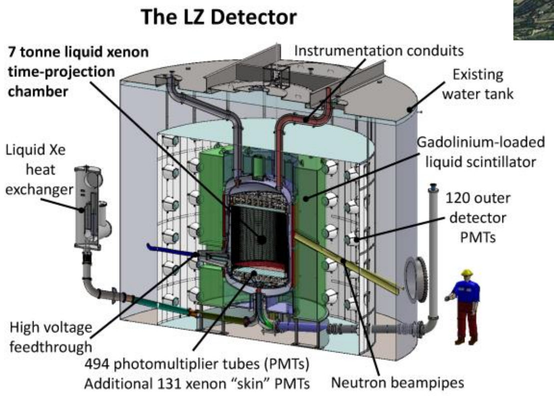
- No significant excess wrt SM. Largest combined deviation of 3.3 (2.1)σ at 1.1 TeV
- The limits are interpreted in the Type-I Two-Higgs-Doublet Model and the Minimal Supersymmetric Standard Model, and constrain parameter space not previously excluded by other searches

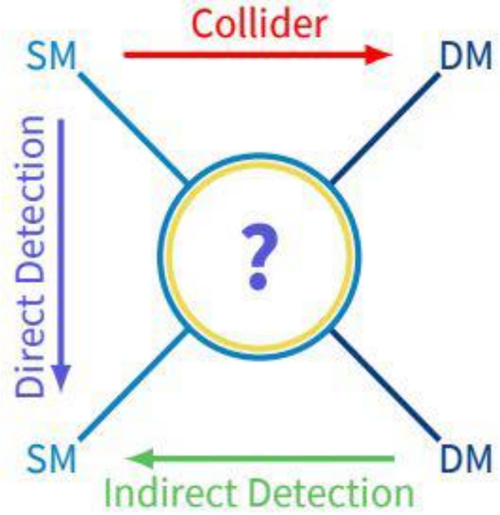


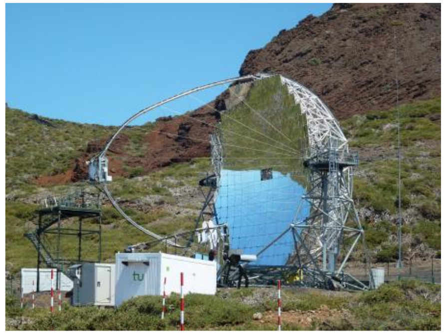
Searches for Dark Matter (DM)



Direct production
of DM
ATLAS, CMS







Indirect detection
Detect ordinary matter resulting from
decay/annihilation of dark matter
(ICECUBE, HESS)

Dark matter

- candidates:
- stable (non-interacting directly, MET signatures) or with a
-     lifetime high enough (LLP signatures)
- electrically neutral
- with a mass reachable at the LHC
- **DM signatures** **(two substances - DM particle and mediator):**
- fully visible (mediator only, a new resonance
-     in dijet/dilepton/diboson etc. spectra)
- MET - decay to DM particle pair (+ a visible “tag”)
- non-standard properties of SM particles
-     (higgs sector – higgs boson pair production, h125   to invisible…)

There are three complementary philosophies to search for DM at the LHC

- Effective Field Theory (EFT)-typically depends on two Degrees of Freedom (M_DM and M* -UV cut off scale) : Contact interactions

- Simplified (or simple) models-minimal number of DOF, typically 4 or more:

Higgs portal, dark photon, Z' boson, squarks

- Complete models like SUSY, possibly with a smaller, phenomenologically motivated parameter set like the pMSSM, Little Higgs, Universal Extra Dimensions

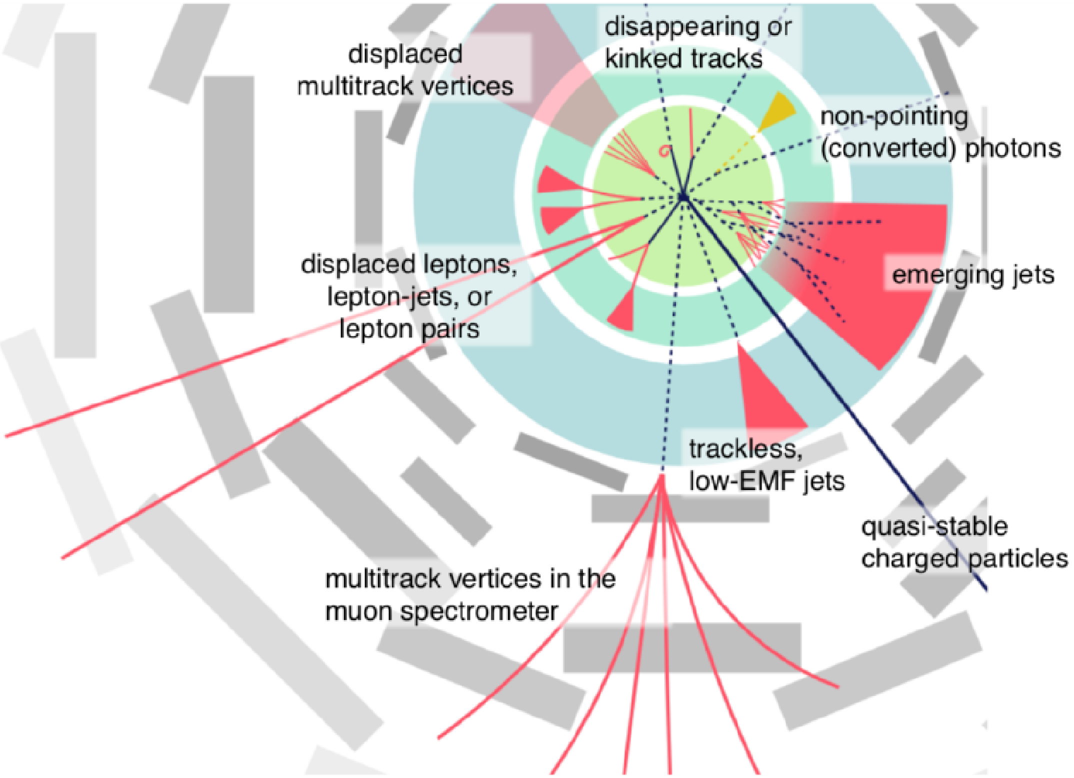
Dark sector with Long-Lived Particles at the LHC

LLP:
a proper lifetime cτ0 is greater than or comparable to the characteristic size of the (sub)detectors

small cτ0 that comparable to the inner tracker size, no displaced tracks "standard" prompt decay

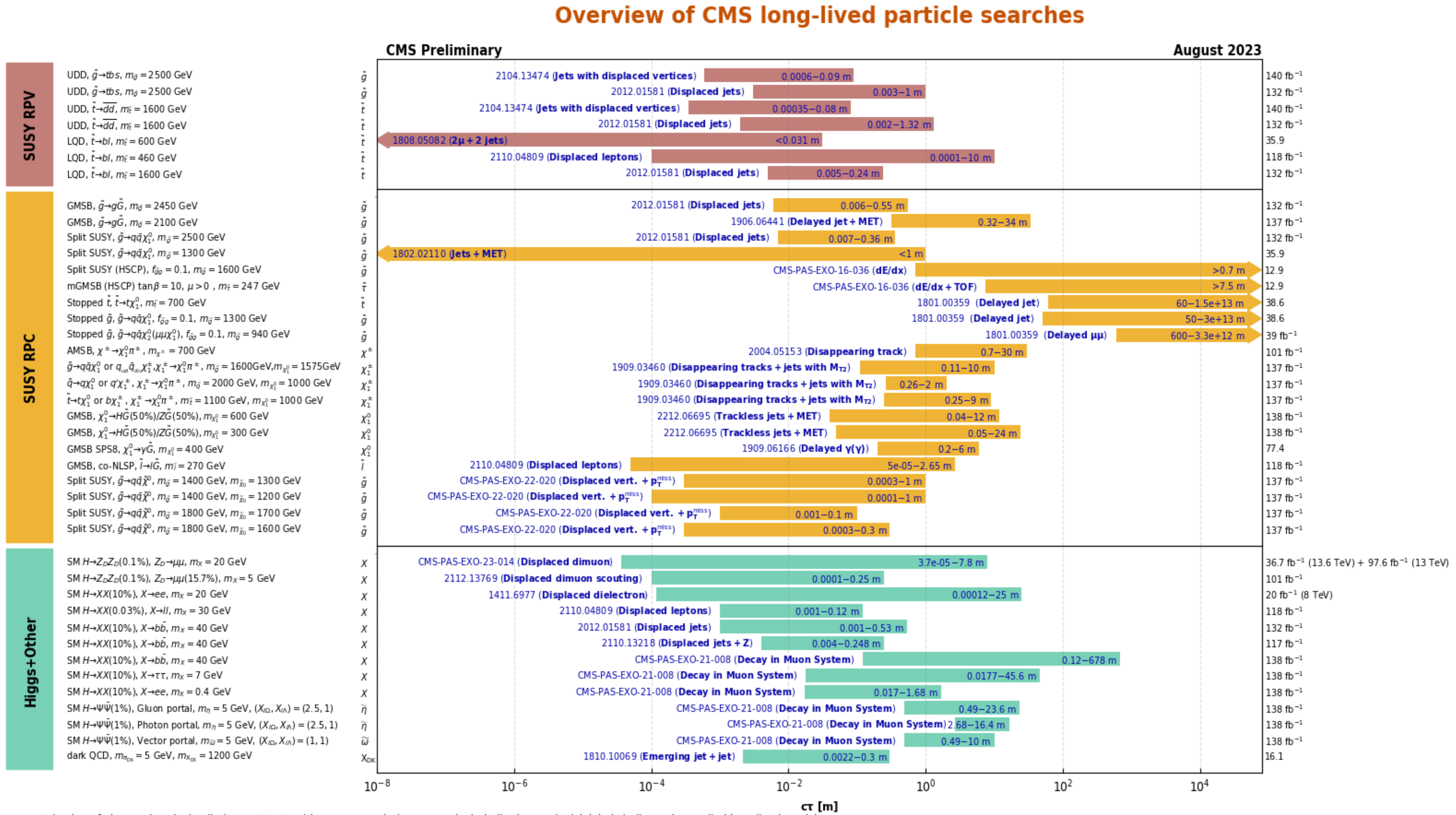
intermediate cτ0 LLP

very large/infinite large cτ0 stable particles, "standard" MET signatures



Searching for long-lived particles beyond the Standard Model at the Large Hadron Collider, arXiv:1903.04497

the lifetime reach of CMS long-lived particle analyses for a selected set of new physics phenomen

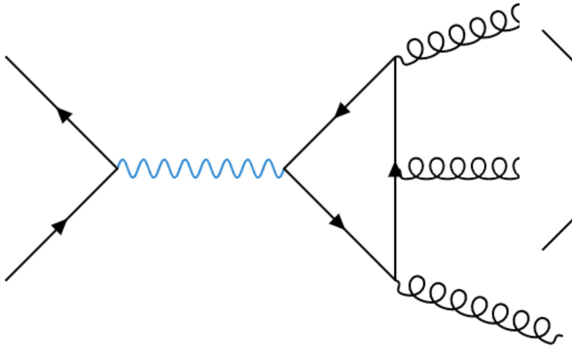


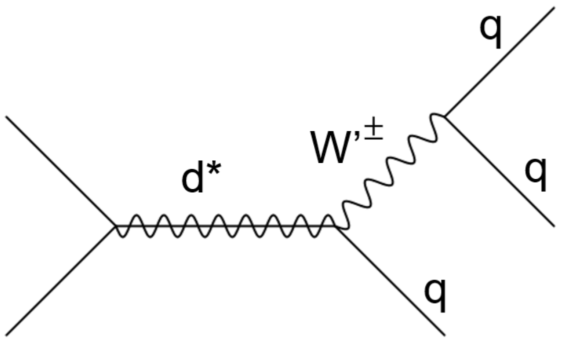
Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The y-axis tick labels indicate the studied long-lived particle.

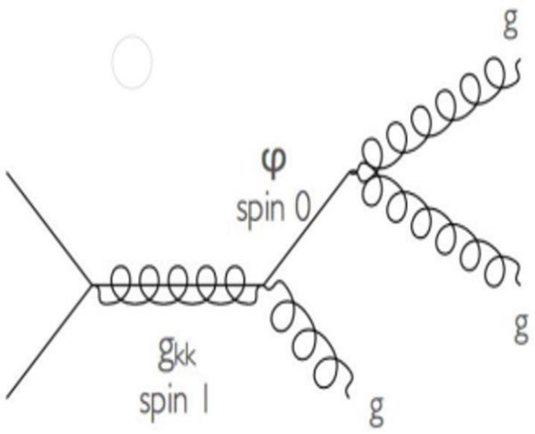
A.Myagkov NRC KI - IHEP

Search for resolved high-mass trijet resonances CMS-PAS-EXO-22-008

- Targeted both the 3-body decay ($X \rightarrow jjj$) and cascade decay ($X \rightarrow Yj \rightarrow jjj$) in [1.75, 9.0] TeV. Extended a previous CMS search [Phys. Lett. B 832 (2022) 137263]for the cascade decay
- Background estimated from parametric function fits to the data
- No significant excess. Limits could be easily reinterpreted with other models predicting such new heavy resonances

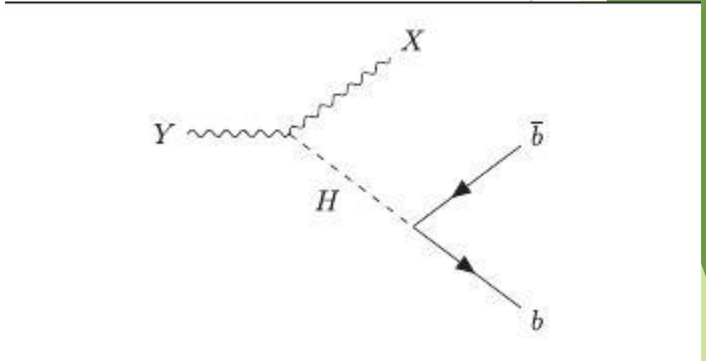


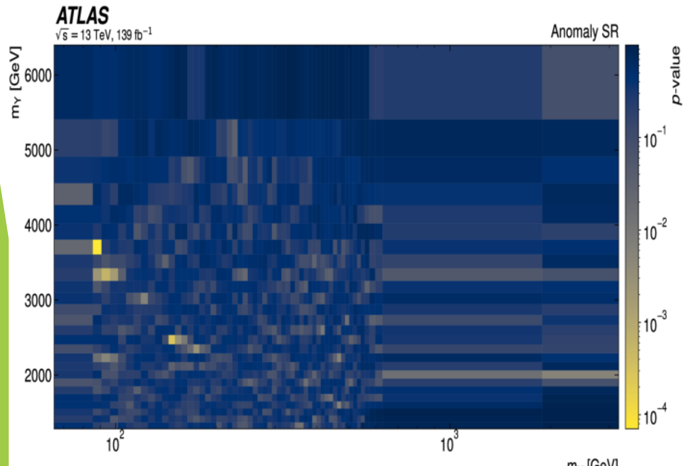




Anomaly detection search for new resonances decaying into a Higgs boson and a generic new particle X PHYS. REV. D 108, 052009 (2023)

- The anomaly detection in this search is performed with a
- jet-level anomaly score (SA). The SA value is given by
- a variational recurrent neural network (VRNN), which
- consists of a variational autoencoder (VAE) whose latent
- space is updated at each time step of a recurrent neural
- network (RNN).

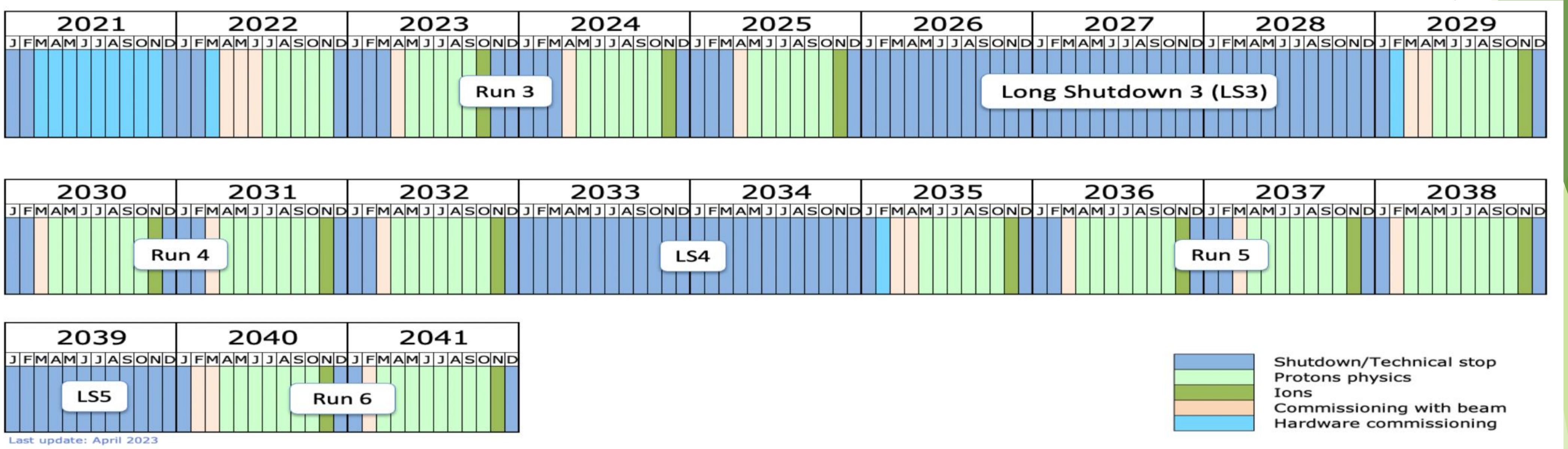




The lowest observed p-value corresponds to the bin with $mY \in [3608, 3805]$ GeV and $mX \in [75.5, 95.5]$ GeV

1.4σ global significance in BumpHunter

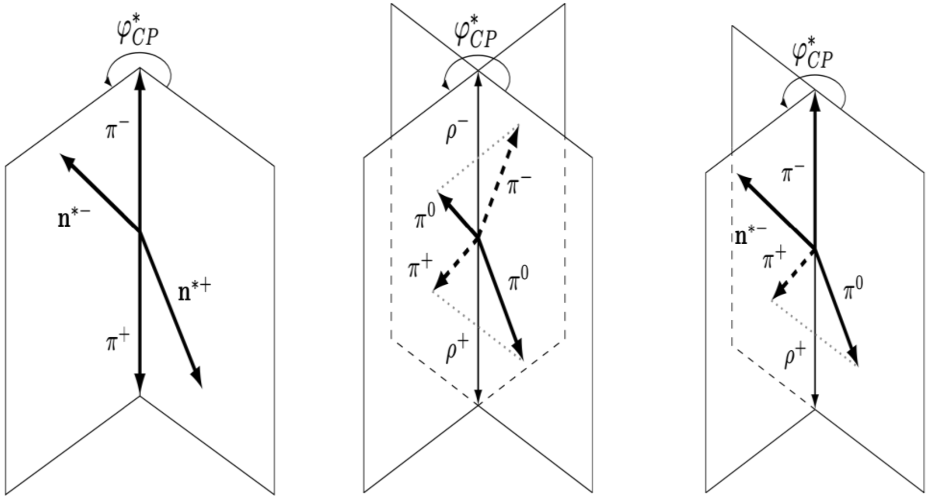
HL-LHC



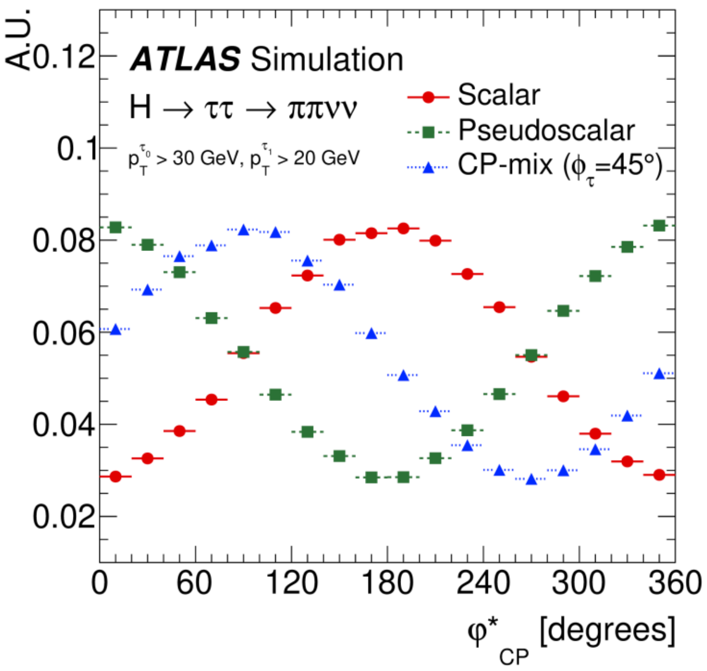
Run 2: 140/fb
Run 3: ~450/fb
HL-LHC: ~3000/fb
(~20 x today's dataset)

- Thank you for attention

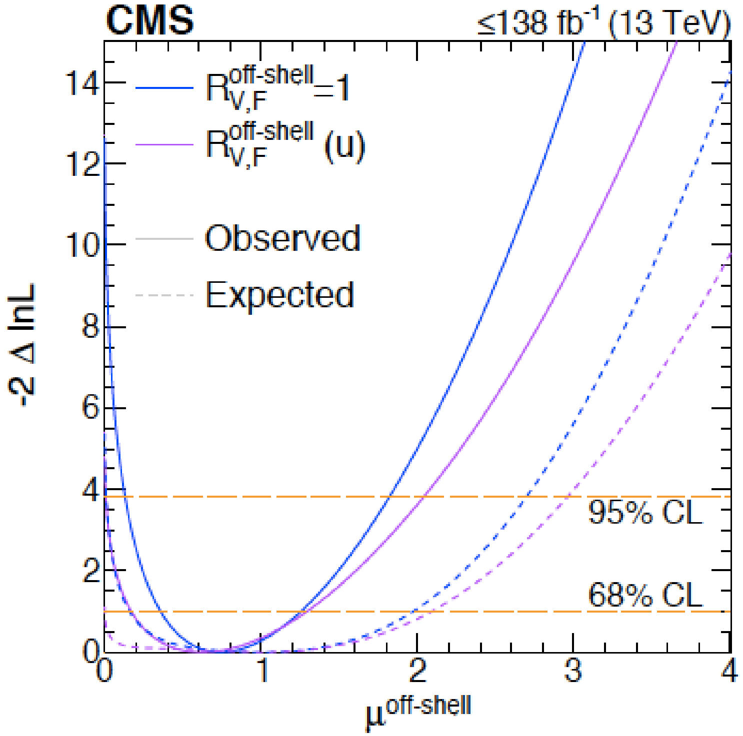
H→ττ CP structure arXiv:2212.05833

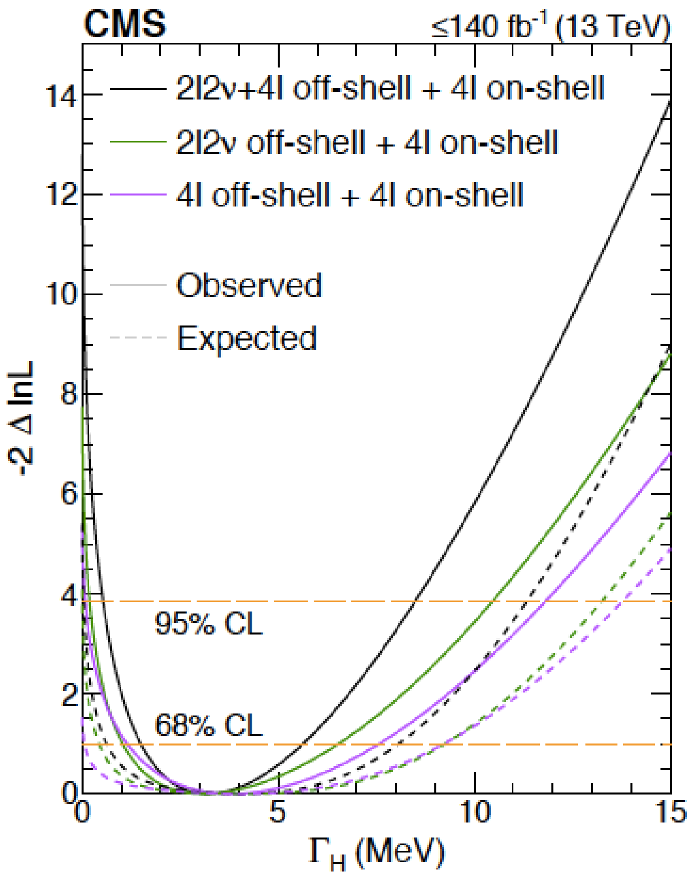


$H \to \tau^+\tau^- \to \pi^+\pi^- + 2\nu$ $\quad H \to \tau^+\tau^- \to \pi^+\pi^0\nu\pi^-\pi^0\nu$ $\quad H \to \tau^+\tau^- \to \pi^+\pi^0\nu\pi^-\nu$



Evidence for off-shell Higgs and Measured Width





off-shell Higgs evidence: 3.6σ

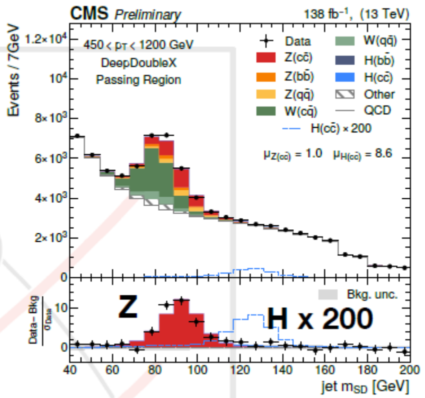
Observed $\Gamma_H = 3.2^{+2.4}_{-1.7}\,\text{MeV}$

ggH Analysis

- Boosted cc system in the final state

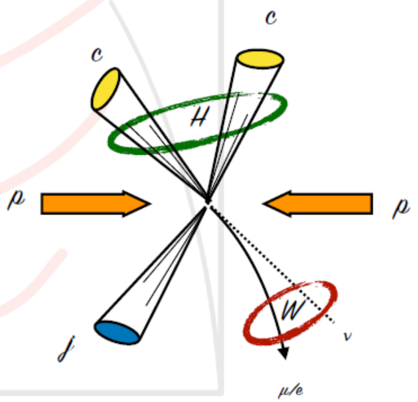
$$\mu_H = 8.6^{+19.9}_{-19.4},$$

45 (38) at the 95% CL.



VH Analysis of the Run 2 datasets

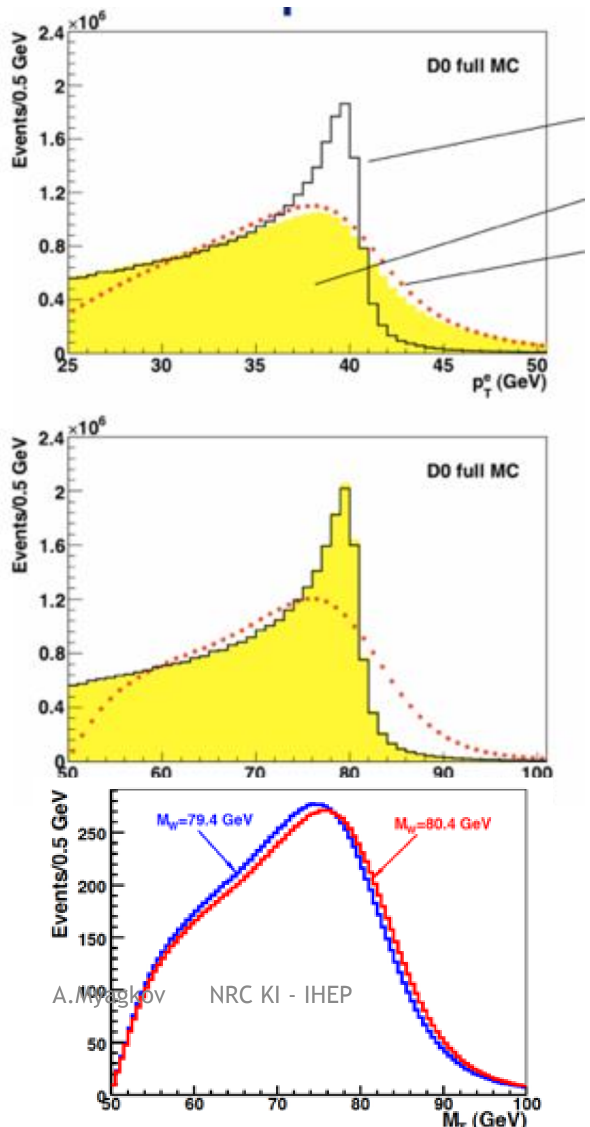
- Higgs to charm reconstructed both in the **boosted** (p_T>300 GeV) and **resolved** regimes



Resolved regime:

- Using deep neural network to improve rejection of light quarks vs b jets (DeepJet)
- Dedicated energy regression
- 3 Categories: 0 lepton, 1 lepton, and 2 lepton targeting Z→νν, W→ℓν, and Z→ℓℓ

Methods of W mass measurements

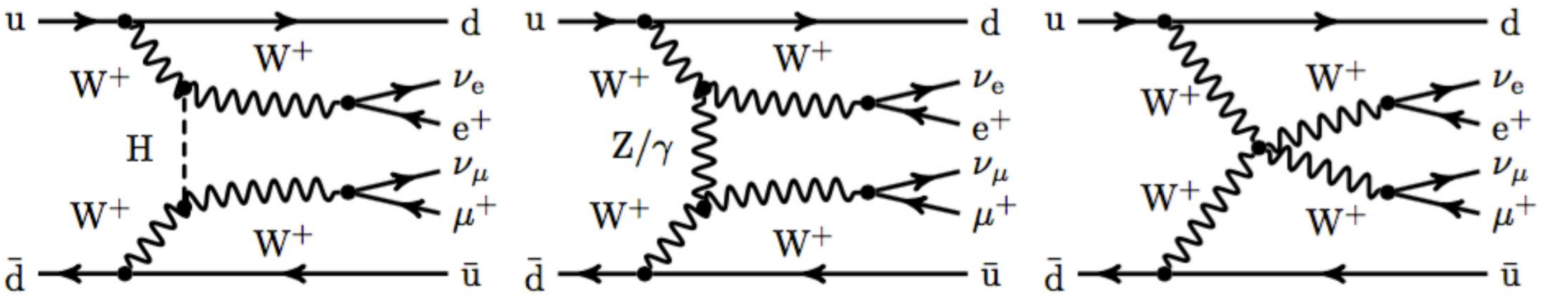


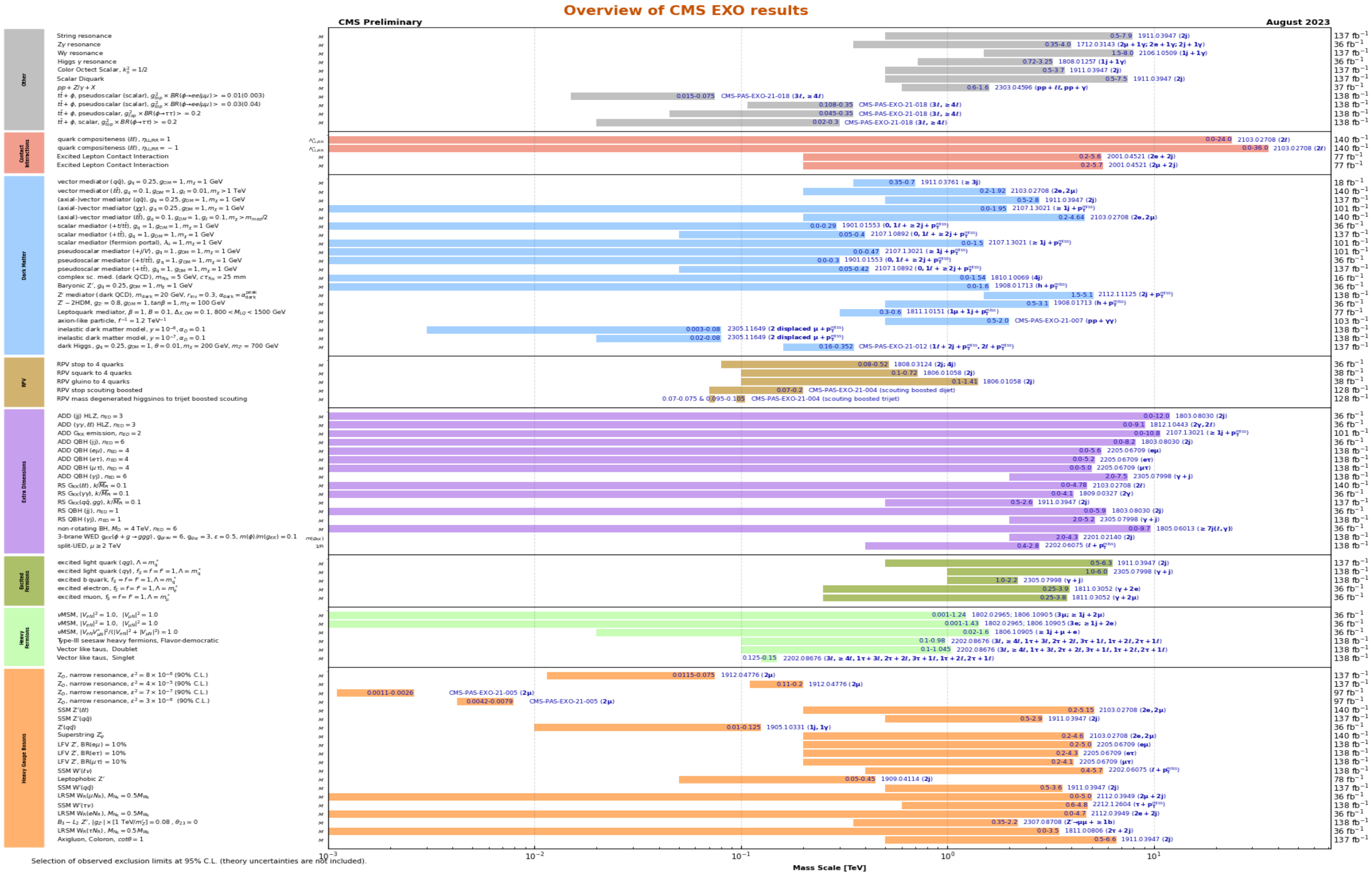
The transverse mass is
- less sensitive to the qT(W) spectrum
- much more sensitive to the hadronic recoil

But, due to pile-up, lepton pT is more promising at the

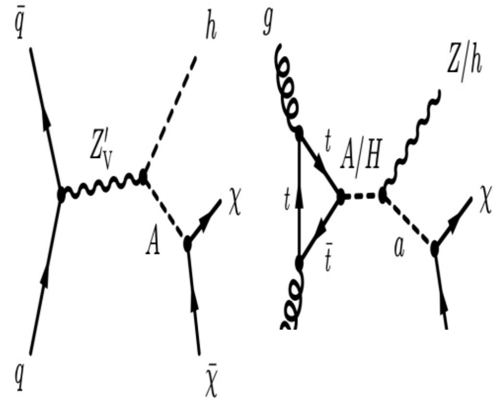
Experimental challenges
- control the lepton energy scale at < 0.1%
- pile up conditions

EW Vector Boson Scattering

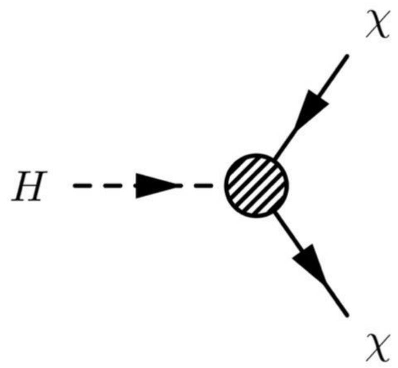



Overview of CMS EXO results
CMS Preliminary
August 2023
Other
Contact Interactions
Dark Matter
RPV
Extra Dimensions
Excited Fermions
Heavy Fermions
Heavy Gauge Bosons
Mass Scale [TeV]
Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included).

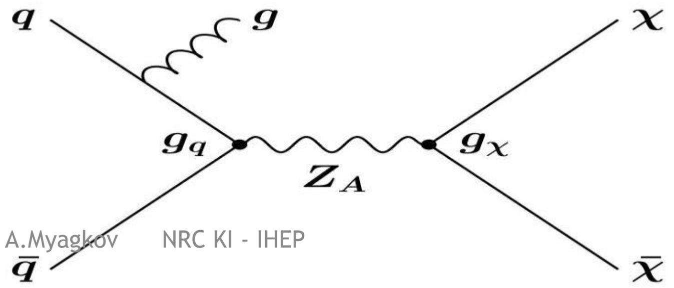
Dark matter models



Simplified models



Higgs portal



Extended
Higgs sector

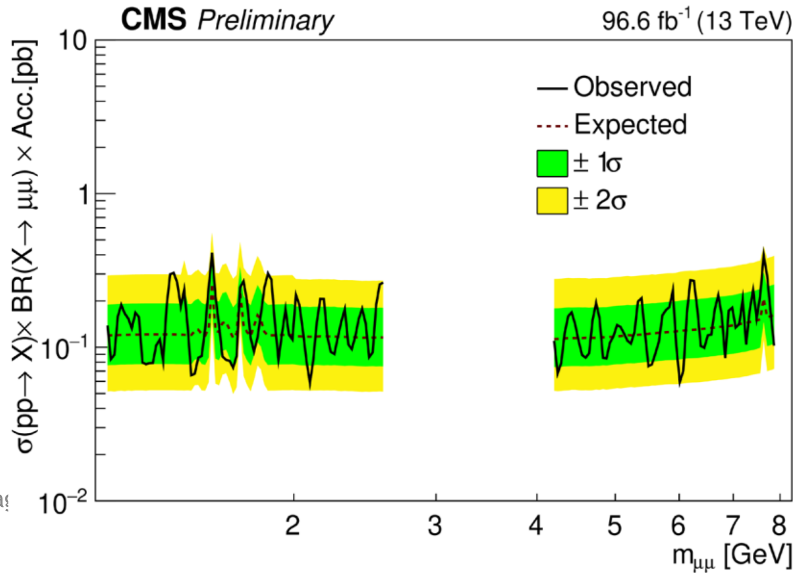
Prompt low mass di-muon with scouting

- Targeted signature: 2 muons with small primary vertex displacement
- • Triggering on double muons (>3 GeV) with the scouting method
- • 2017 + 2018 data (97 fb-1)
- • Benchmark model: Hidden Abelian Higgs Model, 2HDM+s

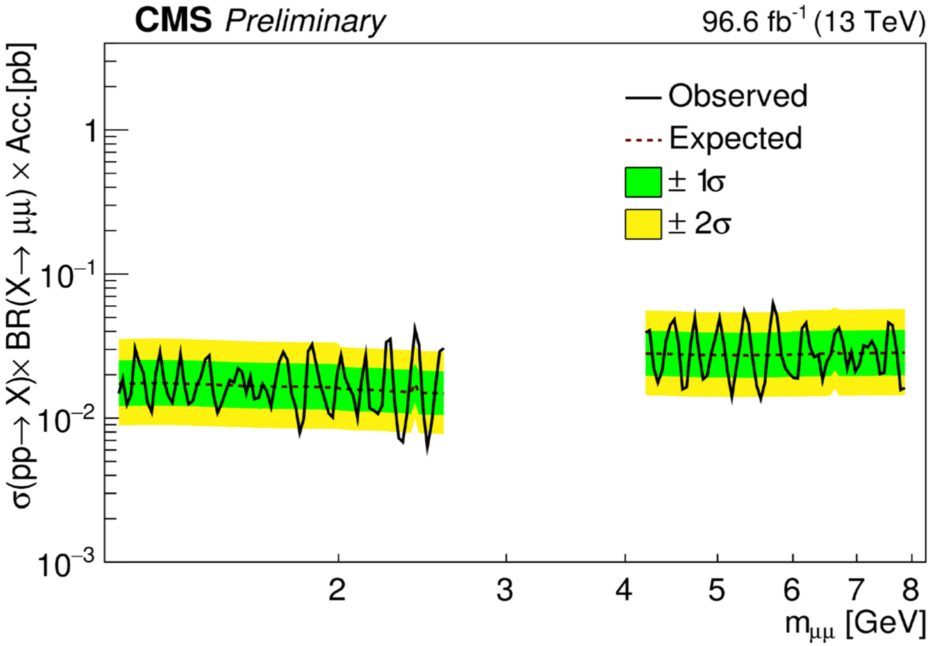
- Baseline selections
- > 1 opposite sign muon pair
- $ppTT$>4GeV,$\eta\eta$<1.9
- |PV -BeamSpot| (L) < 0.2 cm
- Pass two custom muon BDT IDs
- ($mm\mu\mu\mu\mu$ $<$ 4GeV: J/$\psi\psi mm\mu\mu\mu\mu$ $>$ 4GeV: Upsilon)

Prompt low mass di-muon with scouting

- Bump-hunt on the di-muon mass spectra
- Limits are set for $m\mu\mu$ in [1.1, 2.6] and [4.2, 7.9] GeV
- • Largest excess @ 2.41 GeV in the boosted category, low mass selection
- Local 3.2σ, global 1.3σ



A.Myag



CMS PAPER TOP-23-001

- Analysis strategy: use leptonic final states to measure the
- helicity angle cos $\varphi \equiv \ell 1 \cdot \ell 2$ (measured in the top reference frame)
- The entanglement proxy D is extracted with a template fit
- ○ All systematic effects included as nuisances

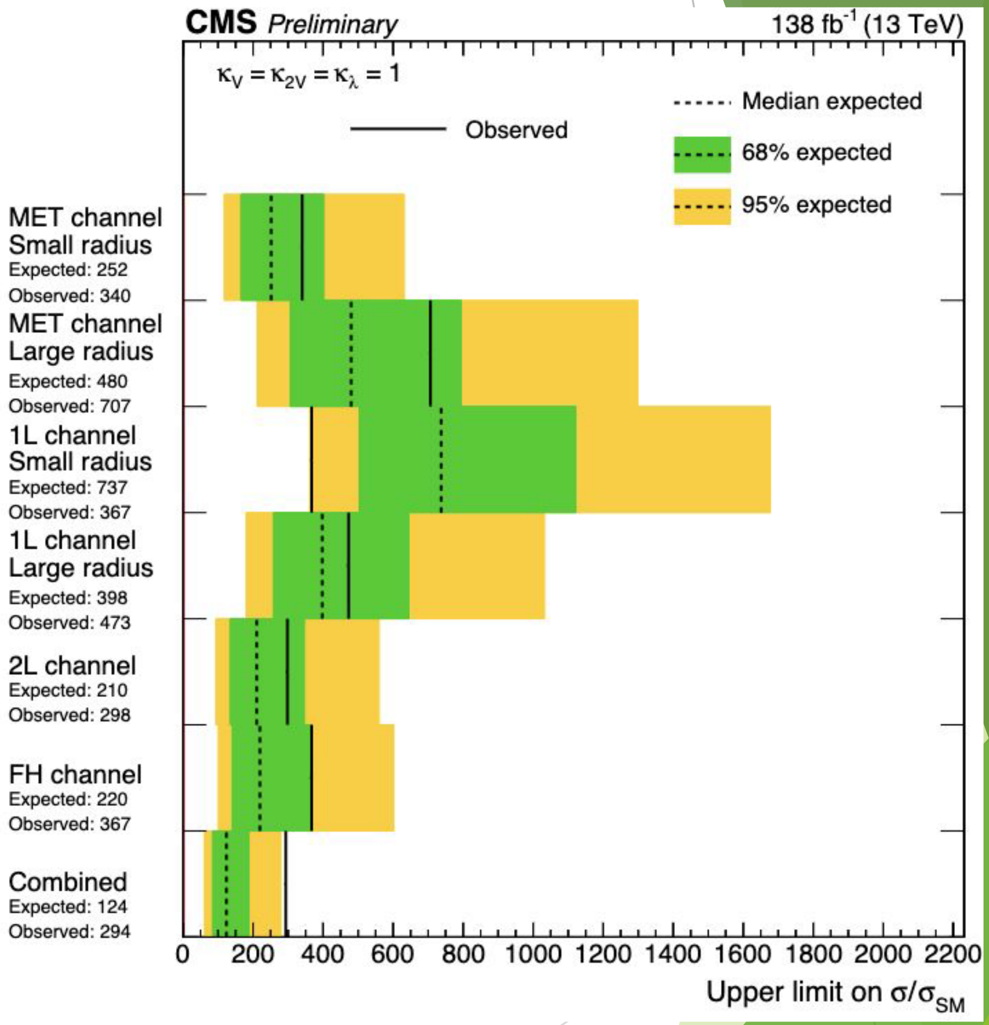
$$D_{obs} = -0.478 \pm 0.017\,(\text{stat})\,^{+0.018}_{-0.021}\,(\text{syst})$$

$$D_{exp} = -0.465^{+0.016}_{-0.017}\,(\text{stat})\,^{+0.019}_{-0.022}\,(\text{syst})$$

- Interpretations
- Deviations from SM in high energy region can be expressed as anomalous triple/quartic gauge couplings
- and can be interpreted using different theoretical approaches.
- Effective field theory (EFT)
- ➢ Modern model independent approach to parameterize BSM effects (deviations from SM in
- the measurements) in the Lagrangian
- ➢ Effective Lagrangian is based on Taylor expansion in local operators with mass dimension >4:

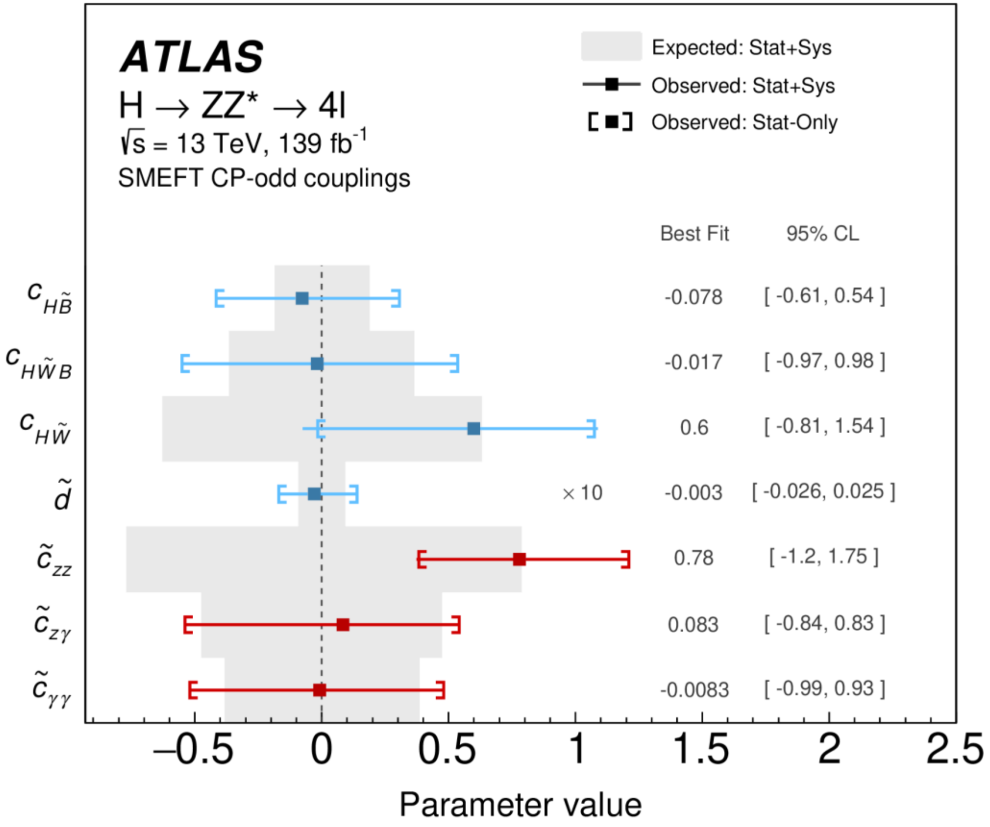
CMS 1 chan!

- Exclusion limit on HH production cross section:
- ❑ Observed (expected): σHH < 52 (97) σHH(SM)
- ❑ Constraint on Higgs self coupling modifier:
- ❑ Observed (expected): -25.8 (-14.4) < kλ < 24.1



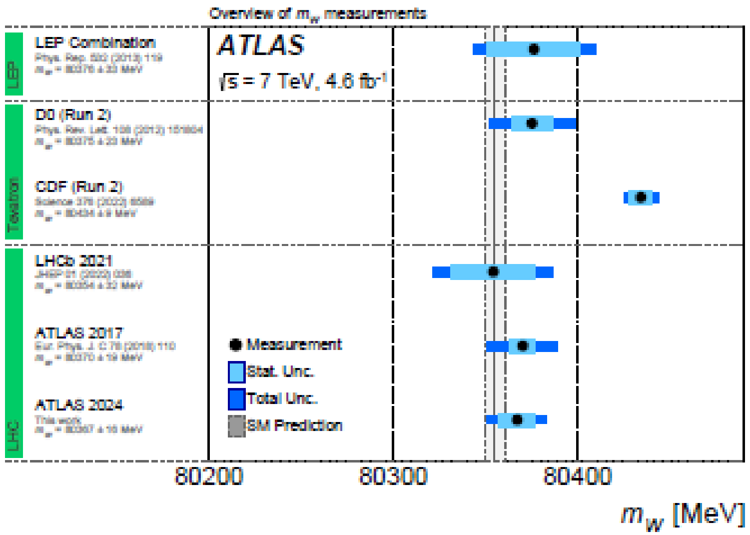
HVV anomalous coupling $H \to ZZ \to \ell\ell\ell\ell$ arXiv:2304.09612

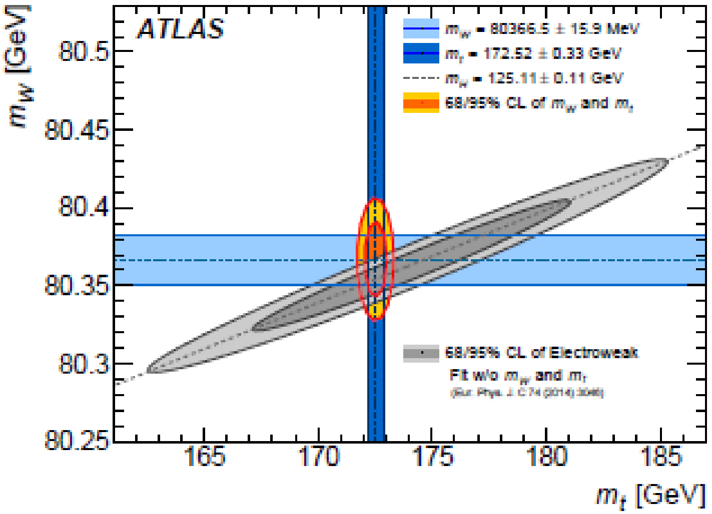
- A neural-network trainning performed to enhance the VBF purity
- ✓ 4 VBF SRs defined with NN output
- • Three types of fit perform
- ✓ Production → CR(ZZ, VBF-dep)+SR(VBF1-4)
- ✓ Decay → CR(ZZ)+SR(inclusive)
- ✓ Combined → CR(ZZ)+SR(VBF-dep, VBF1-4)



Measurement of the W Mass at the LHC 2403.15085

ATLAS 7 TeV
mW = 80366.5 ± 9.8 (stat.) ± 12.5 (syst.) MeV = 80366.5 ±15.9 MeV,





H mass arXiv:2207.00320

One of the fundamental parameters of the standard model (SM)

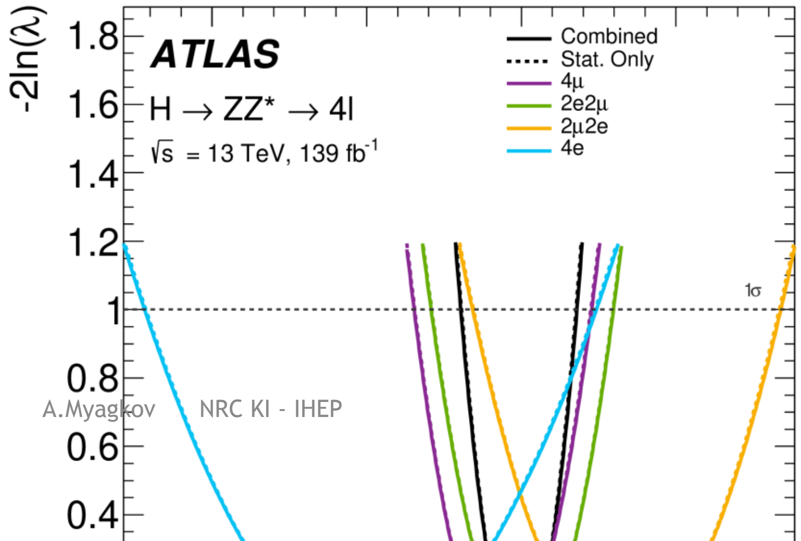
Uncertainties : lepton and photon energy scales

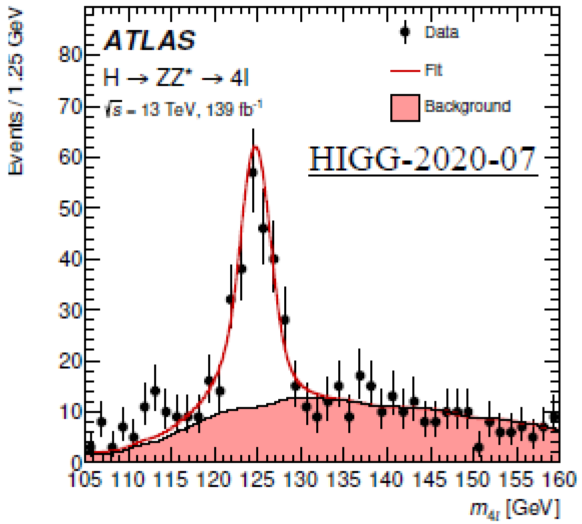
ATLAS Legacy : combination of Run I and Run II measurements in H → γγ and H → 4l

$m_H = 125.11 \pm 0.09_{stat} \pm 0.06_{syst}$ GeV : precision $\mathcal{O}(0.09\%)$

PhysRevLett.131.251802

The combined measurements profit from the increased dataset, and from significantly improved calibrations of the electron and photon energy [16, 21] and of the muon momentum [17, 22].





mH = 125.04 ± 0.11stat ± 0.05syst GeV

darkHiggs(WW) + MET (CMS) PAS EXO-21-012

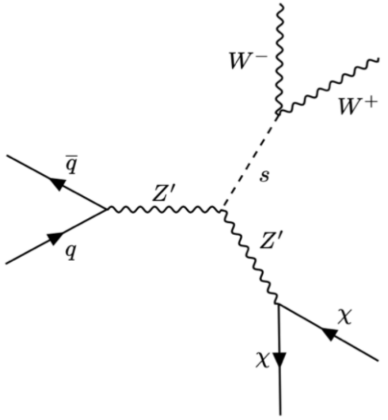
$\chi\chi$mass through dark Higgs (s) Yukawa coupling
- two mediators: ZZ', ss
- free parameters: $mm_{ss}, mm_{\chi\chi}, mm_{ZZ'}, gg_{\chi\chi}, gg_{qq}$

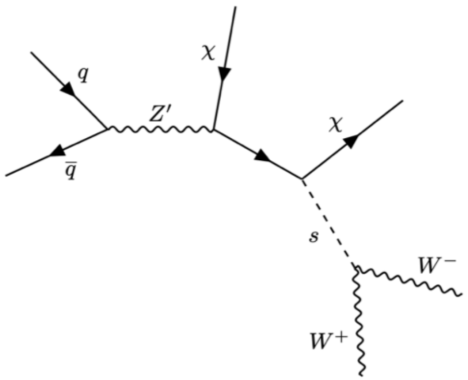
Two final states are considered:

$s \rightarrow WW \rightarrow l\nu l\nu$ (di-leptonic)

$ss \rightarrow WW \rightarrow l\nu jj$ (semi-leptonic, resolved)

Limits are set on dark matter production in the contex
dark Higgs simplified model, with a dark Higgs mass ab
W+W− mass threshold





A.Myagkov   NRC KI - IHEP