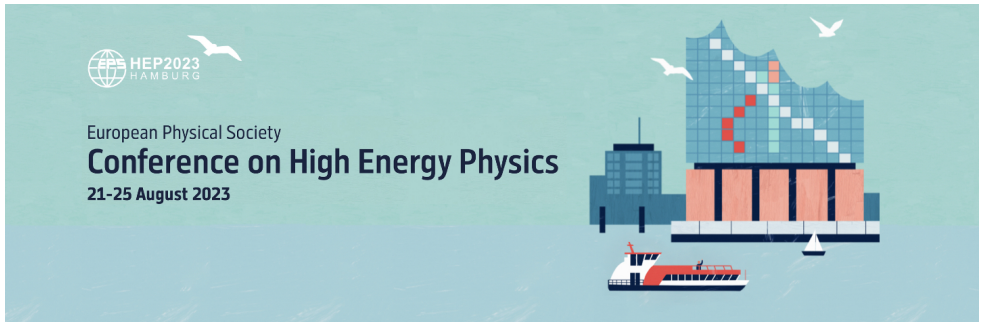
EPS-HEP2023 conference in Hamburg: selected highlights

CPPM seminar

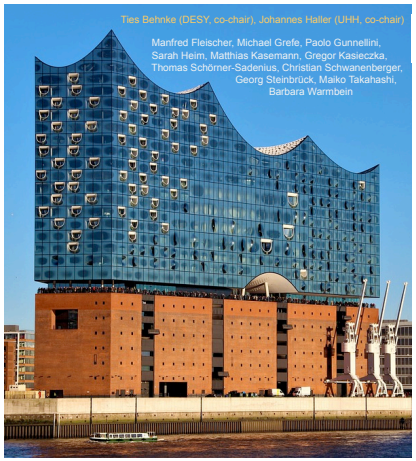
Timothée Theveneaux-Pelzer

CPPM – CNRS/IN2P3 – Aix-Marseille Université



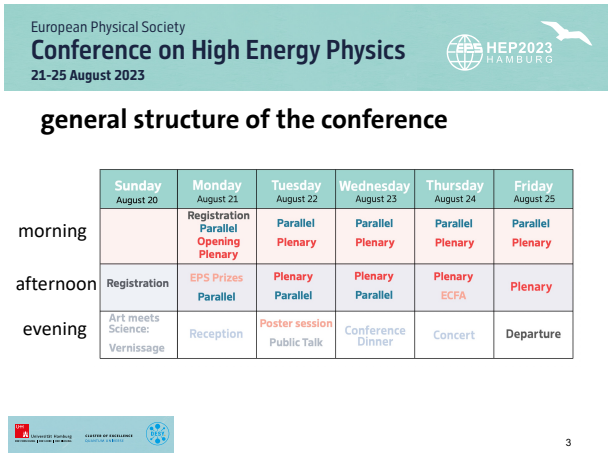
The EPS-HEP2023 conference

- Conference organised in Hamburg, by Universität Hamburg and DESY
  - first EPS-HEP conference in person since 2019
  - most speakers present in person, though remote participation was still possible
  - 5 days (Mon-Fri) instead of 7 (Thu-Wed), no excursion - quite convenient (I think)
- Conference website: https://www.eps-hep2023.eu/
  - plenary sessions (incl. EPS prizes, ECFA) + 10 parallel sessions (14 topics) + posters



2019 closing slides

2021 closing slides



2023 opening slides

- I will present few highlights of results shown this year
  - numerous interesting talks were given, so I can only show a partial selection
  - the selection of results is absolutely biased!

List of sessions

- Opening Link - Plenary Link - Closing Link
- Posters Link - EPS prizes Link - ECFA Link
- Astroparticle Physics and Gravitational Waves Link
- Gravitation and Cosmology Link
- Dark Matter Link
- Neutrino Physics Link
- Ultra-Relativistic Nuclear Collisions Link
- QCD and Hadronic Physics Link
- Top and Electroweak Physics Link
- Flavour Physics and CP Violation Link
- Higgs Physics Link
- Searches for New Physics Link
- Quantum Field and String Theory Link
- Detector R&D and Data Handling Link
- Accelerators for HEP Link
- Outreach, Education and EDI Link

Outline

Neutrinos: current status

Plenary talk: J. Łagoda

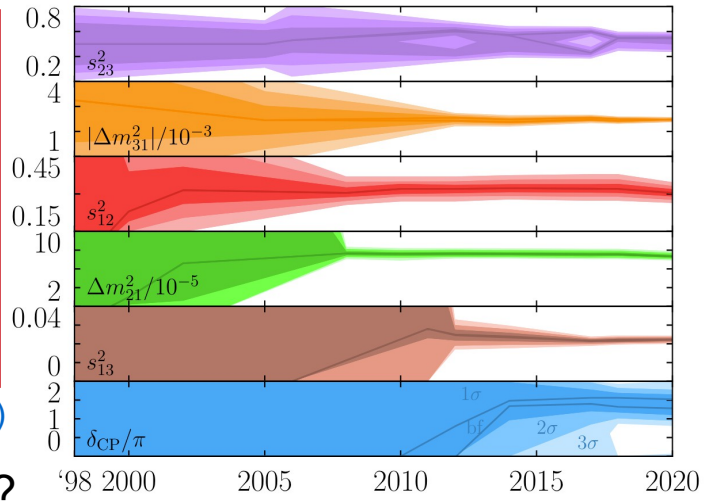
Current knowledge and open questions

- precise measurements test the 3-flavor paradigm

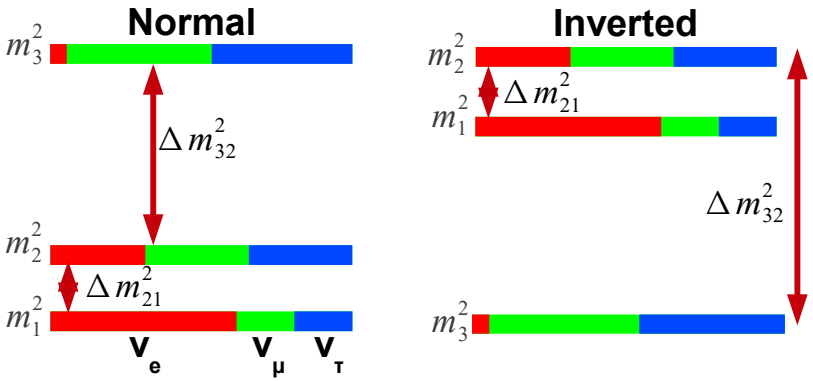
$\sin^2(\theta_{12}) = 0.307 \pm 0.013$
$\Delta m^2_{21} = (7.53 \pm 0.18) \times 10^{-5}$ eV^2
$\sin^2(\theta_{23}) = 0.539 \pm 0.022$ (S = 1.1) (Inverted order)
$\sin^2(\theta_{23}) = 0.546 \pm 0.021$ (Normal order)
$\Delta m^2_{32} = (-2.536 \pm 0.034) \times 10^{-3}$ eV^2 (Inverted order)
$\Delta m^2_{32} = (2.453 \pm 0.033) \times 10^{-3}$ eV^2 (Normal order)
$\sin^2(\theta_{13}) = (2.20 \pm 0.07) \times 10^{-2}$
δ, *CP* violating phase $= 1.36^{+0.20}_{-0.16}\ \pi$ rad

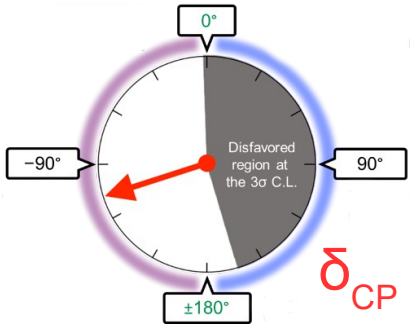
PTEP 2022, 083C01 (2022)

©P.Denton



- θ_{23} octant, mass ordering, CP violation ???





T2K Nature 580, 339 (2020)

Not covered by this talk: direct mass measurements, Dirac/Majorana nature of neutrinos, origin of masses and mixing

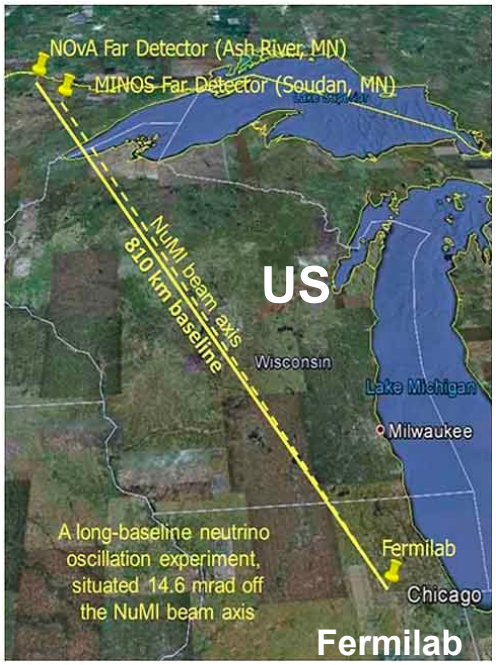
Neutrinos: T2K and NOvA

Plenary talk: J. Łagoda

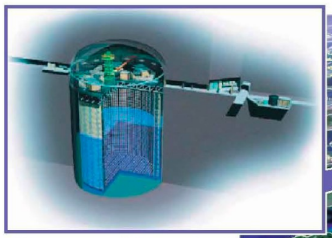
- Two ongoing neutrino experiments using ν_μ and $\bar{\nu}_\mu$ beams from π decays in flight

T2K and NOvA

	T2K	NOvA
baseline	**295** km	**810** km
peak energy	**600** MeV	**2** GeV
CP effect	32%	22%
Matter effect	9%	29%
Near Detector	multi-purpose (TPC, FGD, ECAL) magnetized	extruded plastic cells filled with liquid scintillator
Far Detector	50 kton Water Cherenkov	14 kton scintillator



PRD 106, 032004 (2022)



Super-Kamiokande
(ICRR, Univ. Tokyo)

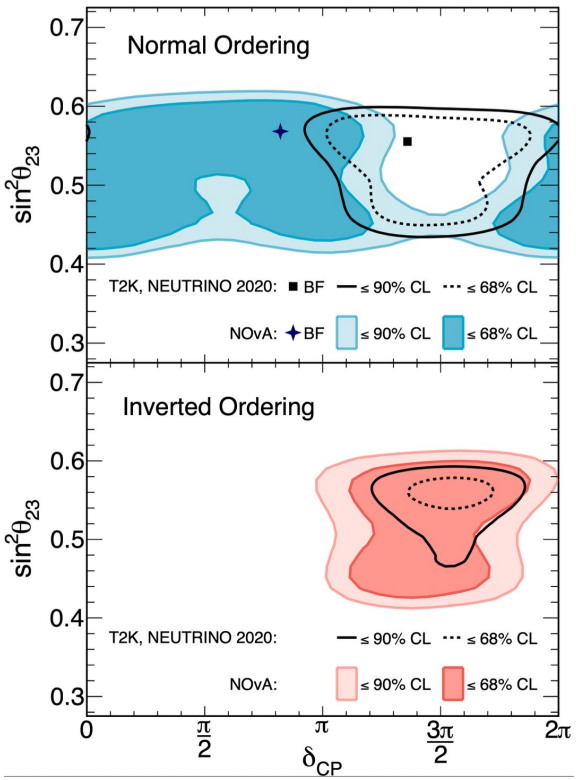
J-PARC Main Ring
(KEK-JAEA, Tokai)

T2K

PoS ICHEP2022 (2022) 606

Neutrinos: comparison of T2K and NOvA results

Plenary talk: J. Łagoda



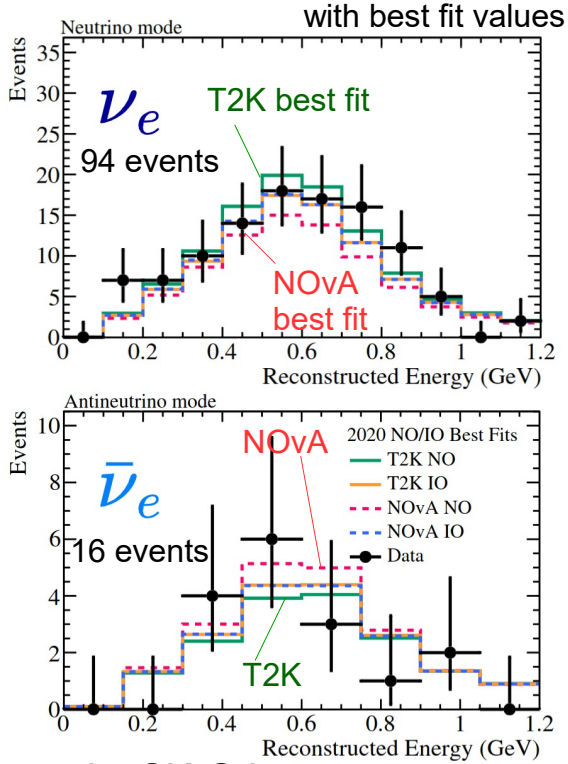
T2K vs. NOvA

- both show a **weak preference for NO**
- some tension in δ_{CP} but remember: current results are **statistically limited!**
  - if IO: consistent preference for the 3π/2 (-π/2) region, small preference for upper octant
- **more data needed** in both experiments!

- joint analysis T2K-NOvA in progress, results expected soon
- T2K statistical update expected soon
- new analyses from both expected 2024

- Both undergoing upgrade:
  - NOvA – beam power → 900+ kW
  - T2K – beam power → 1.3 MW, ND280 upgrade, SK-Gd
  - Goal: 3σ sensitivity for CPV (T2K) and MO (NOvA)

points - T2K data
histograms – predictions
with best fit values



Neutrinos: CP violation in T2K

Parallel talk: Y. Prabhu

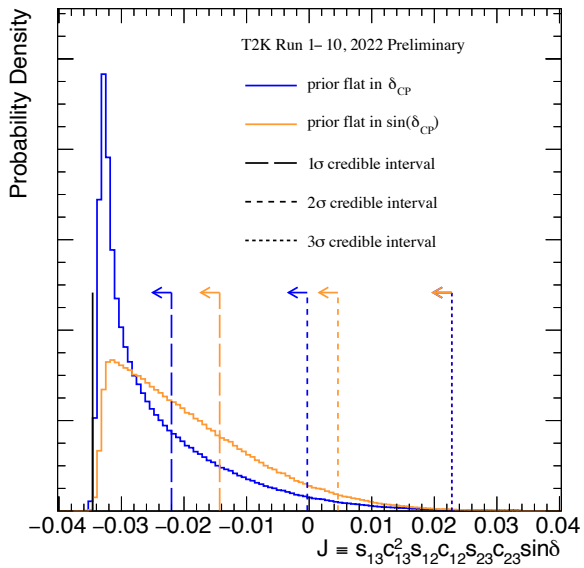
- Use of Jarlskog invariant to assess presence of CP-violation
  - same invariant as for quark sector - EPS HEP prize awarded to Cecilia Jarlskog
- Absence of CP violation (J=0) disfavored

Results - Jarlskog Invariant, J_{CP}

Jarlskog Invariant, $J_{CP} \equiv \sin\theta_{13}\cos^2\theta_{13}\sin\theta_{12}\cos\theta_{12}\sin\theta_{23}\cos\theta_{23}\sin\delta_{CP}$

- Introduced J_{CP} as a measurable parameter to search for CP violation as it is PMNS parametrization independent.
- Although J_{CP} results depend on the choice of using flat prior in $\delta_{CP}/\sin\delta_{CP}$, **we still exclude $J_{CP} = 0$** (implying CP conservation) at 90% credible interval.
- Preference for maximal CP violation still valid.

Jarlskog Invariant, Both Hierarchies

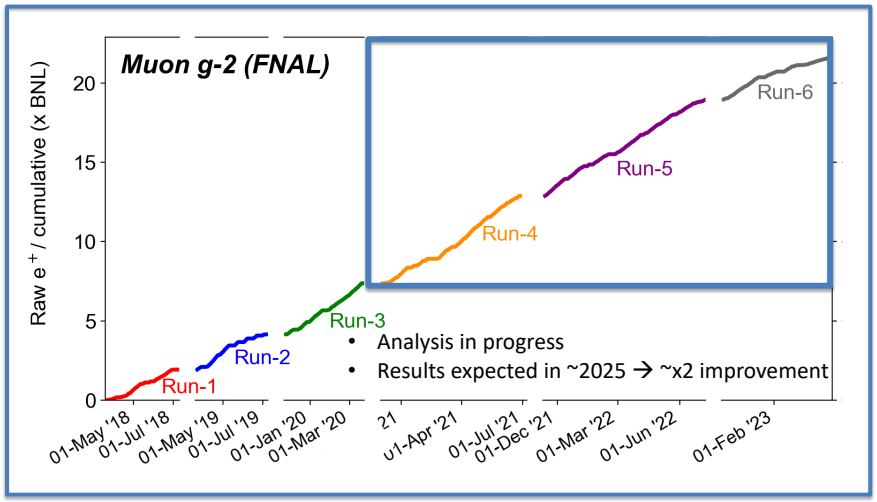


- Note: θ_{13} reactor constraint is applied ($\sin^2 2\theta_{13} = 0.0861 \pm 0.0027$)

Muon g-2: latest experimental results

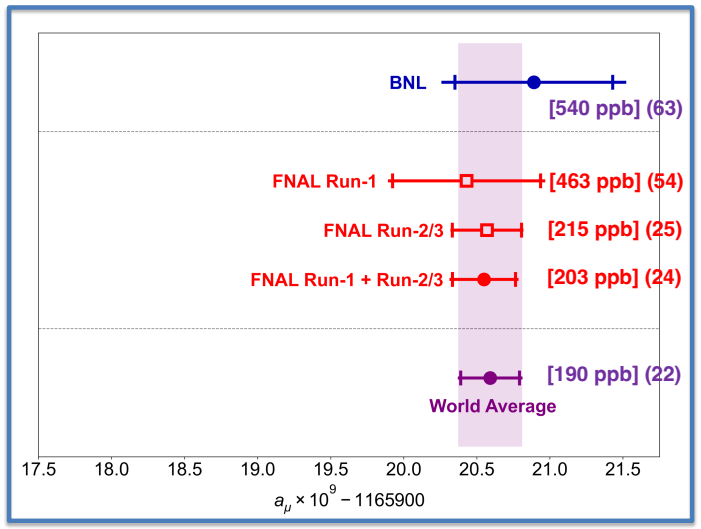
Plenary talk: G. Venanzoni

- 6 runs of data collected by FNAL Muon g-2 experiment
  - only 3 of them analysed so far
- Run-1 result in 2021 confirmed earlier BNL deviation wrt. SM prediction (4.1σ)
- Latest result on August 9th including runs 2&3 - 5.1 σ deviation wrt. SM predictions



Run-2/3 Result: FNAL + BNL Combination

a_μ(FNAL) = 116 592 055(24) x10^{-11} [203 ppb]



- FNAL combination: **203 ppb** uncertainty
- Both FNAL and BNL dominated by statistical error
- Combined world average **dominated by FNAL** values.

a_μ(Exp) = 116 592 059(22) x 10^{-11} [190 ppb]

G. Venanzoni, EPS-HEP2023, Hamburg, 22 August 2023

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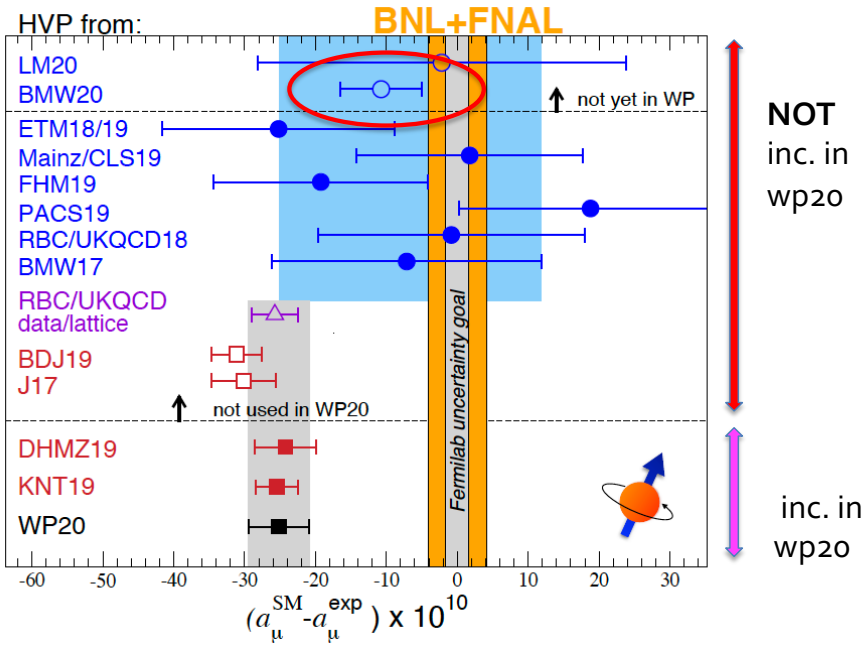
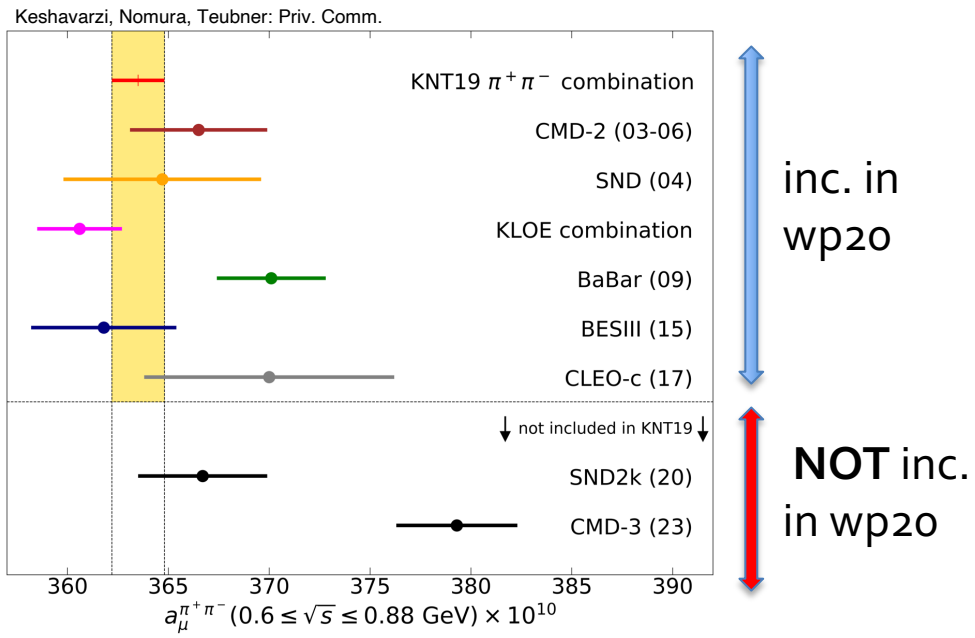
Muon g-2: SM predictions

Plenary talk: G. Venanzoni

- Hadron Vacuum Polarisation estimates dominates SM predictions uncertainties
- White Paper in 2020 included estimates from $e^+e^- \to had$ experiments
  - lattice QCD calculations not sensitive enough to be included
  - ...until BMW20 was released, pretty much compatible with measurement
  - also: new CMD-3 prediction from $e^+e^- \to had$ in 2023, compatible with measurement





Muon g-2: summary

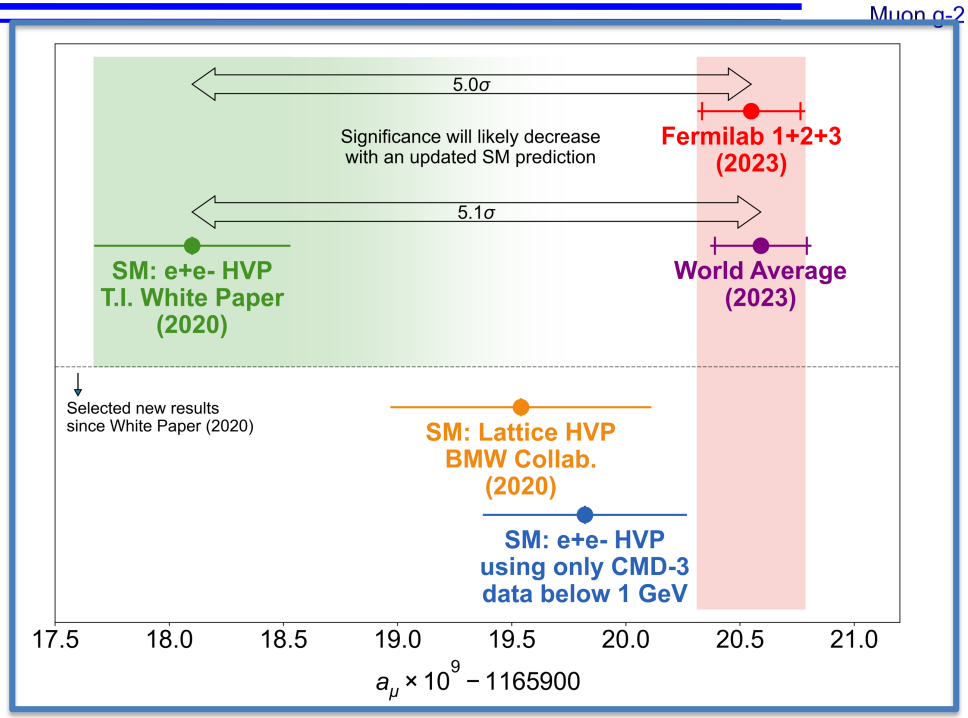
Plenary talk: G. Venanzoni

Comparison with SM prediction (2023)

Comparison with wp20

New results after 2020

Disclaimer: prediction from Lattice taken from Lattice 2023 talk; prediction from CMD3 based on our specific assumption



- A factor ~ x 3 **data** from Run4-6 with a projected twofold improvement on the uncertainty (analysis should be completed by 2025)
- Expect **theory improvement** on a similar timescale (https://muon-gm2-theory.illinois.edu/)
- Look out for other analyses too: **EDM, CPT/LV** and **Dark Matter** searches.

LHCb: more tetraquarks and pentaquarks

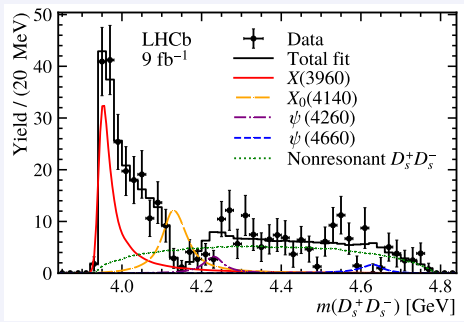
Plenary talk: M. Franco Sevilla

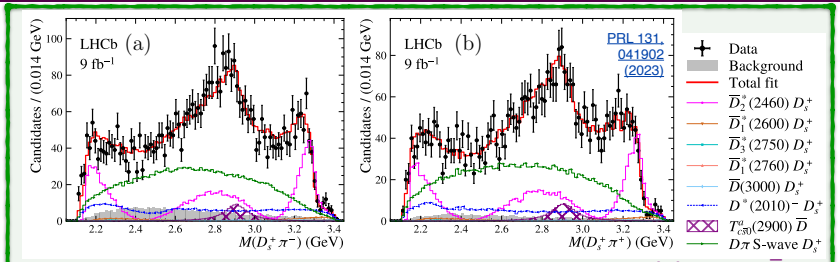
- LHCb is seeing more and more baryons
  - see the full list in the plenary talk!
- Few Tetra- and Penta-quarks since the 2015 observation

Tetraquarks and Pentaquarks

X(3960) possible new tetraquark $T^{\theta}_{\psi\phi}(3960)$ $[c\bar{c}s\bar{s}]$

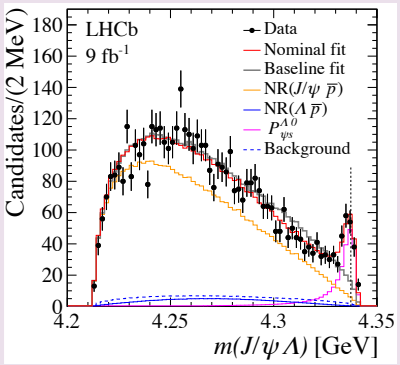
2210.15153 submitted to PRL





First doubly-charged tetraquark $T^a_{c\bar{s}0}(2900)^{++}$ $[c\bar{s}u\bar{d}]$ and isospin partner $T^a_{c\bar{s}0}(2900)^0$ $[c\bar{s}d\bar{u}]$

$50,000 FINE

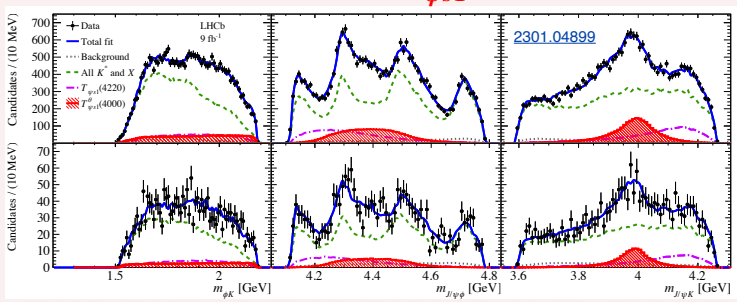


First pentaquark with strangeness $P^{\Lambda}_{\psi s}(4338)^0$ $[c\bar{c}uds]$

PRL 131, 031901 (2023), submitted to PRL

More details on Thursday by G. Robertson

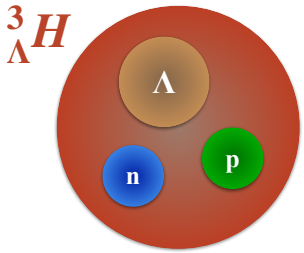
New resonant structure with 4σ, 5.4σ with isospin constraint, candidate for $T^{\theta}_{\psi s1}(4000)^0$ $[c\bar{c}d\bar{s}]$



LHCb: hypertriton

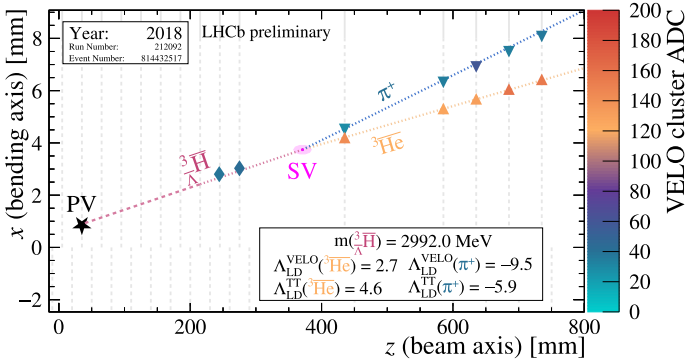
Plenary talk: M. Franco Sevilla – parallel talk: H. Jage

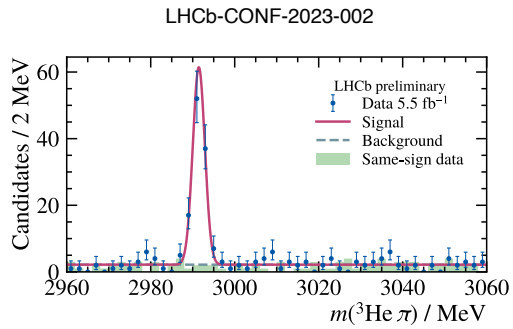
Hypertriton ${}^3_\Lambda H$



- **Hypertriton** is bound state of **neutron**, **proton**, **hyperon**
  - Implications for QCD and astrophysics (neutron stars)
- Reconstructed in ${}^3_\Lambda H \to {}^3He\,\pi^-$ decays
- Exploits **ionization energy** in **silicon trackers** and **drift time**
  - **Doubly-charged ^{3}He** nuclei leave **large signals**

More details in talk this afternoon by H. Jage





Paves way for **rich program** in **pp** and **also pPb/PbPb** where nuclear effects would be more prevalent

- New source of ${}^3\bar{He}$ to explain AMS results?
  - reported ${}^3\bar{He}$ candidates, but no $\bar{d}$
- Possible implications for neutron stars

LHCb: measurement of $\mathcal{R}(D^{(*)})$

Plenary talk: M. Franco Sevilla

- $\mathcal{R}(D^{(*)}) = Br(B \to D^{(*)}\tau\nu_\tau)/Br(B \to D^{(*)}\ell\nu_\ell)$: lepton flavour universality probe
- New results by LHCb, combined with earlier results $\Rightarrow$ 3.3σ tension with SM

$\mathcal{R}(D^0)/\mathcal{R}(D^*)$ results

arXiv:2302.02886, submitted to *Phys. Rev. Lett.*

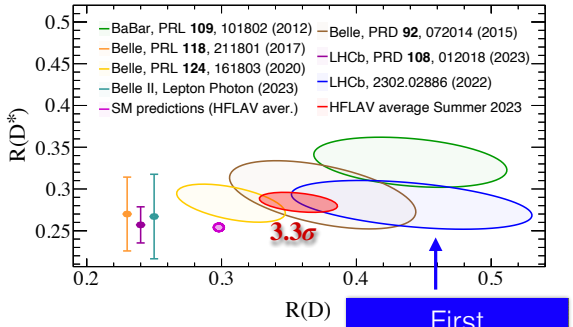
Contribution	Uncert. [%] $\mathcal{R}(D^*)$	$\mathcal{R}(D^0)$
Simulated sample size	5.3	10.2
DD bkg. shape	2.8	7.3
$\overline{B} \to D^{**}(\ell^-/\tau^-)\overline{\nu}$ FFs	2.8	2.7
Signal/norm. FFs	2.5	4.8
Misidentified μ bkg.	2.5	2.7
Baryonic bkg.	2.5	2.7
DD bkg. model	2.1	1.6
$\overline{B} \to D_s^{**}\ell^-\overline{\nu}$ model	2.1	5.4
Total systematic	**8.5**	**15.0**
Total statistical	**6.4**	**13.6**
Total	**10.7**	**20.2**

Note that less than half of the systematic uncertainty is multiplicative, so the majority does not scale with central value

FastSim gives a **factor of 8×**, which **covers Run 2 stats**
Hopefully will scale with data beyond Run 2, but it will require **faster FastSim**, **faster hardware progress**, **or more restrictive generator cuts**

Primarily data driven

May be able to reduce but on a case-by-case basis



First measurement of $\mathcal{R}(D)$ at LHCb

Expect to reduce uncertainties with larger data samples, probably with a **0.5-3% systematics floor**

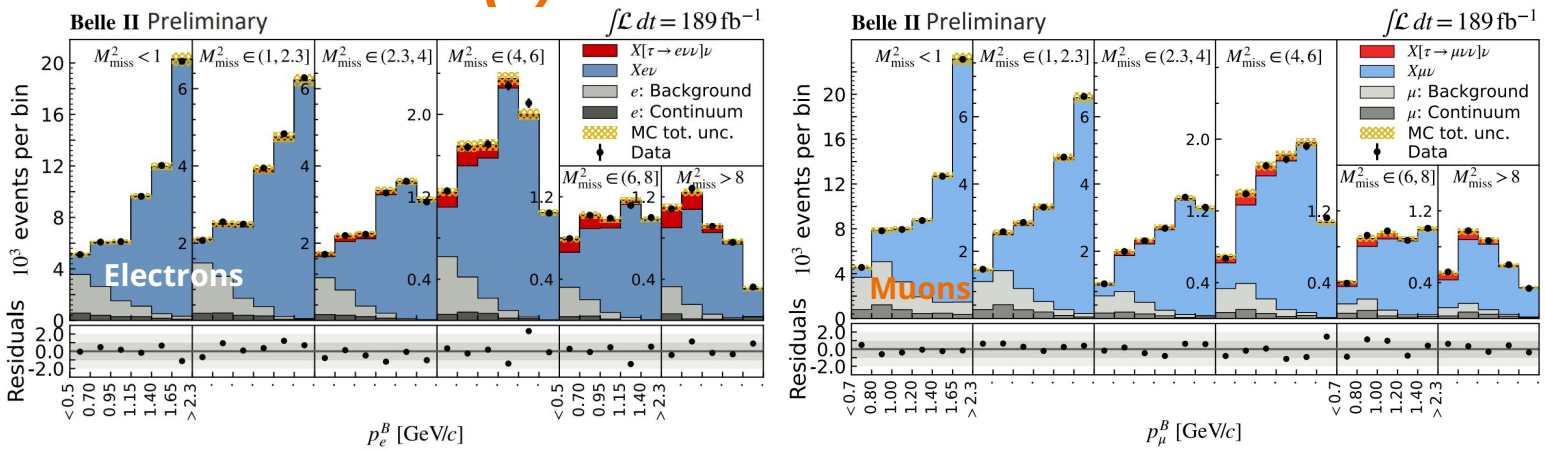
Belle-II: measurement of $\mathcal{R}(X)$

Plenary talk: A. Glazov – parallel talk: T. Koga

- $\mathcal{R}(X^{(*)}) = Br(B \to X\tau\nu_\tau)/Br(B \to X\ell\nu_\ell)$ is an alternative probe
- First measurement at a B factory

Measurement of *R(X)*

See also presentation at EPS



Complex analysis, requiring multiple corrections/reweighting to simulated samples
Excellent agreement between electron and muon channel measurements:

$$R(X_{\tau/e}) = 0.232 \pm 0.020\ (\text{stat}) \pm 0.037\ (\text{syst})$$
$$R(X_{\tau/\mu}) = 0.222 \pm 0.027\ (\text{stat}) \pm 0.050\ (\text{syst})$$

Systematics is largely from data-driven corrections in control regions

Combined result

***R(X)* = 0.228 ± 0.016(stat) ± 0.036 (syst)**

is consistent with SM 0.223±0.006, but also with measurements of $R(D^{(*)})$

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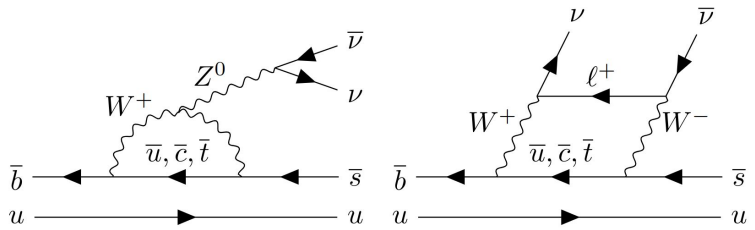
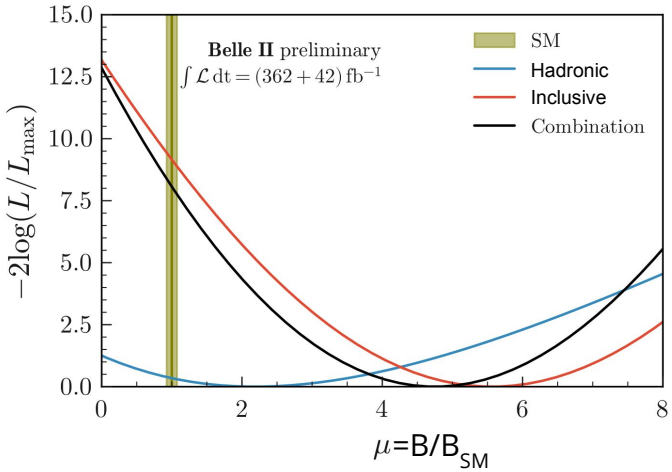
Belle-II: evidence for $B^+ \to K^+\nu\bar{\nu}$ and tension with SM

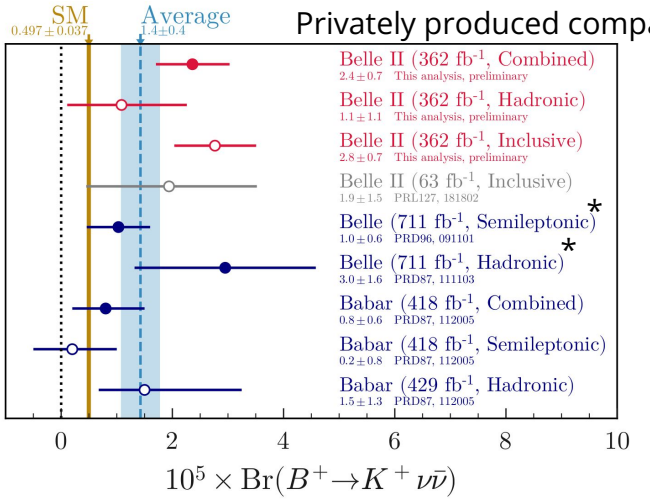
Plenary talk: A. Glazov

- $B^+ \to K^+\nu\bar{\nu}$ not yet observed
- New result released, combining two channels
  - evidence with 3.6σ
  - tension with SM at 2.8σ level



Combination and comparison with other measurements





Privately produced comparison

- Inclusive and hadronic measurements are combined, taking into account common correlated uncertainties. The resulting branching fraction is
  $B_{comb}(B^+ \to K^+ \nu\nu) = (2.4 \pm 0.7) \times 10^{-5}$ $= [2.4 \pm 0.5(stat)^{+0.5}_{-0.4}(syst)] \times 10^{-5}$
  significance of observation is **3.6σ** the result is within **2.8σ** vs standard model
- Some tensions between inclusive and semileptonic results for Belle and BaBar, however overall compatibility of the results is good with χ^2/dof = 4.3/4

*Belle reports upper limits only; branching fractions are estimated using published number of events and efficiency

Example of BSM search with LHC Run 3 data

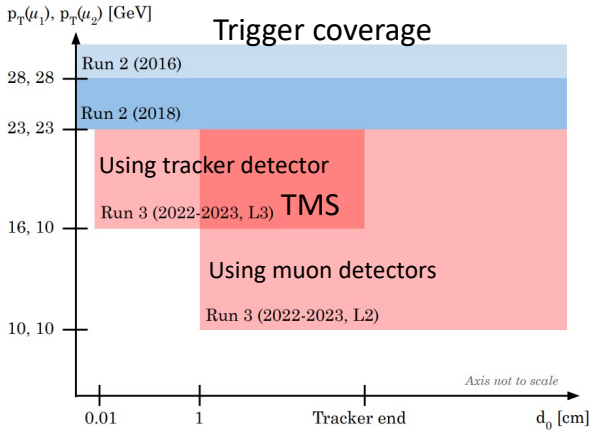
Plenary talk (CMS highlights): F. Canelli

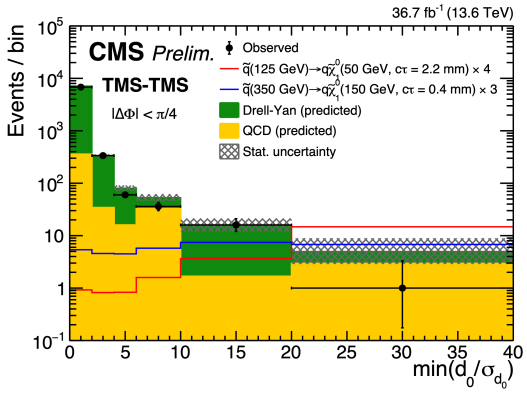
- Search for long-lived particles with CMS using run 3 data
- Improvements in trigger strategy wrt. run 2
  - better results in part of the parameter space, even with less data

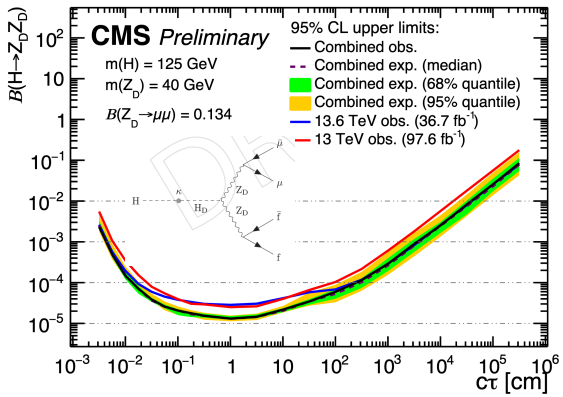
Run 3 results – long lived particles

New

first search for new physics: inclusive search for long-lived exotic particles decaying to a pair of muons
Using 36.7 fb^{-1} of data taken in 2022, selecting muons originating from a common secondary vertex spatially separated from the primary interaction point by distances ranging from several hundred μm to several meters







Substantial improvements in efficiency as compared to the Run 2 analysis, particularly at low masses and long lifetimes, mainly because of improved triggers for displaced muons and analysis refinements

Limits set for two benchmark models: the hidden Abelian Higgs model (HAHM), in which displaced dimuons that could rise from dark photons, and RPV SUSY model

Run 3 is opening opportunities for exploring physics beyond statistical improvements over Run 2

CMS-PAS-EXO-23-014

First Higgs result with run 3 data by ATLAS

Plenary talk (Higgs): T. Masubuchi

First Run 3 Higgs Measurement

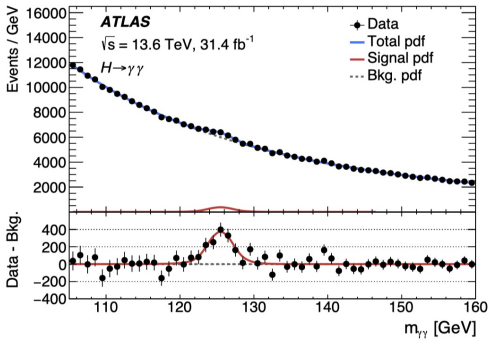
arXiv:2306.11379

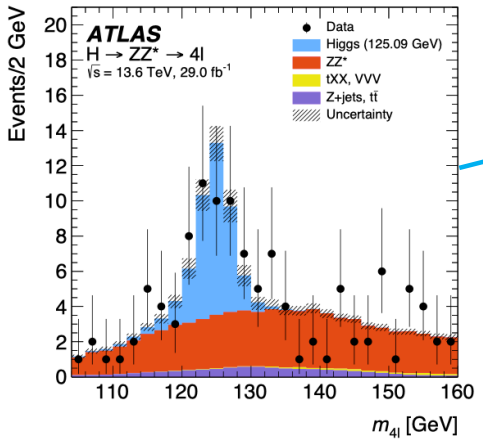
Maria's talk

2023/8/20

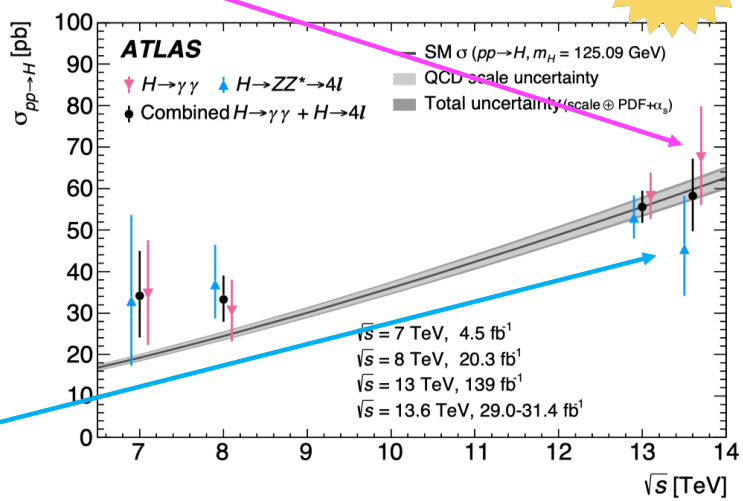
- Measure fiducial and total cross section with H→γγ, H→ZZ→4l channels at 13.6 TeV in 2022 data
- Measured total cross-section
  - 67^{+12}_{-11} pb for H→γγ
  - 46±12 pb for H→ZZ→4l
  - **58.2±8.8 pb for combined**

➔ **Good agreement with SM prediction (59.9±2.6pb)**





NEW



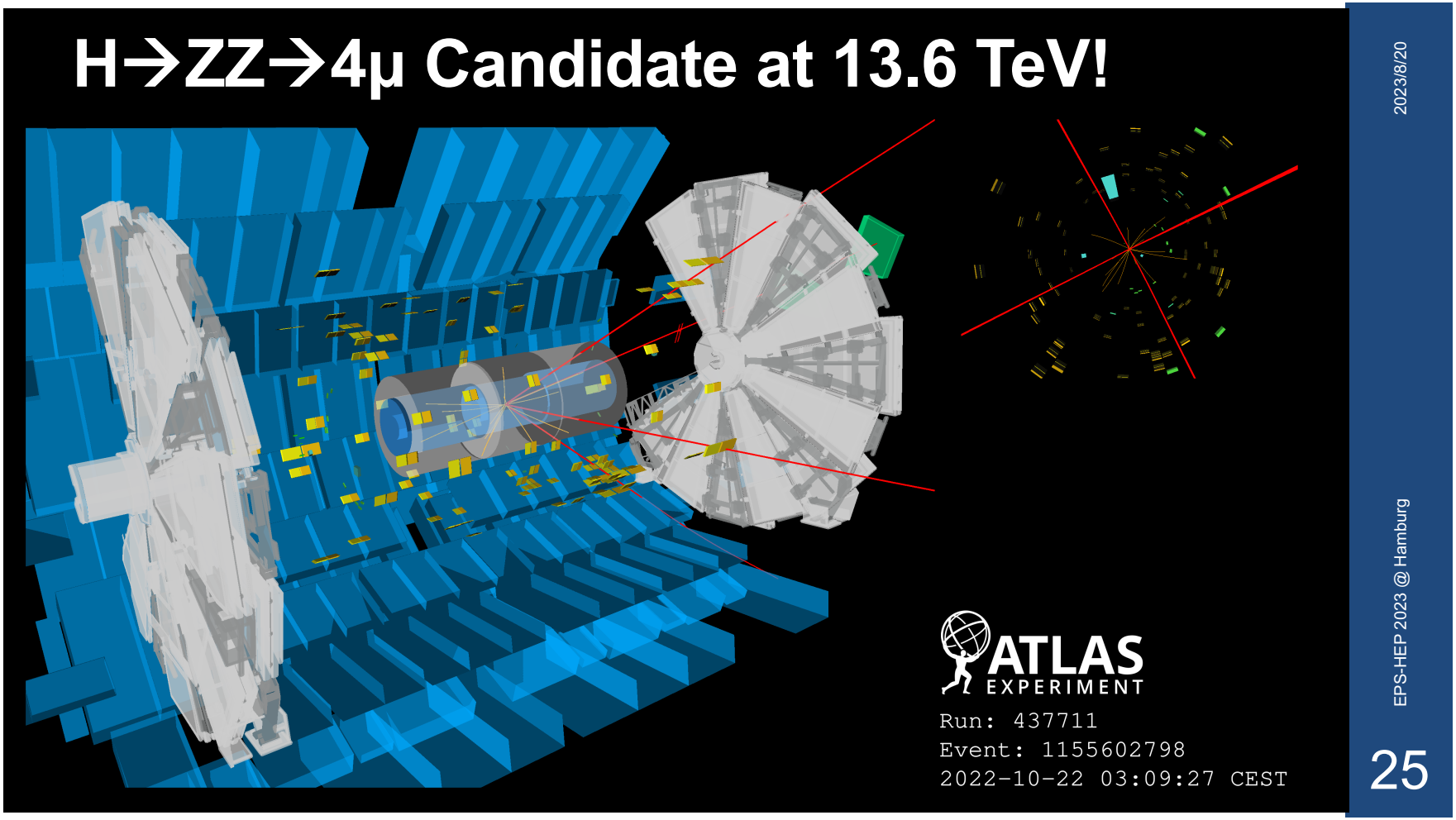
Re-observed at 13.6 TeV!!
More data coming for precise measurement in Run3

EPS-HEP

24

First Higgs result with run 3 data by ATLAS

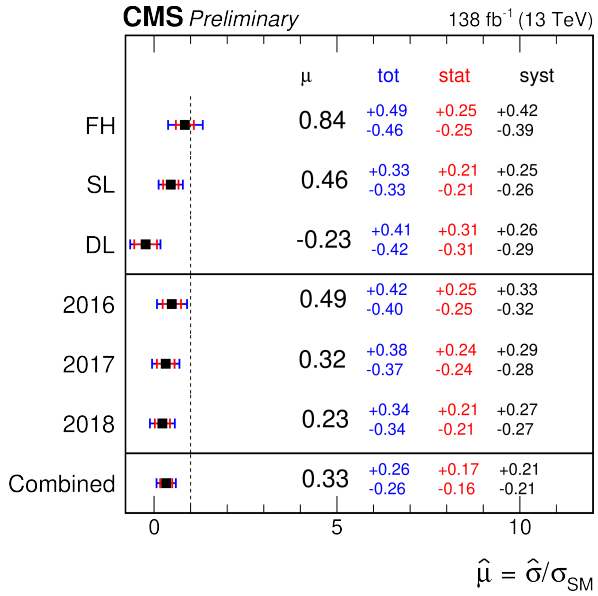
Plenary talk (Higgs): T. Masubuchi

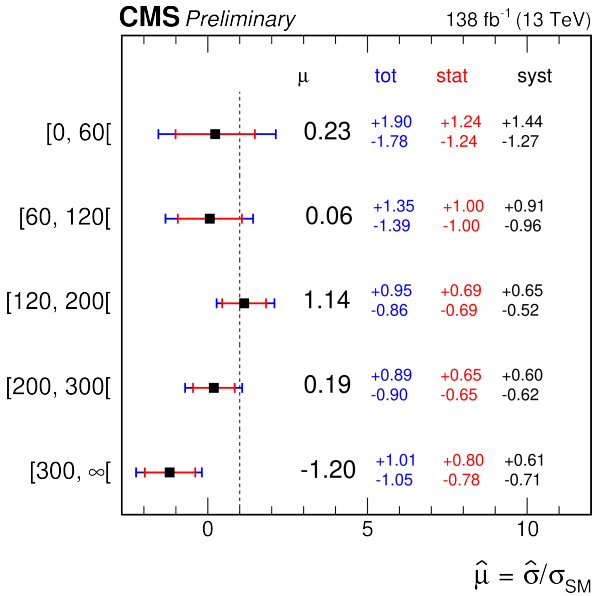


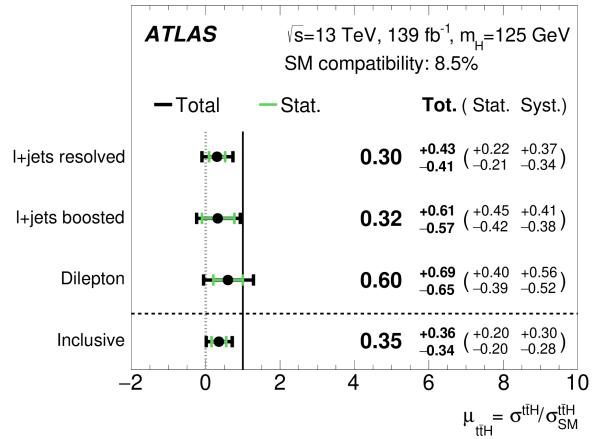
New $t\bar{t}H(H \to b\bar{b})$ result by CMS: CMS-PAS-HIG-19-011

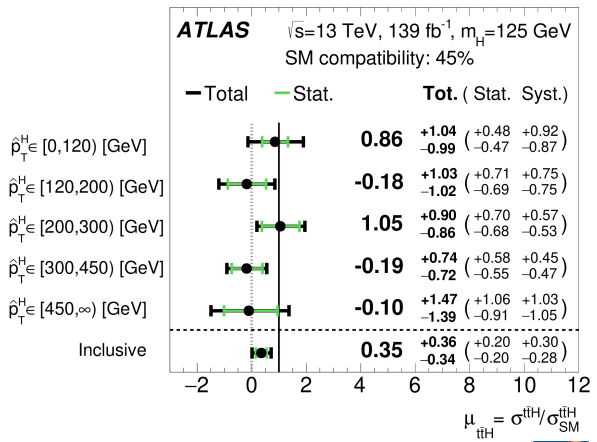
Parallel talk (Higgs): P. Baertschi (and comparison with ATLAS' JHEP **06** (2022) 97)

- First full run-2 CMS result
- Different channels used
  - 0ℓ: CMS only
  - 1ℓ boosted: ATLAS only
- STXS fit in 5 bins
  - highest pT: $>$ 300 GeV (ATLAS $>$ 450 GeV)
  - low pT split 0-60-120 GeV (not in ATLAS)
- Inclusive Xsec lower than SM
  - p-value: 2% (ATLAS 8.5%)
- To be scrutinised:
  - $t\bar{t}b\bar{b}$ model and uncerts.
  - correlations accross years and channels









Updated Higgs mass measurement by ATLAS

Plenary talk (Higgs): T. Masubuchi

- Making the best with run 2 data: updated Higgs mass measurement
- Time-consuming efforts to reduce systematics rewarded by much improved results

Mass Measurement

Stefano's talk

arXiv:2308.07216
arXiv:2308.04775

- Fundamental parameter in the SM, it determines production and decay rates of Higgs
  ➔Need to measure experimentally
- H→γγ has excellent mass resolution
  - Extensive efforts on the photon energy calibration in Run2
  - Reduce photon energy scale/resolution uncertainties

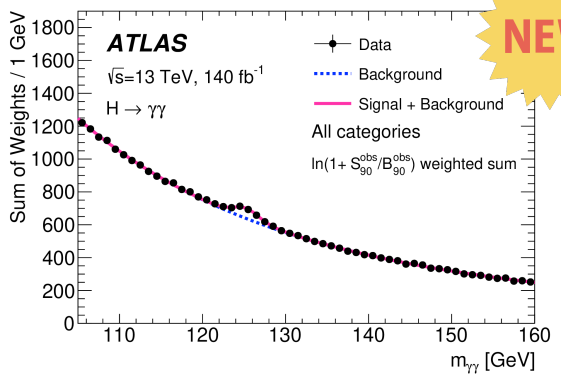
320 MeV (previous Run 2 results) ➔ 80 MeV

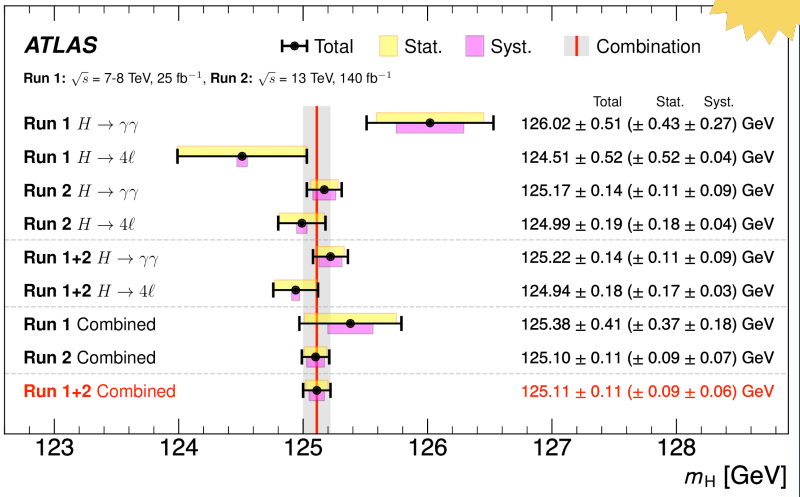
Measured Higgs mass with H→γγ (Run 1+2)

125.22±0.11(stat)±0.09(syst) GeV
(0.11% precision!)

Combine H→γγ and H→ZZ→4l channels (Run1+Run2)

125.11±0.09(stat)±0.06(syst) GeV
(0.09% precision!)



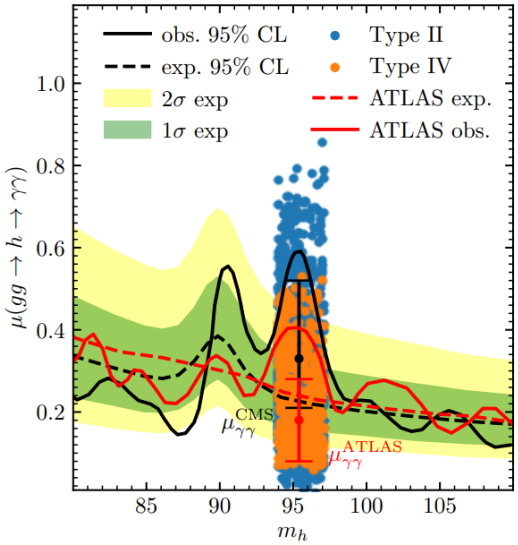


2023/8/20

The excess around 95 GeV

Parallel talk (Higgs and BSM): T. Biekoetter

- CMS $\gamma\gamma$ excess at 95 GeV:
  - 2.9σ (local) released for Moriond 2023
  - ATLAS result in June 23: 1.7σ
  - same mass as for LEP $b\bar{b}$, CMS $\tau\tau$ excesses
- 2HDM interpretation?
  - excess may be the A in 2HDM model
  - would work better as an additional scalar $\Rightarrow$ S2HDM



Combination: $\mu_{\gamma\gamma}^{\text{ATLAS+CMS}} = 0.24^{+0.09}_{-0.08}$

New exp. results in 2023: Full Run 2 di-photon searches below 125 GeV
- → CMS: Significance of excess unchanged, signal strength reduced
- → ATLAS: Same sensitivity, excess at the right spot, but less significance

S2HDM interpretations: $h_{95} \approx h_S$ as singlet-like scalar mixed with h_{125}
- → LEP $b\bar{b}$ excess ✓ CMS + ATLAS $\gamma\gamma$ excess ✓ CMS $\tau^+\tau^-$ excess (✓)
- → Predicts $|c(h_{125}VV)| < 1$, will be probed at HL-LHC and Higgs factory
- → No tension with indirect constraints
- → Interesting connections to other anomalies
  - → Dark matter and galactic-center excess [TB, M.O. Olea, 2108.10864]
  - → W-boson mass discrepancies [TB, S. Heinemeyer, G. Weiglein, 2204.05975]

2HDM interpretations: $h_{95} \approx A$ as dominantly CP-odd scalar
- → LEP $b\bar{b}$ excess ✓ CMS + ATLAS $\gamma\gamma$ excess ✓ CMS $\tau^+\tau^-$ excess ✓
- → Only LEP excess required modifications of h_{125} couplings
- → Light spectrum, H and $H^\pm$ with masses around m_t
- → Tensions with indirect constraints from flavour physics and EDMs

A word about SM predictions

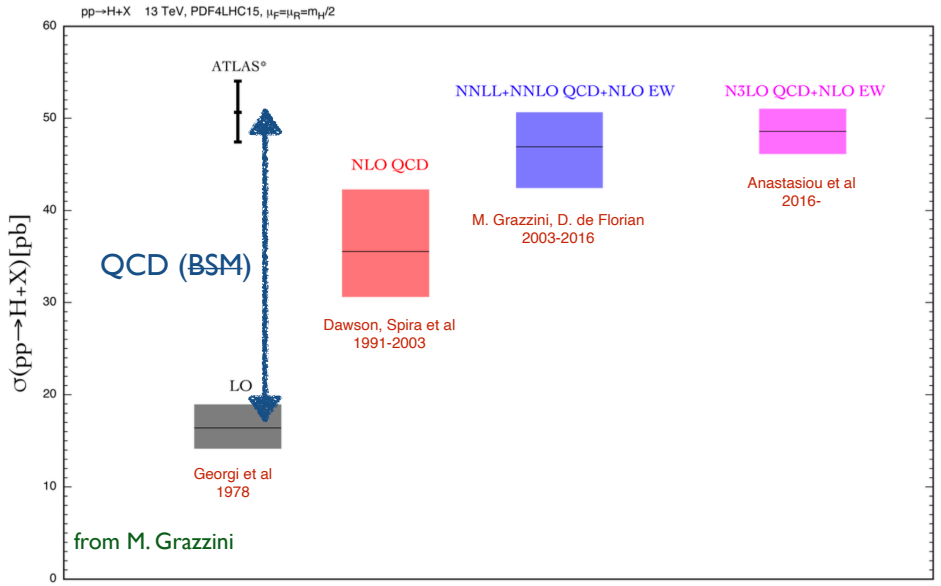
Plenary talk: D. de Florian

LO can (almost) be done by chatGPT

Can you write a Fortran 77 code that computes the DIS cross section at LO using LHAPDFs?

```
sql                                                    Copy code

Sample Fortran 77 code to compute the DIS cross section at LO using LHAPD
in a 5-flavor scheme and neglecting the contribution from the photon PDF

implicit none

Declare the input variables
real*8 x, q2, y, s, tau, pdf, sigma
integer flavor, nset, ievtnum
character*255 pdffile

Declare the LHAPDF functions
external initpdfset, evolvepdf, alphaspdf, endpdfset

Set the input kinematics
x = 0.1d0
q2 = 10.d0**6
y = 0.5d0
s = q2 / x / y
tau = a2 / s
Set the LHAPDF set and initialize it
pdffile = 'cteq66'
call initpdfset(nset,pdffile,0)

Compute the LO partonic cross section for each flavor
sigma = 0.d0
do flavor = 1, 5
   pdf = evolvepdf(x, q2, flavor) / x  ! divide by x to get the PDF for t
   sigma = sigma + alpha_em**2 / (2.d0 * s * q2) * pdf * &
           ((4.d0 / 9.d0 + 16.d0 / 27.d0 * delta(flavor,2)) * (1.d0 + (1.
            (4.d0 / 27.d0 * delta(flavor,2)) * (1.d0 + y**2))
end do

Compute the DIS cross section by convolving with the PDF of the proton
sigma = sigma * 3.d0 / 2.d0 / x / q2 / (1.d0 - y)
```

Inclusive Higgs : an example of precision

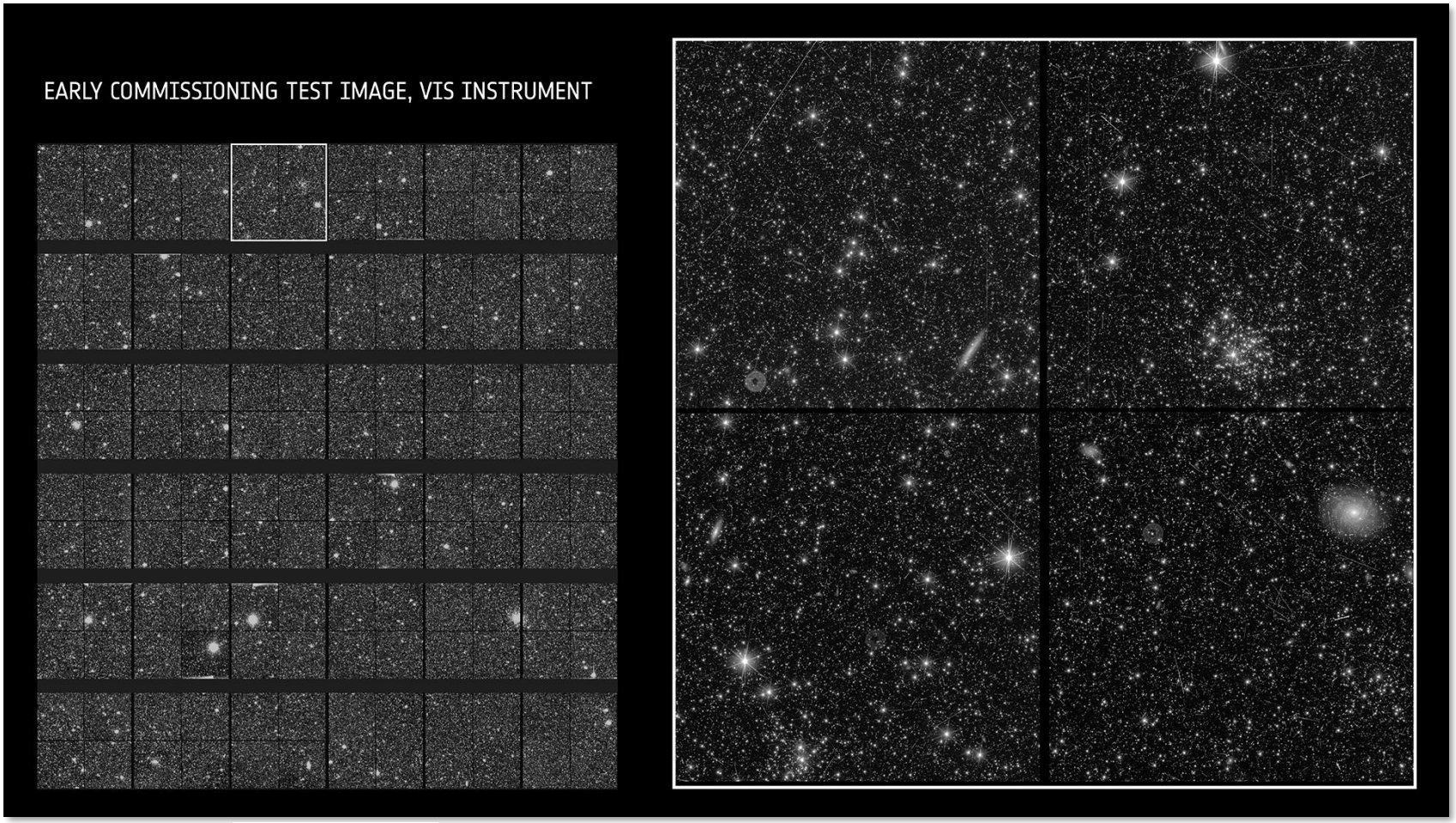


- Excesses should be apreciated with caution, if predictions not accurate enough

Euclid's first light (July 31st)

Plenary talk: J. Liske

- Successfull launch of Euclid $\Rightarrow$ for sure plenty of cosmology results to come



42 arcmin

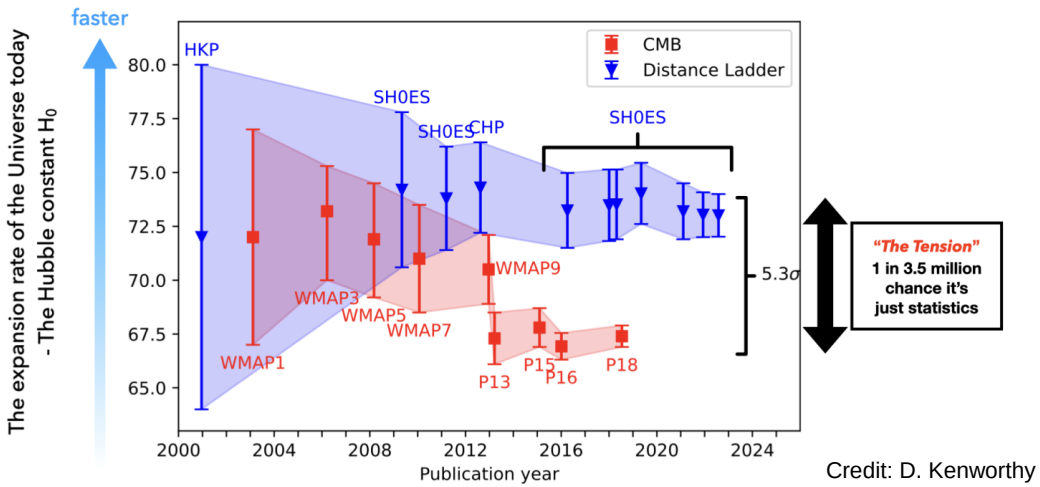
Credit: ESA / Euclid / Euclid Consortium / NASA

- Moon in comparison: 31'2 arcmin

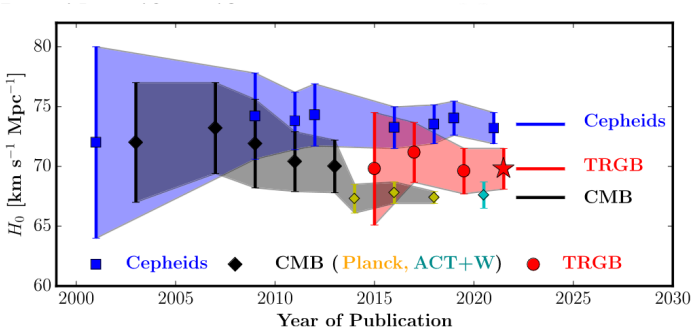
Hubble tension: physics beyond the SM of cosmology?

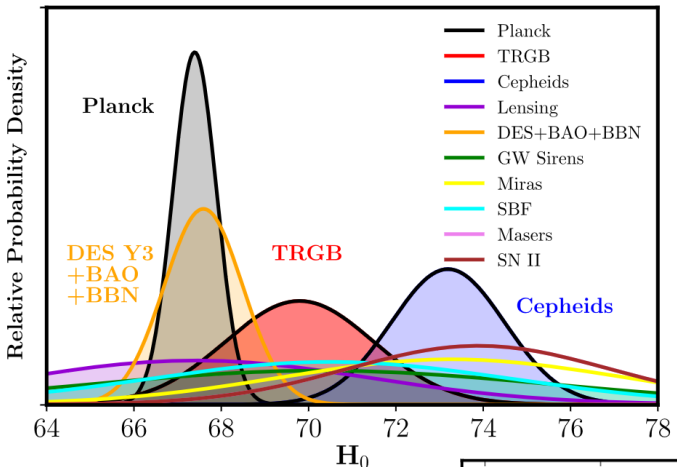
Plenary talk: J. Liske

- Different ways to measure the expansion of the universe (distance vs. redshift)
  - using Cosmological Microwave Background and Baryonic Acoustic Oscillations
  - using type Ia sypernovae, with local distance ladder measurement
- Apparent inconsistency $\Rightarrow \Lambda CDM$ model broken??
  - red giants (TRGB) gives intermediate result
  - gravitational waves may help in the future



Credit: D. Kenworthy





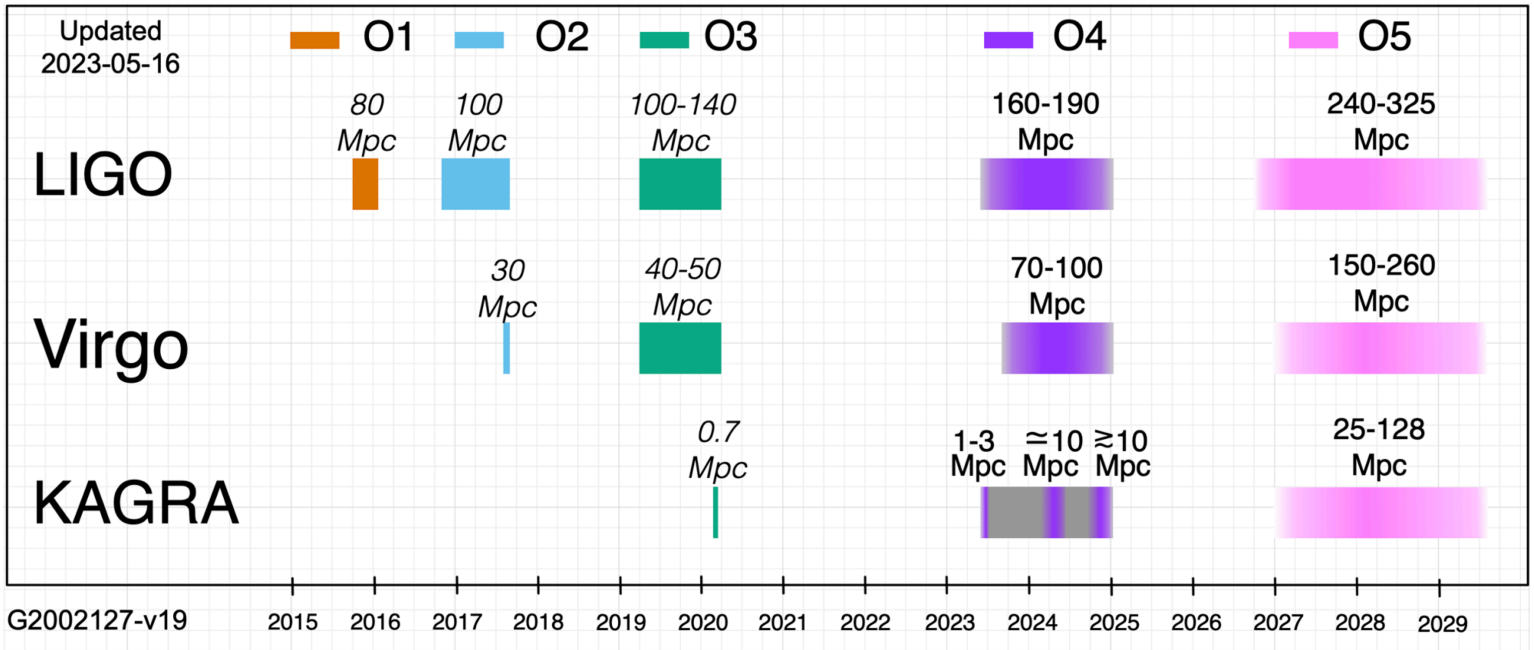
So, what causes the Hubble Tension? We do not know.

- H_0pefully the standard model will break!

Gravitational waves detectors operation

Plenary talk: M. Haney

- Three GW experiments are in operation (4 interferometers)
  - LIGO (US), VIRGO (Italy), KAGRA (Japan)
- Ongoing 4th campaign of data-taking
- Previous campaigns allowed several detections of mergers
  - need at least 3 interferometers for a good localisation of the source
  - multi-messenger astronomy with GW is a reality

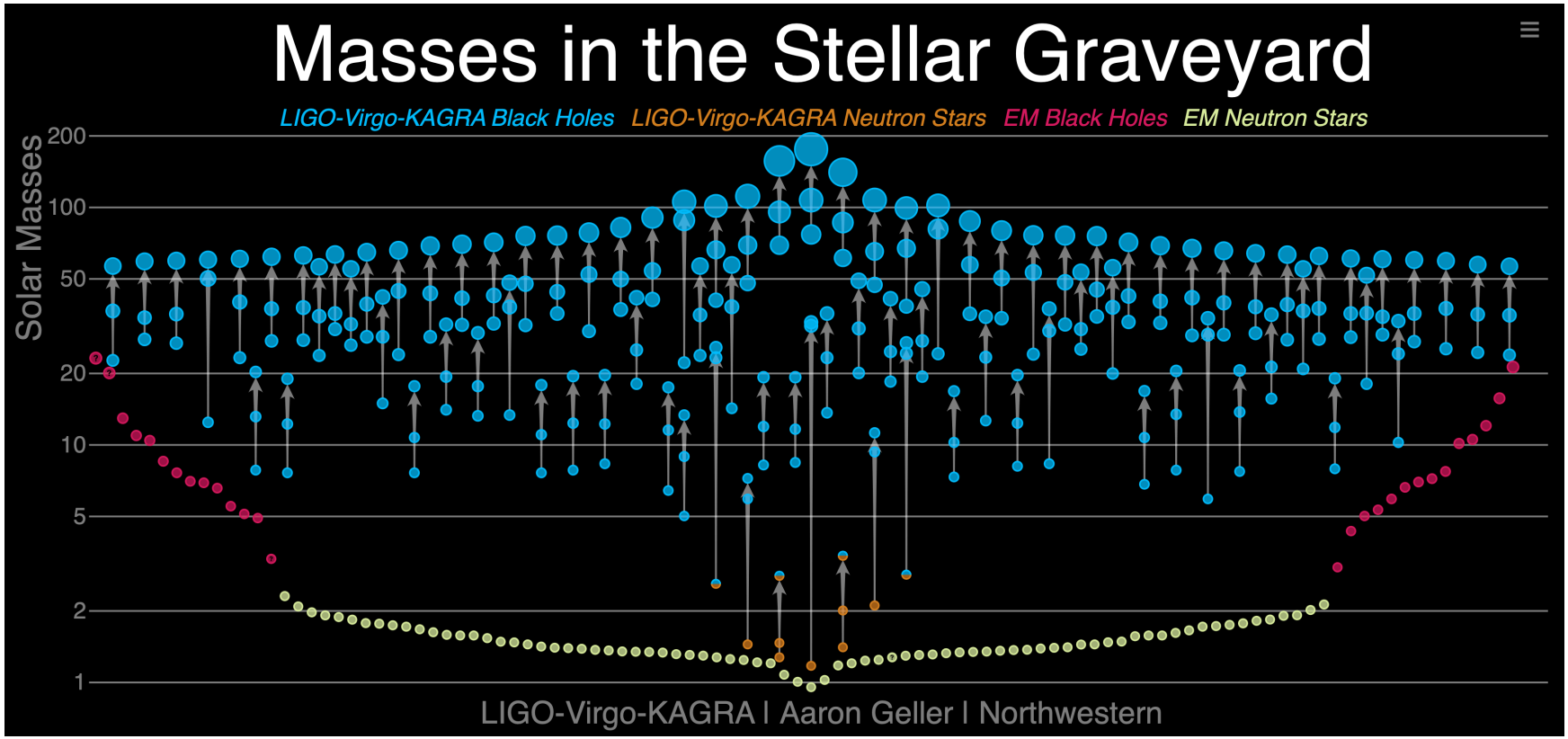


https://observing.docs.ligo.org/plan/

Gravitational waves: visiting the stellar graveyard

Plenary talk: M. Haney

- Graphical representation of known neutron stars and black holes
  - GWs allows to estimate masses of the two merging objects, and of the resulting object
  - user-friendly graphical interface to get all informations on the candidates Link



https://ligo.northwestern.edu/media/mass-plot/index.html

- See also plenary talk on multi-messenger astronomy by F. Calore

Evidence of source association by Icecube

Plenary talk: E. Resconi

- Multi-messenger astronomy is real!

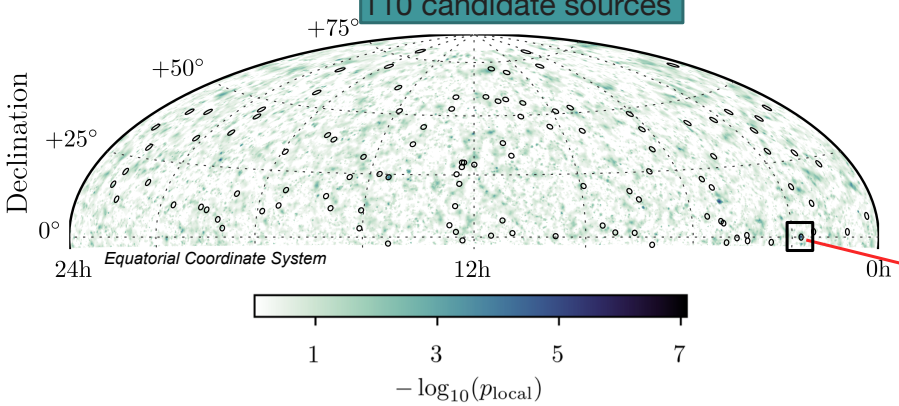
First evidences for source associations

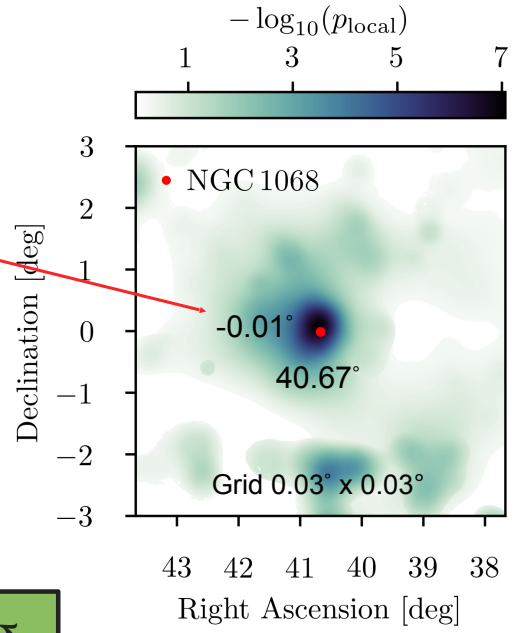
IceCube first association: TXS0506+056 - alert event (~290 TeV) and neutrino flare (2015-2016)

The IceCube Coll. and others, ***Science*** 361 (2018)
The IceCube Coll., ***Science*** 361 (2018)

Major improvement in the data processing, calibration and reconstructions.

110 candidate sources





At the NGC1068 location:

- Astrophysical neutrino events = 79 $^{+22}_{-20}$
- Spectral index = 3.2 ± 0.2

Global significance **4.2σ**

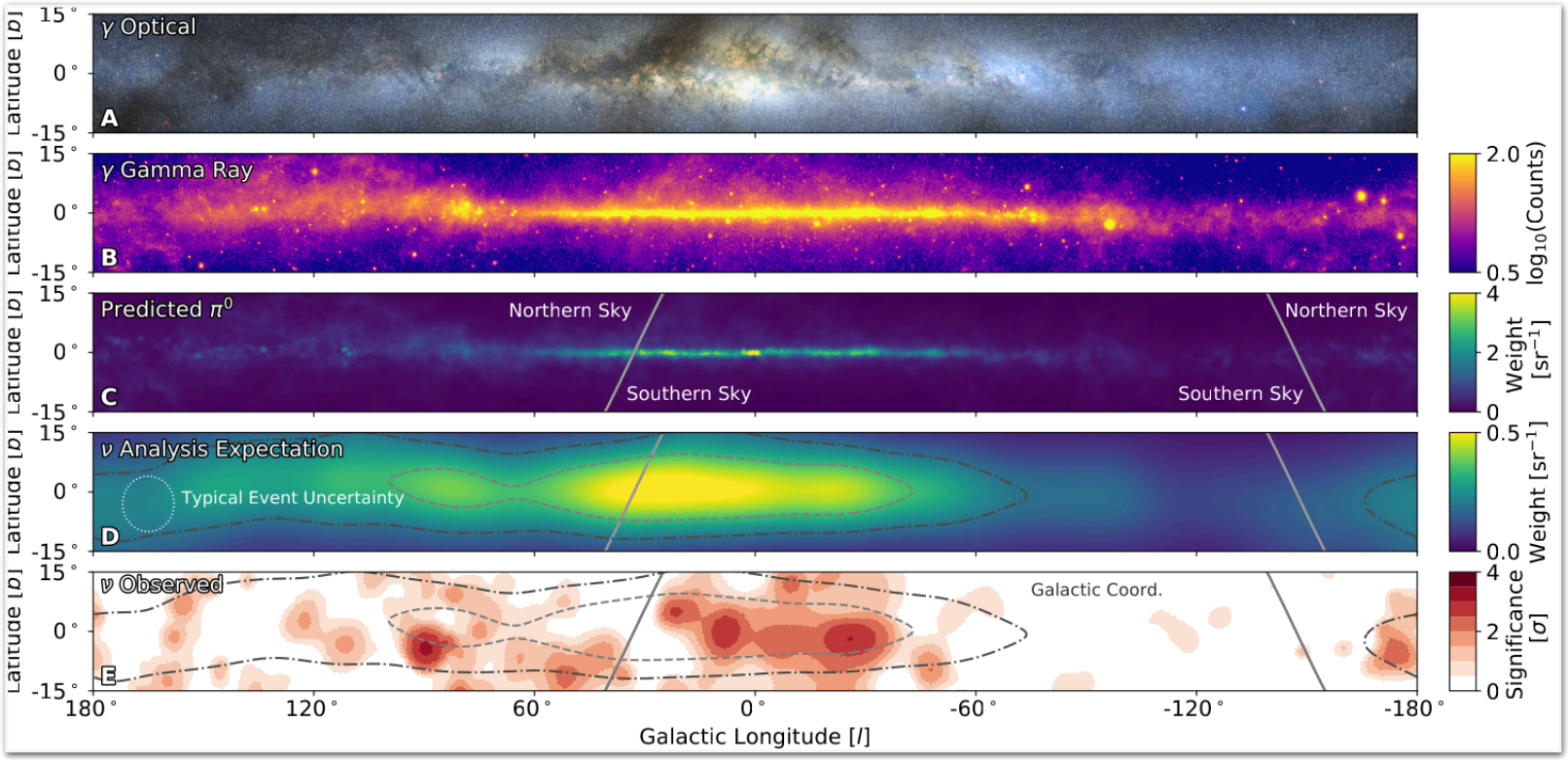
The IceCube Coll., ***Science*** 378 (2022)

The galactic plane seen in neutrinos by Icecube

Plenary talk: E. Resconi

The Galactic plane in neutrinos

The IceCube Coll., ***Science*** 380 (2023)



Global significance **4.5σ**

Paul de Jong (ANTARES)

Elisa Resconi | 24.08.23

Higgs e^+e^- factories: the options

Plenary talk (ECFA): J. List

- Usefull talks in ECFA session (European Committee on Future Accelarators)
- Two classes of options have been studied since about a decade
- New candidates have appeared (e.g. Cool Copper Collider, C3)
- Linear vs. circular choice to be driven by physics targets

They fall into two classes

Each have their advantages

Circular e+e- Colliders
- FCCee, CEPC
- length 250 GeV: 90…100km
- high luminosity & power efficiency at **low energies**
- **multiple interaction regions**
- very clean: little beamstrahlung etc

Linear Colliders
- ILC, CLIC, C^3, …
- length 250 GeV: 4…11…20 km
- high luminosity & power efficiency at **high energies**
- **longitudinally spin-polarised beam(s)**

Long-term vision: re-use of tunnel for pp collider
- technical and financial feasibility of required magnets still a challenge

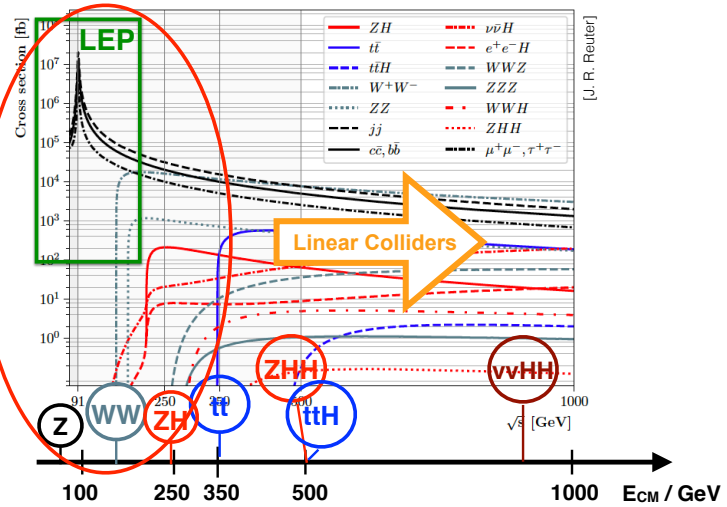
Long-term upgrades: energy extendability
- same technology: by increasing length
- **or by replacing accelerating structures with advanced technologies**
  - RF cavities with high gradient
  - plasma acceleration ?

The key physics at a Higgs Factory

Production rates vs collision energy

considered by all proposed e+e- projects

Circular Colliders



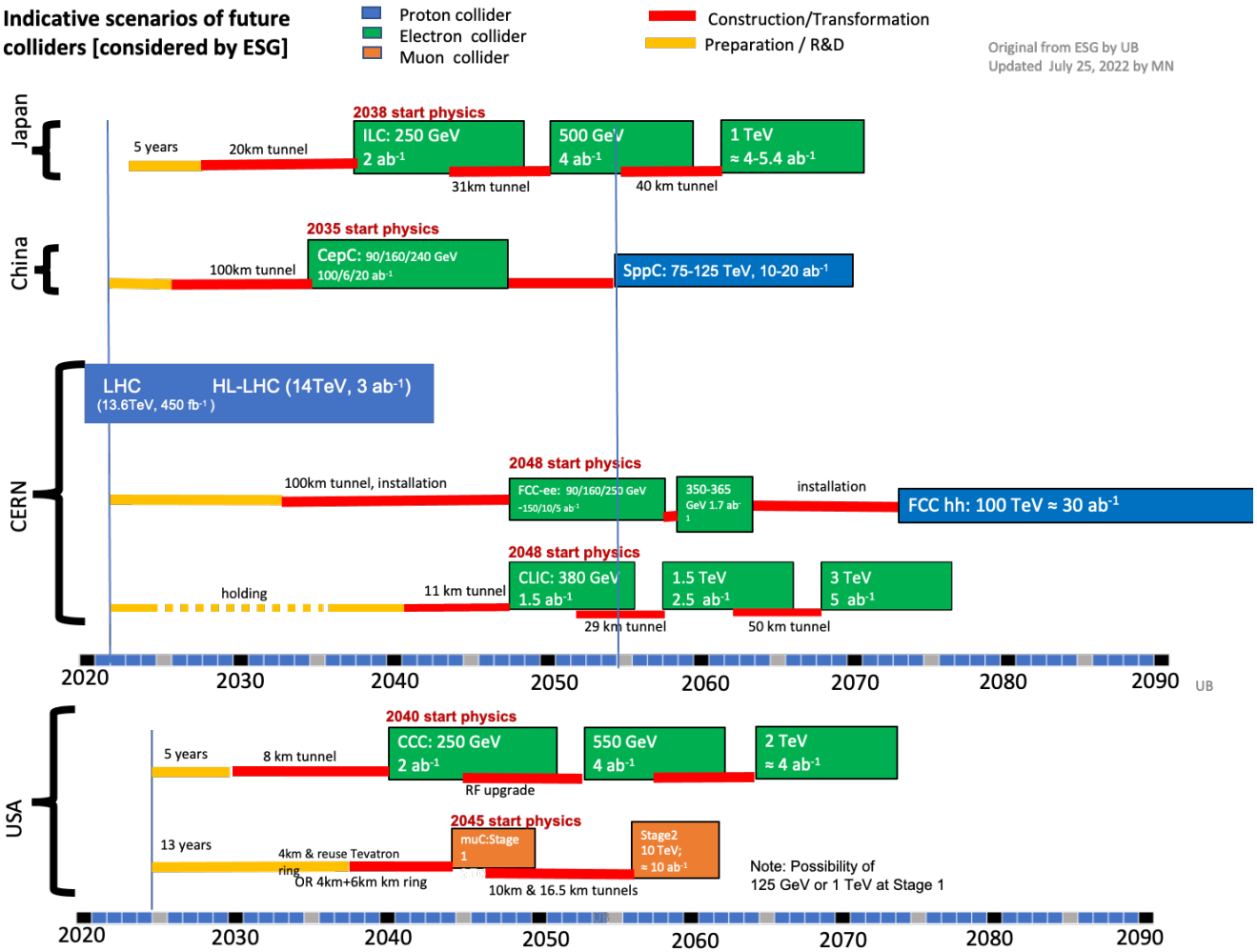
Higgs factories: timelines

Plenary talk (ECFA): J. List

Timelines

As updated for Snowmass

- **Technologically-driven => start of physics in ~late 30ies**
- **Apart from CERN projects** due to coupling to completion of (HL-)LHC programme **=> ~late 40ies**
- **ILC and CEPC require political decisions very soon** to maintain timelines drawn here
- **If Higgs Factory is built elsewhere, CERN could go for FCChh directly (~2060)**



FCC: CERN circular option

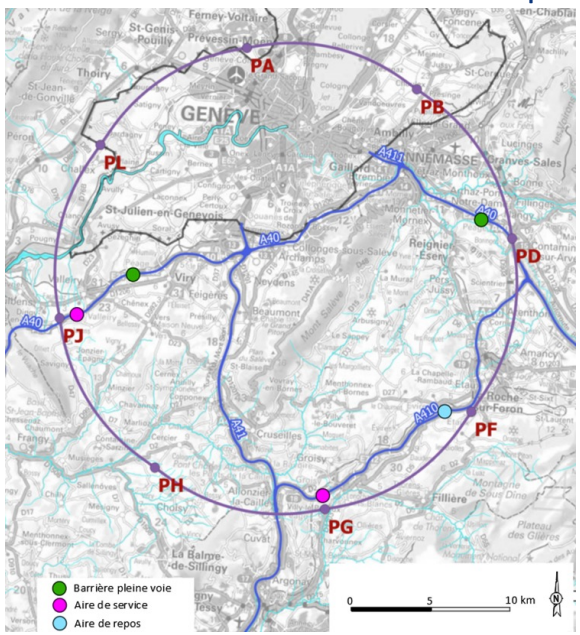
Plenary talk (ECFA): M. Benedikt

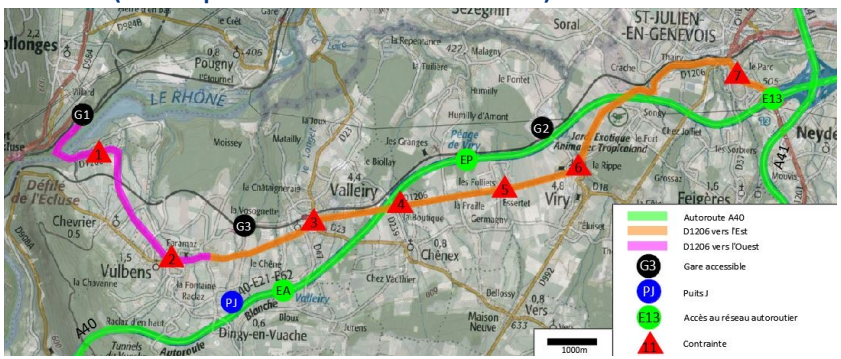
- Detailed are being refined over time
  - ◇ now 8 points (A-L) instead of 12 - point A close to current LHC point 8
- Practical details are being discussed with autorities and operators
  - ◇ road access, electric network connection, etc.

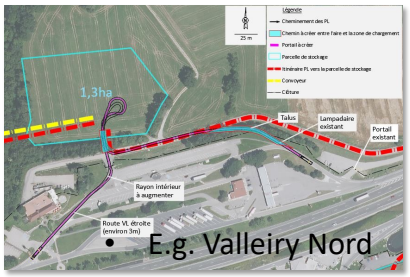
FUTURE CIRCULAR COLLIDER

Connections to transport infrastructure

- Road accesses identified and documented for all 8 surface sites
- Four possible highway connections defined (materials transport)
- Total amount of new roads required < 4 km (at departmental road level)







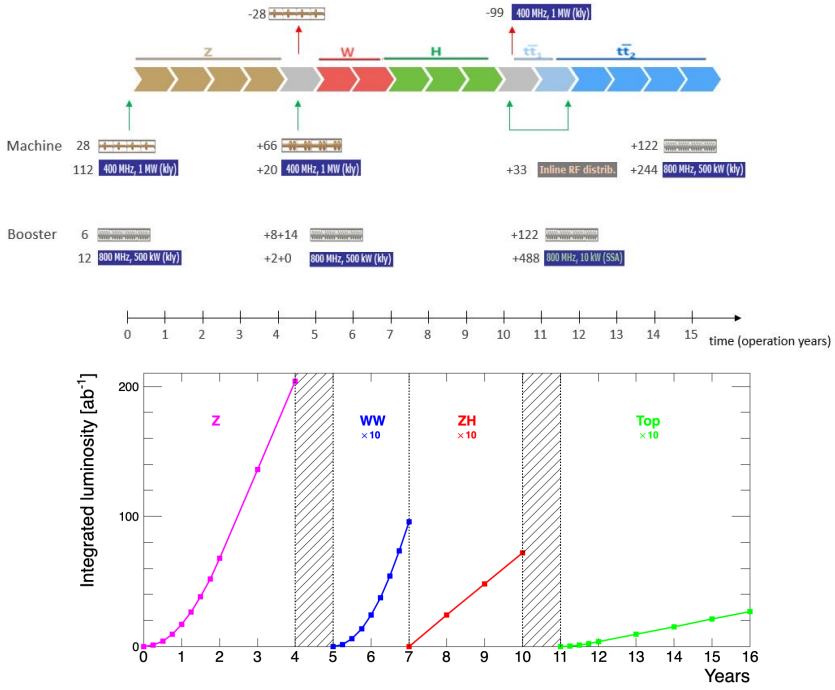
Detailed road access scenarios & highway access creation study **carried out by Cerema, including regulatory requirements in France**

FCC: options for operational sequence

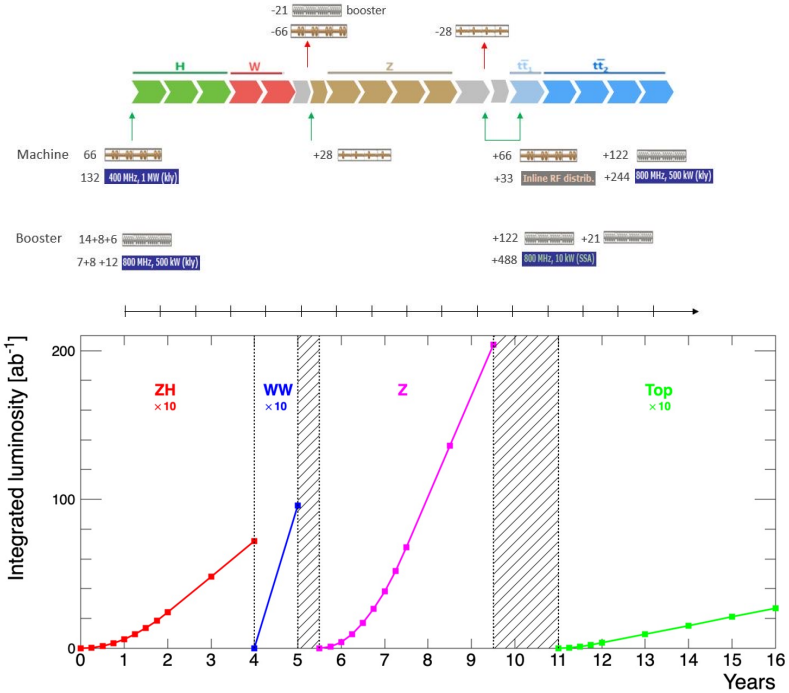
Plenary talk (ECFA): M. Benedikt

- Baseline option is to start with *Z* production (super-LEP style) then rise in $\sqrt{s}$
- Alternative option: starting directly with *ZH*
  - ◇ it could make sense to have the Higgs factory first

baseline operational sequence starting from Z



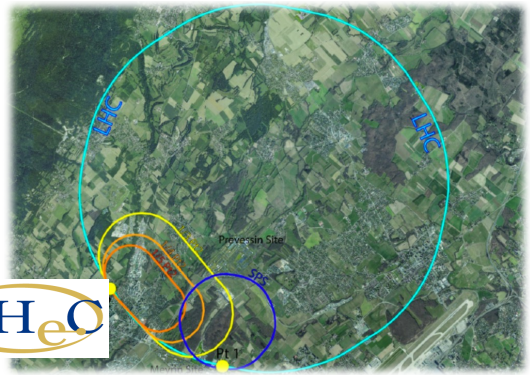
alternative operational sequence starting from ZH



DIS: LHeC and FCC-eh

Parallel talks (Higgs, Top&EW): U. Klein, D. Britzger

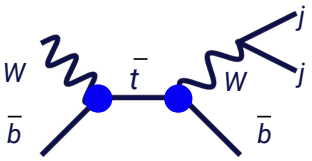
- Parallel sessions talks about future *eh* collisions
  - ◇ either LHeC, or FCC-eh, or both
- Allows to probe very diverse topics with low pileup
- Example here: $|V_{tb}|$ measurement with single-top
- ...not to mention *W* mass, etc.



Concurrent eh and hh operation with same running time!

Genuine Twin Collider idea holds for LHC and FCC-hh.

Direct measurement of $|V_{tb}|$

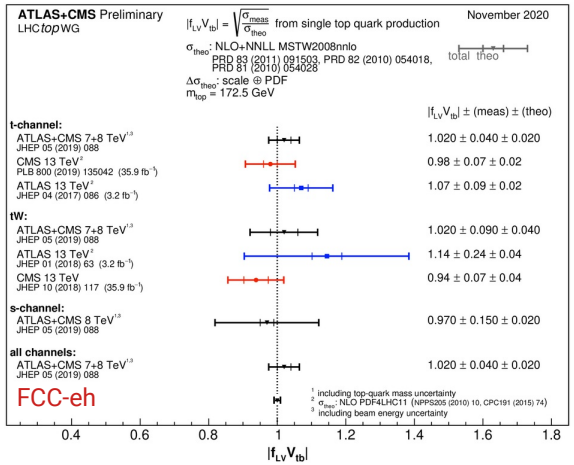


$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Cut-based pseudo-analysis in hadronic channel incl. backgrounds

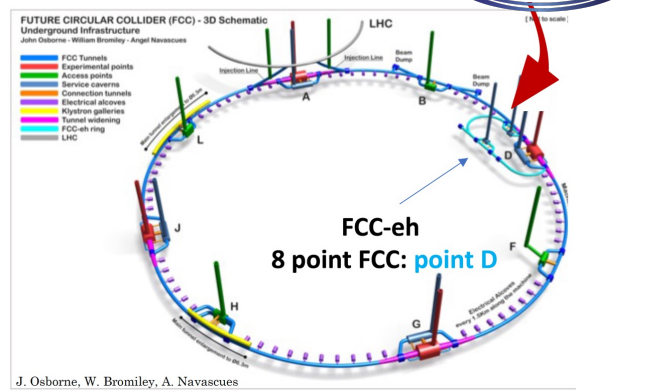
→ Estimated precision on V_{tb} below 1% precision

→ Limits on anomalous *Wtb* couplings: < 0.01



$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$|V_{ts,td}|<0.04$ (@FCC-eh)



Conclusion

- Very interesting conference, with so many results
- Many things I could not include, such as
  - sustainability for future colliders ▸ Link
  - dark matter experiments ▸ Link
  - can PDFs absorb new physics? ▸ Link
  - etc.

EPS-HEP2025

⇒ Next edition of the conference organised in Marseille

- website: https://www.eps-hep2025.eu/ - trailer: https://youtu.be/HcUYKkwvgAY