EPS-HEP 2019 Highlights

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18/11/2019 CPPM Seminar

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Overview

NB: not all areas covered!

Flavour

Hadron spectroscopy

Neutrinos

Standard Model

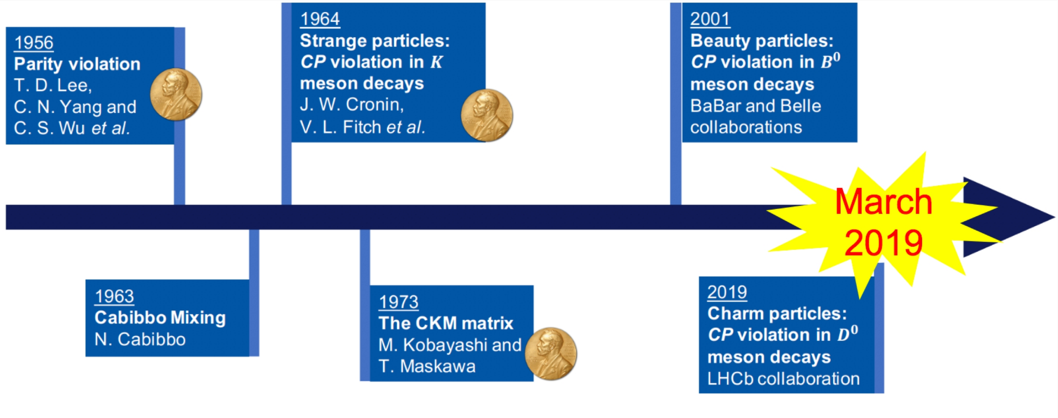
Higgs

Dark matter

Astroparticle physics

Flavour

CP violation in charm



CPV in kaons and B mesons well established.

SM predicts small ($10^{-4} \sim 10^{-3}$) CPV in charm

CP violation in charm

$$\Delta A_{CP} = A_{CP}(K^+K^-) - A_{CP}(\pi^+\pi^-)$$

Tag initial flavour from:

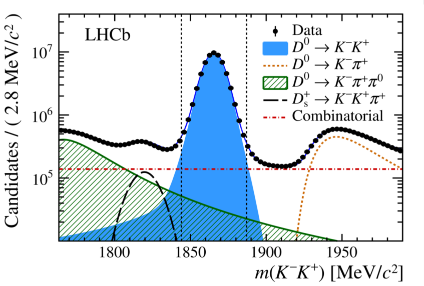
- prompt strong decays ($D^{*+} \to D^0\pi^+$)
- displaced weak B decays ($\overline{B}^0 \to D^0\mu^- X$)

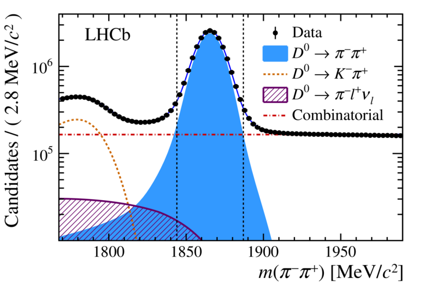
Run 1 + Run 2 LHCb data:

$\Delta A_{CP} = (-15.4 \pm 2.9) \times 10^{-4}$

(5.3σ from 0)

[PRL 122 (2019) 211803]





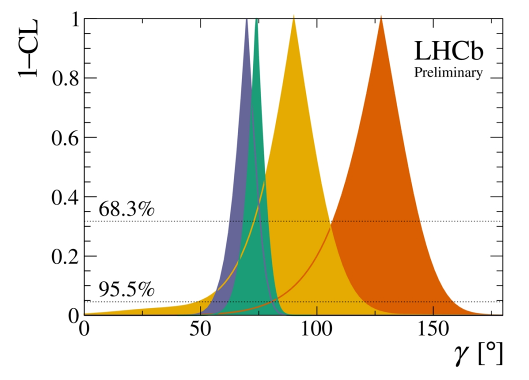
CKM angle γ combination

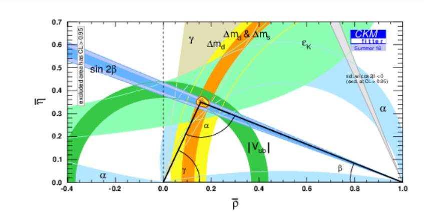
2σ tension between B^+ and B_s results

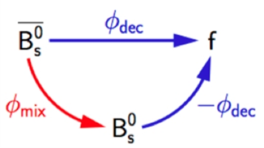
2σ tension between direct measurements and unitarity triangle constraints

(New) LHCb measurement with $B^0 \to D^0 K^{*0}$ of parameter $r_B^{DK^{*0}}$

[JHEP 08 (2019) 041]







ATLAS $B_s \to J/\psi\phi$ (100 fb^{-1})

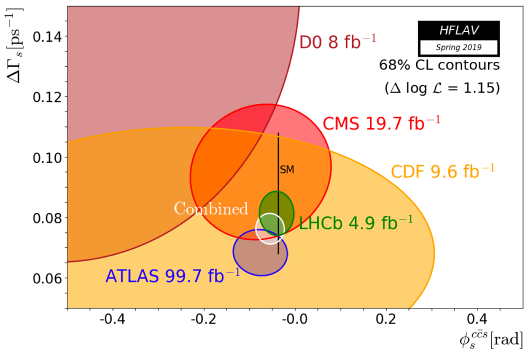
- $\phi_s = -0.076 \pm 0.039$
- $\Delta\Gamma_s = 0.068 \pm 0.005$

[ATLAS-CONF-2019-009]

LHCb $B_s \to J/\psi K^+K^-$ & $J/\psi\pi^+\pi^-$ (5 fb^{-1})

- $\phi_s = -0.041 \pm 0.025$
- $\Delta\Gamma_s = 0.082 \pm 0.005$

[arXiv:1906.08356 and arxiv:1903.05530]



Hadron spectroscopy

Excited Λ_b states

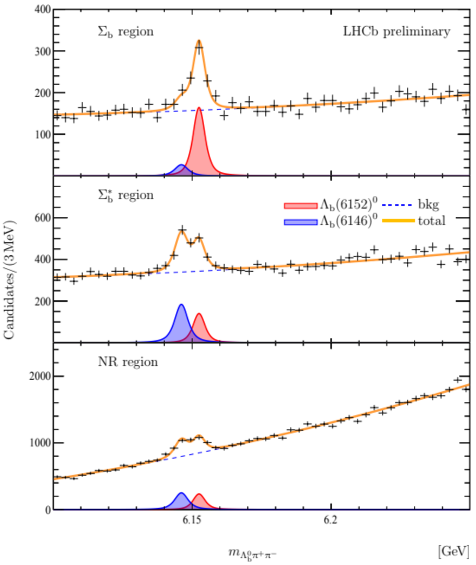
(New)

Two new resonances in $\Lambda_b \pi^+ \pi^-$ spectrum

- $\Lambda_b(6152)$ decays via intermediate $\Sigma_b^{(*)}$
- $\Lambda_b(6146)$ decays via Σ_b suppressed

Masses and mass-splitting in agreement with expectation for $\Lambda_b(1D)$ doublet

[PRL 123 (2019) 152001]



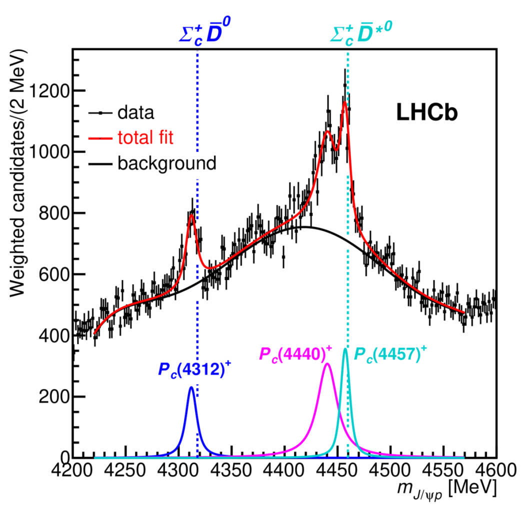
Pentaquarks

Update to 2015 $\Lambda_b \rightarrow J/\psi p K^-$ analysis with full Run 2 statistics

- New peak at 4312 MeV
- Broad peak at 4450 MeV resolves two two narrow peaks at 4440 and 4457 MeV

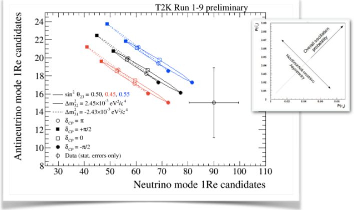
Observed states are narrow and close to $\Sigma_c^+ D^{(*)0}$ thresholds

[PRL 122 (2019) 222001]



Neutrinos

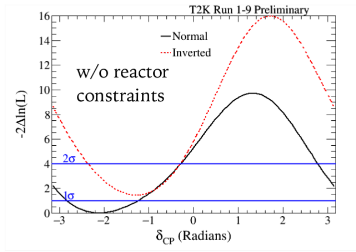
δ_{CP} MEASUREMENT

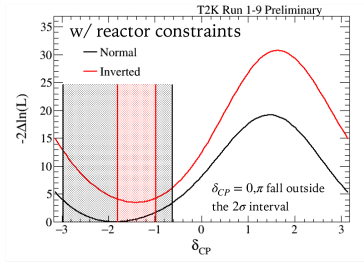


T2K data prefer values of $\delta_{CP} \sim -\frac{\pi}{2}$: mostly driven by the large number of events observed in the e-like sample in neutrino mode.

CP conservation ($\delta_{CP} = 0, \pi$) disfavoured at 2σ for both mass hierarchies.

C.L.	Normal hierarchy	Inverted hierarchy
68%	[-2.51, -1.26]	-
90%	[-2.80, -0.84]	-
2σ	[-2.97, -0.63]	[-1.78, -0.98]

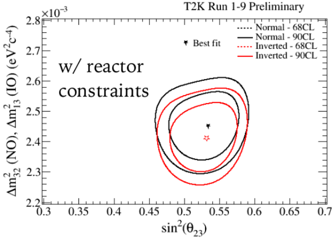


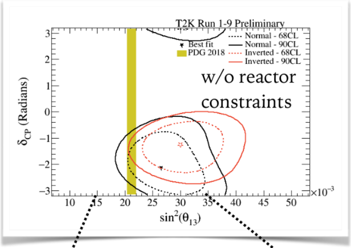


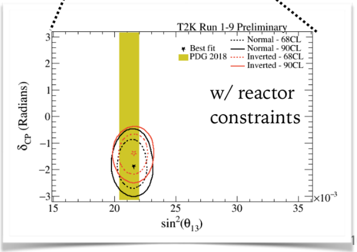
T2K δ_{CP} and oscillation results

Slides nicked from summary by Francesca Di Lodovico

OSCILLATION RESULTS ($\theta_{23}, |\Delta m^2_{23}|, \theta_{13}, \delta_{CP}$)







T2K data compatible with maximal mixing

Parameter	Best Fit NH (IH)	$\pm 1\sigma$ NH (IH)
$\sin^2\theta_{32}$	0.54 (0.53)	[0.490,0.558] ([0.496,0.560])
$\lvert\Delta m^2_{32}\rvert$ ($10^{-3}eV^2/c^4$)	2.46 (2.43)	[2.370,2.498] ([2.362,2.502])
$\sin^2\theta_{13}$	0.0268 (0.0305)	[0.0222,0.0319] ([0.0253,0.0369])

NOνA oscillation results

Slides nicked from summary by Francesca Di Lodovico

NOVA OSCILLATION RESULTS

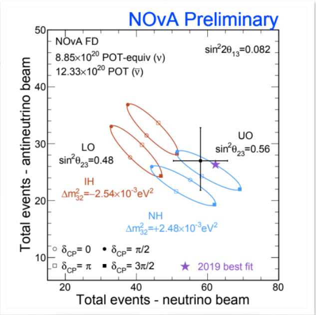
Best fit:

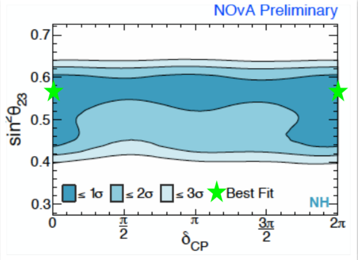
$\sin^2\theta_{23} = 0.56^{+0.04}_{-0.03}$

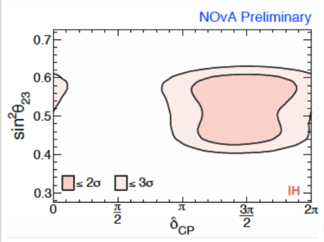
$\Delta m^2_{32} = +2.48 \times 10^3 eV^2$ (NH)

$\delta_{CP} = 0.0^{+1.3}_{-0.4}\pi$

- All values of δ_{CP} are allowed at 1.1σ (NH, Upper octant).
- IH, $\delta_{CP} = \frac{\pi}{2}$ is ruled out > 4σ.
- Inverted Hierarchy is disfavoured at 1.9σ.







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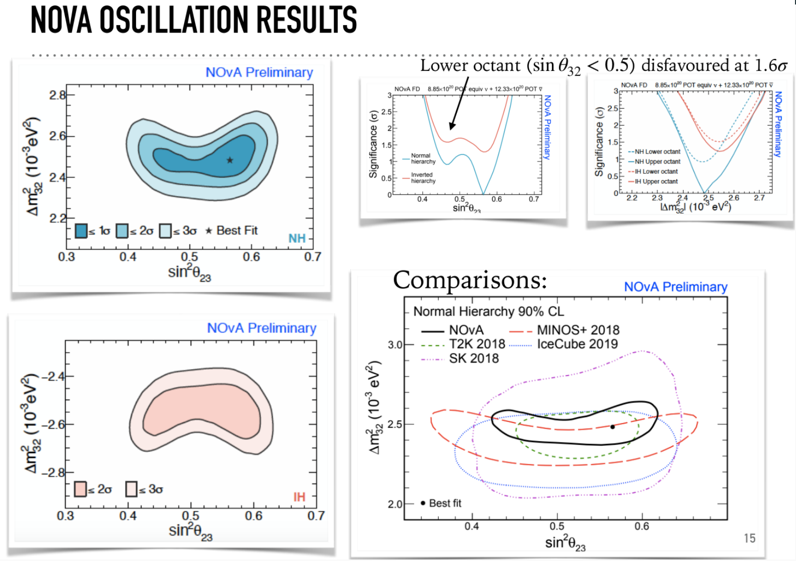
NOνA oscillation results

Slides nicked from summary by Francesca Di Lodovico



Lower octant ($\sin\theta_{32} < 0.5$) disfavoured at 1.6σ

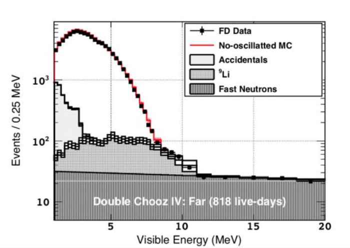
Comparisons:

PMNS angle θ_{13}

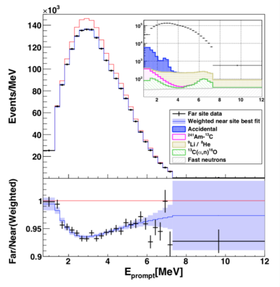
Slide nicked from summary by Gioacchino Ranucci

Double Chooz	Daya Bay	RENO

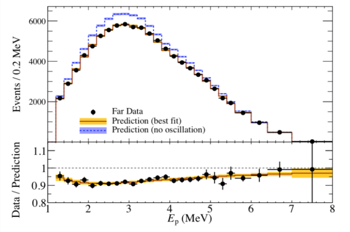
Double Chooz



Daya Bay



RENO



Double Chooz: $\sin^2(2\theta_{13}) = 0.105 \pm 0.014$

Daya Bay: 0.0856 ± 0.0029

RENO: 0.0896 ± 0.0068

Daya Bay:

$$\Delta m^2_{32} = (2.471^{+0.068}_{-0.070}) \times 10^{-3}\text{eV}^2 \ (\text{NO})$$
$$-(2.575^{+0.068}_{-0.070}) \times 10^{-3}\text{eV}^2 \ (\text{IO})$$

RENO:

$$|\Delta m^2_{ee}| = (2.68 \pm 0.14) \times 10^{-3}\text{eV}^2$$

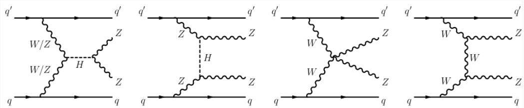
Double Chooz: [arxiv:1901.09445]

Daya Bay: [PRL 121 (2018) 241805]

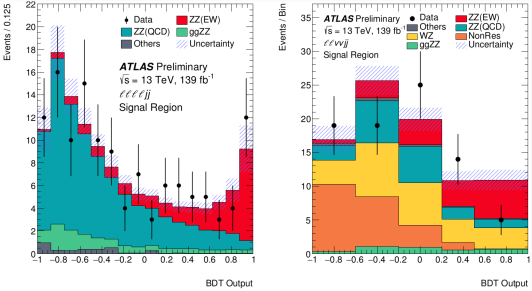
RENO: [PRL 121 (2018) 201801]

Standard Model

Electroweak diboson scattering



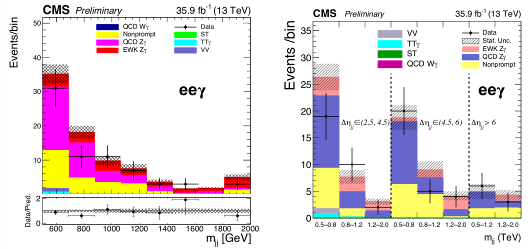
(New) ALTAS: observation of EW $ZZ + jj$



Obs (exp) signifiance: 5.5σ (4.3σ)

[ATLAS-CONF-2019-033]

(New) CMS: evidence for EW $Z\gamma + jj$



Obs (exp) significance: 3.9σ (5.2σ)

Comb. with 8 TeV data: 4.7σ (5.5σ)

[CMS-PAS-SMP-18-007]

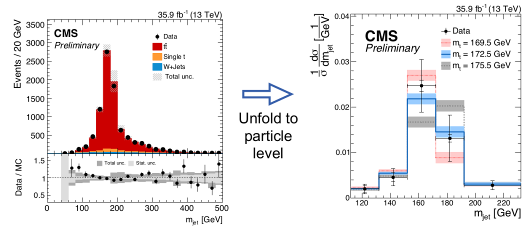
Top quark

(New) CMS: mass with boosted top quarks

Highly boosted top quarks: $p_T > 400$ GeV

$m_t = 172.56 \pm 2.47$ GeV

Uncertainty similar to threshold production



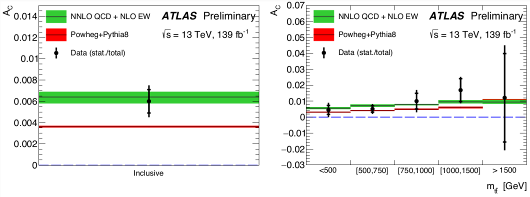
[CMS-PAS-TOP-19-005]

(New) ATLAS: charge asymmetry

$$A_C \equiv \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

$$A_C = (6.0 \pm 1.1 \pm 1.0) \times 10^{-3}$$

4σ from zero: first evidence at LHC

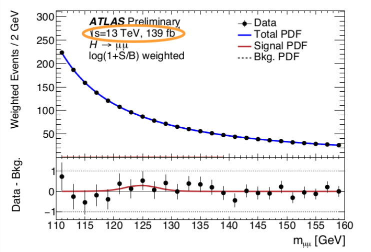


[ATLAS-CONF-2019-026]

Higgs

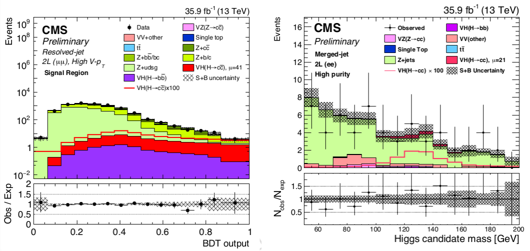
Higgs → 2nd generation searches

(New) ALTAS $H \to \mu^+\mu^-$ search [CONF-HIGG-2019-028]



	obs(exp$^{(*)}$) UL on σ/σ_{SM}	obs(exp) μ	obs(exp) sign
ATLAS 2μ (full Run2)	1.7(1.3)	0.5±0.7(1.0±0.7)	0.8σ(1.5σ)
CMS 2μ (Run1+36/fb Run2)	2.9(2.2)	1.0±1.0(1.0±1.0)	0.9σ(1.0σ)

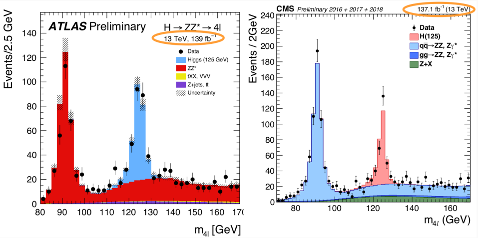
(New) CMS $H \to c\bar{c}$ search [CMS-PAS-HIG-18-031]



	obs(exp) UL on σ/σ_{SM}
ATLAS VHcc (36/fb Run2)	110(150)$^{(*)}$
CMS VHcc (36/fb Run2)	70(37)

‘Discovery’ channels with full Run 2 statistics

$H \to ZZ \to 4\ell$



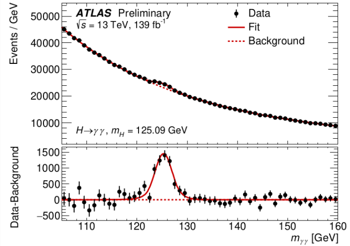
(New)[CONF-HIGG-2019-025]

[CMS-PAS-19-001]

	global signal strength (μ)(*)
ATLAS 4ℓ (full Run2)	$1.04^{+0.12}_{-0.10}$ (tot) $[^{+0.09}_{-0.08}$(stat)$^{+0.04}_{-0.03}$(exp)$^{+0.06}_{-0.05}$(th)$]$
CMS 4ℓ (full Run2)	$0.94^{+0.11}_{-0.10}$ (tot) $[^{+0.07}_{-0.07}$(stat)$^{+0.08}_{-0.07}$ (syst)$]$

$>$ 200 events per experiment

$H \to \gamma\gamma$



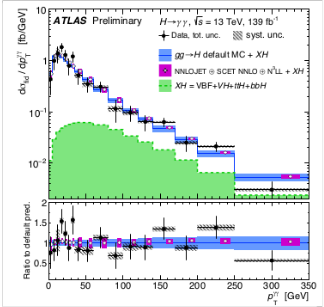
[CONF-HIGG-2019-029]

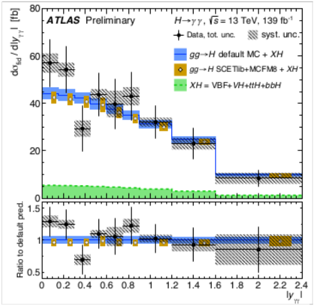
		Total H production xsec
ATLAS	$\gamma\gamma$ (full Run2)	$56.7^{+6.4}_{-6.2}$ pb
	4ℓ (full Run2)	$54.4^{+5.6}_{-5.4}$ pb
	Combination	$55.4\ ^{+3.1}_{-3.1}$ (stat) $^{+3.0}_{-2.8}$ (syst) pb
CMS	$\gamma\gamma$ (36/fb Run2)	$64.4^{+9.6}_{-9.6}$ pb
	4ℓ (36/fb Run2)	$58.2^{+9.8}_{-9.8}$ pb
	Combination	$61.1\ ^{+6.0}_{-6.0}$ (stat) $^{+3.7}_{-3.7}$ (syst) pb
	SM prediction	55.6 ± 2.5 pb

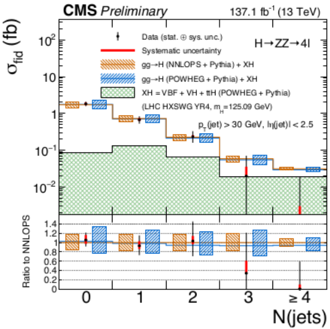
(New)[CONF-HIGG-2019-032] [PLB 792 (2019) 369]

Measure a large number of distributions ($p_T^{\gamma\gamma}$, $p_T^{4\ell}$, $|Y_{\gamma\gamma}|$, $|Y_{4\ell}|$, N_{jets}, p_T^{jet1} m_{jj}, $\Delta\varphi_{jj}$....) and compare with predictions.

Allow constraints on Wilson coefficients of an effective Lagrangian and couplings which aren't directly accessible (e.g. charm–Higgs)







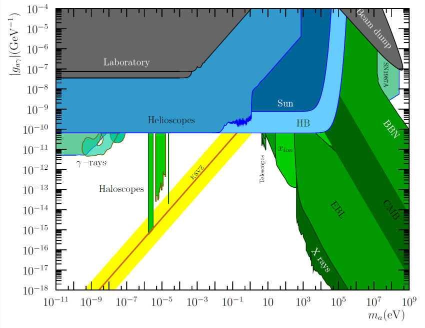
[CONF-HIGG-2019-029]

[CMS-PAS-HIG-19-001]

Dark matter

Dark matter

Conventional QCD axions lie on 'yellow band' and ALPs outside this band.

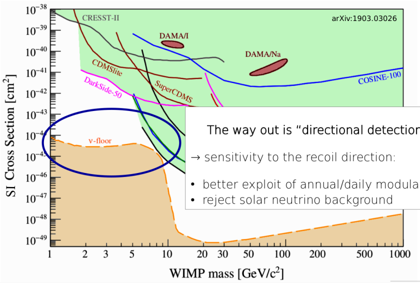


Slide nicked from summary by Igor Garcia Irastorza

Recent 'model building' activity leads to QCD axions outside the band, usually at higher $g_{a\gamma}$

Neutrino floor is 'soft' like a swamp...

For very low m_χ masses, coherent neutrino scattering on target nuclei can mimic a dark matter scattering signal → neutrino "floor" (swampland?)



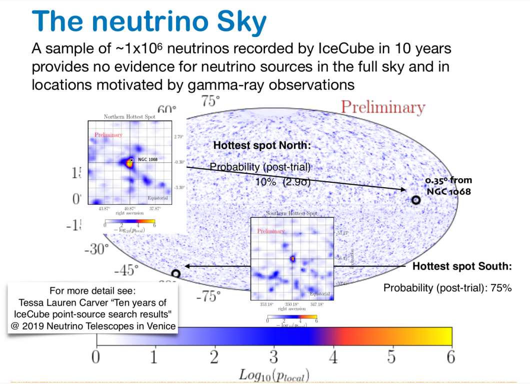
The way out is "directional detection"

→ sensitivity to the recoil direction:

- better exploit of annual/daily modulations
- reject solar neutrino background

Slide nicked from summary by Carlos de los Heros

Astroparticle physics



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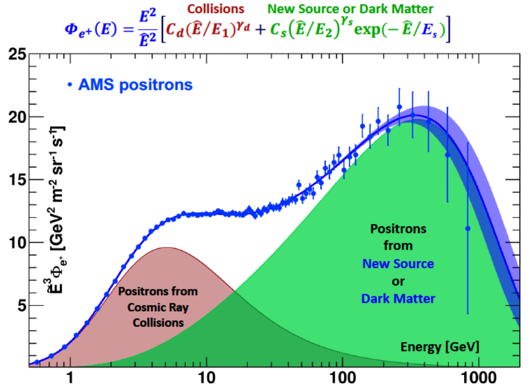
Potential for identifying point sources of high-energy neutrinos, perhaps from Dark Matter annihilation

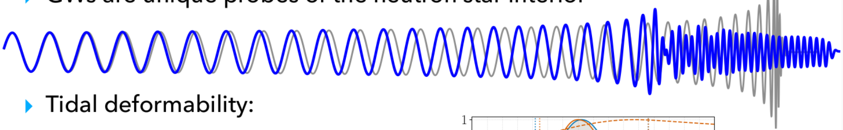


AMS-2 positron excess still unexplained, could be Dark Matter
[PRL 122 (2019) 041102]

NUCLEAR PHYSICS WITH GW170817

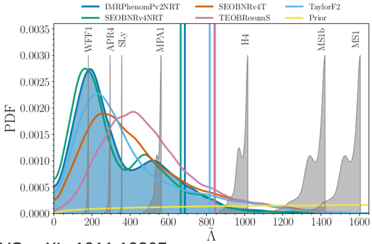
- GWs are unique probes of the neutron star interior

Credit: T. Hinder & T. Dietrich

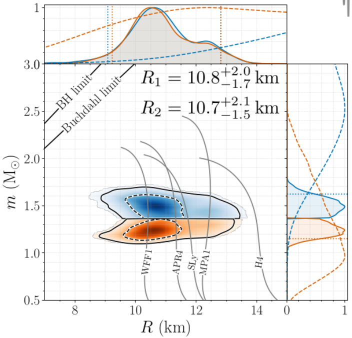


- Tidal deformability:

$$\tilde{\Lambda} = \frac{16}{13}\frac{(m_1 + 12m_2)m_1^4\Lambda_1 + (m_2 + 12m_1)m_2^4\Lambda_2}{(m_1+m_2)^5}$$



LVC, arXiv:1811.12907



LVC, PRL 121 (2018)

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“Flavour”

Photo credit: Christiam Ohm