Highlights from Moriond 2019

A personal selection

Loïc Valéry — ATLAS @ DESY

Disclaimer

Not expert of most of what I present in this talk

Experts: speak up

What we want to know …

SM … and Beyond ?

Dark Matter ?

Flavour anomalies ?

Neutrino masses ?

New particles ?

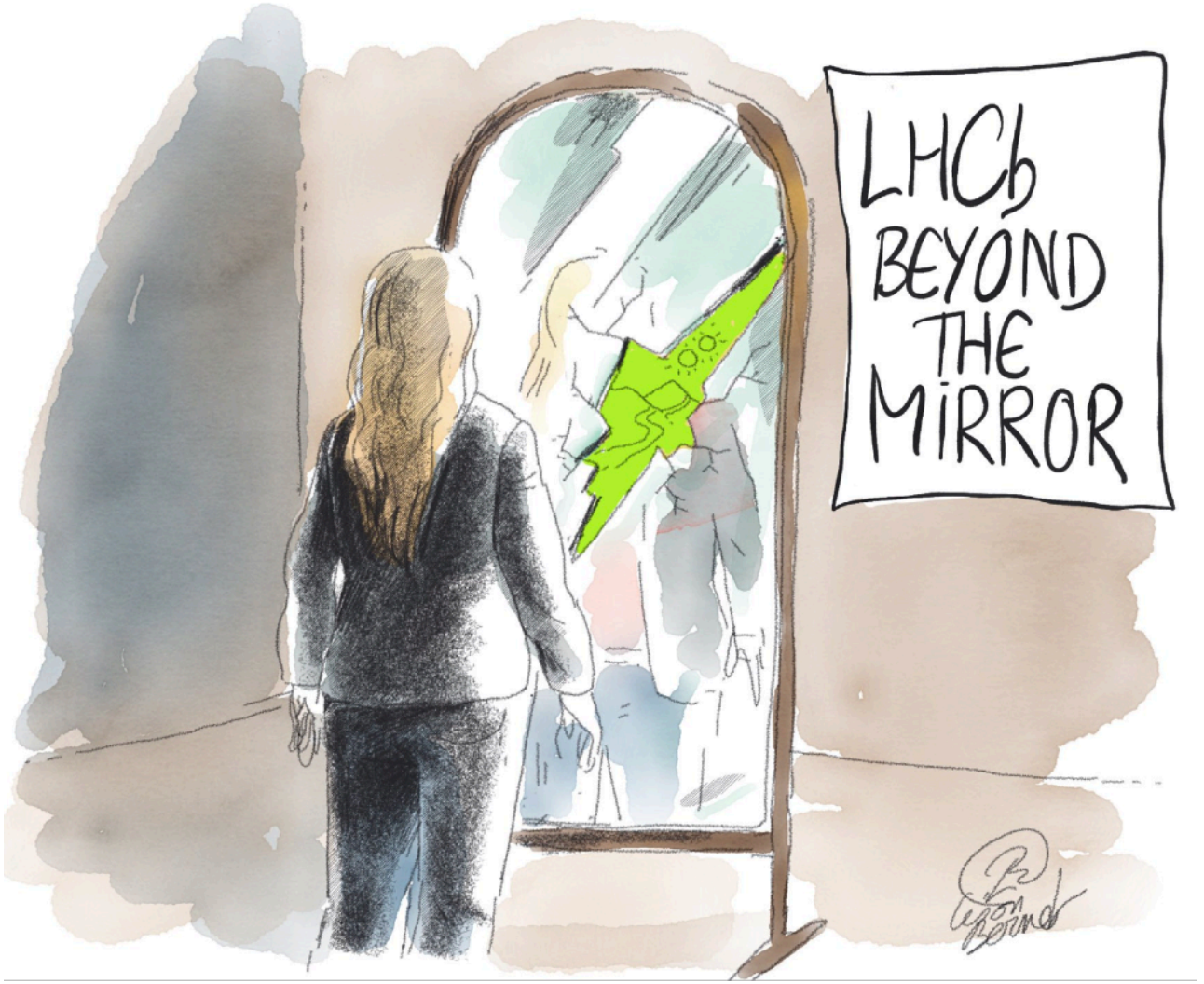
New theories ?

Content of the talk

Tight selection …

- **Flavour physics**: the LHCb big news
- **Neutrino physics**: last measurements and prospects
- **Dark Matter**: from direct detection to LHC searches
- **(Other) BSM searches**: what's up there (ATLAS/CMS/recast) ?

Lison Bernet
@lisbouche

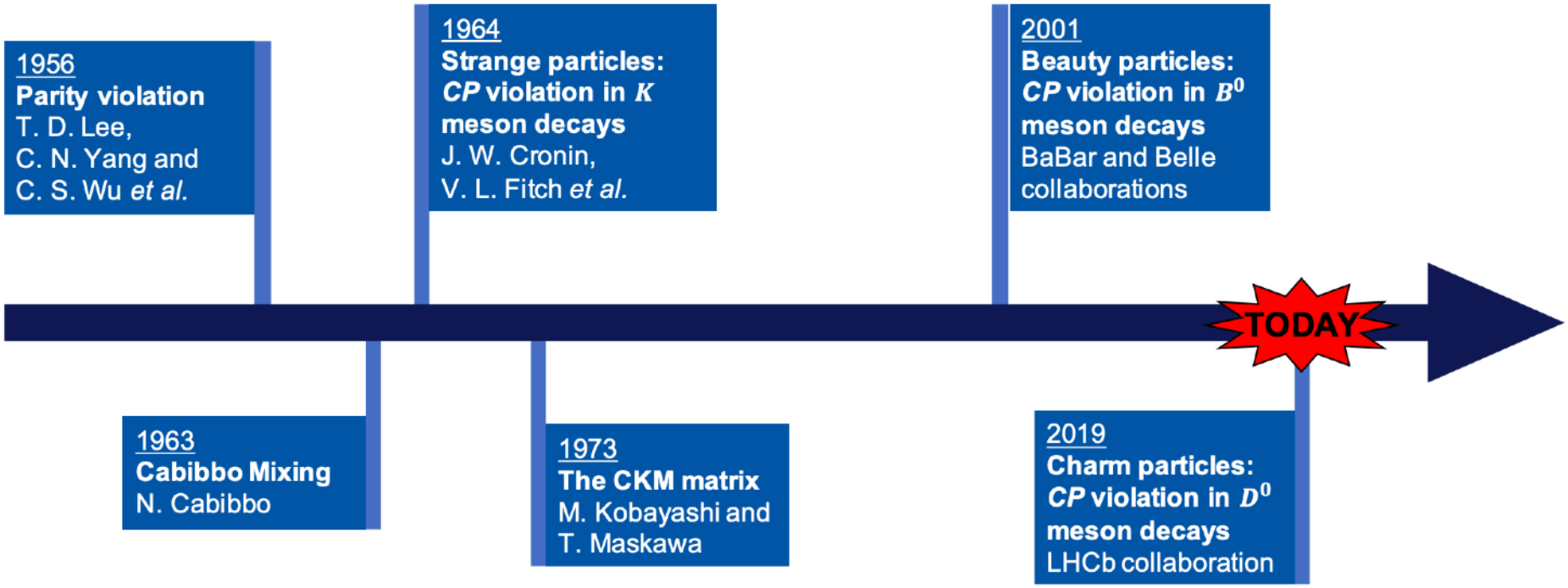


Flavour physics

CP violation

And now, the charm !

Federico Betti



CP violation

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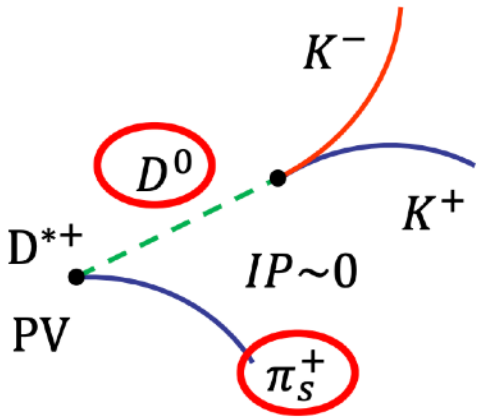

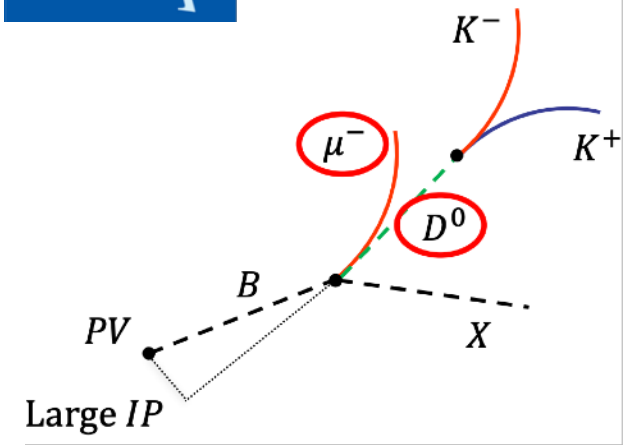

$$A_{CP}(f) = \frac{\Gamma(D^0 \to f) - \Gamma(\overline{D}^0 \to f)}{\Gamma(D^0 \to f) + \Gamma(\overline{D}^0 \to f)}$$

with $f = K^-K^+$ and $f = \pi^-\pi^+$

CP violation

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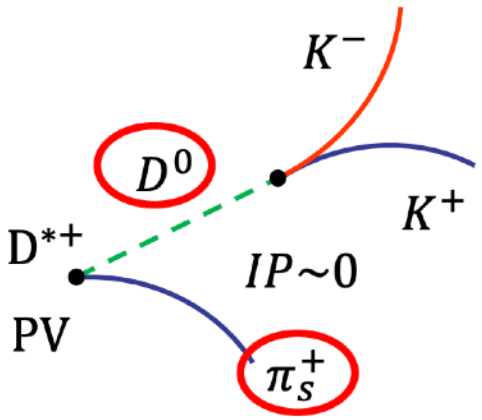

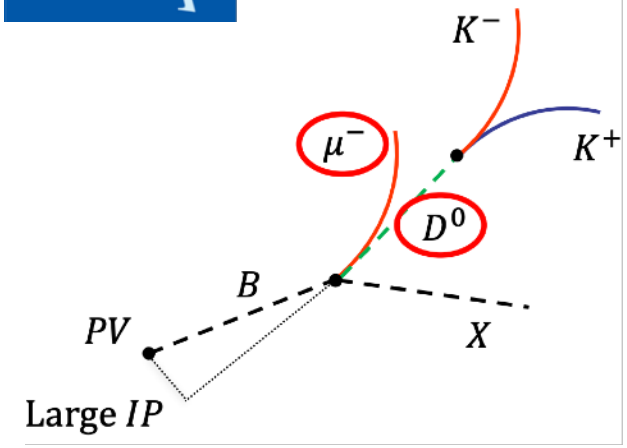

Federico Betti

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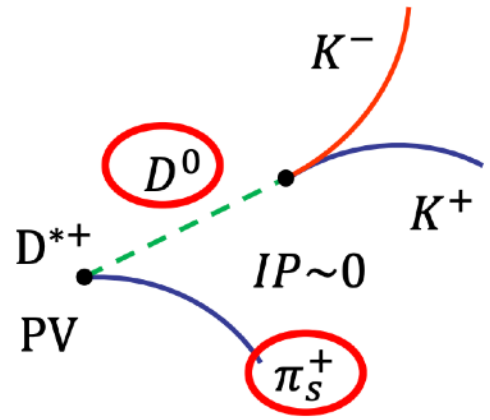
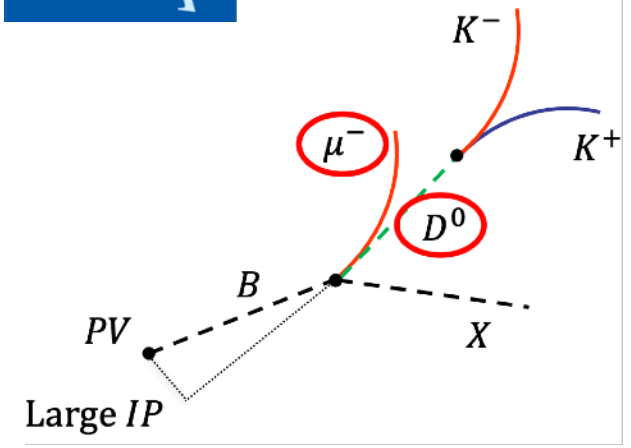
$$A_{\text{raw}}(f) = \frac{N(D^0 \to f) - N(\overline{D}^0 \to f)}{N(D^0 \to f) + N(\overline{D}^0 \to f)}$$

CP violation

And now, the charm !





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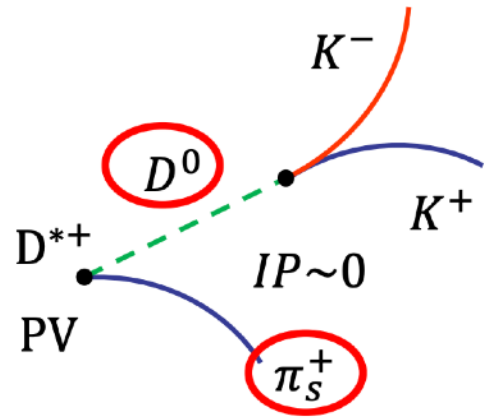
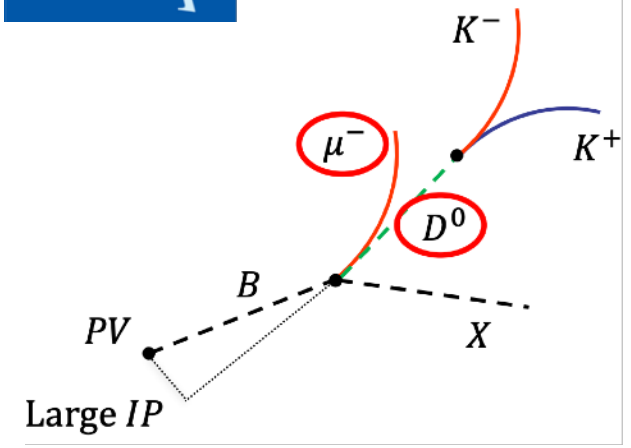
$$A_{\text{raw}}(f) = A_{CP}(f) + A_D(f) + A_D(\pi_s^+) + A_P(D^{*+})$$

CP violation

And now, the charm !





Federico Betti

$$A_{CP}(f) = \frac{\Gamma(D^0 \to f) - \Gamma(\overline{D}^0 \to f)}{\Gamma(D^0 \to f) + \Gamma(\overline{D}^0 \to f)} \quad \text{with } f = K^-K^+ \text{ and } f = \pi^-\pi^+$$

$$A_{\text{raw}}(f) = \frac{N(D^0 \to f) - N(\overline{D}^0 \to f)}{N(D^0 \to f) + N(\overline{D}^0 \to f)}$$

$$A_{\text{raw}}(f) = A_{CP}(f) + \cancel{A_D(f)} + A_D(\pi_s^+) + A_P(D^{*+})$$

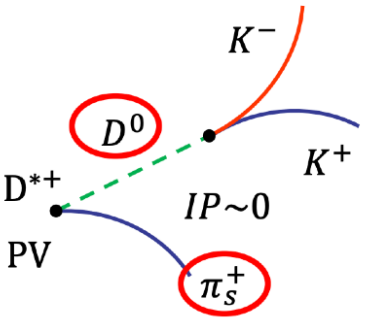
$$\Delta A_{CP} \equiv A_{raw}(KK) - A_{raw}(\pi\pi) = A_{CP}(KK) - A_{CP}(\pi\pi)$$

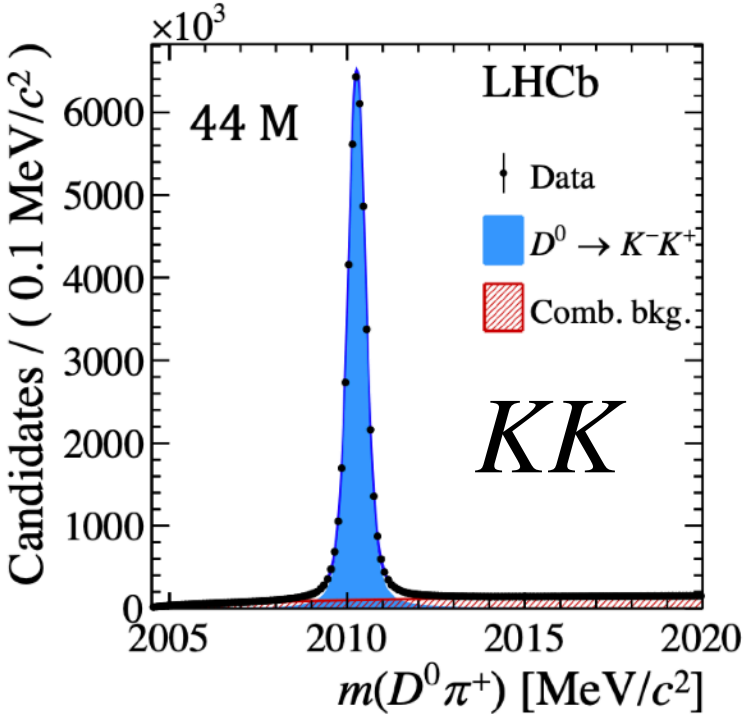
time-integrated CP asymmetry

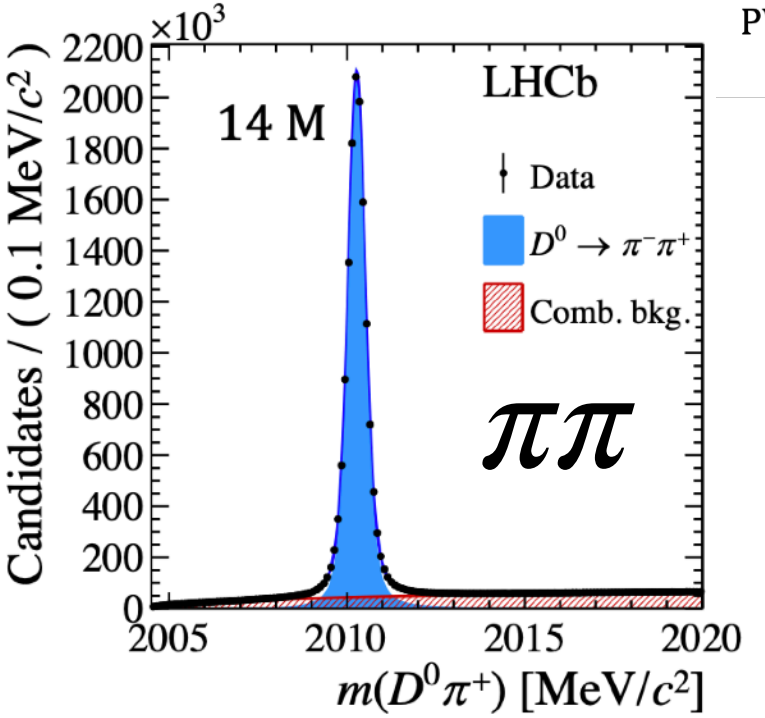
CP violation

And now, the charm !

Federico Betti







$$\Delta A_{CP} = (-15.4 \pm 2.9)\times10^{-4}$$

5.3 standard deviations from zero

Combining Run 1 and Run 2 data

CP violation

And now, the charm !

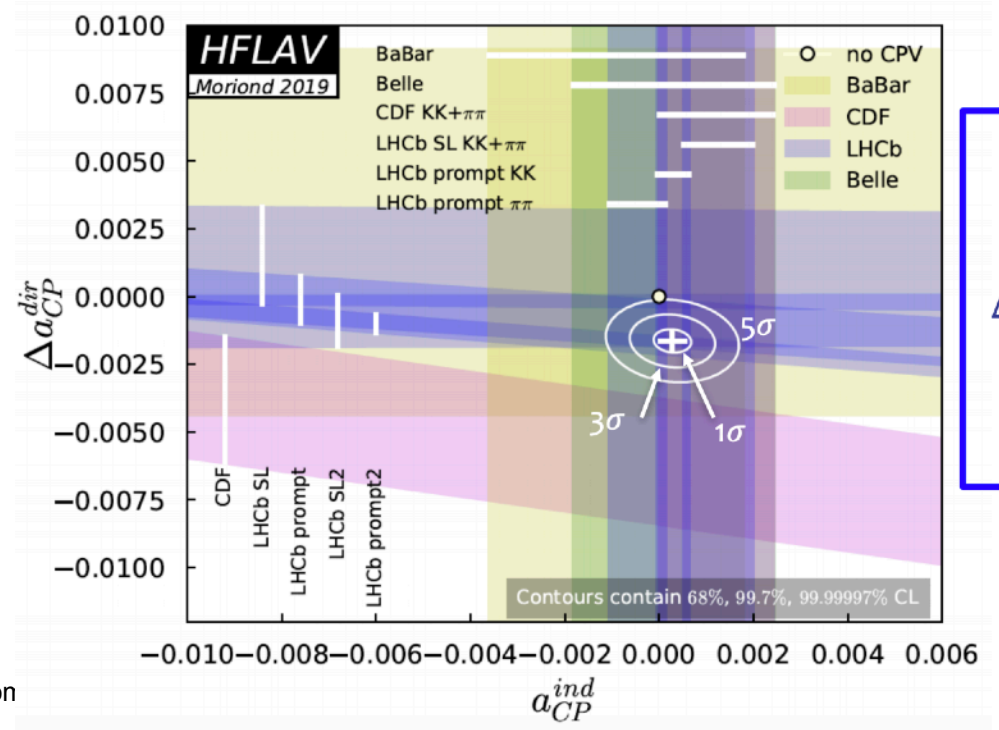
Federico Betti

$$\Delta A_{CP} \simeq \Delta a_{CP}^{\text{dir}} \left(1 + \frac{\overline{\langle t \rangle}}{\tau(D^0)} y_{CP}\right) + \frac{\Delta\langle t \rangle}{\tau(D^0)} a_{CP}^{\text{ind}}$$

direct CP violation

indirect CP violation

$$\boldsymbol{\Delta a_{CP}^{\text{dir}} = (-15.6 \pm 2.9) \times 10^{-4}}$$



HFLAV combination

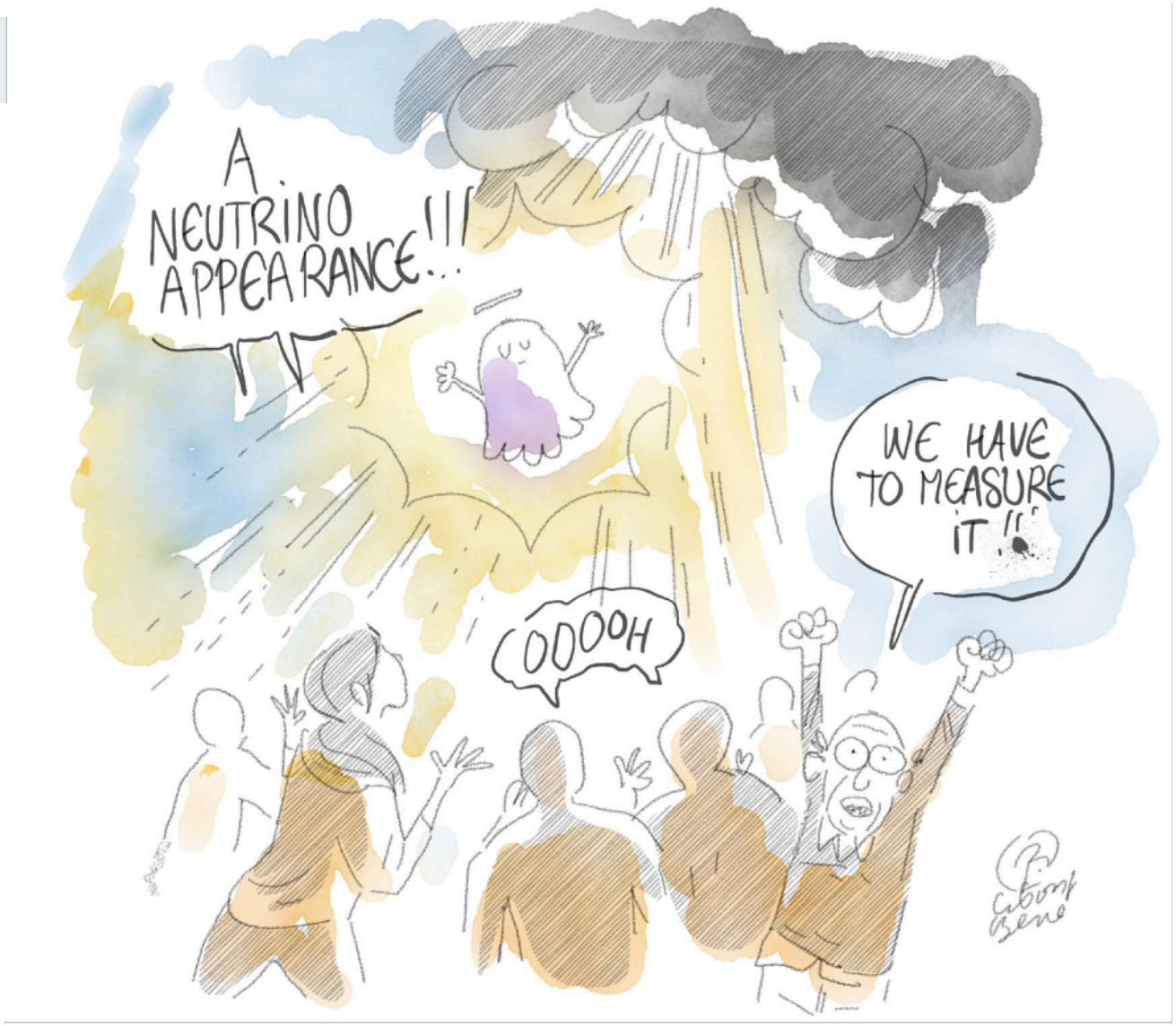
$a_{CP}^{\text{ind}} = (0.028 \pm 0.026)\%$

$\Delta a_{CP}^{\text{dir}} = (-0.164 \pm 0.028)\%$

Consistency with NO CPV hypothesis: 5×10^{-8}


Conclusions
LHCb
• New LHCb measurements of:
○ y_{CP} and x_{CP} (Run 1): $x > 0$ at more than 3σ
○ A_{CP} in $D_s^+ \to K_S^0\pi^+$, $D^+ \to K_S^0K^+$, $D^+ \to \phi\pi^+$ (Run 2)
→ no CP violation in D^0 mixing nor in $D^+_{(s)}$ decays
• New measurement of ΔA_{CP} with full LHCb Run 2 presented today for the first time → $\Delta A_{CP} \neq 0$ at more than 5σ
CP VIOLATION IN CHARM HADRON
TIME

Lison Bernet
@lisbouche



Neutrinos

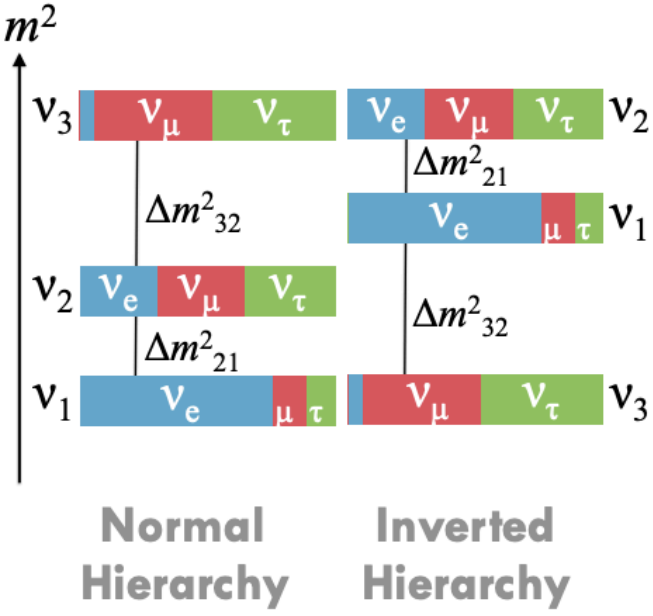
Neutrinos and mixing

Diana Mendez

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = U_{PMNS} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Mixing angles $\theta_{12}, \theta_{13}, \theta_{23}$

CP phase δ_{CP}

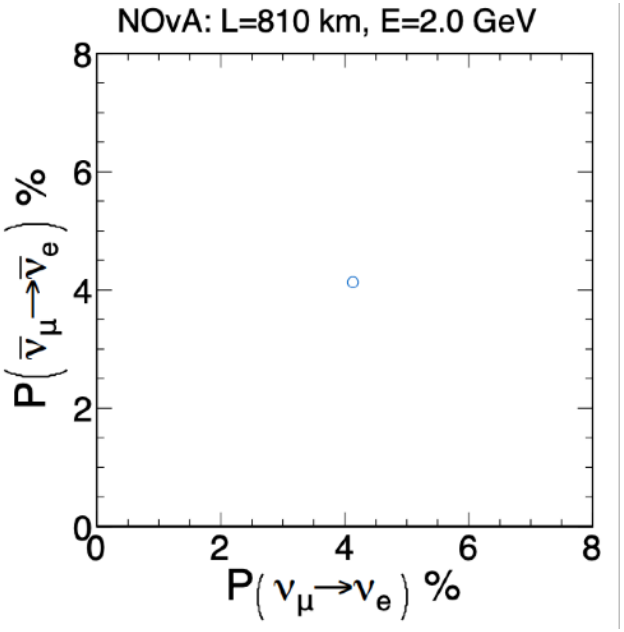


Mass squared difference $\Delta m^2_{21}, \Delta m^2_{32}$

$$P(\nu_\mu \to \nu_\mu) \simeq 1 - \sin^2(2\theta_{23})\sin^2\left(\frac{\Delta m^2_{32} L}{4E}\right)$$

Neutrino news

Diana Mendez - NOvA

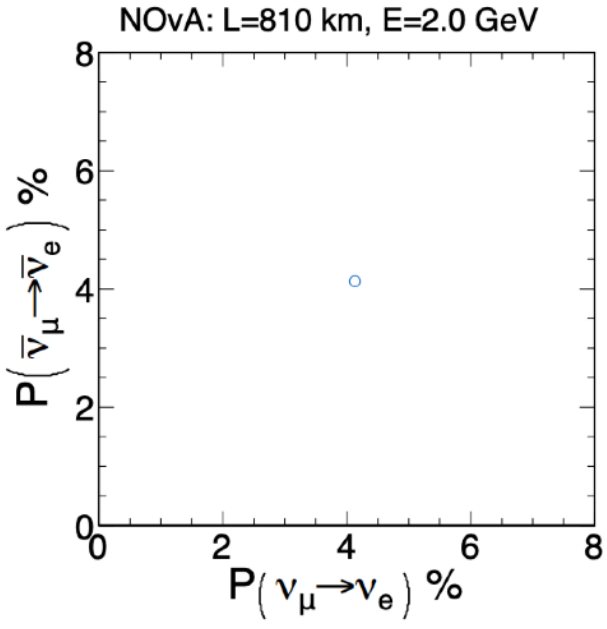


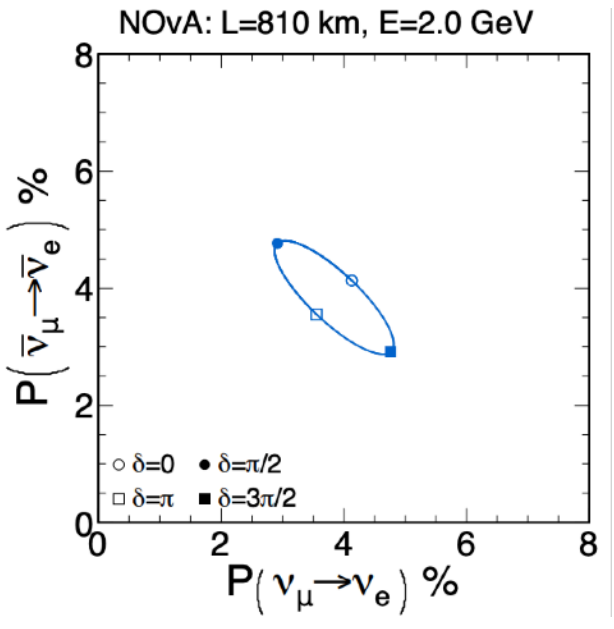
No matter effects

Neutrino-antineutrino
No difference in vacuum

Neutrino news

Diana Mendez - NOvA





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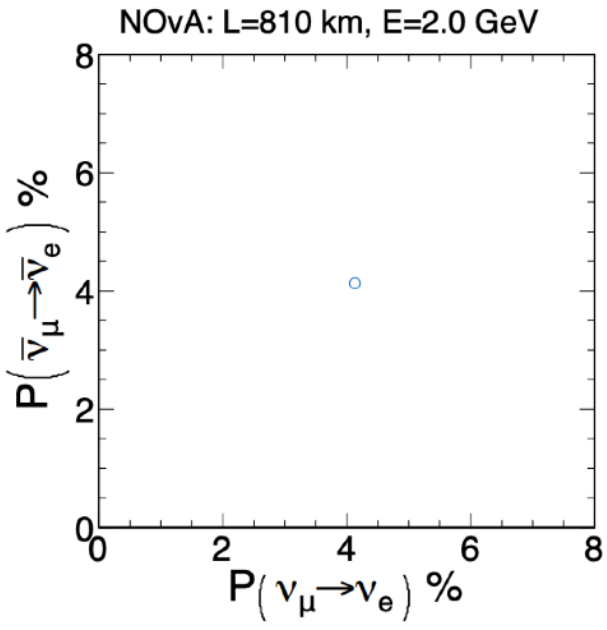
Neutrino-antineutrino
Opposite effects

CP phase δ_{CP}

Neutrino news

Diana Mendez - NOvA



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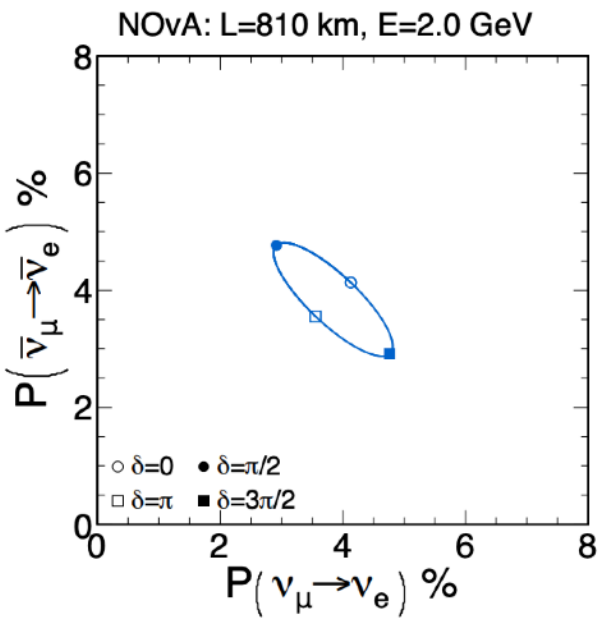

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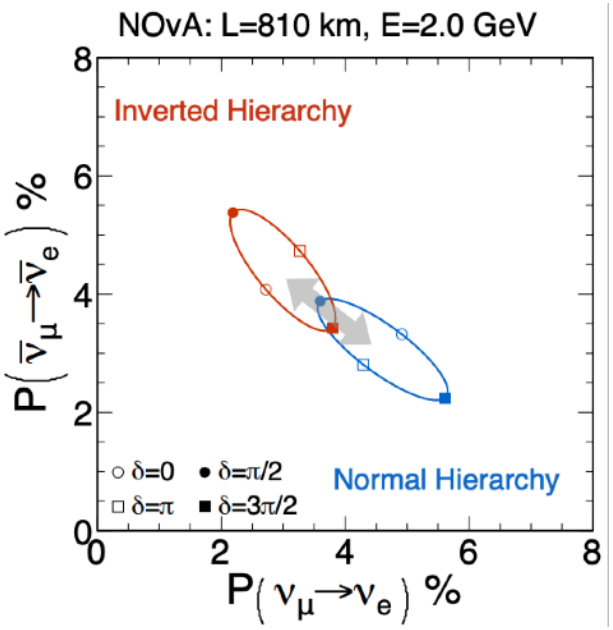
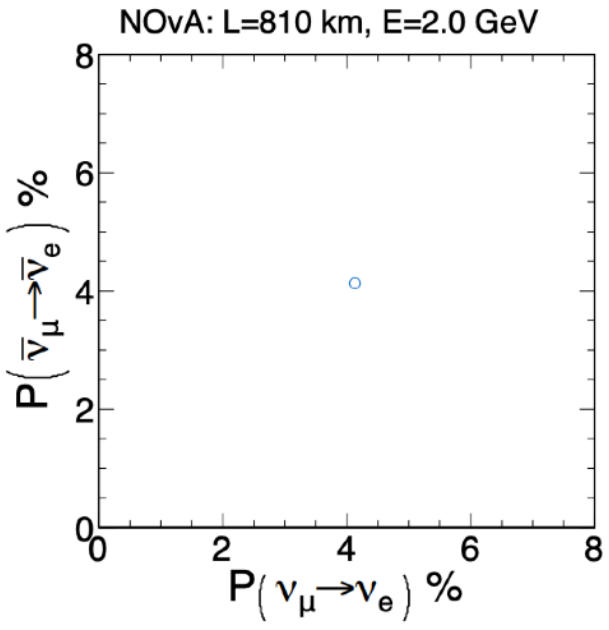
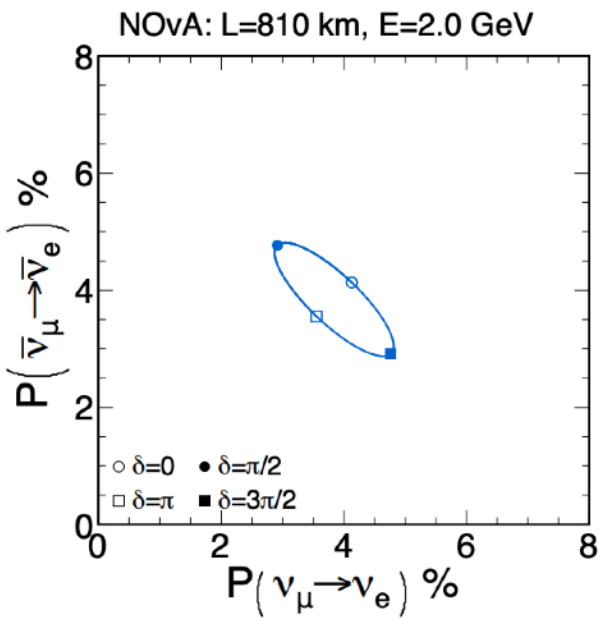


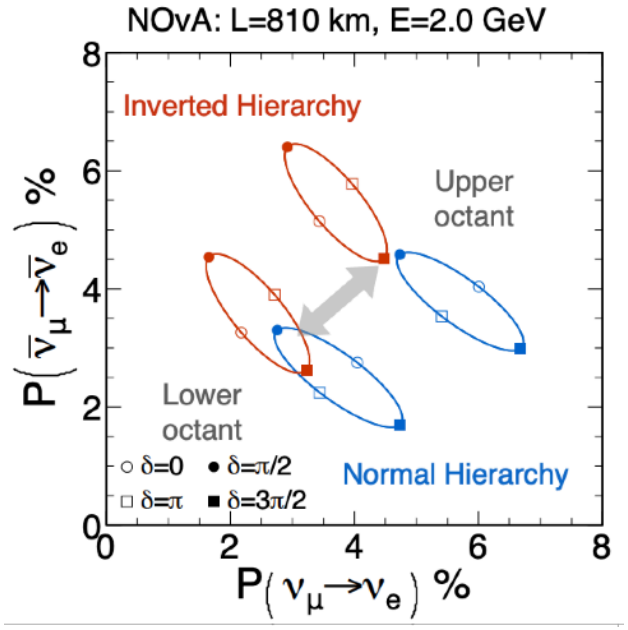
Hierarchy NH, IH

Neutrino news

Diana Mendez - NOvA







No matter effects

Neutrino-antineutrino
No difference in vacuum

Neutrino-antineutrino
Opposite effects

CP phase δ_{CP}

Hierarchy NH, IH

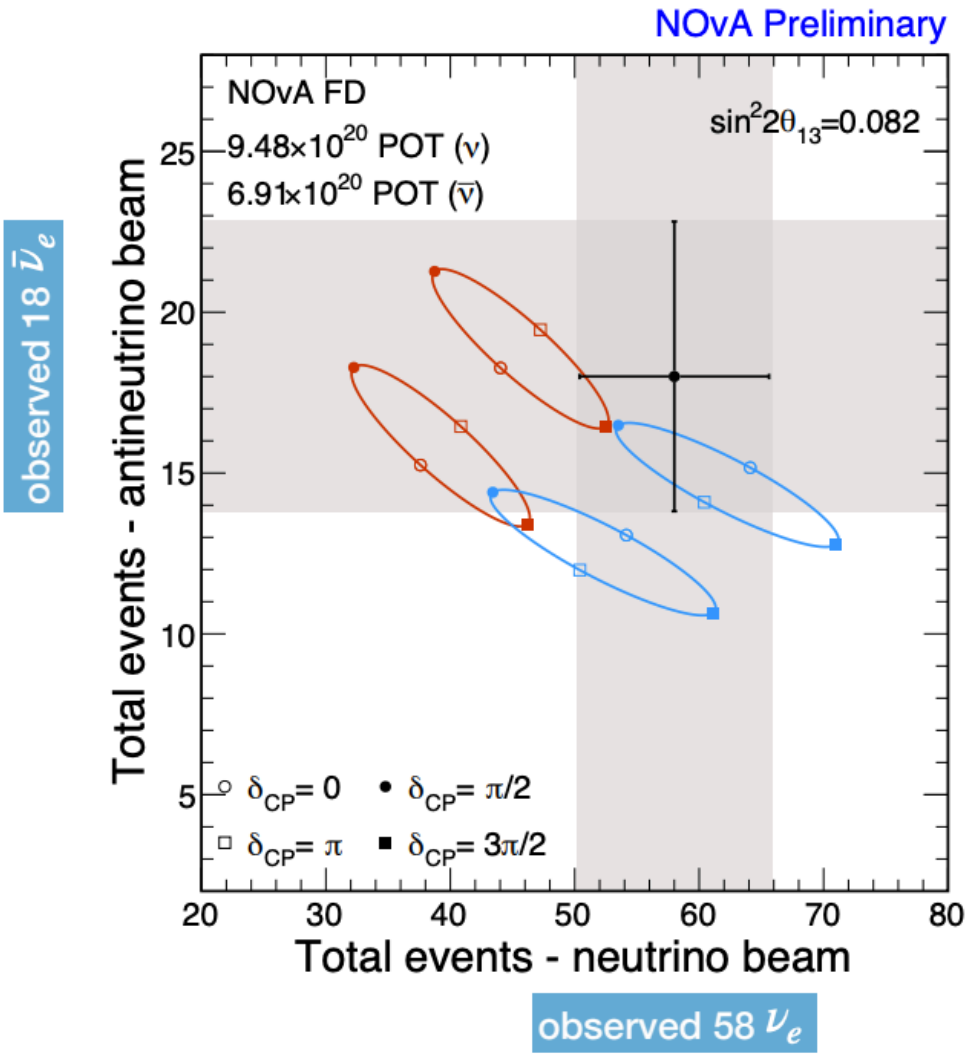
Similar effects

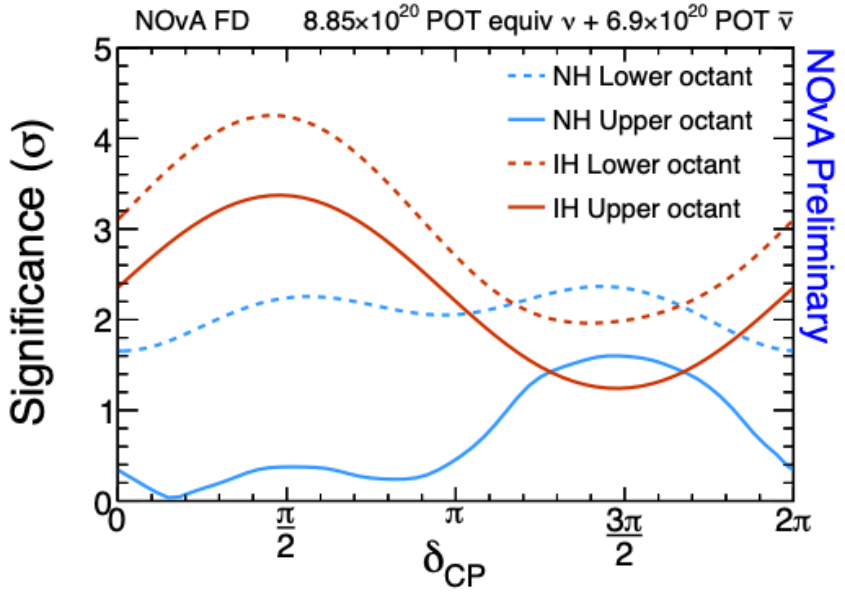
Symmetry θ_{23}

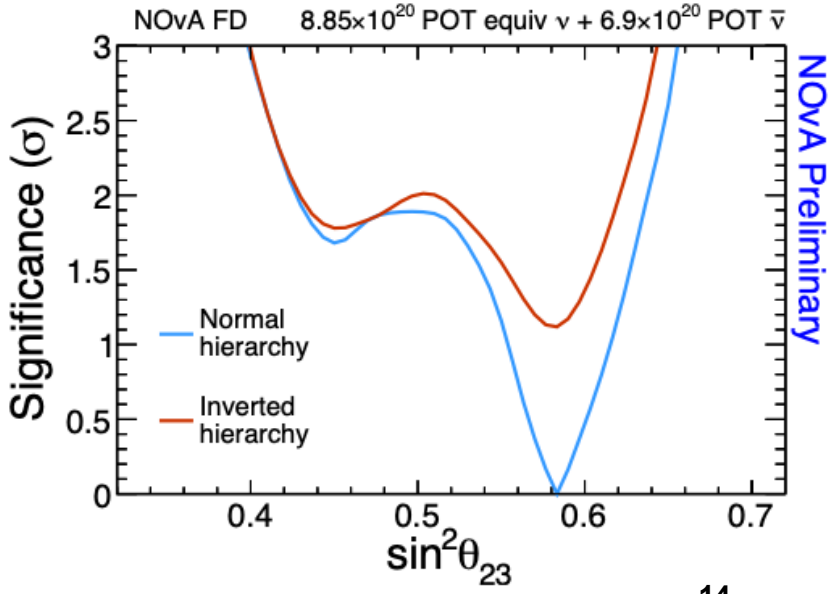
Neutrino news

Alain Blondel - T2K

Diana Mendez - NOvA







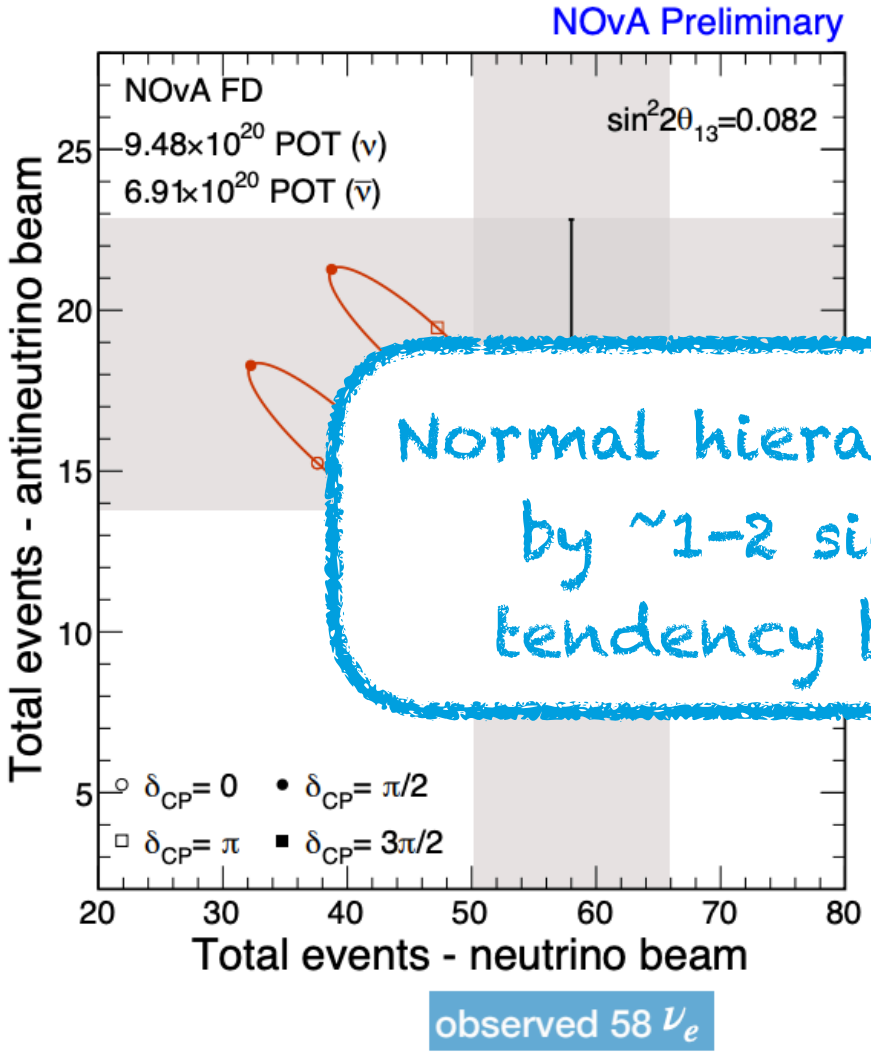
Similar results shown by T2K

Neutrino news

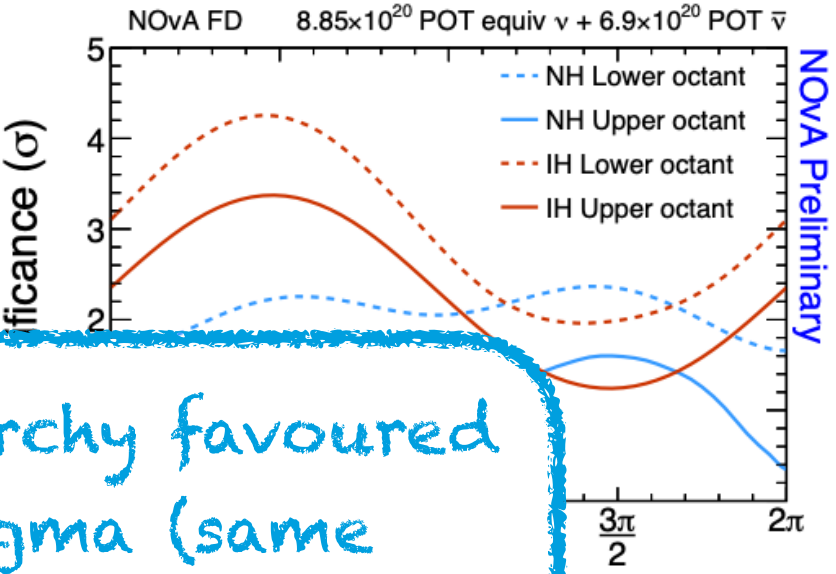
Alain Blondel - T2K

Diana Mendez - NOvA

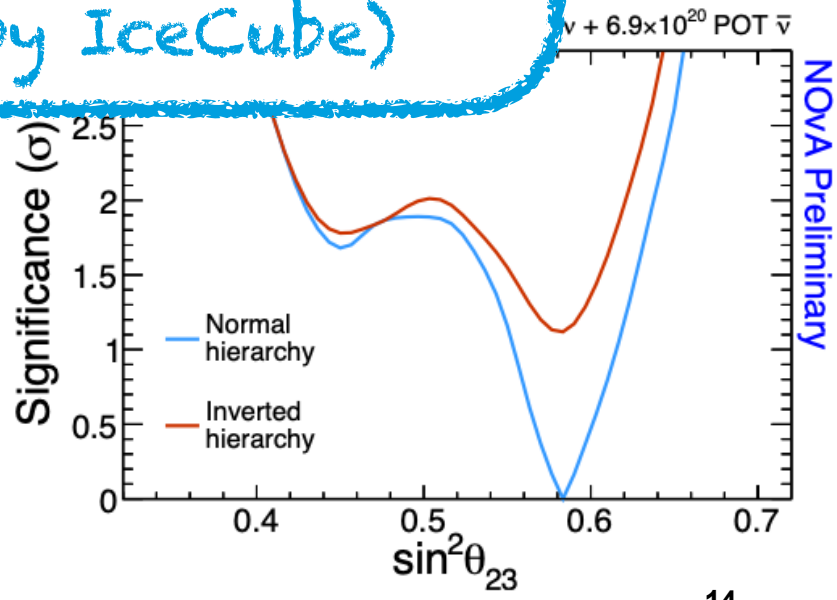
observed 18 $\bar{\nu}_e$



observed 58 ν_e



Normal hierarchy favoured by ~1-2 sigma (same tendency by IceCube)



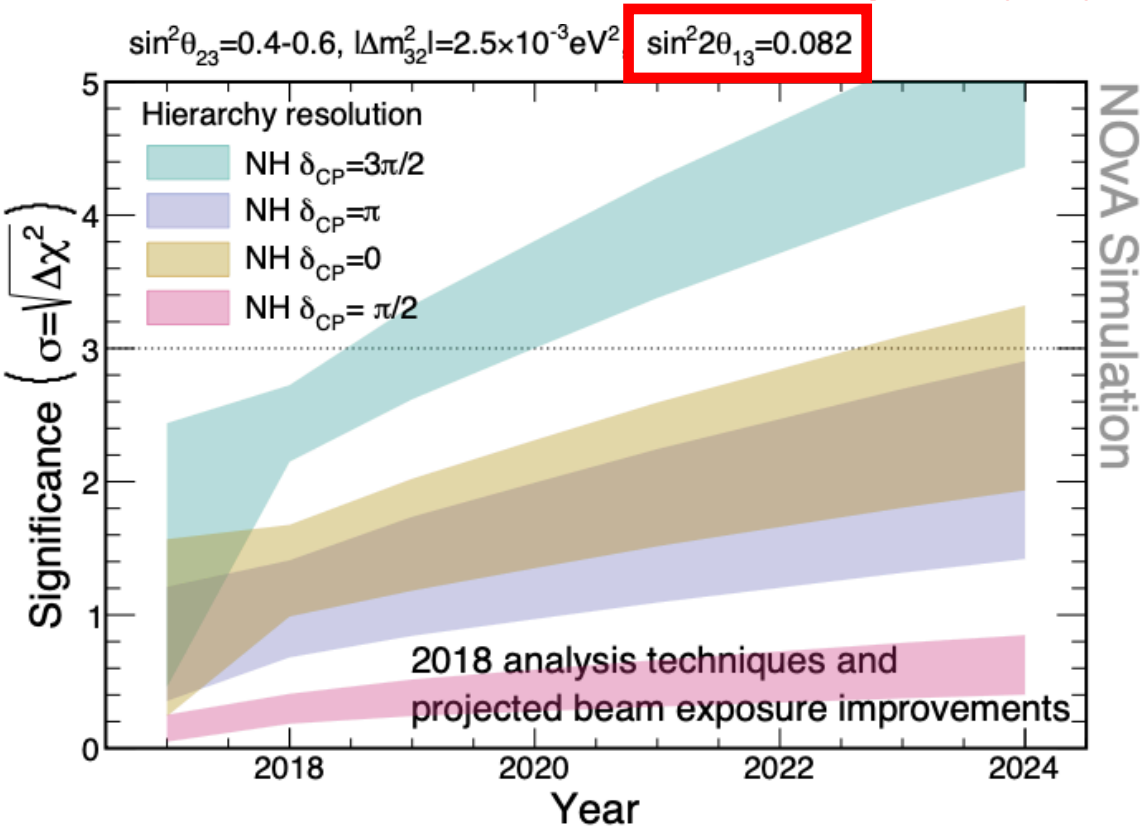
Similar results shown by T2K

Neutrino news

Alain Blondel - T2K | Diana Mendez - NOvA

Prospects

Update by Daya Bay (here)

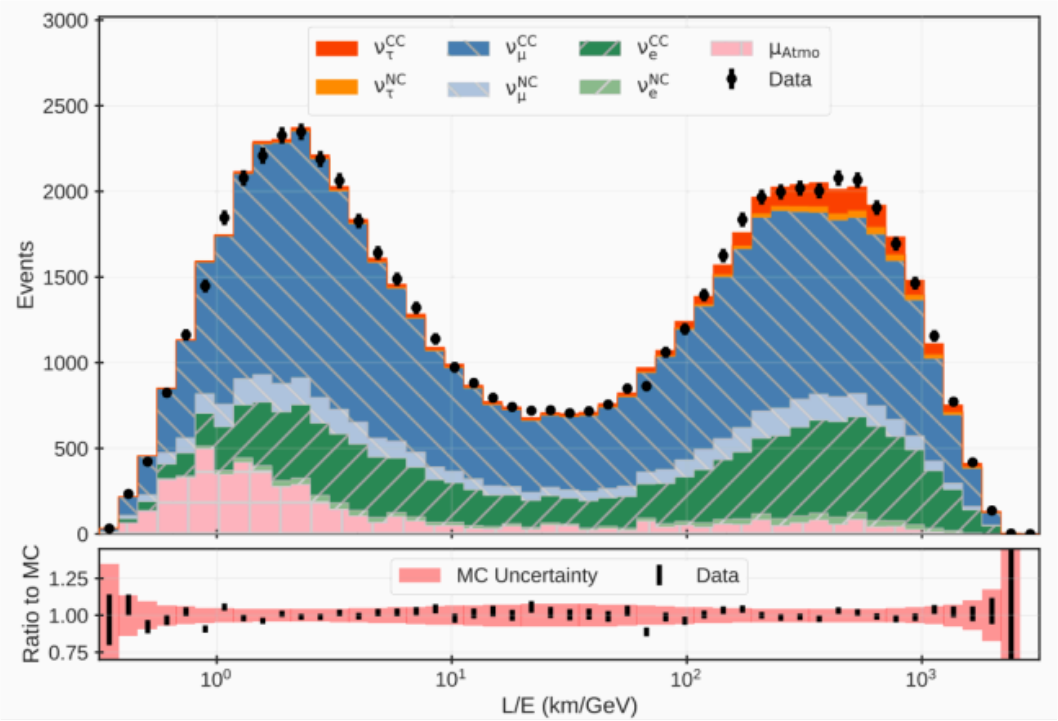


- Analysis improvements and accelerator for up to 900 kW
- 2σ sensitivity to CP violation for favourable parameters by 2024
- Possible hierarchy determination at 3σ in 2020
- Joint NOvA-T2K analysis efforts ramping up

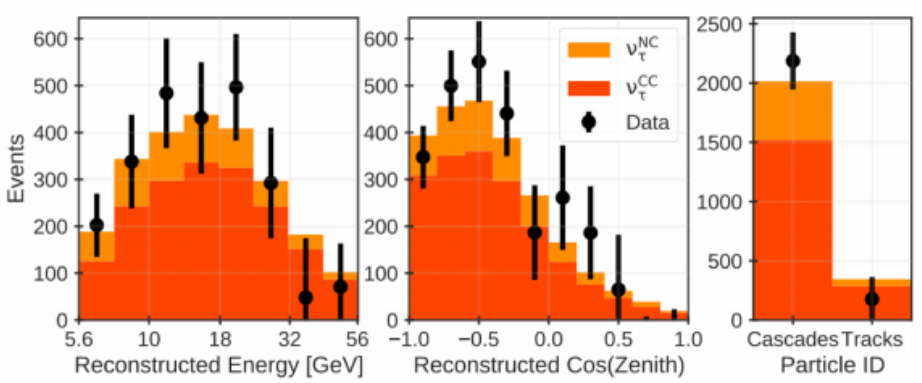
Neutrino news

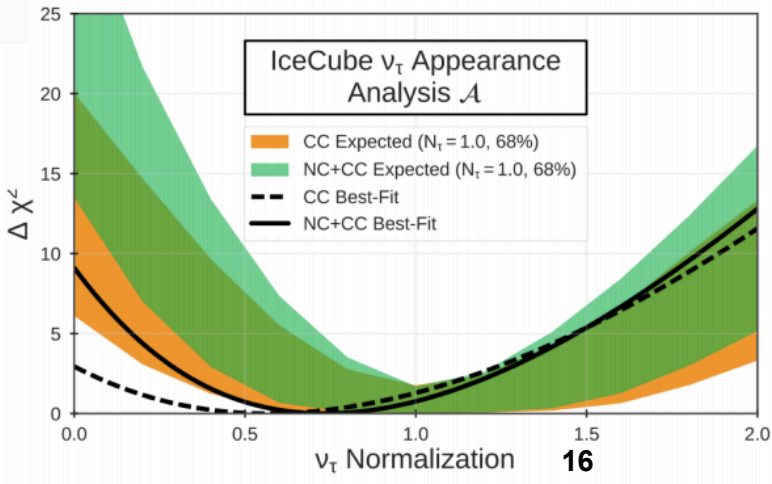
Tau neutrino appearance

Justin Evans - IceCube



Tau neutrino appearance consistent with standard neutrino oscillations





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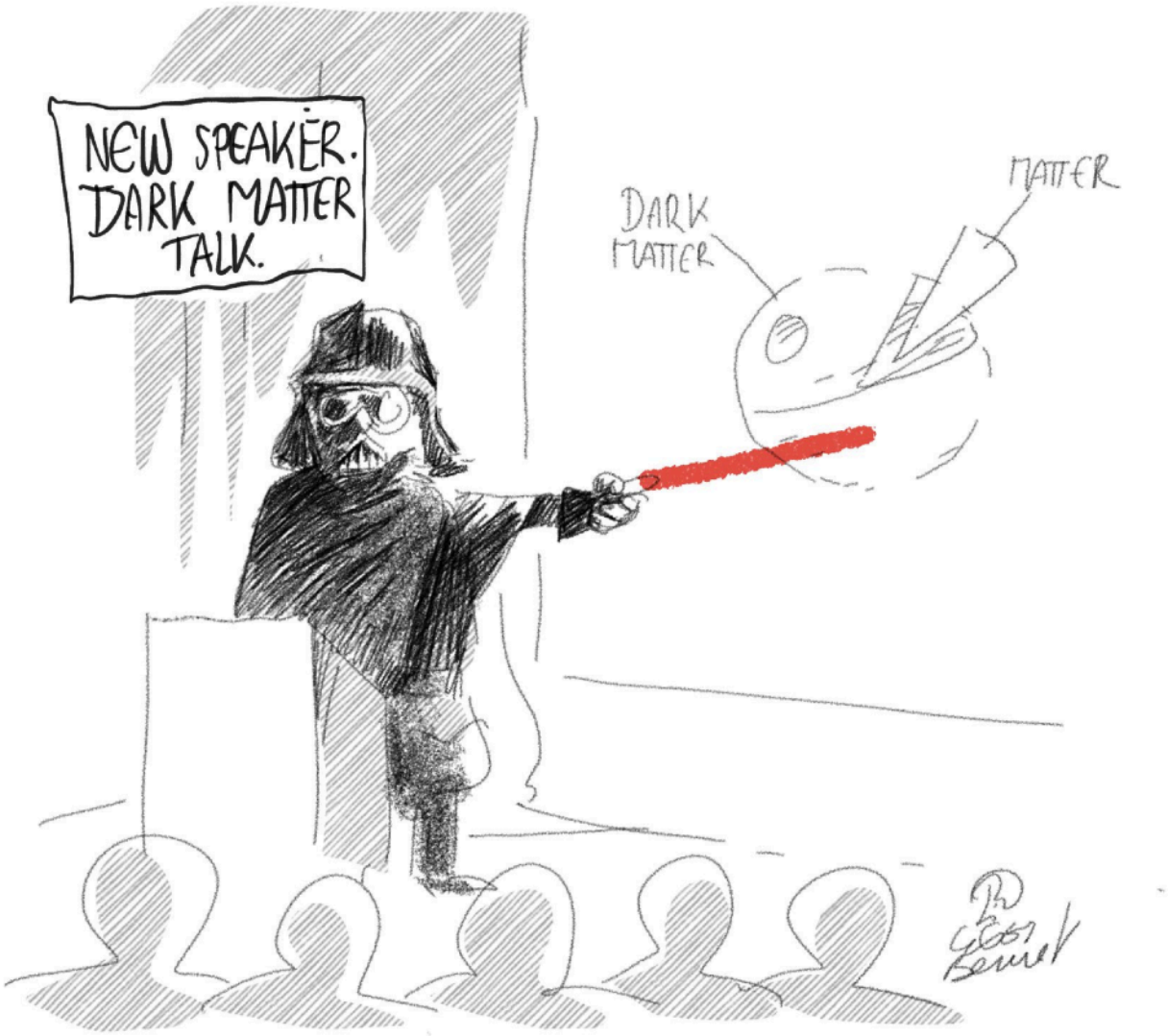
@lisbouche



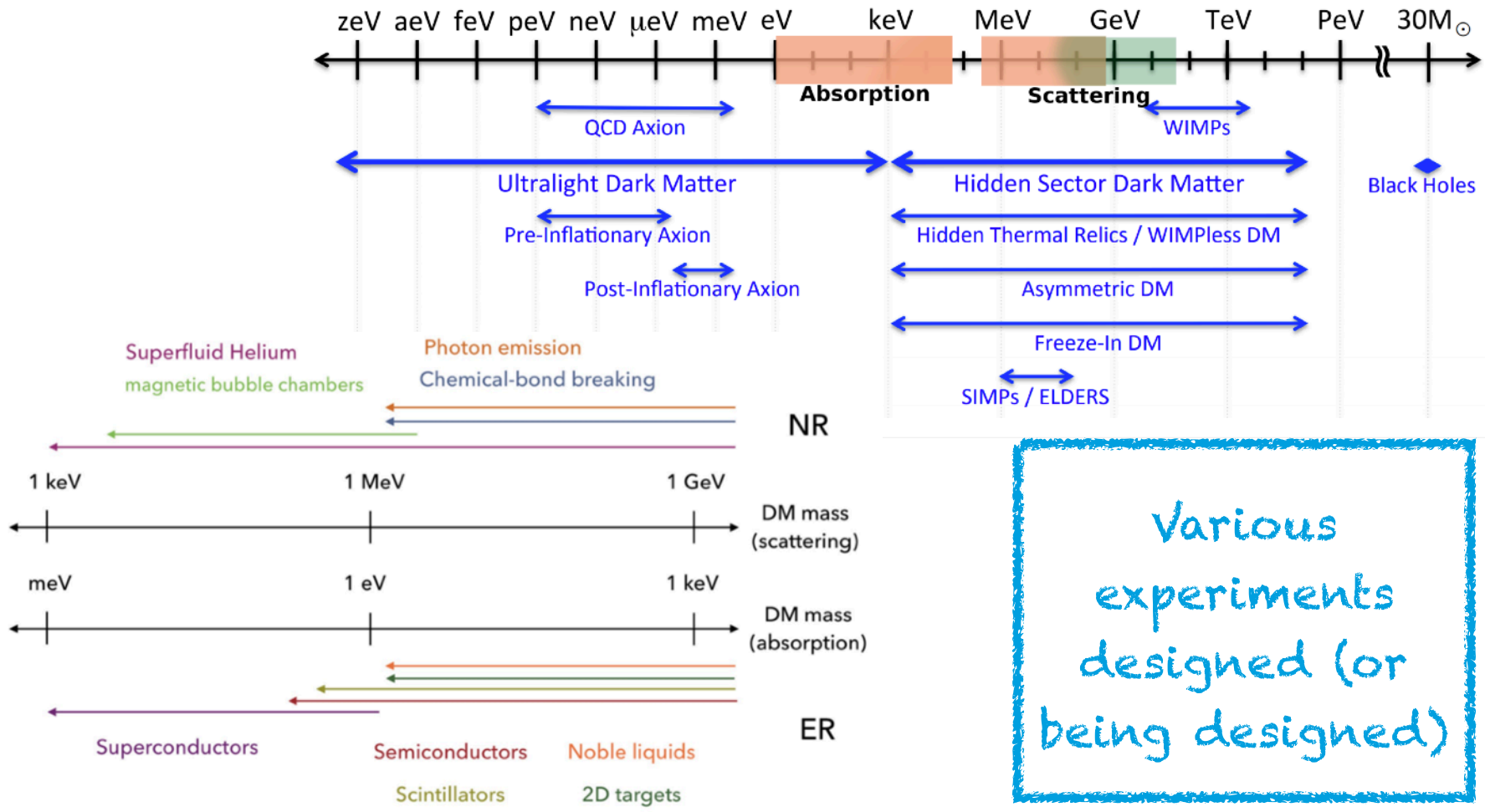
Dark Matter

Dark Matter

Particles and Experiments

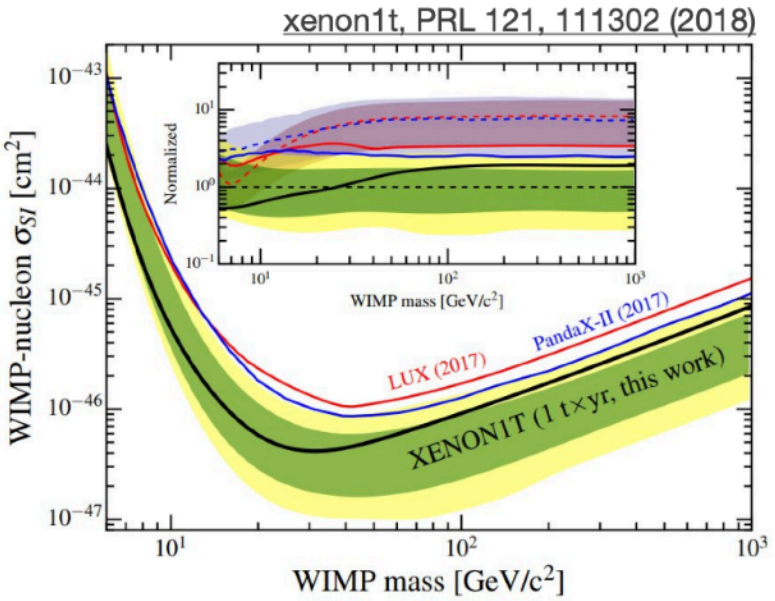
E. Figueroa-Feliciano - SuperCDMS

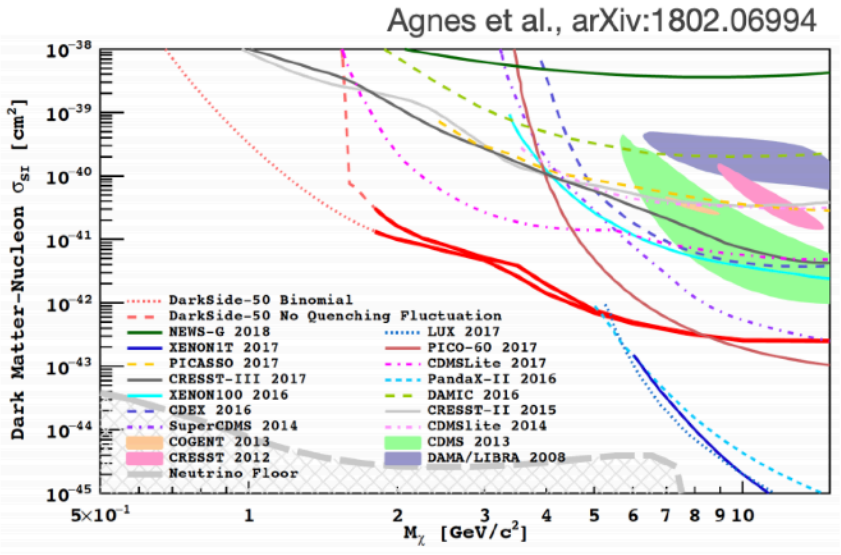
The Dark Matter Mass Spectrum



Various experiments designed (or being designed)

Current status of Direct Dark Matter Searches





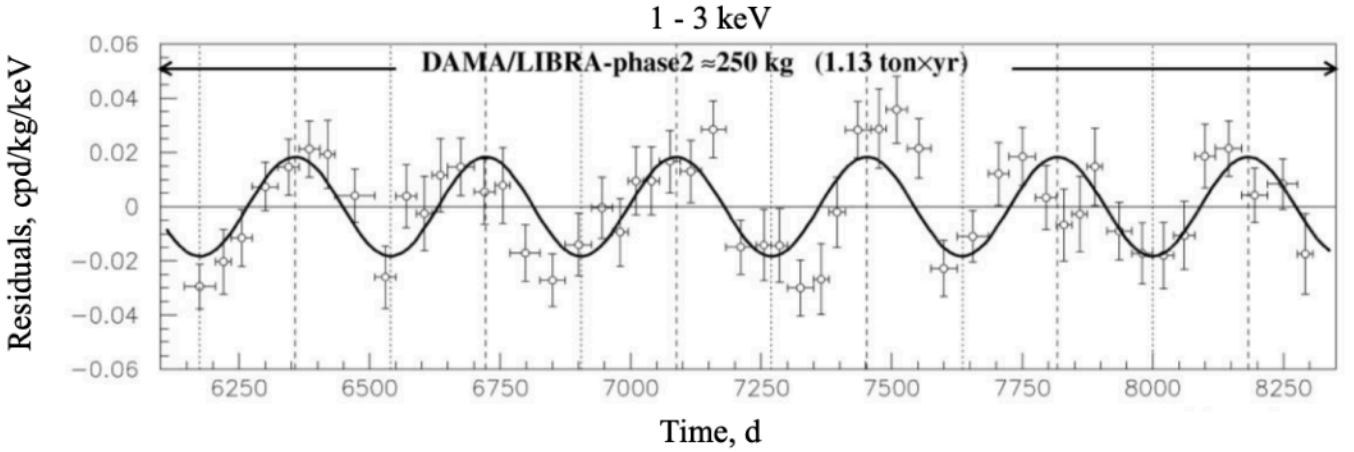
- No sign of WIMPs down to >10^{-46} cm^2 @ 30 GeV from XENON1t, LUX, Panda X
- No sign of spin-dependent WIMPs for >10^{-40} cm^2 from COUPP/PICO/IceCube
- Experiments driving innovations toward low mass dark matter searches
- DAMA's signal remains unresolved

Annual modulation

Cross-check of DAMA observation

Reina Maruyama - COSINE

DAMA observed annual modulation



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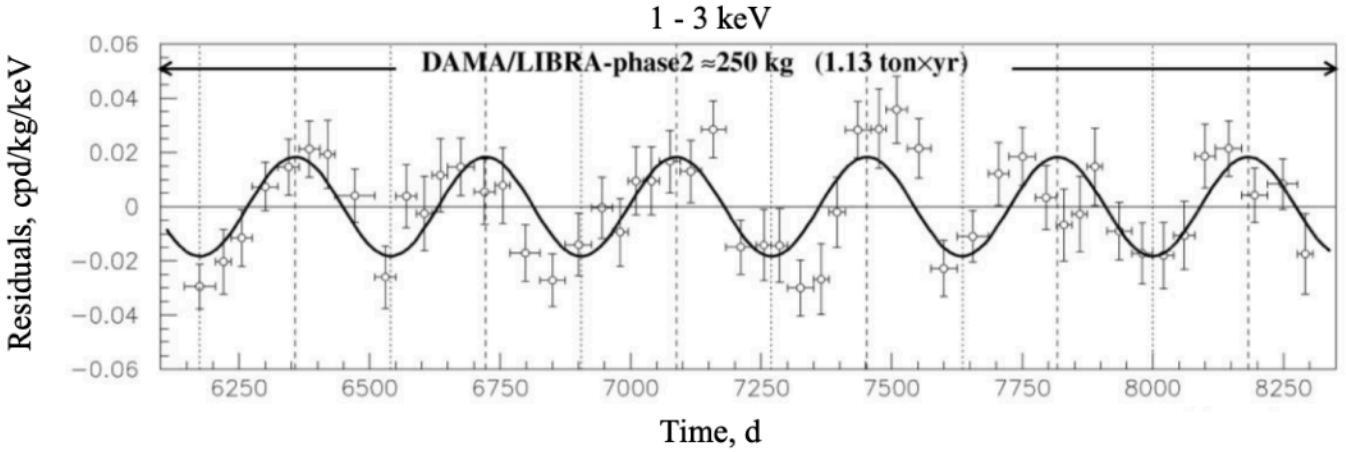
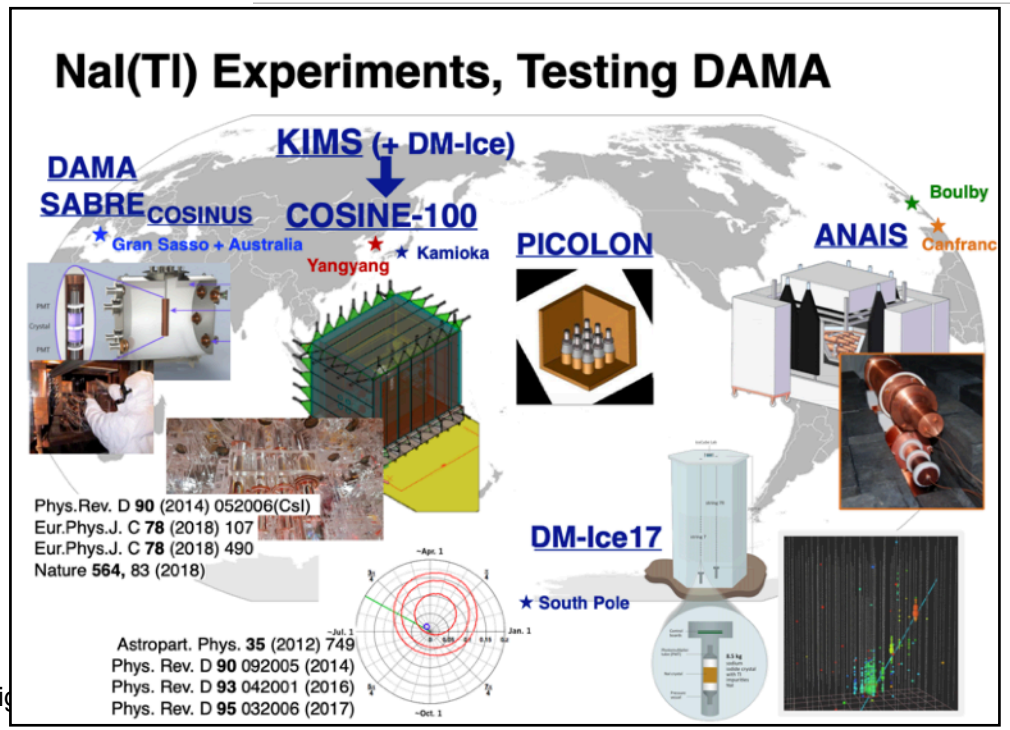


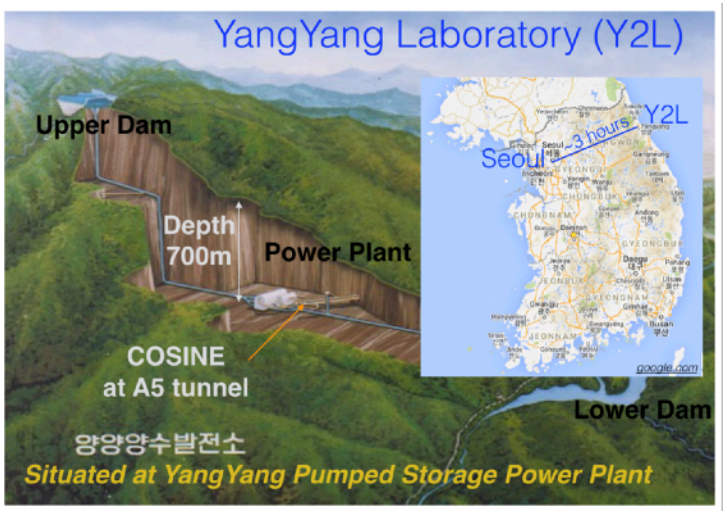


Several experiments being built to confirm or deny DAMA's results

Annual modulation

Cross-check of DAMA observation

Reina Maruyama - COSINE



Annual modulation

Cross-check of DAMA observation

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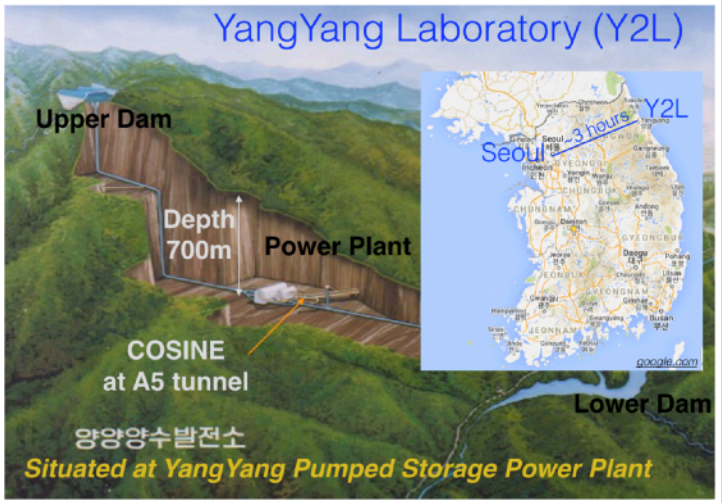
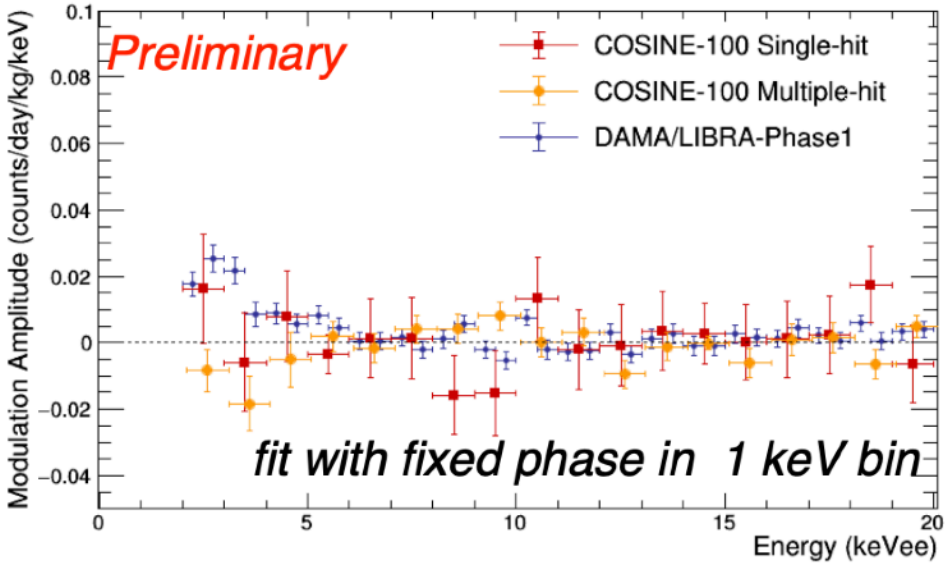
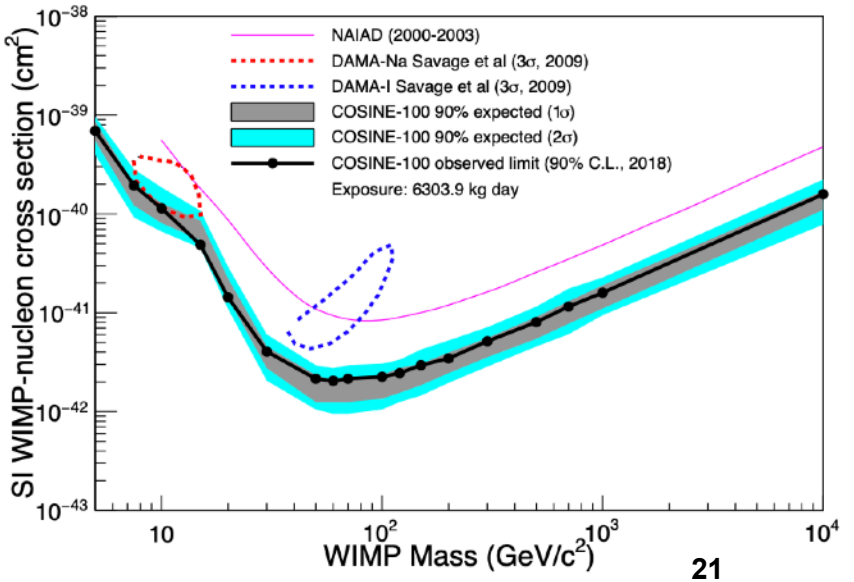




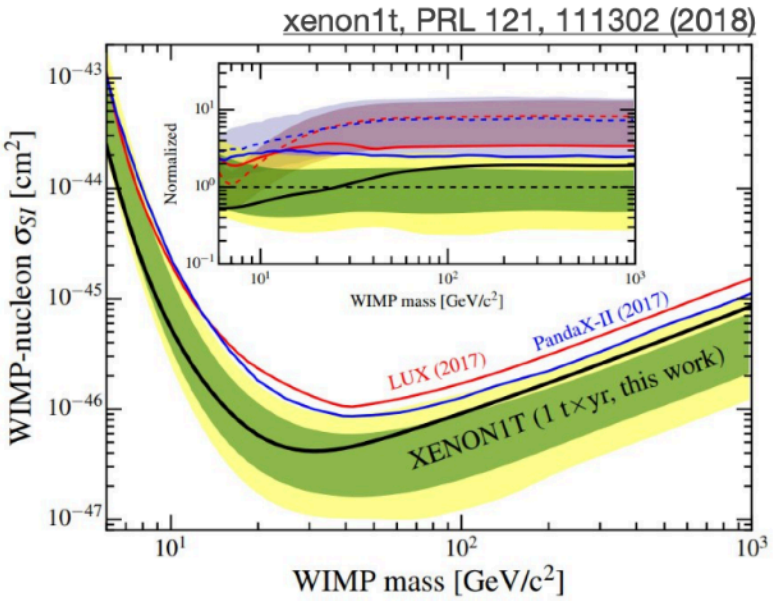
Recent results:

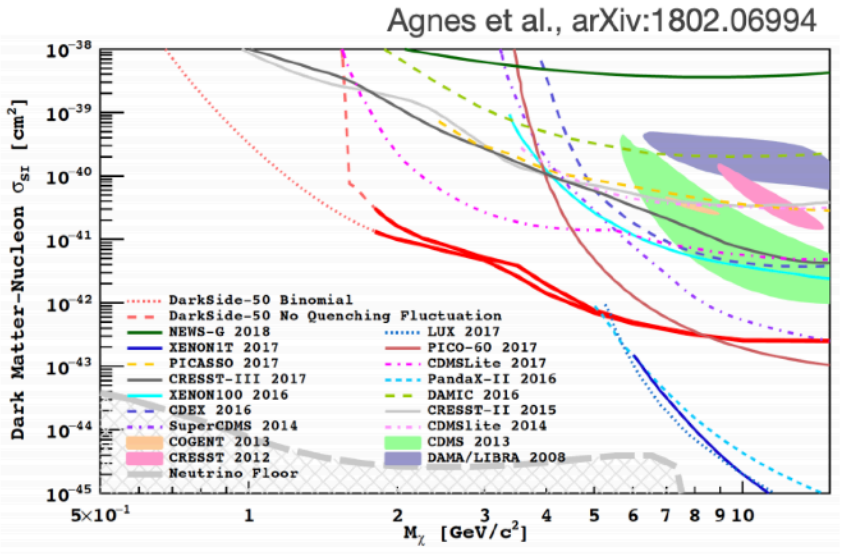
- COSINE-100 disfavors standard spin-indepent WIMP interaction with NaI(Tl) as explanation for DAMA/LIBRA's modulation signal.
- Preliminary modulation analysis with 1.7 years exposure promising.

Results still inconclusive



Current status of Direct Dark Matter Searches





- No sign of WIMPs down to >10^{-46} cm^2 @ 30 GeV from XENON1t, LUX, Panda X
- No sign of spin-dependent WIMPs for >10^{-40} cm^2 from COUPP/PICO/IceCube
- Experiments driving innovations toward low mass dark matter searches
- DAMA's signal remains unresolved

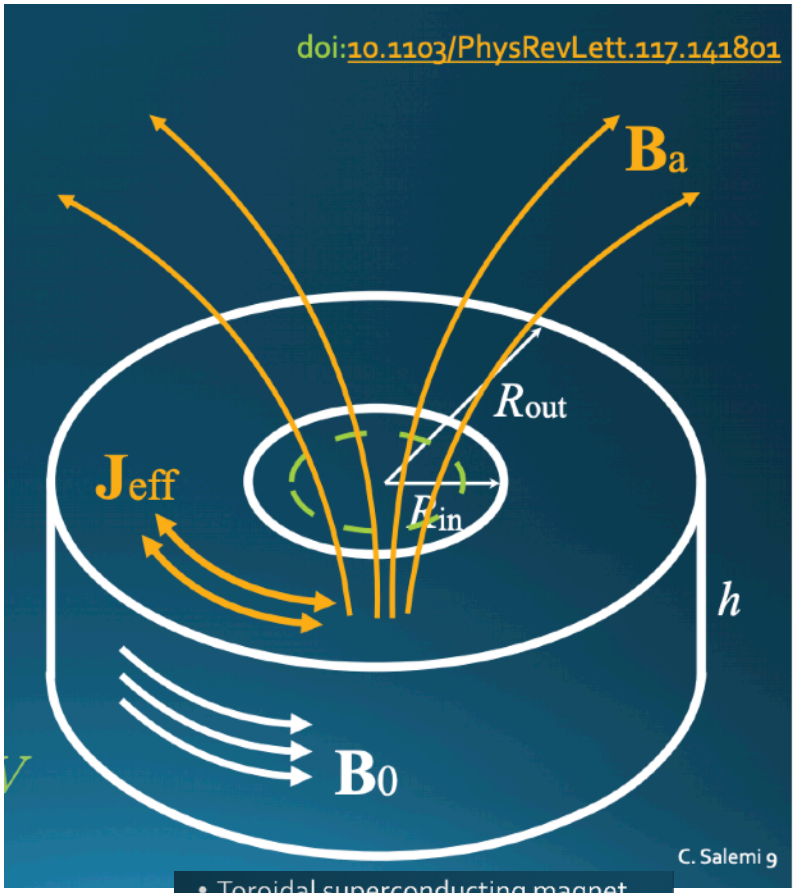
Dark Matter

ABRACADABRA

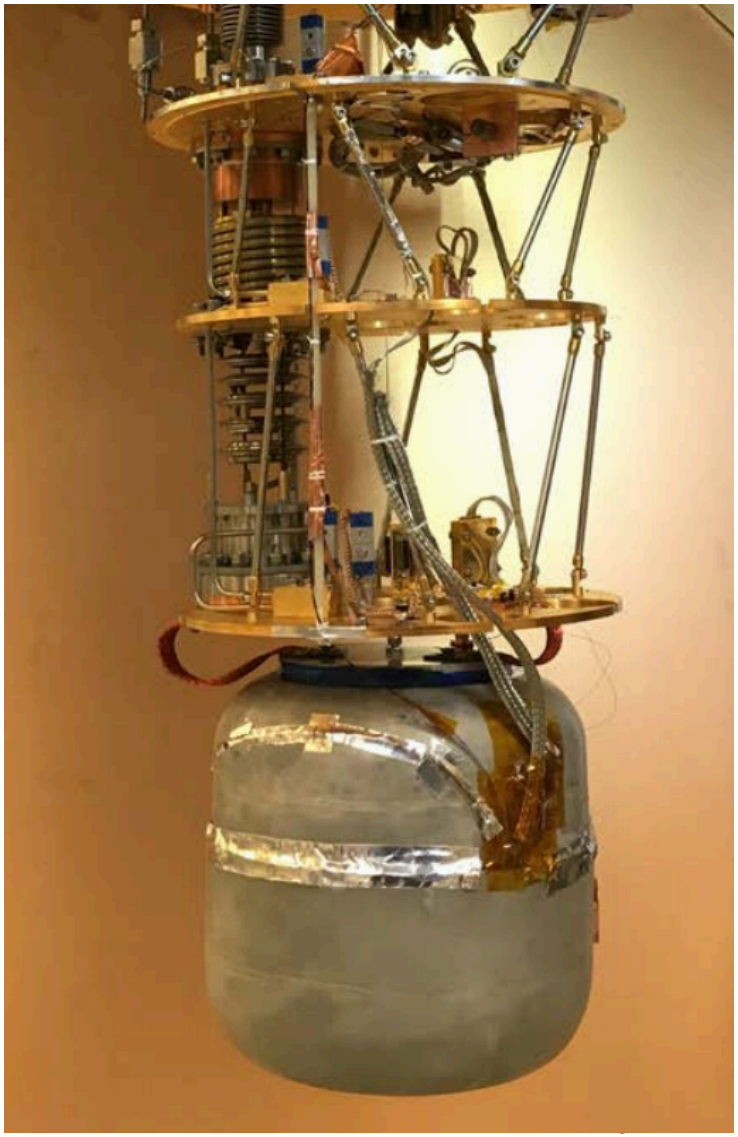
ABRACADABRA-10cm

A Broadband/Resonant Approach to Cosmic Axion Detection with an Amplifying B-field Ring Apparatus

Chiara Salemi - ABRA



- Toroidal superconducting magnet with fixed field, B_0
- Axion dark matter generates parallel oscillating effective current
- ...creating an oscillating magnetic flux through the center of the toroid
- This flux is then read out from a pickup loop using a SQUID current sensor



Dark Matter

ABRACADABRA

ABRACADABRA-10cm

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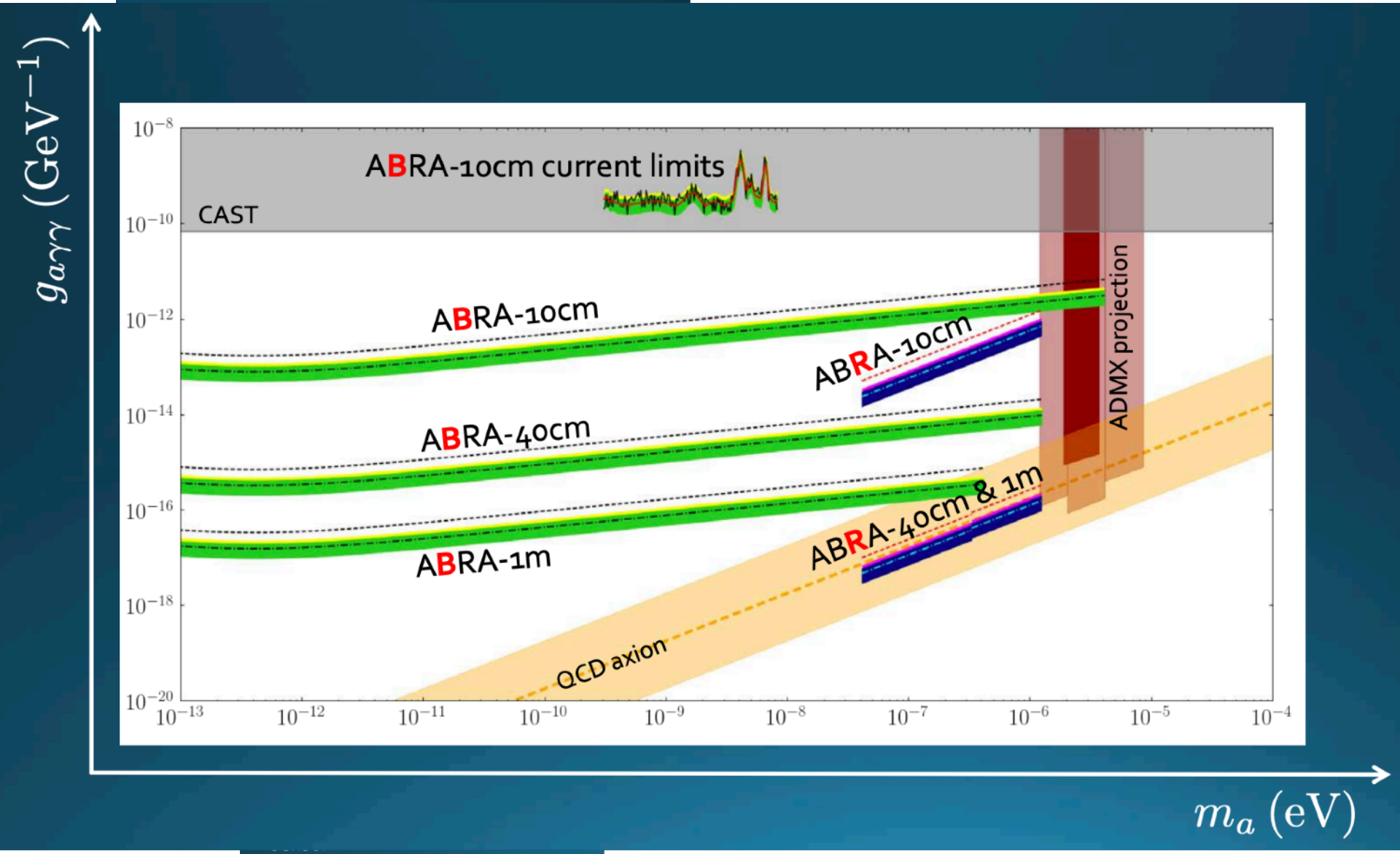
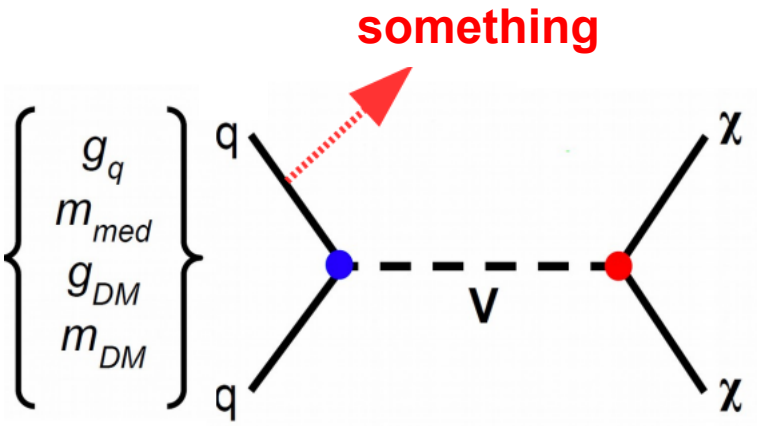
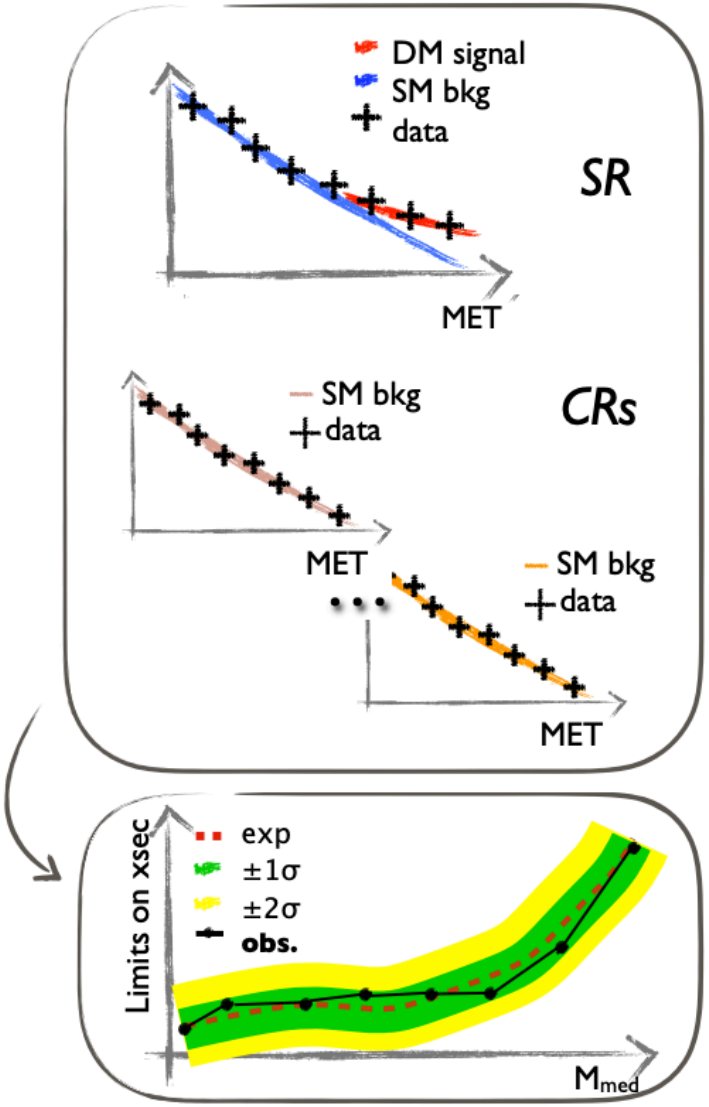


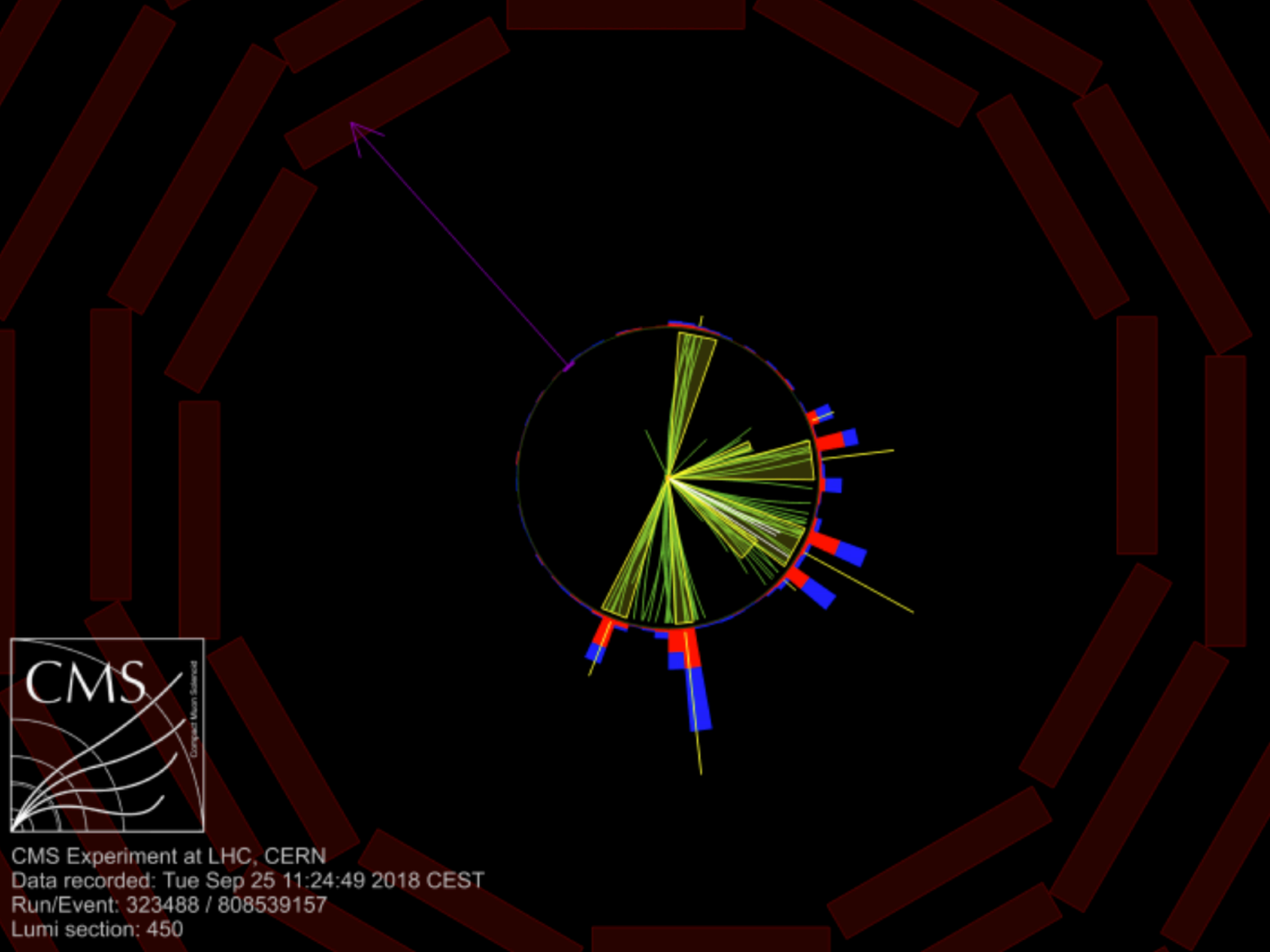
ATLAS/CMS DM searches

Deborah Pinna

Sergey Chekanov






CMS
Compact Muon Solenoid
CMS Experiment at LHC, CERN
Data recorded: Tue Sep 25 11:24:49 2018 CEST
Run/Event: 323488 / 808539157
Lumi section: 450

ATLAS/CMS DM searches

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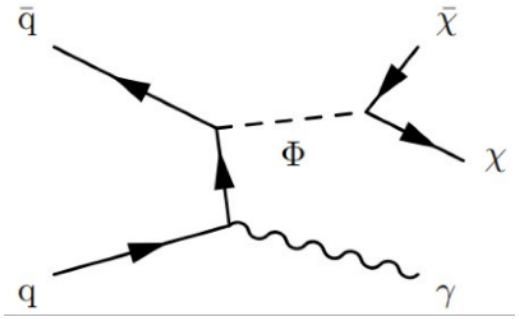
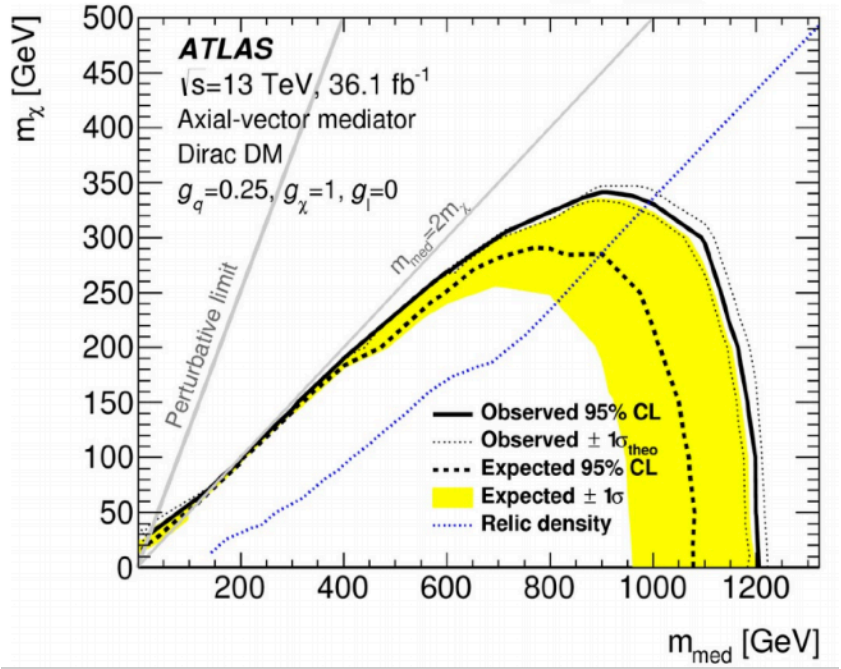
Sergey Chekanov





ATLAS/CMS DM searches

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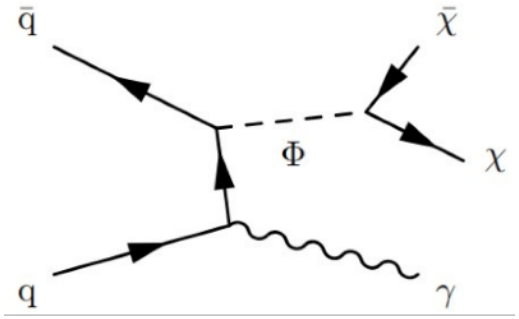
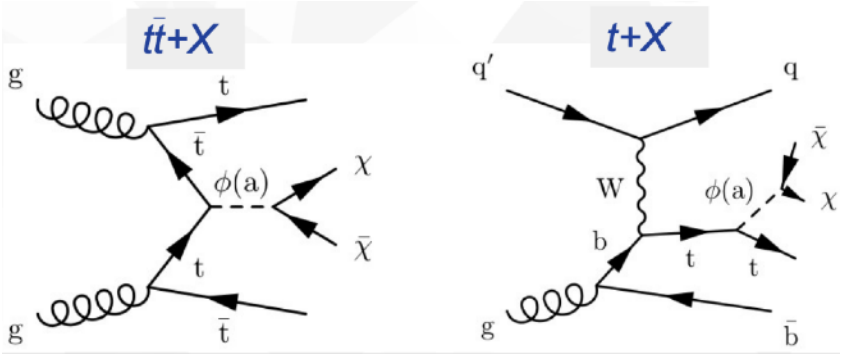
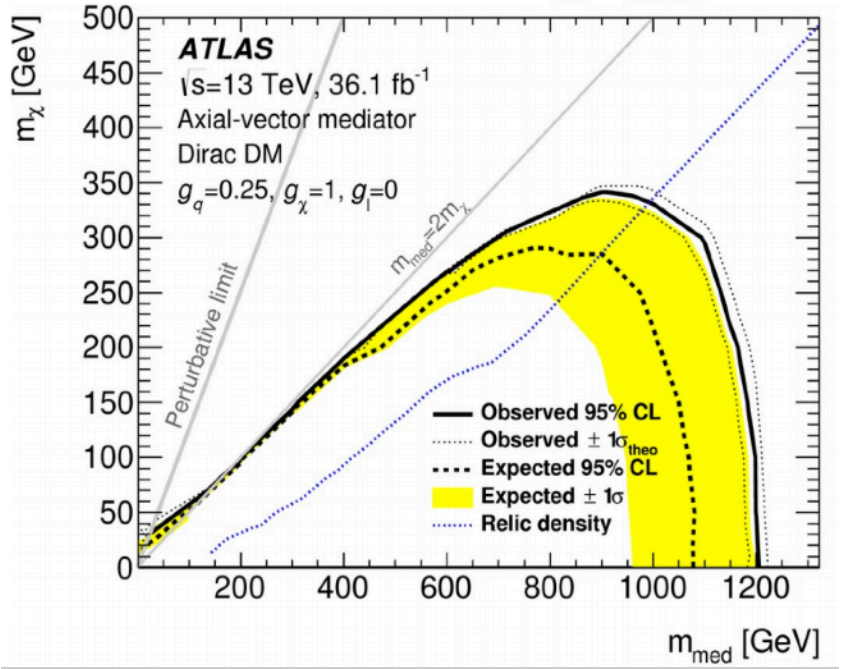
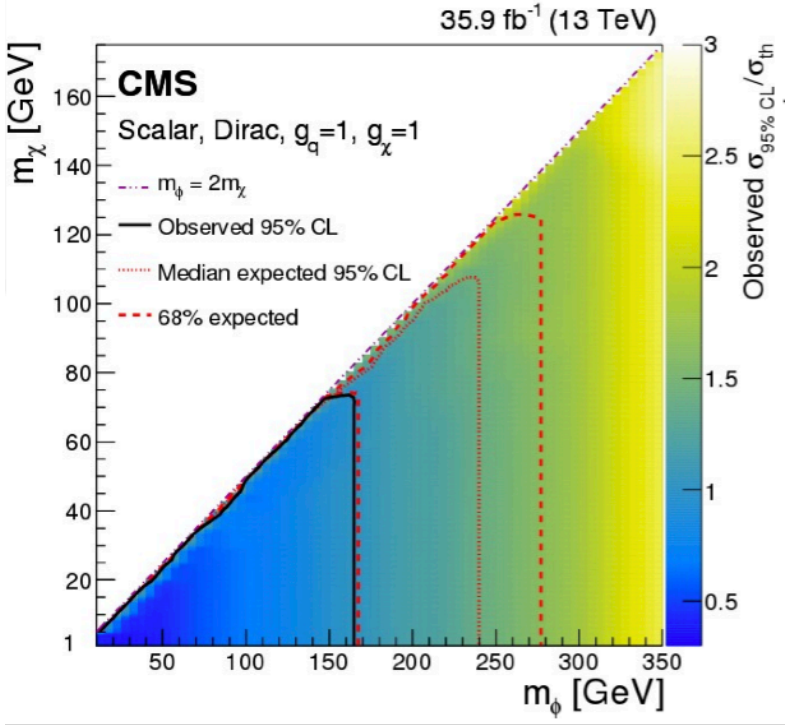
Sergey Chekanov







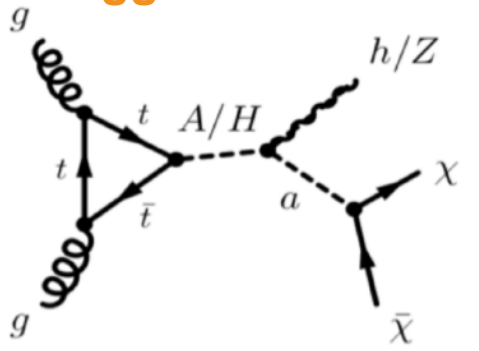


ATLAS/CMS DM searches

And the Higgs ?

Deborah Pinna

Sergey Chekanov



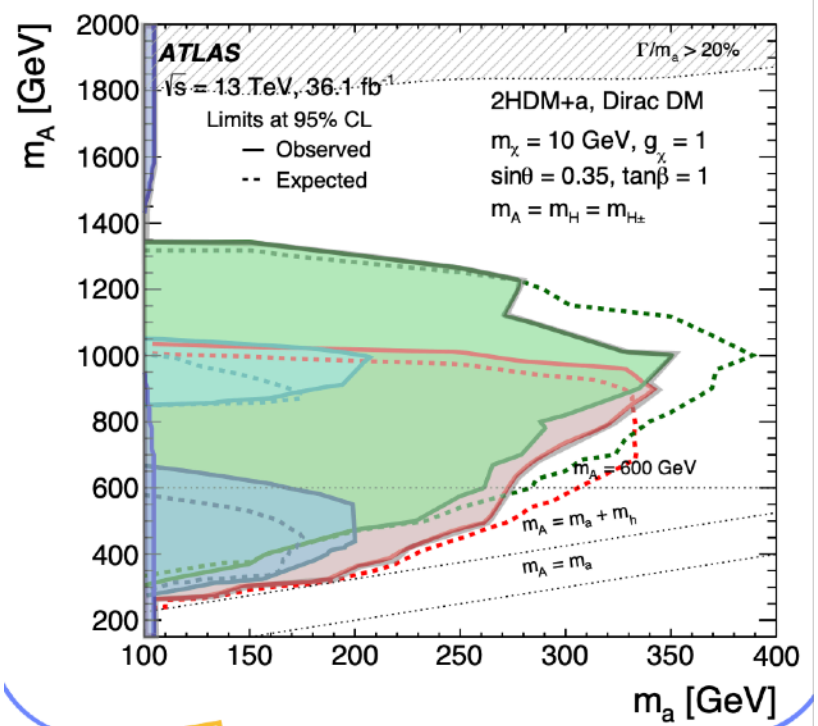
E_T^{miss}+h(γγ) PRD 96 (2017) 112004

E_T^{miss}+Z(ll) PLB 776 (2017) 318

E_T^{miss}+h(bb̄)

E_T^{miss}+Z(qq̄) JHEP 10 (2018) 180

h(inv) $\sqrt{s}$=7,8 TeV;4.7,20.3 fb^{-1} JHEP 11 (2015) 206,

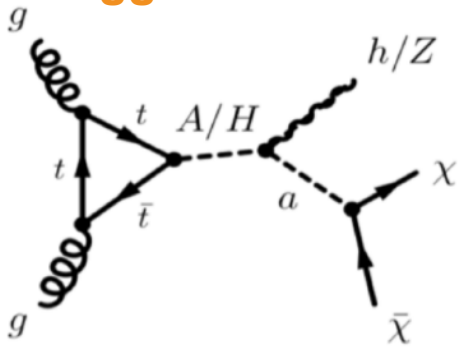


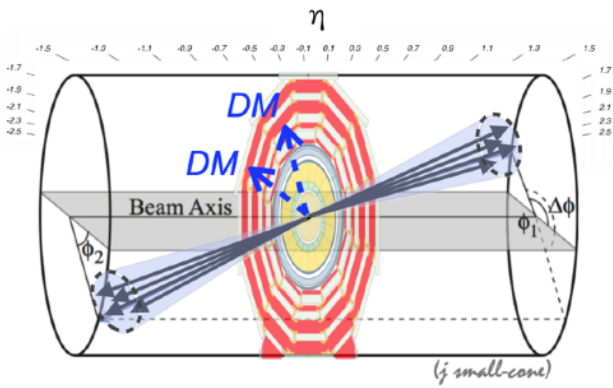
ATLAS/CMS DM searches

Deborah Pinna

Sergey Chekanov

And the Higgs ?





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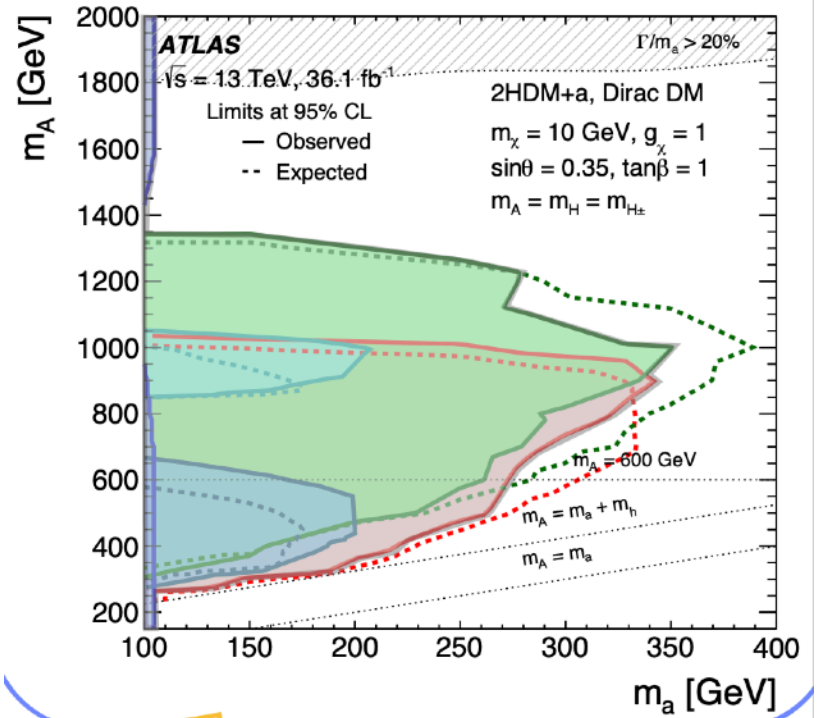
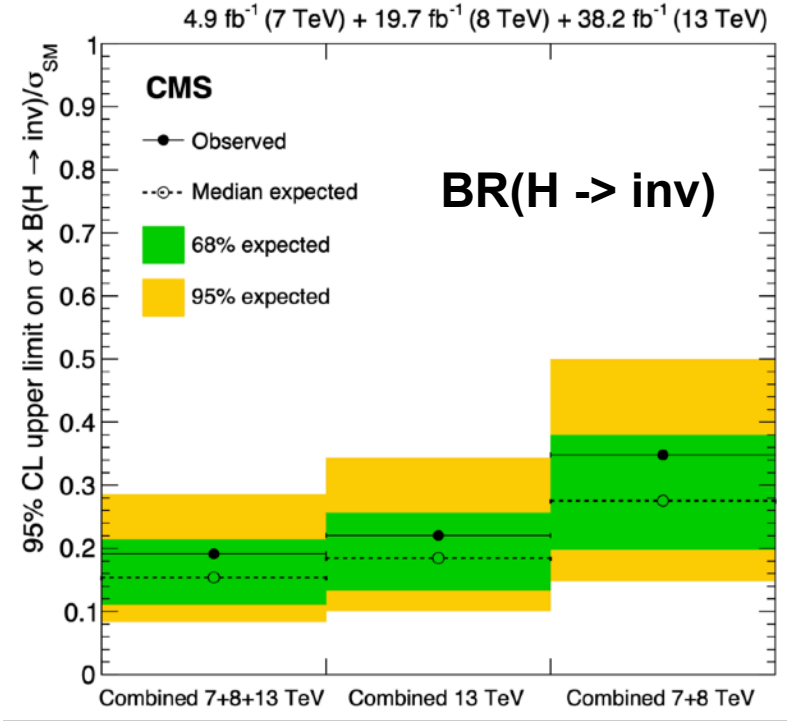
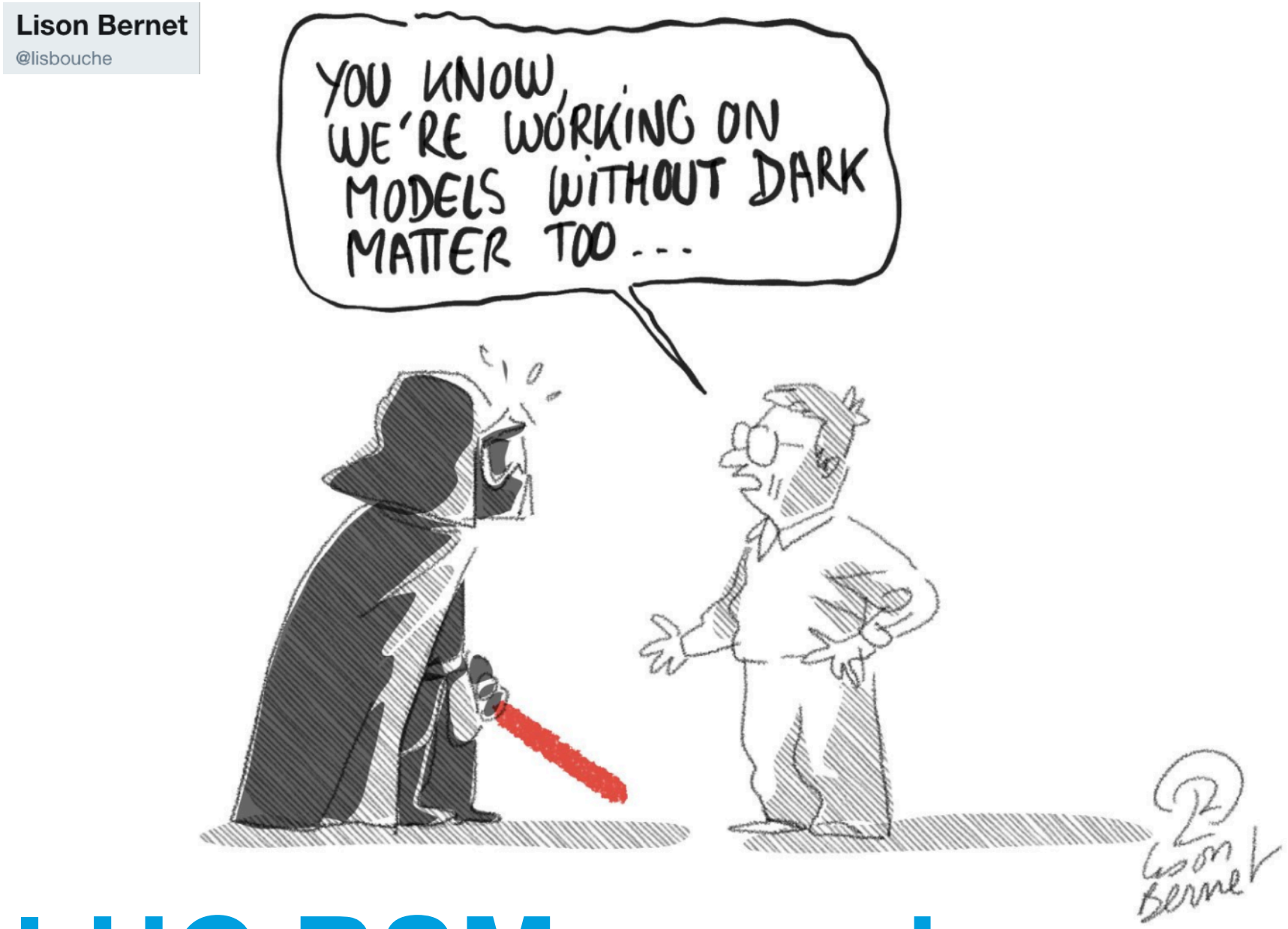






LHC BSM searches

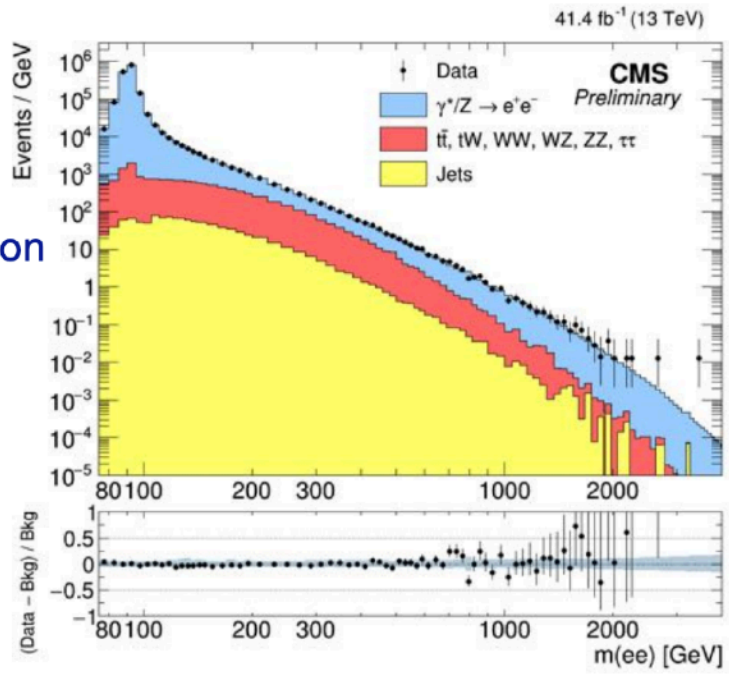
ATLAS/CMS searches

Shahram Rahatalou

Exotica Timeline

Detector Understanding (time)

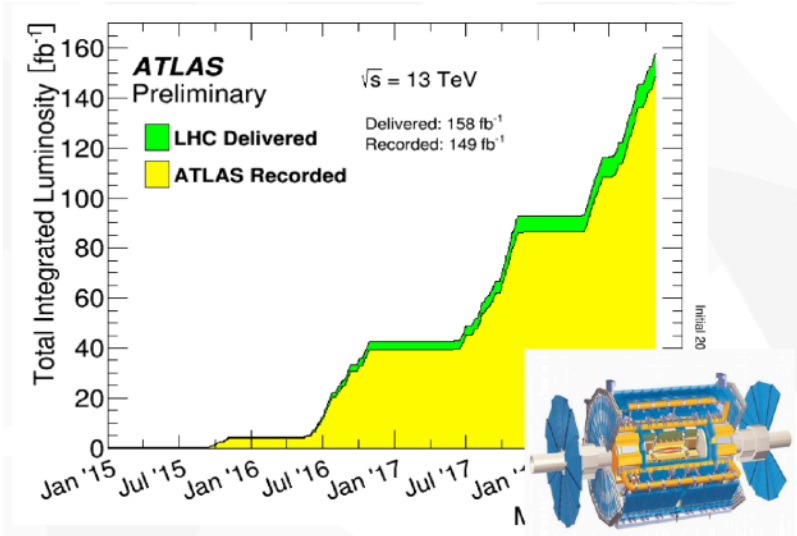
- Two-body resonances from day one: leptons, photons, jets
  - detector effects not critical
  - sensitive to bumps right away
- Increase complexity and multiplicity of final state
  - better understanding and calibration of detector
- Final states with X + MET
- Really exotic signatures such as long-lived particles
  - control of detector conditions over longer period
  - ultimate calibration and alignment
  - optimisation of dedicated algorithms

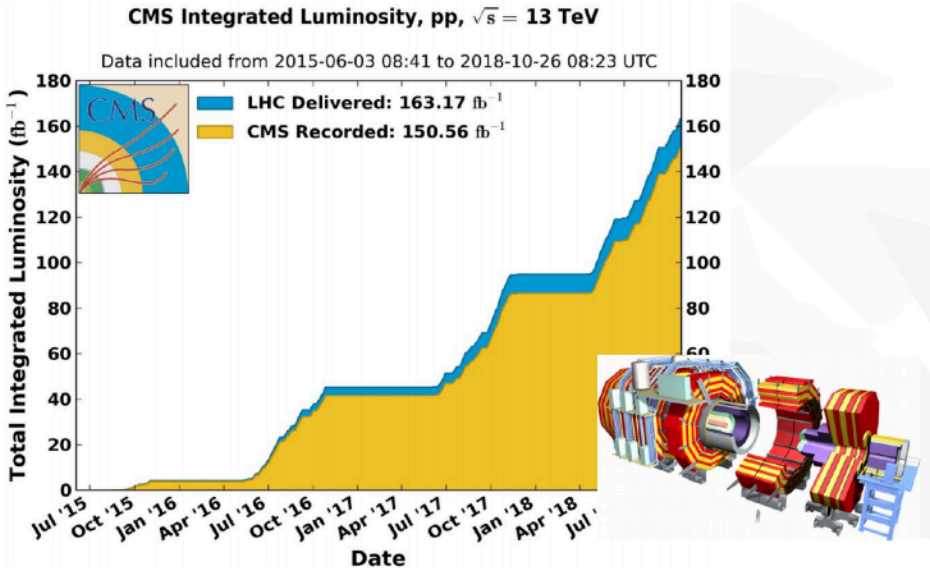


Shahram Rahatlou, Roma Sapienza & INFN

67

ATLAS/CMS searches



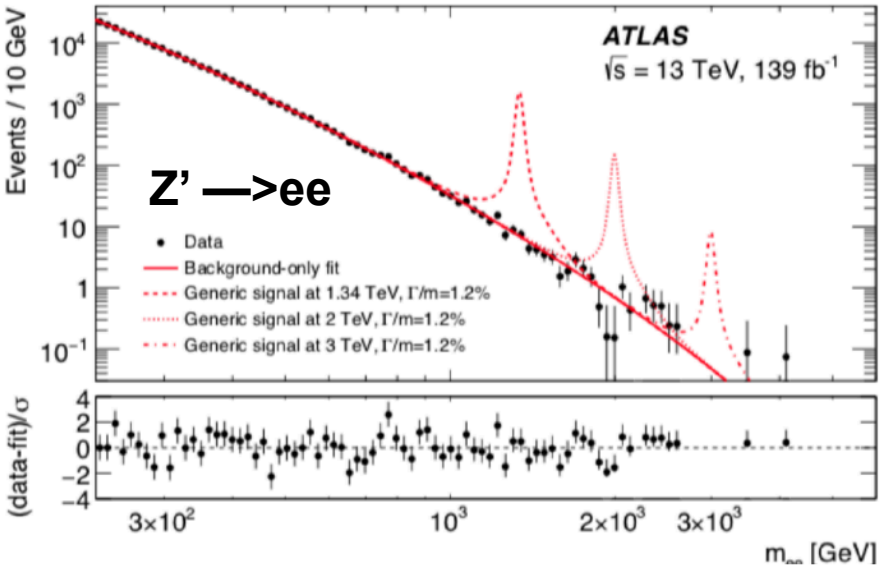


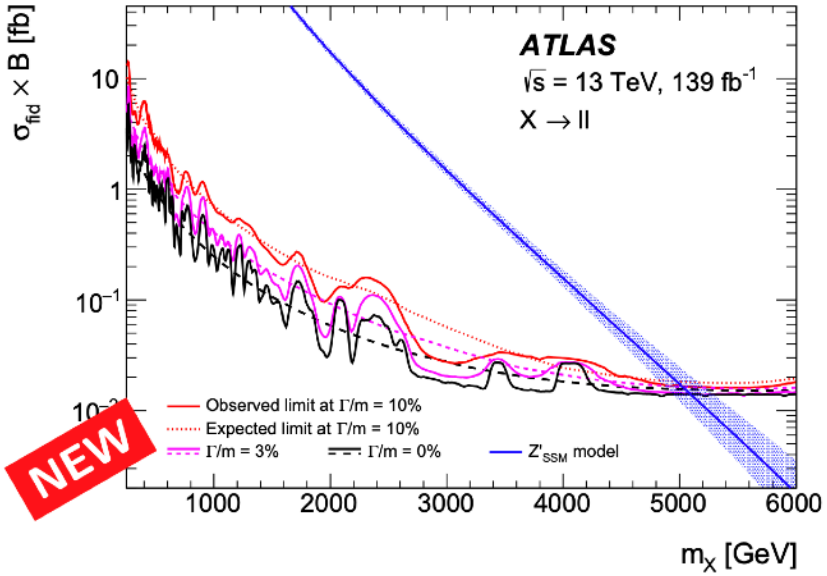
- Several new results with **full LHC Run 2 dataset**
  - Benefit from **increased luminosity**
  - Development/Use of **new techniques**

New Physics searches

Updates with high luminosity

Alberto Zucchetta





New Physics searches

Updates with high luminosity

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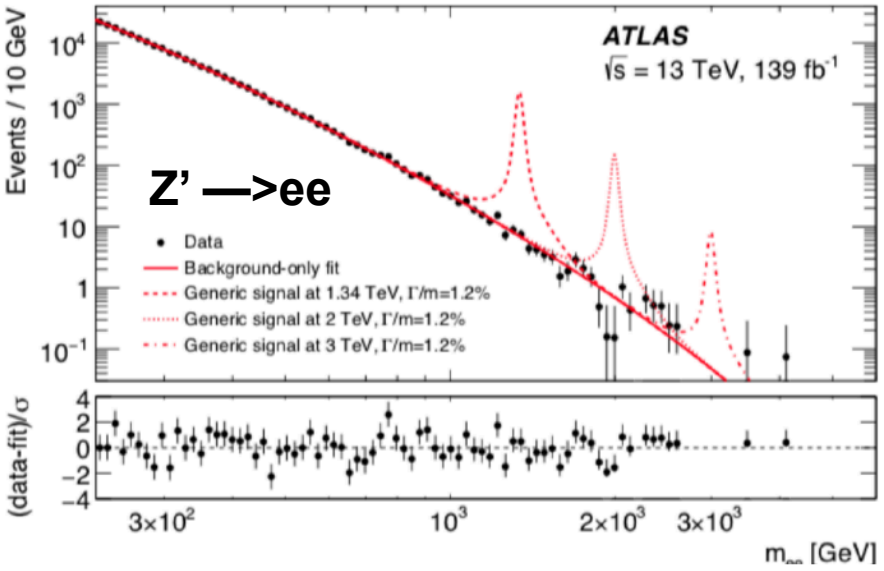
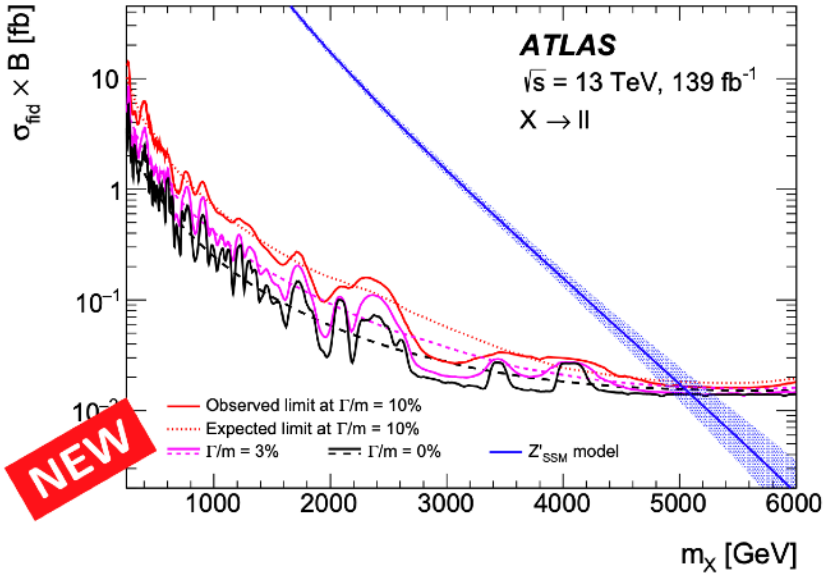
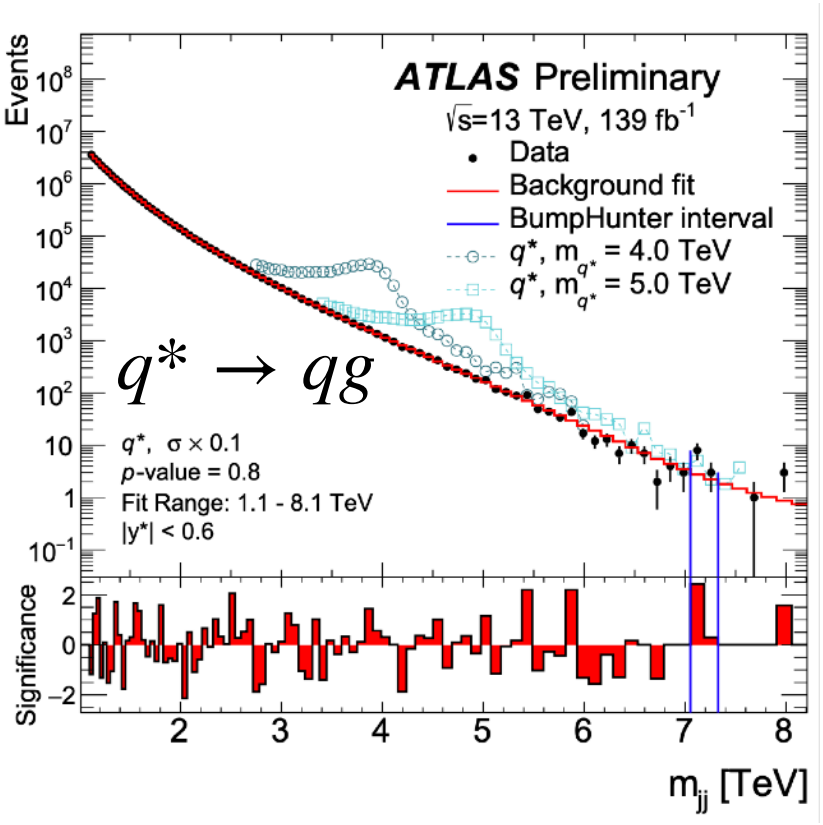




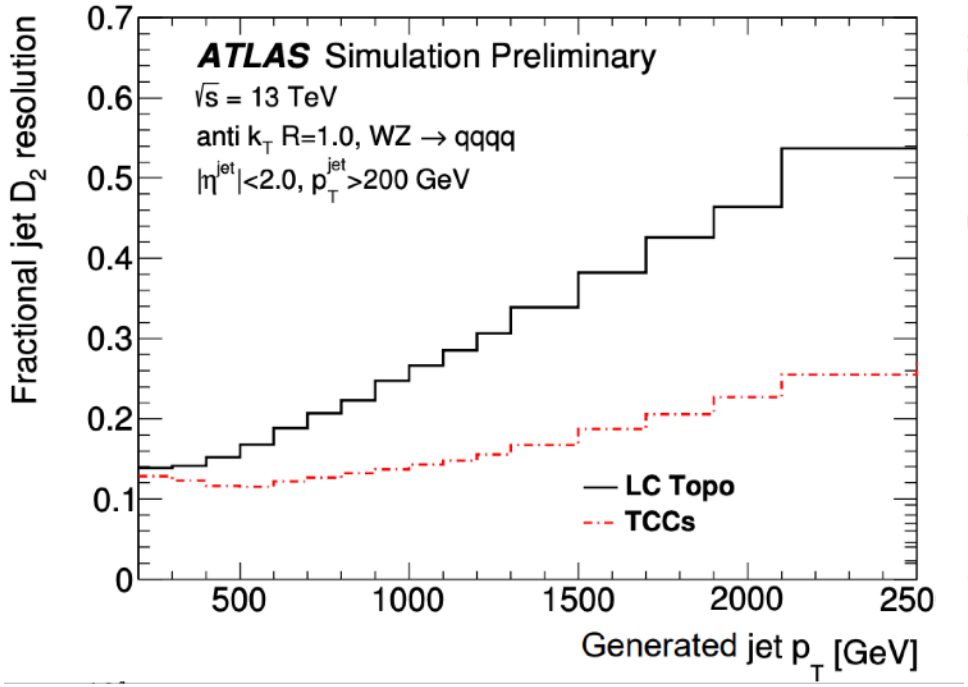


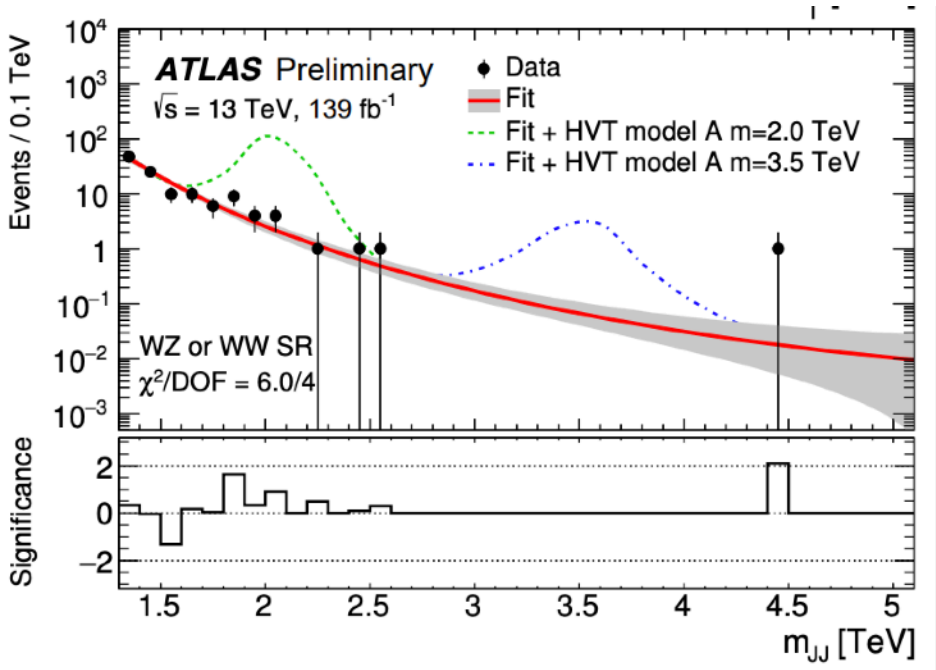
New Physics searches

Marcus M. Morgenstern

Improved performances: diboson resonances

- $W' \to WZ$ or $Z' \to ZZ/WW$
- Improvement in boson-jet identification (TCC jets)

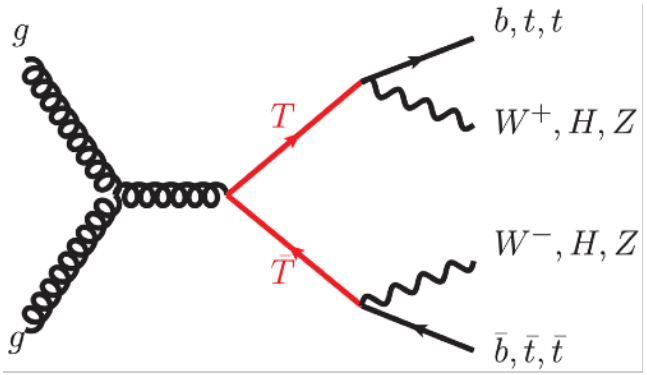




New Physics searches

Stéphanie Beauceron

Improved performances: vector-like quark searches (all-had)



New Physics searches

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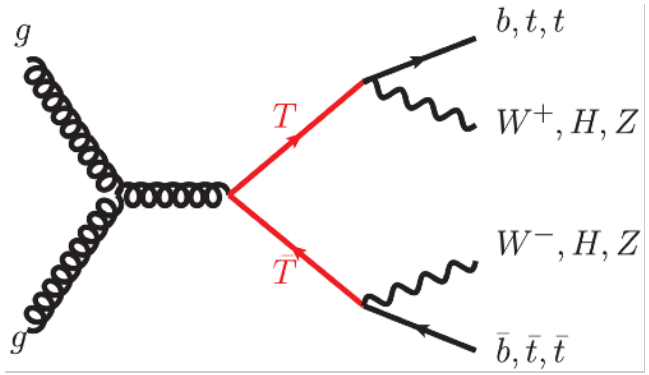
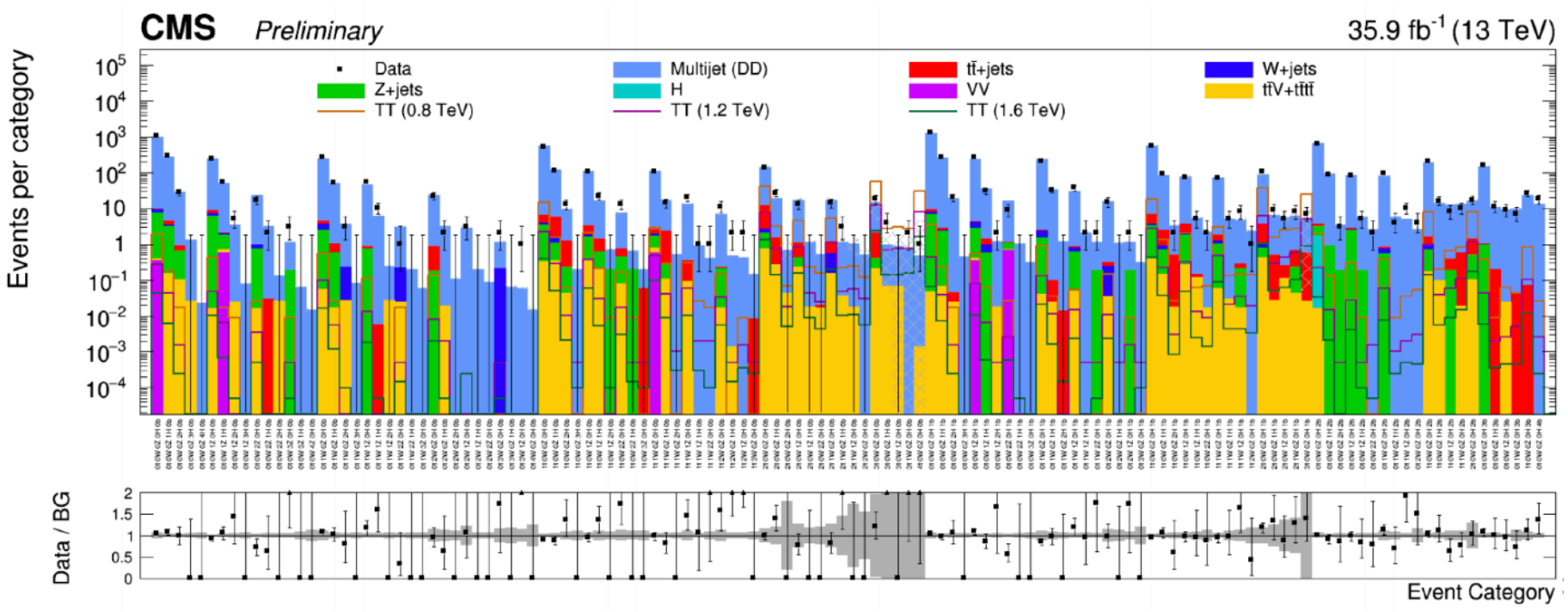


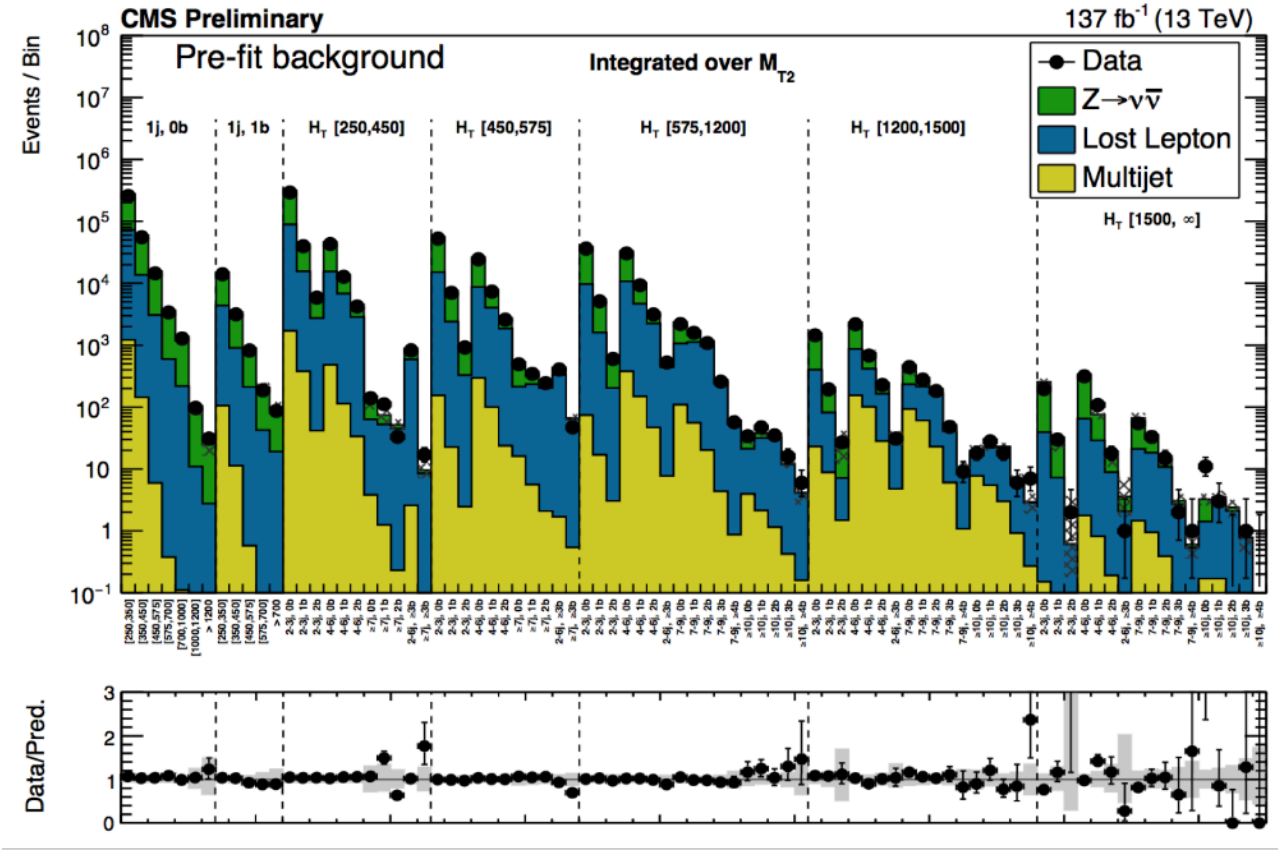
- "BEST" (Boosted Event Shape Tagger) NN used to identify different jet flavours
- Classification of events based on content (126 categories)
- **One of the most sensitive VLQ searches to date**

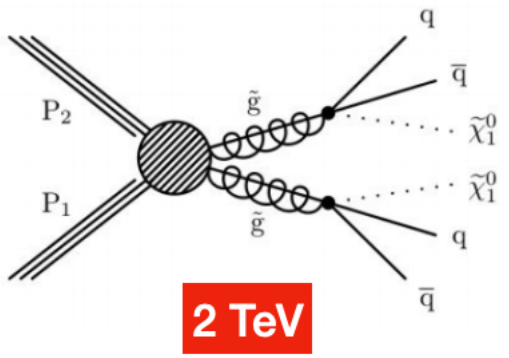


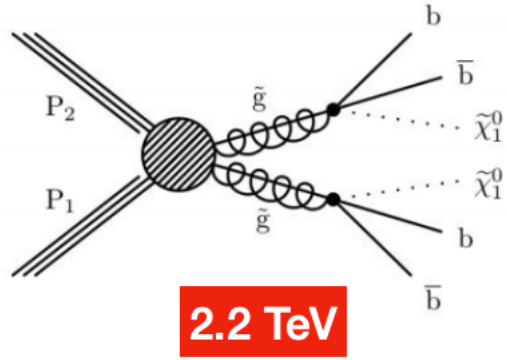
New Physics searches

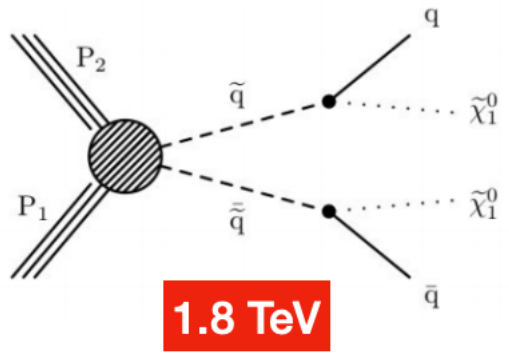
Nadja Strobbe

Improved techniques: generic strong SUSY searches









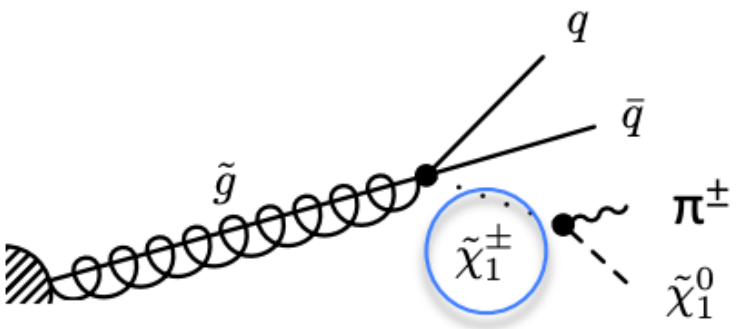
+ shape of discriminating variable (MT2) in each region

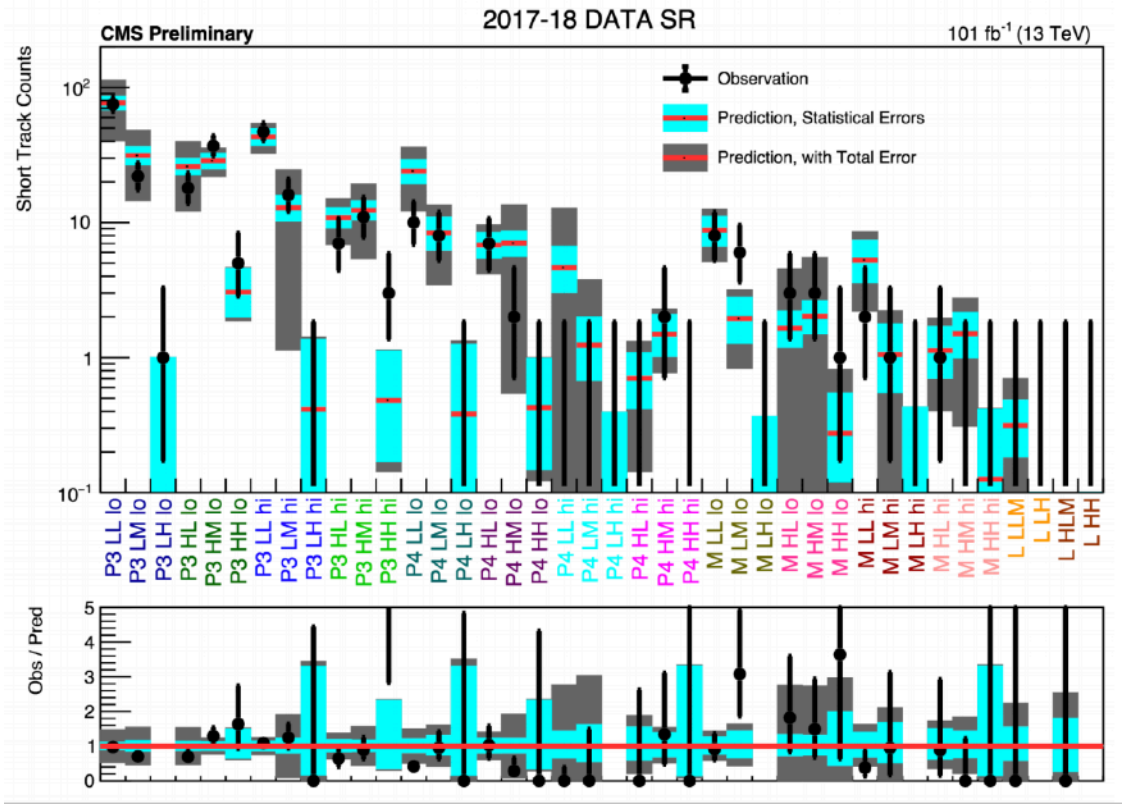
New Physics searches

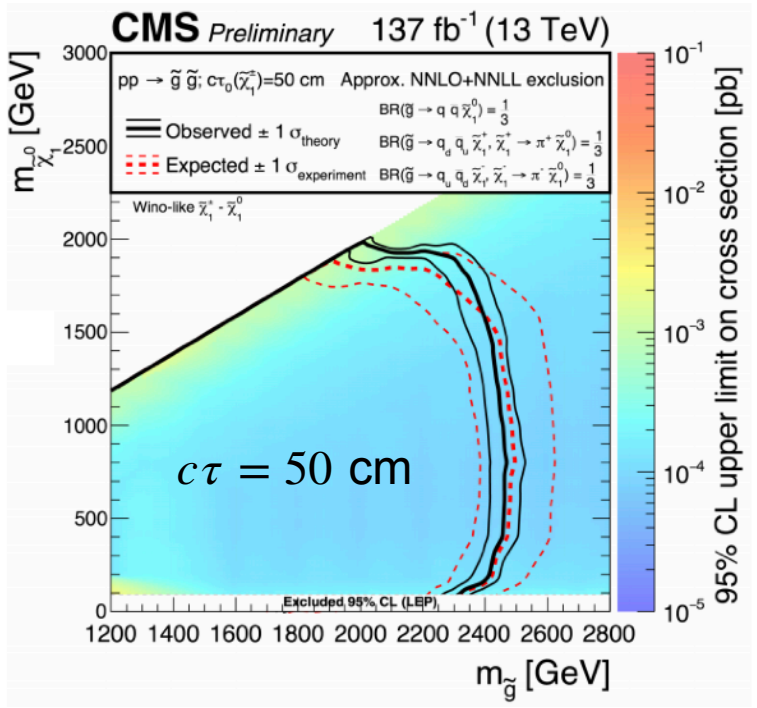
Improved techniques: long-lived particles

Mario Masciovecchio

- Also consider **long-lived charginos**
  - seen as **disappearing tracks**







New Physics searches

Indirect searches: rare decays/production modes

- Several searches for **indirect signs of new physics**
  - enhancements of rare processes (e.g. in the top sector)

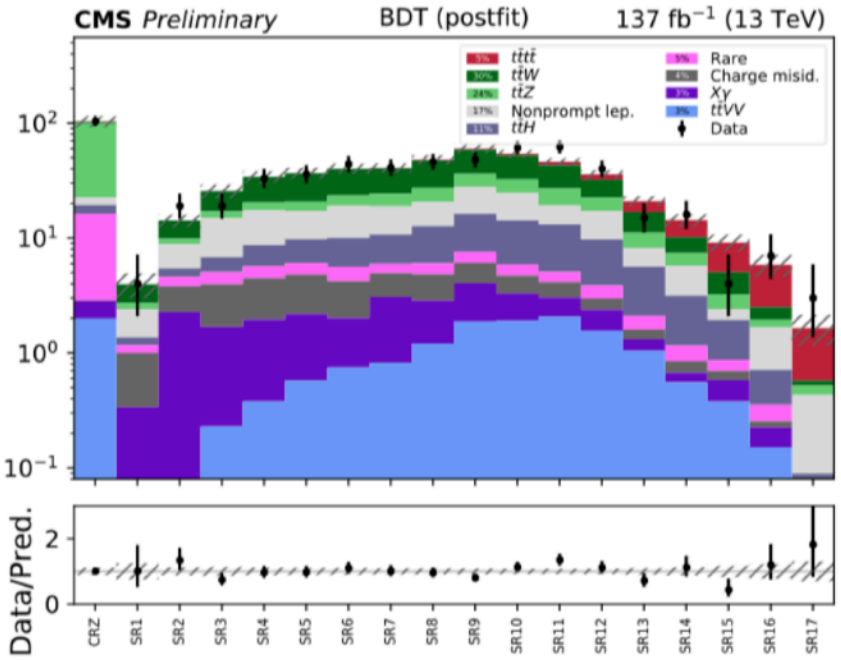
New Physics searches

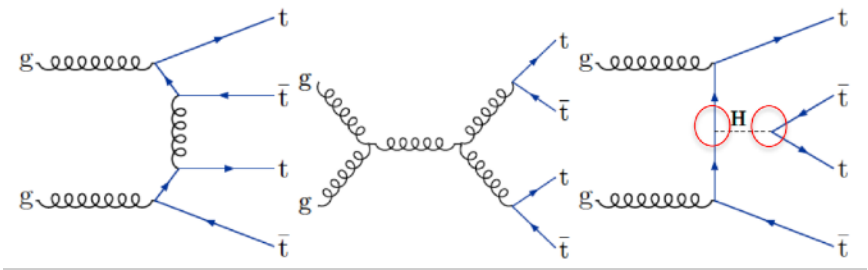
Indirect searches: rare decays/production modes

Kirill Spovpen

Vincenzo Vagnoni

- Several searches for **indirect signs of new physics**
  - enhancements of rare processes (e.g. in the top sector)



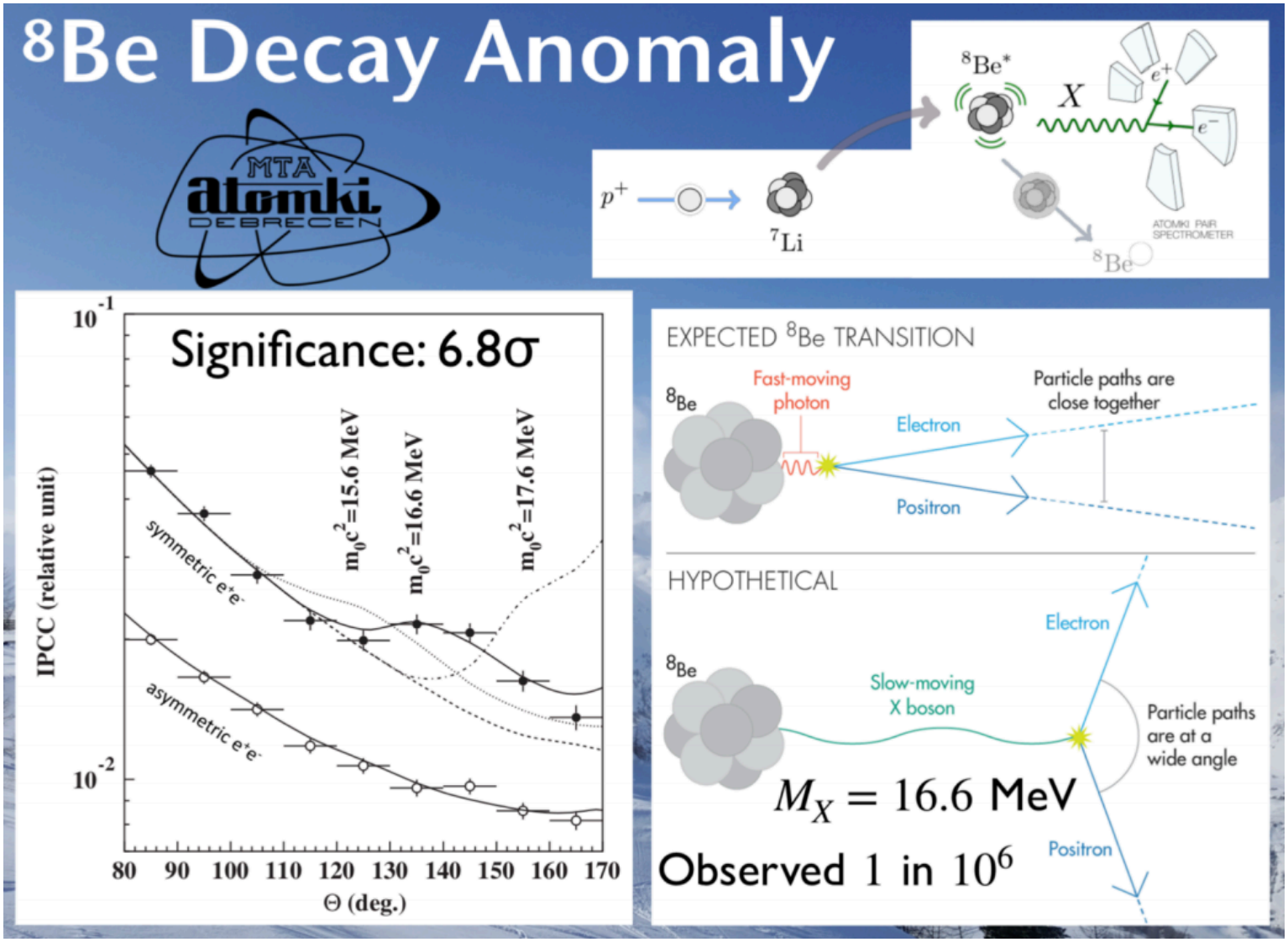


$$|y_t| / |y_t^{SM}| < 1.7 \text{ (95\% C.L.)}$$

Low-energy anomalies

Low-energy anomalies

Simon King



Summary

- Very nice conference **with major announcements !**
- **Many more updates to discover**
  - http://moriond.in2p3.fr/2019/EW/Program.html
  - http://moriond.in2p3.fr/2019/QCD/Program.html
- **Take-away messages**
  - LHCb had **very strong updates** this Moriond (cCPV, LFU)
  - **SM holding still**: predictions tend to be verified (precision)
  - **BSM searches**: some intriguing results still to be investigated/confirmed

Thanks !