Selected results from Moriond

Neutrino physics, flavour physics (quark sector), dark matter (direct detection)

~100 talks and several hundred experimental results

A very limited selection for this discussion

Many slides borrowed from Marumi Kado (thanks!)

Krisztian Peters
DESY, 17.4.2023

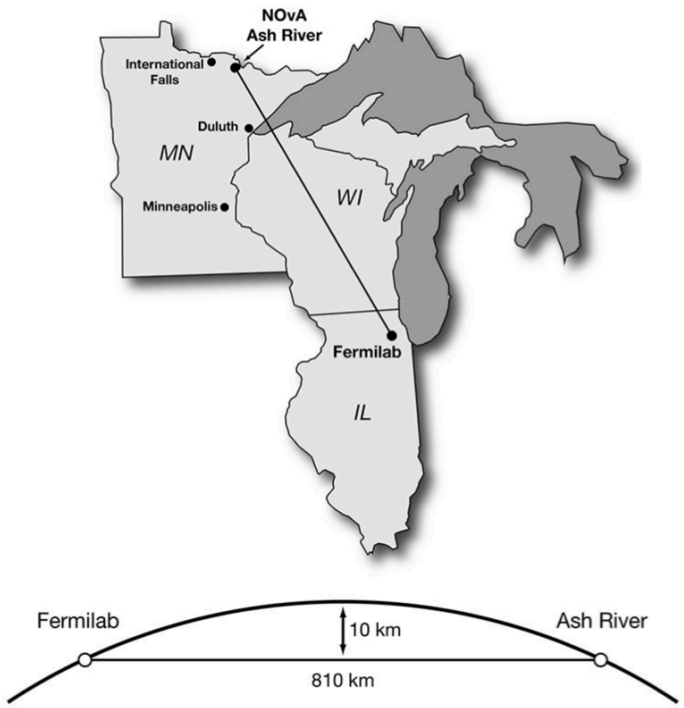
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Accelerator Neutrinos

The current two main players ν_μ-beam experiments!

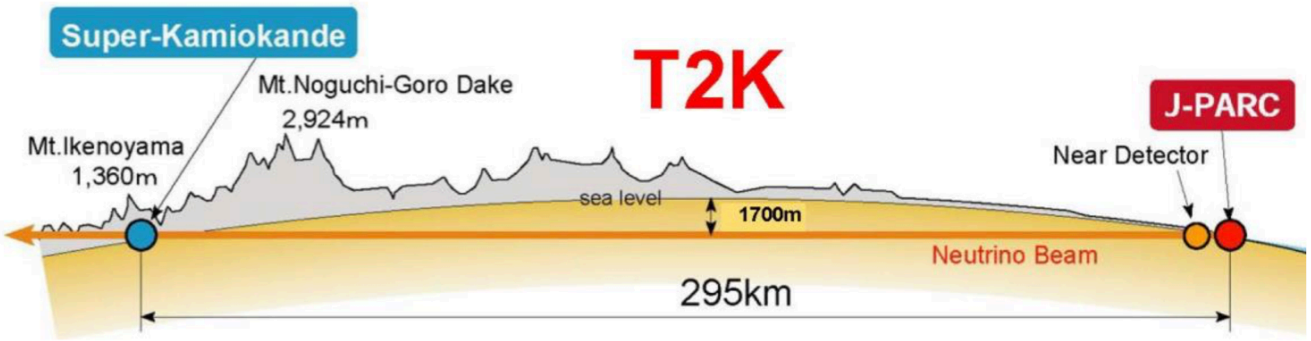
NOvA



810 km/GeV - E 2 GeV - 0.8° off-axis

Improved sensitivity to mass ordering!

T2K



490 km/GeV - E 0.6 GeV - 2.5° off-axis

Parameterisation of neutrino mixing

Pontecorvo-Maki-Nakagawa-Sakata (PMNS) Matrix:

- 3 mixing angles: θ_{12}, θ_{23}, θ_{13} **SINCE 2012: all measured**
- **1 Dirac-phase (CP violating): δ**

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

Really maximal? Octant?

$\Theta_{23} \approx 45°$

atmospheric neutrinos, neutrino beams

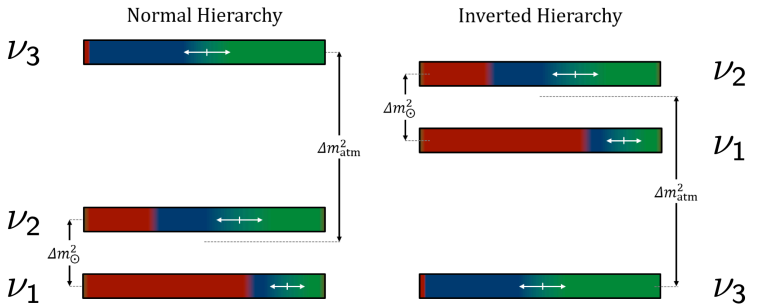
$\Theta_{13} \approx 9°$, δ ?

reactor neutrinos, neutrino beams

$\Theta_{12} \approx 33°$

solar neutrinos, reactor neutrinos

- Flavour eigenstates; ν_e, ν_μ and ν_τ (interact)
- Mass eigenstates; ν_1, ν_2 and ν_3 (propagate)

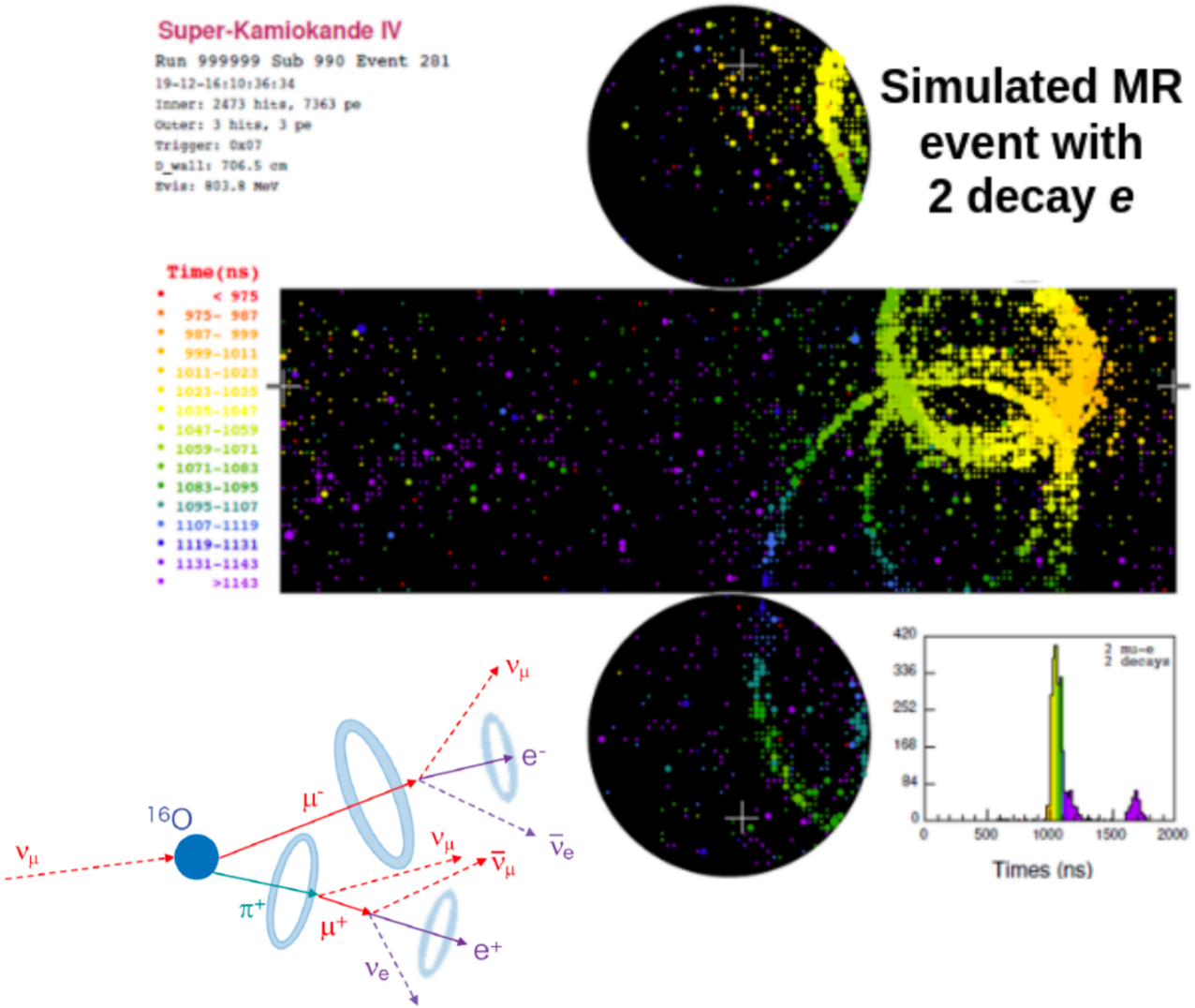


Long-baseline accelerator experiments $L/E \sim 10^{2-3}$ km/GeV are sensitive to

NO/IO, **Θ_{23}** and δ_{CP}
(also θ_{13})

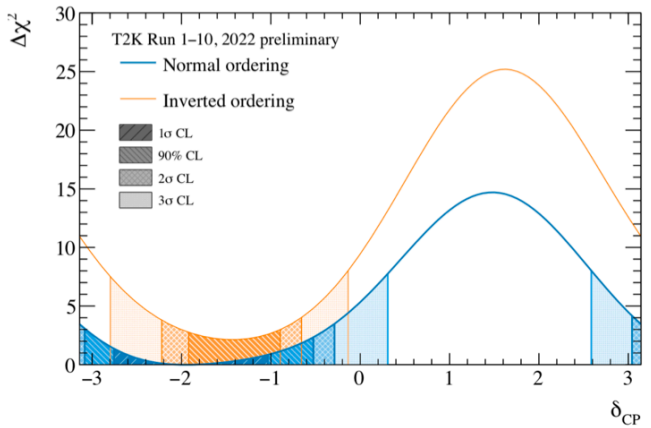
Accelerator Neutrinos

T2K



- New analysis on the ~ 36 × 10^{20} POT collected up to 2020
- New analysis (with the addition of multi-ring events from additional pions/decay products)
- Overall fit uses θ_{13} from reactor data (bayesian and frequentist analyses yielding consistent results), **slight preference for upper octant and normal ordering!**

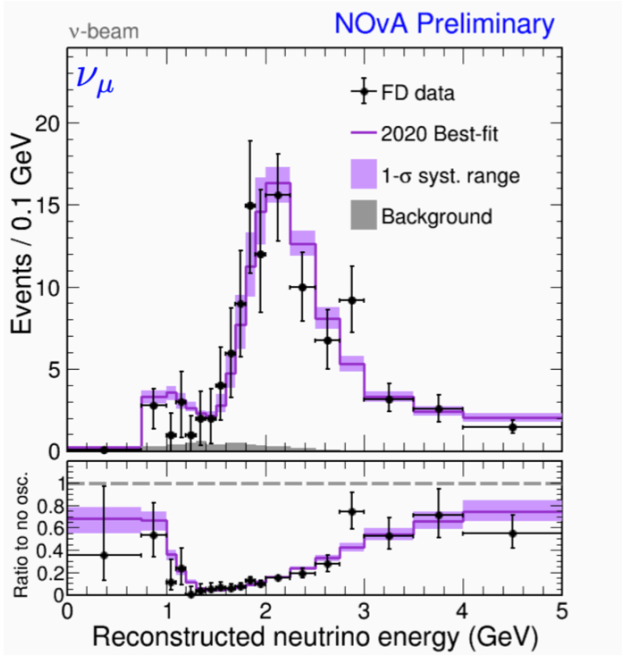
	$\sin^2\theta_{23} < 0.5$	$\sin^2\theta_{23} > 0.5$	Line total
Normal ordering	0.236	0.540	0.776
Inverted ordering	0.049	0.174	0.224
Column total	0.285	0.715	1.000

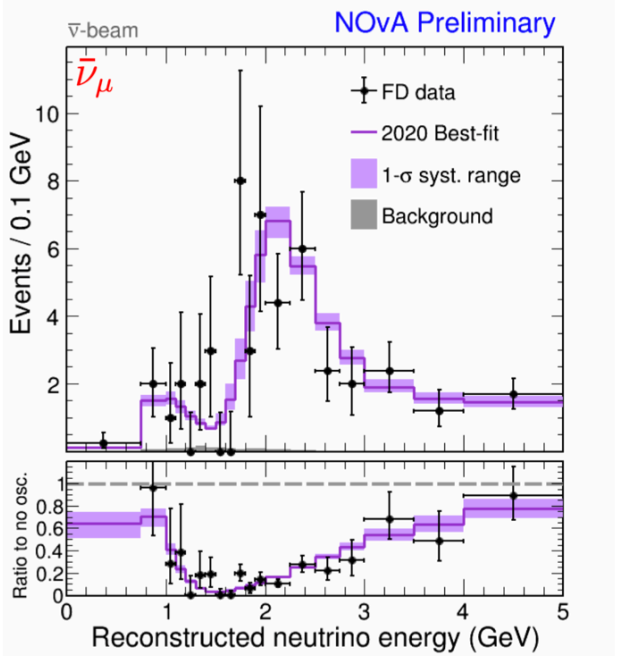


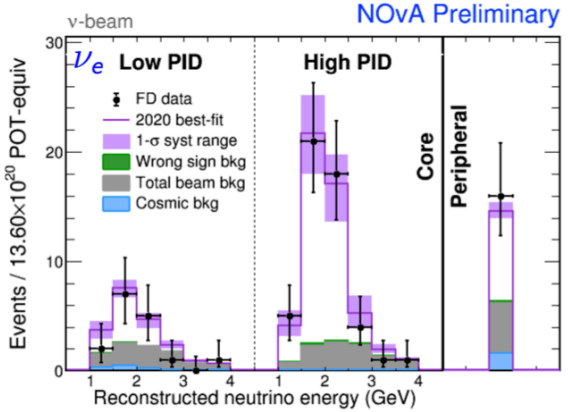
δ_{CP} best fit at -2.18 (-0.694π), CP conserving values 0 and π are outside of 90% CL intervals

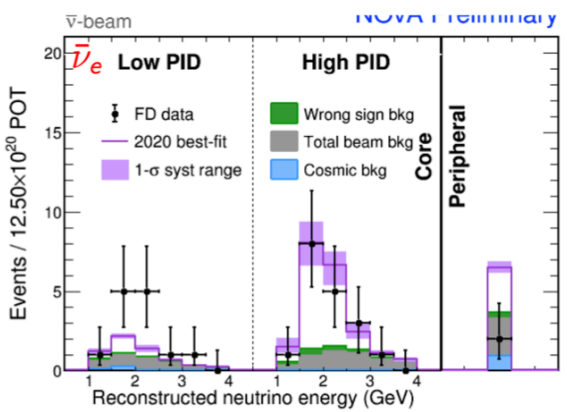
Accelerator Neutrinos

NOvA





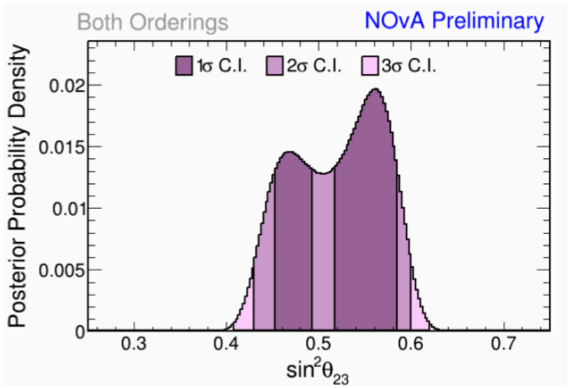


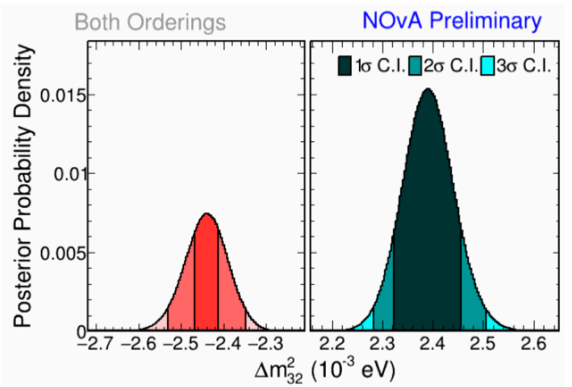


$> 4\,\sigma$ evidence of electron antineutrino appearance

- New analysis on the ~ 26 × 10^{20} POT collected up to 2020 (Bayesian analysis)
- 37 × 10^{20} POT neutrino data available now
- Slight preference for upper octant and normal ordering

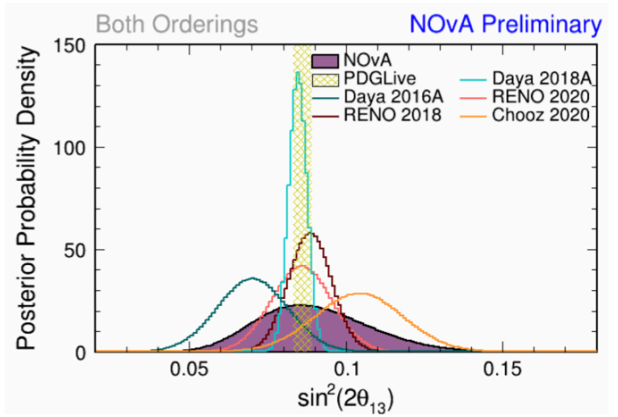
New for Moriond EW 2023





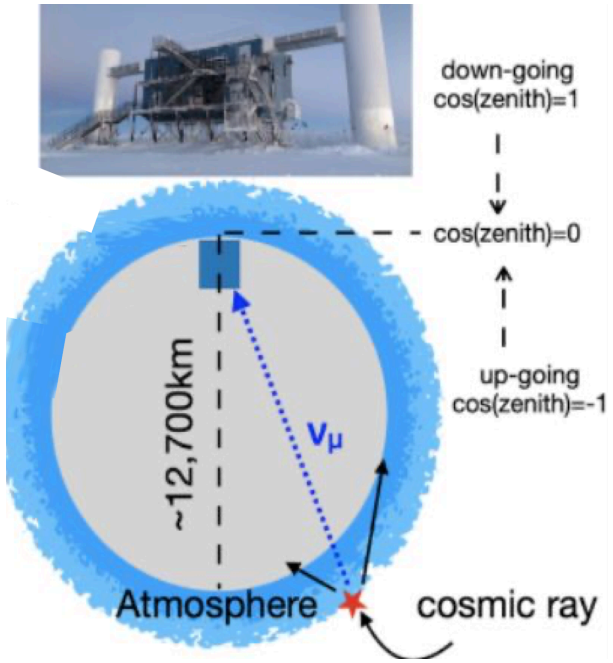
First NOvA measurement of $\sin^2\theta_{13}$

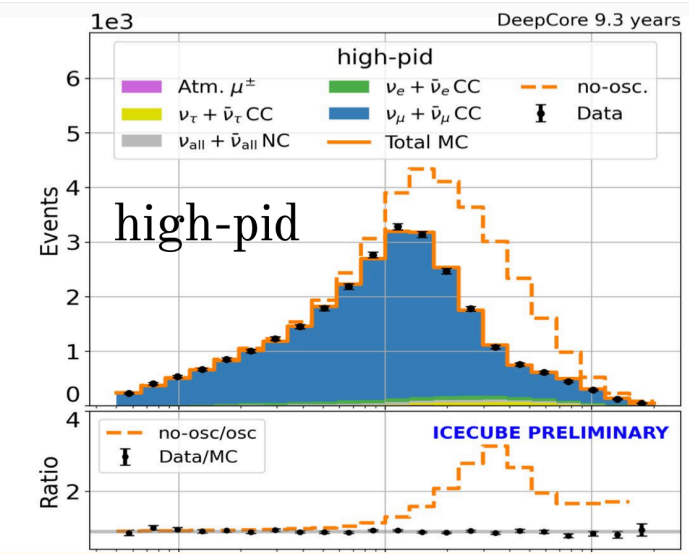
$$\sin^2(2\theta_{13}) = 0.085^{+0.020}_{-0.016}$$

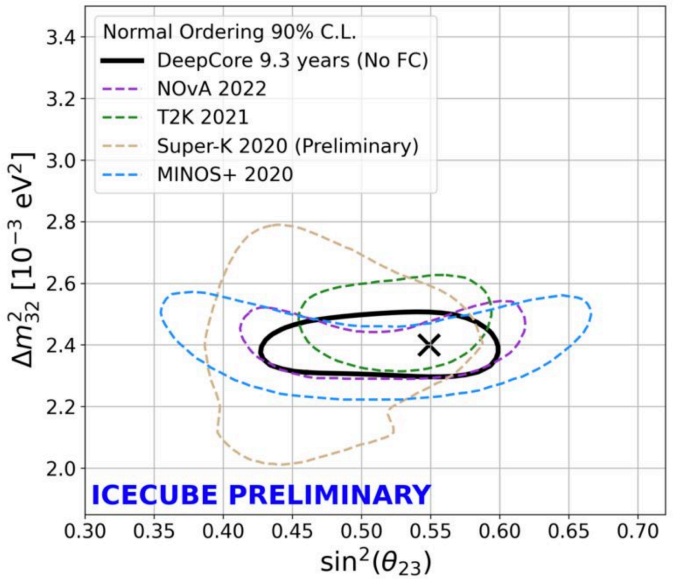


Muon Neutrino Disappearance from Ice Cube

With Deep Core







Wide ranges of both energy (E) and baseline (L), and largest values

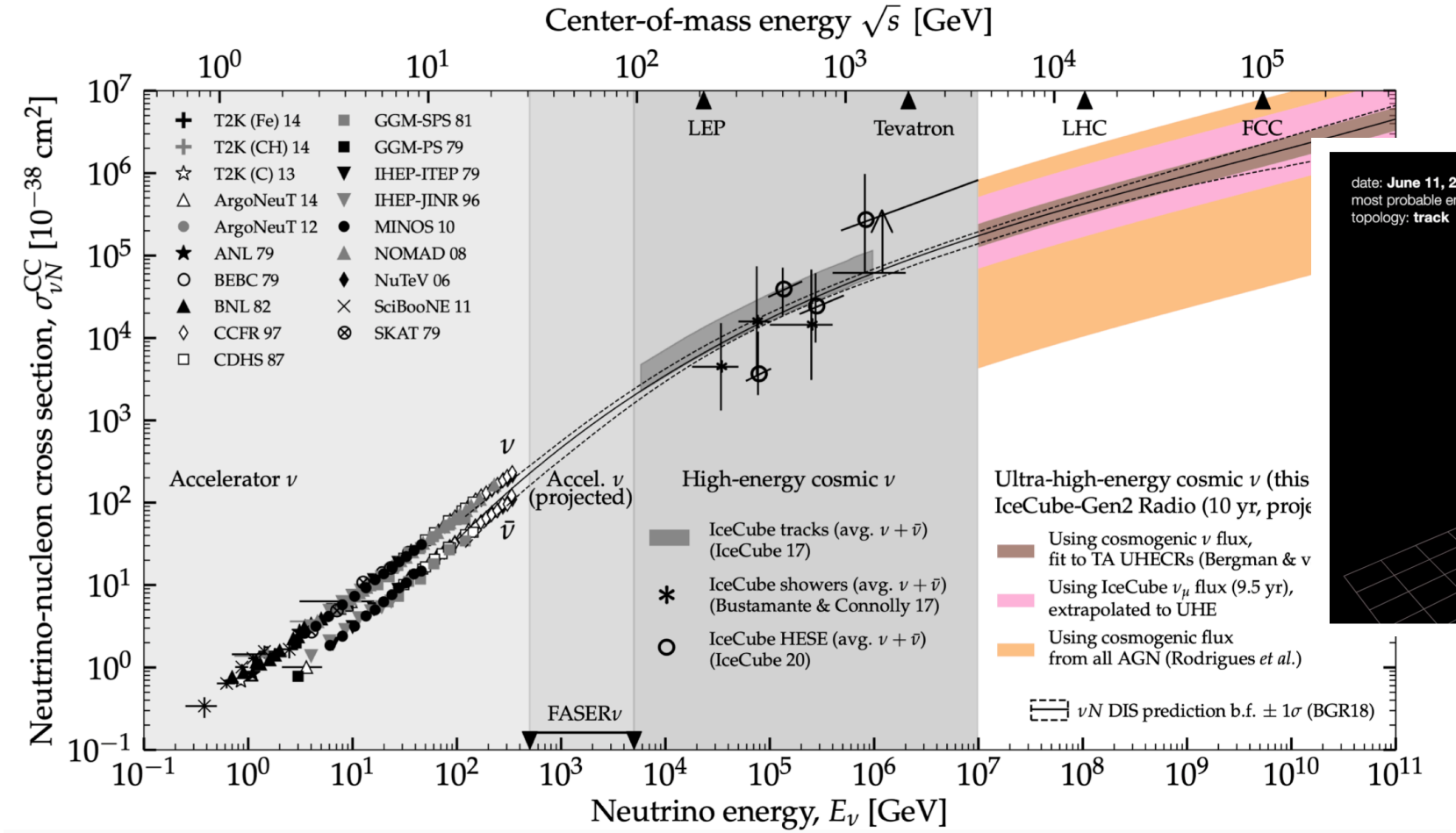
Neutrino distance of travel (L) calculated using arrival direction

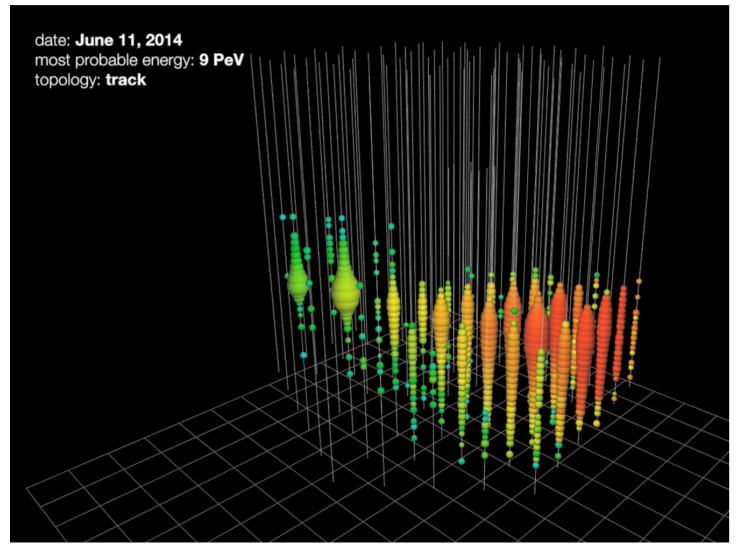
First-time using the highest-statistic (9.3yr) DeepCore atmospheric neutrino dataset for oscillation measurements

Machine learning tools used for multi-purpose reconstruction

Results competitive Long Baseline results!

First decade of high energy neutrino astronomy



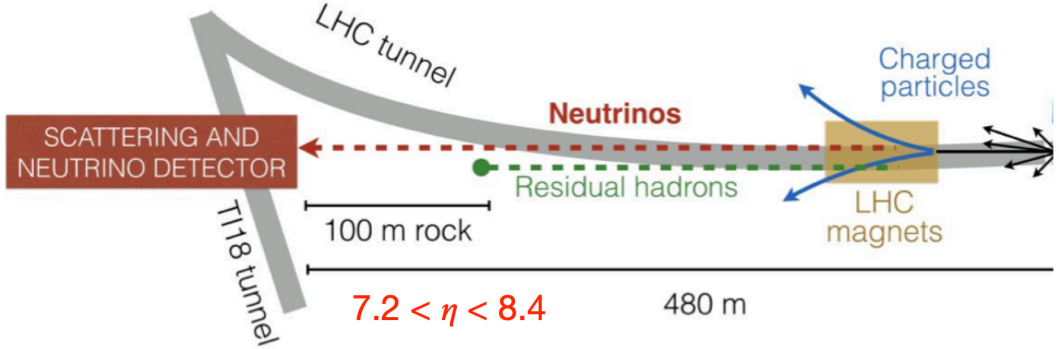


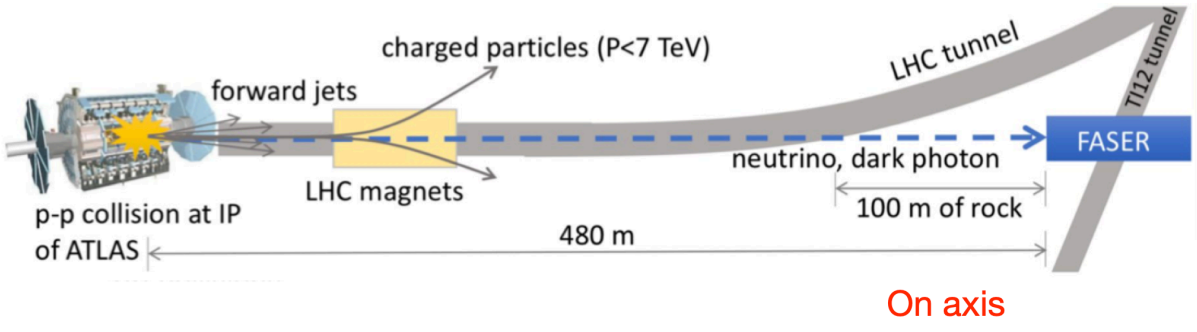
Era of multi-messenger and high-energy neutrino astronomy (e.g. evidence for active galaxies)

Accelerator neutrinos, up to O(100 GeV)

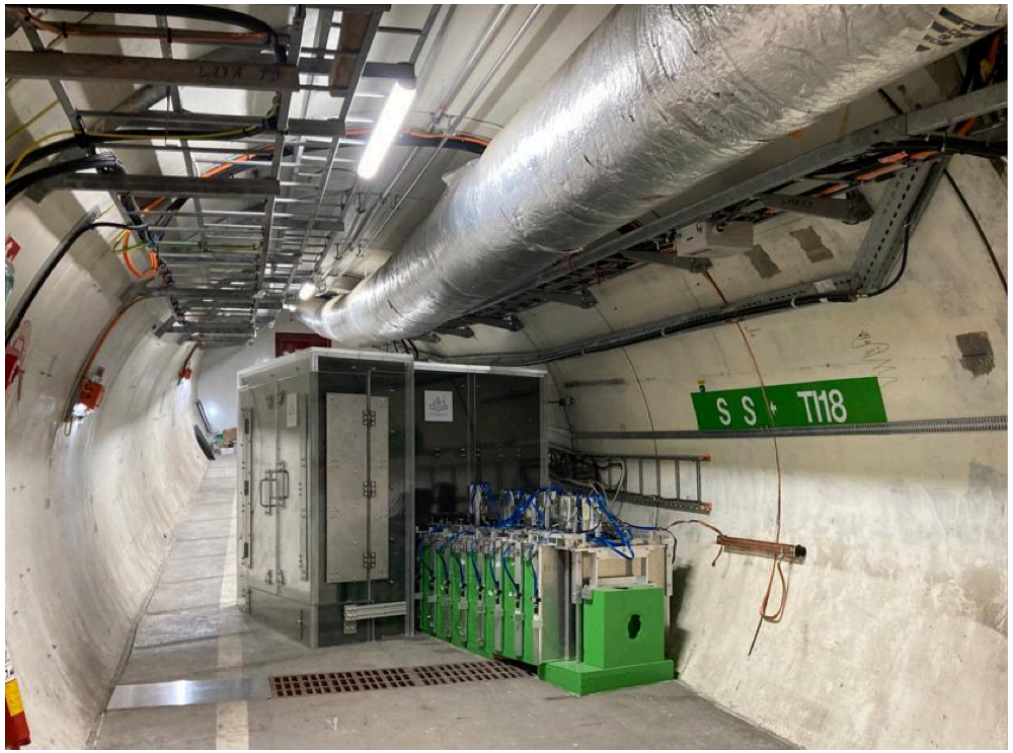
Cosmic neutrinos

Collider neutrinos at the LHC

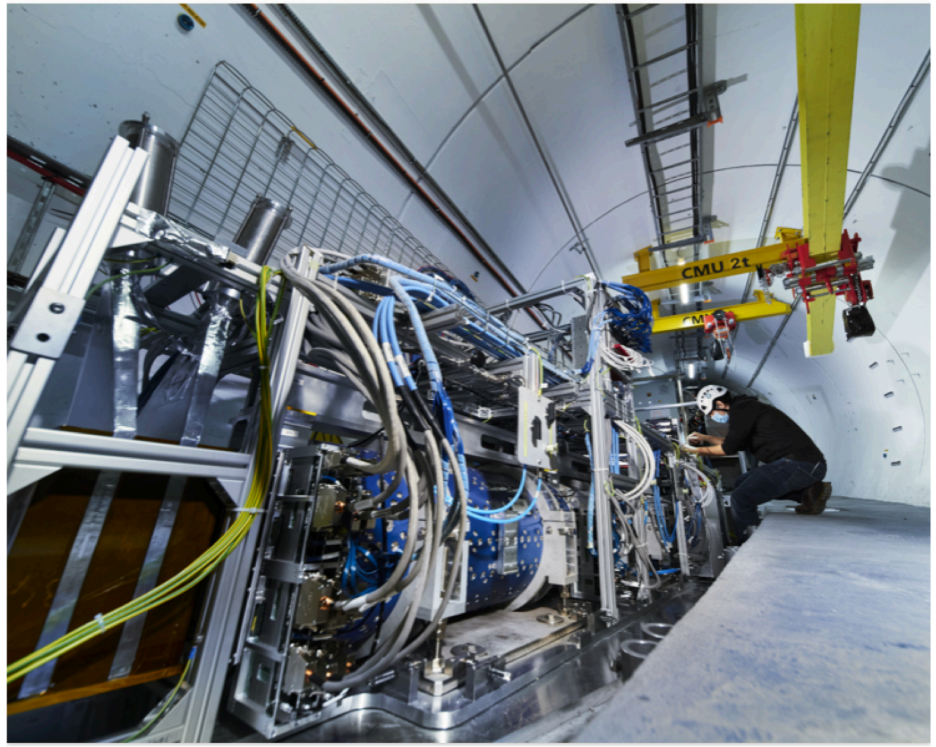




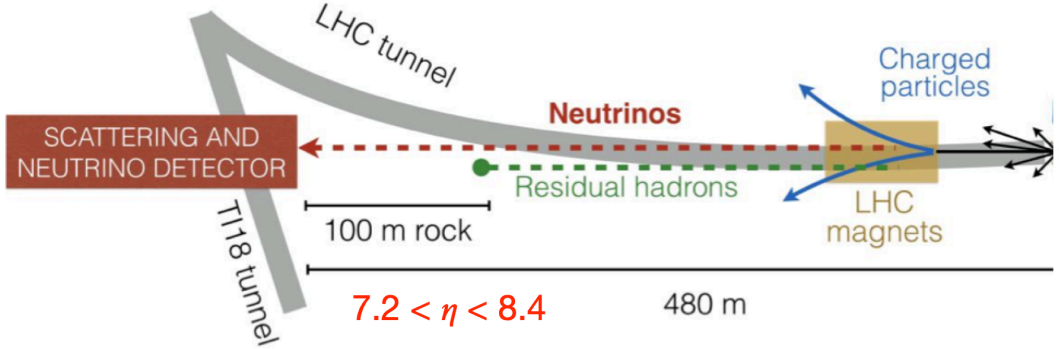
SND

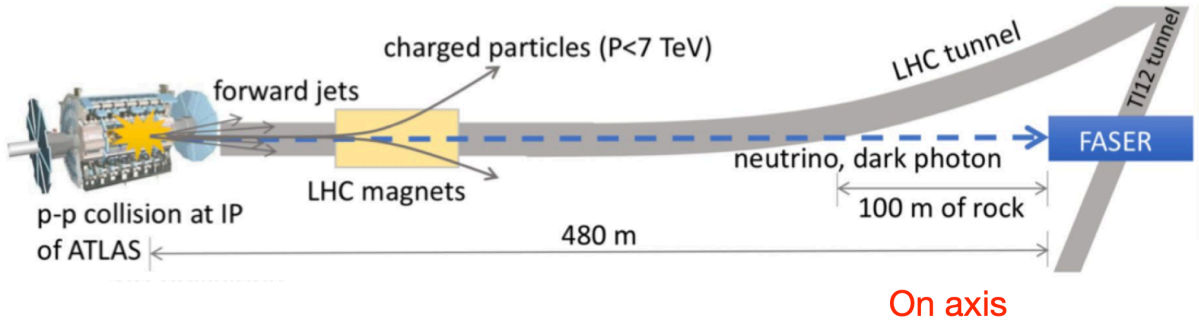


Faser-ν

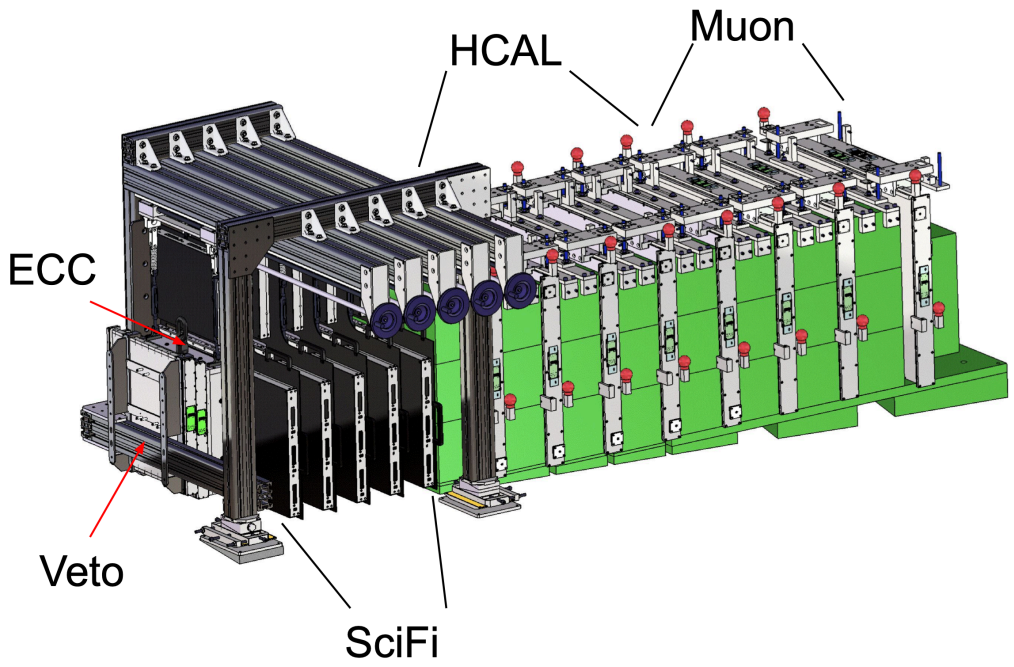


Collider neutrinos at the LHC



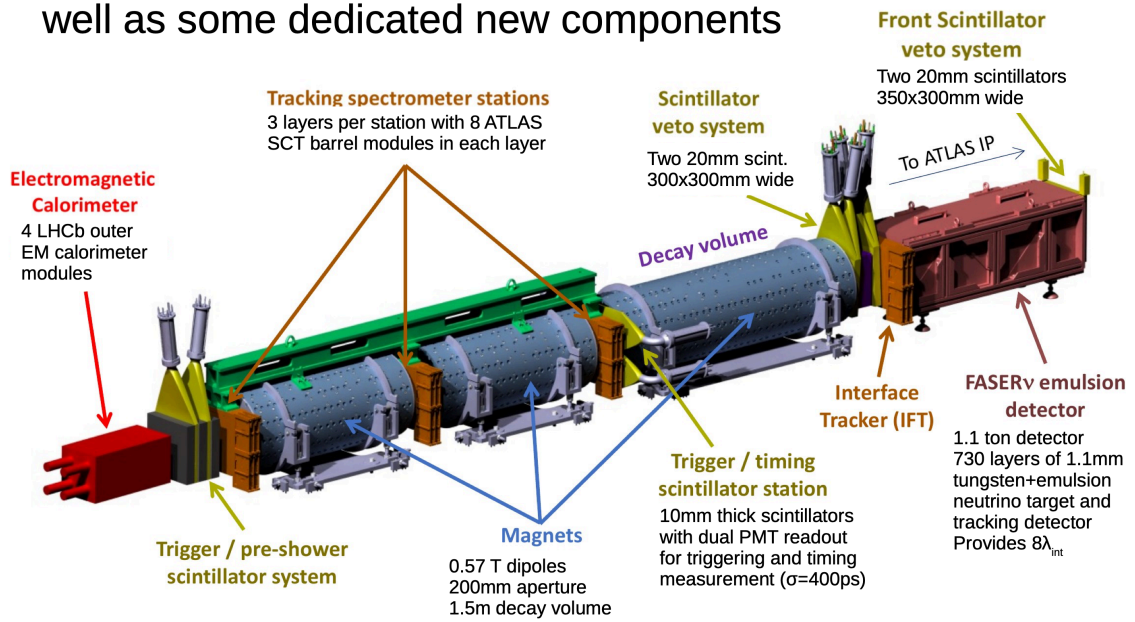


SND

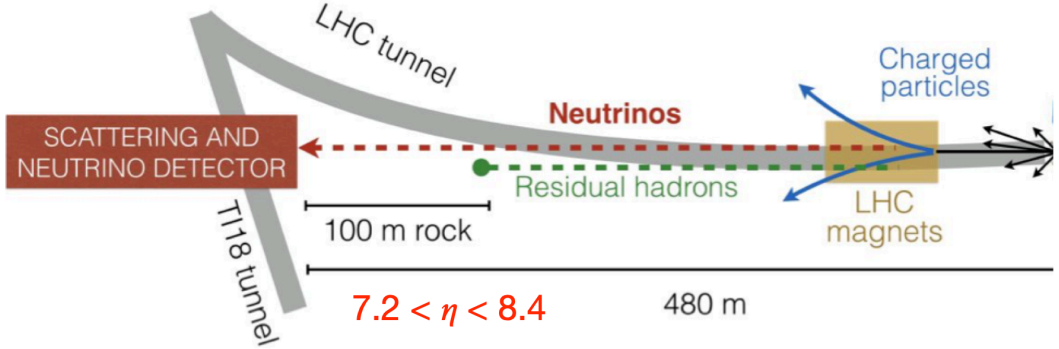


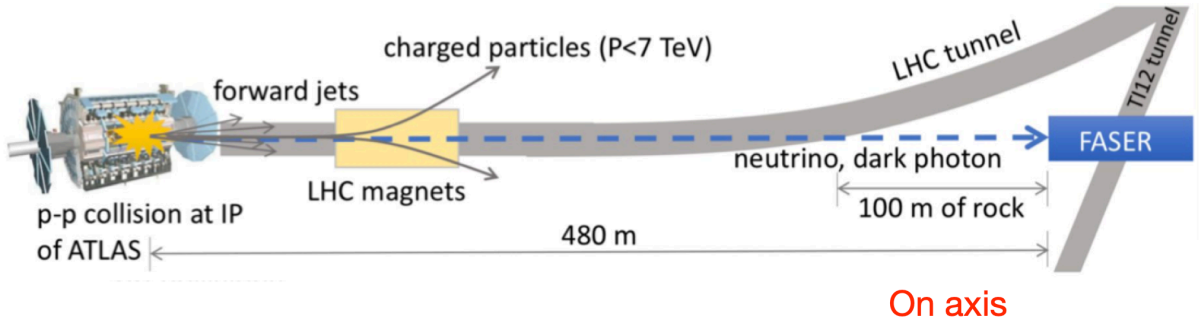
Faser-ν

Experiment built from existing spare parts as well as some dedicated new components

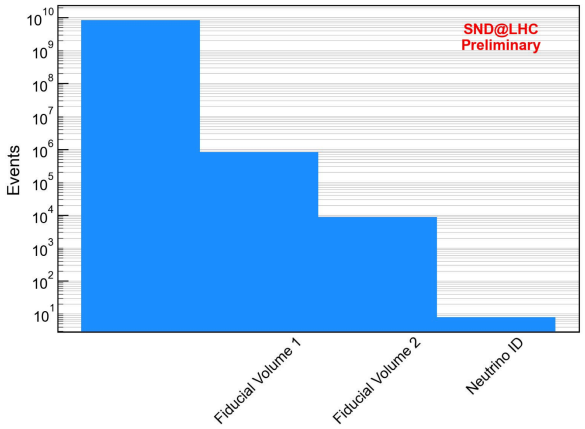


Collider neutrinos at the LHC





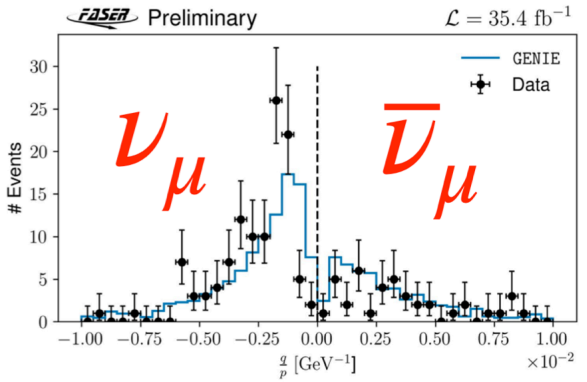
SND



5 events expected and 8 observed (0.2 background)

Approximately 5σ observation!

Faser-v

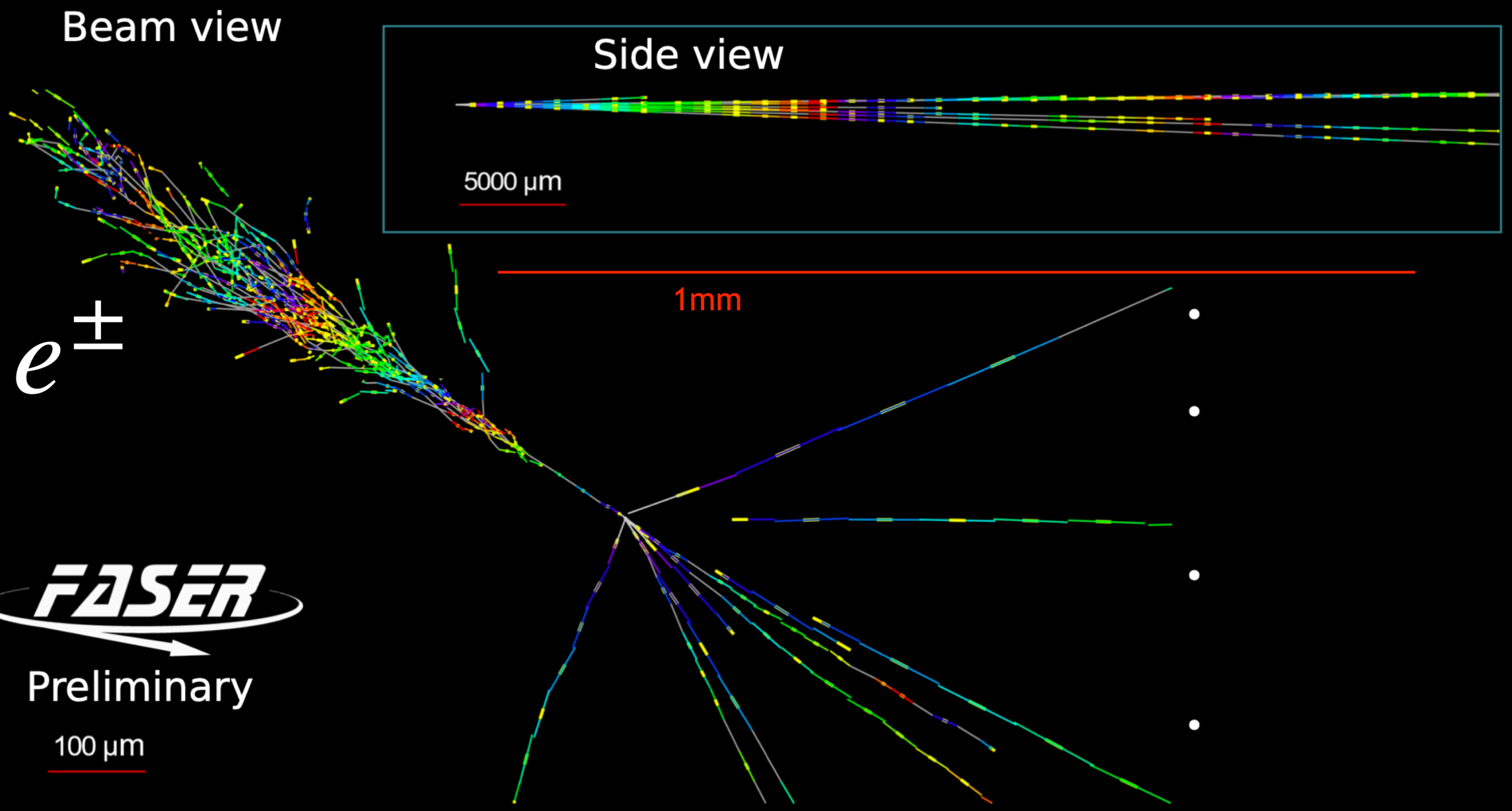


150 events expected and 153 observed (0.2 background!!)

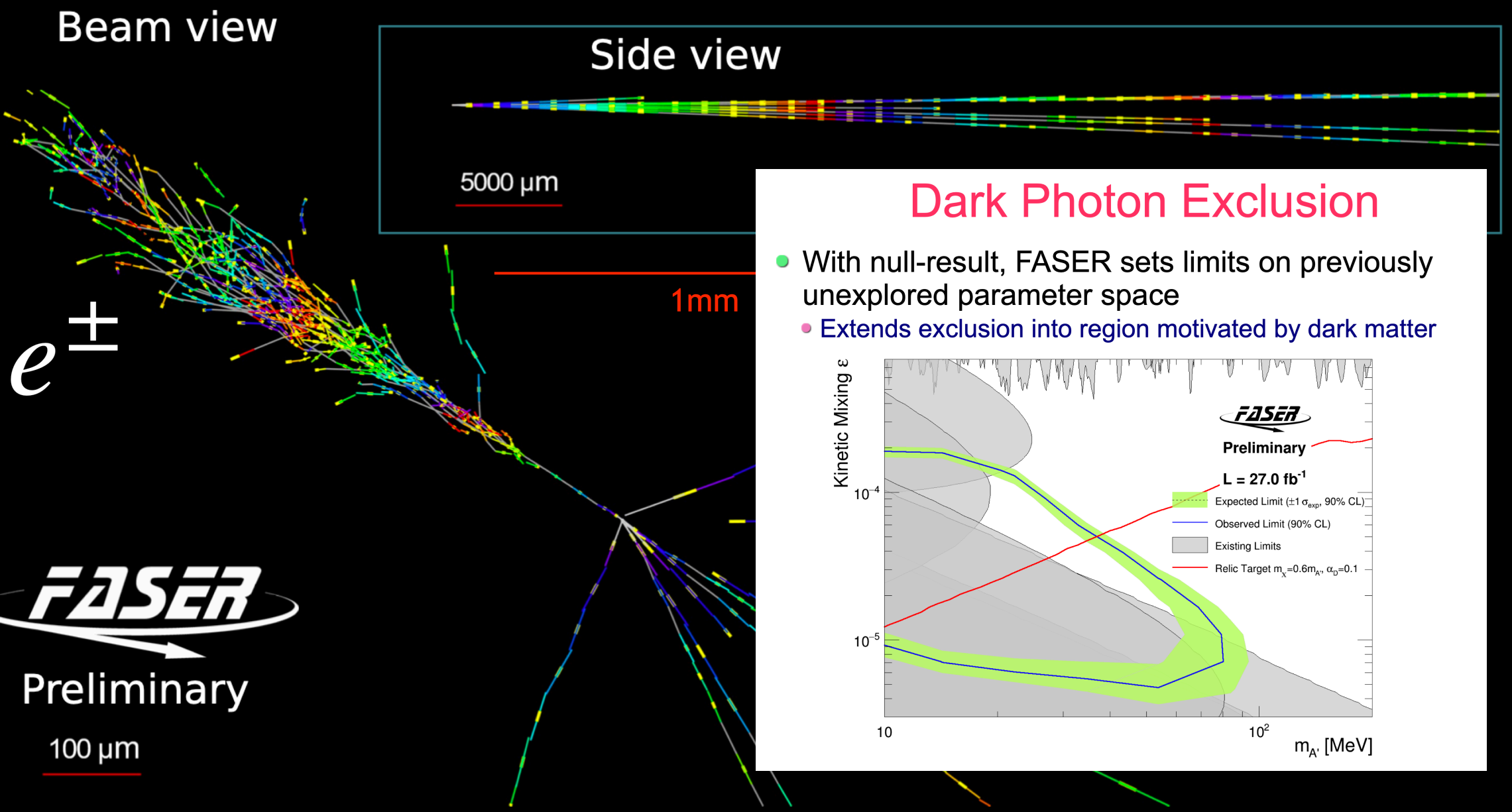
16σ observation!

First time observation of collider neutrinos, a new aspect of neutrino physics

Looking forward to the emulsion results!



Looking forward to the emulsion results!



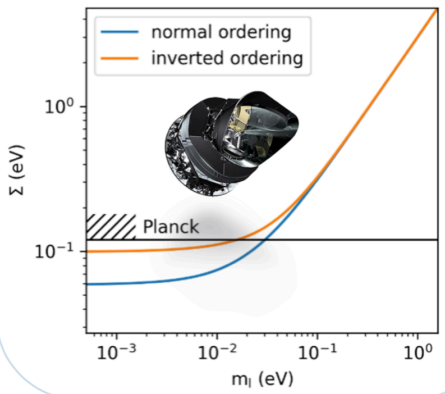
Dark Photon Exclusion

- With null-result, FASER sets limits on previously unexplored parameter space
  - Extends exclusion into region motivated by dark matter

Further neutrino results

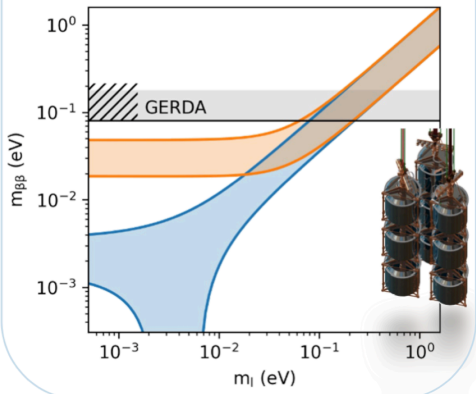
Cosmology

$$\Sigma = \sum_i m_i$$



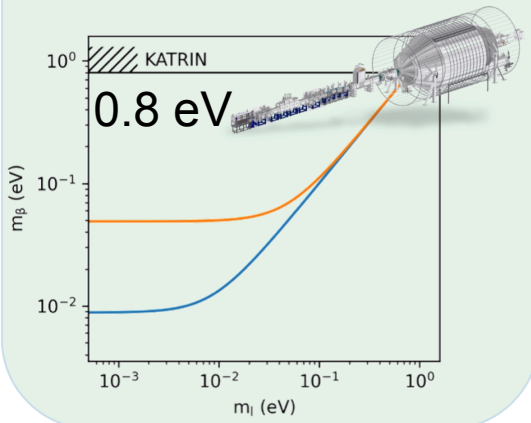
Neutrinoless ßß decay

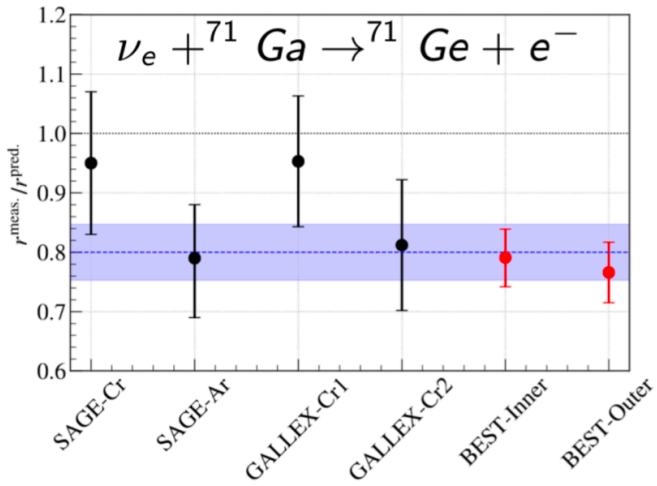
$$m_{\beta\beta} = \sum_i U_{ei}^2 \cdot m_i$$



ß-decay kinematics

$$m^2_{\nu/\beta} = \sum_i |U_{ei}|^2 \cdot m_i^2$$



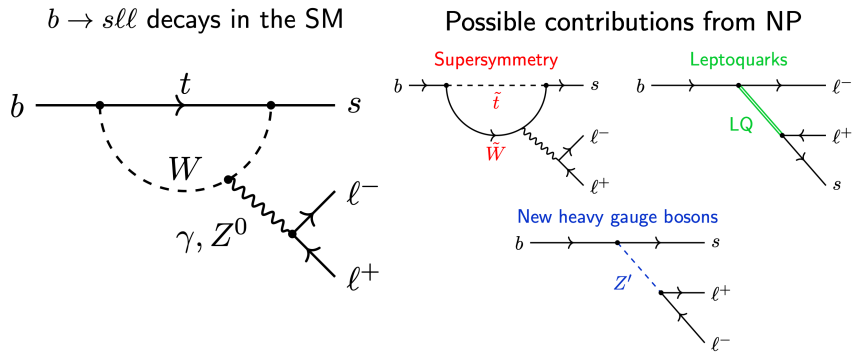


Strong limits from double beta decay experiments and KATRIN

Anomalies do not seem to be interpretable as sterile neutrinos (backgrounds and nuclear models)

Lepton Flavour Universality in $b \to s\ell\ell$ decays

LHCb



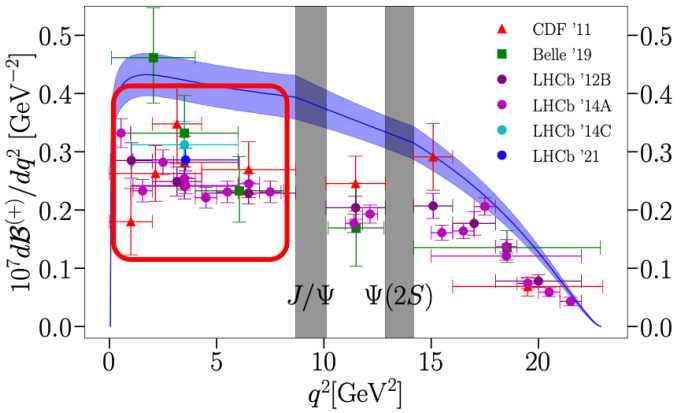
As EXP clean as possible…

$$R_K = \frac{\mathcal{B}(B^+ \to K^+ \mu^+\mu^-)}{\mathcal{B}(B^+ \to K^+ e^+e^-)} \times \overbrace{\frac{\mathcal{B}(B^+ \to K^+ J/\psi(\to e^+e^-))}{\mathcal{B}(B^+ \to K^+ J/\psi(\to \mu^+\mu^-))}}^{r_{J/\psi}^{-1}=1 \text{ [PRD 88 (2013) 3]}}$$

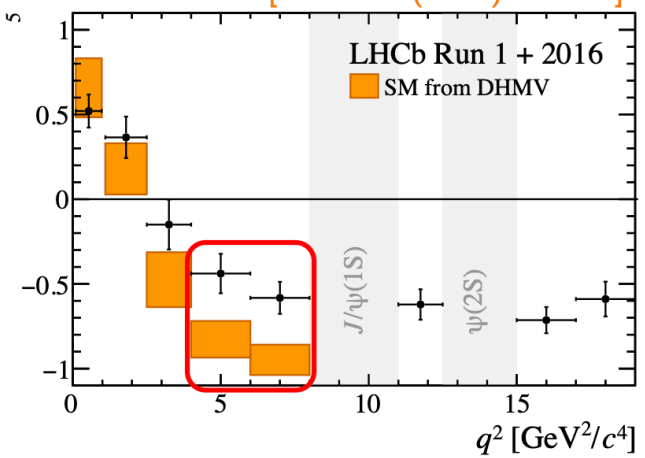
$b \to s\ell\ell$ Observables

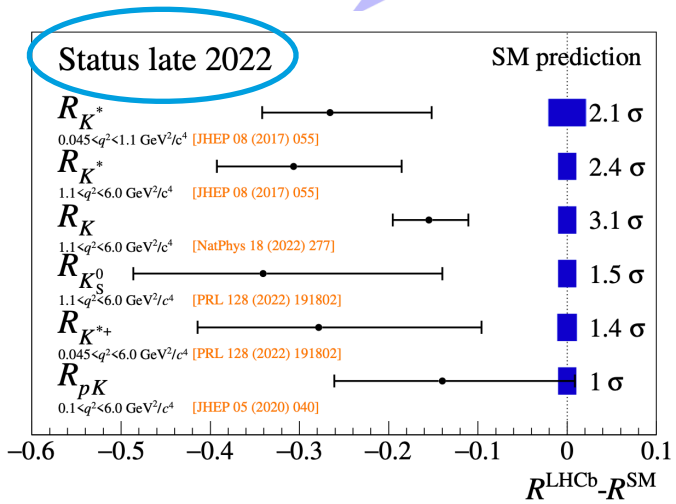
Increasing precision of SM prediction

[JHEP 06 (2014) 133] [PRD 107 (2023) 014511]

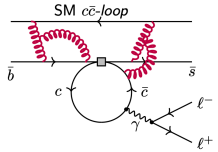


[PRL 125 (2020) 011802]





Branching fractions
affected by form-factors and $c\bar{c}$-loop

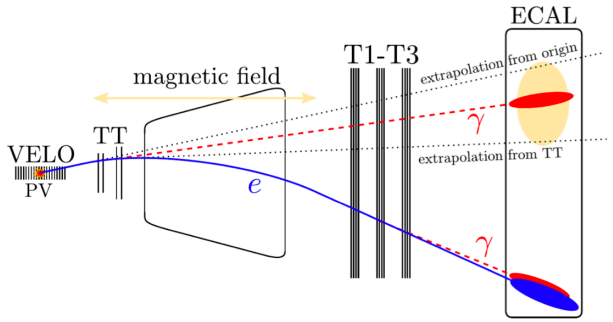


Angular observables
affected by $c\bar{c}$-loop

Lepton Universality Tests
clean
inspired by trying to find TH clean observables

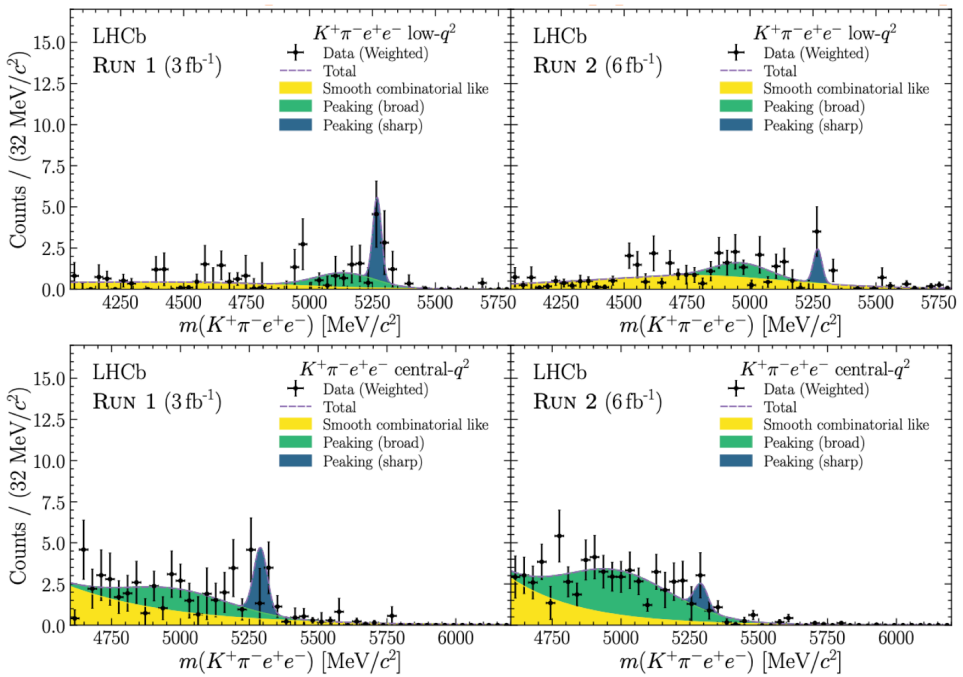
Lepton Flavour Universality in $b \to sll$ decays

LHCb



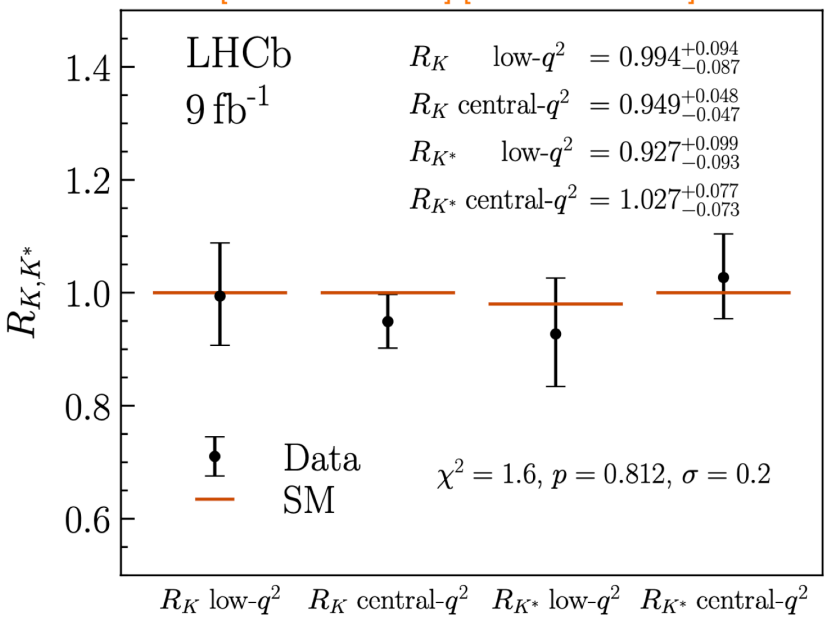
Experimentally electrons are very different than muons and intricate to reconstruct!

Sneaky backgrounds peaking in B mass but at low q^2 were not identified yet (e.g. $KKK, K\pi\pi$)



With a new tighter electron identification and taking into account all backgrounds, measurements are in perfect agreement with the SM!

[arXiv:2212.09152] [arXiv:2212.09153]

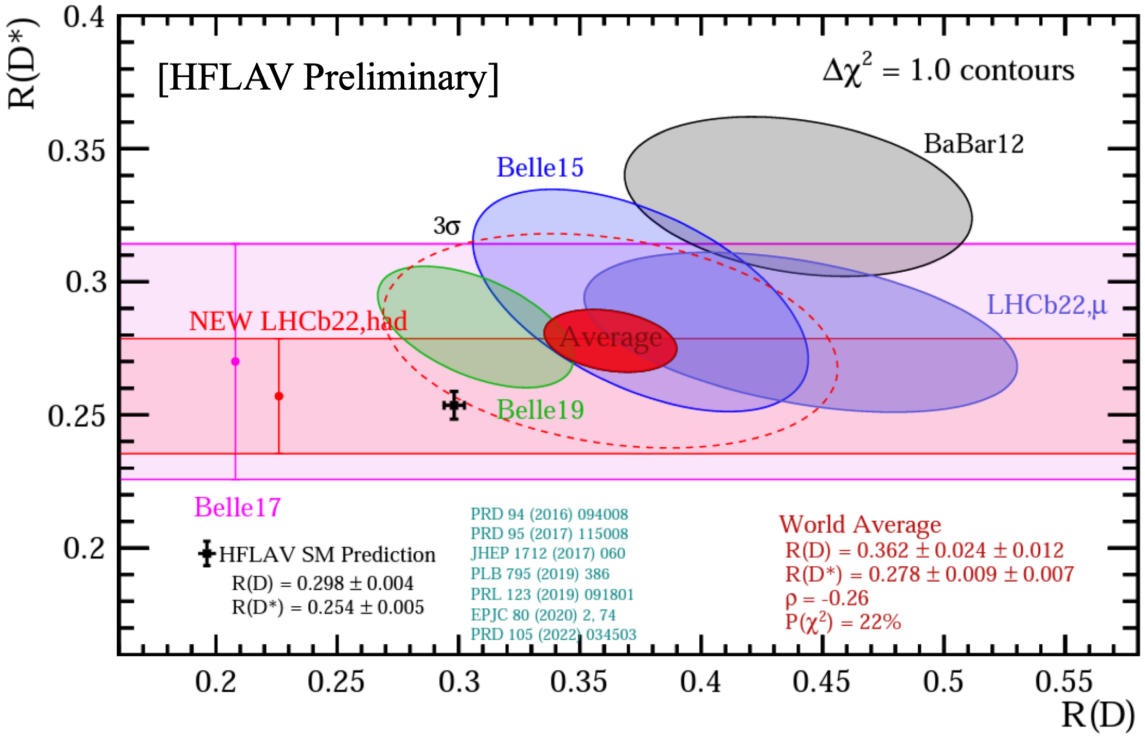


Lepton Flavour Universality at tree-level in $b \to c l \nu$

LHCb

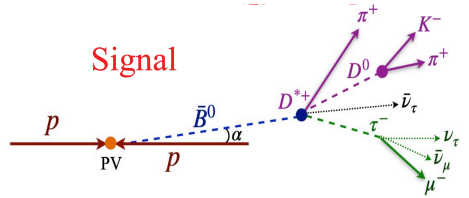
$$\mathcal{R}(D^{(*)}) = \frac{\mathcal{B}\left(B^0 \to D^{(*)-}\tau^+\nu_\tau\right)}{\mathcal{B}\left(B^0 \to D^{(*)-}\mu^+\nu_\mu\right)}$$

Both TH and EXP clean!



Two updates from LHCb:

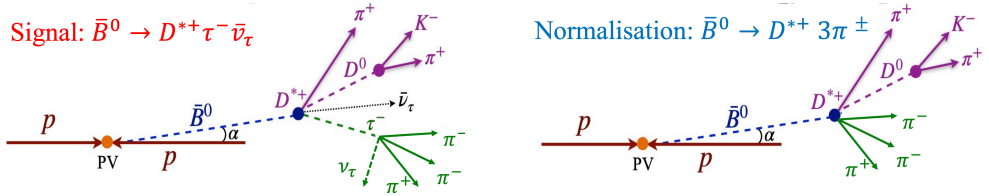
1. Combined measurement of $R(D)$ and $R(D*)$ with a muonic τ decay



1.9σ tension with SM, **WA**:3.3σ →3.2σ wrt SM

New for Moriond EW 2023

2. $R(D*)$ with a hadronic τ decay!



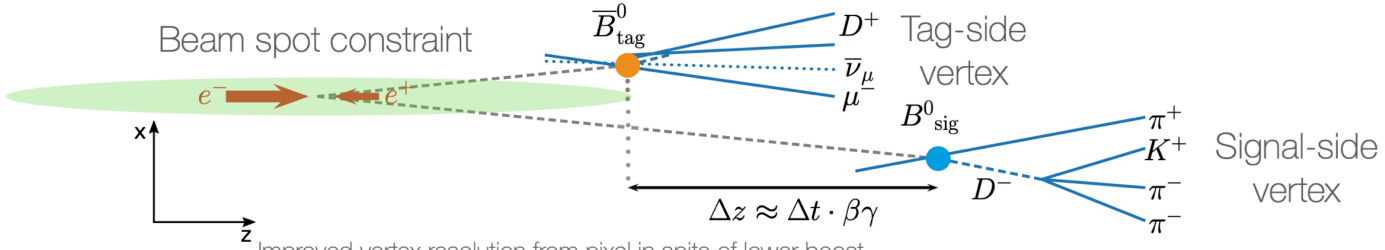
No tension with SM, **WA**:3.2σ →3.0σ wrt SM

LHCb measurement of $R(D*)$ does not show any tension, still present in the more challenging $R(D)$ channel.
Belle will play center stage when new result is out

CPV measurements Belle II

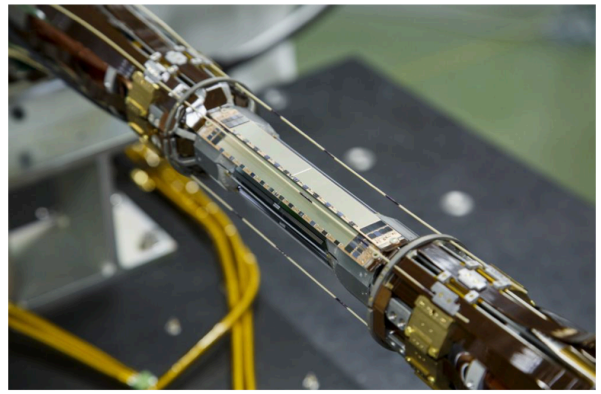
3 new results on time-dependent CP observables with penguins for Moriond

Measure β via time dependent asymmetry of B and $\overline{B}$ decays inferred from the relative position of the decay vertices



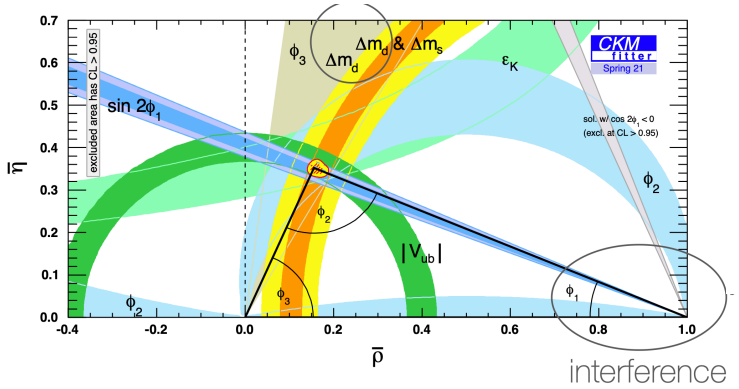
Improved vertex resolution from pixel in spite of lower boost

- Belle: βγ=0.43, Δz≈200μm —> Belle II: βγ=0.29, Δz≈130μm



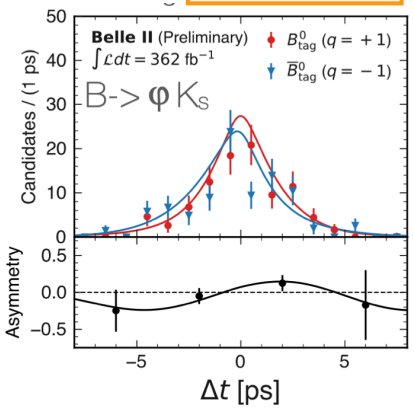
Pixel detector radius ≈ 1.4 cm

$\sin(2\beta^{eff}) \equiv \sin(2\phi_1^{eff})$



interference

New for Moriond EW 2023



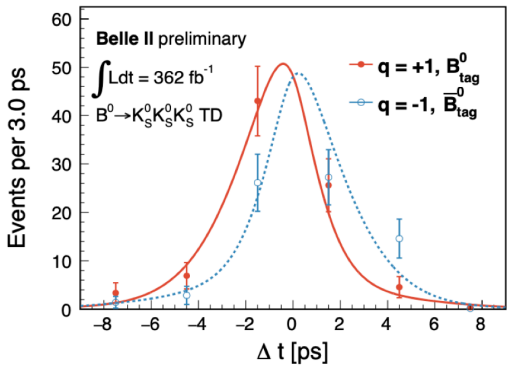
B-> φ K_S

$A_{CP} = 0.31 \pm 0.20^{+0.05}_{-0.06}$

$S_{CP} = 0.54 \pm 0.26^{+0.06}_{-0.08}$

HFLAV: S = $0.74^{+0.11}_{-0.13}$, A = -0.01±0.14

New for Moriond EW 2023



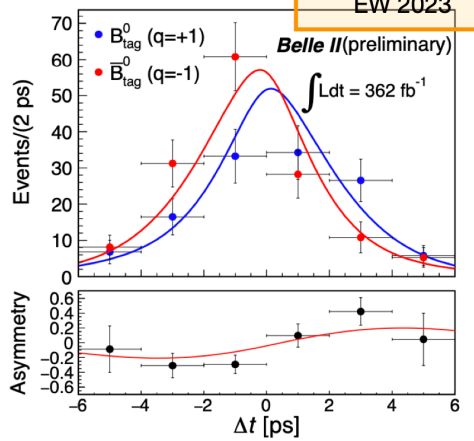
B->$K_SK_SK_S$

$A_{CP} = 0.07^{+0.15}_{-0.20} \pm 0.02$

$S_{CP} = -1.37^{+0.35}_{-0.45} \pm 0.03$

HFLAV: S = -0.83±0.17, A = 0.15±0.12

New for Moriond EW 2023



B->$K_S\pi^0$

$A_{CP} = 0.04 \pm 0.15 \pm 0.05$

$S_{CP} = 0.75^{+0.20}_{-0.23} \pm 0.04$

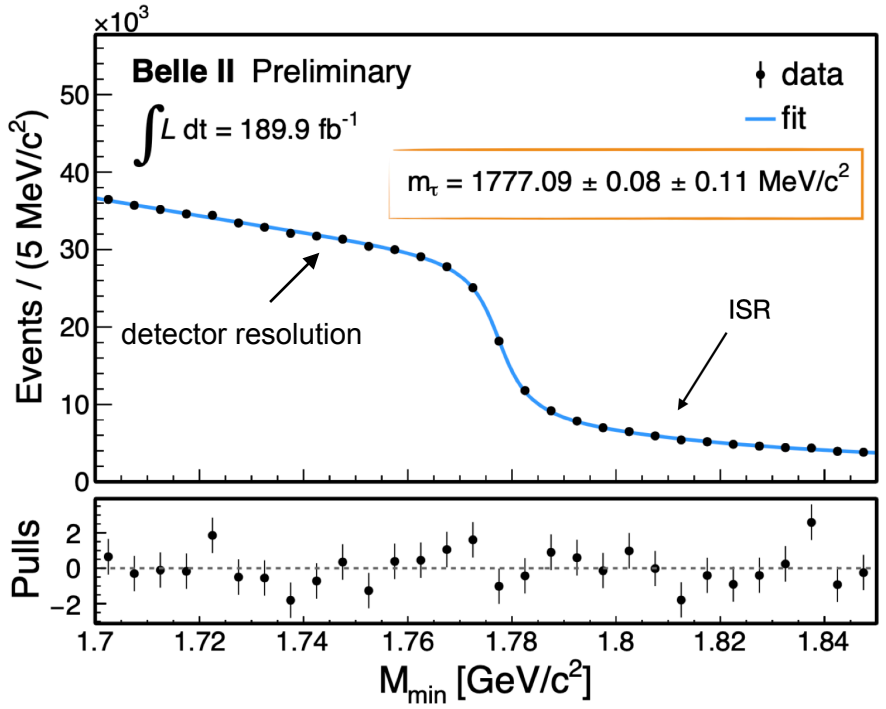
HFLAV: S = 0.57±0.17, A = -0.01±0.10

Results are already on-par or comparable with world's best and illustrate with much less luminosity, the improved performance of Belle-II.

Belle II - Tau Lepton Mass

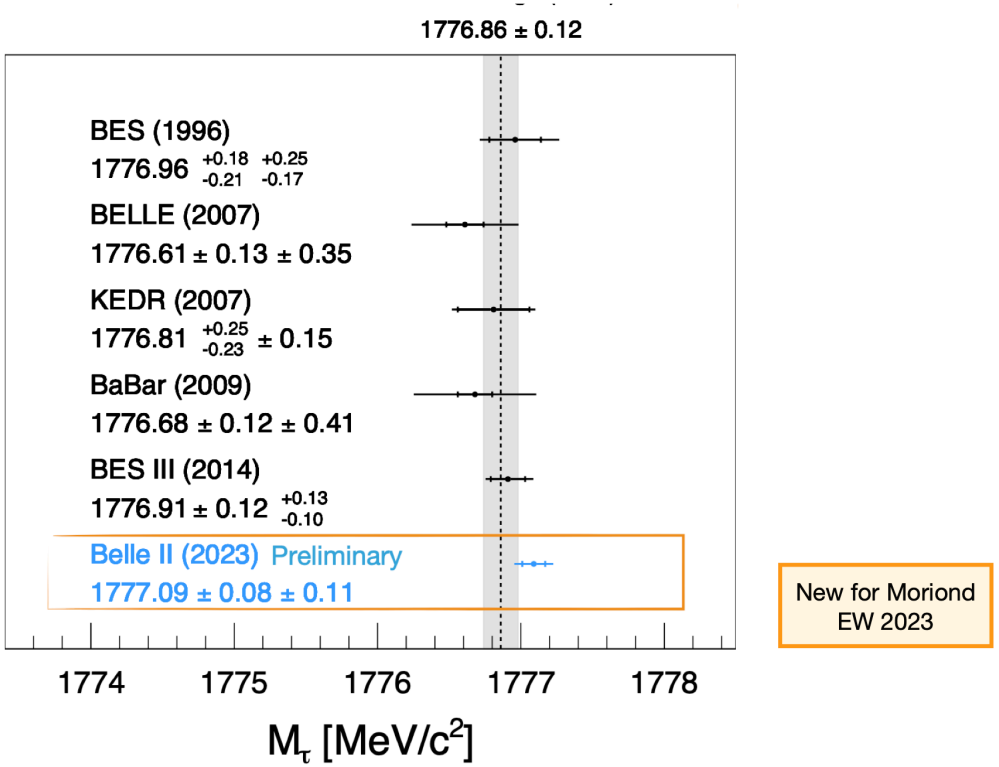
Sasha Dreyer

- Large $e^+e^- \to \tau\tau$ cross-section and clean environment allow high precision τ measurements



- Benchmark for precision capabilities of Belle II
- Control of **systematic uncertainties** is key:
- $M_{\min} = \sqrt{M_{3\pi}^2 + 2(\sqrt{s}/2 - E_{3\pi}^*)(E_{3\pi}^* - P_{3\pi}^*)} \leq m_\tau$

- Reconstruct $\tau_{\text{tag}}^{\pm} \to \pi^{\pm}(\pi^0)\nu, \ell\nu\nu$ and $\tau_{\text{sig}} \to 3\pi\nu$ (ν missing)



New for Moriond EW 2023

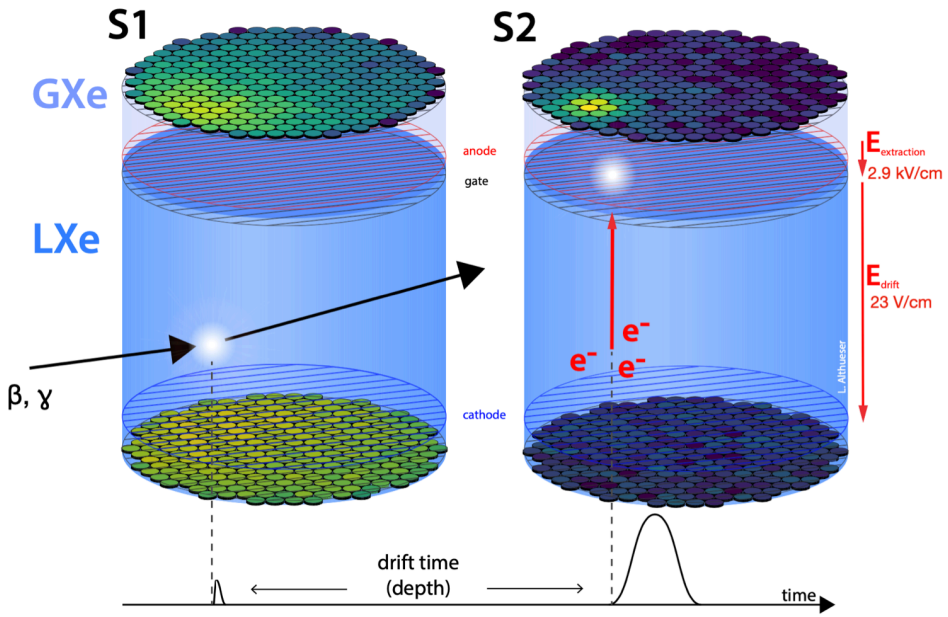
World's most precise measurement of the tau mass ($6 \,.\, 10^{-5}$)!

Direct Dark Matter Searches

Xenon nT Hot Off the Press for Moriond!

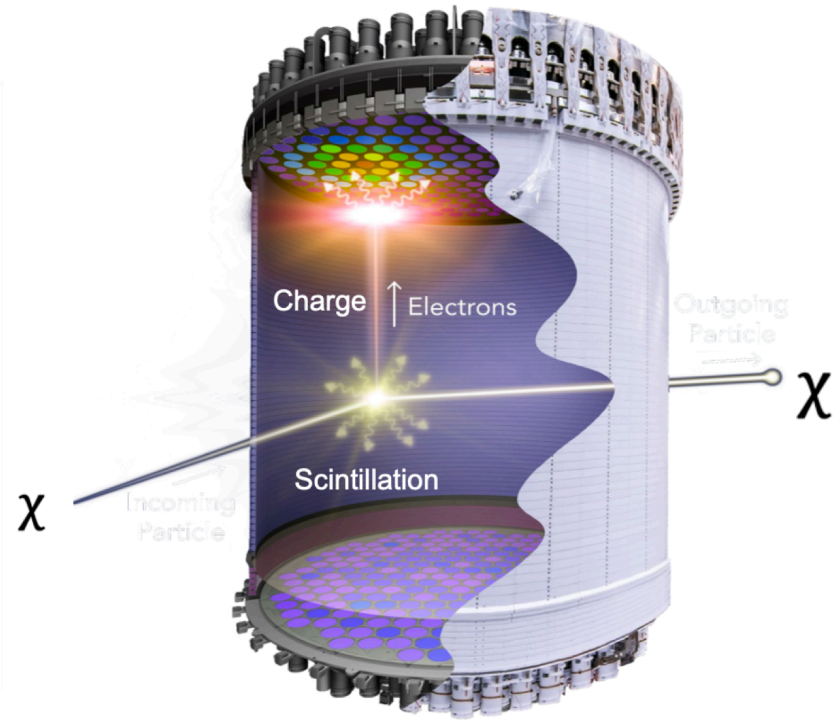
Science Run-0 Nuclear Recoil Search Data
95.1 days exposure
(4.18 ± 0.13) ton Fiducial Volume
Exposure: 1.1 tonne-year

New for Moriond EW 2023



LZ Results

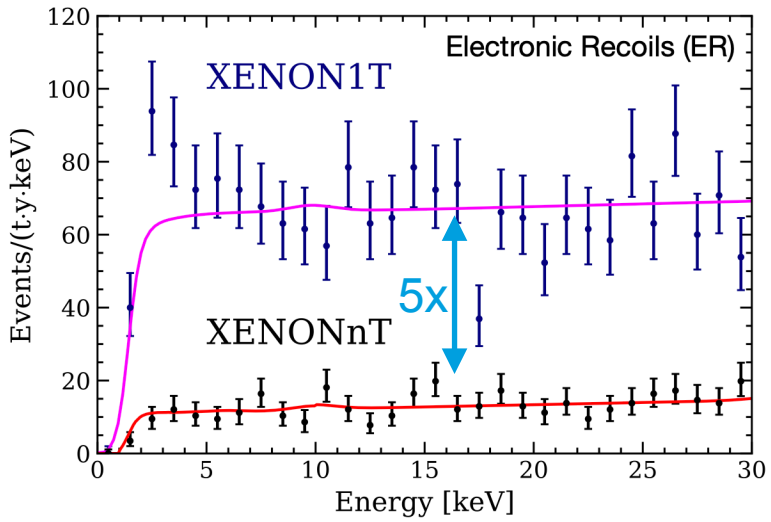
Science Run-0 Nuclear Recoil Search Data
60 days exposure
(5.3 ± 0.2) ton Fiducial Volume
Exposure: 0.9 tonne-year

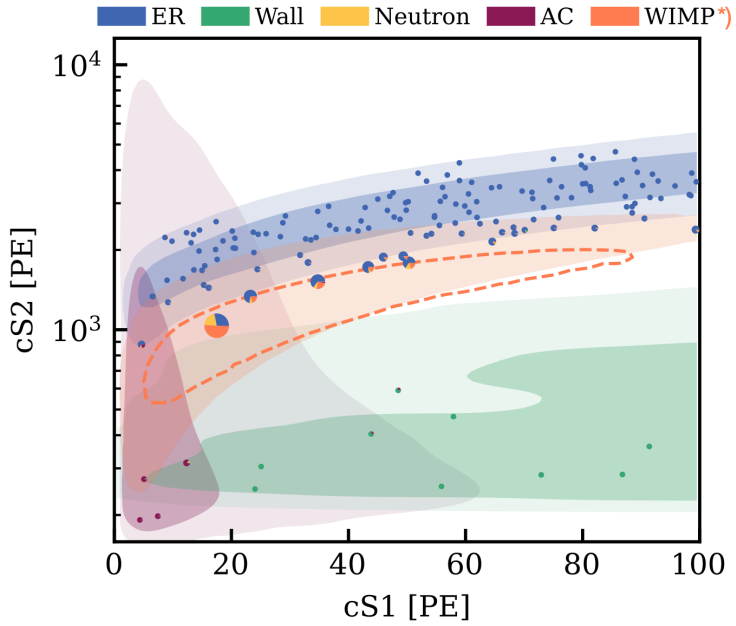


Both are dual phase Xenon TPCs

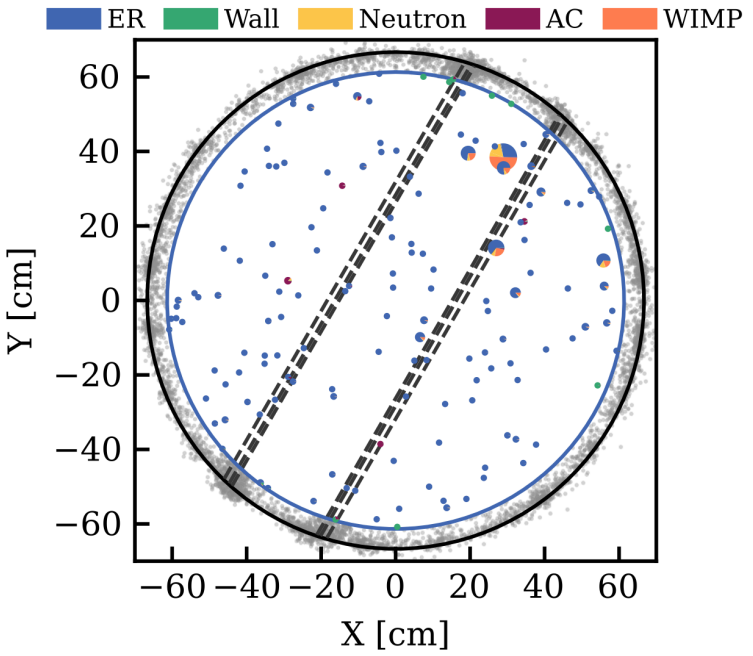
Xenon nT results

New for Moriond





*) Assuming a 200 GeV WIMP and a best-fit σ = 2.5 × 10⁻⁴⁷ cm²



Background reduction: careful screening, material selection and continuous radon removal through distillation

Low energy ER excess gone

152 events in ROI, 16 in blinded region

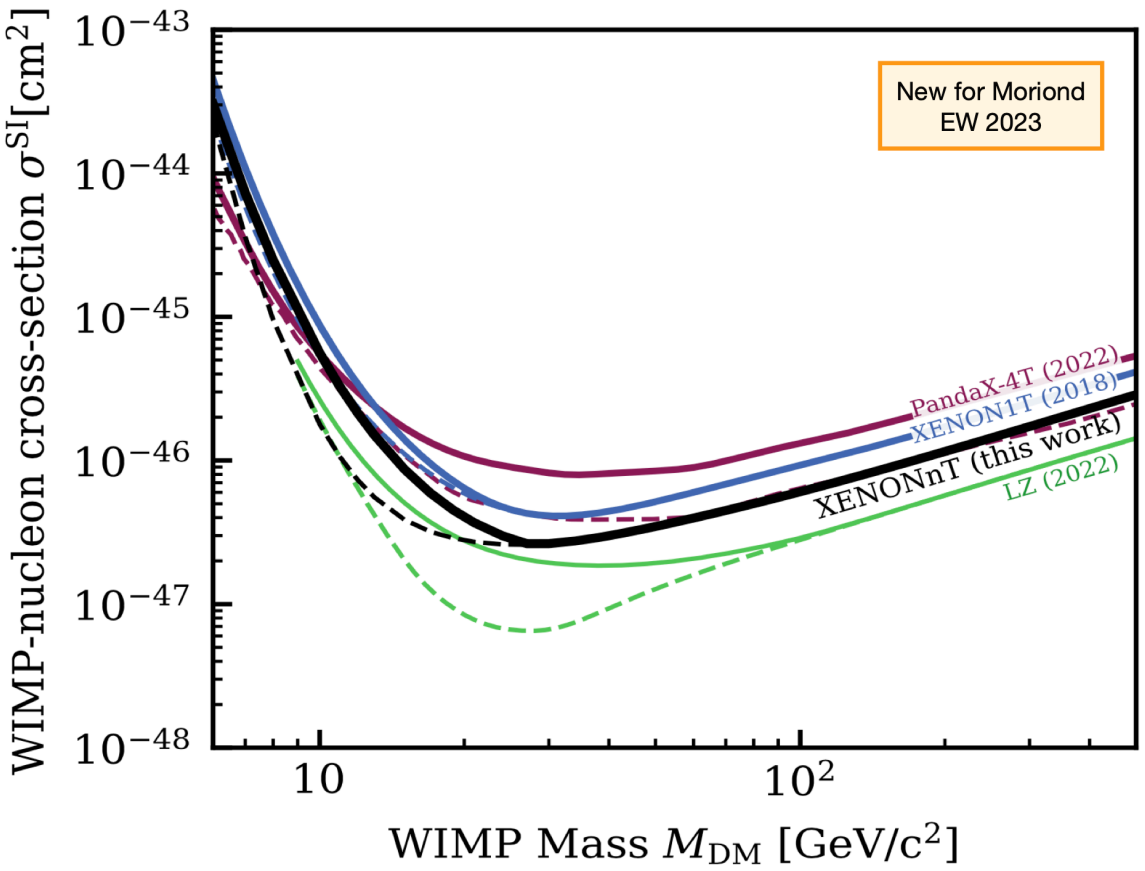
Best fit indicates no significant excess

XY asymmetry in unblinded data (13 events in one quadrant)

Not observed in corrections, quality selection or calibration data

Direct dark matter searches

Xenon nT and LZ



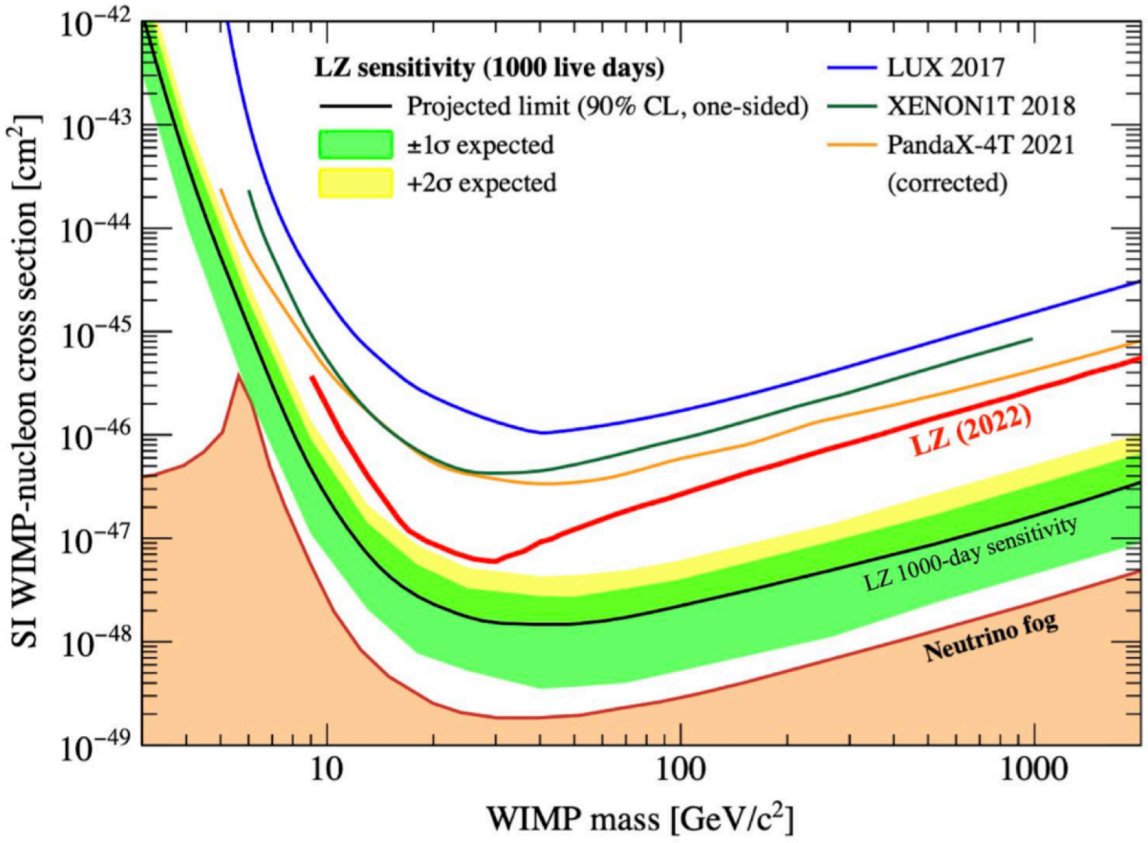
Xenon nT First results!

LZ Achieved leading sensitivity

Xenon/DARWIN and Lux Zeppelin join forces for future project, however meanwhile…

Direct dark matter searches

Xenon nT and LZ



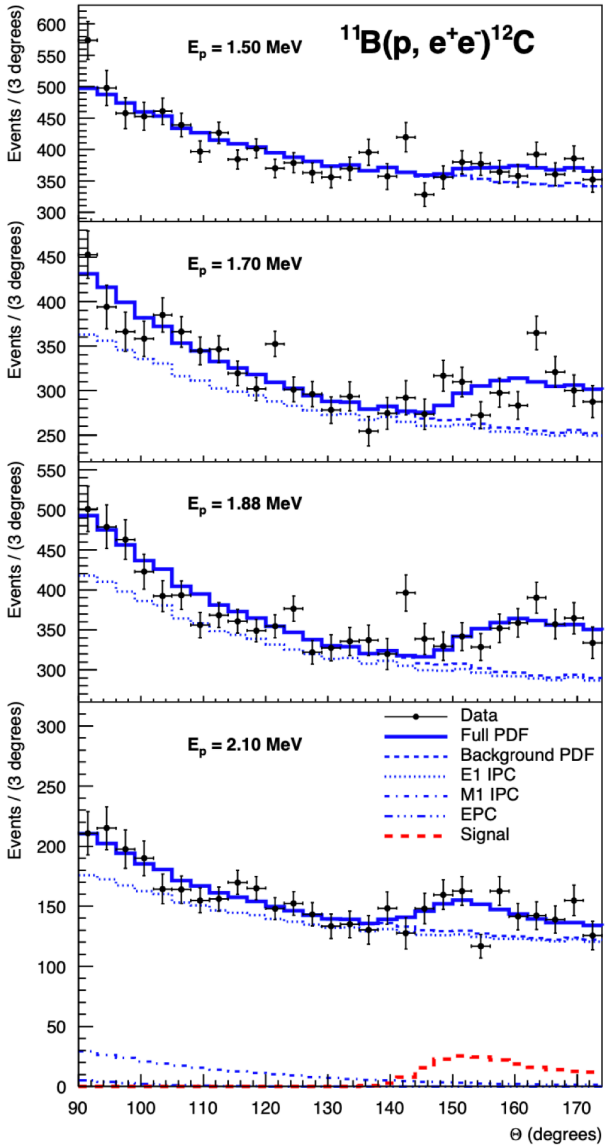
Xenon nT First results!

LZ Achieved leading sensitivity

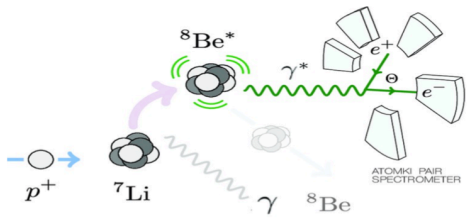
Xenon/DARWIN and Lux Zeppelin join forces for future project, however meanwhile…

Still a lots of data to come!

^{8}Be Anomaly and PADME



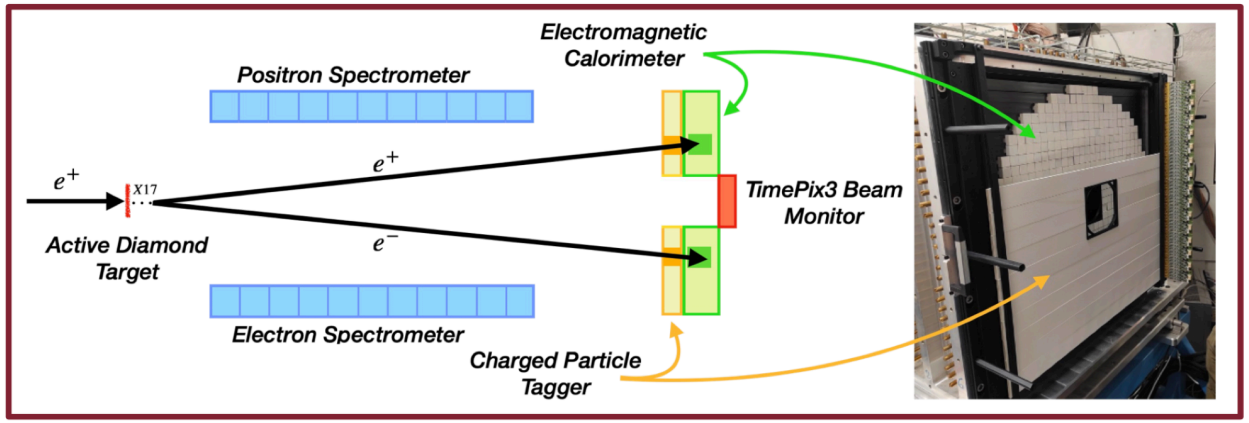
The ATOMKI institute observes the long standing ^{8}Be anomaly, observed also in ^{4}He and ^{12}C, i.e. a significant excess compatible with new particle of 17 MeV mass.



internal pair conversion decays of excited nuclei

DAΦNE Beam Test Facility is the only facility in the world with a positron beam at 282 MeV (yielding 17 MeV centre-of-mass collisions with fixed target electron!)

PADME experiment (**P**ositron **A**nnihilation into **D**ark **M**atter **E**xperiment)



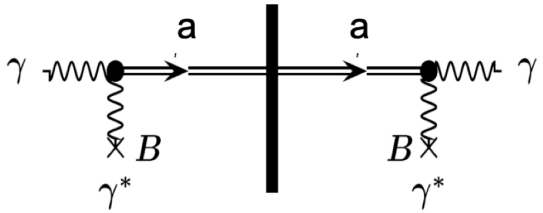
Run has finished and data analysis is ongoing, hoping to shine light on ^{8}Be

Axions : an Ambitious Program… In Hamburg

Andreas Ringwald

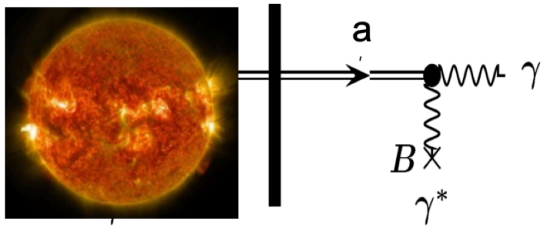
Light shining through a wall (LSW)

[Anselm 85; van Bibber 87]



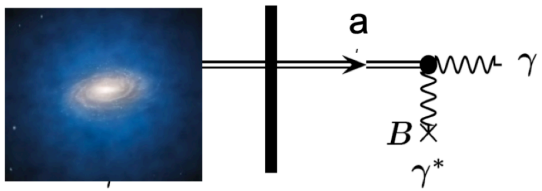
Helioscope: Sun shining through a wall

[Sikivie 83]

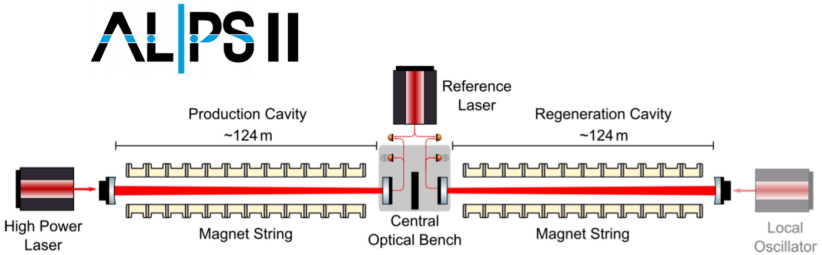


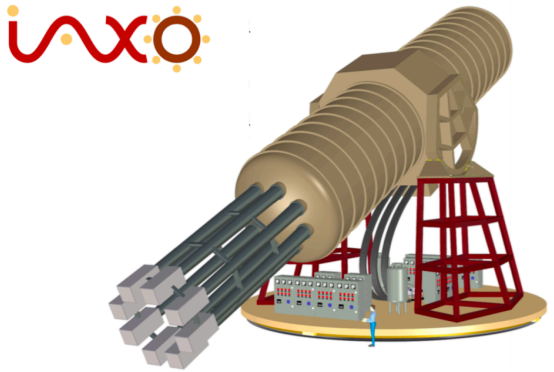
Haloscope: DM shining through a wall

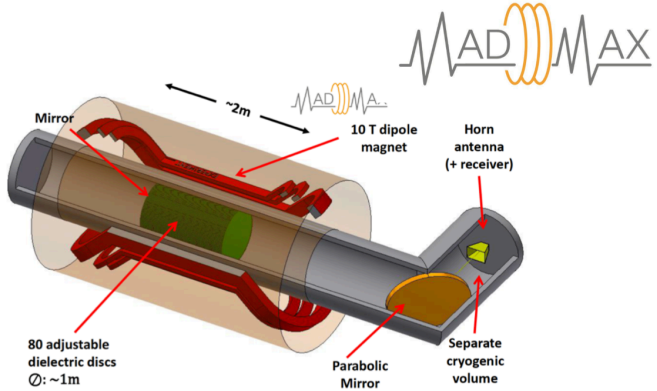
[Sikivie 83]

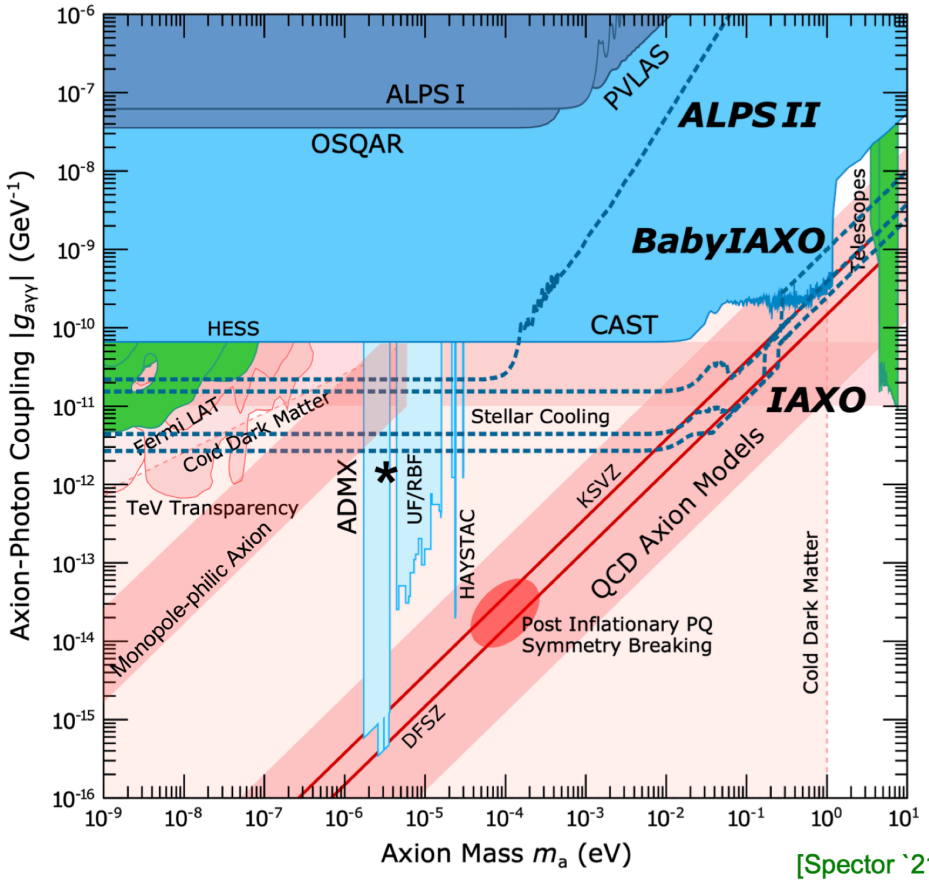


[Lindner]





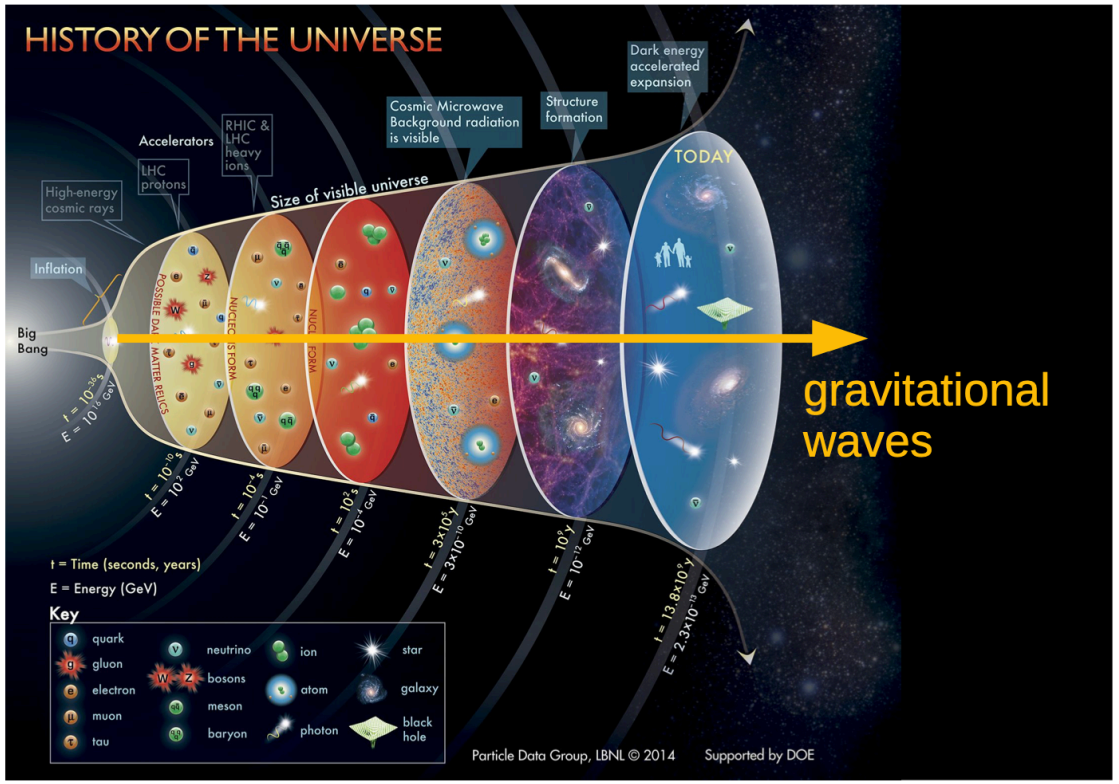




[Spector `21]

Electromagnetic

high-frequency gravitational wave detection



Valerie Domcke
CERN

Moriond Conference, La Thuile
March 18 – 25, 2023

based on 2011.12414
Living Review on UHF GW searches,

and work with Camilo Garcia-Cely, Torsten Bringmann, Elina Fuchs, Joachim Kopp, Sung Mook Lee and Nick Rodd

Thank you

Contact

DESY. Deutsches
Elektronen-Synchrotron

www.desy.de

Krisztian Peters
DESY-ATLAS
E-mail: krisztian.peters@desy.de
Phone: +49 40 8998 3740