XXXVII REUNIÓN ANUAL DE LA DIVISIÓN DE PARTÍCULAS Y CAMPOS DE LA SMF

JUNE 14, CINVESTAV

LUIS J. FLORES

TECNOLÓGICO NACIONAL DE MÉXICO

CAMPUS JEREZ

GENERALIZED NEUTRINO INTERACTIONS IN LOW AND HIGH ENERGY EXPERIMENTS

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Outline

- Motivation
- Formalism
- Constraints
- Final comments

GENERALIZED NEUTRINO INTERACTIONS IN LOW AND HIGH ENERGY EXPERIMENTS

MOTIVATION

VECTOR-LIKE

Easy, model-independent way to introduce BSM physics: Neutrino nonstandard interactions (NSI)

$$\mathcal{L}_{\text{NSI,CC}} = -2\sqrt{2}\,G_F \sum_{f,f',\alpha,\beta} \varepsilon_{\alpha\beta}^{ff',P} (\bar{\ell}_\alpha \gamma_\mu P_L \nu_\beta)(\bar{f}\gamma^\mu P f') + \text{h.c.}$$

$$\mathcal{L}_{\text{NSI,NC}} = -2\sqrt{2}\,G_F \sum_{f,P,\alpha,\beta} \varepsilon_{\alpha\beta}^{f,P} (\bar{\nu}_\alpha \gamma^\mu P_L \nu_\beta)(\bar{f}\gamma_\mu P f)\,.$$

CURRENT NSI CONSTRAINTS

	Allowed ranges at 90% CL (Marginalized)	
	GLOB-OSC	
	LMA	LMA $\oplus$ LMA-D
$\varepsilon_{ee}^{u,V} - \varepsilon_{\mu\mu}^{u,V}$	$[-0.063, +0.36]$	$[-1.1, -0.79] \oplus [-0.063, +0.36]$
$\varepsilon_{\tau\tau}^{u,V} - \varepsilon_{\mu\mu}^{u,V}$	$[-0.0053, +0.017]$	$[-0.021, +0.018]$
$\varepsilon_{e\mu}^{u,V}$	$[-0.057, +0.013]$	$[-0.057, +0.061]$
$\varepsilon_{e\tau}^{u,V}$	$[-0.076, +0.11]$	$[-0.12, +0.11]$
$\varepsilon_{\mu\tau}^{u,V}$	$[-0.0077, +0.0042]$	$[-0.0077, +0.0083]$
$\varepsilon_{ee}^{d,V} - \varepsilon_{\mu\mu}^{d,V}$	$[-0.069, +0.38]$	$[-1.3, -0.91] \oplus [-0.072, +0.38]$
$\varepsilon_{\tau\tau}^{d,V} - \varepsilon_{\mu\mu}^{d,V}$	$[-0.0058, +0.018]$	$[-0.029, +0.019]$
$\varepsilon_{e\mu}^{d,V}$	$[-0.058, +0.014]$	$[-0.058, +0.098]$
$\varepsilon_{e\tau}^{d,V}$	$[-0.079, +0.11]$	$[-0.16, +0.11]$
$\varepsilon_{\mu\tau}^{d,V}$	$[-0.0087, +0.0051]$	$[-0.0087, +0.015]$

	Allowed ranges at 90% CL (Marginalized)
	GLOB-OSC+CEνNS
	LMA = LMA $\oplus$ LMA-D
$\varepsilon_{ee}^{u,V}$	$[-0.038, +0.034] \oplus [+0.34, +0.42]$
$\varepsilon_{\mu\mu}^{u,V}$	$[-0.046, +0.031] \oplus [+0.35, +0.42]$
$\varepsilon_{\tau\tau}^{u,V}$	$[-0.046, +0.033] \oplus [+0.35, +0.42]$
$\varepsilon_{e\mu}^{u,V}$	$[-0.044, +0.0049]$
$\varepsilon_{e\tau}^{d,V}$	$[-0.079, +0.11]$
$\varepsilon_{\mu\tau}^{u,V}$	$[-0.0064, 0.0053]$
$\varepsilon_{ee}^{d,V}$	$[-0.036, +0.031] \oplus [+0.30, +0.39]$
$\varepsilon_{\mu\mu}^{d,V}$	$[-0.040, +0.038] \oplus [+0.31, +0.39]$
$\varepsilon_{\tau\tau}^{d,V}$	$[-0.041, +0.043] \oplus [+0.31, +0.39]$
$\varepsilon_{e\mu}^{d,V}$	$[-0.054, +0.0045]$
$\varepsilon_{e\tau}^{d,V}$	$[-0.051, +0.11]$
$\varepsilon_{\mu\tau}^{d,V}$	$[-0.0075, +0.0046]$

Table 3. 90% allowed ranges for the vector NSI couplings $\varepsilon_{\alpha\beta}^{u,V}$ and $\varepsilon_{\alpha\beta}^{d,V}$ as obtained from the global analysis of oscillation data (left columns, applicable to NSI induced by mediators with $M_{\rm med} \ll 5$ MeV) and also including data from CEνNS experiments (right columns, applicable to NSI induced by mediators with $M_{\rm med} \gtrsim 50$ MeV). The results are obtained after marginalizing over oscillation and the other matter potential parameters either within the LMA only and within both LMA and LMA-D subspaces respectively (this second case is denoted as LMA $\oplus$ LMA-D). Notice that once CEνNS data is included the two columns become identical, since for NSI couplings with $f = u, d$ the LMA-D solution is only allowed well above 90% CL.

P. Coloma, M. C. Gonzalez-Garcia, M. Maltoni, J.P. Pinheiro, S. Urrea 2305.07698

GENERALIZED EFFECTIVE FOUR-FERMION OPERATORS

$$\mathscr{L}_{\text{eff}}^{\text{CC}} = -\frac{G_F^2 V_{ik}}{\sqrt{2}} \sum_j \epsilon_{\alpha\beta}^{ff',j} (\bar{\ell}_\alpha \mathcal{O}_j \nu_\beta)(\bar{f} \mathcal{O}'_j f')$$

$$\mathcal{L}_{\text{eff}}^{\text{NC}} = -\frac{G_{\text{F}}}{\sqrt{2}} \sum_j \epsilon_{\alpha\beta}^{f,j} (\bar{\nu}_\alpha \mathcal{O}_j \nu_\beta)(\bar{f} \mathcal{O}'_j f)$$

ϵ	$\mathcal{O}_j$	$\mathcal{O}'_j$
$\epsilon^{f,L}$	$\gamma_\mu(1-\gamma^5)$	$\gamma^\mu(1-\gamma^5)$
$\epsilon^{f,R}$	$\gamma_\mu(1-\gamma^5)$	$\gamma^\mu(1+\gamma^5)$
$\epsilon^{f,S}$	$(1-\gamma^5)$	1
$-\epsilon^{f,P}$	$(1-\gamma^5)$	γ^5
$\epsilon^{f,T}$	$\sigma_{\mu\nu}(1-\gamma^5)$	$\sigma^{\mu\nu}(1-\gamma^5)$

CONSTRAINTS FROM DIFFERENT EXPERIMENTS

Process		Experiments
CEνNS	$\nu N \to \nu N$	COHERENT CsI & LAr SBC
Neutrino counting	$e^+e^- \to \nu\bar{\nu}\gamma$	ALEPH, DELPHI, L3, OPAL
Neutrino-electron scattering	$\nu_\alpha e^- \to \nu_\alpha e^-$	TEXONO CHARM-II
Deep Inelastic Scattering	$\nu_\alpha q \to \nu_\alpha q$	CHARM CDHS NuTeV FASERν

LJF, N. Nath, E. Peinado, *Phys.Rev.D* 105 (2022) 5, 5 2112.05103
F. Escrihuela, LJF, O. Miranda, J. Rendón, *JHEP* 07 (2021) 061 • e-Print: 2105.06484
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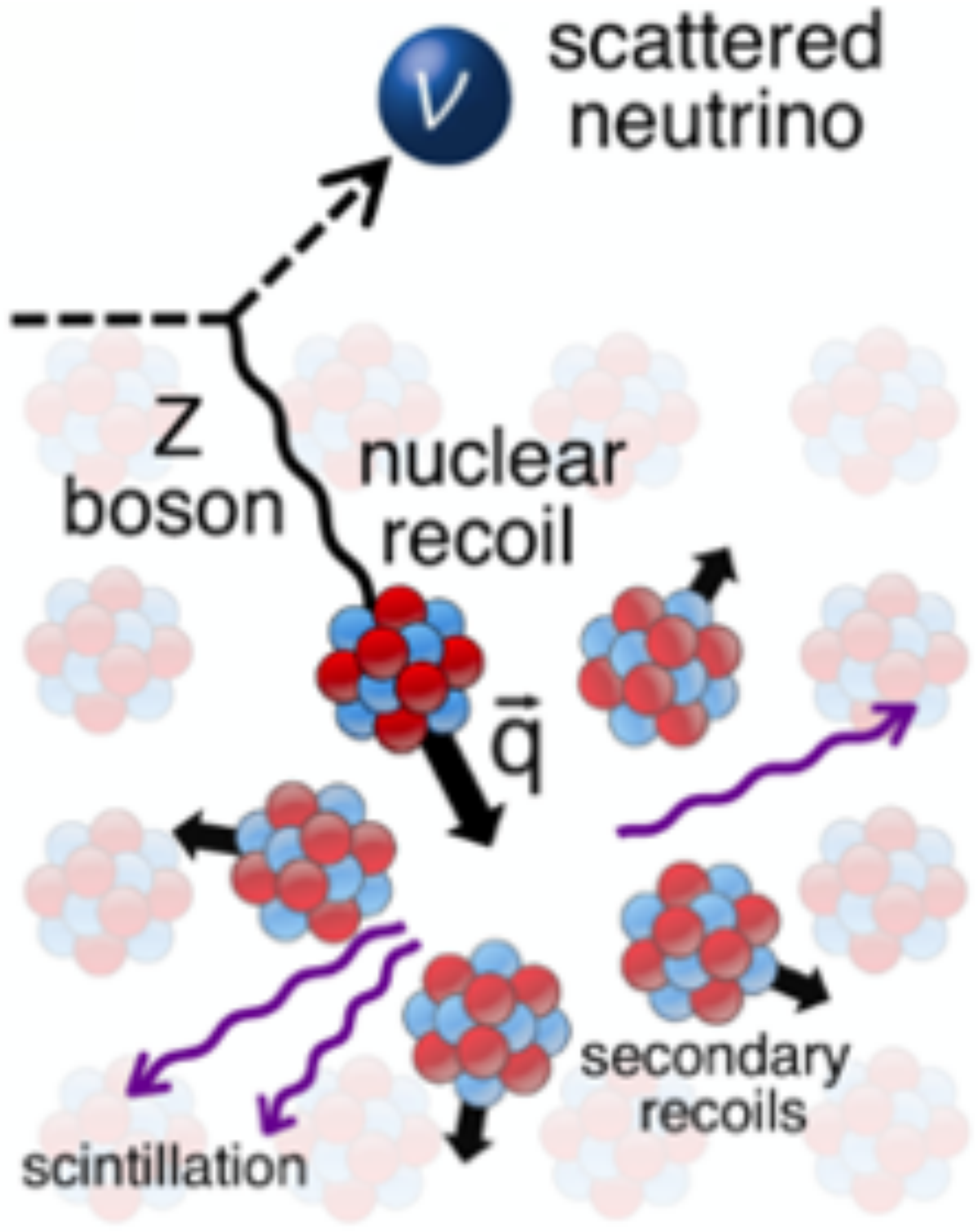
COHERENT ELASTIC NEUTRINO-NUCLEUS SCATTERING (CEVNS)

$E_\nu \leq 50 \text{ MeV}$

$$\frac{d\sigma}{dT} = \frac{G_F^2}{2\pi} M_N Q_w^2 \left(2 - \frac{M_N T}{E_\nu^2}\right)$$

$$Q_w^2 = \left[Z g_p^V F_Z(q^2) + N g_n^V F_N(q^2)\right]^2$$

Weak charge



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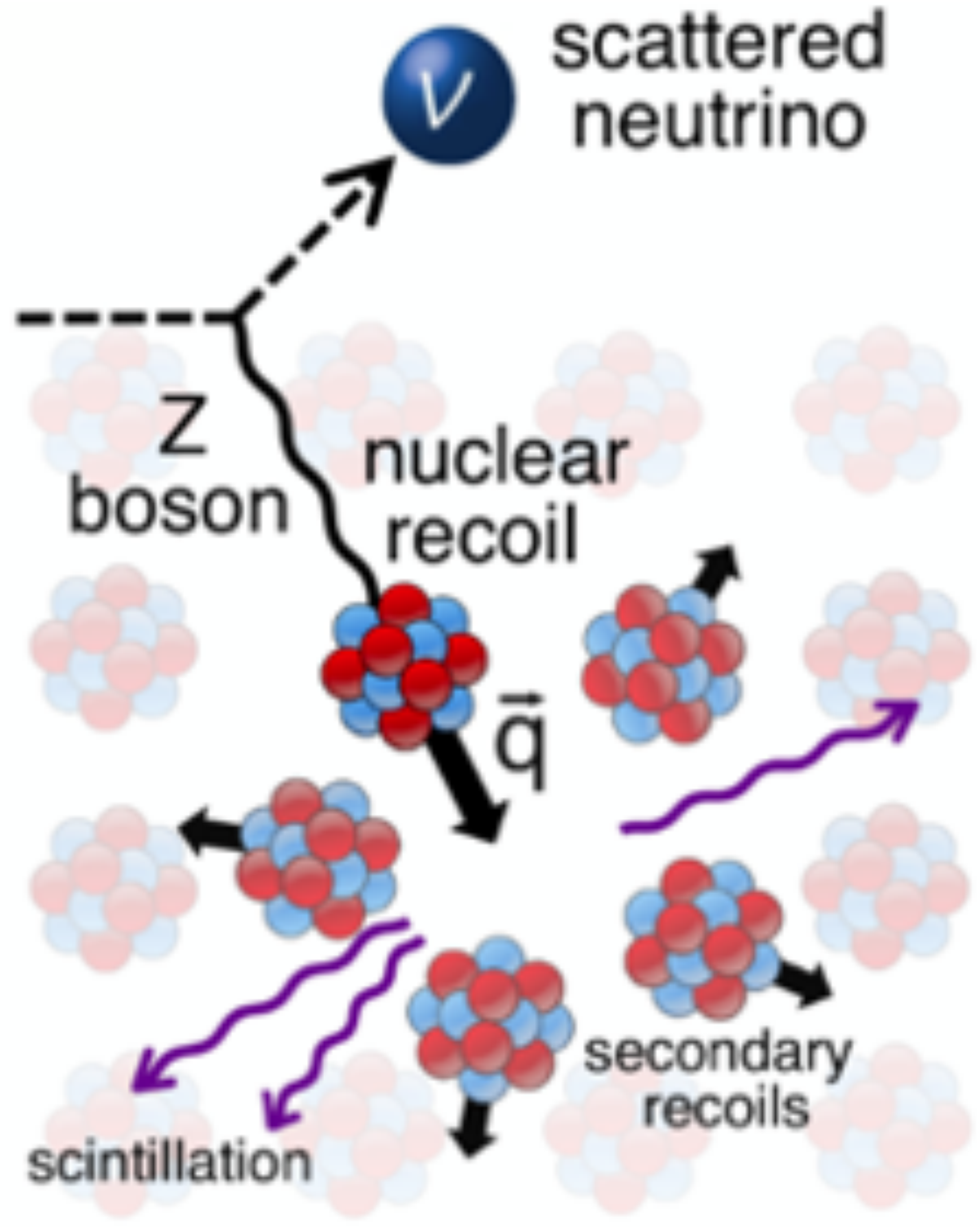


WITH GNI

$$\left(\frac{d\sigma}{dE_r}\right)^f = \frac{G_F^2}{4\pi} M_N N^2 F^2(Q^2) \left[\xi_S^{f2} \frac{E_r}{E_r^{\max}} + (\xi_V^f + A_{\rm SM})^2 \left(1 - \frac{E_r}{E_r^{\max}} - \frac{E_r}{E_\nu}\right) \pm 2\xi_V^f \xi_A^f \frac{E_r}{E_\nu} + \xi_A^{f2}\left(1 + \frac{E_r}{E_r^{\max}} - \frac{E_r}{E_\nu}\right) + \xi_T^{f2}\left(1 - \frac{E_r}{2E_r^{\max}} - \frac{E_r}{E_\nu}\right) \mp R\frac{E_r}{E_\nu} + \mathcal{O}\left(\frac{E_r^2}{E_\nu^2}\right)\right],$$

CEVNS EXPERIMENTS

Stopped-pion beams

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

- Pulsed beam
- Three channels
- Higher recoils

Nuclear Reactors

$$\bar{\nu}_e$$

- Intense flux
- One channel
- Fully coherent

CEVNS EXPERIMENTS

Stopped-pion beams

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\downarrow$$

$$e^+ + \nu_e + \bar{\nu}_\mu$$

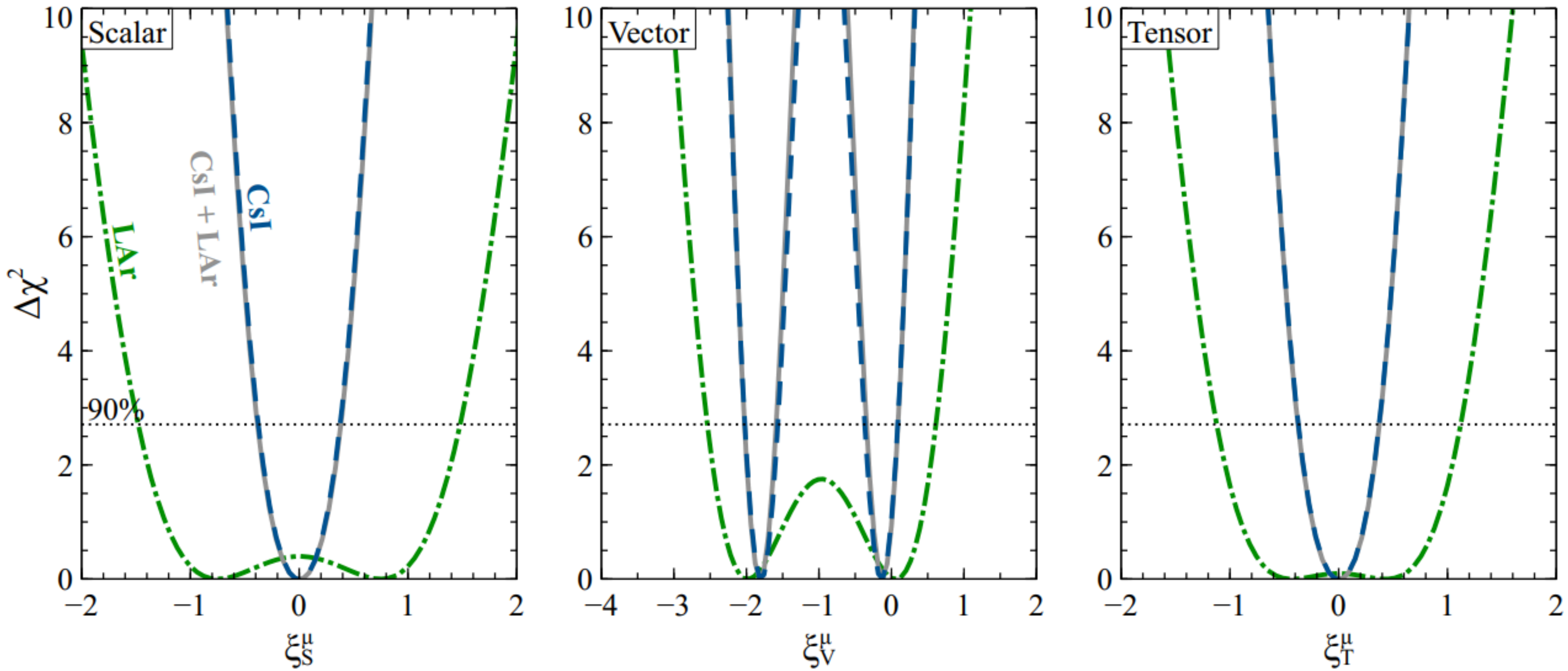
- Pulsed beam
- Three channels
- Higher recoils

Nuclear Reactors

$$\bar{\nu}_e$$

- Intense flux
- One channel
- Fully coherent

CEVNS WITH GNI

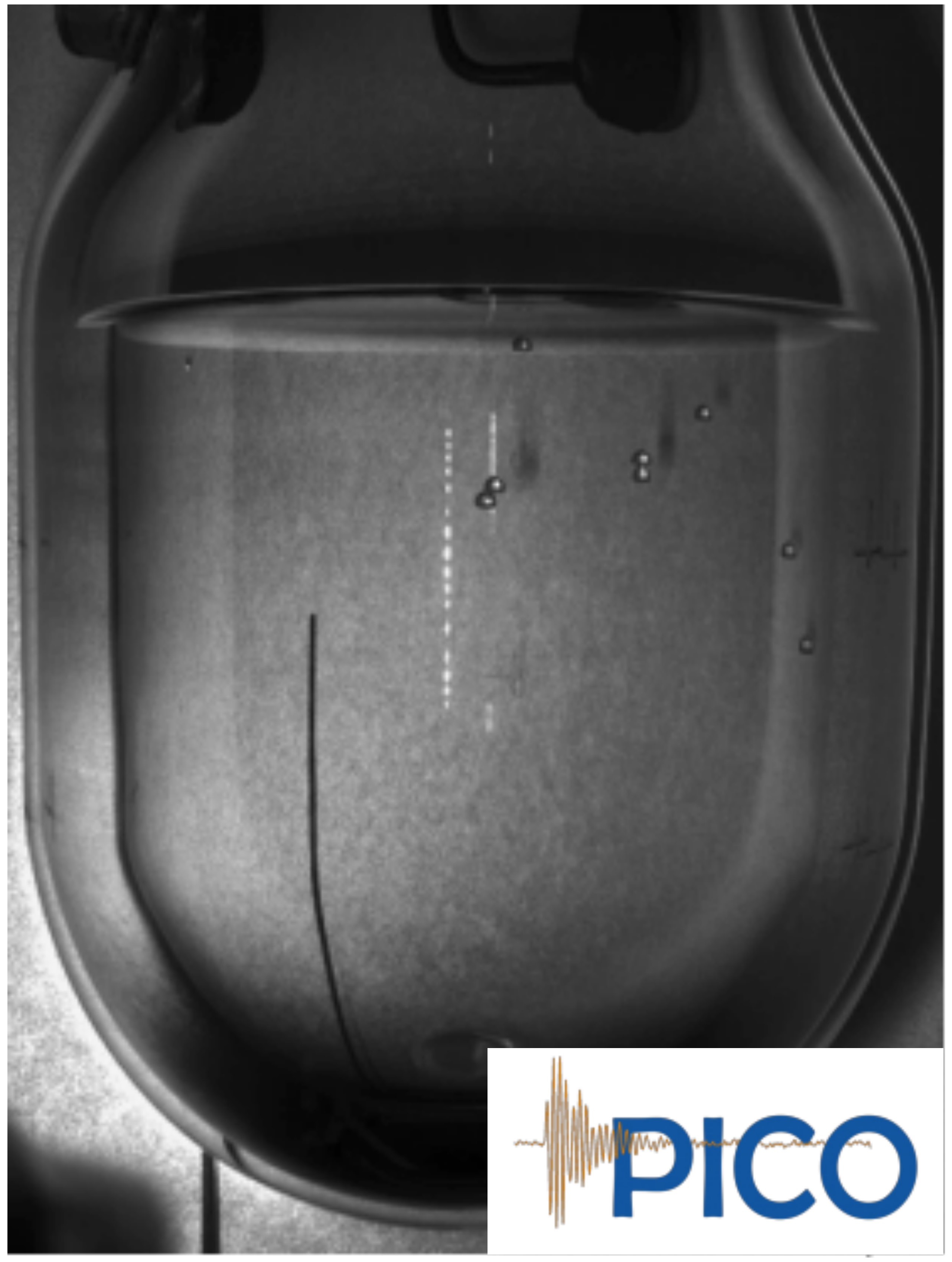


LJF, N. Nath, E. Peinado, *Phys.Rev.D* 105 (2022) 5, 5 2112.05103

UPCOMING REACTOR EXPERIMENT: SCINTILLATING BUBBLE CHAMBER FOR CEVNS

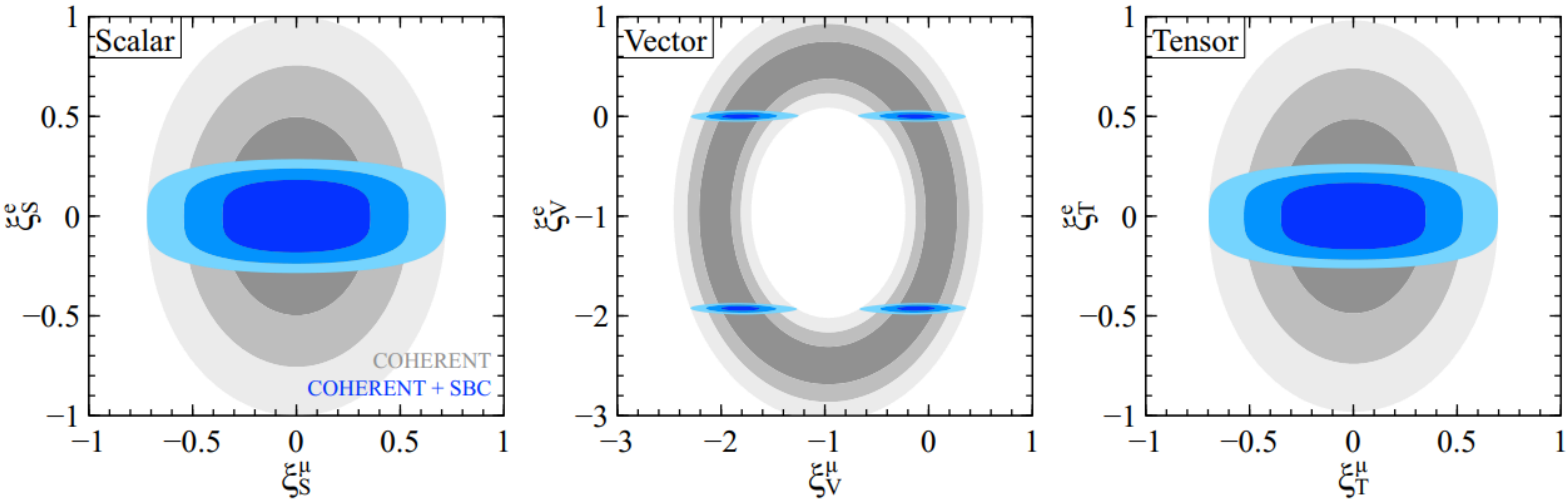
Combines features from scintillators and bubble chambers

- Insensitive to electron recoils
- Sub-keV thresholds (~100 eV)
- Single Bubble nucleation
- Energy resolution for >5 keV backgrounds



*LJF, E. Peinado, E. Alfonso-Pita, E. Vázquez-Jáuregui, SBC Collaboration (https://journals.aps.org/prd/pdf/10.1103/PhysRevD.103.L091301)

CEVNS WITH GNI



LJF, N. Nath, E. Peinado, *Phys.Rev.D* 105 (2022) 5, 5 2112.05103

CROSS SECTION WITH GNI

$e^+e^- \rightarrow \nu\bar{\nu}\gamma$

$$\sigma_0 = \frac{G_F^2 s}{48\pi}\sum_{\alpha,\beta}\left(8|\epsilon_{\alpha\beta}^{e,L}|^2 + 8|\epsilon_{\alpha\beta}^{e,R}|^2 + 3|\epsilon_{\alpha\beta}^{e,S}|^2 + 3|\epsilon_{\alpha\beta}^{e,P}|^2 + 32|\epsilon_{\alpha\beta}^{e,T}|^2\right)$$

$\nu_\alpha + e^- \rightarrow \nu_\beta + e^-$

$$\frac{d\sigma}{dE_r} = \frac{G_F^2 m_e}{\pi}\left[A + 2B\left(1-\frac{E_r}{E_\nu}\right) + C\left(1-\frac{E_r}{E_\nu}\right)^2 + D\frac{m_e E_r}{E_\nu^2}\right]$$

$$A = 2|\epsilon_{\alpha\beta}^{e,L}|^2 + \frac{1}{4}\left(|\epsilon_{\alpha\beta}^{e,S}|^2 + |\epsilon_{\alpha\beta}^{e,P}|^2\right) + 8|\epsilon_{\alpha\beta}^{e,T}|^2 - 2\Re\left(\left(\epsilon^{e,S}+\epsilon^{e,P}\right)_{\alpha\beta}\epsilon_{\alpha\beta}^{e,T*}\right)$$

$$B = -\frac{1}{4}\left(|\epsilon_{\alpha\beta}^{e,S}|^2 + |\epsilon_{\alpha\beta}^{e,P}|^2\right) + 8|\epsilon_{\alpha\beta}^{e,T}|^2,$$

$$C = 2|\epsilon_{\alpha\beta}^{e,R}|^2 + \frac{1}{4}\left(|\epsilon_{\alpha\beta}^{e,S}|^2 + |\epsilon_{\alpha\beta}^{e,P}|^2\right) + 8|\epsilon_{\alpha\beta}^{e,T}|^2 + 2\Re\left(\left(\epsilon^{e,S}+\epsilon^{e,P}\right)_{\alpha\beta}\epsilon_{\alpha\beta}^{e,T*}\right)$$

$$D = -2\Re\left(\epsilon_{\alpha\beta}^{e,L}\epsilon_{\alpha\beta}^{e,R*}\right) + \frac{1}{2}|\epsilon_{\alpha\beta}^{e,S}|^2 - 8|\epsilon_{\alpha\beta}^{e,T}|^2.$$

$\nu q \rightarrow \nu q.$

$$\sigma_{\nu N,S(P)}^{\rm NC} = \sigma_{\bar{\nu}N,S(P)}^{\rm NC} = \frac{G_F^2 s}{24\pi}\left[\left(\epsilon_\alpha^{u,S(P)}\right)^2\left(\frac{f_q+f_{\bar{q}}}{2}\right) + \left(\epsilon_\alpha^{d,S(P)}\right)^2\left(\frac{f_q+f_{\bar{q}}}{2}\right)\right],$$

$$\sigma_{\nu N,T}^{\rm NC} = \sigma_{\bar{\nu}N,T}^{\rm NC} = \frac{28 G_F^2 s}{3\pi}\left[\left(\epsilon_\alpha^{u,T}\right)^2\left(\frac{f_q+f_{\bar{q}}}{2}\right) + \left(\epsilon_\alpha^{d,T}\right)^2\left(\frac{f_q+f_{\bar{q}}}{2}\right)\right],$$

SCALAR AND PSEUDOSCALAR COUPLINGS

Experiment	Observable	Parameters	Limit
ALEPH [47–49]	$\lvert\epsilon^{e,X}_{\text{all}}\rvert$	$\lvert\epsilon^{e,X}_{ee}\rvert, \lvert\epsilon^{e,X}_{\mu\mu}\rvert, \lvert\epsilon^{e,X}_{\tau\tau}\rvert, \lvert\epsilon^{e,X}_{e\mu}\rvert, \lvert\epsilon^{e,X}_{e\tau}\rvert, \lvert\epsilon^{e,X}_{\mu\tau}\rvert$	< 0.535
DELPHI [50]			< 0.830
L3 [51–53]			< 0.745
OPAL [54–56]			< 0.637
CHARM-II [73]	$\lvert\epsilon^{e,X}_{\mu}\rvert$	$\lvert\epsilon^{e,X}_{e\mu}\rvert, \lvert\epsilon^{e,X}_{\mu\mu}\rvert, \lvert\epsilon^{e,X}_{\mu\tau}\rvert$	< 0.401
TEXONO [75]	$\lvert\epsilon^{e,X}_{e}\rvert$	$\lvert\epsilon^{e,X}_{ee}\rvert, \lvert\epsilon^{e,X}_{e\mu}\rvert, \lvert\epsilon^{e,X}_{e\tau}\rvert$	$\lvert\epsilon^{e,S}_{e}\rvert < 0.56, \quad \lvert\epsilon^{e,P}_{e}\rvert < 0.64$
CHARM [67] ($\overset{(-)}{\nu}_e$ beam)	$\lvert\epsilon^{q,X}_{e}\rvert$	$\lvert\epsilon^{q,X}_{ee}\rvert, \lvert\epsilon^{q,X}_{e\mu}\rvert, \lvert\epsilon^{q,X}_{e\tau}\rvert$	< 1.9
CHARM [68] ($\overset{(-)}{\nu}_\mu$ beam)	$\lvert\epsilon^{q,X}_{\mu}\rvert$	$\lvert\epsilon^{q,X}_{e\mu}\rvert, \lvert\epsilon^{q,X}_{\mu\mu}\rvert, \lvert\epsilon^{q,X}_{\mu\tau}\rvert$	< 0.205
CDHS [69]			< 0.198
NuTeV [70]			< 0.11

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TENSOR COUPLINGS

Experiment	Observable	Parameters	Limit
ALEPH [47–49]	$\lvert\epsilon_{\text{all}}^{e,T}\rvert$	$\lvert\epsilon_{ee}^{e,T}\rvert$, $\lvert\epsilon_{\mu\mu}^{e,T}\rvert$, $\lvert\epsilon_{\tau\tau}^{e,T}\rvert$, $\lvert\epsilon_{e\mu}^{e,T}\rvert$, $\lvert\epsilon_{e\tau}^{e,T}\rvert$, $\lvert\epsilon_{\mu\tau}^{e,T}\rvert$	< 0.163
DELPHI [50]			< 0.254
L3 [51–53]			< 0.228
OPAL [54–56]			< 0.194
CHARM-II [73]	$\lvert\epsilon_{\mu}^{e,T}\rvert$	$\lvert\epsilon_{e\mu}^{e,T}\rvert$, $\lvert\epsilon_{\mu\mu}^{e,T}\rvert$, $\lvert\epsilon_{\mu\tau}^{e,T}\rvert$	< 0.036
TEXONO [75]	$\lvert\epsilon_{e}^{e,T}\rvert$	$\lvert\epsilon_{ee}^{e,T}\rvert$, $\lvert\epsilon_{e\mu}^{e,T}\rvert$, $\lvert\epsilon_{e\tau}^{e,T}\rvert$	< 0.073
CHARM [67] ($\overset{(-)}{\nu}_e$ beam)	$\lvert\epsilon_{e}^{q,T}\rvert$	$\lvert\epsilon_{ee}^{q,T}\rvert$, $\lvert\epsilon_{e\mu}^{q,T}\rvert$, $\lvert\epsilon_{e\tau}^{q,T}\rvert$	< 0.127
CHARM [68] ($\overset{(-)}{\nu}_\mu$ beam)	$\lvert\epsilon_{\mu}^{q,T}\rvert$	$\lvert\epsilon_{e\mu}^{q,T}\rvert$, $\lvert\epsilon_{\mu\mu}^{q,T}\rvert$, $\lvert\epsilon_{\mu\tau}^{q,T}\rvert$	< 0.0137
CDHS [69]			< 0.0130
NuTeV [70]			< 0.00754

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GLOBAL CONSTRAINTS

Experiments	Scalar	Pseudoscalar	Tensor
e^-e^+ + TEXONO	$\lvert\epsilon_{ee}^{e,S}\rvert < 0.38$	$\lvert\epsilon_{ee}^{e,P}\rvert < 0.40$	$\lvert\epsilon_{ee}^{e,T}\rvert < 0.07$
e^-e^+ + CHARM-II	$\lvert\epsilon_{\mu\mu}^{e,X}\rvert < 0.31$		$\lvert\epsilon_{\mu\mu}^{e,T}\rvert < 0.03$
e^-e^+	$\lvert\epsilon_{\tau\tau}^{e,X}\rvert < 0.40$		$\lvert\epsilon_{\tau\tau}^{e,T}\rvert < 0.12$
e^-e^+ + TEXONO + CHARM-II	$\lvert\epsilon_{e\mu}^{e,S}\rvert < 0.25$	$\lvert\epsilon_{e\mu}^{e,P}\rvert < 0.25$	$\lvert\epsilon_{e\mu}^{e,T}\rvert < 0.03$
e^-e^+ + TEXONO	$\lvert\epsilon_{e\tau}^{e,S}\rvert < 0.28$	$\lvert\epsilon_{e\tau}^{e,P}\rvert < 0.29$	$\lvert\epsilon_{e\tau}^{e,T}\rvert < 0.07$
e^-e^+ + CHARM-II	$\lvert\epsilon_{\mu\tau}^{e,X}\rvert < 0.25$		$\lvert\epsilon_{\mu\tau}^{e,T}\rvert < 0.03$
CHARM−e	$\lvert\epsilon_{ee}^{q,X}\rvert < 1.9$		$\lvert\epsilon_{ee}^{q,T}\rvert < 0.13$
CHARM + CDHS (+ NuTeV)	$\lvert\epsilon_{\mu\mu}^{q,X}\rvert < 0.15\,(0.1)$		$\lvert\epsilon_{\mu\mu}^{q,T}\rvert < 0.01\,(0.006)$
CHARM−e + CHARM + CDHS (+ NuTeV)	$\lvert\epsilon_{e\mu}^{q,X}\rvert < 0.15\,(0.1)$		$\lvert\epsilon_{e\mu}^{q,T}\rvert < 0.01\,(0.006)$
CHARM−e	$\lvert\epsilon_{e\tau}^{q,X}\rvert < 1.9$		$\lvert\epsilon_{e\tau}^{q,T}\rvert < 0.13$
CHARM + CDHS (+ NuTeV)	$\lvert\epsilon_{\mu\tau}^{q,X}\rvert < 0.15\,(0.1)$		$\lvert\epsilon_{\mu\tau}^{q,T}\rvert < 0.01\,(0.006)$

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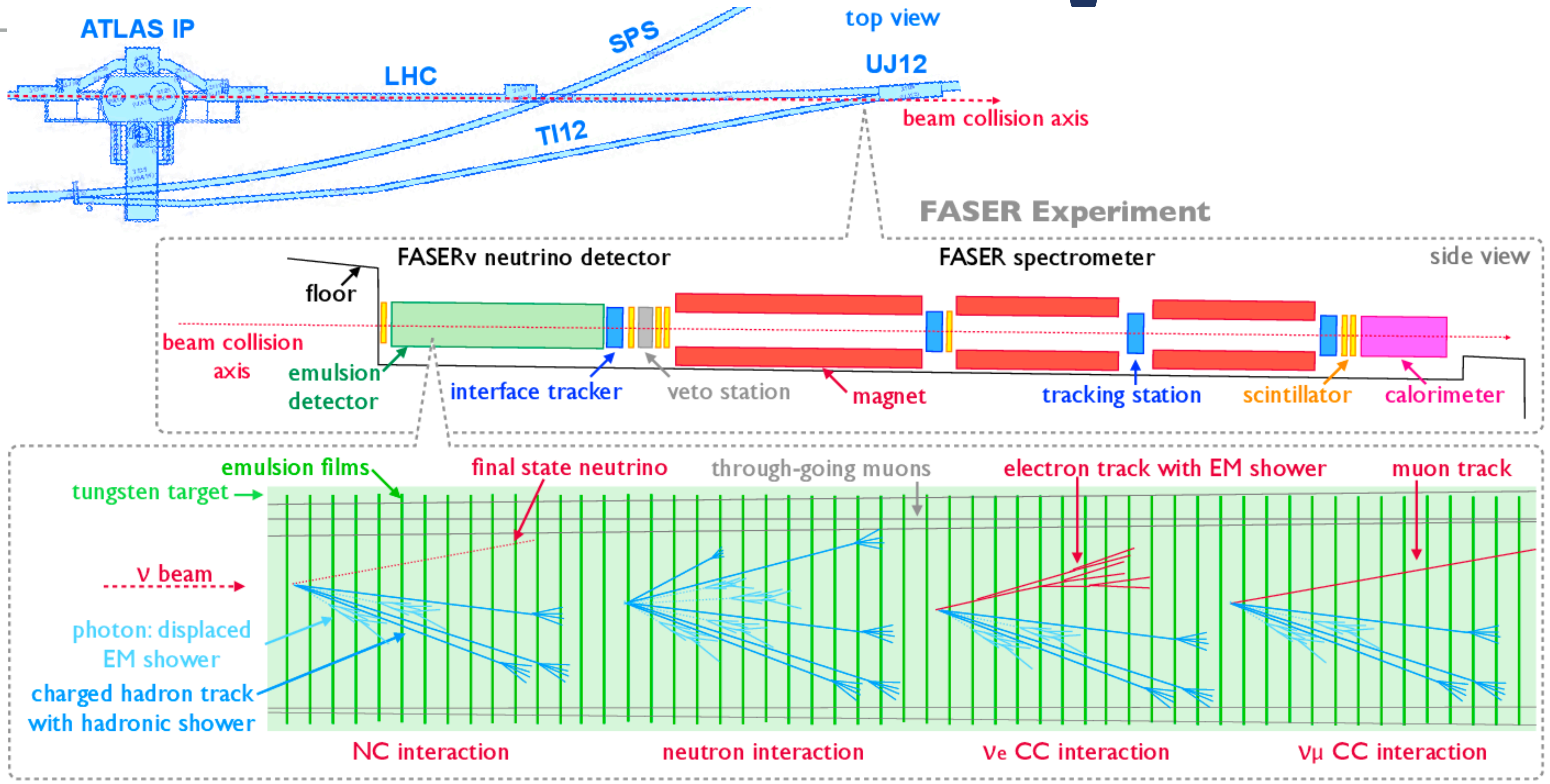
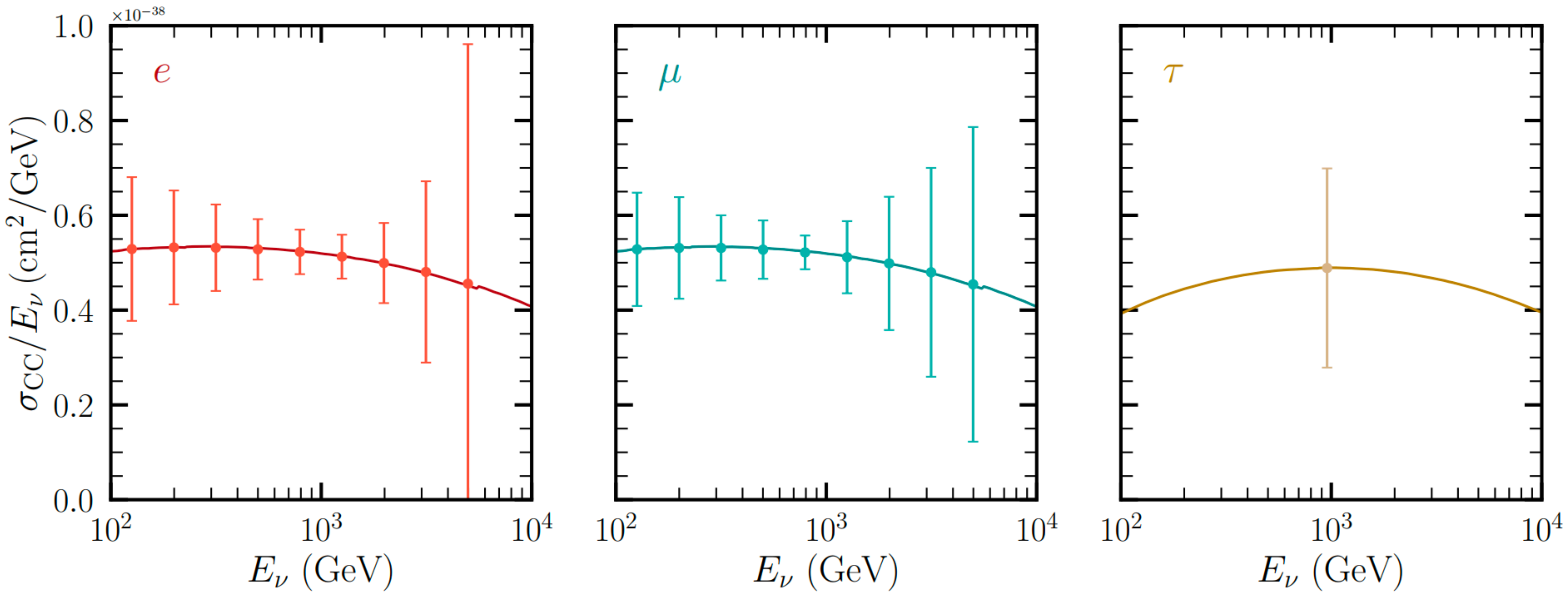
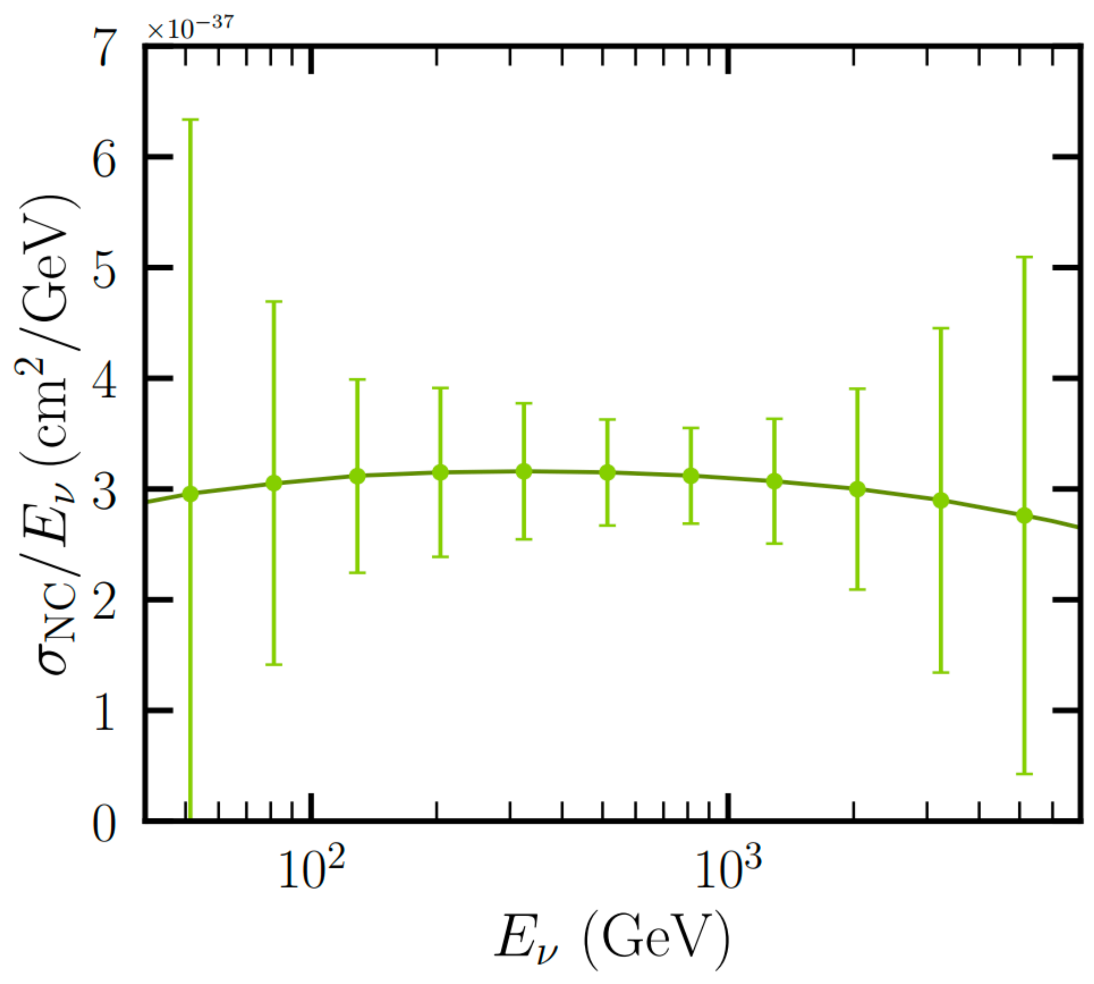
FASERV @ LHC



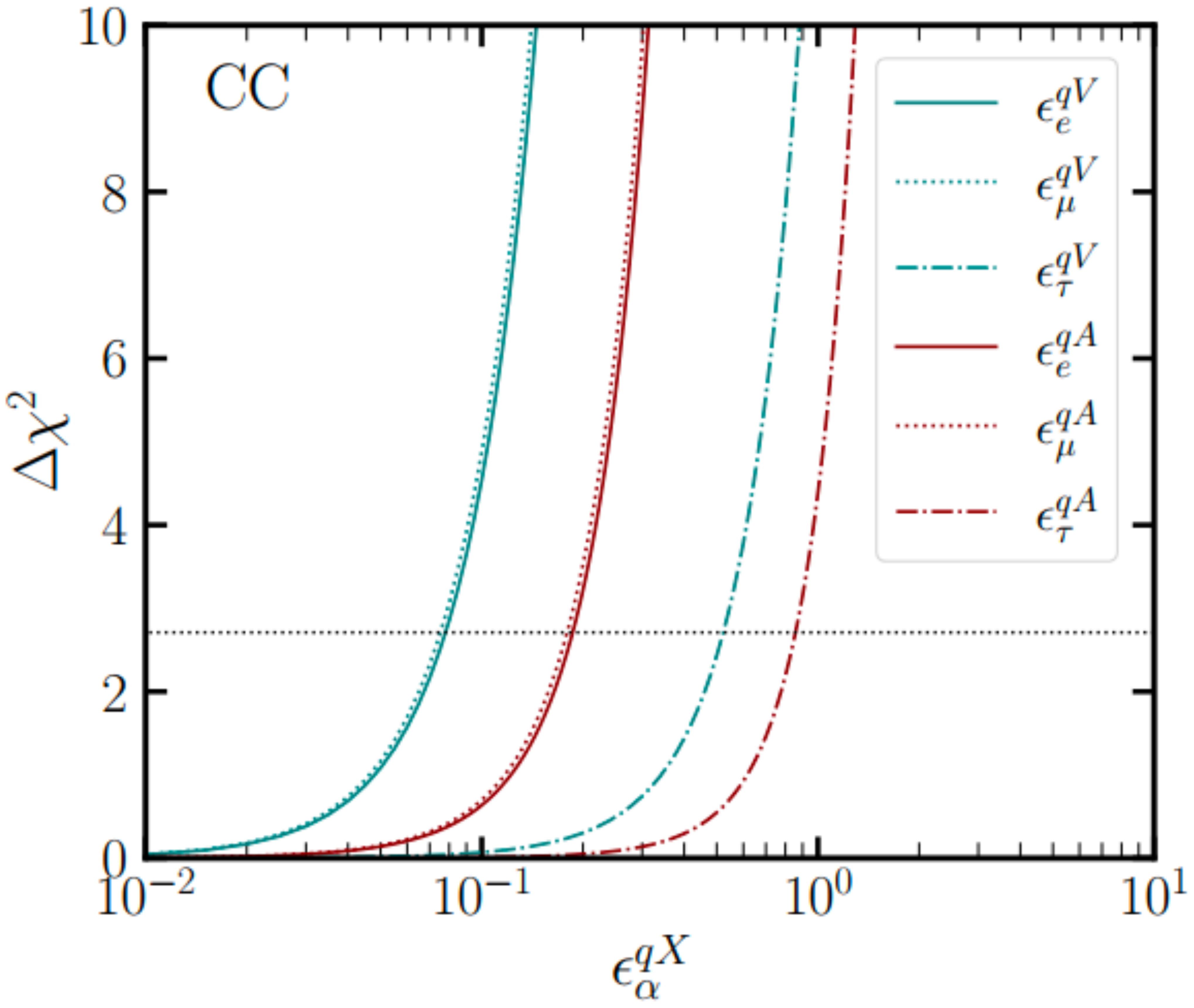
CC events

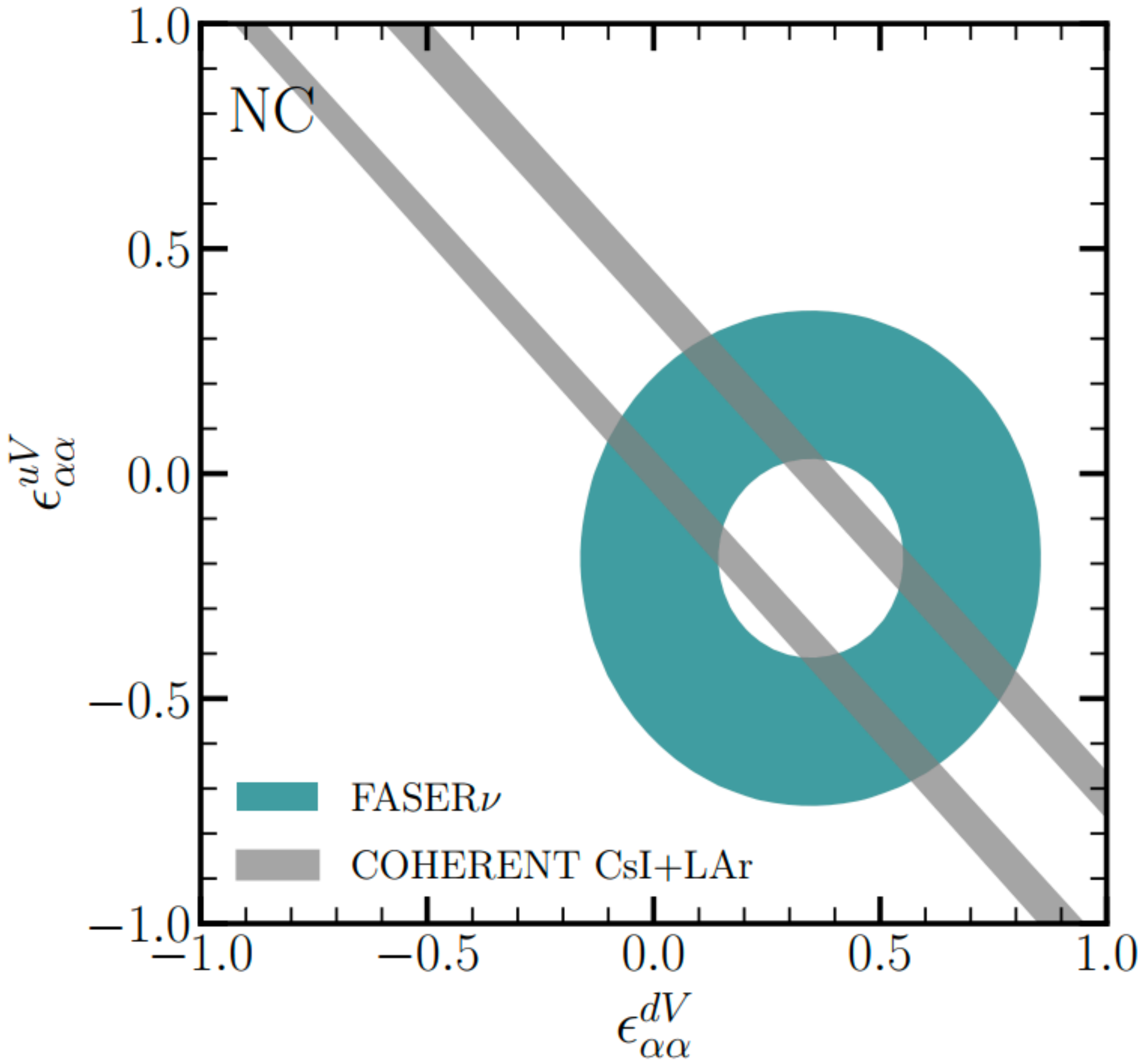


NC events



EXPECTED CONSTRAINTS FROM FASERV





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FINAL COMMENTS

- ✳ Constraints on GNI could provide hints on BSM scenarios
- ✳ Future experiments can provide stronger constraints and even break some degeneracies
- ✳ A full Global analysis of GNI needs to be done

THANK YOU FOR YOUR ATTENTION

BACKUP SLIDES

COUPLING EQUIVALENCE

$$\mathcal{L} = -\frac{G_F}{\sqrt{2}} \sum_{a=S,P,V,A,T} (\bar{\nu}_\alpha \Gamma^a \nu_\beta)(\bar{f}_\gamma \Gamma^a (C^a_{\alpha\beta\gamma\gamma} + \bar{D}^a_{\alpha\beta\gamma\gamma} i\gamma^5) f_\gamma)\,,$$

where the five possible independent combinations of Dirac matrices are given by

$$\Gamma^a \in \{1, i\gamma^5, \gamma^\mu, \gamma^\mu\gamma^5, \sigma^{\mu\nu}\}\,.$$

The relations between the coefficients $C^a_{\alpha\beta\gamma\gamma}$ and $D^a_{\alpha\beta\gamma\gamma} \equiv \begin{cases} \bar{D}^a_{\alpha\beta\gamma\gamma}\,(a = S, P, T) \\ i\bar{D}^a_{\alpha\beta\gamma\gamma}\,(a = V, A) \end{cases}$

$\epsilon^{f,j}_{\alpha\beta\gamma\gamma}$ couplings is given below:

$$\epsilon^L = \frac{1}{4}\left(C^V - D^V + C^A - D^A\right),$$

$$\epsilon^R = \frac{1}{4}\left(C^V + D^V - C^A - D^A\right),$$

$$\epsilon^S = \frac{1}{2}\left(C^S + iD^P\right),$$

$$-\epsilon^P = \frac{1}{2}\left(C^P + iD^S\right),$$

$$\epsilon^T = \frac{1}{4}\left(C^T - iD^T\right).$$

$$\xi_S^{f2} = \frac{1}{N^2}(C_S^2 + D_P^2), \qquad \xi_V^f = \frac{1}{N}(C_V - D_A),$$

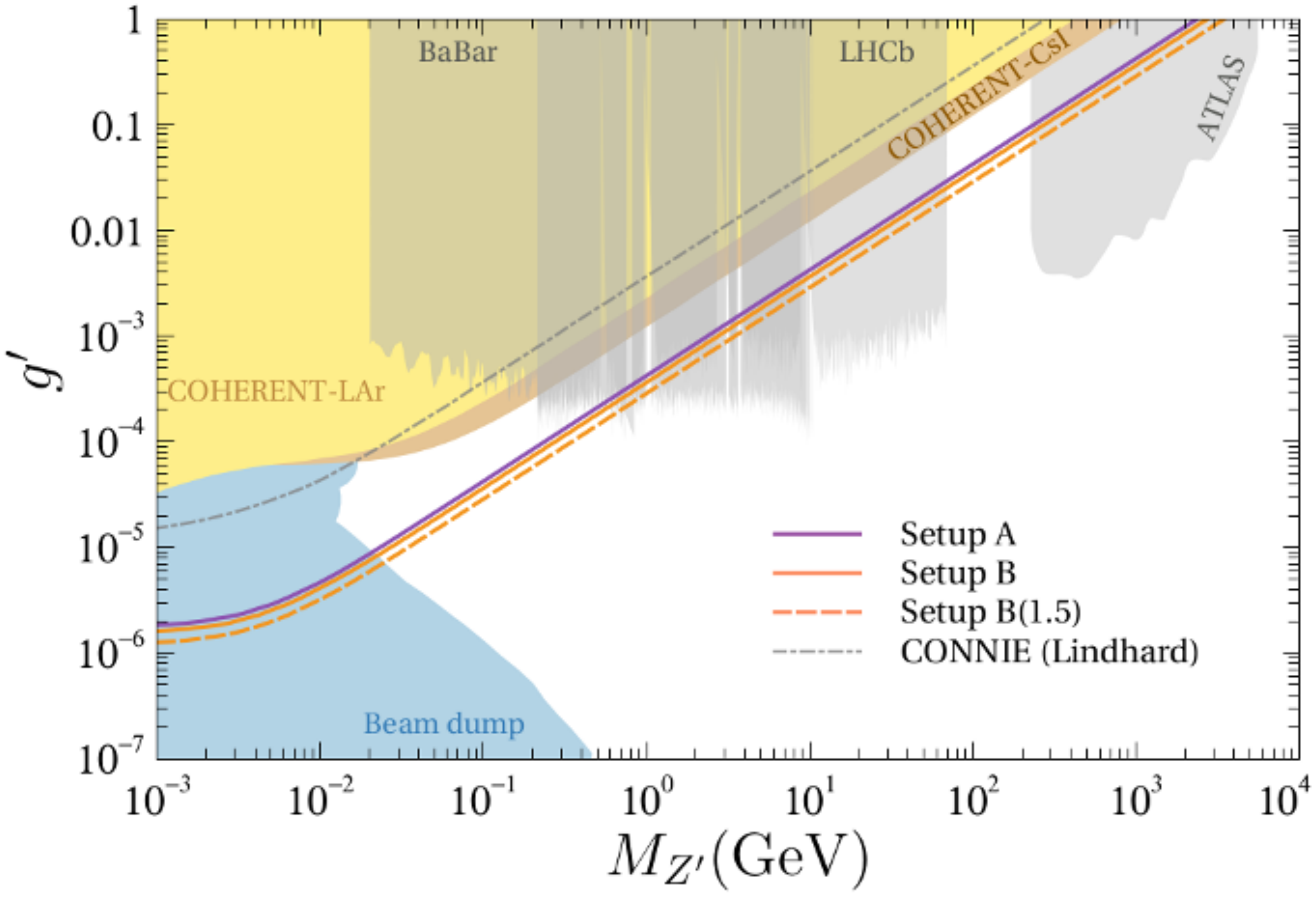
$$\xi_A^f = \frac{1}{N}(C_A - D_V), \qquad \xi_T^{f2} = \frac{8}{N^2}(C_T^2 + D_T^2),$$

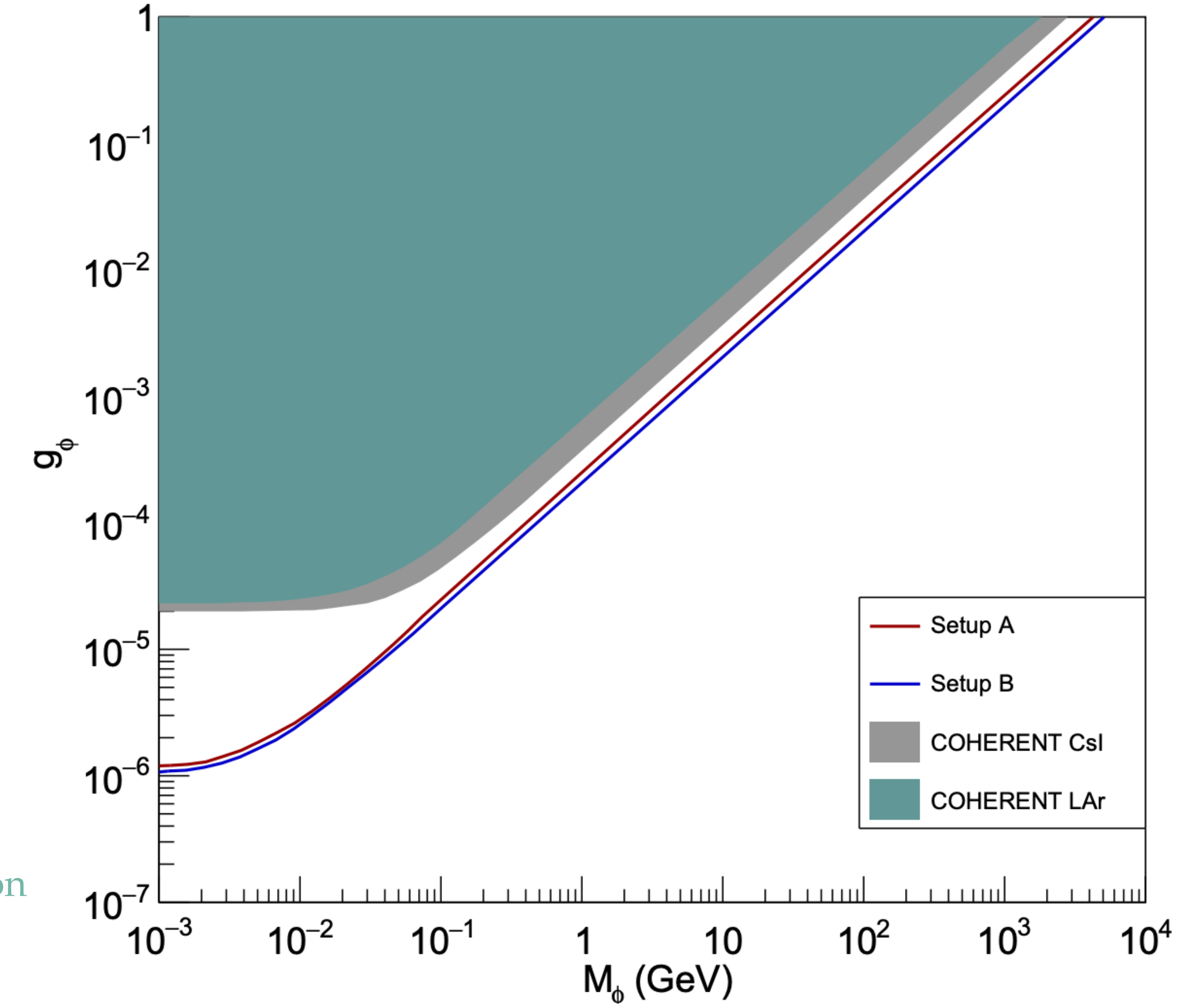
$$R = \frac{2}{N^2}(C_S C_T - C_P C_T + D_S D_T - D_P D_T).$$

FASERV CONSTRAINTS

Charged current (CC)		Neutral current (NC)	
Parameters	90% C.L. limit	Parameters	90% C.L. limit
$\|\epsilon_{ee}^{ud,V}\|$	< 0.078	$\|\epsilon_{\alpha\alpha}^{V}\|$	$<$
$\|\epsilon_{\mu\mu}^{ud,V}\|$	< 0.076	$\epsilon_{\alpha\alpha}^{u,V}$	$(-0.535, 0.158)$
$\|\epsilon_{\tau\tau}^{ud,,V}\|$	< 0.526	$\epsilon_{\alpha\alpha}^{d,V}$	$(-0.091, 0.126) \cup (0.566, 0.786)$
$\|\epsilon_{e\beta}^{ud,V}\|$	< 0.404	$\|\epsilon_{\alpha\beta}^{V}\|$	$<$
$\|\epsilon_{\mu\beta}^{ud,V}\|$	< 0.401	$\|\epsilon_{\alpha\beta}^{u,V}\|$	< 0.293
$\|\epsilon_{\tau\beta}^{ud,V}\|$	< 1.156	$\|\epsilon_{\alpha\beta}^{d,V}\|$	< 0.267
$\|\epsilon_{ee}^{ud,A}\|$	< 0.188	$\|\epsilon_{\alpha\alpha}^{A}\|$	$<$
$\|\epsilon_{\mu\mu}^{ud,A}\|$	< 0.182	$\epsilon_{\alpha\alpha}^{u,A}$	$(-1.06, -0.893) \cup (-0.094, 0.075)$
$\|\epsilon_{\tau\tau}^{ud,A}\|$	< 0.865	$\epsilon_{\alpha\alpha}^{d,A}$	$(-0.062, 0.075) \cup (0.924, 1.063)$
$\|\epsilon_{e\beta}^{ud,A}\|$	< 0.404	$\|\epsilon_{\alpha\beta}^{A}\|$	$<$
$\|\epsilon_{\mu\beta}^{ud,A}\|$	< 0.401	$\|\epsilon_{\alpha\beta}^{u,A}\|$	< 0.293
$\|\epsilon_{\tau\beta}^{ud,A}\|$	< 1.156	$\|\epsilon_{\alpha\beta}^{d,A}\|$	< 0.267
$\|\epsilon_{e}^{ud,S}\|$	< 1.12	$\|\epsilon^{S}\|$	< 0.583
$\|\epsilon_{\mu}^{ud,S}\|$	< 1.15	$\|\epsilon^{u,S}\|$	< 0.854
$\|\epsilon_{\tau}^{ud,S}\|$	< 3.31	$\|\epsilon^{d,S}\|$	< 0.783
$\|\epsilon_{e}^{ud,T}\|$	< 0.295	$\|\epsilon^{T}\|$	< 0.037
$\|\epsilon_{\mu}^{ud,T}\|$	< 0.291	$\|\epsilon^{u,T}\|$	< 0.055
$\|\epsilon_{\tau}^{ud,T}\|$	< 0.875	$\|\epsilon^{d,T}\|$	< 0.051

PHENO FROM CEVNS: LIGHT MEDIATORS





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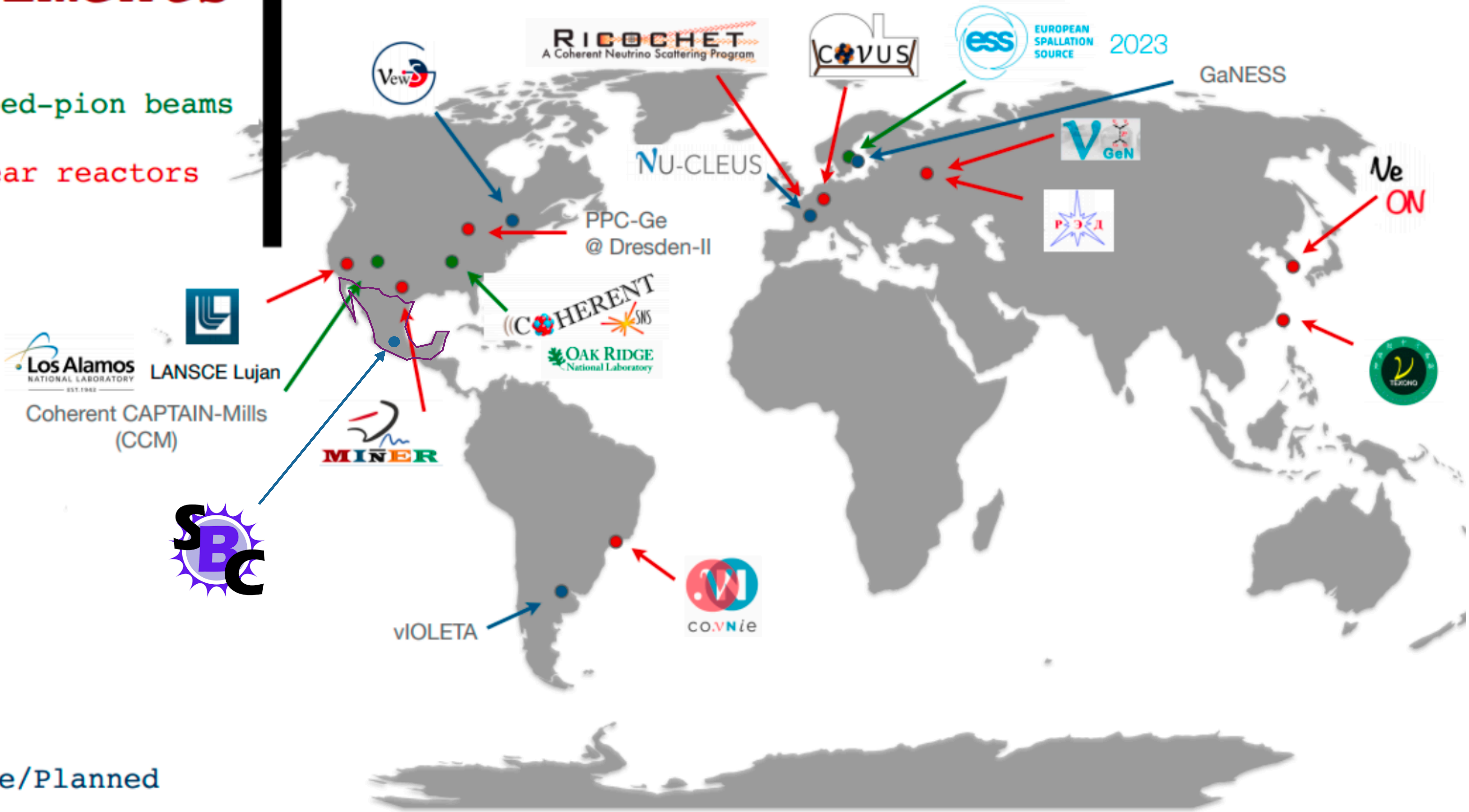
E. Alfonso-Pita, LJF, E. Peinado, E. Vázquez-Jáuregui, 2203.05982

Experiments

- Stopped-pion beams
- Nuclear reactors



- Future/Planned

Adapted fromM. Green talk at Aspen 2019 Winter Conference

Proposed reactor locations

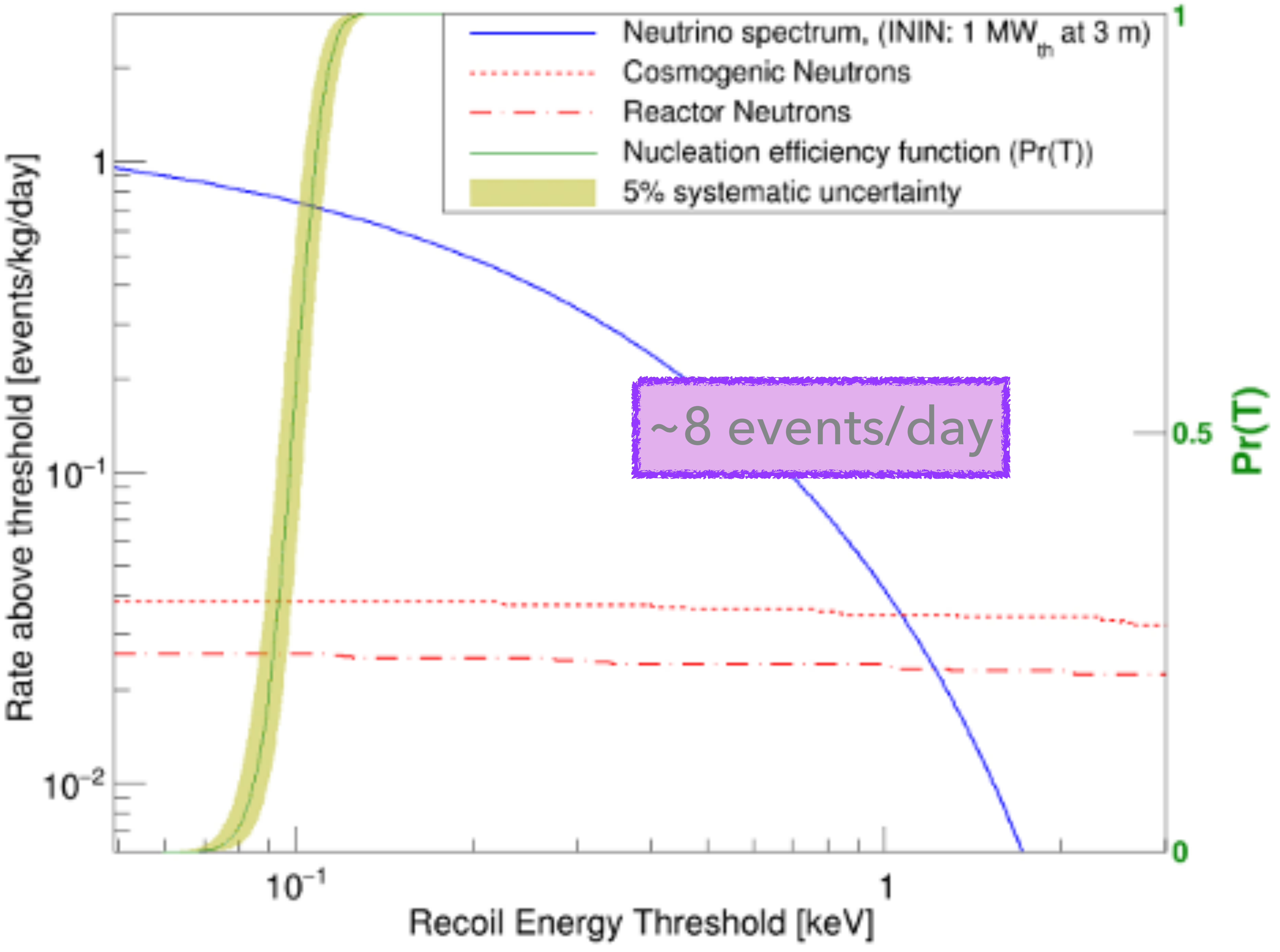
ININ — INSTITUTO NACIONAL DE INVESTIGACIONES NUCLEARES

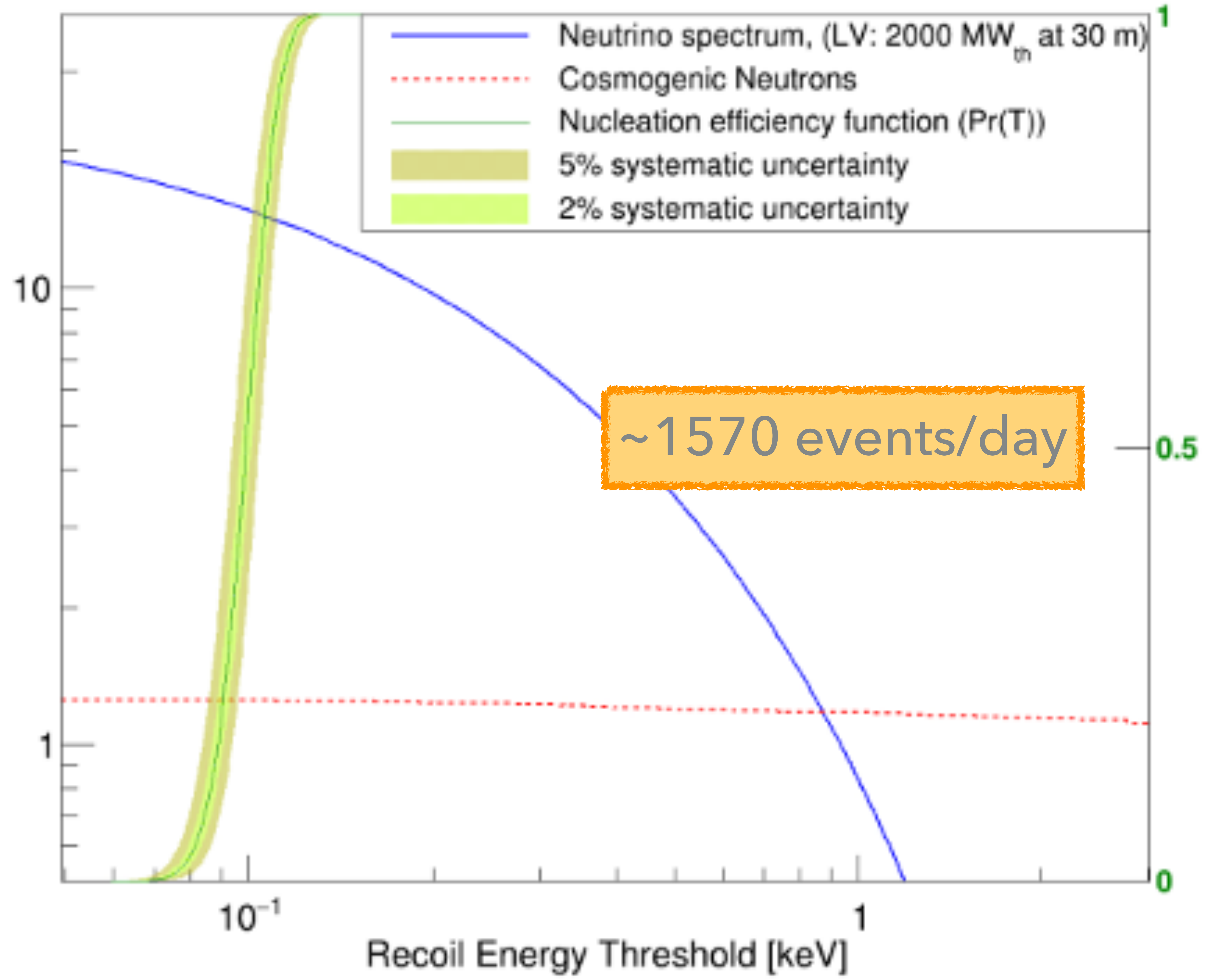
Power	1 MWth
Baseline	3 - 10 m
Target mass	10 kg

Laguna Verde Nuclear Power Plant

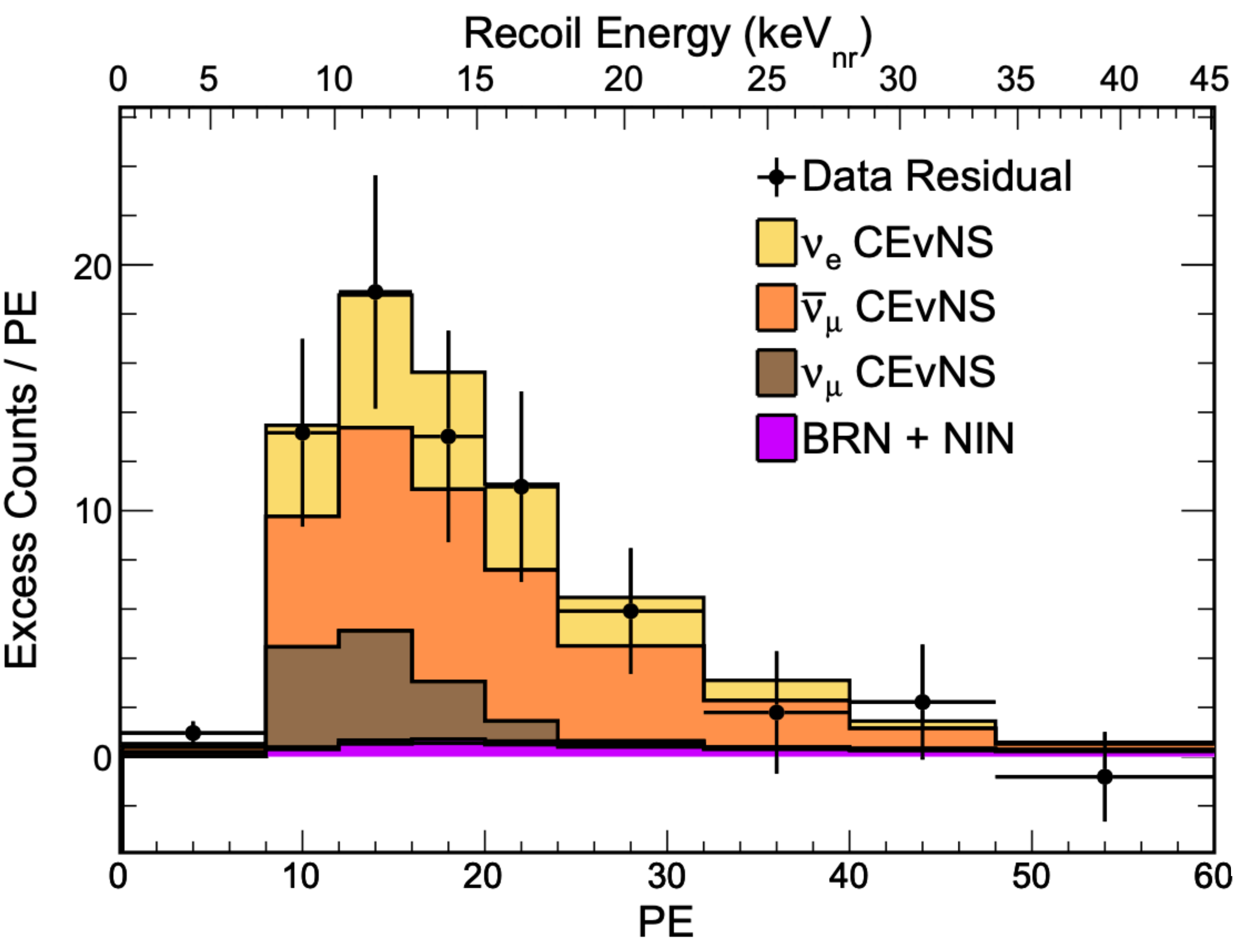
Power	2 GWth
Baseline	30 m
Target mass	100 kg

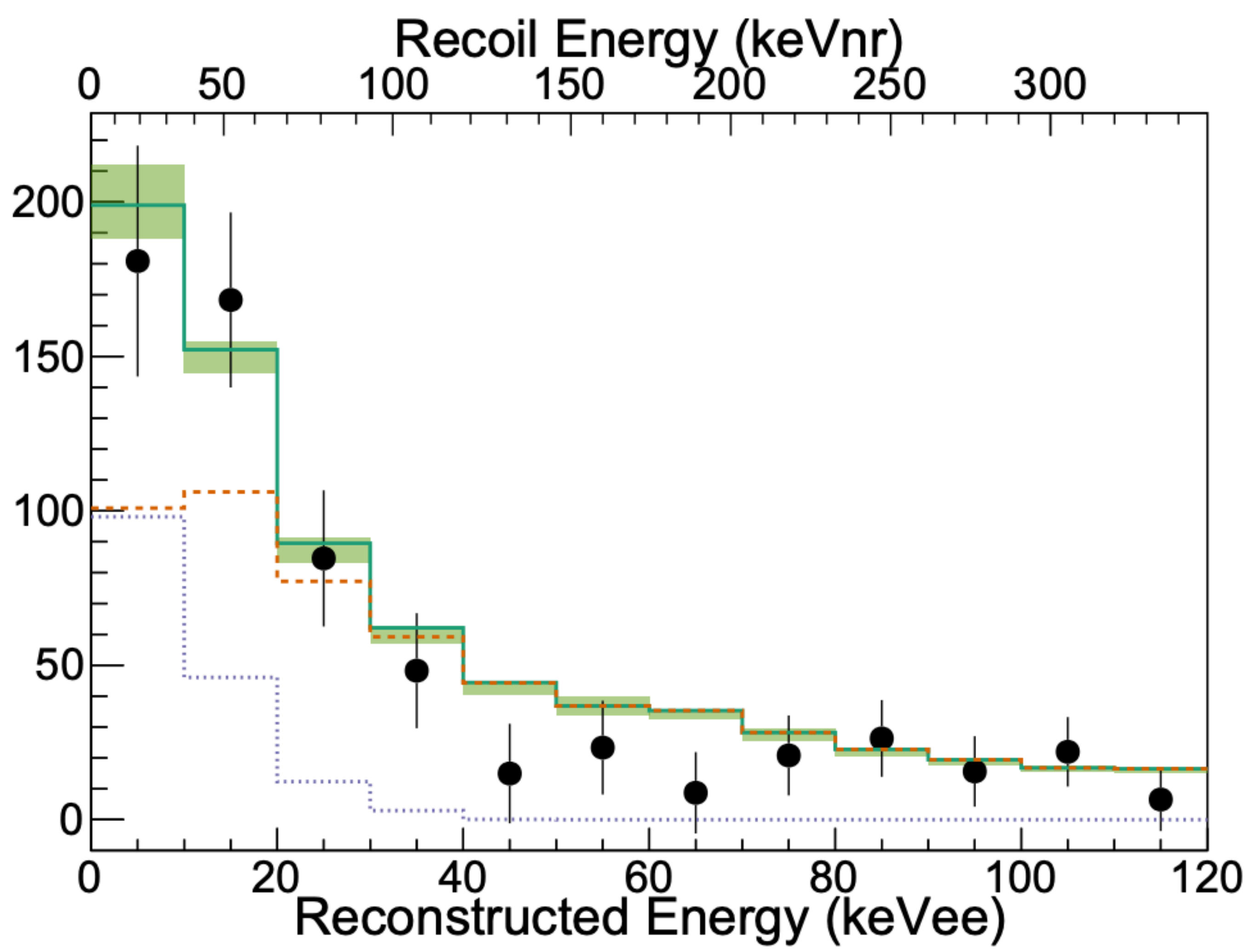
NÚMERO DE EVENTOS ESPERADO

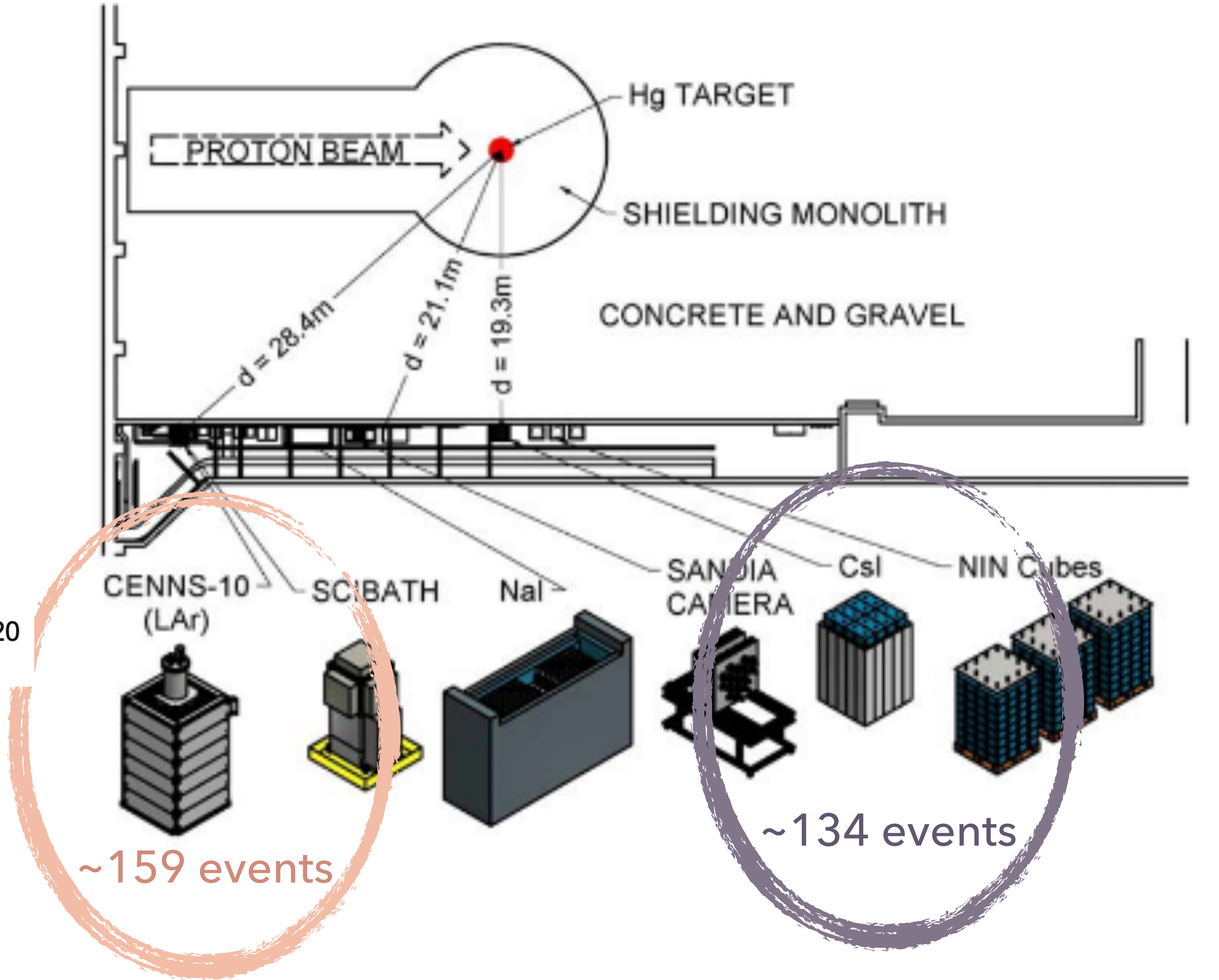




MEASUREMENTS FROM STOPPED-PION SOURCE:





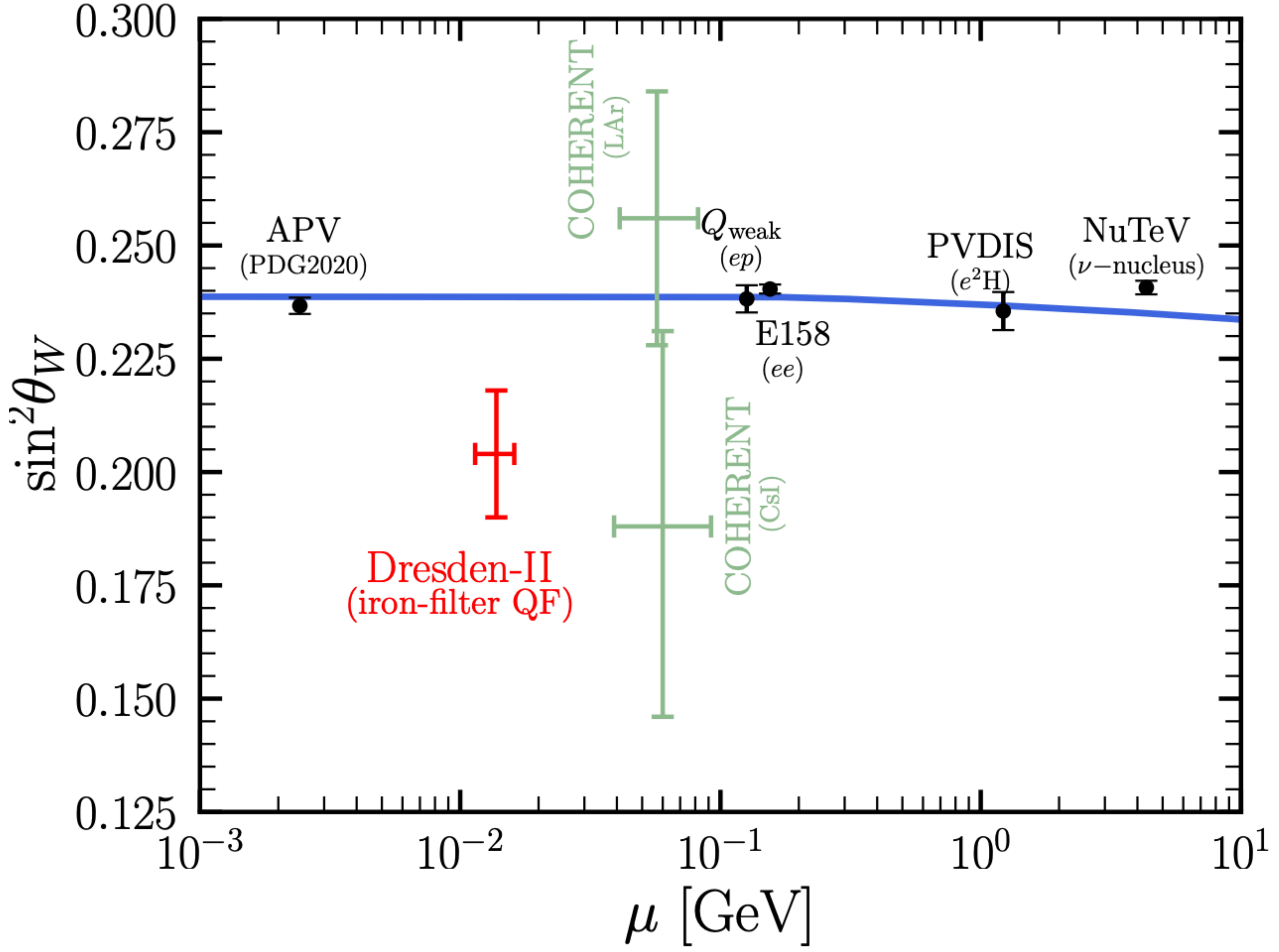


COHERENT Collaboration, Phys.Rev.Lett. 126 (2021) 1, 012002

COHERENT Collaboration, Science 357,1123 (2017) & Phys.Rev.Lett. 126 (2021) 1, 012002

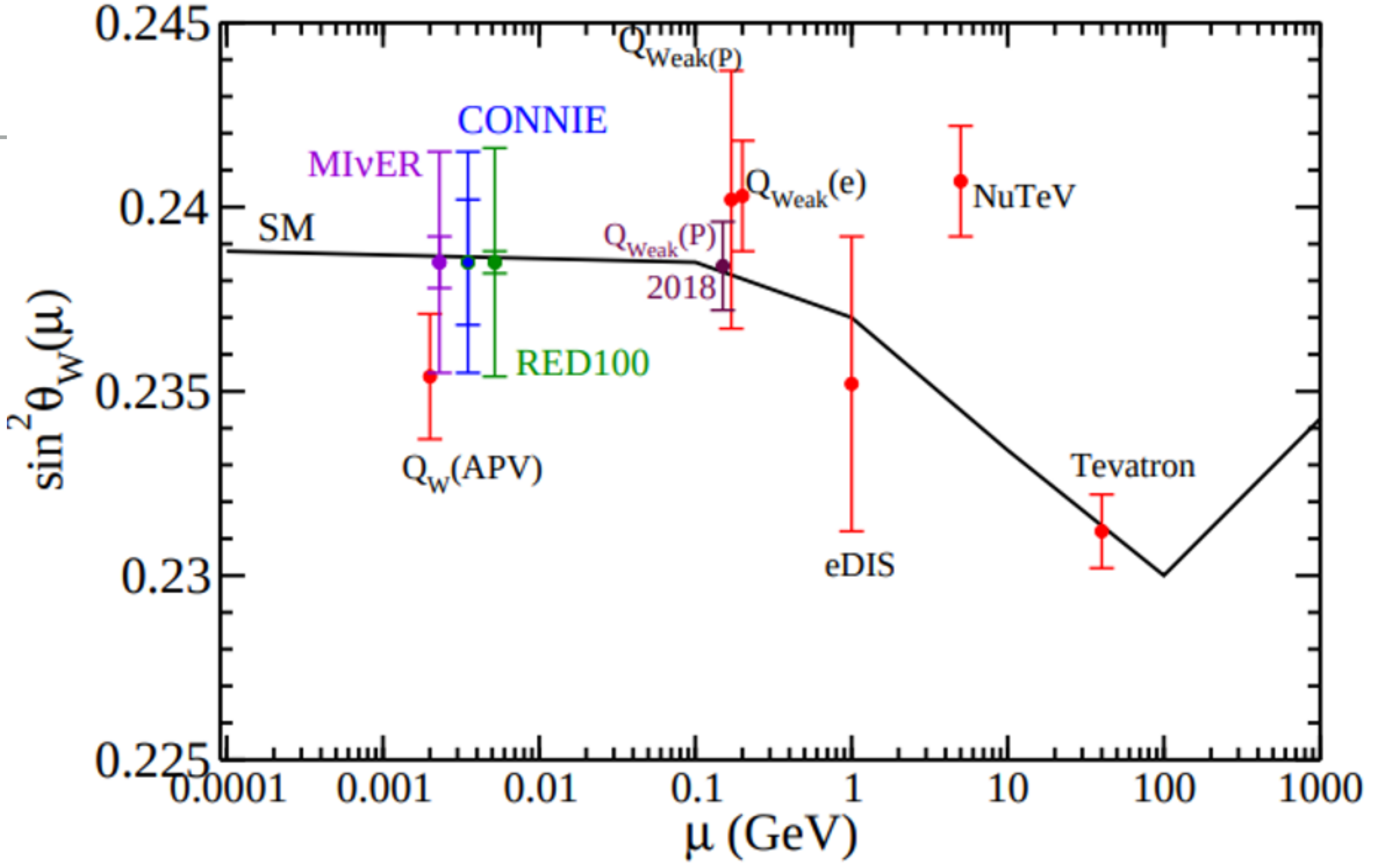
PHENO FROM CEVNS: WEAK MIXING ANGLE

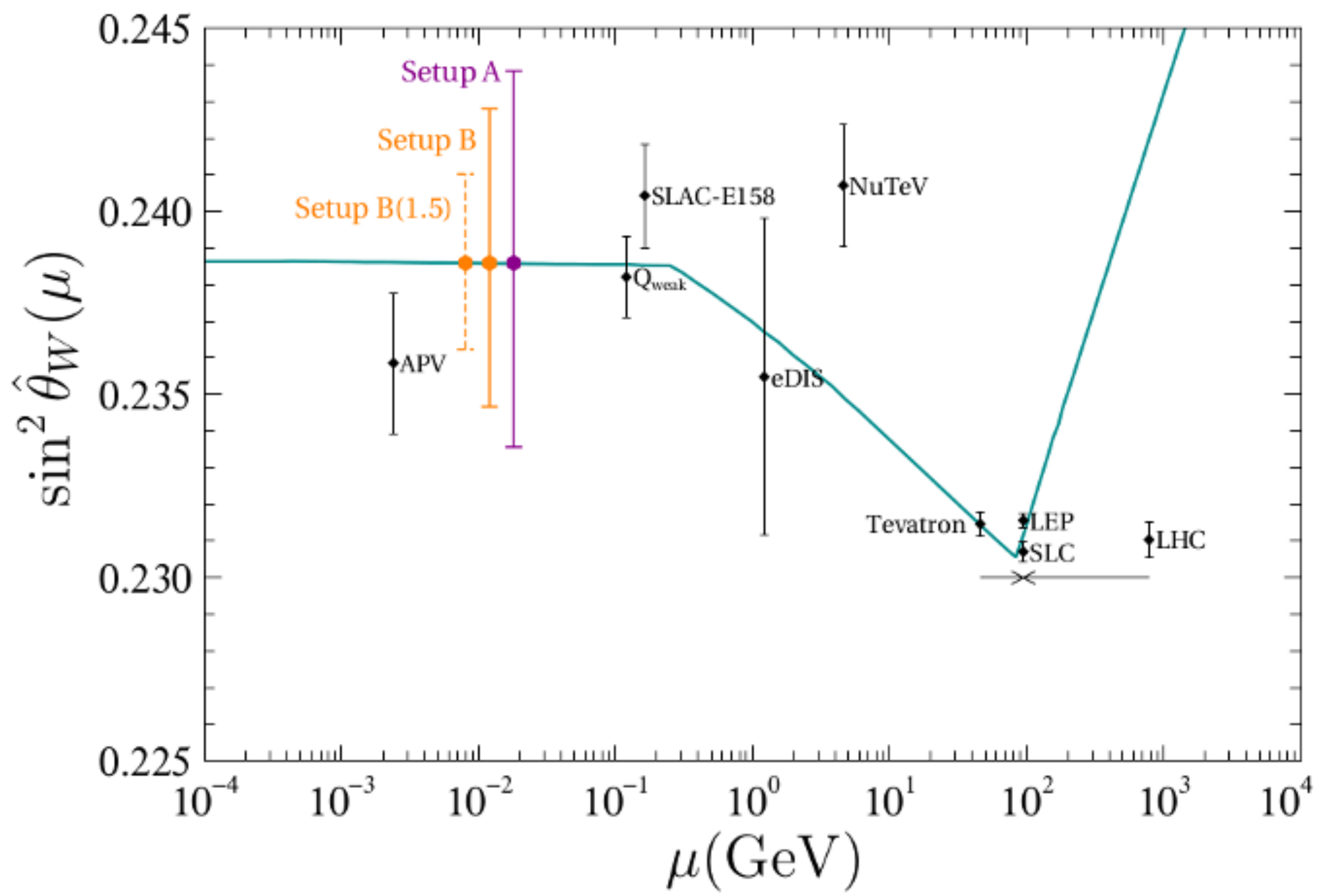
$$Q_w = Z(1/2 - 2\sin^2\theta_W) + N(-1/2)$$



Aristizabal, De Romeri, Papoulias, 2203.02414

Cañas, Garces, Miranda, Parada, Phys.Lett.B784 159 (2018)





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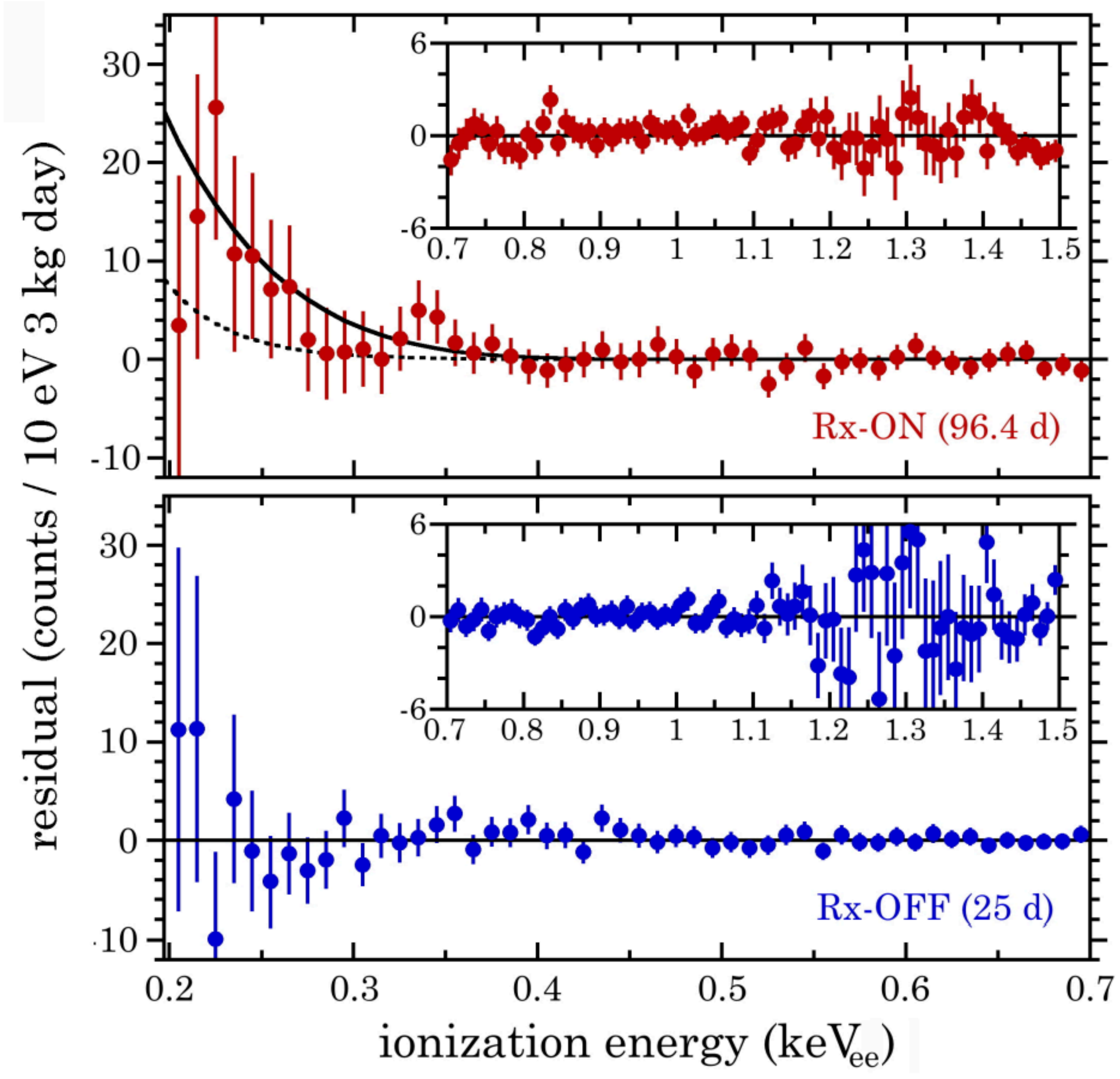
EVIDENCE FROM NUCLEAR REACTOR: NCC-1701 DETECTOR @ DRESDEN II

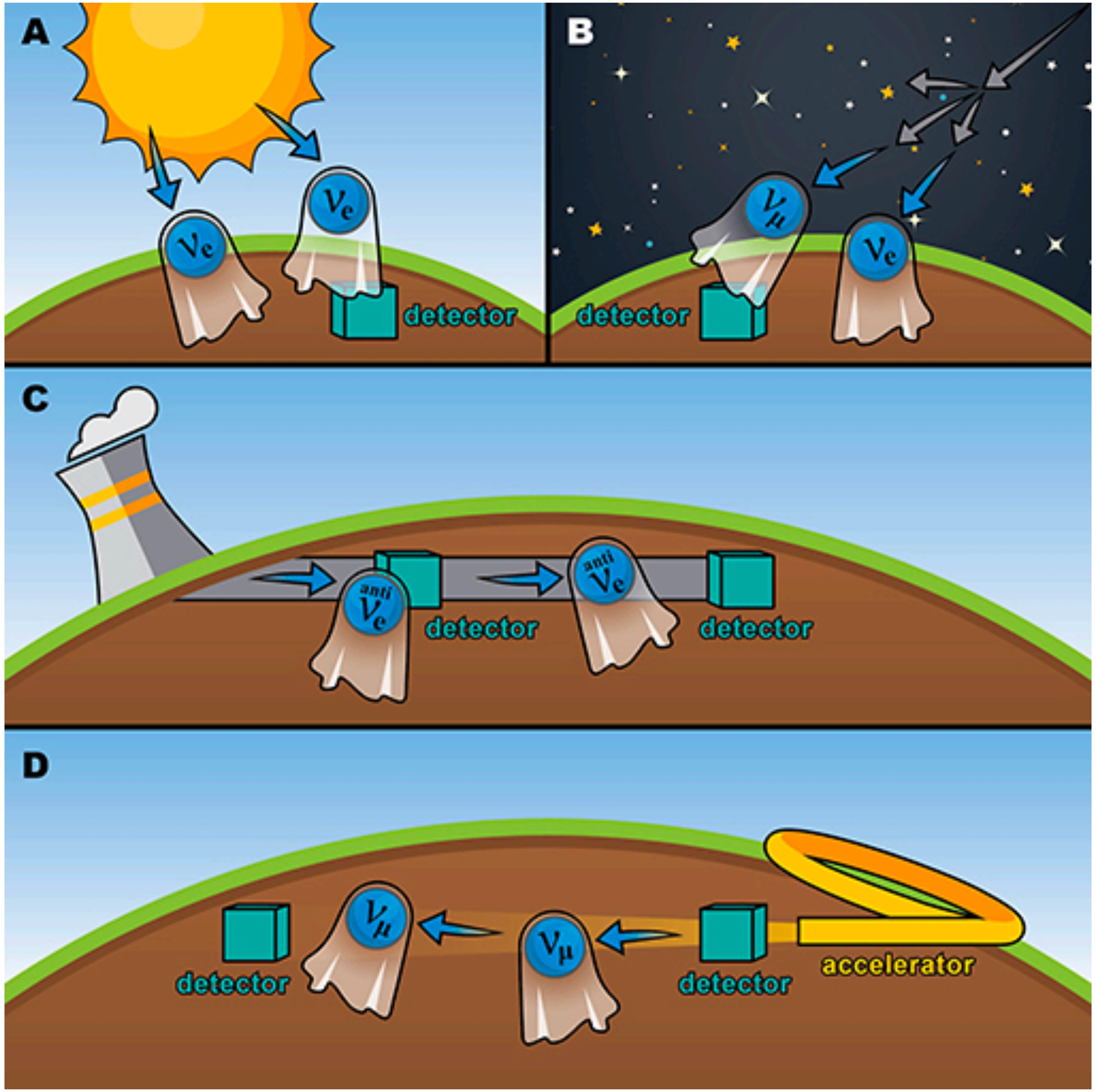


The detector

- PPC Ge
- 2.924 kg
- Threshold: 0.2 keVee

The reactor

- 2.96 GWth
- 10.39 m


A
B
C
D
ν_e
ν_μ
anti ν_e
detector
accelerator