BSM ν_τ Appearance at DUNE-PRISM

Min-Gwa Park

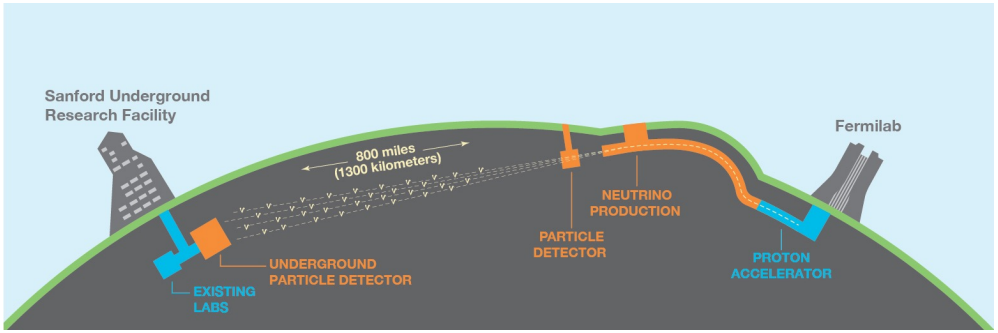
Northwestern University

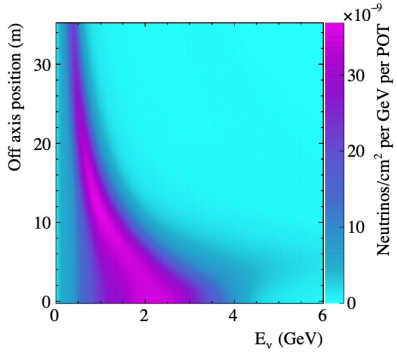
Work with Doojin Kim (South Dakota U.), Seodong Shin (JBNU) [in progress]

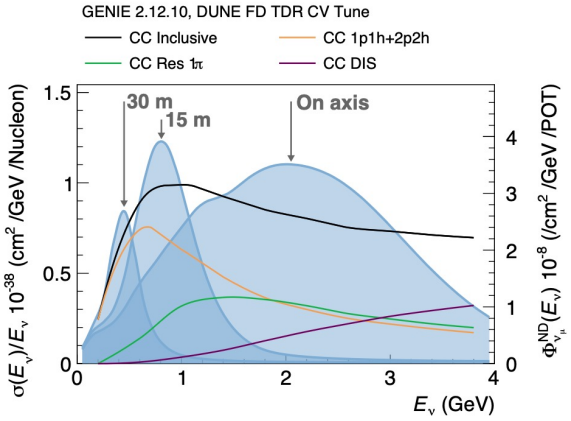
SSU 2026, Busan

Aug 26, 2026

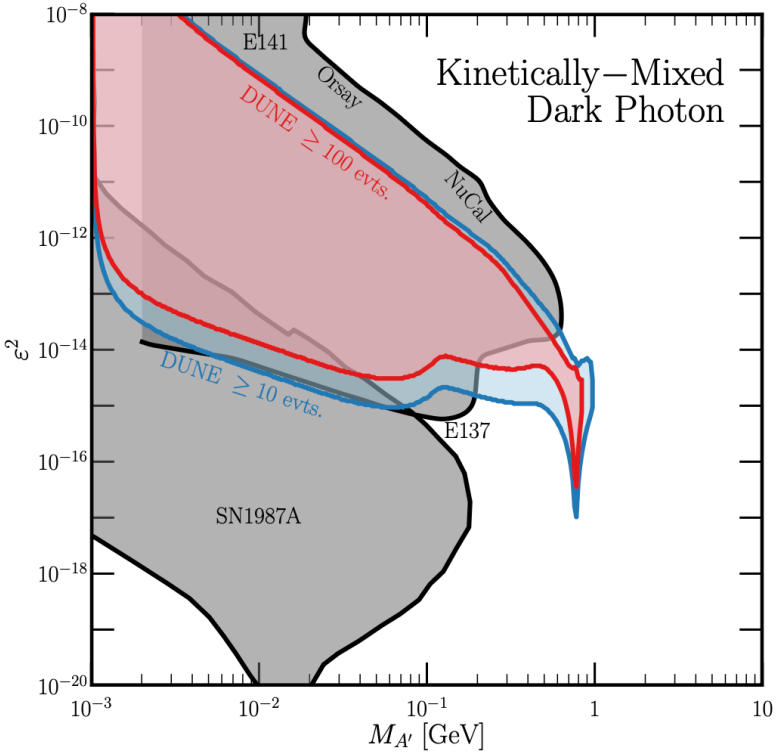
DUNE: Accelerator Neutrino Experiment







DUNE Near Detector Conceptual Design Report

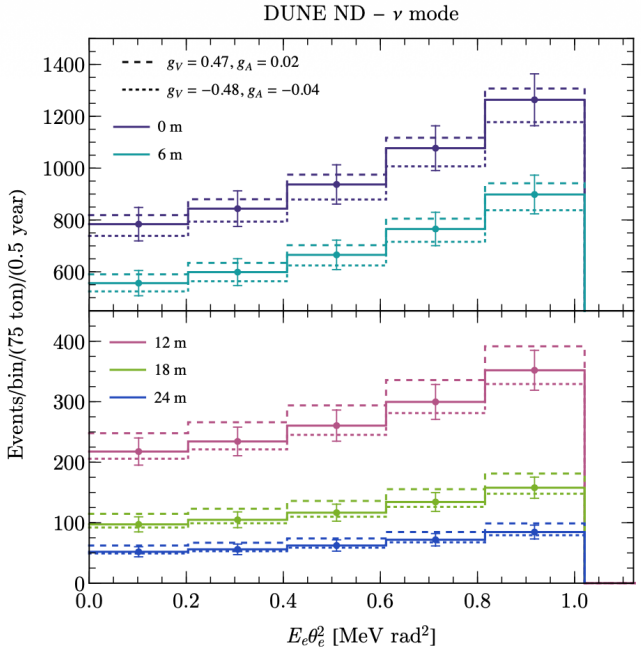


New Physics at DUNE Near Detector

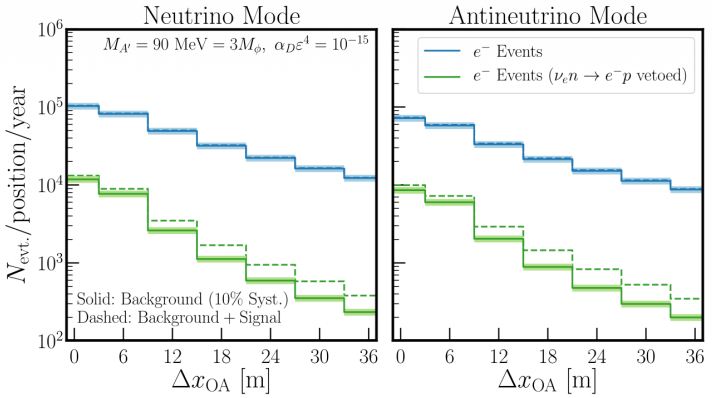
Berryman, de Gouvea, Fox, Kayser, Kelly, Raaf (2020)

Physics Search with DUNE-PRISM

de Gouvea, Machado, Perez-Gonzales, Tabrizi (2022)

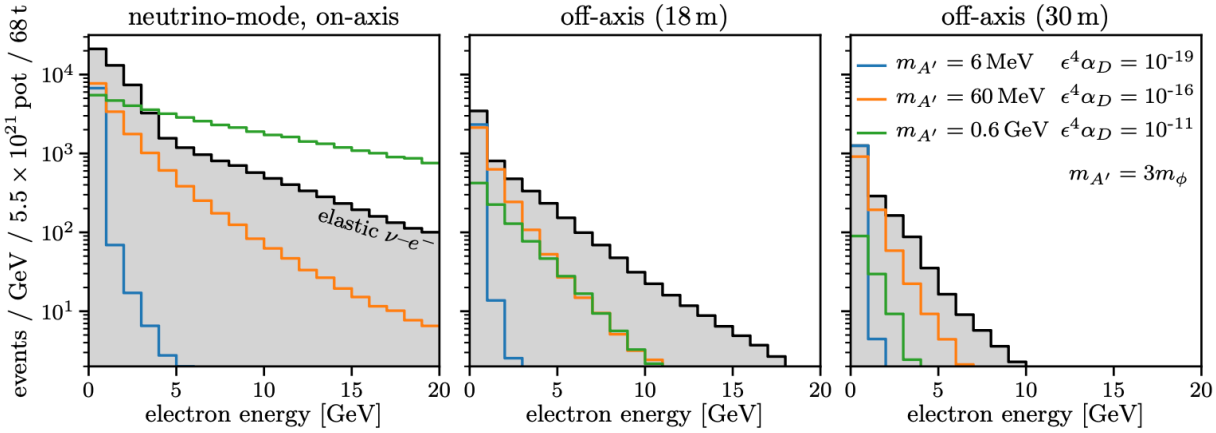


Weak Mixing Angle



New Physics

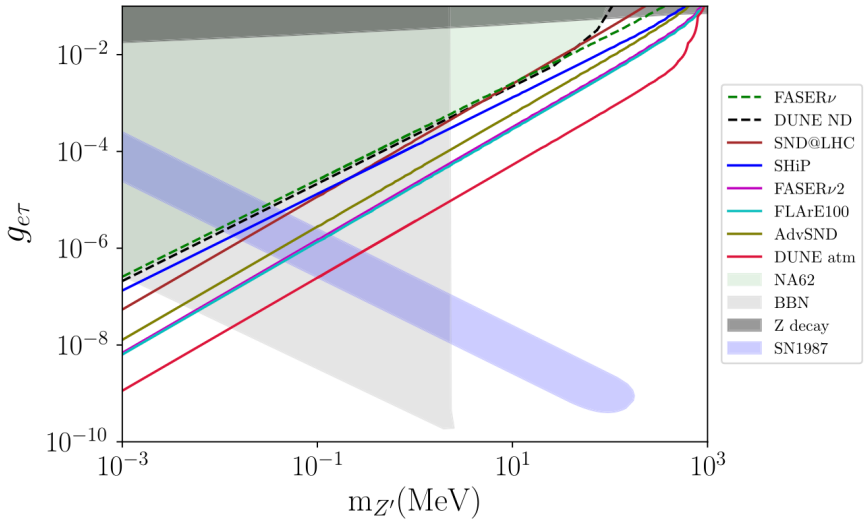
De Romeri, Kelly, Machado (2019)



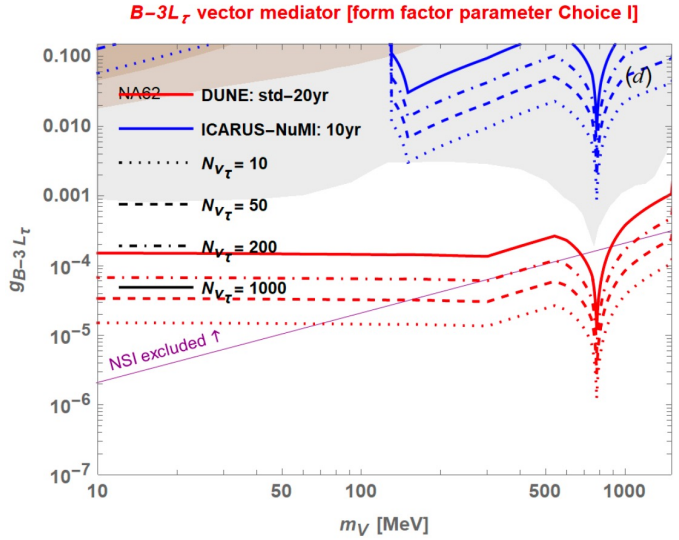
Breitbach, Buonocore, Frugiuele, Kopp, Mittnacht (2022)

Angular, Spectral information increases sensitivity

ν_τ Appearance at DUNE Near Detector



Bakhti, Rajaee, Shin (2024)

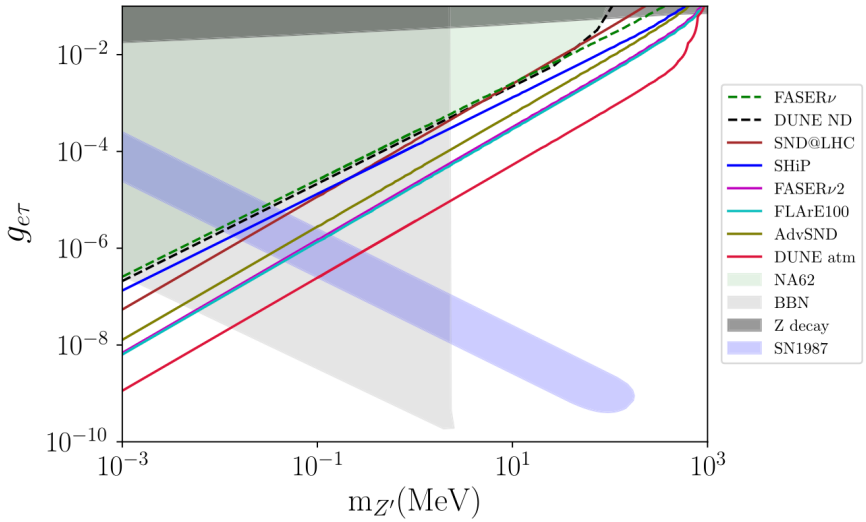


Dev, Dutta, Han, Kim (2024)

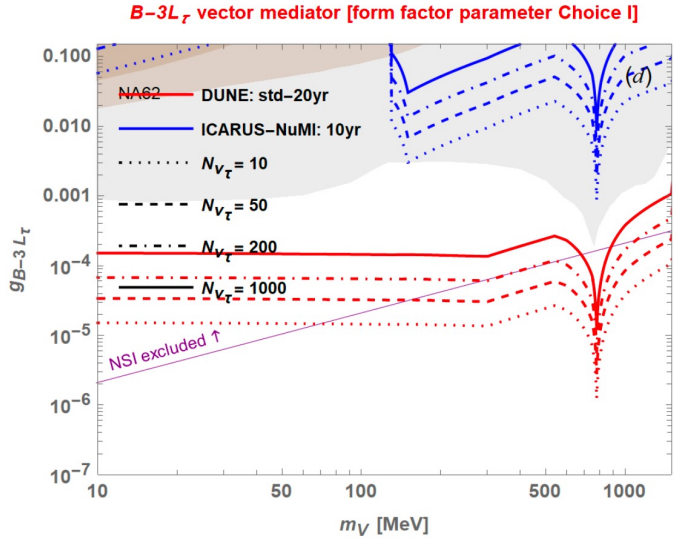
Anomalous meson decay or Proton bremsstrahlung

→ BSM ν_τ flux at DUNE Near Detector

ν_τ Appearance at DUNE Near Detector



Bakhti, Rajaee, Shin (2024)

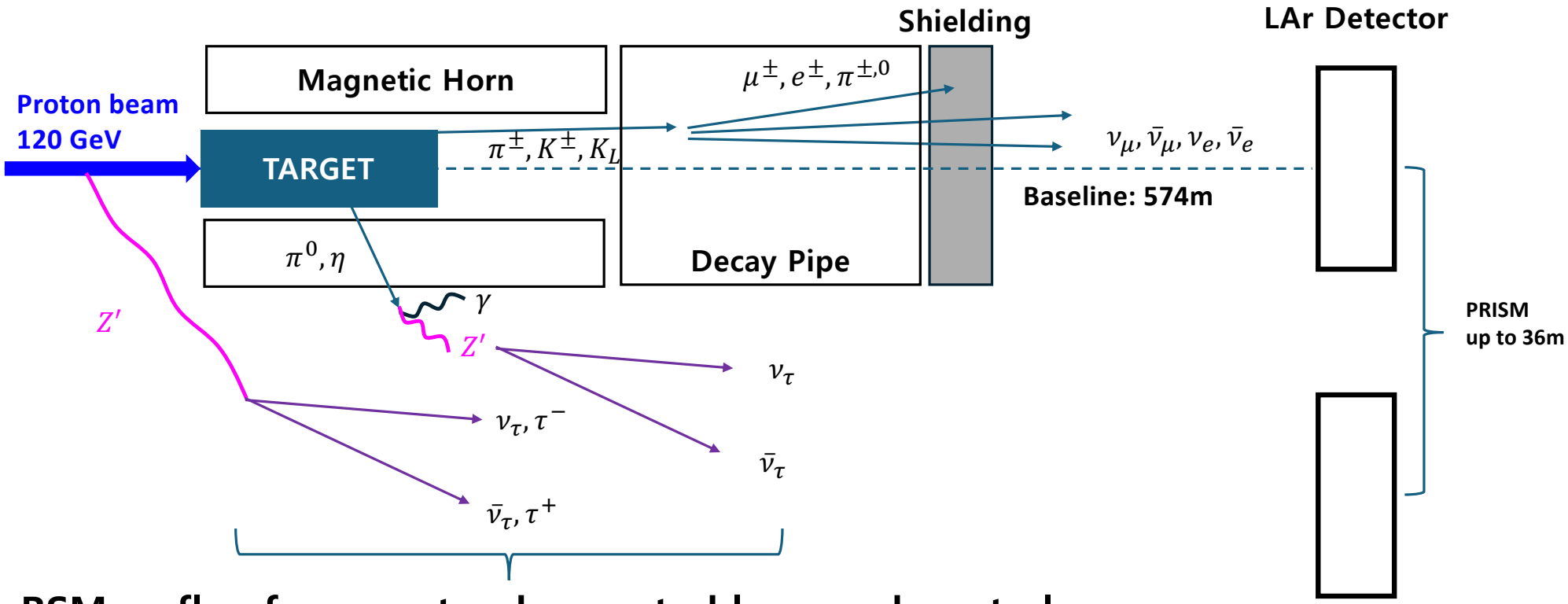


Dev, Dutta, Han, Kim (2024)

Hard & Wide neutrino spectrum from heavy Z'

→ What can we learn about BSM ν_τ flux at DUNE-PRISM?

$B - 3L_\tau$ model Search at DUNE-PRISM

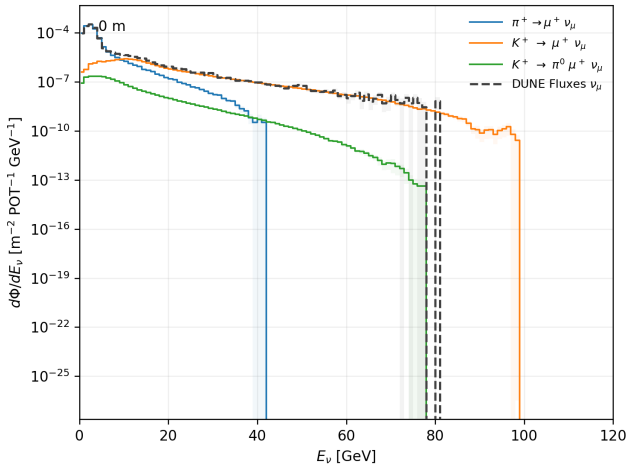


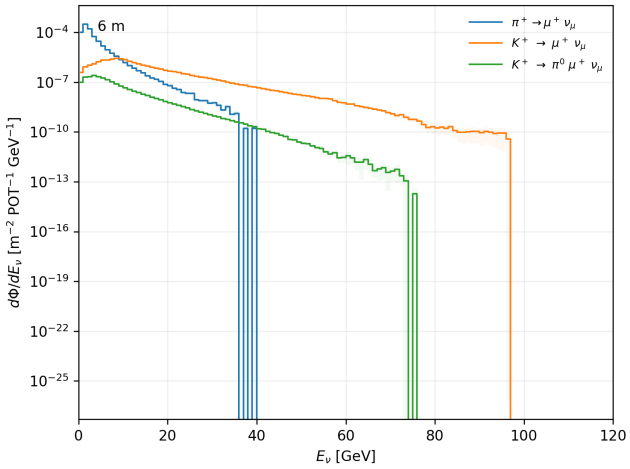
BSM ν_τ flux from proton bremsstrahlung and neutral meson

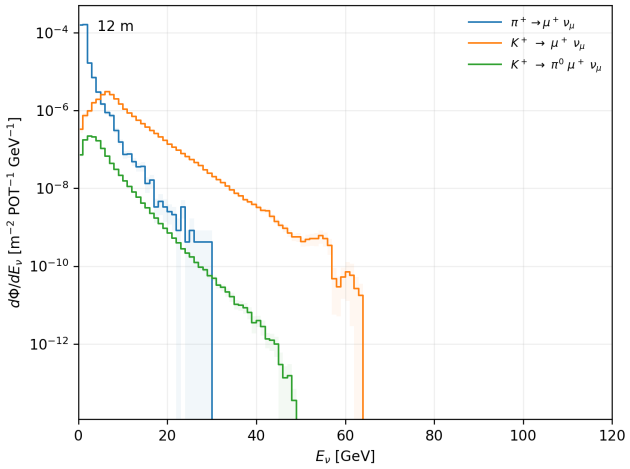
→ Not focused by the magnetic horn

DUNE Fluxes

L. Fields (https://glaucus.crc.nd.edu/DUNEFluxes/)
: Optimized 3-horn Design with 1.5 m target and fully engineered Horns (Sept 2021)





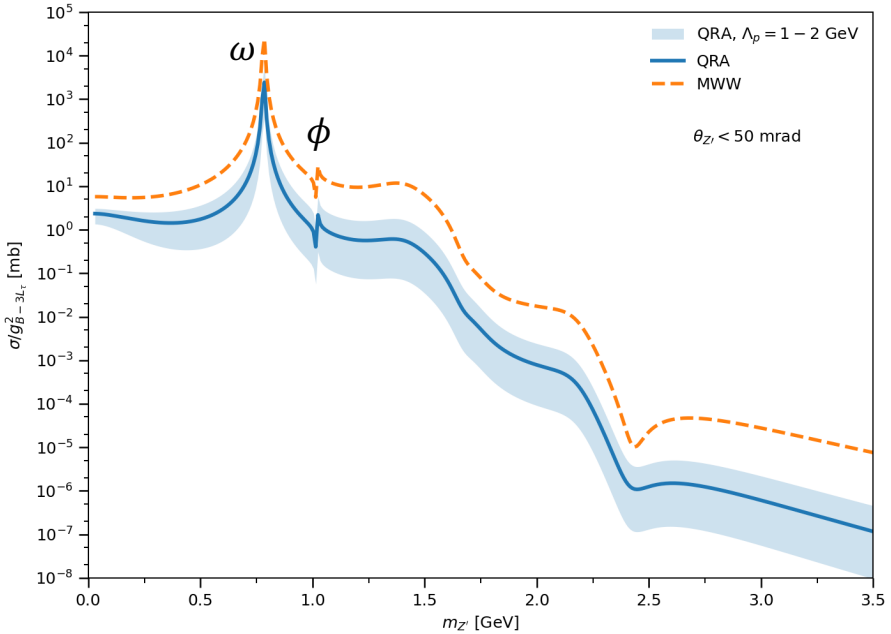


dk2nu file contains $\pi^{\pm}, K^{\pm}, K_L$ and their daughter particles (total 10^7 POT)

Re-decayed parent mesons to get fine MC spectra
& Compared to 'DUNE Fluxes' channel by channel

D_s, π^0, η spectra separately generated with Pythia 8 (SoftQCD:all)

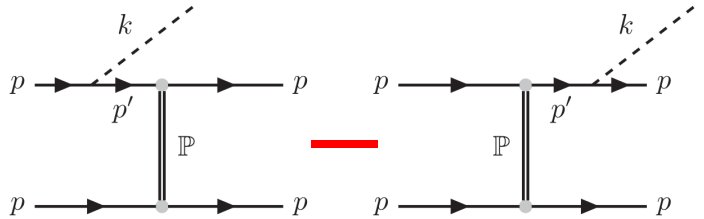
Proton Bremsstrahlung for $B-3L_\tau$ model



Simulated following

Foroughi-Abari, Ritz (2022),
Foroughi-Abari, Reimitz, Ritz (2025),
Kling, Reimitz, Ritz (2026)

Foroughi-Abari, Ritz (2022)

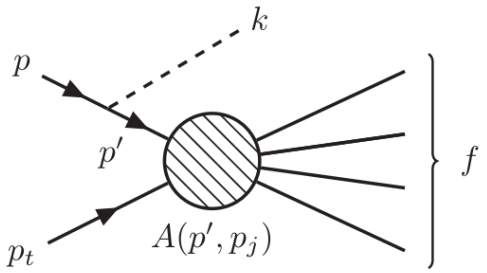


Strong destructive interference between QE ISR & FSR

Previously widely used

$$d\sigma_{MWW} = dP_{ISR}^{split} \times (\sigma^{EL} + \sigma^{SD} + \sigma^{NSD})$$

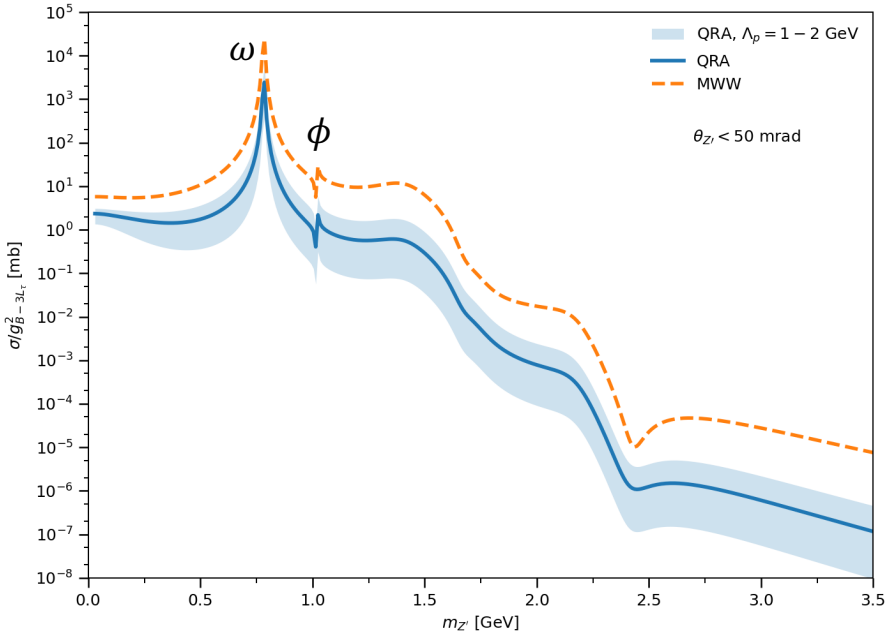
$$>> d\sigma_{QRA} = dP_{ISR}^{split} \times (\cancel{\sigma^{EL} + \sigma^{SD}} + \sigma^{NSD})$$



Non-Single Diffraction:

p + p → X + Y

Proton Bremsstrahlung for $B - 3L_\tau$ model



Simulated following

Foroughi-Abari, Ritz (2022),
Foroughi-Abari, Reimitz, Ritz (2025),
Kling, Reimitz, Ritz (2026)

$$\mathcal{L} \supset g \sum_f x_f \bar{f} \gamma^\mu f \; Z'_\mu$$

$$x_u = x_d = x_s = \frac{1}{3}, \; x_\tau = x_{\nu_\tau} = -3$$

$$x_\omega = 3(x_u + x_d) = 2$$

$$x_\phi = -3x_s = -1$$

$$x_\rho = x_u - x_d = 0$$

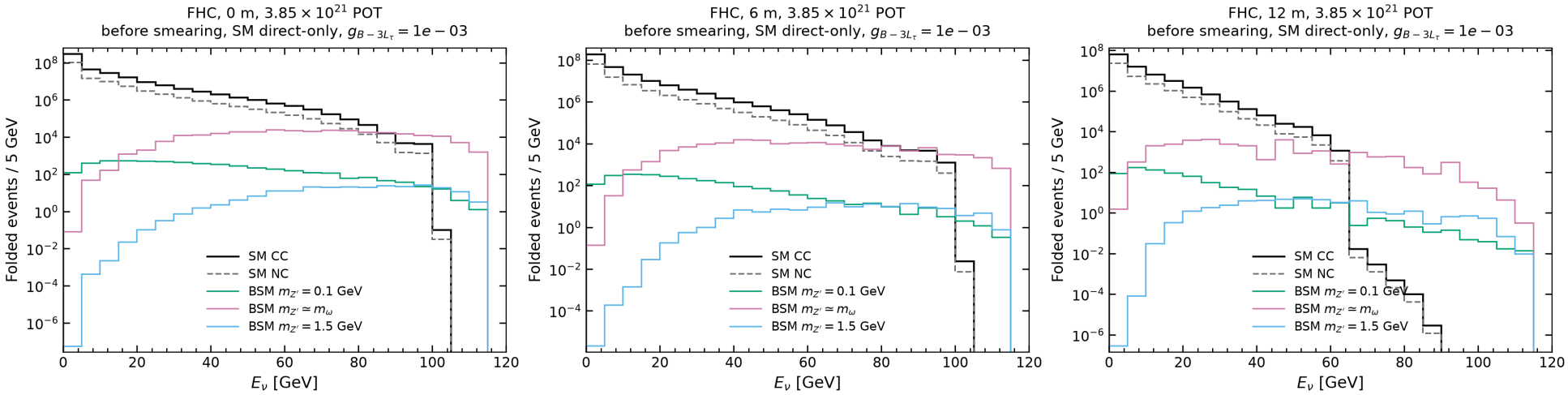
Proton form factors:

$$F_i^p(t) = x_\omega F_{i,\omega}(t) + x_\phi F_{i,\phi}(t) + x_\rho F_{i,\rho}(t)$$

$\phi = s\bar{s}$: **OZI suppressed**

DUNE Flux + BSM ν_τ Flux events

Folded GENIE cross section



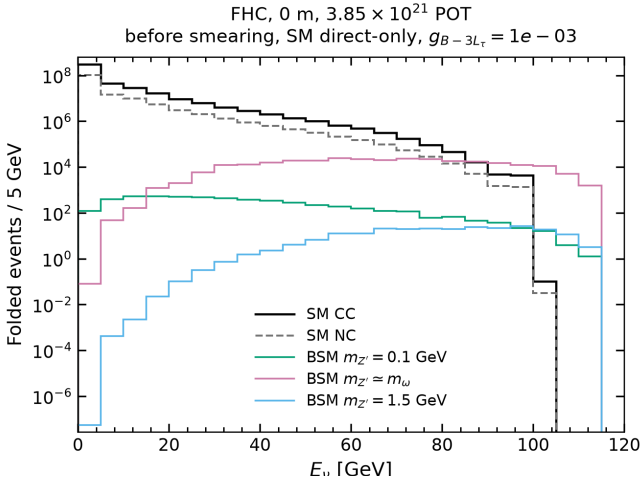
Our 10^7 POT dk2nu files don't include enough high energy mesons,

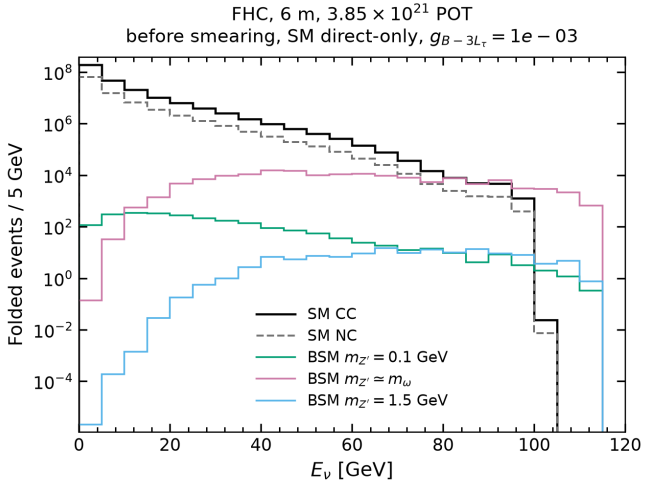
so even many re-decays can't provide high energy neutrino flux.

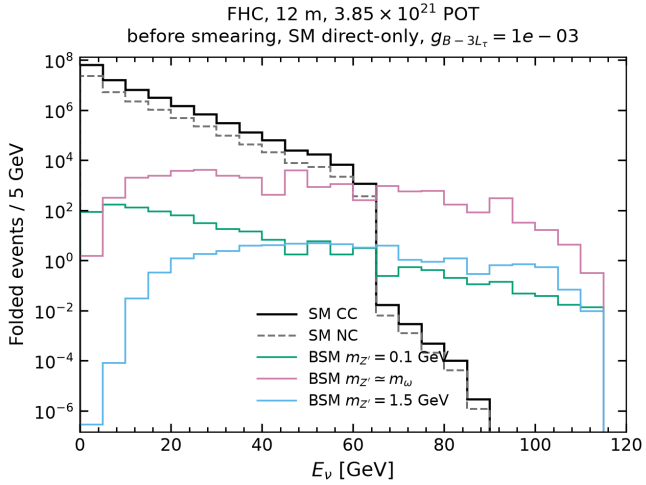
NOT a fair SM background comparison with BSM ν_τ flux!

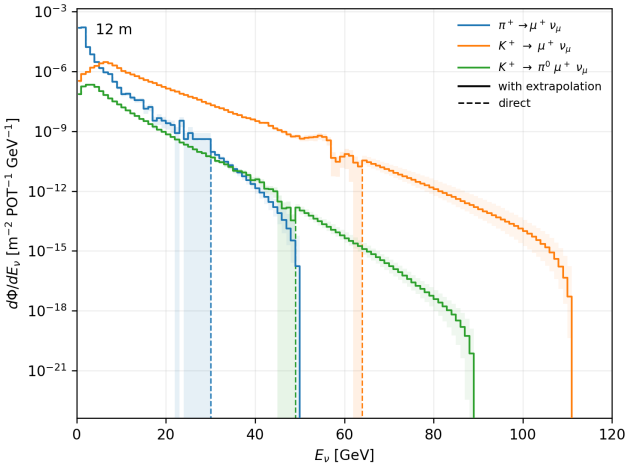
DUNE Flux + BSM ν_τ Flux events

Folded GENIE cross section





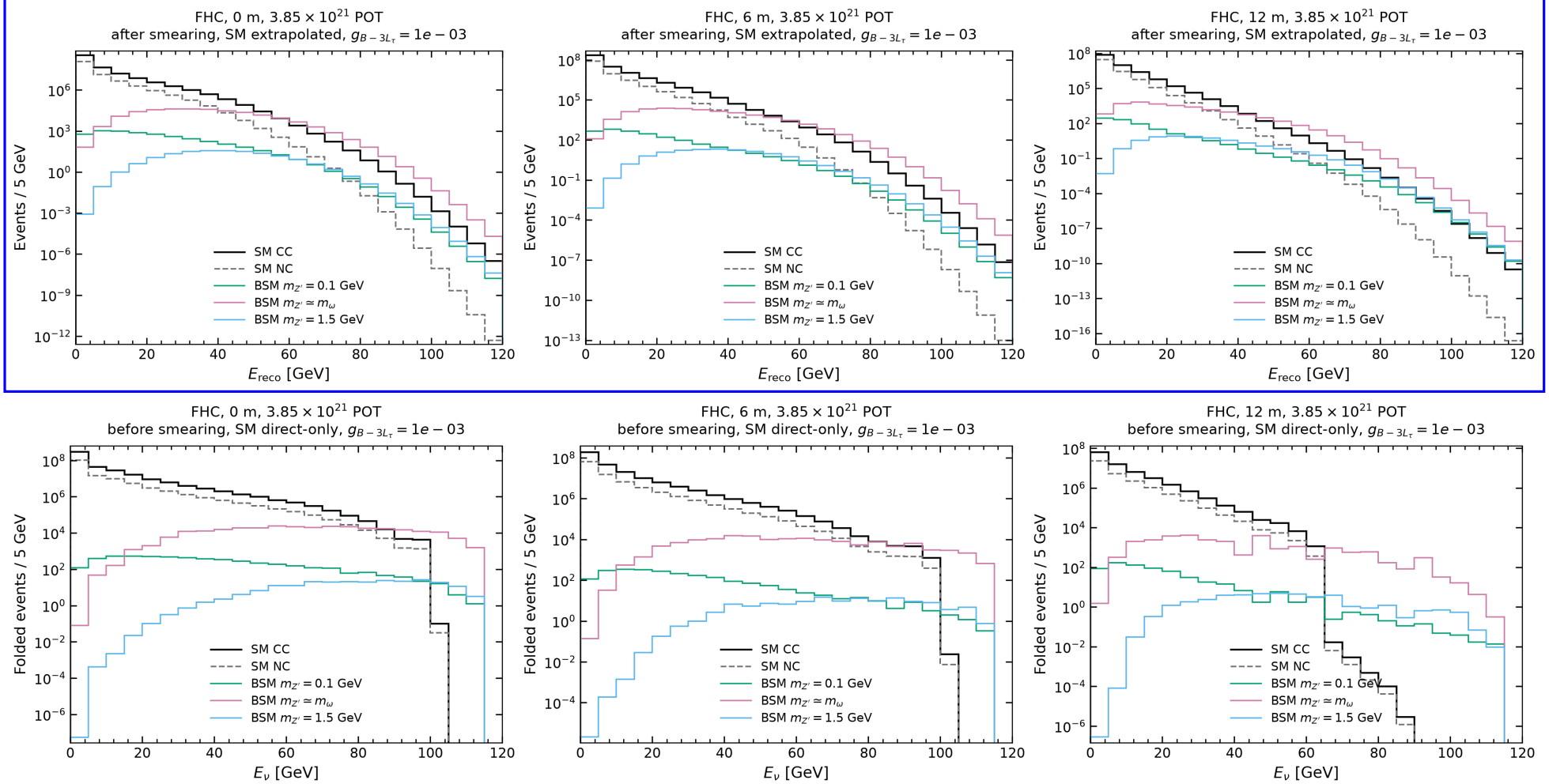




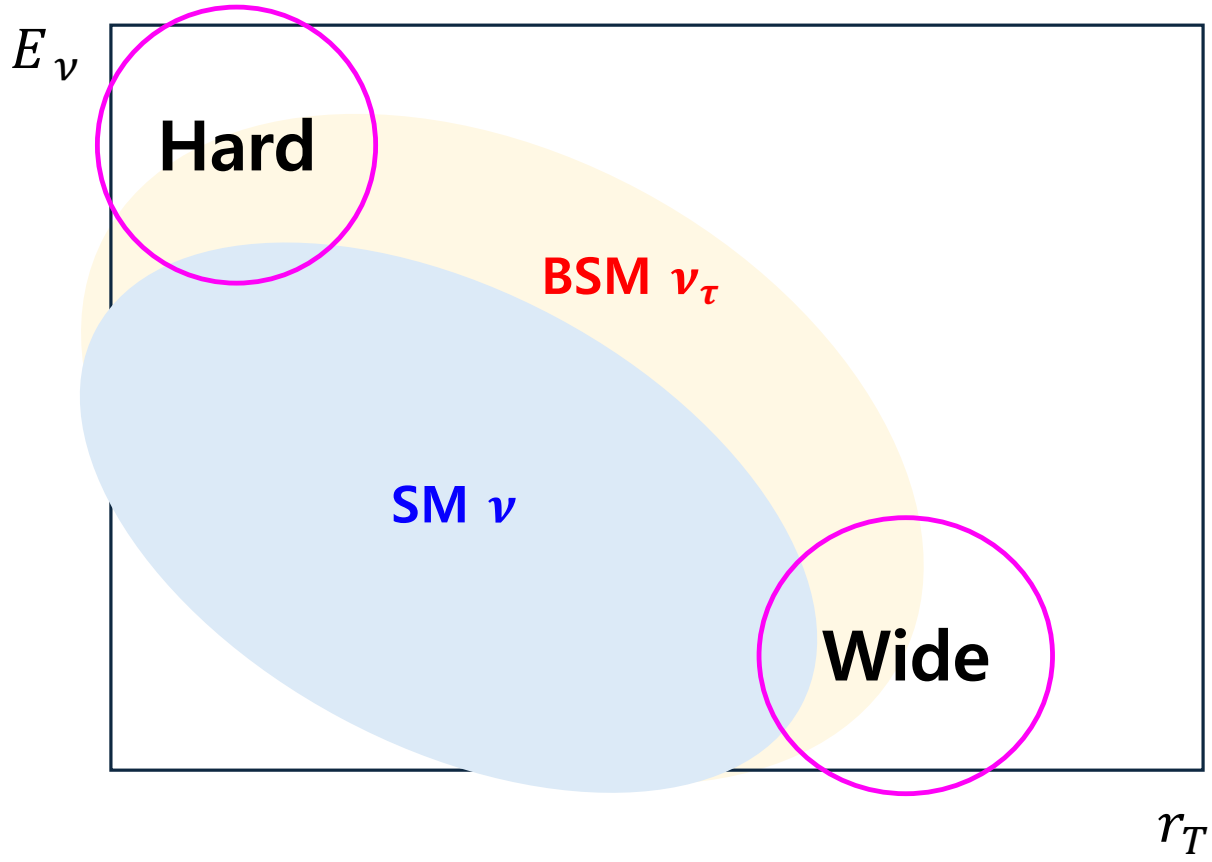
We **extrapolated SM neutrino flux at each x_{OA}** until kinematically allowed endpoints,

which is more fair comparison!

DUNE Flux extrapolated + BSM ν_τ Flux events

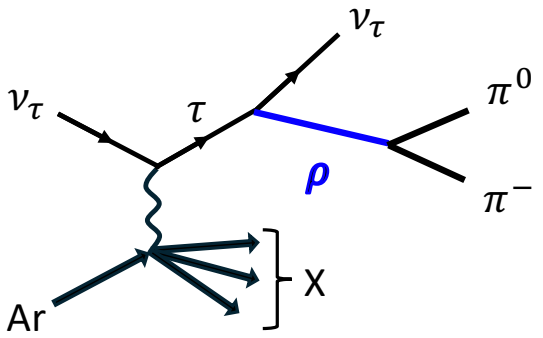


Focusing on Hard & Wide BSM ν_τ Spectrum



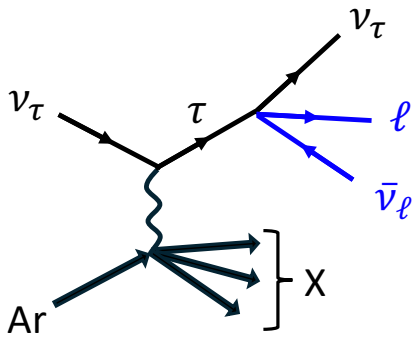
Signal / Background for ν_τ at LAr detector

Signal



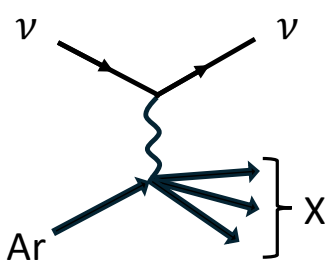
ν_τ CC → ρ channel (BR ≈ 25.5%)

Low efficiency due to ν_e/ν_μ CC



ν_τ CC → e/μ channel (BR ≈ 17.8/17.4%)

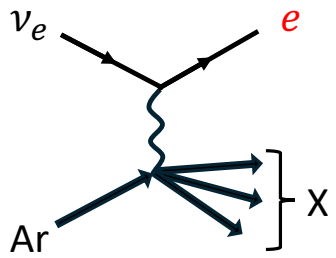
Background



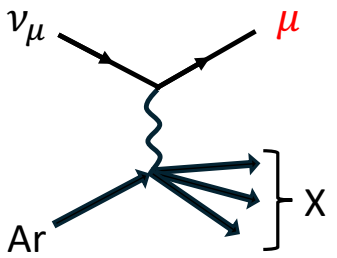
ν NC

~ 10% leakage

Going out of active volume, $\mu^\pm/\pi^\pm$ misidentification, …



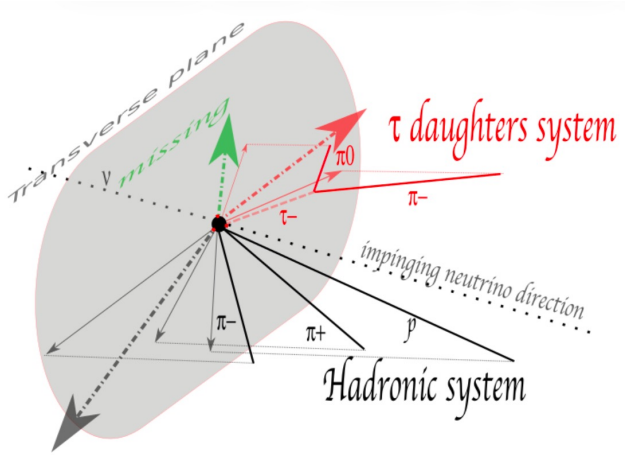
ν_e CC

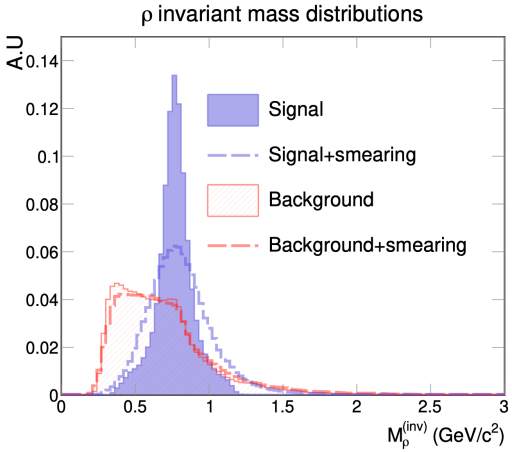


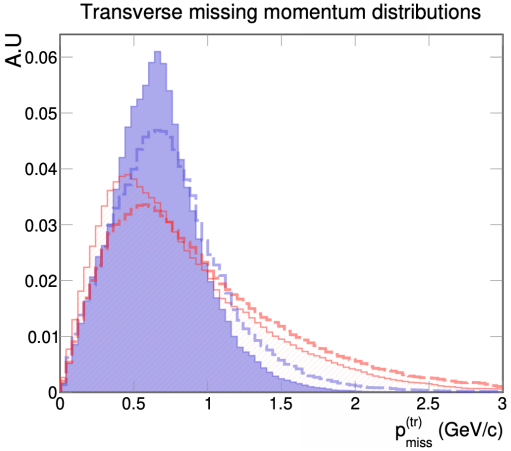
ν_μ CC

Transverse Plane Kinematics

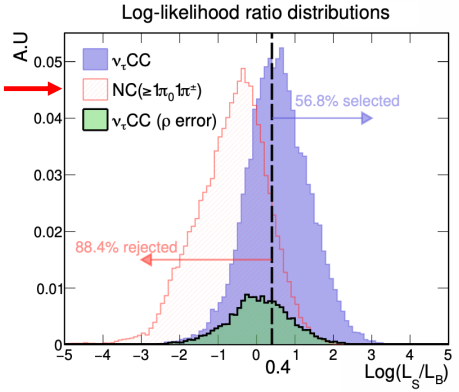
Albright & Schrock, 1979
Thomas Kosc (PhD Thesis), 2021

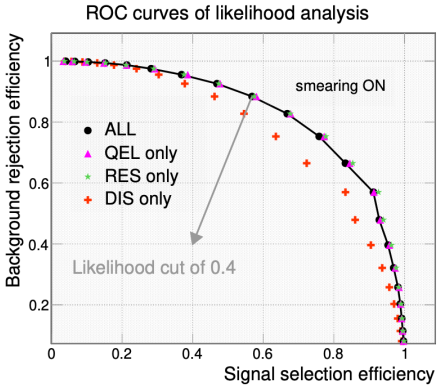






18%





(a) (b)

Likelihood cut	0	0.2	0.4	0.6	0.8	1.0	1.2
fraction of signal kept (%)	75.8	66.8	56.8	46.9	36.9	28.2	21.4
Cases of fake ρ propagated	8.8	7.1	5.6	4.2	2.9	2.0	1.3
fraction of bck contamination	24.8	17.3	11.6	7.4	4.5	2.5	1.3

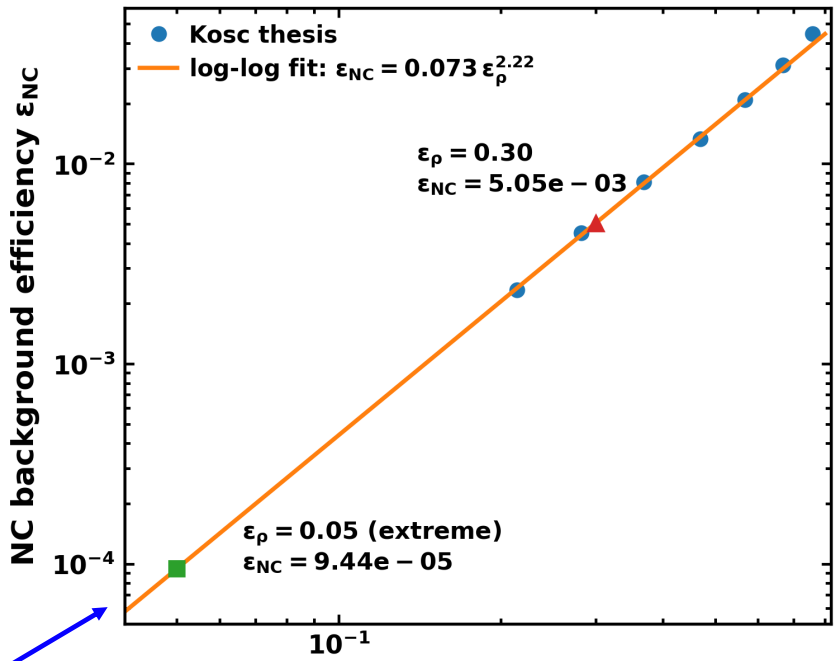
18% of NC events survives topology criteria
+ Transverse missing momentum
+ ρ invariant mass distribution

→ Gives NC-like background efficiency

Transverse Plane Kinematics

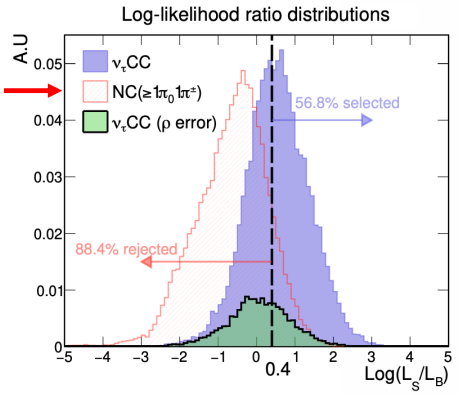
Albright & Schrock, 1979
Thomas Kosc (PhD Thesis), 2021

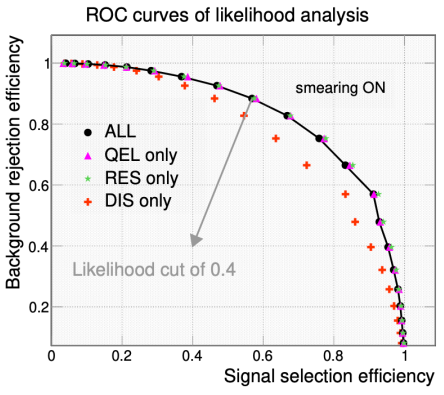
Our signal efficiency choices



Extrapolation

18%





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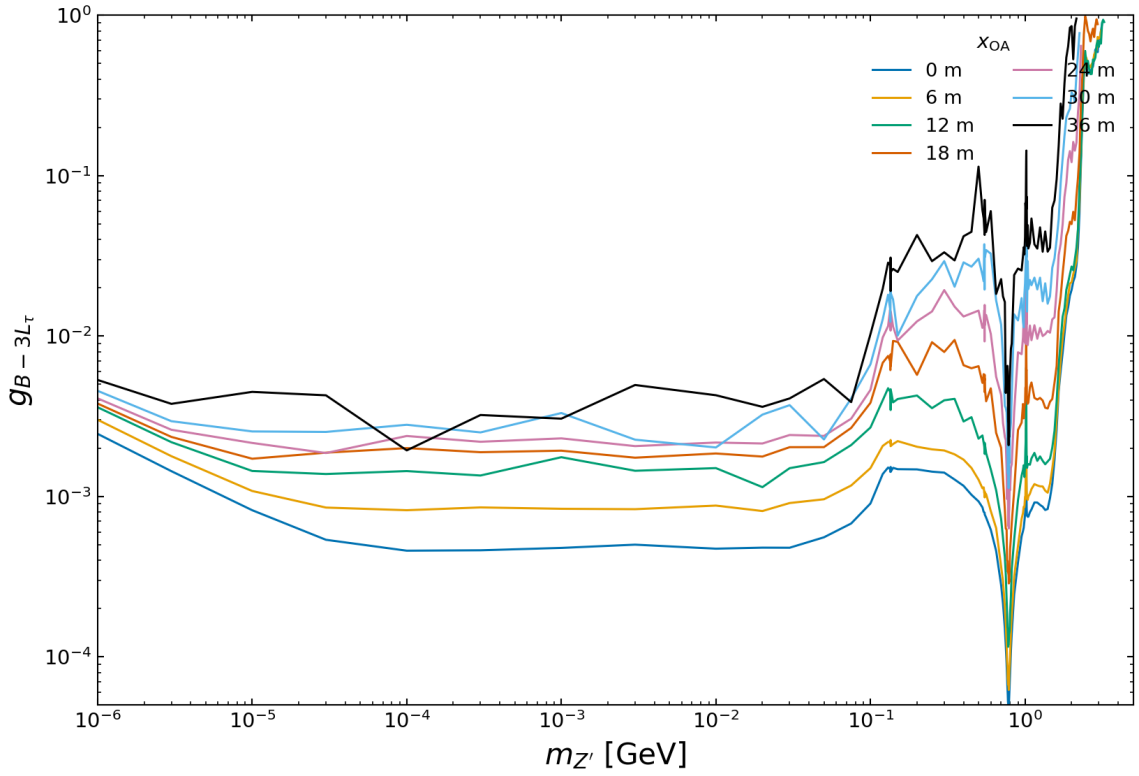
×0.18

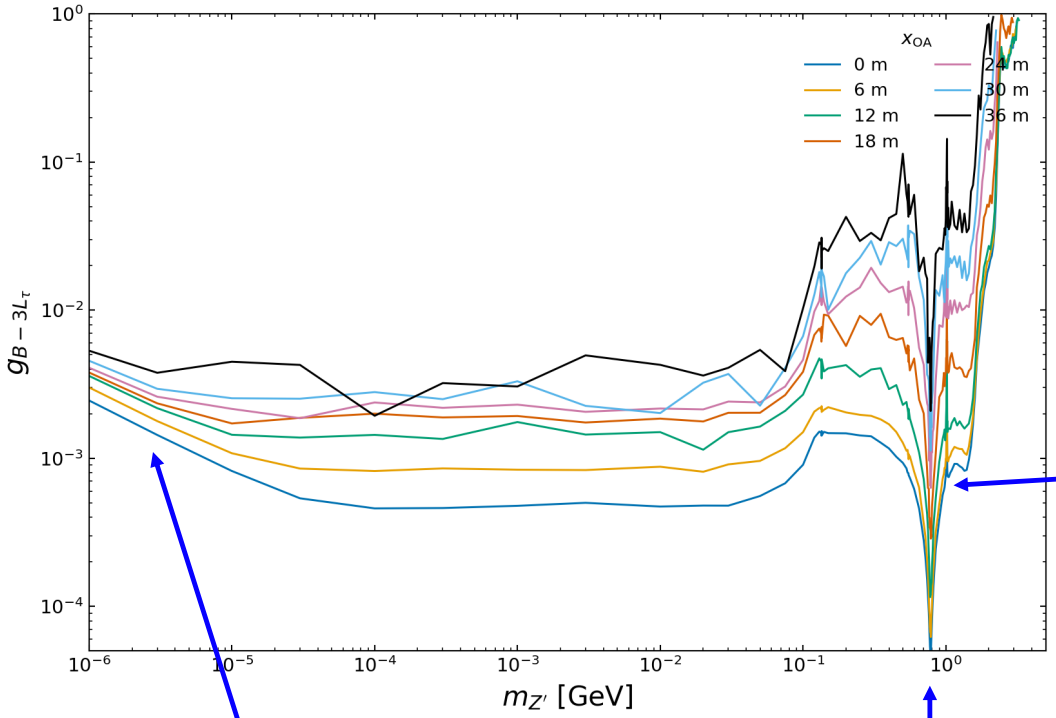
Δ - de Gouvea et al (2019): $\varepsilon_{hadron} = 30\%$, $\varepsilon_{NC} = 0.5\%$
■ - Dev et al (2024): $\varepsilon_\rho = 5\%$, $\varepsilon_{NC} \approx 0$ (from Aurisano)

Slide along ROC curve fit → Conservative efficiency assumption compared to previous works

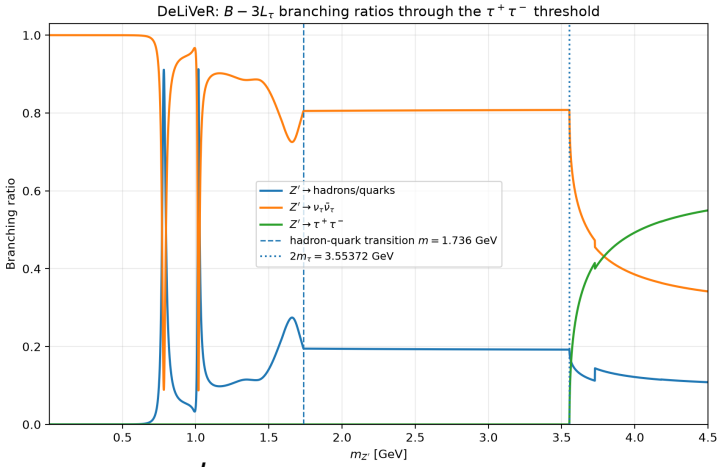
Constraints – off-axis overlayed



Constraints – off-axis overlayed



Foguel, Reimitz, Funchal - DeLiVeR

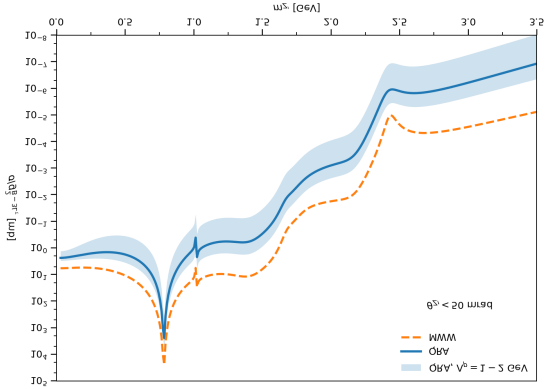


ω ϕ

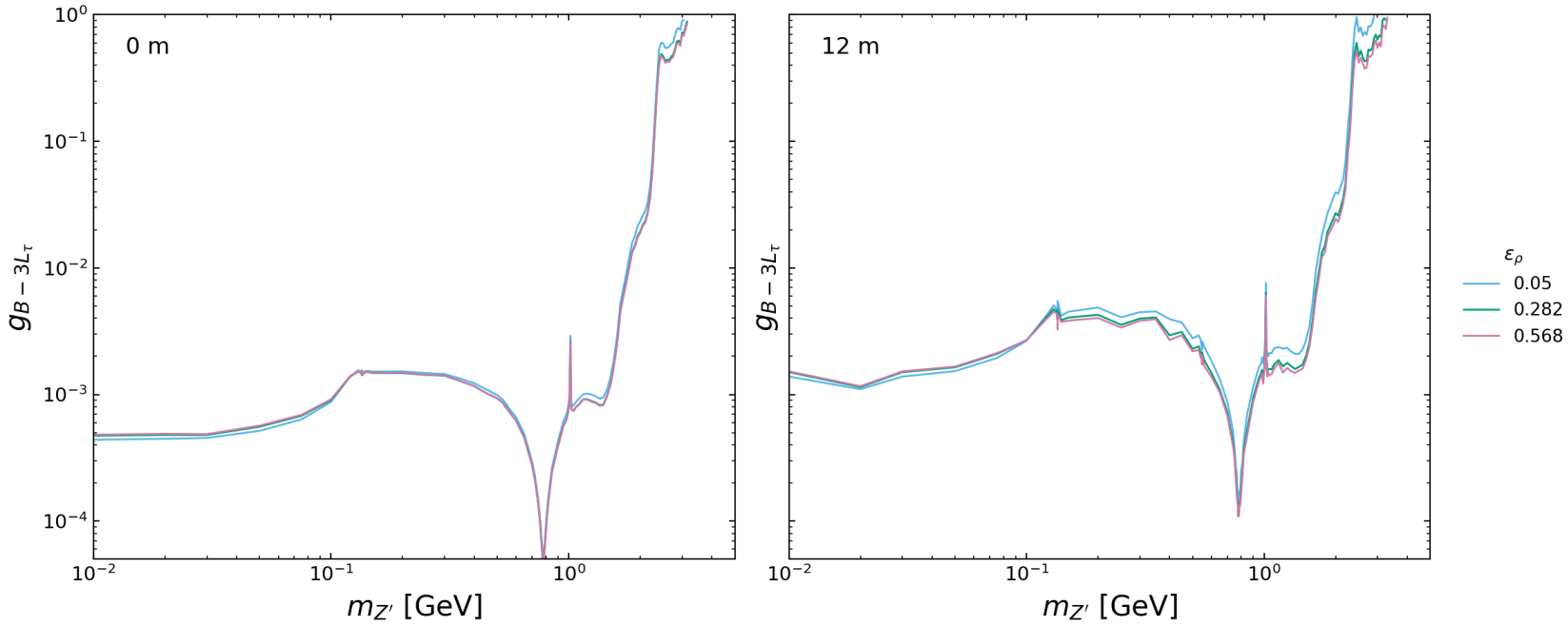
ϕ meson resonance in decay

Z' propagation length become larger, so do not decay before the detector

ω meson resonance in production



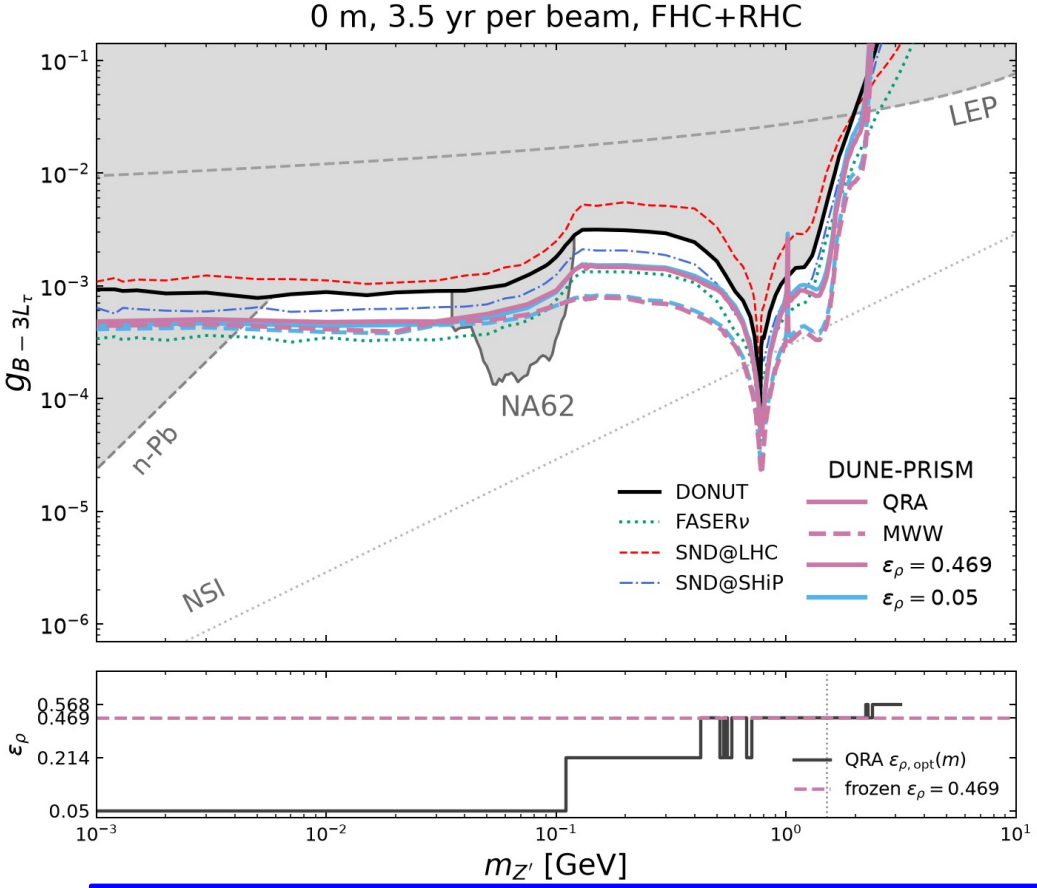
Constraints – off-axis overlayed

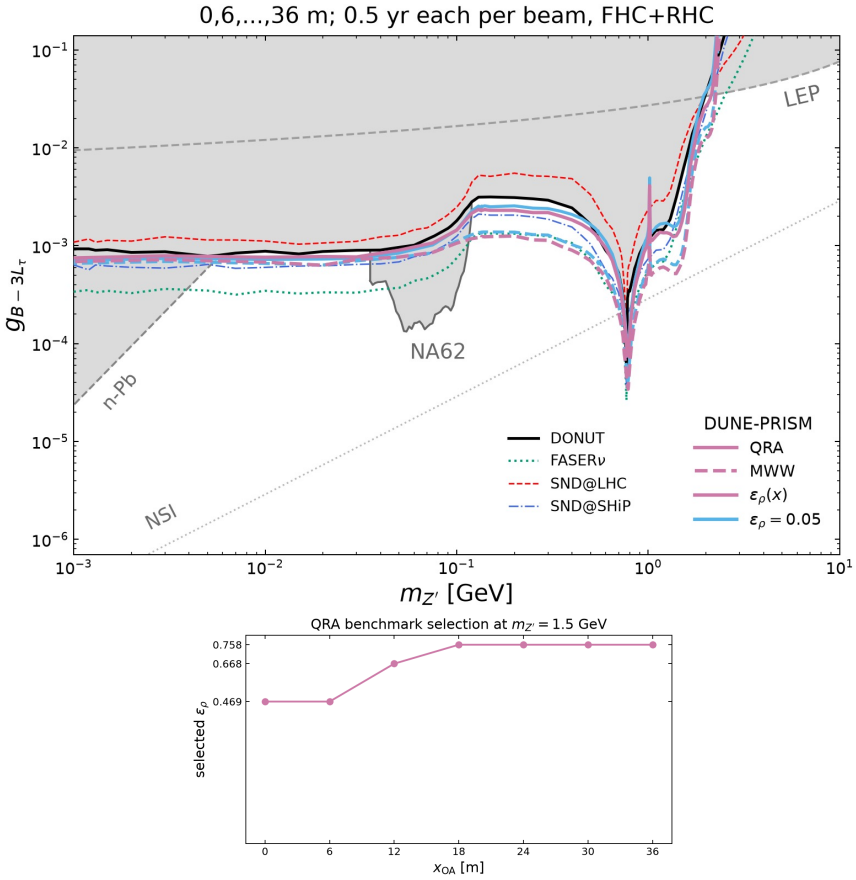


Slide along ROC curve fit → Give better sensitivity, especially at 1.5 GeV shoulder region

Constraints

Comparison with Kling (2020)

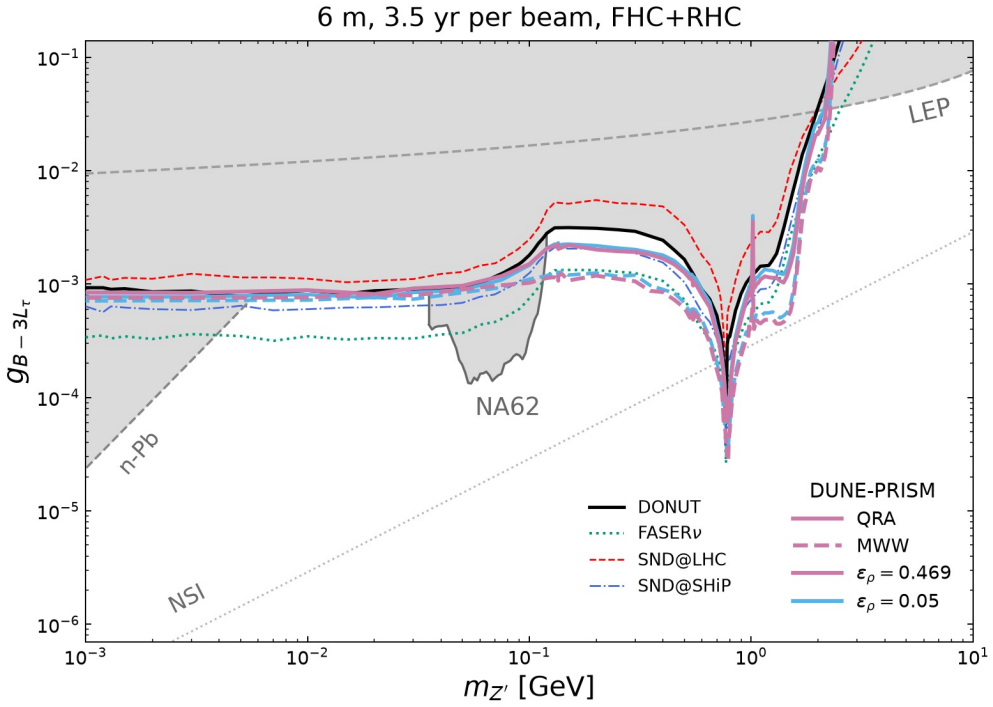


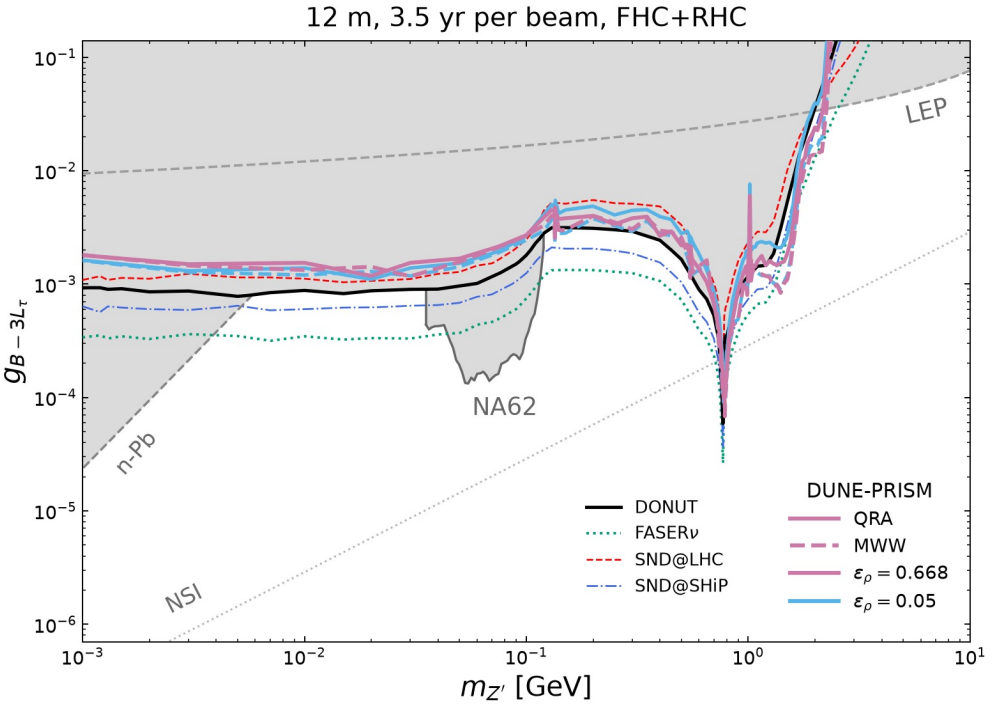


Slide along ROC curve fit → Give better sensitivity, especially at 1.5 GeV shoulder region

Constraints – off axis effect

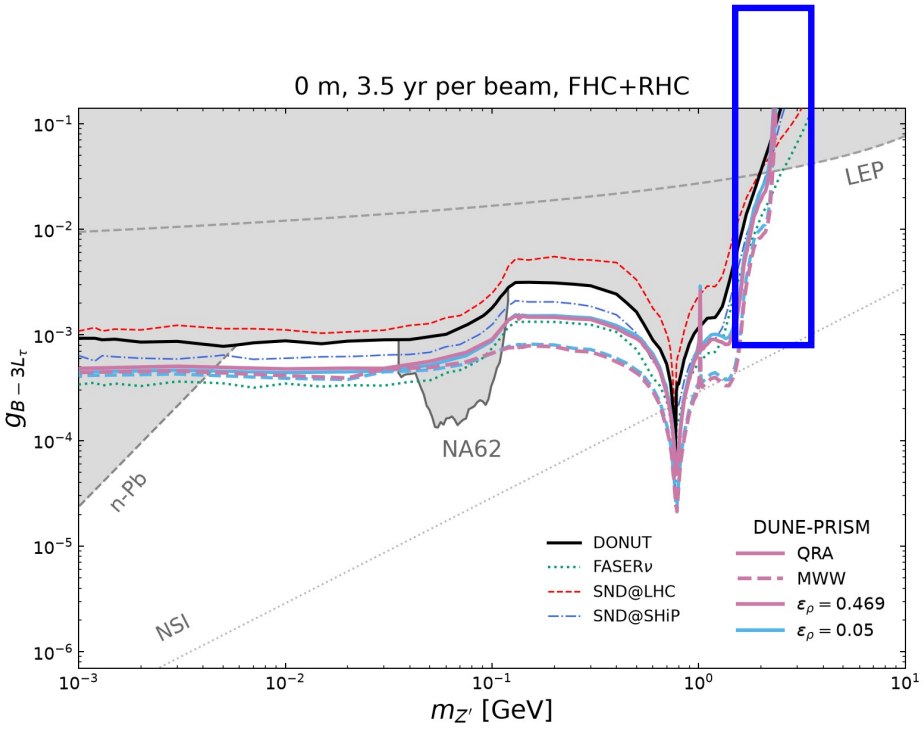
Comparison with Kling (2020)

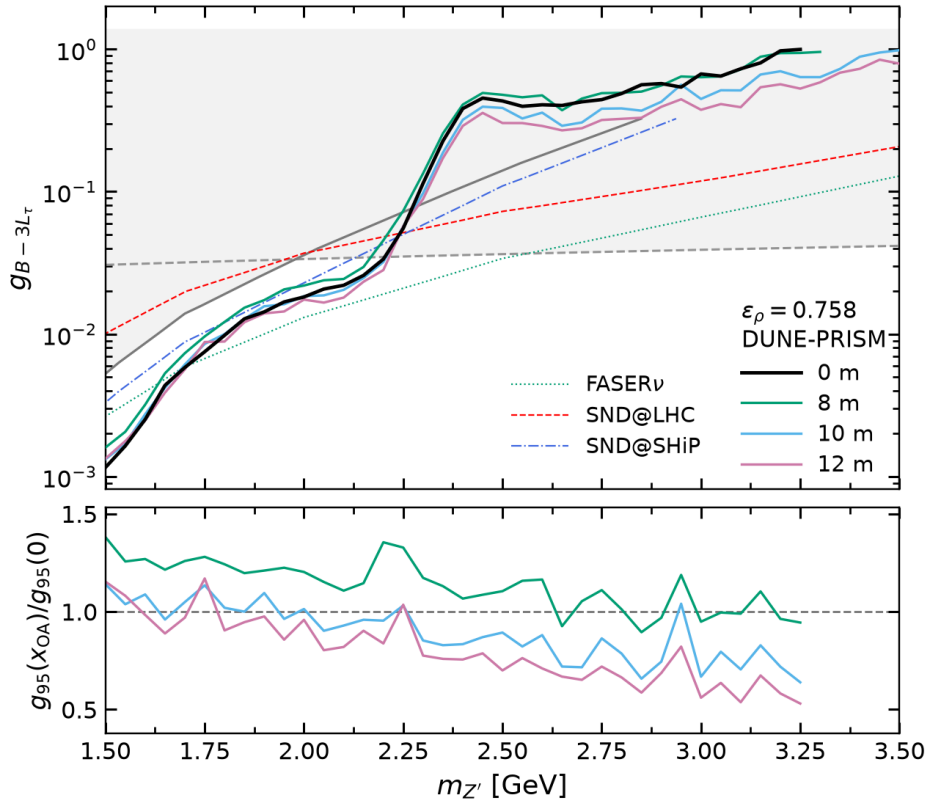




Efficiency choice becomes more important at more off axis position.

Constraints – off axis effect

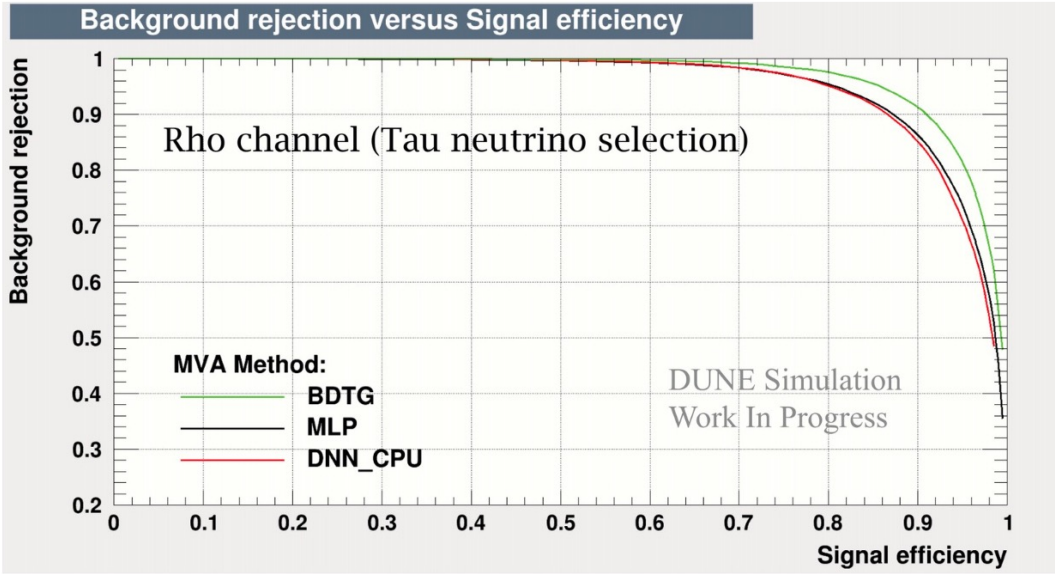




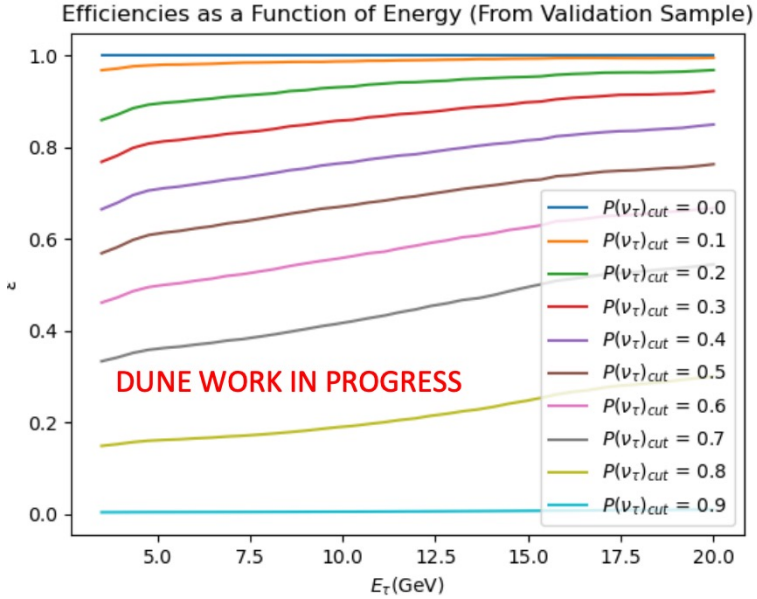
Small advantage at off-axis over on-axis for heavier Z', but mostly already constrained.

Optimistic Background Scenarios?

A. Aurisano (NuFact 2021)



W. Dallaway (NuFact 2025)



Conclusion

Heavy BSM mediator

→ Hard and Wide neutrino spectrum

→ DUNE-PRISM would be nice place to study

Hard spectrum

→ Benefited by loose efficiency choice

Wide spectrum

→ Small effect, but still gives lessen