LEPTOPHILIC Z'
IN NEUTRINO SCATTERING

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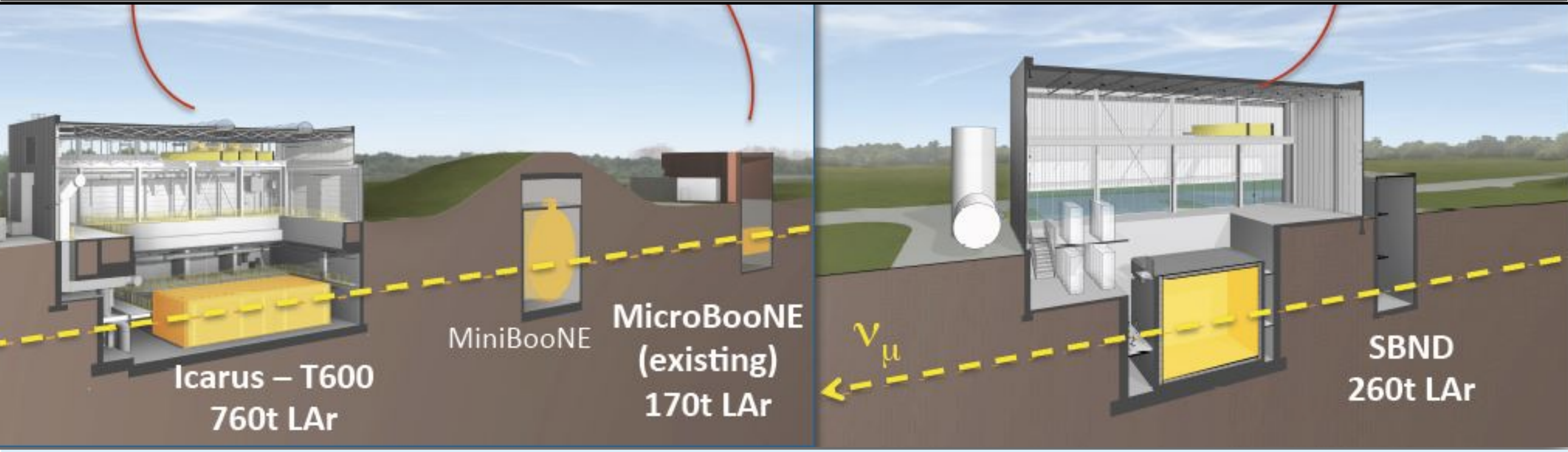
Introduction

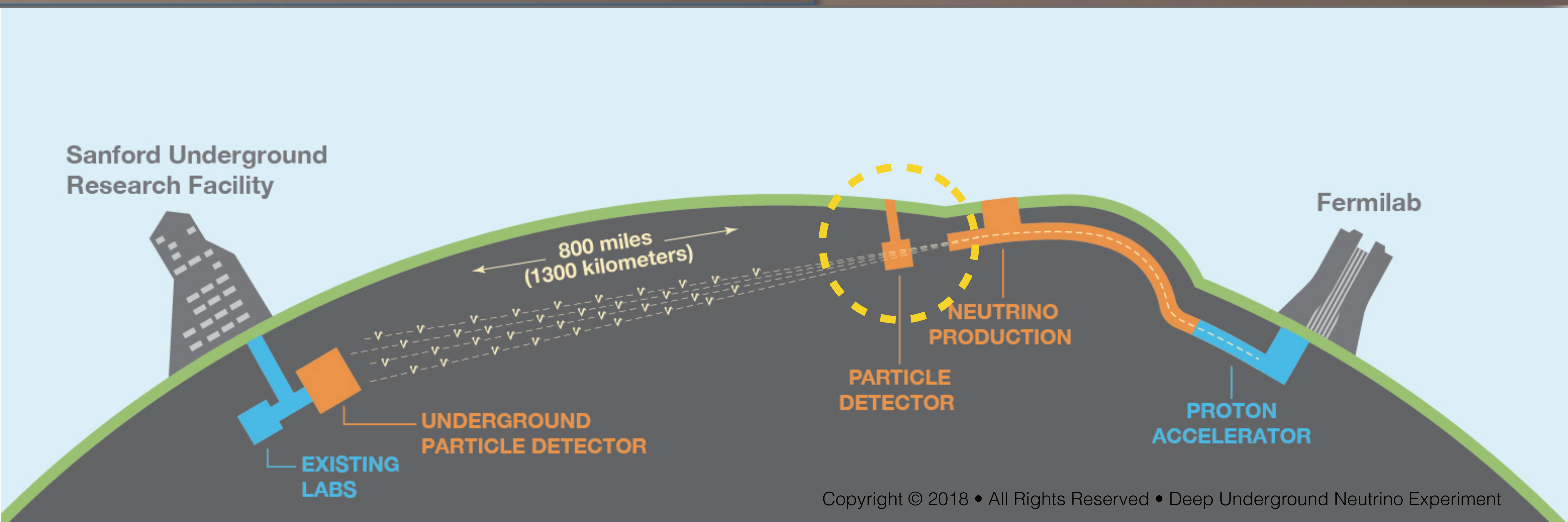
Neutrino sector yet to be fully explored

Precision measurements rely on reducing systematics — **near detectors.**

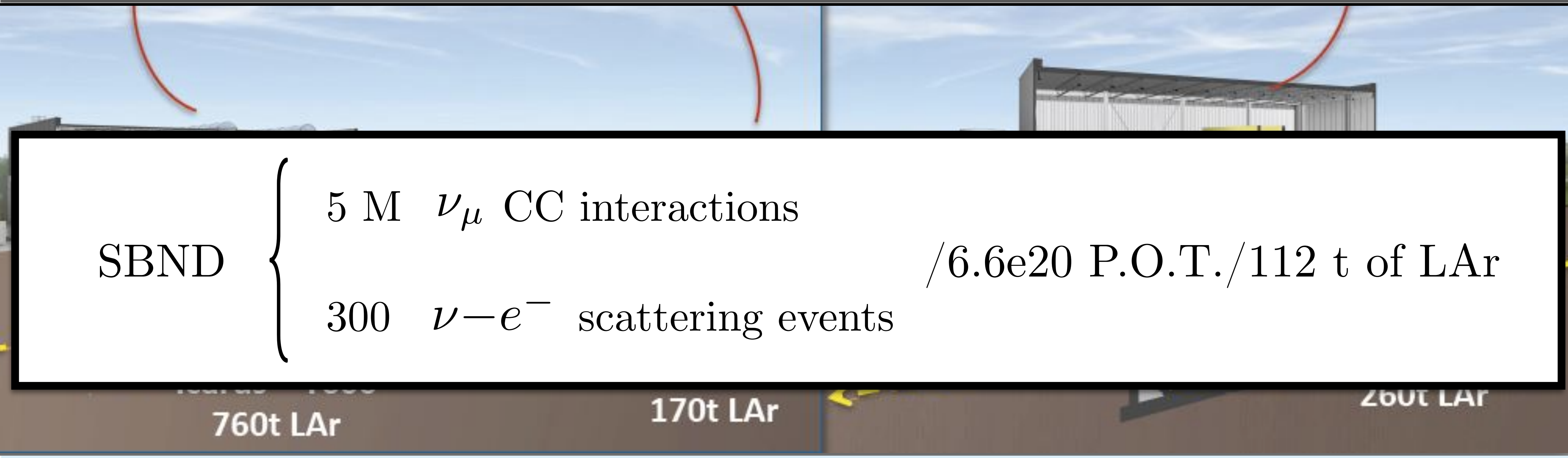
Neutrino physics is pushing the **intensity frontier.**

Near detectors

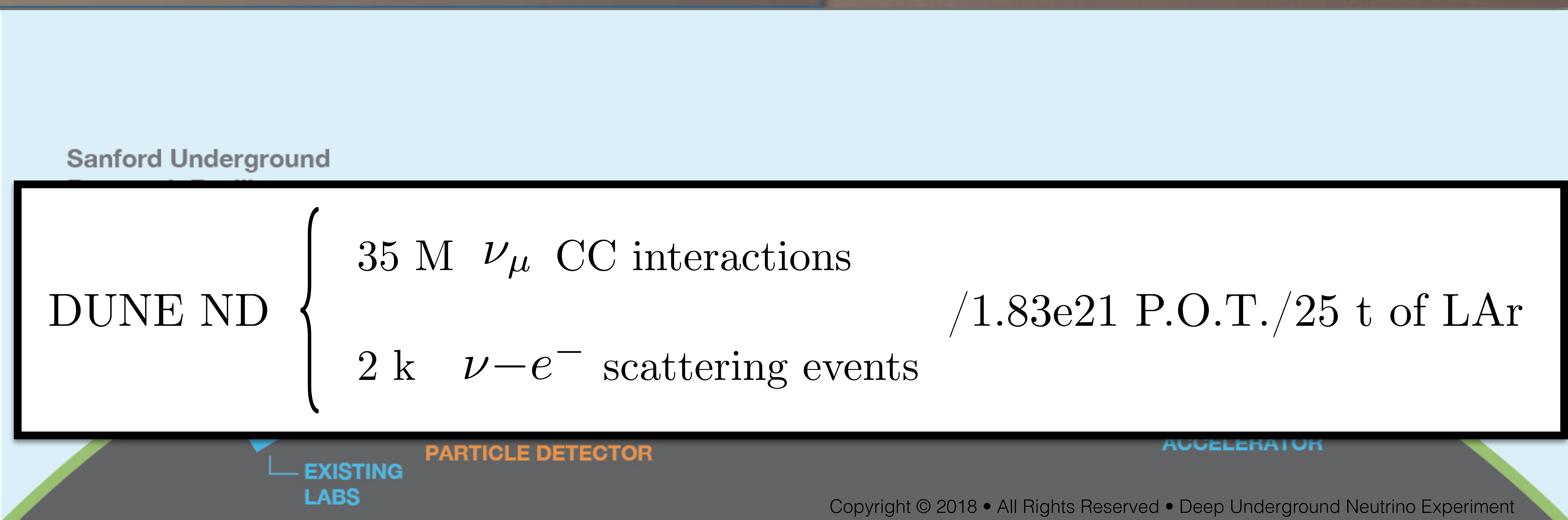




Near detectors



SBND $\begin{cases} 5\ \text{M}\ \ \nu_\mu\ \text{CC interactions} \\ 300\ \ \nu{-}e^-\ \text{scattering events} \end{cases}$ /6.6e20 P.O.T./112 t of LAr



DUNE ND $\begin{cases} 35\ \text{M}\ \ \nu_\mu\ \text{CC interactions} \\ 2\ \text{k}\ \ \nu{-}e^-\ \text{scattering events} \end{cases}$ /1.83e21 P.O.T./25 t of LAr

Rare neutrino scatterings

- Used to neutrino CC and NC interactions and their many hadronic regimes QE/RES/DIS...

- What about higher number of leptonic currents?

Obvious choice: $\nu_\alpha + e^- \to \nu_\beta + \ell_\delta^-$

Much less obvious are multi charged lepton final state processes!

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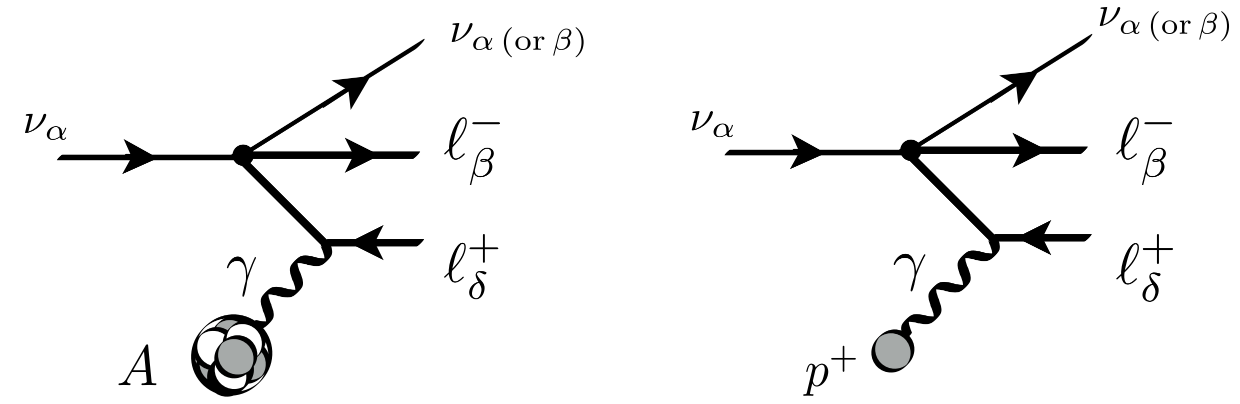
Neutrino trident production

$$\nu_\alpha + \mathcal{N} \to \nu_\beta + \ell_\gamma^+ + \ell_\delta^- + \mathcal{N}$$

Neutrino trident production

Neutrino **INELASTIC** interaction in the coulomb field of the **NUCLEUS**



Previously looked at with **EPA**:

[Altmannshoffer et al, 2014]
[Magill et al, 2016]
[Magill et al, 2017]

NC/CC interference leads to a cancellation of 40%.

Full **4 body phase** space calculation ⟶

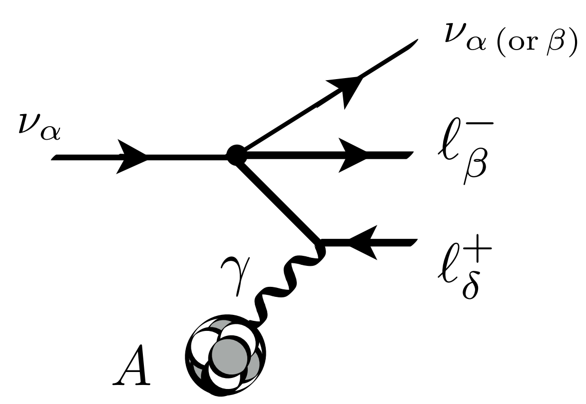
Channel	SM cabontributions	DUNE ND
$\nu_\mu \to \nu_\mu \mu^+ \mu^-$	CC, NC	135 (93)
$\nu_\mu \to \nu_e e^+ \mu^-$	CC	1422 (327)
$\nu_\mu \to \nu_\mu e^+ e^-$	NC	456 (64)

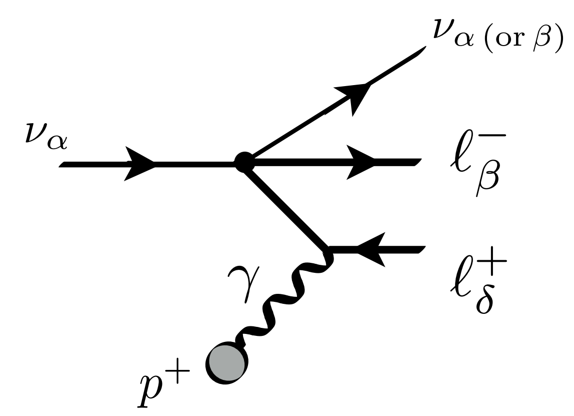
DUNE (nu mode, 62 GeV protons) near detector (25 t) with 12.81e21 POT.

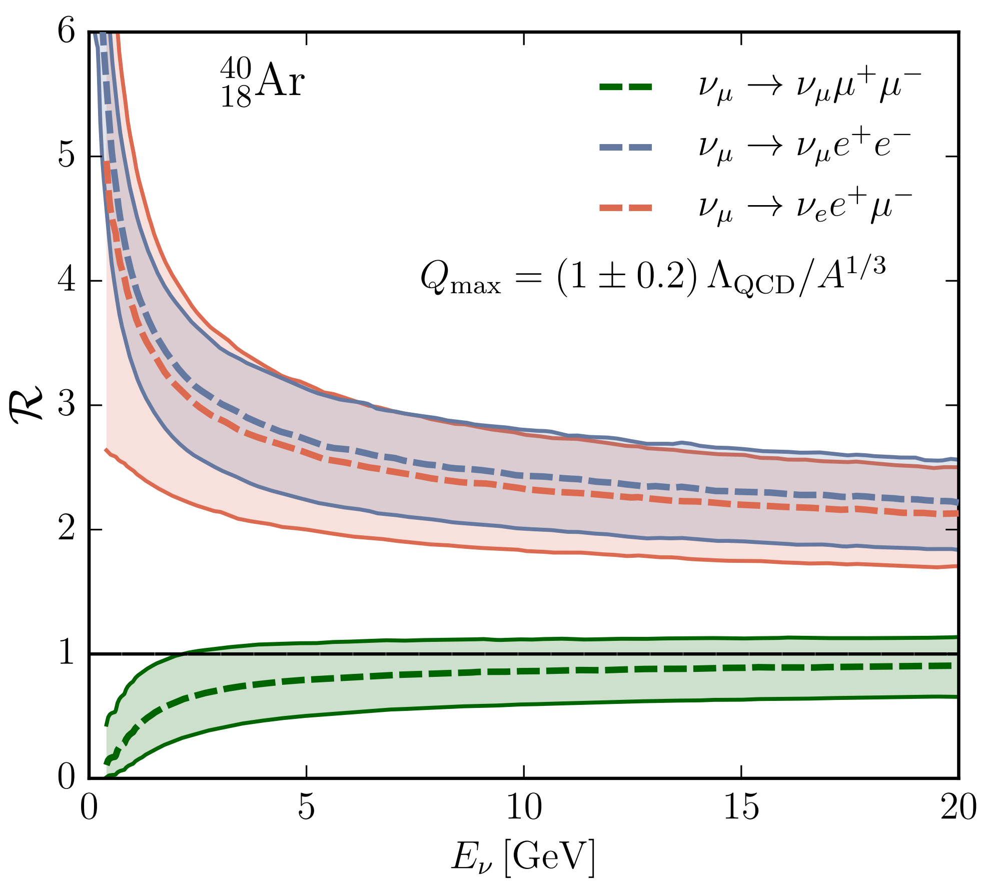
Neutrino trident production

Is the EPA adequate for this process?

$$\mathcal{R} = \frac{\sigma_{\mathrm{EPA}}(E_\nu)|_{Q_{\max}}}{\sigma_{\mathrm{4PS}}(E_\nu)}$$

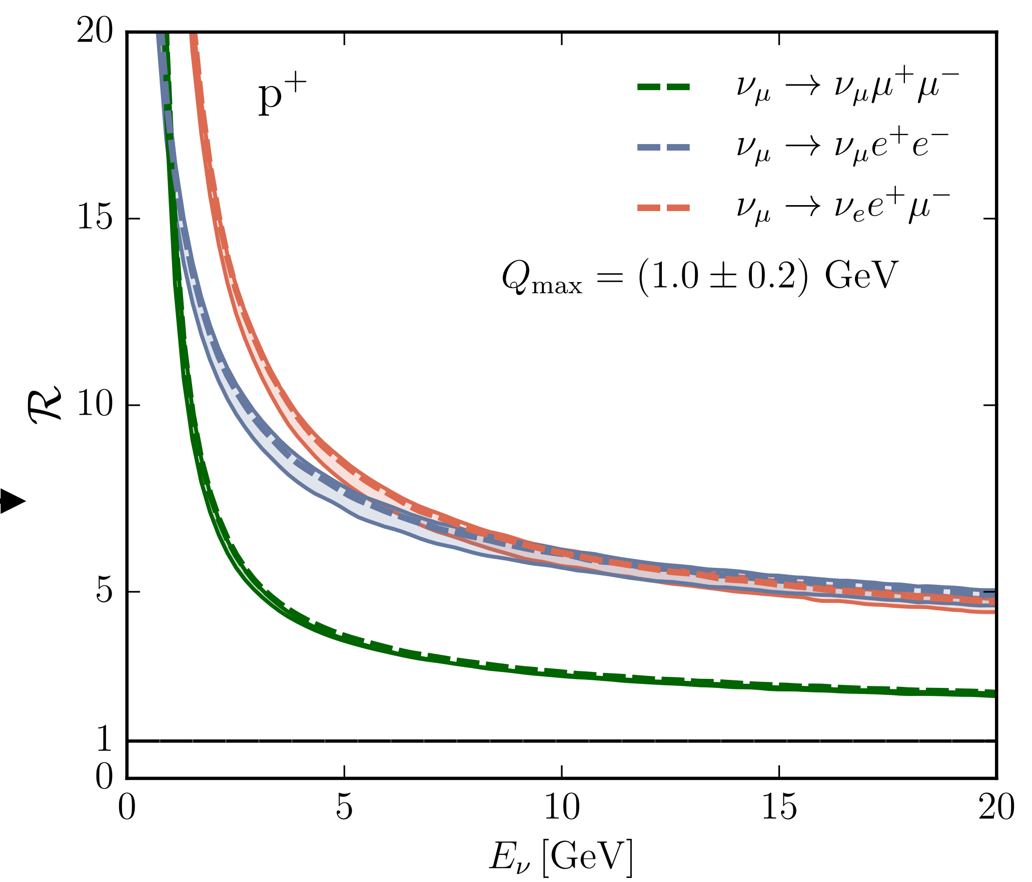






← Coherent

Diffractive →



Neutrino trident production

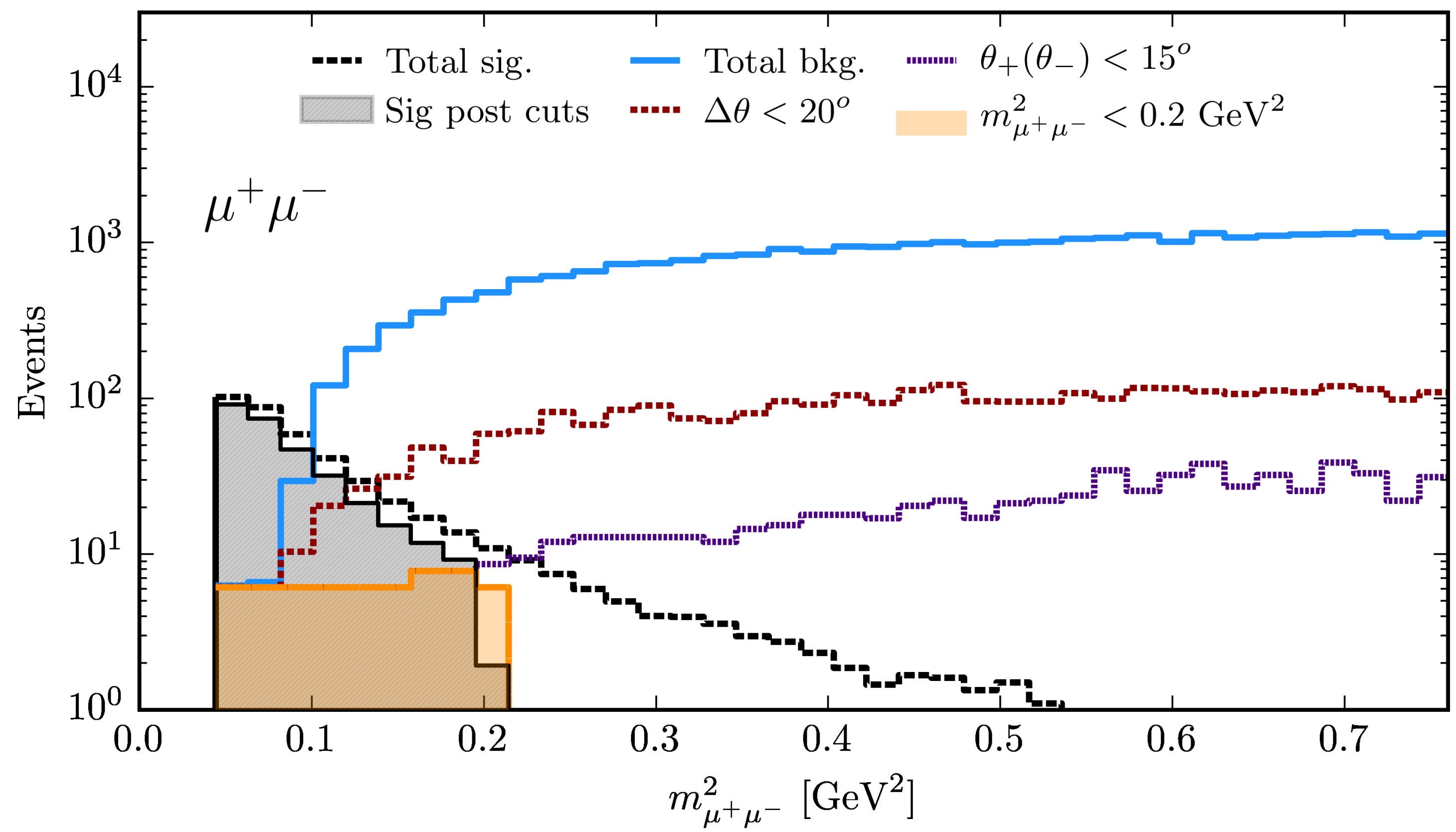
Is it even observable? Expect large backgrounds at DUNE ND...

From events generated with GENIE, largest bkgs. are:

$\mu^+\mu^-$ misID $CC1\pi^{\pm}$

e^+e^- NC single γ production

$e^+\mu^-$ CC misID γ (e.g., $CC1\pi^0$)

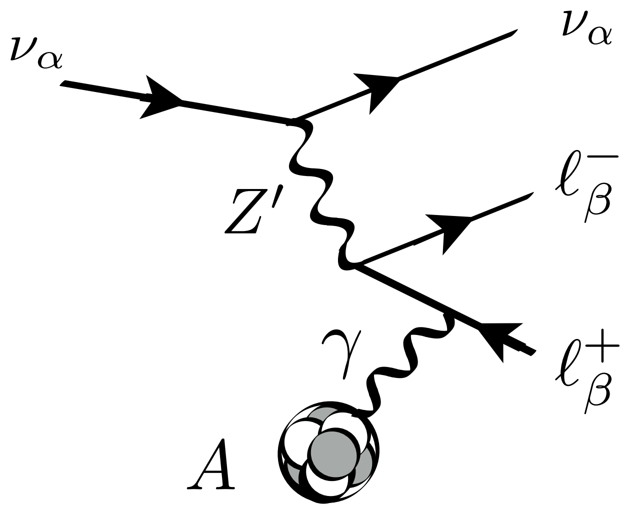


... but can be kept under control with kinematics and hadronic vetoes!

Leptophilic new physics

What can we learn from it?

Process enhanced by light mediator mass. No QED contribution to compete with!



Choose your model, for example: $U(1)_{L_\mu - L_\tau}$

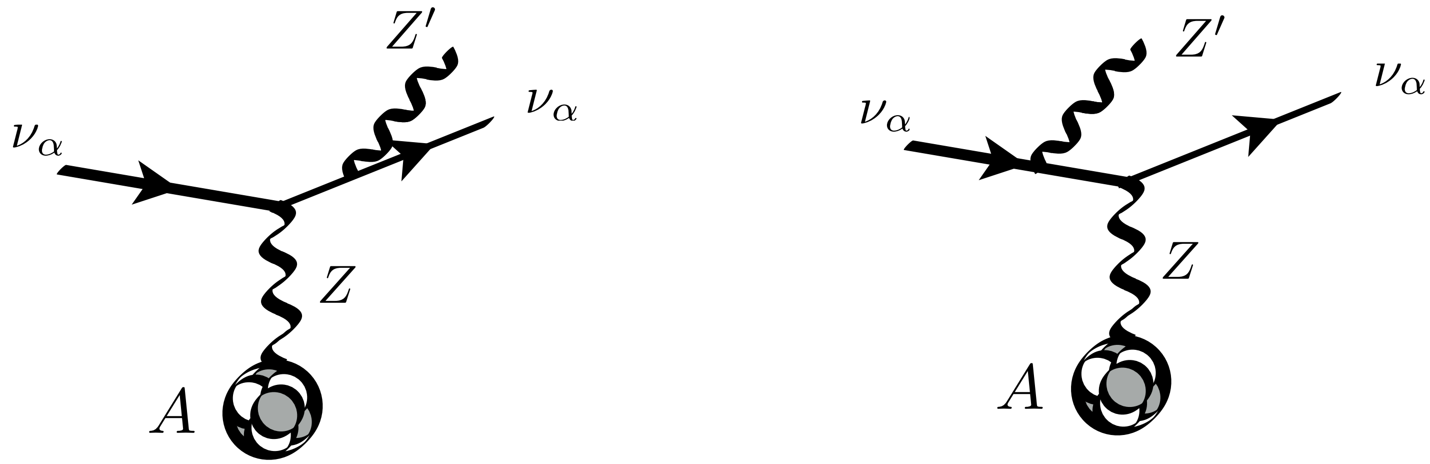
$$\mathscr{L}_{\rm int} \supset g' Z'_\alpha \left(\overline{L}_\mu \gamma^\alpha L_\mu - \overline{L}_\tau \gamma^\alpha L_\tau + \overline{\mu}_R \gamma^\alpha \mu_R - \overline{\tau}_R \gamma^\alpha \tau_R\right)$$

See also [Altmannhofer, 2014]

Leptophilic new physics

Other processes are also relevant if Z' is allowed to decay visibly

"Dark bremsstrahlung"



Final state from $Z' \to \mu^+\mu^-$ looks nothing like trident.

Hunt invariant mass bump close to $M_{Z'}$.

Experimental sensitivity

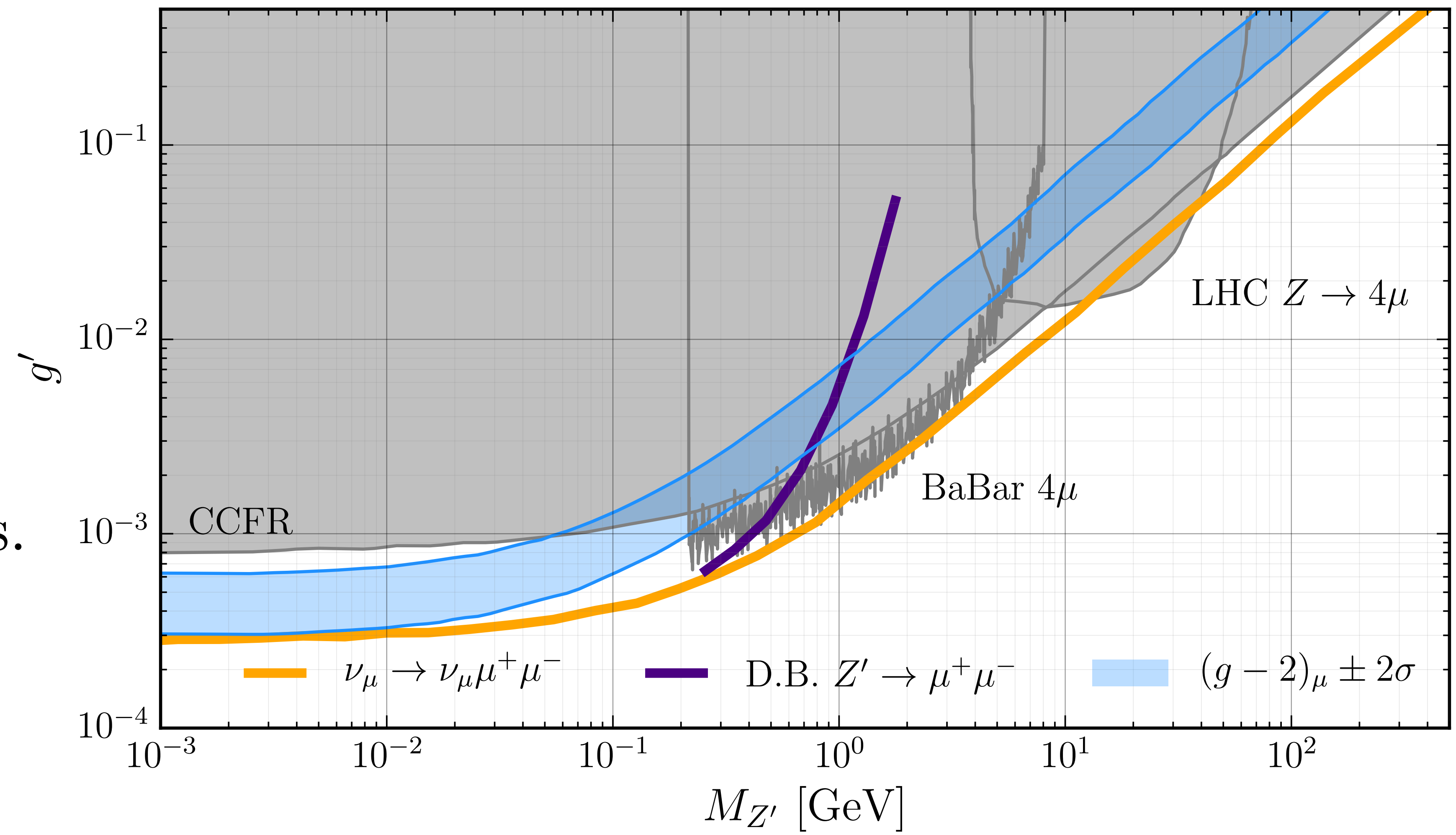
Sensitivity to the very poorly bound gauge

$$U(1)_{L_\mu - L_\tau}$$

SM and misID backgrounds.

Vector boson:

log sensitive to the Z' mass below 50 MeV.



DUNE near detector (25 t) 90 % C.L.

Honourable mentions

- More general anomaly free choices: $\alpha(L_e - L_\mu) + \beta(L_\mu - L_\tau)$

Signals in nu-e scattering, and $\mu^+\mu^-$ and e^+e^- tridents. Many other strong bounds, however.

- How about the other leptonic currents?

What would them teach us?

$$\nu_\alpha + \mathcal{N} \to \begin{cases} \ell_\alpha^- + \ell_\beta^+ + \ell_\beta^- + \mathcal{N}' \\ \ell_\alpha^- + \nu_\beta + \overline{\nu}_\beta + \mathcal{N}' \\ \nu_\alpha + \nu_\beta + \overline{\nu}_\beta + \mathcal{N} \end{cases}$$

Conclusions

- EPA overestimates trident production rates and calculated corrected ones at future experiments.
- Backgrounds to trident can be kept under control.
- DUNE ND would be able to rule out all allowed region of (g-2) in a $L_\mu - L_\tau$ model.
- Much more to look forward to...