



BSM interfaces

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Why do we need generator interfaces to BSM?

Motivation for BSM in neutrino experiments

Flux, geometry and BSM

Spin correlations

Theoretical consistency between signal and background calculation

Signal topology and impact of cuts

Tuning and BSM

Achilles as an example

The neutrino sector is special from a theory perspective

The mechanism of neutrino masses is qualitatively different from charged fermions

Possible realizations span at least 20 orders of magnitude in scale,
from the sub-eV to the grand unification scale,
and there is little to no experimental guidance to the right scale

This is similar to the theory landscape in dark matter physics

From a theory perspective, (LH) is special: it is a gauge-singlet ✓

This is the reason why neutrinos are
one of the three potential renormalizable portals to new physics
together with the Higgs and kinetic mixing portals

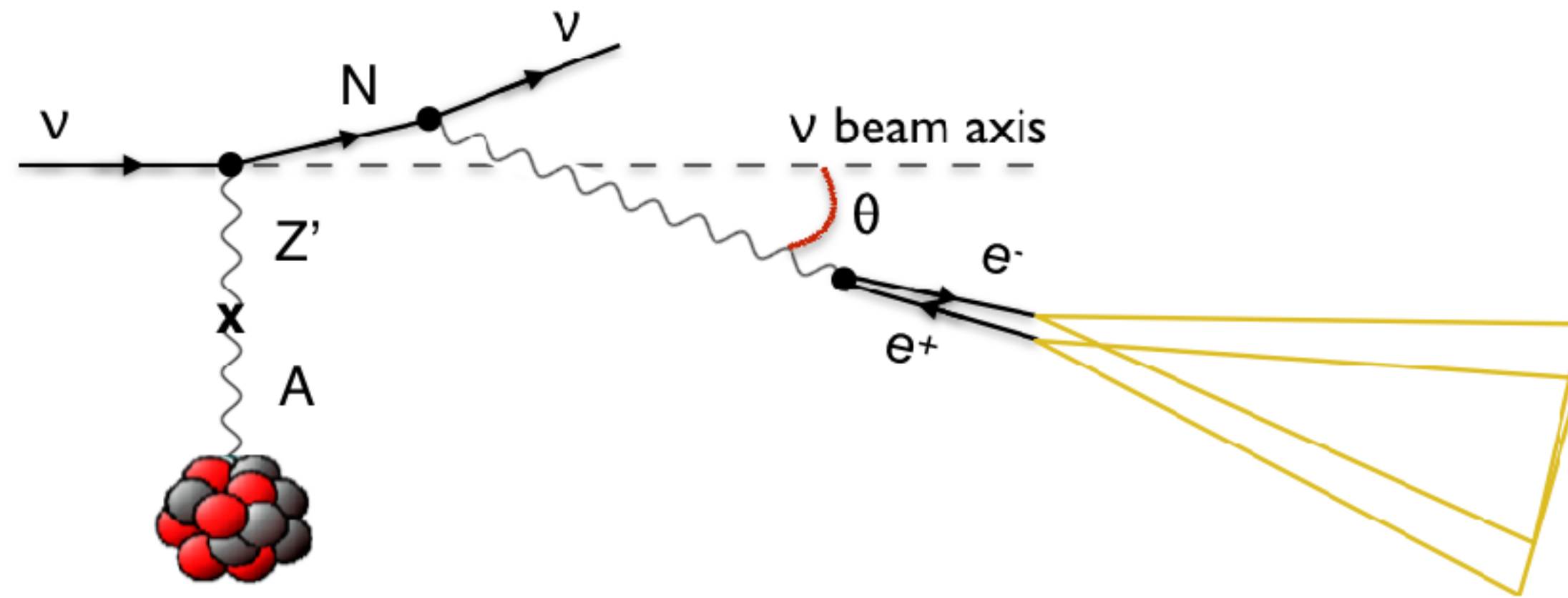
Dark
sector

Weak
sector

The only way to get realistic BSM signatures and consistent estimates for BSM cross sections is to interface new physics models with neutrino event generators

Let me go through a few examples first,
so we understand the relevance of a BSM interface

BSM interfaces in neutrino event generators



Interaction

track

Cherenkov

Candidate

ν_μ CCQE
 $\nu_\mu + n \rightarrow p + \mu^-$

Muon

Electron

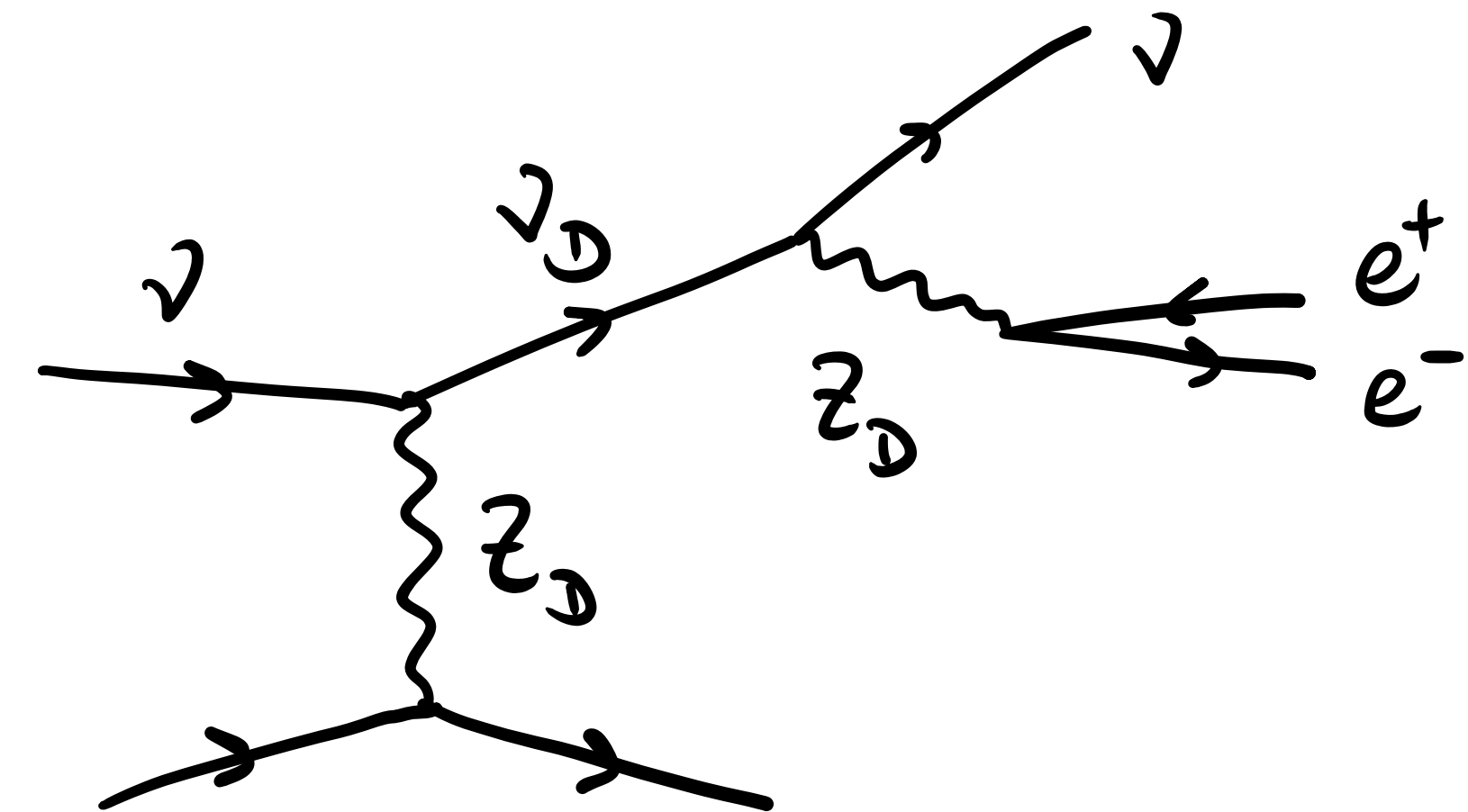
ν_e CCQE
 $\nu_e + n \rightarrow p + e^-$

Neutral pion

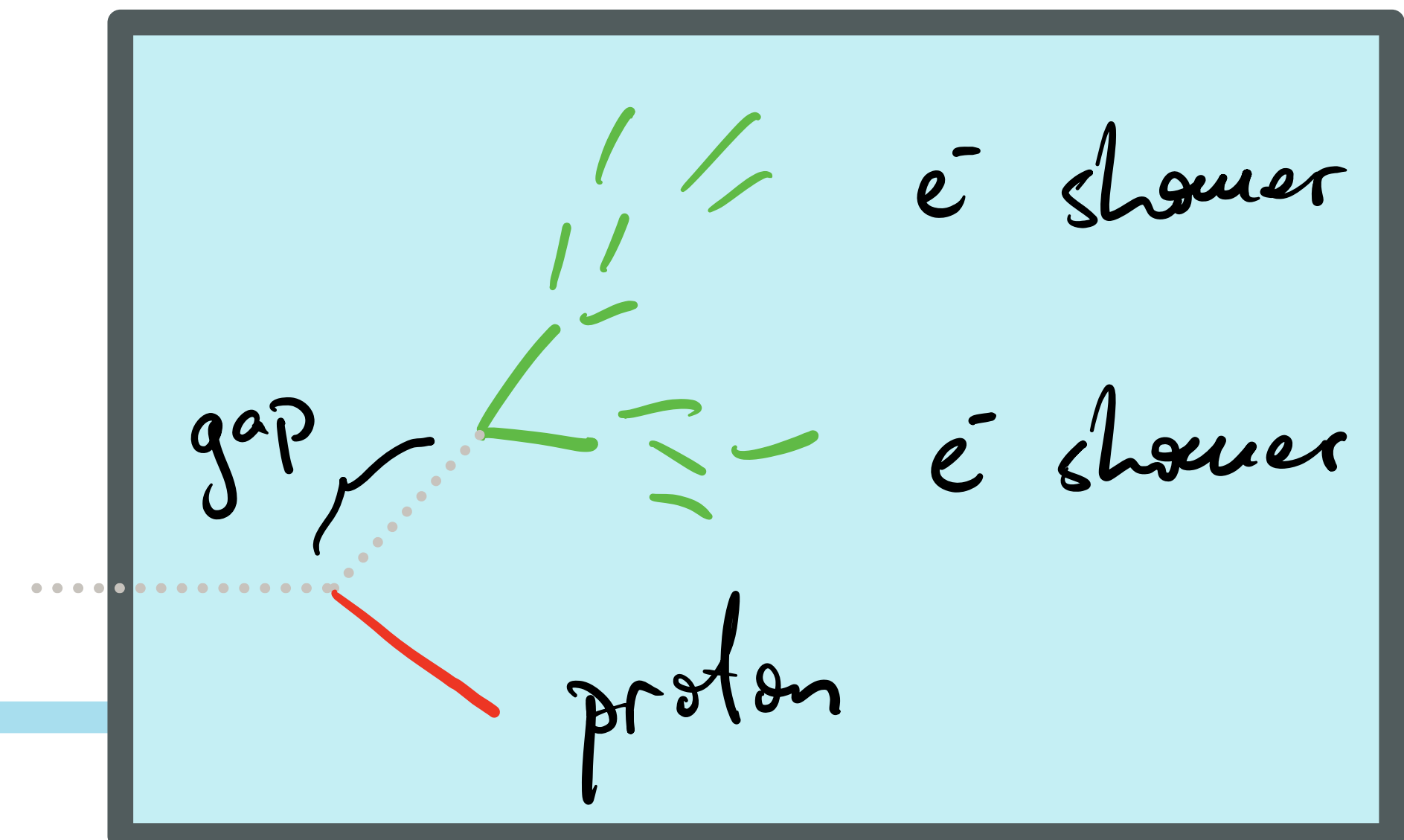
NC π^0

$\nu + N \rightarrow \nu + N + \pi^0$

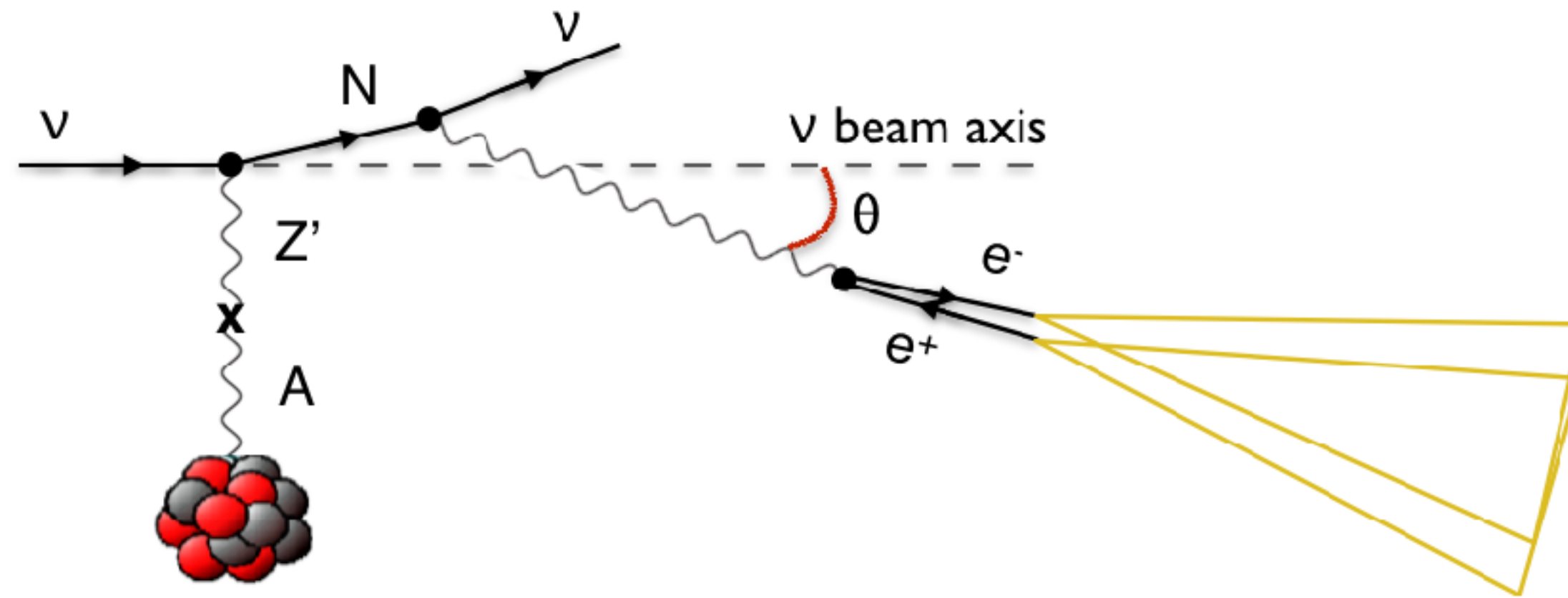
Final state topology can be used to mitigate backgrounds



Bertuzzo [PM et al 1807.09877](#)



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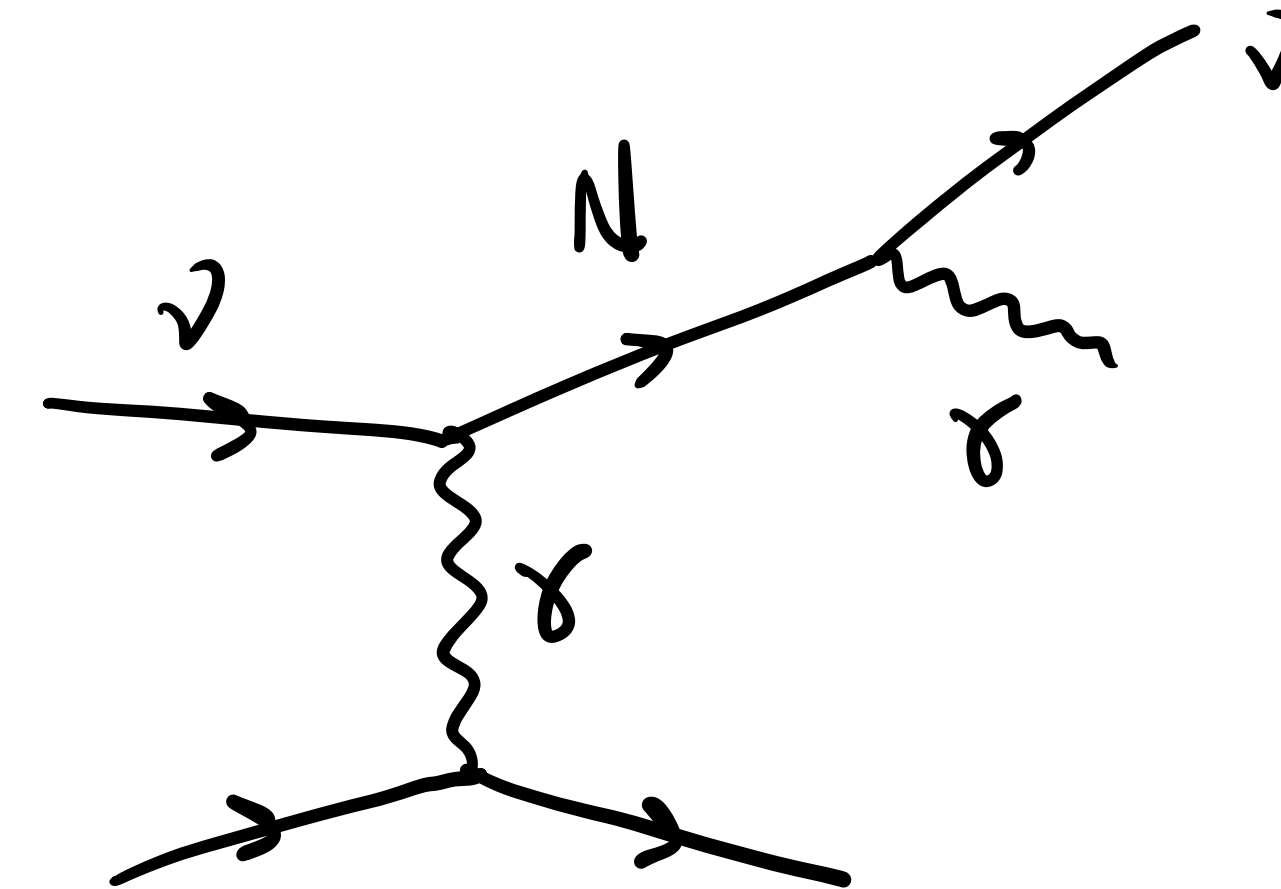
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Neutral pion

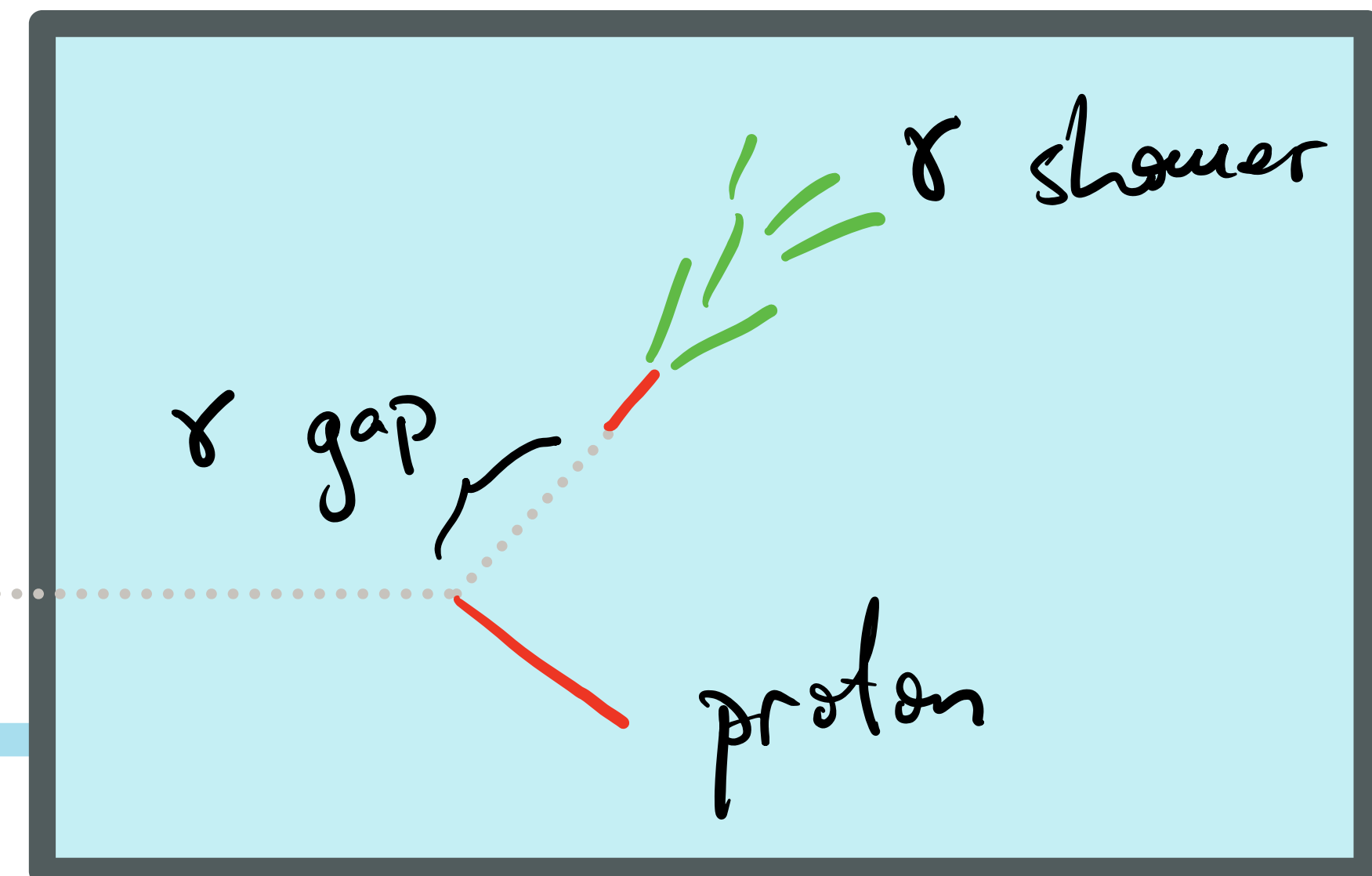
NC π^0

$\nu + N \rightarrow \nu + N + \pi^0$

Final state topology can be used to distinguish models

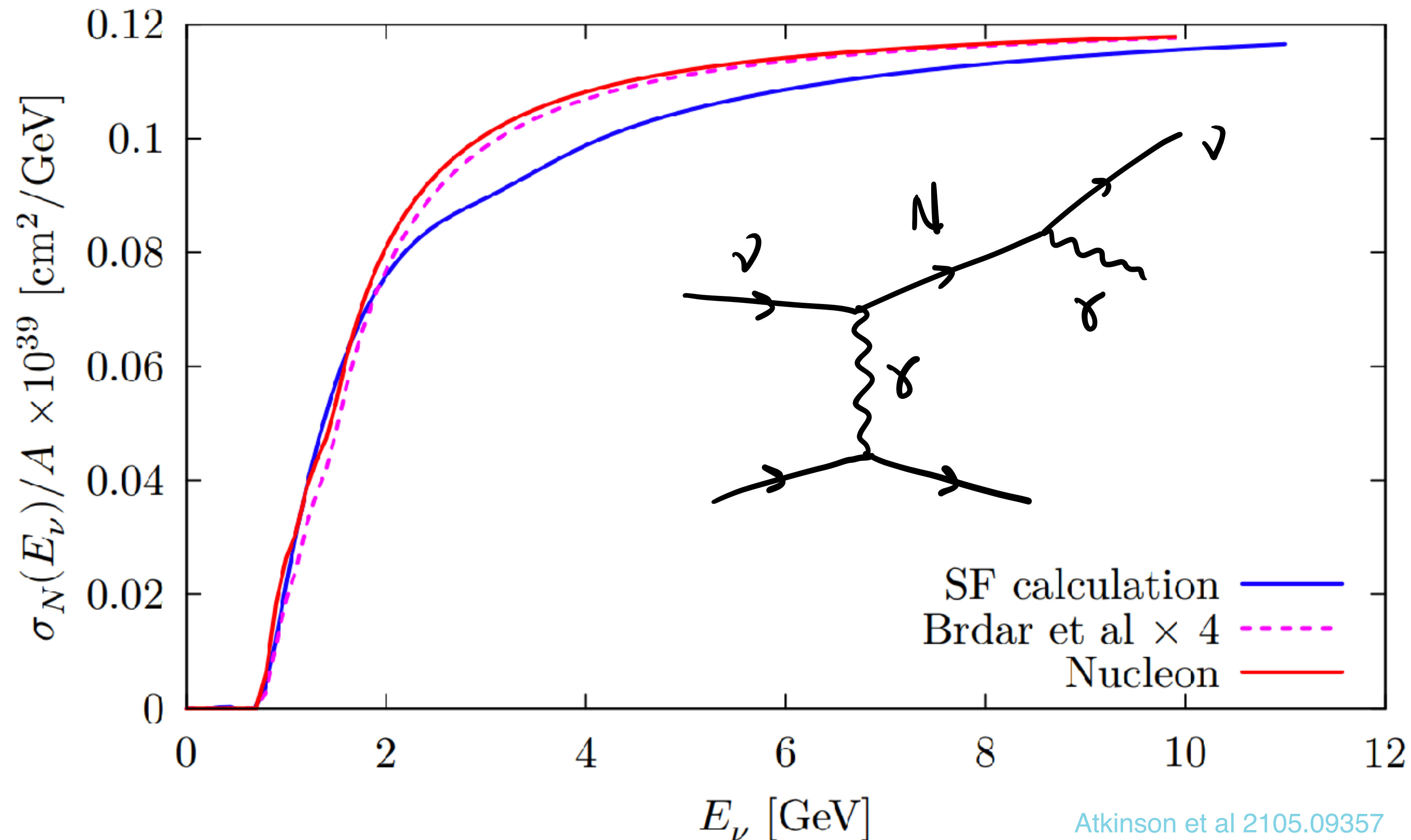


Gninenko 0902.3802



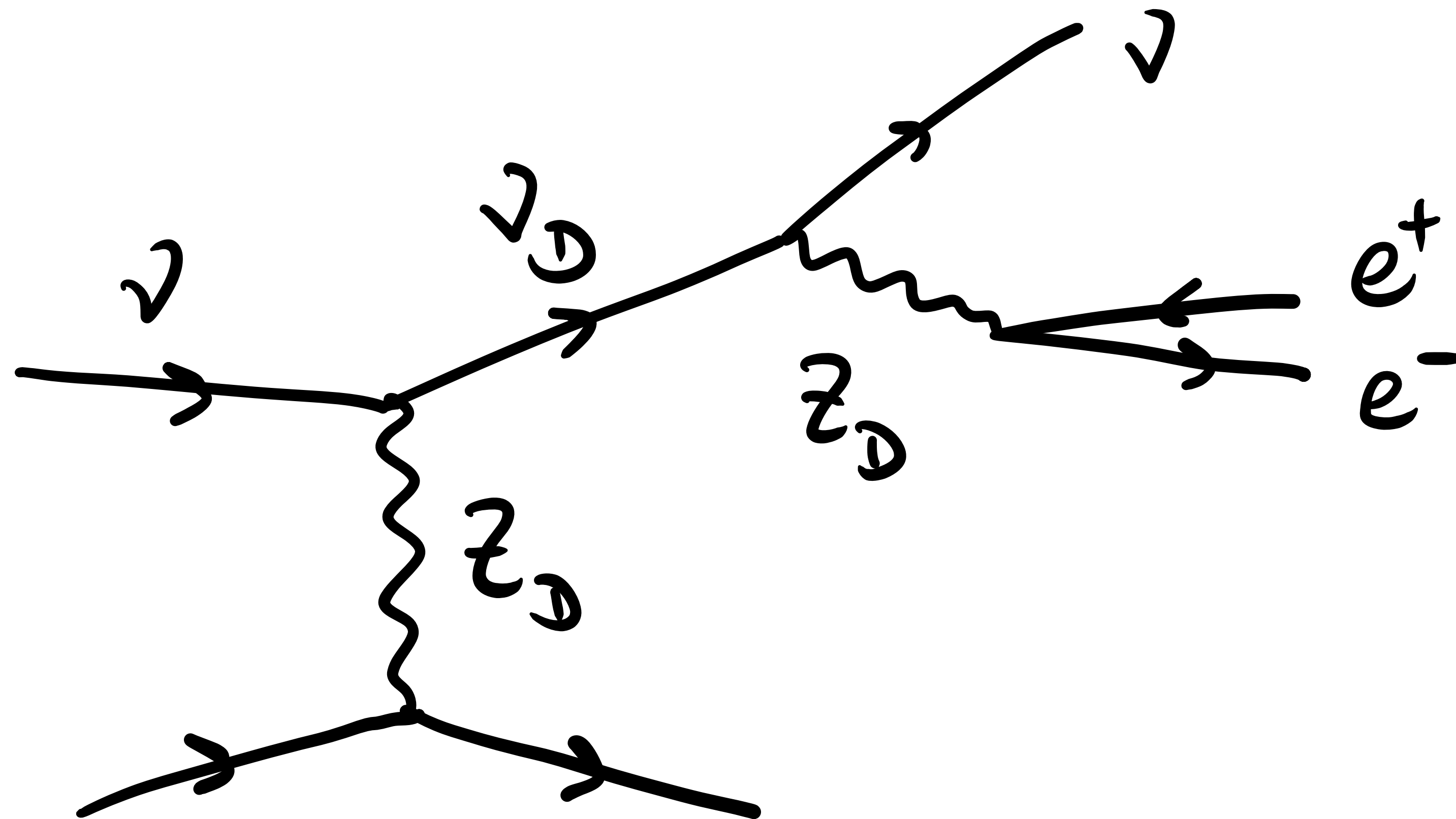
BSM interfaces in neutrino event generators

Properly interfacing BSM with the hadronic part
can have non-negligible impact on the BSM production cross section



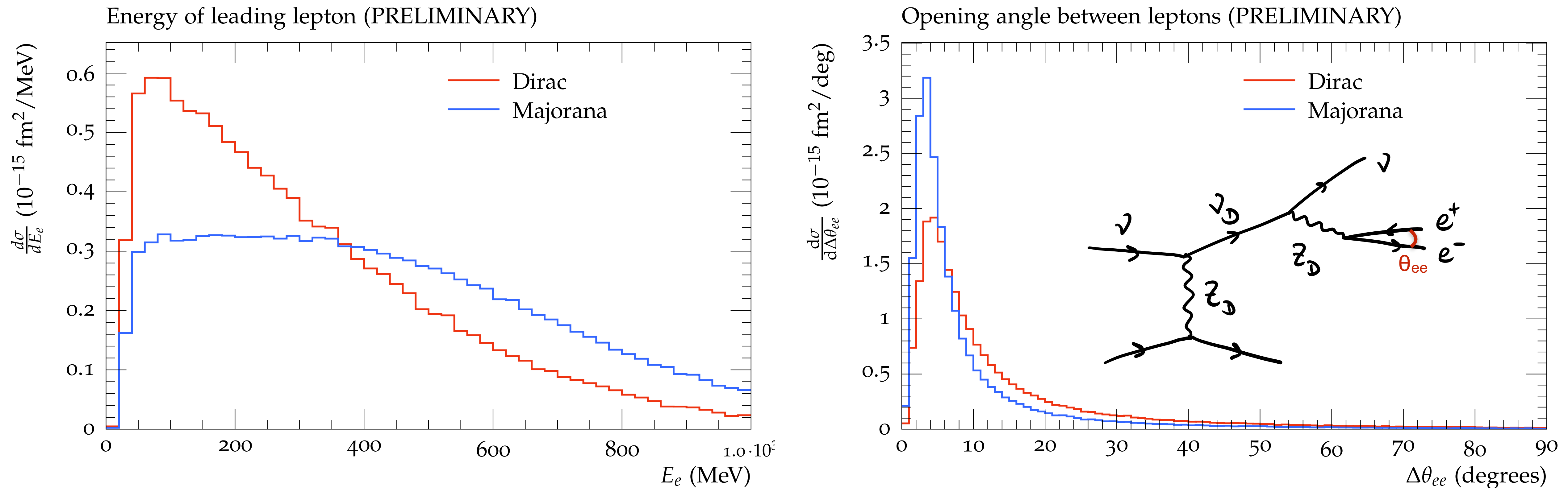
Atkinson et al 2105.09357

Full calculation of scattering amplitude can account for relevant effects, such as spin-correlations, which may end up having an $O(1)$ effect on final state kinematics



BSM interfaces in neutrino event generators

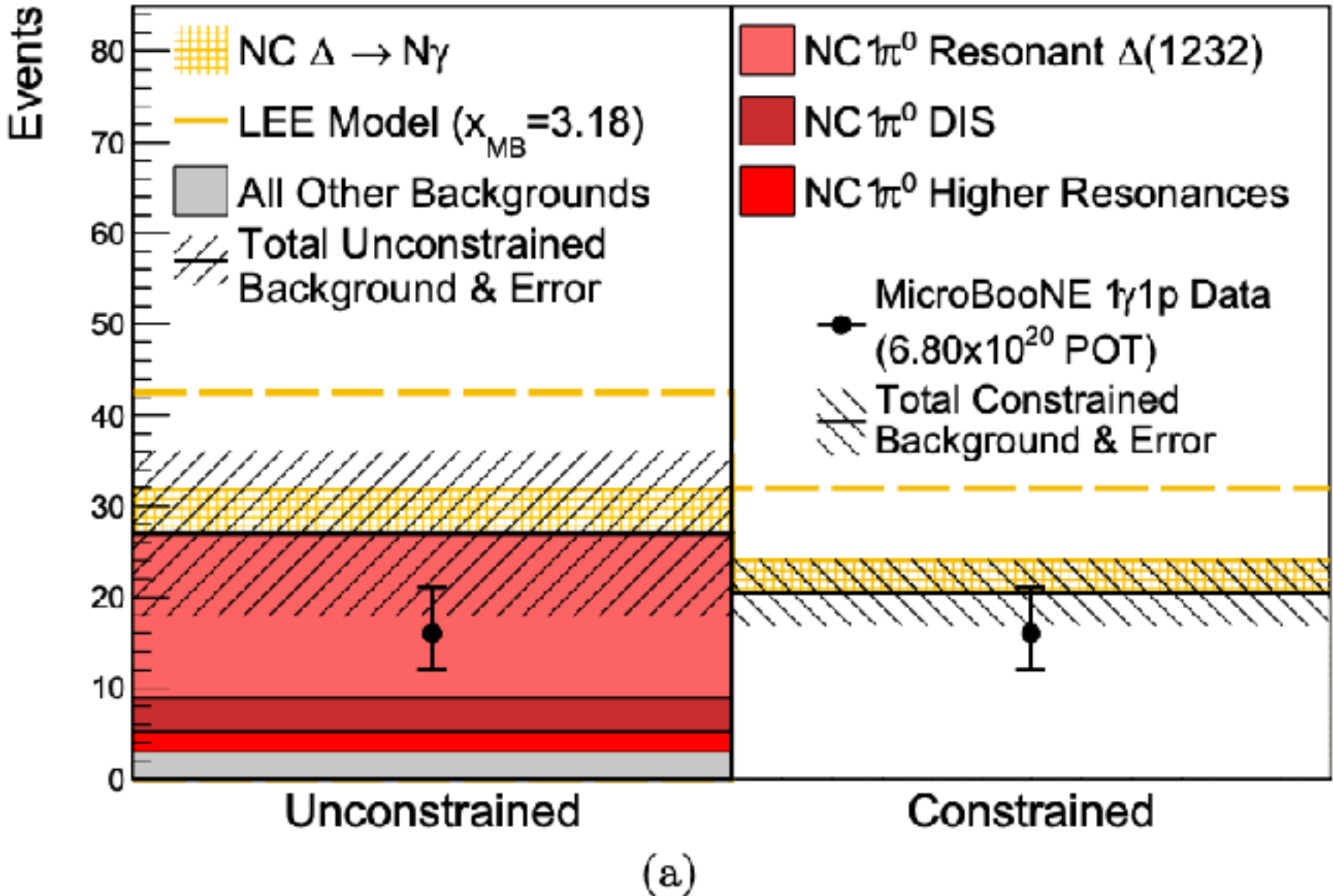
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Dark neutrino observables folded against MiniBooNE ν_μ flux

BSM interfaces in neutrino event generators

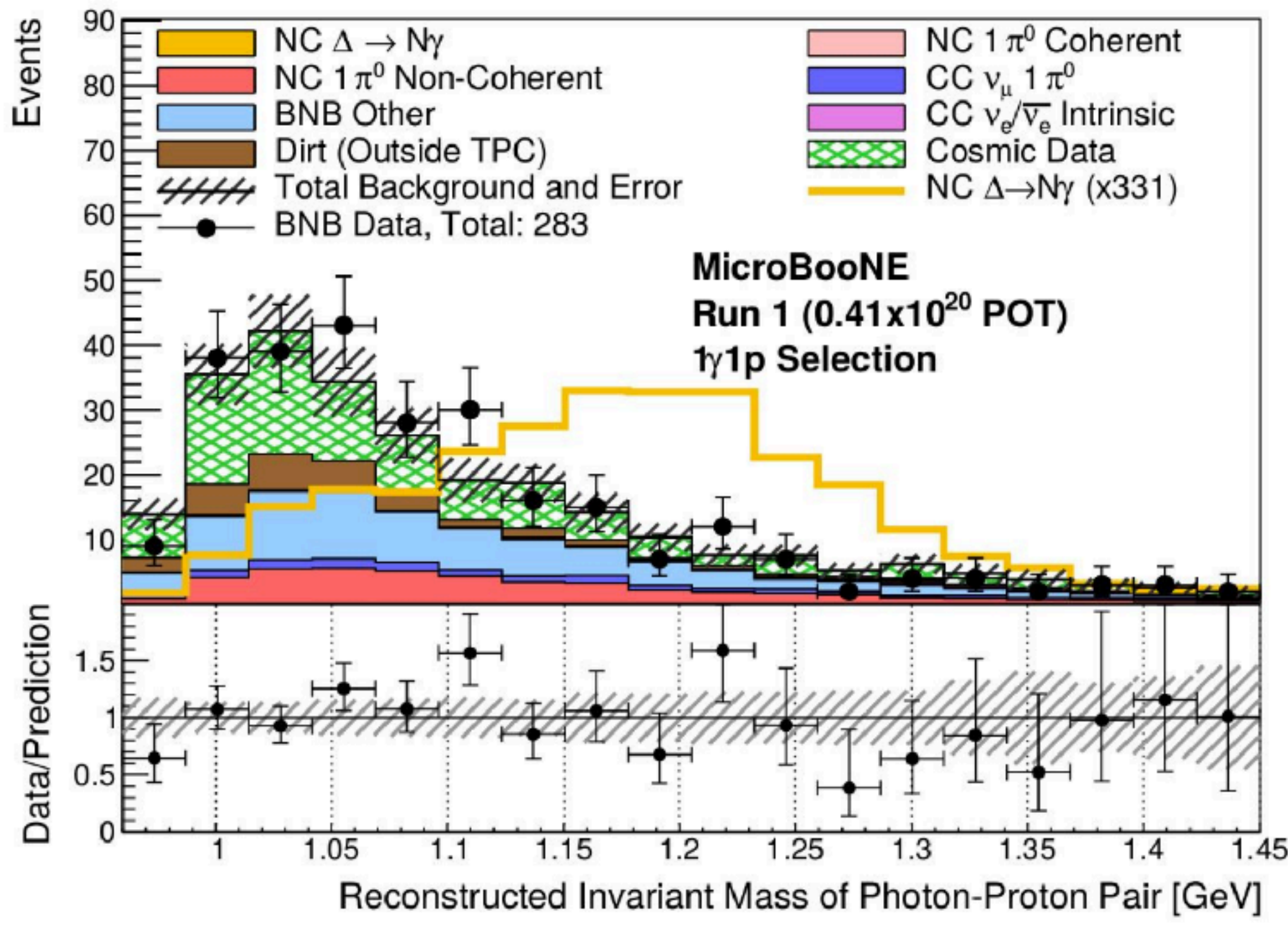
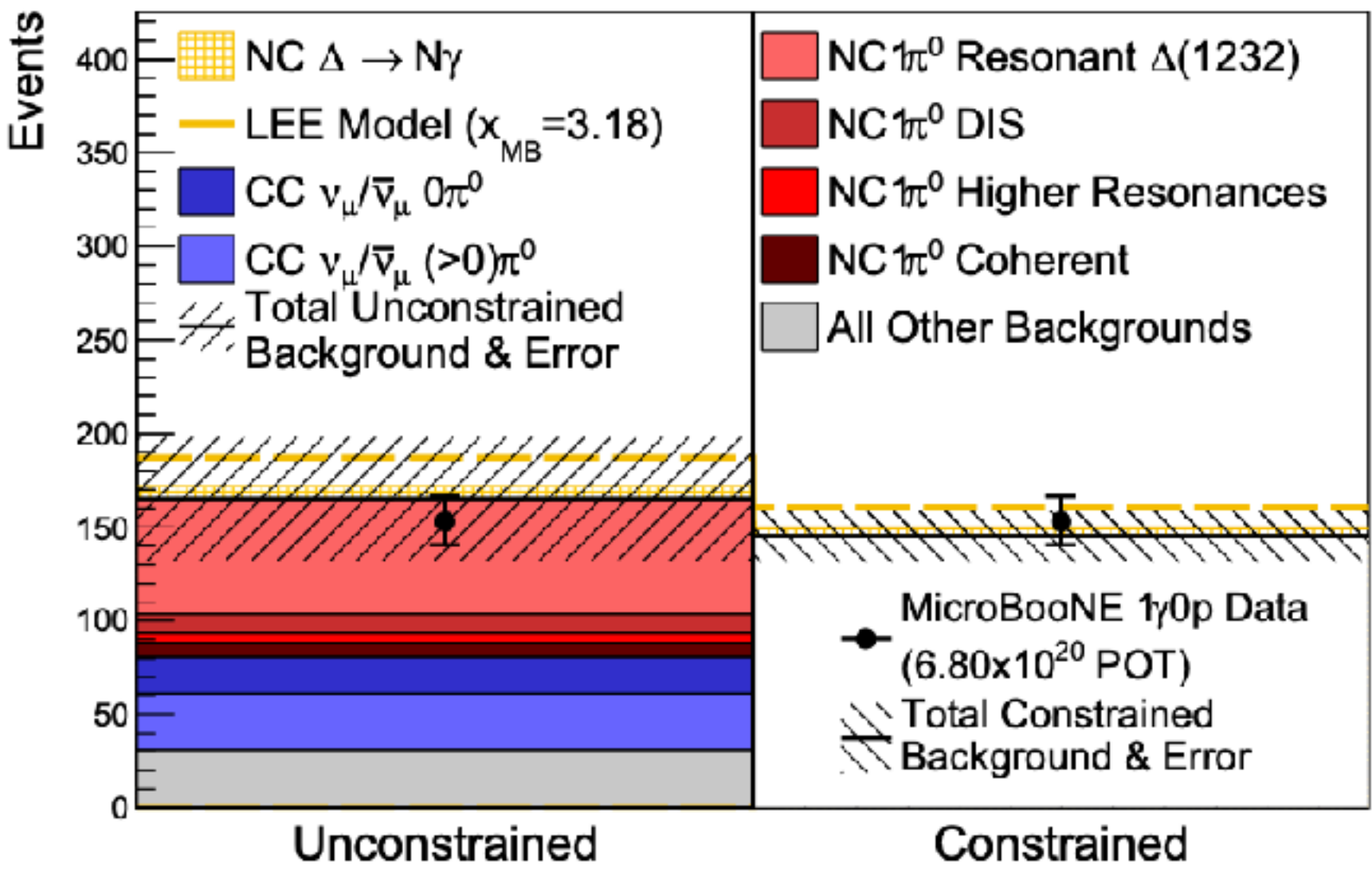
Search for Neutrino-Induced Neutral Current Δ Radiative Decay in MicroBooNE and a First Test of the MiniBooNE Low Energy Excess Under a Single-Photon Hypothesis



	$1\gamma 1p$	$1\gamma 0p$
Unconstr. bkgd.	27.0 ± 8.1	165.4 ± 31.7
Constr. bkgd.	20.5 ± 3.6	145.1 ± 13.8
NC $\Delta \rightarrow N\gamma$	4.88	6.55
LEE ($x_{MB} = 3.18$)	15.5	20.1
Data	16	153

(The MicroBooNE Collaboration)*

Why do you think $1\gamma 0p$ so worse than $1\gamma 1p$??



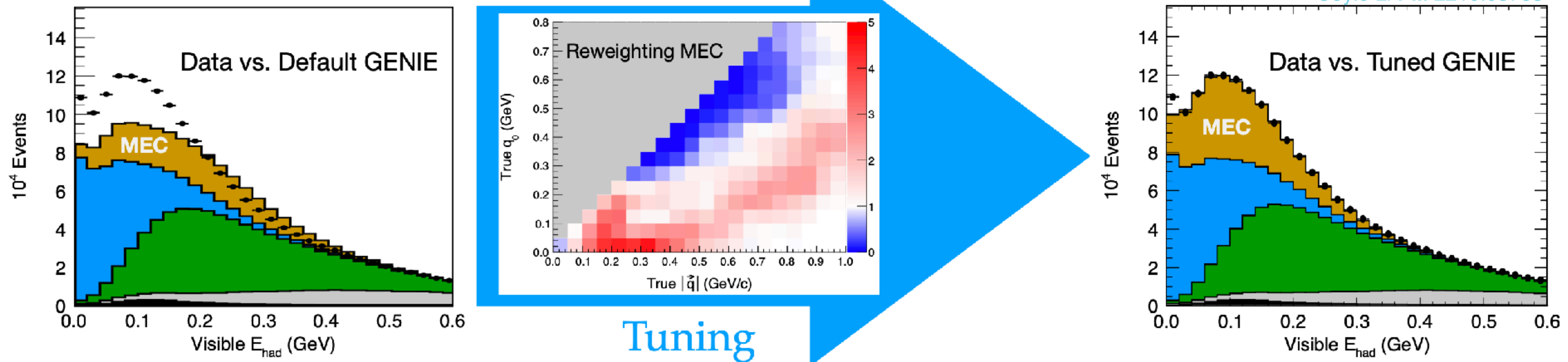
BSM interfaces in neutrino event generators

Tuning is unavoidable in neutrino-nucleus scattering,
and it can change kinematical distributions significantly.

For consistency, the same tuning should be applied to new physics.

See Nina's talk

adapted from NOvA 2006.08727
Coyle Li PM 2210.03753

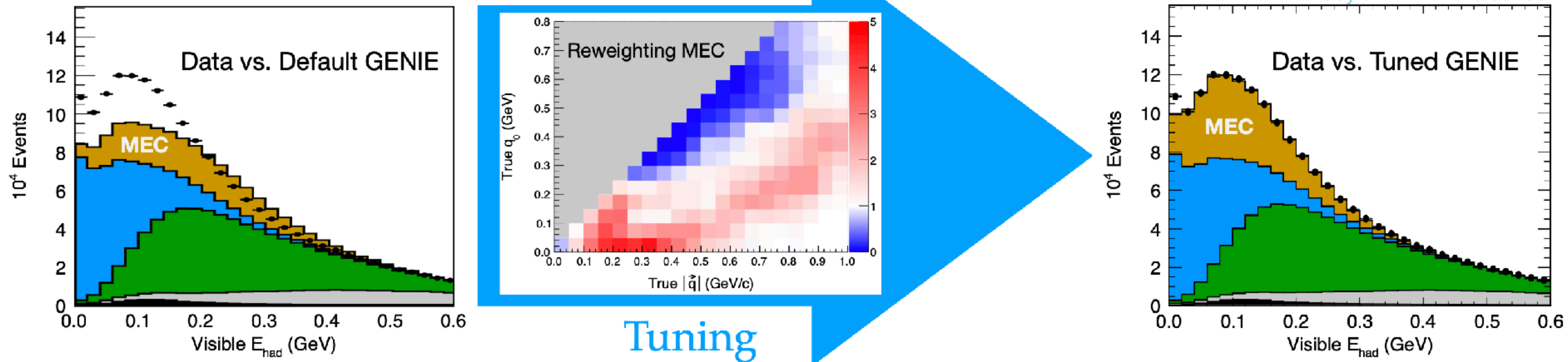


BSM interfaces in neutrino event generators

The same argument applies to experimental cuts, which should affect both signal and background, as well as theory uncertainties

See Nina's talk

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Coyle Li PM 2210.03753

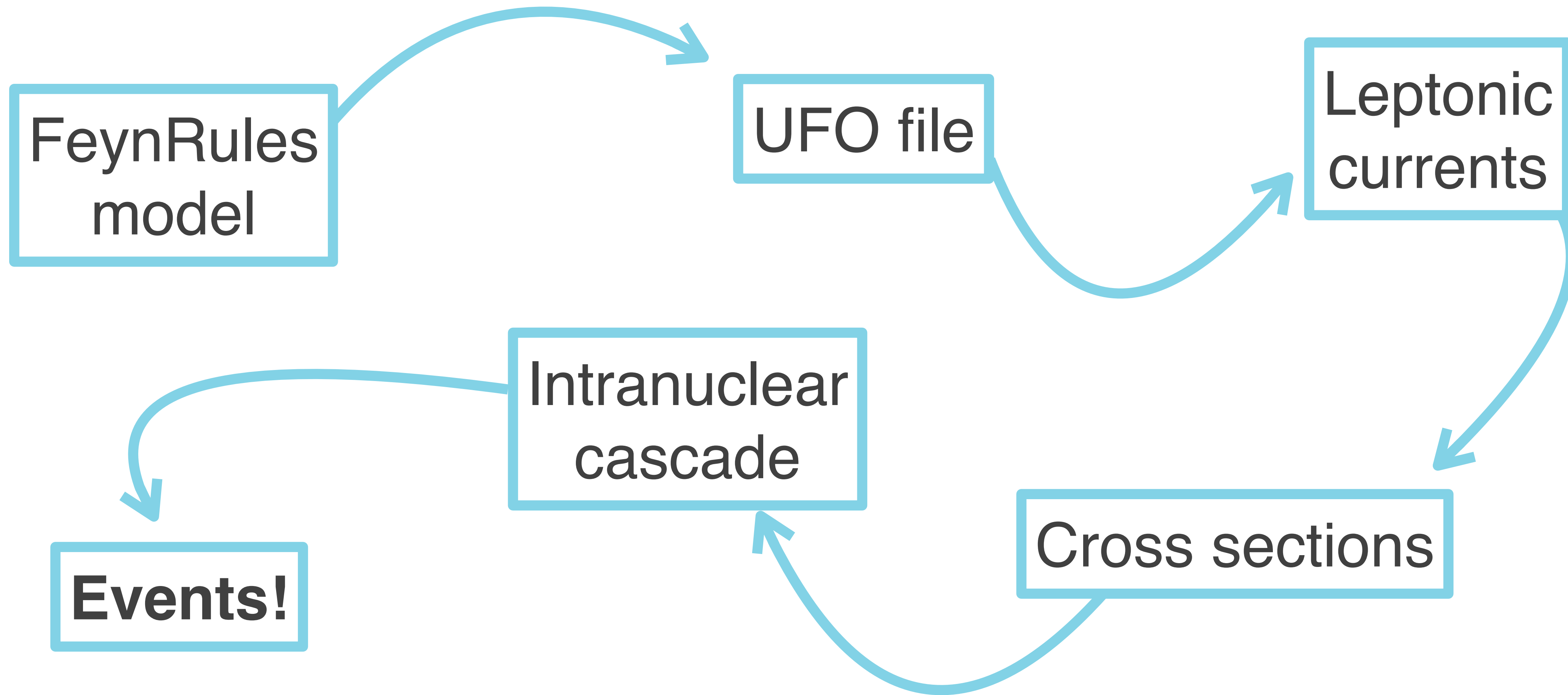


BSM interfaces in neutrino event generators

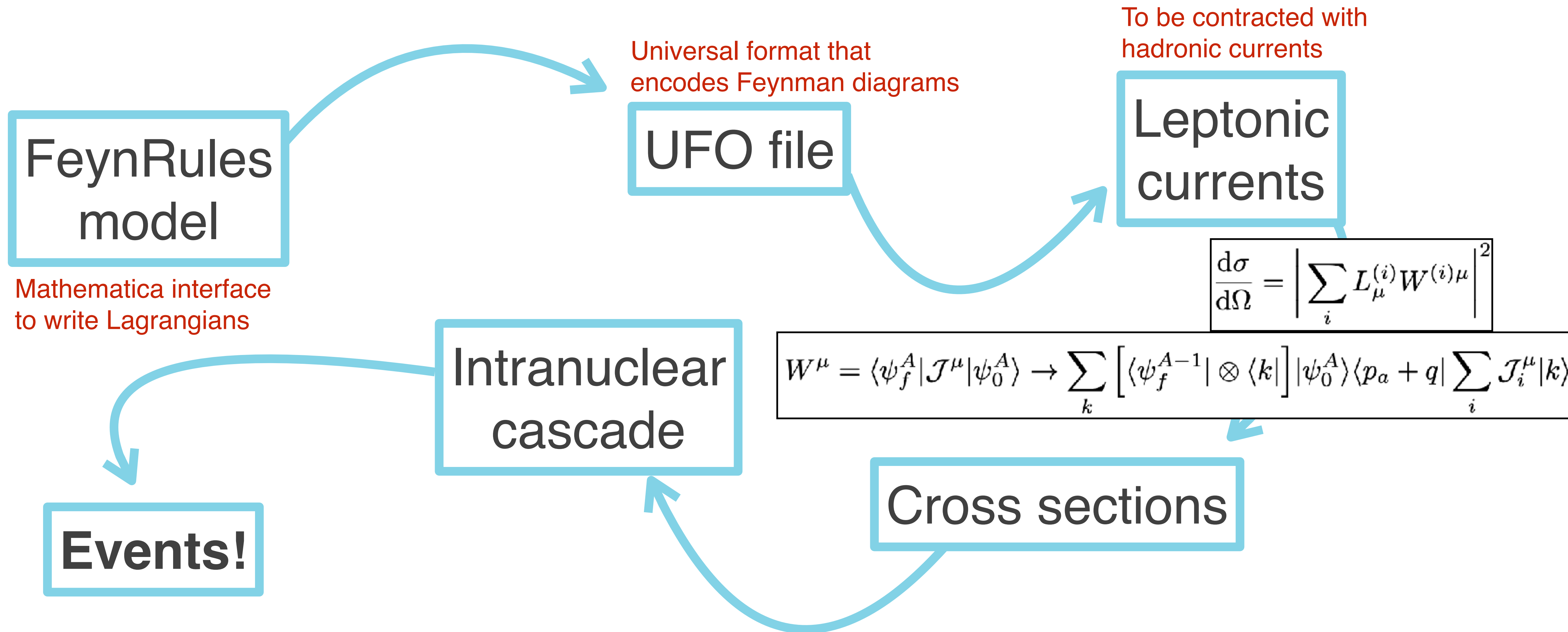
Interfacing BSM to generator with geometry/flux drivers can be very helpful to probe new physics scenarios in near detectors



A working example: Achilles



A working example: Achilles



Conclusions

A vibrant BSM program is vital for the future of neutrino physics

Experimental capabilities and statistics will be too good for back-of-the-envelope estimates

We can only achieve realistic estimates in a theoretically consistent framework by interfacing new physics models with neutrino event generators

Achilles provides a user-friendly BSM interface that can be used for arbitrary new physics in the leptonic current in neutrino-nucleus scattering

There is still a lot of work to do, prospects are good!