BSM searches with near detectors

Pedro A. N. Machado

April 2019

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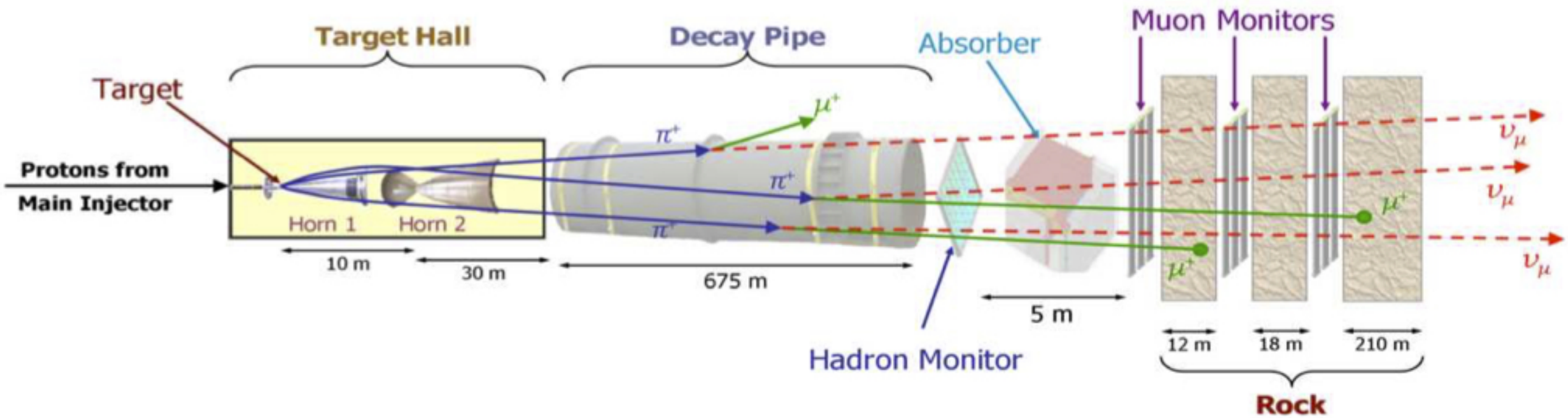
What are near detectors good for?



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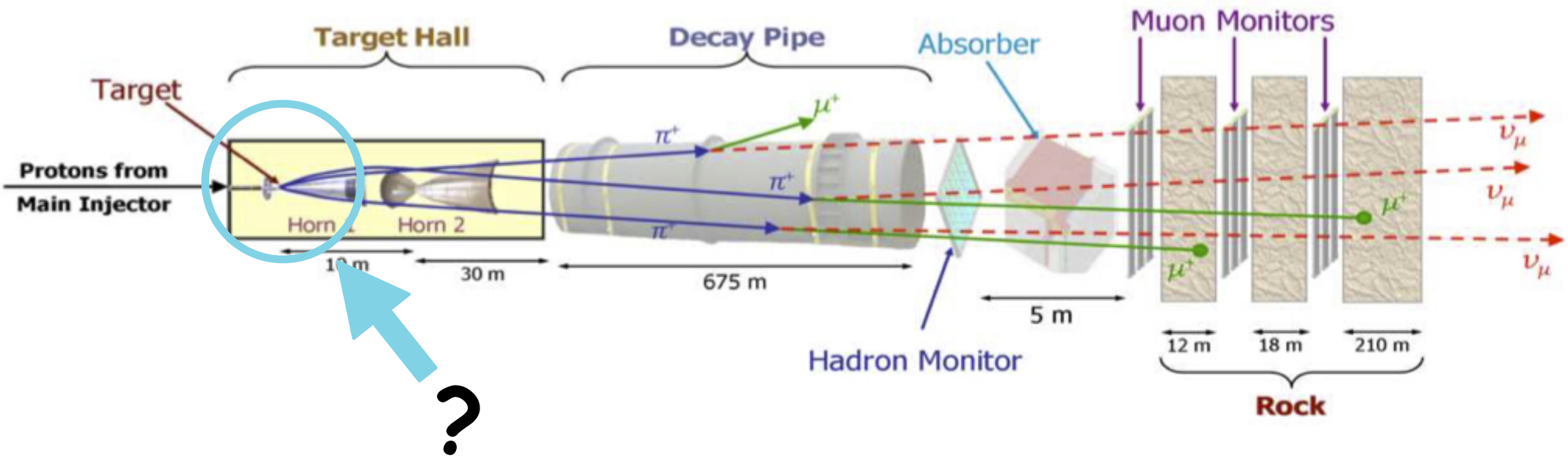

Neutrinos are ultimately produced via QCD, hard to calculate

ND measure P=1 ===> FD measures $P(E_\nu)$

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What makes near detectors distinct?

Proximity to neutrino source ==> higher statistics

Smaller size ==> more complex than FD

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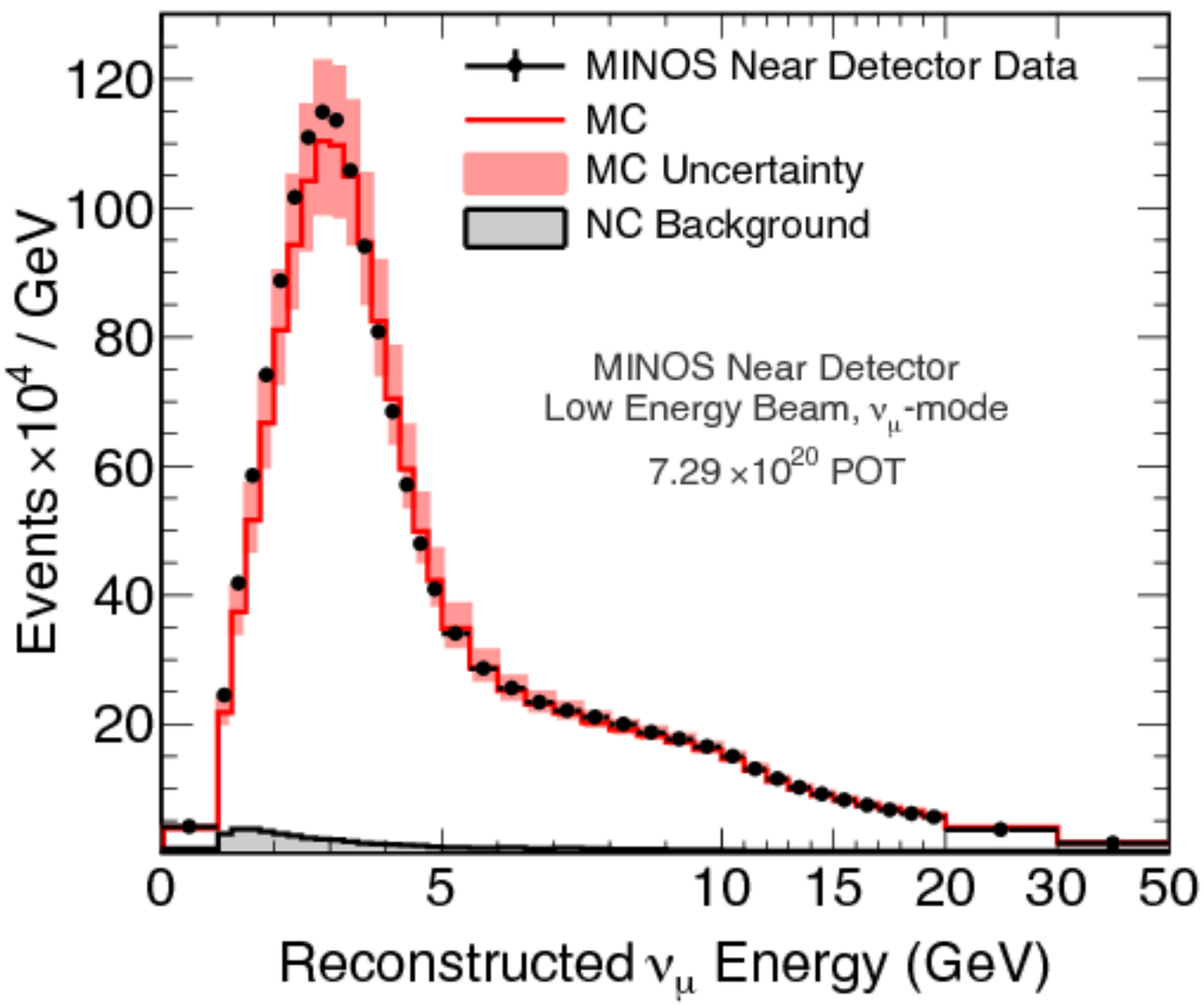

Take MINOS as an example:

- $O(10^7)$ events in low energy configuration
- Magnetized
- + HE configuration

In general, NDs are great for probing rare phenomena

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What near detectors are we talking about?

- LSND
- MiniBooNE
- KARMEN
- MINOS
- NOvA
- T2K
- SBN
- DUNE
- Daya Bay
- RENO

...

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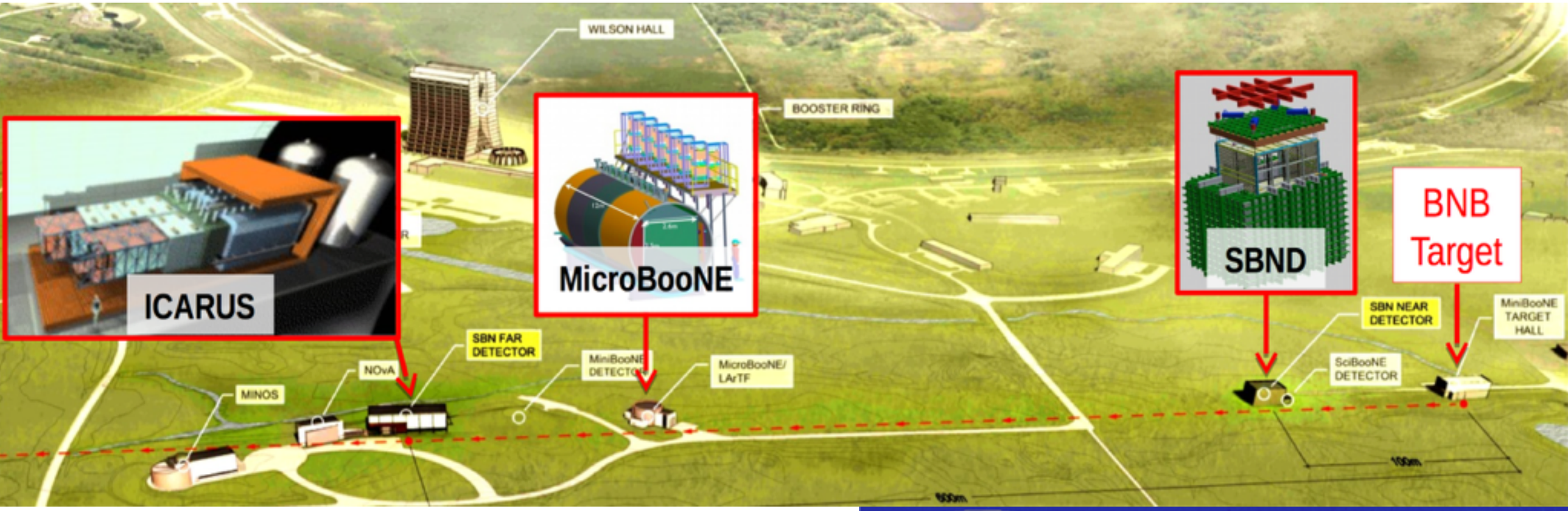
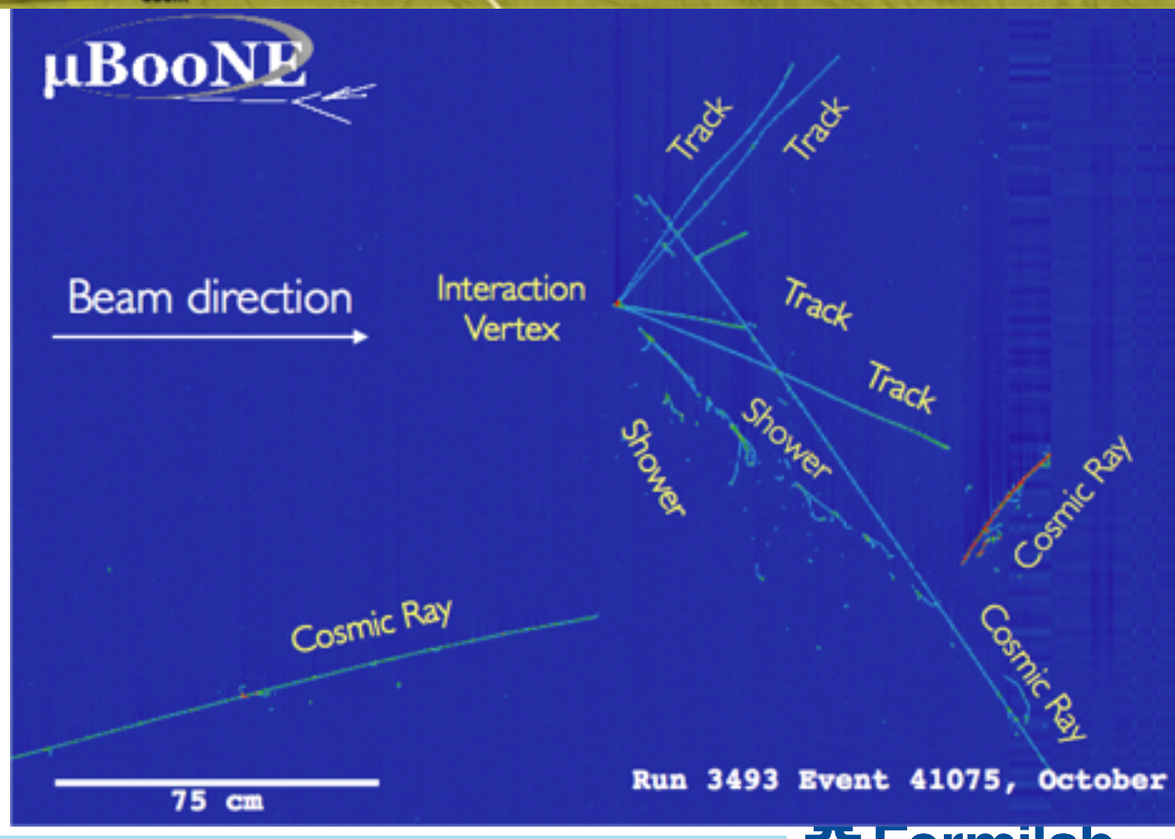
The SBN program



Liquid Argon Time Projection Chambers are "colored" bubble chambers



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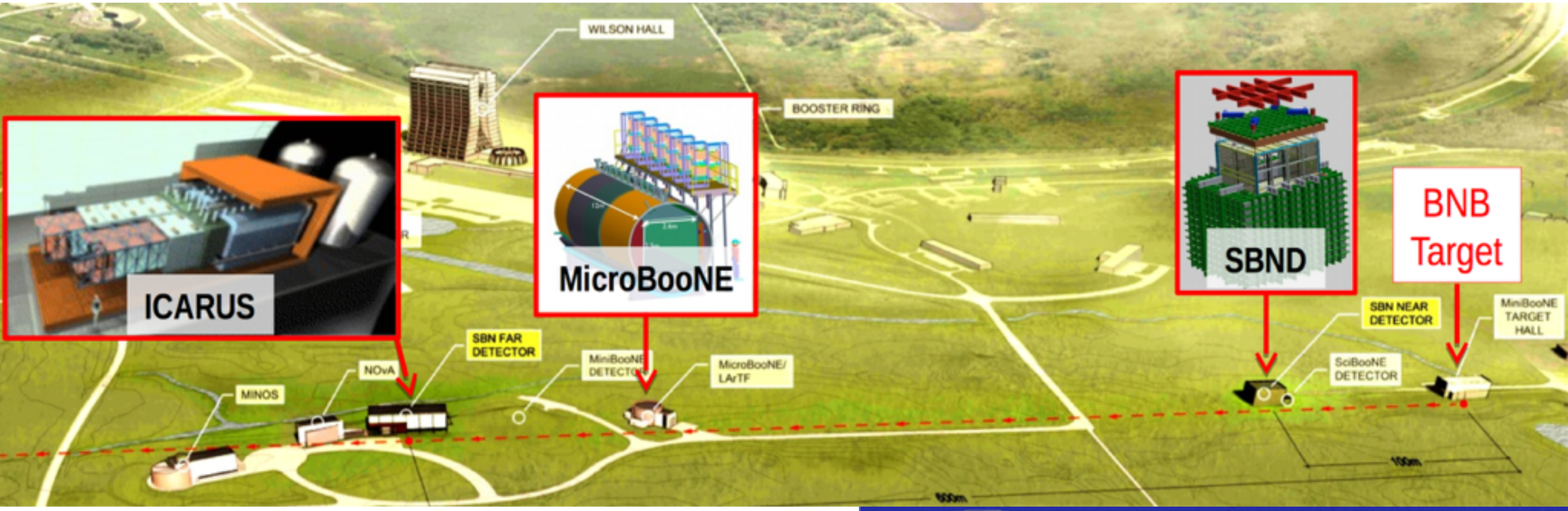
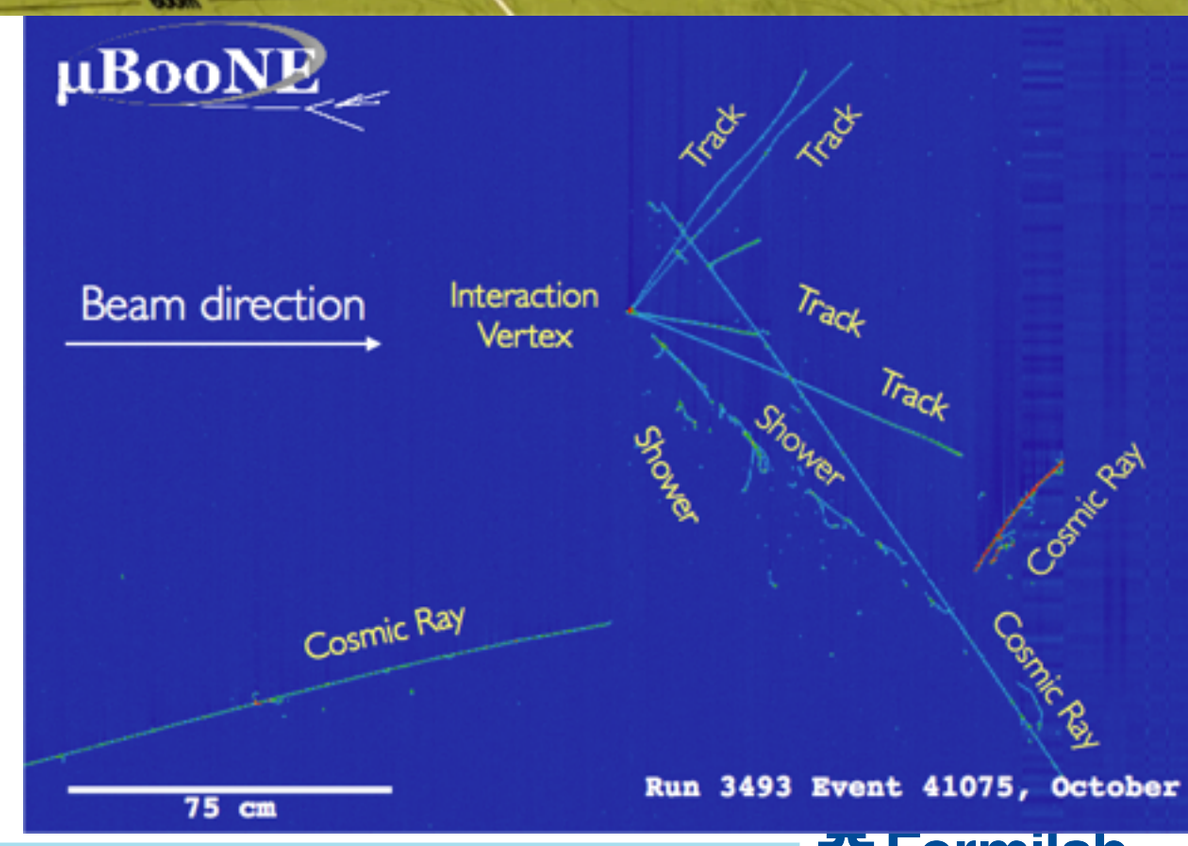


Liquid Argon Time Projection Chambers are "colored" bubble chambers

What can we do with them?

Check
M Palamara Schmitz
1903.04608



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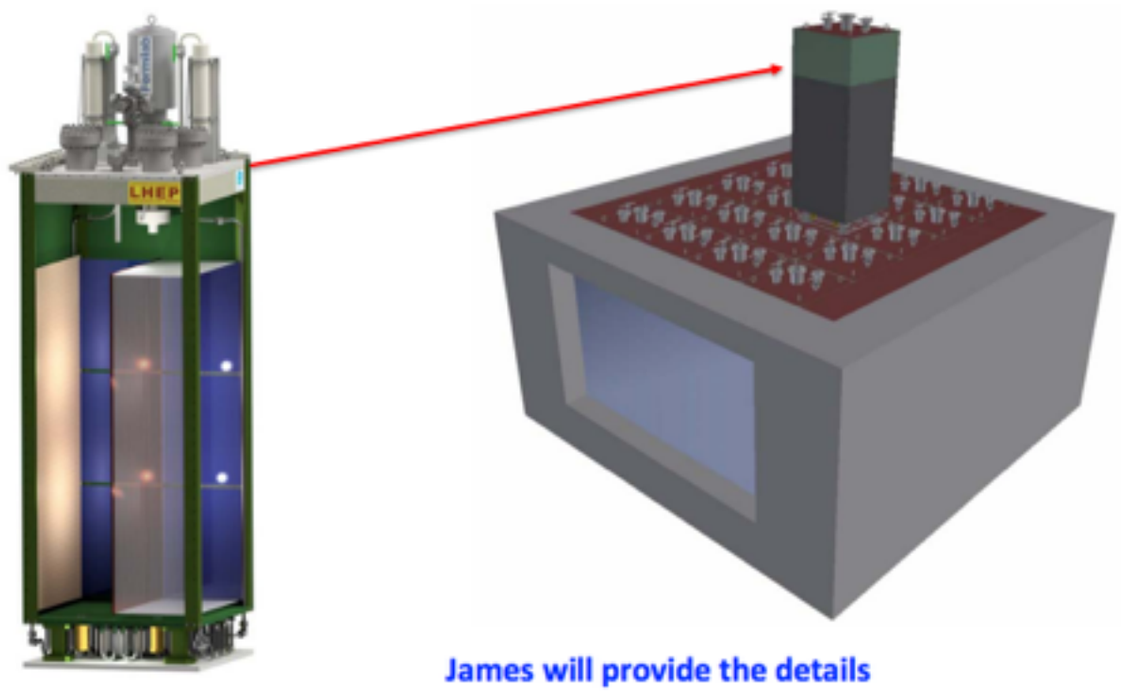
DUNE

Alan Bross' slides at PONDD 2019

LAr: ArgonCube design



James will provide the details

3DST

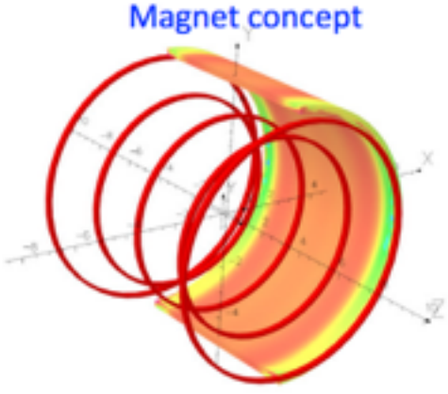
- Magnetized system complementary to MPD/HPgTPC
  - Different target nucleus
  - High statistics tests of neutrino models
  - Connection to the existing catalog of cross section measurements on scintillator (K2K, MiniBooNE, SciBooNEne, MINERvA, T2K, NOVA)
- Can remain on-axis when other detectors move off-axis
  - Accurate determination of the flux
  - High statistics measurement of the beam electron neutrino component

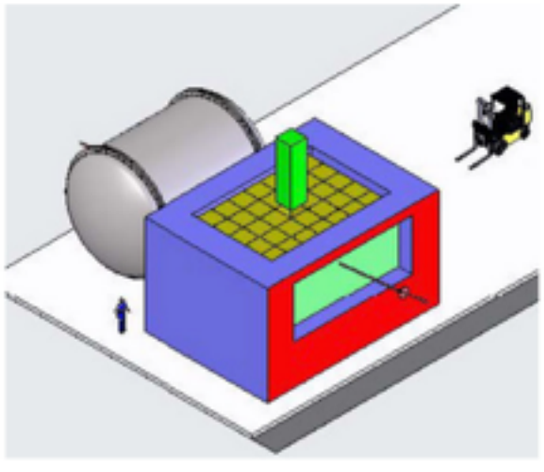
Clark will give the details

MPD

ALICE being lowered into Hall

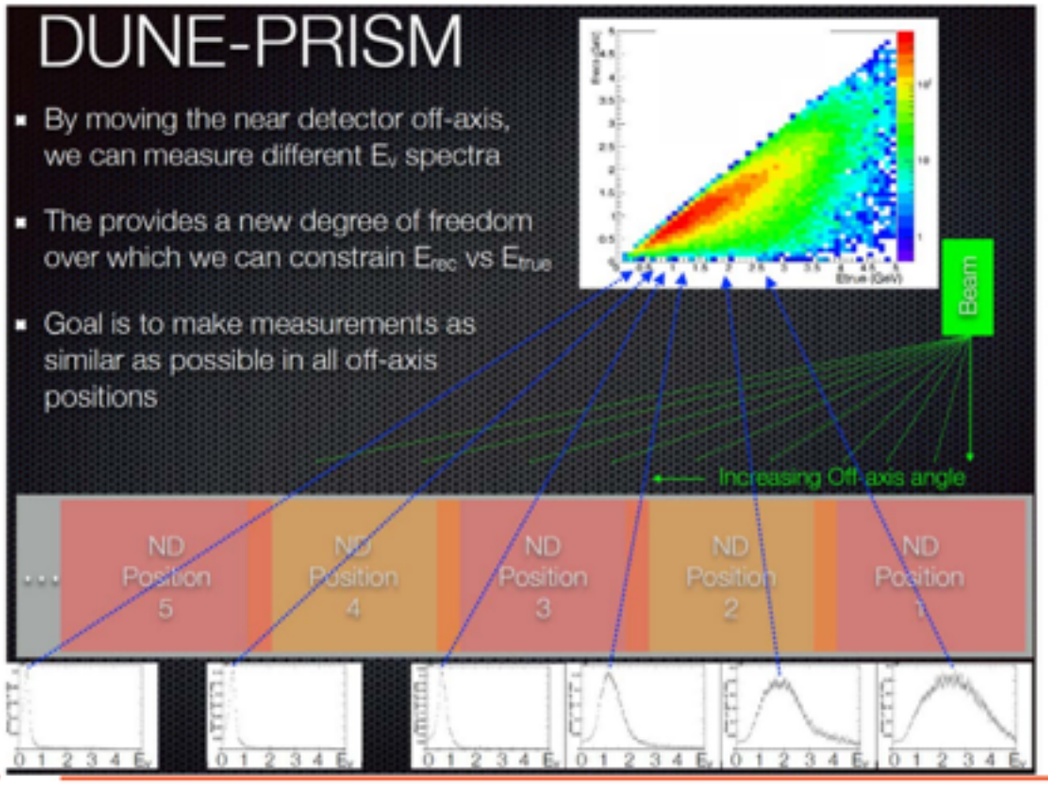
Magnet concept





Tanaz will go into the details

DUNE-PRISM



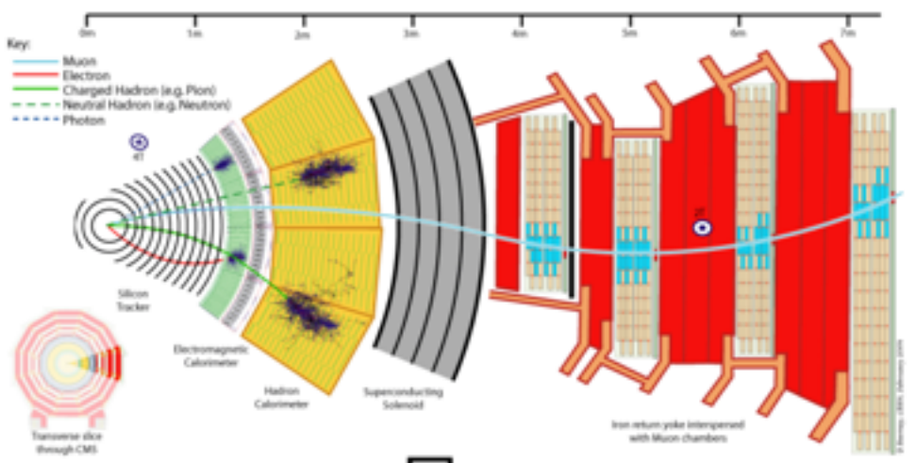
Use linear combinations to disentangle f and x-section effects using different fluxes.

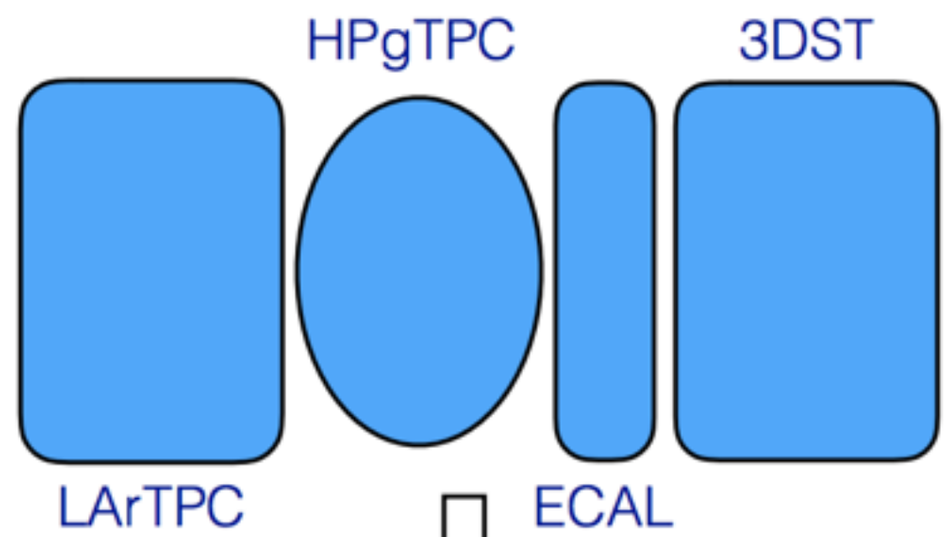
Cristovao will give the details

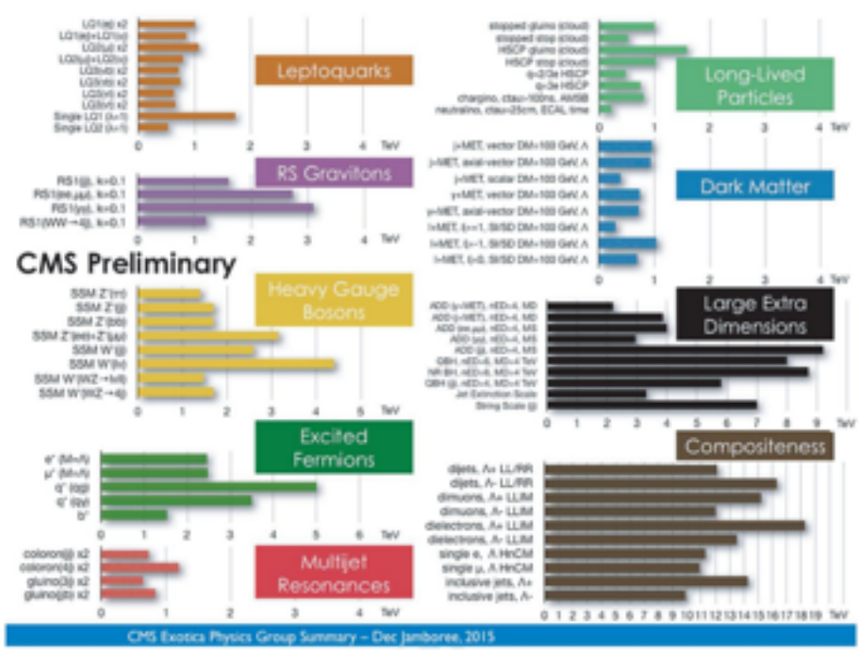
DUNE, a theorist view

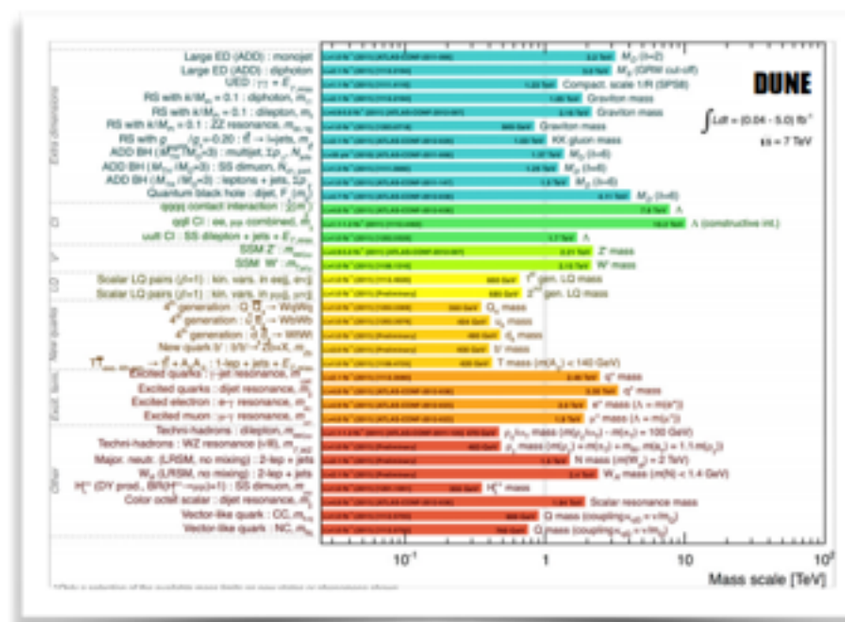
Roni Harnik's slides in PONDD 2019

Multi-Purpose Detectors









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An overview of new physics models that can be probed in near detectors

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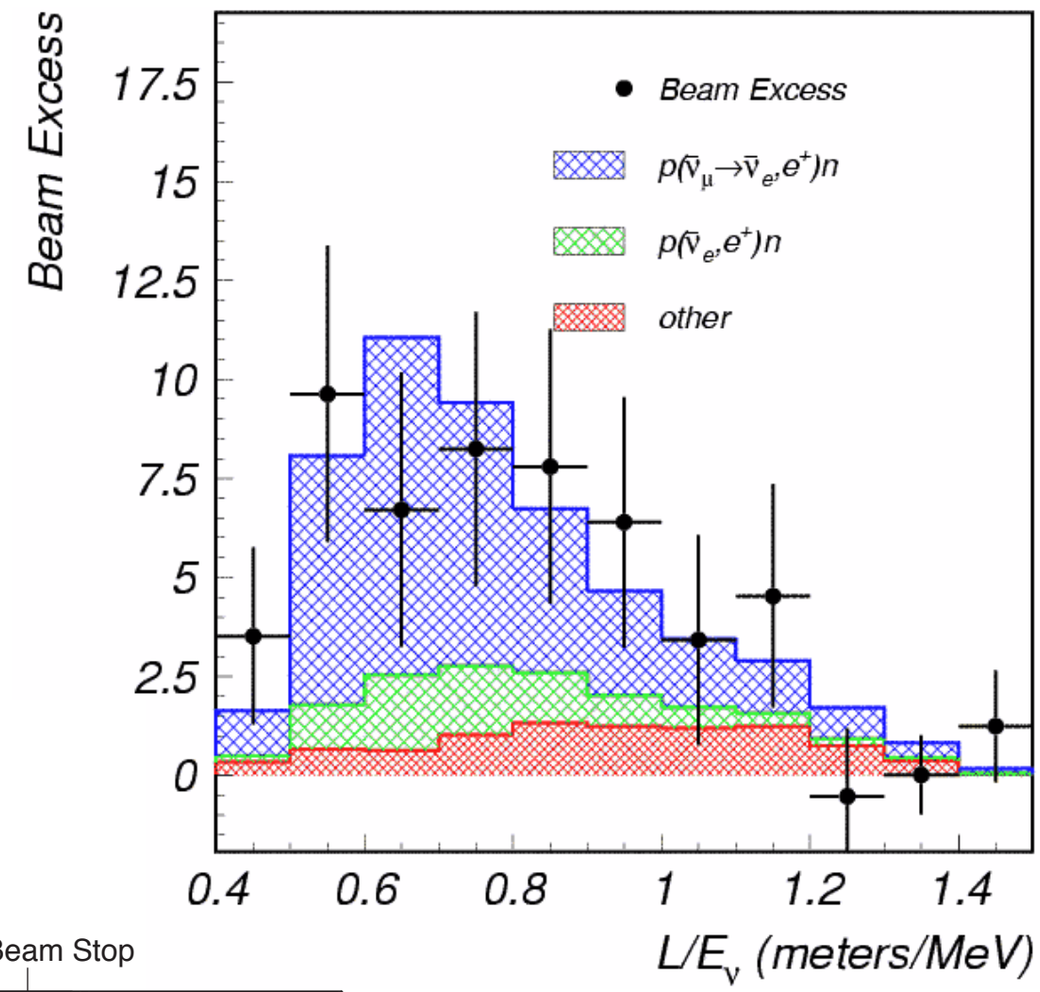
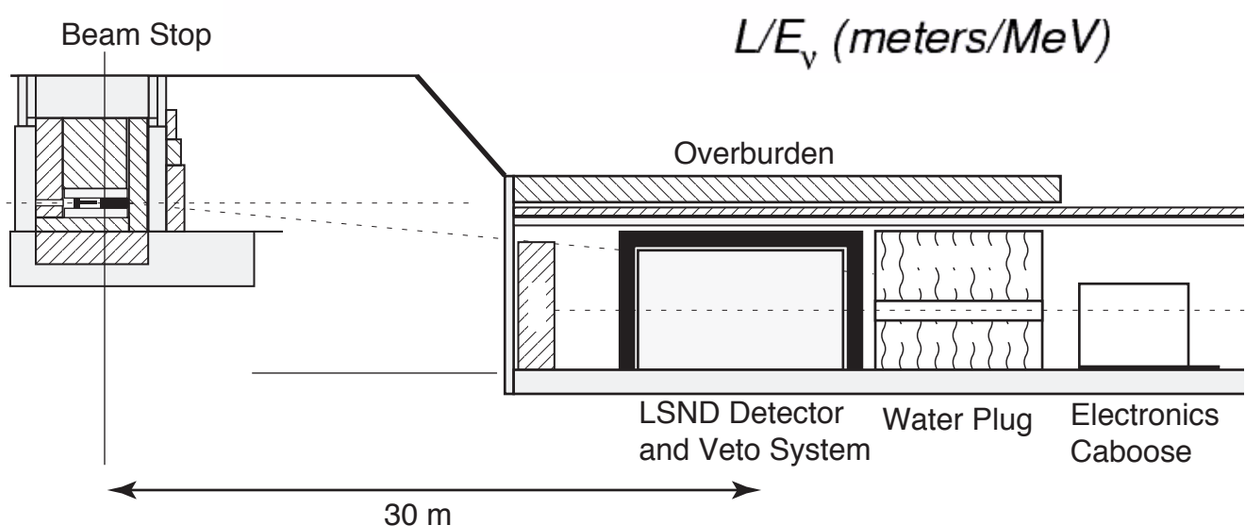
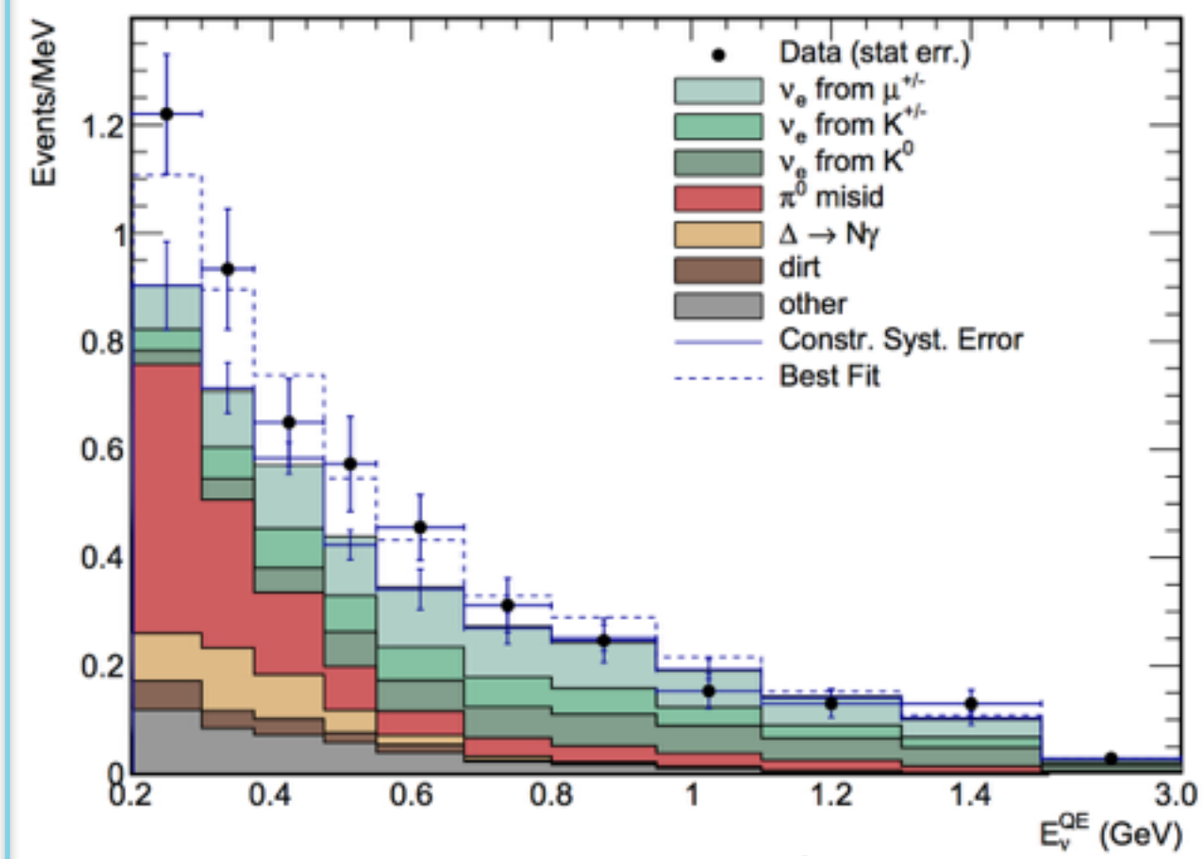
SBSM - Light sterile neutrinos

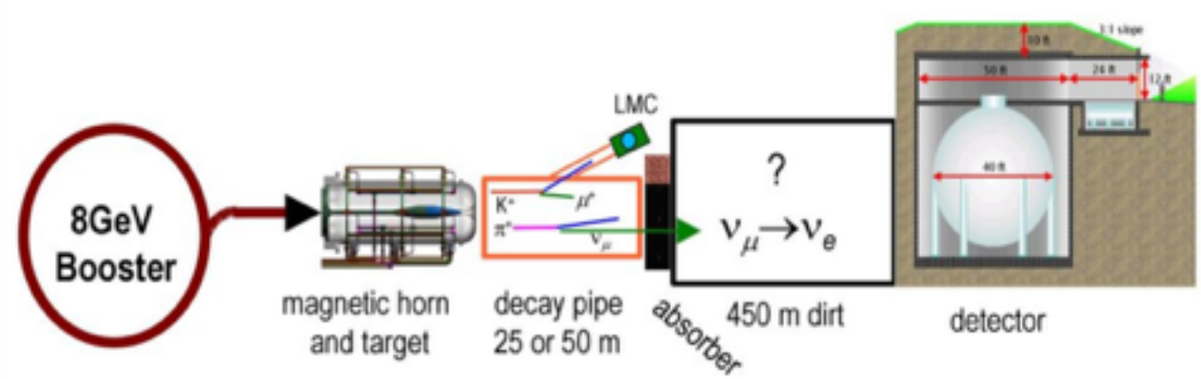
LSND





MiniBooNE





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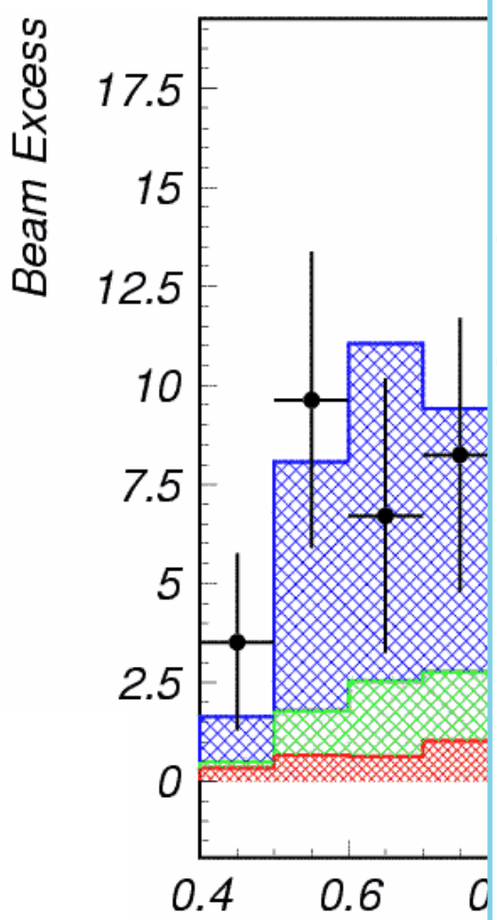
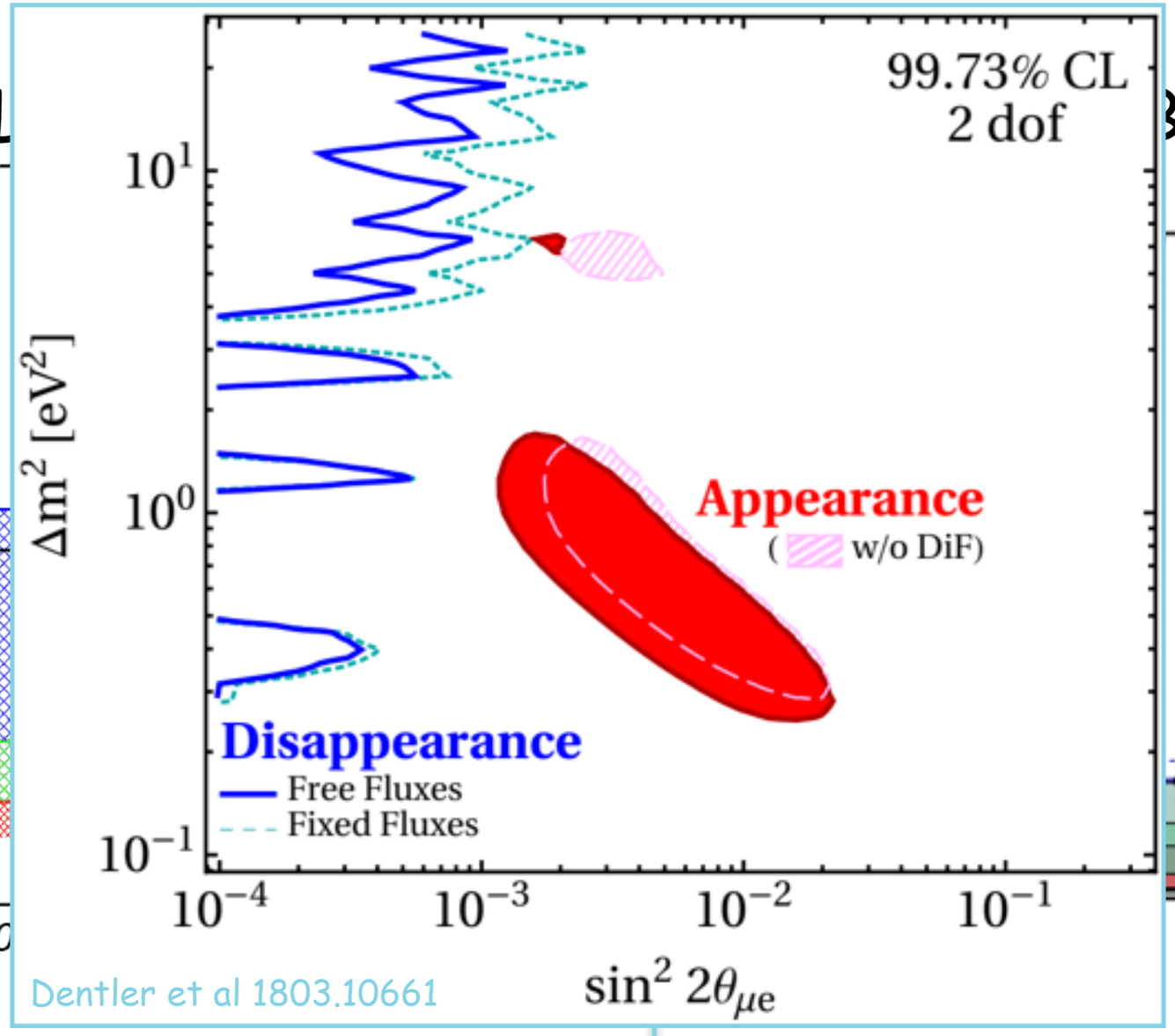
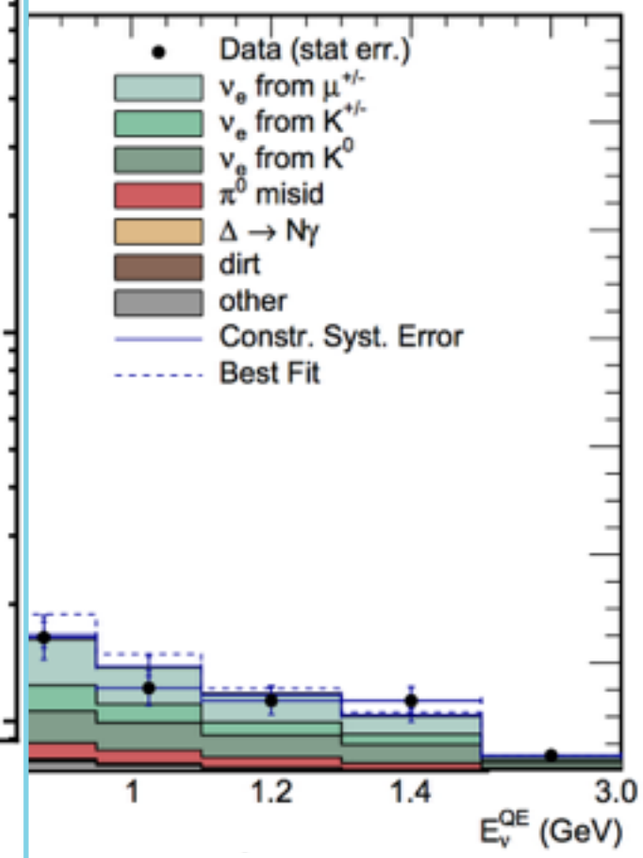
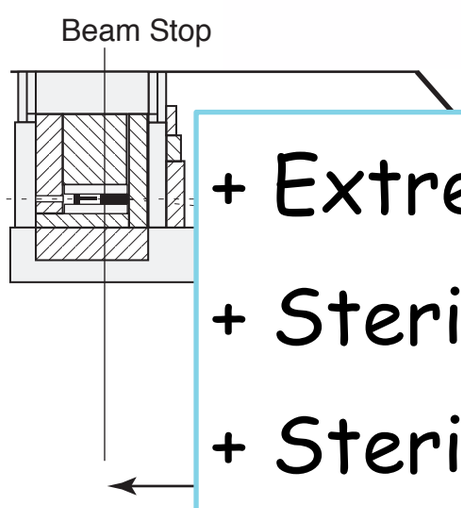




Dentler et al 1803.10661





+ Extremely significant (over 5σ)

+ Sterile neutrinos provide a good fit of LSND+MiniBooNE

+ Sterile neutrinos are a simple, minimal model

- Extraordinary tension with other data set (4.7σ)

SBSM - Light sterile neutrinos

Should we dismiss sterile neutrinos?

Definitely not!

Steriles could be a portal to the neutrino mass generation:

Neutrinos in large extra dimensions

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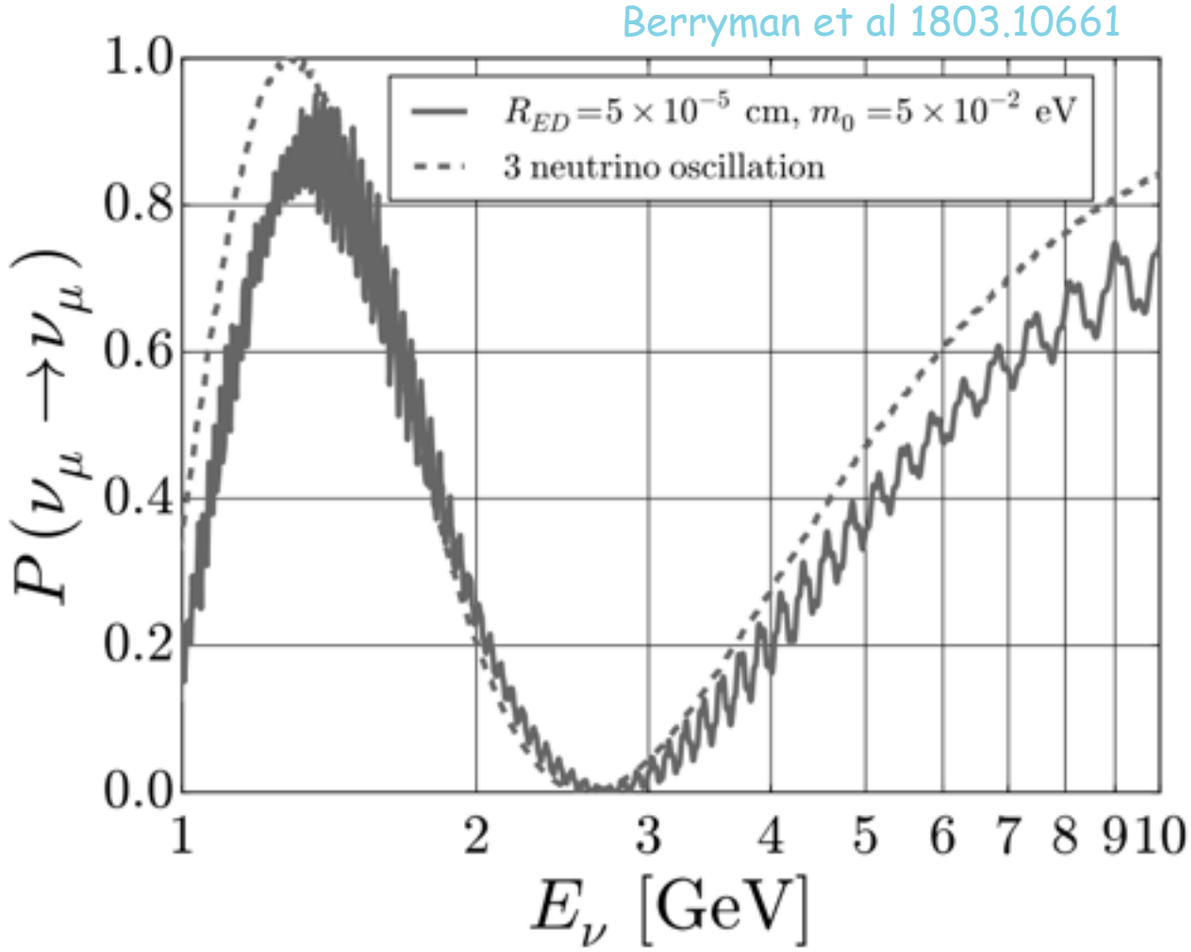
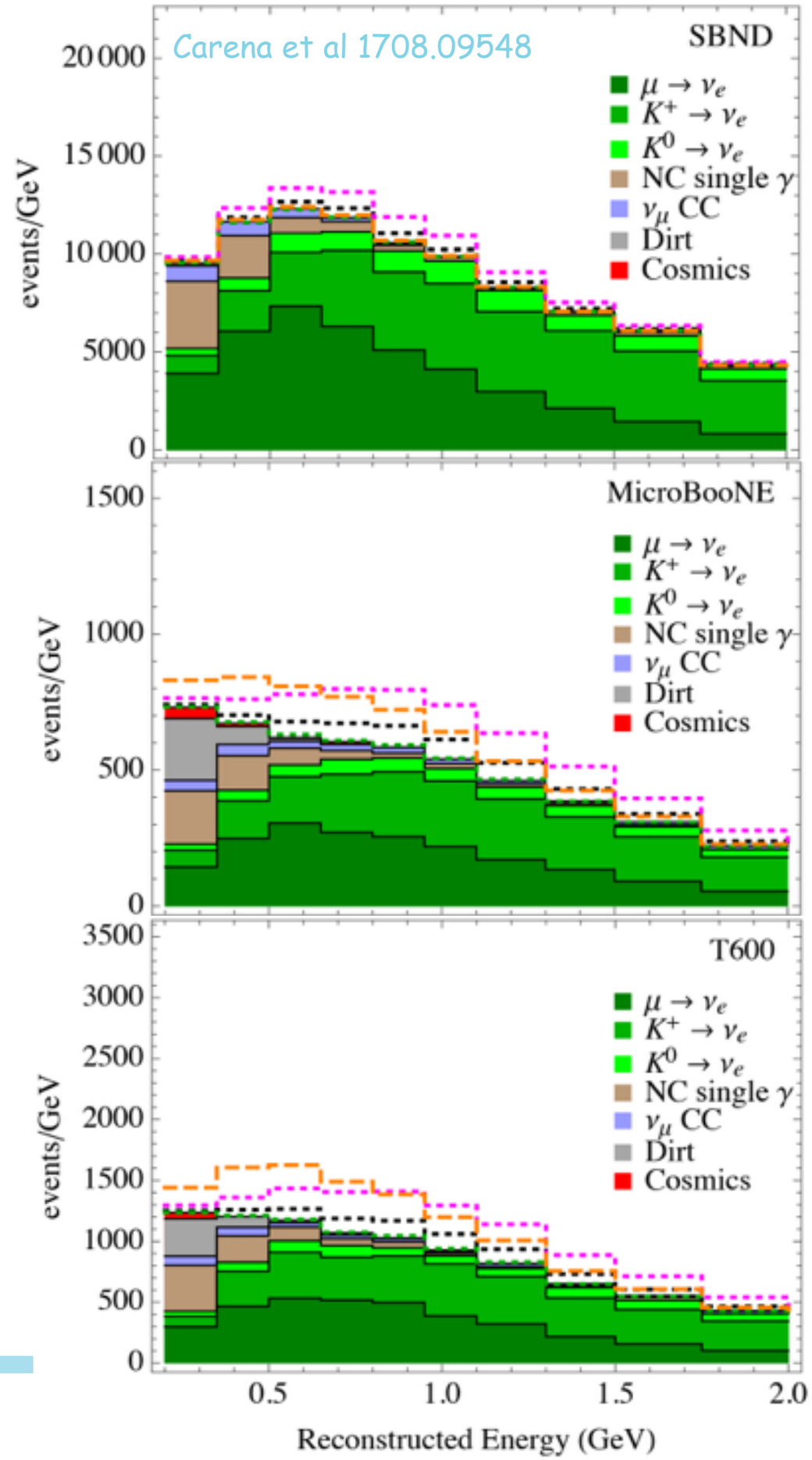
Berryman et al 1803.10661

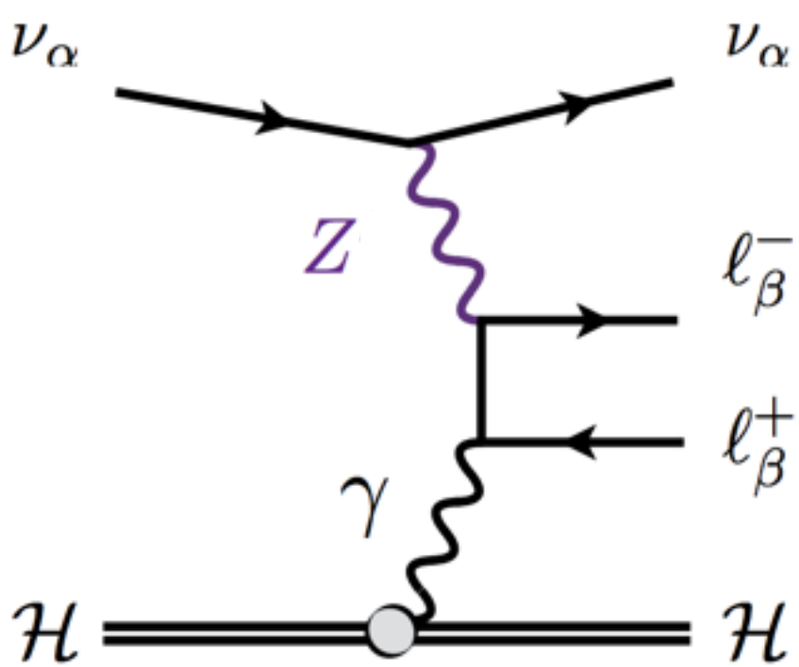


Carena et al 1708.09548



BSBSM - Neutrino tridents

Neutrino tridents are standard model processes



- Only $\mu^+\mu^-$ was observed experimentally
- e^+e^-, μ^+e^-, μ^-e^+ are VERY difficult

Several BSM scenarios can give rise to trident signatures

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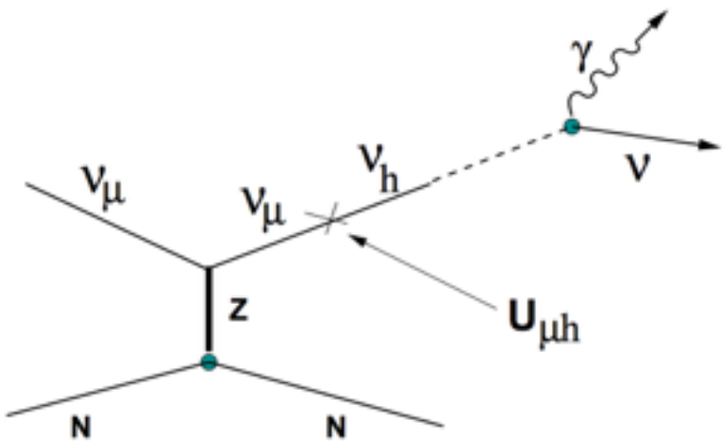
BSBSM - Neutrino tridents

ν magnetic moment



Explains MiniBooNE

Gninenko 0902.3802

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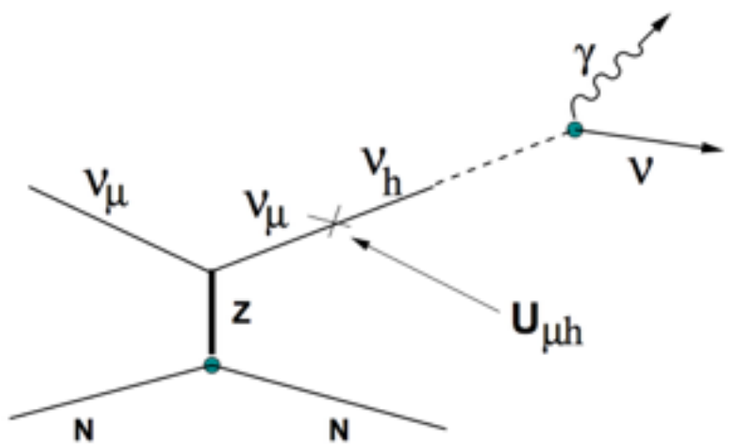

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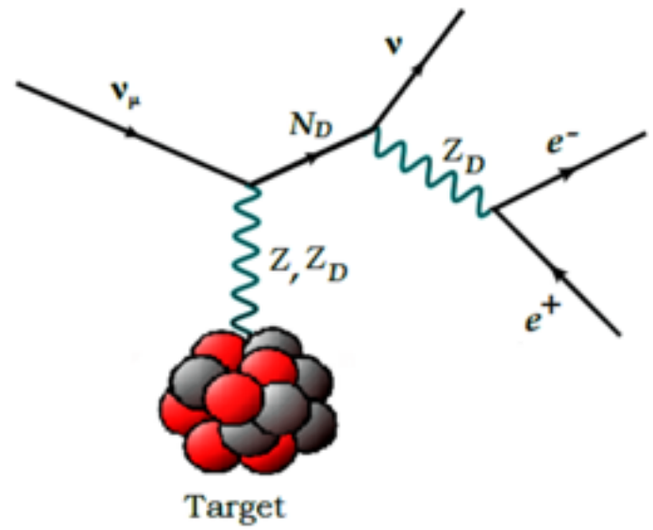
Dark neutrinos



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Explains m_ν

Bertuzzo et al 1807.09877, 1807.02500

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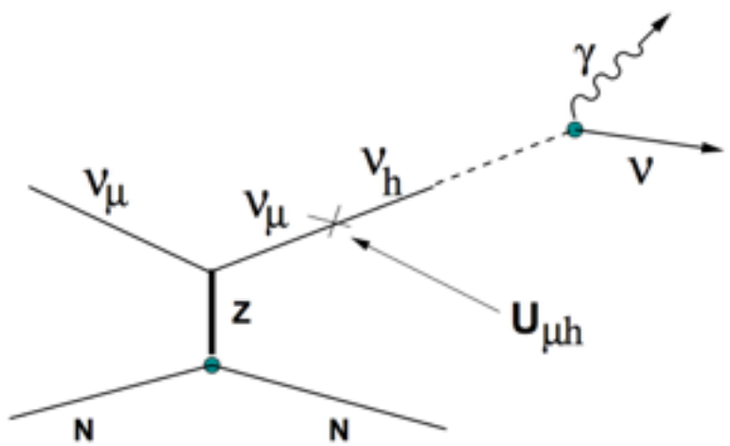

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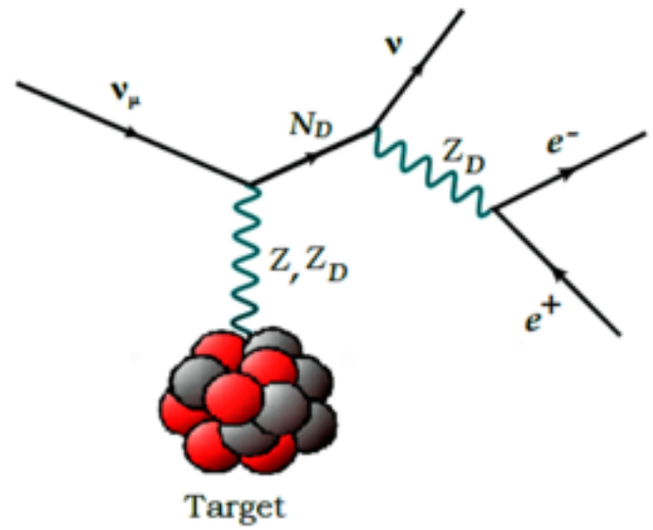

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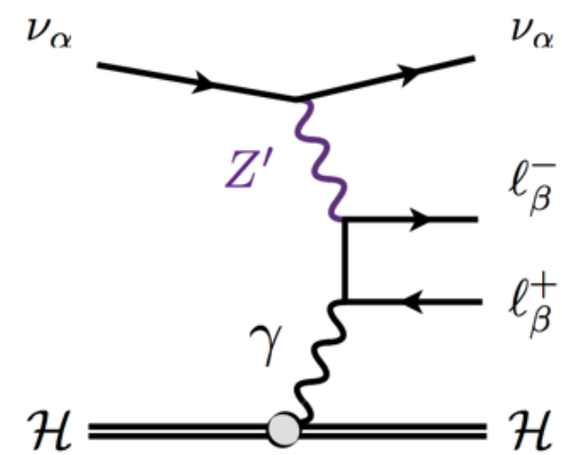
New gauge bosons (e.g. L_μ-L_τ)



Explains $(g\text{-}2)_\mu$

Altmannshofer et al 1406.2332

Ballet et al 1902.08579

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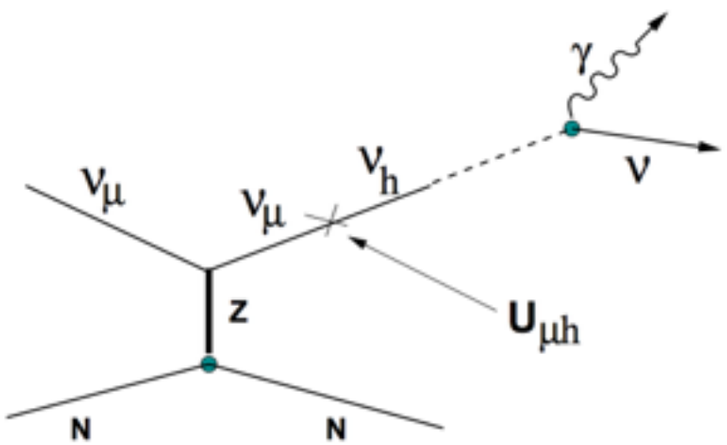

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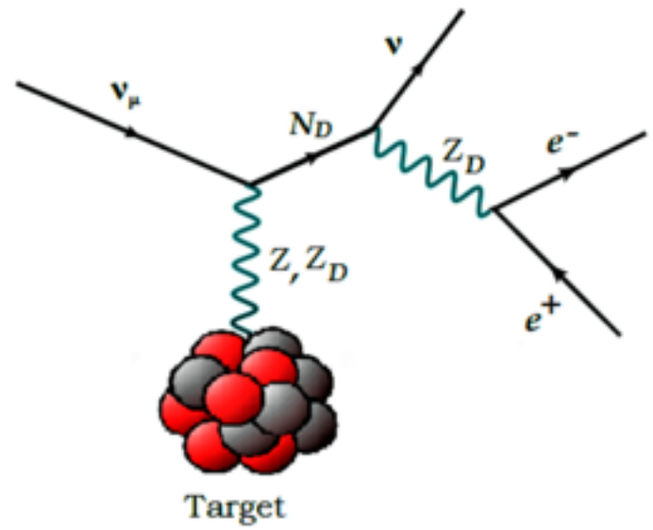

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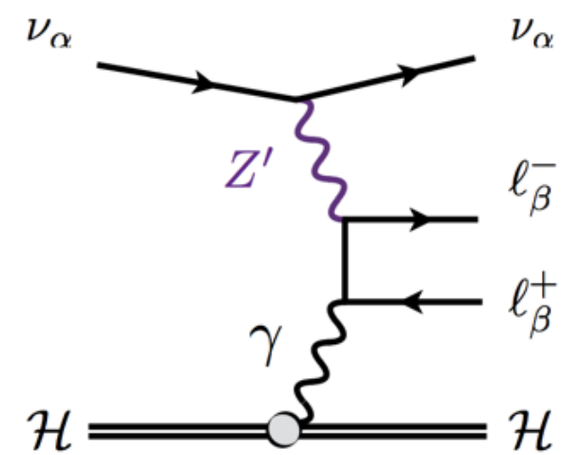

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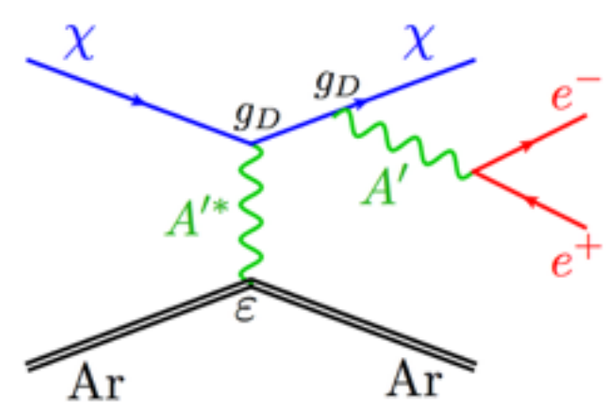
Dark tridents



Explains DM

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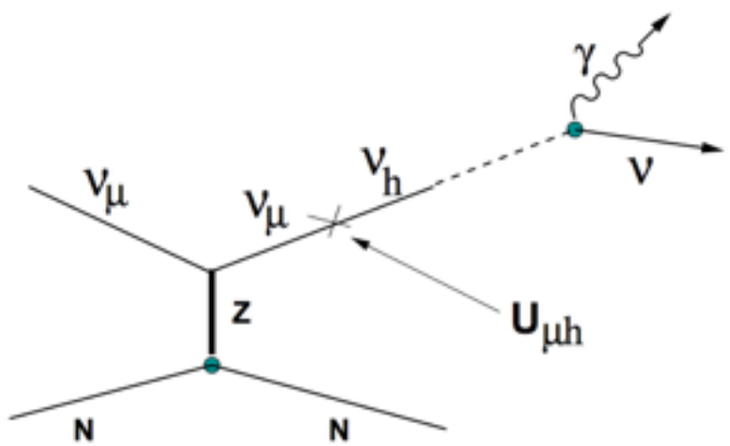

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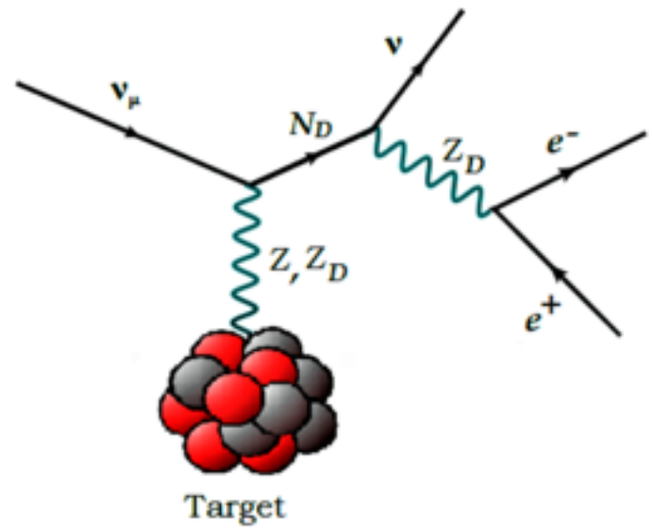

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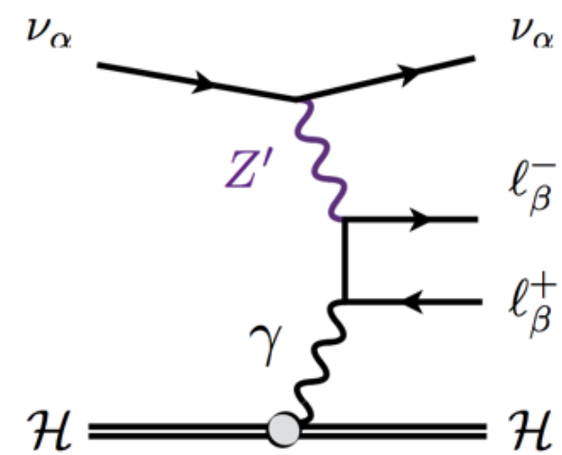

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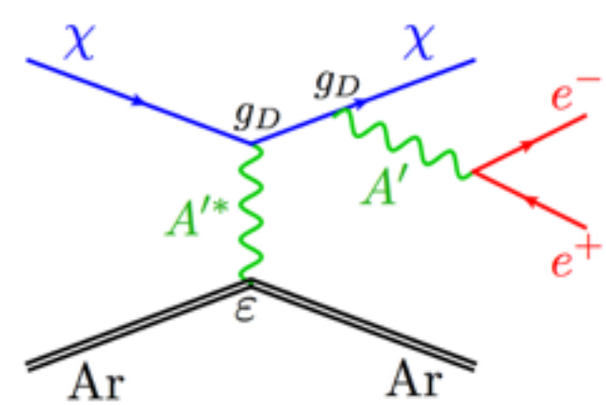
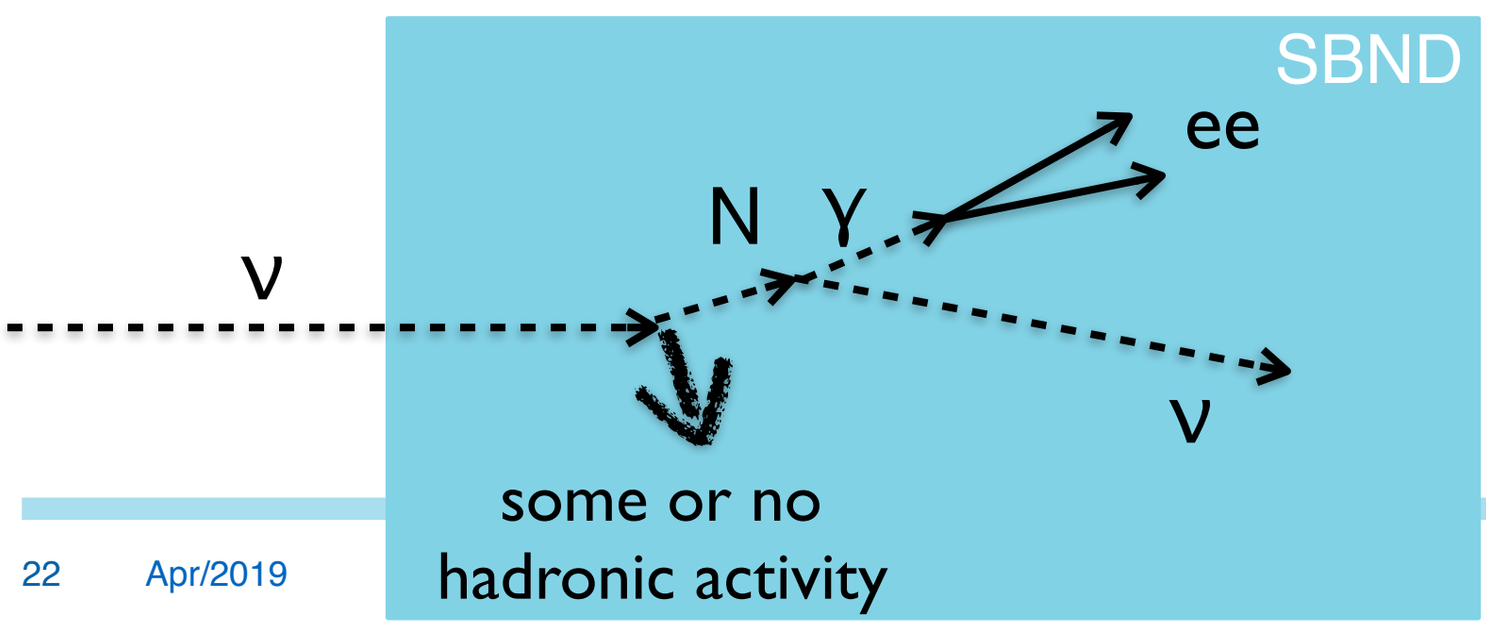


Explains DM



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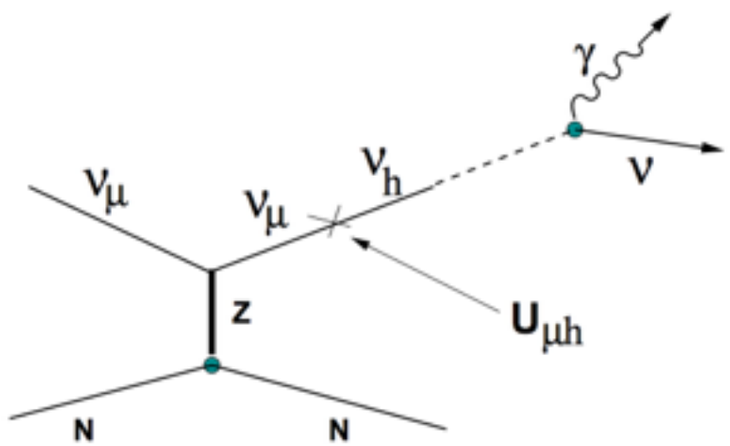

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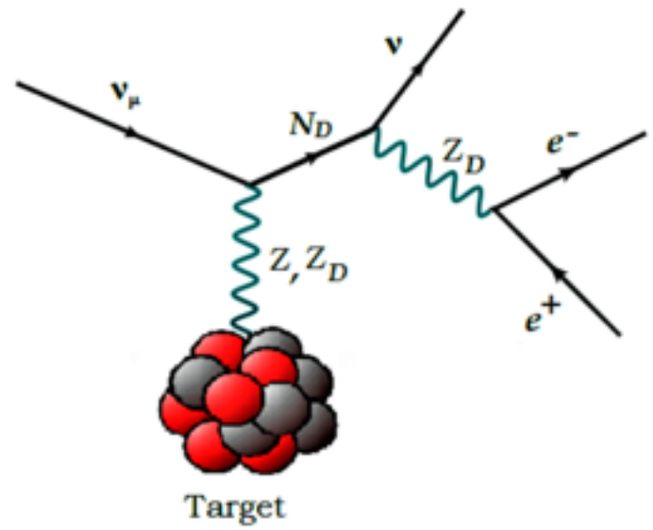

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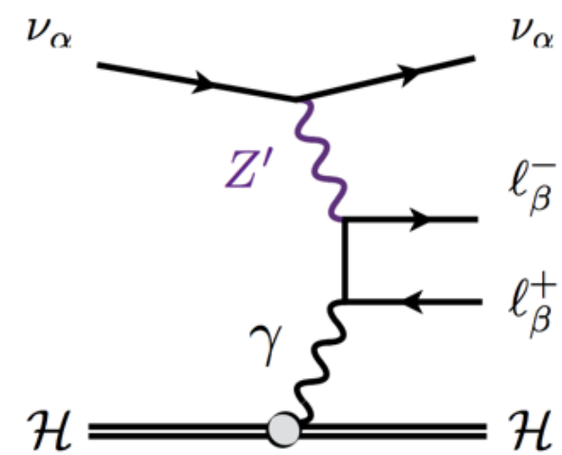

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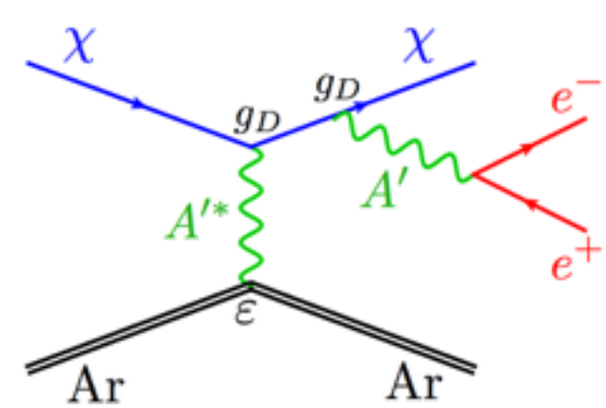
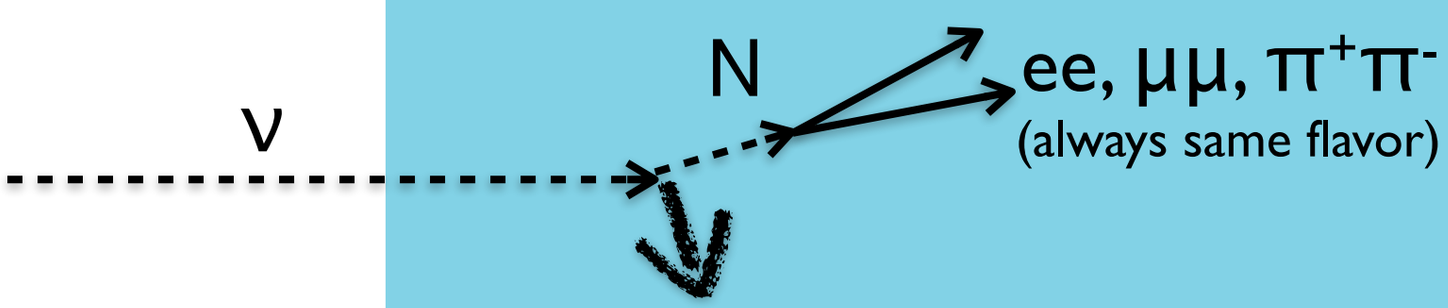
de Gouvêa et al 1809.06388

Dark tridents



Explains DM

SBND



some or no hadronic activity

Pause for thinking

All these searches depend on how neutrinos interact with matter

Neutrino interactions with nucleus have always been challenging

What has changed?

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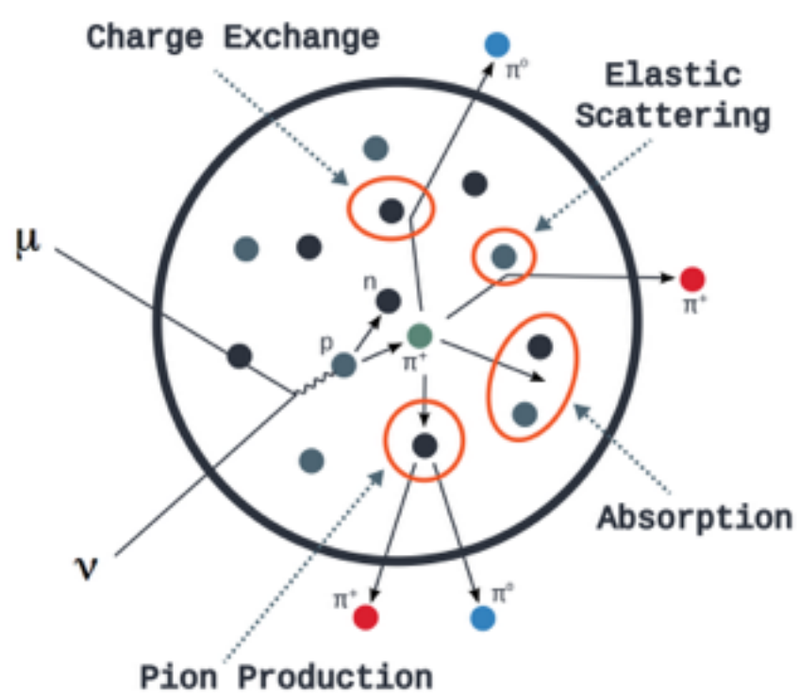
What has changed?

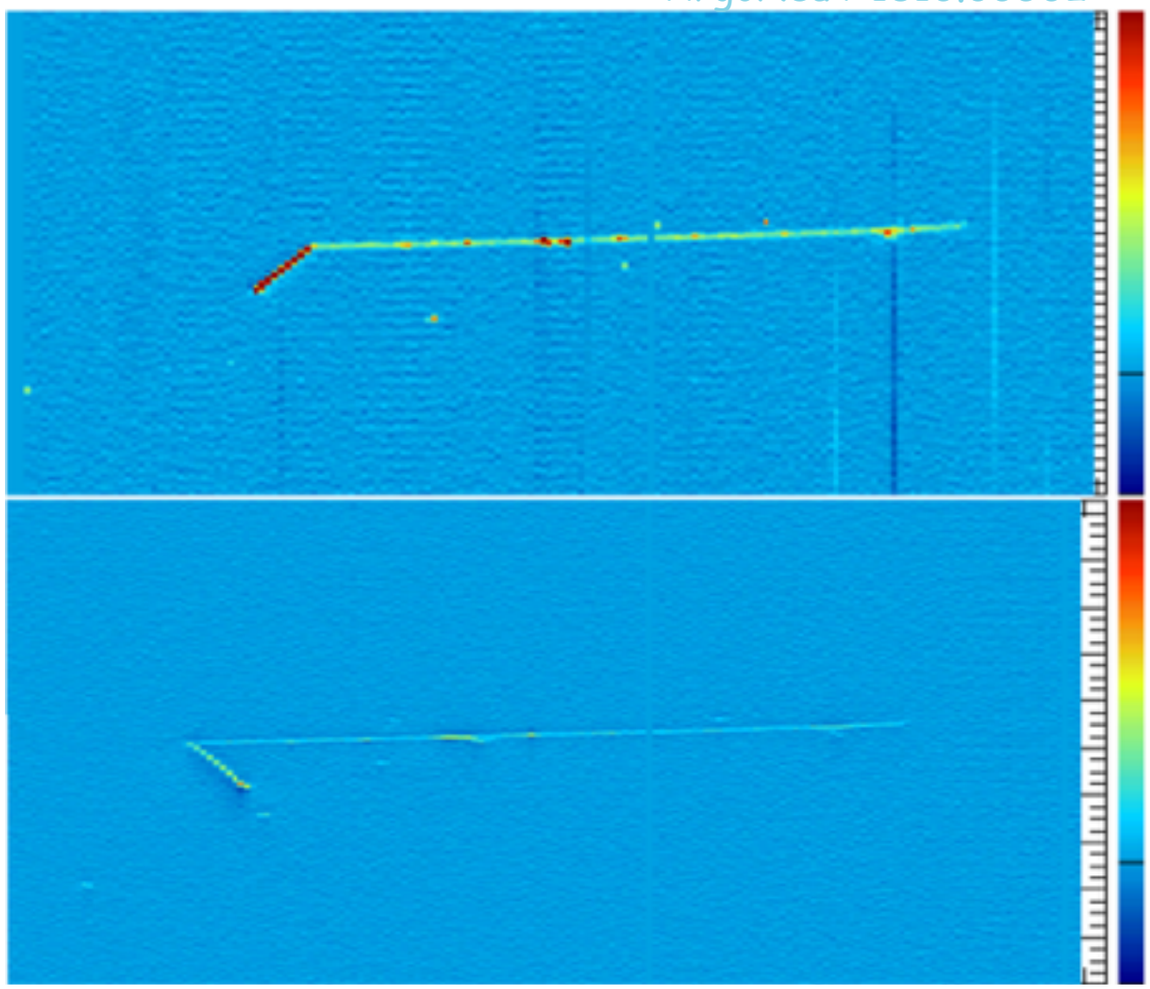
Statistics, precision, precision, precision…



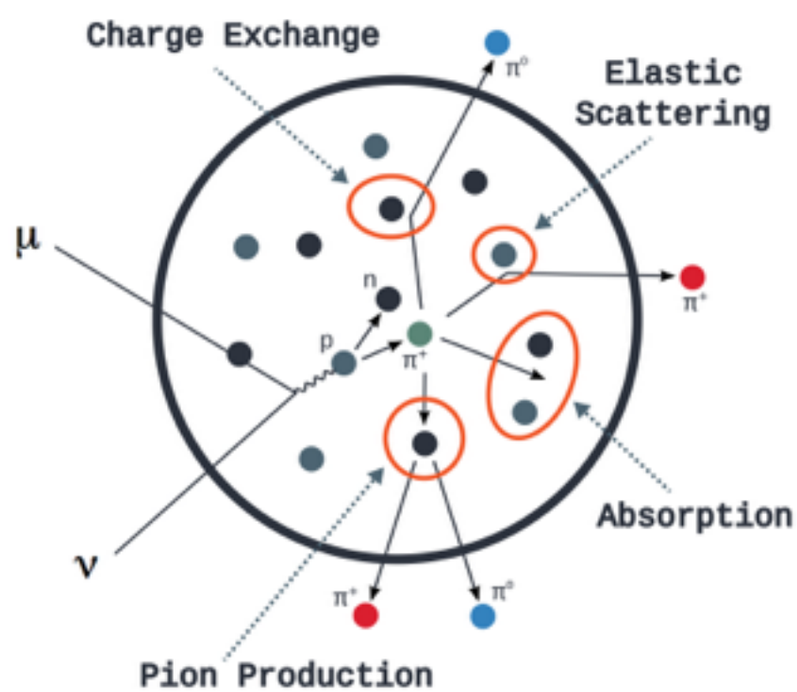
Detailed topology reconstruction (particularly in LArTPCs)

Pause for thinking

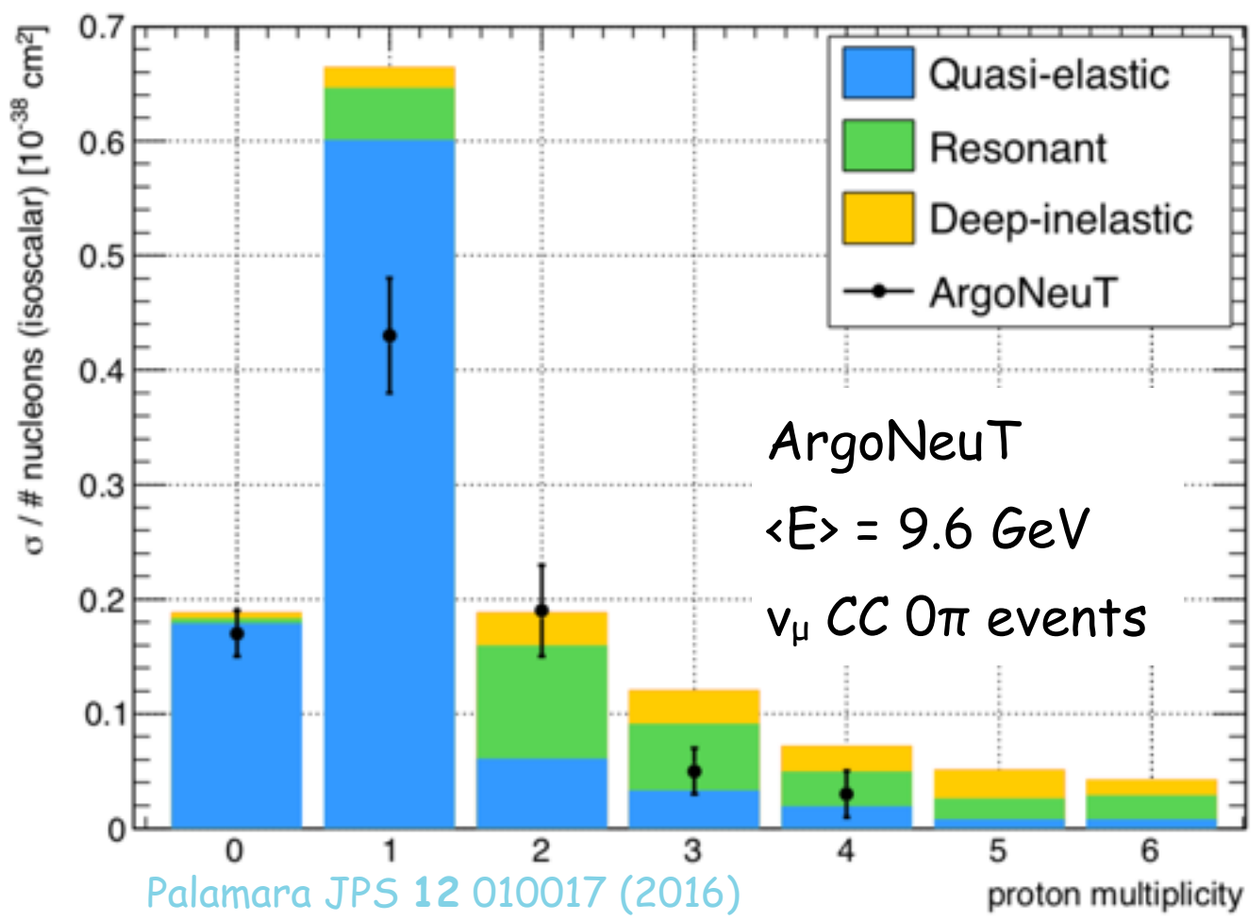
ArgoNeuT 1810.06502



ArgoNeuT demonstrated the LAr capability to detect 21 MeV recoil protons.



Event topology carries extra information



Palamara JPS **12** 010017 (2016)

BSBSM - Light DM

We are talking about new physics below the ~GeV scale

DM interacts with gauge boson A'

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BSBSM - Light DM

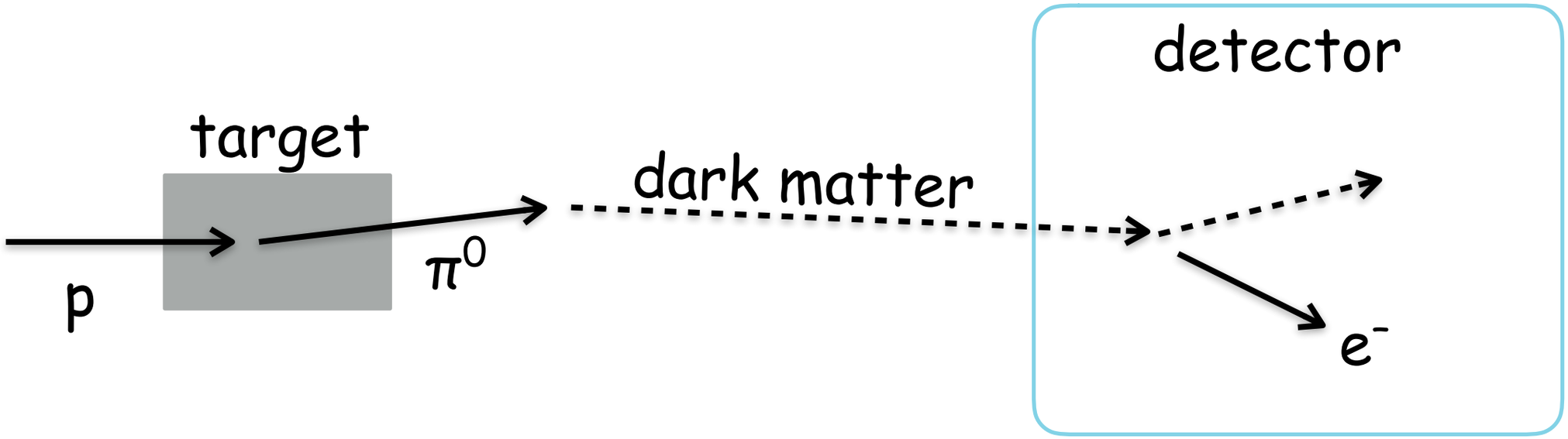
We are talking about new physics below the ~GeV scale

DM interacts with gauge boson A'

A' mixes with our photon via the kinetic term ==> dark photon

Anything that decays to photon can go to A' followed by A' to XX

Neutrino beams are perfect!



Battell et al 0906.5614, de Niverville et al 1107.4580, et al' 1205.3499, et al" 1807.06501, Izaguirre et al 1307.6554, Coloma et al 1512.03852, Jordan et al 1806.05185, de Romeri et al 1903.10505, ...

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BSBSM - Light DM

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DM interacts with gauge boson A'

A' mixes with our photon via the kinetic term ==> dark photon

Anything that decays to photon can go to A' followed by A' to XX

Neutrino beams are perfect!

but...

neutrinos are the background!!!

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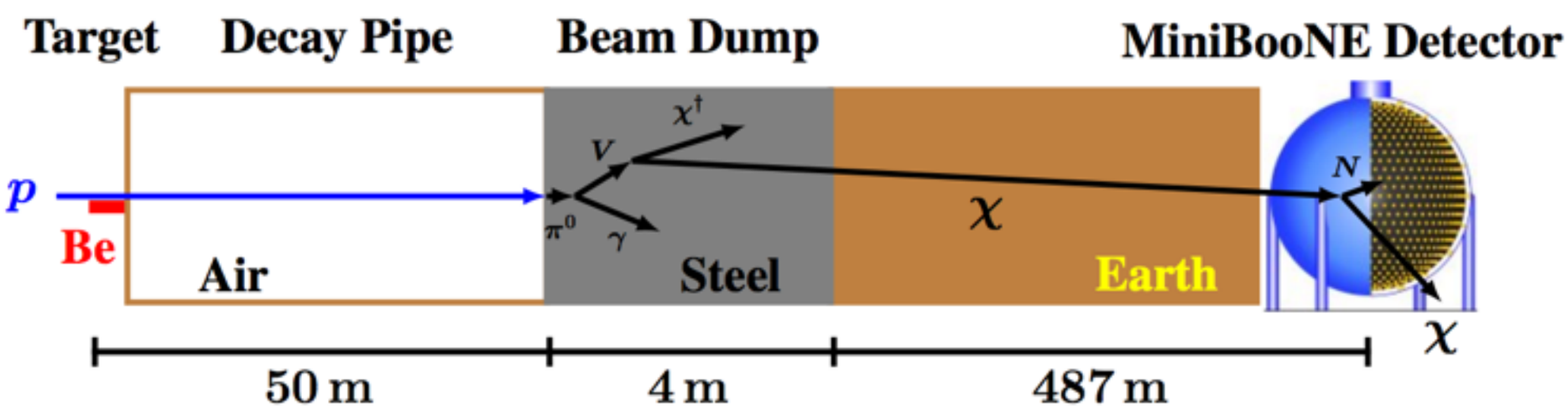
BSBSM - Light DM

Solution 1: turn neutrinos off (i.e. run in beam dump mode)

Dark matter search in nucleon, pion, and electron channels from a proton beam dump with MiniBooNE

(The MiniBooNE-DM Collaboration)

arXiv:1807.06137



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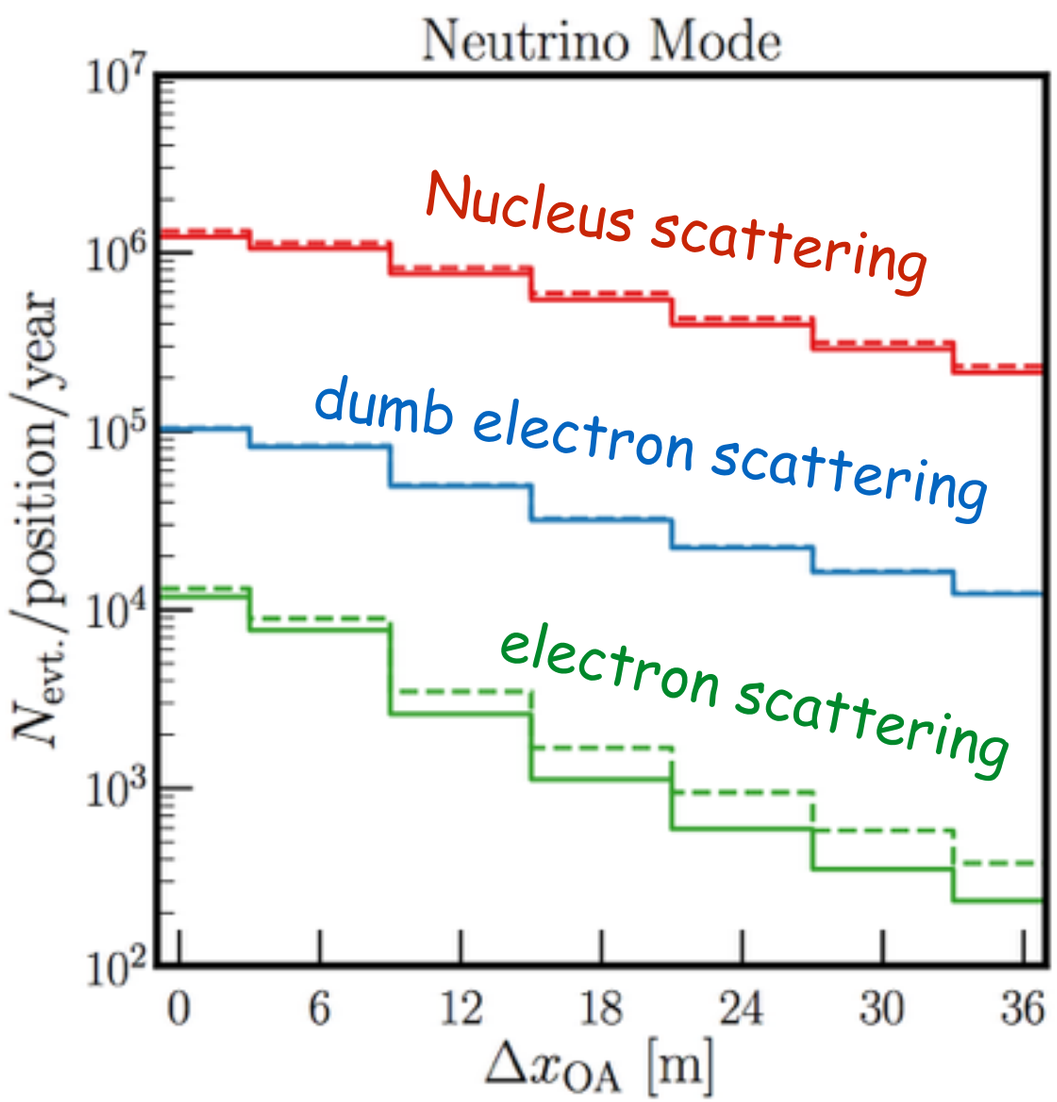
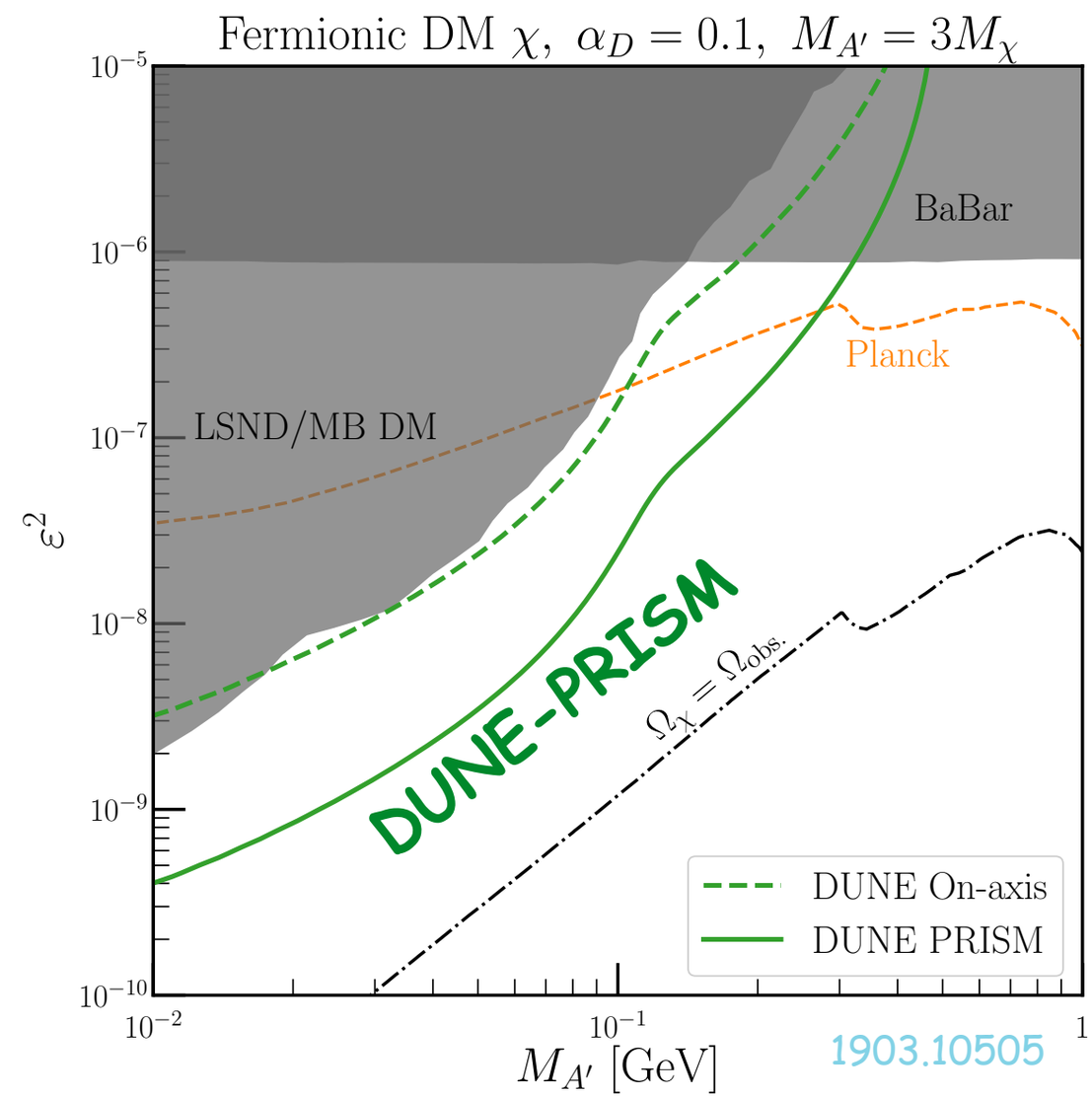
BSBSM - Light DM

Solution 2: go off-axis





etectors

1903.10505

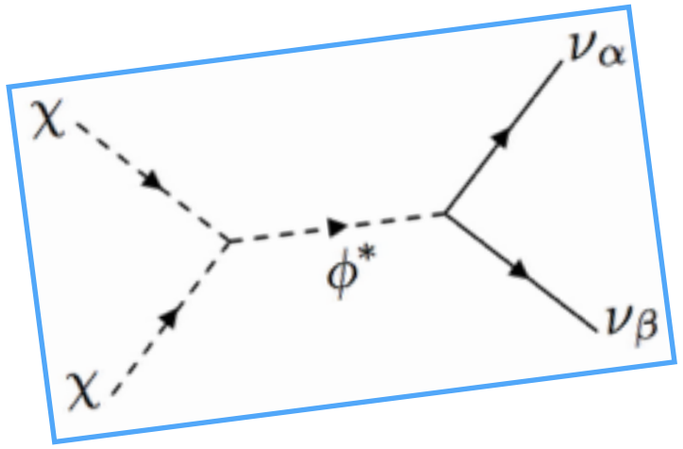
milab
@fnal.gov

BSBSM - Mono-neutrinos

Kelly et al 1901.01259

Say DM couples primarily to nus

$$\mathcal{L}_{\text{portal}} = \frac{(L_\alpha H)(L_\beta H)}{\Lambda^2_{\alpha\beta}}\phi + \text{h.c.} \rightarrow \frac{1}{2}\sum_{\alpha,\beta=e,\mu,\tau} \lambda_{\alpha\beta}\nu_\alpha\nu_\beta\phi + \text{h.c.}$$



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Kelly et al 1901.01259

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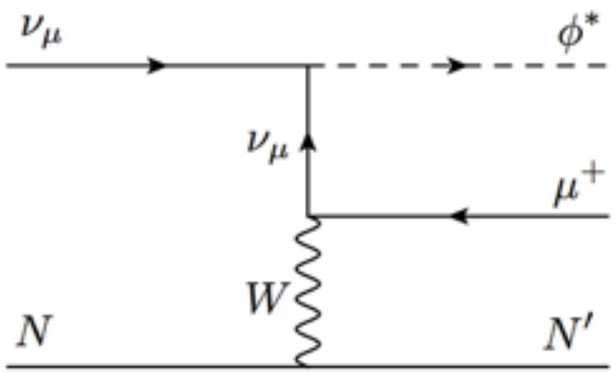
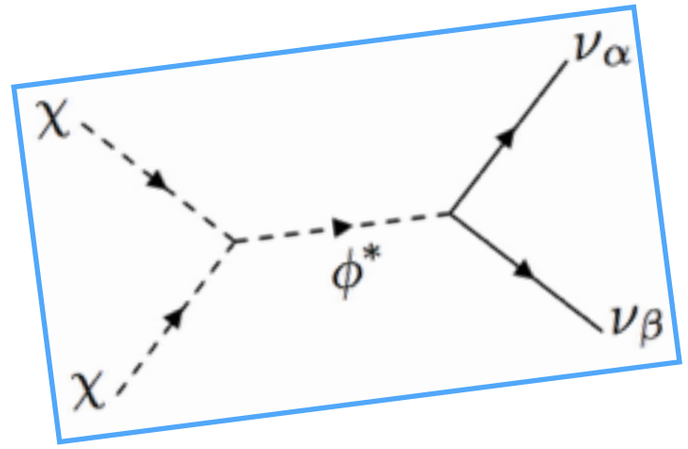
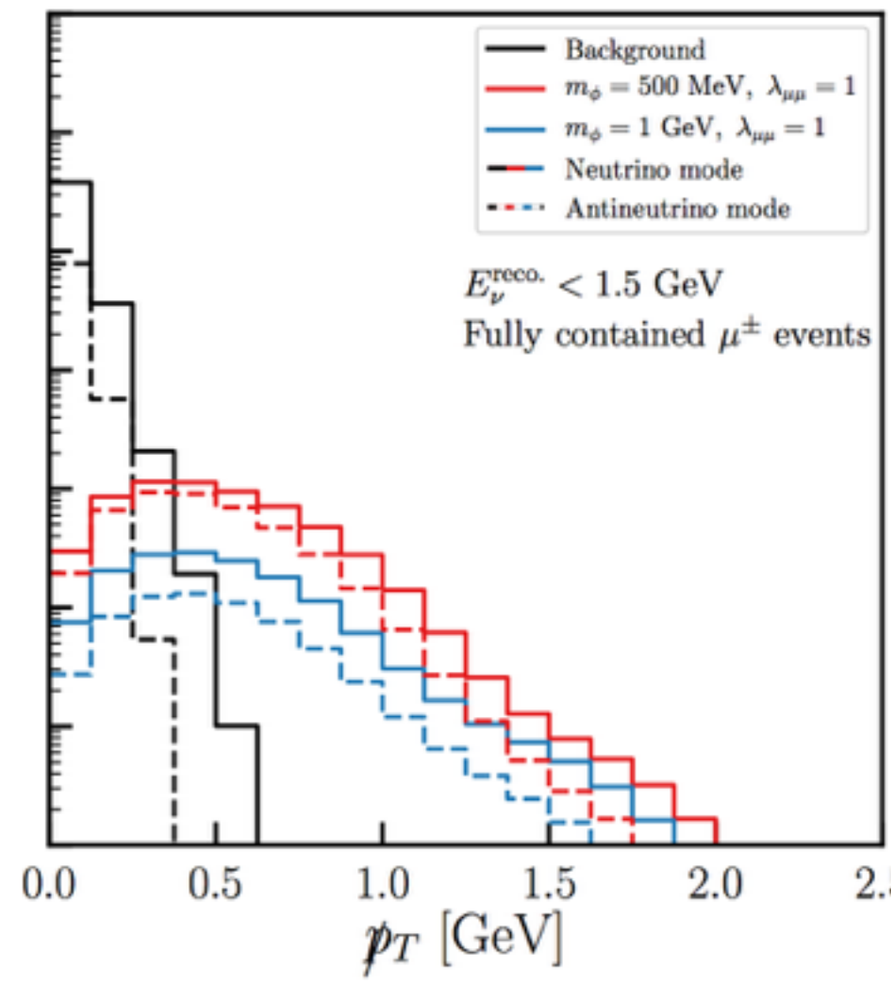
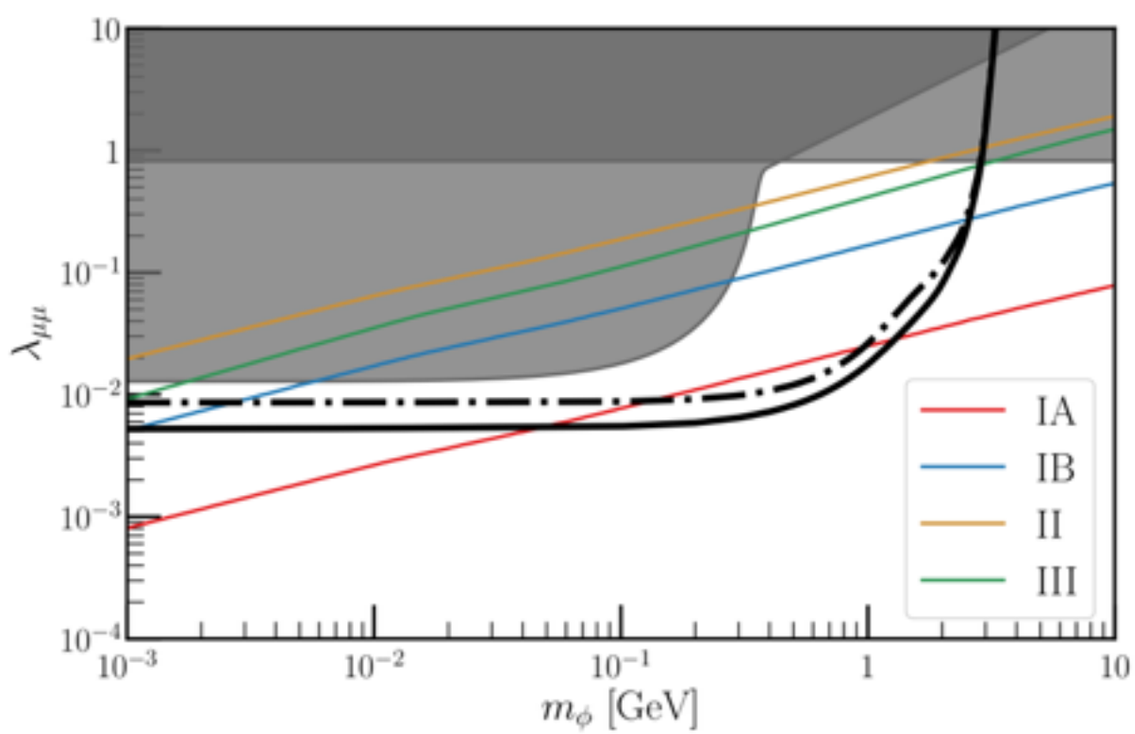
When neutrinos interact, they may emit a mediator





Missing p_T signatures





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Other scenarios

Heavy neutrino decay - Yun-Tse's talk

Millicharged - Yu-Dai's

More DM - Yanou's talk

Coherent scattering - Gleb's talk

CCNSI - no one remembered that?

...

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Conclusions

Near detectors can yield extremely rich physics

In my opinion, NDs have been underestimated/underused for new physics searches

Many novel ideas being developed recently

We should push the physics case for NDs NOW!

(particularly for DUNE…)

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