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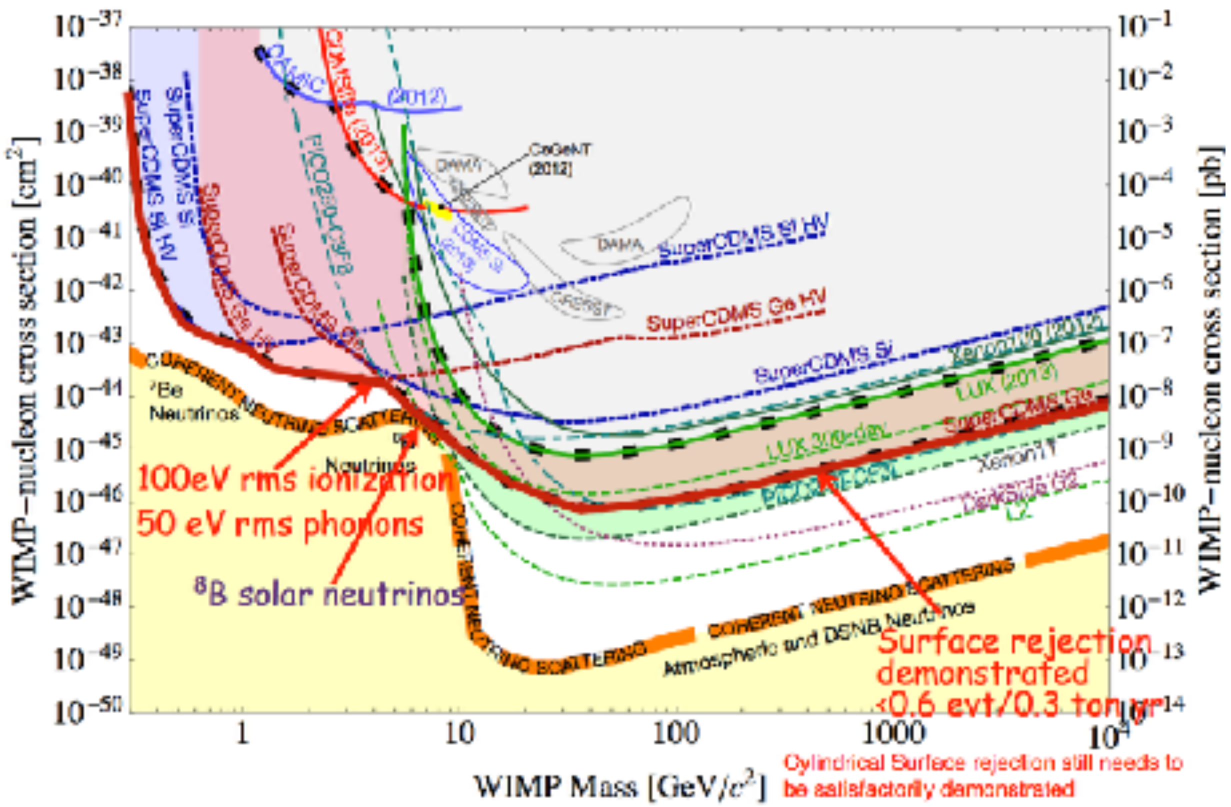
WEIZMANN INSTITUTE OF SCIENCE

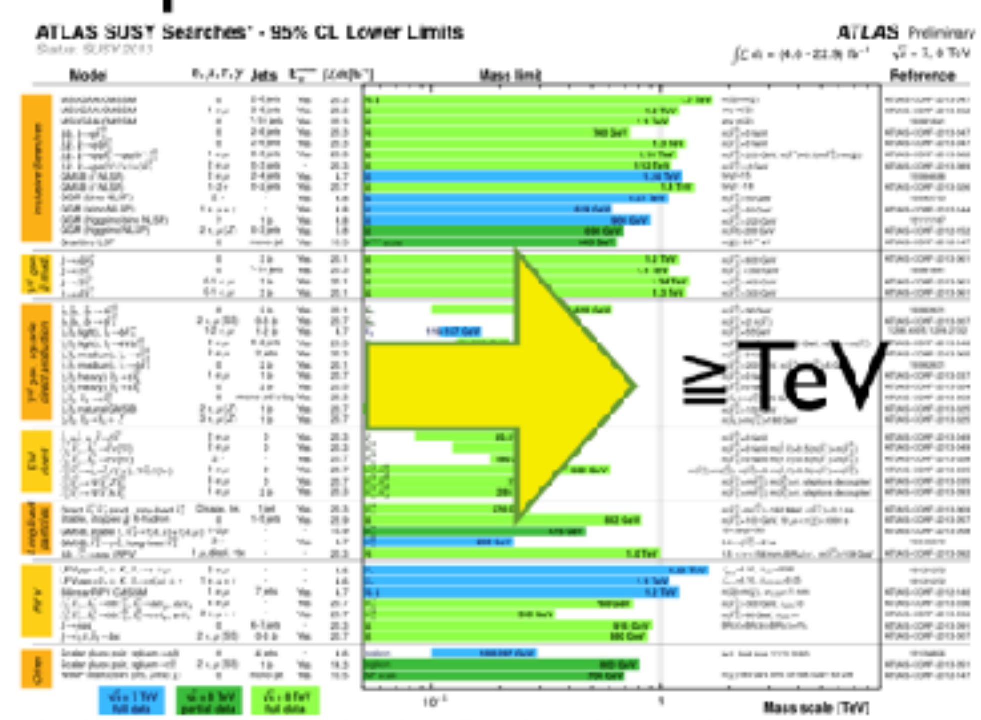
Dark matter beams @ neutrino facilities

Light DM @ isola d'Elba, 26/05/2017

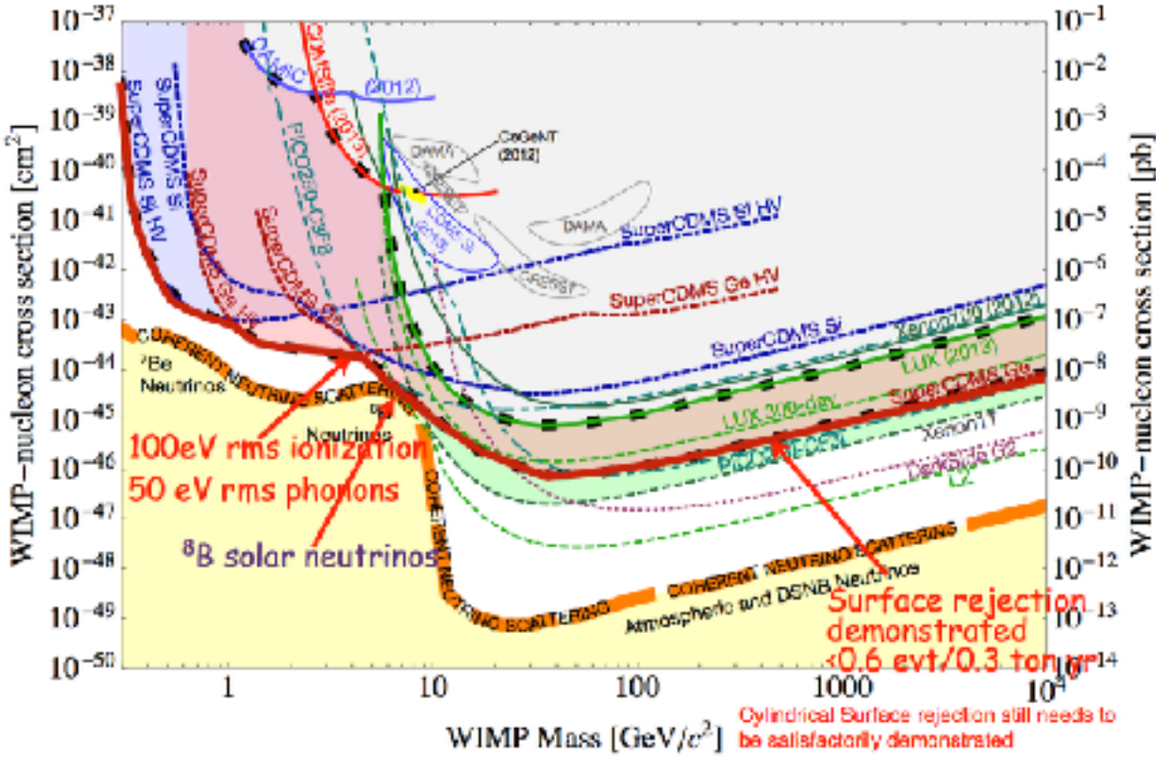
New physics is taking longer than we thought to show up.



No new particles



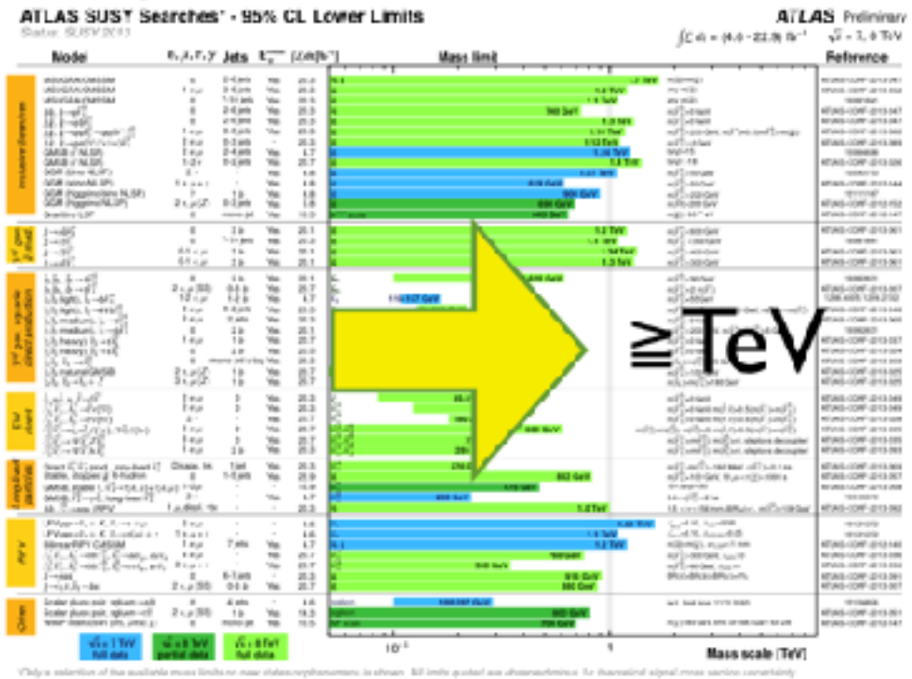
Many new ideas have been explored in the last few years motivating new experimental strategies



DM beyond WIMPS

Neutral naturalness
Relaxion ..

No new particles



Relaxion

A new paradigm, no partners! The Higgs was originally heavy and it then evolved to be light in the early universe.

In this scenario a light spin-0 particle plays the central role, and not new physics at the electroweak scale.

[Graham, Kaplan, Rajendran, 2014]

⇒ Naturalness problem at the “low energy frontier”

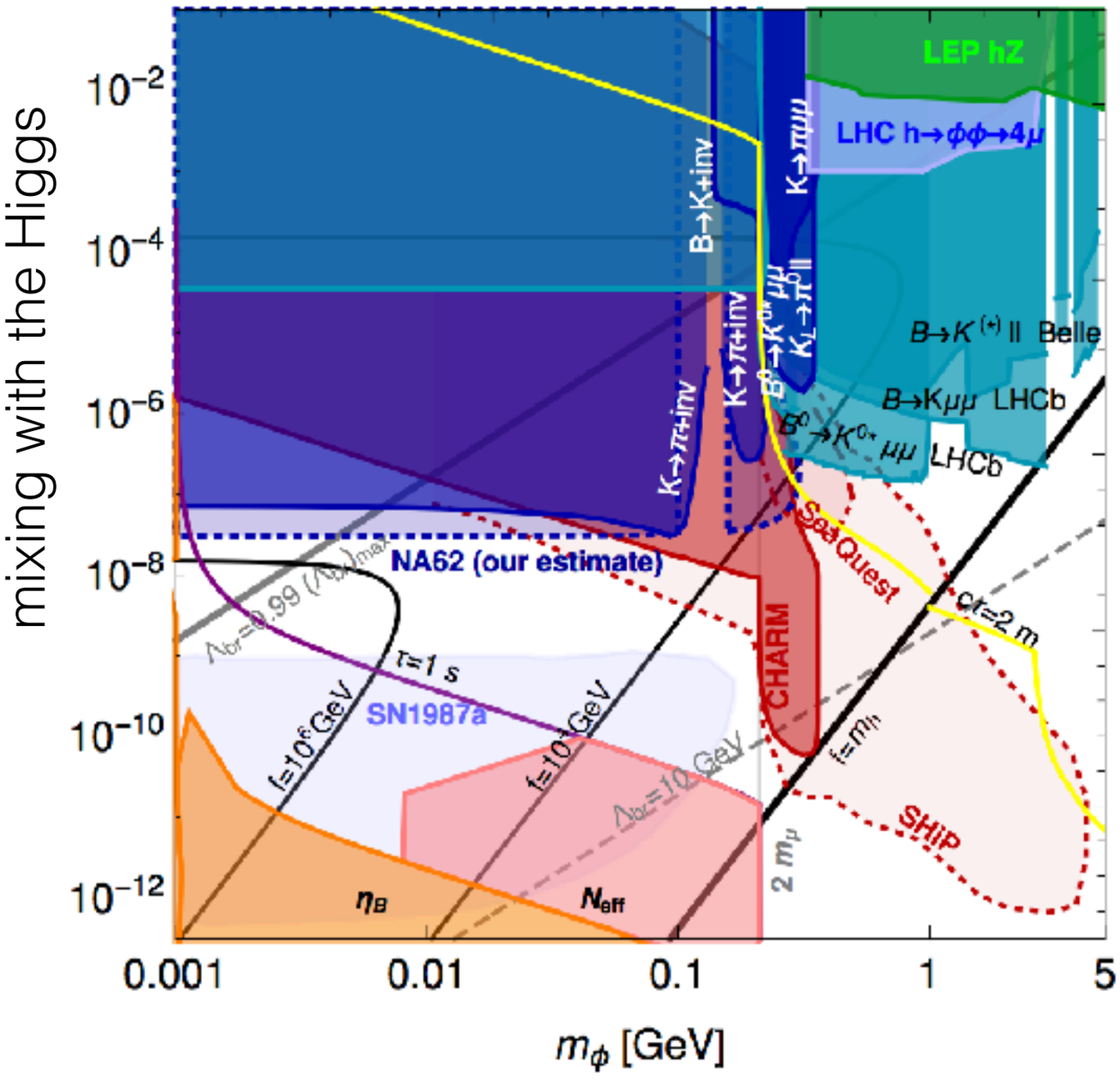
The relaxion mass is not fixed. It could be a sub-eV as well as few GeV range particle!

Broad experimental program is necessary!

MeV-GeV relaxion

In general there is a mixing between the Higgs boson and the relaxion. We can look for it in many existing experiments!

[Flacke,CF, Fuchs,Gupta,Perez 2016]



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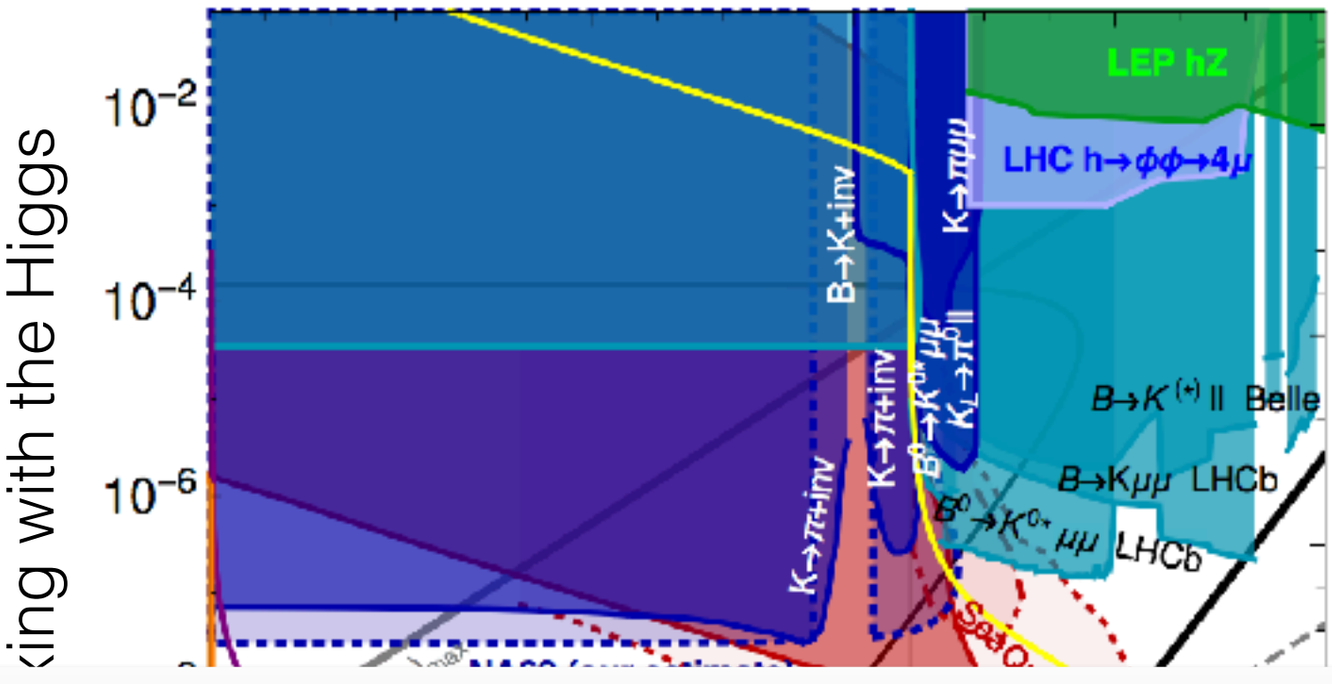
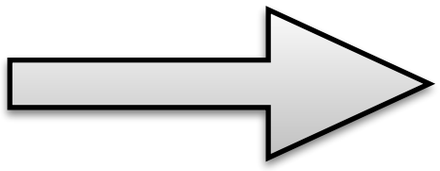


The solution to the hierarchy problem of the electroweak scale might come from a discovery at SPS instead of at the LHC!

Going back to light DM

Traditional direct detection experiments and the LHC have limited sensitivity
to sub-GeV dark matter masses



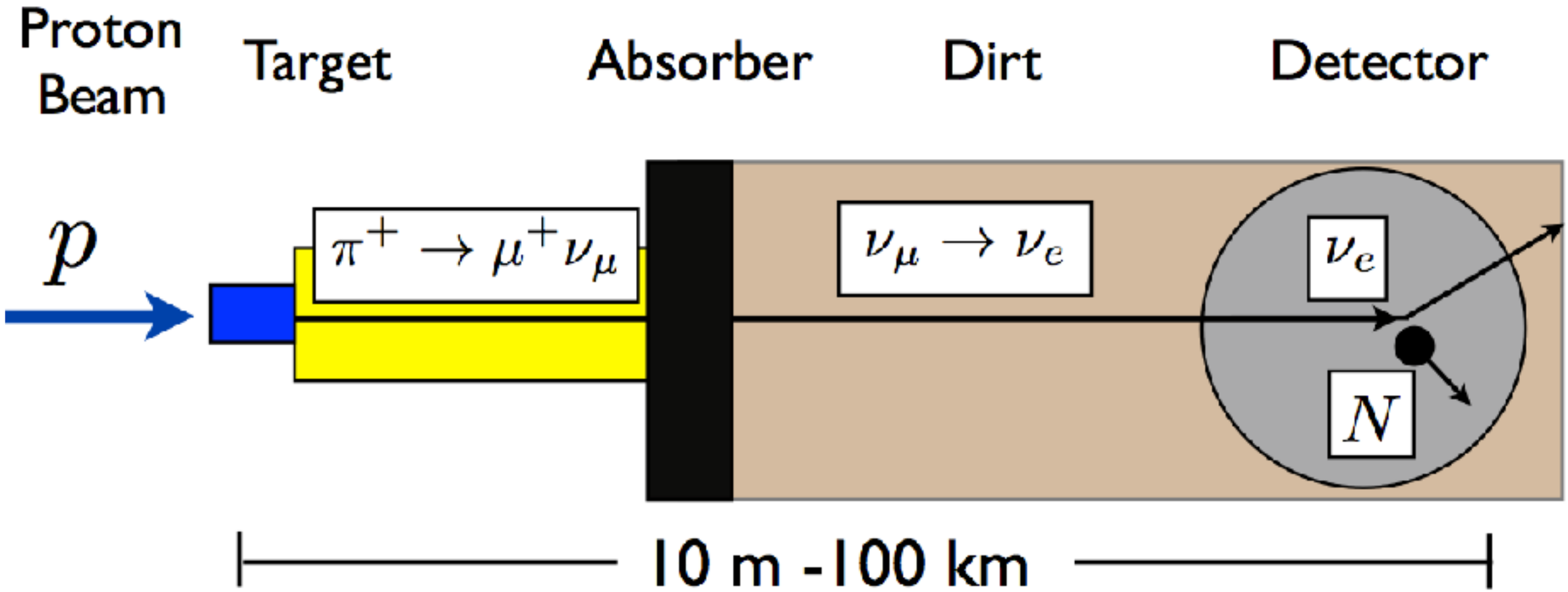
Need of a new experimental program

(a) Electron-light dark matter scattering direct detection experiments.

(b) Neutrino facilities to probe light dark matter-nucleon interactions

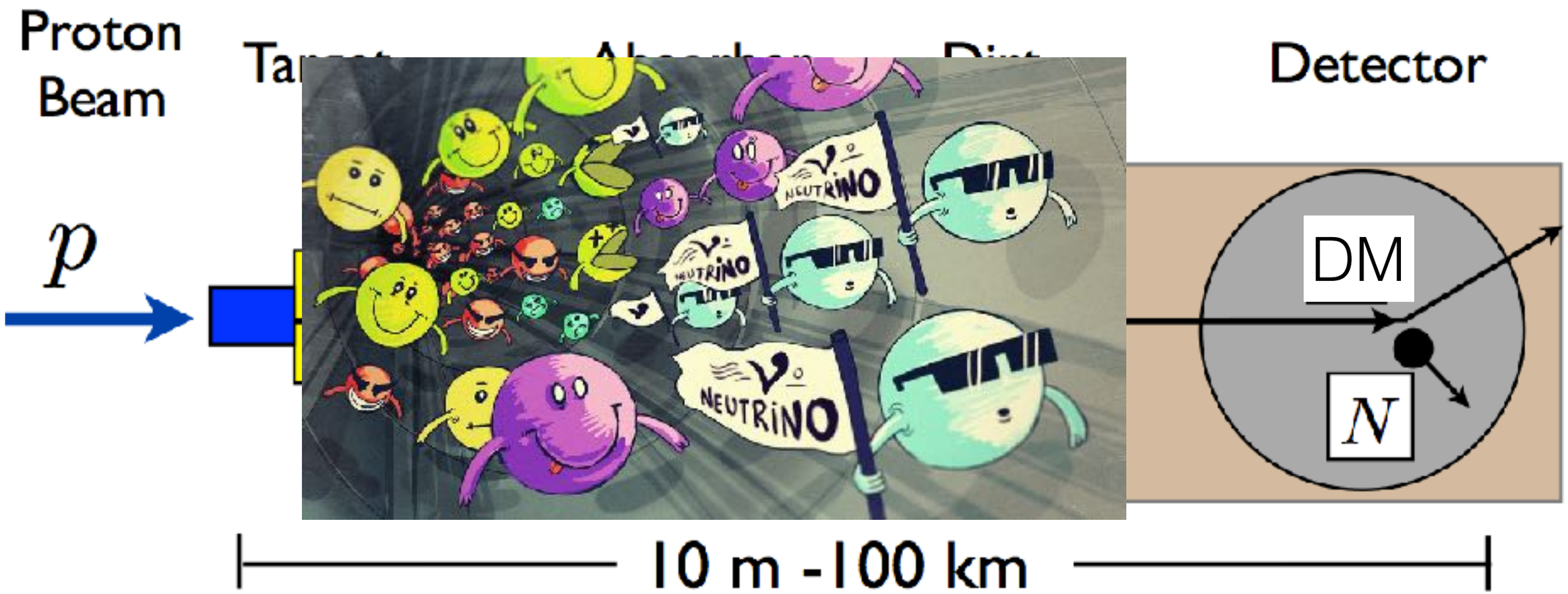
Great complementarity!

Neutrino facilities physics goal: ν masses and mixings



A new goal: discover light dark matter

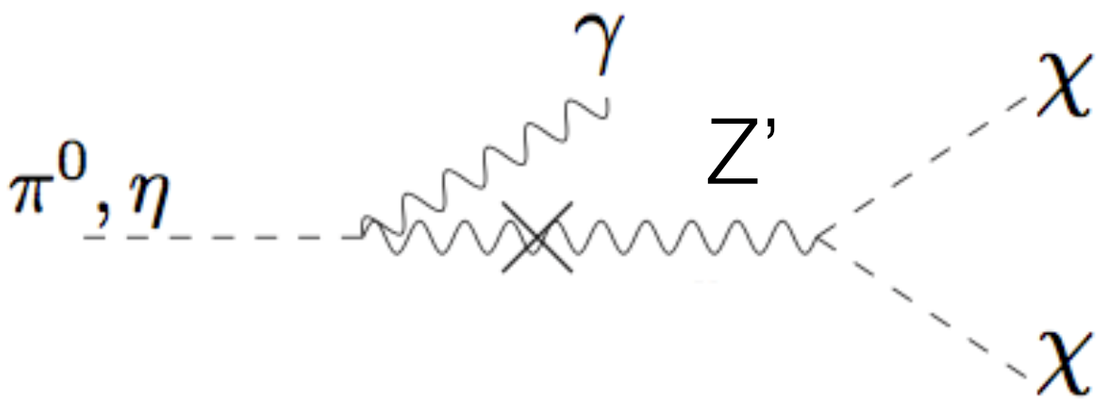
[Batell, Pospelov and Ritz, 2009]



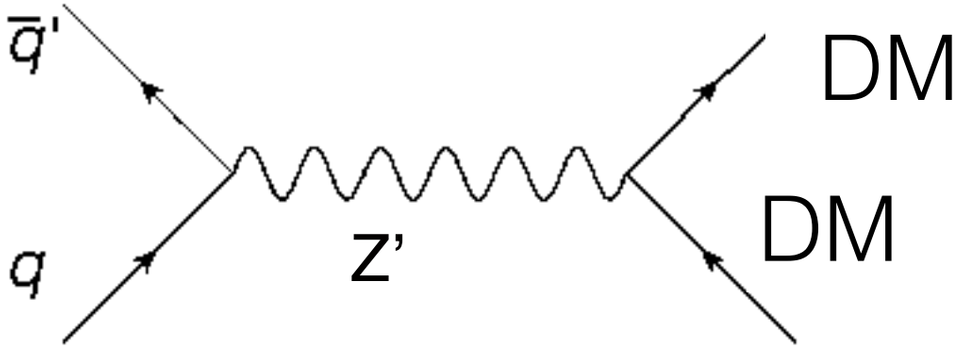
How is a DM beam produced?

Assume dark matter interacts with quarks via a new force mediated by a Z' boson with mass in **MeV-GeV** range

- Production via meson decay



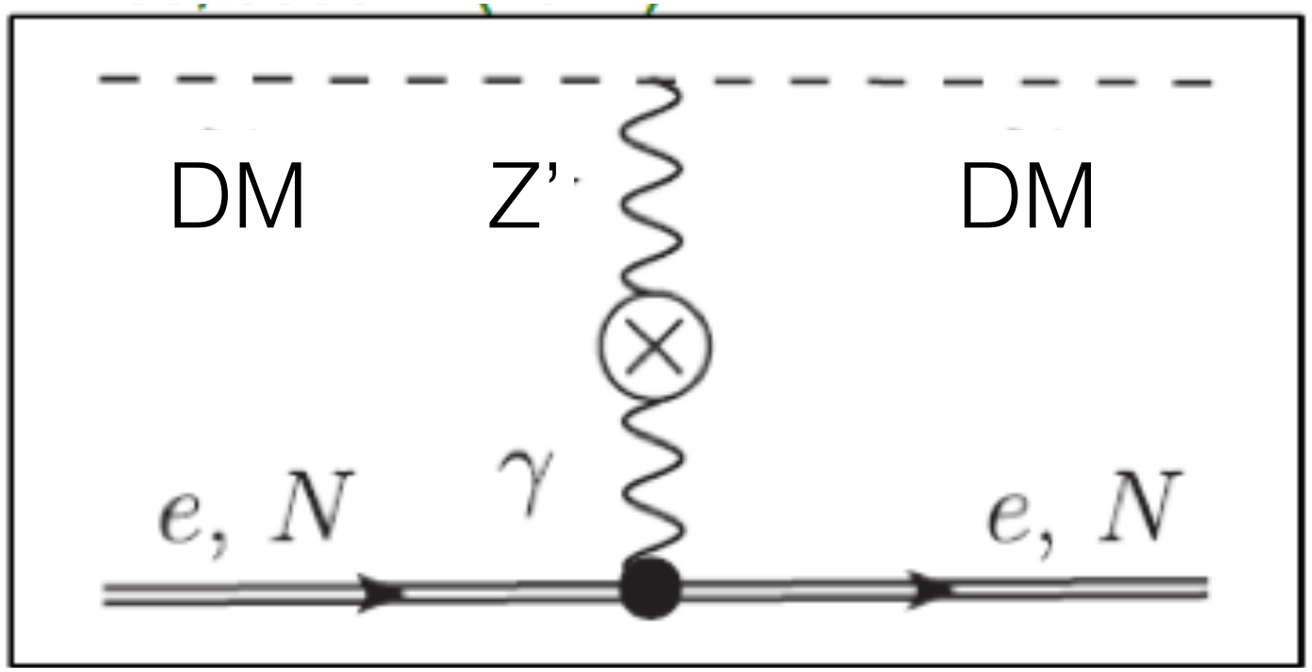
- Direct production



NLO process

$$pp \to Z' j$$

How do we detect DM ?



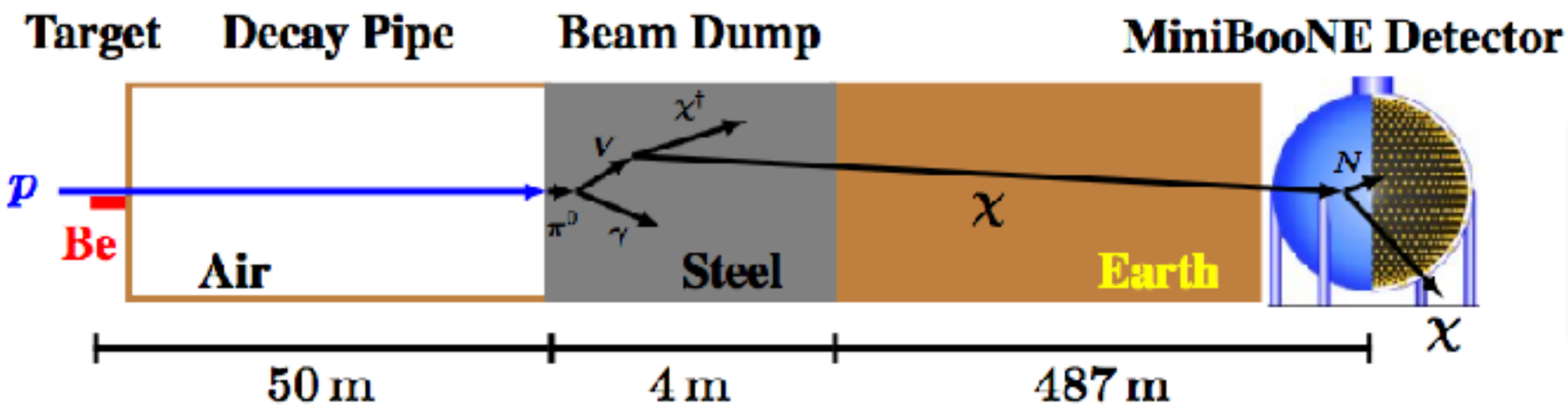
dark matter-nuclei scattering
inside the neutrino near detector

Main challenge:

suppression of neutrino background

DM searches @ MiniBooNE

MiniBooNE:800 tons detector



See talks by
R. Thornton &
R. Van de Water

- Light dark matter search published by the collaboration February 2017 [A.A. Aguilar-Arevalo et al. 2017]

- Strong constraints for sub GeV Z'
  (see Gordan's talk)

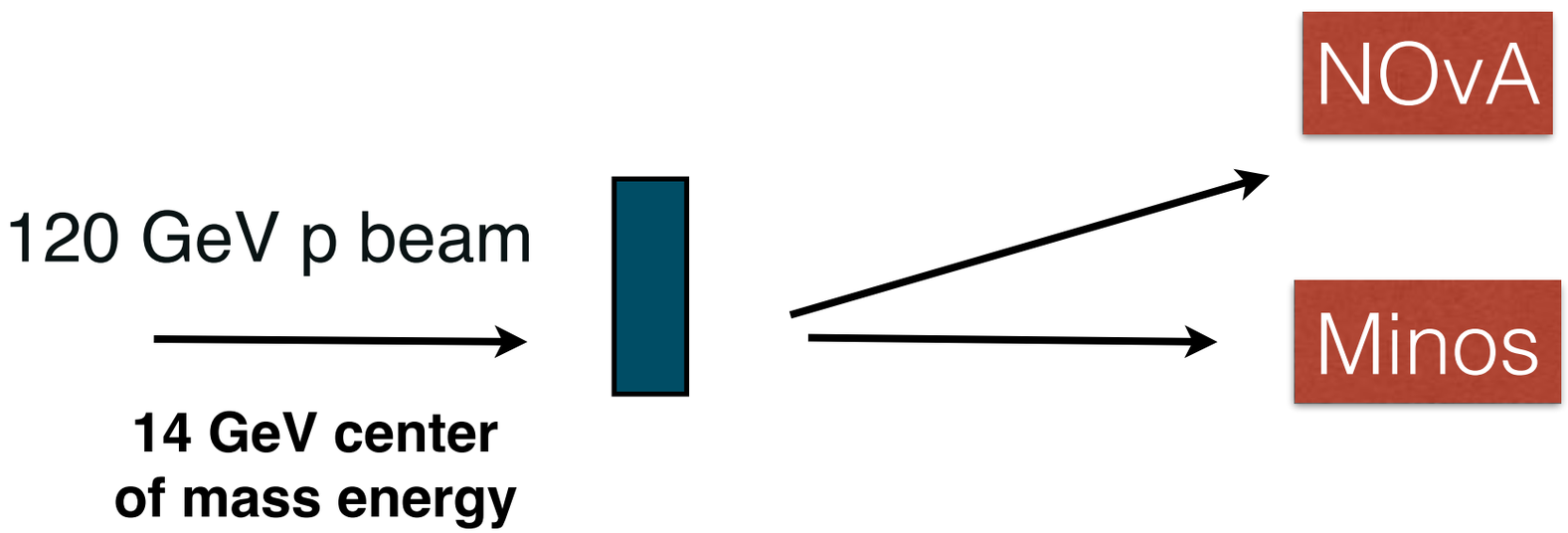
- Light dark matter program calls for a special run to suppress the neutrino background

What are the possibilities at other neutrino facilities?

Main injector facility @ FNAL

[Dobrescu, CF 2014]
[Dobrescu, Coloma, CF, Harnik 2015]
[CF 2017]

What are the physics opportunities of a higher proton beam?

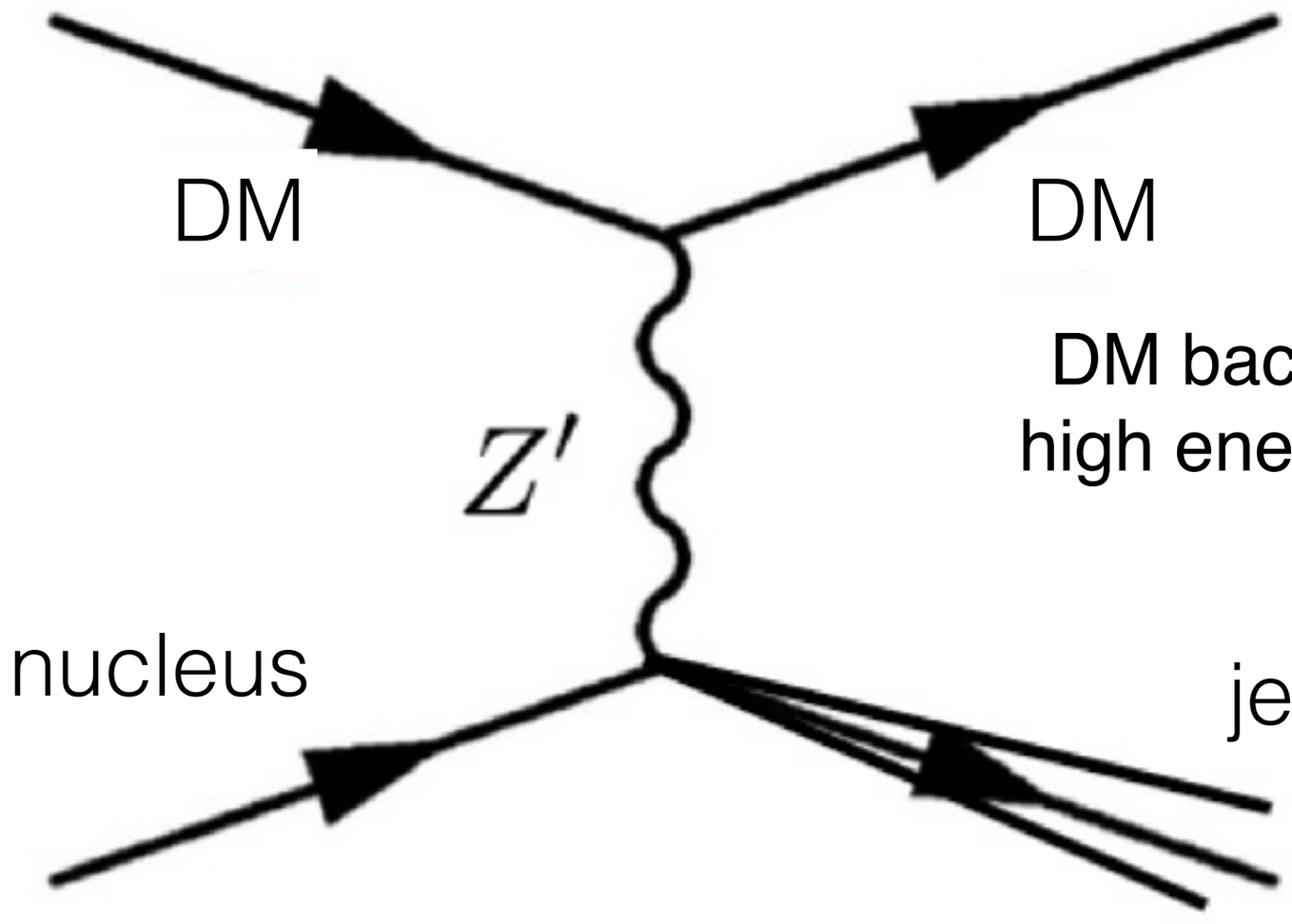


We can produce a large number of Z' gauge bosons with mass up to 7-8 GeV

DM detector signal

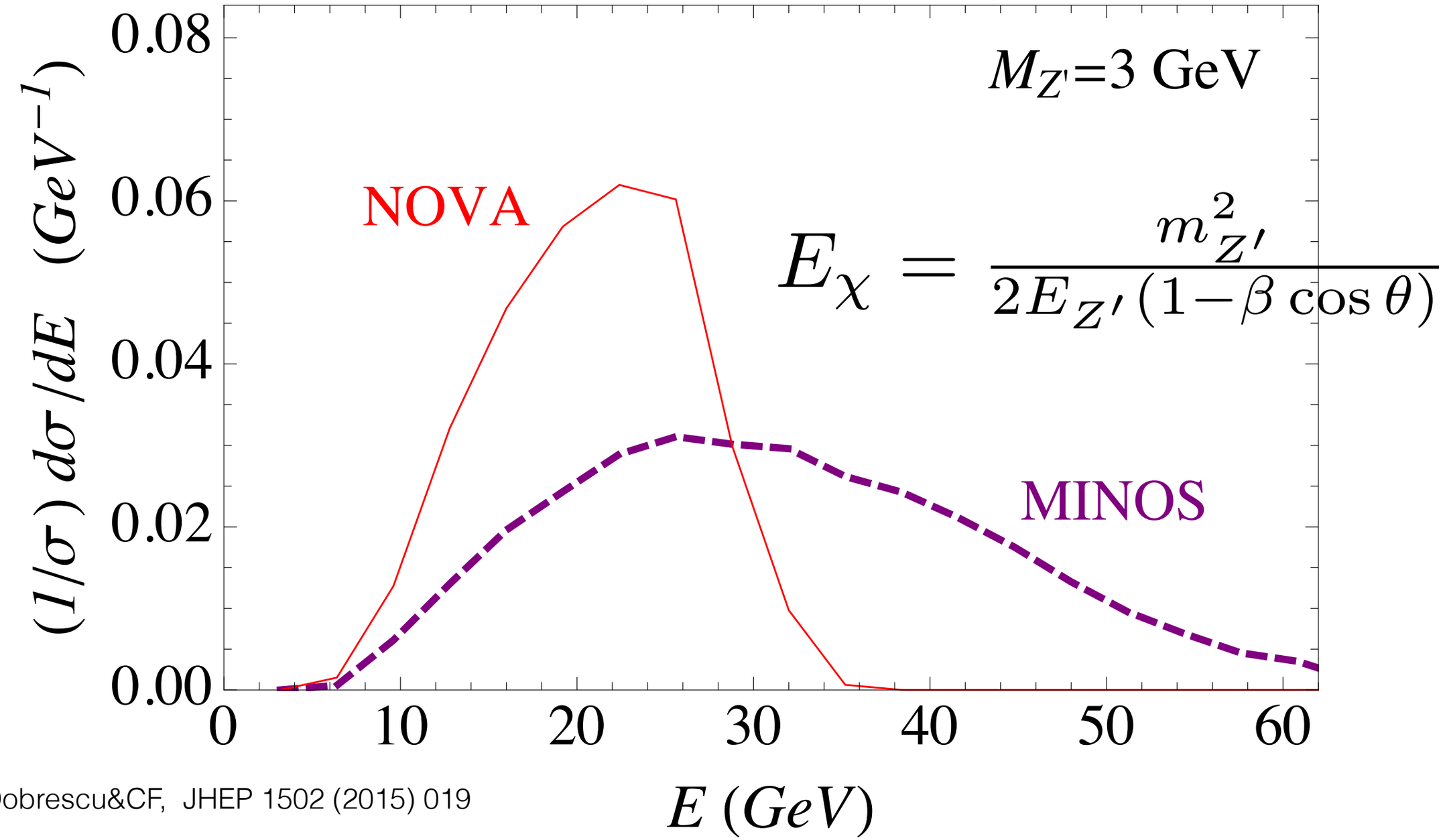
DM enters the detector with high energy

Characteristic signal is deep inelastic scattering with nucleons!



DM background are high energy neutrinos

DM energy spectrum

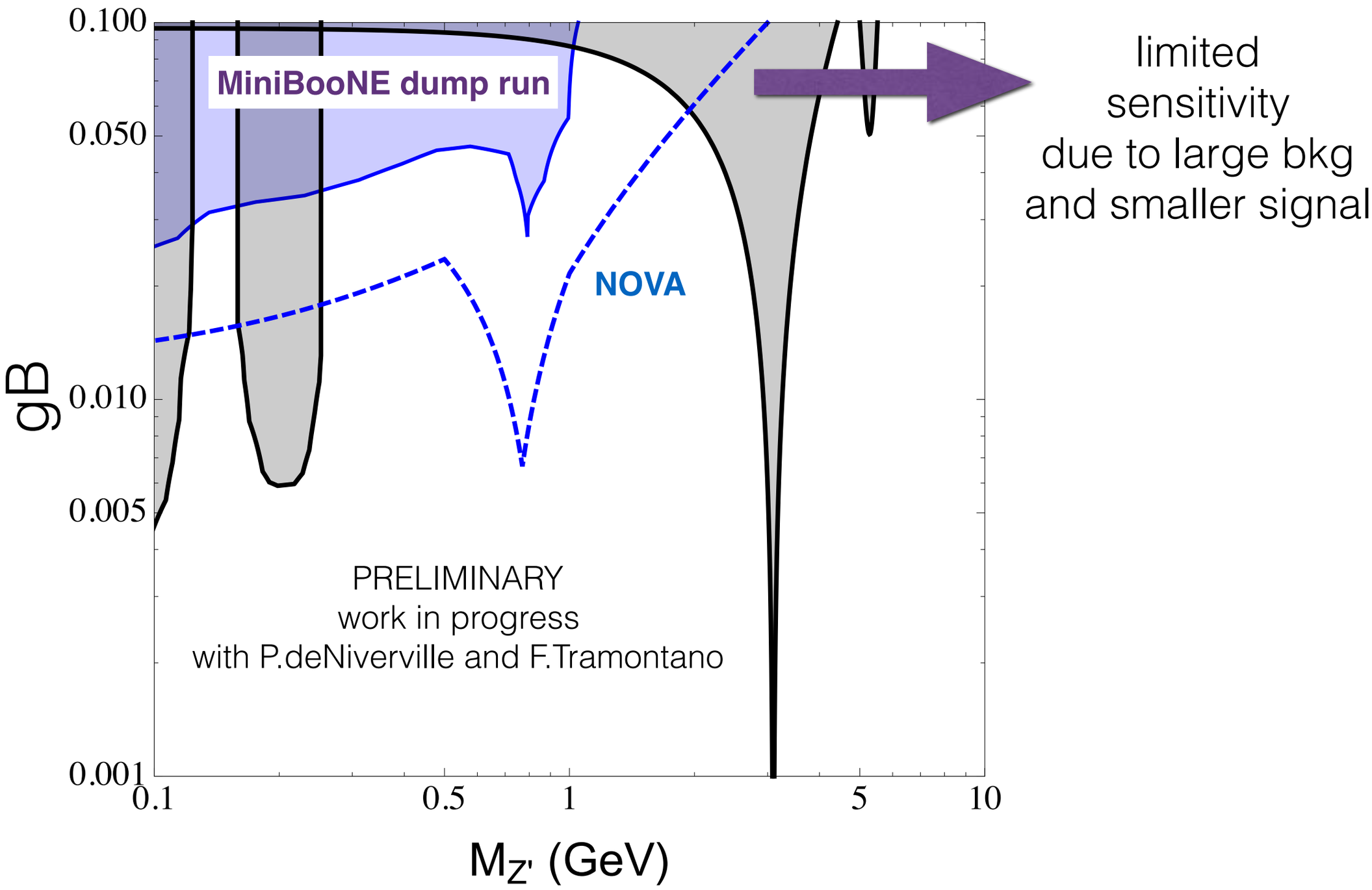


Dobrescu&CF, JHEP 1502 (2015) 019

DM energy peak is significantly higher than neutrino peak

NOVA & MINOS limits

NC DIS neutrinos events $\sim 10^6$ $N_{\mathrm{POT}} = 10^{21}$



limited sensitivity due to large bkg and smaller signal

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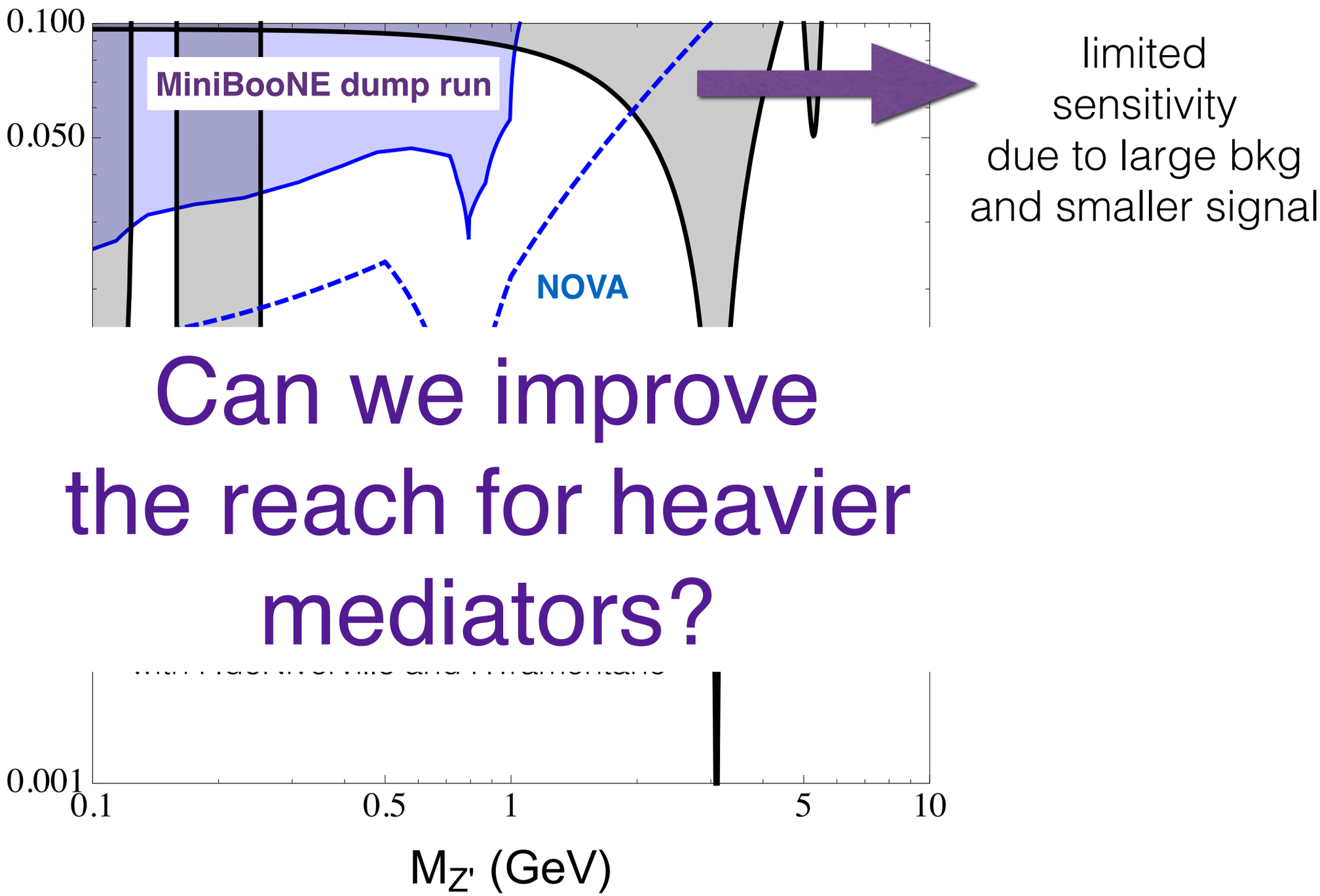
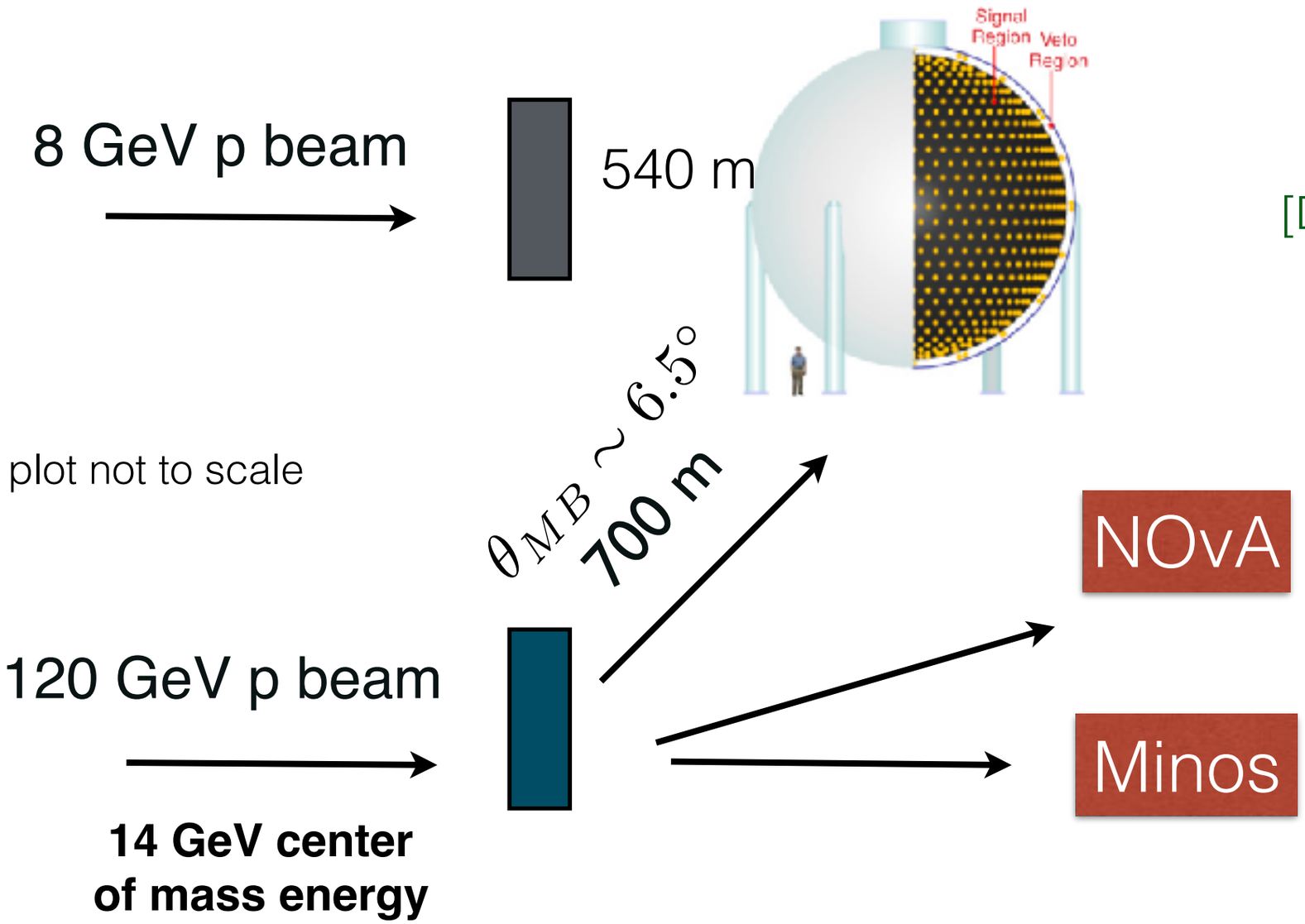


limited sensitivity due to large bkg and smaller signal

Can we improve the reach for heavier mediators?

Main injector facility

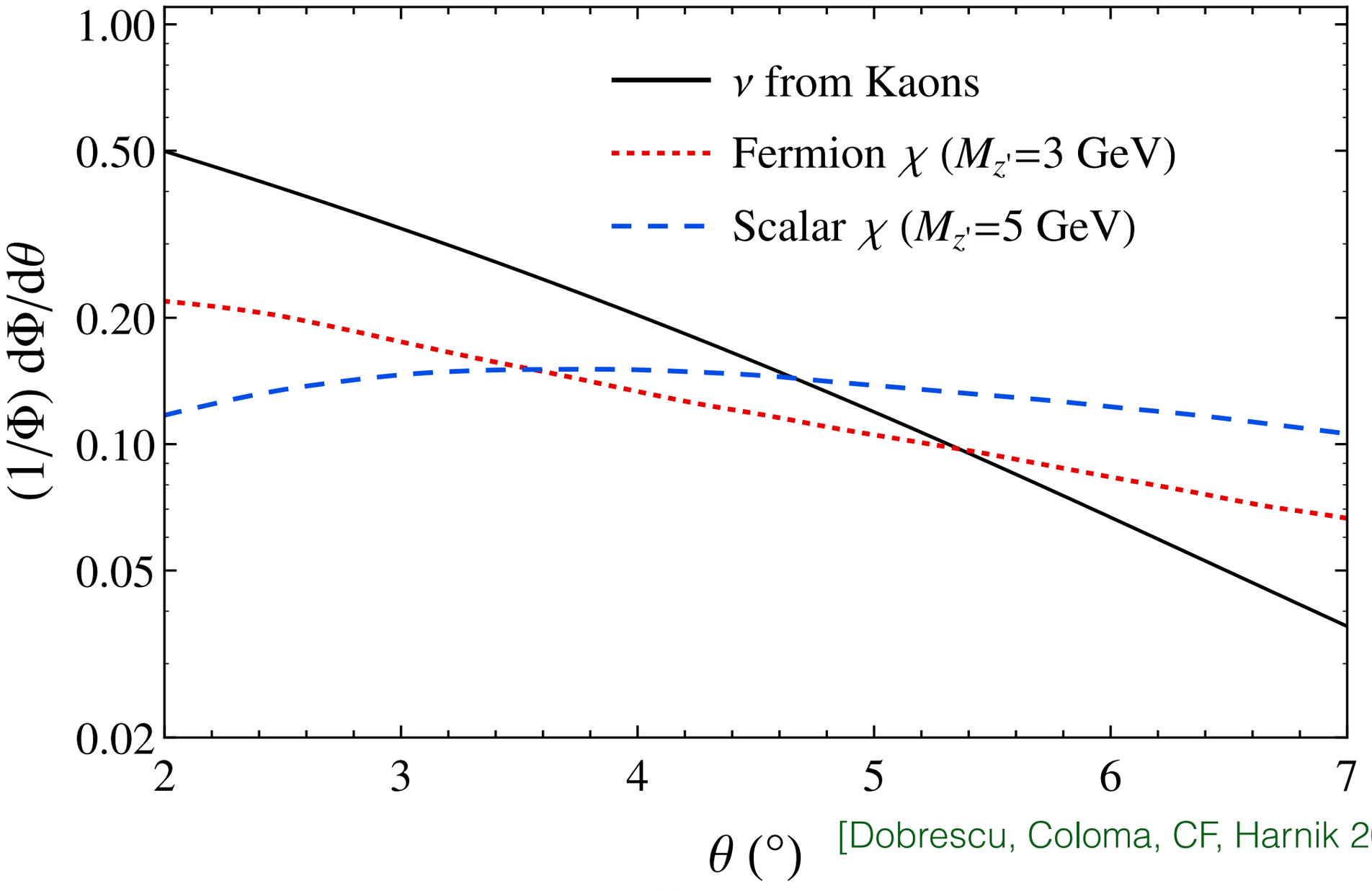


[Dobrescu, CF 2014]
[Dobrescu, Coloma, CF, Harnik 2015]
[CF 2017]

MiniBooNE is an off axis detector for the NuMI facility!

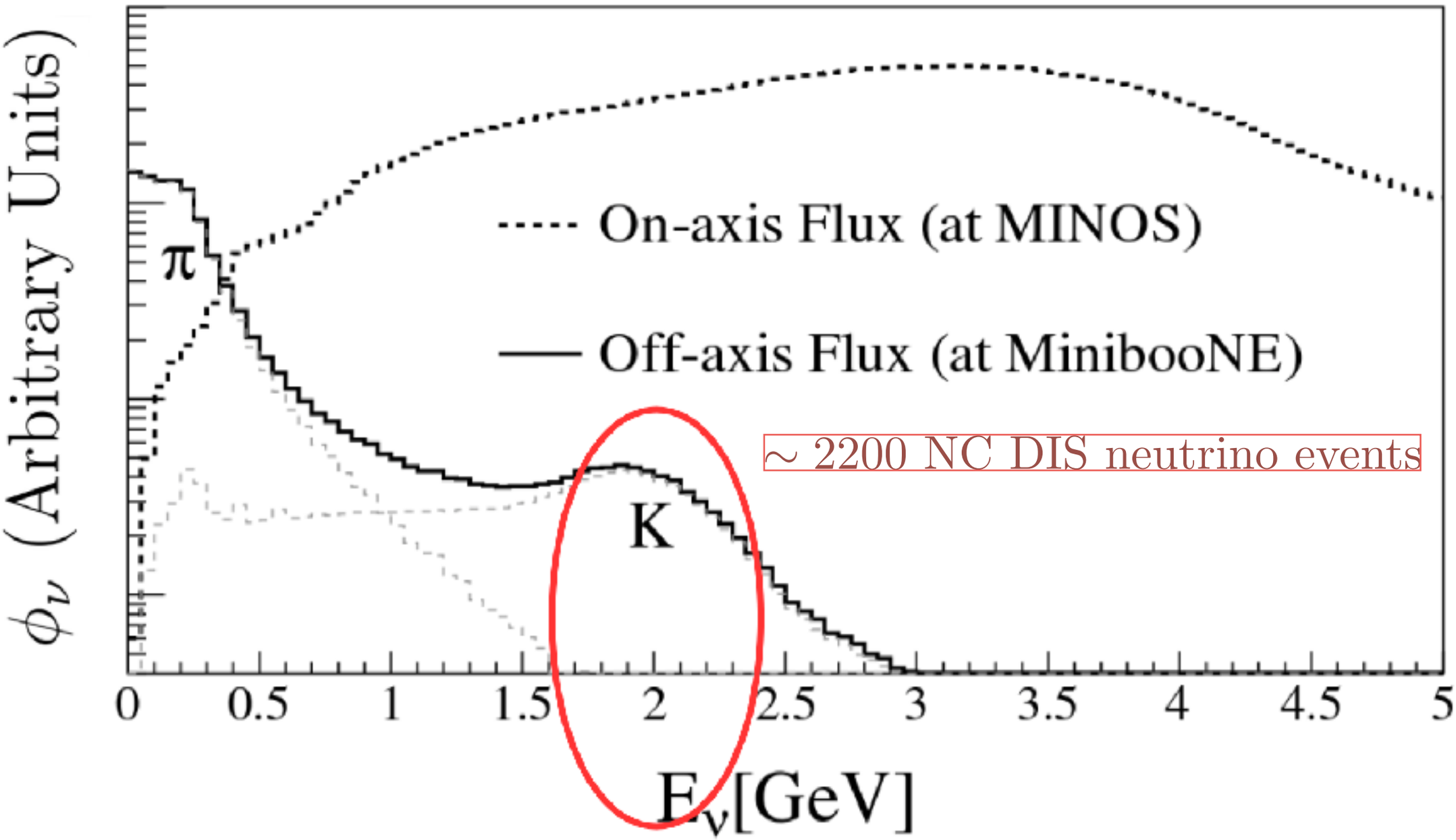
Off-axis detectors for DM

MiniBoonNE's location with respect to the Main injector beam is ideal



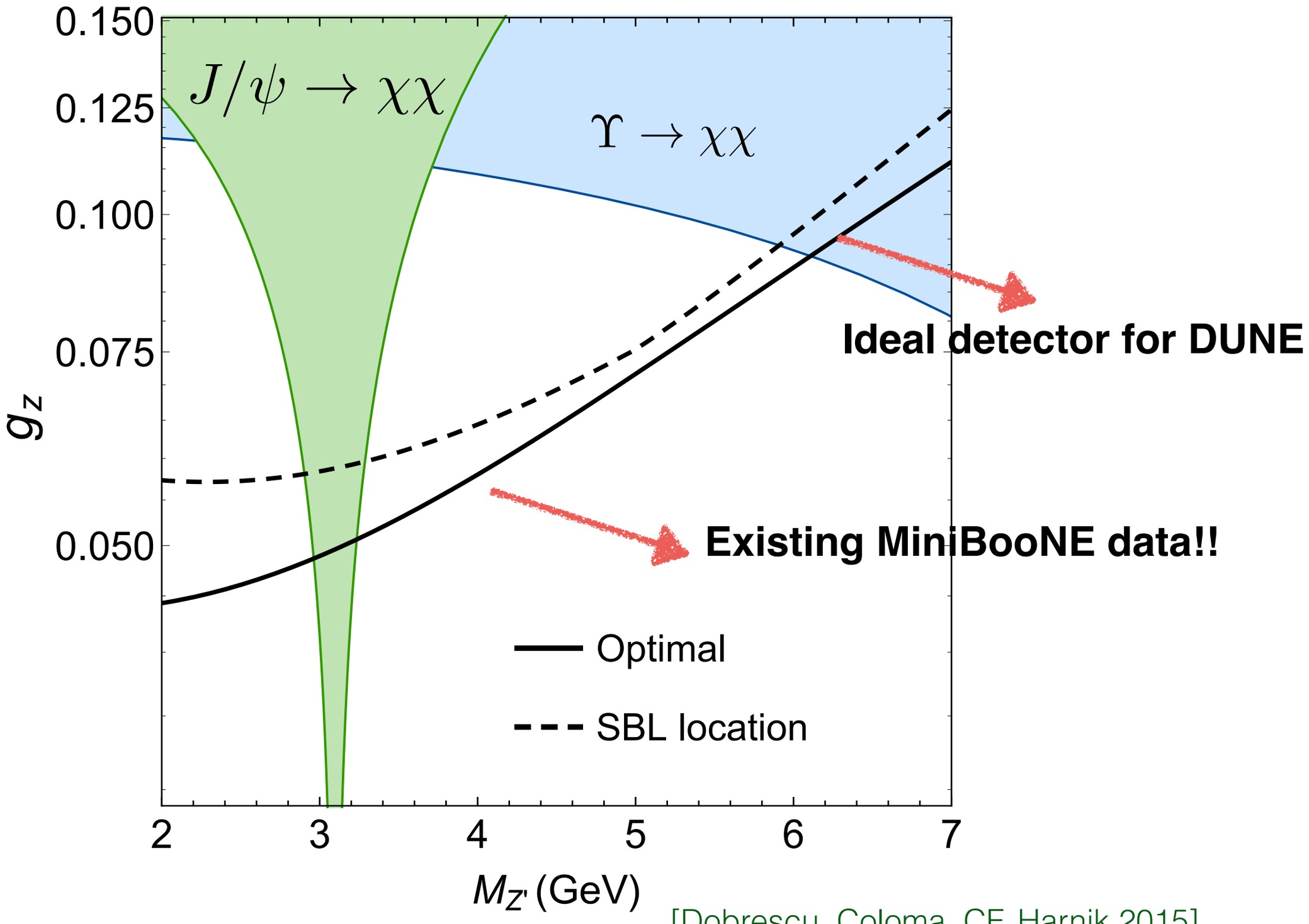
[Dobrescu, Coloma, CF, Harnik 2015]

Off-axis neutrino background



The energy of neutrinos is too
small to give rise to numerous deep inelastic scattering events

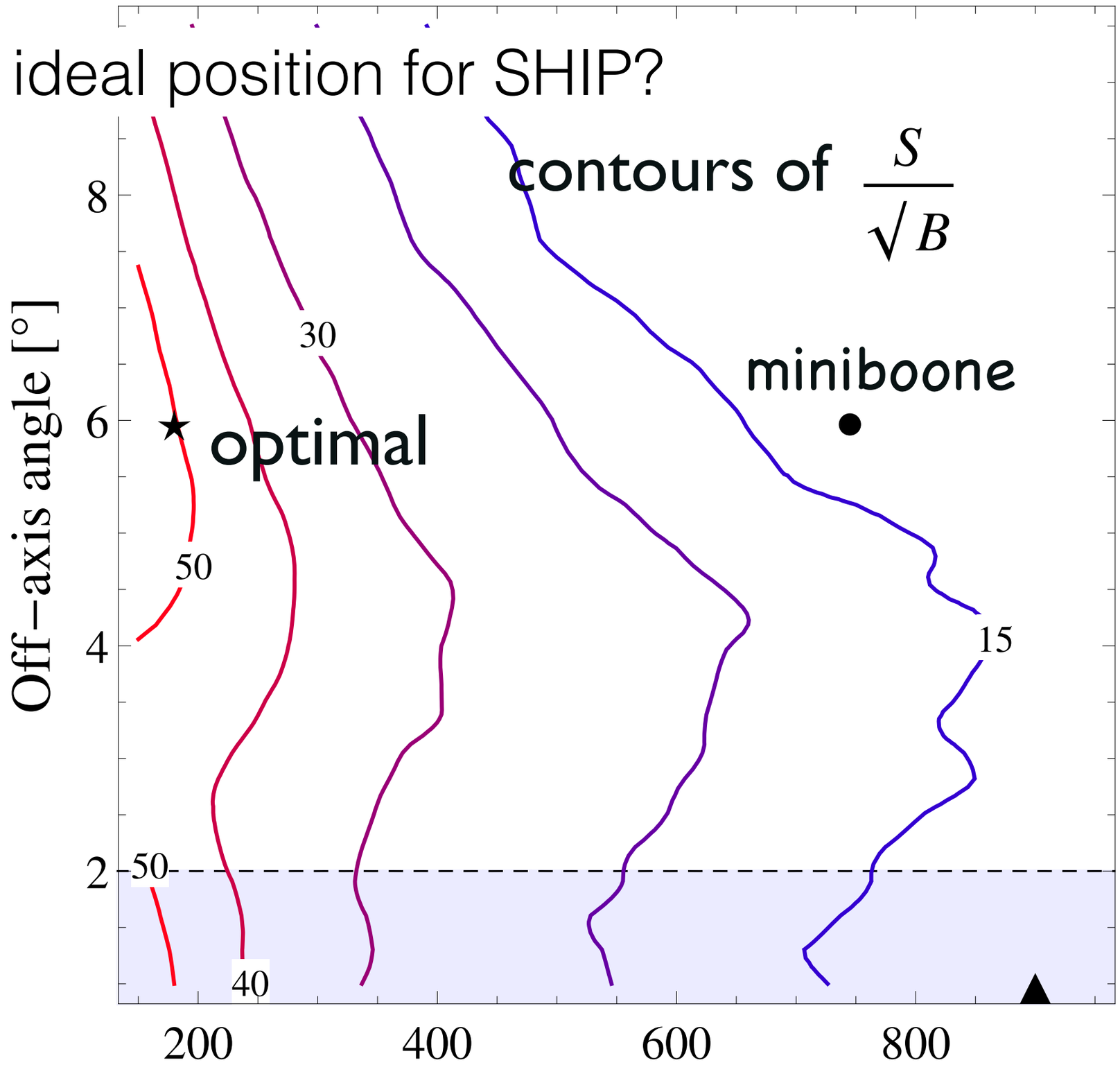
Projected sensitivity



[Dobrescu, Coloma, CF, Harnik 2015]

Ideal position for a future LBNF detector

What is the ideal position for SHIP?

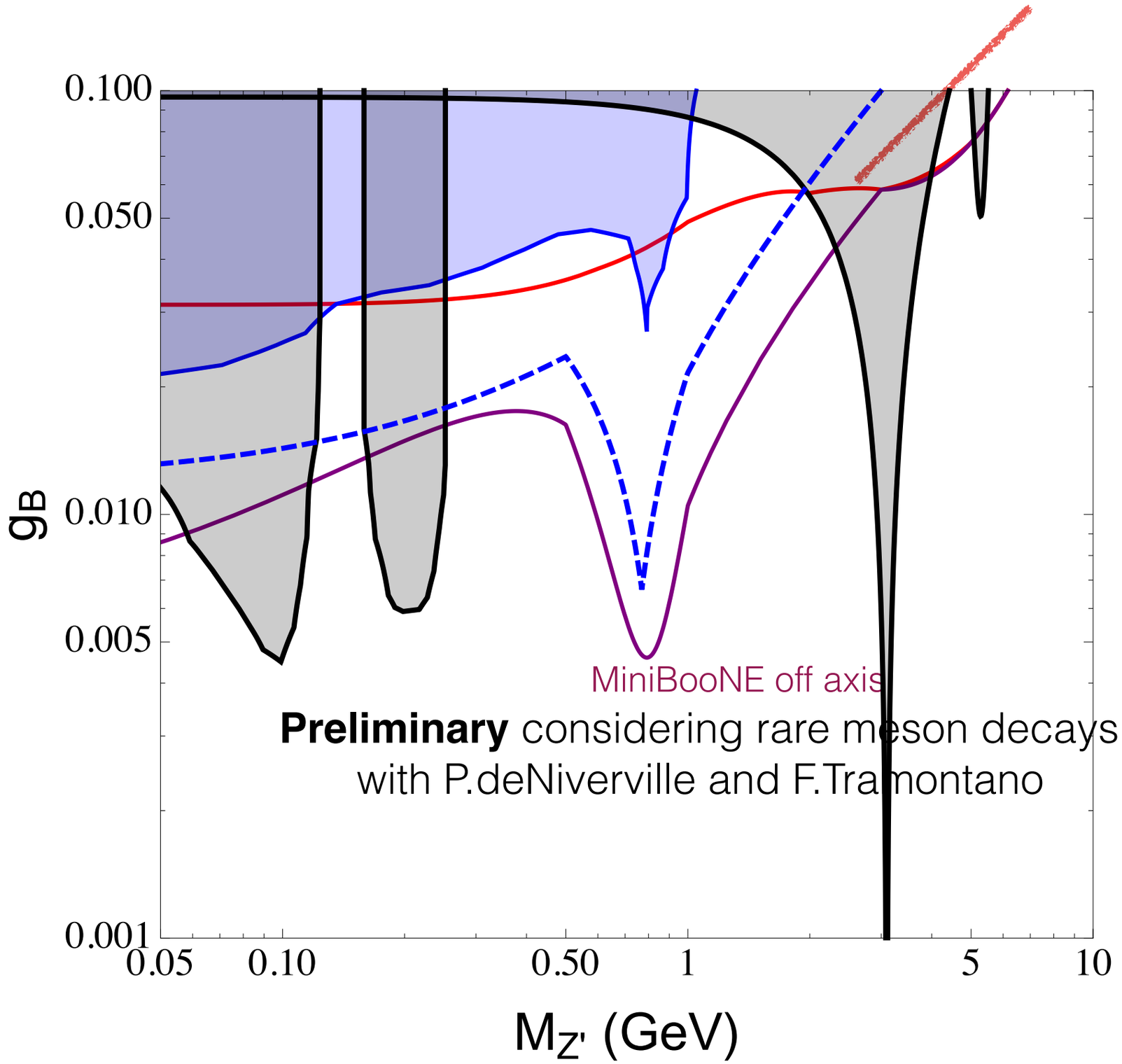


$g_z = 0.1$

[Dobrescu, Coloma, CF, Harnik 2015]

Looking at the entire region

CF, 2017 only considering pp->Z'j



More to explore

- MiniBooNE dedicated analysis (including systematics, etc) using Main Injector data?

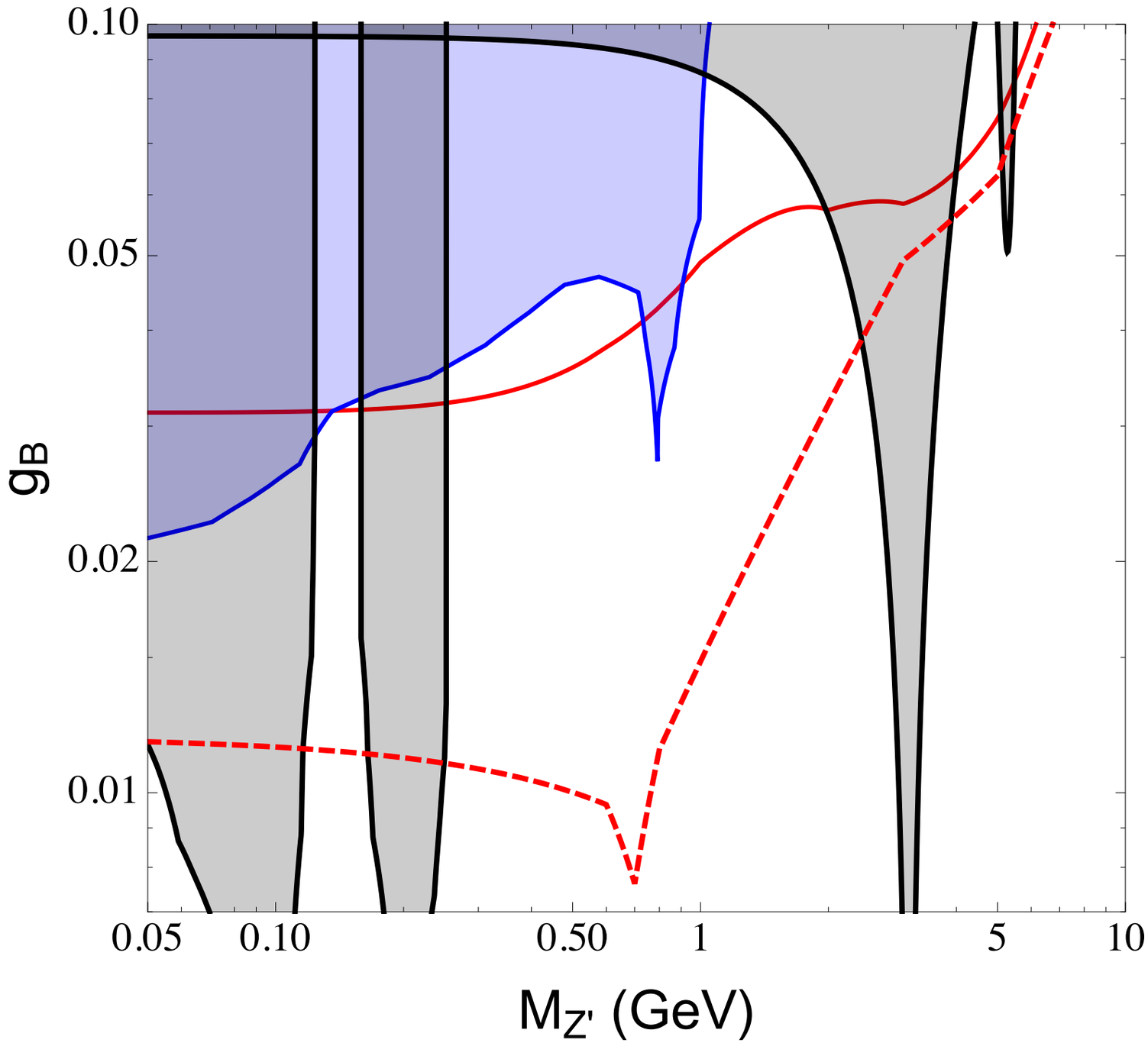
- MiniBooNE prospects for non-minimal dark sectors using Main Injector data (interesting projections for the 8 GeV run Izaguirre et al., 2017)

- What are the prospects to probe dark matter/ nucleon coupling at SHiP (Search for Hidden Particles, the new proposed CERN proton fixed target experiment)?

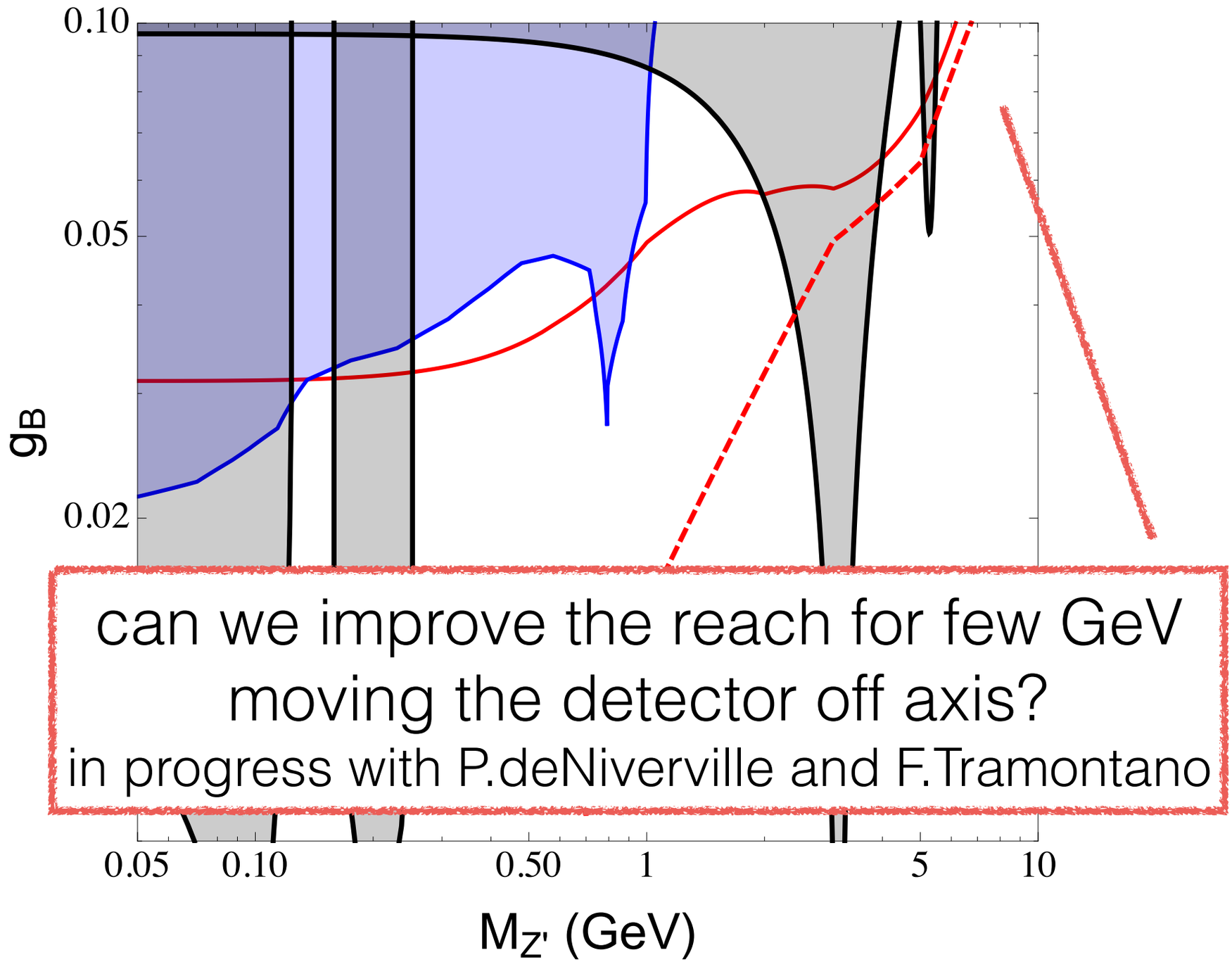
Work in progress with P.deNiverville and F.Tramontano

Back up slide

SHIP projections



SHIP projections



can we improve the reach for few GeV moving the detector off axis?

in progress with P.deNiverville and F.Tramontano