Notes on running this code to calculate DS20k exclusion limits

If you need to set up working on manchester clusters:

Instructions on setting up global protect (needed to ssh into the manchester machines) are on the manchester support portal here - https://manchester.saasiteu.com/Modules/SelfService/#knowledgeBase/view/29A5C080583743E1A0BBCFF8C79CFC39

Then you can do something like:

> globalprotect connect --portal vpnconnect.manchester.ac.uk

Put in your manchester username and passwork (same as for blackboard)

> ssh -XY username@pc2014.hep.manchester.ac.uk

> cd /pc2014-data2/username/ # make a directory to work in somewhere like this eg /pc20**-data*

Dependencies for running the code

I use python3 for running the exclusion limits
Also need to set up 'uproot', which allows you to access data from root files from within the python code easily

On my linux laptop, I just install uproot (eg can use pip - https://pypi.org/project/uproot/)

If you are using the manchester machines, I think you should be able to access by sourcing some environment from cvmfs
Eg. you could try

> source /cvmfs/sft.cern.ch/lcg/views/setupViews.sh LCG_97python3 x86_64-slc6-gcc8-opt

This should set up python3, uproot etc.

Dark matter data files

The data files I have sent include the migdal effect, which is an effect I am currently calculating limits for, where there is an additional electromagnetic signature as well as the nuclear recoil. You can use these datafile to test the limit calculation and understand the S2 only limit and backgrounds, don't need to worry too much about the details of the migdal signal.

They are named 'Ar_O1/spectra_ds20k_Ar_O1_0.root'
The 'O1' just refers to the EFT operator - where O1 is the standard momentum-independent interaction. The number at the end is the spectra number, with each file referring to a different dark matter mass.
The spectra I include here correspond to the masses, in GeV

> np.concatenate([np.logspace(-1.2,-1.05,4) , np.logspace(-1,1,30)])

This is not ideal (just because I ran 30 masses then decided to look at some lower masses), but is fine as long as you remember to plot against the correct mass values.

You can open these root files and plot the spectra directly from these
For example if you open the root file (eg num 10) you can see the different hist contained

> root -l spectra_ds20k_Ar_O1_10.root
> .ls

Some examples:

- 'hSum10' : total spectrum of non-migdal NR energy + ER energy
- 'hNR10' : this is the spectrum of JUST the NR energy

Eg can plot with something like

> hNR10->Draw()

You can use this information to change my code to calculate the limit using just the NR energy and see how this differs from the migdal limit (which the code is currently set up to calculate)

Codes

These code are currently in jupyter notebooks, but feel free to just copy them into python scripts if that works better for you.

DarkSide20k_plottingBackgrounds
This code essentially just loads in the different background sources, and an example dark matter spectrum and plots them.

DarkSide20k_FullProjectedLimit
This is the code which calculates the 90% exclusion limit for the ds20k data

get_dm_spectra() is the function which loads the dm data from the root files

An energy scale uncertainty is included which is why we look at the DM spectra for shifted up and down energy scale, and include this as a nuisance parameter in the likelihood

get_limit_ds20k() is the function which will actually calculate the exclusion limit

It uses minuit to minimise the -2logLikelihood

Backgrounds

The source of background included at the moment are :

- 39Ar : in the code that plots the backgrounds you can see that a factor of 0.7/2.7 is applied to the data read in , this is because the data file is for 39Ar + 85Kr, so we use this to approximate the rate of just the 39Ar
- SiPM gamma background : again a factor is used because we are estimating the backgrounds based on DS50 PMT backgrounds
- CEvNS : this is read in from a root file

On each background we include a 15% uncertainty, as well as the energy scale uncertainty