F29-Ne29-shell-model-calculations

December 20, 2023

1 KSHELL calculations of the $^{29}F \rightarrow ^{29} Ne$ beta decay

We performed a series of calculations using kshell to investigate the role of $\hbar\omega$ excitations in the decay strength to the first excited state.

Notes on modified interactions:

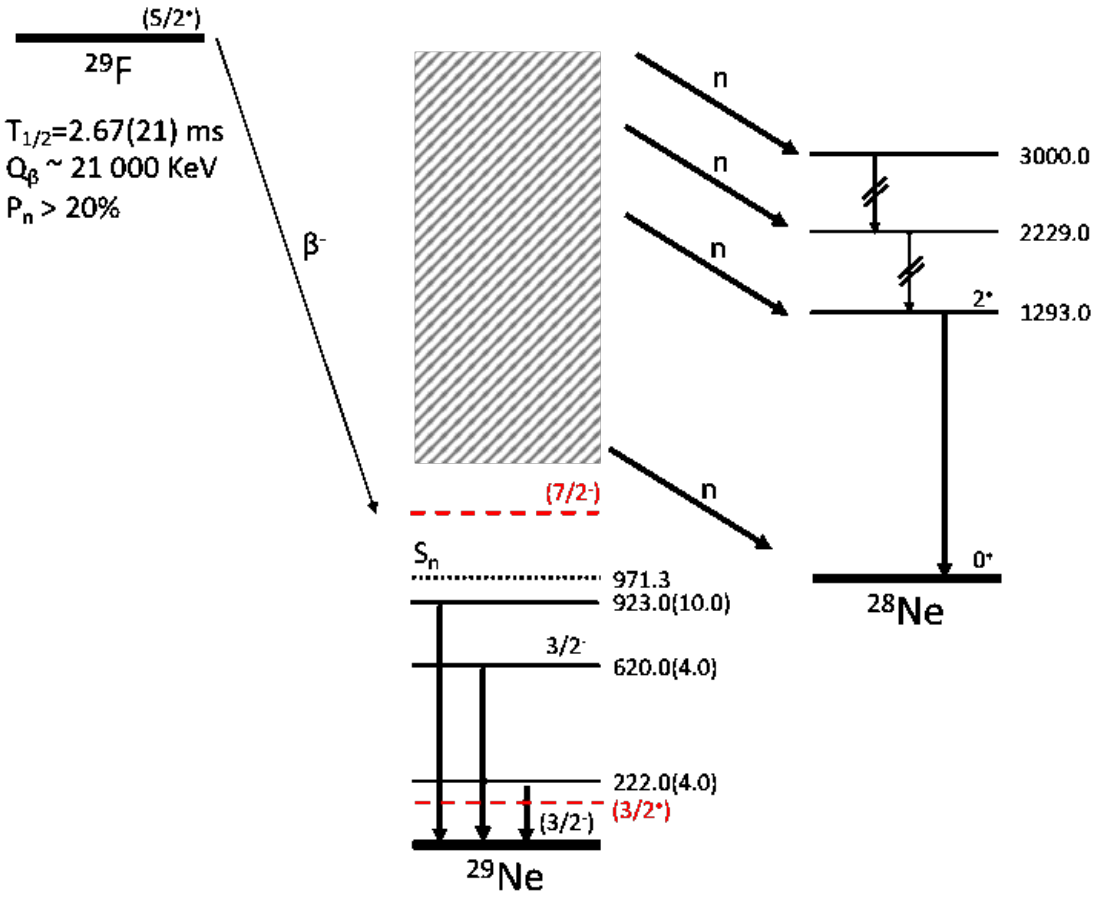
- Prime modifier (') $\rightarrow \nu p_{3/2}$ - 0.5 MeV
- `p32low` and '$p_{32}-$' $\rightarrow \nu p_{3/2}$ - 0.75 MeV
- `f72low` and '$f_{72}-$' $\rightarrow \nu f_{7/2}$ - 0.5 MeV

All calculations are stored in the ACF under

`~/lustre/calculations/IslandOfInversion/F29/`

The decay scheme looks like this:

[ ]:
```
using Plots,Images,PrettyTables,StatsPlots

levels=load("./images/level-scheme.gif")
```



We define a handy function to calculate log(ft) from the BGT strength from shell model

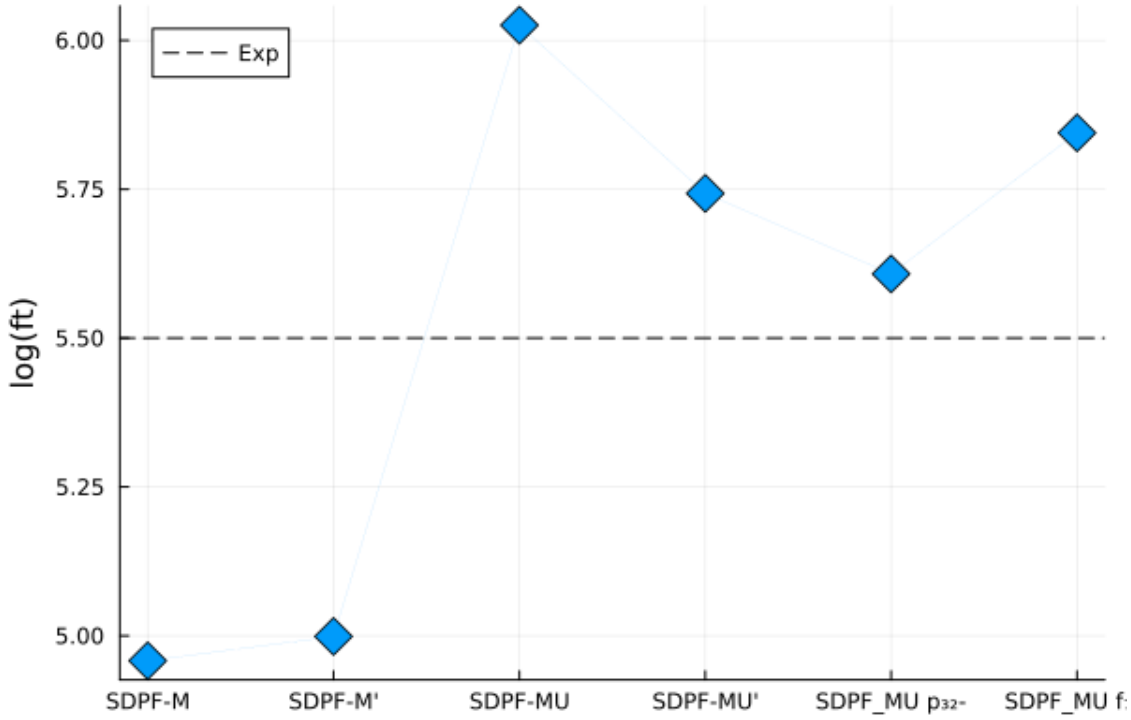
[ ]:
```
logft(bgt)=log10(6144.2/(1.2761^2*bgt*0.77^2))
```

```
logft (generic function with 1 method)
```

1.1 BGT $(5/2^+ \rightarrow 3/2^+)$

[ ]:
```
sdpfmbgt5p3p = 0.0701 ; lftsdpfm5p3p = logft(sdpfmbgt5p3p)
sdpfmubgt5p3p = 0.006 ; lftsdpfmu5p3p = logft(sdpfmubgt5p3p)
sdpfmprime5p3p =0.0638 ;  lftsdpfmprime5p3p = logft(sdpfmprime5p3p)
sdpfmuprimebgt5p3p = 0.0115 ; lftsdpfmuprime5p3p = logft(sdpfmuprimebgt5p3p)
sdpfmup32lowbgt5p3p = 0.0157 ; lftsdpfmup32low5p3p = logft(sdpfmup32lowbgt5p3p)
sdpfmuf72lowbgt5p3p = 0.0091 ; lftsdpfmuf72low5p3p = logft(sdpfmuf72lowbgt5p3p)


plot(["SDPF-M","SDPF-M'","SDPF-MU","SDPF-MU'","SDPF_MU p -","SDPF_MU f -"],
[lftsdpfm5p3p,lftsdpfmprime5p3p,lftsdpfmu5p3p,lftsdpfmuprime5p3p,lftsdpfmup32low5p3p,lftsdpfmu
line=false,marker=:diamond,markersize=10,label="",ylabel="log(ft)")
```

```
hline!([5.5],linestyle=:dash,linecolor=:black,label="Exp")
```



[ ]:
```
pretty_table(["log(ft)";;
lftsdpfm5p3p;;lftsdpfmprime5p3p;;lftsdpfmu5p3p;;lftsdpfmuprime5p3p;;
  ↪lftsdpfmup32low5p3p;;lftsdpfmuf72low5p3p],
header=["","SDPF-M","SDPF-M'","SDPF-MU","SDPF-MU'","SDPF-MU p -","SDPF-MU f -"])
```

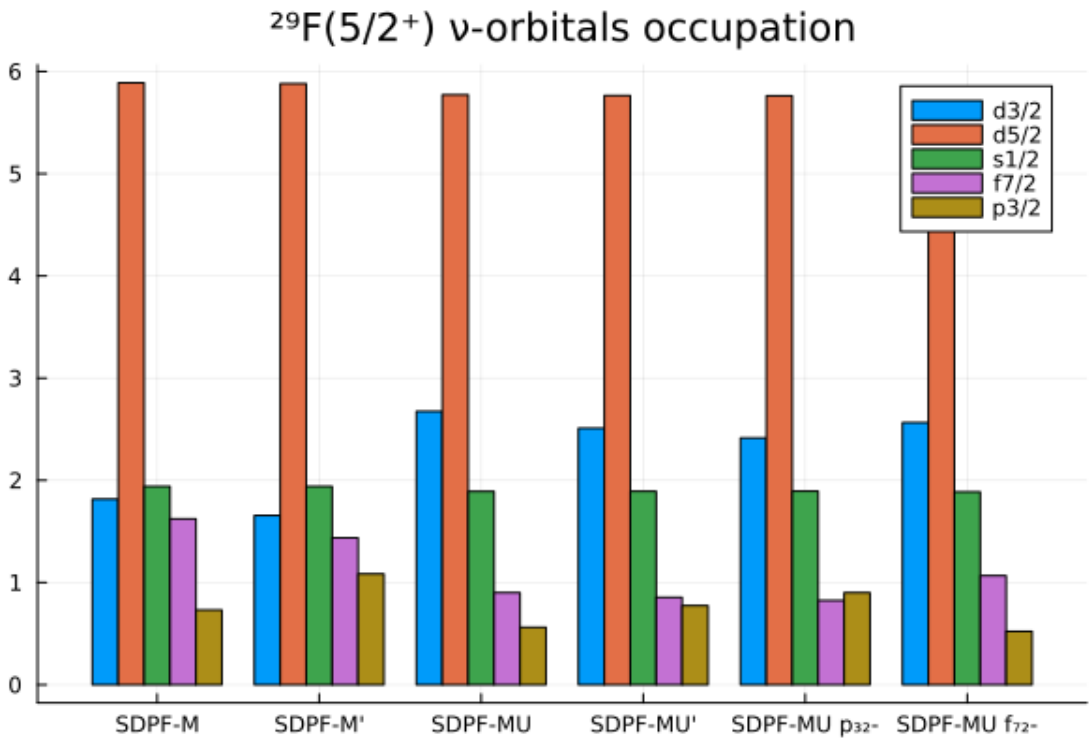
	SDPF-M	SDPF-M'	SDPF-MU	SDPF-MU'	SDPF-MU p -	SDPF-MU f -
log(ft)	4.958	4.99889	6.02556	5.74302	5.60781	5.84467

1.2 Wavefunction composition of the $^{29}F(5/2^+)$

[ ]:
```
orbitals=["d3/2" "d5/2" "s1/2" "f7/2" "p3/2"]

#              d3/2   d5/3   s1/2   f7/2   p3/2
sdpfm29f5p=[0.024  0.910  0.060  0.005  0.001    #p
            1.816  5.889  1.941  1.623  0.731]    #n

sdpfmprime29f5p = [0.025  0.894  0.074  0.004  0.002
                   1.656  5.881  1.941  1.438  1.084]

sdpfmu29f5p = [0.917  0.018  0.024  0.015  0.017  0.005  0.004
               5.772  2.675  1.892  0.901  0.118  0.562  0.079]

#                      d5/2  d3/2   s1/2   f7/2   f5/2  p3/2    p1/2
 sdpfmuprime29f5p = [0.910  0.020  0.031  0.015  0.016  0.005  0.004
                     5.765  2.510  1.893  0.855  0.116  0.774  0.087]

 sdpfmup32low29f5p = [0.907  0.021  0.035  0.014  0.015  0.005  0.004
                      5.762  2.414  1.894  0.824  0.113  0.901  0.091]

  sdpfmuf72low29f5p = [0.914  0.020  0.026  0.015  0.017  0.004  0.004
                       5.766  2.565  1.887  1.067  0.118  0.523  0.075]
```

```
2×7 Matrix{Float64}:
 0.914  0.02   0.026  0.015  0.017  0.004  0.004
 5.766  2.565  1.887  1.067  0.118  0.523  0.075
```

[ ]:
```
groupedbar(["SDPF-M","SDPF-M'","SDPF-MU","SDPF-MU'","SDPF-MU p -","SDPF-MU␣
 ↪f -"],
 permutedims([sdpfm29f5p[2,:];;sdpfmprime29f5p[2,:];;
 [sdpfmu29f5p[2,2];sdpfmu29f5p[2,1];sdpfmu29f5p[2,3:4];sdpfmu29f5p[2,6]];;
 [sdpfmuprime29f5p[2,2];sdpfmuprime29f5p[2,1];sdpfmuprime29f5p[2,3:4];
 ↪sdpfmuprime29f5p[2,6]];;
 [sdpfmup32low29f5p[2,2];sdpfmup32low29f5p[2,1];sdpfmup32low29f5p[2,3:4];
 ↪sdpfmup32low29f5p[2,6]];;
 [sdpfmuf72low29f5p[2,2];sdpfmuf72low29f5p[2,1];sdpfmuf72low29f5p[2,3:4];
 ↪sdpfmuf72low29f5p[2,6]]]),
 labels= orbitals,title="²F(5/2⁺) -orbitals occupation"
 )
```

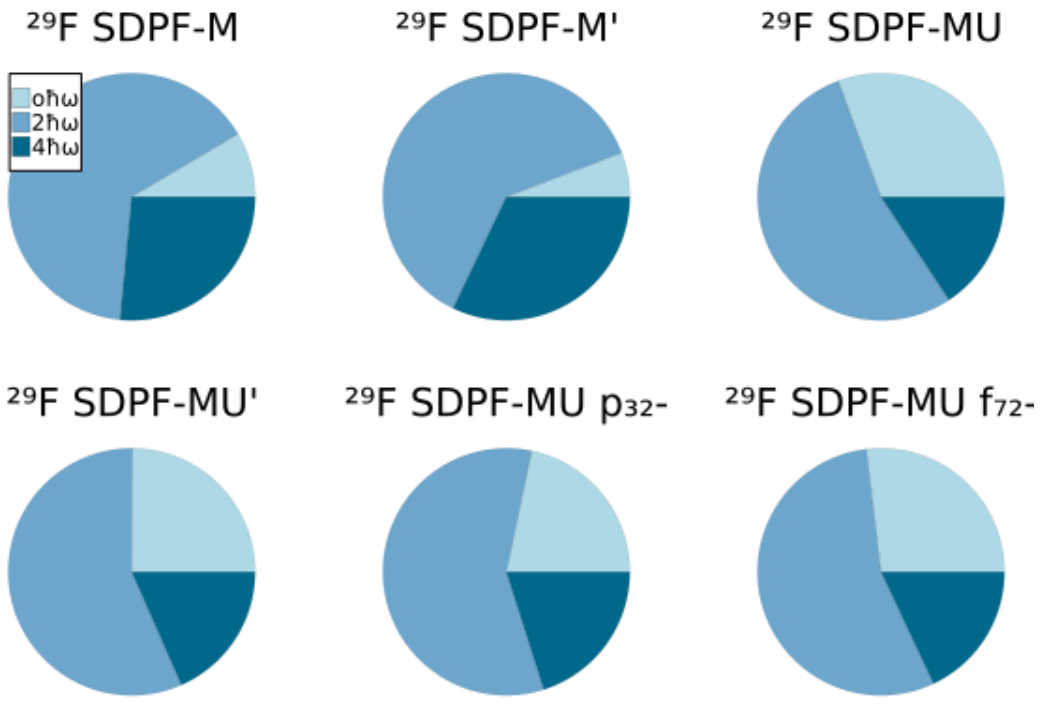


[ ]:
```
pretty_table([["d3/2","d5/2","s1/2","f7/2","p3/2"];;
sdpfm29f5p[2,:];;sdpfmprime29f5p[2,:];;
[sdpfmu29f5p[2,2];sdpfmu29f5p[2,1];sdpfmu29f5p[2,3:4];sdpfmu29f5p[2,6]];;
 [sdpfmuprime29f5p[2,2];sdpfmuprime29f5p[2,1];sdpfmuprime29f5p[2,3:4];
 ↪sdpfmuprime29f5p[2,6]];;
 [sdpfmup32low29f5p[2,2];sdpfmup32low29f5p[2,1];sdpfmup32low29f5p[2,3:4];
 ↪sdpfmup32low29f5p[2,6]];;
 [sdpfmuf72low29f5p[2,2];sdpfmuf72low29f5p[2,1];sdpfmuf72low29f5p[2,3:4];
 ↪sdpfmuf72low29f5p[2,6]]],
header=["","SDPF-M", "SDPF-M'", "SDPF-MU", "SDPF-MU'", "SDPF-MU p -","SDPF-MU␣
 ↪f -"])
```

	SDPF-M	SDPF-M'	SDPF-MU	SDPF-MU'	SDPF-MU p -	SDPF-MU f -
d3/2	1.816	1.656	2.675	2.51	2.414	2.565
d5/2	5.889	5.881	5.772	5.765	5.762	5.766
s1/2	1.941	1.941	1.892	1.893	1.894	1.887
f7/2	1.623	1.438	0.901	0.855	0.824	1.067
p3/2	0.731	1.084	0.562	0.774	0.901	0.523

1.3 Fraction of $\hbar\omega$ excitations in ^{29}F

[ ]:
```
sdpfmhw=[0.085,  0.650, 0.265]
sdpfmprimehw=[0.058, 0.621 ,0.321]
sdpfmuhw=[0.306, 0.536, 0.157]
sdpfmuprimehw=[0.249 ,0.567 ,0.184]
sdpfmup32lowhw=[ 0.217 ,0.582 ,0.201]
sdpfmuf72lowhw=[ 0.269 ,0.551 ,0.180]



plot(pie(["oħ ","2ħ ","4ħ "], sdpfmhw,title="²F SDPF-M",color=[:lightblue,:
 ↪skyblue3,:deepskyblue4],line=false,legend=:topleft),
pie(["oħ ","2ħ ","4ħ "], sdpfmprimehw,title="²F SDPF-M'",color=[:lightblue,:
 ↪skyblue3,:deepskyblue4],line=false,label=false),
pie(["oħ ","2ħ ","4ħ "], sdpfmuhw,title="²F SDPF-MU",color=[:lightblue,:
 ↪skyblue3,:deepskyblue4],line=false,label=false),
pie(["oħ ","2ħ ","4ħ "], sdpfmuprimehw,title="²F SDPF-MU'",color=[:lightblue,:
 ↪skyblue3,:deepskyblue4],line=false,label=false),
pie(["oħ ","2ħ ","4ħ "], sdpfmup32lowhw,title="²F SDPF-MU p -",color=[:
 ↪lightblue,:skyblue3,:deepskyblue4],line=false,label=false),
pie(["oħ ","2ħ ","4ħ "], sdpfmuf72lowhw,title="²F SDPF-MU f -",color=[:
 ↪lightblue,:skyblue3,:deepskyblue4],line=false,label=false))
```

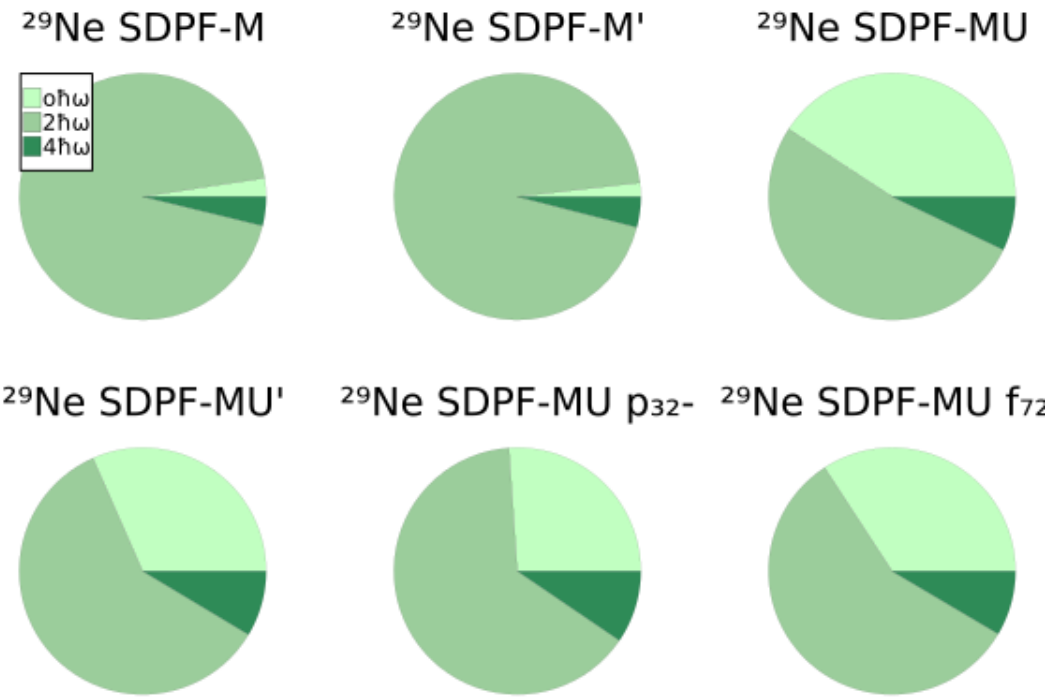


[ ]:
```
pretty_table([["ħ ","2ħ ","4ħ "];;
sdpfmhw;;sdpfmprimehw;;sdpfmuhw;;sdpfmuprimehw;;sdpfmup32lowhw;;sdpfmuf72lowhw],
header=["","SDPF-M", "SDPF-M'", "SDPF-MU", "SDPF-MU'", "SDPF-MU p -","SDPF-MU␣
 ↪f -"])
```

	SDPF-M	SDPF-M'	SDPF-MU	SDPF-MU'	SDPF-MU p -	SDPF-MU f -
ħ	0.085	0.058	0.306	0.249	0.217	0.269
2ħ	0.65	0.621	0.536	0.567	0.582	0.551
4ħ	0.265	0.321	0.157	0.184	0.201	0.18

1.4 Fraction of $\hbar\omega$ excitations in ^{29}Ne $3/2^+$ state

[ ]:
```
sdpfm29nehw=[ 0.024, 0.937 ,0.038]
sdpfmprime29nehw=[0.018 ,0.942 ,0.040]
sdpfmu29nehw=[0.408 ,0.521 ,0.071]
sdpfmuprime29nehw=[0.316 ,0.598 ,0.086]
sdpfmup32low29nehw=[0.261 ,0.644 ,0.095]
sdpfmuf72low29nehw=[0.342 ,0.573 ,0.085]


plot(pie(["oħ ","2ħ ","4ħ "], sdpfm29nehw,title="² Ne SDPF-M",color=[:
 ↪darkseagreen1,:darkseagreen3,:seagreen],line=false,legend=:topleft),
pie(["oħ ","2ħ ","4ħ "], sdpfmprime29nehw,title="² Ne SDPF-M'",color=[:
 ↪darkseagreen1,:darkseagreen3,:seagreen],line=false,label=false),
pie(["oħ ","2ħ ","4ħ "], sdpfmu29nehw,title="² Ne SDPF-MU",color=[:darkseagreen1,:
 ↪darkseagreen3,:seagreen],line=false,label=false),
pie(["oħ ","2ħ ","4ħ "], sdpfmuprime29nehw,title="² Ne SDPF-MU'",color=[:
 ↪darkseagreen1,:darkseagreen3,:seagreen],line=false,label=false),
pie(["oħ ","2ħ ","4ħ "], sdpfmup32low29nehw,title="² Ne SDPF-MU p -",color=[:
 ↪darkseagreen1,:darkseagreen3,:seagreen],line=false,label=false),
pie(["oħ ","2ħ ","4ħ "], sdpfmuf72low29nehw,title="² Ne SDPF-MU f -",color=[:
 ↪darkseagreen1,:darkseagreen3,:seagreen],line=false,label=false))
```



[ ]:
```
pretty_table([["ħ ","2ħ ","4ħ "];;
sdpfm29nehw;;sdpfmprime29nehw;;sdpfmu29nehw;;sdpfmuprime29nehw;;
 ↪sdpfmup32low29nehw;;sdpfmuf72low29nehw],
header=["","SDPF-M", "SDPF-M'", "SDPF-MU", "SDPF-MU'", "SDPF-MU p -","SDPF-MU␣
 ↪f -"])
```

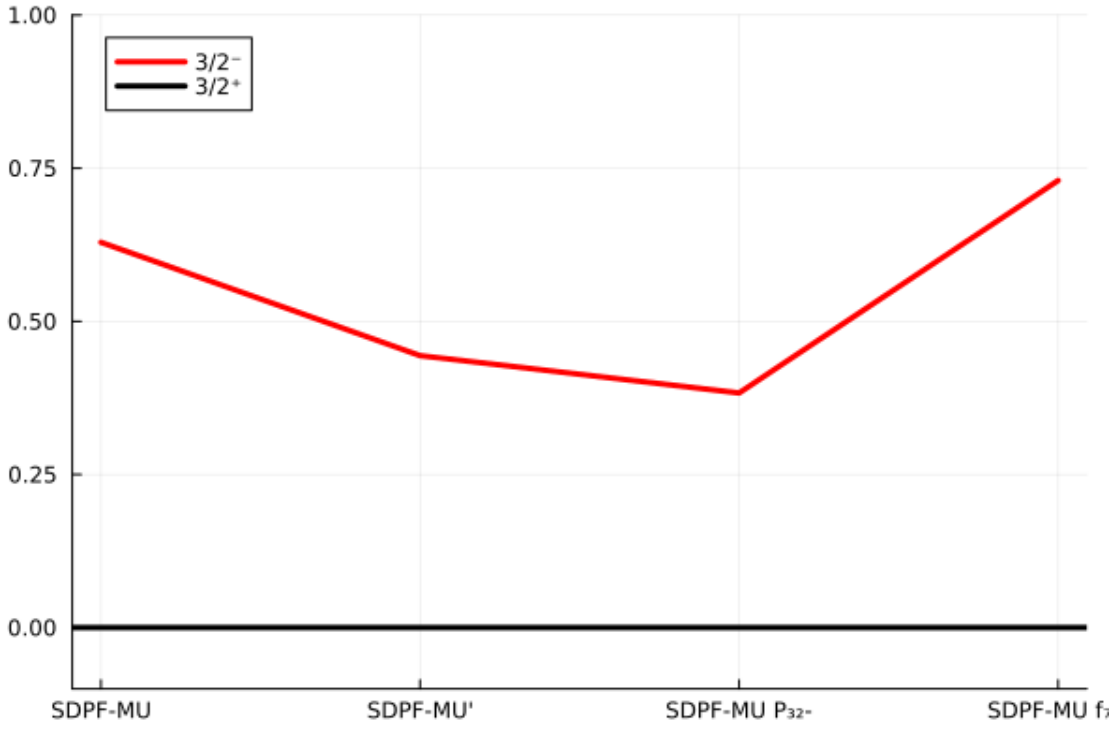
	SDPF-M	SDPF-M'	SDPF-MU	SDPF-MU'	SDPF-MU p -	SDPF-MU f -
ħ	0.024	0.018	0.408	0.316	0.261	0.342
2ħ	0.937	0.942	0.521	0.598	0.644	0.573
4ħ	0.038	0.04	0.071	0.086	0.095	0.085

1.5 The ground state of ^{29}Ne

So far we have investigated the role of the $p_{3/2}$ orbital in driving down the log(ft) for the decay of ^{29}F. However we can also investigate the fact that the ground state of ^{29}Ne is now known to be a $3/2^-$. We plot the energy split of the $3/2^+$ and $3/2^-$ for the different SDPF-MU models we have used.

The first calculation here was done up to $3\hbar\omega$, due to the large computational cost of $5\hbar\omega$

[ ]:
```
E32minus=[]
sdpfmu32minus = 0.629; push!(E32minus,sdpfmu32minus)
sdpfmuprime32minus = 0.444; push!(E32minus,sdpfmuprime32minus)
sdpfmup32low32minus = 0.383; push!(E32minus,sdpfmup32low32minus)
sdpfmuf72low32minus = 0.730; push!(E32minus,sdpfmuf72low32minus)


plot(["SDPF-MU","SDPF-MU'","SDPF-MU P -","SDPF-MU f -"],E32minus,
ylims=(-0.1,1.0),linewidth=3,linecolor=:red,label="3/2 ")
hline!([0.0],linecolor=:black,linewidth=3,label="3/2 ")
```



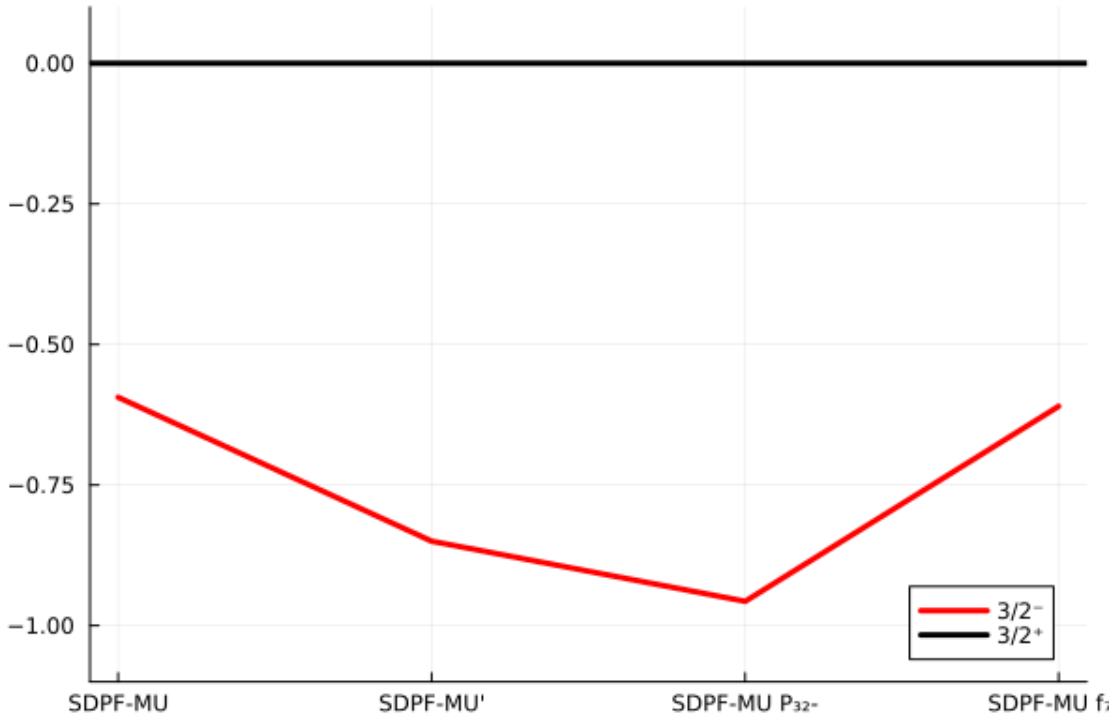
[ ]:
```
pretty_table(["E   (MeV)";;permutedims(hcat(E32minus))],
header=["","SDPF-MU","SDPF-MU'","SDPF-MU P -","SDPF-MU f -"])
```

	SDPF-MU	SDPF-MU'	SDPF-MU P -	SDPF-MU f -
E (MeV)	0.629	0.444	0.383	0.73

1.5.1 Energy of the $3/2^-$ in ^{29}Ne calculated at $5\hbar\omega$

We got the calculations at $5\hbar\omega$ done on campus-beacon-long

[ ]:
```
E32minus5hw=[]
sdpfmu32minus5hw = -0.594; push!(E32minus5hw,sdpfmu32minus5hw)
sdpfmuprime32minus5hw = -0.850; push!(E32minus5hw,sdpfmuprime32minus5hw)
sdpfmup32low32minus5hw = -0.957; push!(E32minus5hw,sdpfmup32low32minus5hw)
sdpfmuf72low32minus5hw = -0.610; push!(E32minus5hw,sdpfmuf72low32minus5hw)


plot(["SDPF-MU","SDPF-MU'","SDPF-MU P -","SDPF-MU f -"],E32minus5hw,
ylims=(-1.1,0.1),linewidth=3,linecolor=:red,label="3/2 ")
hline!([0.0],linecolor=:black,linewidth=3,label="3/2 ")
```



[ ]:
```
pretty_table(["E   (MeV)";;permutedims(hcat(E32minus5hw))],
header=["","SDPF-MU","SDPF-MU'","SDPF-MU P -","SDPF-MU f -"])
```

	SDPF-MU	SDPF-MU'	SDPF-MU P -	SDPF-MU f -
E (MeV)	-0.594	-0.85	-0.957	-0.61