Test example for K=2, one link

These are mesons in large N limit with antiperiodic boundary conditions for fermions and periodic boundry conditions for bosons (no zero modes).
No symmetries.

```
In[122]:= << "/home/jdbratt/hamiltonianMatrices.m"
```

■ Write out matrix

These are the |ket> 's with daggers implicit.

```
In[123]:= listOfStates[2, 1, none]
```

```
Out[123]= {State[b[1/2, -1/2], d[3/2, -1/2]], State[b[1/2, -1/2], d[3/2, 1/2]],
 State[b[1/2, 1/2], d[3/2, -1/2]], State[b[1/2, 1/2], d[3/2, 1/2]],
 State[b[3/2, -1/2], d[1/2, -1/2]], State[b[3/2, -1/2], d[1/2, 1/2]],
 State[b[3/2, 1/2], d[1/2, -1/2]], State[b[3/2, 1/2], d[1/2, 1/2]],
 State[b[1/2, -1/2], a[1, -2], d[1/2, -1/2]], State[b[1/2, -1/2], a[1, -2], d[1/2, 1/2]],
 State[b[1/2, -1/2], a[1, -1], d[1/2, -1/2]], State[b[1/2, -1/2], a[1, -1], d[1/2, 1/2]],
 State[b[1/2, -1/2], a[1, 1], d[1/2, -1/2]], State[b[1/2, -1/2], a[1, 1], d[1/2, 1/2]],
 State[b[1/2, -1/2], a[1, 2], d[1/2, -1/2]], State[b[1/2, -1/2], a[1, 2], d[1/2, 1/2]],
 State[b[1/2, 1/2], a[1, -2], d[1/2, -1/2]], State[b[1/2, 1/2], a[1, -2], d[1/2, 1/2]],
 State[b[1/2, 1/2], a[1, -1], d[1/2, -1/2]], State[b[1/2, 1/2], a[1, -1], d[1/2, 1/2]],
 State[b[1/2, 1/2], a[1, 1], d[1/2, -1/2]], State[b[1/2, 1/2], a[1, 1], d[1/2, 1/2]],
 State[b[1/2, 1/2], a[1, 2], d[1/2, -1/2]], State[b[1/2, 1/2], a[1, 2], d[1/2, 1/2]]}
```

```
In[124]:= Length[%]
```

```
Out[124]= 24
```

```
In[125]:= generalMatrix[makeham, 2, 1, 0, 1, {μB, μF, g^2, κS, κA, β, λ1, λ2, λ3, λ4, λ5}, none]
```

$$\text{Out[125]= } \Big\{\Big\{\frac{3\,g^2 + 4\,\kappa_A^2 + 4\,\kappa_S^2 + 16\,\pi\,\mu_F^2}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{g^2}{\pi},\ 0,\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},$$
$$\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0\Big\},$$
$$\Big\{0,\ \frac{3\,g^2 + 4\,\kappa_A^2 + 4\,\kappa_S^2 + 16\,\pi\,\mu_F^2}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{g^2}{\pi},\ 0,\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},$$
$$-\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0\Big\},$$

$$\left\{0,\ 0,\ \frac{3\,g^2+4\,\kappa_A^2+4\,\kappa_S^2+16\,\pi\,\mu_F^2}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{g^2}{\pi},\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\right.$$
$$\left.-\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}}\right\},$$
$$\left\{0,\ 0,\ 0,\ \frac{3\,g^2+4\,\kappa_A^2+4\,\kappa_S^2+16\,\pi\,\mu_F^2}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{g^2}{\pi},\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\right.$$
$$\left.-\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}}\right\},$$
$$\left\{-\frac{g^2}{\pi},\ 0,\ 0,\ 0,\ \frac{3\,g^2+4\,\kappa_A^2+4\,\kappa_S^2+16\,\pi\,\mu_F^2}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\right.$$
$$\left.-\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0\right\},$$
$$\left\{0,\ -\frac{g^2}{\pi},\ 0,\ 0,\ 0,\ \frac{3\,g^2+4\,\kappa_A^2+4\,\kappa_S^2+16\,\pi\,\mu_F^2}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\right.$$
$$\left.-\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}}\right\},$$
$$\left\{0,\ 0,\ -\frac{g^2}{\pi},\ 0,\ 0,\ 0,\ \frac{3\,g^2+4\,\kappa_A^2+4\,\kappa_S^2+16\,\pi\,\mu_F^2}{3\,\pi},\ 0,\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\right.$$
$$\left.-\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0\right\},$$
$$\left\{0,\ 0,\ 0,\ -\frac{g^2}{\pi},\ 0,\ 0,\ 0,\ \frac{3\,g^2+4\,\kappa_A^2+4\,\kappa_S^2+16\,\pi\,\mu_F^2}{3\,\pi},\ 0,\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\right.$$
$$-\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \left\{-\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\right.$$
$$-\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},$$
$$-\frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\,(i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,(-i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},$$
$$\left.\frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ 0,\ \frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ 0,\ 0\right\},$$
$$\left\{-\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\right.$$
$$\frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\kappa_S^2}{3\,\pi},\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},$$
$$\left.\frac{2\,\kappa_S^2}{3\,\pi},\ 0,\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ 0,\ \frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ 0\right\},$$
$$\left\{-\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{2\,(-i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\right.$$
$$\frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},\ \frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ 0,\ \frac{2\,(i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},$$
$$\left.\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ -\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0\right\},$$
$$\left\{-\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\right.$$
$$\frac{2\,\kappa_S^2}{3\,\pi},\ -\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},\ 0,\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},$$
$$\left.\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\kappa_S^2}{3\,\pi},\ 0,\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ -\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi}\right\},$$
$$\left\{-\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{2\,(i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\right.$$

$$\frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ 0,\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},\ -\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\,(-i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},$$
$$\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ 0,\ 0,\ \frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0\Big\},$$
$$\Big\{\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\kappa_S^2}{3\,\pi},$$
$$0,\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ \frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},$$
$$\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\kappa_S^2}{3\,\pi},\ 0,\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ 0,\ 0,\ \frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi}\Big\},$$
$$\Big\{-\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ 0,\ \frac{2\,(-i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},$$
$$\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,(i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},$$
$$\frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ 0,\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ -\frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ 0\Big\},$$
$$\Big\{\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ 0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},$$
$$\frac{2\,\kappa_S^2}{3\,\pi},\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\kappa_S^2}{3\,\pi},\ \frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},$$
$$0,\ 0,\ 0,\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ -\frac{2\,\kappa_A\,\kappa_S}{3\,\pi}\Big\},$$
$$\Big\{0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},$$
$$0,\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ 0,\ 0,\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},$$
$$-\frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\,\kappa_S^2}{3\,\pi},\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\kappa_S^2}{3\,\pi},\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ 0\Big\},$$
$$\Big\{0,\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},$$
$$0,\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ 0,\ -\frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},$$
$$-\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,(-i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,(i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},\ 0,\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi}\Big\},$$
$$\Big\{0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},$$
$$0,\ \frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ \frac{2\,\kappa_S^2}{3\,\pi},\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},$$
$$\frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},\ \frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ 0,\ \frac{2\,\kappa_S^2}{3\,\pi},$$
$$\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi}\Big\},\ \Big\{0,\ 0,\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ \frac{4\,i\,\kappa_A\,\mu_F}{3\,\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\,\sqrt{\pi}},$$
$$0,\ \frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ 0,\ \frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ 0,\ 0,\ -\frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ -\frac{(\frac{1}{3}+\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},$$
$$\frac{2\,(i\,\kappa_A^2+\kappa_S^2)}{3\,\pi},\ -\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},$$
$$0,\ \frac{2\,(-\kappa_A^2+\kappa_S^2)}{3\,\pi},\ \frac{(\frac{1}{3}-\frac{i}{3})\,\kappa_A\,\kappa_S}{\pi},\ \frac{2\,(-i\,\kappa_A^2+\kappa_S^2)}{3\,\pi}\Big\},$$

$$\left\{0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\sqrt{\pi}},\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\sqrt{\pi}},\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\sqrt{\pi}},\ 0,\ \frac{\left(\frac{1}{3}-\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ 0,\ 0,\right.$$
$$0,\ -\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ -\frac{\left(\frac{1}{3}+\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ 0,\ \frac{2\,\kappa_S^2}{3\,\pi},\ -\frac{\left(\frac{1}{3}+\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\left(-\kappa_A^2+\kappa_S^2\right)}{3\,\pi},\ 0,$$
$$\left.\frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},\ -\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\,\kappa_S^2}{3\,\pi},\ \frac{\left(\frac{1}{3}-\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi}\right\},$$
$$\left\{0,\ 0,\ \frac{4\,i\,\kappa_A\,\mu_F}{3\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\sqrt{\pi}},\ 0,\ -\frac{4\,i\,\kappa_A\,\mu_F}{3\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\sqrt{\pi}},\ 0,\ \frac{\left(\frac{1}{3}-\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ 0,\ 0,\ 0,\right.$$
$$-\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ -\frac{\left(\frac{1}{3}+\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ -\frac{\left(\frac{1}{3}-\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\left(-i\,\kappa_A^2+\kappa_S^2\right)}{3\,\pi},\ 0,\ \frac{2\,\left(-\kappa_A^2+\kappa_S^2\right)}{3\,\pi},$$
$$\left.\frac{2\,i\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},\ \frac{\left(\frac{1}{3}+\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\left(i\,\kappa_A^2+\kappa_S^2\right)}{3\,\pi}\right\},$$
$$\left\{0,\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\sqrt{\pi}},\ \frac{4\,\kappa_A\,\mu_F}{3\sqrt{\pi}},\ -\frac{4\,\kappa_A\,\mu_F}{3\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\sqrt{\pi}},\ 0,\ 0,\ 0,\ -\frac{\left(\frac{1}{3}-\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\right.$$
$$0,\ -\frac{\left(\frac{1}{3}+\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ 0,\ -\frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ \frac{2\,\left(-\kappa_A^2+\kappa_S^2\right)}{3\,\pi},\ 0,\ \frac{2\,\kappa_S^2}{3\,\pi},\ \frac{\left(\frac{1}{3}+\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},$$
$$\left.\frac{2\,\kappa_S^2}{3\,\pi},\ \frac{\left(\frac{1}{3}-\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi},\ \frac{2\,\kappa_A\,\kappa_S}{3\,\pi}\right\},$$
$$\left\{0,\ 0,\ \frac{4\,\kappa_A\,\mu_F}{3\sqrt{\pi}},\ -\frac{8\,\kappa_S\,\mu_F}{3\sqrt{\pi}},\ 0,\ -\frac{4\,\kappa_A\,\mu_F}{3\sqrt{\pi}},\ 0,\ -\frac{8\,\kappa_S\,\mu_F}{3\sqrt{\pi}},\ 0,\ 0,\ 0,\ -\frac{\left(\frac{1}{3}-\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\right.$$
$$0,\ -\frac{\left(\frac{1}{3}+\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ 0,\ -\frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ 0,\ \frac{2\,\left(-\kappa_A^2+\kappa_S^2\right)}{3\,\pi},\ \frac{\left(\frac{1}{3}-\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\left(i\,\kappa_A^2+\kappa_S^2\right)}{3\,\pi},$$
$$\left.\frac{\left(\frac{1}{3}+\frac{i}{3}\right)\kappa_A\,\kappa_S}{\pi},\ \frac{2\,\left(-i\,\kappa_A^2+\kappa_S^2\right)}{3\,\pi},\ \frac{2\,\kappa_A\,\kappa_S}{3\,\pi},\ \frac{2\left(\kappa_A^2+\kappa_S^2+3\left(-2\,g^2+\sqrt{6}\,g^2+\pi\,\mu_B^2+4\,\pi\,\mu_F^2\right)\right)}{3\,\pi}\right\}\right\}$$

■ Eigenvalues for just g^2 interactions

```
In[126]:= expr =
            N[generalMatrix[makeham, 2, 1, 0, 1, {0, 0, 1, -0.323, 0.162, 0, 0, 0, 0, 0, 0}, none]];
```

This is a list of the different elements of the matrix

```
In[127]:= Union[Flatten[expr]]

Out[127]= {-0.31831, -0.0111039, -0.00555196 - 0.00555196 i, -0.00555196 + 0.00555196 i,
           0., 0. - 0.0111039 i, 0. + 0.0111039 i, 0.00555196 - 0.00555196 i,
           0.00555196 + 0.00555196 i, 0.0111039, 0.0165702, 0.0221393 + 0. i,
           0.0221393 - 0.00556915 i, 0.0221393 + 0.00556915 i, 0.313863, 0.373727}

In[128]:= Sort[Chop[Eigenvalues[expr]]]

Out[128]= {0.0554169, 0.0554169, 0.0554169, 0.0554169, 0.286154, 0.286154, 0.286154, 0.286154,
           0.286154, 0.286154, 0.286154, 0.286154, 0.286154, 0.297292, 0.297292, 0.308431,
           0.374711, 0.38585, 0.38585, 0.396988, 0.692037, 0.692037, 0.692037, 0.692037}
```

These are the diagonal matrix elements

```
In[129]:= diag = Table[expr[[i, i]], {i, Length[expr]}]

Out[129]= {0.373727, 0.373727, 0.373727, 0.373727, 0.373727, 0.373727, 0.373727, 0.373727,
           0.313863, 0.313863, 0.313863, 0.313863, 0.313863, 0.313863, 0.313863, 0.313863,
           0.313863, 0.313863, 0.313863, 0.313863, 0.313863, 0.313863, 0.313863, 0.313863}
```

■ Eigenvalues for mass, g^2, and kappa interactions

The gluon effective potential interactions are not relevant here.

```
In[130]:= expr = N[generalMatrix[makeham, 2, 1, 0, 1,
              {0.1803, 0.362, 1, -0.323, 0.162, 0, 0, 0, 0, 0, 0}, none]];
```

This is a list of the different elements of the matrix

```
In[131]:= Union[Flatten[expr]]

Out[131]= {-0.31831, -0.0441151, -0.0111039, -0.00555196 - 0.00555196 i,
           -0.00555196 + 0.00555196 i, 0., 0. - 0.0111039 i, 0. + 0.0111039 i, 0. - 0.0441151 i,
           0. + 0.0441151 i, 0.00555196 - 0.00555196 i, 0.00555196 + 0.00555196 i,
           0.0111039, 0.0165702, 0.0221393 + 0. i, 0.0221393 - 0.00556915 i,
           0.0221393 + 0.00556915 i, 0.0441151, 0.175916, 1.07263, 1.42723}

In[132]:= Sort[Chop[Eigenvalues[expr]]]

Out[132]= {0.484571, 0.493583, 0.493583, 0.502998, 1.28064, 1.31202, 1.31202, 1.39094,
           1.39952, 1.39952, 1.39952, 1.39952, 1.39952, 1.39952, 1.41965, 1.41965,
           1.43932, 1.48958, 1.48958, 1.5321, 1.7394, 1.73983, 1.73983, 1.74031}
```

These are the diagonal matrix elements

```
In[133]:= diag = Table[expr[[i, i]], {i, Length[expr]}]

Out[133]= {1.07263, 1.07263, 1.07263, 1.07263, 1.07263, 1.07263, 1.07263, 1.07263,
           1.42723, 1.42723, 1.42723, 1.42723, 1.42723, 1.42723, 1.42723, 1.42723,
           1.42723, 1.42723, 1.42723, 1.42723, 1.42723, 1.42723, 1.42723, 1.42723}
```