{tikz-feynman}

Feynman diagrams with Ti*k*Z

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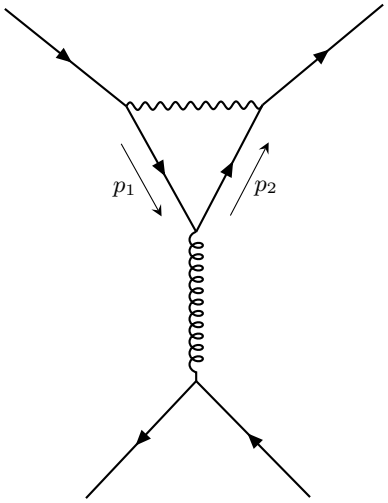
by Joshua Ellis




```
\begin{tikzpicture}
  \graph [feynman, node distance=2.5cm, edges={thick}, vertical= e to f]
  {
    a - [fermion] b - [photon] c - [fermion] d,
    b - [fermion, momentum=\(p_{1}\)] e - [fermion, momentum=\(p_{2}\)] c,
    e - [gluon]  f,
    h - [fermion] f - [fermion] i;
  };
\end{tikzpicture}
```

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1 Introduction

This package provides a set of pre-defined styles in order to draw Feynman diagrams using Ti*k*Z more easily and consistently. The set of styles defined here were originally inspired by this answer on `http://tex.stackexchange.com`, so due credit must go to Jake.

If you have any suggestions or have found any bugs, please feel free to create a new issue or pull request on the Github page: `https://www.github.com/JP-Ellis/tikz-feynman`.

1.1 Installation

This package is *not* currently offered on CTAN as it is just a personal project of mine; however, if enough people find it useful, I will look into making it available through CTAN.

In order to use this as it is, simply download `tikz-feynman.sty` and place it in the same directory as your TEX file and include it using the usual `\usepackage{tikz-feynman}`. Alternatively, it is also possible to install `tikz-feynman` system-wide by placing it inside TEX's search path (which will vary based on your operating system).

In v3.0.0 of Ti*k*Z, there is a bug in the Lua component of the graphdrawing library which prevents it from handling coordinate nodes properly. This bug does not seem to affect the usual Ti*k*Z drawing library. If you wish to use the `\graph` command with any of the options that require Lua, you will need to apply the following patch:

```
--- a/generic/pgf/graphdrawing/lua/pgf/gd/interface/InterfaceToDisplay.lua
+++ b/generic/pgf/graphdrawing/lua/pgf/gd/interface/InterfaceToDisplay.lua
@@ -263,6 +263,13 @@ end

 function InterfaceToDisplay.createVertex(name, shape, path, height, binding_infos, anchors)

+  -- The path should never be empty, so we create a trivial path in the provided
+  -- path is empty.  This occurs with the ‘coordinate‘ shape for example.
+  if #path == 0 then
+    path:appendMoveto(0, 0)
+    path:appendClosepath()
+  end
+
   -- Setup
   local scope = InterfaceCore.topScope()
   local binding = InterfaceCore.binding
```

2 Usage

`tikz-feynman` has three ways of setting up the Feynman diagram. The placement of vertices can either be fully-automated using some algorithm; specified related to other vertices; or fully manual using coordinates. Each method is mostly compatible with the others, so it is possible to specify a an initial set of vertices using one of the graph algorithms, and then place additional vertices relative to these.

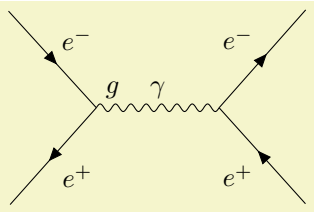
There is one exception: a `\graph` with `feynman spring layout` or `feynman electrical layout` must consist entirely of new nodes and *cannot* anchor to nodes defined outside the graph.

The three methods of placing nodes are illustrated below and see also the examples for uses in different contexts.

2.1 Automatic Placement

The Ti*k*Z graphdrawing library offers the ability to automatically position the vertices of a Feynman diagram by following an algorithm. For some of these algorithm, LuaTEX is required as the edges are modelled by springs, and the vertices may be given charges.

`tikz-feynman` pre-defines three graph styles: `feynman spring layout`, `feynman electrical layout` and `feynman layered layout`. By default, when using `\graph [feynman]`, the spring layout is used which models each edge as springs.

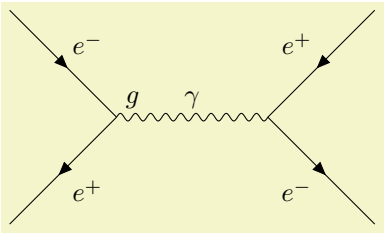



```
\tikz \graph [feynman, horizontal'=a to b] {
    a1 - [fermion, edge label=\(e^{-}\)] a [label=70:\(g\)] - [fermion, edge
label=\(e^{+}\)] a2,
    a  - [photon, edge label=\(\gamma\)] b,
    b1 - [fermion, edge label=\(e^{+}\)] b - [fermion, edge
label=\(e^{-}\)] b2;
  };
```

2.2 Semi-automatic Placement

Ti*k*Z also provides the ability to place vertices relative to other previously labelled vertices using various `above=of name`, `left=of name`, and similar keys. `tikz-feynman` also provides the command `\vertex` which just a shorthand for `\node[vertex]`. In the future, `\vertex` is intended to intelligently recognize when a vertex has a name and adapt the style to display the name.

Once the nodes have been placed, it is possible to use a simple `\graph` environment in order to draw in the edges, or alternatively, using the `\draw` command.

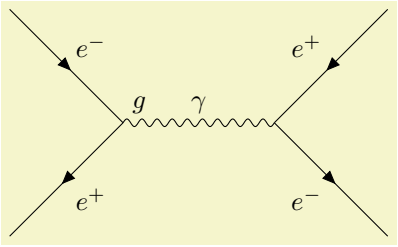



```
\begin{tikzpicture}[feynman]
  \vertex [label=70:\(g\)] (a) {};
  \vertex (b) [right=of a] {};
  \vertex (a1) [above left=of a] {};
  \vertex (a2) [below left=of a] {};
  \vertex (b1) [above right=of b] {};
  \vertex (b2) [below right=of b] {};

  \graph {
    (a1) - [fermion, edge label=\(e^{-}\)] (a) [label=70:\(g\)] - [fermion, edge label=\(e^{+}\)] (a2),
    (a)  - [photon, edge label=\(\gamma\)] (b);
    (b1) - [fermion, edge label'=\(e^{+}\)] (b) - [fermion, edge label'=\(e^{-}\)] (b2);
  };
\end{tikzpicture}
```

2.3 Manual Placement

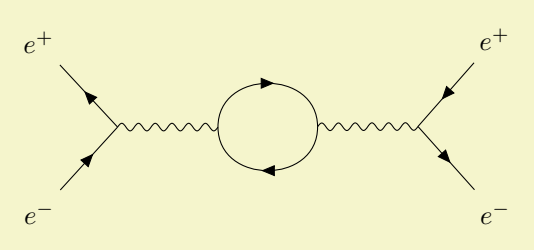
Lastly, it is possible to fully specify each vertex' coordinates.



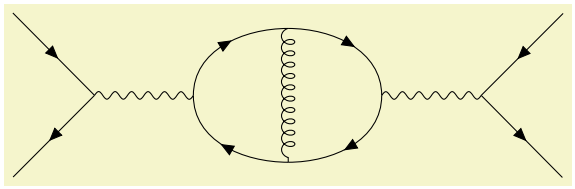

```
\begin{tikzpicture}[feynman]
  \vertex[label=70:\(g\)] (a) at (-1, 0) {};
  \vertex (b)  at (1, 0)       {};
  \vertex (a1) at (-2.5, 1.5)  {};
  \vertex (a2) at (-2.5, -1.5) {};
  \vertex (b1) at (2.5, 1.5)   {};
  \vertex (b2) at (2.5, -1.5)  {};

  \graph {
    (a1) - [fermion, edge label=\(e^{-}\)] (a) [label=70:\(g\)] - [fermion, edge label=\(e^{+}\)] (a2),
    (a)  - [photon, edge label=\(\gamma\)] (b);
    (b1) - [fermion, edge label'=\(e^{+}\)] (b) - [fermion, edge label'=\(e^{-}\)] (b2);
  };
\end{tikzpicture}
```

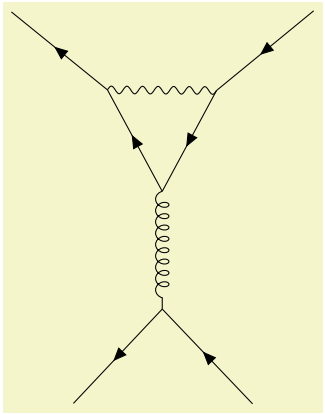
3 Examples



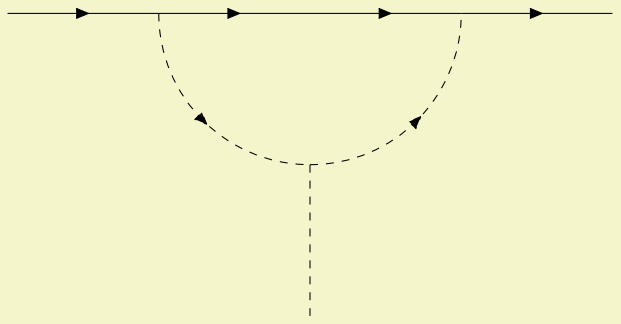

```
\begin{tikzpicture}
  \graph [feynman, horizontal=a to b1]
  {
    ai [particle=\(e^{-}\)] - [fermion] a - [fermion] af [particle=\(e^{+}\)],
    a  - [photon] b1 - [fermion, semi-left] b2 - [fermion, semi-left] b1,
    b2 - [photon] c,
    ci [particle=\(e^{+}\)] - [fermion] c - [fermion] cf [particle=\(e^{-}\)];
  };
\end{tikzpicture}
```



```
\begin{tikzpicture}
  \graph [feynman, horizontal=b1 to b3]
  {
    ai - [fermion] a - [fermion] af,
    a  - [photon] b1,
    b3 - [photon] c,
    ci - [fermion] c - [fermion] cf;
    {[edges={fermion, looseness=1}]
      b1
      - [out=90, in=180] b2
      - [out=0, in=90] b3
      - [out=-90, in=0] b4
      - [out=180, in=-90] b1,
    };
  };
  \draw[gluon] (b2) - (b4);
\end{tikzpicture}
```

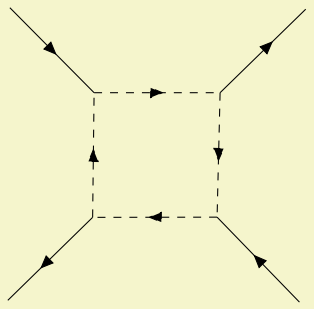


```
\begin{tikzpicture}
  \graph [feynman, vertical=e to f]
  {
    a - [fermion] b - [photon] c - [fermion] d,
    b - [fermion] e - [fermion] c,
    e - [gluon]  f,
    h - [fermion] f - [fermion] i;
  };
\end{tikzpicture}
```

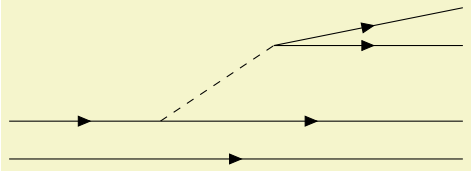


```
\begin{tikzpicture}[feynman]
  \graph [feynman layered layout, grow=right, edges={fermion}] {
    a - b - c - d - e
  };
  \vertex (v) [below=of c] {};
  \vertex (h) [below=of v] {};

  \draw[charged scalar] (b) to [out=-90, in=180] (v);
  \draw[charged scalar] (v) to [out=0, in=-90] (d);
  \draw[scalar] (v) to (h);
\end{tikzpicture}
```

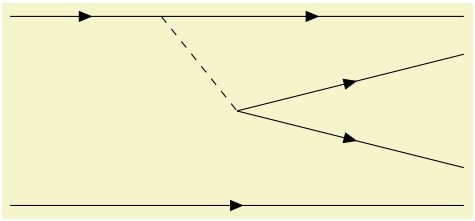


```
\begin{tikzpicture}
  \graph [feynman electrical layout, horizontal=a to b] {
    { [edges={charged scalar}]
      a - b - c - d - a
    },
    a1 -[fermion] a,
    b1 -[anti fermion] b,
    c1 -[fermion] c,
    d1 -[anti fermion] d;
  };
\end{tikzpicture}
```



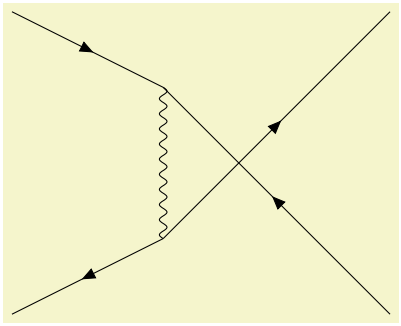
```
\begin{tikzpicture}[feynman]
  \vertex (a1) {};
  \vertex (a2) [right=of a1] {};
  \vertex (a3) [right=4cm of a2] {};
  \vertex (b2) [above=1cm of a3] {};
  \vertex (b1) [left=2.5cm of b2] {};
  \vertex (c)  [above=0.5cm of b2] {};
  \vertex (s1) [below=0.5cm of a1] {};
  \vertex (s2) [below=0.5cm of a3] {};

  \graph {
    {[edges={fermion}]
      (a1) - (a2) - (a3),
      (b1) - (b2),
      (b1) - (c),
      (s1) - (s2),
    },
    (a2) - [scalar] (b1),
  };
\end{tikzpicture}
```



```
\begin{tikzpicture}[feynman]
  \vertex (a1) {};
  \vertex (a2) [right=of a1] {};
  \vertex (a3) [right=4cm of a2] {};
  \vertex (b2) [below=0.5cm of a3] {};
  \vertex (b1) [below left=0.75cm and 3cm of b2] {};
  \vertex (b3) [below=1.5cm of b2] {};
  \vertex (s1) [below=2.5cm of a1] {};
  \vertex (s2) [below=2.5cm of a3] {};

  \graph {
    {[edges={fermion}]
      (a1) - (a2) - (a3),
      (b1) - (b2),
      (b1) - (b3),
      (s1) - (s2),
    },
    (a2) - [scalar] (b1),
  };
\end{tikzpicture}
```



```
\begin{tikzpicture}[feynman]
  \vertex (a1) {};
  \vertex (a2) [below=4cm of a1] {};
  \vertex (b1) [below right=1cm and 2cm of a1] {};
  \vertex (b2) [above right=1cm and 2cm of a2] {};
  \vertex (c1) [right=5cm of a1] {};
  \vertex (c2) [right=5cm of a2] {};

  \graph {
    { [edges=fermion]
      (a1) - (b1),
      (c2) - (b1),
      (b2) - (a2),
      (b2) - (c1),
    },
    (b1) - [photon] (b2),
  };
\end{tikzpicture}
```

4 Documentation

/tikz/feynman (no value)

Sets certain options within the scope to be so that they work consistently across the various positioning methods. Note that any `\graph`

Sets the `below=of name` spacing to values consistent with the way graphs will place the nodes.

4.1 Graph Drawing

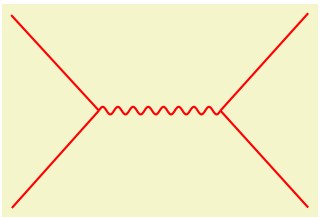
The following keys are defined for the `\graph` command. Please refer to the graphdrawing documentation in the main Ti*k*Z manual for additional information.

/tikz/graphs/feynman (no value)

The default style for Feynman diagrams; simply a shorthand for `feynman spring layout`.

/tikz/graphs/every feynman (no value)

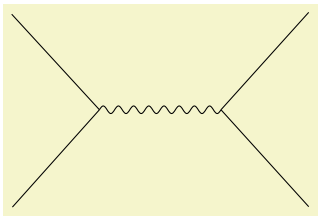
Provides the basic underlying style to all Feynman diagrams created using `\graph`.



```
\tikzset{graphs/every feynman/.append style={edges={red, thick}}}
% ...
\tikz \graph [feynman, horizontal=c to d] {
  {a, b} - c - [photon] d - {e, f}
};
```

/tikz/graphs/feynman spring layout (no value)

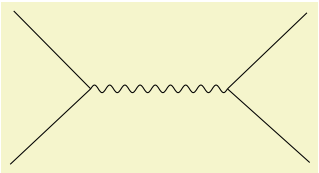
Models each edge as a spring when determining the final placement of the vertices. This requires LuaTEX.



```
\tikz \graph [feynman spring layout, horizontal=c to d] {
  {a, b} - c - [photon] d - {e, f}
};
```

/tikz/graphs/feynman electrical layout (no value)

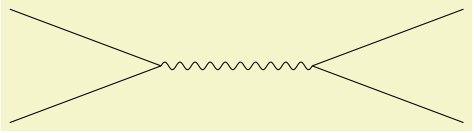
Models each edge as a spring and gives each vertex a charge when determining the final placement of the vertices. This requires LuaTEX.



```
\tikz \graph [feynman electrical layout, horizontal=c to d] {
  {a, b} - c - [photon] d - {e, f}
};
```

/tikz/graphs/feynman layered layout (no value)

Models each edge as a spring and gives each vertex a charge when determining the final placement of the vertices. This requires LuaTEX.

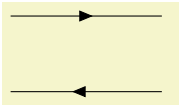


```
\tikz \graph [feynman layered layout, grow=right] {
  {a, b} - c - [photon] d - {e, f}
};
```

4.2 Edge Styles

/tikz/with arrow (no value)
/tikz/with reversed arrow (no value)

Adds an arrow in the middle pointing forwards in the case of `with arrow`, or pointing backward in the case of `with reversed arrow`.



```
\begin{tikzpicture}
  \draw[with arrow]          (0, 1) to (2, 1);
  \draw[with reversed arrow] (0, 0) to (2, 0);
\end{tikzpicture}
```

/tikz/photon (no value)

Sinusoidal line for photons.


```
\tikz \draw[photon] (0, 0) to (2, 0);
```

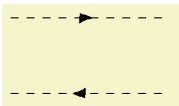
/tikz/scalar (no value)

Dashed line for scalars.


```
\tikz \draw[scalar] (0, 0) to (2, 0);
```

/tikz/charged scalar (no value)
/tikz/anti charged scalar (no value)

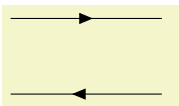
Dashed line with an arrow for charged scalars. The arrow is reversed for `anti charged scalar`.



```
\begin{tikzpicture}
  \draw[charged scalar]      (0, 1) to (2, 1);
  \draw[anti charged scalar] (0, 0) to (2, 0);
\end{tikzpicture}
```

/tikz/fermion (no value)
/tikz/anti fermion (no value)

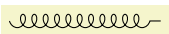
Solid line with an arrow for fermions. The arrow is reversed for `anti fermion`.



```
\begin{tikzpicture}
  \draw[fermion]      (0, 1) to (2, 1);
  \draw[anti fermion] (0, 0) to (2, 0);
\end{tikzpicture}
```

/tikz/gluon (no value)

Coils for gluons.



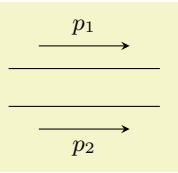
```
\tikz \draw[gluon] (0, 0) to (2, 0);
```

4.2.1 Momentum Arrows

/tikz/momentum=⟨*label*⟩ (default empty)
/tikz/momentum'=⟨*label*⟩ (default empty)

Draw an arrow parallel to the edge with ⟨*label*⟩ if specified. The alternative momentum' places the arrow on the other side of the edge.

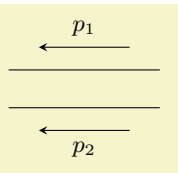
The separation between the edge and the arrow, and the label and the arrow can be changed through the momentum/distance and momentum/label distance keys. Similarly, the distance by which the arrows are shortened compared to the edge is specified in momentum/shorten.




```
\begin{tikzpicture}
  \draw[momentum'=\(p_1\)]  (0, 0.5) to (2, 0.5);
  \draw[momentum=\(p_2\)]   (0, 0) to (2, 0);
\end{tikzpicture}
```

/tikz/reversed momentum=⟨*label*⟩ (default empty)
/tikz/reversed momentum'=⟨*label*⟩ (default empty)
/tikz/rmomentum=⟨*label*⟩ (default empty)
/tikz/rmomentum'=⟨*label*⟩ (default empty)

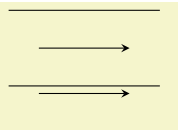
The same as momentum and momentum' respectively, with the arrow direction reversed. The rmomentum and rmomentum' keys are simply abbreviations.




```
\begin{tikzpicture}
  \draw[reversed momentum'=\(p_1\)]  (0, 0.5) to (2, 0.5);
  \draw[reversed momentum=\(p_2\)]   (0, 0) to (2, 0);
\end{tikzpicture}
```

/tikz/momentum/distance=⟨*distance*⟩ (default 3mm)

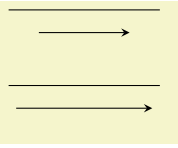
Specify the distance separating the arrow and edge



```
\begin{tikzpicture}
  \draw[momentum/distance=5mm, momentum] (0, 1) to (2, 1);
  \draw[momentum/distance=1mm, momentum] (0, 0) to (2, 0);
\end{tikzpicture}
```

/tikz/momentum/shorten=⟨*distance*⟩ (default 4mm)

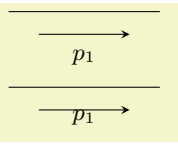
Specify the amount by which the momentum arrows are shortened compared to the end.



```
\begin{tikzpicture}
  \draw[momentum/shorten=4mm, momentum] (0, 1) to (2, 1);
  \draw[momentum/shorten=1mm, momentum] (0, 0) to (2, 0);
\end{tikzpicture}
```

/tikz/momentum/label distance=⟨*distance*⟩ (default 2.5mm)

Specify the distance separating the momentum arrow label and the momentum arrow.

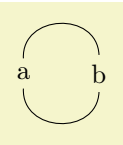



```
\begin{tikzpicture}
  \draw[momentum/label distance=3mm, momentum=\(p_1\)] (0, 1) to (2, 1);
  \draw[momentum/label distance=1mm, momentum=\(p_1\)] (0, 0) to (2, 0);
\end{tikzpicture}
```

4.2.2 Edge Modifiers

/tikz/semi-left (no value)

Causes the edge to turn left and complete a semicircle until it reaches the next node.




```
\tikz \graph[horizontal=a to b] { a -[semi-left] b -[semi-left] a };
```

/tikz/semi-right (no value)

Same as /tikz/semi-left, but going around the other way.

4.3 Vertex Styles

/tikz/vertex (no value)

The base node style used in Feynman diagram.

/tikz/every vertex (no value)

A style applied to all vertices in a Feynman diagram.


```
\tikzset{every vertex/.style={red, shape=circle}}
% ...
\tikz \graph[feynman, horizontal=a to b] {a - b};
```

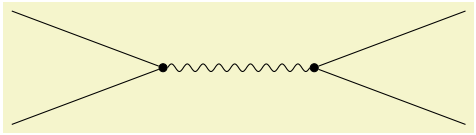
/tikz/particle=⟨*name*⟩ (no default)

Place the particle ⟨*name*⟩ at the location of the vertex. This should only be used for terminal vertices.


```
\tikz \graph[feynman, horizontal=a to b] {
  a [particle=\(e^{-}\)] - [fermion] b [particle=\(e^{-}\)]
};
```

/tikz/dot (no value)

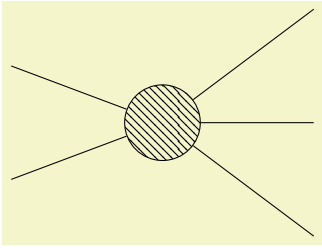
Style the vertex as a dot.



```
\tikz \graph[feynman layered layout, grow=right] {
  {a, b} - c [dot] - [photon] d [dot] - { e, f }
};
```

/tikz/blob (no value)

Style the vertex as a blob.



```
\tikz \graph[feynman layered layout, grow=right] {
  {a, b} - c [blob] - {d, e, f}
};
```

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This index only contains automatically generated entries. A good index should also contain carefully selected keywords. This index is not a good index.

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