- **10 pairs of random massless leptons**
  4 momenta are {vec p, E}

In[812]:=
```
pairs
```

Out[812]=
```
{{{21.691, -12.223, -7.6778, 26.055}, {30.149, 27.176, -27.178, 48.848}},
 {{-8.1957, -7.3859, -3.0376, 11.443}, {19.244, -7.2294, 28.897, 35.463}},
 {{2.8428, -2.3513, 0.13646, 3.6917}, {7.6949, 18.795, 25.084, 32.275}},
 {{28.192, 0.74774, 4.8632, 28.618}, {8.0718, 1.5359, 0.037766, 8.2167}},
 {{6.898, -19.743, -36.677, 42.221}, {1.336, 1.3785, -0.93809, 2.1367}},
 {{-26.931, -0.062688, 21.151, 34.244}, {1.5524, 4.9809, 9.0425, 10.44}},
 {{9.9862, -15.769, -11.921, 22.147}, {8.2757, 1.9508, 5.1564, 9.9439}},
 {{-6.3636, -6.1292, 4.7521, 10.032}, {-1.4069, -1.5201, -3.0108, 3.6544}},
 {{-10.007, 18.829, 6.3049, 22.236}, {2.4327, -2.479, 4.074, 5.3536}},
 {{32.456, -24.36, 7.6178, 41.29}, {-17.126, 1.8017, 16.718, 24.001}}}
```

- the invariant mass of the first particle listed

In[824]:=
```
dot[pairs[[1, 1]], pairs[[1, 1]]]
```

Out[824]=
$$2.2737 \times 10^{-13}$$

- **sums Q for each pair**

Out[813]=
```
{{51.84, 14.953, -34.856, 74.903}, {11.048, -14.615, 25.859, 46.906},
 {10.538, 16.444, 25.22, 35.967}, {36.264, 2.2837, 4.901, 36.835},
 {8.234, -18.365, -37.615, 44.357}, {-25.379, 4.9182, 30.194, 44.684},
 {18.262, -13.818, -6.7641, 32.091}, {-7.7705, -7.6493, 1.7414, 13.687},
 {-7.574, 16.35, 10.379, 27.589}, {15.33, -22.558, 24.336, 65.291}}
```

- **normalized hatZ 4-vectors for each pair**
  The formula is hatZ = Z^\mu/Sqrt[- Z^\nuZ^\nu]

```
Table[ qnow = pairs[[p, 1]] + pairs[[p, 2]] ;
 hatz[qnow], {p, Length[pairs]}]
```

Out[814]=
```
{{0., 0., 1.1298, -0.52574}, {0., 0., 1.1986, 0.66079},
 {0., 0., 1.4026, 0.98354}, {0., 0., 1.009, 0.13425}, {0., 0., 1.8868, -1.6},
 {0., 0., 1.3566, 0.91666}, {0., 0., 1.023, -0.21563},
 {0., 0., 1.0082, 0.12827}, {0., 0., 1.0793, 0.40602}, {0., 0., 1.0777, 0.40167}}
```

- **Check every hatZ is 4D orthogonal to every Q**
  and every one is normalized

Out[816]=
$$\left\{0.,\ 3.5527 \times 10^{-15},\ 0.,\ 8.8818 \times 10^{-16},\ 0.,\ 0.,\ -8.8818 \times 10^{-16},\ -8.8818 \times 10^{-16},\ 1.7764 \times 10^{-15},\ 0.\right\}$$

Out[817]=
```
{-1., -1., -1., -1., -1., -1., -1., -1., -1., -1.}
```

- **The lepton momentum differences diff=(k1-k2)/2 for each pair**

Out[818]=
```
{{-4.2286, -19.7, 9.75, -11.396}, {-13.72, -0.078233, -15.967, -12.01},
 {-2.4261, -10.573, -12.474, -14.292}, {10.06, -0.3941, 2.4127, 10.201},
 {2.781, -10.561, -17.869, 20.042}, {-14.242, -2.5218, 6.0544, 11.902},
 {0.85527, -8.8599, -8.5385, 6.1015}, {-2.4783, -2.3045, 3.8815, 3.1889},
 {-6.2197, 10.654, 1.1155, 8.4411}, {24.791, -13.081, -4.5502, 8.6444}}
```

- **res= cos theta = hat difference dot hat z**
  hat difference = diff^mu /Sqrt[-diff_nu diff^nu]

Out[819]=
```
{-0.26078, 0.6479, 0.414, -0.60219, 0.2714, 0.26425, 0.69212, -0.86663, 0.24525, 0.30964}
```

- **here' s a histogram of 1000 such cos theta's the error bars are root-n points in the bin**

In[798]:=
```
histo[.1, res]
```

Out[798]=