Data analysis exercises

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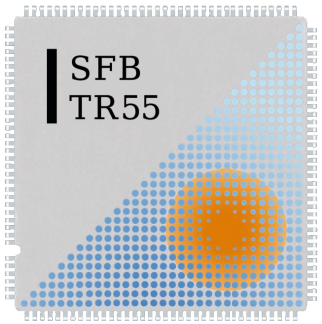

Lattice Practices 2012
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please copy the directory
/afs/ifh.de/group/ape/lap/12/analysis/octave_routines
please start octave either locally or on pax8x
/afs/ifh.de/group/ape/lap/12/octave

Octave basics

Octave is an interpreter:

```
octave:1> a=1
a =  1
```

Don't print results:

```
octave:1> a=1;
```

Print an expression:

```
octave:1> a
a =  1
```

Octave arrays

Octave can handle arrays well:

```
octave:1> a=[1,2,3,4,5]
a =
   1   2   3   4   5
```

Simpler:

```
octave:1> a=1:5
a =
   1   2   3   4   5
```

Also with step sizes:

```
octave:1> a=5:-0.5:3
a =
    5.0000    4.5000    4.0000    3.5000    3.0000
```

Octave treats objects as matrices:

```
octave:1> a=[1,1;0,2]
a =
   1   1
   0   2
```

Arithmetic operations are natively matrix:

```
octave:1> a^2
ans =
   1   3
   0   4
```

If you want it element-wise:

```
octave:1> a.^2
ans =
   1   1
   0   4
```

Octave vectors

Octave octave distinguished between row vectors

```
octave:1> a=[1,2]
a =
   1   2
```

and column vectors

```
octave:1> b=[1;2]
b =
   1
   2
```

Transposition is simple:

```
octave:1> b'
ans =
   1   2
```

Octave matrix multiply

If we define a row vector

```
octave:1> a=[1,2]
a =
   1   2
```

there is of course a difference between

```
octave:1> a*a'
ans =  5
```

and

```
octave:1> a'*a
ans =
   1   2
   2   4
```

Octave eigenvalues

Let us define a symmetric matrix:

```
octave:1> m=[2,1;1,4]
m =
   2   1
   1   4
```

We can find the eigenvalues:

```
octave:1> eig(m)
ans =
   1.5858
   4.4142
```

Octave example

To find the eigenvectors as well, use:

```
octave:1> [vec,val]=eig(m)
vec =
  -0.92388   0.38268
   0.38268   0.92388
val =
Diagonal Matrix
   1.5858         0
        0   4.4142
```

So we can reconstruct the original matrix:

```
octave:1> vec*val*vec'
ans =
   2.00000   1.00000
   1.00000   4.00000
```

Octave matrix functions

Initializing matrix (zeros, rand, diag) example:

```
octave:1> m=rand(2)
m =
   0.089507   0.047387
   0.718905   0.878561
```

Sum (and prod) reduces one dimension:

```
octave:1> sum(m)
ans =
   0.80841   0.92595
octave:2> sum(m,2)
ans =
   0.13689
   1.59747
```

Octave cell arrays

One last detail: cell arrays

```
octave:1> a={1,"string"}
a =
{
  [1,1] =  1
  [1,2] = string
}
```

They may contain different objects and are accessed as:

```
octave:1> a{1}
ans =  1
octave:2> a{2}
ans = string
```

Octave cell arrays

Cell arrays can easily be enlarged:

```
octave:1> a=[a [1,2]]
a =
{
  [1,1] =  1
  [1,2] = string
  [1,3] =
     1   2
}
octave:2>a{3}
ans =
   1   2
```

Let's start!

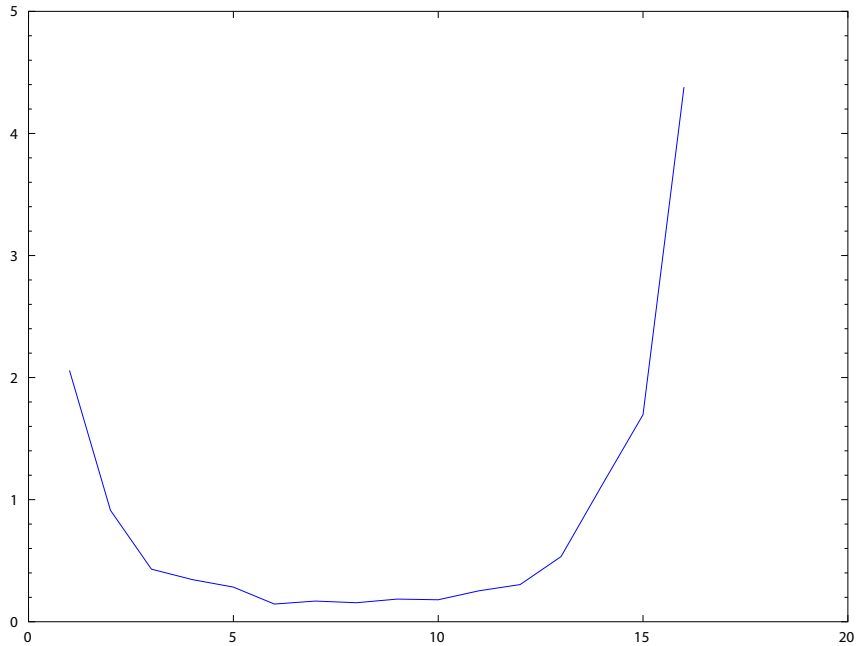
Please open the file "readme.m"

Produce one fake "pion" propagator:

```
octave:1> myprop1=piprop(16)
```

and plot it:

```
octave:1> plot(myprop1{1})
```



directory:

```
/afs/ifh.de/group/ape
/lap/12/analysis
/octave_routines
```

Displaying data

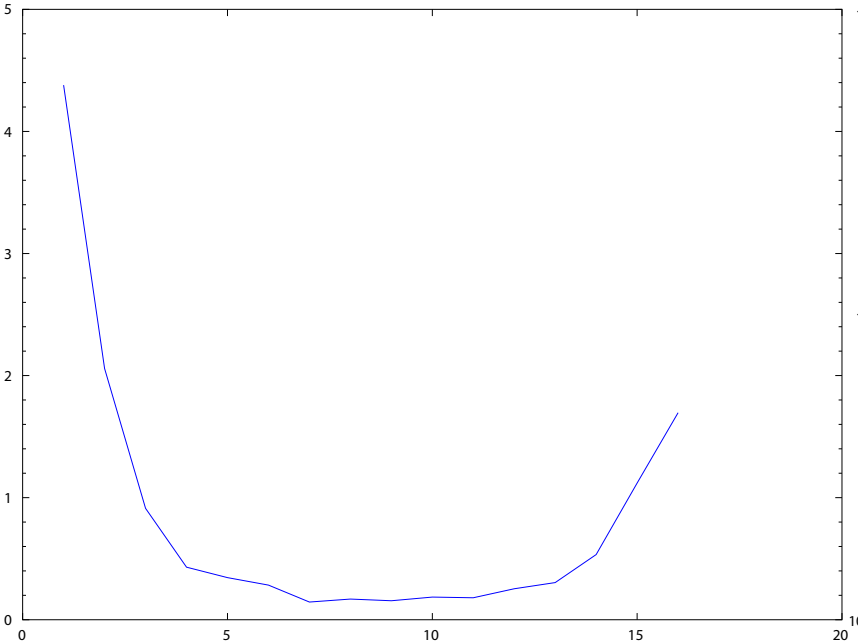
Please don't look at "piprop.m" or any "[..]prop.m" file yet!

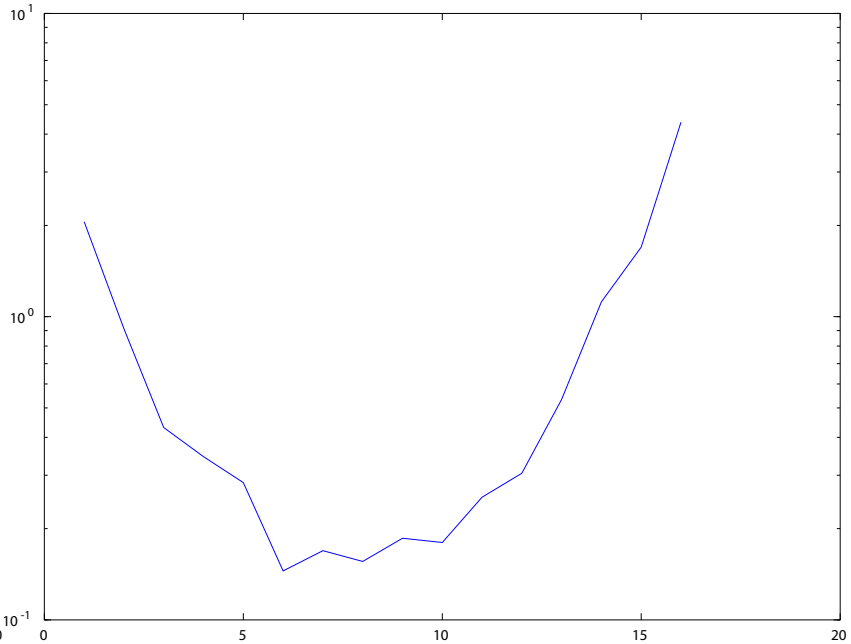
If you like the origin at 0 instead of 16:

```
octave:1> plot(myprop1{1}([end 1:end-1]))
```

For a logarithmic y-scale plot:

```
octave:1> semilogy(myprop1{1})
```





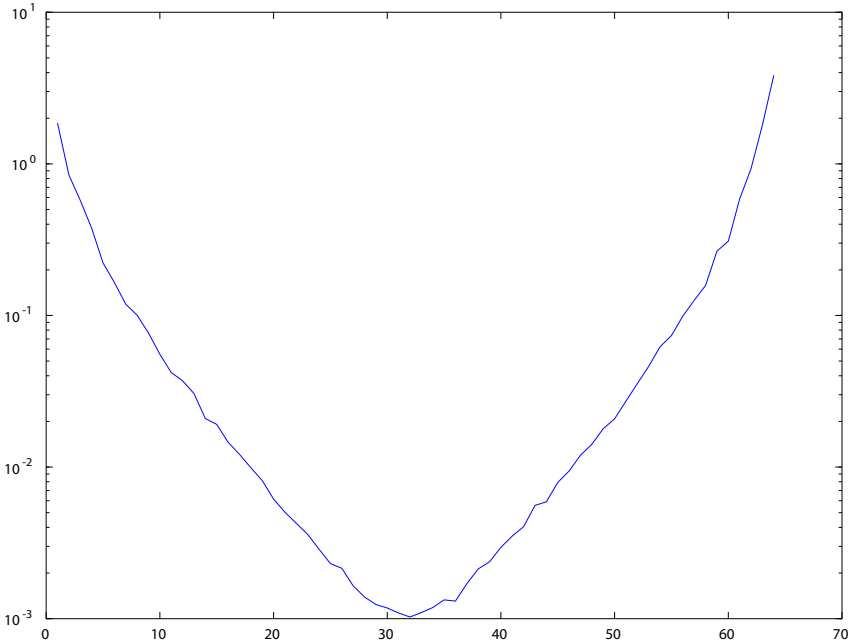
The first ensemble

Now 100 configs with $N_T = 64$:

```
octave:1> prop=piprop(64,100);
```

For a logarithmic y-scale plot:

```
octave:1> semilogy(prop{1})
```



Bootstrapping

Produce 200 bootstrap samples:

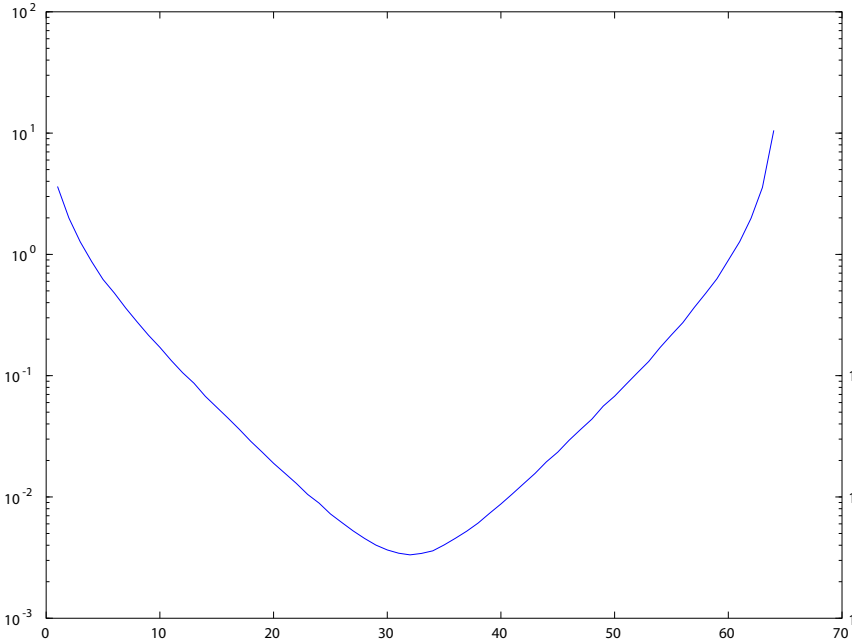
```
octave:1> bp=boot(prop,200);
```

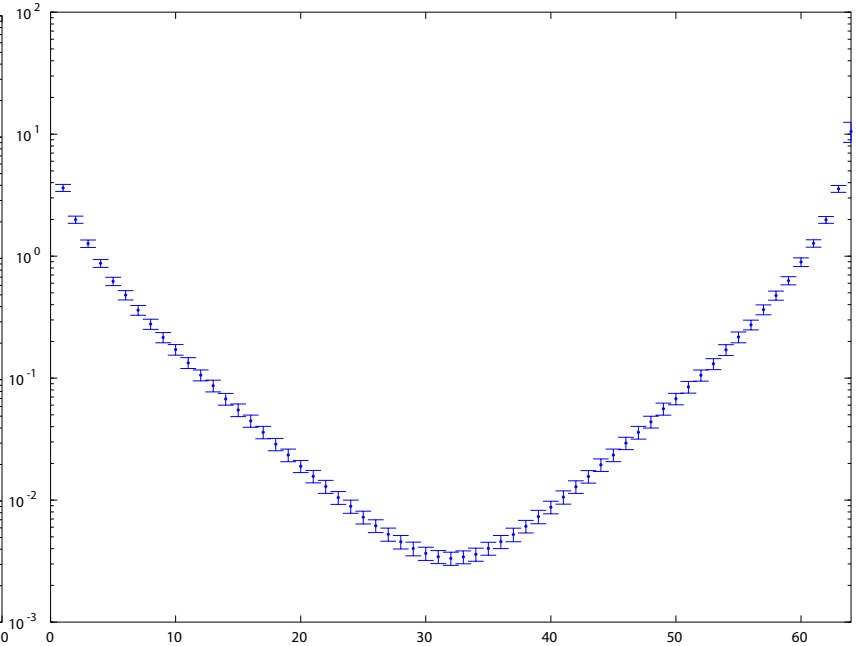
Plot the average (column 201):

```
octave:1> semilogy(bp(:,end))
```

Routine for plotting with errors:

```
octave:1> plotprop(bp)
```





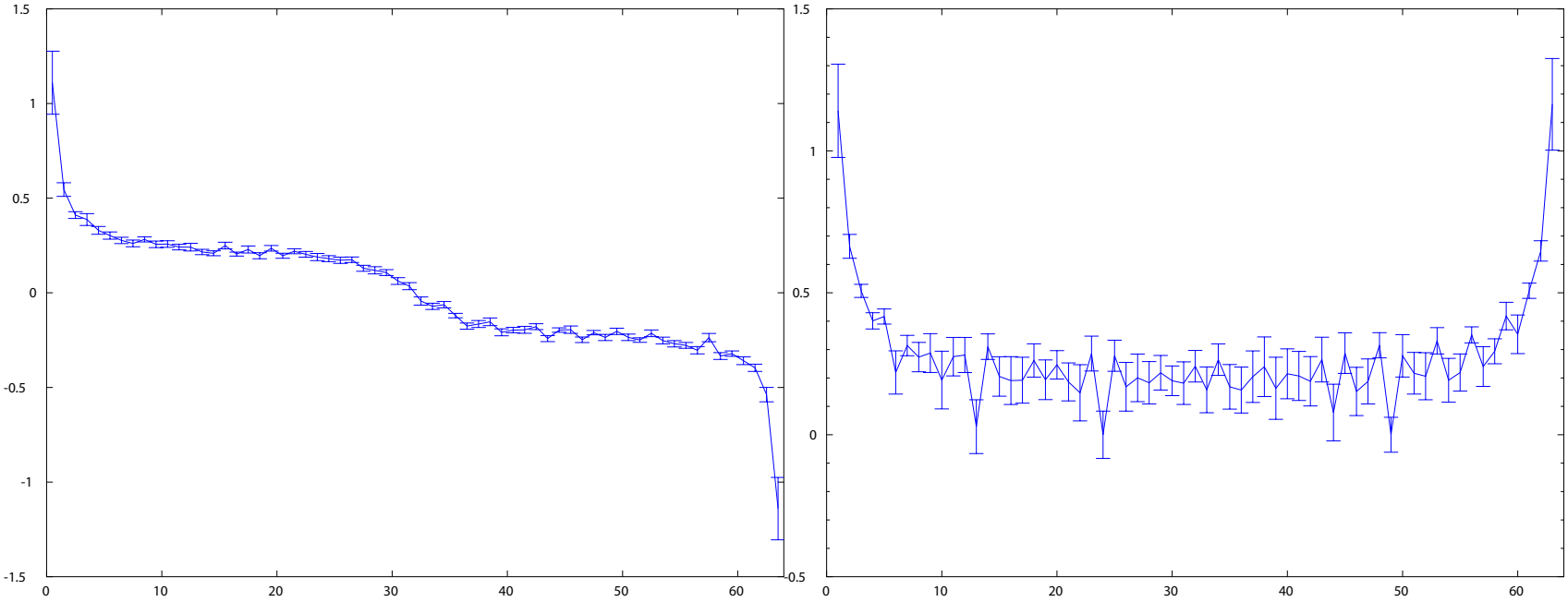
Effective mass

Effective mass with simple exp:

```
octave:1> plotplat(bp)
```

Effective mass with cosh:

```
octave:1> plotsymplat(bp)
```

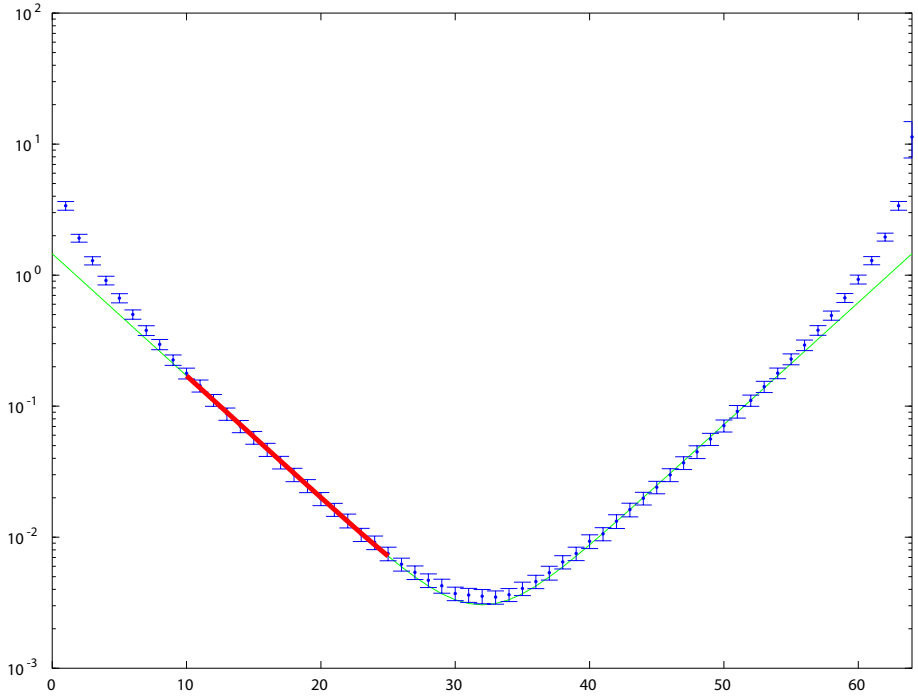


Mass fit

```
uncorrelated_fit=0
fully_correlated_fit=-1

central_value_only=1
full_bootstrap_fit=0

do_plot=1
dont_plot=0
```




```
massfit(bp,uncorrelated_fit,10,25,
                central_value_only,do_plot)
```

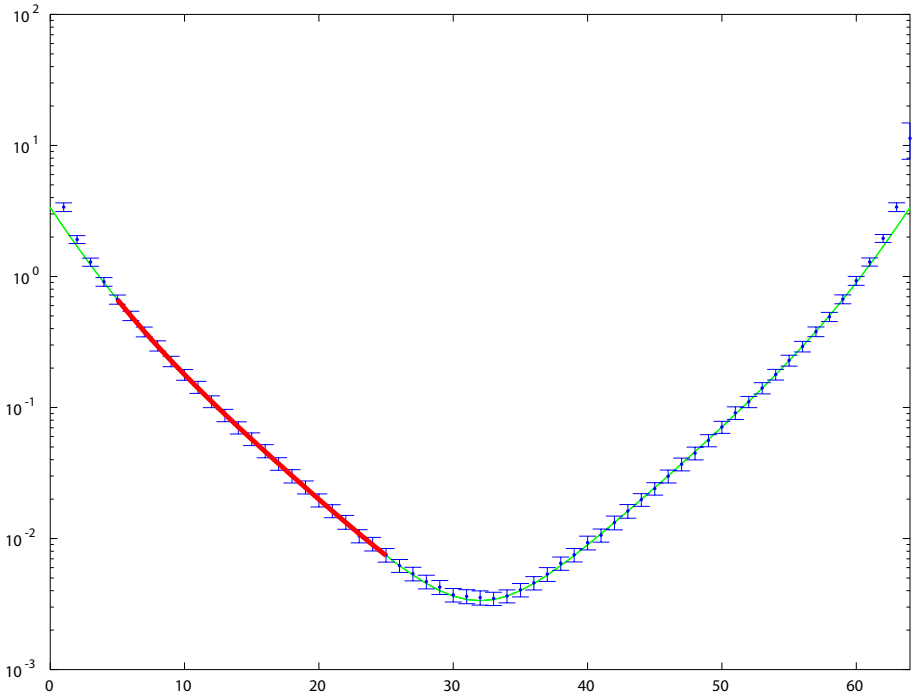
Multiple output variables

```
octave:1> [m,em,c,ec,fitq]=massfit(bp,0,10,25)
m =  0.21448
em =  0.0024118
c =  1.4575
ec =  0.13362
fitq =  0.99984
```

Excited state fit

You might want to try a fit with 2 coshs:

```
octave:1> [m,em,c,ec,fitq,m2,em2,c2,ec2]=
                    exsfit(bp,0,5,25,0,1)
m =   0.20403
em =   0.0028877
c =   1.1466
ec =   0.15216
fitq =   1.00000
m2 =   0.43349
em2 =   0.026877
c2 =   2.2185
ec2 =   0.28166
```



Correlation matrix eigenvalues

Eigenvalues of correlation matrix:

```
octave:1> correlation_matrix_solution(bp(10:25,:))
ans =
   1.1263e-03
   1.5686e-03
   1.8096e-03
   2.8204e-03
   3.8986e-03
   7.4055e-03
   8.9888e-03
   1.2718e-02
   1.6033e-02
   2.2189e-02
   2.8986e-02
   3.4987e-02
```

Your routine

Eigenvalues of correlation matrix:

```
function ev=correlation_matrix_template(bp)
# this is a template for a routine that should
# compute the normalized correation matrix and
# its eigenvalues from a bootstrap array
   N=size(bp)(1);     # number of points
   NB=size(bp)(2)-1; # number of bootstrap samples

# insert code here

   ev=eig(cor);
endfunction
```

Correlation matrix solution

```
# take out normalization
   bav=sum(bp(:,1:NB),2)/NB;
   ac=sqrt((sum(bp(:,1:NB).^2,2)/NB-bav.^2)*
                  (1+(1/(NB-1))));

# form the covariance matrix
   cor=zeros(N); # initialize cor as N*N matrix
   for x=1:N
       for y=1:N
           cor(y,x)=(bp(y,1:NB)-bav(y))*
                          (bp(x,1:NB)-bav(x))'/
                         (NB-1)/(ac(x)*ac(y));
       end
   end
```

Find the mass!

- Explore the fitting routine
- Try varying nfonf, nboot, NT, fit range, correlation
- Find the “pion” mass and its error
- Upload your results to

`/afs/ifh.de/group/ape/lap/12/analysis/mpi_results/xxxx_mpi`

`/afs/ifh.de/group/ape/lap/12/analysis/mpi_results/xxxx_err`

- If you are done, you can try “rhoprop” instead of “piprop”

have fun!

Going to the physical point

Please open the file “day2.m”

generate one well behaved ensemble at “bare quark mass” mq:

```
NT=64
NBOOT=100
NCONF=100
mq=-0.01

octave:1> prp=easy_piprop(NT,mq,NCONF);
```

Bootstrap it and look at the pion mass:

```
octave:1> bpr=boot(prp,NBOOT);
octave:2> m=massfit(bpr,0,15,30,1,1)
Only central value computed!
m =  0.57282
```

Finding

The physical point

We are at $1/a = 1.5$ GeV, so the target "physical" $m_\pi a = 0.09$

Produce ensembles that allow you to go to the physical point

- You can either interpolate or extrapolate
- Neat the "physical point" propagators are more noisy

Generating ensembles

Template ensemble generation:

```
# a random table of quark masses
masstab=[0,-0.04,-0.06,-0.08]

for i=1:length(masstab)
    prp=easy_piprop(NT,masstab(i),NCONF);
    bp{i}=boot(prp,NBOOT);
# mb and cb are bootstrap results for m and c
    [m,em,c,ec,q,mb{i},cb{i}]=massfit(bp{i},0,15,30);
# extract f from c=f^2*m^2
    fb{i}=sqrt(abs(cb{i}))./mb{i};
end
```

Going to the physical point

Please open the file “chiralfit_template.m”

This is a long fit routine with a very simple core:

```
        stp=[d0,k0];
# do the constrained fit
        [par,ch2c,info]=sqp(stp',@constrainedfit,
                                  [],[],[],[],1000);
```

A χ^2 function is minimized, x-errors are yet ignored

Function to minimize

```
function chisq=constrainedfit(par)
# chi^2 function for constrained fpi-mpi^2 fit
   global _f _m _er _n

   chisq=0;
   for i=1:_n
       mm=_m(i);
       ff=fps(mm,par);
       ex=[_m(i)-mm,_f(i)-ff];
       chisq+=ex*_er{i}*ex';
   end
   chisq;
endfunction
```

Fit function

x-values (_m), y-values (_f) and the inverse covariance matrix (_er) are global:

```
global _f _m _er

octave:1> global _f
octave:2> _f
_f =
   0.068717   0.072484   0.075524   0.073040
```

The actual linear fit function:

```
 function ff=fps(m,c)
# the actual fit function
    ff=c(1)+c(2)*m;
endfunction
```

Full fit exercise

Then all masses are added as parameters:

```
stp=par';
for i=1:N
    stp=[stp _m(i)];
end
```

And the full fit is performed:

```
[par,ch2,info]=sqp(stp',@fullfit,[],[],[],[],1000);
```

Complete the routine fullit!

The solution is in “chiralfit_solution.m”

Completing full fit

```
function chisq=fullfit(par)
# chi^2 function for full fpi-mpi^2 fit
   global _f _m _er _n

###################
# YOUR CODE GOES HERE
# remember: par(3:) are
# the fitted masses
# (x-axis)
###################
endfunction
```

The solution is in “chiralfit_solution.m”

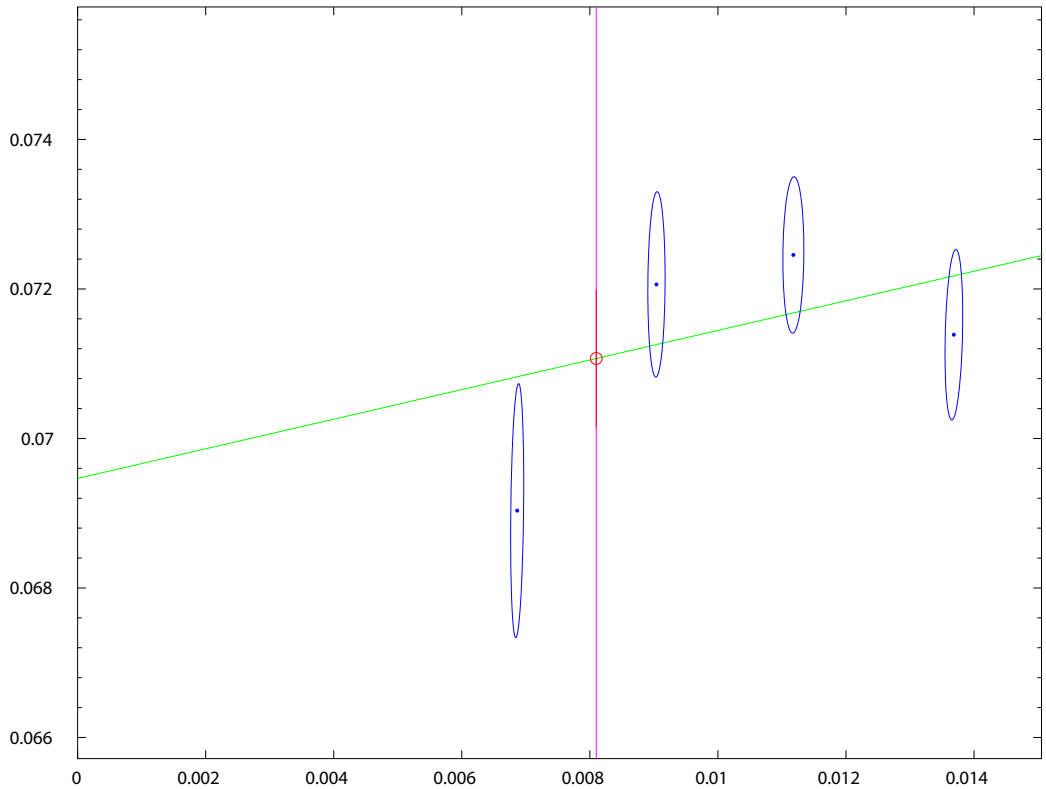
```
function chisq=fullfit(par)
# chi^2 function for full fpi-mpi^2 fit
   global _f _m _er _n

   npar=2;
   chisq=0;
   for i=1:_n
       mm=par(npar+i);
       ff=fps(mm,par(1:npar));
       ex=[_m(i)-mm,_f(i)-ff];
       chisq+=ex*_er{i}*ex';
   end
   chisq;
endfunction
```

Doing the fit

Using the chiral fit:

```
> [fpi,efpi,q,qc]=chiralfit_solution(fb,mb,-1,0,1)
fpi =  0.071069
efpi =  9.1972e-04
q =  0.51122
qc =  0.49685
```



Different fit forms

Setting the x-axis as m^2 (line 33):

```
# use mpi^2 as x-axis
      mb{i}=mb{i}.^2;
```

Vary the 2-parameter fit form (end of file):

```
function ff=fps(m,c)
# the actual fit function
    ff=c(1)+c(2)*m;
endfunction
```

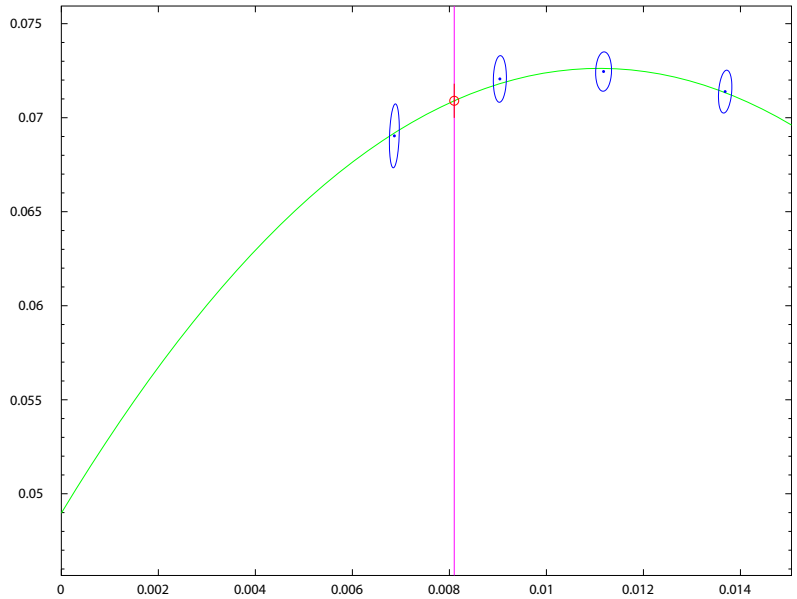
Do a 3-parameter fit:

```
[fpi,efpi,q,qc]=chiralfit_quadratic(fb,mb,-1,1,1)
```

Quadratic fit

Using the chiral fit:

```
> [fpi,efpi,q,qc]=chiralfit_quadratic(fb,mb,-1,0,1)
fpi =  0.070900
efpi =  9.0830e-04
q =  0.97827
qc =  0.97816
```



Vary the 3-parameter fit form (end of file):

```
function ff=fps(m,c)
# the actual fit function
    ff=c(1)+c(2)*m+c(3)*m.^2;
endfunction
```

Find f at the physical point!

- Explore the fitting routines - change fit forms
- Try varying ensembles and fit parameters
- Find the “decay constant” *f* and its error
- Upload your results to

`/afs/ifh.de/group/ape/lap/12/analysis/fpi_results/xxxx_fpi`

`/afs/ifh.de/group/ape/lap/12/analysis/fpi_results/xxxx_err`

- If you are done, try estimating the systematics
- If you want the solution, look at “cheat.m” and “physpoint.m”

have fun!