Summary of L/T/LT/TT-separation iterative procedure

Garth Huber

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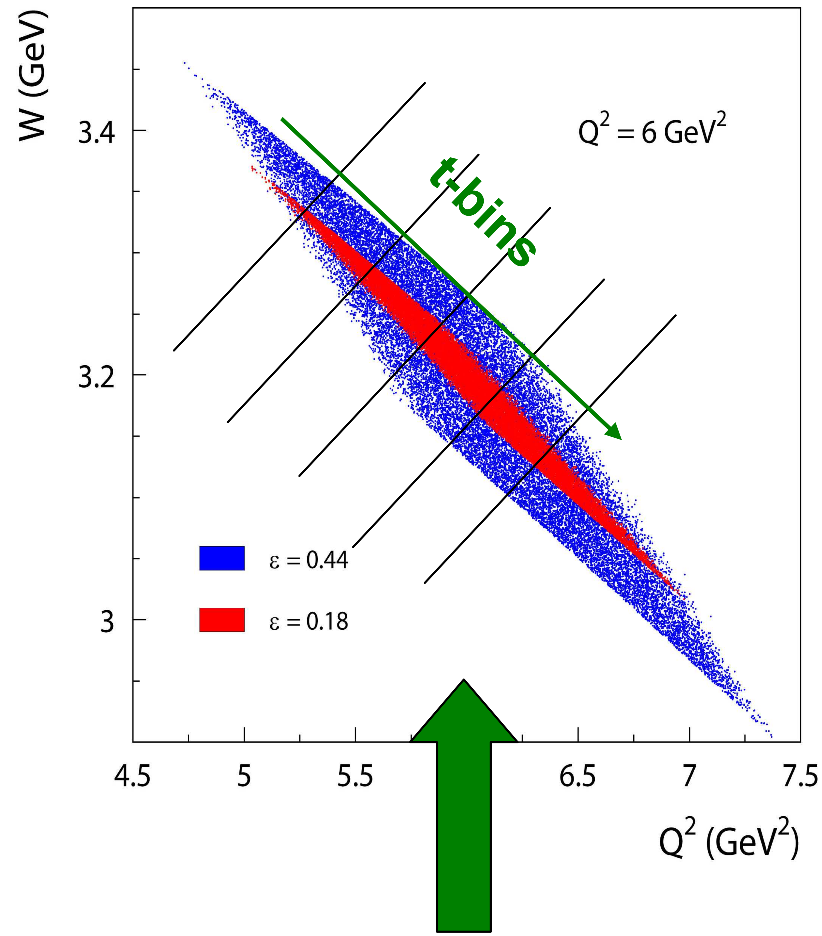
Pre-requisite: Stable and finalized data!

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

- **Before starting the L/T/LT/TT-separation procedure, it is essential that you have:**
  - **Final normalized yields (counts/mC) for all settings, with all efficiencies, livetimes, cryotarget, FADC-DT and other yield corrections tested for reliability over a wide rate range and applied**
  - **All kinematic offsets determined and finalized**
- This is because it is essential that the one thing that is kept constant in the iterations is the experimental normalized yield and distributions.
- If any subsequent changes are made to any part of the experimental distributions, the iteration procedure must be repeated to ensure the result remains self-consistent.
- **Failure to respect this restriction will result in significant wasted time!**

Pre-requisite – Choose a functional form

- **The cross section varies across experimental acceptance.**
- **It is needed to choose a functional form that will reasonably take into account this variation.**
- Of course you don't know in advance what to choose, therein the uncertainty.
- All you can do is to make a choice, and start the iteration process with it.
- Then you need to do tests to see if the functional dependence reproduces the variation of the data.
- If the tests fail, then you need to modify the functional form and try again until you get something that works better.



Each t bin has a different average value of W, Q^2.
This dependence must be taken into account

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

Example parameterization

- Replace physics_pion.f with physics_iterate.f in SIMC

```
libra:/home/huberg/r2d2/simc/simc_fpi2
File  Edit  View  Search  Terminal  Help
* Models for sigL, sigT, sigLT, sigTT  for Deuterium.

***
* Parameterization revised for IT26, 12.11.09
           q2_set=2.45
           tav=(0.0735+0.028*log(q2_set))*q2_set
           ftav=(abs(t_gev)-tav)/tav
           ft=t_gev/(abs(t_gev)+0.139570**2)**2

           sigl=(fitpar(1)+fitpar(2)*log(Q2_g))
     1           *exp((fitpar(3)+fitpar(4)*log(Q2_g))*(abs(t_gev)-0.2))
           sigt=fitpar(5)+fitpar(6)*log(Q2_g)
     1           +(fitpar(7)+fitpar(8)*log(Q2_g))*ftav

           siglt=(fitpar(9)*exp(fitpar(10)*abs(t_gev))
     1           +fitpar(11)/abs(t_gev))*sin(thetacm)
           sigtt=(fitpar(12)*Q2_g*exp(-Q2_g))*ft*sin(thetacm)**2

           tav=(-0.178+0.315*log(Q2_g))*Q2_g



           sig219=(sigt+main%epsilon*sigl+main%epsilon*cos(2.*phicm)*sigtt
     >          +sqrt(2.0*main%epsilon*(1.+main%epsilon))*cos(phicm)*siglt)/1.d0

c now convert to different W
c W dependence given by 1/(W^2-M^2)^2
c factor 15.333 is value of (w**2-ami**2)**2 at W=2.19

c         wfactor=15.333/(s-(targ.Mtar_pion/1000.)**2)**2
*         wfactor=8.539/(s-(targ.Mtar_pion/1000.)**2)**2

c         wfactor=1.D0/(s-(targ.Mtar_pion/1000.)**2)**2
          wfactor=1.D0/(s_gev-mtar_gev**2)**2
          sig=sig219*wfactor
          sigl=sigl*wfactor
          sigt=sigt*wfactor
          sigtt=sigtt*wfactor
          siglt=siglt*wfactor
```

- **fitpar()** is an array of free parameters that will be determined as part of the L/T-iteration process.
- It is the functional dependence that needs to be determined first, not the parameters.
- However, it is also essential that you make some good guesses of initial parameter values for your first iteration.

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

It is crucial to keep organized

- **Each Q^2,W should be done separately.**
- **It is too much to expect the procedure to work globally, we only need to properly take into account the kinematic variation across a single diamond at a time.**
- Keep each iteration in a different directory, e.g. Q2_xx/IT_yy
- Keep ALL output. Don't throw anything away!
- Example fitpar() for Q^2=2.45 LD+ iteration #11

```
libra> cd it11/
libra> ls
par.pl_245
libra> cat par.pl_245
 0.82135E+03  0.12595E+03   1           4.1
-0.41000E+03  0.00000E+00   2           4.1
-0.24615E+02  0.12942E+01   3           4.1
 0.11100E+02  0.00000E+00   4           4.1
 0.35925E+02  0.18332E+01   5           0.4
-0.18000E+02  0.00000E+00   6           0.4
 0.27316E+02  0.62567E+01   7           0.4
-0.31000E+02  0.00000E+00   8           0.4
 0.00000E+00  0.00000E+00   9          47.4
-0.20000E+02  0.00000E+00  10          47.4
-0.12451E+03  0.98541E+01  11           1.2
 0.00000E+00  0.00000E+00  12           1.2
libra>
```

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

Step 1 – SIMC distributions

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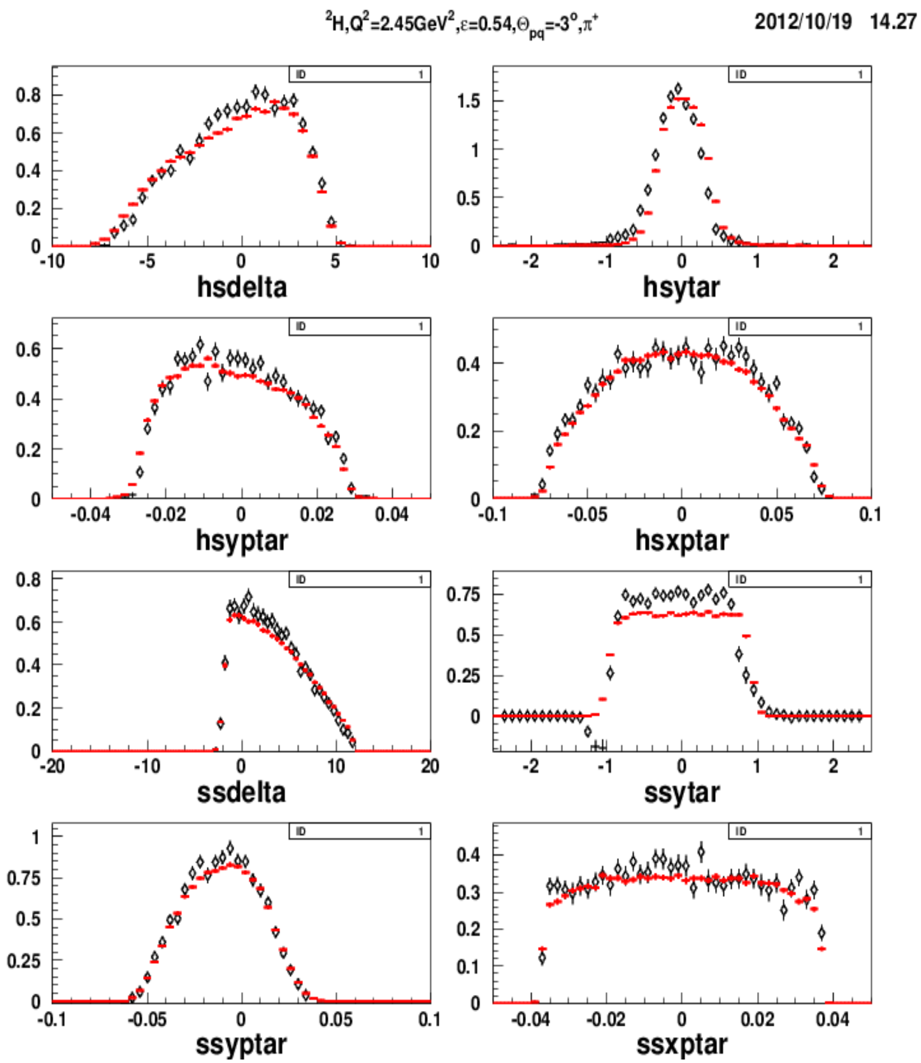
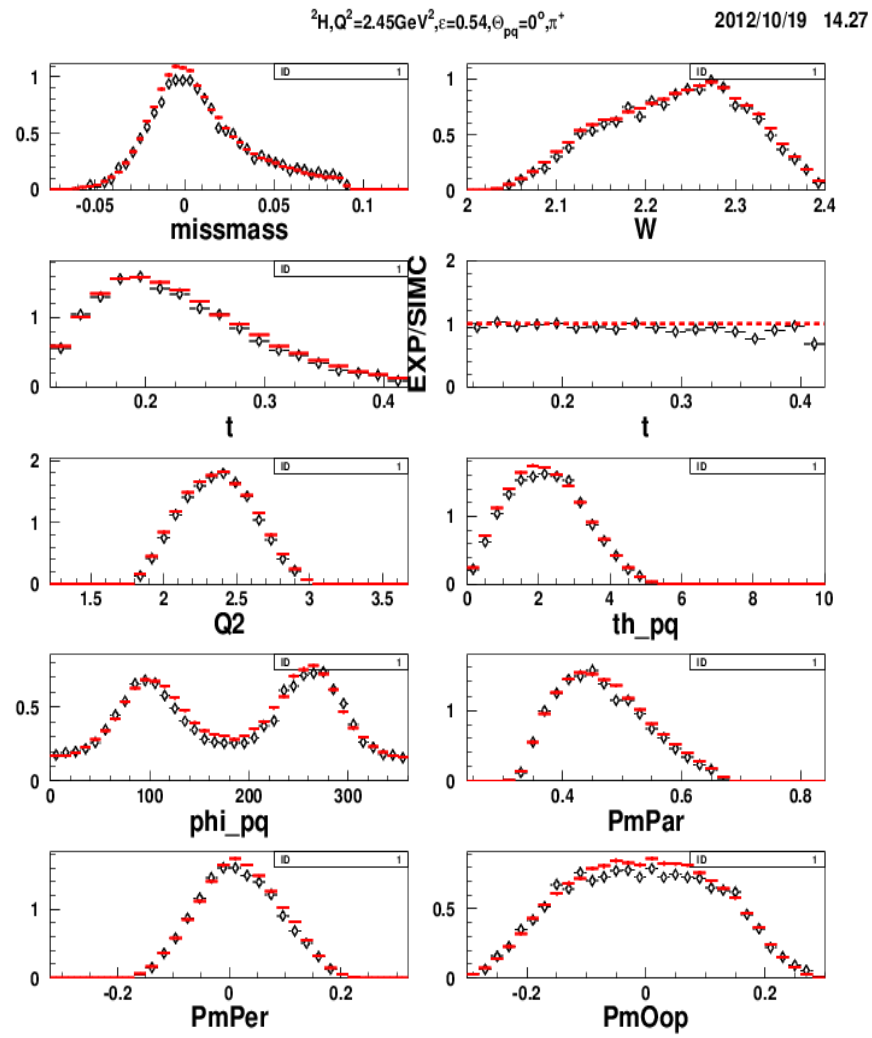
- Run SIMC for large number of events and generate distributions for spectrometer and physics variables using the functional form and fitpar() from previous page
- **Do this SETTING BY SETTING for given Q^2,W** (example is iteration #11)





Step 2 – Combine SHMS settings

- **Add together Left, Center, Right SHMS settings at high and low ε, for each (W,Q^2,t,φ,ε) bin for both Data and MC**
- Calculate statistical errors for each (W,Q^2,t,φ,ε) bin
- Obtain Y_{exp}, δY_{exp}, Y_{sim}, δY_{sim}, $R = Y_{exp}/Y_{sim}$, δR for each (W,Q^2,t,φ,ε) bin
- Data only have to be done once. MC has to be done every iteration.

Step 3 – Calculate average kinematics

- Need mean data values of W, Q^2, θ, ε for each t bin at high and low ε for both data and MC
- These values will differ slightly between high and low ε, and change slightly as model is iterated
- My recollection is that we took average of high and low ε values

```
libra> cat avek.245.dat
 2.30345 0.01952 2.14461 0.06477   6.13085   5.79187  1
 2.26790 0.02474 2.26473 0.07924  10.28234  10.06806  2
 2.23517 0.02790 2.36921 0.08675  13.26958  13.09284  3
 2.20674 0.02955 2.45983 0.09053  15.81400  15.65749  4
 2.17764 0.02889 2.54832 0.08724  17.95443  17.80887  5
 2.15312 0.02685 2.62646 0.08146  19.96777  19.83086  6
libra> 
```

W δW Q^2 δQ^2 θ_+ θ_- #tbin

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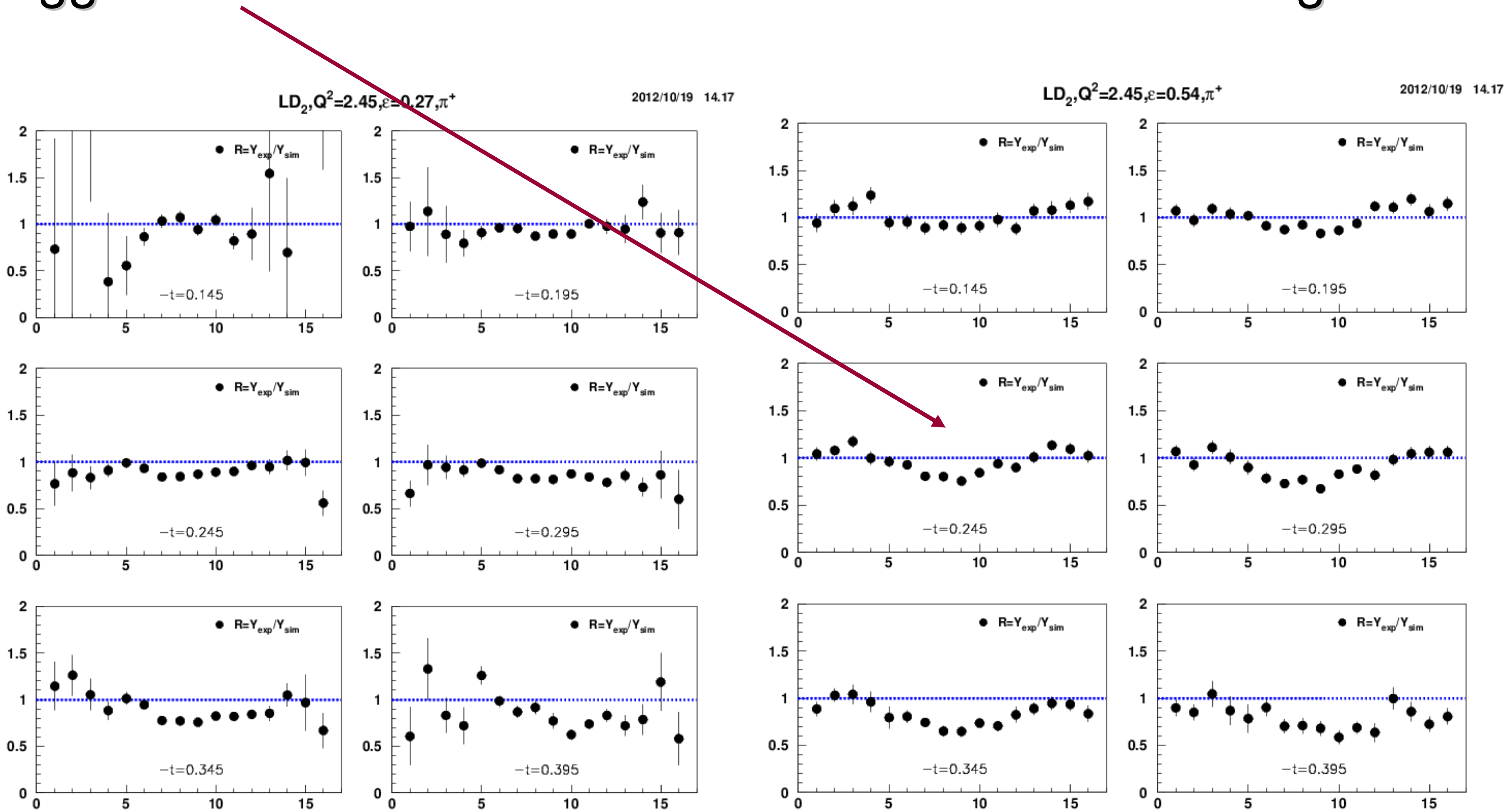
Step 4a – Inspect and understand

- Deviations between Data and MC usually are indicated as wiggles in R. We desire R≈1 over broad kinematic range



Example shown is iteration #11

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Step 4b – Inspect and understand

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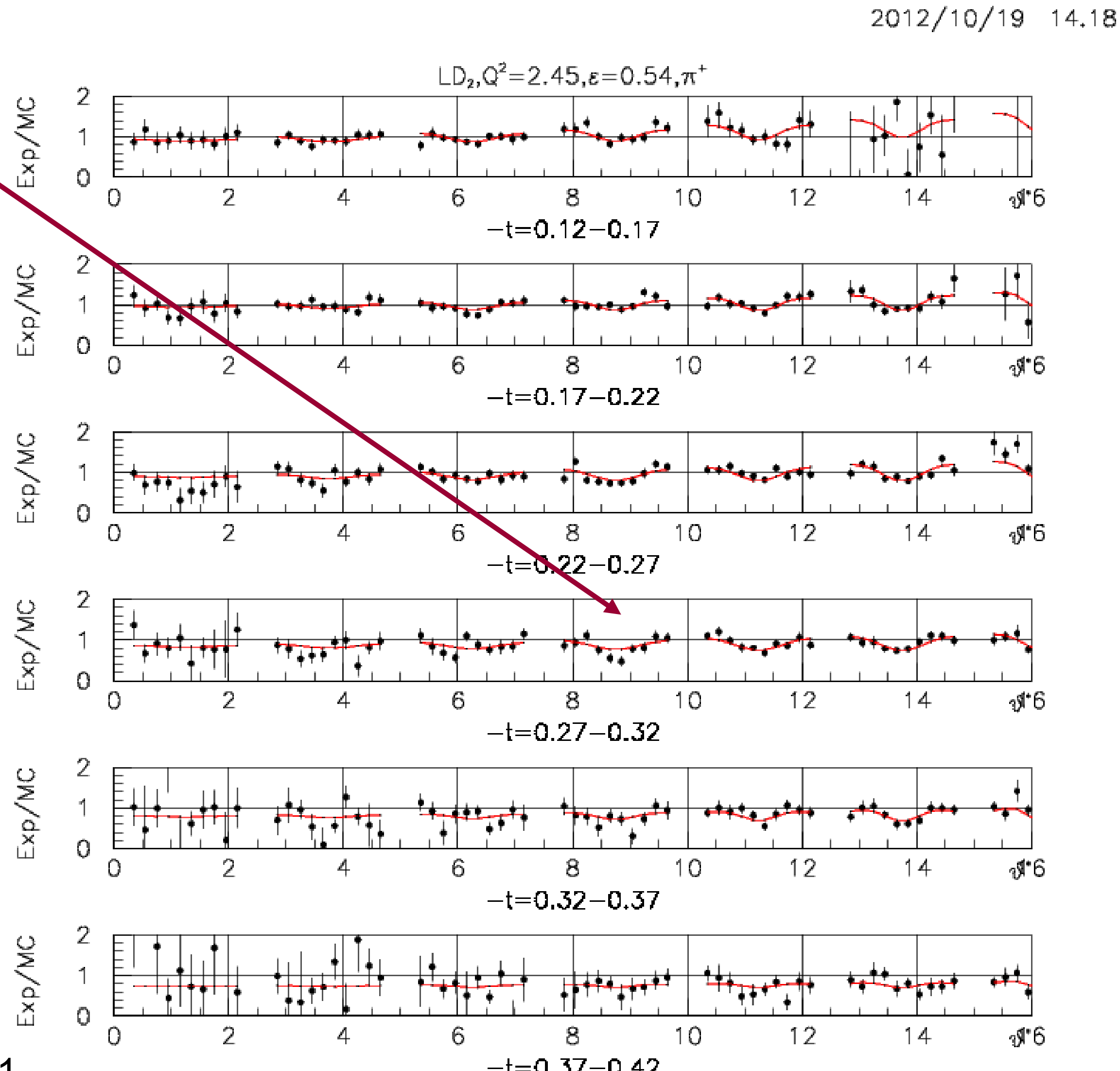
- Deviations between Data and MC usually are indicated as wiggles in R. We desire R≈1 over broad kinematic range

- Errors in W, Q^2, t, φ dependence of SIMC model are indicated by too large/small value of R
- φ distributions for each t-bin, subdivided into 8 θ* bins (since LT, TT depend also on θ*)
- Red lines are fits to make wiggles more clearly visible



 Example shown: LD+ Q^2=2.45 iteration #11

Step 5 – Calculate unseparated $d^2\sigma/dtd\phi$

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- Using the fitpar() for the iteration, evaluate the model at average kinematics of the data for each t-bin

were fitted. For all five t bins at every (central) Q^2 setting, ϕ-dependent cross sections were determined at both high and low ϵ for chosen values of $\overline{W}$, $\overline{Q}^2$ (and corresponding values of θ_π and ϵ) according to

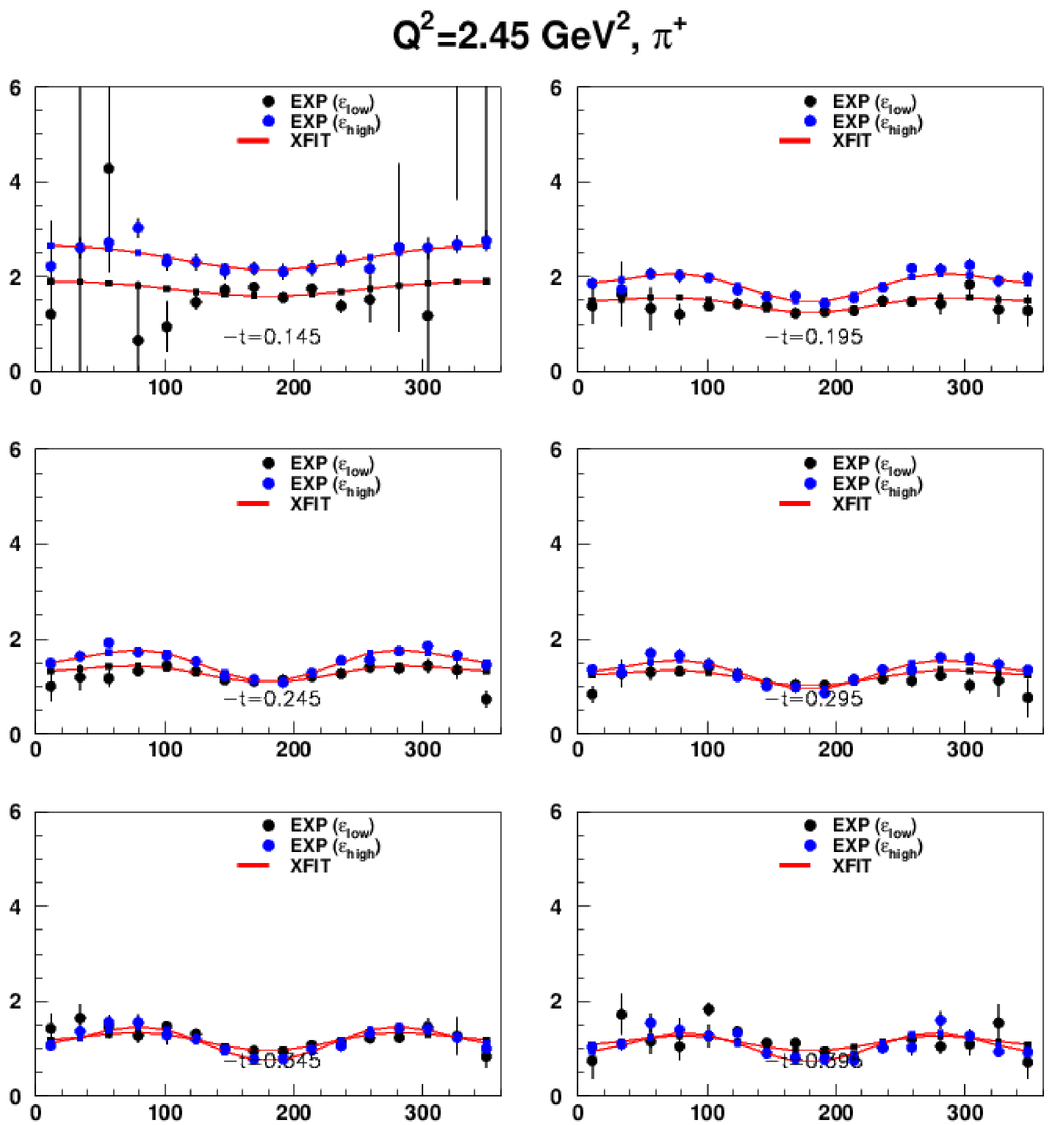
$$\sigma_{\rm exp}(\overline{W}, \overline{Q}^2, t, \phi; \overline{\theta}, \overline{\epsilon}) = \frac{\langle Y_{\rm exp} \rangle}{\langle Y_{\rm sim} \rangle} \sigma_{\rm MC}(\overline{W}, \overline{Q}^2, t, \phi; \overline{\theta}, \overline{\epsilon}). \quad (14)$$

The fitting procedure was iterated until $\sigma_{\rm exp}$ changed by less than a prescribed amount (typically 1%). A representative

Read over the text from Blok et al, PRC 78 (2008) 045202 very carefully!

Step 6 – Fit Rosenbluth Eqn

$$2\pi \frac{d\sigma}{dt\,d\phi} = \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_T}{dt} + \sqrt{2\varepsilon(\varepsilon+1)}\frac{d\sigma_{LT}}{dt}\cos\phi + \varepsilon \frac{d\sigma_{TT}}{dt}\cos 2\phi$$



- **Each t-bin is fit separately**
- Fit result gives L, T, LT, TT cross sections for each t bin

Example shown is iteration #11

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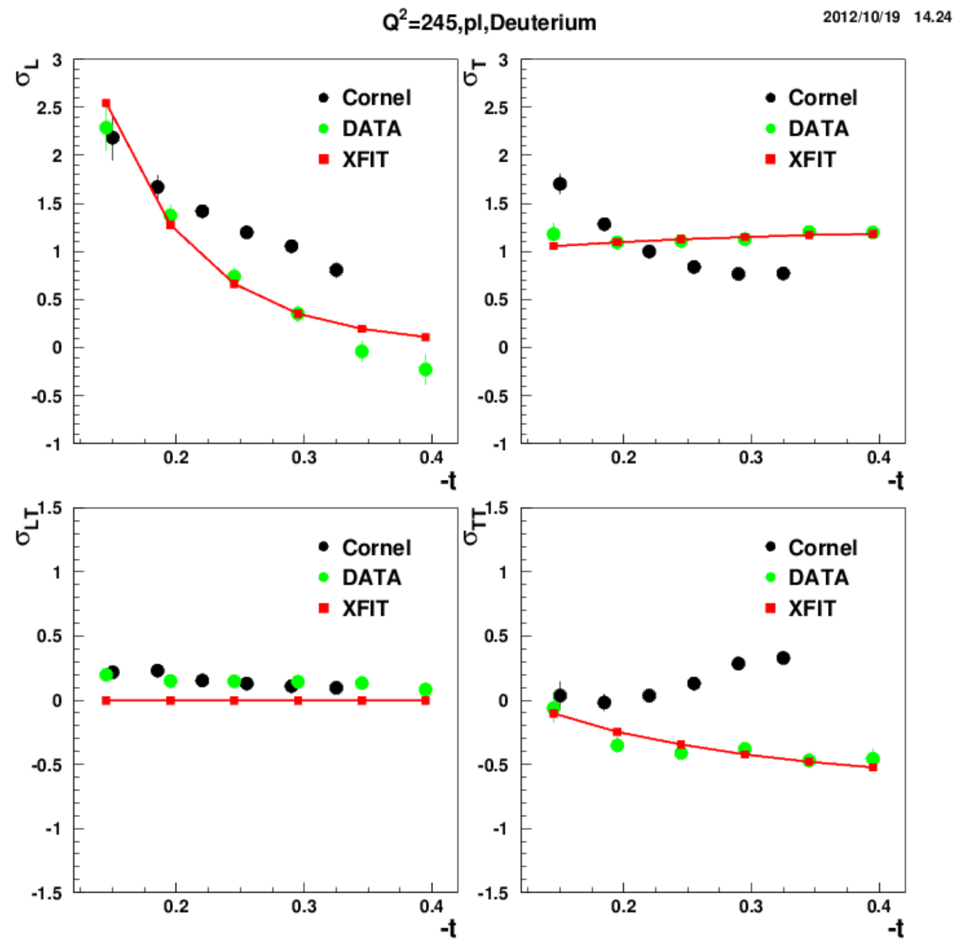
Step 7 – Fit L/T/LT/TT to get new fitpar()

- **Compare t-bins with each other**
- Fit with physics_iterate.f functions to give next iteration model parameters
- Repeat steps 1-7 until separated cross sections are stable (change <1% from previous iteration)
- Do not rerun SIMC! Simply recalculate weight for each event.



Example shown is iteration #11

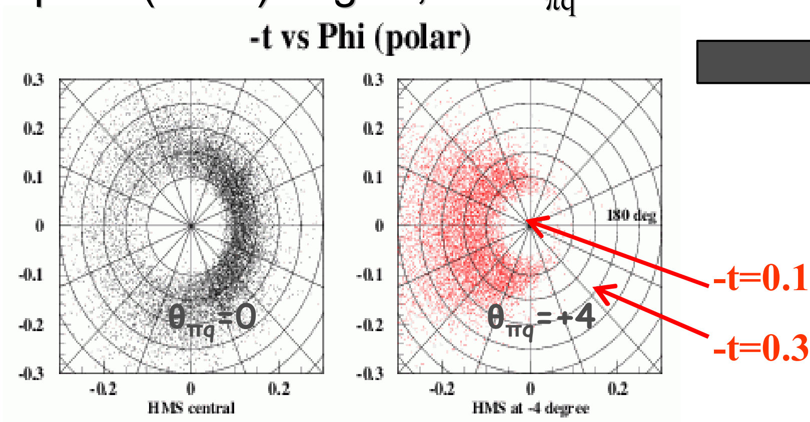
```
libra> cd it12
libra> ls
par.pl_245
libra> cat par.pl_245
 0.88669E+03  0.13897E+03   1           3.0
-0.41000E+03  0.00000E+00   2           3.0
-0.25327E+02  0.12613E+01   3           3.0
 0.11100E+02  0.00000E+00   4           3.0
 0.31423E+02  0.17166E+01   5           0.6
-0.18000E+02  0.00000E+00   6           0.6
 0.16685E+02  0.59226E+01   7           0.6
-0.31000E+02  0.00000E+00   8           0.6
 0.20000E+02  0.00000E+00   9          34.9
-0.34000E+01  0.00000E+00  10          34.9
-0.14742E+03  0.90362E+01  11           1.3
 0.00000E+00  0.00000E+00  12           1.3
libra>
```

fitpar() used in iteration #12

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

Iteration procedure summary

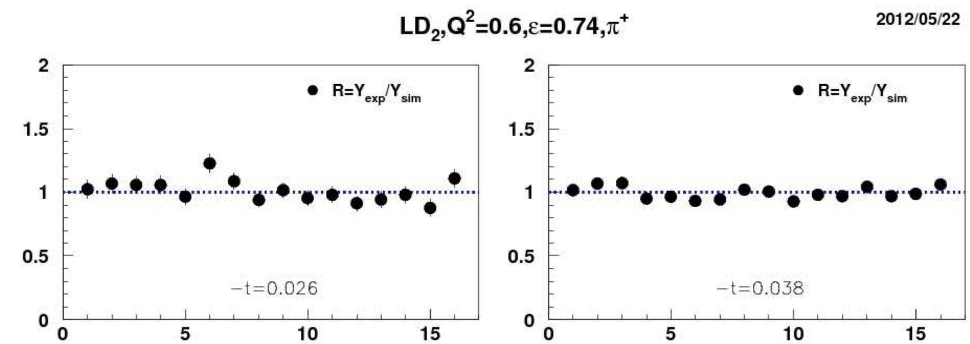
Improve φ coverage by taking data at multiple π (HMS) angles, $-4^o<\theta_{\pi q}<4^o$.



For each π HMS setting, form ratio:

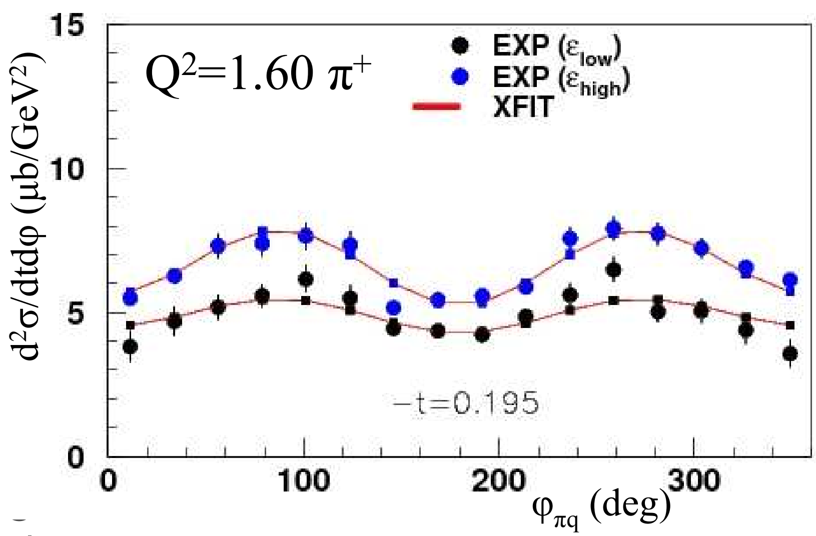
$$R=\frac{Y_{EXP}}{Y_{SIMC}}$$

Combine ratios for π settings together, propagating errors accordingly.



$$\left.\frac{d^2\sigma}{dtd\varphi}\right._{EXP}=\left(\frac{Y_{EXP}}{Y_{SIMC}}\right)\left.\frac{d^2\sigma}{dtd\varphi}\right._{SIMC}$$

Extract via simultaneous fit of L,T,LT,TT



$$2\pi\frac{d\sigma}{dtd\phi}=\varepsilon\frac{d\sigma_L}{dt}+\frac{d\sigma_T}{dt}+\sqrt{2\varepsilon(\varepsilon+1)}\frac{d\sigma_{LT}}{dt}\cos\phi+\varepsilon\frac{d\sigma_{TT}}{dt}\cos2\phi$$

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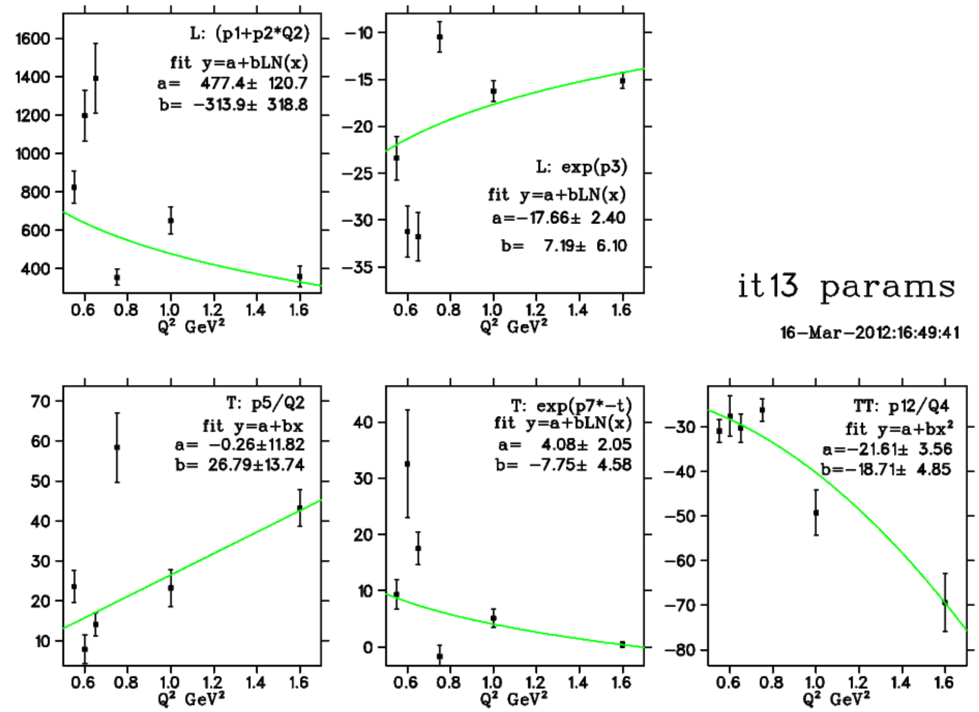
Evaluating if Fit equations are okay

- Usually the procedure works okay, but for some kinematics in π^-/π^+ analysis the σ would not converge
- One thing we tried was to compare fitpar() from different Q^2,W to see if they were slowly varying
- If not, we could use their variation as a suggestion of alternate functional form to try
- This is similar in concept to the feedback Vijay got last week on the offsets, i.e. things will behave in a consistent manner if the correct solution is found



More details are found in LD2 analysis technical report HallC-docDB-773

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.

A few pointers

- Read over the Blok paper VERY CAREFULLY
- Also see tutorial slides Bill made for you at beginning of KaonLT run (Nov 28, 2018) and his comments in the code

- A single Q^2,W iteration should only take 1-2 hours
- I was able to do several iterations in a day, between teaching and other duties
- The fitpar() should converge in a few iterations to give $0.5<R<2$
- The main work is in getting R to be acceptably flat and in getting stable cross sections

Dr. Garth Huber, Dept. of Physics, Univ. of Regina, Regina, SK S4S0A2, Canada.