Lecture 4

- Continue with strange quarks
- Other hadrons

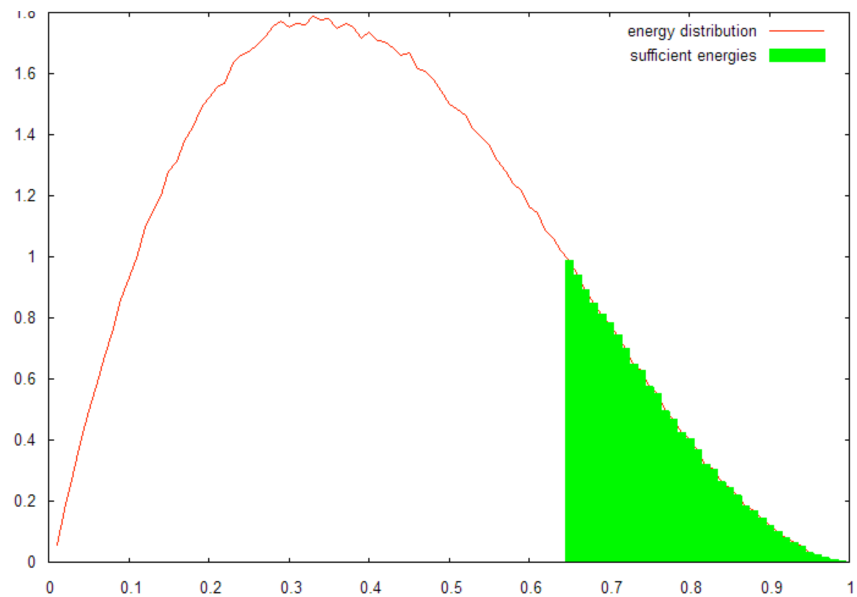
- add s-sbar pairs to Fock state expansion
- include s-quark mass in Monte Carlo calculation of momentum distributions for *n*-parton states
- add suppression of s-sbar rates

Weighted Strange Sea Probability

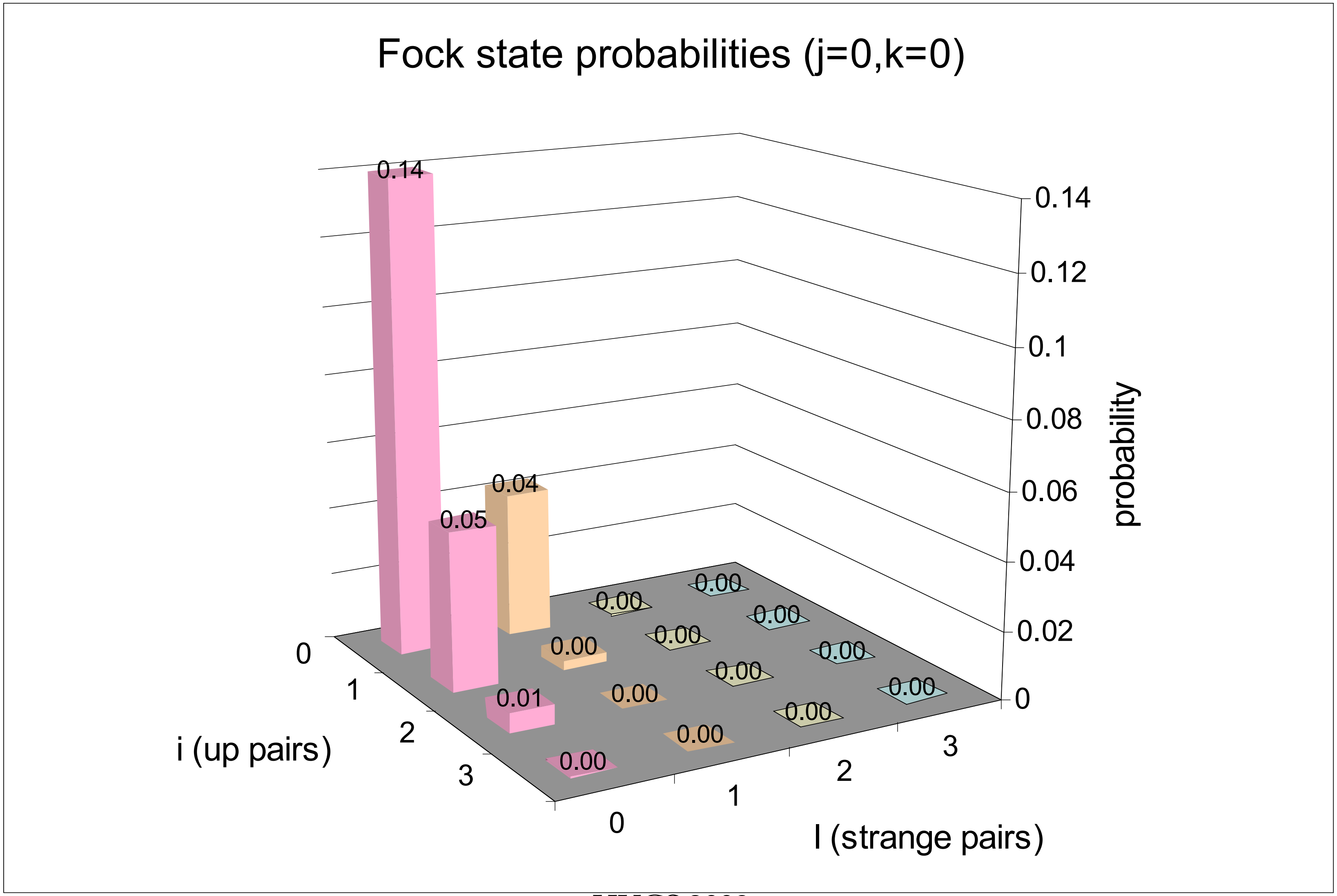
The up and down sea quarks in the proton have such a small mass compared to the proton that we can assume them to be massless. The much higher mass of the strange quarks does not allow this assumption and so we need to introduce a weighting factor in calculating the probability of any fock state with an $s\bar{s}$ pair $(l > 0)$.

In order for a gluon to split into an $s\bar{s}$ pair it must have an energy greater than twice the mass of the strange quark. From our MC method we can find the energy distribution for a gluon in any fock state. Integrating this distribution function over energies greater than twice the strange quark mass we get a weighting factor γ.

$$\gamma(i,j,k,l) = \int_{2M_s}^{E_{max}} f_{i,j,k+1,l-1}(E)dE$$



Fock State Probabilities



Parton Distributions

After finding the fock state probabilities $\rho_{i,j,k,l}$ for a large number of states of the proton (we took i,j, and k up to 8 and l up to it's maximum of 3) we can combine them with the distributions from the MC procedure to get an overall parton distribution of the proton.

For each state we take the numbers of each type of parton in the state and multiply by the x-distribution $h_{i,j,k,l}(x)$ for that parton. Weighting these distributions by the probability of the state and then summing over all states gives us the overall parton distributions.

$$u(x) = \sum_{i,j,k,l} \rho_{i,j,k,l} h_{i,j,k,l}(x)(i+2)$$

$$d(x) = \sum_{i,j,k,l} \rho_{i,j,k,l} h_{i,j,k,l}(x)(j+1)$$

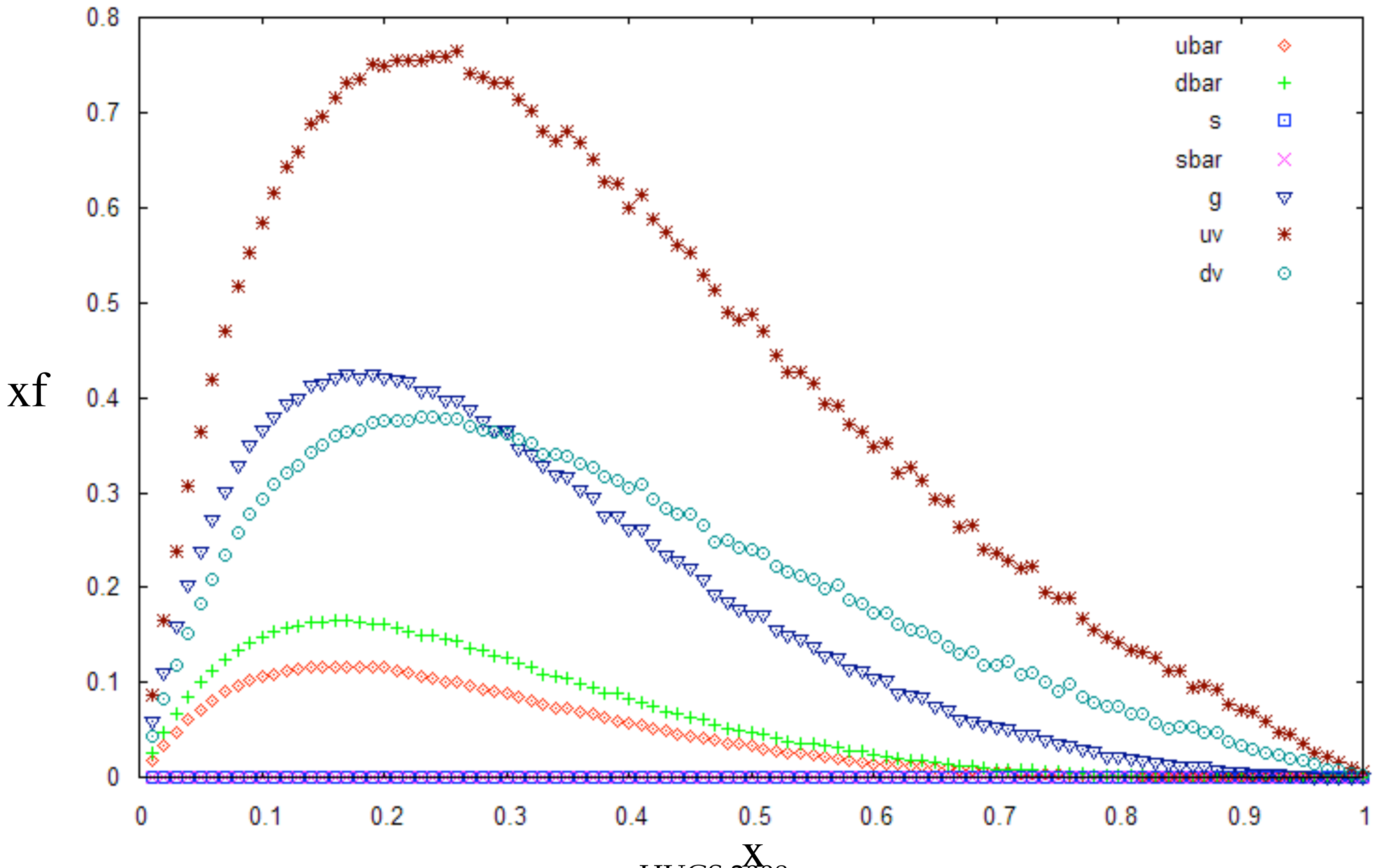
$$\bar{u}(x) = \sum_{i,j,k,l} \rho_{i,j,k,l} h_{i,j,k,l}(x) i$$

$$\bar{d}(x) = \sum_{i,j,k,l} \rho_{i,j,k,l} h_{i,j,k,l}(x) j$$

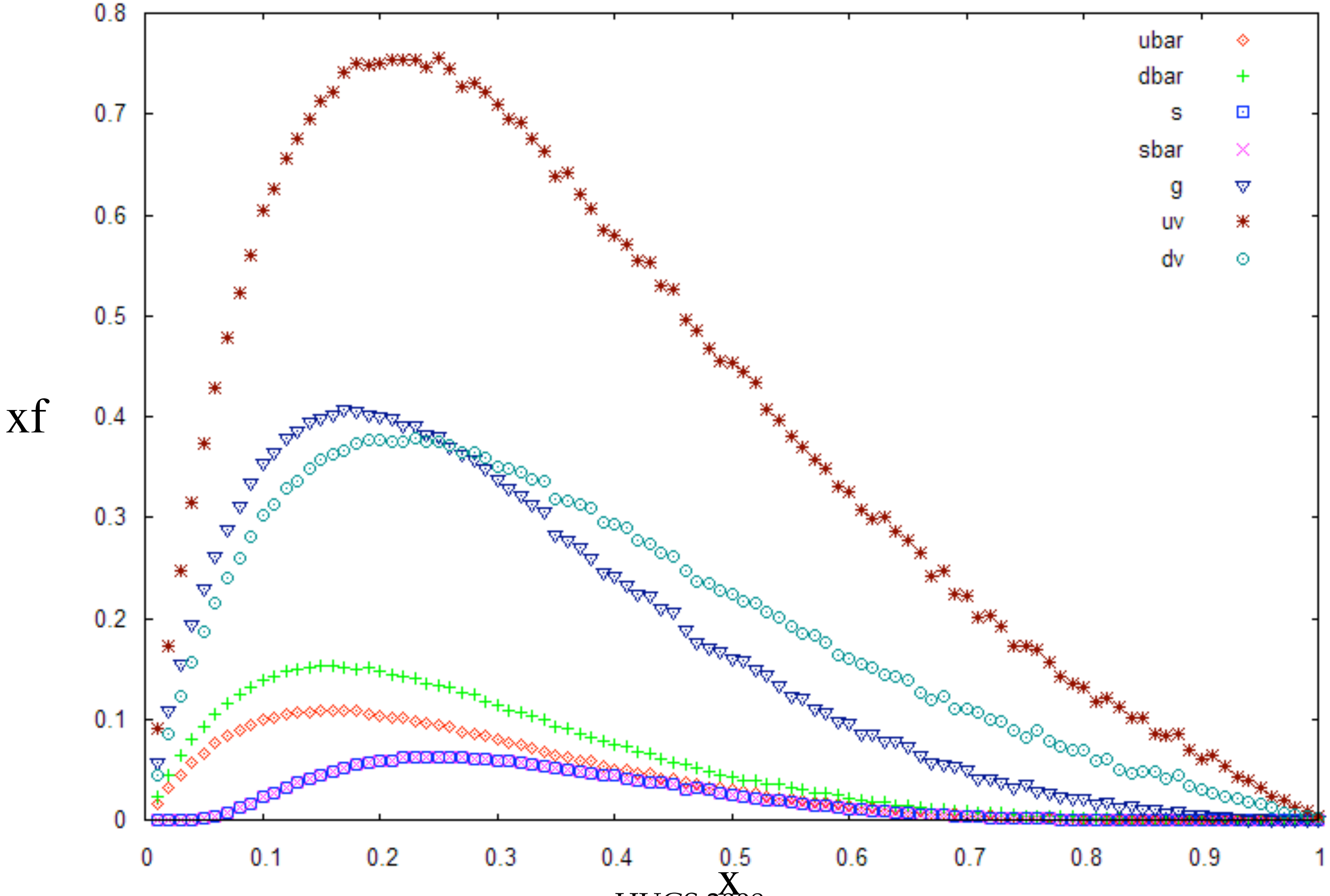
$$g(x) = \sum_{i,j,k,l} \rho_{i,j,k,l} h_{i,j,k,l}(x) k$$

$$s(x) = \bar{s}(x) = \sum_{i,j,k,l} \rho_{i,j,k,l} h^{m}_{i,j,k,l}(x) l$$

Parton xf distribution for proton with no strange sea



Parton xf distribution for proton with strange sea



Analysis

The $s(x)$ distribution is similar to the $\bar{u}(x)$ and $\bar{d}(x)$ distributions. It is naturally a little lower reflecting the lower probability of strange quarks in the proton. Also it drops off a little sooner as x approaches zero. This is easy to understand since

$$x = \frac{E - p_z}{M}$$

where E is the energy and p_z is the z-momentum component of the parton and M is the mass of the proton. Since the strange quark's mass is not negligible compared with the proton's, it's energy and momentum are never equal so it can not have low x-values.

We can also calculate the overall occurrence of each parton type in the proton. We first define the two distributions $u_v(x) = u(x) - \bar{u}(x)$ and $d_v(x) = d(x) - \bar{d}(x)$ which are the up and down valence quarks. Then by integrating under the distributions we get

$$u_v = 1.95 \quad d_v = 0.973.$$

These of course should be 2 and 1 respectively which suggests a computational error of just under 3%. For the other partons we get

$$\bar{u} = 0.274 \quad \bar{d} = 0.385$$

$$s = \bar{s} = 0.0883 \quad g = 1.03.$$

Summary of strange sea calculation

Using the principle of detailed balance along with an appropriate weighting factor for the strange quarks we were able to calculate the Fock state probabilities of the proton.

Combining these probabilities with the distributions given by the Monte Carlo phase space calculation allowed us to find the parton distributions within the proton.

Though this model can give only a rough statistical approximation, it does show the basic features of the parton distributions and gives a good prediction for the strange quark distribution.

The model may be able to be improved by using the general balance principle instead of the detailed balance used here, since the general balance model considers all states when balancing rather than just two states at a time.

References

[1] Y. Zhang, B. Zhang, B. Ma, Phys. Lett. B 523 (2001) 260-264.

[2] Y. Zhang, B. Zou, L. Yang, Phys. Lett. B 528 (2002) 228-232.

[3] R. Kleiss, W.J. Stirling, S.D. Ellis, Comp. Phys. Comm. 40 (1986) 359-373.

[4] Y. Zhang, W. Deng, B. Ma, Phys. Rev. D 65 (2002)

The Proton and the Pentaquark

Sierra Gardner

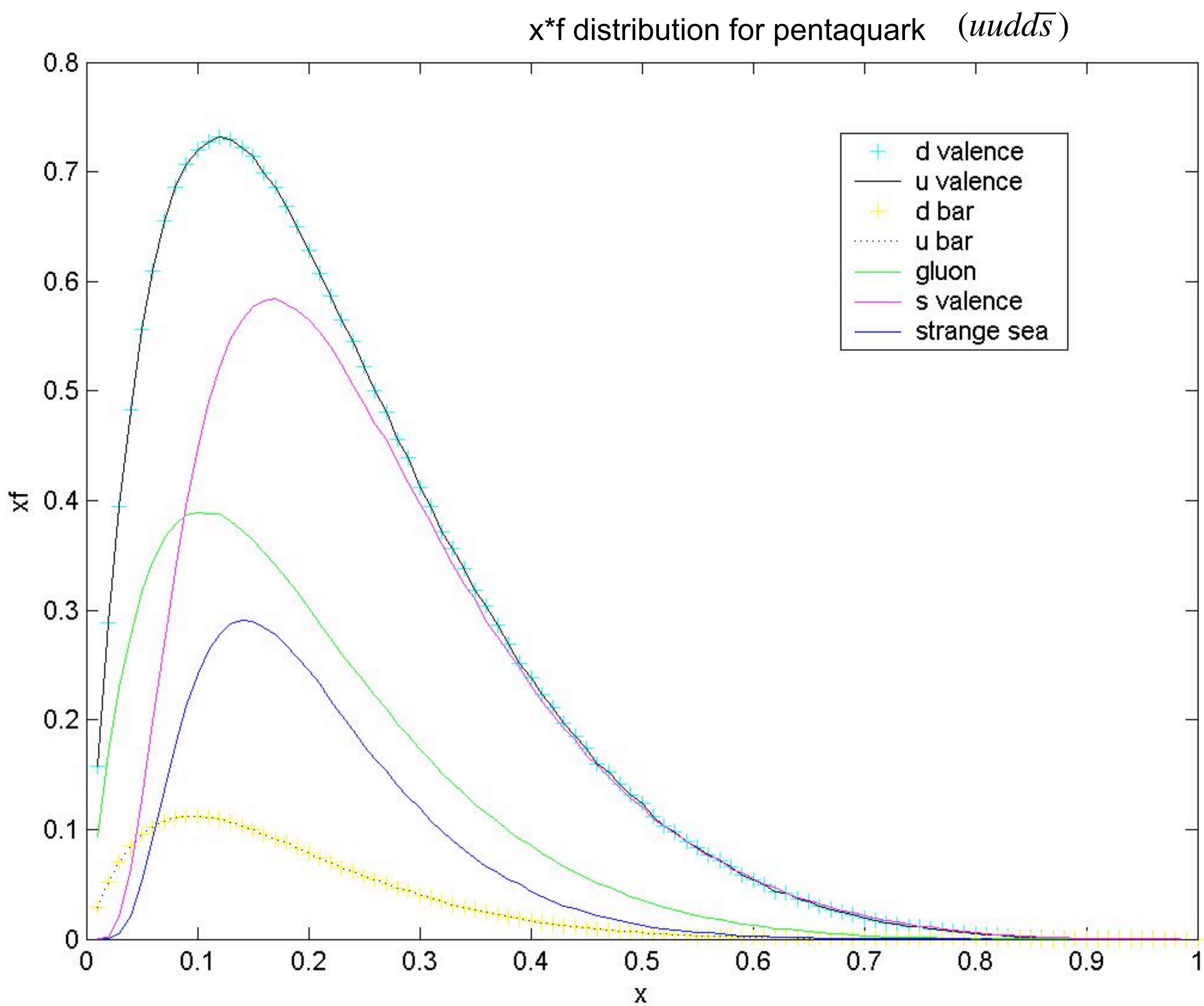
For the proton,

$$\frac{\rho_{i,j,k}}{\rho_{0,0,0}} = \frac{2}{i!(i+2)!j!(j+1)!} * \prod_{m=1}^{k} \frac{3+2i+2j+m-1}{(3+2i+2j)m+\frac{m(m-1)}{2}}$$

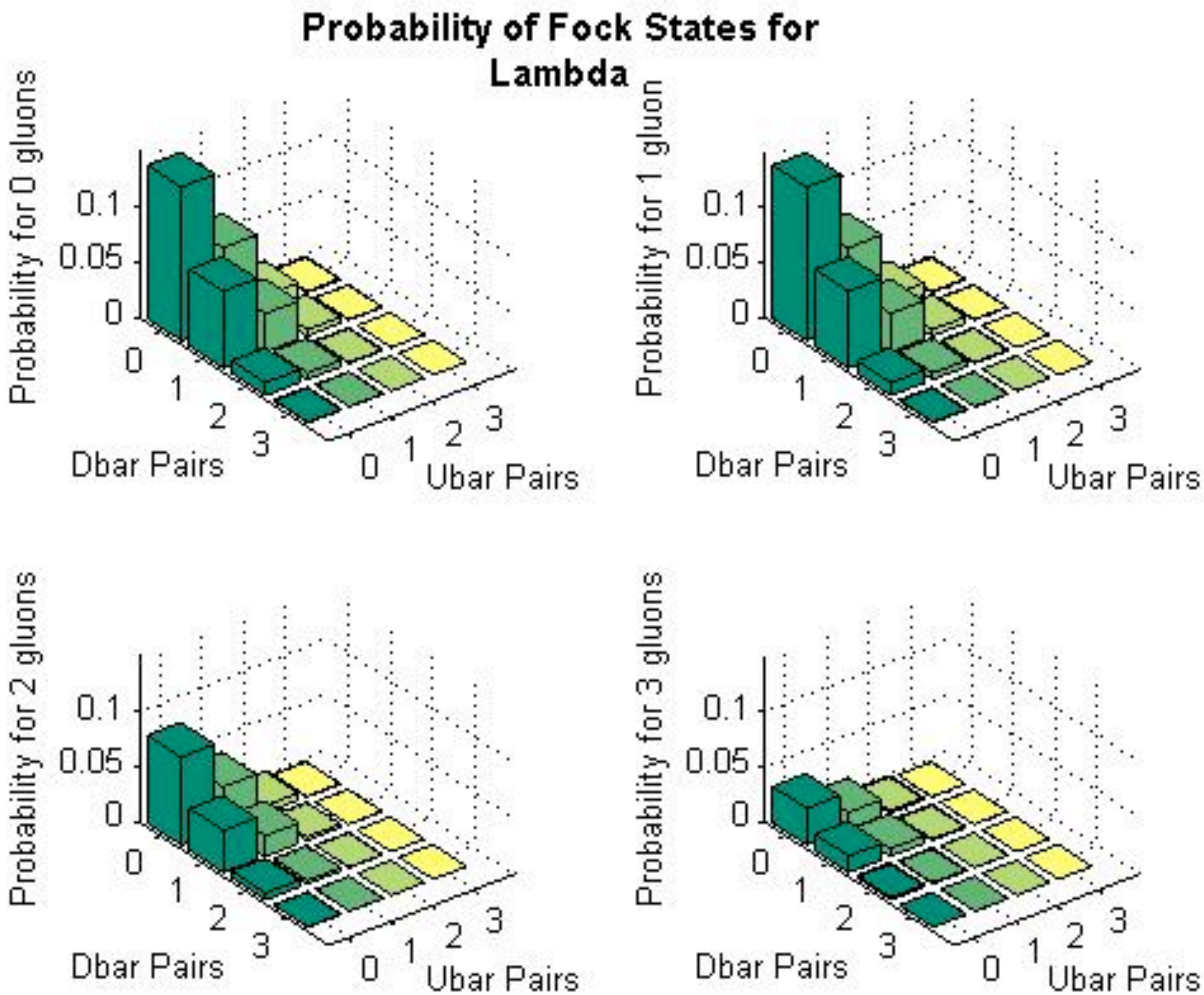
A very similar process can be repeated for the pentaquark but including the interactions of the strange quark and introducing a new factor of $l!(l+1)!$

$$\frac{\rho_{i,j,k,l}}{\rho_{0,0,0,0}} = \frac{4}{i!(i+2)!j!(j+2)!\,l!(l+1)!} * \prod_{m=1}^{k} \frac{5+2i+2j+2l+m-1}{(5+2i+2j+2l)m+\frac{m(m-1)}{2}}$$

Pentaquark distributions

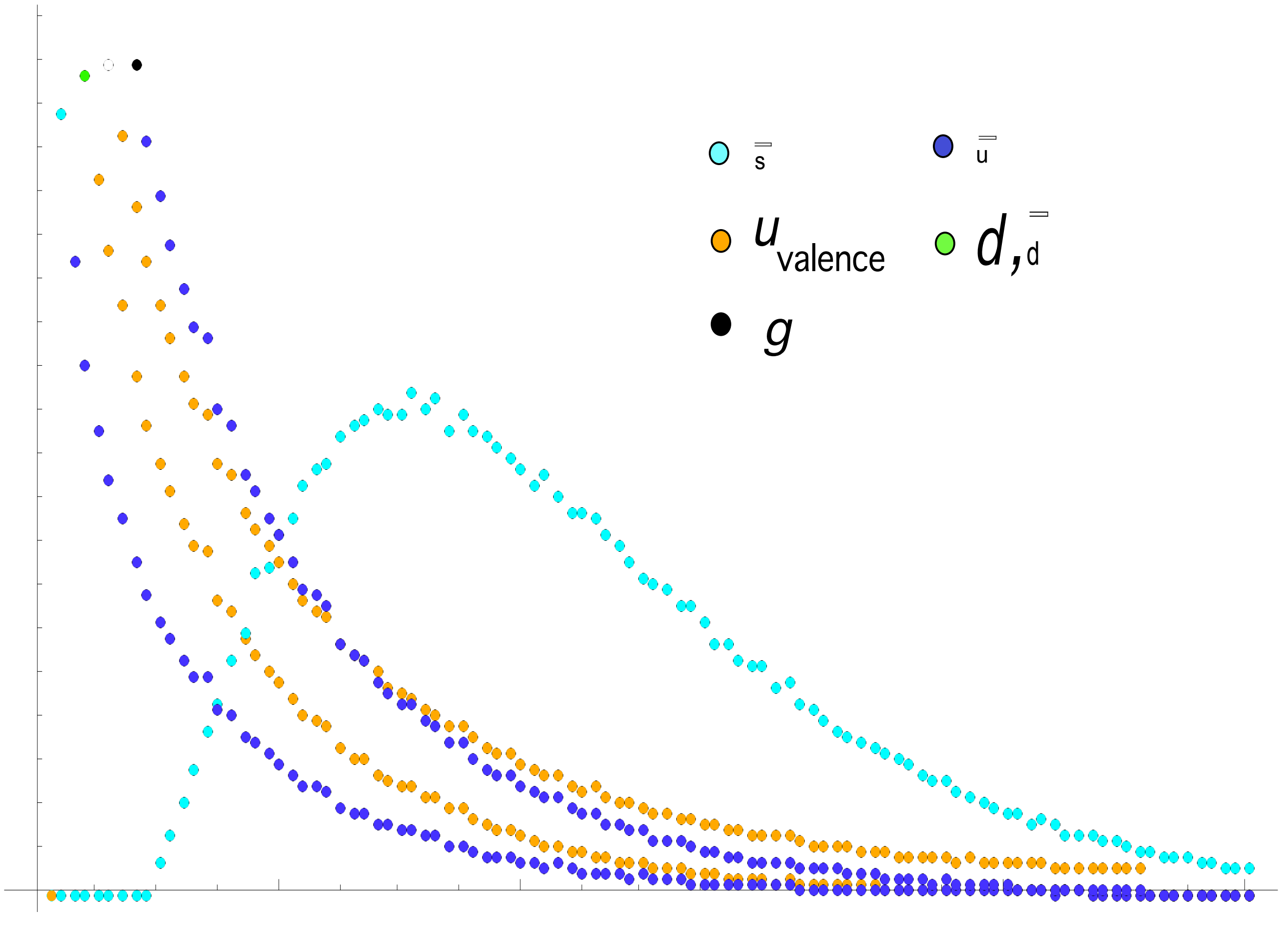


Lambda distributions



x-Distribution of Partons in Kaon

(massive strange quark)



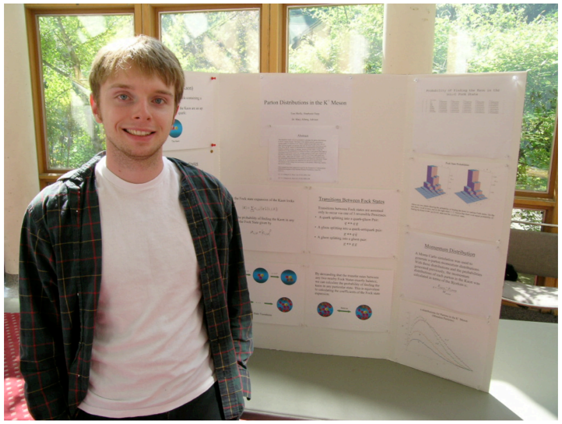
Flavor distribution in hadrons

	$u\bar{u}$	$d\bar{d}$	gluons	total
proton	0.304	0.426	1.11	5.57
pion	0.423	0.423	1.14	4.83
kaon	0.424	0.685	1.12	5.34
lambda	0.427	0.427	1.10	5.81

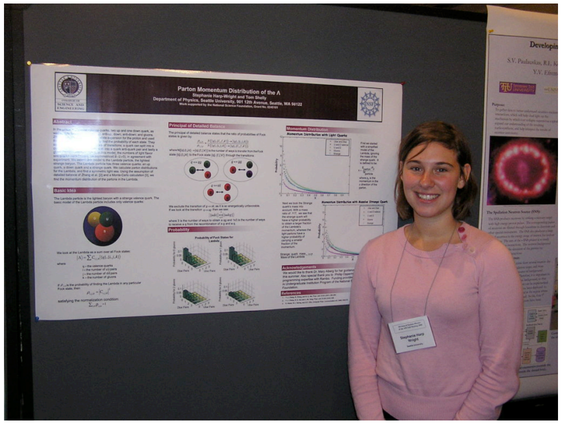
- Only a light sea was included. The total includes valence quarks.
- Exercise for students: show that for detailed balance, the number of gluons will always be 1.

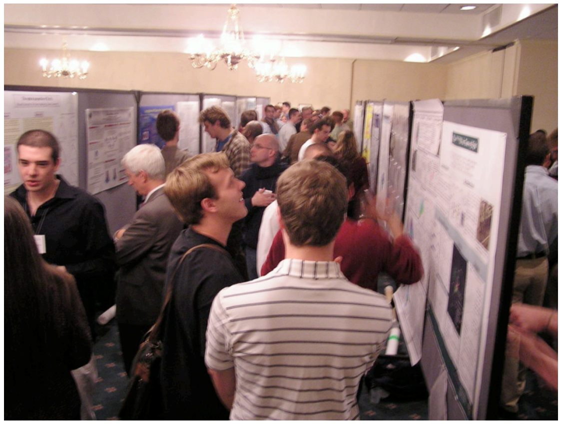
Student Presentations

Seattle University



CEU at DNP'06, Nashville





Importance

- input pdfs required at low scale for evolution to LHC energies
- Understanding of non-perturbative QCD
- Extensive discussion of LHC experiments followed

Conclusions

- A statistical model using the principle of detailed balance can reproduce the essential features of unpolarized parton distributions.
- It is in good agreement with the overall light flavor asymmetry of the proton sea, but fails to reproduce the momentum dependence.
- Calculations of the valence quark distribution functions for the pion are in reasonable agreement with experiment.
- Calculations for other hadrons are in progress

Future Directions

- Both perturbative and non-perturbative processes need to be included
- Statistical model will be used to determine structure of "bare hadrons" in the Fock state expansion for the meson cloud model