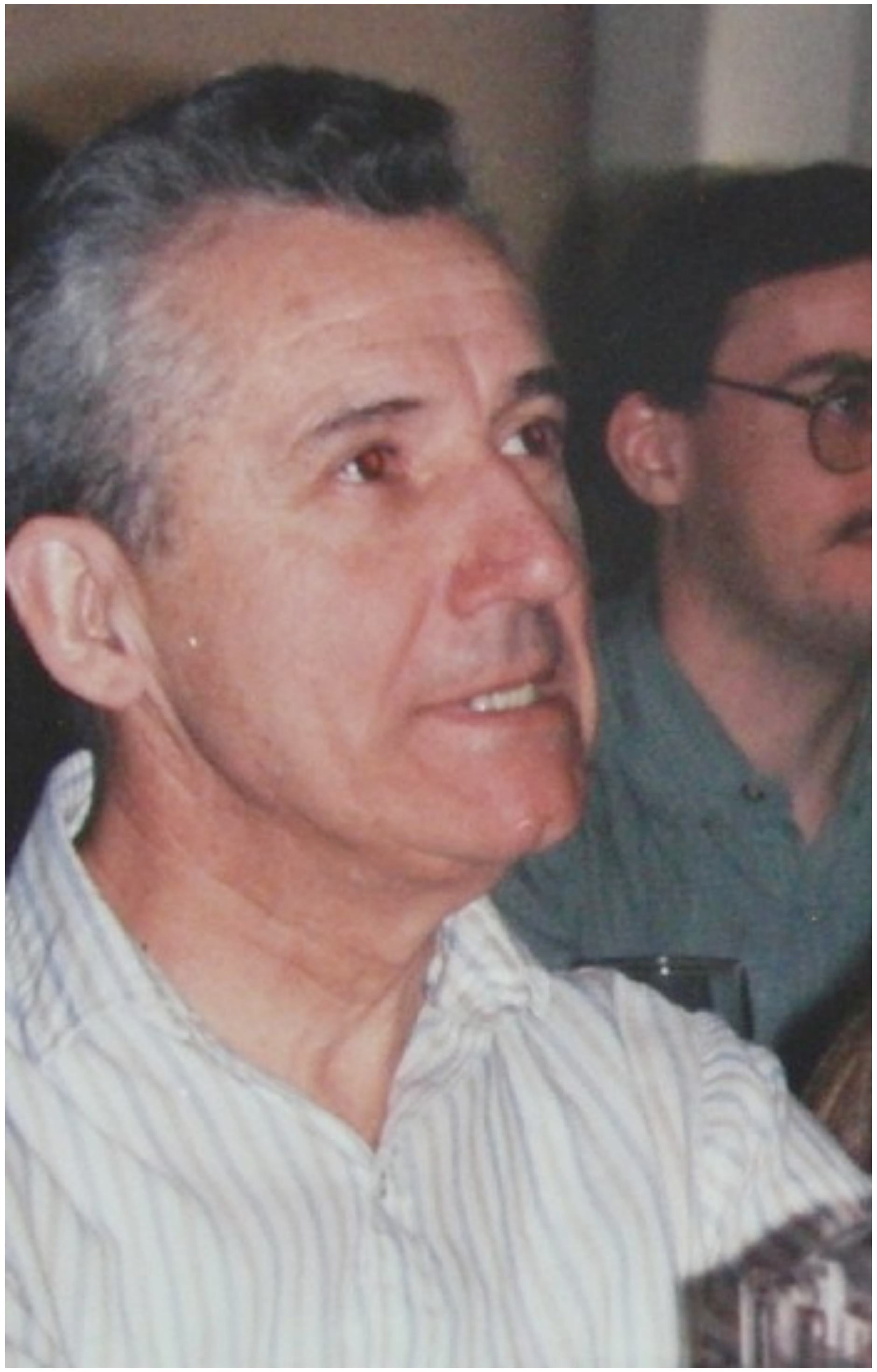
Being Wit-ty:
or
How to catch a “fat” proton

Berndt Müller

p(d)+A Workshop
MIT, 17-18 May 2013

Recollections of Wit (1)



Fascinated by new data

Recollections of Wit (2)

Argumentative.....
but in a friendly way

Recollections of Wit (3)

Never waste a good photo op!

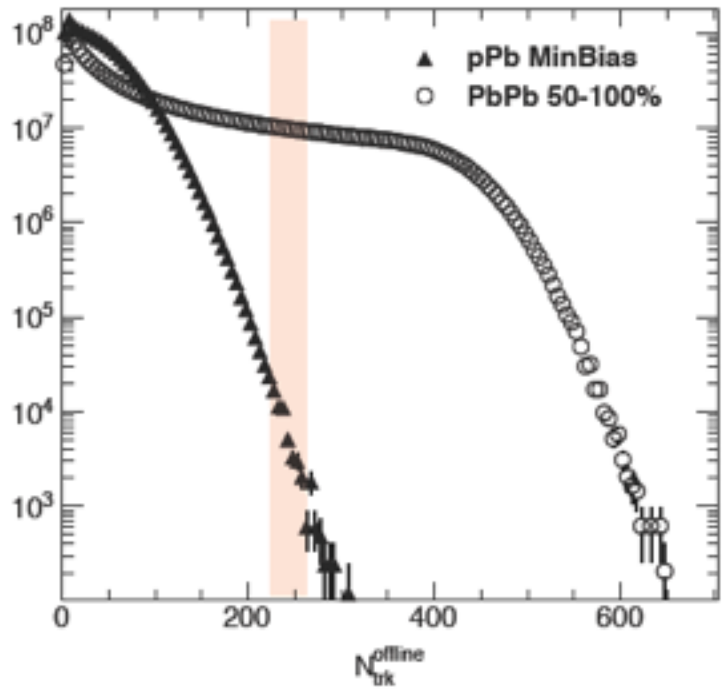
The biggest smile in the room

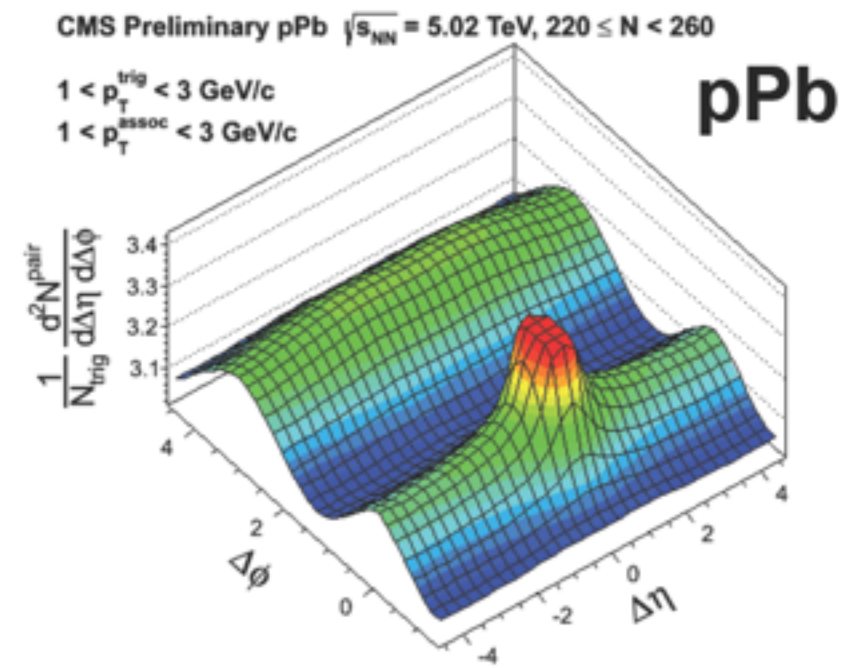
Thoughtful, when others sleep

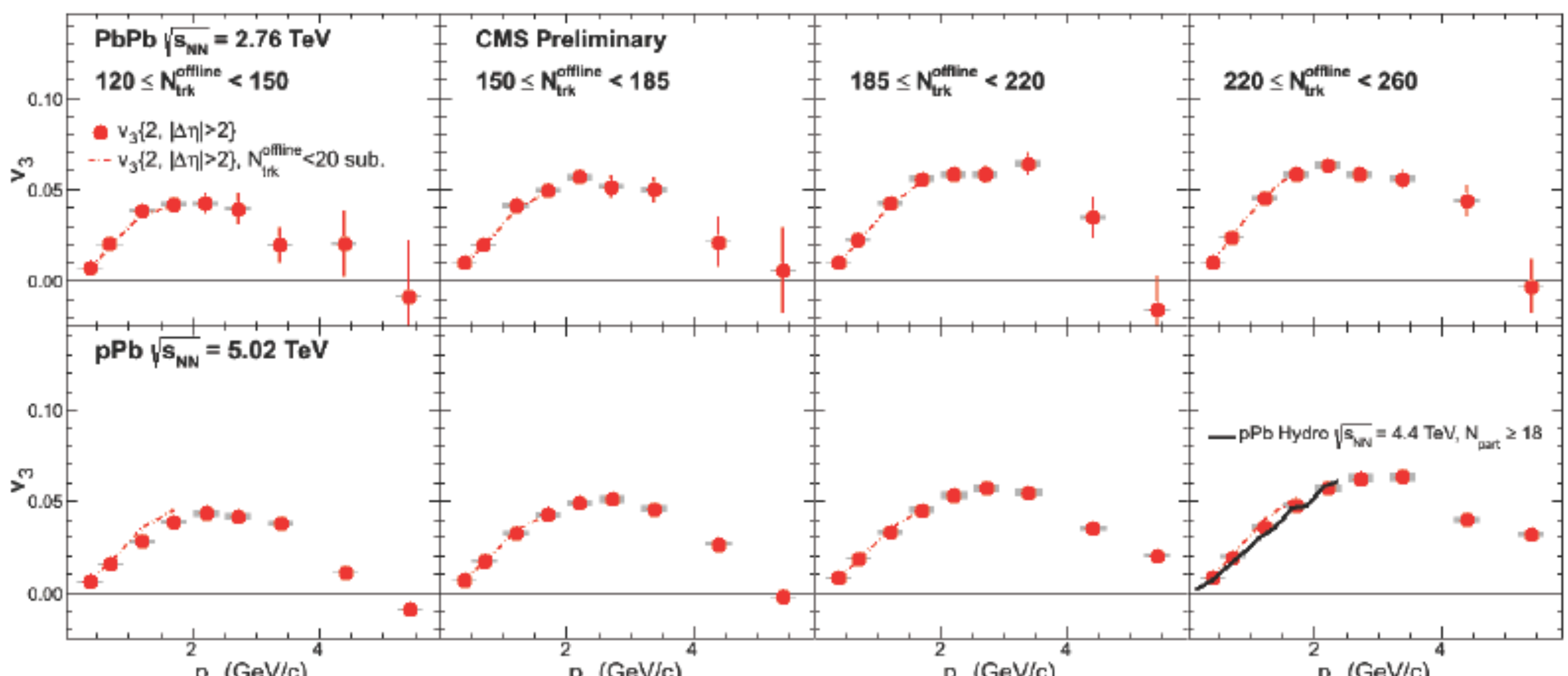
Never waste a moment !

Friend, I need your advice...

The p+Pb conundrum







PbPb

pPb

After the p+Pb run

A nagging question

Can it really be hydrodynamics?

The standard folklore (before 2012): Protons are small.

But are they really? Compared to what?

$\eta/s = 1/4\pi$ together with kinetic theory $\eta = np\lambda/3$ implies

$$\lambda = 3s/(4\pi np) \approx 1/p \approx 1/(3T) \approx 0.2 \text{ fm}$$

We also know that protons are fluctuating quantum systems.
Sometime they are tiny: “Color transparency”.
Maybe sometimes they can be “fat” !?

How to catch them? You need a net: A heavy nucleus.

It's not a new idea.....

TIME

Science & Space

Astrophysics: Where Is the Fat Proton From?

Friday, Mar. 15, 1963

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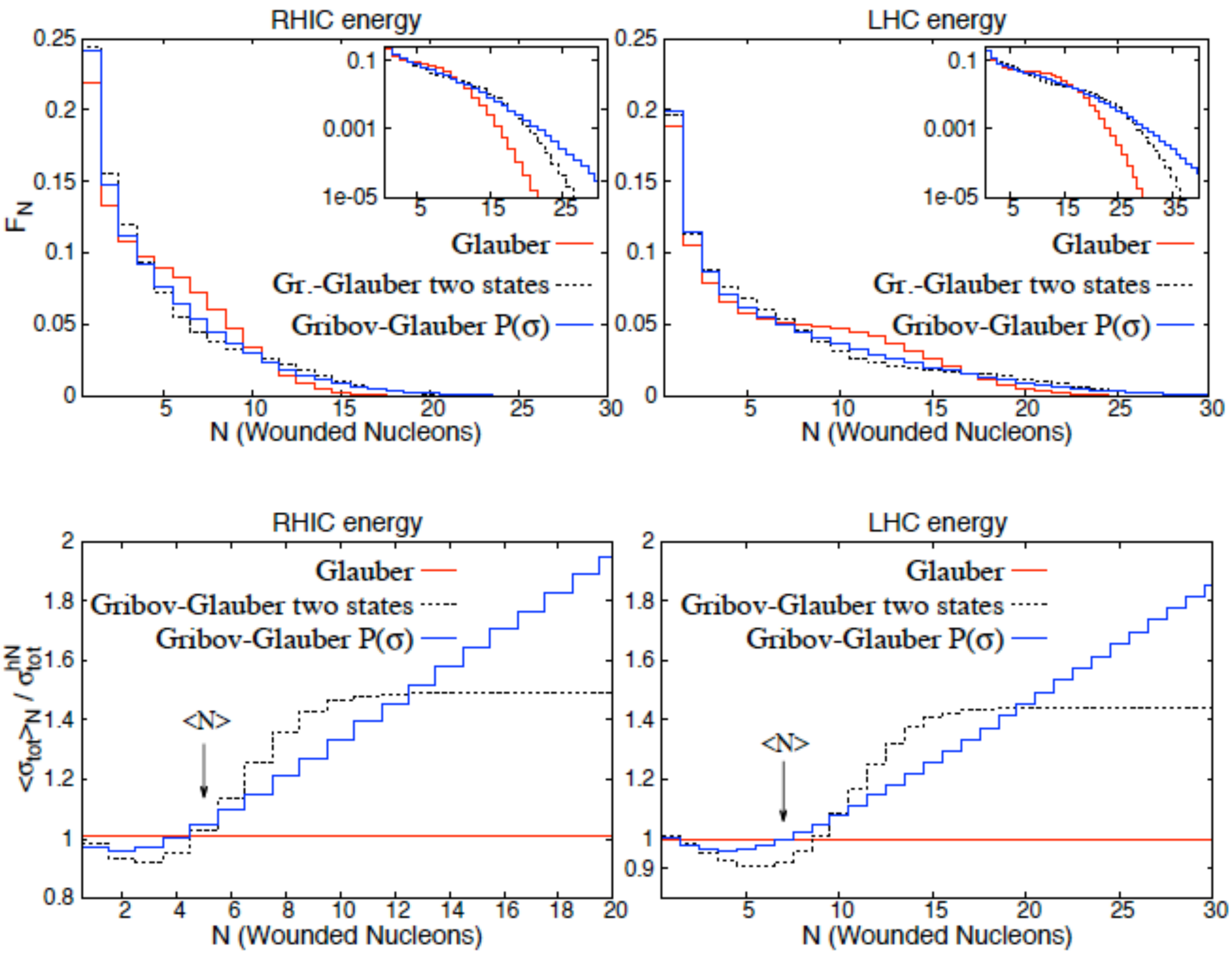
Spread over miles of desert near Albuquerque, shallow disks of special plastic material bake in the sun. Connected by wire to a central laboratory, they are scintillometers set out to watch for enormously powerful cosmic rays that smack into atoms in the high atmosphere and, as a result of the crash, spray the earth's surface with millions of subatomic particles. Despite the minute size of his quarry, Physicist John Linsley of M.I.T., who operates the ray trap, reported a tremendous catch: a shower of 50 billion particles.

More recently: $P(\sigma_{NN})$



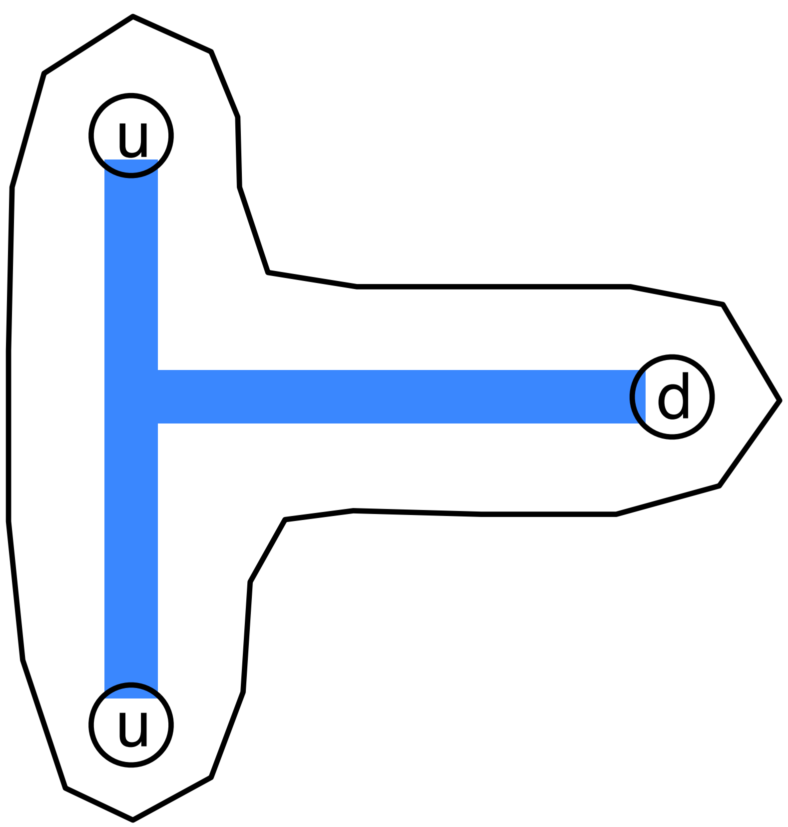
Alvioli & Strikman 1301.0728

Large N_{WN} picks out large σ

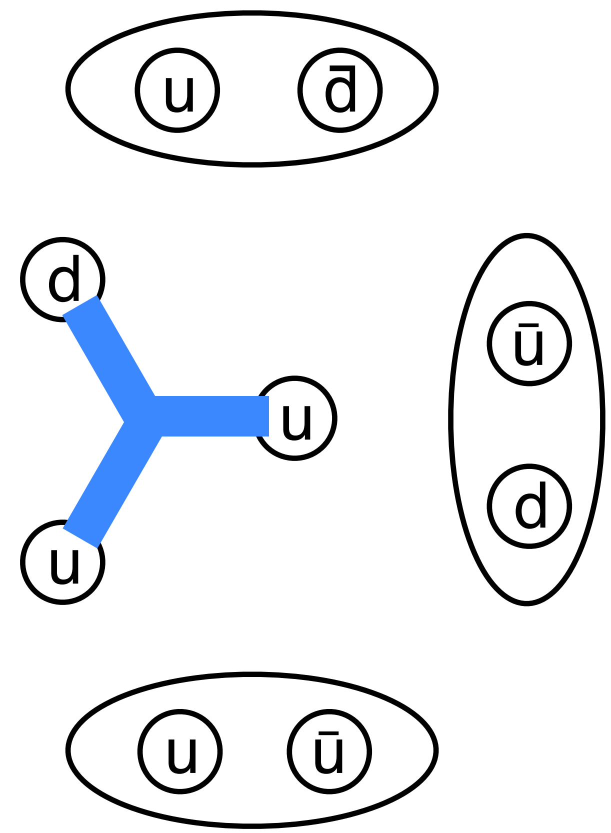
"Obese" protons

What does a "fat" proton look like?

The "stringy" proton



The "cloudy" proton



Pictures*

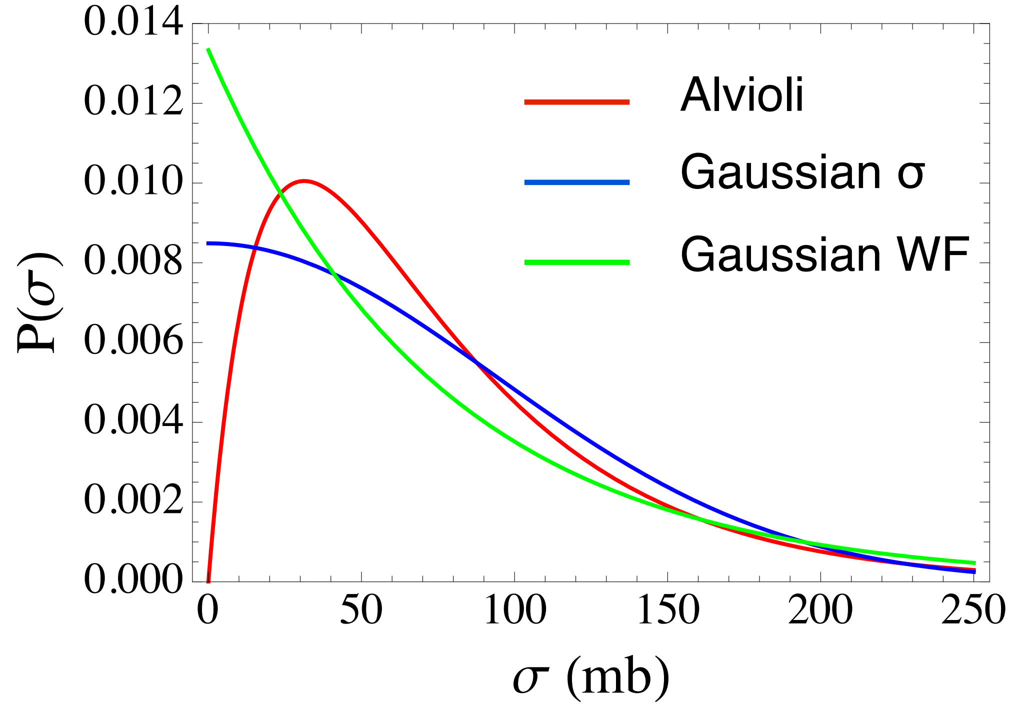
The “stringy” proton

The “cloudy” proton

*Thanks to Chris Coleman-Smith

Fat proton "net"

Some models of P(σ):

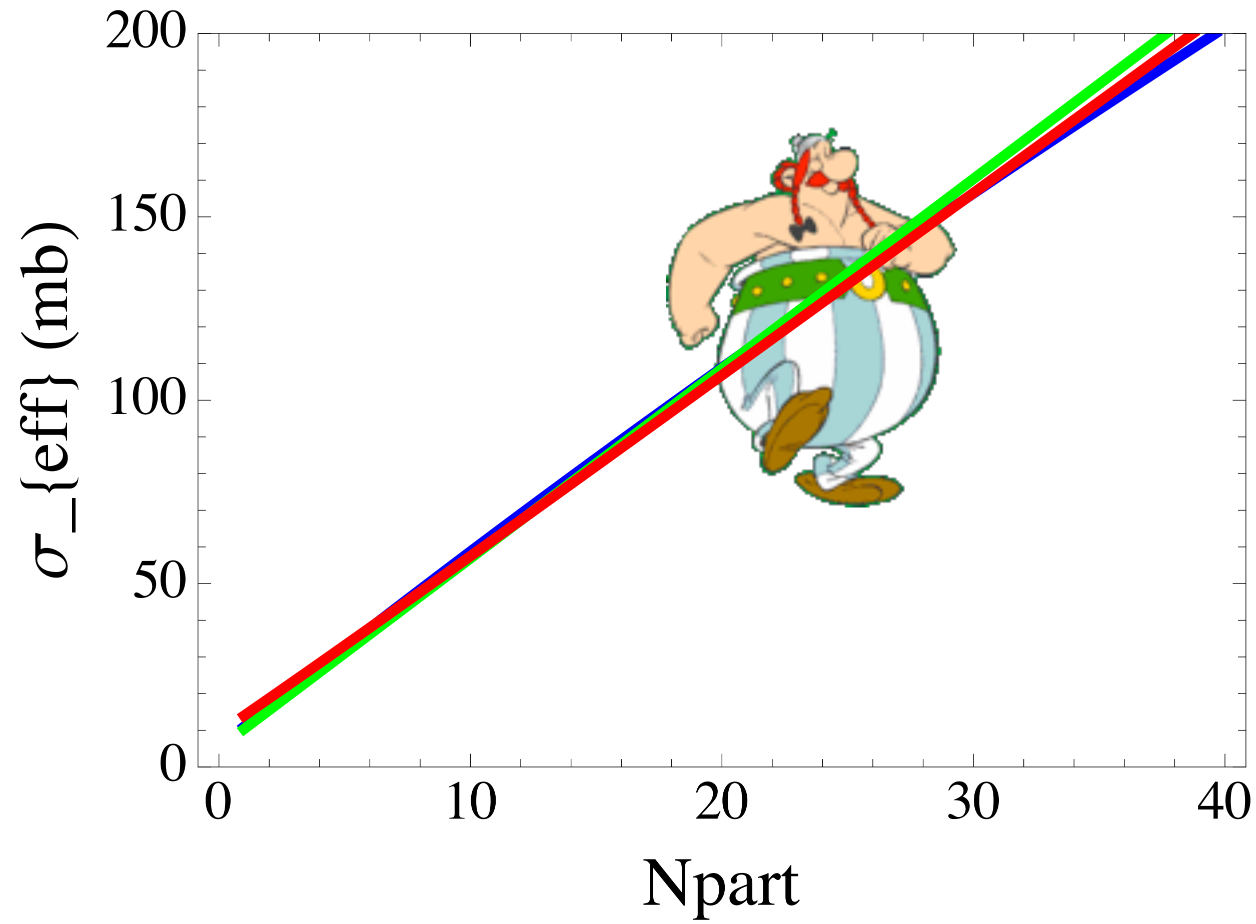


Npart serves as a "net" catching "fat" protons

N_{part} depends on σ:

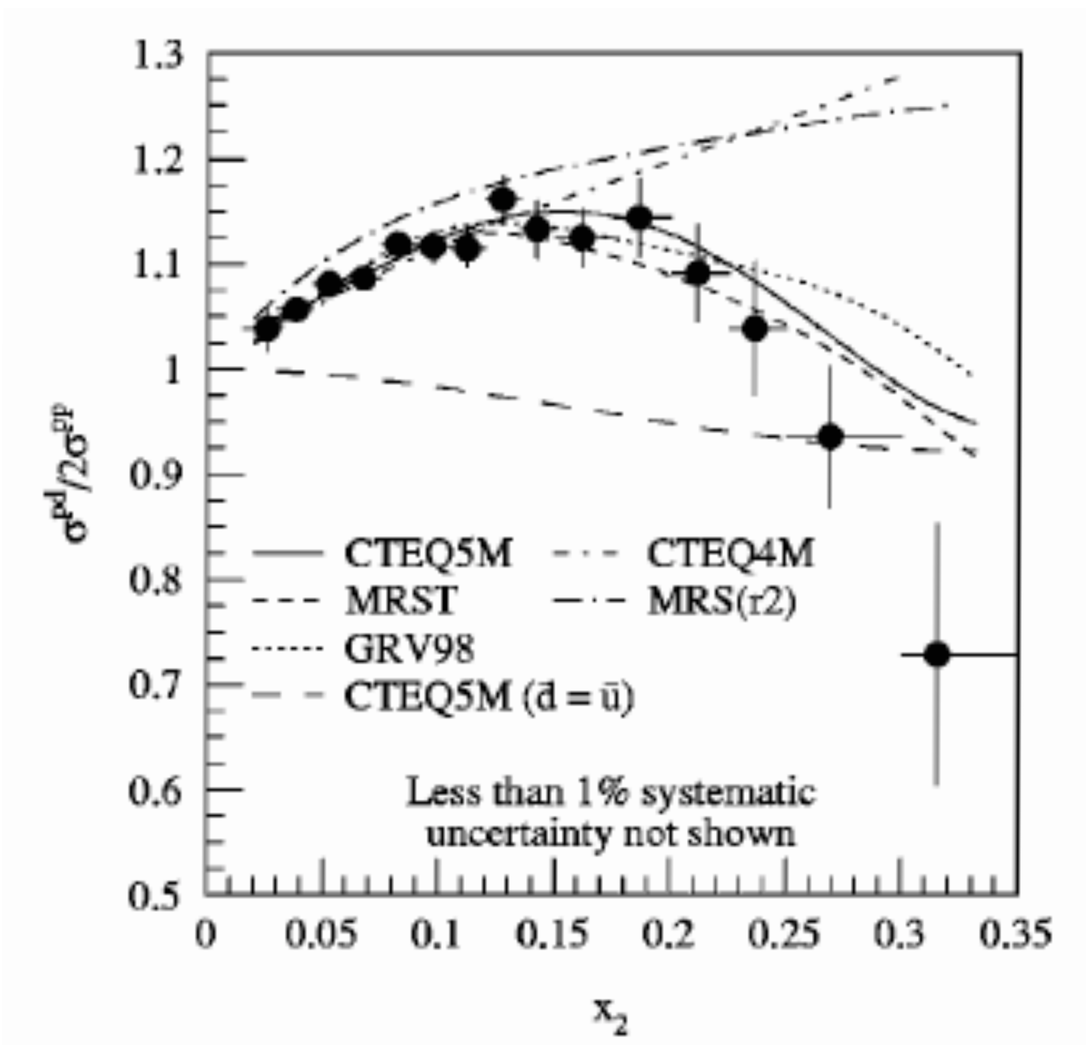
$$W(N,\sigma) = e^{-\bar{n}(\sigma)} \frac{\bar{n}(\sigma)^N}{N!}$$

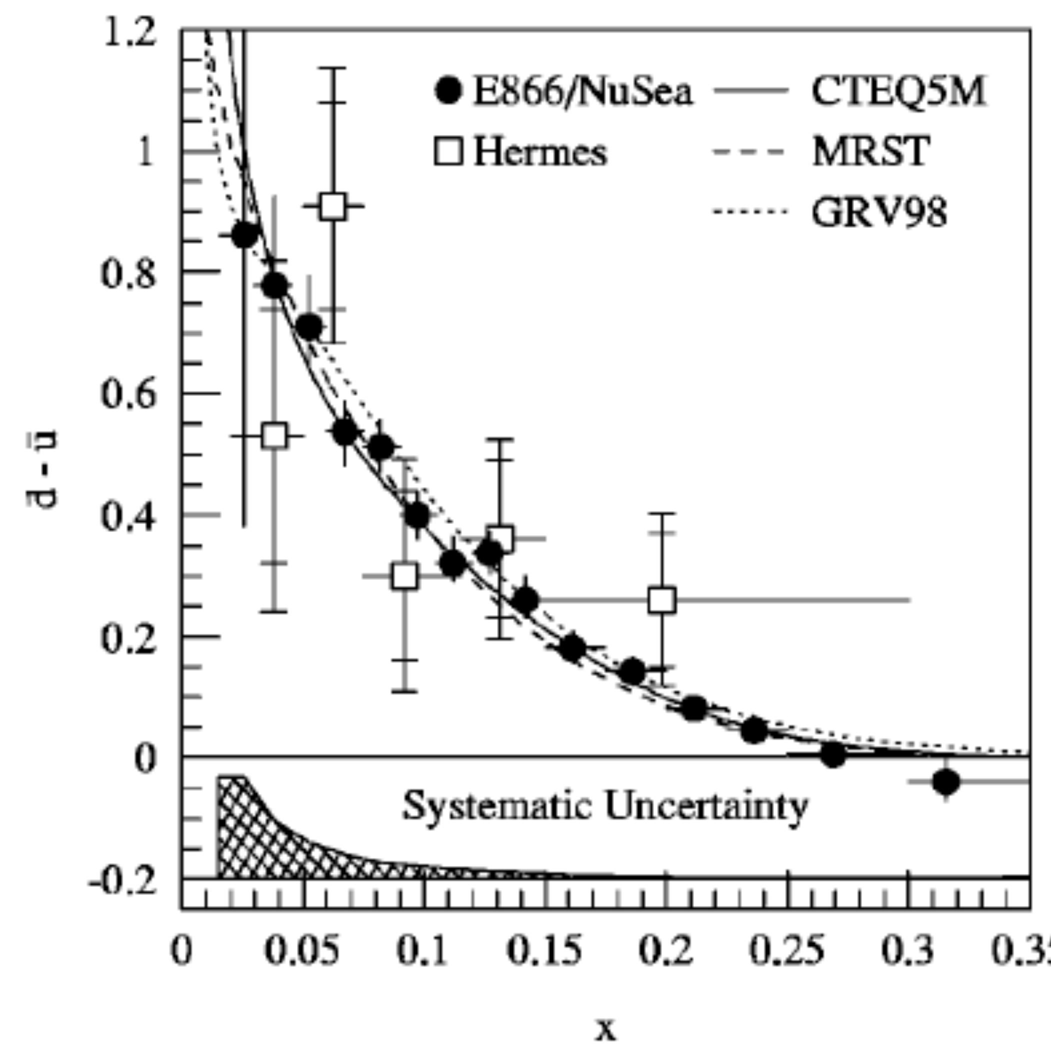
$$\sigma_{\rm eff}(N_{\rm part}) = \frac{\int \sigma \, d\sigma \, W(N_{\rm part},\sigma) P(\sigma)}{\int d\sigma \, W(N_{\rm part},\sigma) P(\sigma)}$$



π cloud: exp. evidence

R.S. Towell et al. (E866/NuSea Collaboration), PRD64, 052002 (2001)





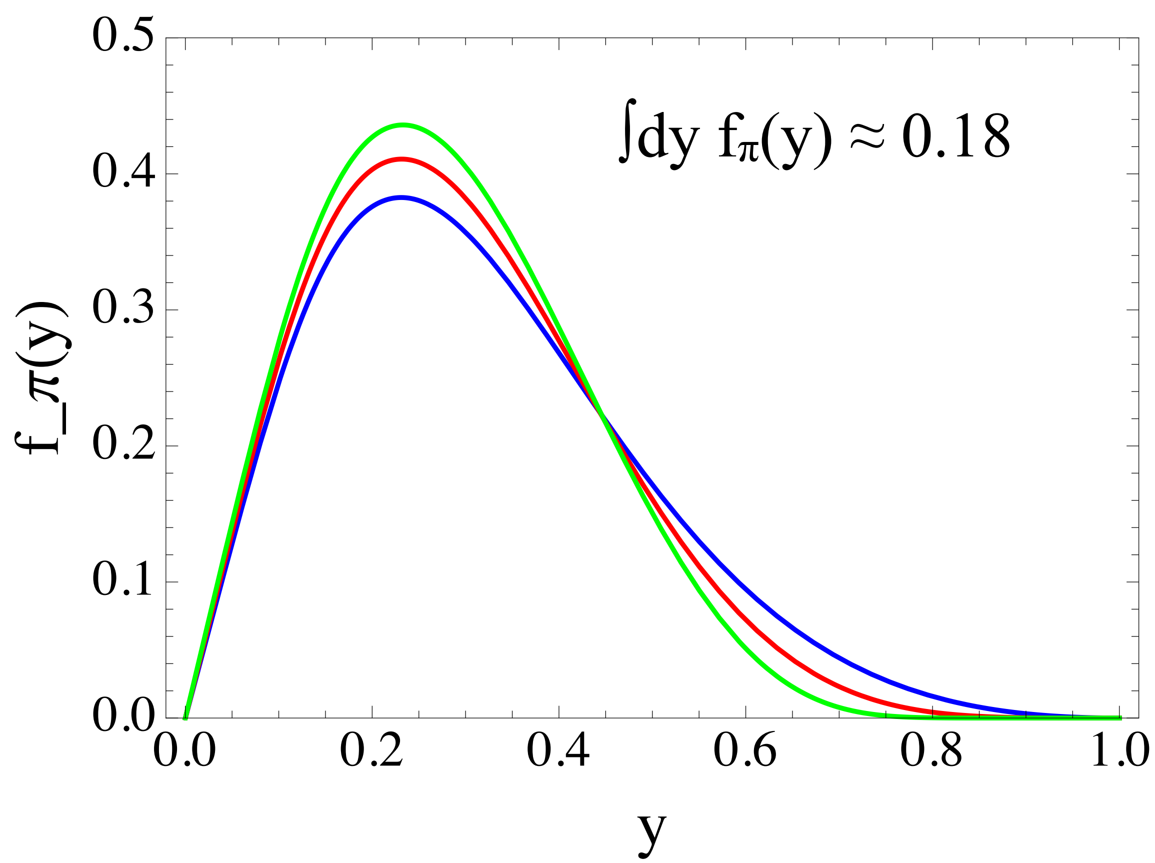
$\int dx(\bar{d}-\bar{u}) = 0.118 \pm 0.012$

Pion cloud models

Kumano, PRD 43, 59 (1991)

P_N = probability for a proton to be accompanied by N virtual pions

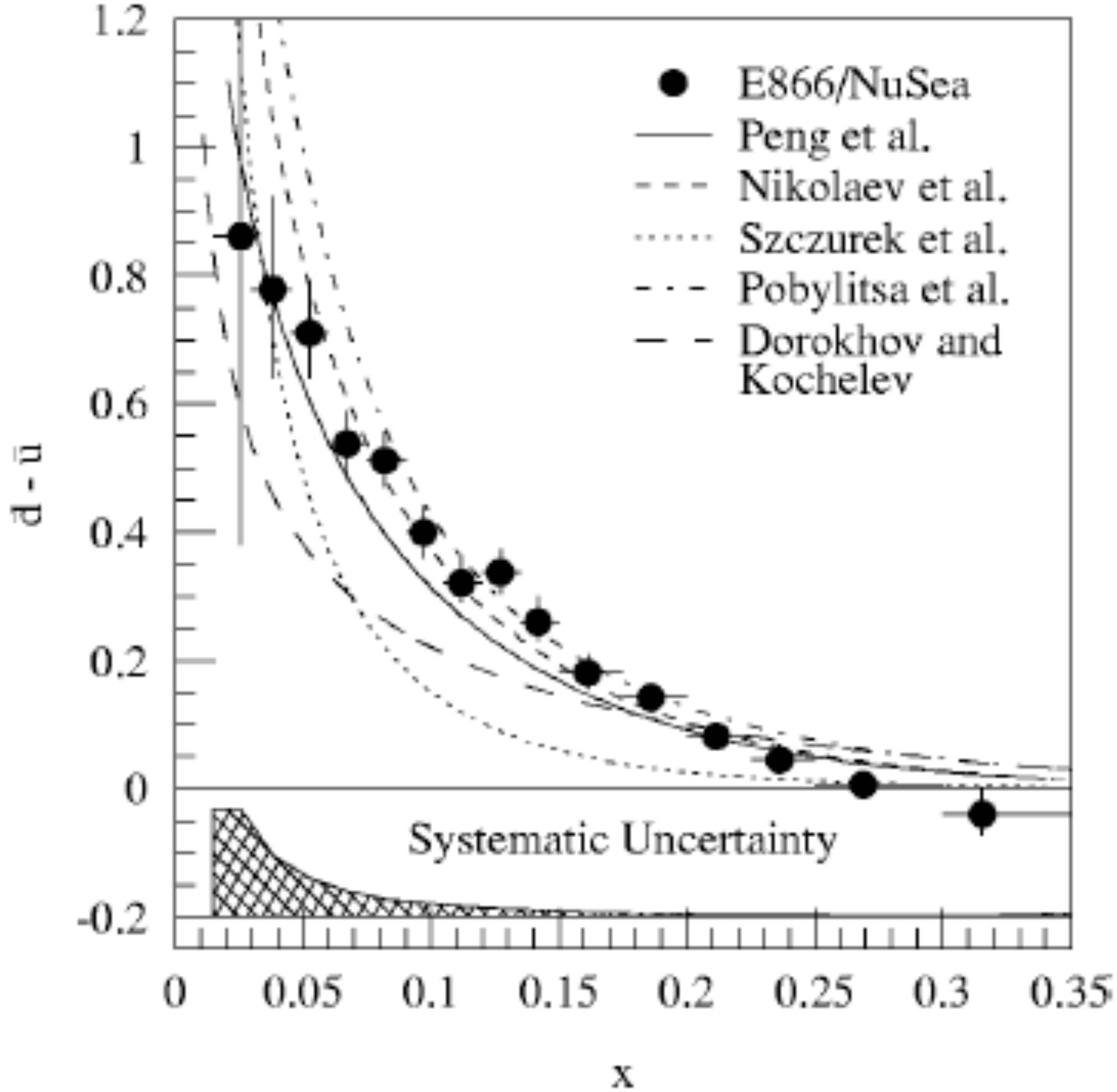
$$f_\pi(y) \sim \frac{g_{\pi NN}^2}{(4\pi)^2}\, y \int_{-\infty}^{t_{\max}} dt\, \frac{-t}{(-t+m_\pi^2)^2} F_{\pi NN}(t)^2$$



N	P_N	$N_Q/3$
0	0.84	1
1	0.15	1.67
2	0.014	2.33
3	8.1×10^{-4}	3
4	3.7×10^{-5}	3.67
5	1.3×10^{-6}	4.33
6	4×10^{-8}	5

Antiquark distribution

$$\bar{q}(x) = \int_x^1 \frac{dy}{y} f_\pi(y)\bar{q}(x/y)$$



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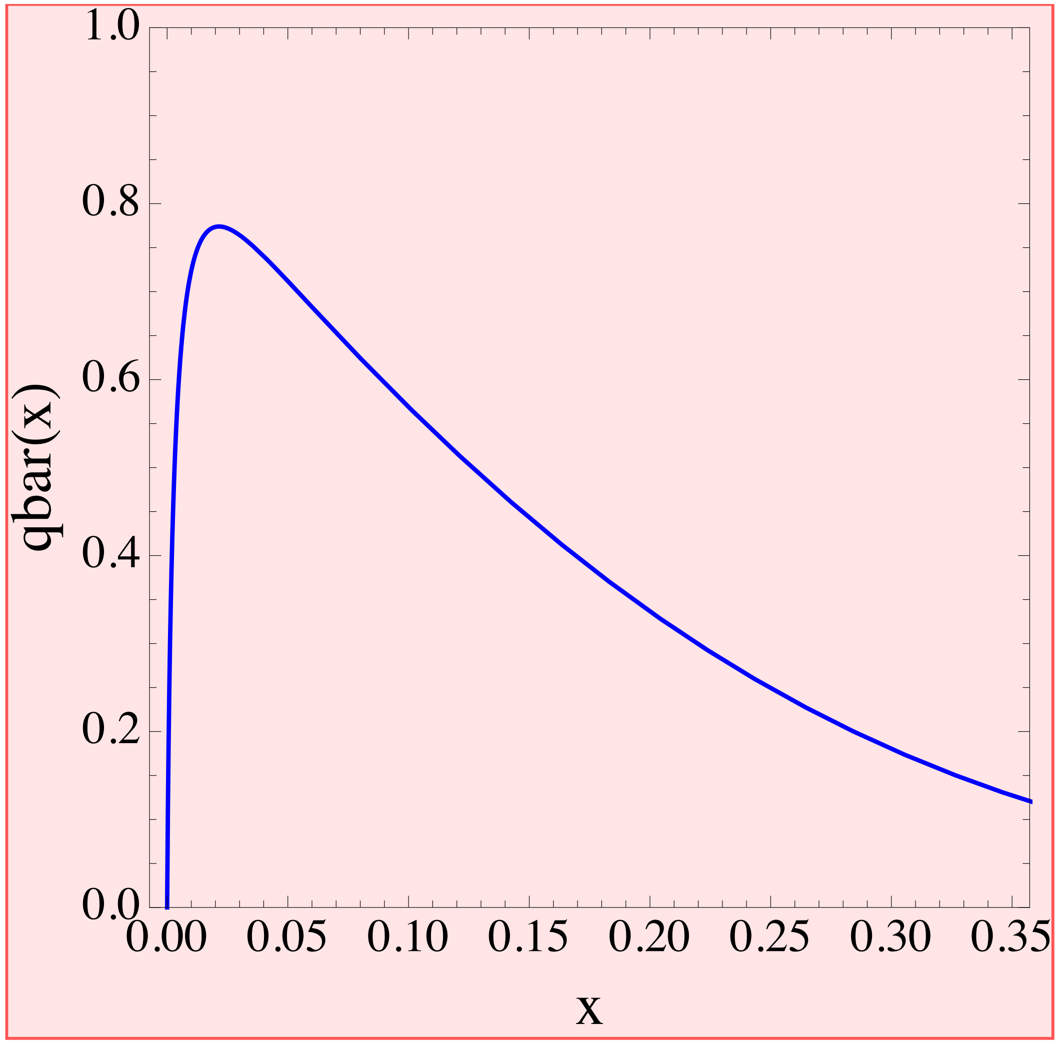


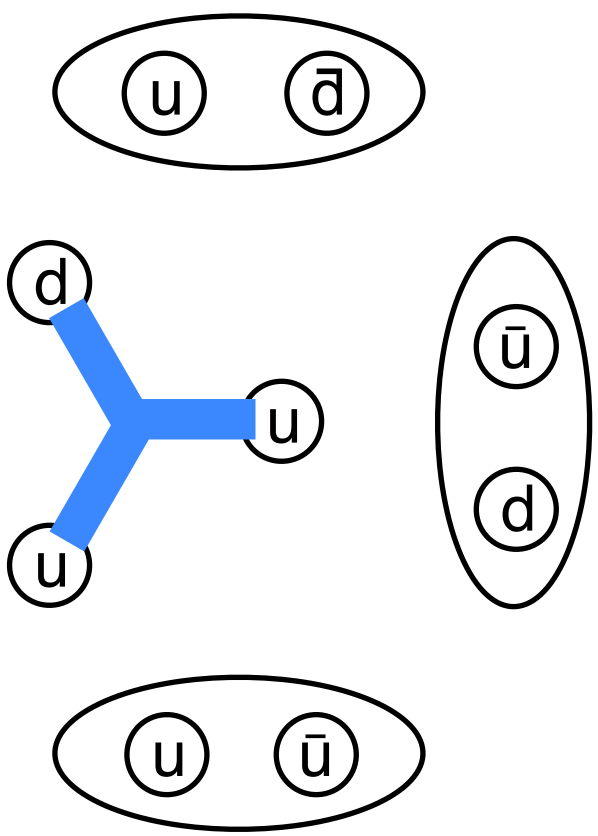
“Obese” protons

We can estimate the probability of finding a “cloudy” proton:

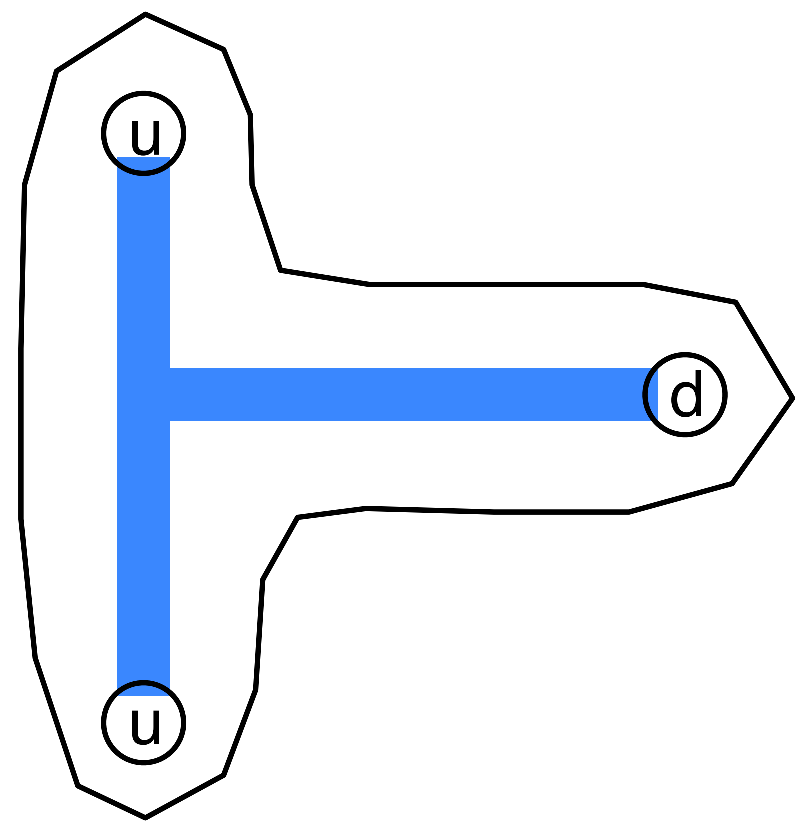
Can we estimate the probability of finding a “stringy” proton?

The “cloudy” proton

$\sim 10^{-3}$



The “stringy” proton



Experimental tests?

- Fat protons have more “soft” partons and fewer large-x partons.
- Fat “stringy” protons should have a surplus of soft gluons with similar x-distribution as a normal proton.
- Fat “cloudy” protons have a surplus of quarks and antiquarks in the range $x \approx 0.1$.
- This should lead to a suppression of high-pt mesons and jets in high-multiplicity p+A and d+A events.

Please continue....

...to teach us how to do good physics

...and to dance through life