The Gluon Exchange Model for diffractive and inelastic collisions

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1. **Introduction ;**
2. **The Gluon Exchange Model ;**
3. **Results ;**
4. **Conclusions.**

Based on:

1) APPB 51 (2020) 1207
2) PLB 816 (2021) 136200
3) ArXiv: 2105.13741

For a review, see

4) ArXiv: **2106.14972**

… or solving the puzzle of nuclear stopping power

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This talk will be concerned with "soft" proton-proton and proton-nucleus collisions at $\sqrt{s} \sim 20$ GeV.

The implications touch all the high energy scale (LHC, cosmic), and also nucleus-nucleus (heavy ion) physics.

The main problem which we will address is the following:

- in a proton-nucleus (pA) collision, how does the proton *encode* knowledge on the number of nucleons which it collides with ?

"The puzzle of nuclear stopping power"

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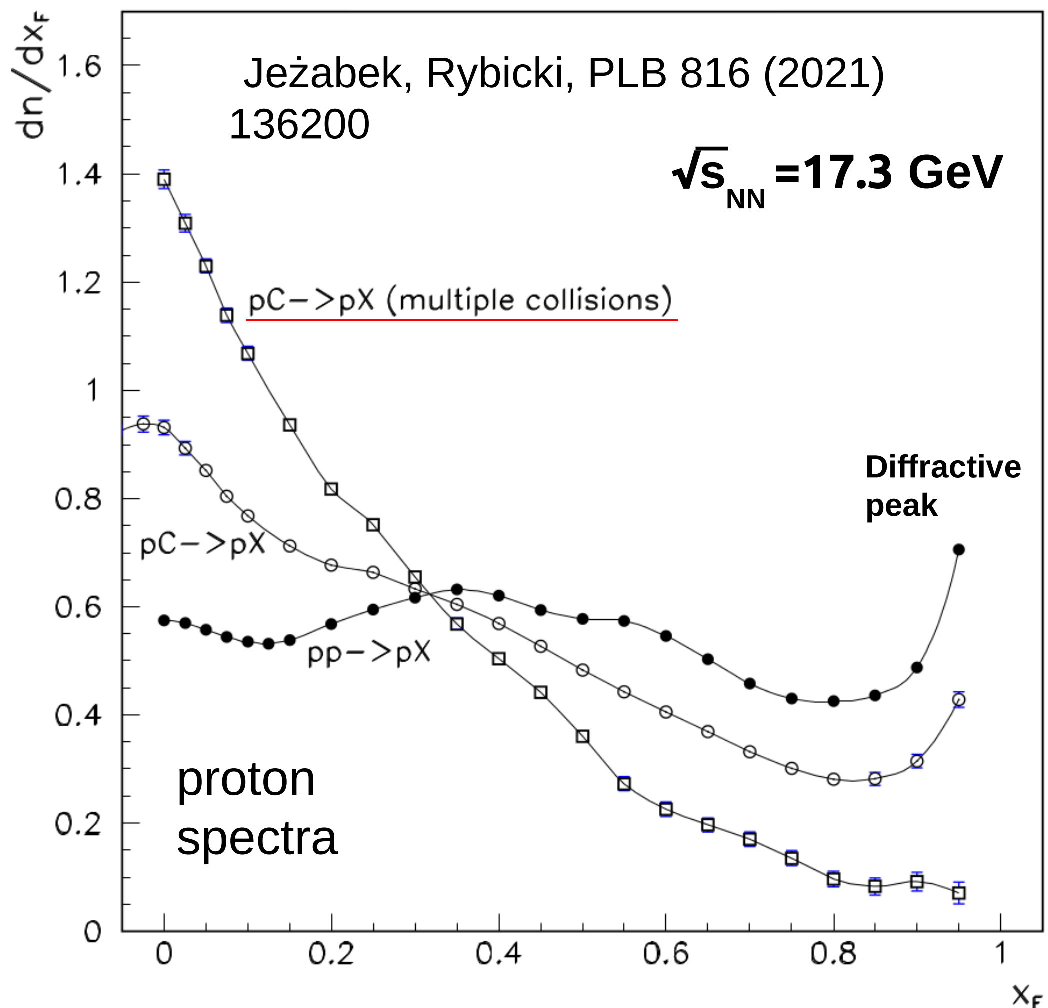
Proton-proton vs proton-nucleus collisions

$$\frac{dn}{dx_F}(pC_{\text{multiple collisions}} \to pX) = \frac{1}{1-P(1)}\left(\frac{dn}{dx_F}(pC \to pX) - P(1)\cdot\frac{dn}{dx_F}(pp \to pX)\right)$$

1. pp and pC data from the same NA49 experiment (Eur. Phys. J. **C65**, 9 (2010), Eur. Phys. J. **C73**, 2364 (2013)).
2. **P(1)** - probability of proton collision with one wounded nucleon.
3. **Advantage**: we can extract pC collisions in which the proton collides with **multiple** (more than one) nucleons.



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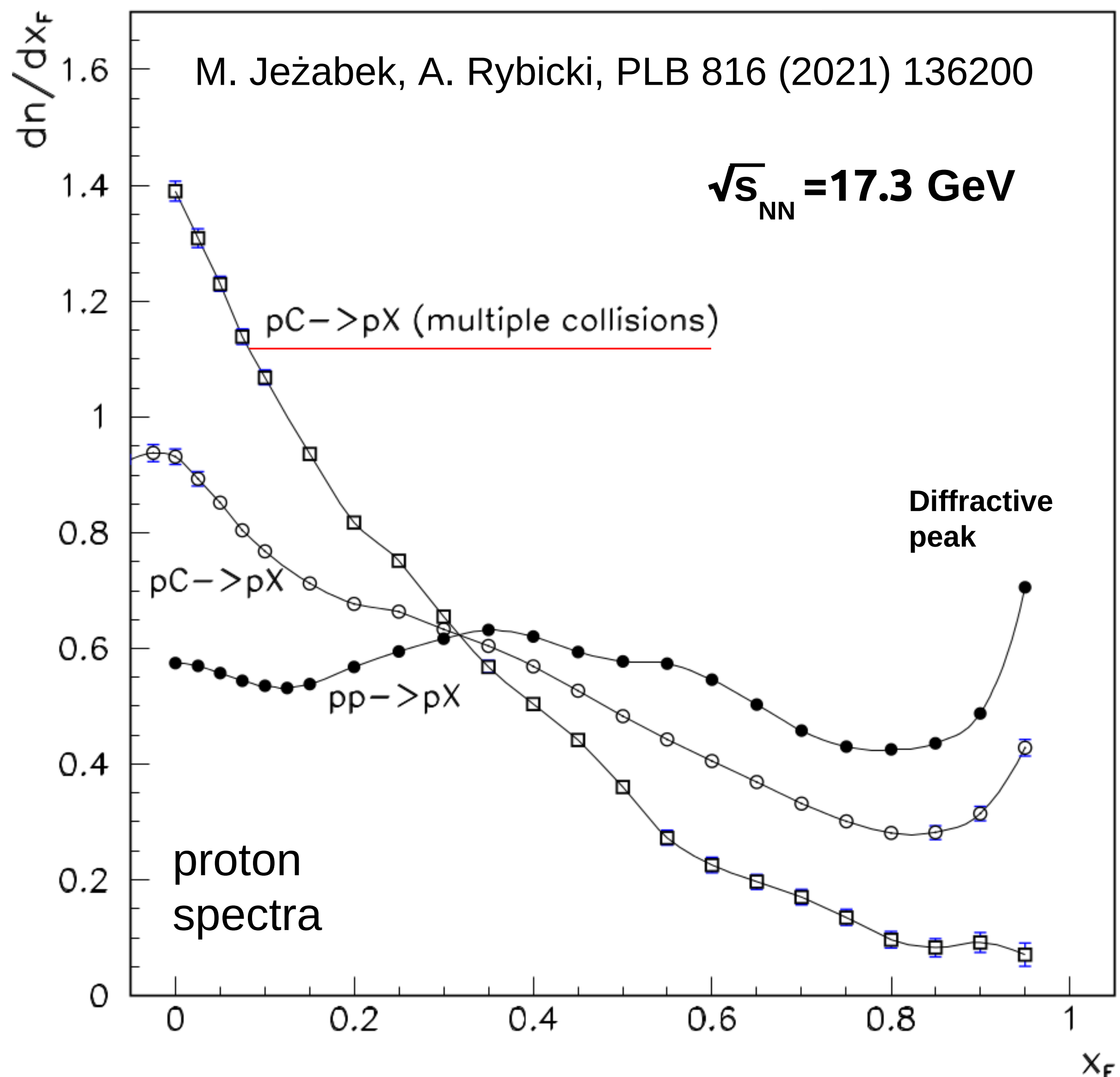
Qualitative difference between single and multiple proton-nucleon collisions!

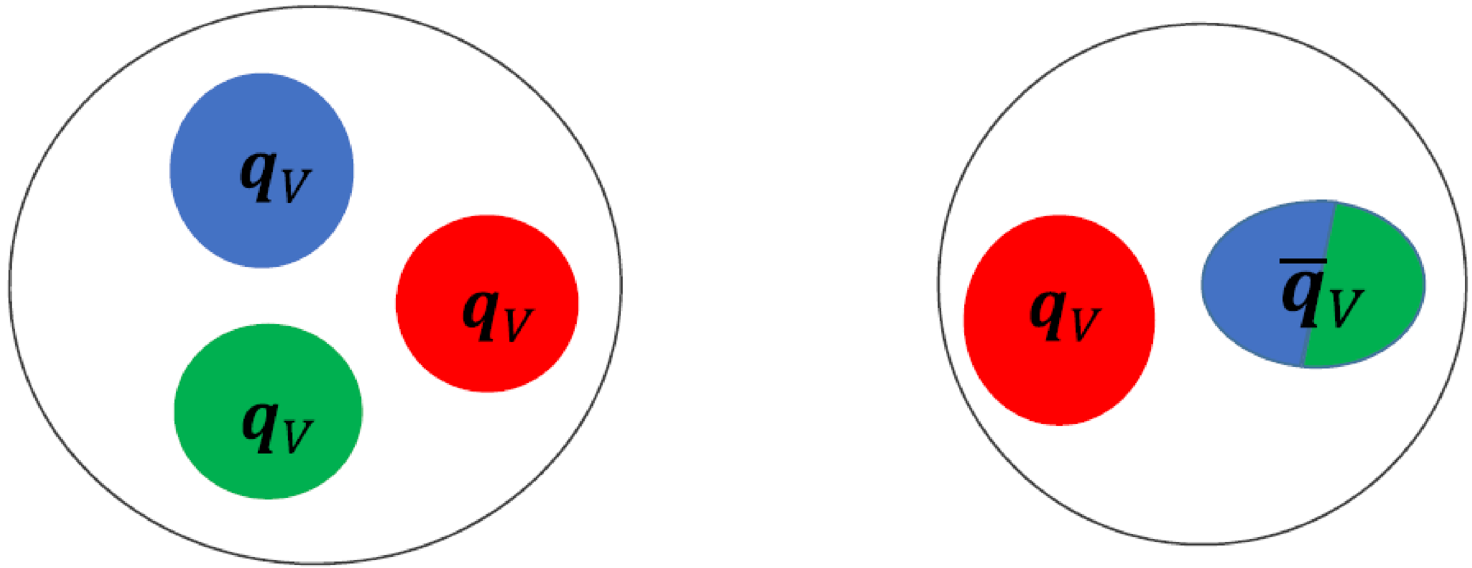
How does the projectile know about the number of wounded nucleons ?

→ The Gluon Exchange Model :

→ The projectile is a system of constituents : valence quarks (color triplets) and sea quark-antiquark pairs (color octets).

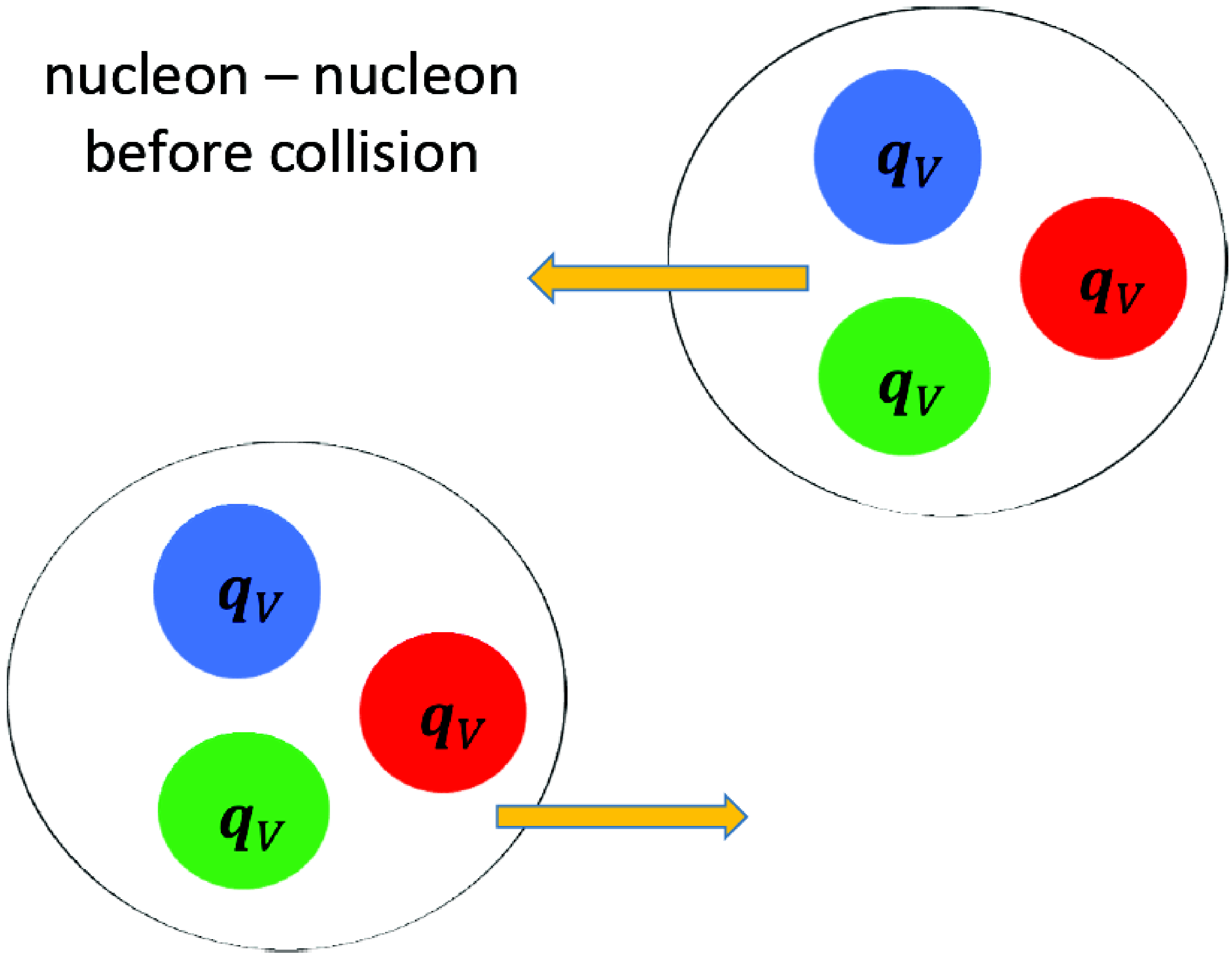
→ The interaction is governed by the number of exchanged color octets (gluons).



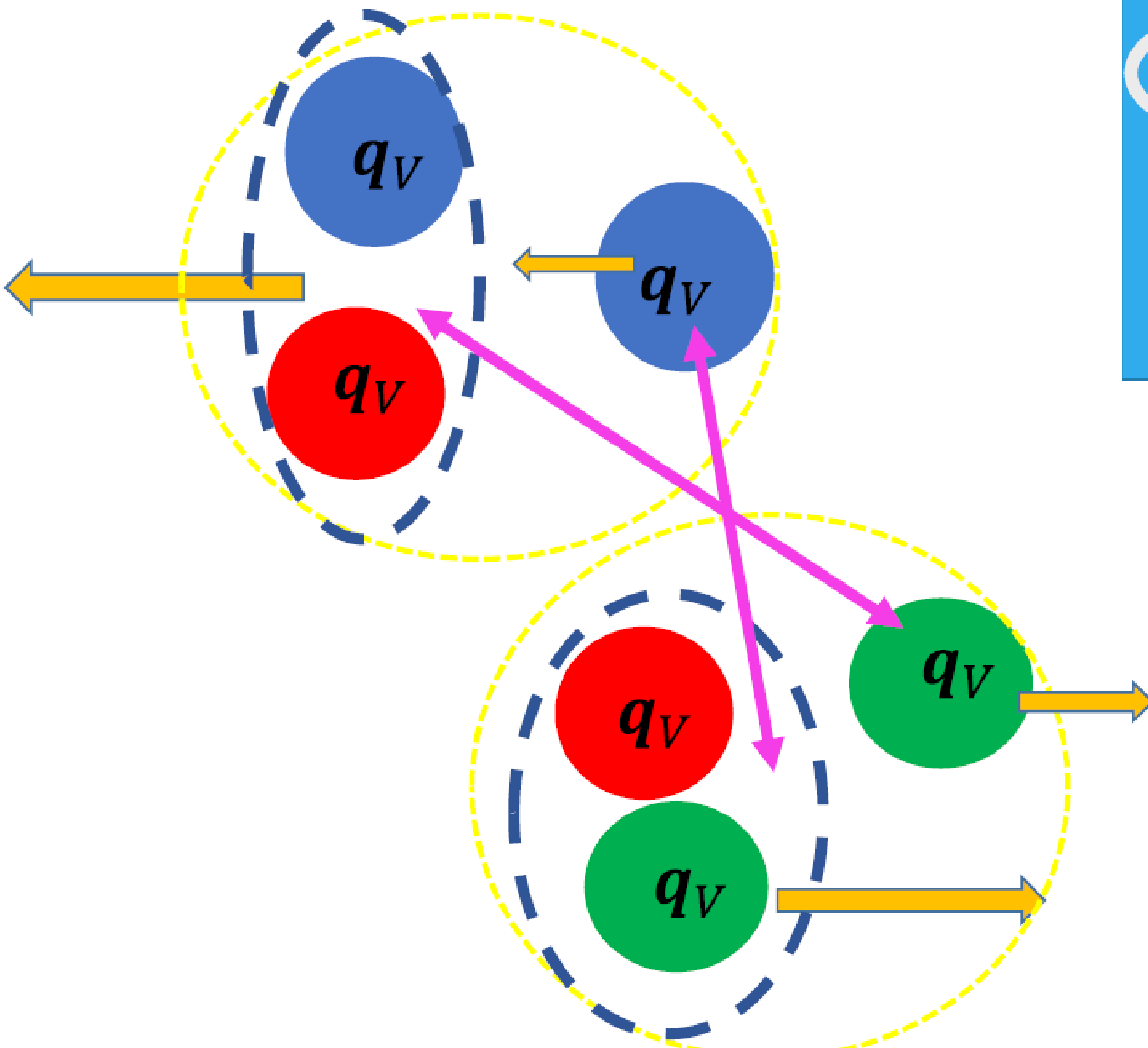


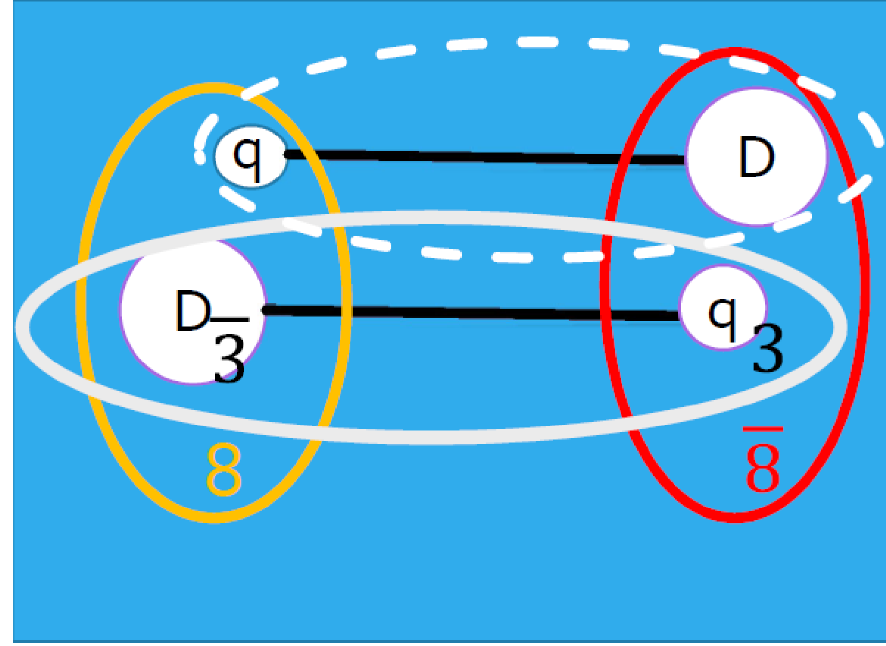
Baryon Meson

nucleon – nucleon
before collision



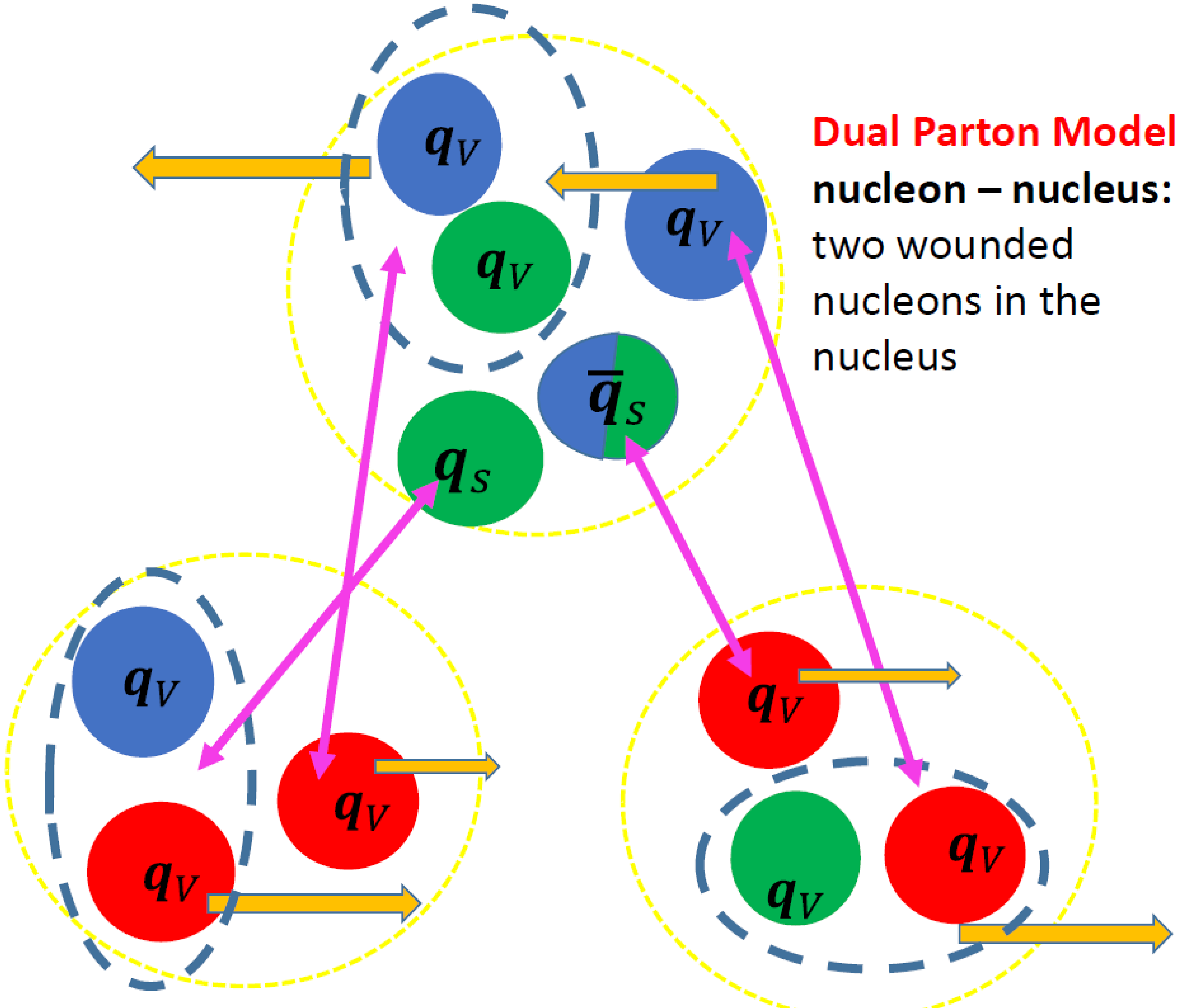
nucleon – nucleon after collision





Note: this is like in the Dual Parton Model.

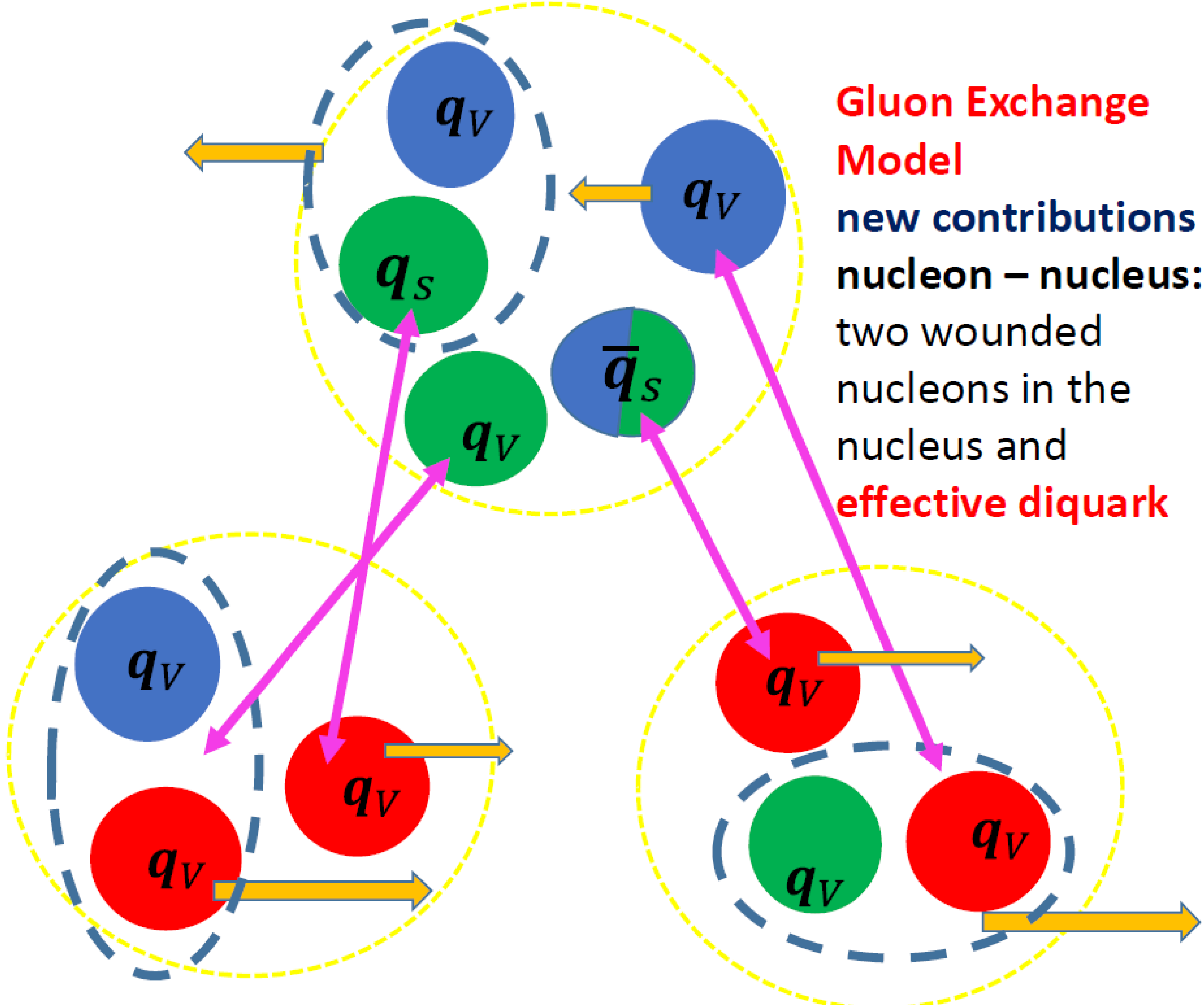
A. Capella and J. Tran Thanh Van, PLB **93**, 1980,
M. Jeżabek, J. Karczmarczuk, M. Różańska, ZPC **29**, 1985.



Dual Parton Model

nucleon – nucleus:

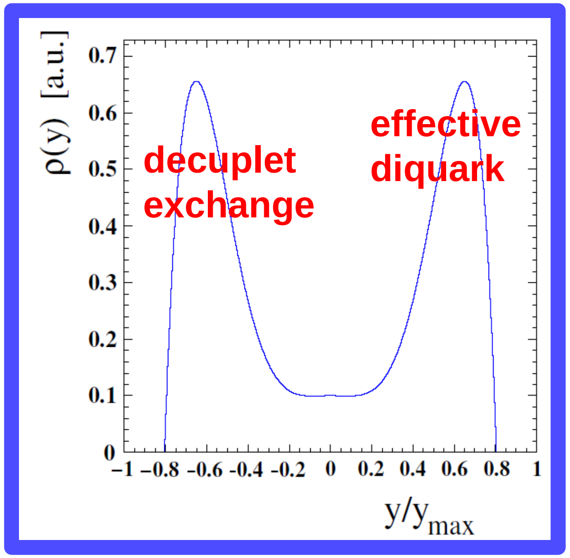
two wounded nucleons in the nucleus

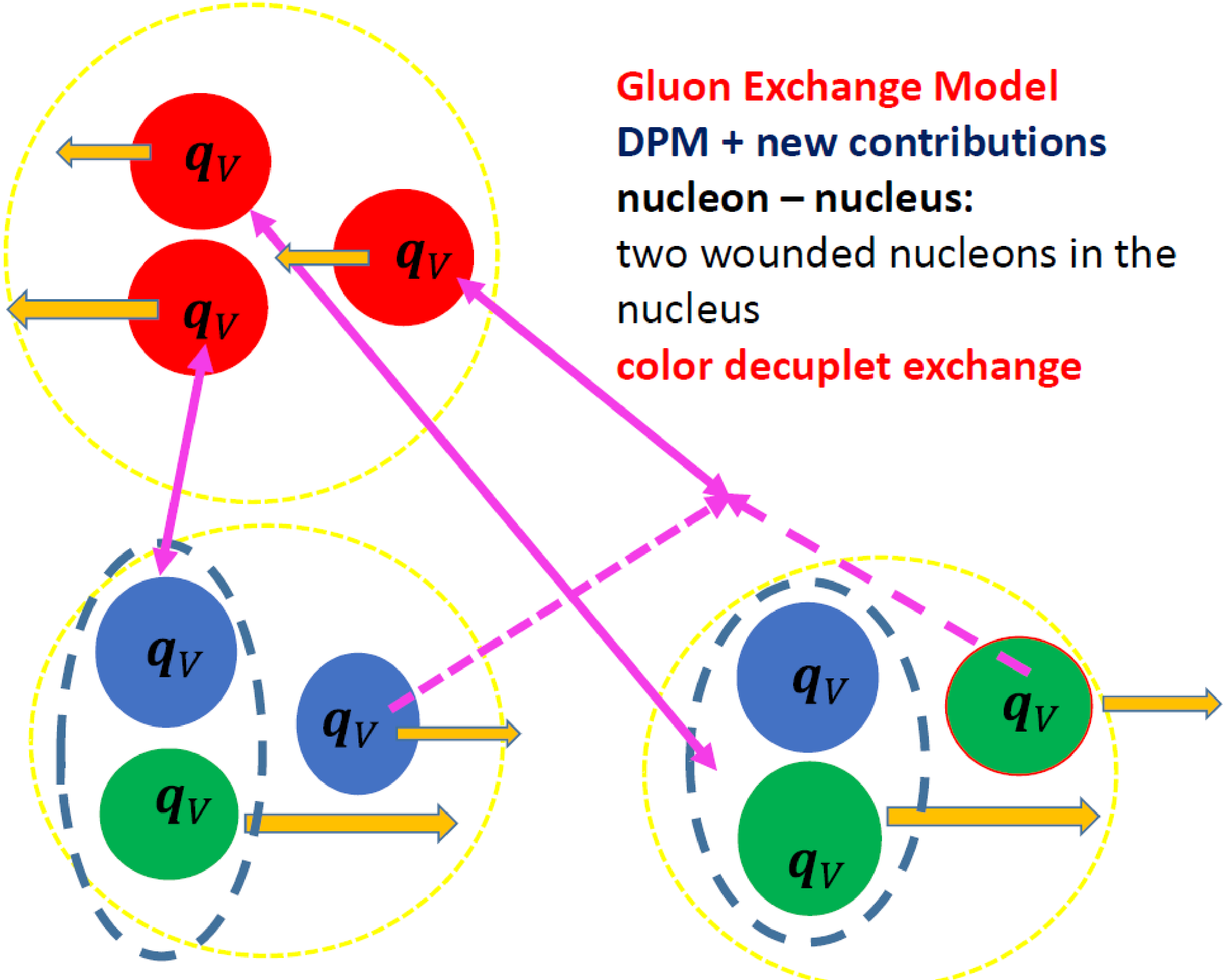


Gluon Exchange Model

new contributions nucleon – nucleus:

two wounded nucleons in the nucleus and **effective diquark**





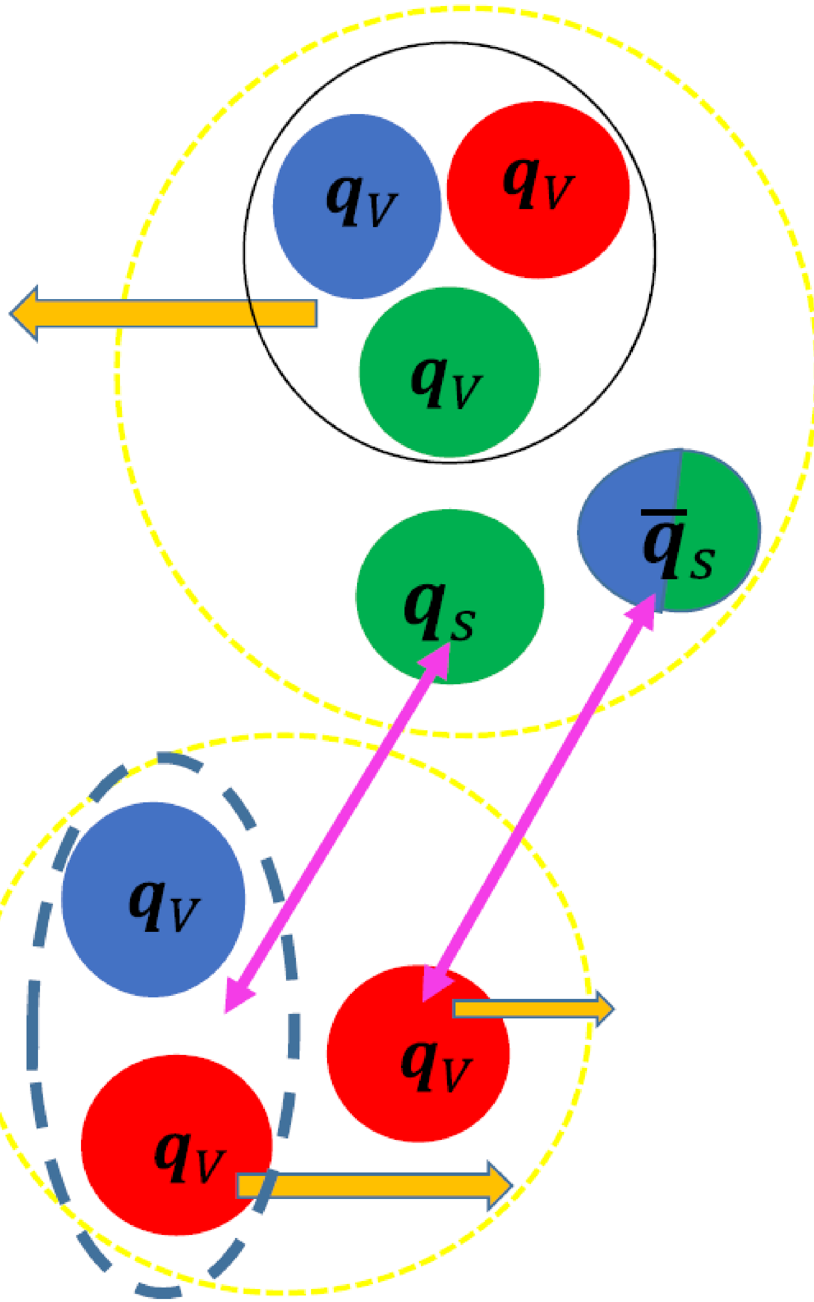
Gluon Exchange Model

DPM + new contributions

nucleon – nucleus:

two wounded nucleons in the nucleus

color decuplet exchange



Bonus...

Gluon Exchange Model

DPM + new contributions

nucleon – nucleon:

inelastic diffraction

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Four classes of events in the projectile hemisphere of pp/pA reactions, which differ in terms of momenta of final state baryons:

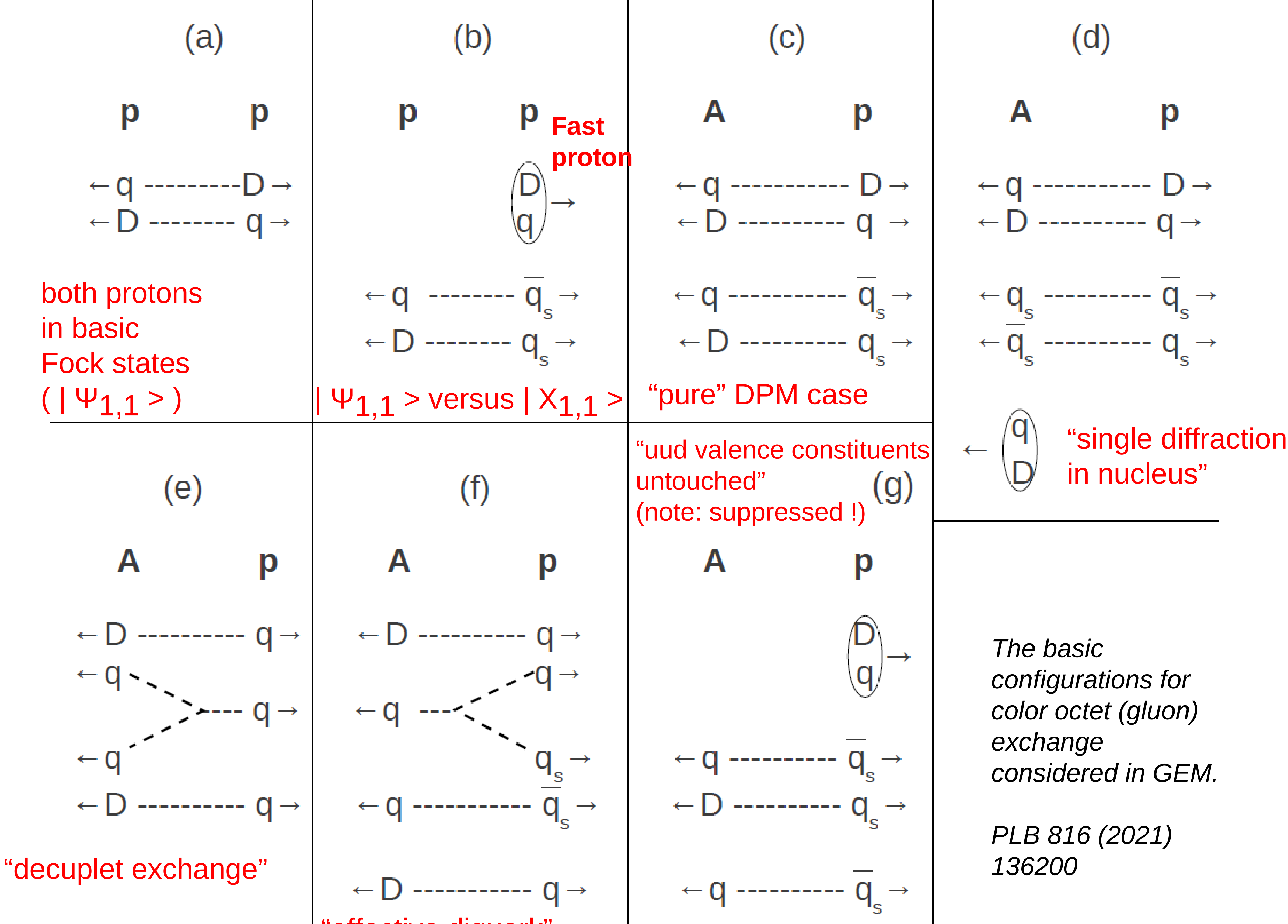
1. “inelastic diffraction" (→ very fast proton).

2. diquark made by two valence quarks (→ diquark preserving, like in DPM).

3. effective diquark, made from one valence quark and one sea quark (→ softer baryon).

4. decuplet exchange (→ with large probability, no baryon in the projectile hemisphere).

The relative contributions of the different classes will depend on the atomic mass A, or the centrality of the pA collision.


(a)
p p
←q ---------D→
←D -------- q→
both protons
in basic
Fock states
(| Ψ1,1 >)
(b)
p p
Fast
proton
D q →
←q -------- q̄s →
←D -------- qs →
| Ψ1,1 > versus | X1,1 >
(c)
A p
←q ---------- D→
←D ---------- q →
←q ---------- q̄s →
←D ---------- qs →
"pure" DPM case
(d)
A p
←q ---------- D→
←D ---------- q→
←qs ---------- q̄s →
←q̄s ---------- qs →
← q D
"single diffraction
in nucleus"
(e)
A p
←D ---------- q→
←q
---- q→
←q
←D ---------- q→
"decuplet exchange"
(f)
A p
←D ---------- q→
q→
←q ---
qs →
←q ---------- q̄s →
←D ---------- q→
"effective diquark"
"uud valence constituents
untouched"
(note: suppressed !)
(g)
A p
D q →
←q ---------- q̄s →
←D ---------- qs →
←q ---------- q̄s →
←D ---------- qs →
The basic
configurations for
color octet (gluon)
exchange
considered in GEM.
PLB 816 (2021)
136200

- Note!
- Below we will discuss NET baryon spectra.
- Baryon-antibaryon pair production has been subtracted from all the distributions!
- Unlike at the LHC, at the SPS the pbar/p ratio is ~0.25 at y(c.m.s.)=0 .

GEM in pp collisions

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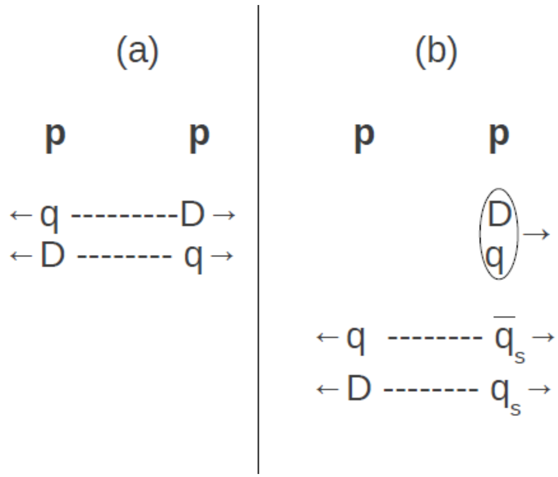

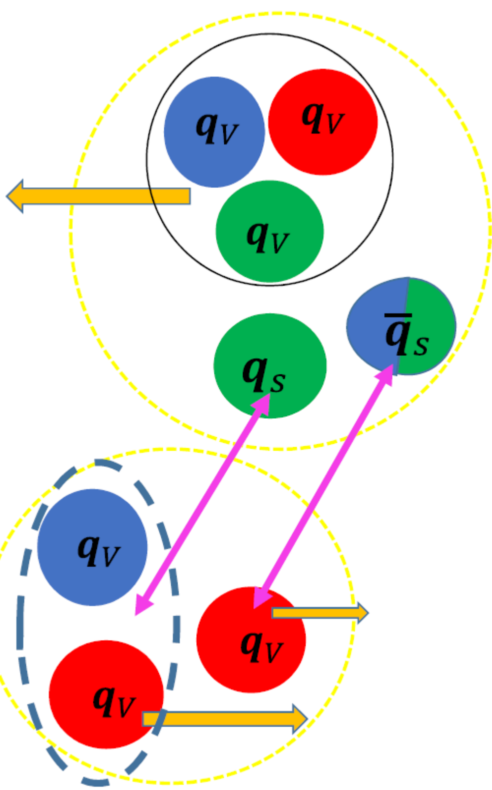

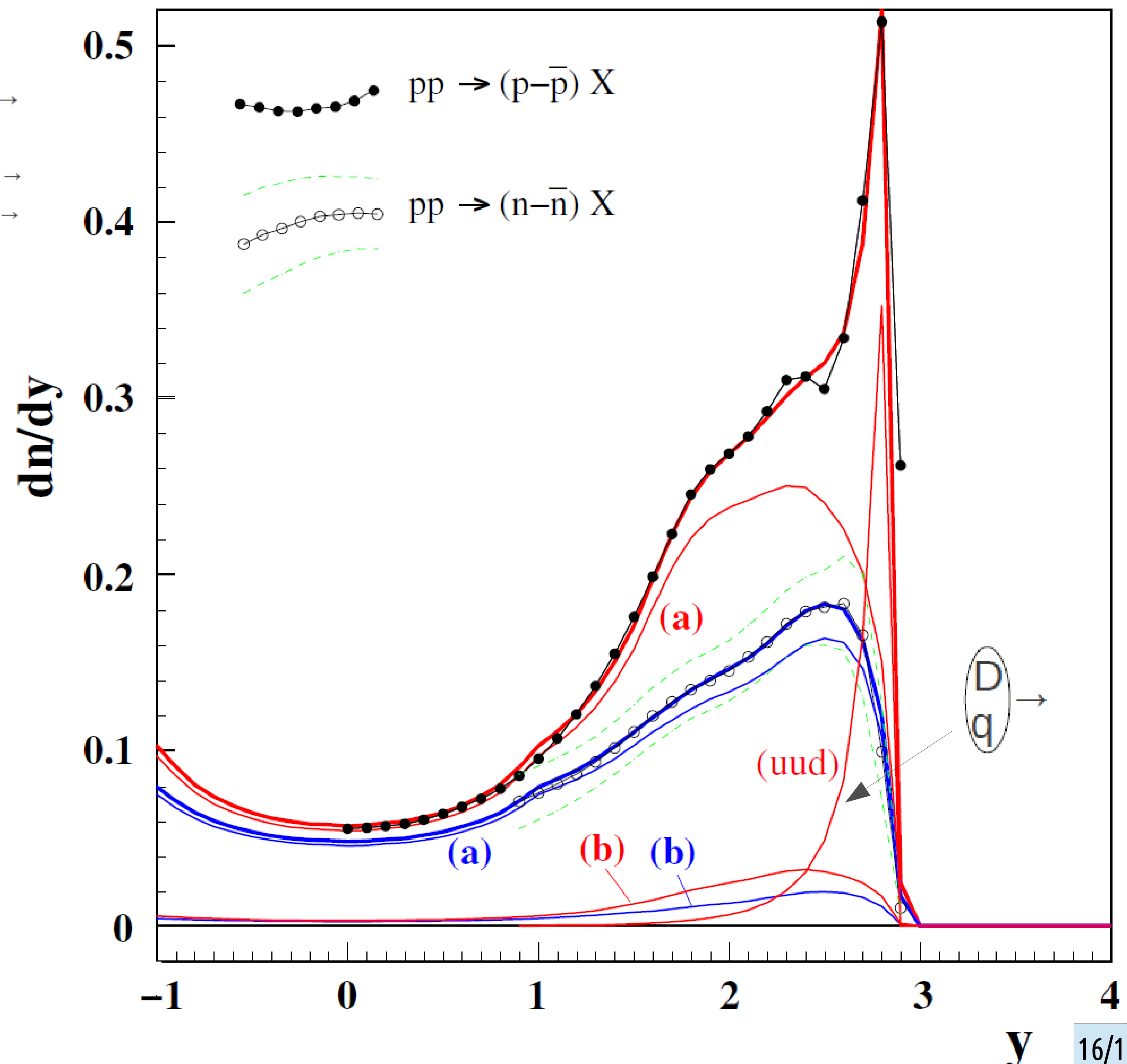

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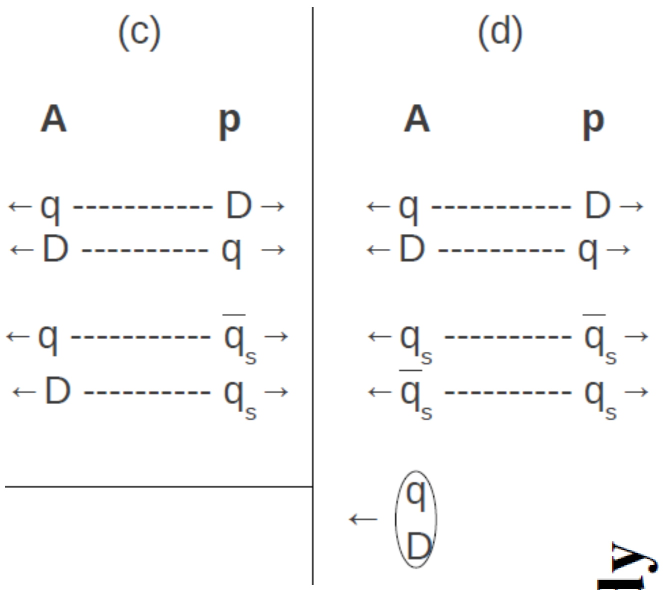
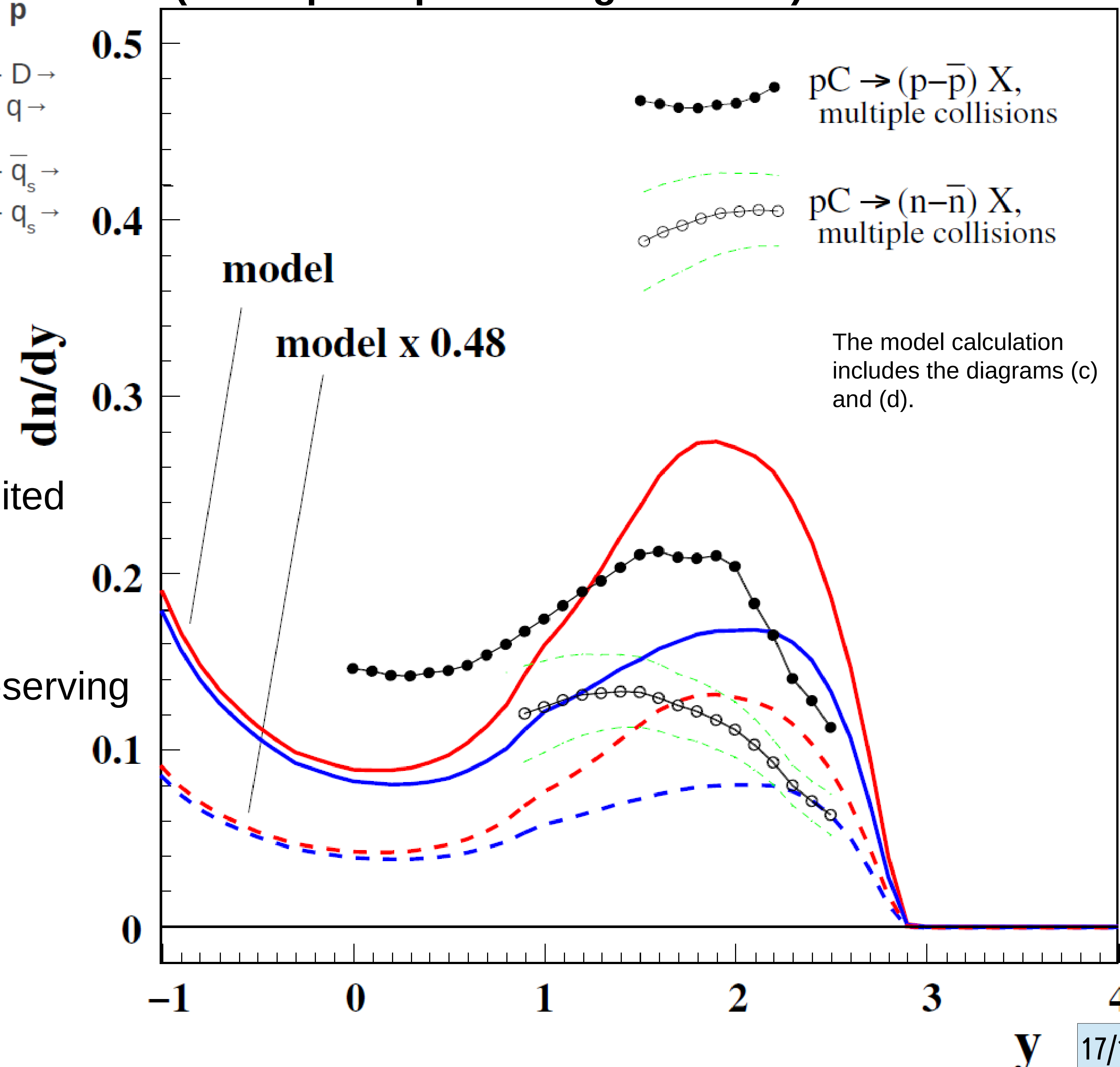
GEM in pA collisions (the diquark-preserving scenario)



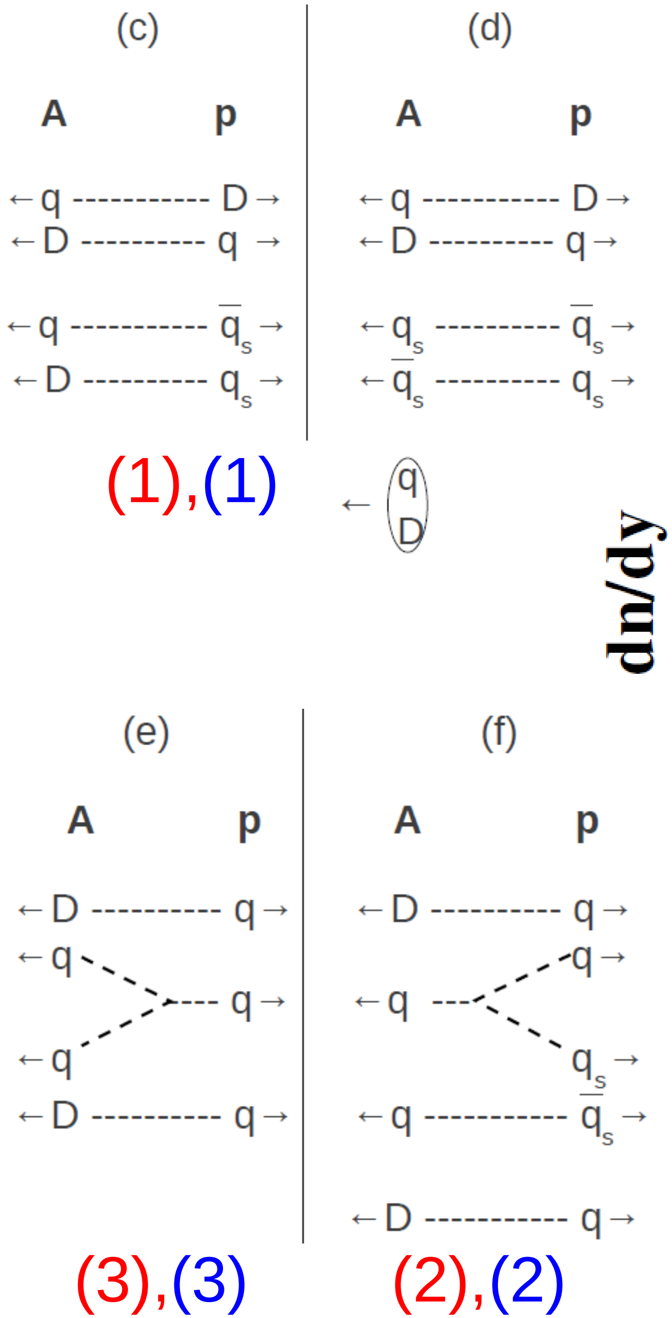


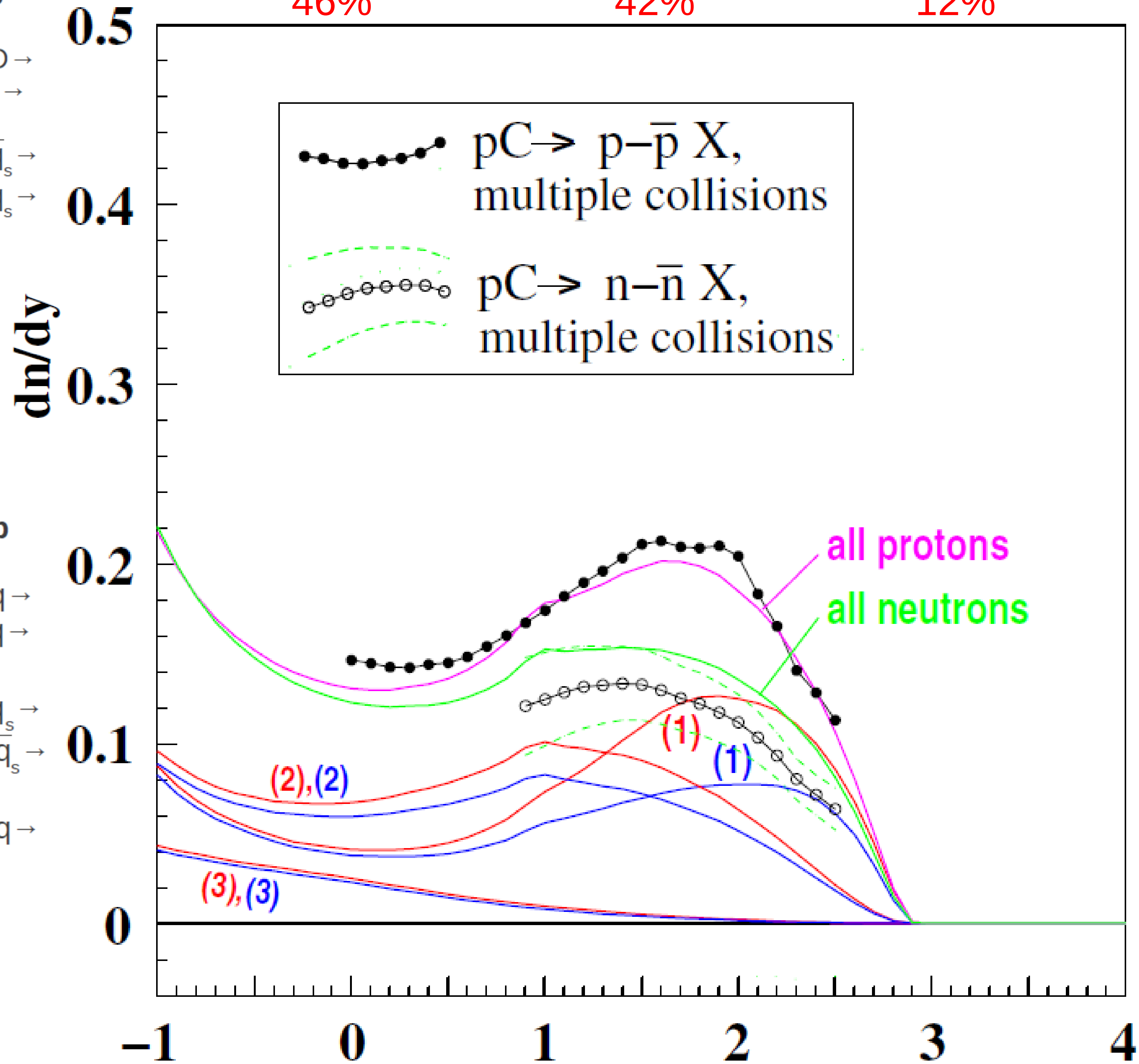
- GEM calculation is limited to diquark-preserving diagrams (c,d) ;
- Exp. data: diquark-preserving diagrams cannot be responsible for 100% of baryon “stopping” ;
- Upper limit for this contribution : 48% .

ArXiv: 2105.13741

GEM in pA collisions

(1) diquark-preserving 46% **(2) effective diquark** 42% **(3) decuplet exchange** 12%





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Conclusions

1. There is a qualitative difference between single and multiple proton-nucleon collisions;

2. Spectra of baryons are governed by color configurations of constituents (valence, sea);

3. These configurations depend on the number of exchanged gluons and are richer in the multiple collision process, which results in stronger baryon stopping.

For a review, see ArXiv: **2106.14972**

… thank you !