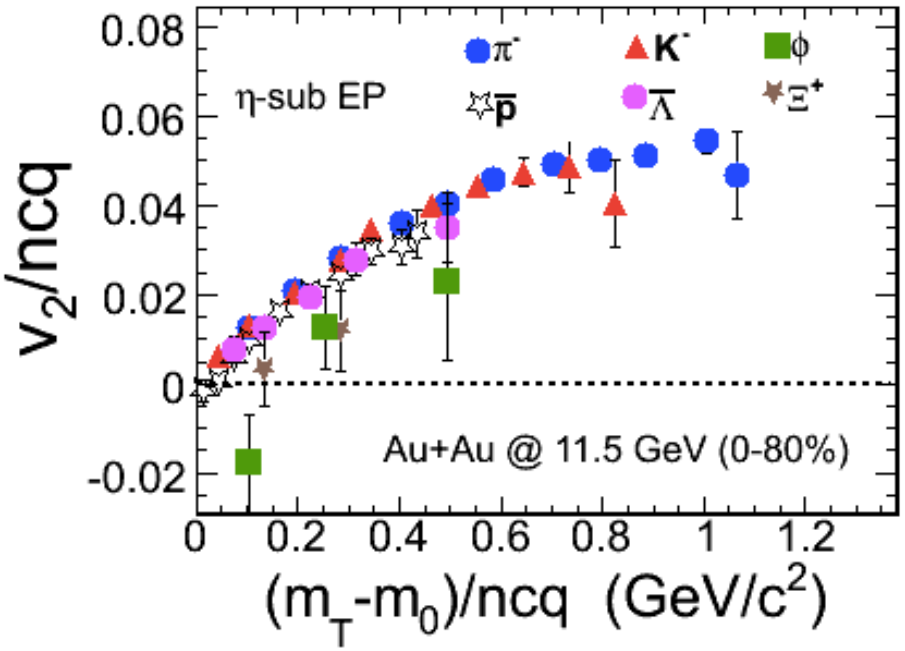
NCQ scaling violation due to baryon number transport ("stopping")

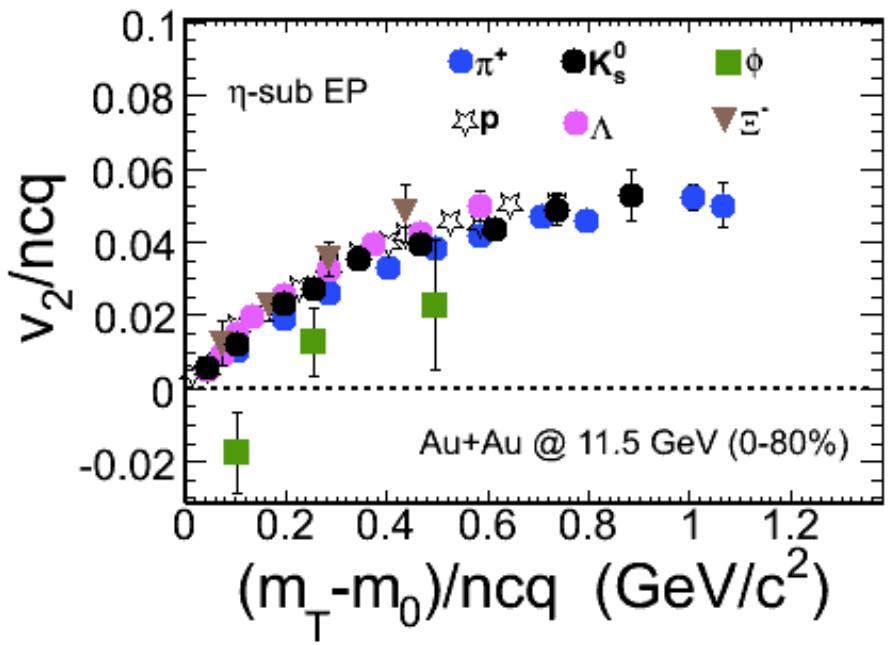
Mike Lisa

with Jamie Dunlop & Paul Sorensen

At low sqrt(s) (<39 GeV) NCQ scaling of hadron v2 breaks down
approximate “grouping” – (but not by charge...)

well-defined ordering. phi





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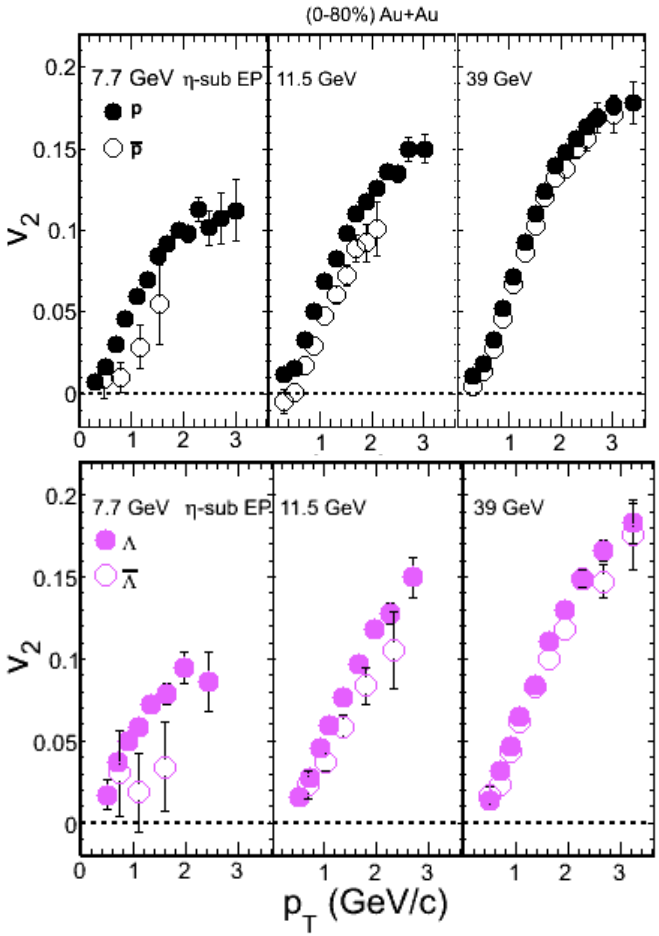
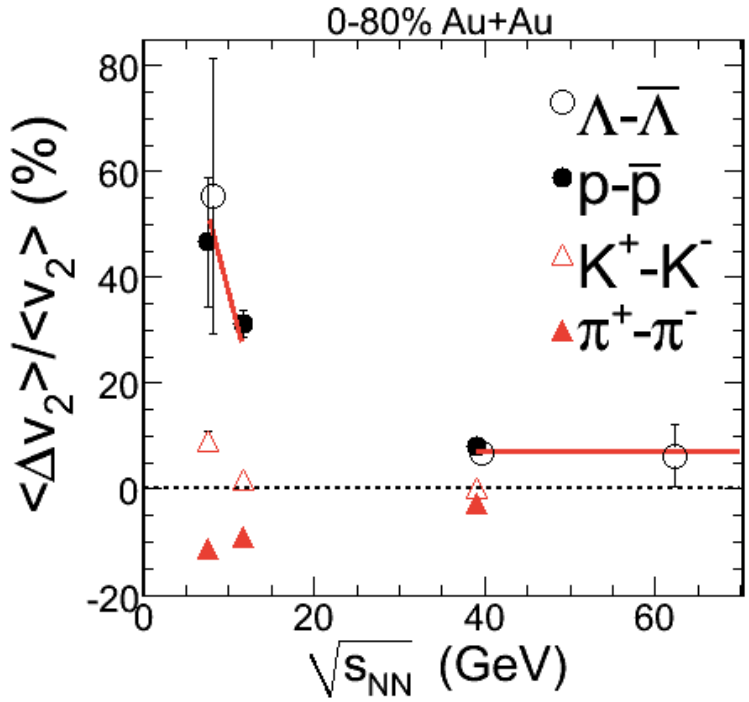
(anti-)Particle v_2 vs. $\sqrt{s_{NN}}$





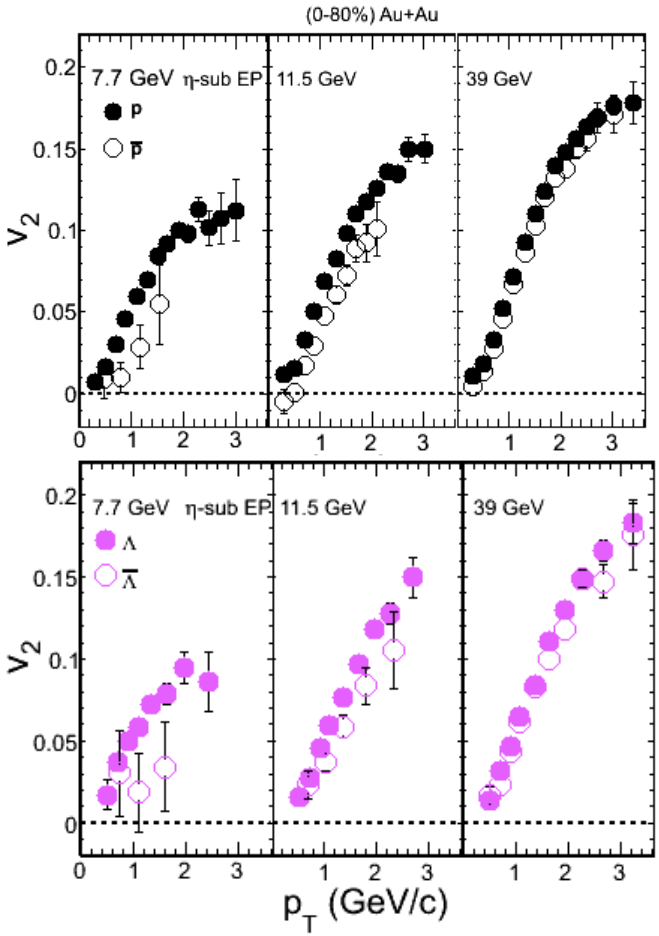
At $\sqrt{s_{NN}} \leq$ *11.5 GeV:*

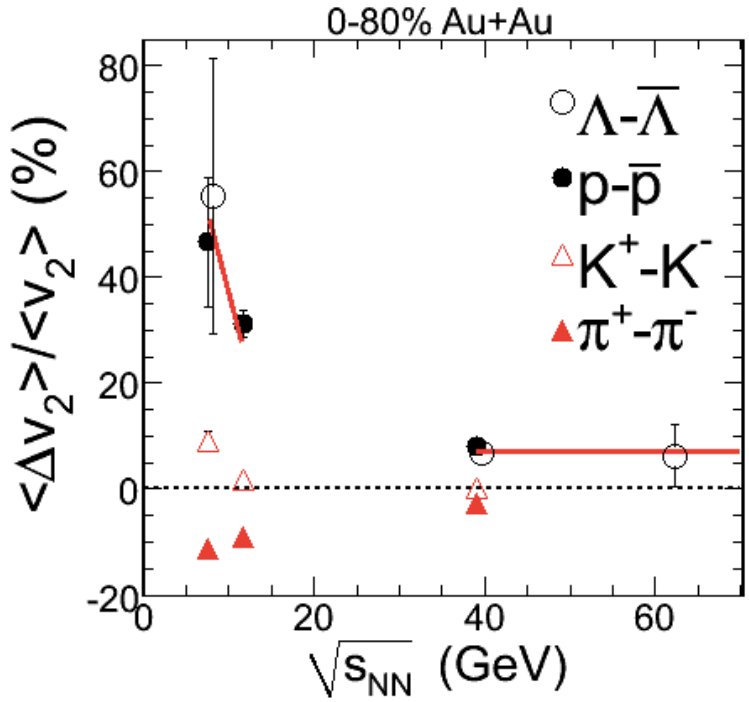
- v_2(baryon) > v_2(anti-baryon)
- v_2(π^+) < v_2(π^-)
- v_2(K^-) < v_2(K^+)

STAR: Quark Matter 2011

Hadronic interactions appear dominant

(anti-)Particle v_2 vs. $\sqrt{s_{NN}}$





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does data necessitate this?

STAR: Quark Matter 2011

Hadronic interactions appear dominant

What changes as √s is reduced?

NCQ scaling break-down

$$v_2\left[\pi^+\right] < v_2\left[\pi^-\right]$$

$$v_2\left[K^+\right] > v_2\left[K^-\right]$$

$$v_2\left[p\right] > v_2\left[\bar{p}\right]$$

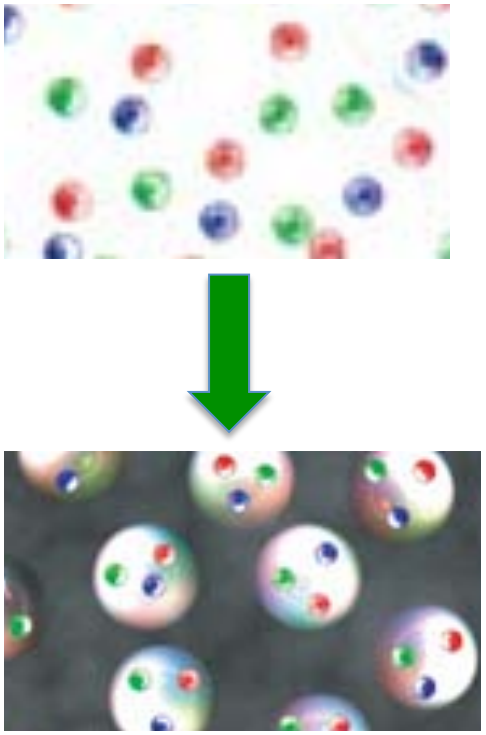
$$v_2\left[\Lambda\right] > v_2\left[\bar{\Lambda}\right]$$

$$v_2\left[\bar{\Xi}^+\right] < v_2\left[\Xi^-\right]$$

not complete kinetic thermalization

What changes as √s is reduced?

Change in degrees of freedom?



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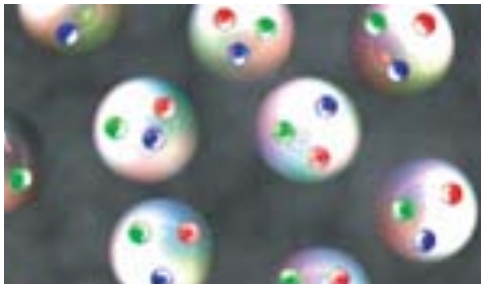

NCQ scaling break-down

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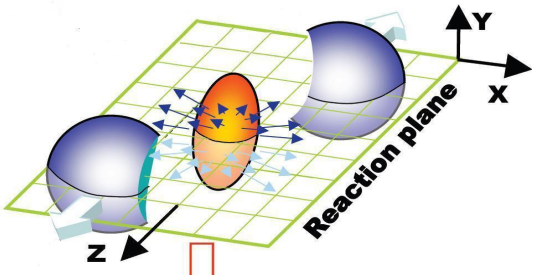
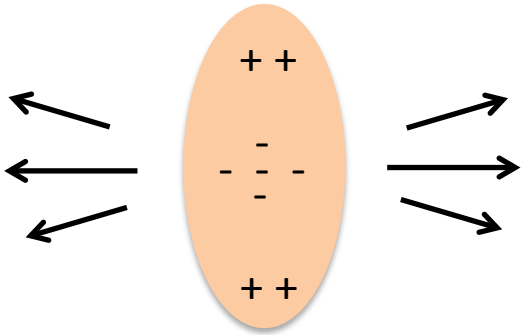
Electric quadrupole moment due to chiral magnetic waves?





negative particles get a v2 boost

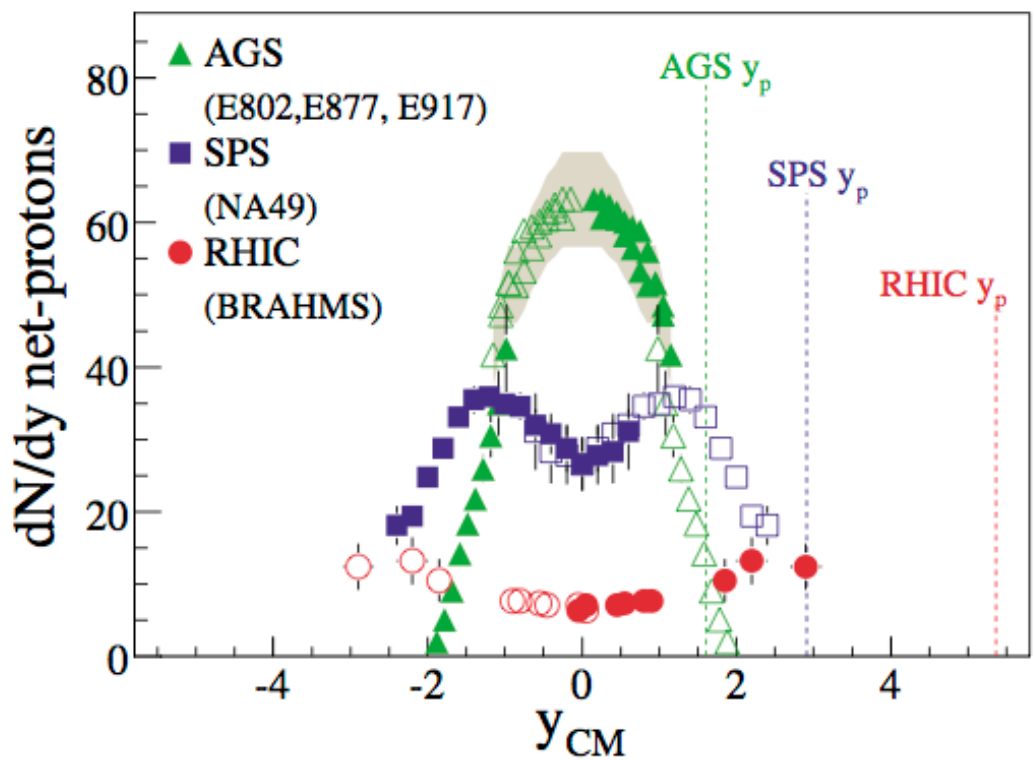
Burnier, Kharzeev, Liao, Yee, PRL 107 052303 (2011)

What changes as √s is reduced?

Change in degrees of freedom?

Electric quadrupole moment due to chiral magnetic waves?

Increased baryon transport from entrance channel ("stopping")
(no question mark needed)



Without invoking phase change or exotic effects, can we understand the pattern of scaling violations?

Let's try:

- remain in paradigm of flowing constituent quarks that later coalesce
  - incompletely thermalized distribution (insufficient scattering at low √s)
- transported u and d quarks scatter more → more thermalized (more flow) than for produced $u, d, s, \bar{u}, \bar{d}, \bar{s}$

hadron	yield	u	d	s	$\bar{u}$	$\bar{d}$	$\bar{s}$
π^+	72.9	72.9				72.9	
π^-	84.8		84.8		84.8		
π^0 (*)	78.85	39.43	39.43		39.43	39.43	
ϕ	1.17			1.17			1.17
K^+	16.4	16.4					16.4
K^-	5.58			5.58	5.58		
K^0 (*)	10.99		10.99				13.84
$\bar{K}^0$ (*)	10.99			10.99		10.99	
p	46.1	92.2	46.1				
n (*)	70.84	70.84	141.68				
Λ	13.4	13.4	13.4	13.4			
Ξ^-	0.93		0.93	1.86			
$\bar{p}$	0.06				0.12	0.06	
$\bar{n}$ (*)	0.04				0.04	0.08	
$\bar{\Lambda}$	0.1				0.1	0.1	0.1
Sum		305.17	337.33	33	130.07	123.56	28.66

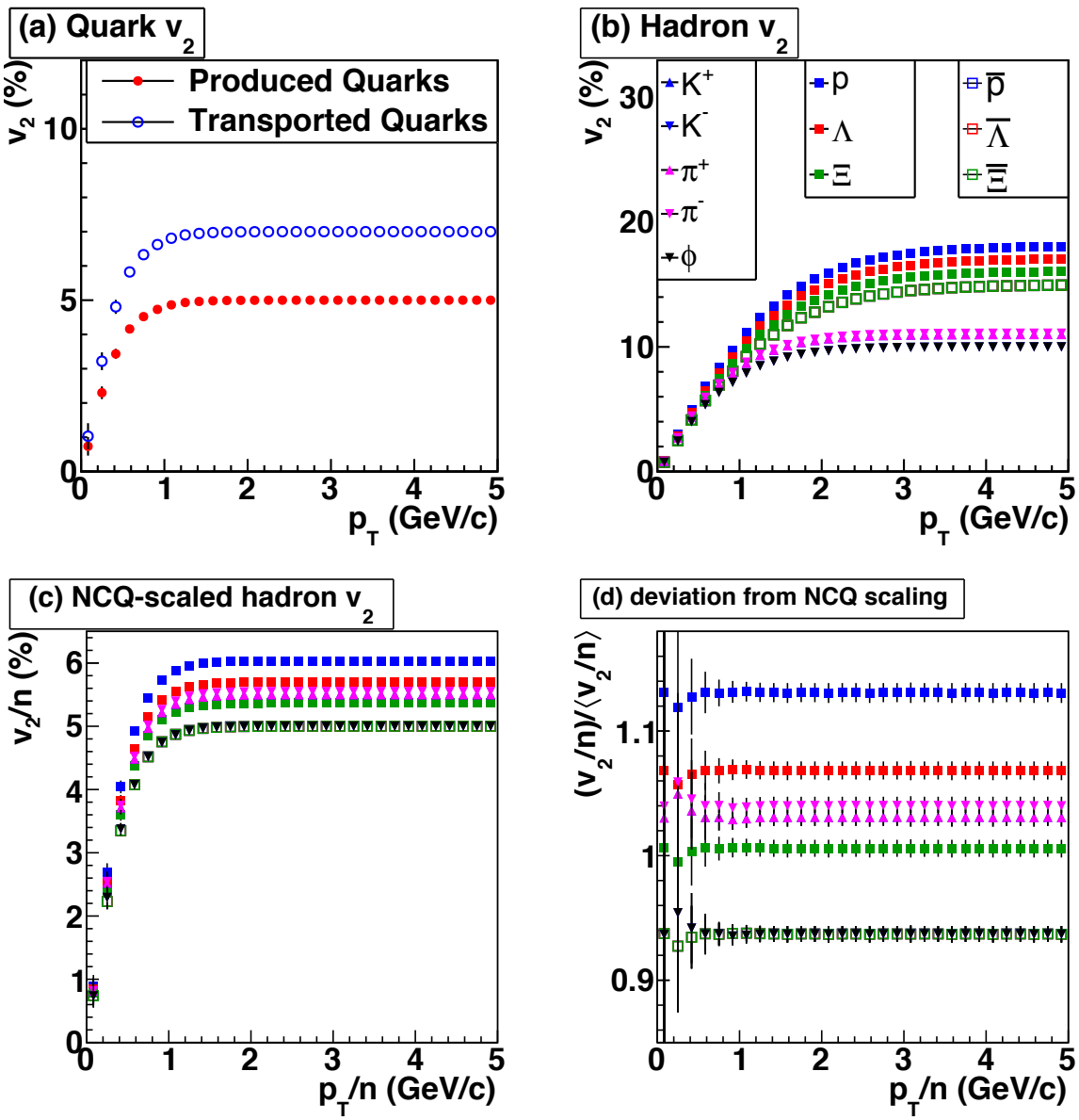
stopping is a **huge** effect:

estimates from measured yields:
at √s= 8.9 GeV (6.4 GeV)...

- 50% (57%) of u quarks at y=0 come from transport
- 55% (63%) of d quarks at y=0 come from transport

J.C. Dunlop, MAL, P. Sorensen arXiv:1107.3078

Constituent quark coalescence, accounting for stopping...



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Constituent quark coalescence, accounting for stopping...

NCQ scaling break-down

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$$v_2\left[\bar{\Xi}^+\right] < v_2\left[\Xi^-\right] \quad ✓$$

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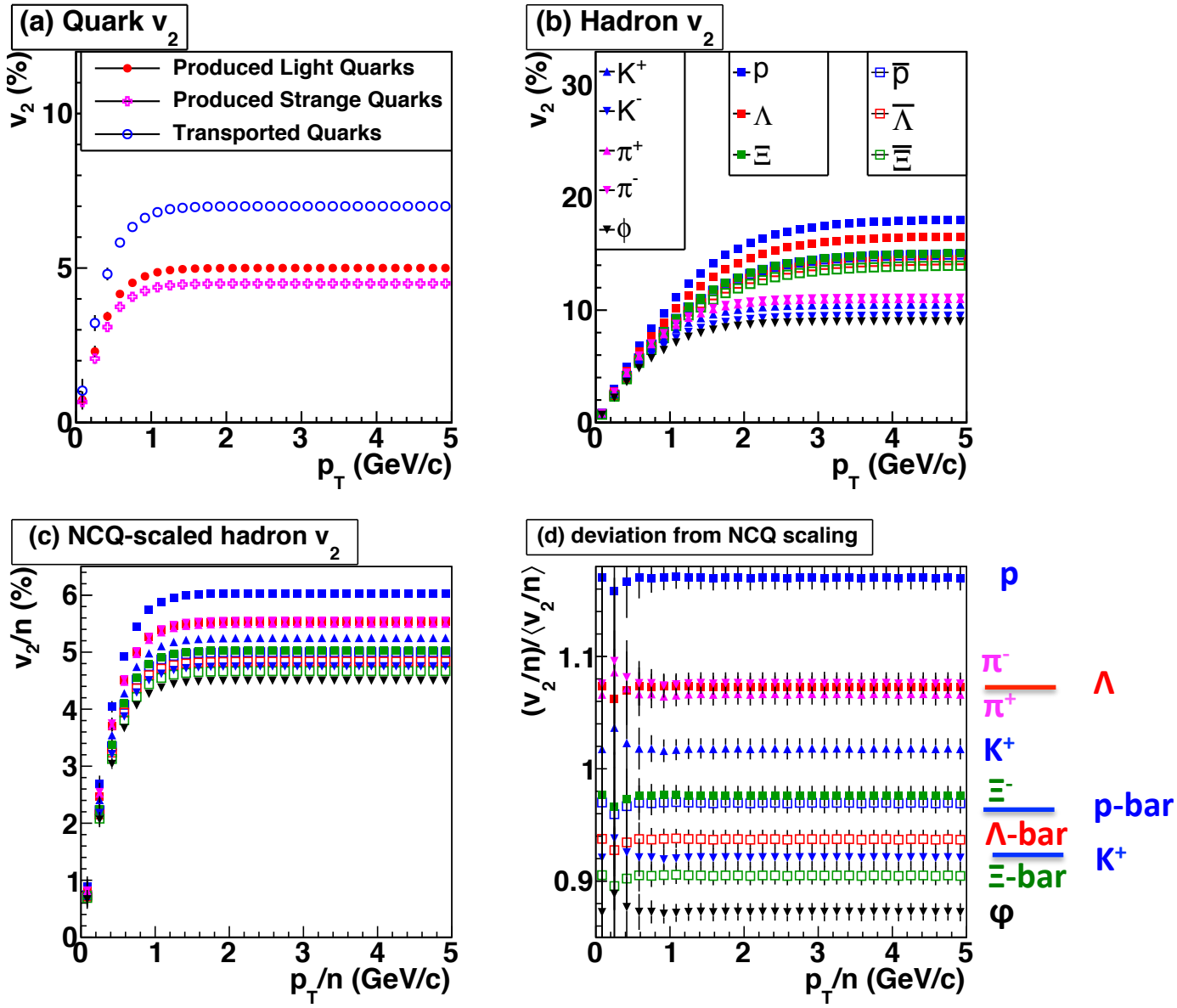
Conclusion

Without invoking phase change or exotic effects, can we understand the pattern of scaling violations?

- probably. at least much of it.

- stopping at low(er) energies is a huge effect – we should consider effects we already know must be present

Constituent quark coalescence, accounting for stopping and a touch less strange flow

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