Collectivity from interference

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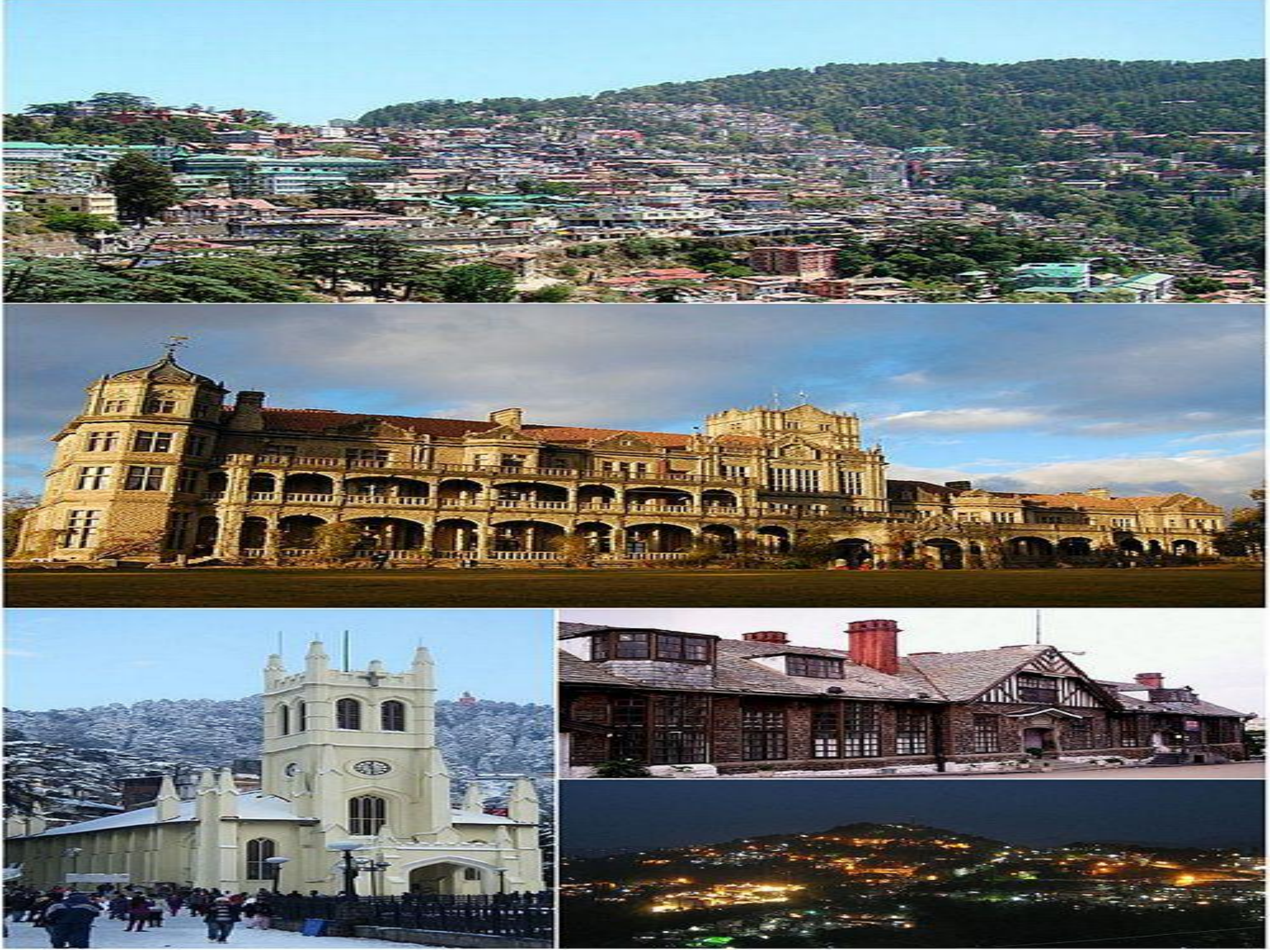


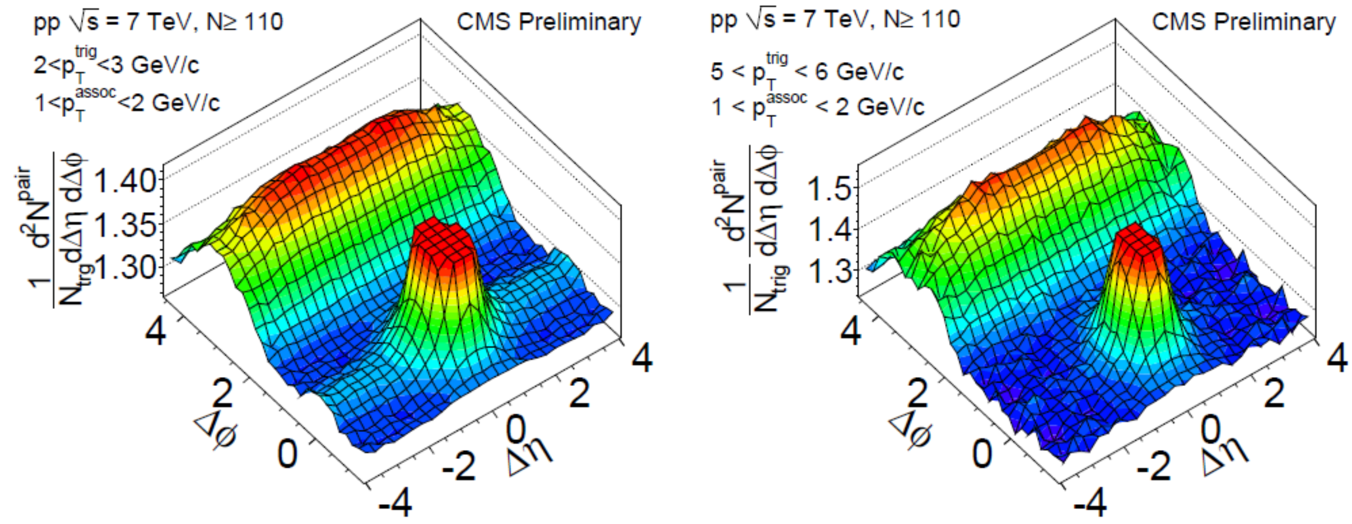
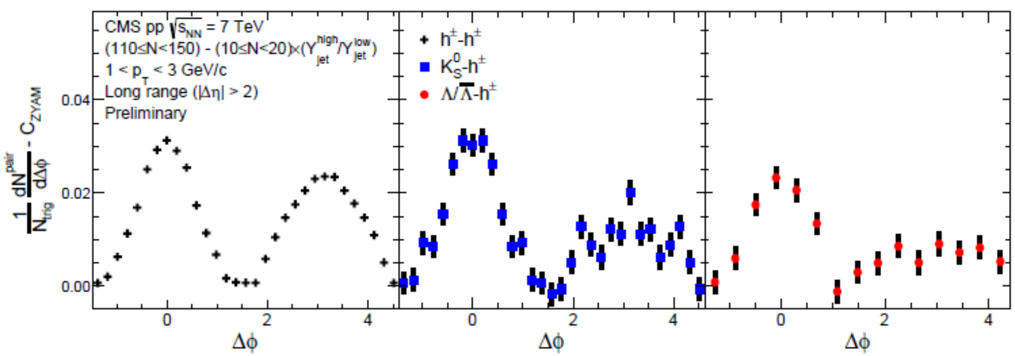


Figure 1: Two-dimensional (2-D) per-trigger-particle associated yield of charged hadrons as a function of $\Delta\eta$ and $\Delta\phi$ with jet peak cutoff for better demonstration of the ridge from high multiplicity ($N \geq 110$) pp collisions at $\sqrt{s} = 7$ TeV, for (a) $2<p_T^{trig}<3$ GeV/c and $1<p_T^{assoc}<2$ GeV/c and (b) $5<p_T^{trig}<6$ GeV/c and $1<p_T^{assoc}<2$ GeV/c



Pictures from CMS 2016

Figure 5: The 1-D $\Delta\phi$ correlation functions in the multiplicity range $110 \leq N_{trk}^{offline} < 150$ of pp collisions at $\sqrt{s} = 7$ TeV after subtracting results from $10 \leq N_{trk}^{offline} < 20$, for trigger particles composed of inclusive charged particles (left), K_S^0 particles (middle), and $\Lambda/\overline{\Lambda}$ particles (right). Selection of a p_T^{trig} and p_T^{assoc} range of both 1–3 GeV/c is shown for the long-range regions.

Ridge correlations were first found in A-A collisions at RHIC,
And since are considered important sign of creation of Quark-Gluon Plasma.
They are successfully described by hydrodynamic model . Jet quenching in AA collisions is another sign of creation of QGP. So both-jet quenching and success of hydrodynamics—signs of large final state interactions/final state rescattering.
Recently using kinetic equations it was possible to derive hydrodynamic model from final state interactions (G.Moore, A. Kurkella and their collaborators), taking as a basis bottom-up termalization scenario (Baier,Mueller,Schiff,Son).

Ridge- 1) long range i.e. rapidity-independent correlations
2) transverse momentum correlations of created hadrons, described by cumulants, measured by experimentalists for N=2,4,6,..

However ridge was found also in pp and pA collisions at LHC (along with AA collisions) by all 3 collaborations: CMS(2012), Alice (2013), ATLAS (2013).

Paradox-1) there is no evidence for large final state interactions in pp and probably In pA
2)jet quenching coefficient in both pp and pA is equal to R=1
So hydrodynamical interpretation of ridge in pp and pA collisions looks unnatural
(A. Mueller InInitial Stages, Lissabon)

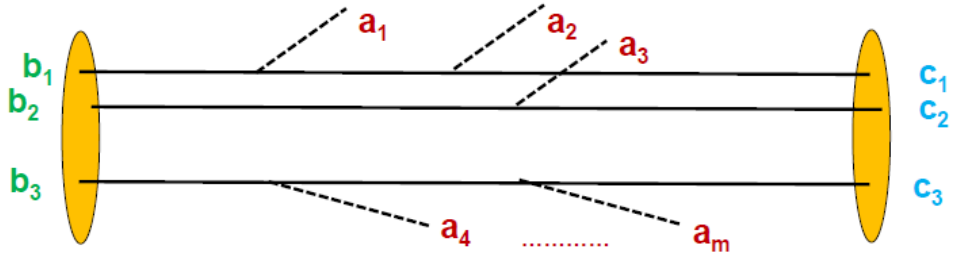
Question: can ridge have different origin on pp than in AA?

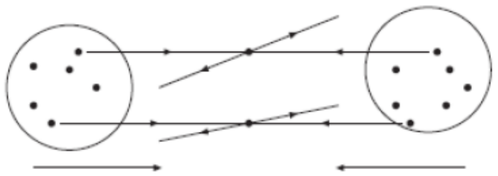
Indeed, there were several attempts to explain ridge correlations in pp:
1) Hydrodynamics 2) transport models (all need large final state interactions)
3) High density Color Glass Condensate approach (Altinoliuk,Armesto,Beuf, iancu,Kovner,Lublinsky, Jalalian-Marian,Levin,Gotsman, Tribedi,Venugopalan,…)
Hoewer: such an approach means that saturated initial state is needed to describe Underlying Event in pp collisions at LHC. On the other hand we know for quite A long time that UE is well described by MC generators, that work in dilute regime (small relative to CGC gluon densities)
4) The same problem is in applying strongly coupled paradigms i.e. ADS/CFT-radical change of known description of UE by MC generators

Another way-Low density scenario, Collectivity from interference –This Talk

1. *No initial density, no initial asymmetry, no final state interactions*
2. *The cumulants narurally come from quantum-mechanical (QM) interference and color correlations.*

Hence:1)does not imply jet quenching in pp/pA
2) natural extension of MC generators, that contain in UE up to 10-20 MPI events (Sjostrand)
The interference occurs not between gluons radiated by separate partons, but between different Hard processes, i.e. different MPIs, which we call "sources".





Basic ideas about MPI geometry used in this talk:

1. *Hadronic cross sections with N hard processes simultaneously are characterized by*

$$\sigma_{N\,\mathrm{MPI}} = \frac{\sigma_1 \ldots . \sigma_N}{K_N} .$$

N=2 case is called DPS and characterized by

$$\sigma_{2\ MPIs} = \frac{\sigma_1\ \sigma_2}{\sigma_{\text{eff}}}$$

$$\frac{1}{K_N} = \int \left(\prod_{i=1}^{N} \frac{d\boldsymbol{\Delta}_i}{(2\pi)^2} \right) \frac{G_N(\{x_i\},\{Q_i^2\},\{\boldsymbol{\Delta}_i\})\, G_N(\{x_i'\},\{Q_i^2\},\{\boldsymbol{\Delta}_i\})}{\prod_{i=1}^{N}(f(x_i,Q_i^2)\, f(x_i',Q_i^2))} \delta^{(2)} \left(\sum_{i=1}^{N} \boldsymbol{\Delta}_i \right)$$

The Generalized parton distributions GPD encode geometry of the process.We work Here in mean –field approximation neglecting 1-2 mechanism (Ladder splitting, probably not so big in UE)

$$G_N(\{x_i\},\{Q_i^2\},\{\boldsymbol{\Delta}_i\}) = \prod_{i=1}^{N} G_1(x_i,Q_i,\boldsymbol{\Delta}_i) = \prod_{i=1}^{N} f(x_i,Q_i) F_{2g}(\boldsymbol{\Delta}_i) .$$

Choosing $F_{2g}^2(\Delta) = \exp(-B\Delta_i^2)$ for simplicity to be of Gaussian form

$F_N(\Delta_1,\ldots,\Delta_N) = \prod_{i=1}^{N} \exp(-B\Delta_i^2)$

$B = 2\,\mathrm{GeV}^{-2} \quad \longleftrightarrow \quad \sigma_{\text{eff}} \approx 20\,\mathrm{mb}$

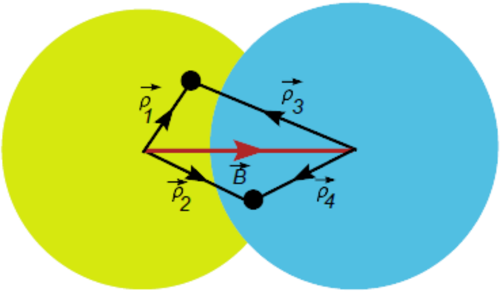
$$F_N(\boldsymbol{\Delta}_1,\ldots\boldsymbol{\Delta}_N) = \frac{G_N^2(\boldsymbol{\Delta}_1,\ldots\boldsymbol{\Delta}_N)}{\prod_{i=1}^{N} f(x_i,Q_i)\, f(x_i',Q_i)}$$

Number compatible to LHC data

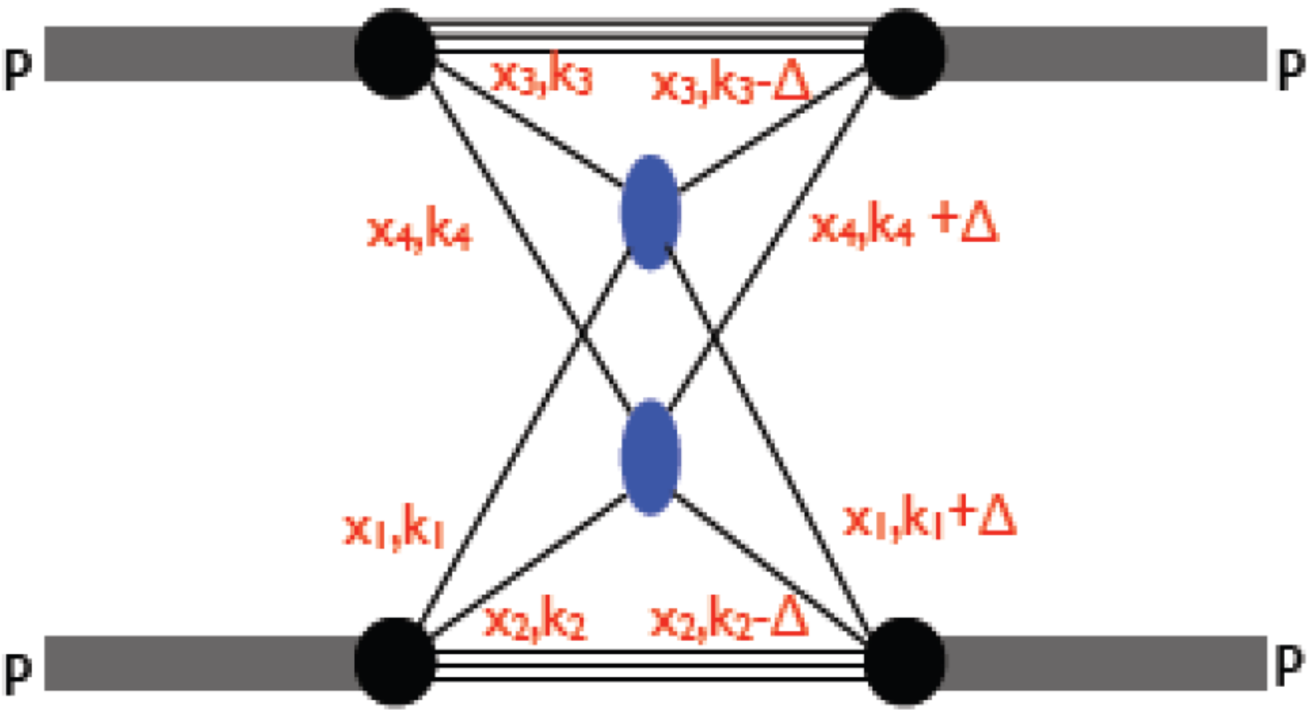
In coordinate space:

$$\frac{d\sigma_N}{\sigma_N\, d\mathbf{k}_1 ... d\mathbf{k}_m} = \frac{\int \left(\prod_{i=1}^{N} d\mathbf{y}_i\right) \int d\mathbf{b}\, |\mathcal{M}^2(\mathbf{k}_1, \cdots, \mathbf{k}_m; \mathbf{y}_1, \cdots, \mathbf{y}_N)| \rho(\mathbf{y}_1 ... \mathbf{y}_N, \mathbf{b})}{\int \left(\prod_{i=1}^{N} d\mathbf{y}_i\right) d\mathbf{b}\, \rho(\mathbf{y}_1 ... \mathbf{y}_N, \mathbf{b})}.$$

$$\rho\left(\{\mathbf{y}_i\}, \mathbf{b}\right) = \prod_j \frac{1}{(4\pi B)^2} \exp\left[-\frac{\mathbf{y}_j^2}{4B}\right] \exp\left[-\frac{(\mathbf{y}_j - \mathbf{b})^2}{4B}\right]$$



We work in the case b=0 (central collisions)



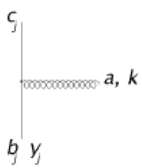
Basic ideas of the model:

$$\frac{d\Sigma}{d\mathbf{k}_1 \ldots d\mathbf{k}_m} = \int \left(\prod_{i=1}^{N} d\mathbf{y}_i \right) \rho(\{y_i\})\, \hat{\sigma}\left(\{\mathbf{k}_j\}, \{y_i\}\right) .$$

Each hadron collision is characterized by a set $\{\mathbf{y}_i, b_i\}$, $i \in [1, N]$, of N particle emitting sources distributed at transverse positions $\mathbf{y}_i$ with initial colors b_i in the adjoint representation.

Assume LPHD

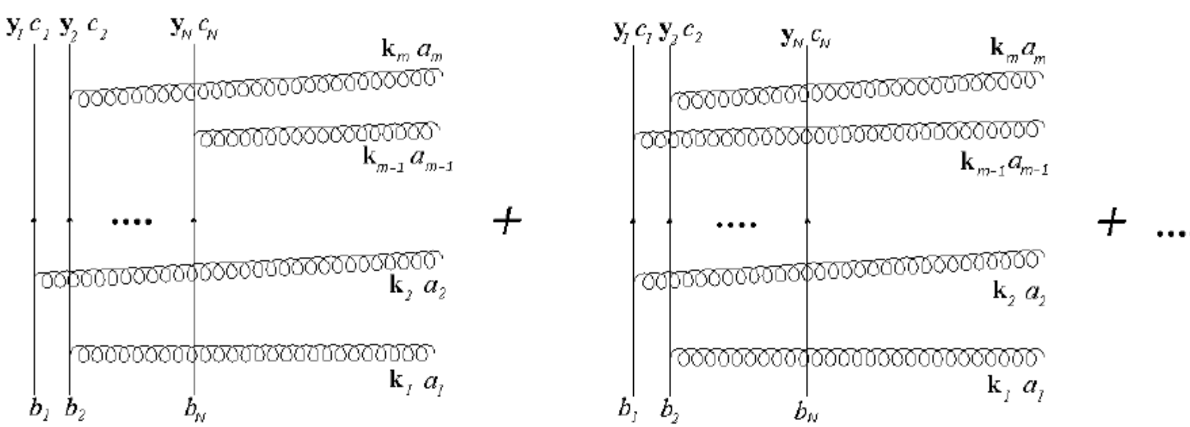
Gluon emission



$$= T^a_{b_j c_j} \int d\mathbf{x}\, \vec{f}(\mathbf{x} - \mathbf{y})\, e^{i\,\mathbf{k}.\mathbf{x}} \equiv T^a_{b_j c_j}\, \vec{f}(\mathbf{k})\, \exp\left[i\, \mathbf{y}.\mathbf{k}\right] .$$

Coulombic radiation:

$$\vec{f}(\mathbf{k}) \propto g\mathbf{k}/\mathbf{k}^2 .$$



Cumulants:

$$T_n(k_1,k_2) = \binom{m}{2} \int_\rho \int_0^{2\pi} d\phi_1\, d\phi_2\, \exp\left[in(\phi_1-\phi_2)\right] \left(\int \prod_{b=3}^{m} k_b\, dk_b\, d\phi_b \right) \hat{\sigma}$$

Norm:

$$\overline{T}(k_1,k_2) = \binom{m}{2} \int_\rho \int_0^{2\pi} d\phi_1\, d\phi_2 \left(\int \prod_{b=3}^{m} k_b\, dk_b\, d\phi_b \right) \hat{\sigma}$$

Second cumulant:

$$\langle\langle e^{in(\phi_1-\phi_2)}\rangle\rangle(k_1,k_2) \equiv \frac{T_n(k_1,k_2)}{\overline{T}(k_1,k_2)} . \qquad v_n^2\{2\}(k_1,k_2) \equiv \langle\langle e^{in(\phi_1-\phi_2)}\rangle\rangle(k_1,k_2) \qquad v_n\{2\}(k) \equiv \sqrt{\langle\langle e^{in(\phi_1-\phi_2)}\rangle\rangle(k,k)} .$$

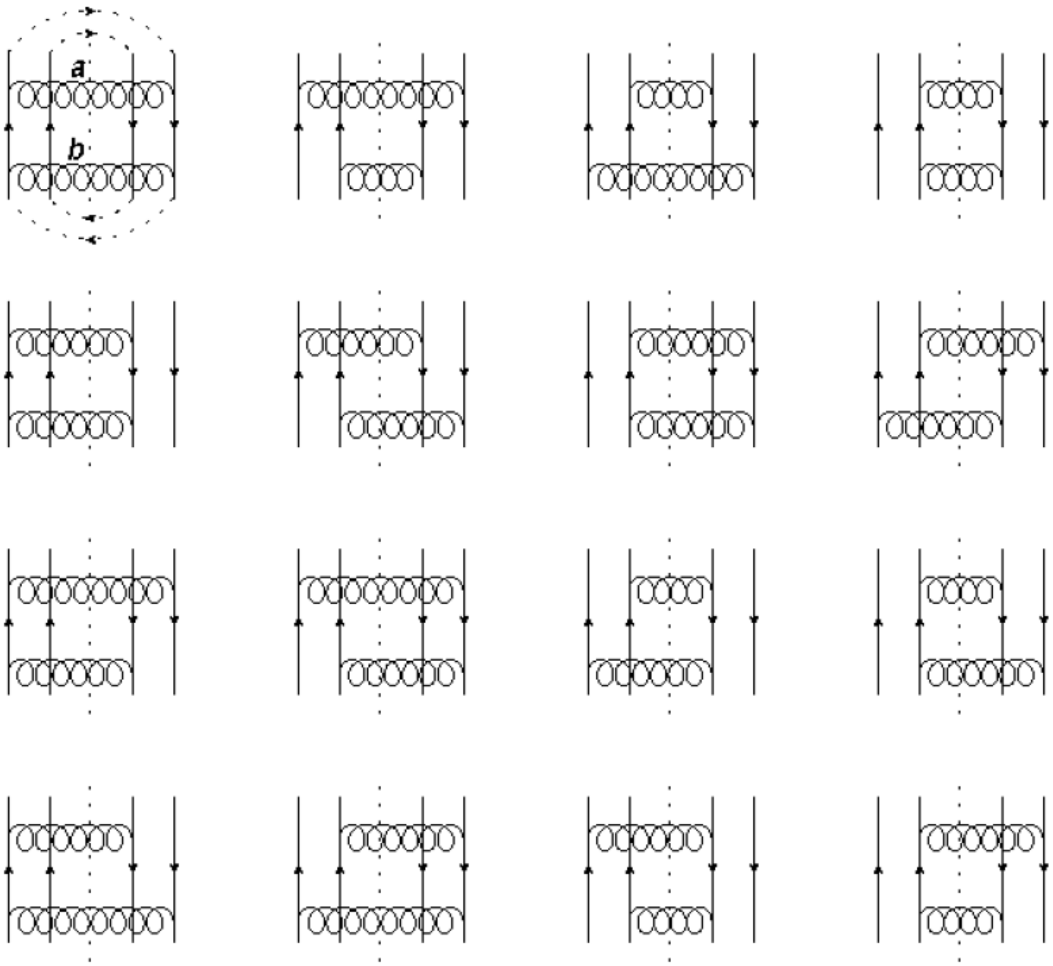
4th cumulant

$$S_n(k_1,k_2,k_3,k_4) = \binom{m}{4} \int_\rho \int_0^{2\pi} d\phi_1\, d\phi_2\, d\phi_3\, d\phi_4\, e^{in(\phi_1+\phi_2-\phi_3-\phi_4)} \left(\int \prod_{b=5}^{m} k_b\, dk_b\, d\phi_b \right) \hat{\sigma} ,$$

$$\langle\langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle_c = \langle\langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle - \langle\langle e^{in(\phi_1-\phi_3)}\rangle\rangle\langle\langle e^{in(\phi_2-\phi_4)}\rangle\rangle - \langle\langle e^{in(\phi_1-\phi_4)}\rangle\rangle\langle\langle e^{in(\phi_2-\phi_3)}\rangle\rangle ,$$

Higher cumulants –in the same way, see Ollitrault and his collaborators.

Dipole interference term



Direct calculation: m=2 N=2

$$\rho\left(\mathbf{y}_1,\mathbf{y}_2\right)=\frac{1}{(2\pi B)^2}\exp\left[-\frac{\mathbf{y}_1^2}{2B}-\frac{\mathbf{y}_2^2}{2B}\right].$$

$$\hat{\sigma}\left(\{\mathbf{k}_1,\mathbf{k}_2\},\{\mathbf{y}_1,\mathbf{y}_2\}\right)\propto N_c^2\,\left(N_c^2-1\right)^2\left|\vec{f}(\mathbf{k}_1)\right|^2\,\left|\vec{f}(\mathbf{k}_2)\right|^2 \times\left\{4+\frac{1}{(N_c^2-1)}\left(e^{i(\mathbf{k}_1+\mathbf{k}_2).(\mathbf{y}_1-\mathbf{y}_2)}+e^{i(\mathbf{k}_1-\mathbf{k}_2).(\mathbf{y}_1-\mathbf{y}_2)} +e^{i(\mathbf{k}_1+\mathbf{k}_2).(\mathbf{y}_2-\mathbf{y}_1)}+e^{i(\mathbf{k}_1-\mathbf{k}_2).(\mathbf{y}_2-\mathbf{y}_1)}\right)\right\}$$

Dipole color suppression

$$\mathrm{Tr}\left[T^aT^b\right]\mathrm{Tr}\left[T^bT^a\right]=N_c^2\,\left(N_c^2-1\right).$$

$$\mathrm{Tr}\left[T^aT^bT^bT^a\right]\mathrm{Tr}\left[\mathbb{1}\right]=N_c^2\,\left(N_c^2-1\right)^2$$

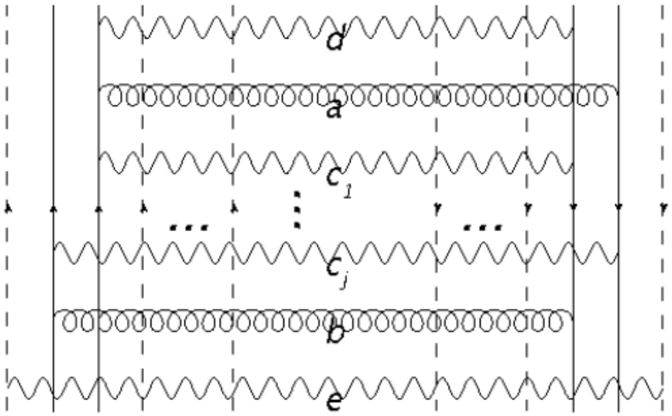
Final answer:

$$\frac{d\Sigma}{d\mathbf{k}_1d\mathbf{k}_2}\propto\left|\vec{f}(\mathbf{k}_1)\right|^2\,\left|\vec{f}(\mathbf{k}_2)\right|^2\left[1+\frac{\left(e^{-B(\mathbf{k}_1+\mathbf{k}_2)^2}+e^{-B(\mathbf{k}_1-\mathbf{k}_2)^2}\right)}{(N_c^2-1)}\right].$$

For $B = 1/Q_s^2$, this QCD dipole radiation agrees with CGC calculations.

Saturated initial state not assumed here.

N=2, arbitrary m, diagonal gluons



$$T^{c_j} T^a T^{c_j} = \frac{1}{2} N_c T^a \, .$$

$$\hat{\sigma} \propto (N_c^2 - 1)^N N_c^m \left(\prod_{i=1}^{m} \left| \vec{f}(\mathbf{k}_i) \right|^2 \right)$$
$$\times \Big\{ N^m + F_{\text{corr}}^{(2)}(N,m) \frac{N^{m-2}}{(N_c^2-1)} \sum_{(ab)} \sum_{(ij)} 4 \cos(\mathbf{k}_a . \mathbf{\Delta y}_{ij}) \cos(\mathbf{k}_b . \mathbf{\Delta y}_{ij})$$
$$+ O\left(\frac{1}{N} \frac{1}{(N_c^2-1)} \right) + O\left(\frac{1}{(N_c^2-1)^2} \right) \Big\} \, .$$

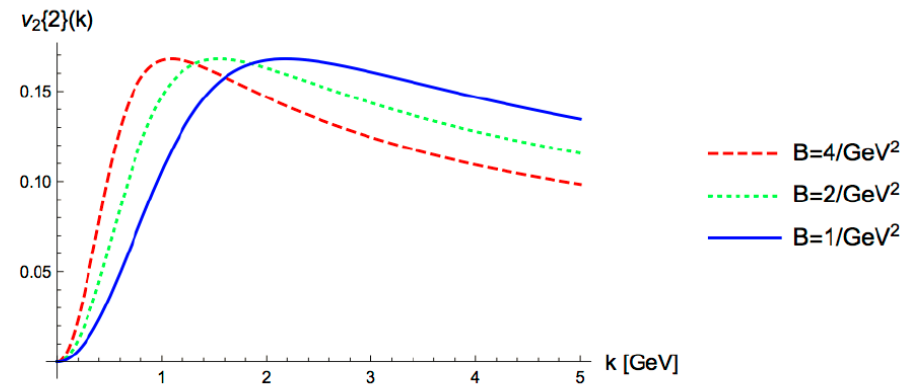
$$F_{\text{corr}}^{(2)}(N,m) = \frac{1}{\mathcal{N}_{\text{incoh}}} \sum_{j=0}^{m-2} N^{m-2-j} (m-1-j) \left(\sum_{l=0}^{j} \binom{j}{l} 2^l (N-2)^{j-l} \frac{1}{2^l} \right)$$
$$= \frac{2}{m(m-1)} N^{1-m} \left(N(N-1)^m + mN^m - N^{1+m} \right) \, .$$

2^{nd} order cumulant: v_2

$$v_2^2\{2\}(k_1,k_2) \equiv \langle\langle e^{i2(\phi_1-\phi_2)}\rangle\rangle(k_1,k_2)$$

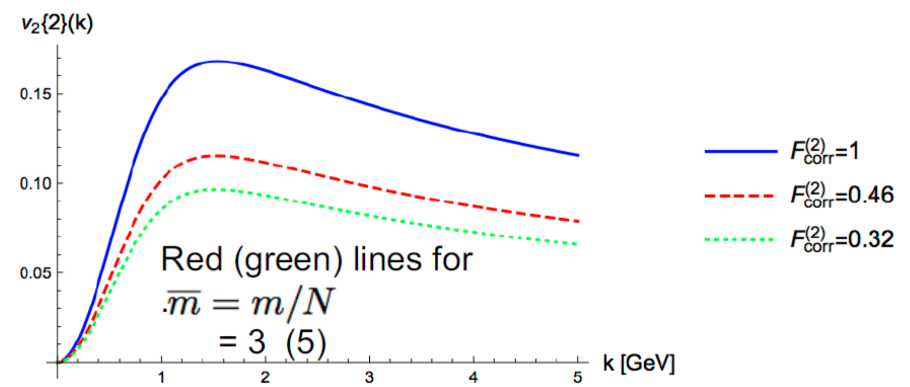
$$\equiv \frac{F^{(2)}_{\rm corr}(N,m)\int_\rho \frac{1}{N^2}\sum_{(ij)} 2^2 J_2\left(k_1\Delta y_{ij}\right)\, J_2\left(k_2\Delta y_{ij}\right)}{(N_c^2-1)+F^{(2)}_{\rm corr}(N,m)\int_\rho \frac{1}{N^2}\sum_{(ij)} 2^2 J_0\left(k_1\Delta y_{ij}\right)\, J_0\left(k_2\Delta y_{ij}\right)} + O\left(\frac{1}{(N_c^2-1)^2}\right)$$

- Partonic v_2, may be modified by hadronization
- Signal persists to multi-GeV region



- For fixed average multiplicity per source, $\overline{m} = m/N$

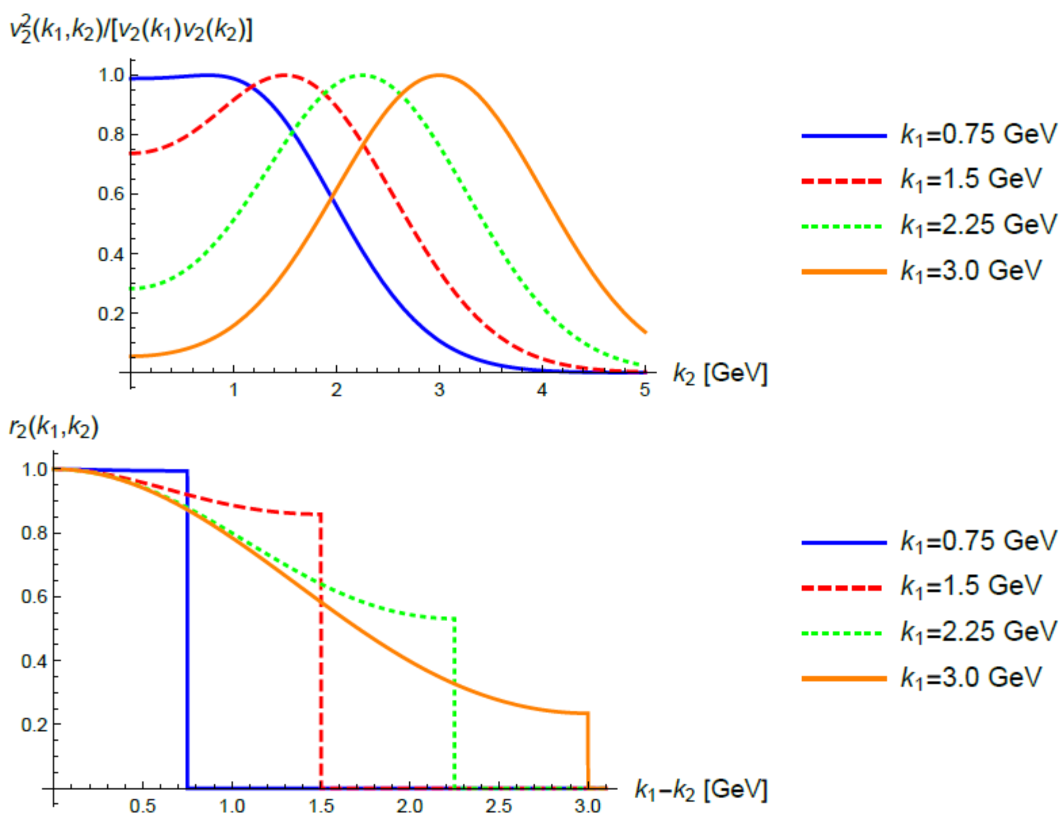
$$\lim_{m\to\infty} F^{(2)}_{\rm corr}(m/\overline{m}, m) = \frac{2\overline{m} + 2e^{-\overline{m}} - 2}{\overline{m}^2}\,.$$



For any multiplicity m, $v_2^2\{2\}$ *is finite in the limit* $N \to \infty$ *of a large number of sources.*

$v_2^2\{2\}(k_1, k_2)$ *does not factorize except for small transverse momentum.*

For any finite number of sources N, $v_2^2\{2\}(k_1, k_2)$ *vanishes in the high-multiplicity limit.*



4^{th} *cumulant and collectivity.*

Full result in large N limit

$$
\begin{aligned}
\hat{\sigma} \propto N_c^m \left(N_c^2-1\right)^N \left(\prod_{i=1}^{m} \left|\vec{f}(\mathbf{k}_i)\right|^2\right) N^{m-4} \\
\times \Bigg\{ N^4 + F_{\rm corr}^{(2)}(N,m)\frac{N^2}{(N_c^2-1)} \sum_{(ab)} \sum_{(lm)} 2^2 \cos(\mathbf{k}_a.\Delta\mathbf{y}_{lm}) \cos(\mathbf{k}_b.\Delta\mathbf{y}_{lm}) \\
+ F_{\rm corr}^{(3i)}(N,m)\frac{N}{(N_c^2-1)^2} \sum_{(abc)} \sum_{(lm)(mn)(nl)} 2^3 \cos(\mathbf{k}_a.\Delta\mathbf{y}_{lm}) \\
\times \cos(\mathbf{k}_b.\Delta\mathbf{y}_{mn}) \cos(\mathbf{k}_c.\Delta\mathbf{y}_{nl}) \\
+ F_{\rm corr}^{(4i)}(N,m)\frac{1}{(N_c^2-1)^2} \sum_{(lm),(no)} \sum_{(ab)(cd)} 2^4 \cos(\mathbf{k}_a.\Delta\mathbf{y}_{lm}) \cos(\mathbf{k}_b.\Delta\mathbf{y}_{lm}) \\
\times \cos(\mathbf{k}_c.\Delta\mathbf{y}_{no}) \cos(\mathbf{k}_d.\Delta\mathbf{y}_{no}) \\
+ F_{\rm corr}^{(4ii)}(N,m)\frac{1}{(N_c^2-1)^3} \sum_{(lm)(mn)(no)(ol)} \sum_{(abcd)} 2^4 \cos(\mathbf{k}_a.\Delta\mathbf{y}_{lm}) \cos(\mathbf{k}_b.\Delta\mathbf{y}_{mn}) \\
\times \cos(\mathbf{k}_c.\Delta\mathbf{y}_{no}) \cos(\mathbf{k}_d.\Delta\mathbf{y}_{ol}) \\
+ F_{\rm corr}^{(5)}(N,m)\frac{N^{-1}}{(N_c^2-1)^3} \sum_{[(lm)(mn)(nl)](op)} \sum_{(abc)(de)} 2^2 \cos(\mathbf{k}_d.\Delta\mathbf{y}_{op}) \cos(\mathbf{k}_e.\Delta\mathbf{y}_{op}) \\
\times 2^3 \cos(\mathbf{k}_a.\Delta\mathbf{y}_{lm}) \cos(\mathbf{k}_b.\Delta\mathbf{y}_{mn}) \cos(\mathbf{k}_c.\Delta\mathbf{y}_{nl}) \\
+ F_{\rm corr}^{(6)}(N,m)\frac{N^{-2}}{(N_c^2-1)^3} \sum_{(lm)(no)(pq)} \sum_{(ab)(cd)(ef)} 2^2 \cos(\mathbf{k}_a.\Delta\mathbf{y}_{lm}) \cos(\mathbf{k}_b.\Delta\mathbf{y}_{lm}) \\
\times 2^2 \cos(\mathbf{k}_c.\Delta\mathbf{y}_{no}) \cos(\mathbf{k}_d.\Delta\mathbf{y}_{no})\, 2^2 \cos(\mathbf{k}_e.\Delta\mathbf{y}_{pq}) \cos(\mathbf{k}_f.\Delta\mathbf{y}_{pq}) \\
+ O\left(\frac{1}{N}\right) + O\left(\frac{1}{(N_c^2-1)^4}\right) \Bigg\},
\end{aligned}
$$

$F_{\rm corr}^{(*)}(N,m)$

Color correction factors can be determined explicitly as for dipole

Fourth order cumulant in leading order in $1/(N_c^2-1)$

$$
\begin{aligned}
\langle\langle e^{i2(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle_c = {} & \left(Bk_1^2\right)\left(Bk_2^2\right)\left(Bk_3^2\right)\left(Bk_4^2\right) \\
& \left\{ \frac{1}{(N_c^2-1)^2}\left(2\,F^{(4i)}_{\rm corr} - 2F^{(2)}_{\rm corr}F^{(2)}_{\rm corr} + O\left(N^{-1}\right)\right)\right. \\
& \quad + \frac{1}{(N_c^2-1)^3}\left(2\,F^{(6)}_{\rm corr}(m-4)(m-5) - 4\,F^{(2)}_{\rm corr}\,F^{(4i)}_{\rm corr}(m-2)(m-3)\right. \\
& \qquad +4\,F^{(5)}_{\rm corr}(m-4) - 4\,F^{(2)}_{\rm corr}F^{(3)}_{\rm corr}(m-2) \\
& \qquad \left.\left. +2\,F^{(4ii)}_{\rm corr} + 8\left(F^{(2)}_{\rm corr}\right)^3 - 4\,F^{(4i)}_{\rm corr}F^{(2)}_{\rm corr}\right) + O\left(N^{-1}\right)\right\} \\
& +O\left(1/(N_c^2-1)^4\right) .
\end{aligned}
$$

However direct calculation shows that $\frac{1}{(N_c^2-1)^2}$ *term is* *zero*

So first nonzero term is:

$$\langle\langle e^{i2(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle_c = (Bk_1^2)\,(Bk_2^2)\,(Bk_3^2)\,(Bk_4^2)\,\frac{2}{(N_c^2-1)^3}\,(7+m-m^2) + O\left(1/(N_c^2-1)^4\right)\,.$$

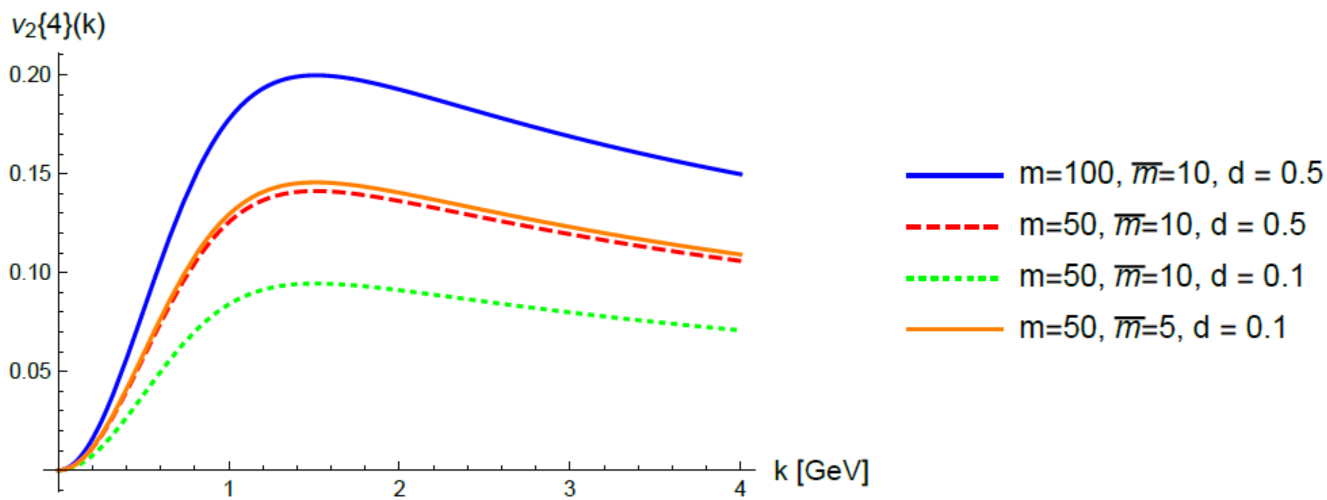
This term appears only in $1/(N_c^2-1)^3$ *limit*

This term is negative and we have collectivity

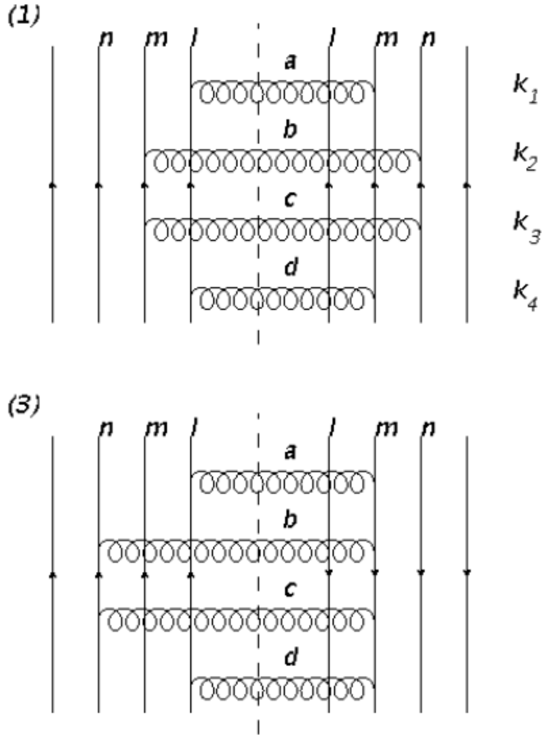
$$v_n\{4\} \equiv \sqrt[4]{-\langle\langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle_c}\,.$$

$$v_2\{4\}(k) \simeq \frac{1}{(N_c^2-1)^{3/4}}\,2^{1/4}\sqrt{m}\,B\,k^2$$

CGC result for $v_2\{4\}$ has same N_c but different m- (N?)-dependencies,



Odd harmonics



$$\mathrm{Tr}\,[\mathbb{1}]\ \mathrm{Tr}\left[T^c T^b\right]\ \mathrm{Tr}\left[T^b T^c T^d T^a\right]\ \mathrm{Tr}\left[T^a T^d\right] = N_c^4\ \left(N_c^2-1\right)^2$$

$$\mathrm{Tr}\,[\mathbb{1}]\ \mathrm{Tr}\left[T^b T^c\right]\ \mathrm{Tr}\left[T^c T^d T^b T^a\right]\ \mathrm{Tr}\left[T^a T^d\right] = \frac{1}{2} N_c^4\ \left(N_c^2-1\right)^2$$

$$\mathrm{Tr}\,[\mathbb{1}]\ \mathrm{Tr}\left[T^b T^c\right]\ \mathrm{Tr}\left[T^d T^c T^b T^a\right]\ \mathrm{Tr}\left[T^a T^d\right] = N_c^4\ \left(N_c^2-1\right)^2$$

$$\mathrm{Tr}\,[\mathbb{1}]\ \mathrm{Tr}\left[T^c T^b\right]\ \mathrm{Tr}\left[T^b T^d T^c T^a\right]\ \mathrm{Tr}\left[T^a T^d\right] = \frac{1}{2} N_c^4\ \left(N_c^2-1\right)^2$$

Different color factors lead to breaking of a k -k symmetry present in large N limit, and appearance of sinuses:

$$e^{i\,\mathbf{k}_2.\mathbf{\Delta y}_{mn}}\left(e^{i\,\mathbf{k}_3.\mathbf{\Delta y}_{mn}}+\frac{1}{2}e^{-i\,\mathbf{k}_3.\mathbf{\Delta y}_{mn}}\right)+e^{-i\,\mathbf{k}_2.\mathbf{\Delta y}_{mn}}\left(\frac{1}{2}e^{i\,\mathbf{k}_3.\mathbf{\Delta y}_{mn}}+e^{-i\,\mathbf{k}_3.\mathbf{\Delta y}_{mn}}\right)$$
$$=3\cos\left(\mathbf{k}_2.\mathbf{\Delta y}_{mn}\right)\,\cos\left(\mathbf{k}_3.\mathbf{\Delta y}_{mn}\right)-\sin\left(\mathbf{k}_2.\mathbf{\Delta y}_{mn}\right)\,\sin\left(\mathbf{k}_3.\mathbf{\Delta y}_{mn}\right).$$

Arise in the present set-up from a purely non-abelian mechanism

However: odd harmonics are parametrically suppressed by 1/N

Conclusions

We calculated QCD interference effects based on MPI and found that

1. *We have the correct form for 2 point cumulant*
2. *Collectivity-4th cumulant is negative*
3. *The cumulants calculated with MPI parameters have correct order of magnitude*
4. *Odd harmonics naturally appear as a result of nonabelian nature of the model.*

We see that no-interaction baseline including QCD/QM interference effects due to different MPIs make significant if not dominant contribution in ridge in pp and pA.

Our model disentangles in calculation of cumulants QCD interference effects from effects that depend on parton density in initial state. Its relation to other approaches, such as CGC can be further clarified.

Further tasks: get closer to phenomenology, more rigorous derivation of our model from QCD, further understanding of final states in pp collision, effects of 1/N, hadronization/LPHD,………...