Direct Photons at Low Pt : a QGP Signal in pp Collisions at LHC

F.M. Liu IOPP/CCNU, Wuhan, China

K. Werner Subatech, Nantes, France

F.M.Liu, K.Werner, arXiv:1102.1052v2 [hep-ph],
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outline

- Motivation
  - QGP formation in Au+Au at RHIC
  - Direct photon enhancement at low pt region
- Approach
  - Initial condition from strings (multiple scattering)
  - Hydrodynamic description of the evolution
- Results
  - Prompt photon production from pp at 7TeV
  - Thermal photons from plasma formed in pp at 7TeV
- conclusions

QGP formation in Au+Au at RHIC

- Suppression of high pt hadrons
  (centrality dependence, d+Au)

- Back-to-back di-hadron correlation
  (pp, dAu, AA centralities)

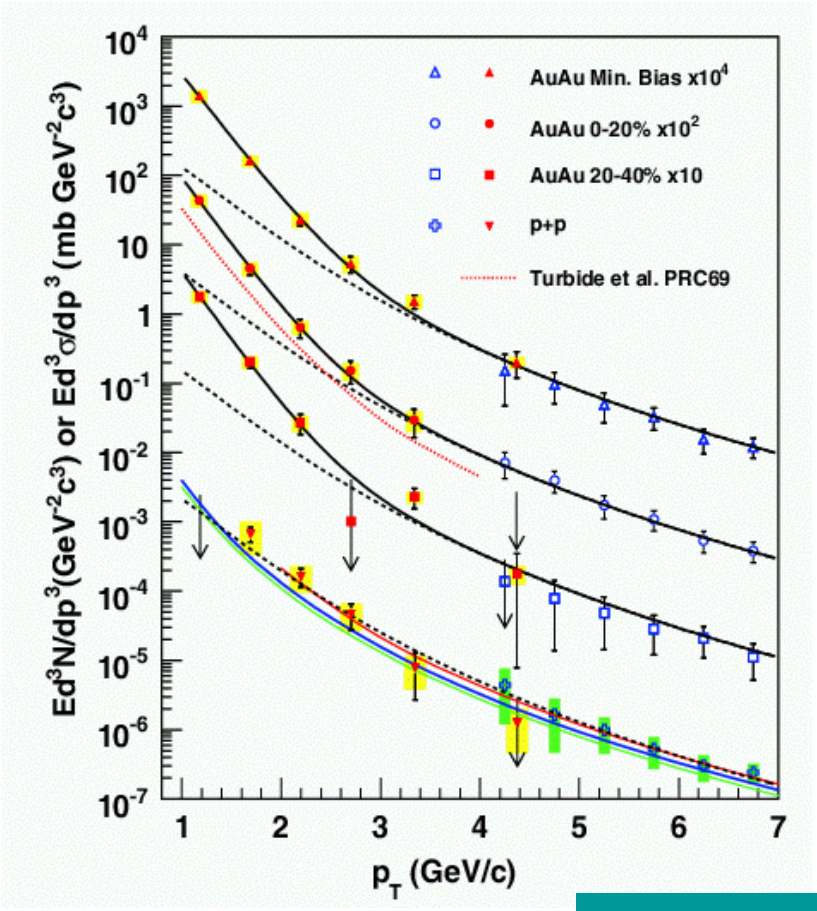
- v2 scaling

- .....

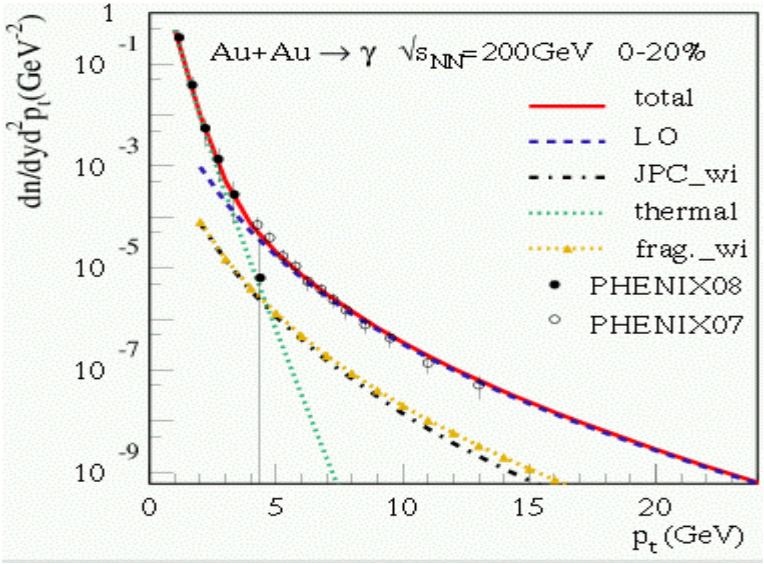
- Direct photon enhancement at low pt

direct photon enhancement at low pt

PHENIX, Phy.Rev.Lett.104:132301, 2010



F.M. Liu, T.Hirano, K.Werner, Y. Zhu, J.Phys.G36: 064072, 2009, Phys.Rev.C79:014905,2009.



QCD phase diagram, QGP, heavy ion collisions.
pp collisions, with higher energy?

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Hadron production in pp collisions

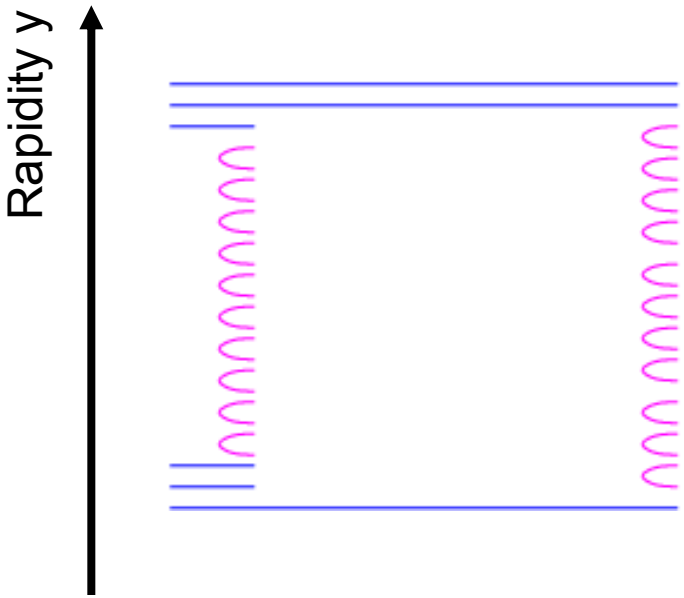
Usually, **a pair of strings** are formed via

a) longitudinal excitation

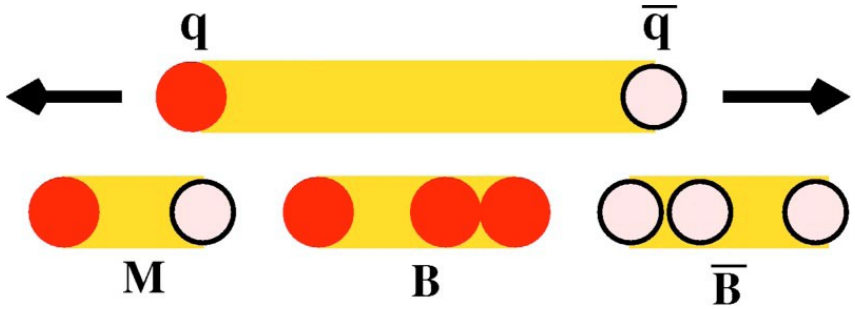
HIJING,PYTHIA, UrQMD…

b) color exchange

DPM,VENUS,QGSM…



hadron production: string fragmentation, *i.e.*

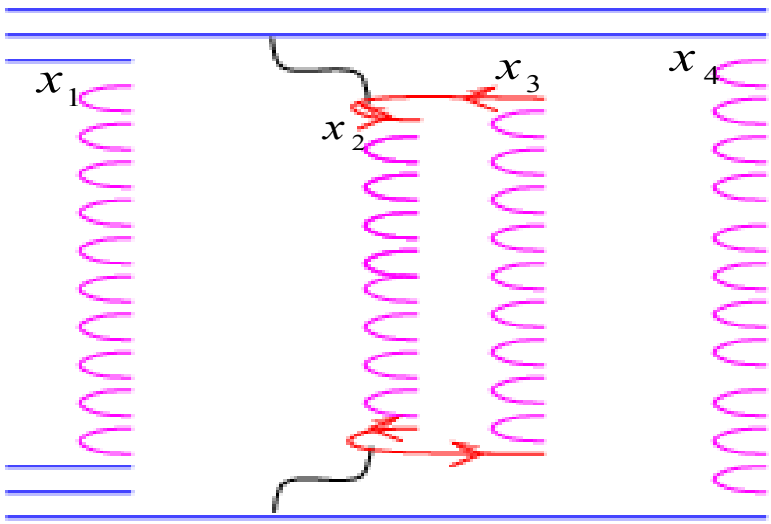


String models are successful in giving both pt-dis. and y-dis. of produced hadrons.

It can distribute the injected energy in the momentum space correctly!

Multiple scattering theory in pp

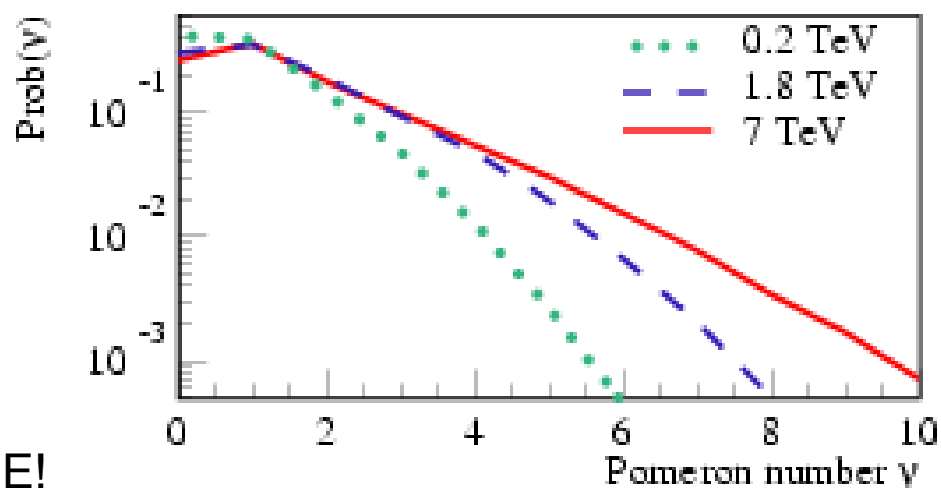
At high collision energy (above 100GeV),
multiplicity distribution and increase of central rapidity density
requires more strings (Pomerons).



Centrality
- AA: Nbinary nucleon pairs
- pp: Nbinary parton pairs

Challenge!

H.J.Drescher *et al*, Phys.Rept.**350**,93(2001);
F.M.Liu *et al*, PRD **67**, 034011 (2003)



Condition to produce particles:

$$x^+ x^- \sqrt{s} > E_0$$

Small x becomes important at high E!

Fluctuation of string numbers is big at high E!

Thermal photons from bulk

$\varepsilon, p, u^{\mu}, s, B, \ldots(\tau, x, y, z)$ described with 3+1D hydrodynamics

Initial condition: based on string picture, we have some knowledge at one moment. Translate to τ_0

$$T^{\mu\nu}_{\text{hydro}}(\tau_0, \vec{r}) = T^{\mu\nu}_{\text{particle}}(\tau_0, \vec{r}) = \frac{\sum_{\text{particle}\ i \in \Delta V} p_i^{\mu} p_i^{\nu}}{\Delta V}$$

Evolution:

$$T^{\mu\nu} = (e + P)u^{\mu}u^{\nu} - Pg^{\mu\nu} + \cdots$$

Hydrodynamic equation $\partial_{\mu} \boldsymbol{T}^{\mu\nu} = 0$

Equation-of-State: Lattice QCD

(S. Borsanyi *et al*, arXiv: 1007.2580)

Freeze-out:

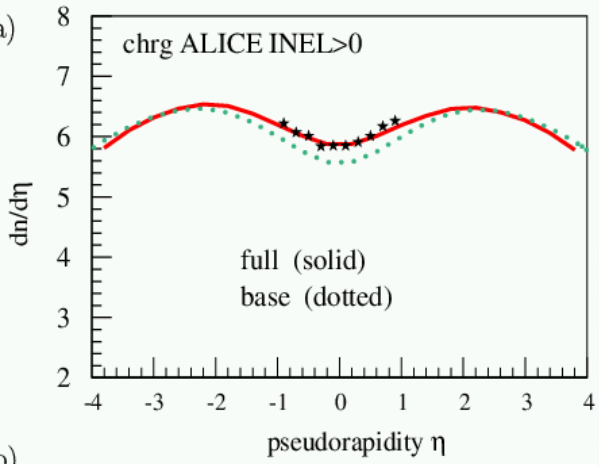
$$e^{th} = 0.08\,\text{GeV}/\text{fm}^3 \quad \text{or} \quad T^{th} \sim 100\,\text{MeV}$$

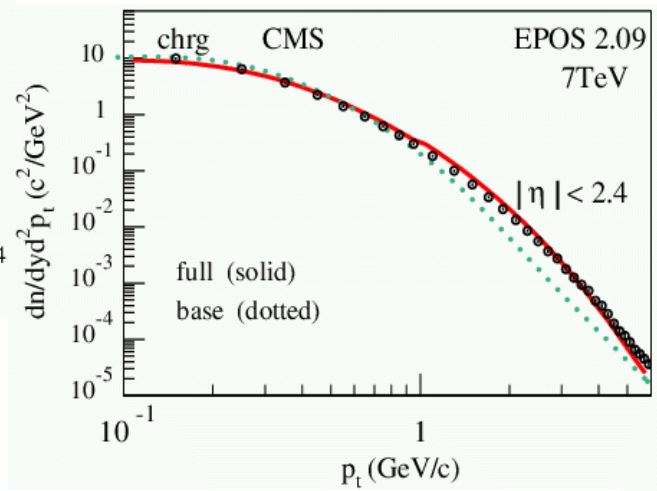
Question: Hydrodynamics should not be used in pp---only few hadrons are produced.

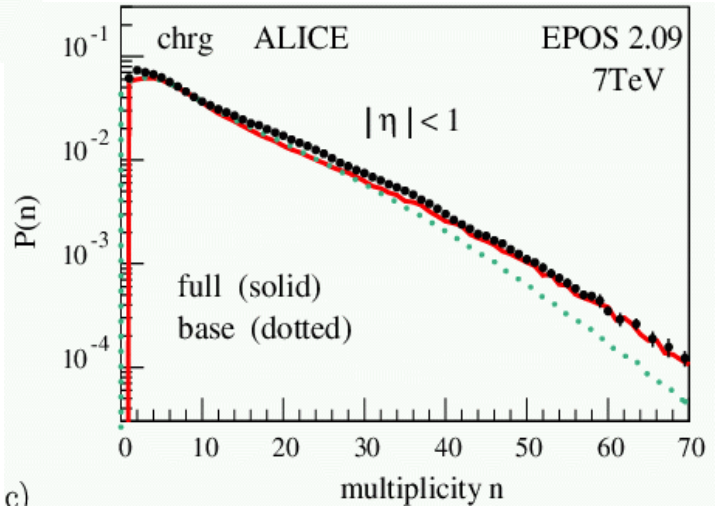
Answer: Please look into the sky instead the ground when there is a festival firework!

Flow effect to Hadron production

K.Werner, Iu.Karpenko, T.Pierog, Phy.Rev.Lett.106, (2011) 122004.







Collective flow can redistribute the injected Energy in the momentum space—but not a dramatic change!

Here charged hadron distribution is not sensitive to the space-time evolution!

One should look at those sensitive observables--- Correlations (HBT, Ridge, …), heavy flavors, photons!

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Direct photon production in pp

1. Prompt photons at the early stage

$$\frac{d\sigma^{\text{Prompt}}}{dyd^2p_t} = \sum_{ab} dx_a dx_b G_{a/p}(x_a, M^2) G_{b/p}(x_b, M^2) \frac{\hat{s}}{\pi} \frac{d\sigma}{d\hat{t}}(ab \to cd)\delta(\hat{s}+\hat{t}+\hat{u})$$

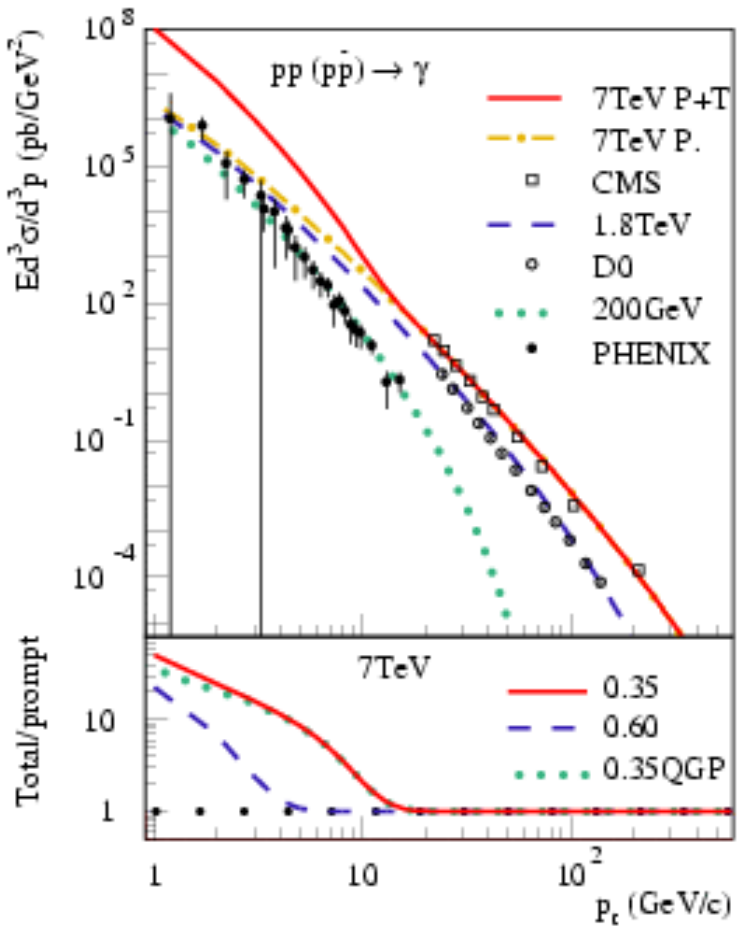
$$+ \sum_{c=q,g} \int dz_c \frac{d\sigma^c}{dyd^2p_{\text{t}}} \frac{1}{z_c^2} D^0_{\gamma/c}(z_c, Q^2)$$

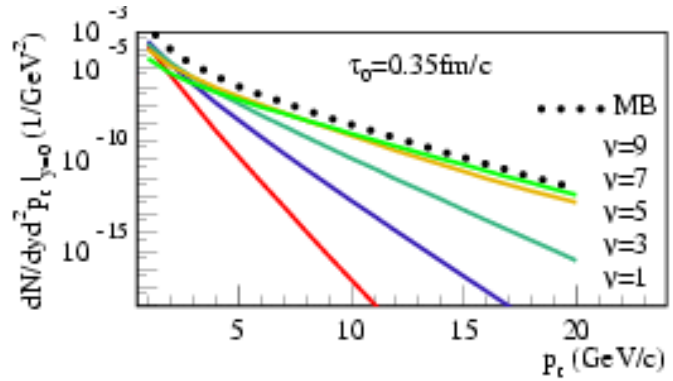
2. Thermal photons from plasma

$$\frac{dN^{\text{thermal}}}{dyd^2p_t}(\nu) = \int d^4x \Gamma_{\text{thermal}}(E^*, T), \quad E^* = p^\mu u_\mu$$

$$\frac{d\sigma^{\text{thermal}}}{dyd^2p_t}(\text{MB}) = \sigma_{pp}^{\text{inel}} \cdot \sum_\nu \frac{dN^{\text{thermal}}}{dyd^2p_t}(\nu) \cdot \text{Prob}(\nu)$$

Direct photons from pp at 7TeV



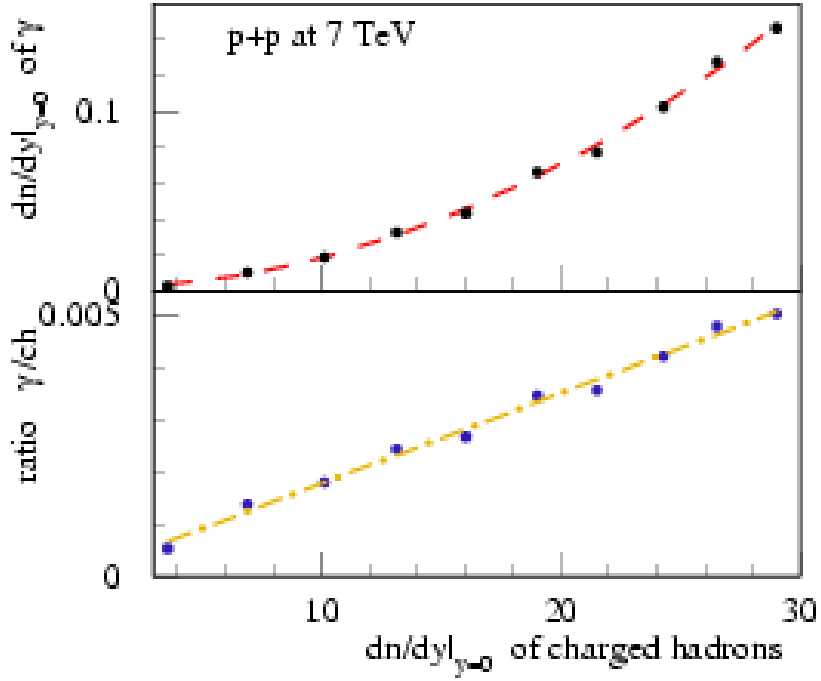


Events with 7~9 Pomerons dominate the sensitive pt region!

QGP photons from pp collisions at 7TeV dominate low pt region Up to 10GeV/c!

Measurements????

Centrality dependence in pp



Volume effect can be seen
In the ratio of gamma/ch.

Conclusion

1. It is possible to form a QGP in pp collisions under the two conditions:
   - The collision energy is high;
   - The collision centrality is high.

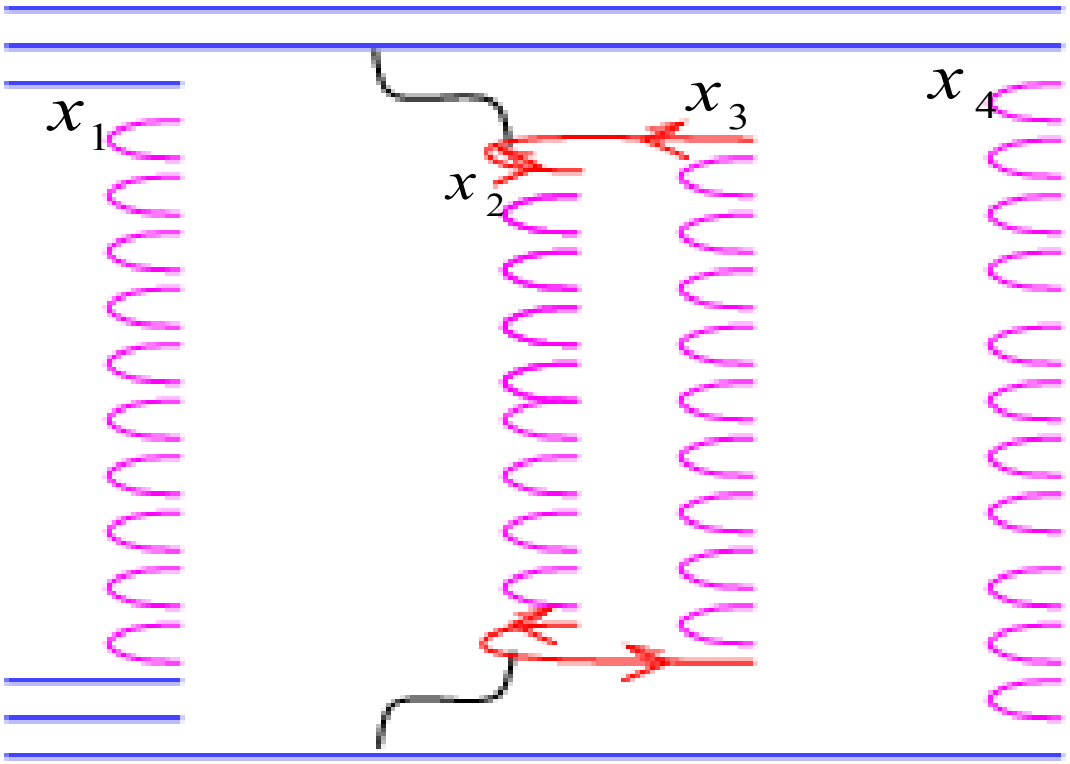
2. Two sources of direct photons should be considered in pp collisions at very high energies:
   - Prompt photons at the early stage;
   - Thermal photons from plasma.

3. We predict that thermal photons from pp collisions at 7TeV largely dominate over the prompt ones at pt lower than 10GeV/c.

4. We will have a chance to study QGP properties (jet quenching, heavy flavor, ..) under a much more clean background! No CNM effect!

Thank you!

Energy Conservation



x_i : lightcone momentum fractions satisfy $\sum x_i = 1$ due to energy - momentum conservati on. So Pomerons are correlated through energy - momentum sharing!