Revealing the source of the radial flow patterns in proton-proton collisions using hard probes

Héctor Bello[2,1], Gyula Bencédi[3,1], Antonio Ortíz[1].

[1] Instituto de Ciencias Nucleares, UNAM D. F., México.
[2] Facultad de Ciencias Físico Matemáticas, BUAP, Puebla, México.
[3] Centro de Investigación Wigner, Budapest, Hungría.

DPC-SMF

XXXI Reunión Anual de la División de Partículas y Campos de la SMF
Cinvestav-Zacatenco
24-26 mayo 2017

SMF
Sociedad Mexicana de Física

Paper Published JPG:

Revealing the source of the radial flow patterns in proton–proton collisions using hard probes
Antonio Ortiz (Mexico U., ICN), Gyula Bencedi (Mexico U., ICN & Wigner RCP, Budapest), Héctor Bello (Mexico U., ICN & Puebla U., Mexico). Aug 16, 2016. 14 p
Published in **J.Phys. G44 (2017) no.6, 065001**
DOI: 10.1088/1361-6471/aa6594
e-Print: **arXiv:1608.04784 [hep-ph] | PDF**

Outline

- Introduction
- What will be shown?
- Monte Carlo Simulation setup

  -EPOS3

  -Pythia8
- Results and discusion

  -proton to pion ratio

  -Blast Wave analysis for invariant yield of LF-particles
- Conclusions

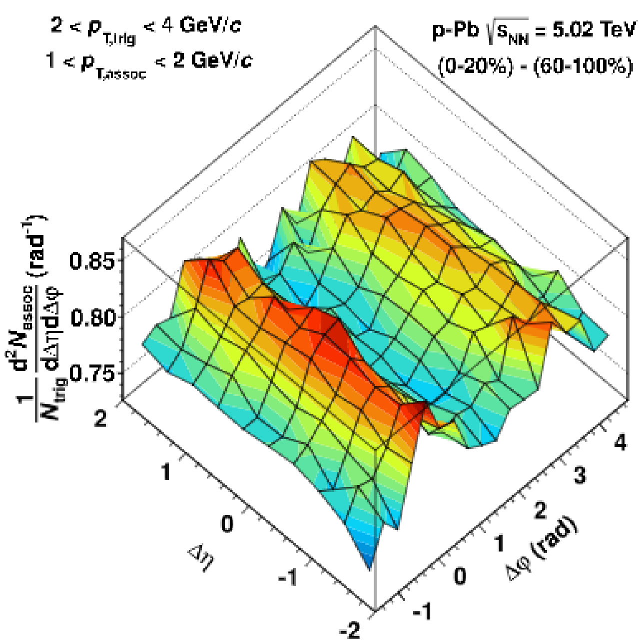
Introduction

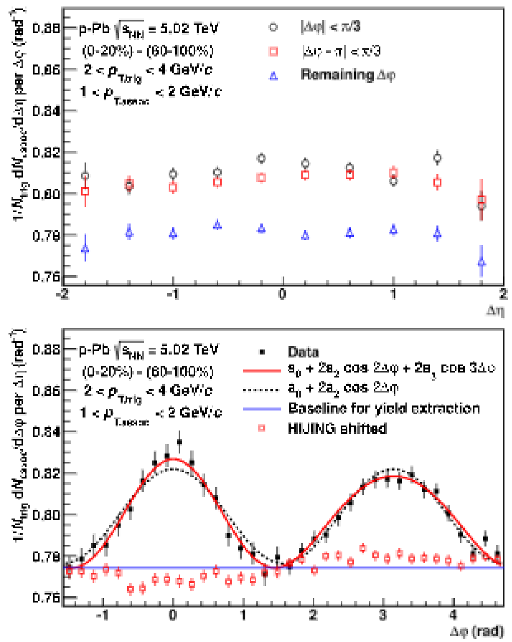
The study of particle production in HM events in small collision systems at LHC has revealed unexpected collective-like phenomena. For HM pp and p-Pb collisions we have:

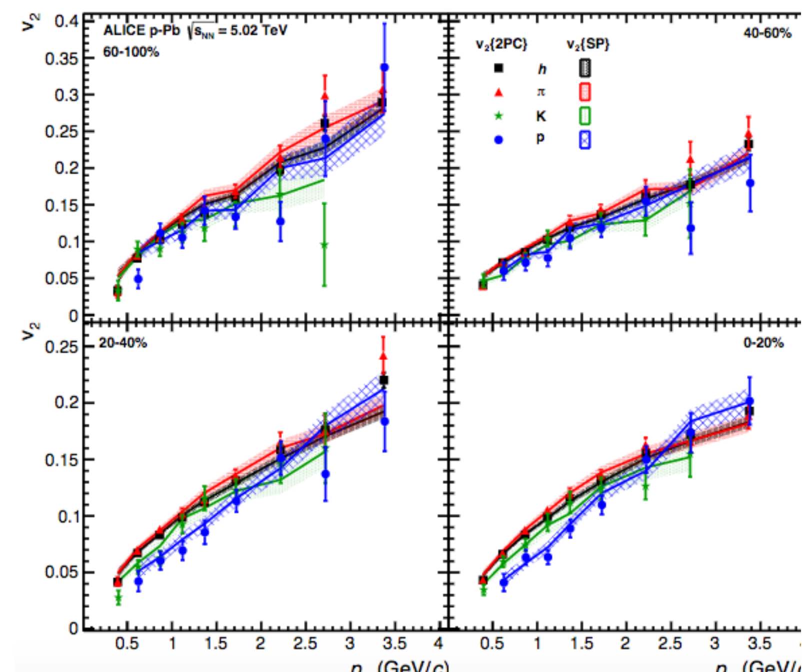
- Long-range angular correlations, radial flow signals strangeness enhacement

Phys.Lett. B719 (2013) 29-41

Phys. Lett. B 726 (2013) 164-177







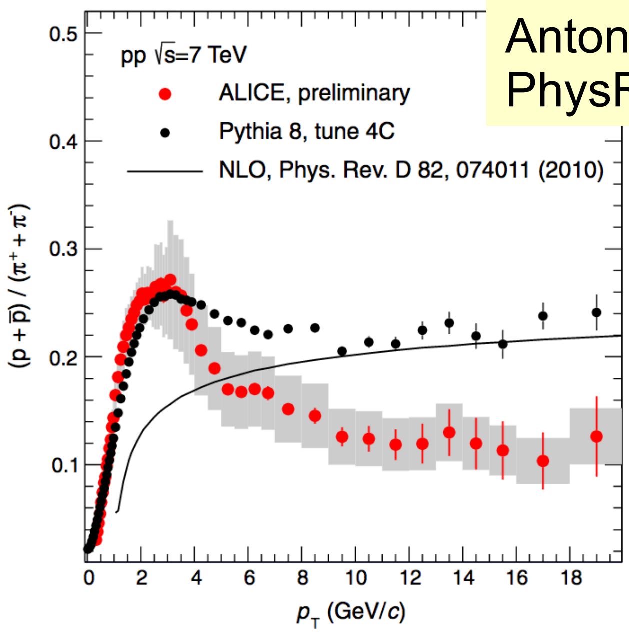
- Understanding the phenomena in pp collisions is crucial for HI physics, Because pp and p-Pb collisions is used to extract the QGP effects. However, no jet quenching effects have been found so far in p-Pb collisions, suggesting that other mechanisms could play a role in producing collective-like behaviour in small collision systems

Introduction

Some mechanisms for collectivity

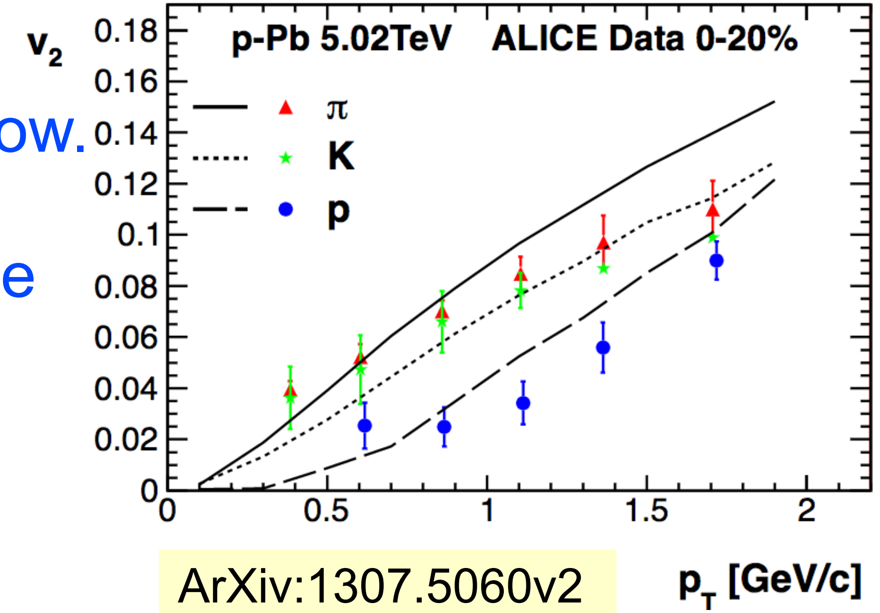
- Hydrodynamic calculations reproduce flow.

- Also, Color Reconstruction (CR) reproduce
- flow like effects.



Antonio Ortiz et all.
PhysRevLett.111.042001

FIG. 1 (color online). Proton to pion ratio from pp collisions at $\sqrt{s} = 7$ TeV. ALICE data are compared to results from PYTHIA 8 tune 4C, as well as next-to-leading order (NLO) QCD calculation [7].



ArXiv:1307.5060v2

FIG. 4. $v_2\{2\}$ for pions, kaons and protons in p-Pb collisions calculated with the hydrodynamic model, as a function of the transverse momentum. The data come from Ref. [7].

There are other mechanism like:

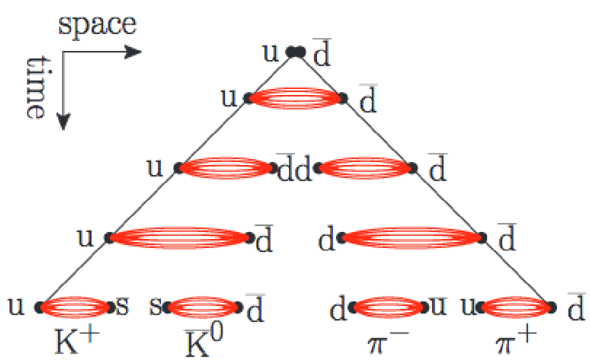
-color glass condensate, ArXiv:1509.03499v2

-string melting in MPT ArXiv:1404.4129v2

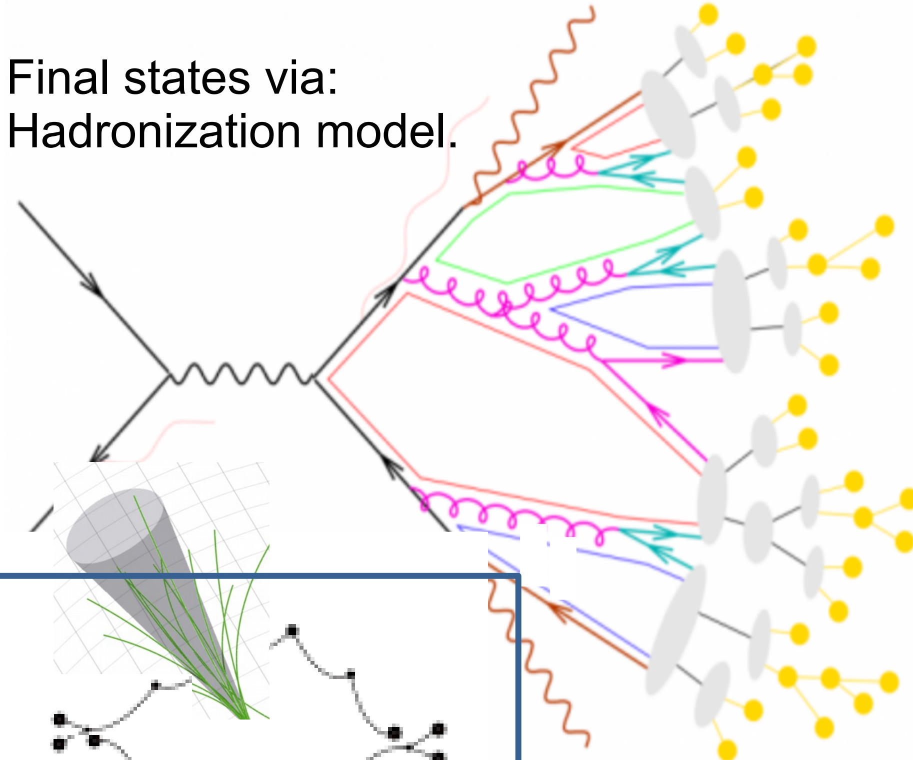
-color ropes in Dypsi C. Bierlich et all. ArXiv:1412.6259v3

Introduction   Color Reconnection (PYTHIA8)

Production via:
Lund String fragmentation
Model

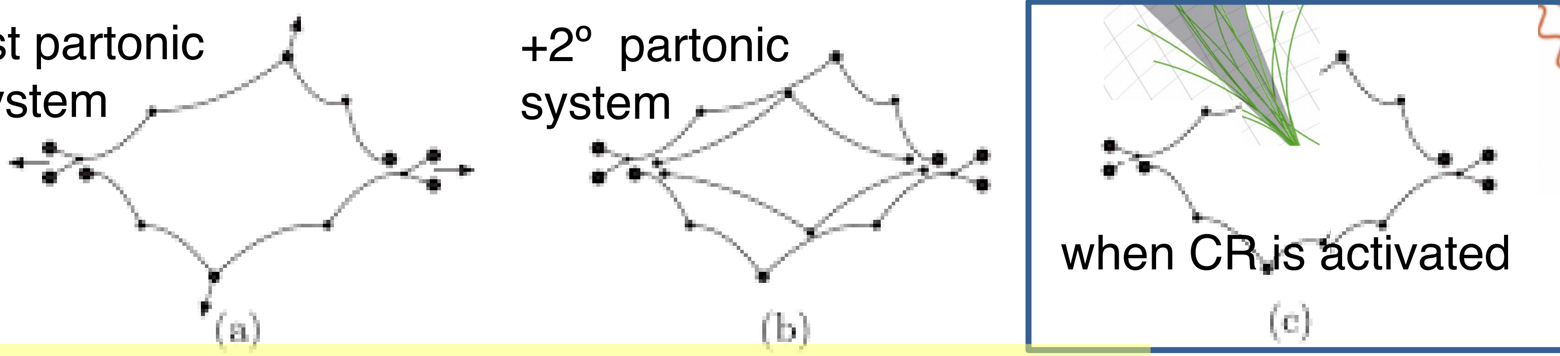


Final states via:
Hadronization model.

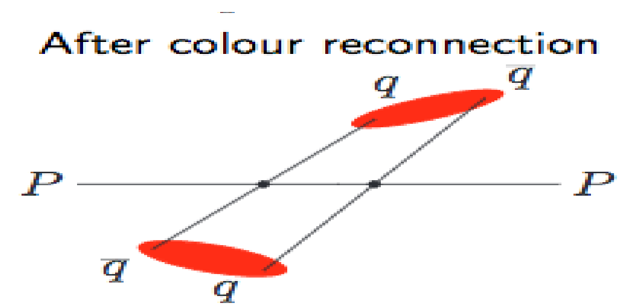


1st partonic
system

+2º partonic
system



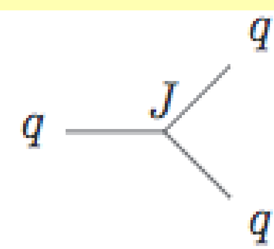
· Figure taken from: G. Gustafson, Acta Phys. Polon. B40, 1981 (2009)
Effects of CR on hadron flavor observables, C. Bierlich and J. R. Christiansen,
PRD 92 (2015) 9, 094010



From: Jesper Roy Christiansen MPI@LHC 2014

QCD rules say how
reconnection is allowed
(epsilon color tensor)

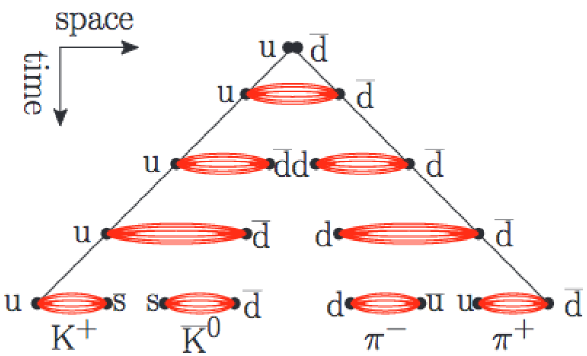
$q^i q^j q^k \epsilon^{ijk} \rightarrow$



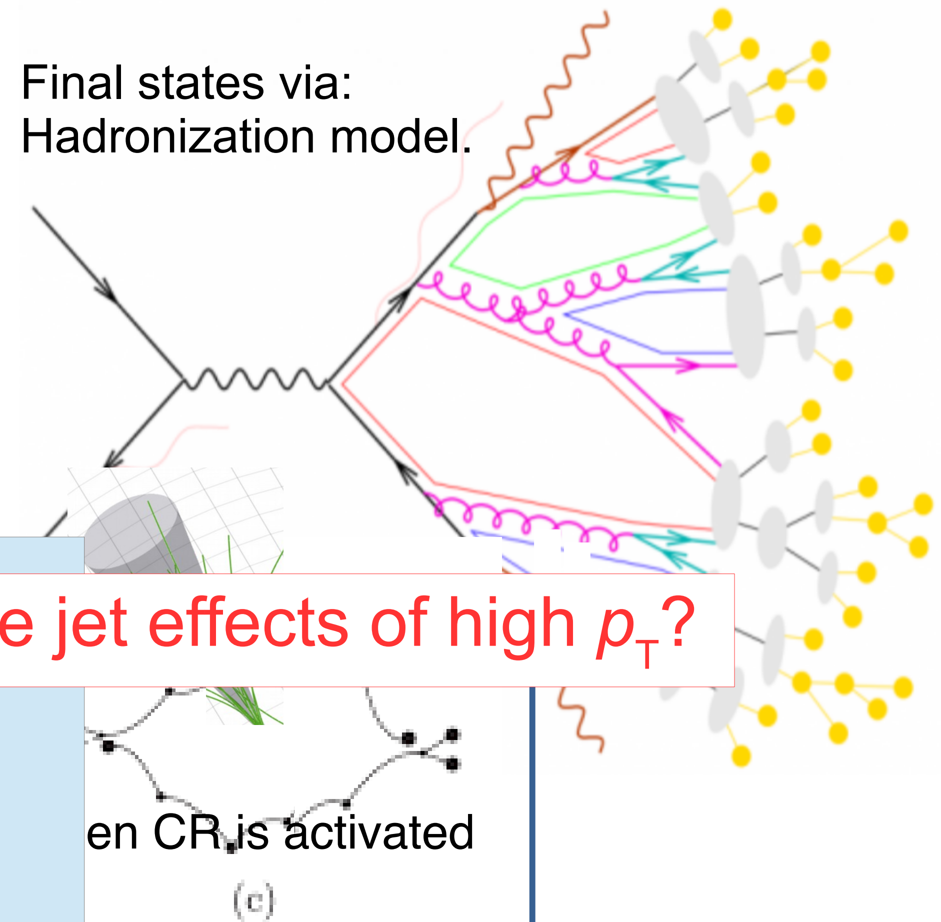
The minimum string length
tell us the configuration

Introduction Color Reconnection (PYTHIA8)

Production via:
Lund String fragmentation
Model



Final states via:
Hadronization model.



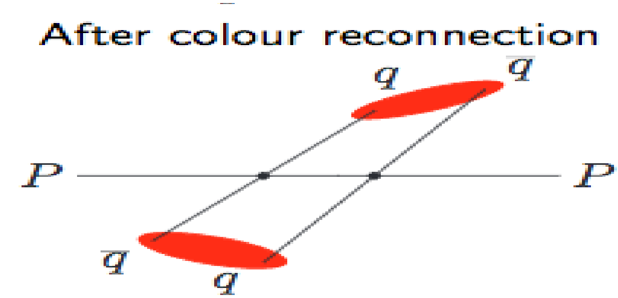
- Can we cuantify the jet effects of high p_T?

In the CR model used in tune Monash2013 a MPI system with a p_{T0} scale of hard interaction (normally 2 ➞ 2)
Can be joined with one of a harder scale with a probability given by:

$$P(p_T) = \frac{(RR \times p_{T0})^2}{(RR \times p_{T0})^2 + p_T^2}$$

Reconnection Range (*RR*): 0-10

http://home.thep.lu.se/~torbjorn/pythia82html/Welcome.html



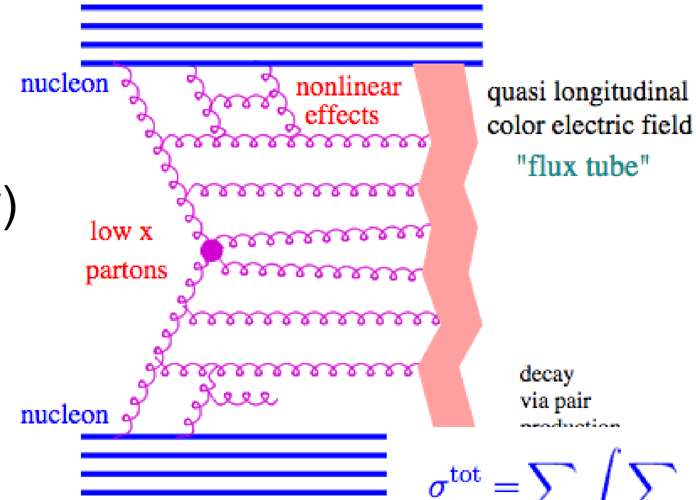
From: Jesper Roy Christiansen MPI@LHC 2014

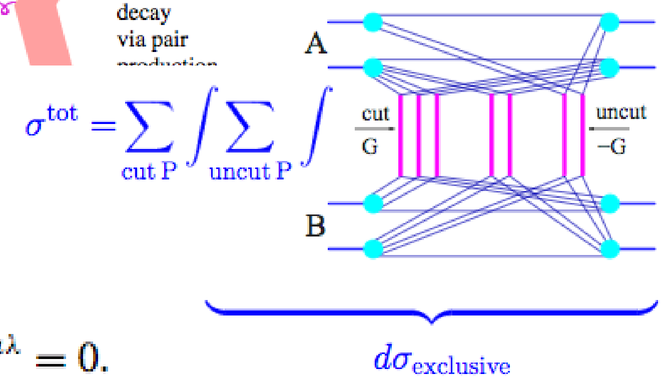
The minimum string length
tell us the configuration

Introduction 3+1D Hidrodynamics (EPOS 3)

Model with:

Energy conservation in multiple scattering
Parton modelled by (Gribov–Regge Theory)
Off-shell, remanents
Saturation



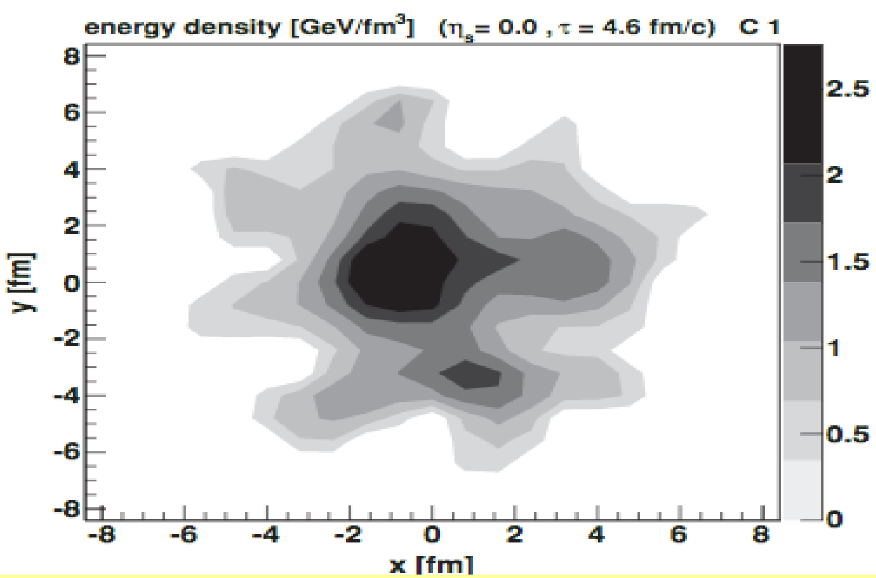


"Core-corona" separation

Core→high string density
Corona→low string density
with "Core"=Hidrodynamics
No "Core"=just string model

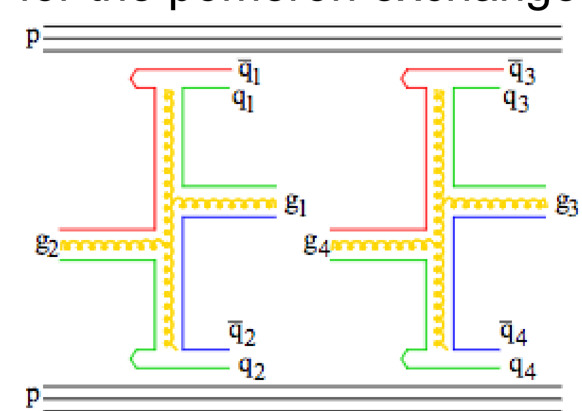
$$\partial_{;\nu} T^{\mu\nu} = \partial_\nu T^{\mu\nu} + \Gamma^{\mu}_{\nu\lambda} T^{\nu\lambda} + \Gamma^{\nu}_{\nu\lambda} T^{\mu\lambda} = 0.$$

K. Werner et al., PRC89 (2014) 6, 064903



K. Werner et al., PRC 82 (2010) 044904

Color flux tubes for the pomeron exchange.

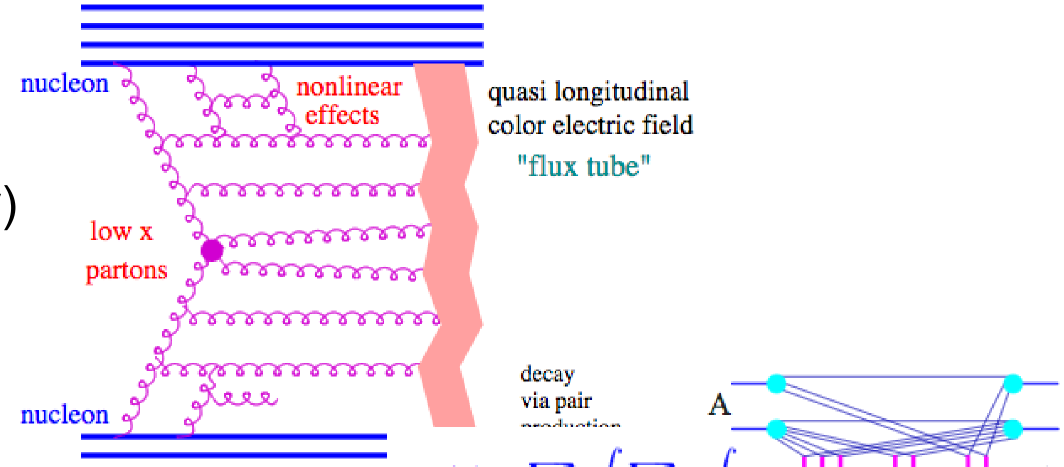


K.Werner et al, PRC 92 (2015) 034906

Introduction 3+1D Hidrodynamics (EPOS 3)

Model with:

Energy conservation in multiple scattering
Parton modelled by (Gribov–Regge Theory)
Off-shell, remanents
Saturation



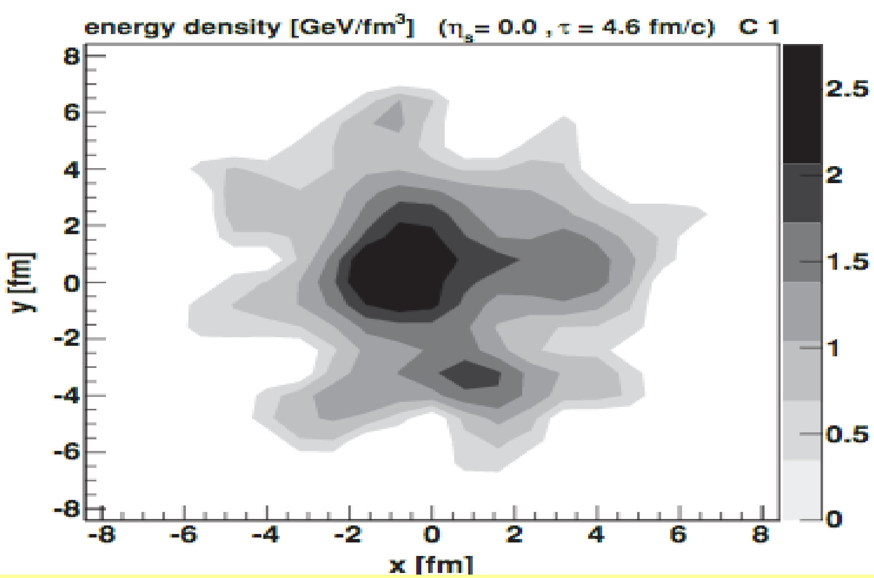
“Core-corona” separation

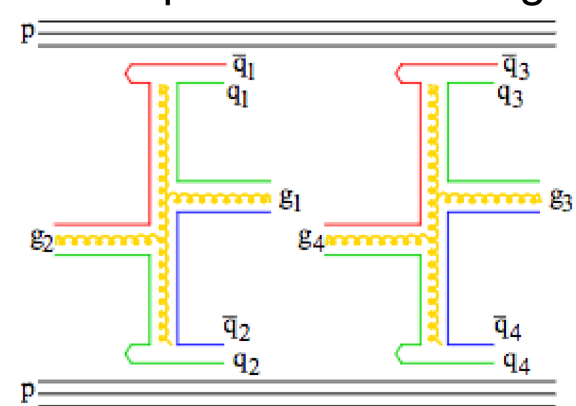
Core→high strin
Corona→low str
with “Core”=Hic
No “Core”=just s

- What happend to jets of high p_T within EPOS?

K. Werner et al., PRC89 (2014) 6, 064903

Color flux tubes for the pomeron exchange.





K. Werner et al., PRC 82 (2010) 044904

K.Werner et al, PRC 92 (2015) 034906

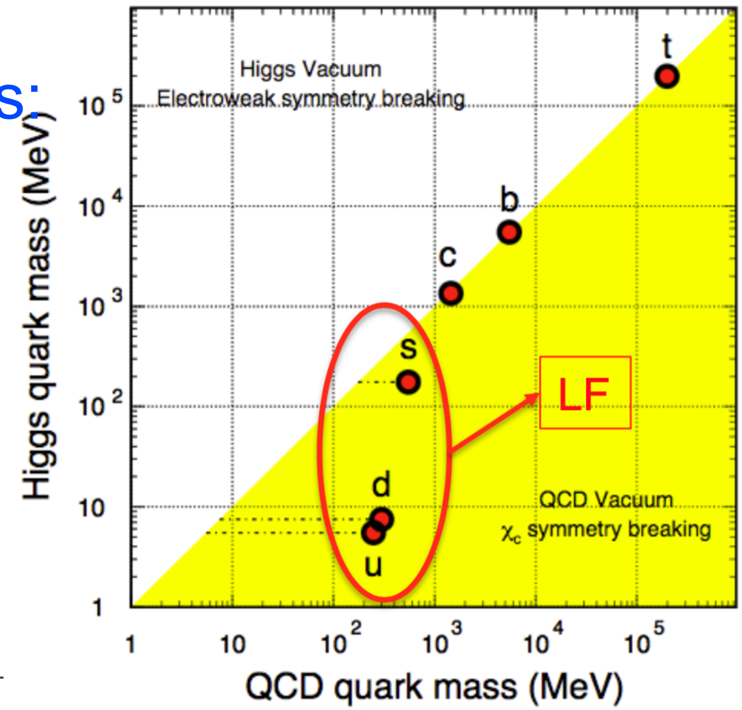
What will be shown?

For light flavor hadrons with constituent quarks:

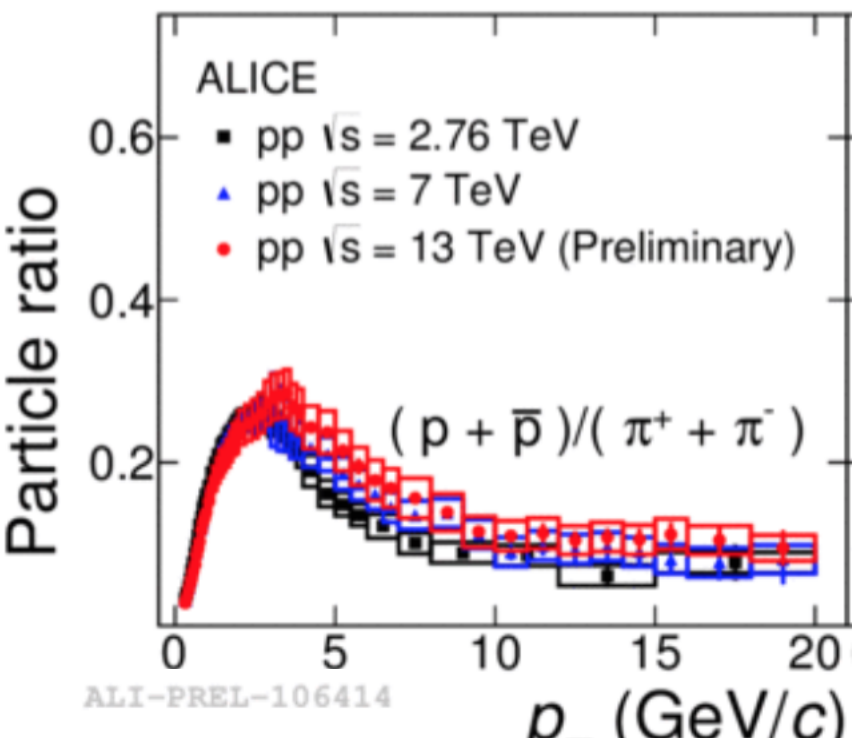
$m_u \approx 2.2$ MeV, $m_d \approx 4.7$ MeV, $m_s \approx 96$ MeV $< \Lambda_{QCD} << m_c \approx 1.3$ GeV

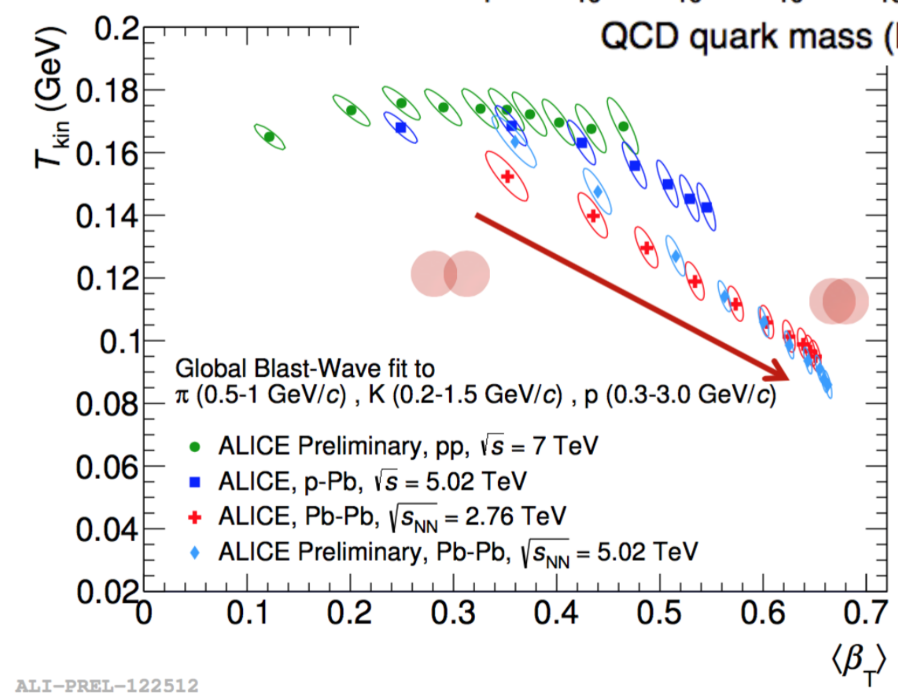
(mases generated dinamically) **$\pi^{\pm}$, $K^{\pm}$, p,**

arXiv:nucl-ex/0610043



We will see **how jets affect** the proton to pion ratio and the blast wave analysis **within the models** of Hydrodinamics and Color Reconnection





- See Irais Bautista talk

Simulation Setup

Pythia 8.212 Generator

- Monash 2013,
- 900M events

P. Skands, EPJC74 (2014) 8, 3024

EPOS 3.117, Generator

- 1000M events

K. Werner et al., PRC89 (2014) 6, 064903
K. Werner et al., PRC 82 (2010) 044904
H.J. Drescher et al., PR 350 (2001) 93-289

FastJet 3.1.3, Jet Finder

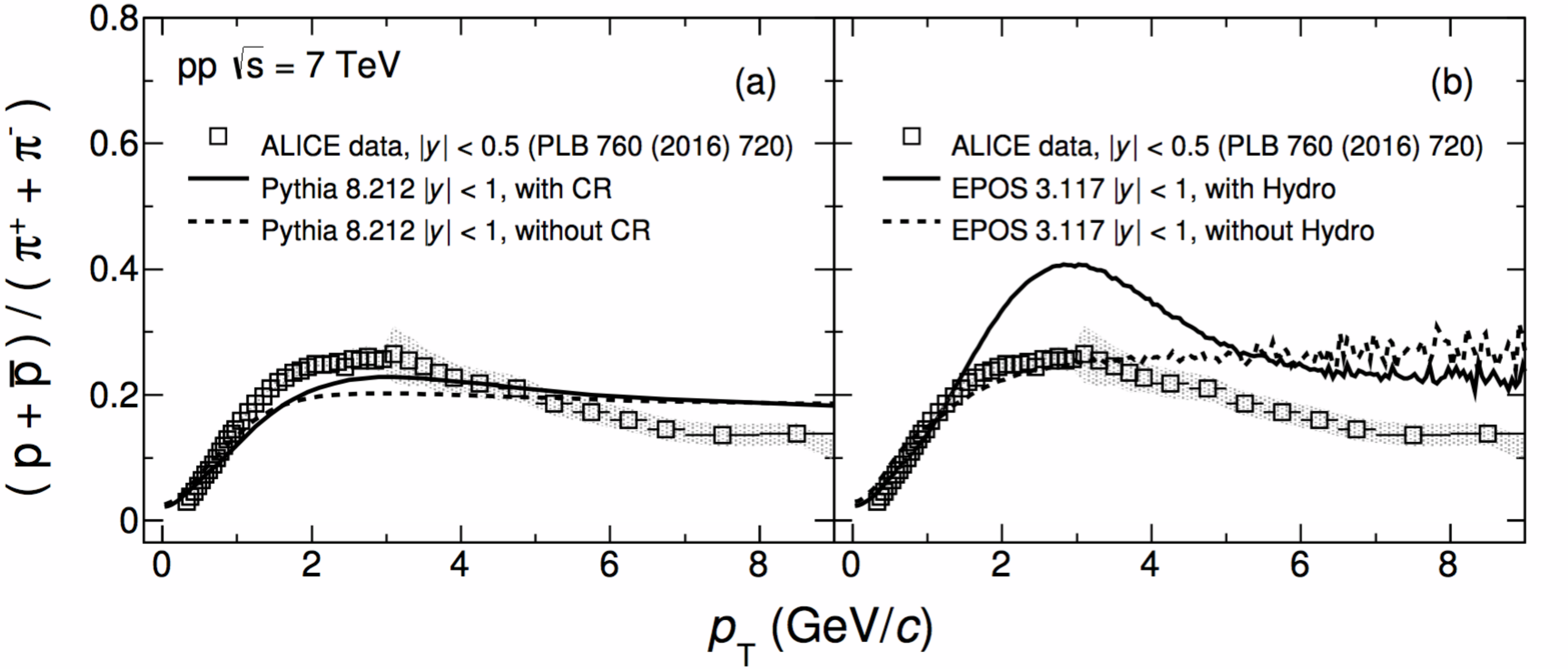
M. Cacciari et al., EPJC72(2012)1896

- Anti-*k*T Algoríthm
- R=0.4
- *p*Tmin = 5 GeV
- Maximum p_T of the partonic scatterings 25 GeV

Stable and primary particles were considered for the jet reconstruction.

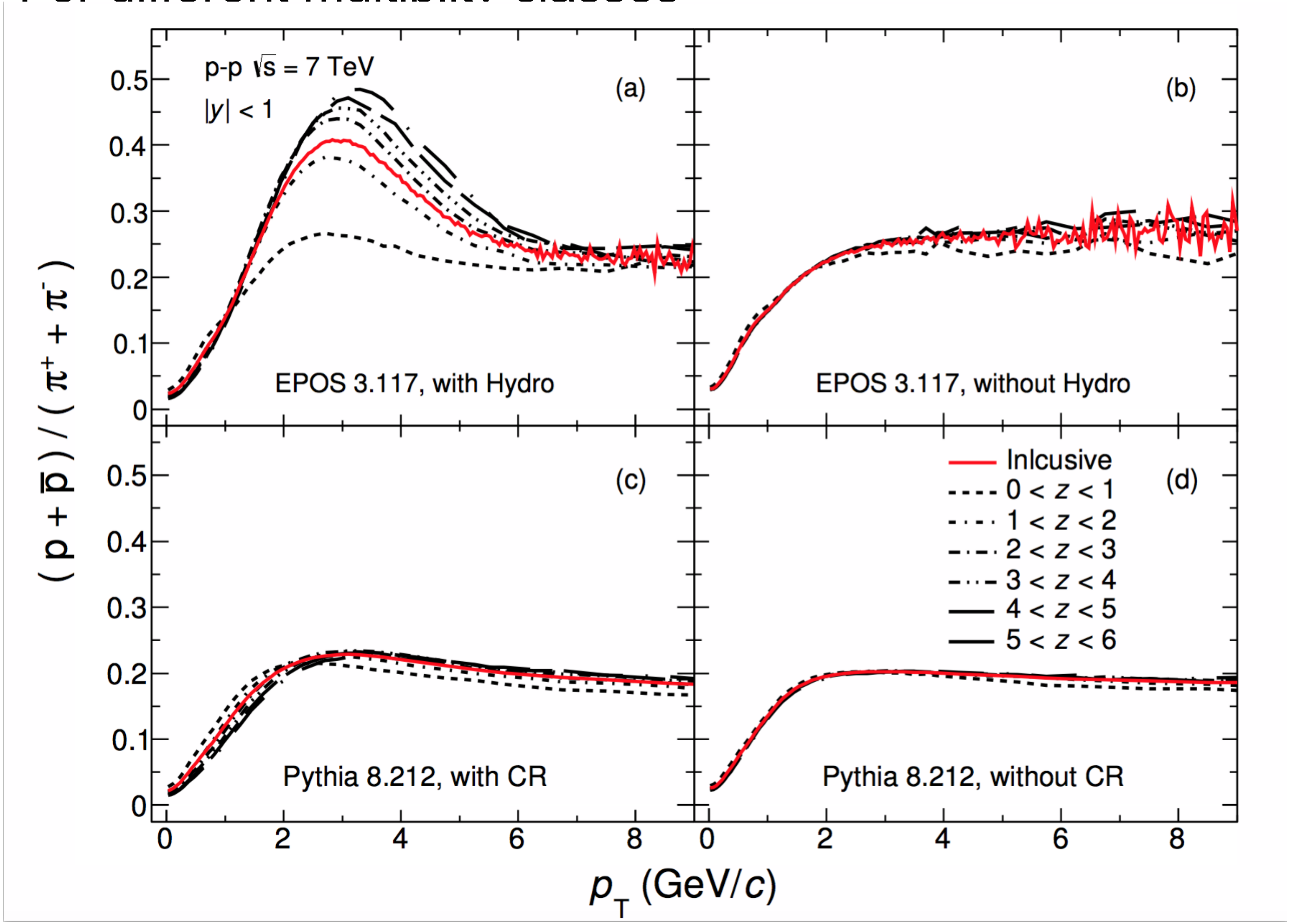
Monte Carlo Models and data

Epos3 and Pythia 8.212 comparison with data



Monte Carlo Models

Epos3 comparison with Pythia 8.212, with and without Hydro and CR
For different multiplity classes



Results and discussion (using jets reconstruction)

Proton to pion ratio

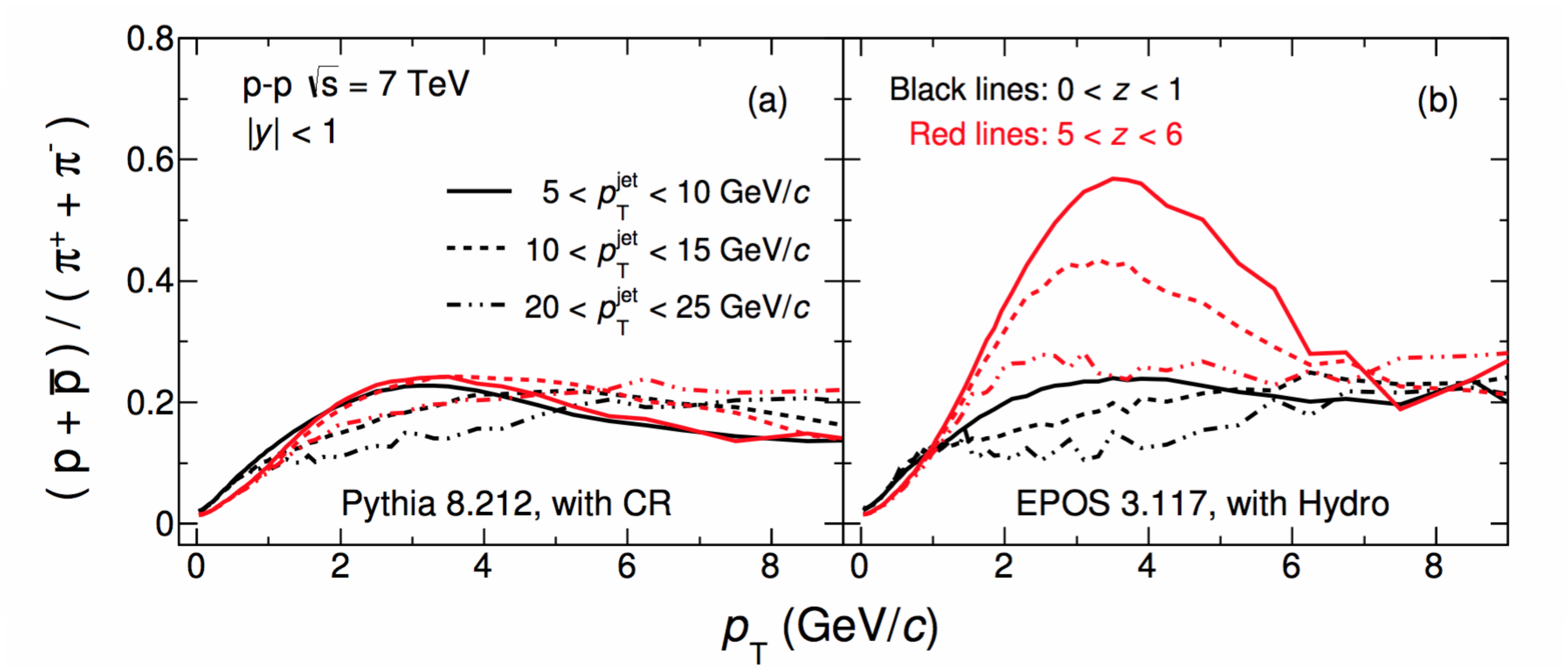


Fig. 4: (Color online) Inclusive proton-to-pion ratio as a function of p_T for two multiplicity classes, $0 < z < 1$ (black lines) and $5 < z < 6$ (red lines); and for different p_T^{jet} intervals. Results are shown for both (a) PYTHIA 8 and (b) EPOS 3.

Results and discussion (using jets reconstruction)

BG-Blast Wave analysis

The blast-wave model describes a locally thermalised medium which experiences a collective expansion with a common velocity field and undergoing an instantaneous common freeze-out

$$\frac{1}{p_{\mathrm{T}}}\frac{\mathrm{d}N}{\mathrm{d}p_{\mathrm{T}}} \propto \int_0^R r\,\mathrm{d}r\,m_{\mathrm{T}} I_0\left(\frac{p_{\mathrm{T}}\sinh\rho}{T_{\mathrm{kin}}}\right) K_1\left(\frac{m_{\mathrm{T}}\cosh\rho}{T_{\mathrm{kin}}}\right) \qquad \rho = \tanh^{-1}\beta_{\mathrm{T}} = \tanh^{-1}\left(\left(\frac{r}{R}\right)^n \beta_{\mathrm{S}}\right)$$

From the simultaneous fit of the blast-wave model to the p_T spectra of different particle species we extract two parameters, the temperature at the kinetic freeze-out, (T_{kin}), and the average transverse expansion velocity (β_T). To fit the pT distributions we use:

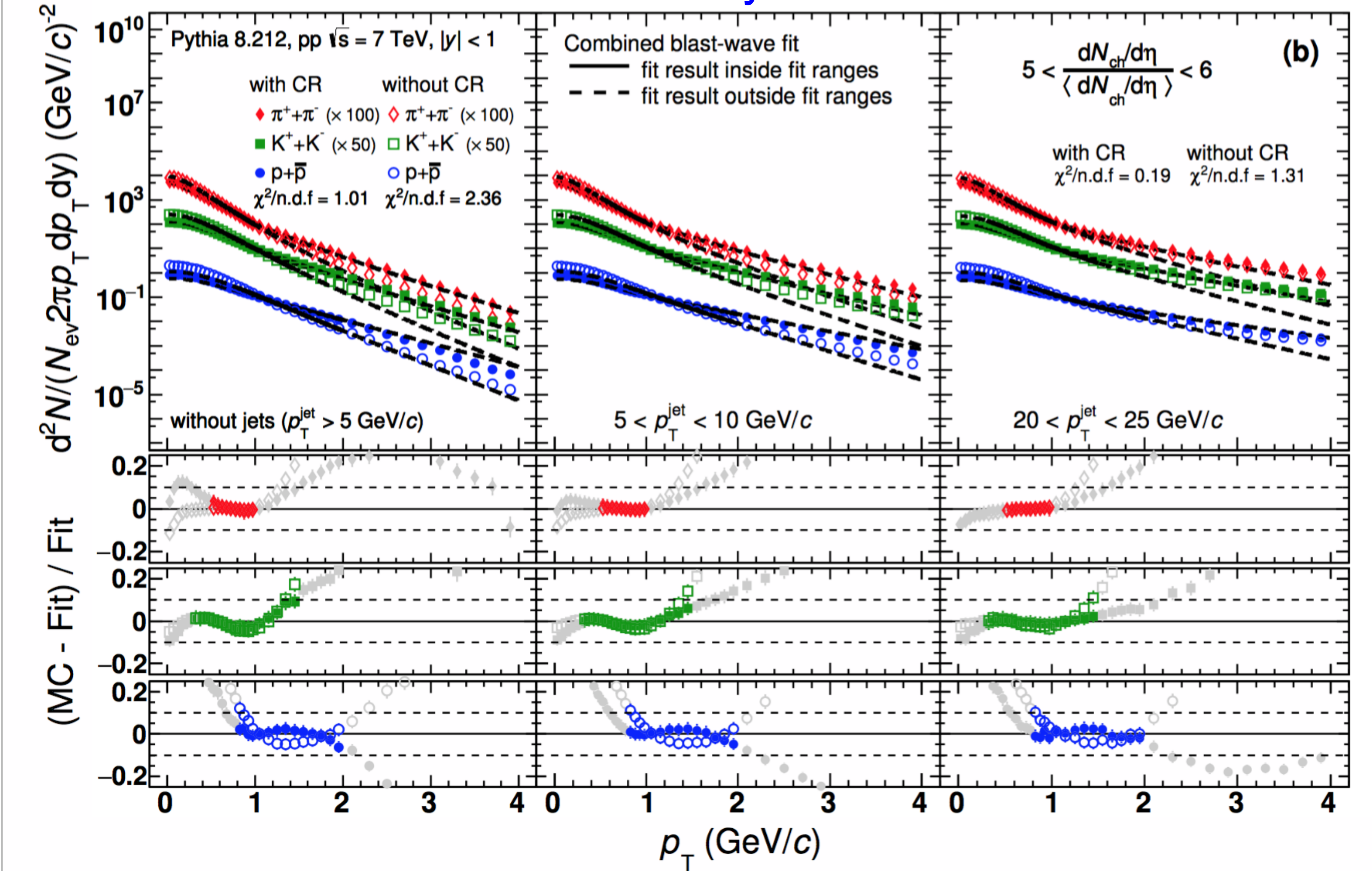
π	K	p
0.5-1.0	0.3-1.5	0.8-2.0

p_T ranges (GeV/c)

For this ranges the spectra is described by the BW fit within 10%

Results and discussion

Blast-wave model fits to invariant yield PYTHIA

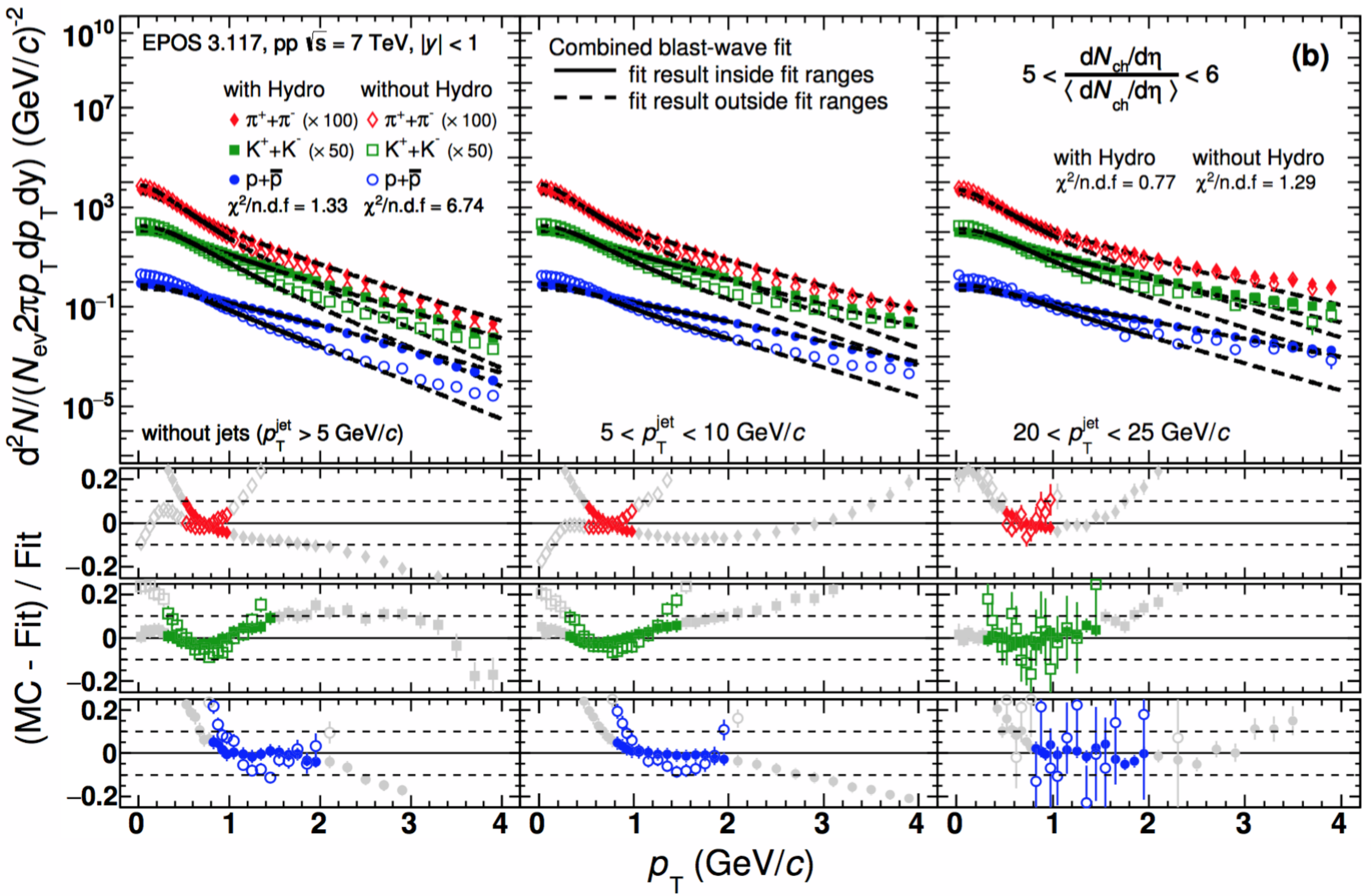


At HM, the BW model fails to describe the p_T spectra when CR is not included,

On the other hand, with CR the agreement between the BW parametrization and the p_T spectra improves with increasing pTjet. This reflects Pythia8 interaction between jets and UE is crucial for generating a collective-like behaviour.

Results and discussion

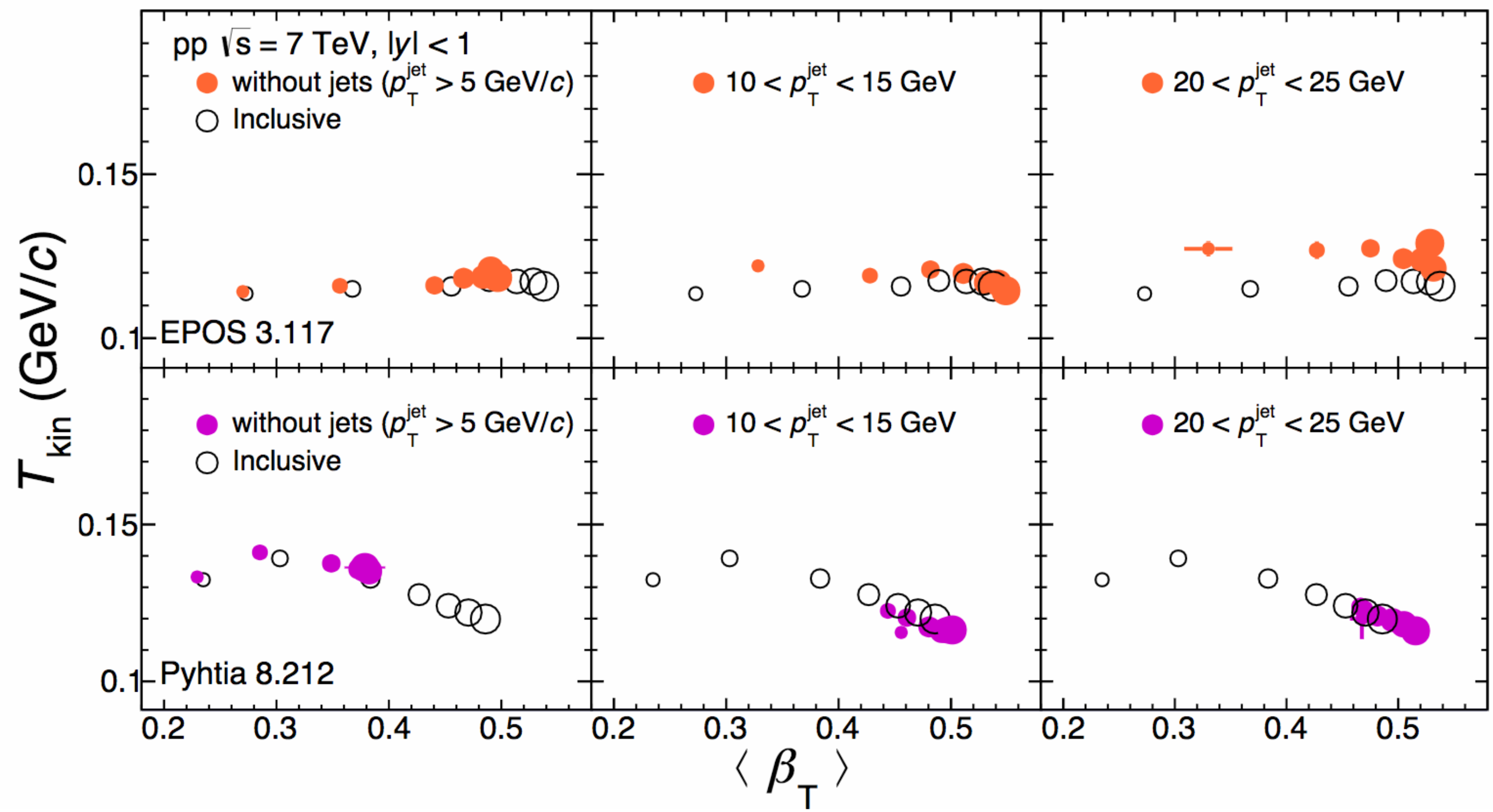
Blast-wave model fits to invariant yield EPOS



At high multiplicity its clear the effect for Hydro and no Hydro in EPOS, although the jet contribution to the radial flow patterns is smaller than in Pythia8.

Results and discussion

Blast-wave model parameters EPOS vs PYTHIA



-For events having jets and being in the same multiplicity $<\beta_T>$ increases with respect to the inclusive case. For jets with 20< pTjet<25 GeV/c and the highest multiplicity class the effect is weaker in Epos3 than in Pythia8.

Conclusions

- We have studied the underlying physics mechanism (hydro and CR) using Epos3 and Pythia8, for the proton to pion ratio and BW analysis

- Proton to pion ratio shows a bump at around 3 GeV, more differential clasification was done using the leading jet transverse momentum, at low multiplicity radial flow patterns arise while hydrodinamics and CR effects are small.

- For HM events particle composition is different in Pythia and EPOS, visible in the proton to pion ratio when the multiplicity vary, EPOS change while Pythia don´t.

- Agreement between the blast-wave and the LF spectra significantly improveswith the increasing of the leading jet $p_{T.,}$ also found at low Nch events suggesting the presence of collective behaviour due by jets

- The multiplicity dependence of the average transverse expansion velocity is found to be more affected by jets in Pythia8 than in Epos3

What is next?

Still working on the data analysis of

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE

CERN

ALICE-ANA-2014-xxx
May 16, 2017

Spherocity analysis for $\langle p_T \rangle$ vs N_{ch} in pp colisions at $\sqrt{s}$= 13 TeV

Héctor Bello Martínez[1,2], Arturo Fernández Téllez[1], Antonio Ortiz Velasquez[2], Guy Paić[2]

… to get another paper
it flows ok then I will show in
Puerto Vallarta XVI MWPF, stay tunning

Thank you for your attention

and thanks to organizers

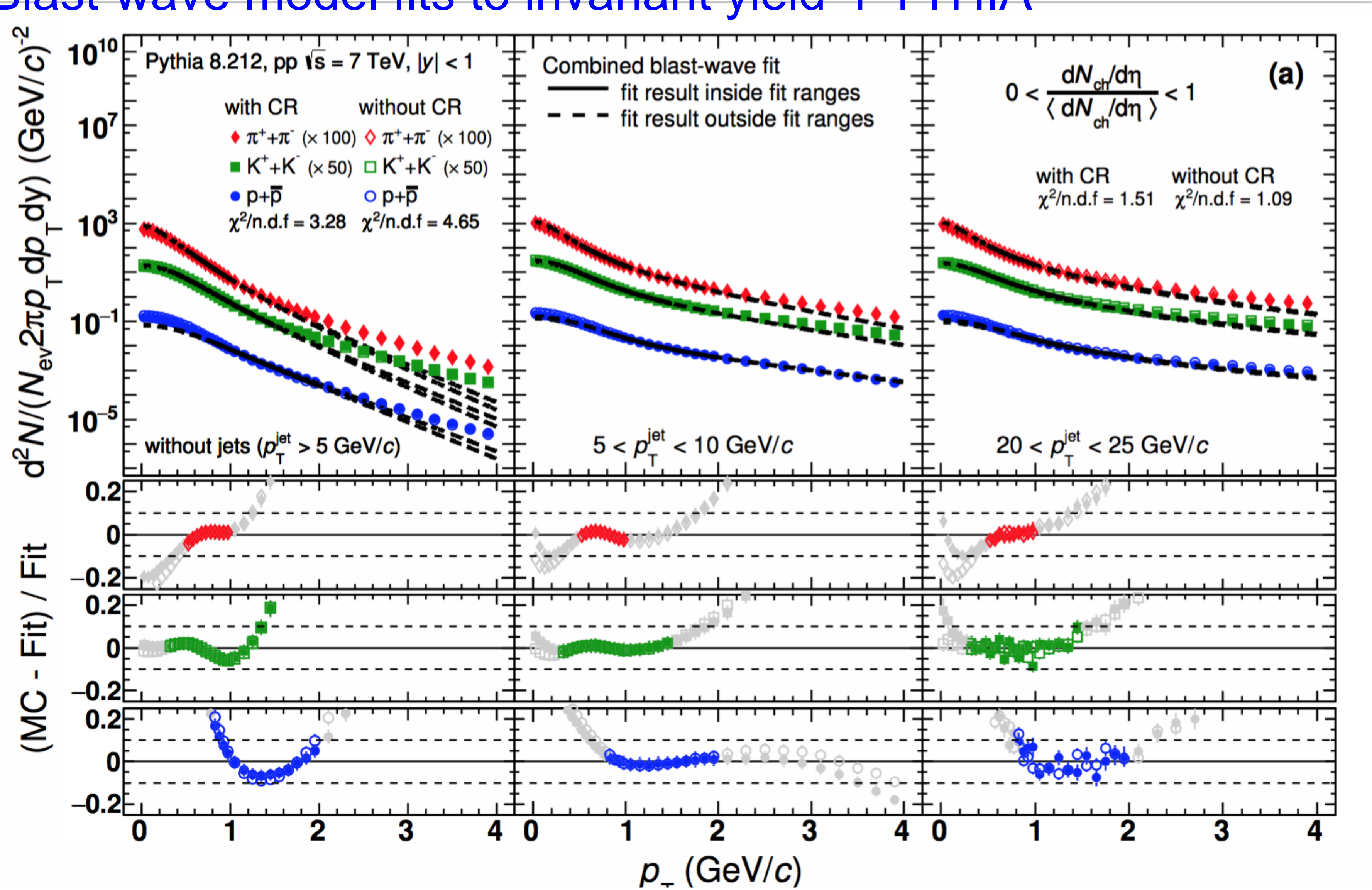
Dr. Roig, Pablo
Dr. Heredia de la Cruz, Ivan
Dr. Fernandez Tellez, Arturo
Dr. De La Cruz Burelo, Eduard
Dr. López Castro, Gabriel

and Cinvestav for the hospitality

backup

Results and discussion

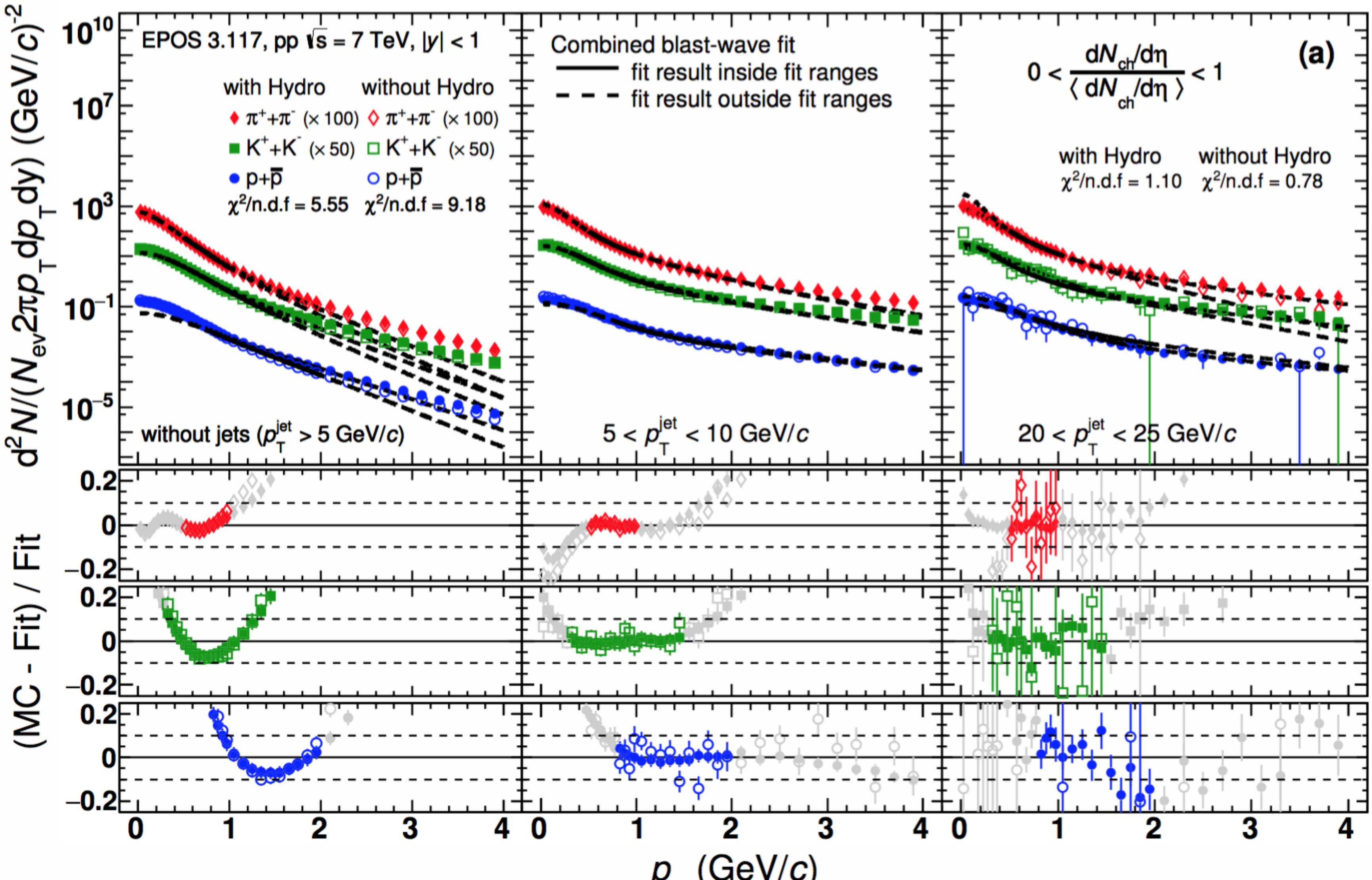
Blast-wave model fits to invariant yield PYTHIA



At low multiplicity where color reconnection effects are negligible, it is possible to find an event class where the radial flow-like patters pop up. Especially, in events having pTjet>5 GeV/c the pT distributions of identified hadrons are better described by the blast-wave model than in those without jets.

Results and discussion

Blast-wave model fits to invariant yield EPOS



At low multiplicity no difference when we impose Hydro and no Hydro in EPOS, though the jet contribution to the radial flow patterns is smaller than in Pythia8.

dN/deta		Beta_T			Tkin			Chi2_miFCN	
binz	ptjet>5	5<ptjet<10	20<ptjet<25	ptjet>5	5<ptjet<10	20<ptjet<25	ptjet>5	5<ptjet<10	20<ptjet<25
0	0.235603	0.458924	0.466984	0.130237	0.117952	0.116517	3.28347	0.0844051	1.50712
1	0.267855	0.405684	0.471974	0.150281	0.130901	0.122964	1.23443	0.211819	0.192153
2	0.3295	0.42466	0.46066	0.148746	0.131665	0.128196	1.08755	0.371459	0.186932
3	0.352988	0.436739	0.47314	0.147962	0.131716	0.126577	1.03196	0.412505	0.220832
4	0.359541	0.441606	0.489634	0.147945	0.132362	0.123212	1.00389	0.413585	0.177859
5	0.364311	0.445365	0.50315	0.146718	0.132845	0.119781	1.01403	0.434367	0.194666
6	0.33475	0.447905	0.509936	0.150597	0.132922	0.120431	0.8561	0.360656	0.243851
7	0.300812	0.452296	0.510851	0.155789	0.132336	0.123777	0.917585	0.390048	0.516841
8	0.606388	0.45846	0.556484	0.0850605	0.129104	0.093683	0.611003	0.713898	0.531304
9	0.680481	0.376818	0.516938	0.0301462	0.126063	0.112439	0.458924	1.26018	1.19458

				NCR					
dN/deta		Beta_T			Tkin			Chi2	
binz	ptjet>5	5<ptjet<10	20<ptjet<25	ptjet>5	5<ptjet<10	20<ptjet<25	ptjet>5	5<ptjet<10	20<ptjet<25
0	0.226345	0.379451	0.473676	0.126855	0.118919	0.106398	4.64743	0.224575	1.08961
1	0.233474	0.29872	0.401718	0.135569	0.131603	0.123453	2.84187	0.581838	0.249739
2	0.230267	0.276472	0.320491	0.138533	0.13477	0.134393	2.62436	1.46475	0.306867
3	0.225967	0.264389	0.299972	0.140717	0.137974	0.135953	2.51269	1.7393	1.03019
4	0.221177	0.25672	0.291328	0.142214	0.14039	0.138698	2.42478	1.77893	1.35173
5	0.215434	0.25176	0.287311	0.143364	0.142208	0.140576	2.35625	1.794	1.3117
6	0.20888	0.249787	0.284437	0.144076	0.143188	0.141798	2.61223	1.732	1.29118
7	0.199028	0.24756	0.282802	0.143745	0.144687	0.143726	1.49569	1.68982	1.56443
8	0.237967	0.246738	0.284919	0.124701	0.145402	0.14233	0.803444	1.85746	1.45582
9	0.104439	0.244971	0.2768	0.3	0.147127	0.147067	0	2.23838	0.819405

				Hydro					
dN/deta		Beta_T			Tkin			Chi2	
binz	ptjet>5	5<ptjet<10	20<ptjet<25	ptjet>5	5<ptjet<10	20<ptjet<25	ptjet>5	5<ptjet<10	20<ptjet<25
0	0.25899	0.421773	0.33	0.122323	0.0999429	0.12596	5.55015	0.169318	1.10106
1	0.317589	0.446456	0.400229	0.134396	0.123279	0.142804	1.42341	0.360365	0.611004
2	0.400424	0.471146	0.443002	0.138082	0.133573	0.147498	1.08763	0.561077	0.620219
3	0.424769	0.480138	0.473513	0.142014	0.138155	0.144622	1.05433	0.694378	0.556179
4	0.438677	0.486788	0.482207	0.144909	0.141056	0.149161	1.14148	0.821225	0.731736
5	0.443575	0.491549	0.505442	0.14873	0.142965	0.140963	1.32596	0.923565	0.767189
6	0.457889	0.491209	0.507069	0.141779	0.145135	0.143377	1.47847	1.0541	0.730442
7	0.449659	0.498149	0.536677	0.130512	0.144498	0.125934	1.50268	1.22357	1.30293
8	0.592093	0.490303	0.555372	0.0432197	0.147059	0.118906	0.921137	1.43058	1.04094
9	0.104439	0.496513	0.603596	0.3	0.139891	0.0907416	0	1.87702	1.35148
				NoHydro					
dN/deta		Beta_T			Tkin			Chi2	
binz	ptjet>5	5<ptjet<10	20<ptjet<25	ptjet>5	5<ptjet<10	20<ptjet<25	ptjet>5	5<ptjet<10	20<ptjet<25
0	0.235603	0.418811	0.466984	0.130237	0.117952	0.116517	3.28347	0.0844051	1.50712
1	0.267855	0.405684	0.471974	0.150281	0.130901	0.122964	1.23443	0.211819	0.192153
2	0.3295	0.42466	0.46066	0.148746	0.131665	0.128196	1.08755	0.371459	0.186932
3	0.352988	0.436739	0.47314	0.147962	0.131716	0.126577	1.03196	0.412505	0.220832
4	0.359541	0.441606	0.489634	0.147945	0.132362	0.123212	1.00389	0.413585	0.177859
5	0.364311	0.445365	0.50315	0.146718	0.132845	0.119781	1.01403	0.434367	0.194666
6	0.33475	0.447905	0.509936	0.150597	0.132922	0.120431	0.8561	0.360656	0.243851
7	0.300812	0.452296	0.510851	0.155789	0.132336	0.123777	0.917585	0.390048	0.516841
8	0.606388	0.45846	0.556484	0.0850605	0.129104	0.093683	0.611003	0.713898	0.531304
9	0.680481	0.376818	0.516938	0.0301462	0.126063	0.112439	0.458924	1.26018	1.19458