Predictions for 5.02A TeV Pb+Pb Collisions from A Multi-Phase Transport Model

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Results are mainly based on
G.L. Ma & ZWL,
A Multi-Phase Transport Model (AMPT) aims to provide a comprehensive kinetic description of essential stages of high energy heavy ion collisions.

A+B

Initial conditions

Parton Interactions

Hadronization

Hadron Cascade

Final particle spectra

Long paper: ZWL, Ko, Li, Zhang and Pal, PRC 72 (2005);
source codes at the ECU website http://myweb.ecu.edu/linz/ampt/
Structure of the String Melting version of AMPT

A+B

Generate parton space-time

Partons freeze out

Hadronization (Quark Coalescence)

Extended ART (hadron cascade)

Final particle spectra

HIJING1.0: minijet partons (hard), excited strings (soft), spectator nucleons

Strings melt to q & qbar via intermediate hadrons

ZPC (elastic parton cascade)

String melting version of AMPT

Generate parton space-time

Partons freeze out

Hadrons freeze out (at a global cut-off time); then strong-decay all remaining resonances

Final particle spectra
One Au+Au event at 200AGeV from String Melting AMPT

60fm-long box

Side view:

Beam axes

Animation is available at the AMPT webpage
One Au+Au event at 200AGeV from String Melting AMPT

at time=5 fm/c
AMPT webpage at http://myweb.ecu.edu/linz/ampt/

AMPT source codes

(updated October 28, 2016):

Each of the following versions contains:
the source codes, an example input file, a Makefile, a readme, a required subdirectory for storing output files, and a script to run the code.

1. ampt-v1.11-v2.11.tgz (11/2004)
2. ampt-v1.21-v2.21.tgz (10/2008)
3. ampt-v1.25t3-v2.25t3.tgz (8/2009)
4. ampt-v1.25t7-v2.25t7.zip (9/2011)
5. ampt-v1.25t7d-v2.25t7d.zip (4/2012)
6. ampt-v1.26t1-v2.26t1.zip (9/2012)
7. ampt-v1.26t4-v2.26t4.zip (8/2014)
8. ampt-v1.26t5-v2.26t5.zip (4/2015)
9. ampt-v1.26t7-v2.26t7.zip (10/2016)

This readme file lists the main changes up to version v1.26t7-v2.26t7 ("t" means a version under test):
String Melting AMPT at 200A GeV and 2.76A TeV: model can reasonably reproduce bulk $\pi$ & K data at low $P_T$

$dN/dy$ of $\pi$ & K:

ZWL, PRC 90 (2014)
String Melting AMPT at 200A GeV and 2.76A TeV

$p_T$-spectra of $\pi$ & K (in central collisions):

ZWL, PRC 90 (2014)
String Melting AMPT at 200A GeV and 2.76A TeV

ZWL, PRC 90 (2014)

Elliptic flow $v_2$ of $\pi$ & $K$ (in mid-central collisions):

We then use the same model parameters for 2.76TeV Pb+Pb collisions to predict 5TeV Pb+Pb collisions:

G.L. Ma & ZWL, PRC 93 (2016)
AMPT predictions for 5TeV Pb+Pb: $dN_{ch}/d\eta$

Although we had these $dN/d\eta$ results before the announcement of the ALICE 5.02 TeV data arXiv:1512.06104, we did not post these before the data. So the 5TeV $dN/d\eta$ results at $\eta \sim 0$ are strictly speaking not predictions. The full $dN/d\eta$ curves are still predictions.


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**Graph Description: AMPT predictions for 5TeV Pb+Pb:**

- **Graph a)** Pb+Pb 2.76TeV
- **Graph b)** Pb+Pb 5.02TeV

**Legend:**
- **ALICE data**
- **AMPT**

**Axes:**
- $\eta$ (eta)
- $dN_{ch}/d\eta$ (dN_ch/deta)

**Centrality:**
- 0-5%
- 20-30%
AMPT predictions for 5TeV Pb+Pb: charged particle flows $v_2, v_3, v_4$

ALICE $v_2$ data at 5.02TeV announced later in arXiv:1602.01119
AMPT predictions for 5TeV Pb+Pb: charged particle $v_2(\eta)$

ALICE $v_2(\eta)$ data at 2.76TeV announced later in arXiv:1605.02035
AMPT predictions for 5TeV Pb+Pb: longitudinal correlations

The initial spatial geometry including the event plane depends on $\eta$ but also has longitudinal correlations.

- Symmetries
  - Pb nucleus=208 nucleons
  - Lorentz contraction projects the nuclear sphere on the transverse plane
  - Elementary collisions deposit energy at the transverse location of the nucleons
  - Thus the initial density profile is typically uniform longitudinally, but with a bumpy transverse profile

Gelis 1110.1544
Boost-invariant hydrodynamics, from Ollitrault, Quark Matter 2015

This longitudinal correlation comes naturally in string melting AMPT, since each wounded nucleon (string) can produce multiple initial partons that have almost the same transverse position but a range of different $\eta$ values.
AMPT predictions for 5TeV Pb+Pb: longitudinal correlations

The initial spatial geometry including the event plane depends on $\eta$ but also has longitudinal correlations.

The azimuthal anisotropies $v_n$ then has correlations over a finite $\eta$ range.

Charged particle

$$r_2(\eta^a, \eta^b)$$

Ma & ZWL, PRC93 (2016)

For results of AMPT (as initial condition) +hydro, see Pang et al. PRC91(2015) & EJPA52 (2016).
Summary

AMPT serves as a comprehensive model for heavy ion collisions:
• Event-by-event from initial condition to final observables
• Can address non-equilibrium dynamics
• Self-consistent chemical and kinetic freeze-out

It is a test-bed of different ideas & can lead to new discoveries:
• Example: the discovery of the triangular flow $v_3$
• Example: $v_2$ & $v_3$ may be dominated by anisotropic escape instead of hydrodynamics flow, due to low/modest opacity

Significant further developments are needed:
• improve dynamical quark coalescence / parton recombination;
• include gluons and inelastic parton reactions;
• high $P_T$ (with radiation energy loss);
• …