Hydro+Cascade: The Standard Picture

Use hydro for QGP and mixed Phase:

Does it reproduce Flow at the SPS?
- Radial?
- Elliptic?

Do Results depend on Tswitch?

- Implement Chemical Freezout in Hydro

Predictions for RHIC
- How do they depend on EOS?
Hydro takes as input an Equation Of State

2 + 1 Bjorken Hydro

Parameters in the code

\[ \frac{dN_{\text{ch}}}{dy} \rightarrow \text{Entropy Density} \]

\[ \frac{dN_{B}}{dy} \rightarrow \text{Baryon Density} \]

\( V_i \) is 0 at \( \tau = 1 \) fm/c and builds up over time.
Radial Flow: Does H2H Work at the SPS?

The graph shows the slope of the T (in GeV) vs. Mass (in GeV) for different particles:

- LH4 EoS
- LH8 EoS
- LH16 EoS
- NA49
- WA97

The legend indicates that the graph reproduces flow systematics.
Radial Flow: Does H2H Work at the SPS?

Favors LH8 or Harder
Implementing Chemical Freezout in Hydro

\[ \partial_{\mu} S^\mu = \partial_{\mu} N_\pi^\mu = \partial_{\mu} N_K^\mu = 0 \]

At Chemical Freezout $n_\pi/s$, $n_K/s$, ... are fixed

$T_{\text{switch}}$

$n_\pi/s$, $n_K/s$, $n_{\Lambda}/s$... are const.

\[ \mu (\text{GeV}) \]

\[ T (\text{GeV}) \]
How does chemical Freezout affect the EOS?

With out $\mu$

$P$ (Gev/fm$^3$)

With $\mu$

$\varepsilon$ (Gev/fm$^3$)

With $\mu$

A factor = 2

With out $\mu$

$\varepsilon$ (Gev/fm$^3$)

T (Gev)
Bulk quantities (slopes, radii, etc...) no longer depend on $T_{\text{switch}}$. 

$T_{\text{slope}}$ (GeV) as a function of $T_{\text{switch}}$ (GeV) for different values of $\mu_\pi$:
- $\mu_\pi = 0$
- $\mu_\pi > 0$

$\tau$ (fm/c) as a function of $T_{\text{switch}}$ (GeV) for different methods:
- Hydro + RQMD
- Hydro Only
- $\mu_\pi = 0$
- $\mu_\pi > 0$
SPS Elliptic Flow

$V_2$ (all pions)

EOSQ $T_i=120$ MeV

Favors LH8 or Softer
Elliptic Quantities STILL Depend on Tswitch

Is this Viscosity?

\[ \mu_\pi = 0 \]

\[ \mu_\pi > 0 \]

\[ T_{\text{switch}} \text{(GeV)} \]

\[ S_2 \text{ (%)} \]

Hydro+RQMD

Hydro Only

\[ \mu_\pi > 0 \]

\[ \mu_\pi = 0 \]

\[ T_{\text{switch}} \text{(GeV)} \]
RHIC Radial Flow predictions

\[ b = 6 \text{ fm} \]

\[ T_{\text{slope}} \text{ (GeV)} \]

- RG EoS
- LH8 EoS
- LH16 EoS
- LH∞
- NA49 Data

\[ p \]

\[ \pi^- \]

SPS

RHIC

\[ dN_{\text{ch}}/dy \]
RHIC Radial Flow predictions

LH8

dN/dy = 220.
dN/dy = 280.
dN/dy = 345
dN/dy = 405

dN/dy = 466

T (GeV)

Mass (GeV)

π^−, K^+, p, φ, Λ, Σ, Ξ, Ω, Ω̅
The curvature is a sign of Flow
Radial Flow, RQMD contribution

LH8 Protons

Hydro + RQMD

Hydro Only
The Difference Between LH8 and Infinity

- LH8 EoS
- LH∞ EoS

Hydro+RQMD
Hydro Only

SPS      RHIC
\( dN_{ch}/dy \)

Time(fm)
R(fm)

SPS      RHIC
\( dN_{ch}/dy \)
Elliptic Flow Predictions for RHIC

$LH8$ EoS
- CERN PbPb
- RHIC AuAu
- STAR Data
- Na49 Data
Elliptic Flow, RQMD contribution

![Graph showing elliptic flow with RQMD contributions for different energies.](image-url)
Elliptic Flow, RQMD contribution
Elliptic Flow, RQMD contribution

$V_2$ (all Charged)

- LH8 EoS
- LH Infinity

$P_T$ (GeV)
EoS Dependence at RHIC

The graph shows the temperature (T) dependence on mass (GeV) for different particles and particle species. The axes are labeled as follows:

- Y-axis: Temperature (T) in (GeV)
- X-axis: Mass (GeV)

The graph includes the following symbols and lines:
- Red dots: RG EOS
- Green line: LH8 EOS
- Blue dotted line: LH16 EOS
- Pink line: LH Infinity

Particles and their masses are indicated as follows:
- $\pi^-$
- $K^+$
- $p$
- $\phi$
- $\Lambda$
- $\Sigma$
- $\bar{\psi}$
- $\Omega$

The graph illustrates the temperature-mass relationship for these particles and particle species, demonstrating the dependence of temperature on mass.
Summary:

Model works at SPS for Elliptic and Radial flow.

Model predicts at RHIC for Elliptic and Radial flow.

Chemical Freezout is essential for a smooth transition to RQMD

Can not separate plasma push from softness (yet)