Quark Gluon Plasma in Laboratory and in the Universe

December 2, 2008, NTU, Taipei

[I] Vacuum Structure and the early Universe in the Lab.
Micro-Bang and Big-Bang
[II] Hadronization of the Quark Universe
[III] Recombination of Quarks into Hadrons
Statistical Hadronization and study of QGP properties
[IV] Chemical potentials in the early Universe
Particle populations in the early Universe

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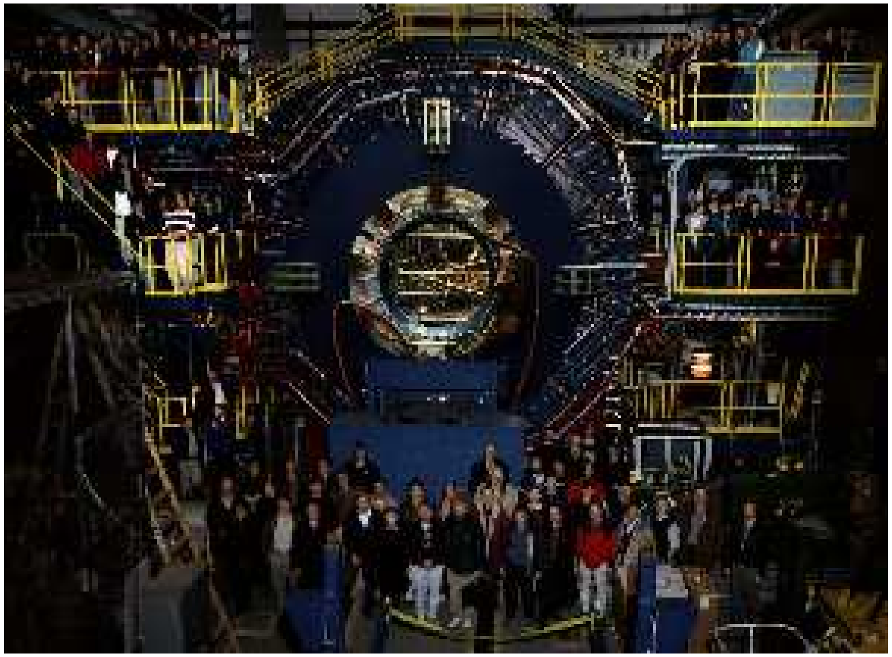
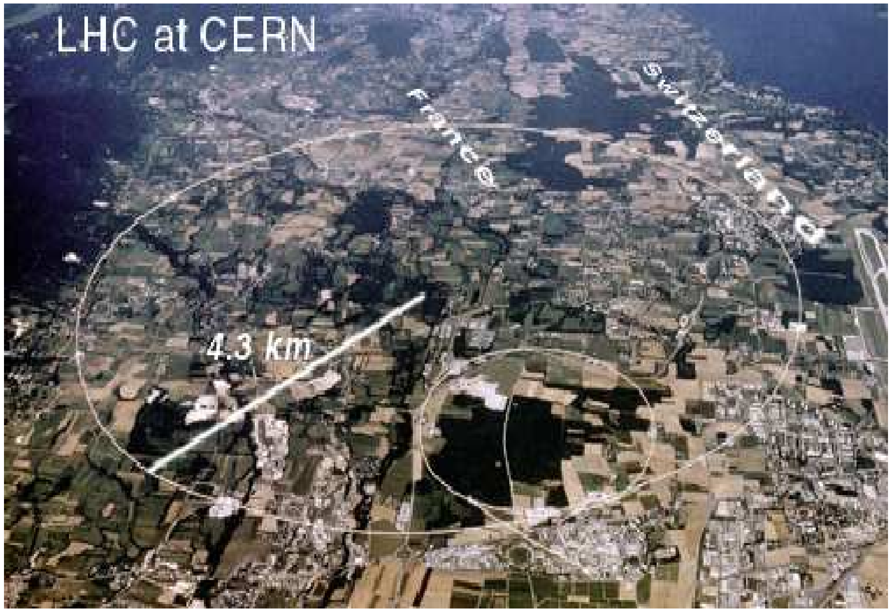
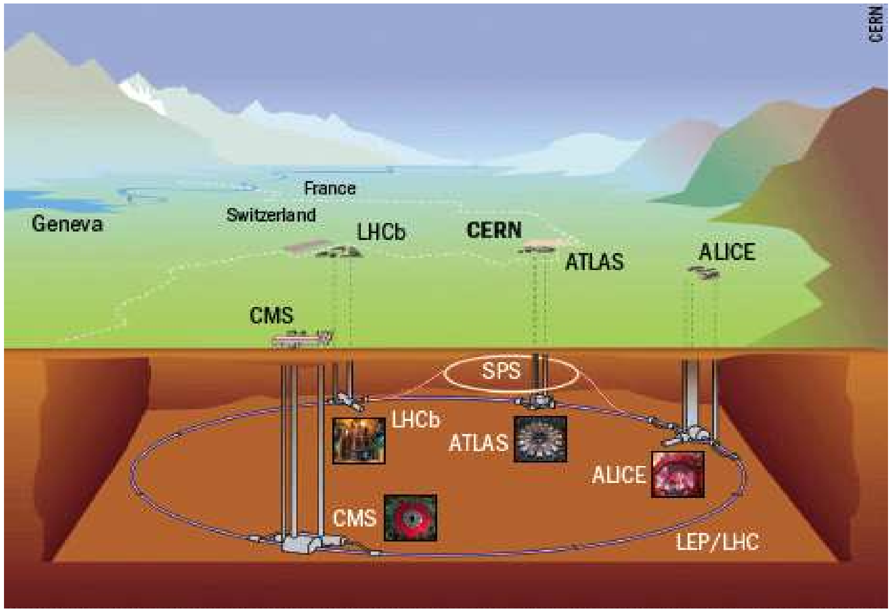
presented by Johann Rafelski

Relativistic heavy ion collisions at BNL-RHIC and (soon) CERN-LHC

Heavy ions: atomic nuclei e.g. Au, Pb
Relativistic: at RHIC $E = 100mc^2$,
and at LHC (see below): $E = 3,500mc^2$
Experimental tools: BIG,
large collaborations
(on right: STAR at RHIC 1999)







ROOTS OF RELATIVISTIC HEAVY ION COLLISION PROGRAM

STRUCTURED VACUUM – ORIGIN OF MASS:

Melt the vacuum structure and demonstrate mobility of quarks – ‘deconfinement’ – vacuum state determines what fundamental laws prevail in nature. The confining vacuum state is the origin of 99.9% of the rest mass present in the Universe.

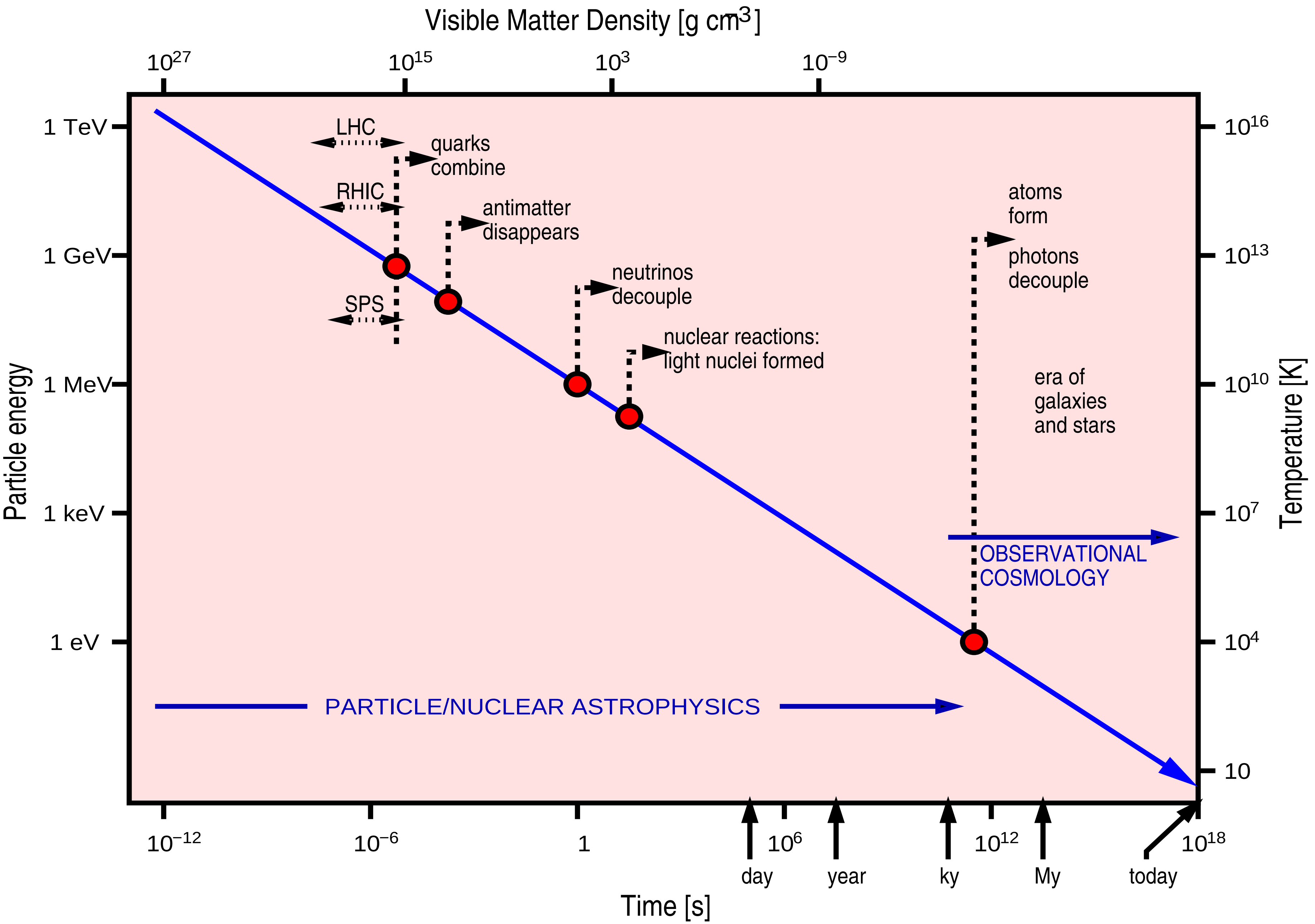
The celebrated Higgs mechanism covers the remaining 0.1% .

RECREATE THE EARLY UNIVERSE IN LABORATORY:

Recreate and understand the high energy density conditions prevailing in the Universe when matter formed from elementary degrees of freedom (quarks, gluons) at about 10-40 μs after big bang.

Hadronization of the Universe led to nearly matter-antimatter symmetric state, the sequel annihilation left the small 10^{-10} matter asymmetry, the world around us.

Stages in the evolution of the Universe



What is deconfinement?

A domain of (space, time) much larger than normal hadron size in which color-charged quarks and gluons are propagating, constrained by external 'frozen vacuum' which abhors color.

We expect a pronounced boundary in temperature and density between confined and deconfined phases of matter: phase diagram. Deconfinement expected at both:

high temperature and at high matter density.

In a finite size system not a singular boundary, a 'transformation'.

THEORY: What knowledge we need

Hot QCD in equilibrium (QGP from QCD-lattice) and out of chemical equilibrium

DECONFINEMENT NOT A 'NEW PARTICLE',

there is no good answer to journalists question:

How many new vacuua have you produced today?

Vacuum structure

Quantum vacuum is polarizable: see atomic vac. pol. level shifts
Quantum structure of gluon-quark fluctuations:
glue and quark condensate evidence from LGT, 'onium sum rules
Permanent fluctuations/structure in 'space devoid of matter':

even though $\langle V|G^a_{\mu\nu}|V\rangle = 0,$ **with** $G^2 \equiv \sum_a G^a_{\mu\nu}G^{\mu\nu}_a = 2\sum_a[\vec{B}_a^{\,2} - \vec{E}_a^{\,2}]\,,$

we have $\langle V|\frac{\alpha_s}{\pi}G^2|V\rangle \simeq (2.3 \pm 0.3)10^{-2}\mathrm{GeV}^4 = [390(12)\,\mathrm{MeV}]^4\,,$

and $\langle V|\bar{u}u + \bar{d}d|V\rangle = -2[225(9)\,\mathrm{MeV}]^3\,.$

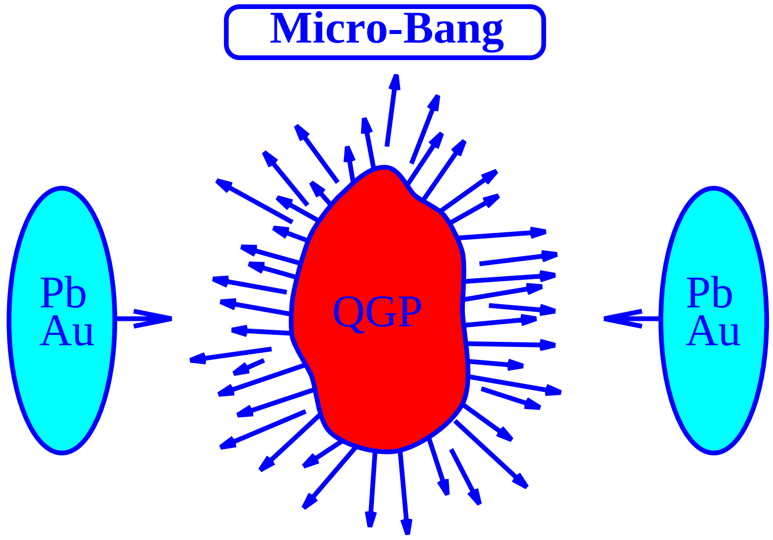
Vacuum and Laws of Physics

Vacuum structure controls early Universe properties
Vacuum determines inertial mass of 'elementary' particles by the way of the Higgs mechanism,

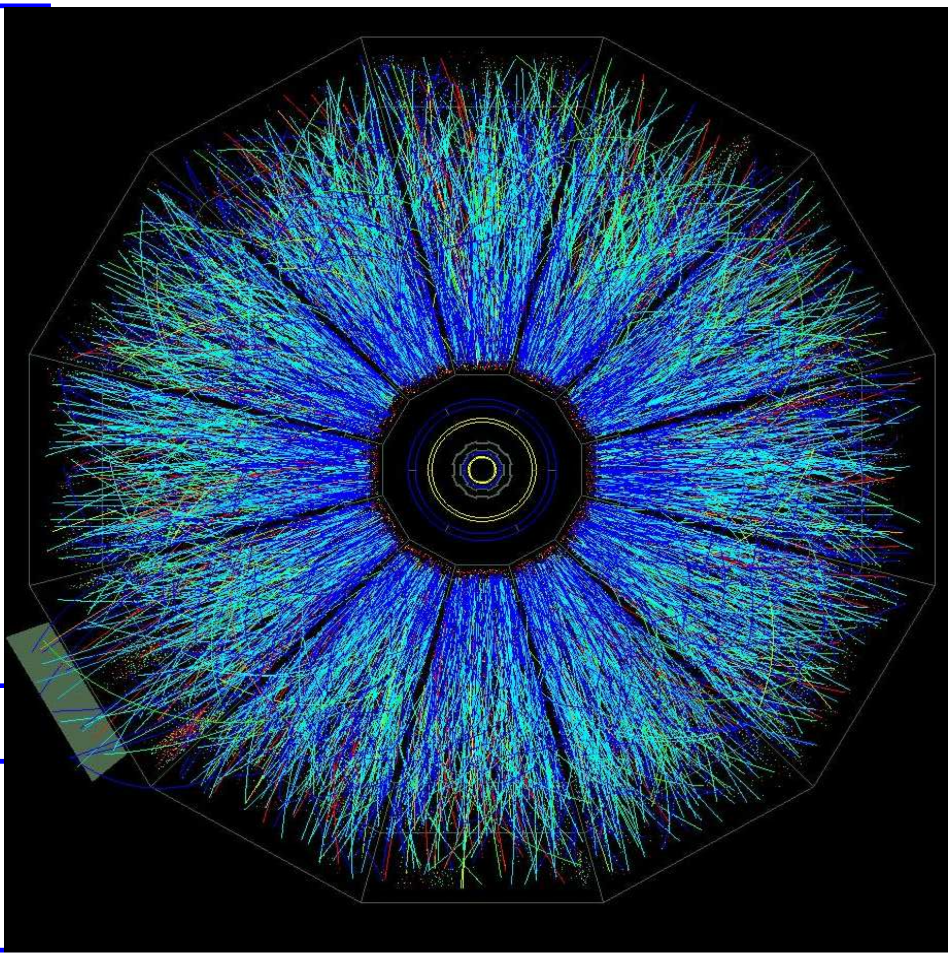
$$m_i = g_i\langle V|h|V\rangle\,,$$

Vacuum is thought to generate color charge confinement:
hadron mass originates in QCD vacuum structure.
Vacuum determines interactions, symmetry breaking, etc.....
DO WE REALLY UNDERSTAND HOW THE VACUUM CONTROLS INERTIA (RESISTANCE TO CHANGE IN VELOCITY)??

RECREATING THE EARLY UNIVERSE IN LABORATORY



Big-Bang	Micro-Bang
$\tau \simeq 10\mu s$	$\tau \simeq 4\ 10^{-23}s$
$N_B / N \simeq 10^{-10}$	$N_B / N \simeq 0.1$



STAR at RHIC

Orders of Magnitude

ENERGY density	ϵ	$\simeq 1\text{–}\mathbf{50GeV/fm^3} = 0.18\text{–}9\ 10^{16}\mathbf{g/cc}$
Latent vacuum heat	B	$\simeq 0.1\text{–}\mathbf{0.4GeV/fm^3} \simeq (166\text{–}234\mathbf{MeV})^4$
PRESSURE	P	$= \frac{1}{3}\epsilon = (0.52 - 26)\ 10^{30}\ \mathbf{barn}$
TEMPERATURE	T_0, T_f	**700–250, 175–145 MeV;** **300MeV≃3.5** 10^{12}**K**

Where is T, μ_b phase boundary

System very fine-tuned. Is there a Phase transition, what if? Latent heat? Will lattice yield answers, are heavy ion experiments ABLE to provide the answer? Another fine-tuning: the "true" vacuum state has about 100 orders of magnitude lower energy density than the deconfined phase.

- **Lattice explores equilibrium conditions, temperature of phase transition depends on available degrees of freedom.**

  For 2+1 flavors: $T = 162 \pm 3 \pm 10$
  For 2 flavors $T \rightarrow 170$ **MeV, the nature of phase transition/transformat**
  changes when number of flavors rises from 2 to 2+1 to 3

- **Nuclear collision explore non-equilibrium, there are two distinct dynamical effects**
  - **Matter expansion, flow effect:**
    colored partons like a wind, displace the boundary
  - **Active degrees of freedom are** $2 + \gamma_s$

Challenge: Discover / Diagnosis and Study of QGP properties at 10^{-23} s scale

- **Deep probes (diletpons and photons)**
- J/Ψ
- **Dynamics of quark matter flow**
- **Jet tomography**
- **Strangeness**
- **Strange Antibaryons**

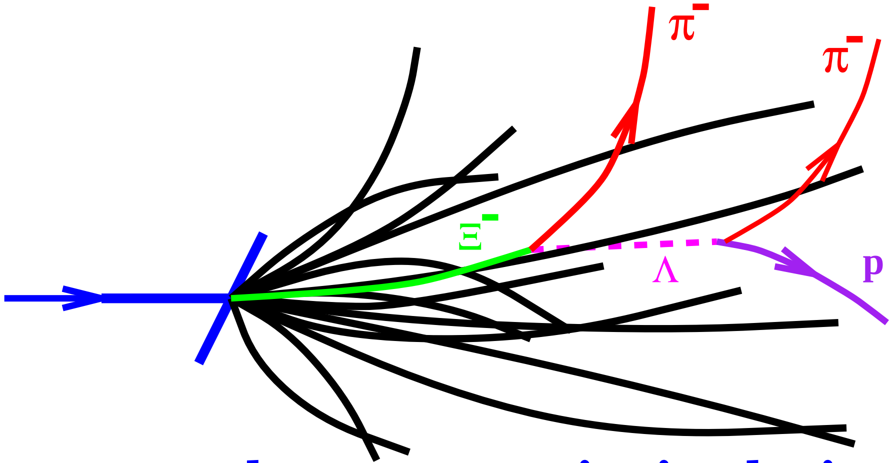
Strangeness: a popular laboratory QGP diagnostic tool

- There are many strange particles allowing to study different physics questions $(q=u,d)$:

$$\phi(s\bar{s}),\quad K(q\bar{s}),\quad \overline{K}(\bar{q}s),\quad \Lambda(qqs),\quad \overline{\Lambda}(\bar{q}\bar{q}\bar{s}),$$

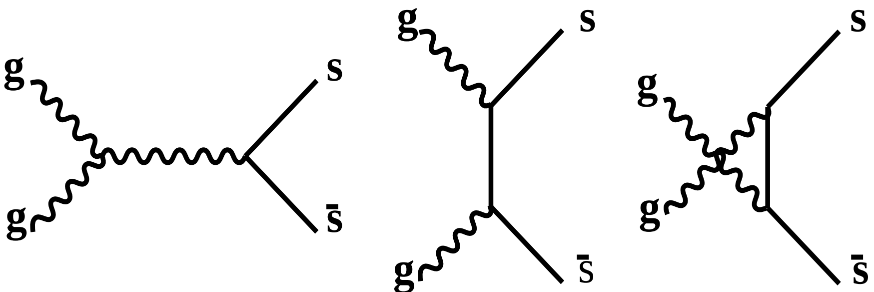
$$\Xi(qss),\quad \overline{\Xi}(\bar{q}\bar{s}\bar{s}),\quad \Omega(sss),\quad \overline{\Omega}(\bar{s}\bar{s}\bar{s})\quad \ldots\textbf{resonances}\ldots$$

- Several strange hadrons subject to a self analyzing decay within a few cm from the point of production



- Production rates hence statistical significance is high

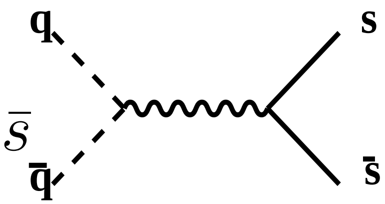
- **production of strangeness in thermal processes in plasma**



dominant processes:
$\langle GG\rangle_T \to s\bar{s}$

strangeness abundance due to 'free' gluons =evidence for plasma

10–15% of total rate: $\langle q\bar{q}\rangle_T \to s\bar{s}$



- **coincidence of scales:**
$\boxed{m_s \simeq T_c} \to \boxed{\tau_s \simeq \tau_{\rm QGP}} \to$
clock for QGP phase
strangeness chemical equilibration in QGP possible

- $\boxed{\bar{s} \simeq \bar{q}} \to$ **strange antibaryon enhancement**
at RHIC (anti)hyperon dominance of (anti)baryons.

QCD Thermal strangeness production/equilibration

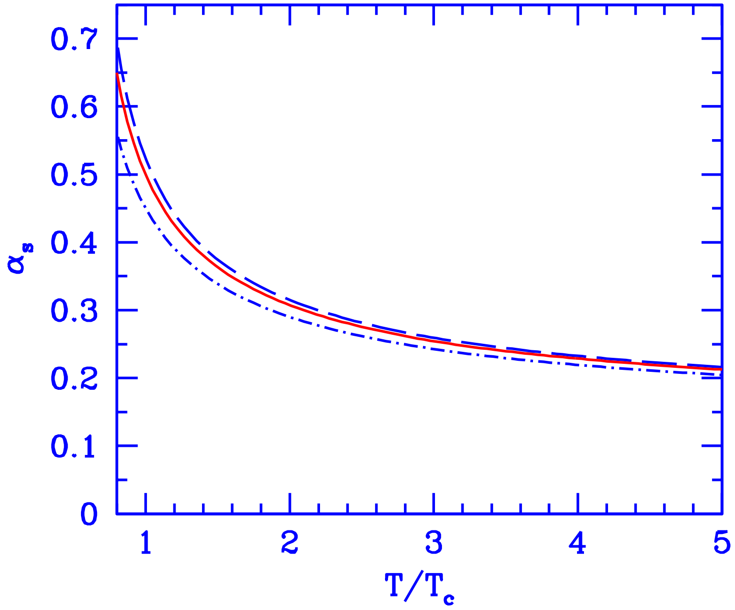
Kinetic (momentum) equilibration is faster than chemical, use thermal particle distributions $f(\vec{p}_1, T)$ to obtain average rate:

$$\langle \sigma v_{\rm rel} \rangle_T \equiv \frac{\int d^3p_1 \int d^3p_2 \sigma_{12} v_{12} f(\vec{p}_1, T) f(\vec{p}_2, T)}{\int d^3p_1 \int d^3p_2 f(\vec{p}_1, T) f(\vec{p}_2, T)} \,.$$

The generic angle averaged cross sections for (heavy) flavor s, $\bar{s}$ production processes $g + g \to s + \bar{s}$ and $q + \bar{q} \to s + \bar{s}$, are:

$$\bar{\sigma}_{gg\to s\bar{s}}(s) = \frac{2\pi\alpha_{\rm s}^2}{3s}\left[\left(1 + \frac{4m_{\rm s}^2}{s} + \frac{m_{\rm s}^4}{s^2}\right)\tanh^{-1}W(s) - \left(\frac{7}{8} + \frac{31m_{\rm s}^2}{8s}\right)W(s)\right] ,$$

$$\bar{\sigma}_{q\bar{q}\to s\bar{s}}(s) = \frac{8\pi\alpha_{\rm s}^2}{27s}\left(1 + \frac{2m_{\rm s}^2}{s}\right)W(s) \,. \qquad W(s) = \sqrt{1 - 4m_{\rm s}^2/s}$$



PARTIAL RESUMMATION

The relatively small experimental value $\alpha_{\rm s}(M_Z) \simeq 0.118$, established in recent years QCD resummation with running $\alpha_{\rm s}$ and $m_{\rm s}$ taken at the energy scale $\mu \equiv \sqrt{s}$. Effective T-dependence:

$$\alpha_s(\mu = 2\pi T) \equiv \alpha_s(T) \simeq \frac{\alpha_s(T_c)}{1 + (0.760 \pm 0.002)\ln(T/T_c)}$$

with $\alpha_s(T_c) = 0.50 \pm 0.04$ and $T_c = 0.16$ GeV.

NOTE: α_s^2 varies by factor 10

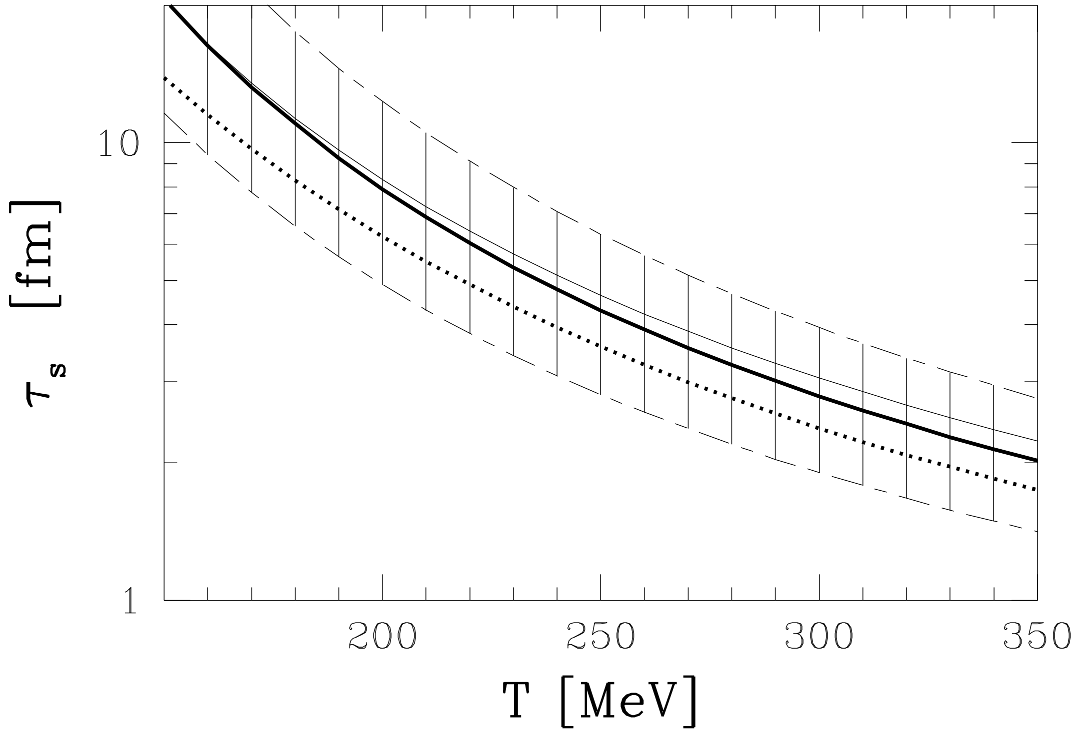
Strangeness relaxation to chemical equilibrium in QGP

Strangeness density time evolution in local rest frame:

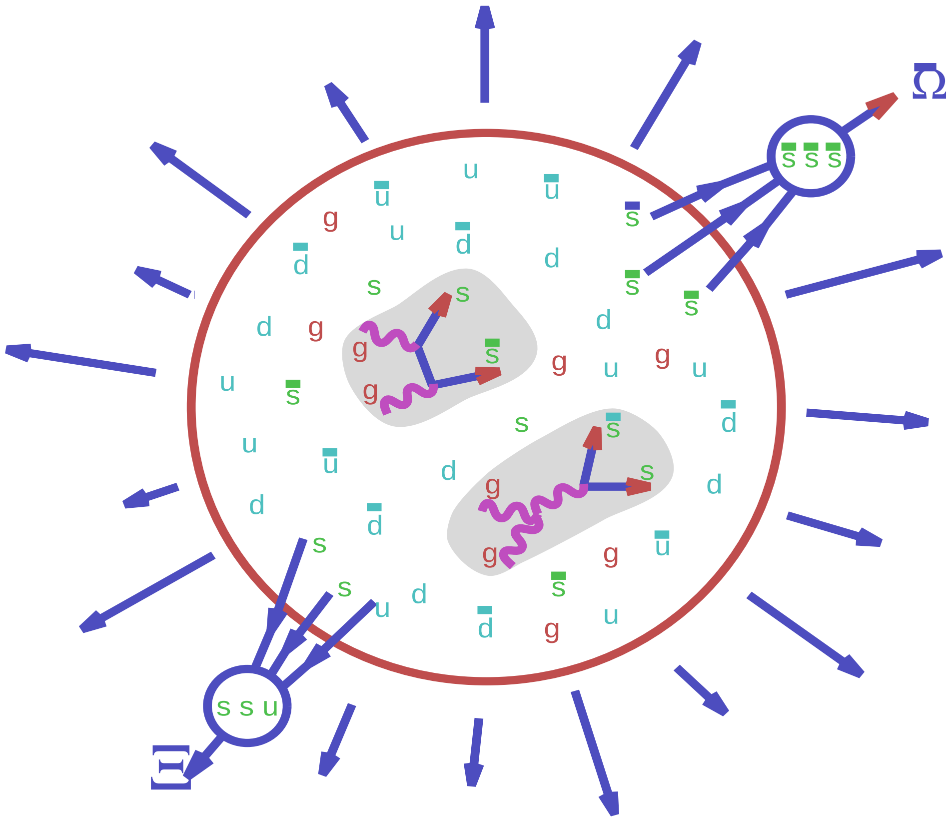
$$\frac{d\rho_s}{d\tau} = \frac{d\rho_{\bar{s}}}{d\tau} = \frac{1}{2}\rho_g^2(t)\,\langle\sigma v\rangle_T^{gg\to s\bar{s}} + \rho_q(t)\rho_{\bar{q}}(t)\langle\sigma v\rangle_T^{q\bar{q}\to s\bar{s}} - \rho_s(t)\,\rho_{\bar{s}}(t)\,\langle\sigma v\rangle_T^{s\bar{s}\to gg,q\bar{q}}$$

Evolution for s and $\bar{s}$ identical, which allows to set $\rho_s(t) = \rho_{\bar{s}}(t)$.
Note invariant production rate A and the characteristic time constant τ_s:

$$A^{12\to 34} \equiv \frac{1}{1+\delta_{1,2}}\gamma_1\gamma_2\rho_1^\infty\rho_2^\infty\langle\sigma_s v_{12}\rangle_T^{12\to 34}\,. \qquad 2\tau_s \equiv \frac{\rho_s(\infty)}{A^{gg\to s\bar{s}}+A^{q\bar{q}\to s\bar{s}}+\dots}$$



NEW HADRON FORMATION MECHANISM FROM QGP



1. $GG \to s\bar{s}$ (thermal gluons collide)

   $GG \to c\bar{c}$ (initial parton collision)

   $GG \to b\bar{b}$ (initial parton collision)

   gluon dominated reactions

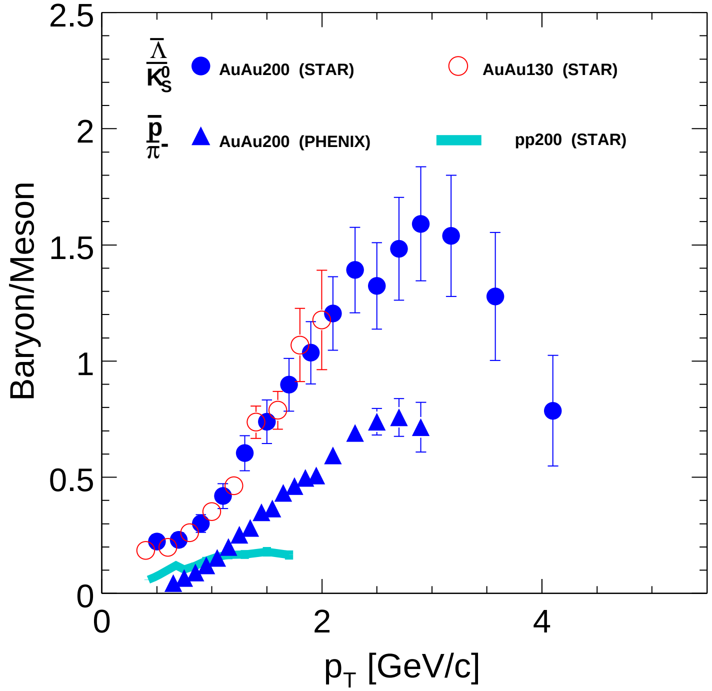
2. **RECOMBINATION of pre-formed**

   $s,\ \bar{s},\ c,\ \bar{c},\ b,\ \bar{b}$ quarks

Formation of complex rarely produced multi flavor (exotic) (anti)particles from QGP enabled by coalescence between $s,\ \bar{s},\ c,\ \bar{c},\ b,\ \bar{b}$ quarks made in different microscopic reactions; this is signature of quark mobility and independent action, thus of deconfinement. Moreover, strangeness enhancement = gluon mobility.

Enhancement of flavored (strange, charm,. . .) antibaryons progressing with 'exotic' flavor content.

A new dominant mechanism of particle formation clearly visible



Baryon to Meson Ratio

Ratios $\overline{\Lambda}/K_S$ and $\bar{p}/\pi$ in Au-Au compared to pp collisions as a function of $p_\perp$. The large ratio at the intermediate $p_\perp$ region: evidence that particle formation (at RHIC) is distinctly different from fragmentation processes for the elementary e^+e^- and pp collisions.

In statistical hadronization: nonequilibrium parameters needed

- γ_q $(\gamma_s, \gamma_c, \ldots)$: u, d $(s, c, \ldots)$ **quark phase space yield, absolute chemical equilibrium:** $\gamma_i \to 1$

$$\frac{\text{baryons}}{\text{mesons}} \propto \frac{\gamma_q^3}{\gamma_q^2} \cdot \left(\frac{\gamma_s}{\gamma_q}\right)^n$$

- γ_s/γ_q **shifts the yield of strange vs non-strange hadrons:**

$$\frac{\overline{\Lambda}(\bar{u}\bar{d}\bar{s})}{\bar{p}(\bar{u}\bar{u}\bar{d})} \propto \frac{\gamma_s}{\gamma_q}, \qquad \frac{\mathrm{K}^+(u\bar{s})}{\pi^+(u\bar{d})} \propto \frac{\gamma_s}{\gamma_q}, \qquad \frac{\phi}{h} \propto \frac{\gamma_s^2}{\gamma_q^2}, \qquad \frac{\Omega(sss)}{\Lambda(sud)} \propto \frac{\gamma_s^2}{\gamma_q^2},$$

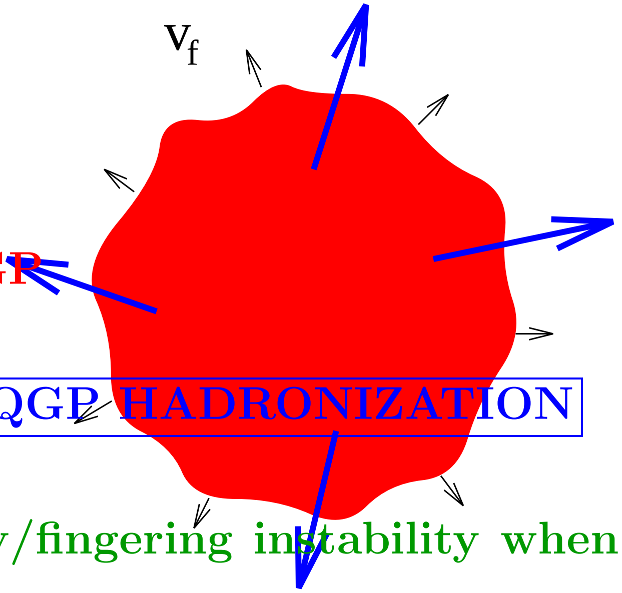
MATTER-ANTIMATTER SYMMETRY (COMPARE TO EARLY UN

Recombination hadronization implies symmetry of $m_\perp$ spectra of (strange) baryons and antibaryons also in baryon rich environment.

THIS IMPLIES: A common matter-antimatter particle formation mechanism, AND negligible antibaryon re-annihilation/re-equilibration/rescattering.

Such a nearly free-streaming particle emission by a quark source into vacuum also required by other observables: e.g. reconstructed yield of hadron resonances and HBT particle correlation analysis

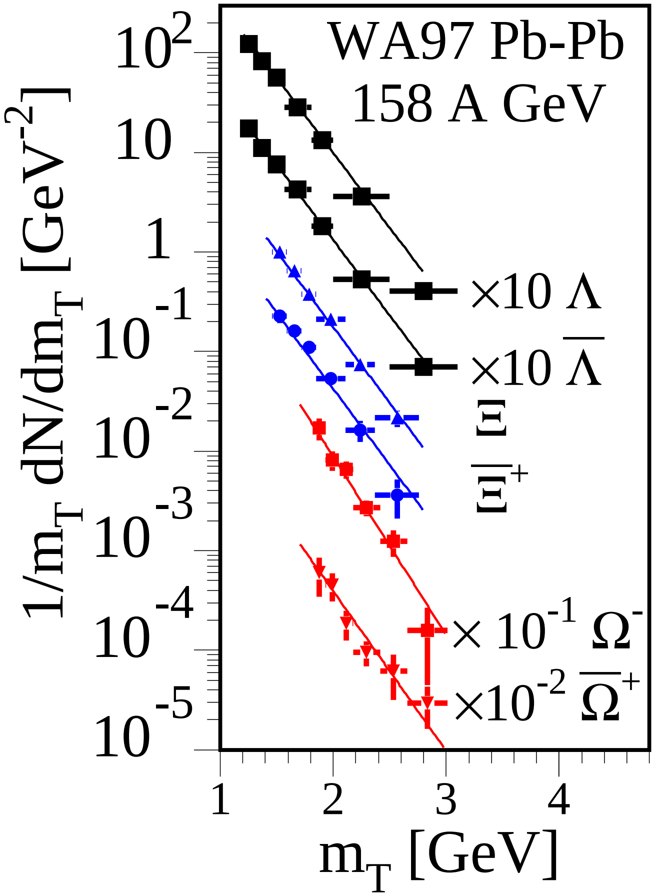
Practically no hadronic 'phase'
No 'mixed phase'
Direct emission of free-streaming
hadrons from exploding filamentary QGP



Develop analysis tools viable in SUDDEN QGP HADRONIZATION

Possible reaction mechanism: filamentary/fingering instability when in expansion the pressure reverses.

WA97	$T_\perp^{\rm Pb}$ [MeV]
$T^{\rm K^0}$	**230 ± 2**
T^{Λ}	**289 ± 3**
$T^{\overline{\Lambda}}$	**287 ± 4**
T^{Ξ}	**286 ± 9**
$T^{\overline{\Xi}}$	**284 ± 17**
$T^{\Omega+\overline{\Omega}}$	**251 ± 19**



Λ within 1% of $\overline{\Lambda}$

Kaon – hyperon difference:

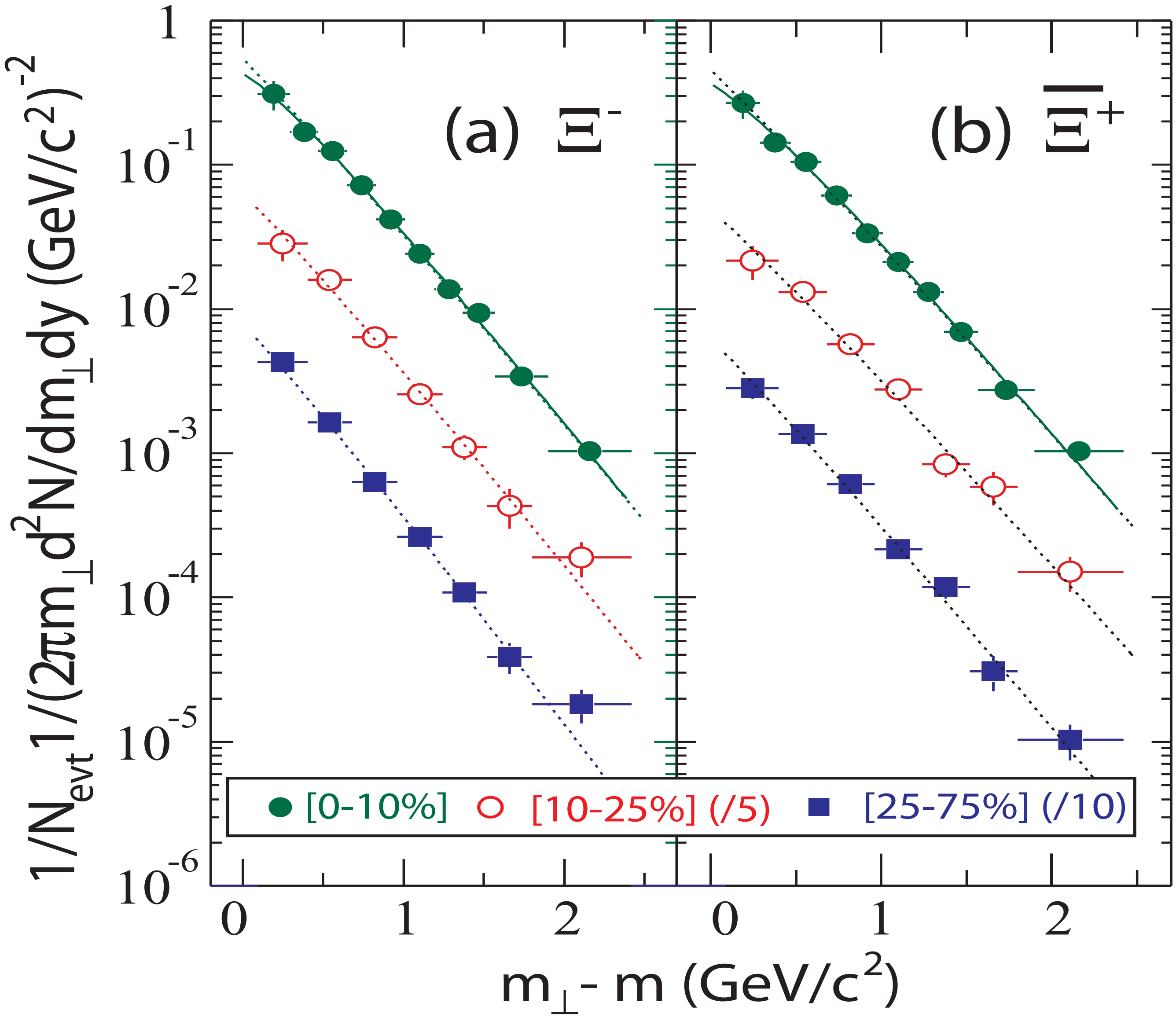
EXPLOSIVE FLOW effect

Difference between $\Omega+\overline{\Omega}$:

presence of an excess of low $p_\perp$ particles

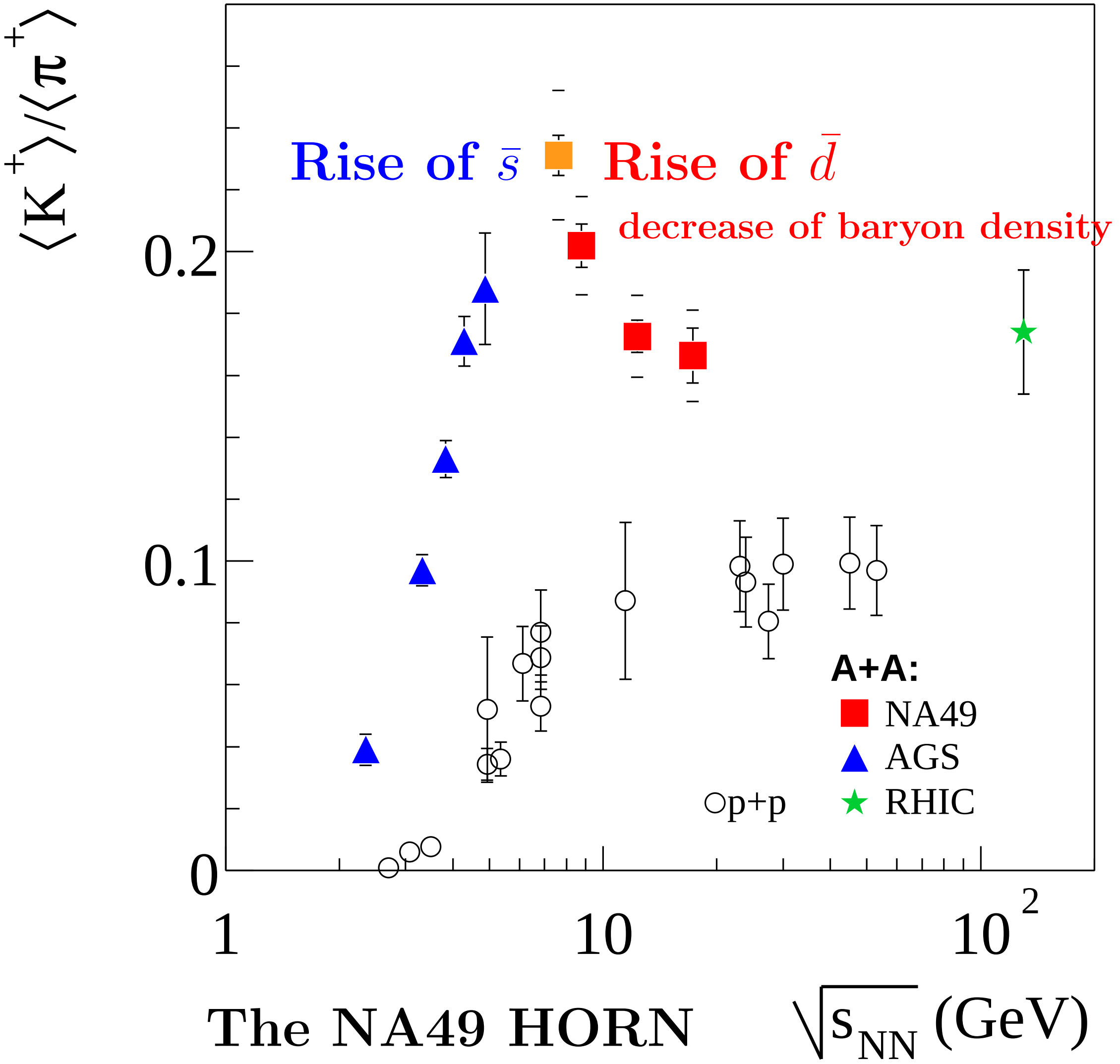
we will return to study this in spectral analysis

$\Xi^-, \overline{\Xi^-}$ Spectra RHIC-STAR 130+130 A GeV



Where is phase boundary as function of energy?

Competition between speed of strangeness production and baryon density (i.e. transparency).

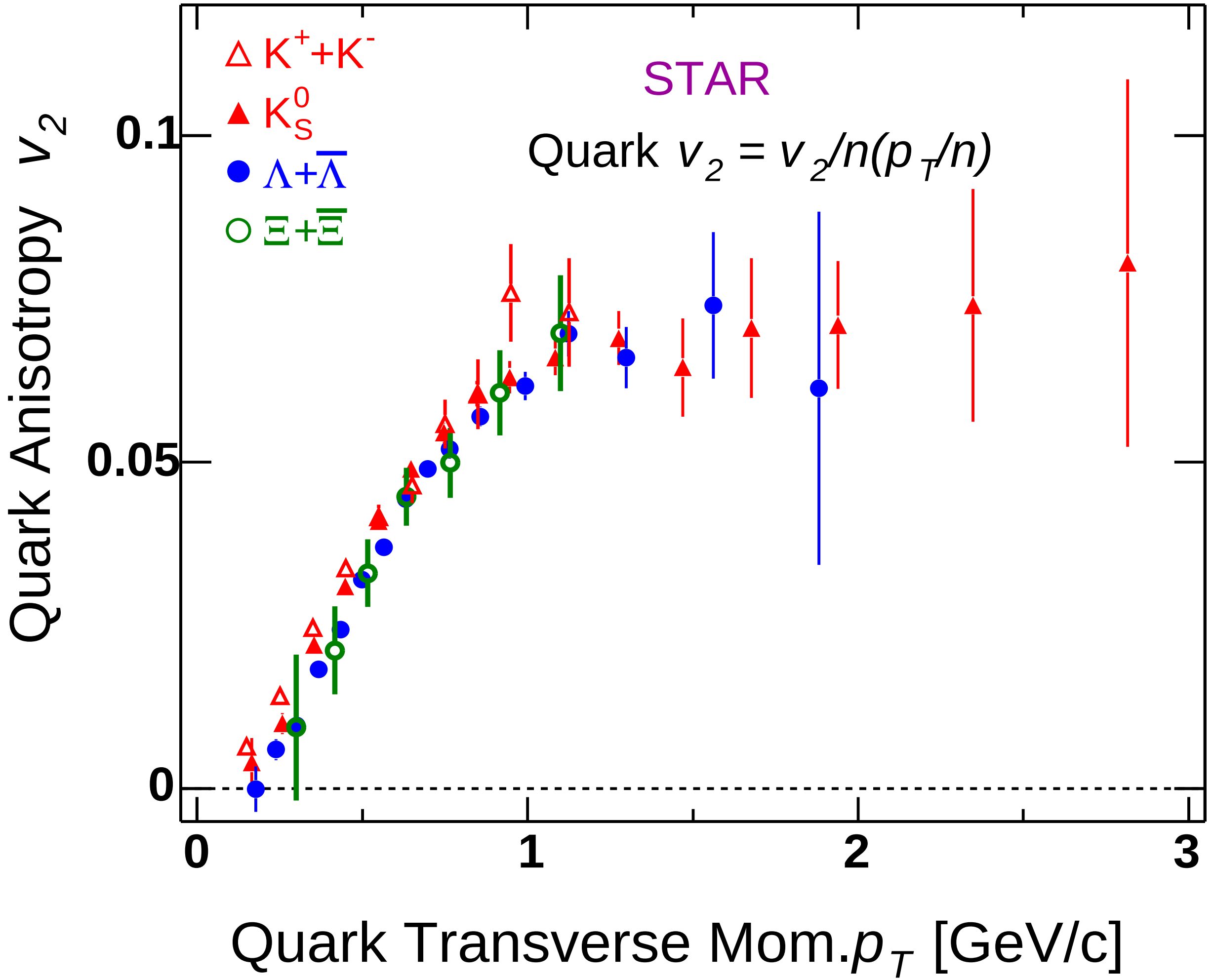


Rise of $\bar{s}$ **Rise of $\bar{d}$**

decrease of baryon density

The NA49 HORN

Discovery of early thermalization: Azimuthal asymmetry



Evidence for common bulk $q, \bar{q}, s, \bar{s}$-partonic matter flow. The absence of gluons at hadronization is consistent with the absence of charge fluctuations, Quark scaling seen at STAR: A superb confirmation that dynamics of the fireball is in thermal partonic degrees of freedom, and quarks hadronize.

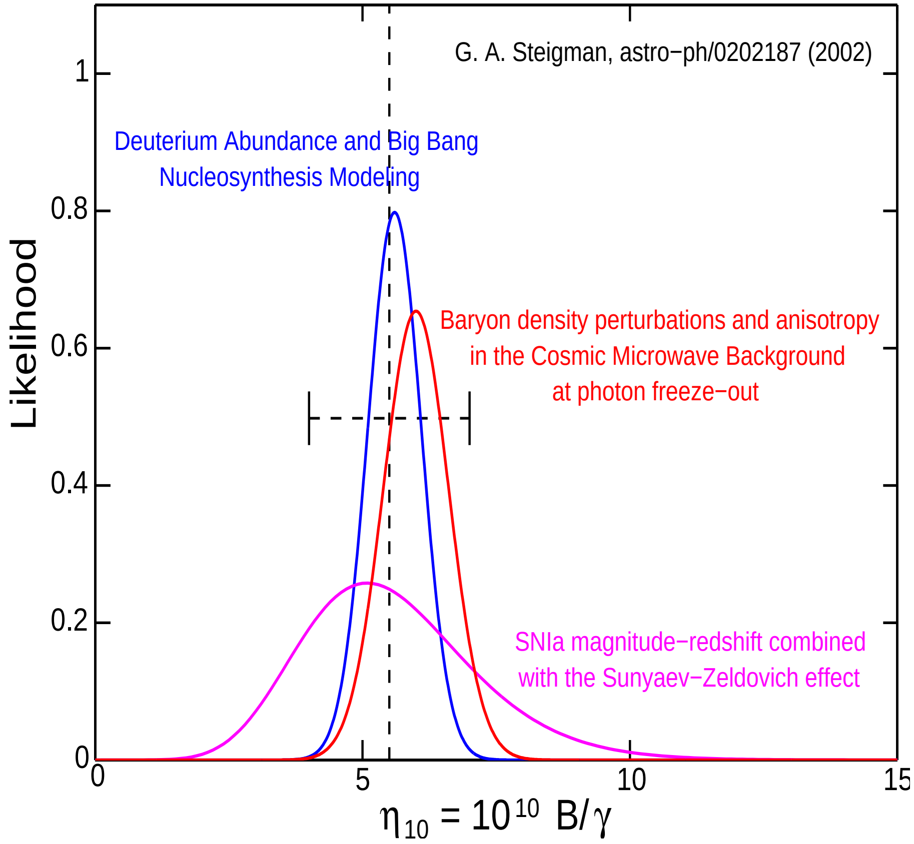
Hadronization of the Quark Universe

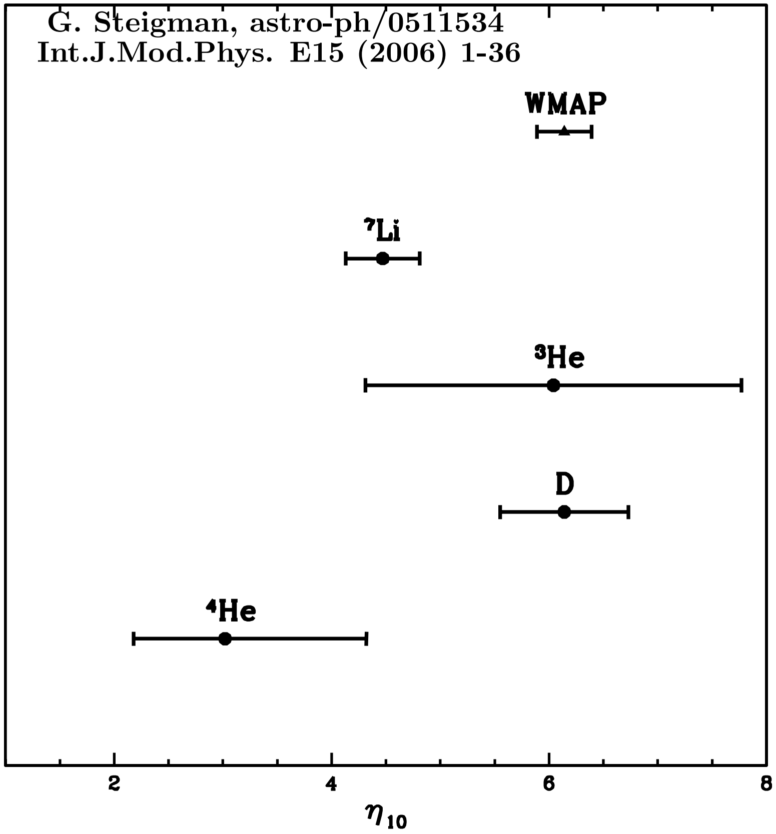
Just about the same as in laboratory (first impression)

Upon QGP hadronization there is initially nearly as much matter as antimatter . In an initially nearly homogeneous Universe this symmetry remains during the ensuing annihilation period till annihilation consumed all but the tiny initial state asymmetry that remains today. This remnant is an INPUT into any analysis, derives from Baryon/Photon ratio (= baryon/entropy).

- **When do antinucleons, strangeness, pions disappear in homogeneous Universe?**
- **What happens to the Universe during matter-antimatter annihilation?**
- **When is pion density equal to baryon density?**

Baryon to photon ratio in the Universe





Deuteron abundance, W-MAP: $\eta_{10} = 6.1 \pm 0.15 \times 10^{-10}$**;**

This yields entropy per baryon:

$$\frac{S}{B-\bar{B}} = \frac{S}{N n_\gamma}\,\frac{N_\gamma}{B-\bar{B}} = \frac{8.0}{\eta} = 1.3 \pm 0.1\, 10^{10}$$

$(S_\gamma + S_\nu + S_i)/n_\gamma$ **is evaluated using stat.mech. and remembering** e^+e^- **reheating of photons.**

Hadronization of the Quark Universe

- **We need to establish chemical conditions in the early Universe (chemical potentials, equilibria);**
- **We need to resolve conflict of Gibbs hadronization conditions with superselection rules such as local charge conservation/neutrality, require mixed phase, separation of phases**

To obtain the evolution of hadron yields: Quantitative Tasks

1)Time scale of Universe hadronization determines which interactions are active.

2) Identify the chemical conservation laws constraining potentials $\mu_i(T)$ and the pertinent conservation laws;

3) Trace out chemical potentials as function of T, (which we can study separately as function of time);

4) Evaluate the composition of the Universe during evolution toward the condition of neutrino decoupling at

$$T \simeq 1\,\mathbf{MeV} \qquad t \simeq 10\,s$$

5) Explore the quark-hadron phase transformation dynamics, and distillation of conserved quantum numbers: baryon, electrical charge (not in this talk, time constraint).

Compare time scales in QGP hadronization

STRONG INTERACTIONS TIME CONSTANT:

Nucleon size / light velocity$\simeq 10^{-23}$**s**

The expanding Universe cools, the hot quark-gluon plasma freezes into individual hadrons. In laboratory we do this suddenly, in the early Universe slowly as seen on time scale of strong interactions.

UNIVERSE HADRONIZATION TIME CONSTANT:

$$\tau_{\rm U} = \sqrt{\frac{3c^2}{32\pi G\mathcal{B}}} = 36\,\mu\mathrm{s}\ \sqrt{\frac{\mathcal{B}_0}{\mathcal{B}}}, \qquad \mathcal{B}_0 \simeq 0.19\,\frac{\mathbf{GeV}}{\mathbf{fm}^3}$$

Here, $4\mathcal{B}$ **is energy density inside particles like protons, and is the amount of energy required per unit of volume to deconfined quarks.**

IN THE EARLY UNIVERSE aside of strong also EM and WEAK reactions relax towards equilibrium. Many additional (compared to heavy ion reactions) active degrees of freedom.

CHEMICAL POTENTIALS IN THE UNIVERSE

The slow hadronization of the Universe implies hadronic chemical equilibrium and full participation of electromagnetically interacting photon and lepton degrees of freedom.

- **Photons in chemical equilibrium, Planck distribution, zero photon chemical potential; i.e.:** $\mu_\gamma = 0$
- **reactions such as $f + \bar{f} \rightleftharpoons 2\gamma$ are in equilibrium, (here f and $\bar{f}$ are a fermion – anti-fermion pair), hence:** $\mu_f = -\mu_{\bar{f}}$
- **Minimization of the Gibbs free energy implies that chemical equilibrium arises for the condition:** $\nu_i \mu_i = 0$
  for any reaction $\nu_i A_i = 0$, where ν_i are the reaction equation coefficients of the chemical species A_i;
- **Example: weak interaction reactions lead to:** $\mu_s = \mu_d = \mu_u + \Delta\mu_l$
  $\mu_e - \mu_{\nu_e} = \mu_\mu - \mu_{\nu_\mu} = \mu_\tau - \mu_{\nu_\tau} \equiv \Delta\mu_l$
- **For the "large mixing angle" solution the neutrino oscillations $\nu_e \rightleftharpoons \nu_\mu \rightleftharpoons \nu_\tau$ imply that:** $\mu_{\nu_e} = \mu_{\nu_\mu} = \mu_{\nu_\tau} \equiv \mu_\nu$
  neutrino mixing may be accelerated in 'dense' matter.

Physical observables and chemical conditions

The three chemical potentials not constrained by chemical reactions are obtained from three physical constraints:

i. *Local electrical charge neutrality* **($Q = 0$):**

$$n_Q \equiv \sum_i Q_i\, n_i(\mu_i, T) = 0,$$

where Q_i and n_i are the charge and number density of species i.

ii. *Net lepton number equals net baryon number* **($L = B$):**

$$n_L - n_B \equiv \sum_i (L_i - B_i)\, n_i(\mu_i, T) = 0,$$

(standard condition in baryo-genesis models, generalization to finite $B - L$ easily possible)

iii. Universe evolves adiabatically i.e. at *constant in time entropy-per-baryon S/B*

$$\frac{\sigma}{n_B} \equiv \frac{\sum_i \sigma_i(\mu_i, T)}{\sum_i B_i\, n_i(\mu_i, T)} = 1.3 \pm 0.1 \times 10^{10}$$

THE (EARLY) UNIVERSE: PROCEDURE:

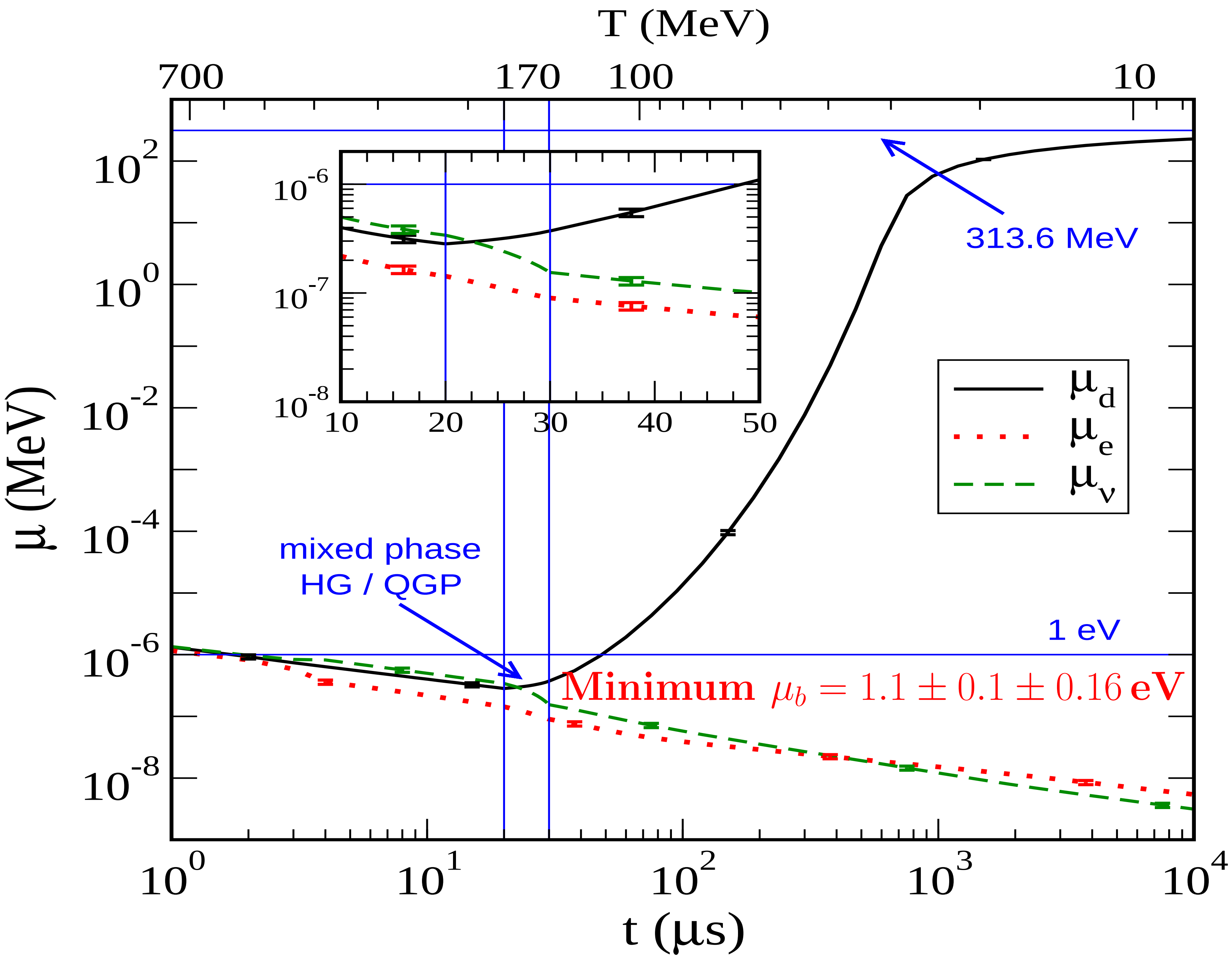
There are three chemical potentials which are 'free' and we choose to follow: μ_d, μ_e, and μ_ν.
(we need physical observables to fix these values)

Quark chemical potentials are convenient to characterize the particle abundances in the hadron phase, e.g. $\Sigma^0\,(uds)$ has chemical potential $\mu_{\Sigma^0} = \mu_u + \mu_d + \mu_s$

The baryochemical potential is:

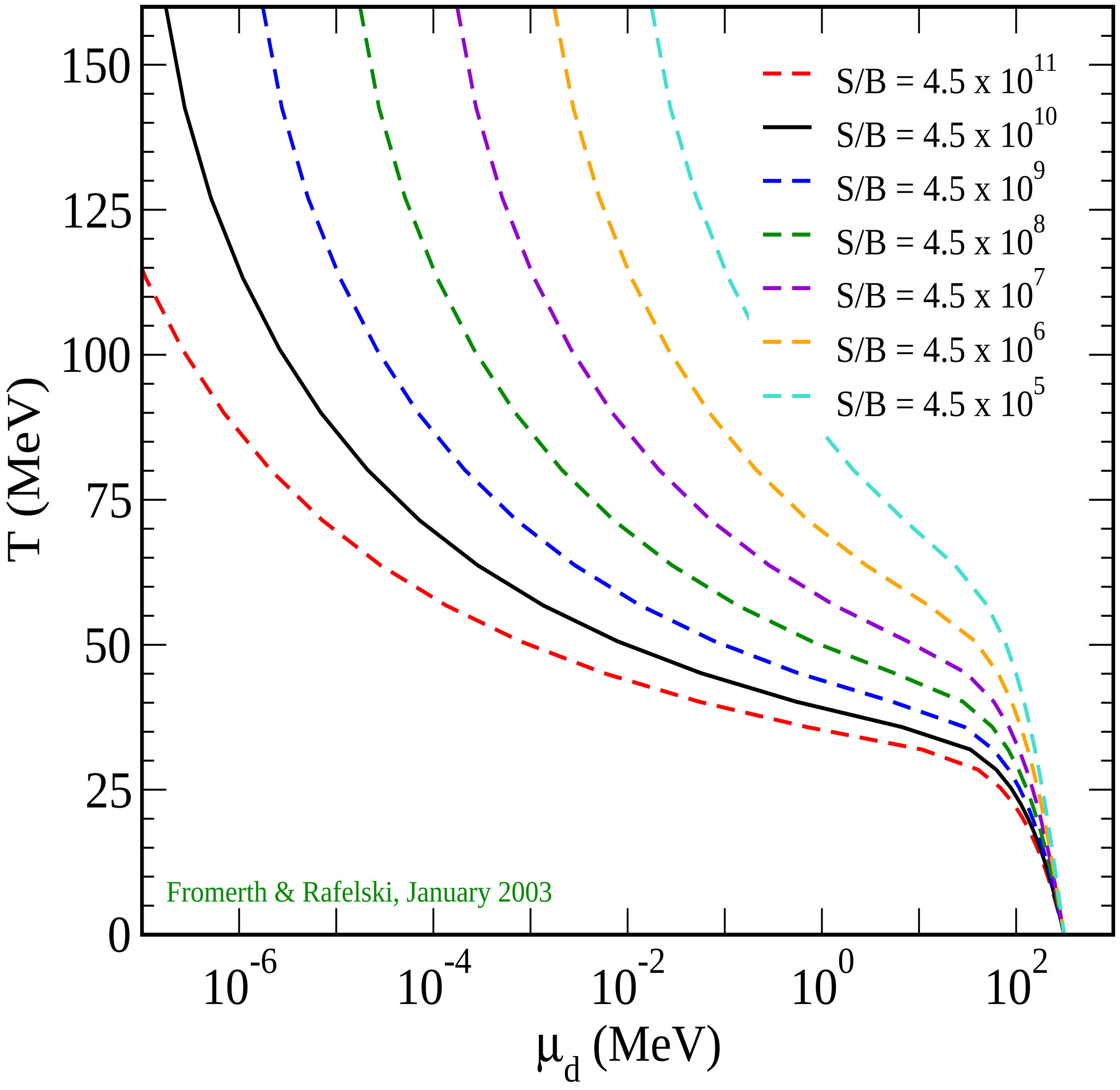
$$\mu_b \equiv \frac{\mu_P + \mu_N}{2} = 3\,\frac{\mu_d + \mu_u}{2} = 3\mu_d - \frac{3}{2}\Delta\mu_l = 3\mu_d - \frac{3}{2}(\mu_e - \mu_\nu).$$

TRACING μ_d IN THE UNIVERSE

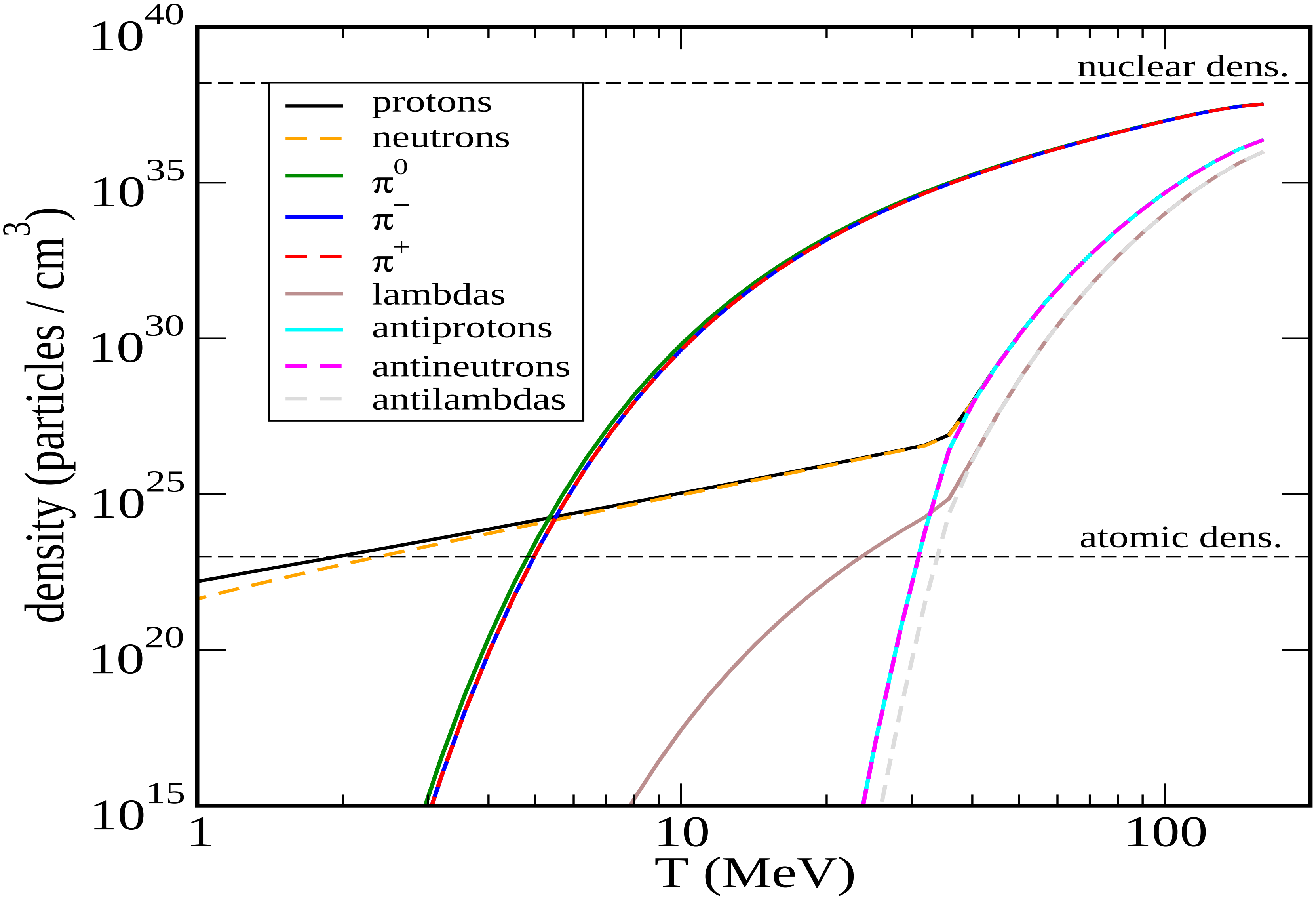


Minimum $\mu_b = 1.1 \pm 0.1 \pm 0.16\,$**eV**

TRACING μ_d IN A UNIVERSE: different presentation

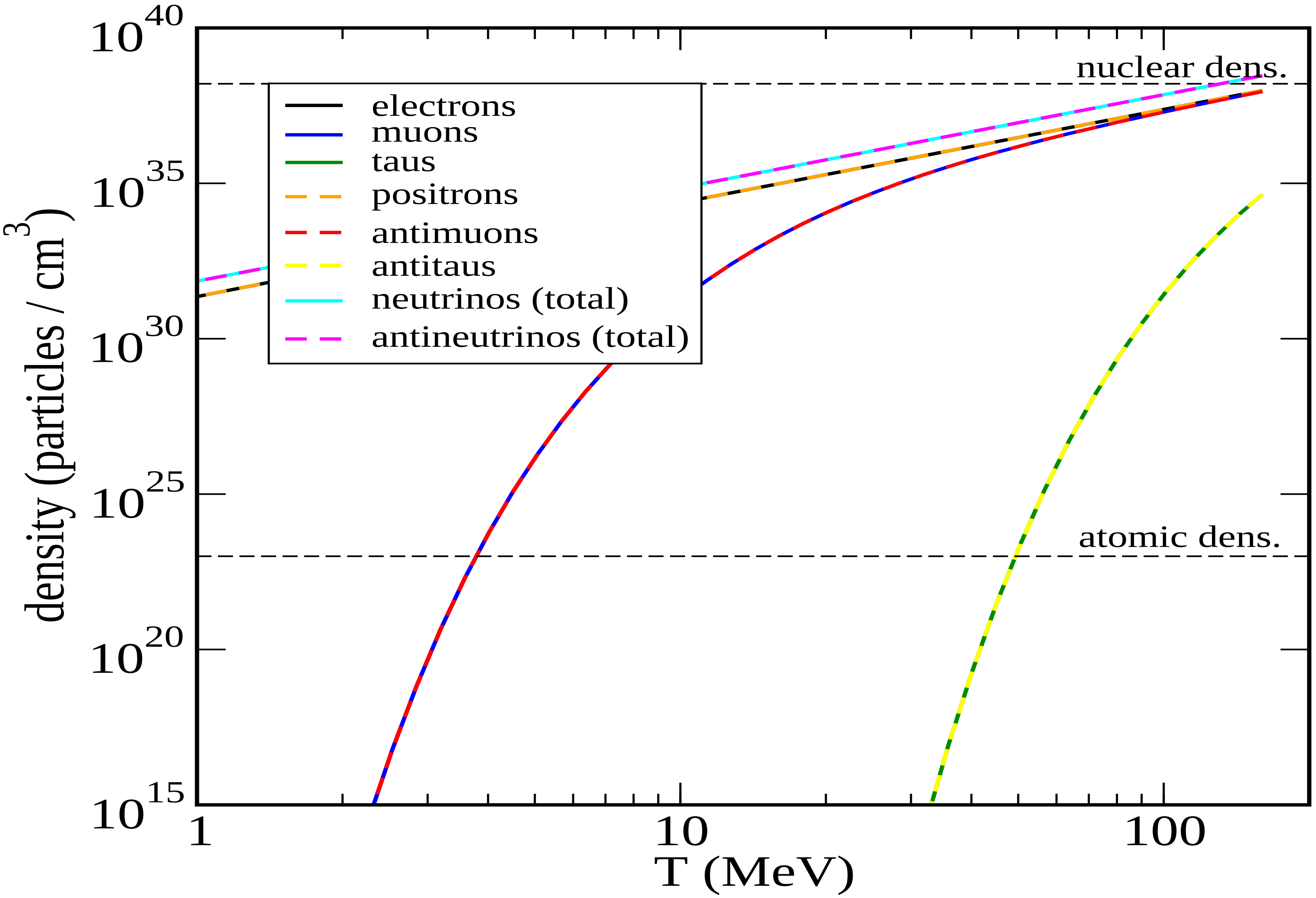


Hadronic Particle Densities



Note the baryon freeze-out at $T \simeq 37$ MeV and that pion density remains at baryon density down to $T \simeq 4.5$ MeV

Lepton Densities



Distillation Process–Separation of Phases

Strangeness distillation mechanism proposed for QGP hadronization. In HI collisions no time to distill, applicable in early Universe to electrical charge, baryon number etc. distillation. Mixed phase partition function for the SLOW phase transformation period:

$$\ln Z_{\rm tot} = \frac{V_{\rm HG}}{V_{\rm tot}} \ln Z_{\rm HG} + \frac{V_{\rm QGP}}{V_{\rm tot}} \ln Z_{\rm QGP} \qquad V_{\rm tot} = V_{\rm HG} + V_{\rm QGP}$$

At QGP hadronization there is in general unequal conserved quantum number density in QGP and in hadron gas (HG) phases.

The constraints are accordingly, e.g. for electrical charge:

$$Q = 0 = n_Q^{\rm QGP}\, V_{\rm QGP} + n_Q^{\rm HG}\, V_{\rm HG} = V_{\rm tot}\left[(1 - f_{\rm HG})\, n_Q^{\rm QGP} + f_{\rm HG}\, n_Q^{\rm HG}\right]$$

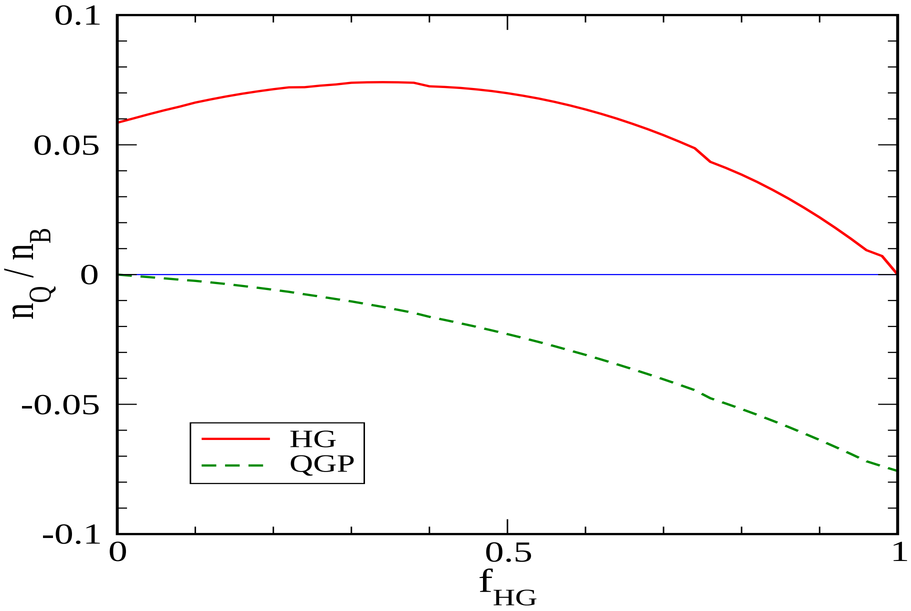
$f_{\rm HG} \equiv V_{\rm HG}/V_{\rm tot}$ **is the fraction of space belonging to HG phase.**

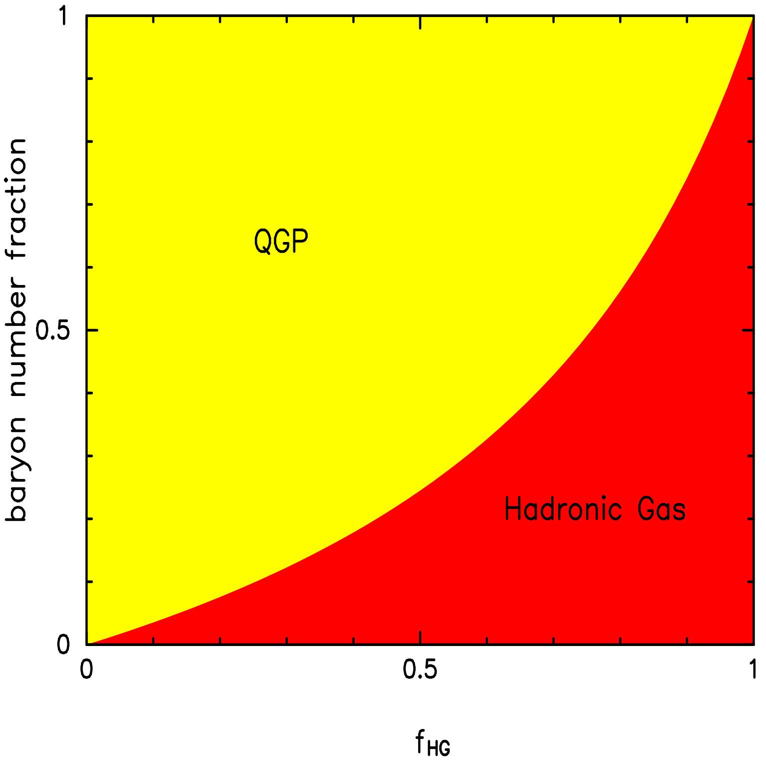
Note: Mixed phase lasts $\simeq 10\,\mu s$ **(25% of prior lifespan), we had assumed that** $f_{\rm HG}$ **changes linearly in time. Actual values will require dynamic nucleation and transport theory description of the phase transformation.**

Charge (and baryon number) asymmetry distillation

Initially at $f_{\mathrm{HG}} = 0$ all matter in QGP phase, as hadronization progresses with $f_{\mathrm{HG}} \to 1$ the baryon component in hadronic gas reaches 100%.

The constraint to a charge neutral universe conserves the SUM of charges in both fractions. Charge in each fraction can be and is non-zero.





Even a small charge separation between phases introduces a finite non-zero local Coulomb potential and this amplifies any existent baryon asymmetry (protons vs antiprotons).

SUMMARY–EARLY UNIVERSE

There is a lot left to do.

Nonequilibrium effects for $1 < T < 45$ MeV: kinetic reaction method to describe evolution, statistical densities no reliable.

Separation of phases leads to inhomogeneous Universe, how is this erased, and or not, signatures?

Influence and participation of dark matter.

QGP Study Summary

- **Strangeness experimental results fulfill all our expectations: clear production anomalies following pattern predicted for QGP**
- **Analysis of strangeness and hadron energy excitation functions and centrality dependence is now available. Behavior agrees with kinetic models of QCD thermal strangeness production**
- **QCD based kinetic evaluation of the two QGP global observables γ_s and s/S agrees with experiment. CHEMICAL equilibration of the QGP at RHIC;**
- **QCD kinetic model tuned to describe strangeness at RHIC, predicts further increase of specific enhancement at LHC.**
- **Strangeness equilibration can impact phase boundary and transition properties since QCD matter with 2+1 flavors exceptionally fine tuned.**