Stopping and the K/π horn

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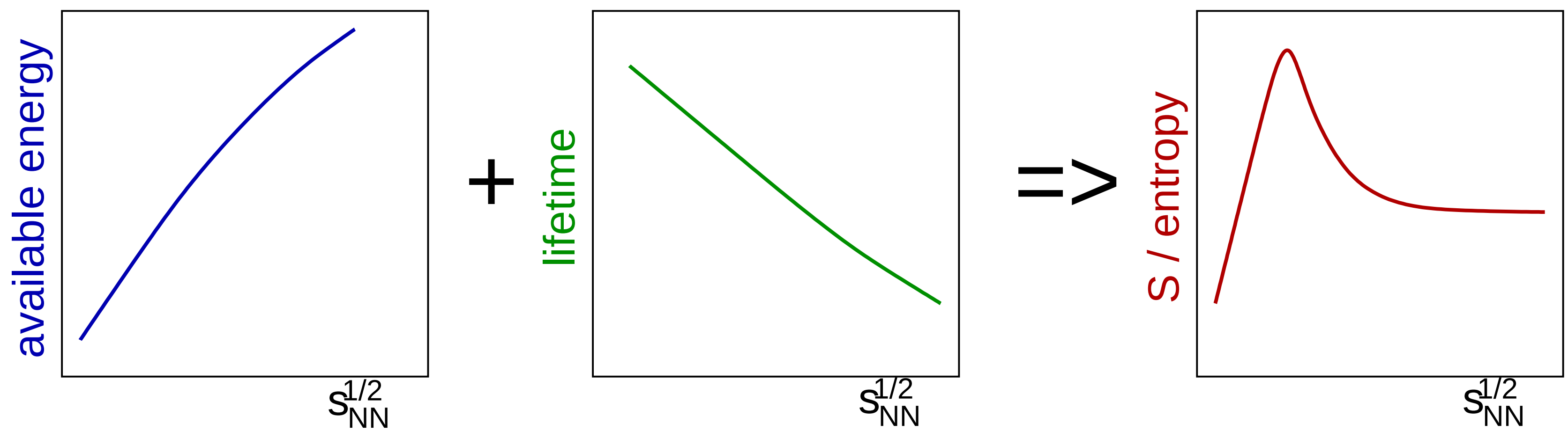
1 Introduction: strangeness production in nuclear collisions

Two handles for the strangeness production:

- energy (density)
- total time

A cartoon of the working hypothesis:



- we try hadronic scenario; intrinsically assume non-equilibrium

2 The model

- want to calculate ratios of yields → look at densities of species
- study evolution of the (kaon, pion, strangeness, ...) densities

$$\frac{dn_K}{d\tau} = \frac{d}{d\tau}\frac{N_K}{V} = -\frac{N_K}{V}\frac{1}{V}\frac{dV}{d\tau} + \frac{1}{V}\frac{dN_K}{d\tau}$$

$$\frac{dn_K}{d\tau} = \quad n_K\left(-\frac{1}{V}\frac{dV}{d\tau}\right) + \sum_{ij}\langle v\sigma_{ij}^{+}\rangle\, n_i\, n_j - \sum_{i}\langle v\sigma_{Ki}^{-}\rangle\, n_K\, n_i$$

expansion rate — ansatz for this

production rate, annihilation rate — calculate from known cross-sections and evolved densities

Ansatz for the expansion

$$\varepsilon(\tau) = \begin{cases} \varepsilon_0(1 - a\tau - b\tau^2) & \tau < \tau_s \quad \text{acceleration} \\ \frac{\beta}{(\tau-\tau_0)^\alpha} & \tau > \tau_s \quad \text{power-law expansion} \end{cases}$$

$$n_{B,I}(\tau) = \begin{cases} n_{0;B,I}(1 - a\tau - b\tau^2)^\delta & \tau < \tau_s \quad \text{acceleration} \\ \frac{\gamma}{(\tau-\tau_0)^{\alpha\delta}} & \tau > \tau_s \quad \text{power-law expansion} \end{cases}$$

- explore a range of values for the model parameters
- at the end power-law scaling suggested by HBT
- this is a parametrisation "between Landau and Bjorken"

Production and annihilation

Calculation of densities:

- explicit kinetic calculation: K^+, K^0, K^{*+}, K^{*0}
- chemical equilibrium: non-strange species
- relative chemical equilibrium: $S < 0$ sector ($\bar{K}$, Λ, Σ, Ξ, Ω)
- no antibaryons assumed at these energies

Implemented K-production (and annihilation) rates:

$$\pi N \leftrightarrow KY, \quad \pi N \to NK\bar{K}, \quad \pi\Delta \leftrightarrow KY, \quad \pi\Delta \to NK\bar{K}$$

$$NN \to KNY, \quad NN \to NNK\bar{K}, \quad NN \to \Delta KY$$

$$N\Delta \to NYK, \quad N\Delta \to NNK\bar{K}, \quad N\Delta \to \Delta KY$$

$$\Delta\Delta \to \Delta YK, \quad \Delta\Delta \to NNK\bar{K}$$

$$\pi\pi \leftrightarrow K\bar{K}, \quad \pi\rho \leftrightarrow K\bar{K}, \quad \rho\rho \leftrightarrow K\bar{K},$$

$$K^* \leftrightarrow K\pi, \quad \pi Y \leftrightarrow K\Xi,$$

How to control K^+, K^-, and Λ production

- density of $S > 0$ species (K^+, K^0, K^{*+}, K^{*0}) is controlled by time and also temperature

- density of $S < 0$ species must balance strangeness such that total strangeness of the system remains 0

- density of K^- relative to that of Λ is given by temperature and chemical potentials (relative equilibrium)

Final and initial conditions

• use fit results to chemical FO [Becattini et al., PRC **69** (2004) 024905]:
T, μ_B, μ_3, μ_S, γ_S $\rightarrow$ get ε_{FO}, $n_{B,FO}$, $n_{3,FO}$

• choose initial ε_0 and total lifetime; parametrise evolution from initial state to freeze-out by Becattini et al.

$\Rightarrow$ this helps to aim the parametrisation for the correct final state

• initial strangeness content estimated from pp (pn, nn) collisions

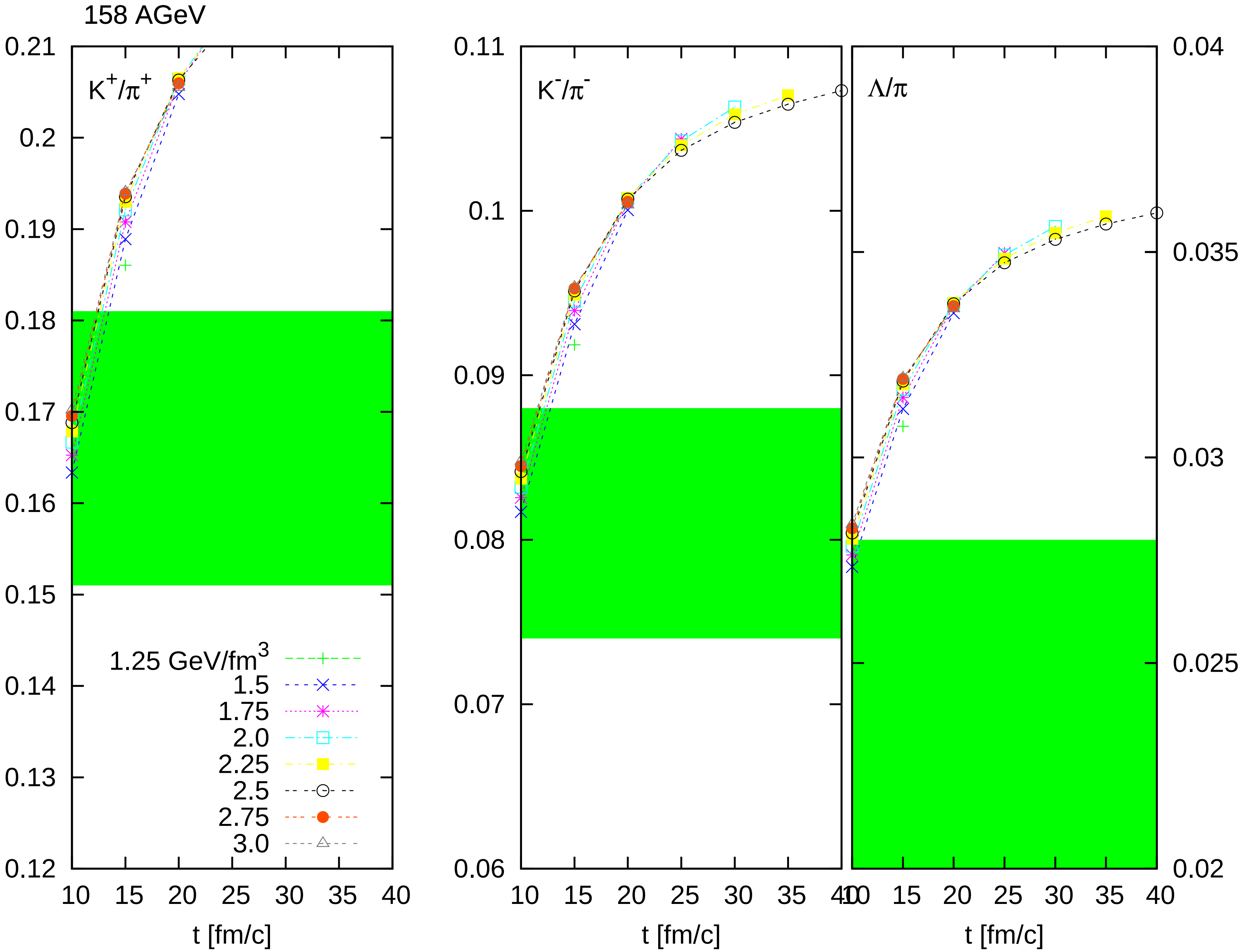
3 Results

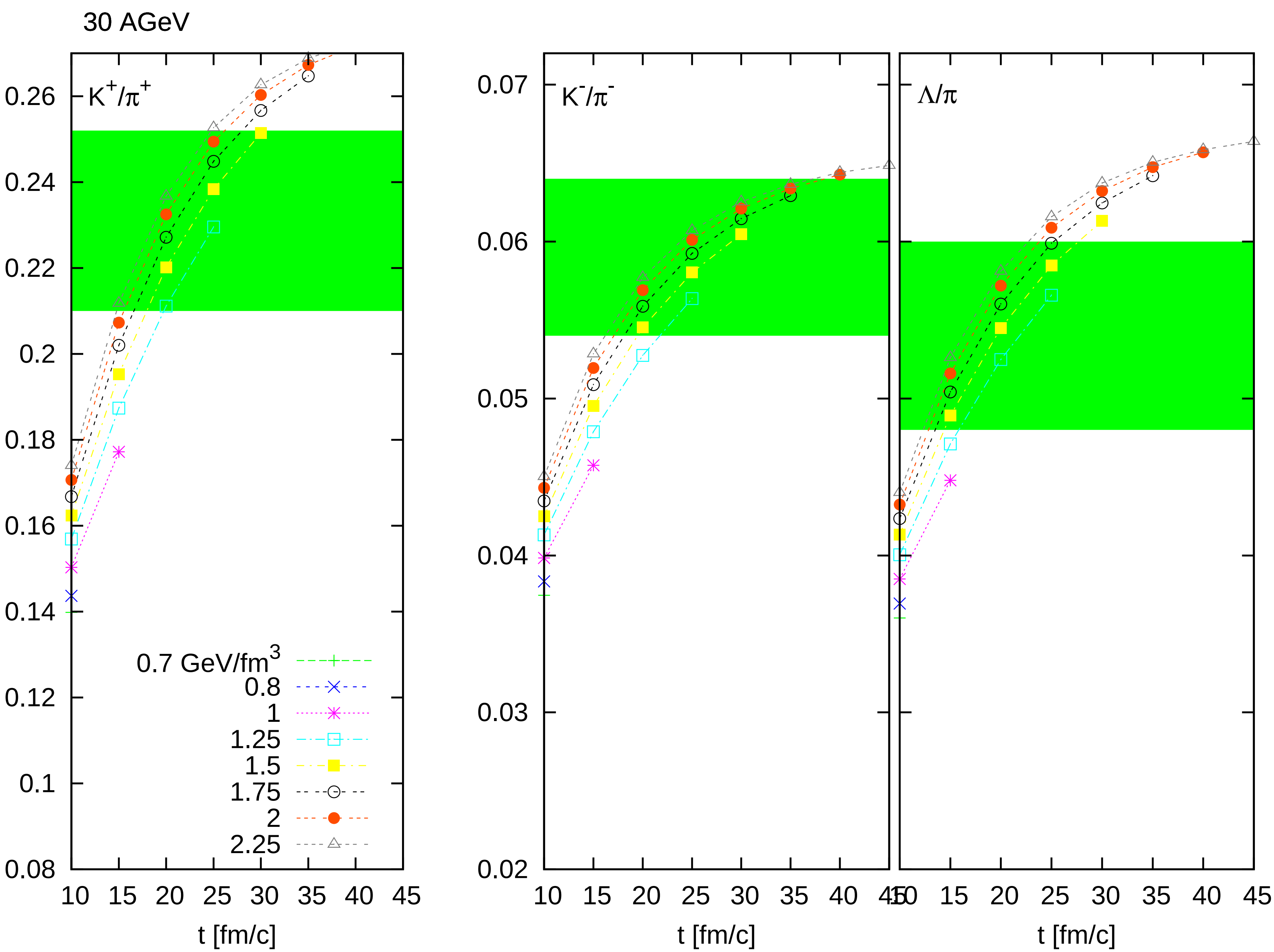
• ratios of K^+/π^+, K^-/π^-, Λ/π as a function of time and initial energy density as they result from the various parametrised evolution scenarios

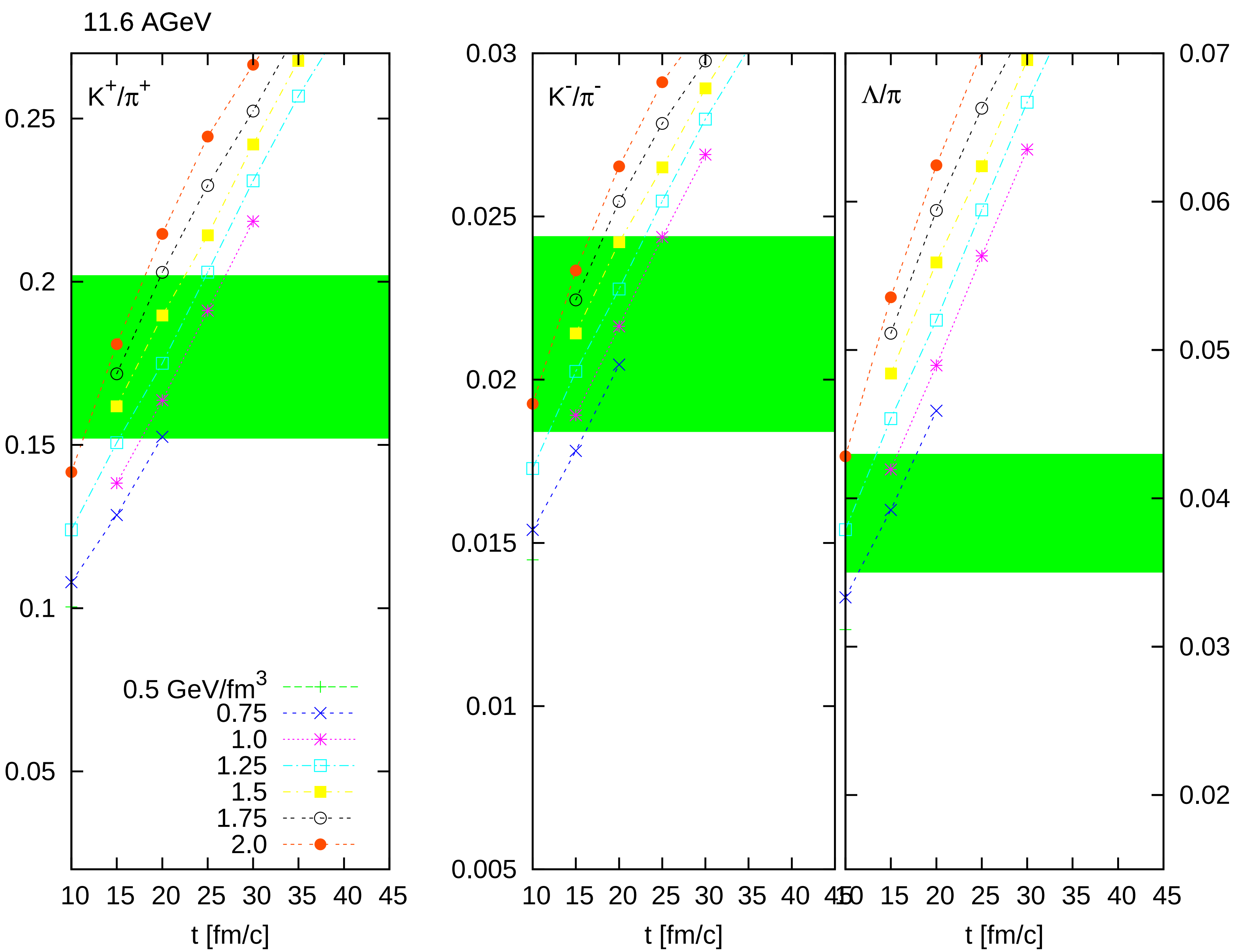
observe:

- strong dependence on the total lifetime
- weaker dependence on (initial) energy density (particularly at higher collision energies)

• dependence on total lifetime is plotted
• different curves correspond to different initial energy densities
• green bands show measured values with errobars

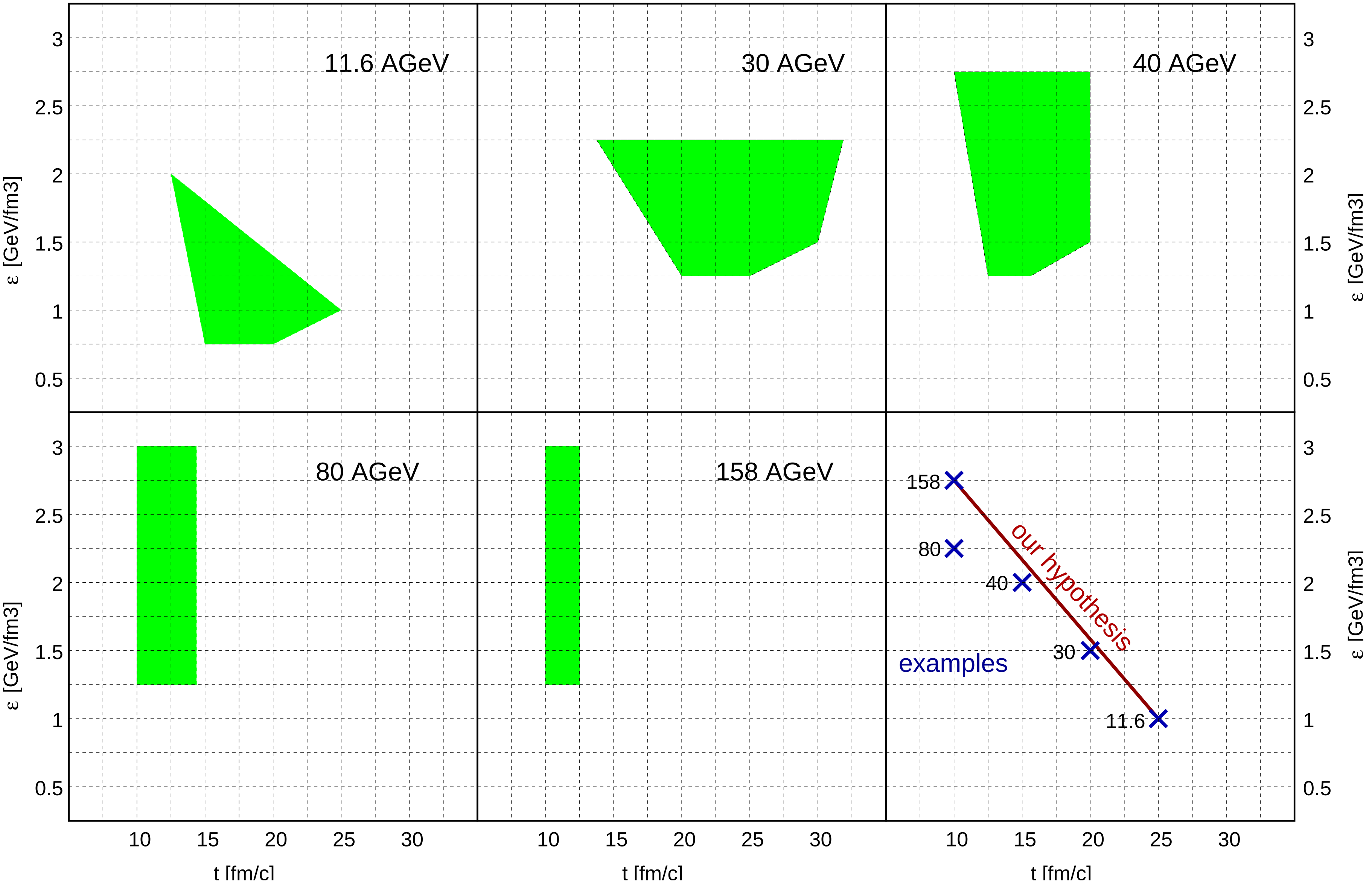

158 AGeV
K+/π+
K-/π-
Λ/π
1.25 GeV/fm3
1.5
1.75
2.0
2.25
2.5
2.75
3.0
t [fm/c]
t [fm/c]
t [fm/c]


30 AGeV
K+/π+
K-/π-
Λ/π
0.7 GeV/fm3
0.8
1
1.25
1.5
1.75
2
2.25
t [fm/c]
t [fm/c]
t [fm/c]

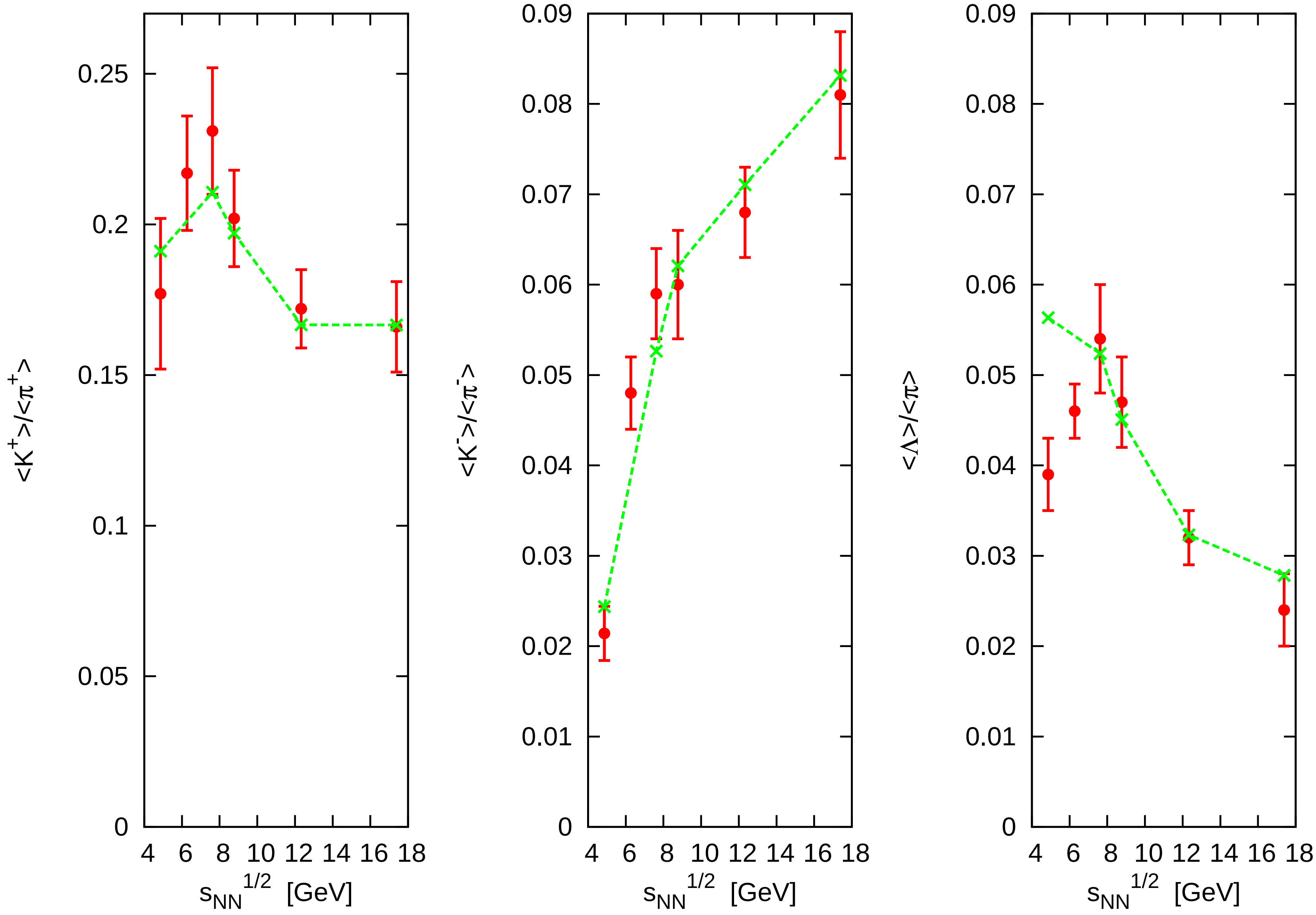


11.6 AGeV
K+/π+
K-/π-
Λ/π
0.5 GeV/fm3
0.75
1.0
1.25
1.5
1.75
2.0
t [fm/c]
t [fm/c]
t [fm/c]

Summary of allowed lifetimes and initial energy densities



Comparison to data



4 Conclusions

- $\sqrt{s_{NN}}$ dependence of strangeness production can be interpreted in terms of decreasing stopping with growing collision energy.
(We may need to re-tune the evolution scenario for AGS energies.)

- this conjecture should be cross-checked with
  - careful analysis of kinetic and chemical freeze-out (spectra, HBT, abundancies)
  - dilepton spectra
  - ...