Medium Modifications of the $\triangle(1232)$

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Motivation

- Main features of low-energy QCD:
  - confinement: relevant degrees of freedom hadrons
  - spontaneously broken chiral Symmetry

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- Main features of low-energy QCD:
  - confinement: relevant degrees of freedom hadrons
  - spontaneously broken chiral Symmetry
- Lattice: At $T_c \sim$ 150-200 MeV phase transition/crossover
  - deconfined partonic matter ("Quark-Gluon Plasma")
  - restored chiral symmetry

Motivation

- Medium modifications of hadrons

  - Heavy-Ion Collisions: dilepton spectra direct probe to hot/dense phase

  - enhancement of dilepton yield $\lesssim \rho$ peak (SpS)

  - baryons important for in-medium modification of vector mesons

  - more detailed treatment of in-medium baryon spectrum desirable

  - Δ accessible through πN invariant-mass spectra preliminary measurements from STAR
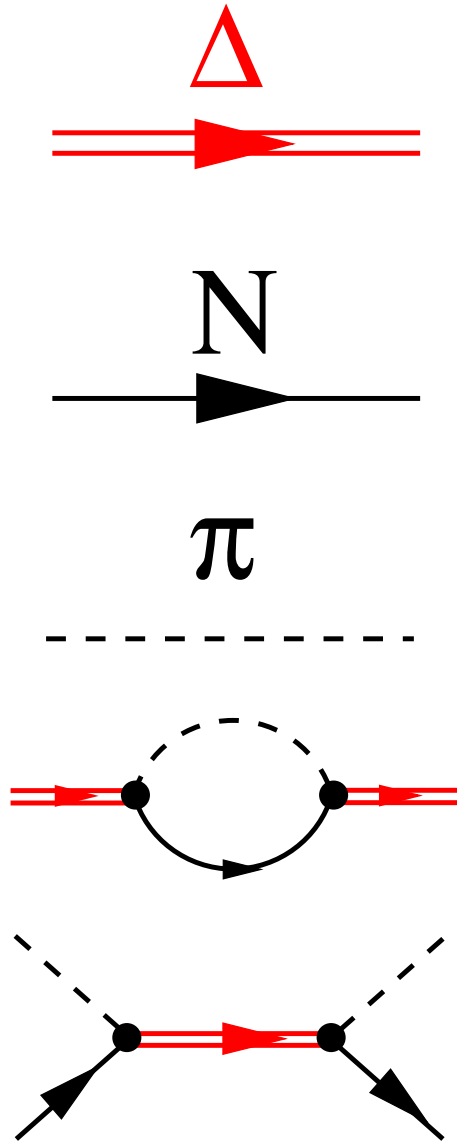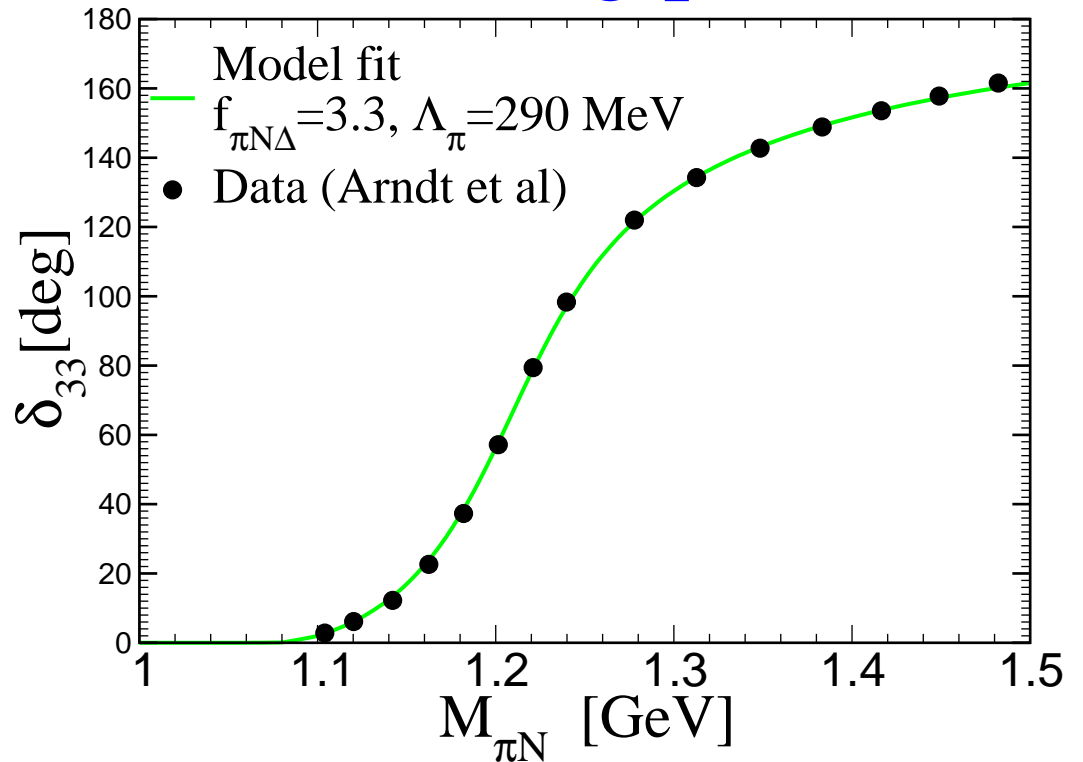
Hadronic model in the vacuum

- hadronic fields: nucleons, pions, $\Delta(1232)$

- pions fully relativistic

- baryons: anti-particle poles neglected

- $\pi N \Delta$ vertex: p wave

- form factor $F_{\mathsf{mono}}(|\vec{k}|) = \Lambda^2 / (\Lambda^2 + \vec{k}^2)$
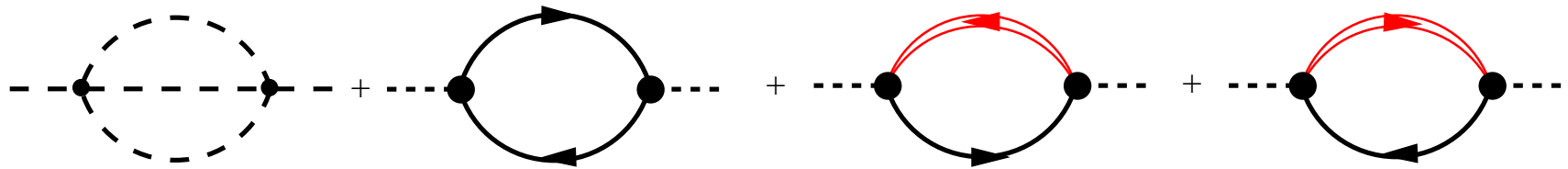
Hadronic model in the vacuum

Δ

N

π

π N scattering phase shift

Model fit
$f_{\pi N\Delta}$=3.3, Λ_π=290 MeV

● Data (Arndt et al)

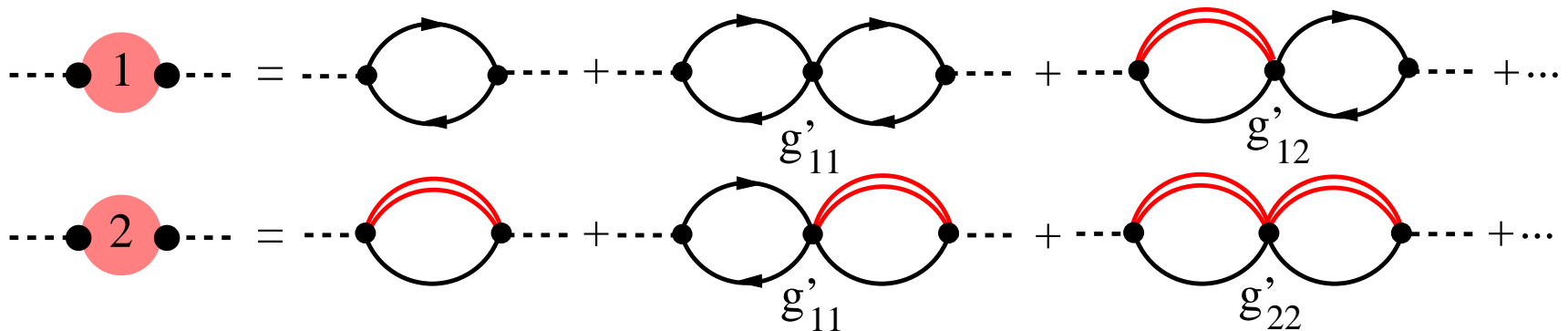δ_{33} [deg]

$M_{\pi N}$ [GeV]

Medium Modifications of pions

- pions: nucleon and $\triangle$-hole excitations

- short-range correlations: Migdal resummation

Medium Modifications of Pions

In-Medium π Spectral Function

$\rho_N = 0.68\rho_0$

$k = 0.3\,\text{GeV}$

Legend:
- T=0
- T=180 MeV
- T=180, $\rho_N = 0$

Axes: $-\text{Im}\, G_\pi\ [\text{GeV}^{-2}]$ vs $k_0\ [\text{GeV}]$
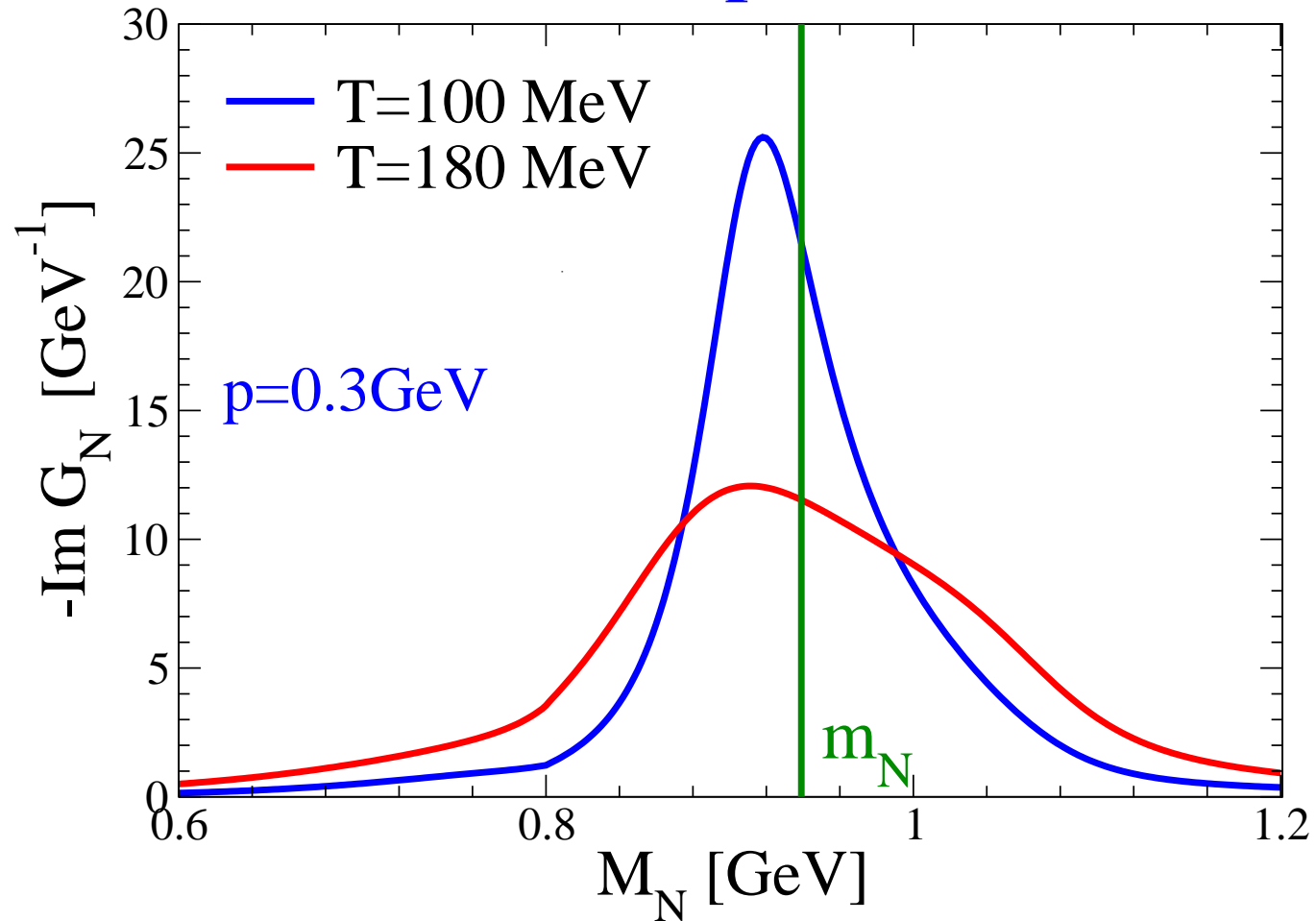
Medium Modifications of Nucleons

- nucleons: πN and πB, $B = \Delta(1232)$, $N^*(1440)$, $N^*(1535)$, $\Delta^*(1600)$, $\Delta^*(1620)$

- coupling constants fitted to partial decay widths $B \to \pi N$

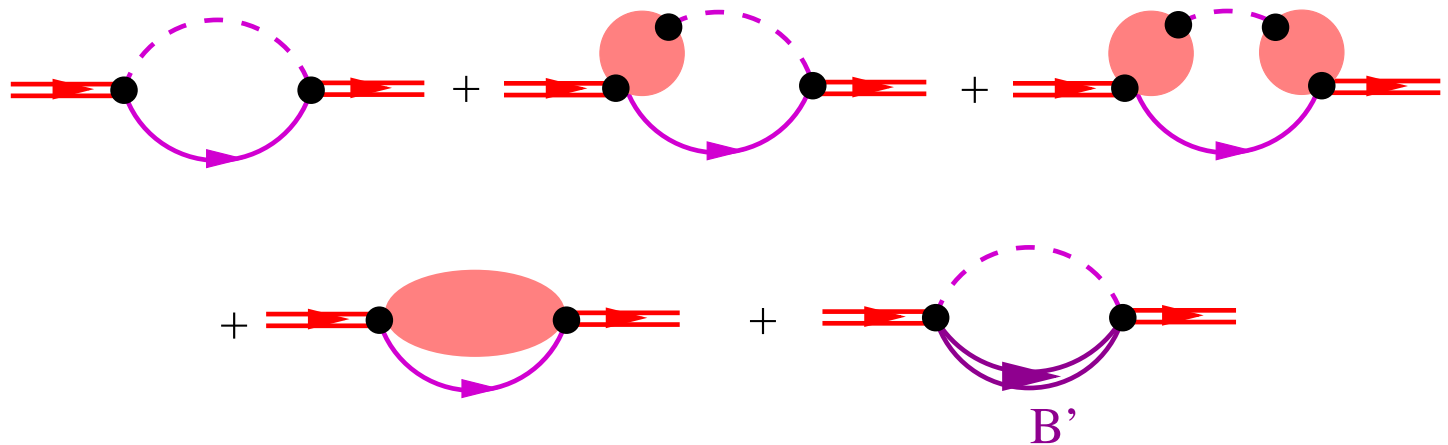# Medium Modifications of Nucleons

In Medium N-spectral function

T=100 MeV, ϱ_N=0.12ϱ_0, μ_π=96 MeV
T=180 MeV, ϱ_N=0.68ϱ_0, μ_π=0

Medium Modifications of the △

- same diagram as in vacuum with dressed pion- and nucleon propagators

- vertex corrections: same resummed Migdal loops as for the pion

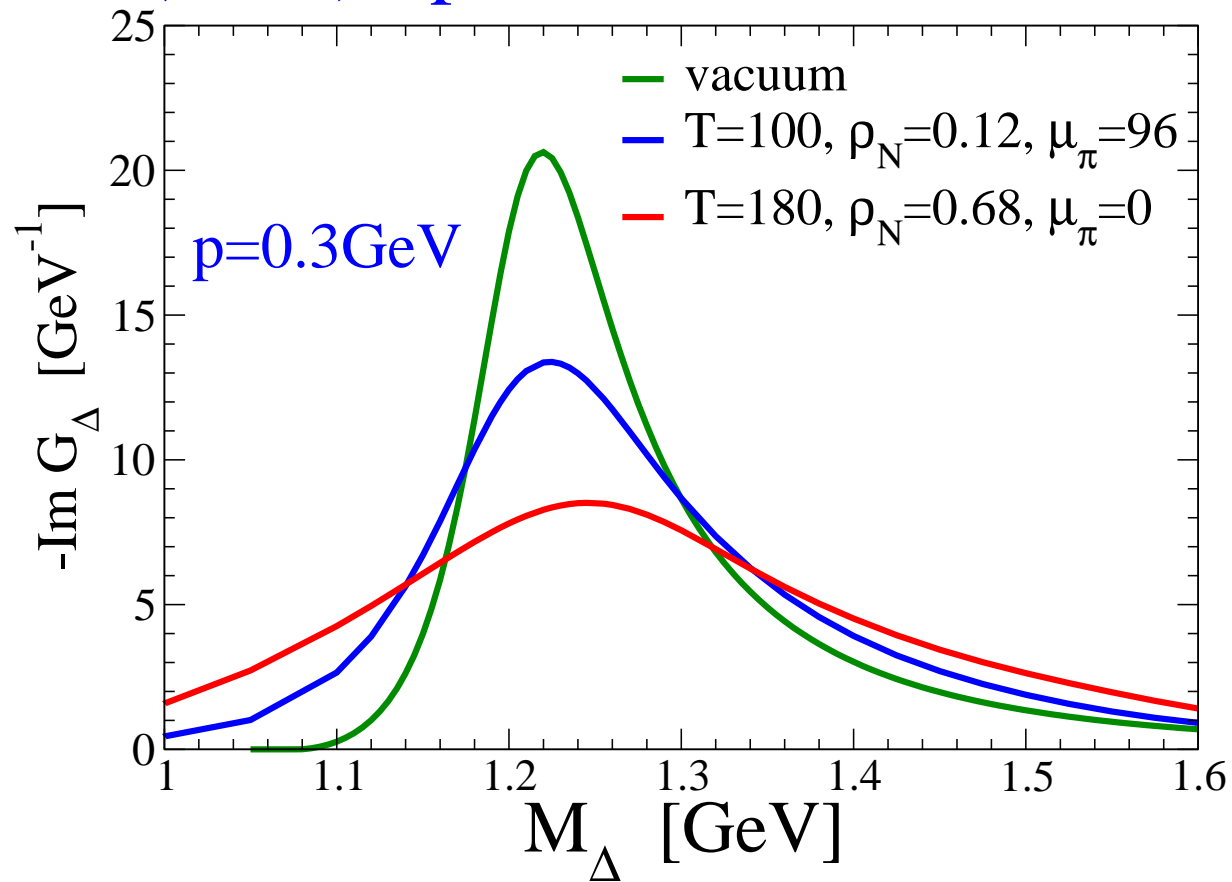- 4-fermion vertices: same Migdal parameters as for the pion

- $B' = \Delta(1232), N^*(1440), N^*(1520), \Delta^*(1600), \Delta^*(1620), N^*(1700), \Delta^*(1700)$
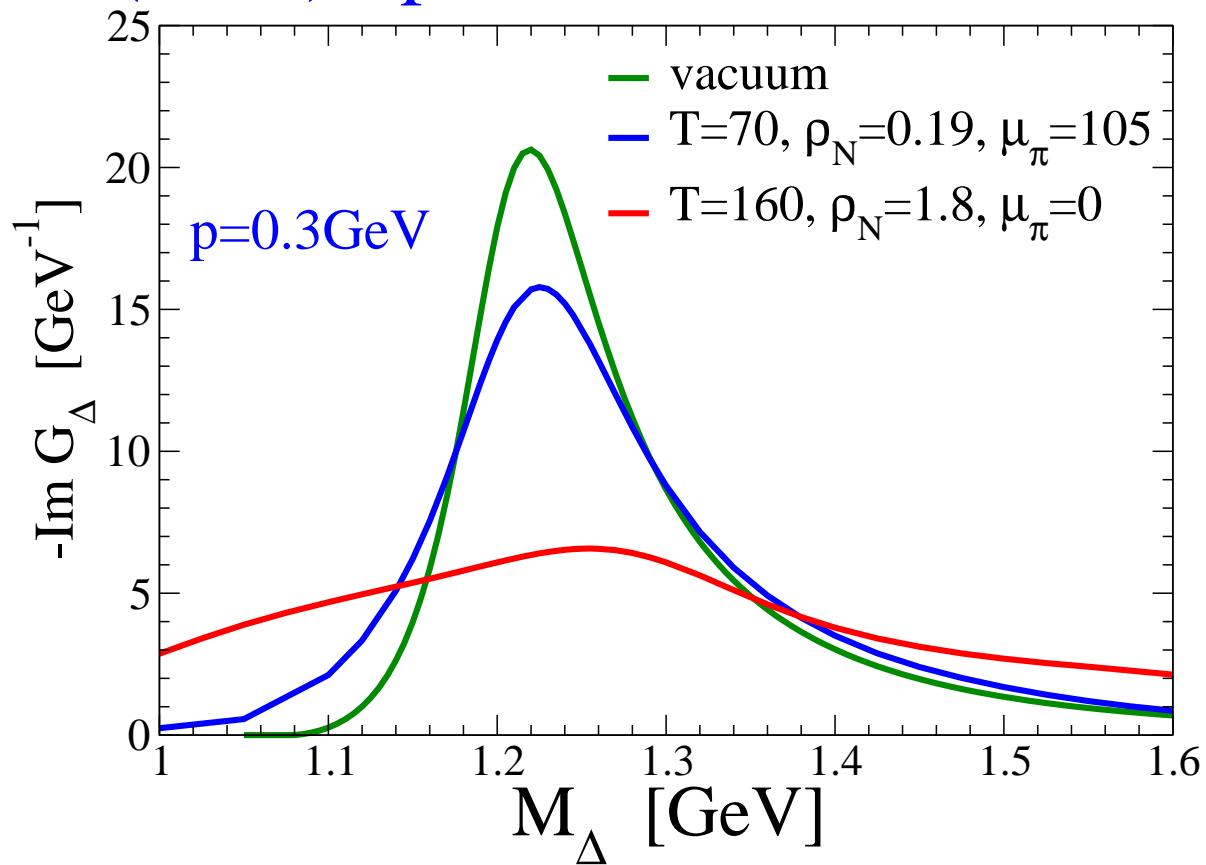
Medium Modifications of the $\triangle$

$\Delta(1232)$ Spectral Function at RHIC

Medium Modifications of the △

Δ(1232) Spectral Function at SIS-06

Conclusions and Outlook

- study of the $\Delta N\pi$ system in hot/dense matter

- results qualitatively in line with preliminary STAR data for πN invariant-mass spectra

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- further developments:
  - medium effects on excited resonances
  - comparison with πN invariant-mass spectra: detailed treatment of freezeout dynamics
  - coupling to vector mesons within chiral framework
  - role of medium modifications of the Δ for electromagnetic emission spectra (soft photons at SpS?)