A method of η′ rejection in p+p and Au+Au collisions

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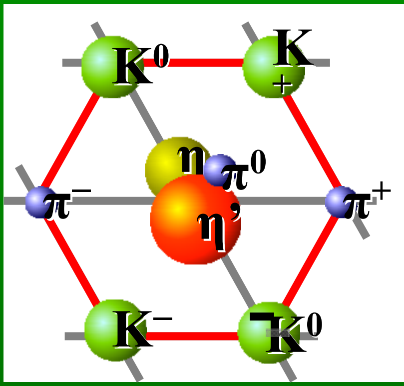


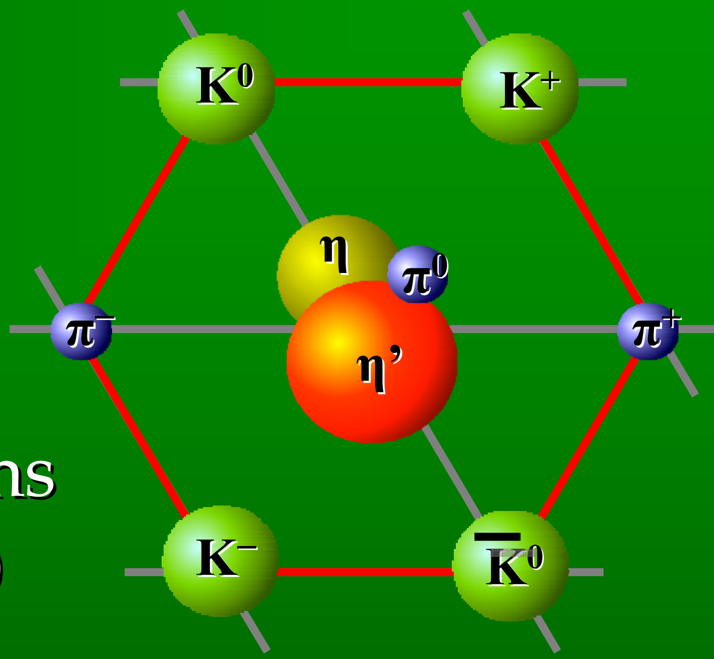
- Mass drop of the η′ and HBT
- Kinematical cuts to reject π from η′
- Efficiency and loss analysis

VI Workshop on Particle Correlations and Femtoscopy

Kiev, September 14-18, 2010

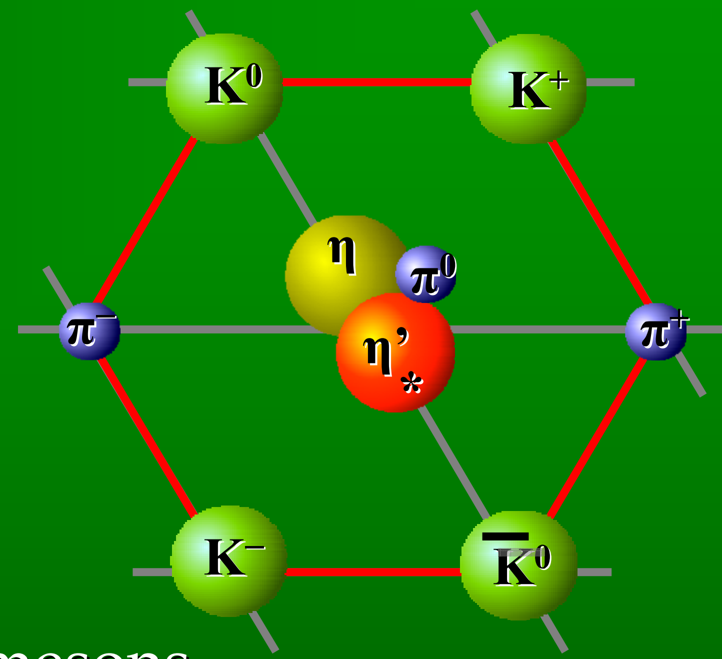
Chiral Symmetry Breaking

- The three-quark model
  - SU(3) flavour-symmetry
  - Spontaneously broken
    => 9 Goldstone bosons
  - Corresponding to light mesons
    - There are only 8! (Meson-octet)



- $U_A(1)$ chiral symmetry explicitly broken
  - Distinct topological vacuum-states
  - Tunneling b/w them – quasiparticles (instantons)
  - 9th boson gains mass – η′ (958 MeV)

Restoration of the Symmetry



- High energy densities
  - Asymptotic freedom $\alpha_s \to 0$
  - Nontrivial topology vanishes
  - U(1) no more broken
  - SU(3) restored

    Remark:

    From SSB, One expects massless mesons.
    However, the flavour symmetry is inexact.

- Mass reduction

$$m_{\eta'} = m_0 + \Delta m$$

Lower bound (Gell-Mann – Okubo):

$$m_0^2 = \frac{1}{3}\left(2\mathrm{m}_K^2 + m_\pi^2\right);\ m_0 \approx 400 MeV$$

Upper bound (S,NS isosinglet eigenstates):

$$m_S^2 = 2\mathrm{m}_K^2 + m_\pi^2; \quad m_S \approx 700 MeV$$

Δm is the extra mass from instantons in a not-so-dense medium

Signature: Particle Abundancy

- Hagedorn-model
  - Production of light mesons:

$$\sigma_i \sim (m/2\pi)^{3/2} e^{-m/T_H}$$

T_H~160 MeV Hagedorn-temperature

- In case of a possible mass drop:
  - Number of η‘s would be small: $N_{\eta'}/N_{\pi^0} \sim 2\text{x}10^{-2}$
  - With a strongly reduced η‘ mass: $N_{\eta'}/N_{\pi^0} \sim 1$
    - An enhancement of a factor of 50 at maximum
    - Increased weight of strange states, rather 3 to 16
- Consequence of the reduced mass:
  An increased abundancy of η′ mesons

The η' through Phase Transition

- Hadronization
  - Reduced-mass η' mesons produced with a decreased mass with an increased abundancy
- Decoupling from non-Goldstonic matter
  - Mean free path for annihilation is large
  - Long lived
- "Condensate" in the medium
  - Low-p_T η' mesons are unable to get on-shell in the vacuum
  - Medium acts as a trap for low- p_T η' mesons
- As medium dissolves, the η' mesons regain their original mass

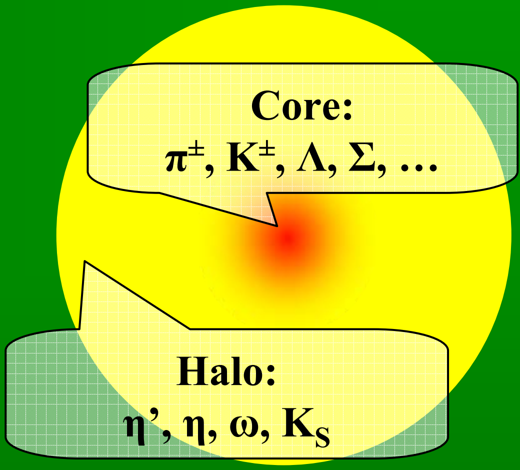
The Return of the prodigal Goldstone boson. J. I. Kapusta, D. Kharzeev, L. D. McLerran Phys.Rev.D53:5028-5033,1996. Hep-ph/9507343

Channels of Observation

- Direct leptonic decay $\eta'\to\ell^+\ell^-$
  - Increased η'/π proportion in the low-p_T range
  - Excess in the $\ell^+\ell^-$ spectrum under the ρ mass
- η meson (BR=73%) $\eta'\to\eta\pi^+\pi^-$
  - Including decay through ρ
  - Decay of η meson
    - 23% $\eta\to\pi^+\pi^-\pi^0$ ✓
    - 5% $\eta\to\pi^+\pi^-\gamma$ ✓
    - 39% $\eta\to2\gamma$ ✘
    - 33% $\eta\to3\pi^0$ ✘
  - Enhanced production of uncorrelated pions
  - BEC of charged pions
    - Sensitive to the sources of the pions
- Direct measurement $\eta'\to\gamma\gamma$
  - Would be convincing, however, poor S/B ratio ($\pi^0\to\gamma\gamma$)

Correlations & Core-Halo picture

- Pions from QM freezeout
  - Primordial (from phase transition)
  - Fast decaying resonances
  - Long-life resonances (ω, η, η', K_S^0)
  - Core/halo ratio: $\lambda(p_t)$
  - BEC intercept parameter



Hot and dense matter: η' mass reduction

$\Downarrow$

Enhanced η' content

Decay: $\eta' \to \eta + \pi^+ + \pi^- \to (\pi^0 + \pi^+ + \pi^-) + \pi^+ + \pi^-$

Average p_t of π's 138 MeV

$\Downarrow$

More non-interacting π's at low p_t

$\lambda(p_t)$ measures fraction of interacting π's

$\Downarrow$

A hole in $\lambda(m_t)$

Kapusta, Kharzeev, McLerran
Phys.Rev.D53:5028-5033,1996

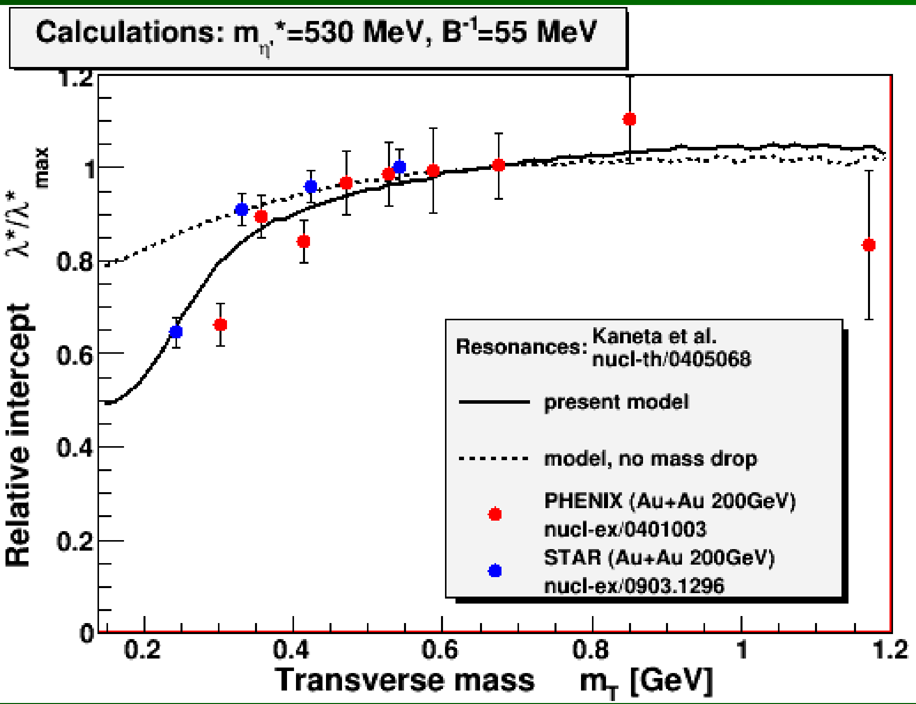
Z. Huang, X-N. Wang
Phys.Rev.D53:5034,1996

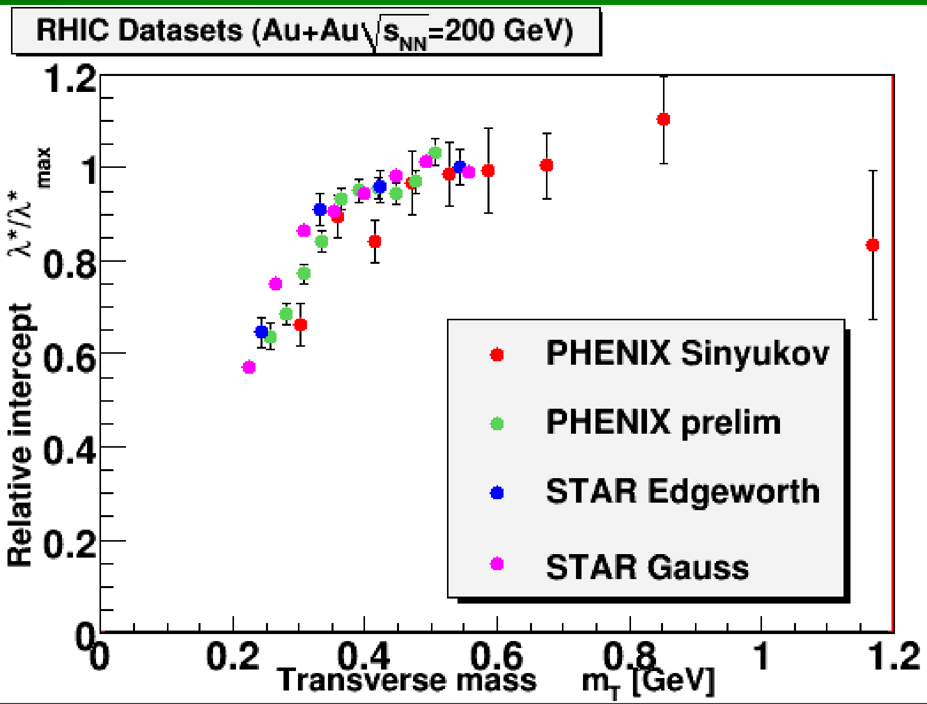
Vance, Csörgő Kharzeev
Phys.Rev.Lett.81:2205-2208,1998

T. Hatsuda, T. Kunihiro
Phys. Rept. 247:221,1994

Simulations & experimental results

- Vértesi, Csörgő, Sziklai: Nucl.Phys.A830:631,2009
- Mass drop compatible with the data

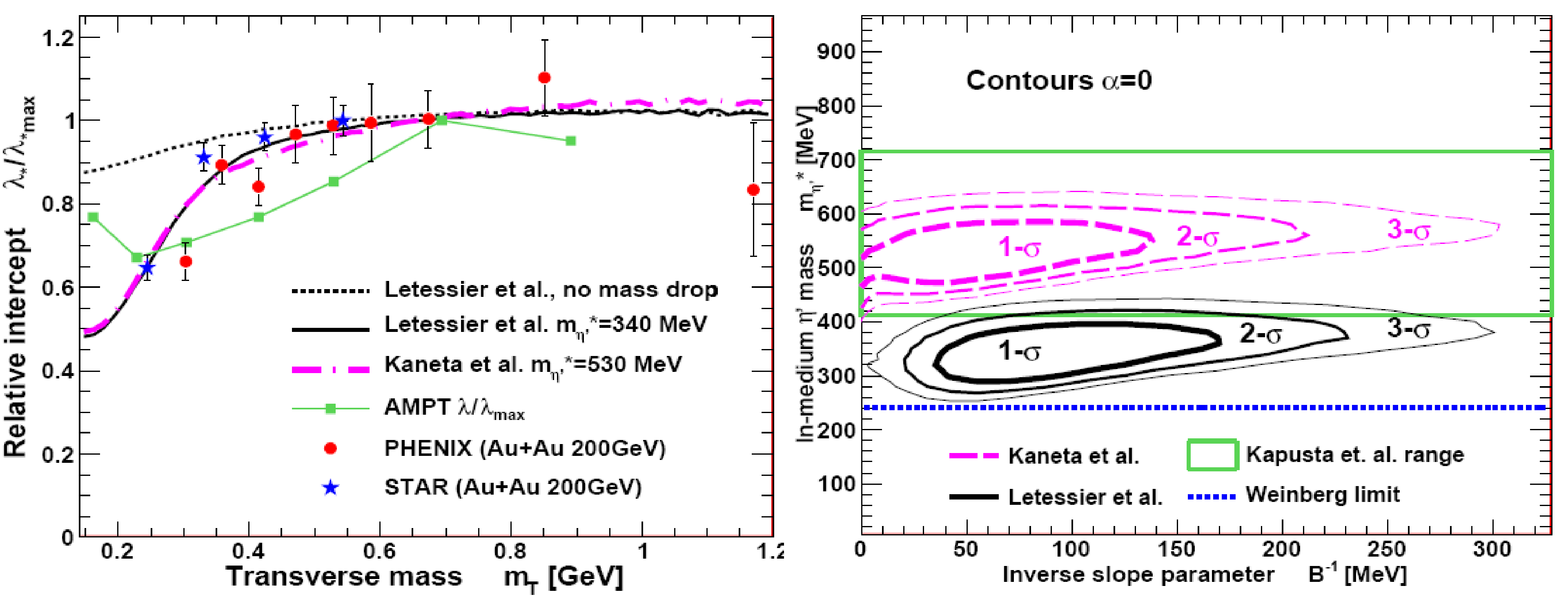




- Other reasons possible?

Detailed analysis

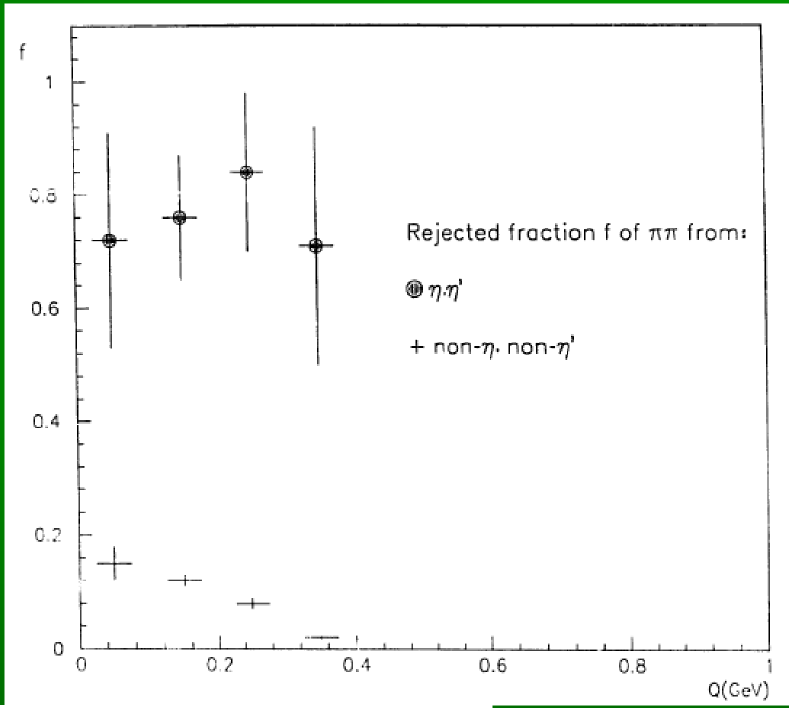
- Mass drop analyzed in detail
  - Csörgő, Vértesi, Sziklai: arXiv:0912.0258, .5526

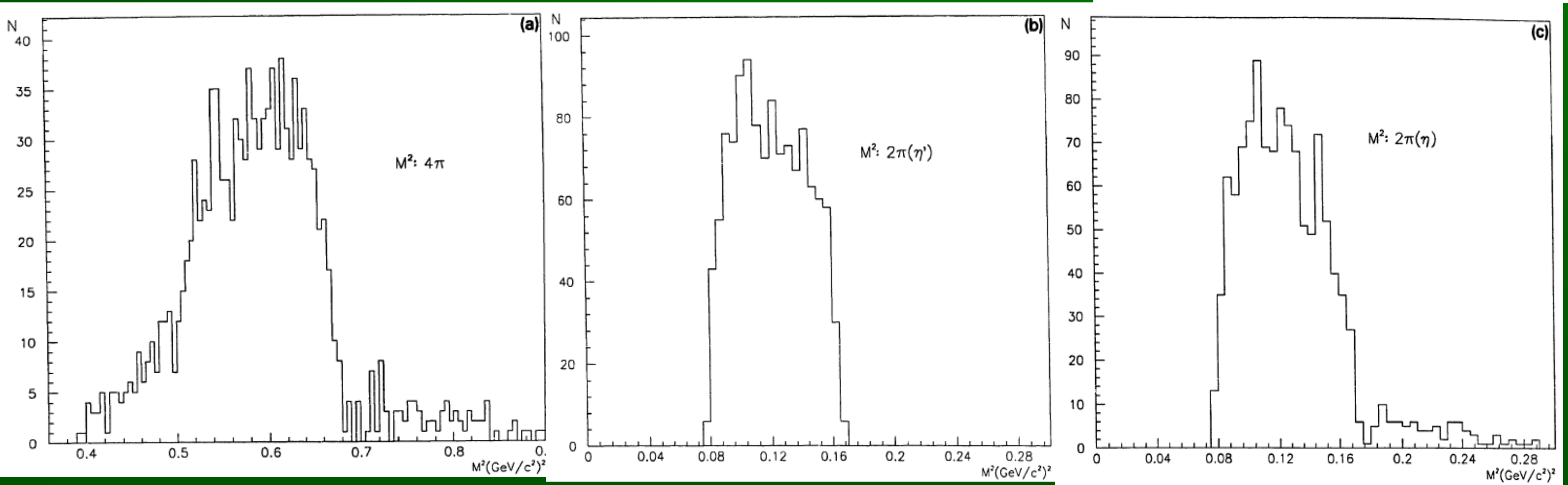


- Maximal mass with 5σ contours: 730 MeV
- Best fit between 340-530 MeV

Need for confirmation

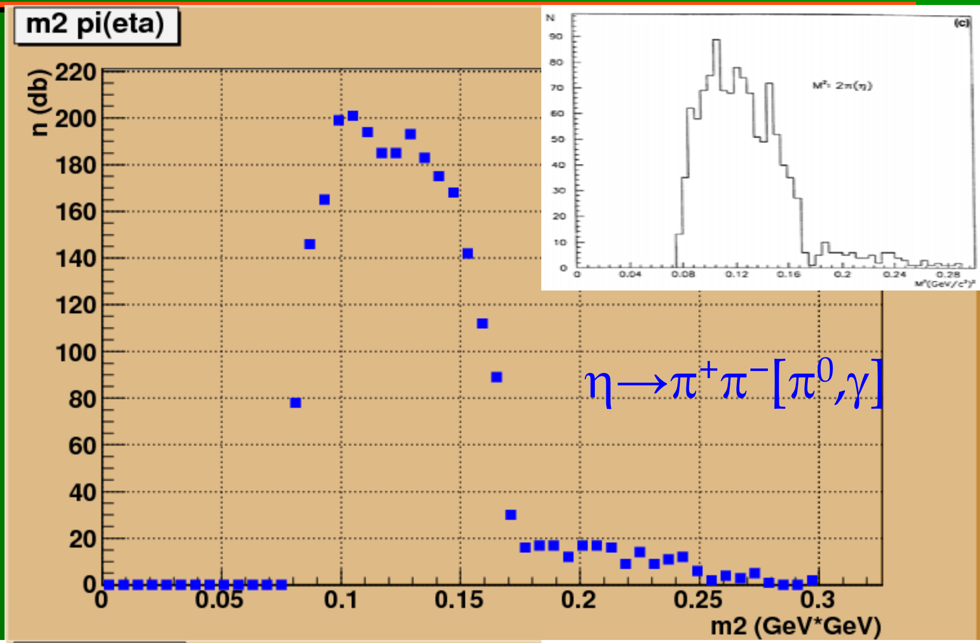
- Idea: reject pions from η′
- Method already tested
  - Kulka and Lörstad
    NIM A295, 443 (1990)
- In electron-positron
- Lund MC

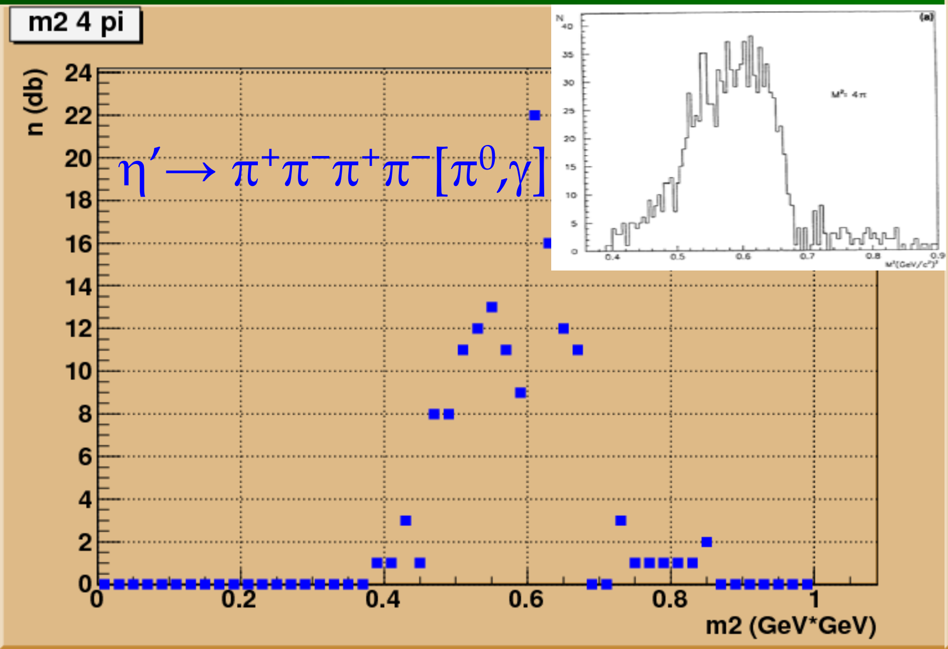


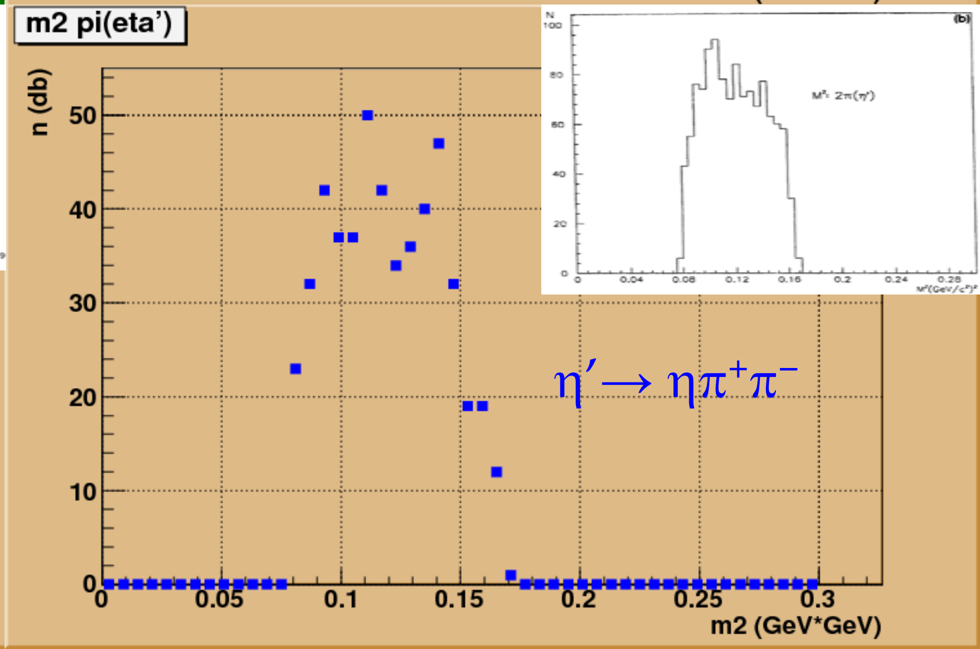


Pion distribution analysis

- Kinematics as expected
- Cut possible
- Optimal cut to be explored







Rejection method

- Analyze $\pi^+\pi^+\pi^-\pi^-$ quadruplets
- Check if they fall within the kinematical cuts
  - m_{+-}^2 in 0.075 to 0.171 GeV^2/c^2 (in both combinations)
  - m_4^2 in 0.43 to 0.69 GeV^2/c^2
- Apply this to pairs:
  - Look for all quadruplets with this pair in it
  - If inside mass interval, it is FOUND
  - Check if from η′ or not
- Apply this to particles:
  - Look for all quadruplets with this particle in it
  - If inside mass interval, it is FOUND
  - Check if from η′ or not
- Acceptance cuts make it more complicated

Scenarios

- We checked several scenarios:
  - Pair or particle cuts
  - Acceptance: total, rapidity cut (η<0.35), angular cut (cut out a PHENIX-like half)
  - Negative or positive pions (essentially the same, will quote only π^+)
- Two simulations: Pythia and HIJING
- Au+Au and p+p, 200 GeV and 14 TeV
- Important numbers
  - Cut efficiency (% of η' descendants tagged)
  - Cut loss (% of non-η' descendants NOT tagged)

14 TeV p+p results

- No acceptance cut
  - Pairs: Efficiency 70%, Loss 40%
  - Particles: Efficiency 98%, Loss 5%
- Rapidity cut
  - Pairs: Efficiency 31%, Loss 16%
  - Particles: Efficiency 64%, Loss 14%
- Rapidity & transverse angular cut
  - Pairs: Efficiency 17%, Loss 8%
  - Particles: Efficiency 46%, Loss 11%

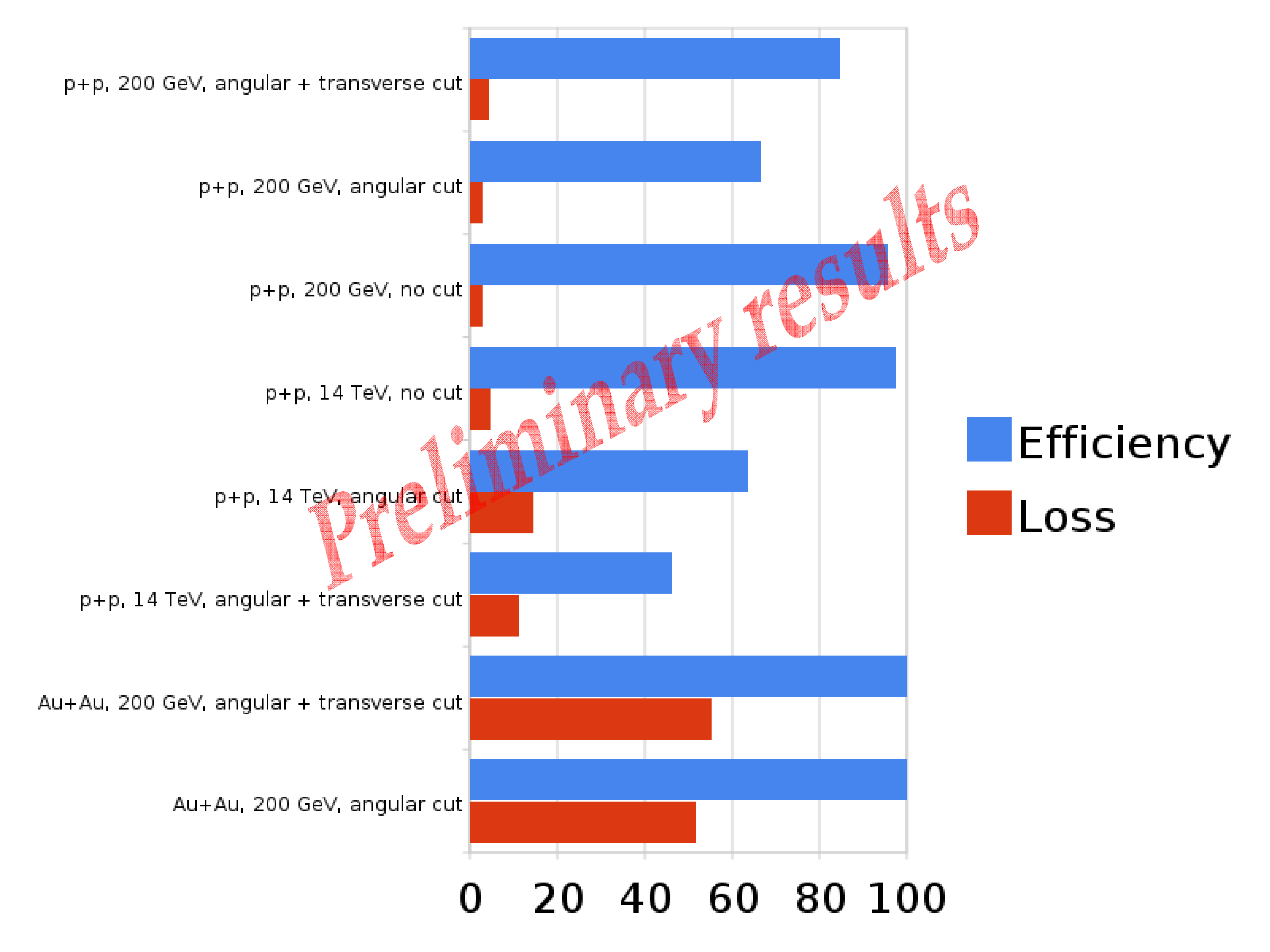
200 GeV p+p results

- No acceptance cut
  - Particles: Efficiency 98%, Loss 22%
  - Pairs: Efficiency 96%, Loss 3%
- Rapidity cut
  - Particles : Efficiency 56%, Loss 8%
  - Pairs : Efficiency 67%, Loss 3%
- Rapidity & transverse angular cut
  - Particles : Efficiency 52%, Loss 6%
  - Pairs : Efficiency 85%, Loss 4%

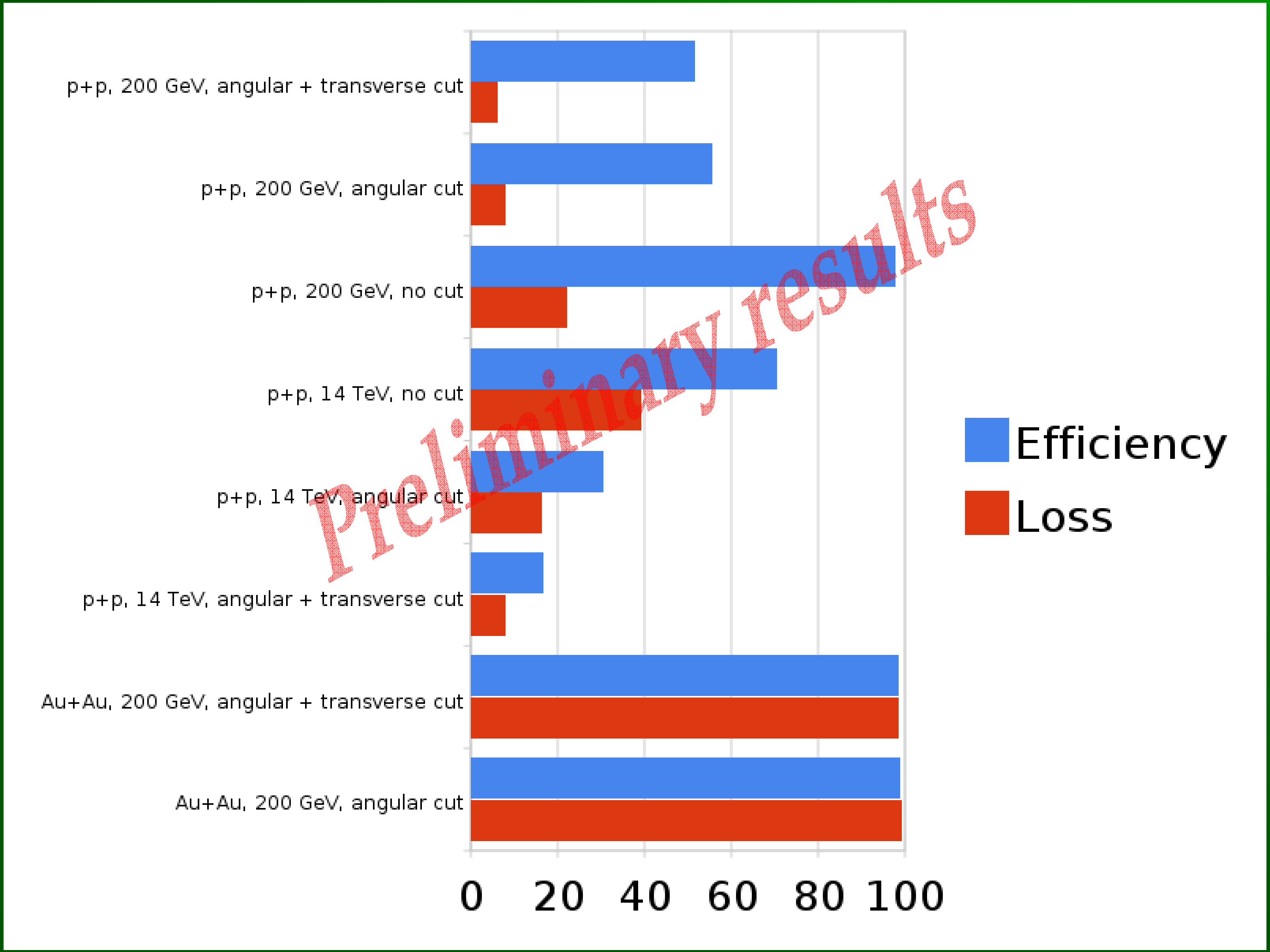
200 GeV Au+Au results

- No acceptance cut
  - Not done due to computing time problems
- Rapidity cut
  - Particles: Efficiency 99%, Loss 99%
  - Pairs: Efficiency 100%, Loss 55%
- Rapidity & transverse angular cut
  - Particles: Efficiency 99%, Loss 99%
  - Pairs: Efficiency 100%, Loss 52%

Results for pairs



Results for particles



Summary

- Proof of concept, done in Au+Au and p+p
- Needs to be cross-checked
- Cut dependence to be explored
- Pair rejection seems to be doable in Au+Au
- Has to be done on an experimental sample

Thank you for your attention