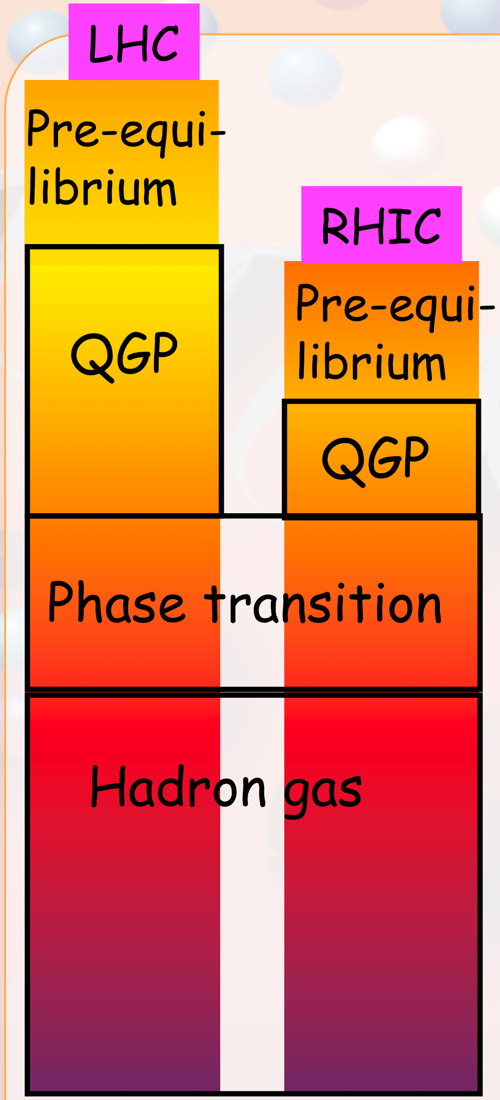
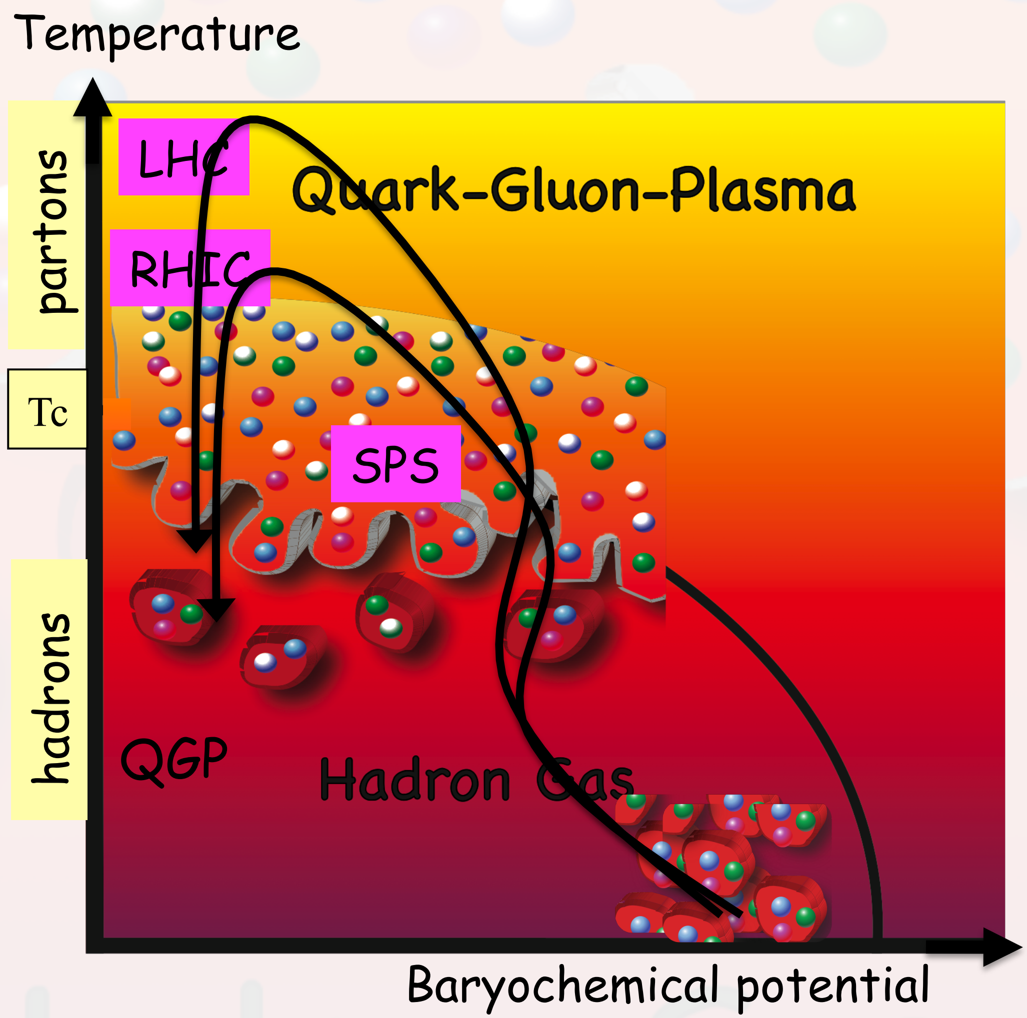
Hadronic resonance measurements what do we know and what are the future plans?

Christina Markert
University of Texas at Austin

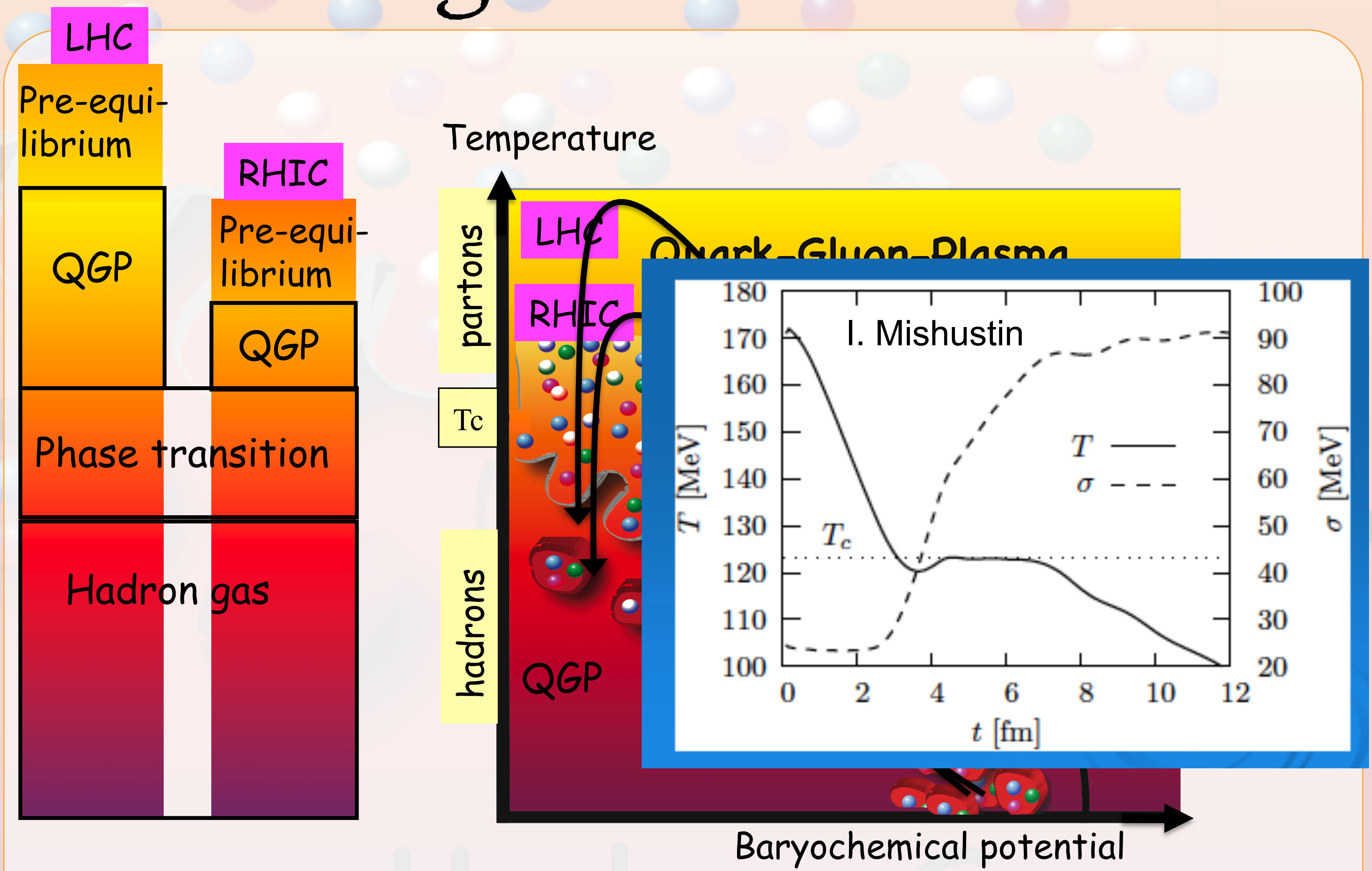
- Resonance production/time
- Hadronic medium
- High momentum resonances
- Conclusion

Phase diagram of nuclear matter

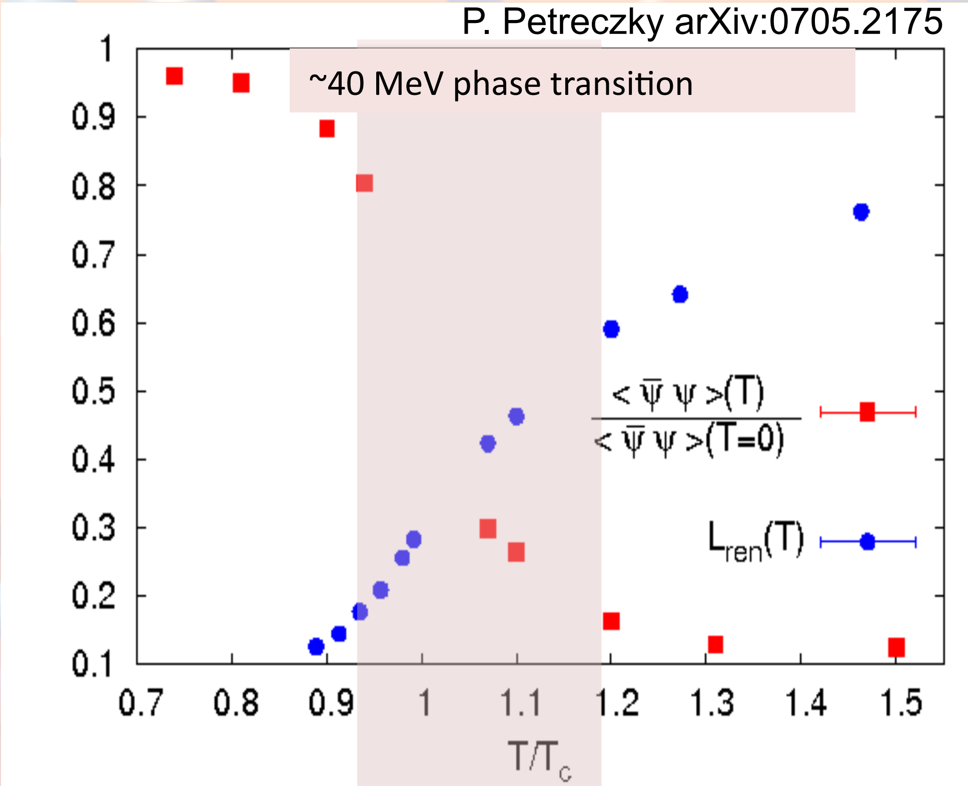




Phase diagram of nuclear matter

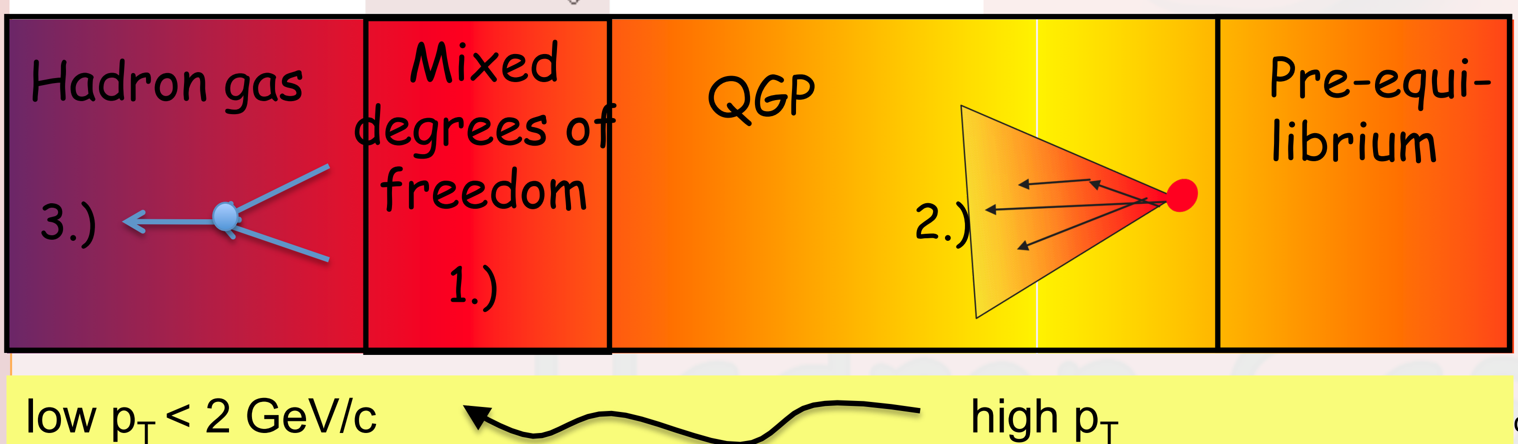


Resonance production

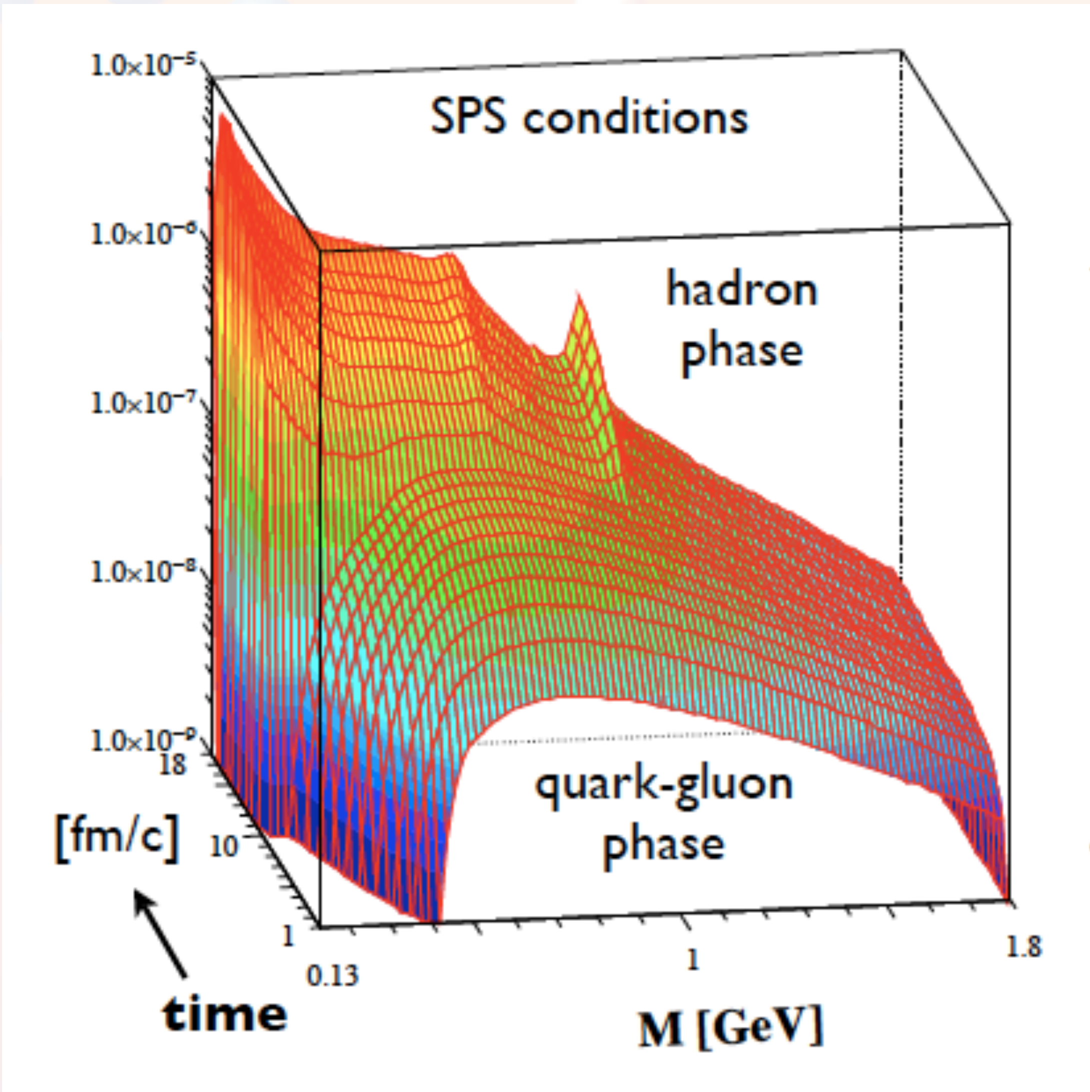


Features of QCD phase transition
(lattice QCD calculations):
deconfinement: Polyakov loop rises
chiral restoration: quark condensate drops hadron masses drop

1.) Medium: resonances are formed when partonic matter transitions into hadronic matter
2.) Hard-scattering: resonances created from a jet within the QGP phase
3.) Regenerated resonances



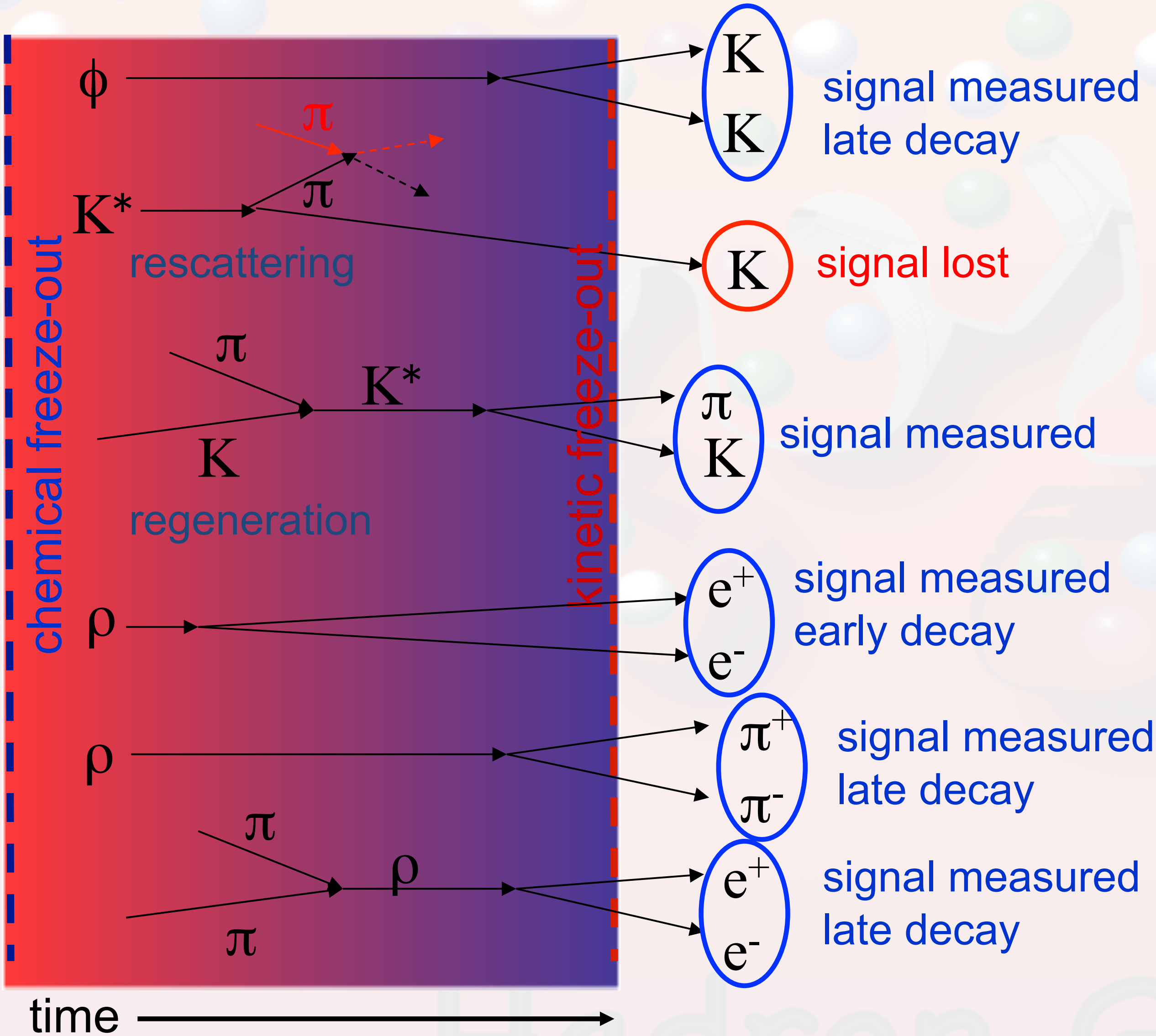
Formation of resonances (spectral funkt.)



T. Renk, R.A. Schneider, W.W.
Phys. Rev. C66 (2002) 014902
Nucl. Phys. A699 (2002) 1

Time →
Temperature ←
Momentum ←

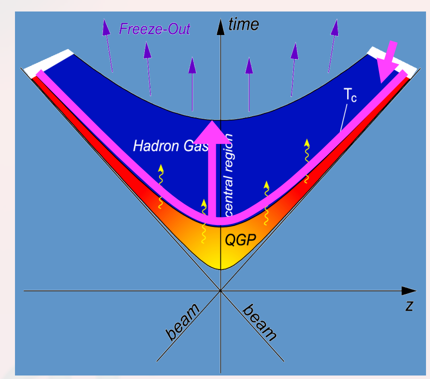
Hadronic phase



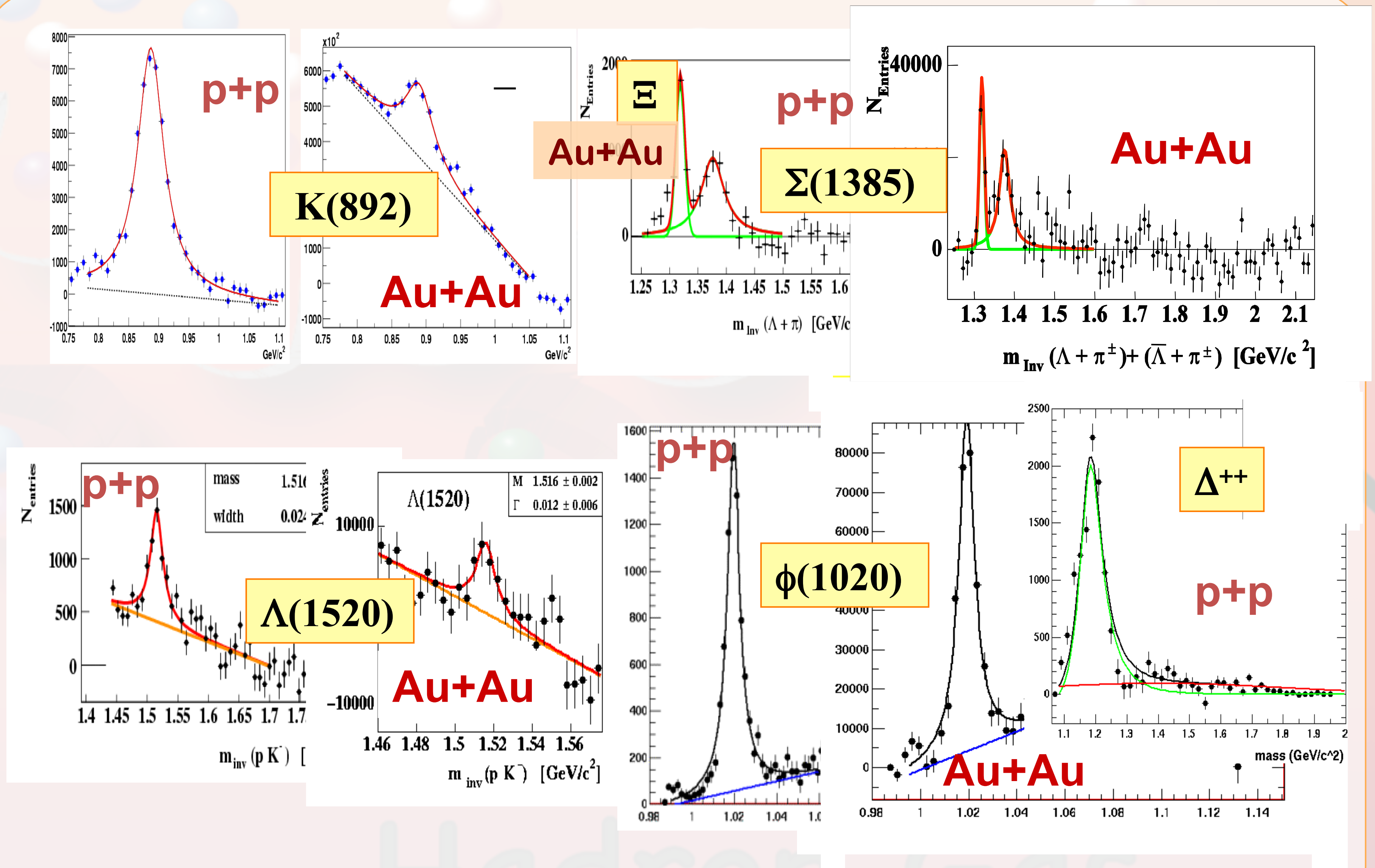
Life-time [fm/c] :

ρ	= 1.3
Δ^{++}	= 1.7
K(892)	= 4.0
Σ(1385)	= 5.7
Λ(1520)	= 13
φ (1020)	= 45

Depends on:
- hadronic phase density
- hadronic phase lifetime

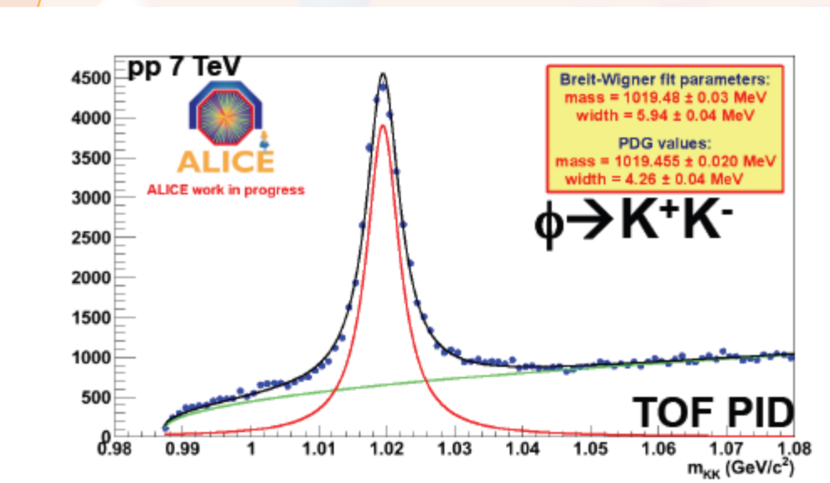


Resonances in p+p and Au+Au at 200 GeV

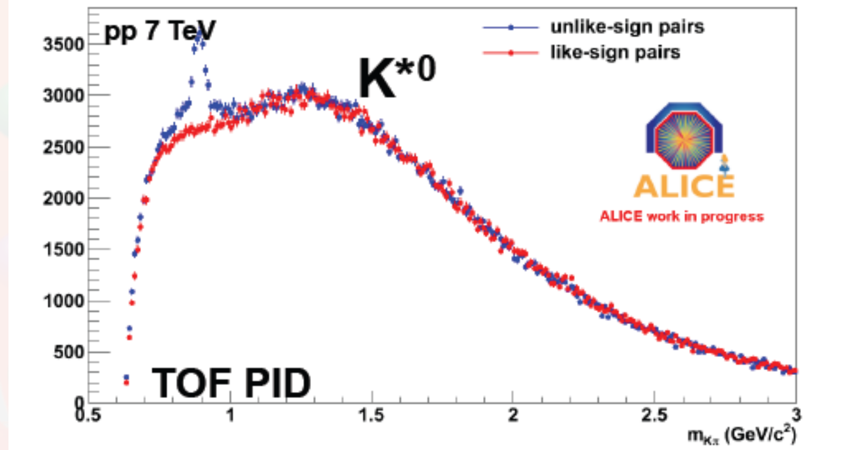


Resonances in p+p collisions ALICE

Markert ICPAQGP2010

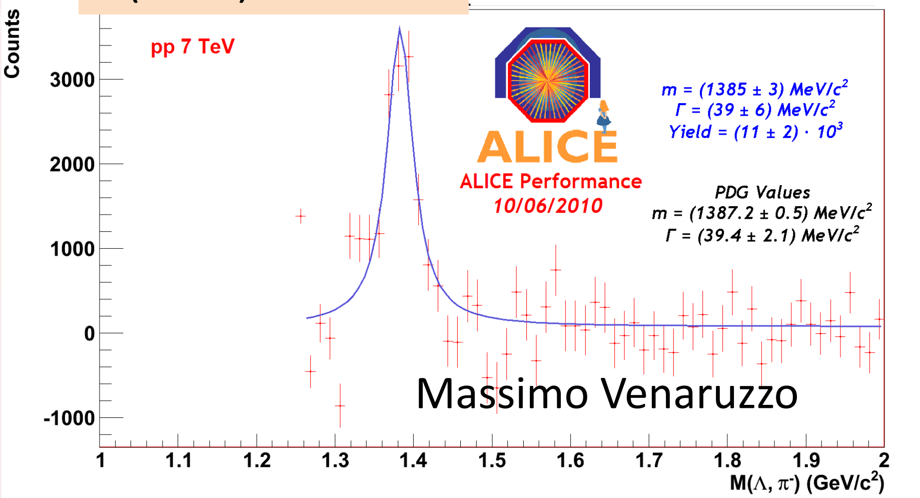


Alberto Pulvirenti



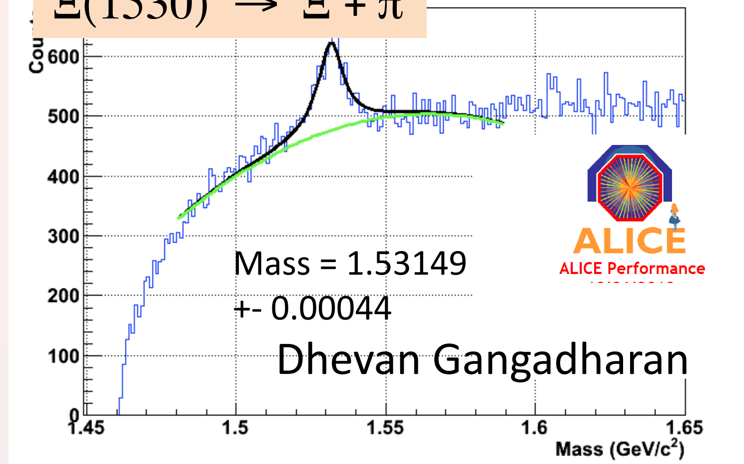
Masses are in agreement with PDG values

$\Sigma(1385) \rightarrow \Lambda + \pi$



Massimo Venaruzzo

$\Xi(1530) \rightarrow \Xi + \pi$

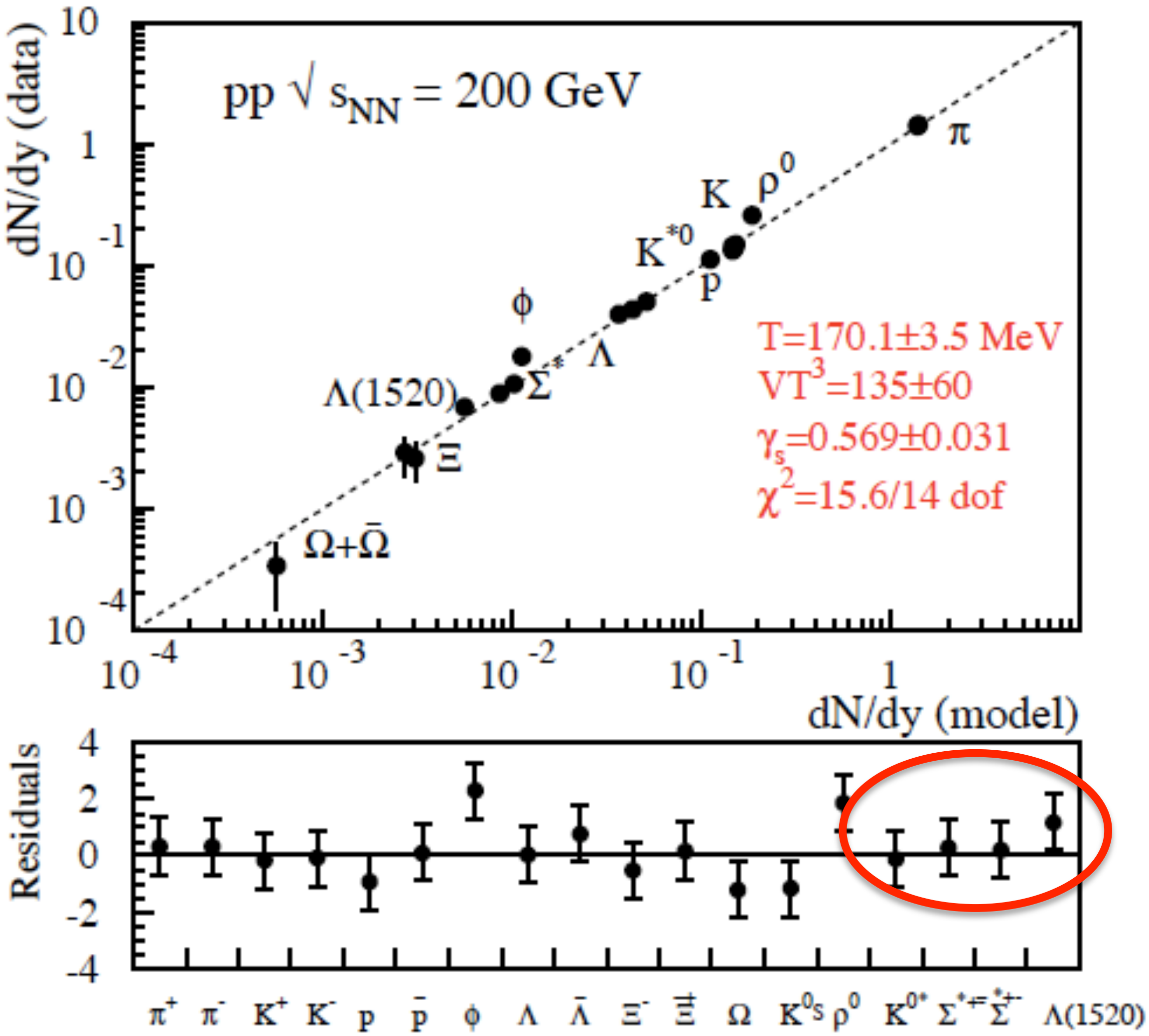


Mass = 1.53149 +- 0.00044

Dhevan Gangadharan

Resonances in p+p at 200 GeV

Eur.Phys.J.C66:377-386,2010

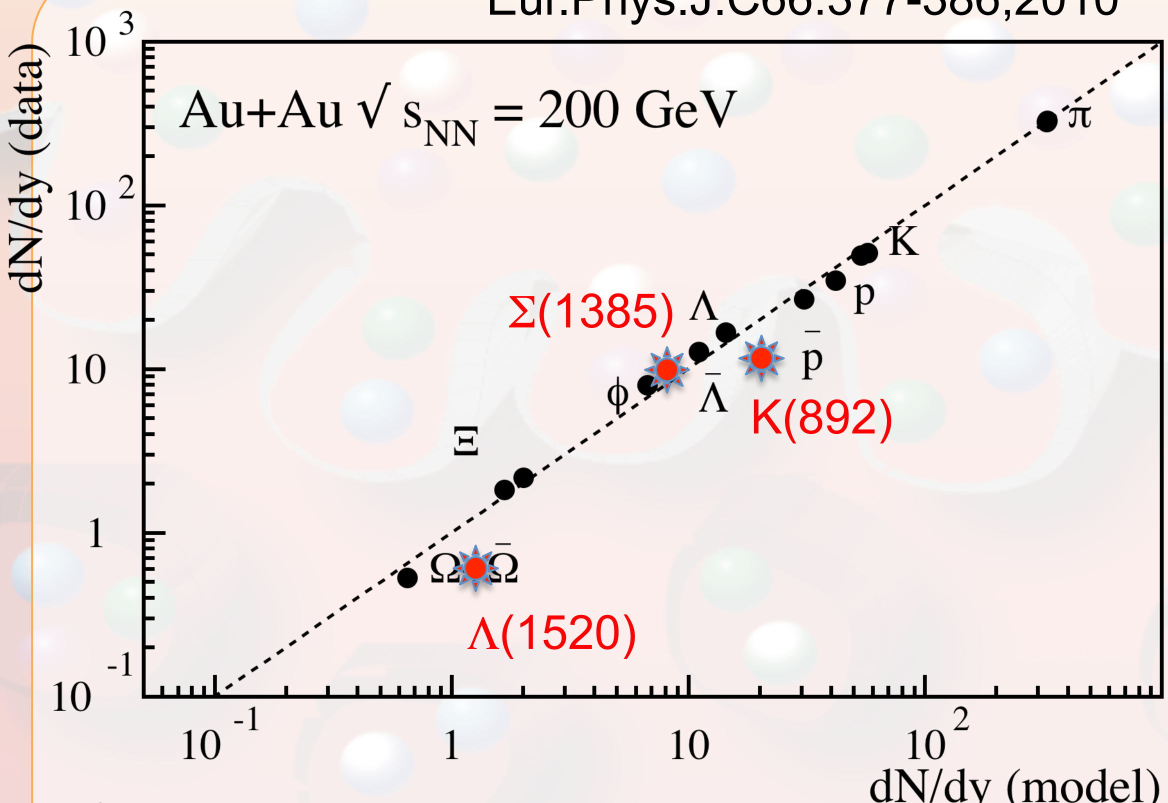


K(892),Σ(1385),Λ(1520) are in agreement with statistical model description

ρ,φ are too low by 2σ

Resonances in Au+Au at 200 GeV

Eur.Phys.J.C66:377-386,2010

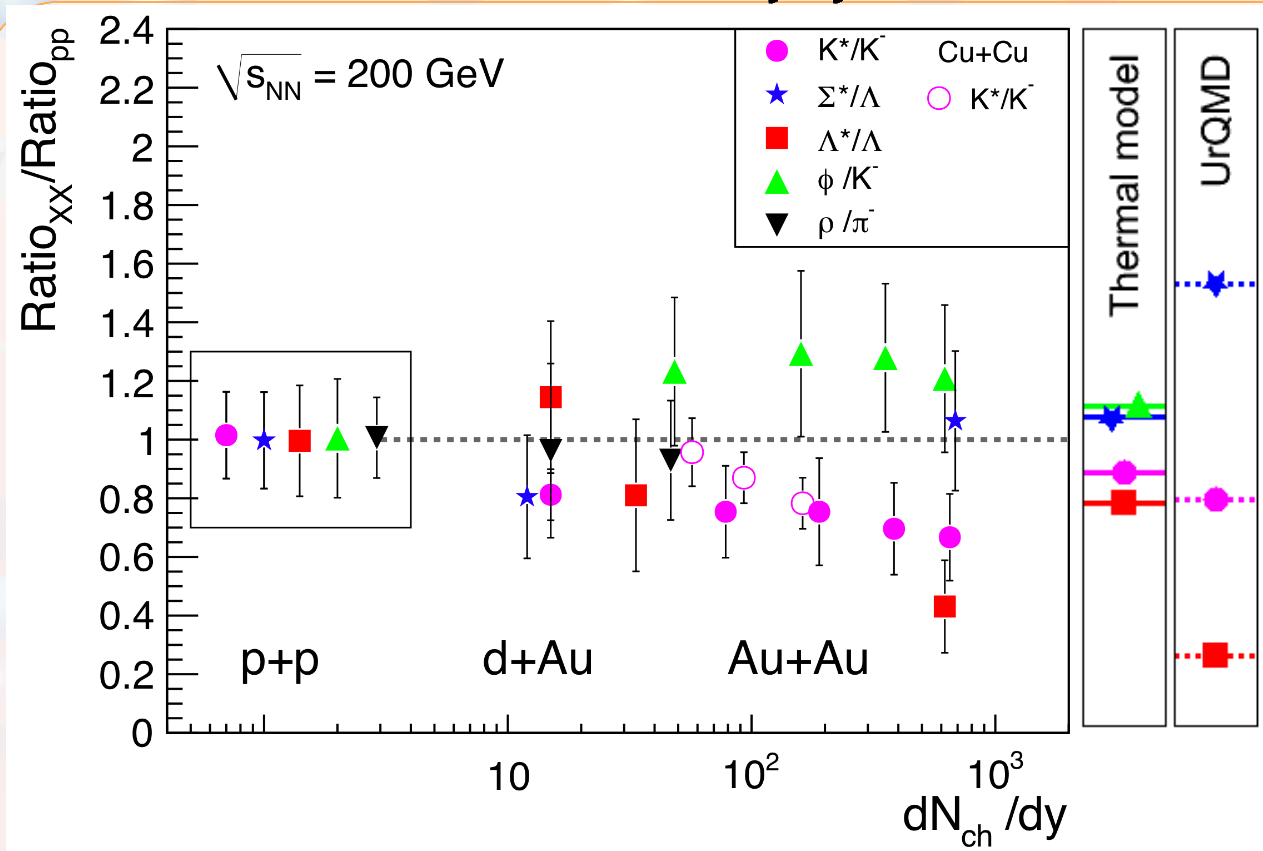


K(892), Λ(1520) Not described by statistical model →re-scattering of decay daughters

T = 168 +- 4 MeV
γs =0.932 +- 0.040

Resonance yields cannot be described with chemical freeze-out model if extended hadronic phase is present (RHIC and SPS (LHC?)

Resonance suppression at RHIC

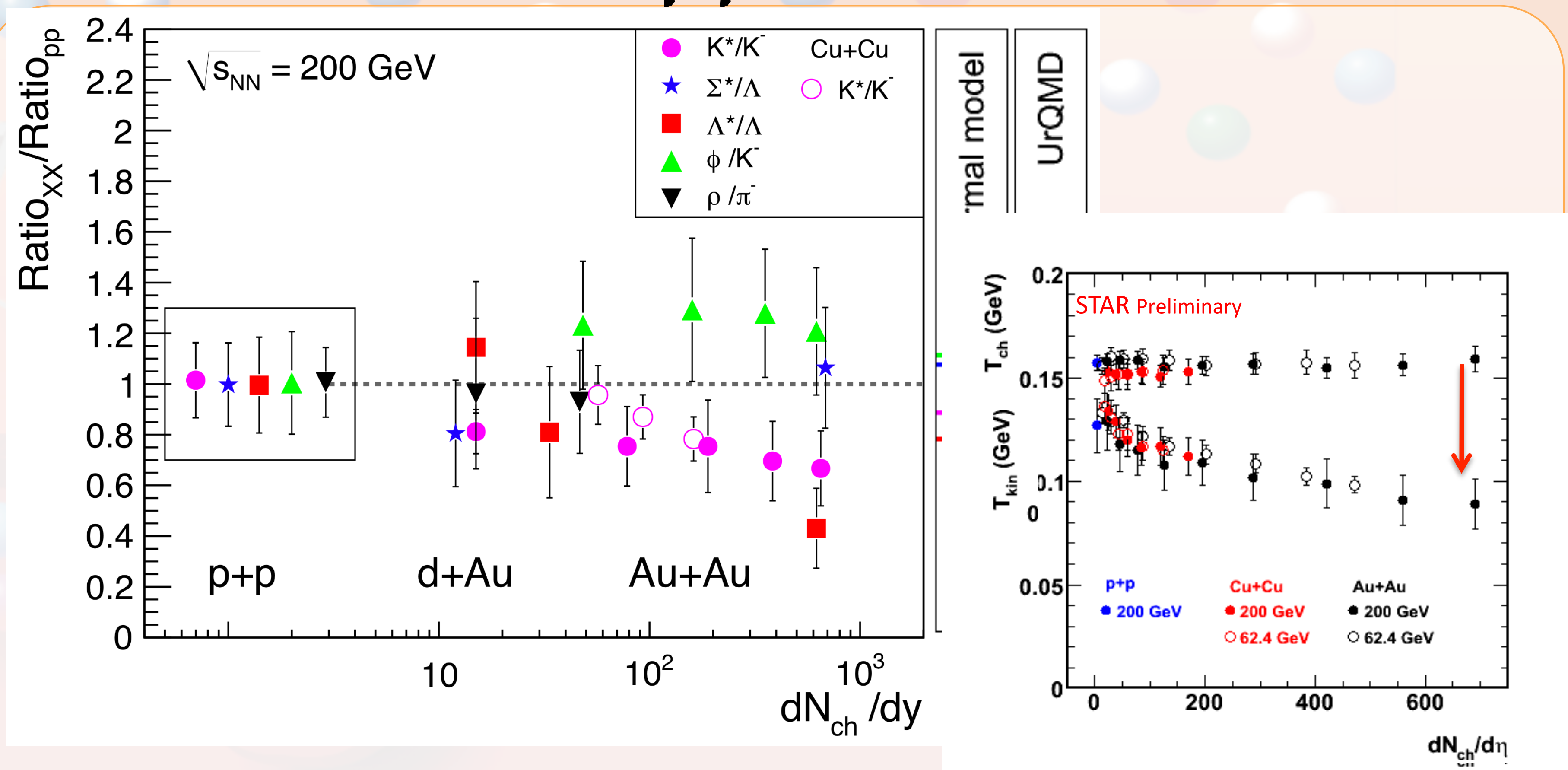


Phys. Rev. Lett. 97 (2006) 132301
Phys. Rev. C 78 (2008) 44906
e-Print Archives (1006.1961)

Hadronic lifetime > 4-5 fm/c (in central collisions)
Fireball lifetime ~ 10 fm/c
→partonic lifetime ~ 5 fm/c

CM, G. Torrieri and J. Rafelski, hep-ph/0206260

Resonance suppression at RHIC



Phys. Rev. Lett. 97 (2006) 132301
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Hadronic lifetime > 4-5 fm/c (in central collisions)
Fireball lifetime ~ 10 fm/c
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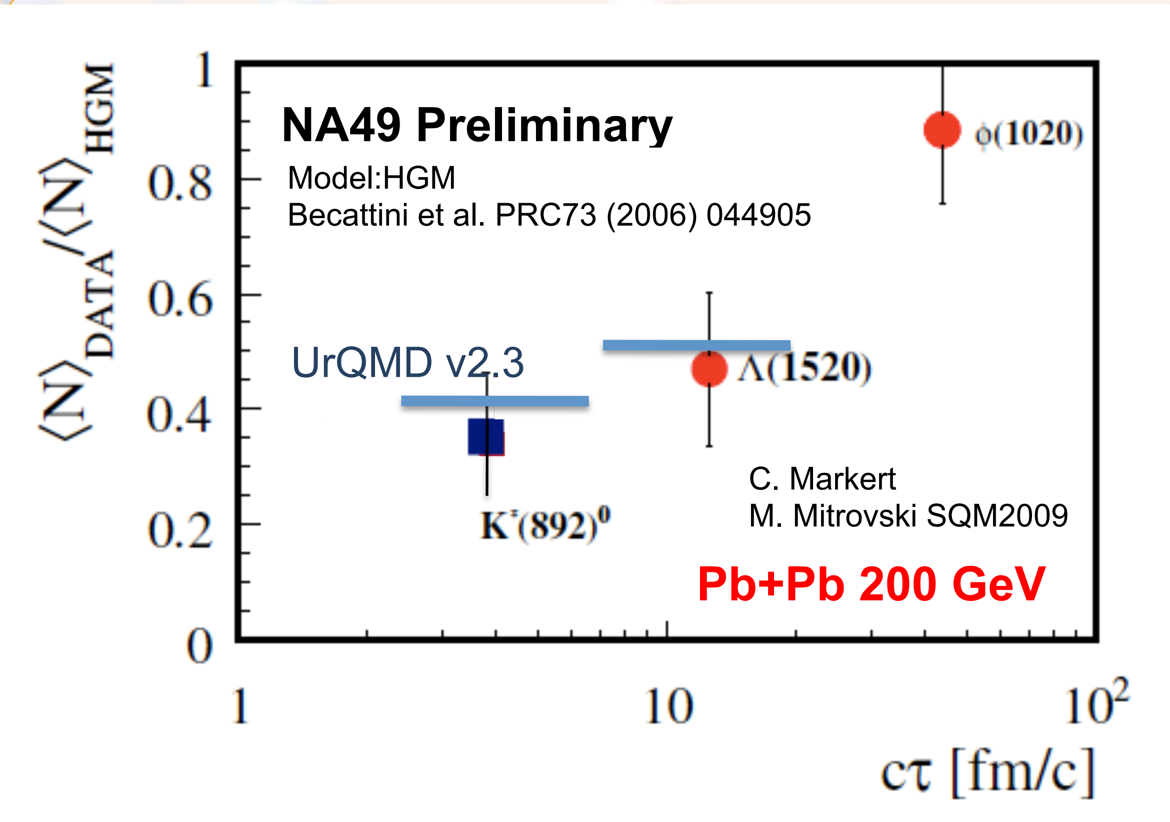
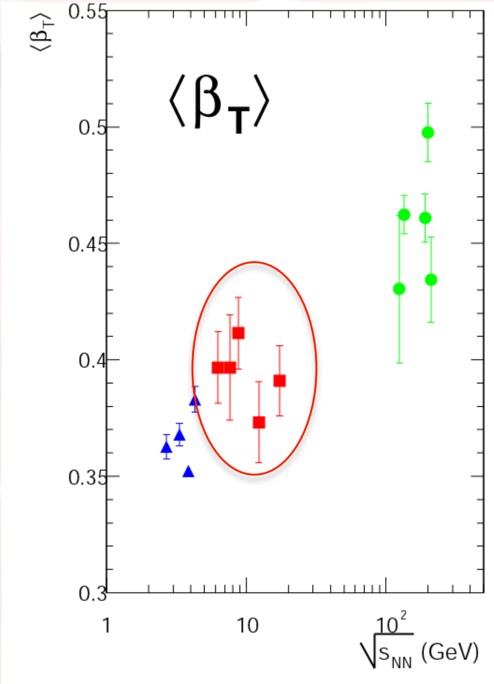
CM, G. Torrieri and J. Rafelski, hep-ph/0206260

Resonances at lower energies (SPS)



Tch and Tkin are similar at SPS and RHIC

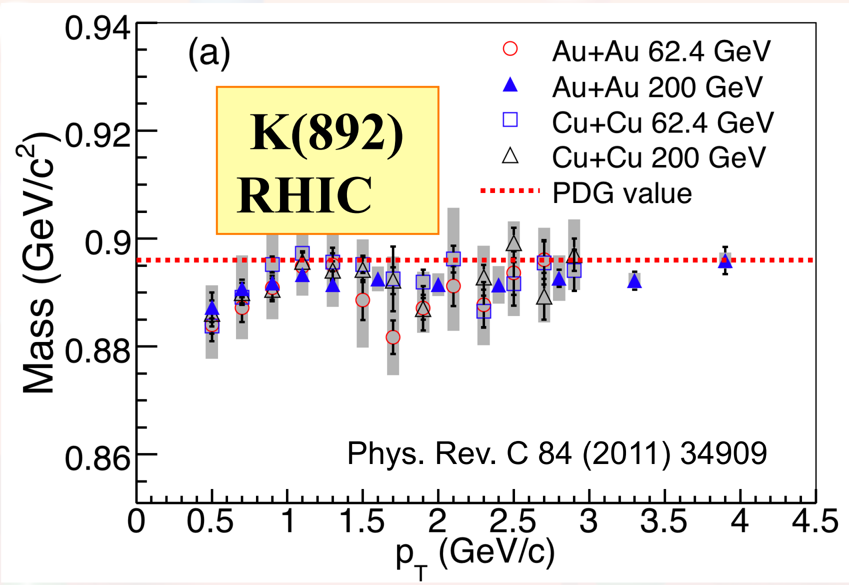


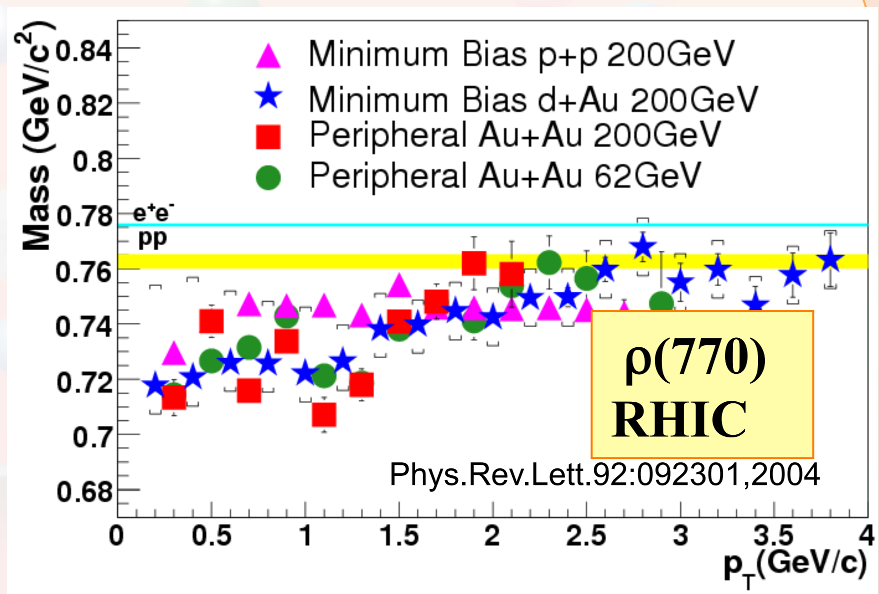
Larger resonance suppression at SPS than at RHIC:

→ More re-scattering than regeneration

→ Suggest longer lifetime of hadronic phase

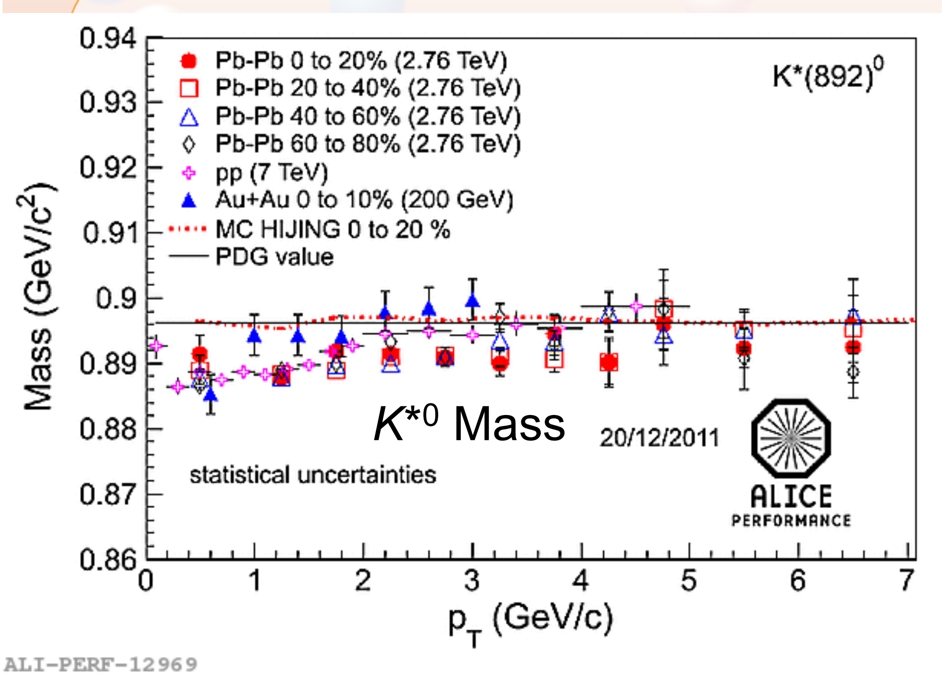
Resonance mass and width (STAR)

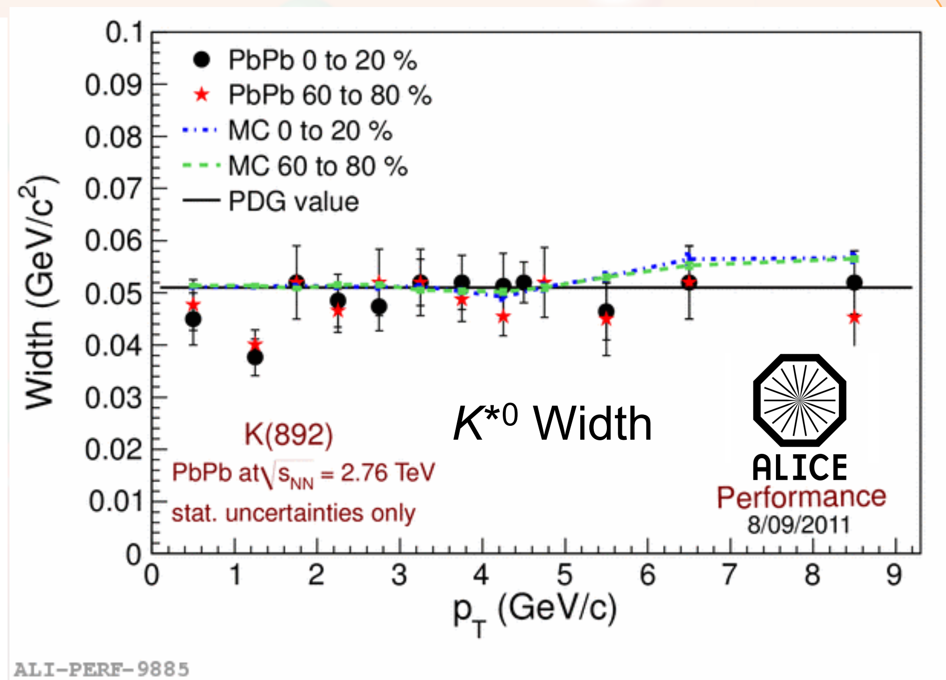


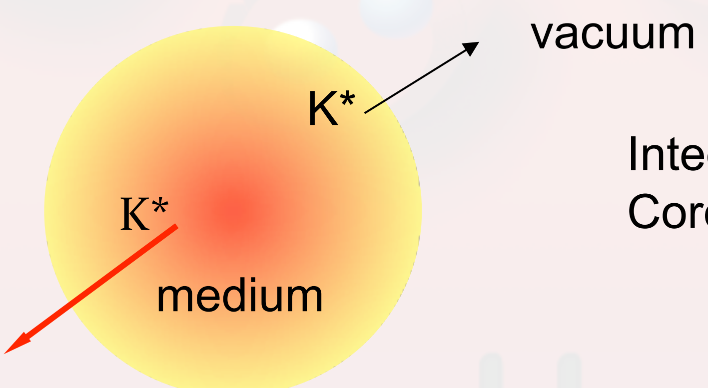


- No mass shift for K(892) visible within statistical and systematical errors.
- ρ same mass shift in all system sizes
- All other resonances don't show mass shift or width broadening (ϕ, Λ^*, Ξ^*, Σ^*)

Resonance mass and width (ALICE)







Integrated over all positions and orientations
Core corona effect ?

Measure chiral symmetry restoration

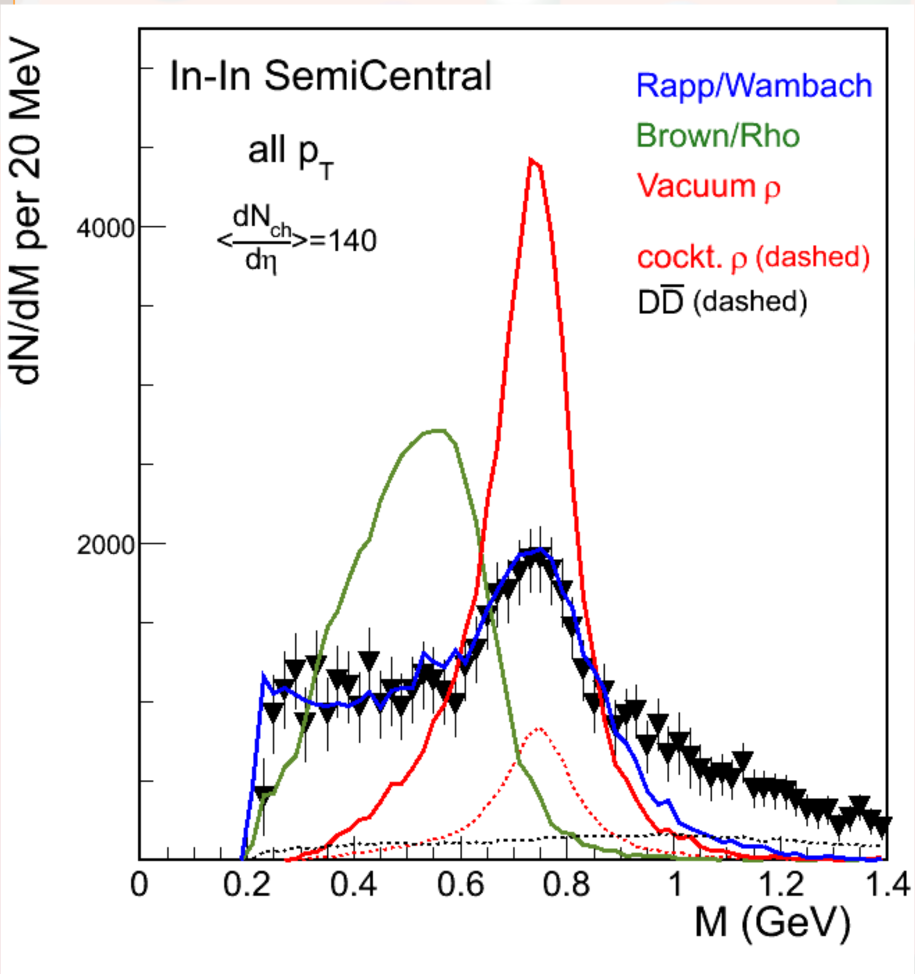
1. via leptonic decay of resonances

→ do not interact with hadronic medium

However leptonic decays from regenerated resonances possible

ρ dropping mass vs broadening NA60 SPS

Rapp-Wambach: hadronic model predicting strong broadening/no mass shift
Brown/Rho scaling: dropping mass due to dropping of chiral condensate



Predictions for In-In by Rapp et al (2003) for $dN_{ch}/d\eta$ = 140, covering all scenarios

Theoretical yields normalized to data in mass interval < 0.9 GeV

Only broadening of ρ (RW) observed, no mass shift (BR)

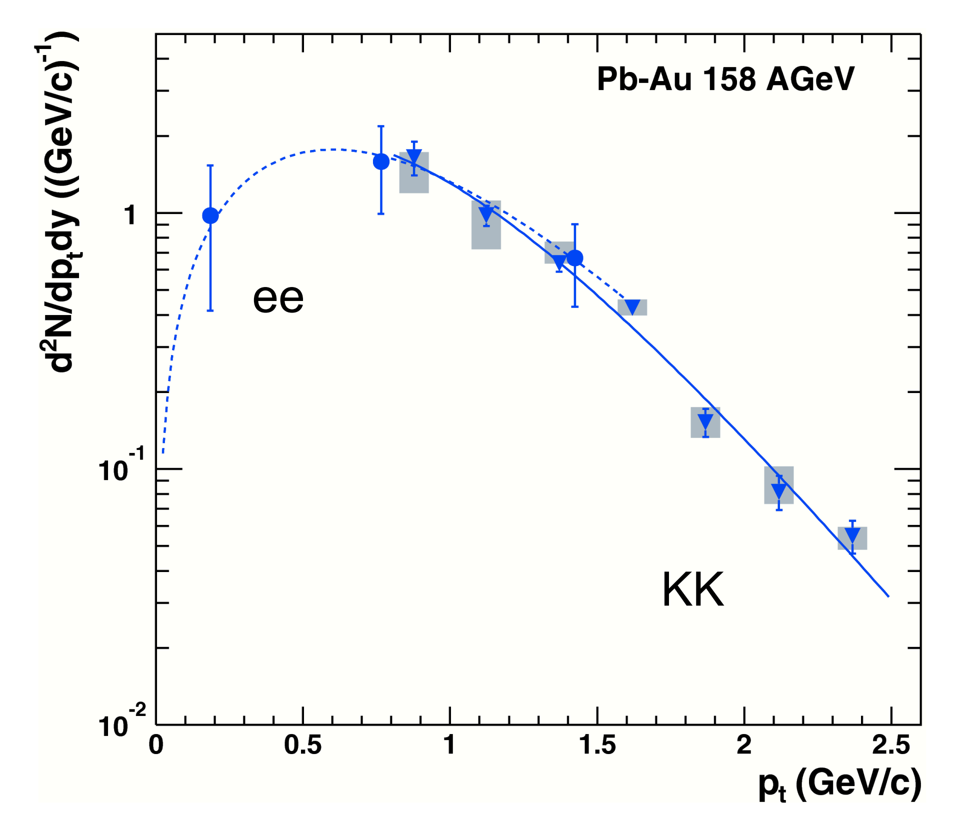
No width broadening at RHIC in hadronic decay

Consistent with other resonances
in all momentum ranges ?

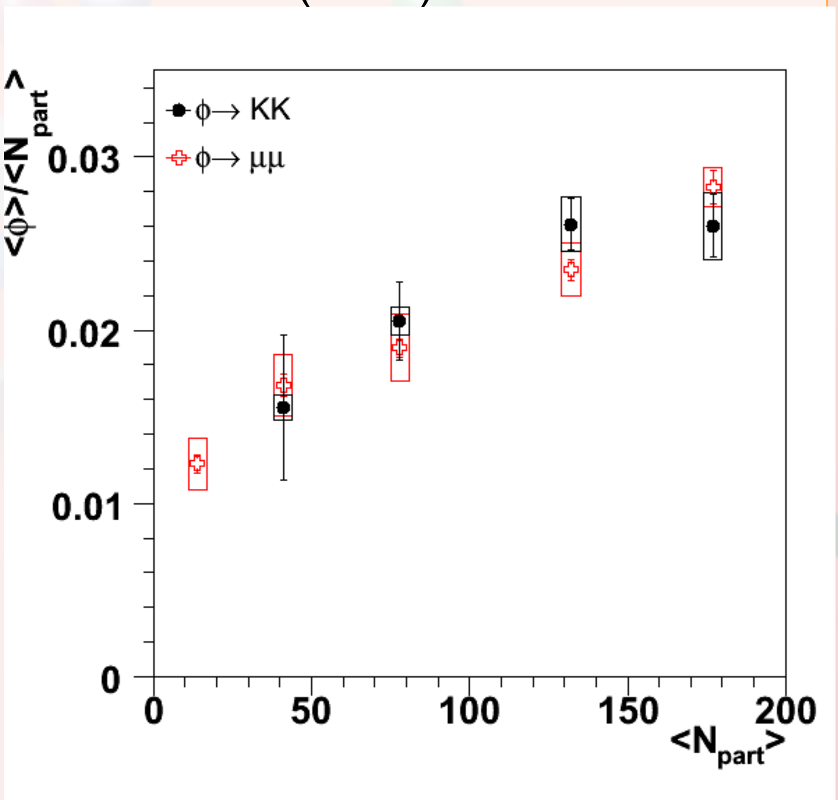
If medium width broadening is only
effecting low pt region
Check with low and high momentum
(pt ≈ 5GeV/c) rho ?
→ Really no width broadening at high pt ?

φ(1020) measurement at SPS

CERES,Phys. Rev. Lett. 96, 152301 (2006)



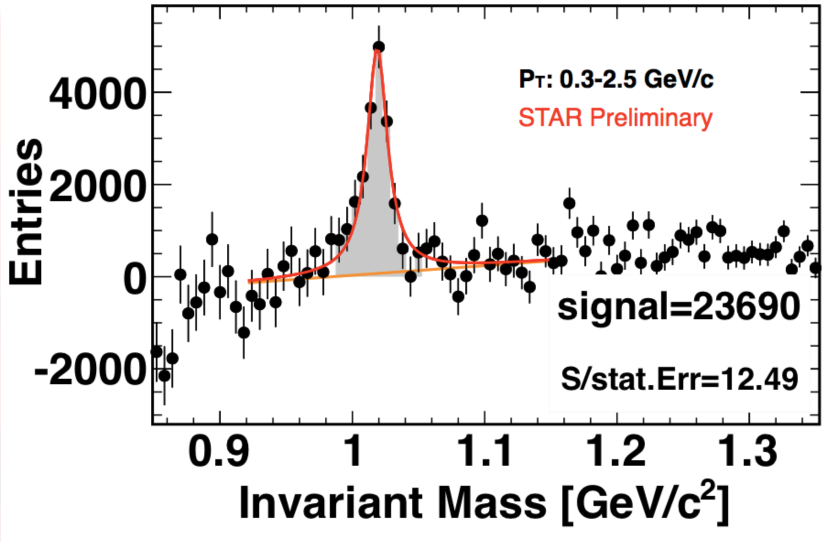
NA60 (In+In)

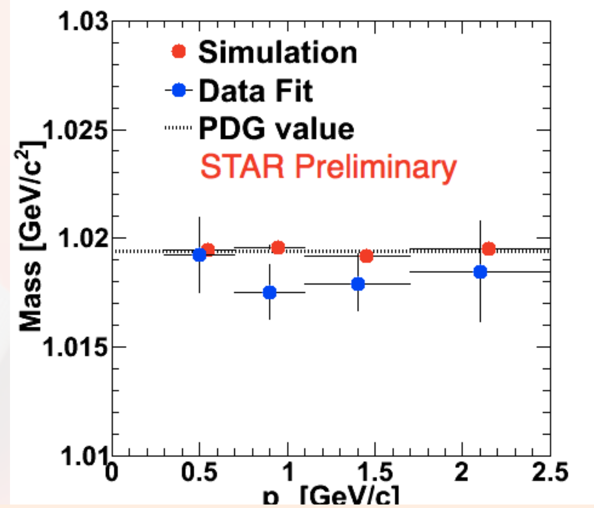


φ(1020) does not show mass shift or width broadening

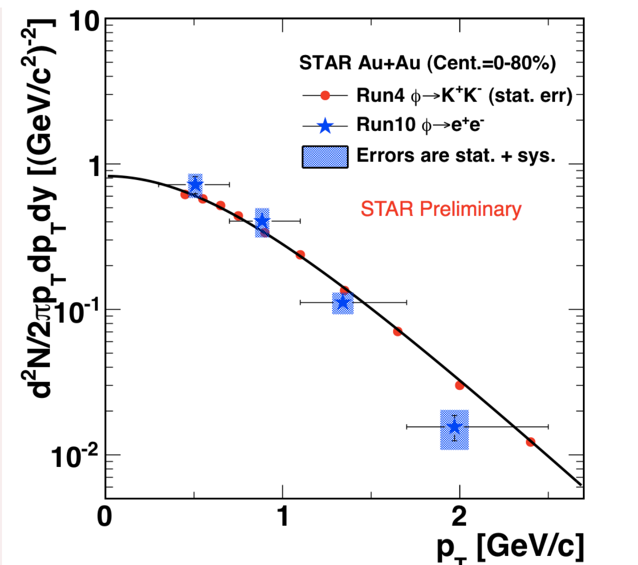
Di-electron measurement (STAR)

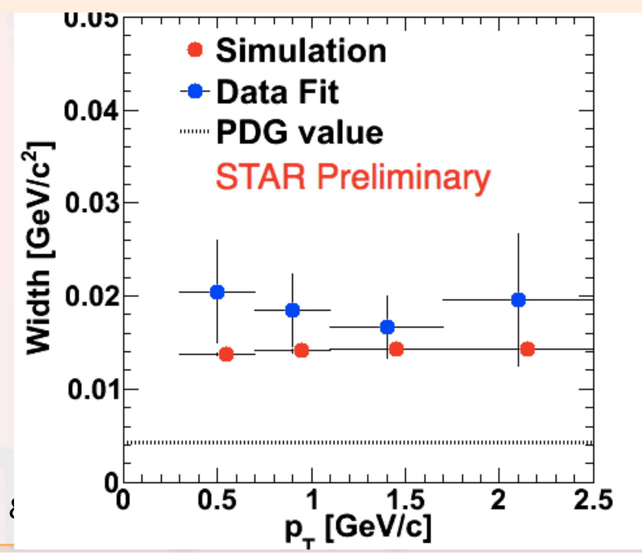
Masayuli Wada Vol. 5 (2012). Acta Physica Polonica B Proceedings SQM2011.





Masses and width are in agreement with PDG+ detector resolution





Measure chiral symmetry restoration

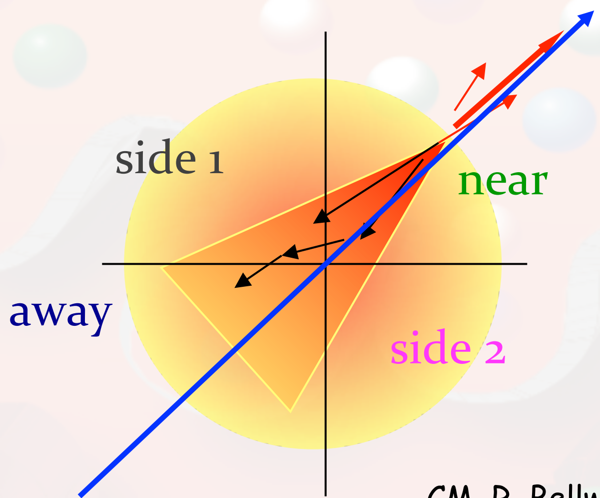
2. Use momentum dependence to avoid hadronic phase.

via resonances from jets

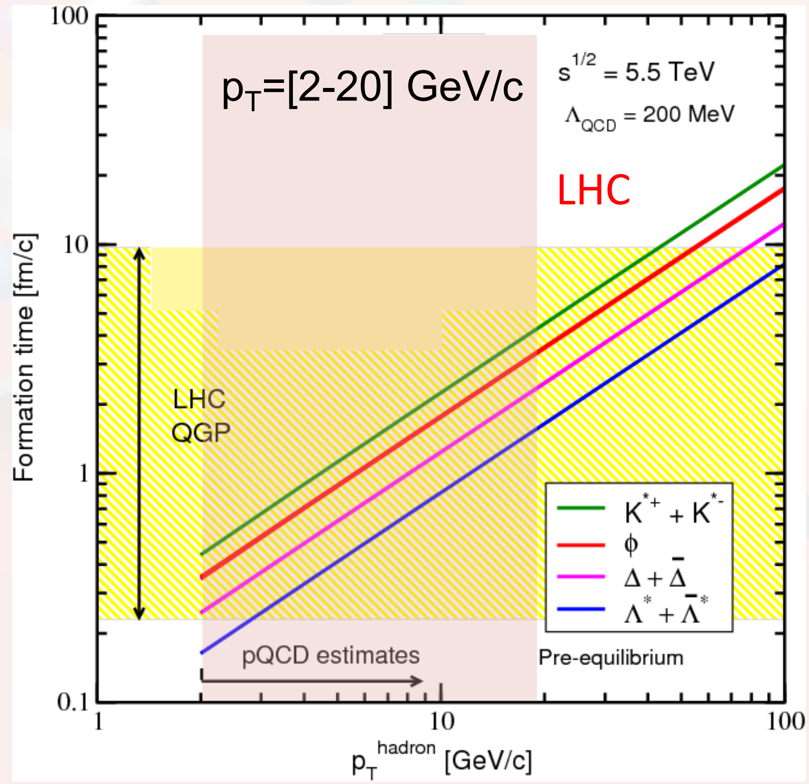
→ filter resonances from early medium

Resonances from jets to probe chirality

Resonance with respect to jet



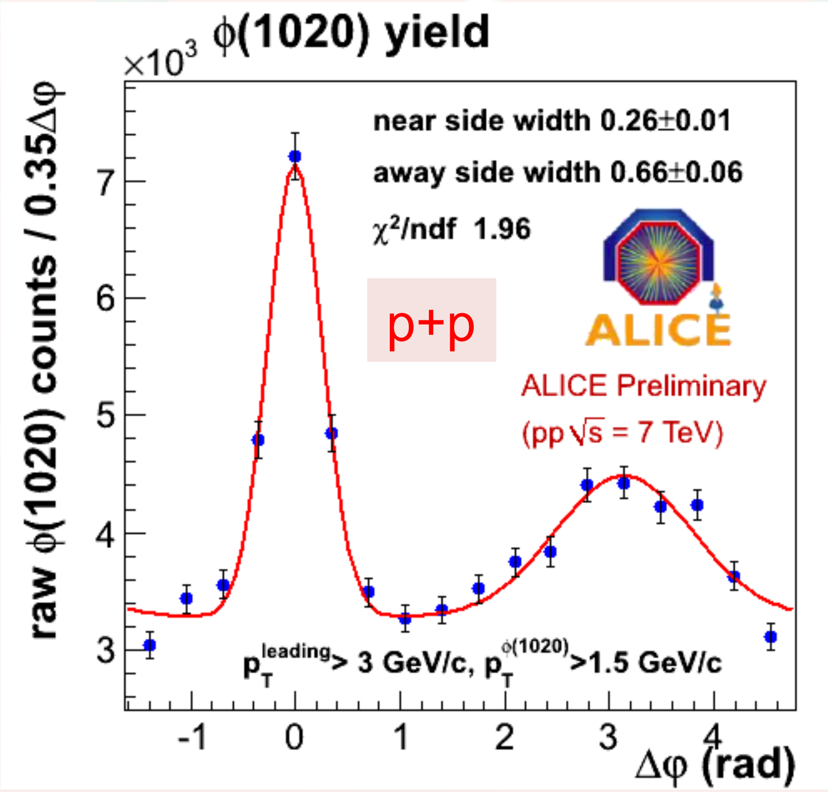
CM, R. Bellwied, I.Vitev, Phys.Lett.B669:92-97,2008



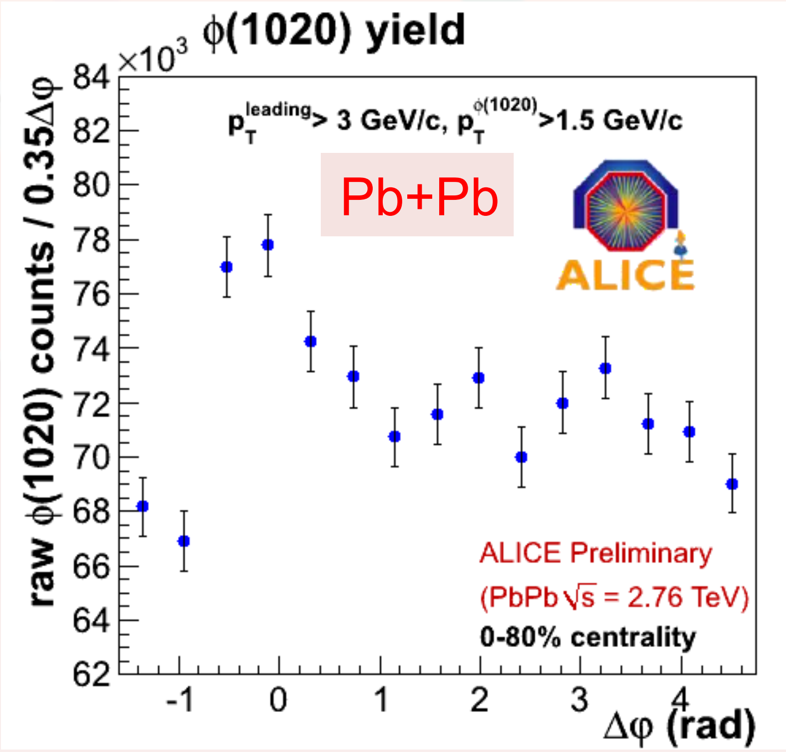
side	Low p_T	High p_T
near	no medium	no medium
away	hadronic medium → Resonance suppression	Partonic or early hadronic medium →Mass shift and/or width broadening →Chiral medium

Hadron – ϕ(1020) correlation

hadron p_T > 3 GeV/c, ϕ(1020) p_T > 1.5 GeV/c

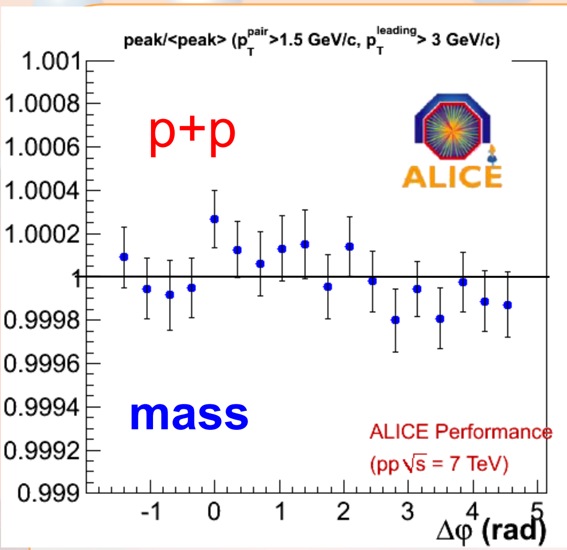


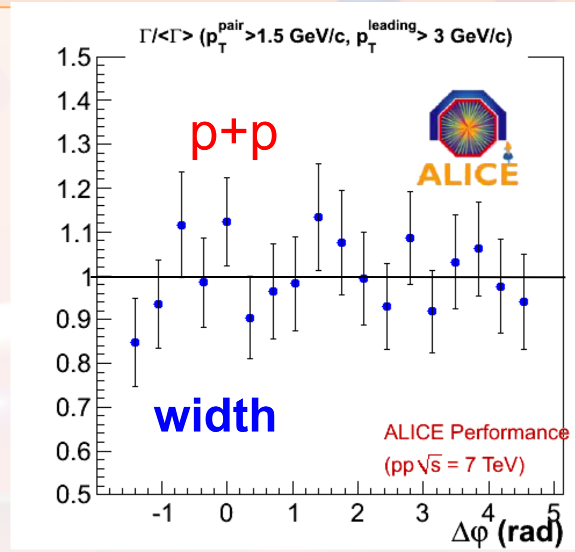
jet/ BG = 1/1



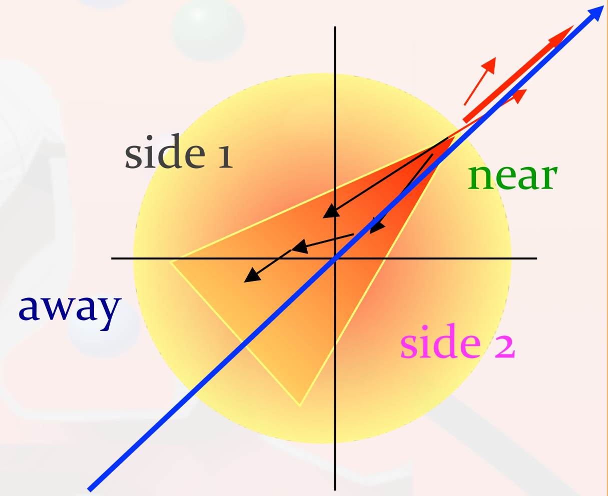
jet/ BG = 1/10

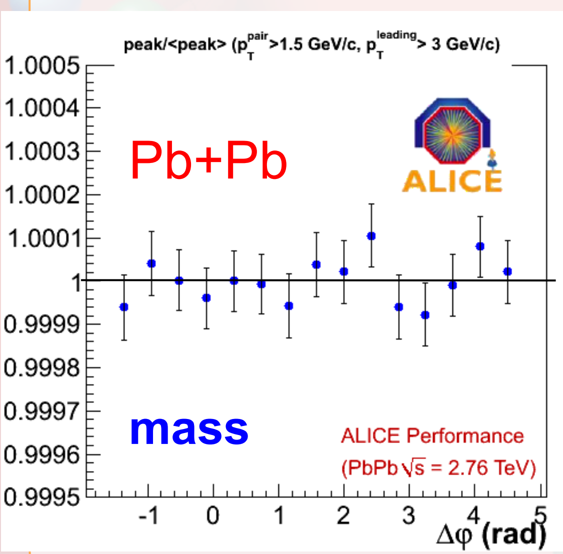
ϕ(1020) - mass and width

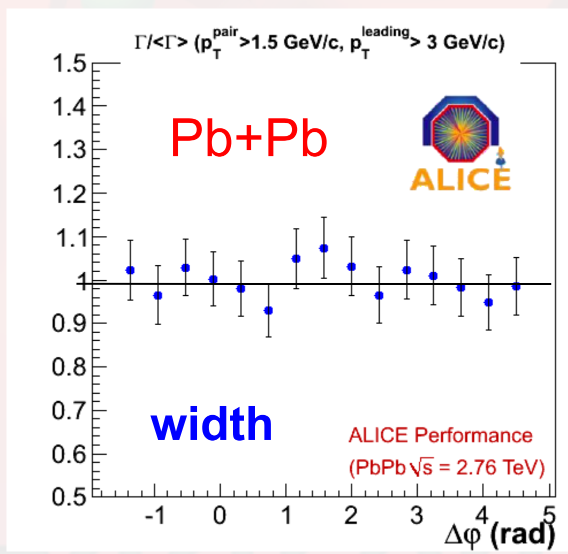




Resonance with respect to jet







Mass and width:
same-side = away-side

Conclusion

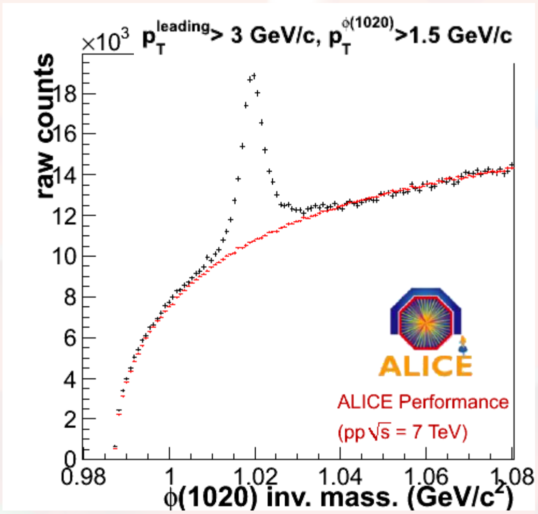
Hadronic resonances are measured at different energies and system sizes. Can be used to extract hadronic lifetime→ partonic lifetime.

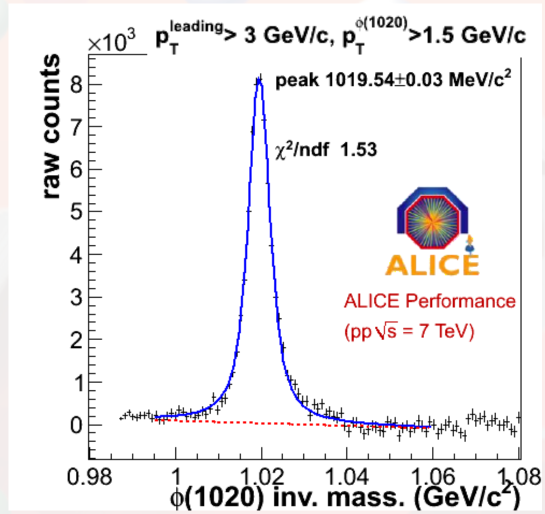
No mass shift observed in heavy ion collisions.

We need to find best momentum range (time window) to test chiral symmetry restoration.

Selected $\phi(1020)$

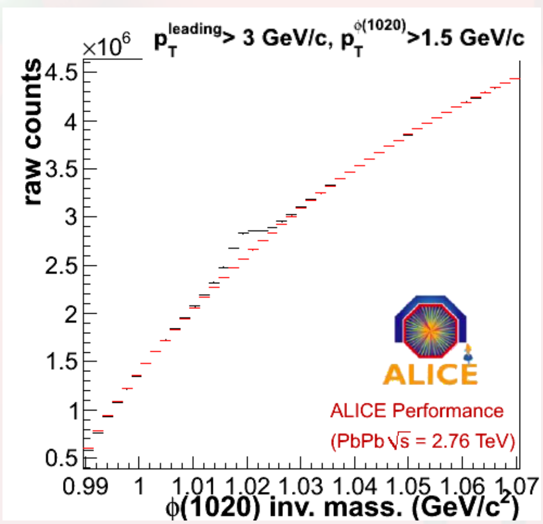
hadron p_T > 3 GeV/c, ϕ (1020) p_T > 1.5 GeV/c

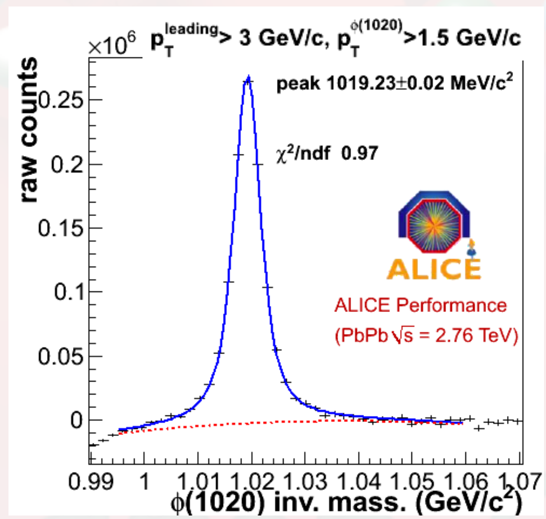




160 M p+p events

Mass is in agreement with PDG value





16 M Pb+Pb events

Formation of Hadronic Resonances (from jets)

light cone variables:

large z (= p_h / p_q)
= Resonance is leading particle in jet
→shortens formation time
→color neutral pre-hadron (resonance)

$$\tau_{\rm form} = \tau_0 \frac{E}{m}$$

τ_o ~ 1 fm/c :

τ ~ 4.5 fm/c

$$\Delta y^+ \simeq \frac{1}{\Delta p^-}$$

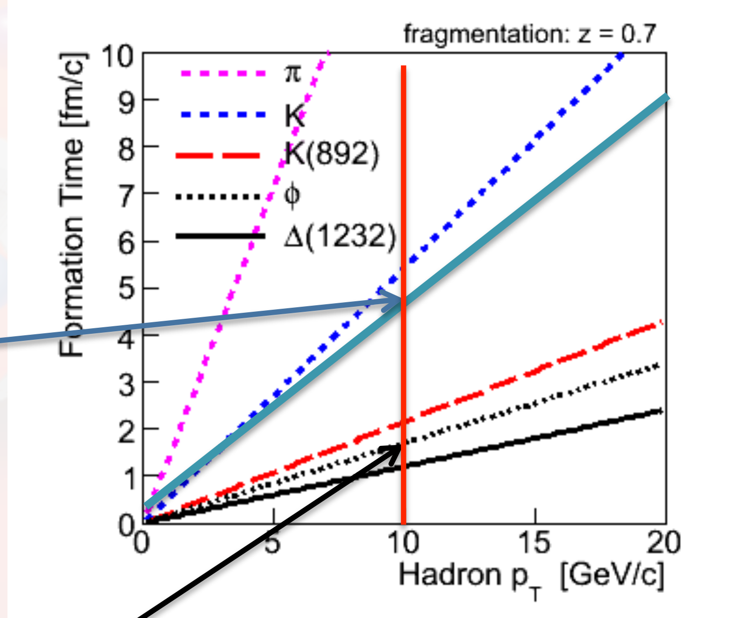
$$= \frac{zp^+}{m_h} \times 2 \left[m_h + \frac{\mathbf{k}^2}{(1-z)m_h} - \frac{z m_q^2}{m_h} \right]^{-1} . \quad (3)$$

The formation time then reads:

$$\tau_{\rm form} = \frac{\Delta y^+}{1+\beta_q} , \quad \beta_q = \frac{p_q}{E_q} .$$

τ ~ 1.5 fm/c

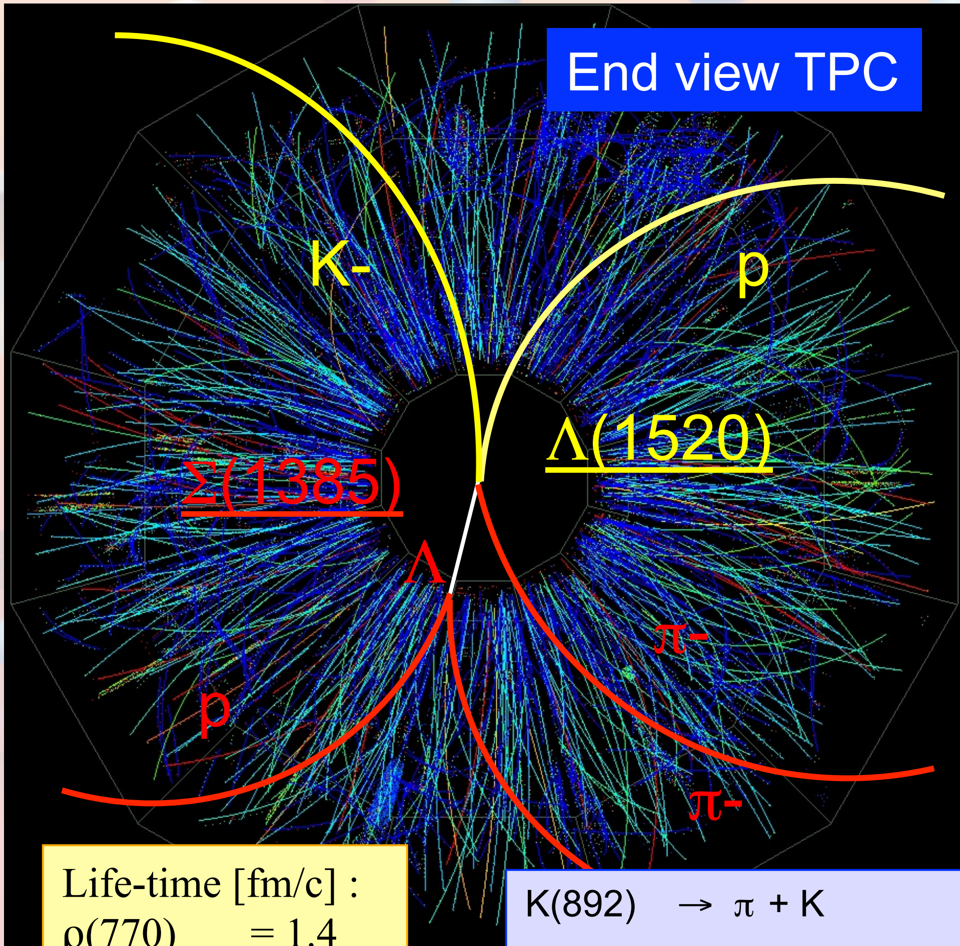
10 GeV/c $\phi(1020)$

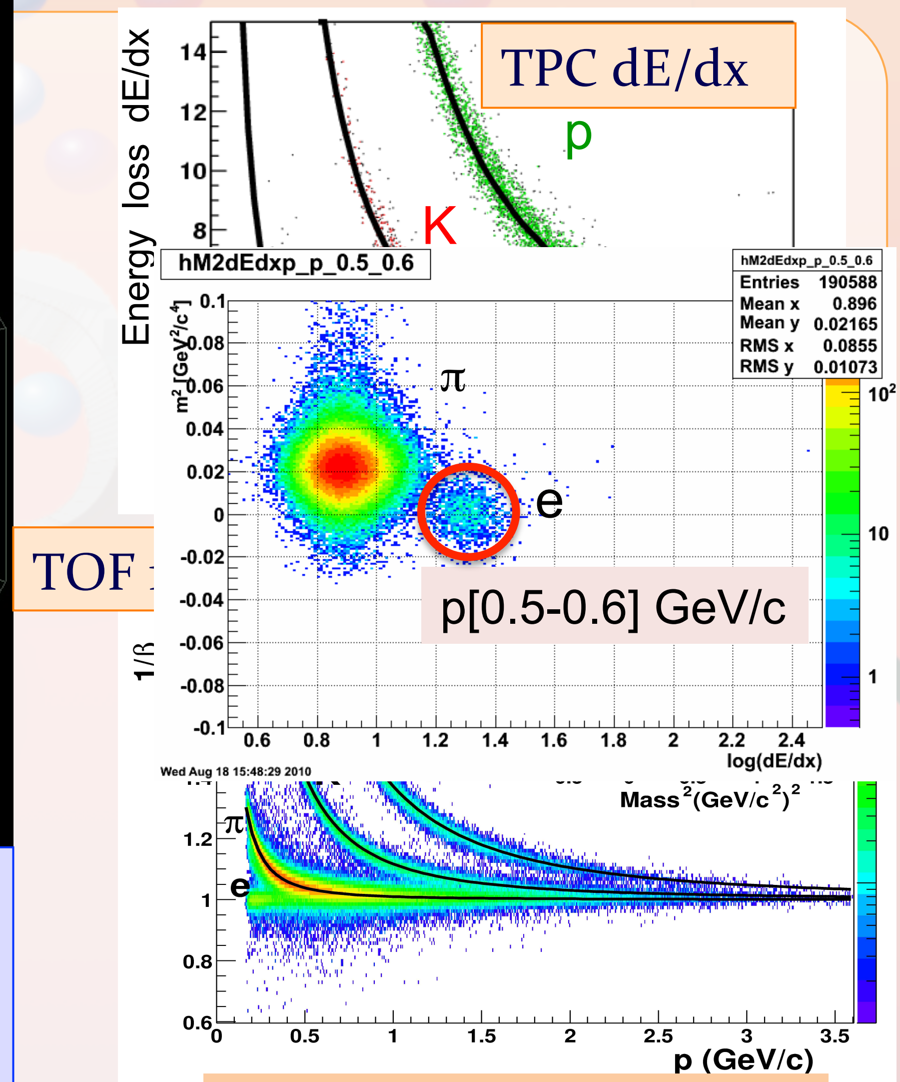


CM, R. Bellwied, I.Vitev, Phys.Lett.B669:92-97,2008

Heavier particles of same momentum formed earlier
High momentum particles formed later

Resonance reconstruction





Life-time [fm/c] :

ρ(770)	= 1.4
Δ(1232)	= 1.6
K(892)	= 4.0
Σ(1385)	= 5.7
Λ(1520)	= 13
Ξ(1530)	= 20
ϕ (1020)	= 45

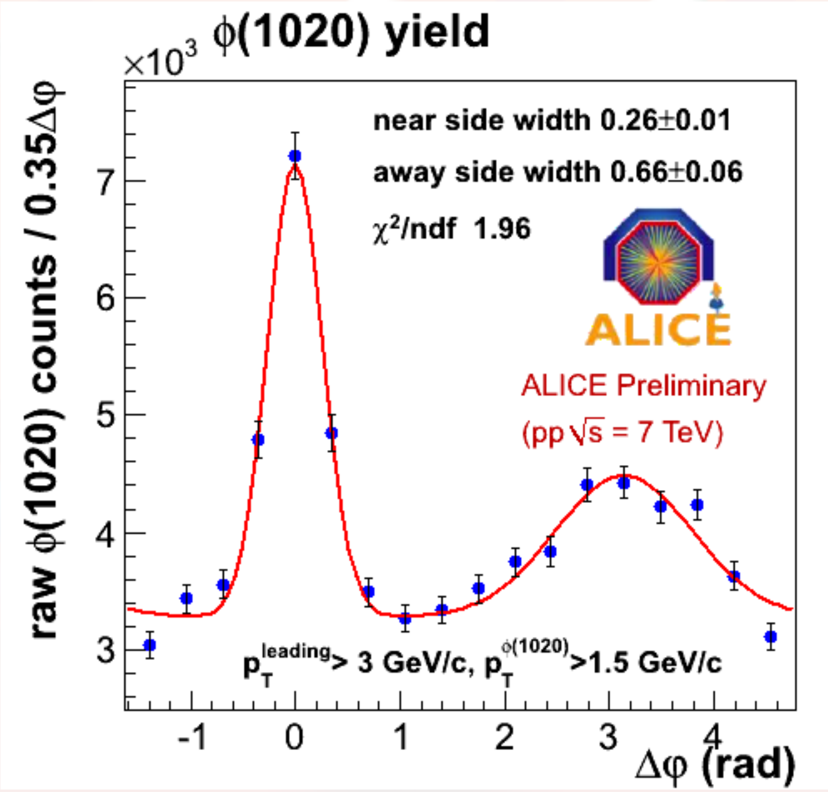
- K(892) → π + K
- ρ(770) → π + π
- ϕ(1020) → K + K, $e^+ + e^-$
- Δ(1232) → p + π
- Σ(1385) → Λ + π
- Λ(1520) → p + K
- Ξ(1530) → Ξ + π

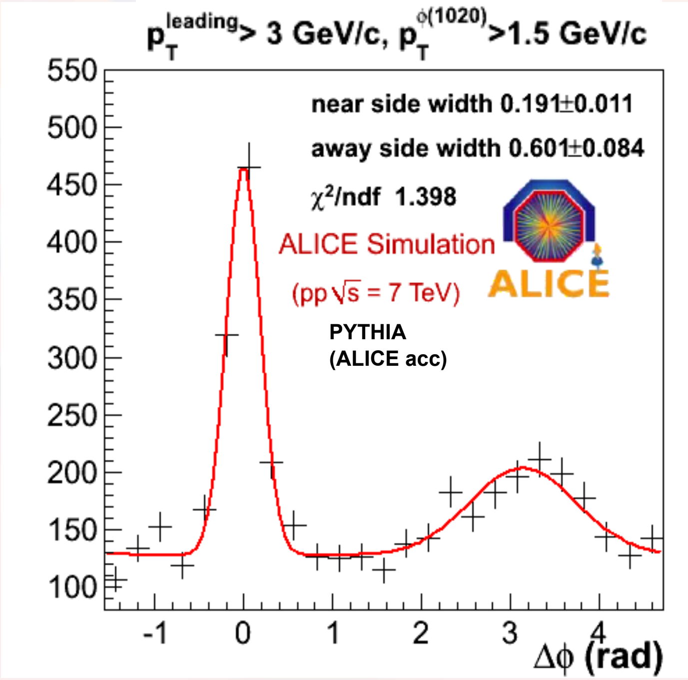
TPC resolution ~ 5-9%

TOF resolution = 100 ps (<1%)

Hadron – ϕ(1020) correlation (p+p)

hadron p_T > 3 GeV/c, ϕ(1020) p_T > 1.5 GeV/c



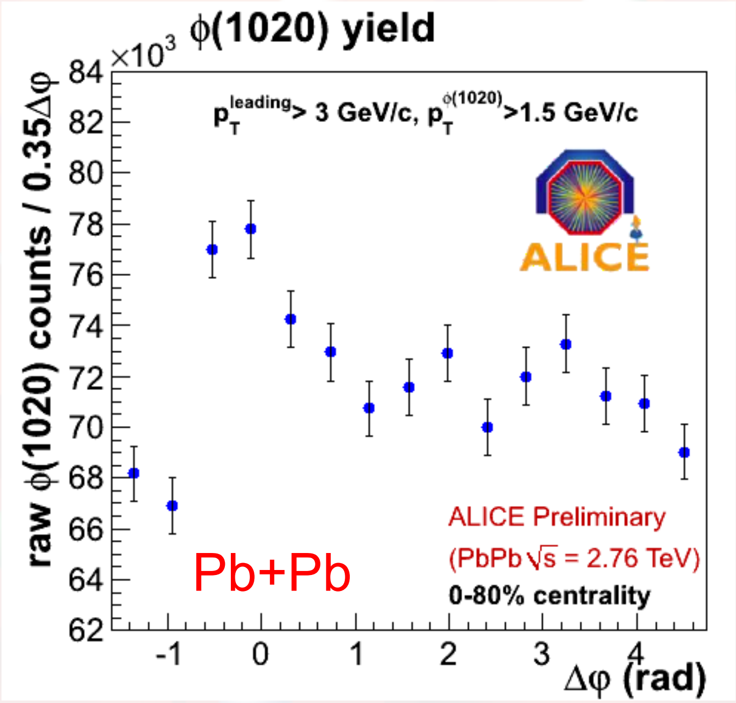


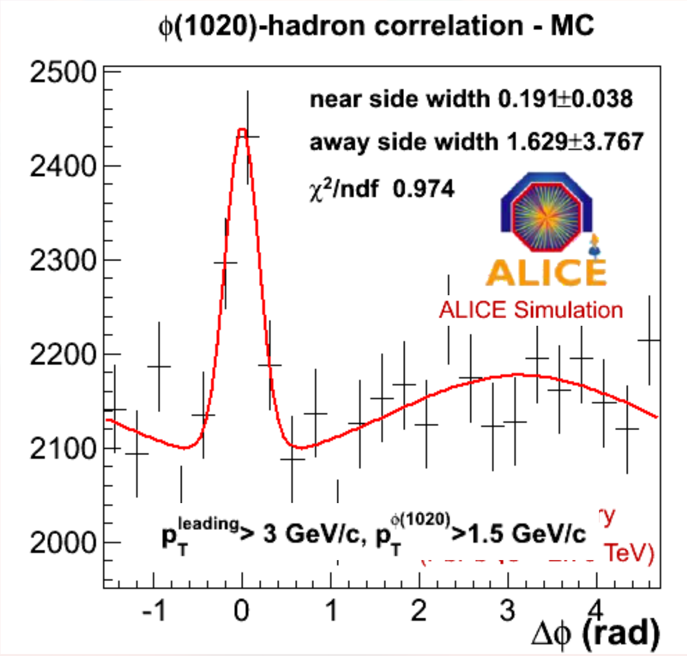
Pythia + ALICE acceptance

jet/ BG = 1/1

Hadron – ϕ(1020) correlation (Pb+Pb)

hadron p_T > 3 GeV/c, ϕ(1020) p_T > 1.5 GeV/c



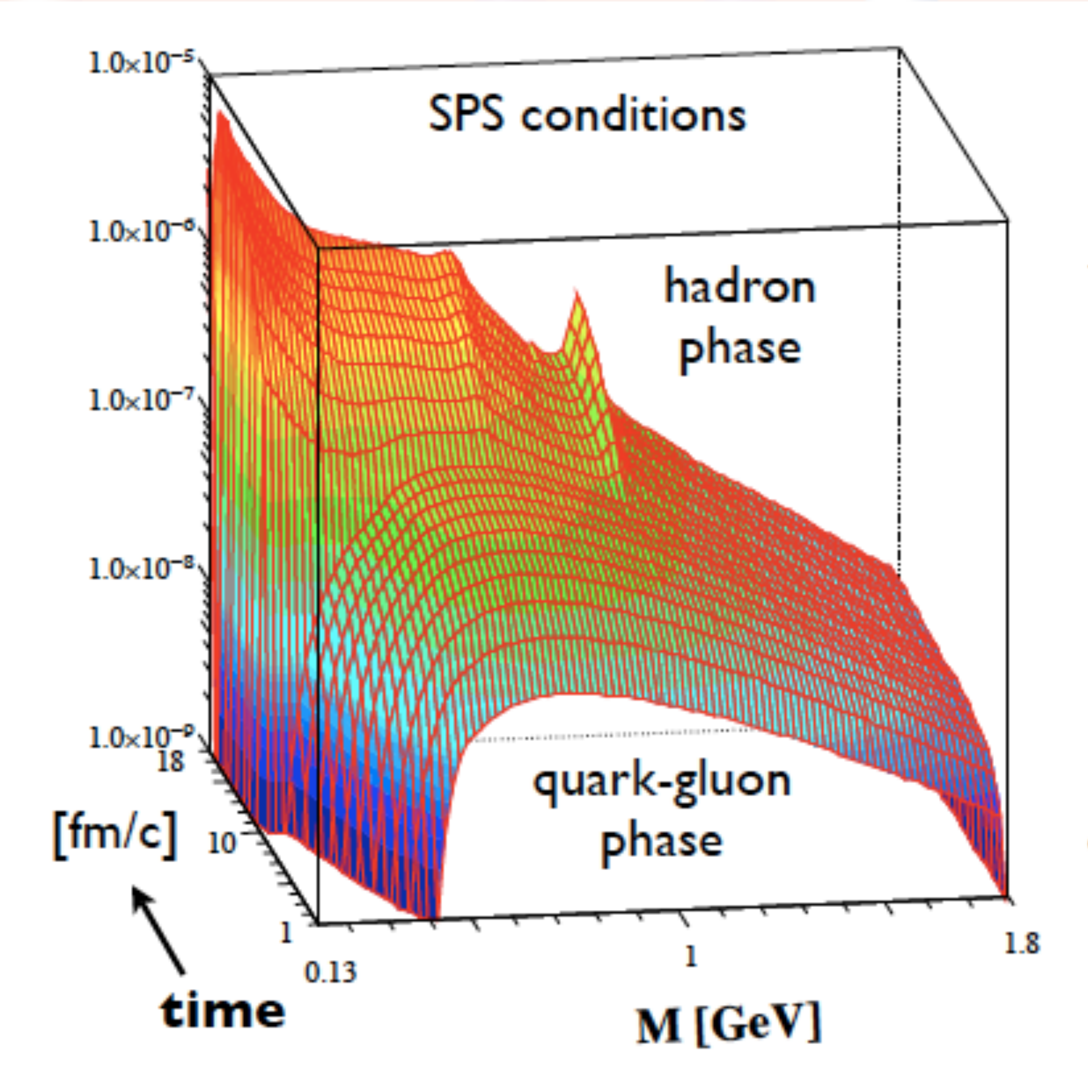


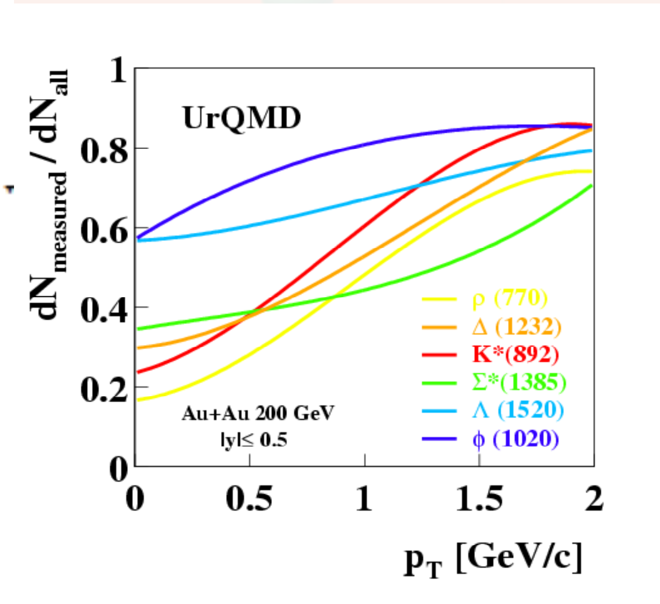
jet/ BG = 1/10

Hijing+ ALICE acceptance

30

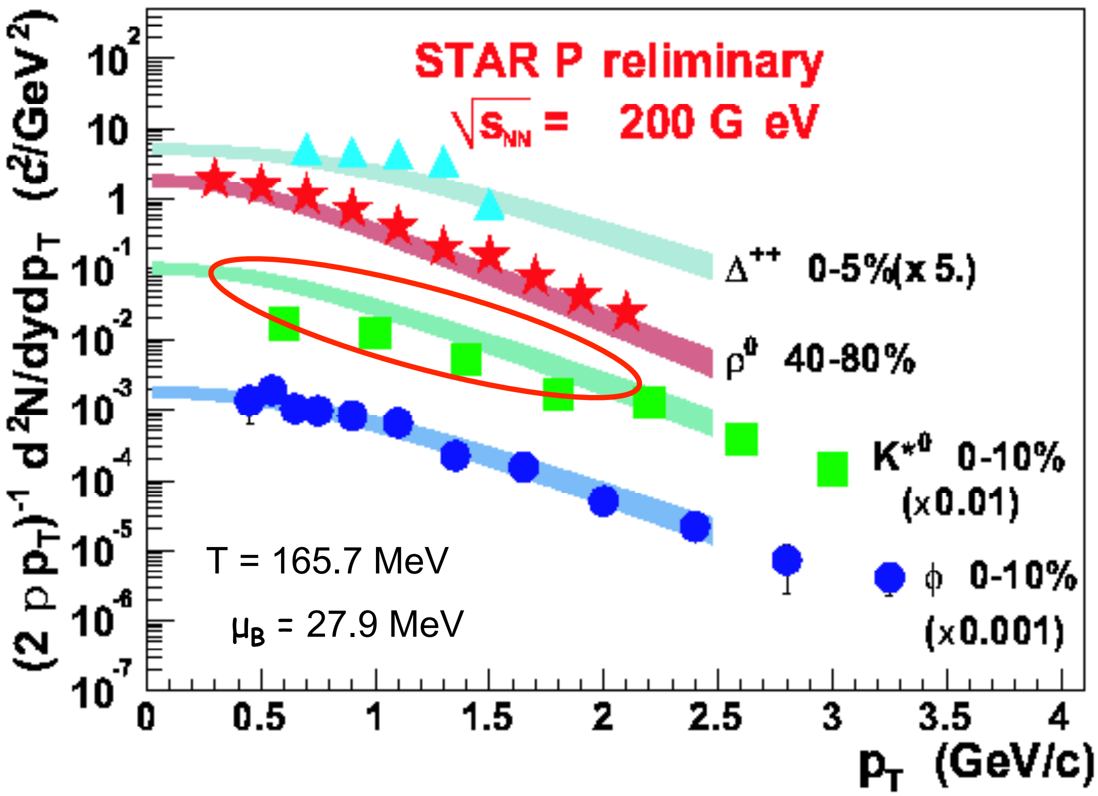
Contribution from momentum range

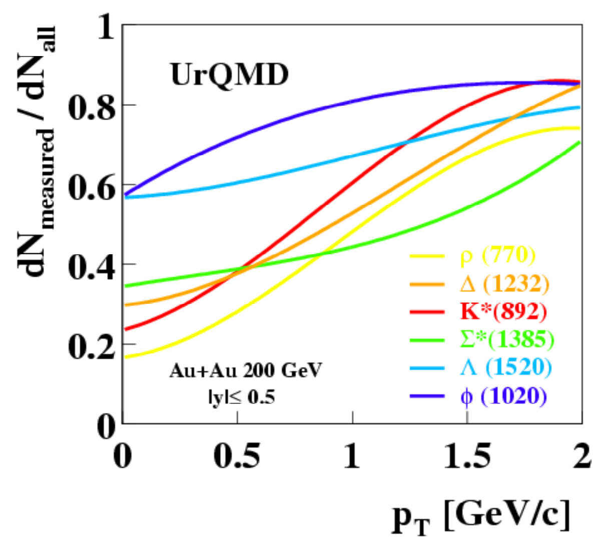




Particle spectra from thermal model

W. Florkowski, SQM2004





Signal loss for K* in low momentum region due to re-scattering in hadronic phase