E917 Results on Strangeness Production in Au+Au Collisions at AGS

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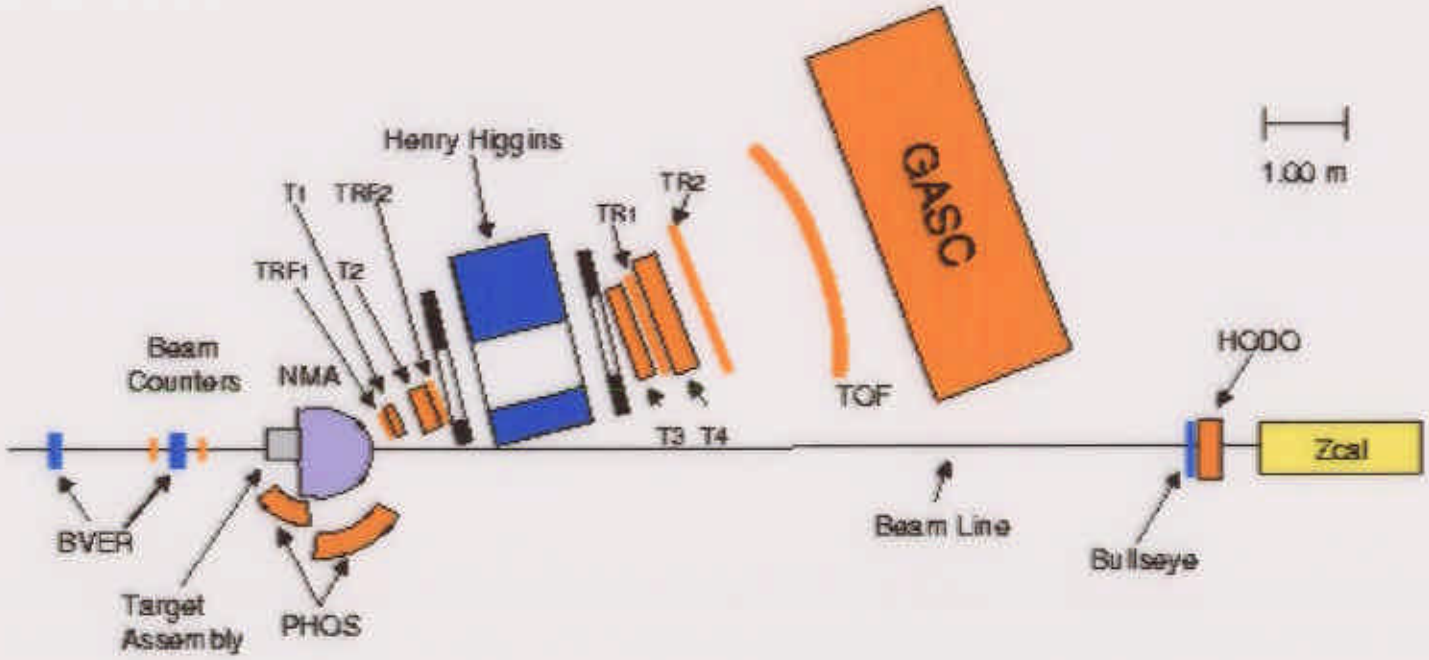
2000/07/27

Strangeness Enhancement as QGP signature

- Strange constituent quarks are absent in the initial state of NN collisions and have higher energy threshold to be produced.
- Strangeness Enhancement in the Relativistic Heavy Ion collisions relative to NN interactions:
  - Hadronic secondary scattering in heavy-ion collisions would help populate the strange hadrons.
  - The occurrence of a de-confined quark matter, Quark-Gluon-Plasma (QGP) in relativistic heavy ion collisions, would result in an abundant production of strange quarks and thus an enhanced production of strangeness-carrying particles after hadronization.
- Experimental baseline by pure (or mostly) hadronic interactions need to be established in order to distinguish the above two scenarios.

E917 Measurement of Strangeness Production at AGS



- K+,K– Yield at 6, 8, 10.8 GeV/c.
- ϕ Yield at 10.8 GeV/c.
- $\overline{\Lambda}$ Yield at 10.8 GeV/c.

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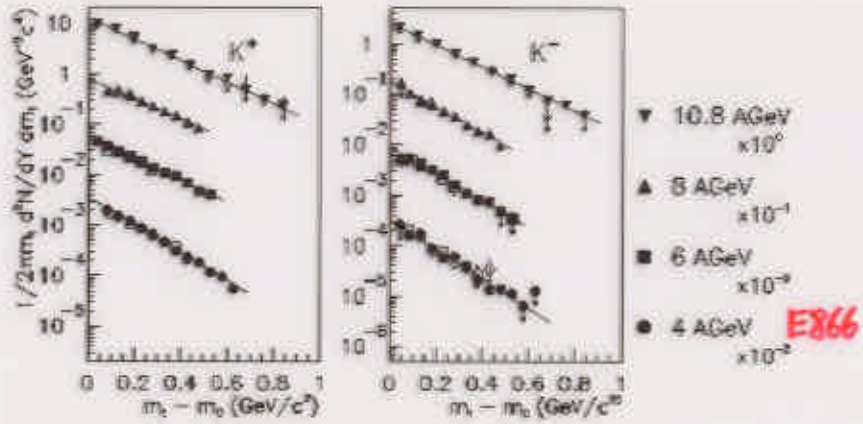
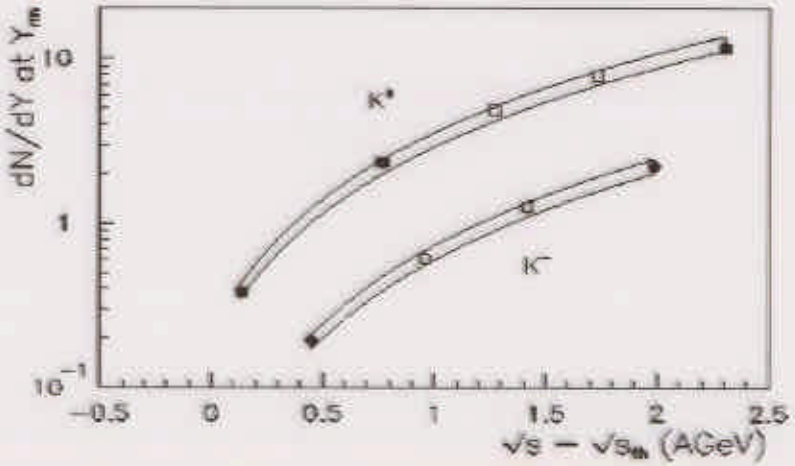
Excitation Function of K+,K–





J.C. Dunlop

- The mid-rapidity spectra and yield of K+ and K– at 4, 6, 8 and 10.8 AGeV.
- K+ , K– and K–/K+ ratio(~0.2) increases with beam energy above production threshold.
- No sudden jump in the production is observed within this energy range.

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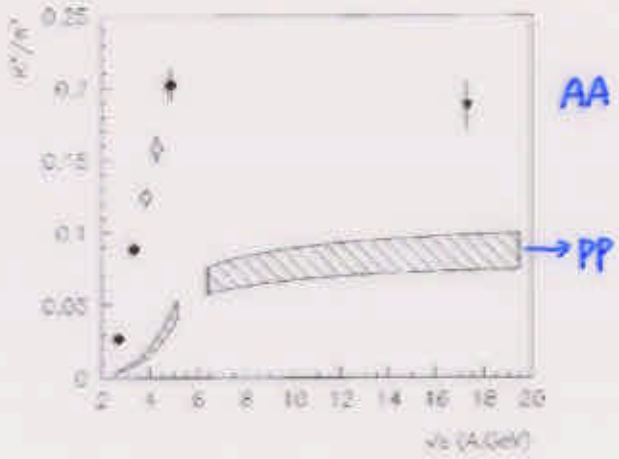
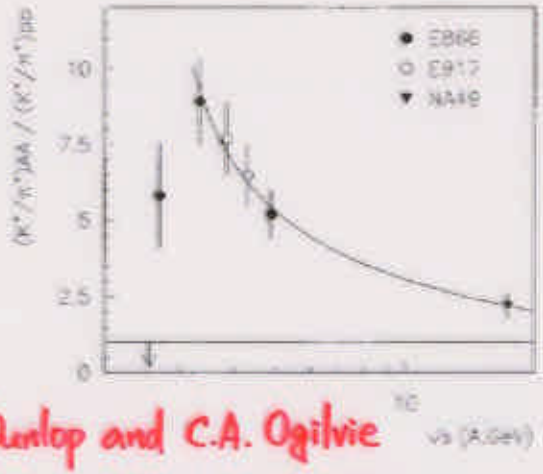
K+/π+ Ratio vs Beam Energy





J.C. Dunlop and C.A. Ogilvie

- Phys. Lett. B476 (2000) 1-8
- Phys. Rev. C61(2000) 031901

- Ratio K+/π+ at y_{CM} increases from 0.027 at 2 AGeV to 0.202 at 10.8 AGeV.
- Re-scattering of hadrons contributes the enhancement of kaons within this energy range (sqrt(s) = 2-6 AGeV) near production threshold.
- The enhancement of $(K/\pi)_{AA}$ to $(K/\pi)_{pp}$ decrease steadily from 4 to 160 A GeV, suggesting that the same enhancement mechanism of hadronic rescattering may be appplicable over this full energy range.

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ϕ Meson as a QGP Probe

$(s\bar{s})$

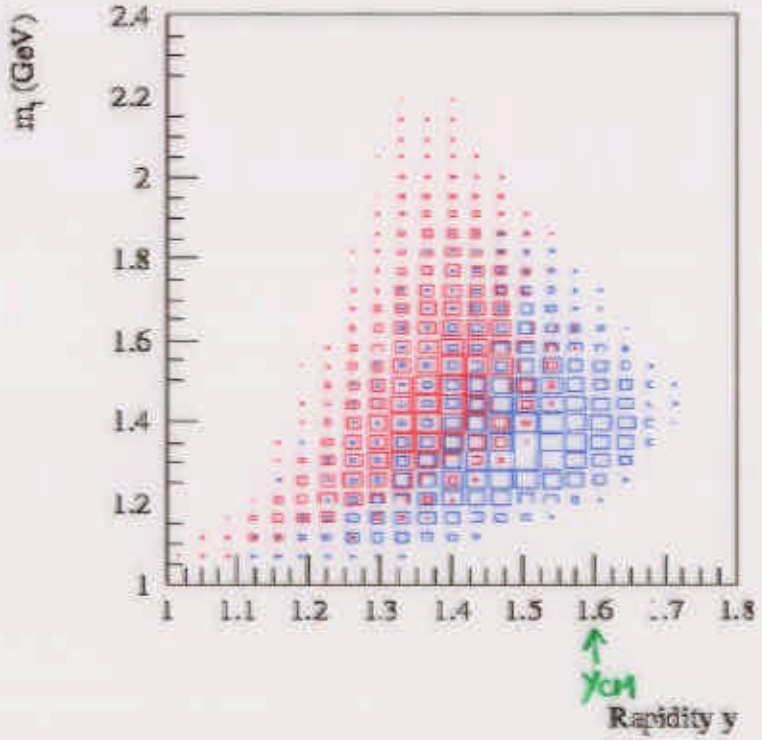
- ϕ is the lightest bound state of hidden strangeness whose production is suppressed by OZI rule in pp and πp collisions. In QGP scenario, ϕ can be easily produced by s and $\bar{s}$ quarks coalescence during hadronization stage.
- That ϕN and $\phi\pi$ re-scattering cross section is small (~1mb) makes ϕ to be a penetrating probe produced inside a decaying QGP.
- The mass and width of vector mesons is theoretically demonstrated to be sensitive to the temperature and baryon density of nuclear medium in heavy-ion collisions.

Experimental Status

	Experiment	Collision	Mom (A GeV)	Sqrt(s) (GeV)	Decay Mode
SIS	FOPI	Ni+Ni	1.93	2.4	K^+K^-
AGS	E917	Au+Au	11.0	4.86	K^+K^-
AGS	E859	Si+Au	14.6	5.4	K^+K^-
SPS	NA50	Pb+Pb	158	17.4	$\mu^+\mu^-$
SPS	NA49	Pb+Pb	158	17.4	K^+K^-

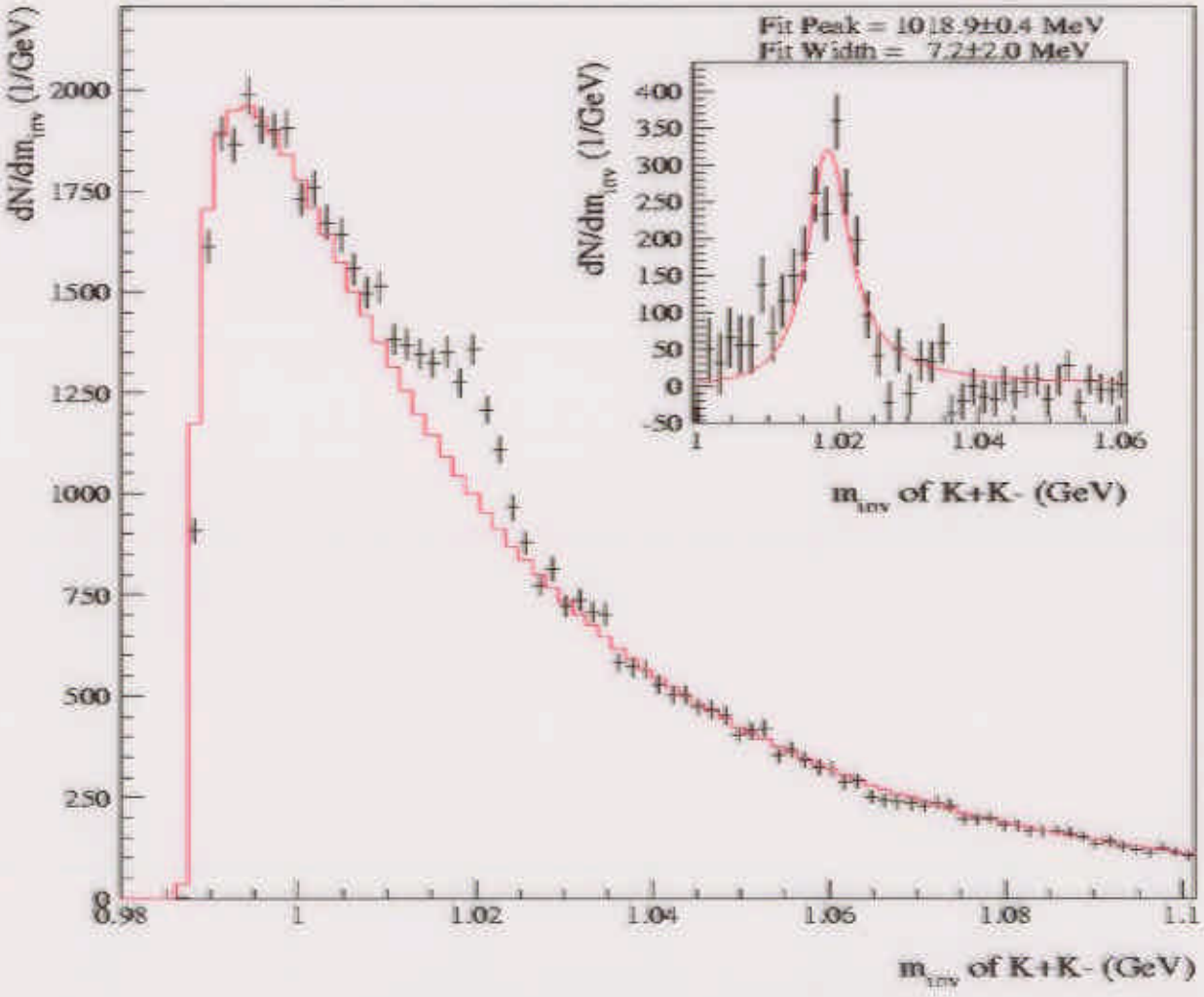
- No modification of ϕ mass or width is reported.
- At SPS, inverse slope parameter (T_{inv}) is larger in the detection of 2K modes (NA49) than that in di-muon mode (NA50).
- NA50: The $\phi/(\rho+\omega)$ ratio increases up to 1 in the most central bin.
- NA49: The $\phi/\langle\pi\rangle$ ratio is a factor of 3-5 larger in Pb+Pb central events compared to that in the pp interactions at the same energy.

The Detection of ϕ Mesons



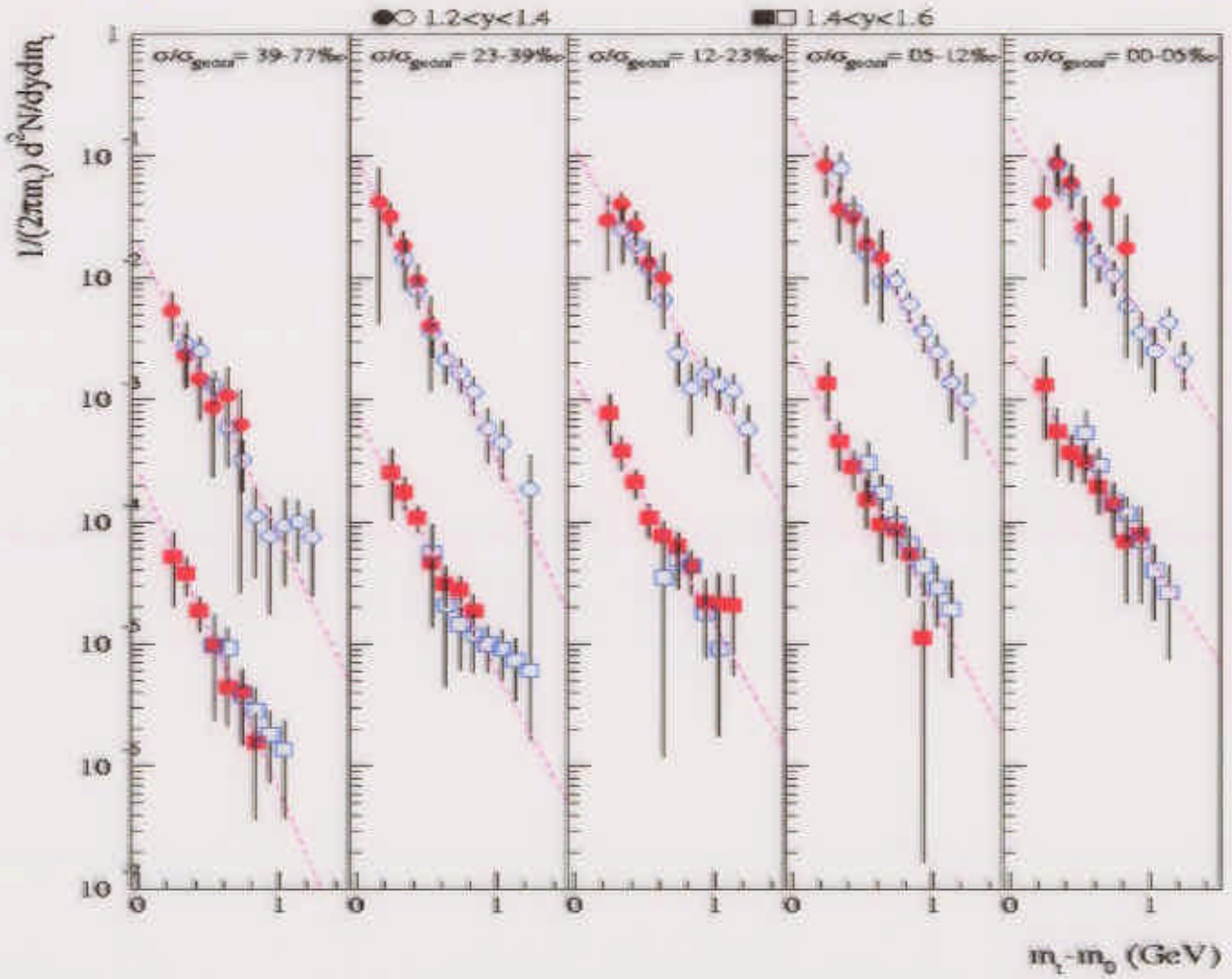
- Au+Au collisions at 10.8 GeV.
- LVL2 Trigger: two-kaons or one pbar.
- Two spectrometer angle settings: 19 and 14 degrees.
- About 3000 ϕ mesons in the total event sample.

K+K– Invariant Mass Distribution



Transverse Mass Spectra of ϕ

Peripheral → Central



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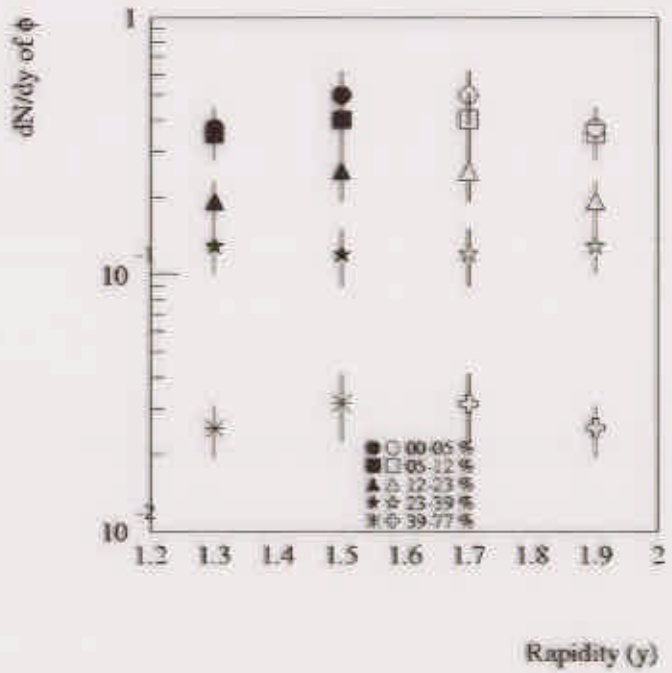
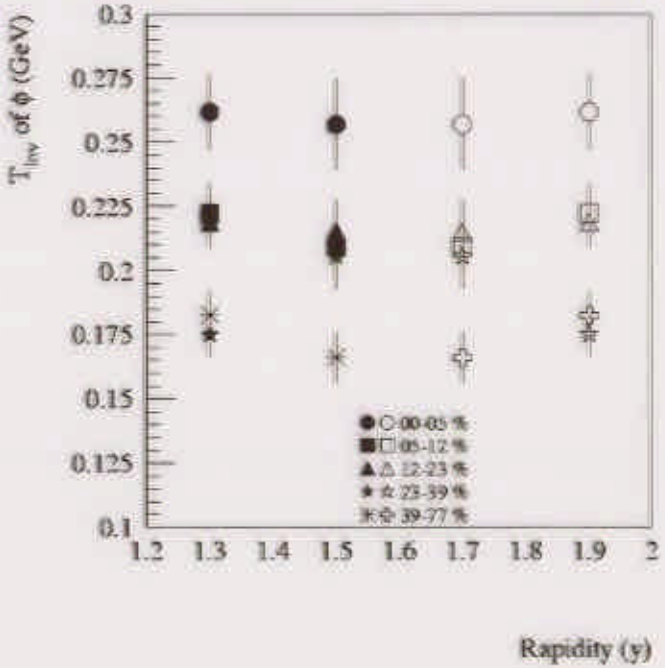
dN/dy and T_{inv} of ϕ vs Centrality

$$\frac{1}{2\pi m_t}\frac{d^2N}{dm_t\,dy} = \frac{dN}{dy}\frac{1}{2\pi(T_{inv}m_0 + T_{inv}^2)}\exp\left(-\frac{m_t - m_0}{T_{inv}}\right)$$





Rapidity Distribution (dN/dy) Inverse Slope Parameter (T_{inv})

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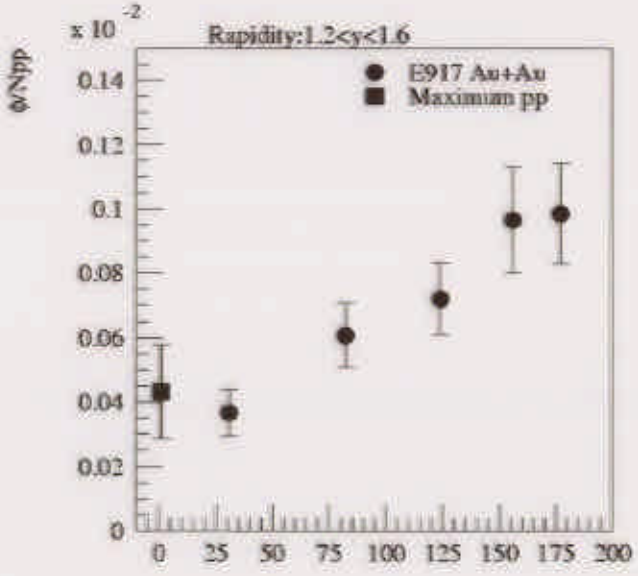
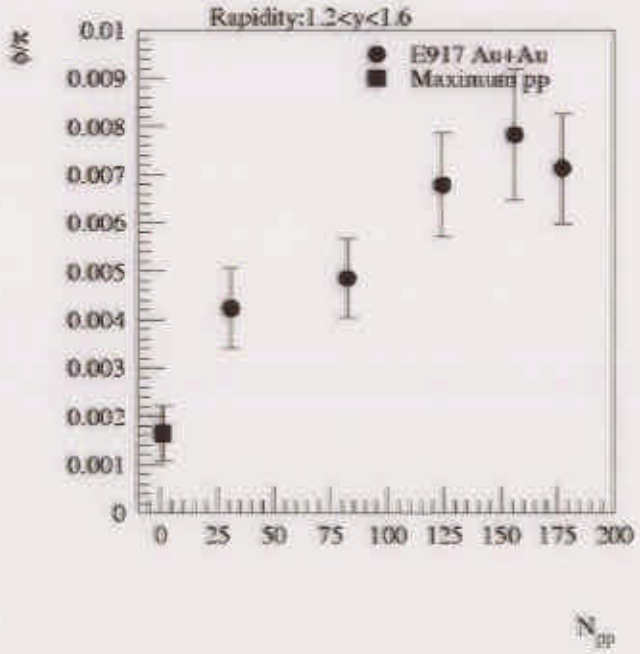
Yield of ϕ per Participant Nucleon



Npp : # of participant nucleon

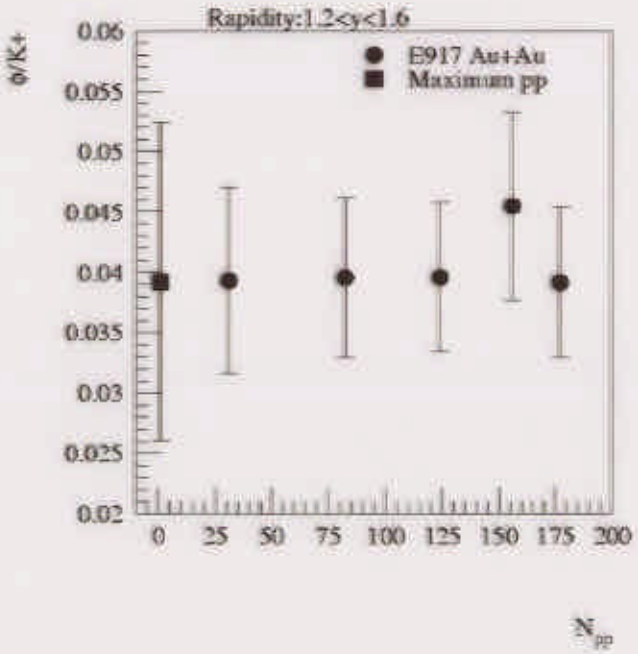
- ϕ/Npp (normalized ϕ yield) increases toward central collisions in backward rapidity region 1.2-1.6.
- A factor of 2.5 enhancement between the most peripheral and central bins.
- The ϕ yield increases non-linearly with Npp, similar to kaons.

$\phi/\langle\pi\rangle$ Ratio



- $\phi/\langle\pi\rangle$ ratio increases strongly with centrality.
- Signifying an enhancement of strangeness production relative to the non-strange mesons in the central collisions of relativistic heavy-ion interactions.

ϕ/K+ Ratio



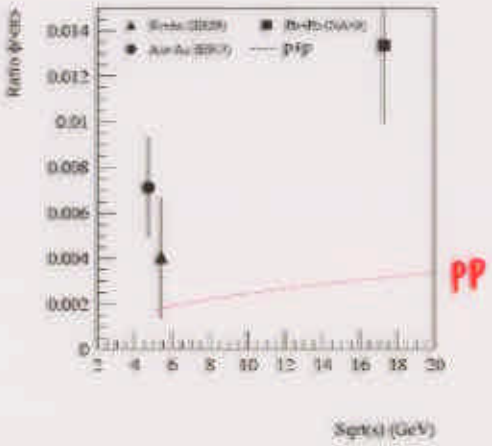
- ϕ/K+ appears to be almost independent of centrality.
- ϕ possesses a similar degree of enhancement over centrality, like K+ and K– (PRC 58, 3523).
- This similarity in centrality dependency of ϕ and kaon yield hints at a common mechanism, possibly the hadronic secondary interaction in the central heavy-ion collisions:

πN [redacted] $\rightarrow \phi N, K\Lambda$

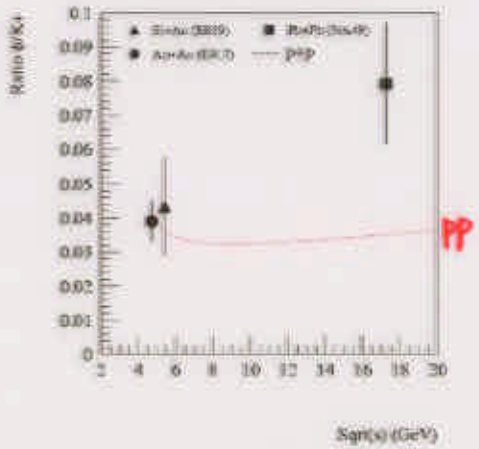
$NN \rightarrow \phi NN, KNN$

Strangeness Enhancement over Beam Energy

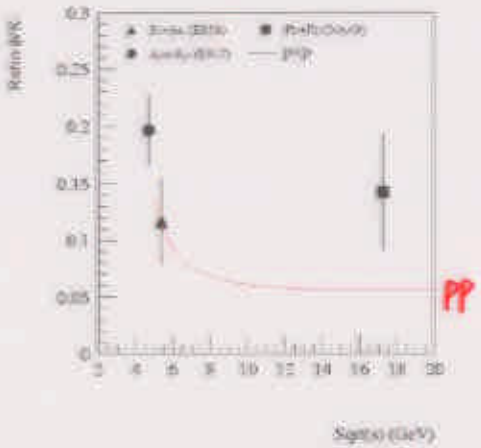
AA Central Collisions



$\phi/\langle\pi\rangle$



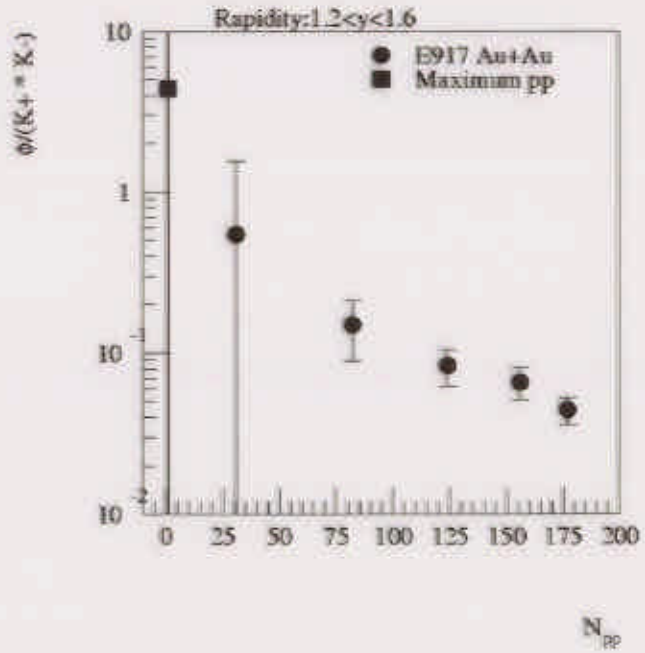
$\phi/K+$



$\phi/K-$

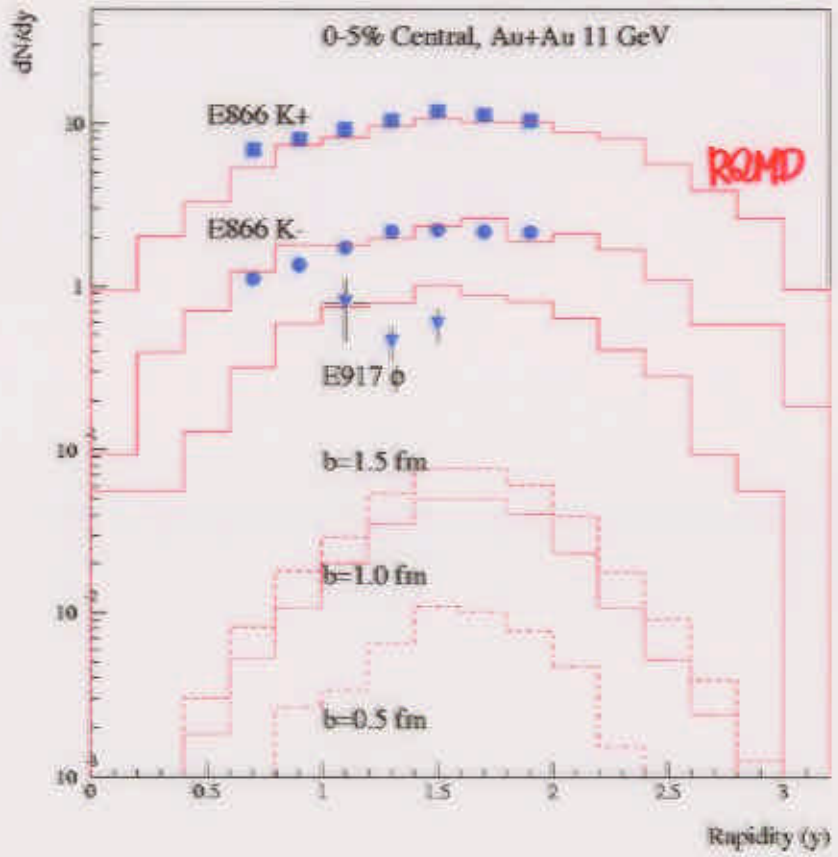
- Ratio $\phi/\langle\pi\rangle$: enhancement in AA relative to pp shows up at sqrt(s)=5 AGeV and become more at SPS.
- Ratio ϕ/K: stronger enhancement in AA relative to pp seen at SPS but values of this ratio are equal around sqrt(s)=5 AGeV.

ϕ /(K+K–) Ratio



- ϕ /(K+K–) strongly decreases with centrality.
- From coalescence model, ϕ /(K+K–) ~ 1 / V and Npp~V.
- The decreasing of the ratio ϕ/(K+K–) vs Npp is consistent with the picture of kaons being coalesced into ϕ.

ϕ Coalescence from Kaons



- ϕ(ss): spin 1, angular momentum = 0; K(us): spin 0.
- Wigner function (phase space density)

$$f^{L=1}(k,r) = [\frac{16}{3}\frac{r^2}{b^2} - 8 + \frac{16}{3}b^2k^2]\exp(-\frac{r^2}{b^2} - b^2k^2)$$

- From charge radius of kaons: b=0.4-0.5 fm.
- Kaon coalescence cannot fully account for total ϕ yield.

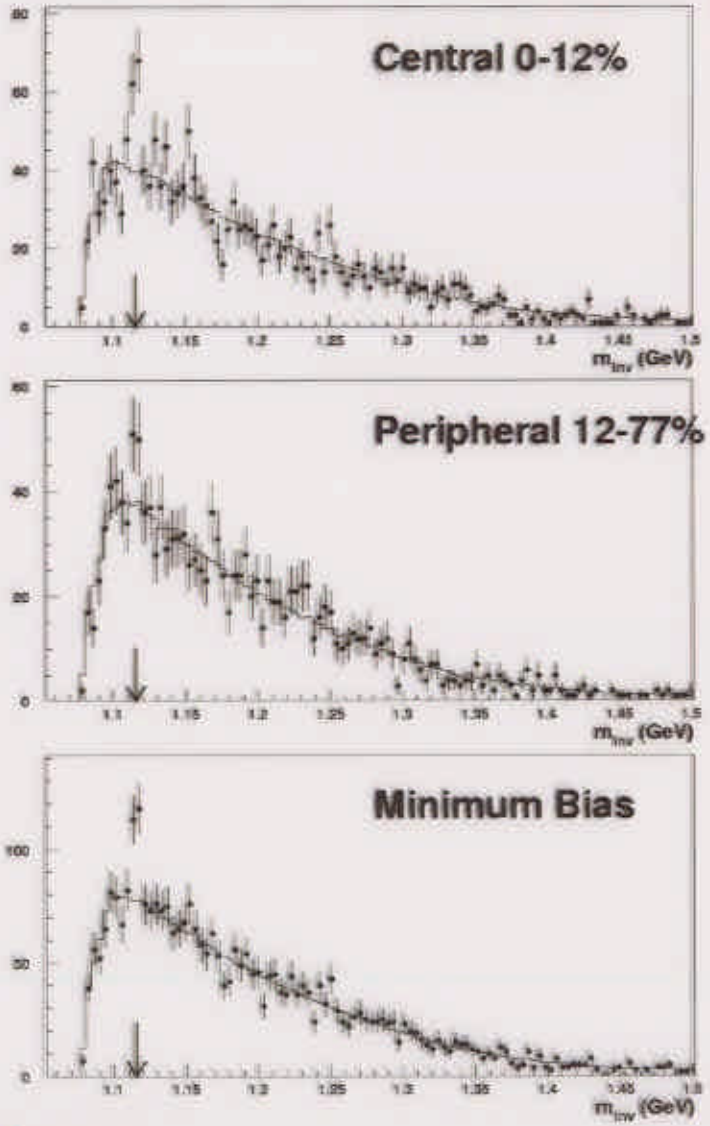
A.J. Baltz and C. Dover
PRC 53, 362

$\overline{\Lambda}/\overline{p}$ Ratio

- Ratio of strange anti-baryon to non-strange one, ($\overline{\Lambda}/\overline{p}$) reflect the relative abundance of $\bar{s}$ quarks to light anti-quarks.
- Hadronic model predicts values in the range 0.8-1.2.
- E859 Si+Au: $\overline{\Lambda}/\overline{p} = 2.9 \pm 0.9 \pm 0.5$.
- E864/E878 discrepancy in $\overline{p}$ measurement at p_t=0: assuming caused by different acceptance of $\overline{p}$ arising from $\overline{\Lambda}$: $\overline{\Lambda}/\overline{p} = 3.5(central), 1.0(peripheral)$.

E917 Measurement of $\overline{\Lambda}/\overline{p}$ Ratio

G. Heintzelman



- Rapidity range: $1.0<y<1.4$.
- Transverse Mom range: $m_t - m_0 > 250$ MeV.
- Ratio:
  - Central 0-12%

    $\overline{\Lambda}/\overline{p} = 3.6^{+4.7}_{-1.8}$
  - Peripheral 12-77%

    $\overline{\Lambda}/\overline{p} = 0.26^{+0.19}_{-0.15}$

Summary

- Hadronic secondary interaction in heavy ion collisions enhances the yield of ϕ mesons as well as kaons per N_{pp} and also relative to non-strange π mesons in the central collisions at AGS.
- At SPS, a larger value of ratio ϕ/K is seen in AA relative to pp interactions, while they are about equal around sqrt(s)=5 AGeV.
- $\overline{\Lambda}/\overline{p}$ ratio is measured by E917 to be larger than 1 in the central collisions and less than 1 in the peripheral events.