Status of the Omega at 158 AGeV
Paper Draft

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Status of Omega Paper

- Dataset: central (20%) Pb+Pb at 158 AGeV (011)
- First results shown on QM02
- For publication:
  - Redo simulations
    - Old simulated data lost
    - Refined procedure
    - Statistics
  - Cross checks
    ✓ Validity of signal
    ✓ Comparison of simulation results and data ($x_{\text{targ}}$, $y_{\text{targ}}$, etc.)
    ✗ Stability of final results with respect to cut variation
Omega and Antiomega Signal

\[ \Omega^- \quad p_t > 0.9 \text{ GeV/c} \quad 1.9 < y < 3.9 \]

\[ \Omega^+ \quad p_t > 0.9 \text{ GeV/c} \quad 1.9 < y < 3.9 \]
QM02 Result: $m_t$ Spectra

\begin{align*}
\Omega^- &: dN(m_t - m_0)/dydm_t \quad \text{vs.} \quad m_t - m_0 (\text{GeV}) \\
\overline{\Omega}^+ &: dN(m_t - m_0)/dydm_t \quad \text{vs.} \quad m_t - m_0 (\text{GeV})
\end{align*}

- blast wave
- $T = 270 \pm 22$ MeV
- $T = 290 \pm 40$ MeV
QM02 Result: Rapidity Spectra

\[ \langle \Omega^- \rangle = 0.47 \pm 0.07 \]
\[ \langle \Omega^+ \rangle = 0.15 \pm 0.02 \]
New Analysis

- Improved background fit
  - Fit with peak+polynomial
  - Peak description from simulation
  - Peak simulated for each phase space bin $\rightarrow$ variation of width included

- Open question:
  - Include $\Omega$ from Bham cut selection to increase statistics?
  - Seems to be less stable

- Simulation
  - So far $2 \times 10^6$ Omegas and $2 \times 10^6$ Antiomegas generated
  - Aim for $6 \times 10^6$ total
  - Work in progress

So far $2 \times 10^6$ Omegas and $2 \times 10^6$ Antiomegas generated.
New Fitting Procedure

1.9 < y < 3.9
1.2 < p_t < 1.5
Degree of polynomial = 7
Fit range = 1.615 - 1.800

Constant background:
- S = 115.0 ± 19.5
- B = 132.0 ± 11.5
- S/B = 0.88 ± 0.17

Fitted background:
- S = 96.1 ± 19.5
- B = 151.9 ± 11.5
- S/B = 0.63 ± 0.14
- Wid = 1.00 ± 0.00

0.040 · 10^3 Ω/event

χ^2/ν = 0.907
New Analysis: Comparison of $m_t$ Spectra
Conclusion

- Finish new simulation in next weeks
  - Rapidity spectra
  - Consistency checks
- Paper draft existing and could be distributed to editorial committee
The production of $\Omega^-$ and $\Omega^+$ in central Pb+Pb collisions at 158 AGeV
has been measured by the NA49 collaboration. While the transverse mass spectra do not show any significant difference
between matter and anti-matter, there appears to be a clear difference between the longitudinal
distributions. From the integration of the rapidity spectra the total yield can be extracted as
$N(\Omega^-) = 53 \pm 7$ and $N(\Omega^+) = 12 \pm 7$.

**Keywords**

Heavy ion collisions at ultra-relativistic energies produce strongly interacting matter under extreme conditions. The main goal of studying heavy-ion reactions is to create a state in which the confinement of quarks and gluons inside hadrons is no longer valid, the so-called quark-gluon plasma [1]. The measurement of multiple strangeness particles is of special interest in this context. Especially the $\Omega^-$ and $\Omega^+$, containing entirely of a $(3)$ quark, provide a very stringent test on the various hadronization scenarios. Microscopic models that produce $\Omega^-$ ($\Omega^+$) via string fragmentation would predict a $\Omega^-/\Omega^+$ ratio of 1. Due to the topology of the string which must include the strong string tension quarks lie their ends [2]. Statistical models on the other side would predict a $\Omega^-/\Omega^+$ ratio of 1 at the effect of a non-vanishing baryonic chemical potential [predictions].

Due to their low cross section with the surrounding hadron matter,
the heavy ion collisions have been measured with the NA49 apparatus. A detailed description of the experimental setup can be found in [3]. The analyzed data set contains 30,431 Pb+Pb events with a beam en-
ergy of 1.56 AGeV, taken in the year 2000 running period. The centrally selected events correspond to the 20% most central part of the total inelastic cross section, resulting in an averaged number of wounded nucleons of \( N_w = 300\pm30 \). Events are reconstructed via their charged decay branches \( \Upsilon \rightarrow \pi^+\pi^- \), \( \Upsilon \rightarrow \rho^+\rho^- \), \( \Upsilon \rightarrow \Delta^+\Delta^- \), \( \Upsilon \rightarrow p\bar{p} \), with a branching fraction of 67.8%. \( \Upsilon \) and \( \Upsilon' \) candidates are formed by combing \( \Lambda(\bar{\Lambda}) \) candidates, reconstructed in the invariant mass window of 1.01 to 1.3 GeV/c^2, with all charged tracks. In order to identify a secondary vertex, both are extrapolated back to the target, following the same procedure as employed in the \( \Xi \) analysis [6]. The resulting combinatorial background can be reduced substantially by applying various cuts. The contribution of fake \( \Lambda(\bar{\Lambda}) \) candidates can be reduced by identifying the decay (anti-)protons via the measurement of their energy loss in the TPCs. In the same way as enriched \( \Xi \) mass is extracted from the charged tracks, a further reduction is achieved by requiring a minimum distance of the secondary vertex to the target position. Additionally, the \( \Upsilon(\Upsilon') \) candidate must point back to the interaction vertex, while on the other side the Kaon track should point away from it. Therefore both are extrapolated back to the target plane and corresponding cuts are placed on the distance of their impact parameter to the interaction point. Figure 1 shows the resulting invariant mass distribution for the sum of \( \Upsilon' \) and \( \Upsilon \). A clear signal at the expected position \( \Delta M = 1.965 \pm 0.015 \) GeV/c^2 [3] is observed.

In order to subtract the resulting combinatorial background, a fitting procedure is employed. A first step signal and background are fitted together with the sum of a Gaussian function and a polynomial. The first one is used phenomenologically to provide the best description of the peak position, while the latter one is used to fit the underlying background. In the second step, the fitted background is subtracted and the remaining signal is integrated in the invariant mass interval \( [\Delta M - \Delta \delta, \Delta M + \Delta \delta] \) with \( \Delta \delta = 7 \) GeV/c^2 to get the signal/background ratio. The raw \( \Upsilon(\Upsilon') \) yield has to be corrected for the effects of the geometrical acceptance and the reconstruction efficiency. The latter one is strongly influenced by the high track density that is prevailing in central Pb+Pb reactions at this beam energy, therefore a very careful estimation of this effect is necessary. The here employed procedure starts with generating simulated \( \Upsilon \) and \( \Upsilon' \) of equal amount, covering the full phase space accessible to our measurement. The Geant3.21 package [7] is used to track the generated particles through a detailed description of the NA49 detector geometry. Taking into account all known detector effects, from these simulated tracks a realistic track reconstruction (ADQ) value is derived. The simulated raw data of a single \( \Upsilon(\Upsilon') \) is added to the raw data taken from a measured event and the summed up data is subjected to the same reconstruction procedure as the normal data. By subtracting the fraction of all simulated \( \Upsilon(\Upsilon') \) that are reconstructed after being embedded this way, the reconstruction efficiency in the environment of a central Pb+Pb event is evaluated. Finally, the correction is applied to the data in the corresponding phase space bins.

Figure 2 displays the resulting transverse mass spectra of \( \Upsilon(\Upsilon') \) in a region of two pions of rapidity around mid-rapidity. No significant difference to the spectral shape between particle and anti-particle can be observed. Consequently, the slope parameters, extracted from a fit with an exponential function (dashed line in Fig. 2) of the form

\[
\frac{dN}{dy} = \sigma \exp\left(-\frac{m_{\text{miss}}}{\bar{P}}\right)
\]

are in good agreement: \( \Upsilon(S) = 77\pm7 \) MeV and \( \Upsilon(\Upsilon') = 106\pm11 \) MeV. These numbers are slightly above the measurement of the WA80 collaboration [8], but still consistent, considering the relatively large statistical errors. However, from this fit the first data points \( (m_{\text{miss}} < 9.25 \text{ GeV}) \), which seem not to follow the exponential behavior, are excluded. A better description of the data points to the whole measured spectrum is achieved by a model based on a hydrodynamical picture and assuming a transversely expanding emission source.
The parameters of this model are the freeze-out temperature $T$ and the mean transverse flow velocity $\langle v \rangle$ ($\rho = \tan^{-1} \langle v \rangle$).

$$\frac{dN}{dN_{\text{m}} \text{d}z} \propto m_{\text{K}^0} \left( \frac{m_{\text{K}^0 \text{cos} \theta}}{T} \right) I \left( \frac{m_{\text{K}^0 \text{sin} \theta}}{T} \right)$$

The curves shown in Fig. 2 (solid line) are calculated for the parameters $T = 129$ MeV and $\langle v \rangle = 0.5$, which provide a reasonable simultaneous fit to all particle species [10]. This would imply that, even though there are more experimental constraints, it is only possible to determine $\langle v \rangle$ as a relative, low single parameter, since the $\Omega^- (\Omega^+)$ transverse mass spectra are still in agreement with the assumption of strong radial flow.

The large acceptance of the NA49 experiment allows us to measure the $\Omega^- (\Omega^+)$ spectra in longitudinal direction. Since the signal/background ratio in the region $p_T < 0.9$ GeV/$c$ is too low to extract a signal, the measured yield has to be extrapolated to the whole $p_T$ range. The used extrapolation factor $f$ is derived from the fit to the momentum spectra and assumed to be $1$ in the $p_T$ range. The uncertainty of the extrapolation includes the difference between the various fits. Figure 3 shows the resulting rapidity spectra for the $\Omega^-$ and $\Omega^+$. Both spectra can be fitted with Gaussians, resulting in a slightly smaller $W$ for the $\Omega^-$ ($W(\Omega^-) = 1.0 \pm 0.2$) as for the $\Omega^+$ ($W(\Omega^+) = 0.7 \pm 0.1$). The fits are used to extrapolate into the unmeasured rapidity region, therefore allow to derive values for the total multiplicities per event: $(\Omega^-) = 9.75 \pm 0.07$ and $(\Omega^+) = 9.15 \pm 0.02$. The corresponding yields at mid-rapidity ($2.4 < y < 3.4$) are $(\Omega^-) = 0.77 \pm 0.07$ and $(\Omega^+) = 0.77 \pm 0.07$.

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[11] The number of measured nucleons is determined following the Gluon approach. Citaions!