Anisotropic Flow of Strange Particles at SPS

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Outline

• Introduction
• Analysis
• Preliminary results on $\Lambda$ elliptic flow
• Comparison with CERES and STAR data
• First preliminary results on $K^0_s$ elliptic flow
• Summary and outlook
**Introduction**

**Elliptic flow**
- an effect of the pressure gradients in the interaction region
- sensitive to EOS and the degree of thermalization
- $v_2$ of heavy and strange particles → insight into very early stages

Initial spatial anisotropy is transformed into momentum anisotropy characterized by

$$v_2 = \langle \cos(2(\varphi - \Phi_r)) \rangle$$

$$E \frac{d^3 N}{d^3 p} = \frac{1}{2\pi} \frac{d^2 N}{p_t dp_t dy} \left\{ 1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\varphi - \Phi_r)) \right\}$$

$$v_n = \langle \cos(n(\varphi - \Phi_r)) \rangle$$
increase with collision energy towards RHIC data and hydrodynamic model predictions?

What is the energy dependence of elliptic flow for heavier hadrons, in particular, strange hadrons?

**Mid-rapidity data, $p_T$ integrated**
Centrality Determination

- centrality selection made by the energy measurement in Veto Calorimeter

Pb+Pb 158A GeV

3M events

semi-central trigger

$\sigma/\sigma_{TOT} < 23.5\%$
Method of elliptic flow analysis

- estimate of the reaction plane by the second harmonic event plane ($\Phi_{2\, EP}$) of primary charged pions
- acceptance correction by recentering and mixed-events
- determination of the event plane resolution by correlation of sub-events ($<\cos(2(\Phi_{EP} - \Phi_{RP}))>$)
- evaluation of the Fourier coefficient $v_2'$ from the $\Lambda$ azimuthal distribution with respect to the event plane
  \[
  \frac{dN}{d(\phi_{lab} - \Phi_{2\, EP})} \sim 1 + 2v_2' \cos[2(\phi_{lab} - \Phi_{2\, EP})] + 2v_4' \cos[4(\phi_{lab} - \Phi_{2\, EP})]
  \]
- correction for the event plane resolution
  \[
  v_2 = \frac{v_2'}{<\cos(2(\Phi_{EP} - \Phi_{RP}))>}
  \]
Selection of $\Lambda$ candidates

$\Lambda \rightarrow p + \pi^-$ (BR = 63.9%, $c\tau = 7.89$ cm)

$1.108$ GeV $< m_{p\pi^-} < 1.124$ GeV

Use of the identified pions and protons significantly reduces the background

Identification of $\Lambda$ decay daughter tracks
Rapidity dependence

Lambda flow

Pb+Pb 158A GeV

\[ \sigma/\sigma_{TOT} = 5.0 - 23.5 \% \]

\[ \Lambda \text{ elliptic flow} \]

Preliminary

Proton flow


- no significant dependence of \( v_2 \) on rapidity for \( \Lambda \) and protons
$p_T$ and centrality dependence

- Significant increase of $\Lambda v_2$ with $p_T$
- Stronger increase in more peripheral collisions

$\sigma/\sigma_{TOT} = 12.5 - 23.5\%$

$\sigma/\sigma_{TOT} = 5 - 12.5\%$

Preliminary

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Strangeness in Quark Matter 2006
• **Comparison with CERES and STAR data**

**Good agreement between NA49 and CERES $v_2(p_T)$ of $\Lambda$ hyperons**

Linear rise of $v_2(p_T)$ up to 2 GeV/c weaker increase at SPS than at RHIC → not explained by slightly different centrality
$K^0_s$ Elliptic Flow - $p_T$ dependence

\[ \frac{\sigma}{\sigma_{TOT}} = 5 - 23.5 \% \]

One can see elliptic flow effect, analysis on the way
Elliptic flow - different species

- linear increase of $v_2$ with $p_T$ for all species in mid-central events
- mass hierarchy $v_2(\pi) > v_2(p) > v_2(\Lambda)$ at $p_T < 2$ GeV/c
- similar magnitude of $v_2$ for all particle species at $p_T \sim 2$ GeV/c
- blast wave fit reproduce $v_2$ (and $p_T$ spectra) quite well

Model:

Data on pions and protons:
Conclusions

- weak dependence of $v_2$ on rapidity
- $v_2$ increases with increasing centrality
- $v_2$ rises with transverse momentum up to 2.5 GeV/c
- slower rise with $p_T$ at SPS than at RHIC
- good agreement with preliminary CERES results
- Blast Wave model reproduces $v_2(p_T)$ and $p_T$ spectra for $\Lambda$, $p$ and $\pi$
The NA49 Collaboration

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NA49 Experiment

- Two Vertex TPC (VTPC-1, VTPC-2) inside magnetic field
- Two Main TPC (MTPC-L, MTPC-R) outside magnetic field
- Veto Calorimeter (VCAL) detects projectile spectators

Target: Pb foil 224 mg/cm²
\[ \Delta p/p^2 = 7 \times 0.3 \times 10^{-4} \, (GeV/c)^{-1} \]  
(VTPC-1, VTPC+MTPC)
dE/dx resolution 3-6 %
Identification of \( \pi^+, \pi^-, K^+, K^-, p, \bar{p}, d, \bar{d} \)
\( K^0_s, \Lambda, \Xi, \Omega, \phi \)