



### Hyperon measurement with Silicon Pixel Detectors in Pb-Pb collisions

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http://na57.web.cern.ch/NA57





- Physics goals
- Experimental apparatus
- Data sets
  - 40 GeV status
  - 160 GeV status
- Summary and Conclusions
- Future Plans



### The NA57 Collaboration



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- Fysisk institutt, Universitetet i Bergen, Bergen, Norway
- Høgskolen i Bergen, Bergen, Norway
- School of Physics and Astronomy, University of Birmingham, Birmingham, UK
- Comenius University, Bratislava, Slovakia
- · Dipartimento di Fisica dell'Università and Sezione INFN, Catania, Italy
- CERN, European Laboratory for Particle Physics, Geneva, Switzerland
- Institute of Experimental Physics SAS, Kosice, Slovakia
- P.J. Safárik University, Kosice, Slovakia
- Fysisk institutt, Universitetet i Oslo, Oslo, Norway
- Dipartimento di Fisica dell'Università and Sezione INFN, Padua, Italy
- Collège de France and IN2P3, Paris, France
- Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic
- Dipartimento di Fisica dell'Università "La Sapienza" and Sezione INFN, Rome, Italy
- Dipartimento di Fisica dell'Università "E.R. Caianiello" and Sezione INFN, Salerno, Italy
- State University of St. Petersburg, St. Petersburg, Russia
- Insitut de Recherches Subatomiques, IN2P3/ULP, Strasbourg, France
- Utrecht University and NIKHEF, Utrecht, The Netherlands





# Strangeness Enhancement in A-A w.r.t. p-p and p-A as a QGP signature:

- proposed by Rafelski and Müller, 1982
- The QGP strangeness abundance is enhanced (partial restoration of chiral simmetry, gluon-gluon fusion, "Pauli blocking")
- As the QGP cools down, eventually the quarks recombine into hadrons ("hadronization")
- The abundance of strange hadrons should also be enhanced
- Enhancement larger for particles of higher strangeness content, e.g.:

 $En(\Omega) > En(\Xi) > En(\Lambda)$ (sss) (ssd) (sud)  $|S| = 3 \quad |S| = 2 \quad |S| = 1$ 





- Physics: Strangeness production in Pb-Pb collisions at central rapidity  $(|y_{CM}| < 0.5)$
- Apparatus: High granularity detectors —> Si pixel planes
   Analysis:
  - Reconstruction of strange particle decays
  - Study of
    - transverse mass distribution dN/a

$$dN/dm_{T} \equiv \int_{-0.5}^{0.5} dy dN/dm_{T} dy$$

- particle yields  $yields \equiv \int dm_T \int dy dN / dm_T dy$
- yields vs nucleon participating to the collision (wounded nucleons)





 $\checkmark$  Λ, Ξ, Ω and K<sup>0</sup><sub>S</sub> + anti-particles by reconstructing weak decay topologies 5 cm







• The long lifetime of these weakly decaying particles allows to separate the secondary decay products from the much more numerous primary collision products, drastically reducing the combinatorial backgrounds e.g.:



- Particle selection criteria are based on geometrical cuts, e.g.:
  - $p-\pi$  closest approach in space
  - V<sup>0</sup> candidates combined with a 3<sup>rd</sup> track  $\rightarrow \Xi/\Omega$  candidates
  - $\Xi/\Omega$  decay distance,  $\Lambda$  decay distance
  - $\pi$  and  $\Lambda$  vs  $\Xi$  impact parameters at the target plane





## In order to correct for acceptance and efficiency losses, a weight is associated with each hyperon in the final sample

#### The weights are calculated by Monte Carlo:

- generated hyperons are traced through a GEANT simulation of the NA57 apparatus (chip-by-chip detector efficiencies)
- the hits are merged with true events
- the result is sent through the standard NA57 reconstruction and analysis chain





#### The NA57 experimental apparatus





#### ♦ The Omega3 pixel ladder:









### NA57 Silicon Pixel Plane





• 4 ladders mounted on a ceramic  $\rightarrow$  array

2 arrays mounted face-to-face and staggered by  $\approx 4$  mm to cover dead areas  $\rightarrow$ (logical) plane,  $\approx 5x5$  cm<sup>2</sup>, 8 ladders,  $\approx 98$ K sensor elements

Thin ceramic













![](_page_16_Picture_0.jpeg)

### WA97 results

![](_page_16_Picture_2.jpeg)

strangeness enhancement in Pb-Pb w.r.t. p-A increases with strangeness —> QGP prediction

#### WA97 Pb-Pb at 160 A GeV/c

(J. Phys. G: Nucl. Part. Phys. 27 (2001) 375-

![](_page_16_Figure_6.jpeg)

No current hadronic microscopic model predicts such a behaviour
 All these features fulfill the predictions of a QGP scenario

![](_page_17_Picture_0.jpeg)

### NA57 physics goals & Data sets

![](_page_17_Picture_2.jpeg)

 $\bigvee$  NA57 searches for the onset of the enhancements:

• Strangeness enhancement pattern at variation of beam energy

- Lower beam momentum from 160 to 40 A GeV/c [√s (40 GeV/c) ~ 1/2 √s (160 GeV/c)] → is strange baryon production still enhanced? by how much?
- Extend centrality range down to  $N_{wound} \sim 50$  in Pb-Pb at 160 A GeV/c

System	Beam	Sample size	Data taking	Reconstruction
	momentum		completed	completed
Pb Pb	160 A GeV/c	230 M events	November 1998	February 2000
p Be	40 GeV/c	60 M events	July 1999	July 2000
Pb Pb	40 A GeV/c	290 M events	November 1999	January 2001
Pb Pb	160 A GeV/c	230 M events	October 2000	December 2001
p Be	40 GeV/c	110 M events	September 2001	Summer 2002 (exp.)

![](_page_18_Picture_0.jpeg)

![](_page_18_Figure_1.jpeg)

- Centrality selection —> charged part. multiplicity (MSD)
- N<sub>wound</sub> from Xsections for each class (Glauber model)
- NA57: most peripheral bin  $--> < N_{wound} > = 62$

![](_page_19_Picture_0.jpeg)

![](_page_19_Picture_1.jpeg)

#### Pb-Pb 40 A GeV/c data set

![](_page_20_Picture_0.jpeg)

![](_page_20_Figure_1.jpeg)

![](_page_20_Figure_2.jpeg)

uncorrected  $\overline{\Lambda}/\Lambda = 0.023 \pm .001$ 

![](_page_21_Picture_0.jpeg)

![](_page_21_Figure_1.jpeg)

 $\searrow$  Next step: absolute values of yields and enhancements for  $\Lambda$  and  $\Xi$ 

![](_page_21_Picture_3.jpeg)

![](_page_22_Picture_0.jpeg)

![](_page_22_Picture_1.jpeg)

#### Pb-Pb 160 A GeV/c data set

![](_page_23_Picture_0.jpeg)

![](_page_23_Picture_1.jpeg)

Aim: extend centrality range of WA97 measurements

 started with Ξ<sup>-</sup> & Ξ<sup>+</sup>: statistics large enough to study the centrality dependence down to N<sub>wound</sub> ~ 50

![](_page_23_Figure_4.jpeg)

![](_page_24_Picture_0.jpeg)

Ξ

Ξ

Λ

Λ

321 ±23

 $287\pm6$ 

 $284 \pm 6$ 

 $284 \pm 17$ 

 $289 \pm 3$ 

 $287\pm4$ 

### $m_T$ distributions & inverse slopes

![](_page_24_Picture_2.jpeg)

![](_page_24_Figure_3.jpeg)

- NA57 inverse slopes compatible with those measured by WA97
- Compatible for particles and antiparticles

![](_page_25_Picture_0.jpeg)

![](_page_25_Figure_1.jpeg)

- $\Xi^-, \overline{\Xi}^+$  results are very stable
- NA57 systematics well under control
- checks of  $\Lambda$  analysis chain are being completed ( $\Lambda$ ,  $\overline{\Lambda}$  preliminary)

![](_page_26_Picture_0.jpeg)

![](_page_26_Picture_1.jpeg)

![](_page_26_Figure_2.jpeg)

The drop is not due to the corrections for acceptance & efficiency nor to the extrapolation to  $p_T = 0$ 

![](_page_27_Picture_0.jpeg)

![](_page_27_Picture_1.jpeg)

NA57 confirms enhancement pattern observed by WA97

![](_page_27_Figure_3.jpeg)

- NA57  $\Xi$  and  $\Lambda$ absolute yields systematically larger than those of WA97 by up ~ 20%
- Significant change of behaviour of  $\overline{\Xi}^+$ enhancement in most peripheral class

 $\checkmark$  Yield per N<br/>wound rises from <N<br/>wound > = 62 ---> 121 bothfor  $\Xi^-$  and for  $\overline{\Xi}^+$ :2.6 for  $\overline{\Xi}^+$  (3.5  $\sigma$  effect)

Steep onset of enhancement?

![](_page_28_Picture_0.jpeg)

![](_page_28_Picture_1.jpeg)

![](_page_28_Picture_2.jpeg)

#### Antihyperon-to-hyperon ratios:

	Pb-Pb		p-Be	
	40 A GeV/c	160 A GeV/c	40 GeV/c	160 GeV/c
$\overline{\Lambda}/\Lambda$	$0.023 \pm 0.001$	$0.133 \pm 0.007$	$0.059 \pm 0.007$	$0.332\pm0.008$
$\overline{\Xi}^+/\Xi^-$	$0.080 \pm 0.025$	$0.249 \pm 0.019$	N/A	$0.45 \pm 0.07$

(40 GeV p-Be: only 1999 data, data taking completed in 2001)

![](_page_29_Picture_0.jpeg)

![](_page_29_Picture_1.jpeg)

- Silicon pixel detector successfully employed as tracking device in high multiplicity environment such as Pb-Pb collisions at SPS energy.
- A new generation of rad-hard silicon pixel detector has been developed for the ALICE (and LHCb) experiment at LHC.
- $\swarrow$  @ 40 A GeV/c: decrease of  $\overline{Y}/Y$  w.r.t. 160 A GeV/c Pb-Pb & p-Be
  - 160 GeV  $\rightarrow$  40 GeV:  $\overline{\Lambda}/\Lambda$  decreases by  $\approx 6$ ;  $\overline{\Xi}^+/\Xi^-$  decreases by  $\approx 3$
  - need analysis of full p-Be reference data set to measure enhancements
- - Yields/participant step increase for <N<sub>wound</sub>> = 62 → 121 both for Ξ<sup>-</sup> and Ξ<sup>+</sup>
     Ξ<sup>+</sup> by a factor 2.6 (3.5 s effect)
  - $\Lambda(\overline{\Lambda})$  preliminary yields suggest similar behaviour with centrality

![](_page_30_Picture_0.jpeg)

![](_page_30_Picture_1.jpeg)

- ♦ @ 160 A GeV/c: the enhancement is larger for particles of higher strangeness content, e.g.: En(Ω) > En (Ξ) > En (Λ), up to a factor ≈15 for Ω (WA97 result).
- ♦ More results to come both at 160 and 40 A GeV/c, e.g.:  $\Omega^-$  and  $\overline{\Omega}^+$  in Pb-Pb at 160 A GeV/c from NA57

→ next Quark Matter, July 2002

![](_page_30_Figure_5.jpeg)

![](_page_31_Picture_0.jpeg)

![](_page_31_Picture_1.jpeg)

#### Indication of onset of enhancements warrants further investigation of the transition region

![](_page_31_Figure_3.jpeg)

- Steep onset of  $\overline{\Xi}^+$  enhancement for  $N_{wound} > 100 \rightarrow \text{onset of}$ deconfinement?
- Since a Pb-Pb collision with  $N_{wound} < 100$  is rather peripheral, it would be important to cross-check the effect with a lighter system.

For N<sub>wound</sub> = 100:  

$$b/R \approx 1.3 \text{ (Pb-Pb)}$$
  
 $b/R \approx 1 \text{ (In-In)}$ 

Expose existing NA57 apparatus to In or Sn beam in 2003