Muli-Strange Particle Enhancements in Pb-Pb Interactions at 158 GeV/c per Nucleon.

David Evans
The University Of Birmingham, UK
for the WA97 Collaboration

ICHEP 2000, Osaka, Japan
27 July - 2 August 2000

Outline of Talk

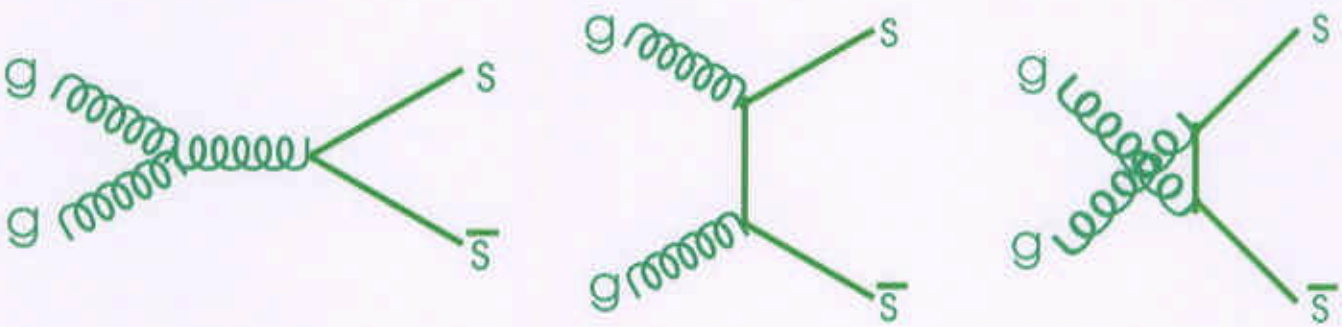
- Introduction
- The WA97 Experiment

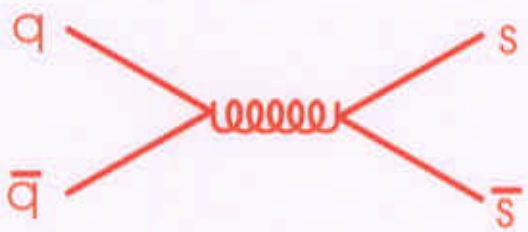
- Inverse M_T Slopes
- Particle Yields
- Strangeness Enhancements

- Summary and Conclusions

Strangeness Enhancement

Gluon rich QGP:





Energy needed to produce $s\bar{s}$ pair
$= 2m_s \sim 300$ MeV.
QGP temperature ~ 200 MeV
$\therefore$ easy to produce $s\bar{s}$ pairs.

Many u and d quarks from initial ions so $u\bar{u}$ and $d\bar{d}$ supressed by Pauli Blocking.

Aim of the WA97 experiment

The WA97 experiment studies the production of

strange and multistrange baryons and antibaryons

Λ, Ξ, Ω, with 1, 2, 3 units of strangeness respectively

$(+ \mathrm{K}^0_\mathrm{S})$

$\Rightarrow$ in Pb–Pb interactions at 158 A GeV/c beam momentum

$\Rightarrow$ in p–Pb and p–Be interactions at the same beam momentum, for comparison

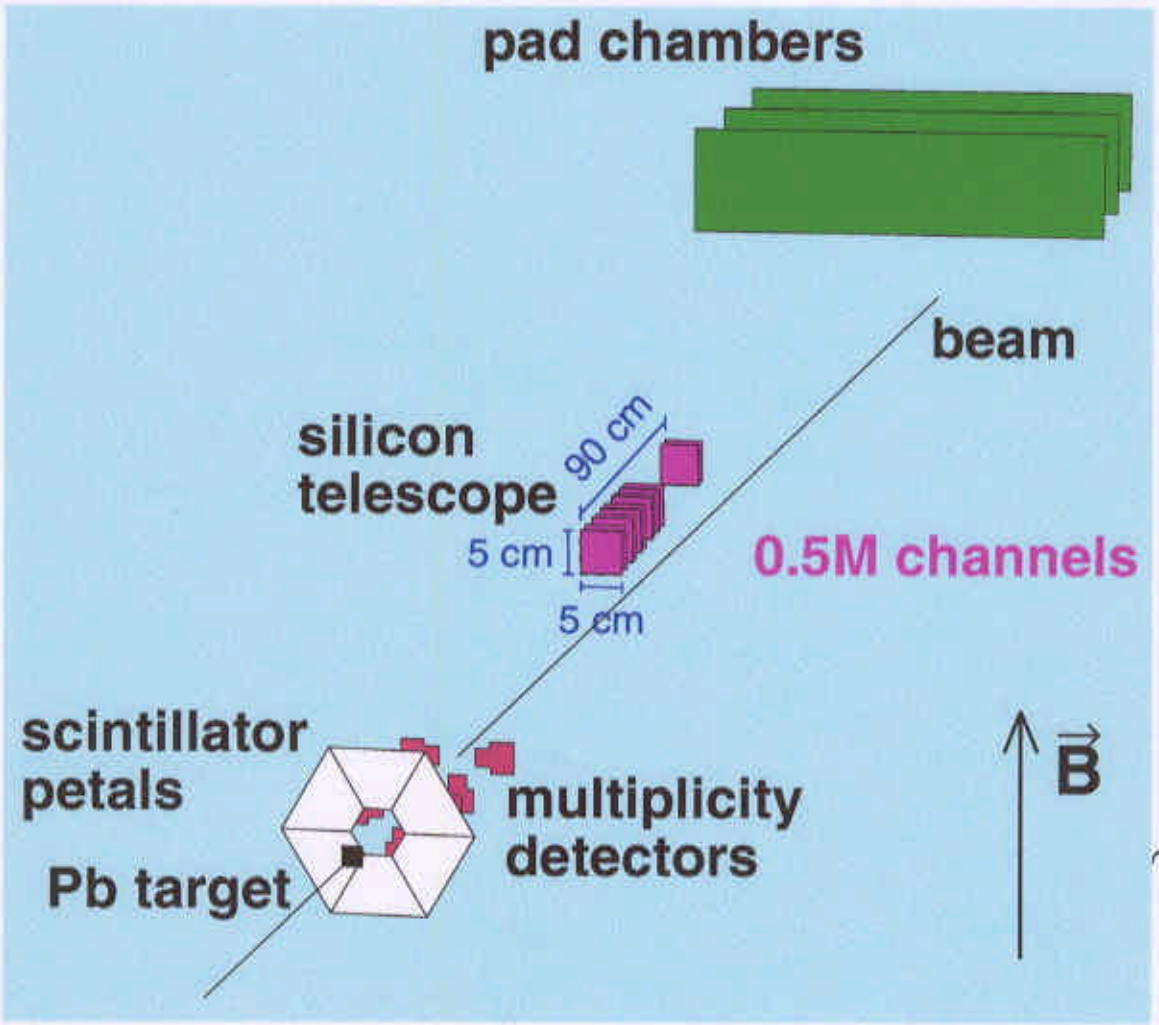
$|y - y_{cm}| \leq 0.5$

$$\begin{aligned} p_T &\geq 0.3 \text{ GeV}/c \text{ for } \pi \\ &\geq 0.7 \text{ GeV}/c \text{ for } \Omega \end{aligned}$$

visit our web site:

http://www.cern.ch/WA97

WA97 set-up



Scintillator petals: most central ($\sim 40\%$) Pb-Pb collisions triggered;

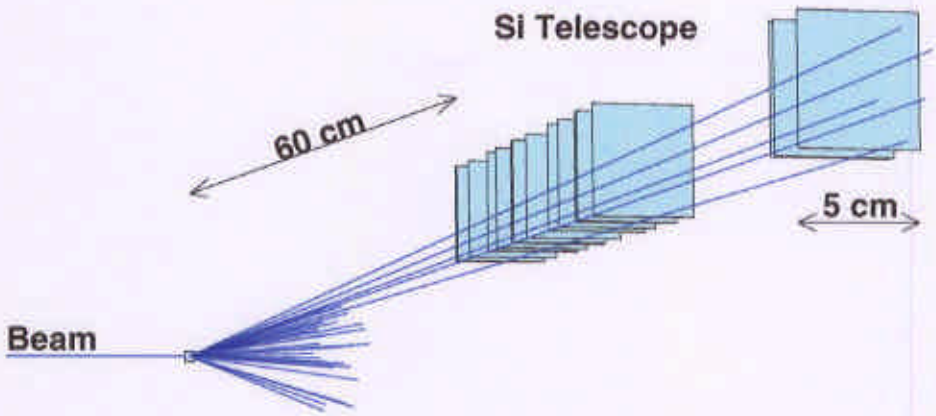
Mult. detectors: sample charged particles multiplicity ($2 < \eta < 4$);

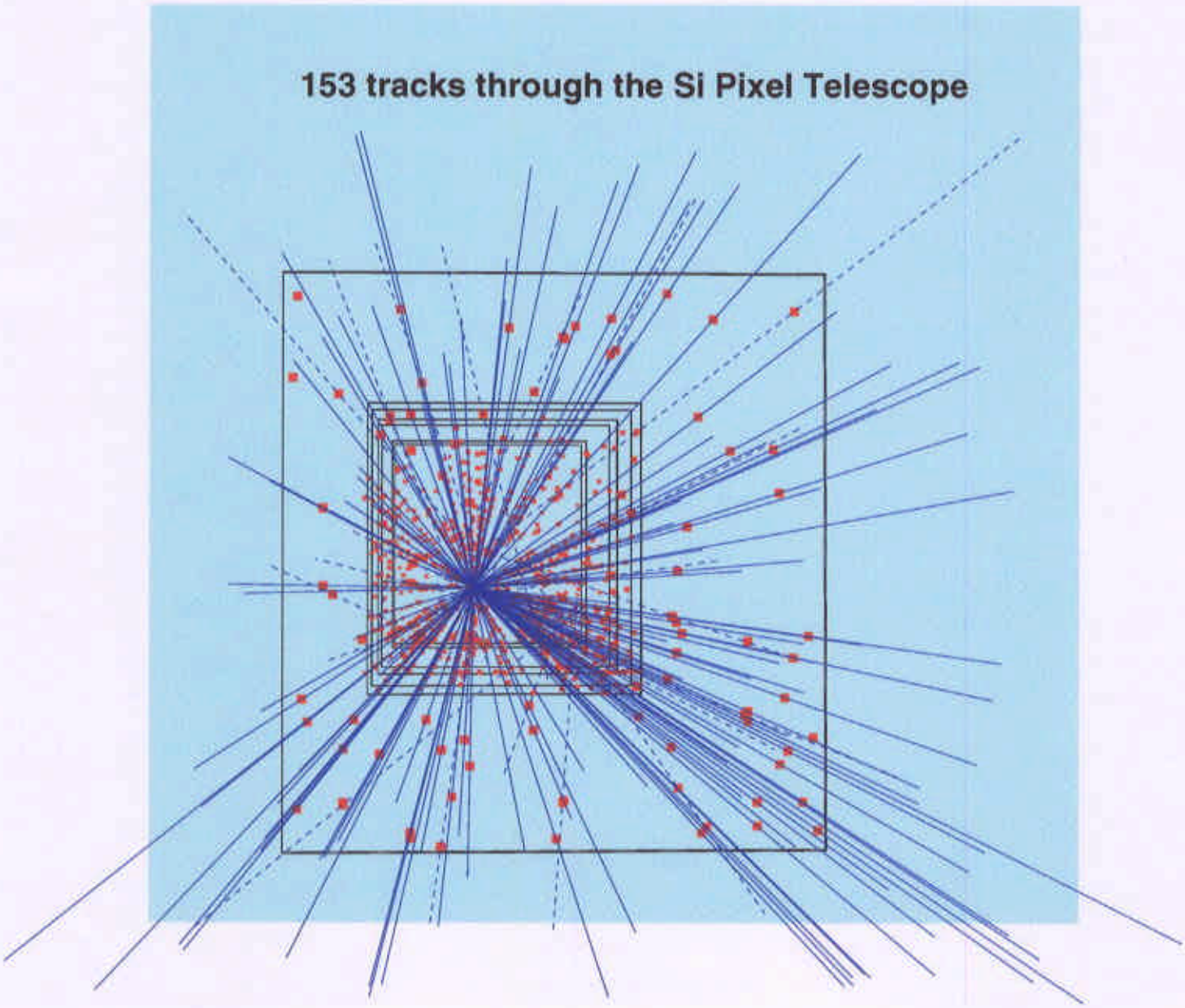
Silicon Telescope: 7 pixel planes with $75 \times 500 \mu m^2$ pixel size
10 microstrip planes with $50 \mu m$ pitch;

Pad chambers: improve momentum resolution of fast tracks;

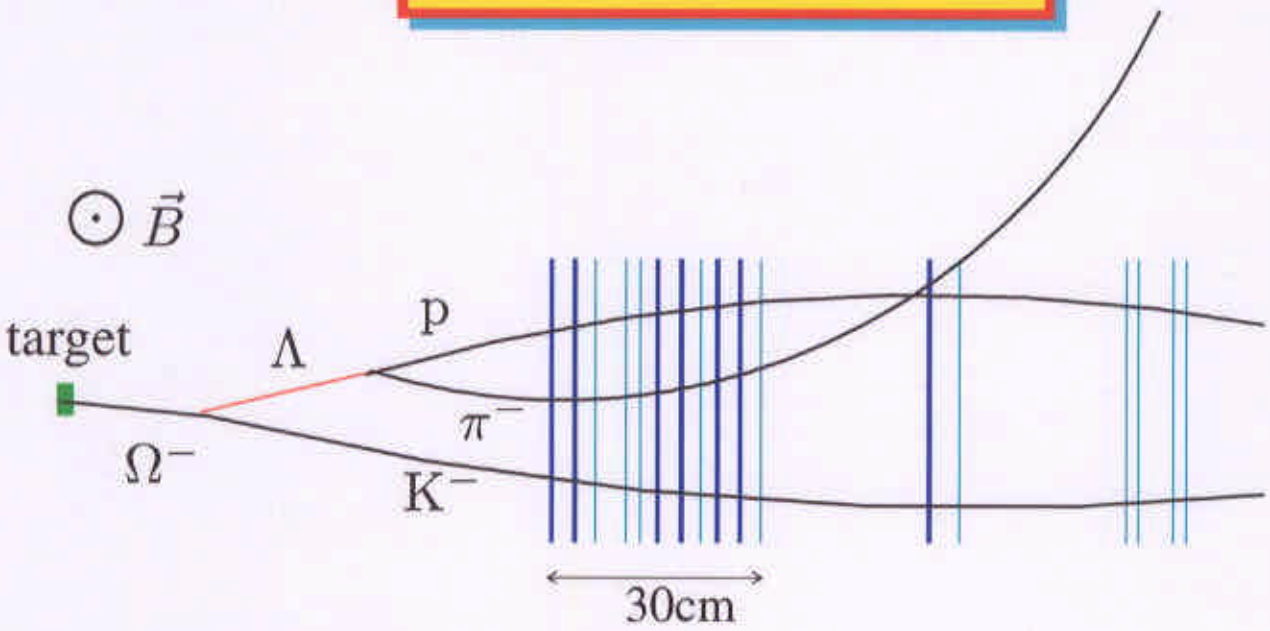
p-Pb trigger: events with at least two tracks in the telescope scintillators;

WA97 Pb–Pb event 1995





Decay reconstruction



Strange baryons:

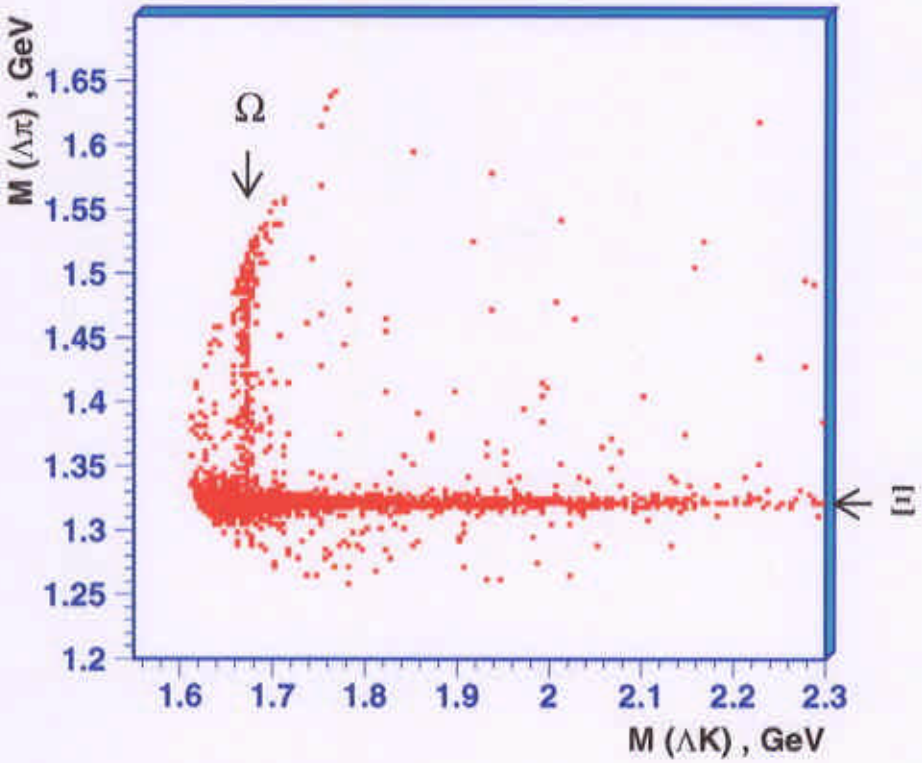
$$\Lambda \rightarrow \quad p + \pi^- \quad BR = 63.9\%$$

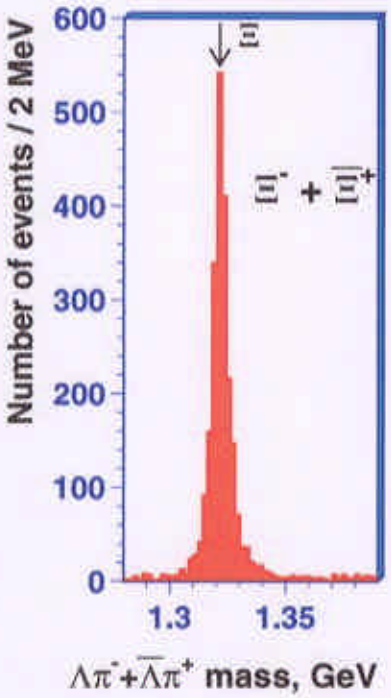
Multi-strange baryons:

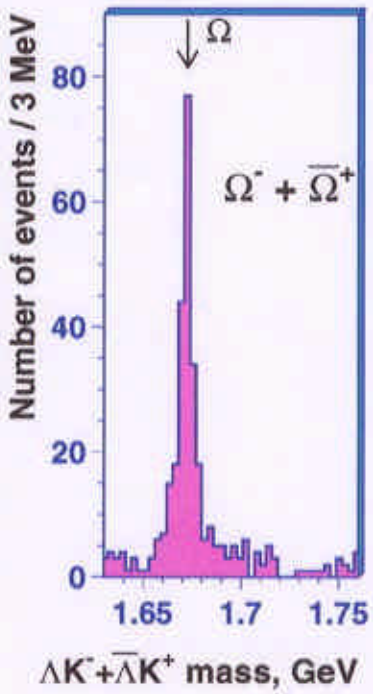
$$\begin{aligned} \Xi^- \rightarrow \quad & \Lambda + \pi^- && BR = 99.89\% \\ & \hookrightarrow p + \pi^- && BR = 63.9\% \end{aligned}$$

$$\begin{aligned} \Omega^- \rightarrow \quad & \Lambda + K^- && BR = 67.8\% \\ & \hookrightarrow p + \pi^- && BR = 63.9\% \end{aligned}$$

Ξ and Ω in Pb–Pb



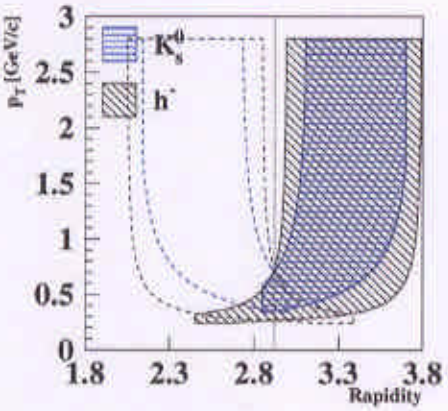




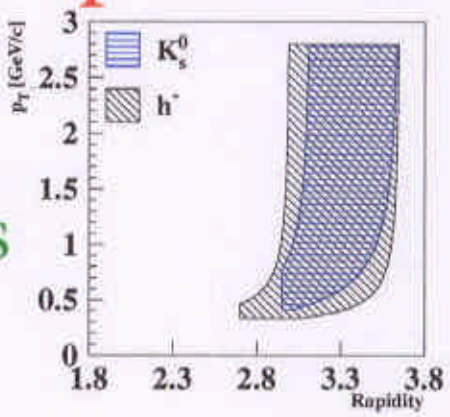
Acceptance Windows

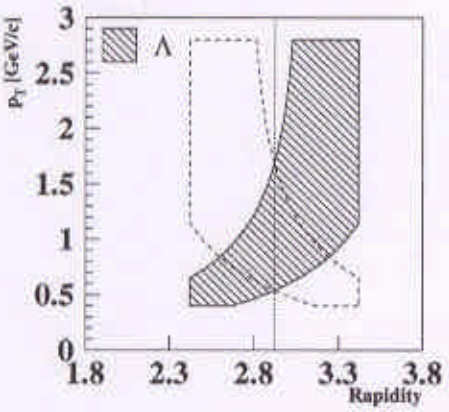
Pb+Pb

p+Pb/Be

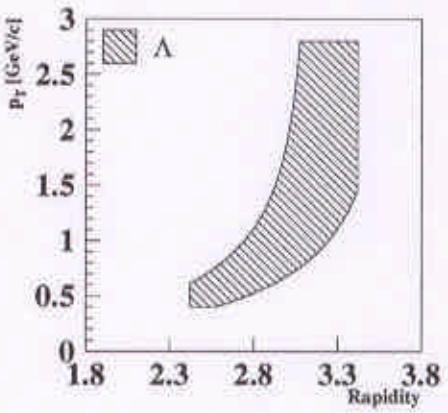


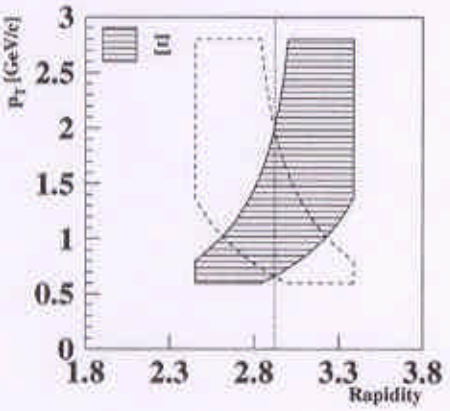
h^-, K^0_s



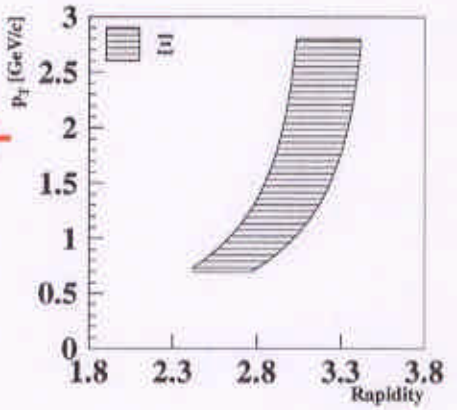


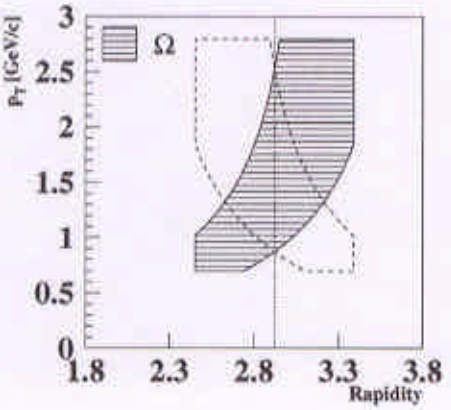
$\Lambda, \bar{\Lambda}$



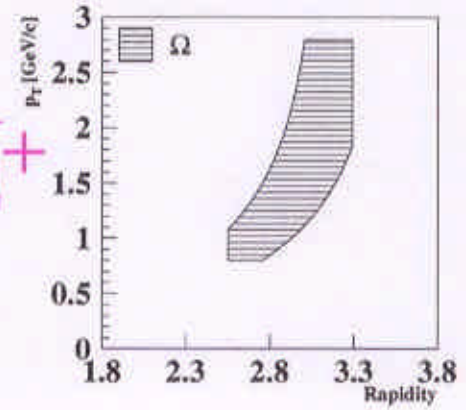


$\Xi^-, \bar{\Xi}^+$



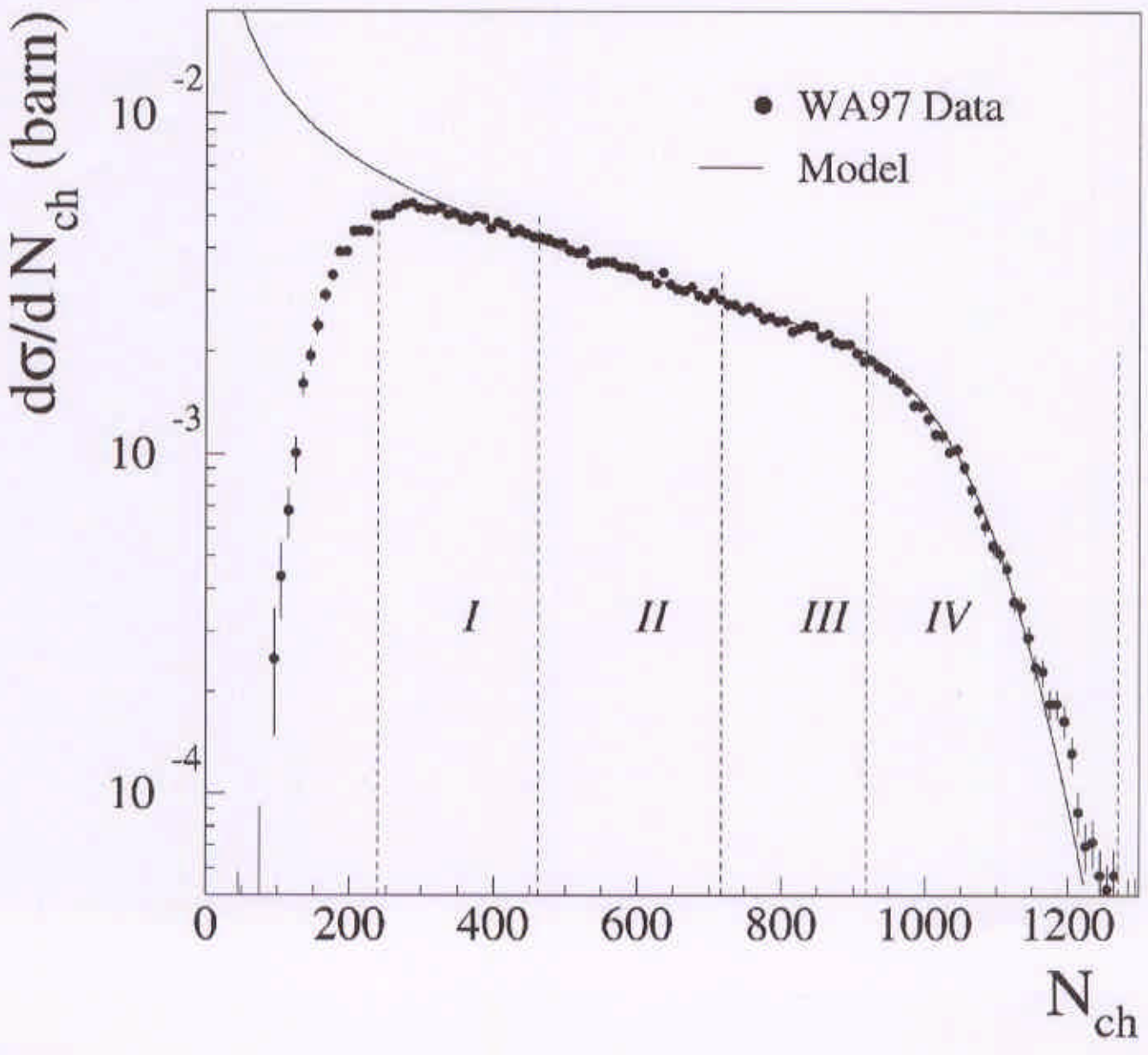


$\Omega^-, \bar{\Omega}^+$



Centrality Measurement

- Full WA97 Pb-Pb sample ~ 40% σ_{inel}
- Centrality measurement based on multiplicity in $2 < \eta < 4$ sampled by the MSD (silicon μ-strips)
- Data fitted with wounded nucleon model $\langle N_{ch} \rangle \propto \langle N_{wound} \rangle$
- WA97 data divided into 4 centrality classes



Results

We determine as a function of centrality:

- Inverse slope T of the m_{T} distributions, parametrized as:

$$\frac{\mathrm{d}N(m_{\mathrm{T}},y)}{\mathrm{d}m_{\mathrm{T}}\mathrm{d}y} = f(y)\, m_{\mathrm{T}} exp(-\frac{m_{\mathrm{T}}}{T})$$

$f(y)$ is assumed to be constant in the acceptance region of the experiment ($|y - y_{cm}| \leq 0.5$)

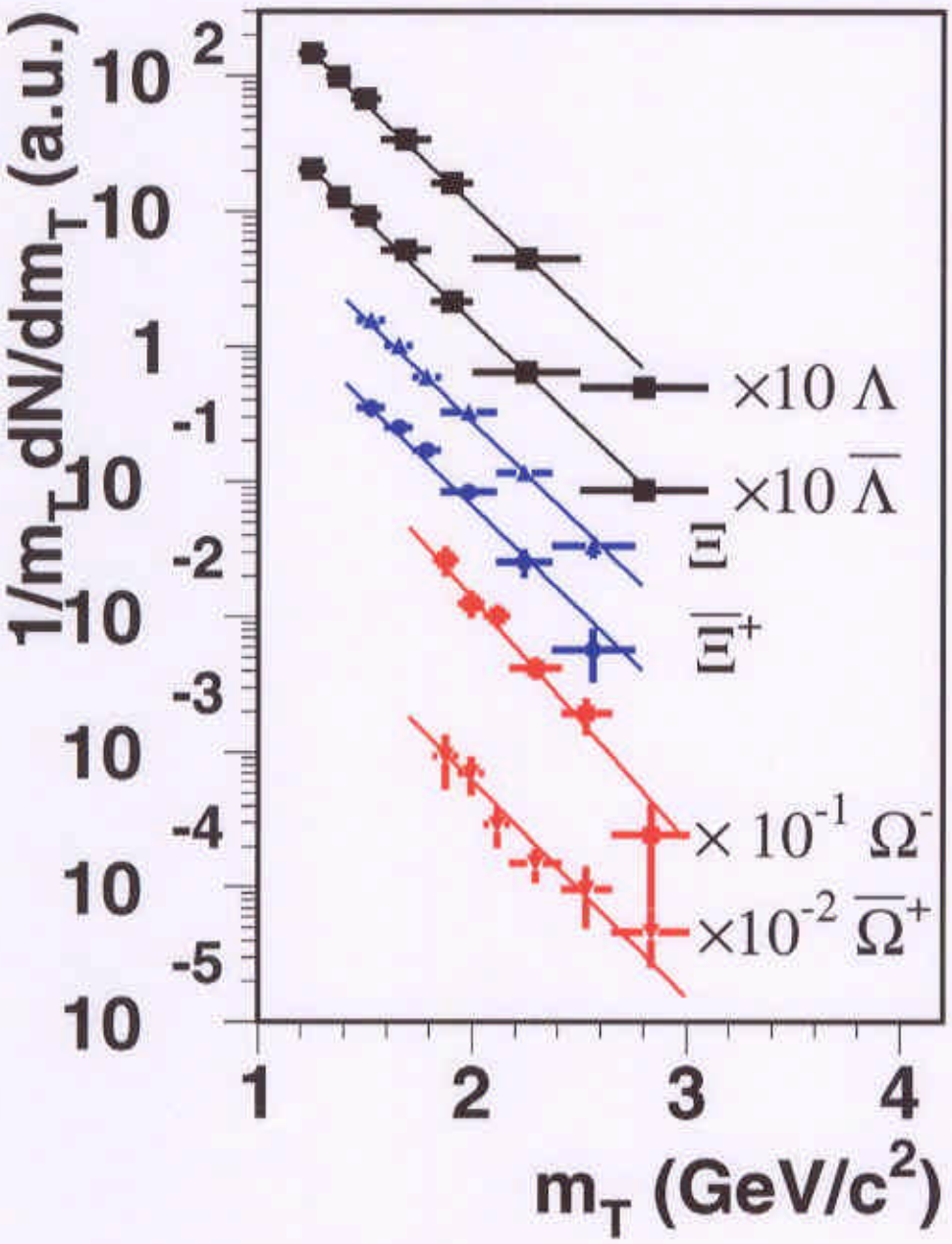
$\Rightarrow$ systematic error largest in p–Pb. Estimated by assuming
$f(y) \rightarrow$ empirical fit to published p–S and p–Au data:

	difference on the m_{T} slope	difference on the yields
Λ	10%	6%
$\bar{\Lambda}$	$< 5\%$	$< 5\%$

- Particle yields:

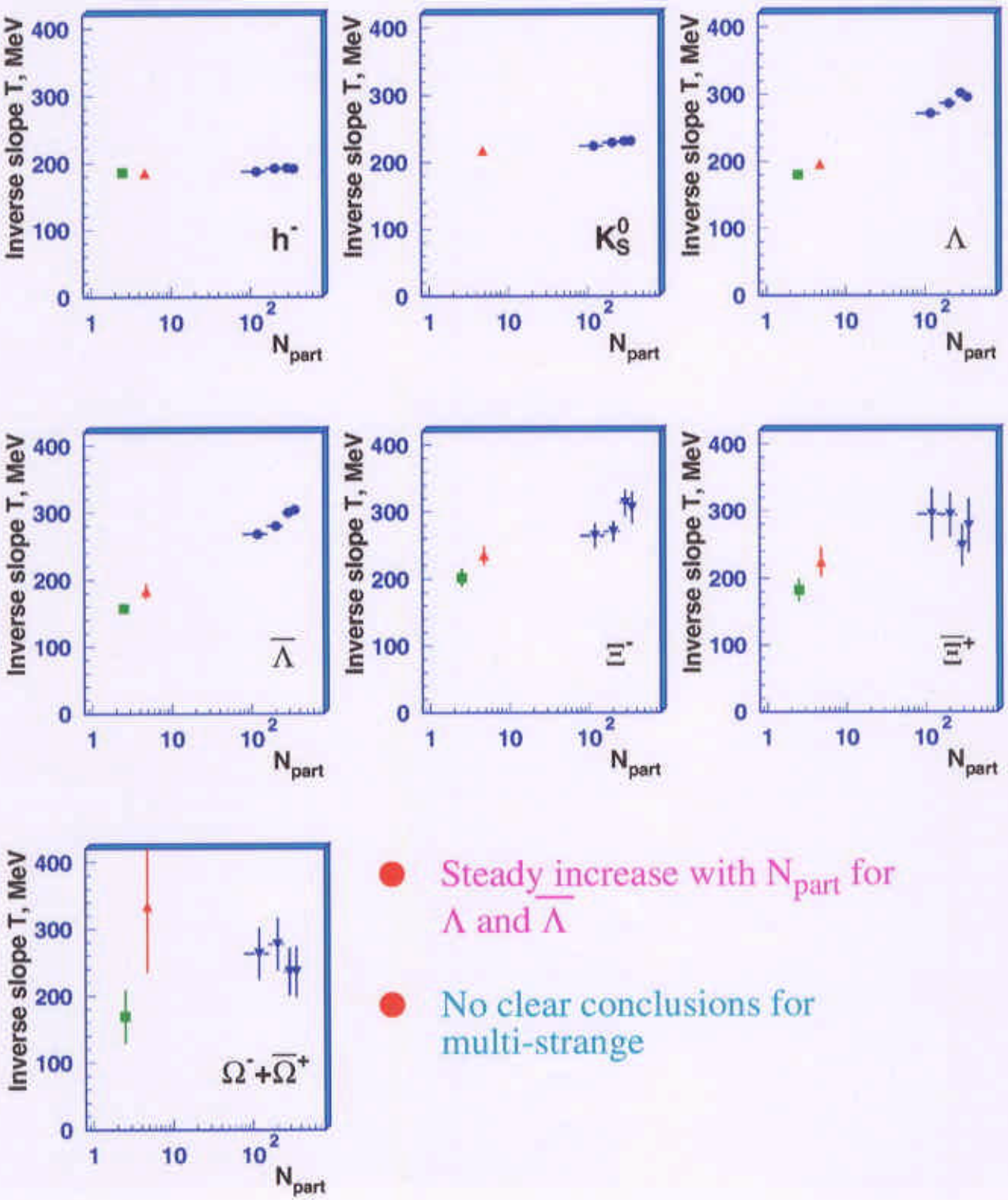
$$Y = \int_{m}^{\infty} \mathrm{d}m_{\mathrm{T}} \int_{y_{cm}-0.5}^{y_{cm}+0.5} \mathrm{d}y \frac{\mathrm{d}N(m_{\mathrm{T}},y)}{\mathrm{d}m_{\mathrm{T}}\mathrm{d}y}$$

Hyperon transverse mass spectra in Pb–Pb



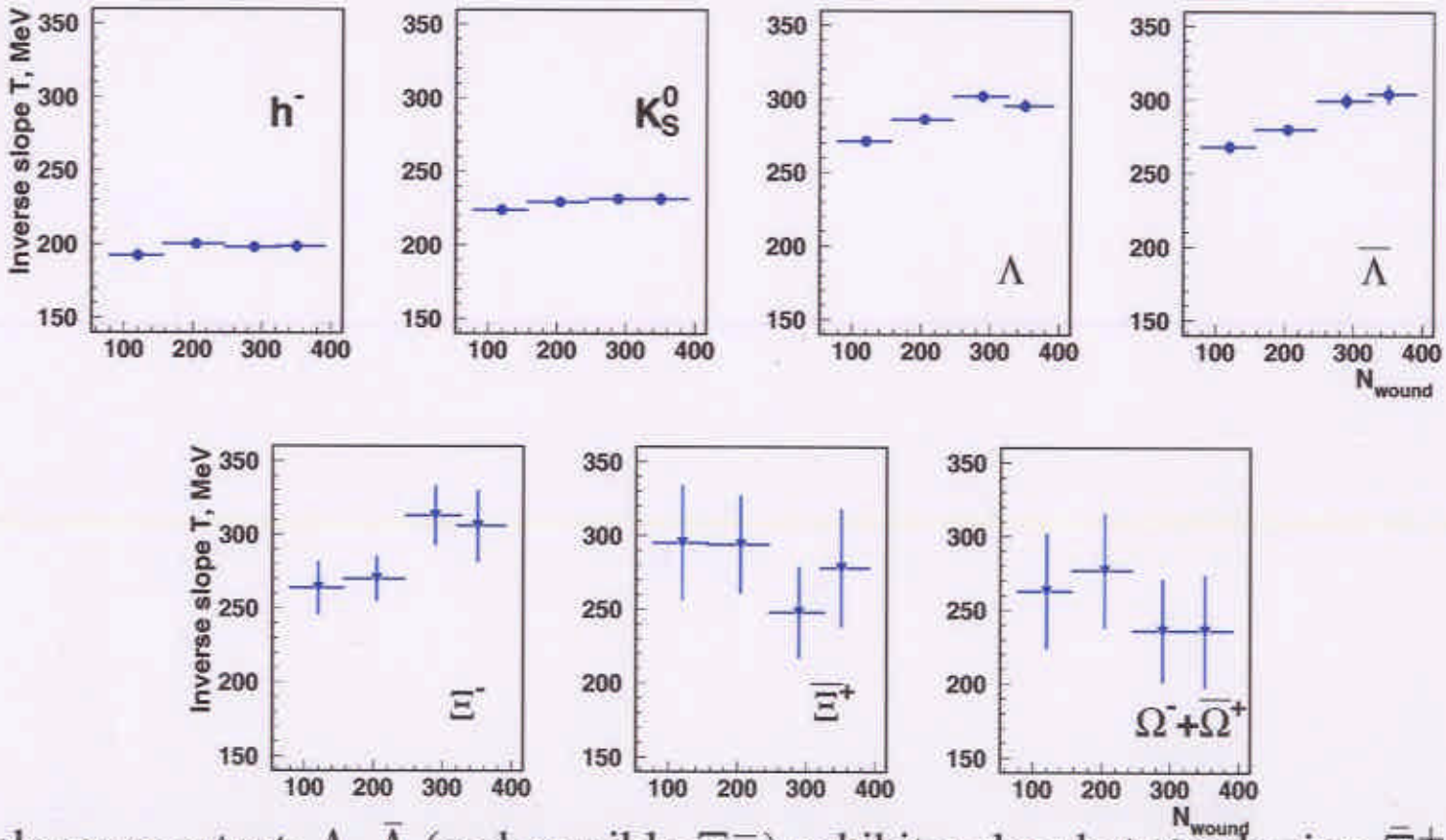
M_T Inverse Slopes vs N_{part}

- Fitted to $\frac{dN}{dm_T} \sim m_T \exp(-m_T/T)$
- p+Be, p+PB, 4 centrality classes in Pb+Pb



- Steady increase with N_{part} for Λ and $\bar{\Lambda}$
- No clear conclusions for multi-strange

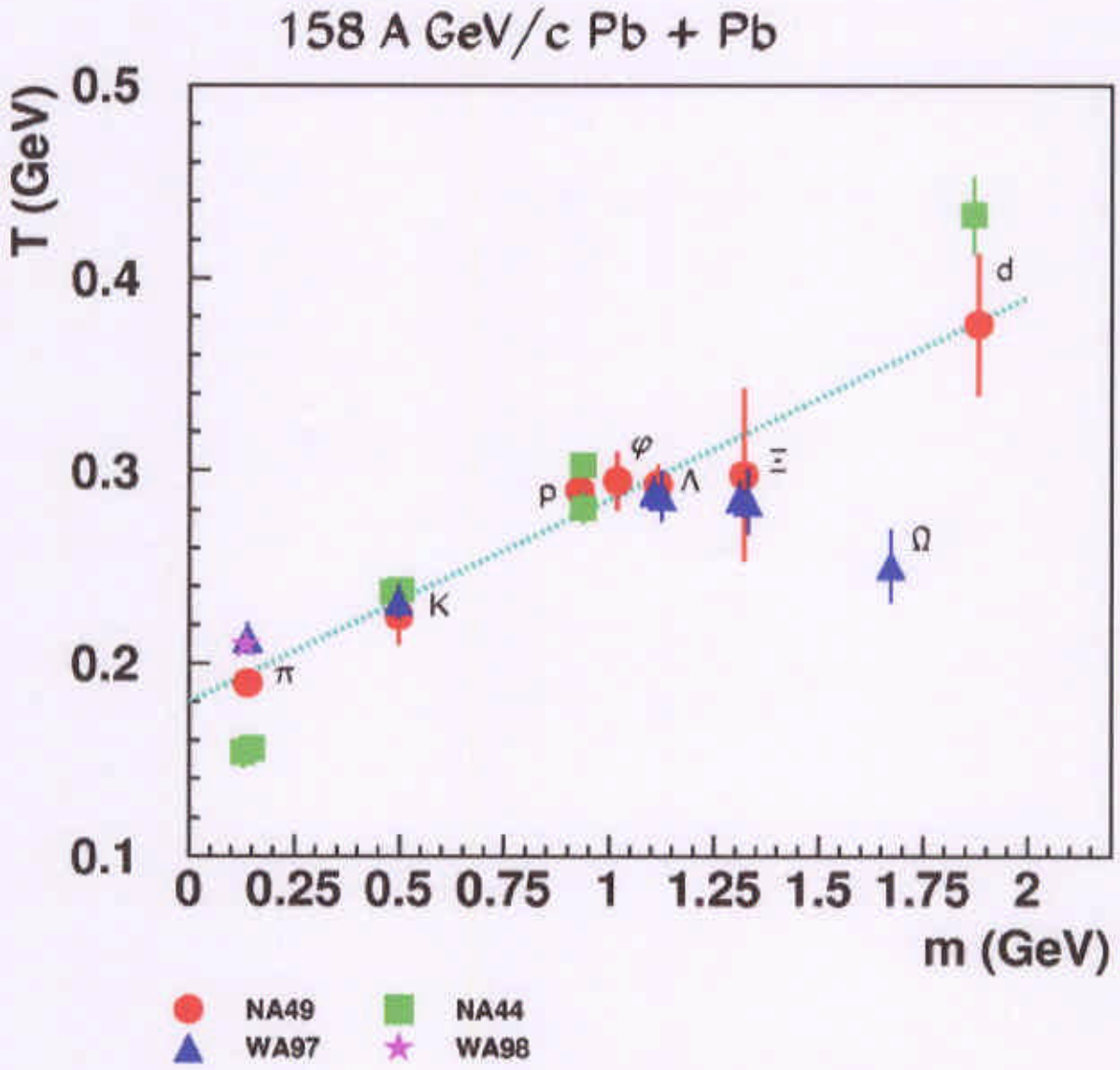
Centrality dependence of m_{T} spectra



h^-, $\mathrm{K}^0_{\mathrm{S}}$slopes constant; Λ, $\bar{\Lambda}$ (and possibly Ξ^-) exhibit a slow but steady rise; $\bar{\Xi}^+$ and Ω not a significant centrality dependence above $N_{wound} = 100$

($\Rightarrow$ more statistics coming)

Pb-Pb: m_T Inverse Slopes vs Particle Mass



- Linear increase with particle mass (global flow expectation)
- Ω inverse slope deviates

Particle Yields

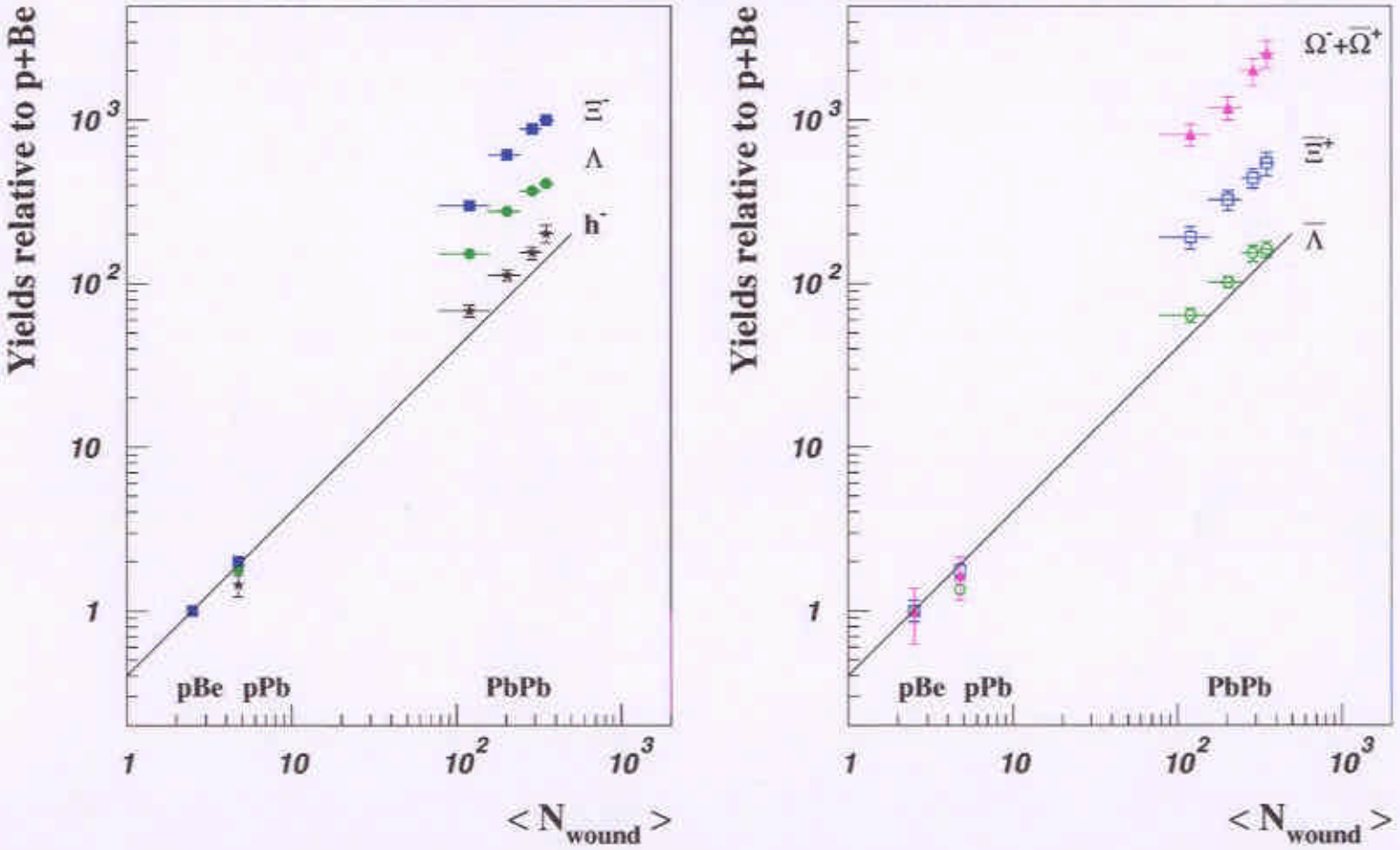
QGP prediction:

- strange (anti)baryon close to hadronic thermal and chemical equilibrium
- the (anti)hyperon enhancement is expected to increase with its strangeness content

$$Enhanc.(\Lambda) < Enhanc.(\Xi) < Enhanc.(\Omega)$$

(J.Rafelski and B. Müller, Phys.Rev.Lett.48 (1982) 1066)

Yields relative to p–Be



⇒ Pb–Pb yields enhanced with respect to p–Be; enhancements increase with strangeness.

⇒ Yields proportional to number of wounded nucleons in Pb–Pb centrality range.

$$Y = N_{wound}^{\beta}$$

Fit to Pb–Pb yields

Particle	β	χ^2	d.o.f
h^-	$0.97 \pm 0.07 \pm 0.04$	0.31	2
Λ	$0.94 \pm 0.08 \pm 0.04$	2.59	2
$\overline{\Lambda}$	$0.91 \pm 0.13 \pm 0.04$	0.62	2
Ξ^-	$1.14 \pm 0.08 \pm 0.05$	2.89	2
$\overline{\Xi}^+$	$0.96 \pm 0.19 \pm 0.04$	0.02	2
$\Omega^- + \overline{\Omega}^+$	$1.06 \pm 0.18 \pm 0.05$	0.95	2

$\Rightarrow \beta \sim 1$ in Pb–Pb centrality range

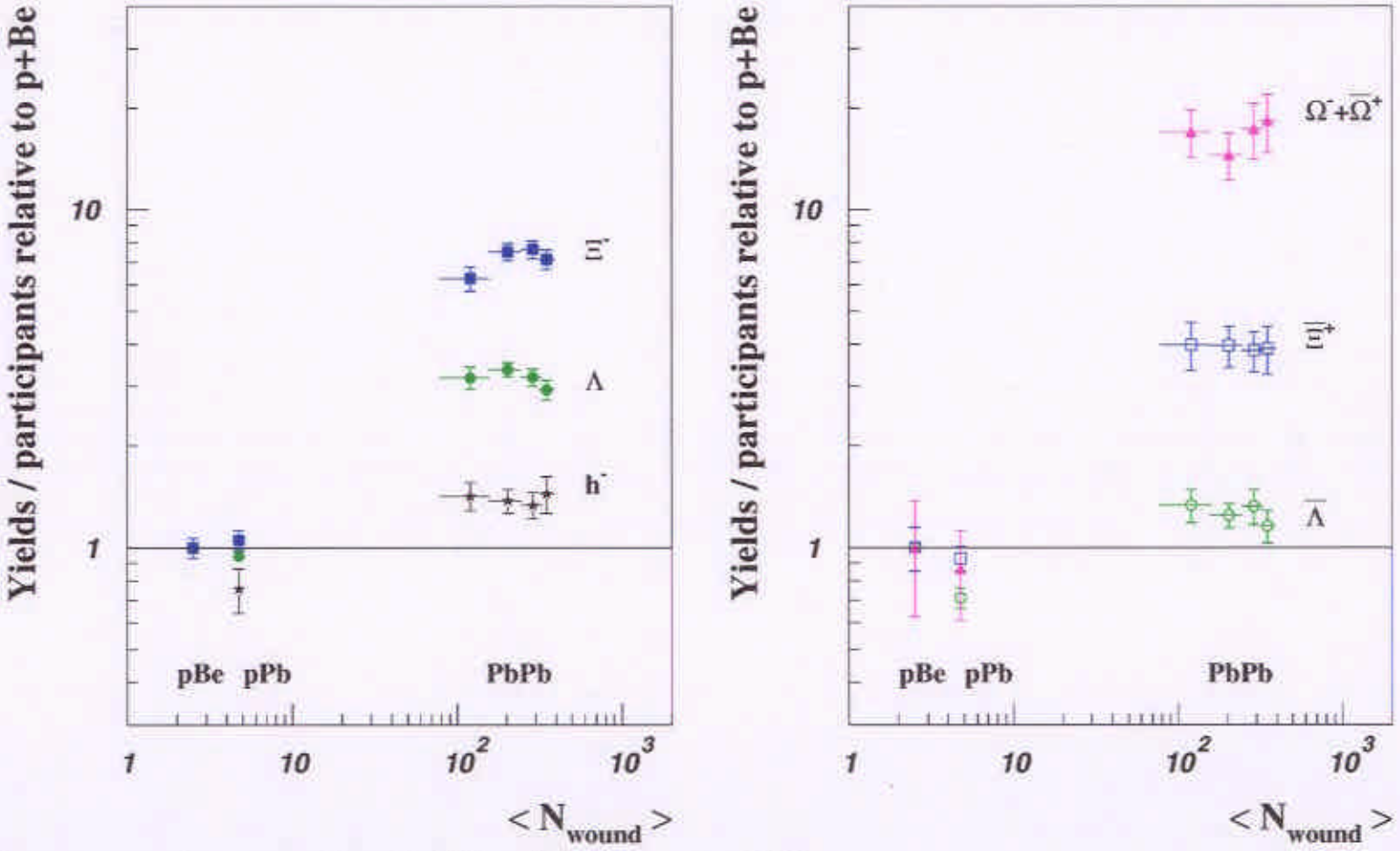
Question: β depending on particle species?

Fit both Pb–Pb AND p–Be yields

Particle	β	χ^2	d.o.f
h^-	$1.073 \pm 0.011 \pm 0.005$	1.07	3
Λ	$1.258 \pm 0.007 \pm 0.005$	21.1	3
$\overline{\Lambda}$	$1.051 \pm 0.012 \pm 0.005$	1.85	3
Ξ^-	$1.426 \pm 0.016 \pm 0.003$	15.8	3
$\overline{\Xi}^+$	$1.291 \pm 0.036 \pm 0.003$	3.12	3
$\Omega^- + \overline{\Omega}^+$	$1.549 \pm 0.080 \pm 0.007$	7.44	3

$\Rightarrow$ not favoured

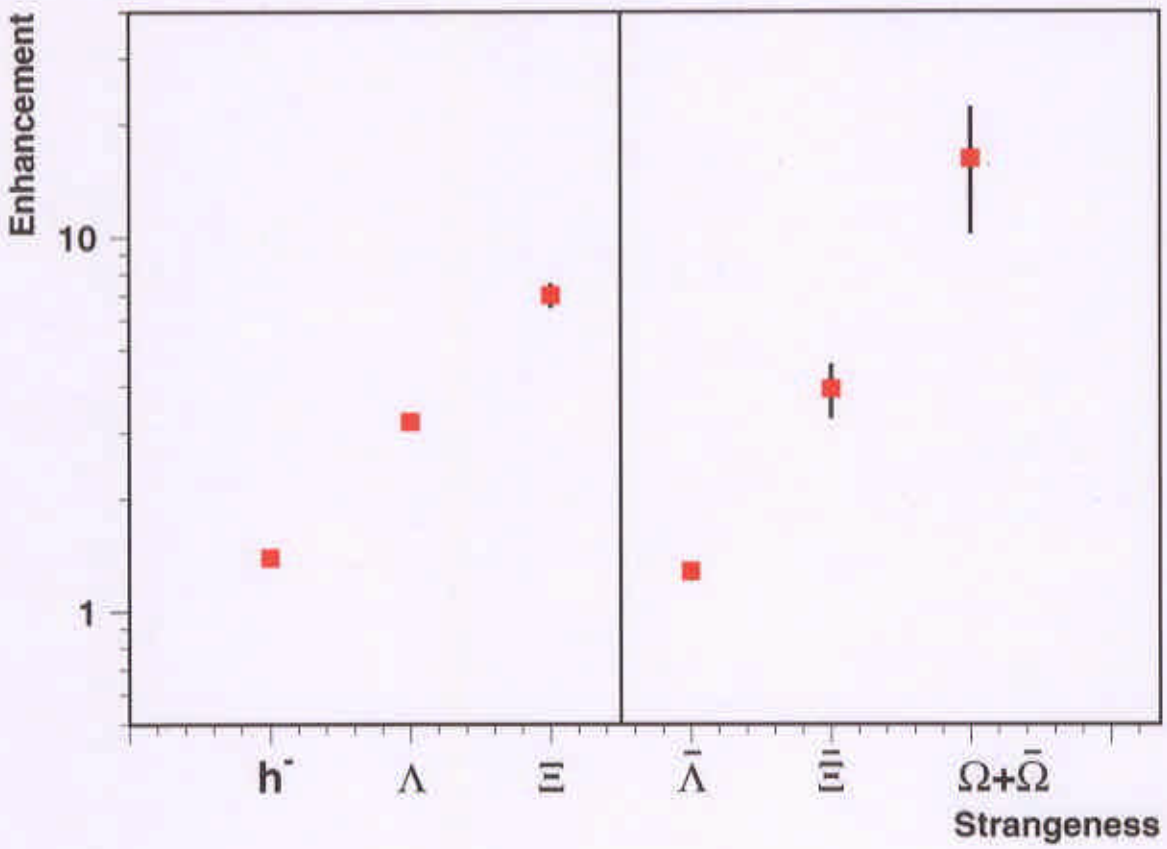
Yield/participants relative to p–Be



$\Rightarrow$ Enhancements are saturated for $N_{wound} > 100$

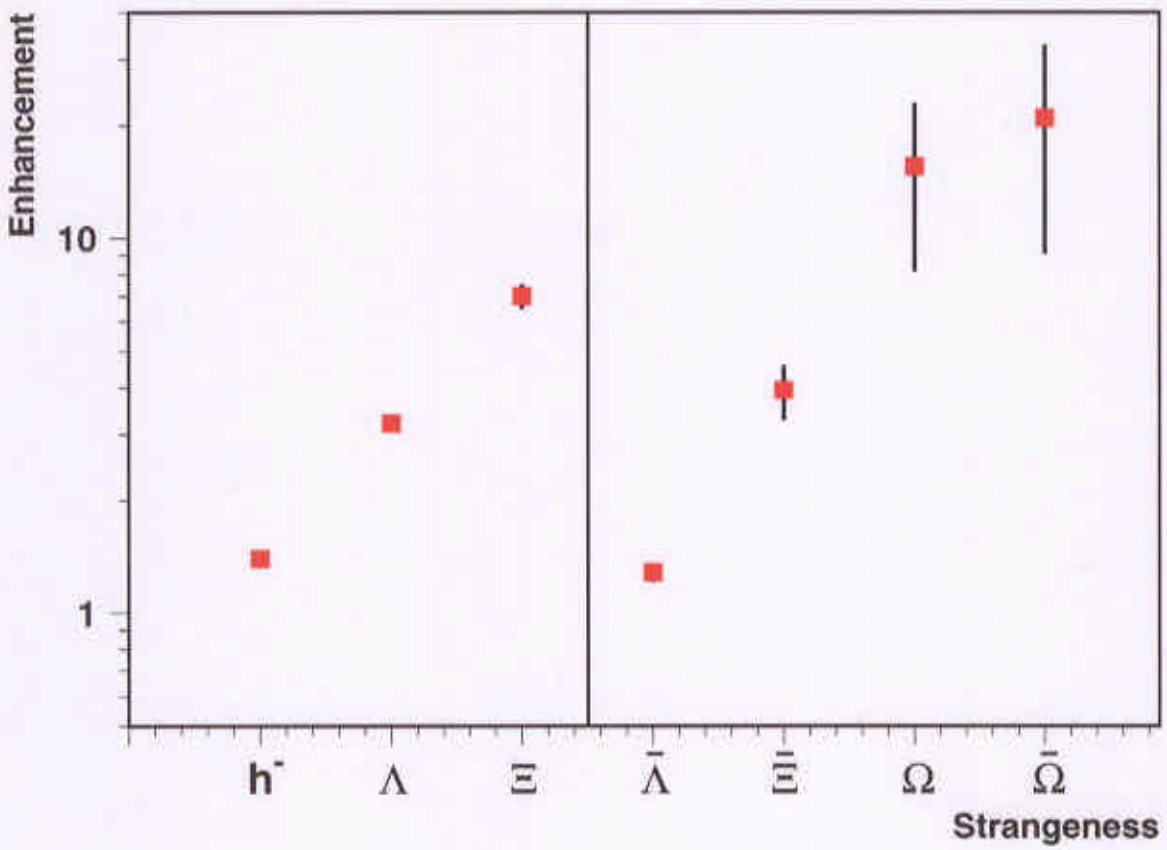
$\Rightarrow$ Enhancement is larger for particles of higher strangeness content

Enhancement relative to p–Be



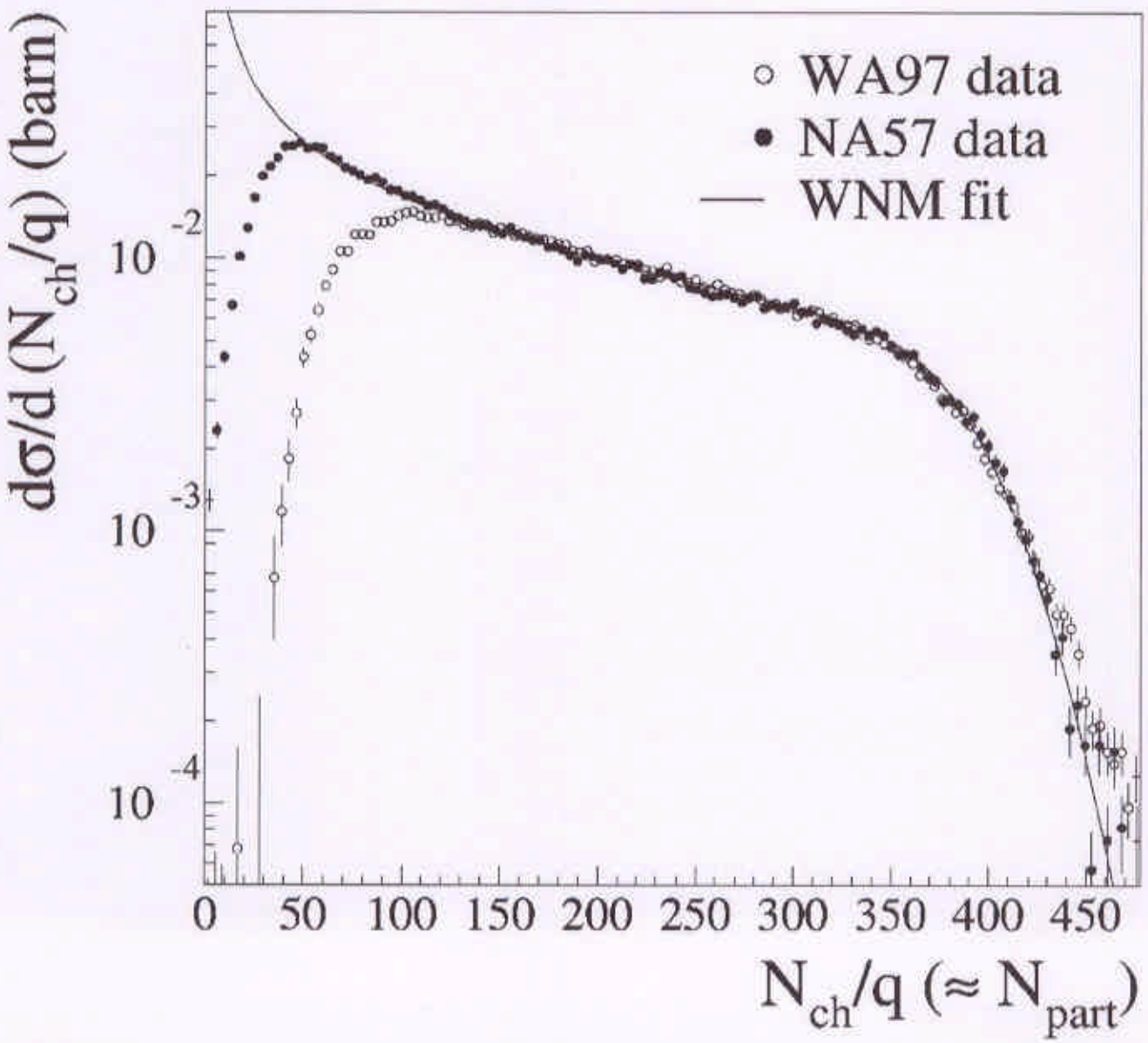
$$E = \left(\frac{\langle Yields \rangle}{\langle N_w \rangle}\right)_{Pb--Pb} / \left(\frac{\langle Yields \rangle}{\langle N_w \rangle}\right)_{p--Be}$$

$E \sim 16$ for $\Omega + \bar{\Omega}$


Enhancement
10
1
h⁻
Λ
Ξ
$\bar{\Lambda}$
$\bar{\Xi}$
Ω
$\bar{\Omega}$
Strangeness

NA57

- Apparatus similar to WA97 (different magnet)
- expect ~ 2 x WA97 statistics at 160 A GeV/c
- 230M events collected in 1998
  (Pb-Pb, 160 A GeV/c, extended centrality range)



Summary & Conclusions

- Inverse m_T slopes constant with N_{wound} for negatives but increase with N_{wound} for Λ, $\bar{\Lambda}$.
- Strange particles enhanced in Pb-Pb interactions w.r.t. p-Be interactions. Strange particles not enhanced in p-Pb ints.
- Enhancement increases with strangeness content. Ωs enhanced by an order of magnitude.
- Mechanism responsible for the enhancement is already saturated at $N_{wound} \sim 100$.
- Results are compatible with Quark-Gluon Plasma formation in central Pb-Pb interactions.
- New data are coming from NA57 (extended centrality, lower beam energy)