Quark Matter 2004
Oakland – January 11-17

Energy dependence of K^0_s and hyperon production at CERN SPS

Domenico Elia
INFN - Bari (Italy)

on behalf of the ***NA57 Collaboration***

Contents

- Physics motivation
- The NA57 experimental apparatus
- Yields and ratios: comparison with NA49
- Energy dependence of K^0_s and hyperon production
- Centrality dependence of K^0_s and hyperon yields
- Hyperon enhancements at 40 A GeV
- Summary

Physics motivation

- NA57 physics goals:

  study of the dependence of hyperon enhancements on

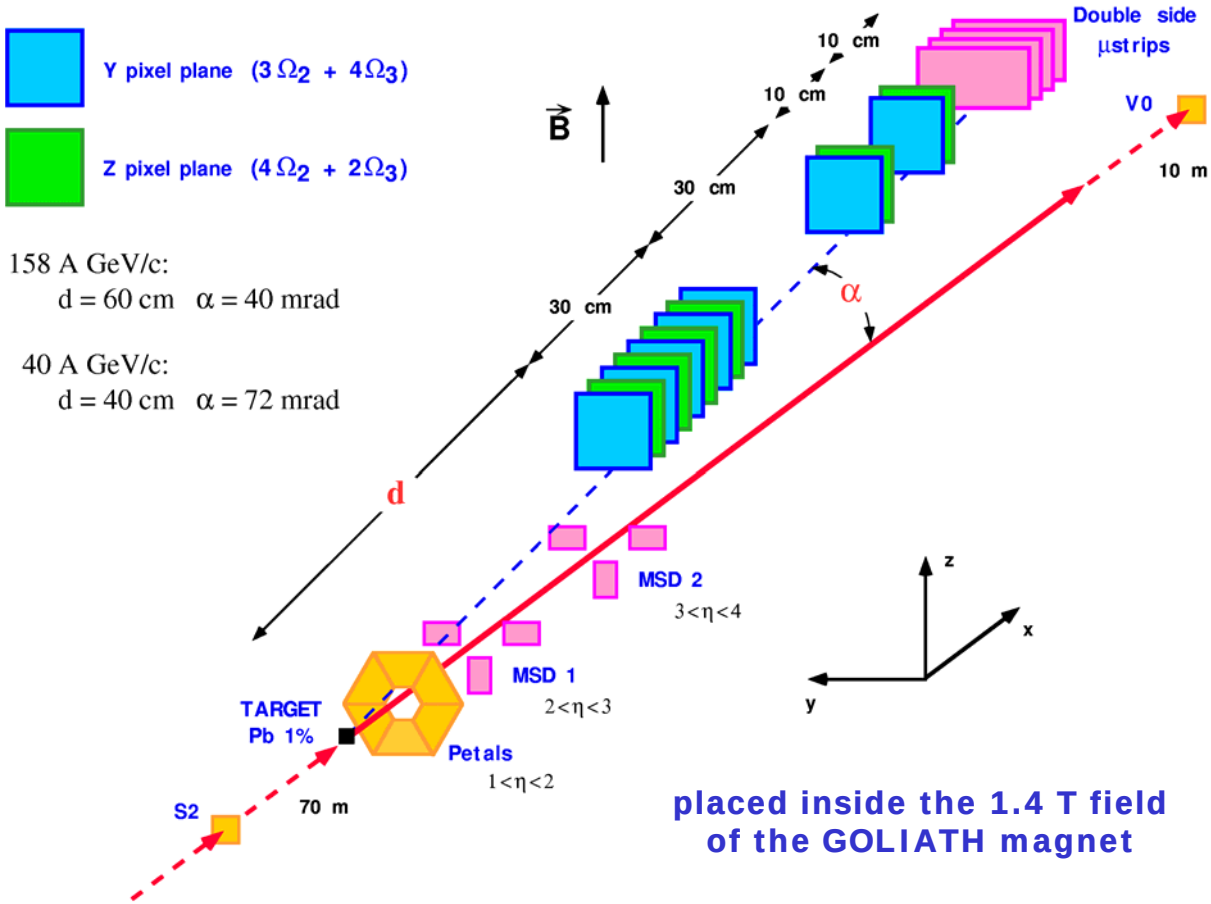
  - **interaction volume** (centrality down to $N_{wound} \sim 50$)
  - **collision energy** (data at both 40 and 160 A GeV)

- Data samples:

System	Beam energy	Sample size
Pb-Pb	160 A GeV	$(230+230) \times 10^6$ evts
Pb-Pb	40 A GeV	240×10^6 evts
p-Be	40 A GeV	$(60+110) \times 10^6$ evts

WA97 p-Be sample used as reference data at 160 A GeV

Experimental apparatus



placed inside the 1.4 T field of the GOLIATH magnet

Target: 1% Pb, 8% Be

Scintillator petals:
centrality trigger (Pb-Pb)

MSD 1 & 2:
multiplicity detector (Pb-Pb)

Tracking device:
silicon pixel planes
(5 x 5 cm^2 cross section,
50 x 500 μm^2 cell size,
total of ~ **1 M channels**)

Lever arm:
pixels + double side μstrips

Strange particle detection

- Reconstructed decay topologies:

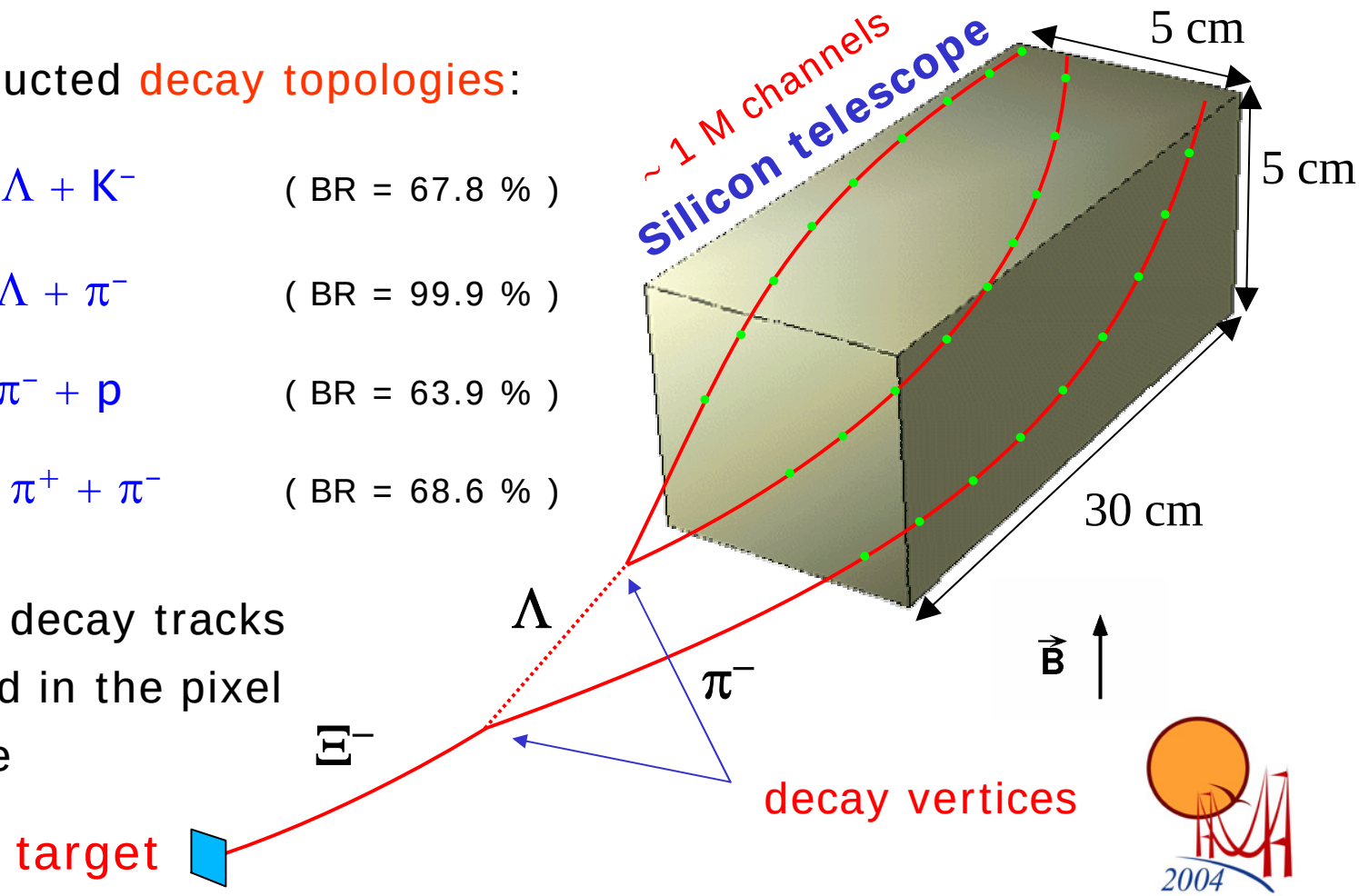
$\Omega^- \rightarrow \Lambda + K^-$ (BR = 67.8 %)

$\Xi^- \rightarrow \Lambda + \pi^-$ (BR = 99.9 %)

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

$K^0_s \rightarrow \pi^+ + \pi^-$ (BR = 68.6 %)

- Charged decay tracks measured in the pixel telescope



Yields and enhancements

- Double differential cross sections for each particle fitted to:

$$\frac{\mathrm{d}^2 N}{\mathrm{d}m_\mathrm{T}\,\mathrm{d}y} = f(y)\, m_\mathrm{T}\, \exp\left(-\frac{m_\mathrm{T}}{T}\right)$$

assuming flat rapidity distribution in the selected acceptance regions
Inverse slope of m_T distribution ($T = T_{app}$) free parameter of the fit.

- **Yield** (i.e. particle per event) extrapolated to a common y-p_T region:

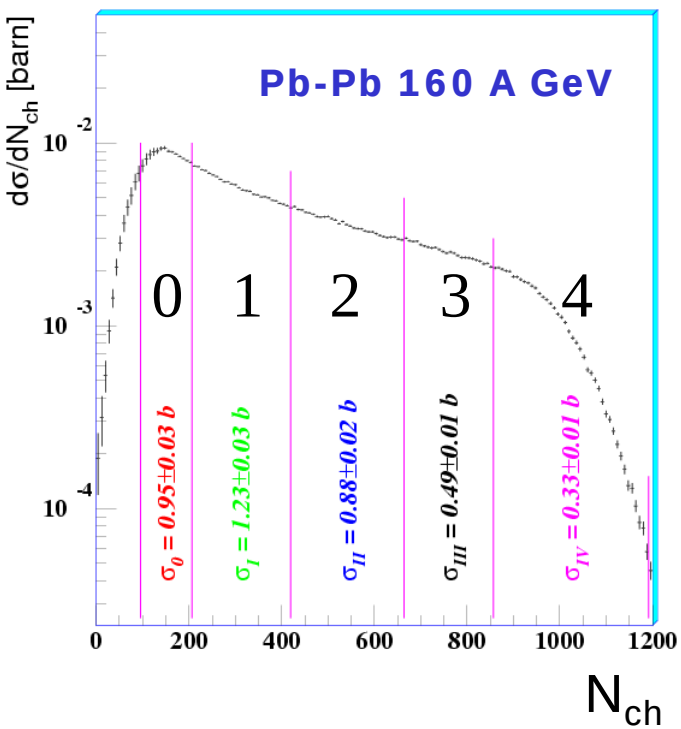
$$Y = \int_m^\infty \mathrm{d}m_\mathrm{T} \int_{y_{cm}-0.5}^{y_{cm}+0.5} \frac{\mathrm{d}^2 N}{\mathrm{d}m_\mathrm{T}\,\mathrm{d}y}\,\mathrm{d}y$$

- **Enhancement:**

$$E = \left(\frac{Y}{\langle N_{wound}\rangle}\right)_{Pb-Pb} \Big/ \left(\frac{Y}{\langle N_{wound}\rangle}\right)_{p-Be}$$

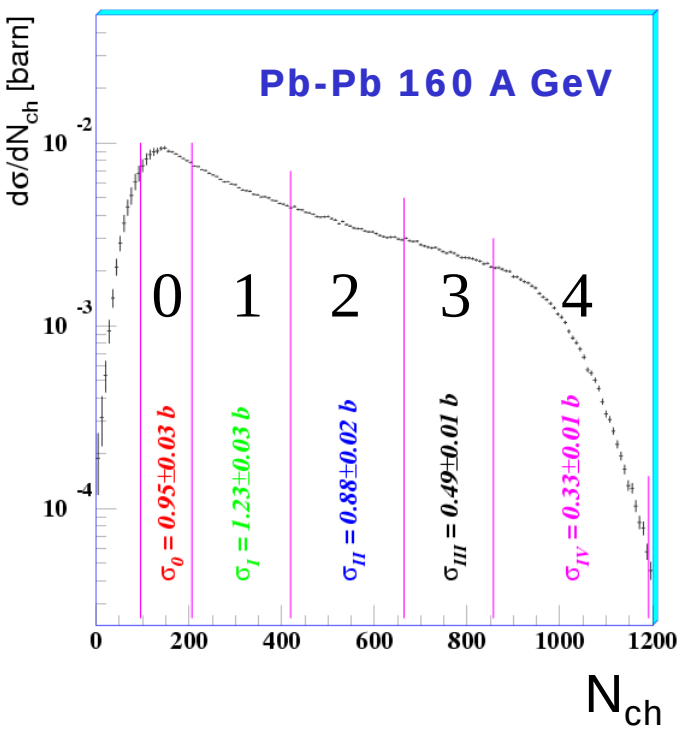
Collision centrality

- Centrality determination from measured charged particle multiplicity
- N_{wound} from trigger cross section (Glauber Model calculations)



Collision centrality

- Centrality determination from measured charged particle multiplicity
- N_{wound} from trigger cross section (Glauber Model calculations)



Class	σ / σ_{tot}	< N_{wound} > 160 GeV	< N_{wound} > 40 GeV
0	42 – 56%	62	57
1	25 – 42%	121	119
2	12 – 25%	209	208
3	5 – 12%	290	292
4	0 – 5%	349	346

- Same class definition at 40 and 160 GeV

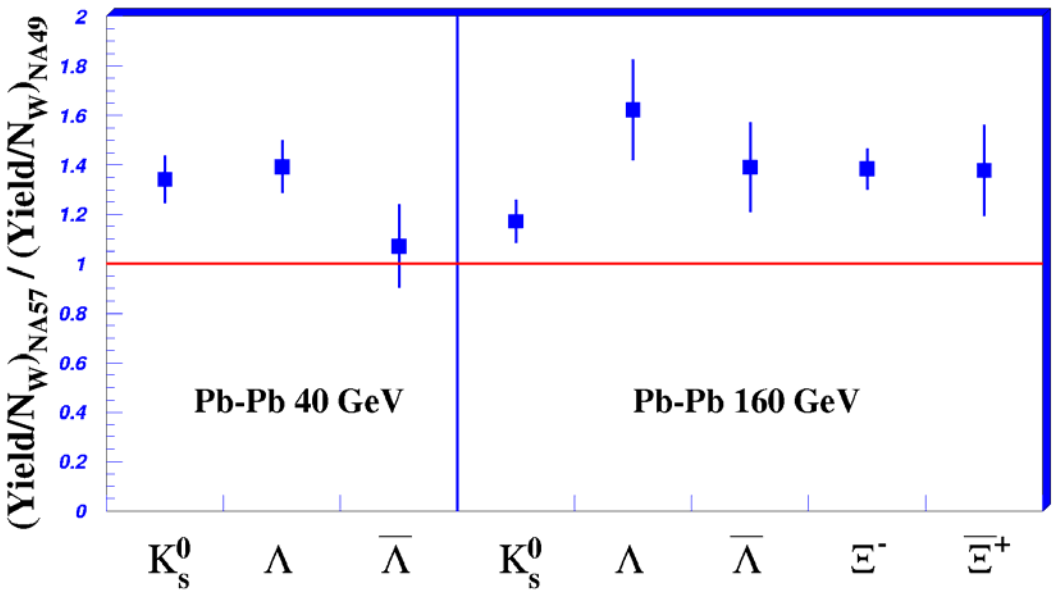
Comparison NA57-NA49

Particle yields per participant

Centrality regions:

	NA57	NA49*
40 GeV	5%	7%
160 GeV (K)	5%	7%
160 GeV (Λ, Ξ)	12%	10%

For NA49: $K^0_S = 0.5*(K^+ + K^-)$



*Refs: Physical Review C 66, 054902 (2002), nucl-ex/0311024,
Phys. Lett. B 538 (2002), 275.

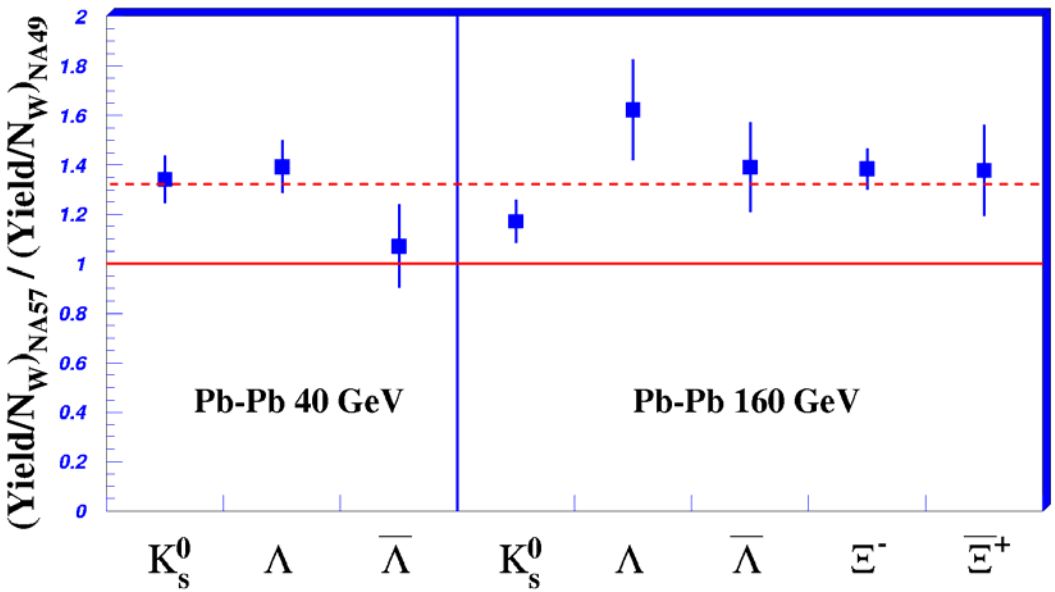
Comparison NA57-NA49

Particle yields per participant

Centrality regions:

	NA57	NA49*
40 GeV	5%	7%
160 GeV (K)	5%	7%
160 GeV (Λ, Ξ)	12%	10%

For NA49: $K^0_S = 0.5*(K^+ + K^-)$

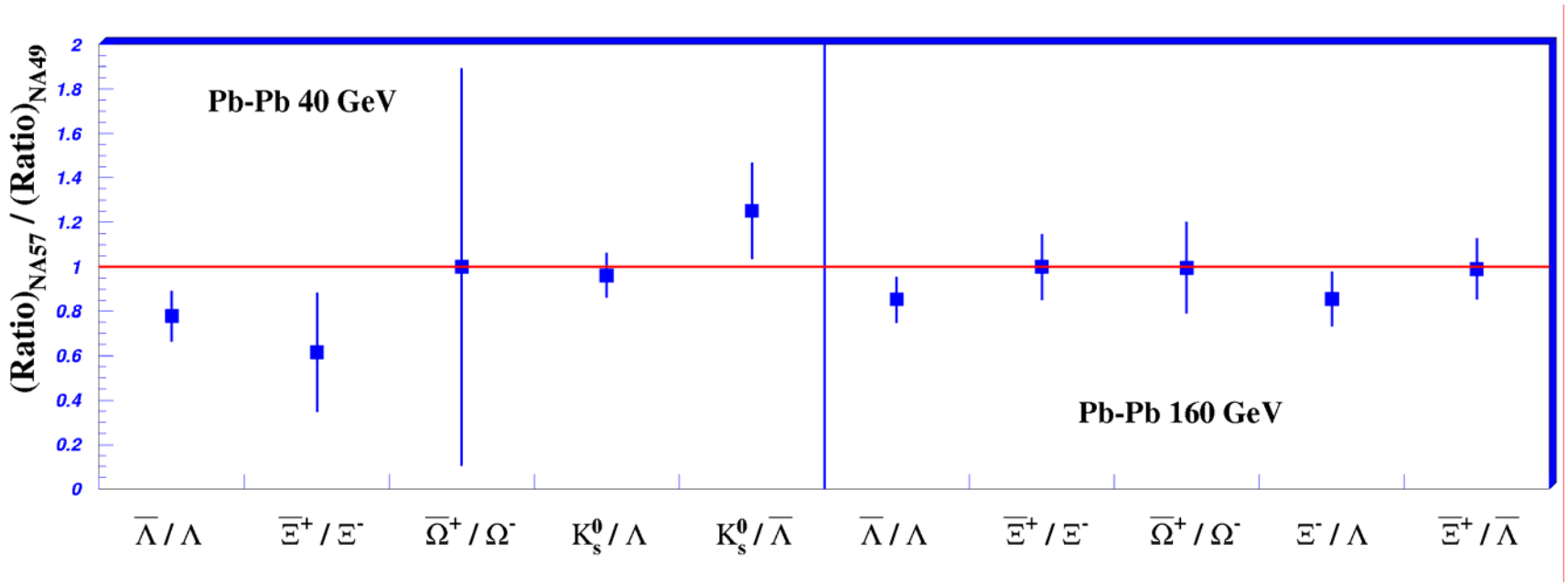


- about 30% systematics on the absolute value of the yields (under investigation) but …

*Refs: Physical Review C 66, 054902 (2002), nucl-ex/0311024, Phys. Lett. B 538 (2002), 275.

Comparison NA57-NA49

Particle ratios



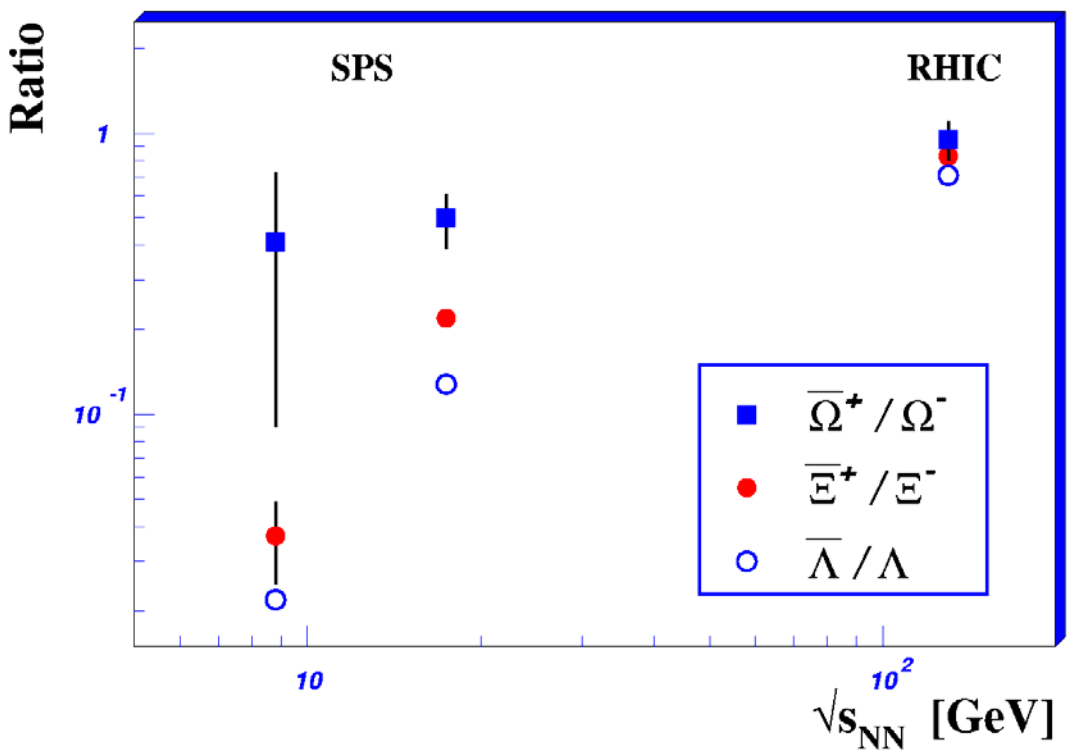
- ... particle ratios compatible within errors

  (i.e. no impact on relative yields)

*Refs: Physical Review C 66, 054902 (2002), nucl-ex/0311024, nucl-ex/0305021, nucl-ex/0311029

Energy dependence
of hyperon ratios from SPS to RHIC

Centrality regions: **NA57:** **0 - 12 %**
STAR*: **0 - 11 %**

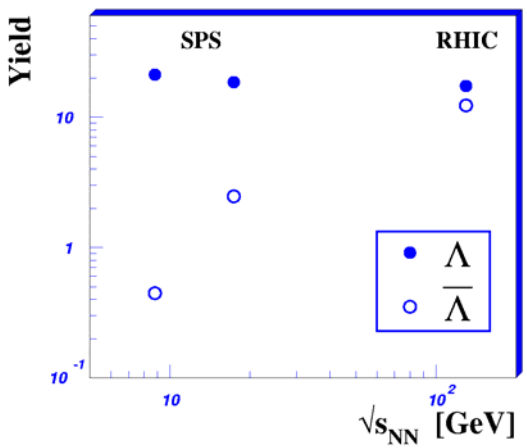


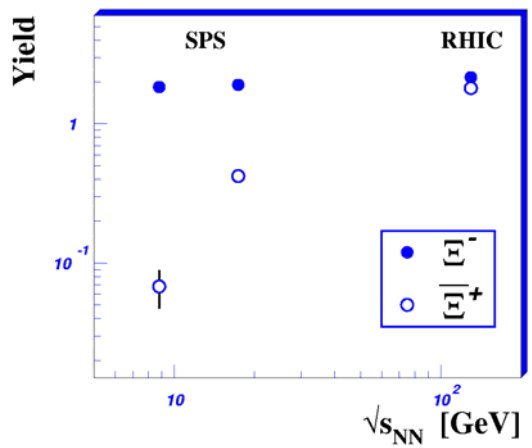
*Ref: Physics Letters B 567 (2003), 167.

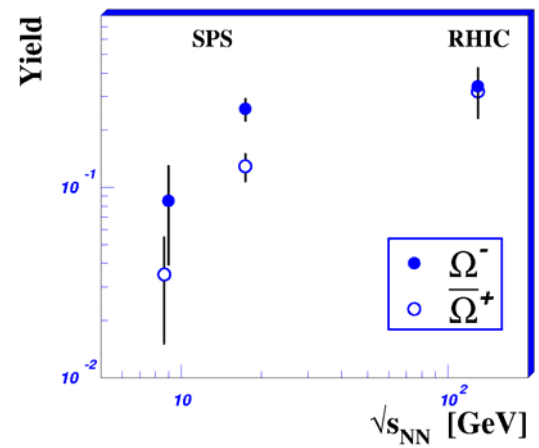
- $\overline{Y}/Y$ ratios increase with energy
- Energy dependence weaker for particle with higher strangeness

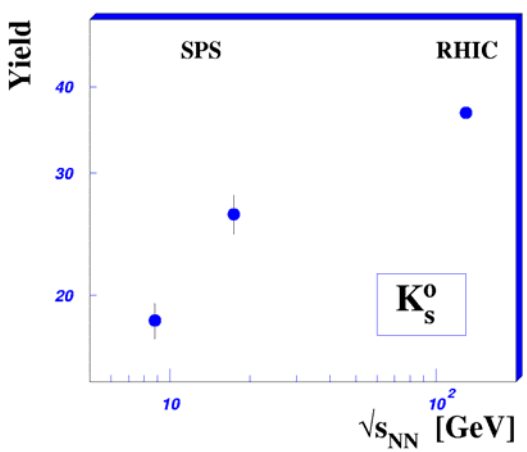
baryon density decreases with energy increase

Energy dependence
of particle yields from SPS to RHIC







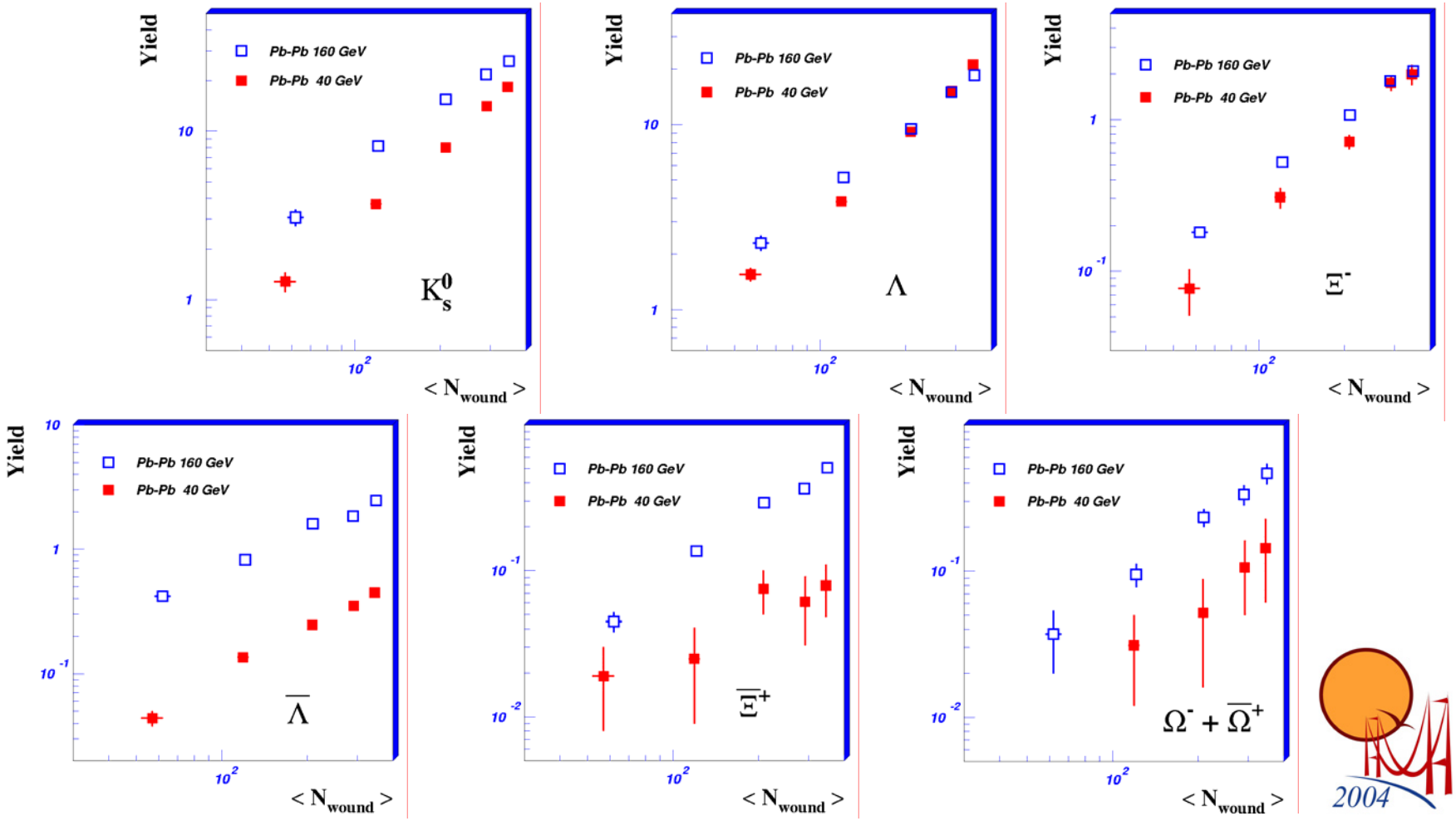


Centrality regions: **NA57: 0-5% (Λ,K), 0-12% (Ξ, Ω)**
STAR*: 0-5% (Λ), 0-6% (K), 0-10% (Ξ, Ω)

- stronger energy dependence for Ω^- and all anti-hyperons

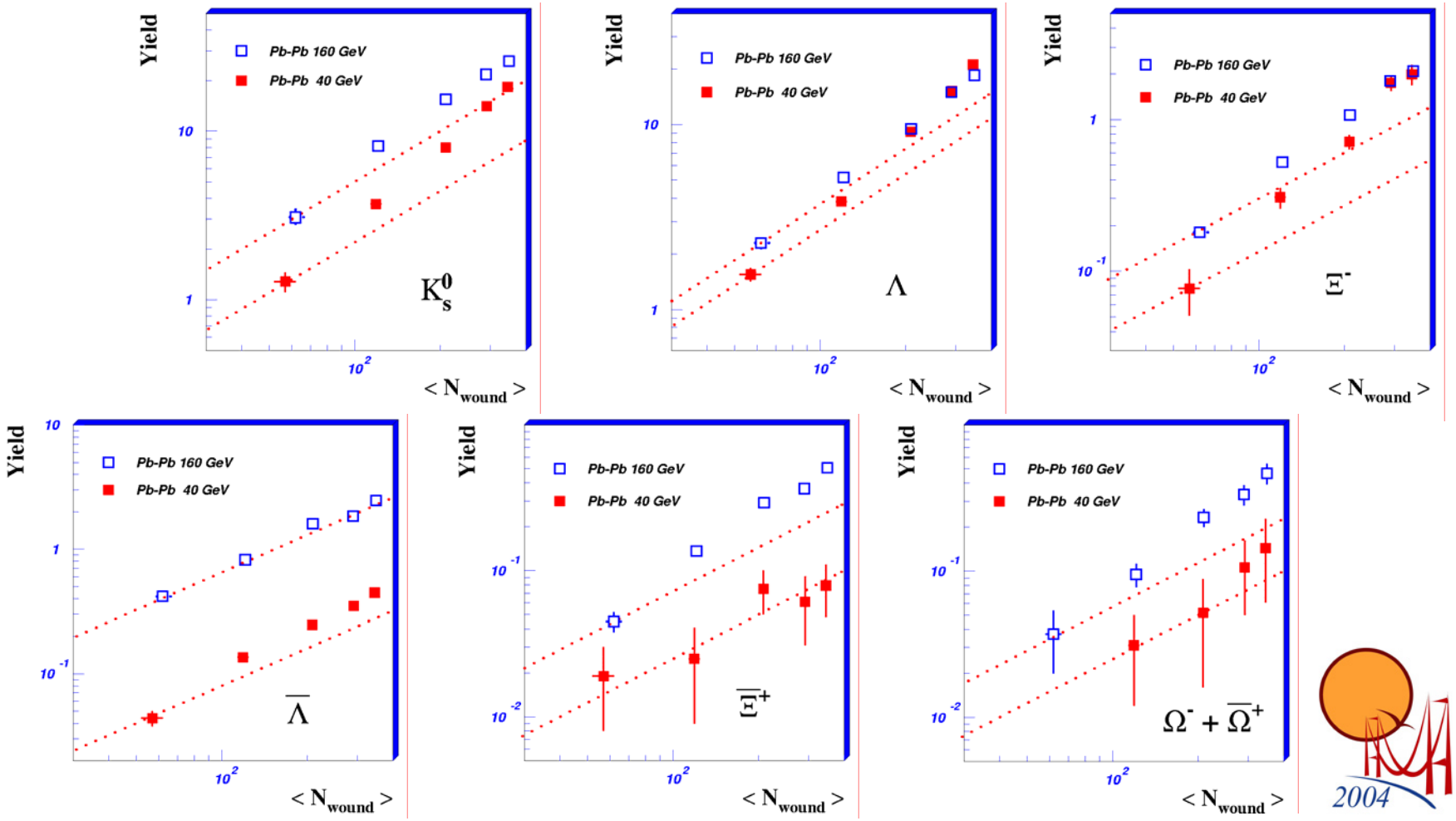
*Refs: Physical Review Letters 89 (2002), 092301
nucl-ex/0206008, nucl-ex/0307024

Centrality dependence
of strange particle yields



Centrality dependence

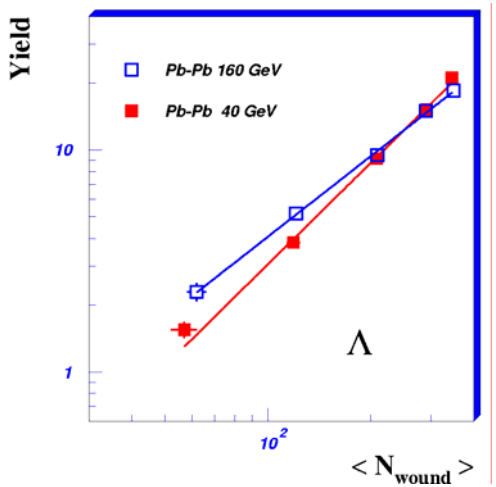
of strange particle yields

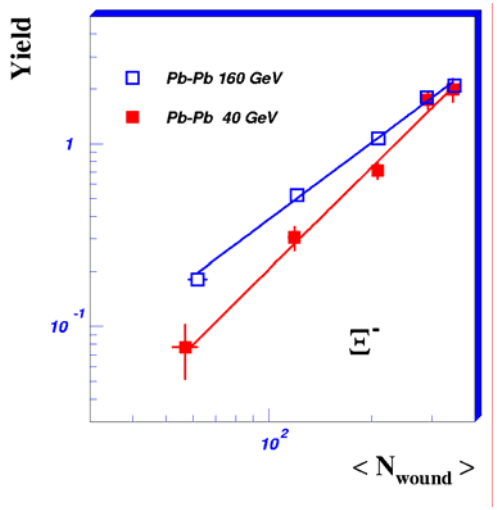


Centrality dependence
of strange particle yields

Yields fitted to:

$$Y \propto \langle N_{wound} \rangle^{\alpha}$$

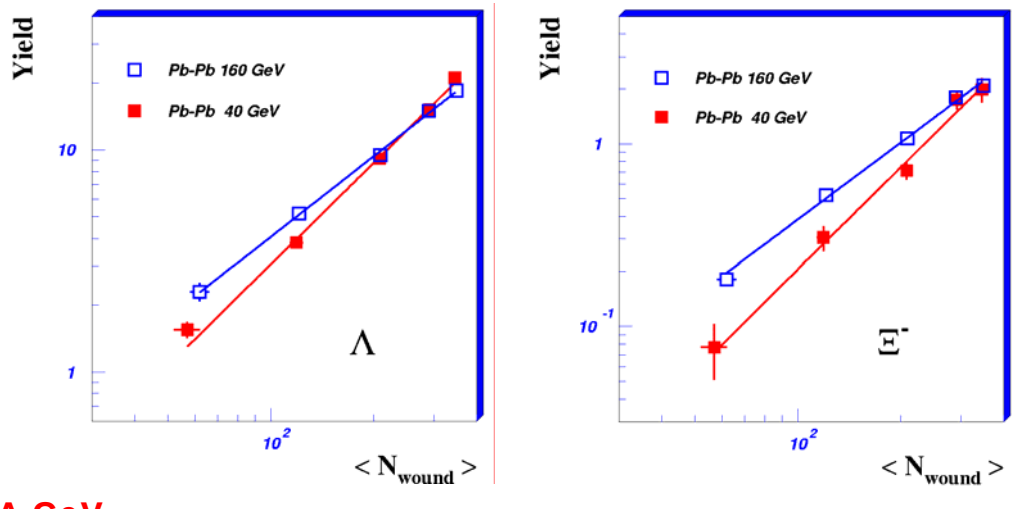




Centrality dependence
of strange particle yields

Yields fitted to:

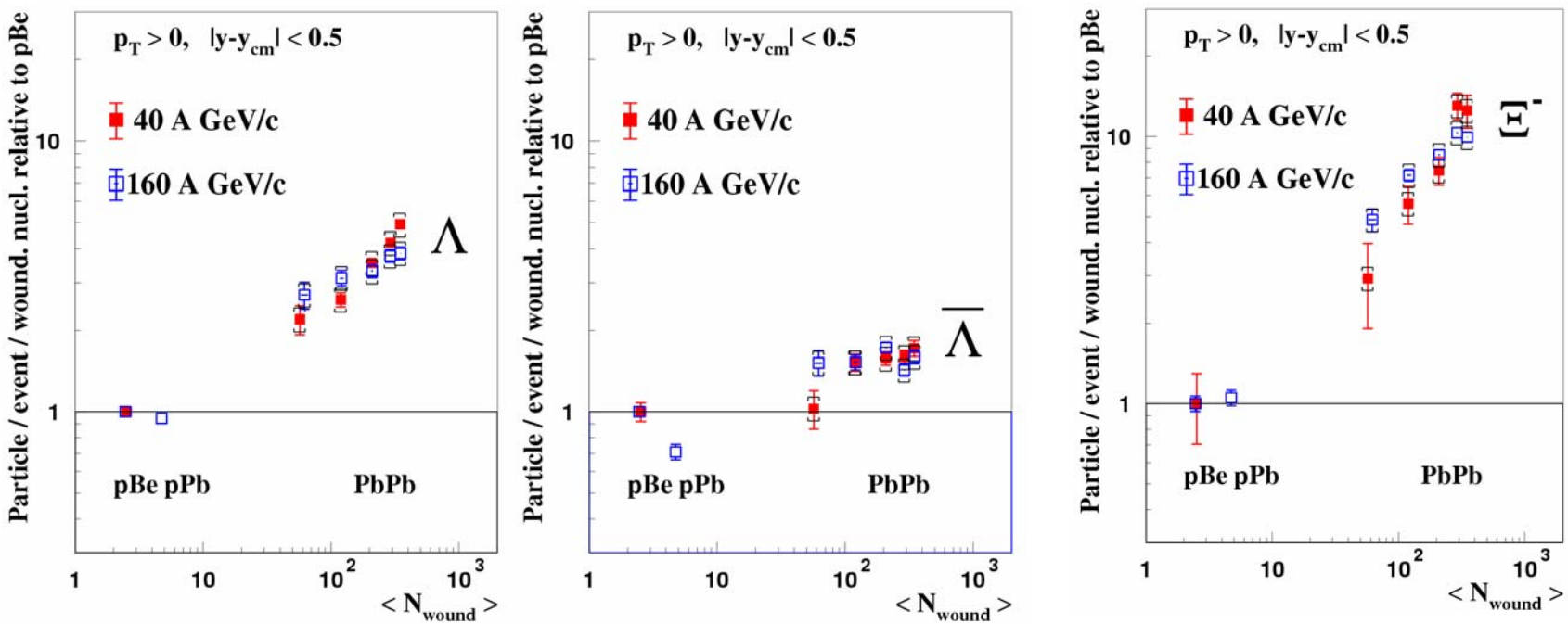
$$Y \propto \langle N_{wound} \rangle^{\alpha}$$



	160 A GeV		40 A GeV	
	α	χ^2 / ndf	α	χ^2 / ndf
K^0_s	1.20 ± 0.04	3.2 / 3	1.49 ± 0.04	1.6 / 3
Λ	1.21 ± 0.05	0.9 / 3	1.52 ± 0.04	6.6 / 3
$\bar{\Lambda}$	1.00 ± 0.07	8.6 / 3	1.18 ± 0.08	4.3 / 3
Ξ^-	1.40 ± 0.04	6.3 / 3	1.85 ± 0.13	6.3 / 3
$\bar{\Xi}^+$	1.30 ± 0.11	5.8 / 3	0.84 ± 0.60	1.1 / 3
Ω^-	1.45 ± 0.28	0.6 / 3	1.45 ± 0.86	0.1 / 2
$\bar{\Omega}^+$	1.49 ± 0.36	0.2 / 3		

- steeper centrality dependence of the 40 A GeV yields

Hyperon enhancements



- enhancements still there at 40 GeV
  (slightly higher then at 160 GeV in the two most central classes)
- same hierarchy at 160 and 40 GeV: $E(\Lambda) < E(\Xi)$

Summary

- Comparison with NA49:
  - ratios compatible, ~ 30% systematics in the yields
- Energy dependence of yields and ratios:
  - stronger dependence for anti-particles than for particles (larger baryon density at 40 A GeV)
- Centrality dependence of the yields:
  - steeper centrality dependence of the 40 A GeV yields
- Enhancements at 40 A GeV:
  - hyperon yields enhanced at 40 A GeV too, $E(\Lambda)<E(\Xi)$
  - steeper centrality dependence at lower energy

The NA57 Collaboration

*Physics Department, University of **Athens**, Greece; Dipartimento IA di Fisica dell'Università e del Politecnico di Bari and INFN, **Bari**, Italy; Fysisk Institutt , Universitetet i Bergen, **Bergen**, Norway ; Høgskolen i Bergen, Bergen, Norway; University of Birmingham, **Birmingham**, UK; Comenius University, **Bratislava**, Slovakia; University of Catania and INFN, **Catania**, Italy; **CERN**, European Laboratory for Particle Physics, Geneva, Switzerland; Institute of Experimental Physics Slovak Academy of Science, **Kosice**, Slovakia; P.J. Safárik University, Kosice, Slovakia; Fysisk institutt, Universitetet i Oslo, **Oslo**, Norway; University of Padua and INFN, **Padua**, Italy; Collège de France, **Paris**, France; Institute of Physics, **Prague**, Czech Republic; University "La Sapienza'' and INFN, **Rome**, Italy; Dipartimento di Scienze Fisiche "E.R. Caianiello'' dell'Università and INFN, **Salerno**, Italy; State University of St. Petersburg, **St. Petersburg**, Russia; IReS/ULP, **Strasbourg**, France; Utrecht University and NIKHEF, **Utrecht**, The Netherlands.*