New results from the NA57 experiment

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For the NA57 Collaboration

Contents

- Physics motivations
- Transverse mass spectra at 160 GeV
  - Centrality dependence of freeze-out from blast-wave analysis
- Enhancements at 40 GeV
  - centrality dependence
  - comparison with 160 GeV
- Conclusions

New at QM04

NA57 presentations at QM 2004:

- D Elia: Energy dependence of K^0_S and hyperon production (Friday, parallel 2)
- I Kralik: Hyperon production in p-Be at 40 GeV (poster)

Aim of the experiment

NA57 studies the production of strange and multi-strange baryons in heavy ion interactions as a function of

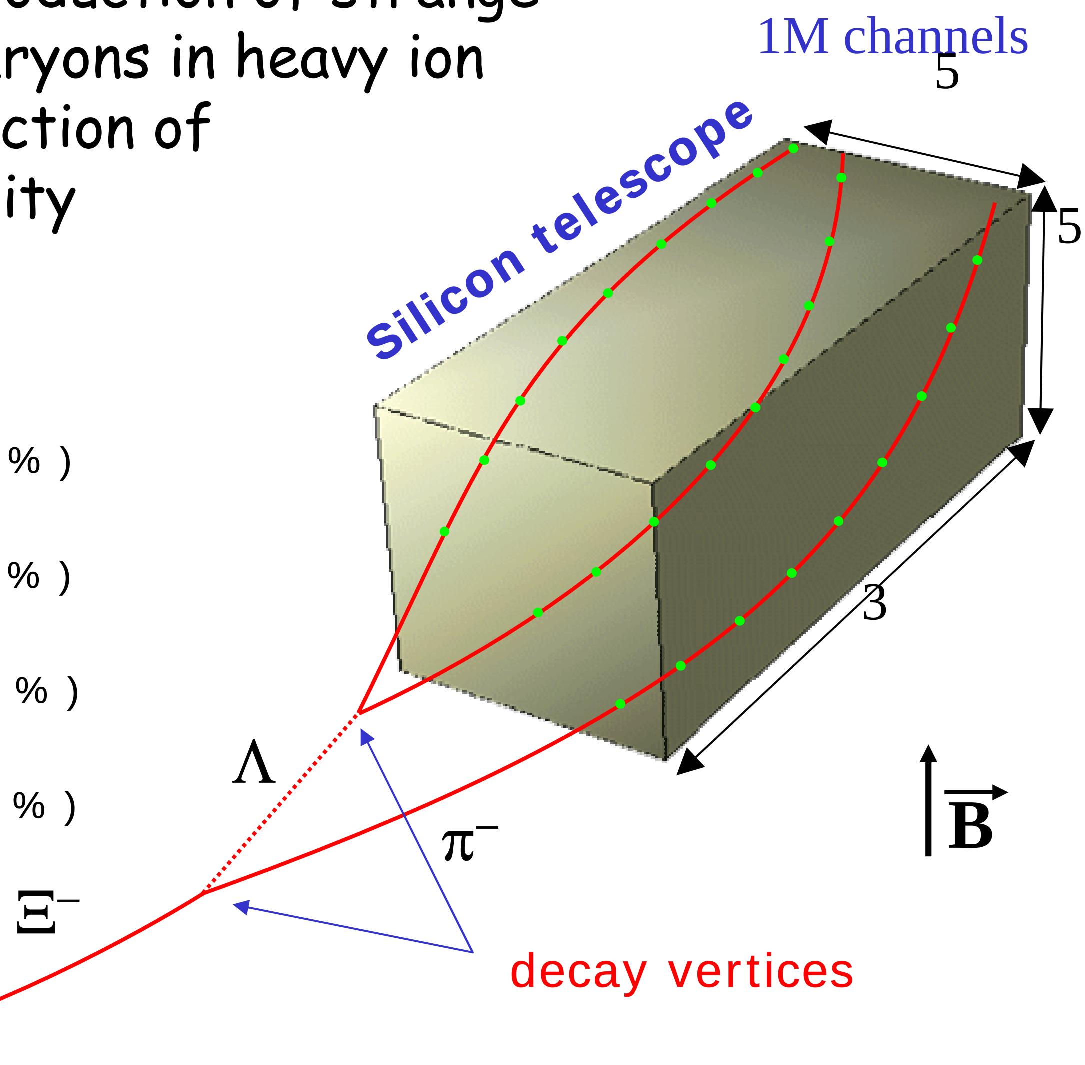
- collision centrality
- collision energy

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

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

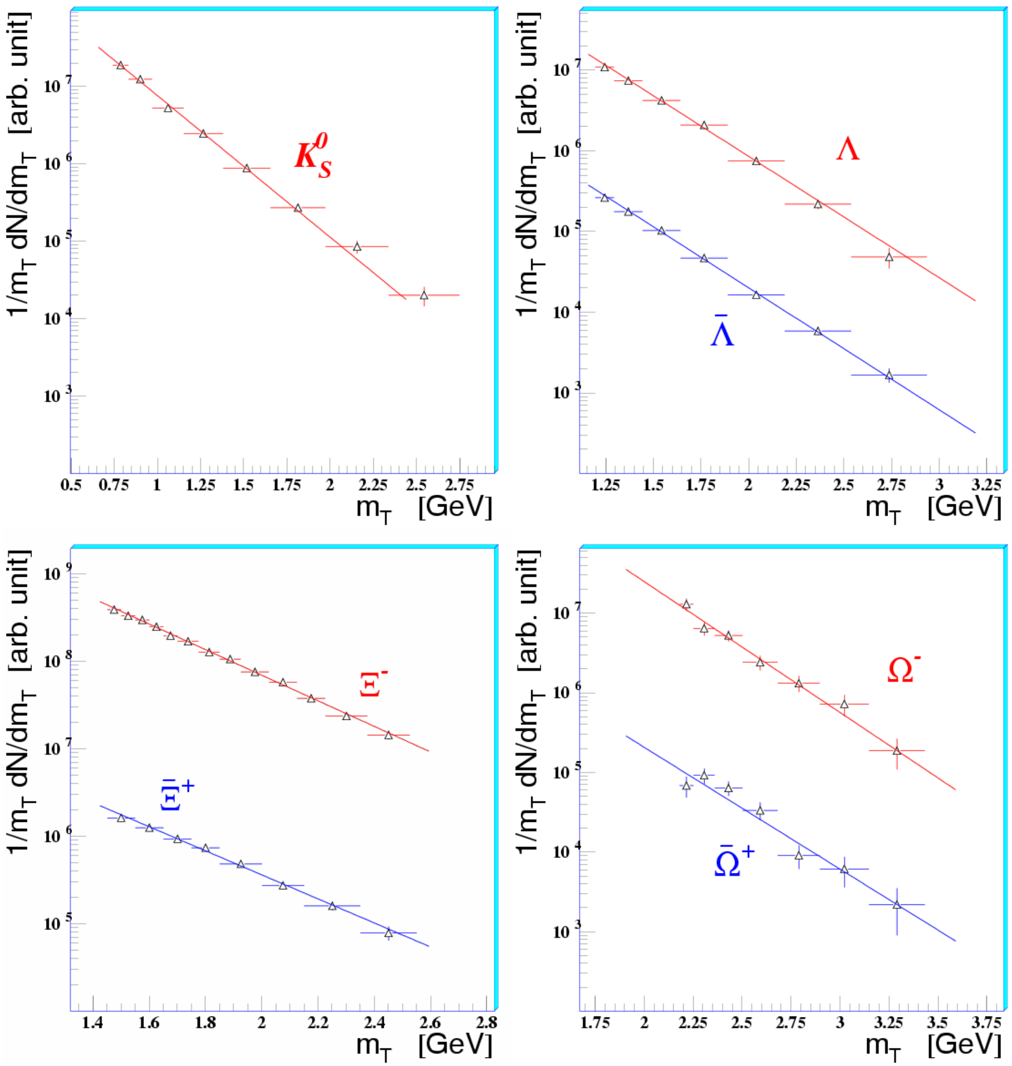
$\Lambda \rightarrow \pi^- + p$ (BR = 63.9 %)

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



Transverse mass spectra in Pb-Pb at 160 A GeV

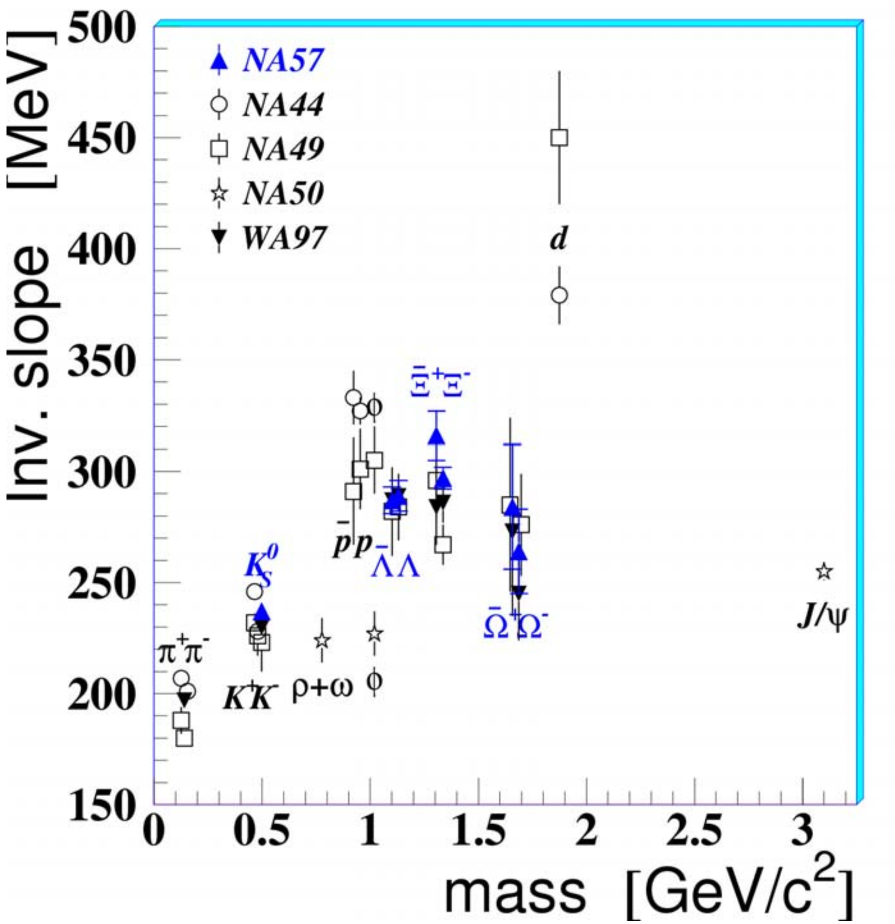
56% most central events



Inverse slopes (MeV)

K^0_S	237±4±24
Λ	289±7±29
$\bar{\Lambda}$	287±6±29
Ξ^-	297±5±30
$\bar{\Xi}^+$	316±11±30
$\Omega^- + \bar{\Omega}^+$	271±16±27
Ω^-	264±19±27
$\bar{\Omega}^+$	284±28±27

Transverse mass spectra in Pb-Pb at 160 A GeV



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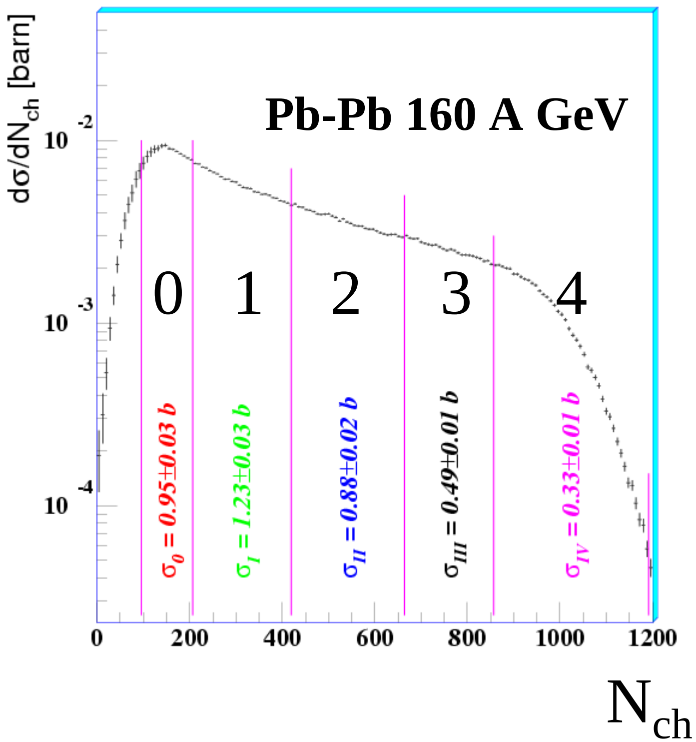
Centrality of the collision

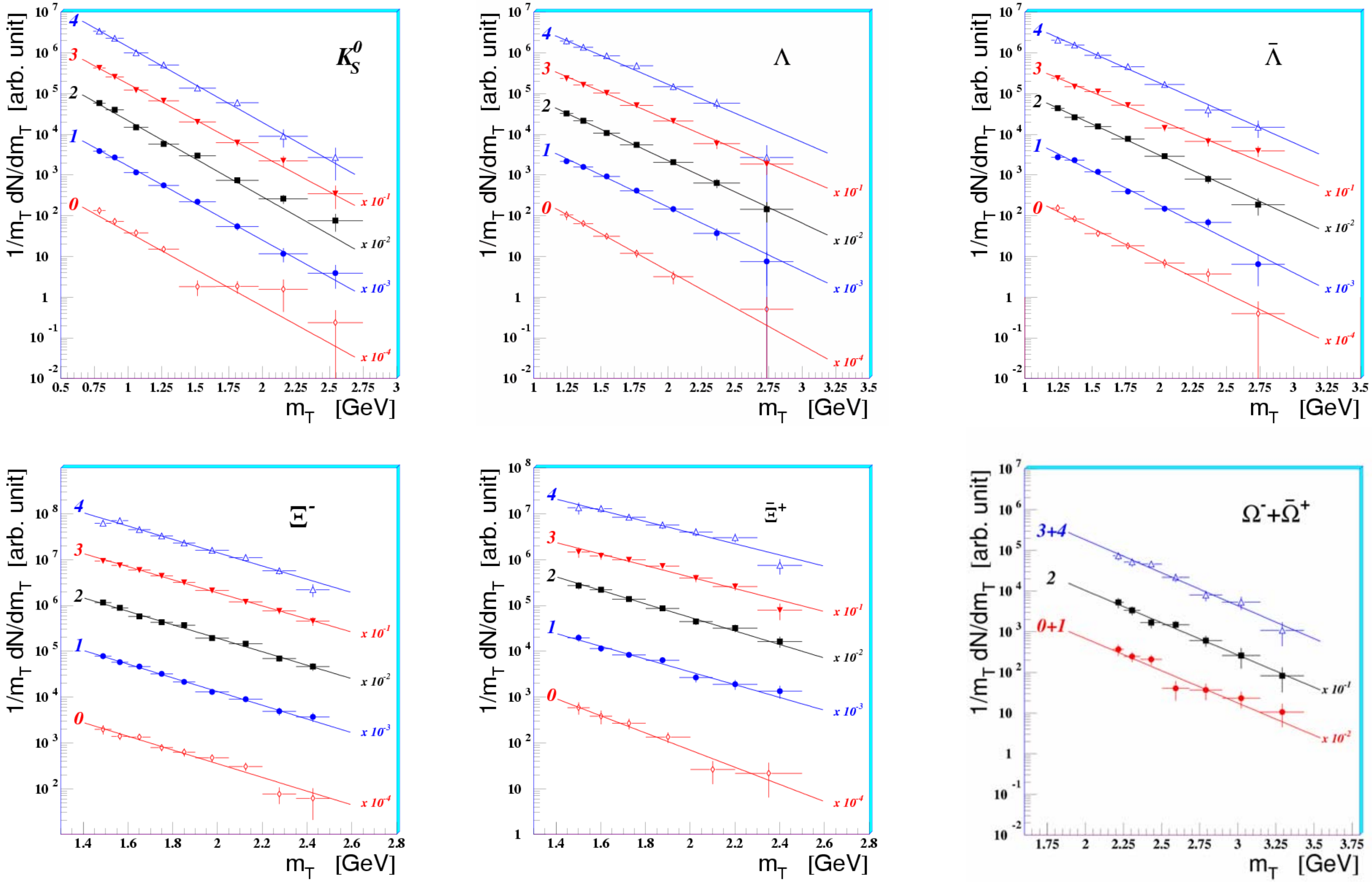
Centrality determination from charged particle multiplicity measurement

N_{wound} from trigger cross section (Glauber model calculations)



		$\langle N_{wound} \rangle$		$\langle N_{bin} \rangle$	
bin	**% of σ_{tot}**	**160**	**40**	**160**	**40**
0	42-56 %	62	57	77	81
1	25-42%	121	119	191	203
2	12-25 %	209	208	395	416
3	5-12 %	290	292	614	644
4	0-5 %	349	346	789	807

Transverse mass spectra in Pb-Pb at 160 A GeV



Inverse slopes at 160 A GeV/c

	p-Be	p-Pb	0	1	2	3	4
K^0_S	197±4	217±6	239±15	239±8	233±7	244±8	234±9
Λ	180±2	196±6	237±19	274±13	282±12	315±14	305±15
$\overline{\Lambda}$	157±2	183±11	277±19	264±11	283±10	313±14	295±14
Ξ^-	202±13	235±14	290±20	290±11	295±9	304±11	299±12
$\overline{\Xi}^+$	182±17	224±21	232±29	311±23	294±18	346±28	356±31
$\Omega^-+\overline{\Omega}^+$	169 ±40	334±99	274±34		274±28	268±23	
Ω^-			264±19				
$\overline{\Omega}^+$			284±28				

- In central and semi-central Pb-Pb collisions (bin 1,2,3,4) we measure compatible slopes for particle and its anti-particle
- This symmetry lost in p-Be

m_T spectra in Pb-Pb at 160 A GeV/c

Hydro-dynamical picture:

the m_T spectra are sensitive to the transverse flow

Blast wave description of the spectra:

$$\frac{d^2 N_j}{m_T dy dm_T} = \int_0^{R_G} A_j m_T \cdot K_1\left(\frac{m_t \cosh \rho}{T}\right) \cdot I_0\left(\frac{p_t \sinh \rho}{T}\right) r dr$$

$$\rho(r) = \tanh^{-1} \beta_\perp(r)$$

$$\beta_\perp(r) = \beta_S \left[\frac{r}{R_G}\right]^n \quad r \le R_G$$

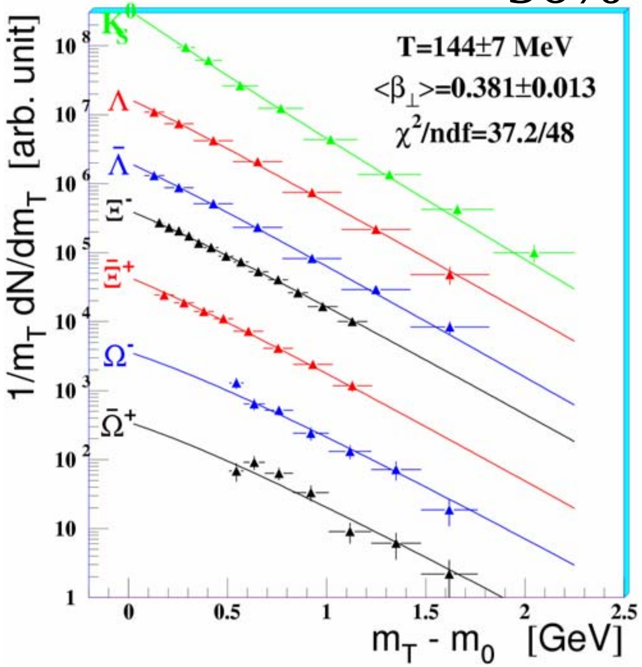
Uniform particle density

$$<\beta_\perp> = \frac{2}{2+n} \beta_S$$

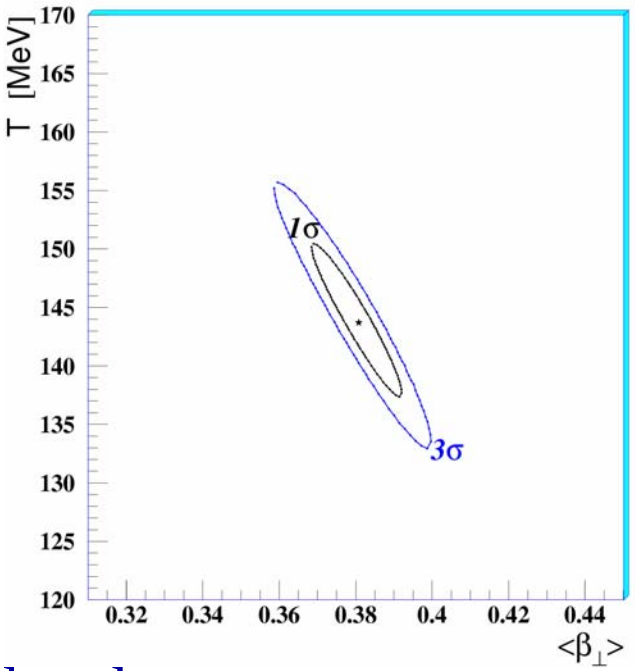
Ref: E Schnedermann, J Sollfrank and U Heinz, **Phys. Rev. C48 (**1993) 2462

Blast wave fit to strange particles

56% most central events



n=1



- statistical errors are highly anti-correlated
- systematic errors: T ≃ 10% , β ≃ 3% (correlated)

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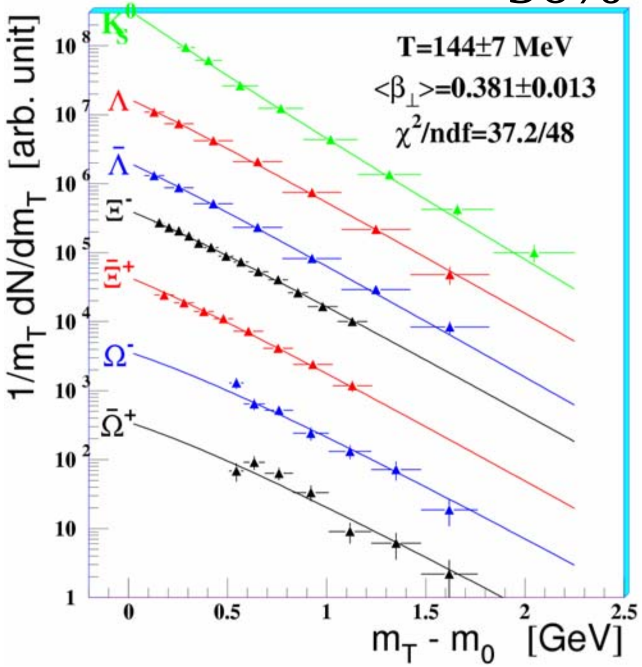

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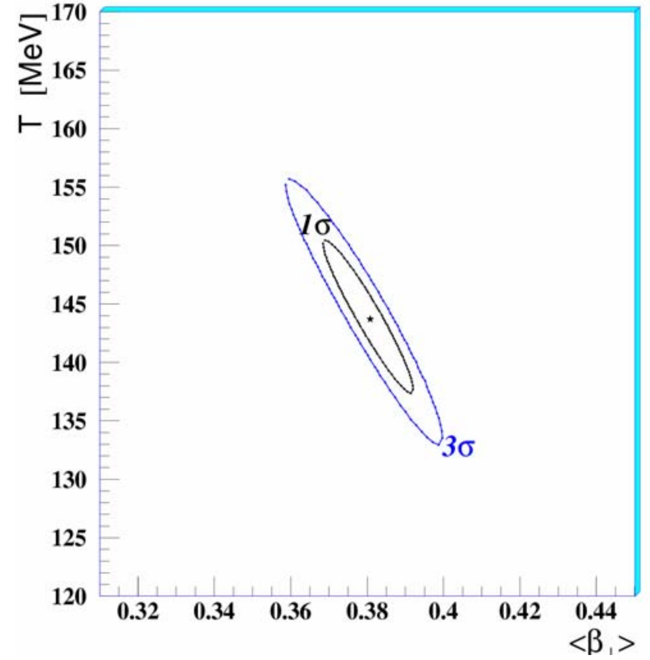
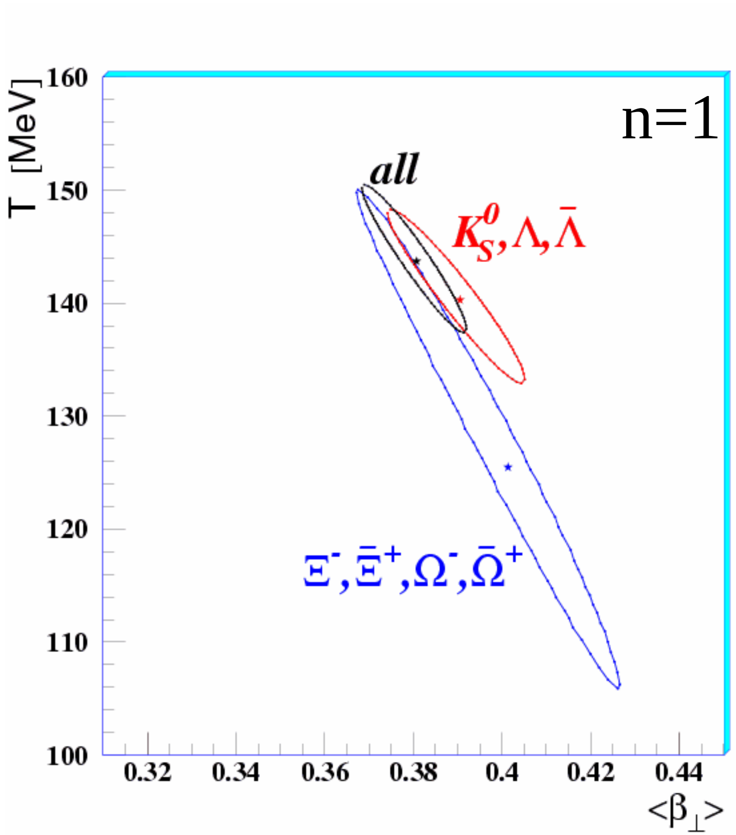


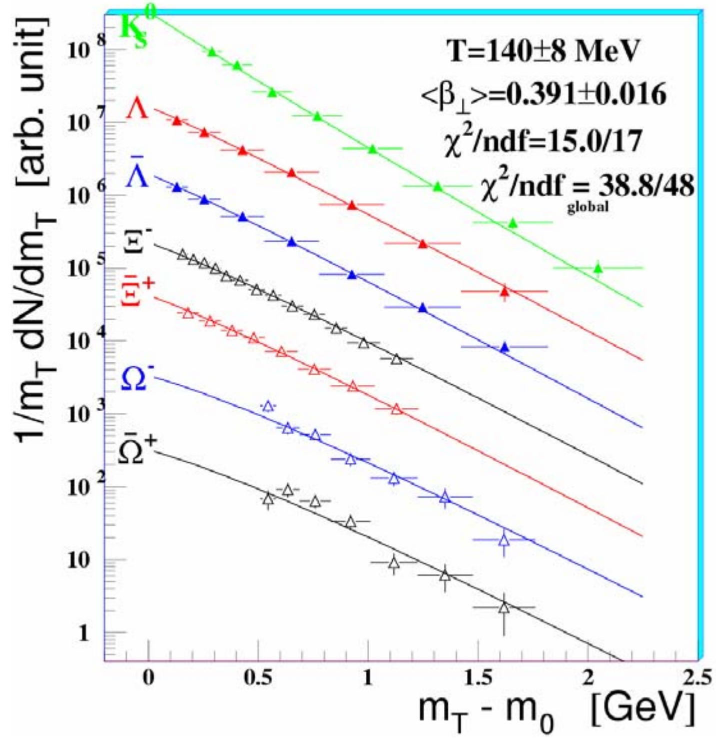
$$T = 144 \pm 7(\text{stat}) \pm 14(\text{syst})$$

$$\langle\beta_\perp\rangle = 0.381 \pm 0.013(\text{stat}) \pm 0.012(\text{syst})$$

- T and $\langle\beta_\perp\rangle$ depend weakly on **n**
- **n**=2 case disfavoured by data (bad χ^2)

Freeze-out parameters: multi- vs. singly strange particles

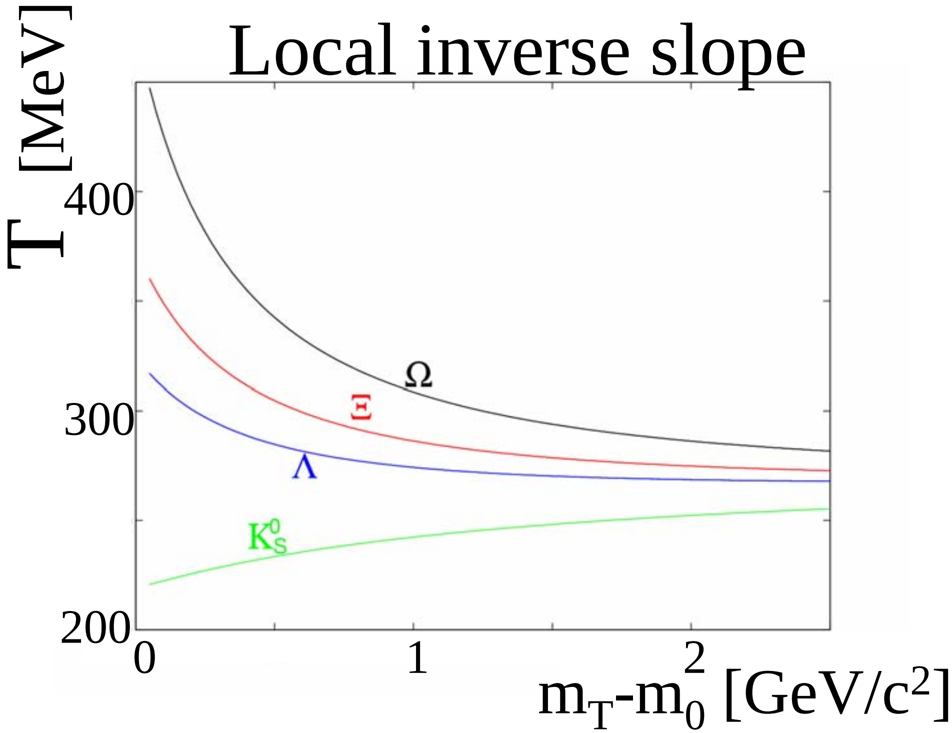


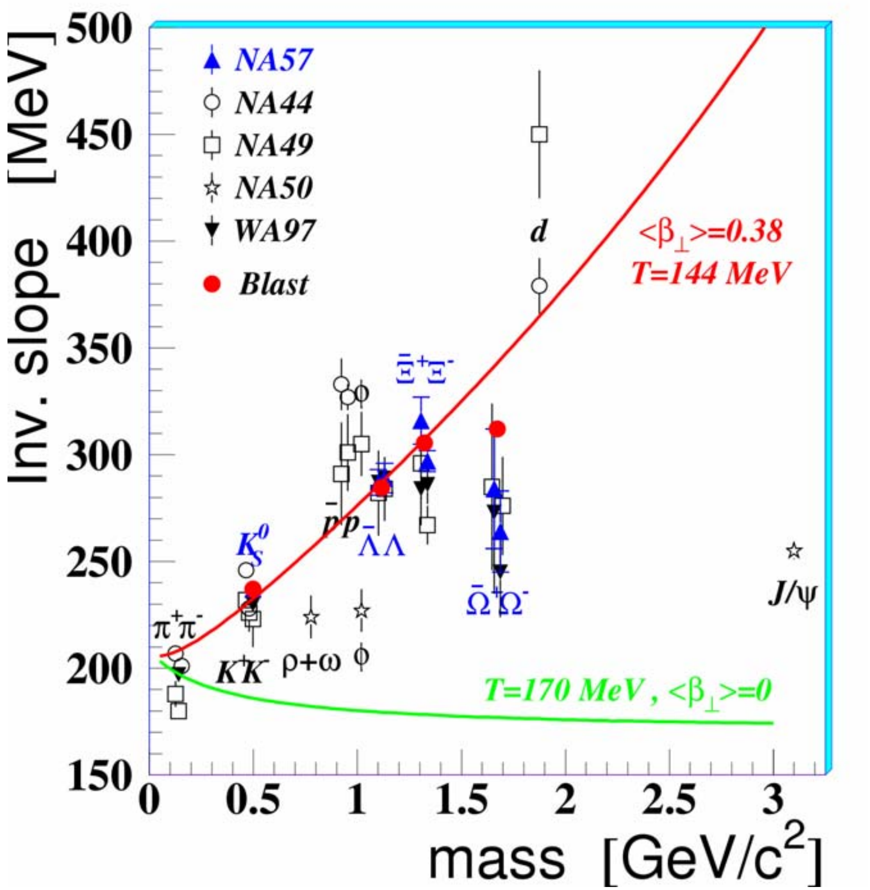


Fit to singly strange particles

- Fit driven by singly strange particles
- Ξ and Ω fit well with same parameters

Blast wave description of the inverse slope values

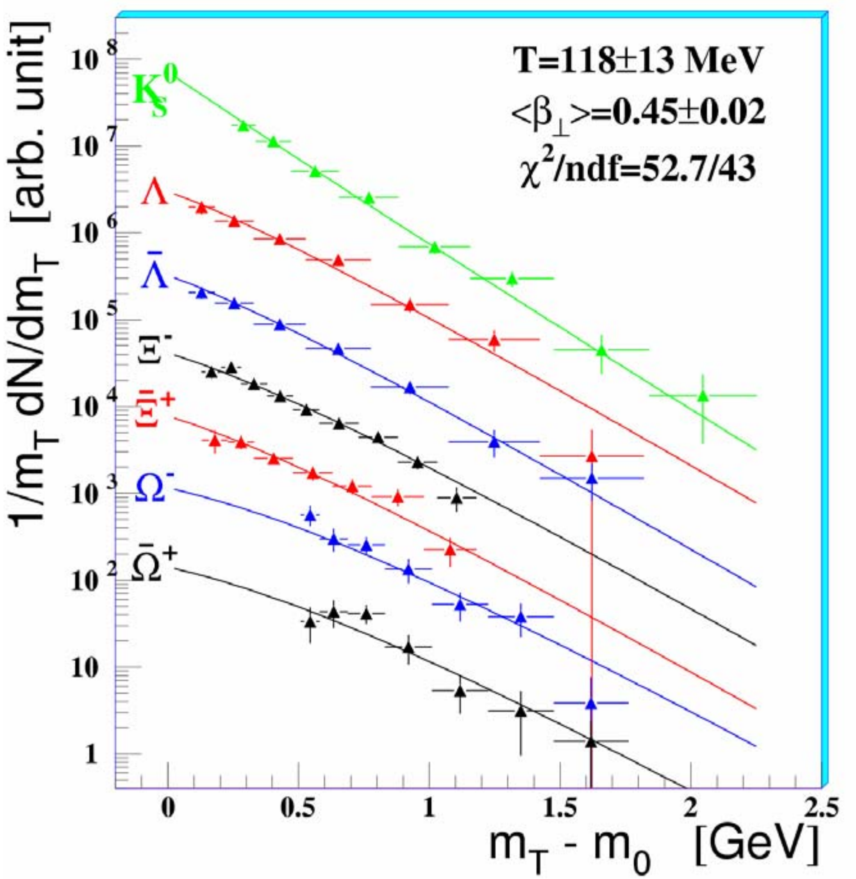




- Inverse slope depends on the m_T range used to fit the spectrum

Blast fit for most central collisions

5% most central events



	n	T (MeV)	$<\beta_\perp>$	χ^2/ndf
NA57	1	118±13	0.45± 0.02	53/43
NA49 (a)	0	127±1	0.48± 0.01	120/43
NA49 (b)	0	114±2	0.50± 0.01	91/41

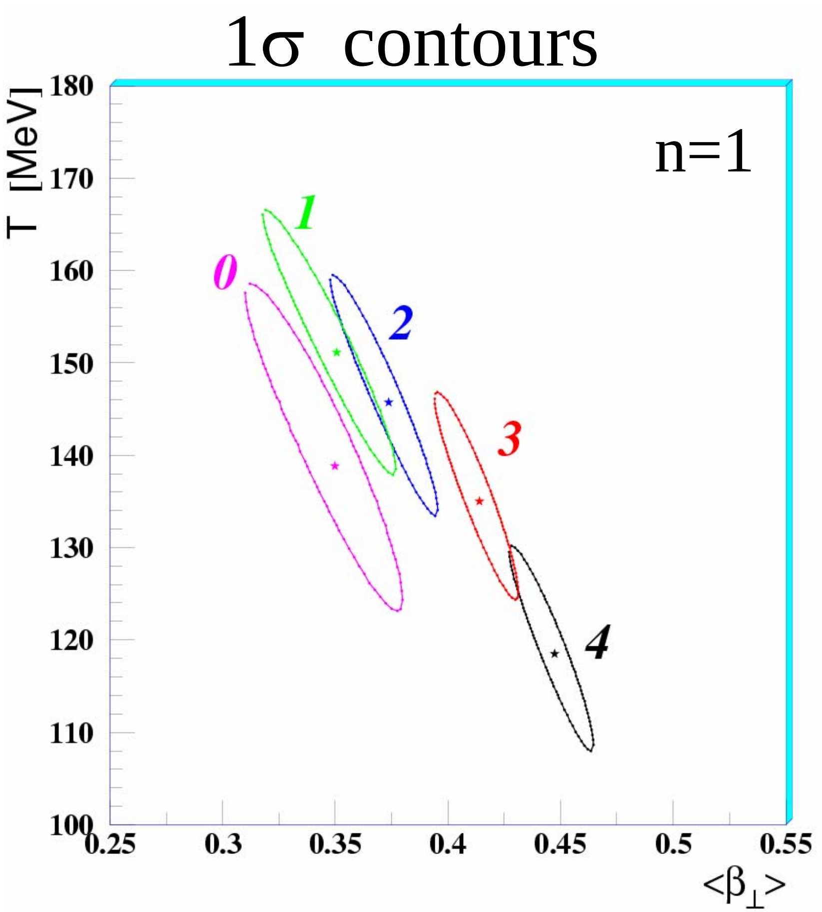
(a) K^+, p, Λ, Ξ^-, Ω^-

(b) K^-, $\bar{p}$, ϕ, $\bar{\Lambda}$, $\bar{\Xi}^+$, $\bar{\Omega}^+$

NA49 centrality: 5% for $K^\pm$, ϕ
10% for p, Λ, Ξ ; 20% for Ω

Ref: M van Leeuwen, **Nucl. Phys. A715 (**2003) 161c

Centrality dependence of the thermal freeze-out in Pb-Pb at 160 A GeV

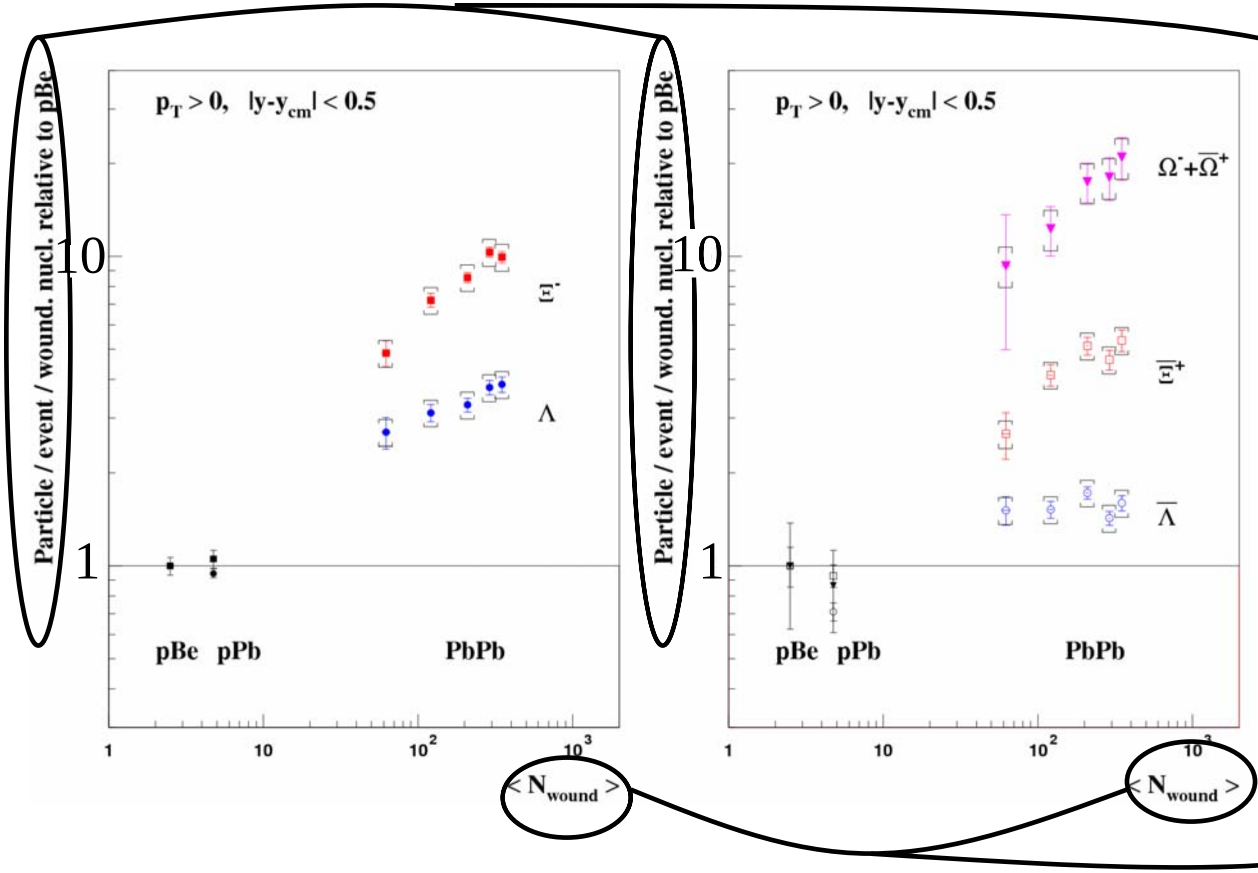


With increasing centrality:

- Transverse flow velocity increases
- Freeze-out temperature decreases

Earlier decoupling for peripheral collisions ?

Enhancements at 160 A GeV/c



Errors:

systematic

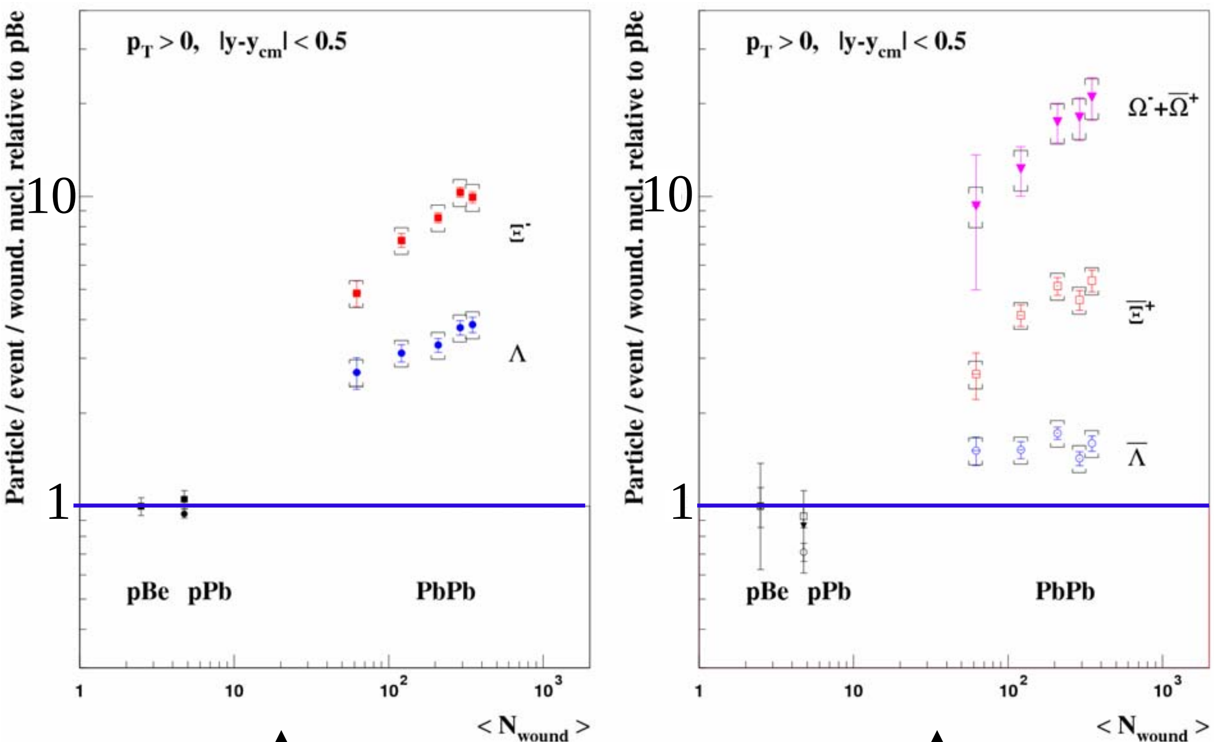
statistic

$$\text{Enhancement} = \frac{\langle \text{Yield} \rangle / \langle N_{part} \rangle}{(\langle \text{Yield} \rangle / \langle N_{part} \rangle)_{p\text{-}Be}}$$

$\langle N_{part} \rangle$

Enhancements at 160 A GeV/c

Errors:
systematic
statistic



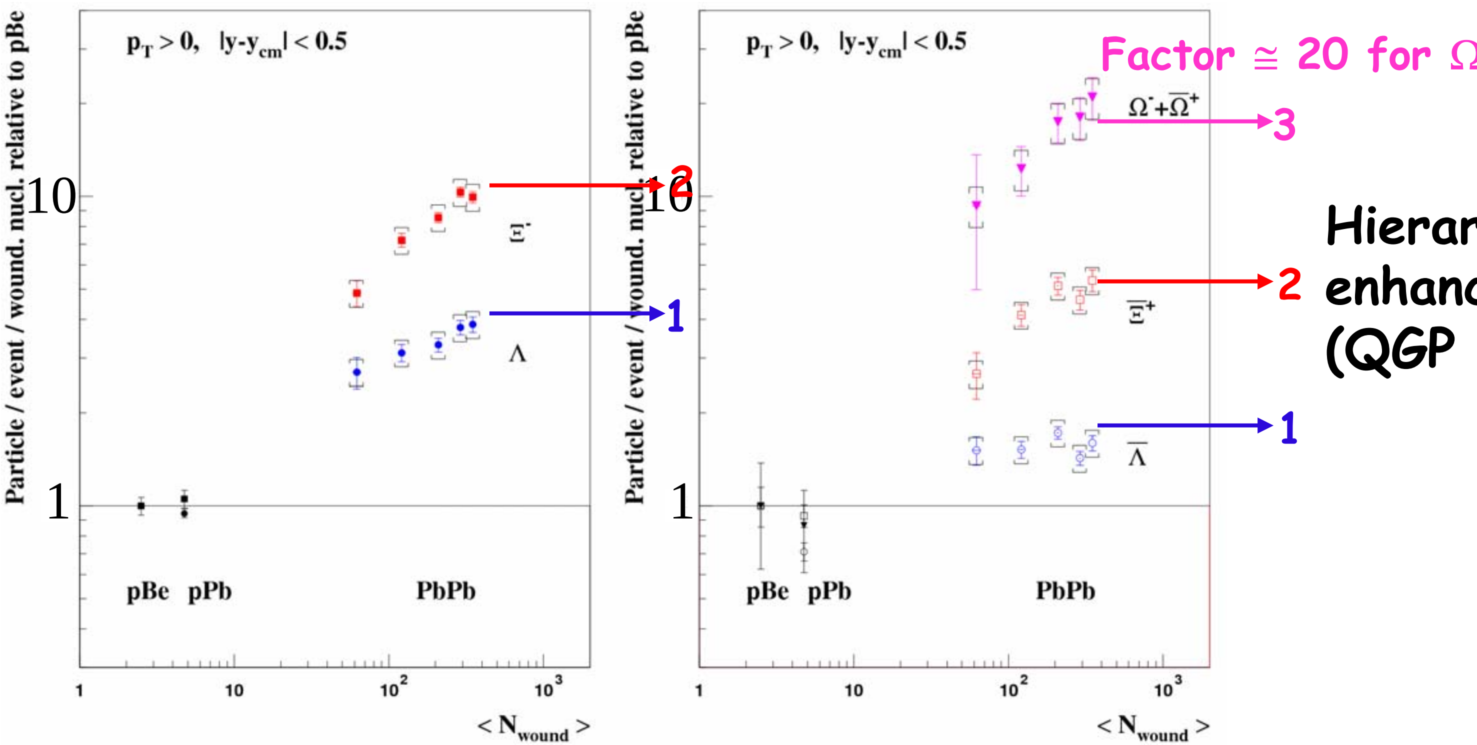
No enhancement

Particles having quarks in common with the nucleon

Particles made up of newly created quarks only

Enhancements at 160 A GeV/c

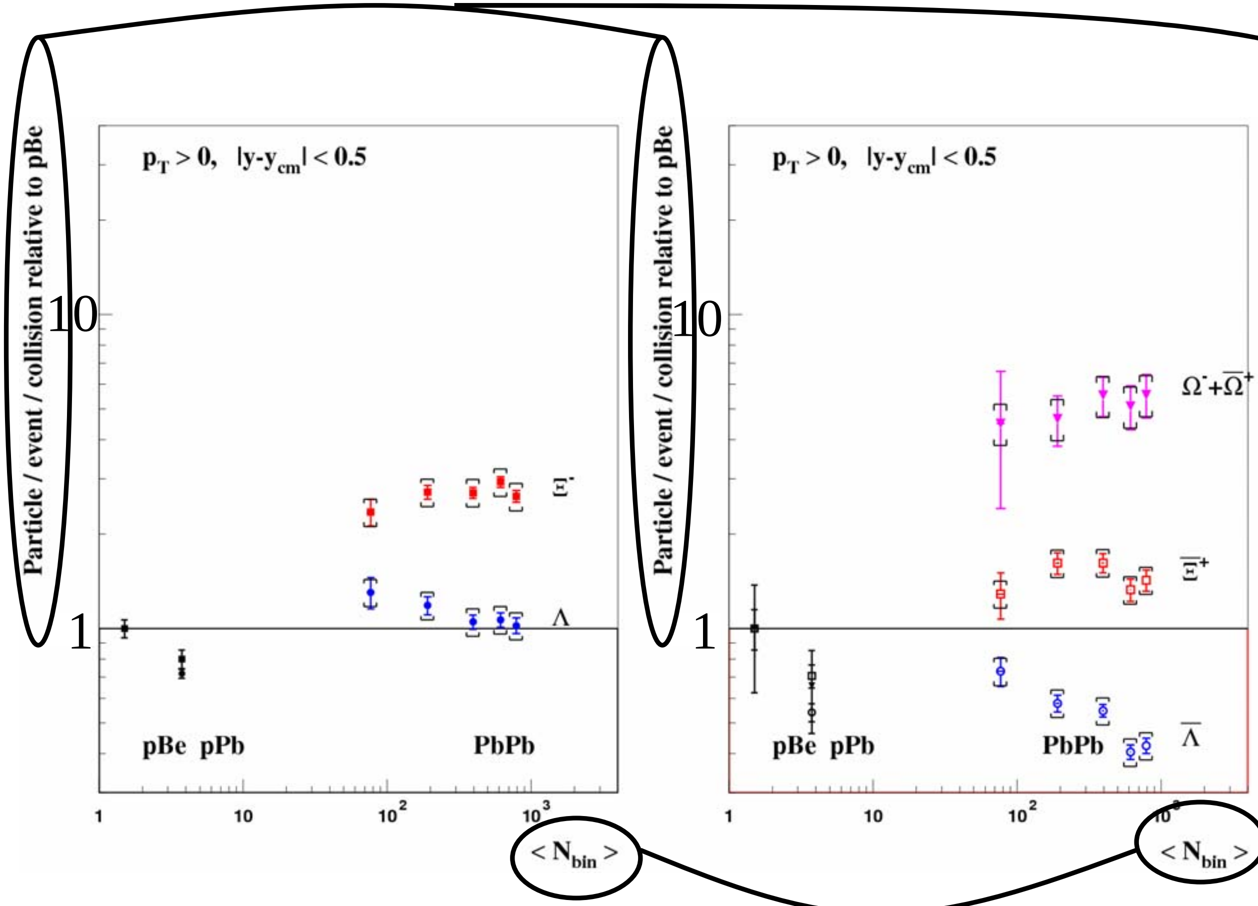
Errors:
systematic
statistic



Hierarchy of the enhancements (QGP prediction)

- Evidence of significant centrality dependence of enhancements in Pb-Pb (measurements in bin 0 essential)
- Saturation for the two-three most central bins ?

Enhancements w.r.t. number of binary collisions at 160 A GeV/c



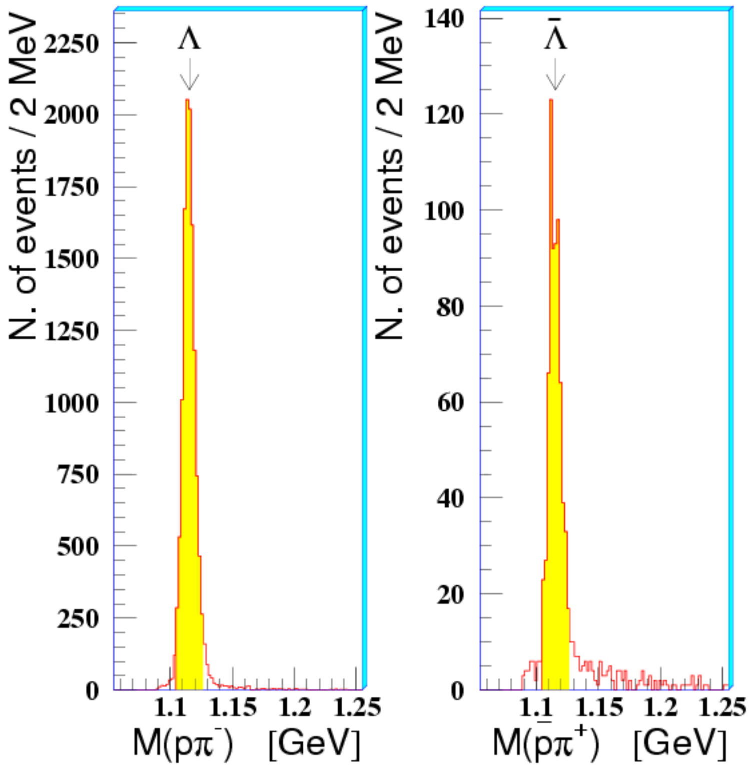
Enhancement = $\dfrac{\langle Yield \rangle / \langle N_{bin} \rangle}{(\langle Yield \rangle / \langle N_{bin} \rangle)_{p\text{-}Be}}$

$\langle N_{bin} \rangle$

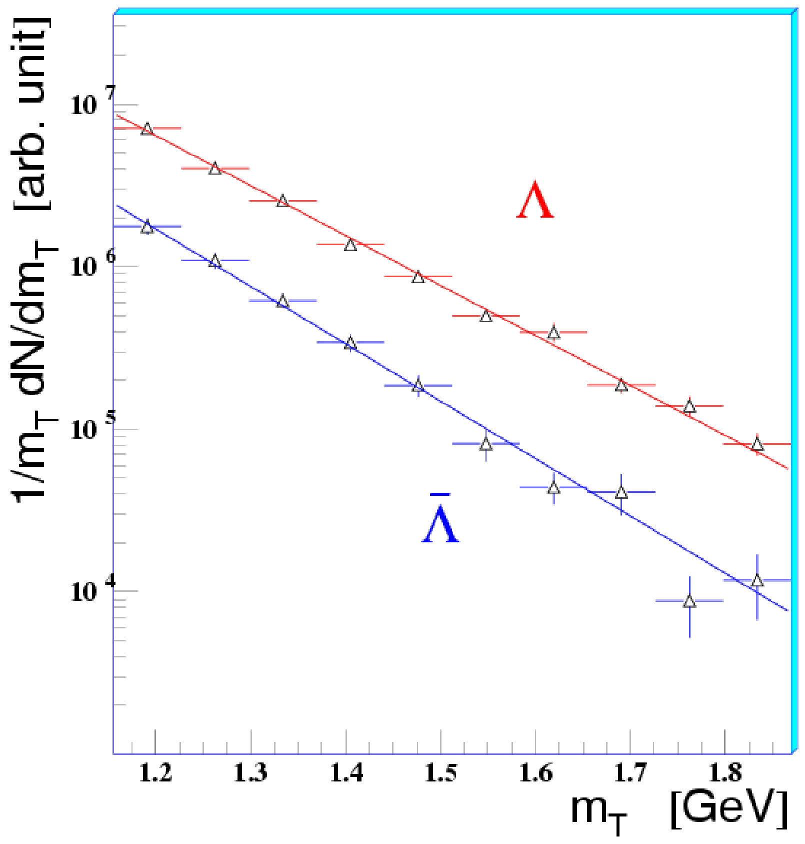
- Going from p-Be to Pb-Pb Ξ and Ω yields scale faster than $\langle N_{bin} \rangle$

Λ and Ξ^- production in p-Be at 40 GeV

invariant mass spectra



transverse mass spectra



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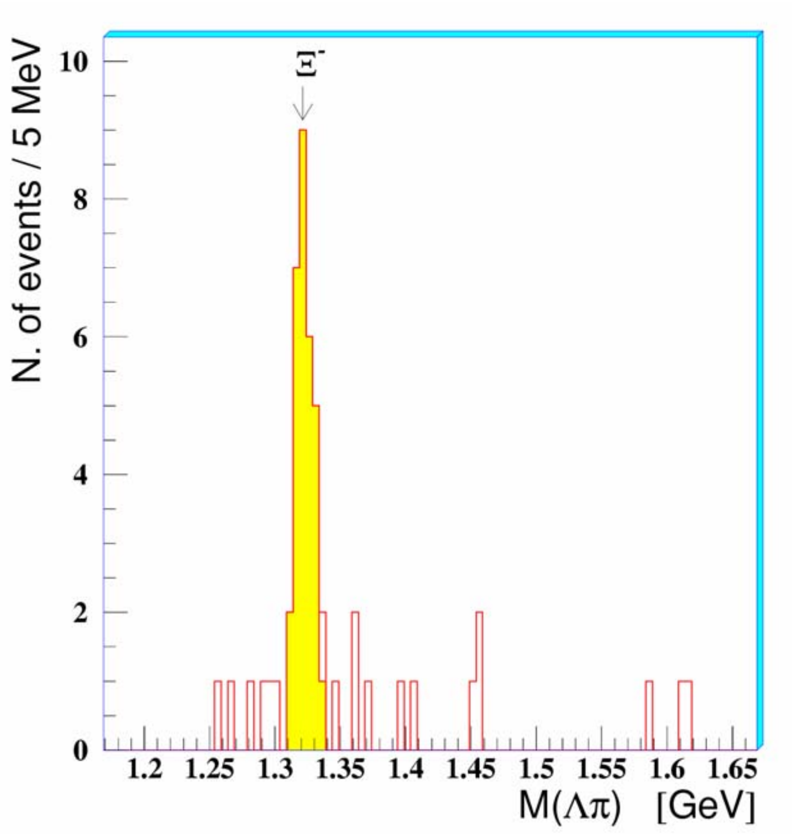

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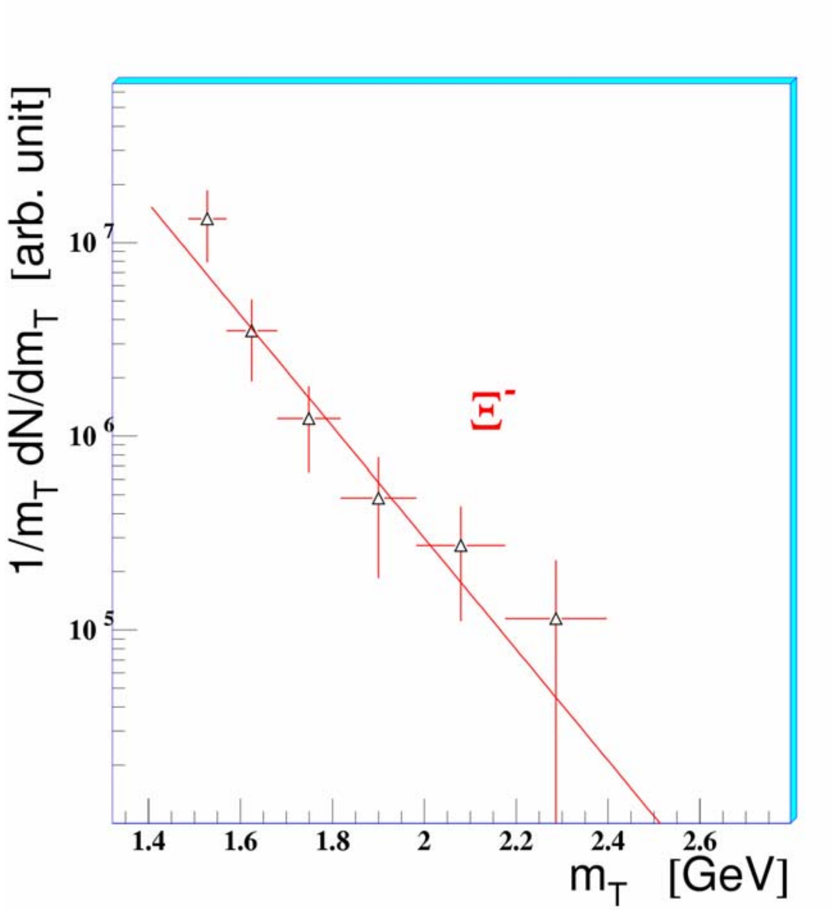
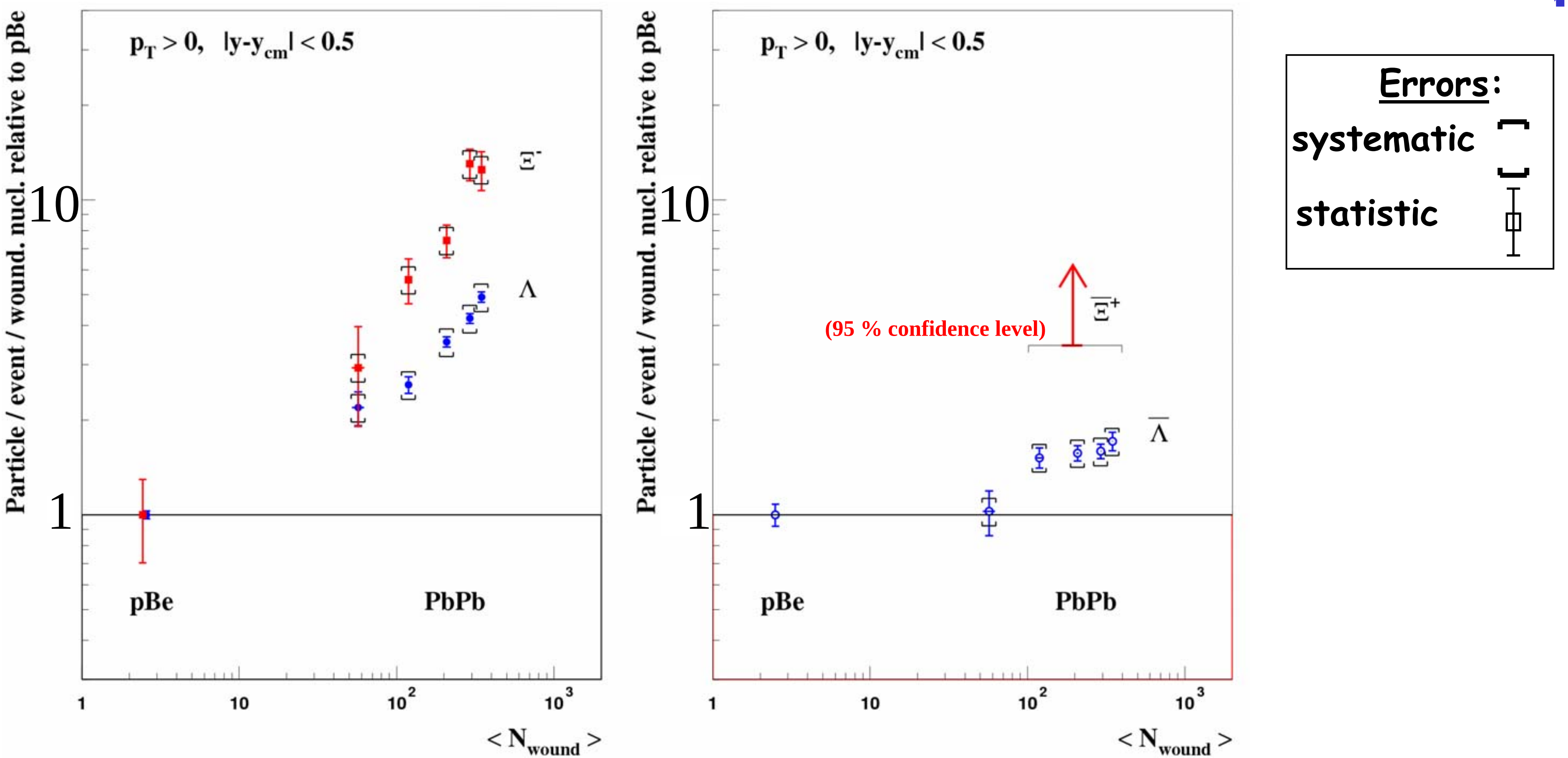
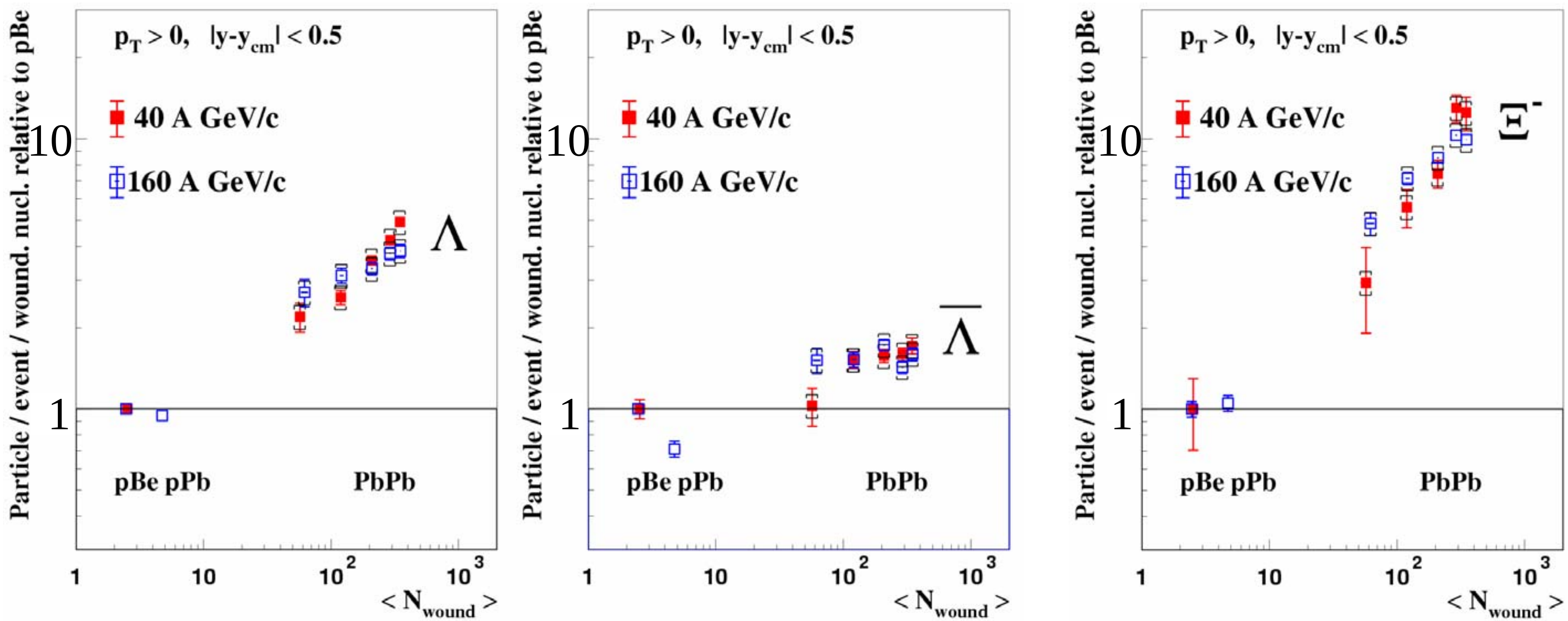


Enhancements at 40 A GeV/c



- Enhancements are still there at 40 GeV, with the same hierarchy as at 160 GeV: E(Λ) < E(Ξ)

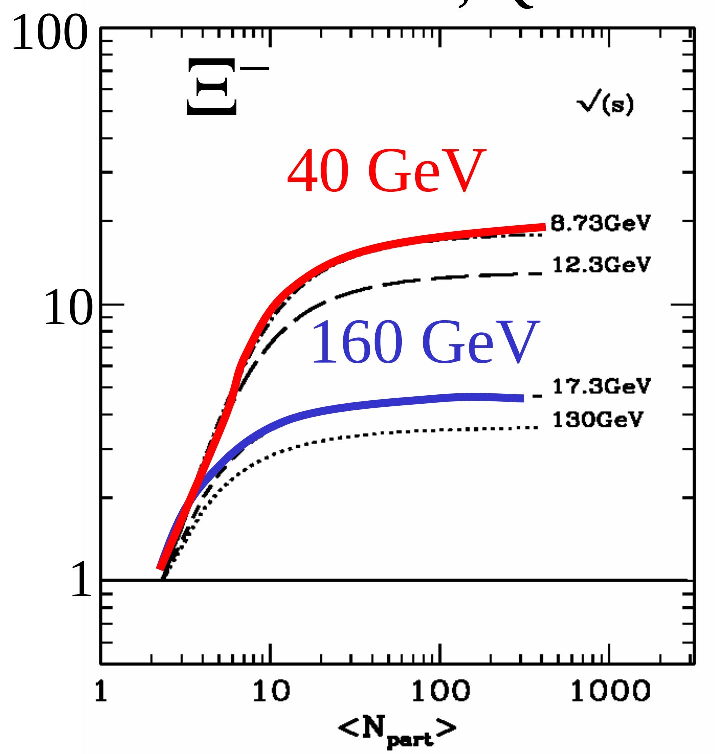
Hyperon enhancements: 40 vs. 160 GeV

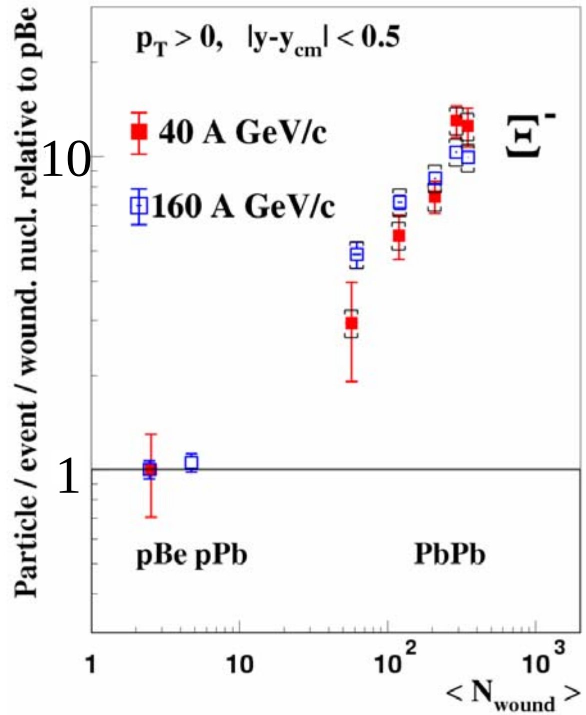


- In most central collisions (bins 3-4): enhancements at 40 are higher than at 160 GeV
- Enhancements increase more steeply at 40 than at 160 GeV

Hyperon enhancements: 40 vs. 160 GeV

Redlich et al., QM02





- In most central collisions (bins 3-4):
  enhancements at 40 are higher than at 160 GeV
- Enhancements increase more steeply at 40 than at 160 GeV

Conclusions (i)

Transverse mass spectra in Pb-Pb at 160 A GeV/c:

- Symmetry between hyperon and anti-hyperon in central and semi-central Pb-Pb collisions (bins 1,2,3,4), not in p-Be

- Description by common freeze-out adequate

- Evidence for a centrality dependence of the thermal freeze-out parameters

Conclusions (ii)

Strangeness enhancement 40 vs 160 A GeV/c:

- Hyperon yields are enhanced at 40 GeV too
  - Same hierarchy as at 160 GeV: $E(\Lambda) < E(\Xi^-)$
    $E(\bar{\Lambda}) < E(\bar{\Xi}^+)$

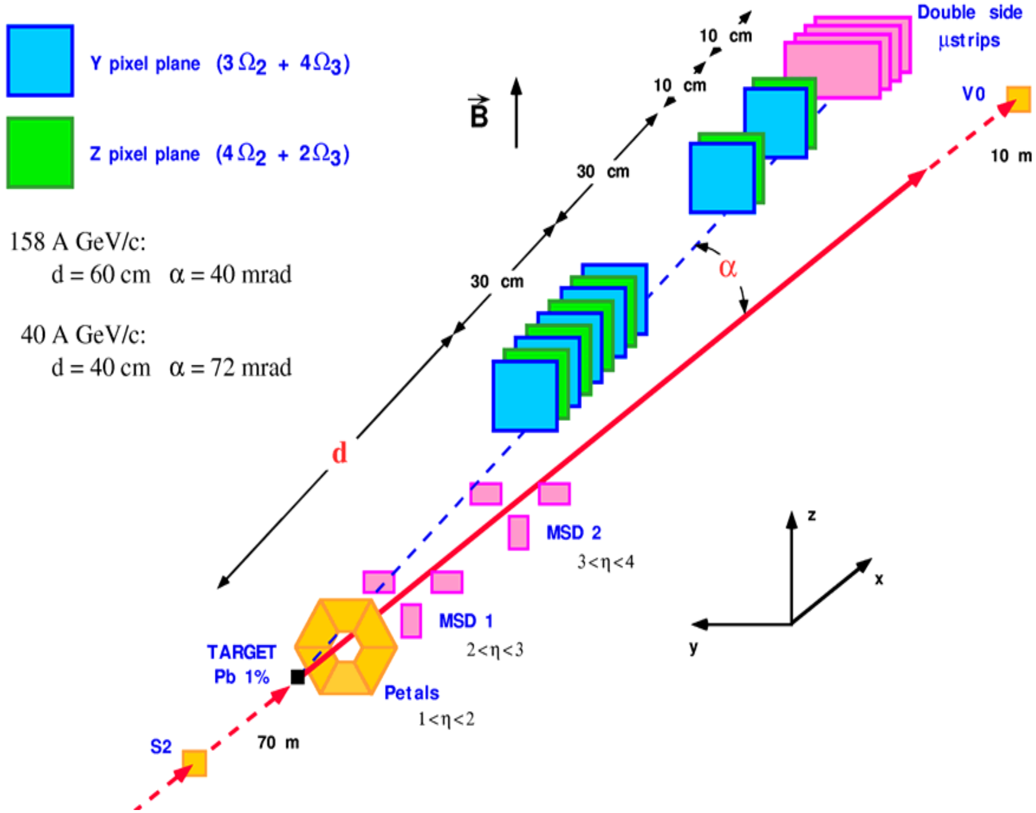
- Enhancements for central collisions are larger at 40 GeV by 10-25%

- Enhancements vs. N_{wound} steeper at 40 than at 160 GeV

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.*

Layout of the NA57 experiment at CERN SPS



Target: 1% Pb , 8% Be

Pb-Pb only

- **Scintillator Petals:** centrality trigger
- **MSD:** Multiplicity Silicon Detector

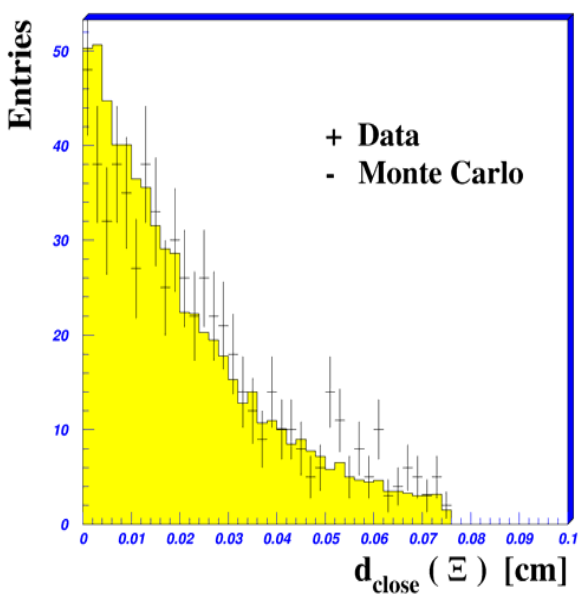
≈ 1M channels

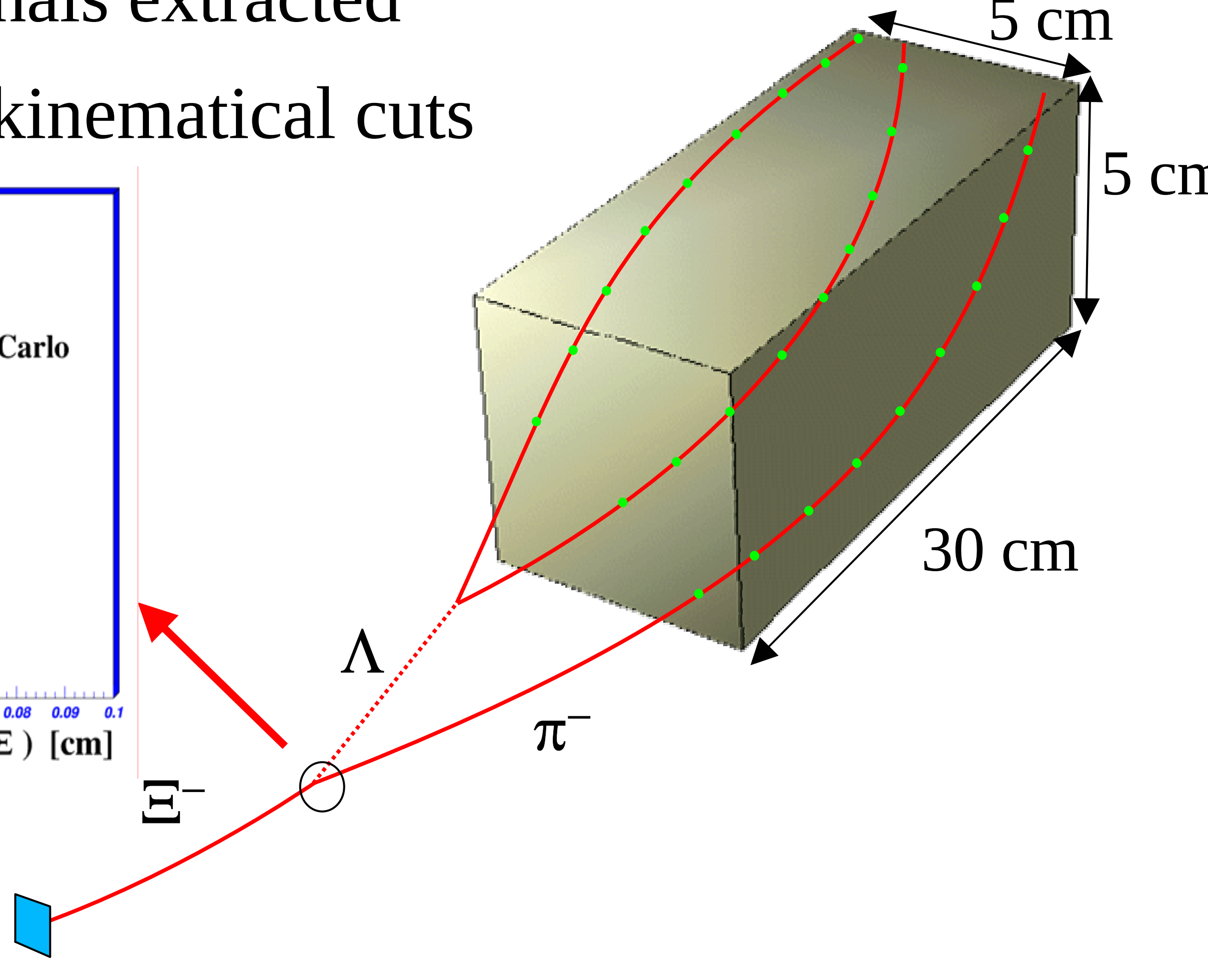
- **Tracking device:**
  - silicon pixel planes (5 x 5 cm^2)
  - pixel size: 50×500 μm^2
- **Lever arm:**
  - pixel planes & double side μstrips

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

Selection of hyperons and K^0_S at 40 A GeV

- Strange particle signals extracted by geometrical and kinematical cuts





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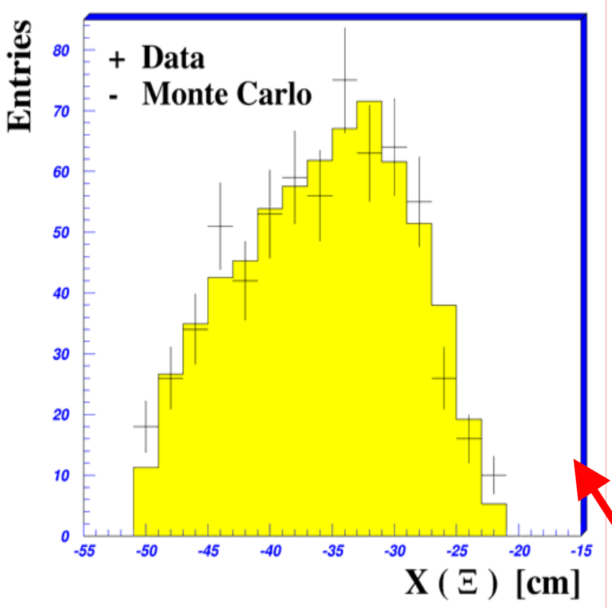

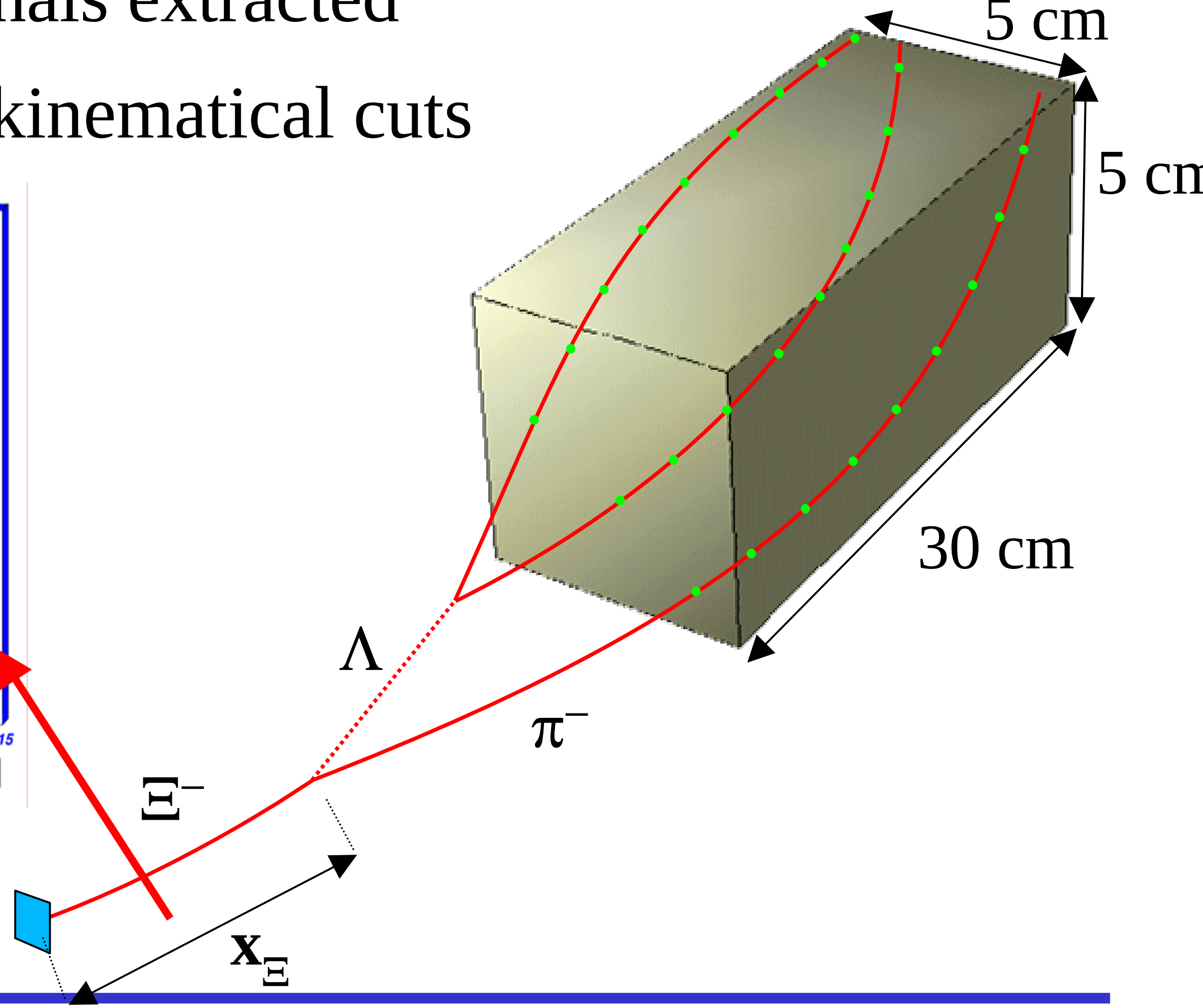

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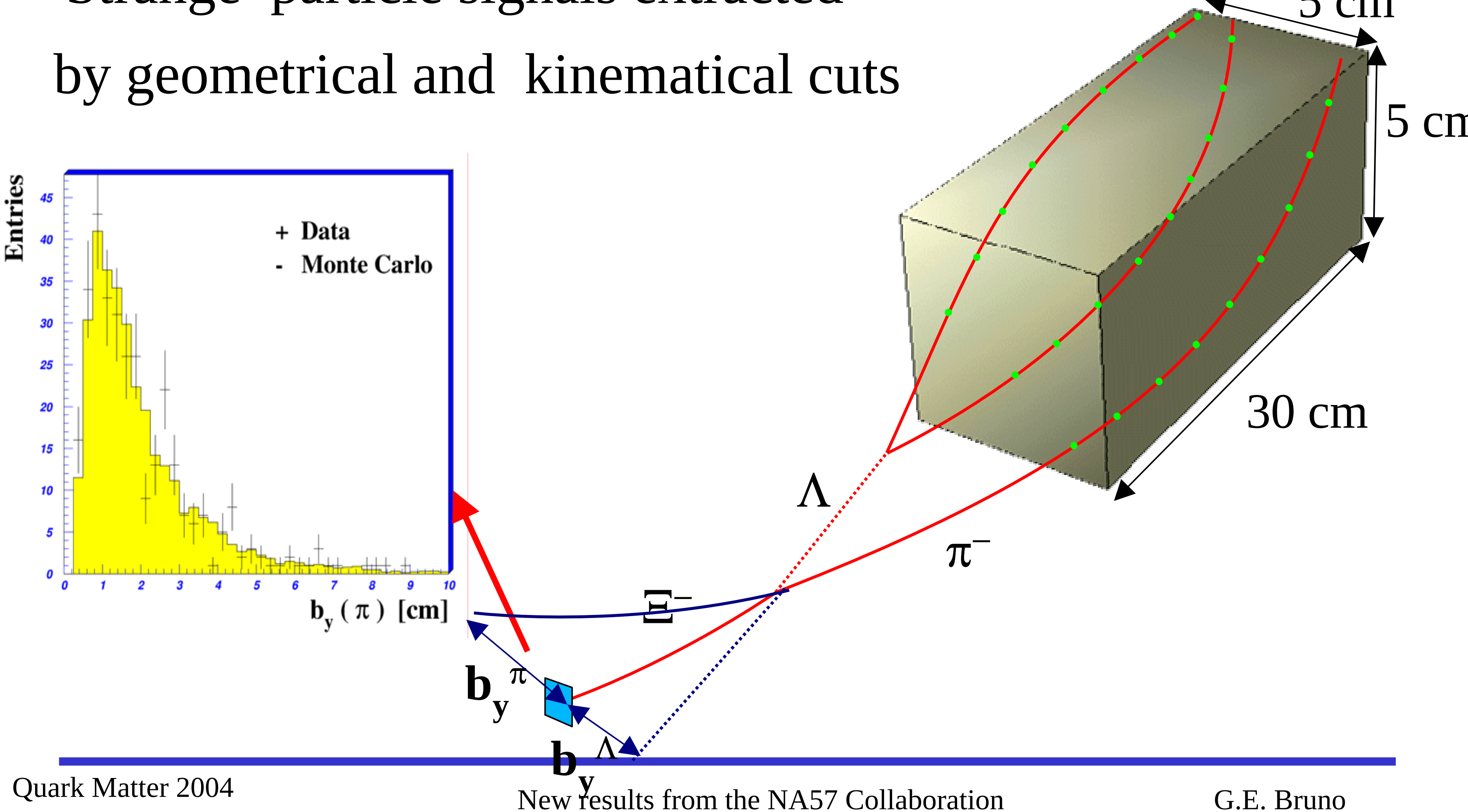

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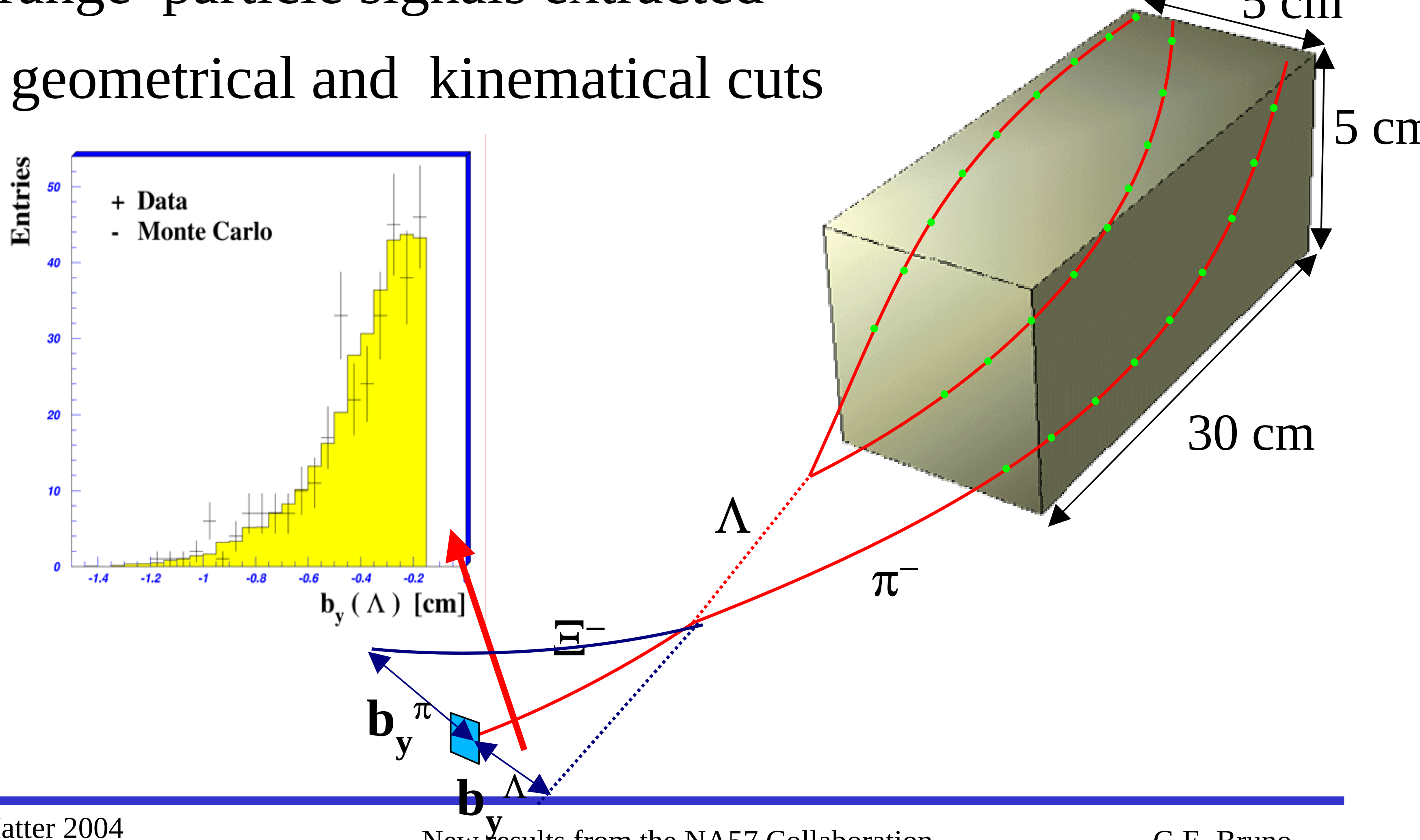
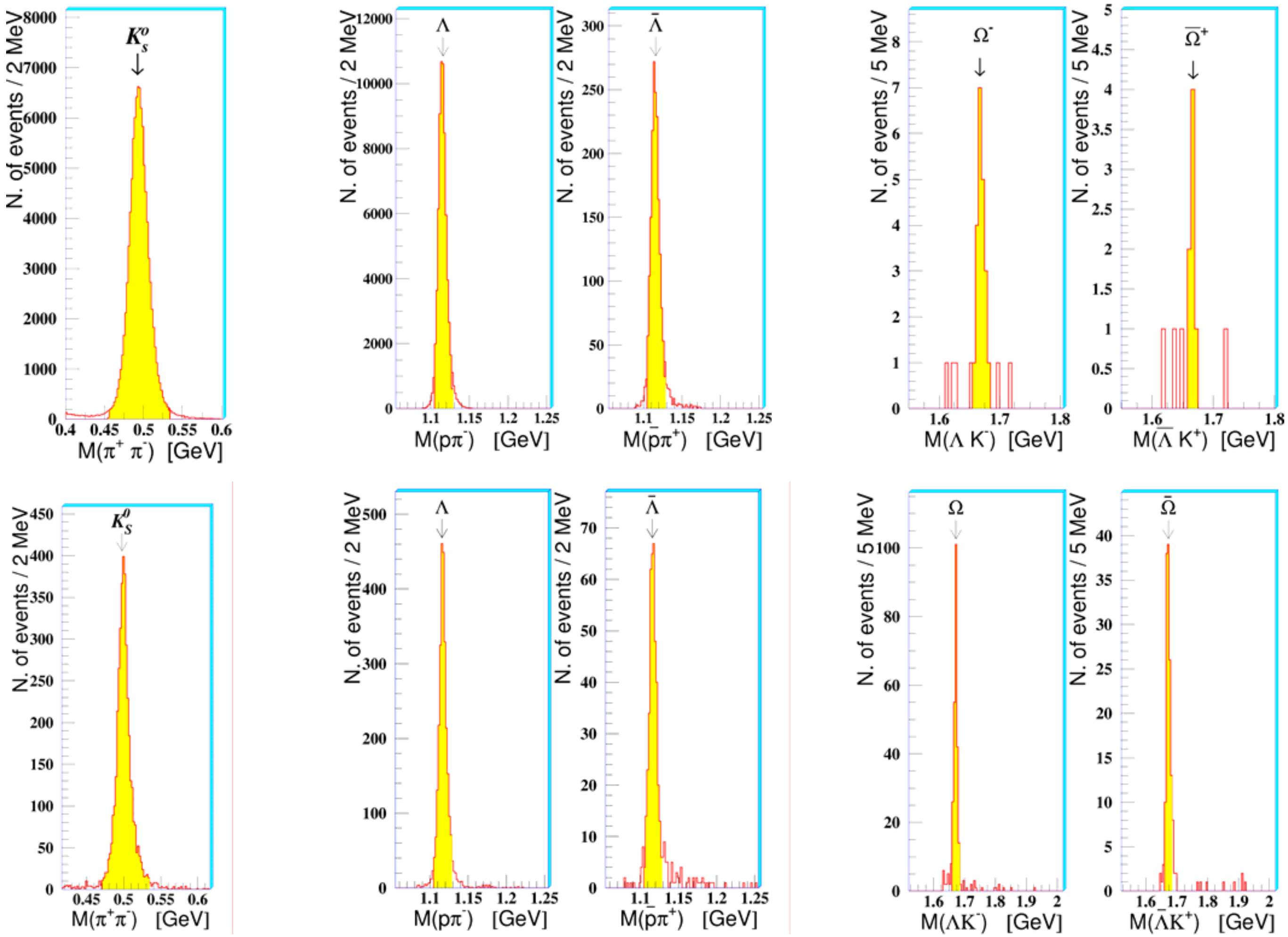


Selected signals



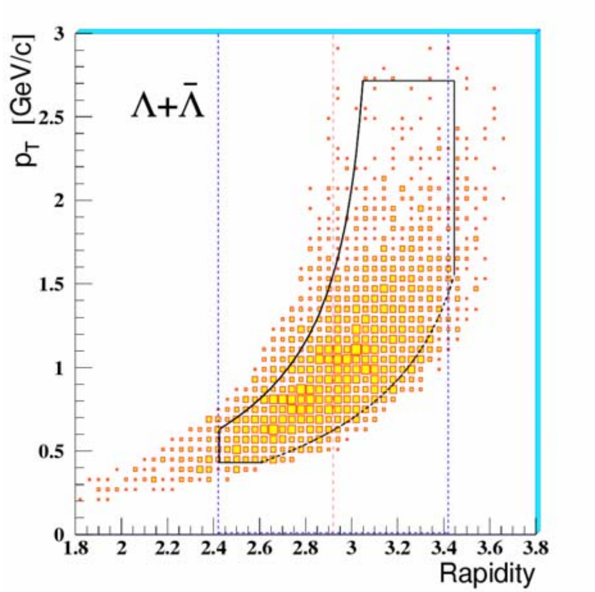
40 A GeV

160 A GeV

Hyperon yield measurements

- Data corrected for acceptance and also for detector and reconstruction efficiency by Monte Carlo simulation
- In the acceptance window:
  - Yield

    (i.e. particle per event)
  - Transverse mass spectra (T_{app})
- Extrapolation to a common window:
  - one unit of rapidity about y_{cm}
  - full range of p_T



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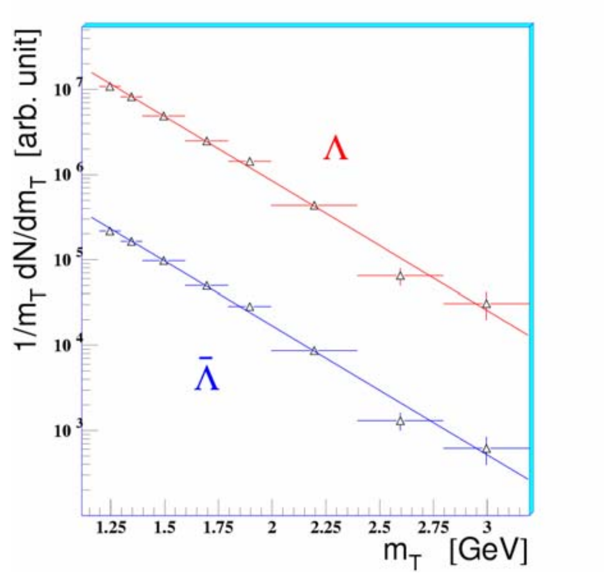
$$m_T = \sqrt{p_T^2 + m_0^2}$$

$$\frac{d^2 N}{dy dm_T} = A m_T \exp\left(- \frac{m_T}{T_{app}} \right)$$



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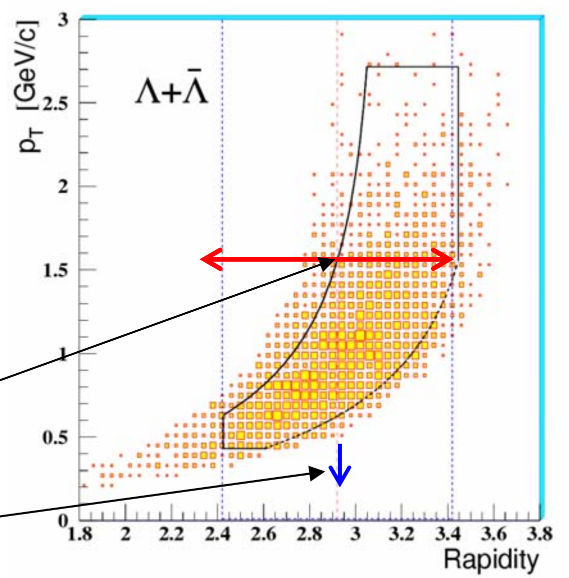


$$Y_{extr} = \int_{y_{CM}-0.5}^{y_{CM}+0.5} dy \int_{m_0}^{\infty} dm_T \frac{d^2N}{dm_T\,dy}$$

$$\beta_\perp(r) = \beta_S \left[\frac{r}{R_G} \right]^n$$

	n=0	n=1/2	n=1	n=2
T (MeV)	158±6	152±6	144±7	151±11
β_S	0.396 ±0.015	0.493 ±0.016	0.571 ±0.019	0.633 ±0.028
$\langle\beta_\perp\rangle$	0.396 ±0.015	0.394 ±0.013	0.381 ±0.013	0.316 ±0.014
χ^2/ndf	39.6/48	36.9/48	37.2/48	68.0/48

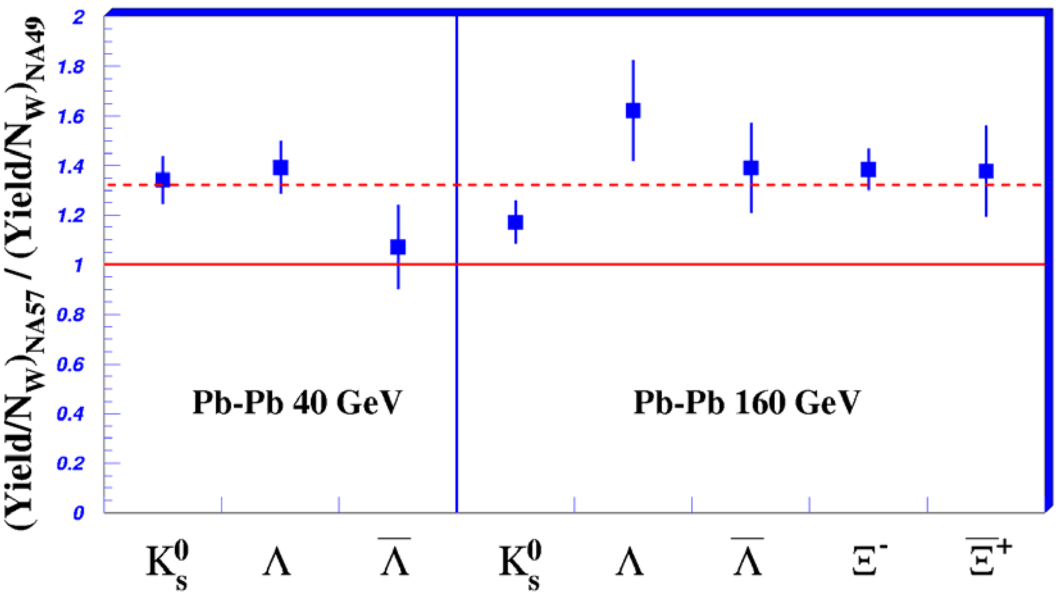
Comparison NA57-NA49

Particle yields per participant

Similar centrality regions:

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

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

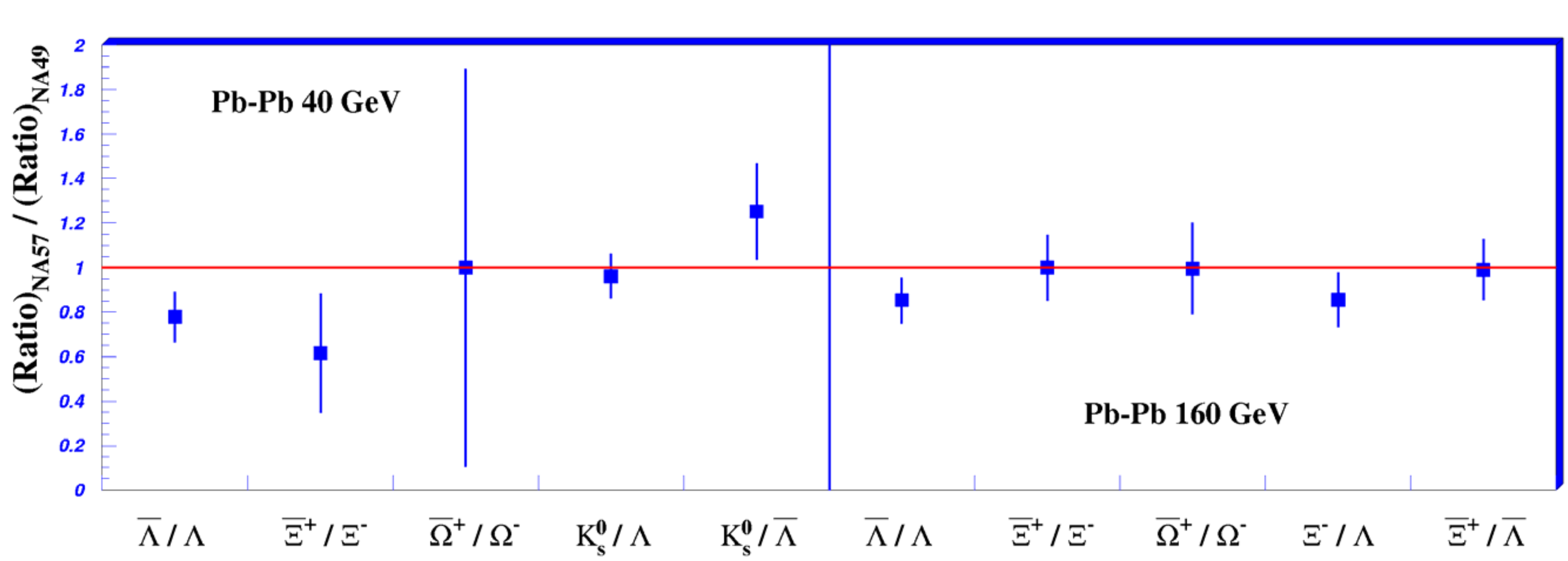


- about 30% systematics on the absolute value of the yields (under investigation) but …

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

Comparison NA57-NA49

Particle ratios



- ... particle ratios compatible within errors

(no impact on relative yields)

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