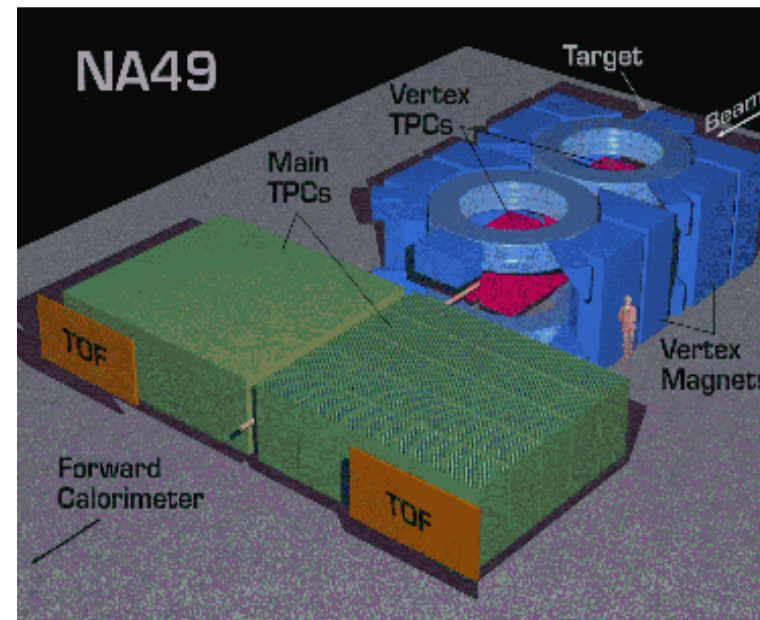




$\Lambda, \bar{\Lambda}, \Xi, \bar{\Xi}, \Xi_{1530}, \bar{\Xi}_{1530}, \Omega, \bar{\Omega},$
 $\pi^+, \pi^-, K^+, K^-, p, \bar{p}, n$



Inclusive production of hyperons, as well as of pions, charged kaons, protons, anti-protons and neutrons in p+p collisions at 158 GeV/c beam momentum

Tome Anticic

for the NA49 collaboration

ICHEP, Paris, July 2010

- Various evidence points to existence of QGP, and to existence of the onset of deconfinement at energies between $\sqrt{s_{NN}} = 6.3 - 17.3$ GeV
- However, a good understanding of the underlying p-p and p-A process necessary to support this conclusion or to perhaps give alternative explanations
- NA49 experiment unique in providing one detector for p-p, p-A, and A-A analysis, by changing targets and incoming beam

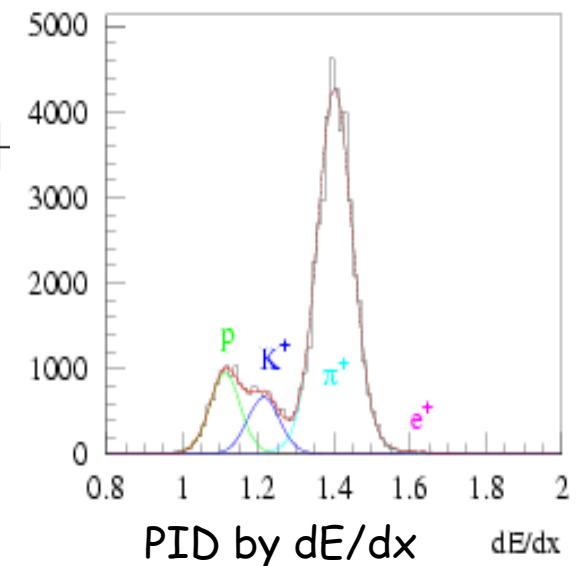
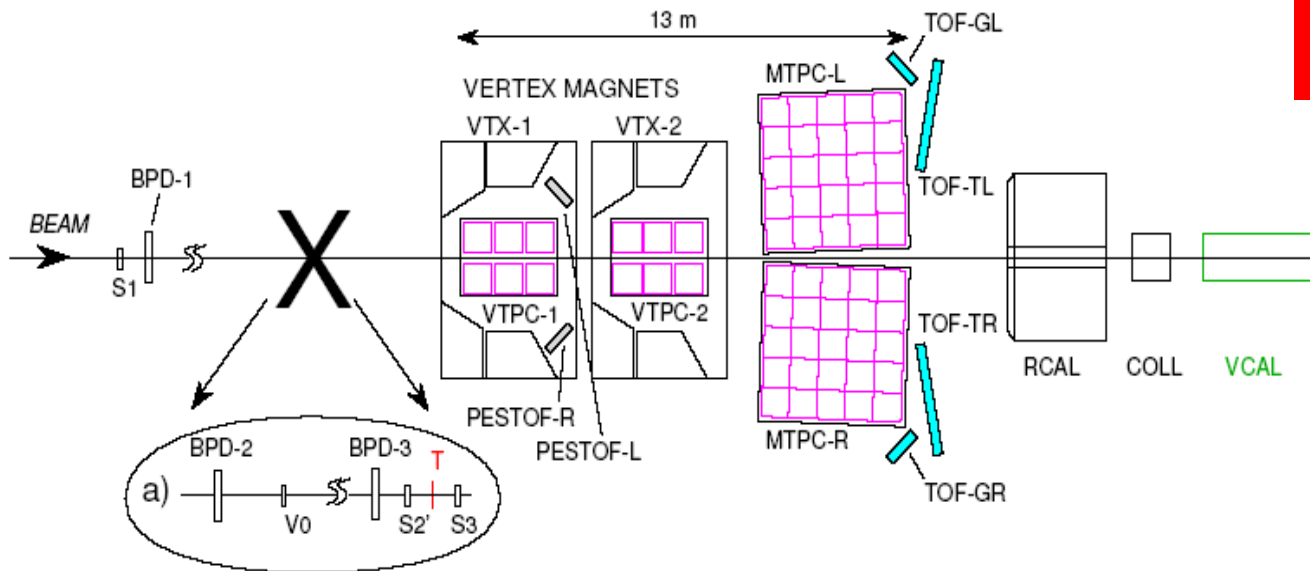
NA49 covers forward hemisphere; because of the symmetry of $p+p$ this allows extraction of 4π integrated multiplicities

Hadron spectrometer

Four TPCs; two in the **B** field and two others outside; for a precise measurement of p and dE/dx

Large acceptance: $\approx 50\%$
High momentum resolution

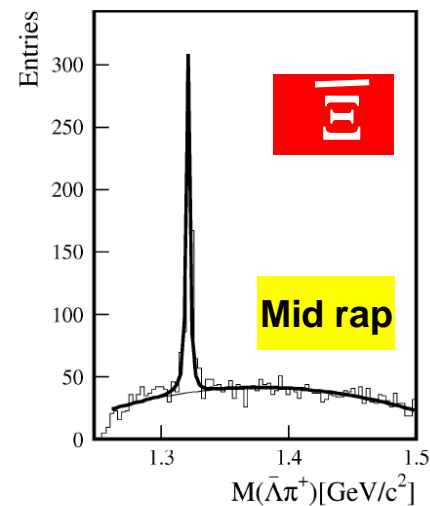
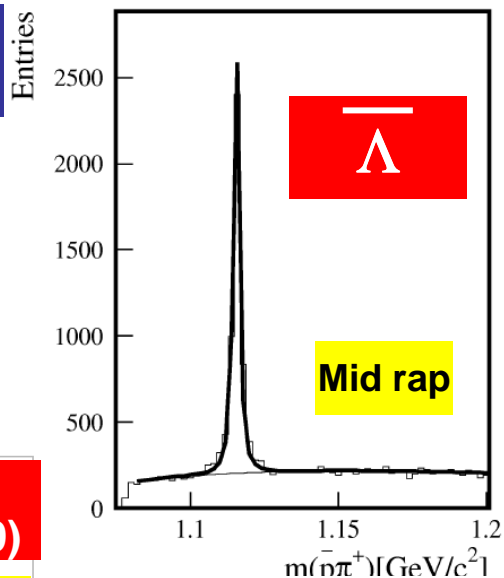
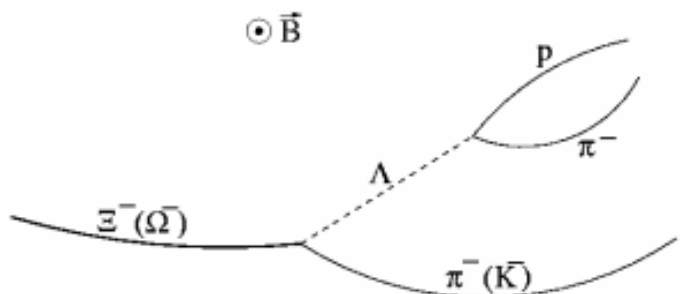
Good particle identification by dE/dx , decay topology, invariant mass



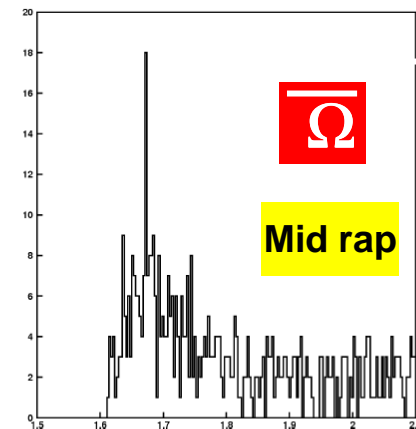
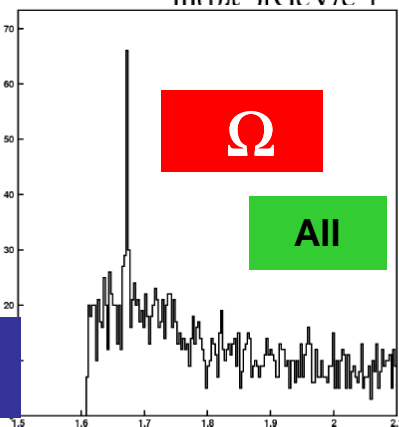
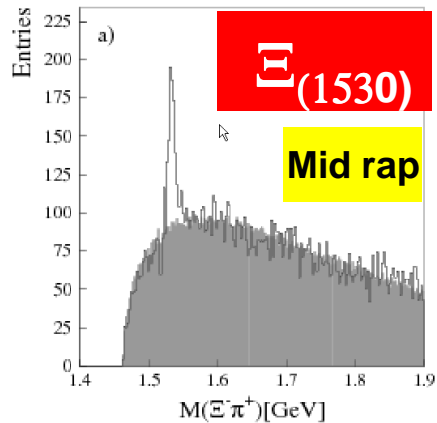
Hyperons

- Strange particles do not exist in colliding protons, and as such are excellent probes of the underlying physics of the production mechanism
- Strangeness enhancement an indication of QGP formation
- Models sensitive to hyperon production at SPS energies

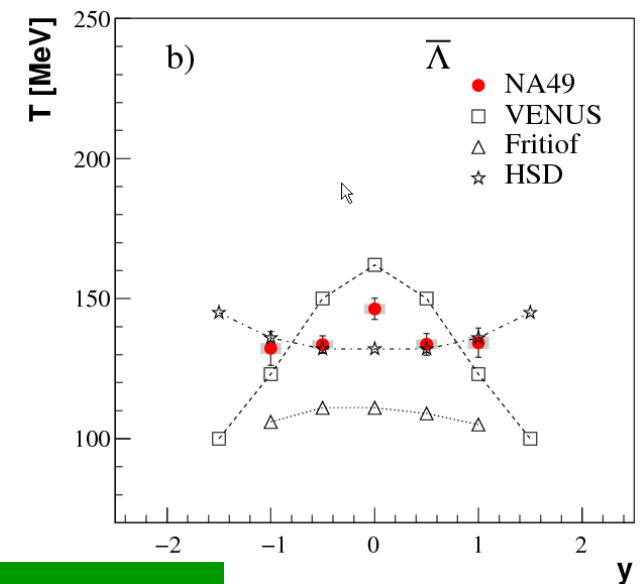
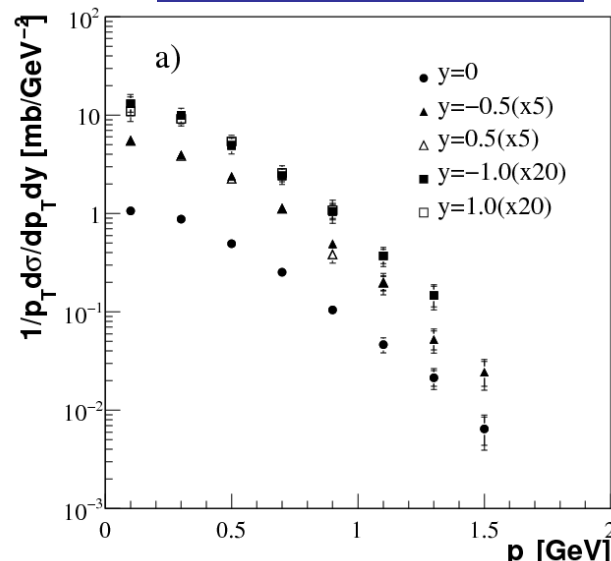
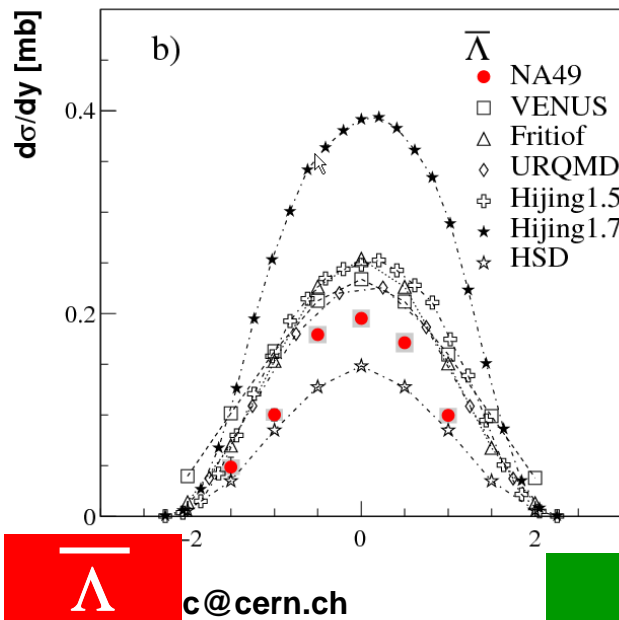
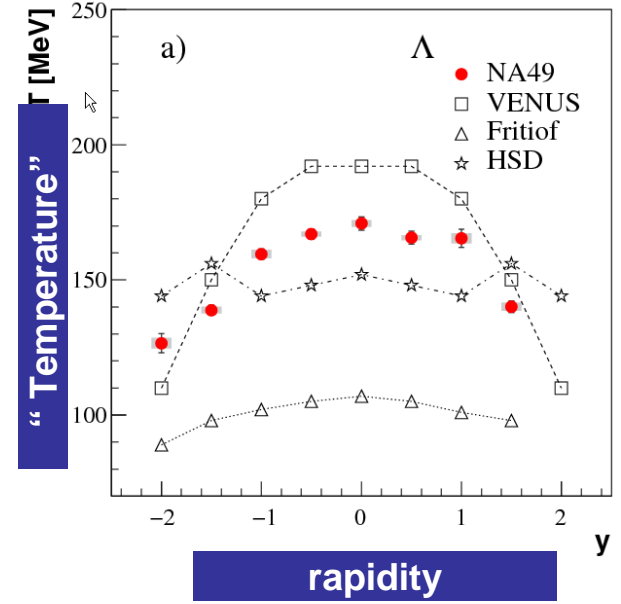
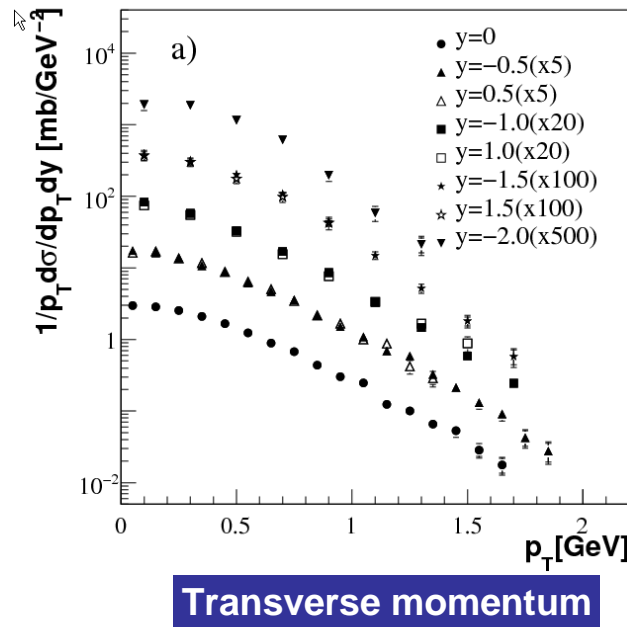
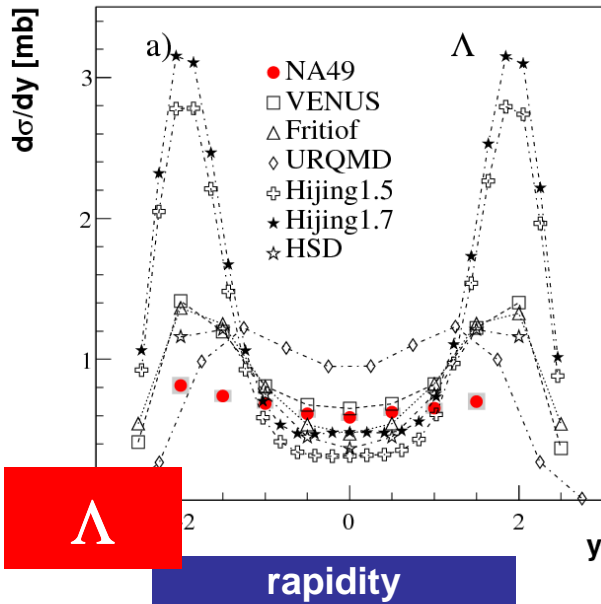
• 8.2 M p-p events before selection

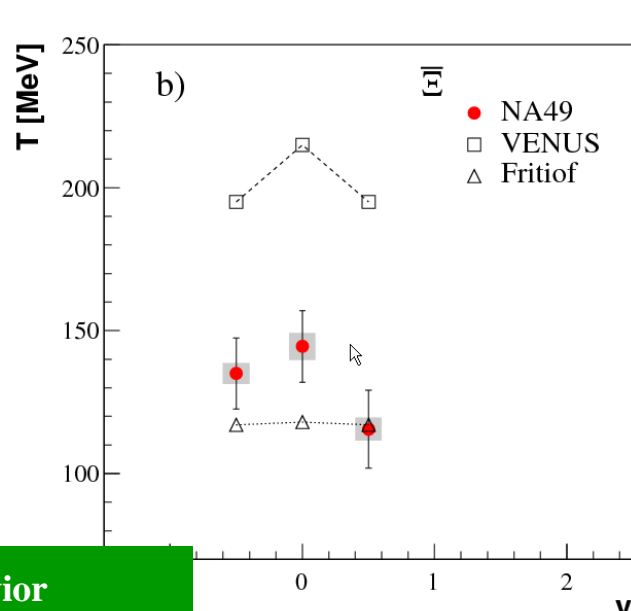
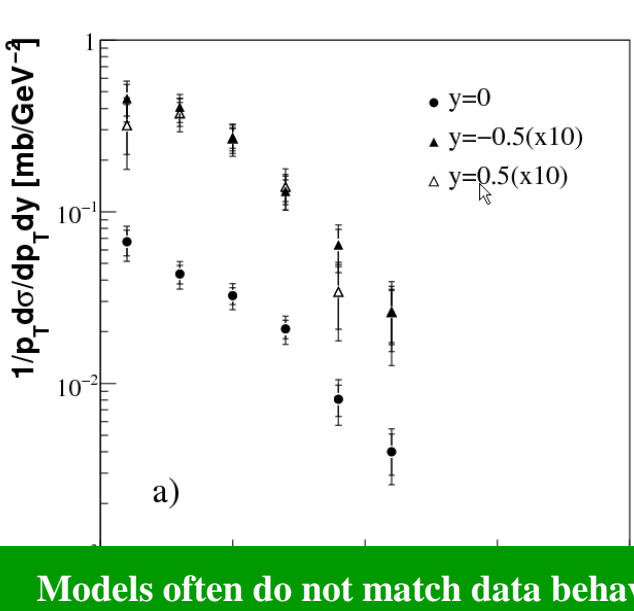
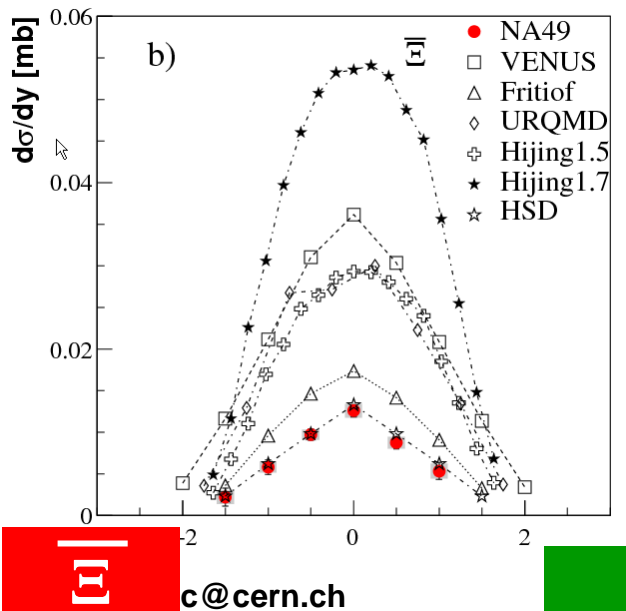
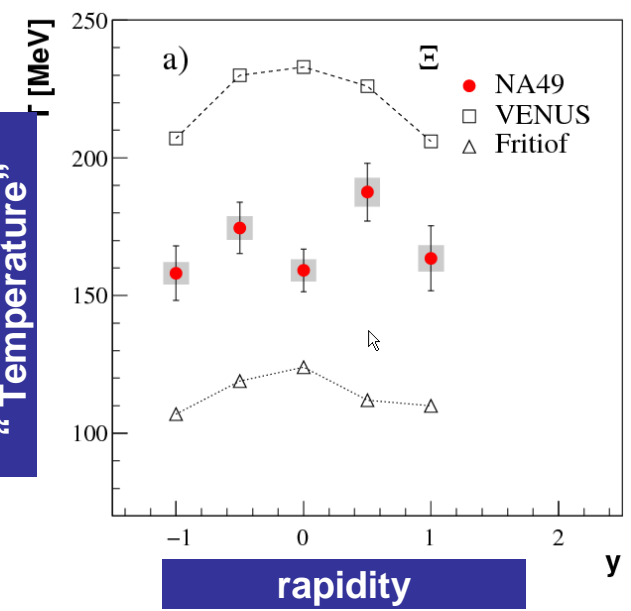
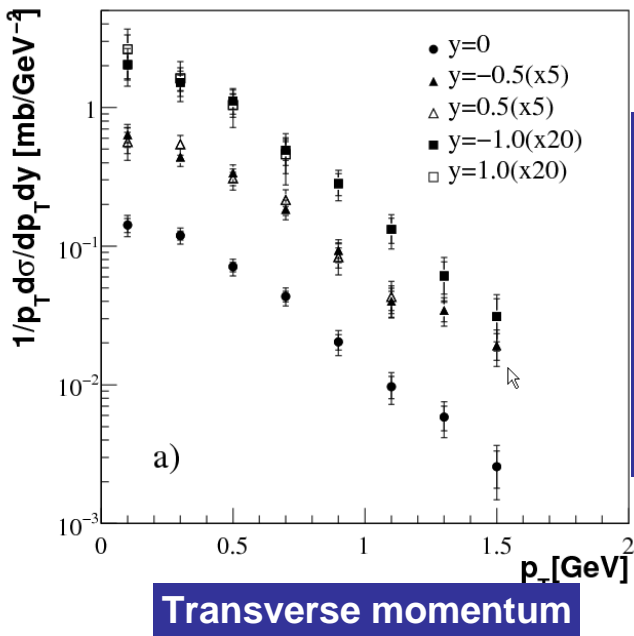
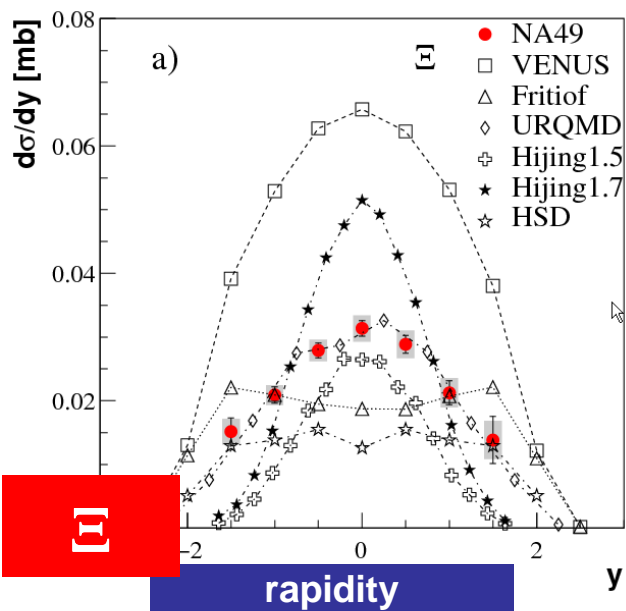


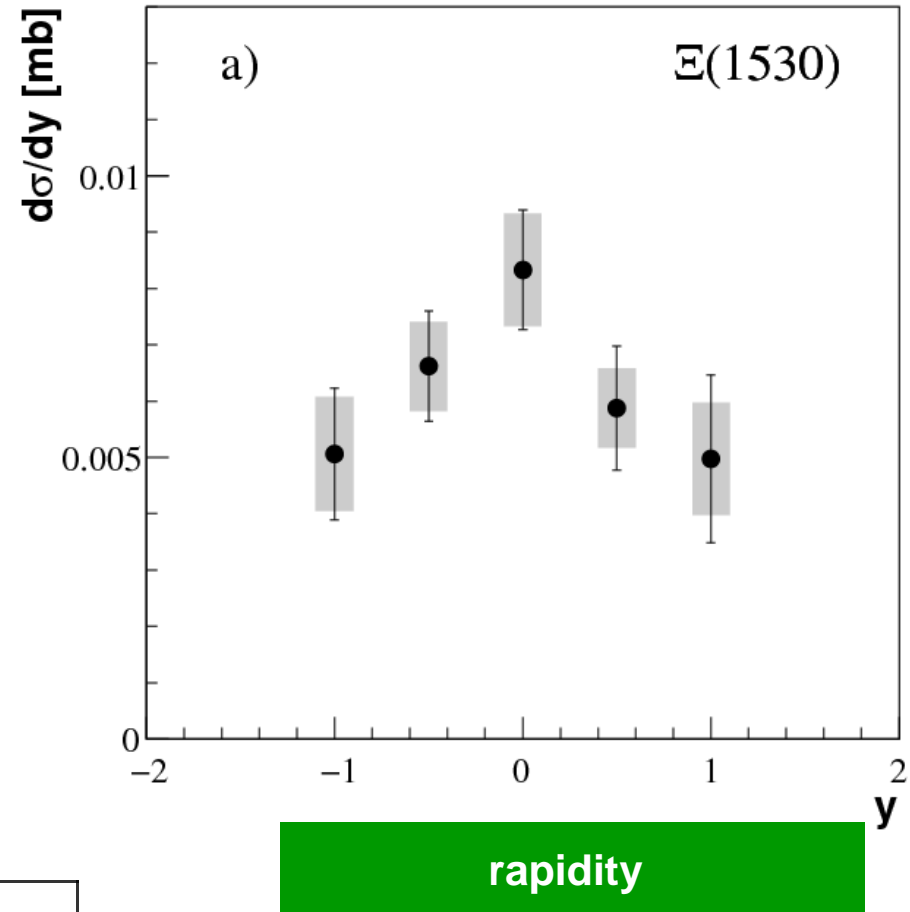
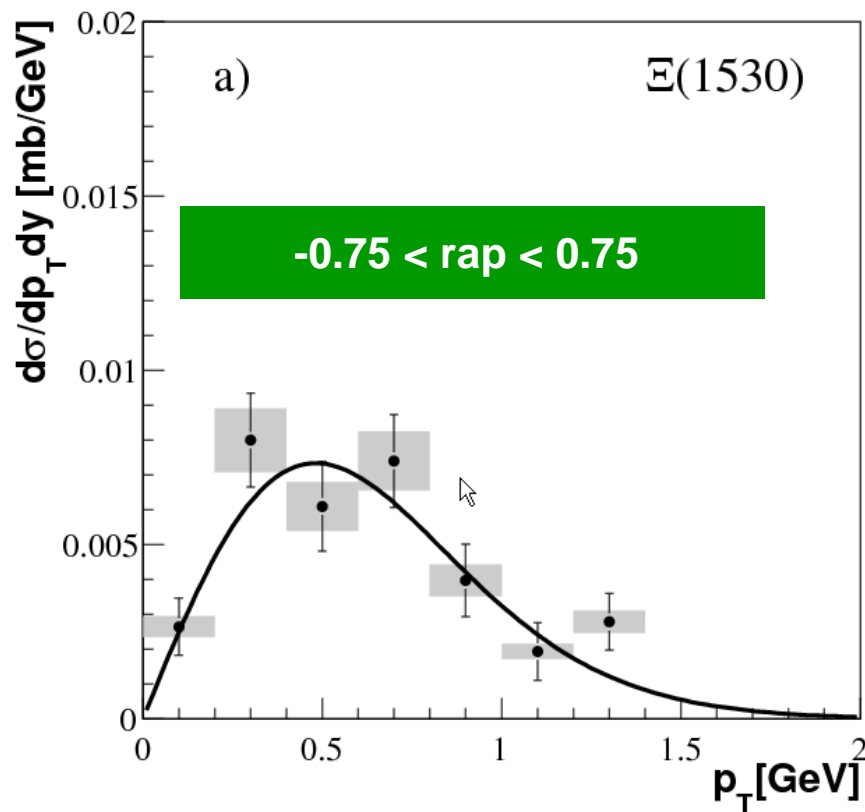
- 77500 Λ
- 14200 Λ
- 3800 Ξ
- 1200 Ξ
- 550 $\Xi(1530)$
- 135 $\Xi(1530)$
- 70 Ω
- 10 Ω



First clear signal at SPS energies in p-p collisions

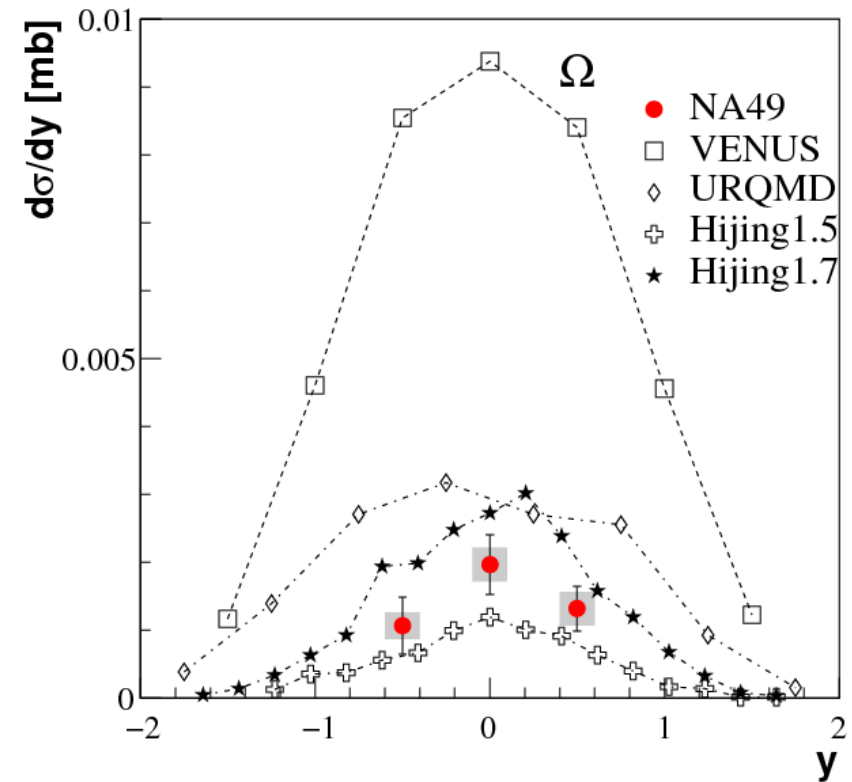
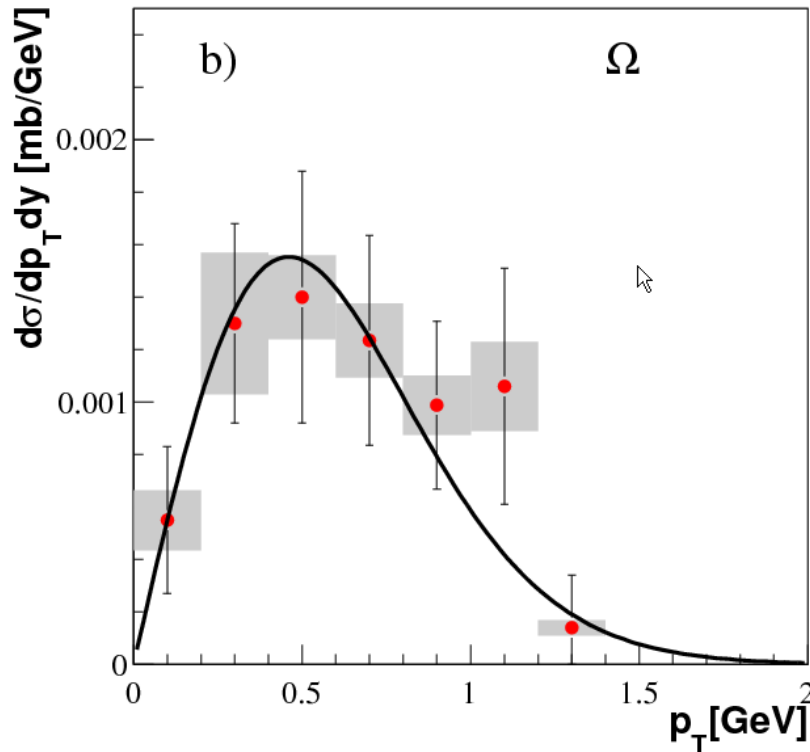






	Ξ_{1530}
$\langle p_T \rangle$	$0.62 \pm 0.06 \pm 0.07$
Temperature	$148 \pm 19 \pm 7$

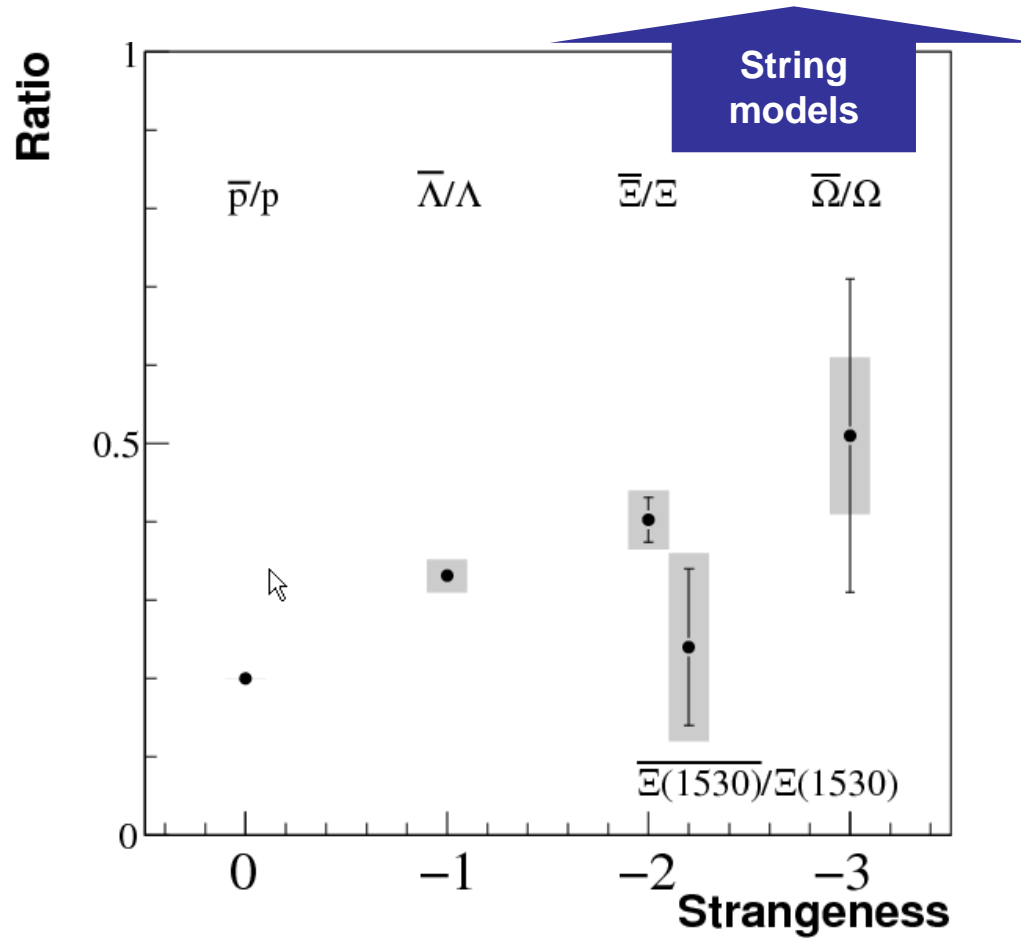
$-0.75 < \text{rap} < 0.75$



rapidity

	Ω
$\langle p_T \rangle$	$0.64 \pm 0.11 \pm 0.09$
Temperature	$137 \pm 27 \pm 6$

Anti baryon/baryon ratio



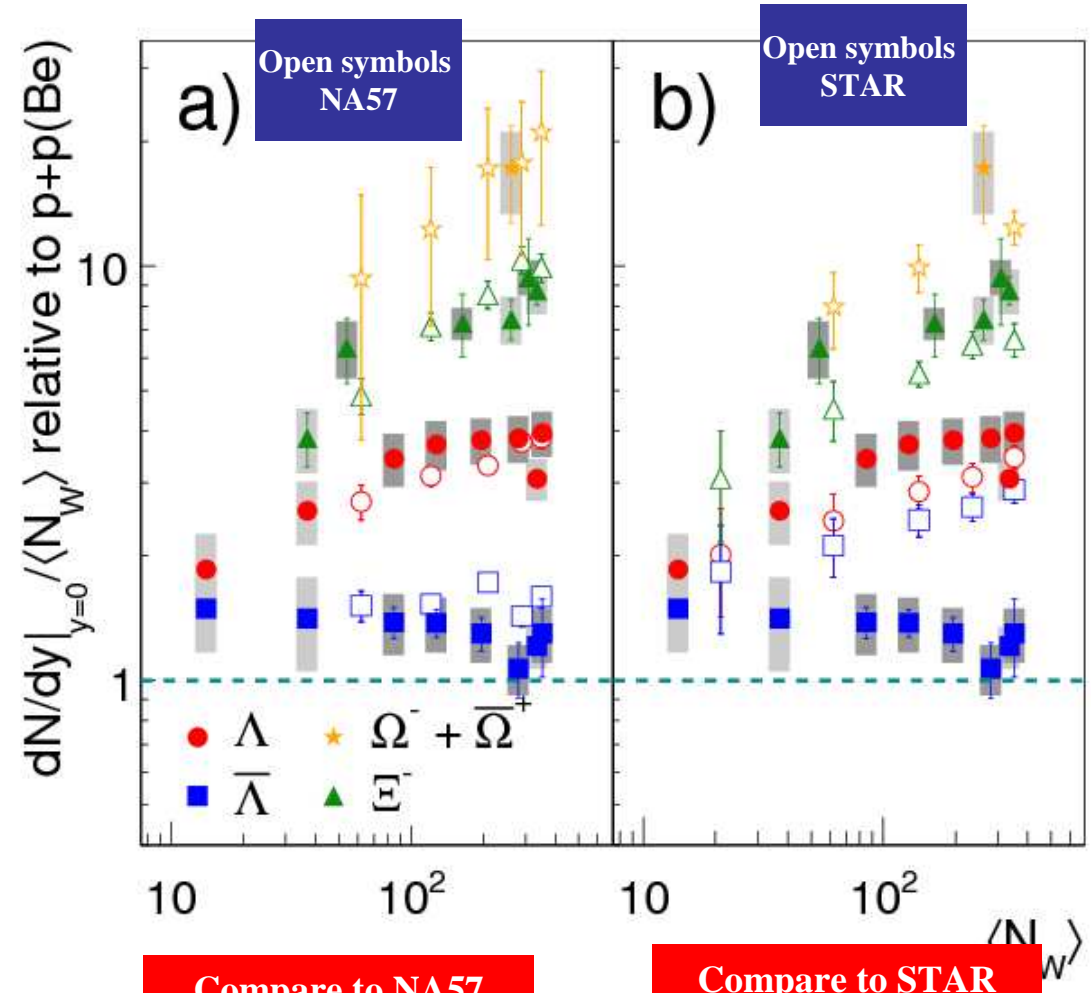
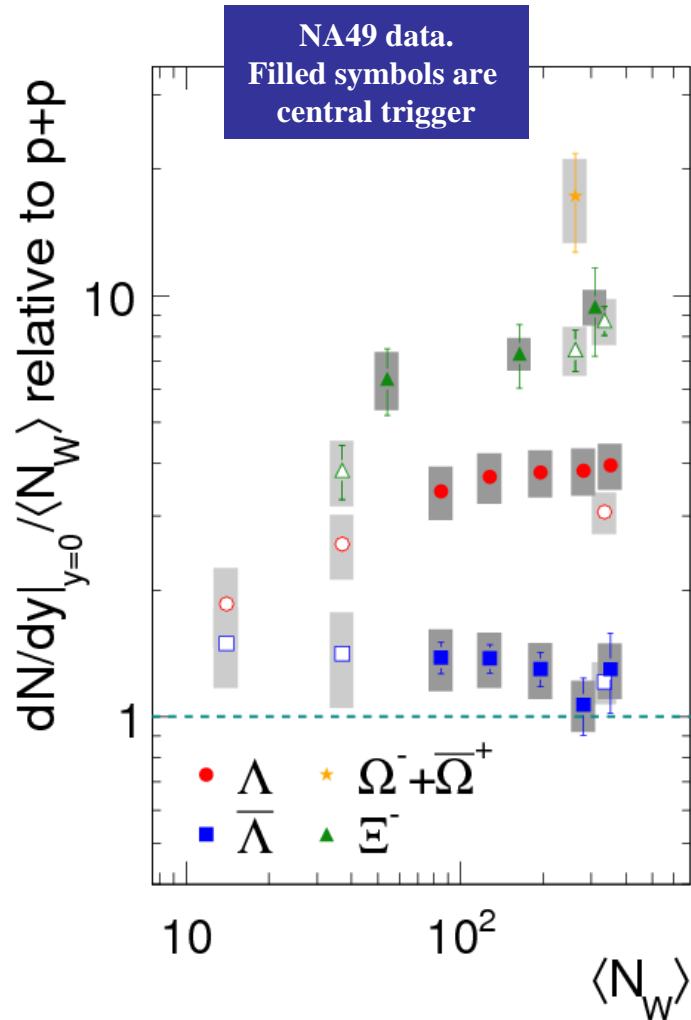
Anti baryon to baryon ratio at $y=0$ as a function of strangeness

String models predict:

$$\begin{aligned} \bar{E}/E &= 0.8 - 1.2 \\ \bar{\Omega}/\Omega &= 1.6 - 1.9 \end{aligned}$$

Strangeness enhancement

$$E = \frac{2}{\langle N_w \rangle} \frac{dN/dy(A+A)}{dN/dy(p+p)}$$



Compare to NA57

Compare to STAR

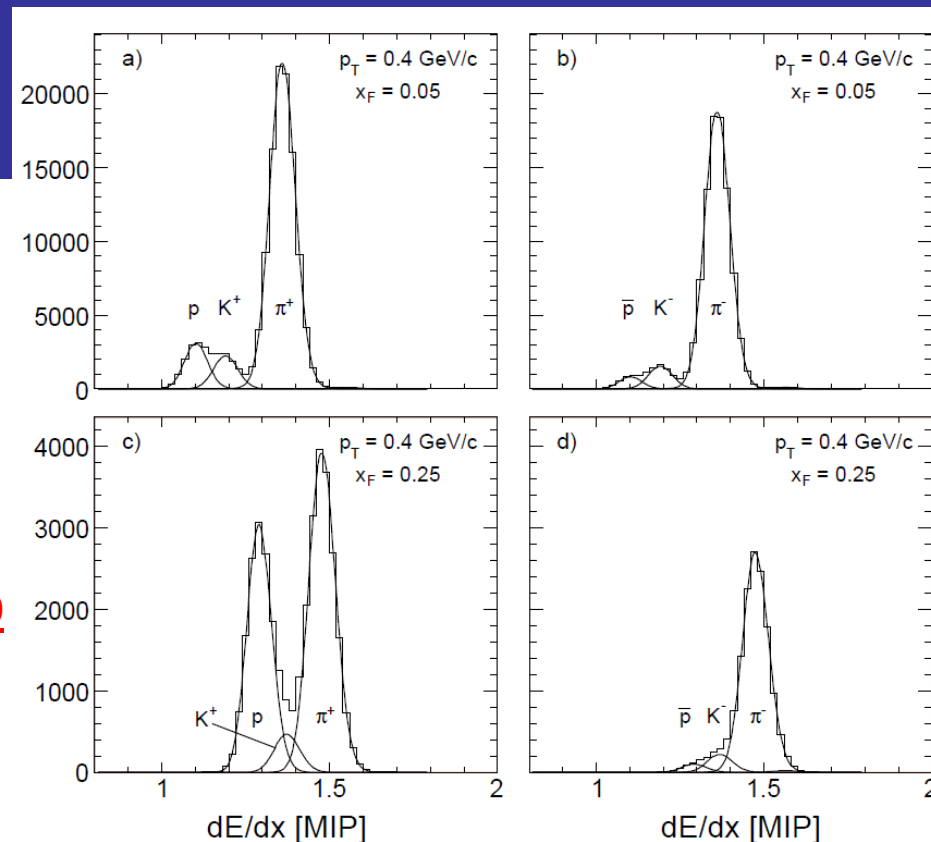
Pions, kaons, protons, neutrons

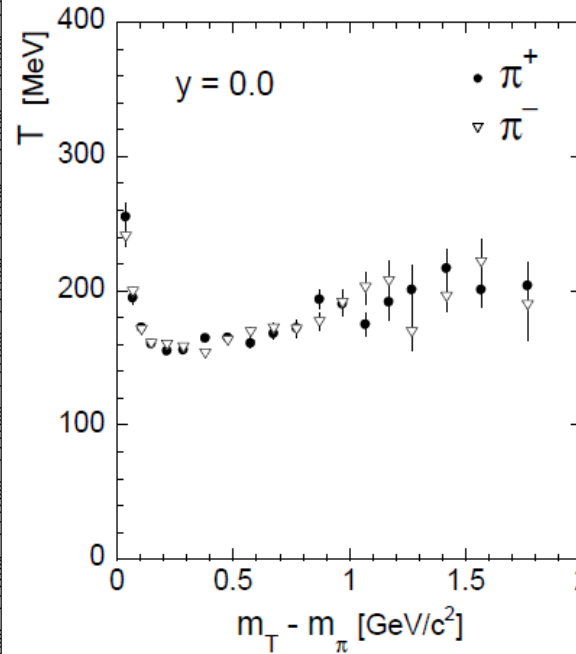
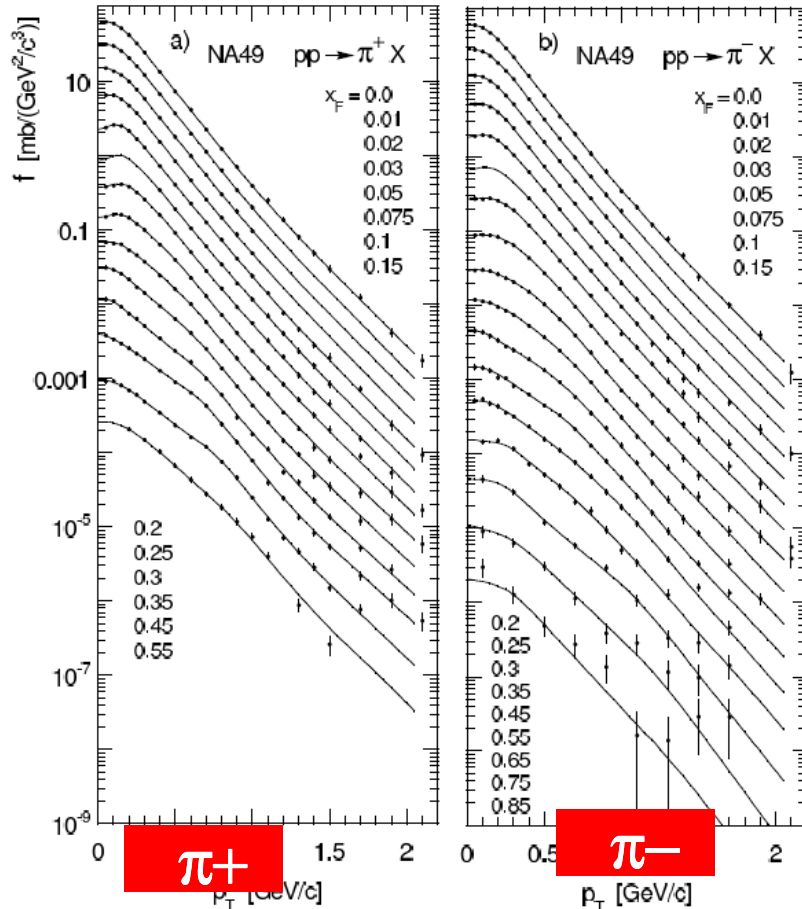
- 6.4 M inelastic p-p events (4.8 M after event cuts)
- Can not use topology for PID, so excellent knowledge of dE/dx required
- To minimize systematic errors on this high statistics sample, also bin size corrections employed
- Results corrected for feeddown from hyperon weak decays
- Detailed comparison with data from other experiments and energies at ISR, SIS, Serpukhov, RHIC, Fermilab, ...
- Detailed study of particle ratios

[C.Alt et al.,EPJC 45 \(2006\) 343](#)

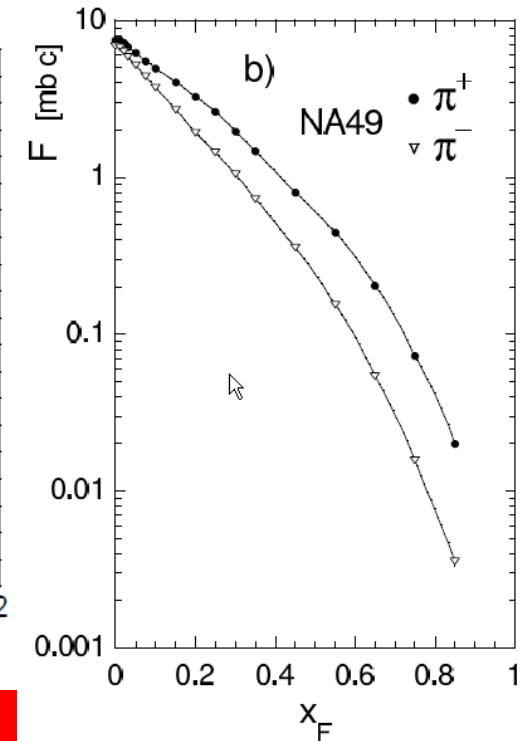
[arXiv:1004.1889v](#)

[T.Anticic et al.,EPJC 65 \(2010\) 9](#)





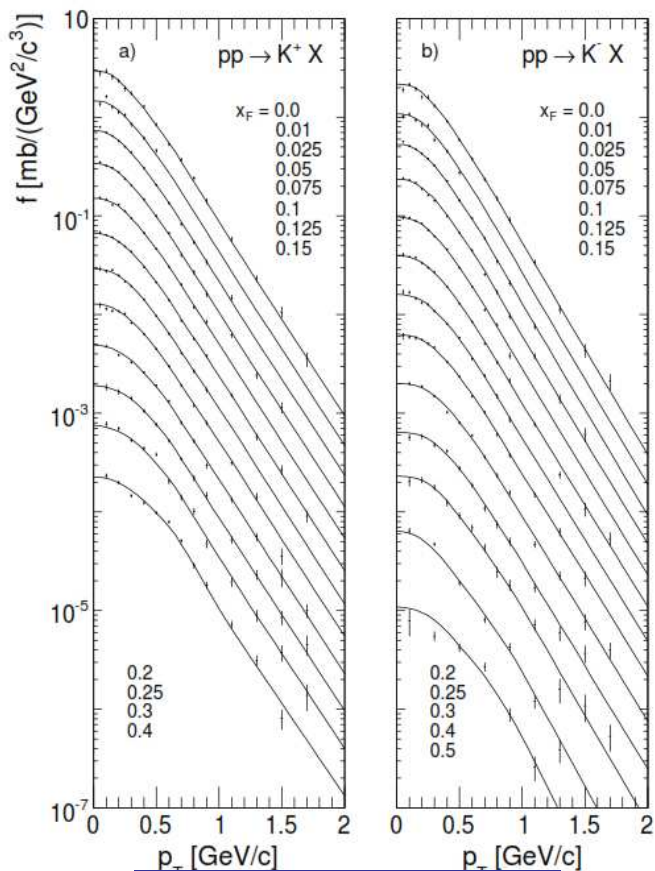
“temperature” a function of transverse mass



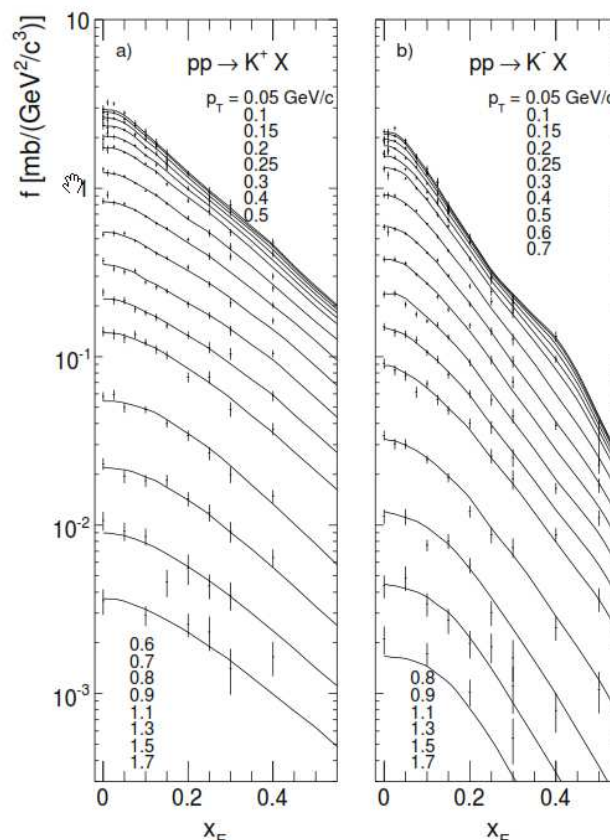
- Systematic and statistical uncertainties well below 5%
- Rich substructure of data (also in the kaon and proton data) – indication that particles are produced via intermediate higher mass resonances
 - profound consequences for the understanding of particle production in the non-perturbative sector of QCD

K⁺, K⁻

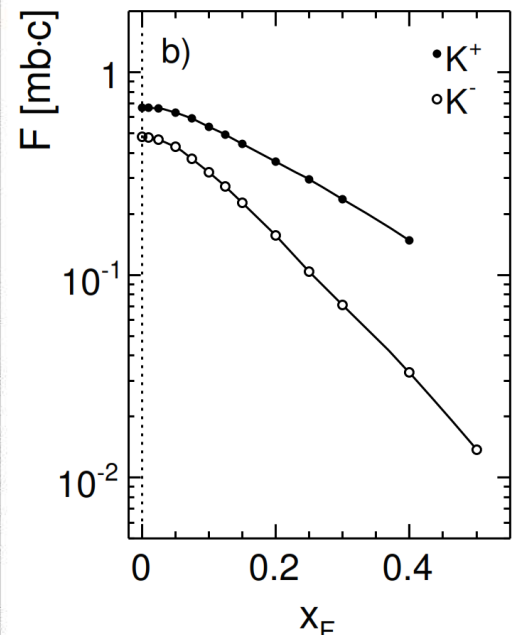
- 0 to 1.7 GeV/c in transverse momentum
- 0 to 0.5 in Feynman x



Transverse momentum



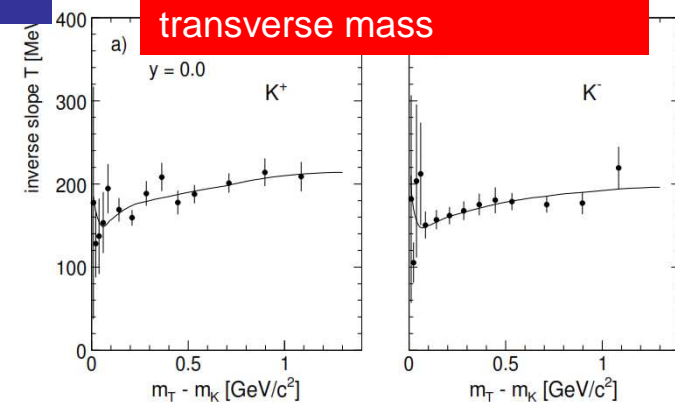
Feynman x



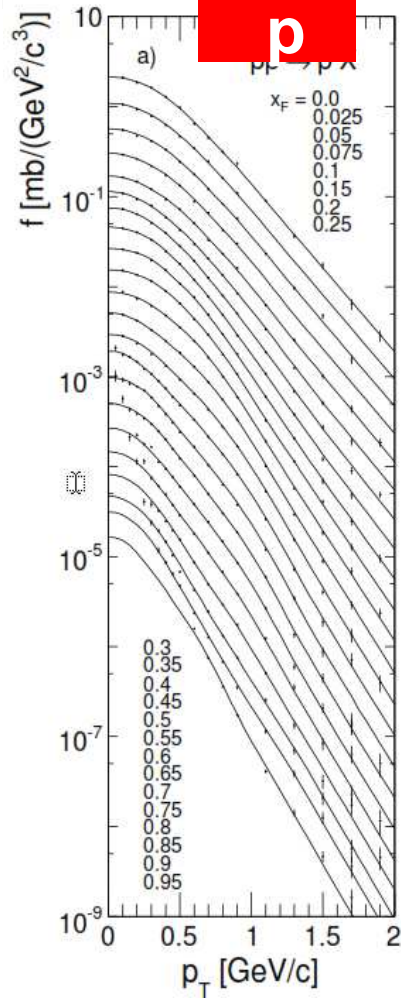
Integrated data

based on high precision NA49 results an internally consistent picture of kaon production was established in the energy range $3 < \sqrt{s} < 1800$ GeV

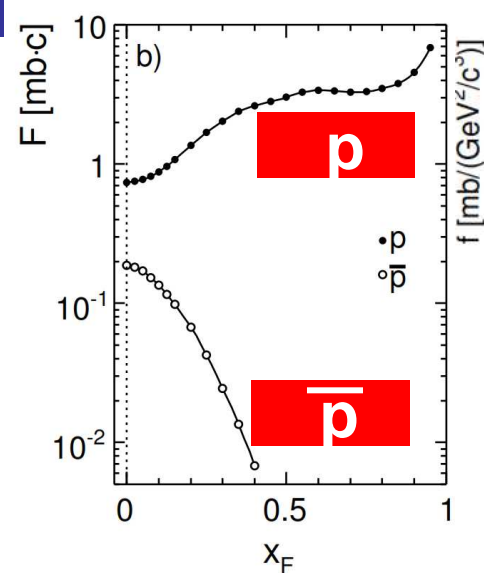
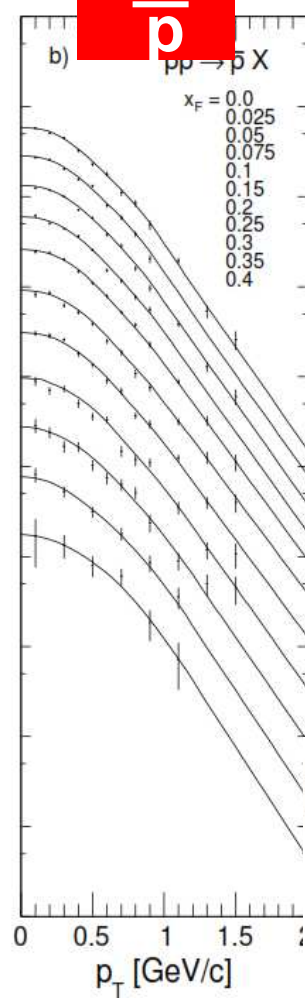
“temperature” a function of transverse mass



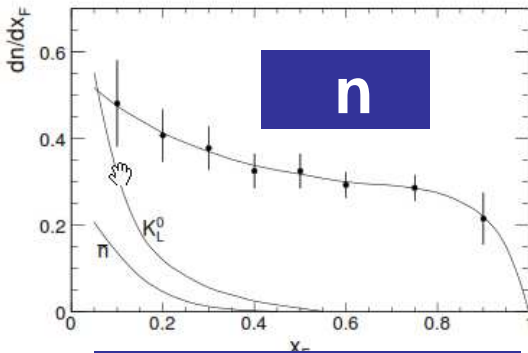
Protons, antiprotons, neutrons



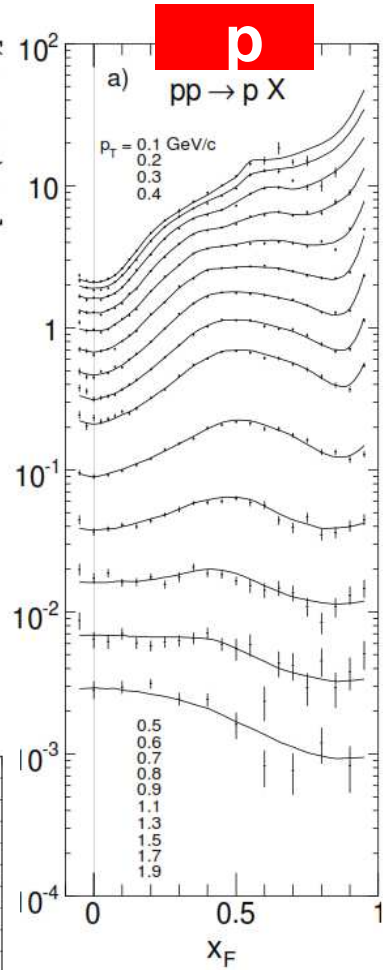
Transverse momentum



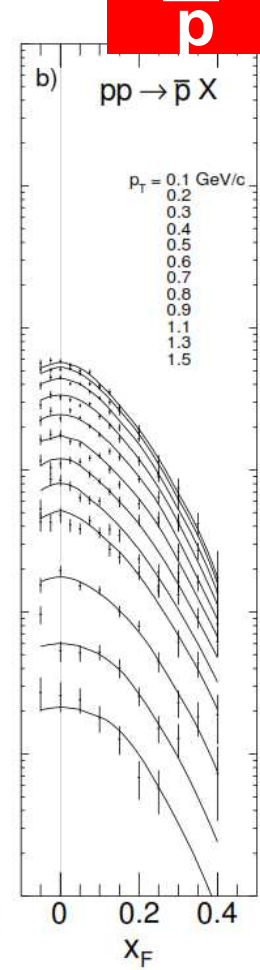
Integrated data



Feynman x



Feynman x



- 0 to 1.9 GeV/c (0 to 1.5 GeV/c) in transverse momentum
- -0.05 to 0.95 (-0.05 to 0.4) in Feynman x for protons (anti-protons), respectively
- p_T integrated neutron cross sections: 0.1 to 0.9 in Feynman x

Yields per inelastic event

Yield per inelastic event												
	NA49			VENUS	Fritiof	EPOS	URQMD	HSD	Hijing1.5	Hijing1.7	Stat models A/B	
π^+	3.018	± 0.0045		2.915	3.0305	3.05854	3.079	2.928			3.25	3.28
π^-	2.360	± 0.0035		2.260	2.3407	2.38359	2.450	2.205020			2.43	2.45
K^+	0.21	± 0.02				0.23669	0.25290	0.272959			0.228	0.200
K^-	0.13	± 0.013				0.13577	0.16463	0.181031			0.119	0.107
p	1.1623	± 0.0035		1.228	1.2653	1.23175	1.311	1.200550			1.094	1.125
\bar{p}	0.03860	± 0.00011		0.045	0.0668	0.03773	0.06033	0.044834			0.0364	0.0445
Λ	0.1095	± 0.0015	± 0.0110	0.152	0.1488	0.13857	0.1428	0.150434	0.199	0.231	0.133	0.117
$\bar{\Lambda}$	0.01425	± 0.00024	± 0.00082	0.0199	0.0185	0.03304	0.01753	0.01043	0.0192	0.0305	0.0147	0.0141
Ξ	0.00265	± 0.00010	± 0.00027	0.00628	0.00260	0.00228	0.002609	0.001726	0.00143	0.00270	0.00285	0.00110
$\bar{\Xi}$	0.000947	± 0.000036	± 0.000075	0.00267	0.00114	0.00059	0.002221	0.000872	0.00207	0.00387	0.00092	0.00039
$\Xi 1530$	0.000630	± 0.00011	± 0.00017	0.00469	0.001309		0.000220					
Ω	0.000122	± 0.000012	± 0.000013	0.00060	0.000014		0.000353	0.000012	0.000050	0.00013	0.000089	0.000021

Significant discrepancies for most models/particles

• High quality double differential data for hyperons, pions, kaons, protons

- basis for interpretation of particle production mechanisms in pp as well as their implication for pA and AA reactions
- important new constraint for string models
- detailed study of hyperon production in pA underway
- In the near future will study an order of magnitude more data at NA61, the upgrade of NA49
 - study of the onset of deconfinement and search for the critical point of strongly interacting matter

