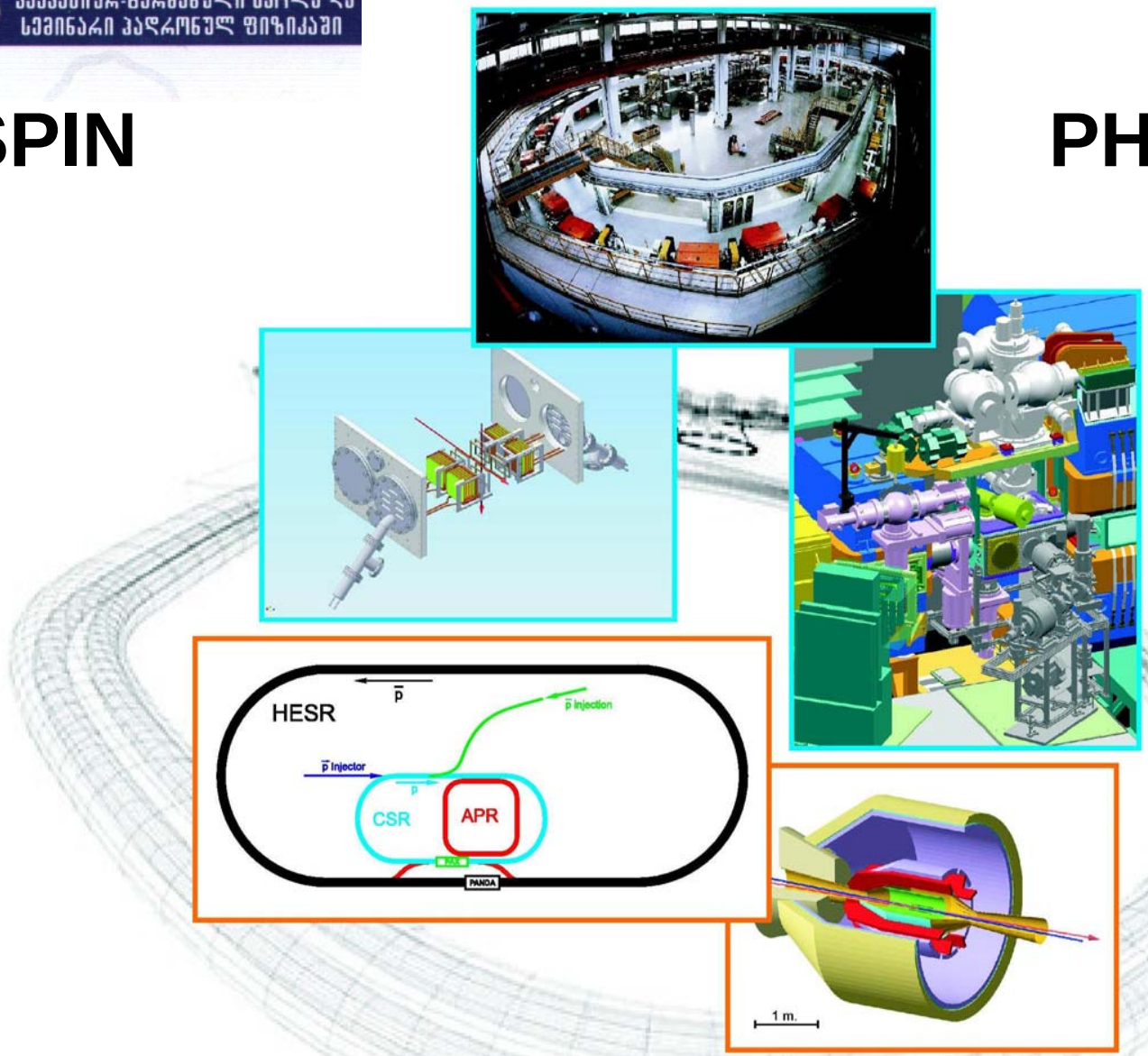
CGSWHP

ქავკასიურ-გერმანული სკოლა და სემინარი პაღრონულ ფიზიკაში

SPIN PHYSICS



COSY → → → → → → → → FAIR

Spin Physics from COSY to FAIR

The SPIN Programme at COSY: Priority Topics

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Spin Physics inside the COSY RING

Proposal presented to the November 2005 PAC

1. Proton-neutron reactions at small momentum transfers.
2. Proton-deuteron reactions at high transfers.
3. Non-strange meson production.
4. Production of strange mesons and baryons.
5. Test of Time-reversal in pd scattering.
6. Spin rotation and birefringence in storage rings.

Available Equipment

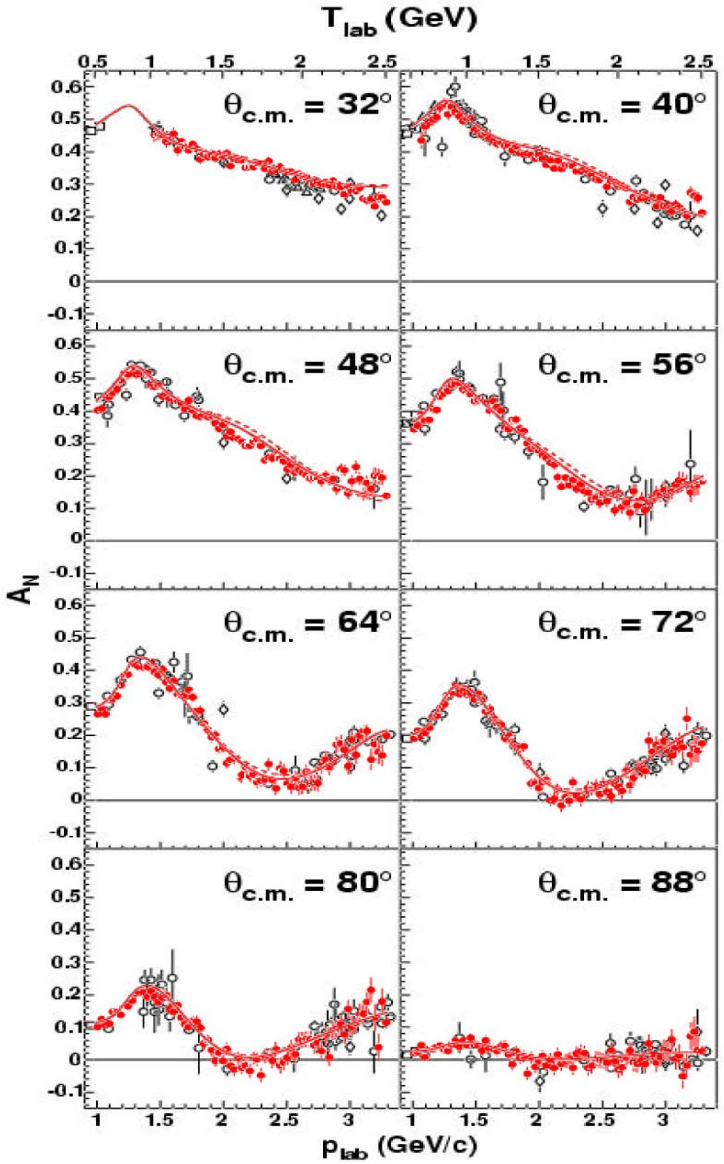
1. ANKE magnetic spectrometer with forward, positive, and negative detectors.
2. Polarised Internal Target (PIT).
3. Polarised proton and deuteron beams and polarised hydrogen and deuterium targets.
4. Silicon tracking telescopes to measure low energy charged particles (including *spectators*) emerging from the target.

But (almost) no measurement of final polarisation.

Nucleon-nucleon elastic scattering

- Thanks largely to EDDA, there is a wealth of differential cross sections, analysing powers and spin-correlations for $T_p < 2.5$ GeV.
- Had a large impact on Phase Shift Analysis for $T_p > 500$ MeV, significantly reducing the ambiguities in *I=1* phase shifts.
- The np situation is poor in comparison and so the *I=0* phase shifts are far more uncertain.

NN-Interaction – The EDDA Legacy



15 distributions of pp analysing power in terms of beam momentum at fixed cm scattering angle.

→ high precision

→ internal consistency

Furthermore, there are unpolarised (σ) and double-polarised (A_{NN} , A_{SS} , A_{SL}) data

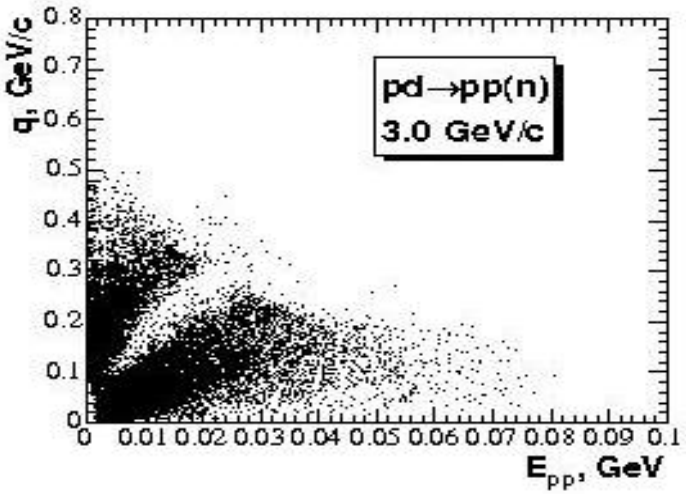
Deuteron Charge-Exchange

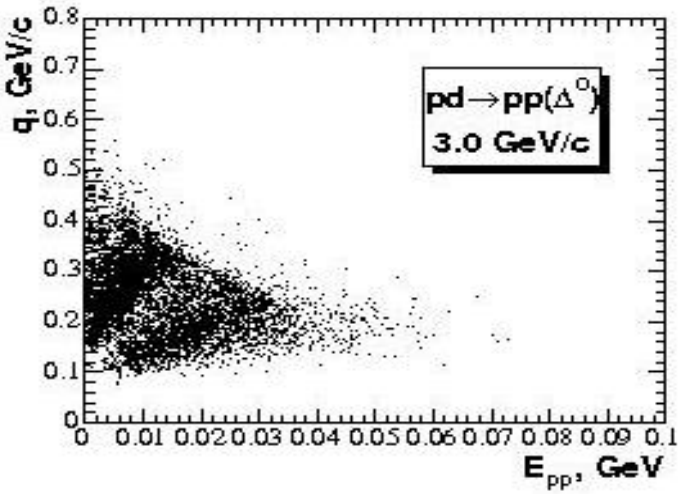
- Due to the Pauli principle, at low excitation energies E_{pp} the *pp* system is a spin-singlet.
- The $dp \rightarrow \{pp\}_S\, n$ reaction involves a spin and isospin flip from the $\{np\}_{S,D}$ to $\{pp\}_S$.
- In impulse approximation, the amplitude is proportional to the $np \rightarrow pn$ spin-flip terms.
- Measurements of σ, A_{xx}, A_{yy} will fix three magnitudes as functions of q. [David Chiladze]
- Spin correlations $C_{y,y}$ & $C_{x,x}$ fix two phases, $A^p{}_y$ a third. Needs polarised cell. [Sergey Dymov]

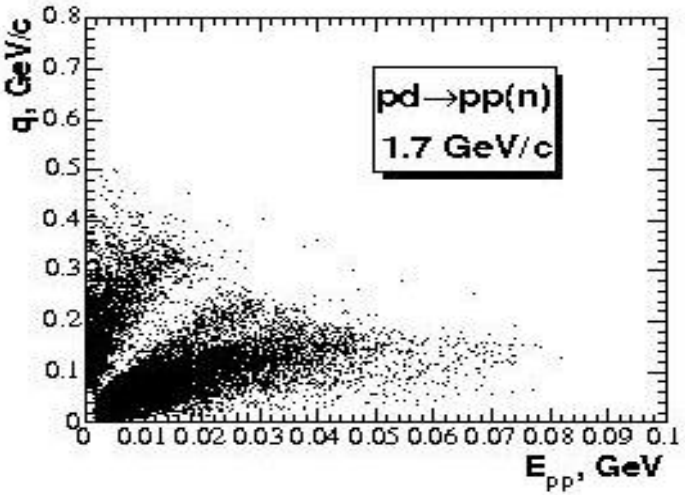
Future Extensions

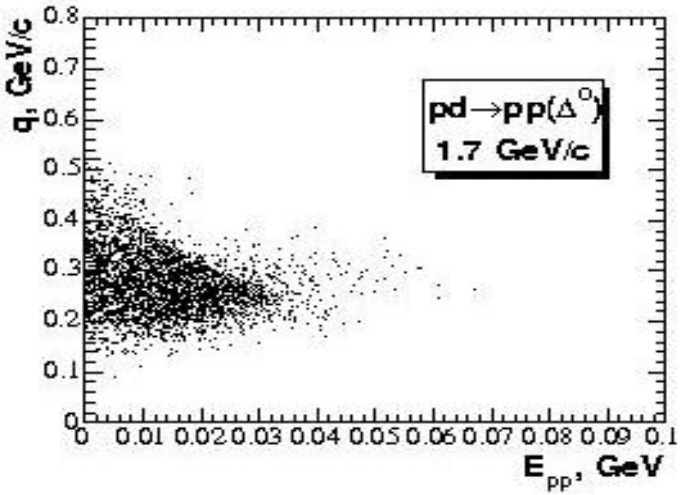
- Work in inverse kinematics and detect the two low energy protons from $pd \rightarrow n\,\{pp\}_S$ in the tracking telescopes. [Dieter Oellers]
- Extends the maximum beam energy per nucleon from ≈1.1 GeV up to ≈3 GeV.
- Also extends considerably the range in momentum transfer (< 120 MeV/c with d beam) since ANKE not needed.
- Allows one to measure $pd \rightarrow \Delta^0\{pp\}_S$ with $\Delta^0 \rightarrow \pi^- p$ being detected in ANKE.

Acceptance simulations of charge-exchange: two protons in the SST





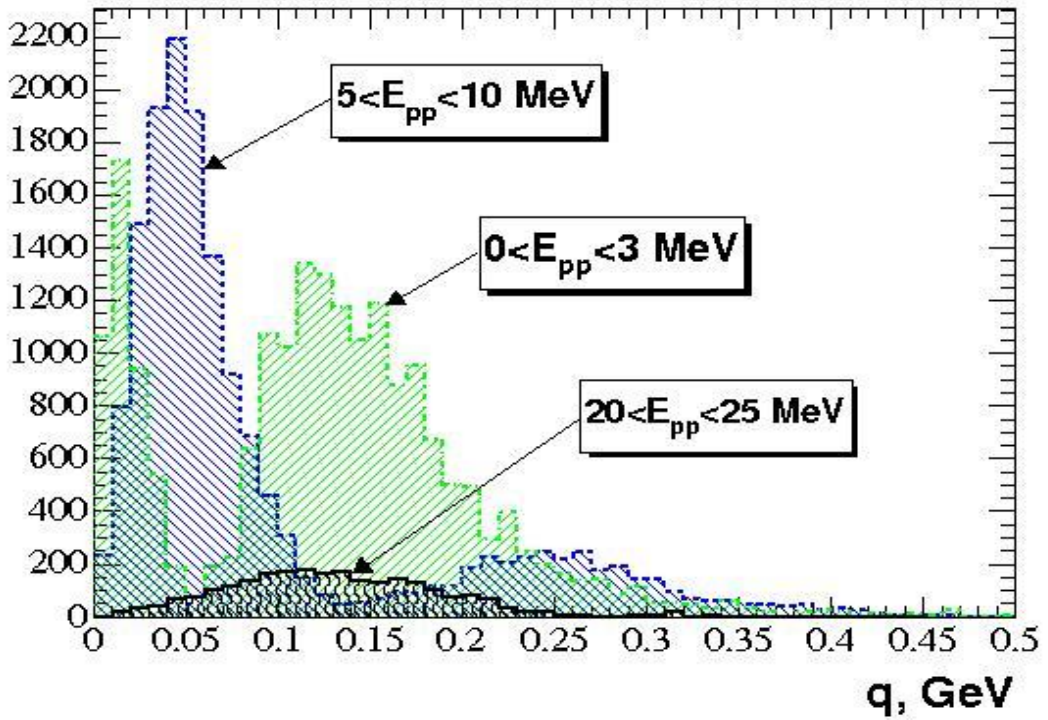




Acceptance simulation for $pd \rightarrow n\{pp\}$

There is possibly a hole between cases where the two protons go into the same or different telescopes

Reaction can be measured in parallel when a polarised D_2 target is being used. Huge statistics!



Predicted acceptance at 3 GeV/c

The $dp \rightarrow \{pn\}_S\, p$ Reaction

- More theoretical analysis needed since $\{pn\}_S$ is a mixture of $T=0$ & $T=1$ states.
- At small momentum transfers much of the final $\{pn\}_S$ flux is swallowed up by the deuteron final state and comes out as dp elastic scattering.
- ($\Delta I=1$, $\Delta S=1$) transitions play a very important role here as well as for deuteron charge exchange.
- The reaction can be very well measured at ANKE.

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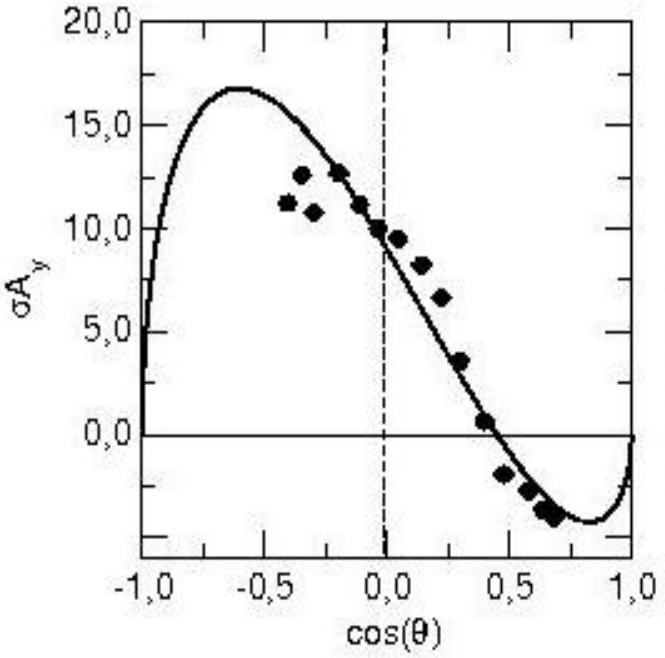
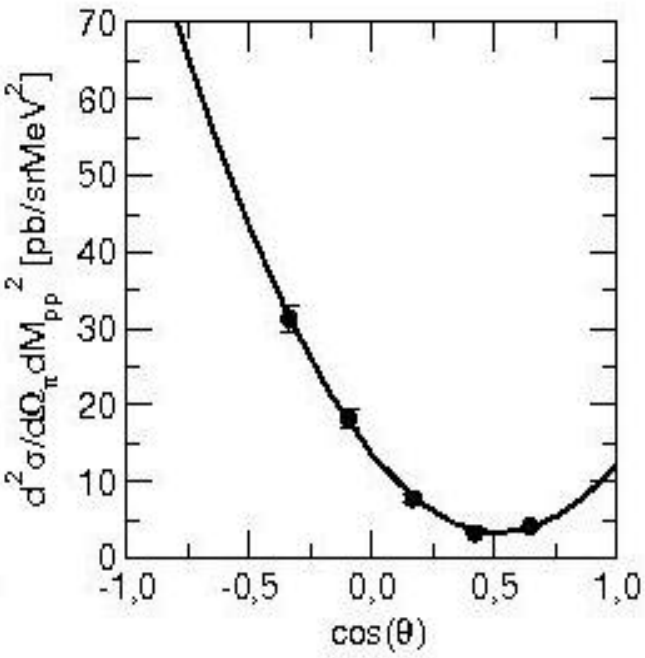
- The reaction can be very well measured at ANKE.
- But surely it must be worth 10% of the experimental budget to extract the PHYSICS from such experiments.

Pion Production in NN Collisions

One very useful ingredient in chiral perturbation theory is the $4N\pi$ contact term, which can be measured in pion production if we can isolate the transition from the *T=0* *np* to the *T=1* $\{pp\}_S$ system.
Only terms up to k_π^2 needed to describe the TRIUMF $np \rightarrow \{pp\}_S\ \pi^-$ data at T_n=353 MeV.

We must measure the analysing power and spin correlations in π^0 and π^- production leading to the $\{pp\}_S$ state.





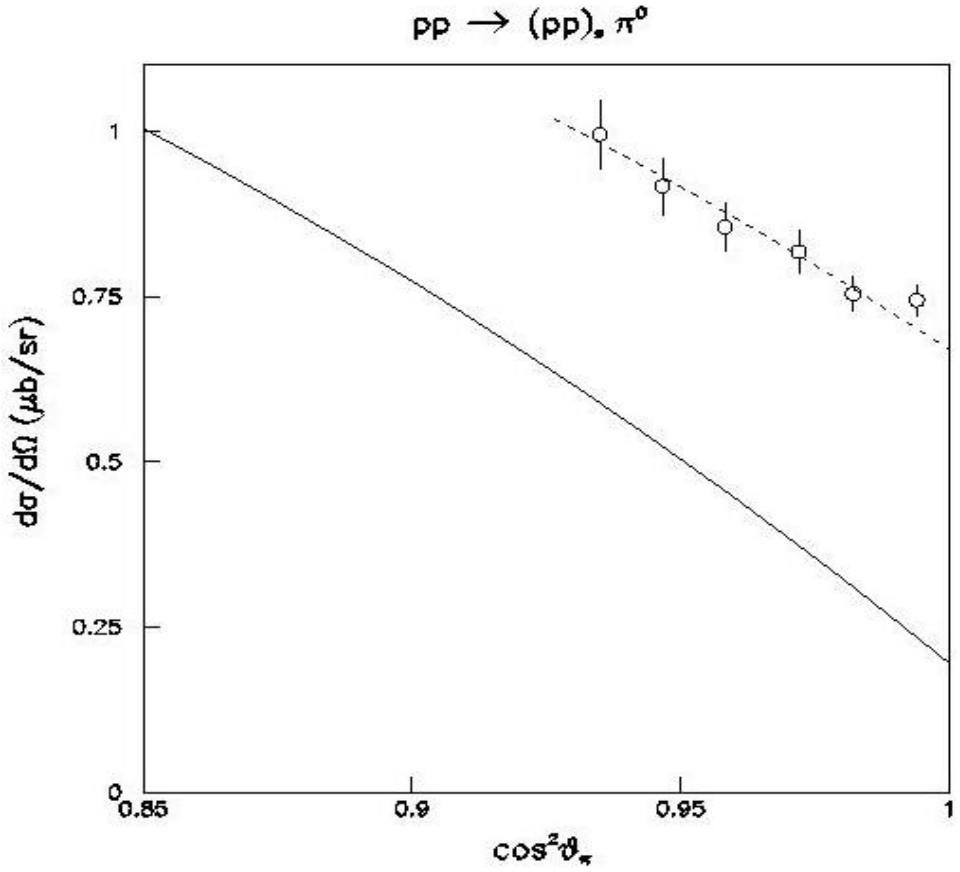
CHALLENGE: *Ayy* for $\vec{n}\,\vec{p} \rightarrow \{pp\}_S\ \pi^-$

The $pp \rightarrow \{pp\}_s \pi^0$ Reaction

Differential cross section measured for $E_{pp} < 3$ MeV at 800 MeV using ANKE. Varies very rapidly with angle, showing a forward dip.

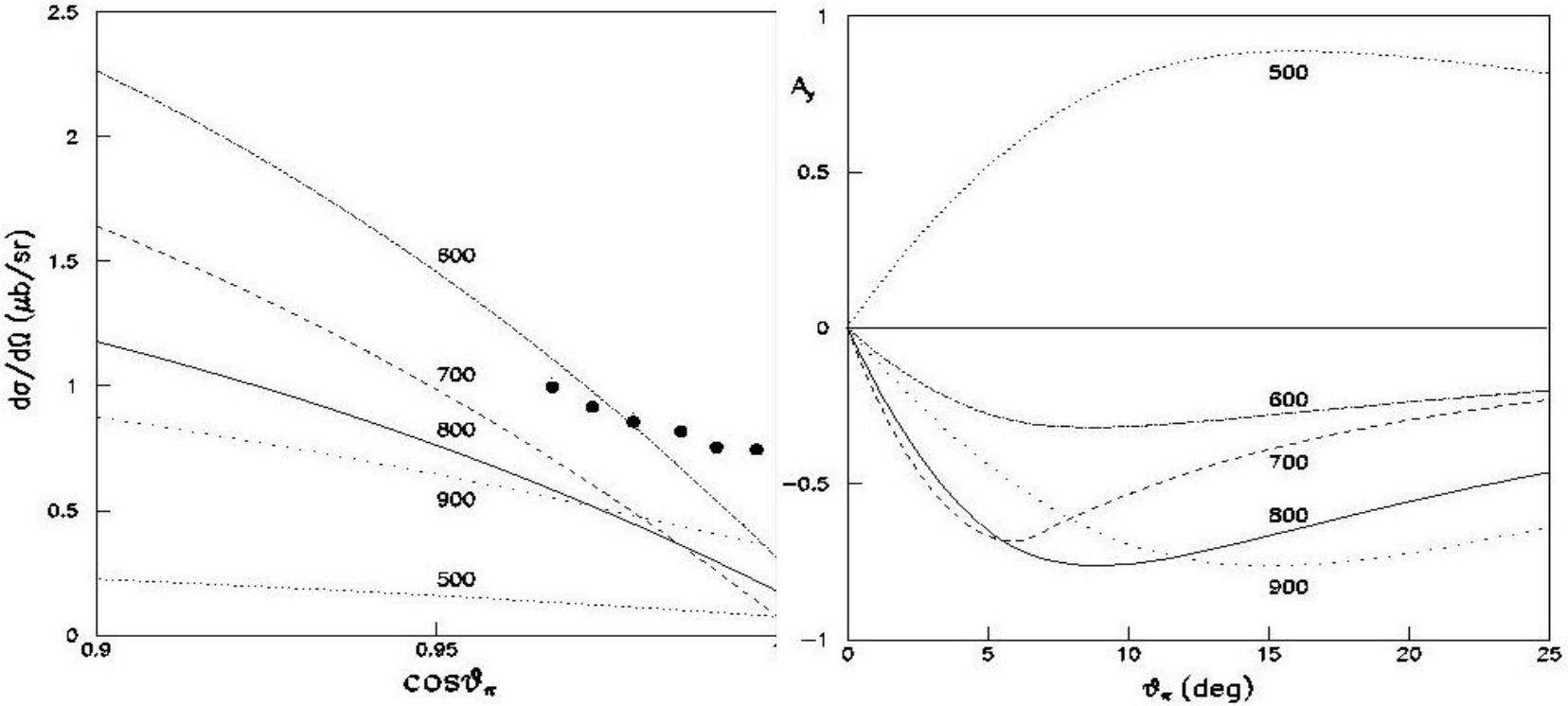
Only two invariant amplitudes and these must cancel near the forward direction.

Niskanen predicted such a behaviour, though his cancellation is at too small a value of $cos^2\theta_\pi$.



Rich Structure predicted for ANKE

In an $N\Delta$ approach the $N\Delta$ S-wave is forbidden for the $pp \to \{pp\}_S\pi^0$ reaction. The P-wave feeds both the pion s- and d-waves, leading to the possibility of cancellations. Violent fluctuations are expected (Niskanen *dixit*).



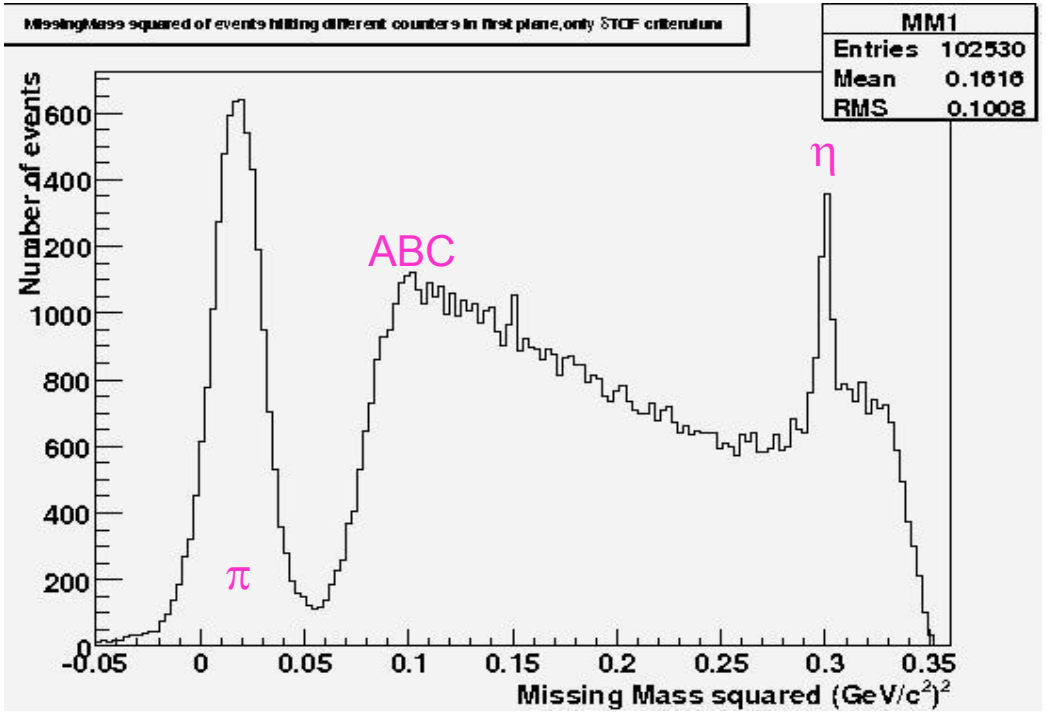
Heavier Non-Strange Meson Production

Spin correlations in $pp \rightarrow pp\,X^0$ give information on the reaction mechanism. Near threshold the decay of the X^0 may already contain much information. [Irakli Keshelashvili for the φ]

ANKE very well equipped to measure diprotons $\{pp\}_S$ at low excitation energy and this can give very clean spectra.

For η & π^0 production there are only two amplitudes. Spin correlations can split them.

The data show very clean two-pion production. The best ABC structure on the market!



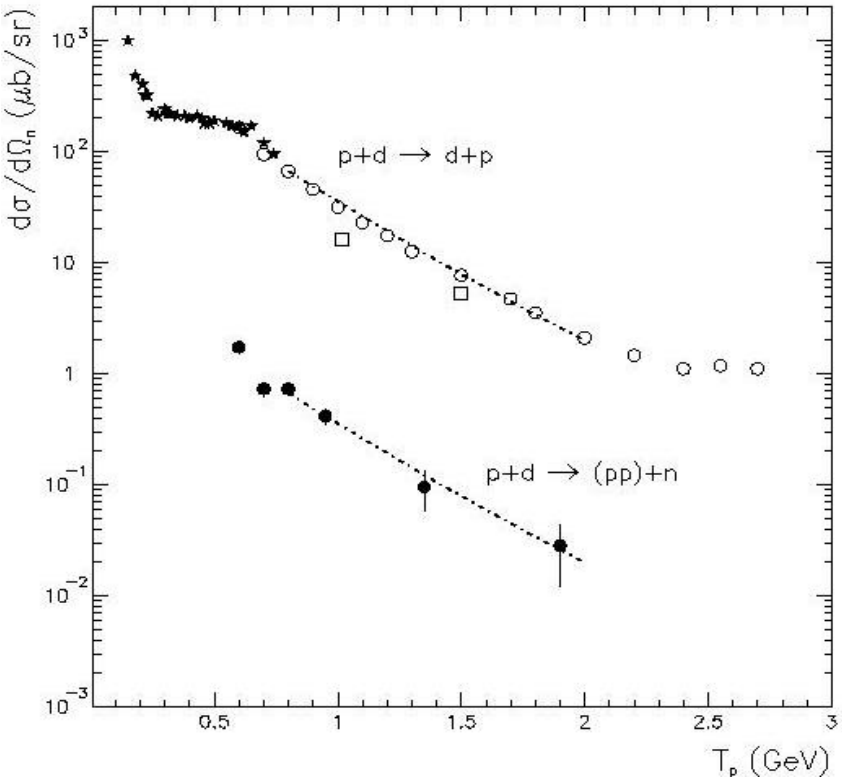
Large Momentum Transfer Reactions

$pd \rightarrow dp$ $pd \rightarrow \{pp\}_s n$

Cross sections and proton analysing power measured for the $pd \rightarrow \{pp\}_s n$ reaction at ANKE. [Andro Kacharava]

Deuteron tensor analysing power would contain far more information on the dynamics. Is it similar to backward elastic *dp* scattering? If so, it might be driven by $pd \rightarrow dp$ followed by a soft charge-exchange by the deuteron on the way out (*fsi*).

There are many other models!



The $pp \to K^+YN$ Reaction

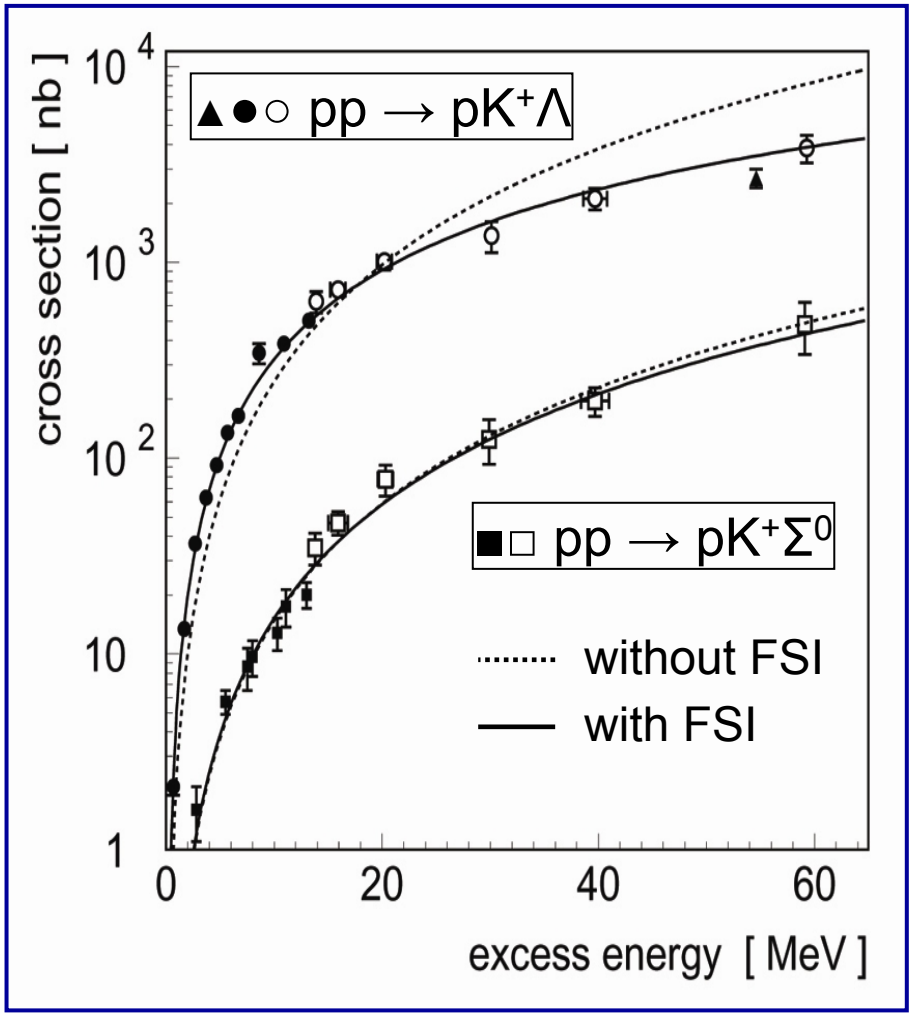
Strangeness production in $pp \to pK^+\Lambda$ shows clear evidence for the *YN fsi;* largely absent in $pp \to pK^+\Sigma^0$.

$\Rightarrow$

Extraction of a Λp scattering length is hampered by having contributions from spin-singlet and triplet.
Hypernuclear data suggest that the singlet interaction is more attractive.

$(1 - C_{NN})\ \sigma(pp \to pK^+\Lambda)$

COSY-11, TOF



leads only to spin-triplet final states for $\theta_K = 0^o$.

The $NN \to K^+\Lambda N$ Challenge

With a long target it might be “easier” to measure *pn* than *pp.*

LET US DREAM !

Due to the weak decay, the $\Lambda \to p\pi^-$ distribution defines P_Λ. Perhaps we can measure spin-transfer and spin-correlation in *pp* and *pn* interactions.

There are only three spin-isospin amplitudes $W_{l,s/t}$ near threshold. D_{NN} sensitive to differences in fsi and hence to ΛN scattering length differences.

$$I(pp \to K^+\Lambda p) = (|W_{1,s}|^2 + 2|W_{1,t}|^2)/4$$
$$I(pn \to K^+\Lambda n) = (|W_{1,s}|^2 + 2|W_{1,t}|2+ |W_{0,t}|^2)/16$$
$$I(pp \to K^+\Lambda p)\, C_{NN}(pp \to K+\Lambda p) = |W_{1,s}|^2/4$$
$$I(pn \to K^+\Lambda n)\, C_{NN}(pn \to K+\Lambda n) = (|W_{1,s}|^2 - |W_{0,t}|^2)/16$$
$$I(pp \to K^+\Lambda p)\, D_{NN}(pp \to K+\Lambda p) = -\,\mathrm{Re}\{W_{1,s}W_{1,t}^*\}/2$$
$$I(pn \to K^+\Lambda n)\, D_{NN}(pn \to K+\Lambda n) = -\,\mathrm{Re}\{(W_{1,s}+W_{0,t})W_{1,t}^*\}/8$$
$$I(pn \to K^+\Lambda n)\, D_{NN}(pn \to K+\Lambda n) = -\,\mathrm{Re}\{(W_{1,s}-W_{0,t})W_{1,t}^*\}/8$$

Priorité à droite !

(Priority on the left ?)

By which I mean that one (wo)man's priority might not be the first choice of somebody else.

I have a vested interest in $dp \rightarrow {}^3\mathrm{He}\,\eta$ [Timo Mersmann] especially with a polarised beam (and possibly target) but I could not sell a four-year programme at COSY on it.

- Good experiments can always struggle to the front.
- Like in a bubble chamber, many experiments will be carried out simultaneously if the trigger conditions are chosen judiciously.

NOW IT IS TIME FOR THE YOUNGSTERS TO DISPLAY THEIR WARES !

LET US HOPE THAT WE GET MORE THAN FOOD FOR THOUGHT !

FOLLOWING OUR 2004 EXPERIENCES I HAVE NO WORRIES IN THIS REGARD. ========〉

PHYSICS PROGRAMME PRESENTED TODAY IS SHORT-TERM FUTURE; FOR MY 75th BIRTHDAY I WANT TO BE WORKING WITH **PAX** !

კოლიბ ვილკინი