Isospin breaking a_0-f_0 mixing

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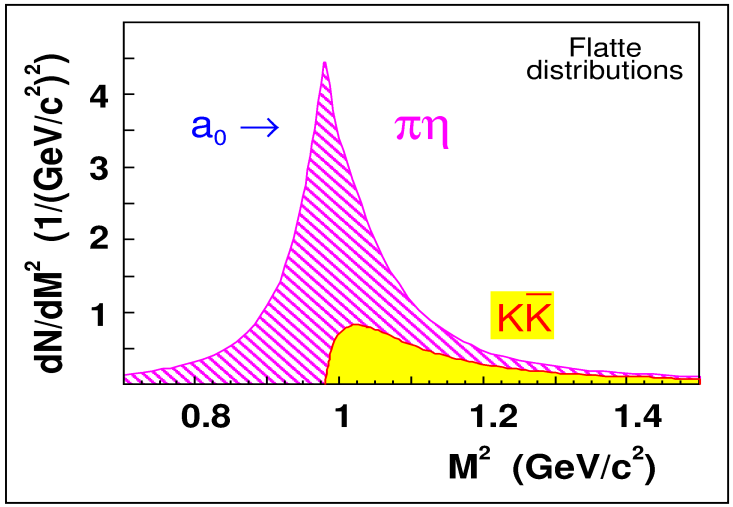
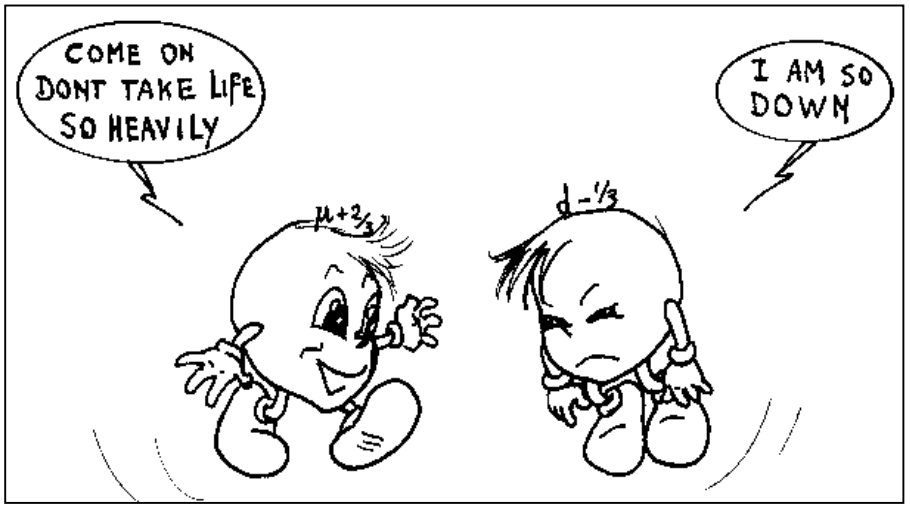
... a tool to investigate (not only!) the structure of the light scalar mesons





Markus Büscher
Forschungszentrum Jülich
Germany

The light scalar resonances

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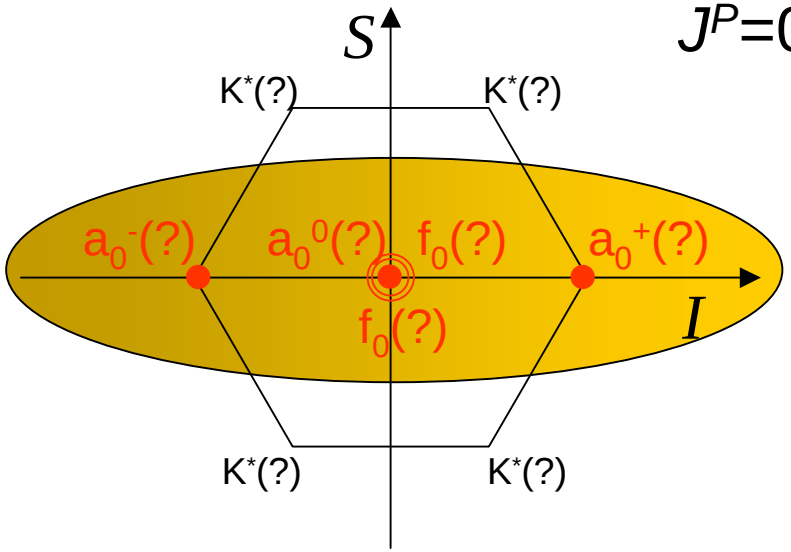
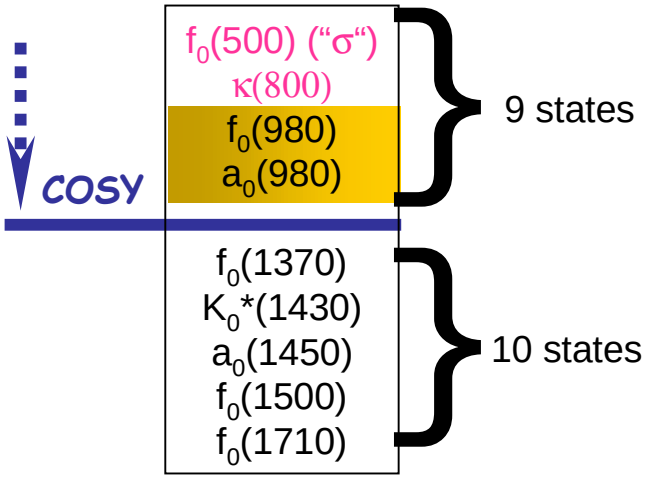
Nonet of light scalar mesons



Possible candidates



Nature of these states??

„Genuine" $q\bar{q}$
4-quark states
$K\bar{K}$ molecules

Observables?

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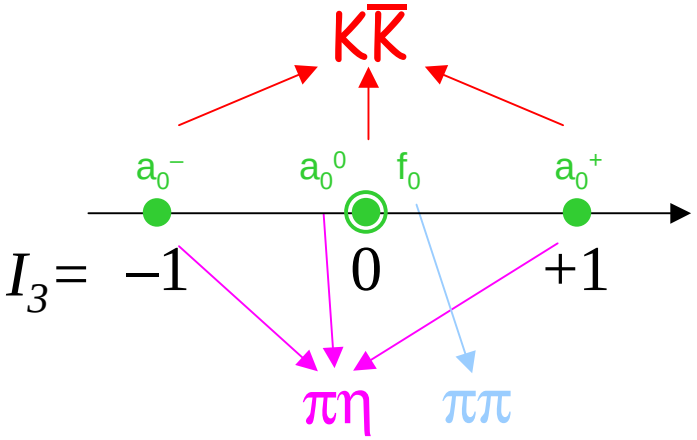
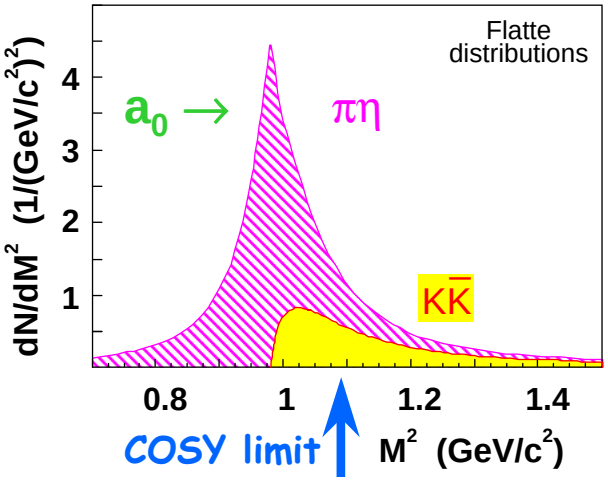


m = (984.7±1.2) MeV/c²	(“average“)	a_0
Γ = (50...100) MeV/c²	(“estimate“)	
Γ(KK/πη) = (0.183±0.024)	(“seen“/“dominant“)	
m = (980±10) MeV/c²	(“estimate“)	f_0
Γ = (40...100) MeV/c²	(“estimate“)	
Γ(KK/ππ) = ...	(“seen“/“dominant“)	



Observables at COSY (yet unknown):

- Mass distributions
- Branching ratios to KK and πη/ππ
- (Differential) production cross sections
- Isospin ratios (e.g. pn vs. pp reactions)
- a_0-f_0 mixing
- Polarization observables

The Accelerator: COSY-Jülich

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COSY (Cooler Synchroton) at FZ-Jülich:

- (polarized) p & d beams
- phase-space cooling
  - electron & stochasting cooling
- p = 0.30 – 3.70 GeV/c
  - $pp \rightarrow pp\ X$ ($m_X \leq 1.1\ GeV/c^2$)
  - $dd \rightarrow \alpha\ X$ ($m_X \leq 1.03\ GeV/c^2$)
  - $pp \rightarrow pK^+ Y^*$ ($m_{Y^*} \leq 1.5\ GeV/c^2$)
- internal & extracted beams

The detectors: ANKE & WASA

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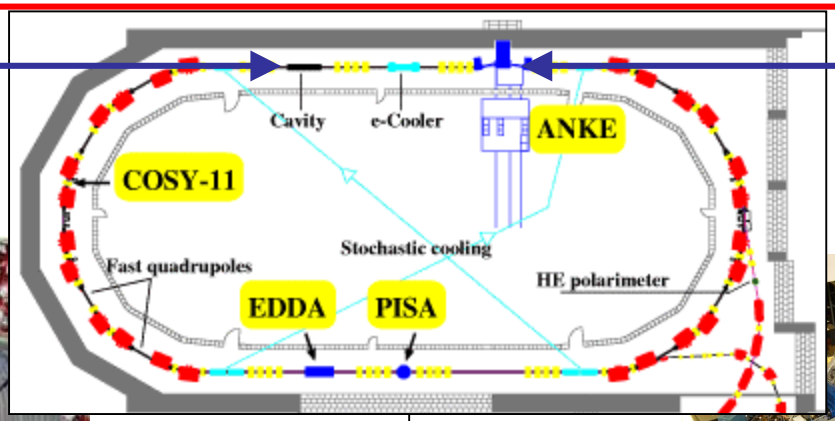
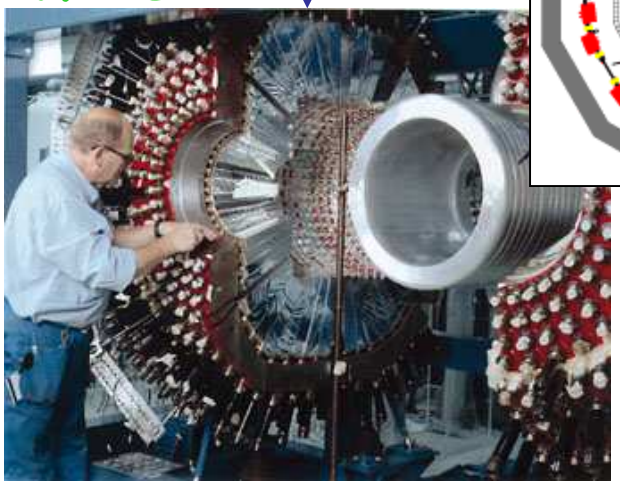
Ready for experiments in 2006

In operation since 1998

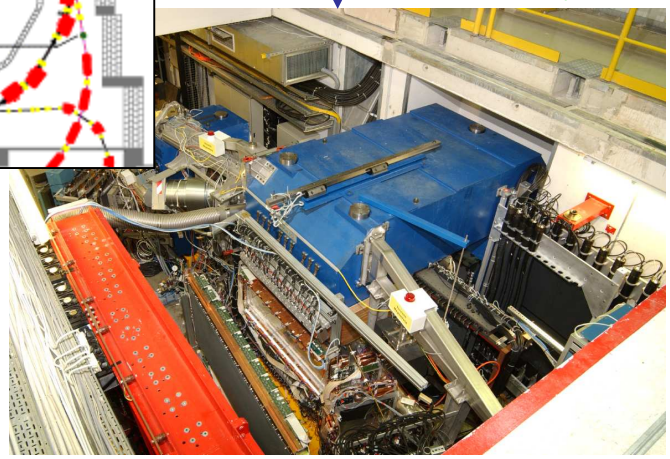


WASA



-currently at CELSIUS (Uppsala)
-nearly 4π coverage
-charged and neutral particle i.d.
-frozen pellet target ($\mathcal{L}$ ~ few·10^{32} $cm^{-2}s^{-1}$)

ANKE



-forward spectrometer (small acceptance)
-optimized for K^+/K^- detection
-cluster jet target ($\mathcal{L}$ ~ few·10^{31} $cm^{-2}s^{-1}$)

The $a_0/f_0(980)$ at COSY

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Reaction	Where?	Result	Goal
$pp \to pp\ K^+K^-$	COSY-11 ANKE	a_0^0/f_0 contribution??	
$pp \to d\ K^+\bar{K}^0$ $\to d\ \pi^+\eta$	ANKE WASA	a_0^+ channel dominates	First „simple" experiment for WASA (≥2006)
$pn \to d\ K^+K^-$ $\to d\ \pi^0\eta$	ANKE WASA	(Feb. 2004)	Angular asymmetries a_0-f_0 mixing
$pd \to {}^3He\ K^+K^-$ $\to {}^3H\ K^+\bar{K}^0$	MOMO	a_0^0/f_0 contribution??	
$dd \to {}^4He\ K^+K^-$ $\to {}^4He\ \pi^0\eta$	ANKE WASA	Winter '04/05?	Isospin violation a_0-f_0 mixing

p(2.65 GeV)p→dK⁺$\bar{K}^0$ at ANKE

V.Kleber et al., PRL **91**, 172304 (2003)

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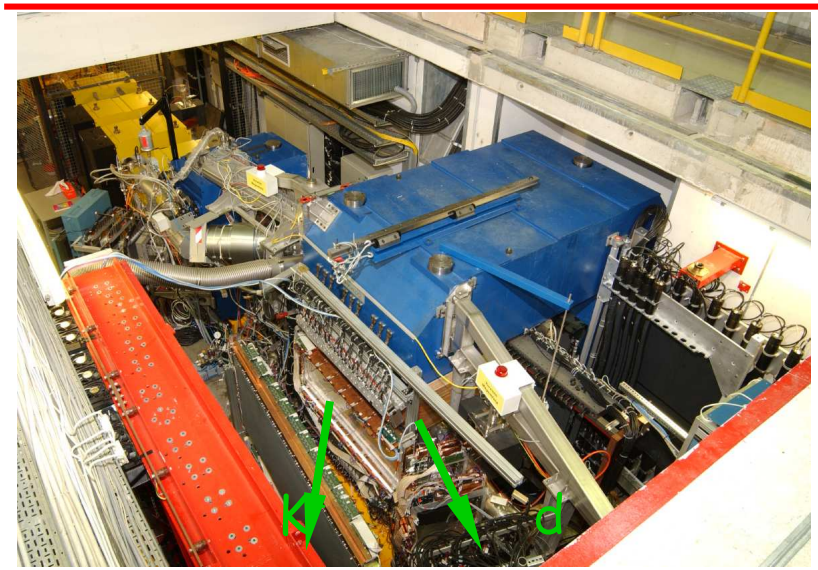
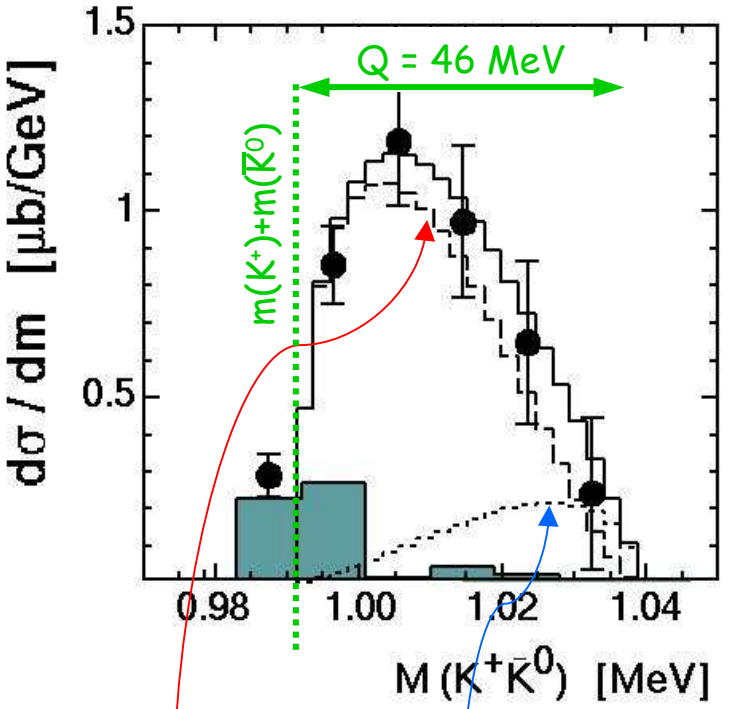


- K⁺d coincidence measurement
- Identification of pp→dK⁺X events
  via TOF, ΔE and particle momenta
- Identification of pp→dK⁺$\bar{K}^0$ events
  via dK⁺ missing mass

$$\sigma_{tot}(pp \to dK^+\bar{K}^0) = (38 \pm 2_{stat} \pm 14_{sys})\ nb$$



Fit: 83%

$$[(K\bar{K})_S d]_P + [(K\bar{K})_P d]_S$$

☞ Dominance of a_0^+ channel

a_0-f_0 mixing in dd → ^{4}He $\pi^0\eta$

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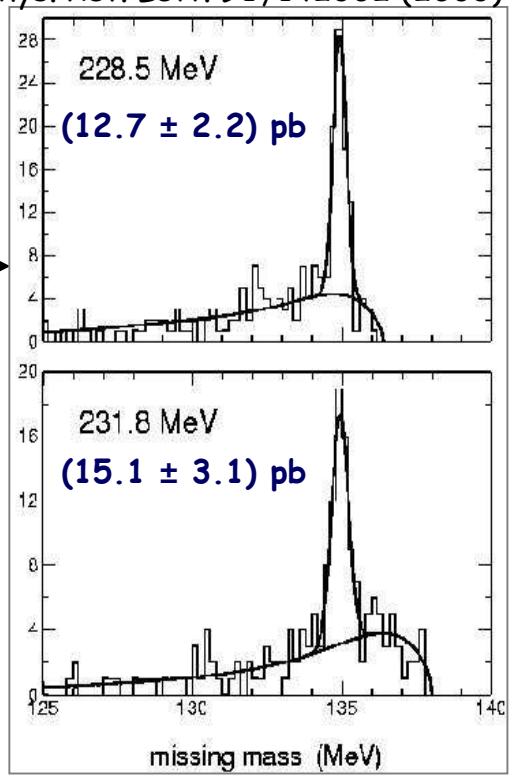
⇨ **Direct production of a_0^0 in dd → ^{4}He a_0^0 (→ $\pi^0\eta$) is forbidden if isospin is conserved**

⇨ **Dominant channel**

dd → ^{4}He $f_0(I=0)$ → ^{4}He $a_0^0(I=1)$ → ^{4}He $\pi^0\eta$??

⇨ **Similar to dd → ^{4}He π^0 experiment @IUCF**

E.J.Stephenson et al.,
Phys. Rev. Lett. **91**, 142302 (2003)



⇨ **Strength of a_0-f_0 mixing unknown**

- Probably larger than π^0-η mixing
- Close & Kirk: mixing intensity = 8±3% (data from WA102) but critizised by Achasov & Kiselev, Oller

⇨ **dd → ^{4}HeX cross section unknown**

- Our estimate: σ(dd → ^{4}He a_0^0) ~ (50 ... 200) pb
- Pilot measurement: dd → ^{4}He a_0^0/f_0 → ^{4}He K^+K^- ANKE

$dd \to \alpha\,(\pi^0\eta)$ vs. $dd \to \alpha\,\pi^0$

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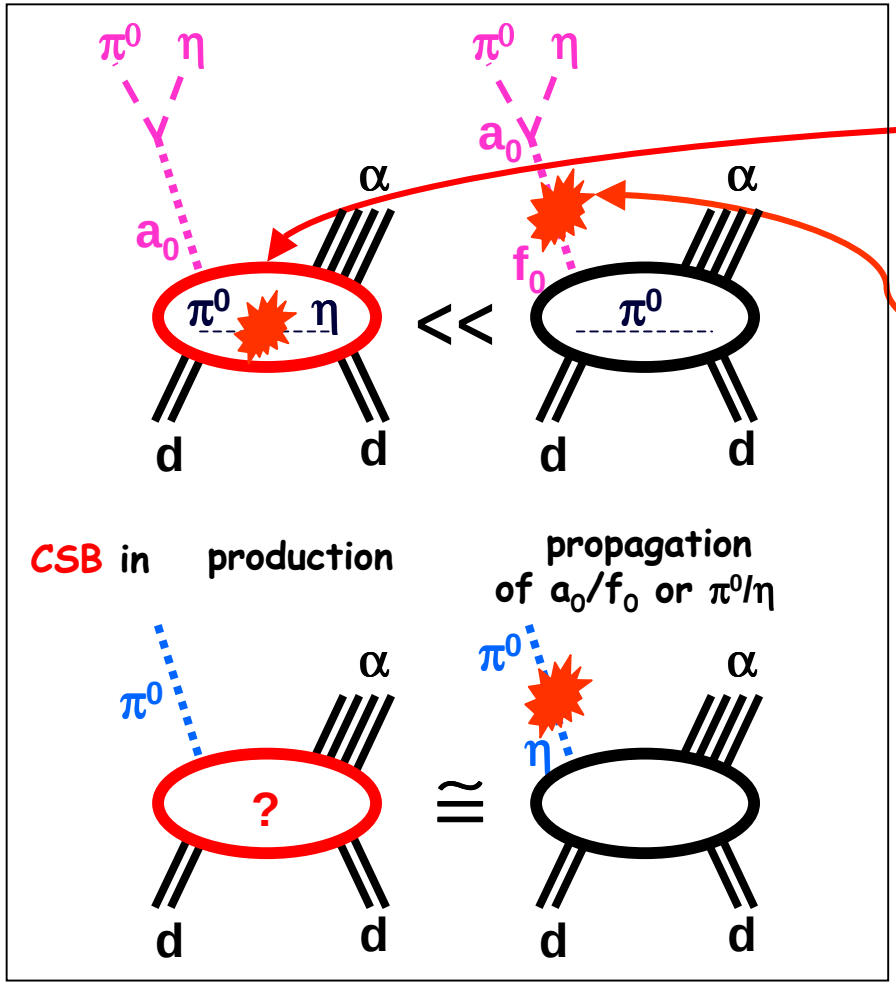

$$\propto \frac{1}{t} \approx \frac{1}{-m_N\, m_{a_0/f_0}}$$

$$\propto \frac{1}{m_{a_0/f_0}\,\Gamma_{a_0/f_0}}$$

$$\mathrm{CSB}\left(\frac{\text{Propagation}}{\text{Production}}\right) \approx \left(\frac{m_N}{\Gamma_{a_0/f_0}}\right) \approx 20$$

Details in: C.Hanhart, nucl-th/0306073

More a_0-f_0 mixing ...

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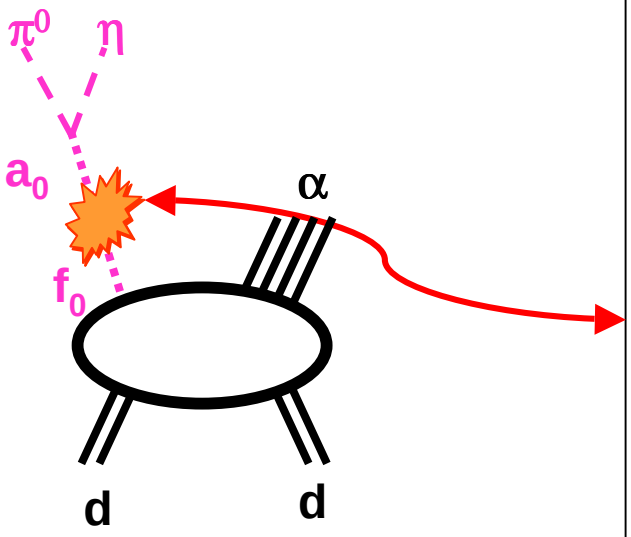
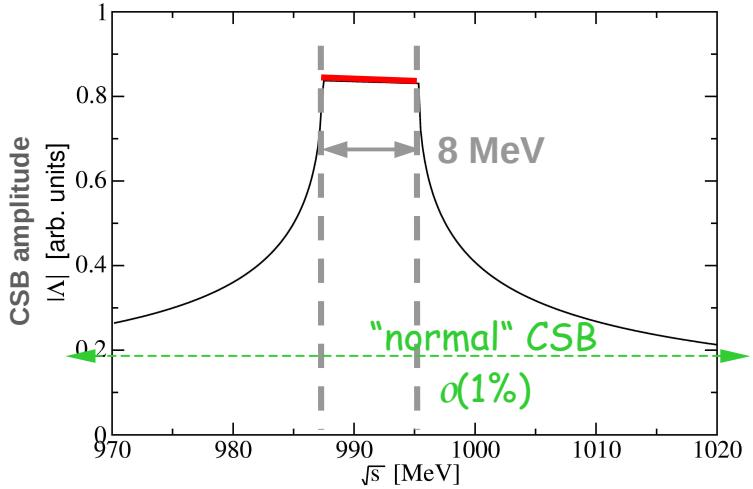


Further enhancement: "Kaon loops"

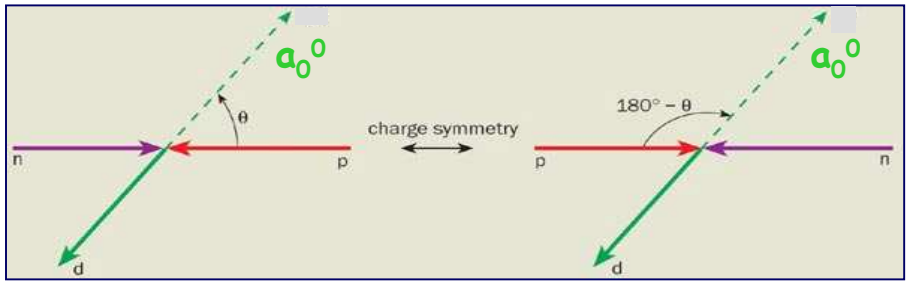
$$\Lambda = \; f_0 \; \overset{K^+}{\underset{K^-}{\bigcirc}} \; a_0 \; - \; f_0 \; \overset{K^0}{\underset{\bar{K}^0}{\bigcirc}} \; a_0$$



$$\Lambda \propto \sqrt{\frac{m_{K^+}^2 - m_{K^0}^2}{m_{K^+}^2 + m_{K^0}^2}} \approx \sqrt{\frac{m_u - m_d}{m_u + m_d}}$$

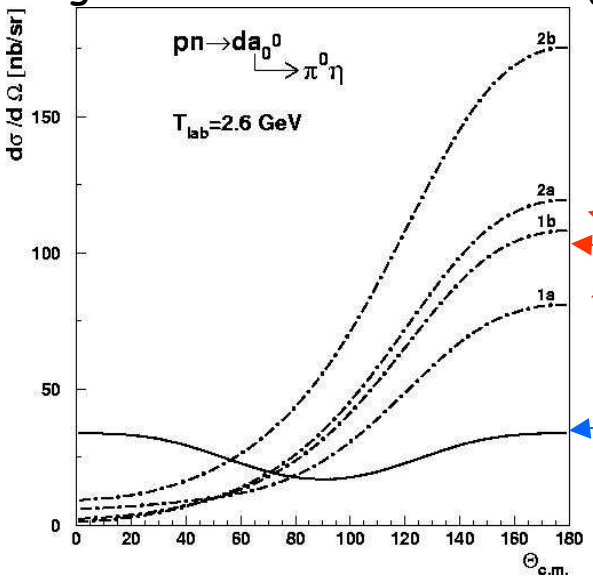
N.N.Achasov et al., PLB **88**, 367 (1979)

a_0/f_0 mixing in pn interactions



☛ Look, e.g., for angular asymmetries around 90° in pn → d+Meson reactions

angular distribution of the a_0



V.Grishina et al., PLB **521**, 217 (2001)

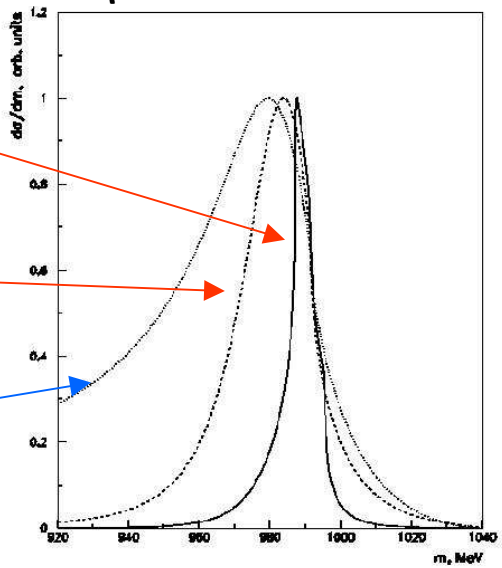
pn → pn(d) $\pi^0\eta$

Kaon loops

„direct"
a_0-f_0 or π-η
mixing

no mixing

πη mass distribution



V.Kudryavtsev et al., PRC **66**, 015207 (2002)

People ...

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INR, Moscow, Russia

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PNPI, Gatchina, Russia

and the ANKE collaboration

Experiment
Theory

→ http:www.fz-juelich.de/ikp/anke

I.d. of $pp \to dK^+\bar{K}^0$ events @ ANKE

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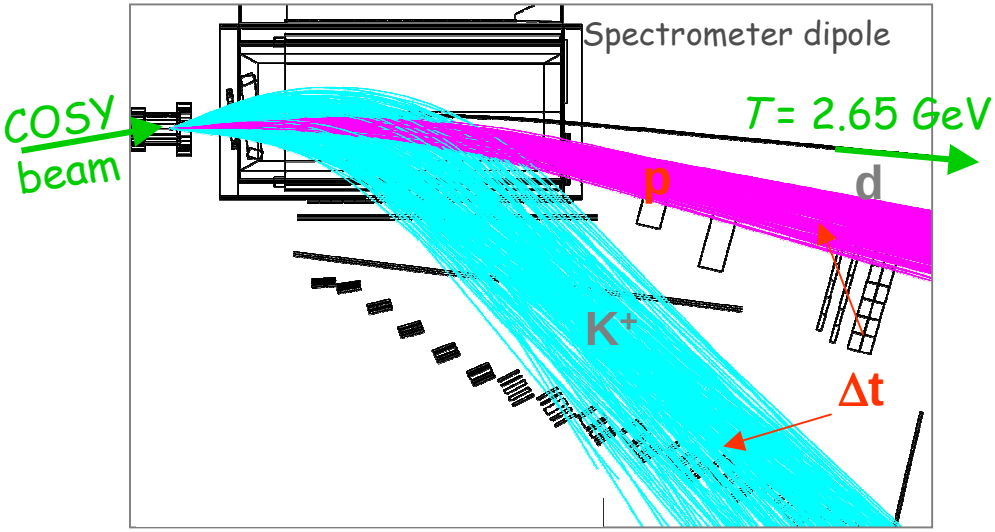
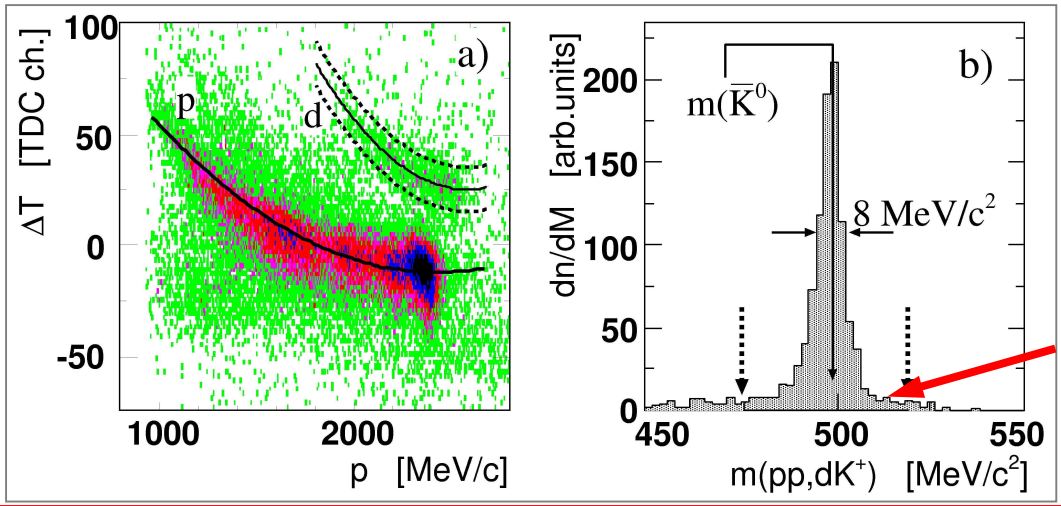


- K^+-d coincidence measurement
- Identification of $pp \to dK^+X$ events via TOF, ΔE and particle momenta
- Identification of $pp \to dK^+\bar{K}^0$ events via dK^+ missing mass



Background < 10%

First Results on the a_0^+

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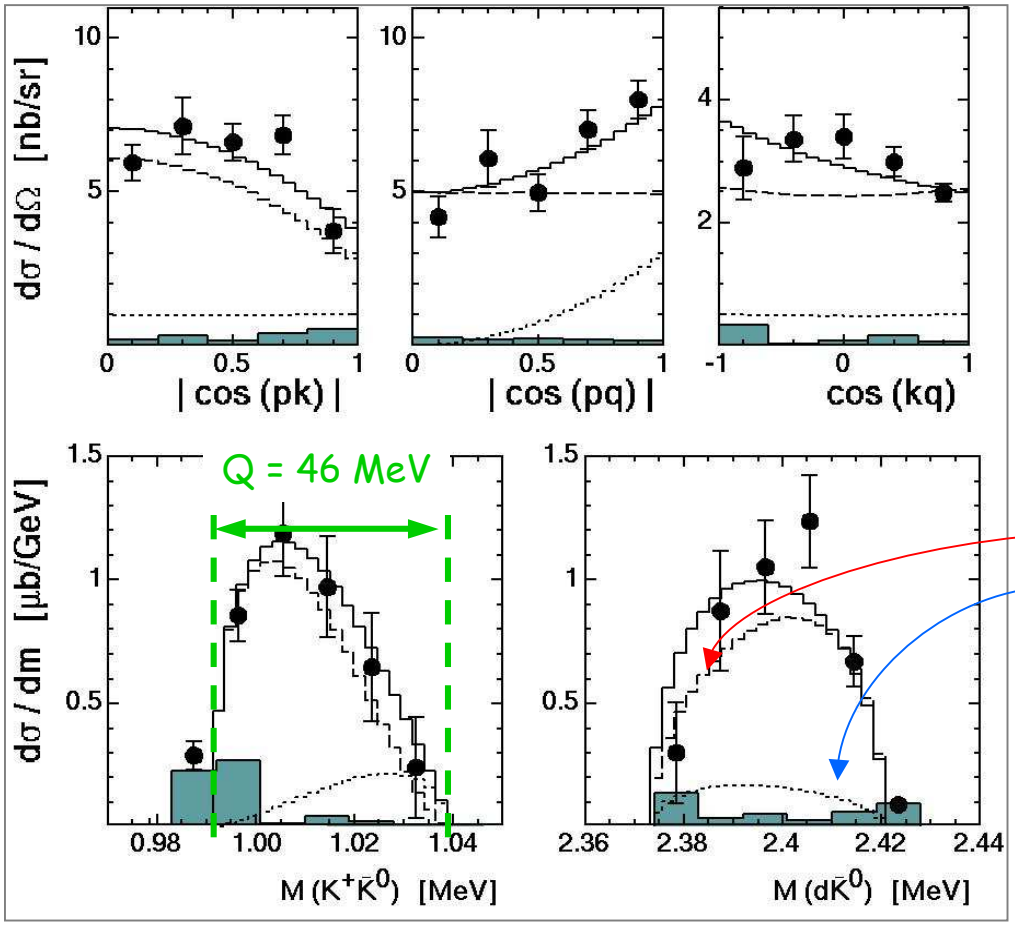
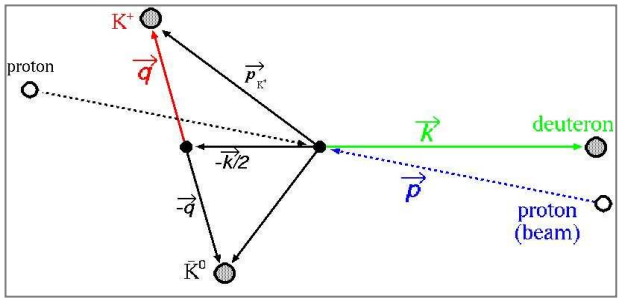
p p → d $K^+\bar{K}^0$ (ANKE)





Fit:
$[(K\bar{K})_P d]_S + [(K\bar{K})_S d]_P$

$\sigma(pp \to da_0^+ \to dK^+\bar{K}^0) = 83\% \cdot \sigma_{tot}$

$\sigma_{tot}(pp \to dK^+\bar{K}^0) = (38 \pm 2_{stat} \pm 14_{sys})$ nb

V.Kleber et al., PRL **91**, 172304 (2003)
nucl-ex/0304020

p(2.65 GeV)n→dK⁺K⁻ at ANKE

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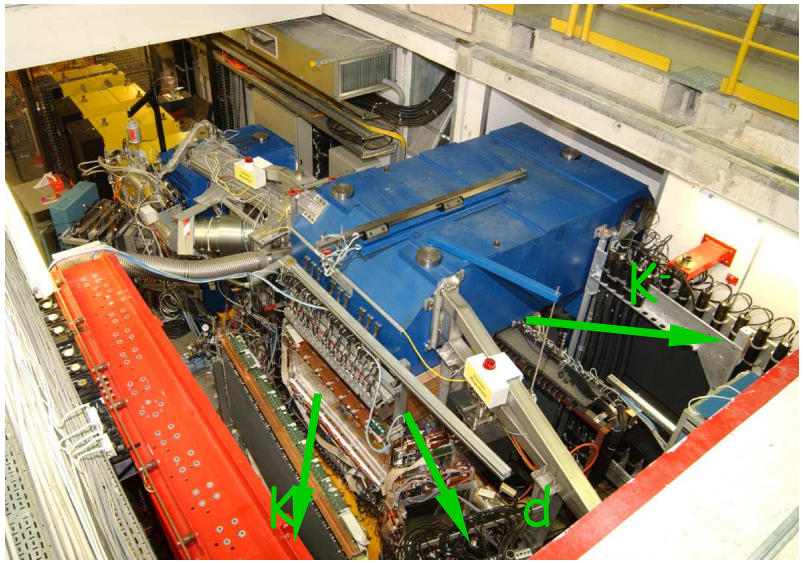
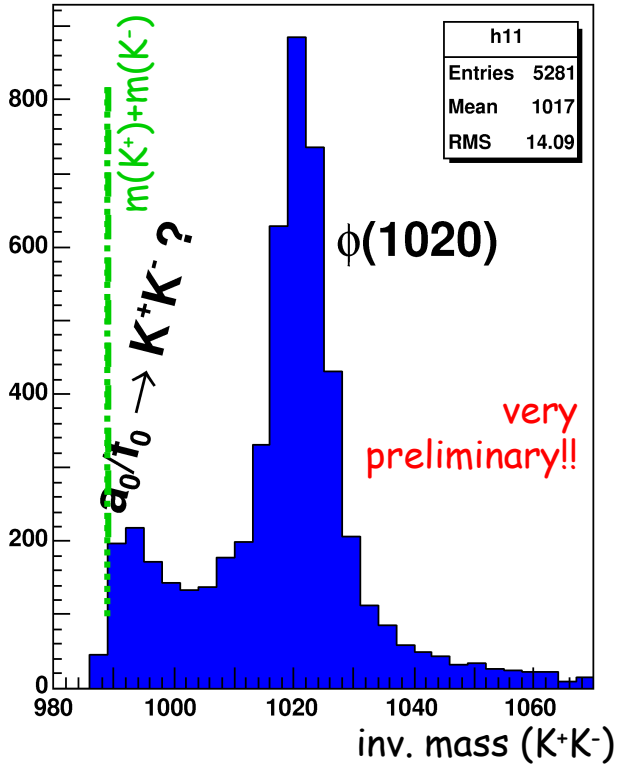


- D_2 as an effective neutron target
- $K^+ K^-$ d coincidence measurement
- unobserved spectator proton



☞ First data on φ-meson production on neutrons

☞ Narrow a_0^0/f_0 signal at small K^+K^- masses??