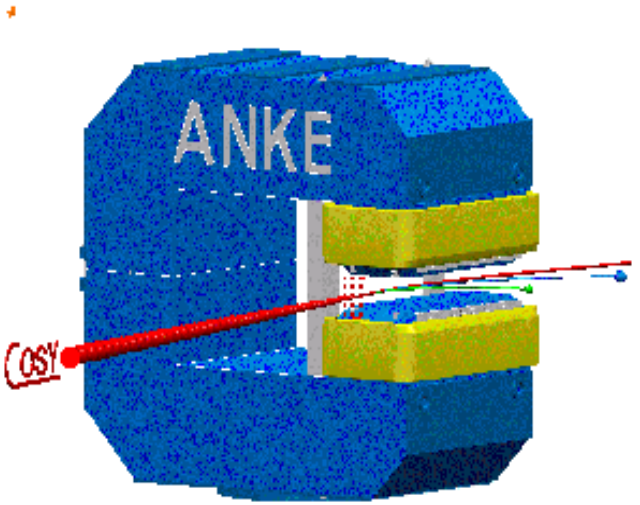
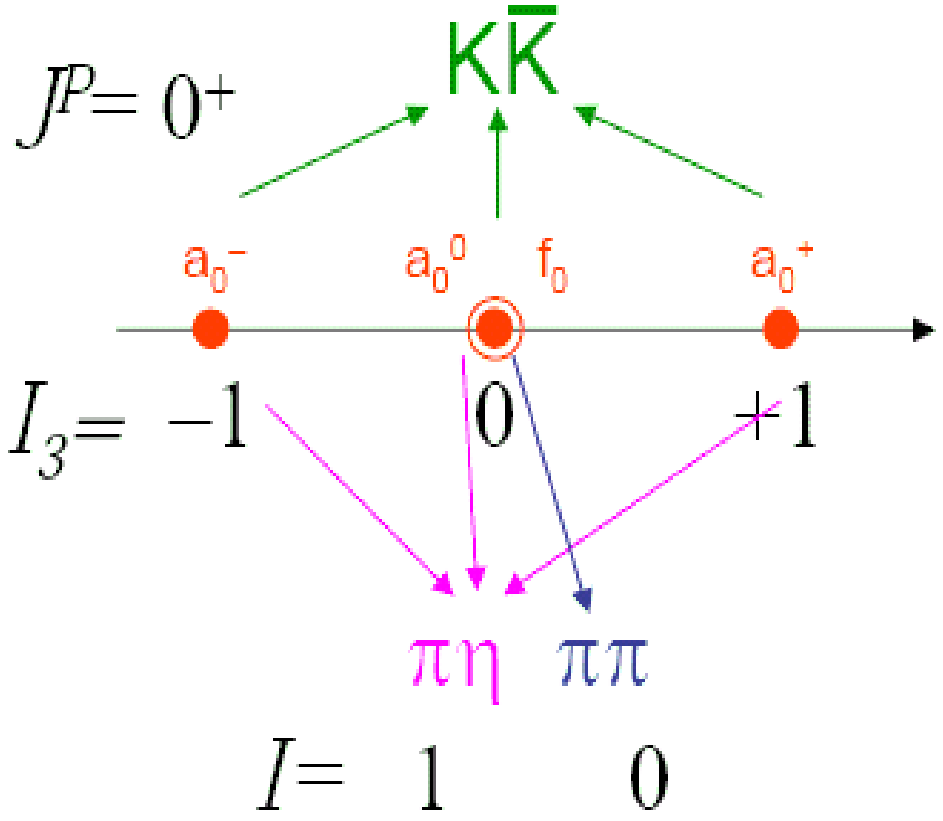
Status of the data analysis on $K\bar{K}$ pair production

Alexey Dzyuba
(PNPI, Gatchina)
for the ANKE collaboration



- Scalar mesons $a_0/f_0(980)$
- Scientific program
- ANKE spectrometer
- $pp \rightarrow dK^+\bar{K}^0$
- $pn \rightarrow dK^+K^-$
- $dd \rightarrow {}^4HeK^+K^-$

Scalar mesons $a_0/f_0(980)$



Masses around $K\bar{K}$ threshold

Widths ~ 50 ... 100 MeV

Unknown nature:

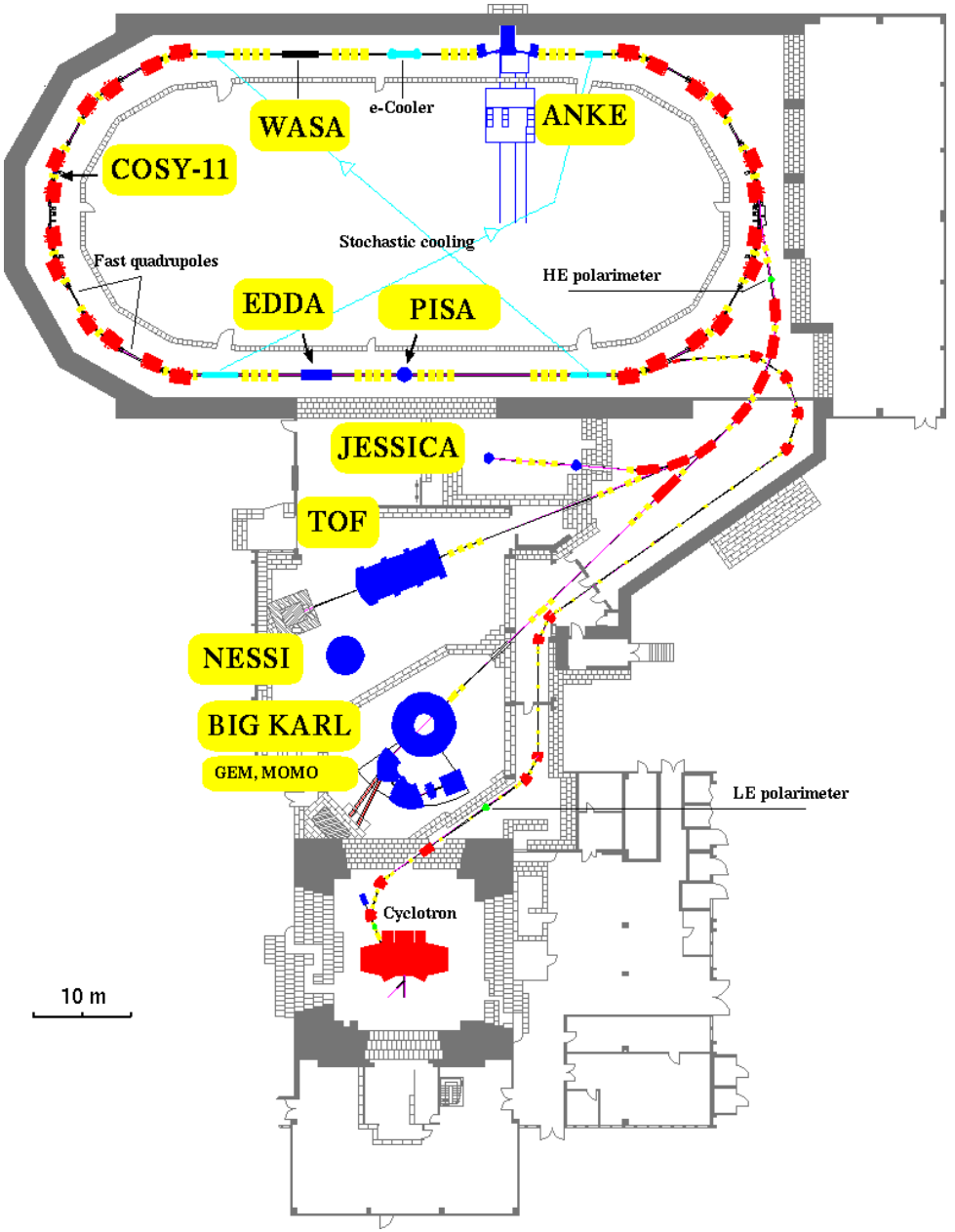
- $q\bar{q}$-state ('true' meson)
- tetraquark
- $K\bar{K}$-molecule

COoler SYnchrotron

- Protons and deuterons
- Polarized and unpolarized
- Momentum up to 3700 MeV/c
- Internal and external experiments

ANKE – best kaons identification

WASA – neutral channels



$a_0/f_0(980)$ production at ANKE and WASA

Reaction	Production	Experiment	T_{beam}, GeV	Status
$pp \rightarrow d\ K^+\bar{K}^0$	a_0^+ (I_{in}=1)	ANKE	2.65 2.83	**V.Kleber et. at. PRL 91 (2003) 377** Paper accepted

$a_0/f_0(980)$ production at ANKE and WASA

Reaction	Production	Experiment	T_{beam}, GeV	Status
$pp \to d\ K^+\bar{K}^0$	a_0^+ (I_{in}=1)	ANKE	2.65 2.83	**V.Kleber et. at. PRL 91 (2003) 377** Paper accepted
$pn \to d\ K^+K^-$ $pp \to pp\ K^+K^-$	f_0/a_0^0 (I_{in}=0,1)	ANKE	2.65	analysis in progress

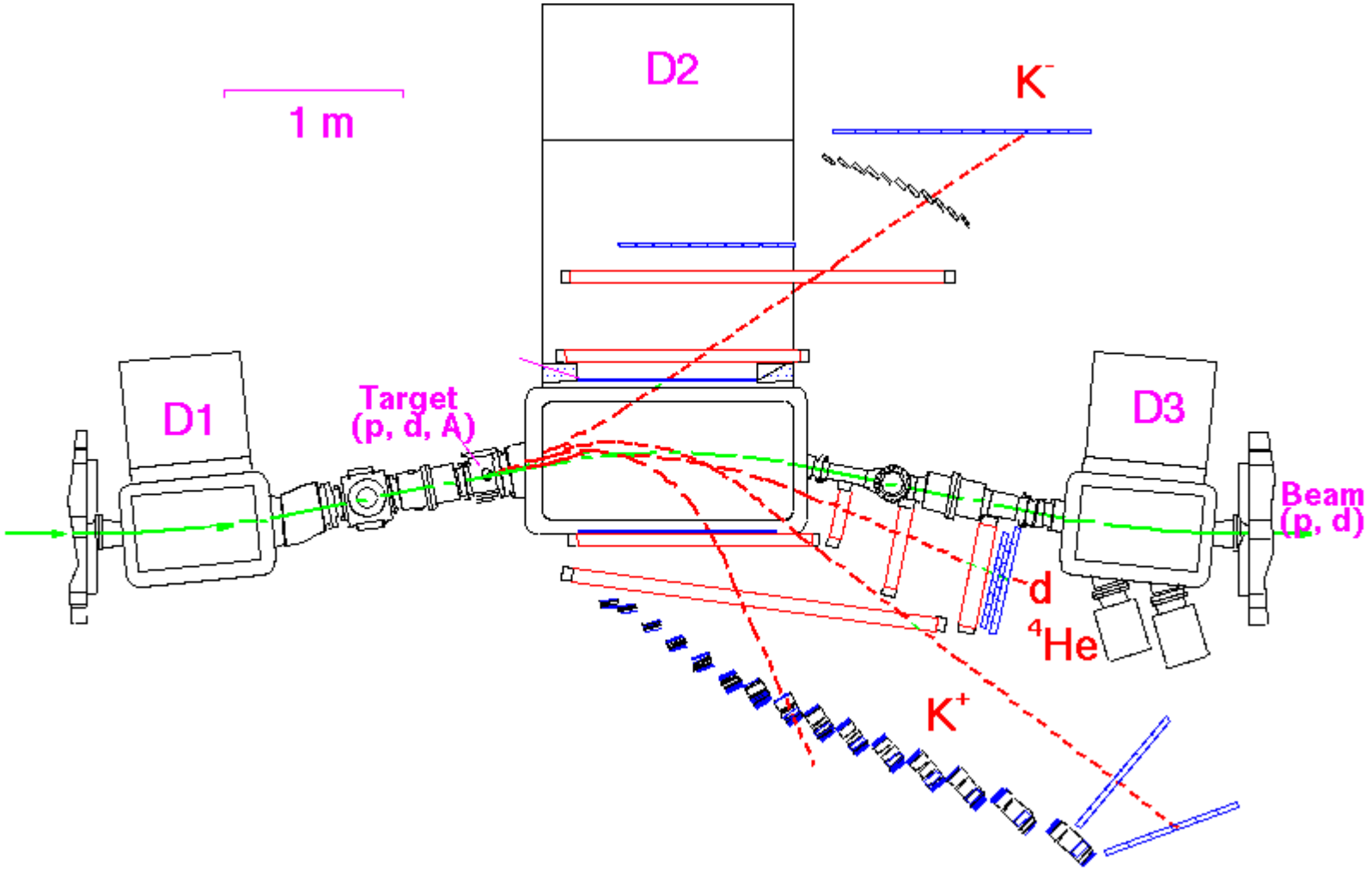
$a_0/f_0(980)$ production at ANKE and WASA

Reaction	Production	Experiment	T_{beam}, GeV	Status
$pp \to d\ K^+\bar{K}^0$	a_0^+ (I_{in}=1)	ANKE	2.65 2.83	**V.Kleber et. at. PRL 91 (2003) 377** Paper accepted
$pn \to d\ K^+K^-$ $pp \to pp\ K^+K^-$	f_0/a_0^0 (I_{in}=0,1)	ANKE	2.65	analysis in progress
$dd \to {}^4He\ K^+K^-$	f_0 (I_{in}=0)	ANKE	2.28	analysis started

$a_0/f_0(980)$ production at ANKE and WASA

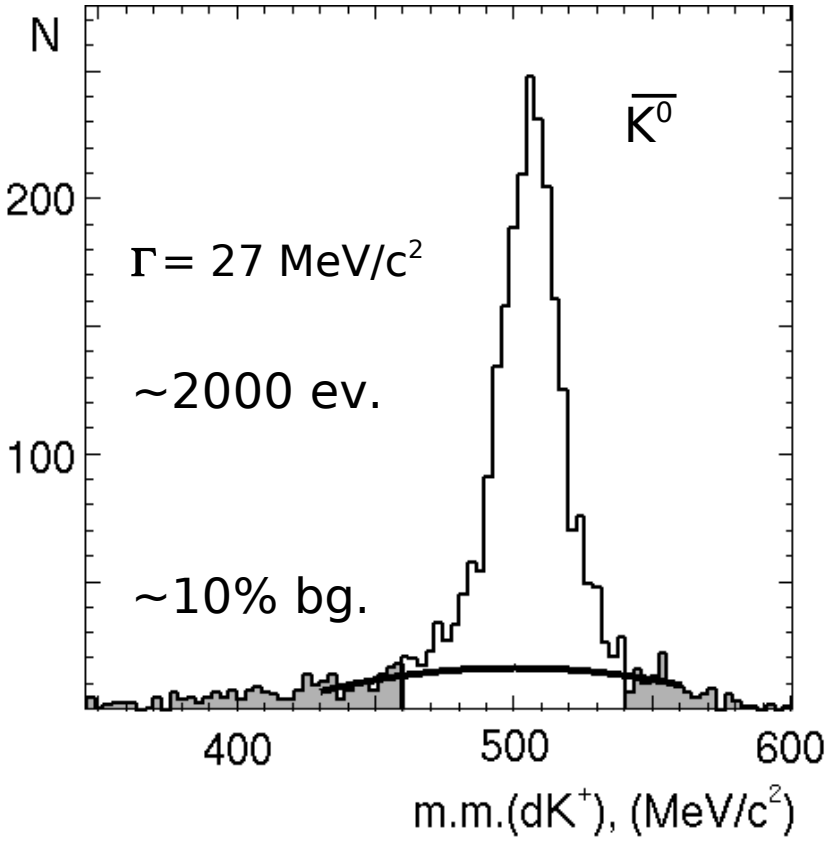
Reaction	Production	Experiment	T_{beam}, GeV	Status
$pp \to d\ K^+\bar{K}^0$	a_0^+ ($I_{in}=1$)	ANKE	2.65 2.83	**V.Kleber et. at. PRL 91 (2003) 377** Paper accepted
$pn \to d\ K^+K^-$ $pp \to pp\ K^+K^-$	f_0/a_0^0 ($I_{in}=0,1$)	ANKE	2.65	analysis in progress
$dd \to {}^4He\ K^+K^-$	f_0 ($I_{in}=0$)	ANKE	2.28	analysis started
$\to {}^4He\ \pi^0\eta$	a_0^0 ($I_{in}=0$, $I_{fin}=1$)	WASA	2.28	≥2007

Apparatus for Nucleonic and Kaon Ejectiles



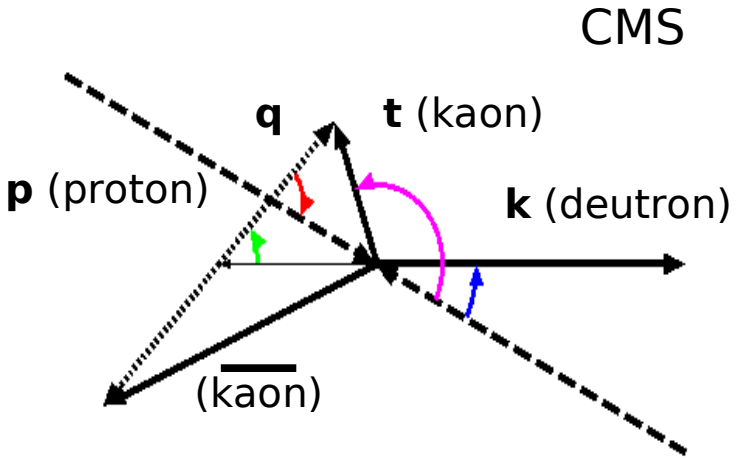
$$pp \rightarrow dK^{+}\bar{K}^{0}$$

$pp \rightarrow dK^+\overline{K}^0$ (T_p=2.83 GeV)



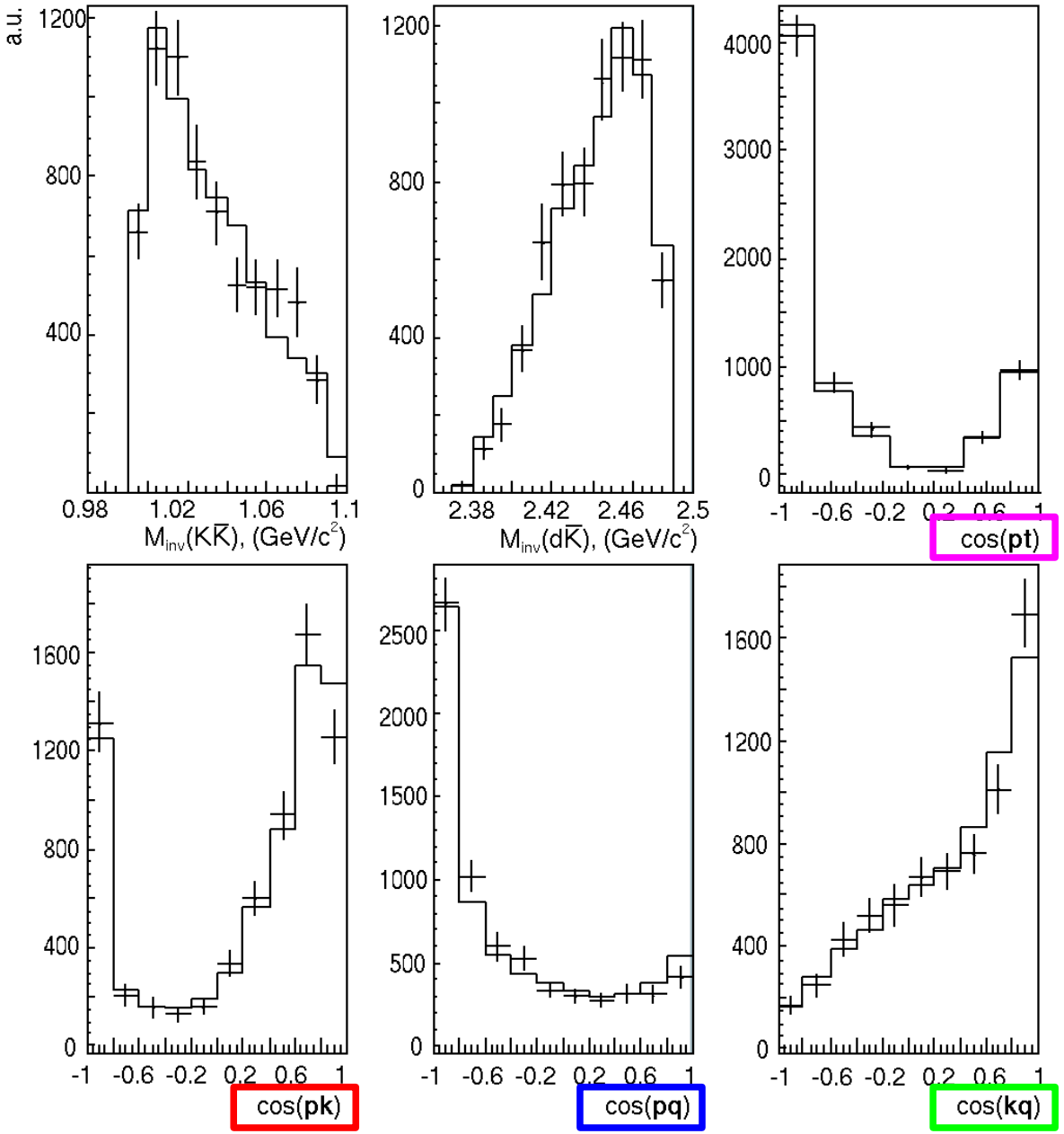
- dK^+ coincidence measurements
- Identification via TOF, ΔE and momenta
- $\overline{K}^0$ via missing mass spectrum
- Background subtraction
- Kinematical fit ($\delta m(K\overline{K})$= 3...10 MeV/c^2)

Differential distributions without acceptance corrections



The transition matrix element under s- and p-waves assumption:

$$|\overline{M}|^2 = C_0^k\,\mathbf{k}^2 + C_1(\mathbf{p}\cdot\mathbf{k})^2 + C_0^q\,\mathbf{q}^2 + C_2(\mathbf{p}\cdot\mathbf{q})^2 + C_3(\mathbf{k}\cdot\mathbf{q}) + C_4(\mathbf{p}\cdot\mathbf{k})(\mathbf{p}\cdot\mathbf{q})$$



Acceptance Corrected Distributions

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

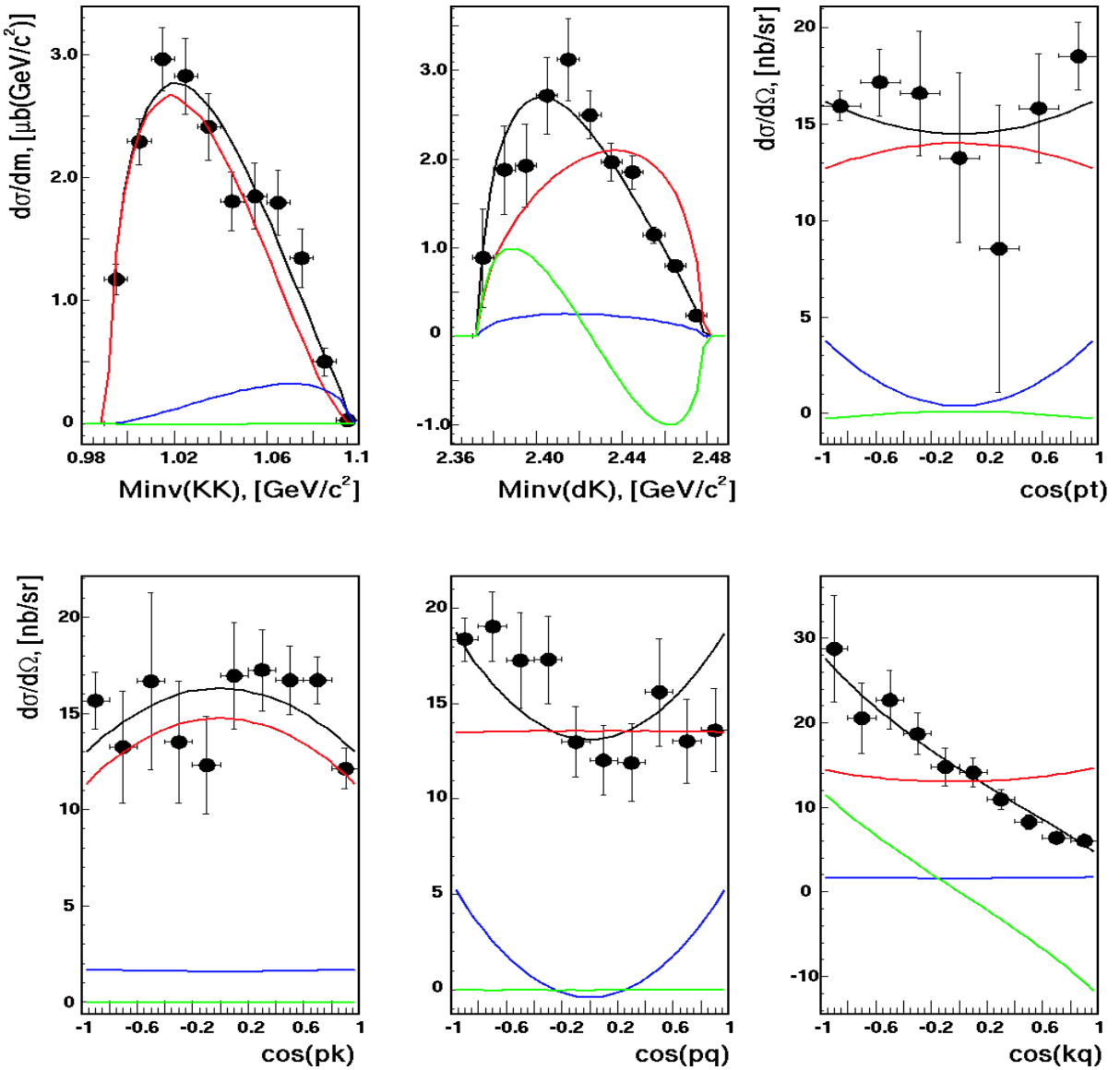
$$|\bar{M}|^2 = C_0^k\,\mathbf{k}^2 + C_1(\mathbf{p}\cdot\mathbf{k})^2 +$$

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

$$+ C_0^q\,\mathbf{q}^2 + C_2(\mathbf{p}\cdot\mathbf{q})^2 +$$

$$+ C_3(\mathbf{k}\cdot\mathbf{q}) + C_4(\mathbf{p}\cdot\mathbf{k})(\mathbf{p}\cdot\mathbf{q})$$

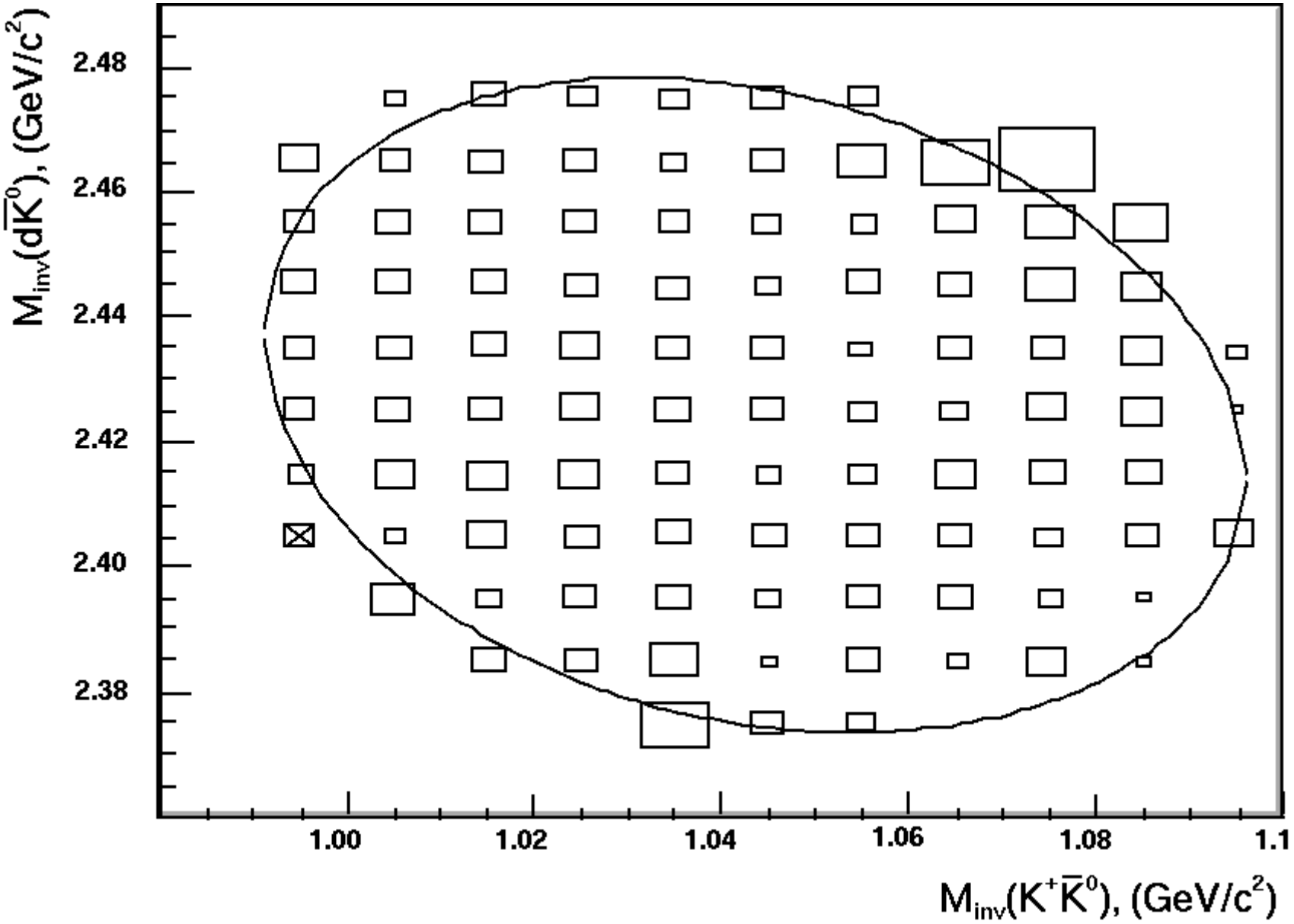
interference term



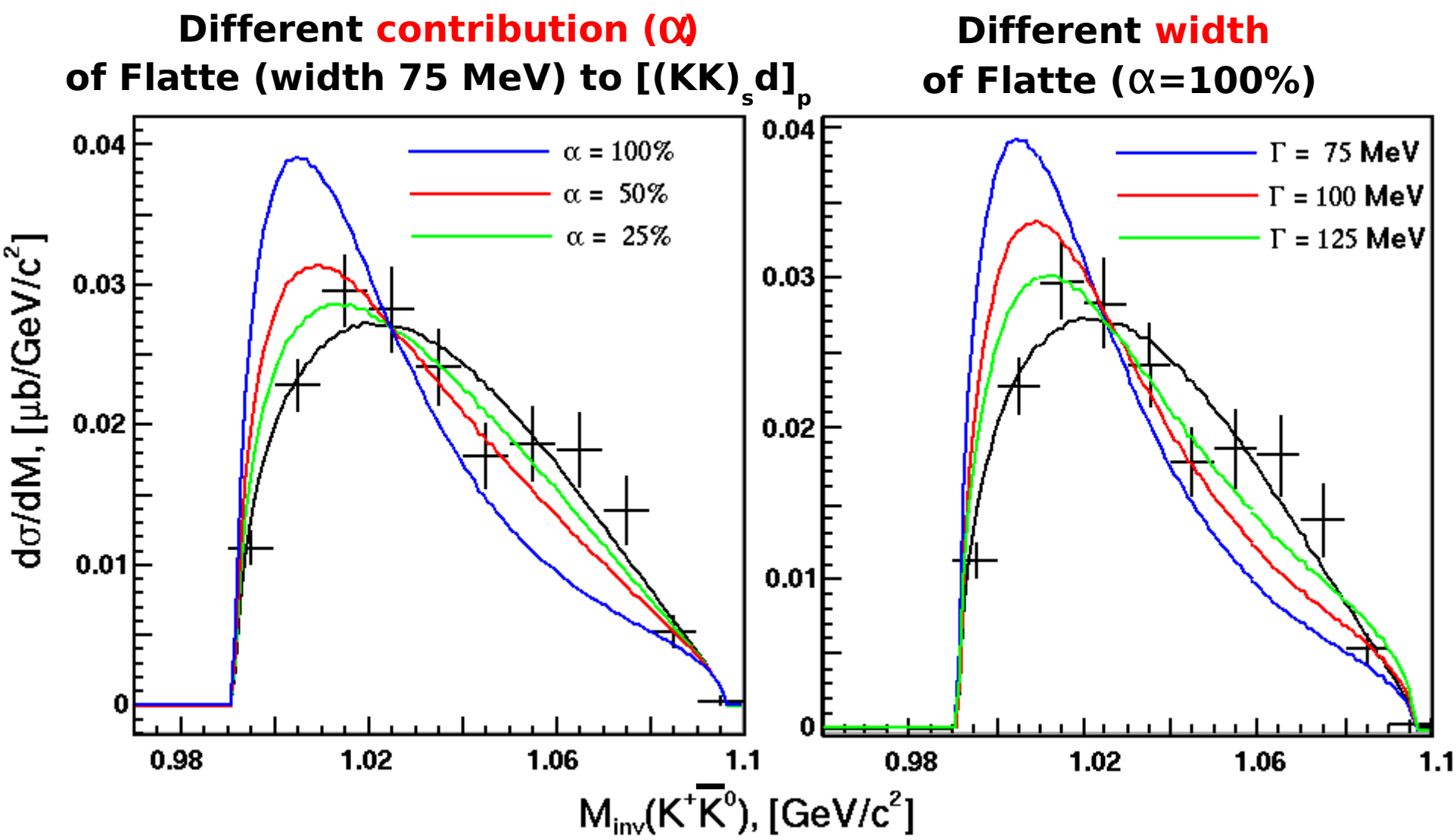
Coefficients fix partial waves contributions:

- ~90% $[(K\bar{K})_s d]_p$ (a_0^+-channel)
- ~10% $[(K\bar{K})_p d]_s$ (only nonresonant)

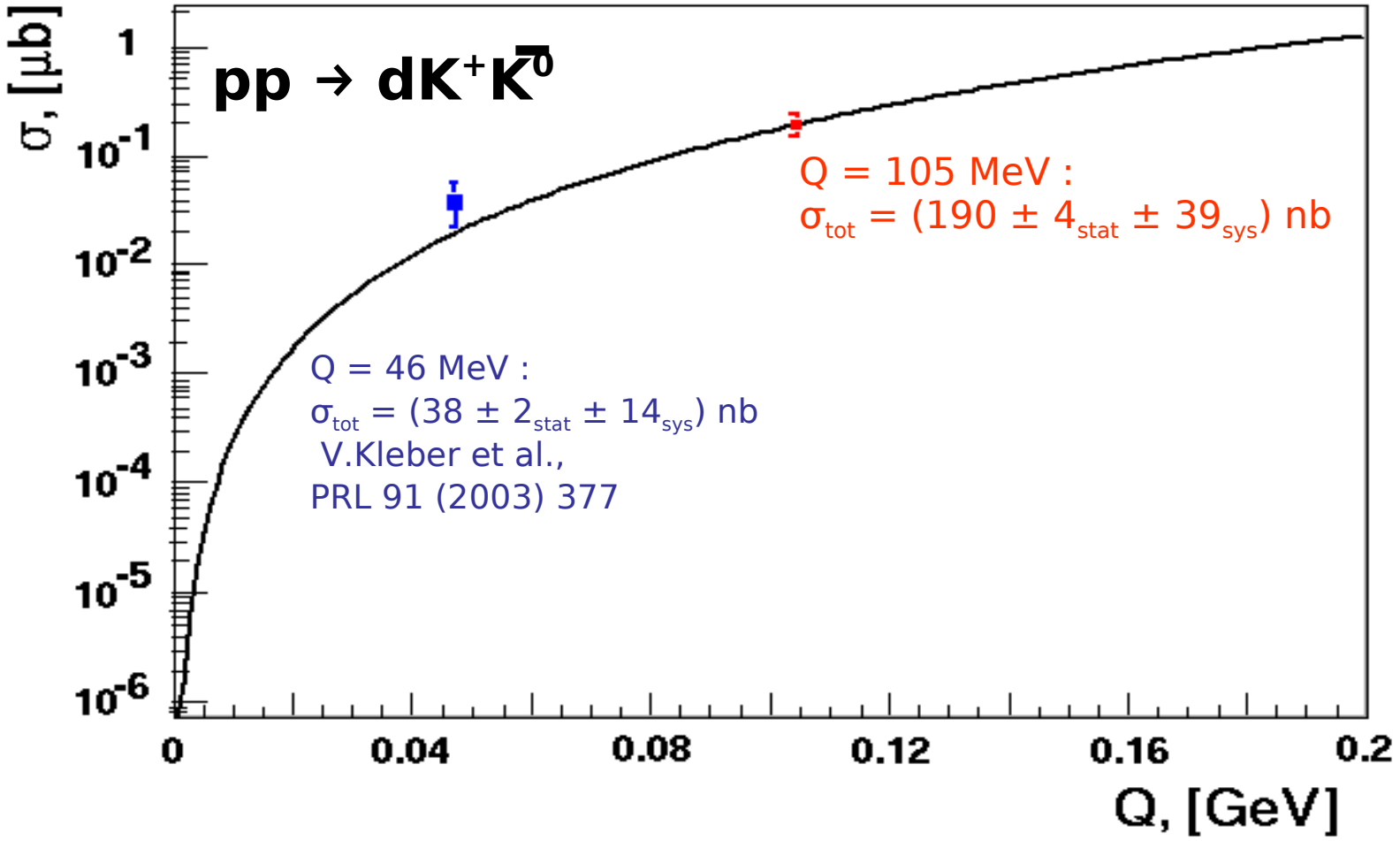
Acceptance corrected Dalitz plot



Where is the $a_0^+(980)$?

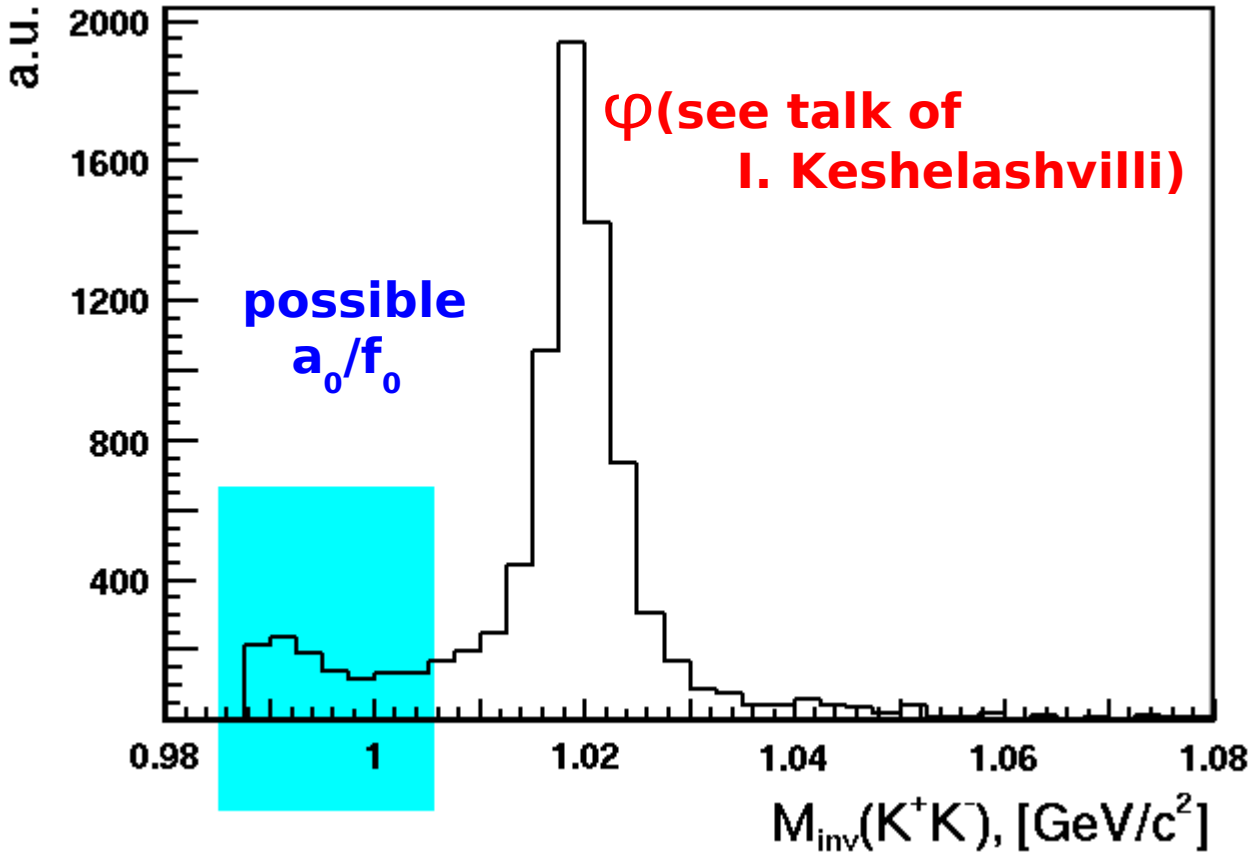


Total cross-section



$pn \rightarrow dK^{+}K^{-}$

pn→ dK^+K^- (T_p=2.65 GeV)

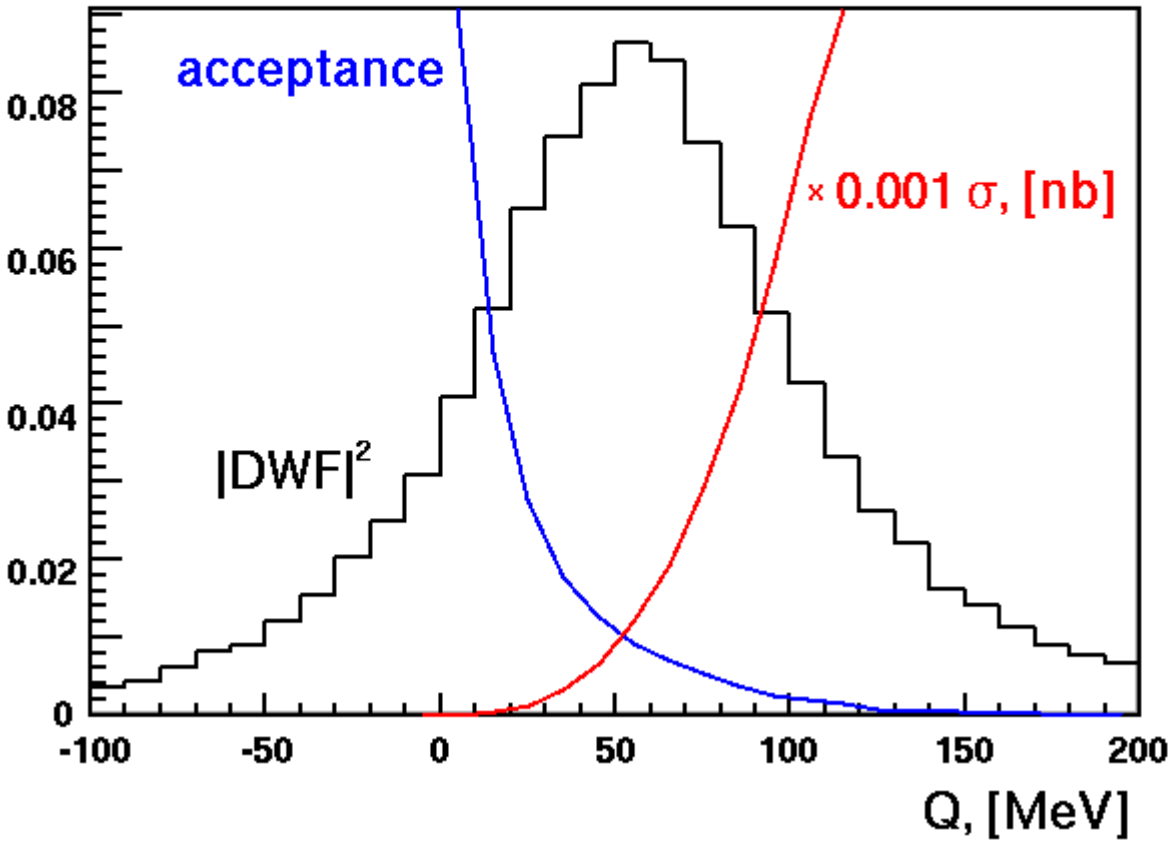


- **D_2 as an effective neutron target, unobserved «spectator» proton**
- **K^+K^-d coincidence measurements**
- **invariant mass spectrum of K^+K^- system**

Rates expected from $pp \rightarrow dK^+\overline{K}^0$

bin: $N_i = 0.25\ \varepsilon\ L\ \alpha_i\ |DWF|^2\ \sigma_i(pp \rightarrow dK^+\overline{K}^0)$;

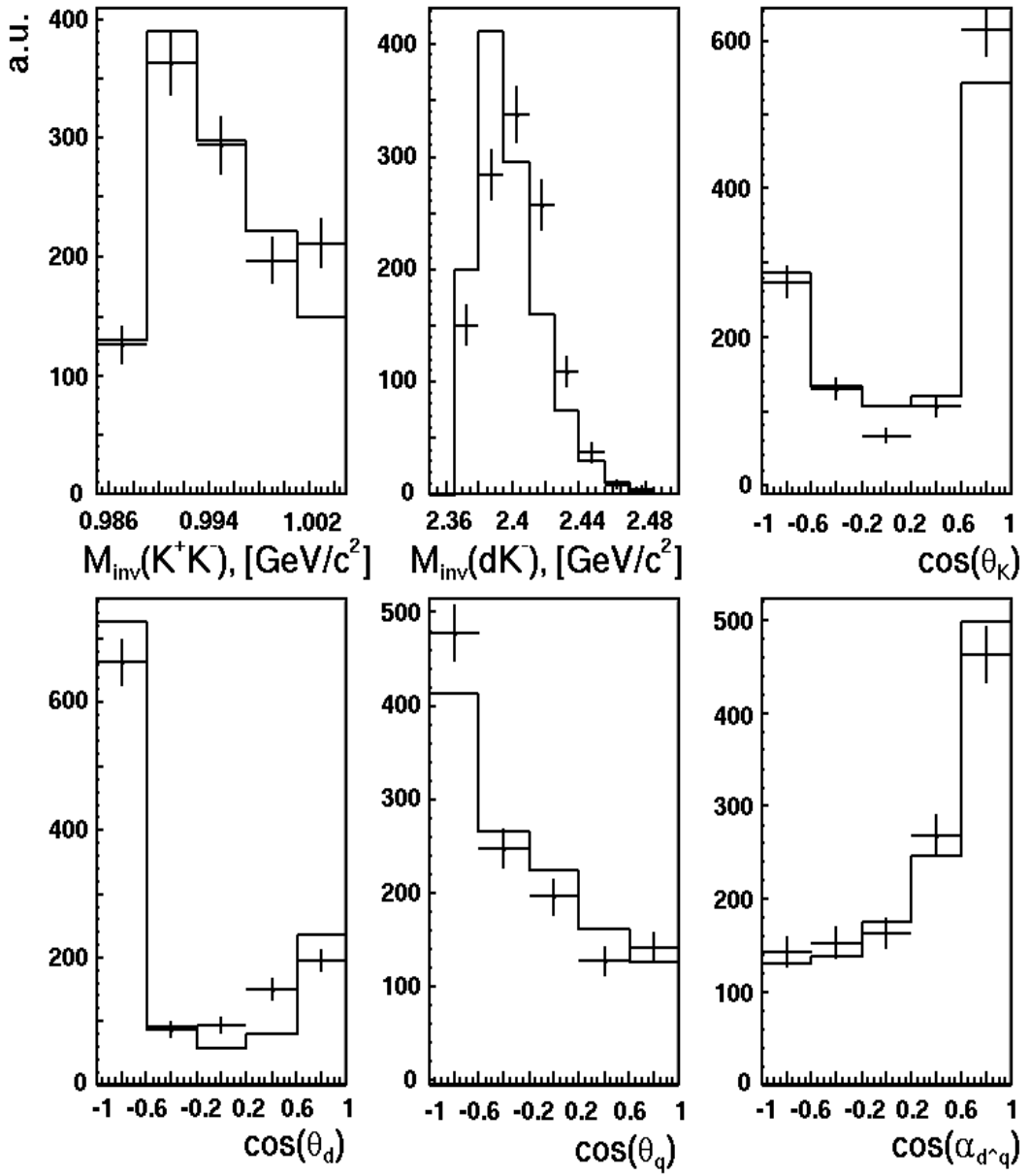
$pn \rightarrow dK^+K^-$: $\varepsilon = 0.53$, $L = 23\ pb^{-1}$



$N_{estimated}$ = 885 events;

$N_{experiment}$ = 1230 events;

Fit of differential distributions



- **cut on $M_{inv}(K^+K^-) < 1.005$ GeV/c^2**
- **different assumption for $|\bar{M}|^2$:**

1) $|\bar{M}|^2$ = const $[(KK)_s d]_s$

2) $|\bar{M}|^2$ as for pp: $[(KK)_s d]_p$ and $[(KK)_p d]_s$

3) (1)+(2) two additional terms (is on this slide)

4) split Q on three part and make the fit (3)

Only 4th has a good χ^2 (< 2/ndf)!

$dd \rightarrow {}^{4}HeK^{+}K^{-}$

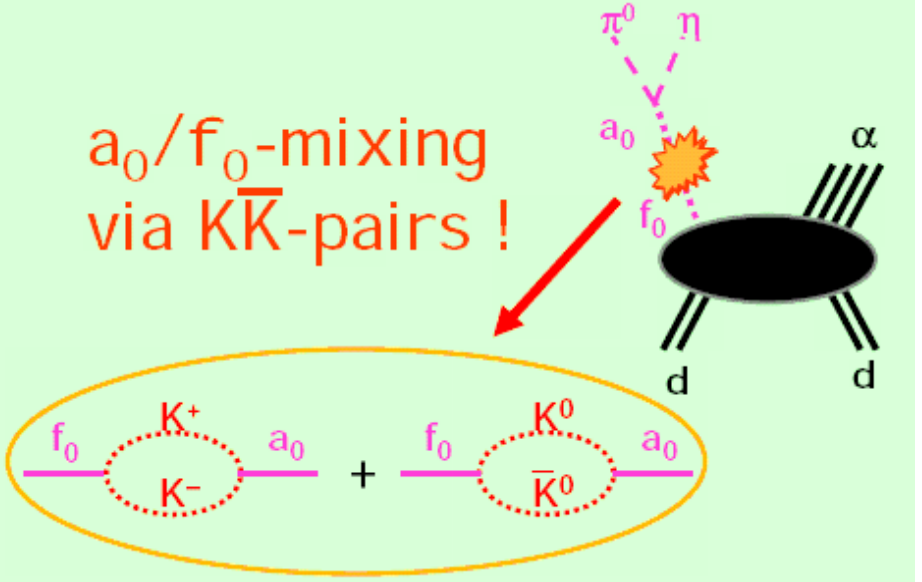
dd→ ^{4}HeK$^+$K$^-$ (T_d=2.28 GeV)

WASA@COSY

The reaction dd → ^{4}He ($\pi^0\eta$)
is forbidden if isospin is conserved

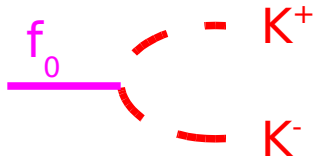
dd → ^{4}He $f_0(I=0)$ → ^{4}He $a_0^0(I=1)$ → ^{4}He $\pi^0\eta$??

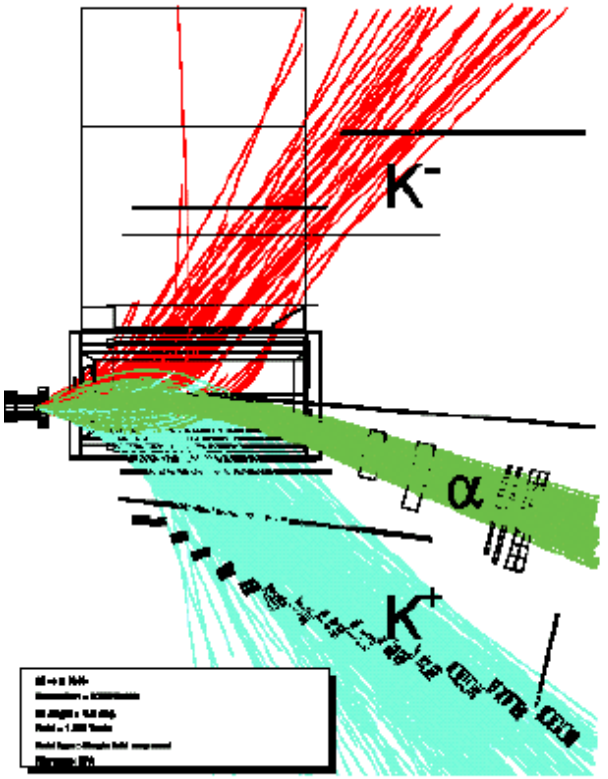
a_0/f_0-mixing via $K\bar{K}$-pairs !



N.N. Achasov et al., Phys. Lett. B 88, 367 (1979)
C. Harnhard, Phys. Rept. 397, 155 (2004)

ANKE@COSY





dd→ ^{4}HeK$^+$K$^-$ (T_d=2.28 GeV)

Setup:

- 4 weeks of beamtime in April
- ^{4}HeK$^+$ coincidence
- Energy loss of ^{4}He in trigger

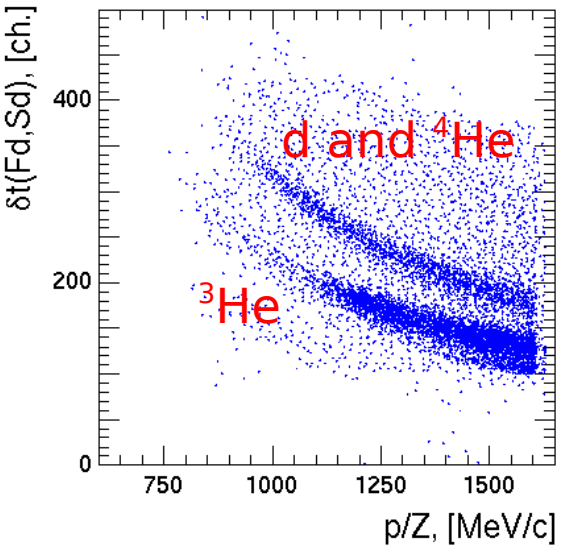
Difficulties:

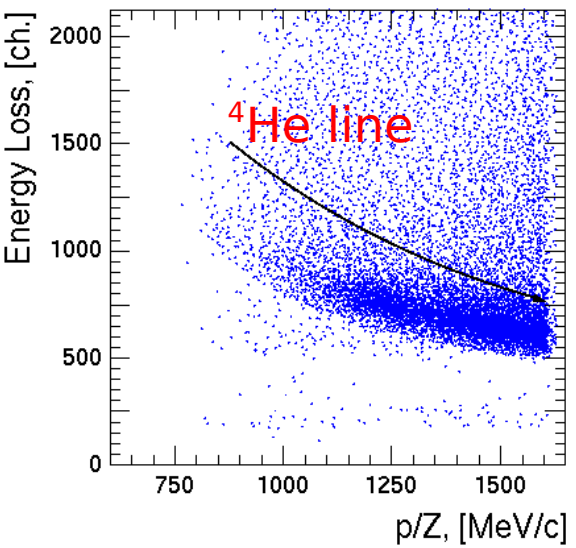
- Huge background
- Small total number of kaons

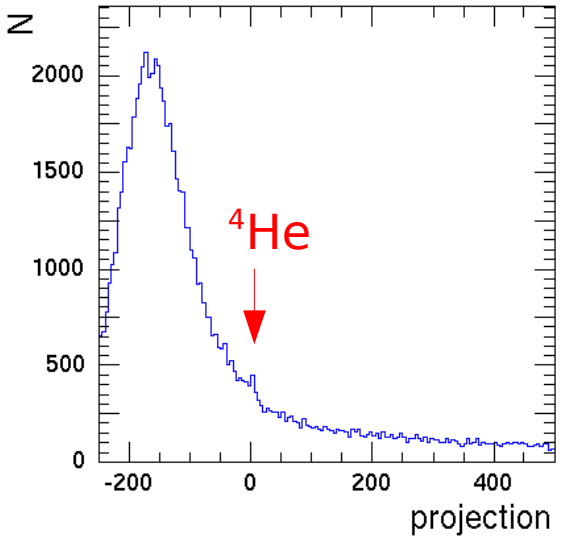
First analysis:

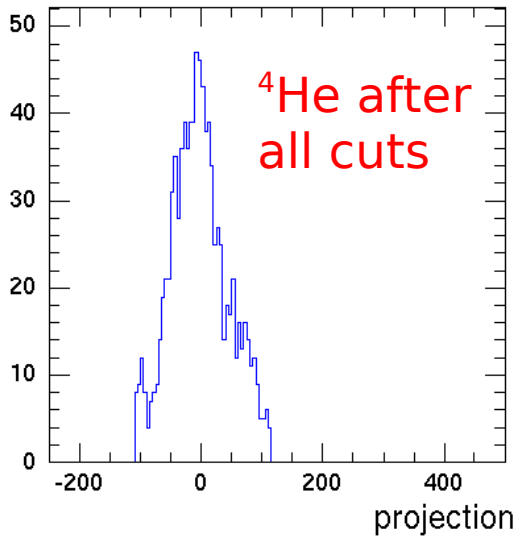
- ^{3}He π ~5000 events
- ^{4}He π ~500 events
- dK$^+$ ~700 events
- ^{4}HeK$^+$ ≤30 events

^{4}He selection in coincidence with pions:









Summary

$pp \rightarrow dK^+\bar{K}^0$:

- **data analysis is finished**
- **dominance of $[(K\bar{K})_s d]_p$ term**
- **no evidence of the $a_0^+(980)$ in $M_{inv}(K\bar{K})$**

$pn \rightarrow dK^+K^-$:

- **phi meson dominance**
- **$\sigma(pn \rightarrow dK^+K^-)$ is the same order as $\sigma(pp \rightarrow dK^+\bar{K}^0)$**
- **differential spectra can be discribed by s- and p- waves**

$dd \rightarrow {}^4HeK^+K^0$:

- **huge background**
- **small number of $^4HeK^+$ events**

People

A.Dzyuba, V.Koptev, S.Mikirtychiants
PNPI, Gatchina, Russia

M.Büscher, P.Fedorets, C.Hanhart, M.Hartmann, V.Hejny,
S.Krewald, Y.Maeda, M.Nekipelov, H.Ströher
IKP, FZ Jülich

C.Wilkin
University of London

U.-G.Meißner, V.Kleber, A.Sibirtsev
Bonn University

L.Kondratyuk, A.Kudryavtsev, V.Tarasov
ITEP, Moscow, Russia

V.Grishina
INR, Moscow, Russia

Experiment

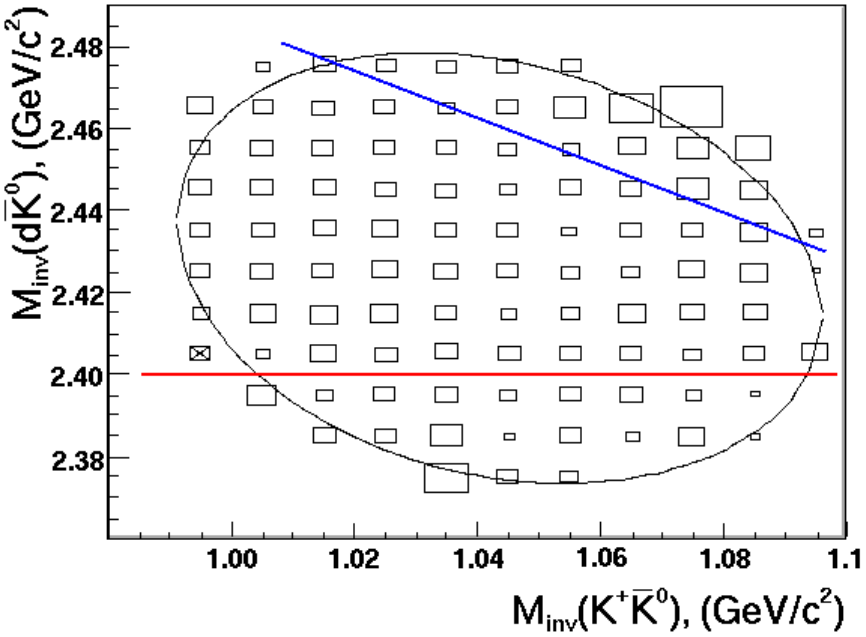
Theory

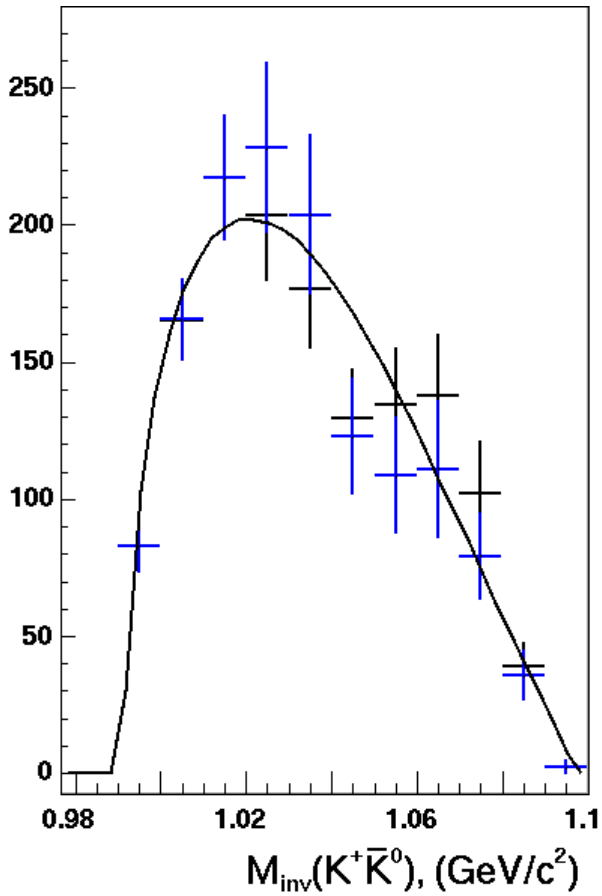
and the ANKE collaboration

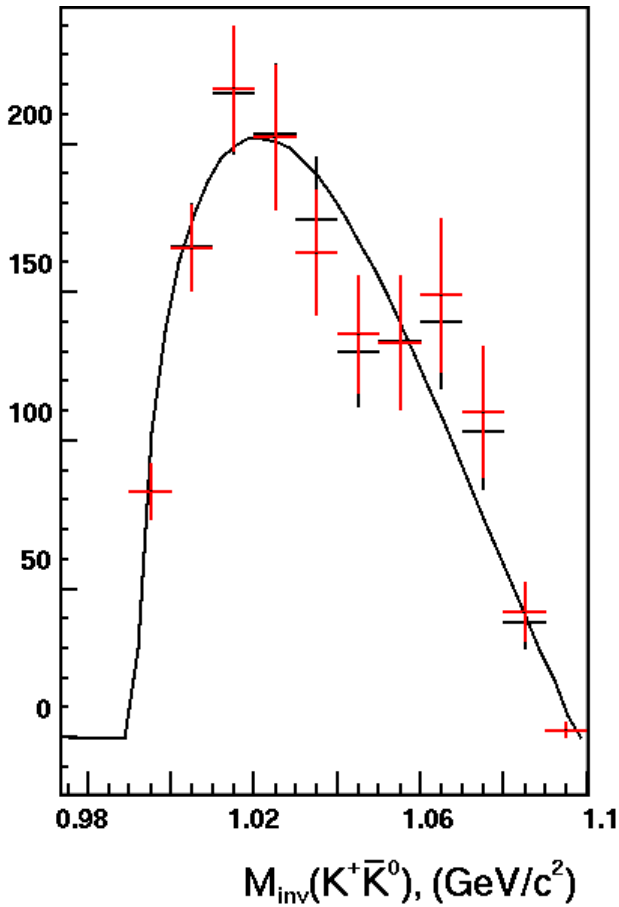
This work is supported by DFG and COSY-FFE projects

Checking for the FSI effects

Cuts on the dK^+ and $d\bar{K}$ invariant mass







Fit Results

T_p	2.65 GeV	2.83 GeV
symbol	squares	circles
c_0^q	-0.30	-0.06
c_0^k	0.89 fixed	
c_1	-0.13	-0.22
c_2	1.09	0.93
c_3	-0.39	-1.29
c_4	-0.68	0.08
χ^2/ndf	~1.4	~1.1

$$|\overline{M}|^2 = \underbrace{C_0^k \mathbf{k}^2 + C_1(\mathbf{p}\cdot\mathbf{k})^2}_{[(KK)_s d]_P} + \underbrace{C_0^q \mathbf{q}^2 + C_2(\mathbf{p}\cdot\mathbf{q})^2}_{[(KK)_p d]_S} + \underbrace{C_3(\mathbf{k}\cdot\mathbf{q}) + C_4(\mathbf{p}\cdot\mathbf{k})(\mathbf{p}\cdot\mathbf{q})}_{\text{interference term}}$$