The near-threshold production of Φ mesons in pN collisions

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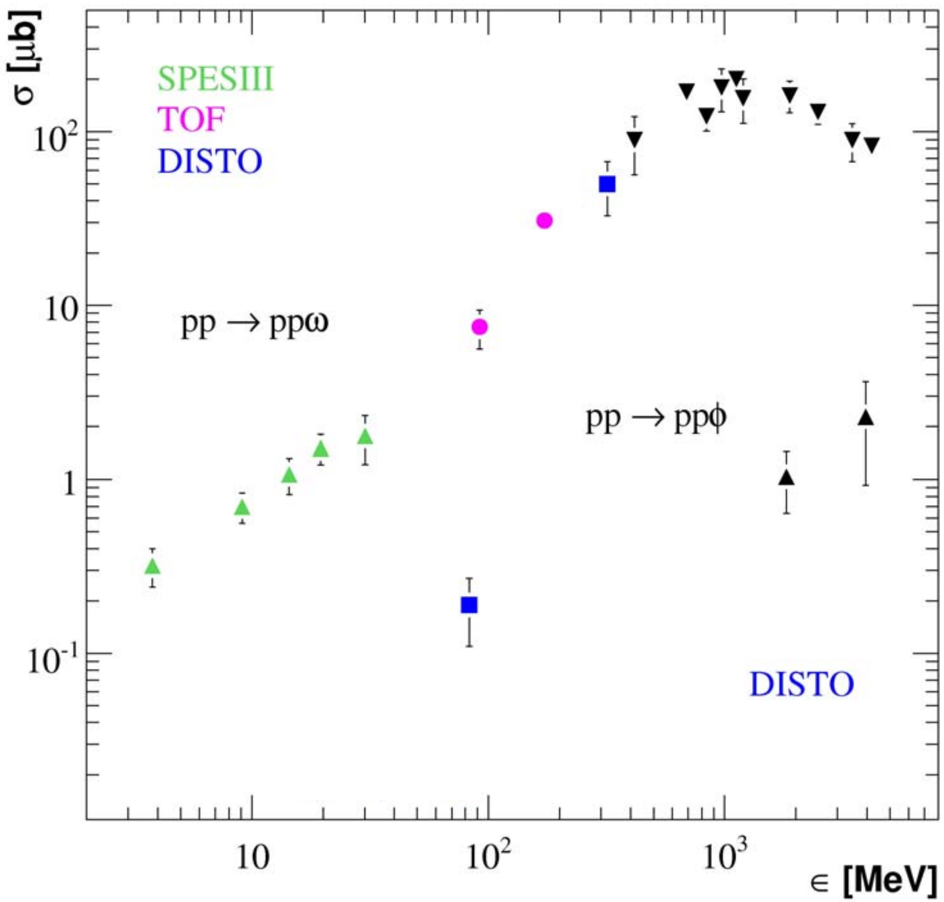
Outline

- Introduction
- ANKE setup
- Data and results: $pp \to pp\phi$ & $pn \to d\phi$
- Summary and Outlook

Φ meson production in pN collisions and Φ/ω ratio



scarce pp→ppϕ data
no pn→dϕ data

energy dependence of the total Φ cross section ⇒ $g_{\phi NN}$

isospin dependence

m_ϕ = 1019 MeV (distance of two colliding nucleons < 0.2fm)

$\Phi = \langle s\bar{s} \rangle$

Okubo-Zweig-Iizuka (OZI) rule

At ANKE: (pp) ε = 18.5, 34.6, 75.9 MeV
(pn) ε up to 80 MeV

OZI rule

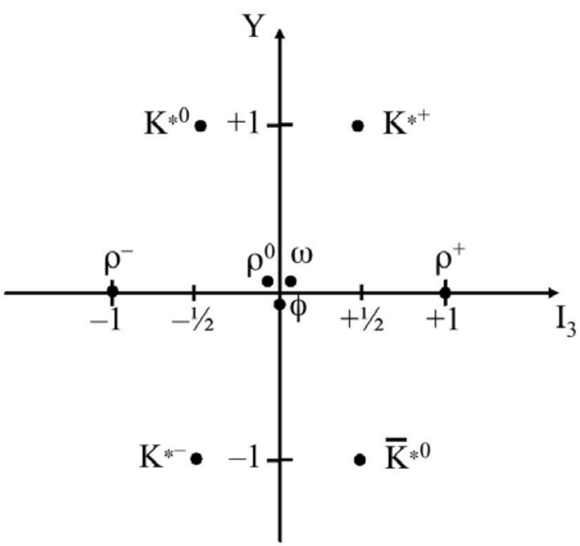
SU(3): $|\omega\rangle_1 = \frac{1}{\sqrt{3}}\left(|u\bar{u}\rangle + |d\bar{d}\rangle + |s\bar{s}\rangle\right)$ $\quad |\phi\rangle = \cos\theta_V|\omega\rangle_8 - \sin\theta_V|\omega\rangle_1 \approx |s\bar{s}\rangle$

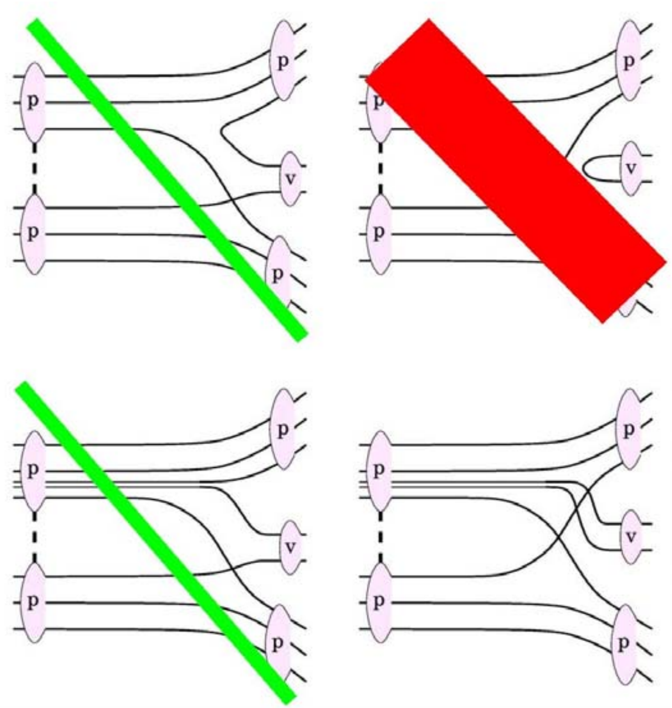
$|\omega\rangle_8 = \frac{1}{\sqrt{6}}\left(|u\bar{u}\rangle + |d\bar{d}\rangle - 2|s\bar{s}\rangle\right)$ $\quad |\omega\rangle = \cos\theta_V|\omega\rangle_8 + \sin\theta_V|\omega\rangle_1 \approx \frac{1}{\sqrt{2}}\left(|u\bar{u}\rangle + |d\bar{d}\rangle\right)$

$$\left(\frac{\sigma_\phi}{\sigma_\omega}\right)_{SU(3)} = \tan^2\Delta\theta_V = 4{,}2\cdot 10^{-3}$$

H.J. Lipkin, Phys. Lett. B 60 (1976) 371.

The vector meson nonet





OZI rule: $4.2\times10^{-3} \equiv R_{OZI}$

$p\bar{p}$ annihilation

$R_{\phi/\omega} \approx (30 \div 70)\times R_{OZI}$

pp collision at $\varepsilon \geq 100$ MeV and πN

$R_{\phi/\omega} \approx 3\times R_{OZI}$

DISTO at ε=83 MeV in pp collision

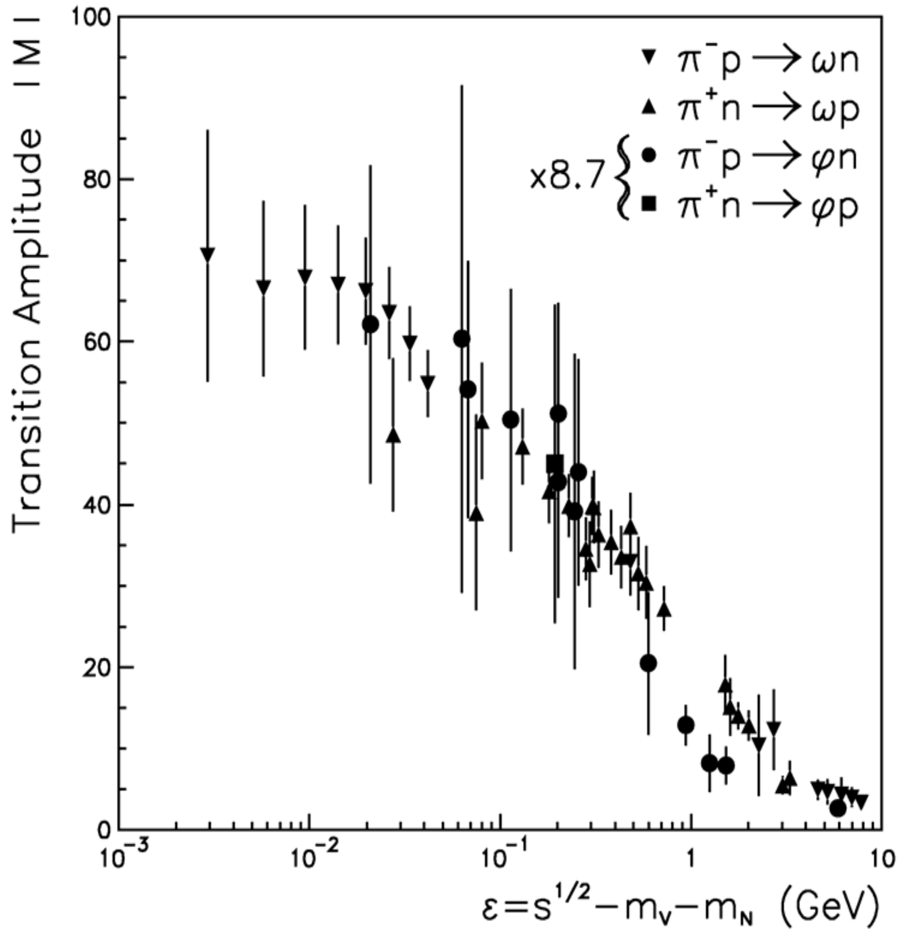
$R_{\phi/\omega} \approx 7\times R_{OZI}$

OZI ratio in πN interaction

$$\frac{\left|M_{\pi N\to\omega N}\right|}{\left|M_{\pi N\to\phi N}\right|}=8.7\pm1.8$$

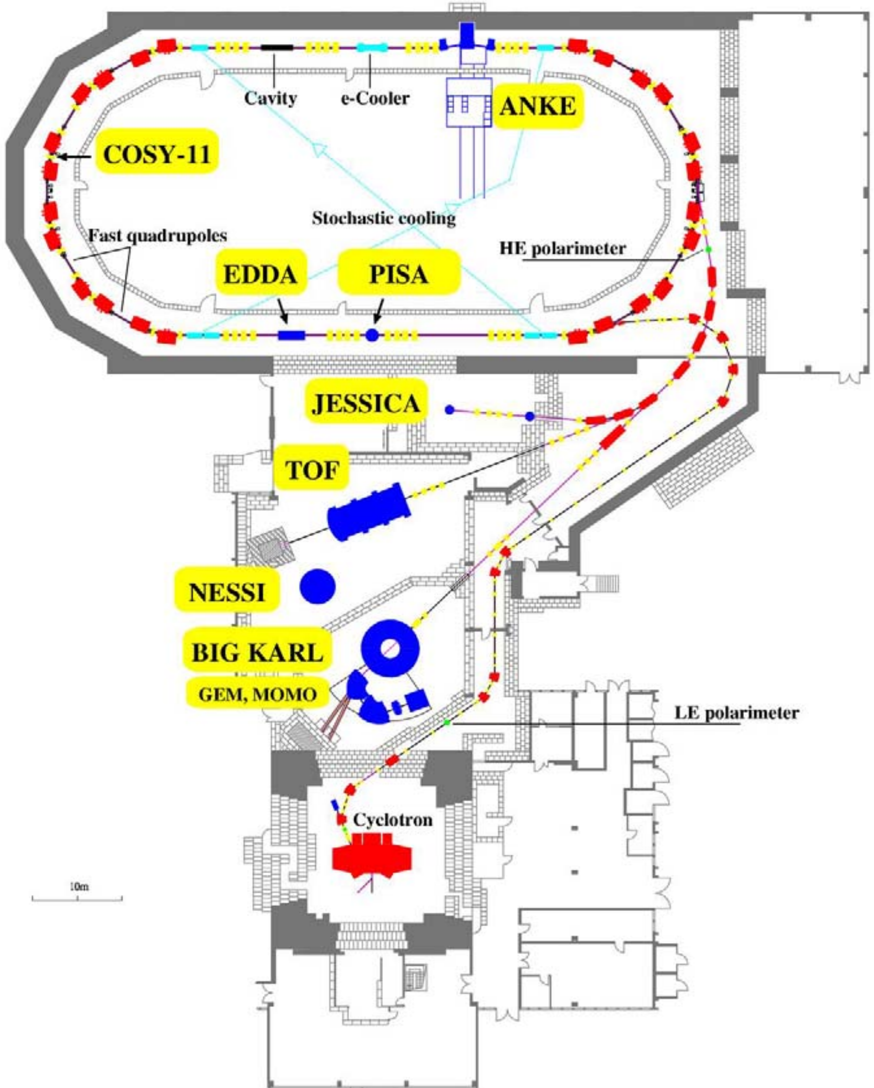
$$R_{\phi/\omega} = (3.2 \pm 0.8)\times R_{OZI}$$

can be understood in terms of the established OZI violation in the $\phi\rho\pi$ and $\omega\rho\pi$ coupling.



A. Sibirtsev *et al.*, Eur. Phys. J. A 7 (2000) 407.

ANKE spectrometer at COSY



ANKE spectrometer

Apparatus for Studies of **N**ucleon and **K**aon **E**jectiles

S. Barsov et al., Nucl. Instr. Meth. A462 (2001) 364

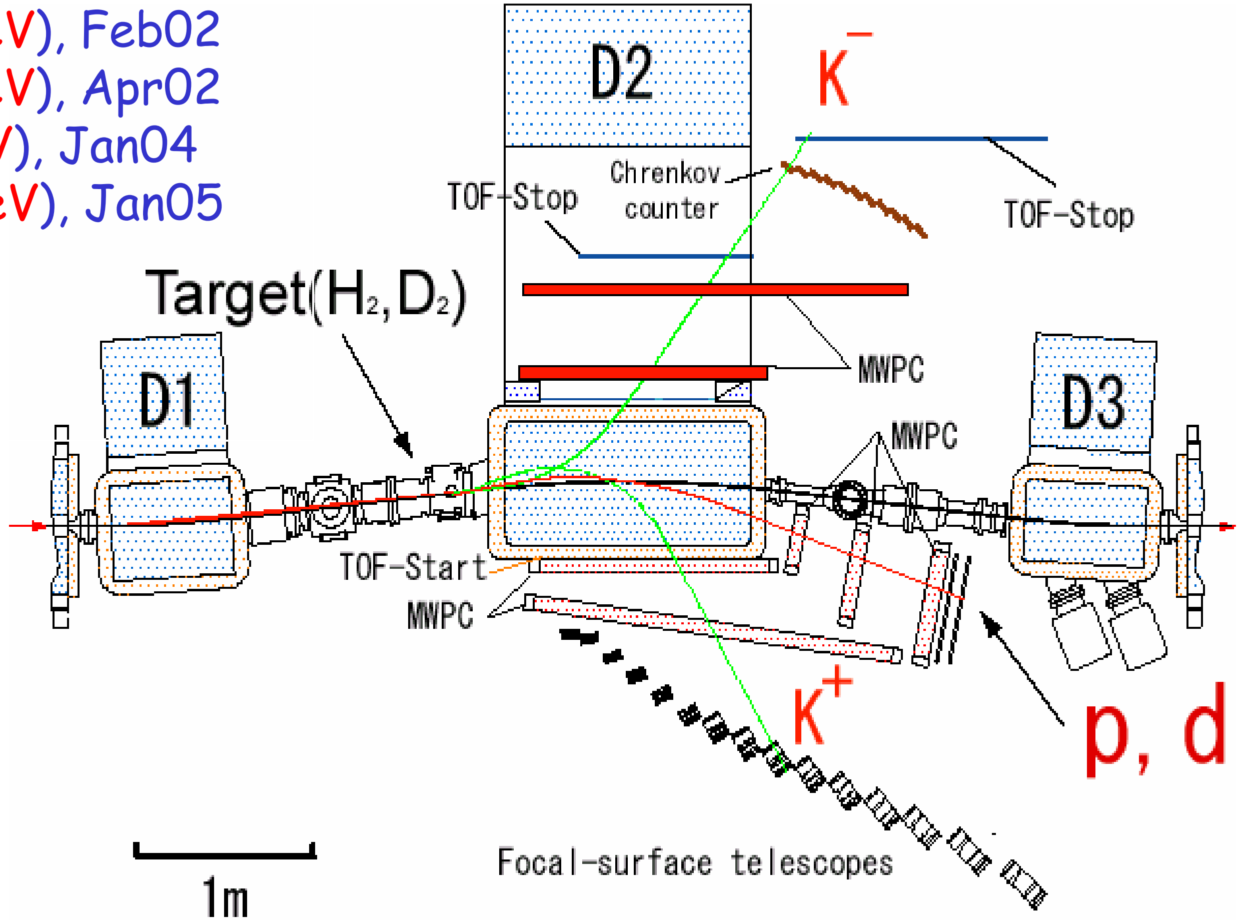
$pp \to pp\phi$

- ✓ 2.83 GeV (75.9 MeV), Feb02
- ✓ 2.70 GeV (34.6 MeV), Apr02
- ✓ 2.65 GeV (18.5 MeV), Jan04
- 2.83 GeV (75.9 MeV), Jan05

$pd \to d\phi\ p$

- ✓ 2.65 GeV, Feb04

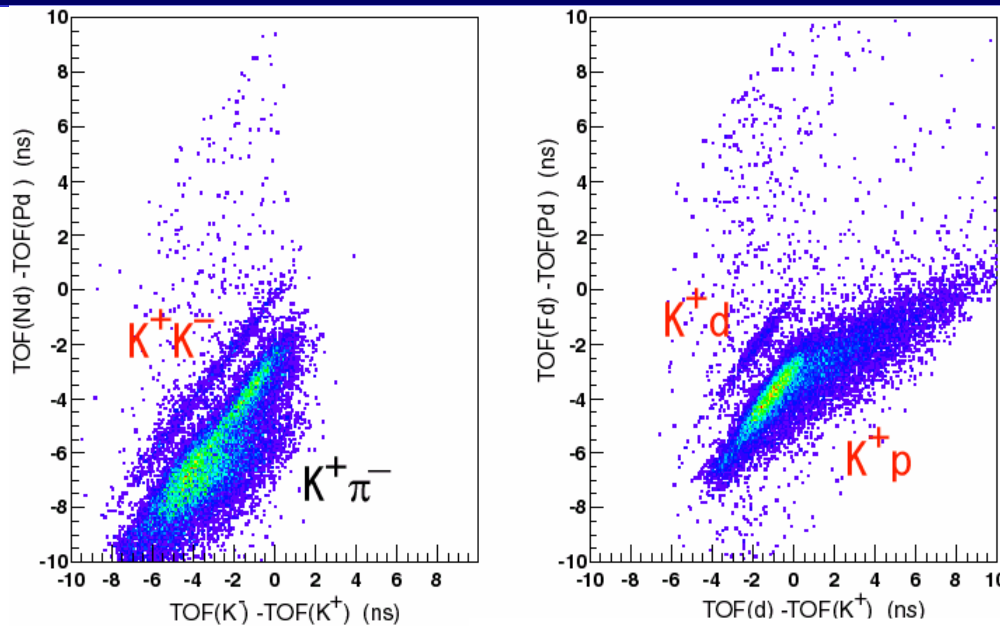
COSY beam

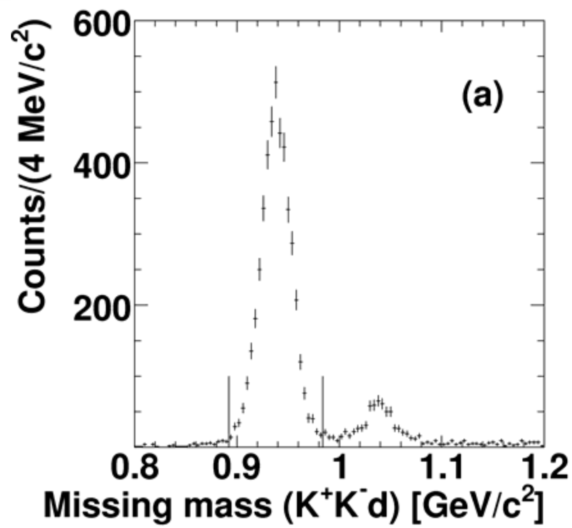


Particle identification

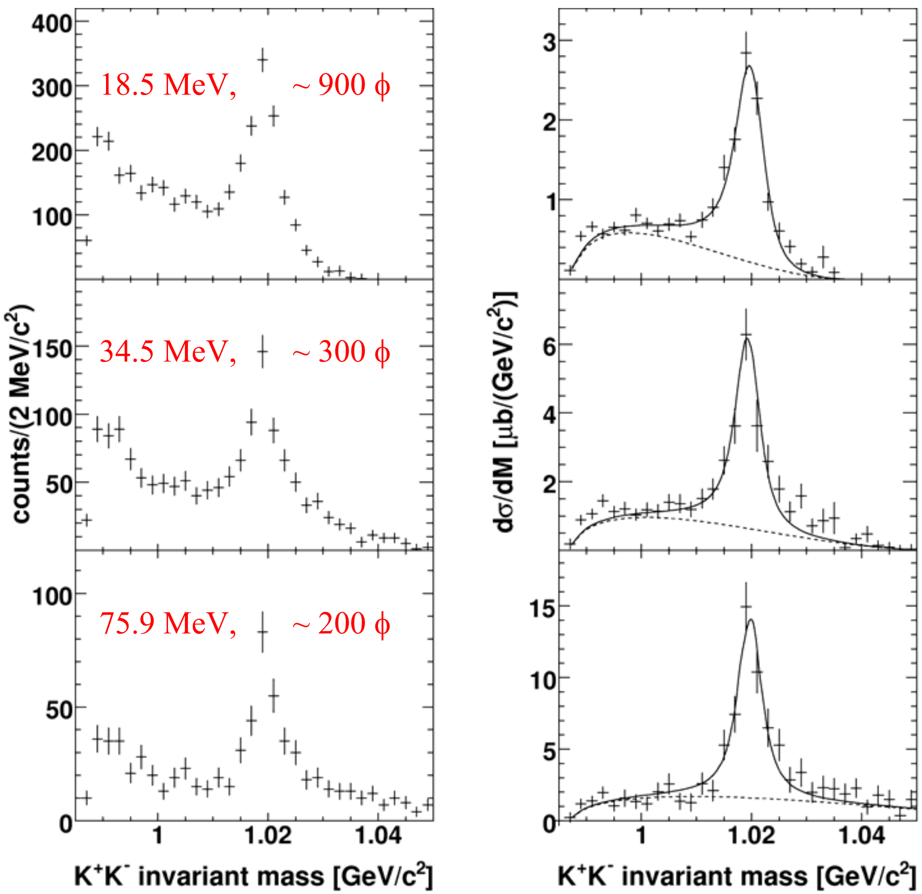
Identification

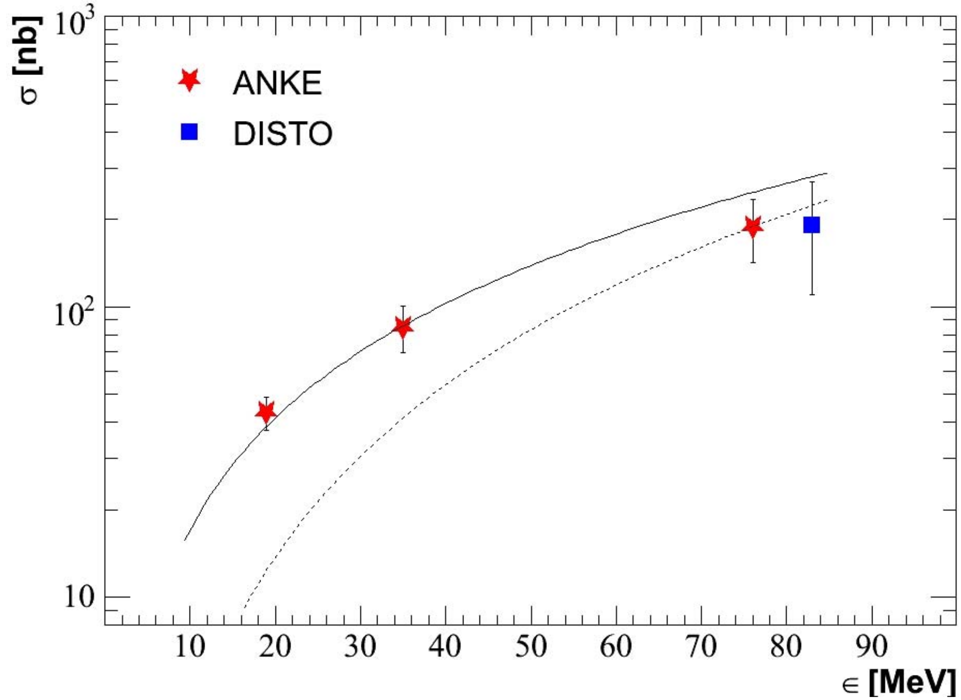
- ✓TOF
- ✓Missing mass
  - $pp \rightarrow pK^+K^-p$
  - $pd \rightarrow dK^+K^-p$





ANKE: pp→ppΦ (total cross sections)





dashed line: phase space
solid line: phase space + pp-FSI (Jost function)
(best fit to the ANKE points)

ANKE: pp→ppΦ (differential cross sections)

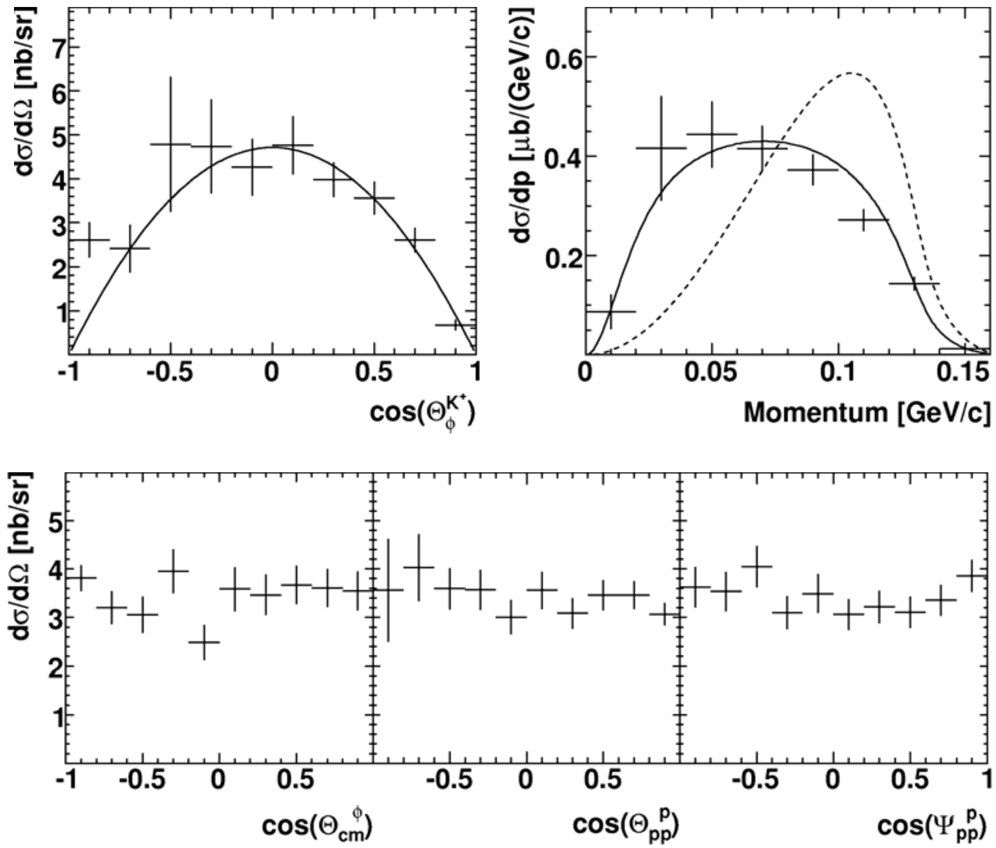
ε= 18.5 MeV

close to threshold the angular decay distribution must display a $\sin^2\Theta_\phi^{K^+}$

Φ in relative S-wave

transition from $^3P_1$ (pp)-entrance channel to $^1S_0$ (pp) final-state

clear effect of pp-FSI



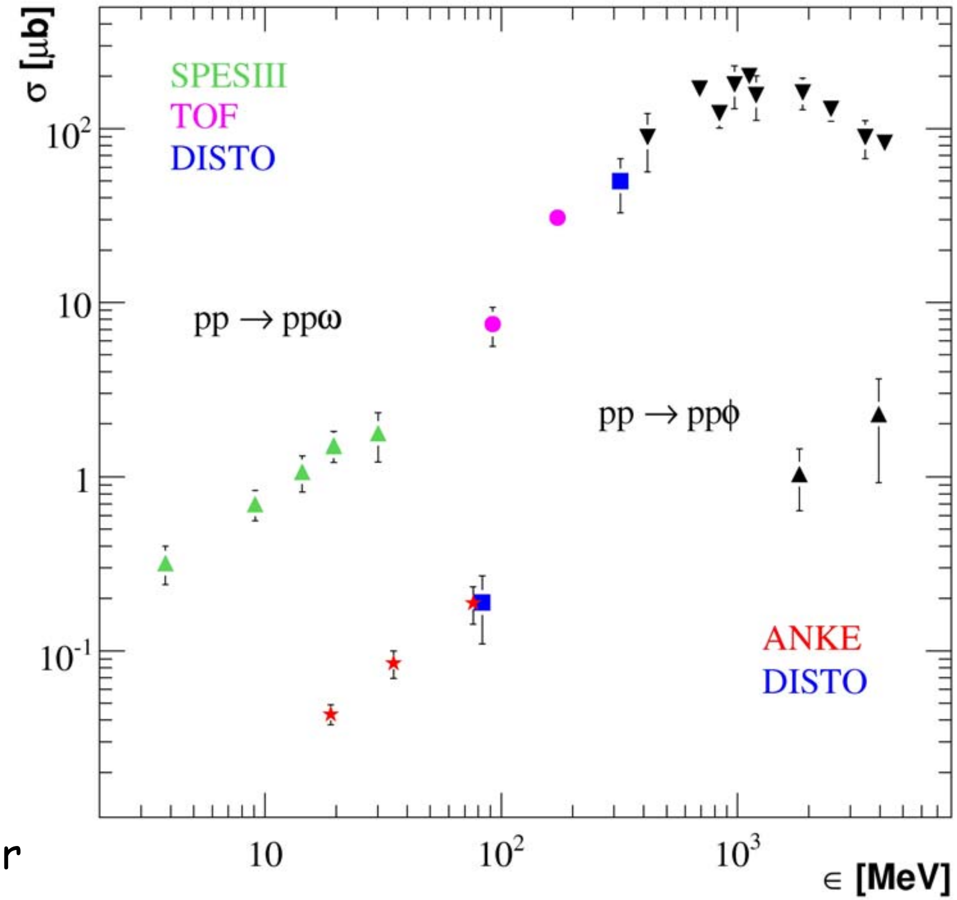
M. Hartmann *et al.* (ANKE), Phys. Rev. Lett. (in print).

The Φ/ω production ratio

OZI: $R_{\phi/\omega}$(high energy)
$\approx$ (1 - 2.4)×R_{OZI}
(in agreement with πN data and
the ϕρπ and ωρπ coupling)

OZI: $R_{\phi/\omega}$(18.5-79.5 MeV, ANKE)

$\approx (3.3 \pm 0.6) \times 10^{-2} \approx 8 \times R_{OZI}$



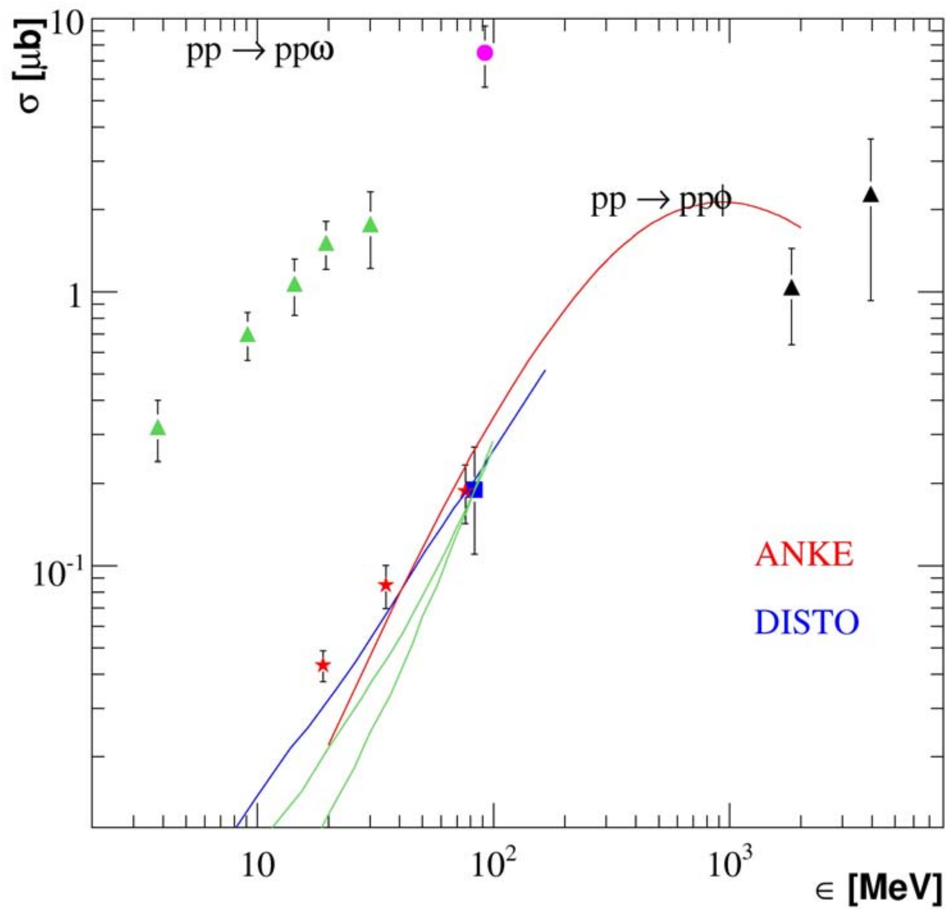
≥ 100 MeV, at the JINR Nuclotron, NIS detector

ANKE: pp→ppΦ compared with theoretical predictions

K. Tsushima and K. Nakayama,
Phys. Rev. *C* 68 (2003) 034612.

L.P. Kaptari and B. Kaempfer,
Eur. Phys. J. *A* 23 (2005) 291.

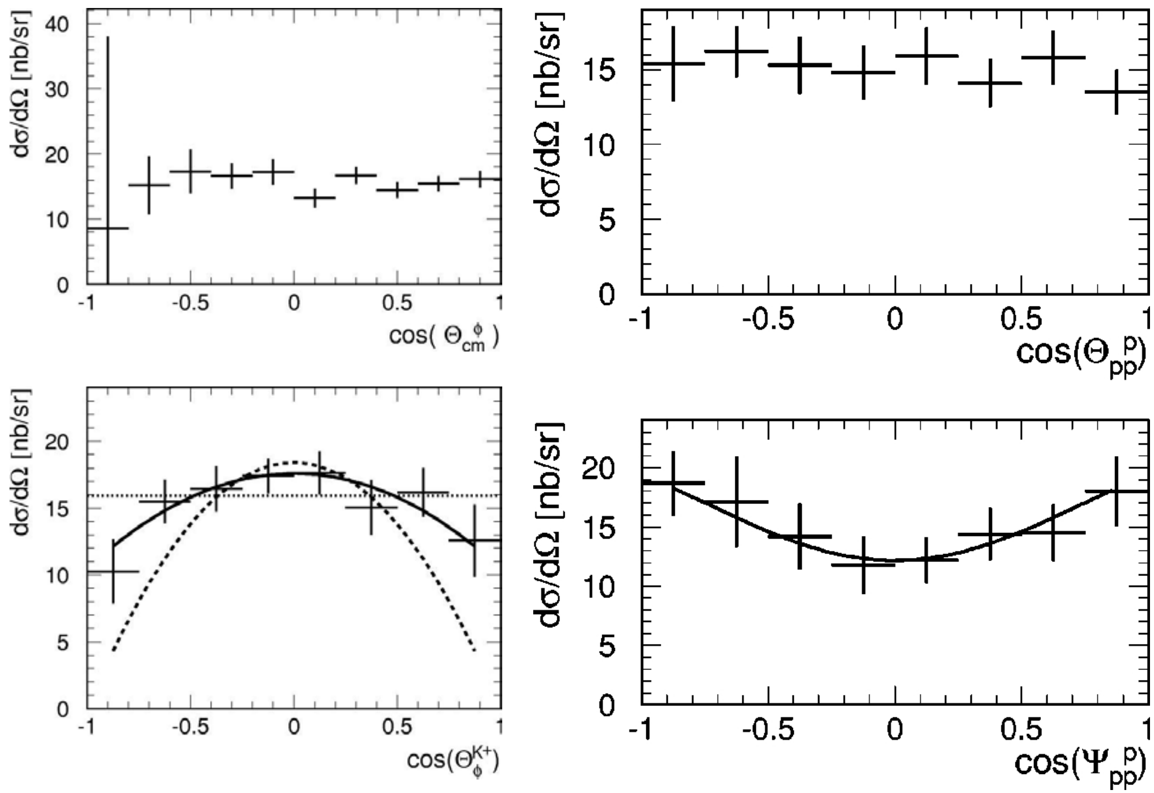
A. Faessler *et al.*,
Phys. Rev. *C* 68 (2003) 068201.
(resonance model, two-step)



DISTO: pp→ppΦ (differential cross sections)

$\varepsilon = 83$ MeV

F. Balestra et al. (DISTO), Phys. Rev. C63(2001) 024004

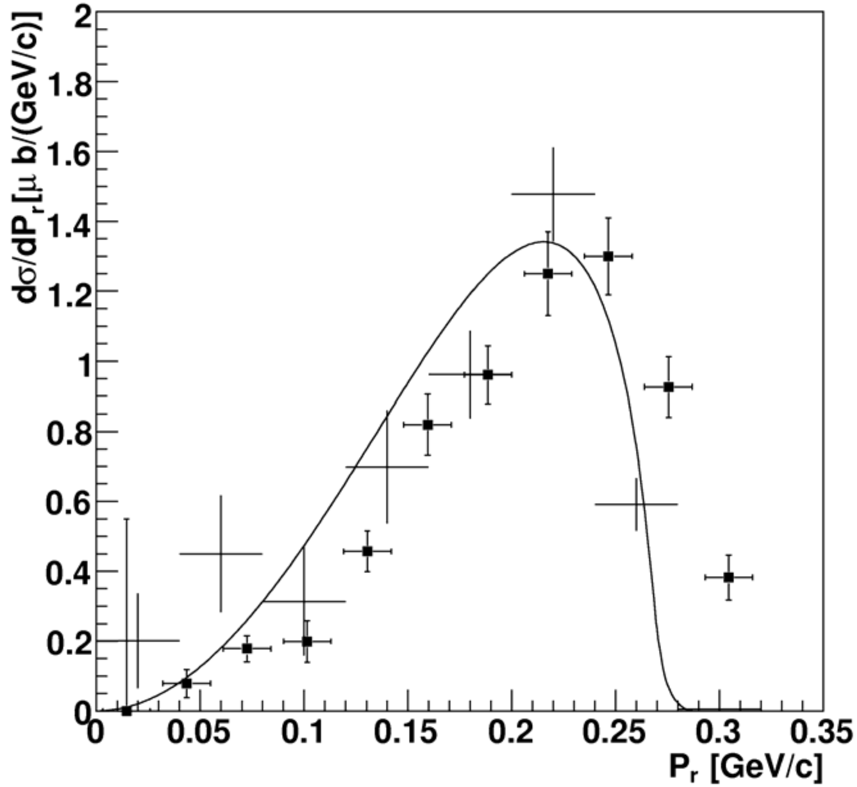


dominantly S-wave, best fit: (28 ± 7)% P-wave constribution

DISTO, ANKE: $pp \to pp\Phi$ (pp-FSI)

ANKE (75.9 MeV,
~ 200 Φ's)

DISTO (83 MeV,
~ 500 Φ's)



higher partial (P-) wave contribution at $\varepsilon \approx$ 80 MeV as 30%,
or production mechanism

Speculation: exotic baryon B_ϕ

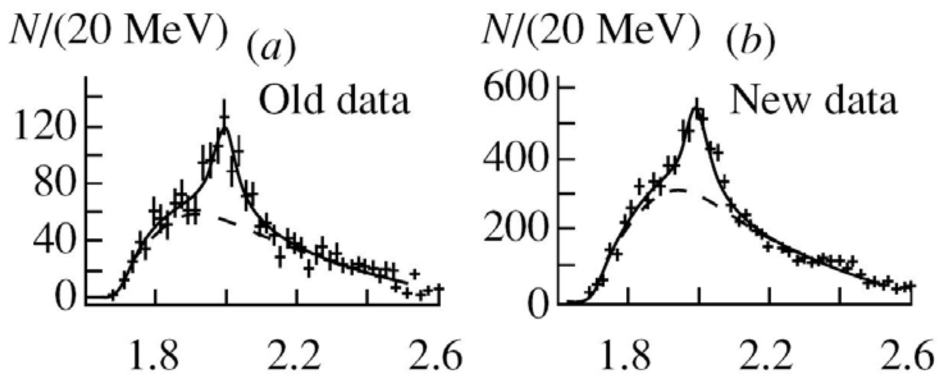
Few years ago Landsberg proposed that ϕp production, which is OZI suppressed for non-resonant reactions, is well suited for the search of cryptoexotic baryons with hidden strangeness, $B\phi = udds\bar{s}$ ($\rightarrow \phi N$, $K\bar{K}$ or YK).

L.G. Landsberg, Phys. Usp. 37 (1994) 1034.
L.G. Landsberg, Phys. Rep. 320 (1999) 223.

experimental limits for the $B\phi$ candidates:

M.W. Arenton *et al.*, Phys. Rev. D. 25 (1984) 2241.
A.N. Aleev *et al.*, Z. Phys. C25 (1984) 205.
V.A. Dorofeev *et al.*, Phys. At. Nucl. 57 (1994) 227.
V.A. Dorofeev *et al.*, Phys. At. Nucl. 57 (1994) 238.
M.Ya. Balatz *et al.*, Z. Phys. C 61 (1994) 223.
D.V. Valvilov *et al.*, Phys. At. Nucl. 63 (2000) 1391.
Yu.M. Antipov *et al.*, Phys. At. Nucl. 65 (2002) 2070.

$\Sigma^0(1385)K^+ \Leftrightarrow \Phi p$

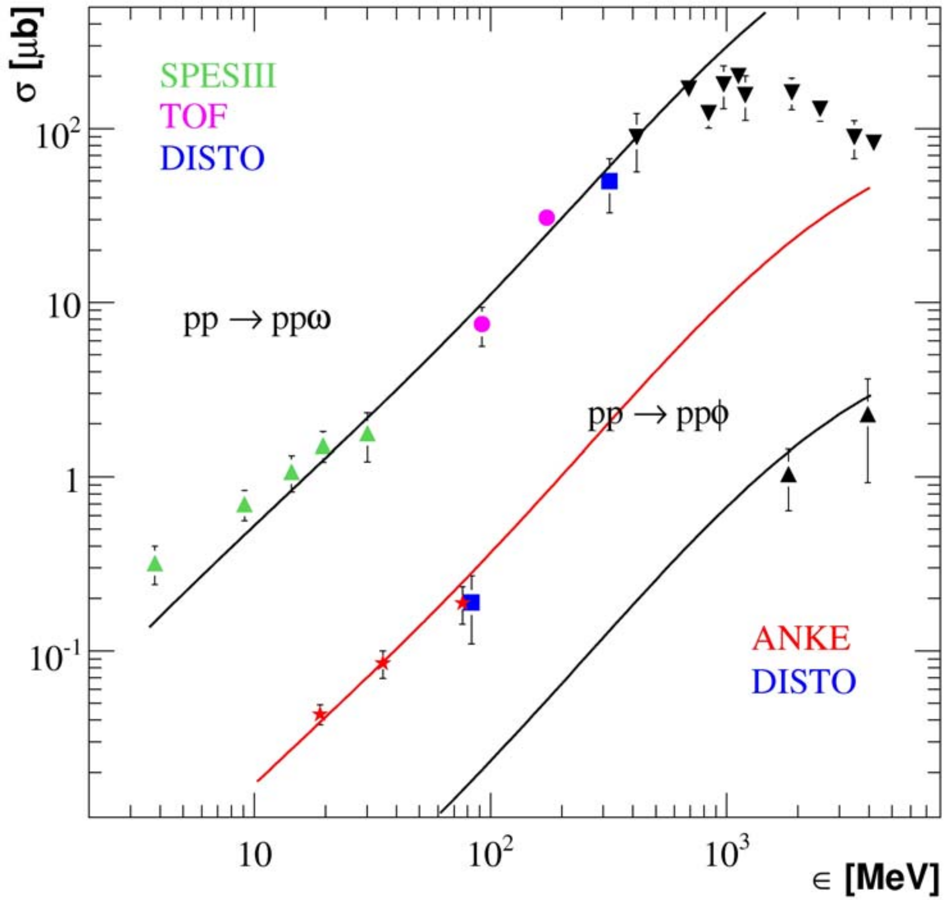


Energy dependence of ϕ production

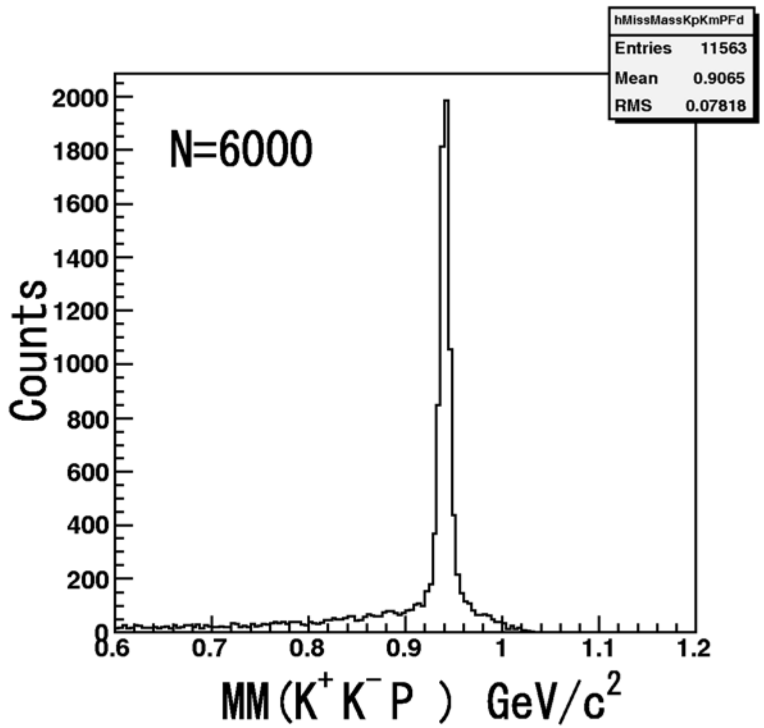
$$\sigma(\epsilon) = \frac{\sqrt{m_N^2 m_\omega}}{2^7 \pi^2 (2m_N + m_\omega)^{3/2}} \frac{\epsilon^2}{\sqrt{s^2 - 4sm_N^2}} \times \left[1 + \frac{4\beta^2 - 4\alpha^2}{\left(-\alpha + \sqrt{\alpha^2 + m_N\epsilon}\right)^2}\right] |\mathcal{M}|^2,$$

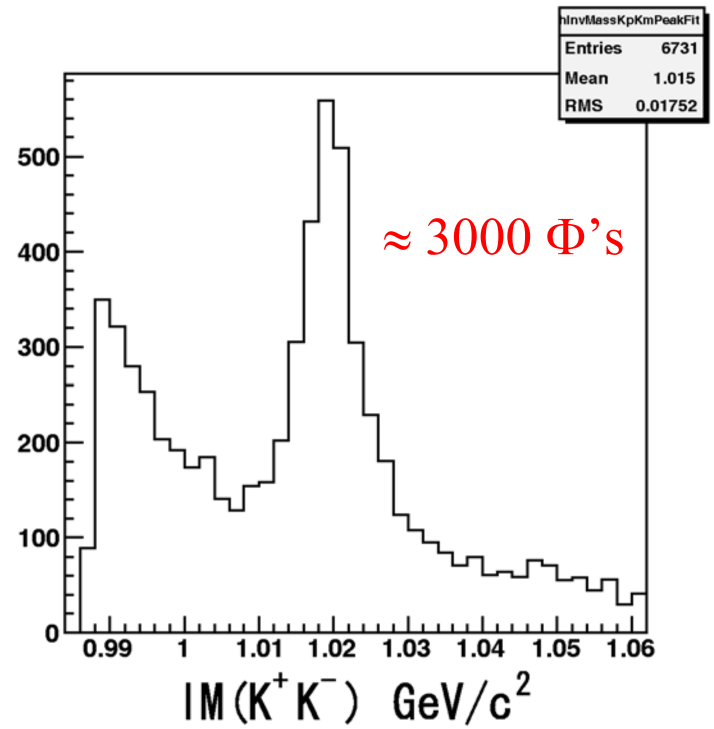
phase space + pp-FSI (means of Jost function)

A. Sibirtsev et al., Eur. Phys. J. A, (2006, in print).



ANKE: New ppΦ data with high statistics at ε=76 MeV

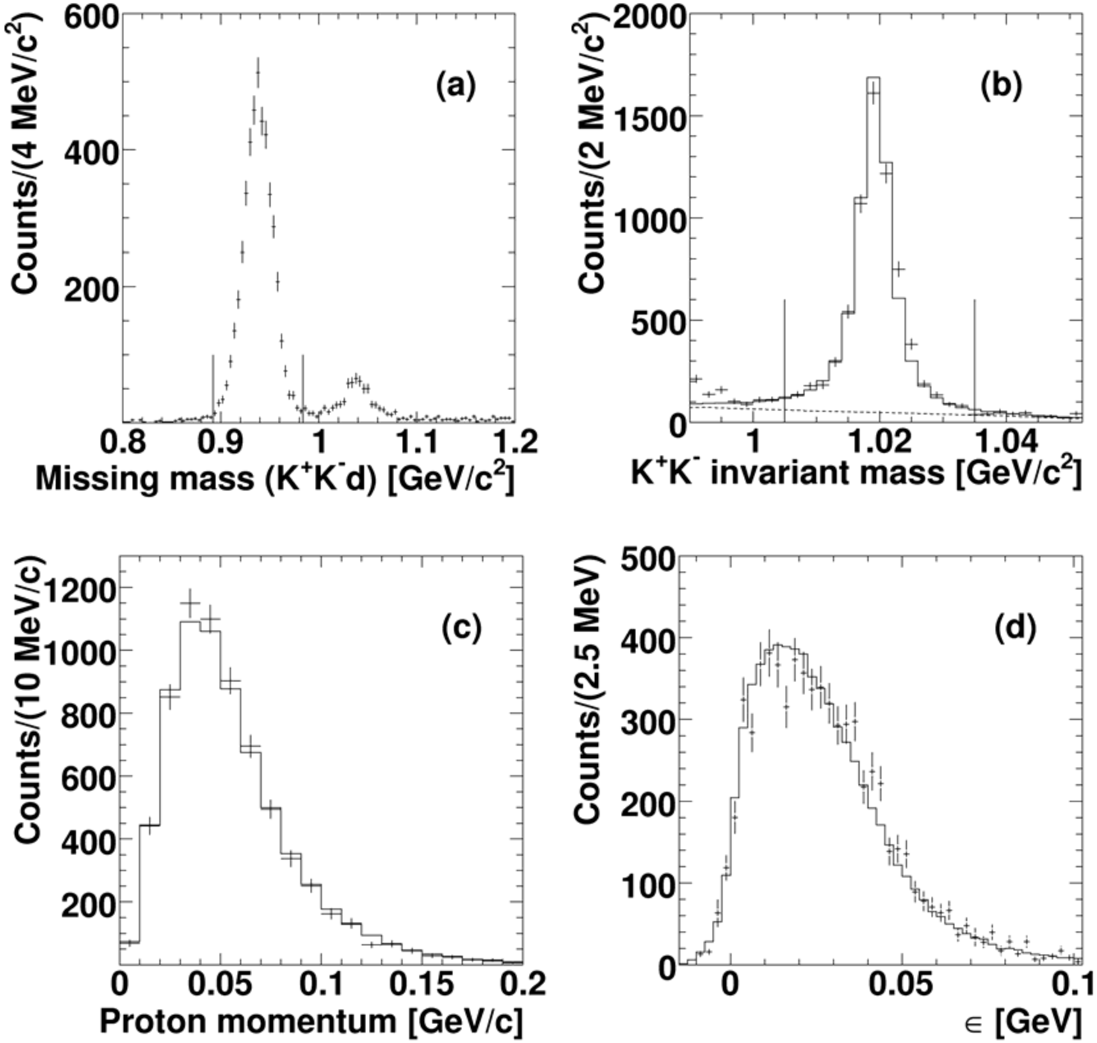




ε=75.9 MeV

analysis not finished yet!

ANKE: pn→dΦ (event selection)



$T_p = 2.65$ GeV

$pd \rightarrow d\Phi(K^+K^-)p_{spectator}$

$pn \rightarrow d\Phi(K^+K^-)$

Monte Carlo simulation:
Fermi momentum in the target deuteron derived from Bonn potential.

$\sigma_\varepsilon \approx 2$ MeV
extract cross section < 80 MeV

ANKE: pn→dΦ (differential cross sections)

1 S + 9 possible P-wave amplitudes !

				Ll_{J_q}
$^1P_1$	$\to$	$^3S_1$	s	Ss
$^3S_1$	$\to$	$^3S_1$	p	S^1p_0
$^3S_1$	$\to$	$^3S_1$	p	S^1p_1
$^3S_1$	$\to$	$^3S_1$	p	S^1p_2
$^3D_1$	$\to$	$^3S_1$	p	S^2p_0
$^3D_1$	$\to$	$^3S_1$	p	S^2p_1
$^3D_1$	$\to$	$^3S_1$	p	S^2p_2

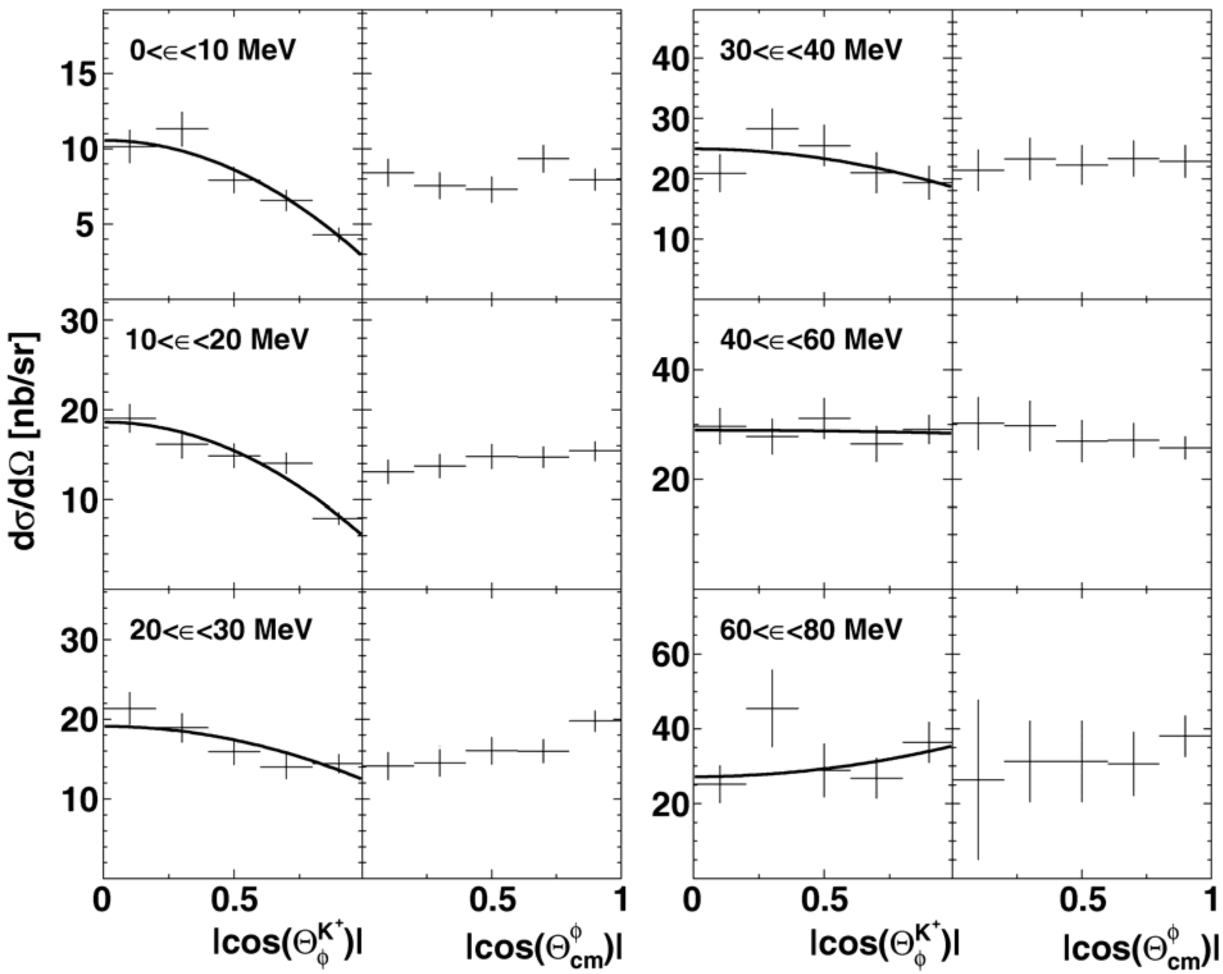
...

to allow for the possibility of higher partial waves …
most general form:

$d\sigma/d\Omega_\Phi^{K^+} = 3(a \sin^2\Theta_\Phi^{K^+} + 2b \cos^2\Theta_\Phi^{K^+})/8\pi$

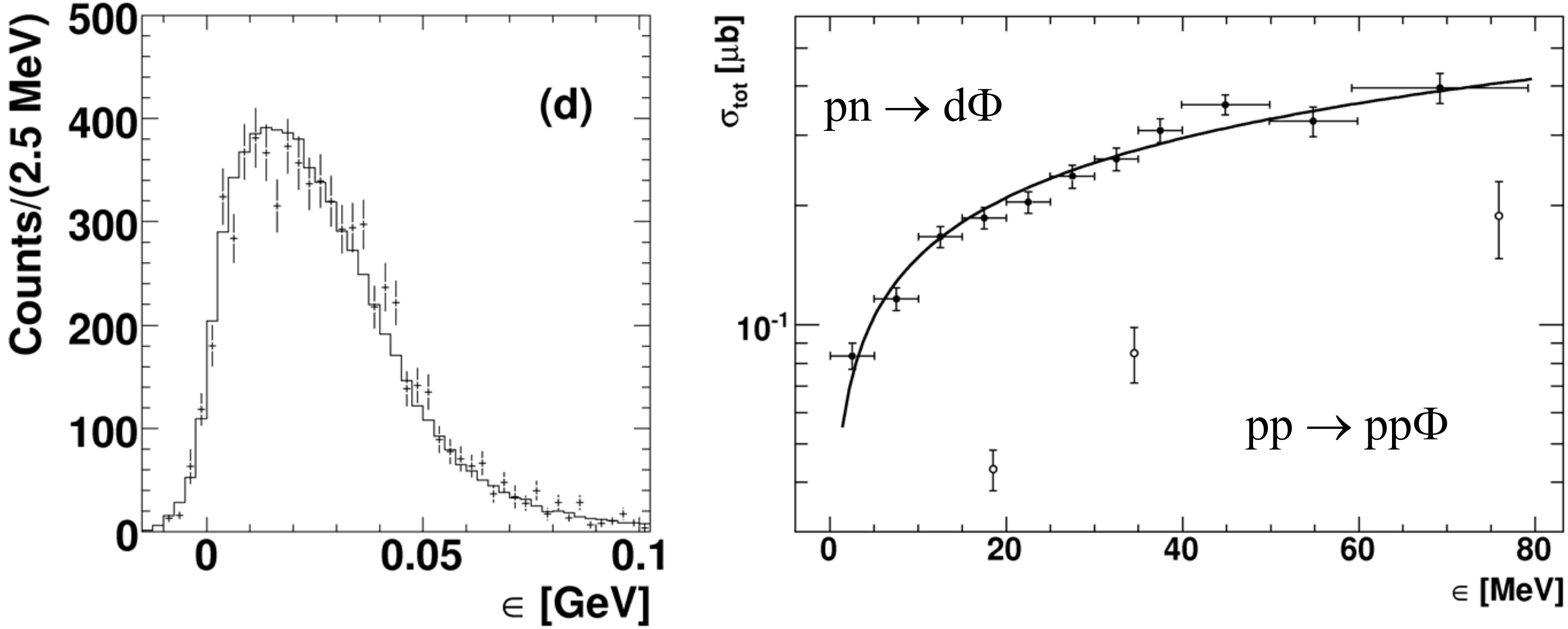
$\sigma_{tot} = a+b$

from fits to these data:
$b/a \approx (0.012 \pm 0.001)(\varepsilon/\mathrm{MeV})$



ANKE: pn→dΦ (differential and total cross sections)

Y. Maeda et al. (ANKE), paper ready!



using final-state-interaction theory (G. Faeldt and C. Wilkin, Phys. Lett. B. 382 (1996) 209).

$\sigma(pn\to pn\Phi)\,/\,\sigma(pp\to pp\Phi) \approx 2.3\pm0.4$

Summary and outlook

$pp \to pp\phi$ (ε=18.5, 34.5 and 75.9 MeV)

ε=18.5 MeV, S-wave production ($^3P_1 \to {}^1S_0$ transition)

clear pp-FSI (energy dependence)

OZI: $R_{\phi/\omega}$(18.5-79.5 MeV) $\approx (3.3\pm0.6)\times10^{-2} \approx 8\times$Rozi

$pn \to d\phi$ (Tp=2.65 GeV, ε up to 80 MeV)

σ_{tot} phase-space energy dependence

P-wave contribution already at low energy

OZI: $R_{\phi/\omega}$ ($\approx$ 60 MeV) $\approx (4.0\pm1.9)\times10^{-2} \approx 9\times$Rozi

S. Barsov et al. (ANKE), Eur. Phys. J. A 21 (2004) 521.

new $pp \to pp\phi$ data at ε=75.9 MeV ($\approx$ 3000 Φ's)

higher partial wave contribution ??