Generalized Dalitz Plot analysis of the near threshold $pp \rightarrow ppK^+K^-$ reaction in view of the K^+K^- interaction

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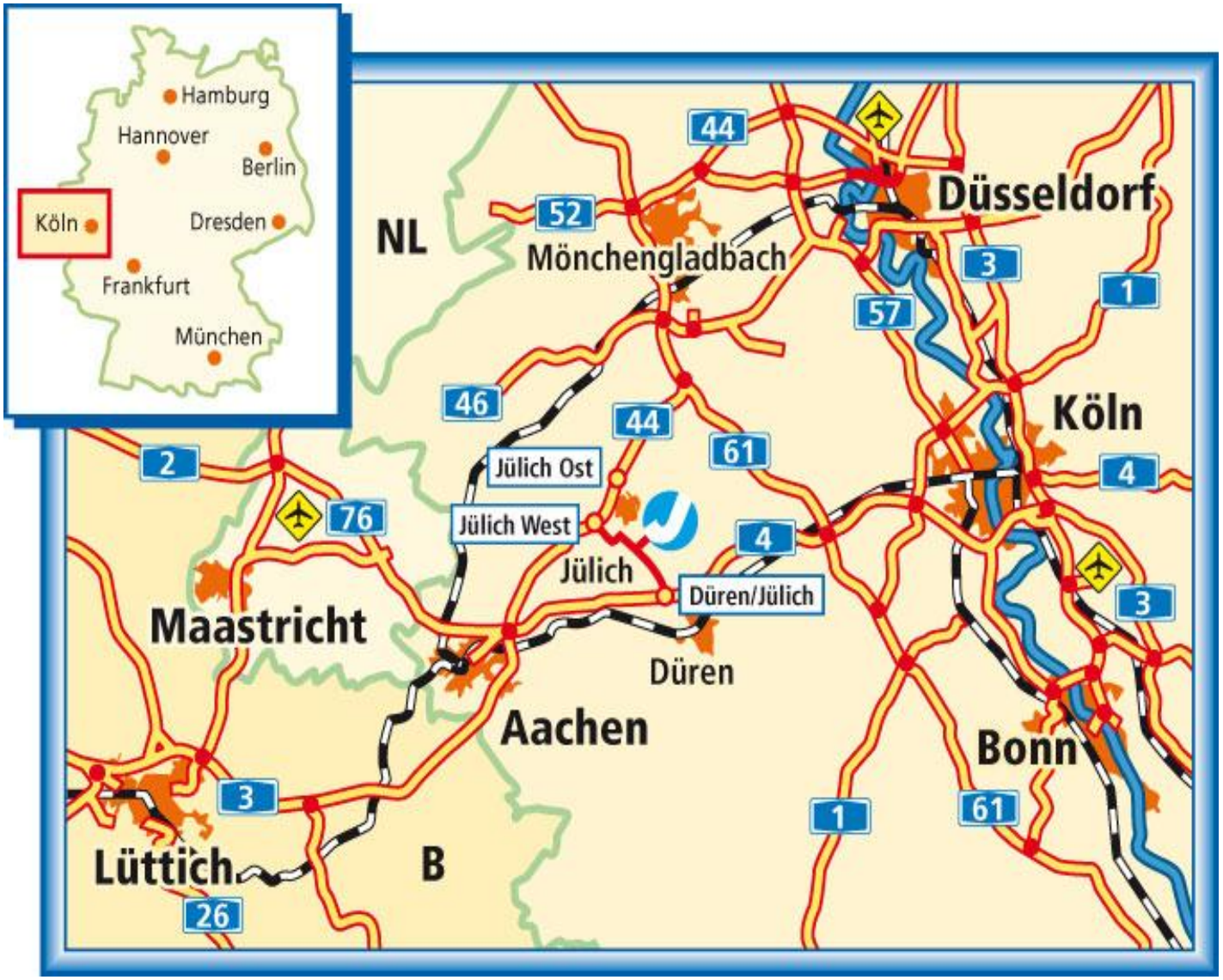
Excited QCD, Stara Lesna, 4th February 2010

Outline

- Physical motivation
- Measurements of the $pp \rightarrow ppK^+K^-$ reaction with COSY-11
- Study of the proton-kaon and kaon-antikaon interactions
  - differential cross sections at excess energy Q = 10 MeV and Q = 28 MeV
  - Generalization of the Dalitz Plot
  - Analysis of the K^+K^- final state interaction
- Summary

Physical motivation

- a_0 and f_0 mesons as a K^+K^- molecules
- Nature of $\Lambda(1405)$ – K^-p bound state (?)
- Mechanism of the $pp \rightarrow ppK^+K^-$ reaction
- Physics of heavy ion collisions
- Physics of neutron stars: kaon condensates


Hamburg
Hannover
Berlin
Köln
Dresden
Frankfurt
München
NL
Mönchengladbach
Düsseldorf
Köln
Bonn
Jülich Ost
Jülich West
Jülich
Düren/Jülich
Düren
Maastricht
Aachen
Lüttich
B
44
52
3
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2
76
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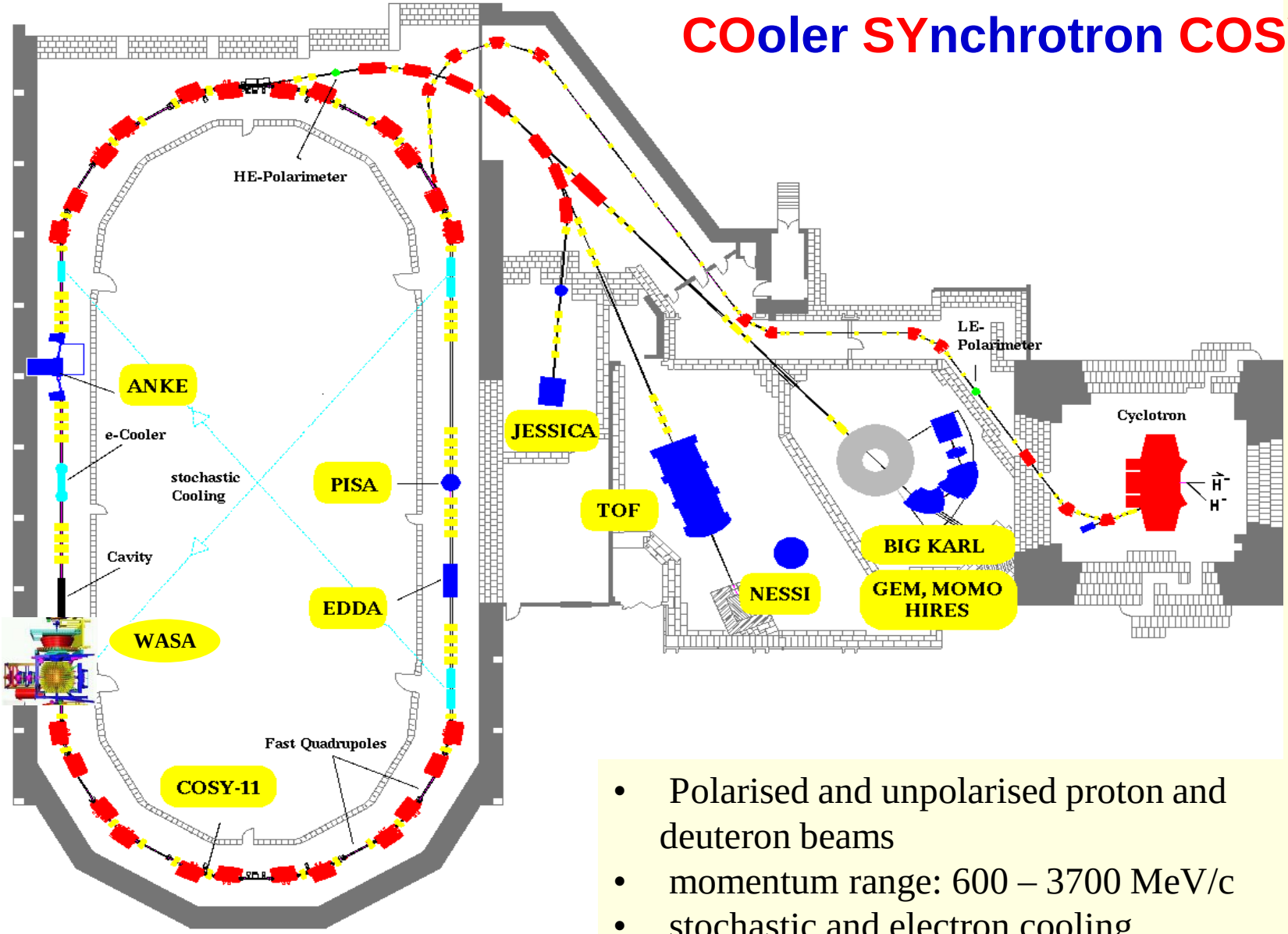
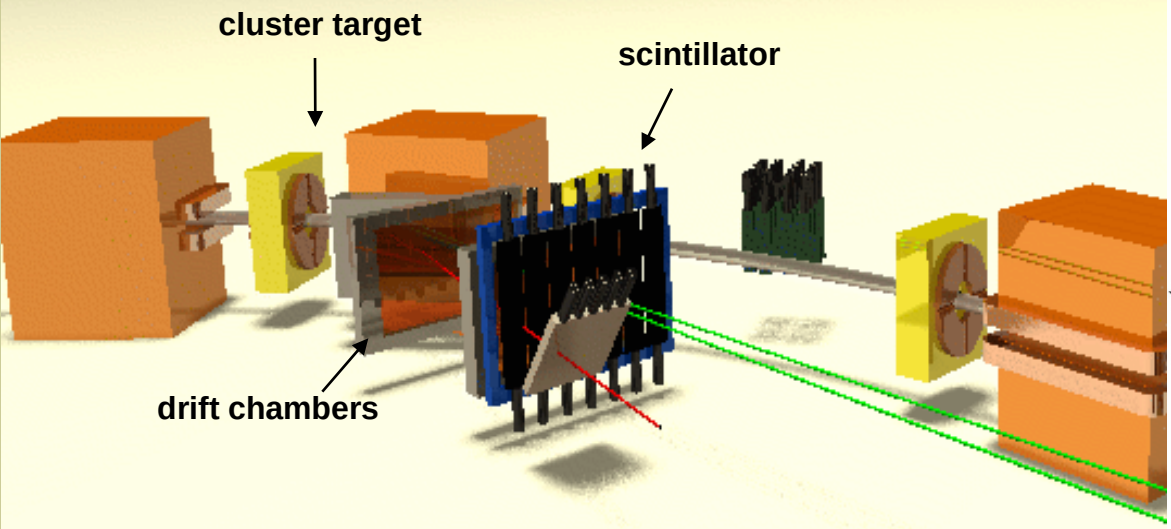
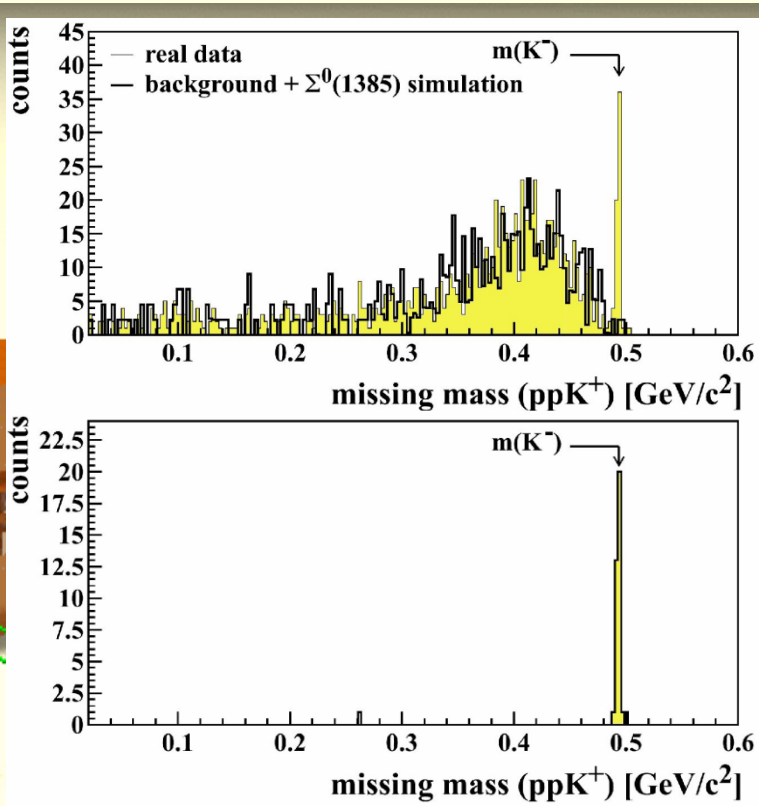
61
26

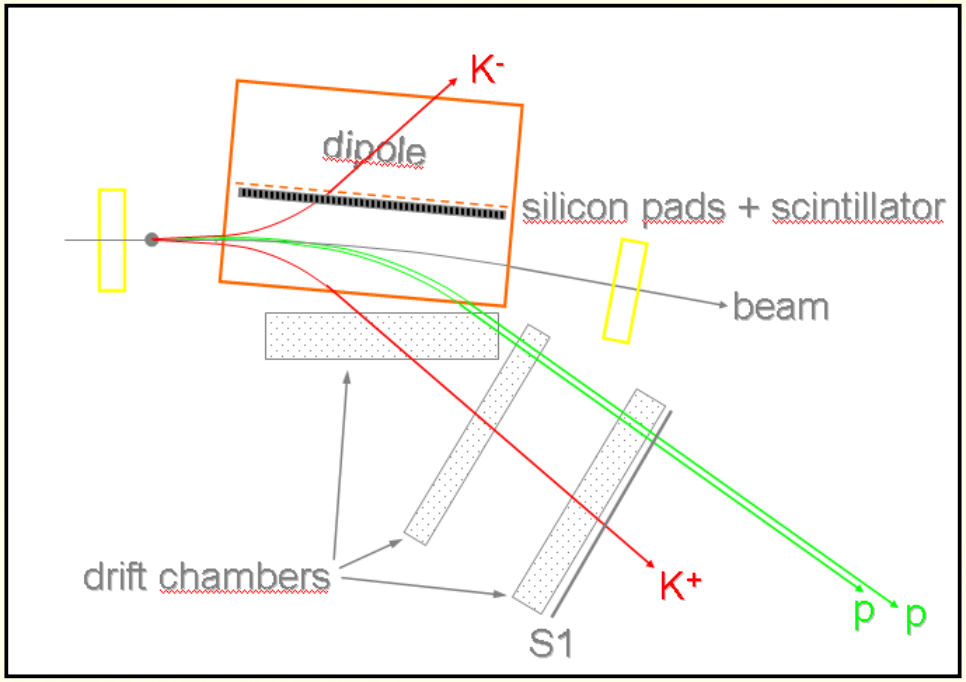
COoler SYnchrotron COSY

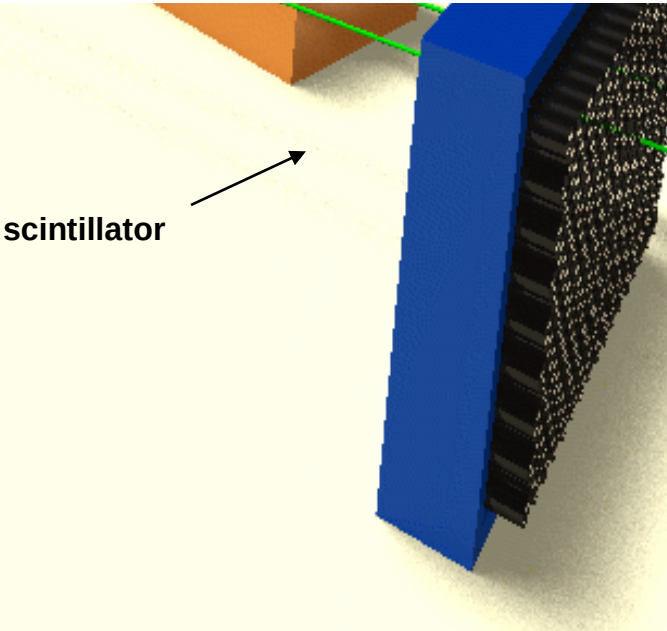


- Polarised and unpolarised proton and deuteron beams
- momentum range: 600 – 3700 MeV/c
- stochastic and electron cooling
- meson production up to $\phi(1020)$


cluster target
scintillator
drift chambers


counts
real data
background + Σ0(1385) simulation
m(K-)
missing mass (ppK+) [GeV/c2]
counts
m(K-)
missing mass (ppK+) [GeV/c2]


K-
dipole
silicon pads + scintillator
beam
drift chambers
K+
p
p
S1


scintillator

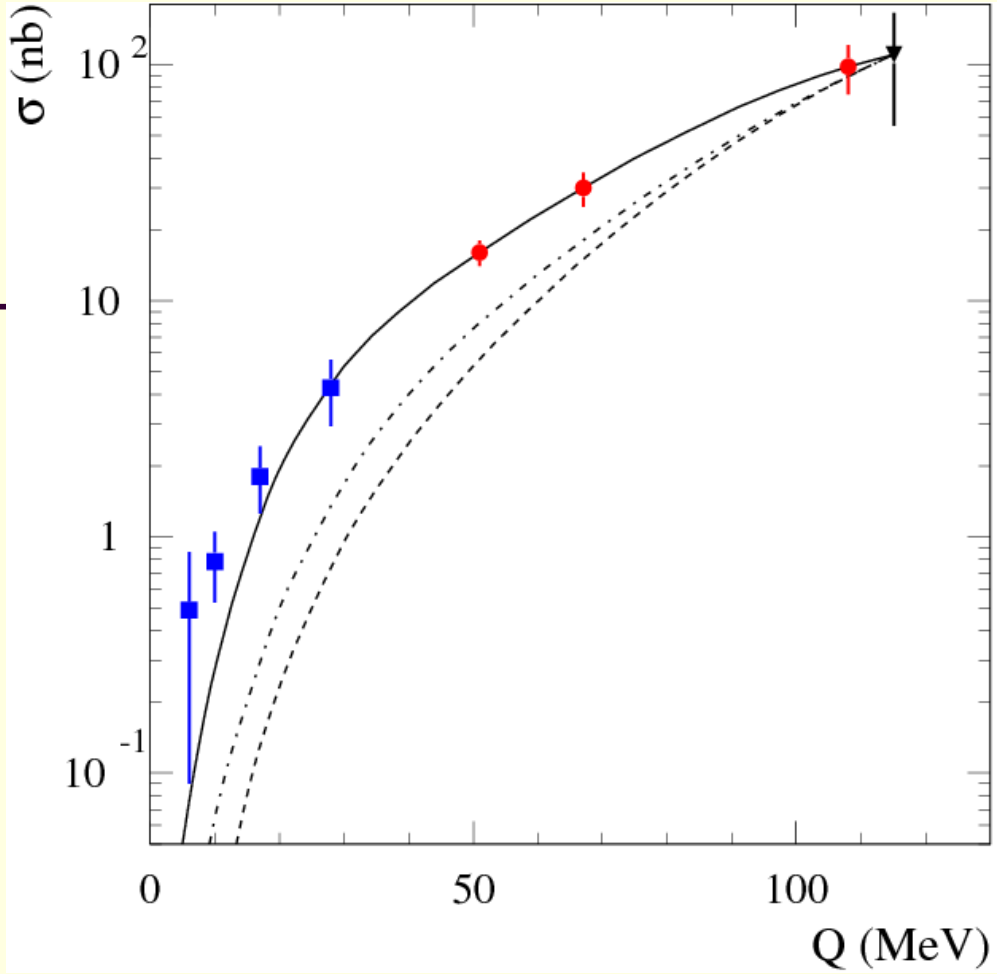
$$\left|M_{pp\to ppK^+K^-}\right|^2 \approx \left|M_0\right|^2 \left|F_{FSI}\right|^2$$

$$F_{FSI} = F_{pp}(q) \times F_{p_1K^-}(k_1) \times F_{p_2K^-}(k_2)$$

$$F_{pp}(q) = \frac{e^{-i\delta_{pp}(^1S_0)} \times \sin\delta_{pp}(^1S_0)}{C \times q}$$

$$F_{pK^-}(k) = \frac{1}{1 - ika}$$

$$a = (0 + i1.5)[\text{fm}]$$



COSY-11: C. Quentmeier et al., Phys.Lett. B 515 (2001) 276-282

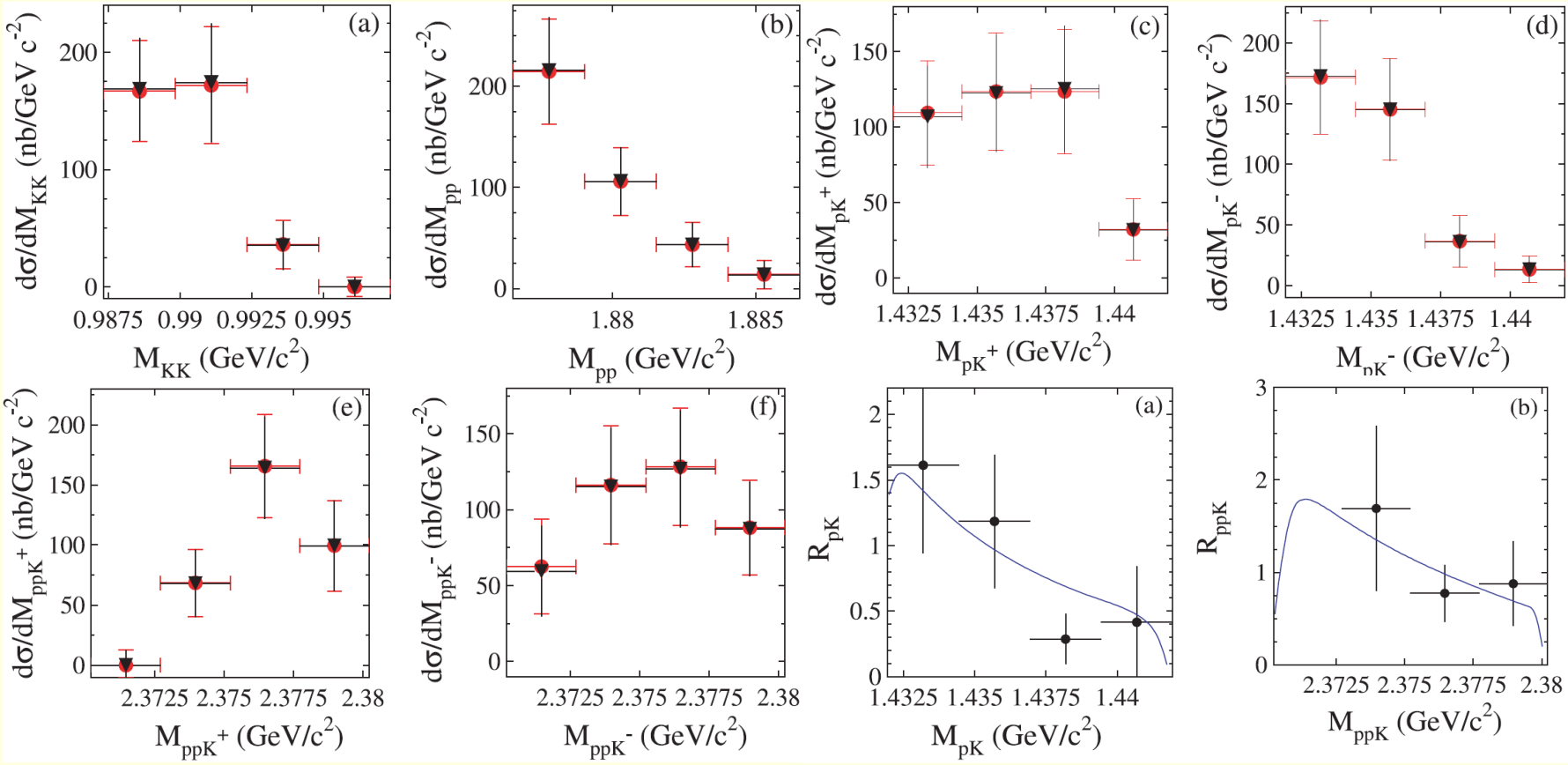
COSY-11: P. Winter et al., Phys. Lett. B 635 (2006) 23-29

COSY-11: M. Wolke, PhD thesis

DISTO: F. Balestra et al.., Phys. Rev. C 63, 024004 (2001)

ANKE: Y.Maeda et al. Phys., Rev. C 77, 01524 (2008)

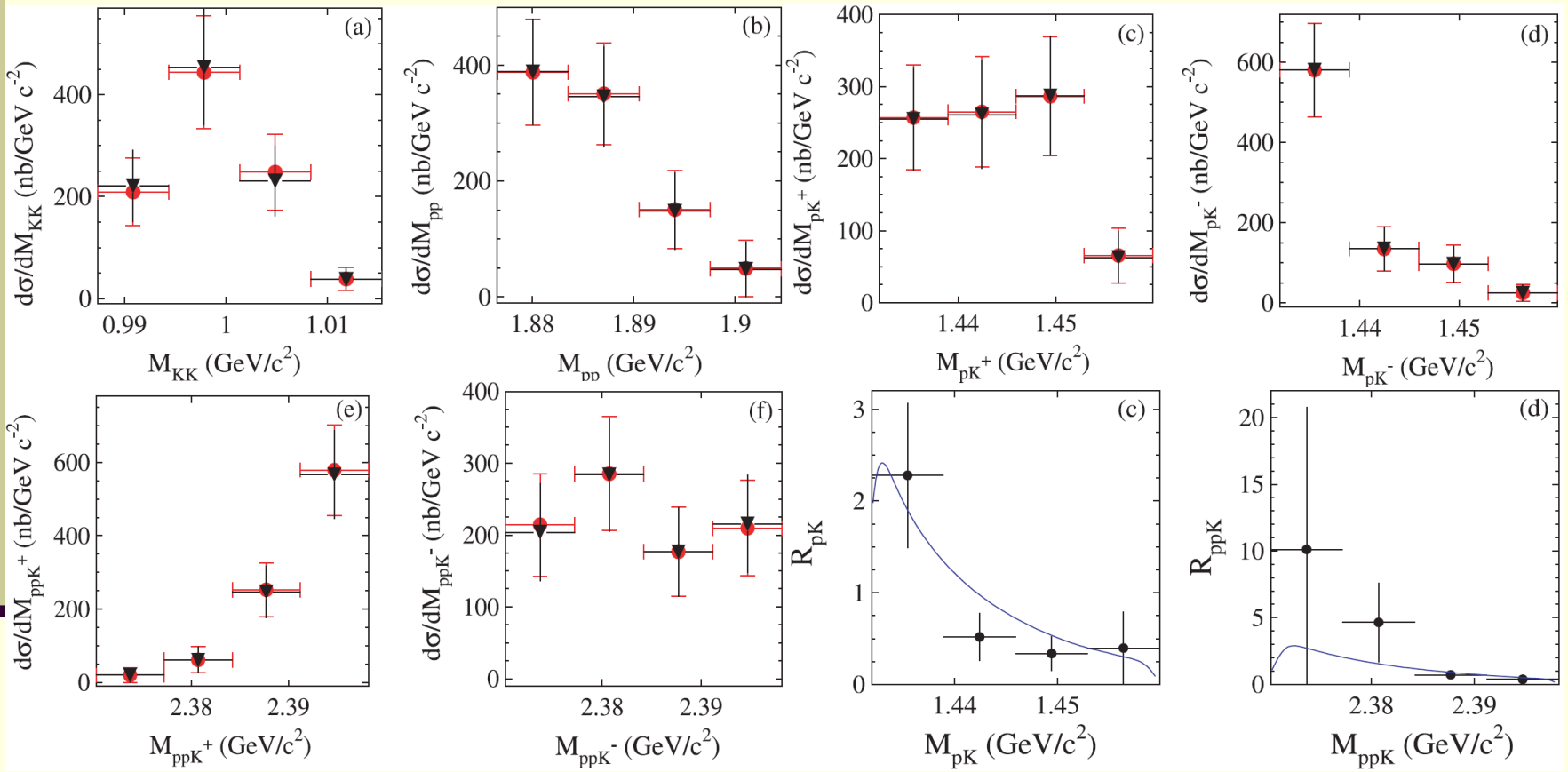
Differential cross sections for the $pp \to ppK^+K^-$ reaction at Q = 10 MeV



$\sigma_{tot} = 0.95 \pm 0.17$ nb

$$R_{pK} = \frac{d\sigma/dM_{pK^-}}{d\sigma/dM_{pK^+}}; \qquad R_{ppK} = \frac{d\sigma/dM_{ppK^-}}{d\sigma/dM_{ppK^+}}$$

Differential cross sections for the $pp \to ppK^+K^-$ reaction at Q = 28 MeV



$\sigma_{tot} = 6.5 \pm 1.1$ nb

$$R_{pK} = \frac{d\sigma/dM_{pK^-}}{d\sigma/dM_{pK^+}}; \qquad R_{ppK} = \frac{d\sigma/dM_{ppK^-}}{d\sigma/dM_{ppK^+}}$$

Generalization of the Dalitz Plot

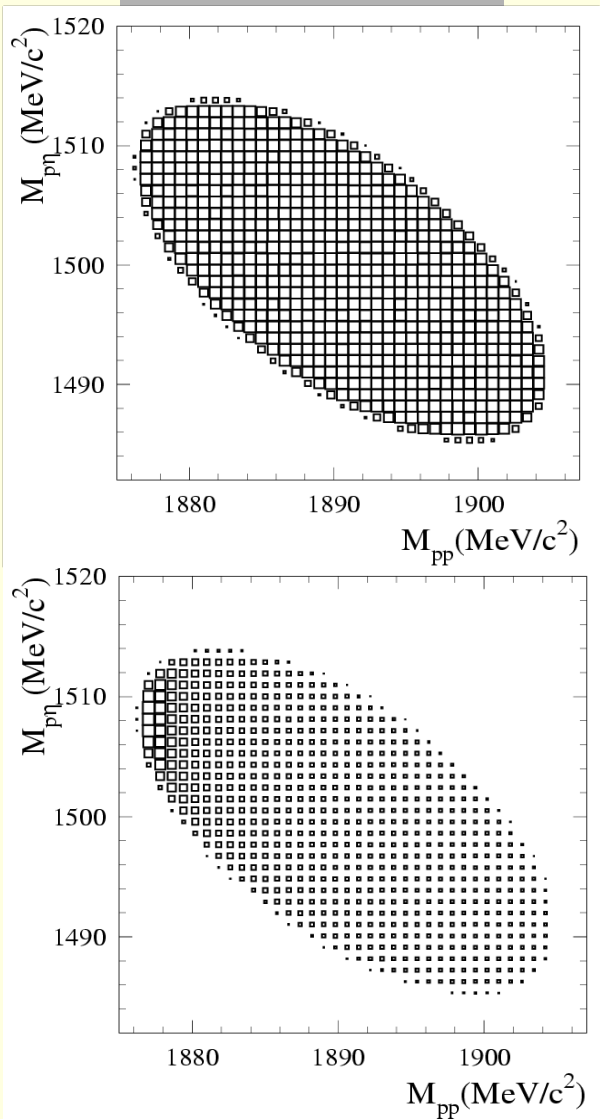
- Event representation: interior of a equilateral triangle

$$\sqrt{s} = E_1 + E_2 + E_3$$

$$dE_i dE_j = \frac{1}{4s} dM_{jk}^2 dM_{ki}^2$$

$$M_{jk}^2 = \left(E_j + E_k\right)^2 - \left(p_j + p_k\right)^2$$

Final state interaction: modification of the homogeneous event distribution



Generalization of the Dalitz Plot

- Probability of reaction yielding a state with the *i*-th particle in momentum range $d\mathrm{p}_i$ (in CM):

$$d^{12}R = d^3p_1 d^3p_2 d^3p_3 d^3p_4 \frac{1}{16E_1E_2E_3E_4}\delta^3\left(\sum_j \vec{p}_j\right)\delta\left(\sum_j E_j - \sqrt{s}\right) f^2$$

- Assuming that f depends only on invariant masses of the particles one obtains (**Nyborg et al. Phys. Rev. 140 922 (1965)**):

$$d^5R = f^2 \frac{\pi^2}{8s\sqrt{-B}} dM_{12}^2 dM_{14}^2 dM_{34}^2 dM_{124}^2 dM_{134}^2$$

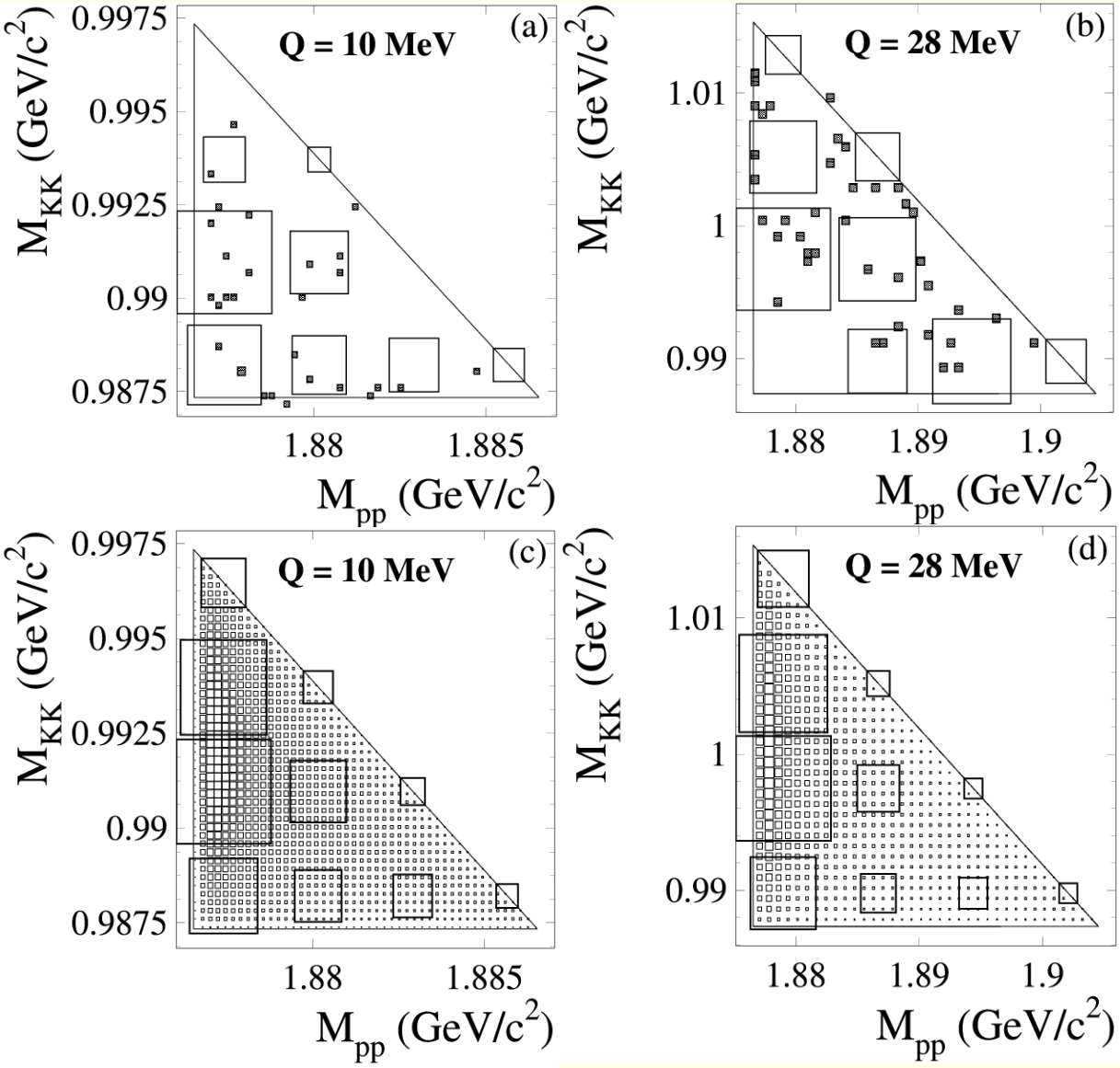
$$B = B\left(M_{12}^2, M_{14}^2, M_{34}^2, M_{124}^2, M_{134}^2, m_1^2, m_2^2, m_3^2, m_4^2, s\right)$$

Analysis of the K^+K^- final state interaction

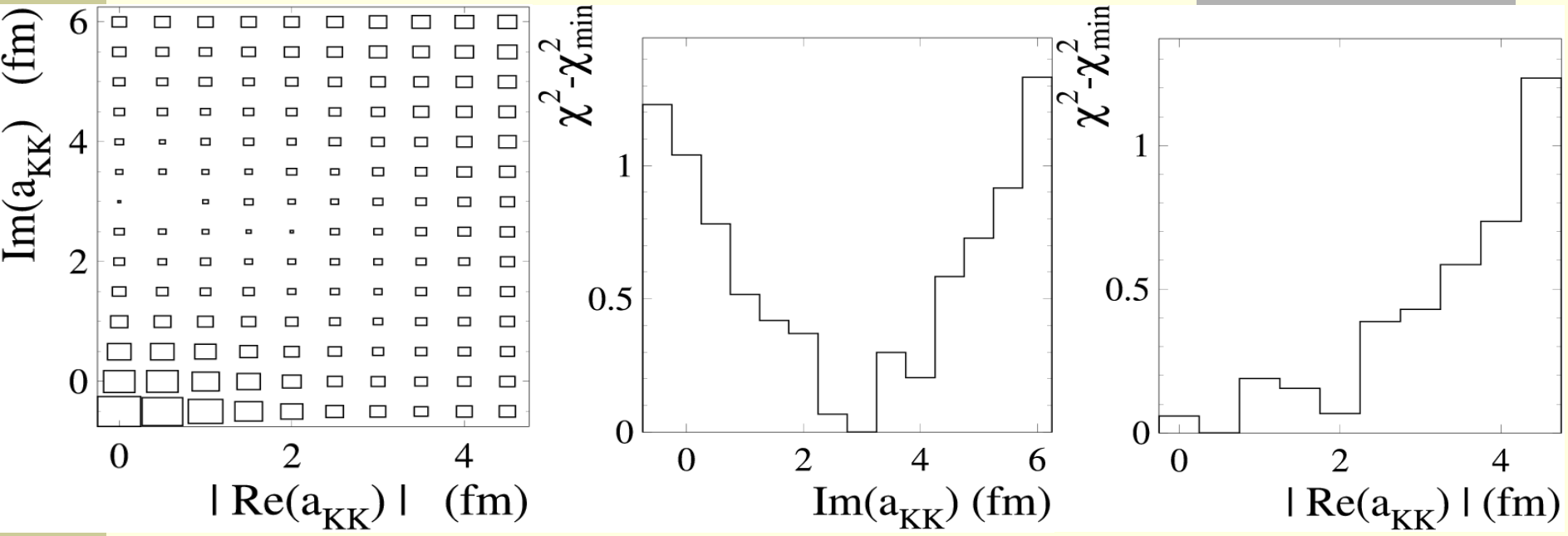
$$\left|M_{pp\to ppK^+K^-}\right|^2 \approx \left|M_0\right|^2 \left|F_{FSI}\right|^2$$

$$F_{FSI} = F_{pp}(q)\times F_{p_1K^-}(k_1)\times$$
$$\times F_{p_2K^-}(k_2)\times F_{K^+K^-}(k_3)$$

$$F_{K^+K^-}(k_3) = \frac{1}{1-ik_3 a_{K^+K^-}}$$



Analysis of the K^+K^- final state interaction



$$\chi^2\left(a_{K^+K^-},\alpha\right)=2\sum_i\left[\alpha N_i^s-N_i^e+N_i^e\ln\left(\frac{N_i^e}{\alpha N_i^s}\right)\right]$$

$$a_{K^+K^-}=\left[\left(0.5^{+4}_{-0.5}\right)+i\left(3\pm3\right)\right]\text{fm}$$

Phys. Rev. C 80, 045202 (2009)

Summary

- Shape of the excitation function for the near threshold $pp \rightarrow ppK^+K^-$ reaction reveal a significant enhancement which may be plausibly assigned to the influence of the pK^- or K^+K^- interaction
- Calculations which take into account the proton-proton and proton-kaon interactions underestimate experimental data very close to threshold
- Ansatz proposed by ANKE collaboration reproduces the experimental ratios R_{pK} R_{ppK} also at significantly lower enegies
- The estimated K^+K^-scattering length amounts to:

$$a_{K^+K^-} = \left[\left(0.5^{+4}_{-0.5}\right) + i(3 \pm 3)\right] \text{fm}$$

☺ Thank You for attention ☺