The Reaction pn→dω or "What I did at COSY"

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ISV Seminar, Uppsala, Feb. 18th 2005

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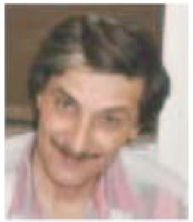

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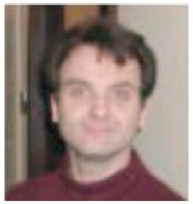

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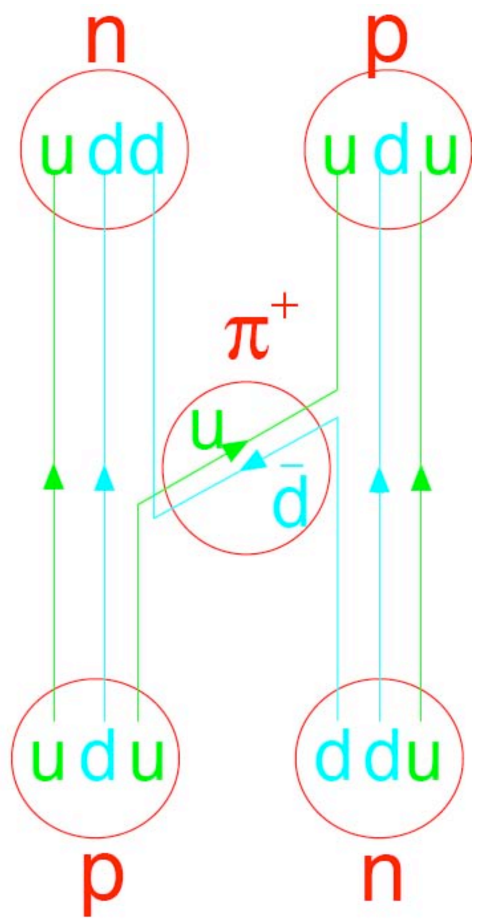
Strong Interactions

- high energies, < 10^{-15} m: gluon exchange
  - perturbative QCD calculations

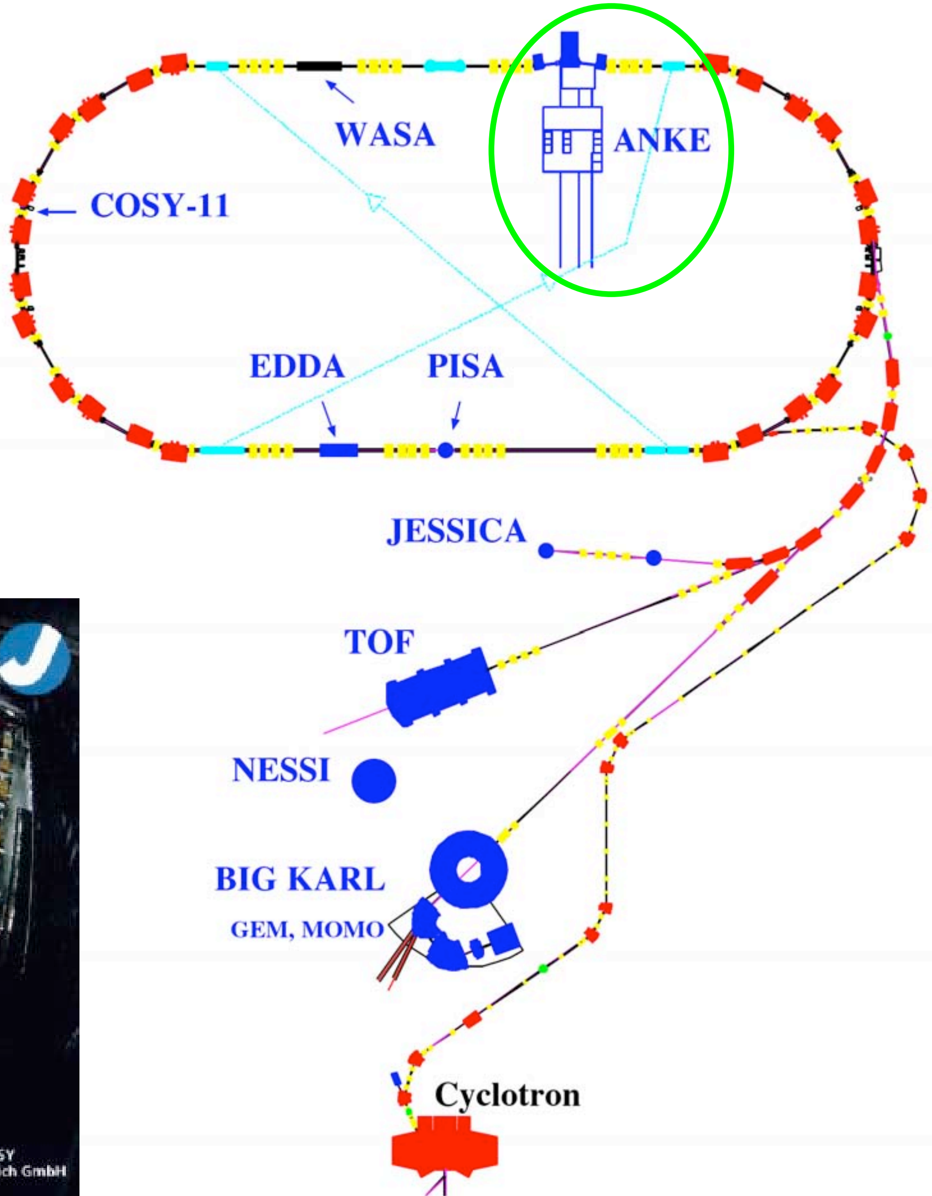
- moderate energies, $\geq 10^{-15}$ m
  - non-perturbative QCD

  $\Rightarrow$ meson exchange
  - effective description of nucleon-nucleon scattering at COSY energies



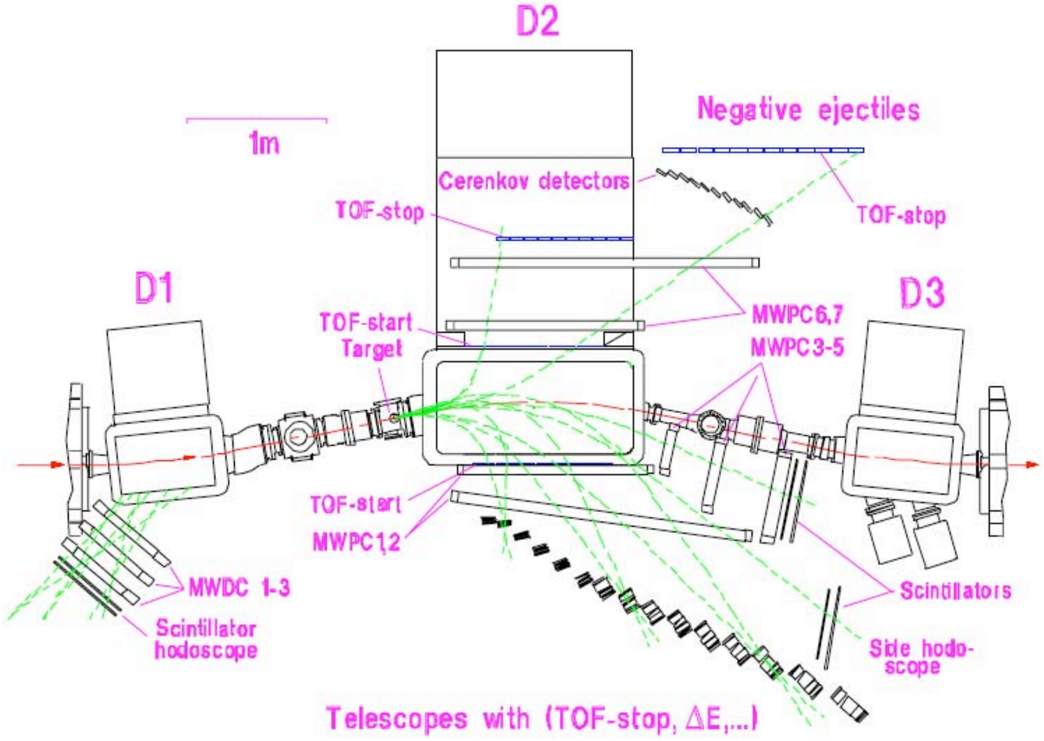
The Cooler Synchrotron COSY

- protons and deuterons up to 3.65 GeV/c
  - ϕ production



The ANKE Experiment

Apparatus for Studies of Nucleon and KaonEjectiles



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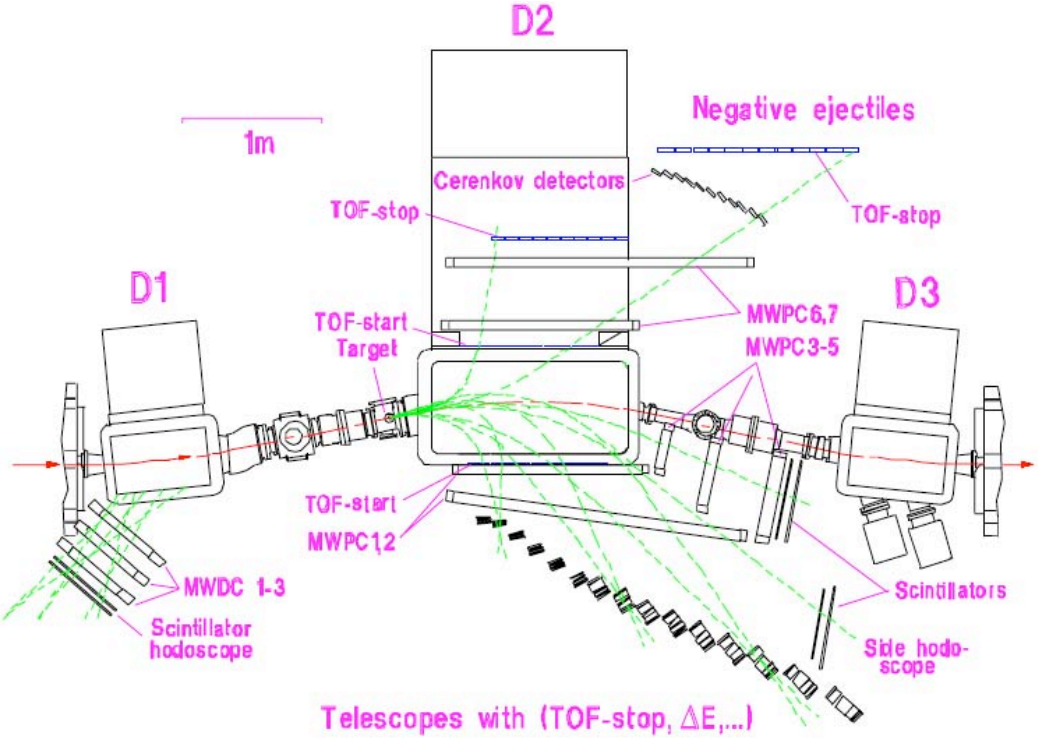
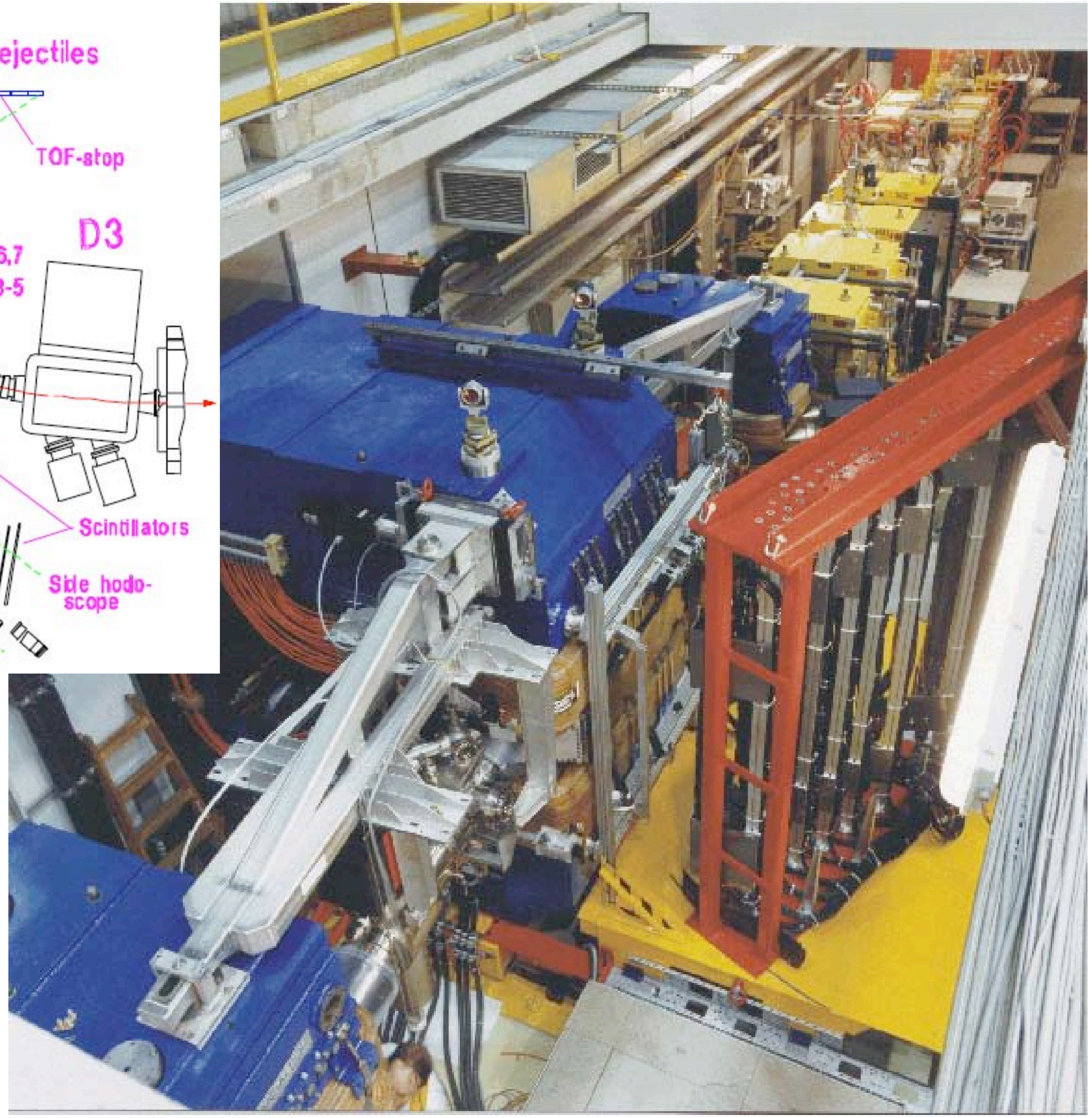
- 0 degree spectrometer
  - kaon identification

The ANKE Experiment

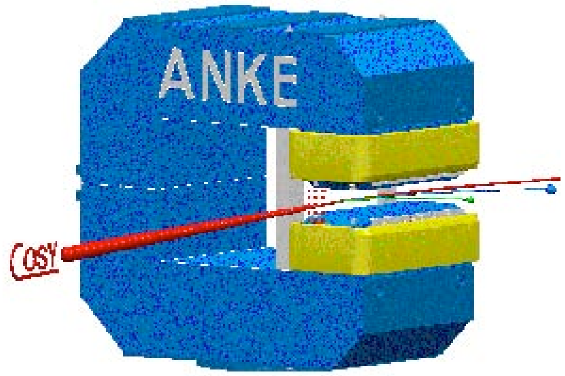
Apparatus for Studies of Nucleon and KaonEjectiles





- 0 degree spectrometer
  - kaon identification

Main Activities



Kaons in Medium

- subthreshold K^+ production
  - $pA \rightarrow K^+Y$; A=D,C,Cu,Au,Ag...
- K^+ correlation studies
  - $pA \rightarrow K^+(p,d,t)Y$; A=D,C,Cu,Au,Ag...

d break-up / charge exchange

- $pd \rightarrow n(pp)_S$

meson production close to threshold

- $dd \rightarrow \alpha\eta$
- nature of the a_0 and f_0
  - $pp \rightarrow da_0^+$; $pn \rightarrow da_0/f_0$
- comparison of isospin channels I=0,1
  - $pn \rightarrow dM$ / $pp \rightarrow ppM$; M = $\pi^0, \eta, \omega, \phi$

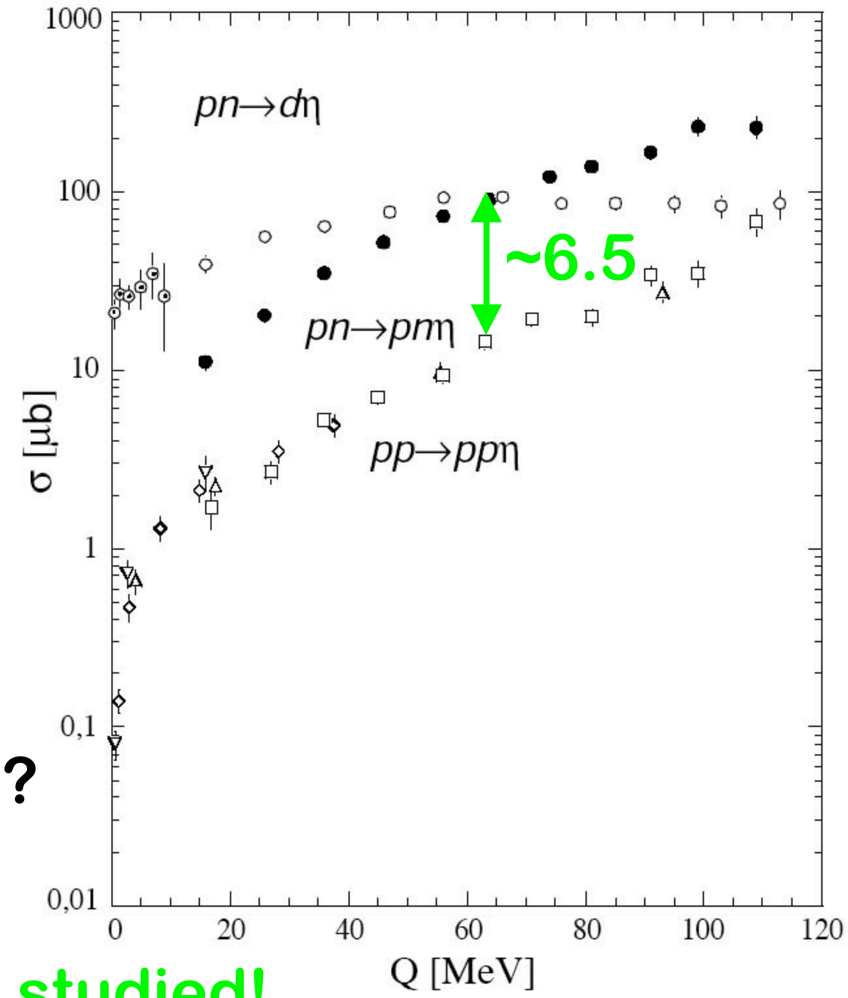
Motivation

- predictions for pure isovector exchange

$$\frac{\sigma_{tot}(pn \to pnM)}{\sigma_{tot}(pp \to ppM)} = 5$$

- agreement in the case of η production (WASA)

- Does this also hold in the case of ω production??

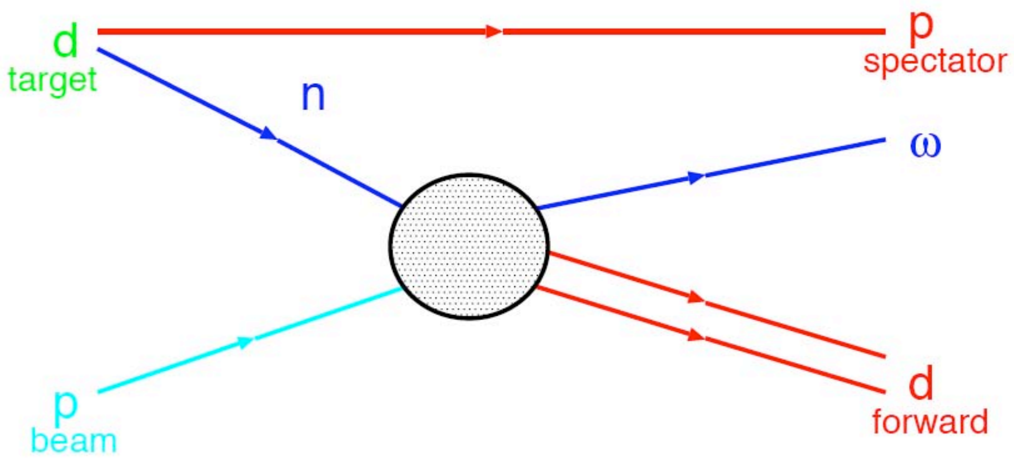


- Only pp→ppω has been studied!
  - measurements of pn→dω at ANKE!

Detection Principle

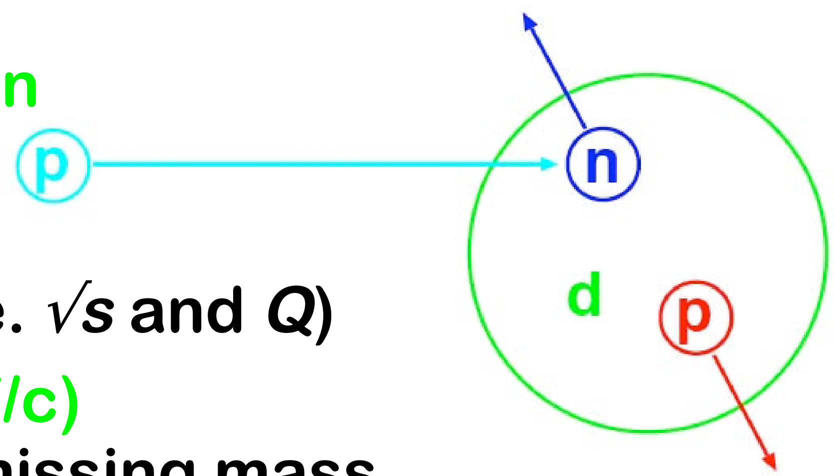
Idea

- measure pn→dω
  - using pd→p_{sp}dω

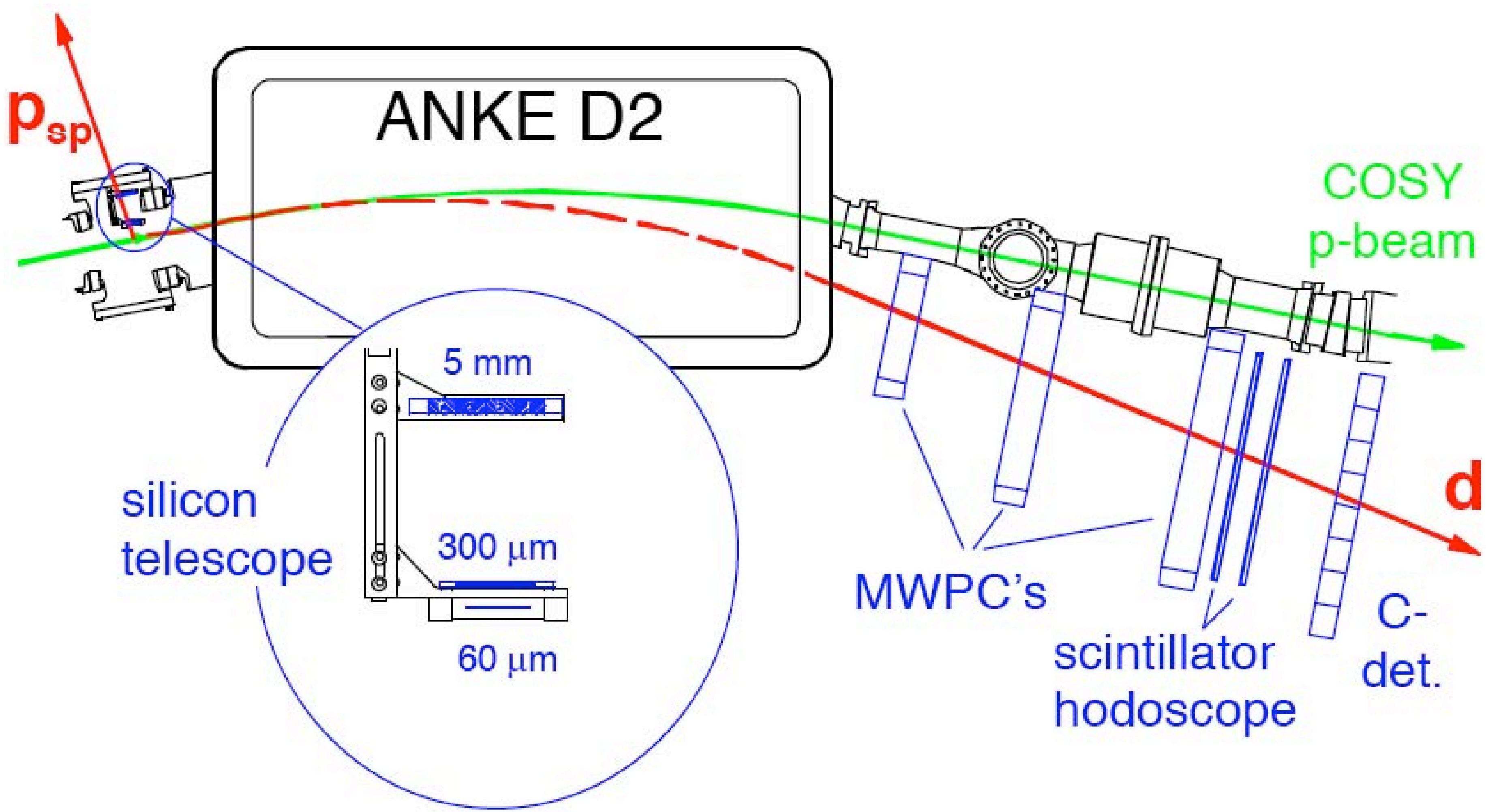


Method

- detect the "spectator" proton
  - reaction on an effective neutron target
  - fixed kinematics in pn (i.e. $\sqrt{s}$ and Q)
- detect the deuteron (~2 GeV/c)
  - Identify the ω meson by missing mass

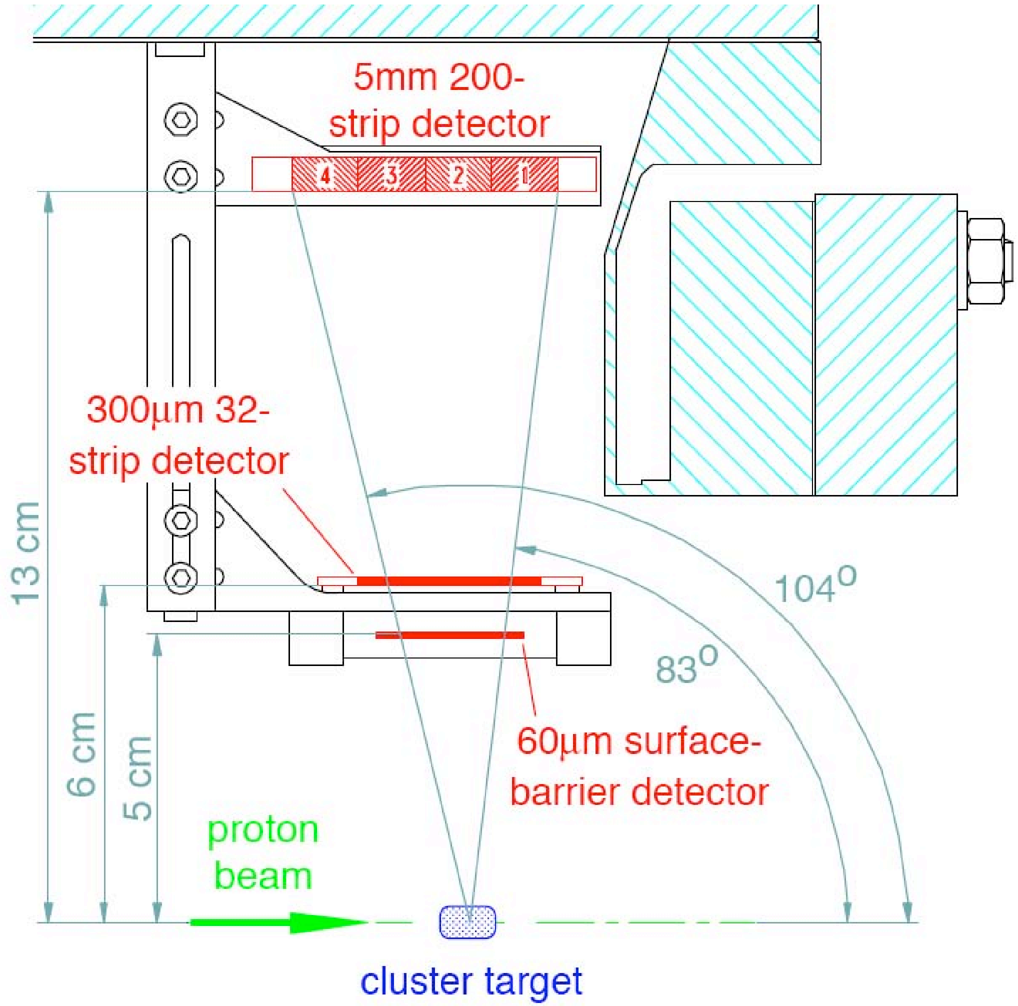


Experimental Set-Up

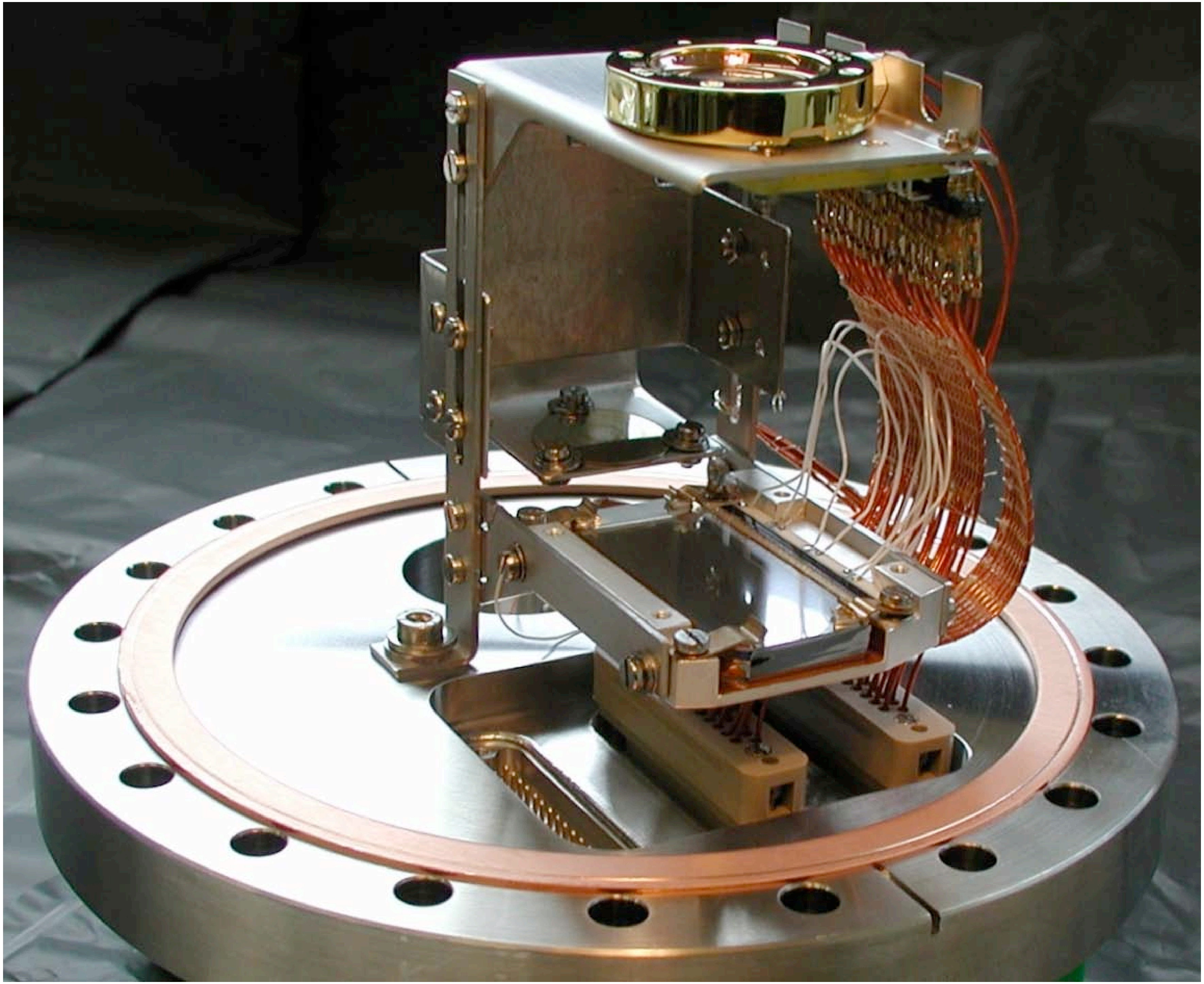


Silicon Telescope

- $\Delta E/E$ identification:
  - T_p = 2.6-4.4 MeV
  - T_p = 8-22 MeV

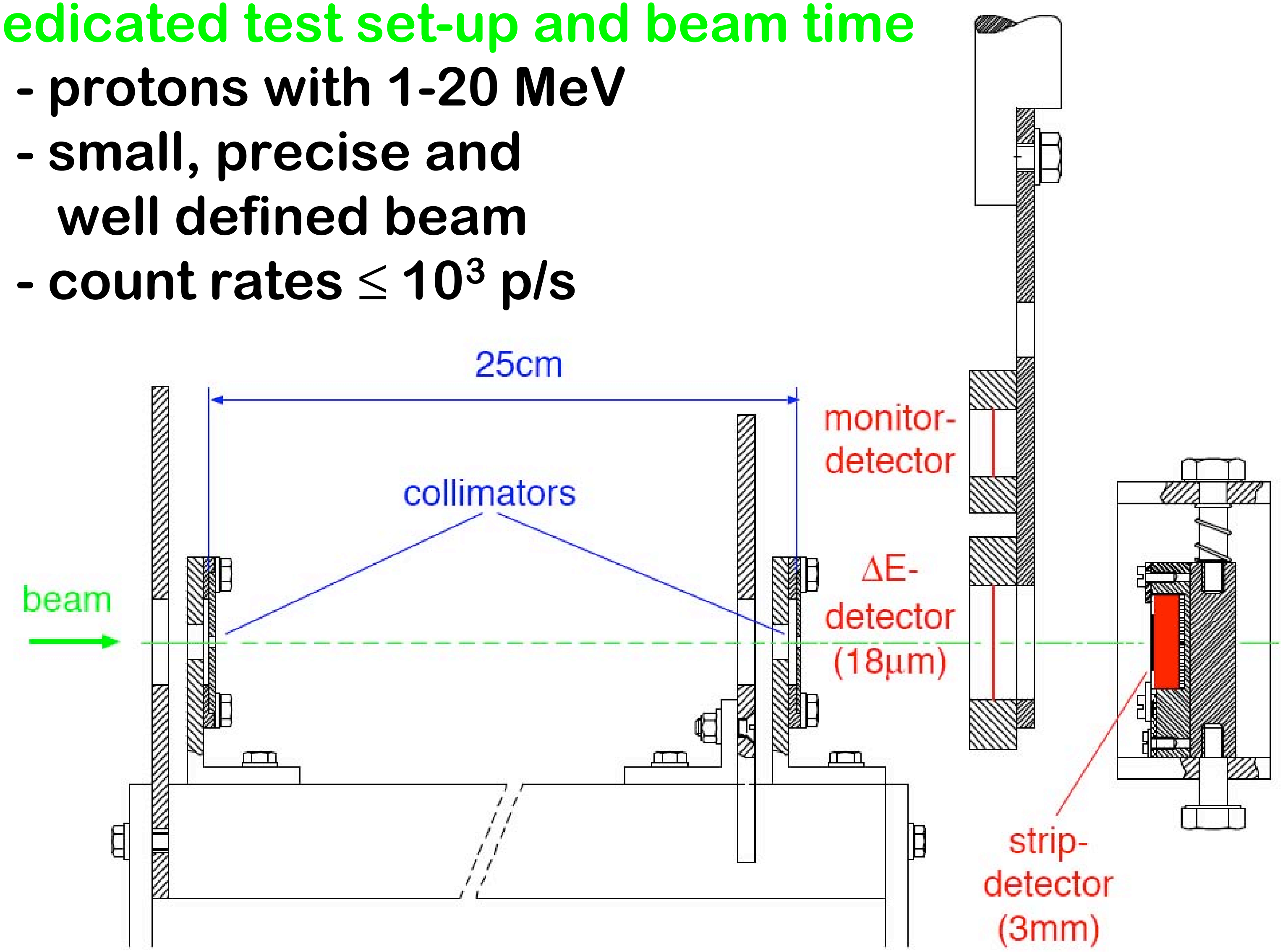


	1st layer	2nd layer	3rd layer
Silicon detector type	Surface barrier	Implanted	Lithium-drifted
Sensitive thickness	60.9 μm	306 μm	5.1 mm
Entrance window [Si-eqv.] (μm)	0.08	⩽1.5	⩽1
Exit window [Si-eqv.]	0.23 μm	⩽1.5 μm	⩽1 mm
Active area (mm^2)	450	32 × 15	47 × 23
Segmentation	1	32	200
Pitch	—	1 mm	235 μm
Noise (keV)	100	70	80



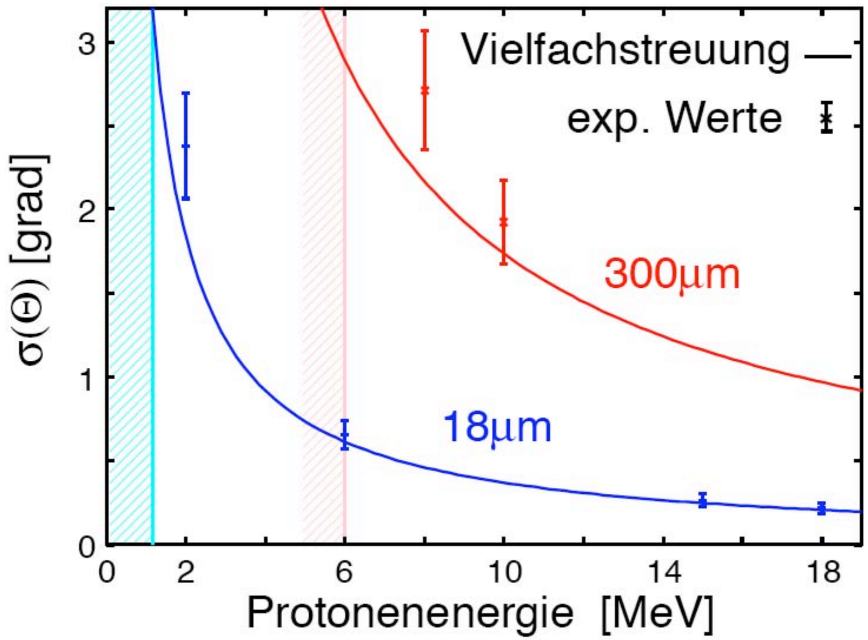
Detector Tests at the Cologne University

- dedicated test set-up and beam time
  - protons with 1-20 MeV
  - small, precise and well defined beam
  - count rates ≤ 10^3 p/s



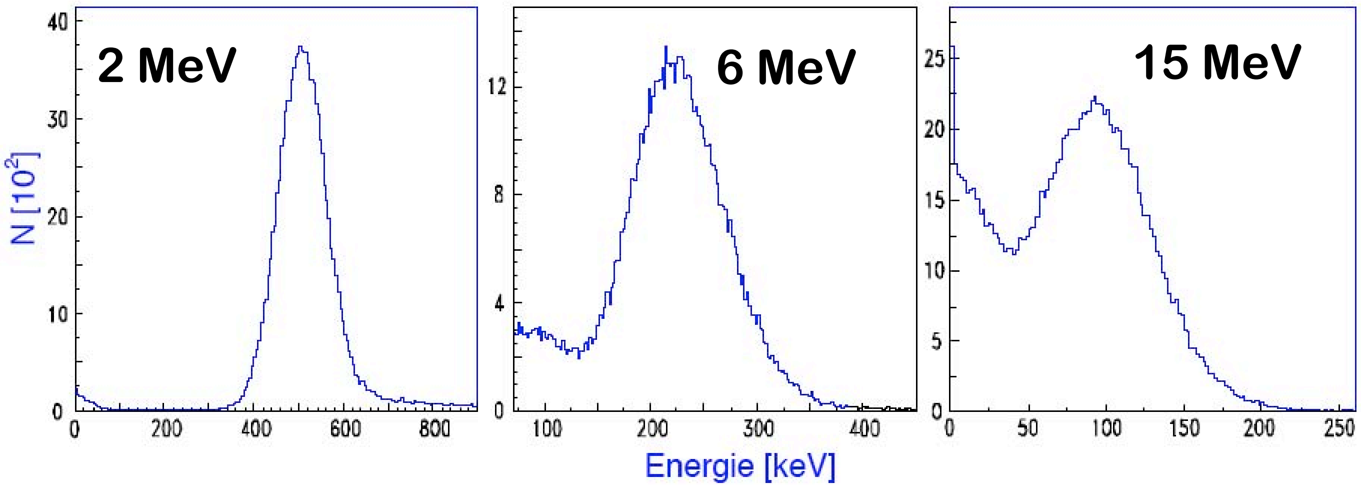
Some Results from Cologne

- angular resolution due to straggling in the 1^{st} (2^{nd}) layer



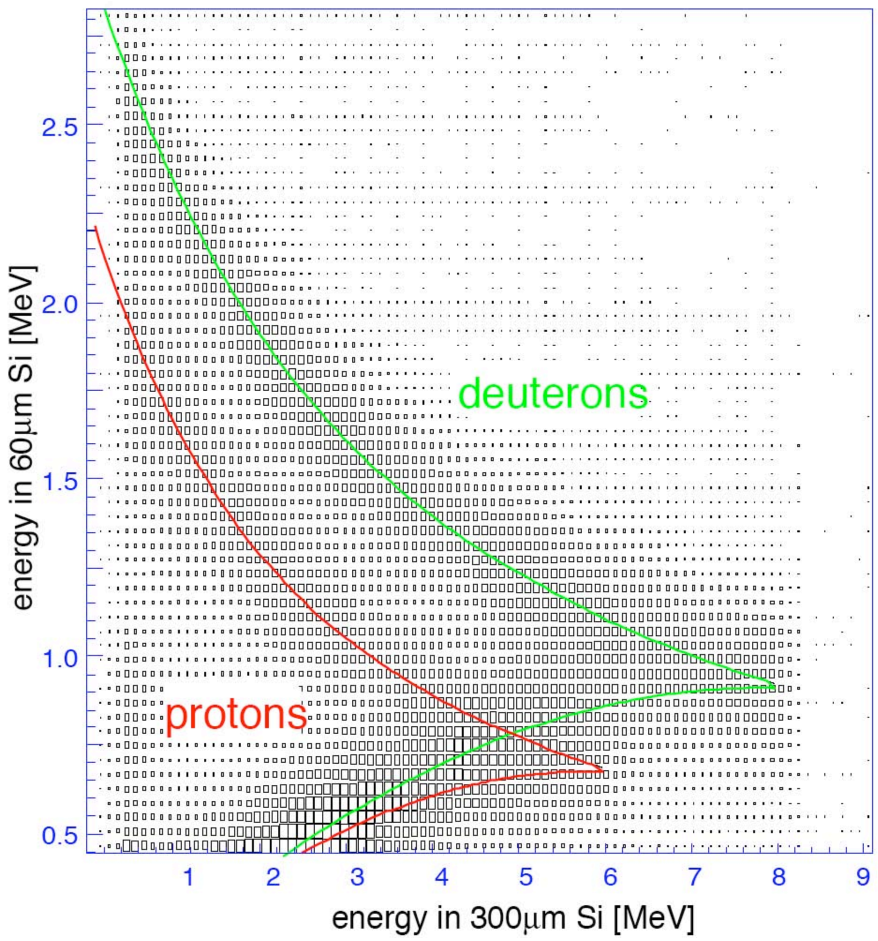
- energy resolution in 18 µm silicon

⇒ 1^{st} layer
60 µm

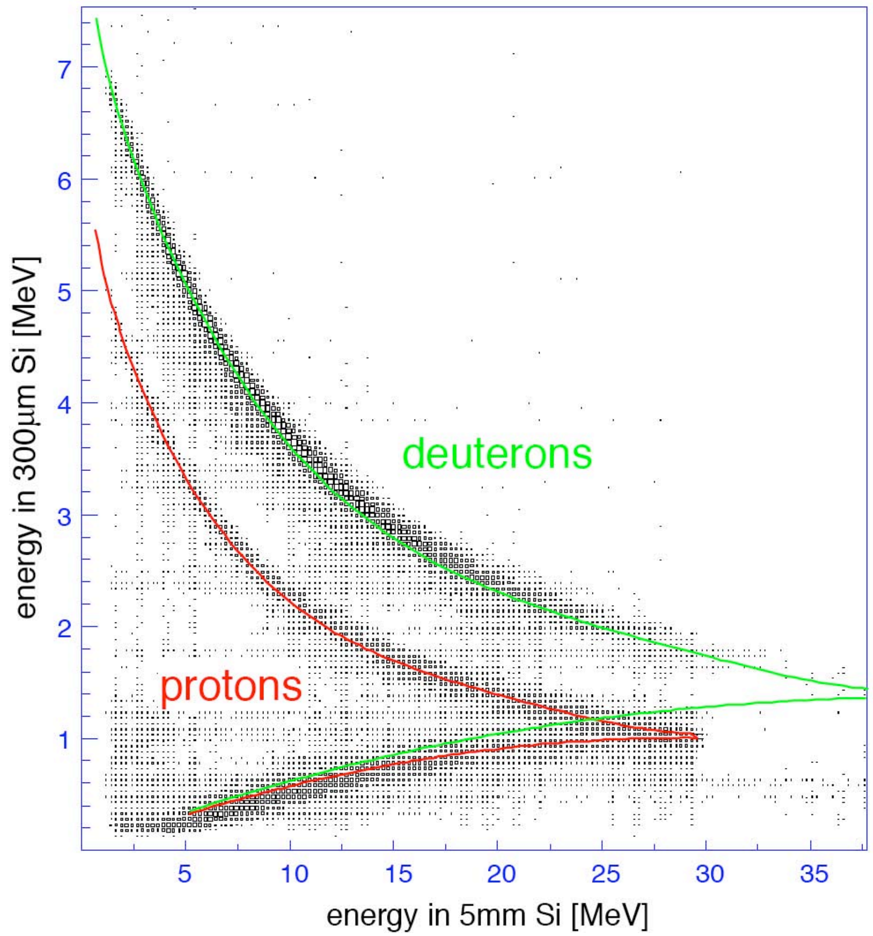


Particle Identification in the Telescope

1st and 2nd layer



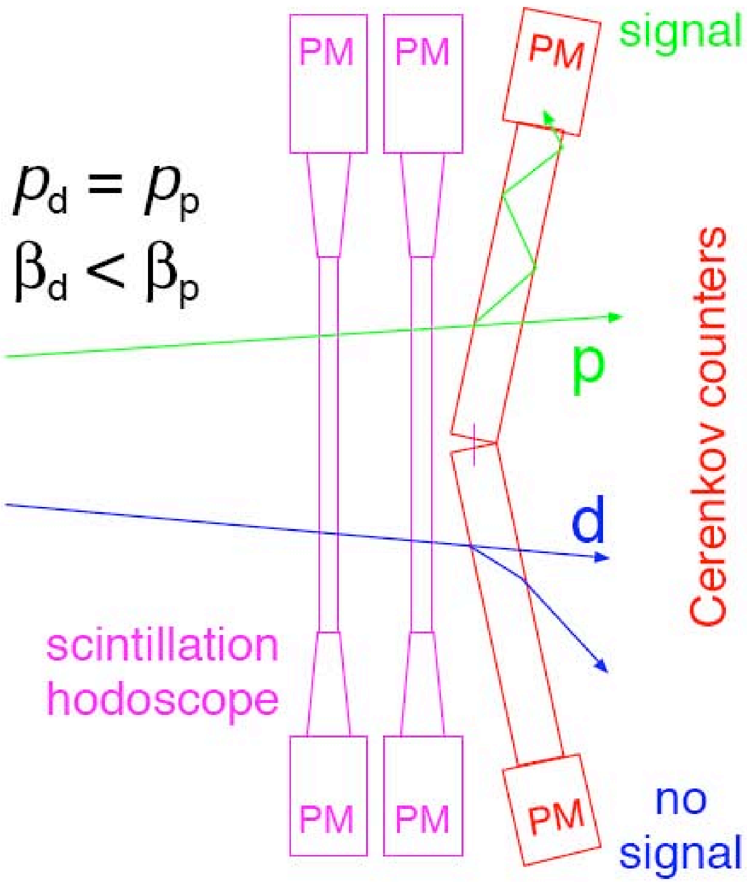
2nd and 3rd layer



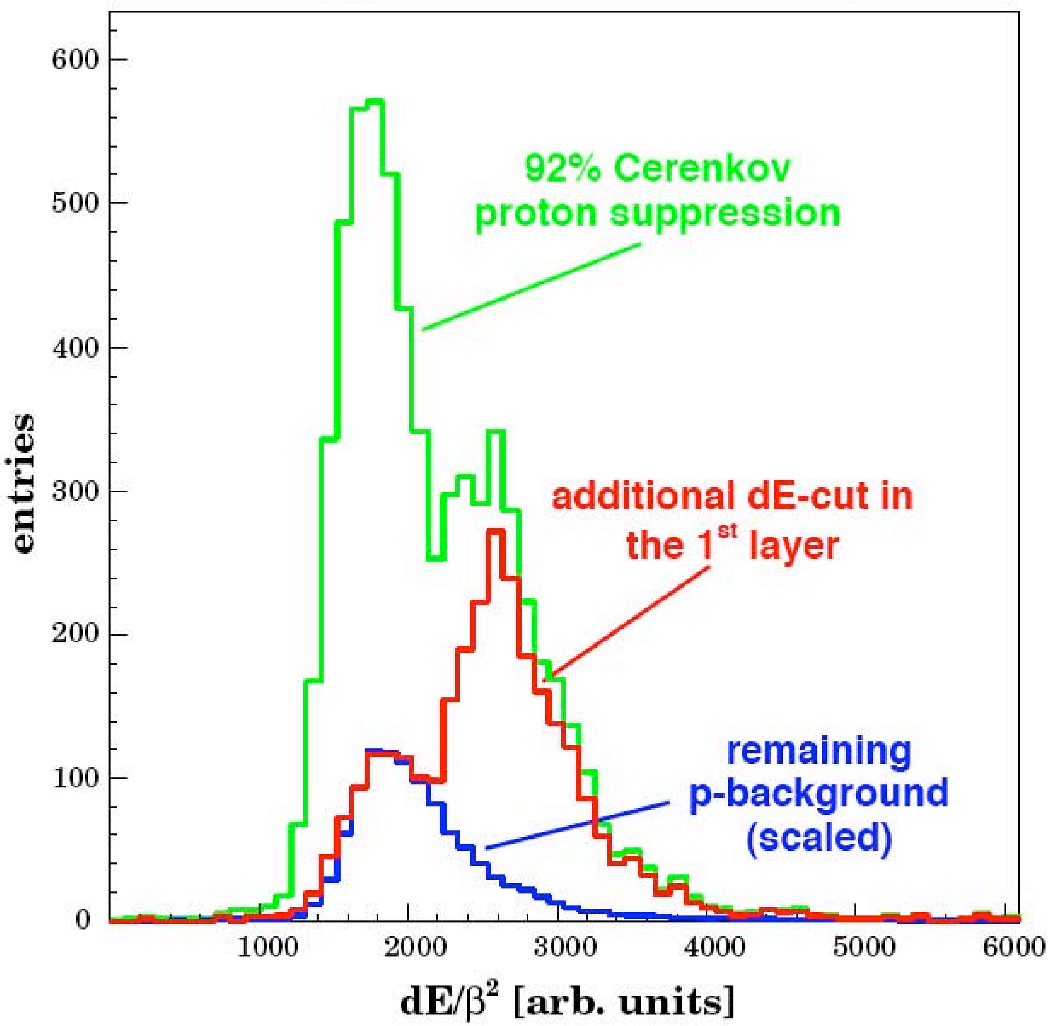
Particle Identification in the Forward Array

2 GeV/c deuterons from a 100 times higher p background

forward setup (partially)

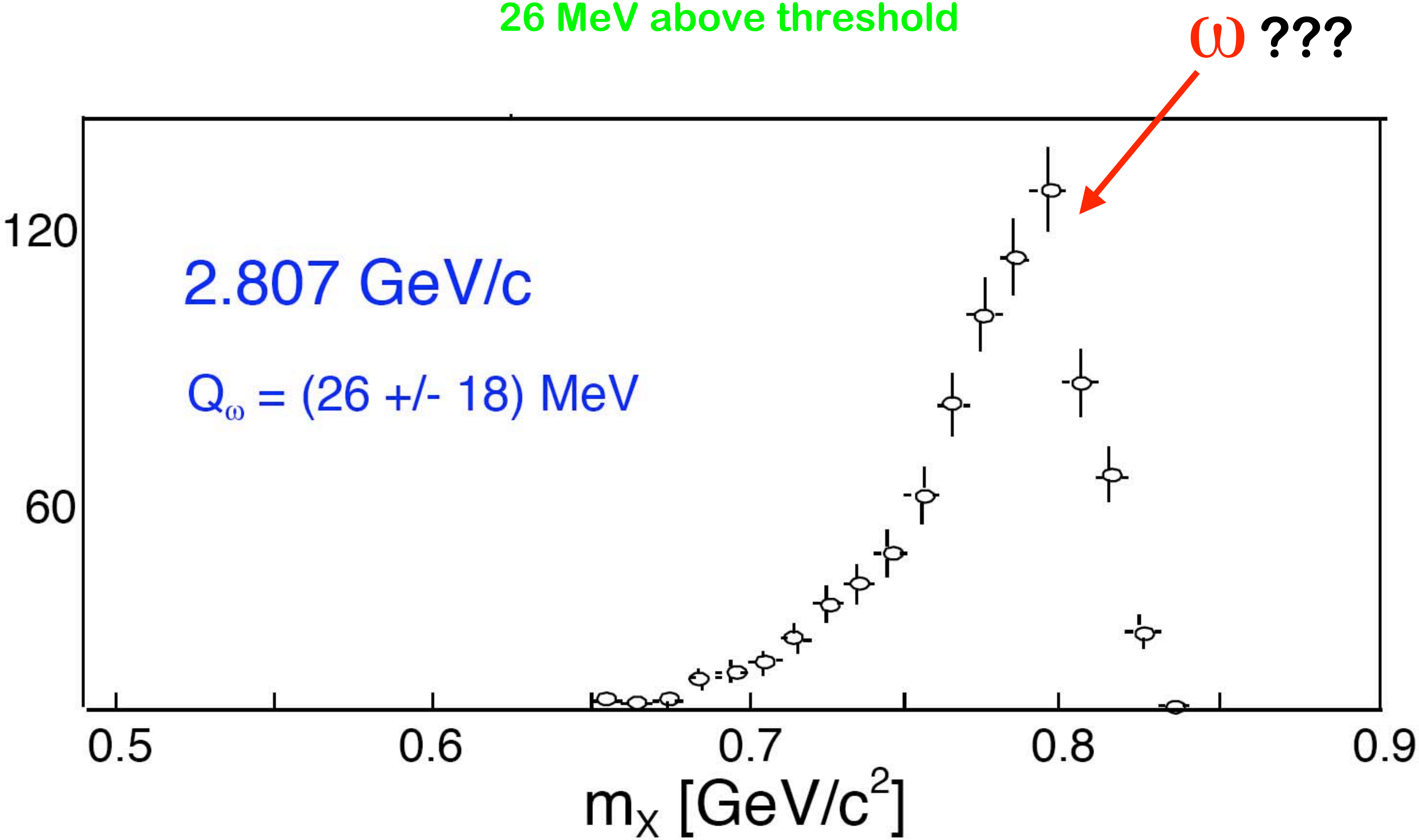


energy loss in the hodoscope



First Look at the Data

26 MeV above threshold



Missing Mass Below the ω Threshold

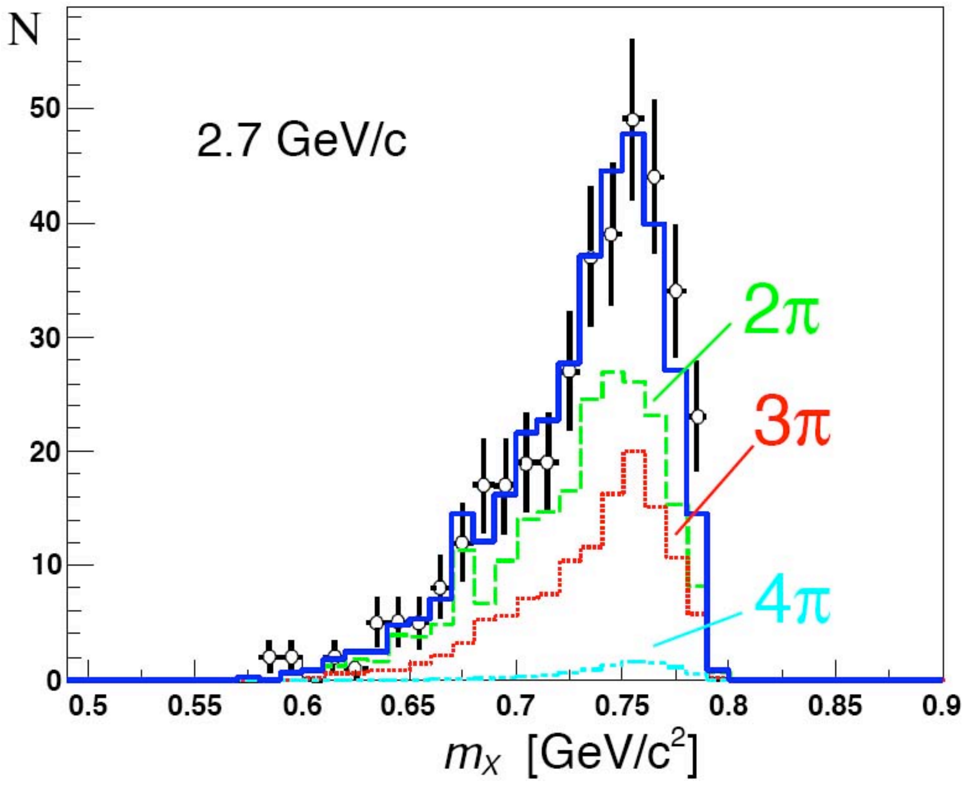
pn→dX events

- use pn→d($N\pi$) to describe our data

$$\sigma(s) = A \left(1 - \frac{s_0}{s}\right)^{p_1} \left(\frac{s_0}{s}\right)^{p_2}$$

- parameterisation of the E dependence of pp→d($N\pi$) to obtain p_1 and p_2

- get A from a fit to our data

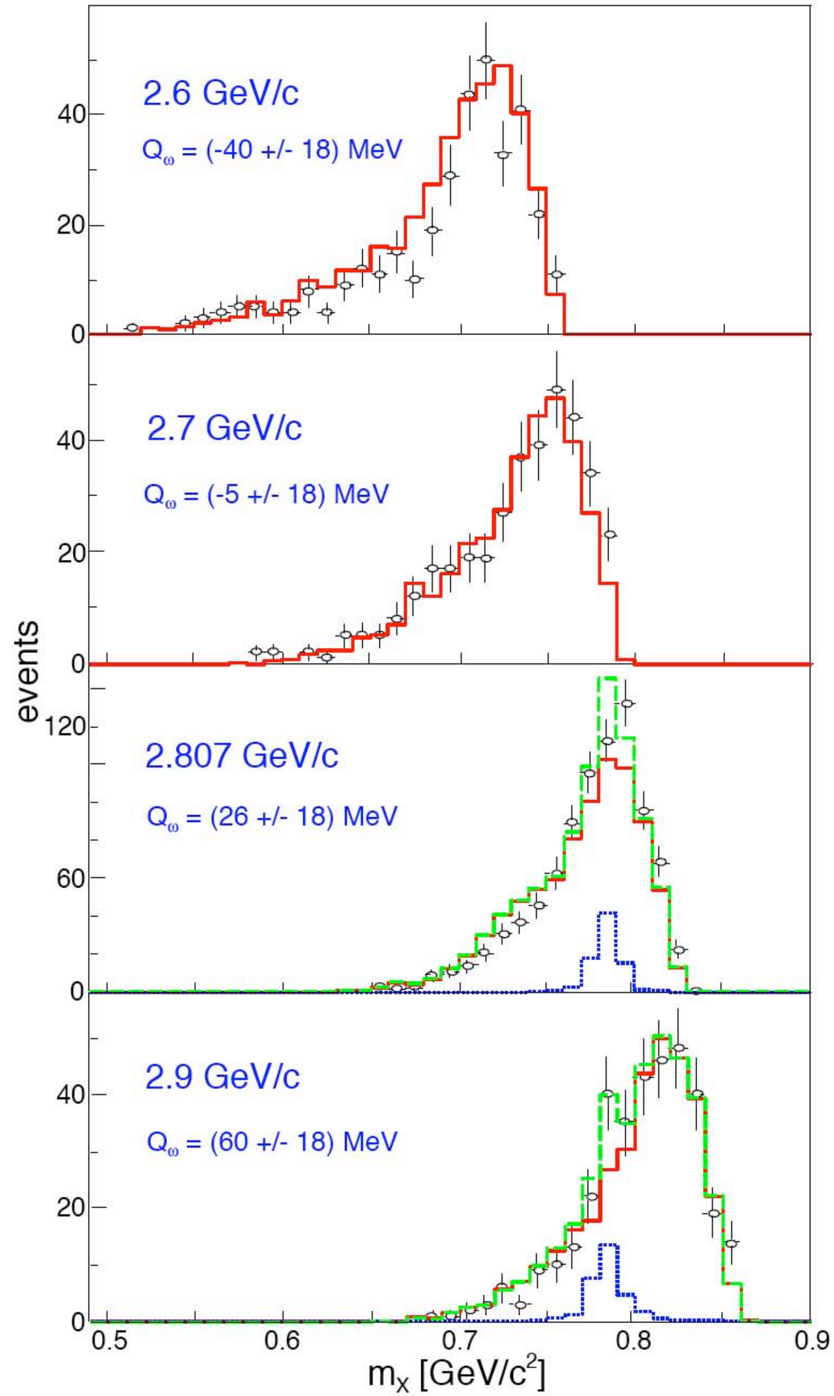


Data Below and Above the Threshold

- Consistent description of the background at all energies

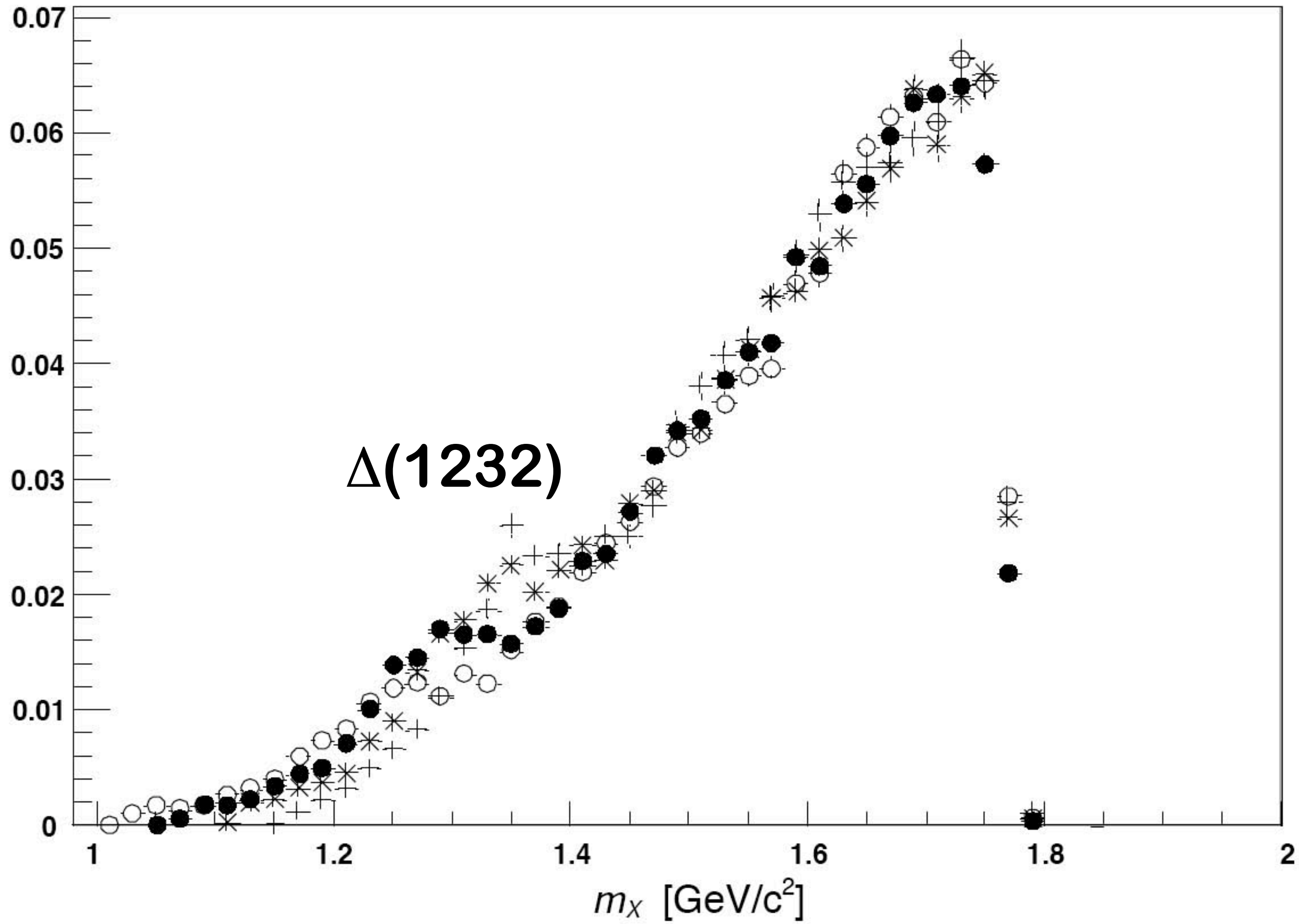
  - evidence for an ω signal at 2.9 GeV/c

  - more model dependent result at 2.8 GeV/c



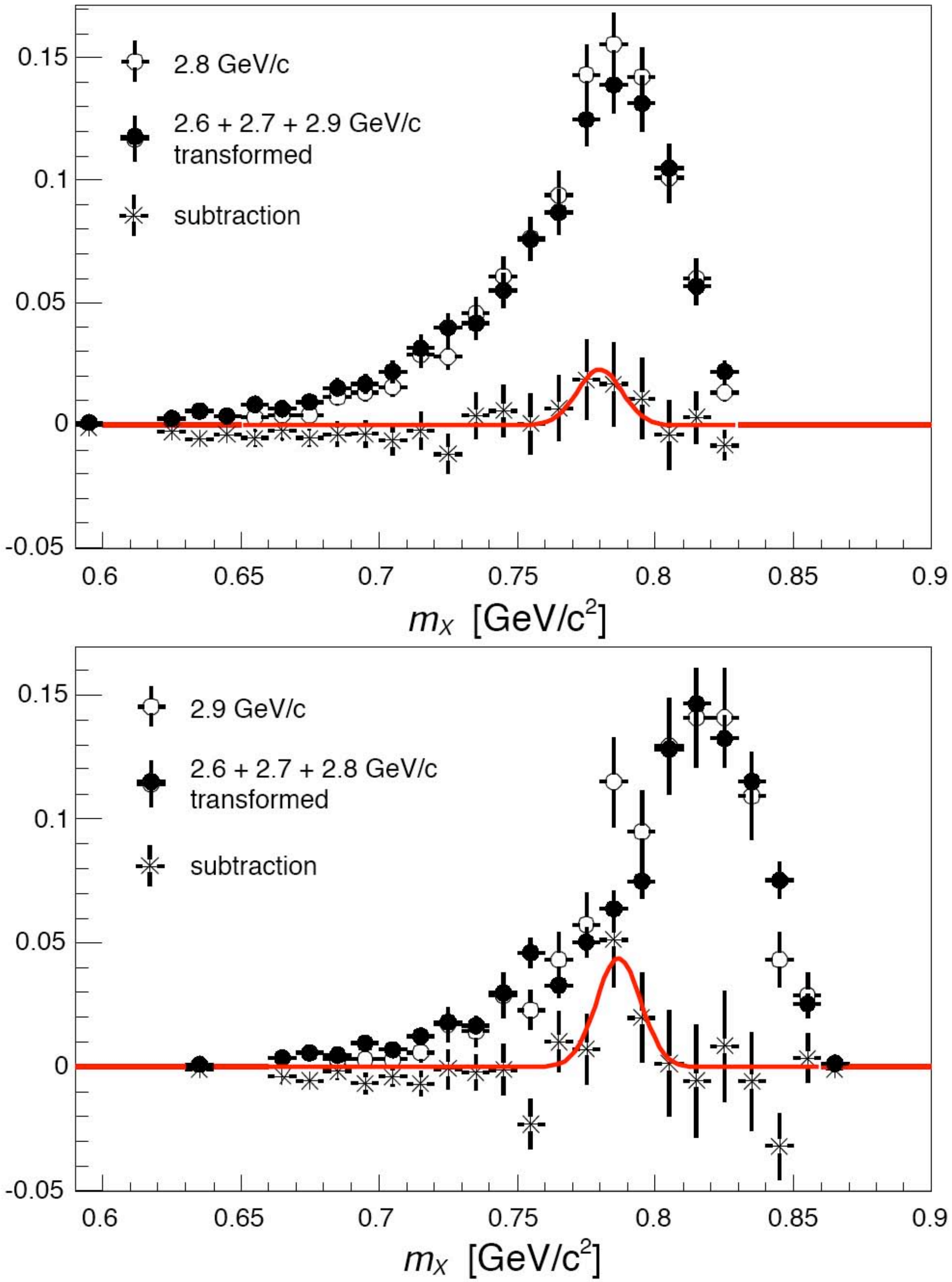
SPESIII Approach

pn→pX events shifted kinematically to 2.9 GeV/c

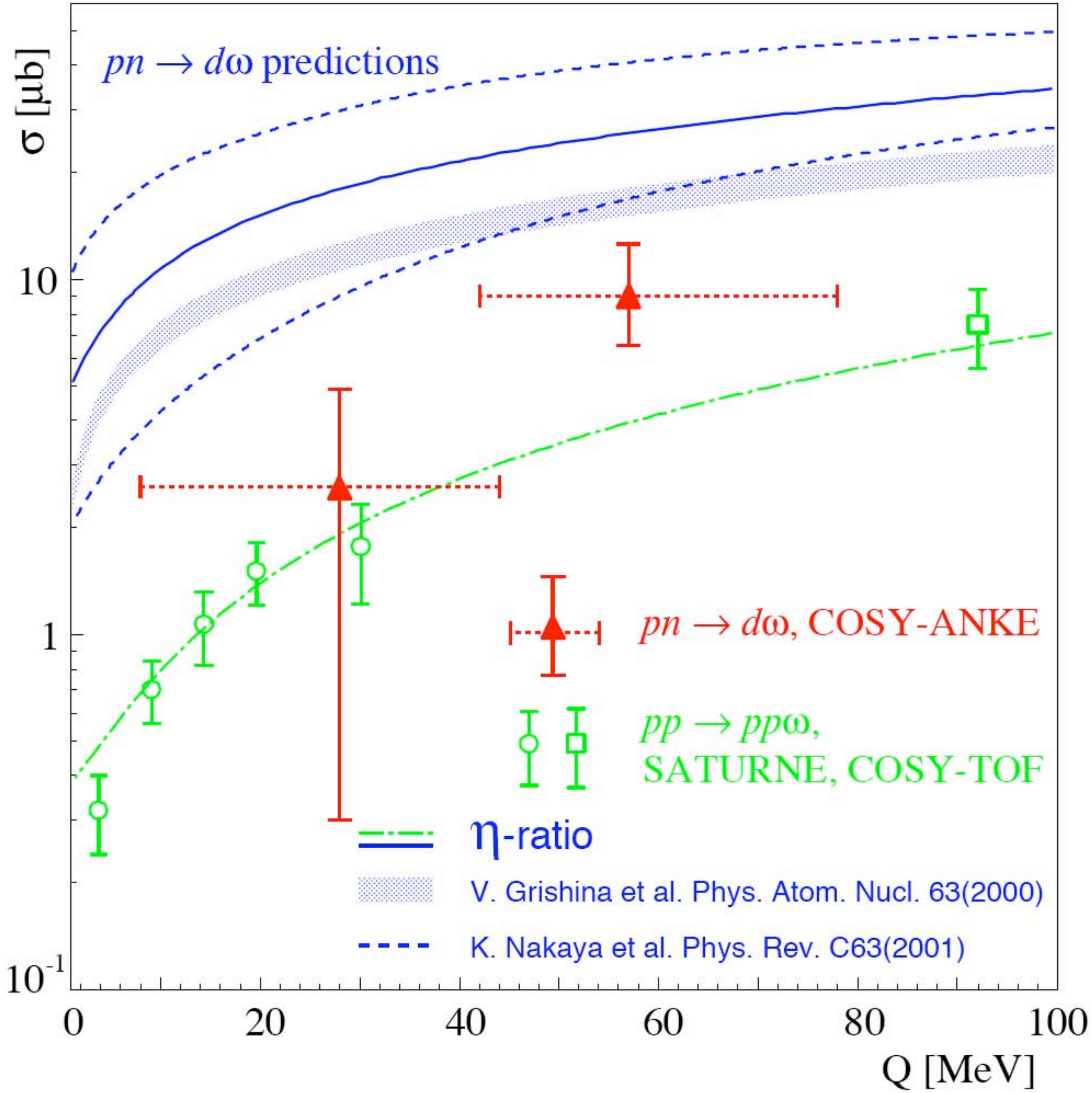


Using pn→dX Data

- Consistent description of the background
  - ω mass found to be 780 ± 8 and 787 ± 4 MeV/c²
  - extracted cross sections agree with those from the first approach



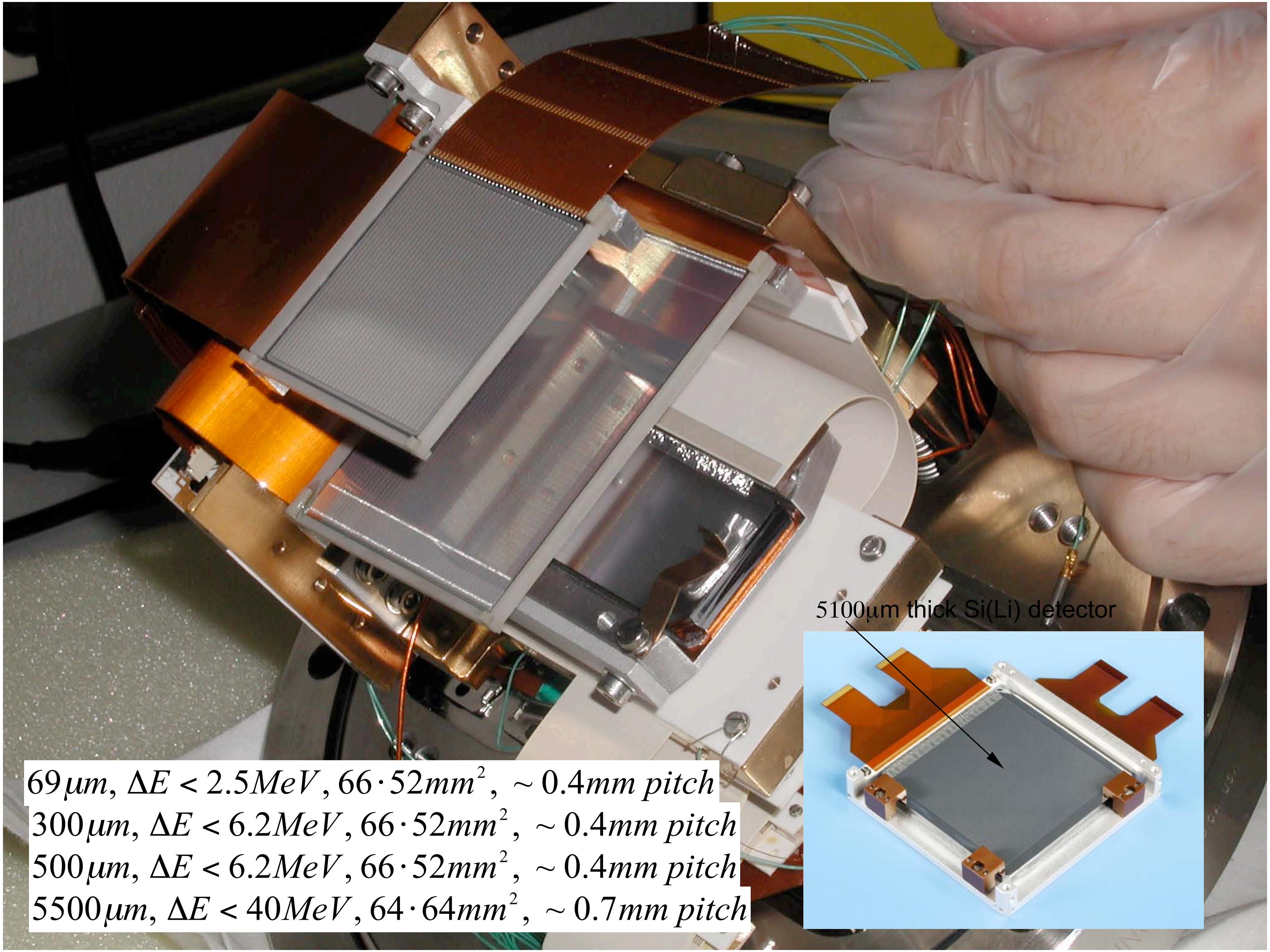
Resulting Cross Sections

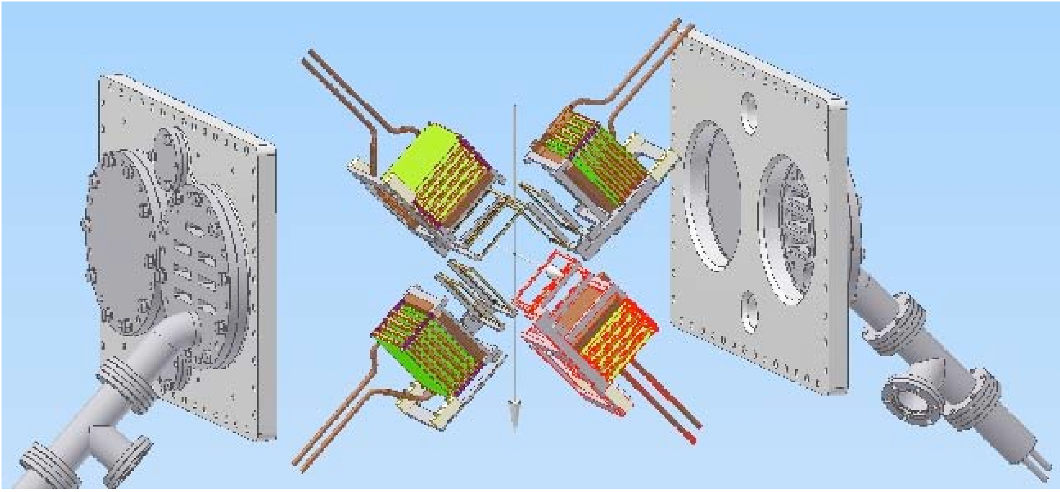


Cross Check

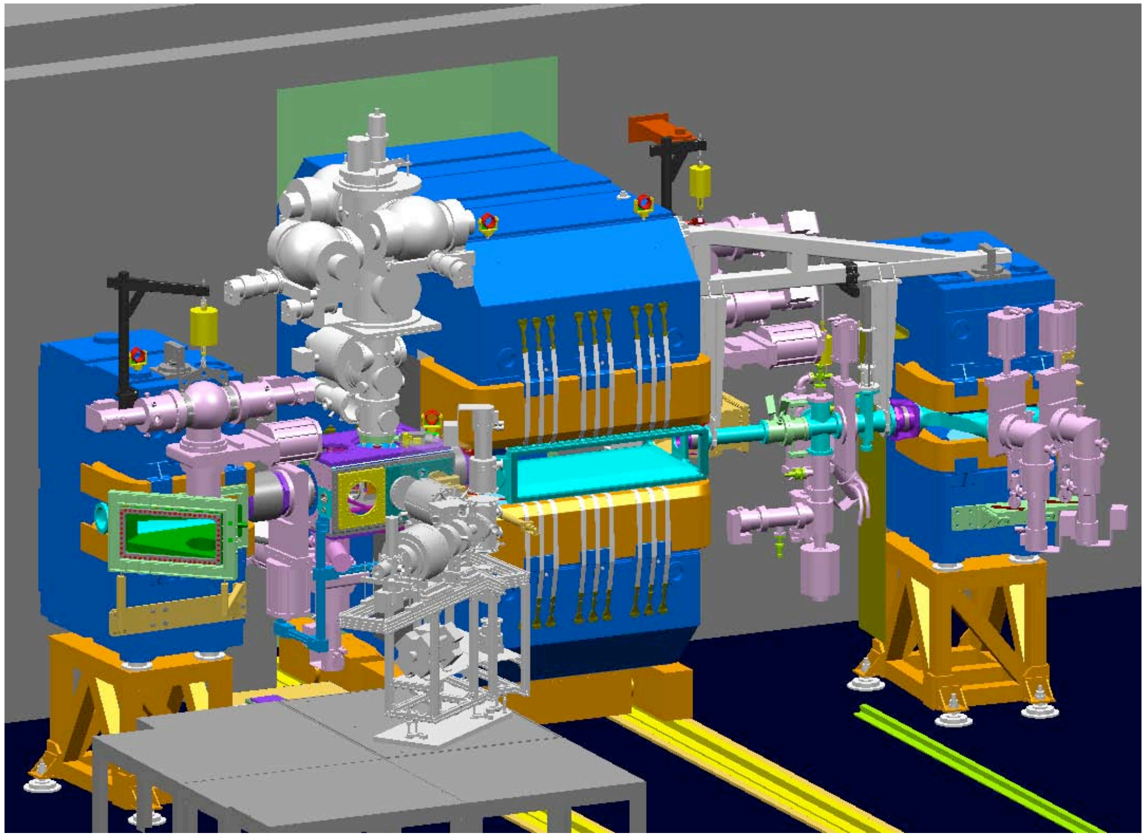
- **$\sigma(pn \rightarrow d\pi^0)$:**
  - **(1.62±0.14)mb**

  with
  - **(1.60±0.14)mb**
  - **(1.53±0.01)mb**


5100μm thick Si(Li) detector
$69\,\mu m,\ \Delta E < 2.5MeV,\ 66\cdot 52mm^2,\ \sim 0.4mm\ pitch$
$300\,\mu m,\ \Delta E < 6.2MeV,\ 66\cdot 52mm^2,\ \sim 0.4mm\ pitch$
$500\,\mu m,\ \Delta E < 6.2MeV,\ 66\cdot 52mm^2,\ \sim 0.4mm\ pitch$
$5500\,\mu m,\ \Delta E < 40MeV,\ 64\cdot 64mm^2,\ \sim 0.7mm\ pitch$



- 4 telescopes
  - ready in 2005



- ABS polarised target
  - installation in summer 2005

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Spectator detection for the measurement of proton–neutron interactions at ANKE

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Abstract

A telescope of three silicon detectors has been installed close to the internal target position of the ANKE spectrometer, which is situated inside the ultra-high vacuum of the COSY-Jülich light-ion storage ring. The detection and identification of slow protons and deuterons emerging from a deuterium cluster-jet target thus becomes feasible. A good measurement of the energy and angle of such a *spectator* proton (p_{sp}) allows one to identify a reaction as having taken place on the neutron in the target and then to determine the kinematical variables of the ion–neutron system on an event-by-event basis over a range of c.m. energies.

The system has been successfully tested under laboratory conditions. By measuring the spectator proton in the $pd \to p_{sp} d\pi^0$ reaction in coincidence with a fast deuteron in the ANKE Forward Detector, values of the $pn \to d\pi^0$ total cross-section have been deduced. Further applications of the telescope include the determination of the luminosity and beam polarisation which are required for several experiments.

PACS: 25.40.Fq; 25.40.Ca; 29.40.Wk; 29.20.−c

Keywords: Proton–neutron quasi-free interactions; Proton spectator detection; Position sensitive silicon telescope

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Abstract. The first measurement of the $pn \to d\omega$ total cross-section has been achieved at mean excess energies $Q \approx 28$ and 57 MeV by using a deuterium cluster-jet target. The momentum of the fast deuteron was measured in the ANKE spectrometer at COSY-Jülich and that of the slow "spectator" proton (p_{sp}) from the $pd \to p_{sp} d\omega$ reaction in a silicon telescope placed close to the target. The cross-sections lie above those measured for $pp \to pp\omega$ but seem to be below theoretical predictions.

PACS. 25.40.Ve Other reactions above meson production thresholds (energies > 400 MeV) – 25.40.Fq Inelastic neutron scattering – 14.40.Cs Other mesons with $S = C = 0$, mass < 2.5 GeV

1 Introduction

The last few years have seen several measurements of η production in nucleon-nucleon collisions [1] but relatively few of ω production [2,3]. The S-wave amplitude in the η case is strong and the total $pp \to pp\eta$ cross-section largely follows phase space modified by the pp final-state interaction up to an excess energy $Q = \sqrt{s} - \sum_f m_f \approx 60$ MeV, though there is some evidence for an ηpp final-state enhancement at very low Q [4]. Here $\sqrt{s}$ is the total centre-of-mass (c.m.) energy and m_f are the masses of the particles in the final state. Quasi-free η production in proton-neutron collisions has been measured by detecting the photons from η decay and it is found that for $Q < 100$ MeV the cross-section ratio $R = \sigma_{tot}(pn \to pn\eta)/\sigma_{tot}(pp \to pp\eta) \approx 6.5$ [5]. Now the $d\eta$ final state is pure isospin $I = 0$, whereas the $pp\eta$ is a mixture of $I = 0$ and $I = 1$. Up to $Q \approx 60$ MeV the cross-section for $pn \to d\eta$ is larger than that for $pn \to pn\eta$ [6], and this can be understood quantitatively in terms of phase space in a largely model-independent way [4]. In all meson production reactions it is important to have data on the different possible isospin combinations in order to constrain theoretical models. It is therefore interesting to see whether a similar isospin dependence is found for the ω, the next heavier isoscalar meson.

Unlike the η case, the ω-meson has a significant width ($8.4\,\text{MeV}/c^2$) and so Q is here defined with respect to the central mass value of $782.6\,\text{MeV}/c^2$ [7]. The $pp \to pp\omega$ total cross-section has been measured at five energies in the range $4 \le Q \le 30$ MeV at the SATURNE SPESIII spectrometer [2] and at $Q = 92$ MeV at COSY-TOF [3] where, in both cases, the ω was identified through the missing-mass technique. The energy dependence deduced is rather similar to that of the η, except that the phase space and pp final-state interaction have to be smeared over the finite ω width, a feature which becomes important close to the nominal threshold [2].

Attempts to measure the $np \to d\omega$ reaction using a neutron beam are complicated by the intrinsic momentum spread, which is typically 7% FWHM even for a stripped deuteron beam [8]. The alternative is to use a deuterium target and effectively measure the momentum of the struck neutron. This is made possible by detecting the very low-momentum recoil protons, $\lesssim 200\,\text{MeV}/c$,

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Conclusions

- such a silicon telescope may be used for:
  - spectator detection and pn tagging
  - luminosity monitoring
  - polarisation measurements
  - vertex detection

- meson production in pn reactions
  - η production (WASA) suggest isovector dominance
  - first cross sections obtained for ω production indicate a different situation here
  - more measurements to follow...
  - only the comparison of several channels can shed light on the production mechanisms