Deuteron Breakup pd → (pp)n at ANKE-COSY: Measurements of the Differential Cross Section

S.Yaschenko for the ANKE Collaboration

Universität Erlangen-Nürnberg, Erlangen, Germany
Joint Institute for Nuclear Research, Dubna, Russia

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Outline

- Physics Motivation
- Experimental Setup
- Data Analysis
- Results and Comparison with Theoretical Model
- Summary and Outlook

Physics Motivation

- pd → ppn in kinematics similar to pd → dp:
  o Short-range structure of NN interactions
  o Study of pd dynamics at high momentum transfer
  o Insight on few nucleon systems at short distances

- Several theoretical models for pd → dp:
  o One nucleon exchange
  o Importance of virtual pions
  o Presence of nucleon resonance (N*) inside the deuteron

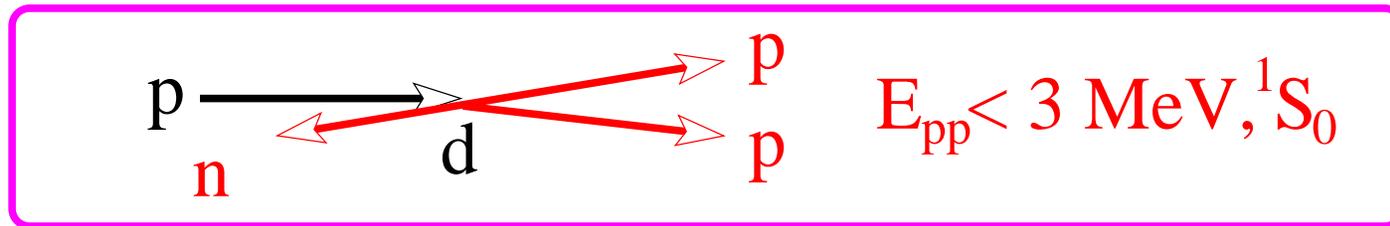# ONE + SS + Δ Model
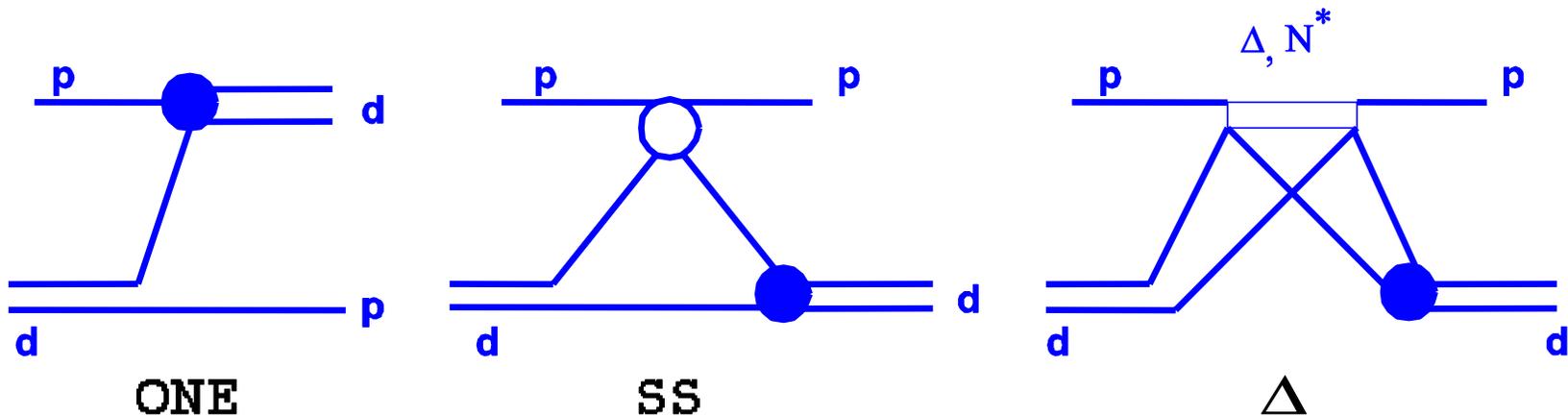
- Proposed by L. Kondratiuk, F. Lev, L. Shevchenko
- Improved by Yu. Uzikov et al.
  - o Describes energy dependence of cross section
  - o Describes T_{20} at energies below 0.5 GeV only
 - o At energies > 1 GeV heavier N* are important

How to suppress Δ, N*?

Deuteron breakup in collinear kinematics

$E_{pp} < 3\ \mathrm{MeV},\ ^1S_0$

- New experimental method to study short-range properties of the NN interactions
- Similar kinematics as in pd → dp but pp-pair in $^1S_0$ state, suppression of Δ by factor of 3 in amplitude
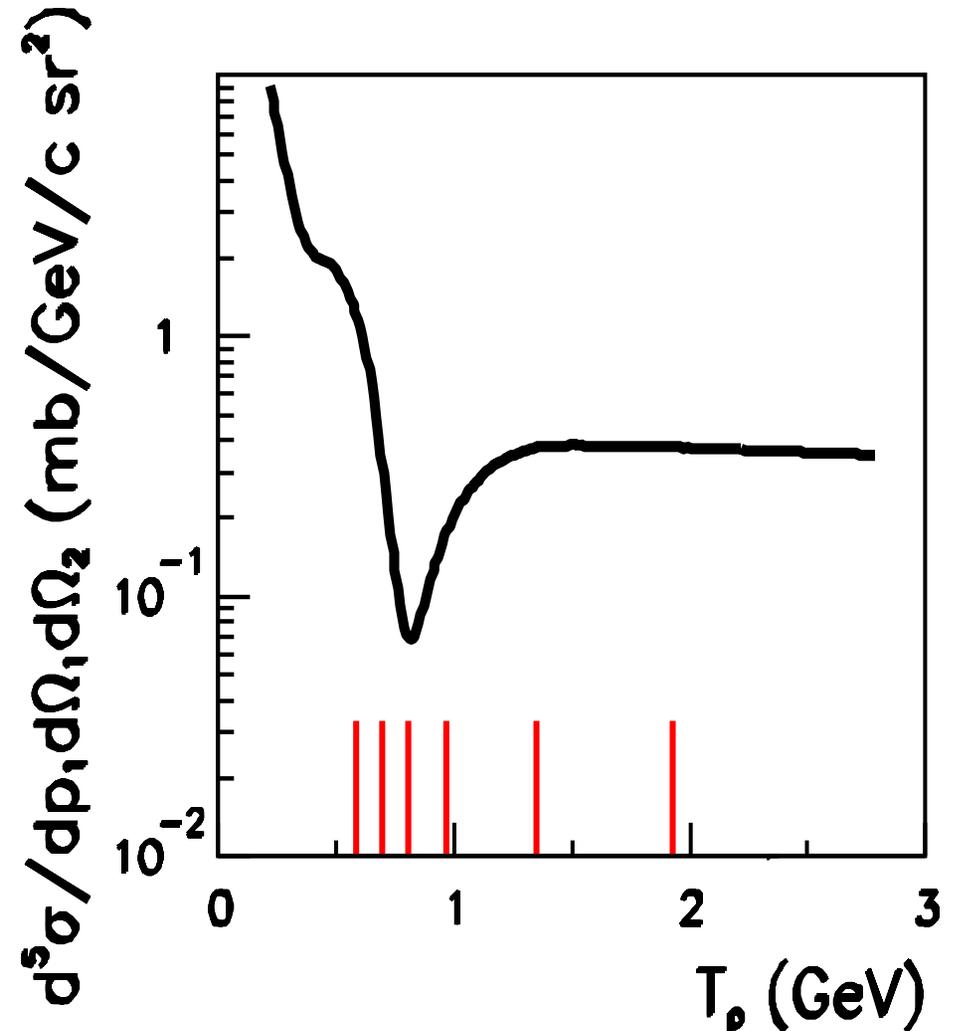- The node in half-of-shell pp amplitude leads to a dip in cross section energy dependence

Predictions for Observables
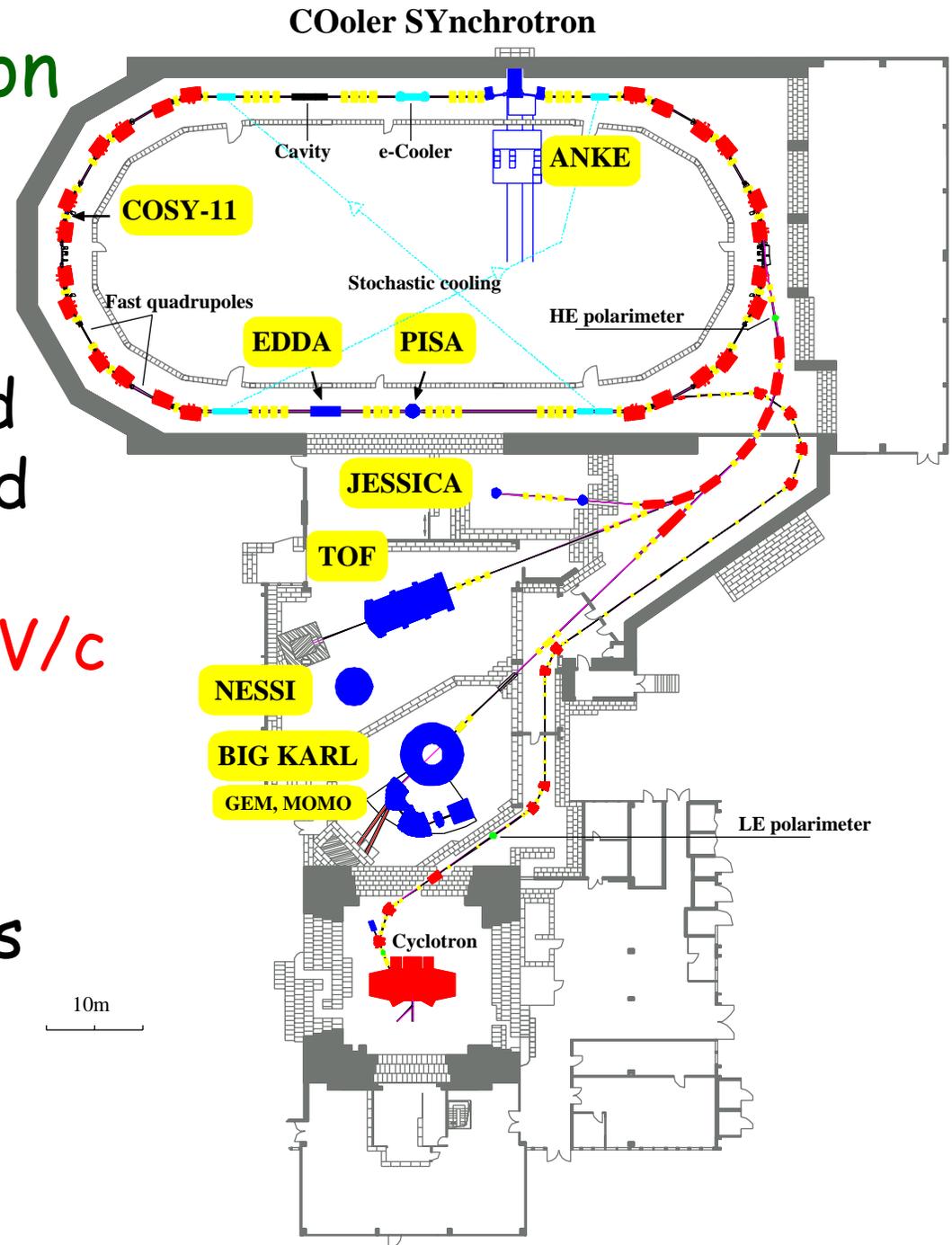## [Yu. Uzikov, J. Phys. G 28 B13 (2002)]
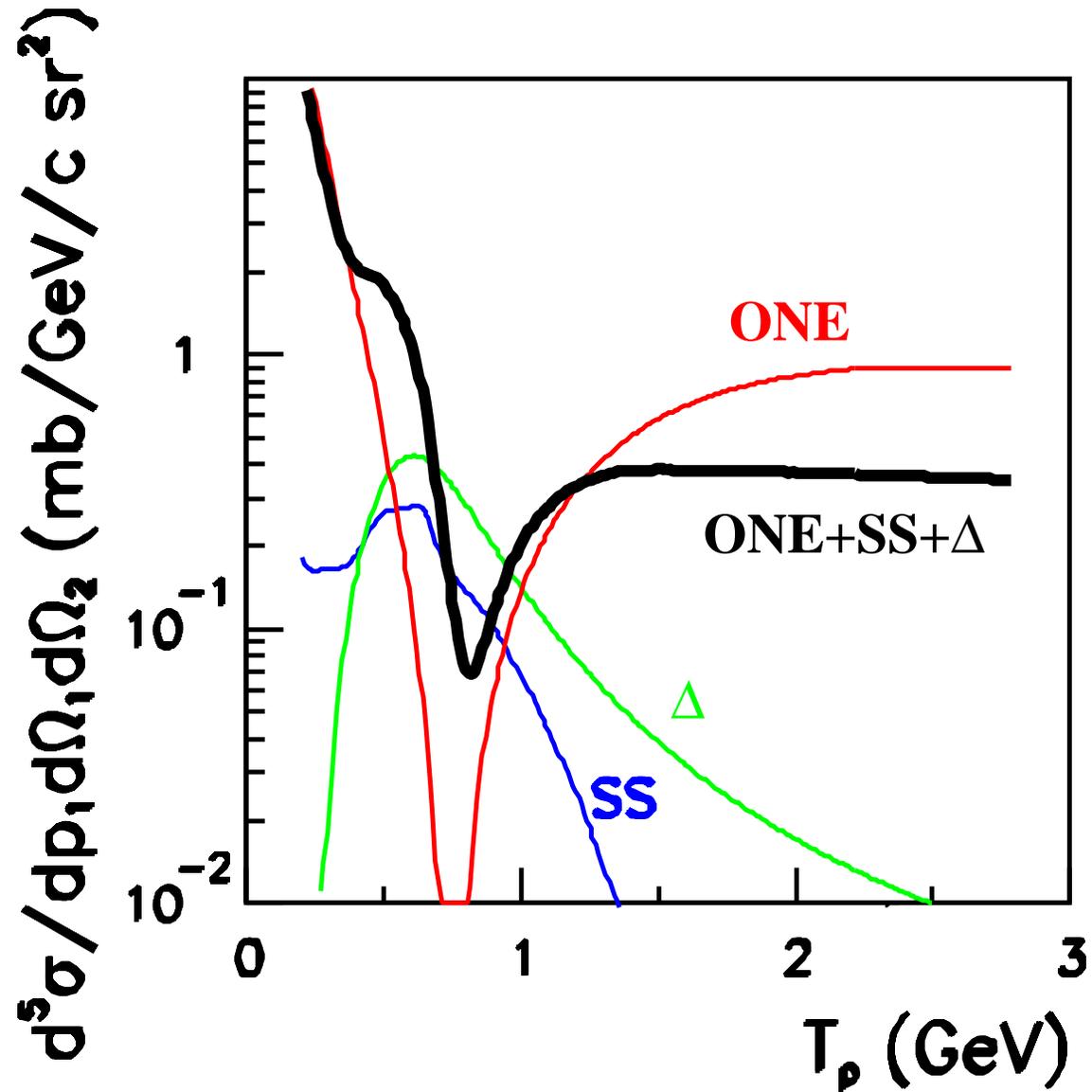
Measurements

- Differential cross section
  at six beam energies:
  0.6, 0.7, 0.8, 0.95,
  1.35, 1.9 GeV

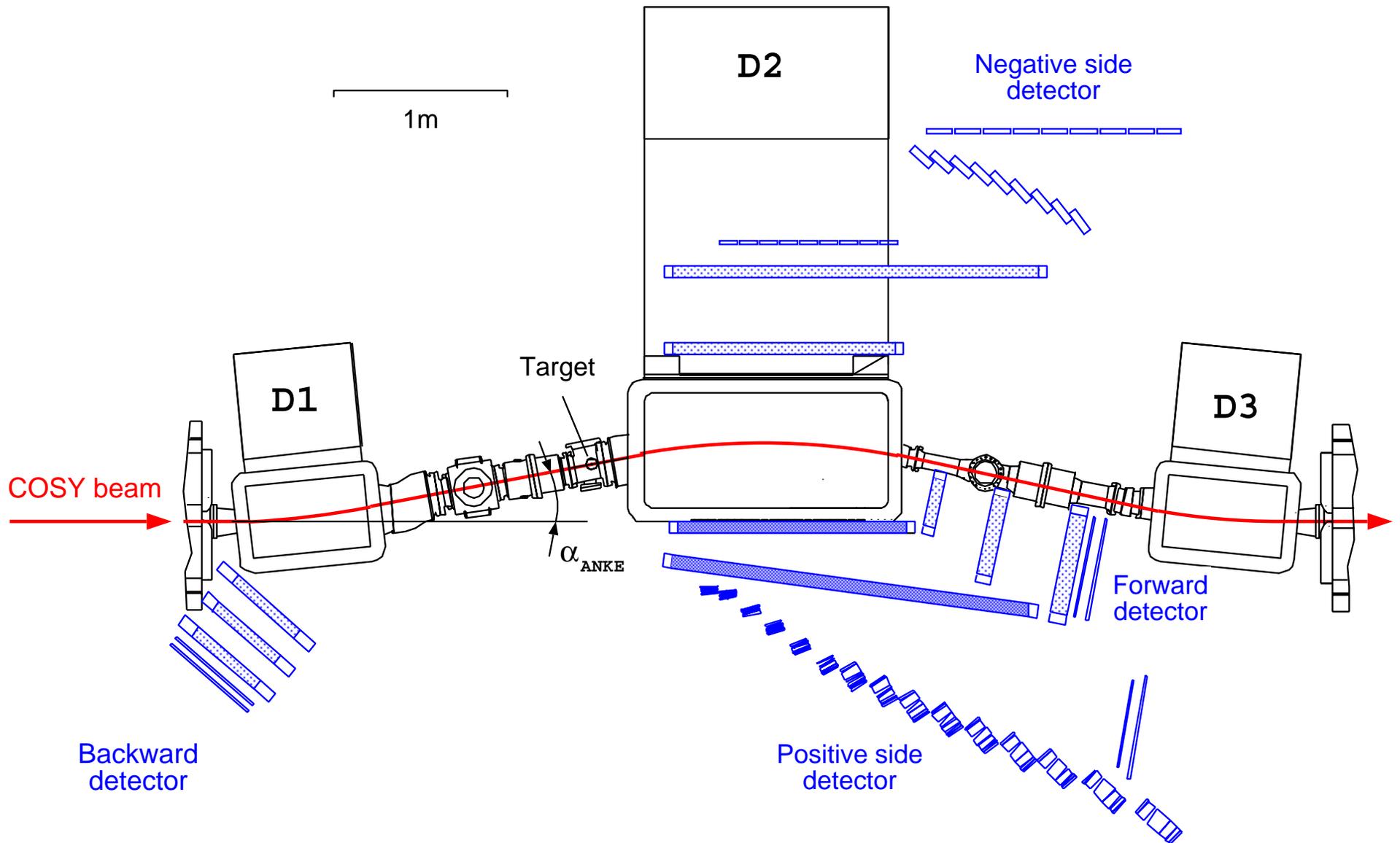 to cover the predicted dip
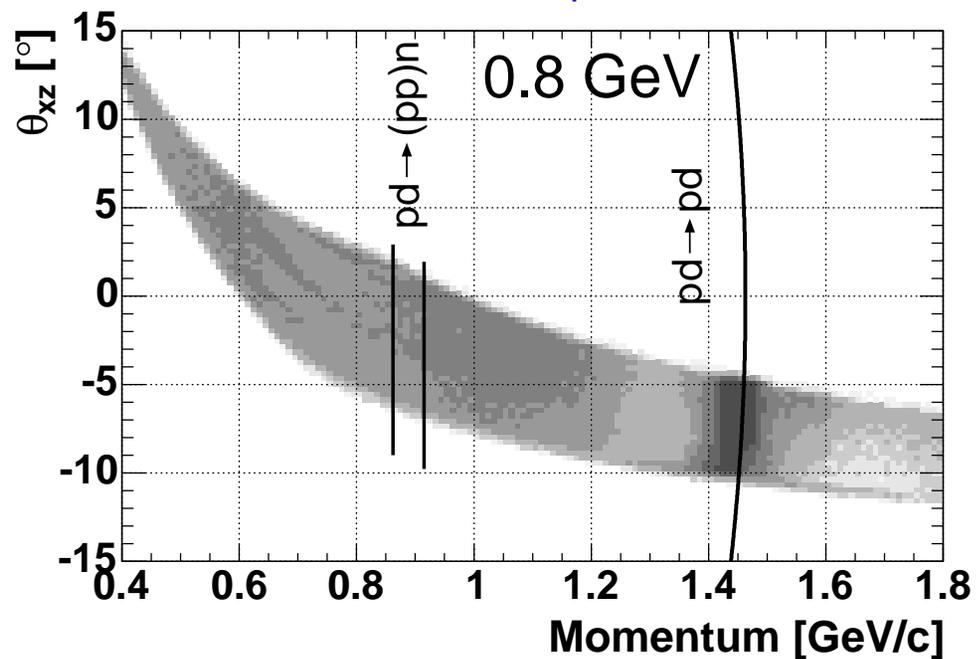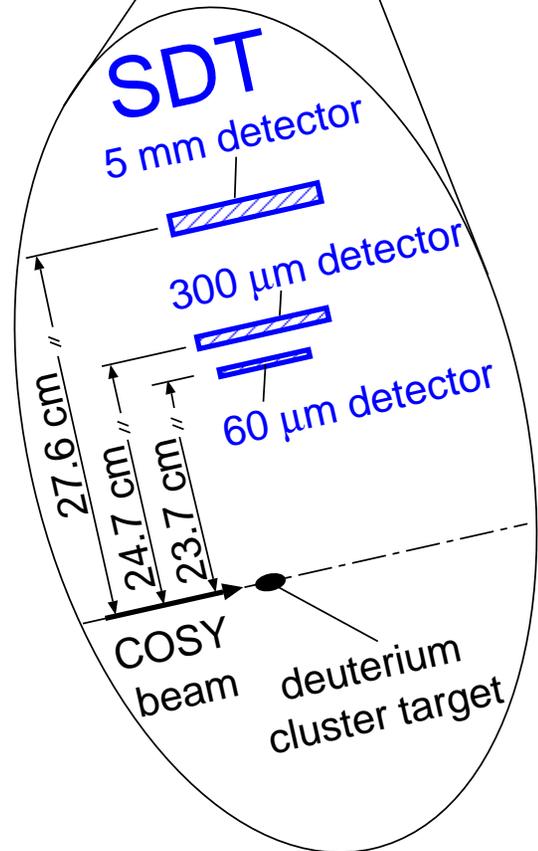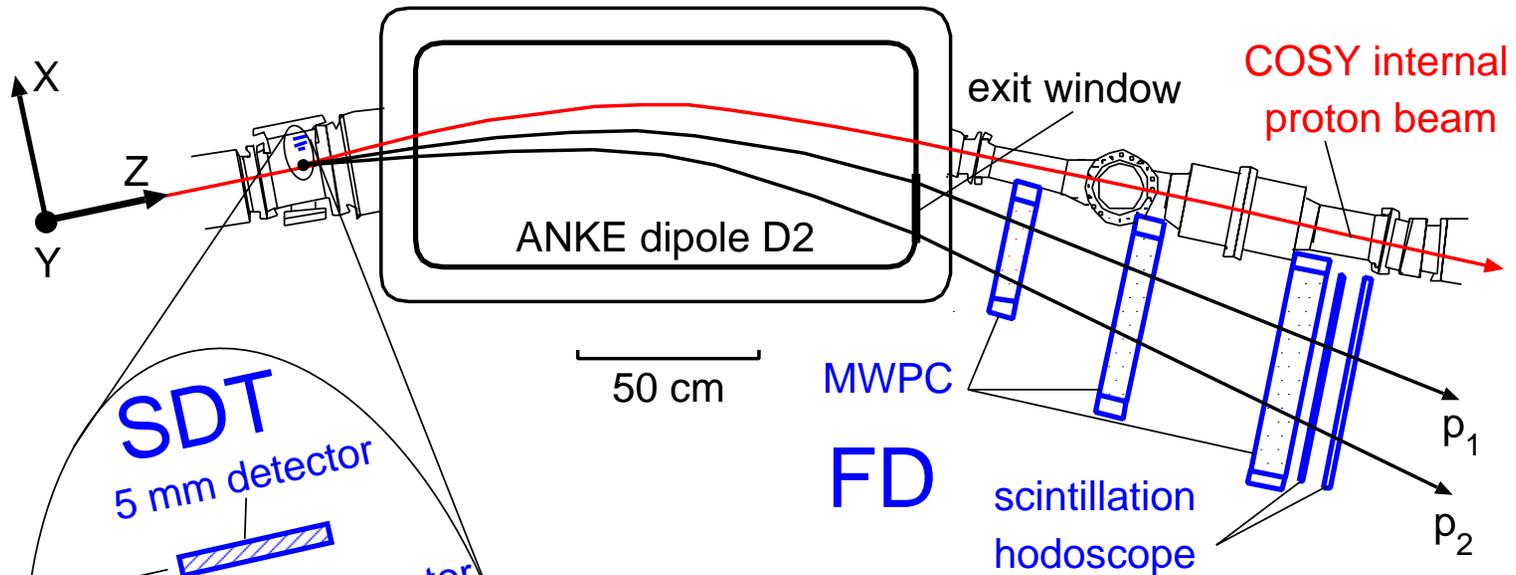 region

COoler SYnchrotron COSY

- Provides polarized and unpolarized proton and deuteron beams with momenta up to 3.7 GeV/c

- ANKE spectrometer is internal experimental setup

COoler SYnchrotron

Cavity   e-Cooler

ANKE

COSY-11

Stochastic cooling

Fast quadrupoles

HE polarimeter

EDDA   PISA

JESSICA

TOF

NESSI

BIG KARL

GEM, MOMO

LE polarimeter

Cyclotron

10m

Spectrometer ANKE

1m

D2

Negative side detector

Target

D1

D3

COSY beam

α_{ANKE}

Forward detector

Backward detector

Positive side detector

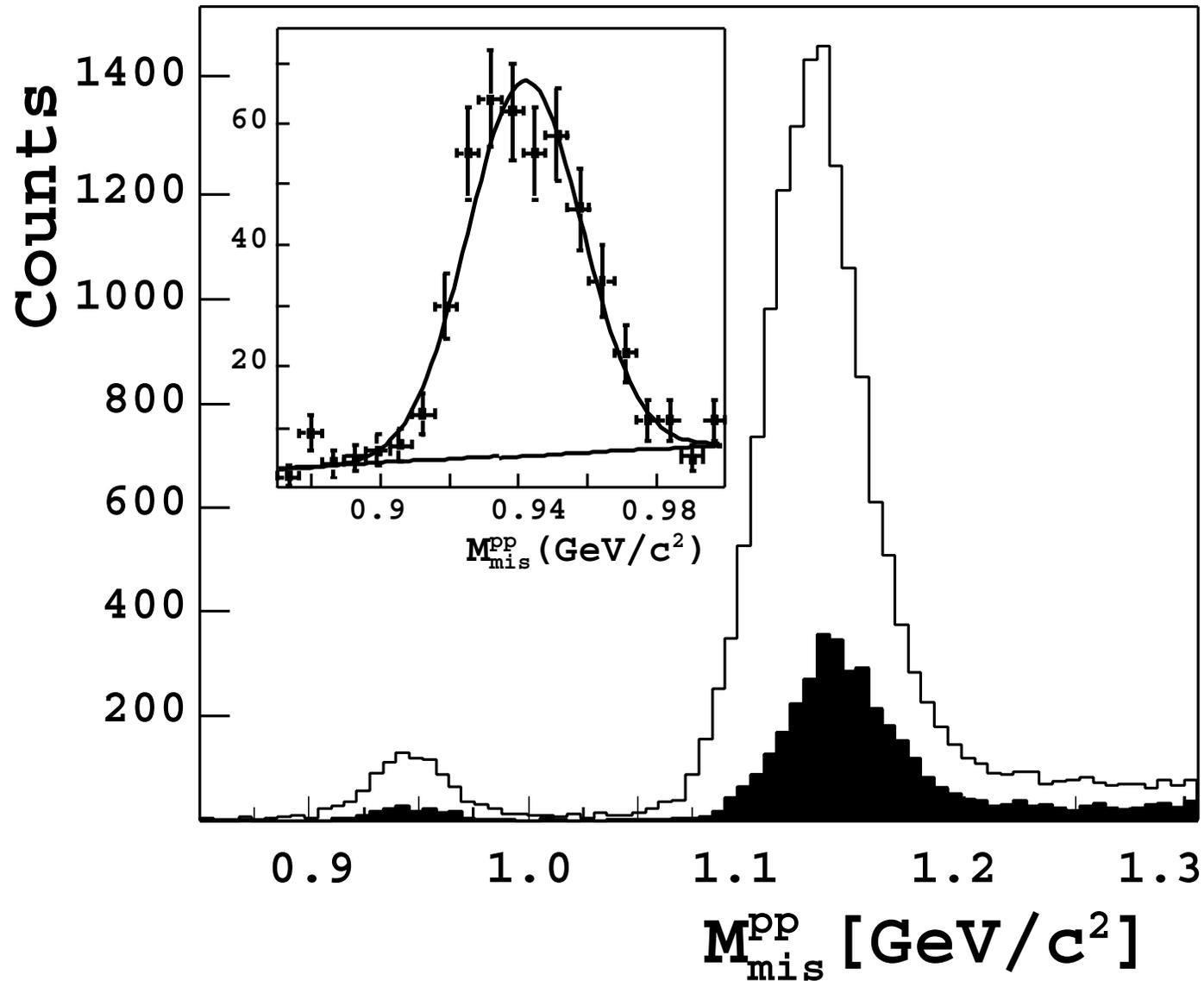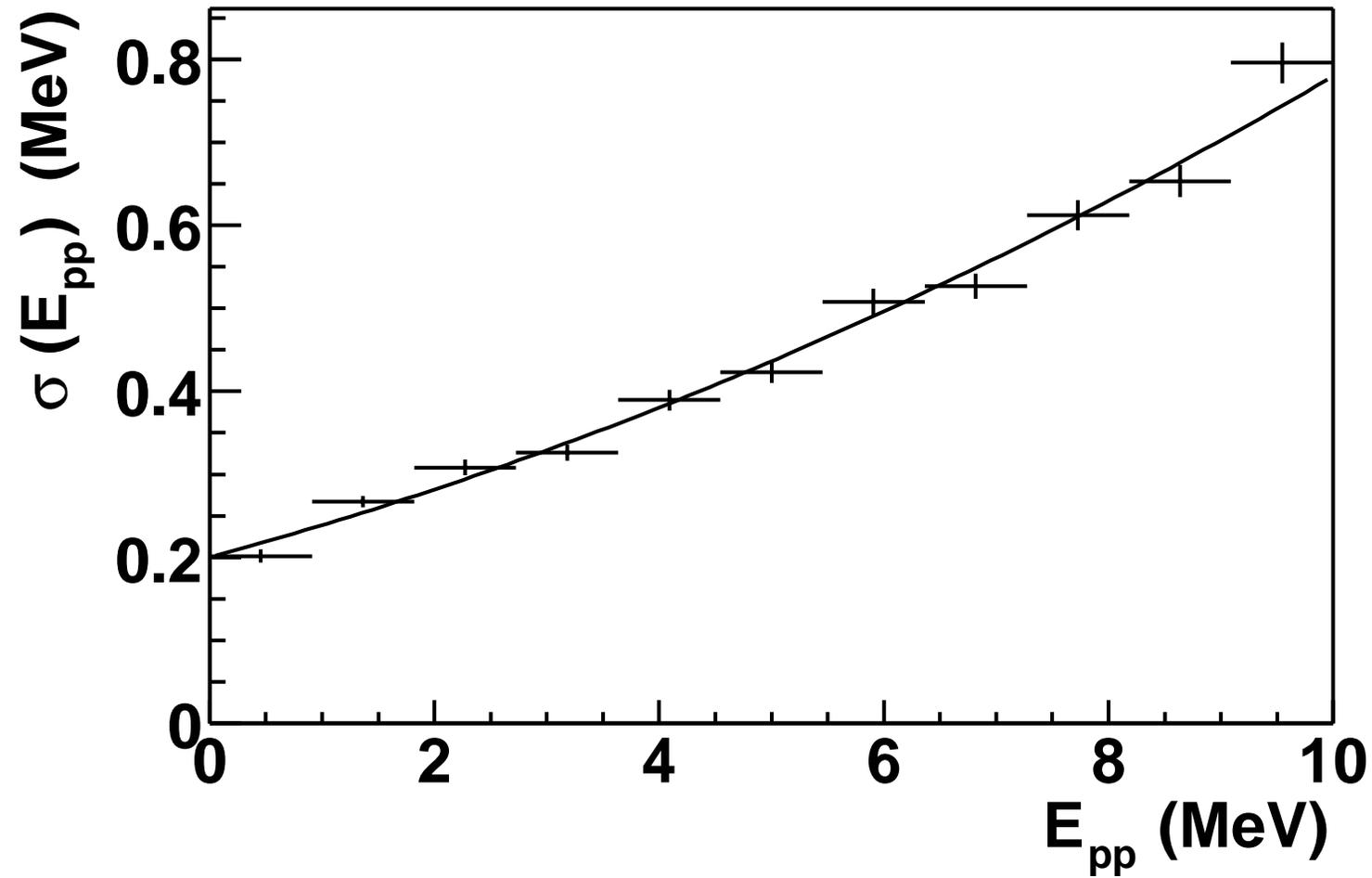# Experimental Setup (Details)

Outline

- Physics Motivation
- Experimental Setup
- Data Analysis:
    - o Event Selection
    - o Luminosity Determination
    - o Acceptance Corrections
- Results and Comparison with Theoretical Model
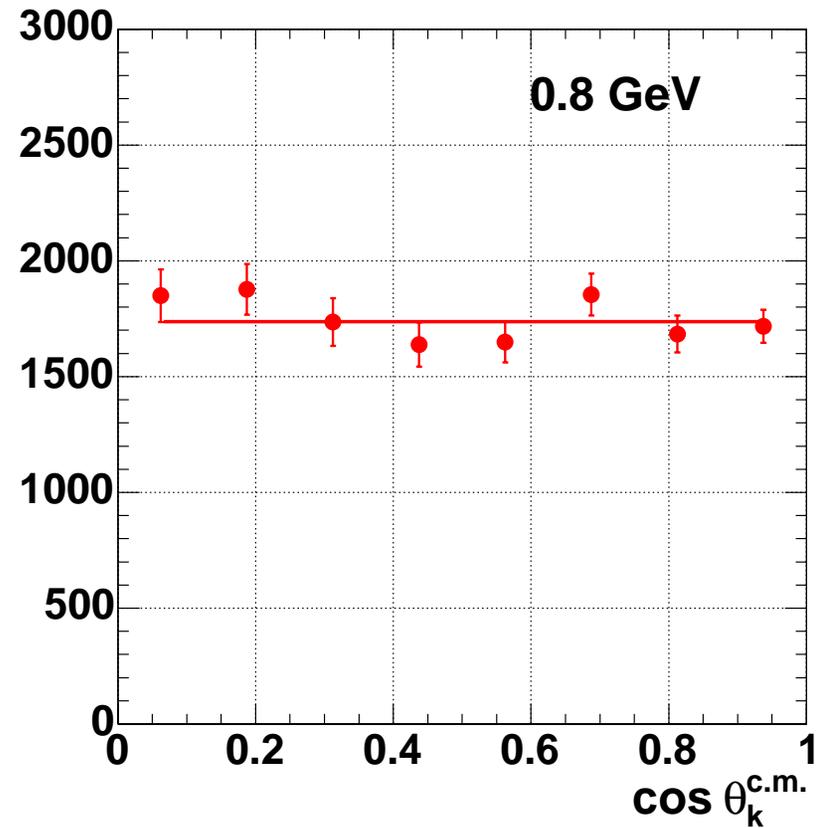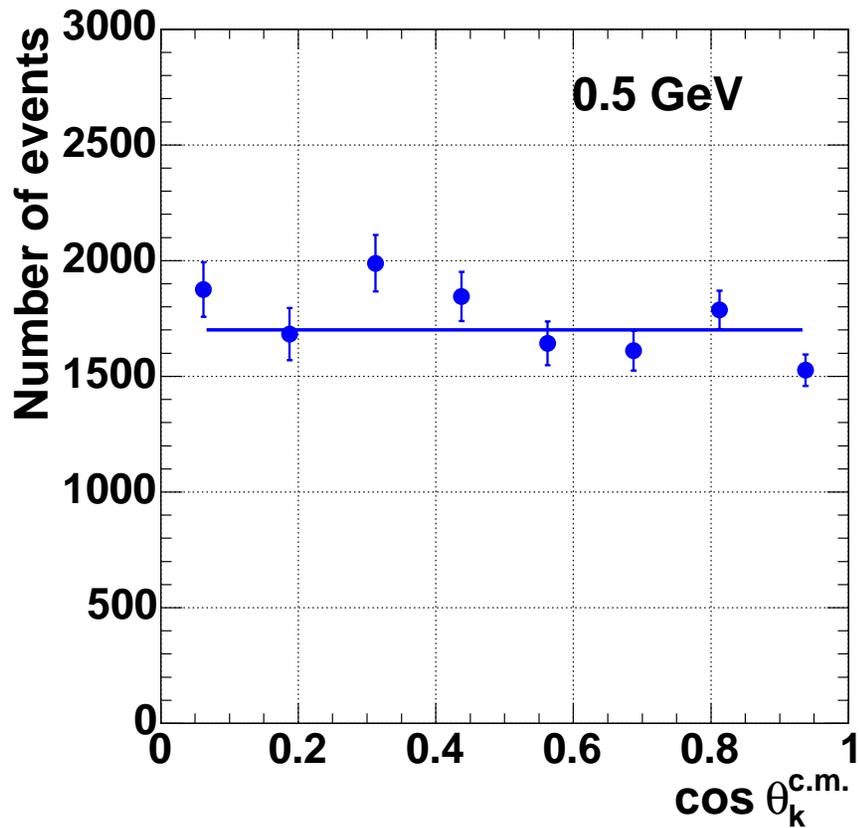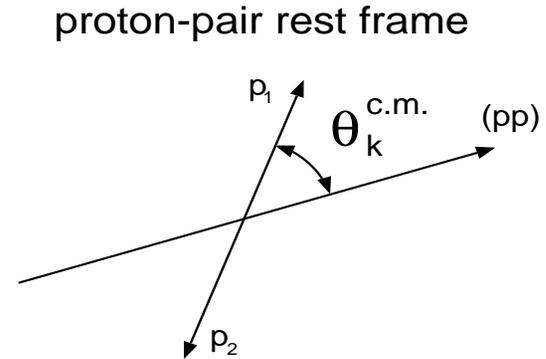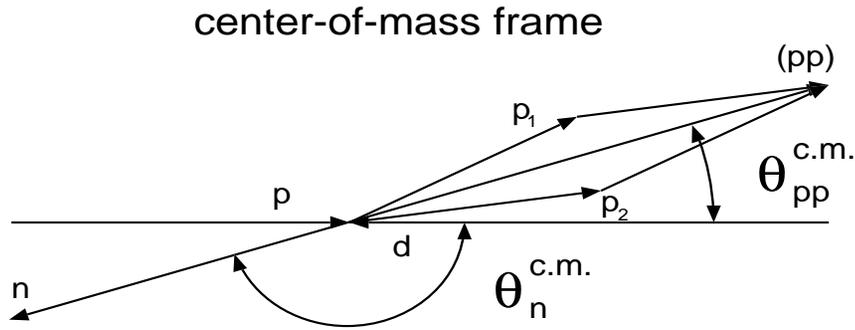- Summary and Outlook

Momentum Correlation and Time of Flight Difference

Selection of pd→(pp)n by Missing Mass

Excitation Energy Resolution

S-wave Dominance

Luminosity Determination

- Luminosity determined from quasi-elastic scattering of protons on deuterons at angles 5 – 10 degree

- Experimentally impossible to separate elastic and inelastic events

- Number of counts related to elastic and inelastic terms in diffractive pd scattering

- Cross section calculated via closure approximation of Glauber-Franco theory (accuracy is about 7 %)

- Cross check using pd forward elastic scattering at 1.9 GeV and pd backward elastic at 0.6, 0.8 GeV

Integral Luminosity = (70 … 140) pb^{-1}

Acceptance Determination

center-of-mass frame

proton-pair rest frame
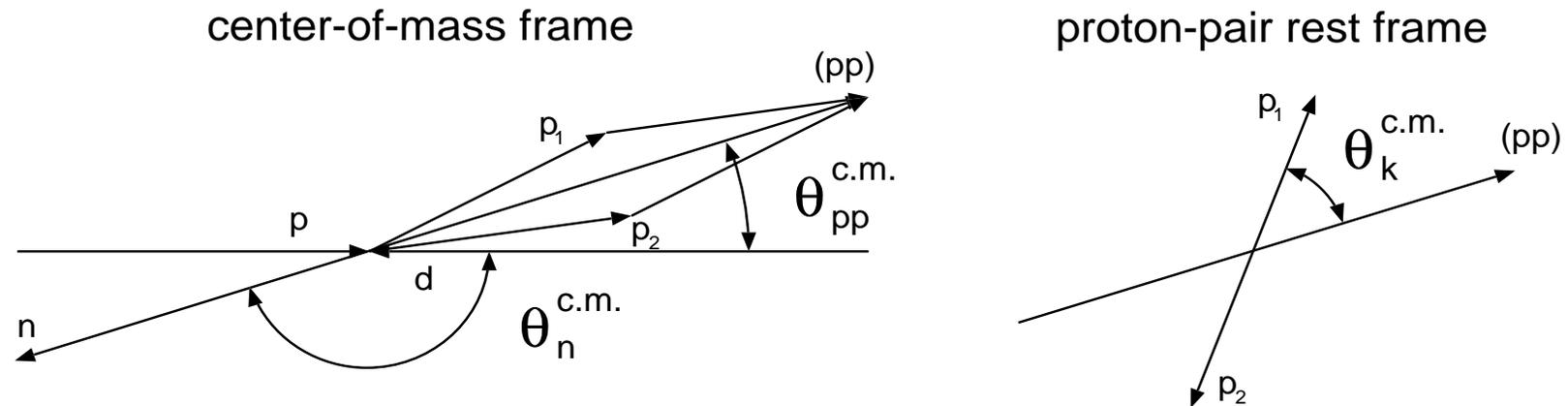
- Simulation of pd → ppn in 5-dimensional phase space: E_{pp}, $\cos \theta_{pp}$, ϕ_{pp}, $\cos \theta_k$, ϕ_k

- Tracing of events through ANKE FD using GEANT taking into account energy losses, multiple scattering, …

- Acceptance calculated as a function of two kinematical parameters $A(E_{pp}, \cos \theta_{pp})$

Experimental Results

- First experimental observation of pd → ppn in such kinematics

- Cross section is two orders of magnitude smaller than for pd → dp

- Differential cross sections measured at 6 beam energies 0.6, 0.7, 0.8, 0.95, 1.35, and 1.9 GeV

- Low statistics → cross sections integrated over E_{pp} from 0 to 3 MeV and averaged over center of mass polar angle θ_{pp} from 0 to 8 degree

- Energy dependence of differential cross section compared with prediction of ONE+SS+Δ model
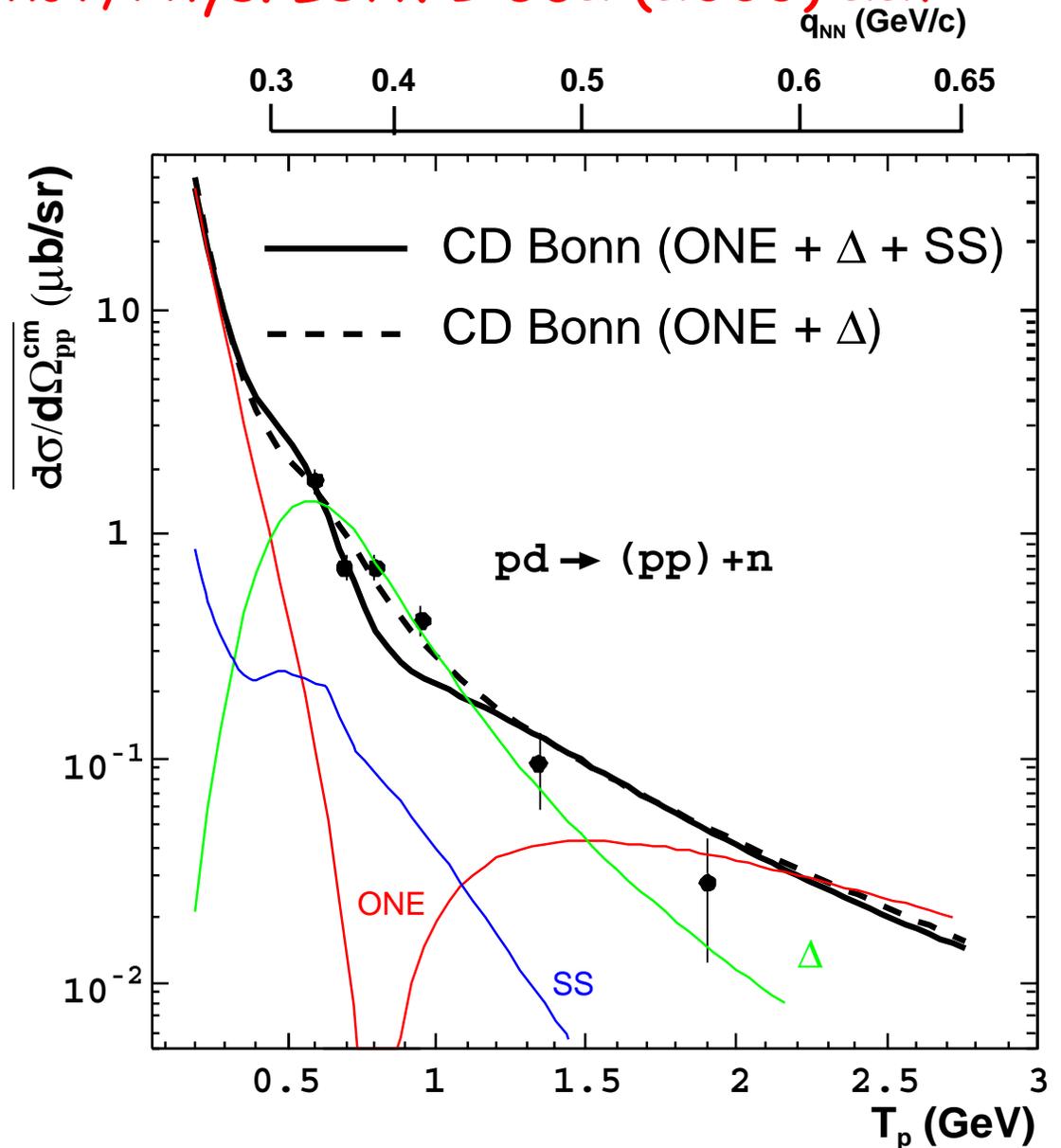
Experimental Results

- Comparison with calculations at the same conditions

- No expected dip

- Different behavior at high energies
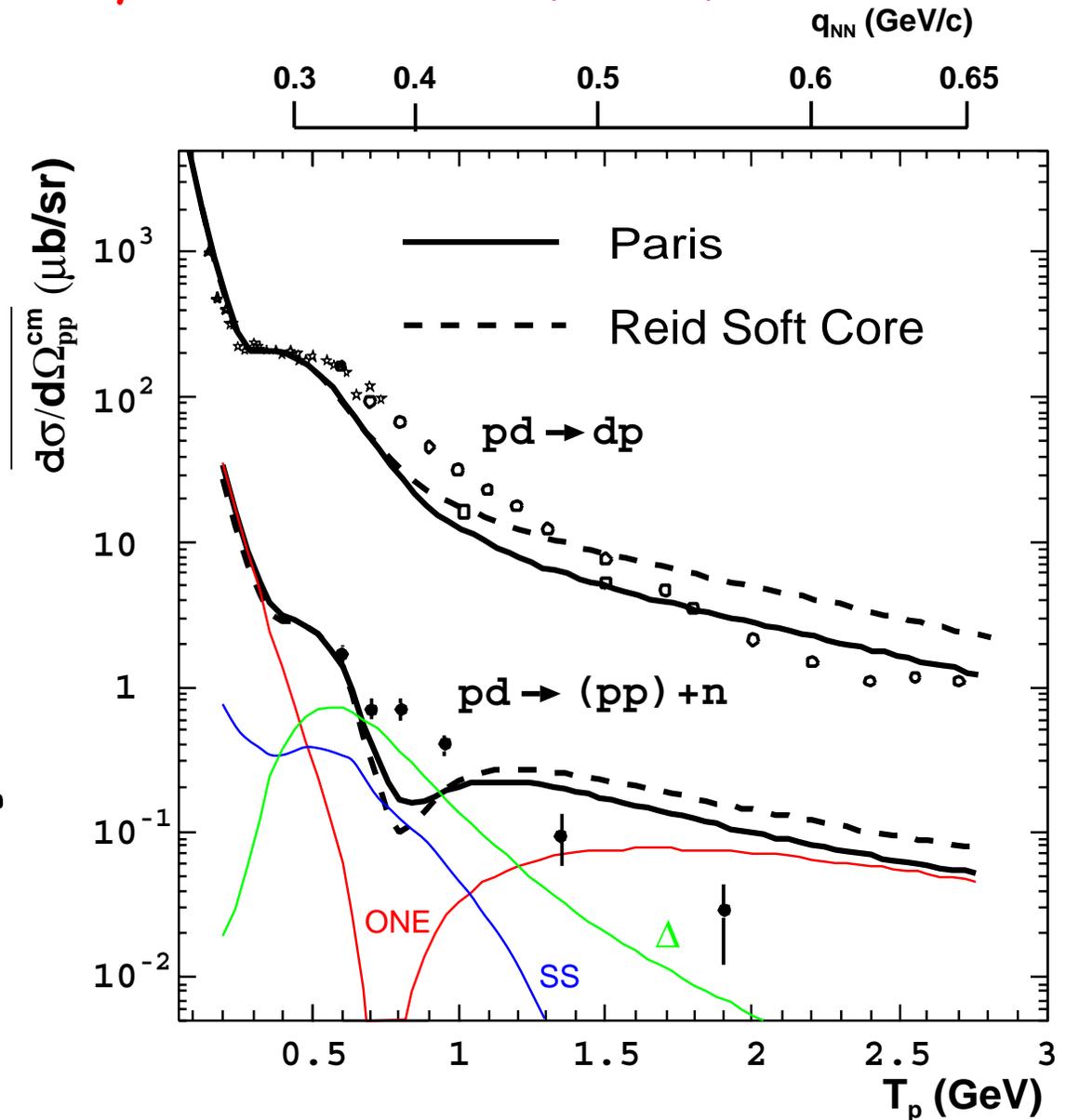
Theoretical Efforts
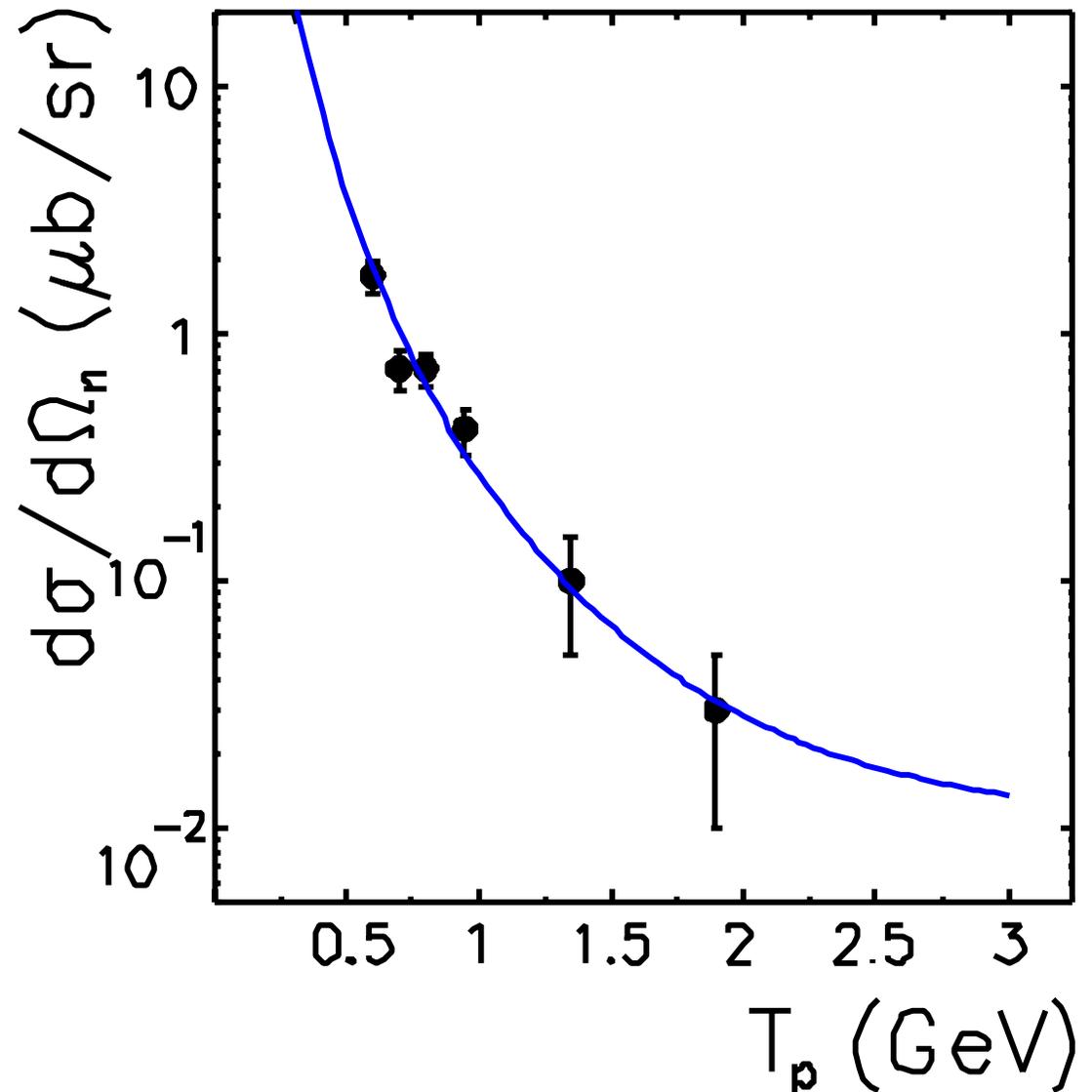
J.Haidenbauer, Yu.Uzikov, Phys. Lett. B 562 (2003) 227

- The same model but with CD Bonn potential

- Different relative contribution of ONE and Δ mechanisms

- Better agreement with the data

- Covariant Bethe-
  Salpeter approach

- Only ONE
  mechanism included

- No initial and final
  state interactions
  considered

Summary

- Measurement of the differential cross section of pd→(pp)n:
  - First observation of the process in such kinematics
  - Measurement of energy dependence of the cross section (T_p = 0.6, 0.7, 0.8, 0.95, 1.35, and 1.9 GeV)
  - Comparison with theoretical model

Outlook

- New experimental data obtained in July 2003:
  - Measurements at 0.5, 0.8, 1.1, 1.4, and 2.0 GeV
  - Data analysis is in progress