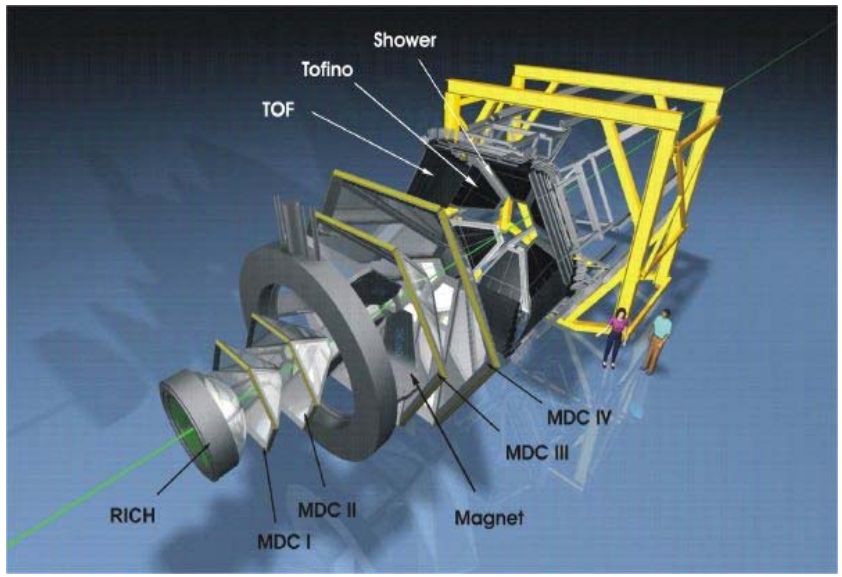
New data on the differential cross section of dp- elastic scattering at 2.5 GeV with HADES Detector



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(*LHEP-JINR*)

For the HADES collaboration

XXI Baldin ISHEPP

Dubna, Russia, 10 – 15 September, 2012

Outline

Introduction

- dp- elastic scattering events selection at 2.5 GeV
- dp- elastic scattering simulation results
- Efficiency and acceptance correction
- Results and discussion

Conclusion

Motivation

- Modern NN potentials (CD-Bonn, AV-18, Njimegen etc) accurately reproduce the NN data set up to about 350 MeV. However they fail in the description of the binding energy and data on unpolarized dp- elastic scattering and breakup reactions.
- Incorporation of three nucleon forces (3NF), when interaction depends on the quantum numbers of the all three nucleon, allows to reproduce the bending energy of the three-nucleon bound systems and the data on unpolarized dp interaction.
- Polarization data for the reaction with participation of three and more nucleons aren't described even with the 3NF inclusion.
- The cross section data for dp- elastic scattering are reproduced well up to 150 MeV taking into account 3NF. Manifestation of three-nucleon forces effect in the cross-section of dp- elastic scattering at this energy: up to 30% in the vicinity of Sagara discrepancy.

nd and pd- elastic scattering measurements at the energy of 250 MeV

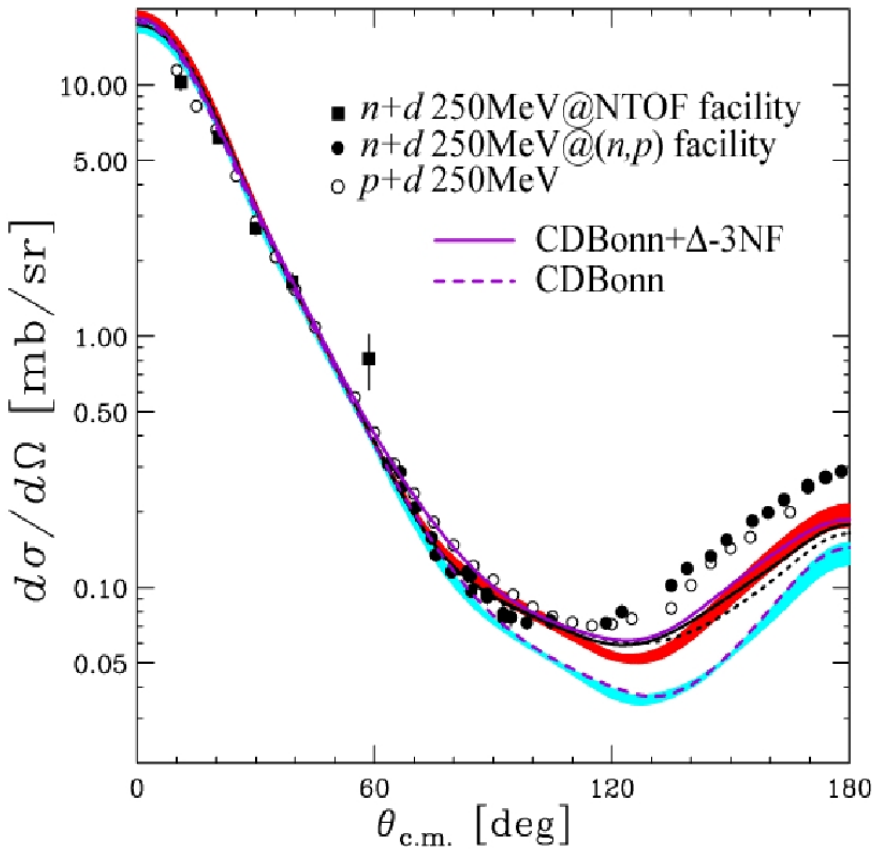
Faddeev calc (by Prof. H. Kamada)
- : *NN* only (CD-Bonn, AV18, Nijmegen-I,II,93)
- : *NN* with TM-3NF
- : AV18+UrbanaIX-3NF
- : CD-Bonn+TM'-3NF

CC calc (by Hannover group)
- : **CD-Bonn**
- : **CD-Bonn+Δ-3NF**

Calculations even including 3NF underestimate the data at $\Theta_{c.m}$ ~110-180 deg

Relativistic calculations improve the fit of the data only at $\Theta_{c.m}$ >160 deg

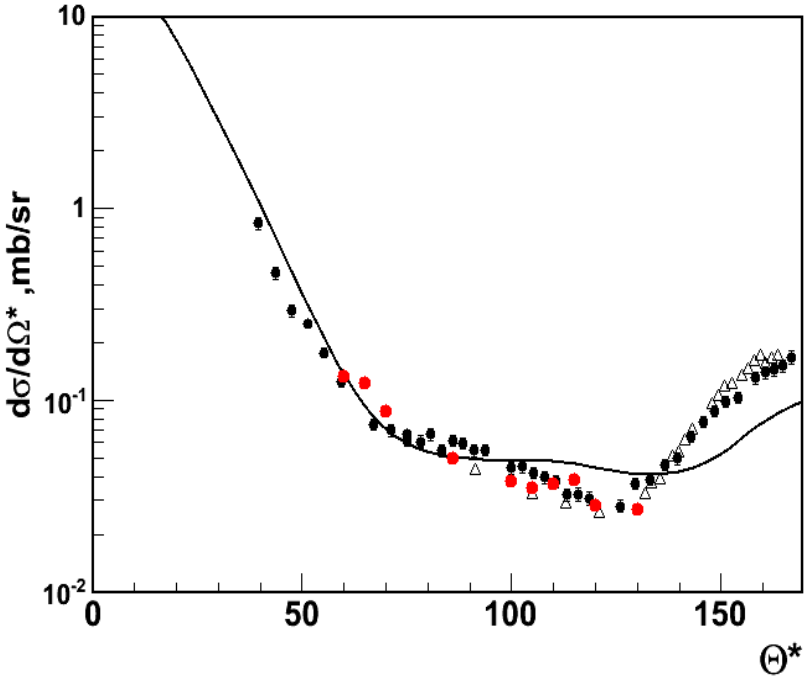
H.Sakai, FB18, Santos, Brazil, (2006)



Y. Maeda et al., Phys. Rev. C 76, 014004 (2007)

K. Hatanaka et al., Phys. Rev. C 66, 044002 (2002)

Cross section in *dp*- elastic scattering at 880 MeV



- The results of the multiple scattering model are in agreement with the cross section data in the range 30 - 130º.
- Double scattering dominates over single scattering at the angles larger than 70º.
- Deviation of the data on the calculations at backward angles are related with the s-type of the FM 3NF.
- Is the deviation on the data from the calculations around 90º manifestation of 3N SRC?

World data:

N.E.Booth et al., Phys.Rev.D4 (1971) 1261

J.C.Alder et al., Phys.Rev.C6 (1972) 2010

Relativistic multiple scattering model calculation:
N.B.Ladygina, Eur.Phys.J, A42 (2009) 91

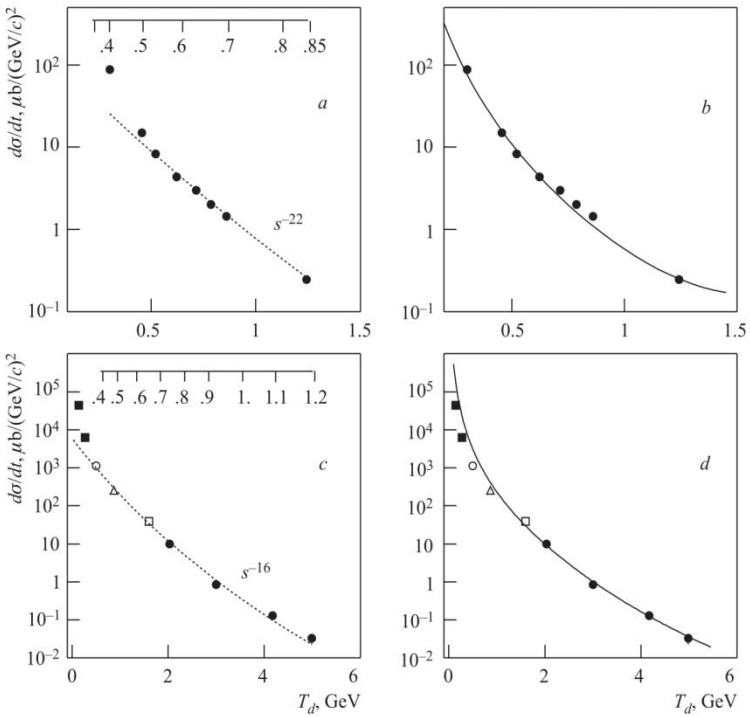
Red circles are the preliminary LHEP-JINR results: DSS-project at Nuclotron (see talk Yu.V.Gurchin)

Quark degrees of freedom

- At high energy s and large transverse momenta p_t the constituent counting roles (CCR) predict the following behavior of the differential cross section for the binary reactions:

$$\frac{d\sigma}{dt}(ab \to cd) = \frac{f(t/s)}{s^{n-2}} \quad ; \quad n = N_a + N_b + N_c + N_d$$

(*Matveev, Muradyan, Tavkhelidze, Brodsky, Farrar et al.*)



Yu. N. Uzikov

(JEPT Lett, 81, pp. 303-306, 2005)

For the reaction dd → ^{3}Hen

$$N_A + N_B + N_C + N_D - 2 = 22$$

For the reaction dp → dp

$$N_A + N_B + N_C + N_D - 2 = 16$$

The regime corresponds to CCR can occur already at $T_d \sim 500$ MeV

HADES experiment at SIS18, GSI

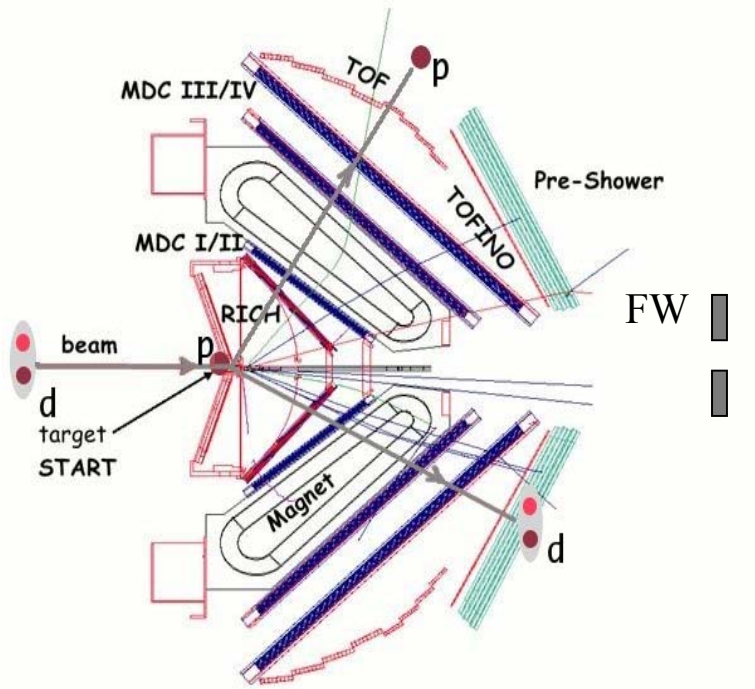
Spectrometer with …

High geometrical acceptance
Full azimuth, polar angles 18˚ - 85˚
Pair acceptance ≈ 0.35

High invariant mass resolution (2.5% at ρ/ω pole mass)
Low-mass tracking (superconducting toroidial magnet & multi-wire drift chamber (MDC), single cell resolution ≈100 mm)

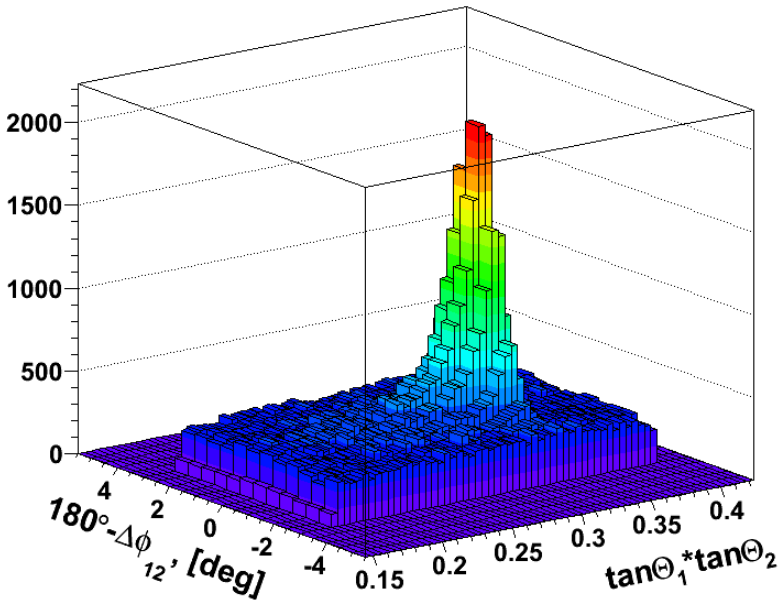
Powerful PID capabilities: d/p/K/p/e
RICH, TOF/TOFino, Pre-Shower,
FW hodoscope: added 2007

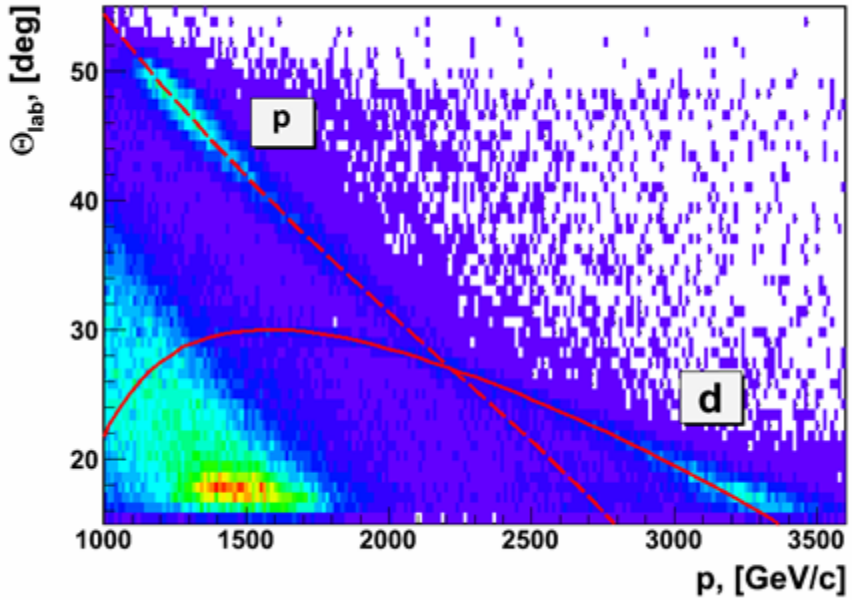
High background rejection & rate capability, dedicated LVL2 trigger:
LVL1: charge particle multiplicity
LVL2: single electron trigger



Schematic view of the HADES spectrometer

dp- elastic events selection at 2.5 GeV



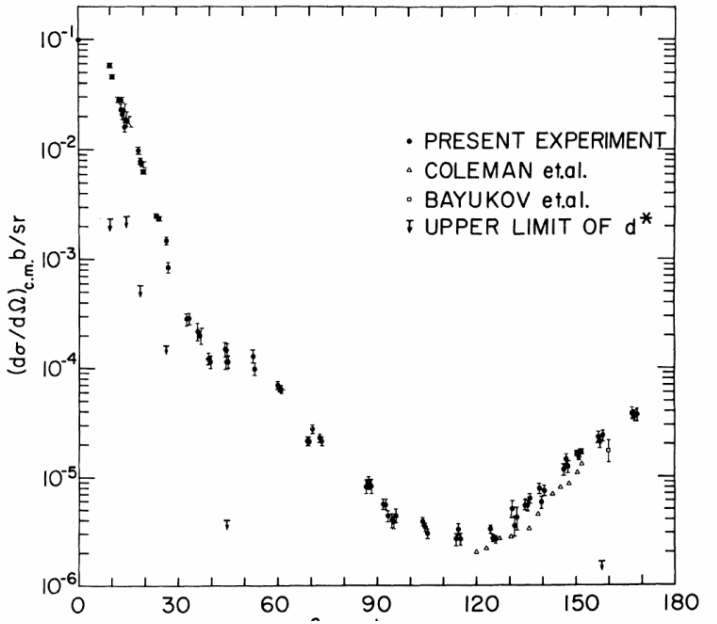


The dp- elastic events candidate selection:

$0.17 < \tan\theta_1 * \tan\theta_2 < 0.4$, $||\varphi_1 - \varphi_2| - 180^\circ| < 3^\circ$

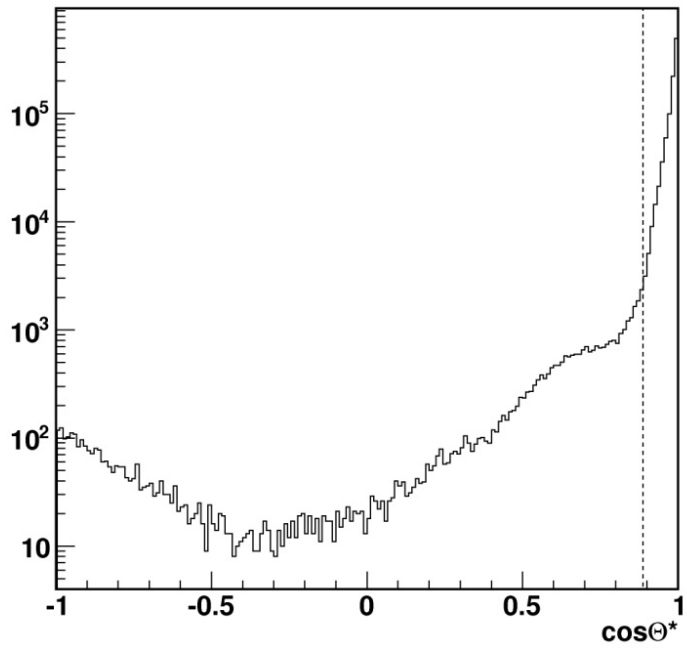
The angle-momentum distribution for dp- elastic scattering candidates compared with kinematical predictions.

Simulation of *dp*- elastic scattering at 2.5 GeV



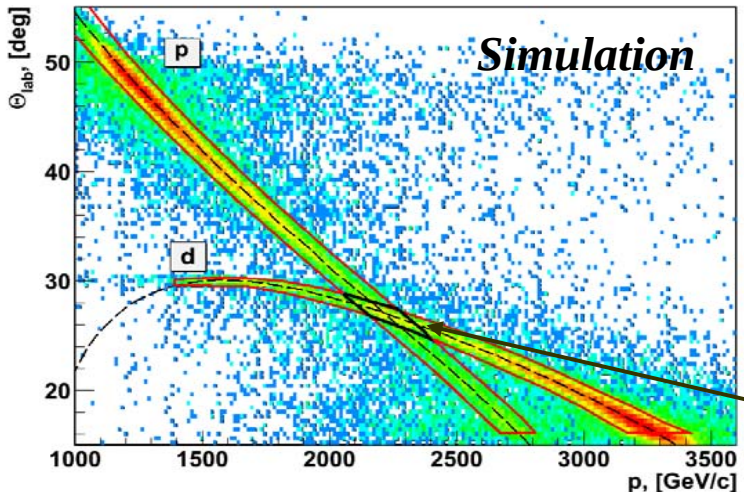
The pd- elastic cross section data versus scattering angle in c.m.s. at 1 GeV.

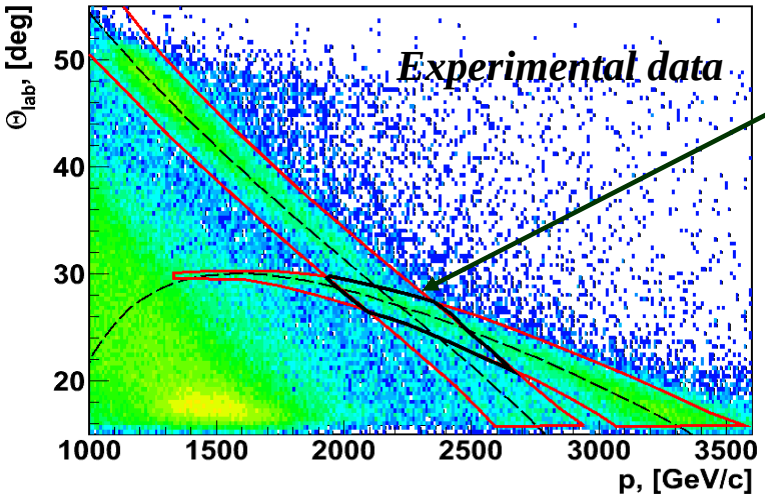
G.W. Bennet et al., Phys. Rev. Lett. 19, 387 (1967)

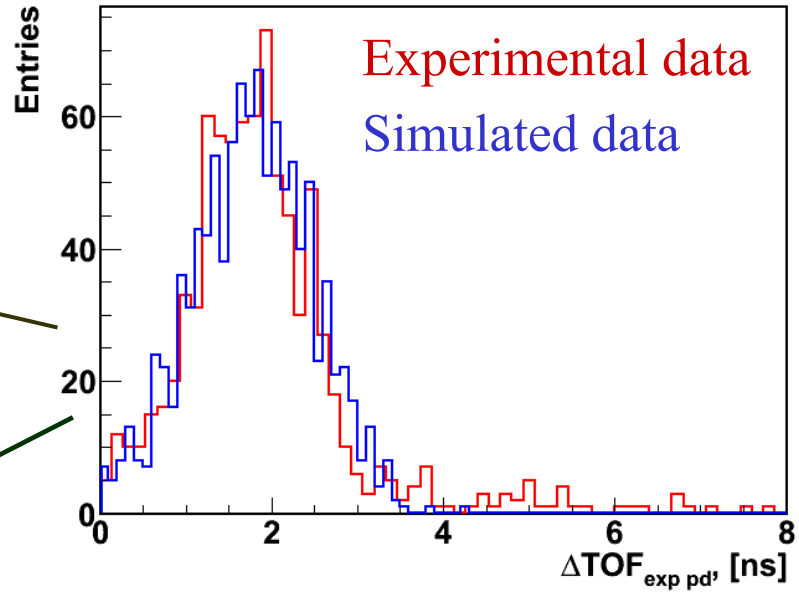


The angular distribution used for simulation of dp- elastic scattering at 1.25 GeV/u. The cross section data was fixed at the $\cos\theta^* > 0.886$.

dp- elastic events selection at 2.5 GeV

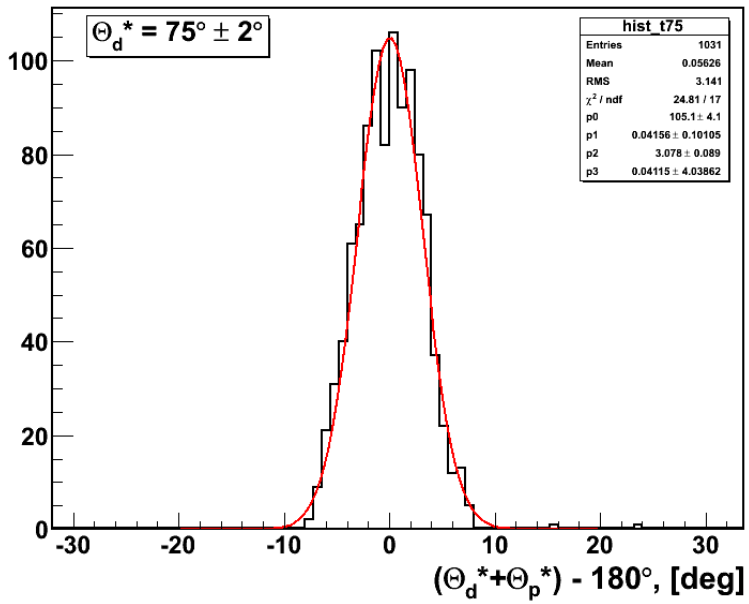


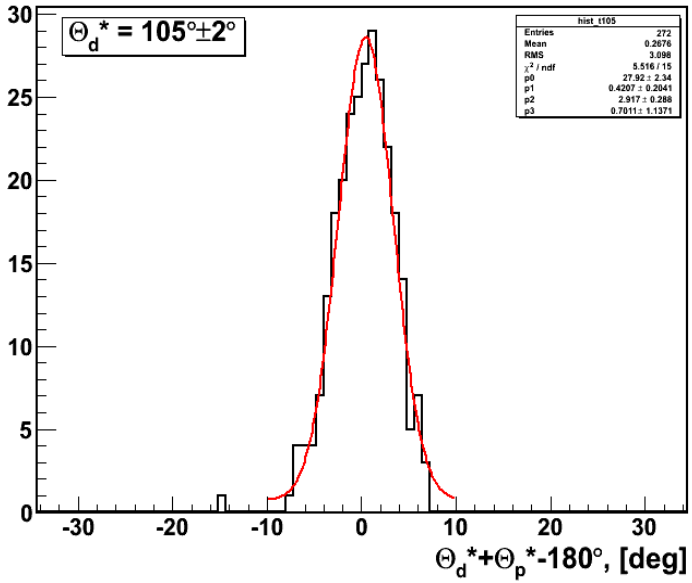




The experimental time difference distribution between two particles for the graphical cuts overlap region.

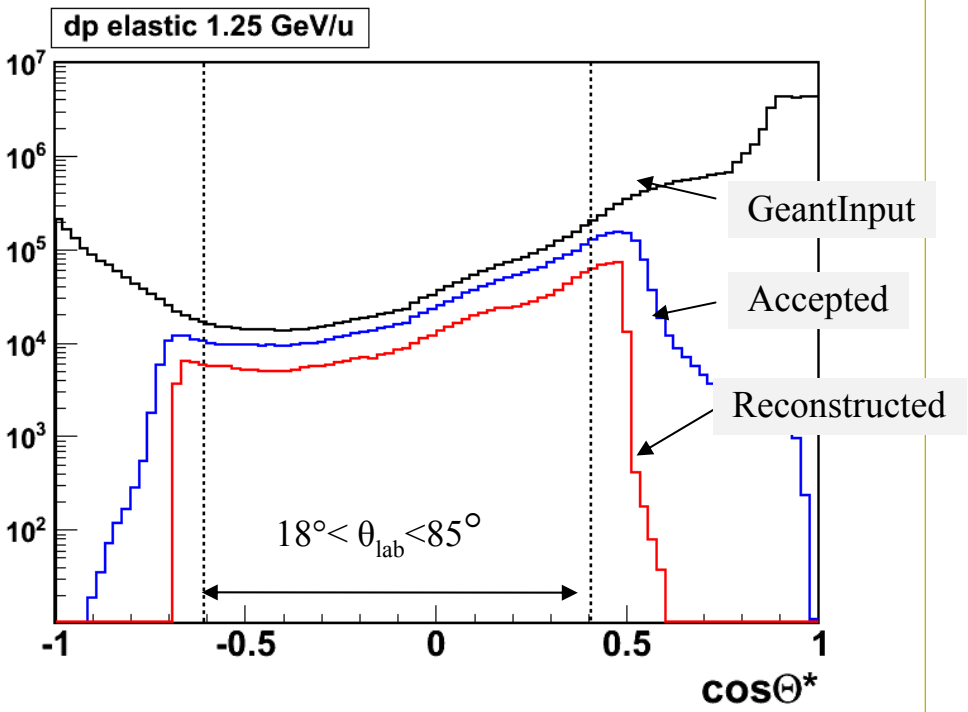
Quality of the *dp*- elastic events selection



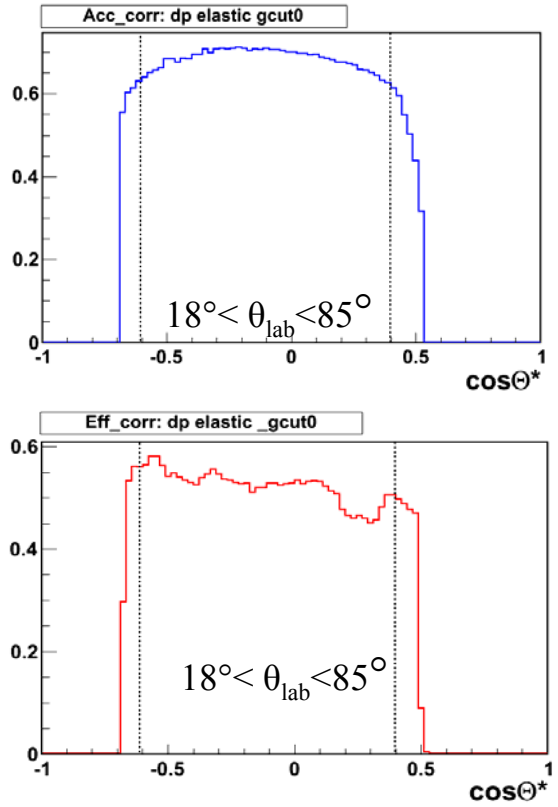


The distribution of the $(\theta_d^*+\theta_p^*)$ - 180º for the angular region 75º ± 2º (Left panel) and for the 105º ± 2º (Right panel) in the c.m.

Results of the *dp*- elastic scattering simulation at 2.5 GeV



Distribution of the dp- elastic scattering yield as a function of the cosθ*. Black, blue and red histograms are the distribution for dp-elastic scattering using as the geant input, accepted and reconstructed, respectively.



Acceptance and efficiency reconstruction coefficients for the dp- elastic scattering events.

Efficiency and acceptance correction for *dp*- elastic scattering at 2.5 GeV

$$\frac{d\sigma_{dp}}{d\Omega^*} = \frac{\sigma_{pp}}{N_{pp}} * \frac{\Delta N_{dp}}{\Delta\Omega^*}$$

$$\Delta\Omega^* = 2\pi * \Delta(\cos\Theta^*)$$

$$\Delta N_{dp} = 128 * dN_{dp}^{\exp}$$

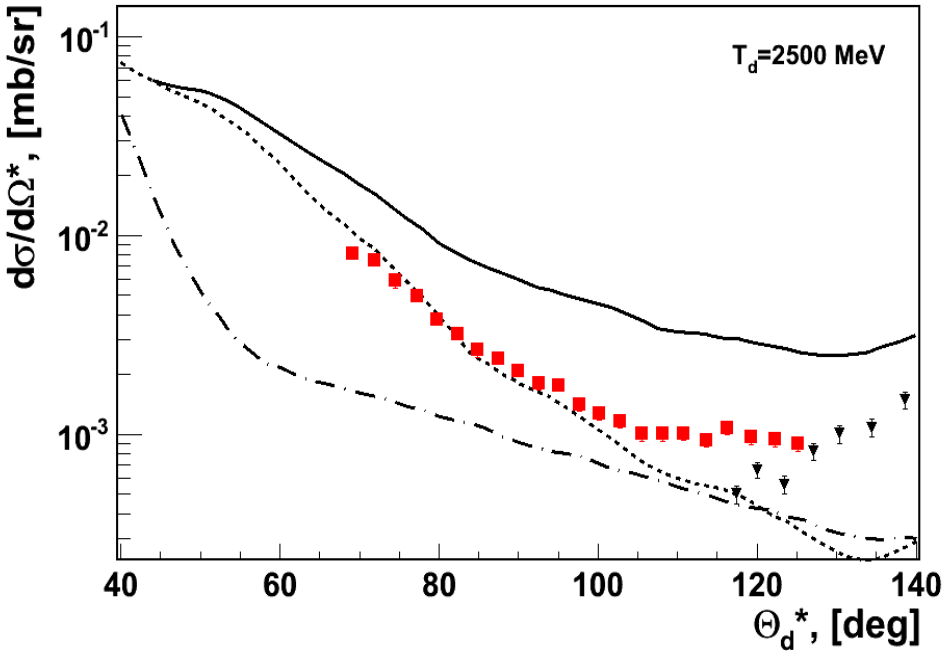
dN_{dp}^{exp} is efficiency and acceptance corrected

- rkMult ≥ 2
- $|\Delta\varphi_{dp}| < 3^o$
- $0.17 < \tan\Theta^*_d * \tan\Theta^*_p < 0.4$
- $18^o < \Theta_{lab}$ [d,p] $< 85^o$
- $\frac{\sigma_{pp}}{N_{pp}} = (3.85 \pm 0.25) * 10^{-9}$ mb/events

http://hades-wiki.gsi.de/pub/SimAna/NormalizationForPpAndDp/pp_elastic260109.pdf

To evaluate the systematic related with the efficiency correction the graphical cut width were changed by the normal distribution in the region $\Delta D \pm 1/4\ \Delta D$

Differential cross section of *dp*- elastic scattering at 2.5 GeV



HADES

SS

SS+DS

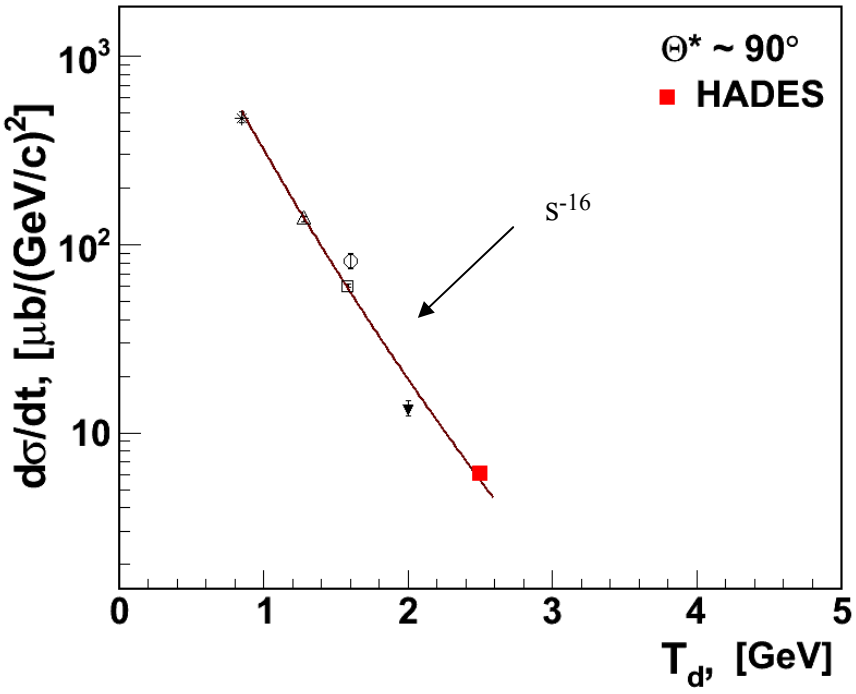
SS+DS $_{\text{w/o pvp}}$

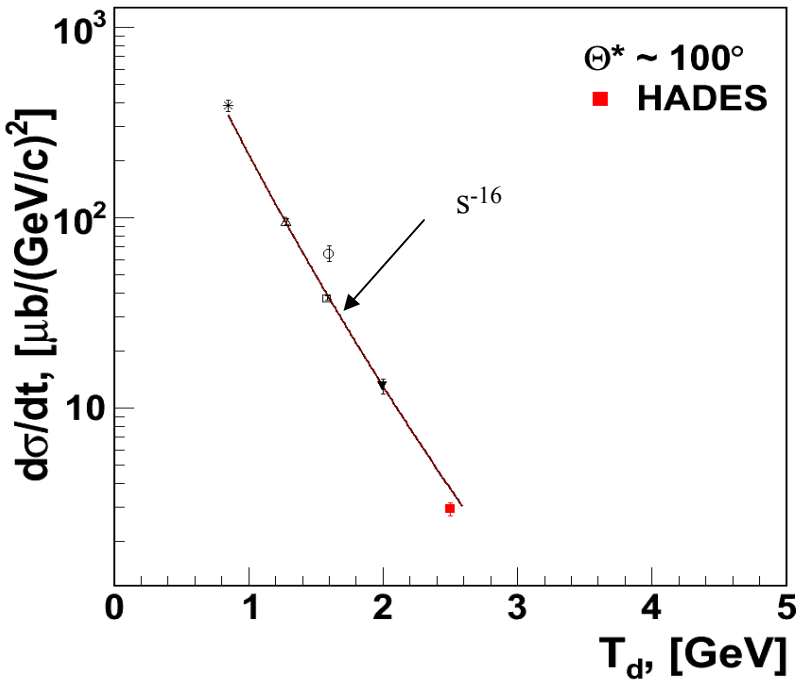
Experimental data:
E.Coleman et al., Phys. Rev. Lett. 16, 741 (1966)

Theoretical calculation:
N.B.Ladygina, Eur.Phys.J, A42 (2009) 91

The angular dependence of the dp-elastic cross section at 1.25 GeV/u compared with the relativistic multiple scattering model calculations. The triangles are the world data obtained at 1.3 GeV/u.

Differential cross section data for *dp* -elastic scattering at fixed scattering angle in the cm.





Experimental data:

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Constituent counting rules:

V.A. Matveev, R.M. Muradyan and A.N. Tavkhelidze, Lett. Nuovo Cimento 7, 719 (1973)
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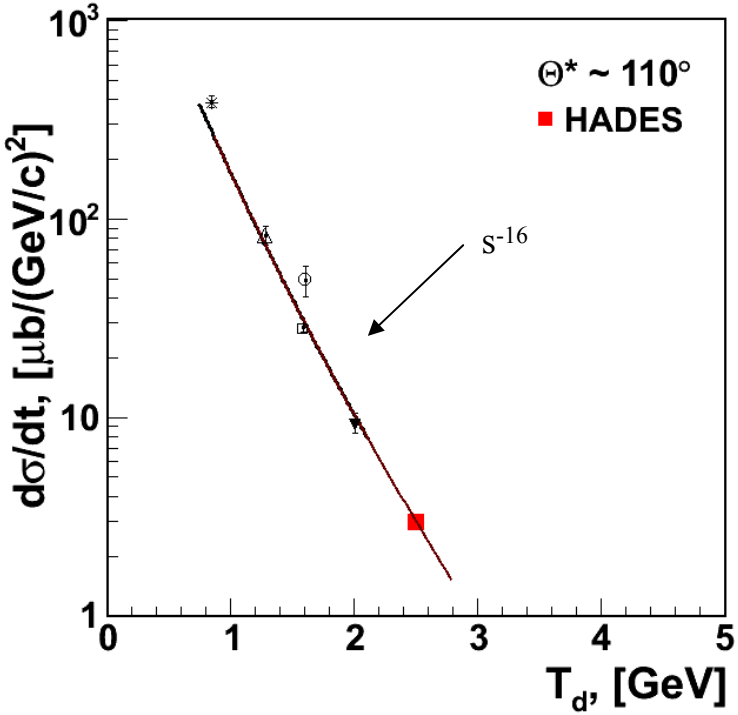
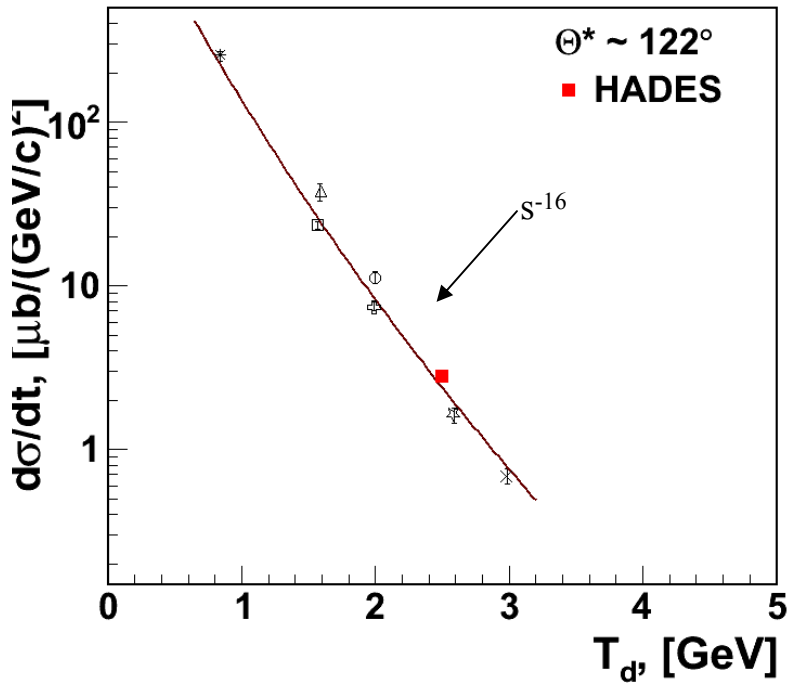
Differential cross section data for *dp*- elastic scattering at fixed scattering angle in the cm.





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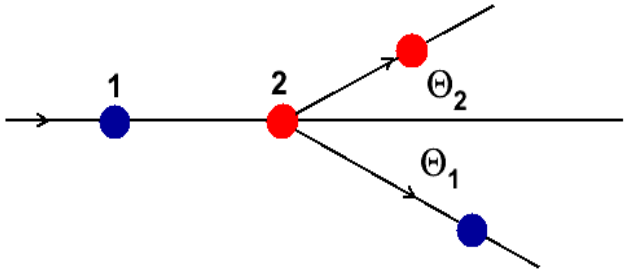
Summary

- The differential cross section for dp- elastic scattering is measured with the HADES spectrometer in the angular range of 68º - 125º in c.m. at 2.5 GeV.
- The dp- elastic scattering data are compared with the relativistic multiple scattering model calculation using CD-Bonn deuteron wave function.
- The behavior of the cross section data at fixed scattering angles in the c.m. is in a satisfactory agreement with the constituent counting rules prediction.

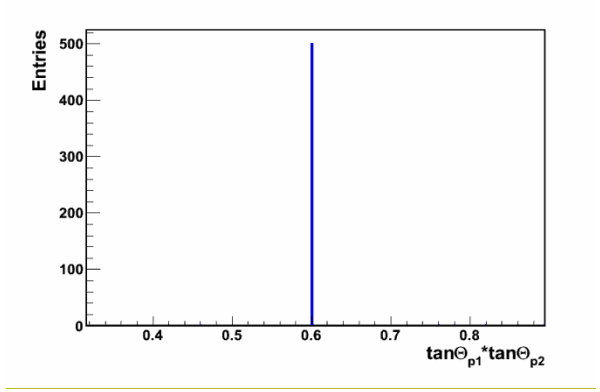
Thank you for your attention!!!

The pp and dp elastic scattering selection

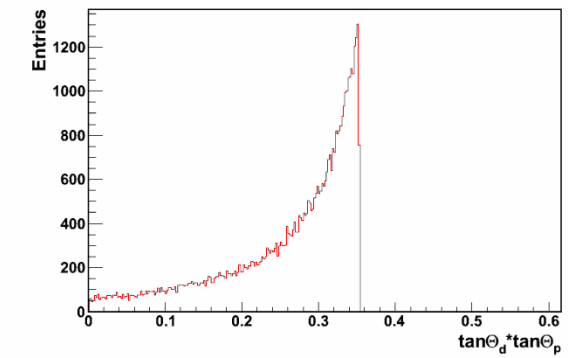


The criteria for elastic scattering process selection:

- $\varphi_1 - \varphi_2 = 180°$
- $\tan\theta_1 * \tan\theta_2$

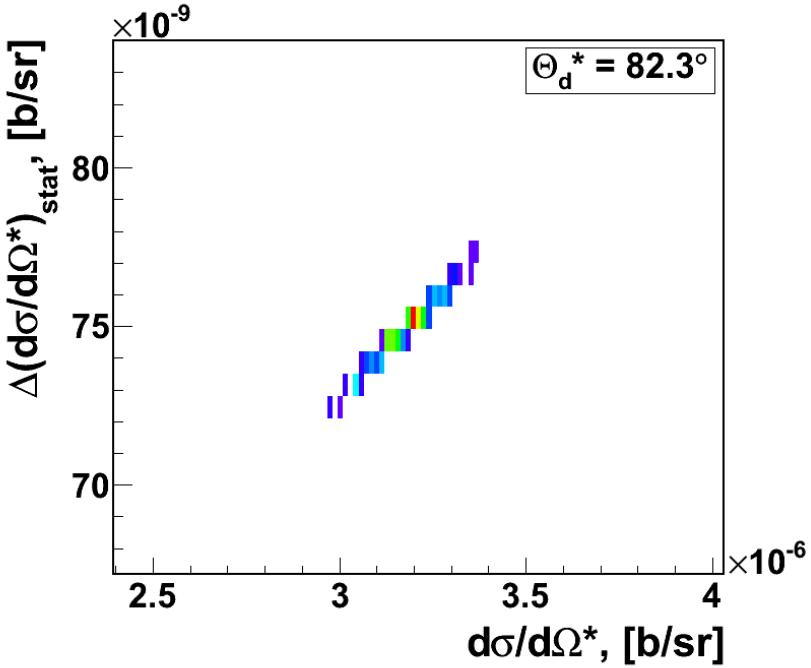


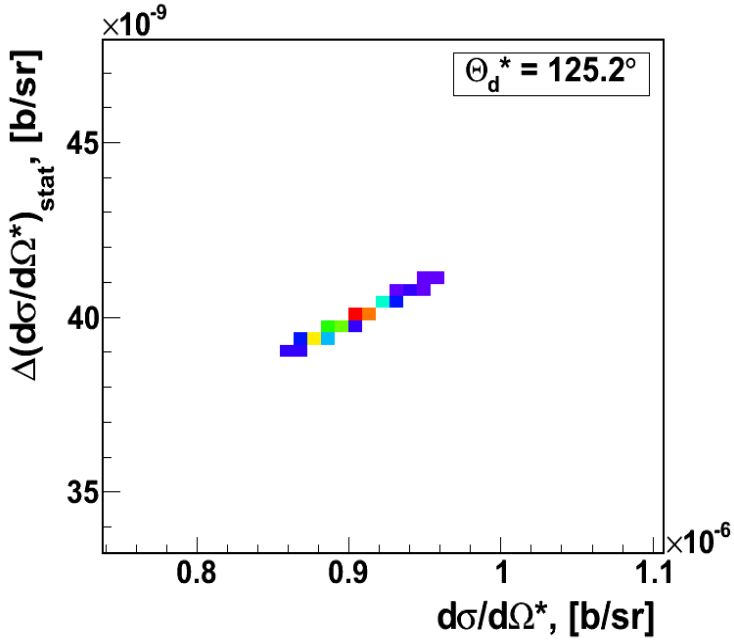
pp elastic scattering at 1.25 GeV



dp elastic scattering at 2.5 GeV

Systematic errors evaluation for the dp-elastic cross section measurement at 1.25 GeV/u





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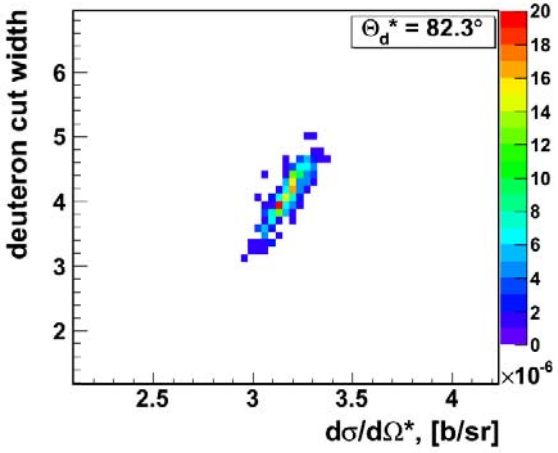
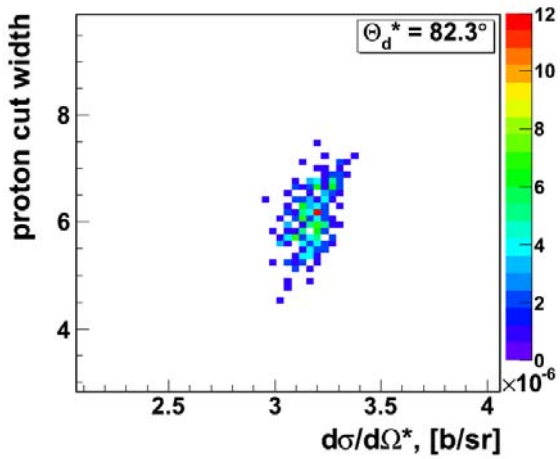
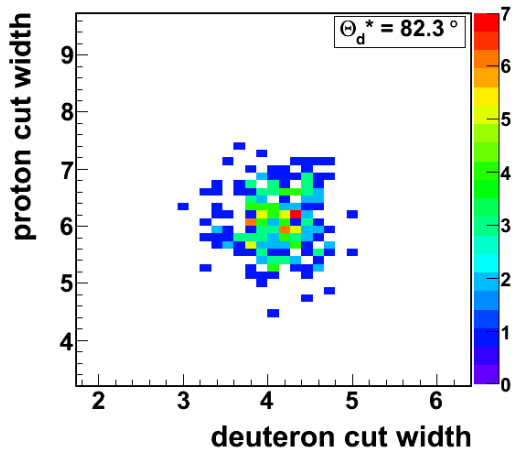
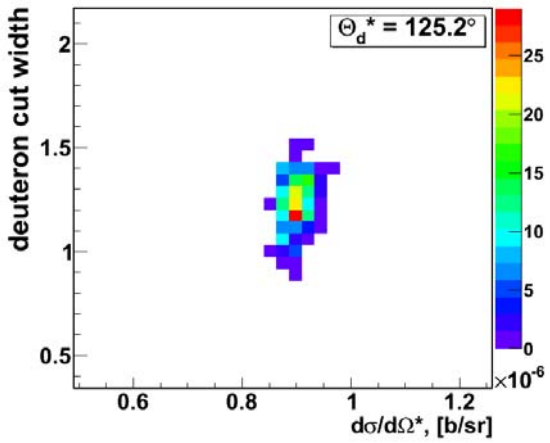
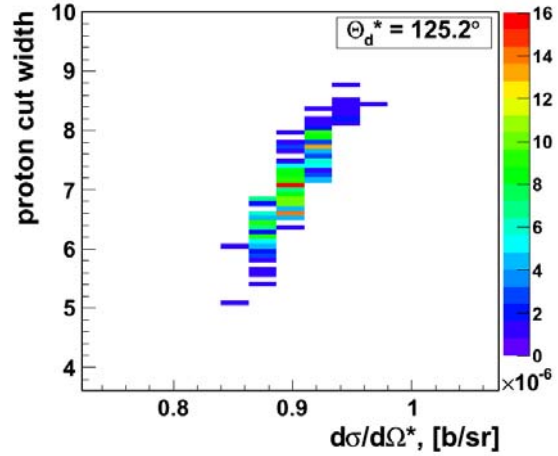
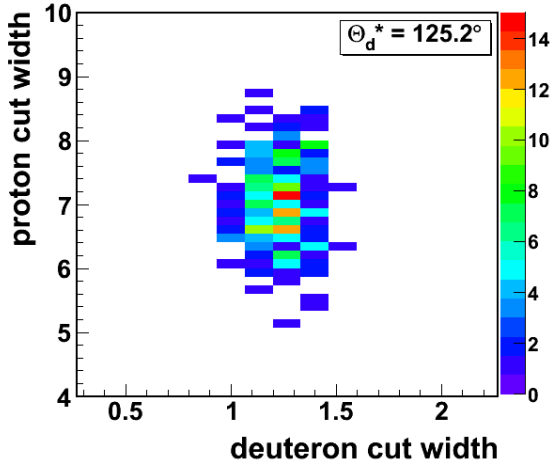






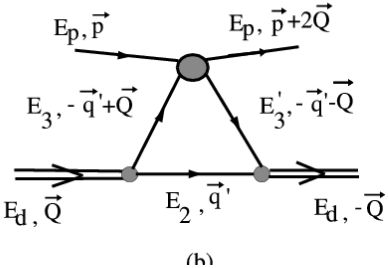






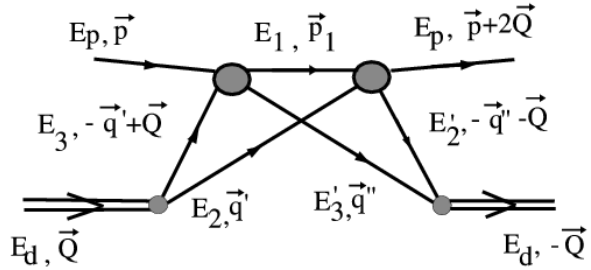
Theoretical model

$$
\begin{aligned}
\mathcal{J}_{dp\to dp} &= \mathcal{J}_{\rm SS} + \mathcal{J}_{\rm DS}, \\
\mathcal{J}_{\rm SS} &= 2 < 1(23)|t_3^{\rm sym}|1(23) >, \\
\mathcal{J}_{\rm DS} &= 2 < 1(23)|t_3^{\rm sym} g_0 t_2^{\rm sym}|1(23) >,
\end{aligned}
$$



(b)

$$
\begin{aligned}
\mathcal{J}_{SS} \; - & \int d\vec{q}\,' < -\vec{Q}\mathcal{M}'_d|\Omega_d^\dagger|\vec{q}\,'\mu_2, -\vec{Q} - \vec{q}\,'\mu'_3 > \qquad (12) \\
& < \vec{p}\,'\mu', -\vec{Q} - \vec{q}\,'\mu'_3|\frac{3}{2}t_{13}^1(E) + \frac{1}{2}t_{13}^0(E)|\vec{p}\mu, \vec{Q} - \vec{q}\,'\mu_3 > \\
& < \vec{q}\,'\mu_2, \vec{Q} - \vec{q}\,'\mu_3|\Omega_d|\vec{Q}\mathcal{M}_d > \quad .
\end{aligned}
$$



(c)

$$
\begin{aligned}
& \mathcal{J}_{DS} - \int d\vec{q}\,' \int d\vec{q}\,'' < -\vec{Q}\mathcal{M}'_d|\Omega_d^\dagger \qquad (13) \\
& |-\vec{Q} - \vec{q}\,''\,\mu'_2, \vec{q}\,''\,\mu'_3 >< \vec{p}'\,\mu', -\vec{Q} - \vec{q}\,''\,\mu'_2, \vec{q}\,''\,\mu'_3| \\
& \frac{t_{12}^1(E')t_{13}^1(E) \;+\; |t_{12}^1(E') \;+\; t_{12}^0(E')||t_{13}^1(E) \;+\; t_{13}^0(E)|/4}{E_d + E_p - E_1 - E_2 - E'_3 + i\varepsilon} \\
& |\vec{p}\,\mu, \vec{q}\,'\,\mu_2, \vec{Q} - \vec{q}\,'\,\mu_3 > \\
& < \vec{q}\,'\,\mu_2,\; \vec{Q} - \vec{q}\,'\,\mu_3|\Omega_d|\vec{Q}\mathcal{M}_d > .
\end{aligned}
$$

$$
\begin{aligned}
& \frac{1}{E_d + E_p - E_1 - E_2 - E'_3 + i\varepsilon} = \qquad (15) \\
& \mathcal{P}\frac{1}{E_d + E_p - E_1 - E_2 - E'_3} - i\pi\delta(E_d + E_p - E_1 - E_2 - E'_3).
\end{aligned}
$$