Count what is countable, measure what is measurable, and what is not measurable, make measurable. - Galileo Galilei

Double polarized DD-fusion

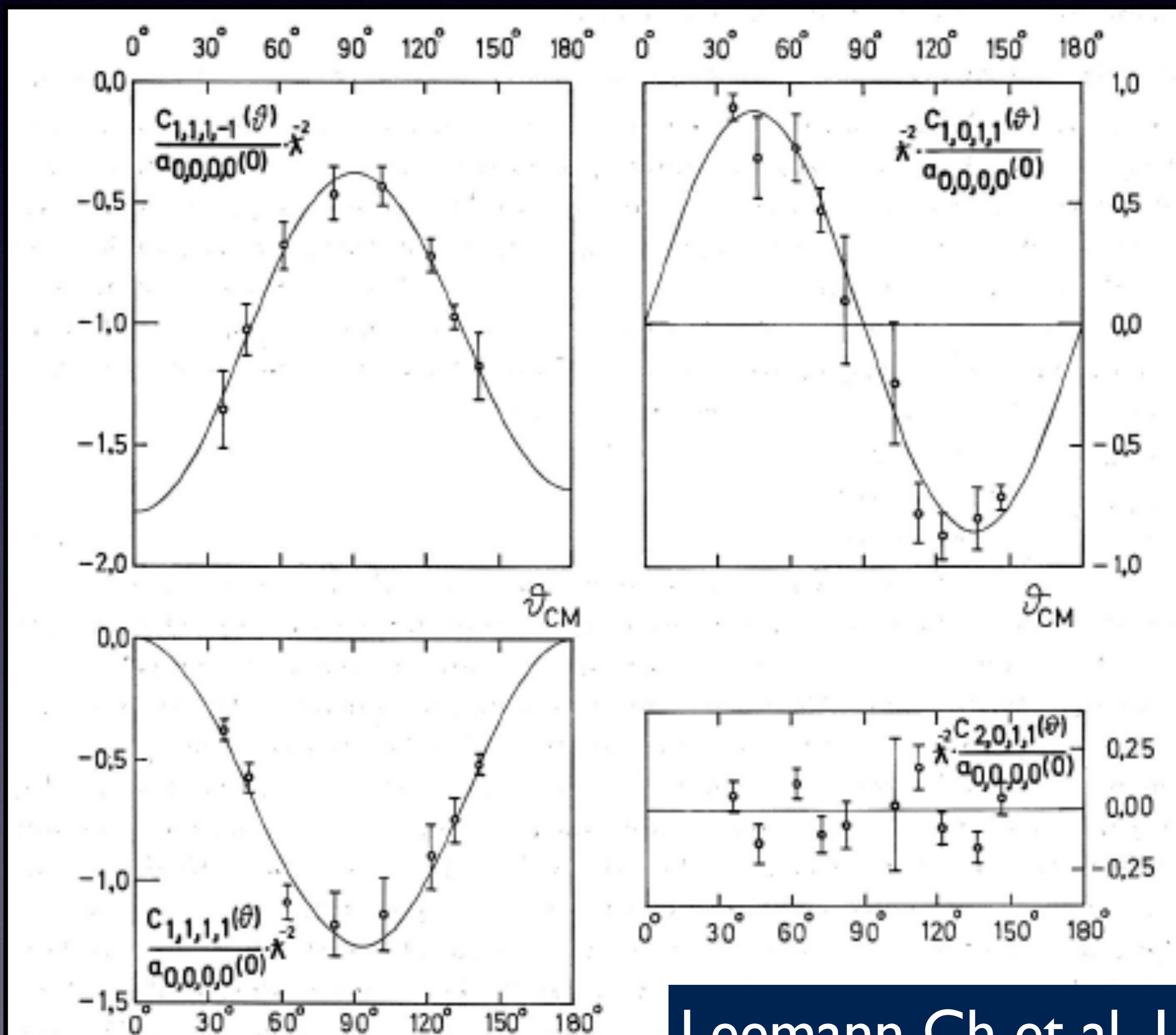
Status of PolFusion experiment

(PNPI, Gatchina, Russia)
Polina Kravchenko
on behalf of collaboration

Motivation
Experimental setup
MC simulations and Mathematical model

Motivation

Increase the gain of nuclear fusion reaction



$$^3\vec{He} + \vec{d} \rightarrow {}^4He + p$$

$$\vec{t} + \vec{d} \rightarrow {}^4He + n$$

Leemann Ch et al. 1971 Helv.Phys.Acta 44, p141

Cross section ↑ with factor 1.5 at 430keV

Motivation

Increase the gain of nuclear fusion reaction

$$^3\vec{He} + \vec{d} \rightarrow {}^4He + p$$

$$\vec{t} + \vec{d} \rightarrow {}^4He + n$$

What about $\vec{d} + \vec{d} \rightarrow {}^3He + n$?

$$\vec{d} + \vec{d} \rightarrow t + p$$

No data in the low energy range 10-100keV

Theoretical predictions are **complicated**

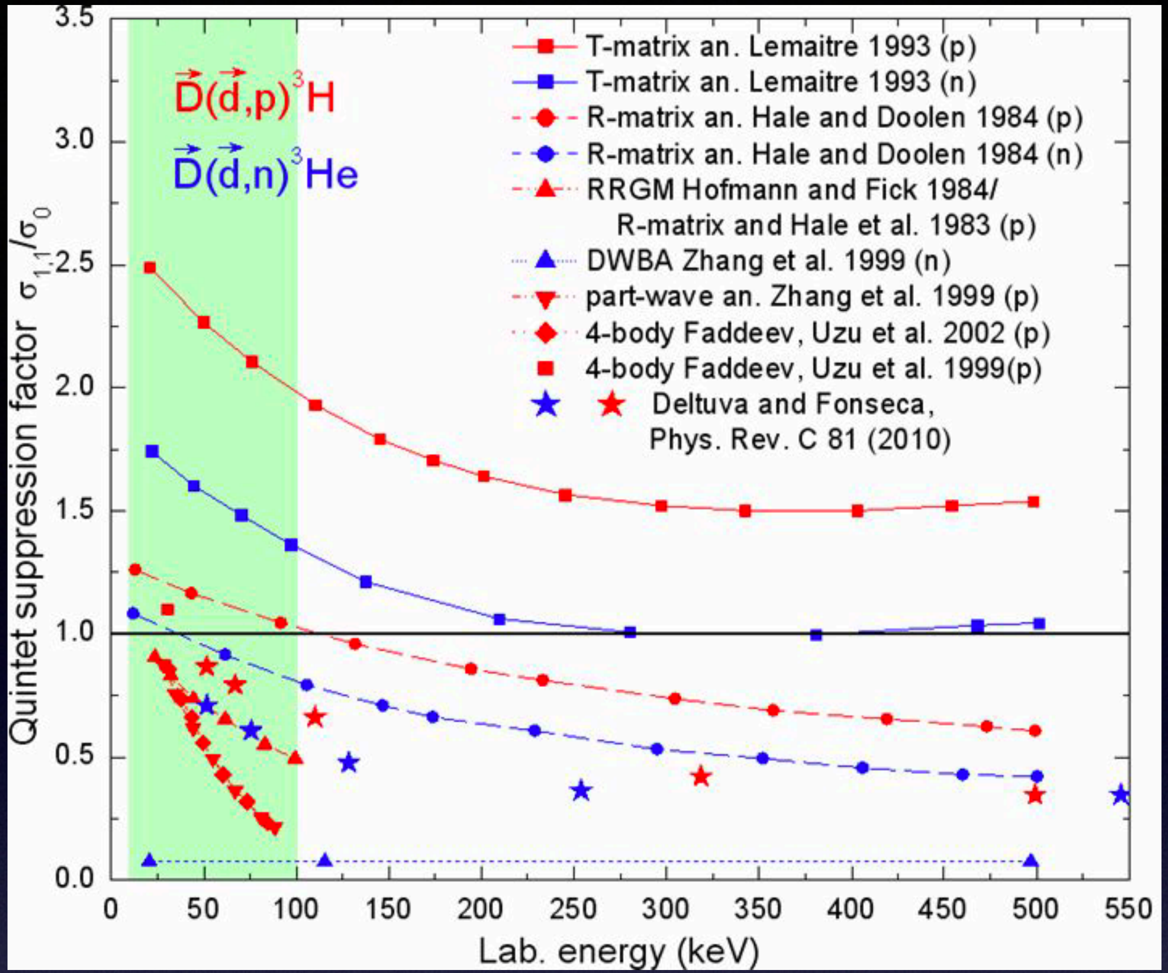
not S-dominated

P-, D-waves **can not be neglected**

Motivation

$$\vec{d} + \vec{d} \rightarrow {}^3He + n$$

$$\vec{d} + \vec{d} \rightarrow t + p$$



Sum of the independent channel-spin cross sections

$$\sigma_0 = \frac{1}{9}(2\sigma_{1,1} + 4\sigma_{1,0} + \sigma_{0,0} + 2\sigma_{1,-1})$$

Quintet **Triplet** **Singlet** **spin configurations**

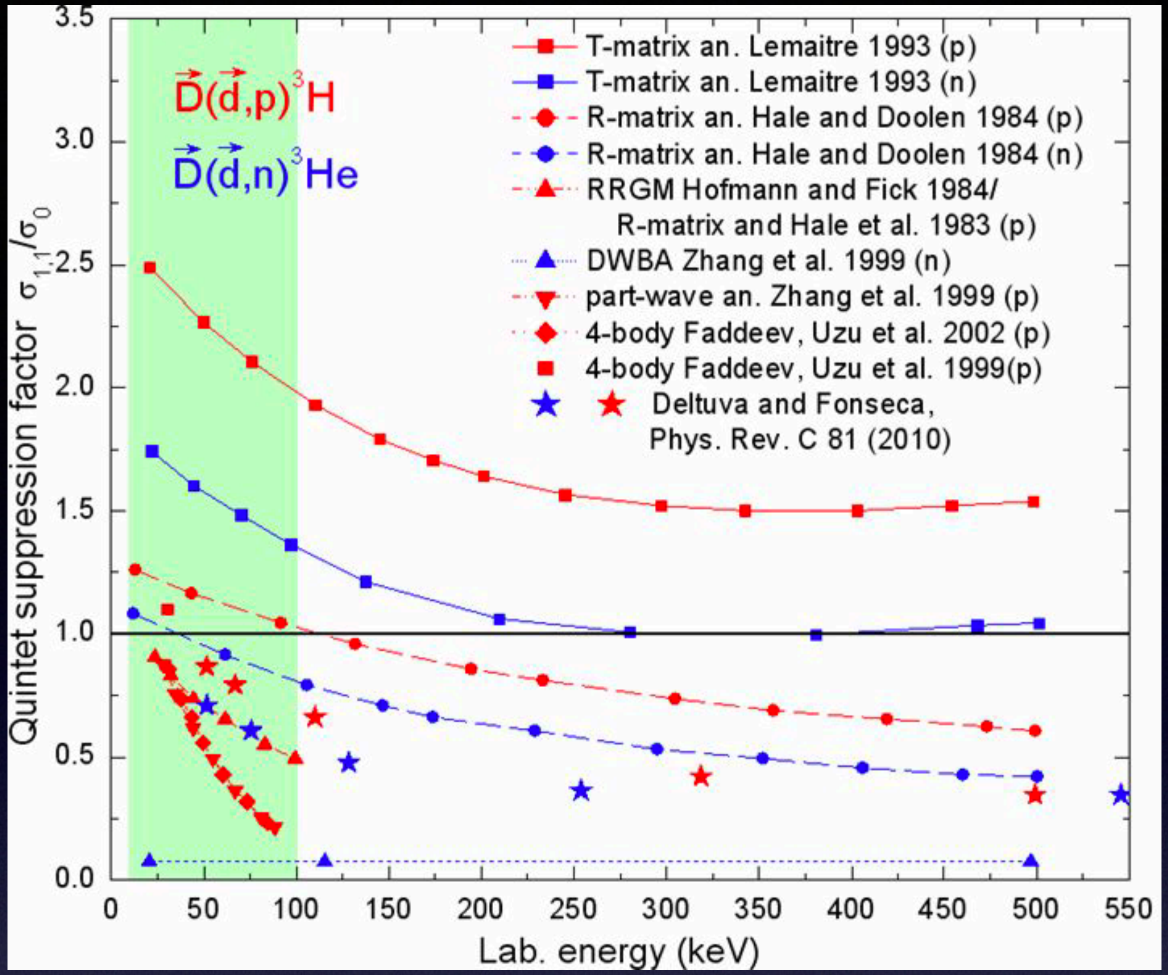
Quintet suppression Factor

$$QSF = \frac{\sigma_{1,1}}{\sigma_0}$$

Motivation

$$\vec{d} + \vec{d} \rightarrow {}^3He + n$$

$$\vec{d} + \vec{d} \rightarrow t + p$$



Sum of the independent channel-spin cross sections

$$\sigma_0 = \frac{1}{9}(2\sigma_{1,1} + 4\sigma_{1,0} + \sigma_{0,0} + 2\sigma_{1,-1})$$

Quintet **Triplet** **Singlet** **spin configurations**

Quintet suppression Factor

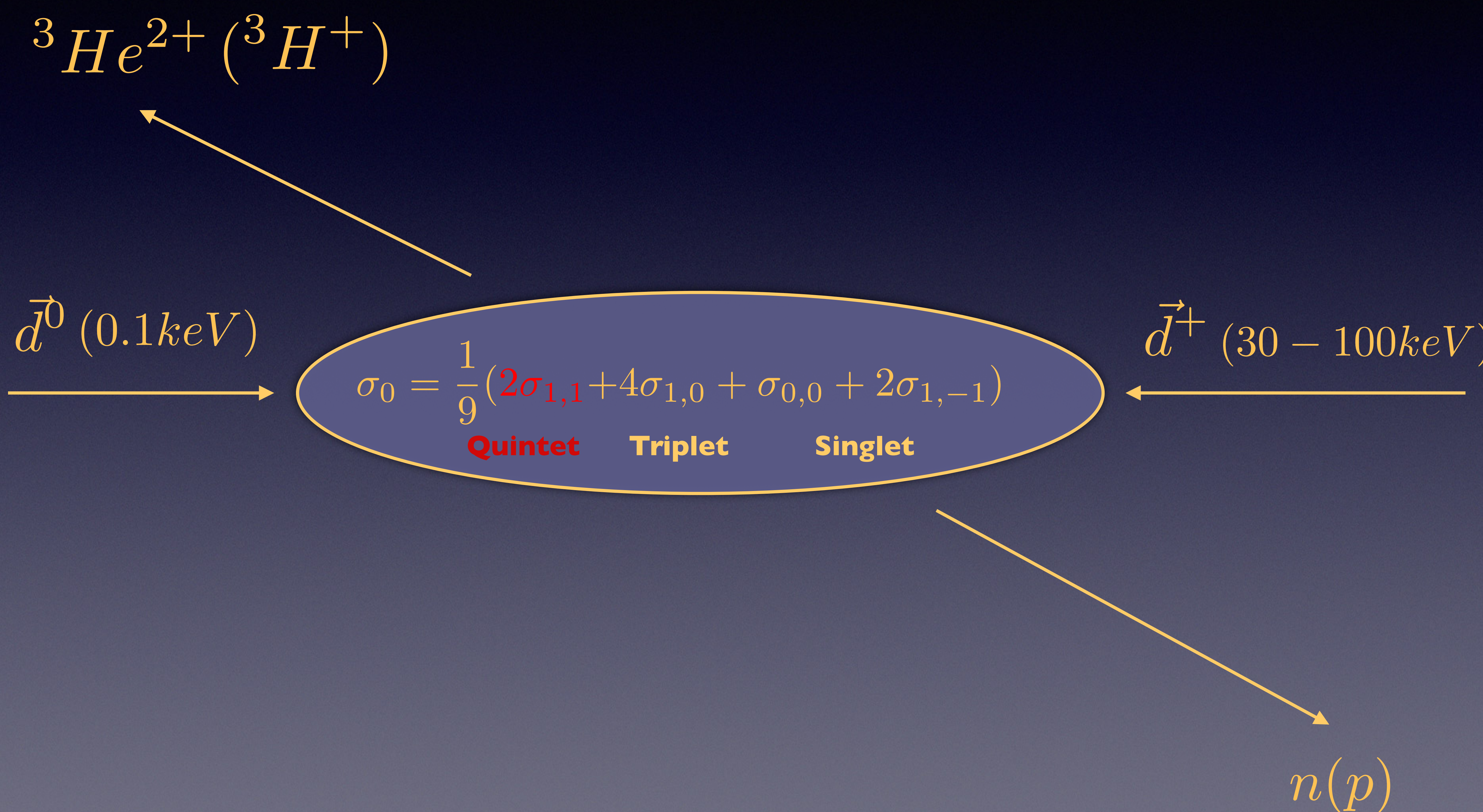
$$QSF = \frac{\sigma_{1,1}}{\sigma_0}$$

PolFusion experiment

- ➢ Cross section at low energy
- ➢ Angular distributions (n reduce the lifetime of reactor ▻better control)
- ➢ QSF direct measurements

Experimental setup

Substantial part of the equipment from:



Experimental setup

Substantial part of the equipment from:

$^3He^{2+}\,(^3H^+)$

Forschungszentrum Jülich, Germany

Polarimetry

KVI, Gronningen, Netherlands

POLarized Ion Source

$\vec{d}^0\ (0.1keV)$

$\vec{d}^+\ (30-100keV)$

$$\sigma_0 = \frac{1}{9}(2\sigma_{1,1} + 4\sigma_{1,0} + \sigma_{0,0} + 2\sigma_{1,-1})$$

Quintet **Triplet** **Singlet**

Atom Beam Source

UNIFE

Ferrara University, Italy

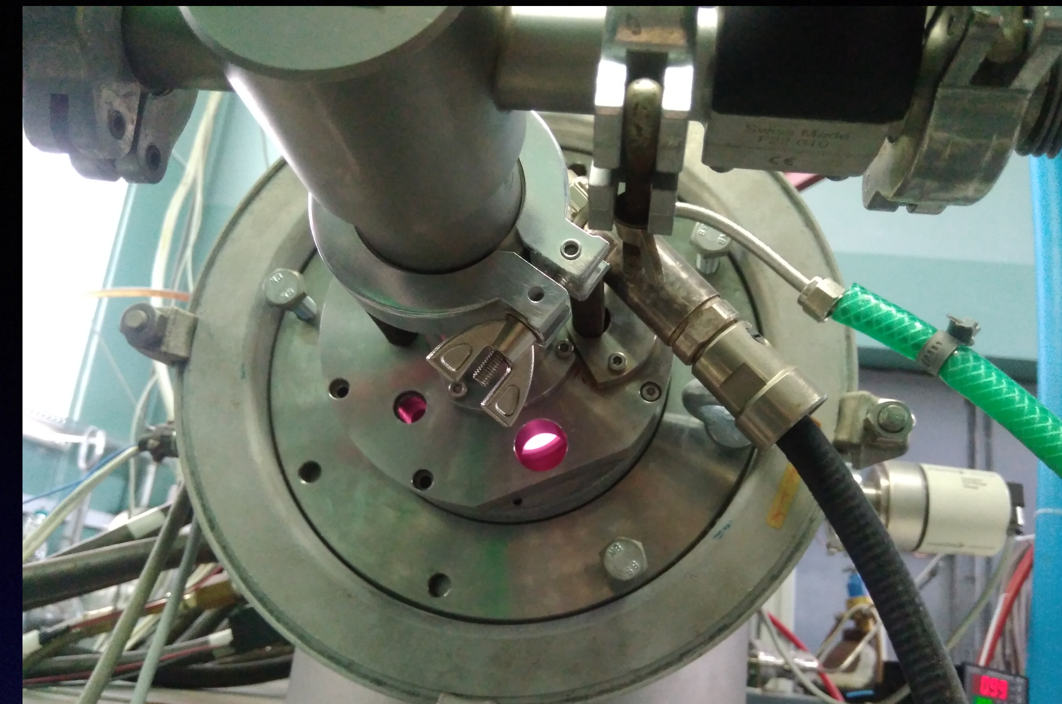
Central 4π detector

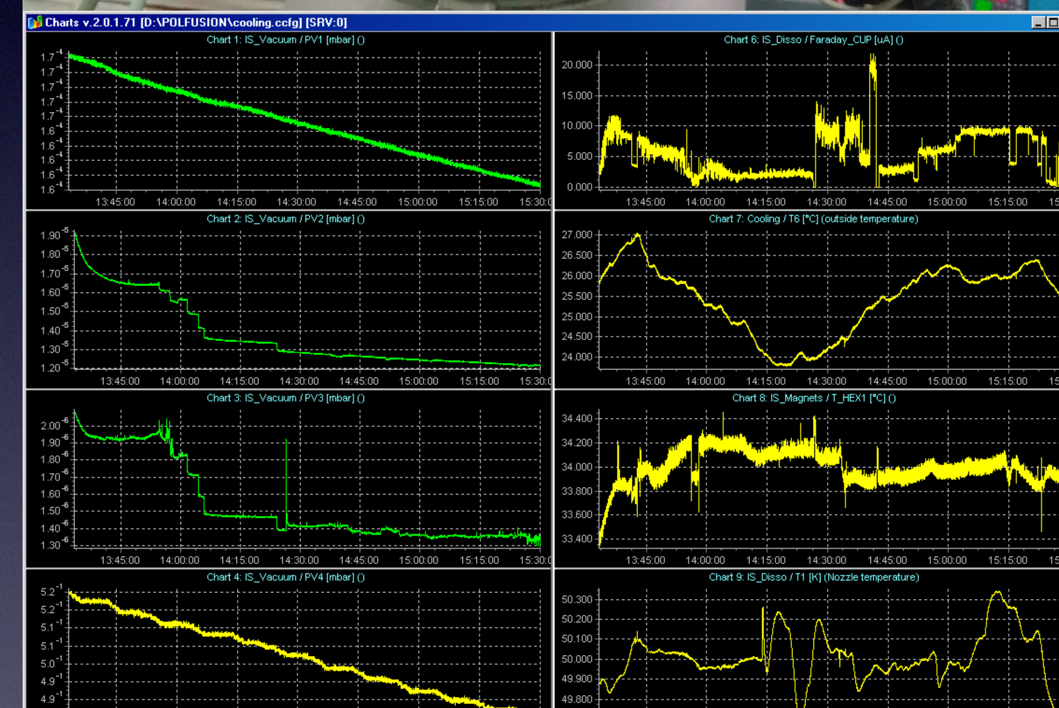
Petersburg Nuclear Physics Institute, Russia

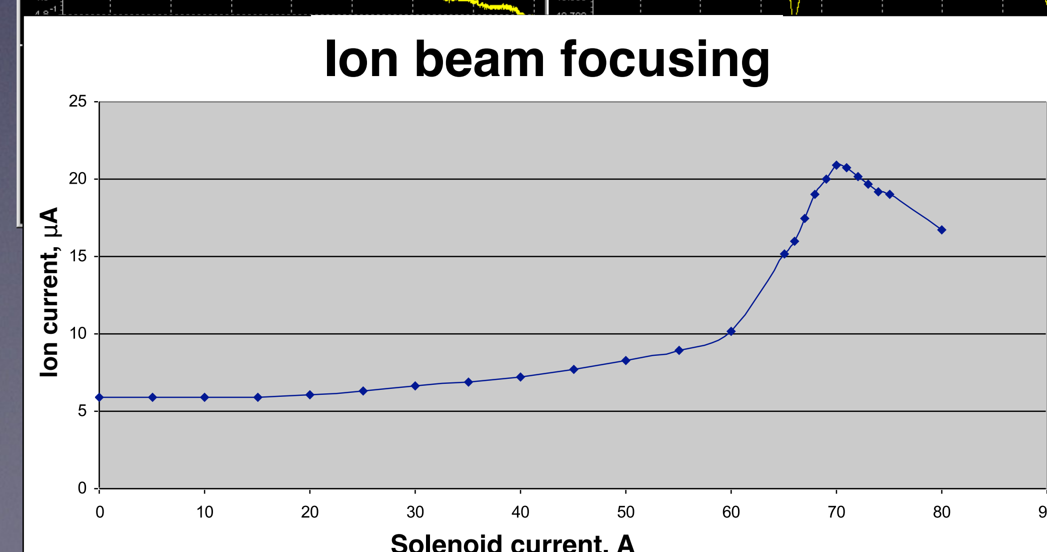
$n(p)$

Ion current at the source up to 20uA
Stable beam
Ionizer for energy up to 100keV

POLIS



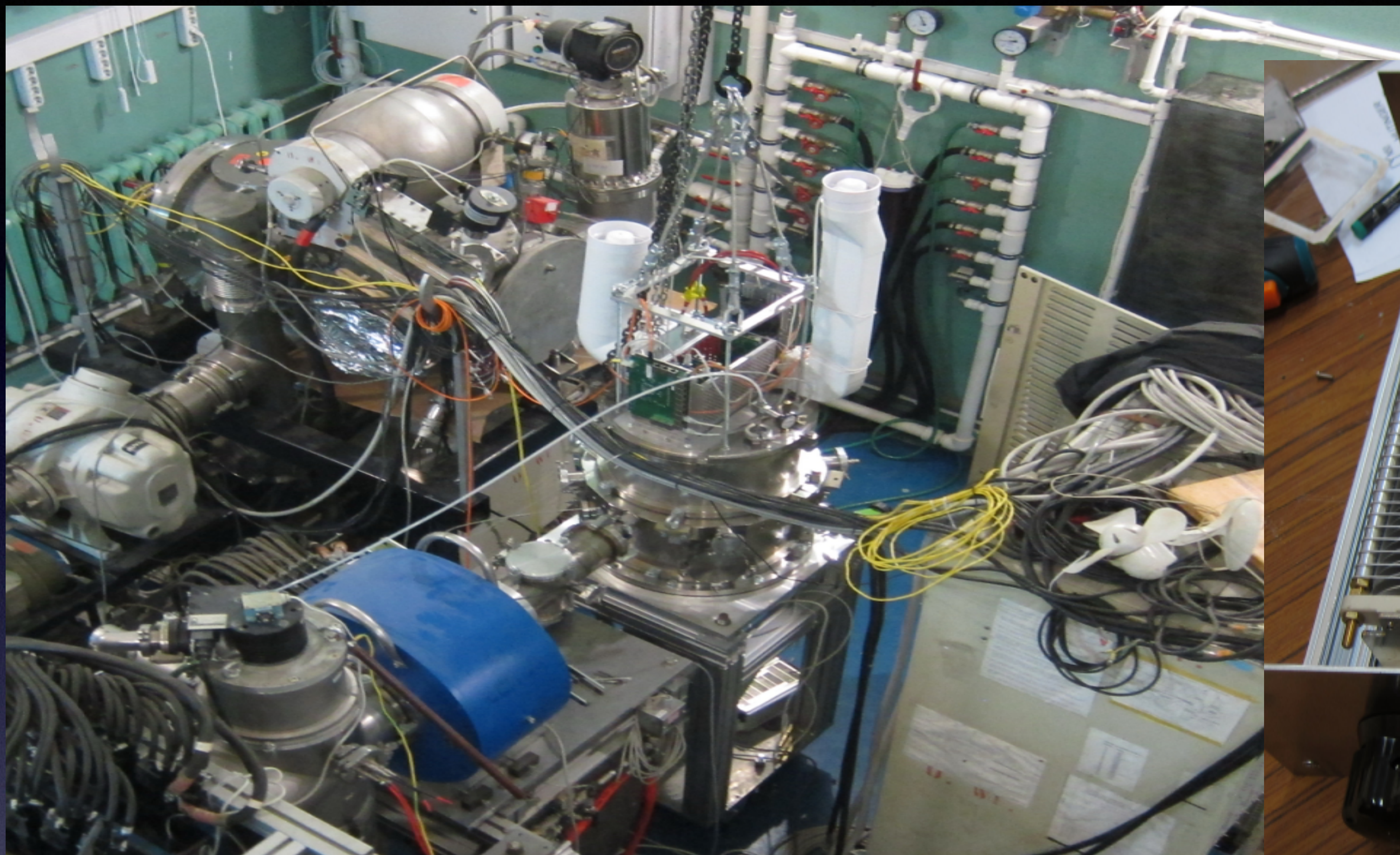


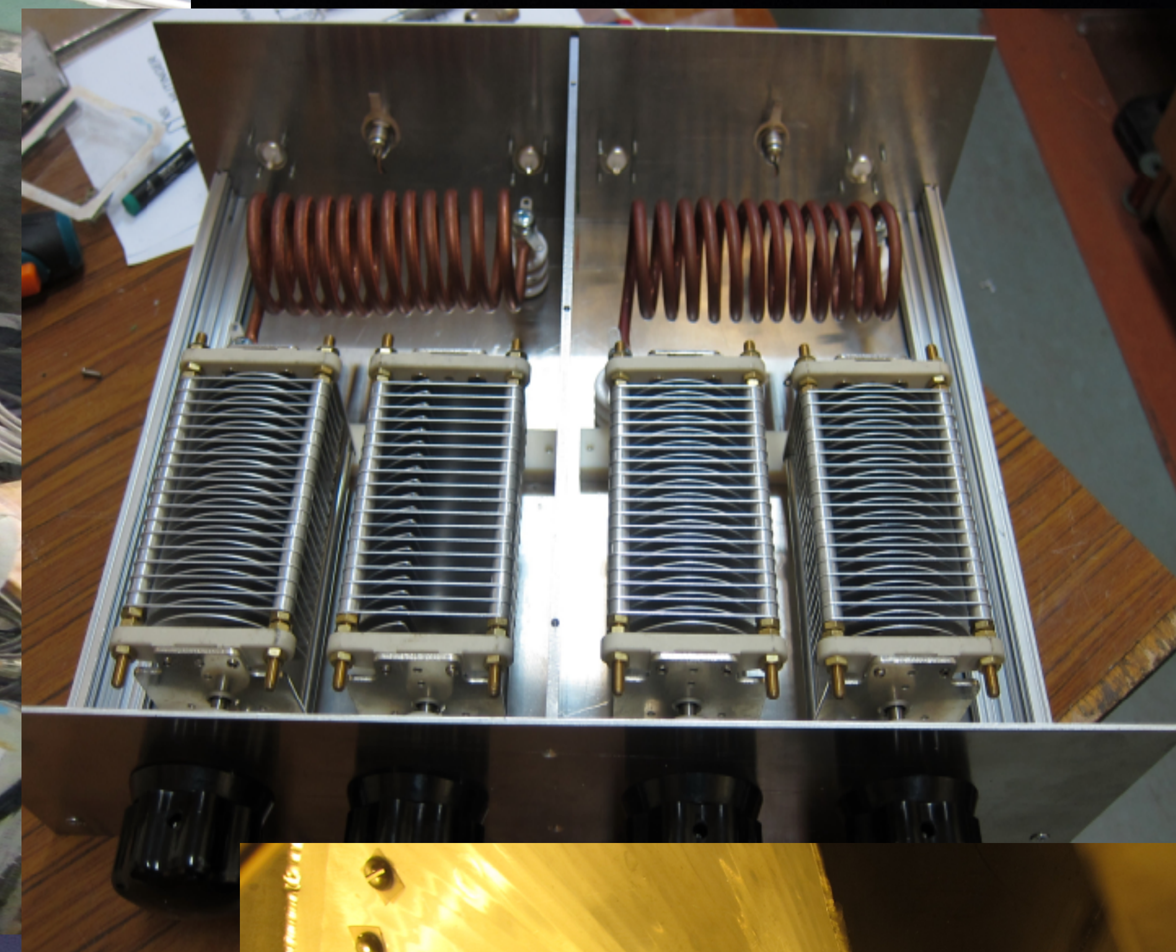


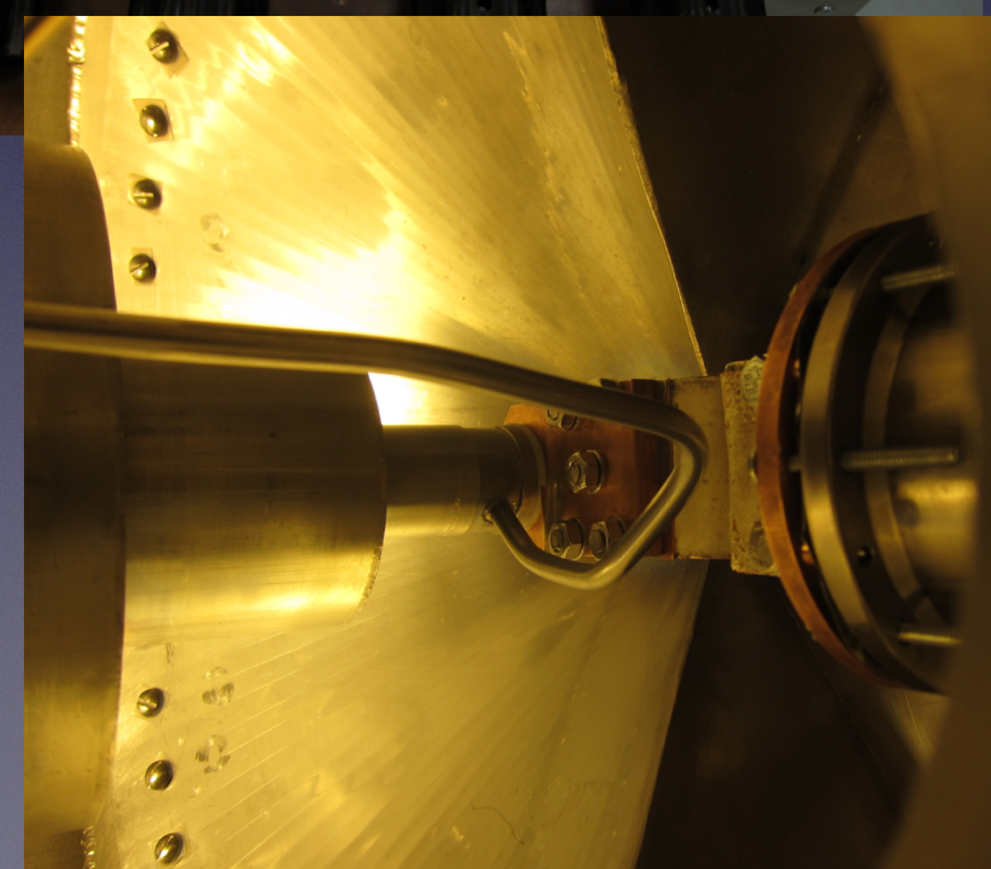
Current working conditions:

Dissociator power 160-300W
Nozzle T 43-55K
D flow 13-22ccm
Pressure: Dissociator 8mbar
HEX1 HEX2 8e-4mbar/1e-5mbar
Ionizer 7e-7mbar
Current HEX1/HEX2 170/150A
Ionizer Power ~150W

ABS







Dissociator upgrade

Reflected power decreased from 150W to 3W (@250W)

Nozzle cooling

Stable temperature down to 55K

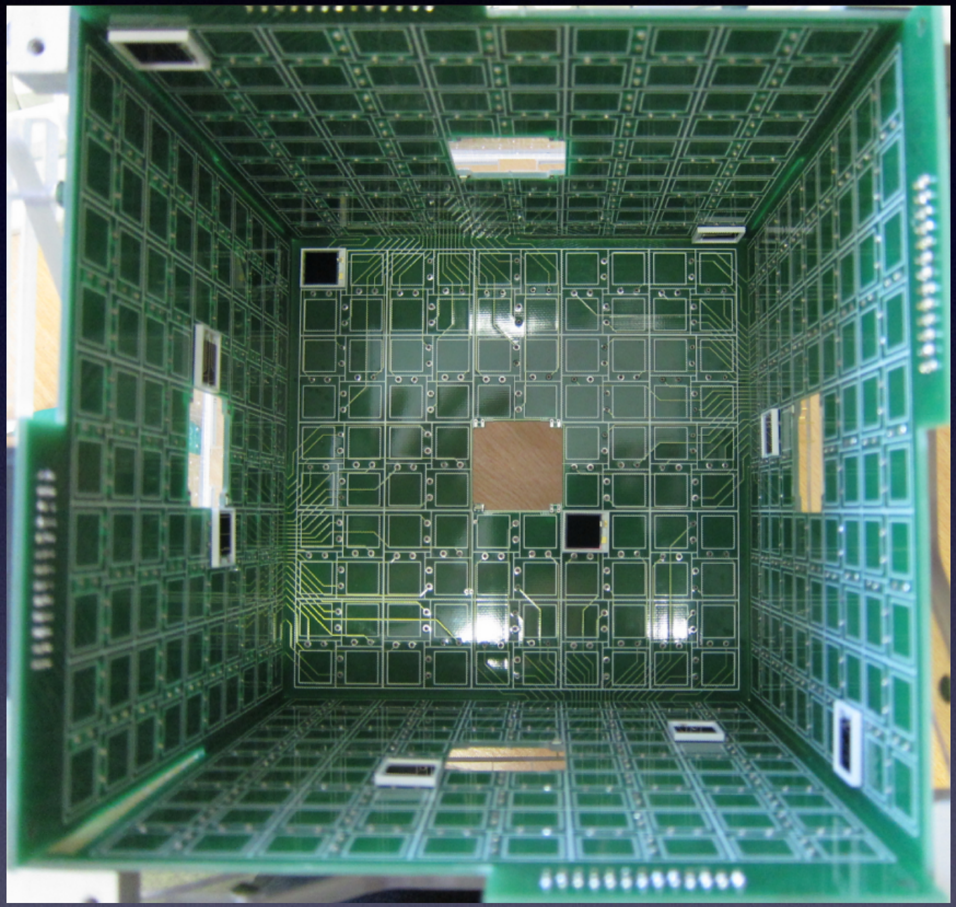
Control system

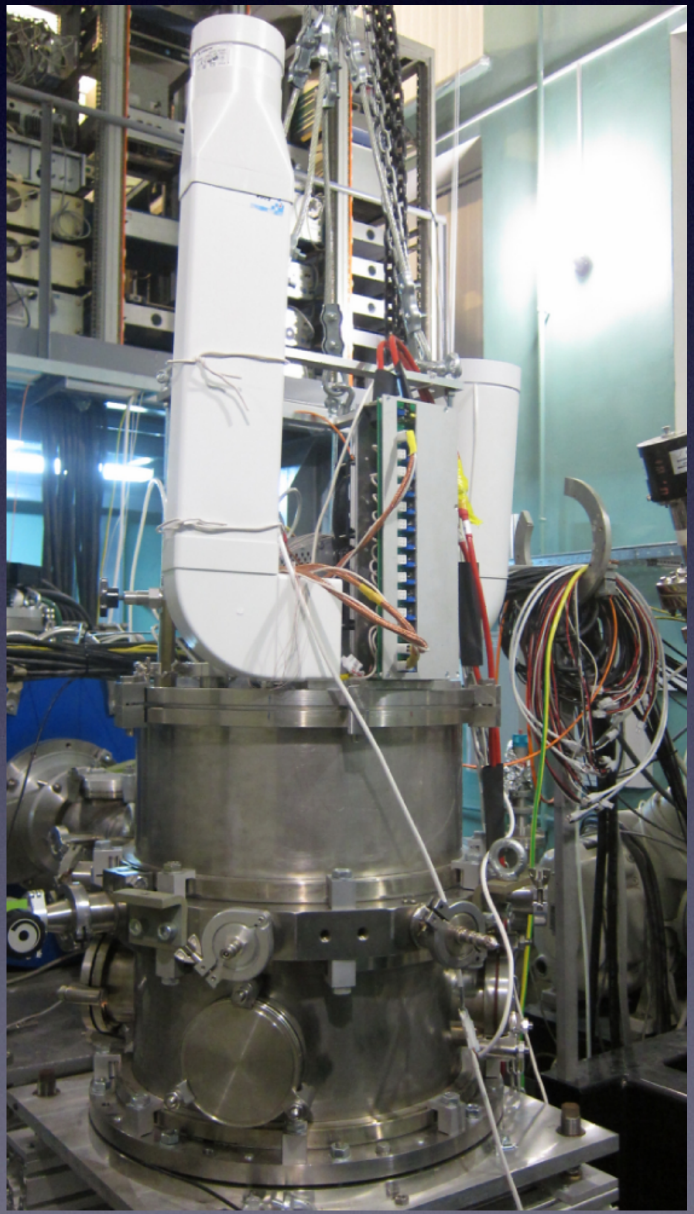
Vacuum system

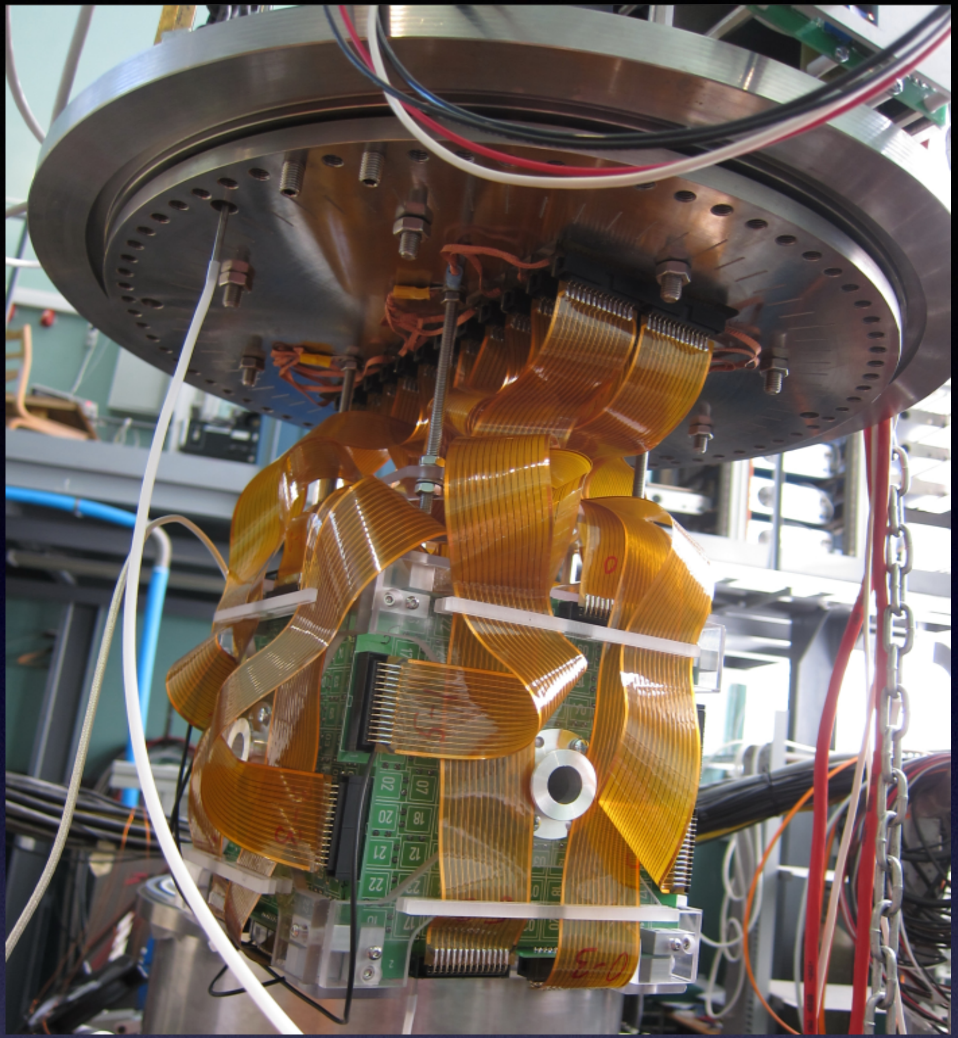
RF transition units.

Central detector

4-π detector with 51% filling
576 Hamamatsu PIN-diodes (S3590-09)
PIN-diode active area: 1 cm²
depleted layer: 300 um
energy resolution: <50keV
low reverse voltage (<=50V)

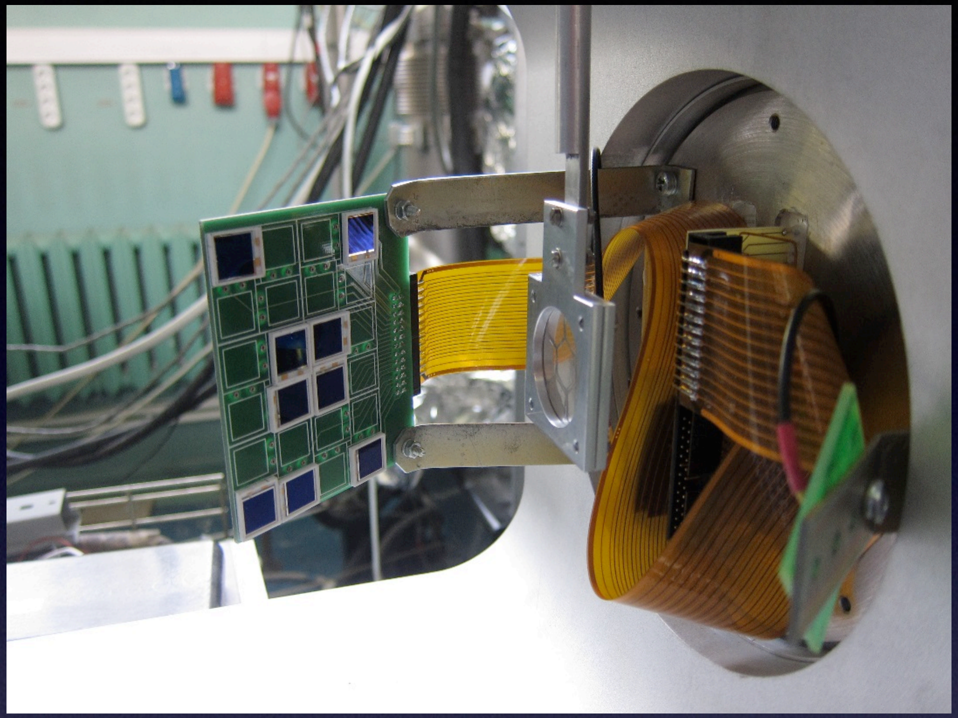


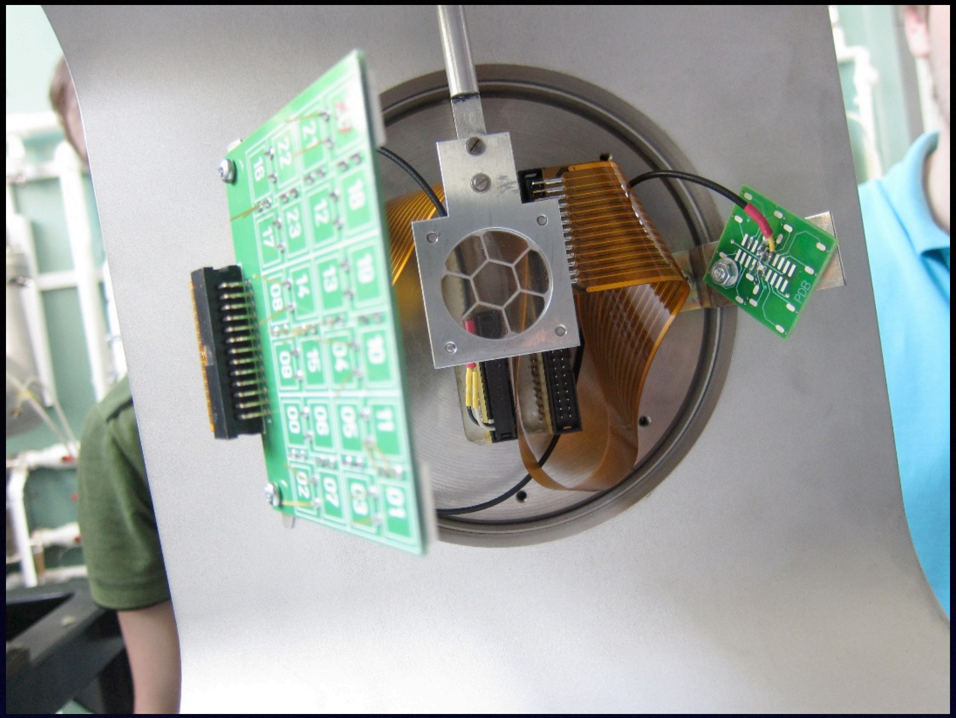




Target: deuterated polymethylmethacrylate
Deuteron beam 15keV ~5uA

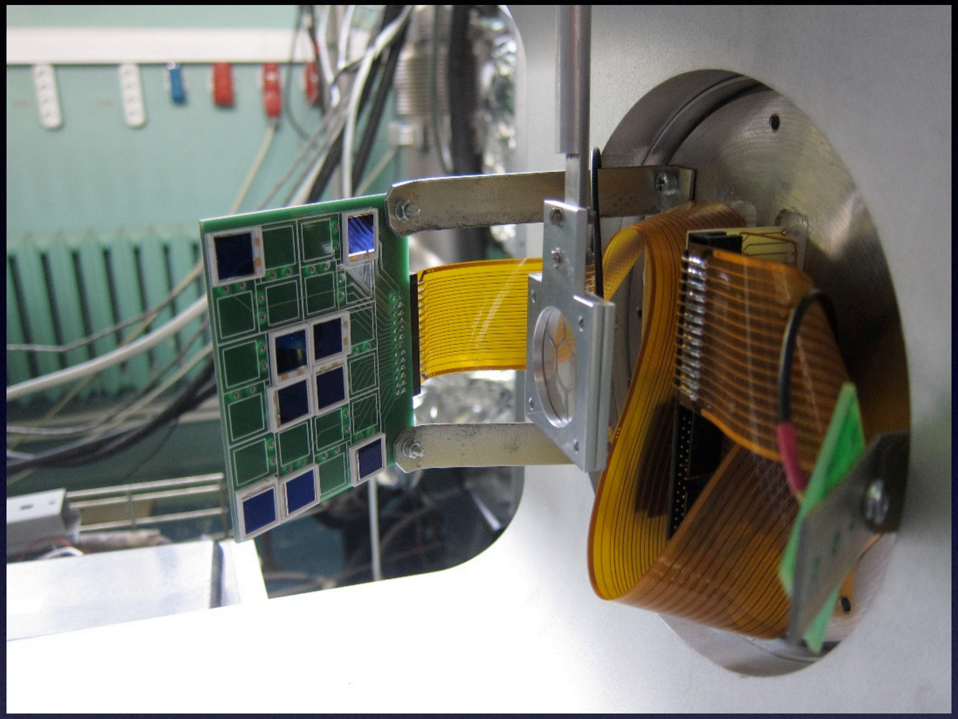
Central detector

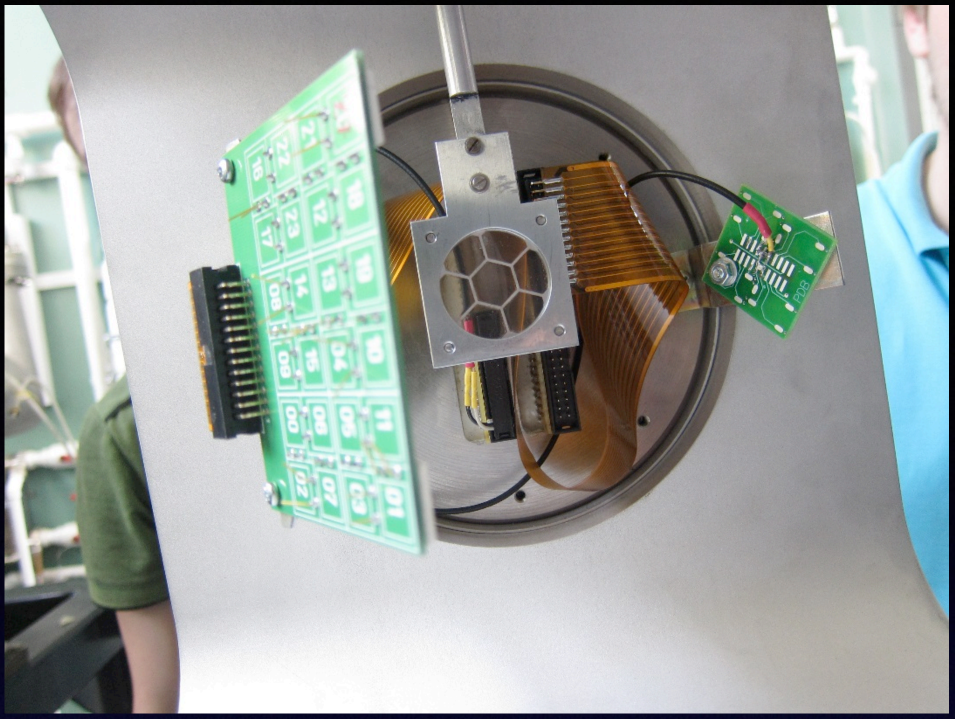




Target: deuterated polymethylmethacrylate
Deuteron beam 15keV ~5uA

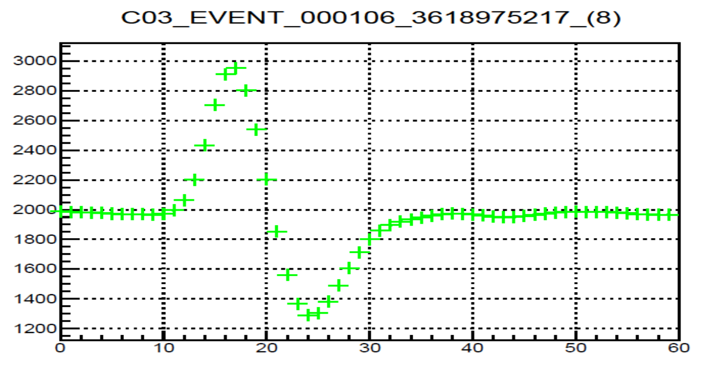
Central detector

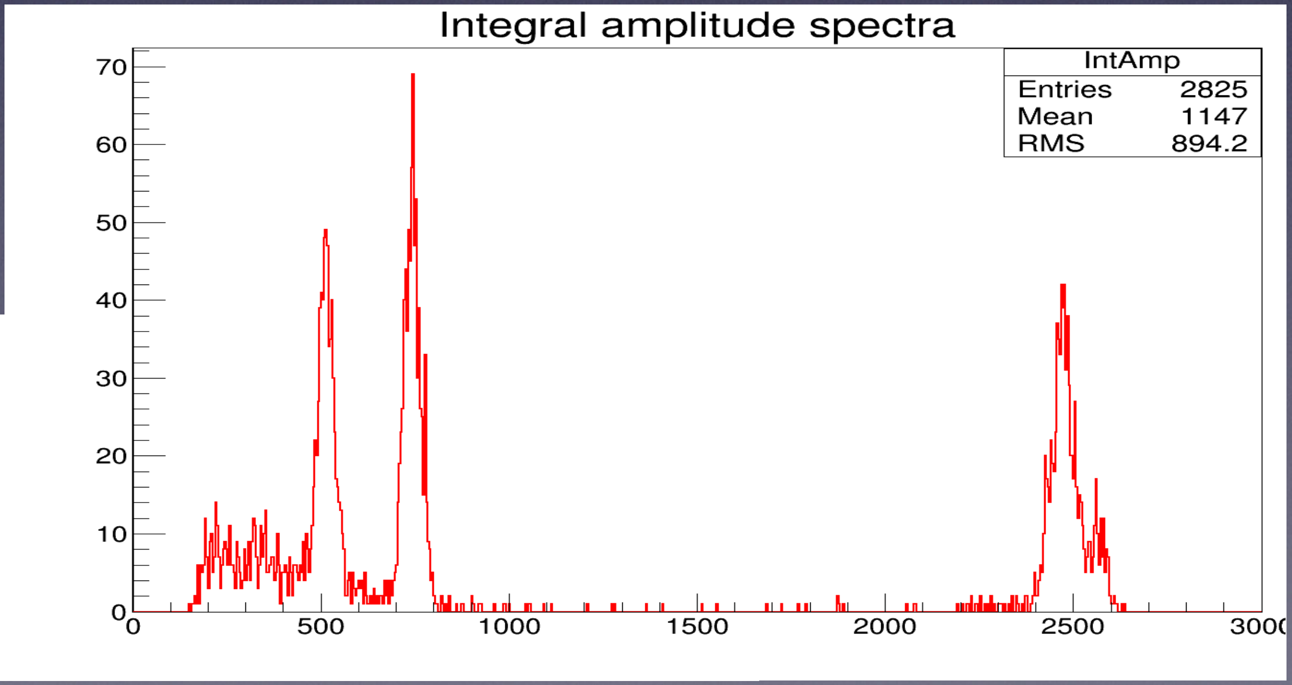




Solid target measurements

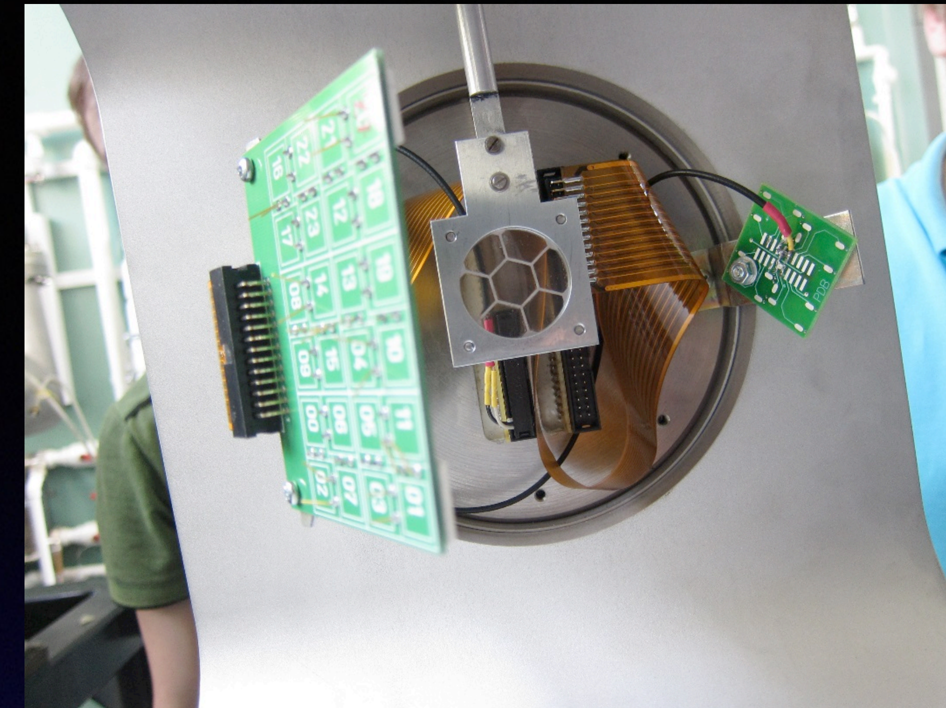
- Signal quality
- Form and sources of electronic background

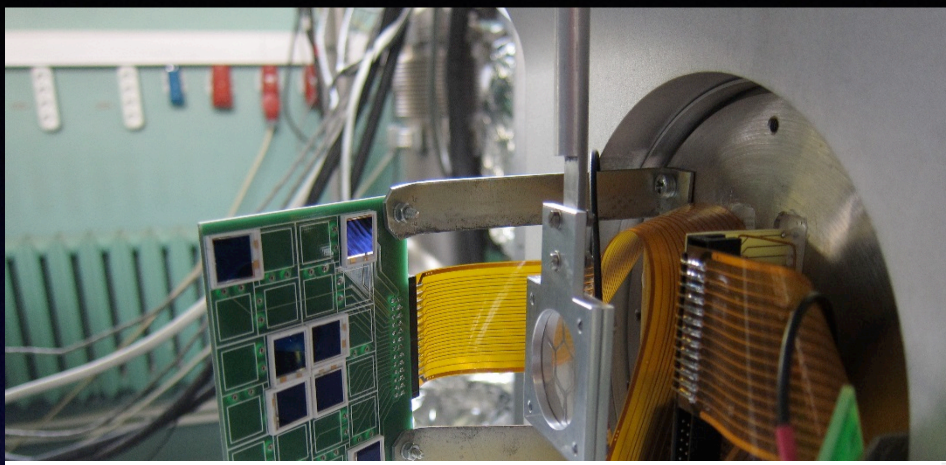


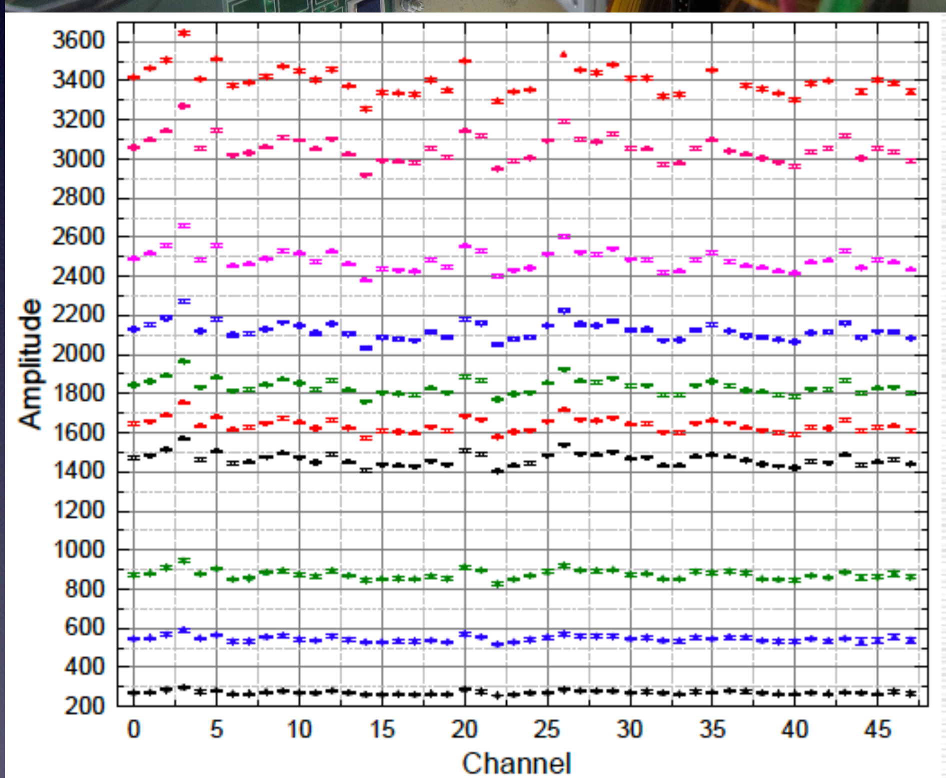


Target: deuterated polymethylmethacrylate
Deuteron beam 15keV ~5uA

Central detector



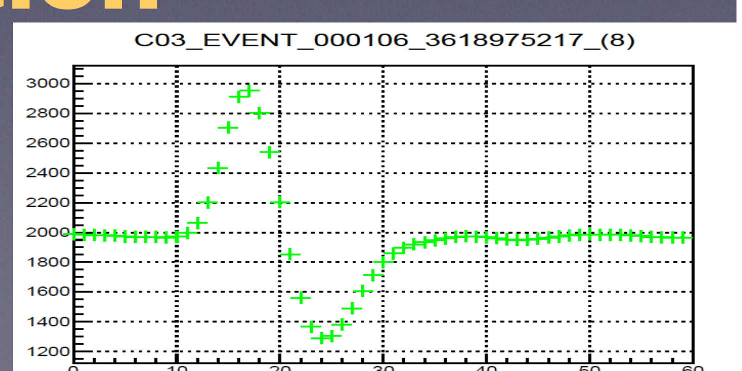


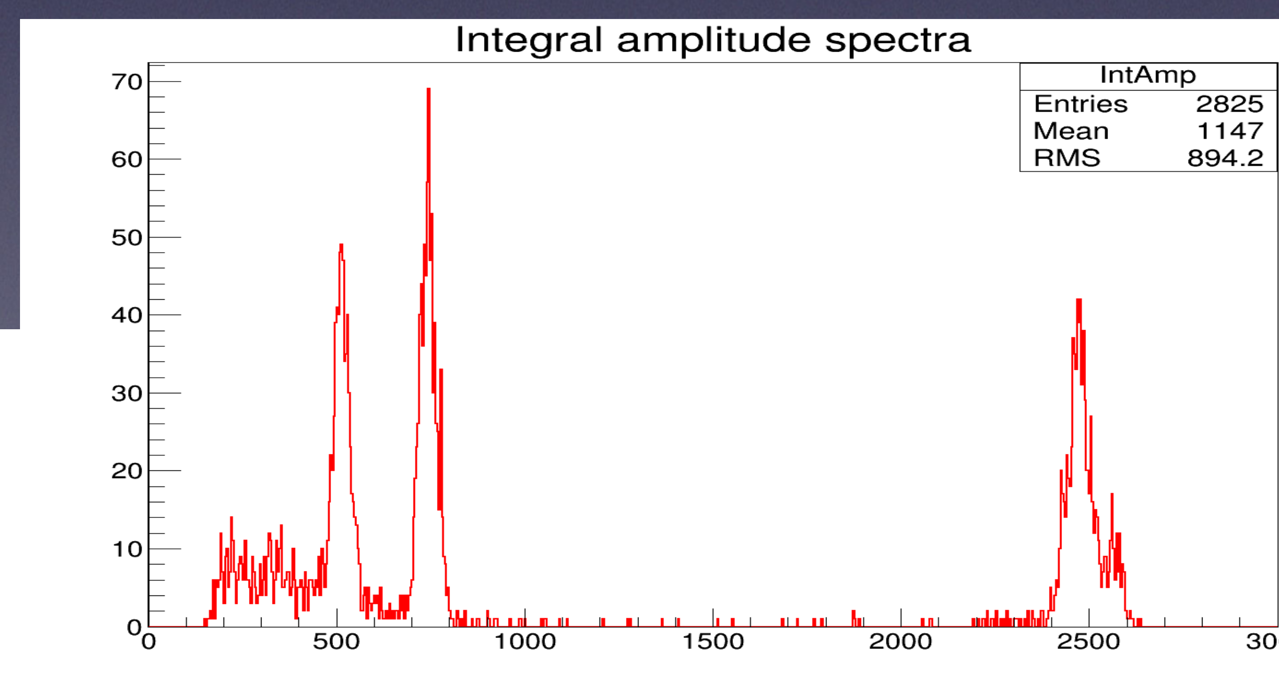


Solid target measurements

- ➢Signal quality
- ➢Form and sources of electronic background
- ➢Energy resolution better then 25keV

ADC calibration





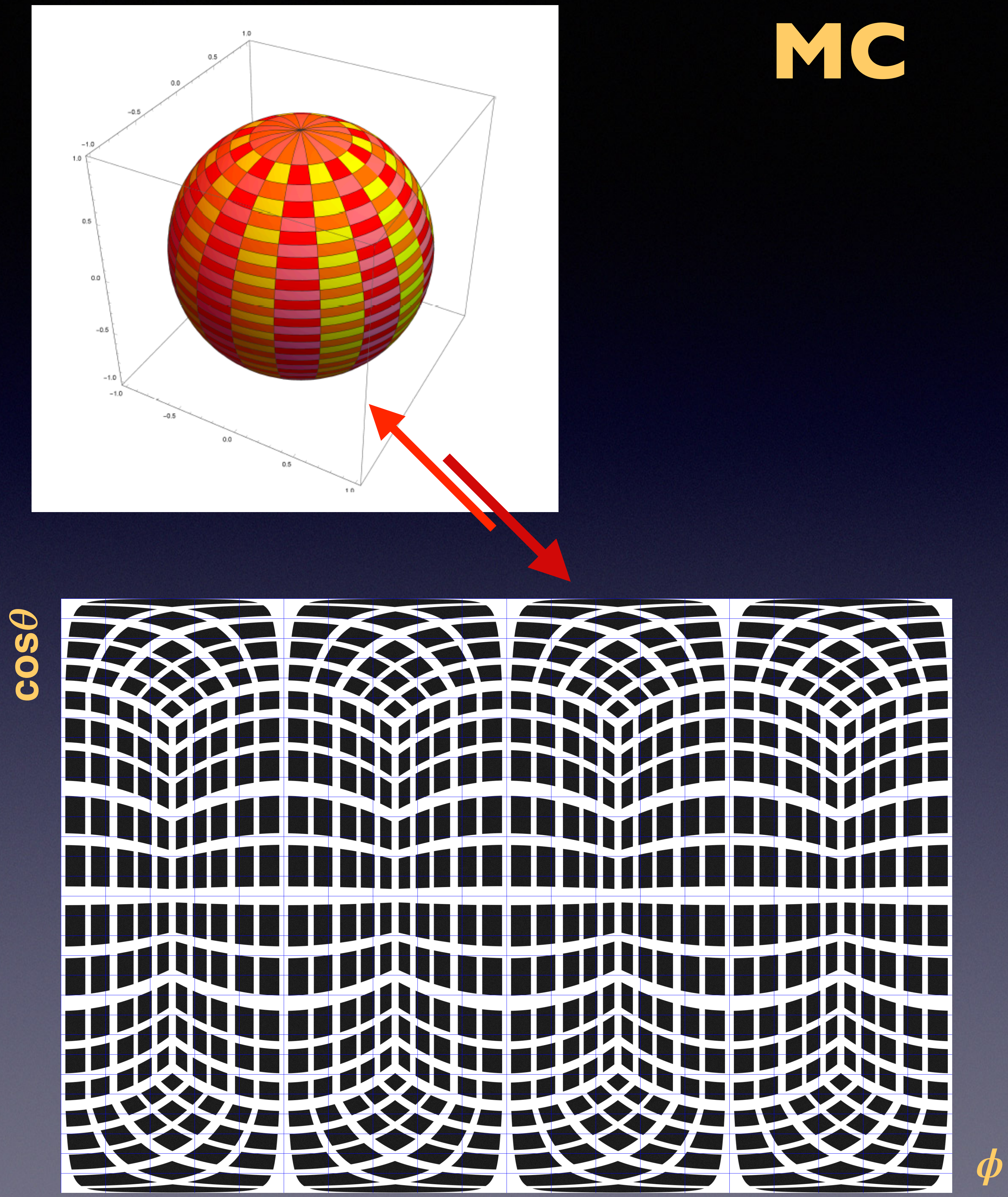
MC

Interaction point

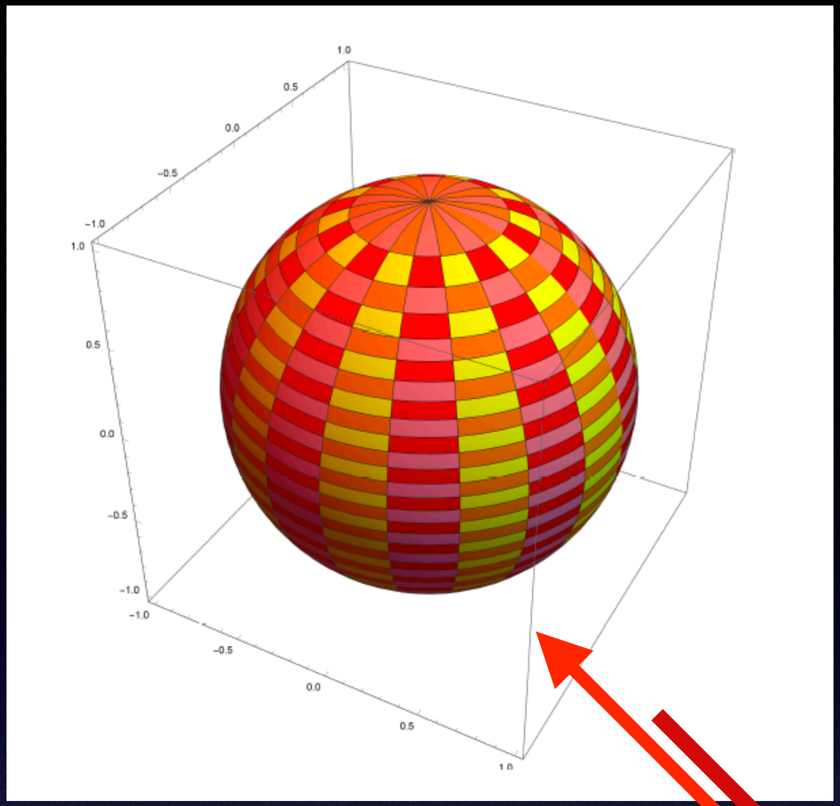
Profiles of ion and atomic beams

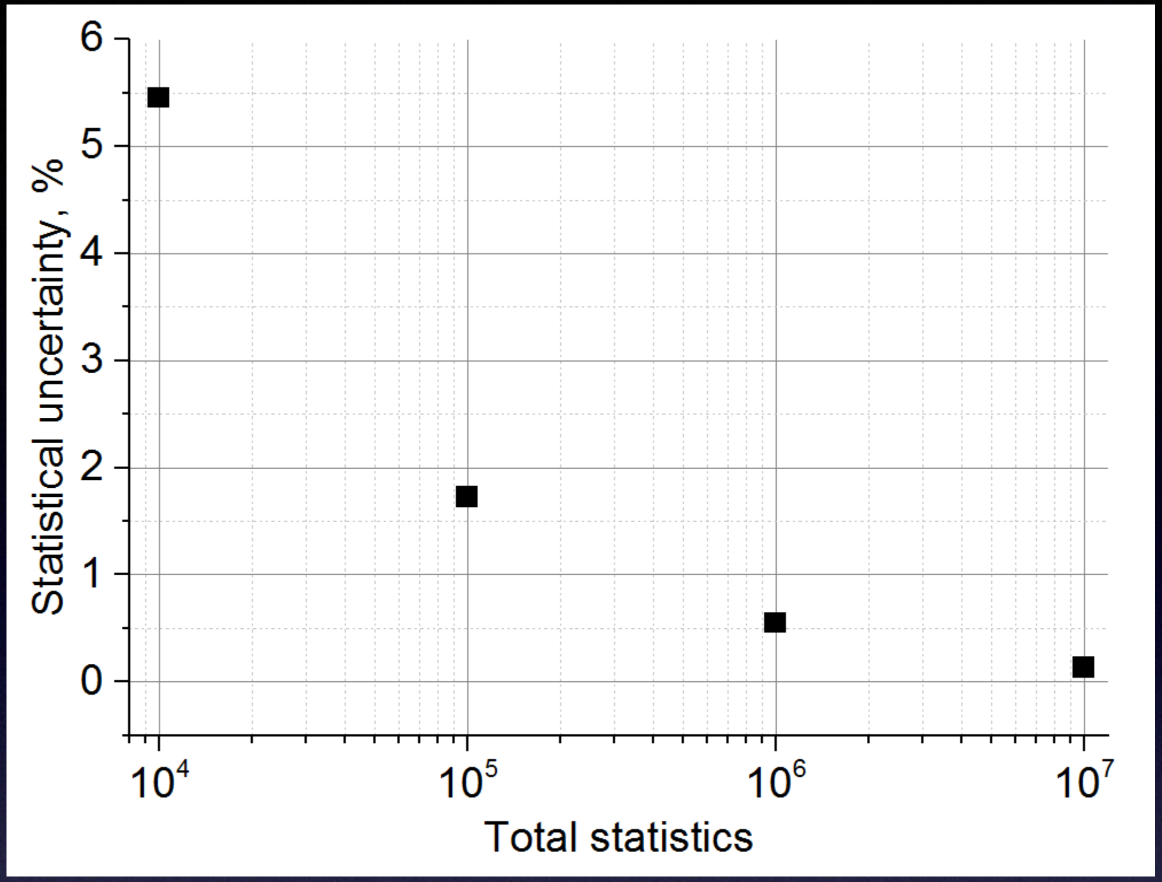
Detector geometry

Kinematics of reaction

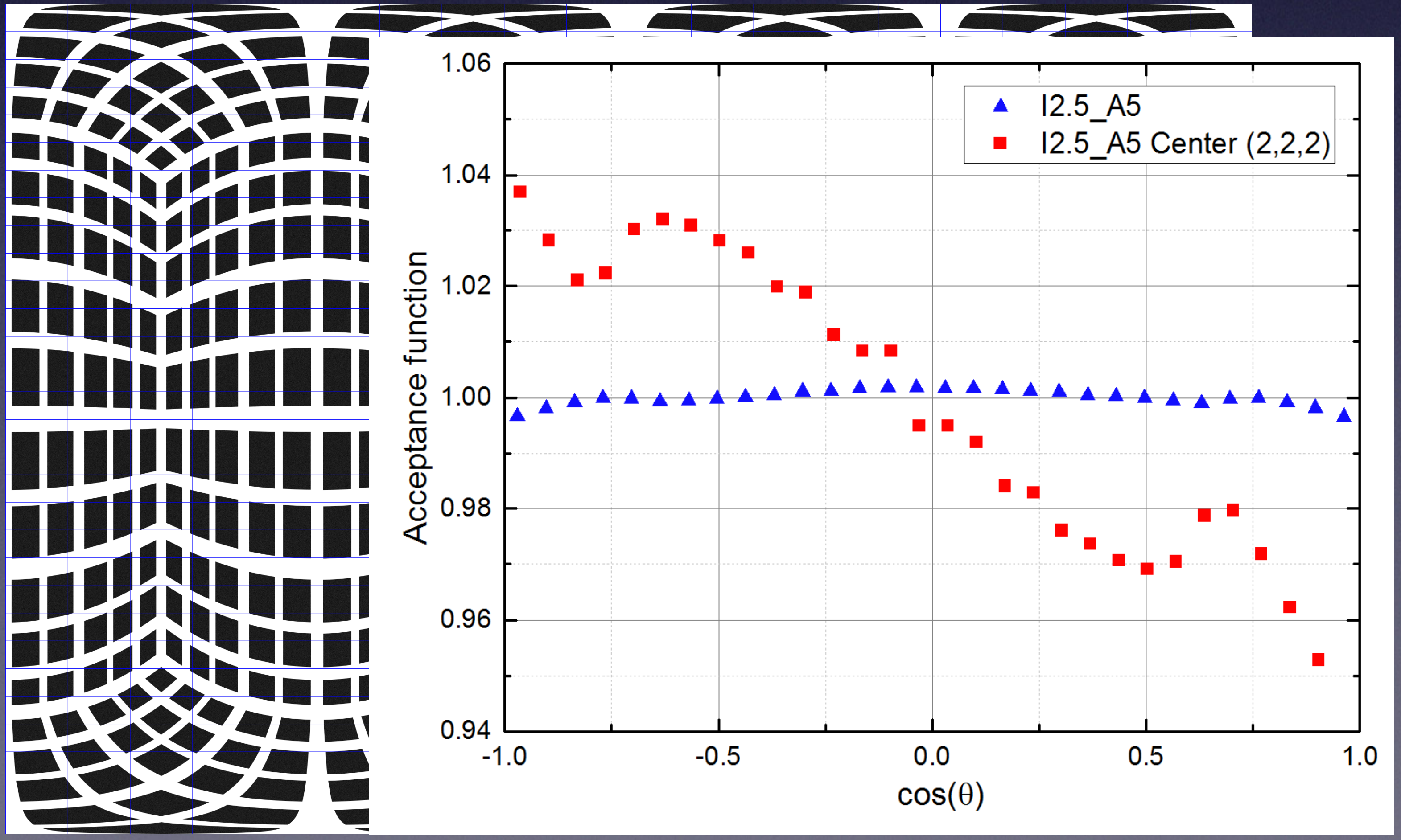


MC





cosθ



~50% of events in detector

Event distributions in space θ and ϕ

Acceptance function

Efficiency

Observables

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega} + \sum_{i=1}^{8} A_i^{(b)} b_i + \sum_{i=1}^{8} A_i^{(t)} t_i + \sum_{i,k=1}^{8} C_{ik}^{(bt)} b_i t_k$$

⇩ unpolarized cross section

⇩ Analyzing powers

⇩ Spin-correlation coefficients

Observables

expressed in Cartesian coordinates

$$\sigma(\Theta,\Phi) = \sigma_0(\Theta)\{1 + \frac{3}{2}\left[A_y^{(b)}(\Theta)p_y + A_y^{(t)}q_y\right] + \frac{1}{2}\left[A_{zz}^{(b)}(\Theta)p_{zz} + A_{zz}^{(t)}(\Theta)q_{zz}\right]$$

$$+ \frac{1}{6}\left[A_{xx-yy}^{(b)}(\Theta)p_{xx-yy} + A_{xx-yy}^{(t)}(\Theta)q_{xx-yy}\right]$$

$$+ \frac{2}{3}\left[A_{xz}^{(b)}(\Theta)p_{xz} + A_{xz}^{(t)}(\Theta)q_{xz}\right]$$

$$+ \frac{9}{4}\left[C_{y,y}(\Theta)p_yq_y + C_{x,x}(\Theta)p_xq_x + C_{x,z}(\Theta)p_xq_z + C_{z,x}(\Theta)p_zq_x + C_{z,z}(\Theta)p_zq_z\right]$$

$$+ \frac{3}{4}\left[C_{y,zz}(\Theta)p_yq_{zz} + C_{zz,y}(\Theta)p_{zz}q_y\right]$$

$$+ C_{y,xz}(\Theta)p_yq_{xz} + C_{xz,y}(\Theta)p_{xz}q_y + C_{x,yz}(\Theta)p_xq_{yz}$$

$$+ C_{yz,x}(\Theta)p_{yz}q_x + C_{z,yz}(\Theta)p_zq_{yz} + C_{yz,z}(\Theta)p_{yz}q_z$$

$$+ \frac{1}{4}\left[C_{y,xx-yy}(\Theta)p_yq_{xx-yy} + C_{xx-yy,y}(\Theta)p_{xx-yy}q_y + C_{zz,zz}(\Theta)p_{zz}q_{zz}\right]$$

$$+ \frac{1}{3}\left[C_{zz,xz}(\Theta)p_{zz}q_{xz} + C_{xz,zz}(\Theta)p_{xz}q_{zz}\right]$$

$$+ \frac{1}{12}\left[C_{zz,xx-yy}(\Theta)p_{zz}q_{xx-yy} + C_{xx-yy,zz}(\Theta)p_{xx-yy}q_{zz}\right]$$

$$+ \frac{4}{9}\left[C_{xz,xz}(\Theta)p_{xz}q_{xz} + C_{yz,yz}(\Theta)p_{yz}q_{yz}\right]$$

$$+ \frac{8}{9}\left[C_{xy,yz}(\Theta)p_{xy}q_{yz} + C_{yz,xy}(\Theta)p_{yz}q_{xy}\right]$$

$$+ \frac{16}{9}C_{xy,xy}(\Theta)p_{xy}q_{xy}$$

$$+ \frac{1}{9}\left[C_{xz,xx-yy}(\Theta)p_{xz}q_{xx-yy} + C_{xx-yy,xz}(\Theta)p_{xx-yy}q_{xz}\right]$$

$$+ \frac{1}{36}C_{xx-yy,xx-yy}(\Theta)p_{xx-yy}q_{xx-yy}$$

$$+ \frac{1}{2}\left[C_{x,xy}(\Theta)p_xq_{xy} + C_{xy,x}(\Theta)p_{xy}q_x + C_{z,xy}(\Theta)p_zq_{xy} + C_{xy,z}(\Theta)p_{xy}q_z\right]\}$$

H. Paetz gen. Schieck, Eur. Phys. J. A 44, 321-354 (2010)

$$\ldots_{i=1}^{8} A_i^{(t)} t_i + \sum_{i,k=1}^{8} C_{ik}^{(bt)} b_i t_k$$

owers

⇩

Spin-correlation coefficients

Observables

H. Paetz gen. Schieck, Eur. Phys. J. A 44, 321-354 (2010)

$$\sigma(\Theta,\Phi)=\sigma_0(\Theta)\{1 + \frac{3}{2}\left[A_y^{(b)}(\Theta)p_y + A_y^{(t)}q_y\right] + \frac{1}{2}\left[A_{zz}^{(b)}(\Theta)p_{zz} + A_{zz}^{(t)}(\Theta)q_{zz}\right]$$
$$+ \frac{1}{6}\left[A_{xx-yy}^{(b)}(\Theta)p_{xx-yy} + A_{xx-yy}^{(t)}(\Theta)q_{xx-yy}\right]$$
$$+ \frac{2}{3}\left[A_{xz}^{(b)}(\Theta)p_{xz} + A_{xz}^{(t)}(\Theta)q_{xz}\right]$$
$$+ \frac{9}{4}\left[C_{y,y}(\Theta)p_y q_y + C_{x,x}(\Theta)p_x q_x + C_{x,z}(\Theta)p_x q_z + C_{z,x}(\Theta)p_z q_x + C_{z,z}(\Theta)p_z q_z\right]$$
$$+ \frac{3}{4}\left[C_{y,zz}(\Theta)p_y q_{zz} + C_{zz,y}(\Theta)p_{zz}q_y\right]$$
$$+ C_{y,xz}(\Theta)p_y q_{xz} + C_{xz,y}(\Theta)p_{xz}q_y + C_{x,yz}(\Theta)p_x q_{yz}$$
$$+ C_{yz,x}(\Theta)p_{yz}q_x + C_{z,yz}(\Theta)p_z q_{yz} + C_{yz,z}(\Theta)p_{yz}q_z$$
$$+ \frac{1}{4}\left[C_{y,xx-yy}(\Theta)p_y q_{xx-yy} + C_{xx-yy,y}(\Theta)p_{xx-yy}q_y + C_{zz,zz}(\Theta)p_{zz}q_{zz}\right]$$
$$+ \frac{1}{3}\left[C_{zz,xz}(\Theta)p_{zz}q_{xz} + C_{xz,zz}(\Theta)p_{xz}q_{zz}\right]$$
$$+ \frac{1}{12}\left[C_{zz,xx-yy}(\Theta)p_{zz}q_{xx-yy} + C_{xx-yy,zz}(\Theta)p_{xx-yy}q_{zz}\right]$$
$$+ \frac{4}{9}\left[C_{xz,xz}(\Theta)p_{xz}q_{xz} + C_{yz,yz}(\Theta)p_{yz}q_{yz}\right]$$
$$+ \frac{8}{9}\left[C_{xy,yz}(\Theta)p_{xy}q_{yz} + C_{yz,xy}(\Theta)p_{yz}q_{xy}\right]$$
$$+ \frac{16}{9}C_{xy,xy}(\Theta)p_{xy}q_{xy}$$
$$+ \frac{1}{9}\left[C_{xz,xx-yy}(\Theta)p_{xz}q_{xx-yy} + C_{xx-yy,xz}(\Theta)p_{xx-yy}q_{xz}\right]$$
$$+ \frac{1}{36}C_{xx-yy,xx-yy}(\Theta)p_{xx-yy}q_{xx-yy}$$
$$+ \frac{1}{2}\left[C_{x,}\ldots\right.$$
$$+C_{xy,}\ldots$$

$$\ldots_{i=1}^{8} A_i^{(t)} t_i + \sum_{i,k=1}^{8} C_{ik}^{(bt)} b_i t_k$$

owers

⇩

Spin-correlation coefficients

Spins of both deuterons are aligned:

Only $p_z, q_z \neq 0$ and $p_{zz}, q_{zz} \neq 0$

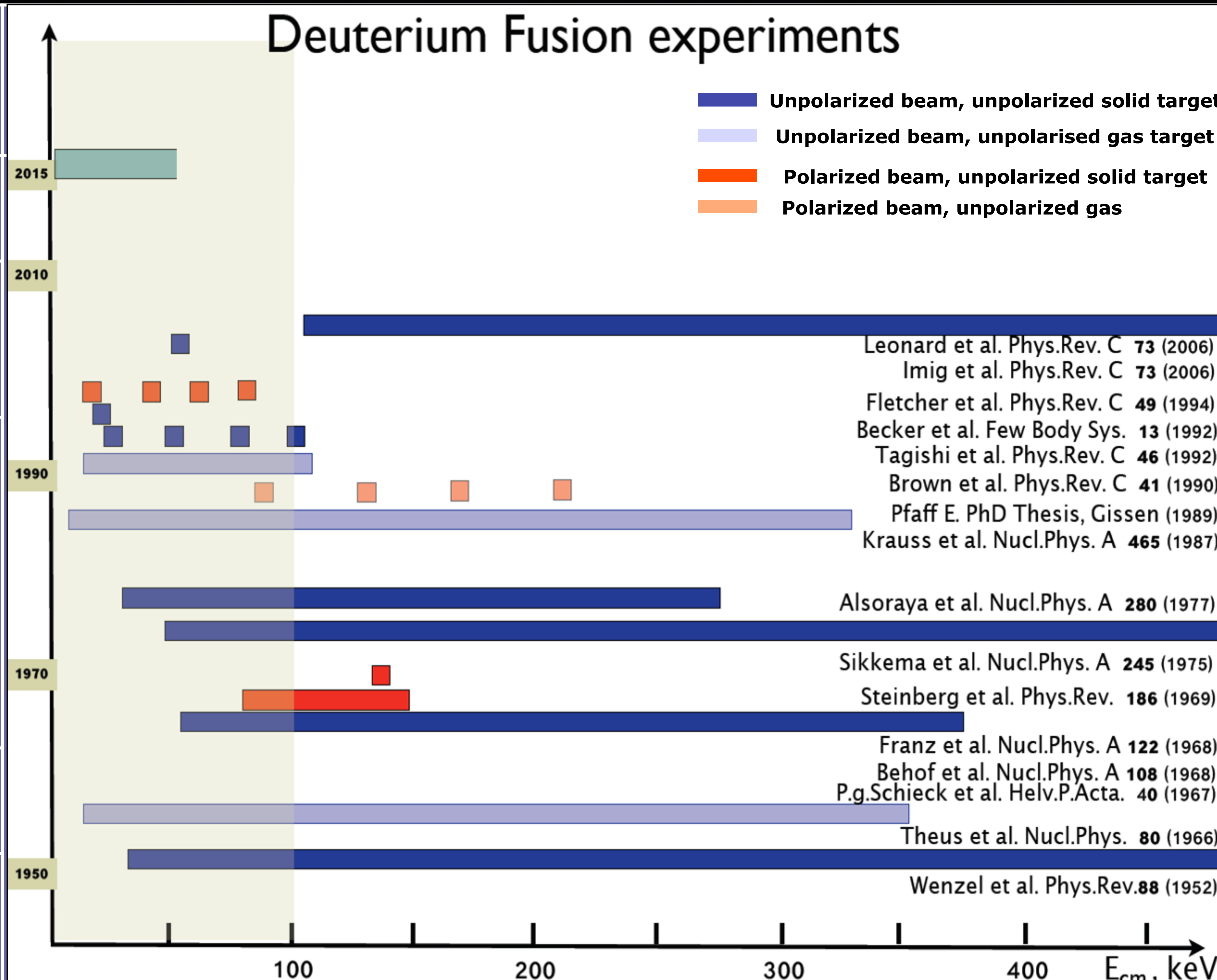
$$\sigma(\Theta,\Phi)=\sigma_0(\Theta)\left(1+\frac{3}{2}[A_{zz}^{(b)}(\Theta)p_{zz}+A_{zz}^{(t)}(\Theta)q_{zz}]+\frac{9}{4}C_{z,z}p_z q_z+\frac{1}{4}C_{zz,zz}(\Theta)p_{zz}q_{zz}\right)$$

QSF direct measurements possible

Observables

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega} + \sum_{i=1}^{8} A_i^{(b)} b_i + \sum_{i=1}^{8} A_i^{(t)} t_i + \sum_{i,k=1}^{8} C_{ik}^{(bt)} b_i t_k$$

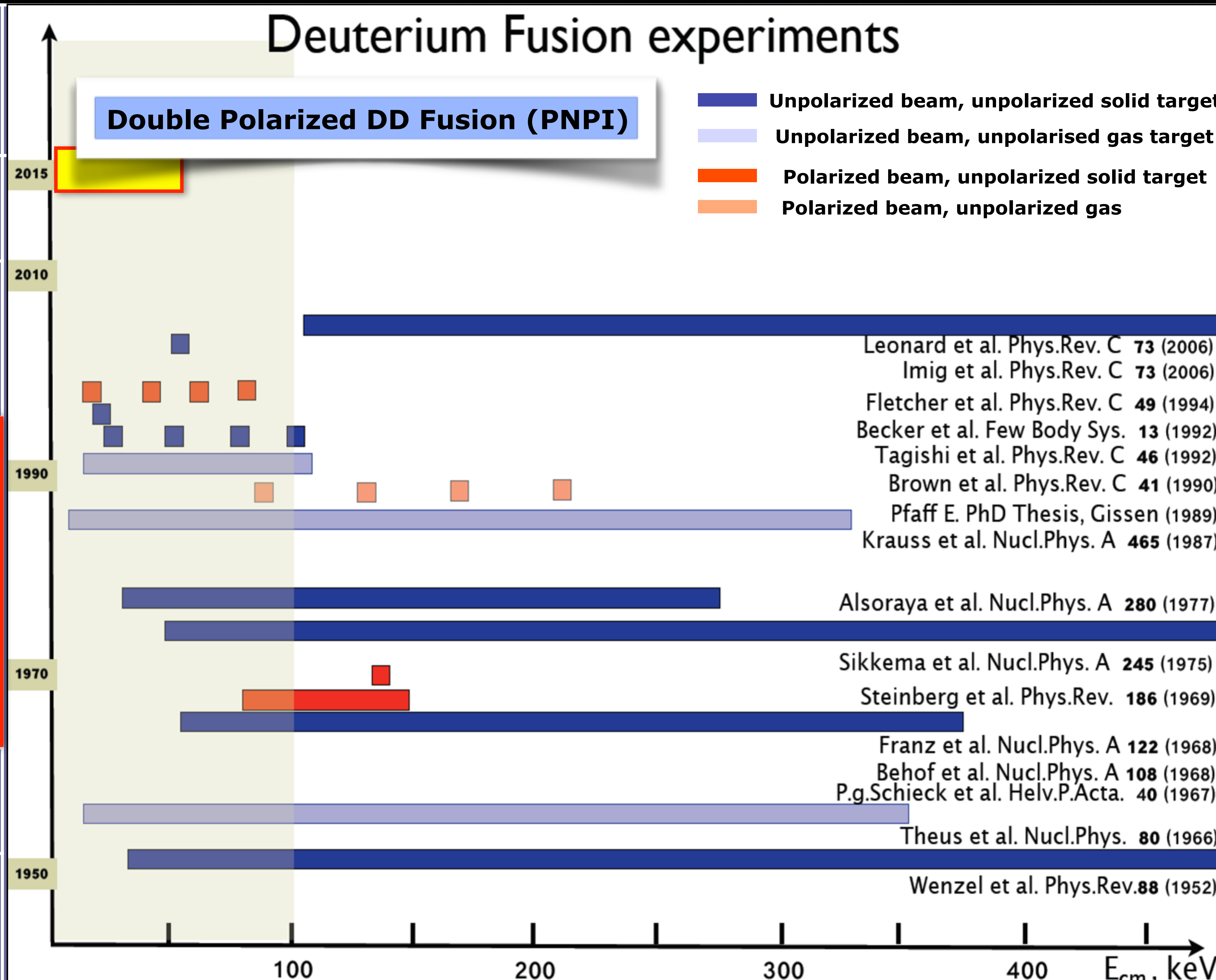
Experiments	
$^2H(d,p)^3H$ $^2H(d,n)^3He$	σ_0
$^2H(d,p)^3H$ $^2H(d,n)^3He$	A_y A_{zz} A_{xz}
$^2H(d,p)^3H$ $^2H(d,n)^3He$	C_{zz} C_{yy} $C_{zz,zz}$ $C_{y,zz}$ $C_{y,xz}$ $C_{zz,xz}$
$^2H(d,p)^3H$ $^2H(d,n)^3He$	$P_{y'}$
$^2H(d,p)^3H$ $^2H(d,n)^3He$	$K^{x'}_{x}$ $K^{y'}_{y}$



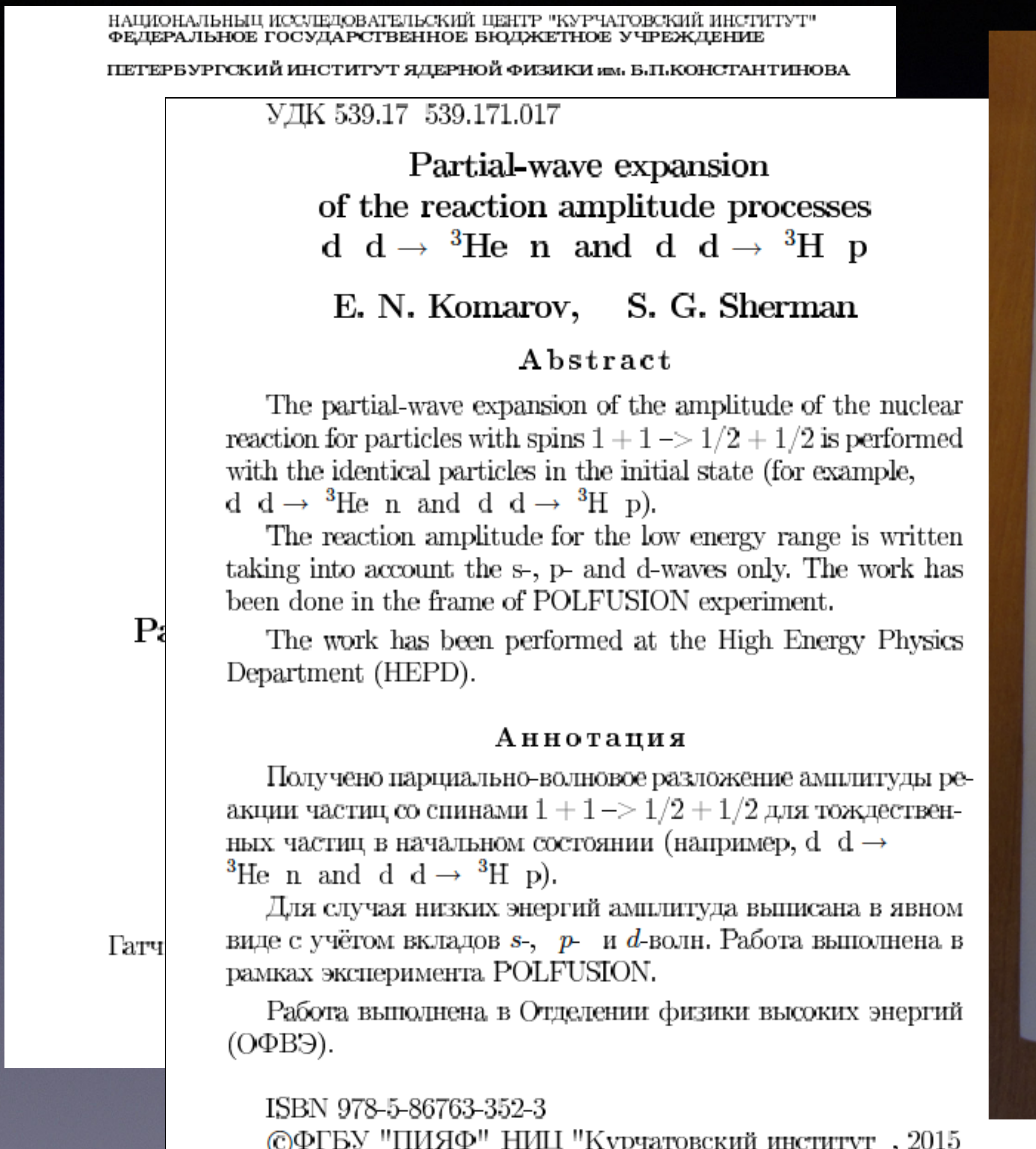
Observables

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega} + \sum_{i=1}^{8} A_i^{(b)} b_i + \sum_{i=1}^{8} A_i^{(t)} t_i + \sum_{i,k=1}^{8} C_{ik}^{(bt)} b_i t_k$$

Experiments	
$^2H(d,p)^3H$ $^2H(d,n)^3He$	σ_0
$^2H(d,p)^3H$ $^2H(d,n)^3He$	A_y A_{zz} A_{xz}
$^2H(d,p)^3H$ $^2H(d,n)^3He$	C_{zz} C_{yy} $C_{zz,zz}$ $C_{y,zz}$ $C_{y,xz}$ $C_{zz,xz}$
$^2H(d,p)^3H$ $^2H(d,n)^3He$	$P_{y'}$
$^2H(d,p)^3H$ $^2H(d,n)^3He$	$K^{x'}{}_x$ $K^{y'}{}_y$



Mathematical model



НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ ЦЕНТР "КУРЧАТОВСКИЙ ИНСТИТУТ"
ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ БЮДЖЕТНОЕ УЧРЕЖДЕНИЕ
ПЕТЕРБУРГСКИЙ ИНСТИТУТ ЯДЕРНОЙ ФИЗИКИ им. Б.П.КОНСТАНТИНОВА

УДК 539.17 539.171.017

Partial-wave expansion of the reaction amplitude processes d d → ^{3}He n and d d → ^{3}H p

E. N. Komarov, S. G. Sherman

Abstract

The partial-wave expansion of the amplitude of the nuclear reaction for particles with spins 1 + 1 –> 1/2 + 1/2 is performed with the identical particles in the initial state (for example, d d → ^{3}He n and d d → ^{3}H p).

The reaction amplitude for the low energy range is written taking into account the s-, p- and d-waves only. The work has been done in the frame of POLFUSION experiment.

The work has been performed at the High Energy Physics Department (HEPD).

Аннотация

Получено парциально-волновое разложение амплитуды реакции частиц со спинами 1 + 1 –> 1/2 + 1/2 для тождественных частиц в начальном состоянии (например, d d → ^{3}He n and d d → ^{3}H p).

Для случая низких энергий амплитуда выписана в явном виде с учётом вкладов *s*-, *p*- и *d*-волн. Работа выполнена в рамках эксперимента POLFUSION.

Работа выполнена в Отделении физики высоких энергий (ОФВЭ).

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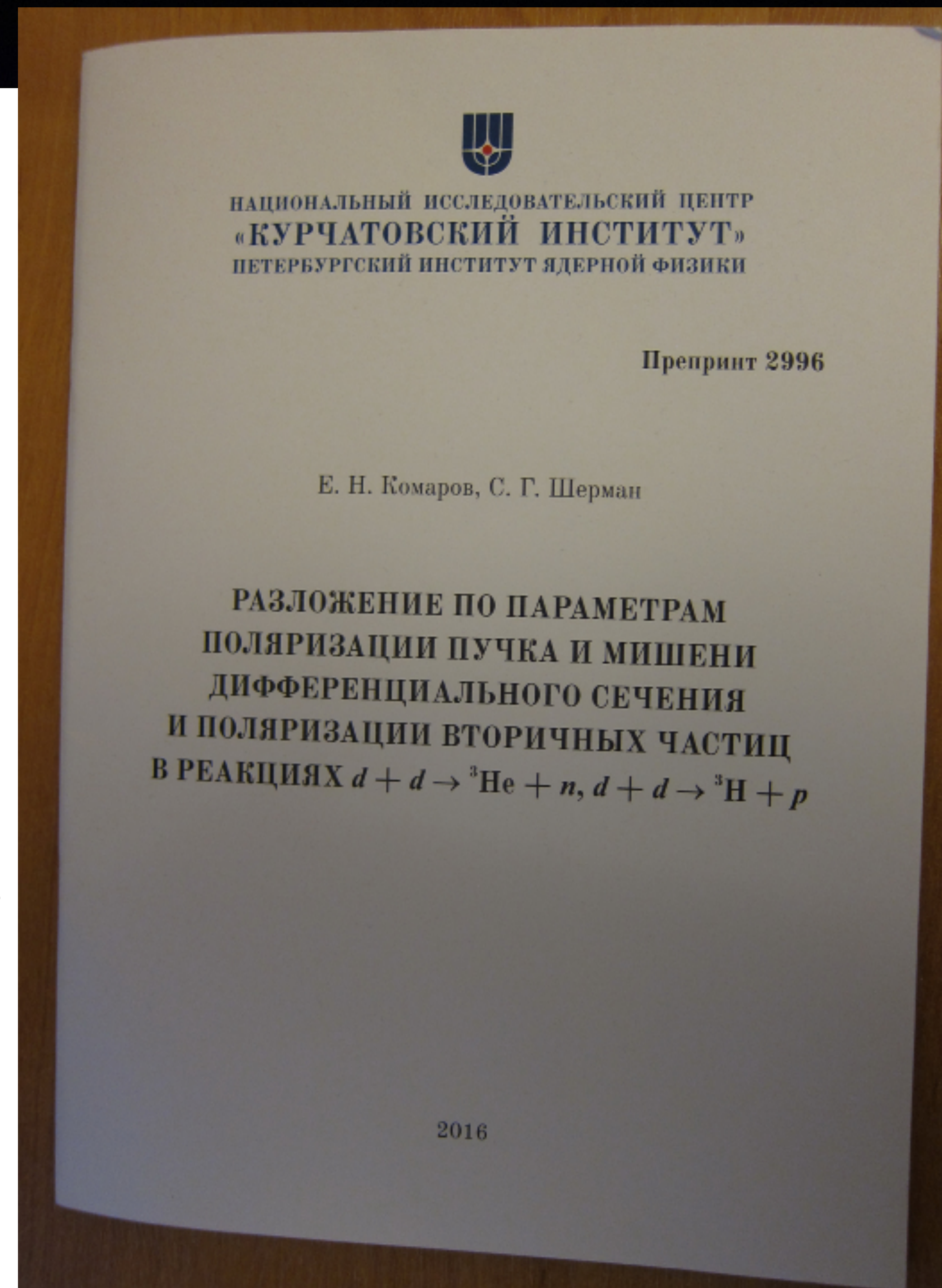

Theory. Partial wave expansion for scattering amplitude two-body reaction with spin 1+1 ⇒1/2+1/2

Differential cross section of the reaction with polarized particles:

$$\frac{d\sigma}{d\Omega} = Spur[\hat{A}\cdot\rho\cdot\hat{A}^{+}]$$

Amplitude: matrix 4X9

$$A = \begin{pmatrix} B^{12}_{12} & B^{12}_{11} & B^{11}_{11} & B^{12}_{10} & B^{11}_{10} & B^{10}_{10} & B^{12}_{1-1} & B^{11}_{1-1} & B^{12}_{1-2} \\ B^{02}_{12} & B^{12}_{01} & B^{11}_{01} & B^{12}_{00} & B^{11}_{00} & B^{10}_{00} & B^{12}_{0-1} & B^{11}_{0-1} & B^{12}_{0-2} \\ B^{02}_{02} & B^{02}_{01} & B^{01}_{01} & B^{02}_{00} & B^{01}_{00} & B^{00}_{00} & B^{02}_{0-1} & B^{01}_{0-1} & B^{02}_{0-2} \\ B^{12}_{-12} & B^{12}_{-11} & B^{11}_{-10} & B^{12}_{-10} & B^{11}_{-10} & B^{10}_{-10} & B^{12}_{-1-1} & B^{11}_{-1-1} & B^{12}_{-1-2} \end{pmatrix}$$

$$B^{s's}_{\sigma'\sigma} = \frac{1}{2i\sqrt{k_i k_f}} \sum_{J=0}^{\infty} \sum_{l=|J-s|}^{J+s} \sum_{l'=|J-\sigma|}^{J+\sigma} i^{l-l'} \sqrt{4\pi(2l+1)}\, C^{JM}_{l0s\sigma} C^{J\sigma}_{l'\sigma-\sigma's'\sigma'} R^{Js's}_{l'l} Y_{l'\sigma-\sigma'}$$

$$Y_{lm}(\cos\theta,\phi) = \sqrt{\frac{2l+1}{4\pi}} P_{lm}(\cos\theta e^{im\phi})$$

Theory. Partial wave expansion for scattering amplitude two-body reaction with spin 1+1 ⇒1/2+1/2

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Factorization using penetrability assumption for energy dependence:

complex partial wave $$R^{Js's}_{l'l}(E) = C(E)\hat{R}^{Js's}_{l'l}$$

Penetrability function → $C(E)$

Energy-independent matrix element → $\hat{R}^{Js's}_{l'l}$

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6 transitions due to the total spin and orbital angular momenta

All states with partial waves up to ℓ=4 taken into account

	S→S'		
a	0→0	*Singlet-singlet*	$a^J_{l'l}$
b	0→1	*Singlet-triplet*	$b^J_{l'l}$
c	1→0	*Triplet-singlet*	$c^J_{l'l}$
d	1→1	*Triplet-triplet*	$d^J_{l'l}$
e	2→0	*Quintet-singlet*	$e^J_{l'l}$
f	2→1	*Quintet-triplet*	$f^J_{l'l}$

$$B^{00}_{00} = \frac{1}{i\sqrt{k_f k_i}}[a^0_{00}P_0 + 5a^2_{22} + 9a^4_{44}P_4]$$

$$B^{10}_{10} = \frac{1}{2i\sqrt{k_f k_i}}[\frac{5}{\sqrt{3}}b^2_{22}P_{21} + \frac{9}{\sqrt{10}}b^4_{44}P_{41}]$$

.

.

$$B^{12}_{12} = \frac{1}{2i\sqrt{k_f k_i}}[(-\frac{10}{3}\sqrt{\frac{1}{7}}f^2_{22} + \frac{2}{3}\sqrt{\frac{5}{2}}f^2_{20} - \frac{5}{3}\sqrt{2}f^3_{22} + \frac{1}{3}\sqrt{\frac{5}{7}}f^2_{24} + \frac{2}{3}\sqrt{5}f^3_{24})P_{21} + ...]$$

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f			

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$$B^{10}_{10} = \frac{1}{2i\sqrt{k_f k_i}}[\frac{5}{\sqrt{3}}b^2_{22}P_{21} + \frac{9}{\sqrt{10}}b^4_{44}P_{41}]$$

$$\frac{d\sigma_0}{d\Omega} = \frac{1}{9}(|A_{11}|^2 + |A_{12}|^2 + |A_{13}|^2 + |A_{14}|^2 + |A_{15}|^2 + |A_{16}|^2 + |A_{17}|^2 ... + |A_{49}|^2)$$

$$B^{12}_{12} = \frac{1}{2i\sqrt{k_f k_i}}[(-\frac{10}{3}\sqrt{\frac{1}{7}}f^2_{22} + \frac{2}{3}\sqrt{\frac{5}{2}}f^2_{20} - \frac{5}{3}\sqrt{2}f^3_{22} + \frac{1}{3}\sqrt{\frac{5}{7}}f^2_{24} + \frac{2}{3}\sqrt{5}f^3_{24})P_{21} + ...]$$

Minimization procedure

$\vec{O}$ = $[M]$ · $\vec{A}$

$\vec{O}$ (measured)
σ_0, $d\sigma_0/d\Omega$
A_y, A_{zz}, A_{xz}
C_{zz}, C_{yy}, $C_{zz,zz}$, $C_{y,zz}$, $C_{y,xz}$, $C_{zz,xz}$
Py'
Kx'_x, Ky'_y

$[M]$: partial wave analysis for two-body reaction with spin 1+1→1/2+1/2 (matrix of coefficients)

calculated from model

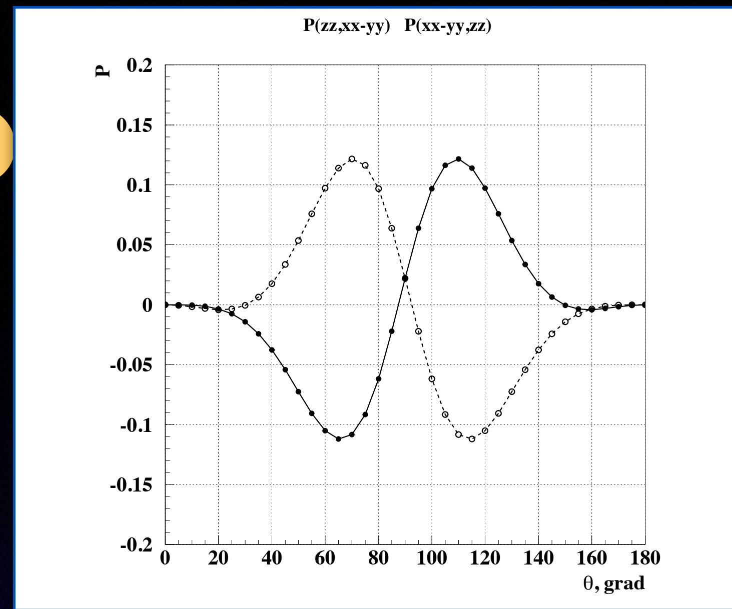
$\vec{A}$ (to be extracted)
$a^J{}_{l'l}$
$b^J{}_{l'l}$
$c^J{}_{l'l}$
$d^J{}_{l'l}$
$e^J{}_{l'l}$
$f^J{}_{l'l}$

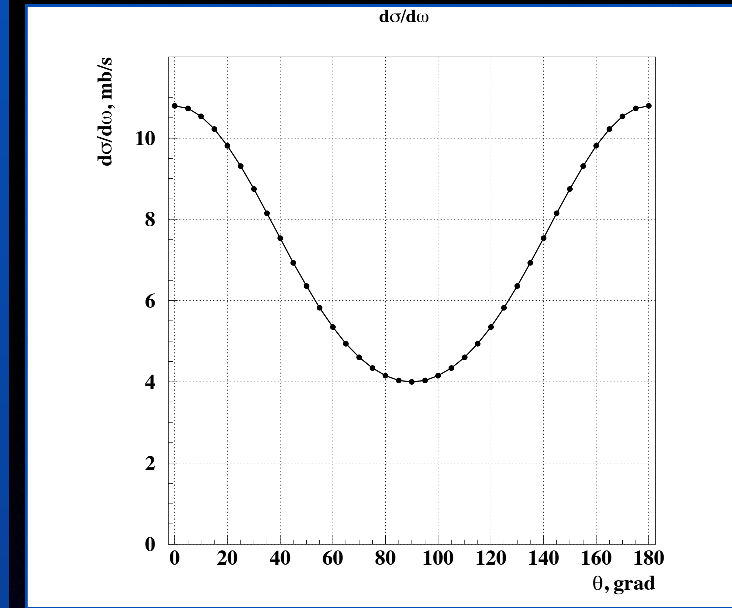
measured

to be extracted

$$\chi^2 = (\vec{O} - [M]\cdot\vec{A})^T V_o{}^{-1} (\vec{O} - [M]\cdot\vec{A})$$

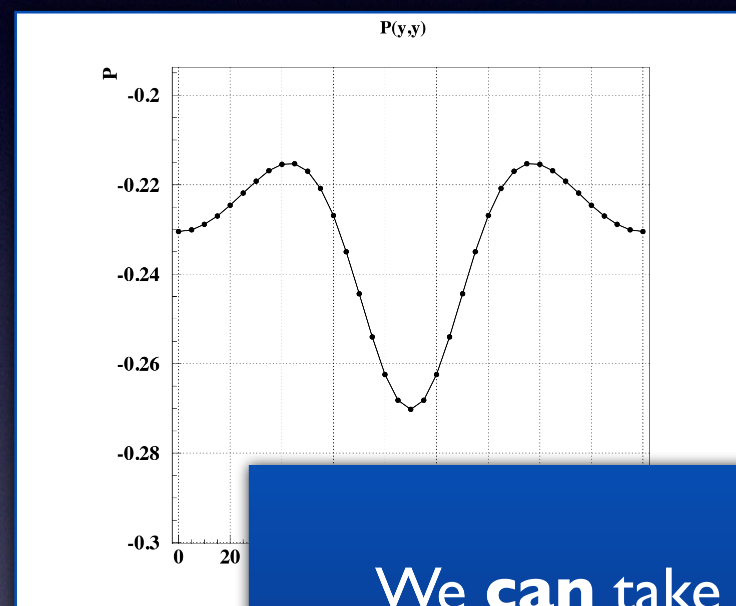
Minimizatio

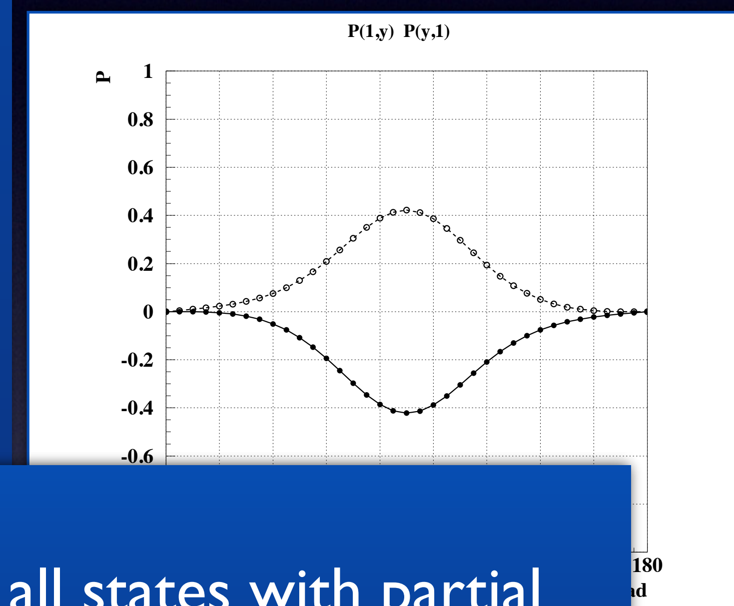




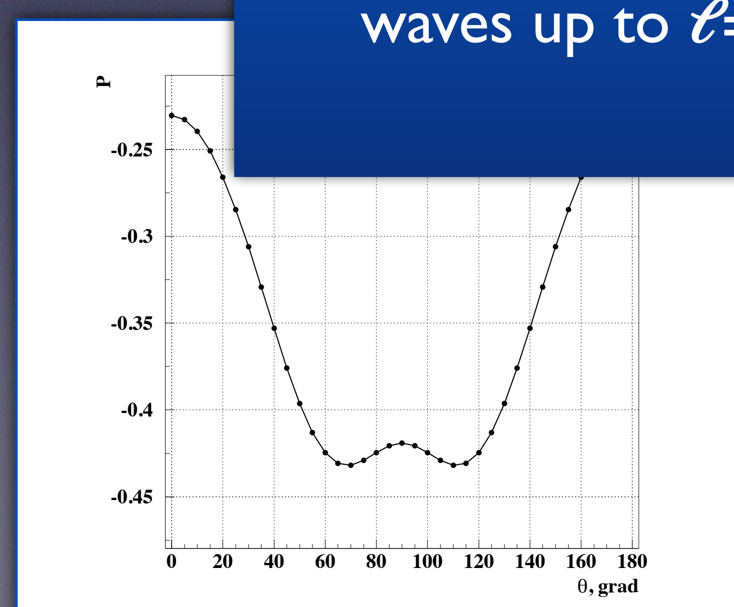
Predicted

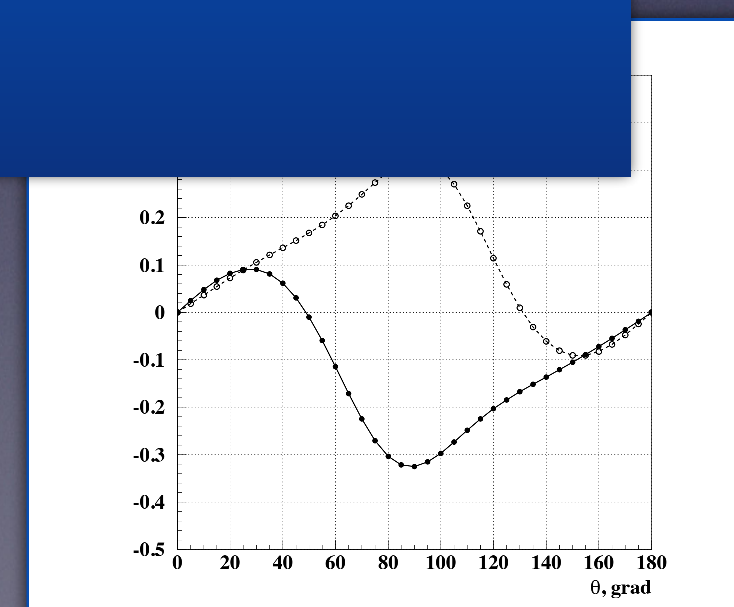
Observab





We **can** take into account all states with partial waves up to ℓ=4.





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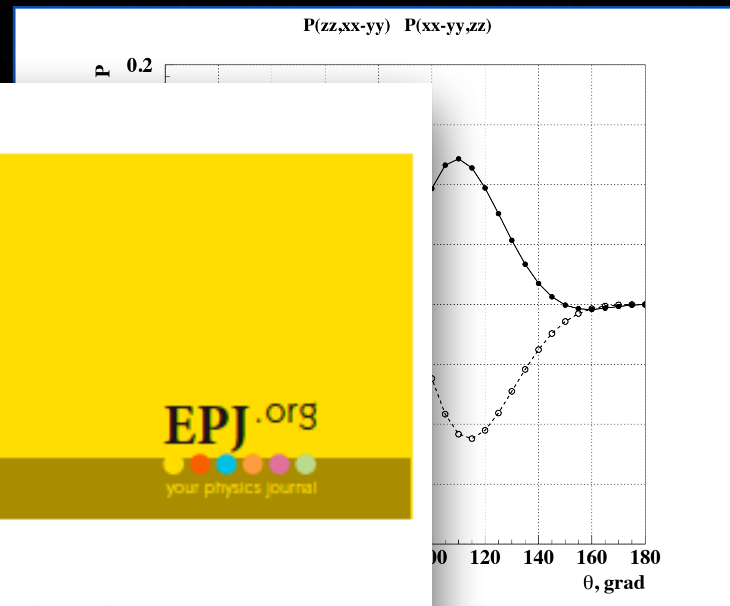
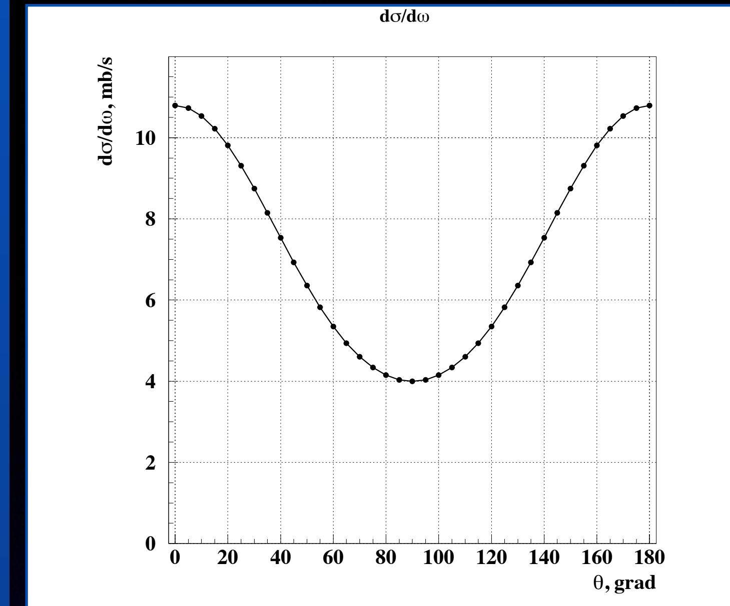
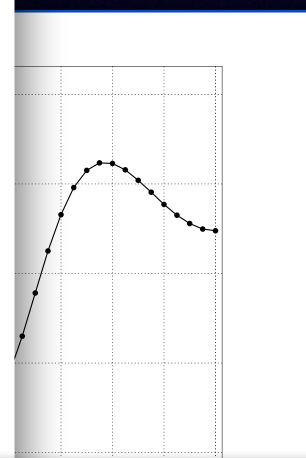
Eur. Phys. J. A **44**, 321–354 (2010) DOI: 10.1140/epja/i2010-10964-4

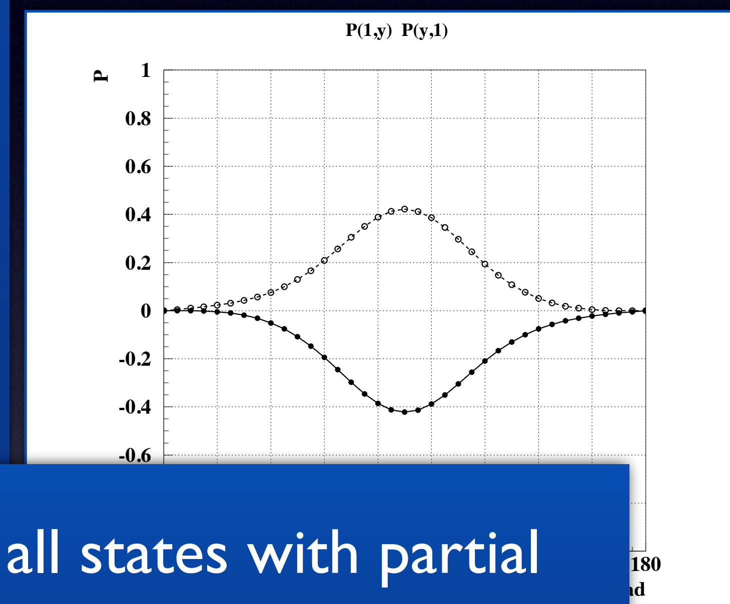
The status of "polarized fusion"

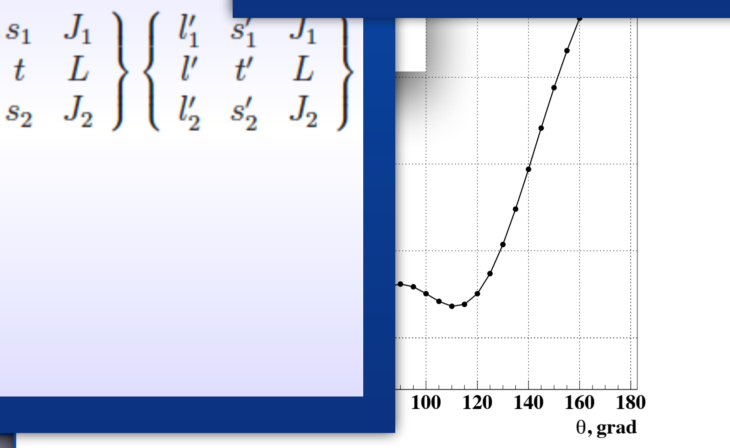
H. Paetz gen. Schieck

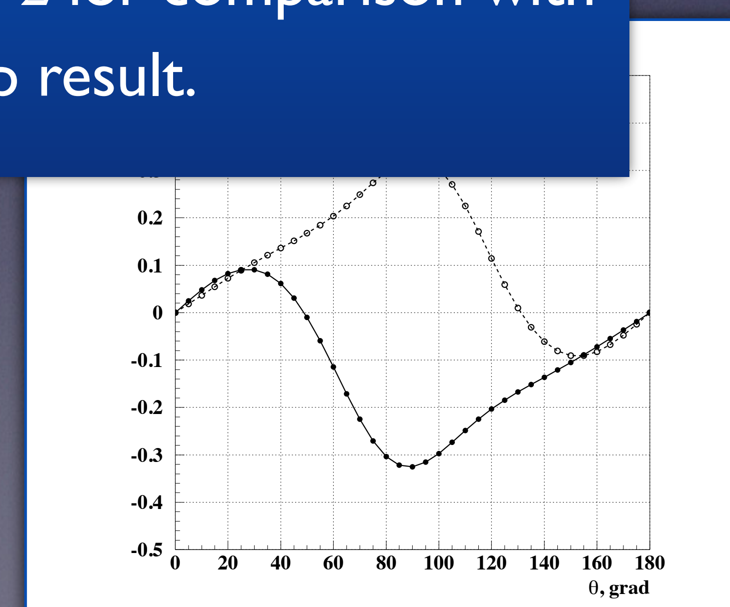












Welton formula

$$
\begin{aligned}
t_{q\gamma,Q\Gamma} &= (2k_{in})^{-2}(\hat{i}\hat{I})^{1/2} \\
&\cdot \sum \begin{Bmatrix} i & I & s_1 \\ q & Q & t \\ i & I & s_2 \end{Bmatrix} \begin{Bmatrix} i' & I' & s_1' \\ q' & Q' & t' \\ i' & I' & s_2' \end{Bmatrix} \begin{Bmatrix} l_1 & s_1 & J_1 \\ l & t & L \\ l_2 & s_2 & J_2 \end{Bmatrix} \begin{Bmatrix} l_1' & s_1' & J_1 \\ l' & t' & L \\ l_2' & s_2' & J_2 \end{Bmatrix} \\
&\cdot (l_1 l_2 00|l0)(l_1' l_2' 00|l'0)(lt0\Lambda|L\Lambda) \\
&\cdot (l't'0\Lambda'|L\Lambda')(qQ\gamma\Gamma|t\Lambda)(q'Q'\gamma'\Gamma'|t'\Lambda') \\
&\cdot T^{J_1^{\pi_1}} T^{J_2^{\pi_2}*} D^L_{\Lambda'\Lambda}(\Phi,\Theta,0) \\
&\cdot (\hat{i}'\hat{I}')^{-1/2} \\
&\cdot t_{q'\gamma',Q'\Gamma'}
\end{aligned}
$$

We **can** take into account all states with partial waves up to ℓ=4. Here $\ell=2$ for comparison with H.Paetz gen Schieck's group result.

Conclusions

Data on polarized d-d cross sections will provide usefull and expected information in

nuclear fusion with polarized fuel and astrophysics

The experimental setup is under construction

Conclusions

Data on polarized d-d cross sections will provide expected information in
nuclear fusion with polarized fuel and ast

The experimental setup is under construction

Agreement for collaboration PREFER is signed
(Polarization Reasearch for Fusion Experiments and Reactors)

AGREEMENT FOR COOPERATION

BETWEEN
Forschungszentrum Jülich GmbH
52425 Jülich
Federal Republic of GERMANY
- hereinafter referred to as „*JÜLICH*" -

AND

Heinrich-Heine Universität Düsseldorf
Universitätsstraße 1
40225 Düsseldorf
Federal Republic of GERMANY
- hereinafter referred to as „*HHUD*" -

AND

Budker Institute of Nuclear Physics of
Siberian Branch Russian Academy of Sciences
Lavrentiev Avenue 11
630090, Novosibirsk
RUSSIA
- hereinafter referred to as „*BINP*" -

AND

Dipartimento di Fisica e Scienze della Terra
Università degli studi di Ferrara
Via Saragat 1
44122 Ferrara
ITALY
- hereinafter referred to as „*UNIFE*" -

AND

INFN-Sezione di Ferrara
Via Saragat 1
44122 Ferrara
ITALY
- hereinafter referred to as „*INFN*" -

AND

National Research Center "Kurchatov Institute"
Petersburg Nuclear Physics Institute
188300, Gatchina,
RUSSIA
- hereinafter referred to as „*PNPI*" -

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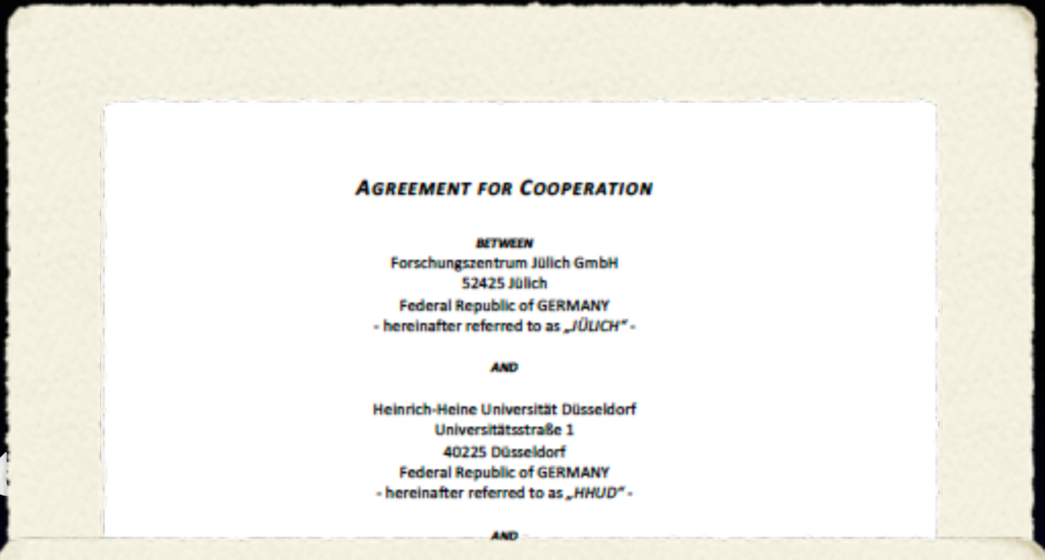
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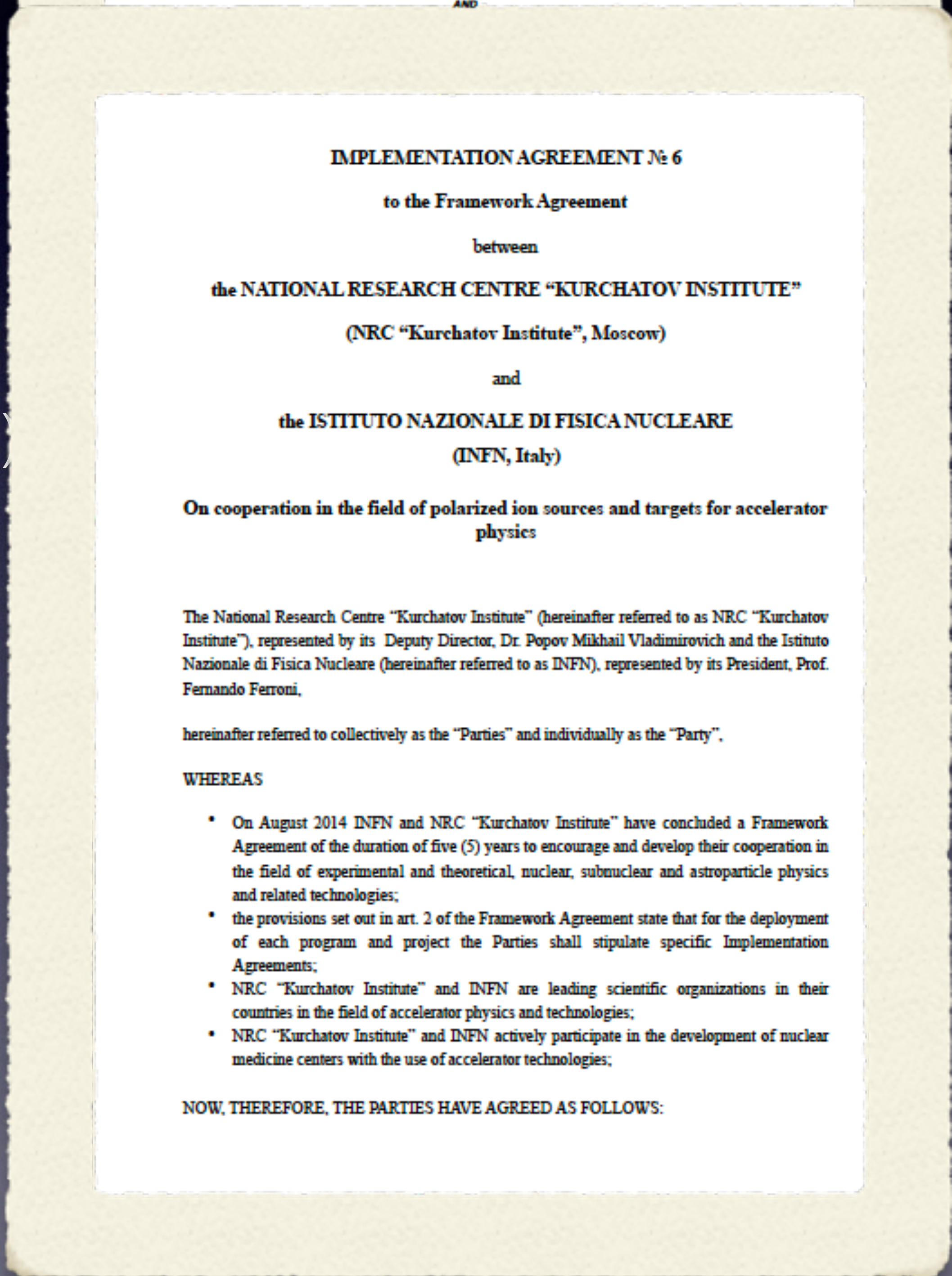
IMPLEMENTATION AGREEMENT № 6

to the Framework Agreement

between

the NATIONAL RESEARCH CENTRE "KURCHATOV INSTITUTE"

(NRC "Kurchatov Institute", Moscow)

and

the ISTITUTO NAZIONALE DI FISICA NUCLEARE
(INFN, Italy)

On cooperation in the field of polarized ion sources and targets for accelerator physics

The National Research Centre "Kurchatov Institute" (hereinafter referred to as NRC "Kurchatov Institute"), represented by its Deputy Director, Dr. Popov Mikhail Vladimirovich and the Istituto Nazionale di Fisica Nucleare (hereinafter referred to as INFN), represented by its President, Prof. Fernando Ferroni,

hereinafter referred to collectively as the "Parties" and individually as the "Party",

WHEREAS

- On August 2014 INFN and NRC "Kurchatov Institute" have concluded a Framework Agreement of the duration of five (5) years to encourage and develop their cooperation in the field of experimental and theoretical, nuclear, subnuclear and astroparticle physics and related technologies;
- the provisions set out in art. 2 of the Framework Agreement state that for the deployment of each program and project the Parties shall stipulate specific Implementation Agreements;
- NRC "Kurchatov Institute" and INFN are leading scientific organizations in their countries in the field of accelerator physics and technologies;
- NRC "Kurchatov Institute" and INFN actively participate in the development of nuclear medicine centers with the use of accelerator technologies;

NOW, THEREFORE, THE PARTIES HAVE AGREED AS FOLLOWS:

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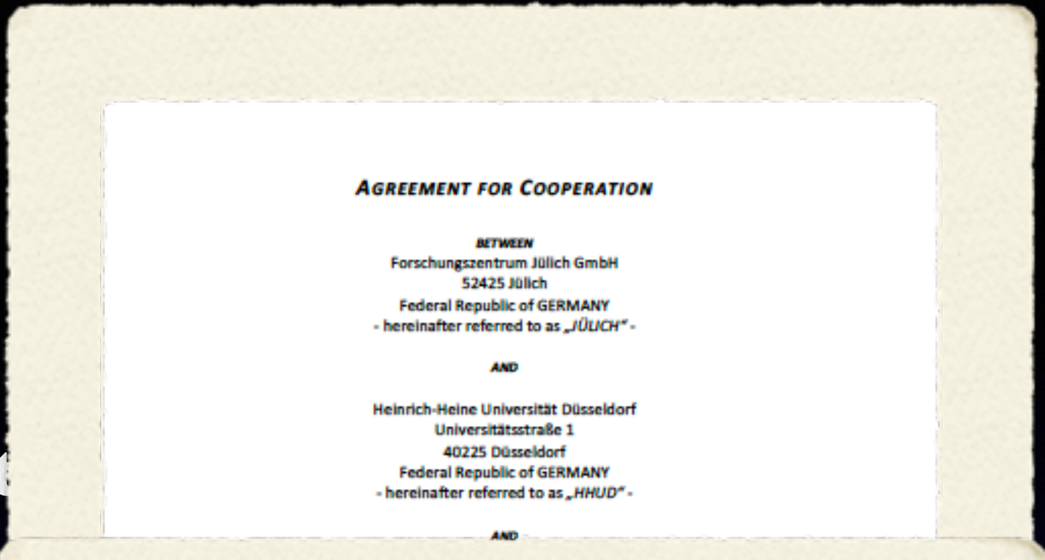
&
the Istituto Nazionale di Fisica Nucleare

We are looking forward for financial supports for hardware and manpower.
2 new Phd students started in Summer 2018

Thank you!



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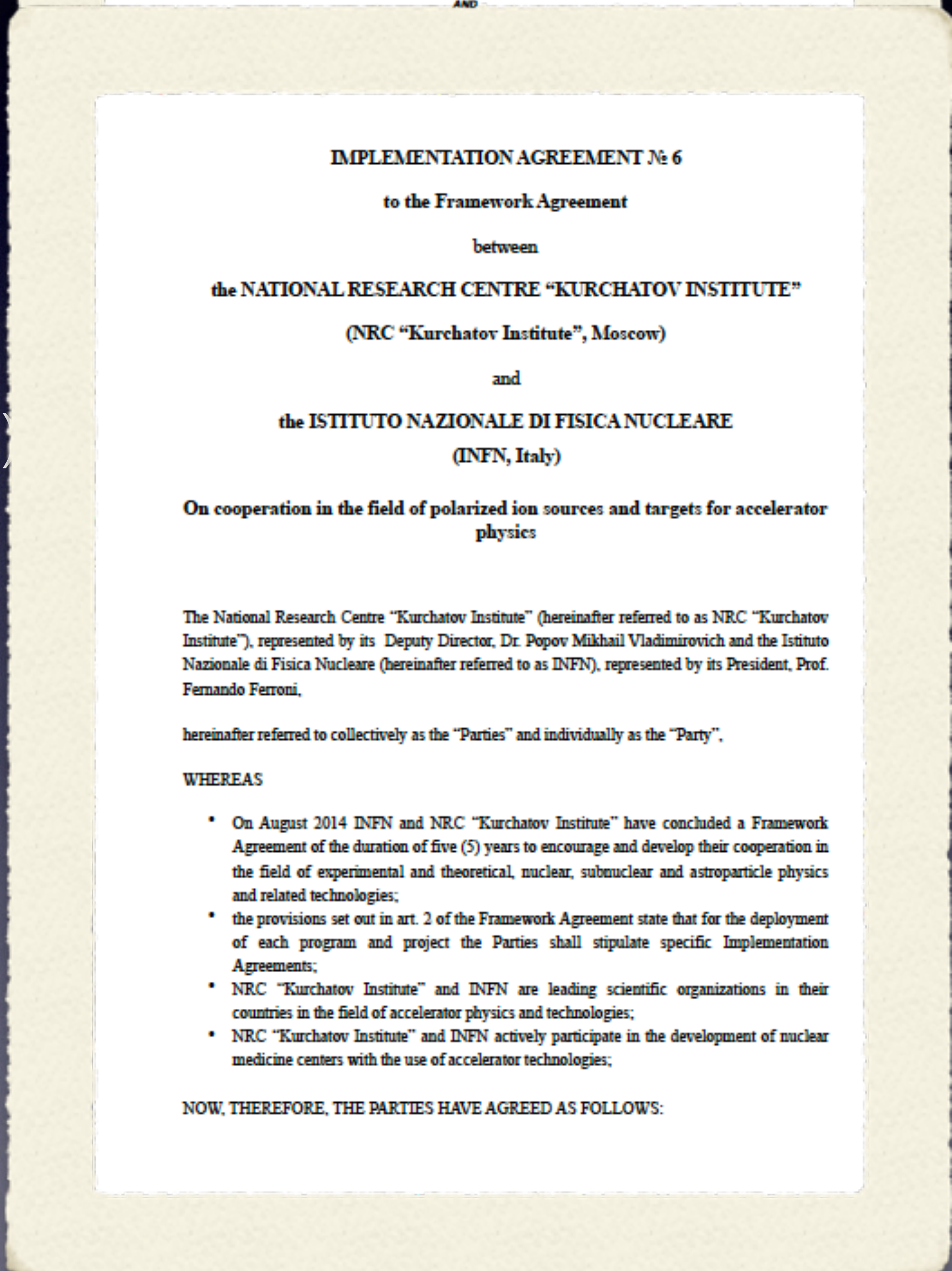

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