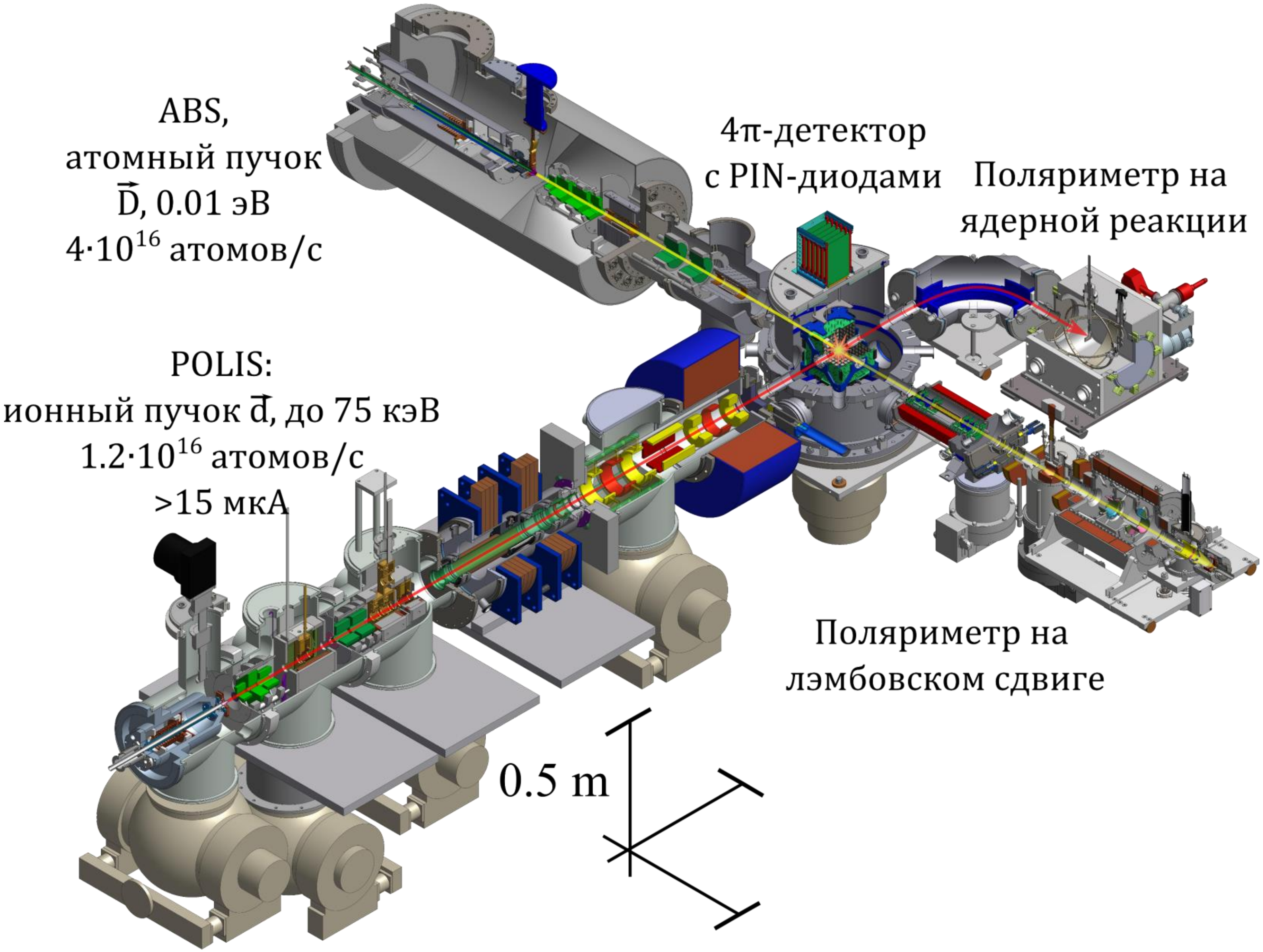
Система поляриметрии в эксперименте POLFUSION

Иван Николаевич Соловьев

научный сотрудник

POLFUSION


ABS,
атомный пучок
D⃗, 0.01 эВ
4·10^16 атомов/с
4π-детектор
с PIN-диодами
Поляриметр на
ядерной реакции
POLIS:
ионный пучок d⃗, до 75 кэВ
1.2·10^16 атомов/с
>15 мкА
Поляриметр на
лэмбовском сдвиге
0.5 m

Поляриметры

1. BRP – Breit-Rabi Polarimeter
2. LSP – Lamb-Shift Polarimeter
3. NRP – Nuclear Reaction Polarimeter
4. IBP – In-Beam Polarimeter

	Частицы	**Энергия**	**Метод**	**Точность**
BRP	атомы 1S	<0.1 эВ	ВЧ переходы	4%
LSP	ионы / атомы 2S	0.5-2 кэВ	Спинфильтр	<1%
NRP	ионы	10-100 кэВ	Ядерная реакция d(d,t)p, 3He(d,p)4He	2-4%
IBP	ионы	>50 кэВ	Упругое рассеяние H(d,d)p	4%

Поляриметр на ядерной реакции (NRP)

$$\sigma = \sigma_0(1+\tfrac{3}{2}P_Z A_y \cos\phi \sin\beta - P_{ZZ} A_{xz} \sin\beta\cos\beta\sin\phi - \tfrac{1}{4}P_{ZZ}(A_{xx}-A_{yy})\sin^2\beta\cos 2\phi + \tfrac{1}{4}P_{ZZ}A_{zz}(3\cos^2\beta-1))$$

G.G Ohlsen, P.W. Keaton, Jr., Nucl. Instr. and Meth. **109**, 41 (1973).

$$\frac{L-R}{L+R} = \frac{\frac{3}{2}P_Z \sin\beta A_y}{1+\frac{1}{2}P_{ZZ}[\sin^2\beta A_{yy}+\cos^2\beta A_{zz}]}$$

$$\frac{U-D}{U+D} = \frac{P_{ZZ}\sin\beta\cos\beta A_{xz}}{1+\frac{1}{2}P_{ZZ}[\sin^2\beta A_{xx}+\cos^2\beta A_{zz}]}$$

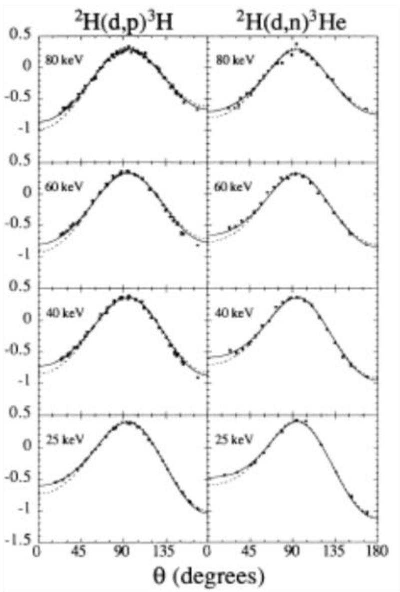
$$\frac{2(L-R)}{L+R+U+D} = \frac{\frac{3}{2}P_Z\sin\beta A_y}{1+\frac{1}{4}P_{ZZ}(3\cos^2\beta-1)}$$

$$\frac{2(U-D)}{L+R+U+D} = \frac{P_{ZZ}\sin\beta\cos\beta A_{xz}}{1+\frac{1}{4}P_{ZZ}(3\cos^2\beta-1)}$$

$$\frac{(L+R)-(U+D)}{L+R+U+D} = \frac{-\frac{1}{4}P_{ZZ}\sin^2\beta(A_{xx}-A_{yy})}{1+\frac{1}{4}P_{ZZ}A_{zz}(3\cos^2\beta-1)}$$

G.G Ohlsen, P.W. Keaton, Jr., Nucl. Instr. and Meth. **109**, 41 (1973).

A_{zz}



K. Fletcher, *et al.*, Phys. Rev. C **49**, 2305 (1994).

Z - ось квантования

z - ось пучка

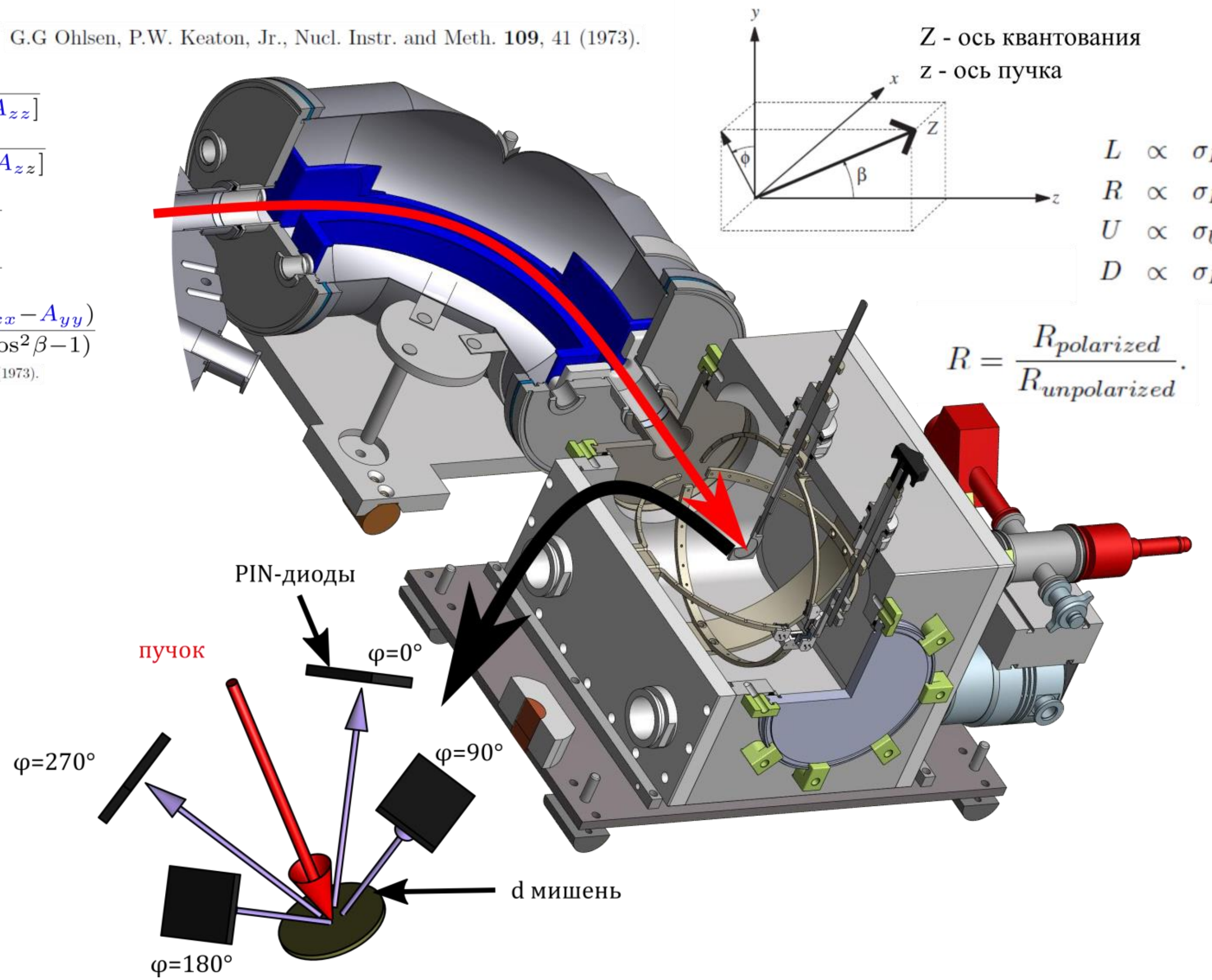
$L \propto \sigma_L$

$R \propto \sigma_R$

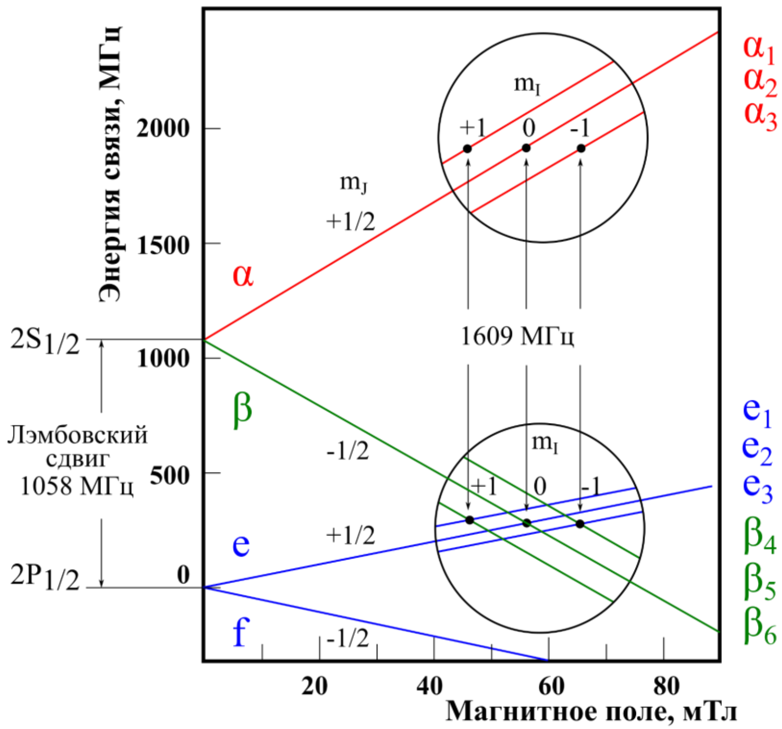
$U \propto \sigma_U$

$D \propto \sigma_D.$

$$R = \frac{R_{polarized}}{R_{unpolarized}}.$$

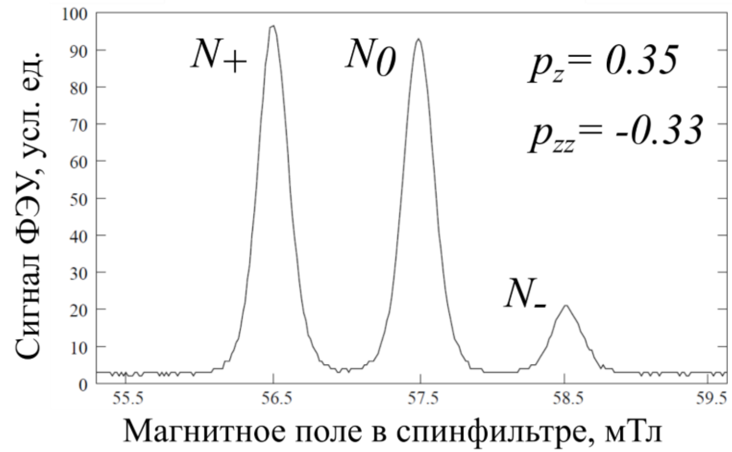


Поляриметр на лэмбовском сдвиге (LSP)

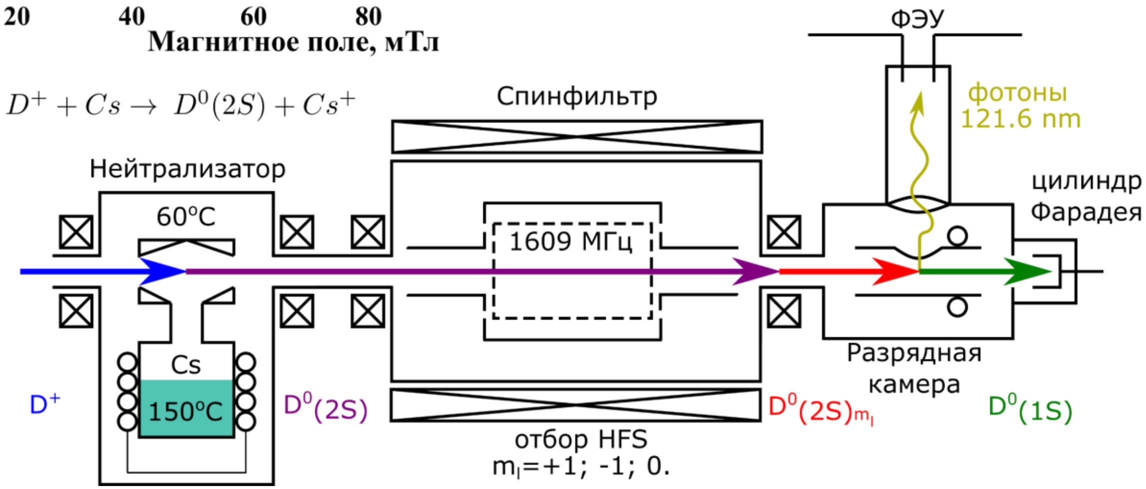


$$p_z = \frac{N_+ - N_-}{N_+ + N_- + N_0}.$$

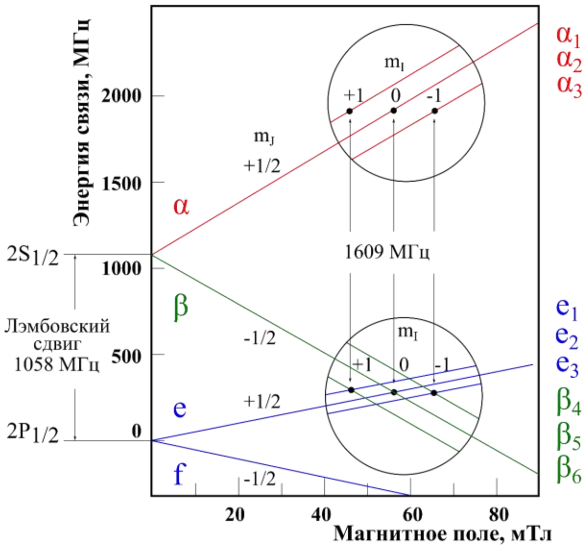
$$p_{zz} = \frac{N_+ + N_- - 2N_0}{N_+ + N_- + N_0}.$$

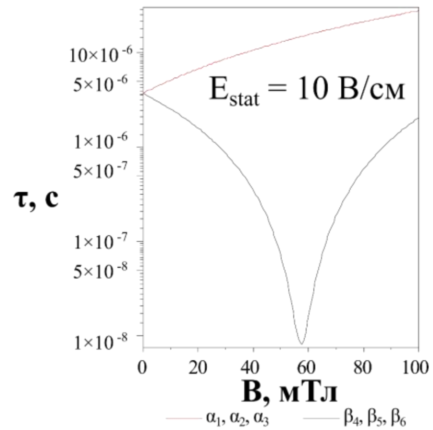


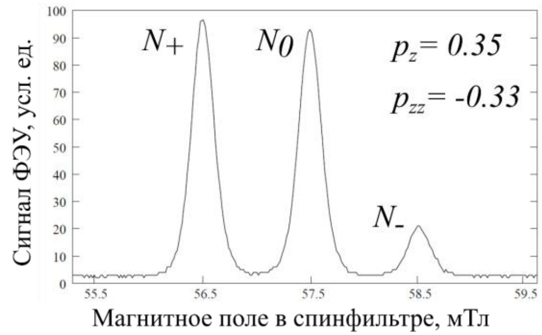
$$D^+ + Cs \rightarrow D^0(2S) + Cs^+$$

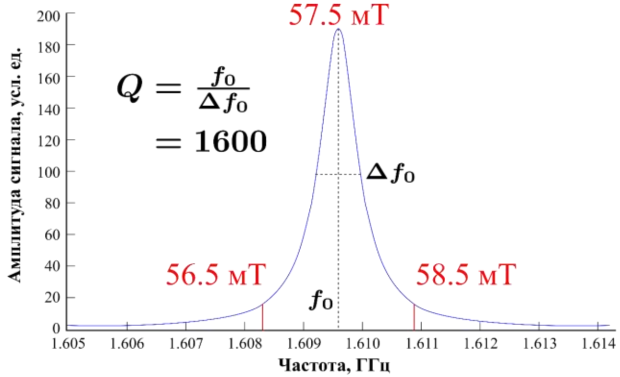


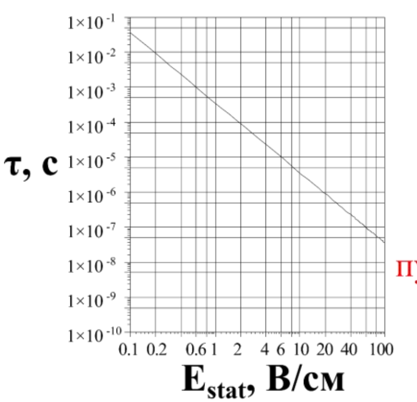
Спинфильтр

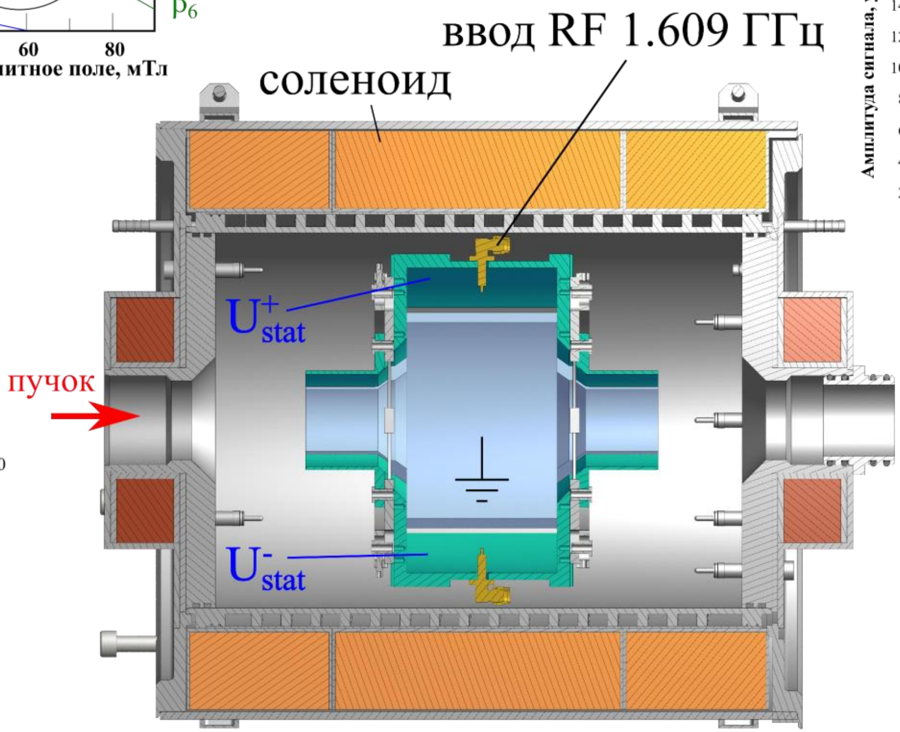

Энергия связи, МГц
2S1/2
2P1/2
Лэмбовский сдвиг 1058 МГц
1609 МГц
mJ
+1/2
-1/2
mI
+1 0 -1
α
β
e
f
α1 α2 α3
e1 e2 e3
β4 β5 β6
Магнитное поле, мТл

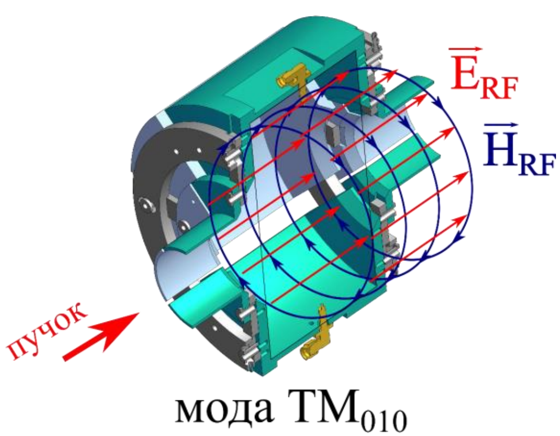

τ, с
E_stat = 10 В/см
B, мТл
α1, α2, α3
β4, β5, β6


Сигнал ФЭУ, усл. ед.
N+
N0
N-
p_z = 0.35
p_zz = -0.33
Магнитное поле в спинфильтре, мТл

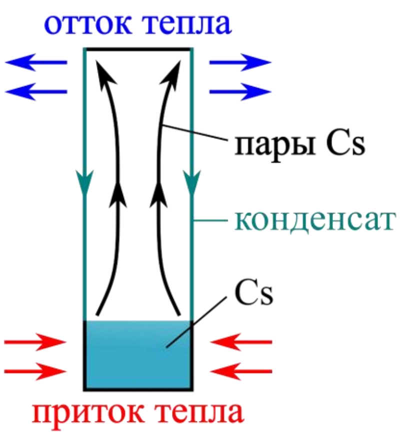

Амплитуда сигнала, усл. ед.
57.5 мТ
56.5 мТ
58.5 мТ
Q = f0/Δf0 = 1600
Δf0
f0
Частота, ГГц

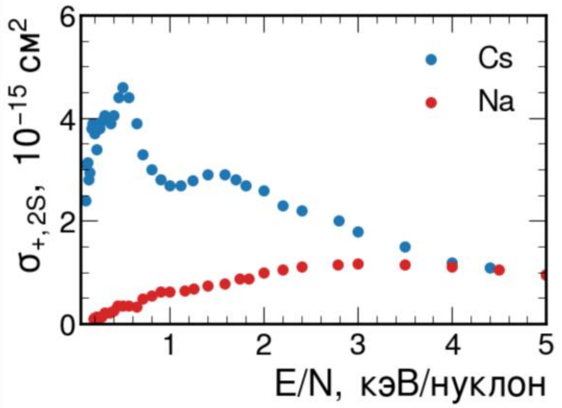

τ, с
E_stat, В/см


ввод RF 1.609 ГГц
соленоид
пучок
U+stat
U-stat


E_RF
H_RF
пучок
мода TM010

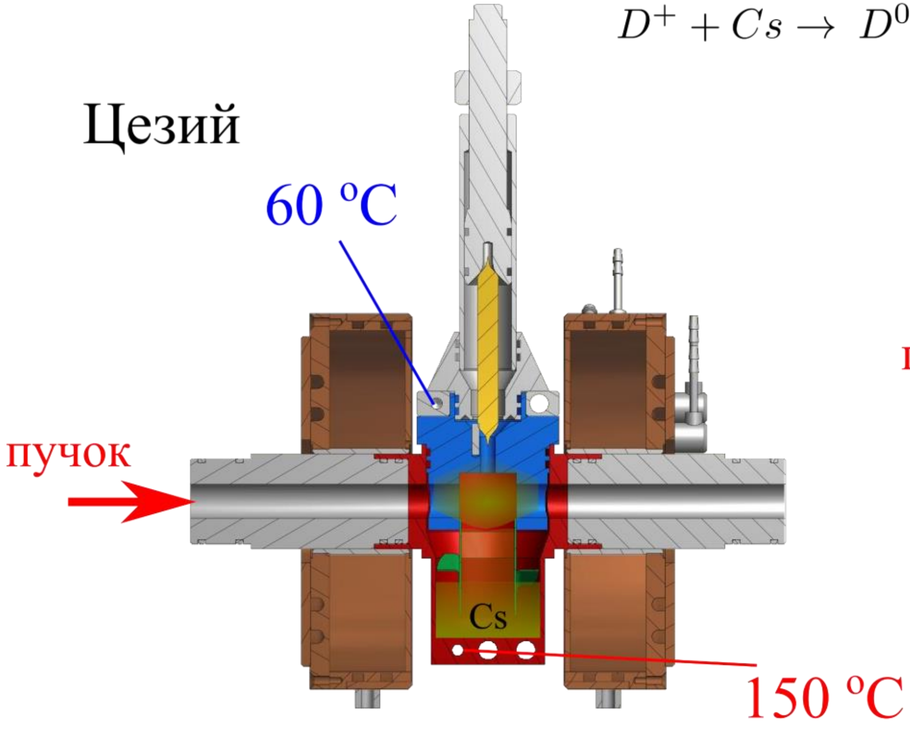
Сравнение нейтрализаторов

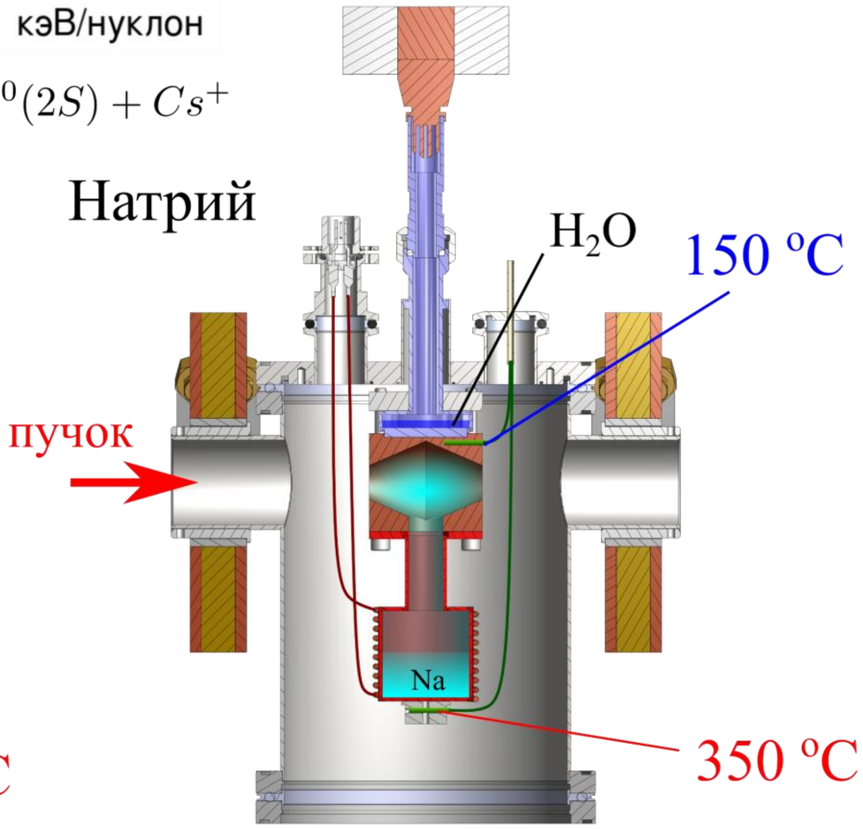




Nagata T., Kuribara M.,
Journal of the Physical Society of Japan,
Vol. 55, No. 2, 1986, pp. 500-506.

$$D^+ + Cs \rightarrow D^0(2S) + Cs^+$$

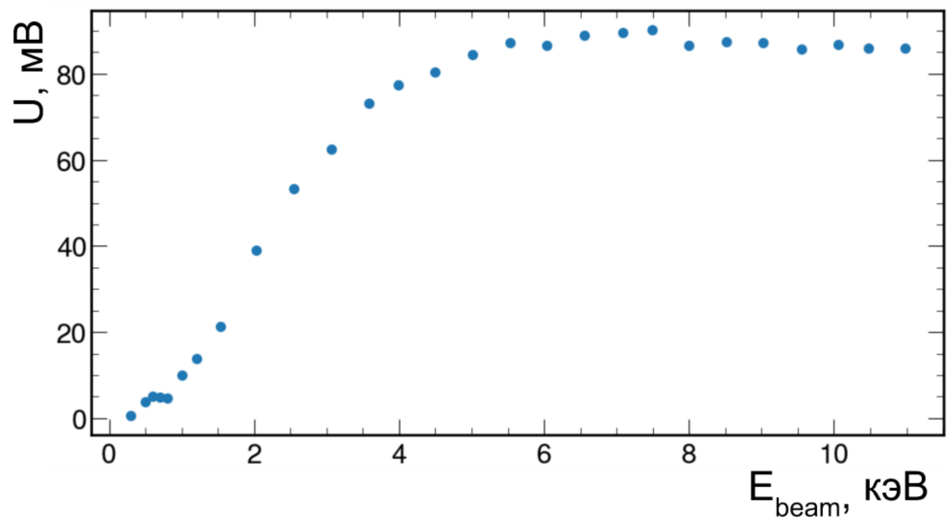


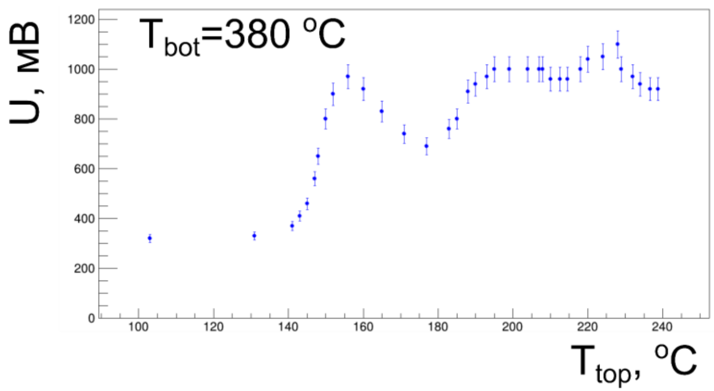


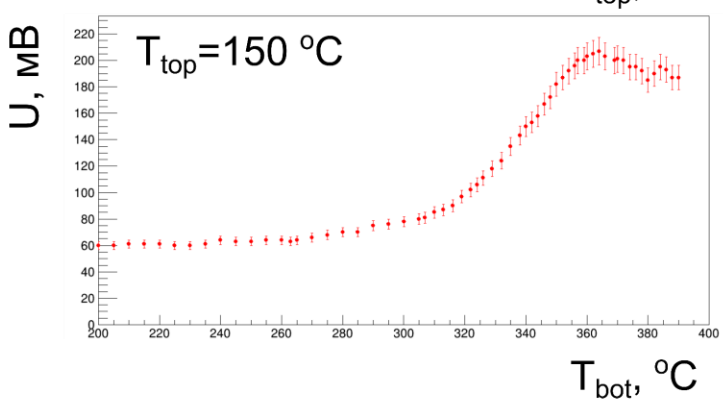
Параметры Na нейтрализатора

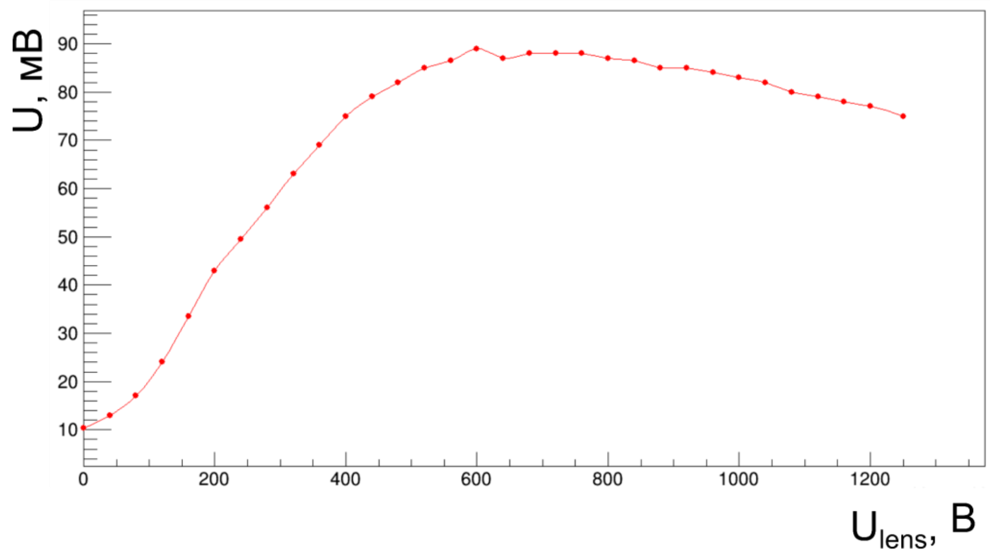
Рабочие параметры

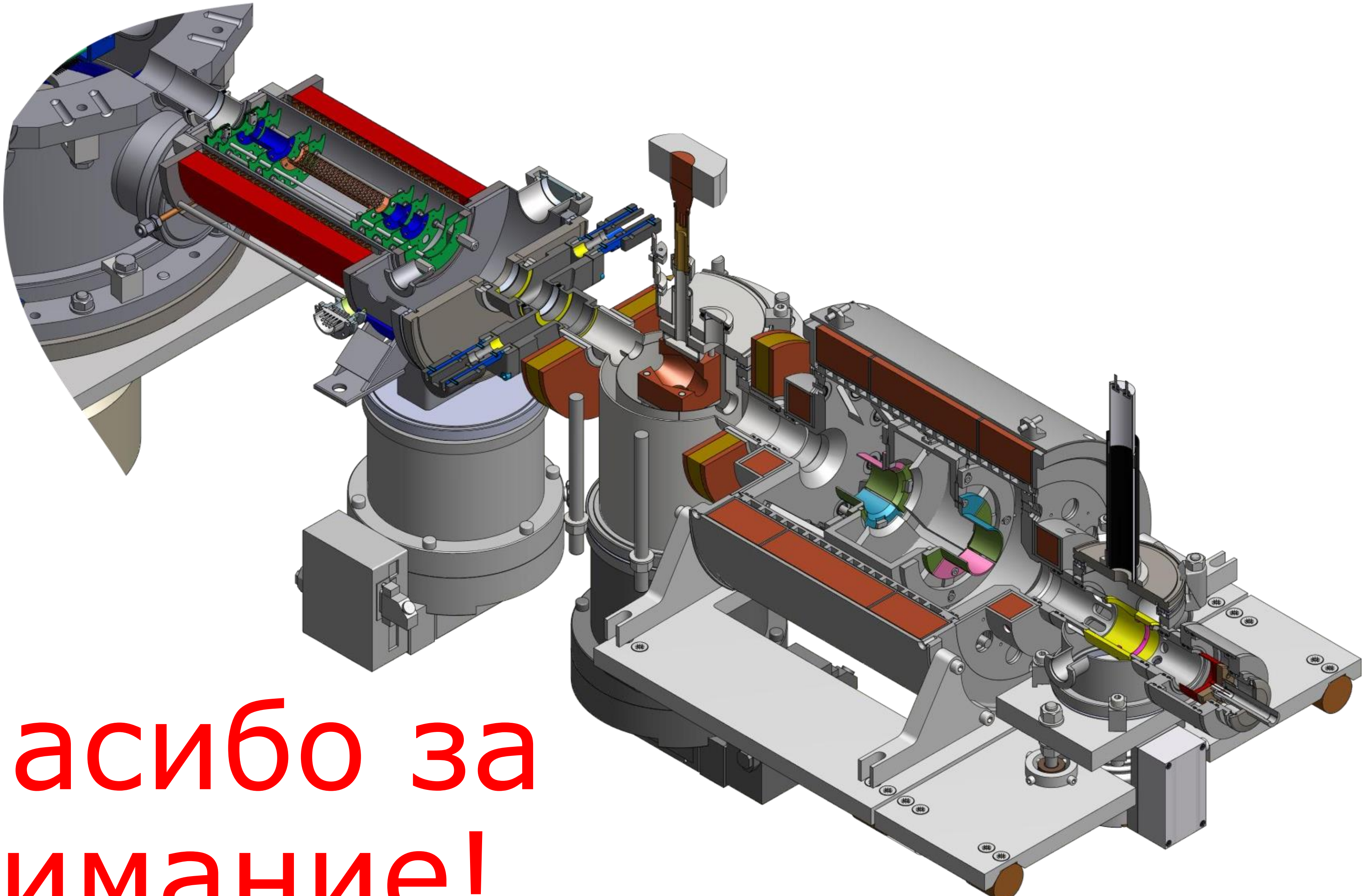
E_{beam}= 6 кэВ
T_{top}= 150 °C
T_{bot}= 360 °C
U_{PMT}= 2 кВ
U_{lens}= 600 В











Спасибо за внимание!

Определение поляризации

$$\sigma(\theta,\phi) = \sigma_0\Big(1+\frac{3}{2}P_Z A_y(\theta)\cos\phi\sin\beta - P_{ZZ}A_{xz}(\theta)\sin\beta\cos\beta\sin\phi - \frac{1}{4}P_{ZZ}\big(A_{xx}(\theta)-A_{yy}(\theta)\big)\sin^2\beta\cos 2\phi + \frac{1}{4}P_{ZZ}A_{zz}(\theta)\big(3\cos^2\beta - 1\big)\Big).$$

G.G Ohlsen, P.W. Keaton, Jr., Nucl. Instr. and Meth. **109**, 41 (1973).

$$\sigma_L = \sigma_0(1+\frac{3}{2}P_Z A_y(\theta)\sin\beta + \frac{1}{2}P_{ZZ}(A_{yy}(\theta)\ \sin^2\beta + A_{zz}\ \cos^2\beta)),$$

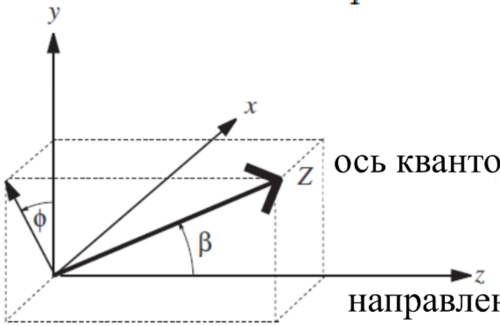
$$\sigma_R = \sigma_0(1-\frac{3}{2}P_Z A_y(\theta)\sin\beta + \frac{1}{2}P_{ZZ}(A_{yy}(\theta)\ \sin^2\beta + A_{zz}\ \cos^2\beta)),$$

$$\sigma_U = \sigma_0(1+P_{ZZ}A_{xz}(\theta)\sin\beta\cos\beta + \frac{1}{2}P_{ZZ}(A_{xx}(\theta)\ \sin^2\beta + A_{zz}\ \cos^2\beta)),$$

$$\sigma_D = \sigma_0(1+P_{ZZ}A_{xz}(\theta)\sin\beta + \frac{1}{2}P_{ZZ}(A_{yy}(\theta)\ \sin^2\beta\cos\beta + A_{zz}\ \cos^2\beta)).$$

$$L \propto \sigma_L \qquad R \propto \sigma_R \qquad U \propto \sigma_U \qquad D \propto \sigma_D.$$

$$R = \frac{R_{polarized}}{R_{unpolarized}}.$$



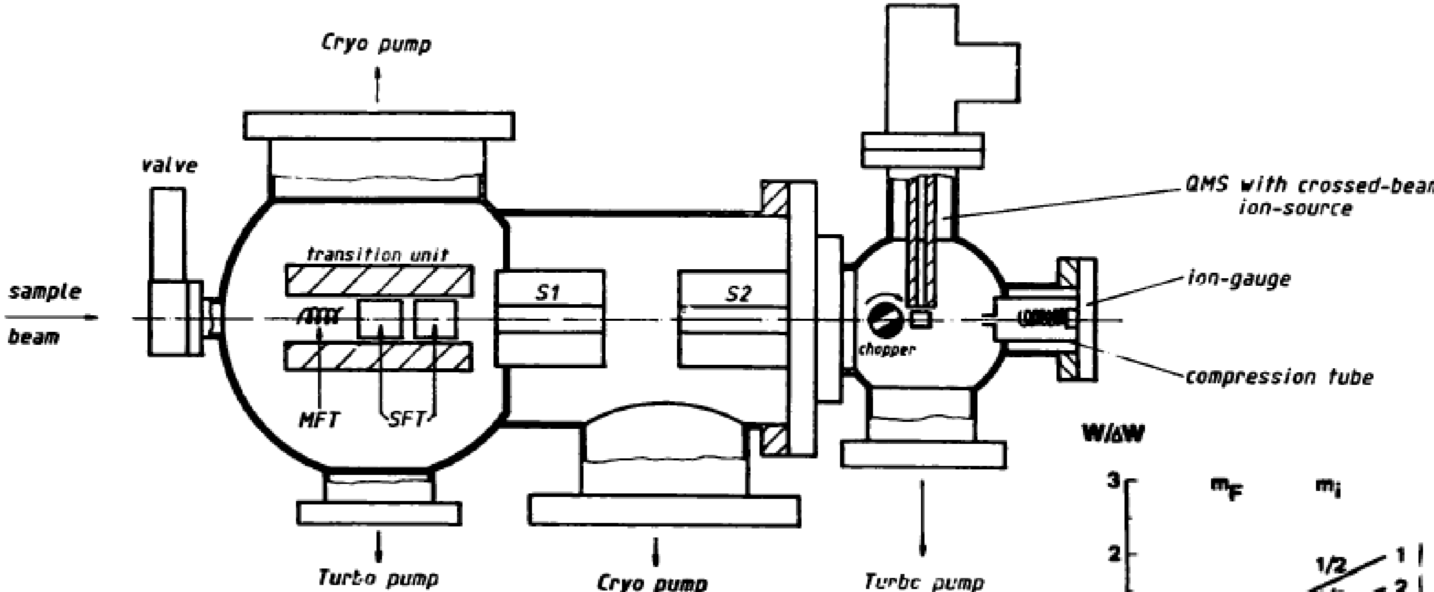
$$\epsilon_1 \equiv \frac{L-R}{L+R} = \frac{\frac{3}{2}P_Z\sin\beta\, A_y}{1+\frac{1}{2}P_{ZZ}[\sin^2\beta A_{yy} + \cos^2\beta A_{zz}]}$$

$$\epsilon_2 \equiv \frac{U-D}{U+D} = \frac{P_{ZZ}\sin\beta\ \cos\beta\, A_{xz}}{1+\frac{1}{2}P_{ZZ}[\sin^2\beta A_{xx} + \cos^2\beta A_{zz}]}$$

$$\epsilon_3 \equiv \frac{2(L-R)}{L+R+U+D} = \frac{\frac{3}{2}P_Z\sin\beta\, A_y}{1+\frac{1}{4}P_{ZZ}[3(\cos^2\beta - 1)A_{zz}]}$$

$$\epsilon_4 \equiv \frac{2(U-D)}{L+R+U+D} = \frac{P_{ZZ}\sin\beta\ \cos\beta\, A_{xz}}{1+\frac{1}{4}P_{ZZ}[3(\cos^2\beta - 1)A_{zz}]}$$

$$\epsilon_5 \equiv \frac{(L+R)-(U+D)}{L+R+U+D} = \frac{-\frac{1}{4}P_{ZZ}\sin^2\beta\ (A_{xx}-A_{yy})}{1+\frac{1}{4}P_{ZZ}[3(\cos^2\beta - 1)A_{zz}]},$$



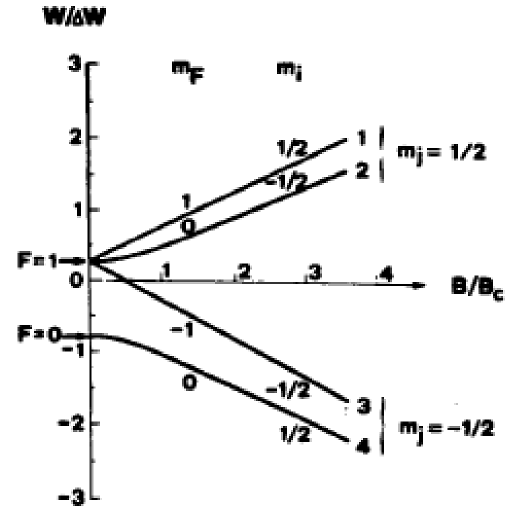
$$n = \begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{pmatrix}$$

$$\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{pmatrix} \xrightarrow{\text{sextupole}} \begin{pmatrix} n_1 \\ n_2 \\ 0 \\ 0 \end{pmatrix} \quad S_0 = K(n_1 + n_2)$$

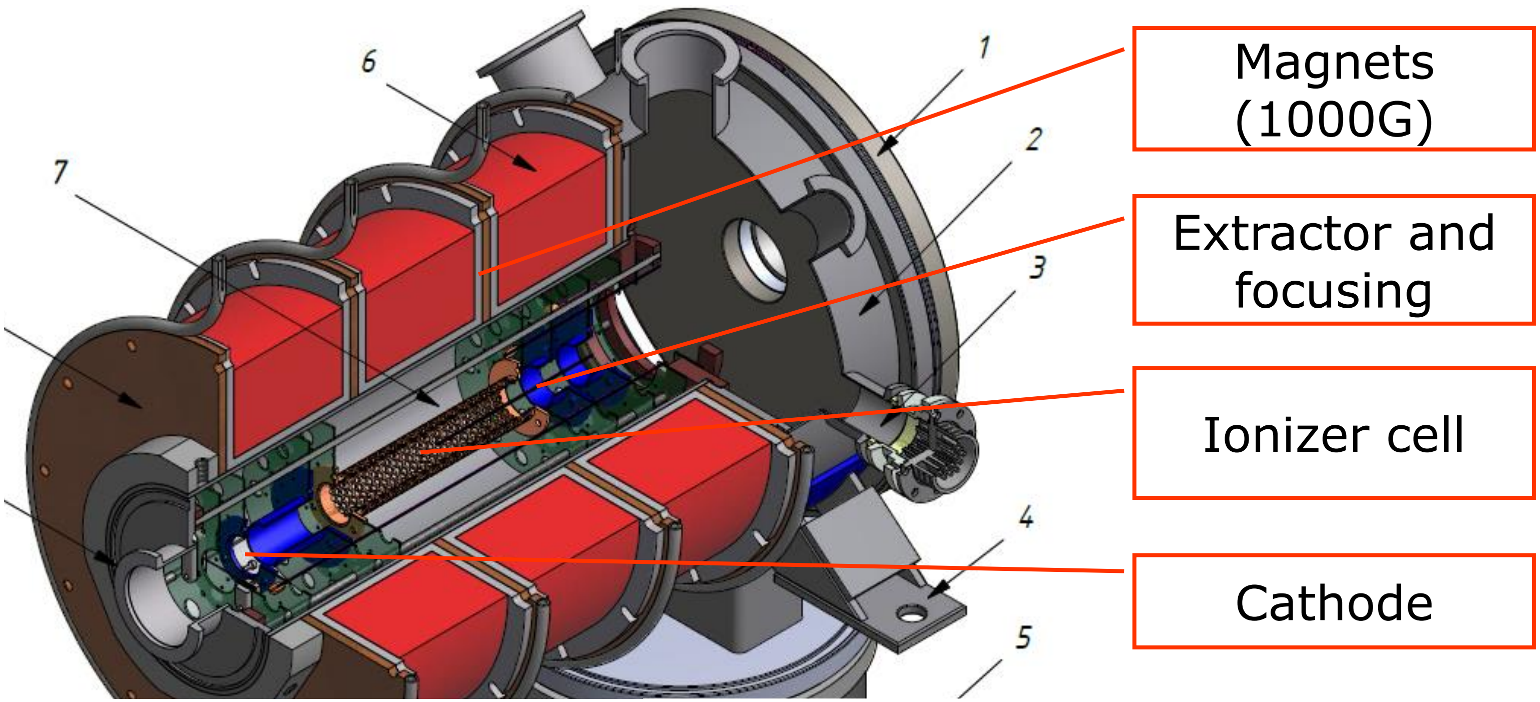
$$R_{24} = \frac{n_1 + n_4}{n_1 + n_2}$$

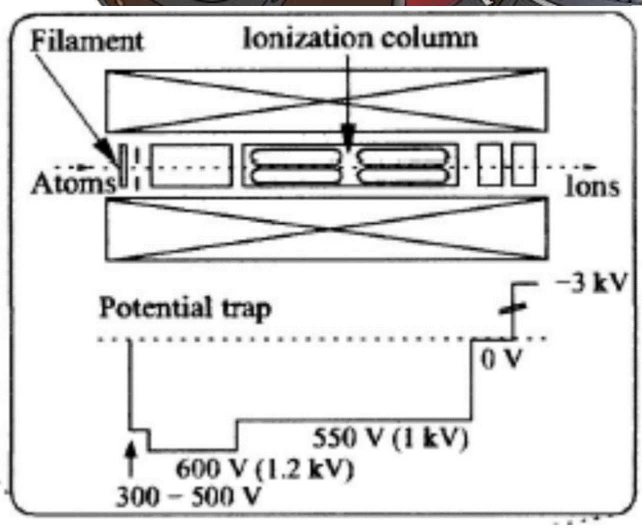
$$\begin{pmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{pmatrix} \xrightarrow{2 \leftrightarrow 4} \begin{pmatrix} n_1 \\ n_4 \\ n_3 \\ n_2 \end{pmatrix} \xrightarrow{\text{sextupole}} \begin{pmatrix} n_1 \\ n_4 \\ 0 \\ 0 \end{pmatrix} \quad S_1 = K(n_1 + n_4)$$

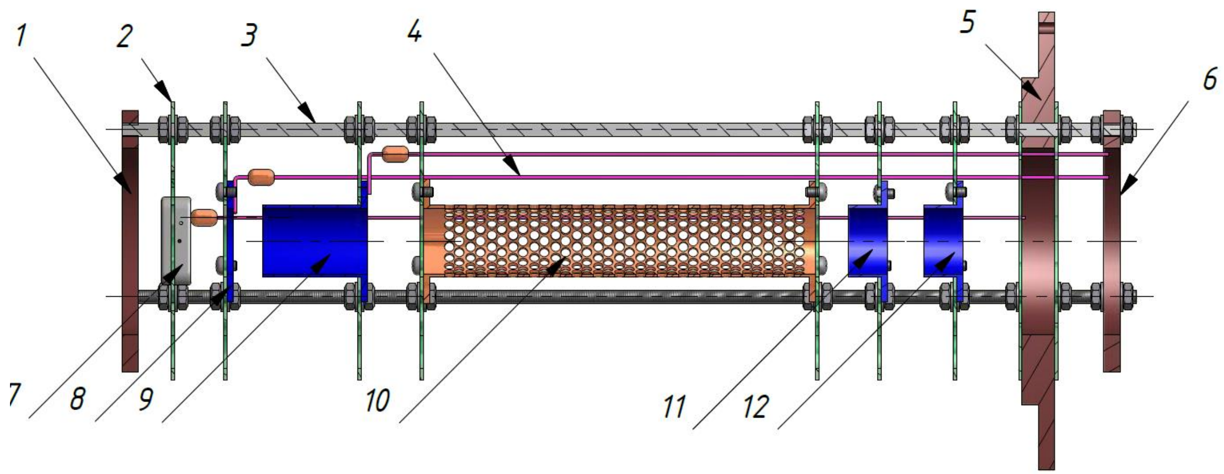
$$\begin{aligned} R_{13}n_1 + (R_{13} - 1)n_2 - n_3 &= 0, \\ (R_{23} - 1)n_1 + R_{23}n_2 - n_3 &= 0, \\ (R_{24} - 1)n_1 + R_{24}n_2 - n_4 &= 0, \\ n_1 + n_2 + n_3 + n_4 &= 1. \end{aligned}$$



Glavish ionizer

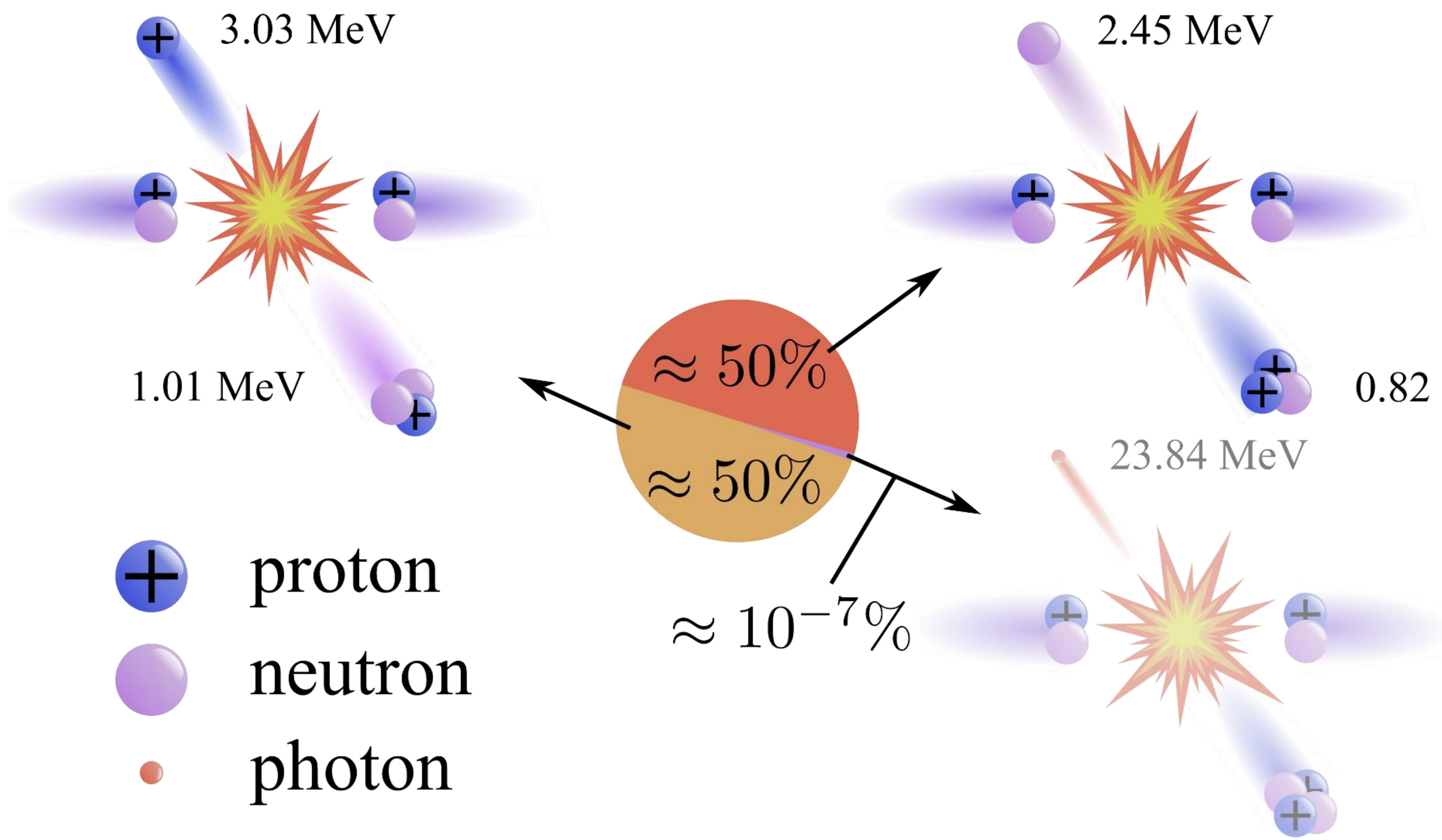






dd fusion reactions

$$^2H + {^2H} \rightarrow {^3H} + p + 4.04\ MeV \qquad {^2H} + {^2H} \rightarrow {^3He} + n + 3.27\ MeV$$



$$^2H + {^2H} \rightarrow {^4He} + \gamma + 23.84\ MeV$$

Applied physics

1st generation:

d + t ⟶ ^{4}He + n (17.6 MeV / 107 keV)

2nd generation:

d + d ⟶ t + p (4 MeV)

d + d ⟶ ^{3}He + n (3.3 MeV)

+

n + ^{6}Li ⟶ ^{4}He + t (4.8 MeV)

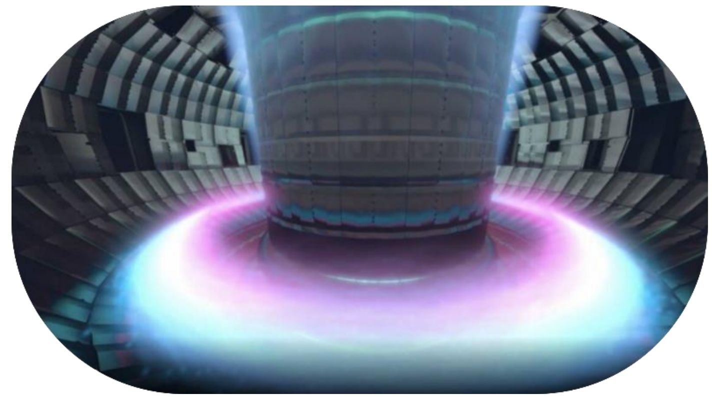
+

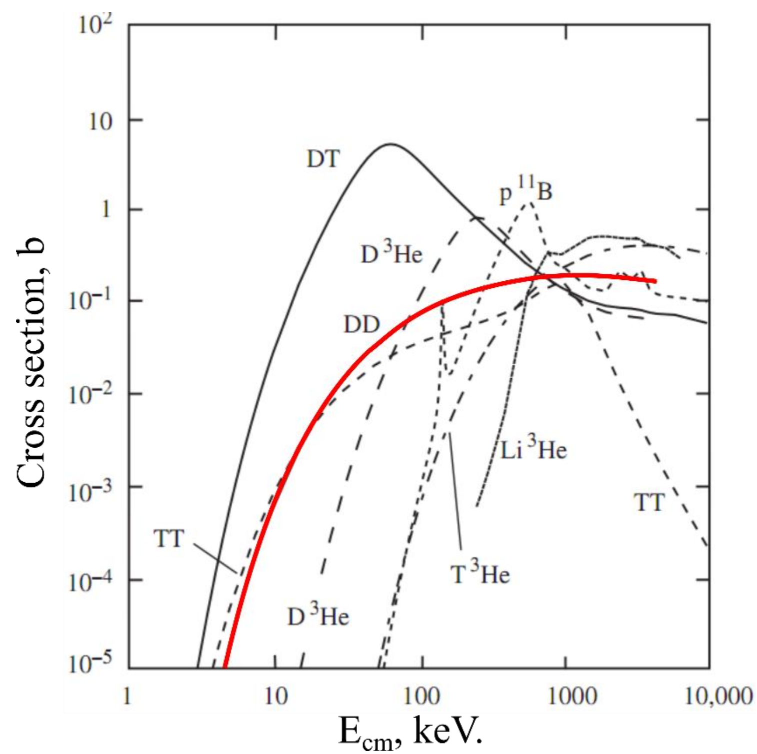
d + t ⟶ ^{4}He + n (17.6 MeV / 107 keV)

d + ^{3}He ⟶ ^{4}He + p (18.3 MeV / 430 keV)

3rd generation:

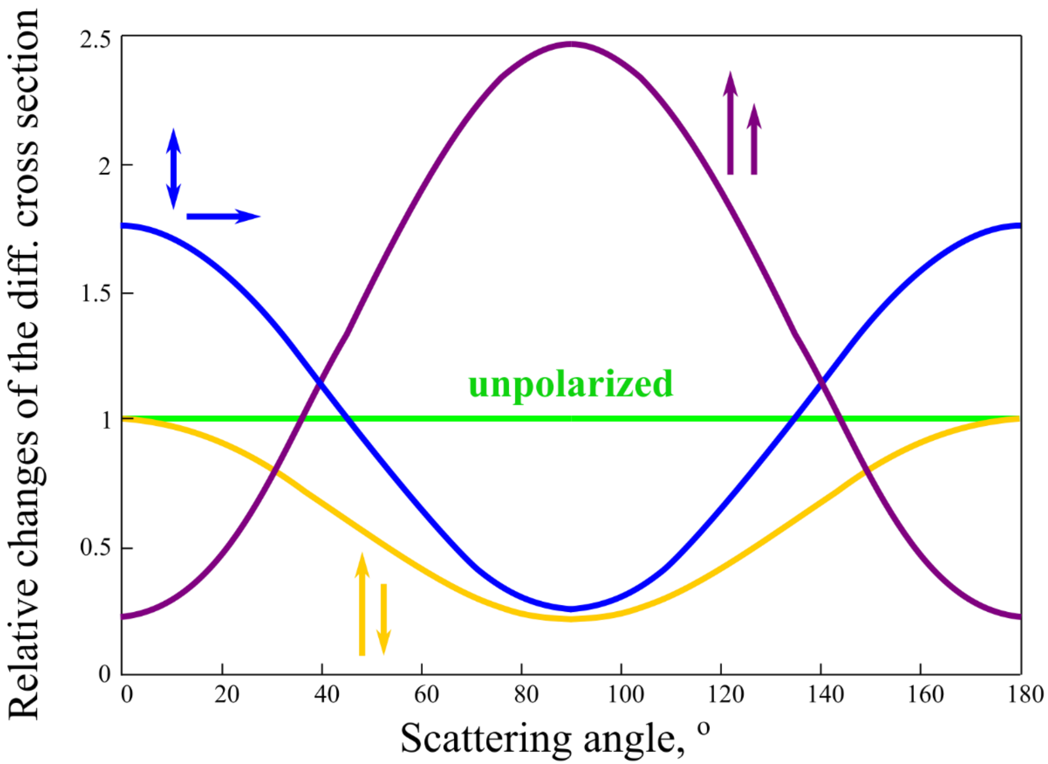
d + ^{3}He ⟶ ^{4}He + p (18.3 MeV / 430 keV)



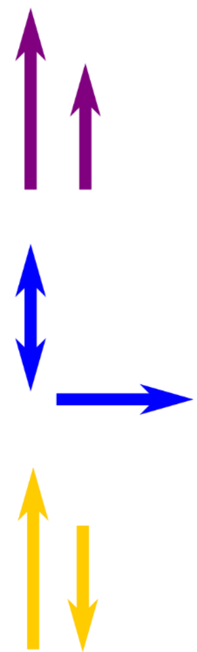


Polarization advantages

1. Cross sections increasement
2. Focussing of the neutrons
3. Suppresion of the neutron channel



Total cross section



Factor 1.5

Factor 1.0

Factor 0.5

$^{3}He(d,p)\alpha$ Exp.: Ch. Leemann et al., Helv. Phys. Acta **44**, 141 (1971)

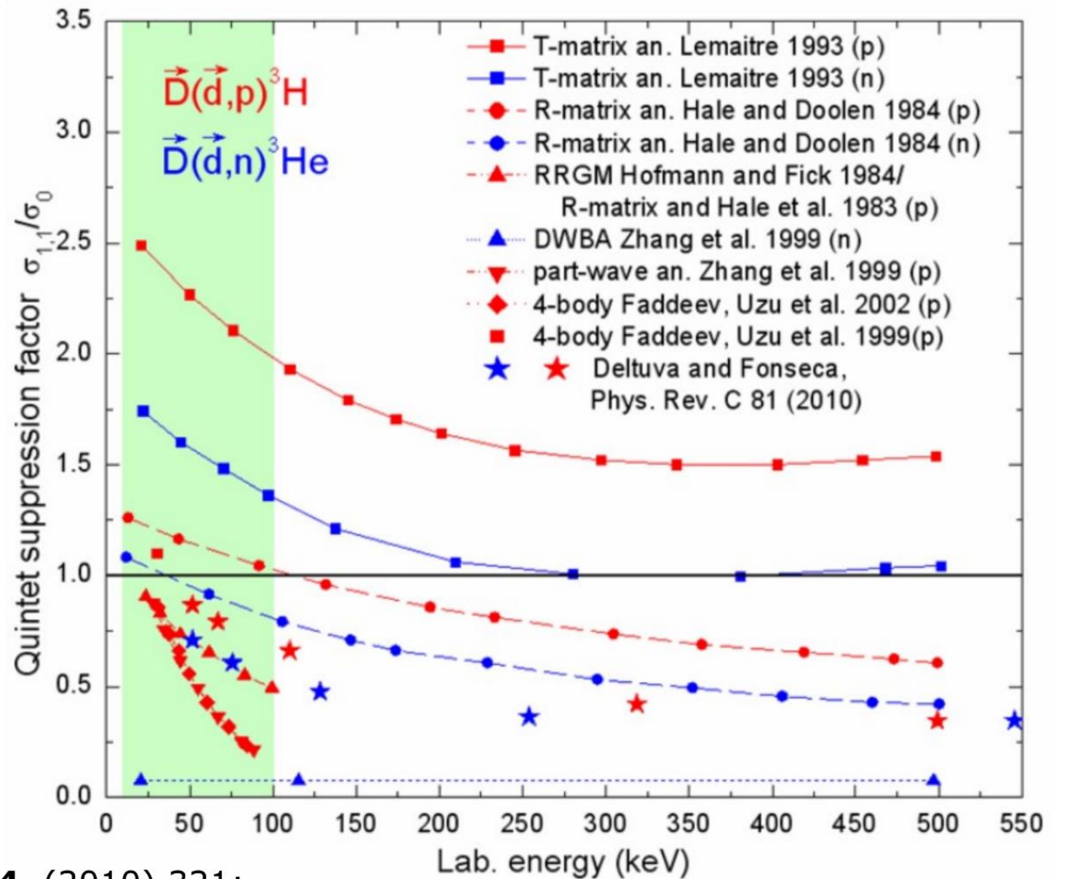
$t(d,n)\alpha$ Theor.: G. Hupin et al., Nature Com. **10**, 321(2019)

Quintet Suppression Factor (QSF)

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

$$\sigma_0 = \frac{1}{9}\left(\underbrace{2\sigma_{1,1}}_{\text{Quintet}} + \underbrace{4\sigma_{1,0}}_{\text{Triplet}} + \underbrace{\sigma_{0,0} + 2\sigma_{1,-1}}_{\text{Singlet}}\right)$$

$$QSF = \frac{33}{16} + \frac{1}{8}A_{zz} + \frac{9}{4}C_{z,z} + \frac{1}{16}C_{zz,zz}$$



H. Paetz gen. Schieck Eur. Phys. J. A **44**, (2010) 321;
H. Paetz gen. Schieck Nuclear physics with polarized particles (Springer Verlag, Berlin, 2012);
H. Paetz gen. Schieck Few-Body Syst. **54** (2013) 2159;
Gerald G. Ohlsen, Rep. Prog. Phys. **35**, 717 (1972)

PNPI - NRC KI

Review of experiments

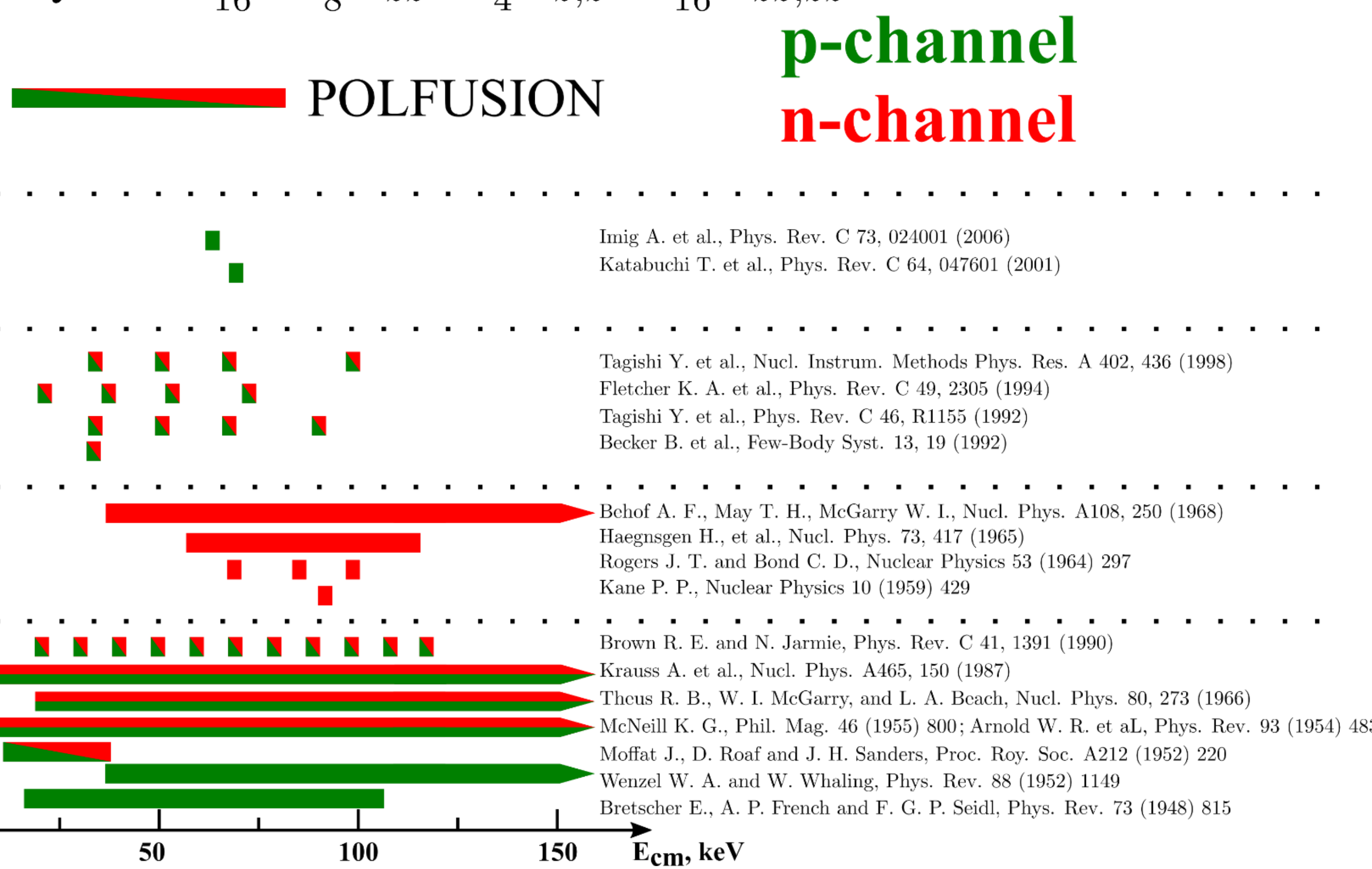
PolFusion

$$\sigma(\theta,\ \phi) = \sigma_0(\theta)\left(1 + \sum_1^9 p_j^b A_j^b(\theta) + \sum_1^9 p_j^t A_j^t(\theta) + \sum_1^9\sum_1^9 p_j^b p_k^t C_{j,k}(\theta)\right)$$

$$p_{l'}\sigma(\theta,\ \phi) = \sigma_0(\theta)\left(P_{l'}(\theta) + \sum_1^9 p_j K_j^{l'}(\theta)\right)$$

$$QSF = \frac{33}{16} + \frac{1}{8}A_{zz} + \frac{9}{4}C_{z,z} + \frac{1}{16}C_{zz,zz}$$

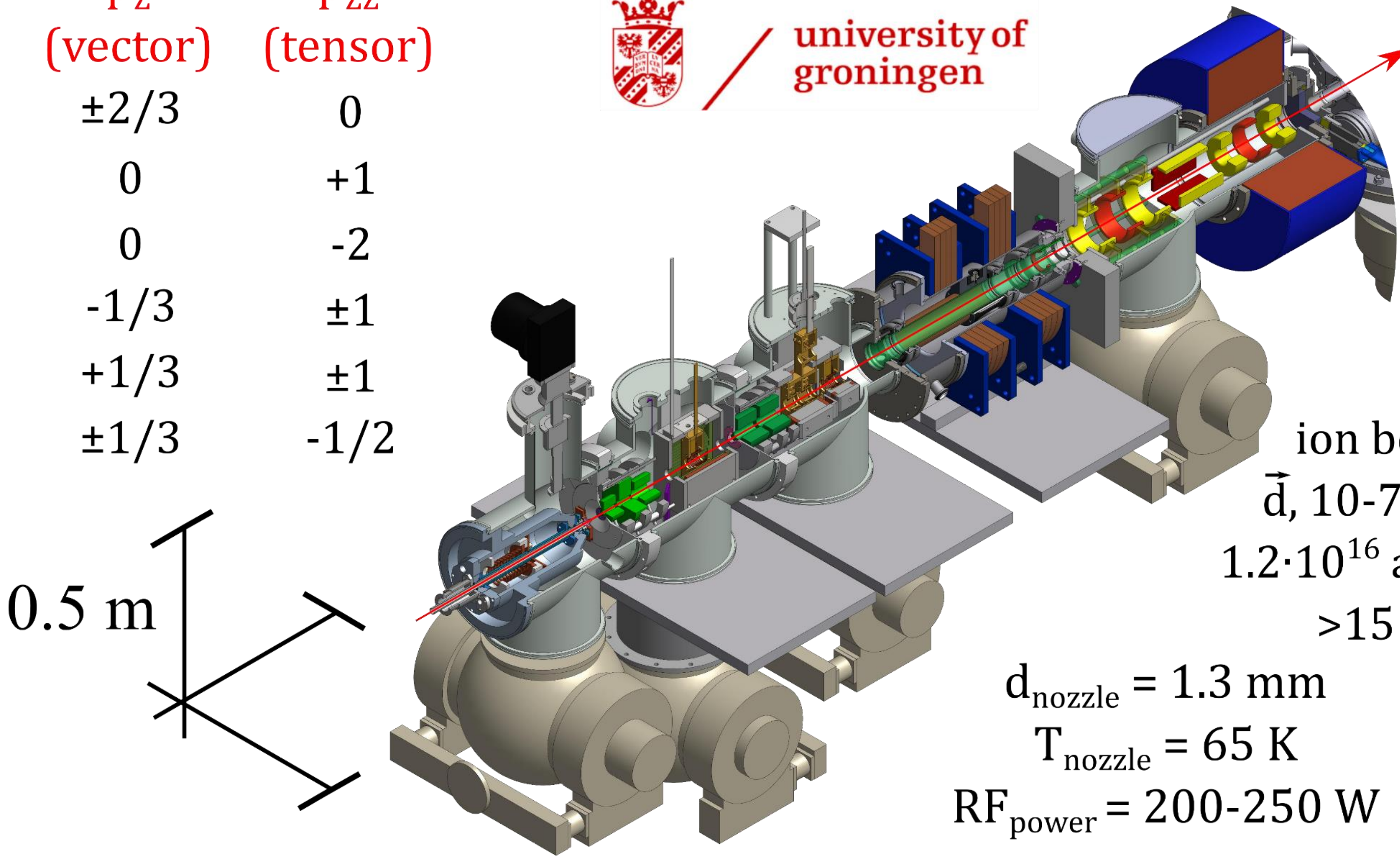
Experiment	Observable
$^2\vec{H}(\vec{d},p)^3H$ $^2\vec{H}(\vec{d},n)^3He$	$C_{z,z}$ $C_{y,y}$ $C_{zz,zz}$ $C_{y,zz}$ $C_{y,xz}$ $C_{zz,xz}$ ...
$^2H(\vec{d},\vec{p})^3H$ $^2H(\vec{d},\vec{n})^3He$	$K_y^{x'}$ $K_y^{y'}$ $K_{xz}^{z'}$ ...
$^2H(\vec{d},p)^3H$ $^2H(\vec{d},n)^3He$	A_y A_{xz} A_{zz} $A_{xx}-A_{yy}$
$^2H(d,\vec{p})^3H$ $^2H(d,\vec{n})^3He$	$P^{x'}$ $P^{y'}$ $P^{z'}$
$^2H(d,p)^3H$ $^2H(d,n)^3He$	σ_0 $\frac{d\sigma}{d\Omega}$



POLarized Ion Source (POLIS)

p_z (vector)	p_{zz} (tensor)
±2/3	0
0	+1
0	-2
-1/3	±1
+1/3	±1
±1/3	-1/2

university of groningen



ion beam
$\vec{d}$, 10-75 keV
$1.2 \cdot 10^{16}$ atoms/s
>15 μA

d_{nozzle} = 1.3 mm
T_{nozzle} = 65 K
RF_{power} = 200-250 W

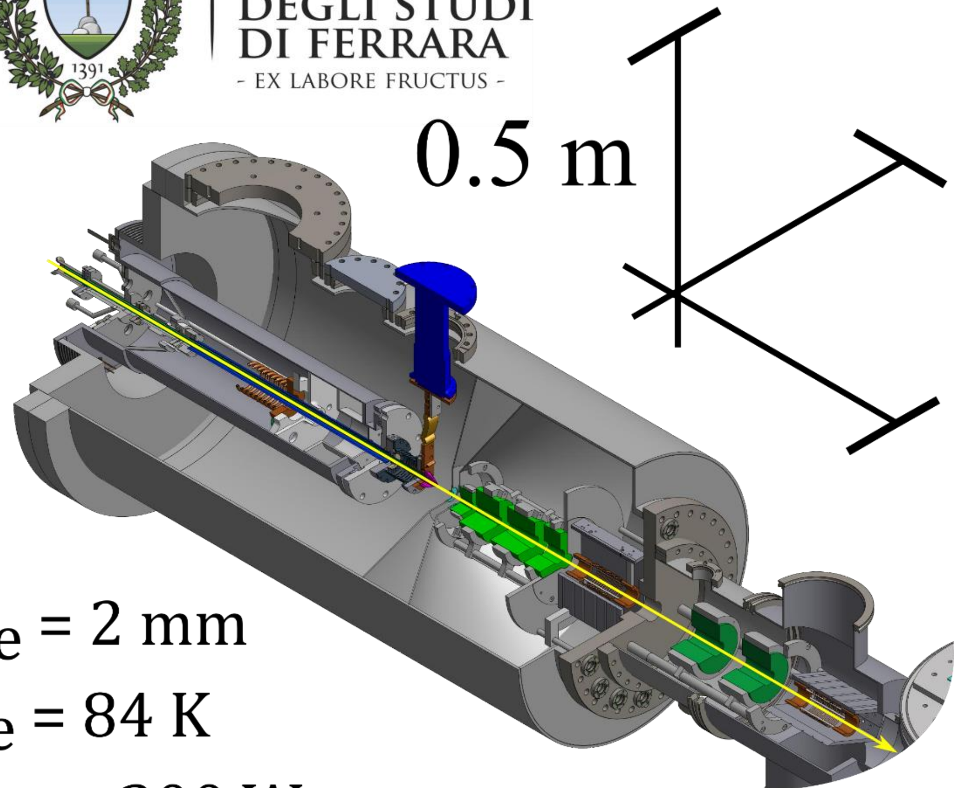
Polarizer:

Sextupoles + WFT + Sextupoles + WFT + SFT1 (460 MHz) +SFT2 (350 MHz)

Atomic Beam Source (ABS)

p_z (vector)	p_{zz} (tensor)
-2/3	0
0	+1
-1/3	+1
-1	+1
±1/2	-1/2

UNIVERSITÀ DEGLI STUDI DI FERRARA
- EX LABORE FRUCTUS -



atomic beam
$\vec{D}$, 0.01 eV
$2 \cdot 10^{16}$ atoms/s

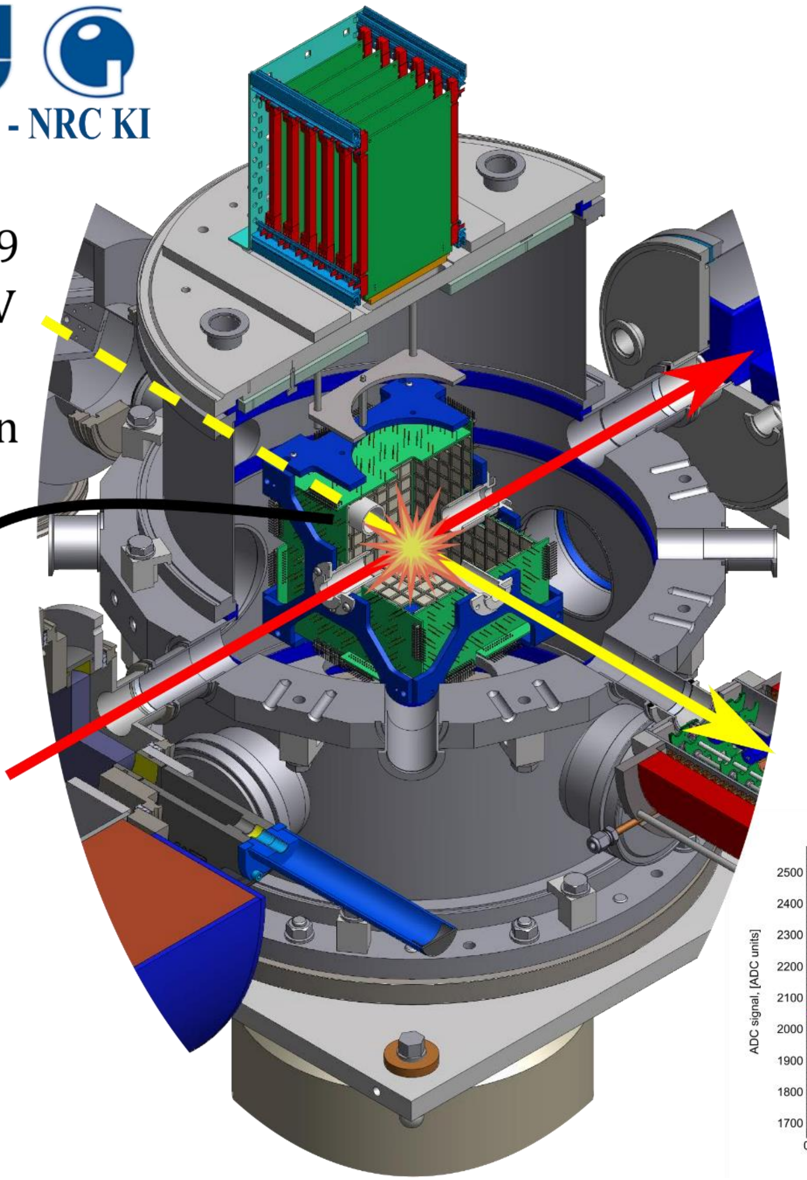
d_{nozzle} = 2 mm
T_{nozzle} = 84 K
RF_{power} = 300 W

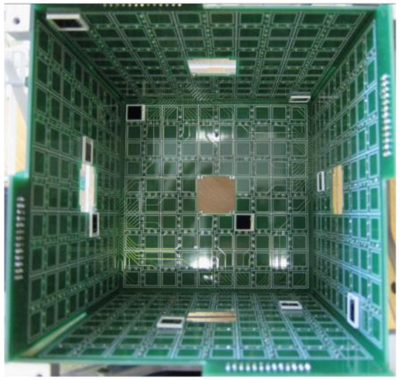
Polarizing system:

Sextupoles + Quadrupoles + MFT + Sextupoles + MFT

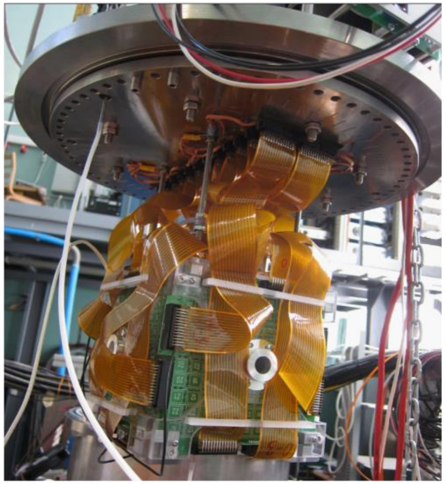
4π-detector

576 PIN diodes
Hamamatsu S3508-09
can detect 0.2 - 4 MeV
charged particles
with energy resolution
< 50 keV



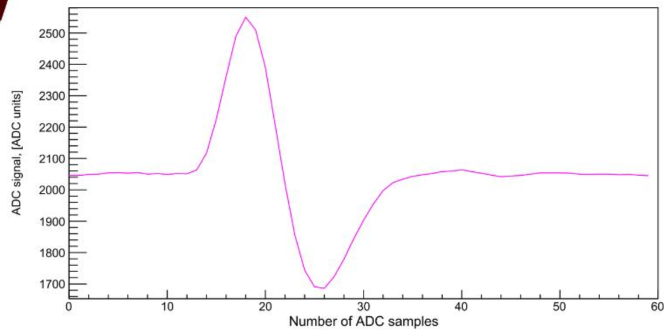


51% effective coverage



10 ns accuracy of recording
the time of signal

typical signal:



Asymmetries

$$Y(\theta,\ \phi) = L \cdot \sigma(\theta,\ \phi)$$

$$\sigma(\theta,\ \phi) = \sigma_0(\theta)\left(1 + \sum_1^9 p_j^b A_j^b(\theta) + \sum_1^9 p_j^t A_j^t(\theta) + \sum_1^9 \sum_1^9 p_j^b p_k^t C_{j,k}(\theta)\right)$$

Gerald G. Ohlsen, Rep. Prog. Phys. **35,** 717 (1972)

polarization sign as subscript: $(L_{POLIS,\ ABS})$

$$L_{++} = L_{-+} = L_{+-} = L_{--}$$

$$\mathcal{A}^b(\theta,\ \phi) = \frac{(Y_{++}+Y_{+-})-(Y_{-+}+Y_{--})}{Y_{++}+Y_{+-}+Y_{-+}+Y_{--}}$$

$$\mathcal{A}^t(\theta,\ \phi) = \frac{(Y_{++}+Y_{-+})-(Y_{+-}+Y_{--})}{Y_{++}+Y_{+-}+Y_{-+}+Y_{--}}$$

$$\mathcal{A}^{b,t}(\theta,\ \phi) = \frac{(Y_{++}+Y_{--})-(Y_{-+}+Y_{+-})}{Y_{++}+Y_{+-}+Y_{-+}+Y_{--}}$$

$C_{z,z}$ and $C_{zz,zz}$

$$\beta^b = \beta^t = 0^\circ :$$

$$\sigma(\theta,\ \phi) = \sigma_0(\theta)\left[1 + \tfrac{1}{2}p^b_{ZZ}A^b_{zz}(\theta) + \tfrac{1}{2}p^t_{ZZ}A^t_{zz}(\theta) + \tfrac{9}{4}p^b_Z p^t_Z C_{z,z}(\theta) + \tfrac{1}{4}p^b_{ZZ}p^t_{ZZ}C_{zz,zz}(\theta)\right]$$

$$\mathcal{A}^b(\theta,\ \phi) = \frac{2|p^b_{ZZ}|A^b_{zz}(\theta)}{4+9C_{z,z}} \qquad \mathcal{A}^t(\theta,\ \phi) = \frac{2|p^t_{ZZ}|A^t_{zz}(\theta)}{4+9C_{z,z}}$$

$$\mathcal{A}^{b,t}_Z(\theta,\ \phi) = \frac{9|p^b_Z||p^t_Z|C_{z,z}(\theta)}{4+2p^b_{ZZ}A^b_{zz}(\theta)+2p^t_{ZZ}A^t_{zz}(\theta)+p^b_{ZZ}p^t_{ZZ}C_{zz,zz}(\theta)}$$

$$\mathcal{A}^{b,t}_{ZZ}(\theta,\ \phi) = \frac{|p^b_{ZZ}||p^t_{ZZ}|C_{zz,zz}}{4+9|p^b_Z||p^t_Z|C_{z,z}}$$

$$p^b_Z = p^t_Z = \pm\tfrac{2}{3}$$

$$p^b_{ZZ} = p^t_{ZZ} = 0$$

$$\mathcal{A}^{b,t}_Z(\theta,\ \phi) = C_{z,z}$$

$$p^b_Z = p^t_Z = +\tfrac{1}{3}$$

$$p^b_{ZZ} = p^t_{ZZ} = \pm 1$$

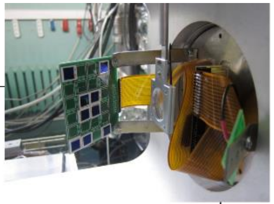
$$\mathcal{A}^{b,t}_{ZZ}(\theta,\ \phi) = \frac{C_{zz,zz}}{4+C_{z,z}}$$

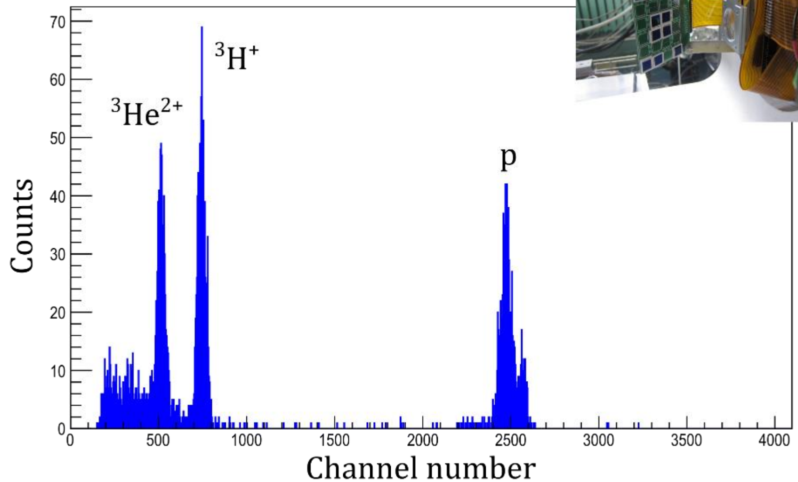
$$\mathcal{A}^b_{ZZ}(\theta,\ \phi) = \frac{2A^b_{zz}(\theta)}{4+9C_{z,z}}$$

$$\mathcal{A}^t_{ZZ}(\theta,\ \phi) = \frac{2A^t_{zz}(\theta)}{4+9C_{z,z}}$$

Test runs

2015





Target: deuterated polymethyl methacrylate

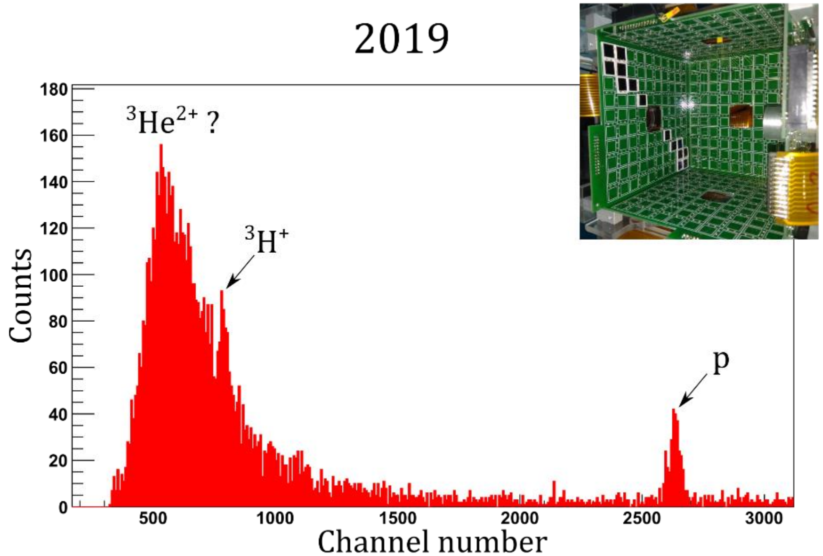
Density: $\sim 10^{17}$ atom/cm^2

Beam: 15 keV $\sim$5μA

Period: $\sim$3 h

Purpose: evaluating the signal quality
ADC calibration

2019



Target: heavy water vapor

Density: $\sim 10^{12}$ atom/cm^2

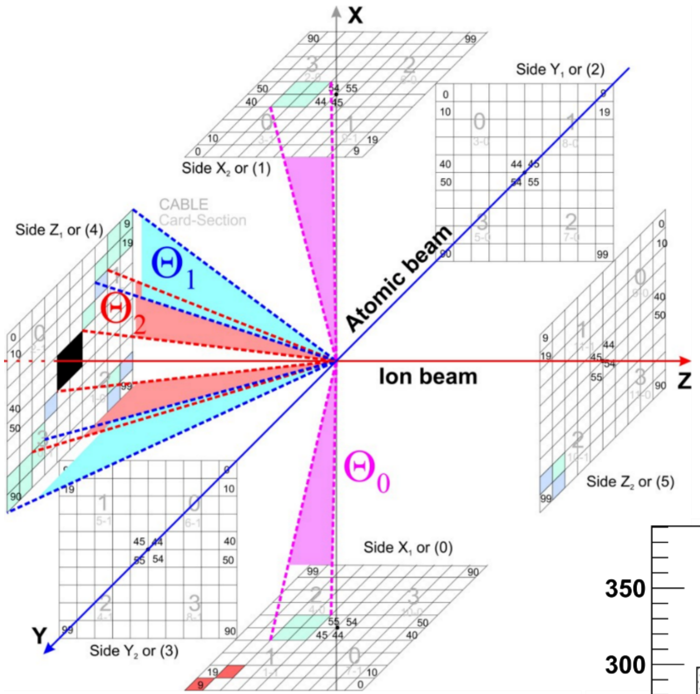
Beam: 10 keV $\sim$10μA

Period: $\sim$200 h

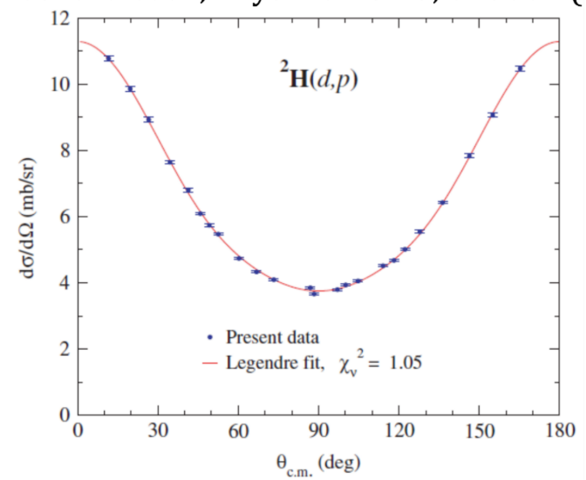
Purpose: simulation of the ABS
evaluation of cosmic background, form and sources of electronic background

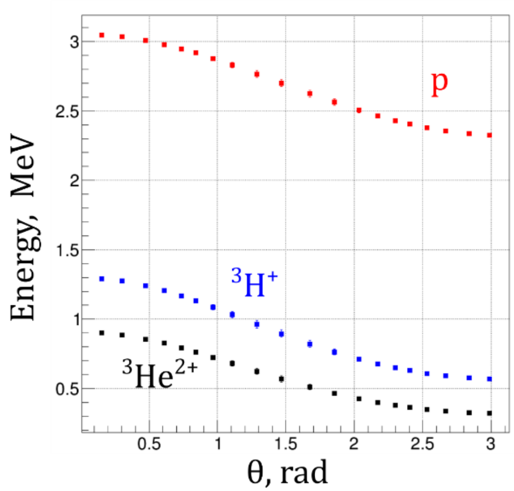
ABS beam density: $2.7\cdot10^{11}$ atom/cm^2 at $4\cdot10^{16}$ atom/s

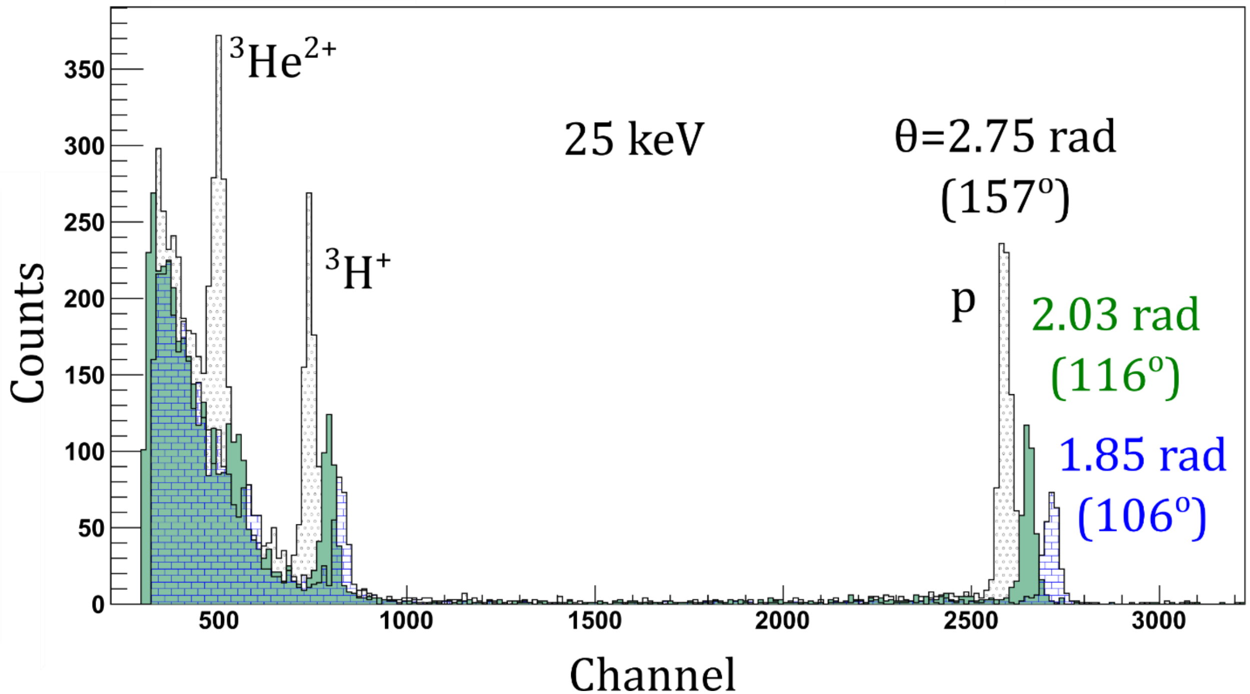
Test run 2020



D.S. Leonard et al., Phys. Rev. C **73**, 045801 (2006).







Plans

2022

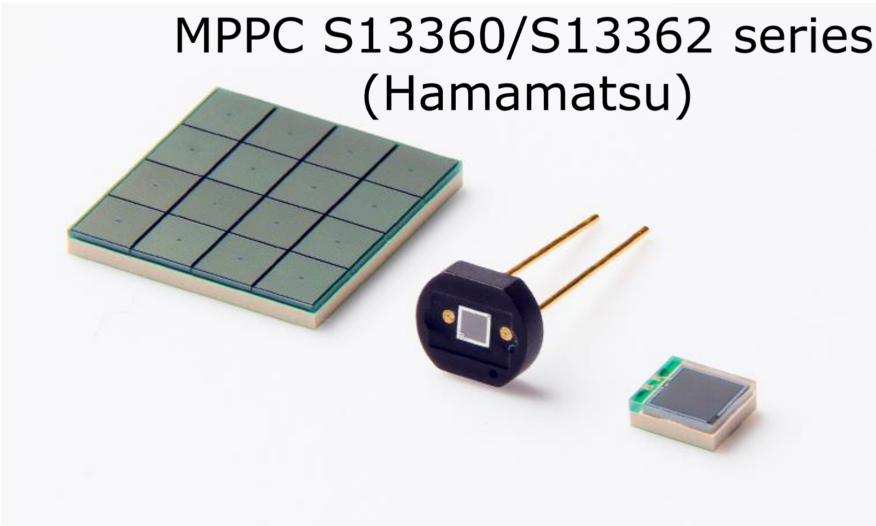
- Commissioning LSP
- Tuning POLIS RF units
- Test run with a polarized ion beam from POLIS and the vapor target
- Run with a polarized ion beam from POLIS and unpolarized atomic beam from the ABS

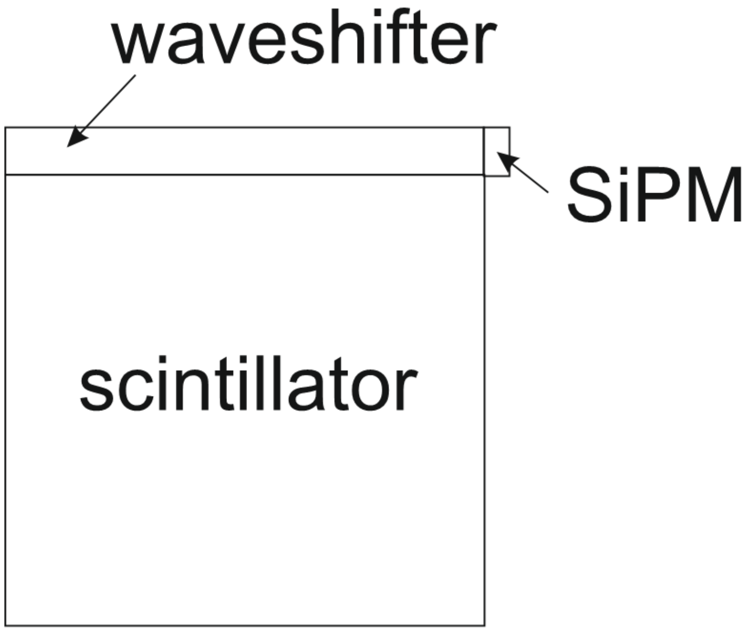
2023-...

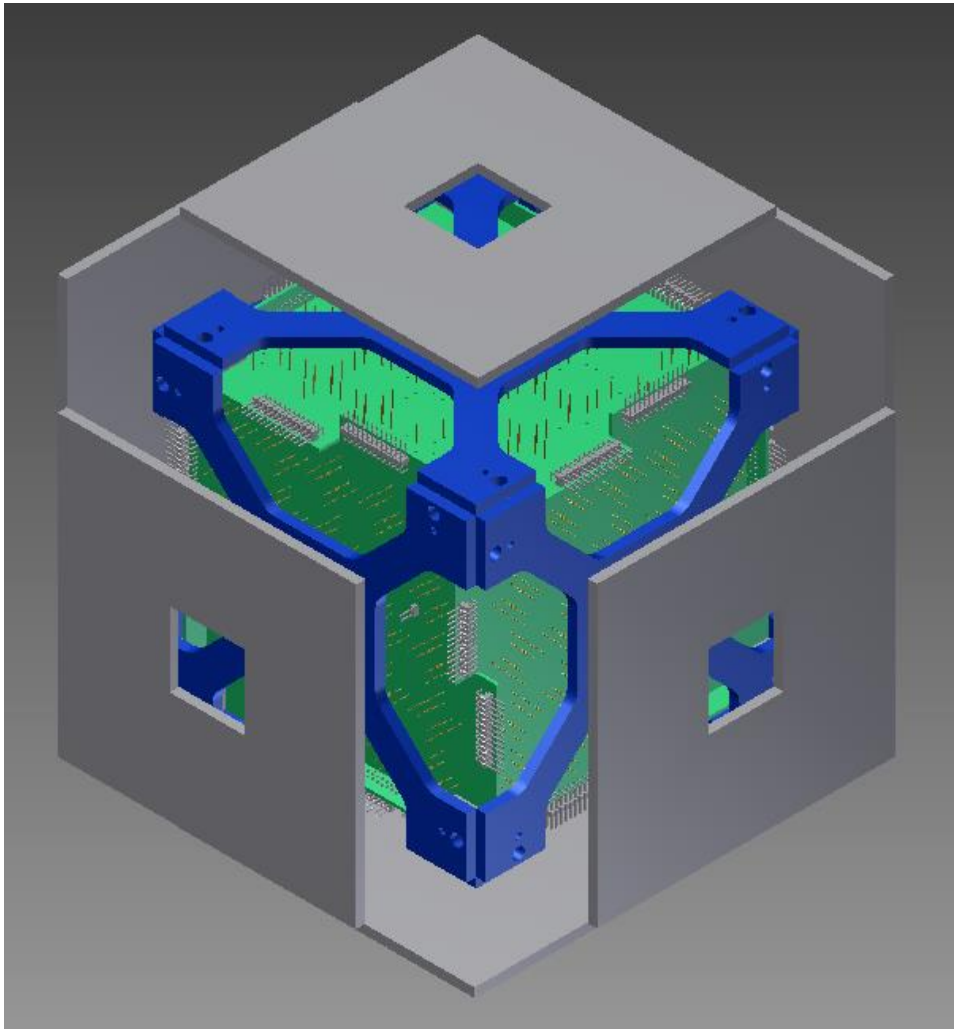
- Manufacturing and assembling the cosmic ray detection system
- Commissioning Glavish ionizer
- Tuning ABS RF units
- Commissioning NRP
- Run with a polarized ion beam from POLIS and polarized atomic beam from the ABS

Thank you for attention!

Cosmic ray detection system







Координатные системы

Basel convention (1961): Huber, P., Meyer, K.P. (eds.): Proceedings of the International Symposium on Polarization Phenomena of Nucleons. Helv. Phys. Acta Suppl. VI. Birkhäuser

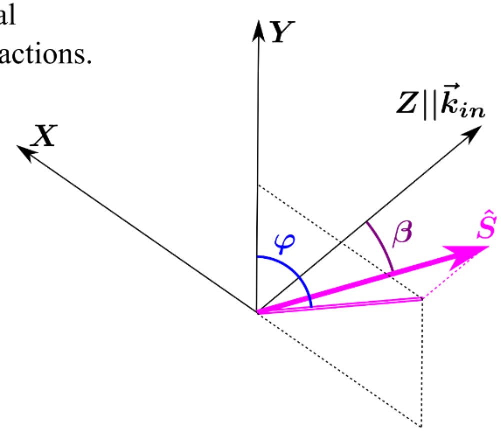
Madison convention (1971): Barschall, H.H., Haeberli, W. (eds.): Proceedings of the 3rd International Symposium on Polarization Phenomena in Nuclear Reactions. University of Wisconsin Press

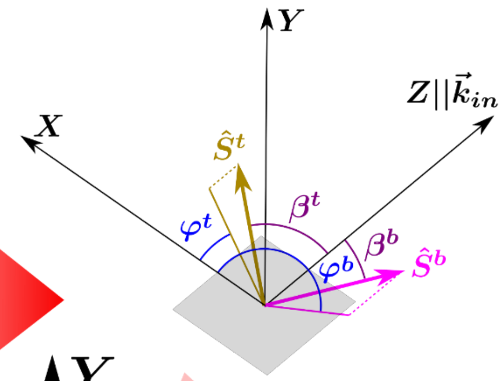
Описание поляризации (фиксированная в пространстве координатная система)

$\vec{k}_{in}$ - момент импульса налетающей частицы

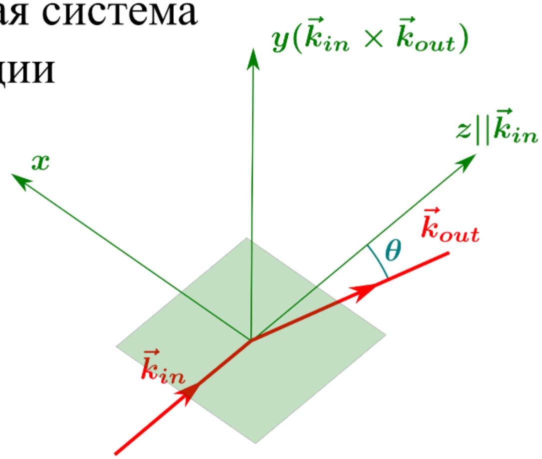
$\vec{k}_{out}$ - момент импульса вылетающей частицы

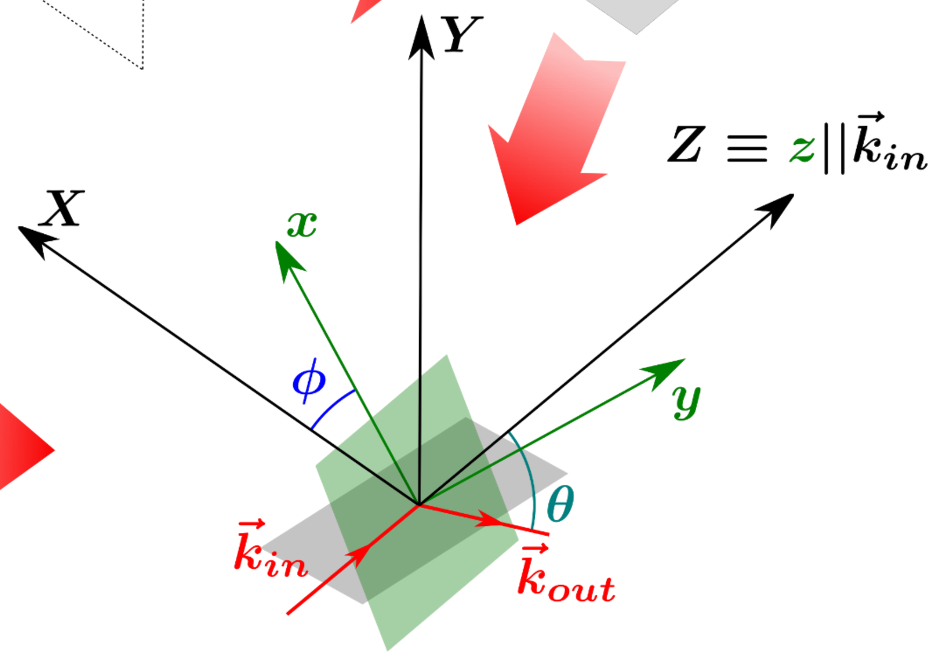
$\hat{S}^b$, $\hat{S}^t$ - оси квантования пучка и мишени





Координатная система реакции





Дифференциальное сечение

$$\sigma(\theta,\ \phi) = \sigma_0(\theta)\left(1 + \sum_{j=1}^{9} \bar{p}_j^b A_j^b(\theta) + \sum_{j=1}^{9} \bar{p}_j^t A_j^t(\theta) + \sum_{j=1}^{9}\sum_{k=1}^{9} \bar{p}_j^b \bar{p}_k^t C_{j,k}(\theta)\right)$$

$$p_{l'}\sigma(\theta,\ \phi) = \sigma_0(\theta)\left(P_{l'}(\theta) + \sum_{j=1}^{9} \bar{p}_j K_j^{l'}(\theta)\right)$$

$$\bar{p}_1 = \tfrac{3}{2}p_x$$

$$\bar{p}_2 = \tfrac{3}{2}p_y$$

$$\bar{p}_3 = \tfrac{3}{2}p_z$$

$$\bar{p}_4 = \tfrac{2}{3}p_{xy}$$

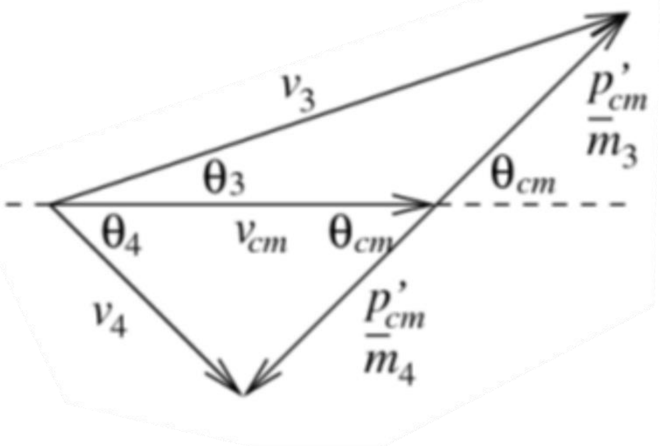
$$\bar{p}_5 = \tfrac{2}{3}p_{xz}$$

$$\bar{p}_6 = \tfrac{2}{3}p_{yz}$$

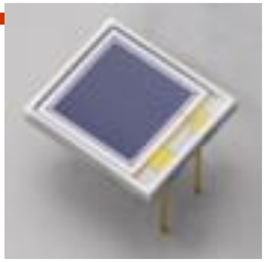
$$\bar{p}_7 = \tfrac{1}{3}p_{xx}$$

$$\bar{p}_8 = \tfrac{1}{3}p_{yy}$$

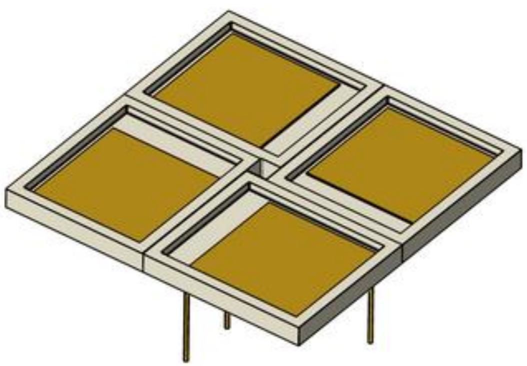
$$\bar{p}_9 = \tfrac{1}{3}p_{zz}$$

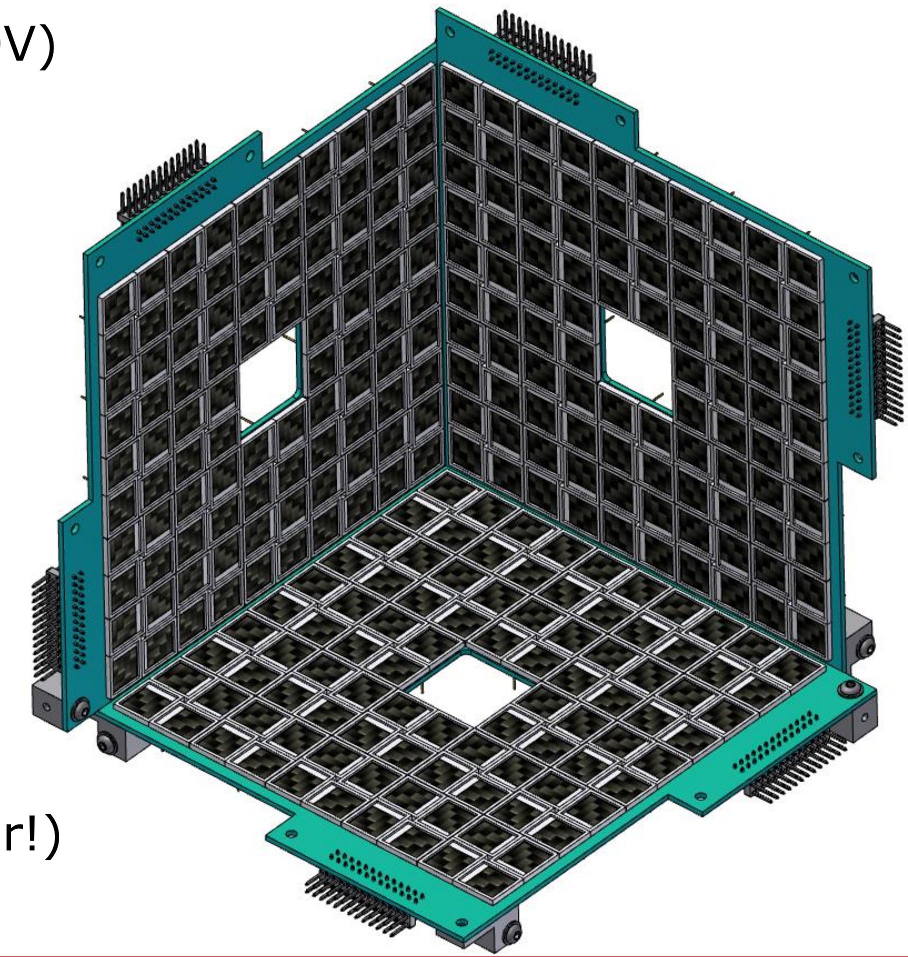


Detector system. PIN diodes version



- 4-π detector with 51% filling
- 576 Hamamatsu PIN-diodes (S3590-09)
- PIN-diode active area: 1 cm^2
- depleted layer: 300 um
- energy resolution: <50keV
- low reverse voltage (<=50V)





Square detector elements (4x4 diodes)
Standard PCB assembly with
spring through-hole mounting (no solder!)

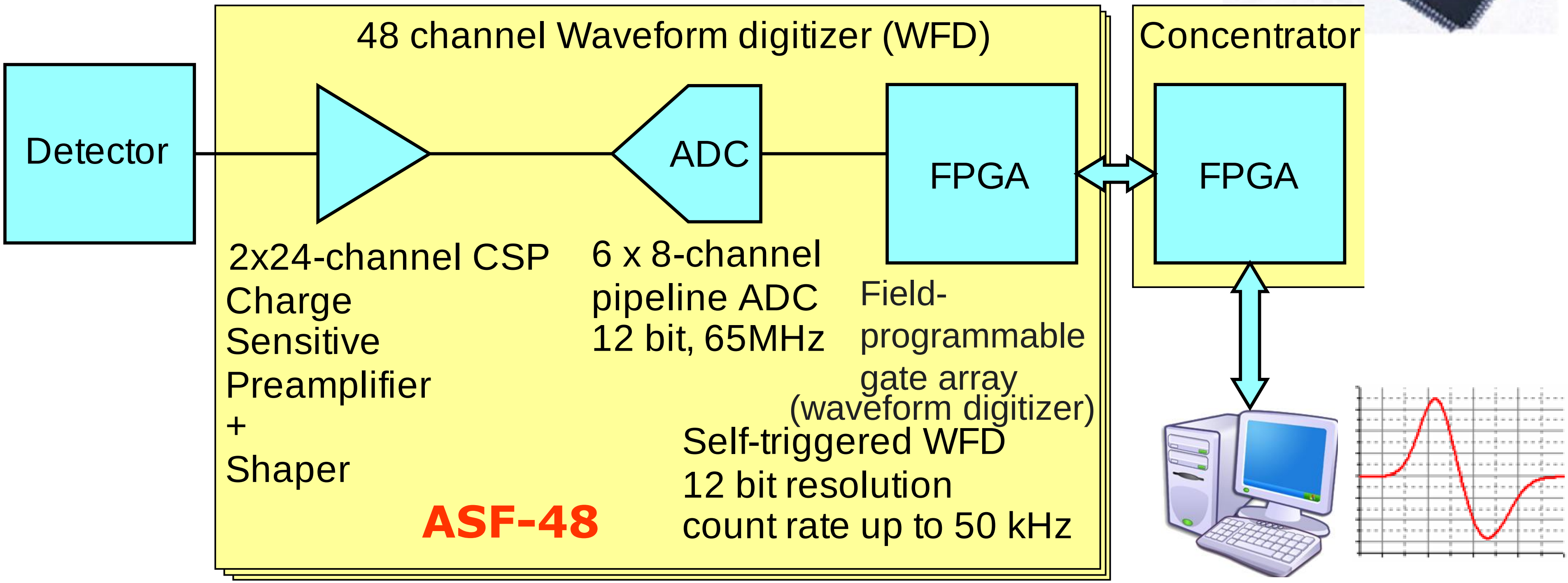
Readout electronics

Readout requirements:

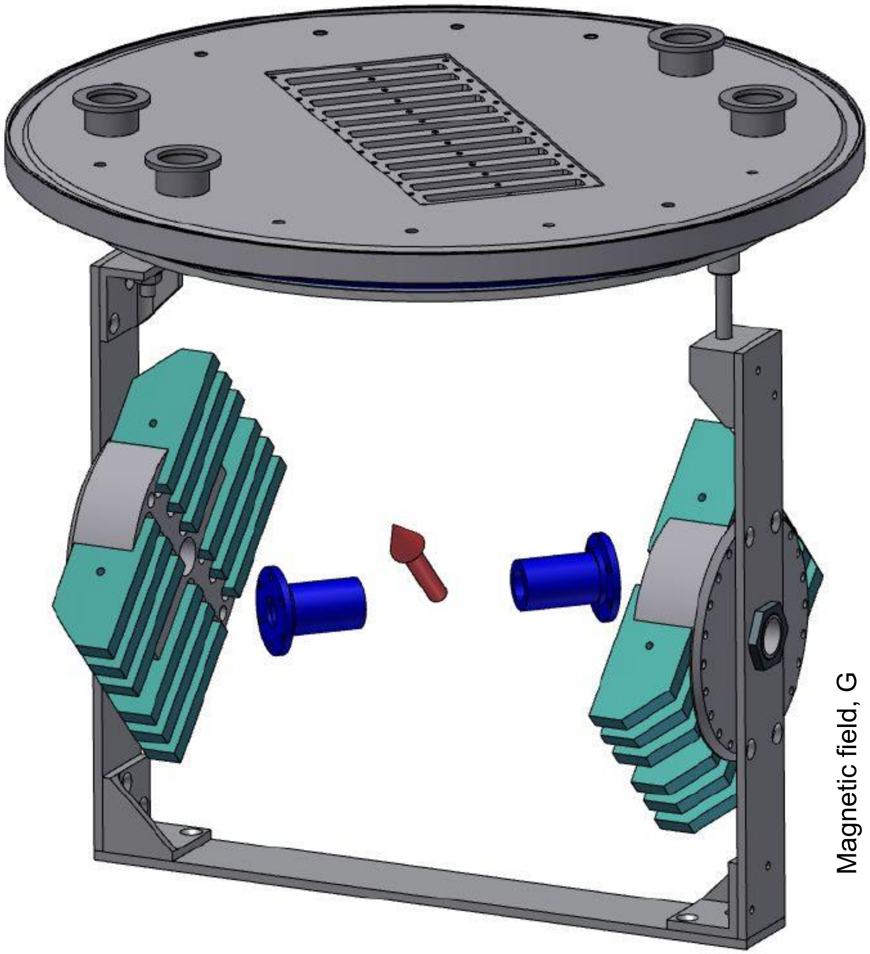
- 600 channels
- Total count rate ≤ 1kHz
- Standard interface (Ethernet?)
- Event synchronization for coincidence trigger

CSP from ATLAS CSC [BNL]

Junnarkar et al. IEEE Nuclear Science Symposium Conference Record (2005)

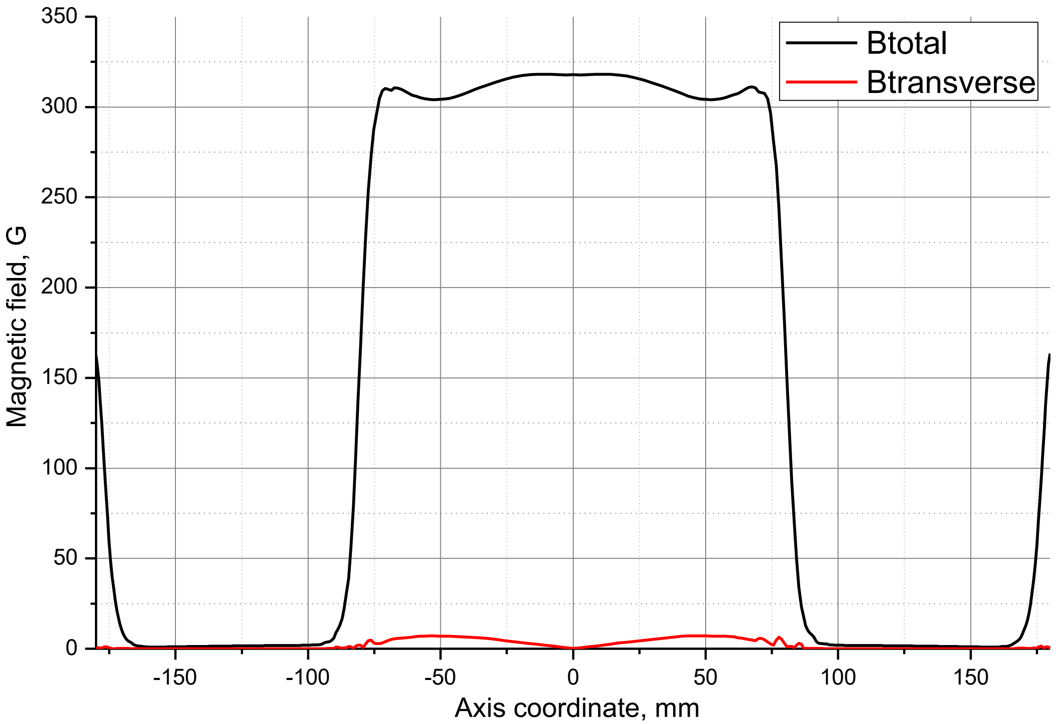


Magnet system

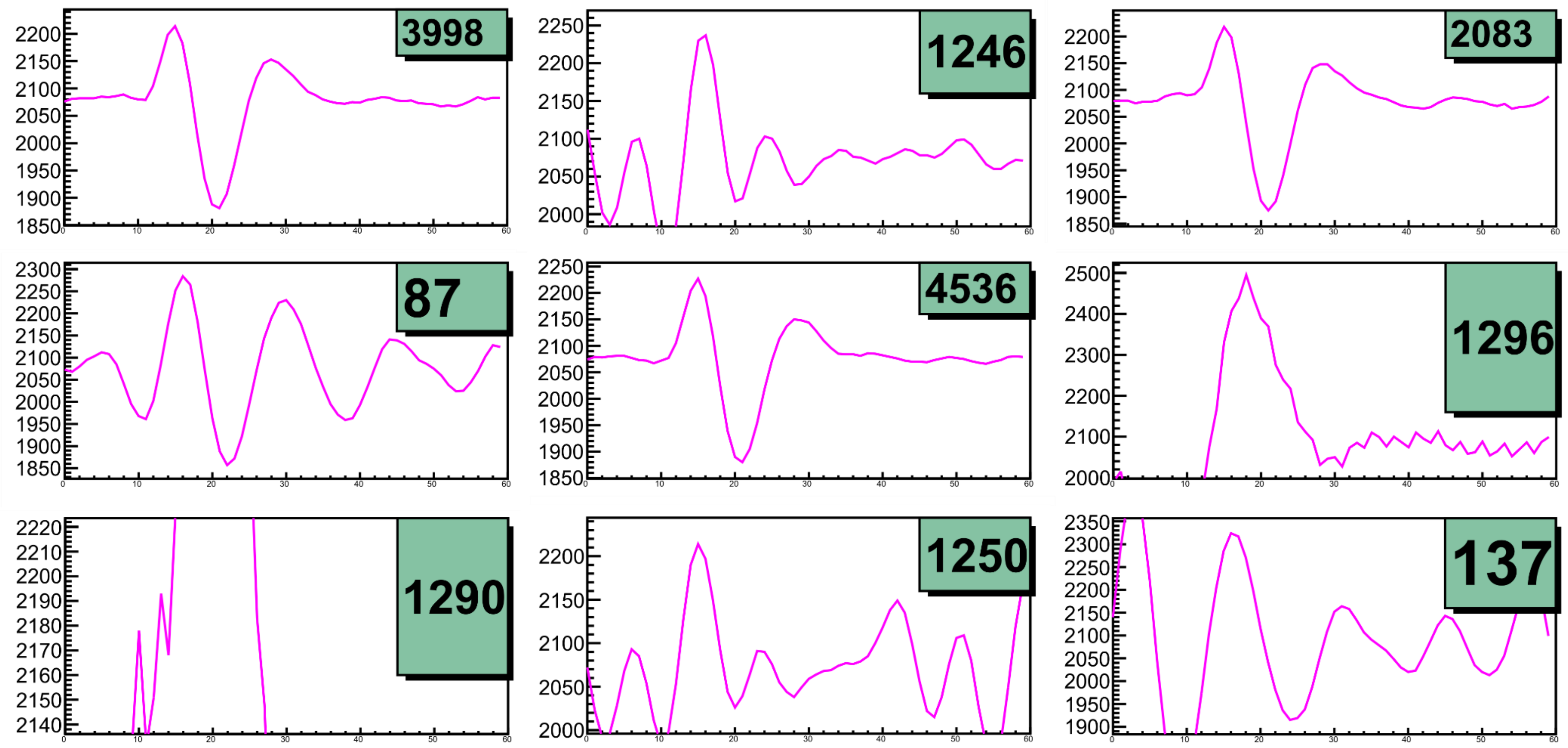


B =300 G = 2.5 B_c

Magnet field is generated by 24 permanent magnets with dimensions 80x40x10 mm^3 with pole tip field of 1.25 T at the surface (NdFeB N40)

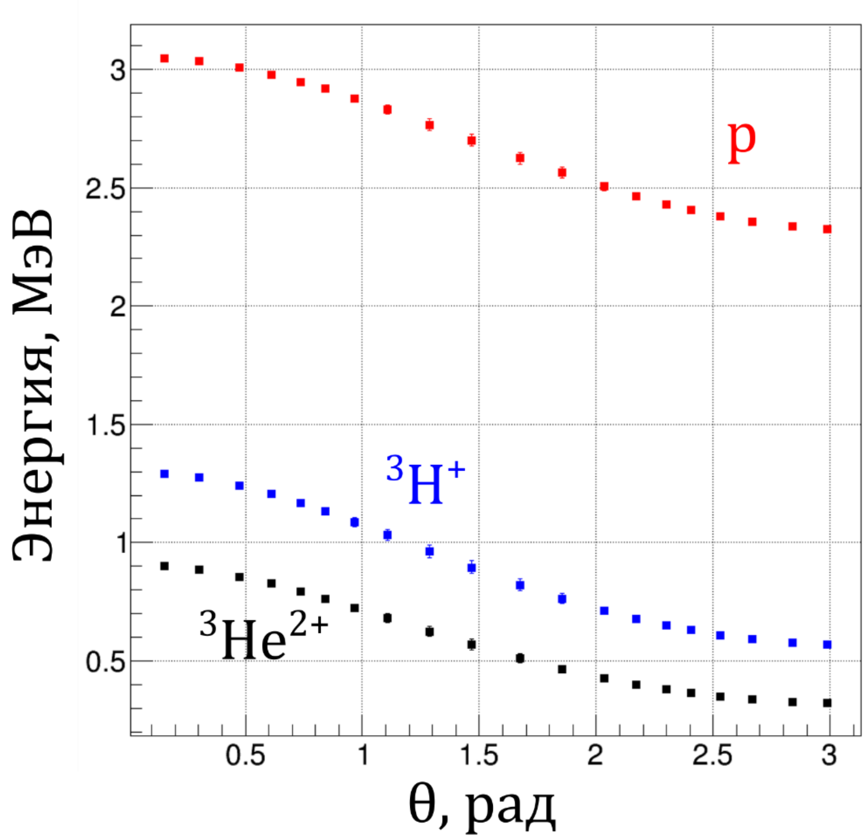


Different signals



Heavy water vapor target

Энергия продуктов реакции от угла рассеяния



На основе формул из [Г.А.Борисов, Р.Д.Васильев, В.Ф.Шевченко Кинематические таблицы ядерных реакций d,n и p,n Издательство стандартов, Москва 1974]