Recommendation. The PAC supports the group's plan to pursue this experiment and recognizes that it will secure JINR's leadership in polarimetry equipment and study. The PAC notes the possible difficulties in allocating the requested 336h of polarized deuteron beam in 2022–2023, due to the strong competition for, and the limited availability of, beam time in this period. The PAC recommends continuation of the ALPOM-2 experiment till the end of 2023 with ranking A.

Measurement of analyzing powers for the reaction p(pol)+CH2 up to 7.5 GeV/c and n(pol)+A up to 6.0 GeV/c at the Nuclotron (ALPOM2 proposal)

Prolongation for 2025-2027 years

S.N. Bazylev, O.P. Gavrishchuk, A.A. Druzhinin, D.A. Kirillov, N.V. Kostayeva, Yu.T. Kiryushin, K.S. Legostaeva, A.N. Livanov, I.A. Philippov, N.M. Piskunov, P.A. Rukoyatkin, R.A. Shindin, A.V. Shipunov, A.V. Shutov, I.M. Sitnik, V.M. Slepnev, I.V. Slepnev, A.V. Terletskiy

Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia

C.F. Perdrisat

the College of William and Mary, Williamsburg, VA 23187, USA

V. Punjabi

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M.K. Jones

Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA

E. Brash

Christopher Newport University and TJNAF

G. Martinska, J. Urban

University of P.J. Šafarik, Jesenna. 5, SK-04154 Košice, Slovak Republic

J. Mušinsky

Institute of Experimental Physics, Watsonova 47, SK-04001 Kosice, Slovak Republic

E. Tomasi-Gustafsson

IRFU, DPHN, CEA, Université Paris- Saclay, 91191 Gif-sur-Yvette, France

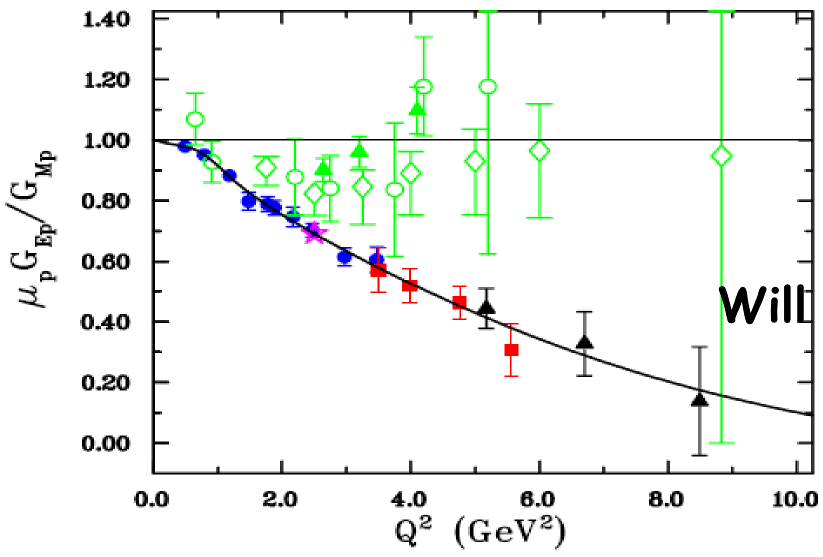
D. Marchand

IPN Orsay, 91406 ORSAY cedex, France

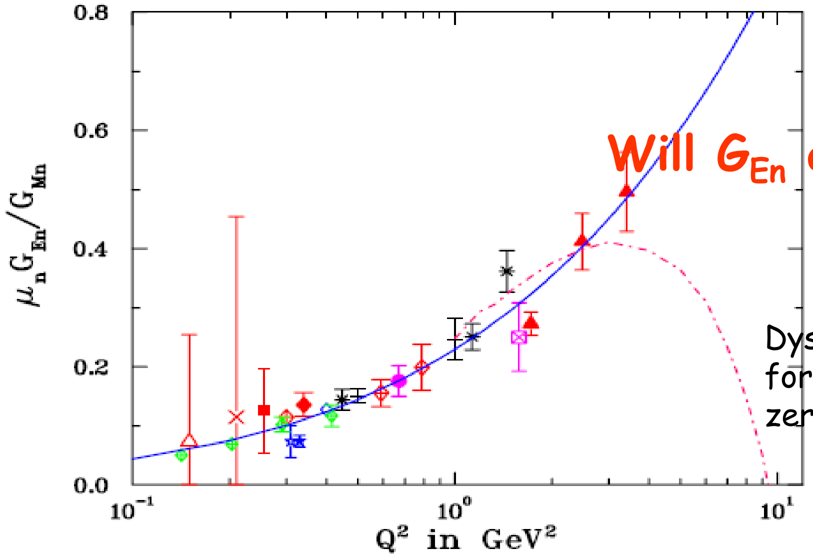
J. R.M. Annand, K. Hamilton, R. Montgomery

University of Glasgow, Glasgow G12 8QQ, Scotland, UK

Nucleon formfactors



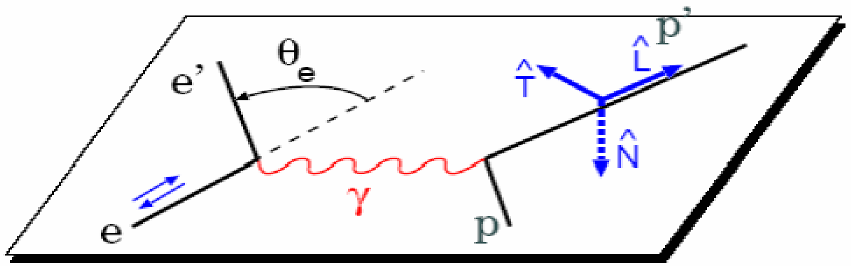
Will G_{Ep} become zero?



Will G_{En} also become zero?

Dyson-Schwinger approach
for neutron predicts a (second)
zero for G_{En}, also near 10 GeV^2.

Spin Transfer Reaction $^1\mathrm{H}(\vec{e}, e'\,\vec{p})$



Transferred polarization is: (Akhiezer & Rekalo)

$$P_n = 0$$

$$\pm h P_t = \mp h\, 2\sqrt{\tau(1+\tau)}\, G_E^p G_M^p \tan\left(\frac{\theta_e}{2}\right) / I_0$$

$$\pm h P_l = \pm h (E_e + E_{e'}) (G_M^p)^2 \sqrt{\tau(1+\tau)} \tan^2\left(\frac{\theta_e}{2}\right) / M / I_0$$

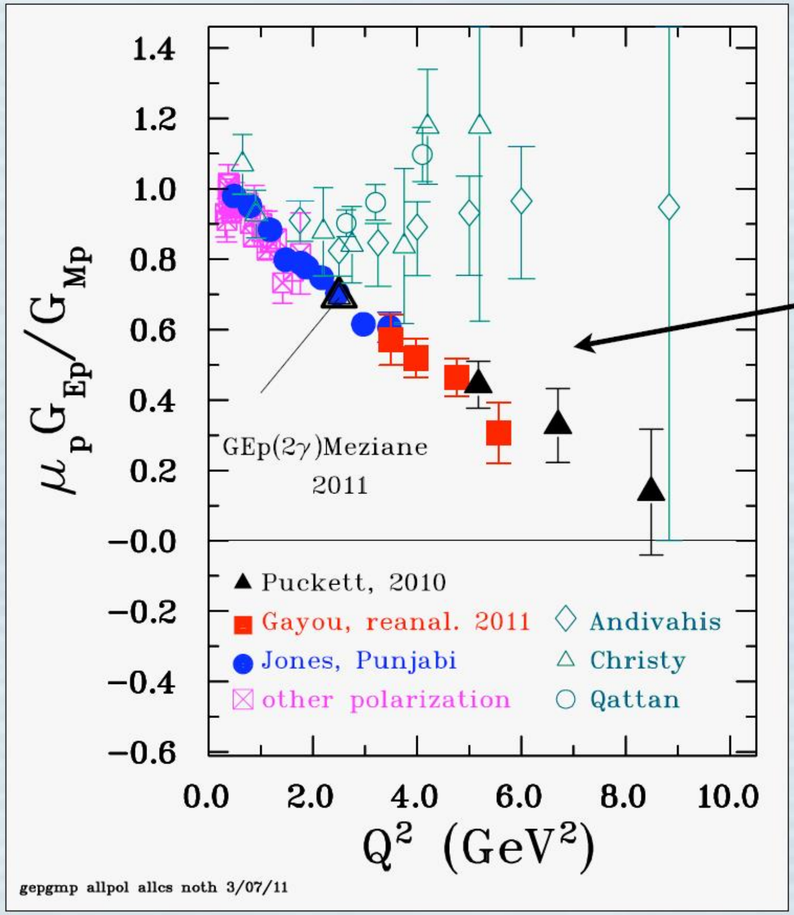
Where, $h = |h|$ is the beam helicity

$$I_0 = (G_E^p(Q^2))^2 + \frac{\tau}{\epsilon}(G_M^p(Q^2))^2$$

$$\Longrightarrow \frac{G_E^p}{G_M^p} = -\frac{P_t}{P_l}\frac{E_e + E_{e'}}{2M}\tan\left(\frac{\theta_e}{2}\right)$$

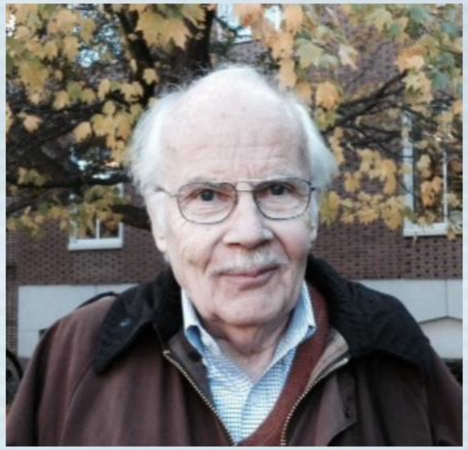
No error contributions from analyzing power and beam polarization measurements

Double polarization techniques brought them right back … with the discovery of the high Q^2 behavior of $\mu_p G_E^p/G_M^p$



Data from both Rosenbluth separations and the double-polarization technique.

Resulted in the 2017 Bonner Prize in Nuclear Physics being awarded to Charles Perdrisat of William and Mary



Explanations for the Q^2 behavior of G_E^p/G_M^p have typically relied upon the role of quark orbital angular momentum.

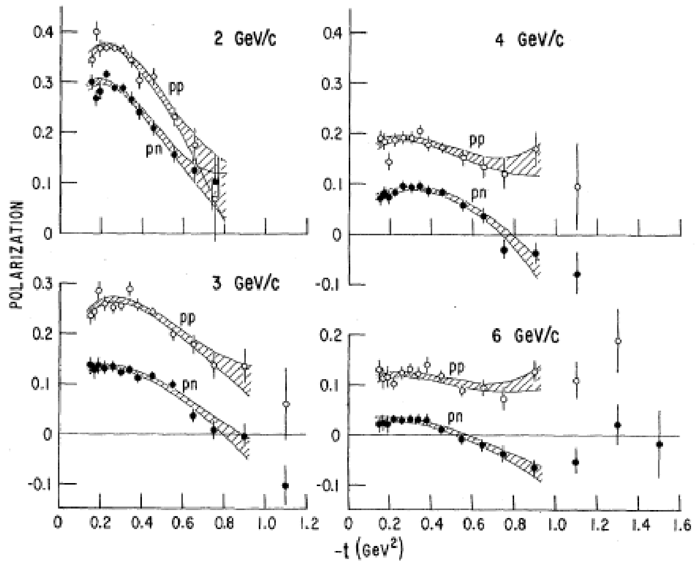
Neutron polarimetry

pp -> pp
pd -> pn + (p)

Phys. Rev. Lett 35 (1975) 632

A_y

decreasing with energy



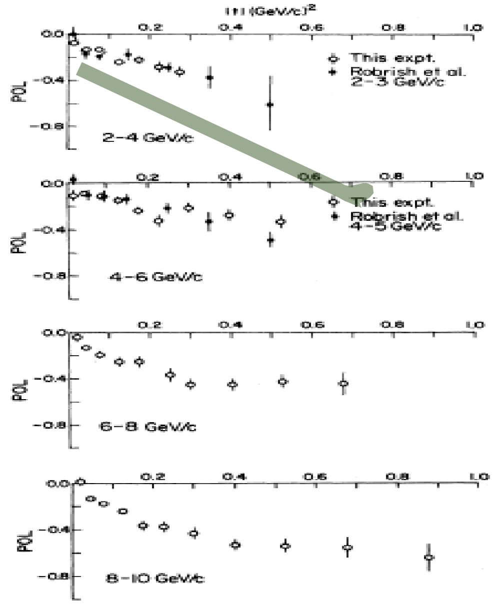
The existing data for A_y in np elastic scattering indicate that the analyzing power decreases faster than the pp analyzing power, becoming very small, then negative around 6 GeV/c neutron momentum.

Phys. Rev. Lett 30 (1973) 1183

np -> pn

- t, GeV^2

increasing with energy



pp -> Δ^{++} n SPD ?

A_y

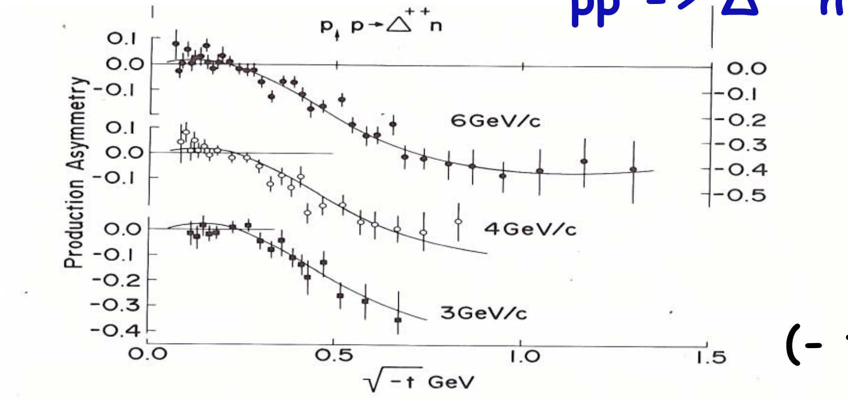
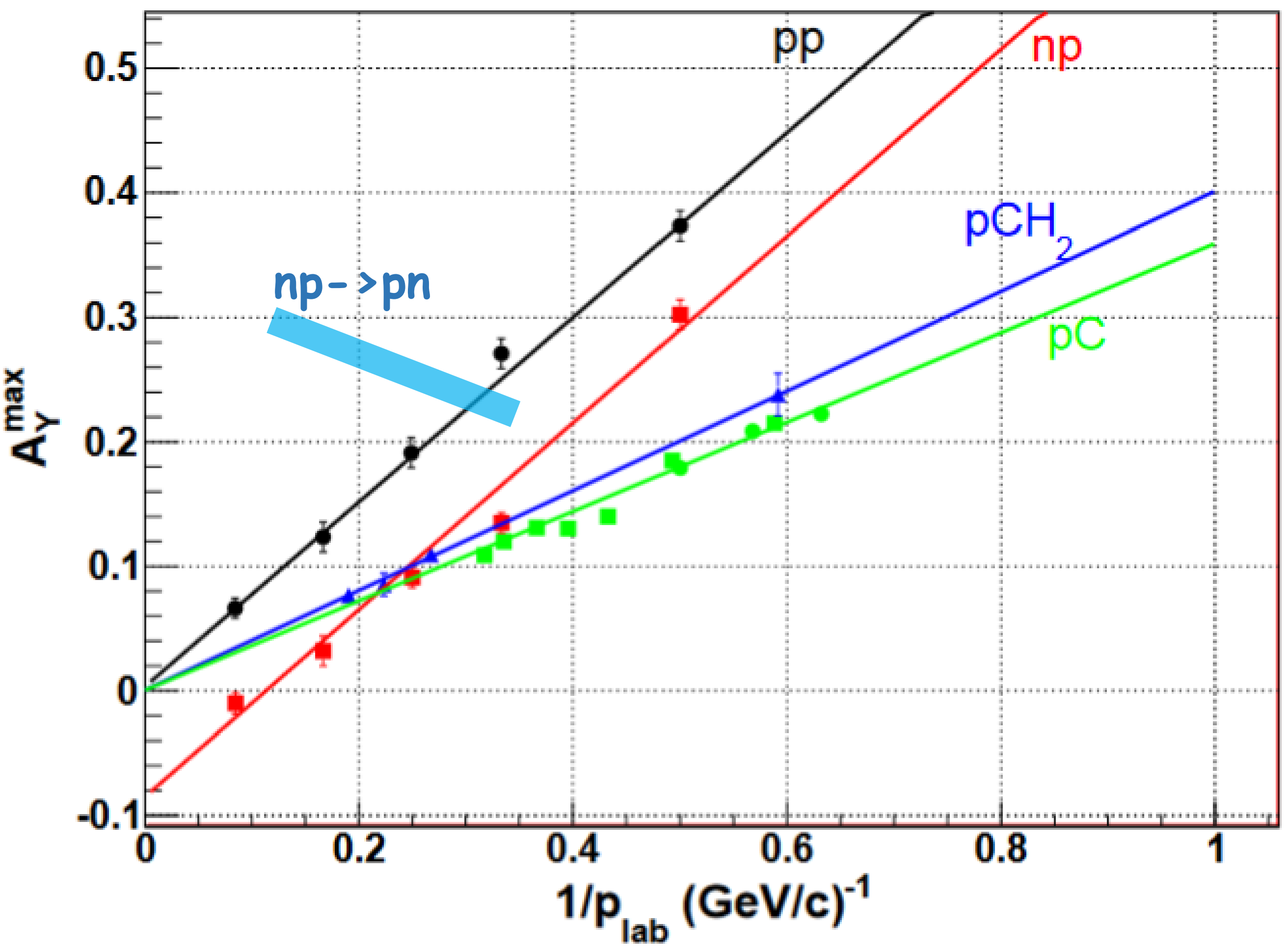


Fig. 1 Overall left-right asymmetries in $p_\uparrow p \to \Delta^{++} n$ at 3, 4, and 6 GeV/c. The curve is an eyeball interpolation of the 6 GeV/c data.

$(-t)^{1/2}$, GeV

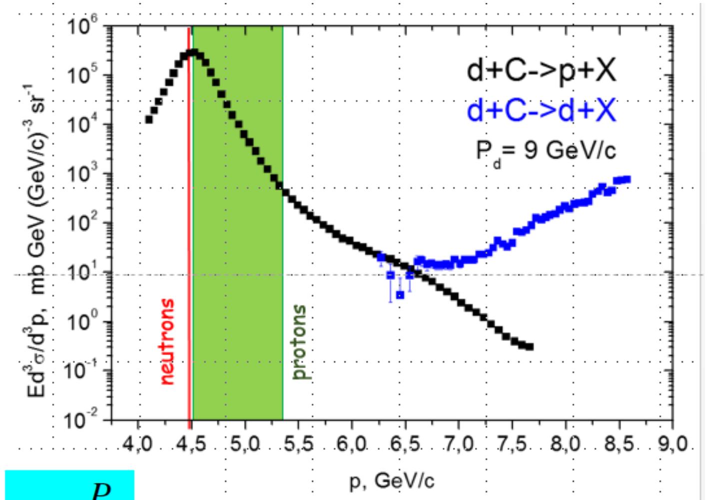
Charge exchange reaction

The dependence of the maximum of A_y on $1/p_{lab}$.

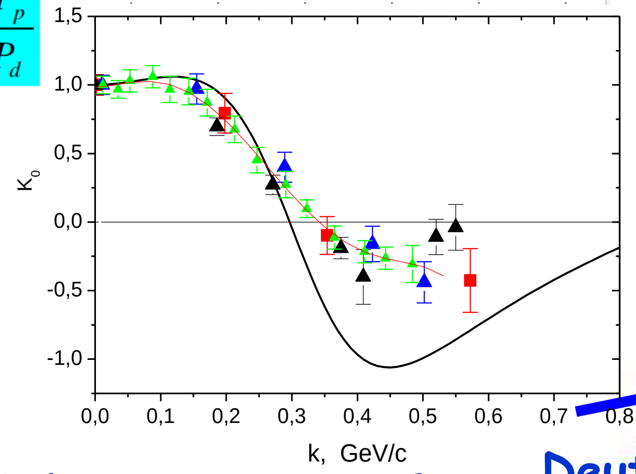


Black circles: ANL d(p,p)n data [29, 30]; black line: linear fit. Red squares: ANL d(p,n)p data [29, 30]; red line: linear fit. Blue triangles [25]: p+ CH2→charged+X; blue line: linear fit [25]. Green squares [31] and circles [32]: p+ C→charged+X; green line: linear fit [25].

Deuteron fragmentation

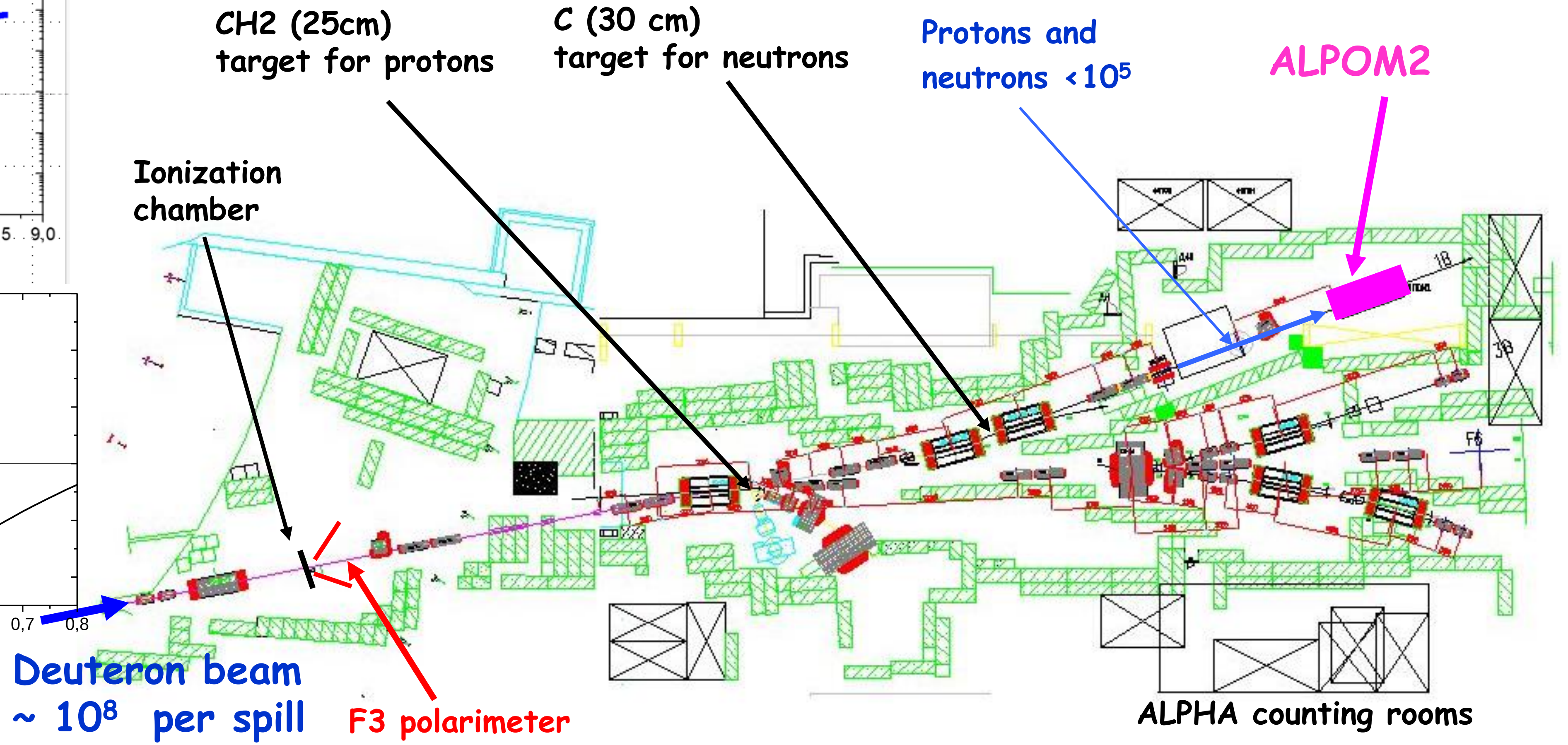


$$k_0 = \frac{P_p}{P_d}$$



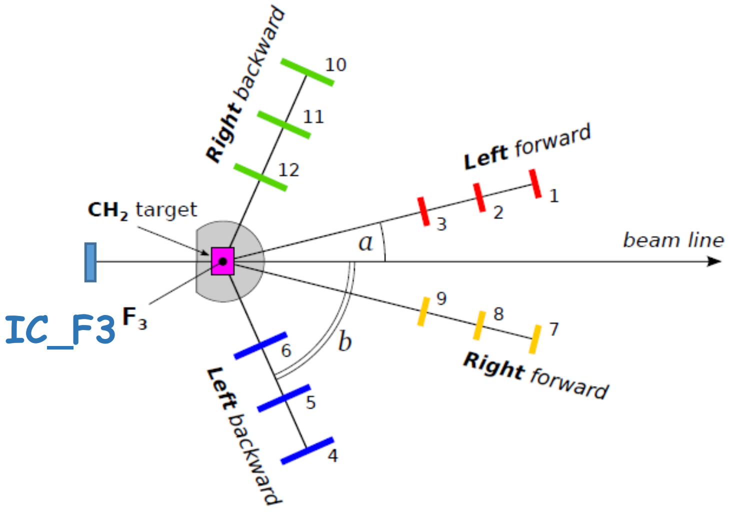
Polarization transfer

Polarized proton and neutron beams



Scheme of transportation polarized beams from Nuclotron to the ALPOM2 setup and the location of F3 polarimeter and production target for proton and neutron beams

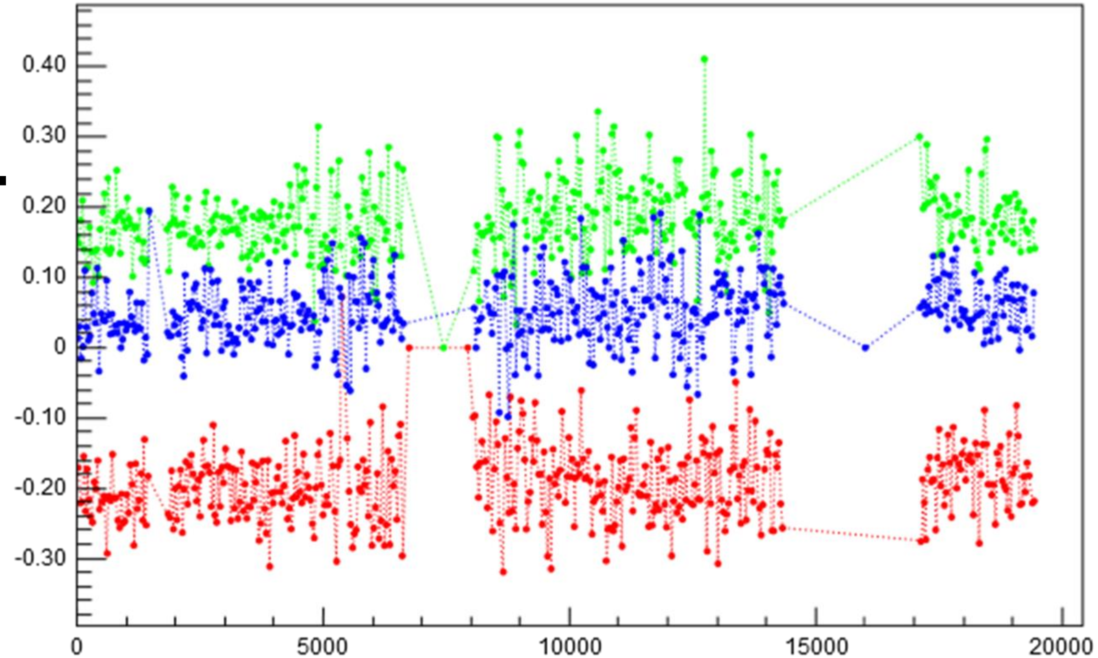
Beam polarization measurements



About 5 hours

each point corresponds to one spill.

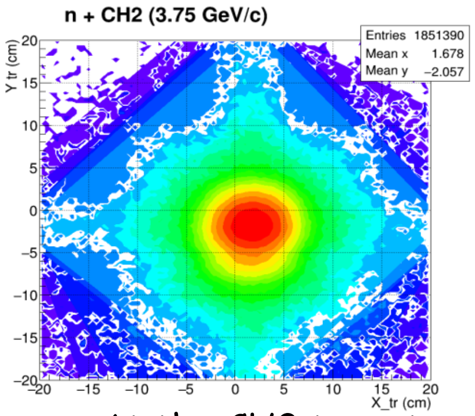
$$\frac{\text{Left-Right}}{\text{IC\_F3}}$$



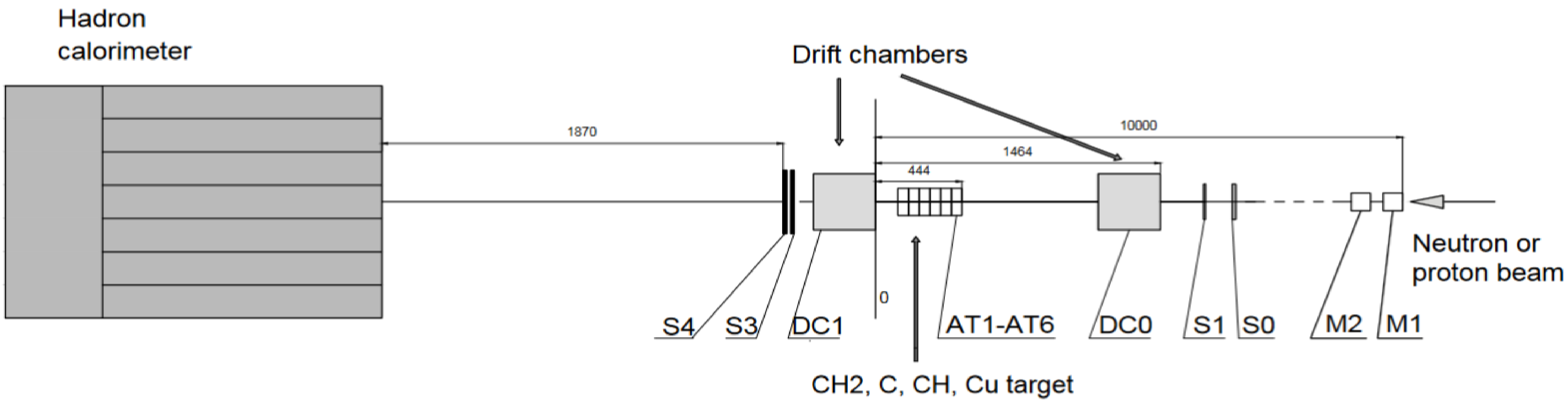
The polarization in one mode
is two times lower than
the other one

P(+) – P(-) = 0,96 ± 0,05

Layout of the setup



At the CH2 target

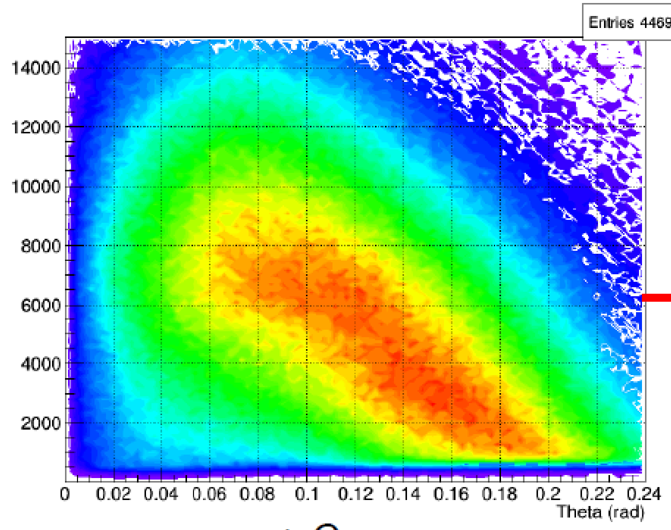


Hadron calorimeter 1

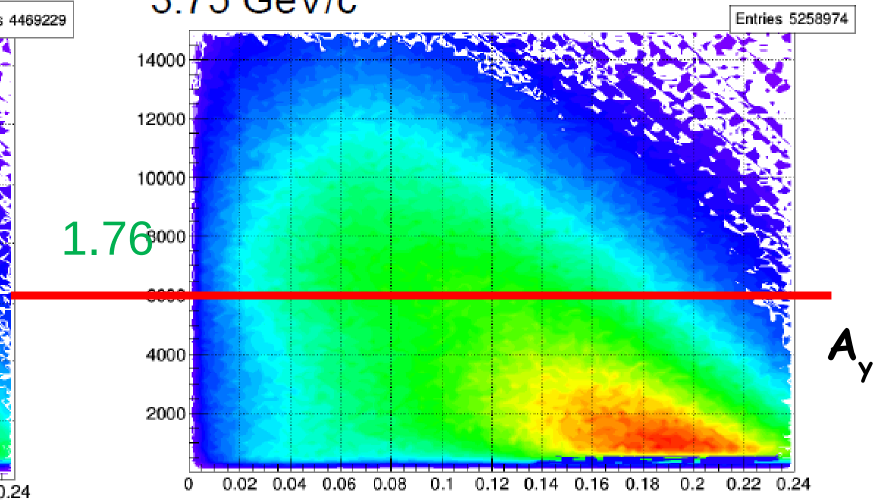
Energy deposit measurements in the hadron calorimeter, 3.75 GeV/c

energy deposit

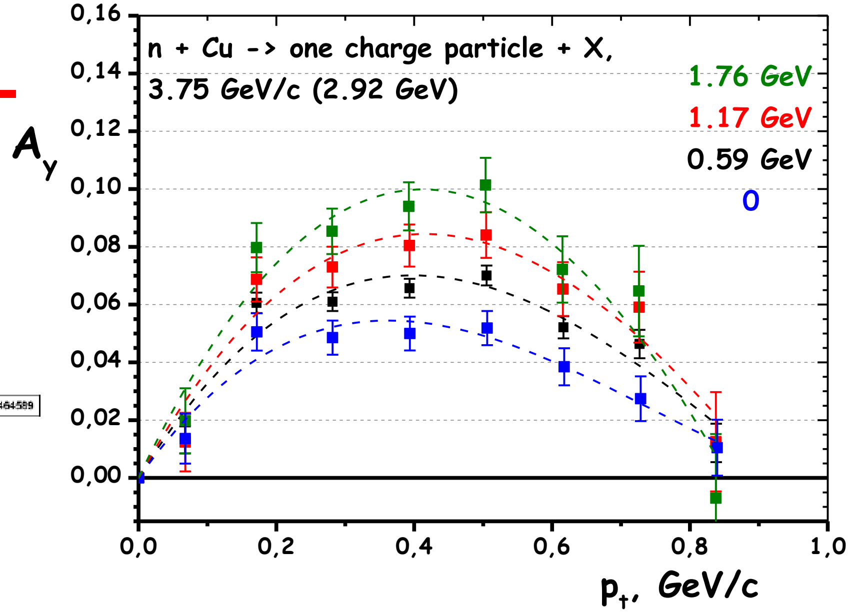
3.75 GeV/c

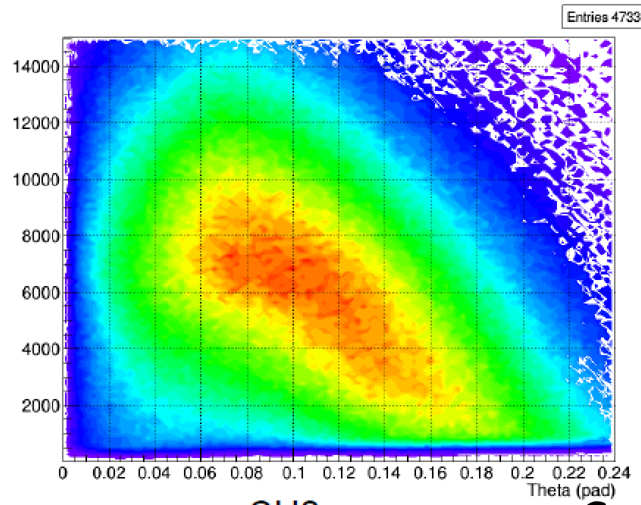


n + C

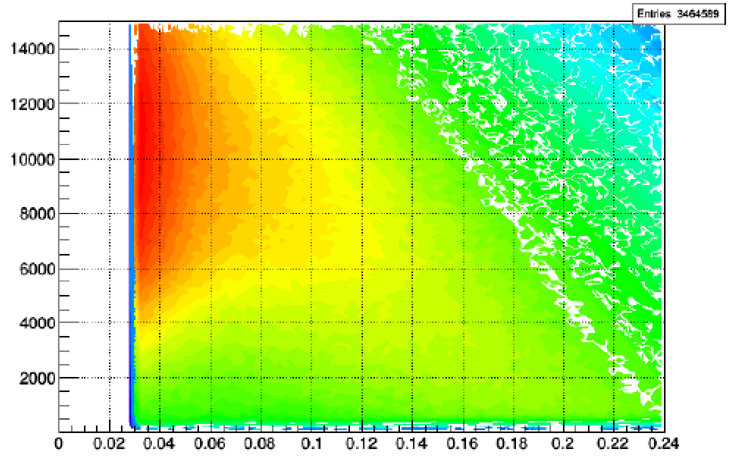


n + Cu





n + CH2



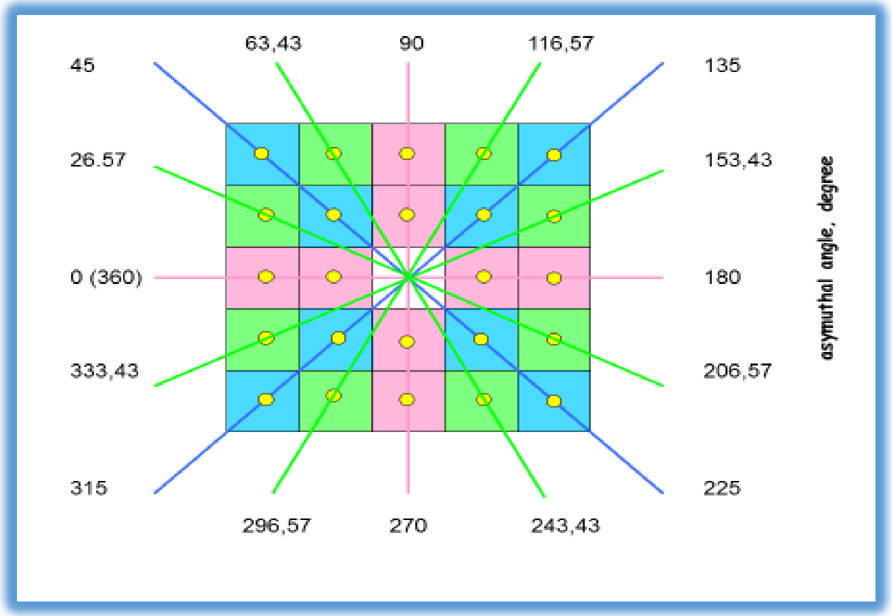
Scattering angle, rad

p +CH2

Hadron calorimeter 2

A very good agreement between tracking and energy deposit data allow us in future experiments used one of these methods

Azimuthal segmentation available from the hadron calorimeter for asymmetry measurements



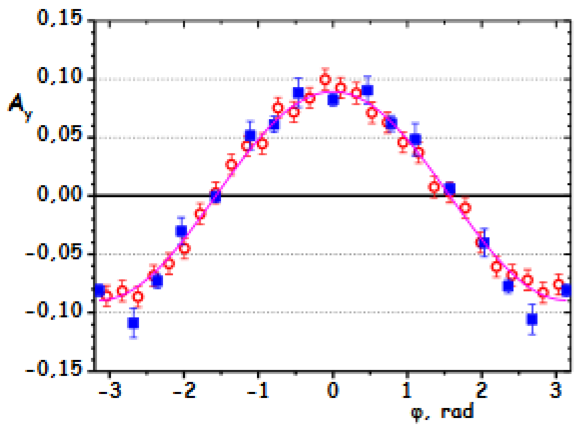


Fig. 17. Azimuthal dependence Ay for p + CH2 scattering at a momentum of 3.0 GeV/c, obtained from the triggered modules of the hadron calorimeter (blue squares) and from the tracks (red circles)

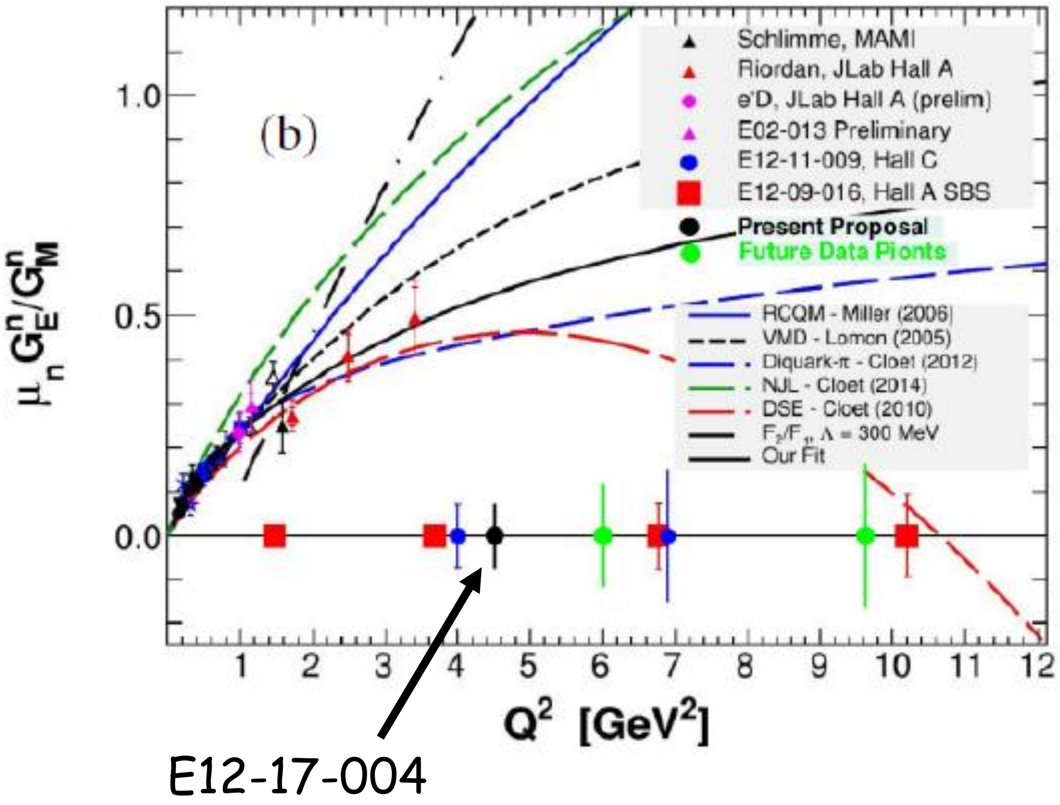
The asymmetry as a function of the azimuthal angle from the calorimeter (blue squares) and from the drift chambers (red circles)

The experimental data obtained in 2016 and 2017 were analyzed and the article **Measurement of neutron and proton analyzing powers on C, CH, CH2 and Cu targets in the momentum region 3-4.2 GeV/c** was published as a *Special Article - New Tools and Techniques in Eur.Phys.J.A 56 (2020) 26*

Three new approaches to the development of polarimetry, namely:

a) turning on the calorimeter to select high-energy nucleons in the final state,
b) using the charge exchange reaction, and
c) replacing the hydrogen-rich light target with heavier nuclei, open the way to simpler and more efficient measurements of nucleon polarization in the region of GeV energies.

Future experiments at Jefferson Lab, requiring recoil polarimetry, have already integrated these concepts in approved experiment E12-17-004, that will start the data taking in April 2024.



The measurements of analyzing powers in nucleon-nucleus scattering at higher energies available only in Dubna now are very important for future experiments in Jlab and JINR

-Hadcal (hadron calorimeter). Instead of the ALPOM2 hadron calorimeter (Fig. 10), it is planned to use the ZDC of the BM@N setup (Fig. 11) in order to increase acceptance of detecting scattering particles and improve angle resolution at small angles. Now the hadcal of the BM@N setup was installed at the beam line, see Fig. 12.

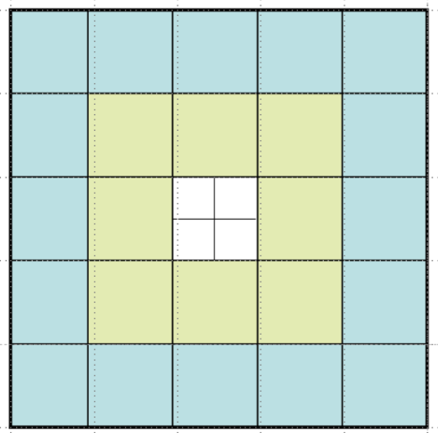


Fig. 10. ALPOM2 calorimeter layout: the central part consists of 4 modules with sizes 7.5×7.5 cm^2, the peripheral part contains 24 modules of 15×15 cm^2.

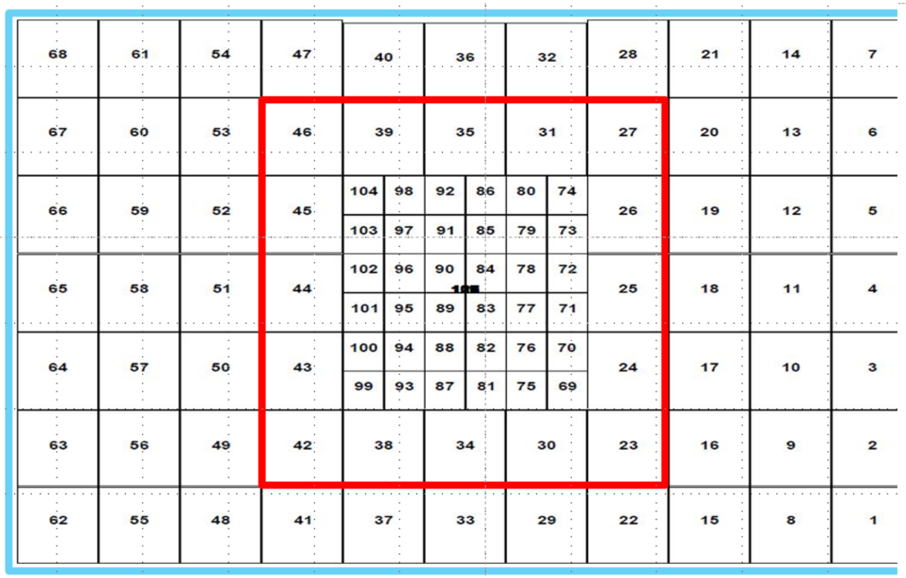


Fig. 11. ZDC layout: the central part consists of 36 modules with sizes 7.5×7.5 cm^2, the peripheral part contains 68 modules of 15×15 cm^2.

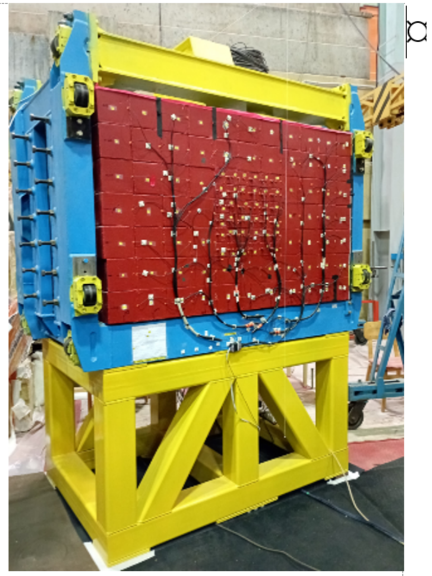


Fig. 12. A photo of the hadcal at the beam line.

A new data acquisition system is installed and software for analysis of experimental data has been developed [29].

New drift chambers

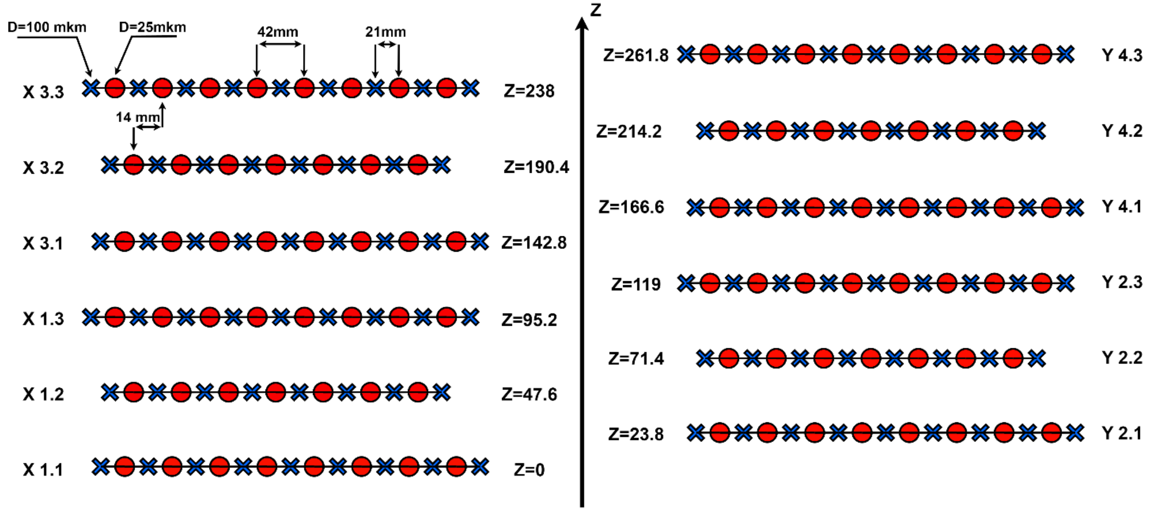
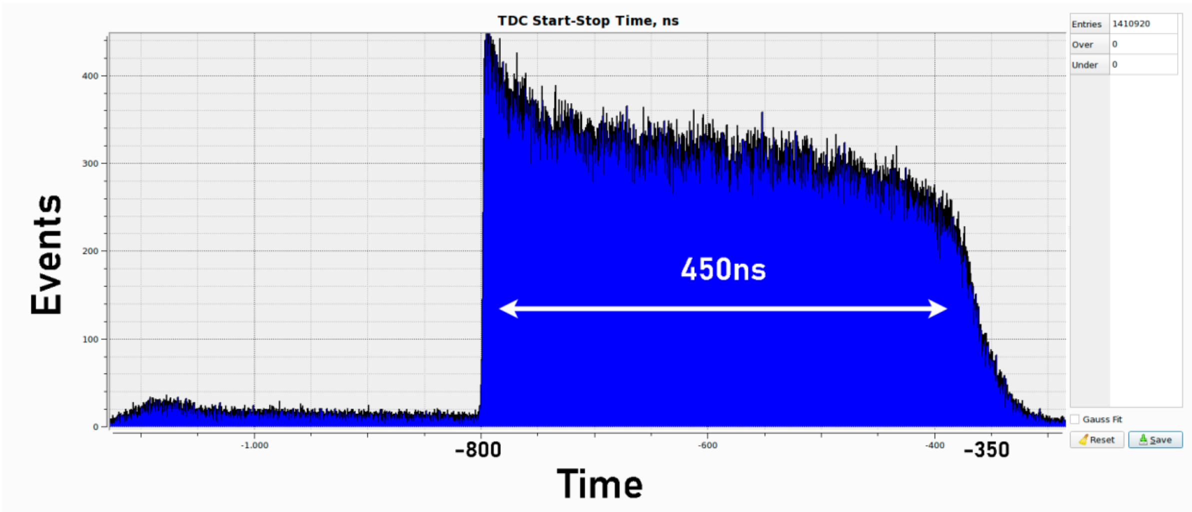
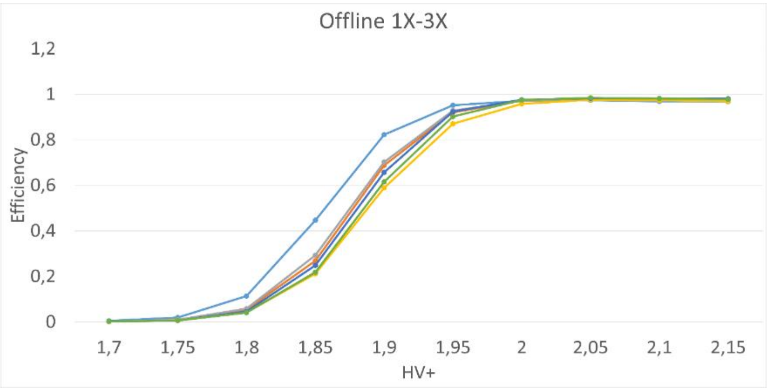


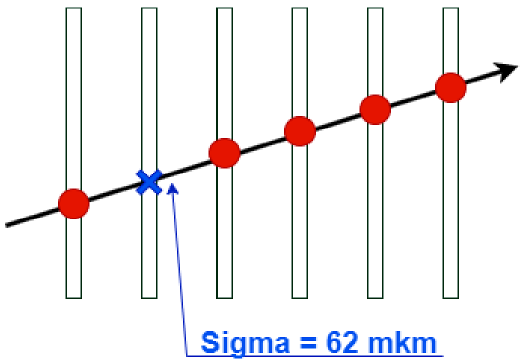
Схема расположения сигнальных и потенциальных проволочек в X и Y-плоскостях

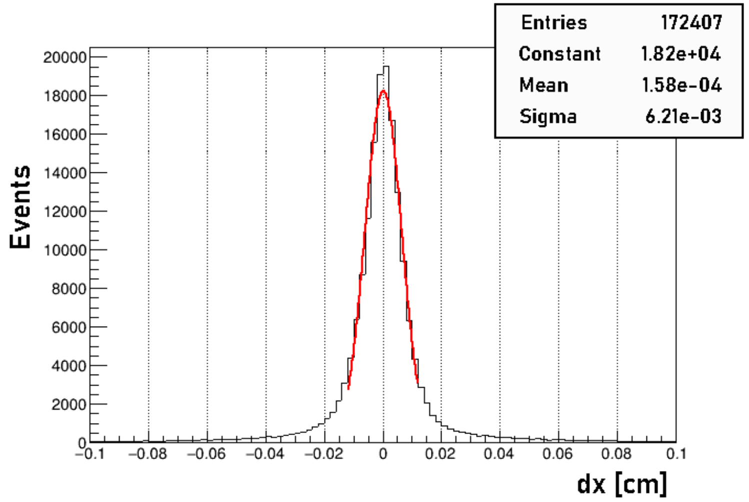


Распределение по времени дрейфа, ширина составляет 450 ns, что соответствует дрейфовому промежутку 21 mm.



Зависимость эффективности регистрации трека частицы (космического мюона) от высокого напряжения на сигнальных проволочках. Плато эффективности 200 V идет от 1.95 до 2.15 kV.





Strengths, weaknesses, opportunities, threats

Strengths: The results will complete and extend data on analyzing powers, in frame of a coherent program, recently performed in Dubna, and earlier at other laboratories, in particular in France, USA, and Japan. The experiment will use polarized deuteron beam that is present only in Dubna. No competition is expected from other laboratories, because GeV energy polarized proton and neutron beams are available only in Dubna. The results are of great interest for all those experiments that need to measure the polarization of protons and neutrons in the GeV range, at hadron and electron accelerators worldwide.

Weaknesses: In connection with the construction of the NICA collider, there is currently no beam schedule for the Nuclotron. The last session on a polarized beam was in the spring of 2017.

Opportunities: When carrying out measurements, it will be possible for the first time to measure the analyzing powers simultaneously for forward scattering and charge exchange scattering; in the case of the interaction of polarized protons with a target, the asymmetries of forward scattering of both one charged particle and a neutral particle will be measured. The obtained results will contain significant material for the defense of PHD thesis by young participants in the experiment.

Threats: The highly professional level of the participants in the experiment, the previous experience of the team, the available equipment and the presence of polarized proton and neutron beams of GeV energies limits essentially the risks. However, the Special military operation could limit the number of participants in the experiment from abroad.

3.2.1. JINR staff

The following Table lists ALPOM2 JINR group members with their roles and participation.

No.	Category of personnel	Full name	Division	Position	Amount of FTE
1.	research scientists	Piskunov N.M.	SEDSPFNS LHEP	Senior Researcher	0.8
2.		Kirillov D.A.	SEDSPFNS LHEP	Head of Sector	0.9
3.		Sitnik I.M.	SEDSPFNS LHEP	Leading Researcher	1.0
4.		Gavrishchuk O.P.		Leading Researcher	0.2
5.		Shindin R.A.	SEDSPFNS LHEP	Senior Researcher	0.9
6.		Kiryushin Yu.T.	SEDSPFNS LHEP	Leading Researcher	0.2
7.	engineers	Livanov A.N.	SEDSPFNS LHEP	Engineer	0.1
8.		Druzhinin A.A. (25 years)	SEDSPFNS LHEP	Engineer	0.9
9.		Kostayeva N.V	SEDSPFNS LHEP	Engineer	1.0
10.		Legostaeva K.S. (27 years)	SEDSPFNS LHEP	Engineer	0.5
11.	technicians	Lyubimtsev D.A.	SEDSPFNS LHEP	Technician	1.0
	Total:				**7.5**

Other authors take part in the implementation of the project as needed.

Schedule of the experiment:

2025-2026 years	Data taking during 336 hours at the deuteron intensity about 5*10**9 per spill. It includes: for proton beam 168 hours a)measurement A_y at proton momentum of 5.3 GeV/c (control point) b)two measurements of transfer polarization, check conservation polarization at k=0.15 GeV/c at deuteron momentum of 11.2 GeV/c (proton momentum 6.5 GeV/c) and deuteron momentum of 13.0 GeV/c (proton momentum 6.5 GeV/c) c)measurement at deuteron momentum of 13.0 GeV/c (proton momentum 7.5 GeV/c) for neutron beam 168 hours measurement A_y at neutron momenta of 5.0 and 6.0 GeV/c .
2026-2027 year	Data analyzes and publication of the results.

Contributions in previous years from collaborators

USA side – crate VME – 8.5 k$; HV supply – 2 k$, .2 TQDC – 8 k$, hadcal modules – 10 k$, HV system SY5527 (Caen) – 14.6 k$

French side – PM XP2020 – 2 items and several electronic modules – 5 k$

Slovak Republic grants – 45 k$, HV supply, computers, electronic modules, drift chambers

We are planning to continue the measurements at higher proton and neutron energies

Thank you

alpom2_2024_jinr_pac

Proposed schedule and resource request for the Project ALPOM2

Expenditures, resources, funding sources			Cost (thousands of US dollars)/ Resource requirements	Cost/Resources, distribution by years				
				1st year	2nd year	3rd year	4th year	5th year
		International cooperation	60	20	20	20		
		Materials	15	5	5	5		
		Equipment, Third-party company services	255	85	85	85		
		Commissioning						
		R&D contracts with other research organizations	30	10	10	10		
		Software purchasing						
		Design/construction						
		Service costs *(planned in case of direct project affiliation)*						
Resources required	**Standard hours**	Resources						
		– the amount of FTE,	22.5	7.5	7.5	7.5		
		– accelerator/installation,	336	168	168			
		– reactor,...						
Sources of funding	**JINR Budget**	JINR budget *(budget items)*	360	120	120	120		
	Extra fudning (supplementary estimates)	Contributions by partners Funds under contracts with customers Other sources of funding						

Project Leader __________/________________/

Laboratory Economist __________/________________/

American
Physical
Society

One Physics Ellipse
College Park, MD 20740-3844
www.aps.org

September 26, 2016

Charles F. Perdrisat
College of William and Mary
Physics Department
PO Box 8795
Williamsburg, VA 23187

Dear Dr. Perdrisat,

On behalf of the American Physical Society, it is my pleasure to inform you that you have been awarded the 2016 Tom W. Bonner Prize in Nuclear Physics, recognizing and encouraging outstanding experimental research in nuclear physics. The prize consists of $10,000, a certificate, travel reimbursement and a registration waiver to attend the April Meeting. We invite you to give an invited talk at the APS April Meeting, next held in Washington, DC, January 28-31, 2017, preferably on the work described in your prize citation:

"For groundbreaking measurements of nucleon structure, and discovering the unexpected behavior of the magnetic and electric nucleon form factors with changing momentum transfer."

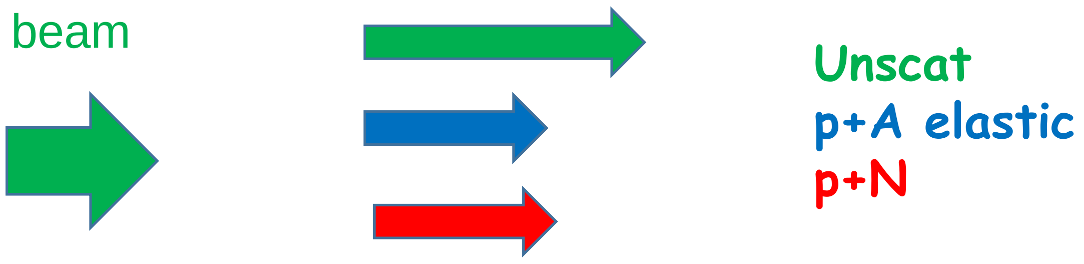
We will work with the APS Division of Nuclear Physics (DNP) to schedule a talk if you are able to attend the meeting. You will receive more information from Mary Raucci, APS Honors Manager, and an invitation letter with meeting abstract submission details in early October. Congratulations on your selection to receive this well-deserved prize.

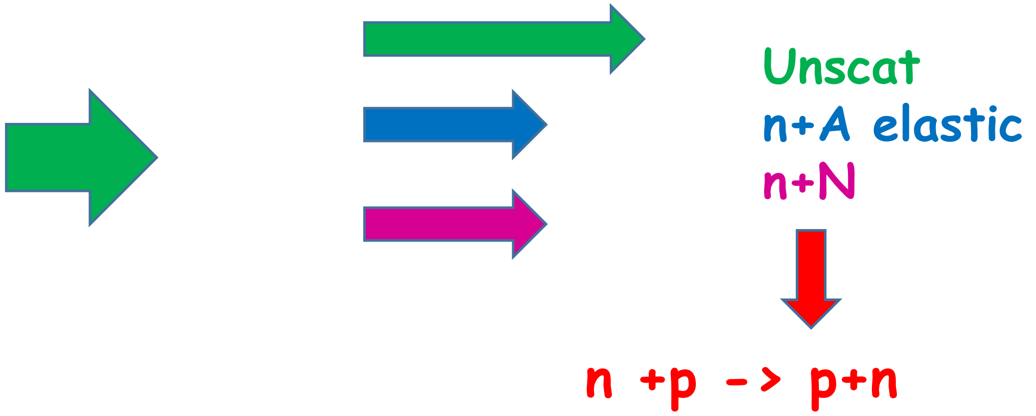
Sincerely,

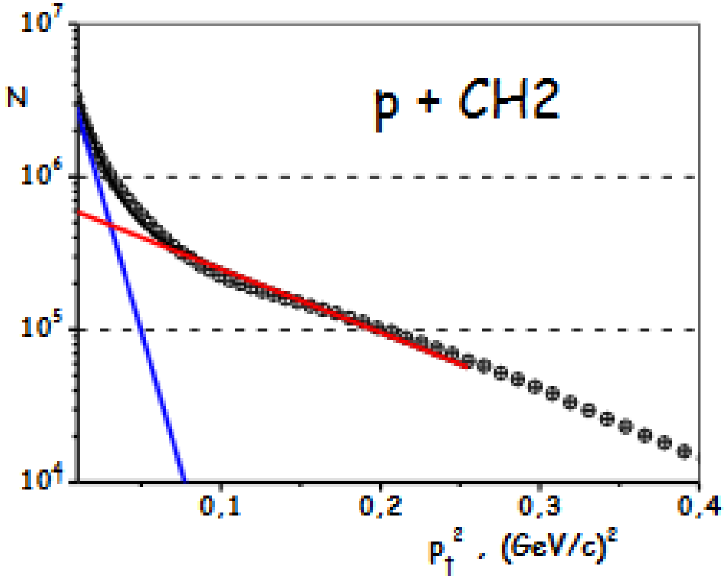
Homer A. Neal

Homer A. Neal, APS President

cc: Carl Carlson, Nominator
Rocco Schiavilla, Tom W. Bonner Prize Selection Committee Chair
Gordon Cates, Division of Nuclear Physics (DNP) Chair
Benjamin Gibson, Division of Nuclear Physics (DNP) Secretary / Treasurer







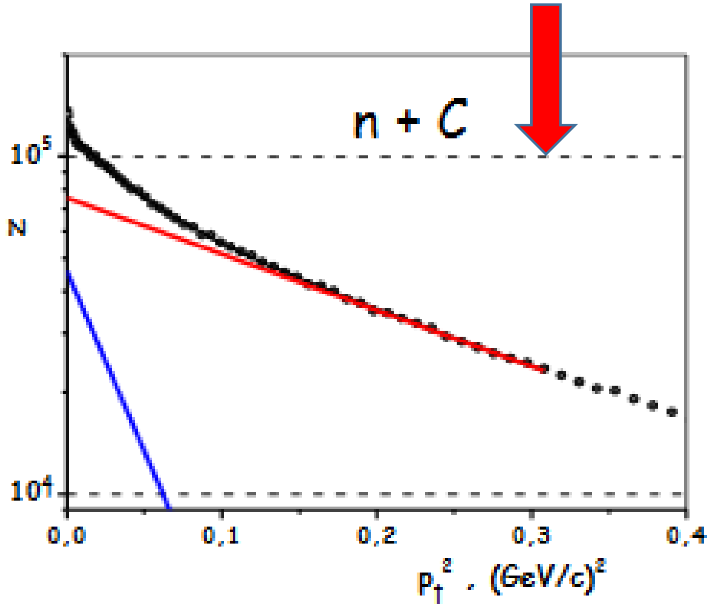


Fig. 14. pt2 -distribution for p + CH2 scattering at 3.75 GeV/c. The black curve is the sum of exponential functions with slope parameters b'1 (blue) and b'2 (red).

Fig. 15. pt2 -distribution for n + C scattering at 3.75 GeV/c. The black curve is the sum of exponential functions with slope parameters b1 (blue) and b2 (red).