Results of measurements on beams of polarized nucleons and plans for their continuation (ALPOM-2 proposal).

Measurement of analyzing powers for the reaction p+CH2 up to 7.5 GeV/c and n+CH up to 4.5 GeV/c at the Nuclotron (ALPOM2 proposal)

S.N. Basilev, Yu.P. Bushuev, O.P. Gavrishchuk, V.V. Glagolev, D.A. Kirillov, N.V. Kostayeva, A.D. Kovalenko, K.S. Legostaeva, A.N. Livanov, I.A. Philippov, N.M. Piskunov, A.A. Povtoreiko, 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

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V. Punjabi

Norfolk State University, Norfolk, VA 23504, USA

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, SPhn, CEA Saclay and IN2P3/IPN Orsay, France

D. Marchand, Y. Wang

IPN Orsay, 91406 ORSAY cedex, France

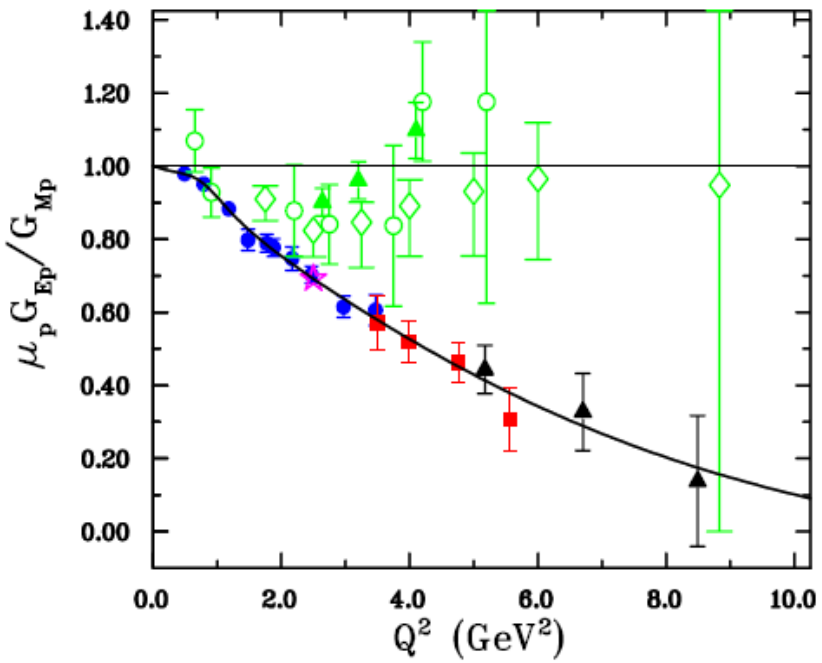
J. R.M. Annand, K. Hamilton, R. Montgomery

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

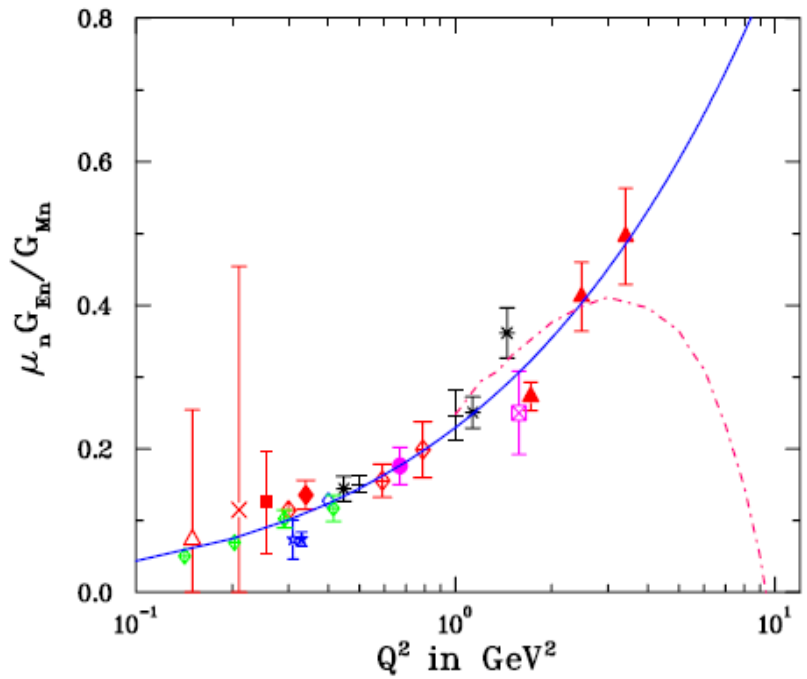
Current situation for G_{Ep}/G_{Mp}, showing unbridgeable discrepancy between cross section (green) and polarization (blue/red/black). Curve is double-polynomial fit.

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

Will G_{Ep} become zero?

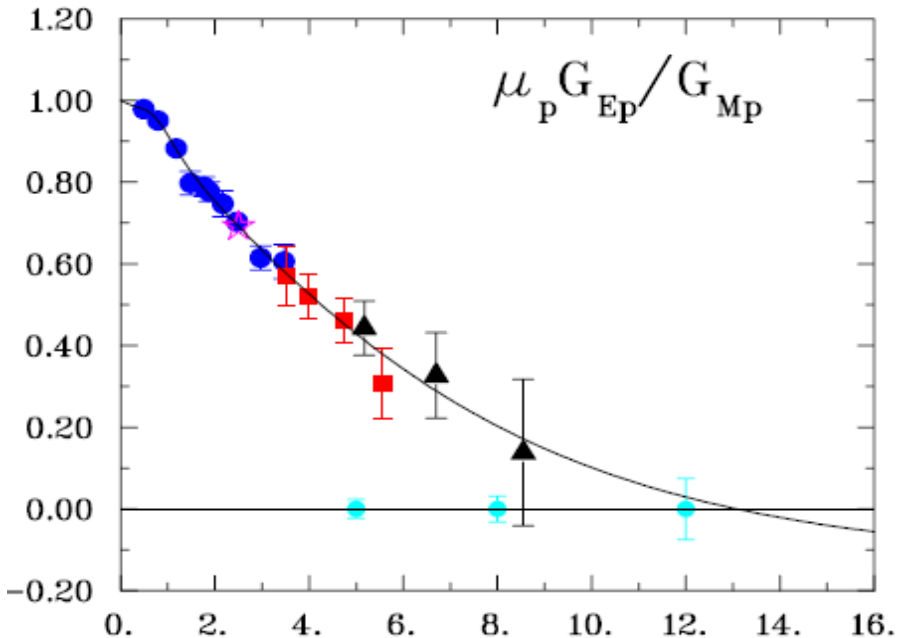


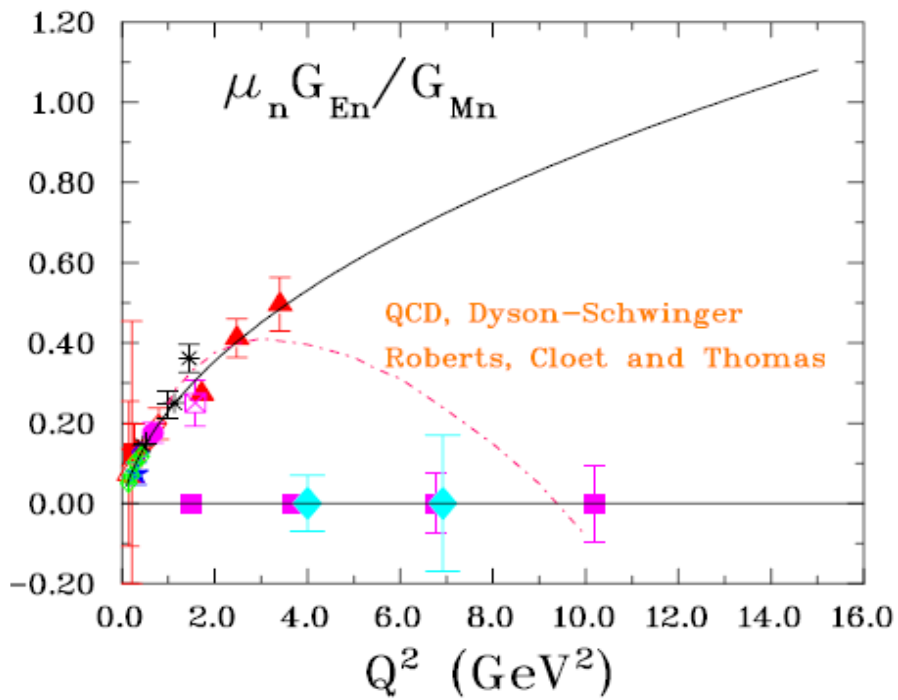
Will G_{En} also become zero?



Approved experiments which will use the 12 GeV beam energy at Jlab in next future. The proton experiment uses recoil polarization as did the first 3 Jlab GEp experiments. The neutron experiments use a polarized 3He target (pink squares), and recoil polarization (pale blue circles).

In addition there is one GEp/GMp (Brash et al) and one GEn/GMn (Annand et al) experiment, both with recoil polarization, **currently not-approved** (because of "unknown" analyzing power); would beneficiate from results of p and n analyzing power proposed here at Nuclotron (JINR).





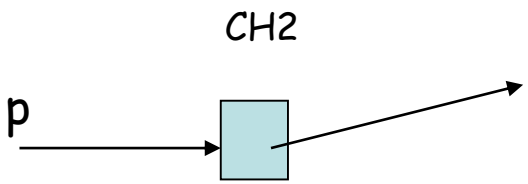
$$\frac{d\sigma^{+}}{d\Omega}(\theta,\varphi) = \frac{d\sigma^{0}}{d\Omega}(\theta)\left(1 + P_z^{+} A_y(\theta)\cos\varphi\right)$$

$$F^2 = \int_{\vartheta} \varepsilon(\theta) A_y^2(\theta) d\theta$$

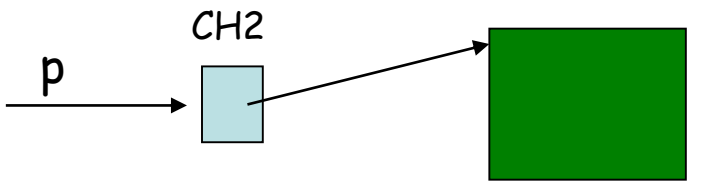
$$\Delta P_y = \sqrt{\frac{2}{N_{inc} F^2}}$$

Proton polarimetry
p + C(CH2) -> charged particle + X

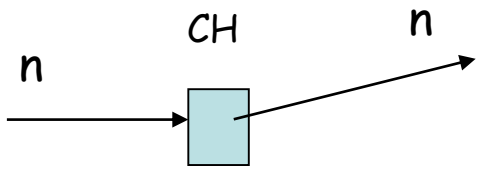
ALPOM 2001

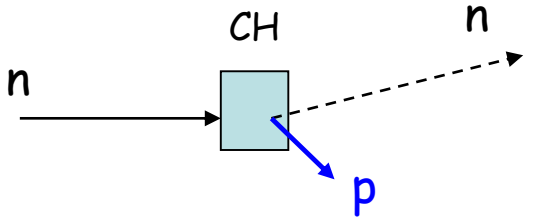


ALPOM2

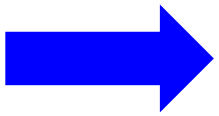


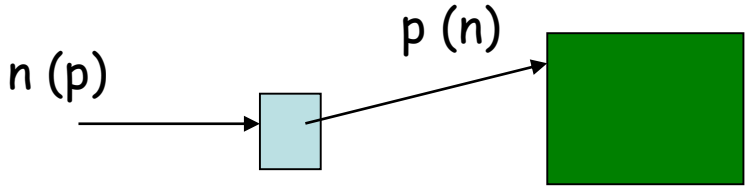
Neutron polarimetry
n + p -> n + p , CH - target





New suggestion: n + p -> p + n
Charge exchange reaction





Proton polarimetry

Current data base of analyzing power: need Ay at 1/p=0.12 GeV^{-1}, or p=7.5 GeV/c

$p + CH_2 \rightarrow$ *one charged particle* $+ X$

Inclusive

1) more reactions at higher energy

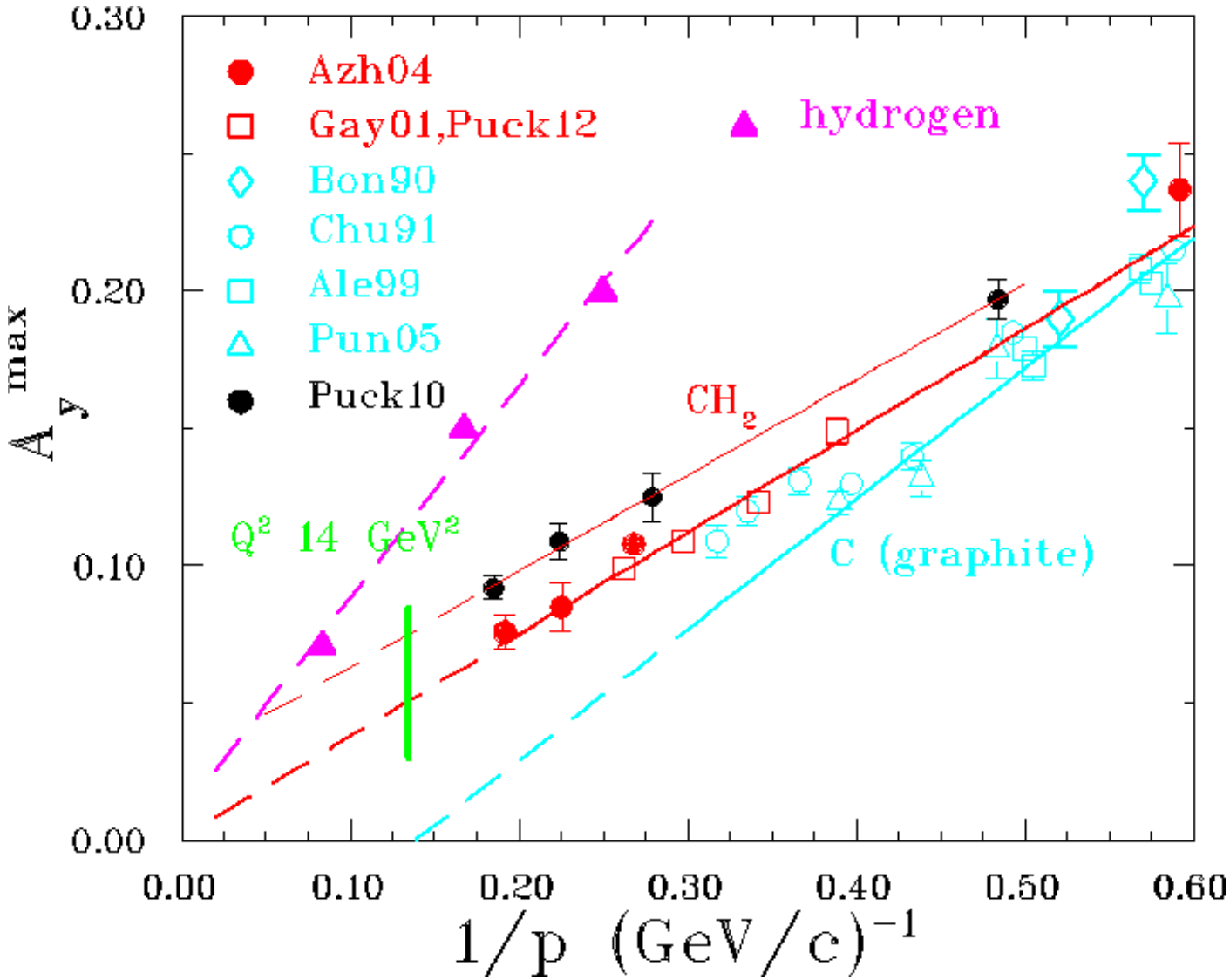
Hadron calorimeter to reject low energy particles

2) maximum of analyzing power A_y

at Pt ~P sinθ ~ 0.3-0.4 GeV/c

Smaller angles at high energies

Drift chambers



Neutron polarimetry

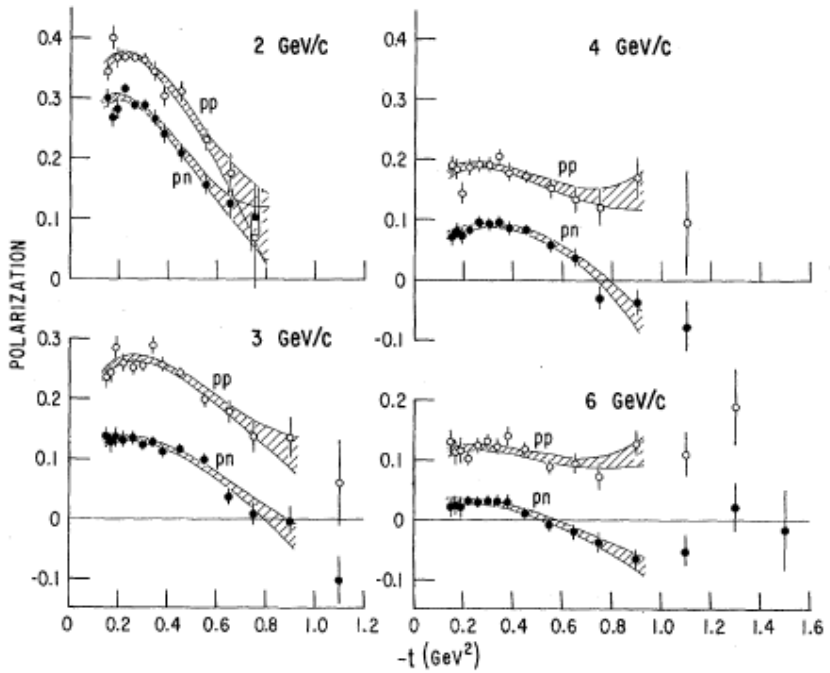
pp -> pp

pd -> pn + (p)

Phys. Rev. Lett 35 (1975) 632

A_y

decreasing with energy



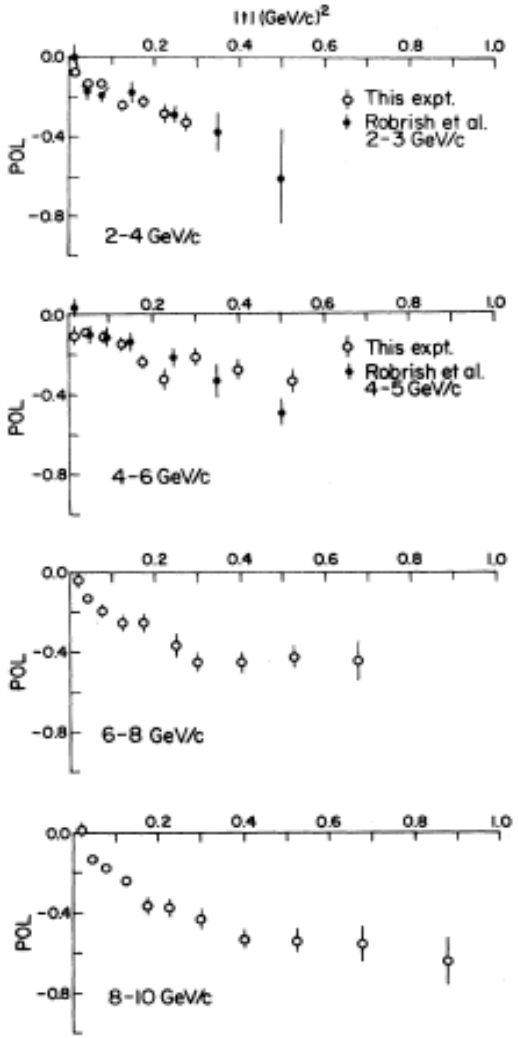
The existing data for A_y in np elastic scattering indicate that the analyzing power decreases faster than the pp analyzing power, becoming very small, then negative around 6 GeV/c neutron momentum.

Phys. Rev. Lett 30 (1973) 1183

np -> pn

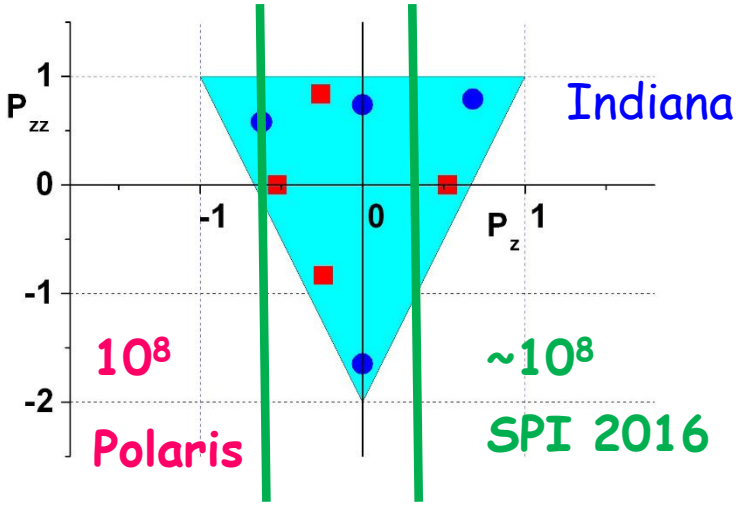
A_y

increasing with energy

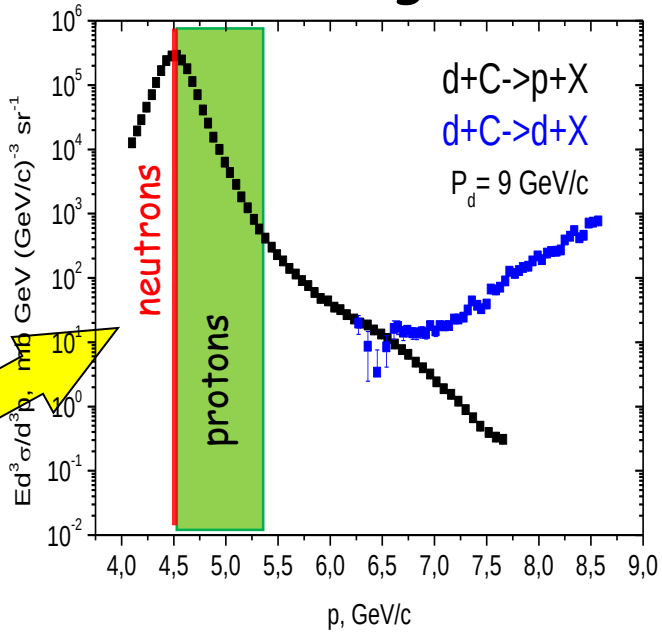


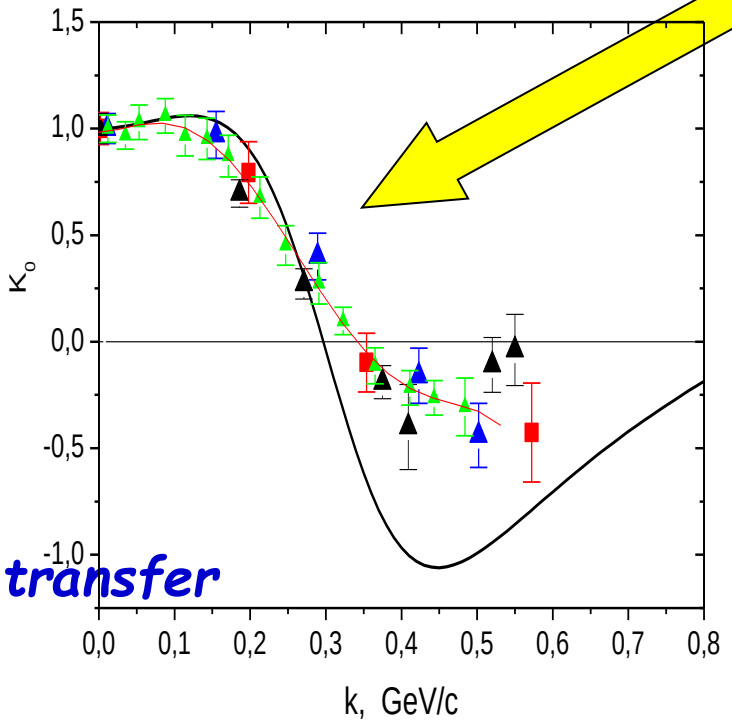
Charge exchange reaction

Polarized proton (neutron) beam



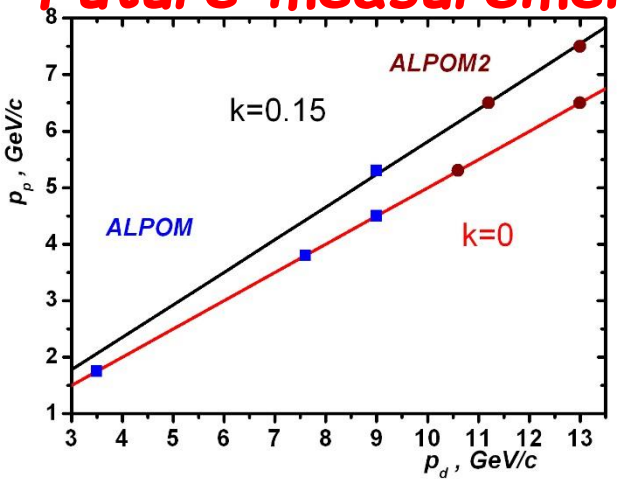
Deuteron fragmentation



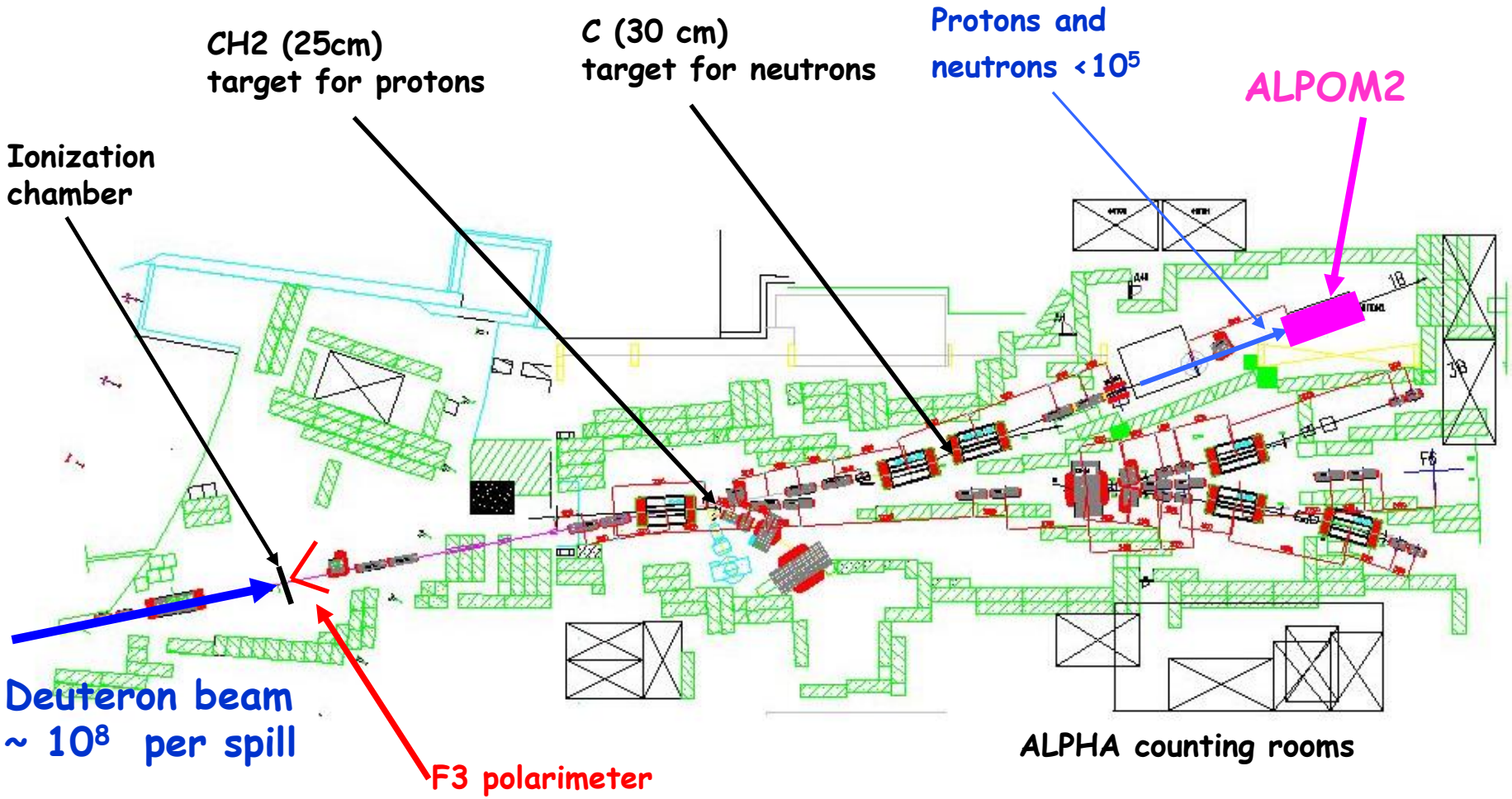


Polarization transfer

Future measurements

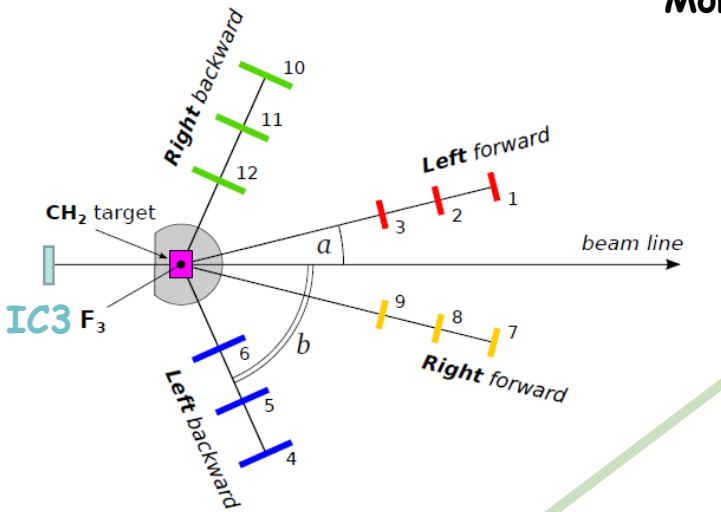


Polarized proton and neutron beams

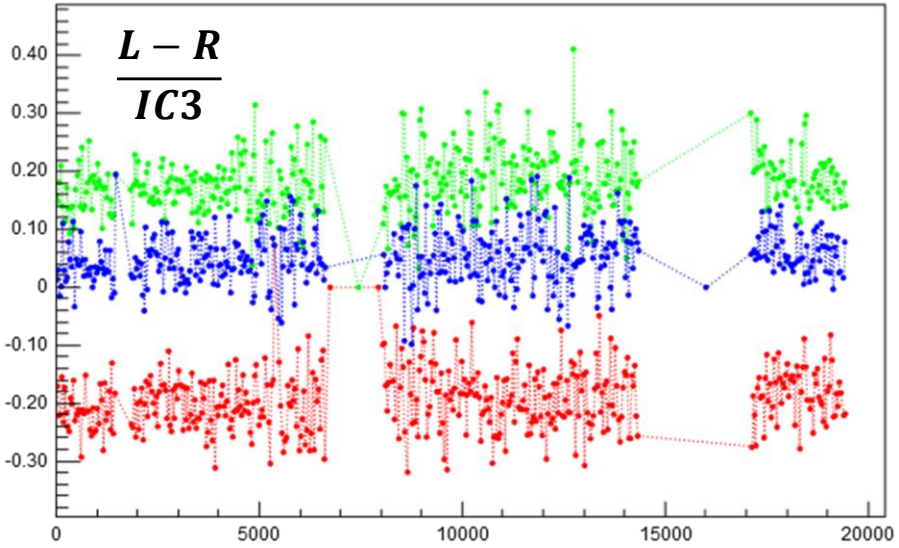


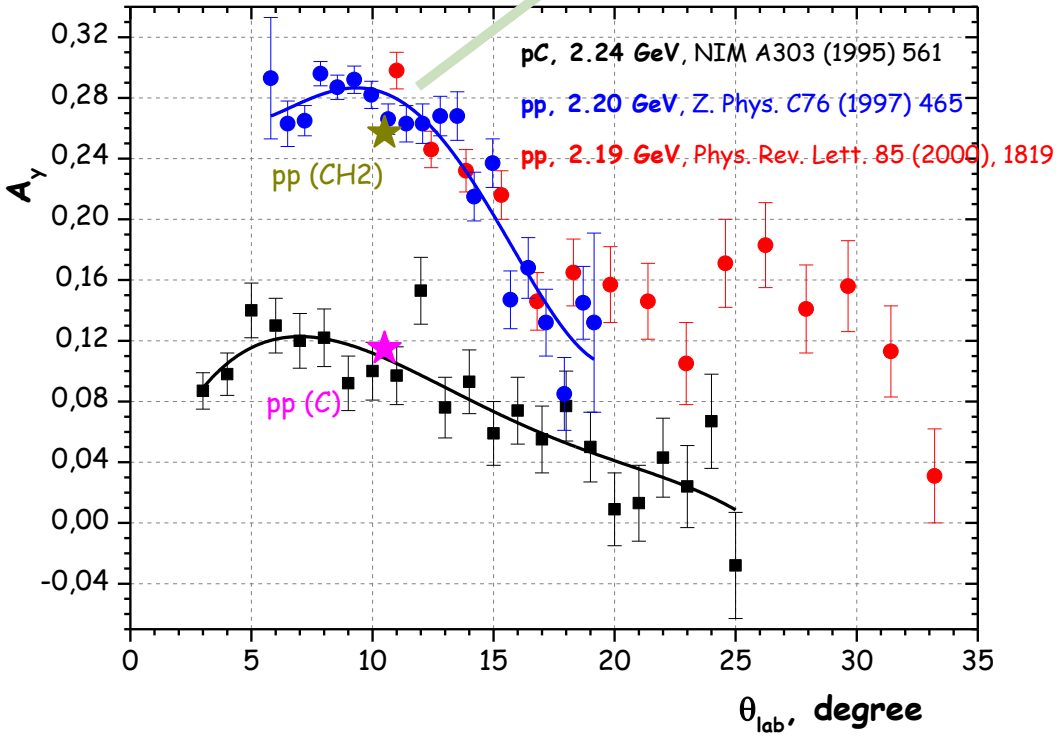
Beam polarization measurements

More details in the talk of R.Shindin

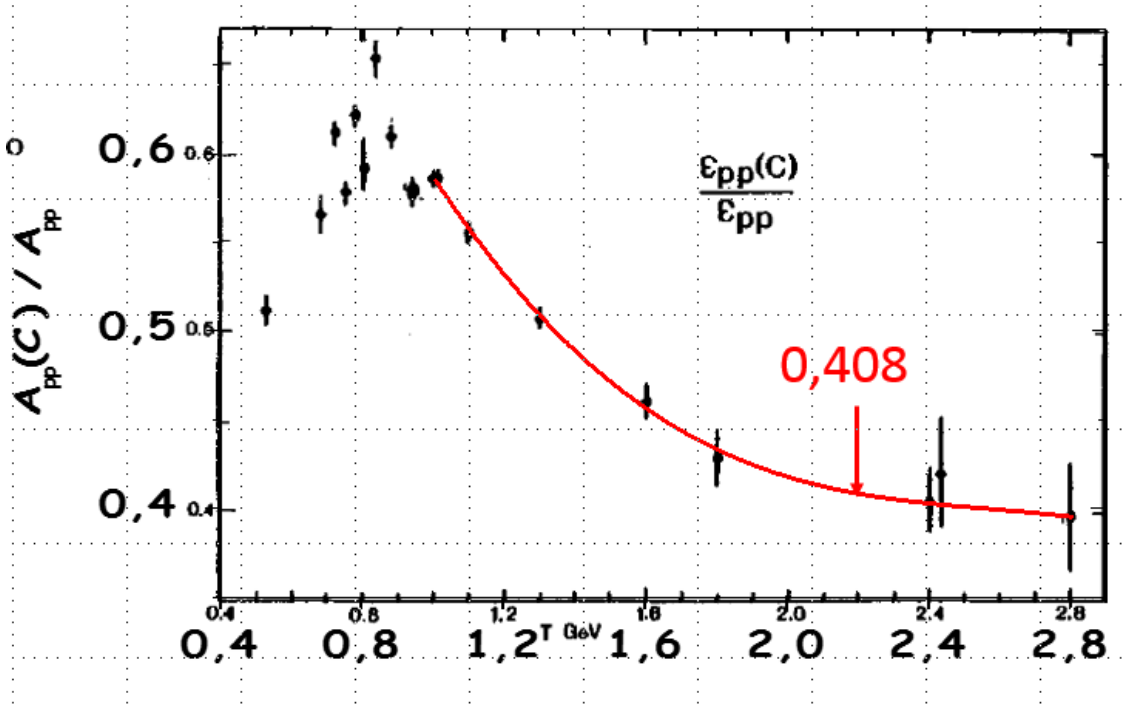


$$P(+) - P(-) = 0{,}96 \pm 0{,}05$$

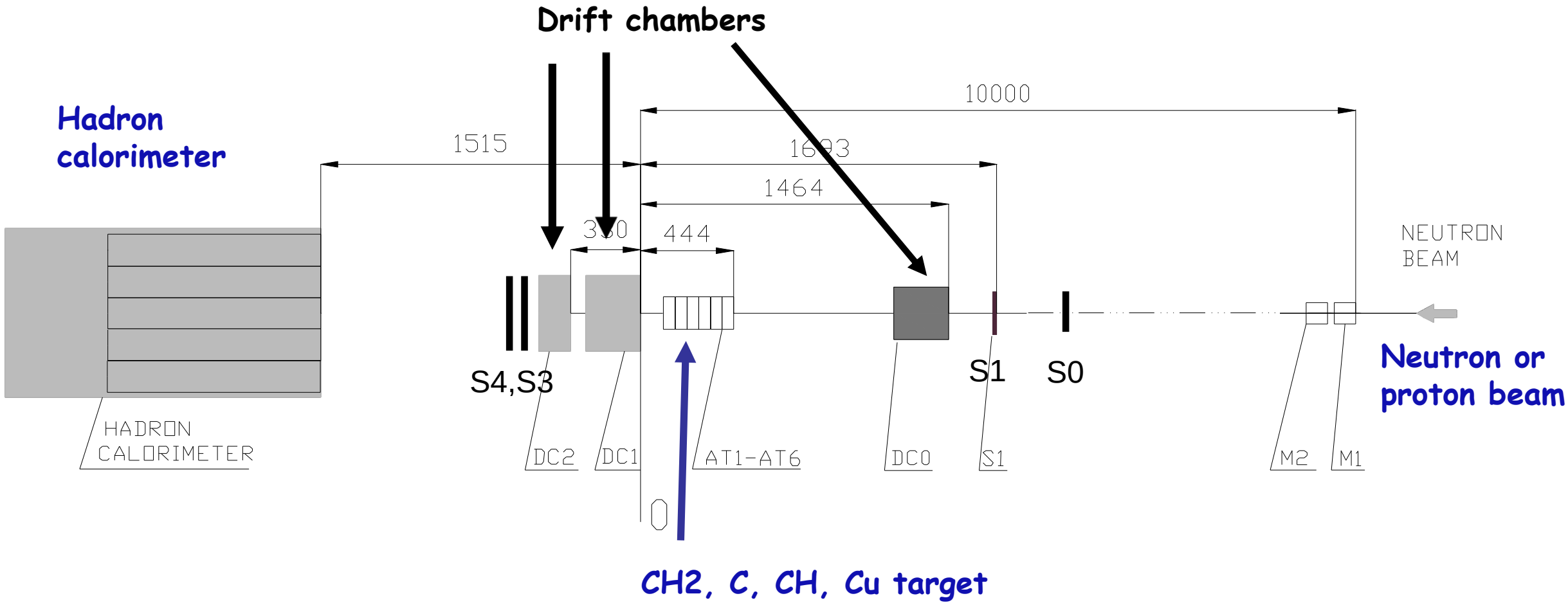




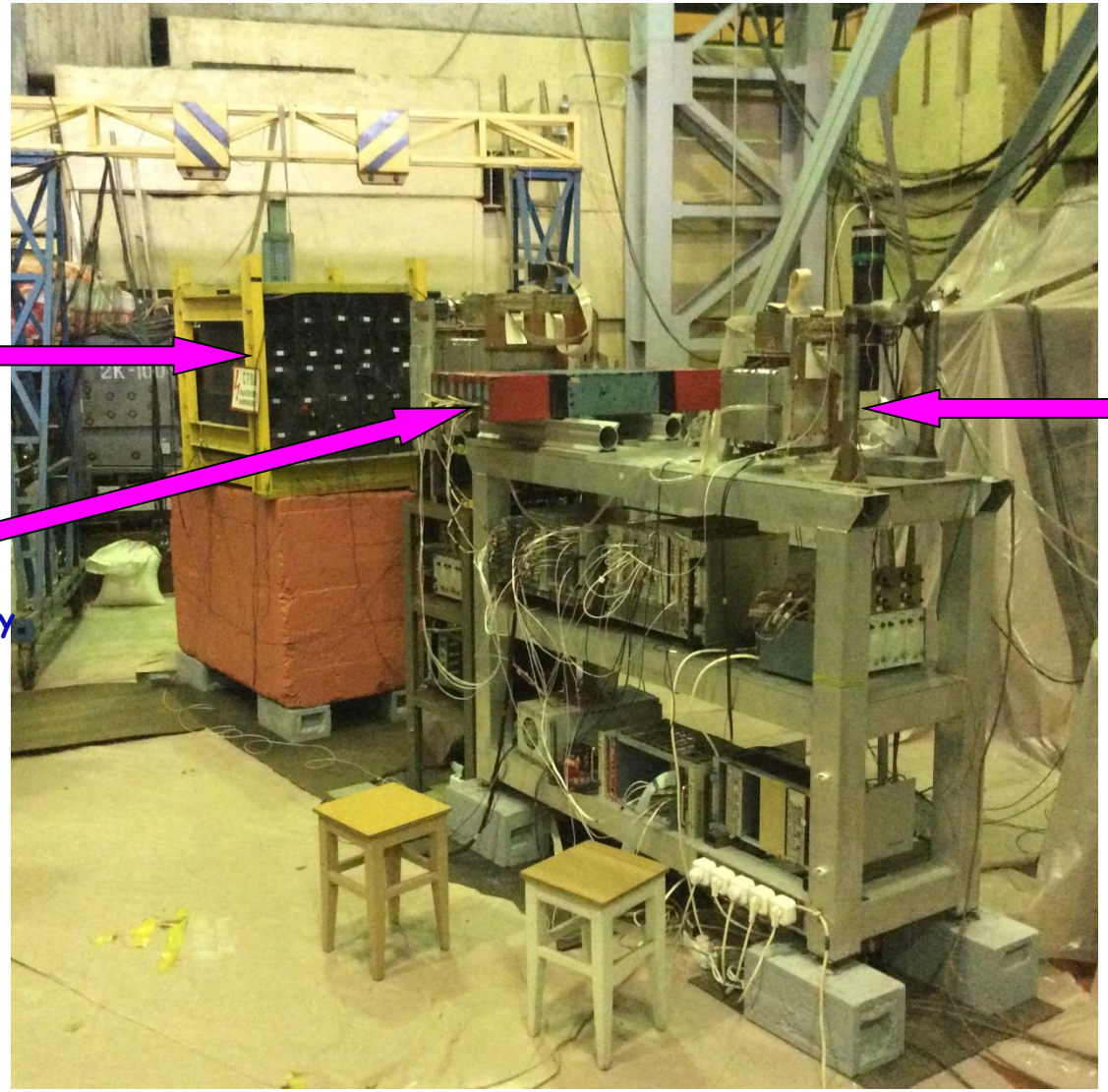
JOURNAL DE PHYSIQUE
Colloque C2, supplément au n02, Tome 46, février 1985 page C2-483



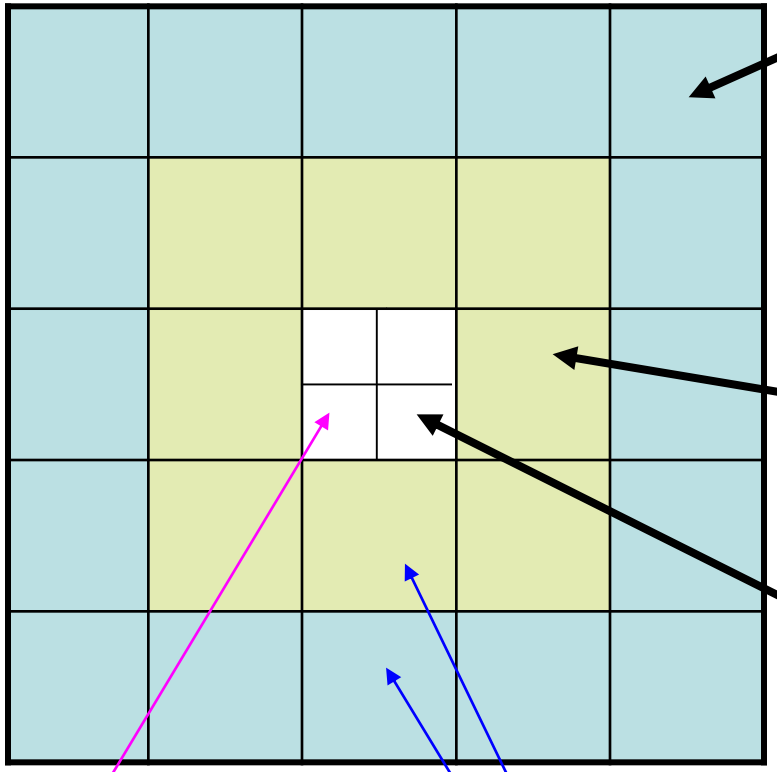
Layout of the setup



Picture of the ALPOM2 Setup



Hadron calorimeter



(20 mm Fe +10 mm Sc) x 34 layers

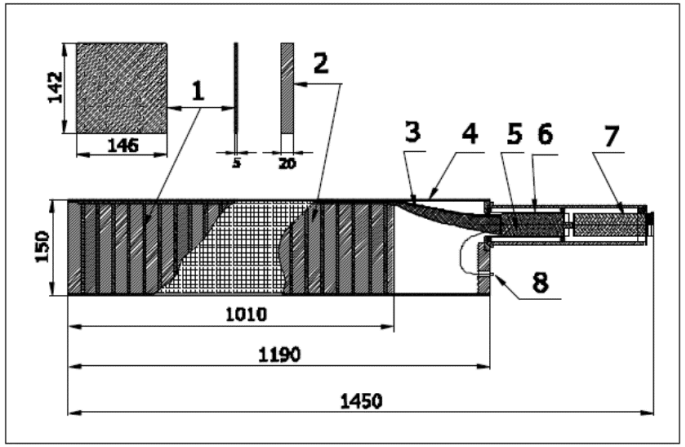
(10 mm Sc+10 mm Pb) x 18 layers +
(10 mm Sc +20 mm Fe) x 20 layers

20 mm Fe

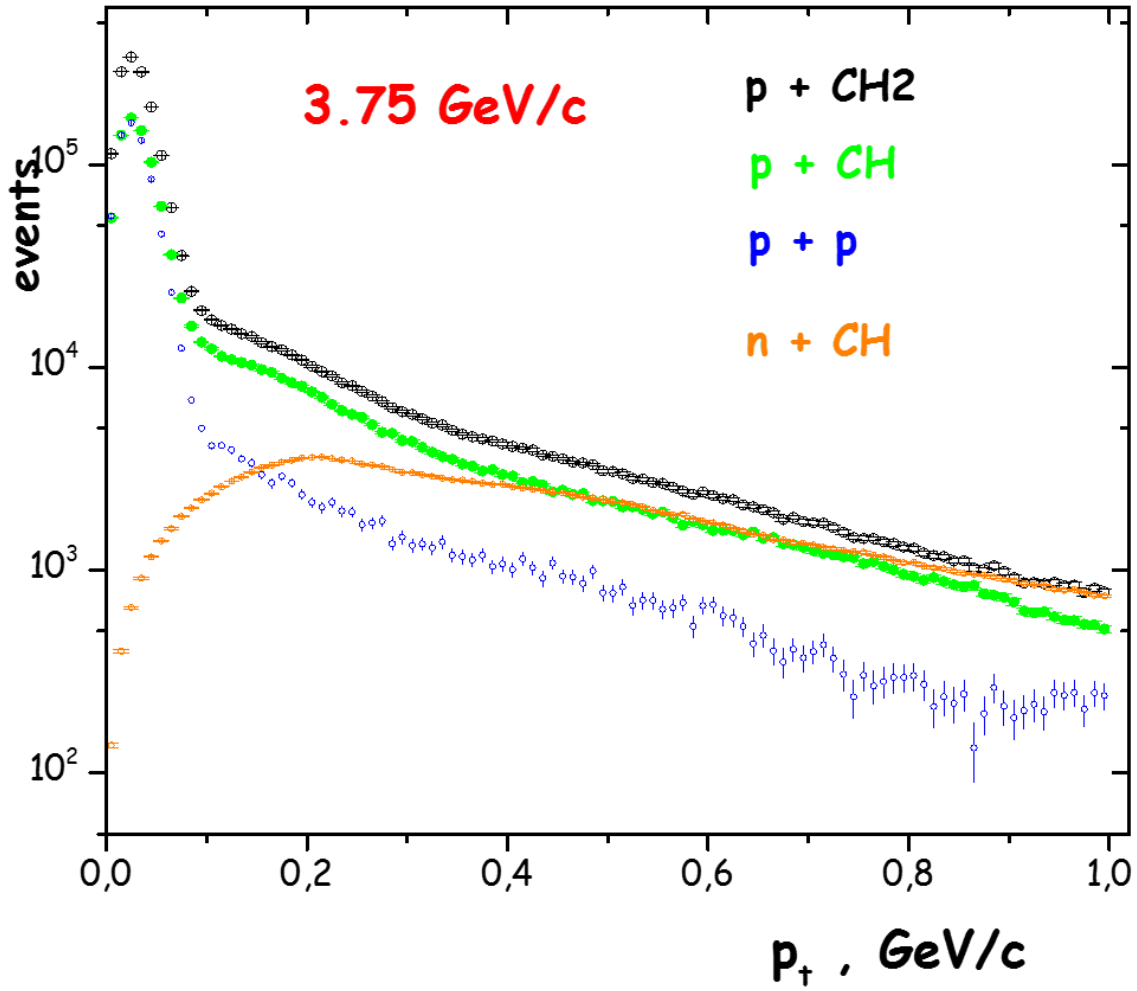
(10 mm Sc +10 mm Pb) x 50 layers

75 x 75 mm^2

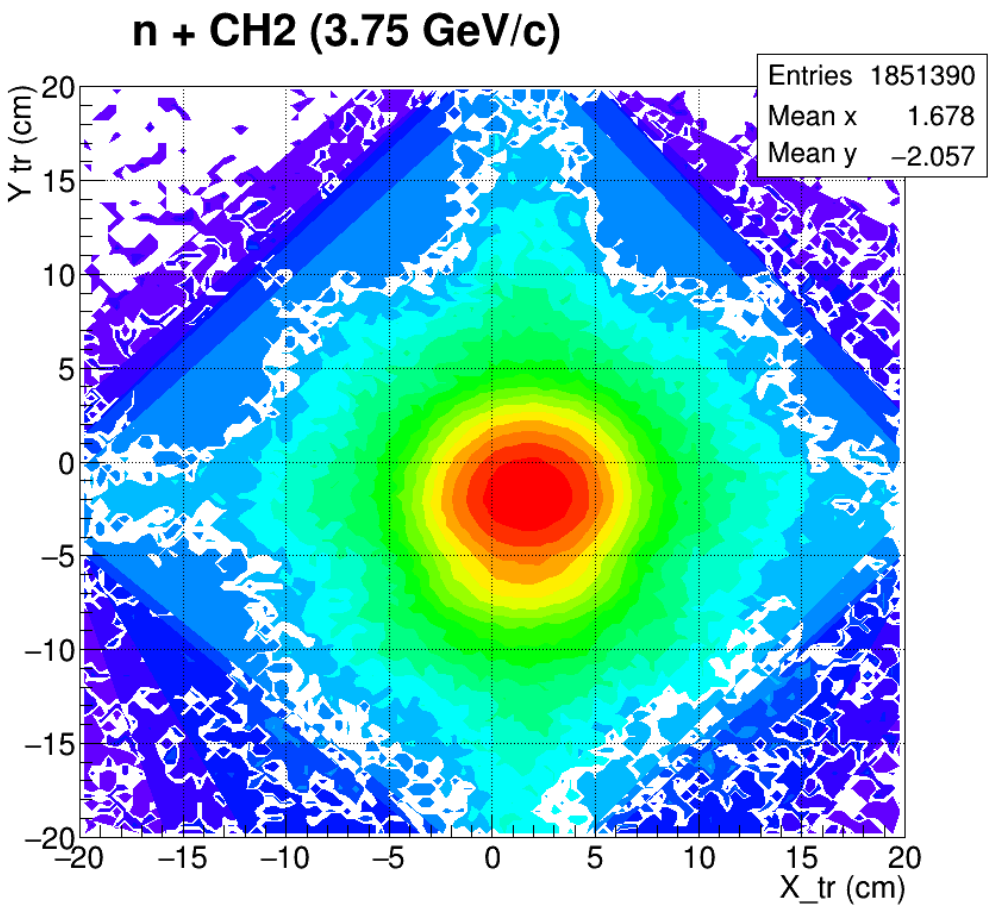
150 X 150 mm^2



target	Z/A	g/cm^3	L, cm	N_A /cm^3	GeV/c
CH2	0,57034	0,919	30 (40)	15.75	3,0; 3,75; 4,2
CH	0,53768	1.06	30	17.09	3,75
C	0,49955	1.68	20	16.8	3,75; 4,2
Cu	0,45636	8,96	4	16.36	3,75

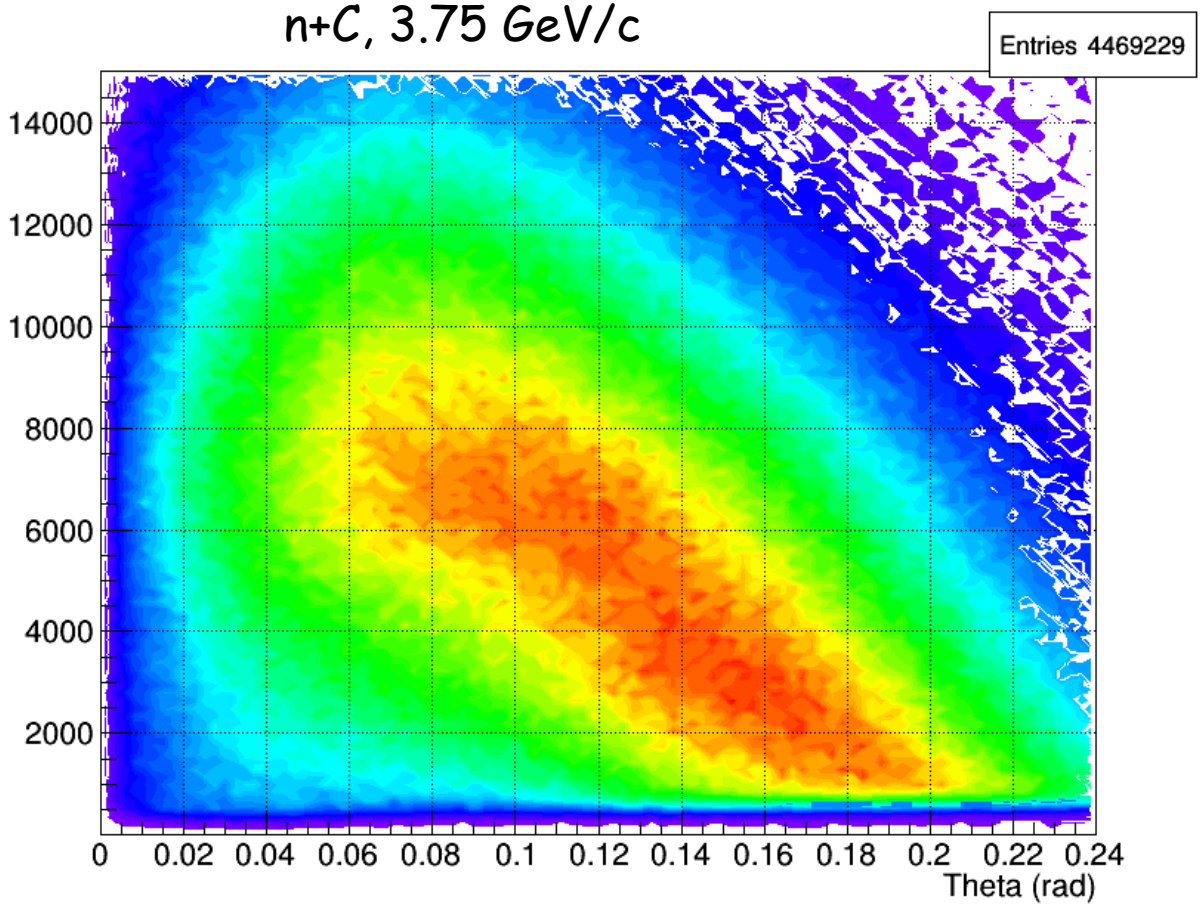


Neutron beam



At the target

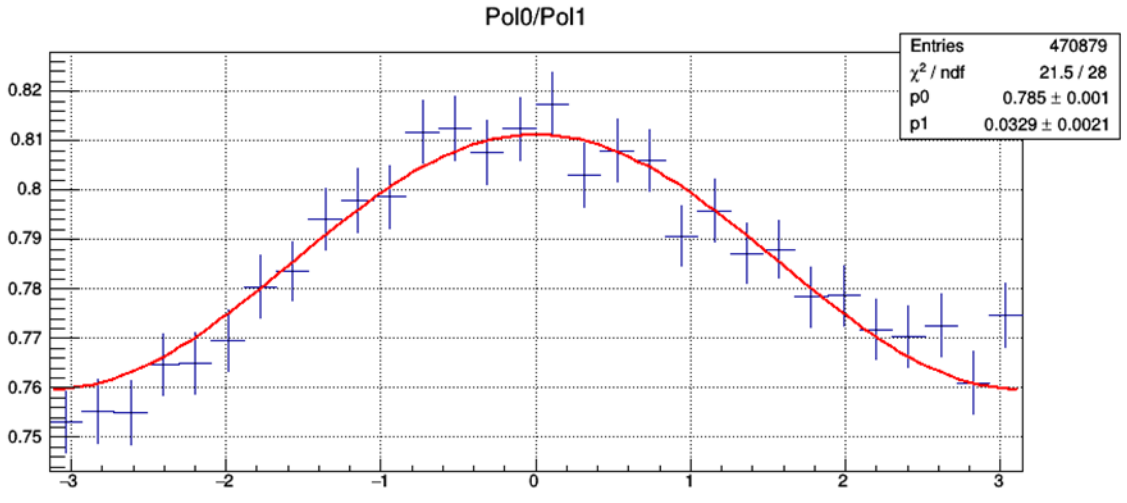
Hadcal, deposit energy
n+C, 3.75 GeV/c

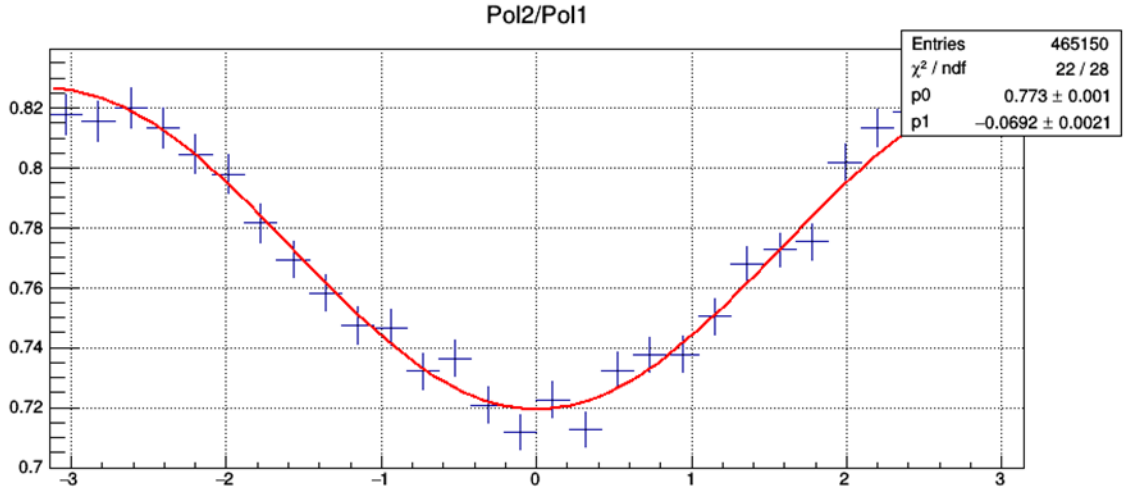


Scattering angle, rad

Measured asymmetries

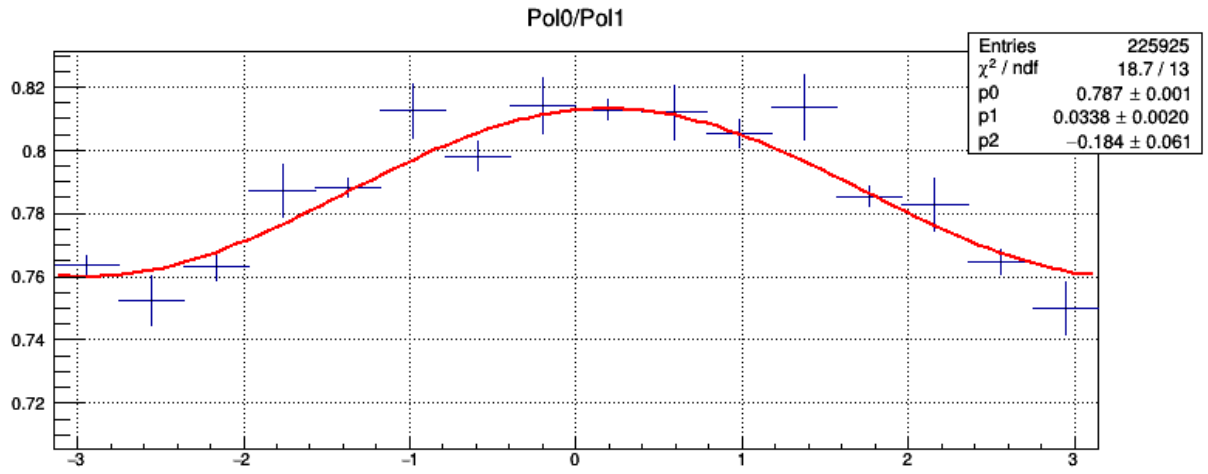
p+CH2, 3.0 GeV/c, tracks, scattering angles 0.03-0.24 rad

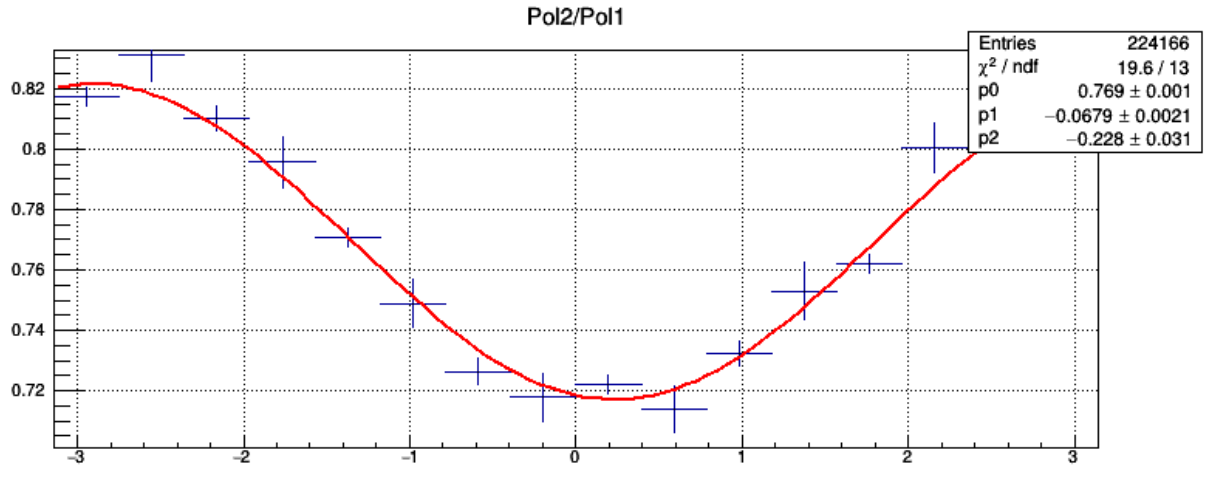




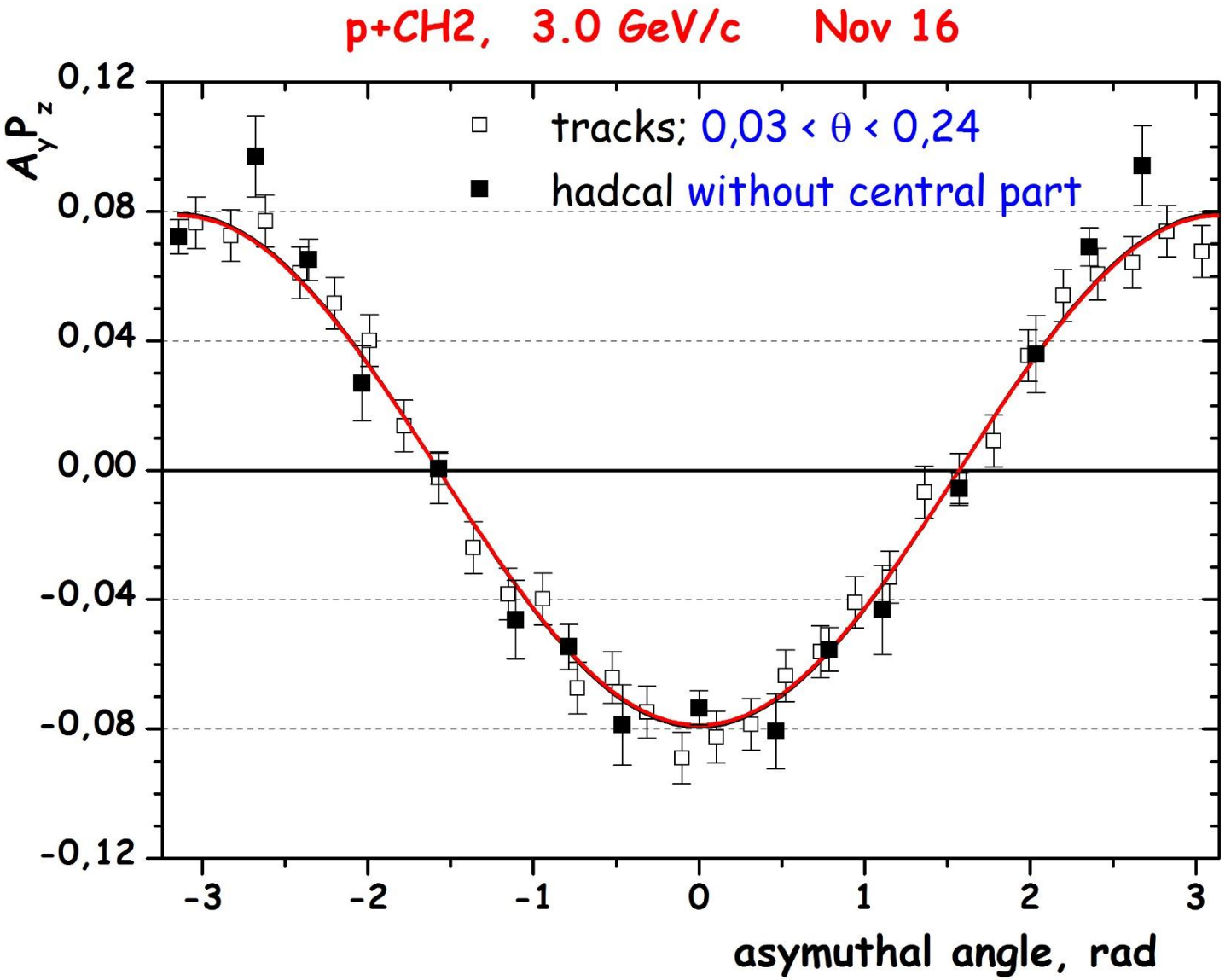
asymuthal angle, rad

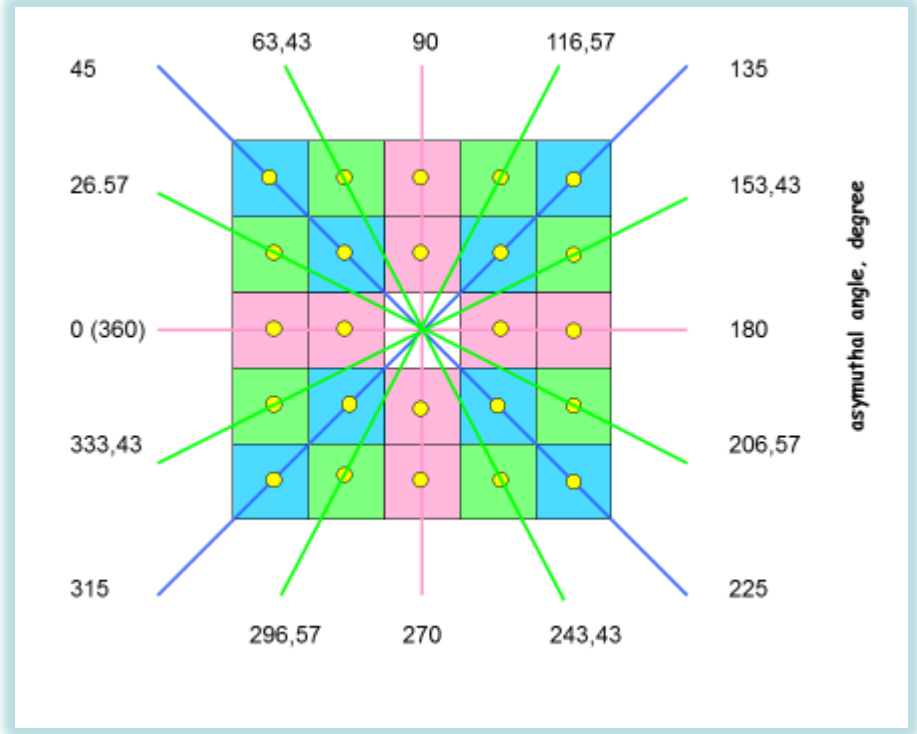
p+CH2, 3.0 GeV/c, hadcal, max amplitude without the central part

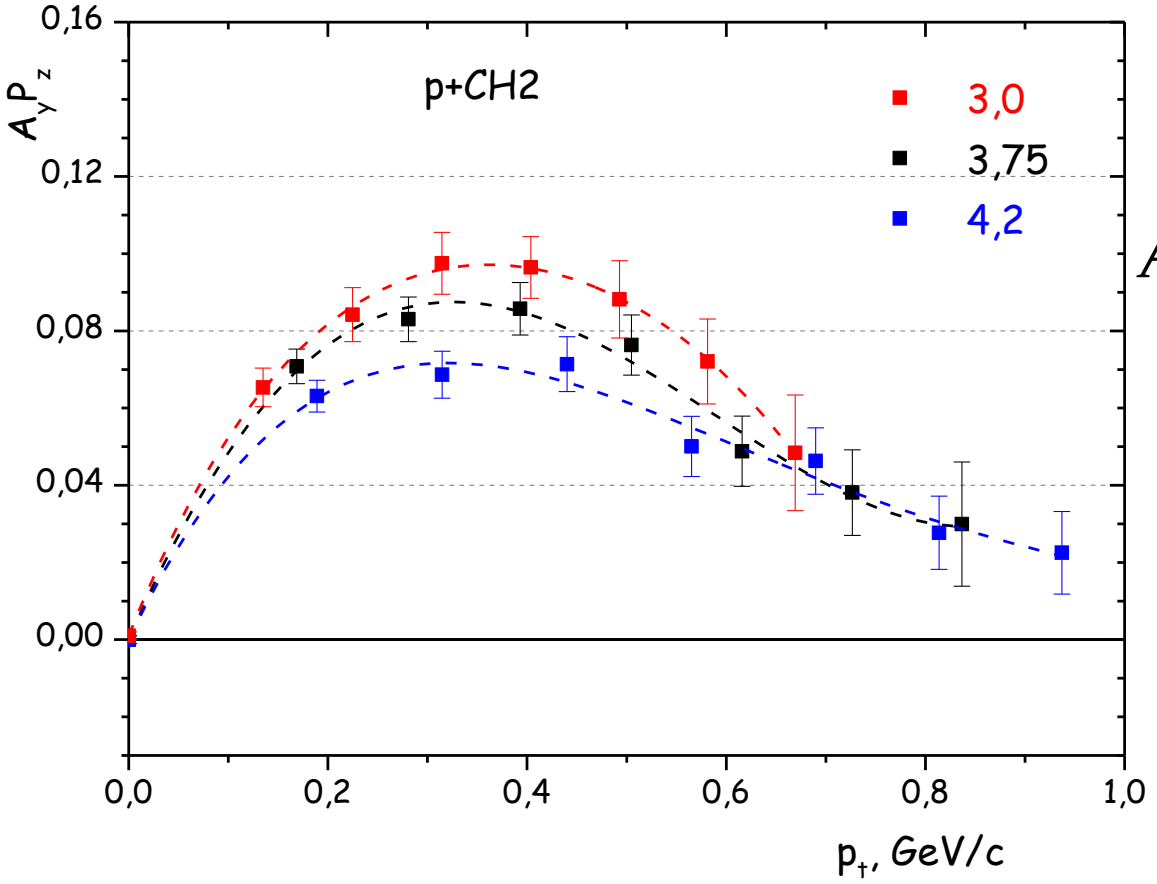




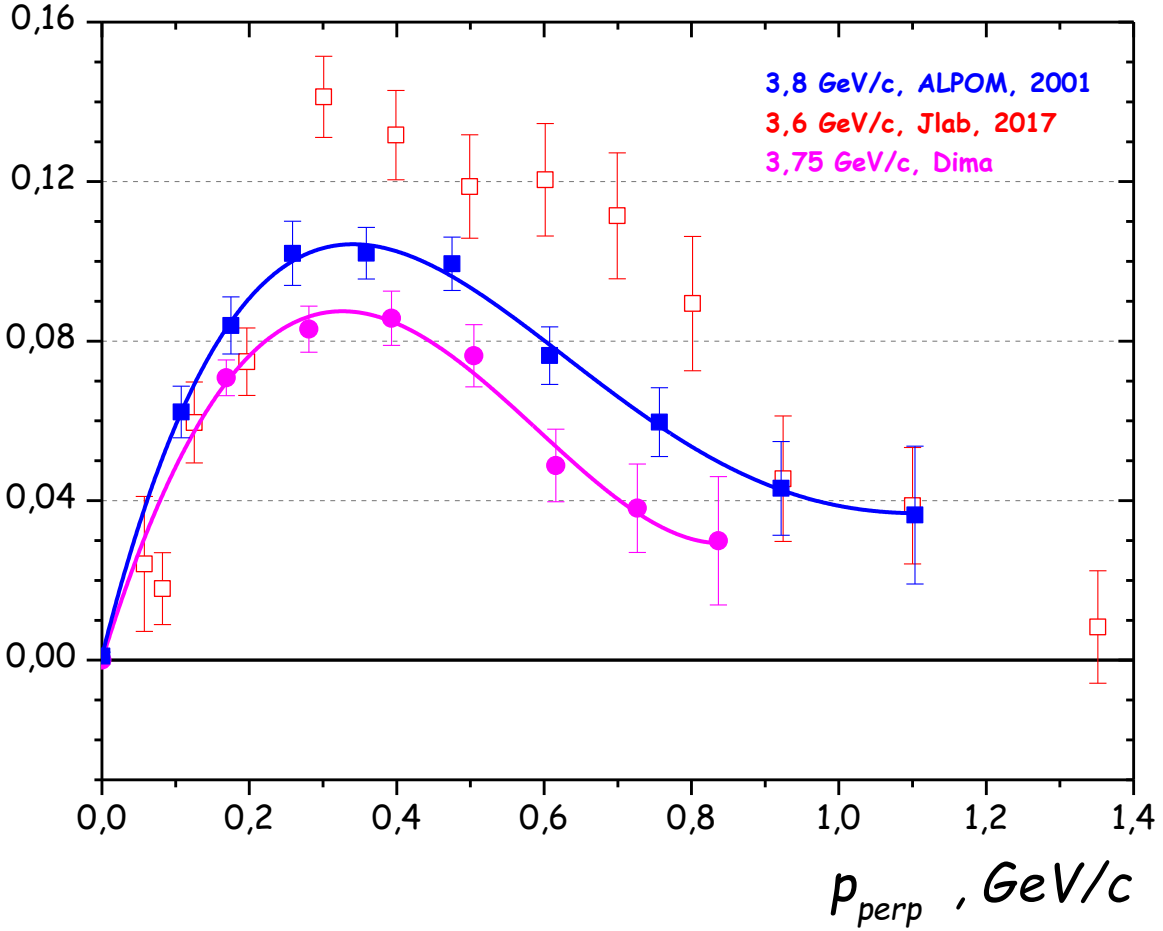
asymuthal angle, rad

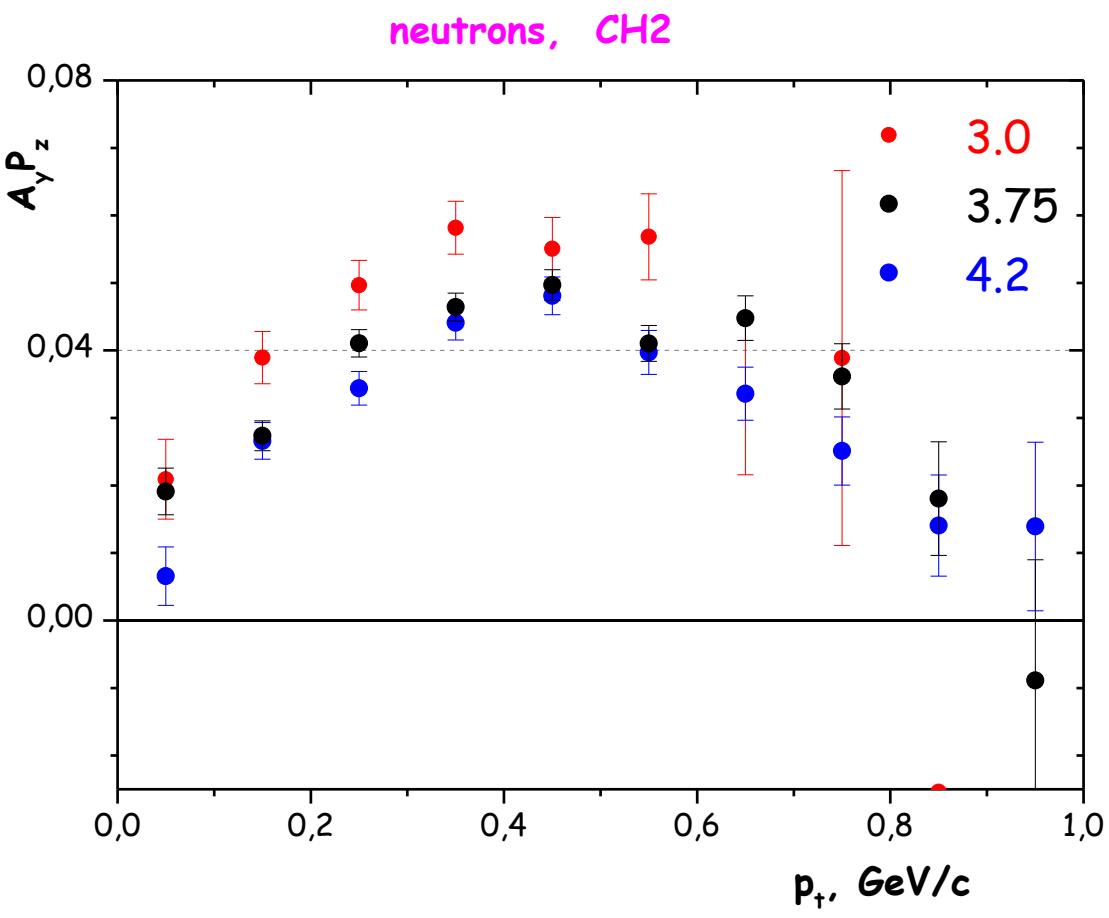

p+CH2, 3.0 GeV/c Nov 16
tracks; 0,03 < θ < 0,24
hadcal without central part
A P y z
0,12
0,08
0,04
0,00
-0,04
-0,08
-0,12
-3
-2
-1
0
1
2
3
asymuthal angle, rad

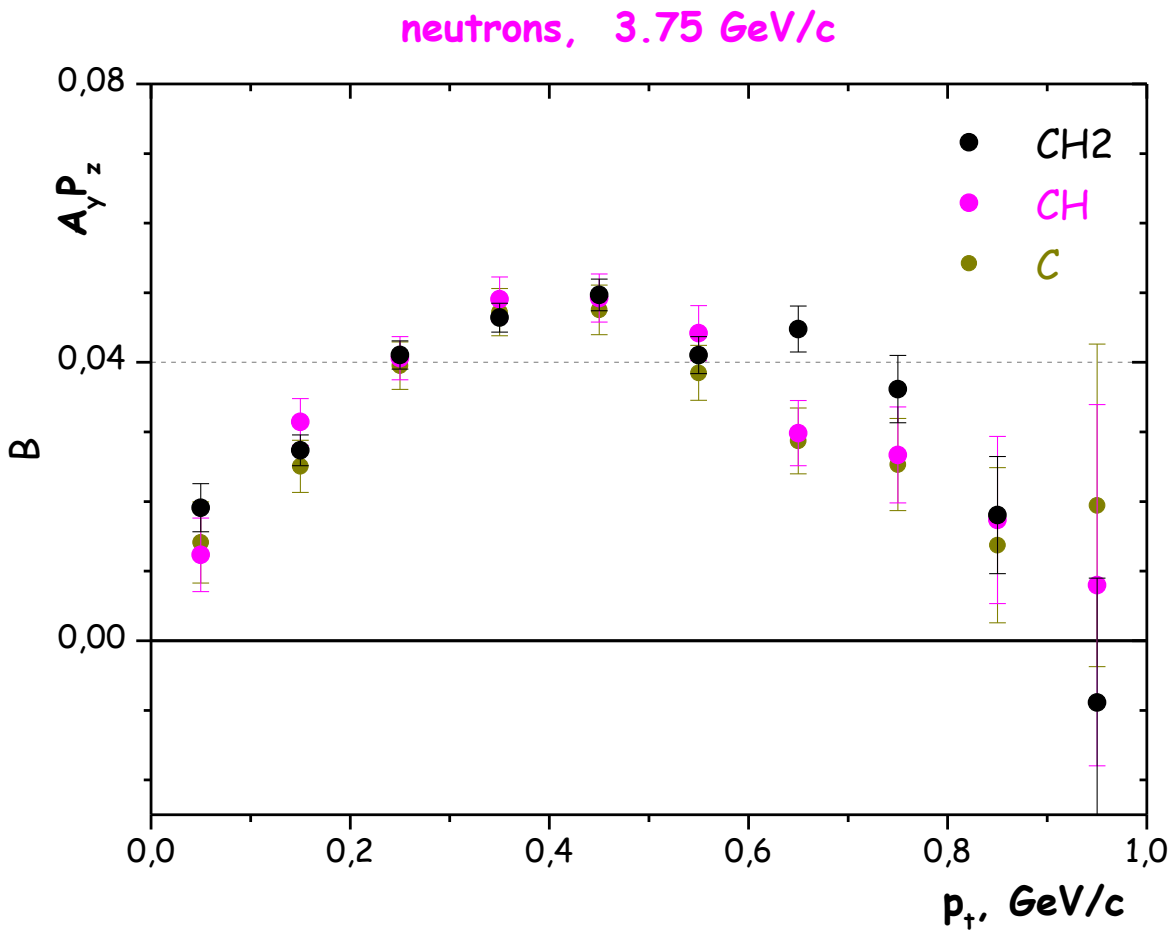

63,43
90
116,57
45
135
26.57
153,43
0 (360)
180
333,43
206,57
315
225
296,57
270
243,43
asymuthal angle, degree

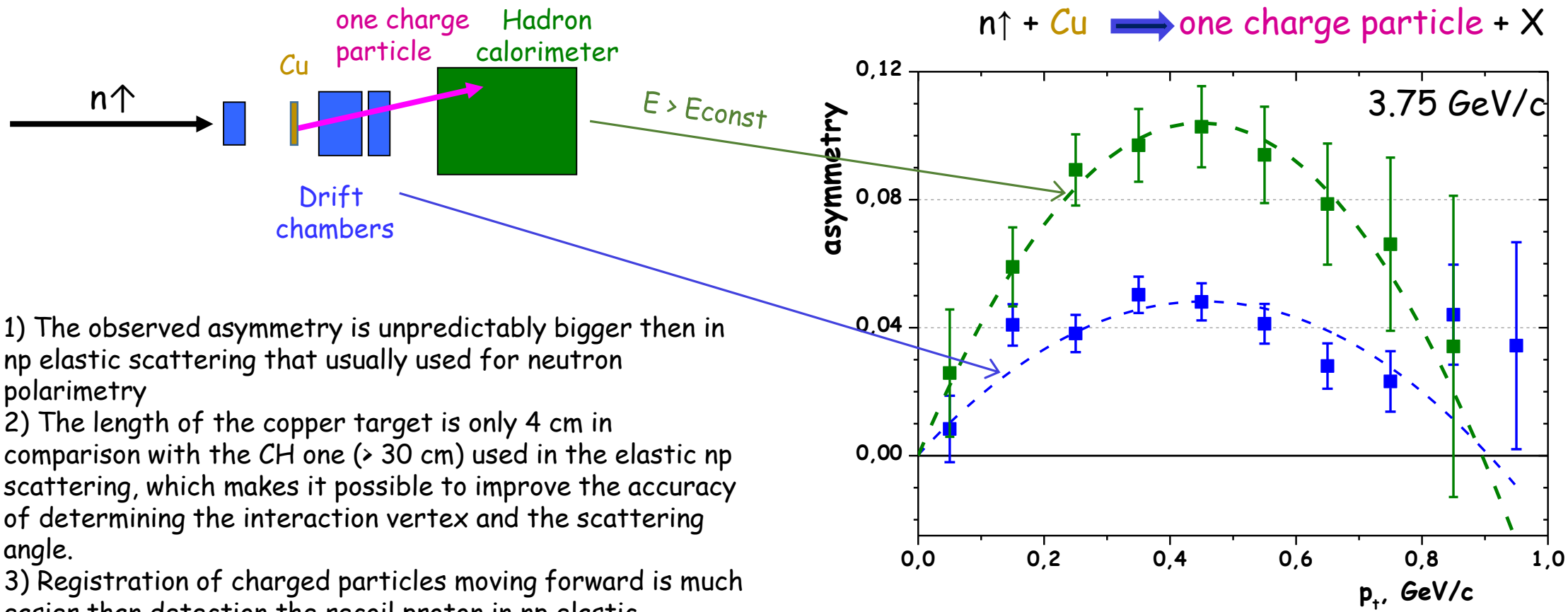

p+CH2
3,0
3,75
4,2
$A_y P_z$
0,16
0,12
0,08
0,04
0,00
0,0
0,2
0,4
0,6
0,8
1,0
p_t, GeV/c

A_y


3,8 GeV/c, ALPOM, 2001
3,6 GeV/c, Jlab, 2017
3,75 GeV/c, Dima
0,16
0,12
0,08
0,04
0,00
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
p_{perp} , GeV/c

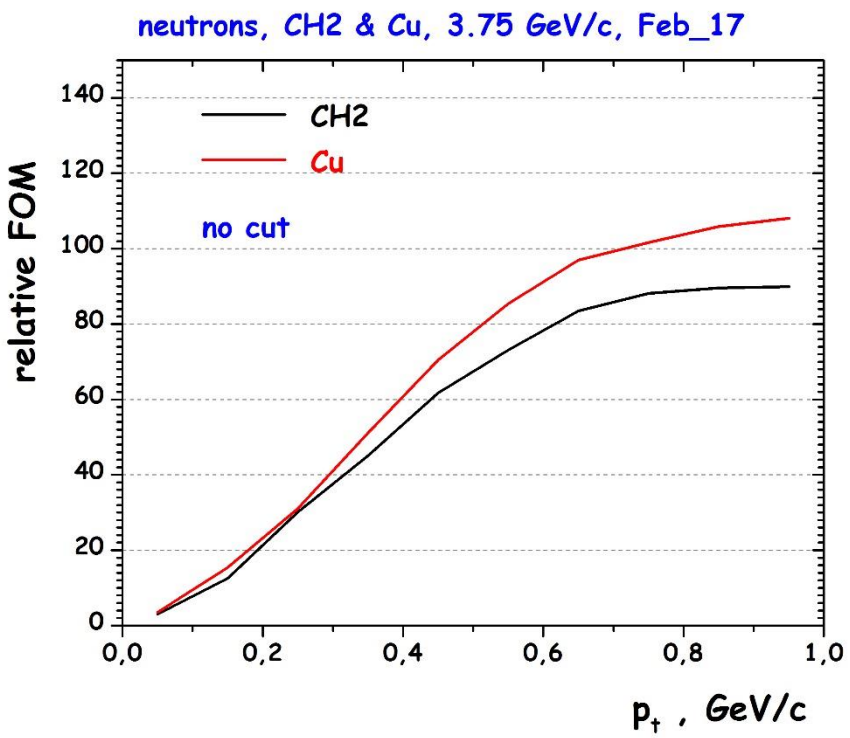

neutrons, CH2
0,08
0,04
0,00
$A_y P_z$
3.0
3.75
4.2
0,0
0,2
0,4
0,6
0,8
1,0
p_t, GeV/c

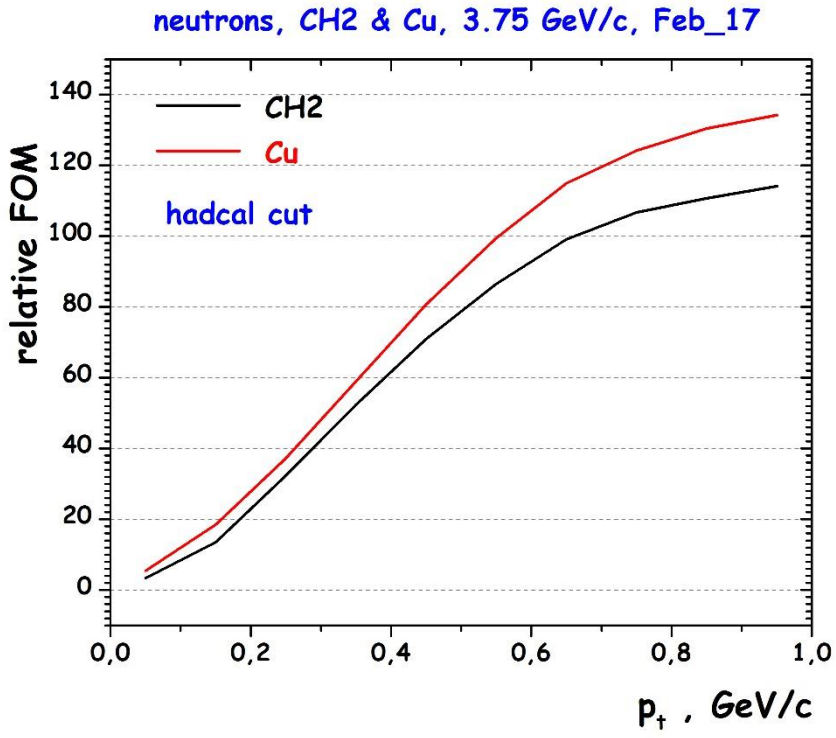

neutrons, 3.75 GeV/c
0,08
0,04
0,00
$A_y P_z$
B
CH2
CH
C
0,0
0,2
0,4
0,6
0,8
1,0
p_t, GeV/c



1) The observed asymmetry is unpredictably bigger then in np elastic scattering that usually used for neutron polarimetry
2) The length of the copper target is only 4 cm in comparison with the CH one (> 30 cm) used in the elastic np scattering, which makes it possible to improve the accuracy of determining the interaction vertex and the scattering angle.
3) Registration of charged particles moving forward is much easier than detection the recoil proton in np elastic scattering

The inverse reaction p+Cu (W) with detection neutron in forward direction by the hadron calorimeter can be used for measurement of the proton polarization at the NICA collider.





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CH	0,53768	1.06	30	17.09	3,75
C	0,49955	1.68	20	16.8	3,75; 4,2
Cu	0,45636	8,96	4	16.36	3,75

Conclusion

The ALPOM2 setup was designed to measure analyzing powers from different analyzer targets, for protons and neutrons. It includes a large size calorimeter to help eliminate multi-particle final states, and correspondingly increase the analyzing power. So far protons and neutrons of 3.0, 3.75 and 4.2 GeV/c momentum have been used. Polarized protons of up to 7.5 GeV/c should become available in the near future.

The proton data in the momentum range available at this point in time are in general agreement with data from various laboratories.

We now have, for the first time, analyzing power data for the charge exchange (pol)n+CH2->n+X reactions, as well as for C, CH (scintillator) and Cu analyzers. Based on the available (and ancient) **charge exchange analyzing power data for np->pn**, the expectation was that the same reaction channel for the complex target available (C, CH, CH2 and Cu) would be significantly larger than for the forward process, np->np. The new data fully support this expectation.

The consistency of these data clearly indicates that the experimental setup is adapted to the challenge, that the beam polarization, intensity and stability are appropriate for this

All data shown are preliminary

New proposal in Jlab has been accepted

PR12-17-004

Scientific Rating: A-

Recommendation: Approve for Five Days

Title: Measurement of the Ratio G^n_E/G^n_M by the Double-polarized ^{2}H(e,e'n) Reaction

Spokespersons: J. Annand (Contact), V. Bellini, M. Kohl, N. Psikunov, B. Sawatzky, B. Wojtsekhowski

Issues: The case for polarimetry via np→pn has recently been strengthened significantly by preliminary data from JINR/Dubna showing a sizable analyzing power for n+A→p+X. Since most of the equipment is standard Hall-A equipment and the polarimeter mainly consists of a simple copper analyzer, no technical issues are foreseen. The TAC report raises the issue of a high DAQ data volume, which has been addressed by the collaboration and does not appear to be a reason for concern. Running consecutively with E12-09-019 appears to be a must.

Workshop on "Proton and Neutron Polarimetry in the GeV region"
was organized in September by French collaborators and partly
supported in the framework of JINR-IN2P3 cooperation

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

Thank you for your attension!

Tuning proton and neutron beams on the setup
7- 8 energies - 1-2 days

Neutron analyzing powers

3.75 GeV/c

protons	Empty, CH2, CH
neutrons	CH2, CH

3.0 GeV/c

> 3.75 GeV/c ?

Expected ~ 40*10^3 per cycle

Needed > 10^7 ~ $\Delta A/A=0.035$

Proton analyzing powers

Only proton & CH2

deuteron momentum	proton momentum
10.6 GeV/c	5.3 GeV/c
11.2 GeV/c	6.5 GeV/c
13.0 GeV/c	6.5 GeV/c
13.0 GeV/c	7.5 GeV/c

Analyzing powers for polarized neutrons exist only for thin hydrogen targets. Cross section and analyzing powers for np, for both elastic scattering and charge exchange are known up to 29 GeV/c. No data exist for thick analyzers. During two beam runs in 2016 and 2017 years, the analyzing powers of protons and neutrons scattering on CH2, CH, C and Cu targets were measured at the nucleon momentum from 3.0 to 4.2 GeV/c with the ALPOM2 setup at the Nuclotron accelerator. The data for polarized neutron beam are obtained for the first time, thanks to the unique polarized deuteron beam that is presently available up to 13 GeV/c. The measurement of the angular dependence of Ay for the neutron is essential to the continuation of neutron form factor measurements to the highest possible transferred momentum-Q2 at JLab. The inverse reaction p+Cu(W) with detection of neutron in forward direction by the hadron calorimeter can be used for measurement of the proton polarization at the NICA collider.

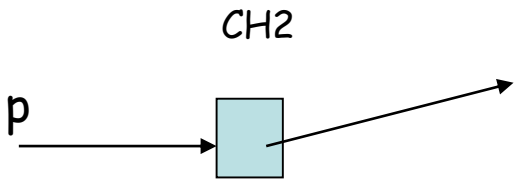
$$F^2 = \int_\theta \varepsilon(\theta) A_y^2(\theta) d\theta$$

$$\Delta P_y = \sqrt{\frac{2}{N_{inc} F^2}}$$

Proton polarimetry

p + C(CH2) -> charged particle + X

ALPOM 2001



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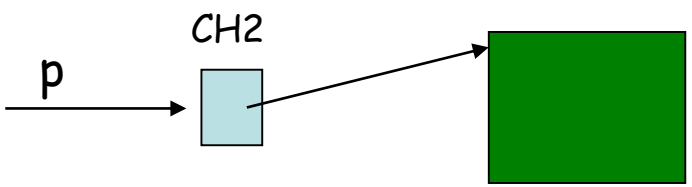
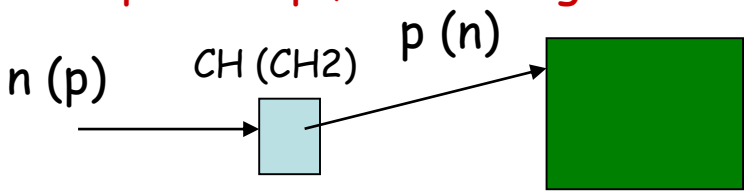


Neutron polarimetry

n + p -> n + p , CH - target



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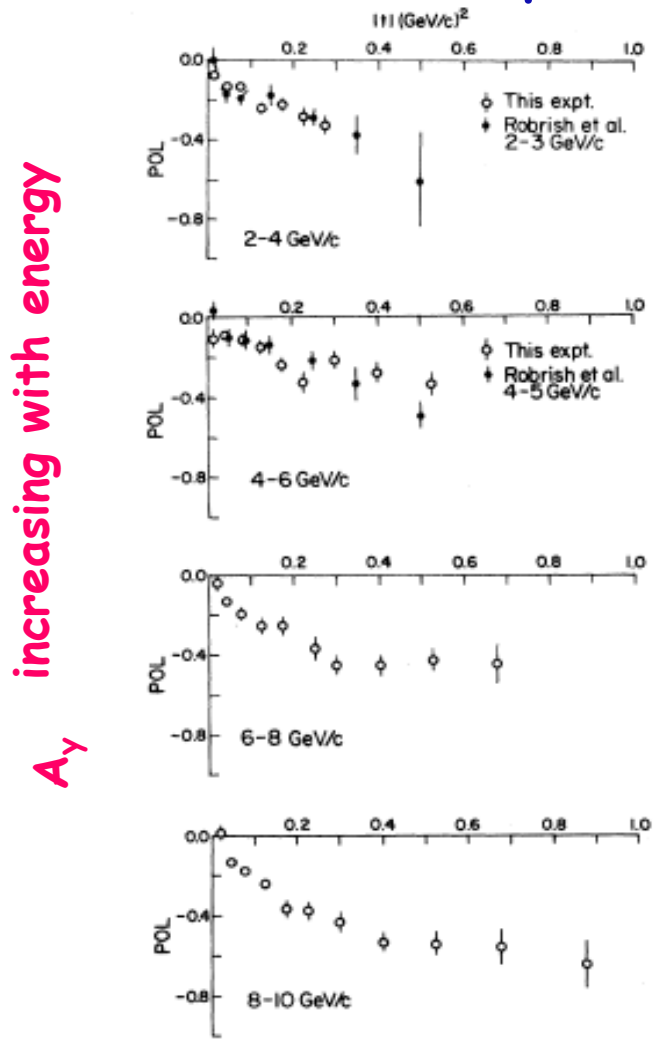
np -> pn



increasing with energy

A_y

New suggestion: n + p -> p + n

Charge exchange reaction

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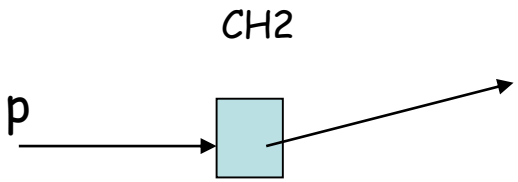

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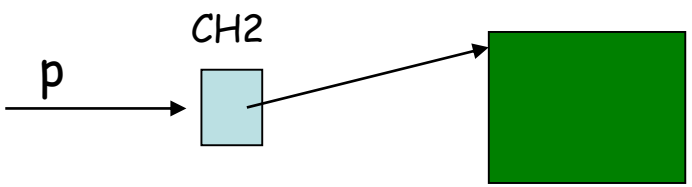

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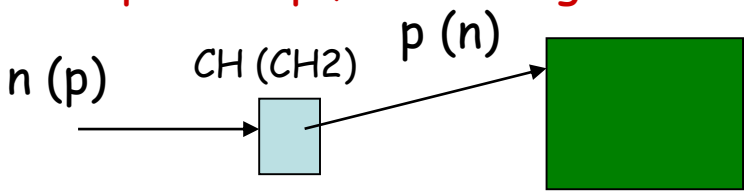

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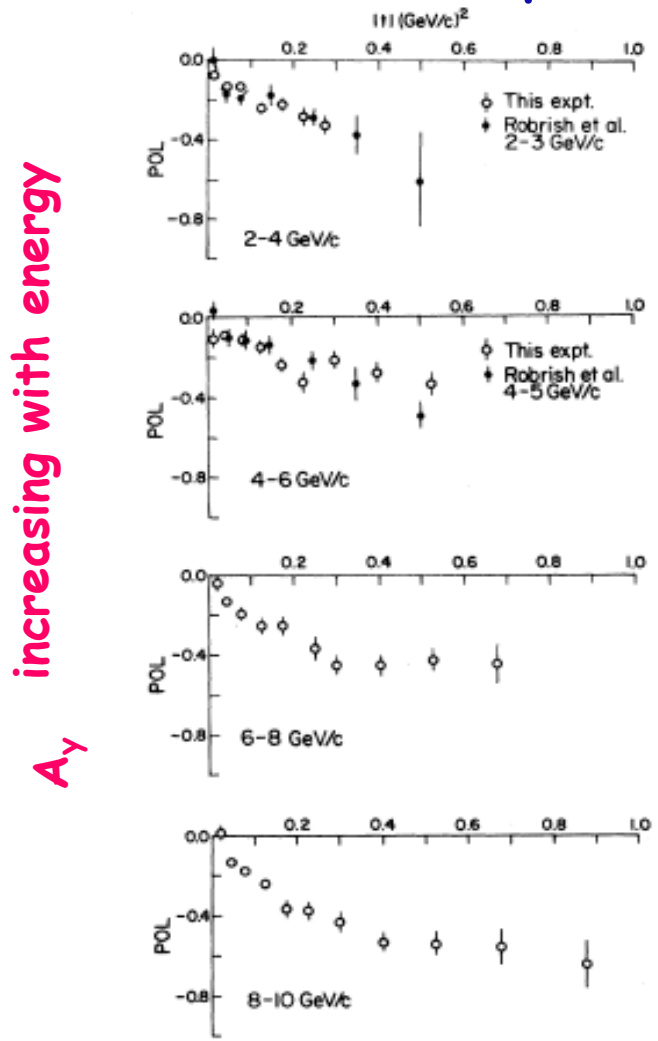

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