Measurement of analyzing powers for neutrons scattering on CH2, CH, C and Cu targets at the momenta from 3.0 to 4.2 GeV/c

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

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

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

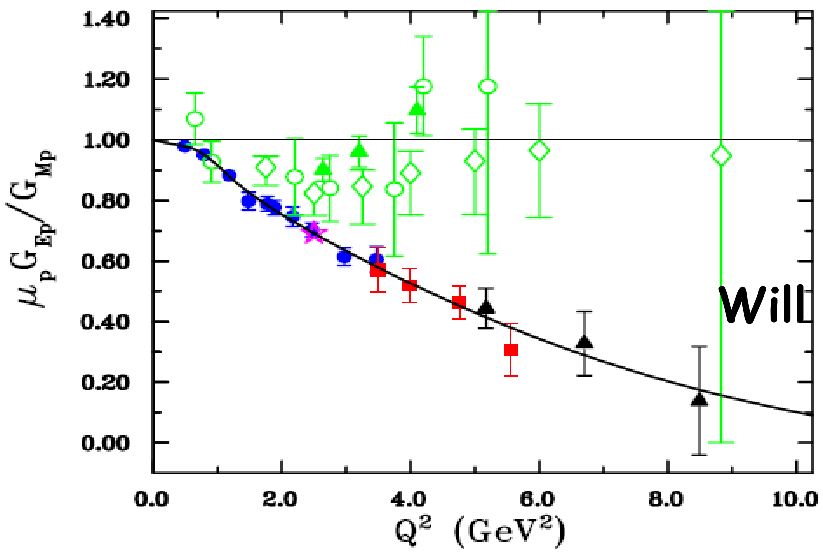
D. Marchand, Y. Wang

IPN Orsay, 91406 ORSAY cedex, France

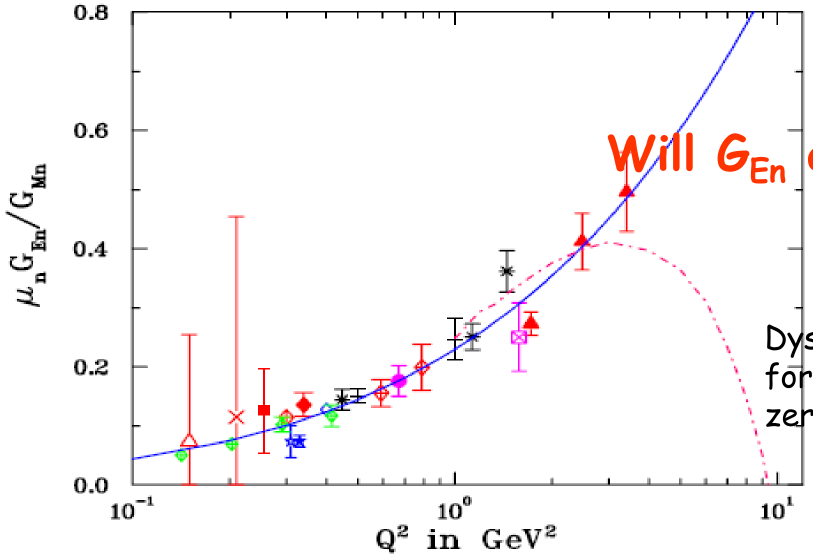
J. R.M. Annand, K. Hamilton, R. Montgomery

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

Nucleon formfactors



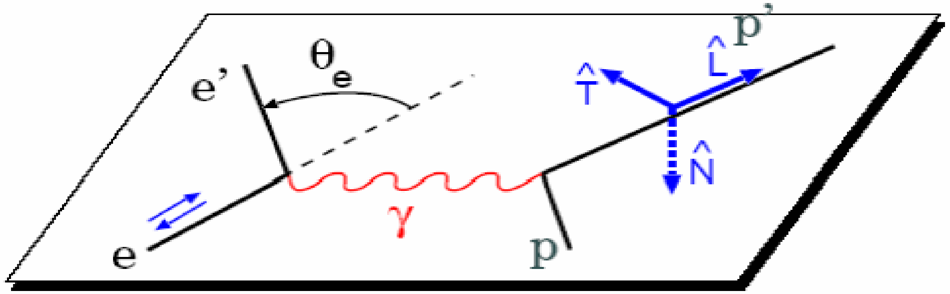
Will G_{Ep} become zero?



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

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

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

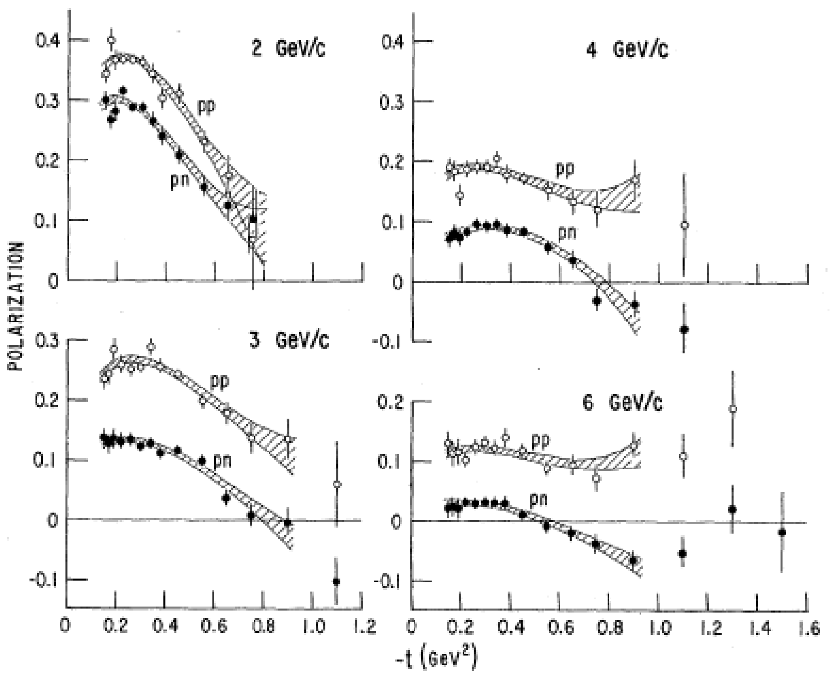
No error contributions from analyzing power and beam polarization measurements

Neutron polarimetry

pp -> pp
pd -> pn + (p)
Phys. Rev. Lett 35 (1975) 632

A_y

decreasing with energy

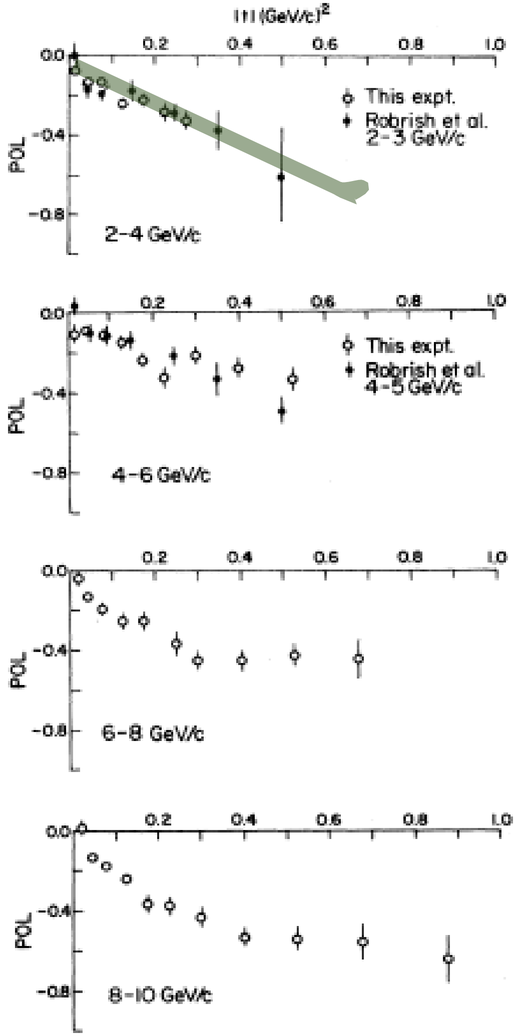


The existing data for A_y in np elastic scattering indicate that the analyzing power decreases faster than the pp analyzing power, becoming very small, then negative around 6 GeV/c neutron momentum.

Phys. Rev. Lett 30 (1973) 1183

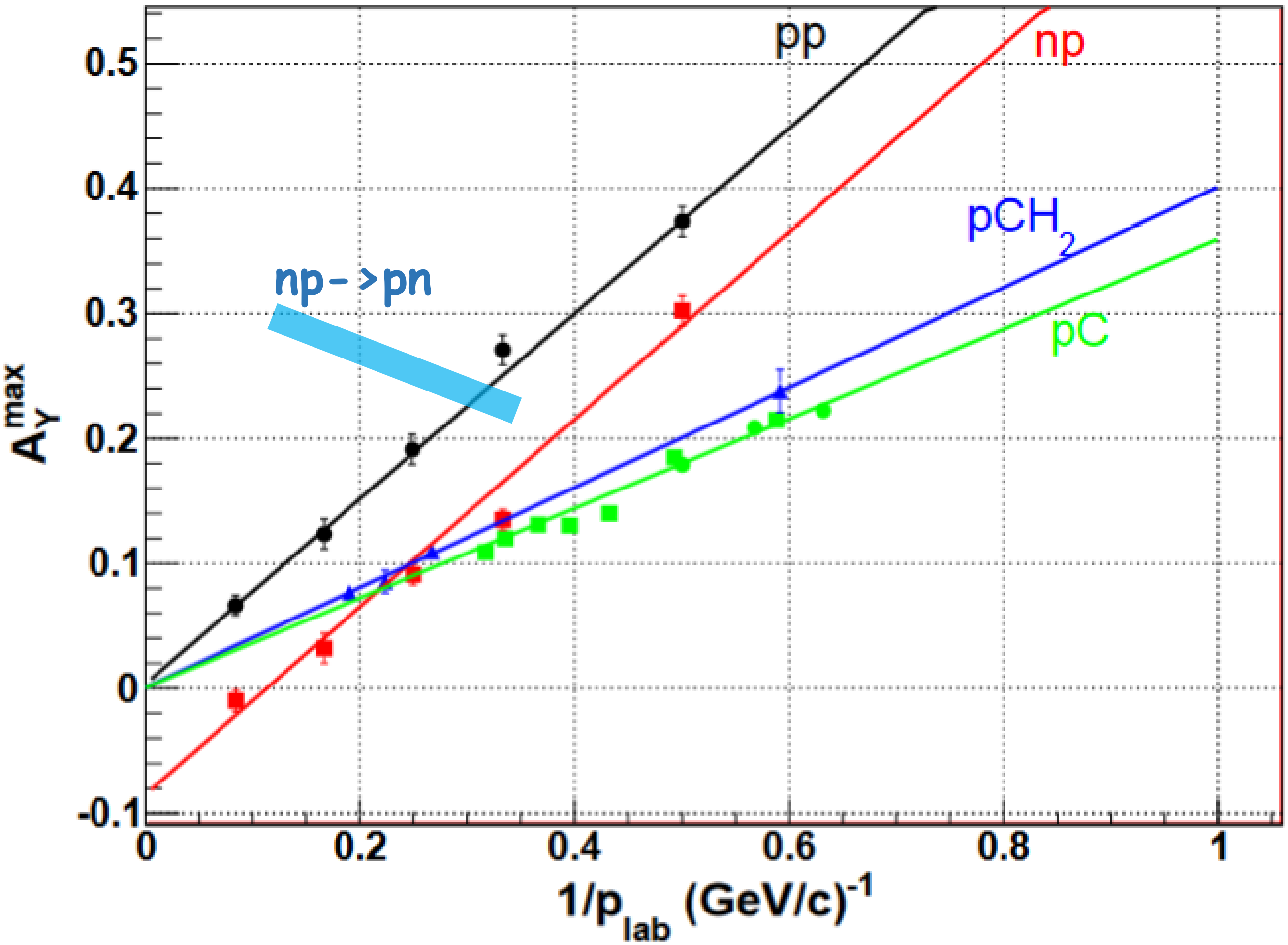
np -> pn

A_y increasing with energy



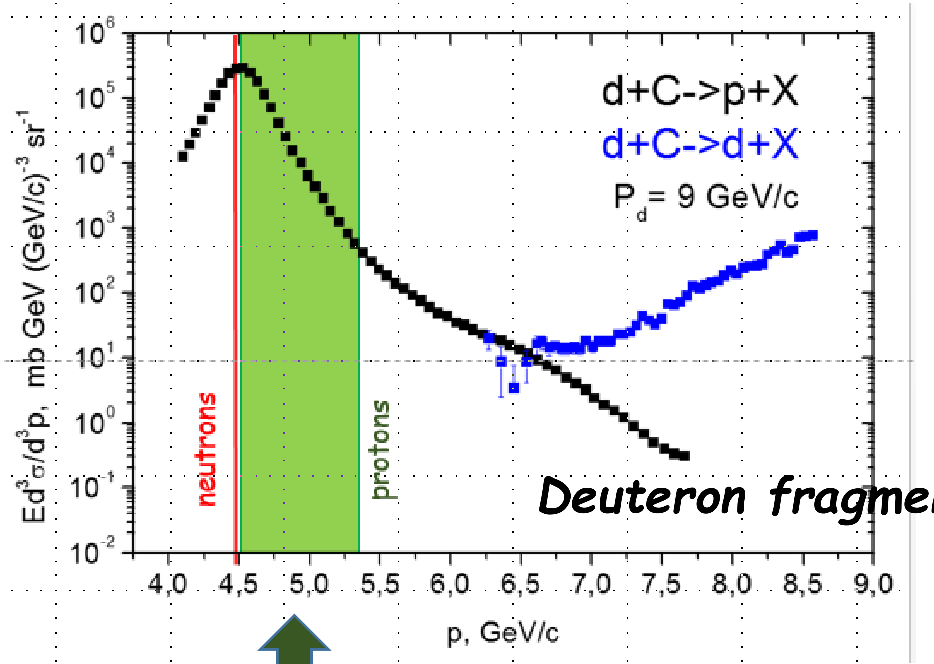
Charge exchange reaction

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



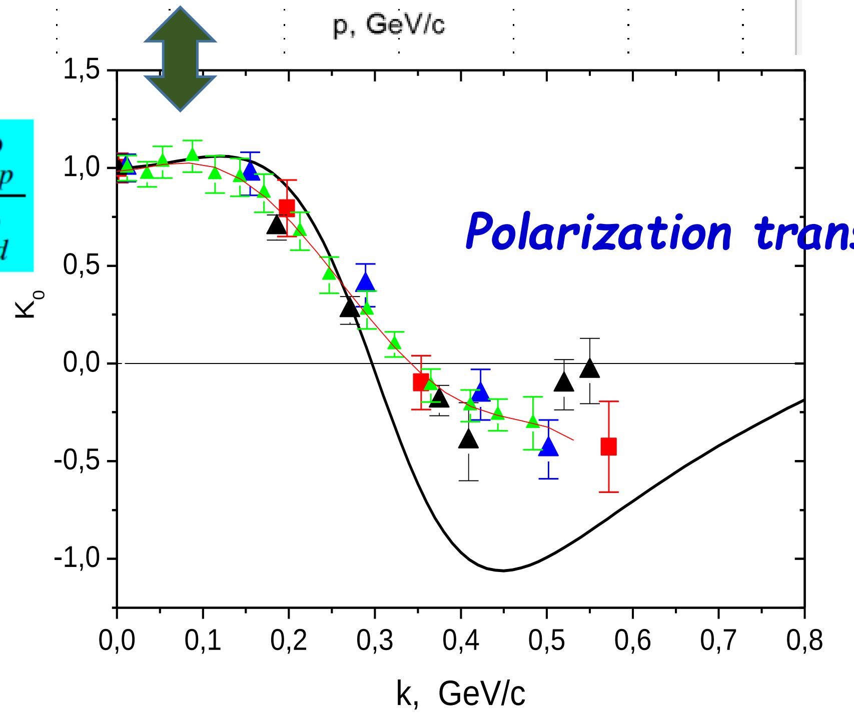
Black circles: ANL d(p,p)n data [29, 30]; black line: linear fit. Red squares: ANL d(p,n)p data [29, 30]; red line: linear fit. Blue triangles [25]: p+ CH2→charged+X; blue line: linear fit [25]. Green squares [31] and circles [32]: p+ C→charged+X; green line: linear fit [25].

Polarized proton (neutron) beam

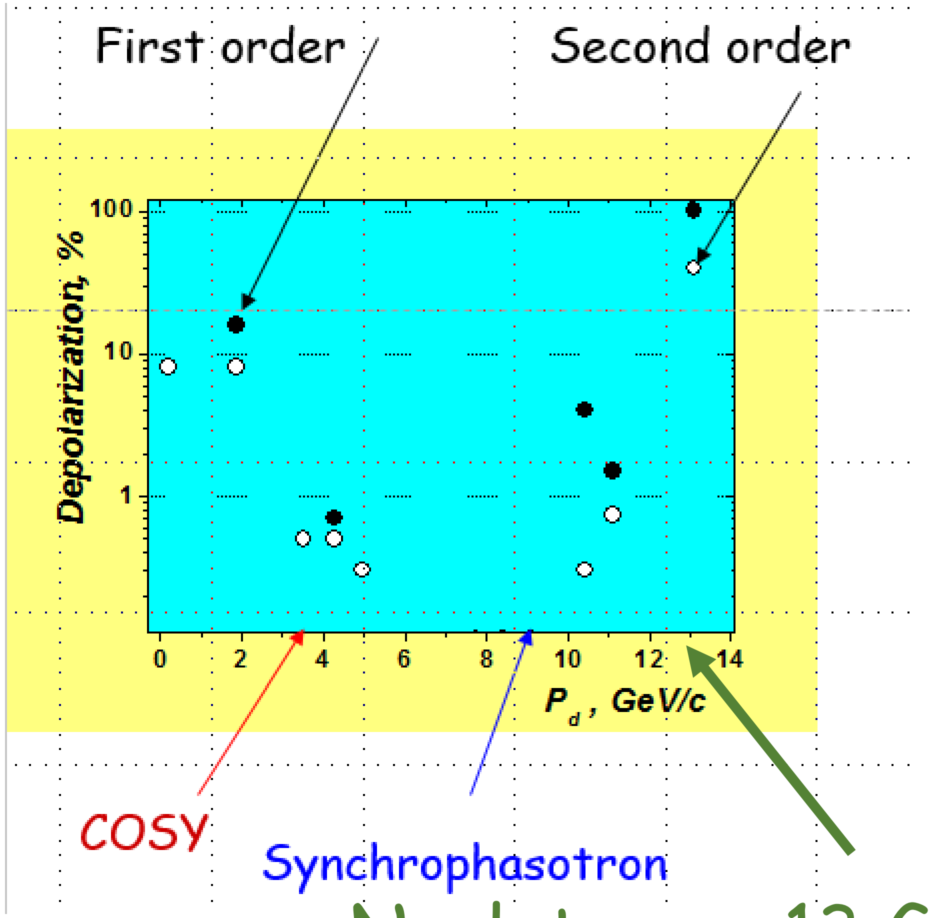


Deuteron fragmentation

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

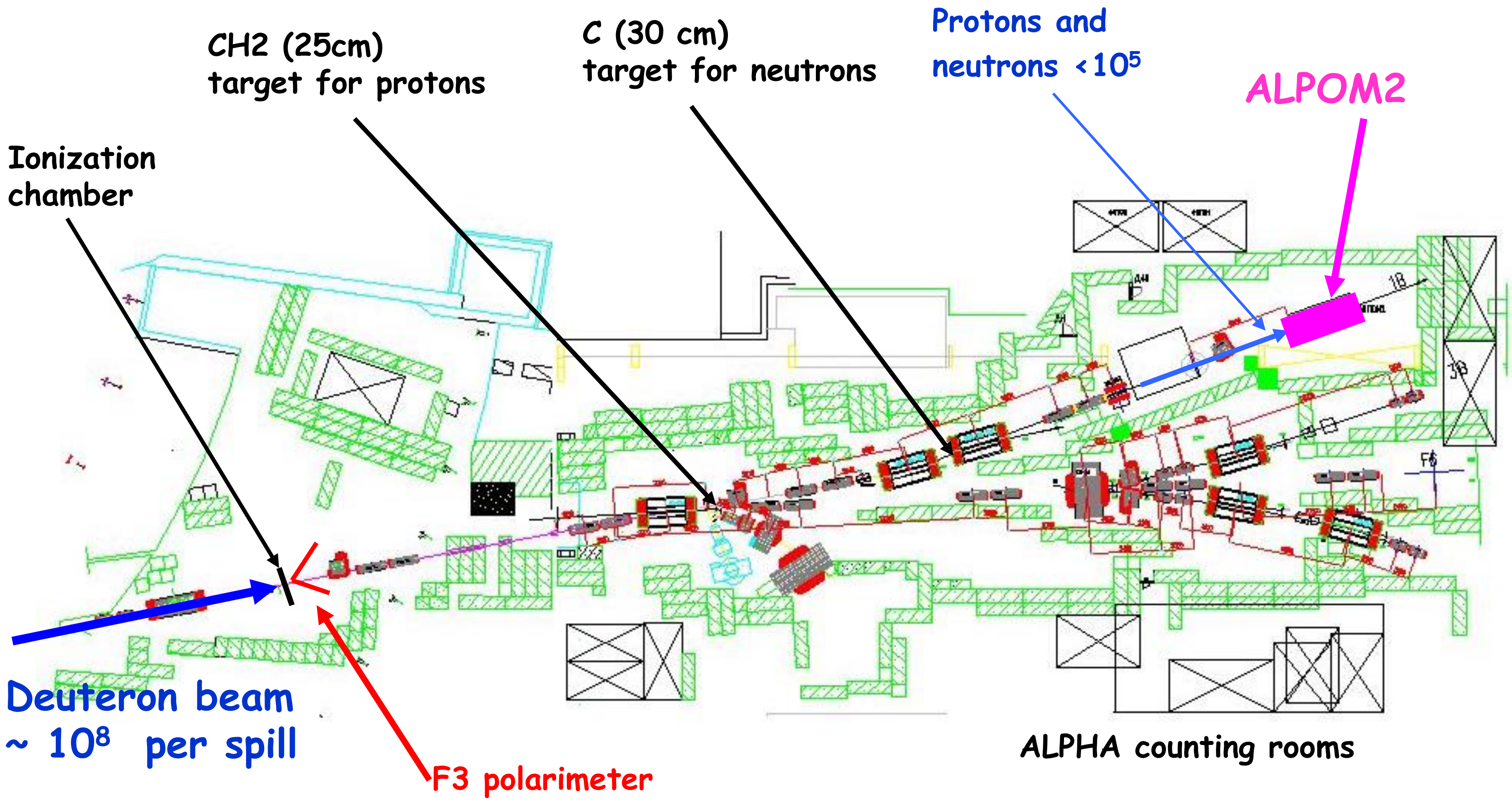


Polarization transfer



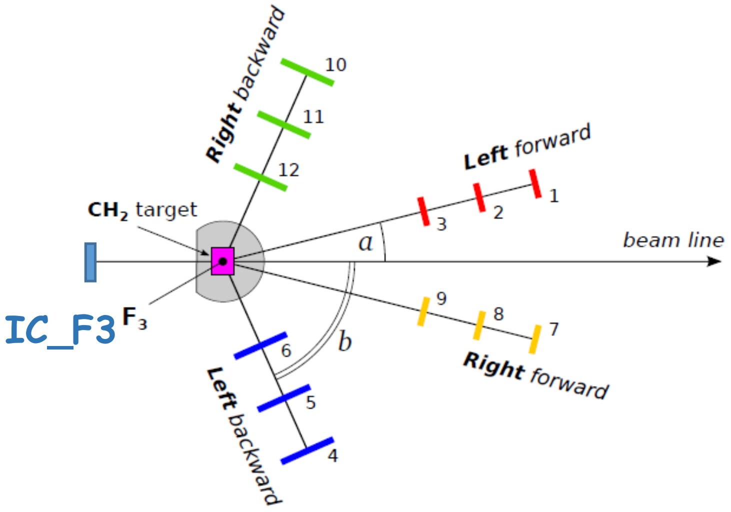
Nuclotron, ~13 GeV/c
neutrons, 6.5 GeV/c
protons, upto 7.5 GeV/c

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

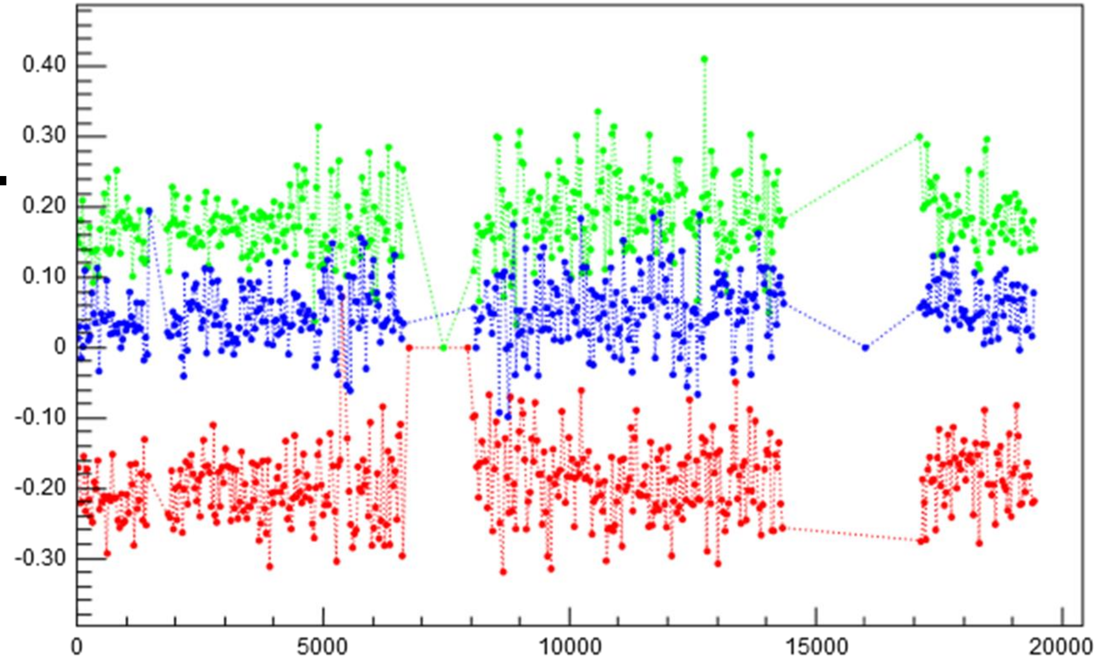
Beam polarization measurements



About 5 hours

each point corresponds to one spill.

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



Time, s

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

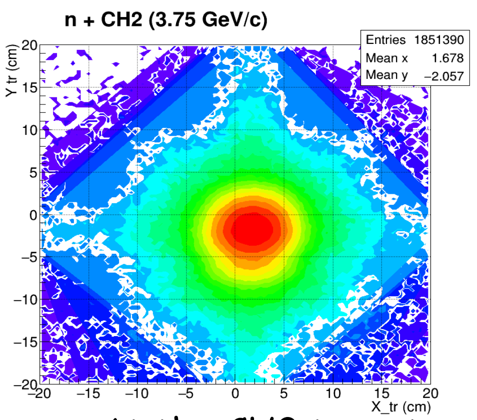
I.Sitnik, 2018

Proton polarization Nov 2016 is (-0.302, +0.590).

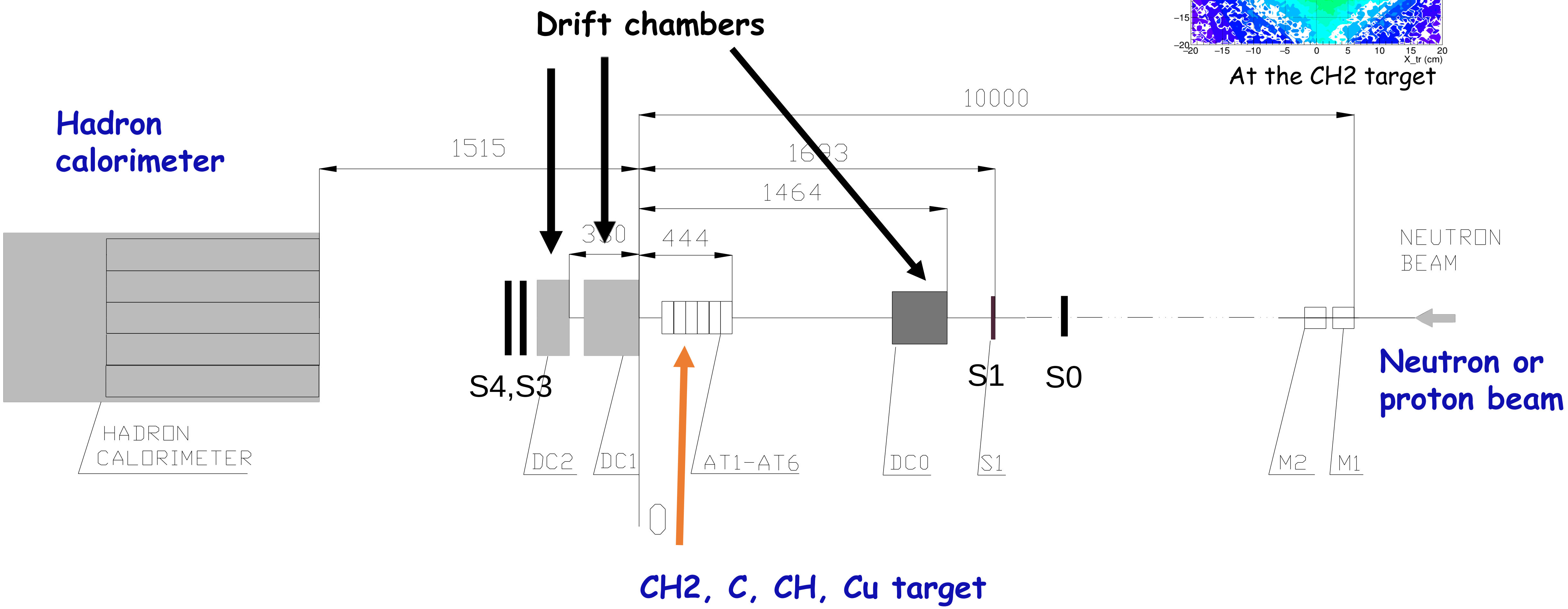
Feb 2017 is (-0.434, +0.525)

MFT - off	WFT 1 → 4	2,3,4	-2/3	0	ALPOM-2 experiment
MFT 3 → 4	SFT 2 → 6	1,6	+1	+1	

Layout of the setup



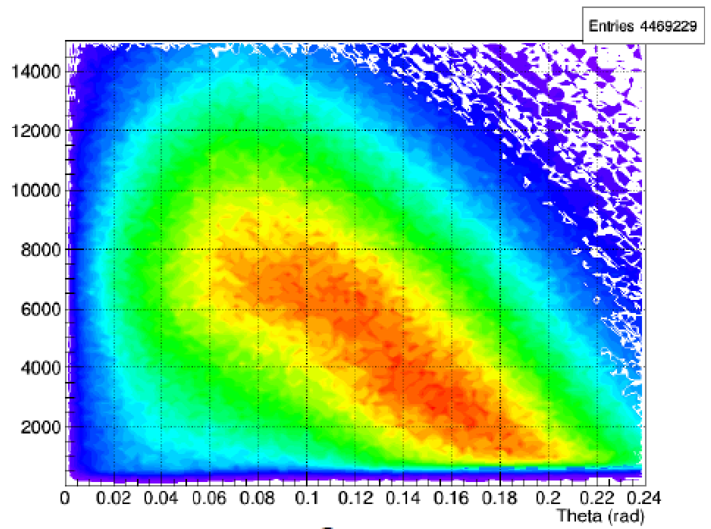
At the CH2 target



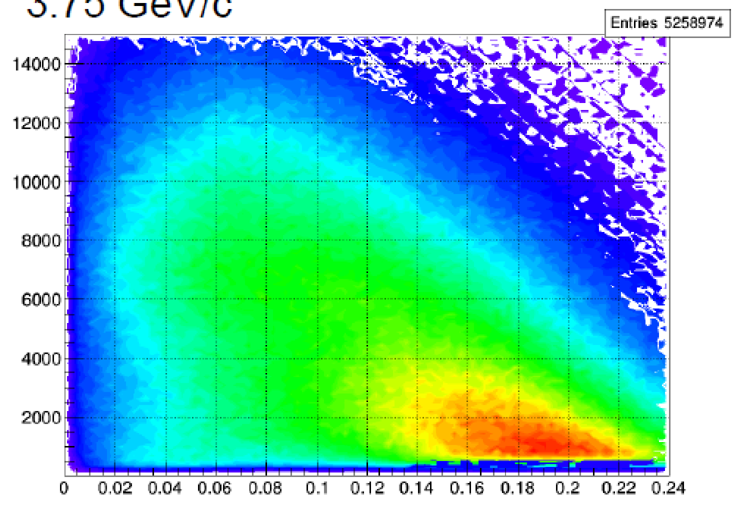
Energy deposit measurements in the hadron calorimeter, 3.75 GeV/c

energy deposit

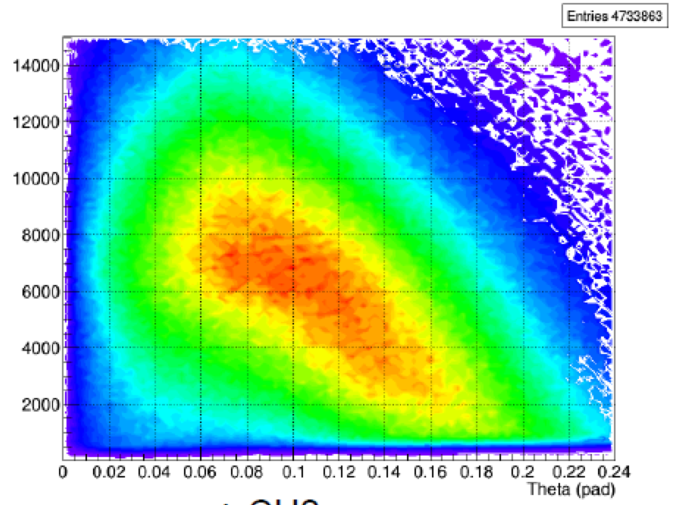
3.75 GeV/c



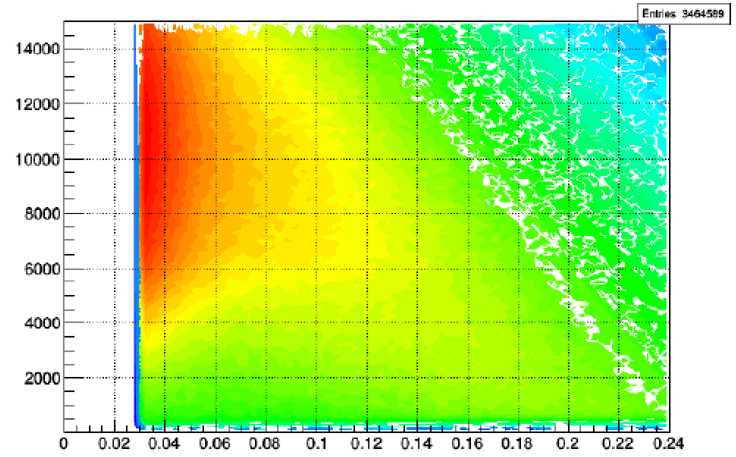
n + C



n + Cu



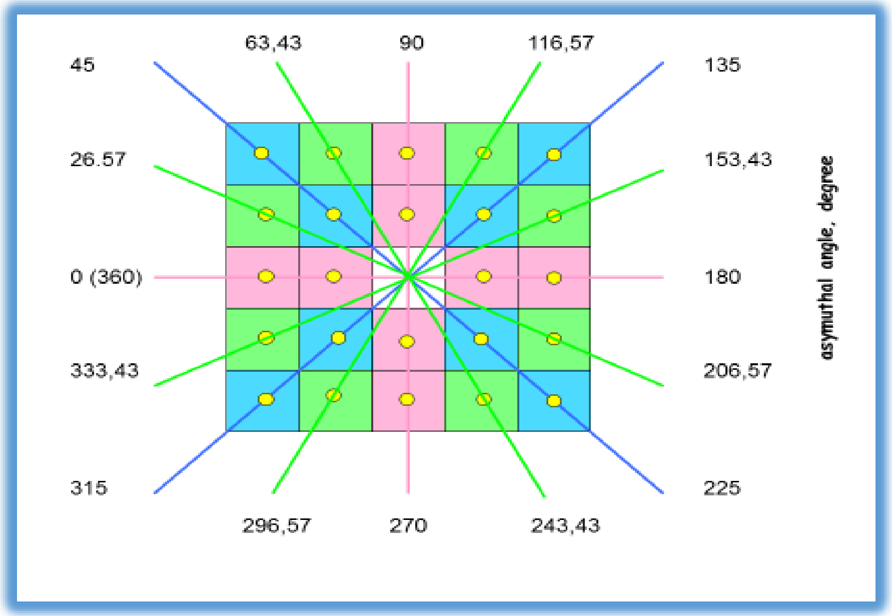
n + CH2



p +CH2

Scattering angle, rad

Azimuthal segmentation available from the hadron calorimeter for asymmetry measurements

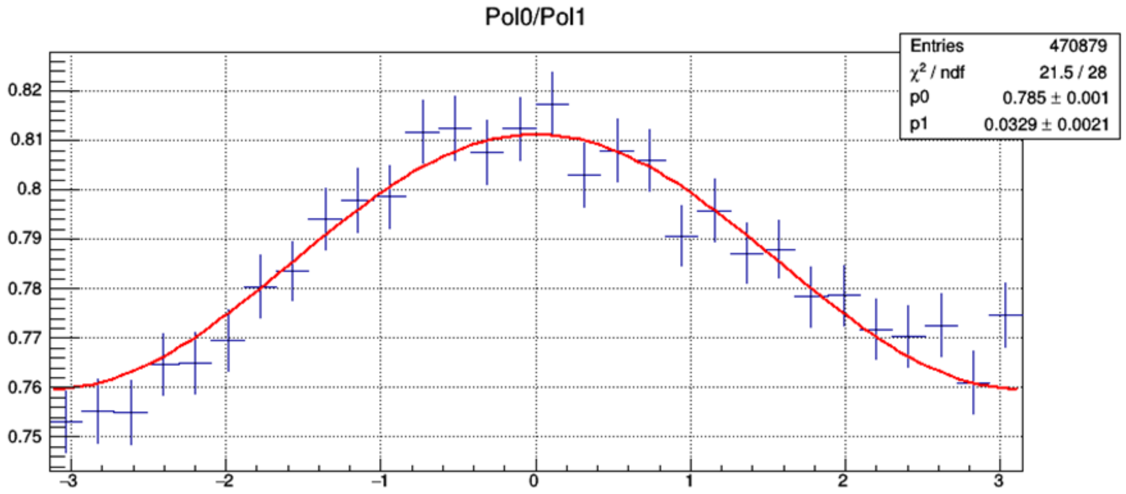


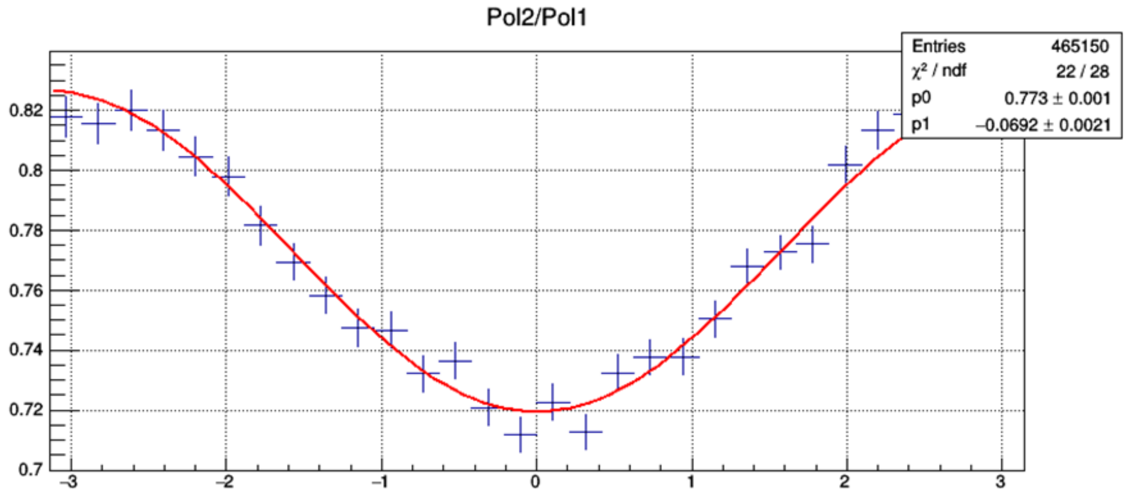
Measured asymmetries

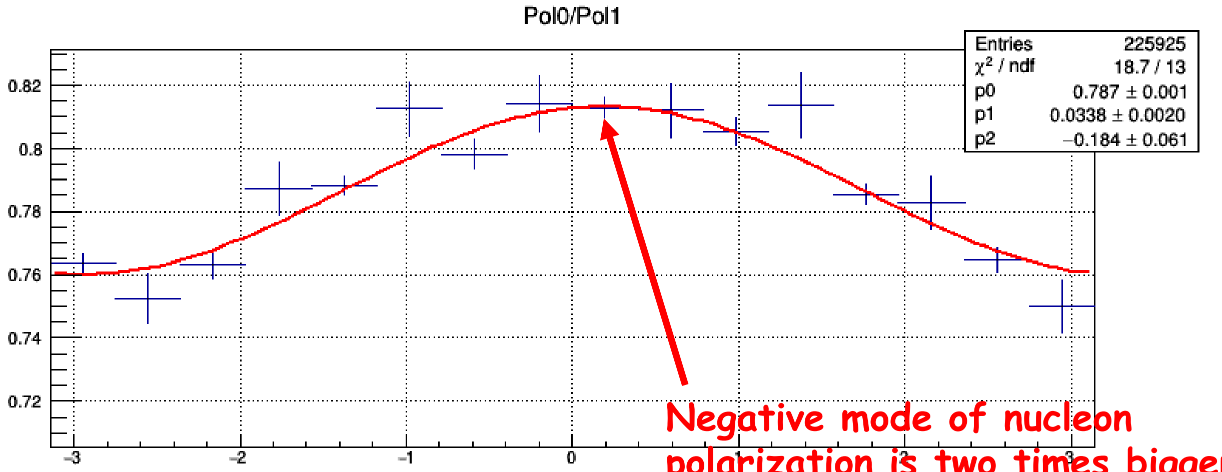
p+CH2, 3.0 GeV/c, tracks, scattering angles 0.03-0.24 rad

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

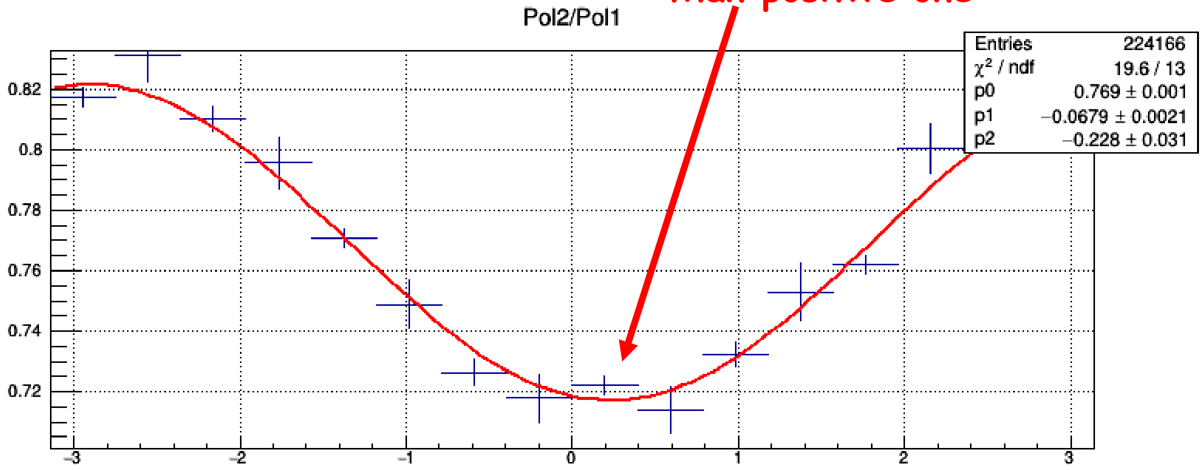
asymmetry







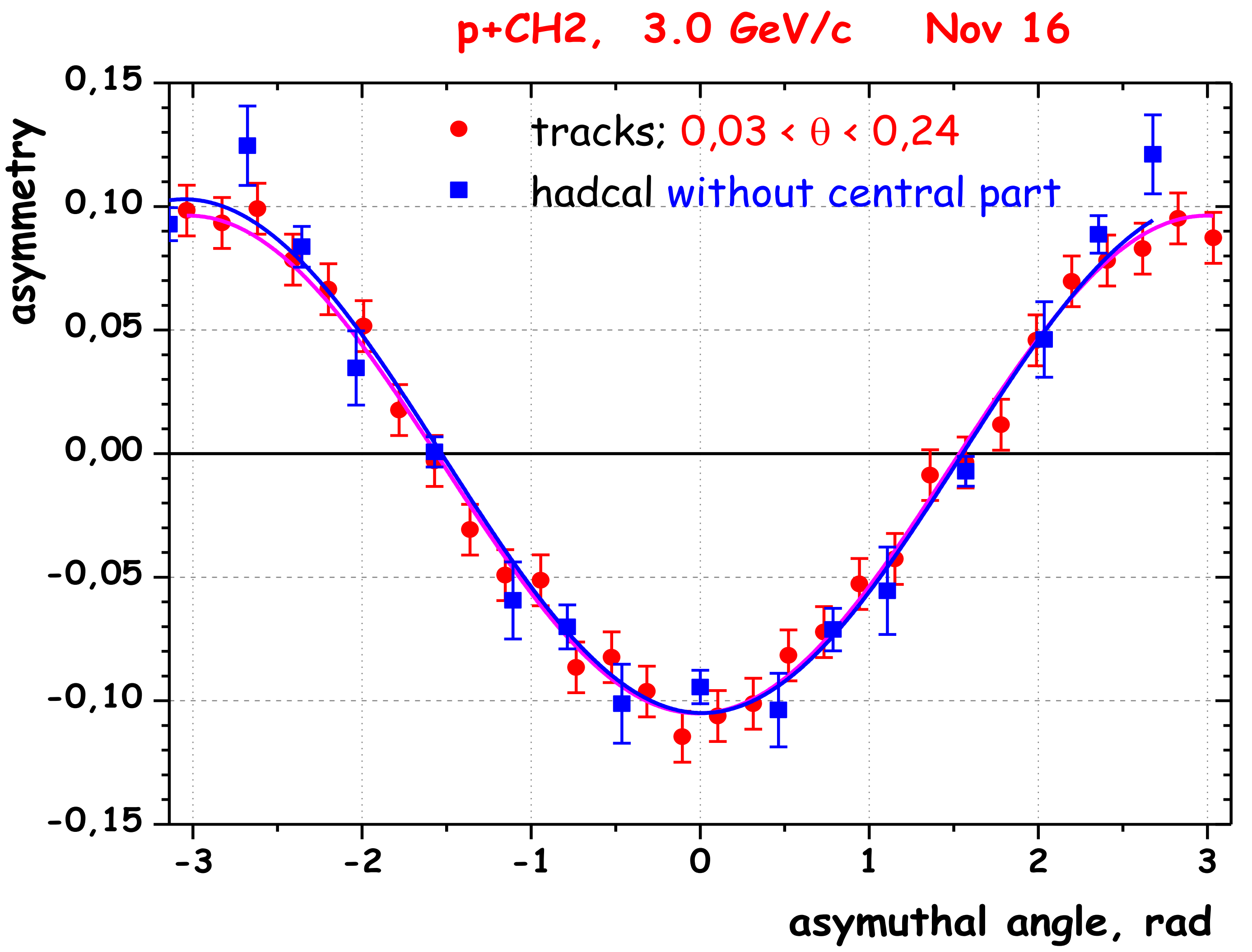
Negative mode of nucleon polarization is two times bigger than positive one



asymuthal angle, rad

asymuthal angle, rad

Combining of two polarization modes

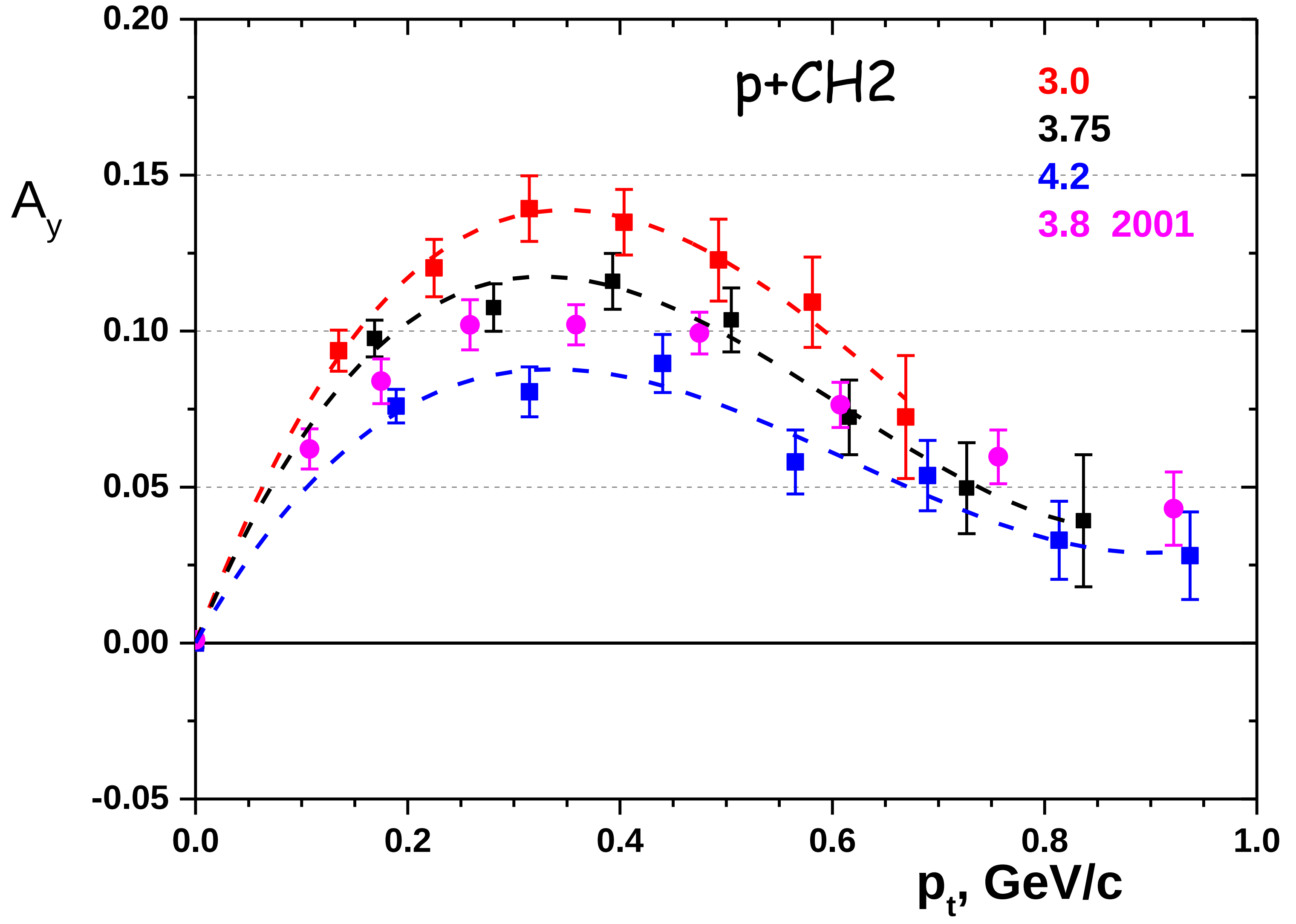


The asymmetry as a function of the azimuthal angle from the calorimeter (blue squares) and from the drift chambers (red circles)

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

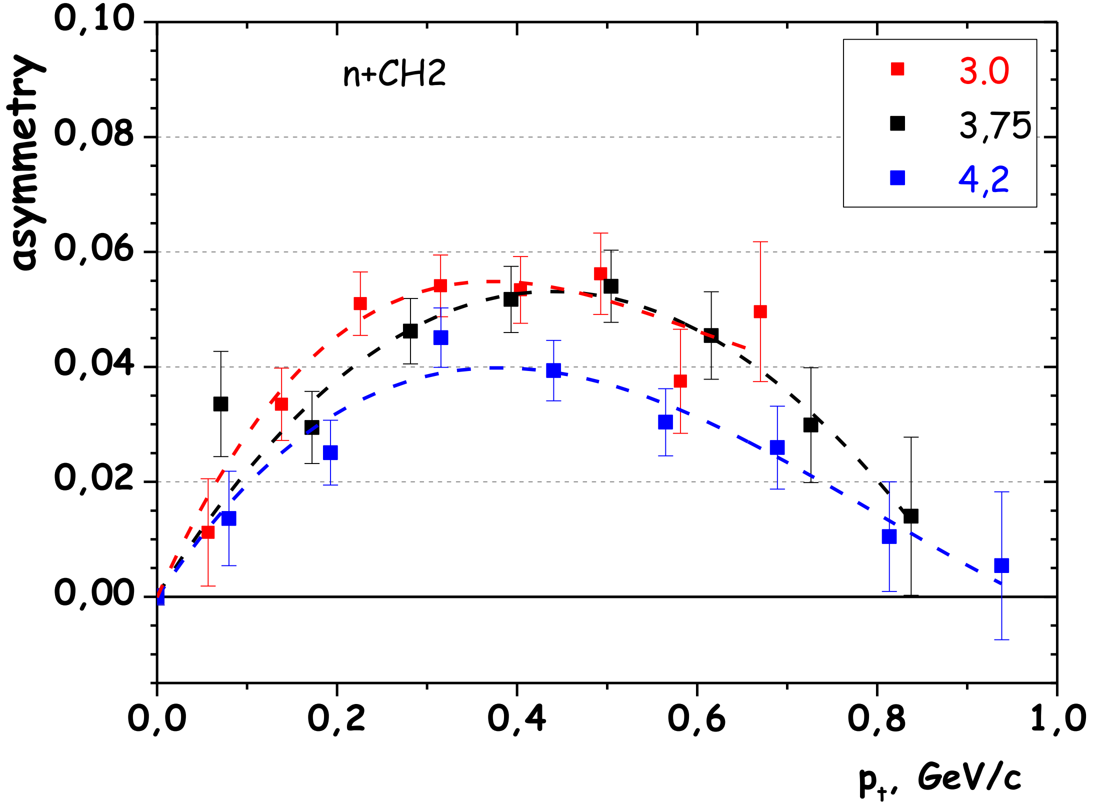
Control measurements, proton beams

good agreement with old data



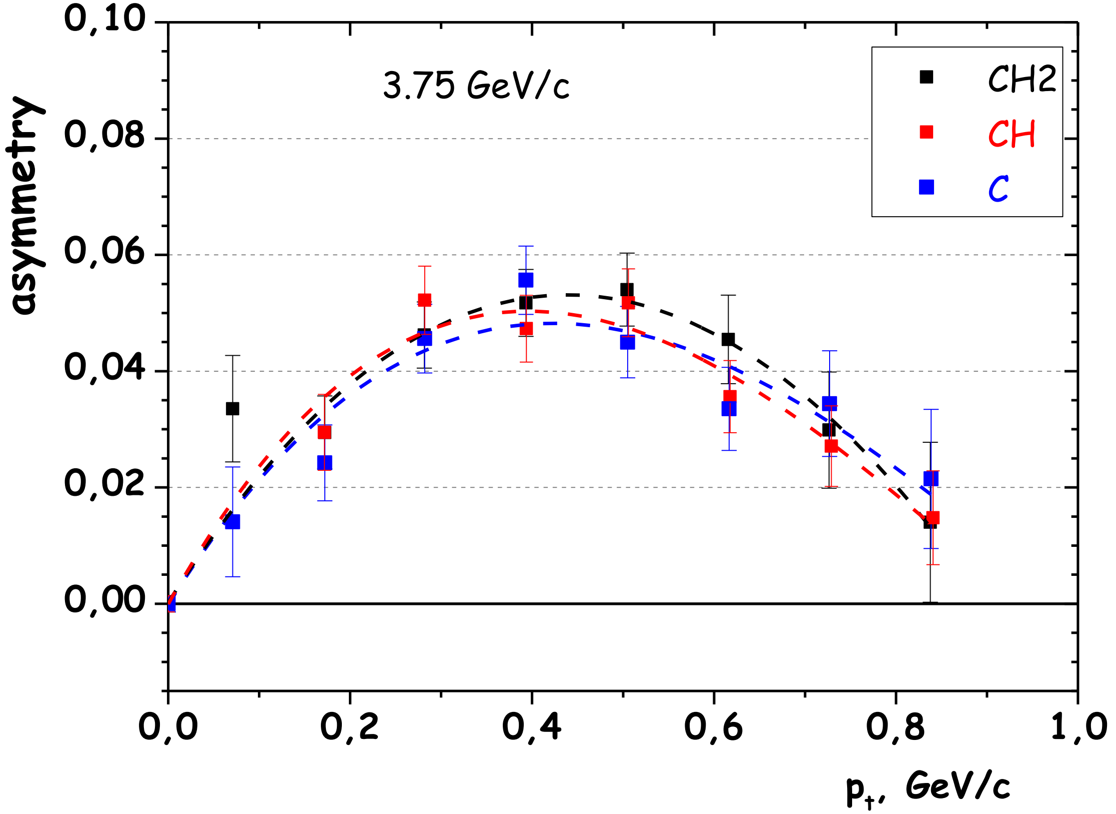
Neutrons

different momenta, CH2 - target



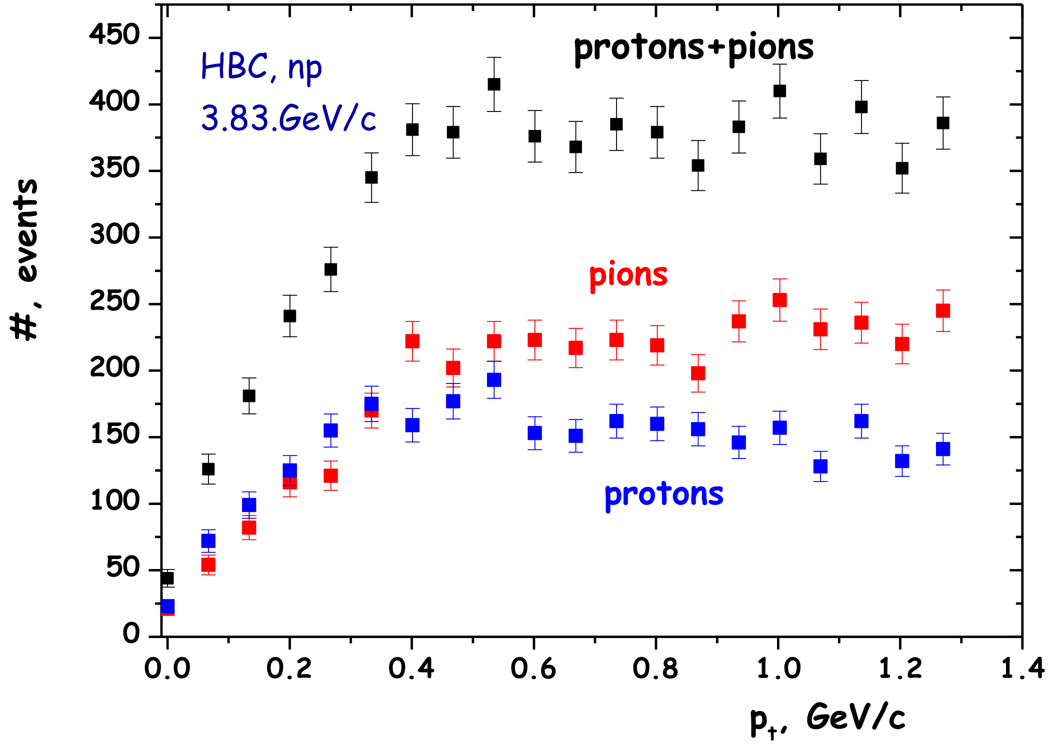
Energy dependence of the neutron asymmetry on CH2 target.

different targets, 3.75 GeV/c

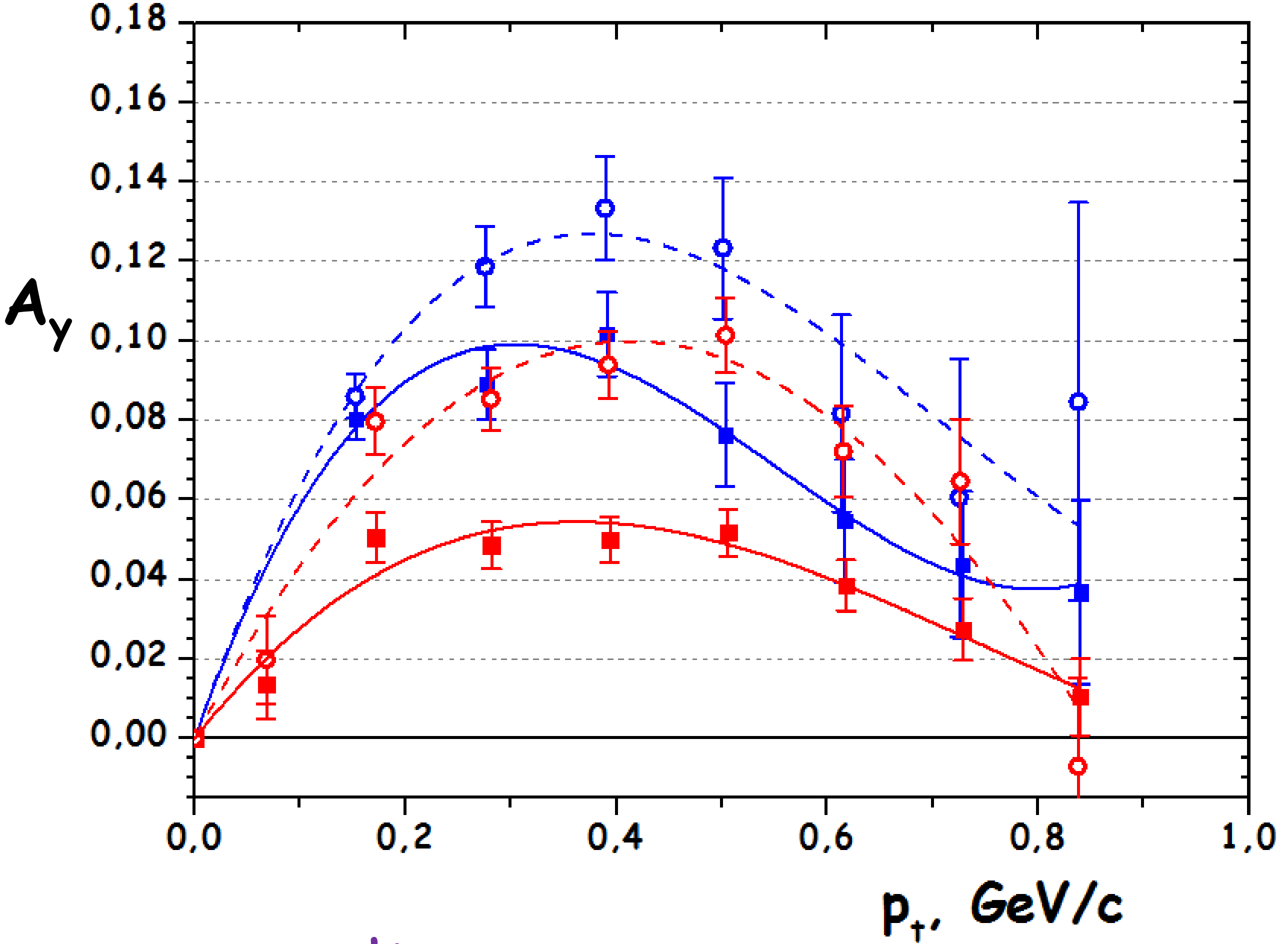


Neutron asymmetry dependence of different target material n(p)↑ + Cu ⟶ one charge particle + X

3.75 GeV/c



n + Cu p + Cu



Full squares – no cut;
open circles – energy deposit cut, 6000.

Advantage of a copper target as an analyzer one

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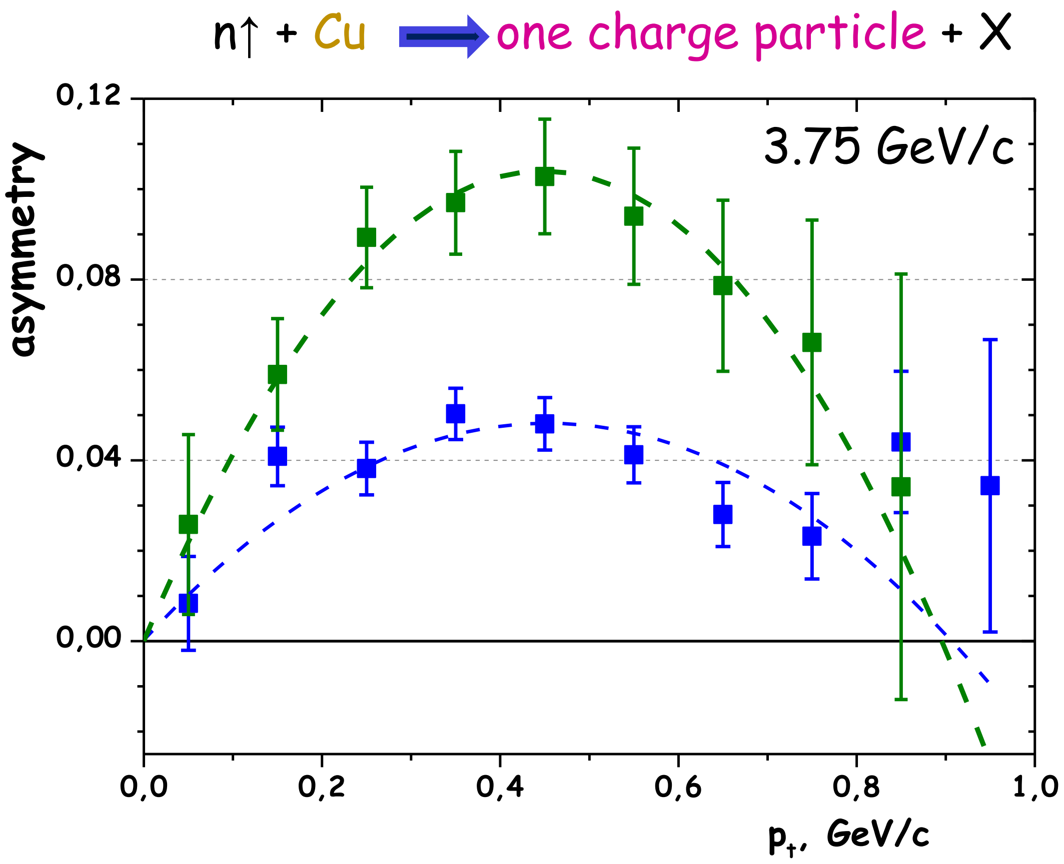
The inverse reaction p+Cu (W) with detection neutron in forward direction by the hadron calorimeter can be used for measurement of the proton polarization at the NICA collider.



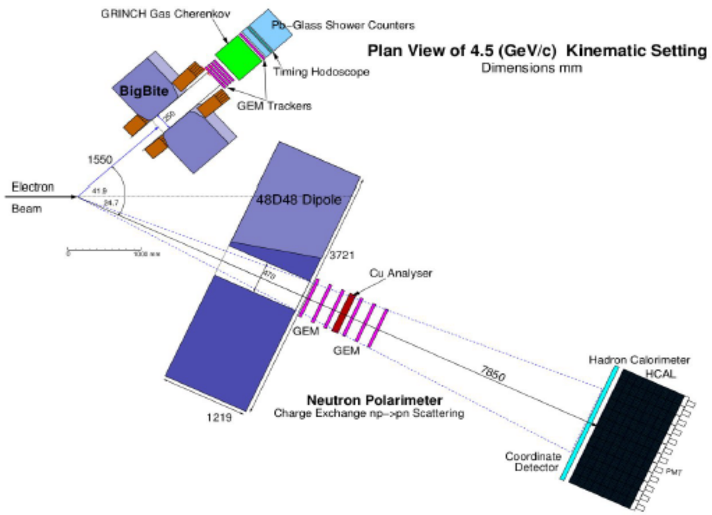
Measurement of the Ratio G_E^n/G_M^n by the Double-polarized $^2\mathrm{H}(\vec{e}, e'\vec{n})$ Reaction

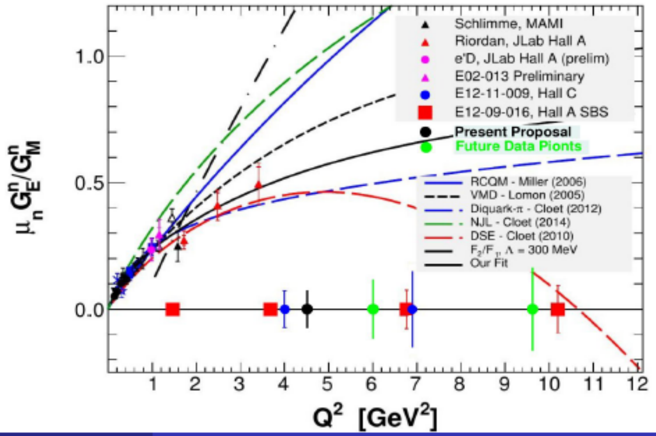
Neutron Form Factor Ratio G_E^n/G_M^n - 3

- E12-17-004 in Hall A (Annand, Bellini, Kohl, Piskunov, Sawatzky, Wojtsekhowski).
- Polarization transfer using $^2\mathrm{H}(\vec{e}, e'\vec{n})p$:

$$\frac{G_E^n}{G_M^n} = -\frac{P_t}{P_l}\frac{E+E'}{2M}\tan\left(\frac{\theta_e}{2}\right)$$

- Electron arm: Super Big Bite Spectrometer.
- Neutron arm: HCal, neutron polarimeter, CDet coordinate detector, scintillation counter.
- Kinematics: $Q^2 = 4.5\ (\mathrm{GeV/c})^2$.
- Beamtime: 5 days.
- Systematic uncertainties about 3%.
- Statistical uncertainties about 8%.
- Will test extension of neutron polarimetry to high Q^2.
- Expected in the next 2-3 years.





Summary of measurements

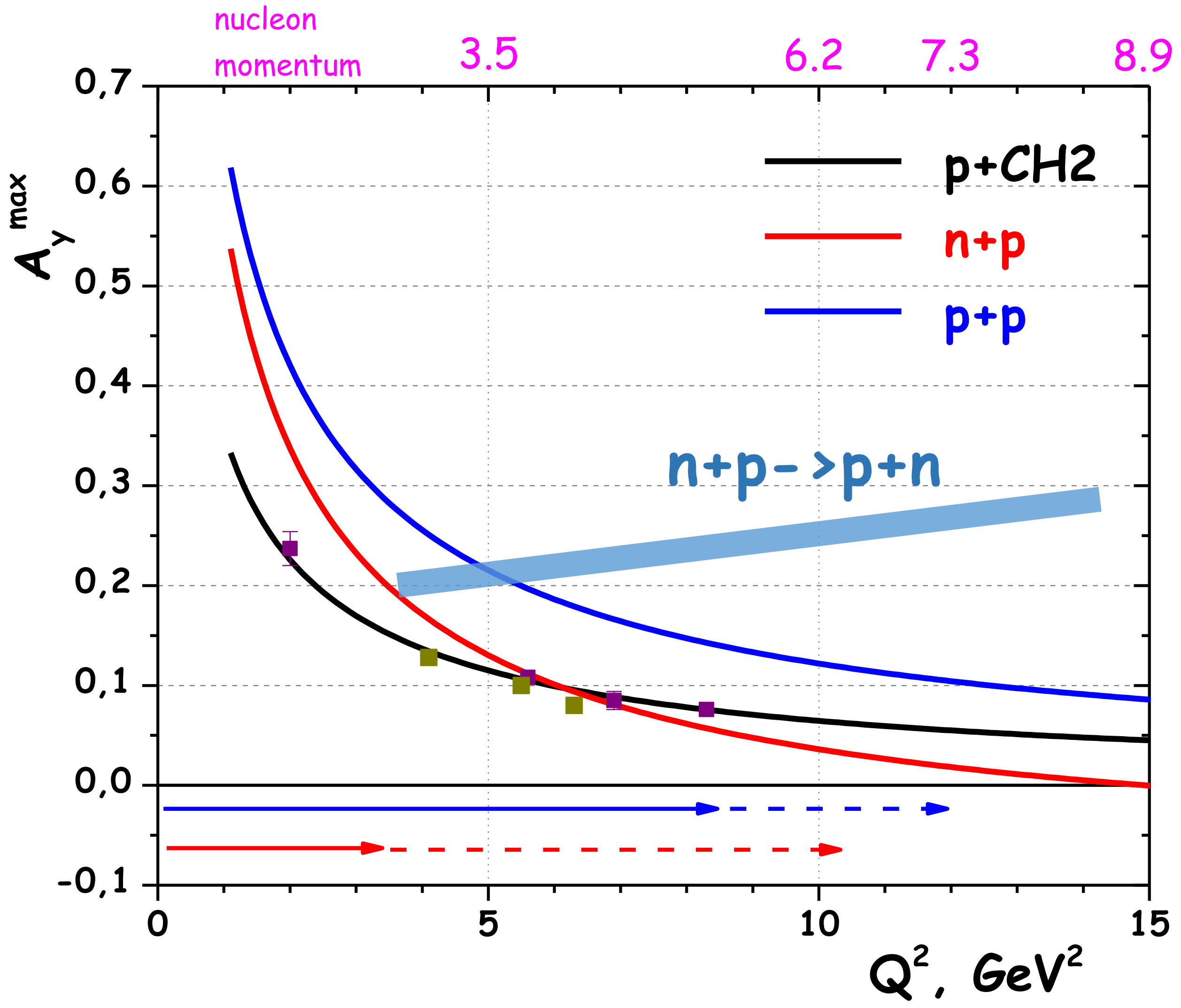
The ALPOM2 setup was designed to measure analyzing powers from different analyzer targets, for protons and neutrons. It includes a large size calorimeter to help eliminate multi-particle final states, and correspondingly increase the analyzing power. So far protons and neutrons of 3.0, 3.75 and 4.2 GeV/c 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

Asymmetries vs Q^2



Exp data: 2001 & 2016

Future runs

Protons, 7,5 GeV/c

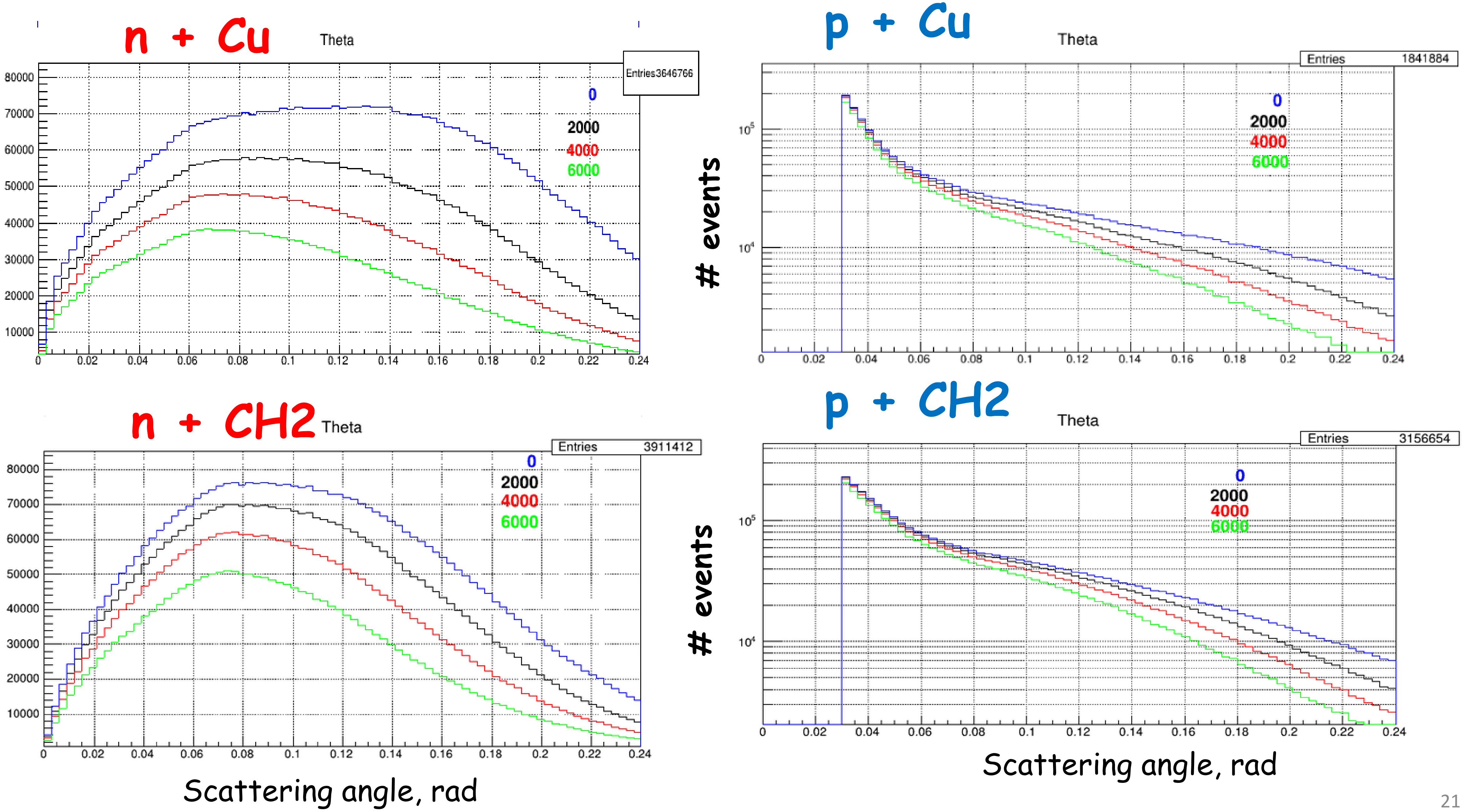
Neutrons, 5 & 6 GeV/c

End of 2019

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

Thank you for your attention

n(p) + Cu(CH2) ➡ one charge particle + X



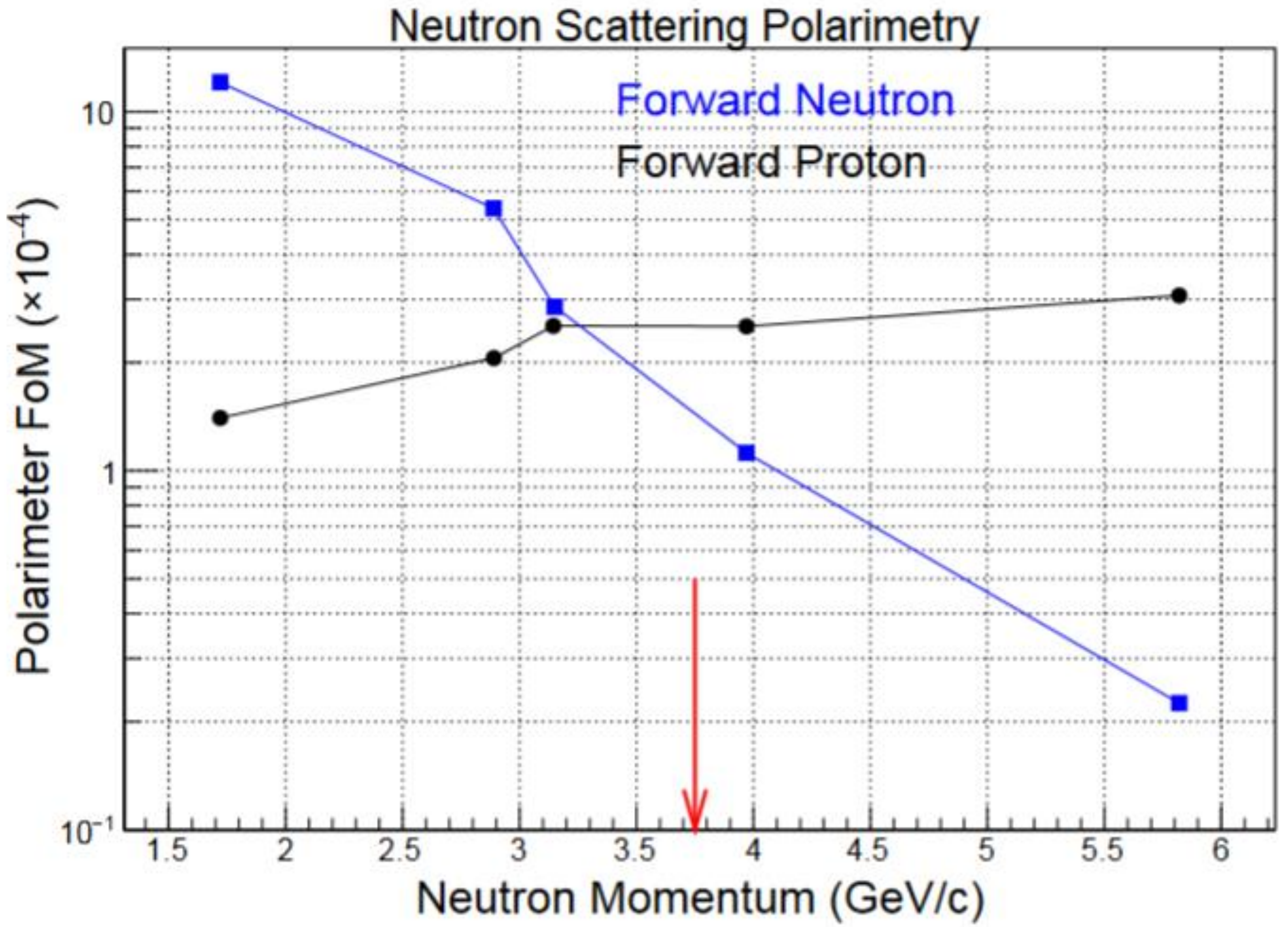
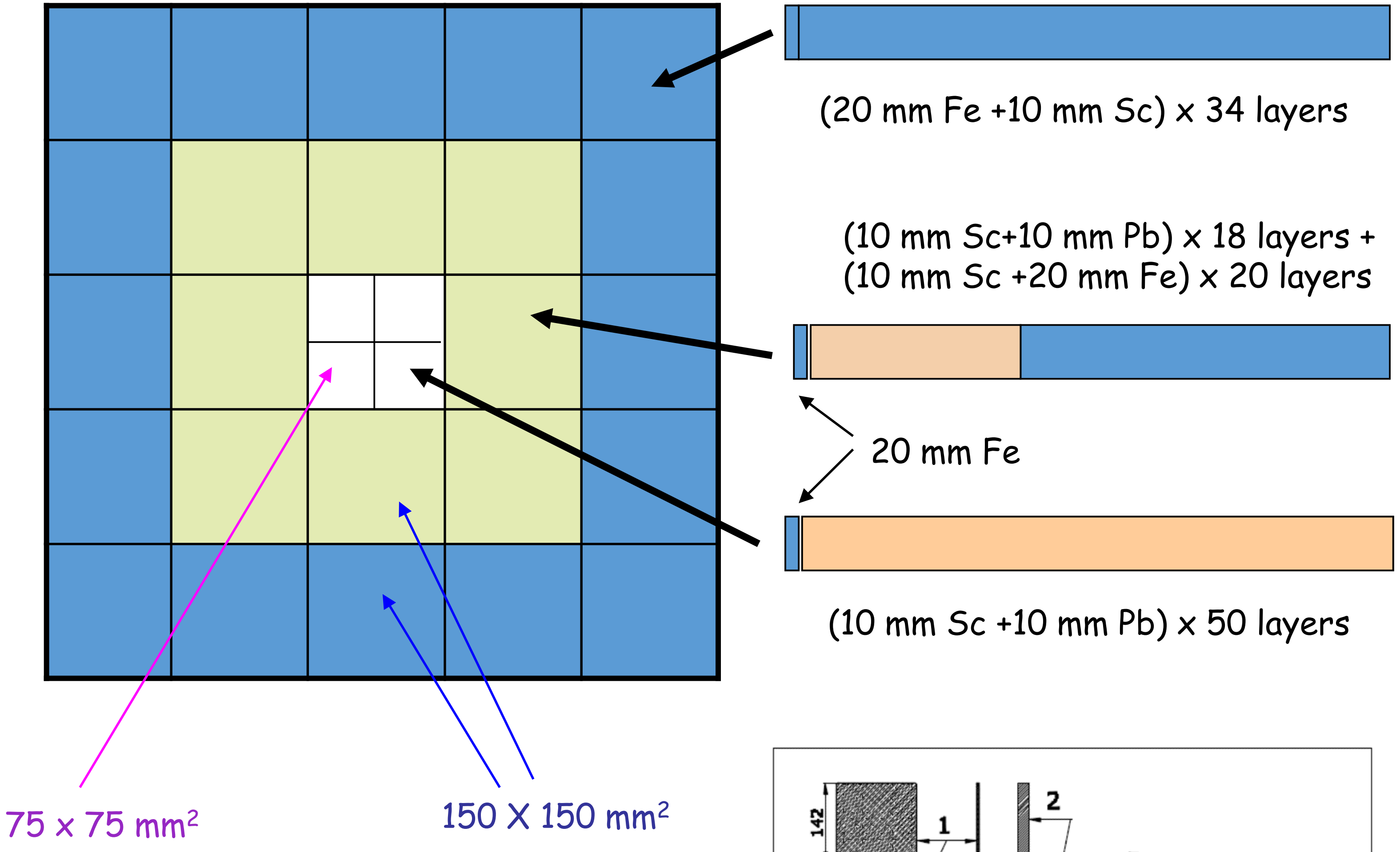
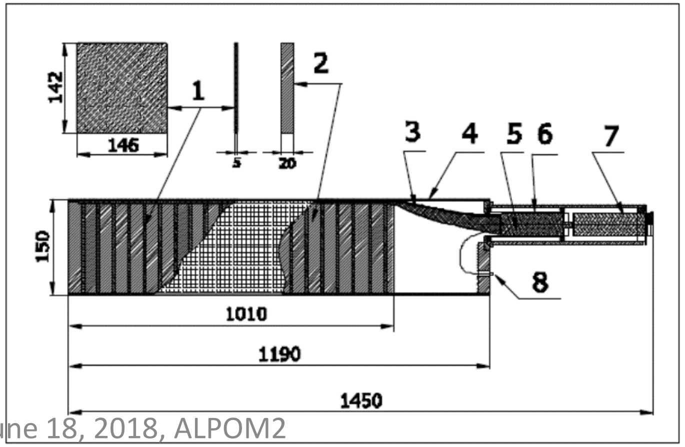
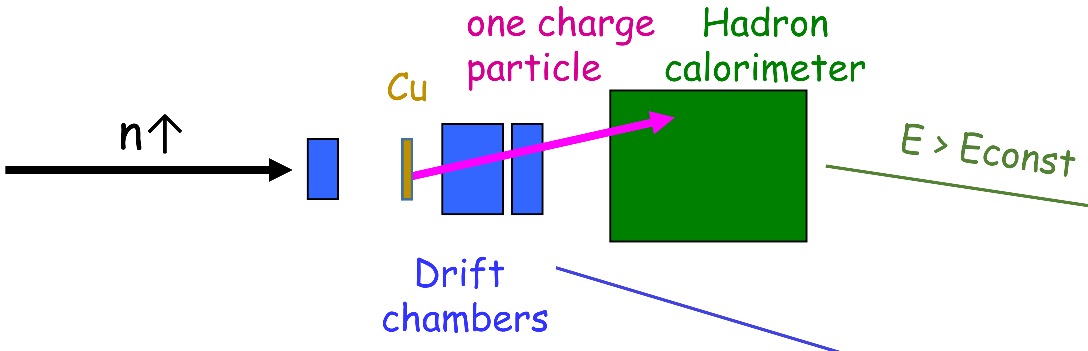


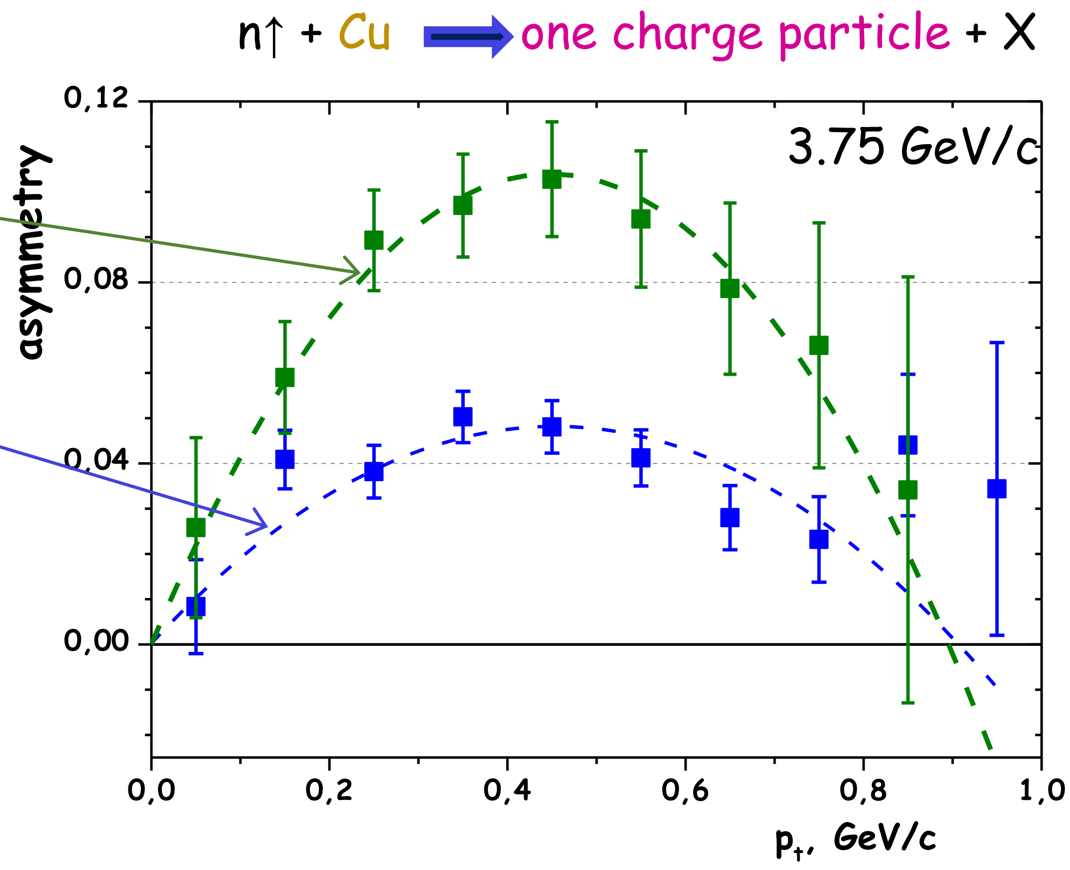
Figure 8: Neutron polarimeter figure of merit as a function of incident neutron momentum for two styles of polarimeter within the SBS apparatus using preliminary data from the recent Dubna measurement. Blue squares: standard $n-p$ scattering from CH scintillator, black circles: charge-exchange $n-p$ scattering from Cu. The red arrow marks the neutron momentum at which a charge-exchange measurement of the analyzing power of Cu was made at Dubna.

Hadron calorimeter









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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