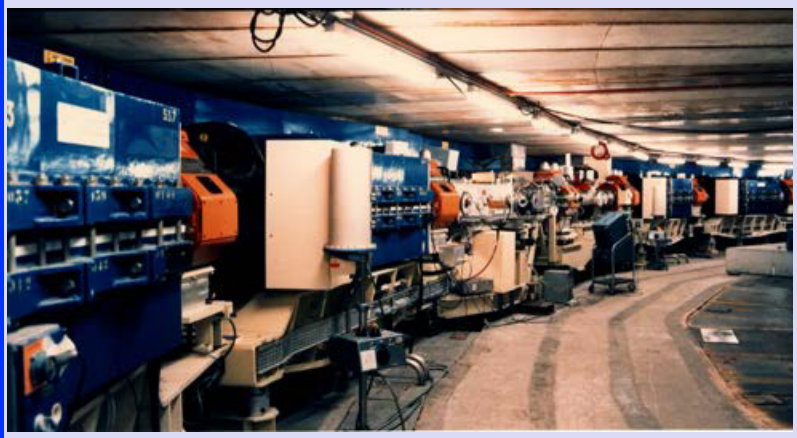
Hadron polarimetry between history and legend



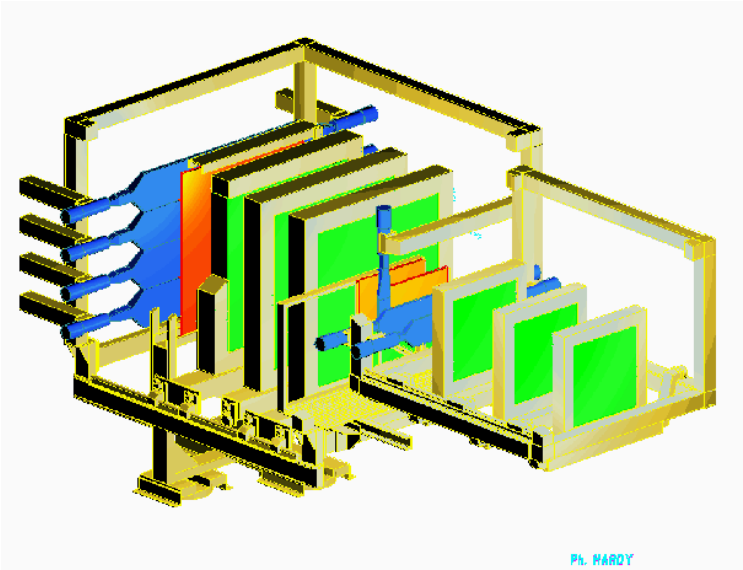
Egle Tomasi-Gustafsson
CEA, IRFU, SPhN
Saclay, France

Veksler and Baldin
LABORATORY
OF HIGH ENERGY PHYSICS

Dubna
April 21,2017

Polarization Phenomena

Complicated formalism,
complex experiments….

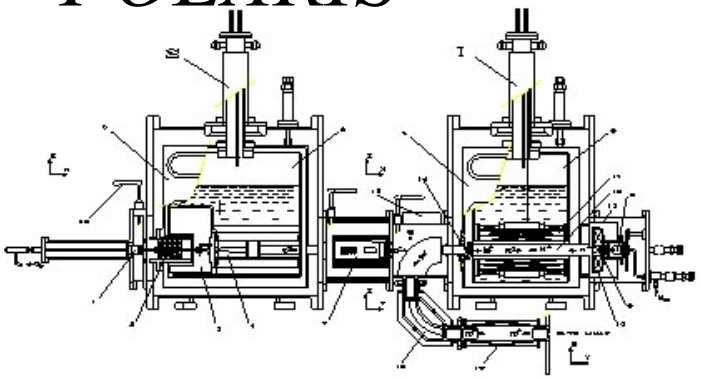


W. Pauli
N.Bohr

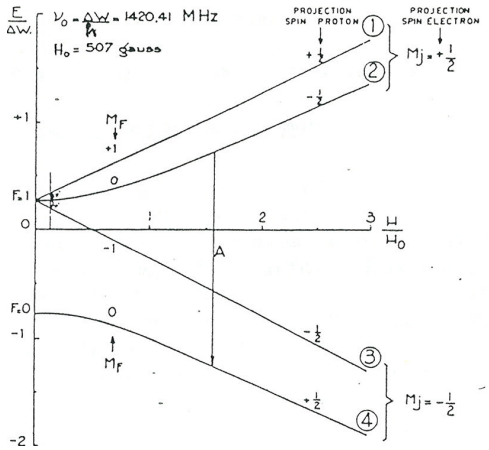
…but unavoidable to learn about nucleon and nuclei structure

The MICROSCOPE

POLARIS



Yu. Pilipenko



Nuclear Instruments and Methods in Physics Research A 356 (1995) 58–61

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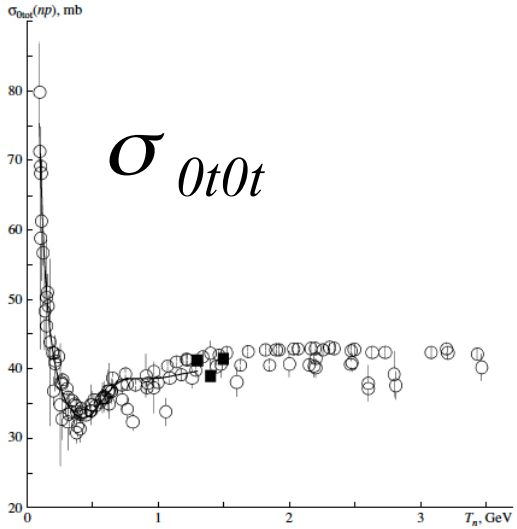
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

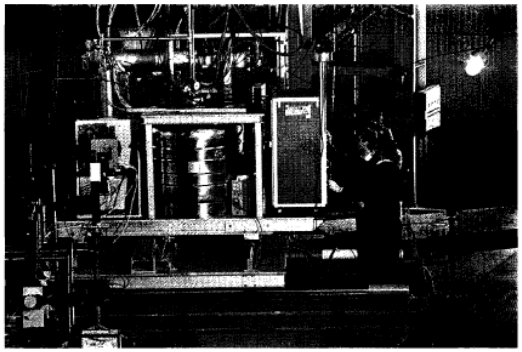
The movable polarized target as a basic equipment for high energy spin physics experiments at the JINR-Dubna accelerator complex

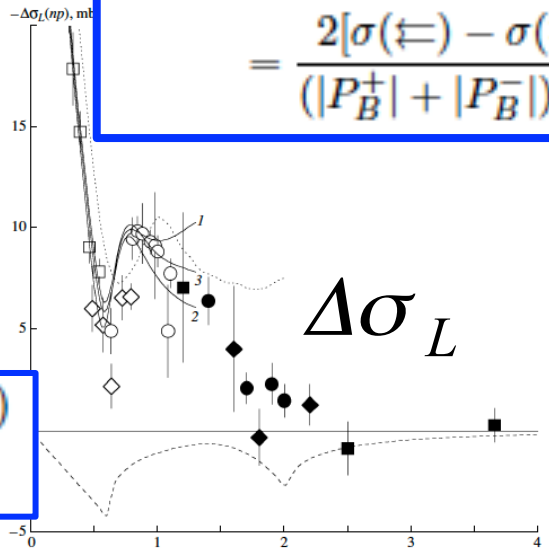


σ_{0t0t}

$$-\Delta\sigma_L(P_T^+) = 2(\sigma_{1\mathrm{tot}} + \sigma_{2\mathrm{tot}})^+ = \frac{2[\sigma(\rightrightarrows) - \sigma(\leftrightarrows)]}{(|P_B^+| + |P_B^-|)|P_T^+|},$$

$$-\Delta\sigma_L(P_T^-) = 2(\sigma_{1\mathrm{tot}} + \sigma_{2\mathrm{tot}})^- = \frac{2[\sigma(\rightleftarrows) - \sigma(\rightleftarrows)]}{(|P_B^+| + |P_B^-|)|P_T^-|}.$$





$\Delta\sigma_L$

$$\sigma_{\mathrm{tot}} = \sigma_{0\mathrm{tot}} + \sigma_{1\mathrm{tot}}(\mathbf{P}_B \cdot \mathbf{P}_T) + \sigma_{2\mathrm{tot}}(\mathbf{P}_B \cdot \mathbf{k})(\mathbf{P}_T \cdot \mathbf{k}),$$

$$\sigma_{0\mathrm{tot}} = (2\pi/K)\mathrm{Im}[a(0) + b(0)],$$

$$-\Delta\sigma_T = (4\pi/K)\mathrm{Im}[c(0) + d(0)],$$

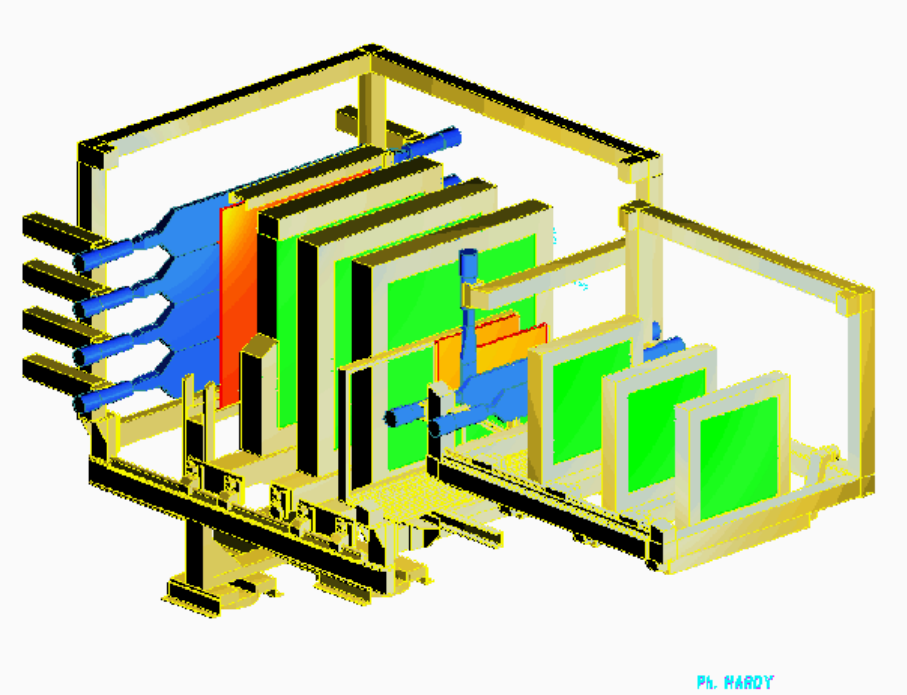
$$-\Delta\sigma_L = (4\pi/K)\mathrm{Im}[c(0) - d(0)],$$

$$\Delta\sigma_{L,T}(I=0) = 2\Delta\sigma_{L,T}(np) - \Delta\sigma_{L,T}(pp).$$

...access fundamental symmetries of the strong interaction

Hadron polarimetry in the GeV region

Azimuthal asymmetry in a secondary scattering



Protons and Deuterons

- *The efficiency*

$$\epsilon(\theta) = \frac{N_{useful}(\theta)}{N_{incident}(\theta)}$$

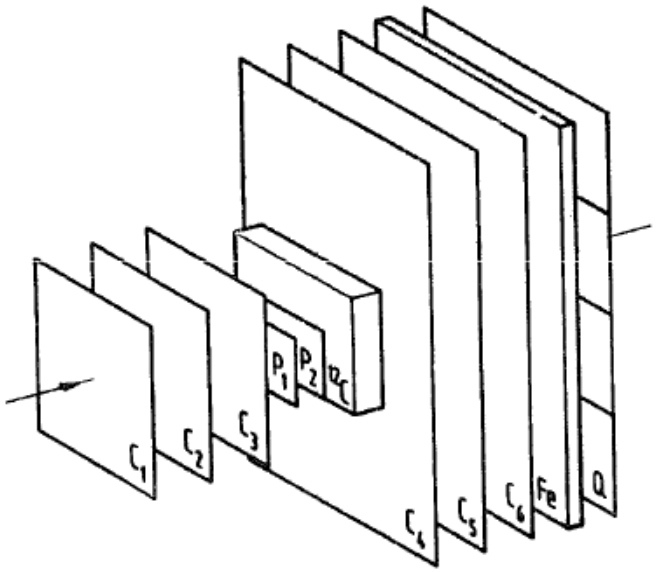
- *The Figure of merit:*

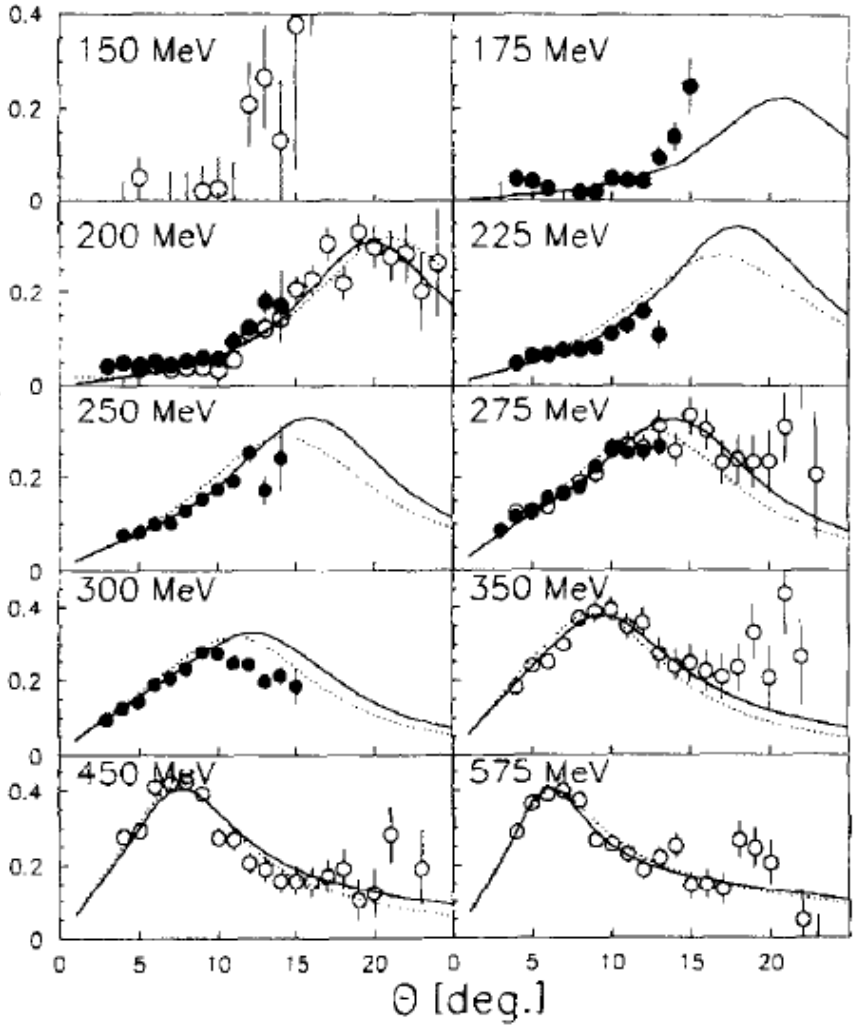
$$\mathcal{F}^2 = \sum_{\theta} \epsilon(\theta)\ \mathcal{A}^2(\theta)$$

- *The error on the polarization measurement*

$$\Delta P = \sqrt{\frac{2}{N_{incident}(\theta)\mathcal{F}^2}}$$

iT_{11} vector analyzing powers d+C→ d+X





Nuclear Instruments and Methods in Physics Research A288 (1990) 389–398
North-Holland

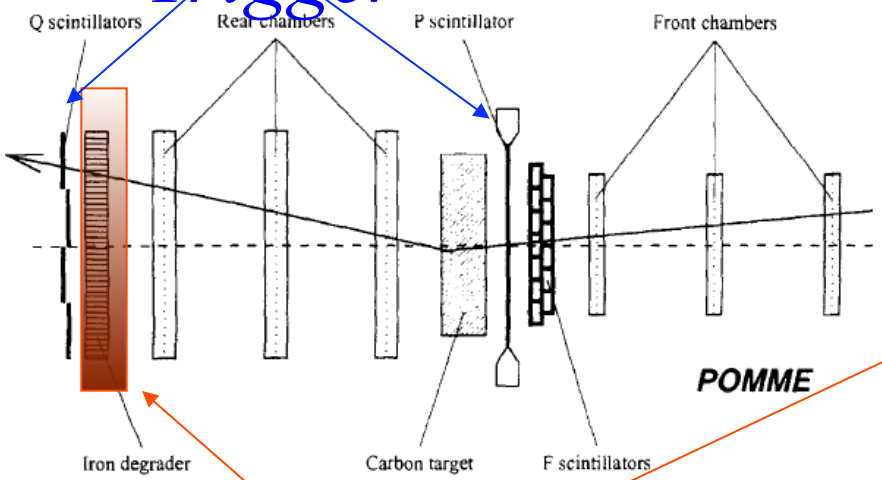
ELSEVIER Nuclear Instruments and Methods in Physics Research A 404 (1998) 129–142

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

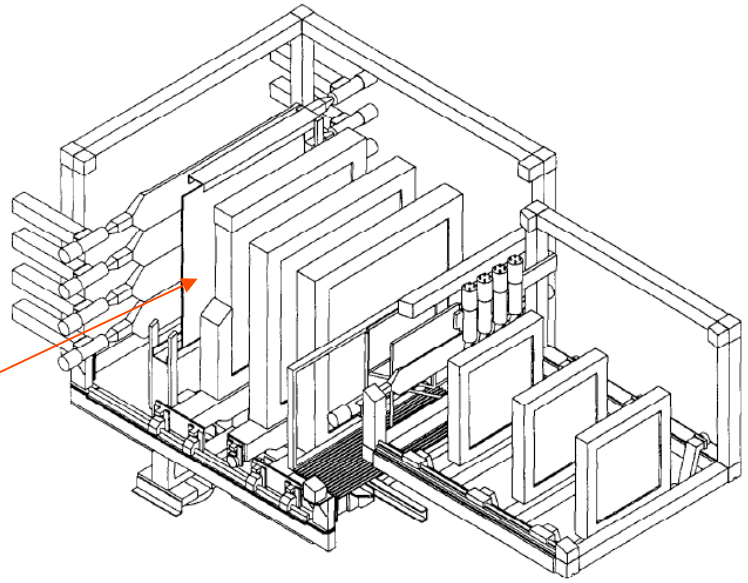
Analyzing powers for the inclusive reaction of deuterons on carbon at energies between 0.175 and 1.6 GeV

V.P. Ladygin[a,f], E. Tomasi-Gustafsson[a,b,*], J. Ball[a,b], L. Bimbot[c], Y. Bisson[c], M. Boivin[a], J.L. Boyard[c], N.E. Cheung[d], Ph. Courtat[c], R. Gacougnolle[c], T. Hennino[c], M.K. Jones[c], R.A. Kunne[a], C.F. Perdrisat[d], N.M. Piskunov[f], V. Punjabi[e], I.M. Sitnik[f], R. Skowron[c], E.A. Strokovsky[f], P. Zupranski[g]

Trigger



Iron degrader



iT_{11} vector analyzing powers d+C→ d+X

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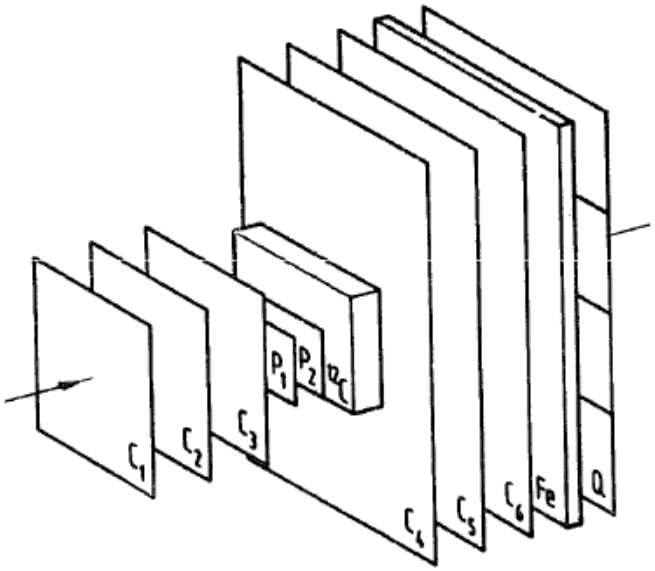
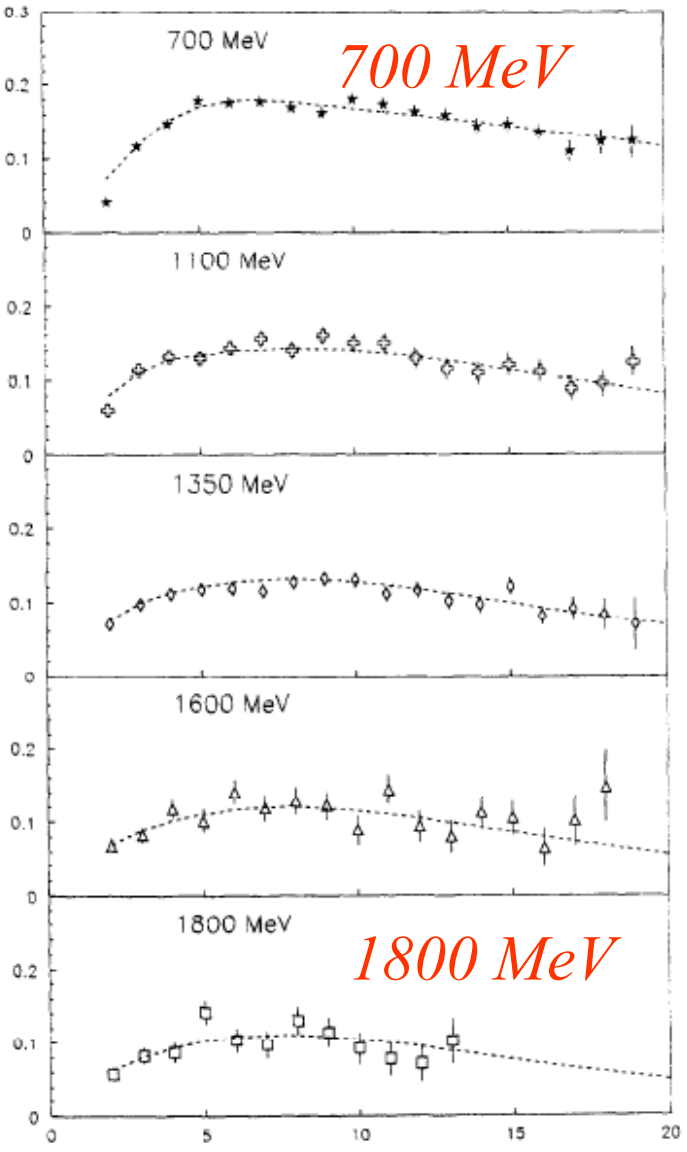
Nuclear Instruments and Methods in Physics Research A 366 (1995) 96–99

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

Calibration of the polarimeter POMME with polarized deuterons at 1.8 GeV





700 MeV

1800 MeV

Data and parametrizations

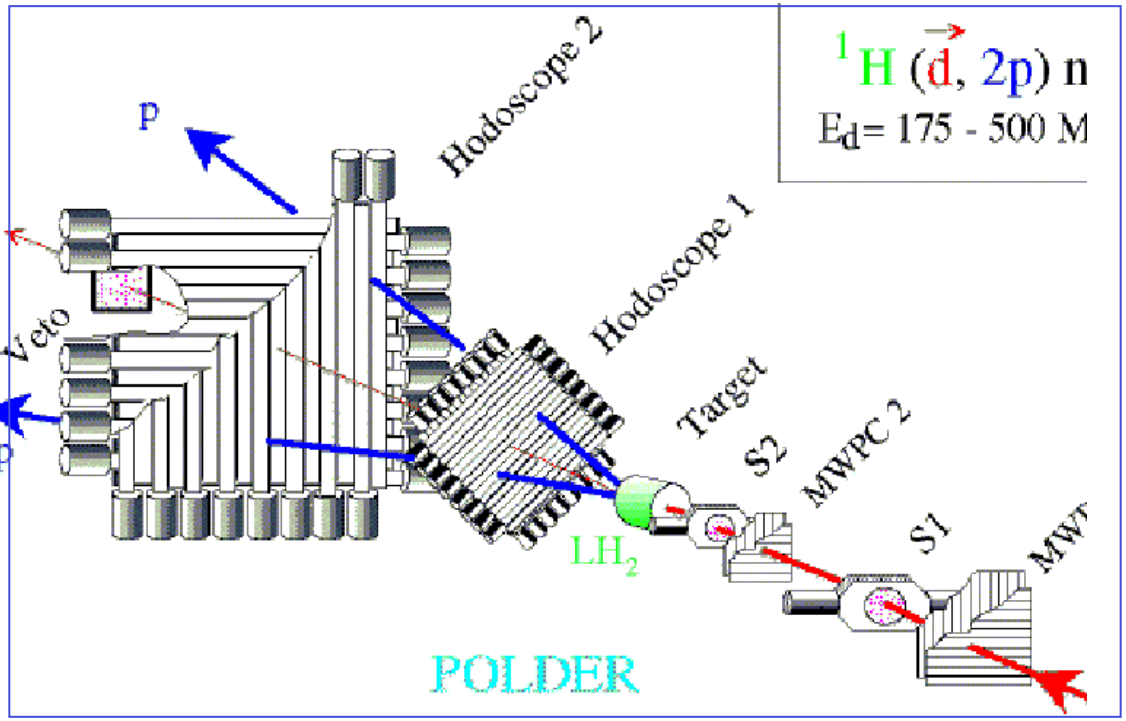
- Angular distributions
- Efficiency
- Figure of merit

Charge exchange reaction

Idea from *I. Pomeranchuk* (1938)

$$d + p \rightarrow (pp) + n$$

The deuteron is a bound np system in T=0, S=1 state (l=0 or 2).



S. Kox et al, NIM 346 (1994) 527

Selecting a pair of protons in relative s-state, requires a spin-flip due to Pauli principle (anti-symmetric total wave function)

Large tensor analyzing powers!

$d+p \rightarrow d+p$ *forward elastic scattering*

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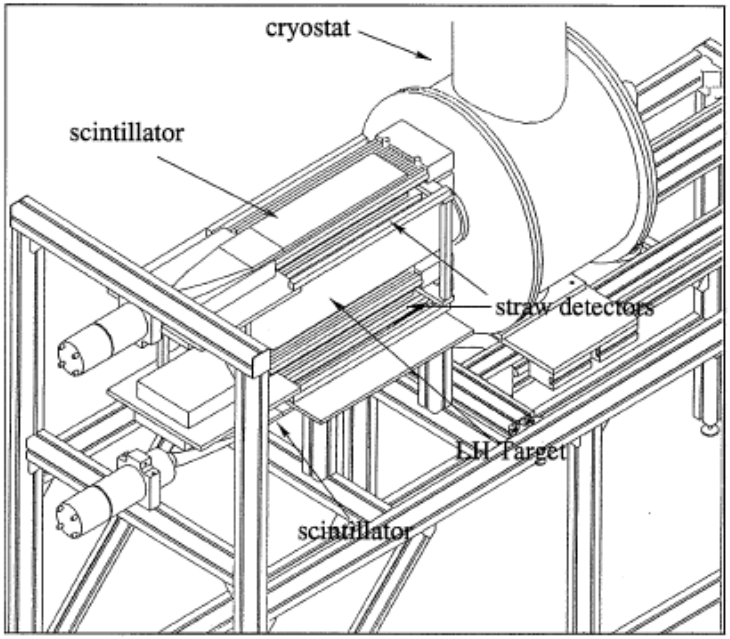
Nuclear Instruments and Methods in Physics Research A 420 (1999) 90–100

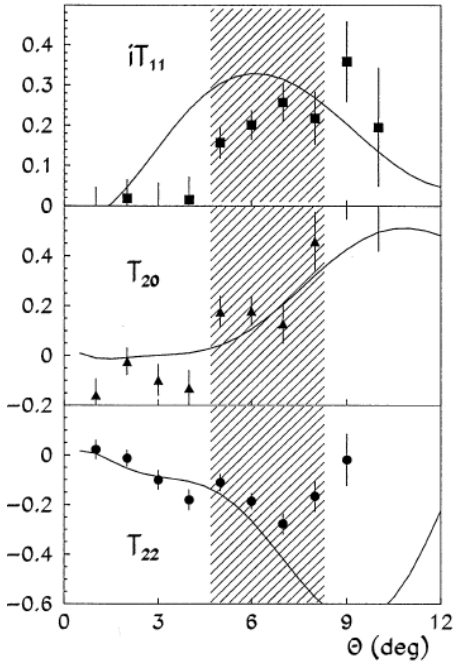
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

A vector and tensor polarimeter for high-energy deuterons

E. Tomasi-Gustafsson[a,b,*], J. Yonnet[a,c], V.P. Ladygin[a,d], J. Ball[a,b], L. Bimbot[c], Y. Bisson[c], M. Boivin[a], Yu. Borzounov[d], J.L. Boyard[c], N.E. Cheung[e], Ph. Courtat[c], R. Gacougnolle[c], R. Skowron[c], L. Golovanov[d], T. Hennino[c], M.K. Jones[e], R. Kunne[a], C.F. Perdrisat[e], N.M. Piskunov[d], V. Punjabi[f], I.M. Sitnik[d], E.A. Strokovsky[d,1], A.P. Tsvinev[d]

Vector AND tensor analyzing powers





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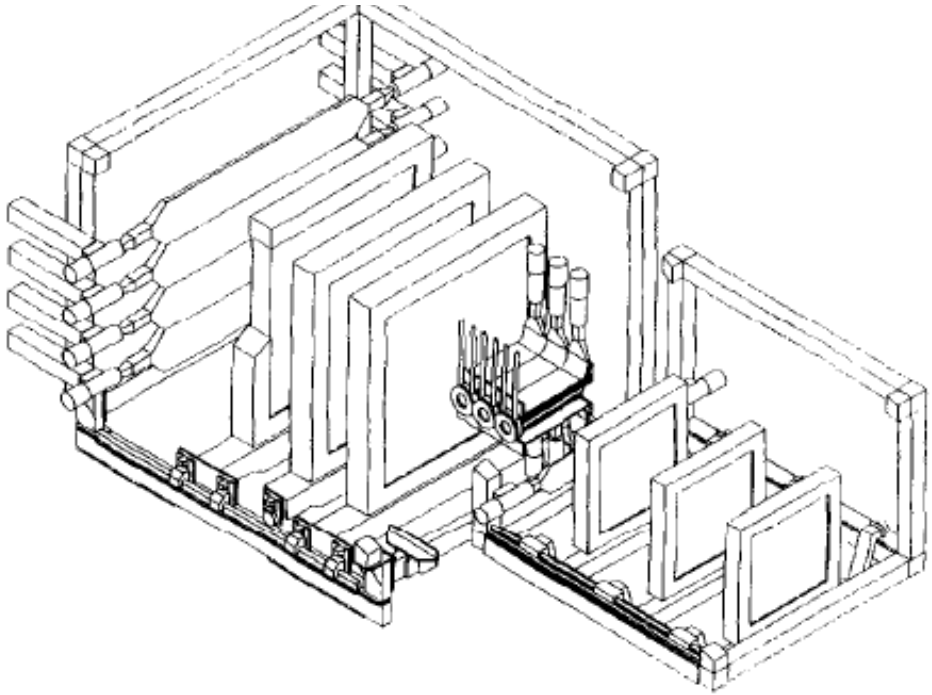
Nuclear Instruments and Methods in Physics Research A 381 (1996) 15–22

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

A three-cell liquid hydrogen target for an extended focal plane polarimeter

L.B. Golovanov[a], Yu.T. Borzounov[a], N.M. Piskunov[a], A.P. Tsvinev[a], J. Ball[b], Ph. Chesny[b], J.M. Gheller[b], G. Guillier[b], V.P. Ladygin[b,1], Ph. Theuré[b], E. Tomasi-Gustafsson[b]



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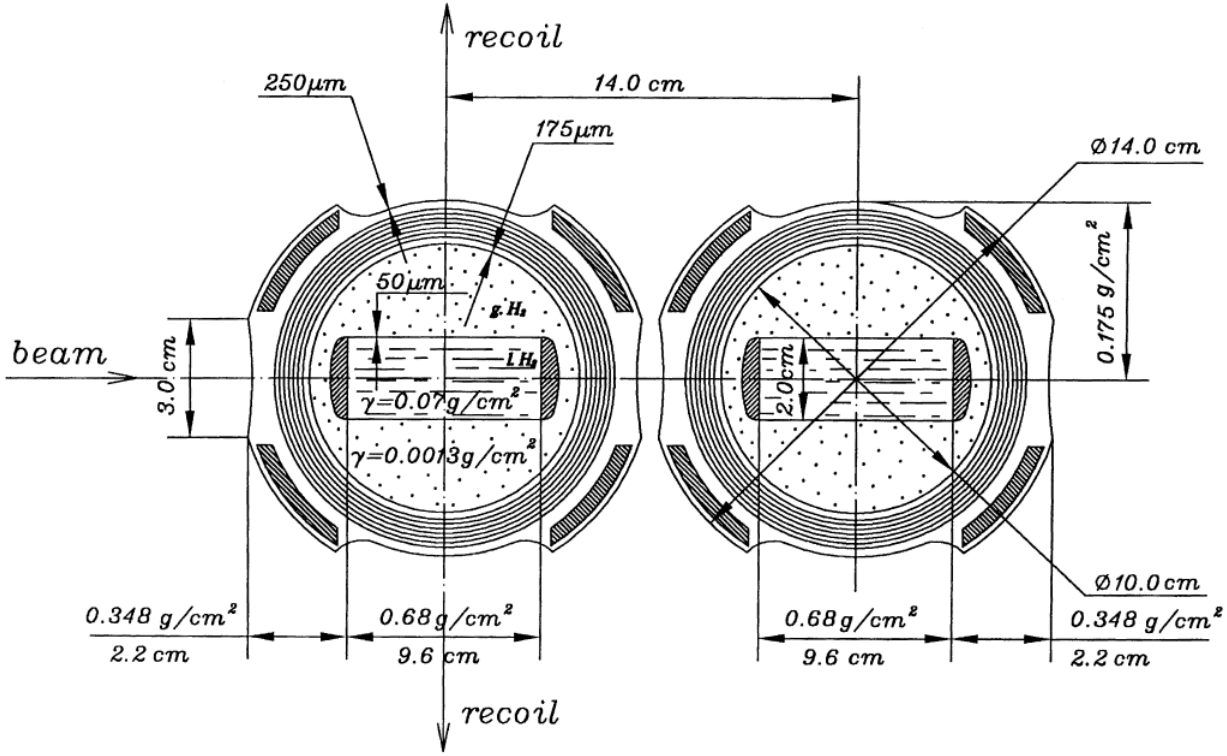
Nuclear Instruments and Methods in Physics Research A 430 (1999) 1–9

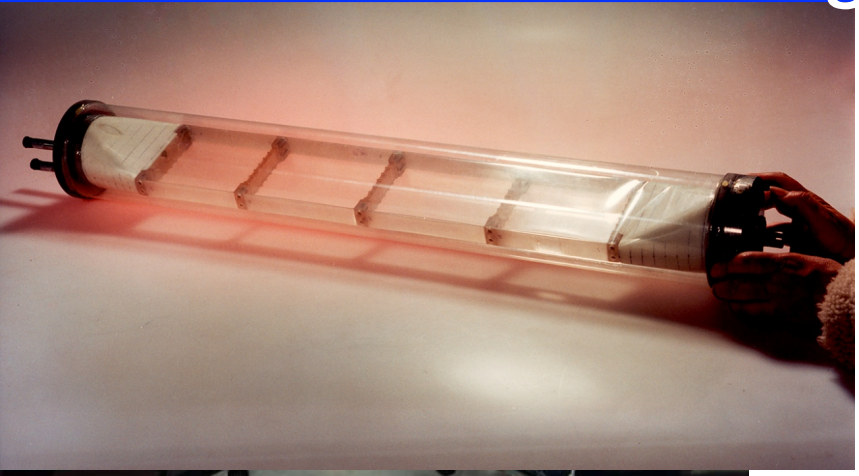
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

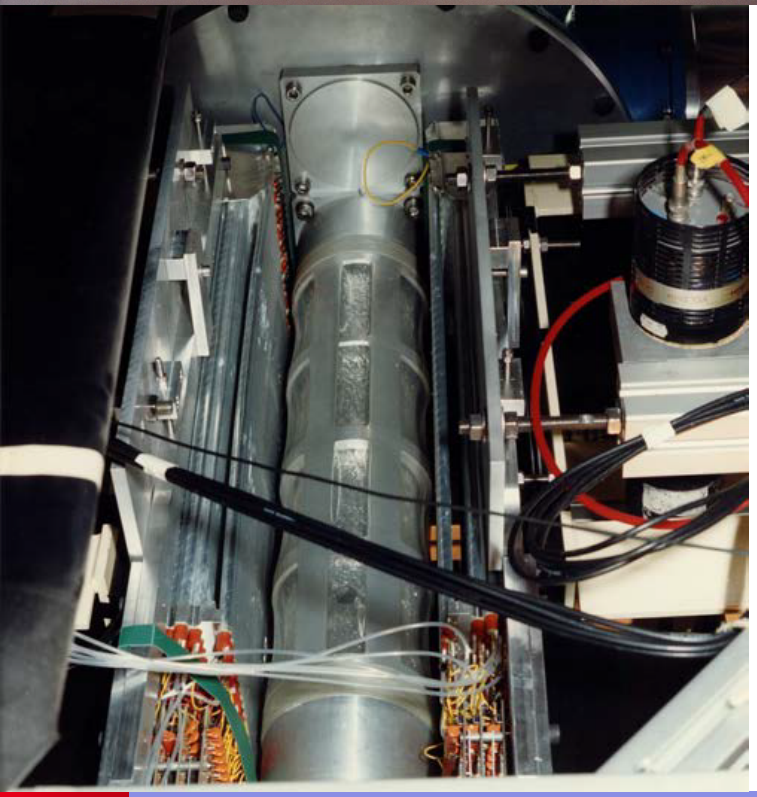
A new target for the HYPOM polarimeter with plane LH_2 cells

L.B. Golovanov[a], Yu. Borzounov[a], N.M. Piskunov[a], A.P. Tsvinev[a], J. Ball[b], J.L. Sans[b,c], E. Tomasi-Gustafsson[b,*]

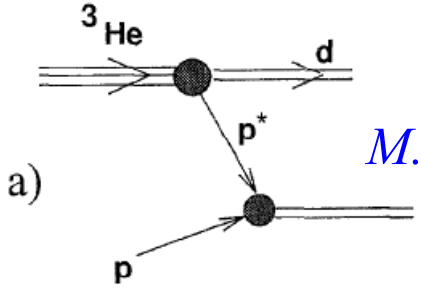


HYdrogen-POMme

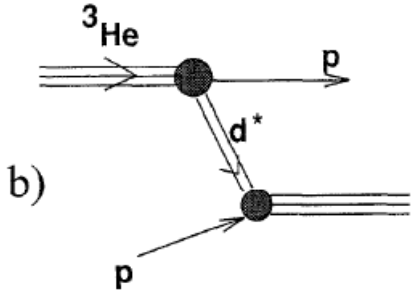


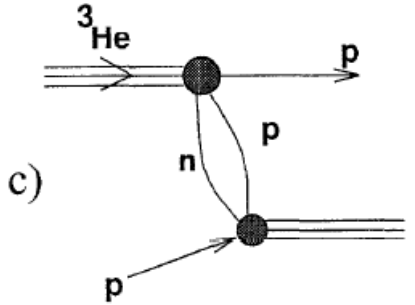


$\vec{p}(\vec{^3He},d)X$



M.P. Rekalo



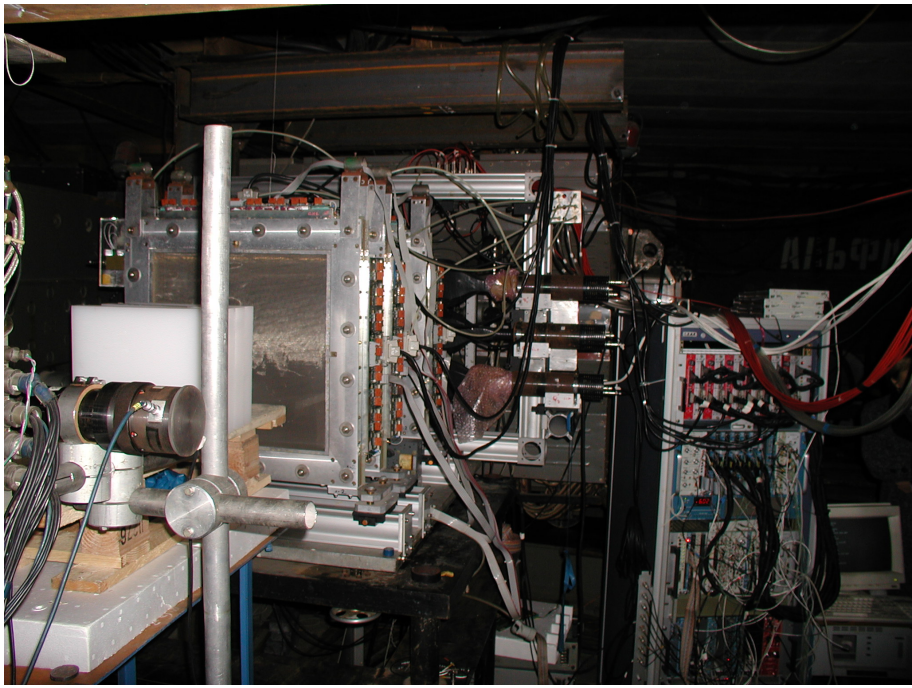


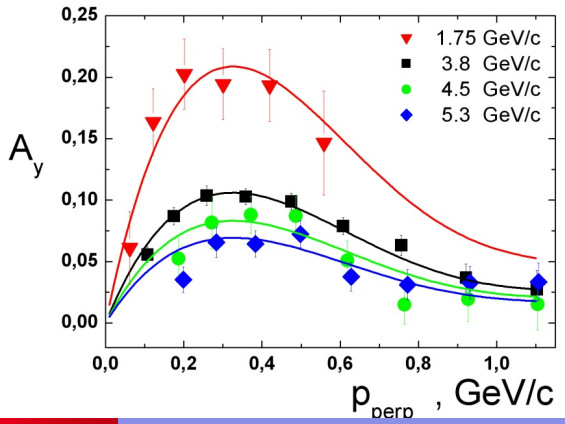
I.M. Sitnik et al., PRC 84, 034006 (2011)

POlarimetre Mobile Moyennes Energies

IPN, DAPNIA, Norfolk, W&M, INRNe-BAS,Jlab,JINR

Dismounting, at LNS (1997).





.....at ALPHA Setup, VBLHEP

The ALPOM run (2001)

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Nuclear Instruments and Methods in Physics Research A 538 (2005) 431–441
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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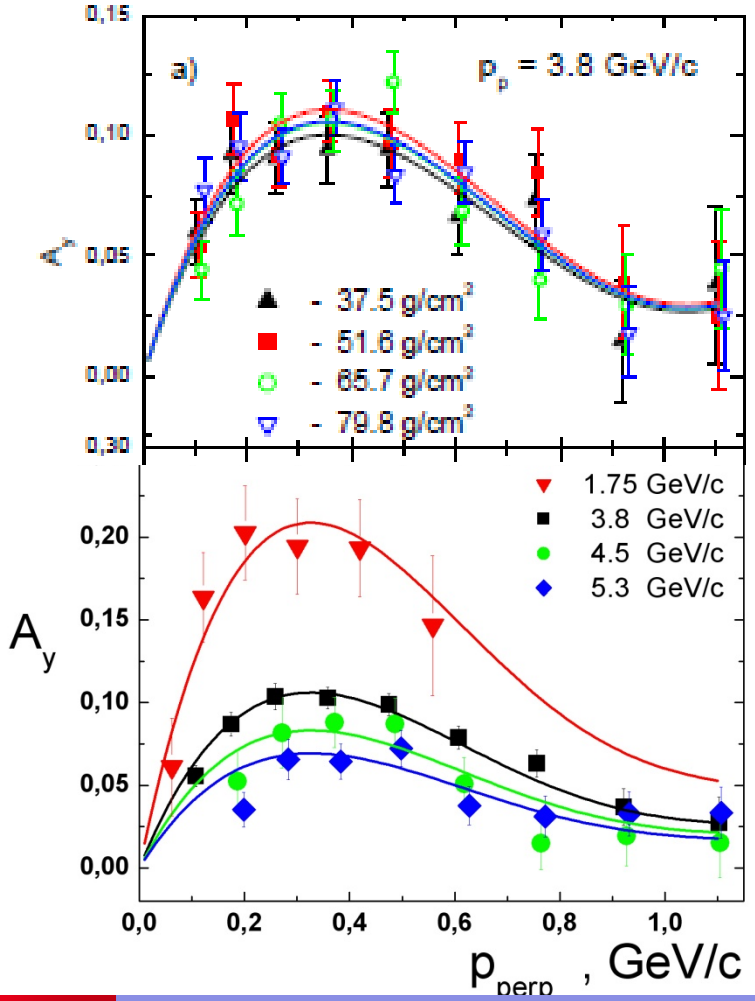
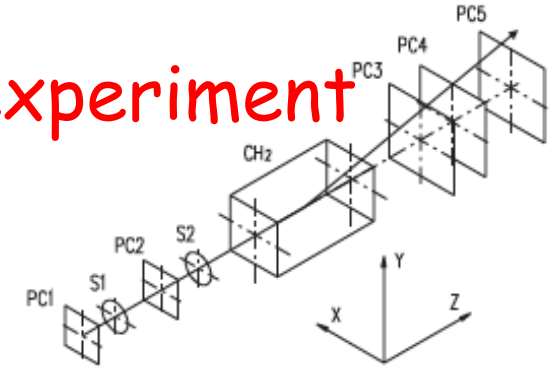
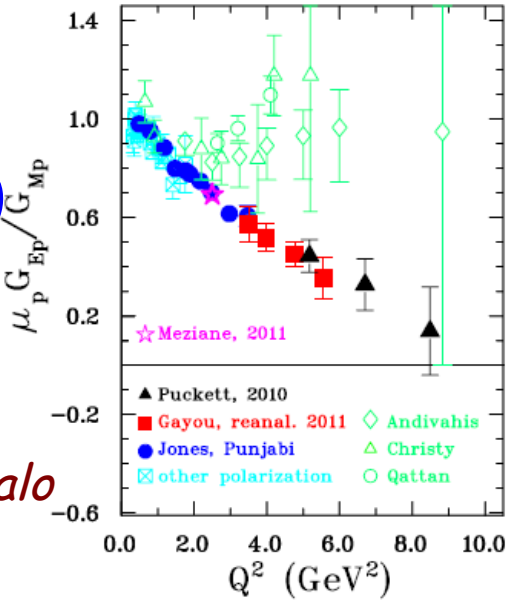


The ALPOM experiment at VBLHEP…



…and the highlight at Jlab (the GEp collaboration)



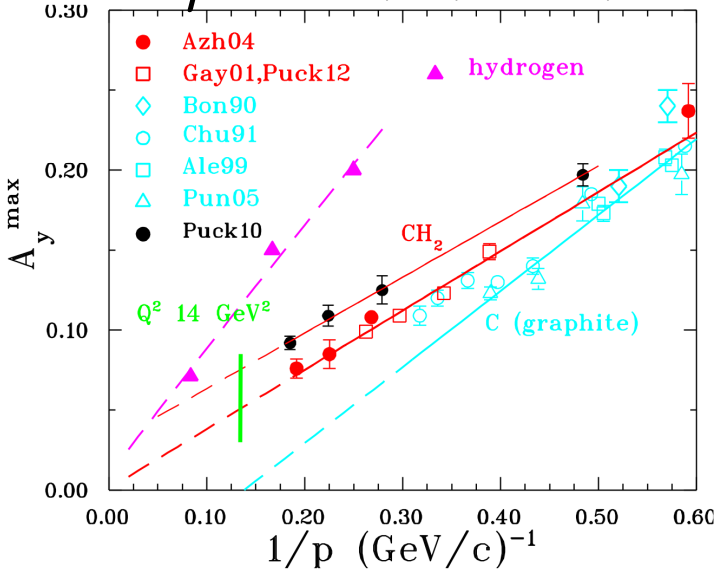
On an idea of A.I. Akhiezer and M.P. Rekalo

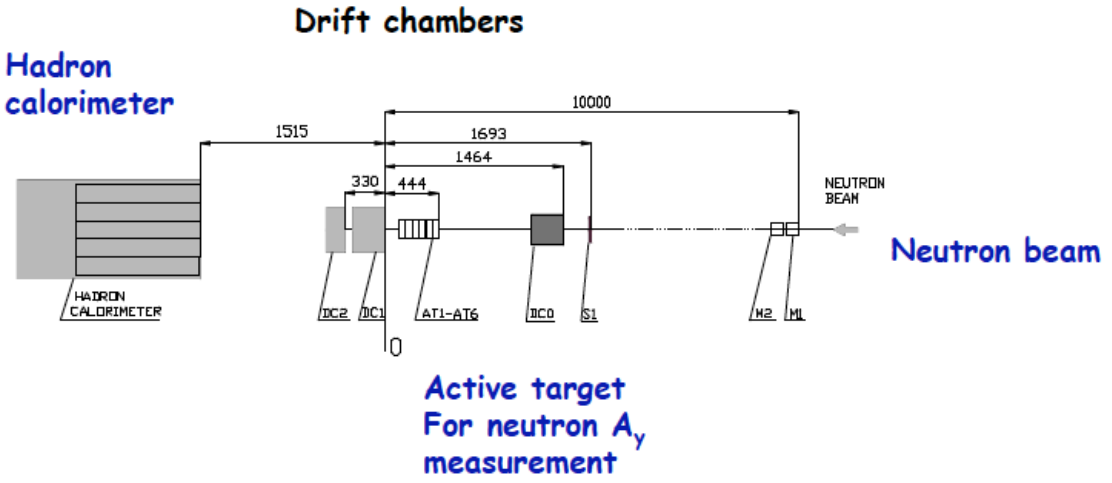
The ALPOM2 collaboration

IPN, IRFU, Norfolk, W&M, INRNe-BAS,Jlab,JINR,Glasgow U.,Kosice U.

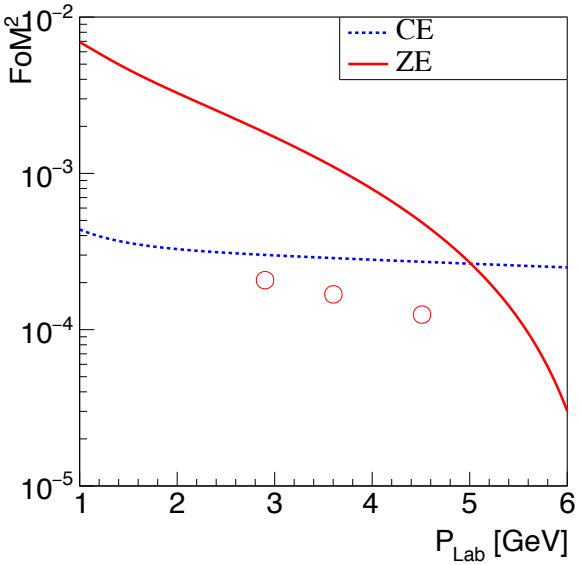
JLab 11 GeV upgrade:

analyzing powers up to 7.5 proton momentum





Charge exchange versus elastic np scattering on different targets



....not only protons

The ALPOM-2 run (2016)

Thank you for the attention