The ‚Bonn' Frozen Spin Target - status and new perspectives

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The ‚Bonn' Frozen Spin Target - status and new perspectives

- General aspects
- GDH - sum rule @ ELSA / MAMI
- 'GDH – Frozen Spin Target' (LAFST)
- new concepts
- conclusions

General aspects

Luminosity L

counting rate:

$$N = L \cdot \frac{d\sigma}{d\Omega} \Delta\Omega$$

$\frac{d\sigma}{d\Omega}$: cross section

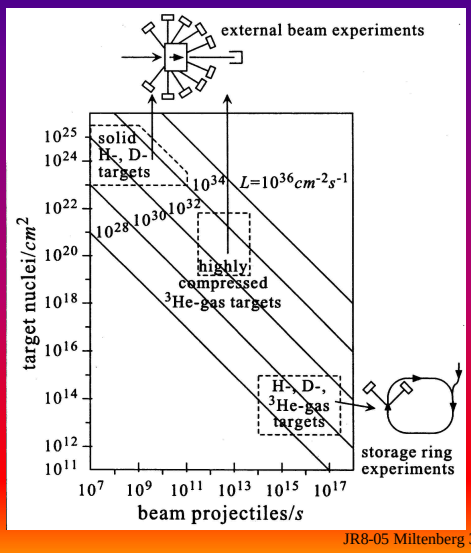
$\Delta\Omega$: angular acceptance

luminosity :

$$L = I \cdot n_t \quad [cm^{-2}\,\mathrm{sec}^{-1}]$$

n_t : areal target density

$$L \approx 10^{29} - 3 \cdot 10^{34} \quad [cm^{-2}\,\mathrm{sec}^{-1}]$$



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General aspects

'Figure of Merit'

Measurement of a polarization observable A

Pure target material (no background nucleons)

$$A = \frac{1}{P_t} \cdot \frac{\overleftarrow{N} - \vec{N}}{\overleftarrow{N} + \vec{N}}$$

P_t : target polarization

$\overleftarrow{N}, \vec{N}$: counting rate

quality factor $f = \frac{\text{polarizable nucleons}}{\text{total number of nucleons}}$

component design magnets, refrigerator, μ-waves etc.

$$A = \frac{1}{P_t} \cdot \frac{1}{f} \cdot \frac{\overleftarrow{N} - \vec{N}}{\overleftarrow{N} + \vec{N}}$$

target material properties

'Figure of Merit'

$$F_{\text{target}} = L \cdot P_t^2 \cdot f_t^2 \approx \frac{1}{\text{measuring time}}$$

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GDH - sum rule @ ELSA / MAMI

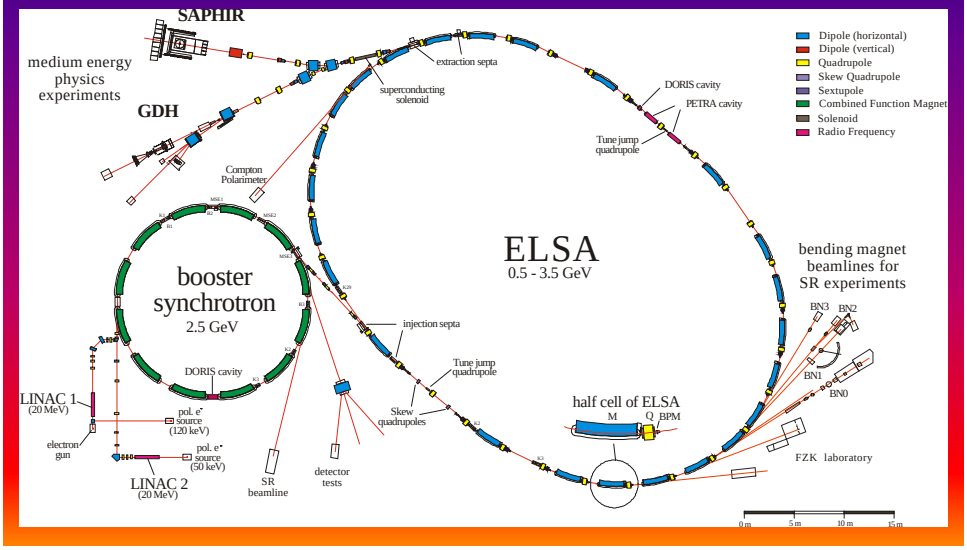
$$I_p^{GDH} = \int_0^\infty \frac{d\nu}{\nu}\left(\sigma_{3/2} - \sigma_{1/2}\right) = \frac{2\pi^2\alpha}{m^2}\kappa_p^2 = 205\mu b$$

- circular polarized photons
- 4π - detector
- longituninal polarized protons (neutrons)

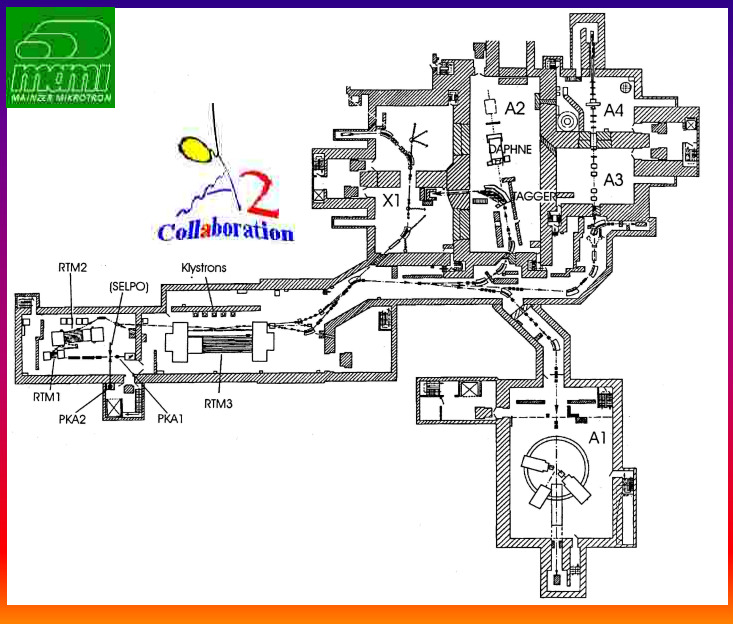
- **MAMI : 140 - 800 MeV (1998) (proton)**
- **ELSA : 750 - 3000 MeV (2002) (proton & neutron)**
- **MAMI: 140 – 800 MeV (2003) (deuteron/neutron)**

GDH - sum rule @ ELSA

The 'Bonn' electron stretcher accelerator ELSA



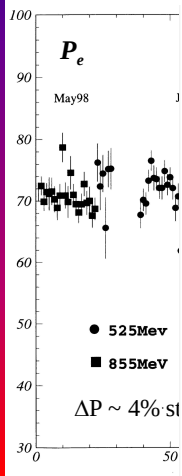
The Mainz microtron MAMI

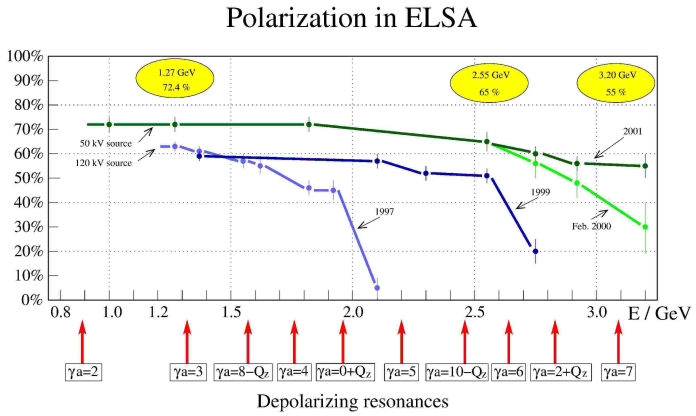


GDH - sum rule @ ELSA / MAMI

conservation of the helicity in the bremsstrahl process

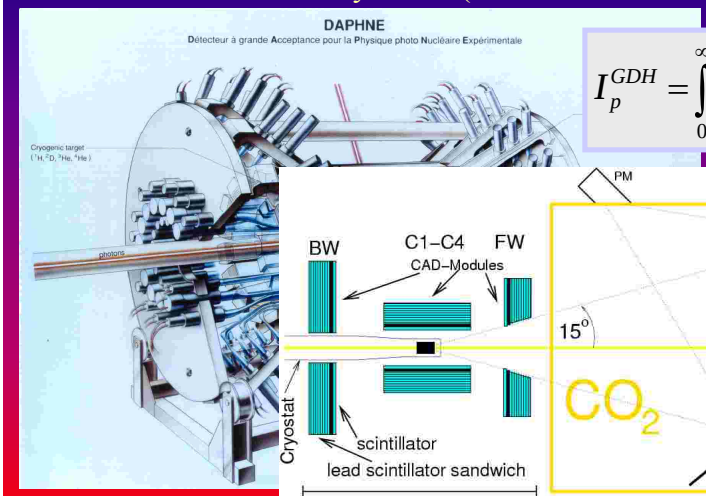
longitudinal polarized elektronen ⇒ circular polarized photons





GDH - sum rule @ ELSA / MAMI

'4π detection systems' (Bonn/Mainz 1998 – 2003)



$$I_p^{GDH} = \int_0^\infty \frac{d\nu}{\nu}\left(\sigma_{3/2} - \sigma_{1/2}\right)$$

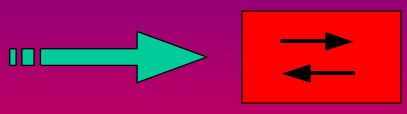
GDH-detector @ ELSA

GDH - Frozen Spin Target (LAFST)

Large Acceptance ‚Frozen Spin' Target for GDH sum rule

$$I_p^{GDH} = \int_0^\infty \frac{d\nu}{\nu}\left(\sigma_{3/2} - \sigma_{1/2}\right)$$

Longitudinal polarized nucleons

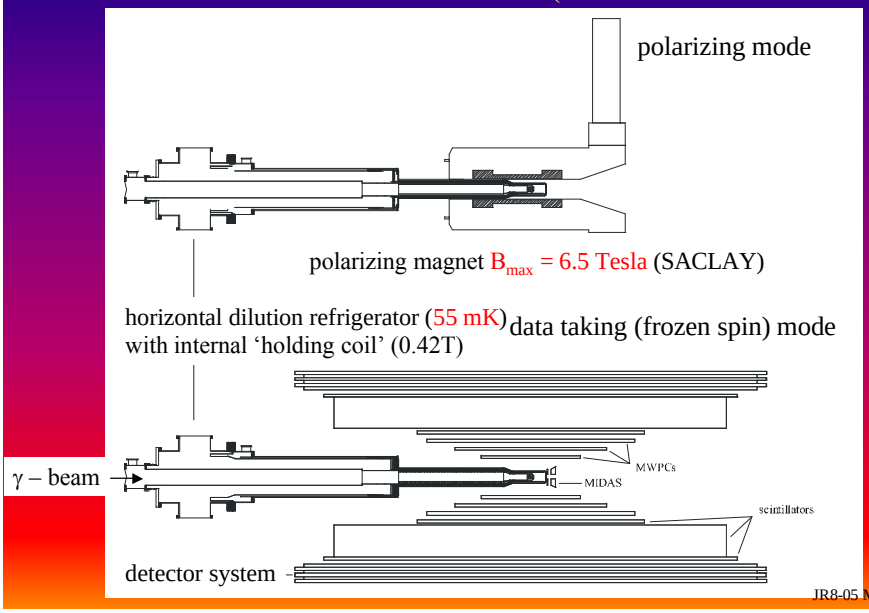


Circular polarized tagged photons (10^7 γ/s)

- **large angular acceptance Ω ≈ 4π (p-direction, reaction)**
- **optimize P and ΔΩ for a 4π detection system**
- **maximize FOM**

GDH - Frozen Spin Target (LAFST)

'measurement of the GDH sum rule' (Bonn/Mainz 1998 – 2003)



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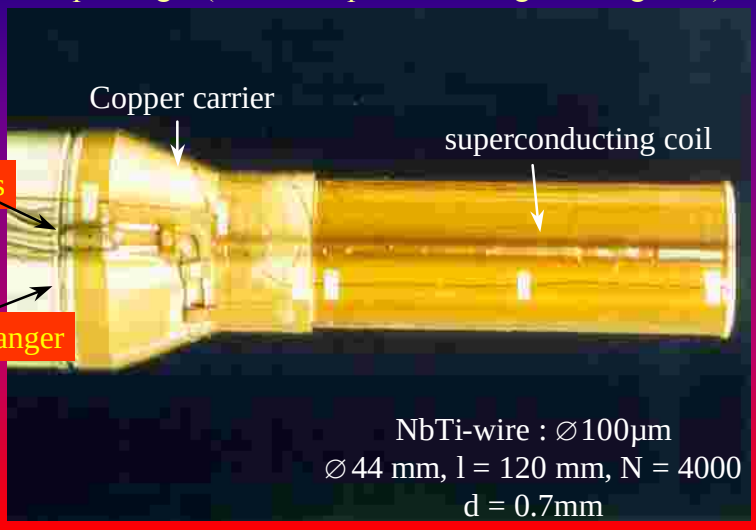
GDH - Frozen Spin Target (LAFST)

GDH – frozen spin target (internal superconducting 'holding coil')



reliable operation at B_h = 0.44 T @ 11.5 A, T < 1.2 K

NIM A 356 (1995) 111, NIM A 418 (1998) 233

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GDH - Frozen Spin Target (LAFST)

'measurement of the GDH sum rule' (Bonn/Mainz 1998 – 2003)

design and set-up : polarized target group' PI Bonn
[NIM A 436 (1999) 430]

first solid state polarized target for '4π detection systems'

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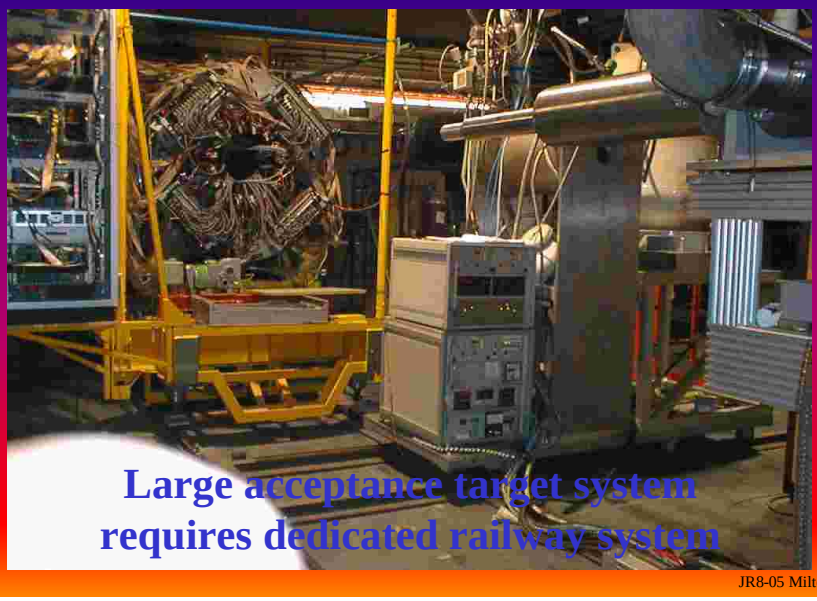
GDH - Frozen Spin Target (LAFST)

A2 - experimental area @ MAMI



Large acceptance target system
requires dedicated railway system

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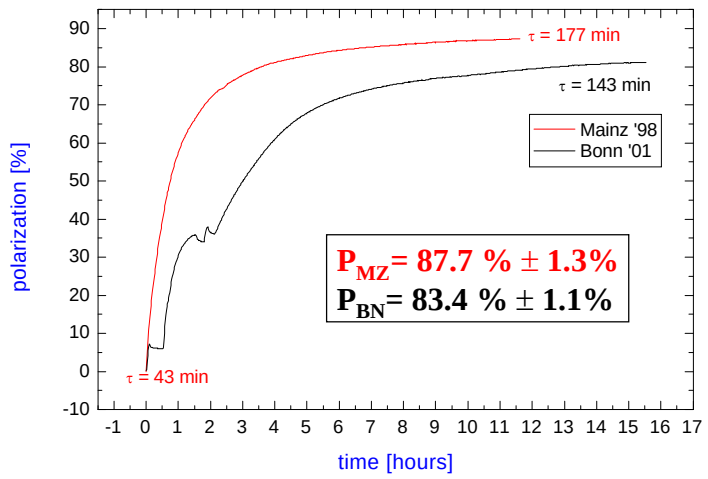
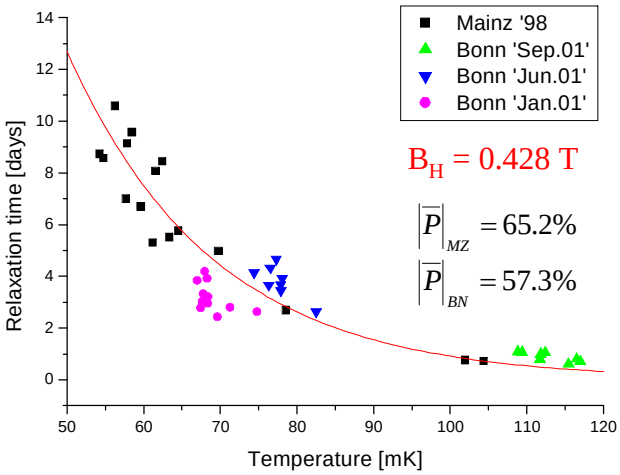
GDH - Frozen Spin Target (LAFST)

GDH – frozen spin target (polarization behavior of butanol)



GDH - Frozen Spin Target (LAFST)

GDH – frozen spin target (relaxation times τ(T) of butanol)

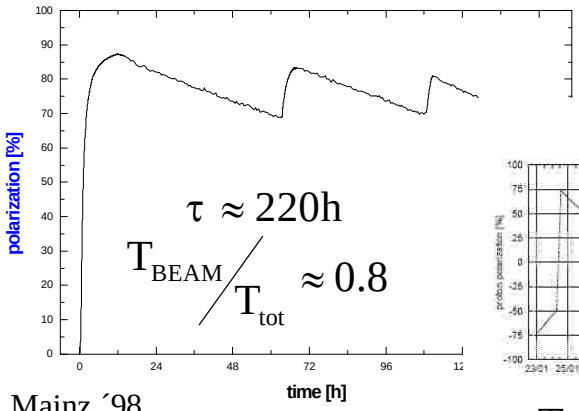


Temperature increase by mixing chamber mismatching

GDH - Frozen Spin Target (LAFST)

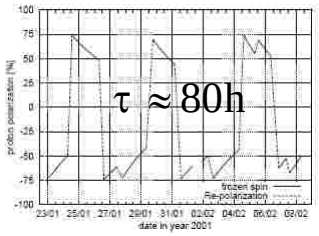
GDH – frozen spin target (relaxation times τ(T) of butanol)

B_H = 0.428 T



Mainz ´98

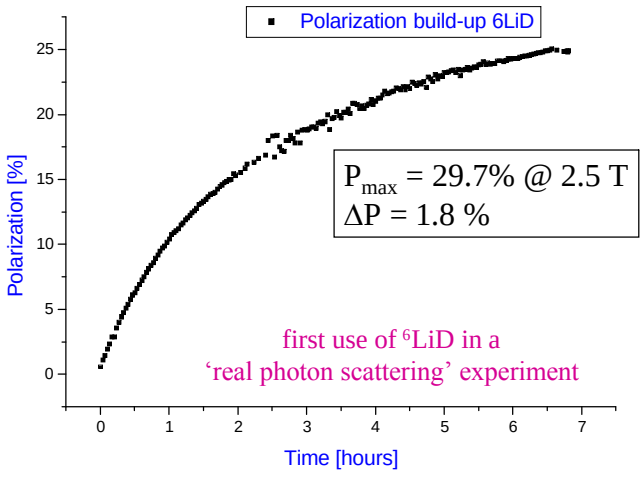
Bonn ´01



$T_{BEAM} / T_{tot} \approx 0.5$

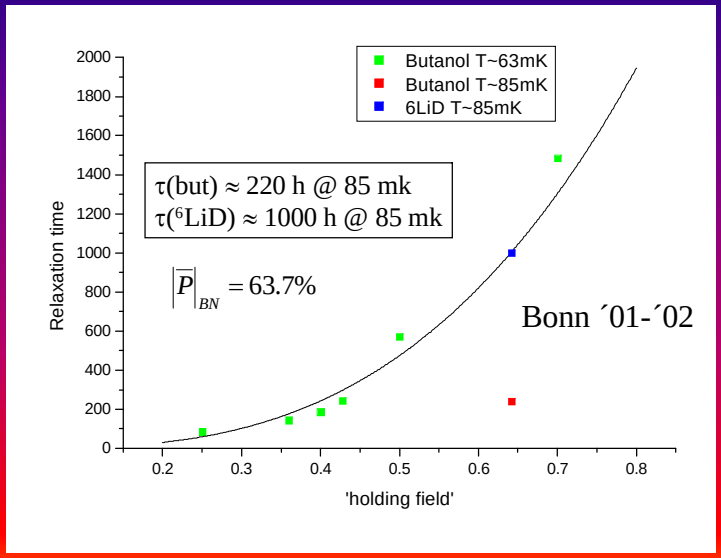
GDH - Frozen Spin Target (LAFST)

GDH – frozen spin target (polarization behavior of ^{6}LiD)



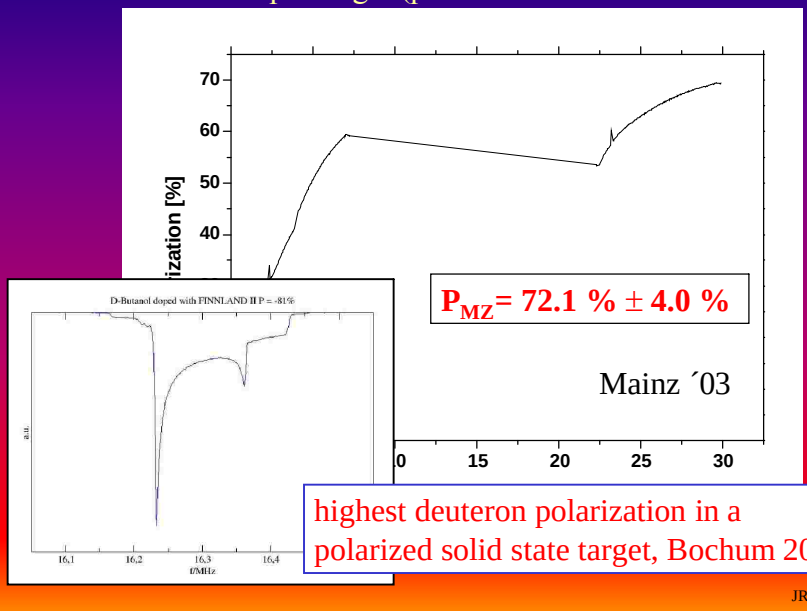
GDH - Frozen Spin Target (LAFST)

GDH – frozen spin target (relaxation times τ(B) of butanol and ^{6}LiD)



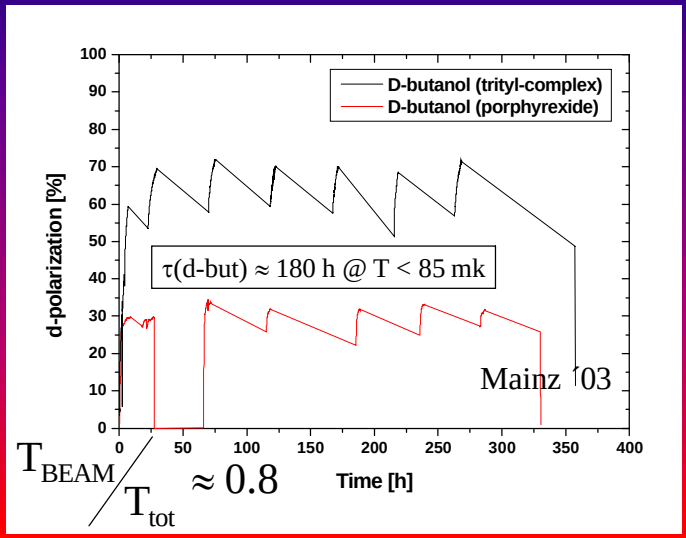
GDH - Frozen Spin Target (LAFST)

GDH – frozen spin target (polarization behavior of d-butanol)



GDH - Frozen Spin Target (LAFST)

GDH – frozen spin target (relaxation times τ(B) of d-butanol)



FOM increased by a factor 4 !! (target material)

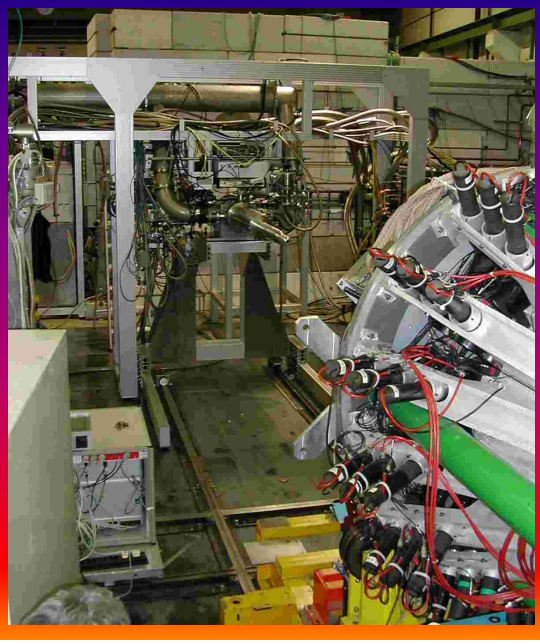
GDH - sum rule @ ELSA (2002)

ELSA

gdh–Collaboration

experimental set-up @ ELSA

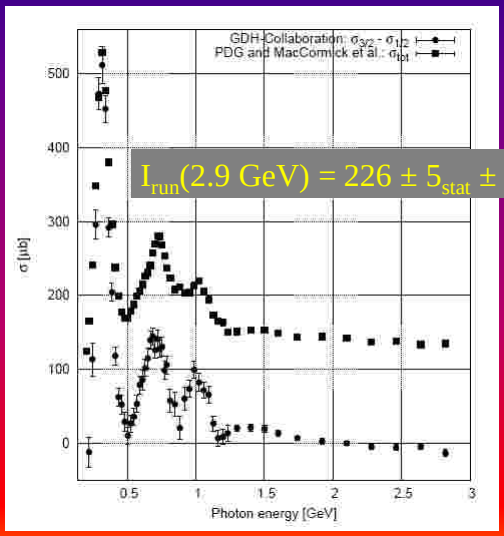
GDH – sum rule @ MAMI (2003)



GDH –Collaboration

GDH - sum rule @ ELSA / MAMI

Cross section difference off the proton

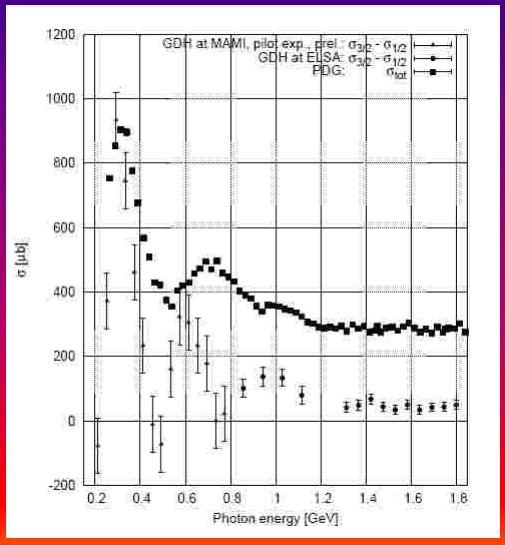


$I_{run}(2.9\ GeV) = 226 \pm 5_{stat} \pm 12_{syst}\ \mu b$.

GDH –Collaboration

GDH - sum rule @ ELSA / MAMI

Cross section difference off the neutron / deuteron



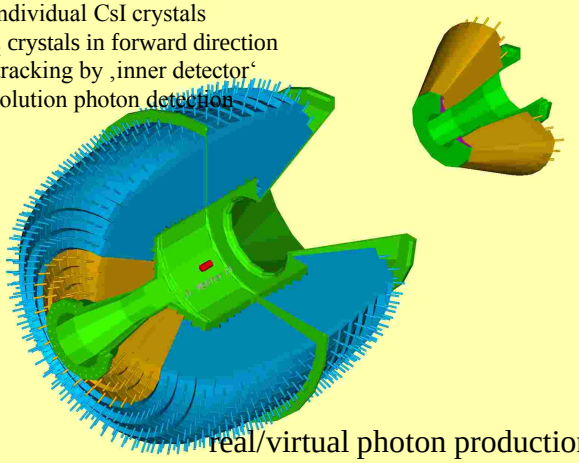
gdh–Collaboration

GDH - Frozen Spin Target (LAFST)

Future experiments with the GDH – Frozen Spin Target @ ELSA

Crystal Barrel detector (ELSA / Bonn)

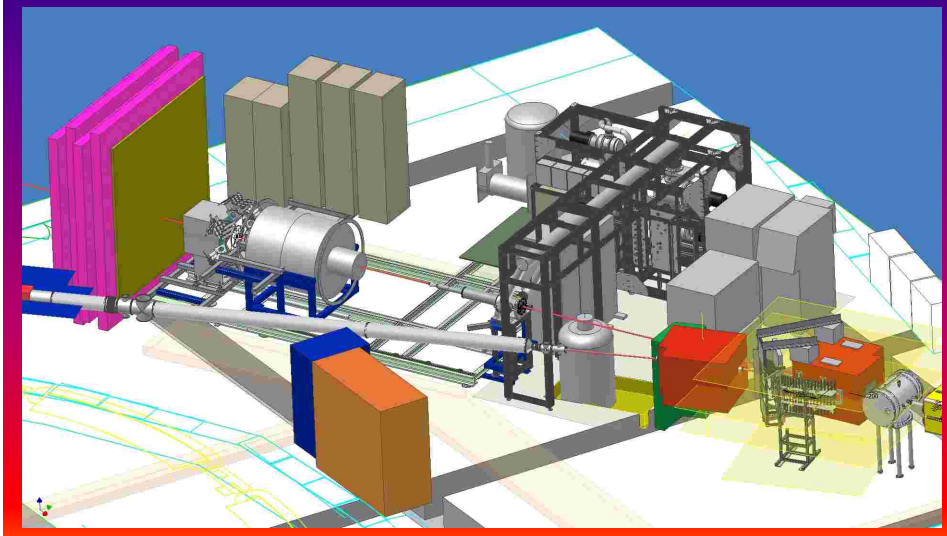
- ~1280 individual CsI crystals
- 60 BaF_2 crystals in forward direction
- central tracking by ‚inner detector'
- high resolution photon detection



real/virtual photon production,
baryon spectroscopy, meson production

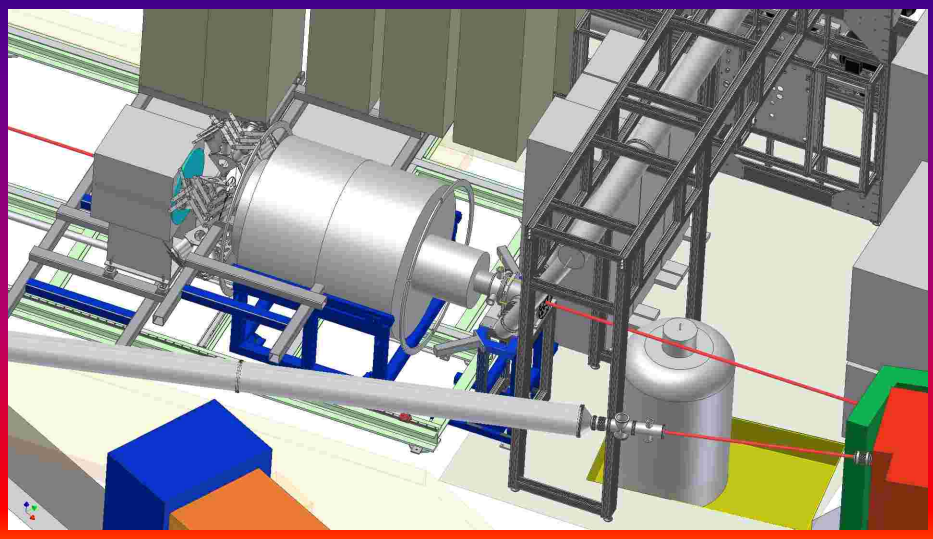
GDH - Frozen Spin Target (LAFST)

Double polarization experiments @ ELSA



GDH - Frozen Spin Target (LAFST)

Double polarization experiments @ ELSA



GDH - Frozen Spin Target (LAFST)

'limitations of the frozen spin principle

'Frozen Spin Target' :

- good angular acceptance (~ 4π)
- moderate luminosity L ~ 10^{30}/cm²s (N ≈ 10^{7}/s)
- no electron scattering experiments
- moderate mean polarization
- moderate beam time efficiency

'continuous mode' target : SLAC, JLAB

- bad angular acceptance (#msrad)
- high luminosity L ~ 10^{35}/cm²s (N ≈ 10^{12}/s)
- high mean polarization
- good beam time efficiency

Scope : combine both concepts

'4π - continuous mode' target :

- good angular acceptance (~ 4π)
- high luminosity L ~ 10^{33}/cm²s (N ≈ 10^{10}/s)
- high mean polarization
- Good beam time efficiency

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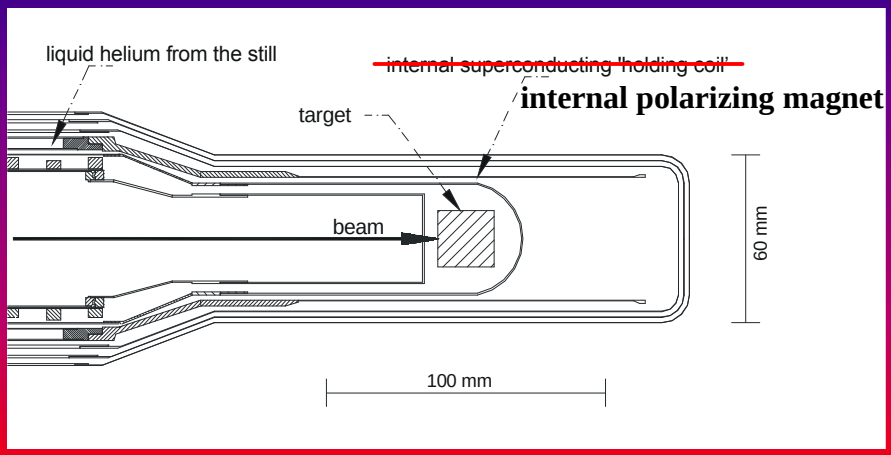
New concepts

'4π continuous mode target'



∅ 44 mm, l ~ 160 mm, d ≤ 1.5 mm

goal : B_p ~ 2.5 Tesla, ΔB/B ~ 10^{-4}

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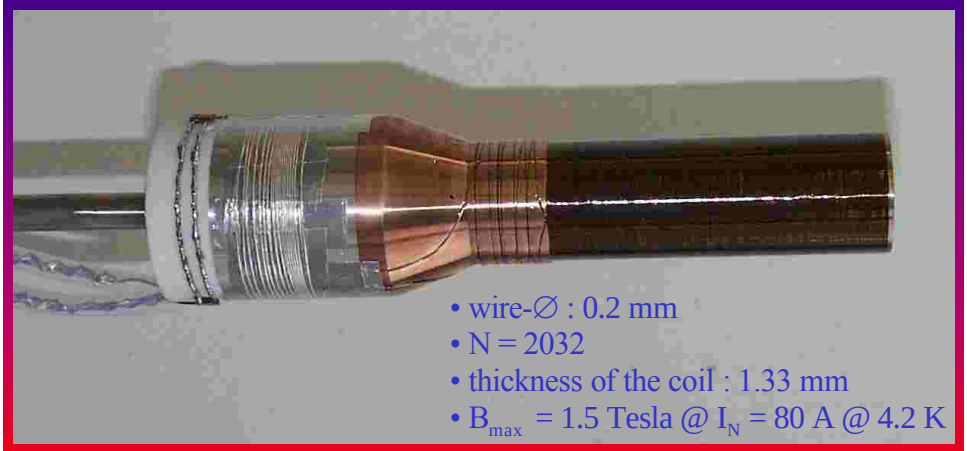
New concepts

‘4π continuous mode target’



- wire-∅ : 0.2 mm
- N = 2032
- thickness of the coil : 1.33 mm
- B_{max} = 1.5 Tesla @ I_N = 80 A @ 4.2 K

in the GDH – cryostat : I_{max} ~ 40 A ⇒ B_{max} ~ 0.8 Tesla

Problem :current leads (cryostat design!!!)

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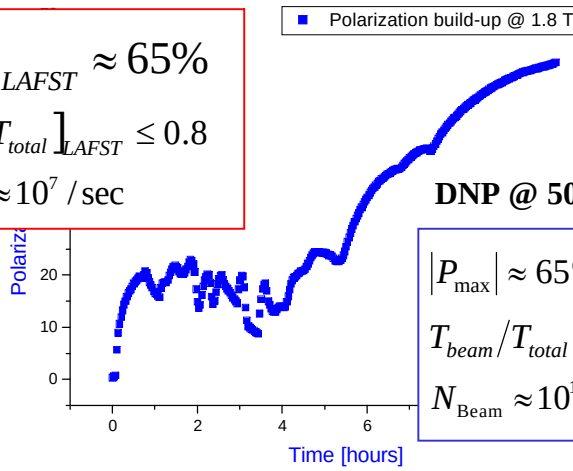
New concepts

‘4π continuous mode target’

$|P_{mean}|_{LAFST} \approx 65\%$

$[T_{beam}/T_{total}]_{LAFST} \leq 0.8$

$N_{Beam} \approx 10^7$ / sec



DNP @ 50 GHz

$|P_{max}| \approx 65\% - 70\%$

$T_{beam}/T_{total} \approx 1$

$N_{Beam} \approx 10^{10}$ / sec

FOM >> ‚frozen spin target‘

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‘4π continuous mode target’

combined ^{4}He-evaporation / ^{3}He/^{4}He dilution refrigerator

new horizontal dilution cryostat with a variable internal magnet system

cut-view without target insert

design studies nearly completed

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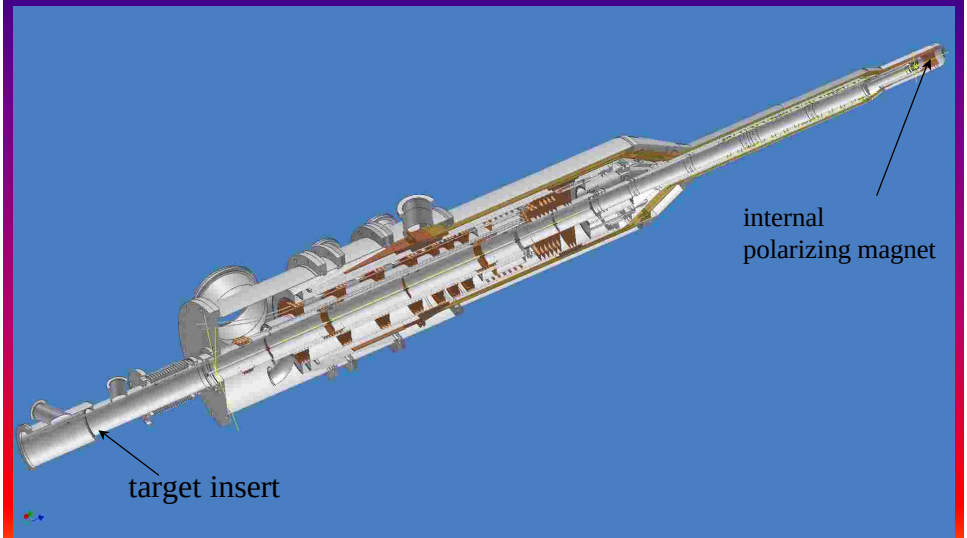
‘4π continuous mode target’

combined ^{4}He-evaporation / ^{3}He/^{4}He dilution refrigerator



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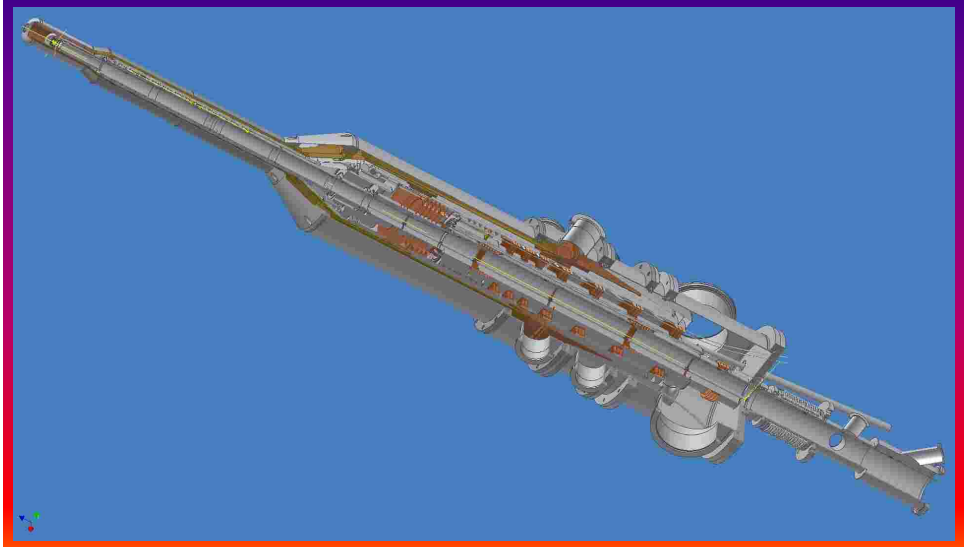
‘4π continuous mode target’

combined ^{4}He-evaporation / ^{3}He/^{4}He dilution refrigerator



Conclusions

component design
magnets, refrigerator

$$F_{\text{target}} = L \cdot P_t^2 \cdot f_t^2 \approx \frac{1}{\text{measuring time}}$$

- GDH-frozen spin target (LAFST) is a reliable tool for double polarization experiments with CB@ELSA
- ‘4π – continuous mode target’
  - **‘high luminosity, large acceptance’ polarized solid state target**
  - internal polarizing magnet
  - no railway system required
  - longitudinal polarization direction
  - transverse polarization as a frozen spin target
  - electron scattering experiments in a 4π detection system
- New dilution refrigerator for ELSA experiments is under construction

GDH - sum rule @ ELSA / MAMI

'The collaboration'

J. Ahrens [1], S. Altieri [12], J.R.M. Annand [6], G. Anton [4], H.-J. Arends [1], G. Audit [14], R. Beck [1], C. Bradtke [3], A. Braghieri [12], N. d'Hose [14], D. Drechsel [1], H. Dutz [2], S. Goertz [3], P. Grabmayr [15], K. Hansen [8], J. Harmsen [3], D.v. Harrach [1], S. Hasegawa [11], T. Hasegawa [11], E. Heid [1], W. Heil [9], K. Helbing [4], H. Holvoet [5], L. van Hoorebeke [5], N. Horikawa [11], T. Iwata [11], P. Jennewein [1], T. Kageya [11], B. Kiel [4], R. Kondratjev [10], J. Krimmer [15], M. Lang [1], B. Lannoy [5], R. Leukel [1], V. Lisin [10], T. Matsuda [9], A. Meier [3], D. Menze [2], W. Meyer [3], T. Michel [4], S. Nakamura [11], J. Naumann [4], A. Panzeri [12][13], P. Pedroni [12], T. Pinelli [12][13], I. Preobrajenski [1], E. Radtke [3], T. Reichelt [2], G. Reicherz [3], Ch. Rohlof [2], F. Sadiq [6], M. Sauer [15], B. Schoch [2], M. Schumacher [7], B. Seitz [7], F. Smend [7], T. Speckner [4], N. Takabayashi [11], G. Tamas [1], A. Thomas [1], R. van de Vyver [5], A. Wakai [11], F. Wissmann [7], F. Zapadtka [7], G. Zeitler [4]

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gdh –Collaboration