

GDH experiment at the present and new LEPS beam lines

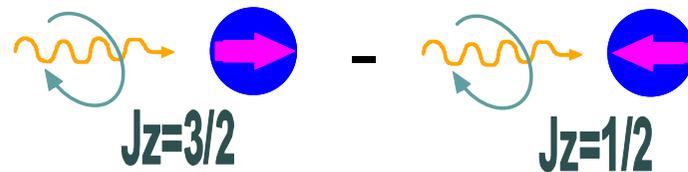
Tatsuro Matsuda
Uni. of Miyazaki

1. GDH Sum Rule and GDH experiment at Spring-8
2. Present status of GDH Sum Rule experiments
3. Request for beam lines (Prof. Iwata's message)

Workshop on LEPS/Spring-8 new beamline
2005/7/28.29 RCNP, Osaka University

GDH sum rule

- Gerasimov-Drell-Hearn sum rule



Circularly polarized gamma &
Spin polarized nucleon target

$$I_{GDH} = \int_{\nu_{\pi}}^{\infty} d\nu \frac{\sigma_{3/2}(\nu) - \sigma_{1/2}(\nu)}{\nu} = \frac{2\pi^2 \alpha}{m_N} \kappa^2$$

ν : photon energy

ν_{π} : pion threshold energy

κ : anomalous magnetic moment

$$\kappa_p = (\mu_p - \mu_N) / \mu_N = 1.79$$

$$\kappa_n = (\mu_n - 0) / \mu_N = -1.91$$

$$I_{GDH,p} = 205 \mu b, I_{GDH,n} = 233 \mu b$$

- S.B. Gerasimov:

Yad. Fiz. 2 (1965) 598 /

Sov. J. Nucl. Phys. 2, 430 (1966)

- S.D. Drell and A.C. Hearn:

Phys. Rev. Lett. 16, 430 (1966)

- M. Hosoda and K. Yamamoto:

Prog. Theor. Phys. 36 (1966) No. 2,

Lett. to Editor 425

→ “DHGHY sum rule”

called by Jaffe (SPIN2000)

nucleon spin structure

Forward Compton Amplitude

$$f(\nu) = \chi_f^\dagger \left[\underbrace{f_1(\nu) \boldsymbol{\varepsilon}_f^* \cdot \boldsymbol{\varepsilon}_i}_{\text{spin non-flip}} + i \underbrace{f_2(\nu) \boldsymbol{\sigma} \cdot (\boldsymbol{\varepsilon}_f^* \times \boldsymbol{\varepsilon}_i)}_{\text{spin flip}} \right] \chi_i$$

ASSUMPTION:
spin flip amplitude
vanishes at infinite energy

$$\lim_{\nu \rightarrow \infty} f_2(\nu) = 0$$

General Principles

Lorenz invariance,
gauge invariance,
causality, relativity,
crossing symmetry,
analytic amplitude

unsubtracted dispersion relation

$$\Re f_2(\nu) = \frac{\nu}{\pi} P \int_0^\infty \frac{\Im m f_2(\nu')}{\nu'^2 - \nu^2} d\nu'$$

optical theorem

$$\Im m f_2(\nu) = \frac{\nu}{8\pi} (\sigma_{3/2}(\nu) - \sigma_{1/2}(\nu))$$

low energy theorem

$$f_2'(\nu) = \left. \frac{\partial f_2}{\partial \nu} \right|_{\nu=0} = \frac{\alpha}{2m^2} \kappa^2$$

Physical cross sections
(from low to high energy scattering)

GDH sum rule

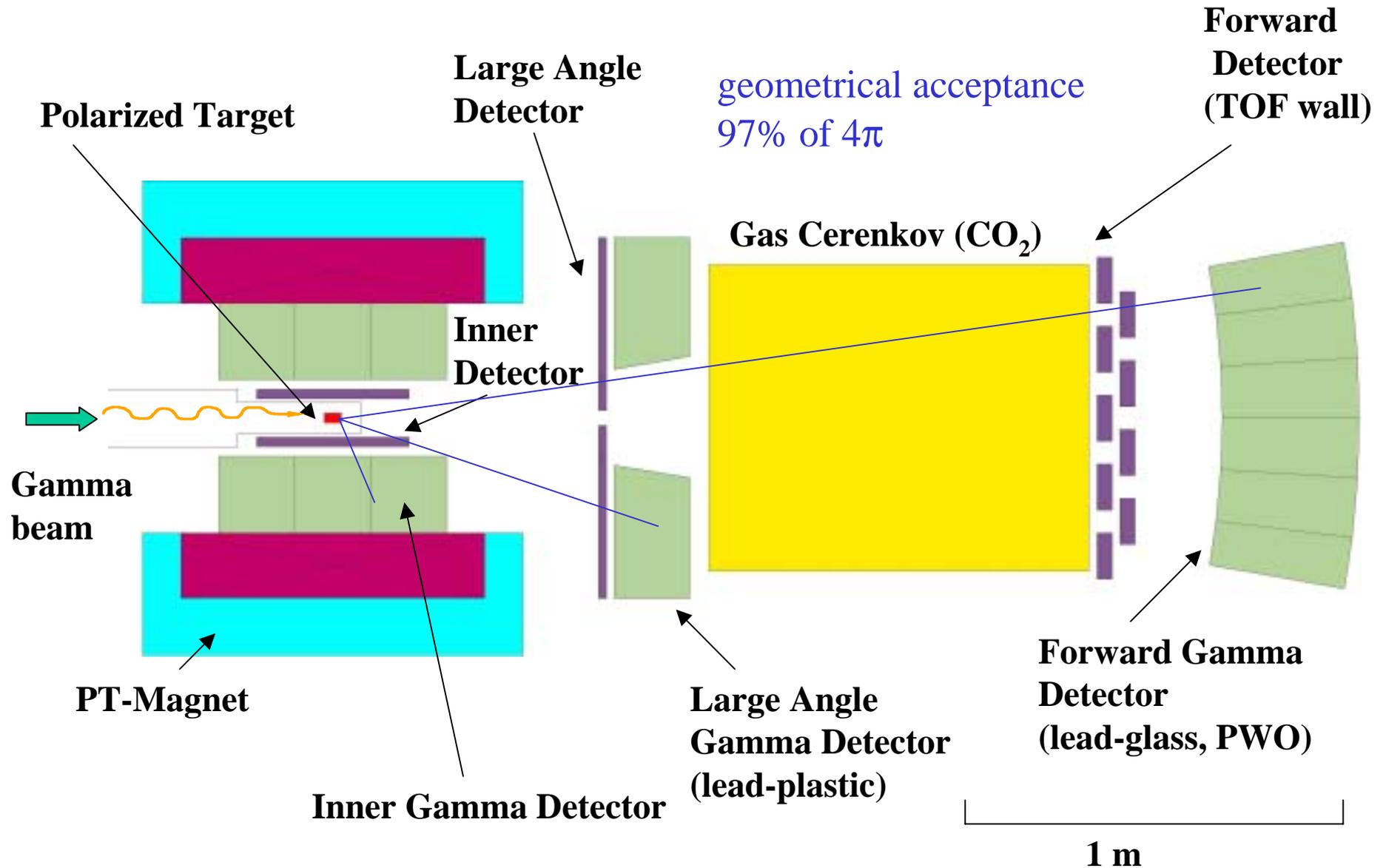
$$\int_{\nu_\pi}^\infty d\nu \frac{\sigma_{3/2}(\nu) - \sigma_{1/2}(\nu)}{\nu} = \frac{2\pi^2 \alpha}{m_N} \kappa^2$$

**Anomalous
Magnetic Moment**
(static property)

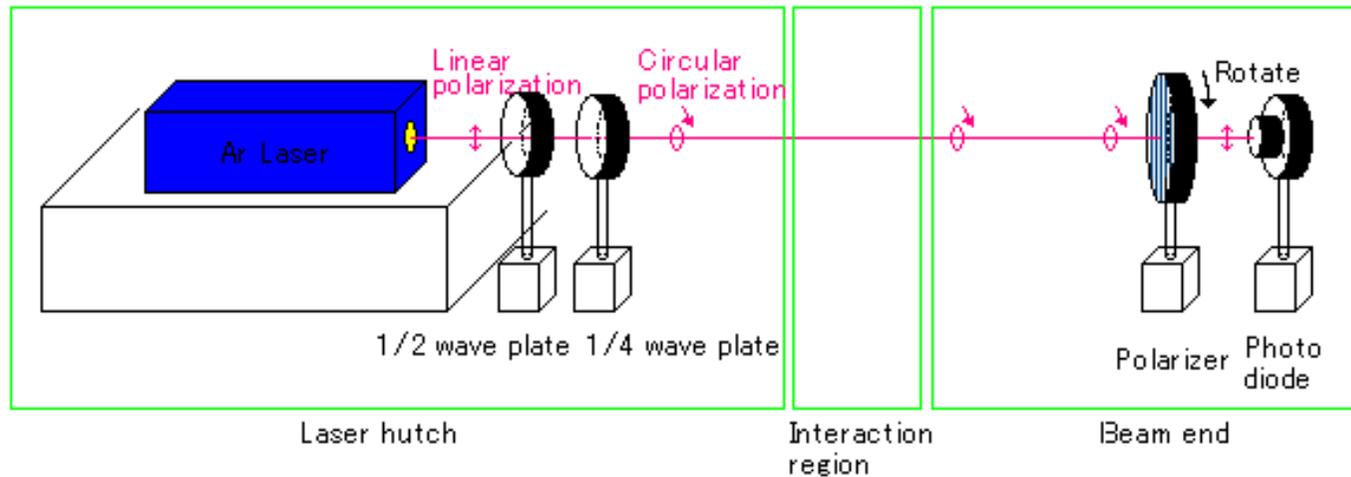
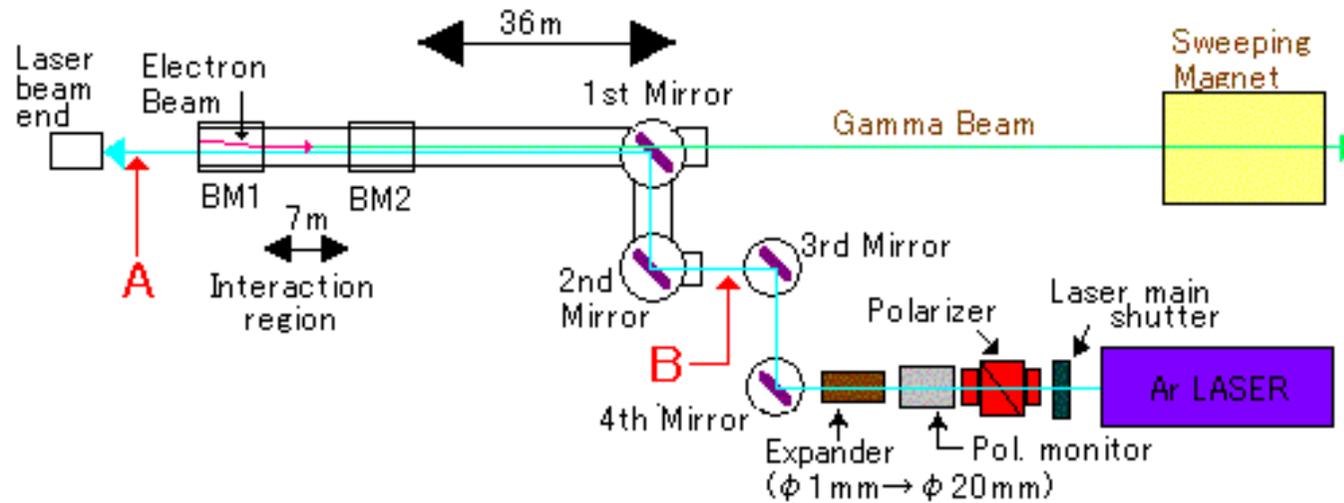
GDH experiment at SPring-8 (SP8-GDH collaboration)

- **Study of the GDH sum rule for proton
(measurement of helicity dependent photo-absorption cross-sections)**
- **Approved in Oct. 2001 (QPAC of RCNP)**
- **Energy region: 1.8 ~ 2.4 GeV & 2.3 ~ 2.8 GeV**
- **Energy settings**
 - 1st phase: $E_{\max}=2.4\text{GeV}$ ($\lambda=351\text{nm}$, 1W)
 - $1.8 < E_{\gamma} < 2.4\text{GeV}$, $I_{\gamma}=10^6/\text{s}$ (full spectrum), $\langle\text{Pol.}\rangle=85\%$
 - 2nd phase: $E_{\max}=2.8\text{GeV}$ ($\lambda=275\text{nm}$, 0.3W)
 - $2.3 < E_{\gamma} < 2.8\text{GeV}$, $I_{\gamma}=10^5/\text{s}$ (full spectrum), $\langle\text{Pol.}\rangle=80\%$
- **Polarized polyethylene target**
- **4π -detector system**

SP8-GDH Setup



Circular polarized photon for circular polarized gamma



Presented by Toi-kun at JPS2004 at Fukuoka

- 円偏光度測定結果

最上図:

改造前の直線偏光

$$P_{lin} = 97.38 \pm 0.57 [\%]$$

上図:

改造前の円偏光

$$P_{cir} = 98.51 \pm 0.05 [\%]$$

下図:

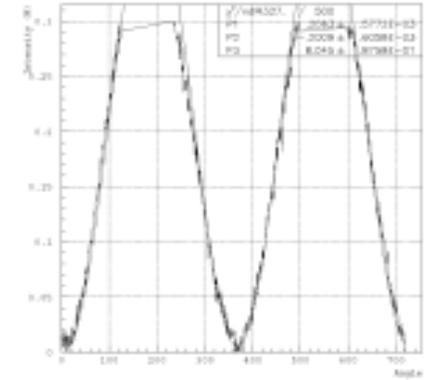
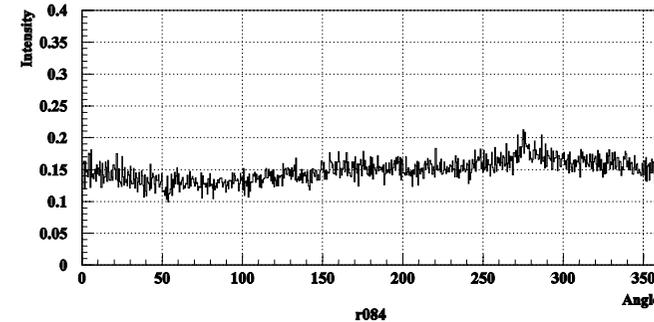
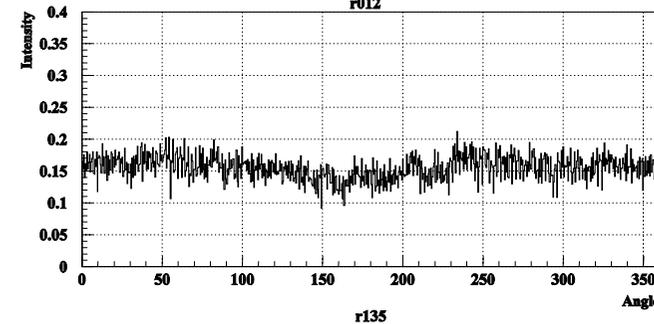
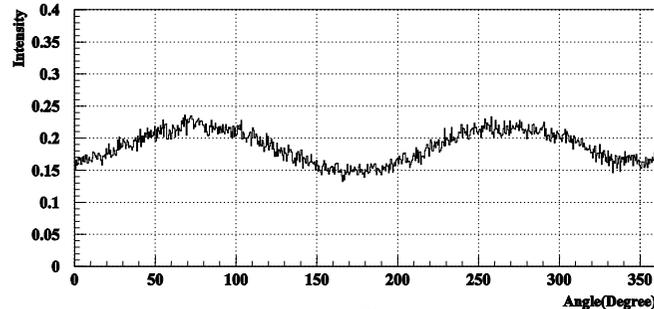
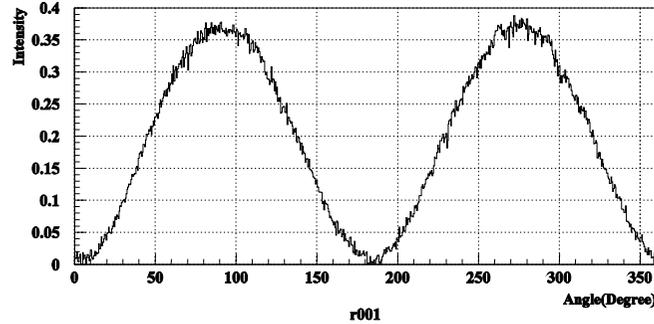
改造後の円偏光

$$P_{cir} = 99.85 \pm 0.02 [\%]$$

最下図:

改造後(1ヵ月)の円偏光

$$P_{cir} = 99.90 \pm 0.01 [\%]$$

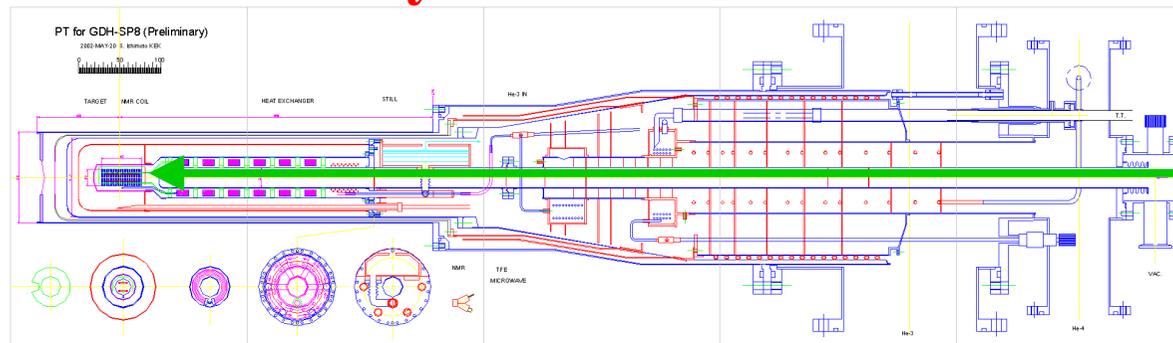


Upper measured points are distorted.

Polarized Target System needs **Cryostat**, **Magnet**, **Micro-wave**
and polarized material to take **D**ynamic **N**uclear **P**olarization method

DNP → polarization reversal by change of microwave frequency
don't have to reverse magnetic field !!

KEK modified Dilution Cryostat @ 100 mKelvin



beam

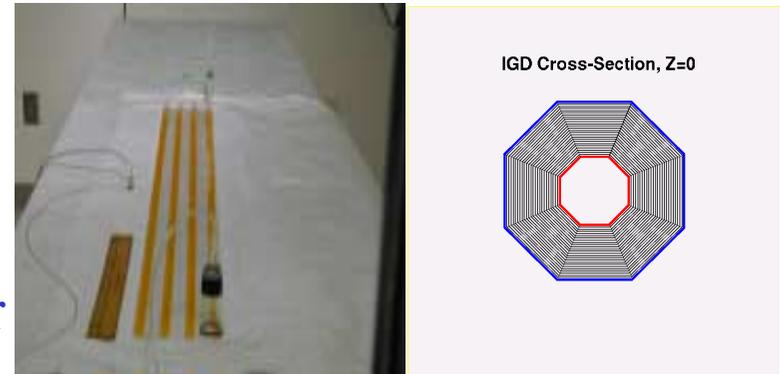
- Top part is being modified and tested at **Yamagata Uni.**
- beam pipe to be rearranged
(Micro Wave guide removed)
 - diameter of the beam pipe is 24mm
 - beam size x: 40mm → need an active collimator?

Magnet @ 2.5 Tesla

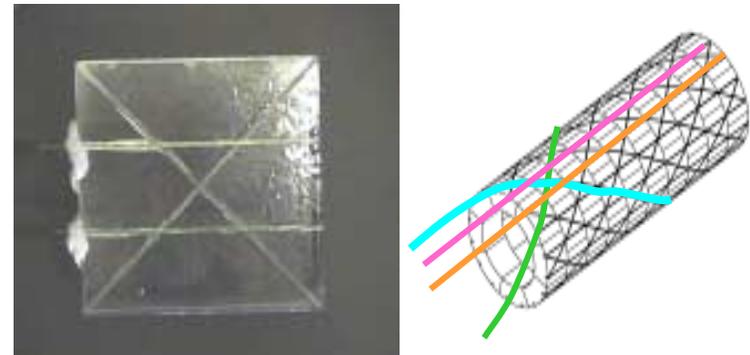


Detectors

Inner gamma detector →
UCLA group will apply DOE budget.
lead-plastic-scintillator Sandwich detector



Inner detector →
Melbourne group made preliminary
Study.
Plastic-scintillator with WLS fiber



Gas Cherenkov detector →
Miyazaki group is making it.
CO₂ gas at 1 atm Cherenkov



GDH activities in the world

	proton	Neutron
MAMI	200-800MeV, complete	200-800MeV, completed (D-butanole)
ELSA	0.68-2.9GeV, complete	0.8-1.8,complete(LiD)
JLAB	2.5-6GeV, proposed	
GRAAL	0.5-1.5GeV,proposed,(HD)	0.5-1.5GeV, proposed (HD)
SLAC	4-40GeV, proposed	
LEGS	130-470MeV, running,(HD)	130-470MeV, running,(HD)
SPring-8	1.8-2.8GeV, proposed, (PE)	1.8-2.8GeV, proposed, (D-butanole)

GDH Sum Rule for proton

MAMI+ELSA results

K. Helbing, Proc. GDH2004

PRL93(2004)32003

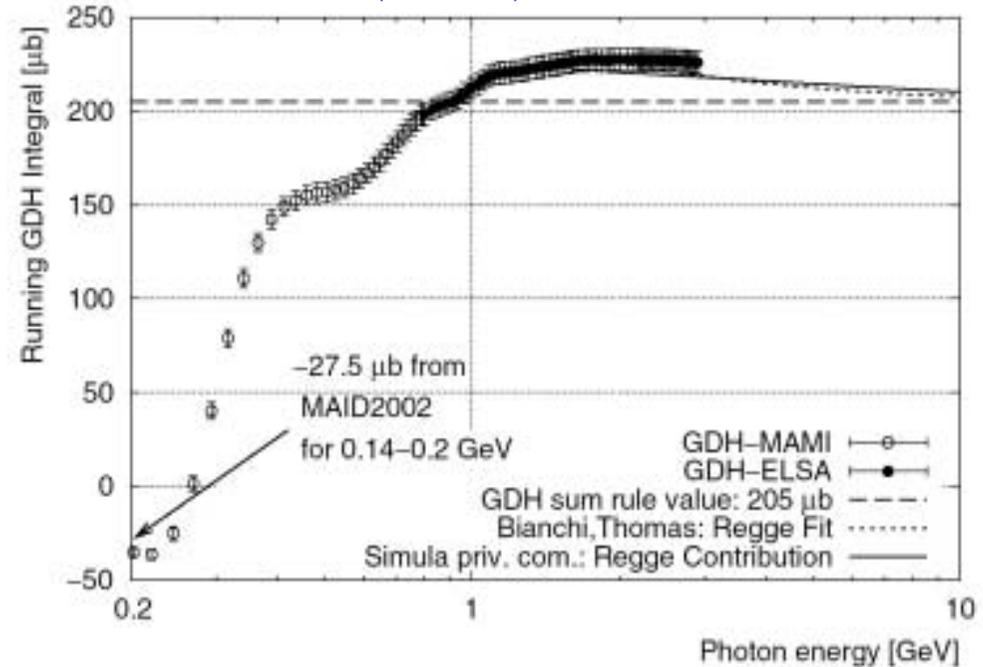
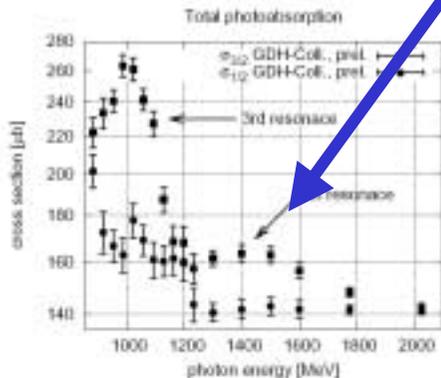
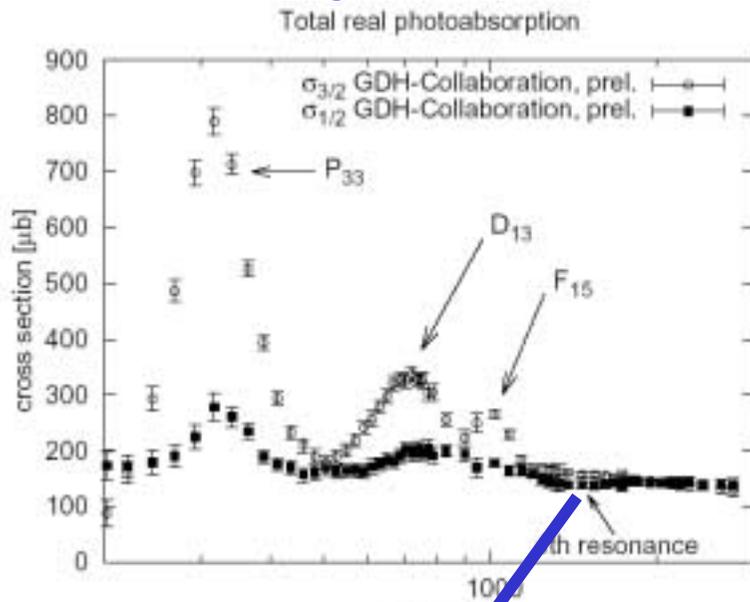
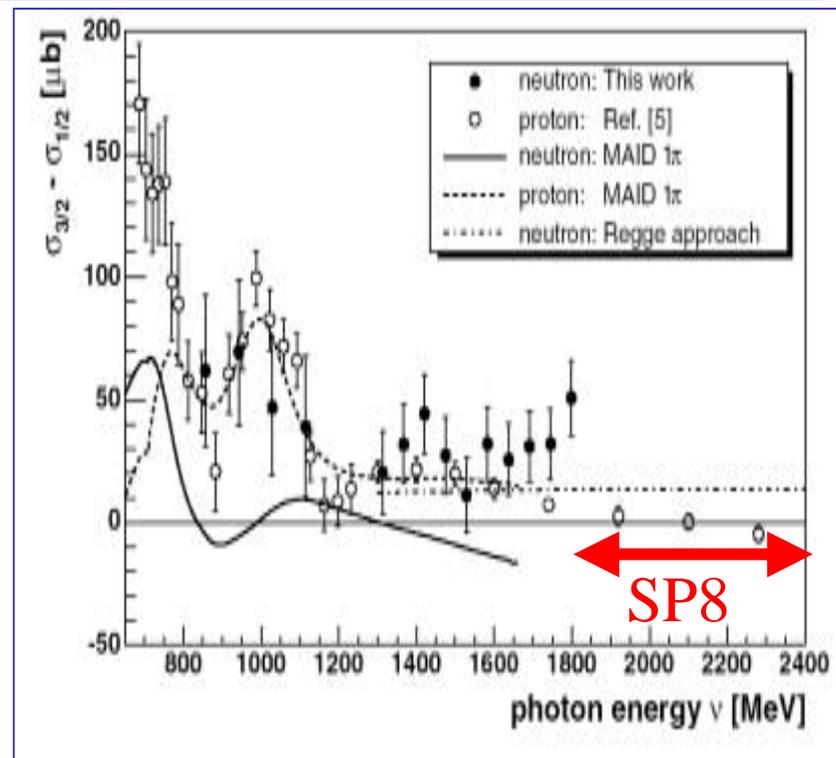
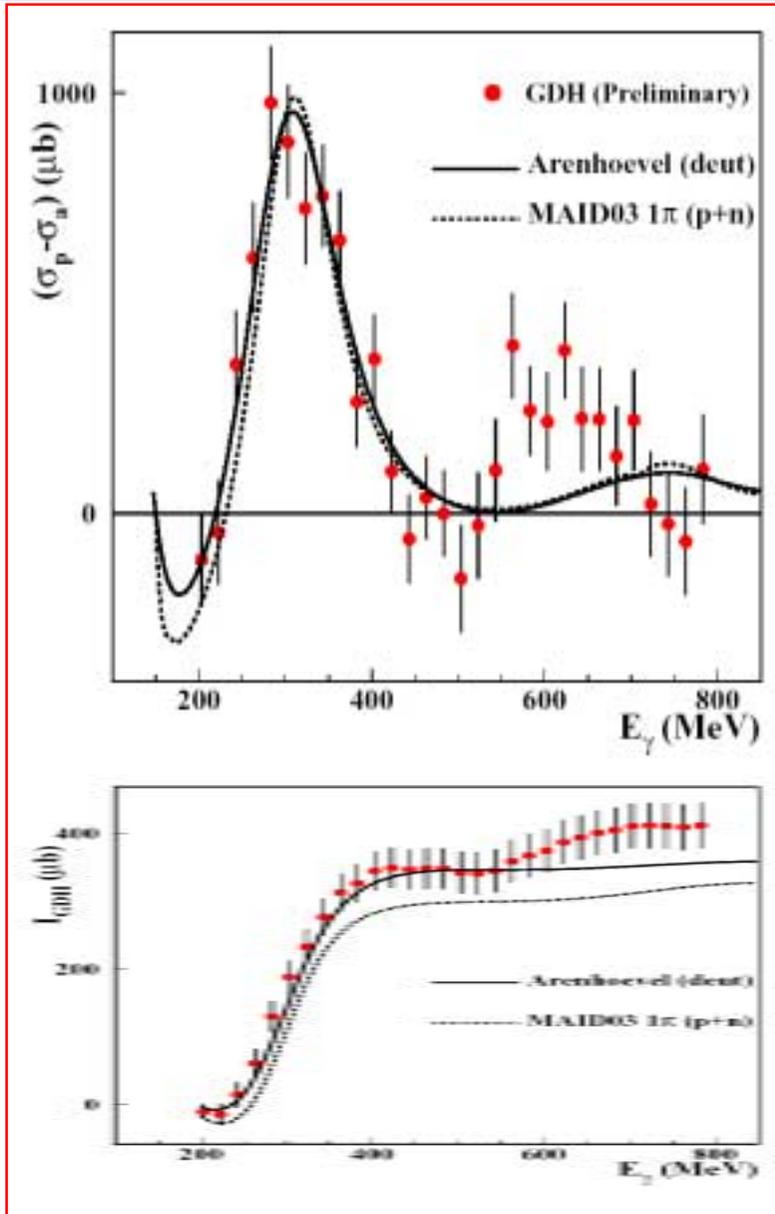


FIG. 4. Measured running GDH integral, I_{GDH} , up to 2.9 GeV together with Regge predictions for the high energy development. Error bars indicate statistical errors only.

$F_{35}+F_{37}$? (not observed at unpolarized measurement)

GDH Sum Rule for neutron



ELSA data

PRL94(2005)162001

MAMI data

O. Jahn, Proc.GDH2004

Comparison of Spring-8 with ELSA

	proton			neutron		
	energy range (GeV)	step (MeV)	error stat.+sys	energy range (GeV)	step (MeV)	error stat.+sys
SPring-8	1.8-2.8	100	1 + 0.7 μb	1.8-2.8	200	5+ 5 μb
ELSA	0.7-2.8	200 (above 1.5GeV)	4 + 0.3 μb	available data only <1.8GeV		

SPring-8-GDH stands at a unique position concerning neutron target.

Prof. Iwata's message before his departure for Czech

* 偏極ターゲットの観点からの新ビームライン

- ビームが細いこと(クライオスタットのビームパイプは25mm)
- ポリエチ5g程度の厚いターゲットでも使用できること(放射線シールド)

* 実験室

- 揚程の大きい3トン程度のクレーンが使える
- 十分に天井が高い
- 床が平らであること
- デュワーの搬入が容易であること
- 外部への排気ラインが備えられている
- ターゲット周辺にポンプが置ける十分なスペースが確保されている
- クライオスタットの上流方向への移動が可能

and more...

- 現在のビームが太いのは、主にレーザーと電子ビームとの衝突点での電子ビームのダイバージェンスによります。コリメータではありません。新ビームラインをデザインする場合、その点を充分考慮してもらえば良いということです。
- より高いエネルギーのビームには、たとえば250nmぐらいの連続波レーザーが必要で、そのようなレーザーはパワーが出ないため、現実的では無いと考えています。また、円偏光を作ることも難しいと思います。
- 純粹にユーザーの立場に立てば、高いエネルギーでGDHのデータを得ることは十分な強度のビームがあれば、有意義だと思えますし、問題なくデータが取れるはずです。
- ビームに関する別のコメントを忘れていました。今度のビームラインは直線部に作るそうなので、いままでのビームラインよりもスペースの余裕があるはずで、すると、レーザーを斜めから入射することで、ミラーをLEPビームが通過しなくても済むようにできるかもしれません。できれば、レーザーを鉛直方向に斜めに入射してやると、ミラーへのX線の入射を減らすことができ、反射率を損なわなくても良いと思います。(上下方向にはスペースが無いかもしれませんが。。。)

Summary

- SP8-GDH preparation is going on. (needs ¥ and \$)
- GDH sum rule for proton is already verified at 10% level.

(High precision data from SP8 are needed to check ELSA results and extrapolate to higher energy behavior.)

- GDH sum rule for neutron needs higher energy data.
- Spin experiments can find unseen resonances in unpolarized experiments.
- Of course spin experiments need polarized and intense gamma beam.
- We can build good beam lines and experimental spaces by using previous experiences.