Science with Photons at 10s of GeV

Frank Zimmermann

many thanks to Jian-Ping Chen, M.W. Krasny, Ying Wu, J.M. Byrd and A. Variola

“Other Science Opportunities at the FCC-ee”, 28 November 2024

FCC-CBS: 1000-100000x more flux & higher energy than ELI-NP

Comparison of ELI-NP and FCC-ee Compton Backscattering Source (FCC-ee-CBS), assuming Yb:YAG laser (2.3 eV)

	ELI-NP	FCC-ee-CBS-20	FCC-ee-CBS-45	FCC-ee-CBS-120
beam energy [GeV]	**0.72**	**20**	**45.6**	**120**
average beam current [A]	**0.8×10^{-6}**	**0.15**	**0.15**	**0.05**
beam size at laser CP [mm]	~0.5	~0.5	~0.5	~0.5
Compton *x* parameter	0.025	0.7	1.6	4.2
max photon energy [GeV]	**0.02**	**8.3**	**28**	**97**
photon flux [1/s]	**10^9**	**$\sim10^{13}$**	**$\sim10^{13}$**	**$\sim10^{13}$**

corrected by L. Serafini

The photon energies are 1000 times higher, the photon flux exceed ELI-NP's by about a factor 10,000. To achieve this rate the laser beam recirculator system of ELI-NP would need to be modified or, possibly, be replaced by an optical cavity, suitable for cw operation.

10.5281/zenodo.7675664

nuclear & hadron physics, QCD exploration

1998

WHAT CAN WE LEARN FROM EXPERIMENTS WITH 10 GEV PHOTONS[1]

Jean-Marc Laget
CEA/Saclay, DAPNIA/SPhN, F91191 Gif-Sur-Yvette Cedex, France

to "see" confinement mechanisms at work:
production of exotic mesons (glueballs, etc...); exchange of, free or bound, partonic systems

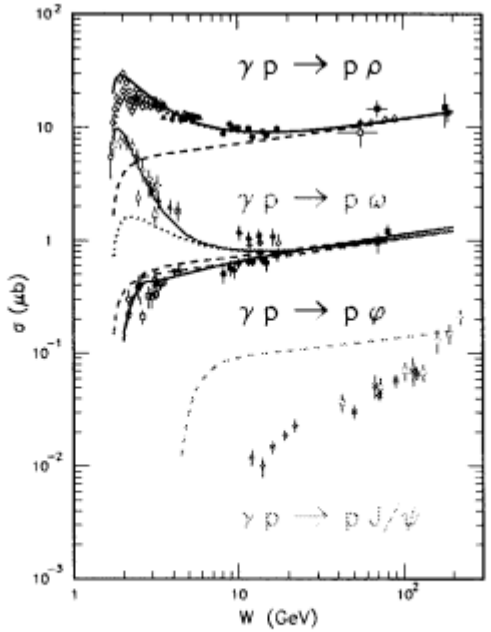

Fig. 12. The cross-section of the photoproduction of the various vector mesons is plotted against the c.m. energy W. Dashed lines include the Pomeron exchange only. Dotted curves include also f_2 exchange. The full curves include also σ exchange (ρ production) or π exchange (ω production).

2003

ELSEVIER
Progress in Particle and Nuclear Physics
Volume 50, Issue 2, 2003, Pages 487-497

Hadron and nuclear physics with inverse compton gamma-rays at SPring-8

M. Fujiwara [a b]

2024

Exclusive photoproduction of a photon-meson pair: A new class of observables to probe GPDs

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ongoing and planned studies at JLAB with 10-20 GeV photons

real photon beam in JLAB Hall D (~10 GeV) is being used for spectroscopy in search of **exotic mesons** (hybrid states) and **near-threshold charm (J/psi) production** to study the **gluon field contribution** (so called trace anomaly) **to the proton mass** (which has been a hot topic in recent years)

JLab upgrade to 22 GeV would yield real photon beam at ~ 20 GeV;
physics case highlighted in JLab22 whitepaper (https://arxiv.org/pdf/2306.09360)

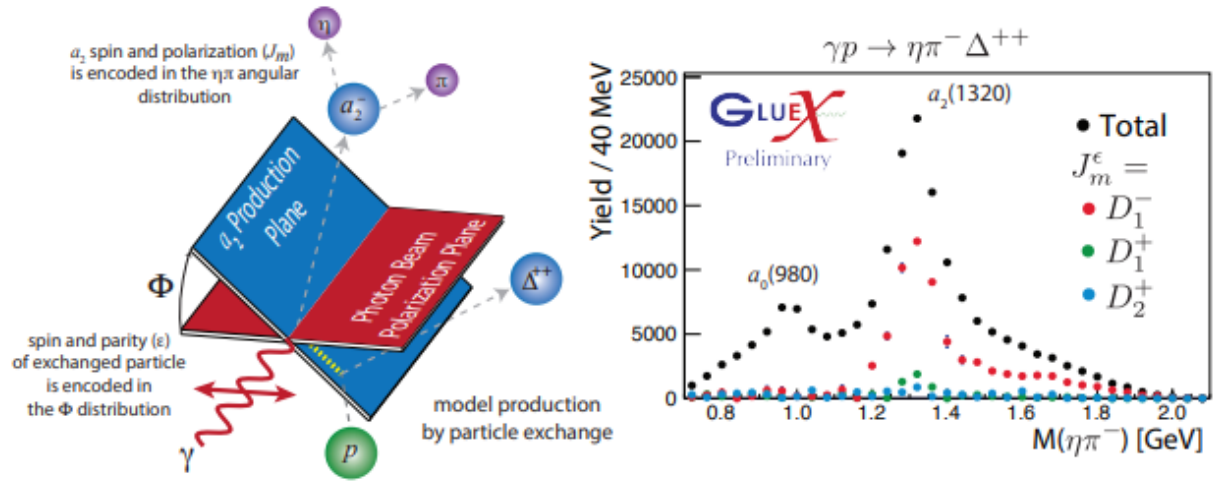


Figure 2: A sketch of the polarized photoproduction of $a_2^-(1320)$ via t-channel interaction with the target. Preliminary data from GlueX indicates that the dominant production mechanism of the spin-2 ($D-$wave) peak consistent with the a_2 in the $\eta\pi^-$ spectrum is by exchange of an unnatural parity particle ($\epsilon = -$).

J.-P. Chen

physics with 40-120 GeV photons

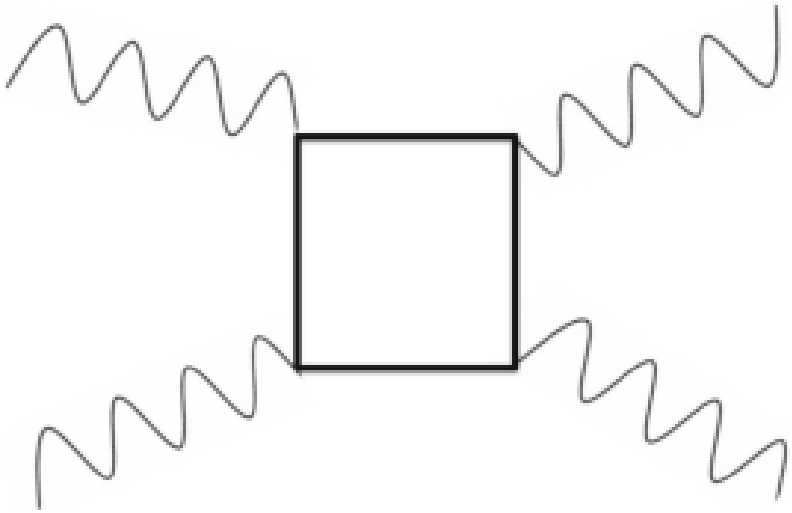
this energy range could cover, in addition to having **much wider phase space for charmonium**, the **beauty quarkonium** and **near-threshold Upsilon productions** (cleaner than J/psi case and **one of the main goals of EIC physics**)

→ important impact on study of gluon field contributions to proton mass

circularly polarized photon beam → polarized gluon distribution, testing the convergence of the polarized sum rule (GDH sum rule) and helping constrain the high energy behavior (the Regge theory parameters)

J.-P. Chen

scattering light off light ?



J. Ellis et al, 2022

Evidence for light-by-light scattering in heavy-ion collisions with the ATLAS detector at the LHC

ATLAS Collaboration

2017

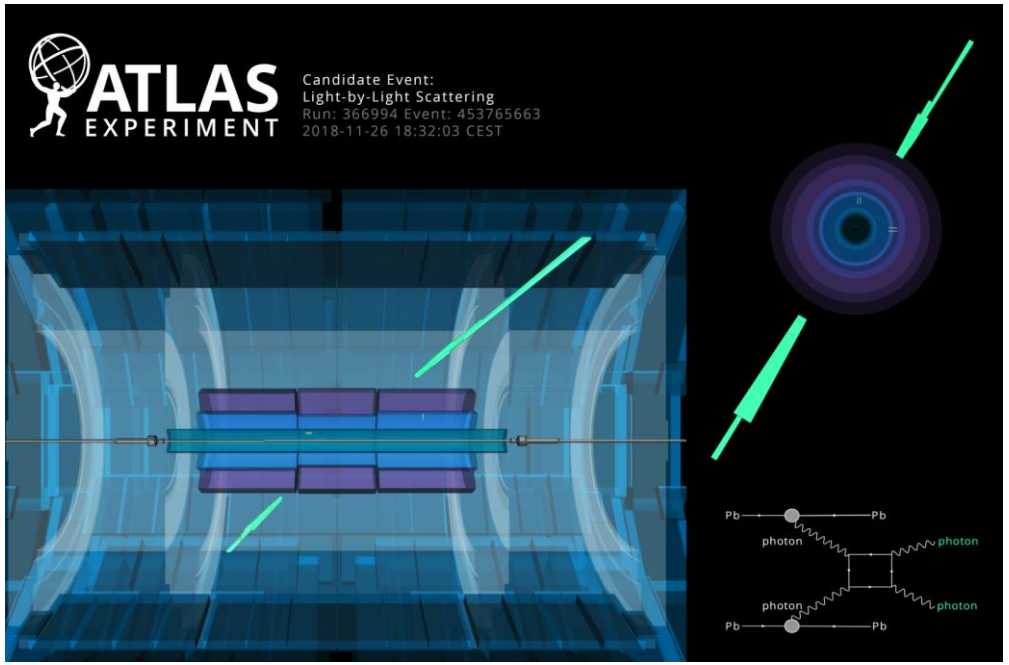
Nature Physics **13**, 852–858 (2017) | Cite this article

ATLAS observes light scattering off light

2019

The ATLAS Collaboration has reported the observation of light-by-light scattering with a significance beyond eight standard deviations

19 MARCH, 2019



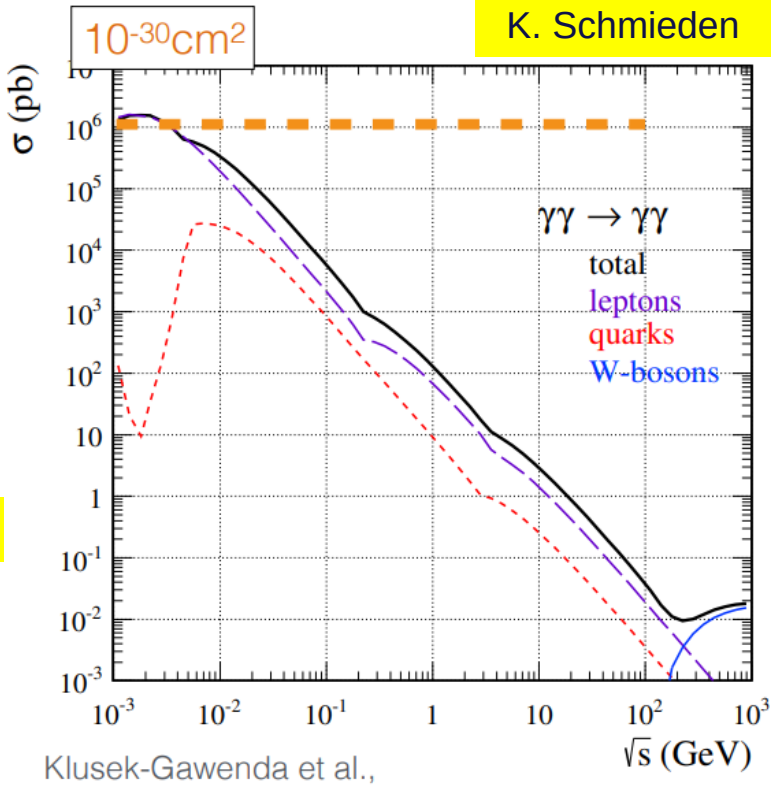
ultra-peripheral heavy-ion collisions

photons (counter propagating) in the energy region just below the e^+e^- production threshold (~ 500 keV) to study the elastic photon-photon collisions (box diagram physics)… small cross-section → Fabry-Perot cavities to enhance flux

W. Krasny

40-60 GeV photons off ~1 eV photons ?
Or 63 GeV photons scattering off 63 GeV photons (Higgs) ?

K. Schmieden



Klusek-Gawenda et al., PRC 93 (2016) 044907

ThomX as a test bed for CBS beam dynamics

Laser /Cavity system

- average power 100W
- **Stored power up to 1 MW** (30 mJ/pulse)

Accelerator

- 1 nc / bunch, f_{rep} 50 Hz
- **50-70 MeV**
- Ring, f_{rep} 16 MHz
- **σ_e ~ 70 µm**
- **ε_N ~ 5-10 mm.mrad**
- τ_e ~ 10-30 ps

Three different regimes:

1. Ring dominated and laser perturbation,
2. Laser ring regime (Thom-X design)
3. Nonlinear laser-interaction with harmonics

design X-ray beam	
Flux ph/s	**10^{13}**
Brightness ph/s/ mm^2 / 0.1% BW / mrad^2	**10^{11}**
Transverse size of the source	**70 µm**
E_X on axis	**40-90 keV**

2m

Y. Chaikovska

	Today	Near future	Next future	Unit
Synchro	Yes (jitters)	Jitters reduced		
Injection frequency	10	50		Hz
e- energy	50	50-70		MeV
Avg stored e- charge	40	250	1000	pC
Avg stored laser power	90	500	700	kW
e- spot size	77			µm
Laser spot size	65		40	µm
X-ray Compton edge	45	45-90		keV
Avg total flux	1.0×10^{10} Not stable	1.5×10^{12} Stable	1.0×10^{13}	ph/s

23 June 2023