The Gamma Factory @ CERN: Extraordinary Tool for Extraordinary Tasks

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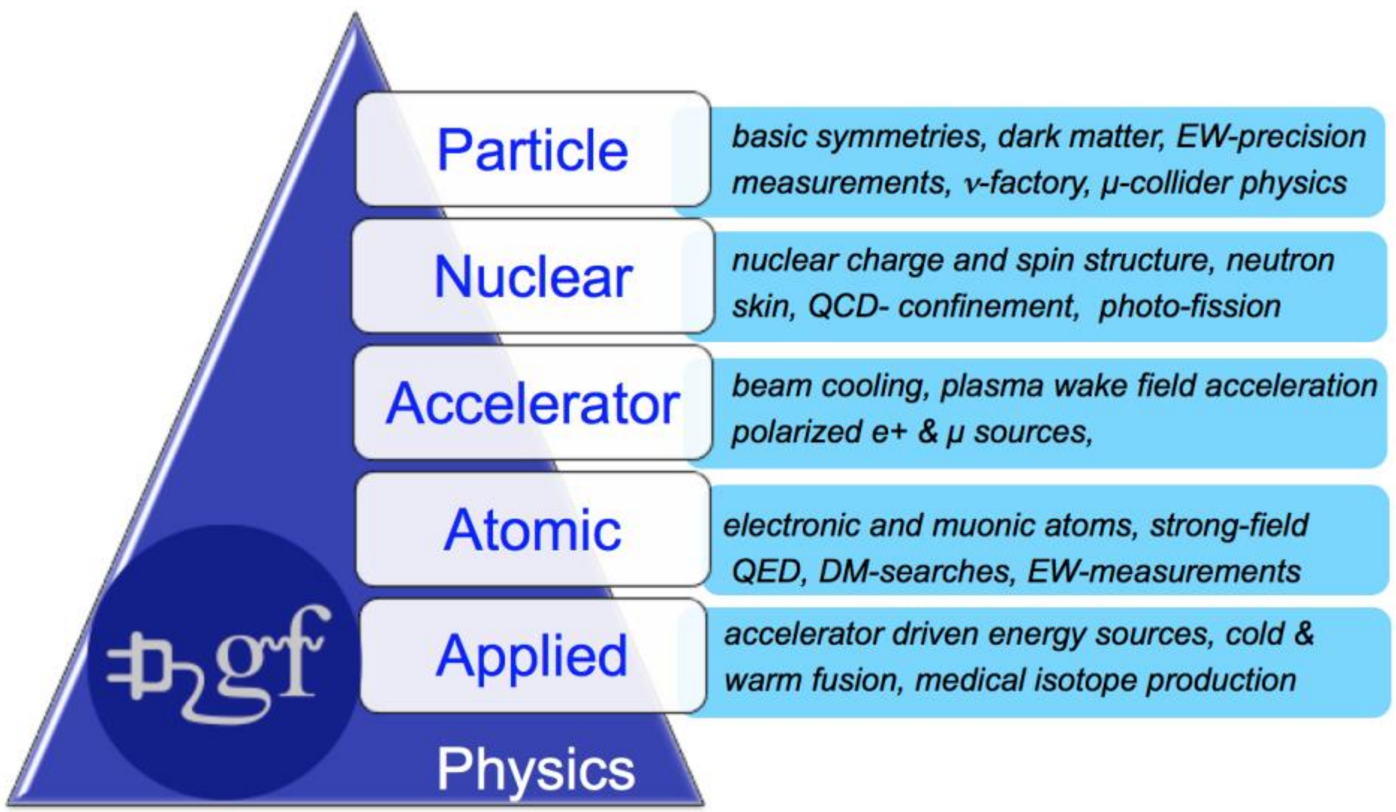
Johannes Gutenberg-Universität Mainz

For the Gamma Factory

Workshop “Present and Future Perspectives in Hadronic Physics”, LNF Frascati, June 17-19, 2024

Physics Opportunities with the Gamma Factory



Examples of physics opportunities (from 2021)
Now **many more** additional papers have been published

Volume 534, Issue 3

Special Issue: Physics Opportunities with the Gamma Factory

March 2022

Issue Edited by: Dmitry Budker, Mikhail Gorchtein, Mieczyslaw Witold Krasny, Adriana Pálffy, Andrey Surzhykov

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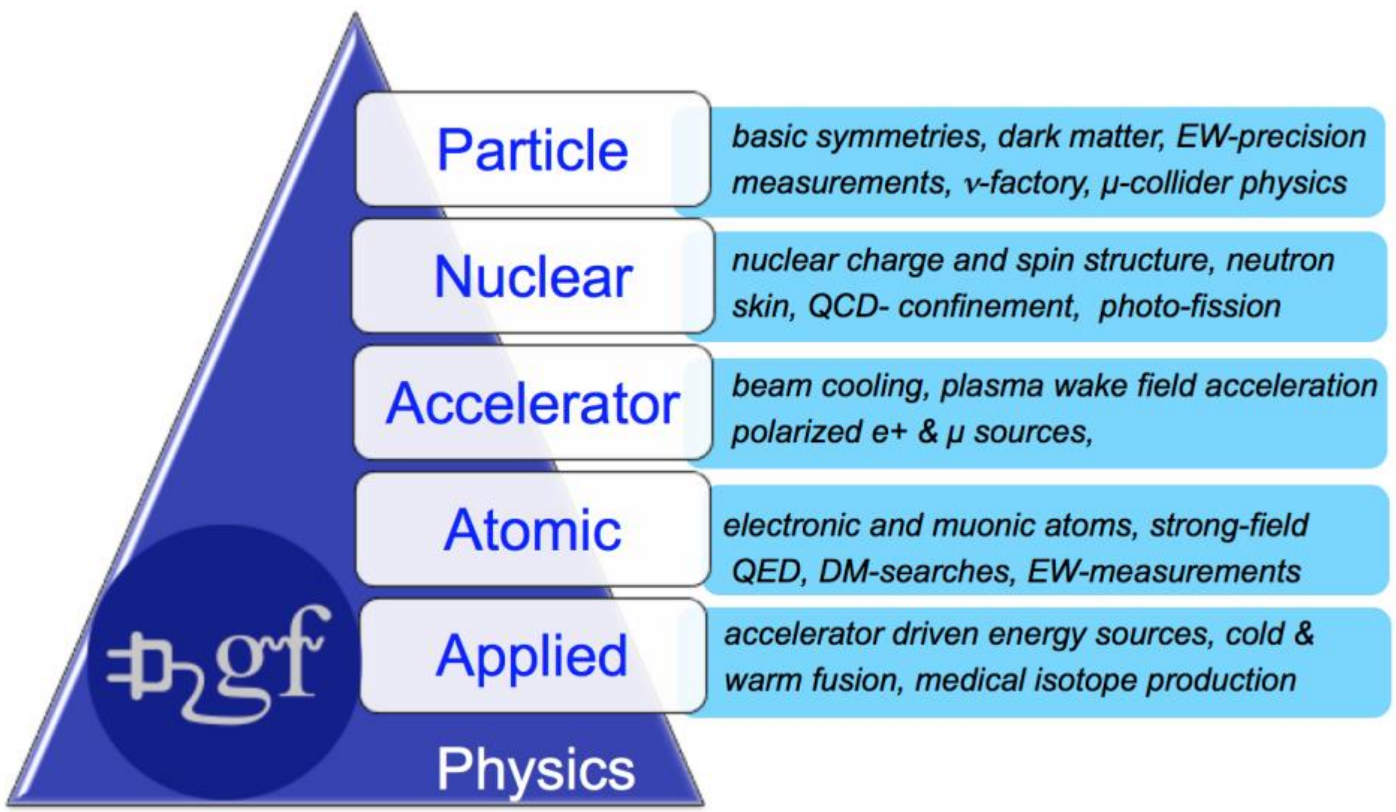

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Review

Open Access
- Expanding Nuclear Physics Horizons with the Gamma Factory

Research Articles

Full Access
- Local Lorentz Invariance Tests for Photons and Hadrons at the Gamma Factory

Full Access
- Electric Dipole Polarizability of Neutron Rich Nuclei

Open Access
- Vacuum Birefringence at the Gamma Factory

Full Access
- Double-Twisted Spectroscopy with Delocalized Atoms

Full Access
- Delta Baryon Photoproduction with Twisted Photons

Open Access
- Resonant Scattering of Plane-Wave and Twisted Photons at the Gamma Factory

Full Access
- Probing Axion-Like-Particles at the CERN Gamma Factory

Open Access
- Charge-State Distributions of Highly Charged Lead Ions at Relativistic Collision Energies

Open Access
- Access to the Kaon Radius with Kaonic Atoms

Full Access
- Radioactive Ion Beam Production at the Gamma Factory

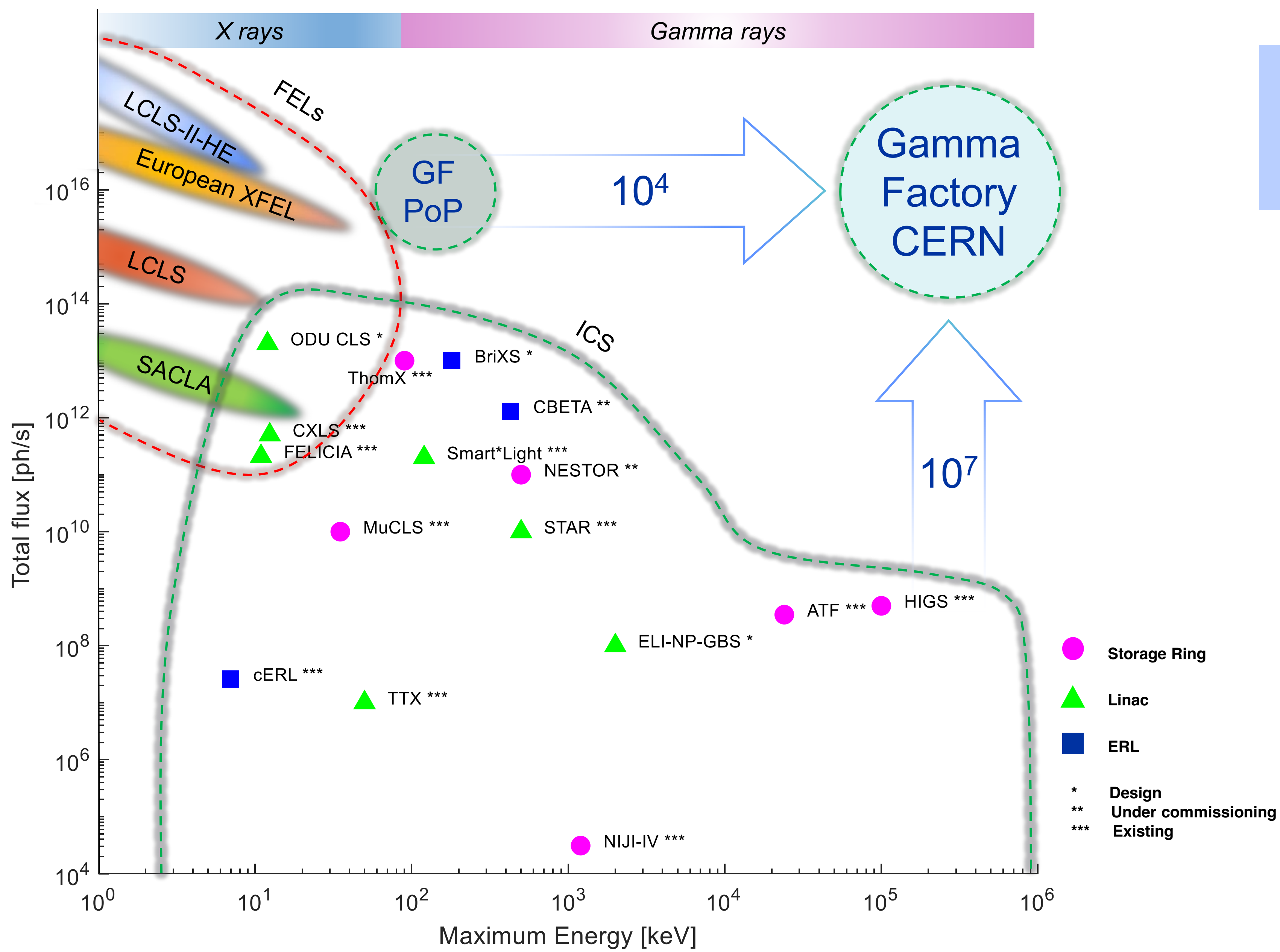
Open Access
- Possible Polarization Measurements in Elastic Scattering at the Gamma Factory Utilizing a 2D Sensitive Strip Detector as Dedicated Compton Polarimeter

Full Access
- Polarization of Photons Scattered by Ultra-Relativistic Ion Beams

GF @ LHC:

A versatile tool for a forefront research in particle, nuclear, atomic, accelerator and applied physics

Comparison to Other Existing X-ray or Gamma-ray Sources



"Can one make a technological leap of 7 orders of magnitude to deliver similar fluxes to FELs in the Gamma-rays?"

Example (GF for nuclear physics app):

European XFEL	Gamma Factory
27,000 pulses/s	20 MHz
24 keV	18 MeV
10^{16} photons/s	3.6 x 10^{17} photons/s
1.4 mJ/pulse	5 mJ/pulse (laser)
38 W (J/s)	**570 kW (kJ/s)**

The Gamma Factory operates with **MW** electric power and 10s **MJ** of stored beam energy

So far, the *only* facility currently providing such parameter space is the **LHC**

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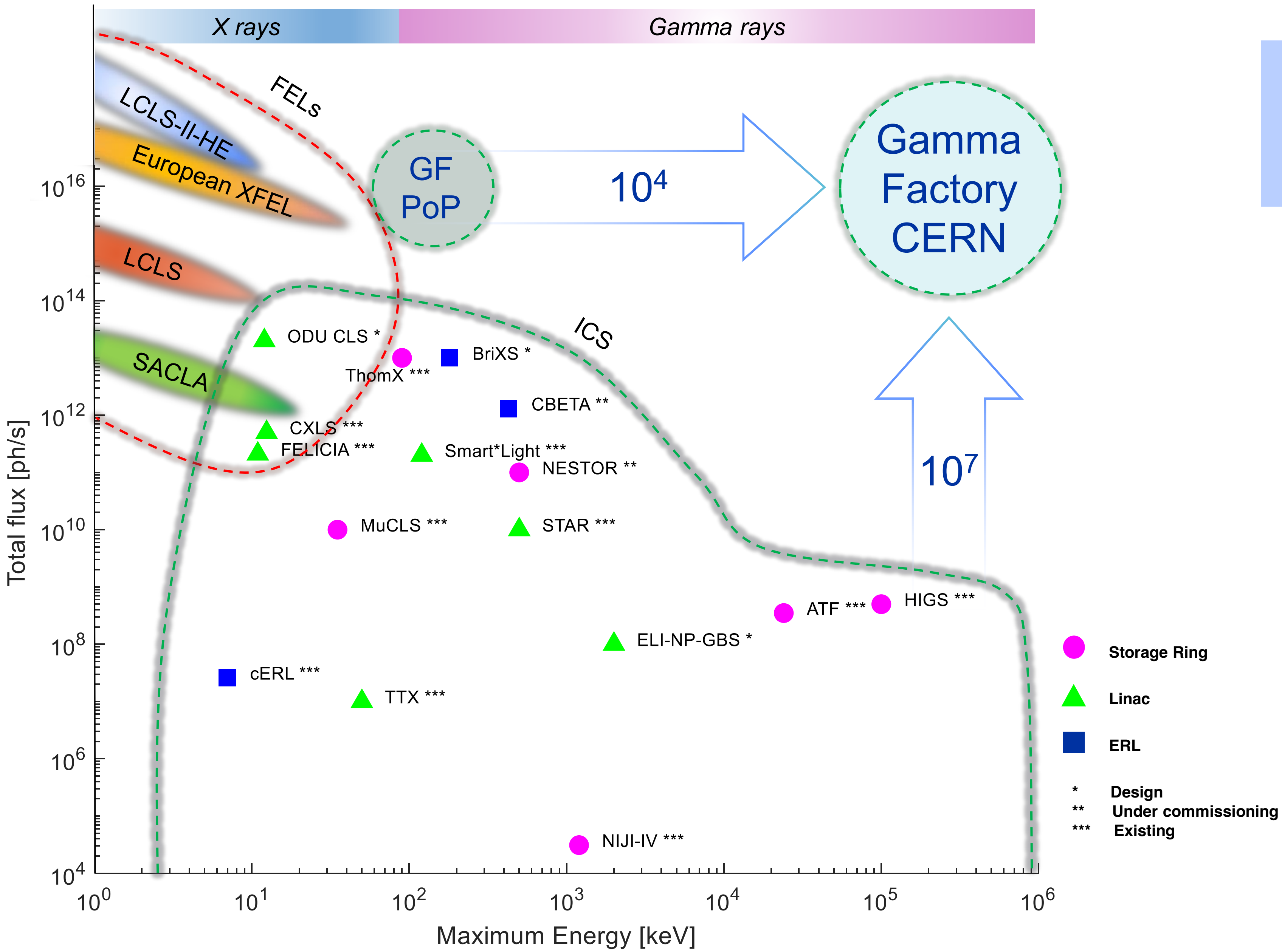

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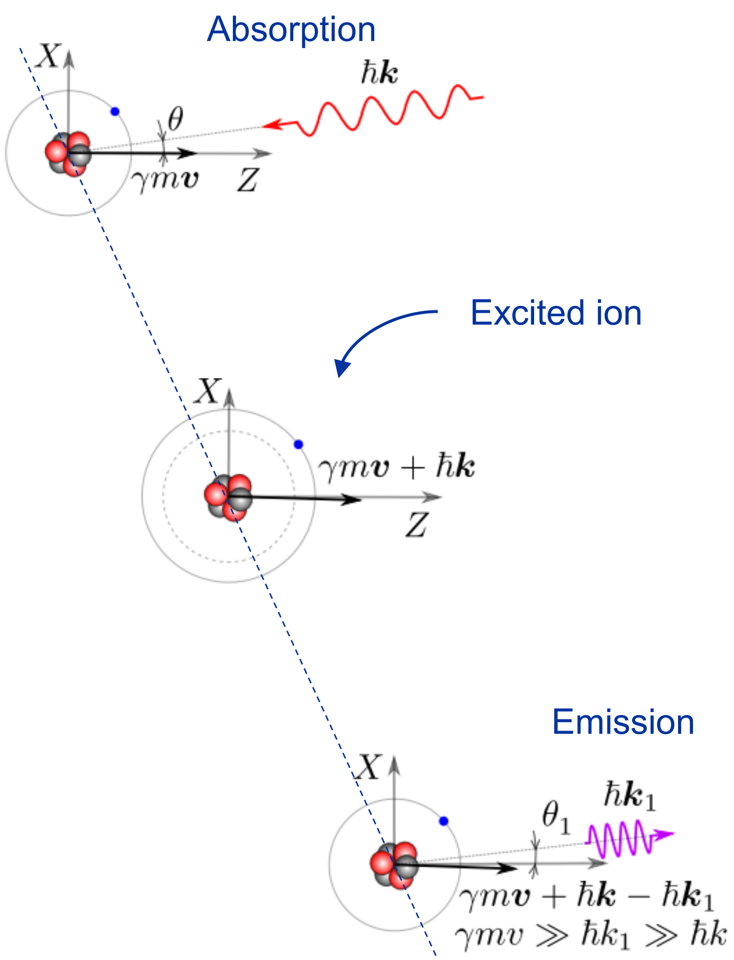
Proof-of-Principle (PoP) experiment at SPS

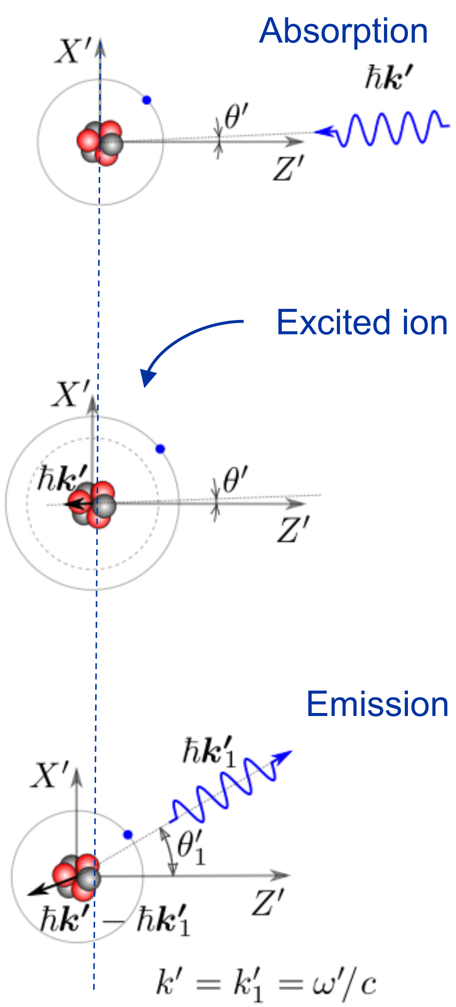
in preparation for 2027

Concept: Doppler effect with relativistic partially-stripped ions

In the lab frame



In the ion frame



Absorption

Lorentz transformation

$$\omega' \sin\theta' = \omega \sin\theta, \qquad \Delta\theta' \approx \frac{\Delta\theta}{2\gamma}$$

$$\omega' = (1 + \beta\cos\theta)\gamma\omega \approx \left(1 + \beta - \beta\frac{\theta^2}{2}\right)\gamma\omega \approx 2\gamma\omega.$$

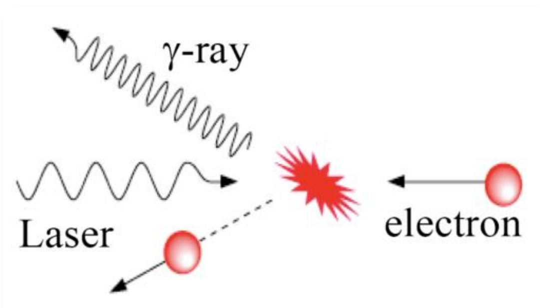
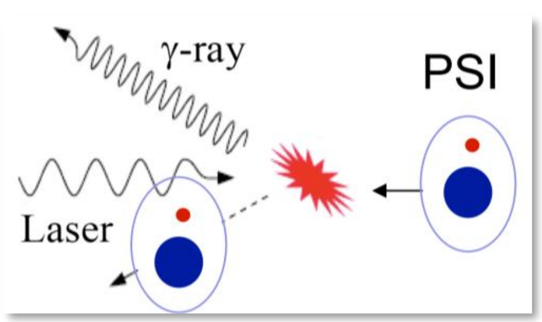
Emission

$$\omega_1 \sin\theta_1 = \omega' \sin\theta'_1 \;\Rightarrow\; \sin\theta_1 = \frac{\sin\theta'_1}{\gamma(1 + \beta\cos\theta'_1)},$$

$$\omega_1 = \gamma(1 + \beta\cos\theta'_1)\omega' \approx 2\gamma^2(1 + \beta\cos\theta'_1)\omega.$$

$$\nu^{max} \longrightarrow (4\,\gamma_L^{\,2})\;\nu_i$$

The Gamma Factory Intensity Leap

	Cross-section	Requirements	Features
Compton backscattering 	Electrons: $\sigma_e = 8\pi/3 \times r_e^2$ r_e - classical electron radius $\sigma_e = 6.6 \times 10^{-25}$ cm^2	E_{beam} = 1.5 GeV LINAC or LWFA Electron fractional energy loss: emission of 150 MeV photon: $E_\gamma/E_{beam} = 0.1$ (electron is lost!)	➢ Relatively "compact" ➢ Large laser system ➢ Low γ photon flux (10^9 ph/s)
	⇩ $\sigma \times 10^9$		⇩ x 10^7 ph/s
Gamma Factory  Example: Pb, hydrogen-like ions, *stored in LHC* γ_L = 2887	Partially Stripped Ions: $\sigma_{res} = \lambda_{res}^2/2\pi$ λ_{res} - photon wavelength in the ion rest frame $\sigma_{res} = 5.9 \times 10^{-16}$ cm^2	E_{beam} = 574 000 GeV (LHC) Electron fractional energy loss: emission of 150 MeV photon: $E_\gamma/E_{beam} = 2.6 \times 10^{-7}$ (ion undisturbed!)	➢ Unique Gamma-ray beam ➢ Modest laser requirements ➢ Ultrahigh γ photon flux (10^{16} ph/s) ➢ Transparent to accelerators ➢ Beam cooling capability

Tune laser frequency to resonant atomic transition —> ~every photon in the bunch interacts

FEL with <400 MeV energy

The Gamma Factory in the Global γ-Source Landscape

Bremsstrahlung tagged-photon facilities

Facility name	MAMI A2	JLab Hall D	ELSA	MAX IV
Location	Mainz	Newport News	Bonn	Lund
Electron energy (GeV)	1.6	12	4.68	220
Max γ energy (MeV)	1600	9200	2400	180
Energy resolution (MeV)	2–4 MeV	30	12.5	0.3
Photon polarization	≤ 0.8	≤ 0.4		–
Max on–target flux (γ/s)	10^8	10^8	5×10^6	4×10^6
Reference	[519]	[520]	[521]	[522]

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Compton backscattering facilities

Facility name	ROKK-1M	GRAAL	LEPS	HIγS	ELI-NP	SLEGS	CLS[a]	GF
Location	Novosibirsk	Grenoble	Harima	Duke	Bucharest	Shanghai	Saskatoon	CERN
Storage ring	VEPP-4M	ESRF	SPring–8	Duke–SR	linac	SSRF	2.9 GeV	LHC
Laser–photon energy (eV)	1.17–4.68	2.41–3.53	2.41–4.68	1.17–6.53	1.50–1.52	0.117 (CO_2)	0.117 (CO_2)	multiple
γ–beam energy (MeV)	100–1600	550–1500	1500–2400	1–100 (158)	0.2–20	<22	≤ 15	≤ 400[b]
$\Delta E/E$	0.01 – 0.03	0.011	0.0125	0.008 – 0.1	0.005	$10^5 - 10^7$	~ 0.0011[c]	$\sim 10^{-4} - 10^{-6}$
Max on-target flux (γ/s)	10^6	3×10^6	5×10^6	$10^4 - 5\times10^8$	8×10^8	$10^9 - 10^{10}$	10^{10}[d]	10^{17}[d]

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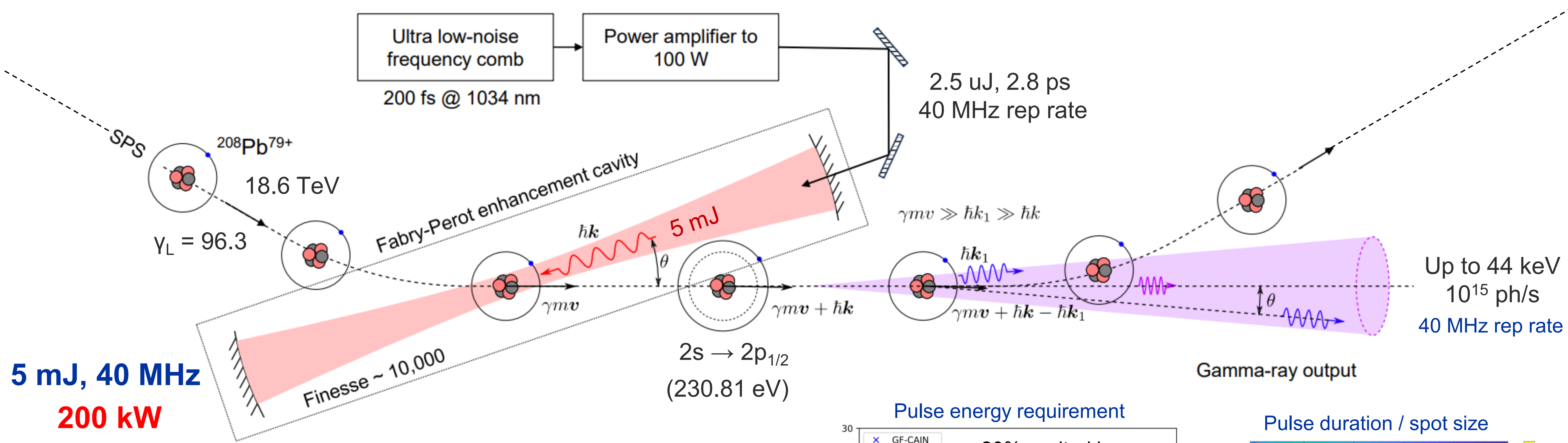
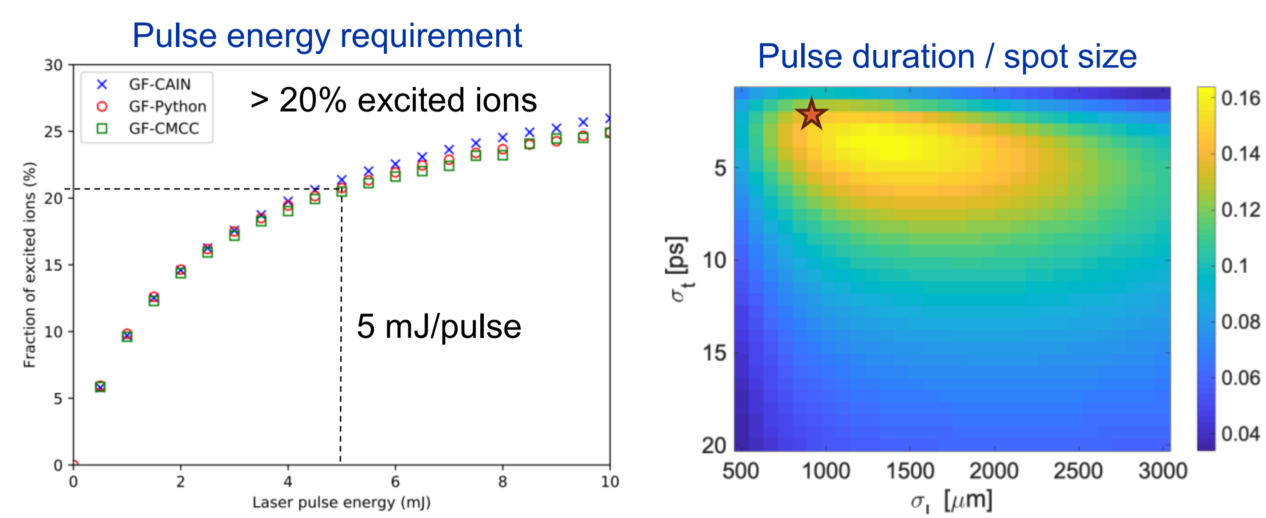
GF @ LHC: unprecedented flux, energy range & resolution

PoP experiment @ SPS setup





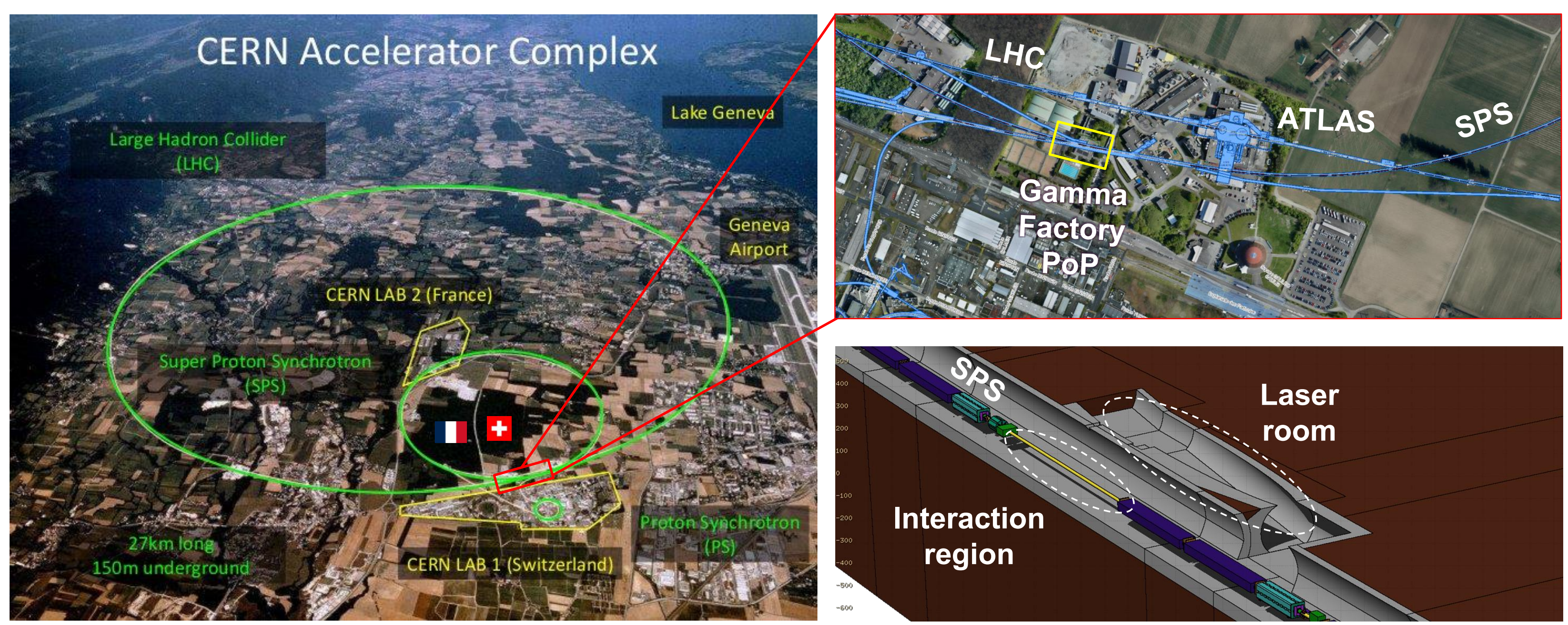
Proposed parameters & status of the PoP experiment @ SPS

Proposed parameters for GF PoP experiment

	GF PoP
Ion beam	$^{208}Pb^{79+}$
	18.652 TeV (SPS)
	40 MHz
Produced photons	**Up to 44 keV**
	10^{15} photons/s
	0.2 uJ/pulse
	7 W (J/s)

Status of the optical systems for PoP experiment

- TI18 area, conversion to a laser lab in LS3
- Ultra low-phase noise laser and amplification chain procurement and commissioning
- Fabry-Perot Cavity with large gain factor pumped by 100W laser at IJCLab. After successful test transfer to CERN
- Laser beam delivery system testing, controls, integration and diagnostics at IP
- Demonstrate full remote end-to-end operation of laser beams and Fabry-Perot cavity



Physics Highlights with Primary, Secondary and Tertiary γ's

Distinction

Primary photons: energy in the c.m. of Ion + γ $\omega_1 = (2\gamma_{\text{ion}})\ \omega_L$

Secondary photons: energy in the LAB frame $\omega_2 \leq (2\gamma_{\text{ion}})^2 \omega_L$

Tertiary photons: energy in the LAB frame $\omega_3 \leq (2\gamma_{\text{ion 1}})^2 (2\gamma_{\text{ion 2}})^2 \omega_L$

Physics tasks for GF can be generically subdivided into 2 classes:

Class 1. Tasks that can only be done at the GF

Class 2. Tasks that can be done at other facilities (but GF do better)

Nuclear physics opportunities with primary γ's

Low-lying nuclear states < 60 keV

Isotope	$T^{g}_{1/2}$	E_e [keV]	I_g	I_e	λL	$T^{rad}_{1/2}$ [s]	$\alpha(K)$	$\alpha(L)$
^{229}Th	7880 y	0.008[a)]	$5/2^+$	$3/2^+$	$M1$	5.19×10^3	–	–
^{235}U	7×10^8 y	0.076	$7/2^-$	$1/2^+$	$E3$	7.03×10^{23} [b)]	–	–
^{201}Hg	stable	1.565	$3/2^-$	$1/2^-$	$M1$	3.76×10^{-3}	–	–
^{205}Pb	1.7×10^7 y	2.329	$5/2^-$	$1/2^-$	$E2$	9.07×10^2	–	–
^{181}Ta	stable	6.238	$7/2^+$	$9/2^-$	$E1$	4.34×10^{-4}	–	–
^{239}Pu	2.4×10^4 y	7.861	$1/2^+$	$3/2^+$	$M1$	2.04×10^{-7}	–	–
^{169}Tm	stable	8.410	$1/2^+$	$3/2^+$	$M1$	1.07×10^{-6}	–	–
^{83}Kr	stable	9.406	$9/2^+$	$7/2^+$	$M1$	2.80×10^{-6}	–	14
^{187}Os	stable	9.756	$1/2^-$	$3/2^-$	$M1$	9.01×10^{-7}	–	–
^{137}La	6×10^4 y	10.560	$7/2^+$	$5/2^+$	$M1$	1.04×10^{-5}	–	93.2
^{45}Sc	stable	12.400	$7/2^-$	$3/2^+$	($M2$)	1.96×10^2	362	54
^{235}U	-[c)]	13.034	$1/2^+$ [d)]	$3/2^+$	M1	2.43×10^{-7} [e)]	–	–

- Nuclear spectroscopy in the ion beam, isomers
- Interaction of atomic and nuclear d.o.f.
- Nuclear clocks (e.g. with Th-229 8eV isomer)
- Laser cooling of ion beams
- Production of higher energy γ's: use GDR at ~15 MeV

P-, CP-Violation with Primary Photons

Compton scattering off relativistic ions at LHC ($\gamma \approx 3000$) $\omega_2 = (2\gamma_{\rm ion})\ \omega_1 \lesssim 60\,{\rm keV}$

Single-spin asymmetry circular photon polarization — clearly parity-violating (PV)

$$A_\gamma \equiv \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = A_\gamma^{\rm PVTC} \cos^4 \frac{\theta}{2} + A_\gamma^{\rm PVTV} \sin^4 \frac{\theta}{2}$$

MG, 0803.0343

Both time-reversal conserving (TC) $\sim \vec{S}_\gamma \cdot (\vec{q} + \vec{q}\,')$ and violating (TV) $\sim \vec{S}_\gamma \cdot (\vec{q} - \vec{q}\,')$ present!

Access P-odd and P,T-odd nuclear polarizabilities

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Motivation: determination of 4-quark effective operators that explicitly violate P or P,T

Complication: these operators are embedded into hadronic/nuclear matrix elements

Requires understanding low-energy nonperturbative QCD

Relevant formalism: chiral EFT that supplanted old DDH (PV meson-mediated nuclear potential)

Desplanques, Donoghue, Holstein Annals Phys. 124 (1980) 449;
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Natural size: $A_\gamma^{\rm PVTC} \sim 10^{-8} \left(\omega_2/m_\pi\right)^3,\ A_\gamma^{\rm PVTV} \lesssim 10^{-11} \left(\omega_2/m_\pi\right)^2$

PVTV Compton scattering @ GF: extend the pool of PVTV observables (beyond EDM & mixings)

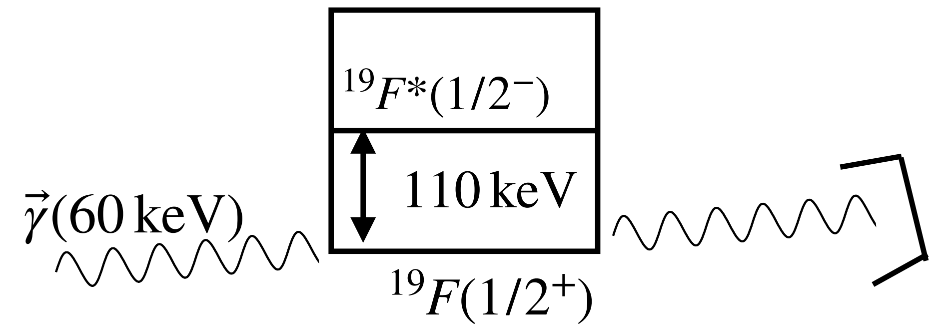
Hadronic P-, CP-Violation with Primary Photons

Look for enhancements: parity doublets

$A_\gamma^{\mathrm{PVTC}} \sim 10^{-8} R \left(\omega_2/E_{pd}\right)^3, \; R = E_N/E_{pd} \gg 1$ with typical nuclear energy scale $E_N \approx 10\,\mathrm{MeV}$

Large PVTC nuclear polarizabilities

Energy not enough to resolve the resonance



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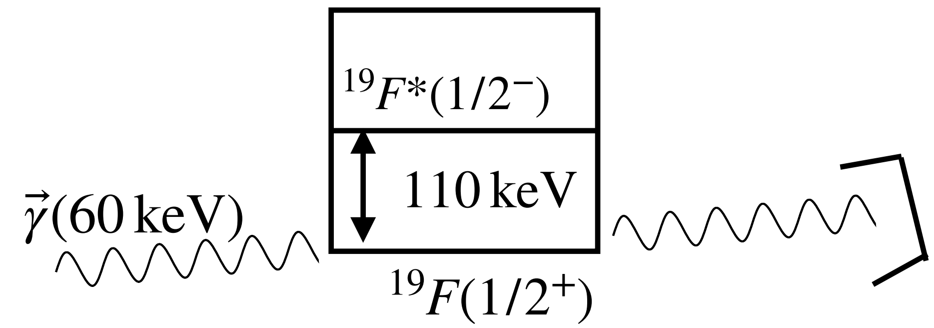

Figure of merit (inverse time needed to observe the asymmetry):

$$\mathrm{FOM} = \mathrm{Rate} \times A^2$$

$$N_{\mathrm{Ions/bunch}} \times N_{\mathrm{bunches}} \times N_\gamma \times \frac{\sigma}{S}$$

σ → Thomson scattering CS $\sigma = \frac{8\pi}{3}\left(\frac{Z^2 \alpha \hbar}{Mc}\right)^2$

S → Laser beam cross section $\approx (20\mu m)^2$

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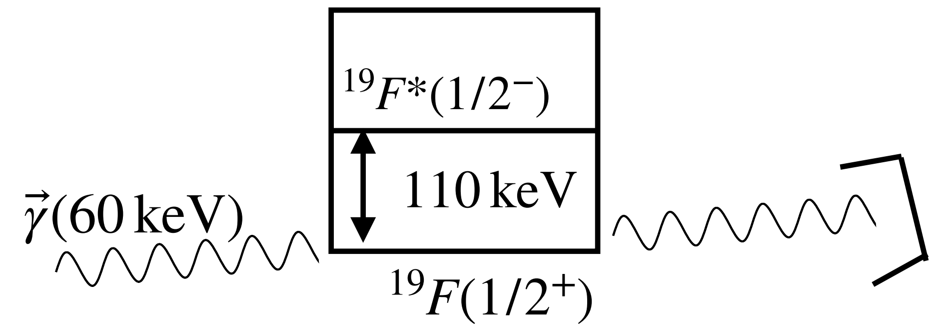

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A study for known parity doublets (fully stripped ions) with 60 keV photons

Isotope	$T_{1/2}$	E_1 (keV)	I_1^P	E_2 (keV)	I_2^P	ΔE (keV)	R	$10^8\ A_\gamma^{\mathrm{PVTC}}$	FOM (s^{-1})
^{18}F (1^+)	109.77(5) min	1042	0^+	1081	0^-	39	256	0.05	2.5×10^{-8}
^{19}F ($\frac{1}{2}^+$)	stable	0	$\frac{1}{2}^+$	110	$\frac{1}{2}^-$	110	91	15	2×10^{-3}
^{20}Ne (0^+)	stable	11255	1^-	11258	1^+	3.2	3125	5×10^{-4}	2.5×10^{-22}
^{21}Ne ($\frac{3}{2}^+$)	stable	2789	$\frac{1}{2}^+$	2795	$\frac{1}{2}^-$	5.7	1754	0.02	4×10^{-9}

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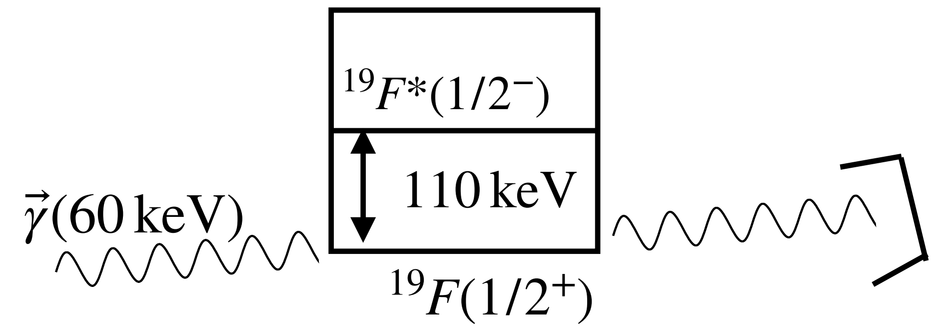

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^{19}F: 10% measurement of a 10^{-7} asymmetry in one day

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Large PVTC nuclear polarizabilities

Energy not enough to resolve the resonance

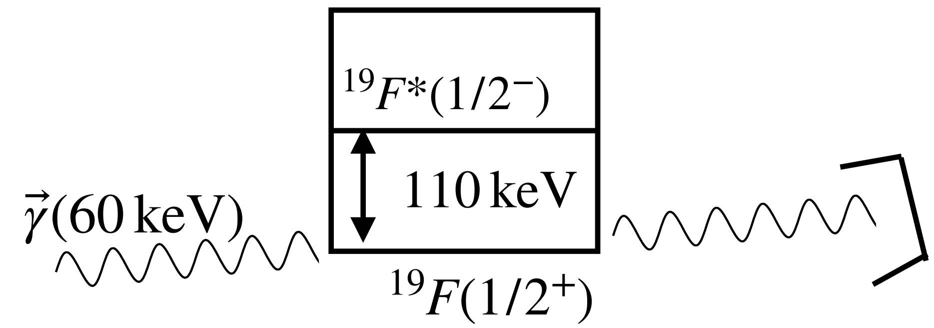


Figure of merit (inverse time needed to observe the asymmetry):

$$\mathrm{FOM} = \mathrm{Rate} \times A^2$$

$$\rightarrow N_{\mathrm{Ions/bunch}} \times N_{\mathrm{bunches}} \times N_\gamma \times \frac{\sigma}{S}$$

$\sigma \rightarrow$ Thomson scattering CS $\quad \sigma = \frac{8\pi}{3}\left(\frac{Z^2 \alpha \hbar}{Mc}\right)^2$

$S \rightarrow$ Laser beam cross section $\approx (20\mu m)^2$

A study for known parity doublets (fully stripped ions) with 60 keV photons

Isotope	$T_{1/2}$	E_1 (keV)	I_1^P	E_2 (keV)	I_2^P	ΔE (keV)	R	$10^8\ A_\gamma^{\mathrm{PVTC}}$	FOM (s^{-1})
$^{18}\mathrm{F}\ (1^+)$	109.77(5) min	1042	0^+	1081	0^-	39	256	0.05	2.5×10^{-8}
$^{19}\mathrm{F}\ (\frac{1}{2}^+)$	stable	0	$\frac{1}{2}^+$	110	$\frac{1}{2}^-$	110	91	15	2×10^{-3}
$^{20}\mathrm{Ne}\ (0^+)$	stable	11255	1^-	11258	1^+	3.2	3125	5×10^{-4}	2.5×10^{-22}
$^{21}\mathrm{Ne}\ (\frac{3}{2}^+)$	stable	2789	$\frac{1}{2}^+$	2795	$\frac{1}{2}^-$	5.7	1754	0.02	4×10^{-9}

^{19}F: 10% measurement of a 10^{-7} asymmetry in one day

Backward angles: for the first time set limits on non-EDM PVTV em observable

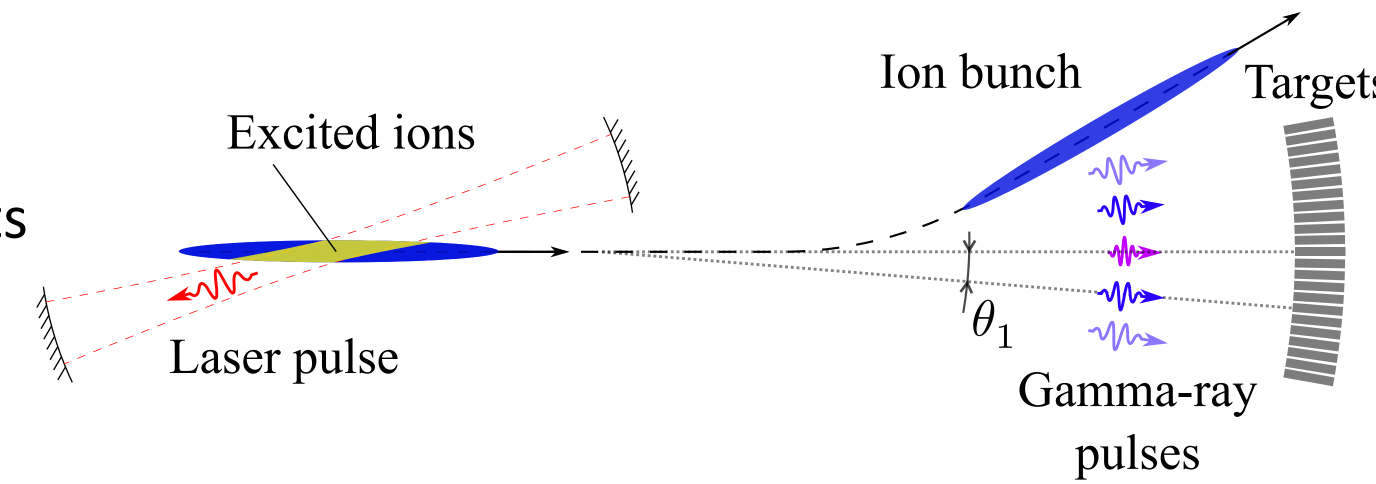
Class-1 task — only feasible with GF @ LHC: $\mathrm{FOM} \propto P_\gamma^2\, Z^2\, \gamma_{\mathrm{Ion}}^6\, N_{\mathrm{Ions}} \times N_\gamma$

Hadronic and Nuclear Physics Highlights: Secondary Photons ($\omega_2 = 40\,\mathrm{keV} - 400\,\mathrm{MeV}$) on Fixed Target

Angle-correlated energy resolution:

Possibility to conduct a range of measurements

With different energies simultaneously



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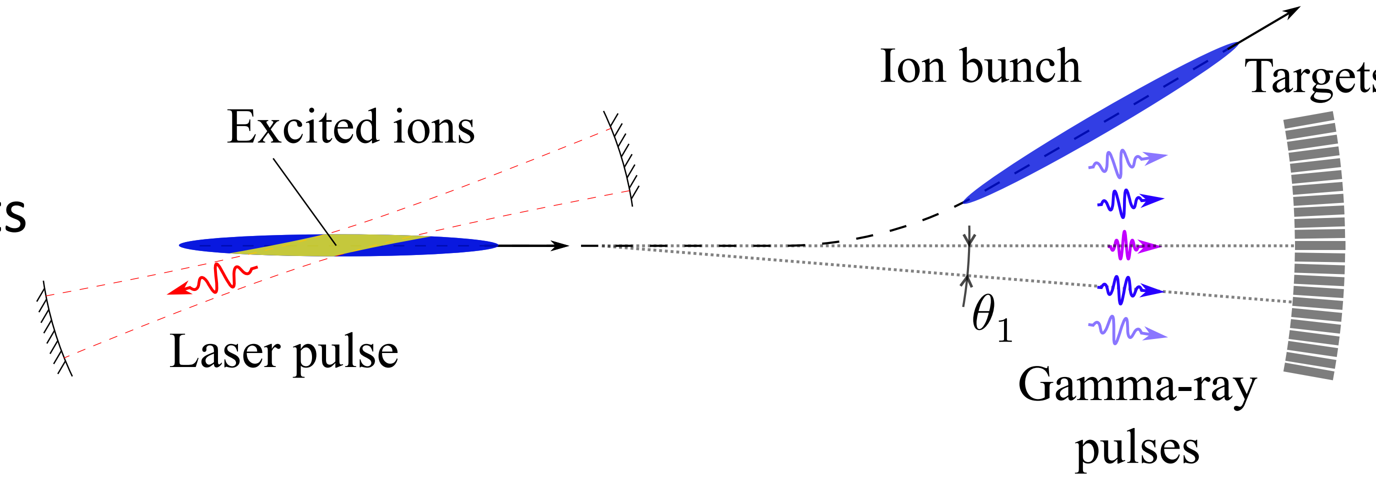

Photoabsorption in the nuclear range

- Spectroscopy: tunable energy + high energy resolution + polarization allows to study narrow states, determine their quantum numbers (E1, M1, pygmy DR)
- Collective nuclear degrees of freedom: Electric/magnetic dipole strengths, neutron skins
- Photon interactions with radioisotopes — capitalize on the proximity of ISOLDE

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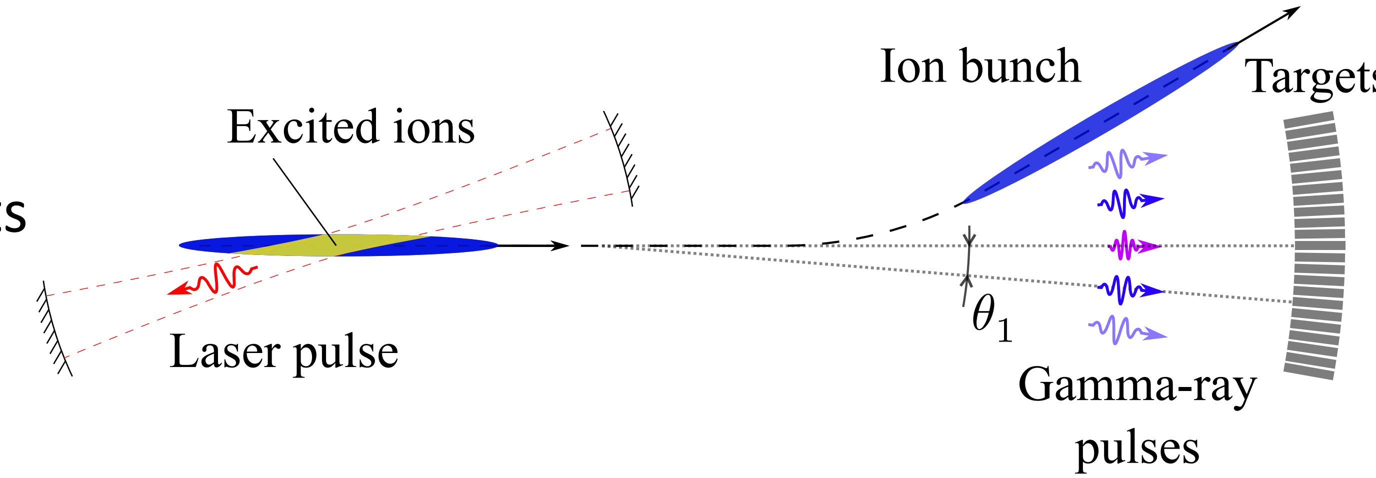

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Class-2 tasks — investigated at other NP gamma-source facilities, but GF offers unique possibilities

Hadronic and Nuclear Physics Highlights: Secondary Photons ($\omega_2 = 40\,\mathrm{keV} - 400\,\mathrm{MeV}$) on Fixed Target

Particle production in the nuclear range

- (γ, α), (γ, p), (γ, n) photonuclear reactions at astrophysical energies:

  reversed astrophysical (α, γ), (p, γ), (n, γ) processes —> nucleosynthesis.
- (γ, α) reactions for α-clustering in heavy nuclei:

  nuclear analog of BCS superconductivity & boson condensation
- (γ, n) reactions and mono energetic neutron source (e.g. on C-13)
- PVTC resonance excitation and hadronic PV: until now studied only in γ-decay mode

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- Nucleon resonances — due to limited energy only $\Delta(1232)$ resonance is accessible
- Neutron skins via coherent π^0 production on heavy nuclei in the $\Delta(1232)$ region
- Photoproduction of bound π^-: ~5 o.o.m. improvement over π^- capture
- Polarizabilities of nucleons and light nuclei, sum rules
- Gamma-asymmetry in FCNC process $\vec{\gamma} + p \to \Sigma^+$; PV pion production

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QCD Highlights:
Secondary Photons in Colliding Mode on proton/ion beam
($\sqrt{s} \leq 100\,\mathrm{GeV}$)

Shoot the secondary photon on the counter-moving proton/ion beam

$\approx (M\gamma, 0, 0, M\gamma)$ $\quad$ $(\omega_2, 0, 0, -\omega_2)$

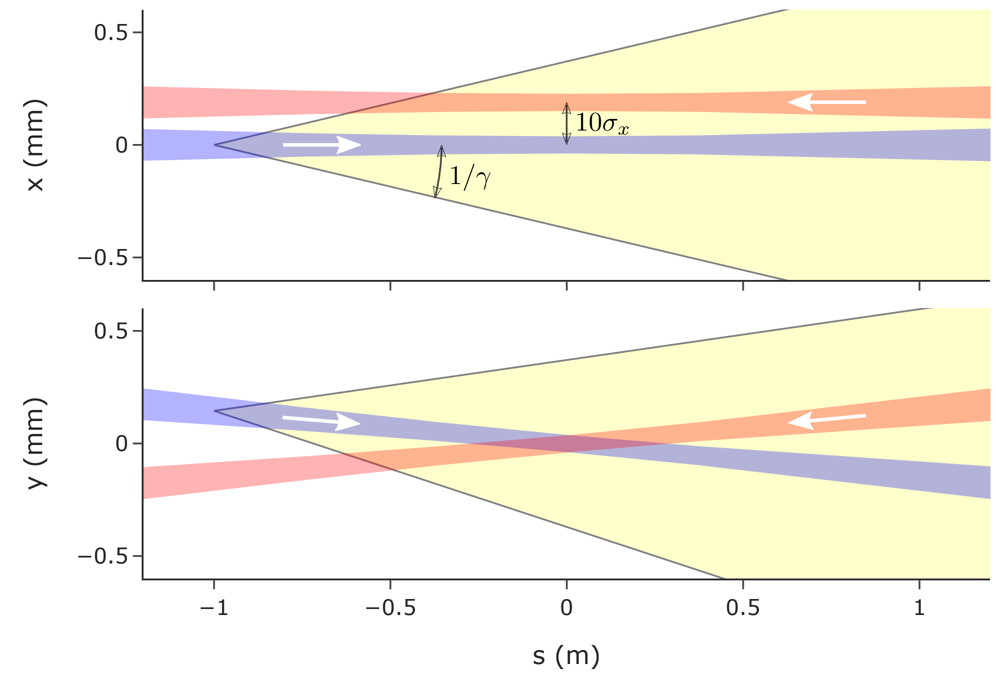

FIG. 27. The typical LHC interaction point (IP) configuration compared to a $1/\gamma$ cone of gamma-radiation. The diameter of the beams in this picture is $4\sigma_{x,y}$ (at the IP $\sigma_{x,y} \approx 19\ \mu$m). The beams are separated by $10\sigma_x \approx 0.2$ mm horizontally in order to avoid stripping of the PSI due to collisions with counter-propagating ion or proton beam.

Accessible energies

$$\sqrt{s} \leq \sqrt{4M_p\gamma\omega_2} \approx 100\,\mathrm{GeV}\sqrt{\frac{\gamma}{7000}\cdot\frac{\omega_2}{400\,\mathrm{MeV}}}$$

Possibility to study inclusive and exclusive processes at (sub) asymptotic energies:

Inclusive structure function — novelty: parity violating SF with real photons

Vector meson photoproduction, wide-angle Compton scattering — access GPD’s, TMD’s

QCD Highlights:
Secondary Photons in Colliding Mode on proton/ion beam
($\sqrt{s} \leq 100\,\mathrm{GeV}$)

Inclusive structure functions (inclusive cross section)

Photon (circular) polarization $\xi = \pm 1$, proton helicity $h = \pm 1/2$

$$\sigma(\xi, h) = \frac{8\pi^2\alpha}{s - M^2}\left[F_1 - 2h\xi g_1 + \frac{\xi}{2}F_3 + 2hg_5\right]$$

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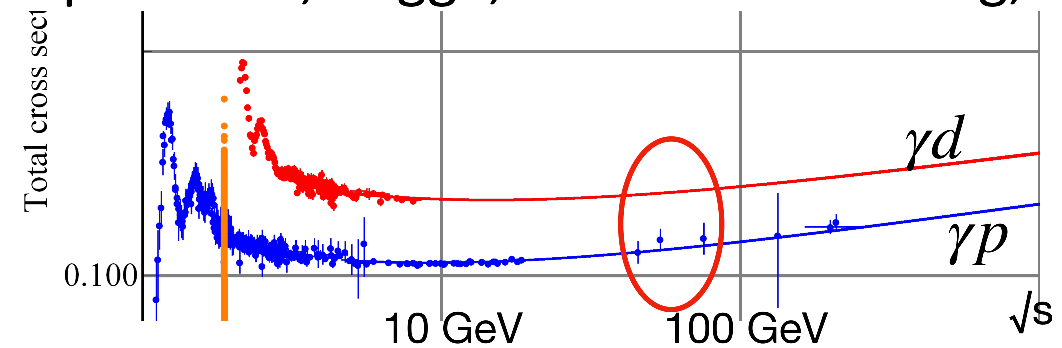
Unpolarized structure function F_1 - pomeron, Regge, nuclear shadowing, …



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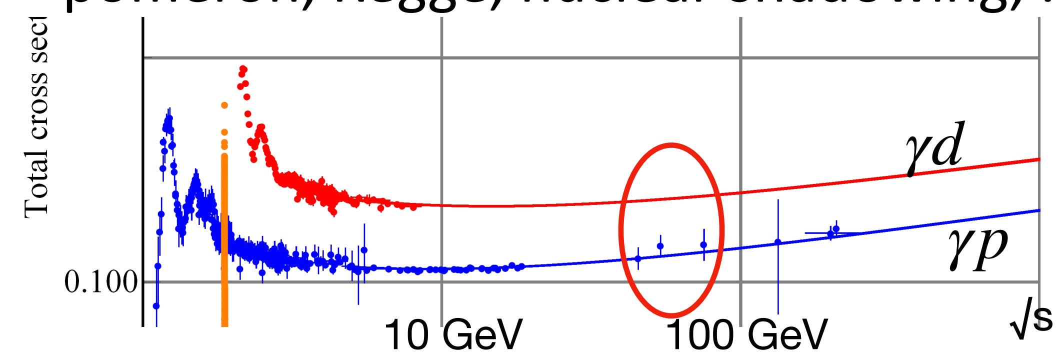
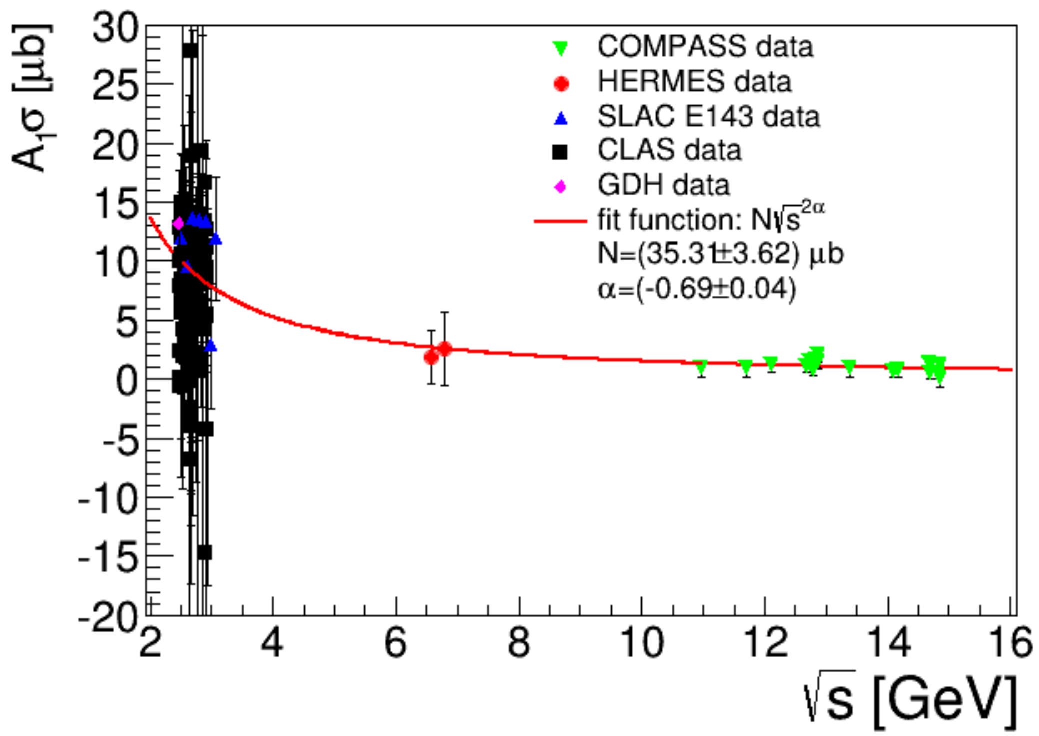


Polarized structure function g_1 -
HE part of the GDH sum rule (axial vector Regge)
Highest energies (low Q2) - COMPASS



Gerasimov-Drell-Hearn sum rule

$$I^{\mathrm{GDH}} \equiv \int_0^\infty \frac{d\nu}{\nu}\left[\sigma(1,1/2) - \sigma(1,-1/2)\right] = 2\pi^2\kappa^2\frac{\alpha}{M^2}$$

Anomalous magnetic moment κ (spin precession)
<—> spin-dependent photoabsorption at HE

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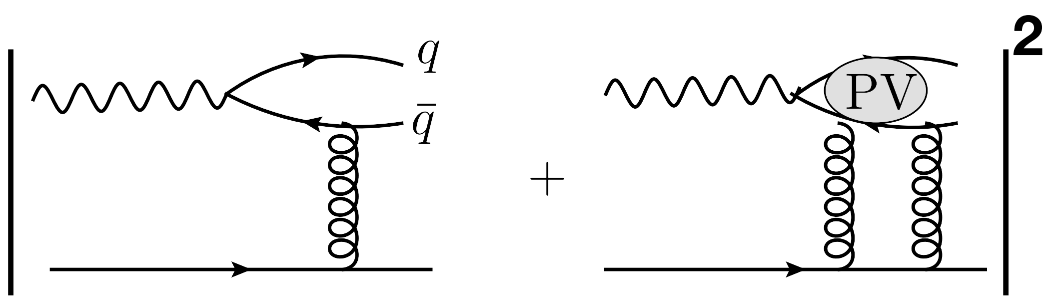
$$\sigma(\xi, h) = \frac{8\pi^2\alpha}{s - M^2}\left[F_1 - 2h\xi g_1 + \frac{\xi}{2}F_3 + 2hg_5\right]$$

PV structure functions: No real photon data available; electron data scarce

F_3 - photon polarization
(PV component of the γ WF)

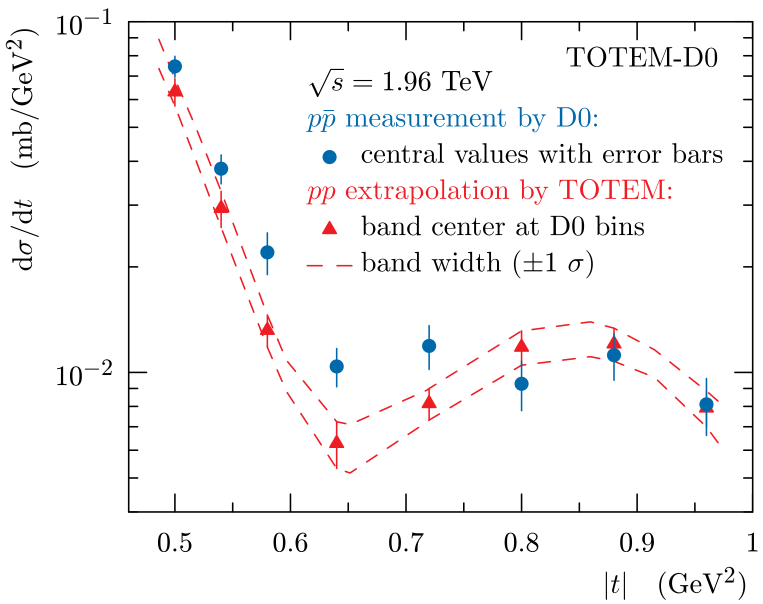
Parity-Conserving F_1: C+, P+ (pomeron)

Parity-Violating F_3: C-, P- (odderon)



Usually need p AND anti-p data to access odderon (C-)

Lukaszuk, Nicolescu, 1973
D0+TOTEM, 2012.03981



With PV signature (photon polarization) can access C- without necessity of antiparticles — LHC self-sufficient

QCD Highlights:
Secondary Photons in Colliding Mode on proton/ion beam
$(\sqrt{s} \leq 100\,\mathrm{GeV})$

PV asymmetry $$A_\gamma^{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{F_3^\gamma}{2F_1} \sim \frac{G_F \Lambda_h^2}{4\pi\alpha\sqrt{2}} \frac{c^- s^{\alpha_-}}{c^+ s^{\alpha_+}} \sim 10^{-4} - 10^{-5}$$

Measurement over a wide energy range:
check the superconvergence sum rule $$\int_0^\infty \frac{d\nu}{\nu} F_3 = 0$$ *Lukaszuk, Kurek, hep-ph/0402297*

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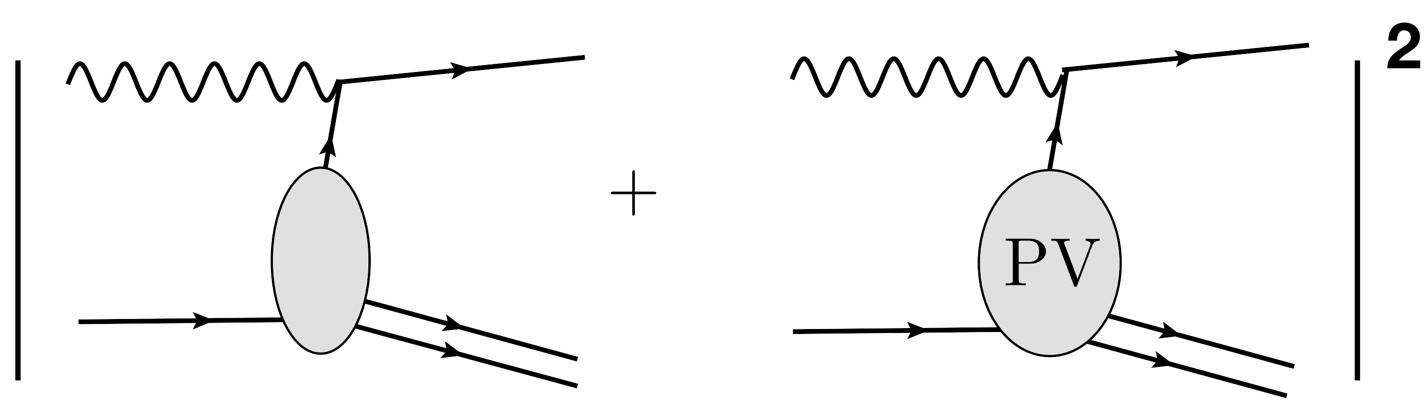
Similarly, g_5 - proton spin
(PV component of nucleon WF)
Need beam polarization



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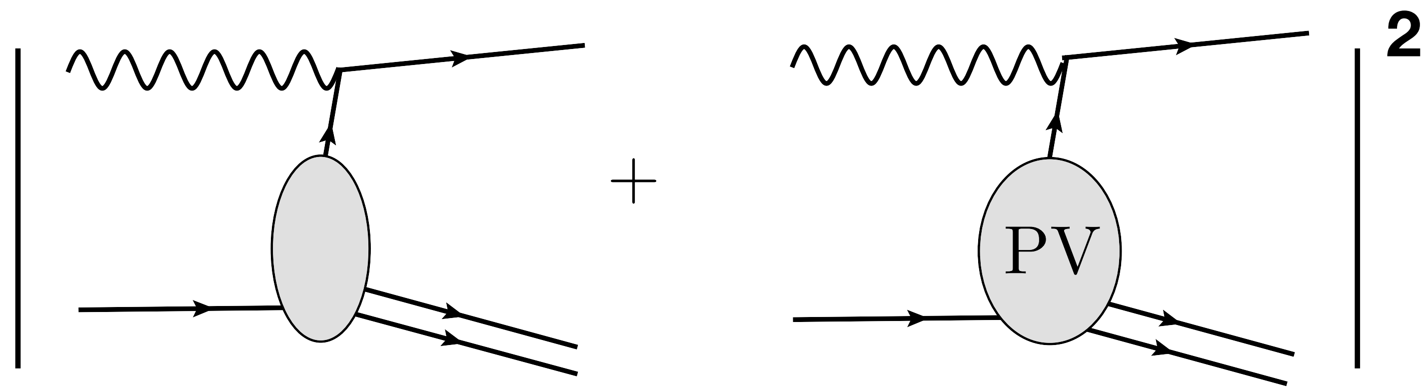

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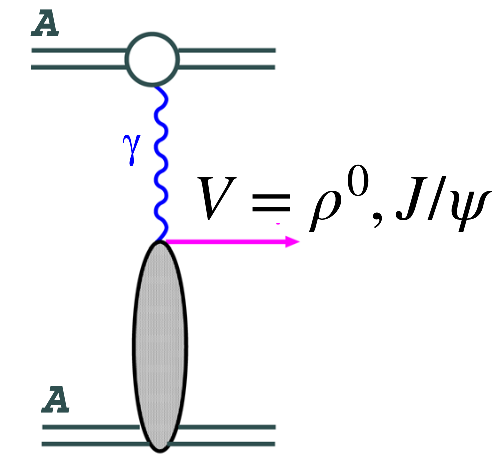
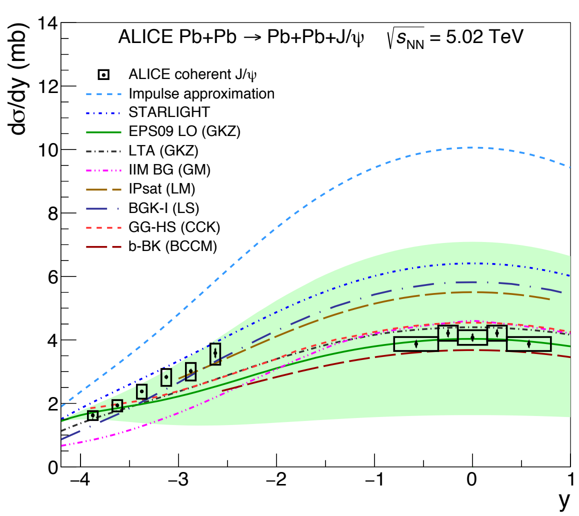
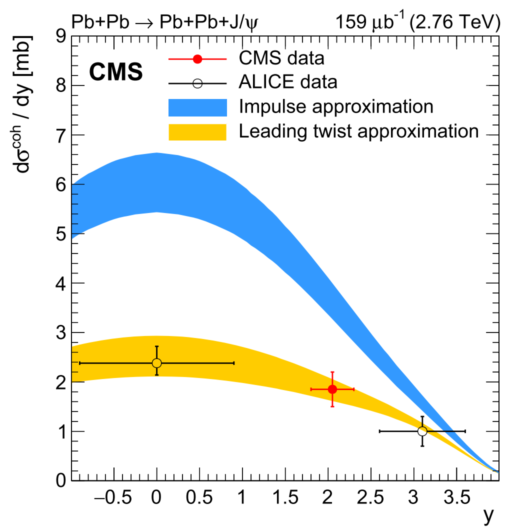
Class-1 task — only feasible with GF @ LHC: Colliding beams + Energy + Rates + Polarization

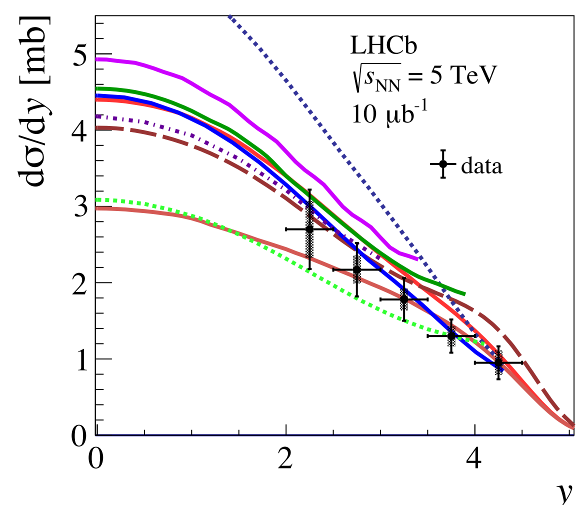
QCD Highlights: Secondary Photons in Colliding Mode on proton/ion beam $(\sqrt{s} \leq 100\,\mathrm{GeV})$

Exclusive/semi-inclusive vector meson photoproduction
At present: UPC at ATLAS, CMS, LHCb, ALICE, STAR
Quasi-real WW photon collinear to the ion beam
+ pomeron from colliding proton/ion beam









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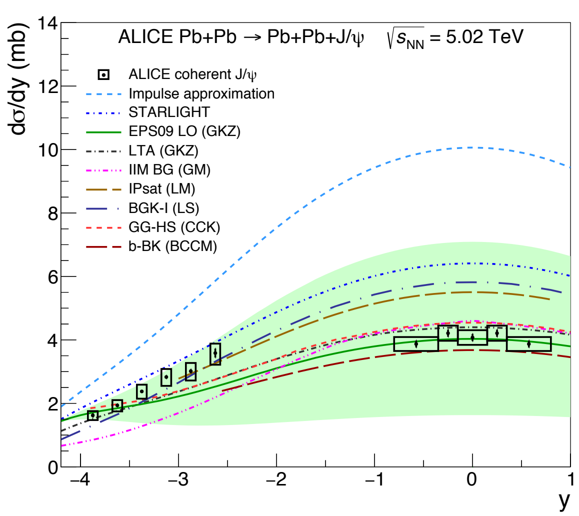
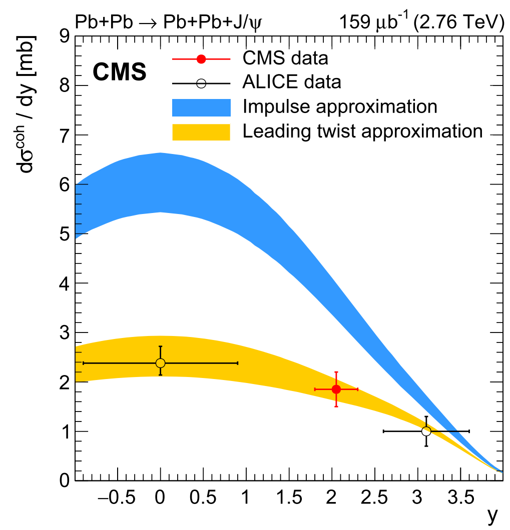
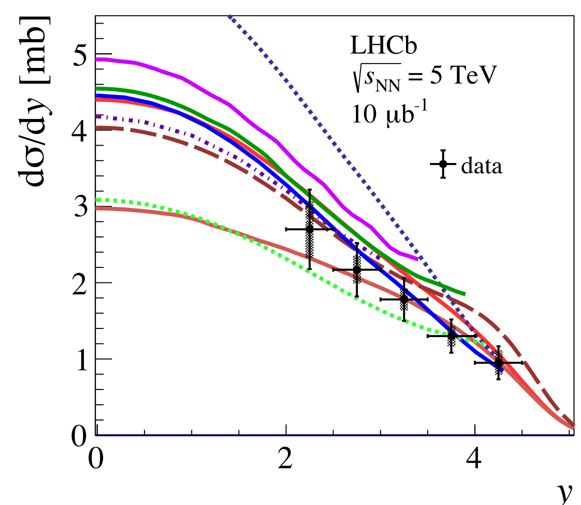
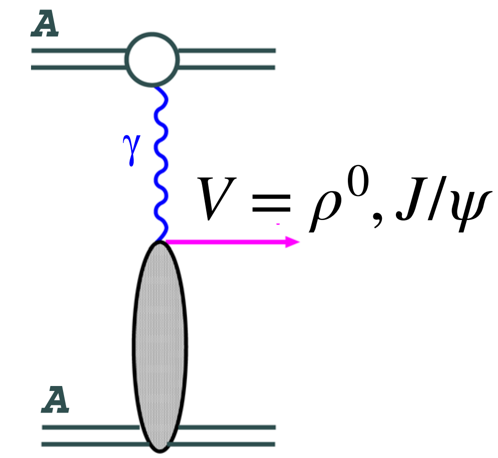
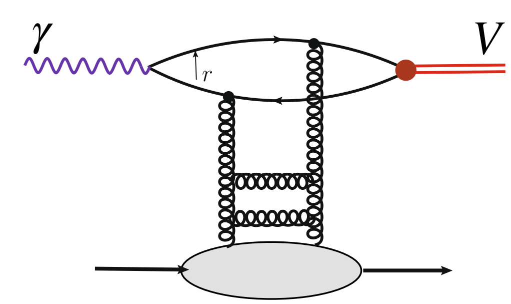


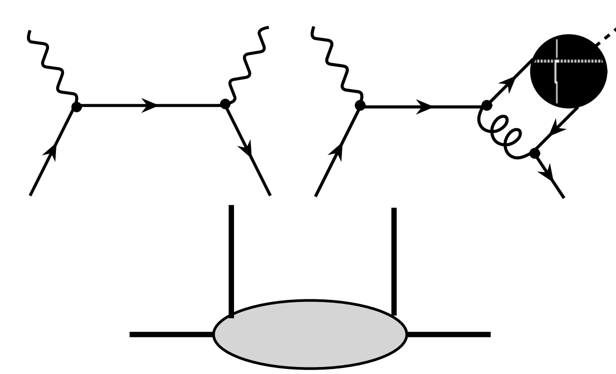








Physics motivation:
unintegrated gluon density in the nucleon/GPDs/TMDs
Depending on exclusive/semi-inclusive,
kinematics and flavor



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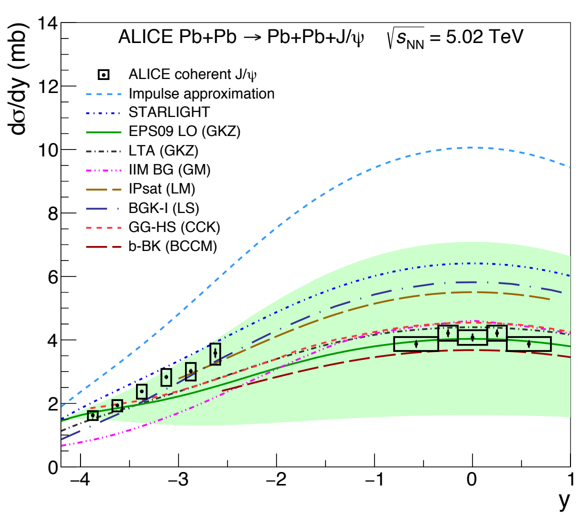

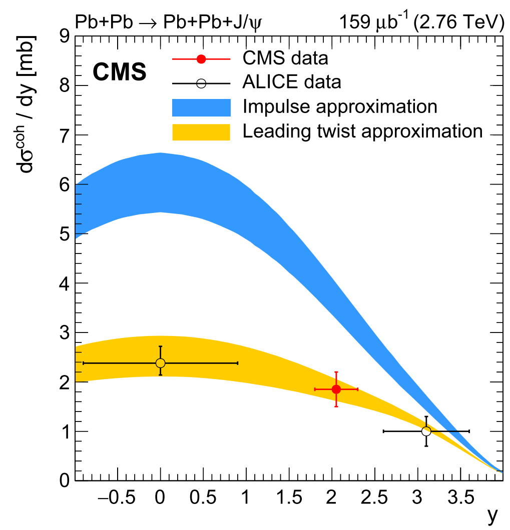

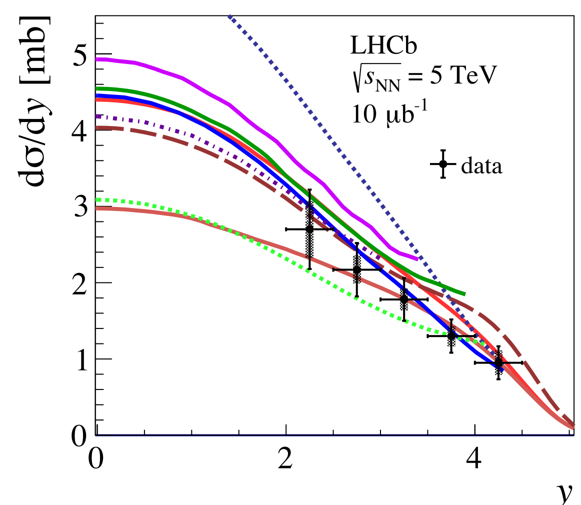

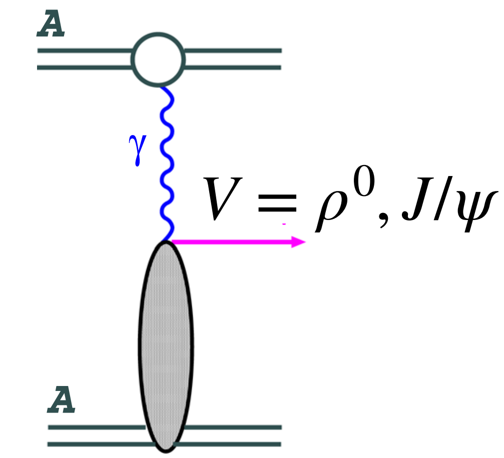

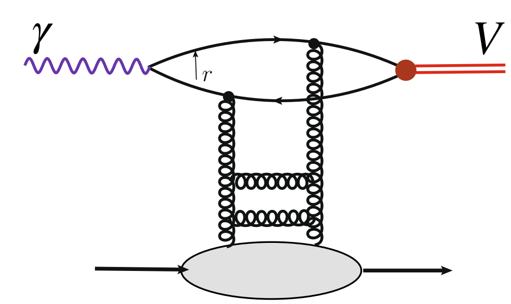

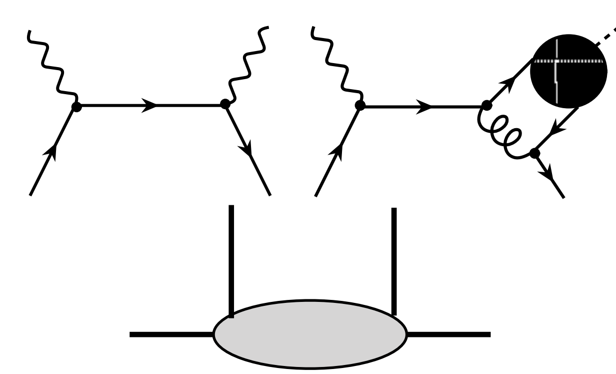

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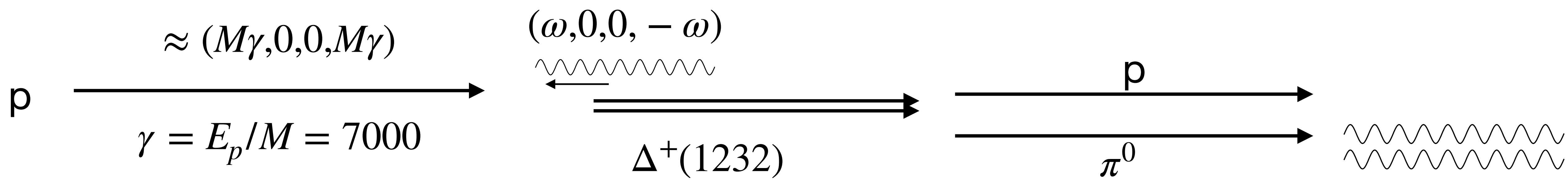
Class-2 task — feasible with UPC or at other facilities;

GF advantageous over UPC due to: well-defined initial conditions + polarization linear/circular

Tertiary Photons ($\omega_3 \leq 3.2\,\mathrm{TeV}$)



Tune the gamma ray to be on the Delta resonance (in the rest frame of the proton beam)

$$p + \gamma \to \Delta \to p + \pi^0 \to p + 2\gamma$$

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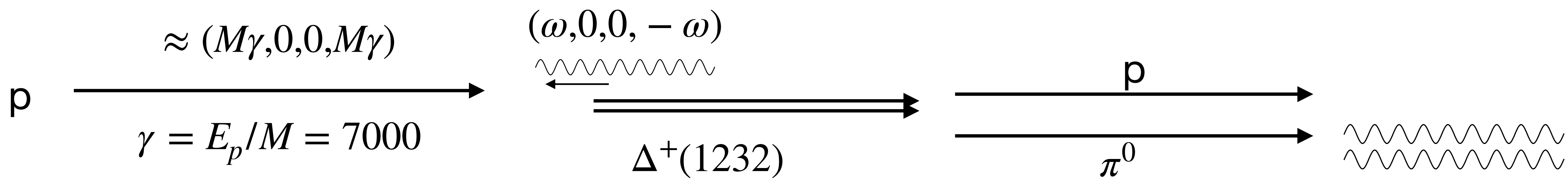

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Incident beam: $\omega \approx 300\,\mathrm{MeV}/2\gamma \sim 22\,\mathrm{keV}$

Pion will be produced at $\omega_\pi \sim 2\gamma\, 230\,\mathrm{MeV} = 3.2\,\mathrm{TeV}$

All pions will decay into 2 photons within $\gamma\tau_{\pi^0} \approx 2.5 \times 10^{-13}\, s$

Ultrarelativistic kinematics: all photons fly forward within an angle $\sim m_\pi/\omega_\pi$

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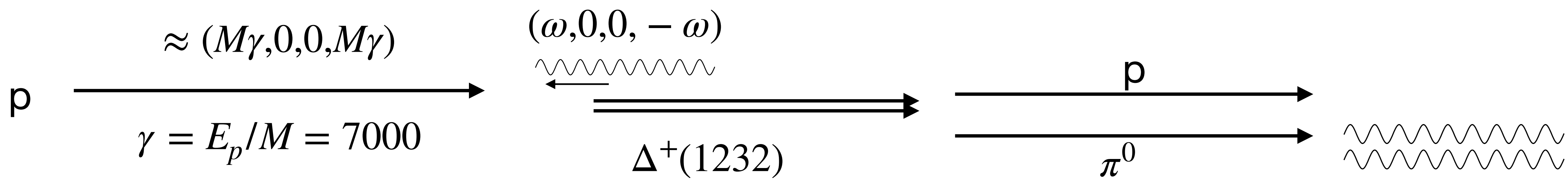

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The highest photon energy produced in the lab - studies relevant for astrophysics

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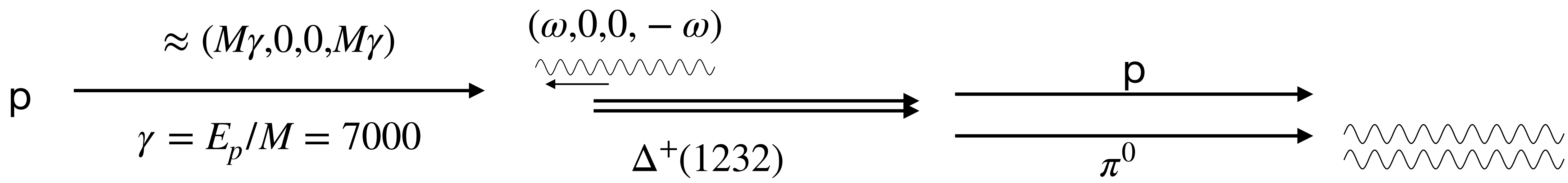

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Class-1 task — only feasible with GF @ LHC: Colliding beams + Energy + Rates

Summary

- The Gamma Factory @ LHC: a unique gamma source
- Unprecedented photon flux, wide energy range, high energy resolution, 100% polarized
- A wide range of physics tasks with photons from 40 keV to 3.2 TeV
- Will deliver crucial insights in atomic, nuclear, hadronic, particle physics, BSM searches
- Will allow to achieve significant improvement in "conventional" physics tasks: spectroscopy, photonuclear reactions on stable and radioactive isotopes, nuclear structure, QCD in the perturbative/non-perturbative regime, …
- Will for the first time allow to study processes that could not be studied before, e.g. Compton scattering with P/CP violation (non-EDM P,CP-V em observable); PV inelastic structure functions and odderon without antiparticles; production of VHEGR in the lab

Gamma Factory Collaboration:

100+ physicists from 40 institutes in 15 countries contributed to the GF studies in its various aspects

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New ideas, applications, collaborations are welcome!