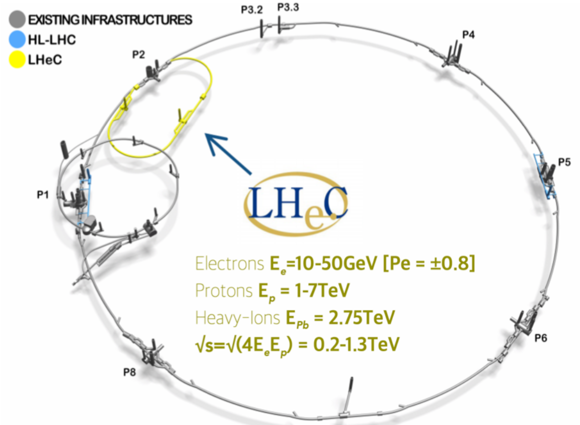
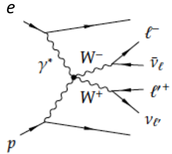
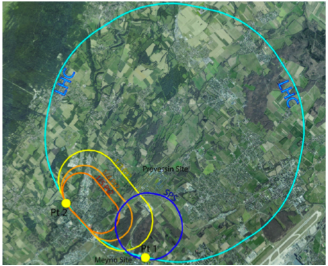
High Energy γγ Interactions at the LHeC (and FCC-eh)

Krzysztof PIOTRZKOWSKI

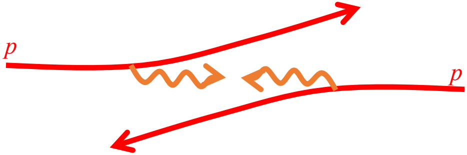
AGH University of Science and Technology, Kraków







As an Introduction: **LHC as High Energy $\gamma\gamma$ Collider**



Phys. Rev. **D63** (2001) 071502(R)
hep-ex/0201027

Initial observation:
Provided efficient measurement of very forward-scattered protons one can study high-energy $\gamma\gamma$ collisions at the LHC

<u>Highlights</u>:

- **$\gamma\gamma$ CM energy *W* up to/beyond 1 TeV (and under control)**
- **Large (quasi-real) photon flux *F* therefore significant (effective) $\gamma\gamma$ luminosity**
- **Complementary (and "clean") physics to *pp* interactions, e.g. studies of exclusive production of heavy particles might be possible ➡ opening new field of high energy $\gamma\gamma$ physics**

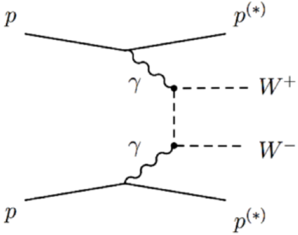
LHC as $\gamma\gamma$ collider: pair production

At high energies two-photon exclusive pair production cross-section is given by:

particle **charge, mass and spin**

for given mass and charge it is largest for vector particles, then for fermions,

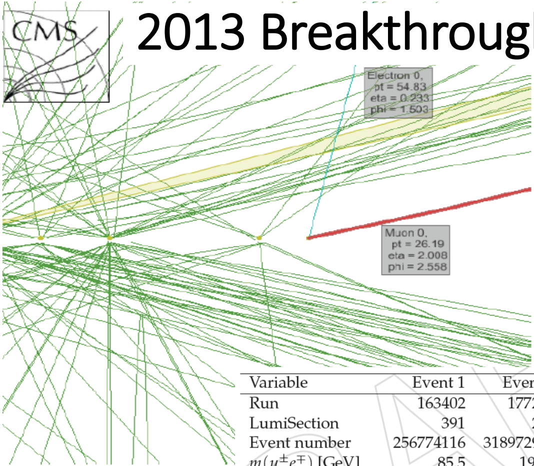
$\gamma\gamma \rightarrow WW$ pair production has a very sizable cross-section at the LHC of ~100 fb, and at least × 4, if inelastic production included (p^*)!

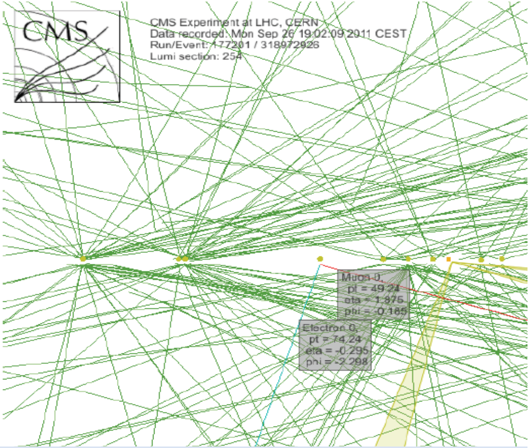


Massive fermions have sizable $\gamma\gamma$ cross-sections up to about 200 GeV masses, for scalars cross-sections are about 5 times smaller, but there is H^{++} case, for example

$\sigma \propto Z^4 \Rightarrow \sigma \times 16$!

2013 Breakthrough





Variable	Event 1	Event 2
Run	163402	177201
LumiSection	391	254
Event number	256774116	318972926
$m(\mu^{\pm}e^{\mp})$ [GeV]	85.5	190.3
1 - $\lvert\Delta\phi(\mu^{\pm}e^{\mp})/\pi\rvert$	0.66	0.33
$p_{T}(\mu^{\pm})$ [GeV]	26.2	49.2
$E_{T}(e^{\pm})$ [GeV]	54.8	74.2
$\eta(\mu^{\pm})$	2.01	1.88
$\eta(e^{\pm})$	0.23	-0.30

First ever $\gamma\gamma \rightarrow WW$!

(at CL > 90%)

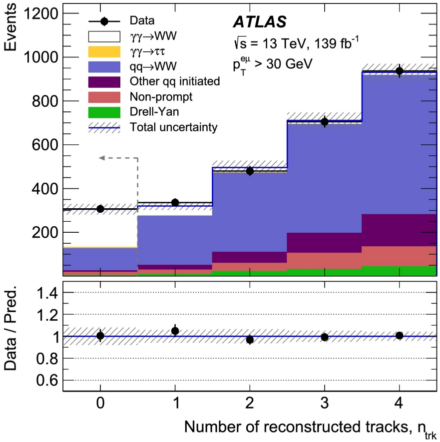
LHC as high energy γγ collider: **recent results**

$$W^+W^- \to e^{\pm}\nu\mu^{\mp}\nu$$

ATLAS Run 2 final result at 13 TeV (average event **PU ≈ 34**):

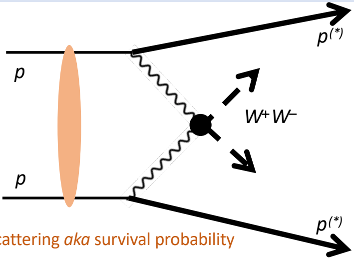
"The data yield in the signal region is 307, compared with 132 background events predicted by the best-fit result. […] This measurement constitutes **the observation of photon-induced *WW* production in *pp* collisions**, a process for which only evidence was previously reported."

doi: 10.1016/j.physletb.2021.136190



Note: in spite of almost 5 times bigger PU, a similar S/B was achieved, as for Run 1 analyses, thanks to improved tracking/ vertexing **and** significantly higher $S_{\gamma\gamma}$ at 13 TeV.

HL-LHC as high energy $\gamma\gamma$ collider: **challenges**



re-scattering *aka* survival probability

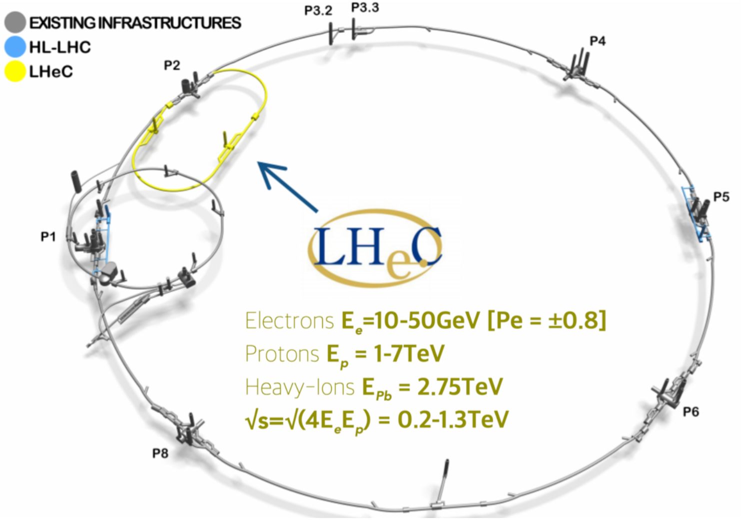
HL-LHC will provide 10 times bigger integrated luminosity, but:

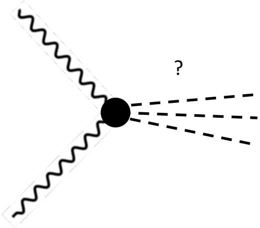
- $S_{\gamma\gamma}$ only marginally higher (thanks to 13 → 14 TeV increase)
- PU yet 4 times higher (≈ 140) than for Run 2 – but new tracking exclusivity might be more performant
- Very high event pileup will make tagging with forward protons even more tricky – **ps resolution timing detectors** are a must – however, the problem of overall efficiency loss still persists
- New ps timing in central detectors could provide much needed handle to further suppress accidental coincidences!

Major challenges for the high luminosity LHC $\gamma\gamma$ collider:

- **Only** tracks can be used for the selection of (quasi-)exclusive production
- **Only** exclusive charged dilepton states could be successfully measured so far (after 10-year efforts)
- And, the **re-scattering suppression** is large and uncertain, especially at very large *W*

New TeV Collider at CERN





Electron-Hadron collisions at TeV scales: State-of-the-art

TOPICAL REVIEW • OPEN ACCESS

The Large Hadron–Electron Collider at the HL-LHC

P Agostini[1], H Aksakal[2], S Alekhin[3,4], P P Allport[5], N Andari[6], K D J Andre[7,8], D Angal-
S Antusch[11], L Aperio Bella[12], L Apolinario[13] + Show full author list

Published 20 December 2021 • © 2021 The Author(s). Published by IOP Publishing Ltd
Journal of Physics G: Nuclear and Particle Physics, Volume 48, Number 11

Reminder:

LH*e*C CDR in 2012 – proposing **concurrent** *ep* collisions at > 1 TeV at the LHC

New LH*e*C proposal in 2020 (337 authors from 156 institutions)

Includes discussion of FCC-*eh* physics (1.2 → 3.5 TeV)

Eur. Phys. J. C (2019) 79:474
https://doi.org/10.1140/epjc/s10052-019-6904-3

Review

FCC Physics Opportunities

https://indico.cern.ch/event/1066234/

Large Hadron *electron* Collider

ERL, or the on-going revolution in high energy electron acceleration techniques

Machine Parameters and Operation - ep

arXiv:2007.14401

Parameter	Unit	LHeC			
		CDR	Run 5	Run 6	Dedicated
E_e	GeV	60	30	50	50
N_p	10^{11}	1.7	2.2	2.2	2.2
ϵ_p	μm	3.7	2.5	2.5	2.5
I_e	mA	6.4	15	20	50
N_e	10^9	1	2.3	3.1	7.8
β^*	cm	10	10	7	7
Luminosity	$10^{33}\,\text{cm}^{-2}\text{s}^{-1}$	1	5	9	23

Energy Recovery Linac technology resulted in the major breakthrough for the LHeC:

> 20 luminosity increase

Large Hadron electron Collider

LHeC is **NOT** a super-HERA "only"!

0.3 → 1.2 TeV

LHeC luminosity ≈ 1000 × HERA

LHeC is not just *ep* **QCD super-collider**–it is much more:

New **very powerful lab** for electroweak & Higgs physics

+

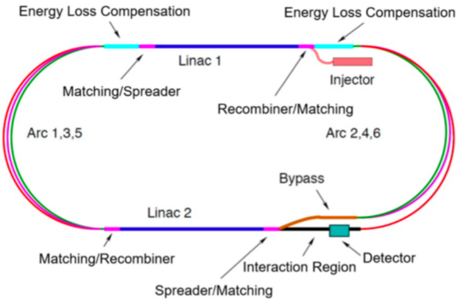
Provides sensitivity to **new BSM signatures**

+

High energy *eA* collider (**very complementary** to EIC)

Energy Recovery Linac at the HL-LHC

ERL geometry

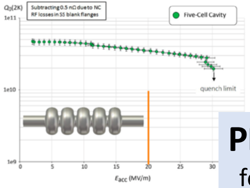


- Two SC linac accelerators
- three-pass return arcs

- ERL main parameters

Parameter	Unit	Value
Beam energy	GeV	50
Bunch charge	pC	499
Bunch spacing	ns	24.95
Electron current	mA	20
trans. norm. emittance	μm	30
RF frequency	MHz	801.58
Acceleration gradient	MV/m	20.06
Total length	m	6665

- Q-parameter of 5-cell prototype



PERLE – ERL demonstrator for LHeC, in preparation at IJCLab, Orsay

Experiment for eh and hh scattering @ IP2

Eur. Phys. J. C (2022) 82:40
https://doi.org/10.1140/epjc/s10052-021-09967-z

THE EUROPEAN PHYSICAL JOURNAL C

Check for updates

Regular Article - Experimental Physics

An experiment for electron-hadron scattering at the LHC

K. D. J. André[1,2], L. Aperio Bella[3], N. Armesto[4,a], S. A. Bogacz[5], D. Britzger[6], O. S. Brüning[1], M. D'Onofrio[2], E. G. Ferreiro[4], O. Fischer[2], C. Gwenlan[7], B. J. Holzer[1], M. Klein[2], U. Klein[2], F. Kocak[8], P. Kostka[2], M. Kumar[9], B. Mellado[9,10], J. G. Milhano[11,12], P. R. Newman[13], K. Piotrzkowski[14], A. Polini[15], X. Ruan[9], S. Russenschuk[1], C. Schwanenberger[3], E. Vilella-Figueras[2], Y. Yamazaki[16]

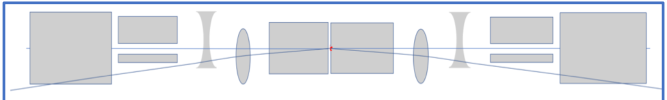


Fig. 14 Schematic view of the combined focusing and beam separation scheme

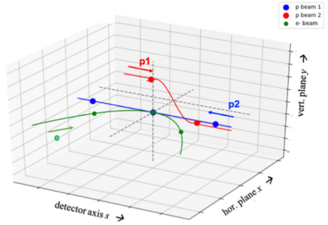


Fig. 17 Schematic view of the three beams in the interaction region. Collisions between electrons and proton beam 1 and a well separated proton beam 2

Experiment for *eh* and *hh* scattering @ IP2

"As described above in Sect. 4.6, the **new accelerator optics is able to provide collisions for *eh* and *hh* configurations in the same interaction point**. As a consequence and if confirmed by further study, IP2 could indeed house one, common multi-purpose detector serving for all of these, mostly related physics programs, of *ep*, *pp*, *eA*, *pA* and *AA* interactions, with high precision and large acceptance, and the **unique advantage for cross-calibration of performance and physics**."

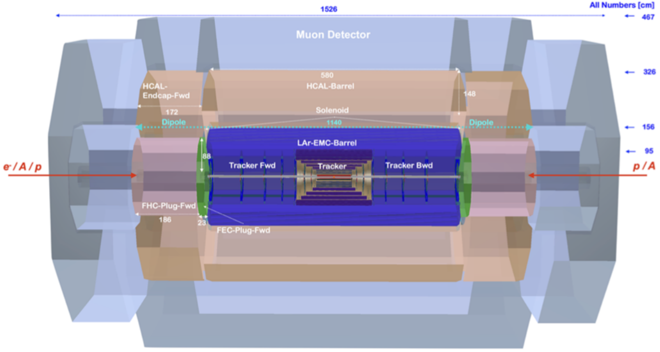
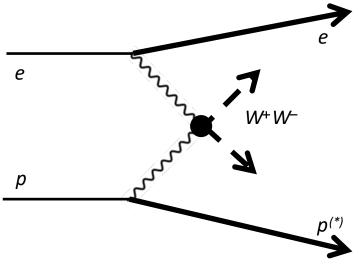
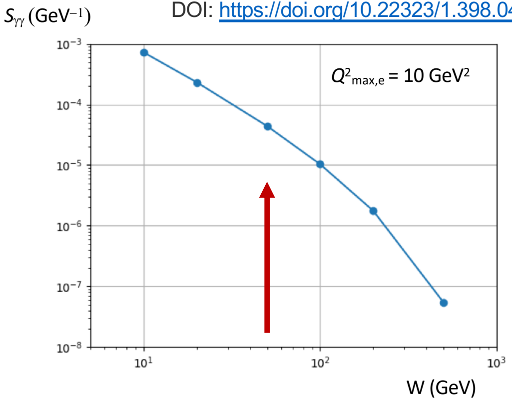


Fig. 24 Side view of a first design of the LHeC detector for both *eh* and *hh* collisions, where the detector coverage of the backward (electron) direction is extended to match that for the forward (hadron) direction.

LHeC as a high energy $\gamma\gamma$ collider



DOI: https://doi.org/10.22323/1.398.0486



Very high LHeC luminosity is the key here ⇒ more than **1 ab^{-1}** (= 1000 fb^{-1}) is expected for *ep* collisions.

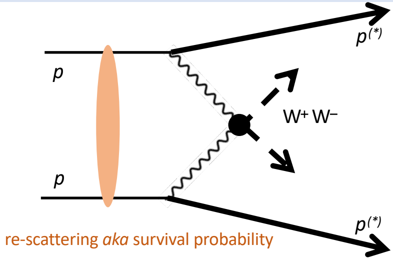
Electrons will have "only" 50 GeV, but **higher** photon flux, as approximately:

$$S_{\gamma\gamma} \propto \ln(Q^2_{max,e}/Q^2_{min,e})\ln(Q^2_{max,p}/Q^2_{min,p})$$

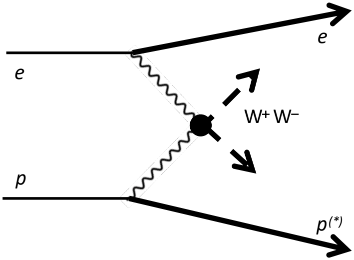
where $Q^2_{min} \propto m^2$, and $Q^2_{max,e}$ can be very high

For W < 50 GeV the *fully* exclusive $\gamma\gamma$ luminosity spectrum is **higher** at the LHeC than at the HL-LHC!

HL-LHC vs. LH*e*C as high energy $\gamma\gamma$ colliders



vs.

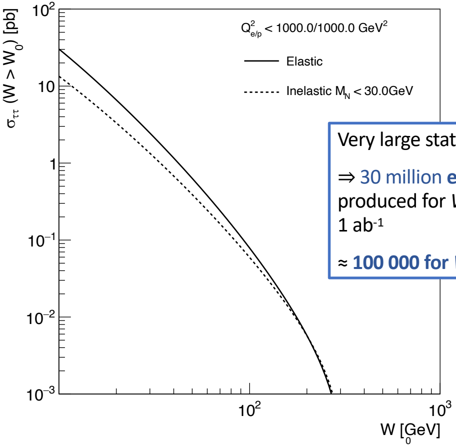


Energy reach for $\gamma\gamma$ interactions is higher at the LHC, however at the highest *W* tagging is not possible and the suppression due to re-scattering becomes large.

Event **pileup is very low at the LHeC** – it is **only 5 %** at the highest *ep* luminosity of **2.3 × 10^{34} cm^{-2}s^{-1}**.

This is not only allowing to **use calorimetry for the selection** of exclusive production, but will also significantly **increase** detection efficiency, including $\gamma\gamma$ tagging, and **suppress** backgrounds!

LHeC: $\gamma\gamma \to \tau\tau$ and $\gamma\gamma \to W^+W^-$

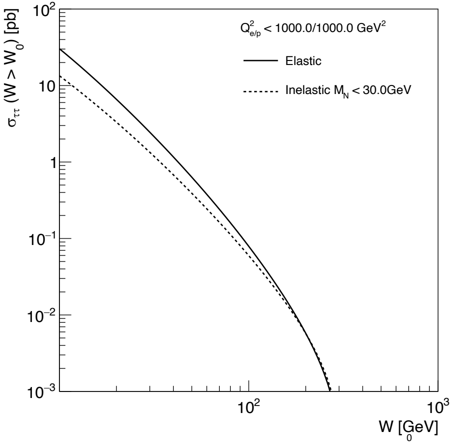


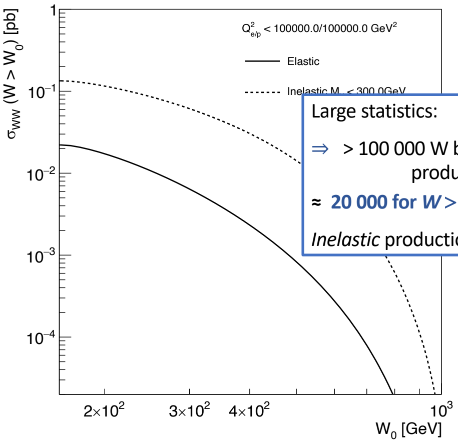
Very large statistics:

⇒ 30 million **elastic** $\tau\tau$ pairs produced for $W >$ 10 GeV at 1 ab^{-1}

≈ **100 000 for $W >$ 100 GeV**

LHeC: $\gamma\gamma \to \tau\tau$ and $\gamma\gamma \to W^+W^-$





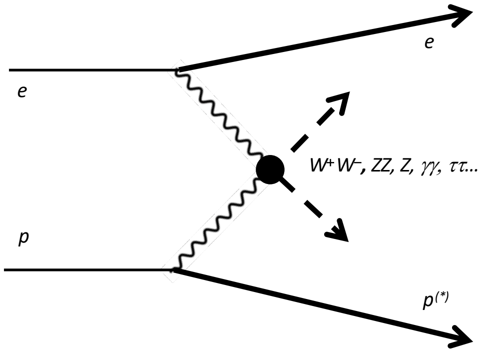
Large statistics:

⇒ > 100 000 W boson pairs produced at 1 ab^{-1}

≈ **20 000 for *W* > 500 GeV**

Inelastic production dominant

LH*e*C as very unique, generic high energy $\gamma\gamma$ collider

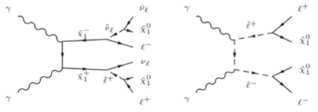


… and big surprises too??

Wide spectrum of $\gamma\gamma$ processes will be studied at the LHeC:

- $\gamma\gamma \to \gamma\gamma$: orders of magnitude higher statistics than for *PbPb* at the HL-LHC + $\gamma\gamma$ tagging ⇒ kinematic fitting
- $\gamma\gamma \to \tau^+\tau^-$: orders of magnitude higher statistics than for *PbPb* at the HL-LHC + $\gamma\gamma$ tagging ⇒ new decay modes
- $\gamma\gamma \to Z$: search for the anomalous single Z boson exclusive production
- $\gamma\gamma \to ZZ$: possibility of first ever detection + stringent limits on anomalous quartic gauge couplings (aQGCs) using semi-leptonic decay modes, $ZZ \to l^+l^-jj$
- $\gamma\gamma \to W^+W^-$: measurements of semi-leptonic decay modes, $W^+W^- \to l\nu jj$, will allow for a use of Optimal Observable methods (even with single $\gamma\gamma$ tagging) for probing aQGCs; yet high statistics (≈ as at the HL-LHC) is expected for fully leptonic W^+W^- decays + tagging

LHeC as high energy γγ collider: new physics?



Detection of two-photon exclusive production of supersymmetric pairs at the LHC

Needs re-visiting for LHeC too…

Nicolas Schul[a] * and Krzysztof Piotrzkowski[a]

[a]Université catholique de Louvain, Center for Particle Physics and Phenomenology (CP3), Louvain-la-Neuve, Belgium

The detection of pairs of sleptons, charginos and charged higgs bosons produced via photon-photon fusion at the LHC is studied, assuming a couple of benchmark points of the MSSM model. Due to low cross sections, it requires large integrated luminosity, but thanks to the striking signature of these exclusive processes the backgrounds are low, and are well known. Very forward proton detectors can be used to measure the photon energies, allowing for direct determination of masses of the lightest SUSY particle, of selectrons and smuons with a few GeV resolution. Finally, the detection and mass measurement of quasi-stable particles predicted by the so-called sweet spot supersymmetry is discussed.

Table 1
Cross sections for several examples of the exclusive two-photon pair production at the LHC. (F for fermion, S for scalar). [1]

Produced pairs	mass [GeV]	σ [fb]
W^+W^-	80	108.5
F^+F^-	100	4.064
F^+F^-	200	0.399
S^+S^-	100	0.680
S^+S^-	200	0.069

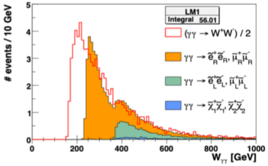
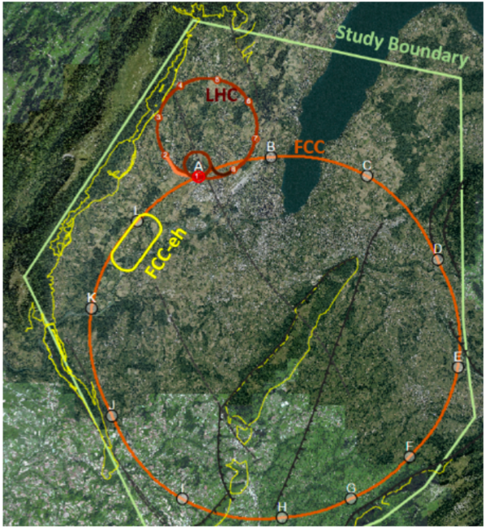


Figure 2. Distribution of two-photon invariant mass $W_{\gamma\gamma}$ for the LM1 benchmark and integrated luminosity L = 100 fb^{-1}. Two visible peaks are due to production thresholds of $\tilde{\ell}_R^+\tilde{\ell}_R^-$ and $\tilde{\ell}_L^+\tilde{\ell}_L^-$ pairs. Various contribution are added cumulatively. The background distribution of WW pairs is shown separately,

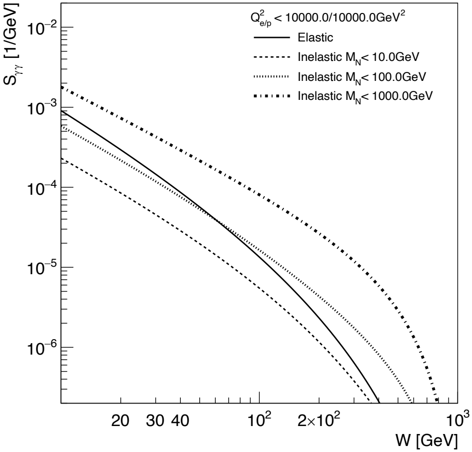
FCC-eh case

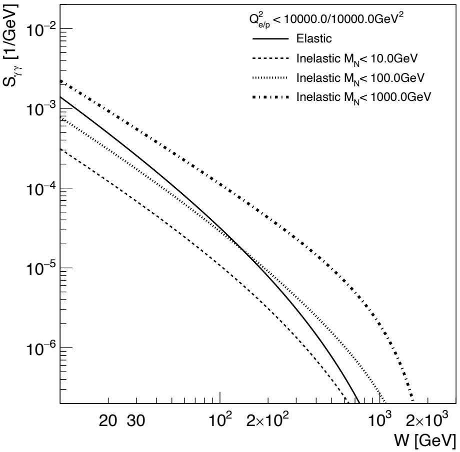
60 × 50000 GeV^2 → **3.5 TeV *ep* collider**
delivering very high luminosity
concurrently with *pp* collisions



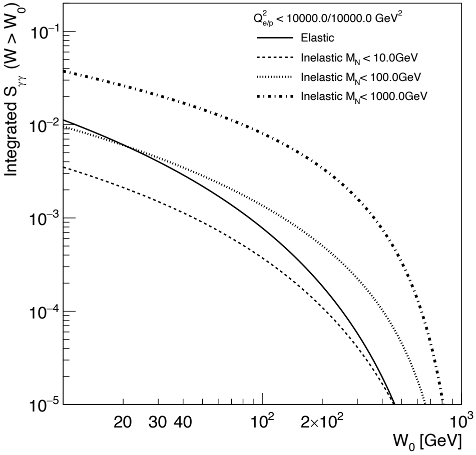
https://indico.cern.ch/event/1072533/contributions/4779225/

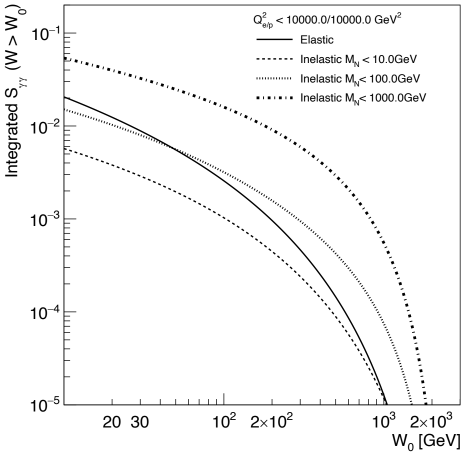
LH*e*C *vs.* FCC-*eh*





LHeC *vs.* FCC-*eh*





LHeC as an extraordinary $\gamma\gamma$ collider: summary & outlook

LHeC will complete the HL-LHC science in a very profound and relevant way, both in the QCD and Electroweak sectors

LHeC offers practically ideal conditions for studying high energy $\gamma\gamma$ interactions

Scientific potential of $\gamma\gamma$ physics at the LHeC, both in testing the electroweak theory and for searches of New Physics signals, will be deeply explored in the near future

Stay tuned!

Thank you for attention!

High energy γγ colliders: Equivalent Photon Approximation

$$\sigma_{ep} = \int dW\, S_{\gamma\gamma}\sigma_{\gamma\gamma}$$

$$S_{\gamma\gamma} = \frac{2}{W}\int_{W^2/s}^{1} dy_e \Phi_e(y_e) y_p \Phi_p(y_p)$$

EPA: Budnev *et al.* (1975)

$S_{\gamma\gamma}$ is analogous to the partonic luminosity, and its integral $\int_{W_0}^{\sqrt{s}} \mathrm{d}W\, S_{\gamma\gamma}$ provides a fraction of the *pp* luminosity "available" for γγ collisions above W_0

Note: There are *elastic* and *inelastic* (when the proton dissociates to p^*) contributions to $S_{\gamma\gamma}$

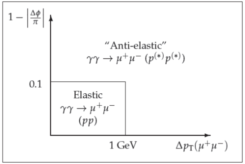
CMS Analysis Note

The content of this note is intended for CMS internal use and distribution only

2011/06/19

Measurement of exclusive $\gamma\gamma \to \mu^+\mu^-$ production at $\sqrt{s} = 7$ TeV

Jonathan Hollar, Krzysztof Piotrzkowski, and Nicolas Schul
Center for Cosmology, Particle Physics and Phenomenology (CP3)
Universite catholique de Louvain, Belgium



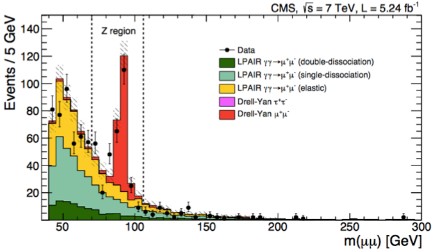


Figure 3: Invariant mass distribution of the muon pairs for the elastic selection with no additional track on the dimuon vertex. The dashed lines indicate the Z-peak region. The hatched bands indicate the statistical uncertainty in the simulation.

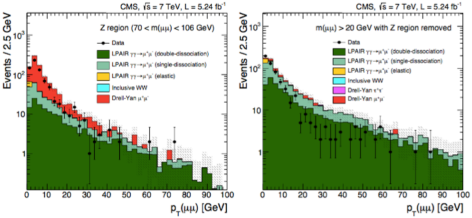
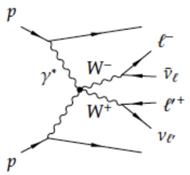


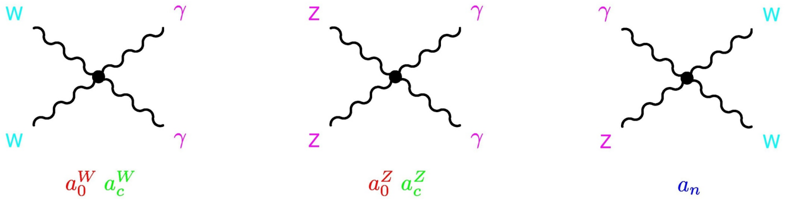
Figure 6: Transverse momentum distribution for $\mu^+\mu^-$ pairs with zero extra tracks passing the dissociation selection, for the Z region only (left), and with the Z region removed (right). The hatched bands indicate the statistical uncertainty in the simulation.

Physics with $\gamma\gamma \rightarrow$ WW (and ZZ)

$\gamma\gamma \rightarrow$ WW and ZZ (=0 at tree level in SM) pairs as a powerful test bench for the gauge boson sector at the LHC



Search for anomalous quartic couplings



LHC PHYSICS

CMS sees first direct evidence for $\gamma\gamma\to WW$

In a small fraction of proton collisions at the LHC, the two colliding protons interact only electromagnetically, radiating high-energy photons that subsequently interact or "fuse" to produce a pair of heavy charged particles. Fully exclusive production of such pairs takes place when quasi-real photons are emitted coherently by the protons rather than by their quarks, which survive the interaction. The ability to select such events opens up the exciting possibility of transforming the LHC into a high-energy photon–photon collider and of performing complementary or unique studies of the Standard Model and its possible extensions.

The CMS collaboration has made use of this opportunity by employing a novel method to select "exclusive" events based only on tracking information. The selection is made by requesting that two – and only two – tracks originate from a candidate vertex for the exclusive two-photon production. The power of this method, which was first developed for the pioneering measurement of exclusive production of muon and electron pairs, lies in its effectiveness even in difficult high-luminosity conditions with large event pile-up at the LHC.

The collaboration has recently used this approach to analyse the full data sample collected at $\sqrt{s}$=7 TeV and to obtain the first direct evidence of the $\gamma\gamma\to WW$ process. Fully leptonic W-boson decays have been measured in final states characterized by opposite-sign and opposite-flavour lepton pairs where one W decays into an electron and a neutrino, the other into a muon and a neutrino (both neutrinos leave undetected). The leptons were required to have: transverse momenta p_T>20 GeV/c and pseudorapidity $|\eta|$<2.1; no extra track associated with their vertex; and for the pair, a total p_T>30 GeV/c. After applying all selection criteria, only two events remained – compared with an expectation of 3.2 events: 2.2 from $\gamma\gamma\to WW$ and 1 from background (figure 2).

The lack of events observed at large values of transverse momentum for the pair, which would be expected within the Standard Model, allows stringent limits on anomalous quartic $\gamma\gamma WW$ couplings to be derived. These surpass the previous best limits, set at the Large Electron–Positron collider and at the Tevatron, by up to two orders of magnitude (figure 3).

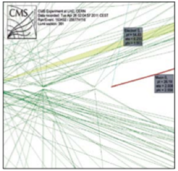


Fig. 1. Above: Proton–proton collisions recorded by CMS at $\sqrt{s}$=7 TeV, featuring candidates for the exclusive two-photon production of a W^+W^- pair, where one W boson has decayed into an electron and a neutrino, the other into a muon and a neutrino.

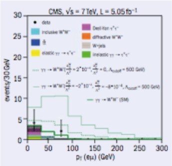


Fig. 2. Top right: The p_T distribution of eμ pairs in events with no extra tracks compared with the Standard Model expectation (thick green line) and predictions for anomalous quartic gauge couplings (dashed green histograms).

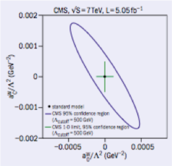


Fig. 3. Right: Limits on anomalous quartic $\gamma\gamma WW$ couplings.

● **Further reading**

CMS collaboration 2013 arXiv:1305.5596 [hep-ex], submitted to *JHEP*.

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 53 NUMBER 6 JULY/AUGUST 2013

Hot news back in 2013…

LHC as a high energy $\gamma\gamma$ collider: **power of modern tracking**

CMS breakthrough in 2011-13 (without tagging):

Track-based only exclusivity selection for charged *dilepton* final states at high event pileup (PU) – resulted in significantly higher $\gamma\gamma$ luminosity thanks to *quasi-exclusive* contributions, but also in no direct control of *W*

Search for the exclusive two-photon production of W^+W^- pairs in pp collisions at 7 TeV

The CMS Collaboration

DRAFT

Abstract

A search for exclusive or semi-exclusive W^+W^- production, $pp \to p^{(*)}W^+W^-p^{(*)} \to p^{(*)}\mu^\pm e^\mp p^{(*)}$, at $\sqrt{s} = 7$ TeV is reported using data corresponding to an integrated luminosity of 5.05 fb^{-1}. Two events passing all selections are observed in data, compared to a Standard Model expectation of 2.7 ± 0.5 signal events with 0.84 ± 0.13 background. The region of high dilepton transverse momentum, $p_T(\mu^\pm e^\mp) > 100$ GeV, is studied for deviations from the Standard Model. No events are observed in this region, and the resulting upper limits are compared to predictions assuming anomalous quartic gauge couplings.

This box is only visible in draft mode. Please make sure the values below make sense.

PDFAuthor: Jonathan J. Hollar, Laurent Forthomme, Krzysztof Piotrzkowski, Gustavo Gil Da Silveira, Finn Rebassoo

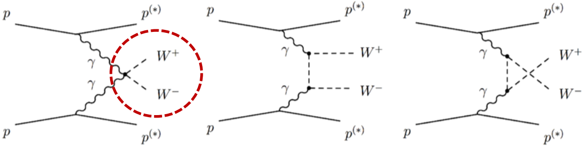


Figure 1. Quartic (left), t-channel (center), and u-channel (right) diagrams contributing to the $\gamma\gamma \to W^+W^-$ process at leading order in the SM. The $p^{(*)}$ indicates that the final state proton(s) remain intact ("exclusive" or "elastic" production), or dissociate ("quasi-exclusive" production).

$$W^+W^- \to e^\pm \nu \mu^\mp \nu$$

CMS Run 1 final result at 7/8 TeV (for mean event PU ≈ 7):

"Upper limits on the anomalous quartic gauge coupling operators $a_{W0,C}$ (dimension-6) and $f_{M0,1,2,3}$ (dimension-8), the **most stringent to date**, are derived from the measured dilepton transverse momentum spectrum."

doi: 10.1007/JHEP08(2016)119

LHC as a high energy $\gamma\gamma$ collider: **recent results II**

"The observation of forward proton scattering in association with lepton pairs ($e^+e^- + p$ or $\mu^+\mu^- + p$) produced via photon fusion is presented. The **scattered proton is detected by the ATLAS Forward Proton spectrometer**, while the leptons are reconstructed by the central ATLAS detector. Proton-proton collision data recorded in 2017 at a center-of-mass energy of $\sqrt{s}$ = 13 TeV are analyzed, corresponding to an integrated luminosity of **14.6 fb^{-1}**."
doi: 10.1103/PhysRevLett.125.261801

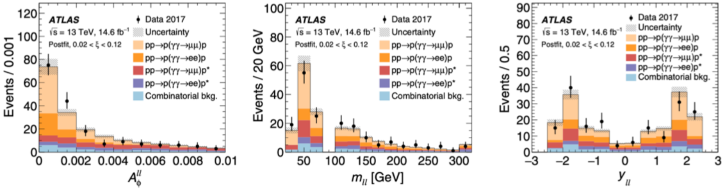


FIG. 3. Distributions of dilepton acoplanarity $A_\phi^{\ell\ell}$ (left), invariant mass $m_{\ell\ell}$ (center), rapidity $y_{\ell\ell}$ (right) satisfying $\xi_{\ell\ell}, \xi_{\rm AFP} \in [0.02, 0.12]$, and $|\xi_{\rm AFP} - \xi_{\ell\ell}| < 0.005$ for at least one AFP side. Events with $70 < m_{\ell\ell} < 105$ GeV are vetoed. The total prediction comprises the signal and combinatorial background processes, where p^* denotes a dissociated proton. The simulated predictions are normalized to data to illustrate the expected signal composition. The rightmost bin of the $m_{\ell\ell}$ distribution includes overflow. The hatched band indicates the combined statistical and systematic uncertainties of the prediction. Error bars denote statistical uncertainties of the data.

(HL-)LHC as a high energy $\gamma\gamma$ collider: **summary**

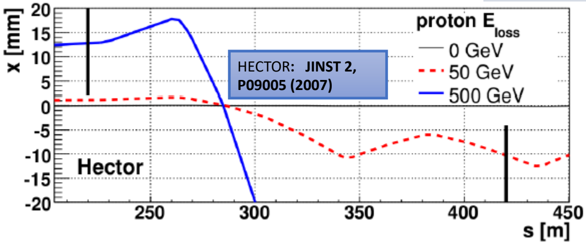
High energy $\gamma\gamma$ physics can be successfully studied at the LHC!

- Fundamental role of exclusive $\mu\mu$ (and *ee*) pairs – they serve as a **standard candle** in many ways: as a precise calibration tool & acceptance verification + a photon-flux-meter
- Use of very forward proton detectors (**AFP!**) is essential for full exploration of $\gamma\gamma$ physics at the LHC – perhaps new channels as semi-leptonic WW can be studied already in Run 3
- HL-LHC opens new horizons in this exploration – to properly profit from that, the development of **dedicated ps resolution timing detectors** is mandatory (+ studies of the potential impact of ps timing in central detectors)
- Precise studies of high-mass diffraction at the LHC are **crucial** for optimal extraction of the $\gamma\gamma$ signals using very forward proton detectors

Picosecond ToF detectors @ LHC

Use very fast ToF detectors to measure *longitudinal vertex position* by *z-by-timing* from forward proton arrival time difference:

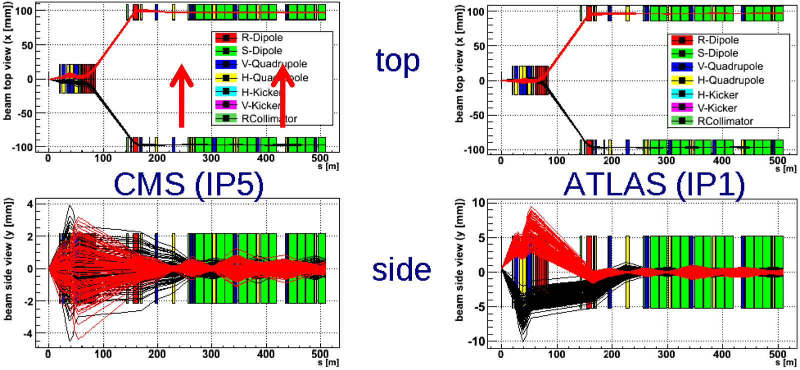
$z = (t_1 - t_2)/2c$



Path length differences are very small for forward protons at LHC, typically << 100 μm corresponding to sub-picosecond time differences.

Ultra fast timing detectors are essential for measuring the exclusive production at LHC, JINST 4 (2009) T10001

Optimal places for tagging Exclusive Production at LHC: @ 220/240m and 420m from IP



Horizontal crossing plane

Vertical crossing plane

HECTOR: **JINST 2, P09005 (2007)**
For <u>nominal</u> low-β LHC optics

HL-LHC as a high energy γγ collider: **new physics?**

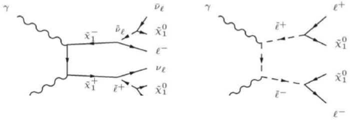
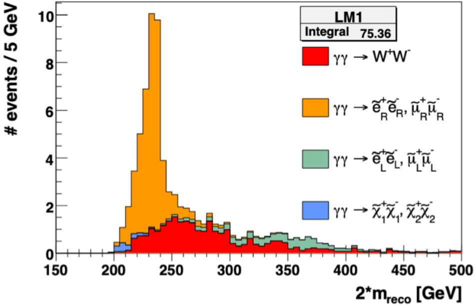


Table 3
LM1 signal and WW background cross sections before and after the acceptance cuts (including the flavor selection), and after the analysis cuts. Values are given in fb. ($\ell = e, \mu$. $i = 1, 2$).

Processes	σ	σ_{acc}	$\sigma_{acc+ana}$
$\gamma\gamma \to \tilde{\ell}_R^+\tilde{\ell}_R^-$	0.798	0.522	0.403
$\gamma\gamma \to \tilde{\ell}_L^+\tilde{\ell}_L^-$	0.183	0.135	0.089
$\gamma\gamma \to \tilde{\tau}_i^+\tilde{\tau}_i^-$	0.604	0.054	0.003
$\gamma\gamma \to \tilde{\chi}_i^+\tilde{\chi}_i^-$	0.642	0.043	0.014
$\gamma\gamma \to H^+H^-$	0.004	/	/
$\gamma\gamma \to W^+W^-$	108.5	3.820	0.255



https://doi.org/10.1016/j.nuclphysbps.2008.07.036

Figure 6. Cumulative distributions of the reconstructed mass $2m_{reco}$ for the LM1 signal and the WW background for the intergrated luminosity L = 100 fb^{-1}.

Need updating for HL-LHC/recent BSM models

LHeC/FCCeh/PERLE Workshop @ Orsay

Wed 26/10 | Thu 27/10 | Fri 28/10 | All days

Print | PDF | Full screen | Detailed view | Filter

Session legend

Welcome and ep / A Physics

14:00

Opening and welcome by IJCLab
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 14:00 - 14:10

Welcome CERN
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 14:10 - 14:25

The Development of the LHeC/PERLE/FCC-eh Project
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 14:25 - 15:00

15:00

eh TeV Scale Physics and Relation to LHC/FCC-hh (I) PDFs/qcd, Small x, Nuclei (20' each)
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 15:00 - 16:00

16:00

Coffee
200/0-Cafétéria , IJCLab 16:00 - 16:30

eh TeV Scale Physics and Relation to LHC/FCC-hh (II) Higgs, Eweak/Top, BSM (20' each)

17:00

200/0-Auditorium - Auditorium P. Lehmann, IJCLab 16:30 - 17:30

New Ideas/Studies

Wed 26/10 | Thu 27/10 | Fri 28/10 | All days

Print | PDF | Full screen | Detailed view | Filter

Session legend

Joint eh/hh Study and PERLE

09:00

The LHeC Detector and the ECFA detector roadmap
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 09:00 - 09:30

Design of the IR at IP2
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 09:30 - 10:00

10:00

The ALICE 3 Project: detector design
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 10:00 - 10:20

The ALICE 3 Project: physics
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 10:20 - 10:40

Discussion
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 10:40 - 11:00

11:00

Coffee break
200/0-Cafétéria , IJCLab 11:00 - 11:30

New Ideas/Studies

12:00

200/0-Auditorium - Auditorium P. Lehmann, IJCLab 11:30 - 12:30

Overview on the PERLE Project
200/0-Auditorium - Auditorium P. Lehmann, IJCLab 12:30 - 13:00

PERLE a key ERL project : HEP and Nuclear Physics communities

ERL machines open a new Frontier for the physics of "the electromagnetic probe"

(1) At low energy e Nuclei (PERLE and Destin@Orsay) 250-500 MeV
(2) At Higher Energy e p (e A) (LHeC and/or FCC-eh) 60 GeV

You need high luminosity ⇒ High current (from 10mA up to 100mA)
You need to increase the energy (remaining compact) ⇒ Multi turns

The (1) machine (PERLE@Orsay)

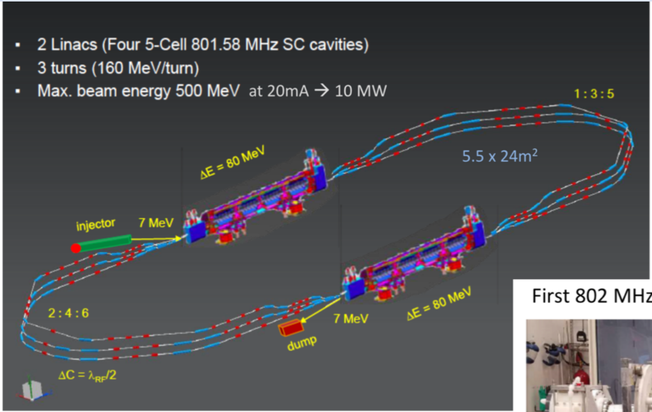
- will be the **first ERL dedicated to Nuclear Physics** for studying the eN interaction with radioactive nuclei.
- It's a **necessary demonstrator for the (2) -HEP machine (LHeC / FCC-eh)-** (same technological choices & beam parameters)

The key points : high power (current x energy) and complex machine in terms of beam dynamics (multi-turns)

+ PERLE@Orsay (*not time today to discuss it)*
- is also a necessary demonstrator for other future machines and applications
- Elastic ep Scattering at PERLE (p Radius, Dark Photons, PV)
- Possibility of Nuclear Photonics (inverse Compton scattering γ's)

Achille Stocchi
IJCLab / Université Paris-Saclay,
IN2P3/CNR

LHeC demonstrator: Powerful ERL for Experiments (PERLE) in Orsay

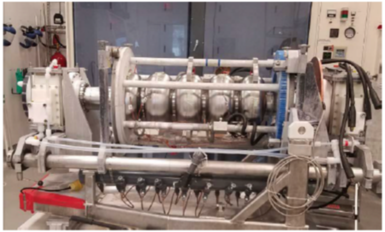


cf Walid Kaabi at Amsterdam FCC

- BINP
- CERN
- Daresbury/Liverpool
- Jlab
- Orsay

→ CDR 1705.08783 [J. Phys G]
→ TDR in 2019

First 802 MHz cavity successfully built (Jlab)



→ **ERL demonstrator**
→ **O(10 MeV) physics**