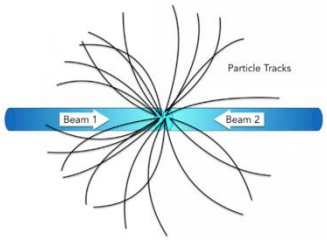
THE HENRYK NIEWODNICZAŃSKI
INSTITUTE OF NUCLEAR PHYSICS
POLISH ACADEMY OF SCIENCES

Division of Particle and Astroparticle Physics (NO1)

Division Head: **Dr. hab. Anna Kaczmarska**

Scientific Departments:



- The Belle II Experiment Department (NZ11)
- Department of Diffractive Processes (NZ13)
- The ATLAS Experiment Department (NZ14)
- The LHCb Experiment Department (NZ17)

- Department of Gamma-Ray Astrophysics (NZ12)
- Department of Cosmic Ray Research and Neutrino Studies (NZ15)

Staff: 56; Researchers: 46; PhD Students: 23;

MAIN RESEARCH ACTIVITIES

- **Division research groups participate in leading particle and astroparticle physics projects conducted by large international collaborations at the world's foremost experimental facilities**
- **We are involved in all phases of these projects**
  - initial design, optimization, and construction of detector systems,
  - development of research programs, active participation in data analysis,
  - maintenance and upgrading of advanced detector technologies.

Experiments at CERN: LHC, HL-LHC

Japan: KEKB, SuperKEKB

ν T2K

BNL: EIC

Astrophysical Observatories

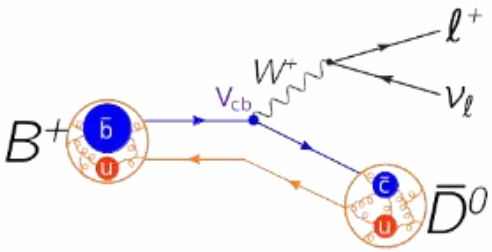
Projects of Future Accelerators

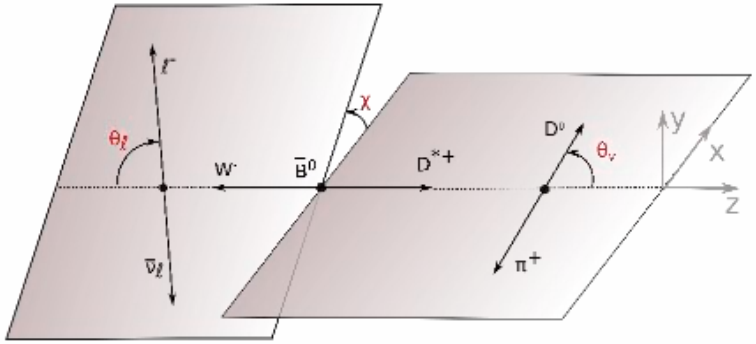
RESULTS: ~260 publications (JCR)/year

*Measurement of Differential Distributions of B→D*ℓν at Belle*

- **Exclusive–Inclusive $|V_{cb}|$ Puzzle:**
- Long-standing tension between inclusive ($B \to X_c \ell \nu$) and exclusive ($B \to D^{(*)} \ell \nu$) determinations
- Each method relies on different **theoretical frameworks** → possible sign of **new physics** or incomplete understanding of **QCD dynamics**

Exclusive $|V_{cb}|$





- **Belle Analysis (711 fb^{-1}, full dataset):**
- Exclusive extraction using $B \to D^{*} \ell \nu$ events.
- Angular observables fitted with two form-factor parametrizations: CLN and BGL.
- Results: stable **|Vcb|** around 40x10^{-3}, consistent across both approaches.
- ~4% below inclusive averages ~42.2x10^{-3}, leaving a ~3σ global tension
- PRL 133, 131801 (2024); Phys. Rev. D 108, 012002 (2023)

Results:

Belle

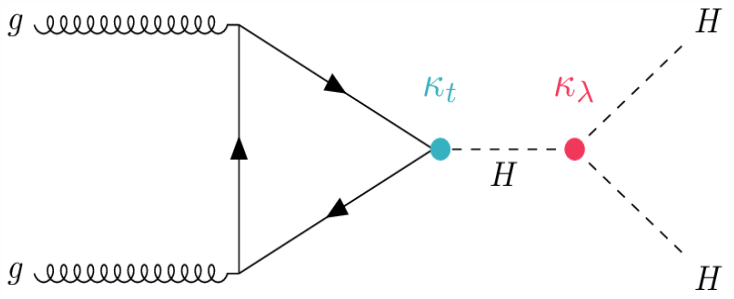
$$|V_{cb}|_{\mathrm{CLN}} = (40.2 \pm 0.9) \times 10^{-3}$$
$$|V_{cb}|_{\mathrm{BGL}} = (40.7 \pm 1.0) \times 10^{-3}$$

Belle II

$$|V_{cb}|_{\mathrm{CLN}} = (40.13 \pm 0.27 \pm 0.93 \pm 0.58) \times 10^{-3}$$
$$|V_{cb}|_{\mathrm{BGL}} = (40.57 \pm 0.31 \pm 0.95 \pm 0.58) \times 10^{-3}$$

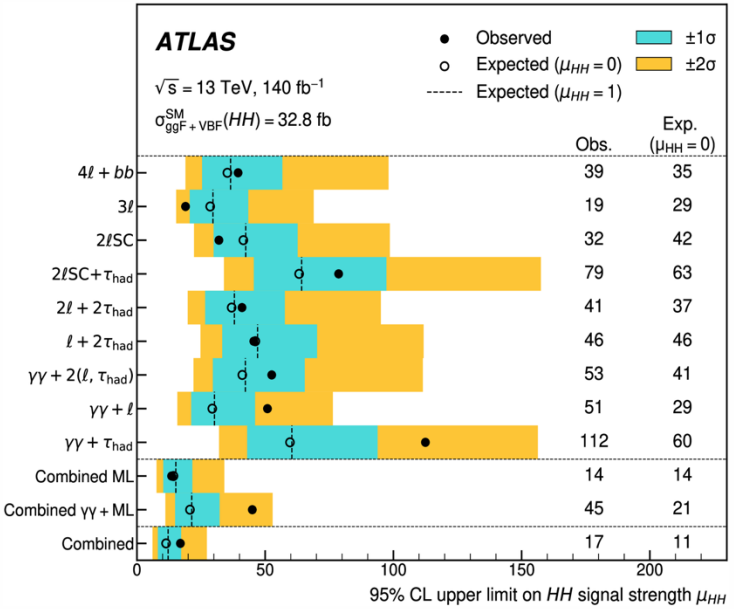
Search for non-resonant Higgs boson pair production (ATLAS, JHEP 08 (2024) 164)

- Higgs pair production (HH) in the SM is ~1000× rarer than single-H production → not observable with current dataset
- Beyond-SM processes could enhance HH production
- Key to probing the Higgs self-coupling (λ_{HHH})

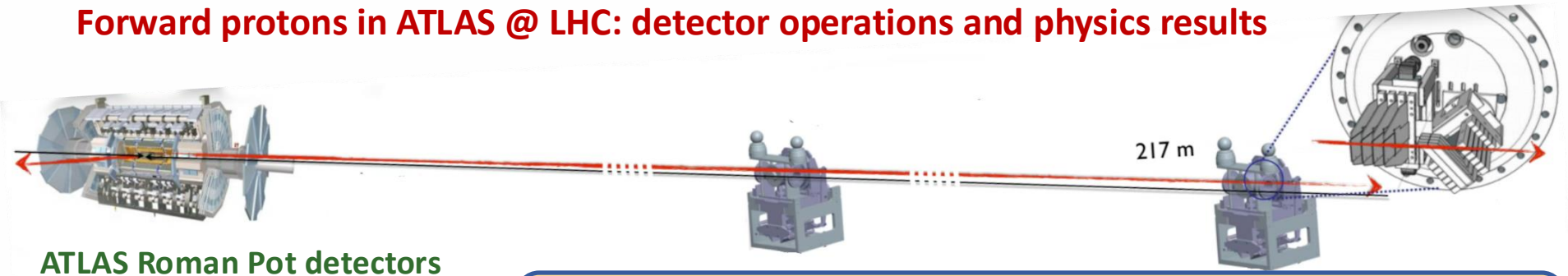


- First ATLAS analysis of this kind
  - multileptons in the final state
- Complements previous HH searches by adding missing channels
- Dataset: pp collisions at $\sqrt{s}$ = 13 TeV, Run 2 (≈140 fb^{-1})

- Data consistent with SM predictions
- Upper limit on HH production: $\mu < 17 * \sigma_{SM}$
- Constraints on Higgs self-coupling: narrowed limits on modifier HHH ($\kappa_\lambda = \lambda_{HHH}/\lambda_{SM}$)



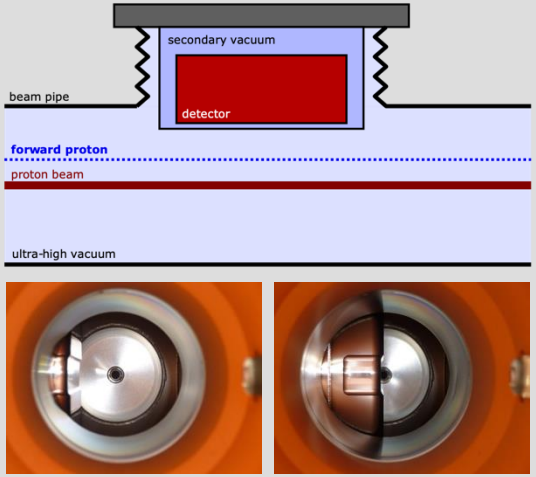
Forward protons in ATLAS @ LHC: detector operations and physics results



ATLAS Roman Pot detectors

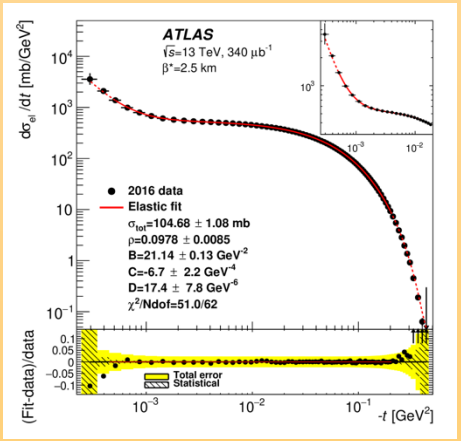
- 200 m from the collision point
- 1–3 mm from the LHC beam
- 2 systems: ALFA and AFP (V & H)

Roman Pot mechanism



Elastic scattering pp → pp

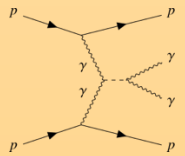
- Sensitivity to fundamental properties of strong interactions in non-perturbative regime
- Results suggests presence of the long-sought Odderon exchange

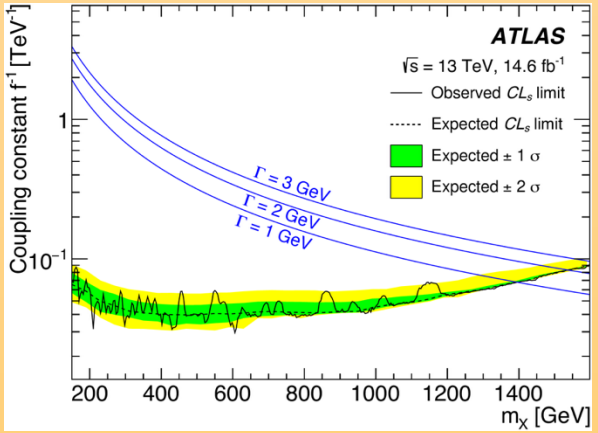


[Eur. Phys. J. C, 83 (2023) 441]

γ-induced axion-like particles (ALPs)

- Probing electroweak sector of SM at very high energies
- Searching for γγ → γγ interactions
- Results: limits on cross section and ALP coupling in a wide energy range



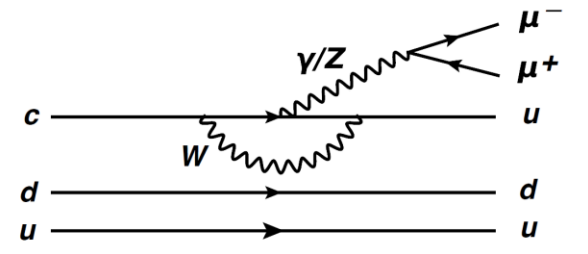


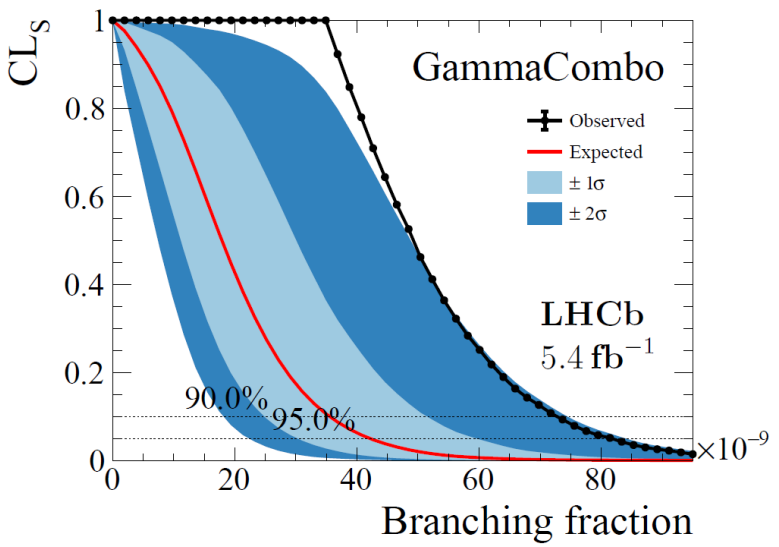
[J. High Energy Phys., 07 (2023) 234]

Search for very rare decay $\Lambda_c^+ \to p\mu^+\mu^-$ at LHCb (Phys. Rev. D 110, 052007)

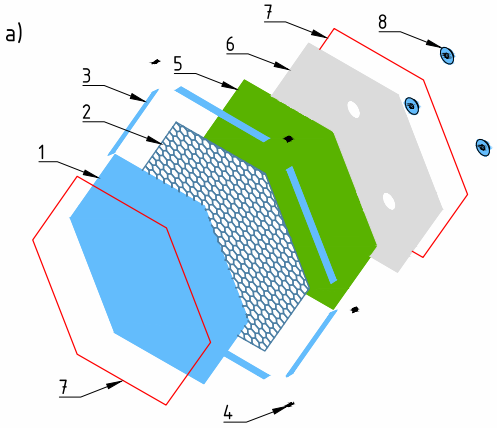
- Searches for rare decays can reveal tiny deviations from SM predictions, providing sensitive probes for new physics that may not be accessible through direct particle production
  - Rare decays like $\Lambda_c^+ \to p\mu^+\mu^-$ allow for model-independent searches
- **Result for Run2 data**
- No evidence for the decay is found
  - ***$\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-) < 7.3 \times 10^{-8}$ at 90% CL***
- Observed upper limit 2σ away from expected (background-only hypothesis)
- Future: observation with Run 3 data?

SM $\mathcal{B}(\Lambda_c^+ \to p\mu^+\mu^-)$ ~10^{-8}

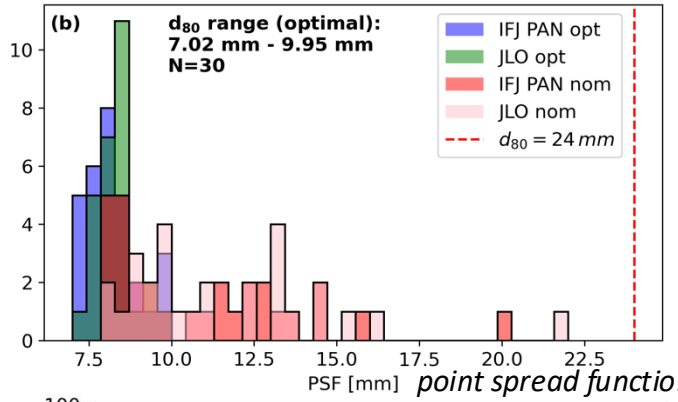




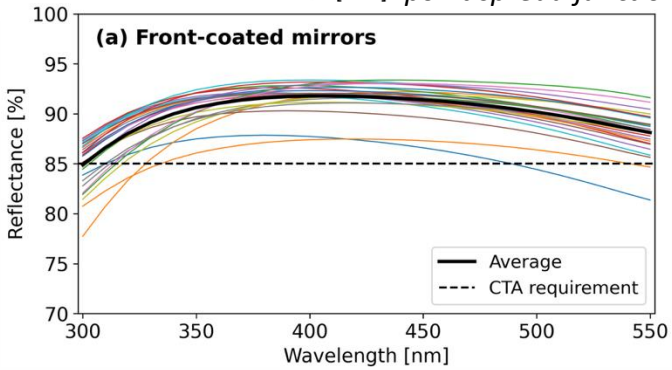
Composite mirrors for Medium-sized Telescopes of CTAO-ERIC



1. Front panel
2. Honeycomb
3. Side walls
4. Corners
5. Rear glass panel
6. White adhesive foil
7. Silicon gasket
8. Mounting pads

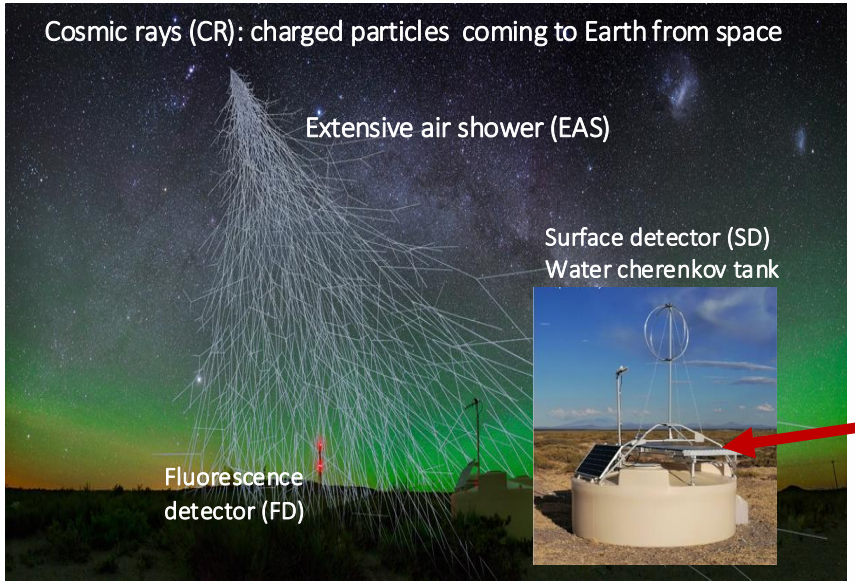


point spread function

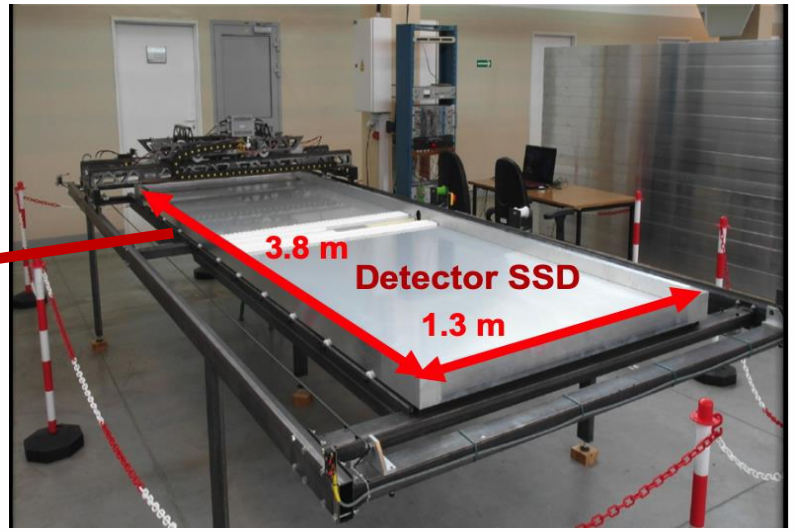


- Manufacturing technologies of glass-aluminium spherical mirrors for MST have been developed at IFJ PAN since 2008
- Final mirror design – a joint Polish-French concept (IFJ PAN, CEA-Saclay, DESY-Zeuthen) mainly based on the Polish solution.
- Technology transferred to industry – production of 30 mirrors in cooperation with Diam Service
- Mass production of 670 mirrors as in-kind contribution to CTAO-ERIC shall start in 2026

Auger Prime – modernization of the Pierre Auger Observatory – precise measurement of the composition of ultra-high-energy cosmic rays (>10^{18} eV)?



Together with engineers from IFJ PAN, 228 (out of 1519) Scintilator Surface Detector (SSD) assembled and tested
JINST 20 (2025) P08002



SSD deployment
2018 - **2021**
(during COVID pandemic)

Upgrade Electronics
2020 - **2023**

Radio Detector:
2023 - **2024**

Modernization of 3000 km^2 array completed in 2024/2025

Operation of the Observatory extended to 2035

Other achievements (construction of equipment):

- Construction of mechanical structures and drive systems of two SST-1M gamma-ray telescopes
  - Astronomical observations in stereoscopic mode at the Ondrejov Observatory since 2022.
- Design and prototyping of front-coated and back-coated mirrors for CTAO-ERIC

- Upgrade I LHCb
  - RICH – design of readout electronics, contribution to testing, construction and commissioning. Simulation of readout electronics response.
  - RTA – Real Time Analysis, development of online reconstruction algorithms for new fully software trigger system
- New ATLAS Inner Tracker for HL-LHC
  - design & development of powering chain for silicon strip sensors and related services
  - Engaging collaboration across INP PAS departments (**DAI** – mechanical design & engineering, **CCB** – proton irradiation)

Other achievements:

- The Particle Physics Summer Student Programme (since 2013)
  - addressed to students of >= 2nd year of physics and similar fields, Poland and abroad
  - introduction to particle physics, opportunity to participate (for the first time) in real scientific research

- Active contribution to the Outreach and Popularization
  - European Researchers' Night, Masterclasses, Festival of Science, classes in schools, popularization movies, "Physics Couch" film series, scientific picnics etc.

The main goals of the Division for the coming years (1)

- ATLAS, LHCb experiments
  - Continuation of maintenance od the detectors and analysis of data taken in Run 3
  - Active involvement in the upgrade of detectors for HL-LHC (design, construction, sw)

- Belle II: Complete research and data taking of 50 ab^{-1} dataset and contribute to the upgrade program beyond 50 ab^{-1}

- Contribution to MUonE (design and construction, simulation and reconstruction software, analysis of data from test runs, and from full run)

- Active participation in new collider and experiment projects, following the European Strategy for Particle Physics Update, in particular, FCC

- Contribution to ePIC@EIC (luminosity system, exclusive production of lepton pairs)

- Continuation of involvement in H.E.S.S., HAWC, and SST-1M gamma-ray observatories. Provide the main M&S items of the Polish in-kind contribution to CTAO-ERIC.

The main goals of the Division for the coming years (2)

- Continuation of research within AugerPrime and the upgraded T2K near detector, with participation in the Hyper-Kamiokande detector's installation.
- Development of P-ONE with the launch of the first detection line in 2025
- Increasing CREDO efforts towards more efficient operability of globally distributed radiation detectors and cosmic ray datasets
- Participate in the Einstein Telescope project, a third-generation gravitational wave detector

Thank you for your attention!