Brazilian Contributions to CMS

From Physics Results to HL-LHC Opportunities

Carsten Hensel, CBPF

Why CMS Matters - In 30 Seconds

A global experiment where Brazil contributes across the full chain.

The Energy Frontier

- CMS is one of the world's two general-purpose detectors at the LHC
- Delivers discoveries from Higgs to precision SM to new-physics searches
- High visibility, high impact: results shape global particle physics

This is where discoveries happen.

Unmatched Scale & Technology

- 40 million collisions per second, petabytes of data
- Advanced detectors, triggers, reconstruction, ML, and HPC
- Global operations with ~4,000 scientists

A living laboratory of frontier physics, computing, and engineering.

Brazil is embedded across CMS

- Physics analyses (Higgs, HI, Dark Matter, Exotics, EWK)
- Detector systems (RPC, GEM, DT electronics, sustainability)
- Computing & software (Tier-2, OpenIPMC, SDN, CMSSW, ML)

Brazil contributes to physics → detector → computing.

CMS: One of the LHC's Two General Purpose Detectors

- CMS = Compact Muon Solenoid
- Wide range of physics program: SM, Higgs, BSM, ...
- ~4000 scientists worldwide
- Brazil participates through 3 institutes
- Brazil is an Associated Member State of CERN since 2024.

CMS Today: Run 3 Physics in Full Swing

- LHC Run-3 data taking ongoing
- Multiple major analyses underway across Higgs, SM, Heavy Ions, BSM
- Detector upgrades already operational for Run-3
- CMS is producing precision measurement and new physics searches in parallel

HL-LHC

The Next Decade of Discovery Potential

- LHC will be upgraded to much higher luminosity (x5-7 more data)
- New detector components, new triggers, new reconstruction paradigms
- Huge data volumes → computing + software challenges for everyone
- This is where strong international + regional cooperation matters.

CMS in Brazil: The 3 Core Institutes

CBPF

National Research Lab

Rio de Janeiro

UNESP

State University

São Paulo

UERJ

State University

Rio de Janeiro

Brazilian groups contribute to physics, detector systems, operations, software and computing within CMS.

Brazilian Impact in CMS - The Three Pillars

Physics

Brazil leads and contributes to Higgs, Heavy Ions, Exotics, EWK, Dark Matter, LLP searches, analysis coordination, and combinations.

Detector

Contributions to HL-LHC: RPC, GEM, DT electronics, gas R&D, sustainability, hardware QA, test stands, and DPG roles.

Computing

SPRACE/UERJ Tier-2, data transfer infrastructure, SDN for science networks, CMSSW contributions, alignment & calibration, physics object performance, data quality, ML inference, and trigger R&D.

Brazil covers the full chain: physics → detector → computing.

Brazilian Contributions to CMS Physics

Brazil is present across the entire physics program: Higgs, HI, EWK, Exotics, and DM.

Higgs & Electroweak Physics

- Photon-photon Higgs production (analyses + tools)
- HH → γγbb and HH → 4b (Run 2/3 involvement)
- Electroweak VV + 2 jets (analysis + internal roles)

Exotics & Dark Matter

- Monopole searches
- Dark matter + jet / + b quarks channels
- Long-lived gluinos
- High-mass resonance searches

Heavy-Ion Physics

- Charm-quark correlations (lead authorship & analysis)
- Azimuthal anisotropy (pp, pPb, PbPb)
- Nonprompt D^0 anisotropy and multiparticle studies

Leadership Roles

- Physics groups coordination
- Analysis editor roles
- Internal note coordination
- Review committee participation
- Brazil contributes to multiple published CMS analyses

About the Highlights

- There is far more Brazilian CMS work than I can cover in 15 minutes.
- The examples shown here are only illustrative highlights, not a ranking or prioritization.
- Every institute in Brazil contributes meaningfully to CMS.

Highlights I – Instrumentation & Computing (SPRACE)

- OpenIPMC: open-source controller adopted by CMS, KIT, and KATRIN
- Brazilian industry production for CERN
- Kytos SDN platform powering international science data links
- SPRACE/UERJ Tier-2: 5,000+/150 cores supporting CMS analyses

100 OpenIPMCs under test at LYNX

Highlights II – Detector & Sustainability (UERJ, CBPF)

- R&D on eco-friendly gas mixtures for RPCs
- Simulations coupling Geant4 & Garfield++
- Brazilian leadership in sustainability within detector R&D
- Part of global CERN effort toward low-emission operation

Highlights III – Muon System & Electronics (CBPF/UERJ)

- HL-LHC Muon upgrade contributions: iRPC, GEM, DT electronics
- New link system: 1.56 ns timing, 10 Gbps data rate
- Local cosmic test stands and module QA in Brazil
- Participation in GEM alignment & MEGA framework


GE2/1 chambers

Highlights IV – Physics Analyses Portfolio

⬡ Search for magnetic Monopoles

◐ Probing charm quark dynamics via multiparticle correlations in PbPb collisions

◐ Observation of correlated azimuthal anisotropy Fourier harmonics in pp and pPb collisions

⬡ Search for axion-like particles via γγ fusion at future e+e- colliders

✵ Measurement of Bose-Einstein Correlations in proton-proton Collisions

⬡ Search for long-lived Gluinos

◐ Studies of charm and beauty hadron long-range correlations in pp and pPb collisions

⬡ Search for dark matter produced with an energetic jet or a hadronically decaying W or Z boson

◐ Higgs Boson Production in photon-photon interactions with proton, light-ion, and heavy-ion beams at current and future colliders

◐ Azimuthal anisotropy of charged hadrons at high transverse momentum in PbPb collision

⬡ Dark sector searches

✵ Bose-Einstein correlations of charged hadrons in proton-proton collisions

⬡ Search for massive resonances decaying into WW, WZ or ZZ bosons in proton-proton collisions

∞ Search for anomalous electroweak production of vector boson pairs in association with two jets in proton-proton collisions

◐ Multiplicity and transverse momentum dependence of two- and four-particle correlations in pPb and PbPb collisions

✵ Overview of high-density QCD studies

✵ Search for new physics in final states with an energetic jet or a hadronically decaying W or Z boson

∞ Search for two Higgs bosons in final states containing two photons and two bottom quarks

⬡ Search for narrow high-mass resonances in proton-proton collisions

⬡ Search for dark matter production in association with bottom quarks and a lepton pair in proton-proton collisions

⚙ Performance of the CMS high-level trigger during LHC Run 2

⬡ Search for a new scalar resonance decaying to a pair of Z bosons in proton-proton collisions

⬡ Search for heavy resonances decaying to two Higgs bosons in final states containing four b quarks

⬡ Search for massive resonances decaying into pairs of boosted bosons

⚙ The Lepton Collider: Future Circular Collider Conceptual Design Report

◐ Measurements of azimuthal anisotropy of nonprompt D^0

◐ Bose-Einstein correlations in pp, pPb, and PbPb collisions

⚙ Future Circular Collider

⬡ Search for exotic resonances decaying into

⚙ The High-Energy Large Hadron Collider: Future

Brazilian Leadership & Responsibilities in CMS

Brazilian groups have consistently held CMS leadership roles from L3 convenerships all the way to L1 management positions, reflecting long-term trust and responsibility within the experiment

Regional Opportunities: Where Latin America Amplifies

People & Training

Joint CLAF–CERN mobility and training programmes including Latin-American Schools in High-Energy Physics, regional fellow/visit grants and workshops to train and retain expertise in the region.

Detector & Industry

Shared test stands and component production across LATAM labs leveraging local industry.

Computing & Software

Distributed computing & SDN networks connecting Tier-2/3 centers and shared ML/CMSSW training.

Brazil in CMS: Impact Today, Opportunities Tomorrow

- **Strong foundation:** Brazilian institutes contribute across physics, detectors, and computing within CMS.
- **Shared expertise:** National coordination and leadership roles reflect maturity and trust in our community.
- **Regional vision:** Together with CLAF and CERN, we can turn local excellence into lasting Latin-American presence at the HL-LHC.
- **Shaping the future:** Brazil participates in the European Strategy for Particle Physics process, bringing regional perspectives into long-term plans for new colliders and detector technologies.

> *Collaboration builds capacity - and capacity builds discovery.*