

Experimento CMS do CERN/LHC

COLABORAÇÃO CMS-BRASIL

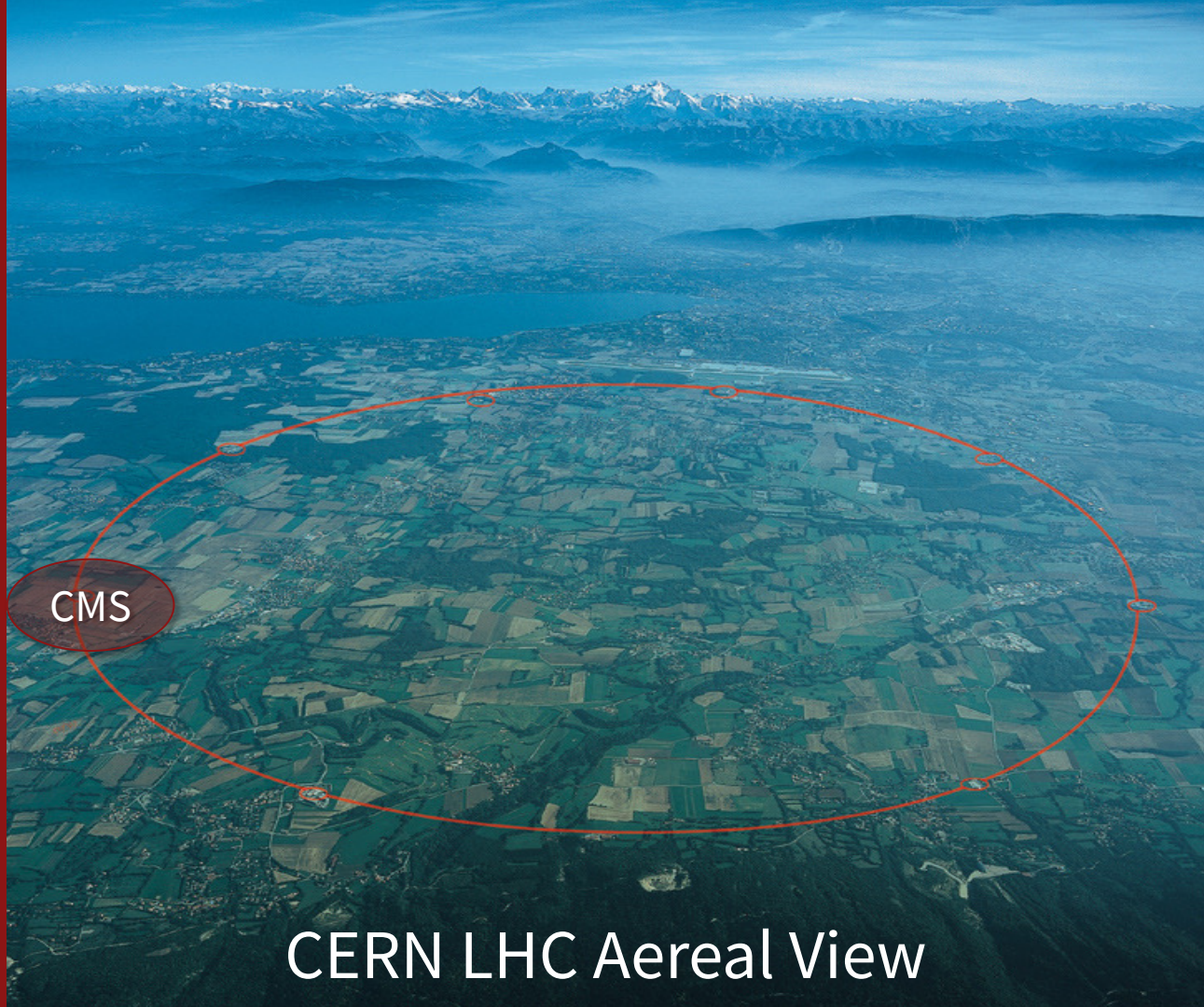
CBPF, UEA, UERJ, UFABC, UFMS, UFRGS, UNESP, UNICAMP



Who We Are

CMS Global

CMS Brasil



CERN LHC Aerial View

The Compact Muon Solenoid Detector

TRIGGER & DATA ACQUISITION

Austria, CERN, Finland, France, Greece, Hungary, Italy, Korea, Poland, Portugal, Switzerland, UK, USA

TRACKER

Austria, Belgium, CERN, Finland, France, Germany, Italy, Japan*, Switzerland, UK, USA

CRYSTAL ECAL

Belarus, CERN, China, Croatia, Cyprus, France, Italy, Japan*, Portugal, Russia, Switzerland, UK, USA

PRESHOWER

Armenia, Belarus, CERN, Greece, India, Russia, Taiwan (PC), Uzbekistan

RETURN YOKE

Barrel: Czech Rep., Estonia, Germany, Greece, Russia
Endcap: Japan*, USA

SUPERCONDUCTING MAGNET

All countries in CMS contribute to Magnet financing in particular:
Finland, France, Italy, Japan*, Korea, Switzerland, USA

HCAL

Barrel: Bulgaria, India, Spain*, USA
Endcap: Belarus, Bulgaria, Russia, Ukraine
HO: India

FEET

Pakistan
China

FORWARD CALORIMETER

Hungary, Iran, Russia, Turkey, USA

MUON CHAMBERS

Barrel: Austria, Bulgaria, CERN, China, Germany, Hungary, Italy, Spain,
Endcap: Belarus, Bulgaria, China, Korea, Pakistan, Russia, USA

Total weight : 12500 T
Overall diameter : 15.0 m
Overall length : 21.5 m
Magnetic field : 4 Tesla

* Only through industrial contracts

The CMS Collaboration

241 Institutes

55 Countries

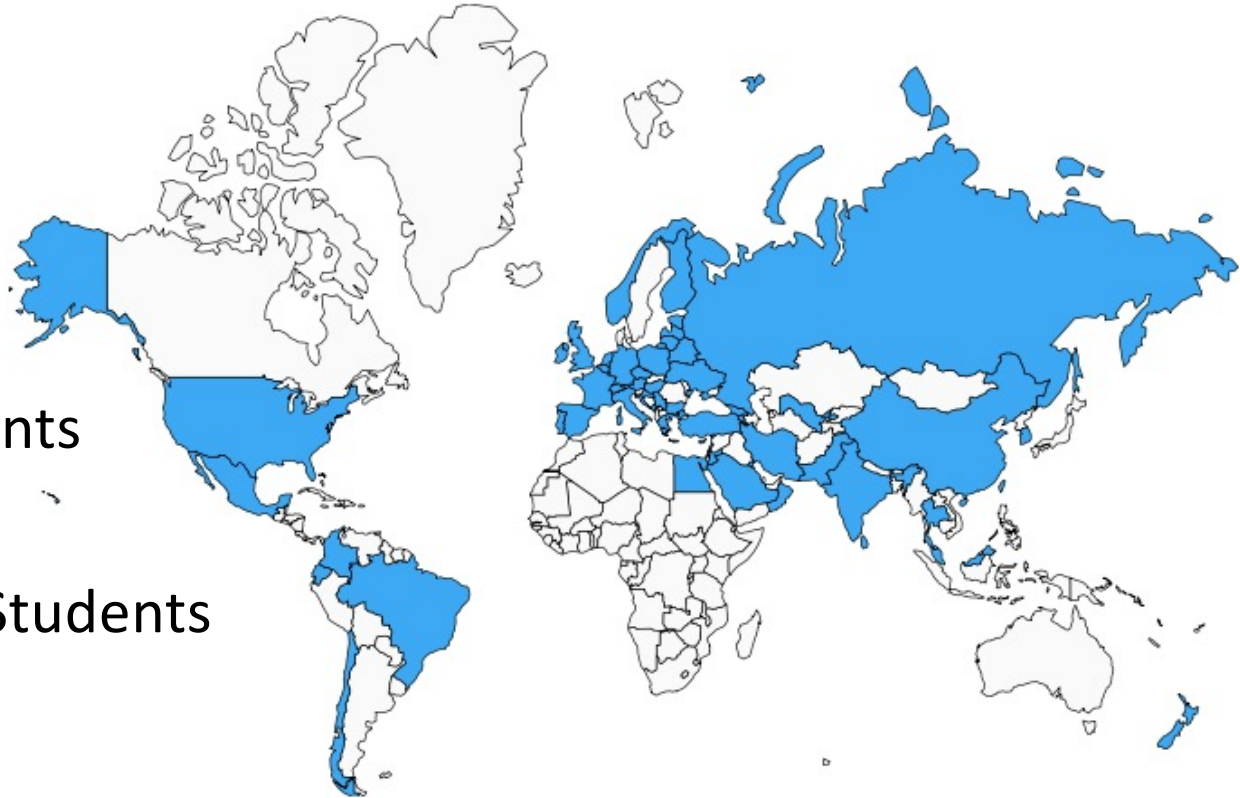
5.754 Members

2.105 Physicists

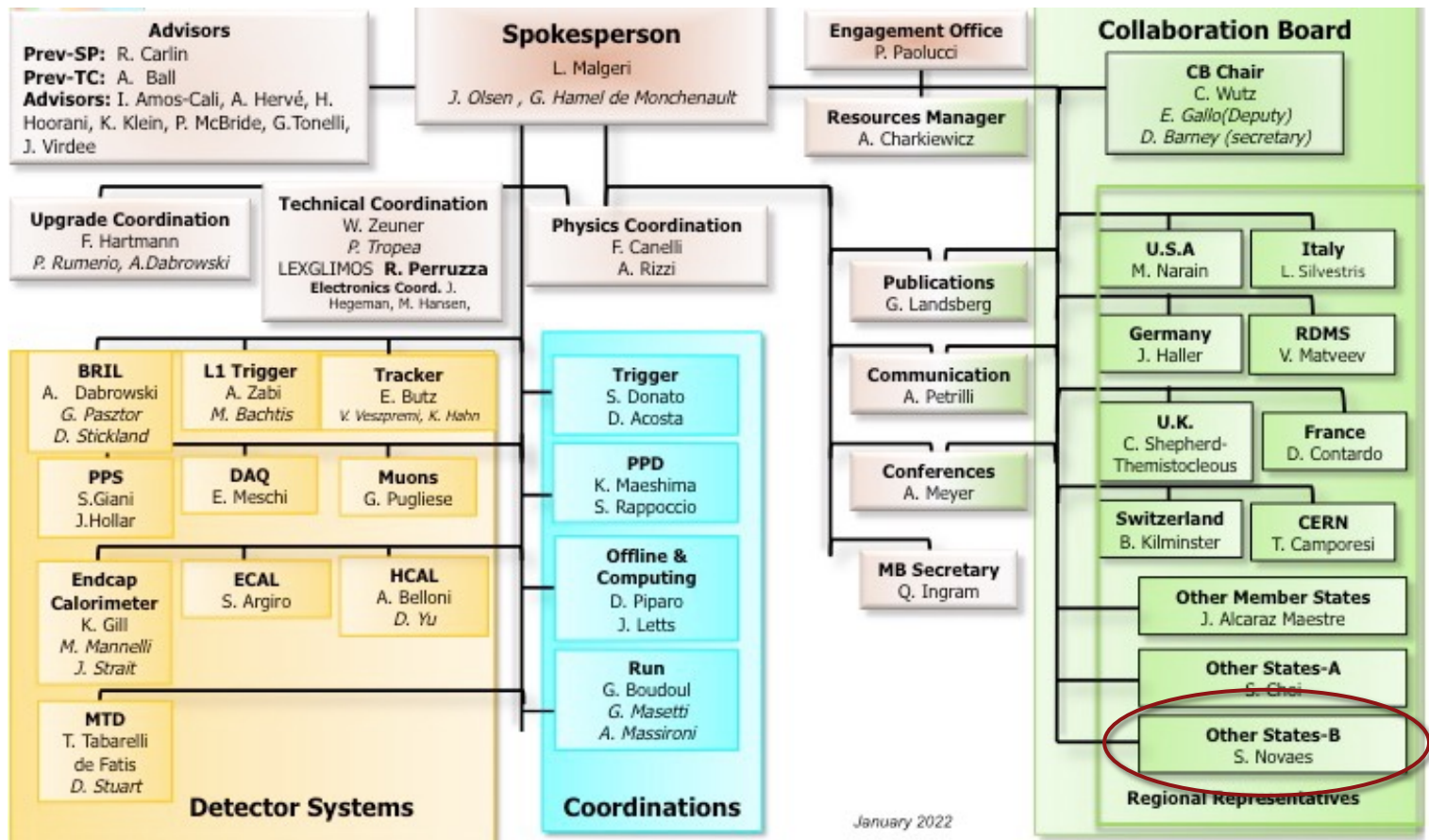
1.101 PhD Students

1.049 Engineers

1.112 Non-PhD Students



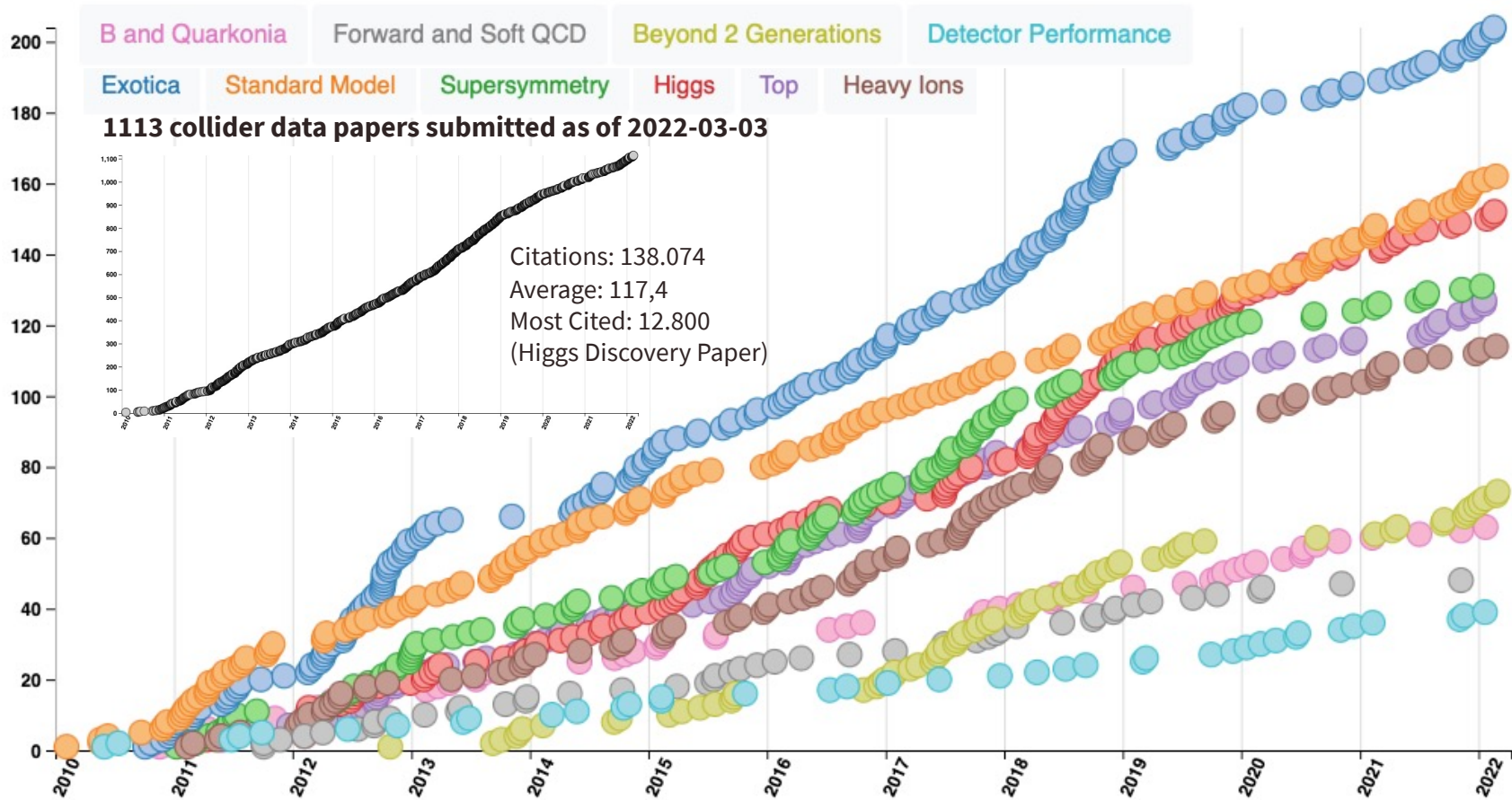
CMS Organization



CMS-BR Responsibilities on Organization

- ❑ OSB Representative on CMS Management Board: Sergio Novaes (UNESP)
- ❑ Physics Performance & Datasets Coordinator: Jordan Martins (UERJ)
- ❑ High-Level Trigger Upgrade Group Convener: Thiago Tomei (UNESP)
- ❑ Tracker Upgrade Steering Group: Eduardo Gregores (UFABC)
- ❑ Proton Physics Object Group Convener: Gustavo Silveira (UFRGS)
- ❑ Aligment, Calibration and Database Convener: Helena Malbouisson (UERJ)
- ❑ Muon Resistive Plate Chamber Subsystem Deputy Manager: Sandro Fonseca (UERJ)
- ❑ Muon Resistive Plate Chamber Subsystem Deputy Run Coord.: Felipe Silva (UERJ)
- ❑ Muon Resistive Plate Chamber Subsystem Deputy Technical Coord.: Kevin Mota (UERJ)
- ❑ CMS Journal Submission Expert Group: Cesar Bernardes (UFRGS)
- ❑ Heavy Ions Publication Committee Board Chair: Sandra Padula (UNESP)
- ❑ Heavy Ions Tracking Working Group Convener: Cesar Bernardes (UFRGS)
- ❑ Heavy Ions High-Level Trigger Group Convener: Dener Lemos (UNESP)
- ❑ Heavy Ions Flow and Correlations Group Convener: Cesar Bernardes (UFRGS)
- ❑ SUSY Monte Carlo Interpretation Group Convener: Carsten Hensel (CBPF)
- ❑ Physics Comparisons and Generators Tuning Co-convener: Arthur Moraes (CBPF)

CMS Production



CMS Maintenance and Operations (M&O)

M&O-A:

- Maintain and operate the already constructed detectors
- Mantain and operate Collaboration-wide facilities

M&O-B:

- Subsystems maintenance and operations expenses

Total	2022	2023	2024	2025	2026
M&O A (kCHF)	15.066	15.318	15.075	14.862	14.742
M&O B (kCHF)	6.089	6.678	7.000	7.380	7.934
Total (kCHF)	21.155	21.996	22.075	22.242	22.676

CMS Brazil Institutions

Brazilian CMS Institutes: 73 members, 29 authors

- ❑ RIO-UERJ CMS Team: 36 members, 17 authors
 - Institutions: UERJ, Unicamp, UFRGS, UEA, UFMS
 - CMS Team Leader: Luiz Mundim
 - CMS Deputy Team Leader: Wagner Carvalho
- ❑ RIO-CBPF CMS Team: 10 members, 5 authors
 - CMS Team Leader: Gilvan Alves
 - CMS Deputy Team Leader: Maria Elena Pol
- ❑ SAO_PAULO CMS Team: 27 members, 7 authors
 - Institutions: Unesp, UFABC, UFRGS
 - CMS Team Leader: Sergio Novaes
 - CMS Deputy Team Leaders: Eduardo Gregores and Sandra Padula

CMS Brazil People (76)

PhD Physicists (32)

- ❑ **CBPF:** Arthur Moraes, Carsten Hensel, Eduardo Coelho, Gilvan Alves, Maria Elena Pol, Patrícia Rebelo Teles
- ❑ **UEA:** Felipe Torres de Araujo
- ❑ **UERJ:** Alberto Santoro, Andre Sznajder, Antonio Vilela Pereira, Clemencia Mora Herrera, Dilson Damião, Eliza da Costa, Helena Malbouisson, Helio Nogima, Luiz Mundim, Mauricio Thiel, Sandro Fonseca de Souza, Sheila Mara do Amaral, Wagner Carvalho, Walter Luiz Aldá Jr.
- ❑ **UFABC:** Eduardo Gregores, Pedro Mercadante, Andre Lessa
- ❑ **UFMS:** Jordan Martins
- ❑ **UFRGS:** Cesar Bernardes, Gustavo Gil da Silveira
- ❑ **UNESP:** Luigi Calligaris, Sandra Padula, Sérgio Novaes, Thiago Tomei
- ❑ **UNICAMP:** Jose Chinellato

CMS Brazil People

PhD Students (15)

- ❑ **CBPF:** Venício Gonçalves, Marcos Sales, Mariana Soeiro, Thales Menezes de Oliveira
- ❑ **UERJ:** Fernando Assunção, Miguel Alves Gallo Pereira, Mapse Barroso Ferreira Filho, Kevin Mota Amarilo, Vitor dos Santos Sousa, Matheus Macedo, João Pinheiro
- ❑ **UNESP:** Breno Orzari, Isabela Silvério, Julia Leite Carvalho, Bruno Lopes da Costa

Non-Doctoral Students (13)

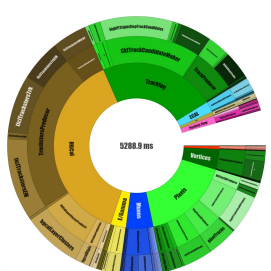
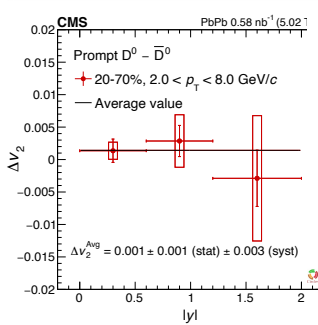
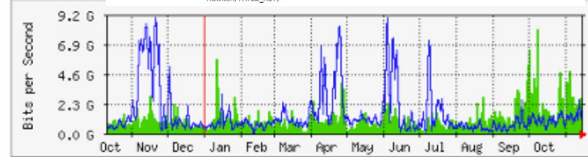
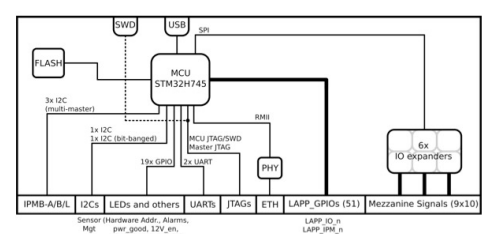
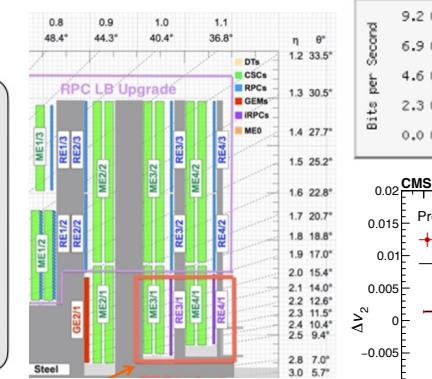
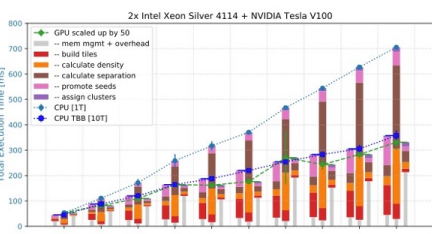
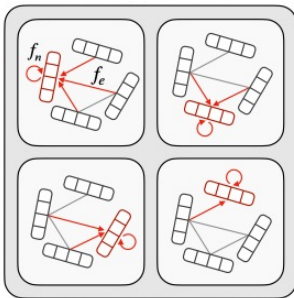
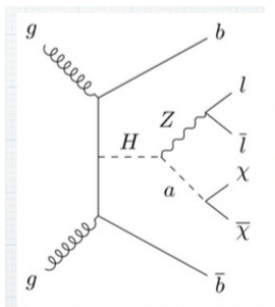
- ❑ **CBPF:** Gabriel Correa
- ❑ **UERJ:** Raphael de Souza, Matheus Reis, Gabriel Campos, Marcelle do Nascimento, Allan Jales, Silas Jesus, Eduardo Brock, Rodrigo Campello
- ❑ **UFABC:** Felipe de Aguiar, Cauê de Sousa
- ❑ **UNESP:** Stephanie Cavalcanti, Luisa Ferreira

Engineers and Technicians (16)

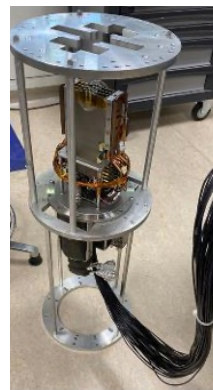
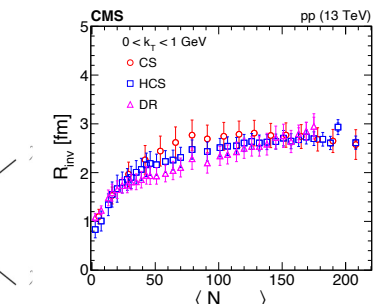
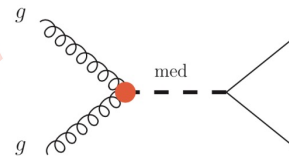
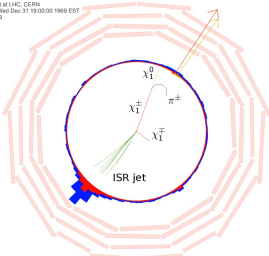
- ❑ **CBPF:** Fabio da Silva
- ❑ **UERJ:** Eduardo Revoredo, Felipe dos Santos, Breno Ferreira, Ana Beatriz Franco, Renan Bernardo Valadão
- ❑ **UNESP:** Lucas Ramalho, Andre Cascadan, Bruno Augusto de Sousa, Antonio Vitor Bassi, Rogerio Luiz Iope, Jadir da Silva, Marcio Antonio Costa, Angelo Santos, Raphael Cobe, Jefferson Coelho

What We Do

Physics Analyses
Instrumentation
Data Processing
HEP Outreach



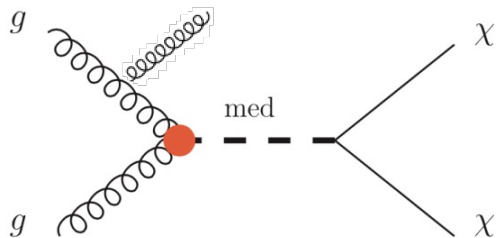
CMS Experiments at LHC, CERN
Data recorded: Wed Dec 31 19:00:00 1999 EST
RunNumber: 1120
LumiSection: 20




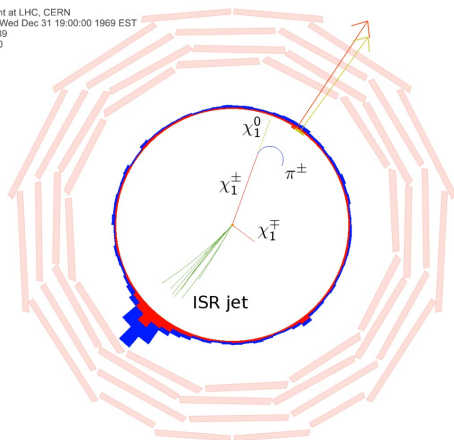
Physics Analyses

EXOTICA
SUPERSYMMETRY
HEAVY IONS
B PHYSICS
FORWARD PHYSICS
MACHINE LEARNING
SIMULATION DEVELOPMENTS

Dark Matter search at the LHC



 CMS Experiment at LHC, CERN
Data recorded: Wed Dec 31 19:00:00 1969 EST
Run/Event: 1 / 39
Lumi section: 20



Model independent searches

- Contact Interaction
- Simplified Models

Basic Signal

- Jet + Missing E_T
 - PRD 97 092005 (2018)

Challenging Signal

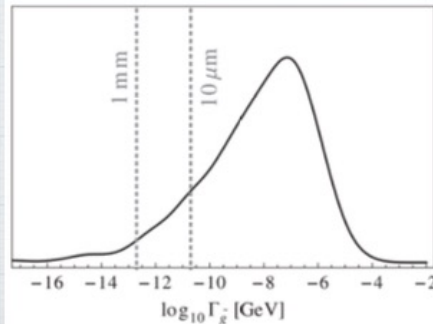
- Models with long-lived mediators
 - Disappearing Tracks signal
 - Reconstruction of a short track

Supersymmetry Searches

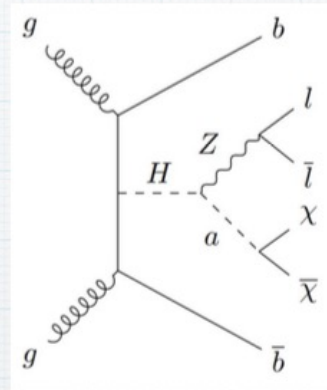
search for long-lived gluinos

- * gluino LSP
- * precision gauge unification leads to compressed mass hierarchy
- * resulting in non-zero gluino lifetime
- * **signature:** hard ISR photon plus very low energetic jets (R-hadron) with secondary vertices
- * collaboration of **CBPF** and **VERJ**

$$\Gamma(\tilde{g} \rightarrow q\bar{q} + \tilde{\chi}_1) \propto \text{gaugino fraction} \times \frac{(m_{\tilde{g}} - m_{\tilde{\chi}_1})^5}{m_{\tilde{q}}^4}$$



search for Dark Matter in association with leptons and b-quarks



- * **signature:** boosted Z and low energetic b quarks
- * novel DM interpretation to the gamma ray excess at the Galactic Center
- * ZHDMa model can deliver consistent DM relic density
- * final state not been considered before
- * collaboration of **CBPF**, **VERJ** and **DESY**

EWkino combination

- * Run1 Legacy result
- * as part of responsibility of the SUSY MC&Interpretation Conveners
- * **CAPI line: SUS-21-008**

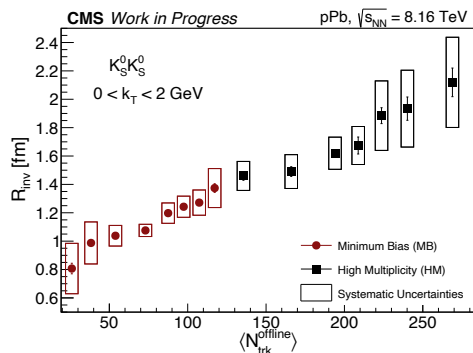
Lepton	compressed SUS-18-004 (SOS) "23 soft" Two or three e (mu), Opposite sign, same flavour pair 53.5 lepton pT > 30 GeV (3)	SUS-19-012 (ML) ≥ 3l Three or four leptons (up to 2 hadronically decaying taus) or two same sign light leptons Leading lepton pT > 30 GeV (3)	SUS-20-001 (zedge) "2l on Z/non-resonant" Two e(mu) Opposite sign, same flavour pair Either on shell or off shell Z
	Lepton-hadronic	SUS-20-003 "1l 2b" - WH One e(mu), H-bb	SUS-20-004 "4b" - HH No leptons Two Higgs bosons, H-bb
			SUS-21-002 "Hadr. WX" Fully hadronic final state; at least 2 jets (AK8) and 2 b jets (AK4) NEW

Heavy Ion Physics

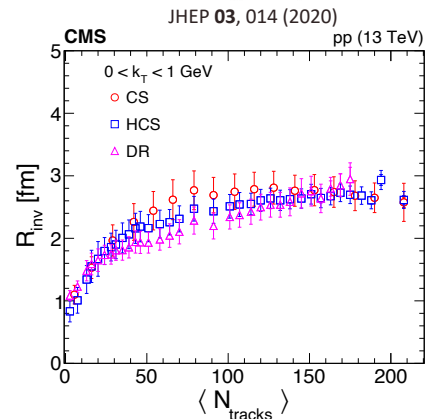
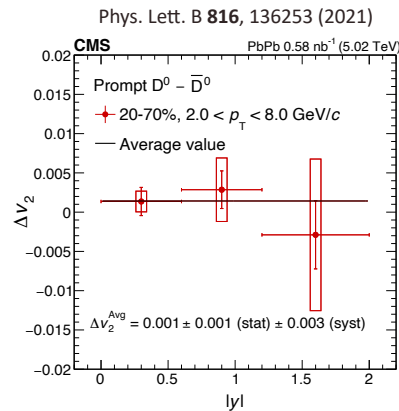
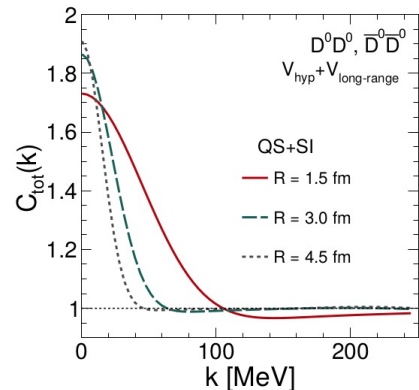
SPRACE group contributes to

- Data analysis probing high-density matter in pp, pPb, and PbPb collisions using the CMS experiment at the LHC
 - Femtosopic correlations
 - Azimuthal correlations
- Data-taking activities in the CMS collaboration
- Phenomenology on femtosopic correlations

Dener's Ph.D. Thesis
<https://repositorio.unesp.br/handle/11449/217847>



Isabela's M. Sc. Dissertation
<https://repositorio.unesp.br/handle/11449/215132>



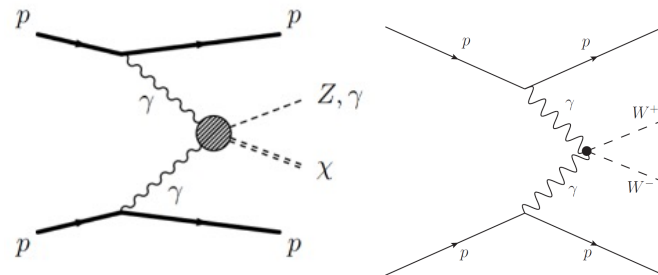
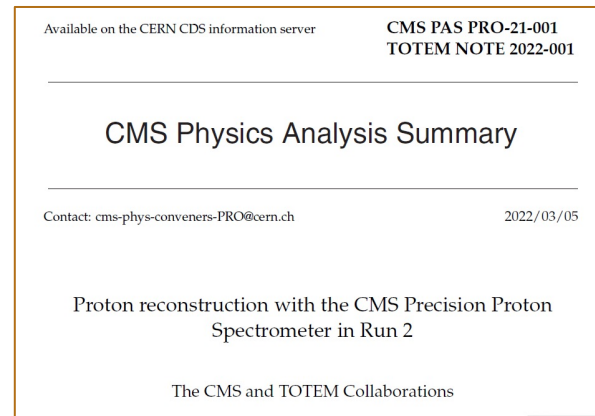
PPS: recent performance & physics results

□ Performance of proton reconstruction from Run 2 :

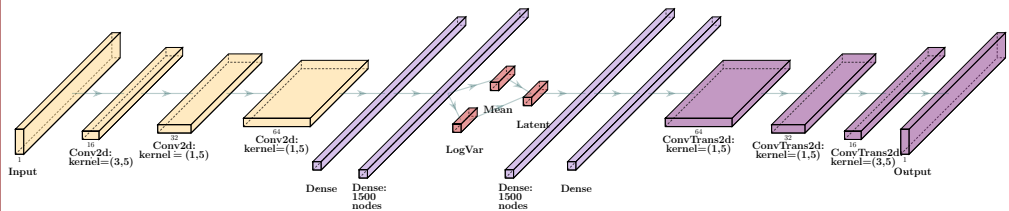
- 57-page review of reconstruction & performance from Run 2 (CMS-PAS-PRO-21-001, TOTEM-NOTE-2022-001). Reference for analyses using PPS protons.
- Highlights successful operation of the detectors, alignment, calibrations & reconstruction chain, simulation & modelling, efficiency measurement and validation.

□ Recent results:

- Search for exclusive $\gamma\gamma \rightarrow WW$ and $\gamma\gamma \rightarrow ZZ$ production in final states with jets and forward protons (CMS-PAS-SMP-21-014, TOTEM-NOTE-2022-004)
- A search for new physics in central exclusive production using the missing mass technique with the CMS-TOTEM precision proton spectrometer (CMS-PAS-EXO-19-009, TOTEM-NOTE-2022-003).



Event Generation with Machine Learning



Event generation

- Accuracy vs. speed continuum
- Sparse datasets

Generative models

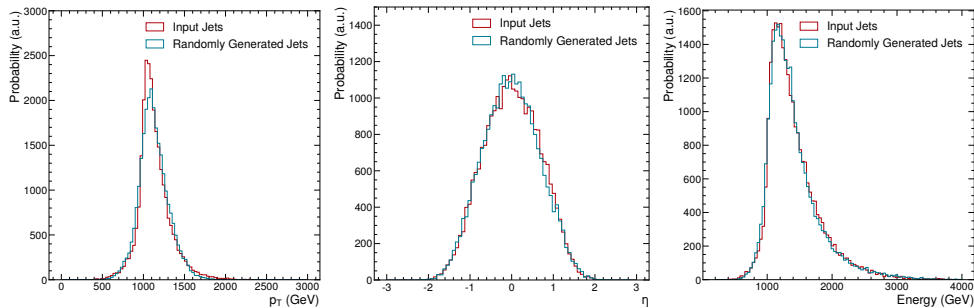
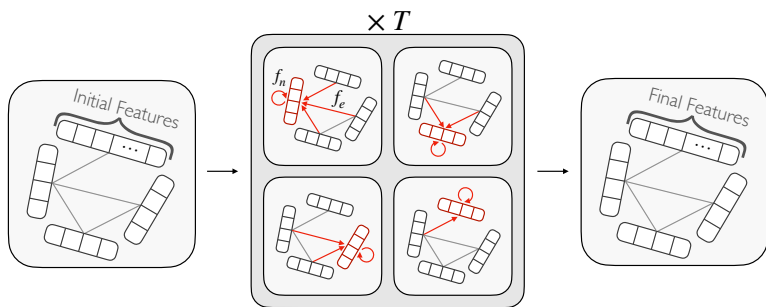
- Variational AutoEncoders
 - Augmented with flows
- Adversarial Networks

Architectures

- Convolutional, graph, message-passing

Some of our results

- <https://arxiv.org/abs/2109.15197>
- <https://arxiv.org/abs/2012.00173>
- <https://arxiv.org/abs/2106.11535>



Monte Carlo Tuning

Physics Comparisons and Generators Tuning Group

- ❑ Sub-grupo do Generators Physics Group
- ❑ Extensão do tuning CPx para descrição de observáveis que dependem do modelamento do sistema de “parton-shower”.
- ❑ Análise do tuning à luz das medidas
 - Minimum bias & underlying events
 - Runs dedicados de “low-pileup”.
- ❑ Ajustes da componente de “multiparton interactions”.
- ❑ Atualização dos tunnings para novos conjuntos de PDFs.

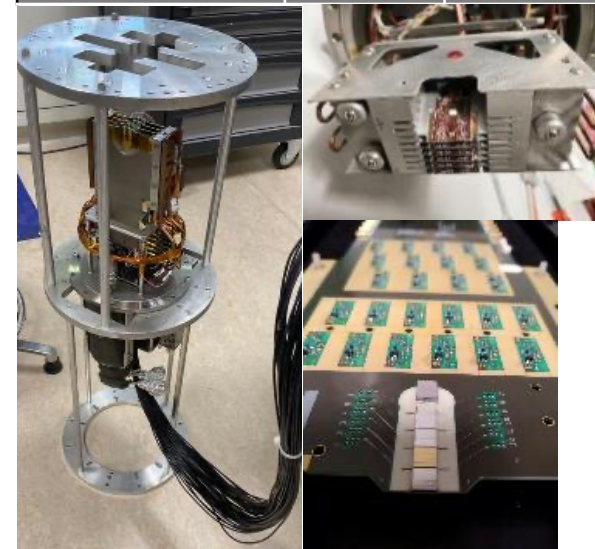
Instrumentation and Online Computing

PRECISION PROTON SPECTROMETER
MUON RESISTIVE PLATE CHAMBERS
HIGH-LEVEL TRIGGER FOR CMS PHASE-2
OPENIPMC FOR PHASE-2 TRACKER UPGRADE

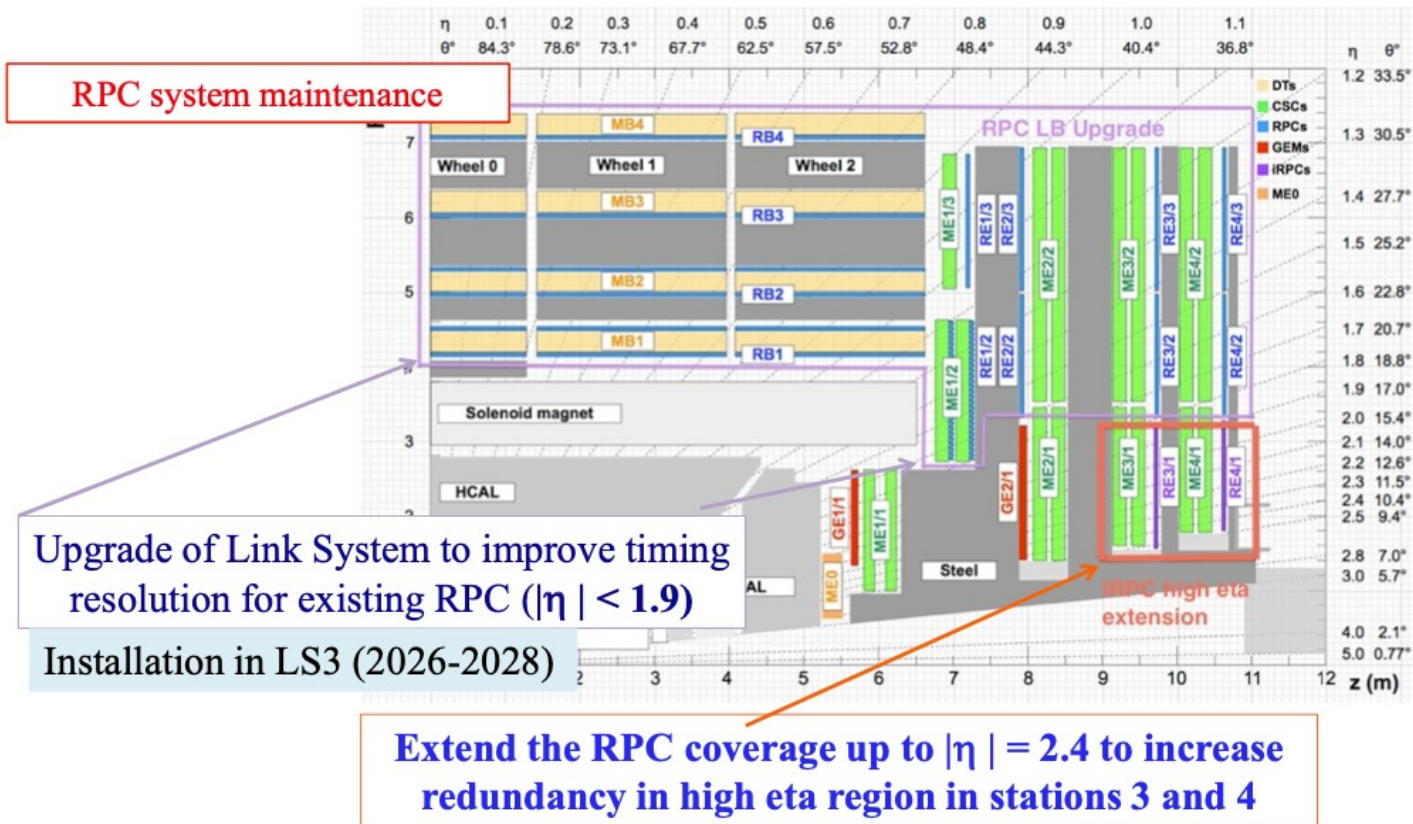
PPS: novel technologies to measure protons at CMS

- ❑ **PPS @ Run 3: Revised pixel and diamond detector packages.**
 - Major updates: i) Pixel internal movement system for radiation damage mitigation. ii) Two timing stations (at least doubled number of detector layers).
- ❑ **PPS timing detectors:**
 - 4 double artificial diamonds (scCVD) planes per RP. 2 Roman pot stations per sector. New pre-amplification stage (controlled remotely) & RF shielding. Read-out: HPTDC mezzanines and NINO (discriminator ASIC). Some sensors monitored with SAMPIC mezzanine for timing calibrations.
 - Expected resolution: $\sim 70\text{ps}/\text{plane}$, $\sim 25\text{ps}/\text{sector}$ (8 DD planes).
- ❑ **PPS 3D pixel detectors:**
 - 2 tracking RPs per arm, 6 planes per package. New 3D pixel detectors produced at FBK in single-sided technology and bump-bonded to the CMS pixel layer-1 PROC600 read-out and token bit manager (TBM10). uTCA backend.
 - New vertical movement system: 10 positions spaced by $500\mu\text{m}$.
 - Minimal efficiency loss by displacing periodically beam-spot induced radiation damage.
- ❑ **DAQ and operations:**
 - Development of timing detector control & configuration software, maintenance of pixel software, detector FSMs, remote firmware uploading software, setup & operation of PPS backend system (DAQ), monitoring of detector conditions & LHC conditions uploader.
- ❑ **Software:**
 - Development, integration and validation of the full simulation.
 - Implementation & maintenance of conditions (calibration, alignment, etc) in the offline database. Migration to new DD4Hep geometry standard and improvement of PPS geometry description.

Run3		
	Planes per RP	Number of RPs
3D Pixels	6	2 & 2
Double Diamond	4	2 & 2



Muon RPC System Upgrade & Maintenance



Installation in YETS 2023-24 & YETS 2025-26

High-Level Trigger Phase-2 Upgrade

HL-LHC conditions

- 75 Hz/nb, $\langle \text{PU} \rangle = 200$

DAQ requirements

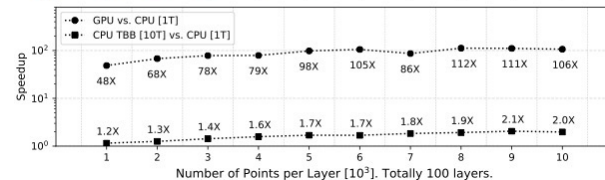
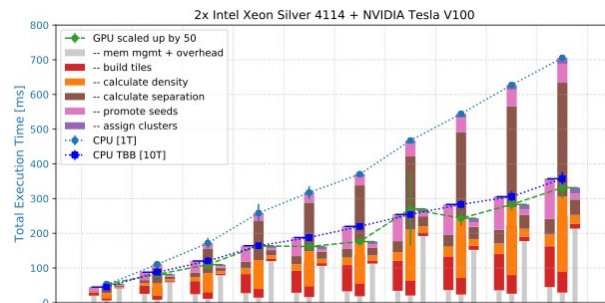
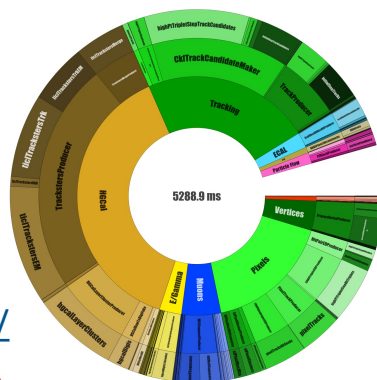
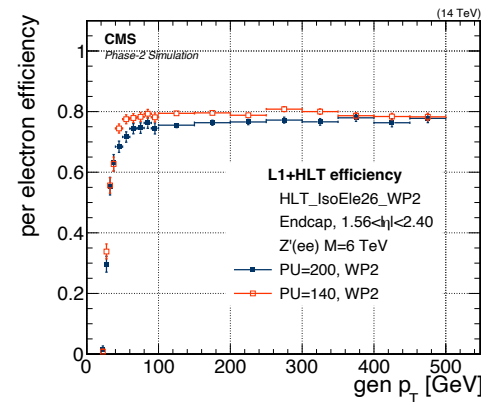
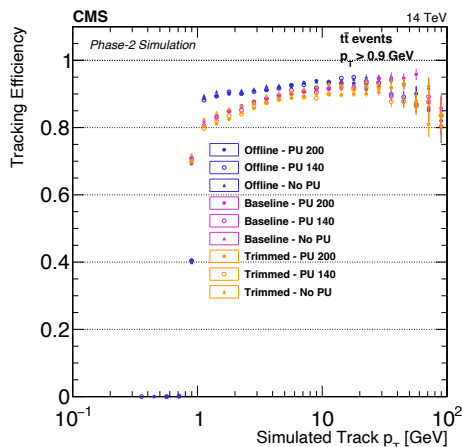
- Input: 750 kHz, 50 Tb/s
- Output: 7.5 kHz, 50 GB/s

HLT requirements

- Same performance as Phase-1
- Budget: 16 MCHF

TDR results

- High-efficiency physics objects
- Simplified menu (50% target rate)
- Roadmap for timing reduction
- Heterogeneous architectures (GPU)
- <https://cds.cern.ch/record/2759072/>



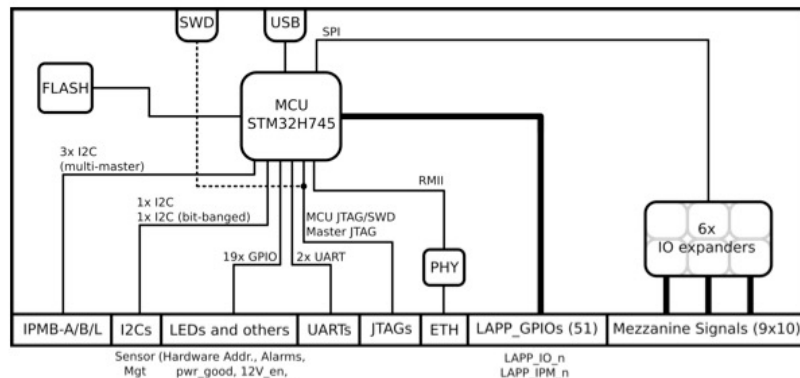
OpenIPMC for Tracker Upgrade Backend

OpenIPMC Software:

- ❑ Open-source portable C code for embedded systems
- ❑ Based on FreeRTOS
- ❑ Executes IPMC functions for PICMG ATCA boards.

OpenIPMC-HW

- ❑ Open-source hardware
- ❑ JEDEC MO-244 miniDIMM form factor
- ❑ Fully pin-compatible with the current solution used in most of the ATCA boards designed for LHC experiments
- ❑ A firmware framework is being developed to adapt it for different ATCA boards
- ❑ Tested on the 3 boards planned to be used by the Tracker: Pulsar2b, Serenity and Apollo
- ❑ Small prototyping lots already assembled in Brazil, Germany and US (Boston)

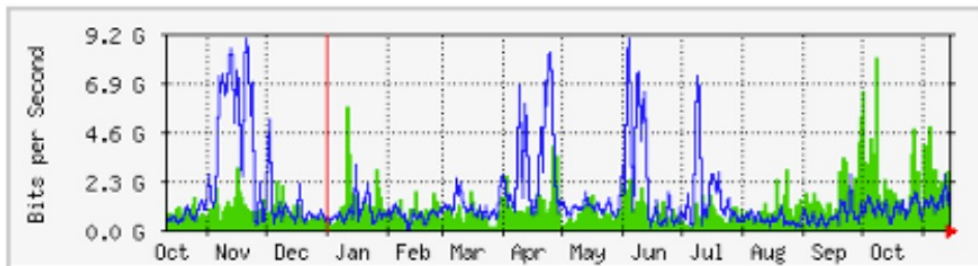


Data Transmission, Processing and Storage

SPRACE TIER-2 OPERATION
UERJ TIER-2 OPERATION
BELLA LINK DEMONSTRATION

BR-SP-SPRACE

- ❑ Tier-2 site of WLCG
- ❑ Highly available and reliable
- ❑ High throughput data transfer
- ❑ Over 7 million hours of data processing for CMS
- ❑ Operational Resources:
 - ❑ Worker Nodes: 128
 - ❑ Processing Cores: 1.792 (2.688)
 - ❑ Processing Power: 29,7 kHS06
 - ❑ Storage: 2,1 PB
 - ❑ Connectivity: 10 → 100 Gbps



Core Hours By VO



	total
cms	7 Mil
osg	883 K
icecube	64 K
glow	64 K
jlab	23 K
/jlab/LocalGroup=enp	10 K
hcc	6 K
sbgrid	116

T2_BR_UERJ



- ❑ Unidade federada da T2-LATINAMERICA do WLCG
- ❑ 220 núcleos de processamento;
- ❑ 270 TB para armazenamento de dados;
- ❑ Servidores adicionais dedicados a disponibilização dos serviços de *Grid*;
- ❑ Conexão de 5Gbps com a rede externa com o apoio da Redecomep (Rede metropolitana do RJ) e RNP;
- ❑ Ambiente multiusuário para o atendimento a outros projetos da universidade que necessitam de computação distribuída;

Ano	Núcleos	Armazenamento
2022	220	270 TB
2023 (estimativa)	300	1 PB

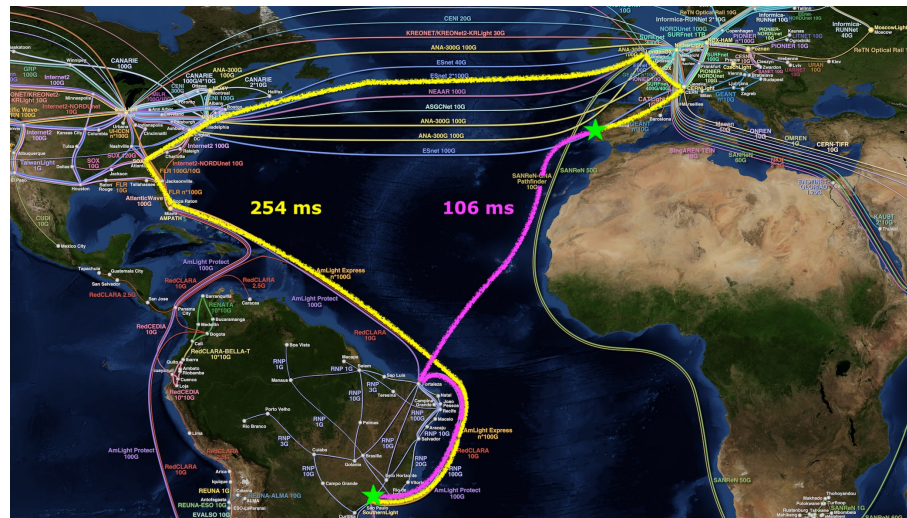
Bella Link Demonstration

Production link: 10Gbps

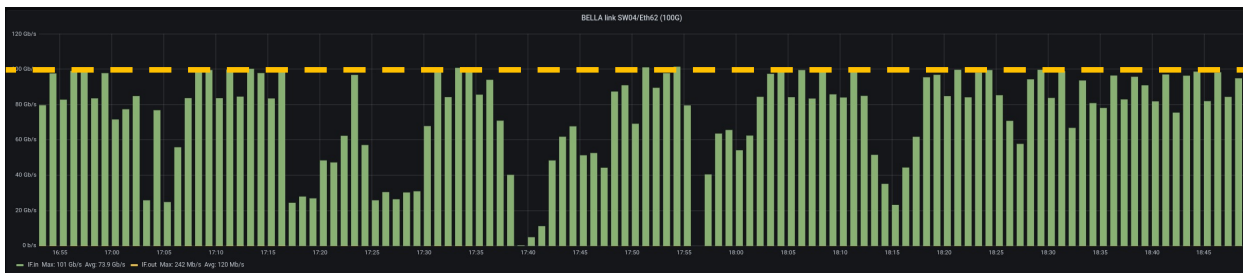
- Bandwidth from/to SPRACE ~ 6 Gbps
- Using ~ 800 iperf streams

EllaLink: 100Gbps

- Bandwidth from/to SPRACE ~ 100 Gbps
- Using ~ 480 iperf streams



100Gb/s



Using 2x INCD servers and 2x **SPRACE** servers (with 100GbE interfaces)

Outreach

INTERNATIONAL MASTERCLASS
SPACE GAME
“THE PARTICLE” APP

Outreach

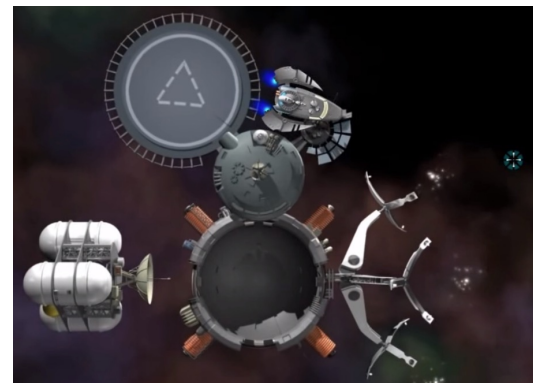
IPPOG International MasterClass

- Uninterrupted from 2008 to 2021
- High School Students: 2.530
- High School Teachers: 439



SPRACE Game

- A particle physics gaming adventure



The Particle

- Portuguese version of the educational application “The Particles”
- Originally developed by Frank Close
- Available for Android users for free



What We Need

Operation (M&O)

Construction

Data Processing

Presence on Site

- ❑ Maintenance Operation
 - General Experiment Operation (M&O-A)
 - Subdetectors Maintenance (M&O-B)
- ❑ Construction
 - Phase-II CMS Upgrade
- ❑ Presence on Site
 - Air Tickets
 - Per-Diem
- ❑ Data Processing
 - SPRACE Cluster
 - UERJ Cluster

Maintenance and Operation

M&O budget divided by all CMS Institutes, in an equity base:

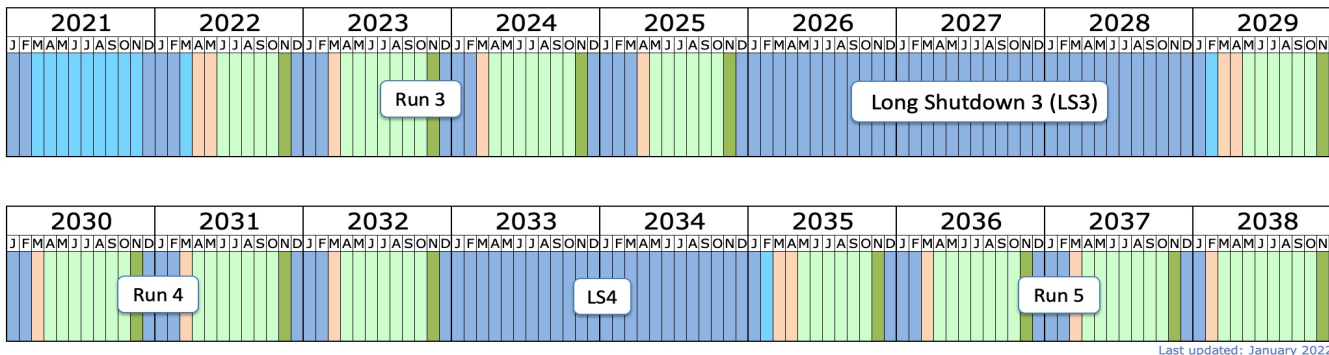
- ❑ Proportional to the number of authors in the CMS Institute (except PhD students)
- ❑ RIO-CBPF: 5 scientists with M&O obligation
- ❑ RIO-UERJ: 17 scientists with M&O obligation
- ❑ SAO_PAULO: 7 scientists with M&O obligation
- ❑ Total CMS-BR: 29 scientists with M&O obligation

CMS-BR fair-share:

- ❑ 29 out of 1.444 qualified authors
- ❑ 1,93% of the total M&O costs

in kCHF	2023	2024	2025	2026	Total
Total (kCHF)	21.996	22.075	22.242	22.676	88.989
BR Fair Share (kCHF)	425	426	429	438	1.717

Phase-2 Upgrade



- ❑ High Luminosity LHC will run from 2029 onwards
- ❑ New detector will be assembled during LS3
- ❑ CMS Upgrade Total Costs: 254.365 kCHF
 - ❑ CMS-BR fair-share (29 authors): **5.344 kCHF**
- ❑ SAO_PAULO is committed to the Tracker Phase-2 Upgrade
 - ❑ SAO_PAULO fair-share (7 authors): **1.290 kCHF**

Data Processing

CMS-BR Tier-2 WLCG sites: BR-SP-SPRACE and T2_BR_UERJ

- ❑ Processing Power: about 33 kHS06
- ❑ Storage: about 2,4 PB

For Typical USCMS T2 Site:

- ❑ Processing Power: 115 kHS06
- ❑ Storage: 3,5 PB

CMS-BR Computing Upgrades and Replacements to remain competitive

in kCHF	2023	2024	2025	2026	Total
Processing	296	311	326	343	1.276
Storage	185	194	204	214	797
Total	481	505	530	557	2.073

On-Site Presence

For each CMS-BR author:

- ❑ 1 month of physical presence at CERN per year
- ❑ 1 travel ticket and 1 month of per diem

For each CMS-BR Team:

- ❑ 6 months of physical presence at CERN for other members
- ❑ 2 travel tickets and 6 months of per diem

in kCHF	Unit (kCHF)	29 Authors	3 Institutes	Total
Tickets	1,20	34,80	7,20	42,00
PerDiem	3,00	87,00	54,00	141,00
Total		121,80	61,20	183,00

CMS-BR Budget Needs

- ❑ We are part of CMS Collaboration for the last 18 years
- ❑ We have always been a productive CMS group
- ❑ To keep our participation on the same level as ever, we need:

in kCHF	2023	2024	2025	2026	Total
M&O	425	426	429	438	1.717
On Site Presence	183	192	202	212	789
Data Processing	481	505	530	557	2.073
Upgrade	1.336	1.336	1.336	1.336	5.344
Total	2.425	2.459	2.497	2.542	9.923

End of Presentation