COMCHA: Computing Challenges for the HL-LHC (and beyond)

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Motivations: New challenges

- The next generation of experiments will bring new computational challenges:
  - Huge amount of data, unseen instantaneous luminosities, ultra-large number of channels.

A 130 vertex event at CMS from an special run…
… expecting about 200 at the HL-LHC
Motivations: New solutions

- New computational technologies are quick and successfully emerging in the last years.
- Research is evolving to use them to face their requirements for the upcoming projects.
- Physics communities are not an exception and are exploring these disruptive technologies.

New hardware Solutions

- New hardware Solutions
- New algorithms (ML)
  - Machine Learning
  - Computer Vision
- Multi-core processing

New reconstruction algorithms

HPC

Multi-core processing

New algorithms (ML)
COMCHA objectives

- **COMCHA emerges to help groups to face the 21st century computational challenges.**
- **Solutions to problems are common in different fields:** interdisciplinary vocation of COMCHA
  - Particle, astroparticle, cosmology, nuclear, medical, applied physics, theory, ...
- **Several key activities to successfully accomplish this goal:**
  1) Collaboration among **Spanish groups** of different projects and areas.
  2) Learn from experienced Spanish people/groups (computing centers).
  3) Clustering/Coordination with other (inter-) national networks and initiatives:
     - HSF, LCG, LHC network, Flavor network, Renata, RES, etc
  4) Optimize usage of national/regional/local infrastructures (GRID, HPC, GPU cluster, etc).
  5) Show successful cases in problem-solving, technology transfer, collaboration with industry.
  6) Discussion and interdisciplinary forum where students can learn and show their work
     - Often not sufficiently appreciated by the physics community.
COMCHA coordinates

- COMCHA started about 1.5 year ago and has been presented several times since then
  - Winter meeting 2019 (XLVII International Meeting of Fundamental Physics)
  - LHC Network Workshop 2019
  - LHC Network Workshop 2018

- Regular meetings (~1 / month) via Vidyo.
- First face-to-face meeting during the 2018 CPAN days in Salamanca.
- COMCHA twiki
  - https://twiki.ific.uv.es/twiki/bin/view/Main/ComCha
- First COMCHA school took place on October 2019 (see later)
- If interested subscribe to the mailing list here:
  - http://pegaso.ific.uv.es/mailman/listinfo/comcha
COMCHA & GRID computing

- **COMCHA does not overlap with GRID** activities, even if we are in good contact.

- Focusing more on “intensive” or “analysis-like” computing challenges such as:
  - Trigger systems, signal reconstruction, data analysis...
  - Making use of novel techniques in the market
  - Improved reconstruction algorithms including ML, Deep Learning, etc.
  - New hardware platforms: GPUS, FPGAs, parallelization of new processors.
Activity example: DNN signal reconstruction

- Deep NN for real-time calorimeter signal reconstruction at the HL-LHC.
- HL-LHC pileup degrades the pulse quality, LHC algos performance deteriorates.
- 128 FPGAs to process the full ATLAS Tile Calorimeter. \[ \text{JINST 14 (2019) no.09, P09002} \]
- Each FPGA processes 96 different signals with 40 MHz rate.

![Graphs of signal reconstruction](image)
Activity example: Fast LLP Tracking algorithm

- Improved algorithms for long lived particles (to be included in the High Level Trigger)
Activity example: Machine Learning for Tracking

- Searches for long lived particles using ML techniques.
- Track reconstruction using **Long Short-Term Memory (LSTM)** NN for displaced tracks.

- Following developments at the Kaggle Machine Learning Tracking Challenge.
- HEP pattern recognition using HL-LHC simulated data.

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**TrackML Particle Tracking Challenge**
High Energy Physics particle tracking in CERN detectors

$25,000 Prize Money
Activity example: Deep Learning & Computer Vision

- Application of **Deep Neural Networks for LHC searches**.
- **Convolutional Neural Networks (Computer Vision)**
  - Event classification, Muon Tomography, Satellite imaging, Medical diagnosis
- **Improvement of PET imaging** (Attenuation correction) with Deep Learning

![Attenuation map](image1)

![Corrected PET](image2)

![ATLAS Preliminary](image3)

![Improvement of PET imaging](image4)
Activity example: Vectorization & bio-inspired models

- Study benefit of **advanced vectorization capabilities of modern processors** (SSE, AVX 2.0…)
- Allows processing of multiple data with a single order
  - Single Instruction Multiple Data (SIMD)
  - e.g.: Matrix calculations for Kalman Filters.
- Natural Parallel computing using bio-inspired models to model complex systems:
  - Cellular automata
  - Membrane Computing
  - Parallel Genetic Algorithms
  - Parallel implementation:
    - Clusters, GPU, Multi-threading.
Interdisciplinary aspects

- COMCHA effort has an interdisciplinary vocation
- Topics of interest of COMCHA are tackled and have application in other areas of knowledge.
- Groups by main area of interest:
  - **LHC & GRID:** USC, UO, IFCA, UB, URL, PIC, IFIC, CIEMAT, UAM
  - Neutrino and Astroparticle physics: IFIC
  - Applied Physics: US, IFIC, IFCA
  - Nuclear Physics: IFIC
  - Cosmology & Astrophysics: IFAE, PIC, UCM
  - Medical Physics: I3M, IFCA
  - Connections with industry
COMCHA initiatives: First COMCHA school

- First COMCHA school on Machine Learning at LaSalle, URL-Barcelona
- Dates: 3-9 October 2019

https://indico.ific.uv.es/event/3825/timetable/?view=standard

- More than 20 participants (16 were students)
- Several challenges proposed to the students.
- Enthusiastic feedback from participants.
COMCHA initiatives: Roadmap

- The COMCHA participants are preparing a **Roadmap** document covering the next 4-5 years:
  - To convert the effort along well defined objectives, milestones and timeline.
  - The effort started right before the summer → a first draft expected in ~ 3 months.
  - First assignment (preliminary) of editors, participants and reviewers is done.

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**COMCHA ROADMAP [2020-2024]**

To be published

The Roadmap for Computing Challenges in Spain during 2020-2024

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1) Introduction to COMCHA
2) Physics areas of interest
3) Spanish facilities (infrastructure)
4) Working program
   1) Working packages
   2) Data management
   3) Algorithms
   4) Machine Learning
   5) New platforms
5) Training, courses, schools
Conclusions

- COMCHA represents an effort to address the new computational challenges:
  - On a national level basis,
  - Aiming to explore new computing models in the market,
  - And sharing the experience among groups, experiments and other physics communities.
- Support from the physics community is appreciated but also really needed.
- COMCHA initiatives are taking shape:
  - Already one year and have a very fruitful meetings and discussions
  - Some international recognition already at this point (HSF, CHEP plenary)
  - COMCHA Roadmap: plan to have a document with detailed objectives (3 months)
  - Regular discussions will resume after CPAN.

THANK YOU