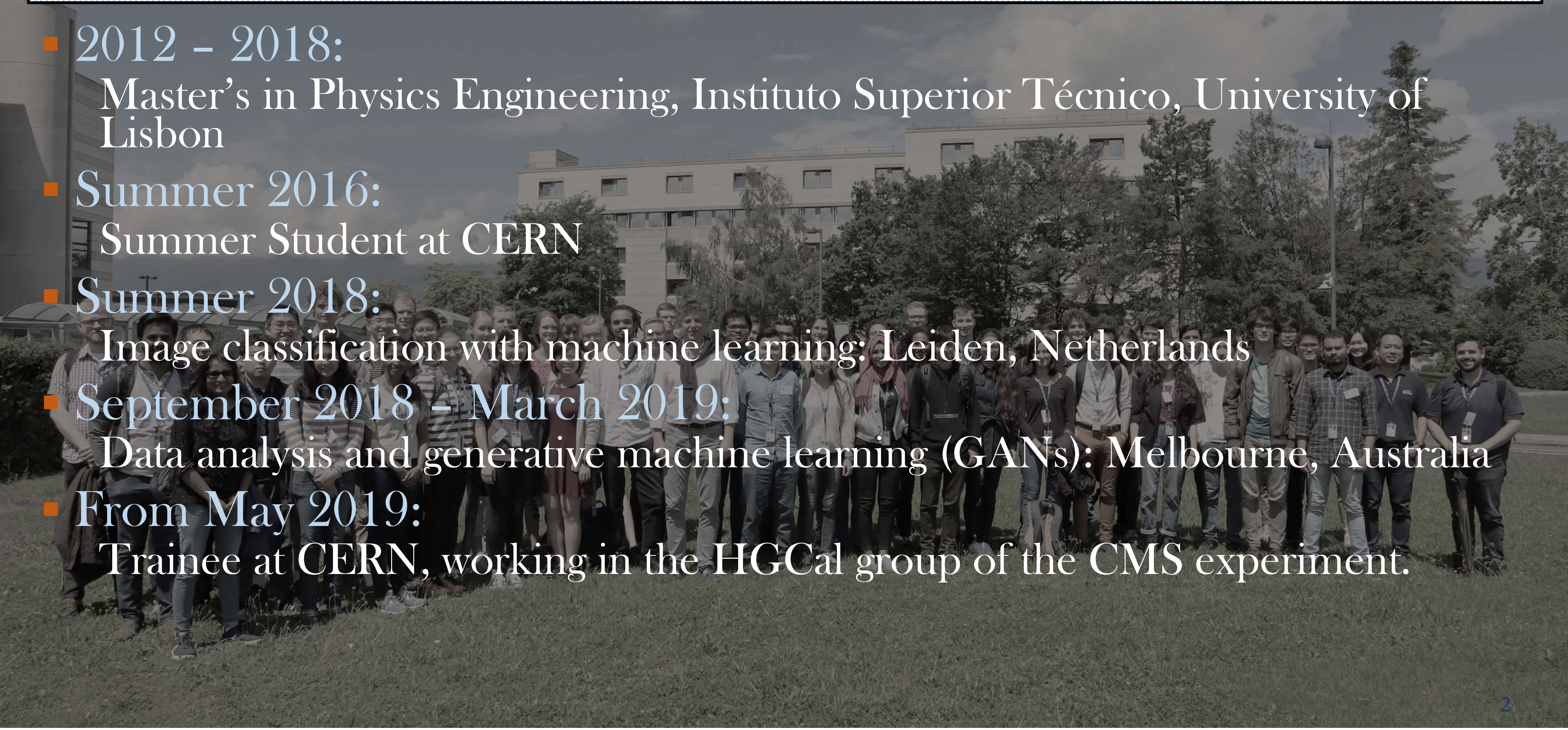
Lightning Talk
Efficient Scientific Computing School

Bruno Alves

Compact Muon Solenoid, CERN, Switzerland

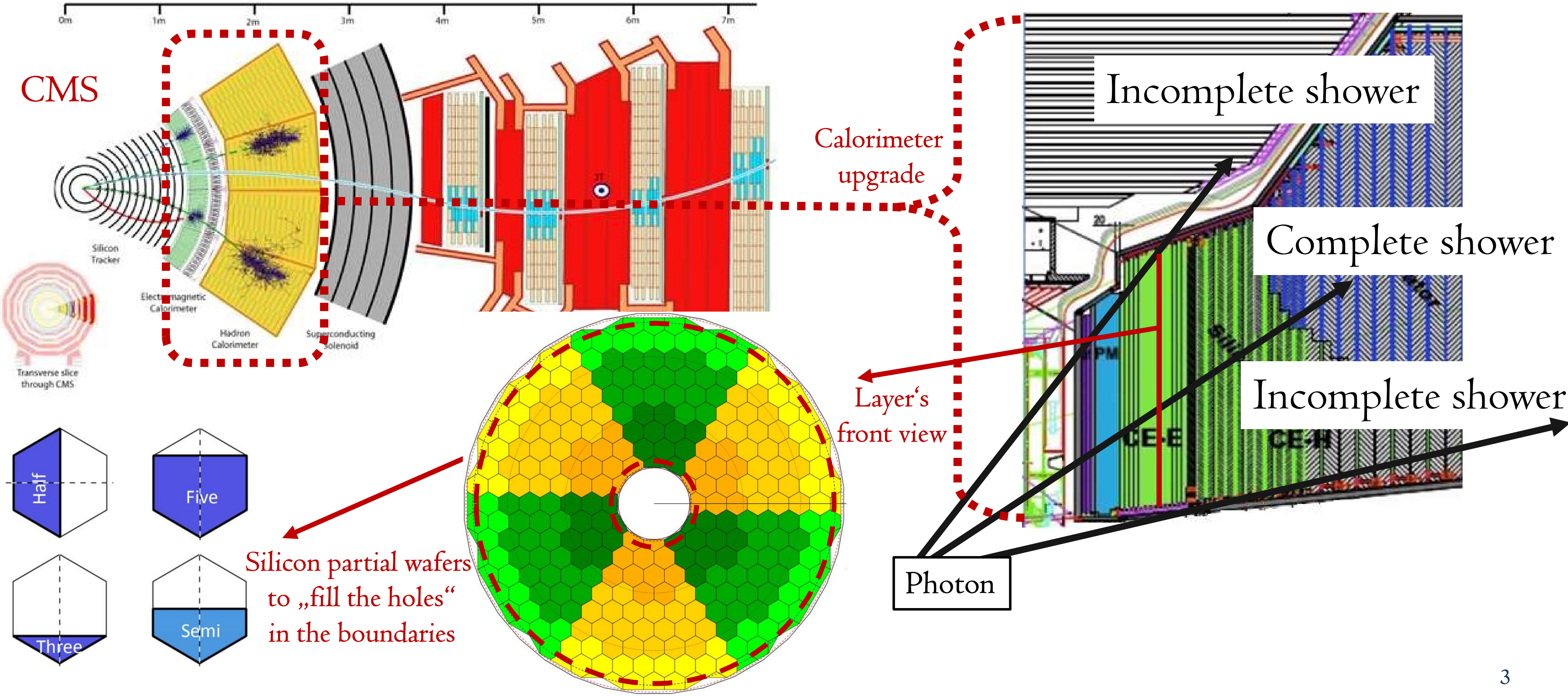
Bertinoro, 21-26 October 2019

Personal overview

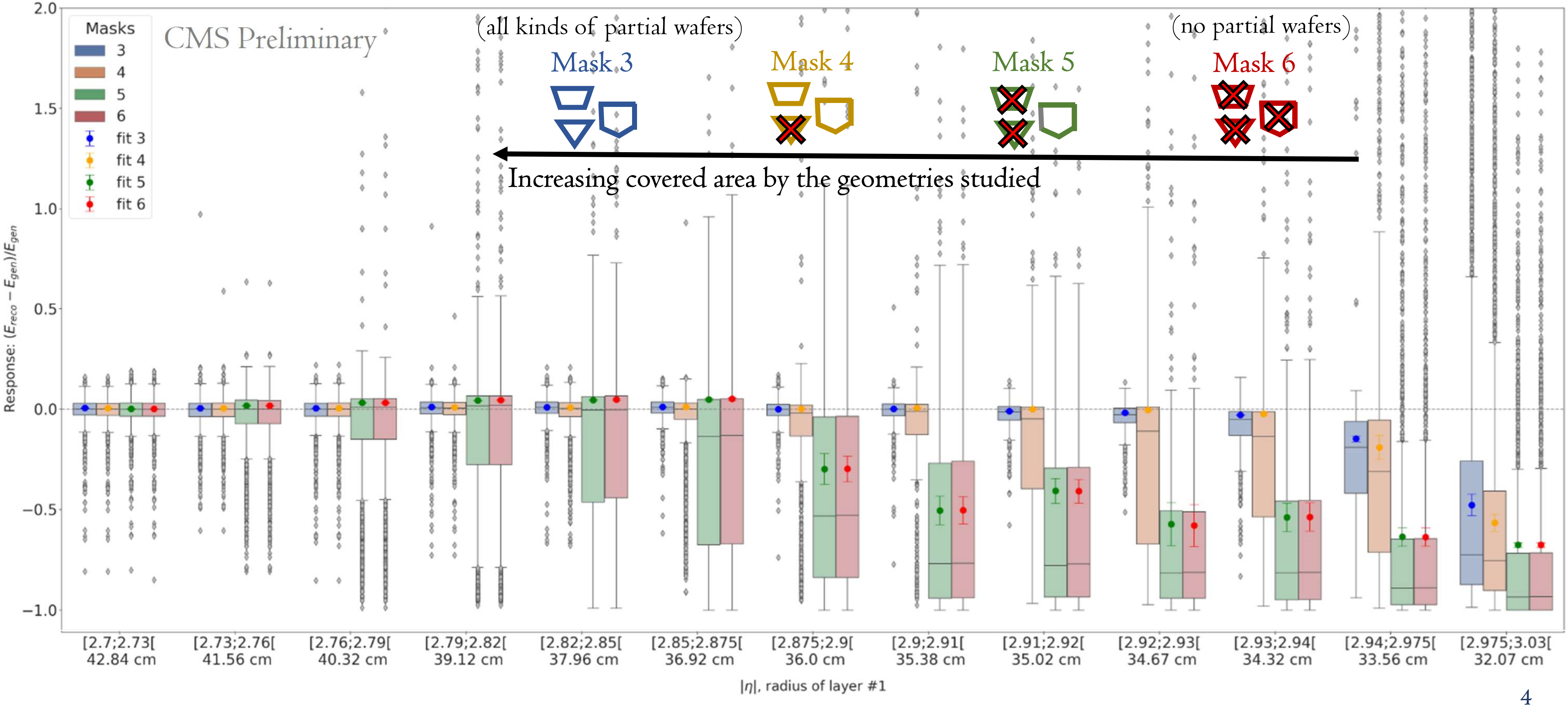


- 2012 – 2018:
  Master's in Physics Engineering, Instituto Superior Técnico, University of Lisbon
- Summer 2016:
  Summer Student at CERN
- Summer 2018:
  Image classification with machine learning: Leiden, Netherlands
- September 2018 – March 2019:
  Data analysis and generative machine learning (GANs): Melbourne, Australia
- From May 2019:
  Trainee at CERN, working in the HGCal group of the CMS experiment.

CMS High Granularity Calorimeter



Performace studies of silicon partial wafers



Scientific computing interests

- Dealing with CERN's huge datasets:

  Parallelism:

  how to best exploit all the available cores;

  best practices to avoid thread concurrent access;

  learn TBB basics;

  have the chance to apply CUDA to a realistic problem;

  know which technology is better fit for each situation.

- C++ usage:

  Efficient coding:

  facilitate auto-vectorization, decrease cache misses, reduce memory usage, use special C++ keywords;

  Scalability:

  write more abstract code maintaining readability and efficiency to avoid long development times when changing small analysis details;

  C++17 and C++20 features:

  avoid old C or C++ constructs when better options are available

Thank you!

About Me…

Name: Paolo Baldan

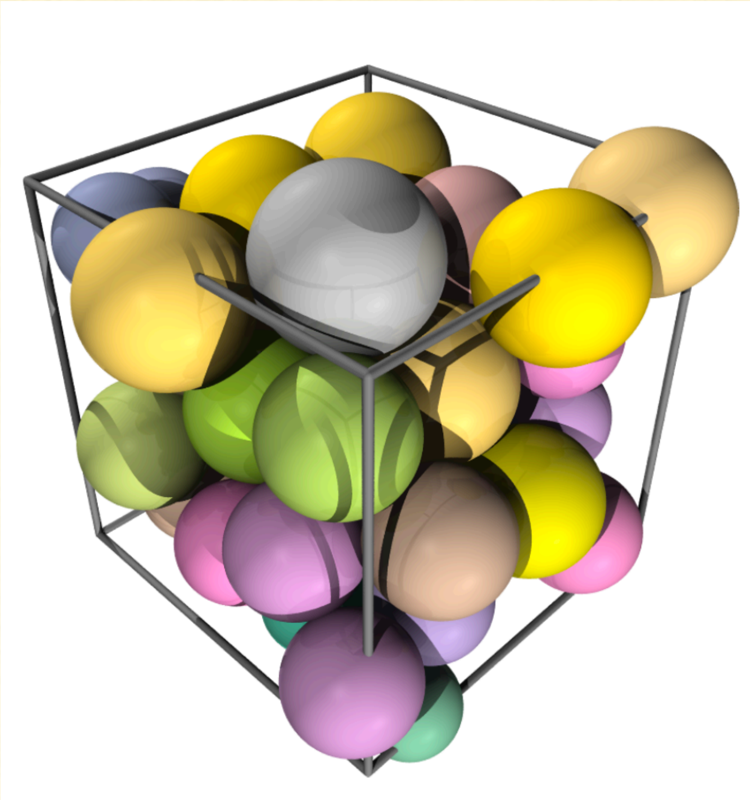
Born: 25th June 1993, Rome

Education:

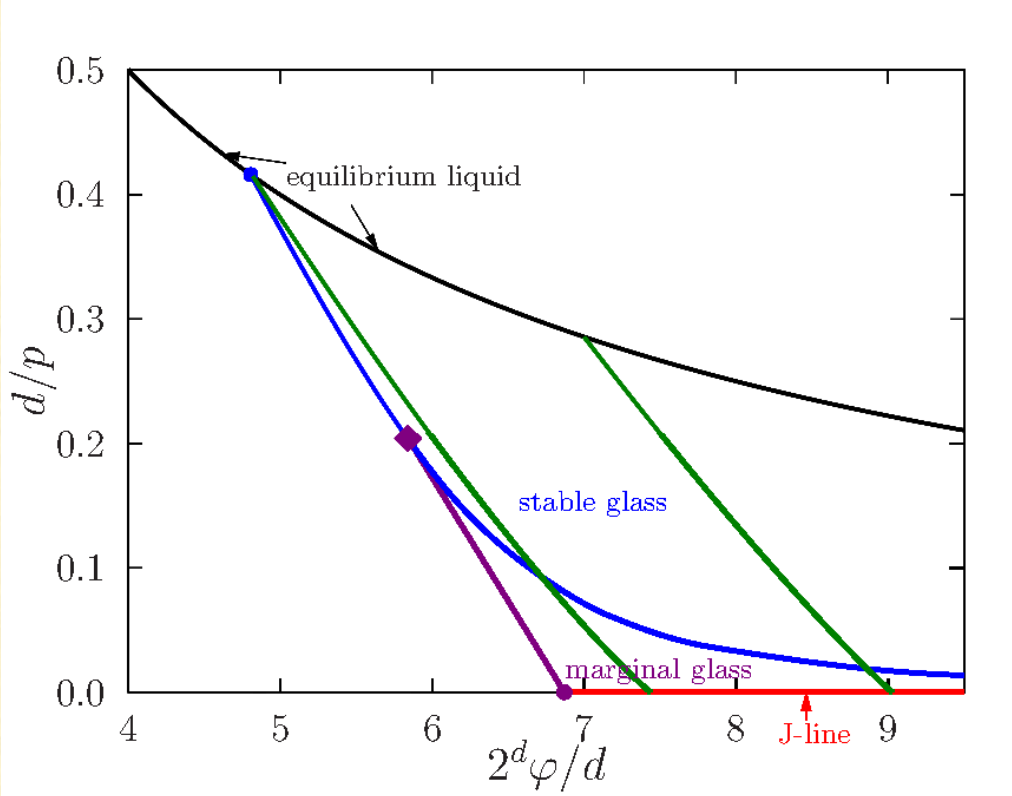
- Bcs at University of Rome Tor Vergata (2015)
- Mcs at University of Rome La Sapienza (2017)
- Phd at University of Rome La Sapienza under the supervision of professor Giorgio Parisi (ongoing).

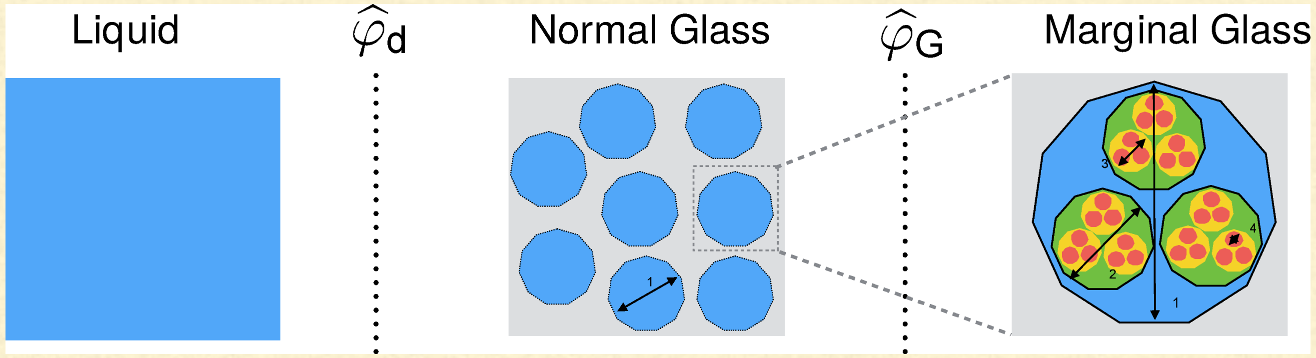
… and my Research

How similar are 3d amorphous materials to their infinite dimensional (Mean Field) counterpart?

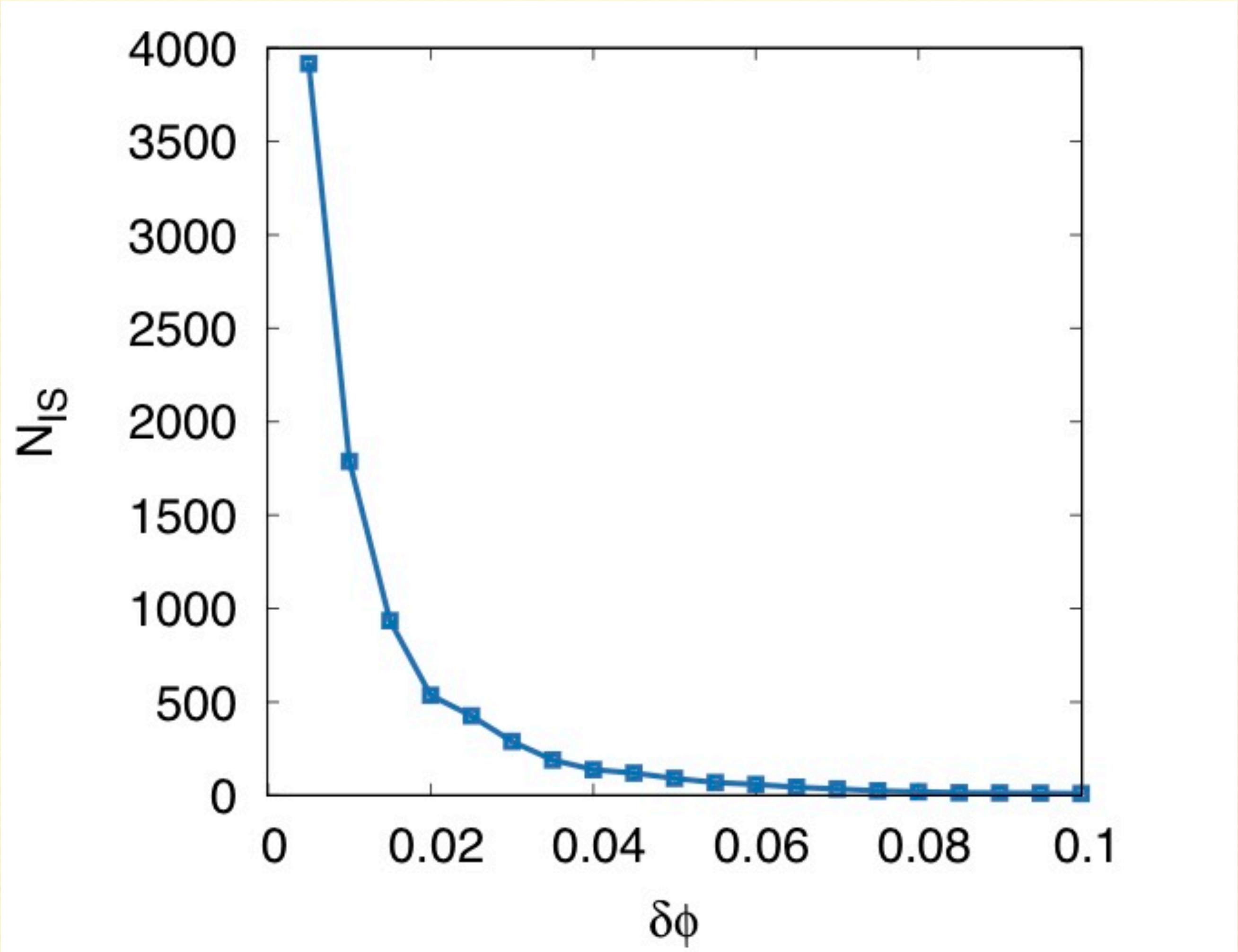


$d \to \infty$

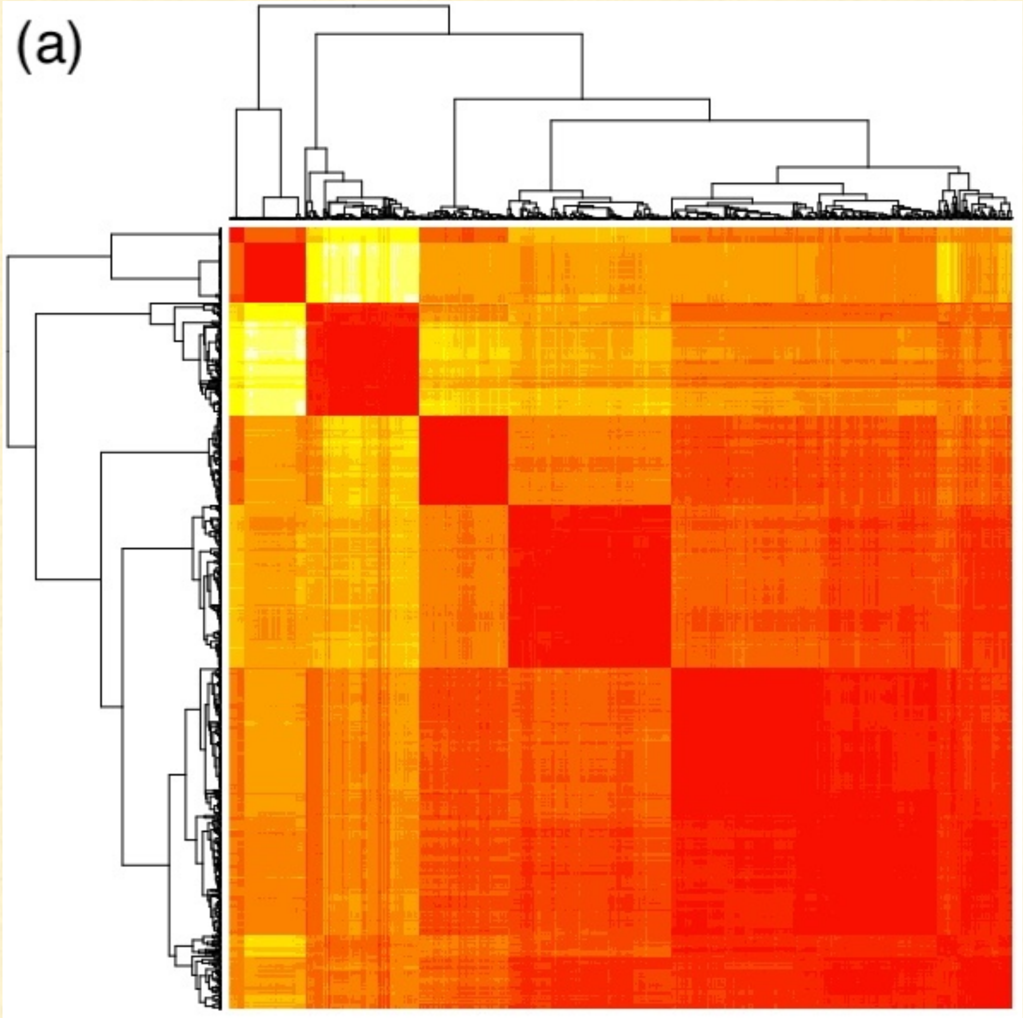




Potential Energy Landscape at Jamming



Steep Increase in the Number of Thermodynamic States



States are Organized in a *Hierarchical* & *Ultrametric* way

Moving Forward

Upcoming Analyses

- Push Compression Further
- Increase Dimensionality
- Increase Sample Size

Computational Challenges

- Steep Increase of the Relaxation Time $\tau \propto e^{E/(T-T_0)}$
- Very Mild increase of the Correlation Length

Beating the Timescale Problem

- Clever (Nonlocal) Montecarlo Moves
- Efficient Hardware Exploitation
- Parallel Computing

Wanna Know More?

Come and See my Poster!

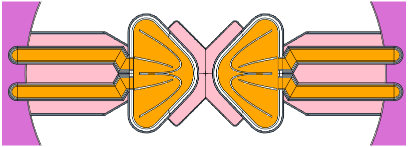
Konstantin Batkov

- Applied nuclear physicist
- Scientist at the MAX IV synchrotron light source
  - Lund, Sweden
- Neutronics (neutron transport through matter)
  - neutron production and moderation
- Radiation shielding calculations

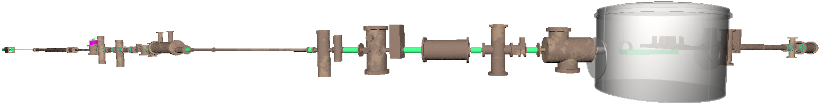
- Extensive Monte Carlo
  - FLUKA, PHITS, MCNP
  - variance reduction
- Complex geometries built with a *bricolage* C++ framework

Konstantin Batkov
Neutronics

- Neutron production calculations for the European Spallation source (accelerator-based neutron source)
- Multidimensional optimisation
  - massive Monte Carlo calculations
  - variance reduction
  - MPI
- Low dimensional moderator concept
  - cold neutron brightness increased by a factor of 2.5



- Radiation shielding at the MAX IV synchrotron light source
- Realistic fully parameterised geometric models
- Variance reduction



- Much more details in the poster

Konstantin Batkov
Interests in scientific computing

- Machine learning
  - ill-posed problems
- Development of large scale scientific applications with modern C++
- Variance reduction
  - quick and memory-efficient operations with tensors
- GPU programming
  - reverse ray-tracing
- MPI programming

Research Activities and Areas of Interest in Scientific Computing

Rajarshi Bhattacharya

Outline

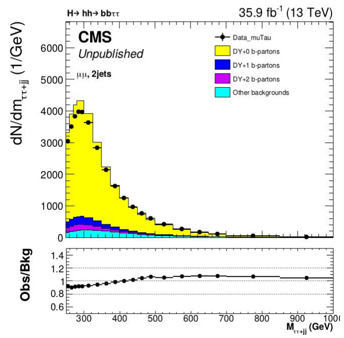
- Physics Analysis in CMS
  - HH → bbττ
  - B_s → φφ → kkkk with L1 tracks for CMS Phase 2 Tracker
  - Optimization of isolation for electron and muon for H → ZZ → 4 leptons analysis
- Service to the experiment
  - Beam Test data analysis for the proposed 2S modules of the CMS Phase-2 outer tracker
  - Calibration of noisy channels for the current CMS tracker
  - Data quality monitoring for the current CMS tracker

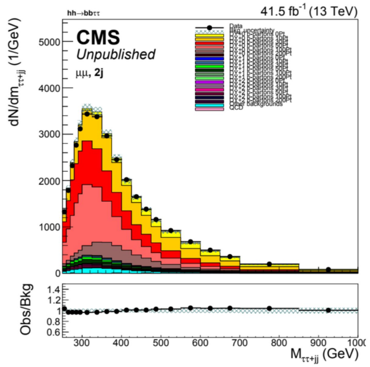
HH → bbττ

- Aim is to explore Higgs-self coupling and any presence of BSM physics
- Dominant production mode:
  - Gluon-gluon Fusion
    - σ_{HH} ~ 33 fb at 13 TeV
- Good compromise between yield and purity

My main contribution

- DY background estimation



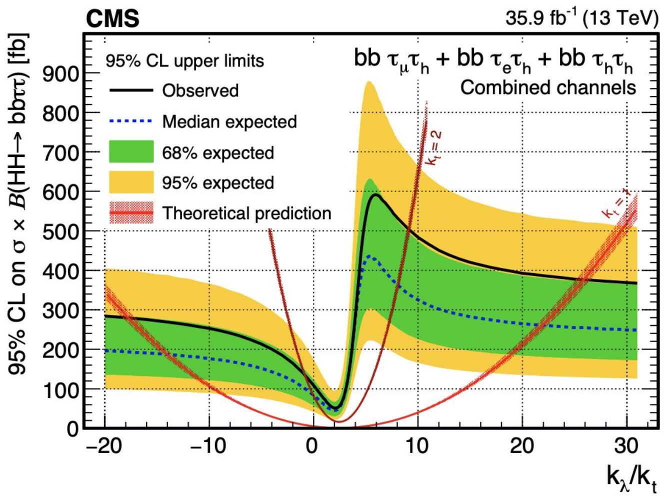


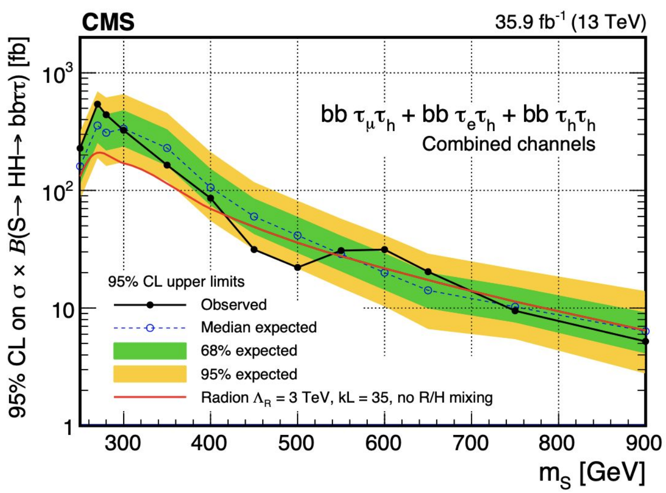
- b-Tagging efficiency measurement and b-Tagging weights calculation

Results

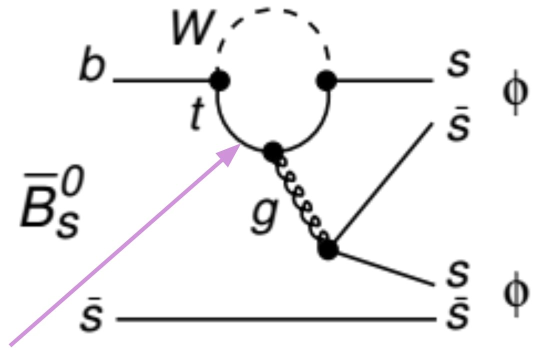
2016 Data (HIG-17-002), PLB

- SM HH production obs (exp) 31 (25) × σ_{SM}
- Both non-resonant and resonant searches





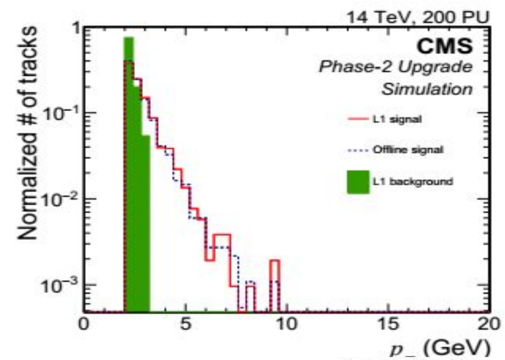
Triggering $B_s \to \phi\phi \to$ kkkk events using L1 tracks with the CMS Phase-2 Tracker



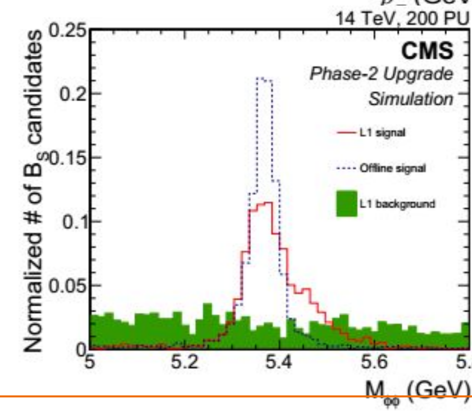
b → sss penguin diagram

- Rare process
  - Br($B_s \to \phi\phi$) ≈ (1.84 ± 0.18) × 10^{-5} (PDG)
- BSM physics which are beyond the direct reach of the LHC may contribute

Softest Track



- Fully hadronic final state
  - CMS can not study such final states with the current detector
  - At Phase-2, a new tracker with L1 tracking capabilities will allow one to trigger such final states efficiently
- Final state kaons are low p_T tracks, close to the L1 tracking threshold of 2 GeV
  - Major source of loss of efficiency



B_s Mass

B_s mass peak is clearly visible at the trigger level even with <PU> = 200

30% signal efficiency can be achieved at a L1 rate of 15 kHz for <PU> = 200

Areas of Interest where efficient computing can be used

- High performance computing is becoming ever more important at the LHC
  - With increasing instantaneous luminosity which causes higher pile-up
  - With ever increasing data volume which require more efficient data access and analysis strategies
- Physics analyses are gradually moving from traditional cut based approach to Machine Learning based approach
  - GPU based computation can help a lot
- Use of GPUs may also improve Trigger latency significantly
- L1 tracking in CMS Phase-2
  - Complex trigger logic implemented in FPGAs
- Core software development
  - Requires expertise on efficient programming, e.g.
    - memory management
    - modern C++ idioms, tools and methodologies

Voids-Lensing Cross Correlation

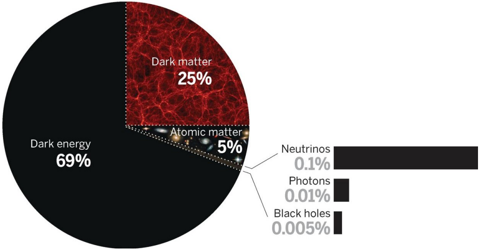
Marco Bonici

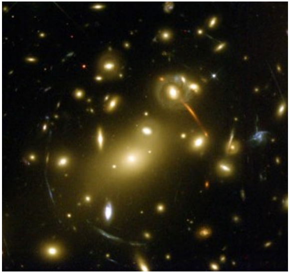
Università degli Studi di Genova

October 21, 2019

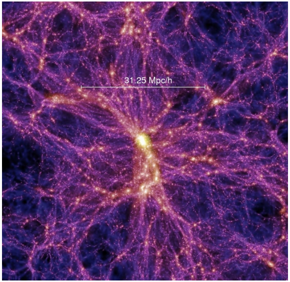
Euclid is an ESA space mission, whose launch is scheduled for 2022. Scientific objectives are

- Dark Energy, responsible of the universe acceleration
- Dark Matter, which drives structure formation
- The sum of neutrino masses





Lensing is a general relativistic effect, the light bending in gravitational field due to the universe mass distribution.



Voids are underdense regions, whose formation and evolution is sensitive to Dark Energy and Neutrinos.

We want to forecast the Euclid sensitivity to cosmological parameters. The tool we use is the Fisher Matrix $F_{\alpha\beta}$, whose inverse gives the exptected parameters uncertainties. It is defined, in general, as

$$F_{\alpha\beta} = -\left\langle \frac{\partial^2 \ln P}{\partial\theta_\alpha \partial\theta_\beta} \right\rangle \tag{1}$$

where α and β span over the cosmological parameters, among which there are the neutrino masses M_ν and the Dark Energy equation of state parameters w_0 and w_a

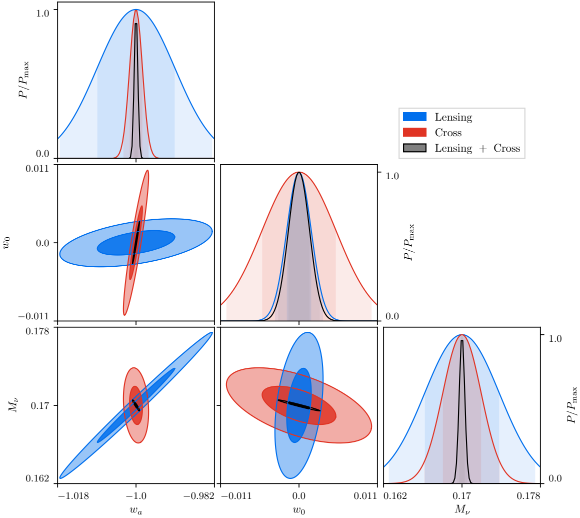
$$w_{DE}(z) \equiv \frac{P_{DE}(z)}{\rho_{DE}(z)} = w_0 + w_a \frac{z}{1+z} \tag{2}$$

The Python code I am developing evaluates the Voids-Lensing Cross correlation Fisher Matrix. The code is divided in three parts:

- Lensing and Voids distribution evaluation for different values of the Cosmological parameters
- Evaluation of the Lensing and Voids distribution derivatives with respect to the Cosmological Parameters
- Fisher Matrix evaluation

The program can run on local machines, but there is the possibility to submit the different jobs in parallel to a computing facility.

Achtung: preliminary result!




THANK YOU FOR
YOUR ATTENTION

REAL TIME DOSIMETRY IN IORT

Francesco Collamati
INFN ROMA

ESC 2019 - Bertinoro (FC)

INTRA **O**PERATIVE **R**ADIO **T**HERAPY

- **TECHNIQUE RATIONALE:**
    - To deliver a high dose (~20 Gy) of radiation precisely to the target area, with minimal impact on surrounding healthy tissue
- **HOW:**
    - The treatment is performed directly in the operating room, in one single shot
    - Use of portable mobile linear accelerators
    - Tipically using 5-10MeV (or 50kV X rays)

INTRA **O**PERATIVE **R**ADIO **T**HERAPY

- **PROs:**
  - A single application (≈min) replaces 30 days of standard RT treatment
    - Public health impact…
  - Organs At Risk can be manually moved away/ protected
  - Much reduced side effects to skin

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- **CONS**
  - Requires non trivial technical organisation
  - Operating Room shielding, radio protection, multi disciplinary team, expensive machine
  - Final global ≈10-15% uncertainty
  - Misalignments, inhomogeneousity, material layers
  - Same dose for every patient
  - No "dosimetric report" after treatment

INTRA OPERATIVE RADIO THERAPY

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INTRA OPERATIVE RADIO THERAPY

No Treatment Planing System is today available for IORT

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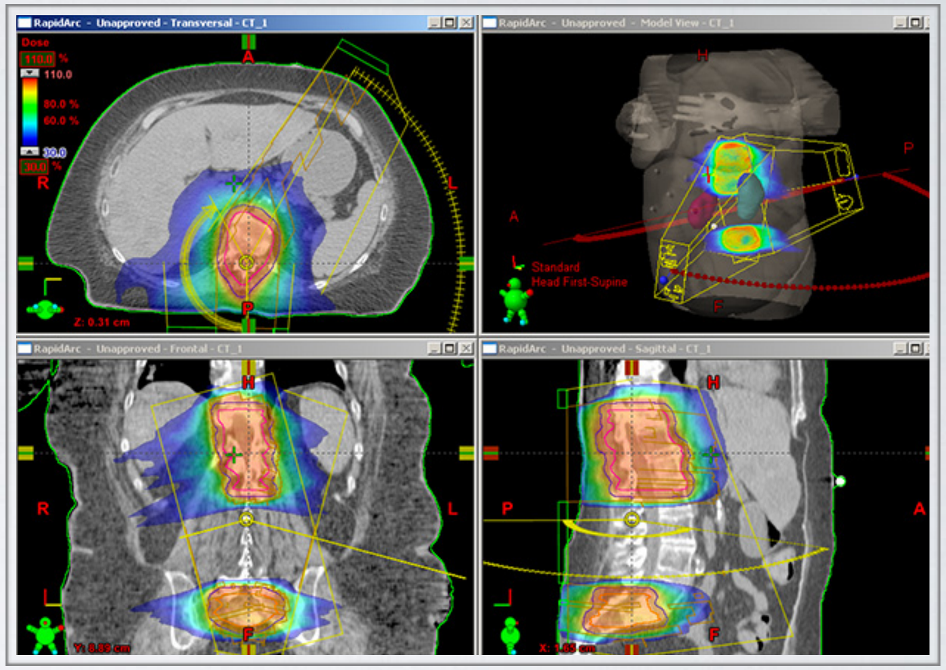
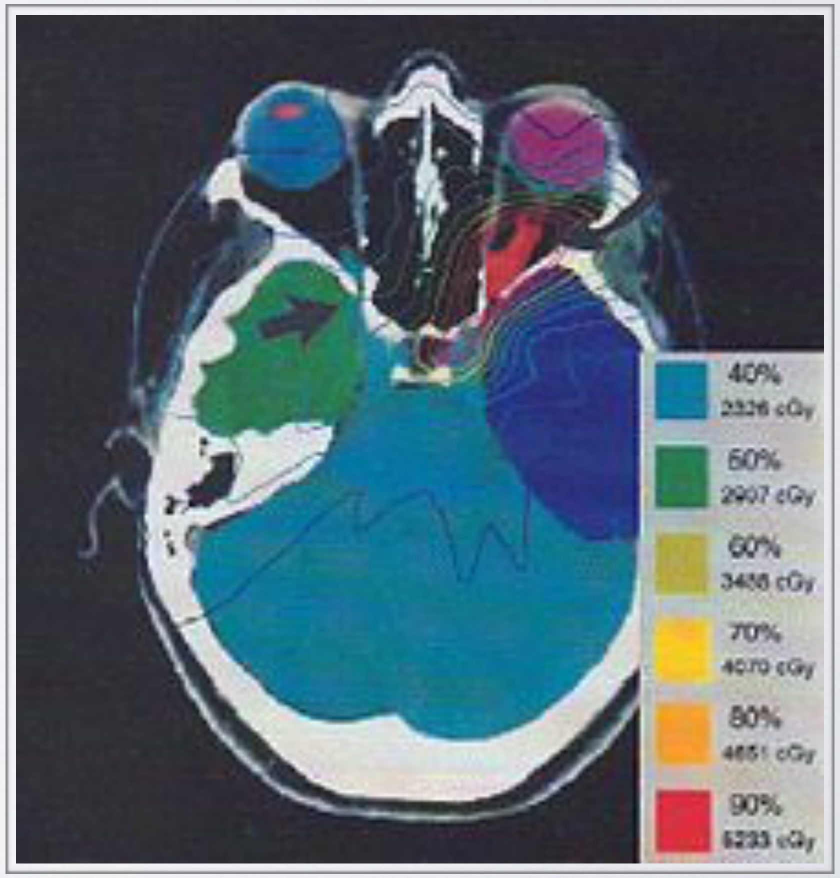
  - No "dosimetric report" after treatment

TREATMENT **P**LANNING **S**YSTEM

- Its the system at the base of Radio Therapy, that allows it to be **effective on the tumor** while **sparing healthy organs** as much as possible
  - Everything starts from patient **CT**, that provides:
    - Shape of the patients
    - Density and material composition
  - A "**virtual patient**" is built
  - The effect of the beam on it is simulated, varying possible parameters (beam number and position, energy, absorbers…) to **find** the **optimal configuration**:
    - Desired dose @ the tumor
    - Minimal dose @ healthy tissue
  - After the treatment, it also provides a "**dosimetric report**": how much dose to the given organ





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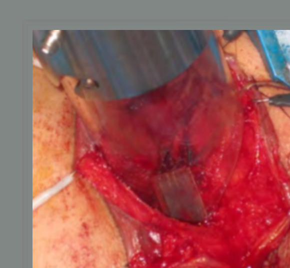
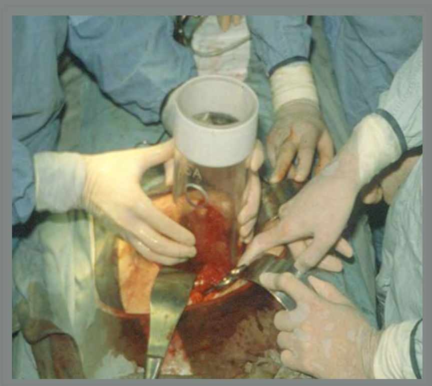
Nothing similar exists today for IORT

↕

No intraoperative "CT" image

Altered anatomy

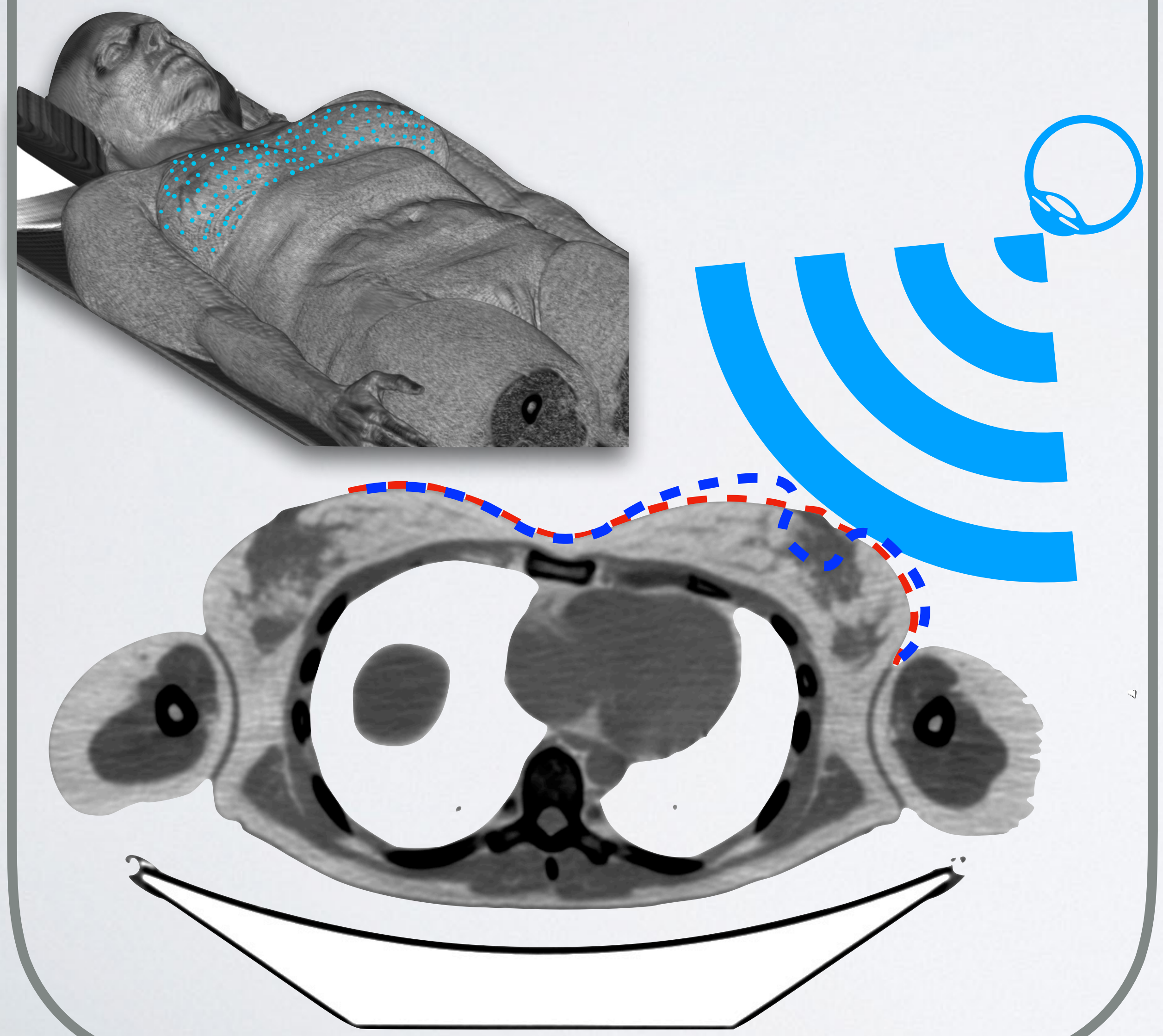




TOWARDS A **TPS** IN **IORT** !?

INTRA OPERATIVE IMAGE

- Fuse pre operative CT + Intra operative image



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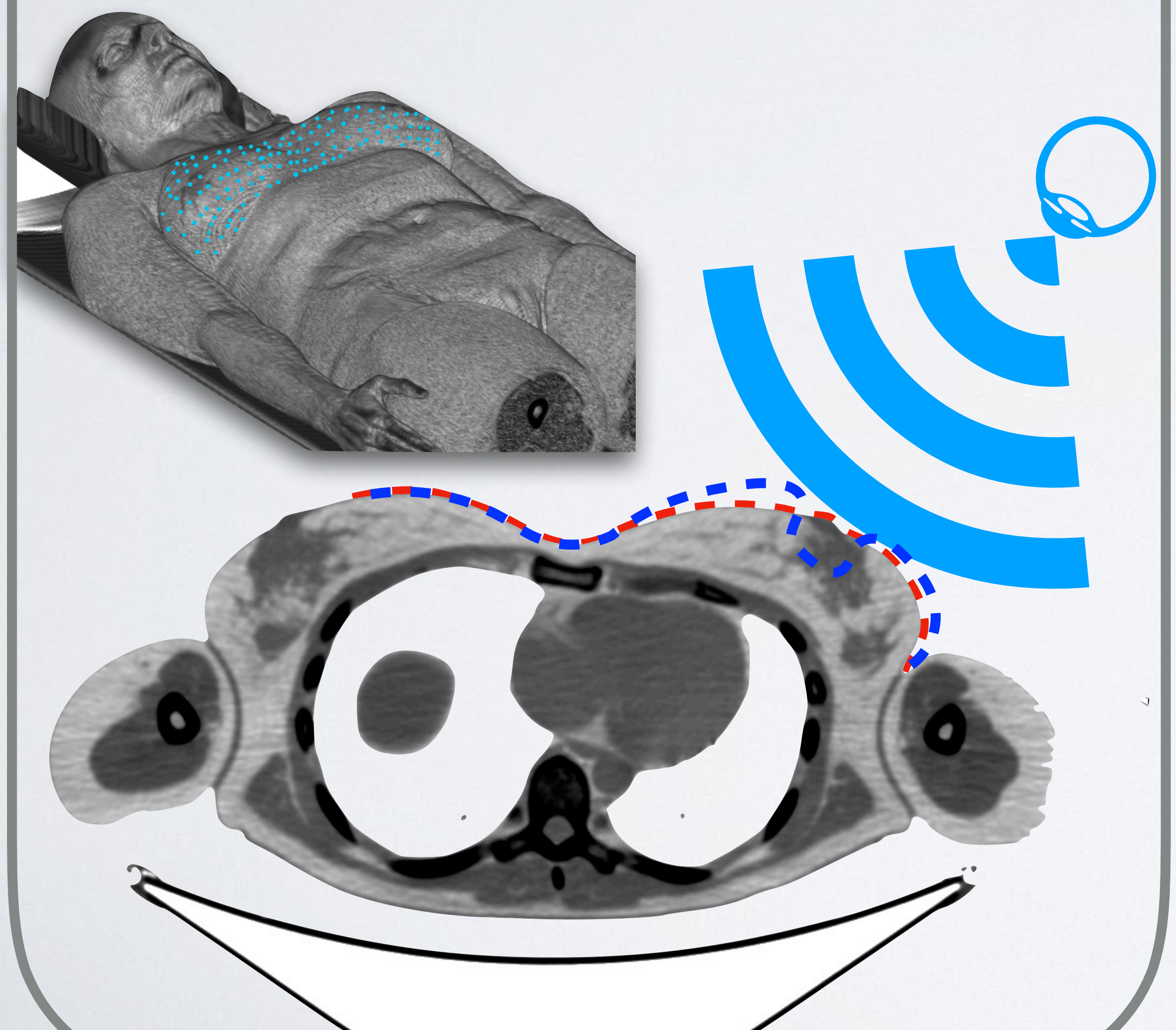
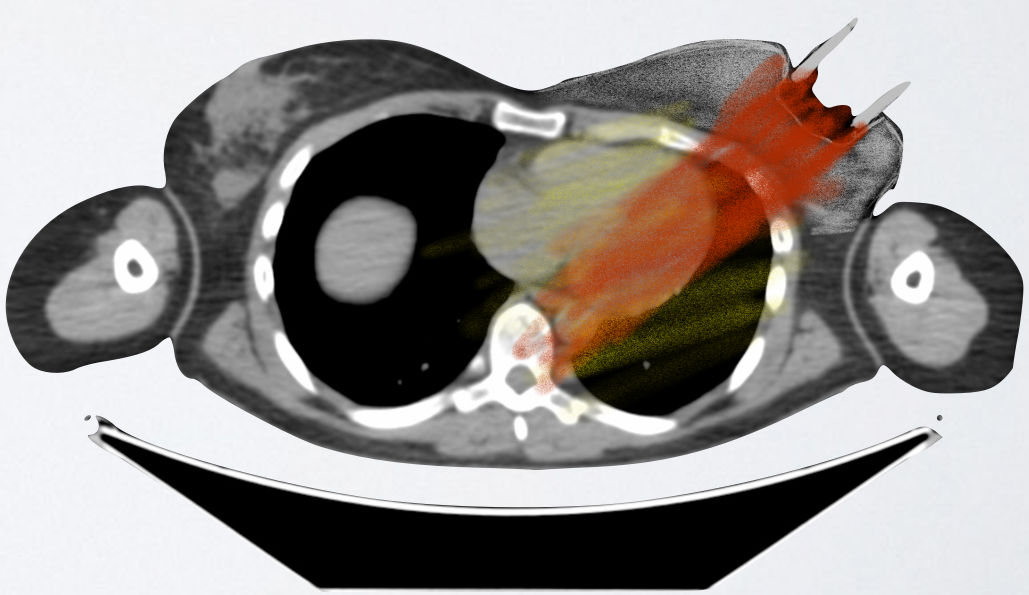


FAST MONTE CARLO

- Image fed to Monte Carlo program for beam simulation
- A very fast simulation could allow real time dosimetry
  - …GPU?



Presentation of research activity

ESC 2019
Architectures, Tools and Methodologies for Developing Efficient Large Scale Scientific Computing Applications

Mattia Faggin

PhD school in Physics

Physics and Astronomy Department “Galileo Galilei”
University of Padova

Dipartimento di Fisica e Astronomia Galileo Galilei

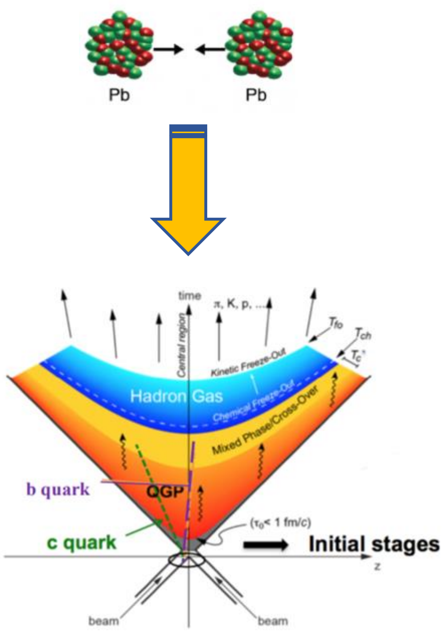
Main research activities

- PhD topic: **"Measurement of heavy-flavor decay electron and heavy-flavour baryon production with ALICE"**
  1. Inclusive measurement of electrons from HF hadron decays (HFe) in Pb-Pb collisions

     → <u>paper committee chair</u> of the article "*Measurement of electrons from heavy-flavour hadron decays at mid-rapidity in pp and Pb-Pb collisions at* $\sqrt{s_{NN}}$ *= 5.02 TeV*"

     → final rounds of collaboration review
  2. Measurement of $\Xi_c^+ \rightarrow pK^-\pi^+$ in pp collisions

$\sqrt{s_{NN}} = 5.02$ TeV



- Main goal of ALICE experiment: study of strongly interacting matter and of Quark Gluon Plasma (QGP)

  → our universe thought to be in such state for the first few millionths of seconds after the Big Bang

  → produced with ultra-relativistic heavy-ion collisions at LHC
- Charm and beauty quarks (HF) are produced in initial hard scattering (large Q^2) before the QGP formation (~ 1 fm/c)
- Unique probes, sensitive to the full QGP evolution

HFe nuclear modification factor (R_{AA})

- HFe from inclusive electron spectrum
  → Statistical removal of hadron contamination
  → Subtraction of non-HFe background
- $p_T^{meas} \rightarrow p_T^{true}$ via unfolding

- In case of no medium effects: $R_{AA} = 1$
- Evident deviation from unity in central and semi-central Pb-Pb collisions
  → quark energy loss in the QGP

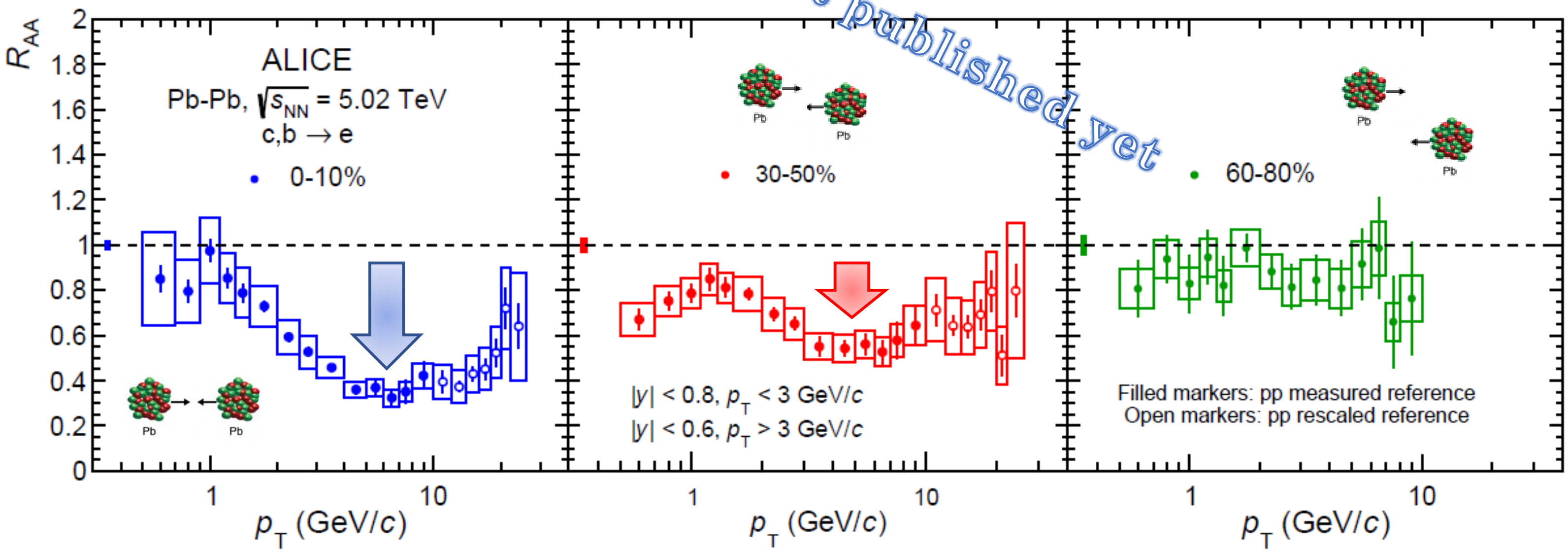
Invariant yield, Pb-Pb @ $\sqrt{s_{NN}} = 5.02$ TeV

$$R_{AA} = \frac{dN_{AA}/p_T}{\langle T_{AA}\rangle \, d\sigma_{pp}/p_T}$$

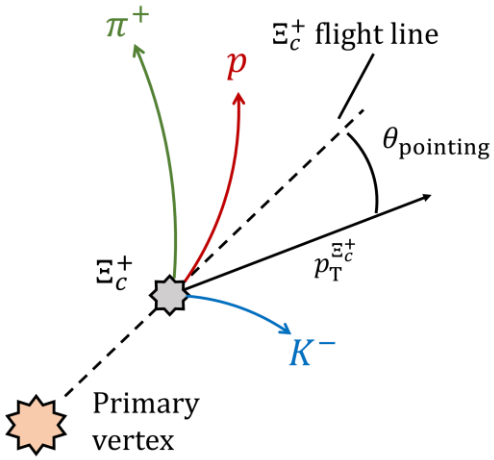
Nuclear overlap function: $\langle T_{AA}\rangle = \langle N_{coll}\rangle / \sigma_{pp}^{inel}$

Invariant cross section, pp @ $\sqrt{s_{NN}} = 5.02$ TeV

Not published yet



Charmed baryon production



- Baryon/meson for charmed hadrons in pp and p-Pb collisions at LHC higher than MC generators tuned to reproduce e^+e^- results
- Even higher values in Pb-Pb and Au-Au collisions at LHC and RICH

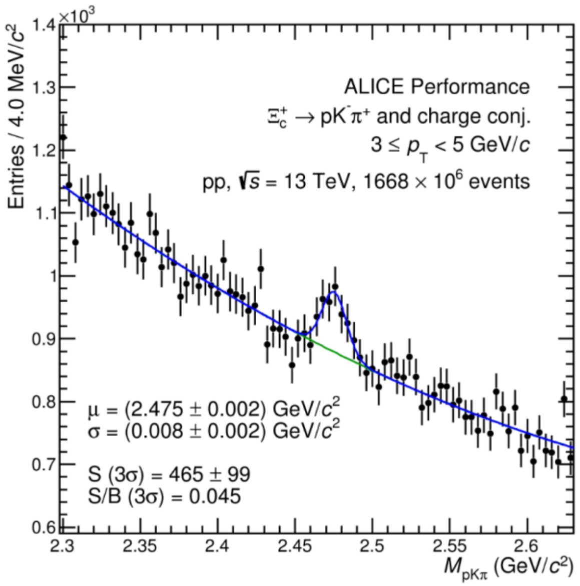
  ⇒ charm hadronization not fully understood

  1. Heavy-quark hadronization influenced by surrounding hadronic environment?
  2. Possibility to hadronized via coalescence in QGP?

- Study of $\Xi_c^+ \rightarrow pK^-\pi^+$ production in pp @ $\sqrt{s} = 13$ TeV

  → topological selections and particle identification

  → next: possibility to adopt machine learning techniques to optimize the signal extraction



Computing interests

1. (Ξ_c analysis) on-the-fly reconstruction of $pK\pi$ candidates
   → Max. combinations: $N \times (N-1) \times (N-2)$
   - (pp) $N \sim 10$: $\sim 10^3$/event combinations → affordable
   - (central Pb-Pb) $N \sim 10^3$: $\sim 10^9$/event → time/CPU consuming !!!

(*) more info in CERN Yellow Report https://arxiv.org/abs/1812.06772

ALICE	LHC Run 2	LHC Run 3 and beyond (*)
L_{int} in pp @ 5 TeV MB trigger	$\sim 19\ nb^{-1}(990 \times 10^6$ events)	$\sim 6\ pb^{-1}(113 \times 10^9$ events)
Pb-Pb events (central 0-10%)	$\sim 130 \times 10^6$	$\sim 10 \times 10^9$

The basics of efficient programming:

- Modern processor architectures
- Efficient floating-point computation
- Tools and methodologies for improved performance
- Efficient exploitation of modern C++
- Managing memory usage

Parallel programming for scientific applications:

- Heterogeneous architectures
- Threading Building Blocks programming
- Effective vectorization
- GP-GPU programming with CUDA
- Cluster computing with MPI

→ Even more challenging situation with Run 3 data
→ I look forward to attending the lectures for many useful inputs

2. Explore new C++ standards and tools (still old-style C++ widely used)

3. Learn as much as possible!

Thank you!

In-silico biomateriomics: efficient GPU acceleration and coarse-grained molecular dynamics approach

Federico Fontana

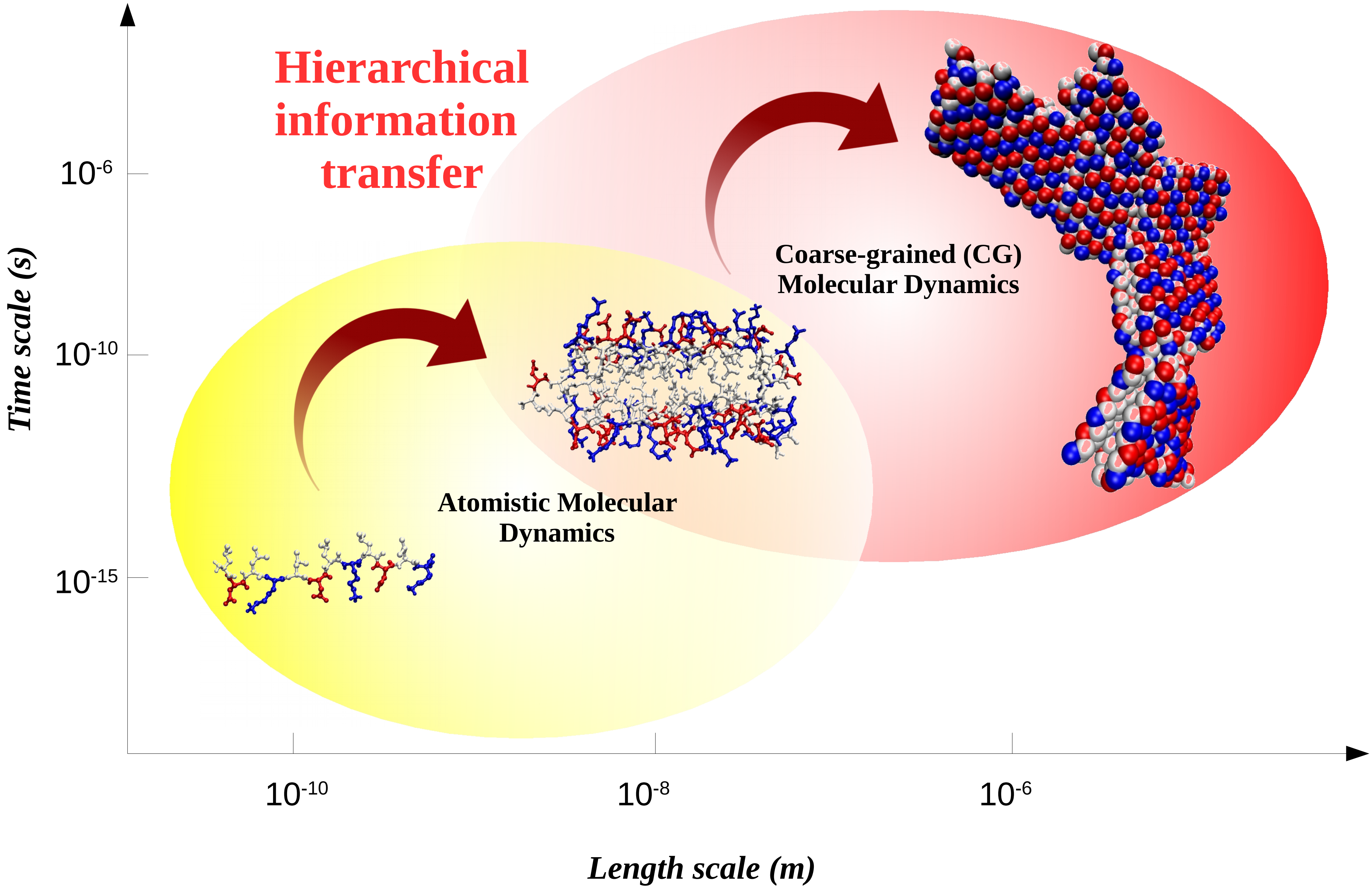
INFN-ESC 2019

21-26 October 2019

Tutor: **Prof. Francesco Nicotra**

Supervisor: **Dott. Fabrizio Gelain**

Multiscale simulation of biomaterials



Molecular dynamics simulations (MD)

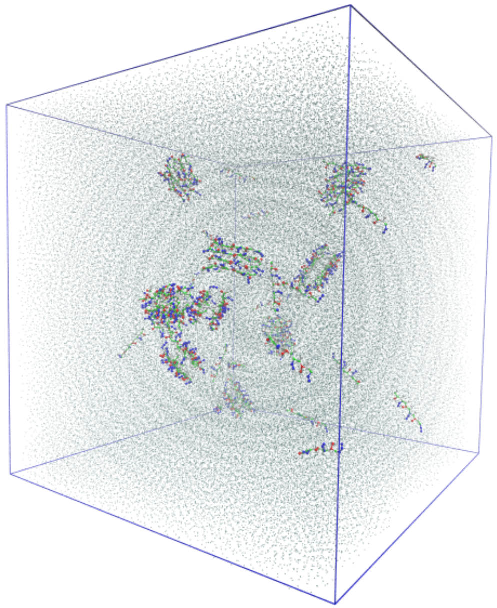
- MD consists in the solution of classical equation of motion (Newton's law) for studying the physical movements of atoms and molecules.
- MD simulations can be performed using different force-field and combining them together

GROMACS version 2016.3

- MPI and OpenMP
- Hybrid parallelization by making use of GPUs for the calculation of non-bonded force
- Multithreading with thread-MPI

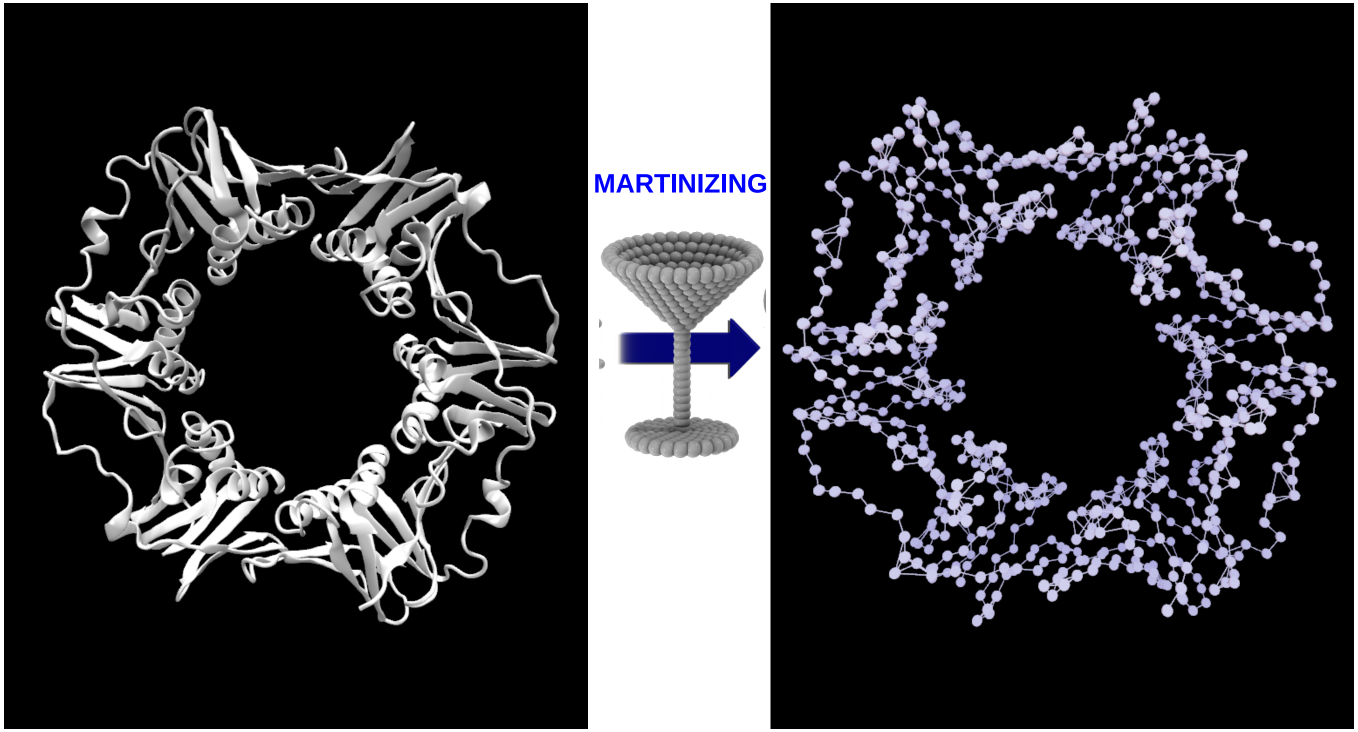
Computational facility@CNTE

- 2 GPU NVIDIA® GeForce GTX 1080
- Cluster server: 4 nodes * 64 processors (AMD Opteron 6272)



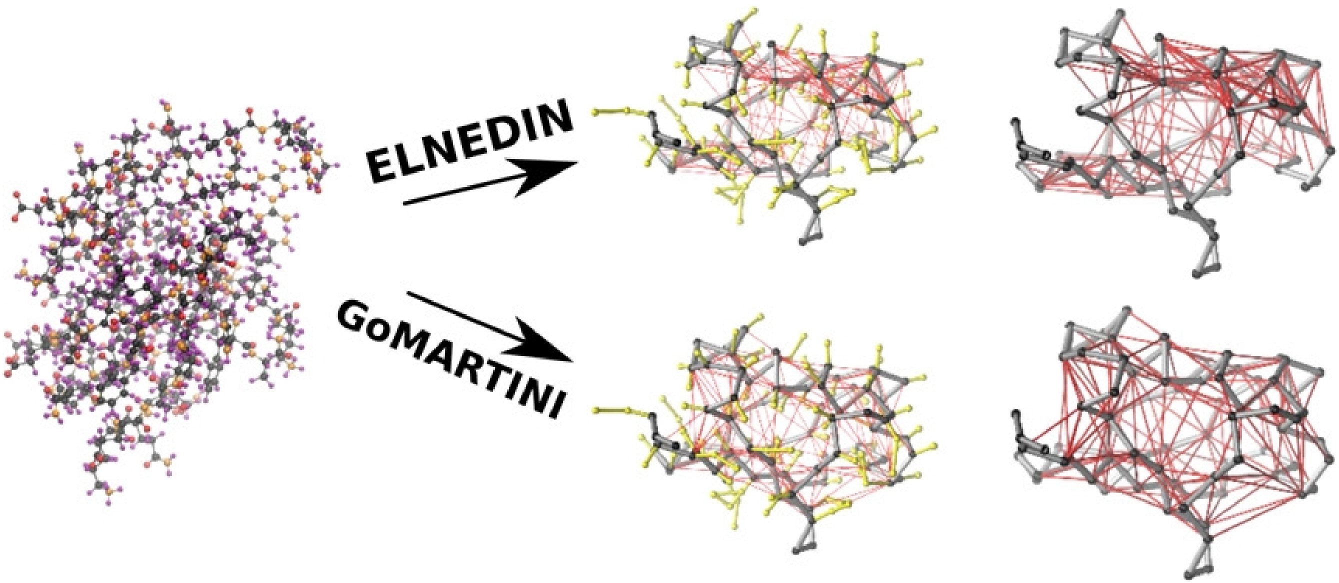
MARTINI force-field

- Compatible with GROMACS simulation package
- 4 heavy atoms (or water molecules) → CG grains
- Reduced computational costs
- **Monitor limited number of** events leading to **nanostructuring**, such as formation or breakage of H-bonds
- **Fixed secondary structure parameters**



GoMARTINI

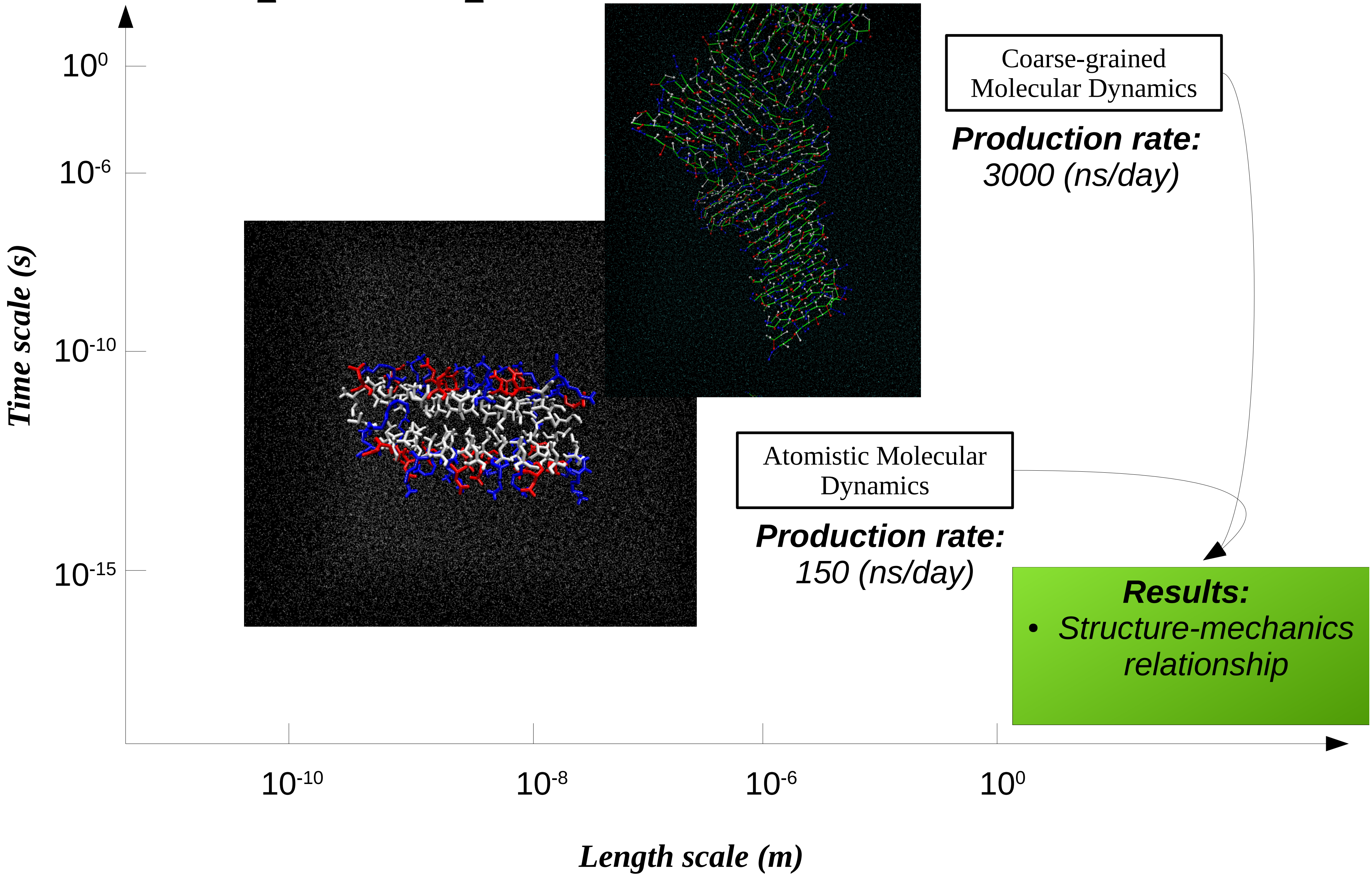
- Mapping according to the MARTINI force-field philosophy
- **No fixed secondary structure parameters**
- Capture structural motion linked to folding or to particular catalytic activity.



AA representation of the protein 1UBQ (ubiquitin, left panel) and its CG representation in the ELNEDIN and GoMARTINI models as indicated.

Poma et al, **2017**, *J. Chem. Theory Comput.*, *13*, 1366-1374

Speed-up the MD simulations



Thank you for your attention

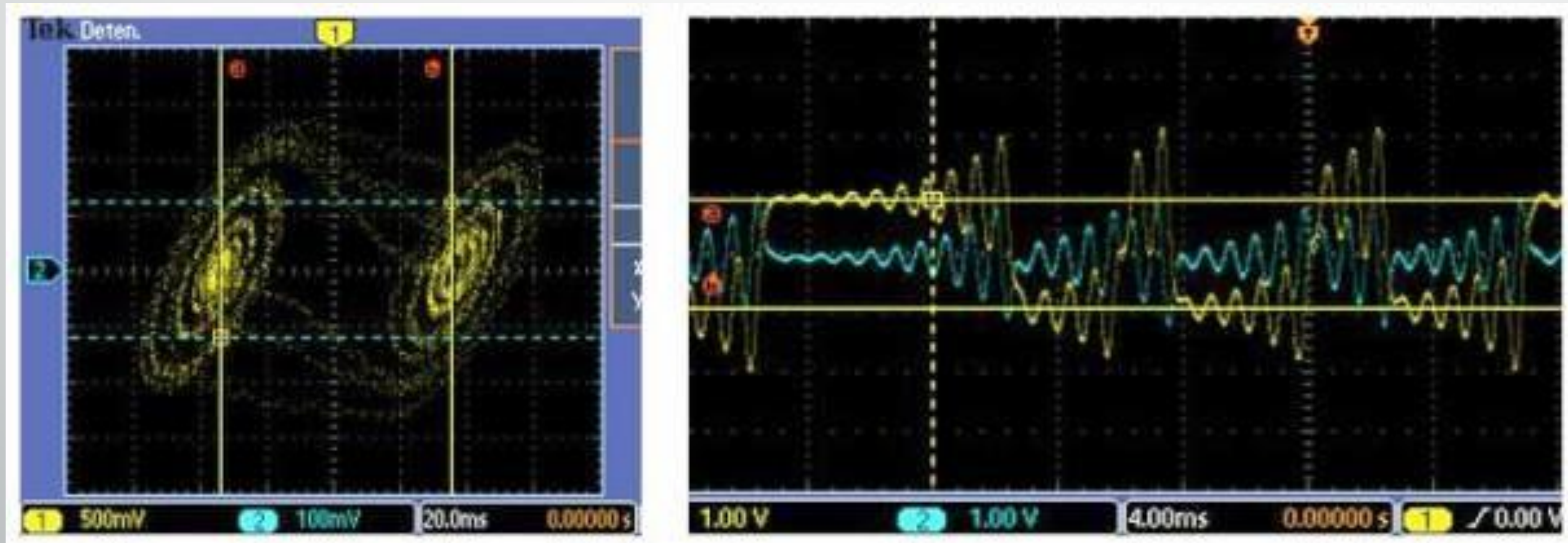
- **Student:**

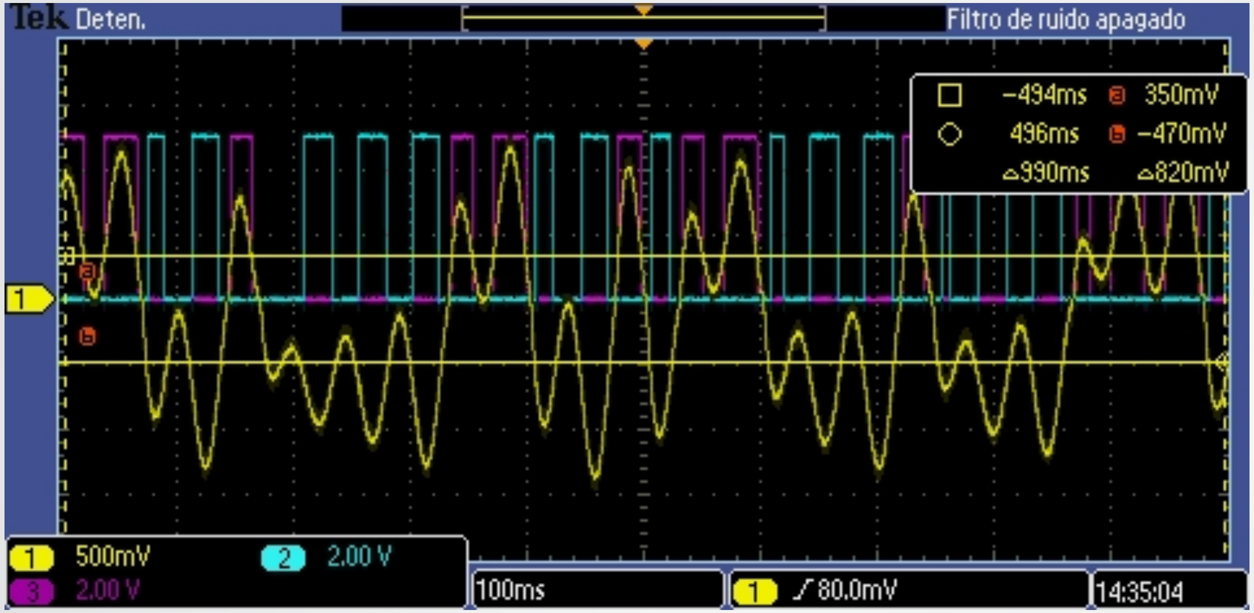
Tonatiuh García Ch.

e-mail: tonaspiuck@gmail.com

- ***Student of PhD in the program:* *Language and Knowledge Engineering, LKE, at Benemérita Universidad Autónoma de Puebla, México.***

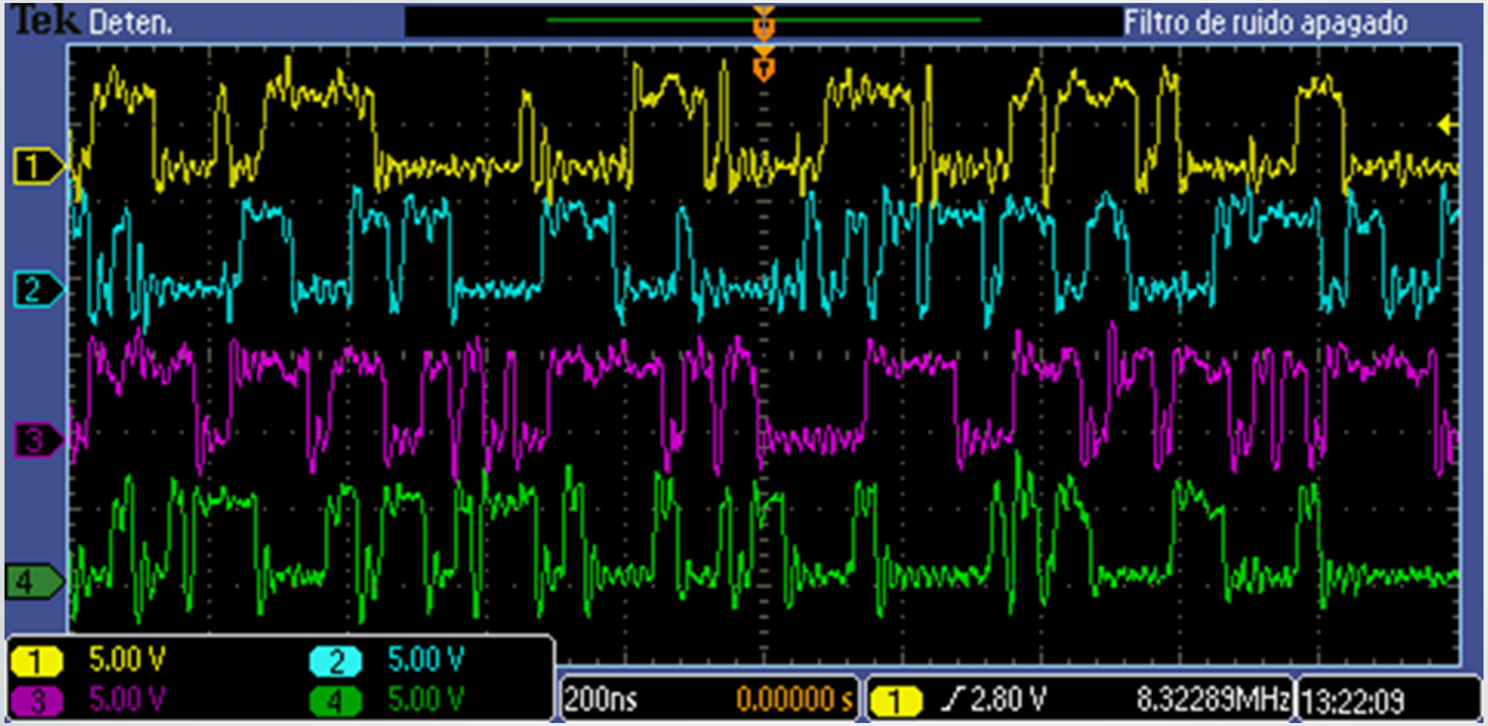
First we start working with simulation, design, characterize and implementation of chaotic dynamical systems with analogous devices, in order to create random numbers. The idea was to enhance the chaotic behavior using an evolutionary algorithm to find the maximized the parameters to be set in the real circuit.





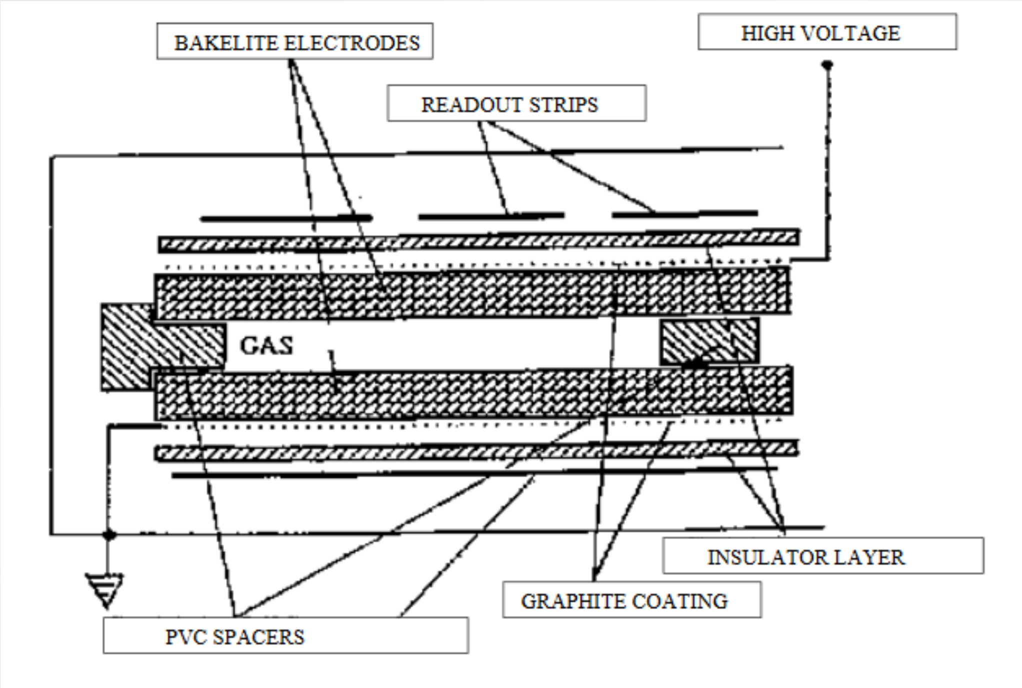
Important aspects:

- *Good performance with basic test.*
- *Good characterization and enhancement of parameters.*
- *With serial or parallel interface with CPU is sufficient.*
- *Slow system for random bit generation.*
- *Difficult to do more demanding tests for the amount of bits needed. (million data per test)*



Important aspects:

- ***Feasibility of carrying out more demanding tests.***
- ***Good performance with less power consumption.***
- ***Feasibility of collect millions of data in much less time.***
- ***Adaptability, the entire system is full digital and programmable.***



Topics:

- ***Muon tomography***
- ***Muon radiography***
- ***Cosmic ray detector for ALICE (ACORDE).*** *[2]*
- ***Particle trace reconstruction.***

1. **Tesi di Dottorato di Giacomo Luca Bruno, The RPC detectors and the muon system for the CMS experiment at the LHC. Universit`a degli Studi di Pavia. 2000-2001.**
2. **A. Fernández, et. Al, ACORDE a cosmic ray detector for ALICE, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 572, Issue 1, 2007, Pages 102-103, ISSN 0168-9002**

High mass di-boson resonances in semi-leptonic final state @ ATLAS experiment

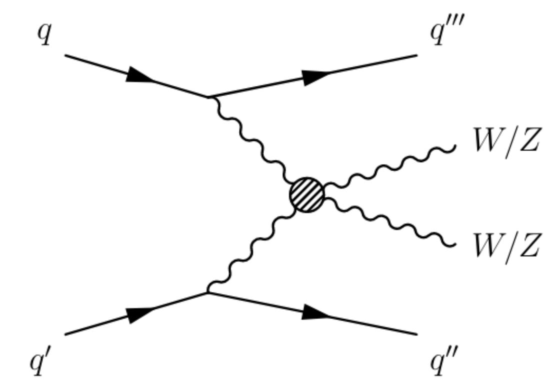
11th INFN ESC School

Bertinoro - 21st October 2019

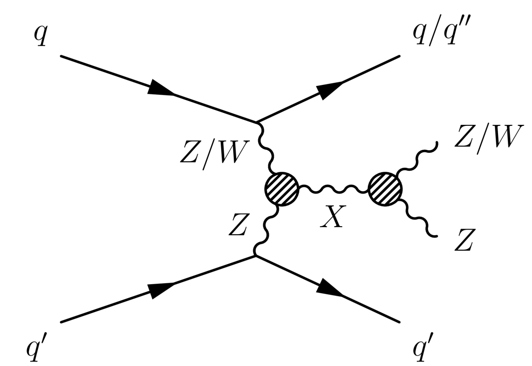
Antonio Giannini

Outline

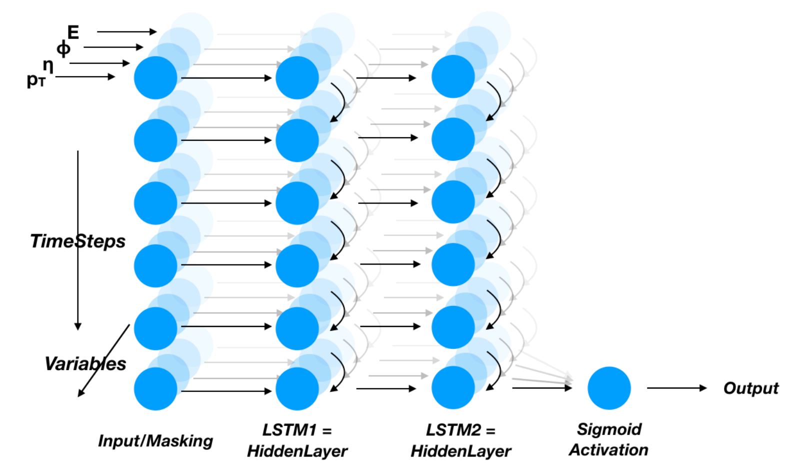
- I am a PhD @ Università Federico II in Naples (February 2017 - 2020) involved in the ATLAS experiment.
- 3rd PhD year at CERN thanks to a simil-fellow contract.
- ***PhD activities:***
    - semi-leptonic di-boson final state signatures for Standard Model measurements and searches of new physics with resonance interpretation, with particular interest in ***Vector Boson Scattering (VBS)*** and ***Vector Boson Fusion (VBF)***.
    - Involved in the JetEtMiss team for developing of ***Quark/ Gluon jets*** tagging techniques.
    - Responsibility in ATLAS derivation framework (data format).
- ***Today:***
    - The ATLAS experiment.
    - A look to di-boson searches.
    - ***Machine Learning*** application in the searches of new physics with the development of a ***Recurrent Neural Network (RNN)*** for the VBF/ggF event classification.
    - ***Interest in scientific computing:***
        - C++/python for analysis frameworks, plots and optimisation.
        - Python and Keras libraries for Machine Learning application.



VBS

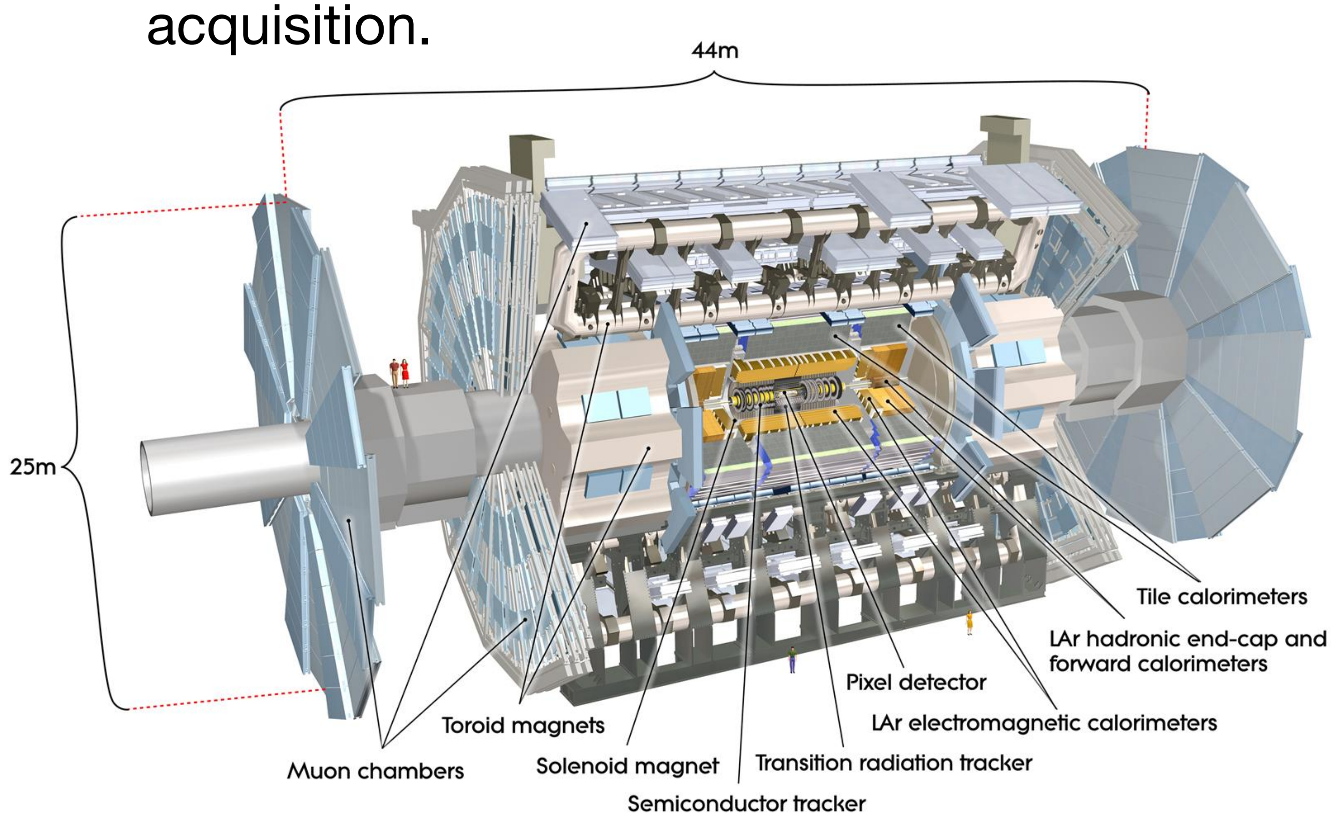


VBF

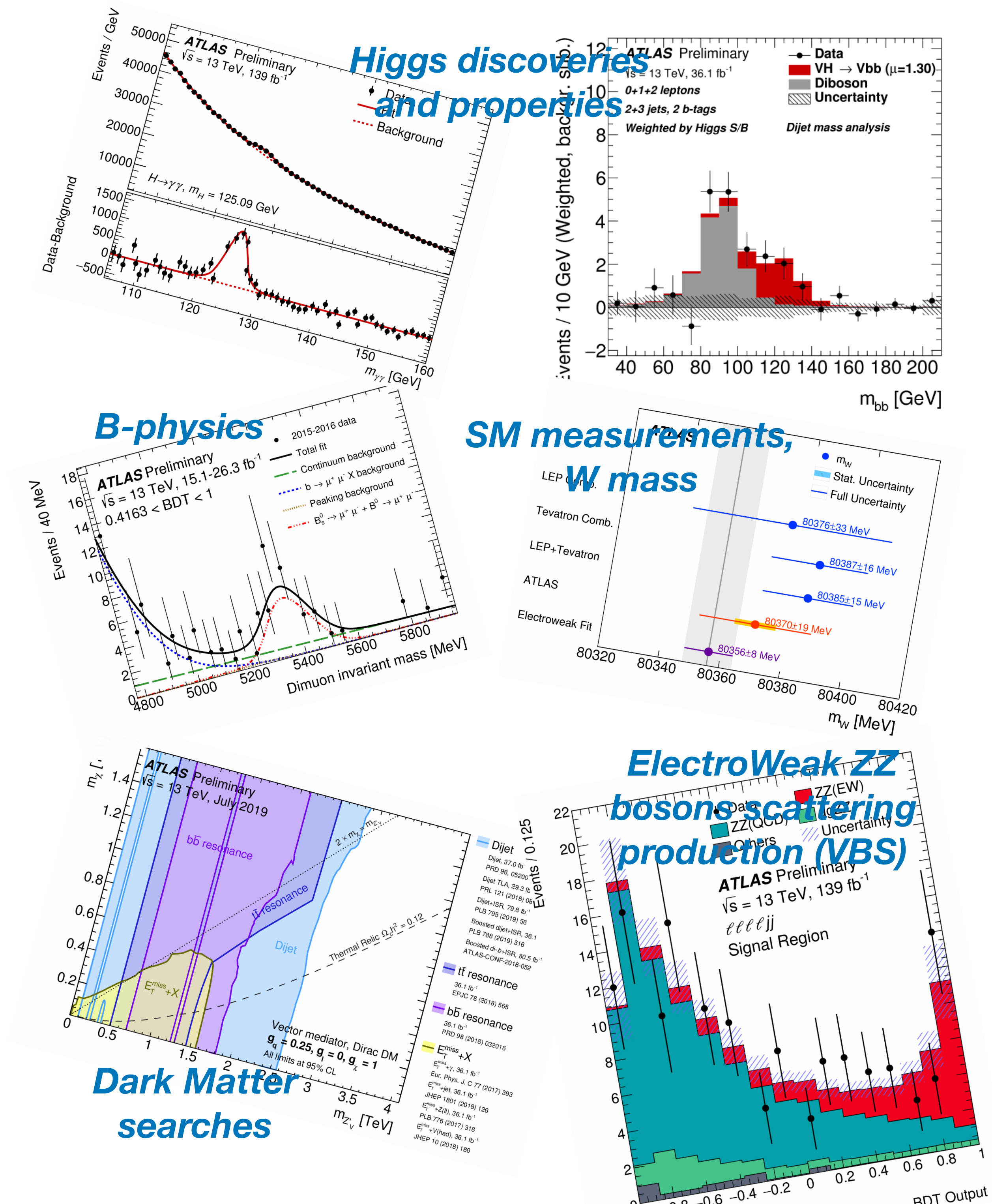


The ATLAS experiment

- ATLAS is a multi-purpose experiment of high energy physics.
- The detector has a cylindrical symmetry around the direction of the colliding beams of protons.
- It is made of some sub-detector:
    - *inner detector*
    - *electromagnetic calorimeter*
    - *hadron calorimeter*
    - *muon spectrometer*
- A trigger system manage the rate of data acquisition.



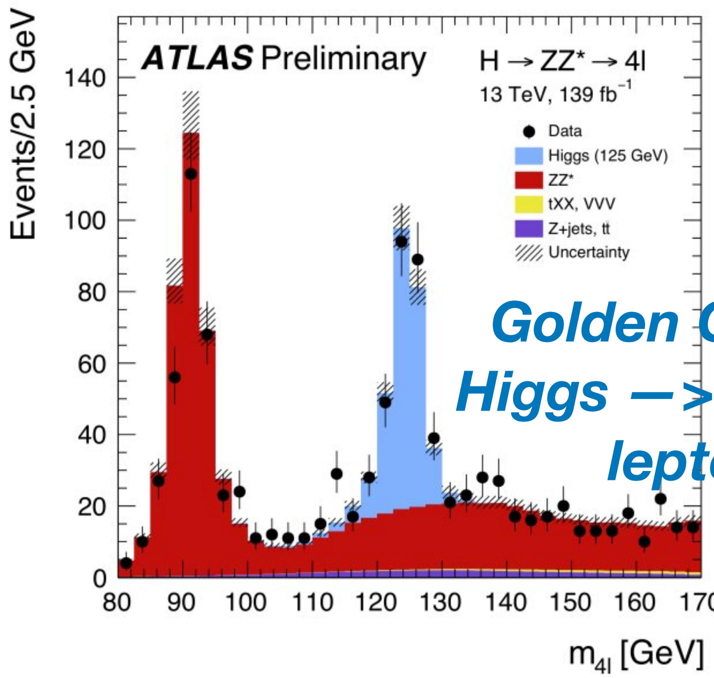
Physics results…



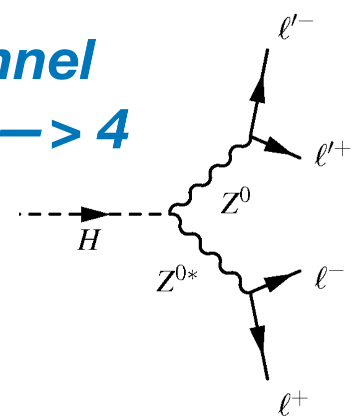
…many more results!

Why di-boson searches?

Higgs boson discovery!



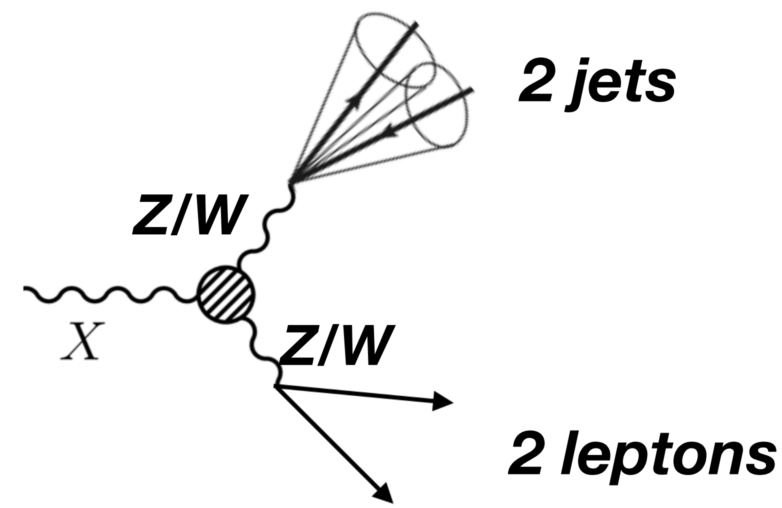
Golden Channel Higgs —> ZZ —> 4 leptons

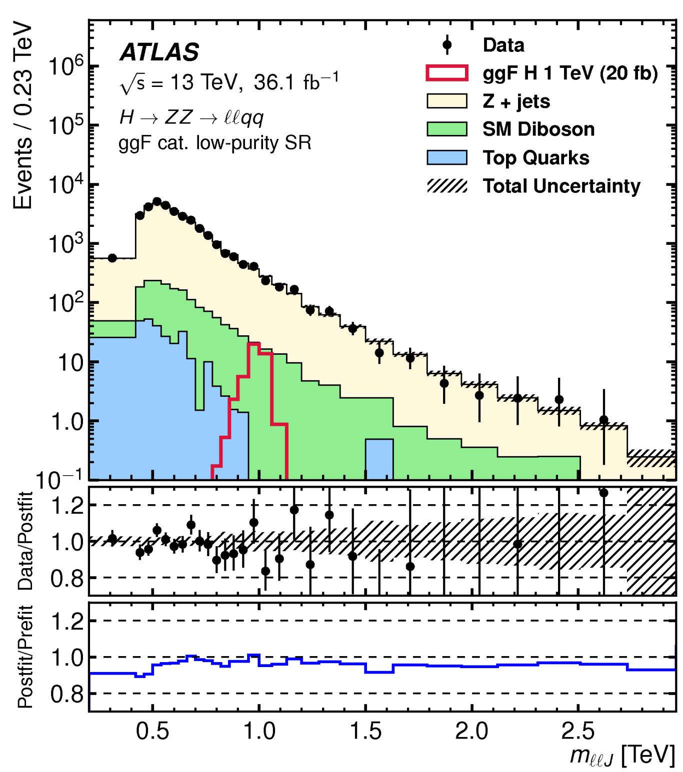


And now?

Diboson semi-leptonic channel (*X —> ZV —> llqq*) as signature for new physics

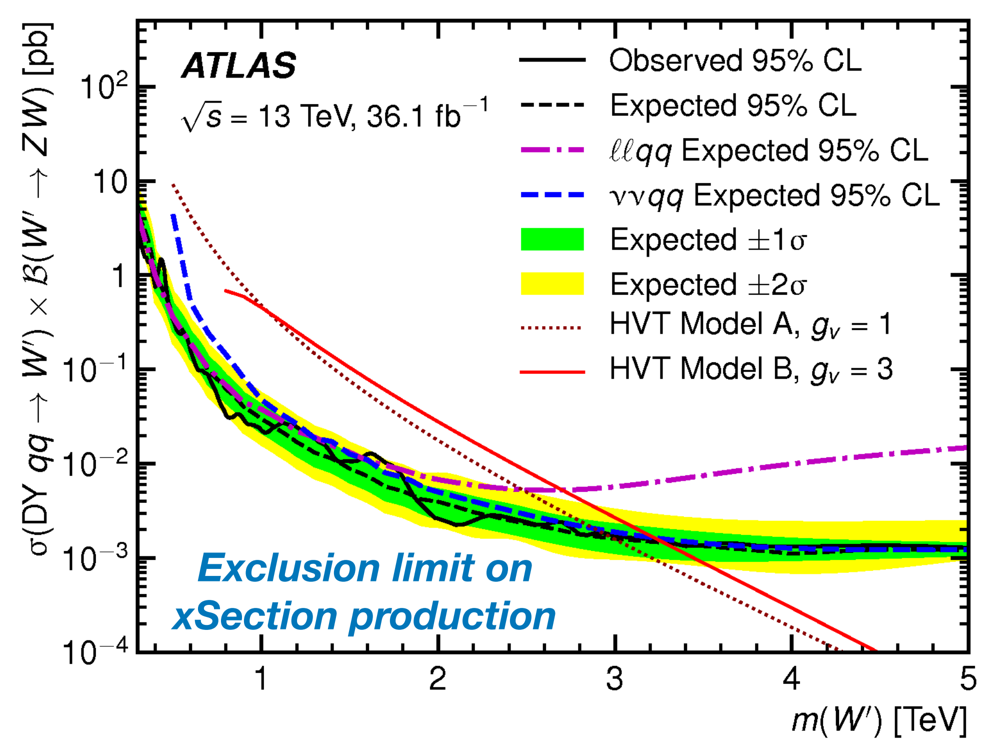
- 2 leptons improves the bkg rejection
- 2 quarks improve the decay rate of V boson





From data 2015-16 paper https://arxiv.org/abs/1708.09638

when no signal of new physics is observed…

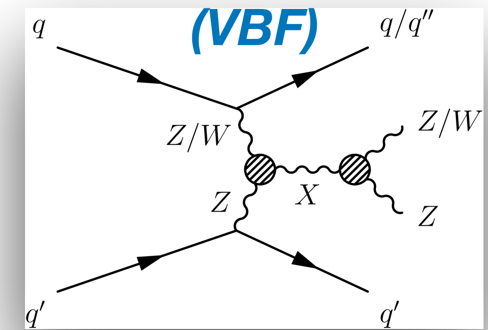


VBF/ggF classification

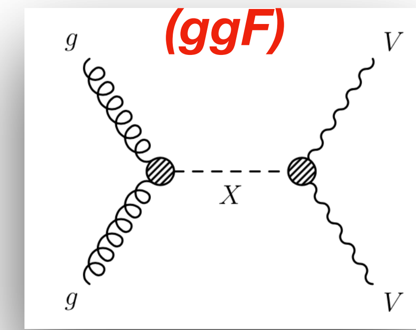
- Event classification according the production mechanism.
- Combination of 2 categories increases also the final sensitivity for exotic searches.

- Move to a new approach Neural Network based.
- Use the 4-momentum of jets:
  - low-level variables.
  - hidden correlation exploited from NN.

Vector Boson Fusion (VBF)

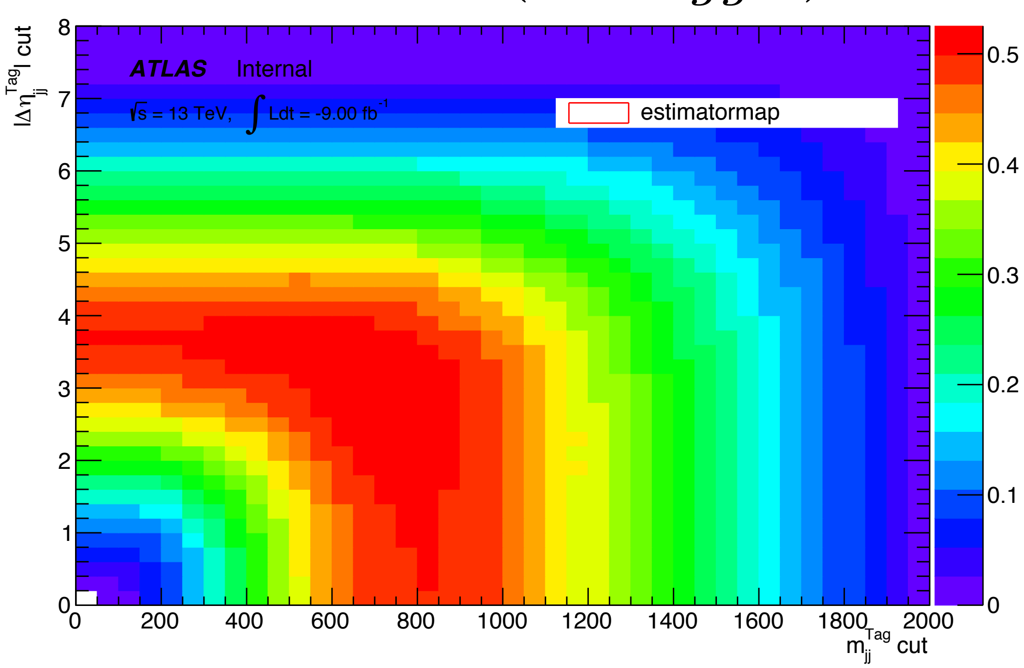


gluon gluon Fusion (ggF)

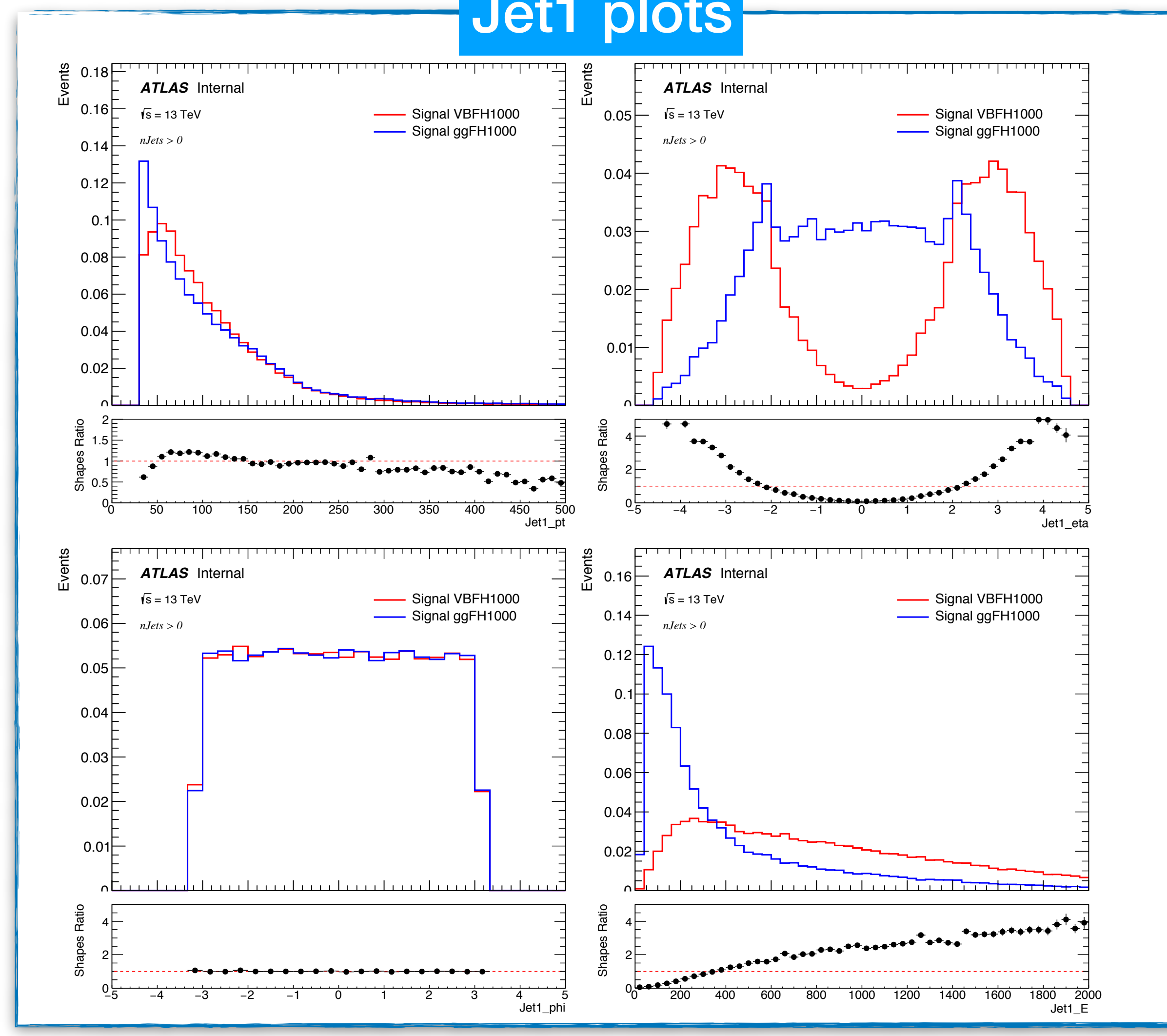


Cut based approach

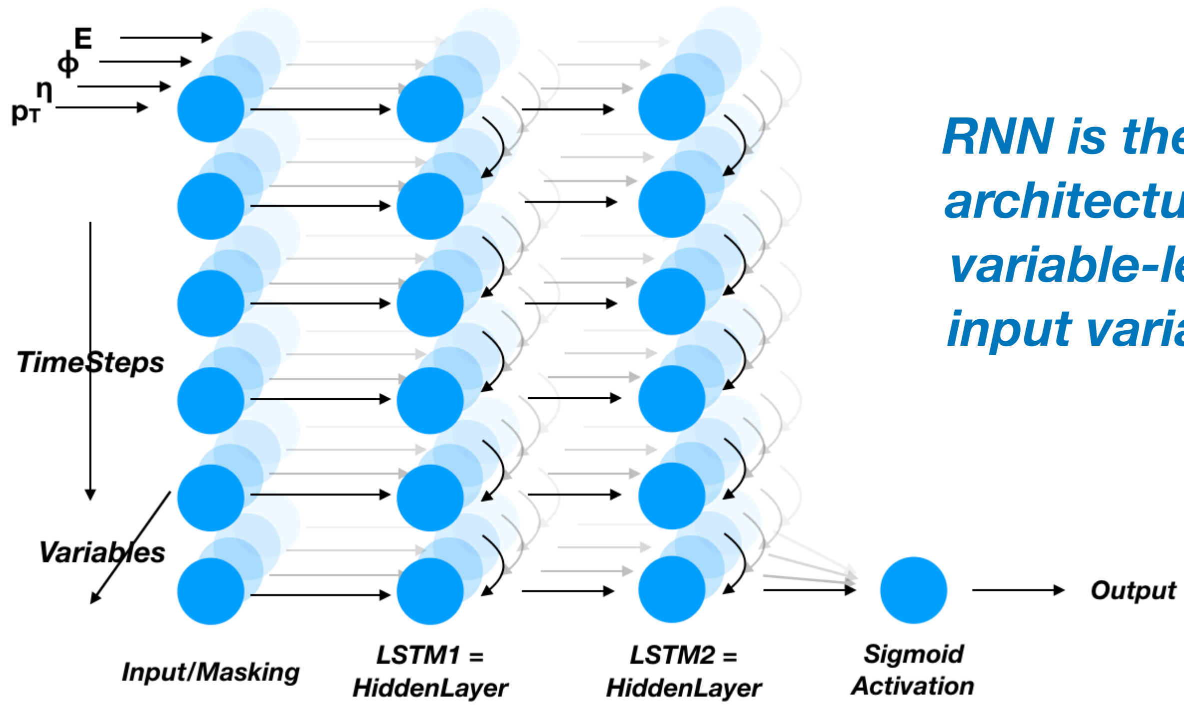
$$\sigma = \epsilon_{VBF}(1 - \epsilon_{ggF})$$



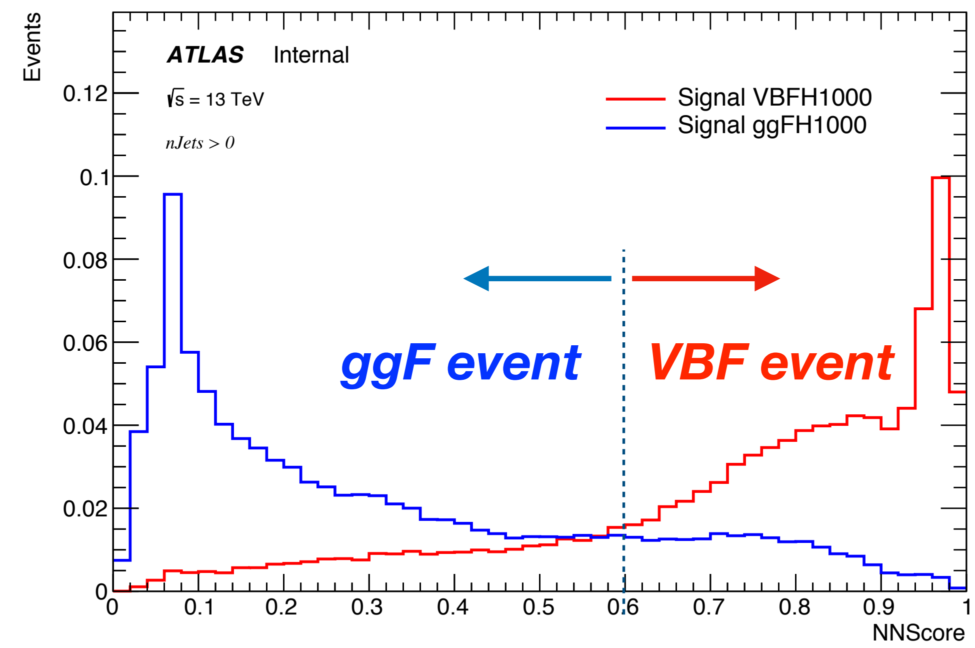
Jet1 plots

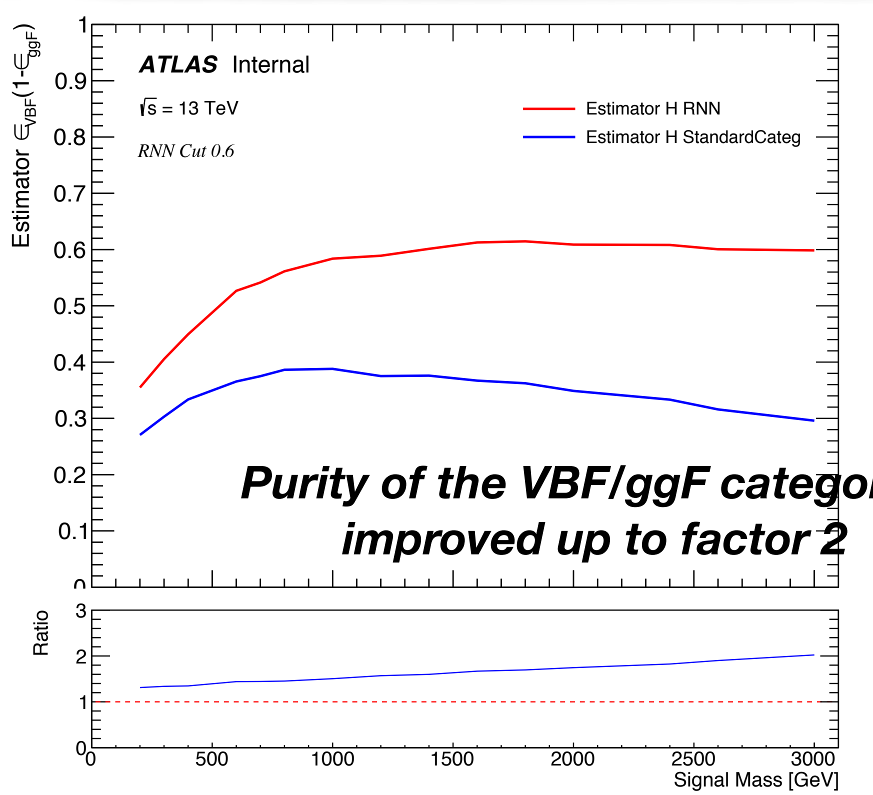


Recurrent Neural Network

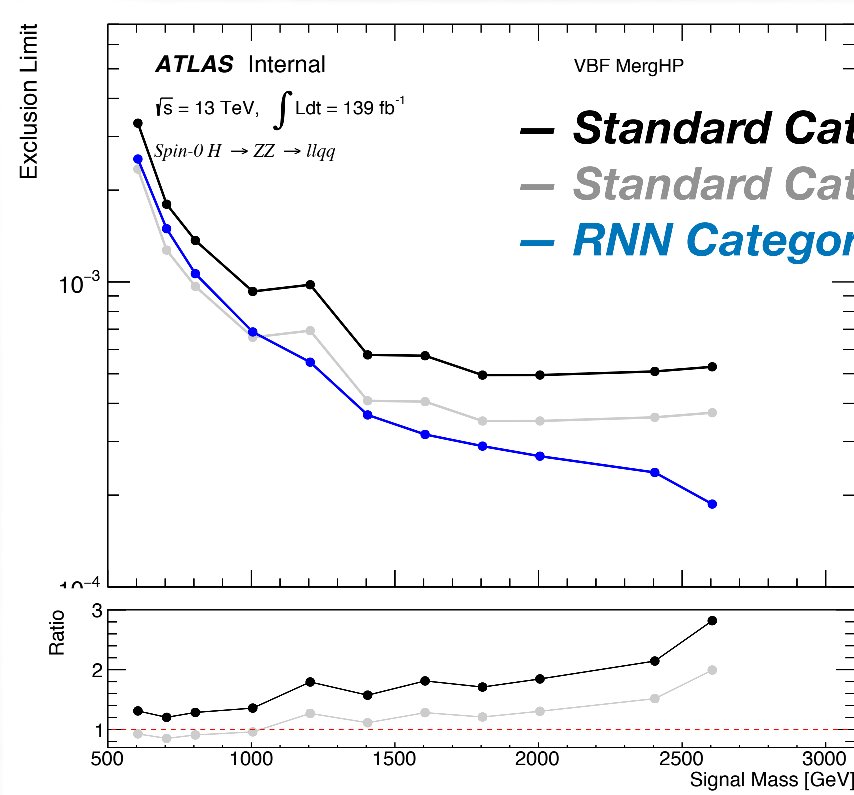


RNN is the best architecture for variable-length input variables!





Purity of the VBF/ggF categories improved up to factor 2



— Standard Categorisation @ 139 fb^{-1}
— Standard Categorisation @ 300 fb^{-1}
— RNN Categorisation @139 fb^{-1}

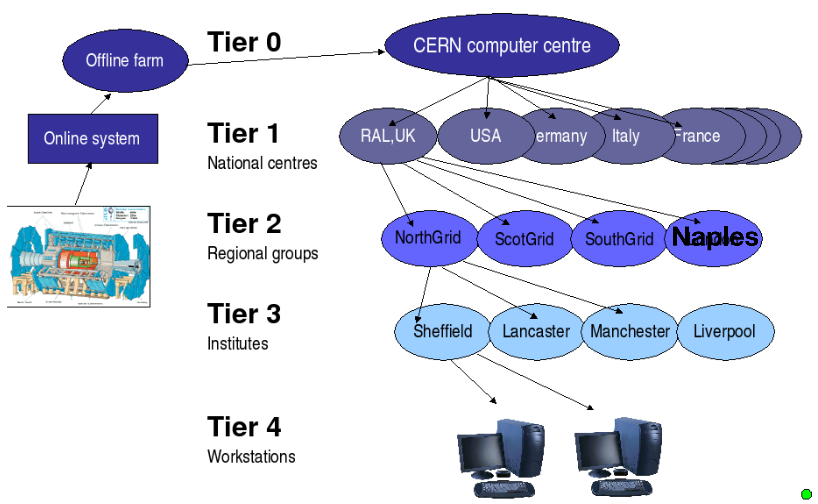
Final analysis sensitivity improved and even better respect perspective of RUN3 with old approaches!

Working on finalise the full Run2 paper

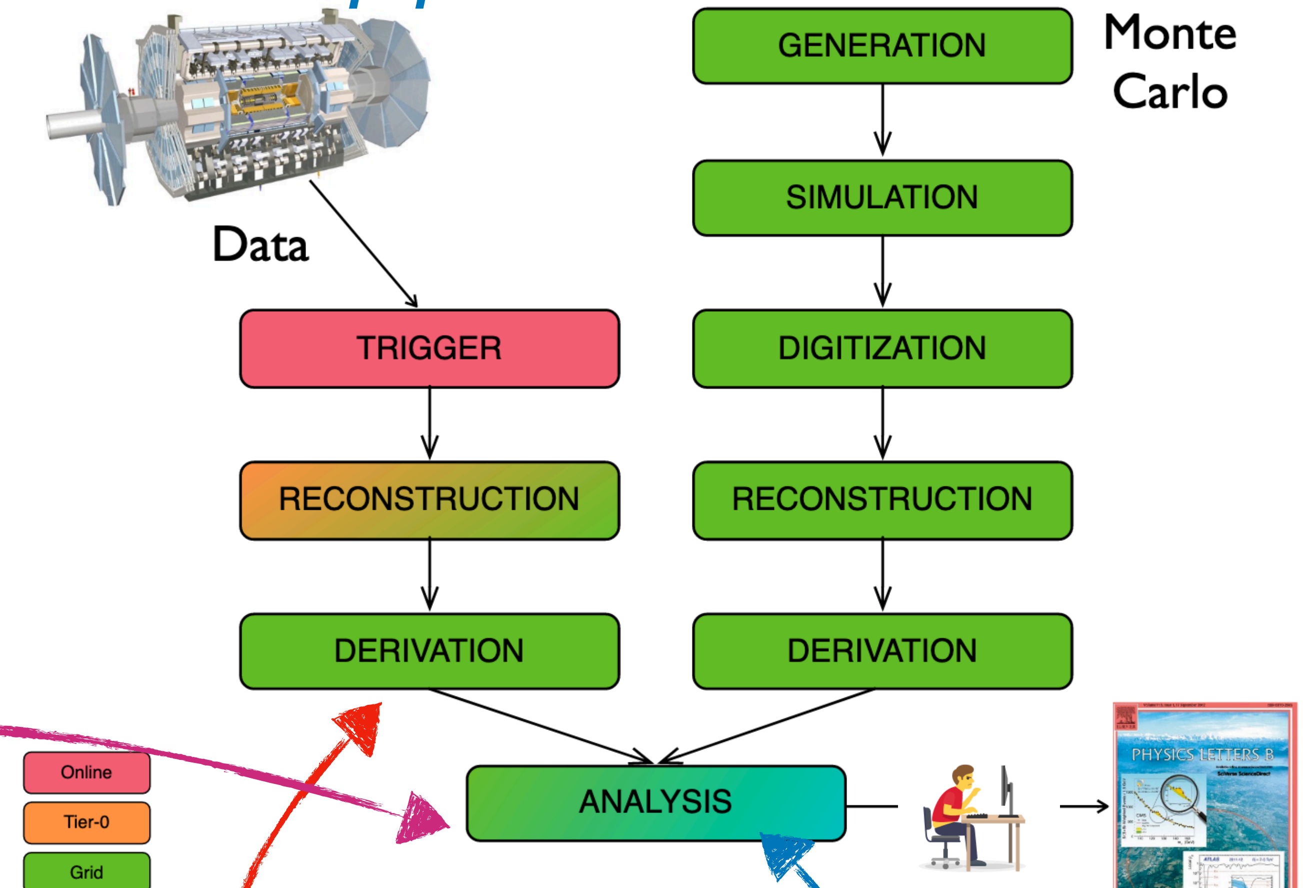
Interest in scientific computing

ATLAS grid computing system

Tier Structure



From collisions to papers



C++ && python frameworks

HTCondor High Throughput Computing

ROOT Data Analysis Framework

Keras

Machine Learning applications

Performances and object reconstructions, b-Jets tagging, tau-Jets reconstructions, …

Event Classification, physics process classification, new physics signal VS Standard Model background …

Backup

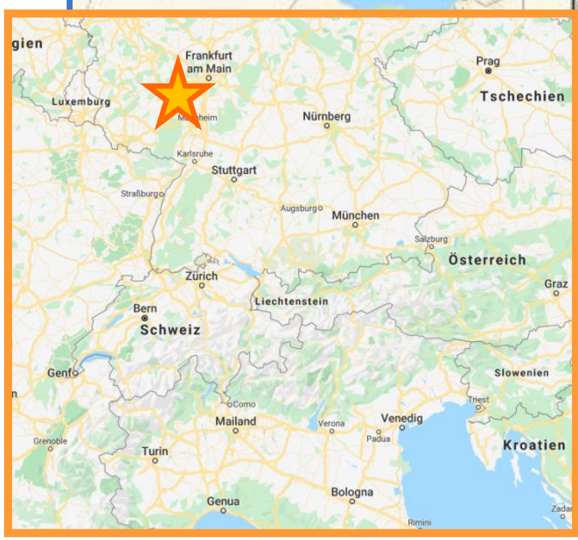
Mathilde Himmelreich

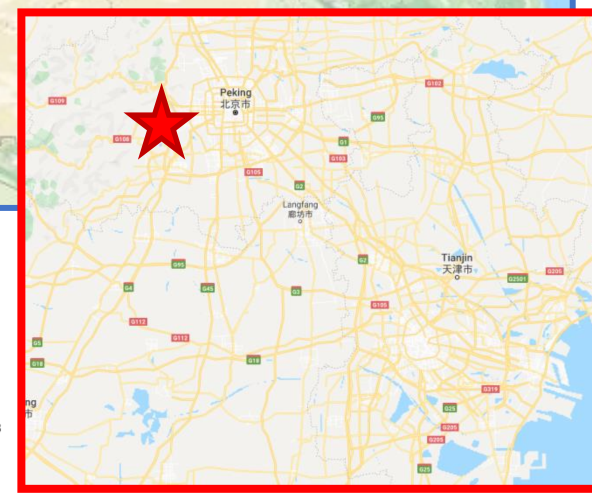
Baryonic decay channels of the Y4260

ESC 2019, Bertinoro, Italy

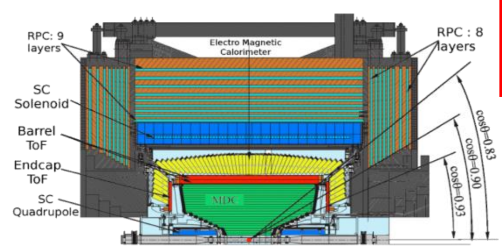
GOETHE UNIVERSITÄT FRANKFURT AM MAIN

GSI, IHEP and BESIII





GSI
Gesellschaft für Schwerionenforschung GmbH



BESIII (Beijing Spectrometer)

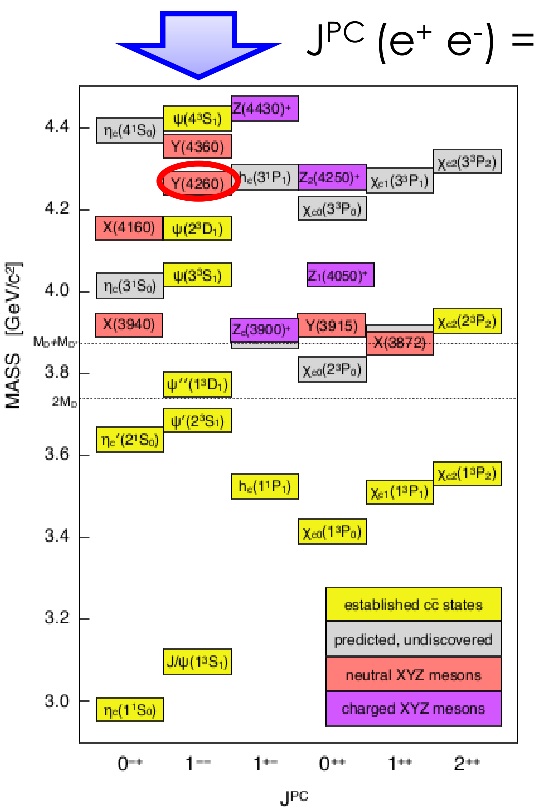
IHEP
Institute for High Energy Physics

Inclusive baryon analysis of the Y4260

Motivation

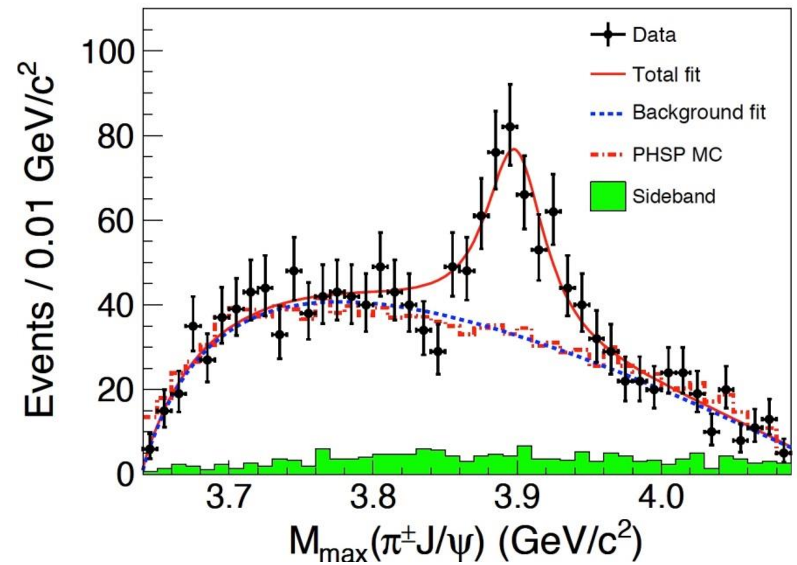
- Search and validation of QCD exotics
- Search for additional final states
- Search for isoscalar partners (I = 0)
- Explanation of measured states

$J^{PC}(e^+ e^-) = 1^{--}$



Spectrum of
charmonium – like mesons

PRL 110 252001 (2013)



Discovery of the $Z_C^{+/-}$ (3900)
in the J/ψ $\pi^{-/+}$ invariant mass spectrum
in the decay Y(4260) → J/ψ $\pi^+\pi^-$

Inclusive baryon analysis of the Y4260

$$e^+ + e^- \rightarrow Y(4260) \rightarrow \begin{cases} \Lambda^0\overline{\Lambda^0} \quad\quad + X \\ \Sigma^0\overline{\Sigma^0} \quad\quad + X \\ \Xi^0\overline{\Xi^0} \quad\quad + X \\ \Omega^- X^+ \end{cases}$$

$$\Lambda^0 \rightarrow p\pi^- + c.c.$$

$$\Sigma^0 \rightarrow \Lambda^0\gamma + c.c.$$

$$\Xi^0 \rightarrow \Lambda^0\pi^0 + c.c.$$

$$\Omega^- \rightarrow \begin{cases} \Lambda^0 \mathrm{K}^- (0.68) \\ \Xi^0\pi^- \,(0.24) \end{cases}$$

Analysing techniques and Computing

- Compute 4-vectors from reconstructed tracks
- Particle identification
- Particle selection
- Vertex fit (geometry)
- Optimisation of cut criteria
- Extract number of particles using mass plots
- Analysis of a high number of decay channels for an inclusive study requires many calculations → high performance required
- Single-Core Software in C++
- Cluster of ~10 k cores used and shared with other collaborations
- Local analysis of processed with ROOT

The BESIII Offline Software System (BOSS) is developed on the operating system of Scientific Linux CERN (SLC), using C++ language and GAUDI framework. The software uses some external HEP libraries such as CERNLIB, CLHEP, ROOT, Geant4 etc. The CMT is used as the software configuration management tool. MYSQL is used as database server.

http://english.ihep.cas.cn/bes/doc/2247.html

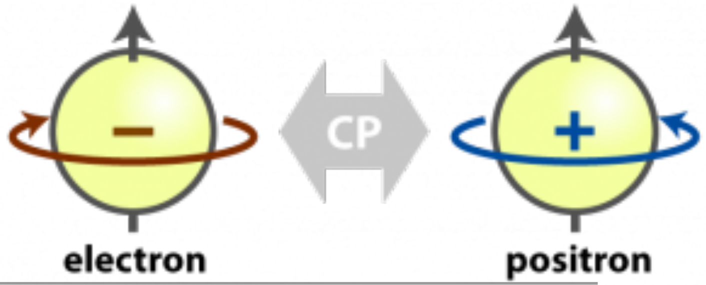
CP violation in charm physics

Serena Maccolini

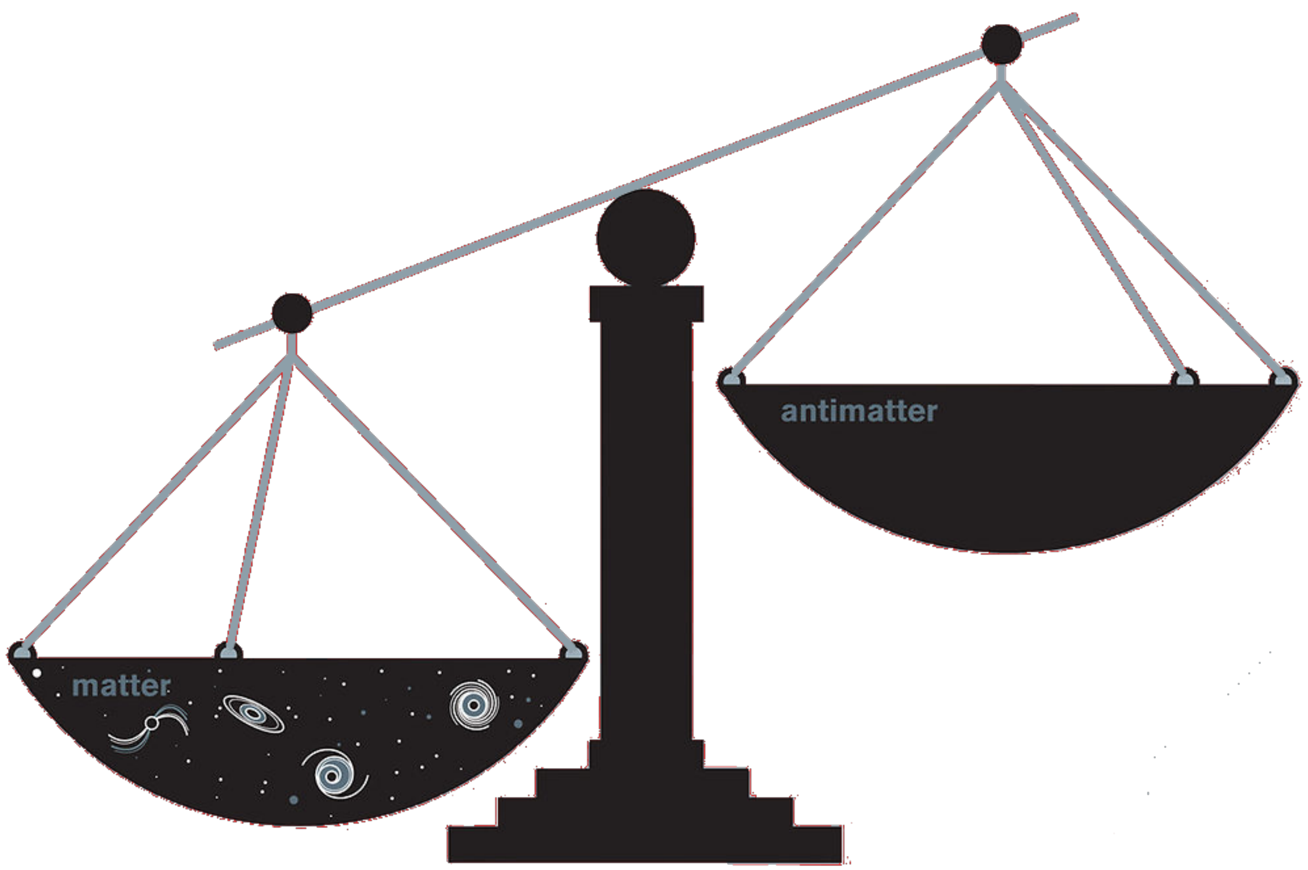
19° Efficient Scientific Computing School
October 21, 2019 - Bertinoro (FC)

serena.maccolini@cern.ch
University of Bologna and INFN-BO

CP violation

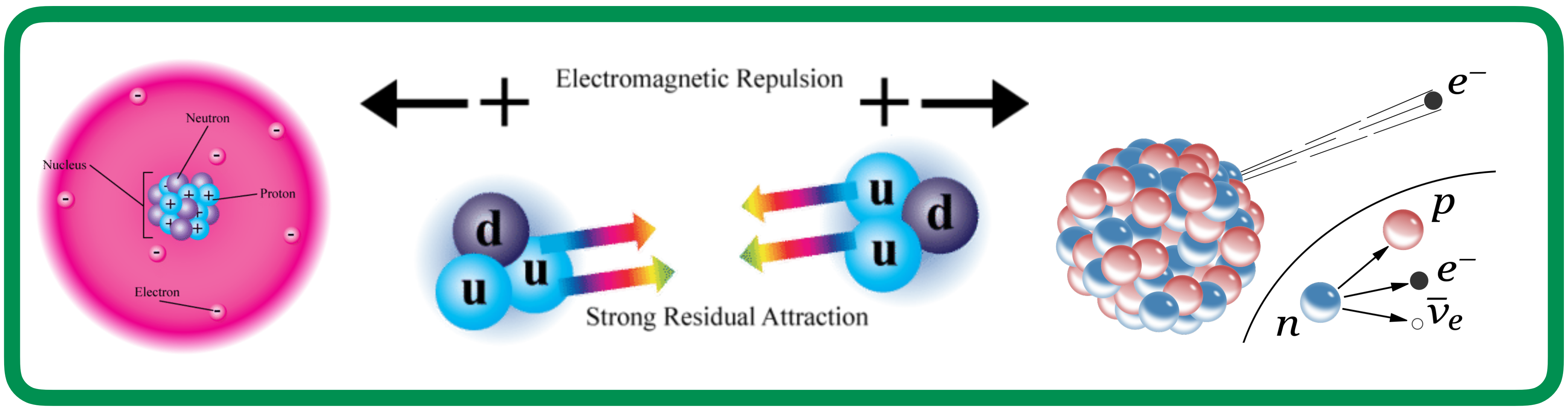


- ***CP*** is the combination of the charge conjugation *C* and parity transformation *P*
- If there is a difference between the ways nature treats ***matter*** and ***antimatter*** then *CP* is violated
- In our **universe**:
  matter is more abundant
  (baryon asymmetry)



The Standard Model

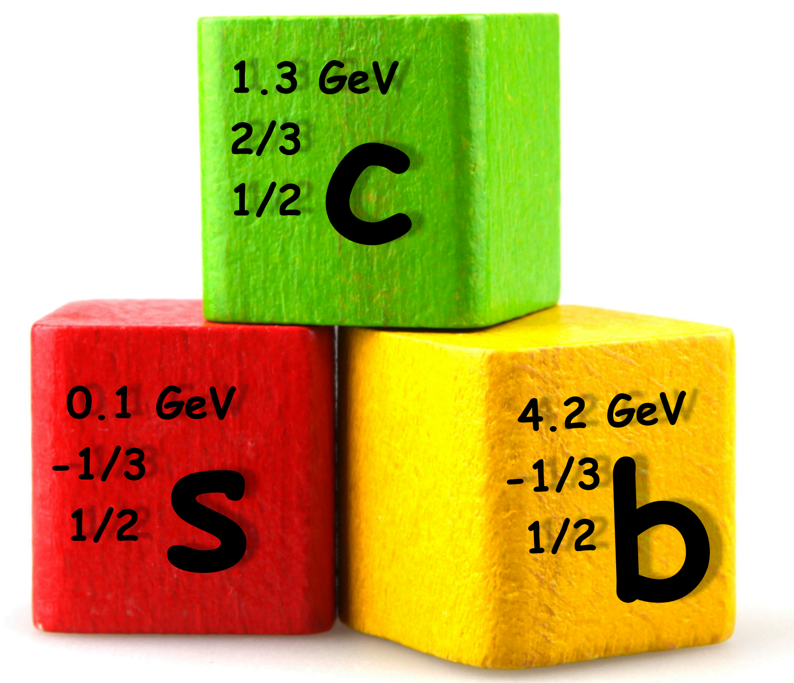
- The **Standard Model** (SM) describes three of the four known fundamental forces (the *electromagnetic*, *strong*, and *weak* interactions, and not including the gravitational force)



- Elementary particles include **bosons** (force carriers, *e.g. Higgs* particle or *gamma* rays) and **fermions** (matter and antimatter, *e.g. electrons* or *quarks*)

Why study *charm* physics?

- *CP* is naturally violated in **weak** interactions of *quarks* but the amount of baryon asymmetry which can be produced is too small
  → we hope that *CP*-violating **new physics** (NP) exists and we are looking for it

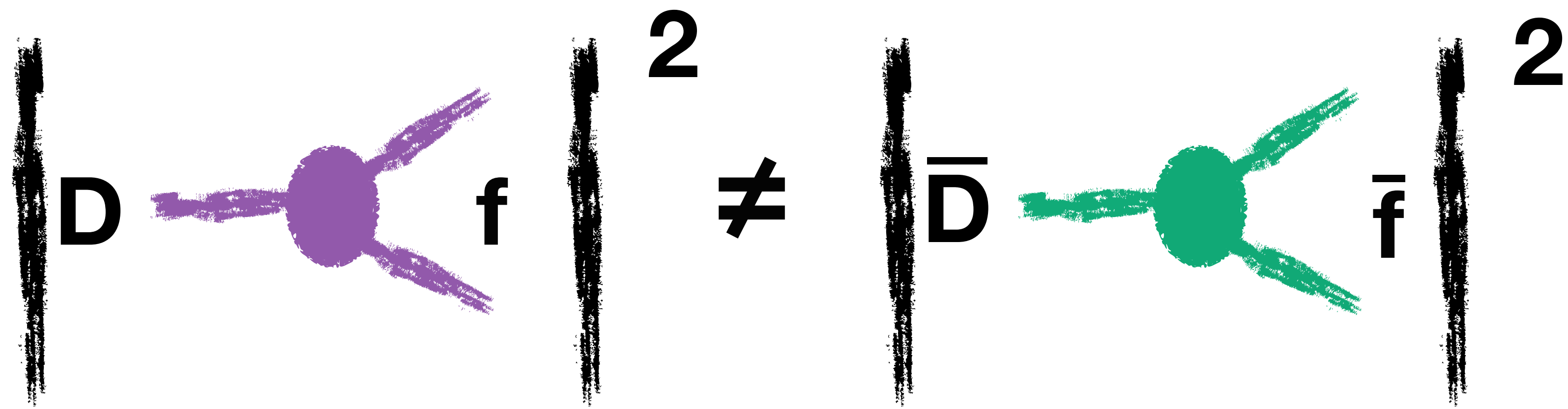


- The best way to search for NP is to study decays of particles containing the quark **charm** where **small** *CP* asymmetries are expected

- This year, *CP* violation in charm has been **finally observed** by the ***LHCb*** experiment!

- The result is *compatible* with SM predictions but contributions from NP cannot be excluded at the moment. For this reason **more experimental inputs** are needed for theoretical tests.

Direct *CP* violation



- Corresponds to

$$\mathcal{A}_{CP} = \frac{|A_f|^2 - |\bar{A}_{\bar{f}}|^2}{|A_f|^2 + |\bar{A}_{\bar{f}}|^2} \neq 0$$

- Most promising channels are **suppressed** decays where underlying physics could hide CP-violating interactions

Experimentally…

- *Raw asymmetry* between the **observed** yields:

$$A(D \to f) = \frac{N(D\to f) - N(\bar{D}\to \bar{f})}{N(D\to f) + N(\bar{D}\to \bar{f})}$$

- Contributions other than **A*CP***

Production asymmetry

$$A_P(D) = \frac{\sigma(D) - \sigma(\bar{D})}{\sigma(D) + \sigma(\bar{D})}$$

Detection asymmetry

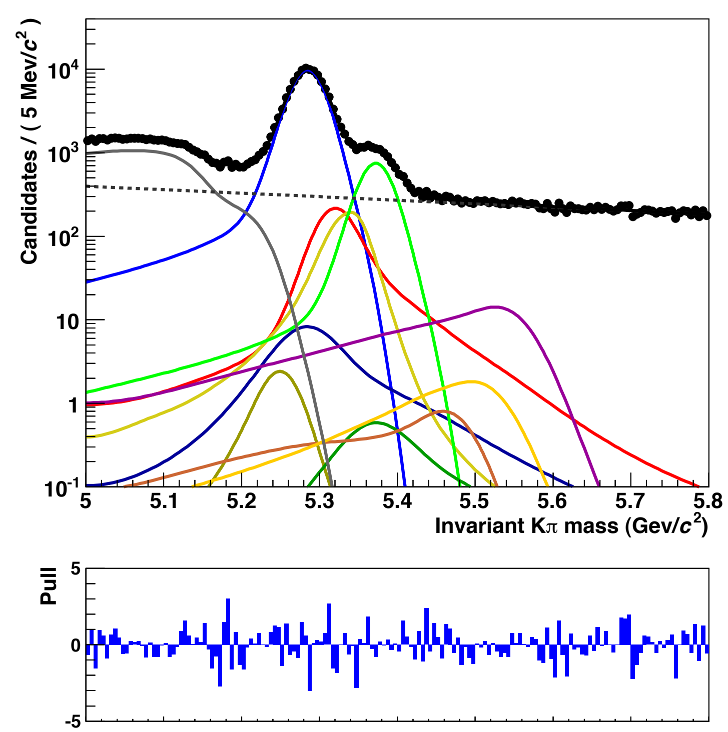
$$A_D(f) = \frac{\epsilon(f) - \epsilon(\bar{f})}{\epsilon(f) + \epsilon(\bar{f})}$$

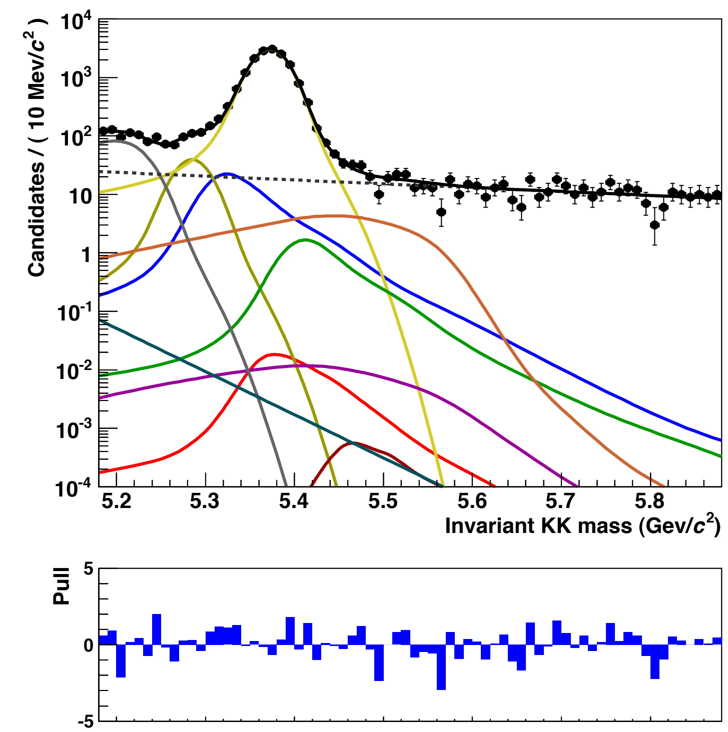
- The tough part is exploiting known decays (control channels) to **correct** these contributions and isolate A_{CP}

Where is the computing?

- Computing power is becoming a limiting factor:
  - Need to handle huge data samples (hundreds of millions events) → efficient memory usage
  - Need to solve maximum likelihood estimation (MLE) problems with complicated probability density functions (PDFs)s → run on graphics processing units (GPUs)

Fit with "only" 55 free parameters and needs about 12 hours to be completed on a single CPU





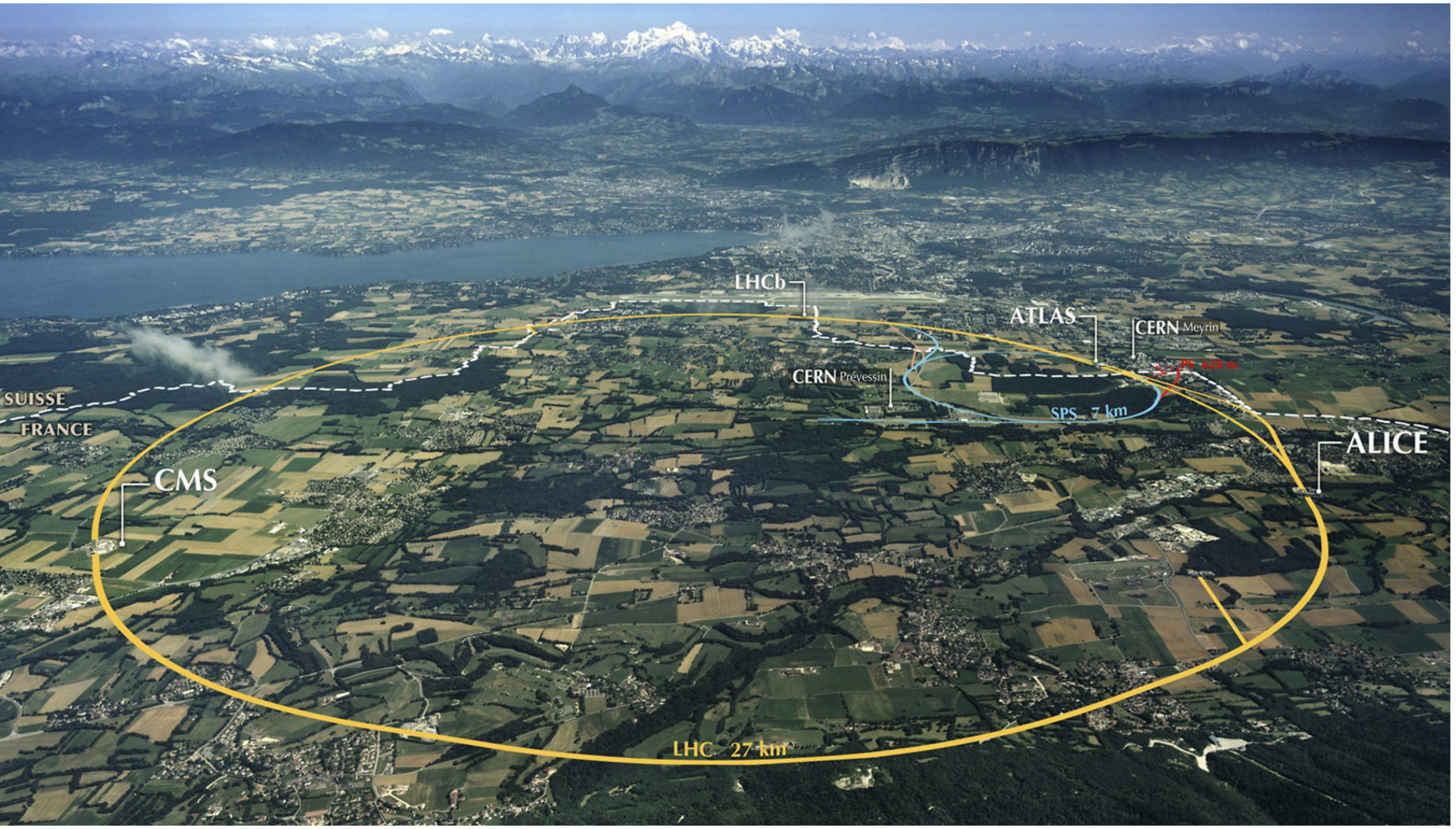

Thanks.
CERN
Physics
Matter
LHCb
Charm
Flavour
CP
asymmetry
violation
interactions
mixing
Weak
anti-matter
Machine learning
Particle
LHC

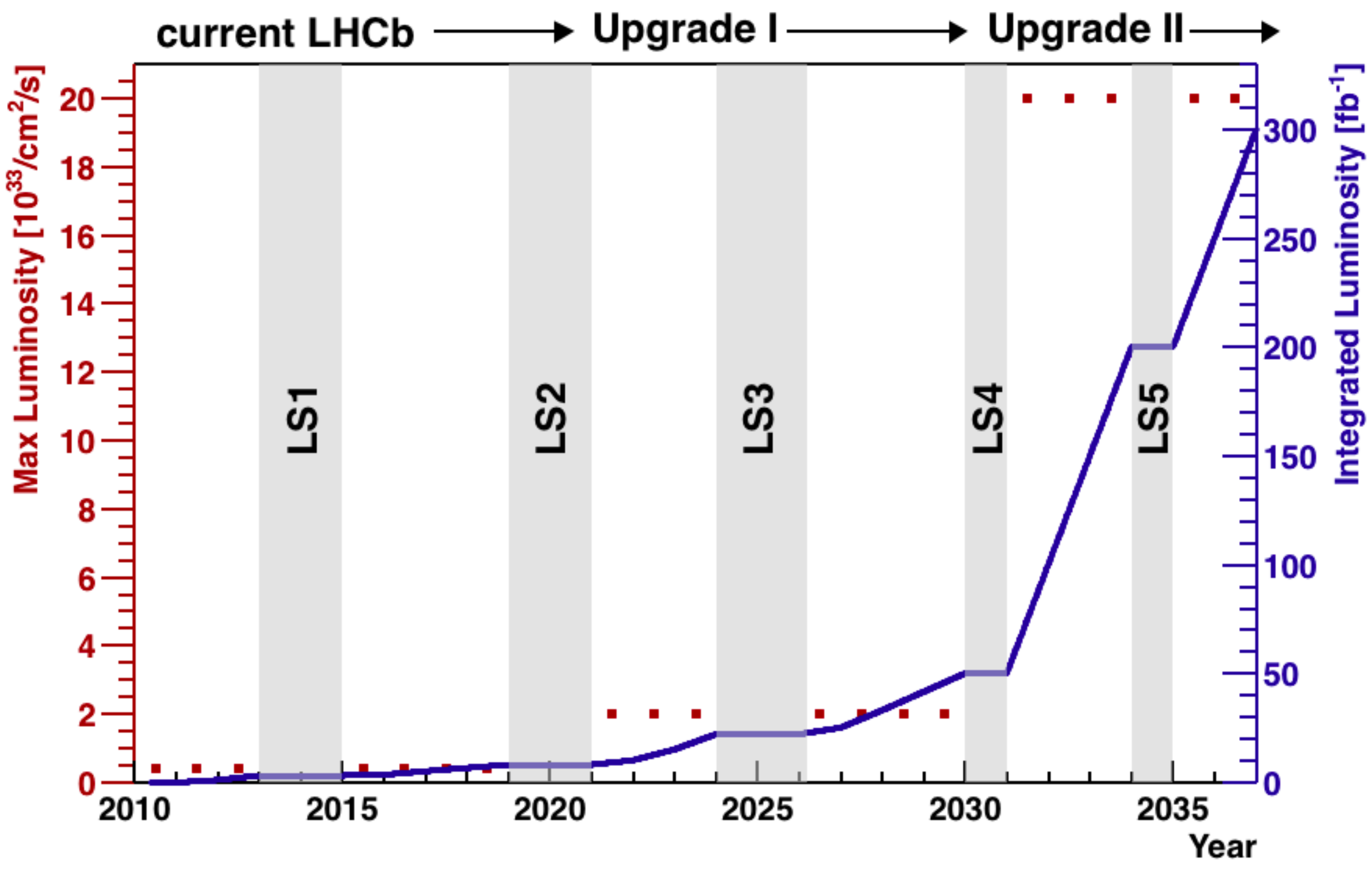
A new ECAL for LHCb experiment

Daniele Manuzzi

11th ESC, 20-26 October 2019, Bertinoro (IT)

The Large Hadron Collider





1Collider

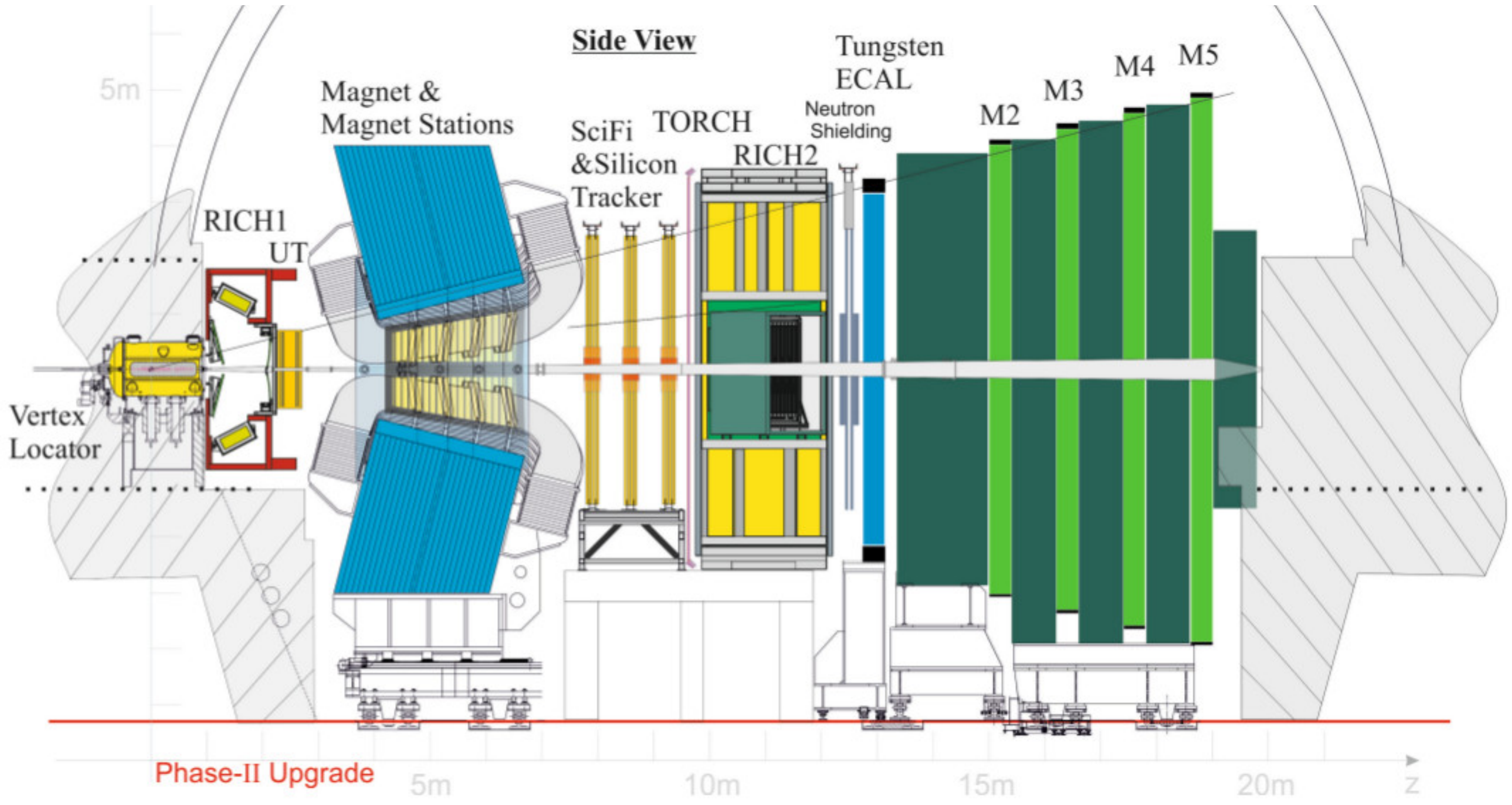
4 Experiments

Frontier of energy

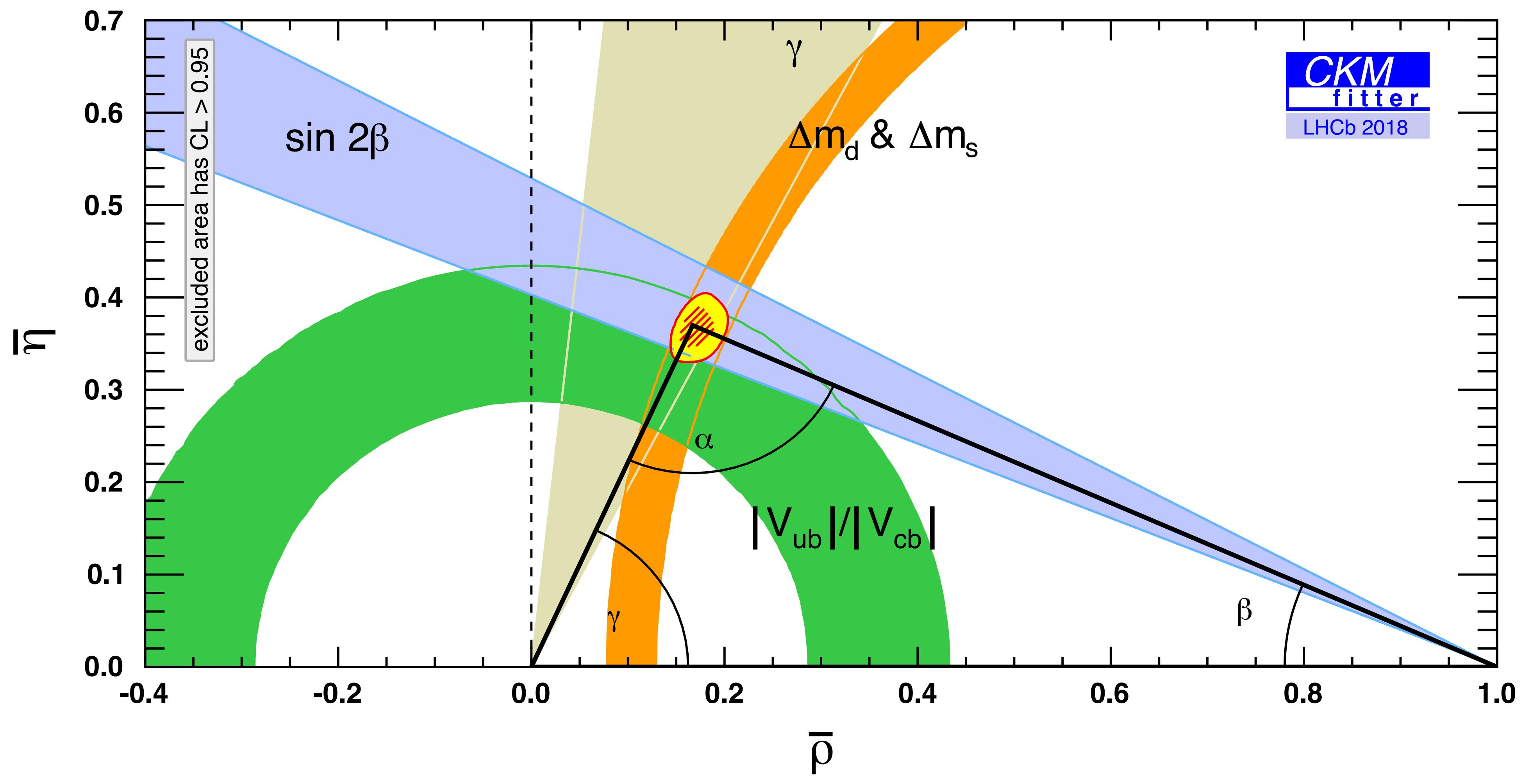
Frontier of "luminosity"

LHCb experiment

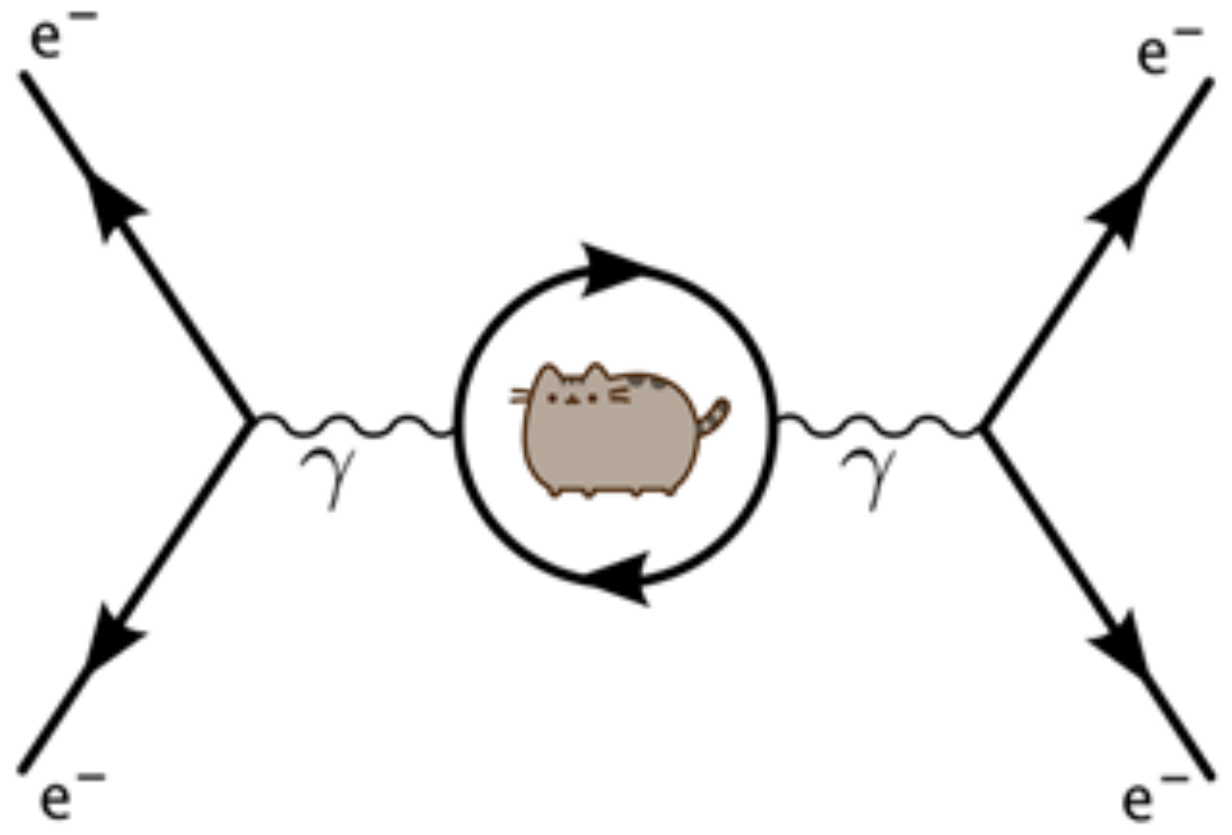
- Forward Spectrometer



- Precise tests of the Standard Model

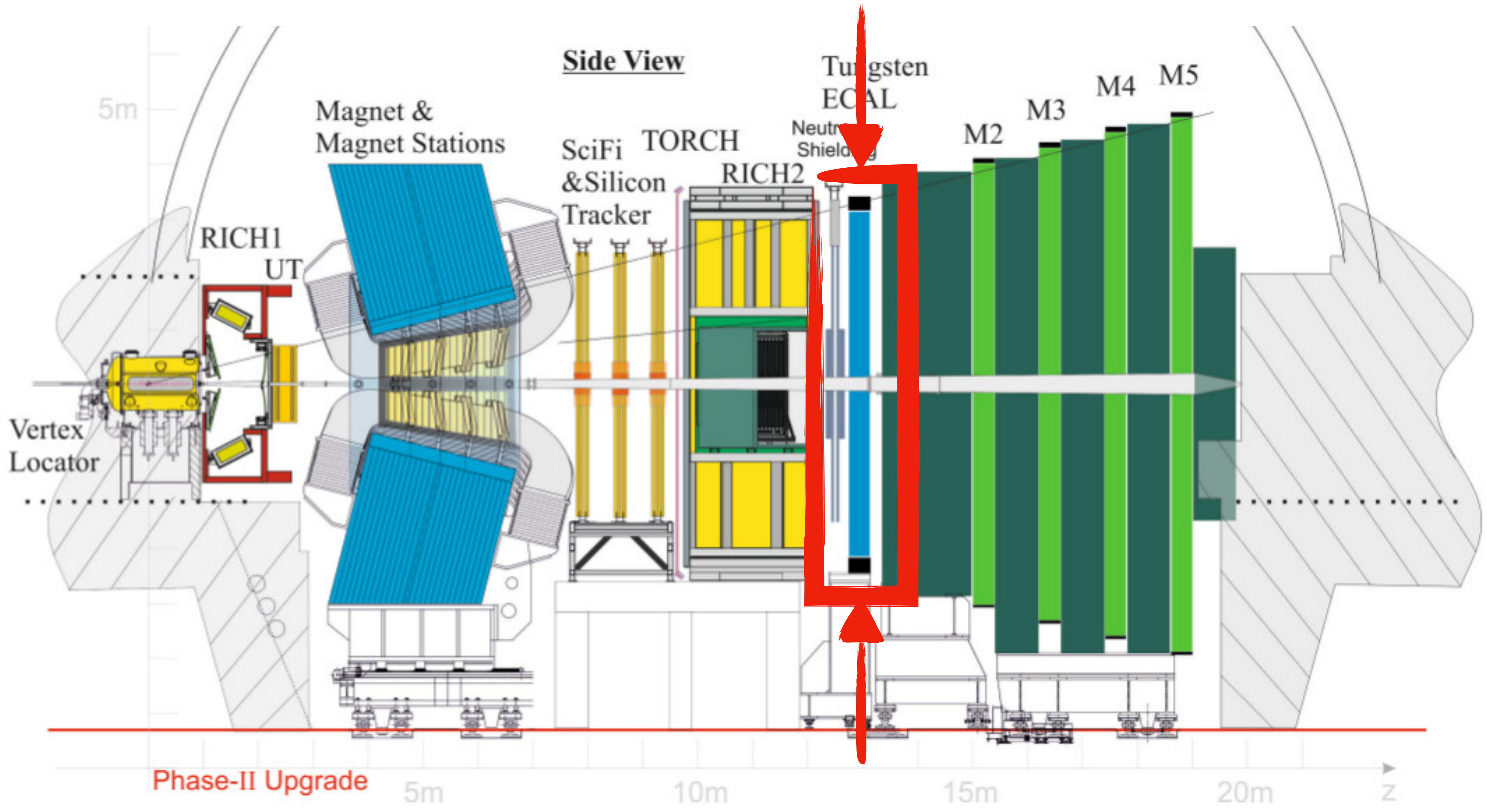


- Indirect search for new physics

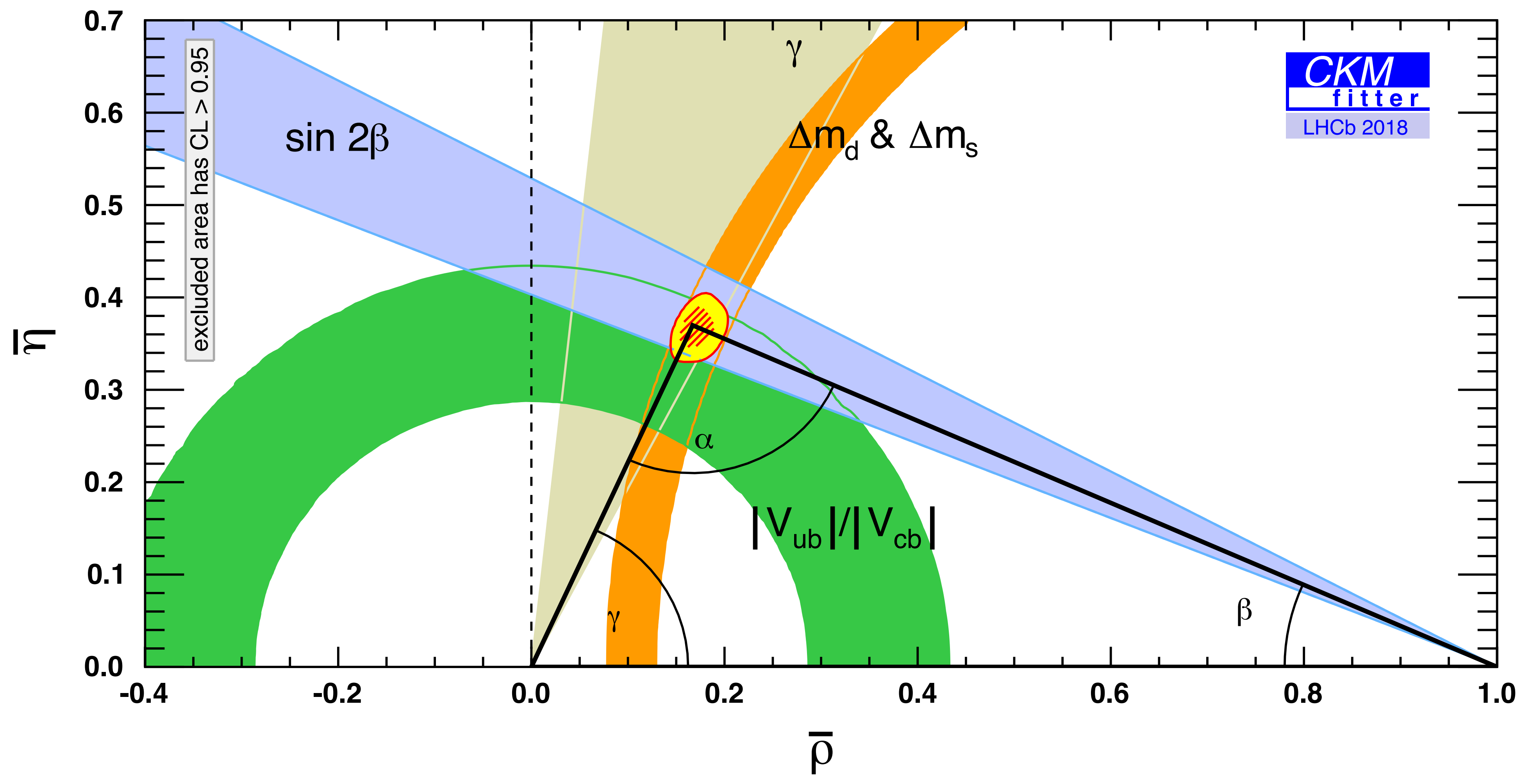


LHCb experiment

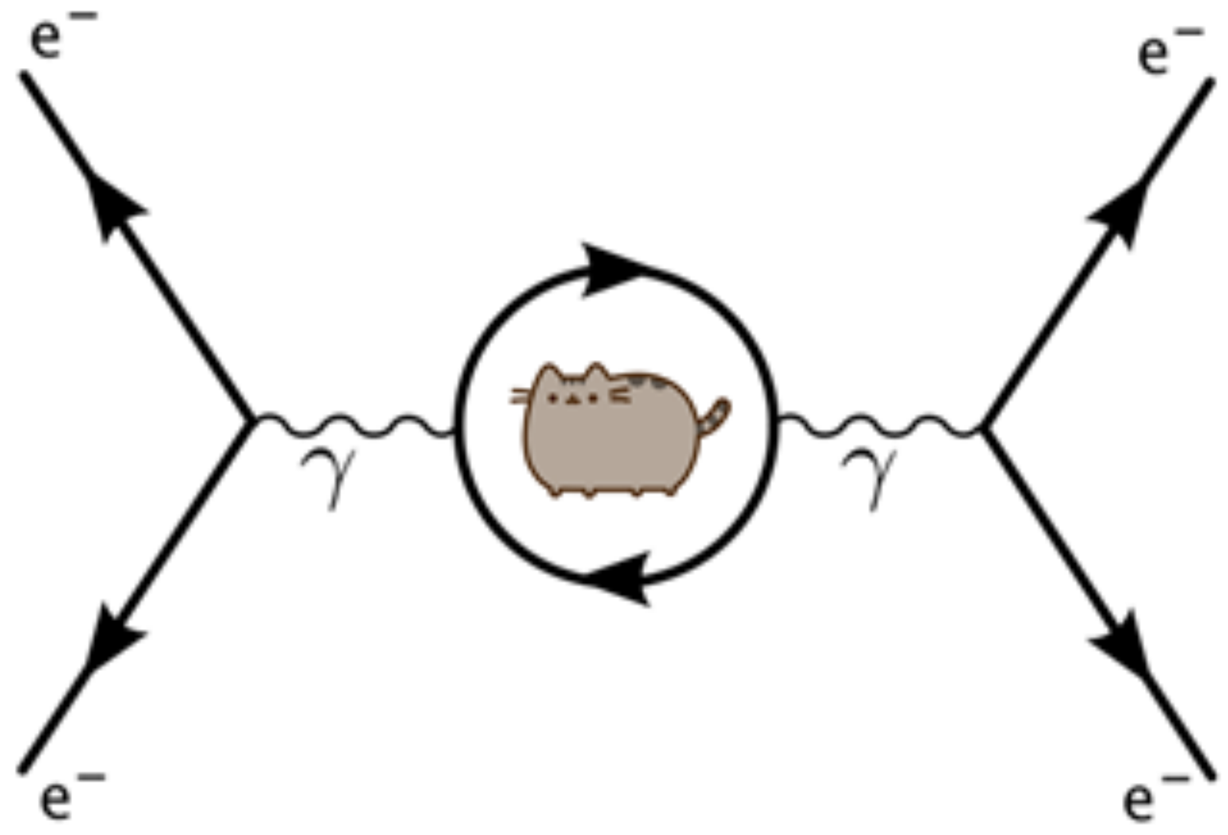
- Forward Spectrometer



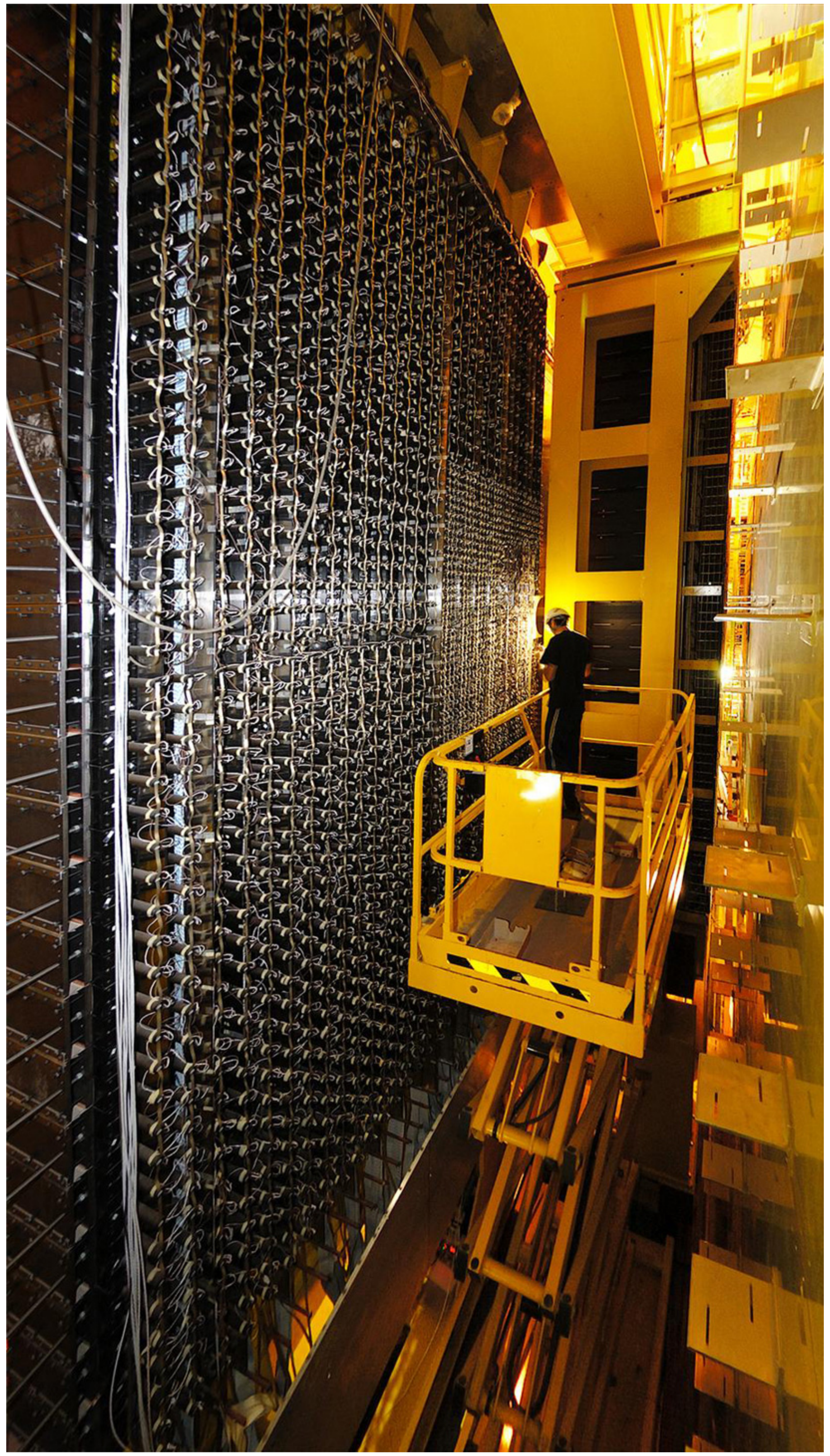
- Precise tests of the Standard Model



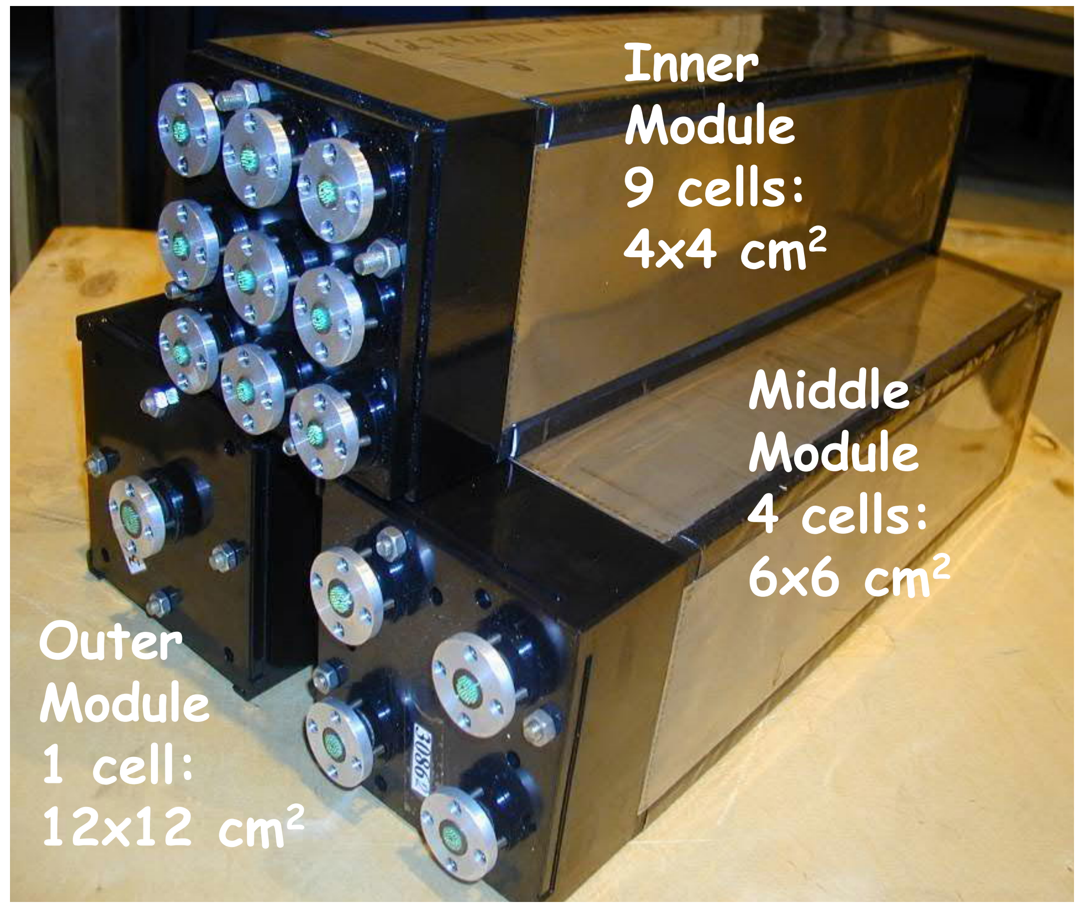
- Indirect search for new physics



Electromagnetic Calorimeter



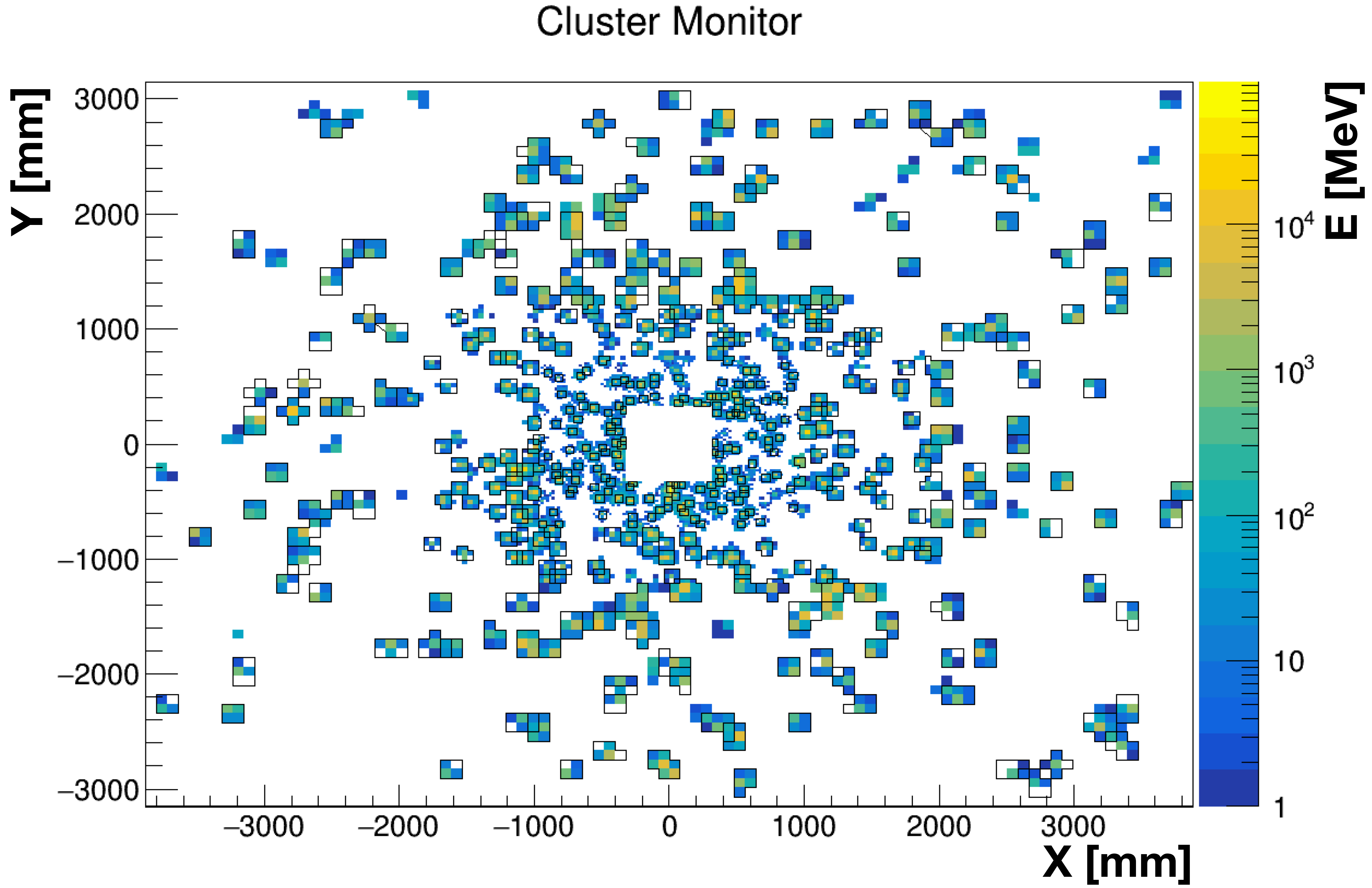
- It is a wall, made of cells able to detect electrons and photons (identity, position, energy)

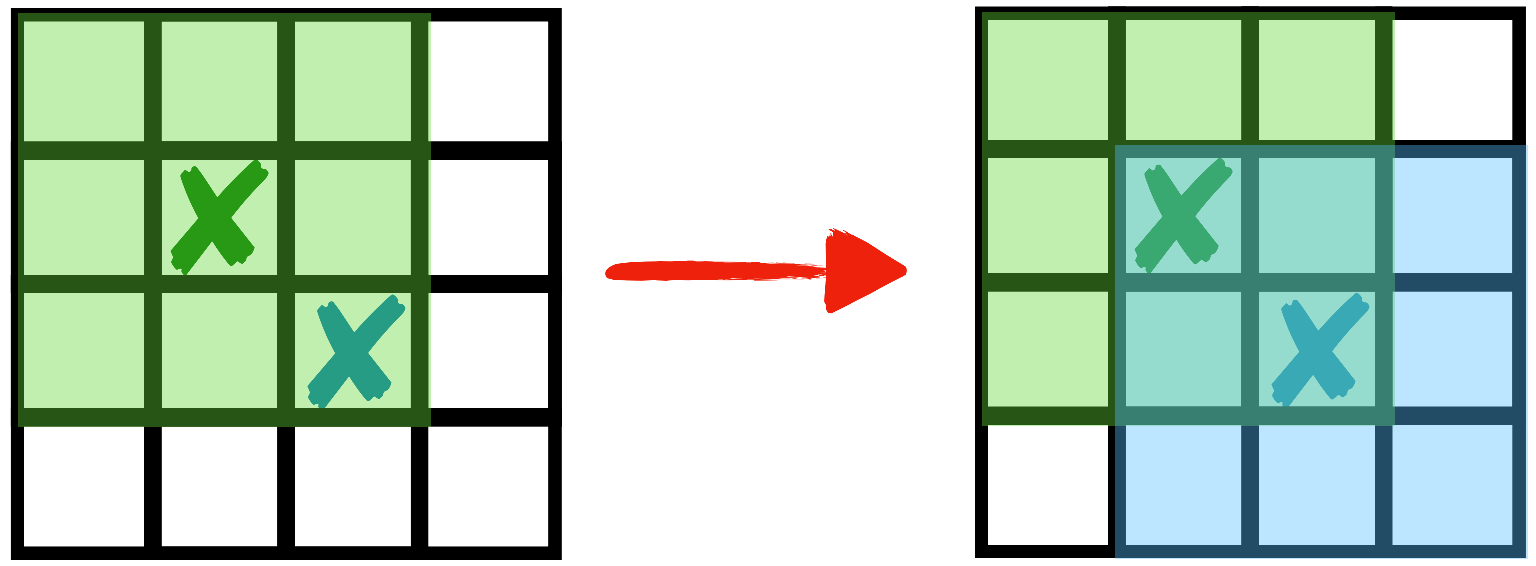


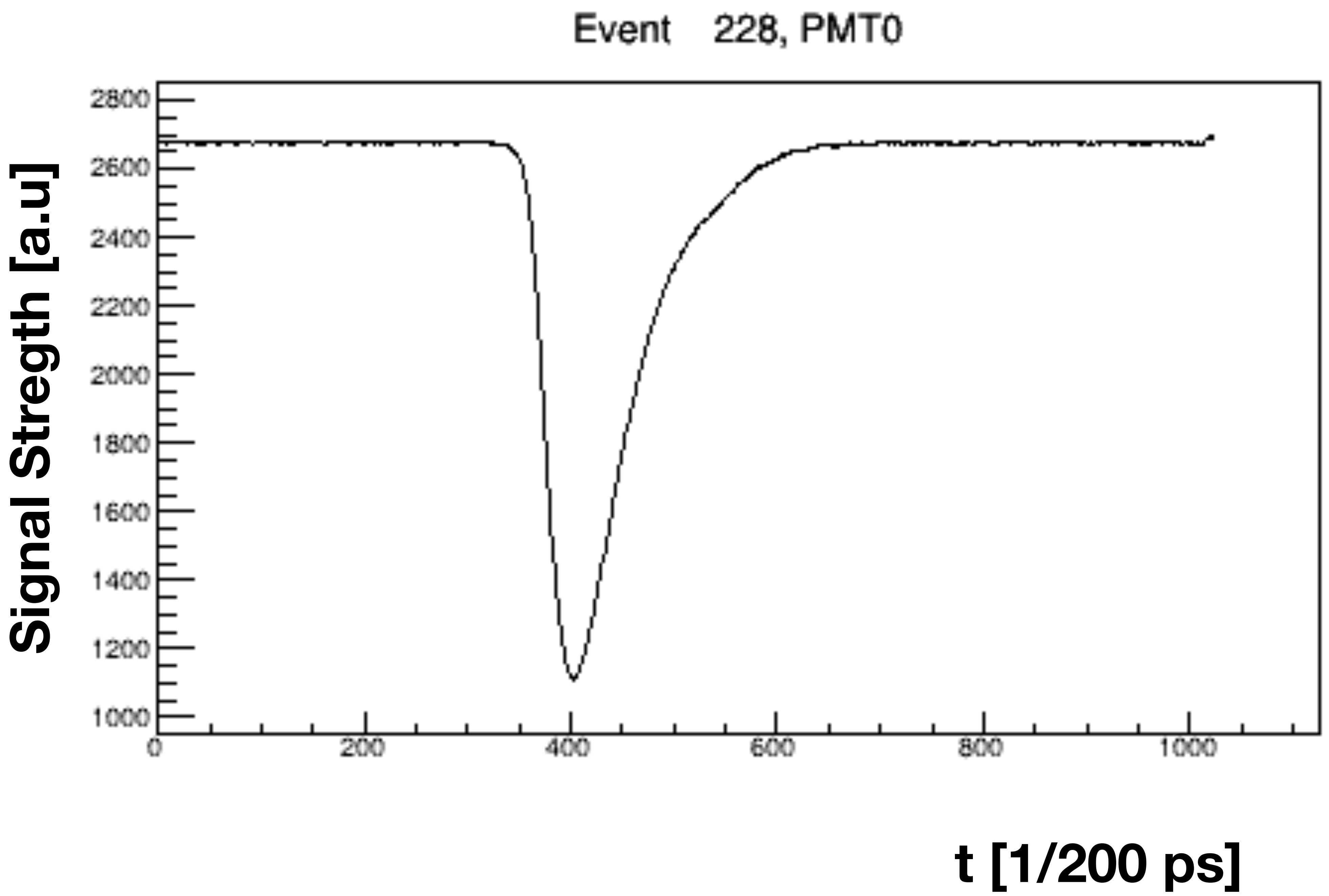
- Problems for the future:
  - Radiation hardness
  - Overlapping showers
  - Large combinatoric background

- Future ECAL design:
  - Smaller cell size
  - Smaller Moliere's Radius
  - Time information
  - New Reco. Algorithms

What I am studying now



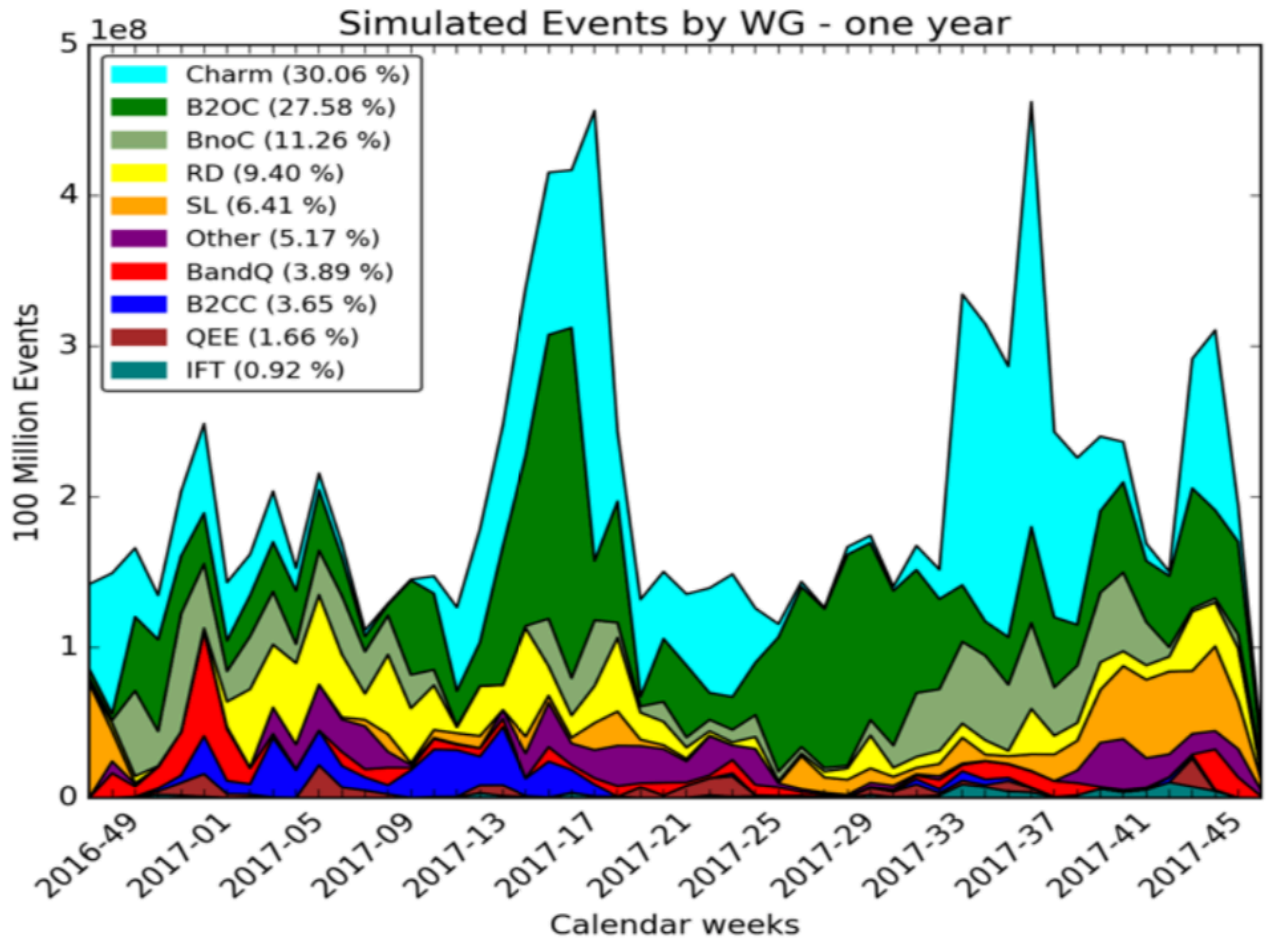




- Simulation of future ECAL response
- New reco. strategy to fight occupancy
- Efficient exploitation time information

Current Computing tasks

- LHCb:
  - Full software trigger *new!*
  - Huge need of resources for simulation



- Me:
  - Need to increase the performance of my code (time and memory consuming jobs)
  - Learn to write clearer scripts to be integrated in LHCb standard software