GPU APPLICATION IN HEP

M. Bauce

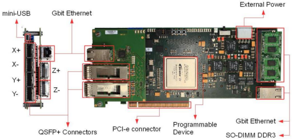
Sapienza Università di Roma

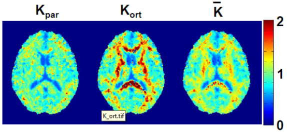
October 21, 2013

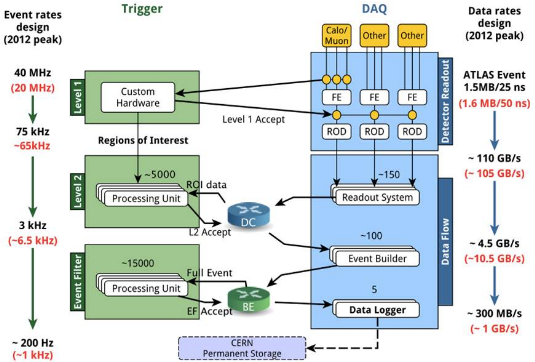
The GAP project

GAP - GPU application project for realtime in HEP and medical imaging, funded by the italian ministry of research.

- Interest in three different fields:
  - Low Level Trigger systems
  - High Level Trigger systems ◄◄
  - Real-time medical imaging

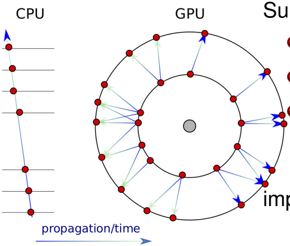






The Atlas trigger

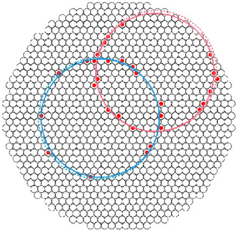
Example of applications



Suitable for parallellized algorithms:

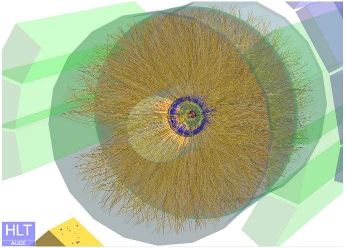
- Path finding
- Track extrapolation
- Simple fits

If fast enough can be implemented in the trigger system.



NA62 Low Level Trigger

ring reconstruction from Cherenkov detector:
$\sim$ 50 ns/ring at L0, $\sim$ 1.5 μs/event at L1



Alice HLTrigger

- Input: 300 Hz - 30 GB/s
- 20k tracks to reconstruct
- All track reconstruction:
  CPU: 1 s $\rightarrow$ GPU: 300 ms

Who i am?

Riccardo Biondi

Born in Matelica (Mc) , 26 years old , always fascinated by science and computers since i was i child, so i decided to be a physicist

Academic path:

- Studied high energy theoretical physics at Università "La Sapienza" in Rome
- Final thesis on: neutrinoless double beta decay
- A numerical computation of nuclear matrix element
- Realistic description of neutron-neutron correlation function

PhD Activity

PhD student ad università dell'Aquila

- Phenomenology of Sterile – Active Neutrino oscillations
- Dark Matter: Mirror Dark Matter models
- Phenomenology of Mirror – Standard neutron oscillations
- Data analysis of UCN trapping experiment ad ILL

Why am i here?

In my activity as PhD student i have to work with tools like:

- Numerical computation
- Experimental data Analysis
- Montecarlo simulations

I am here to improve my abilities in scientific computing and to learn new methodologies to use in my research activities.

A fast overview of ...

New PFA techniques for Jet Energy Resolution improvement toward the ILC experiment. Preliminary study of the e+e- $\rightarrow$ H Z channel

Eté Rémi

Claude Bernard University Lyon 1 - Institut de Physique Nucléaire de Lyon (IPNL)

October 21th , 2013

ESC 13

ILC : International Linear Collider

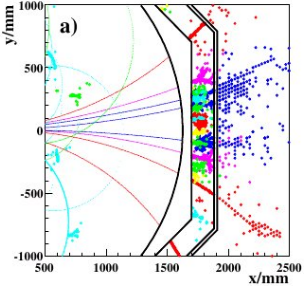
ILD : International Large Detector

Particle Flow Algorithm : Global reconstruction algorithm that follows the particle through the entire detector and measure a given physical quantity in the most appropriated sub detector.

For instance : Measure the momentum in the Tracker (TPC) and the energy of particles in the calorimeters

Current reconstruction code, PandoraPFA :

- Follows the tracks from the TPC and find measure the energy of each particle in the calorimeters (ECal + Hcal).
- Cluster the remaining neutral fragments.
- Loop over the parameters of clustering algorithms and find the best configurations.



Hardware

+

Software

=

***Particle Flow Algorithm*!**

The ILC group of Lyon (IPNL) recently developed a HCal prototype with a semi-digital readout (**SDHCAL**) and a segmentation of **1x1 mm** ... but PandoraPFA optimized for an Analogic HCal (**AHCAL**) with a cell size of **3x3 mm** .

Need a new reconstruction approach mainly for two reasons :

- Need at least one other reconstruction software to validate the event reconstruction
- A higher granularity can help to separate the contributions of the different particles in a better way $\rightarrow$ new clustering methods

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- Studying the separation capability in the SDHCAL using new algorithms
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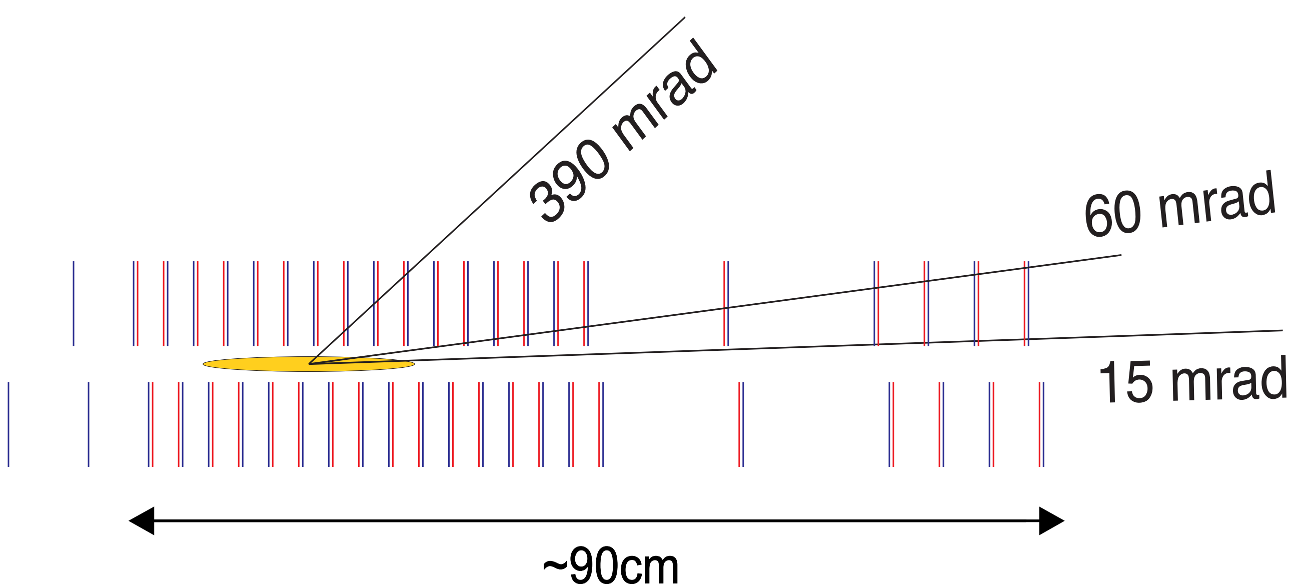
- Apply this set of algorithms on a physics channel : e+e- $\rightarrow$ H Z and compare it with PandoraPFA

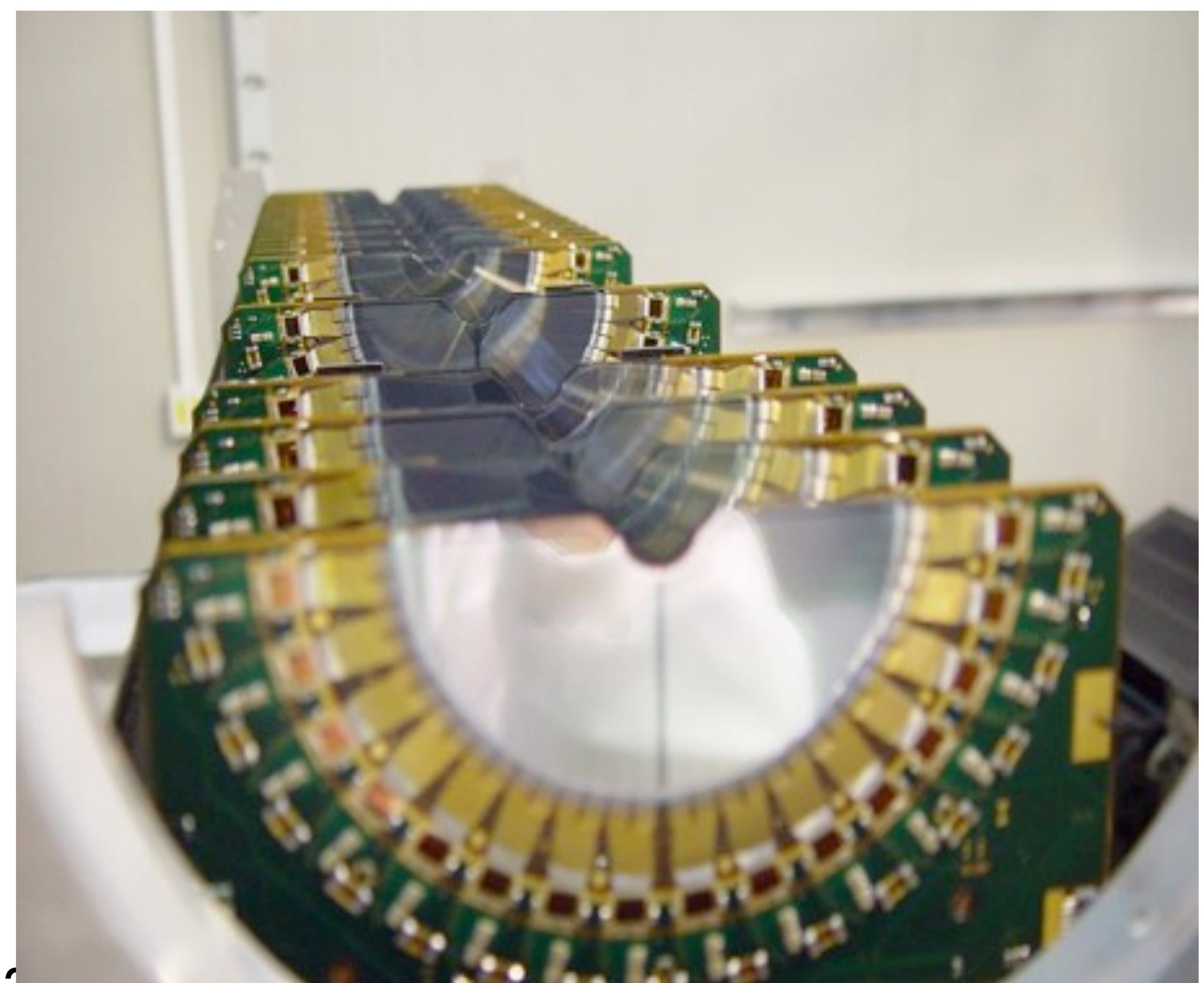
- Need a lot of C++ development and the code has to be really efficient !
- Parallel computing is more than needed. Thousands of calorimeter hits per event for the smallest energy of ILC !
- This school could help me for future choices after the PhD
- I like programming and this is best reason why I should come ! ☺

Stefano Gallorini

- University of Padua -

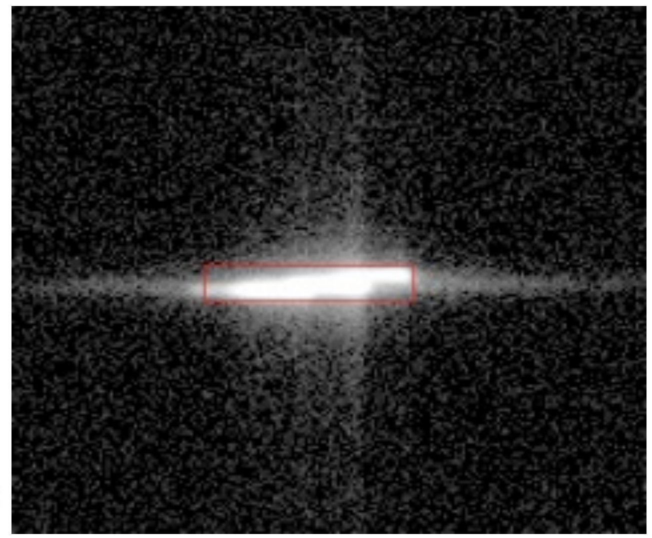
- I’m a member of the LHCb collaboration
- Part of my activity is dedicated to the porting of the tracking algorithm used in the High Level Trigger (HLT) to GPU
- The algorithm reconstructs tracks inside the VELO detector

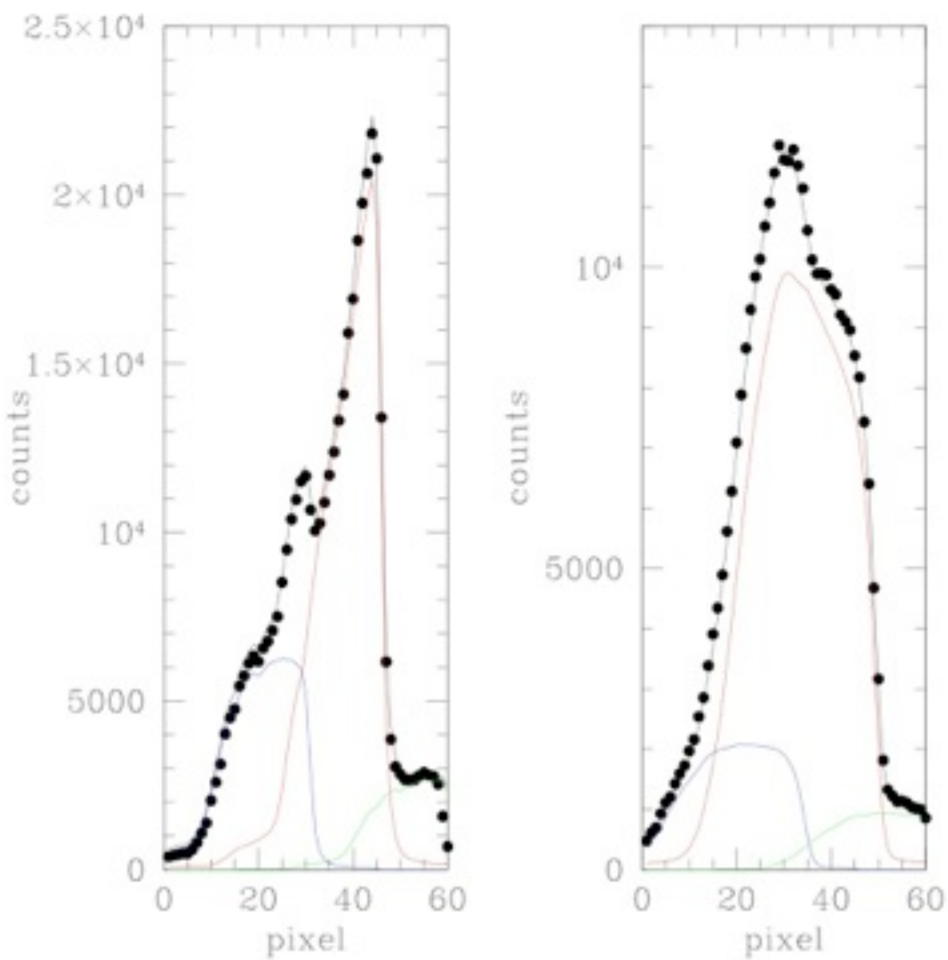


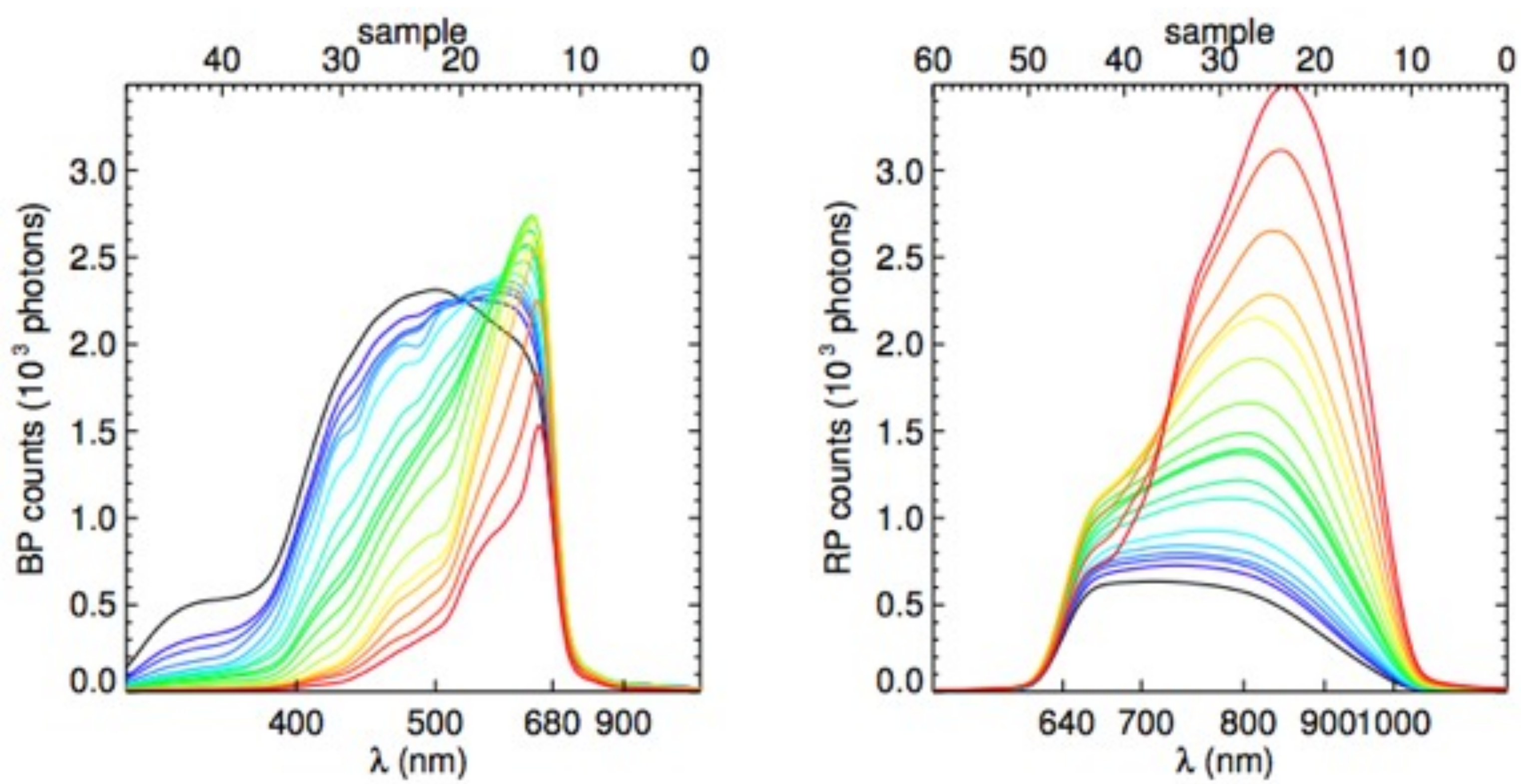


- In a future upgrade of the experiment, the use of GPUs in the HLT will allow to reduce computing time and implement more sophisticated selection algorithms
- Main requirements: high tracking efficiency > 99%, latency of few ms
- In Padua we have 2 GPUs (NVidia Titan & Tesla M2050). The work is just started...

Gaia
BP/RP Deblending







Giuliano Giuffrida (ASDC-INAF)

Gaia

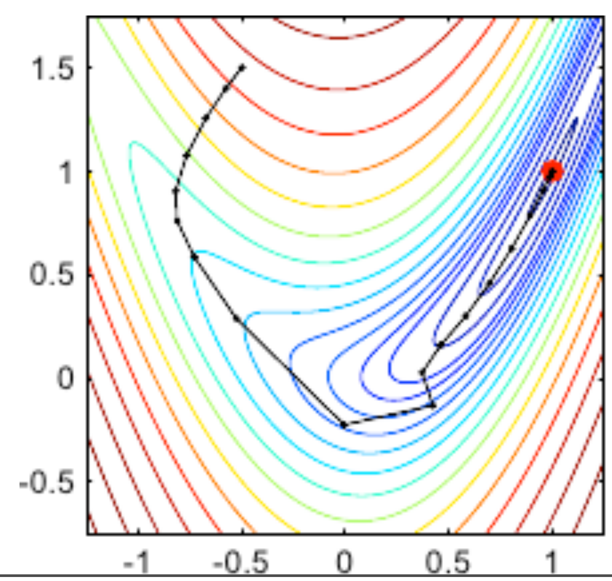
BP/RP Deblending

Algorithm 5: Levenberg-Marquardt algorithm

input : $f : \mathbb{R}^n \to \mathbb{R}$ a function such that $f(\mathbf{x}) = \sum_{i=1}^{m} (f_i(\mathbf{x}))^2$ where all the f_i are differentiable functions from $\mathbb{R}^n$ to $\mathbb{R}$; $\mathbf{x}^{(0)}$ an initial solution

output: $\mathbf{x}^*$, a local minimum of the cost function f.

```
begin
    k ← 0 ;
    λ ← max diag(JᵀJ) ;
    x ← x⁽⁰⁾ ;
    while STOP-CRIT and (k < k_max) do
        Find δ such that (JᵀJ + λdiag(JᵀJ))δ = Jᵀf ;
        x′ ← x + δ ;
        if f(x′) < f(x) then
            x ← x′ ;
            λ ← λ/ν ;
        else
            λ ← νλ ;
        k ← k + 1 ;
    return x
end
```

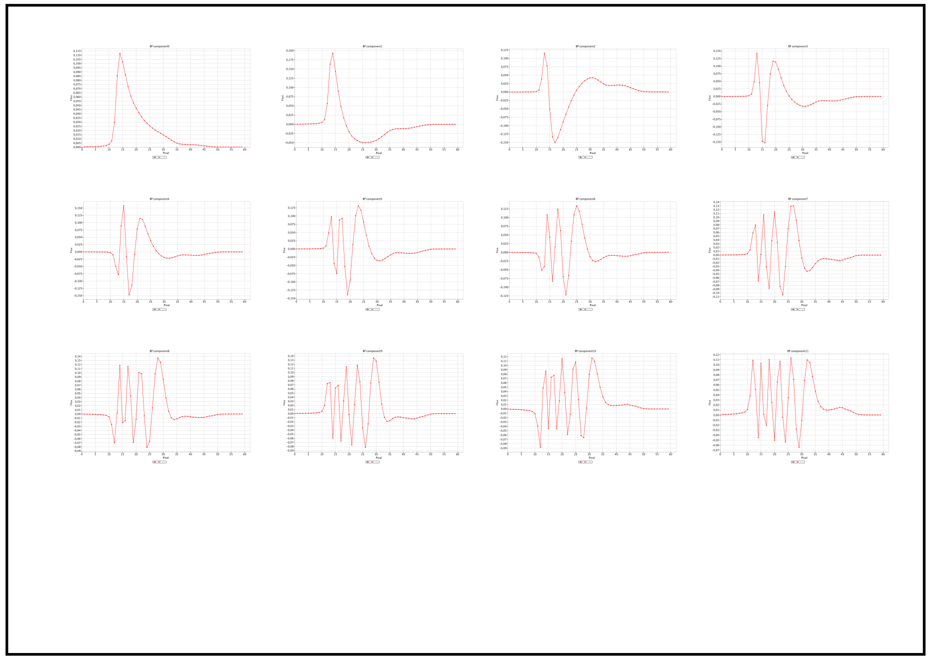


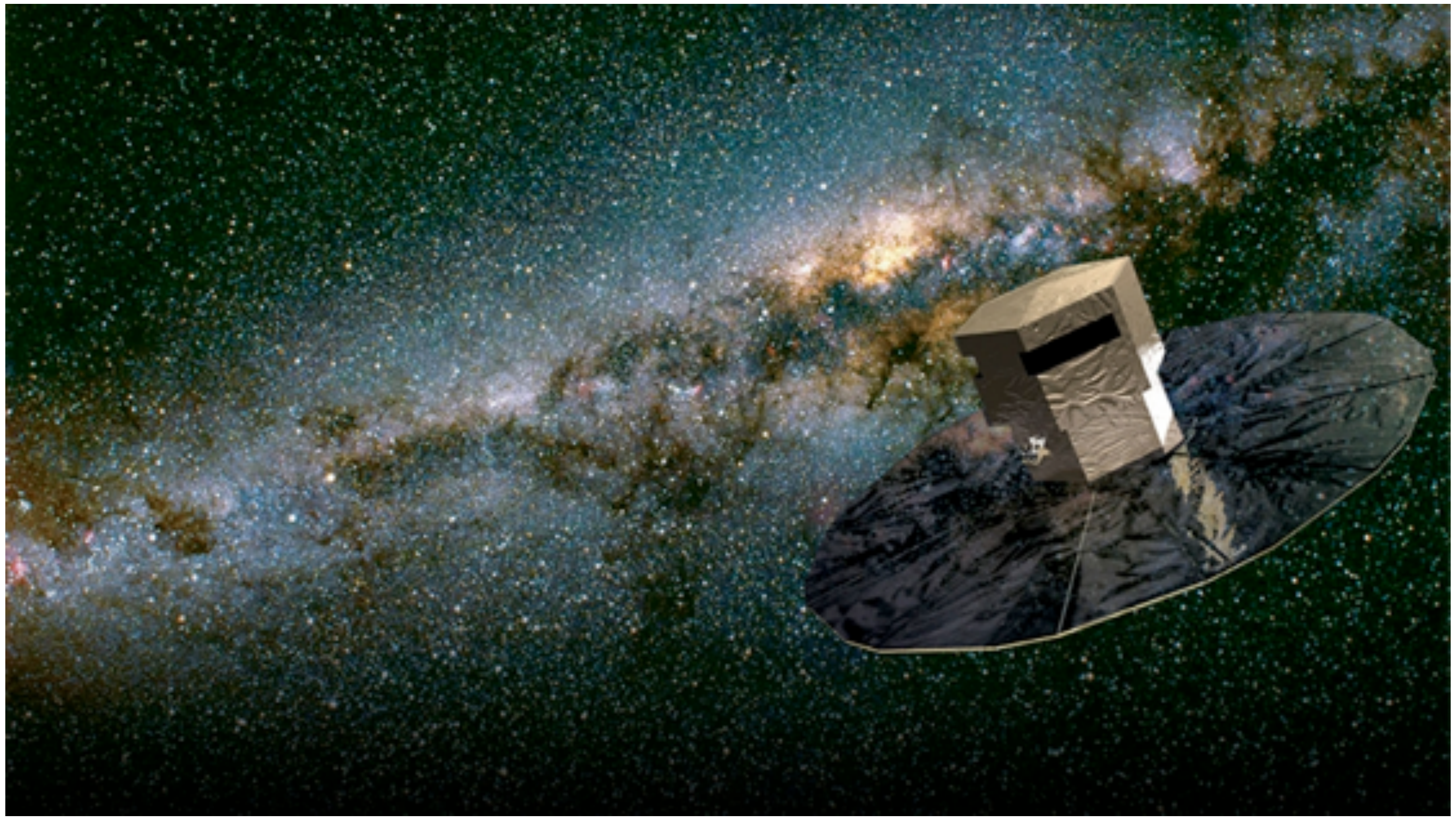
Courtesy of http://www.brnt.eu/phd/node10.html

PCA

Principal Component Analysis

$$S(pix) = \sum_{i=1}^{N} b_i * B_i(pix)$$





Data set size:

- Entire sky scanned 70 times for 1 billion objects
  - images collected 10^{12}
  - number of seconds processing time 10^{8}
  - collected data 150 Terabyte
  - total archive 1 Petabyte
- Nflops 10^{20}–10^{21}

mongoDB

{name: "mongo", type:"DB"}

NOSQL
Document oriented
Flexible "schemas"
Wire Protocol
Fast & Scalable
GeoIndexing

Data analysis activity @ Borexino Experiment

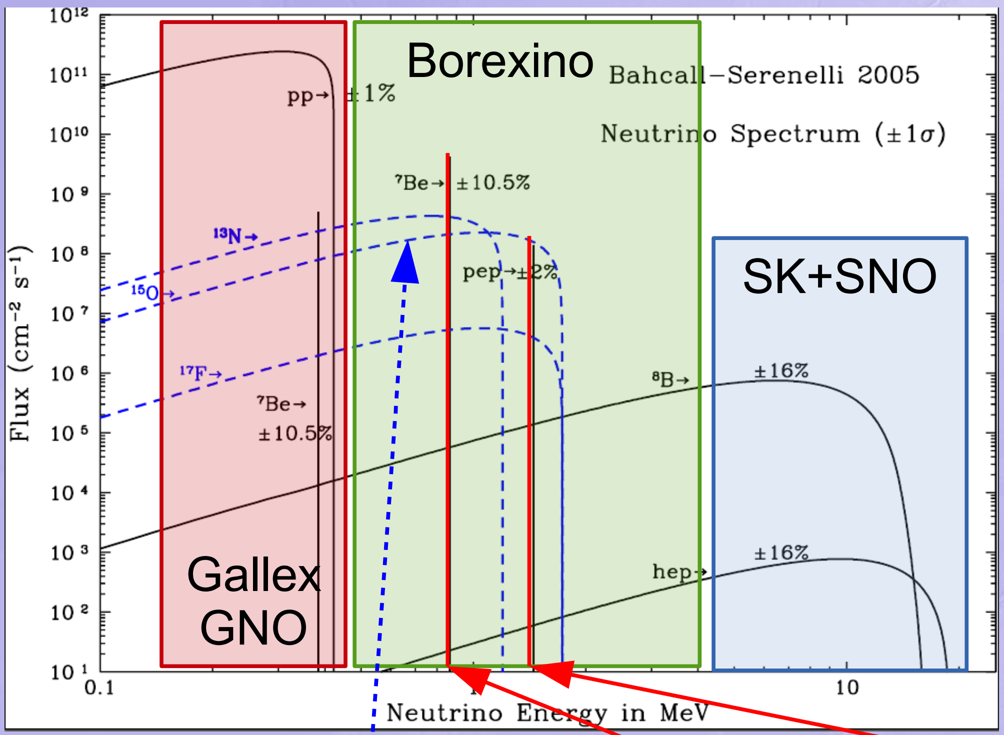
By
Francesco Lombardi
ESC13 - School
Bertinoro 21-26 Oct 2013

The Measurement of the CNO's neutrino fluxes with Borexino in very low S/N ratio conditions.

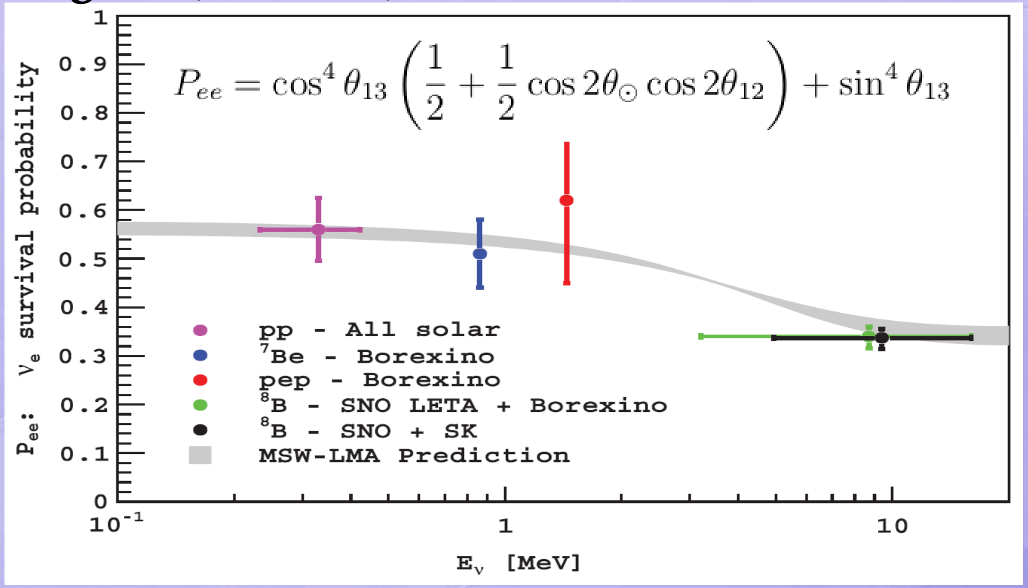
Neutrino Fluxes Measurement

(My Present Activity)

Solar Neutrino Fluxes from SSM



Measurement of the oscillation probability predicted by MSW theory. Borexino put the first point close the transition energy region (1-4 MeV)



First Measurement of *pep* neutrino flux in

Φ_{pep} = 3.1± $_{(stat)}$ 0.5± $_{(sys)}$ 0.2 [cpd/100ton]

Measurement of *Be7* neutrino flux in

Φ_{Be7} = 46± $_{(stat)}$ 1.5± $_{(sys)}$ 1.6 [cpd/100ton]

New task, extremely challenge, will be to make the CNO's neutrino fluxes measurement.

The EXPECTED count rates are:

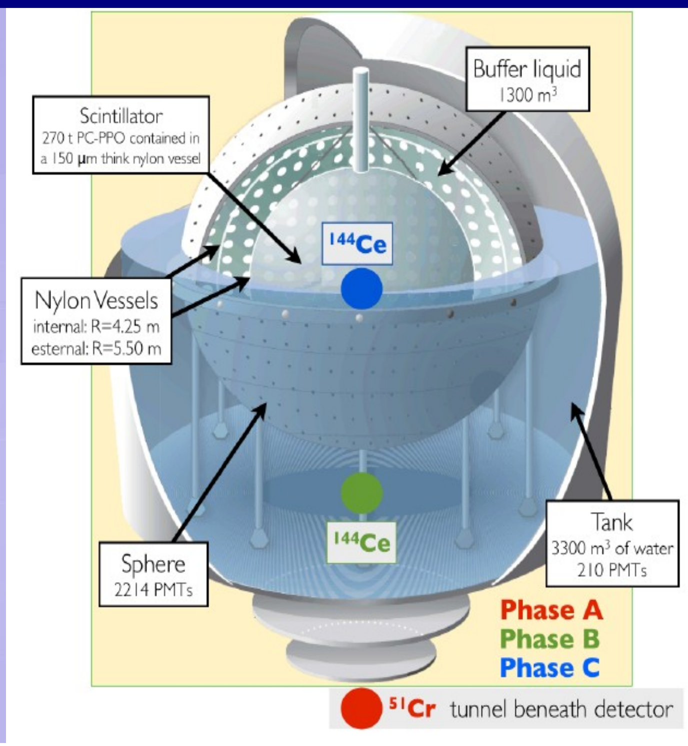
Φ_{CNO}=5.3 [cpd/100ton] from High-Z SM

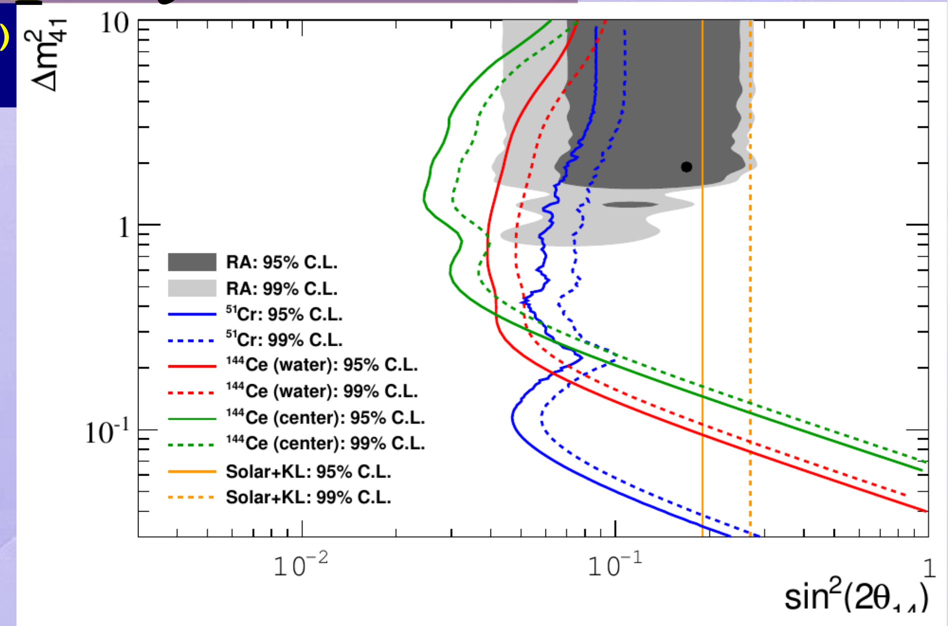
Φ_{CNO}=3.8 [cpd/100ton] from Low-Z SM

SM=Solar Model

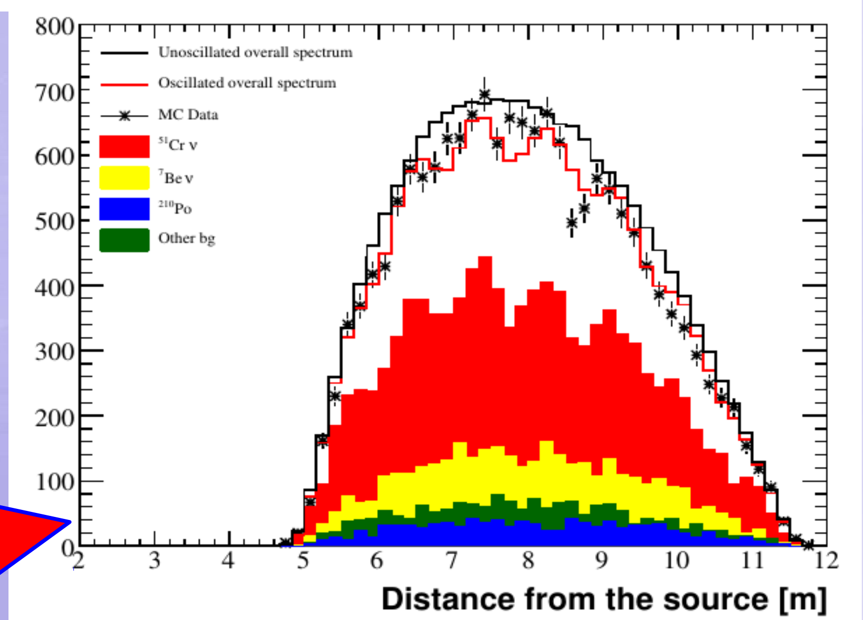
New prospective for data analysis and simulations with Parallel/Distributed calculations for *SOX project*

Simulation of a huge number of events (~10^{17} events/sec) from source (^{51}Cr A=200-400[*PBq*])





$$P_{ee} = 1 - \sin^2 2\theta_{14} \sin^2 \frac{1.27\Delta m^2_{41}(eV^2)L(m)}{E(MeV)}$$



First Simulation of the Expected counts rate for anti-n moving the 51Cr source from Borexino center at 0.7MeV. The disappearance of anti-n expected is due to the existence of 4th neutrino family: the sterile neutrinos.

DREAMS

SCUOLA NORMALE SUPERIORE

Chemistry @ SNS

DREAMS is a Computational Chemistry and Biophysics group led by Prof. Vincenzo Barone. Research topics include:

- ab initio methods, in particular models based on density functional theory (DFT)
- *hybrid QM / QM and QM / MM methods, in both static and dynamic formulations*
- Computational spectroscopy (electronic, vibrational, NMR, EPR ...)
- *molecular mechanics and classical molecular dynamics*
- ab initio dynamics, with specific focus on the "Atom centered Density Matrix Propagation"
- Coarse-graining
- technological expertise for configuring and fully exploiting resources for high-performance computing and "grid" computing
-
- Design of polymeric and nano-structured materials (in collaboration with the CNR)
- Computational modeling of materials and meta-materials (in collaboration with INSTM)
- Computational spectroscopy (in collaboration with LENS)
- Computational modeling for cultural heritage and the 'soft matter' (in collaboration with CSGI)

Giordano Mancini
Scuola Normale Superiore
Pisa, Italy

CECAM

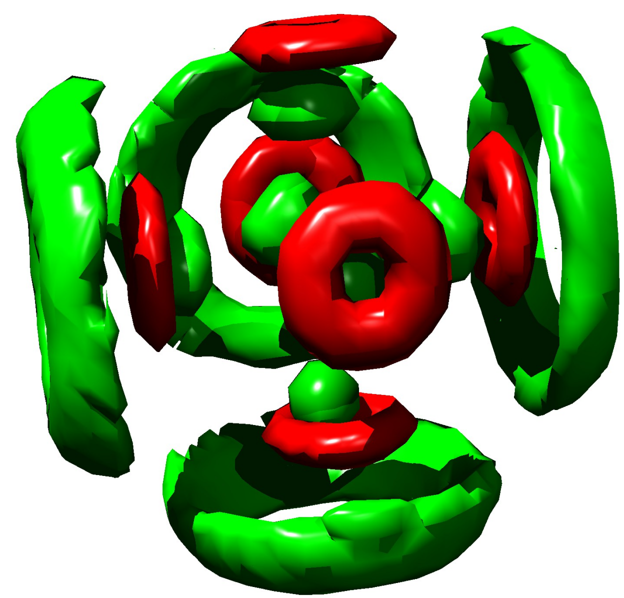
erc European Research Council Established by the European Commission ERC

What I (try to) do (1)

My research interests:

1) Development and implementation of algorithms for classical Molecular Dynamics, including polarizable force fields, NPBC and enhanced sampling
2) MD simulations of biological polymers (proteins, nucleic acids) and artificial molecular devices

Coupling the Fluctuating Charge method, non periodic boundary conditions and enhanced sampling: aqua ions as case studies.
In preparation for J. Chem. Theor. Comput.

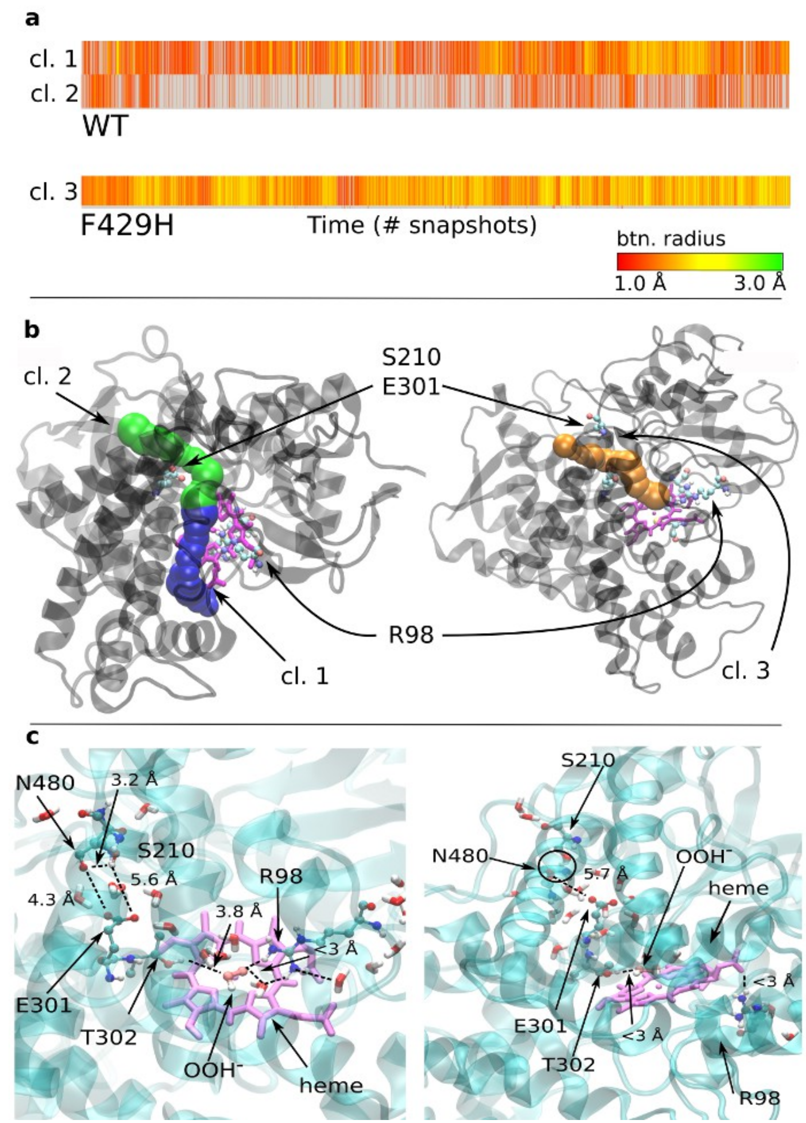


Acknowledgments:
Prof. Vincenzo Barone
Dr. Giuseppe Brancato
Dr. Filippo Lipparini

Giordano Mancini
Scuola Normale Superiore
Pisa, Italy

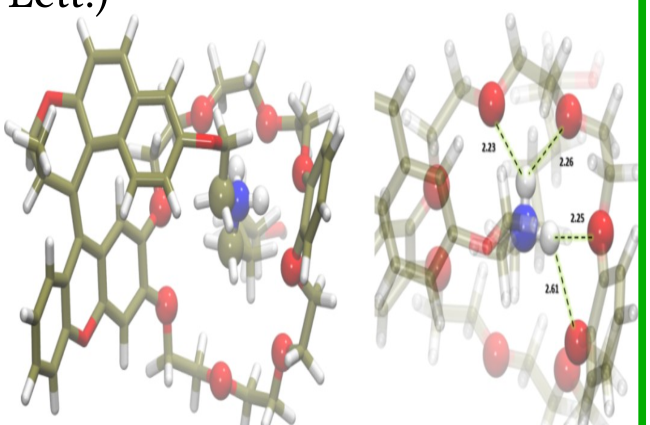
What I (try to) do (2)

MD simulations of biological enzymes:
Cytochrome P450 2B4 versus F429H Mutant: New Insights from Molecular Dynamics Simulations.
In preparation for J. Phys Chem. B



Acknowledgments:
Prof. Vincenzo Barone
Dr. Giuseppe Brancato
Dr. Costantino Zazza
Prof. Sason Shaik*
Dr. Dandamundi* Usharani
*Institute of Chemistry and Lise Meitner-Minerva Center for Computational Quantum Chemistry, Hebrew University of Jerusalem

Molecular Devices:
In silico study of molecular engineered nanodevices: a lockable light-driven motor in dichloromethane solution. (Submitted to J. Phys Chem Lett.)



Giordano Mancini
Scuola Normale Superiore
Pisa, Italy

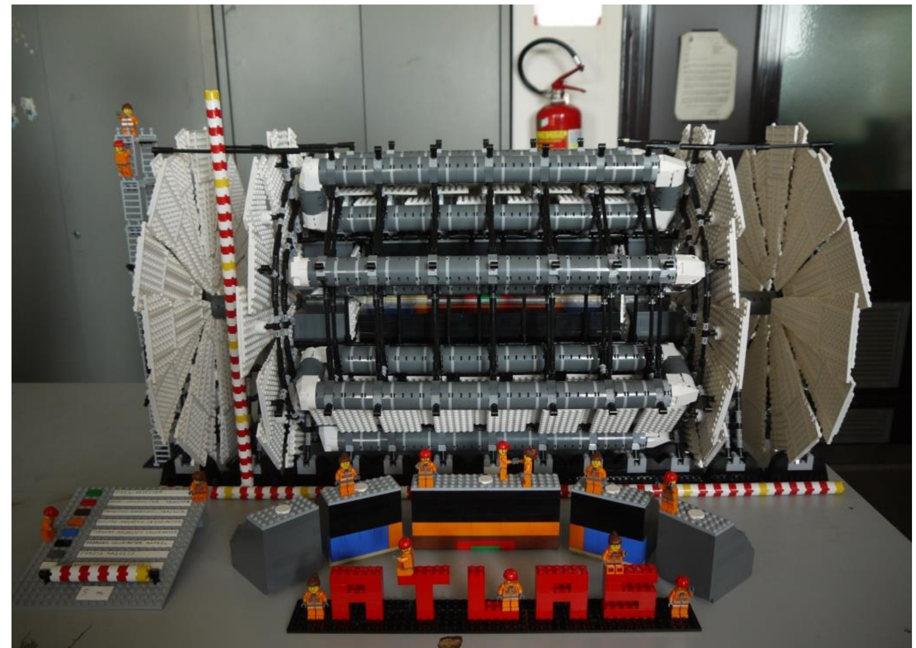
HIGH ENERGY PARTICLE SEARCH AND TOOLS FOR ANALYSIS

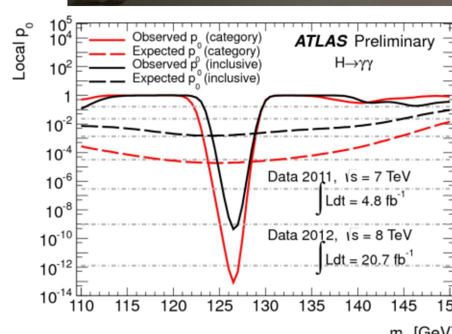
17/10/2013

Simone Mazza

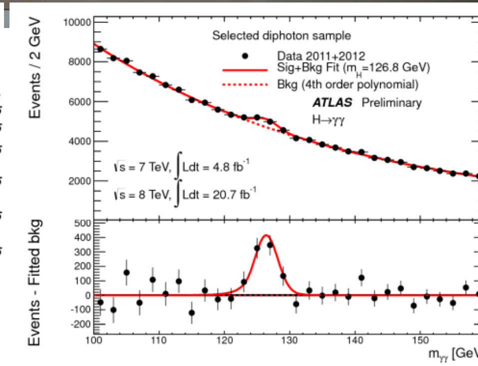
High energy physics research projects

- ATLAS collaboration
- Search of the Higgs boson in the di-photon plus missing transverse energy channel
  - Cutflow analysis (Event selection)
  - Performance of missing transverse energy
  - Higgs signal model fit (simultaneous fit using RooFit)
  - Building of background montecarlo model
  - Statistical analysis (maximum likelihood)
- Higgs mass precision measurement on the di-photon channel
- Future projects: search of graviton resonances in the di-photon channel
  - Randall-Sundrum and ADD model





ATLAS-CONF-2013-012



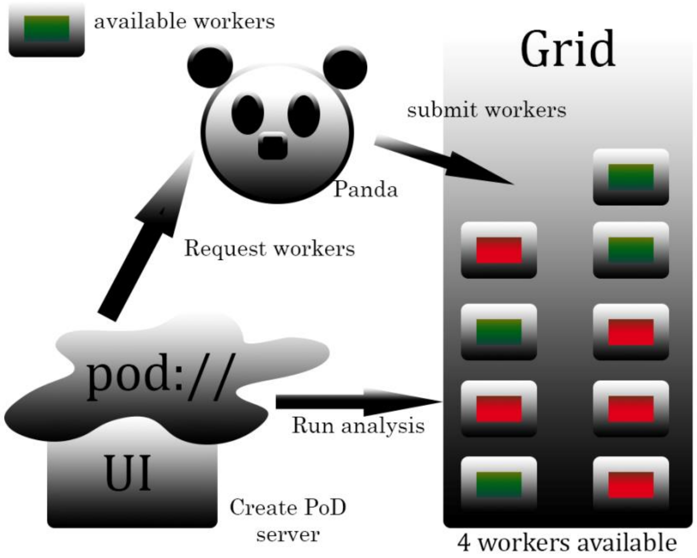
ATLAS-CONF-2013-012

Particle physics analysis and computing resources

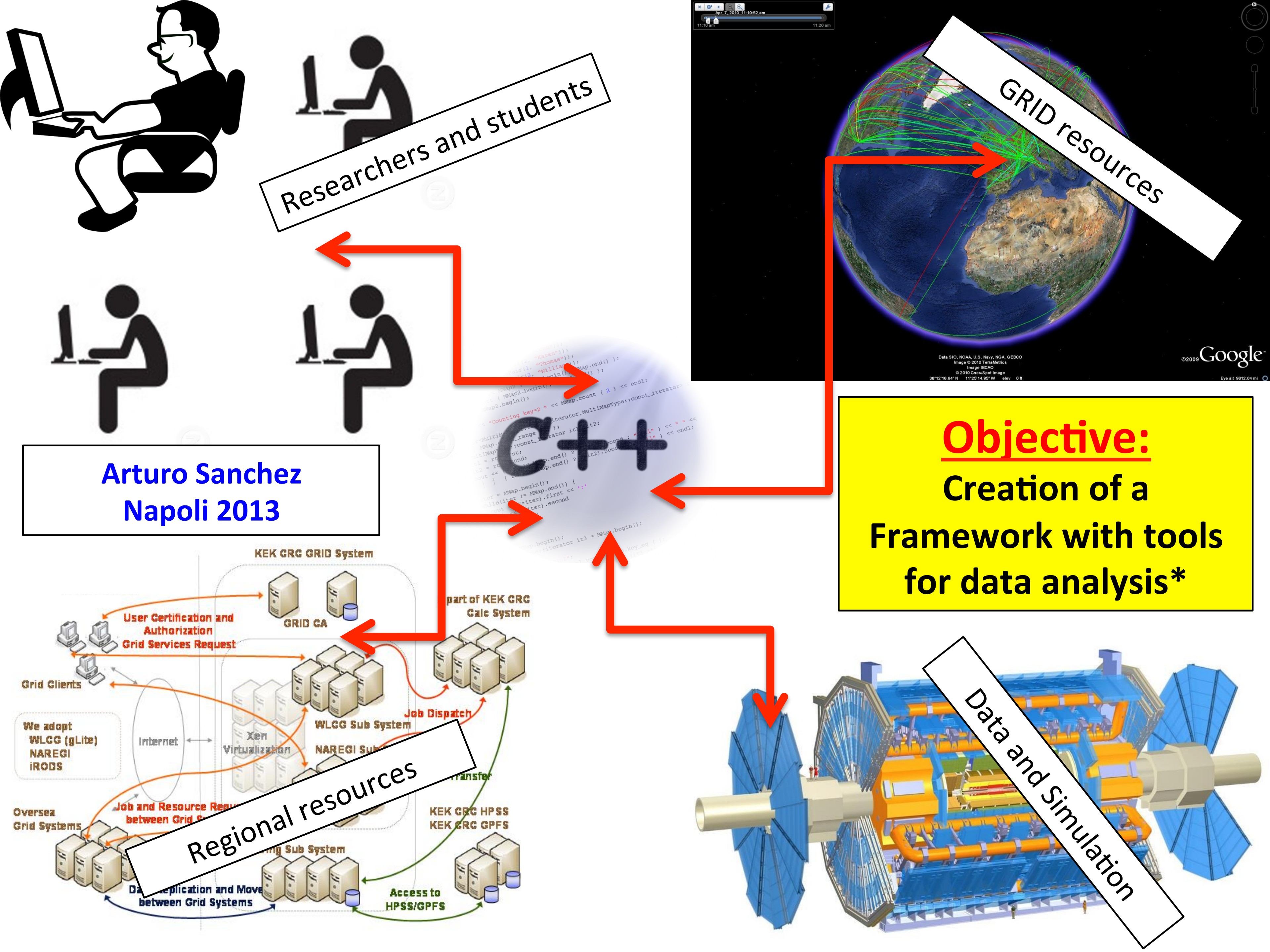
- Most of the time we have to analize huge amount of data that are placed somewere in the world (grid). To speed up the process we can
  - Send request for local copy and analyze locally: one core analysis, multicore analysis, local proof cluster
  - Send analysis job to the grid (where the datasets are) with a standard grid request
  - Pre-skimming of data on the grid, then copy and analyze locally
- Data analysis is a simple problem to parallelize
  - Few hundreds of operation for each event
- Optimizations
  - General code optimization
  - Proof/Prooflite for multicore analysis: computer clusters to analize data using proof (Milano: 192 cores)
  - Optimized data access (D3PDReader)
- What to do next?
  - OpenMP, MPI optimization
  - GPU analysis

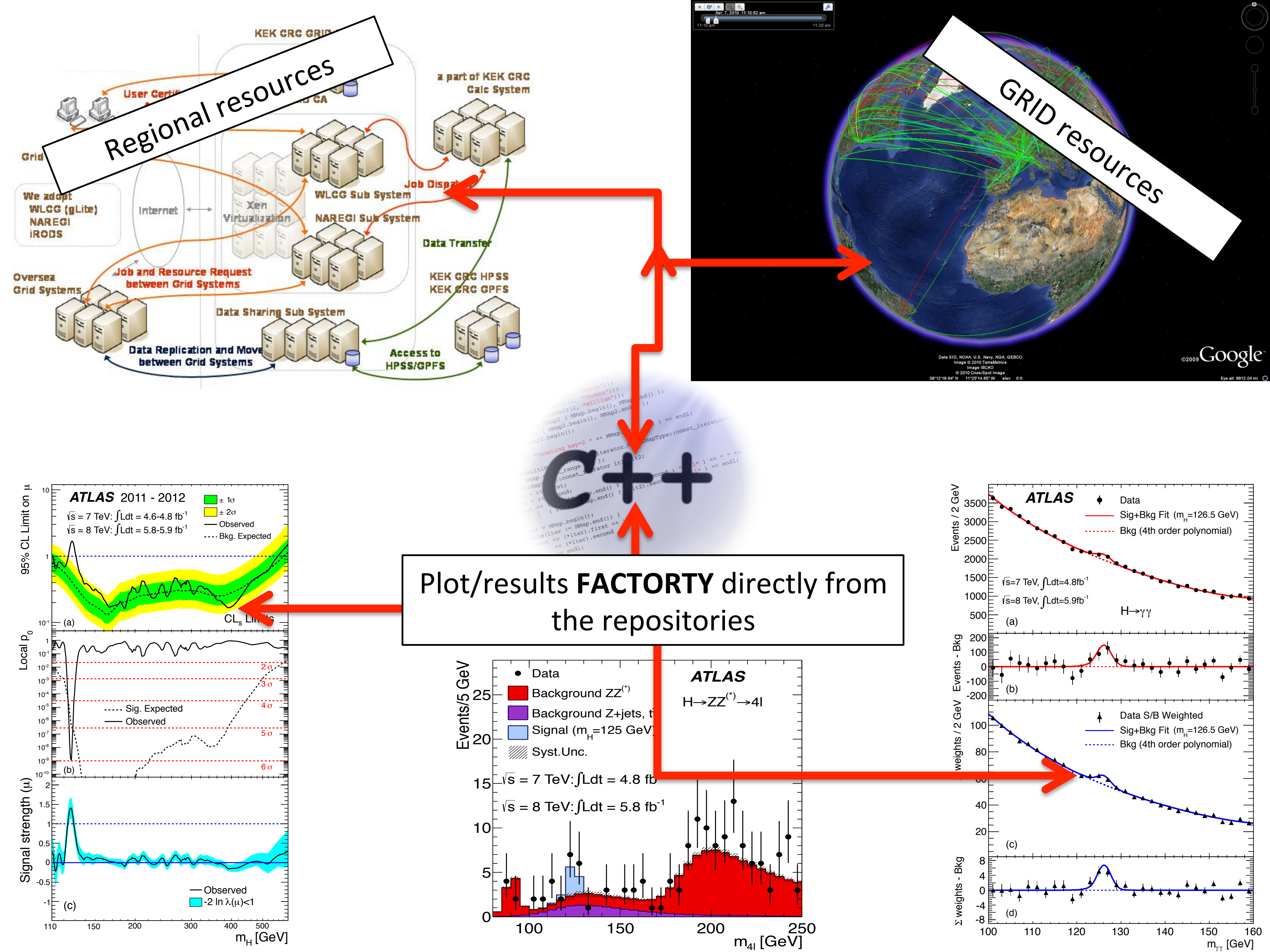
Analysis test in a Grid facilities with the PanDA plugin for PoD

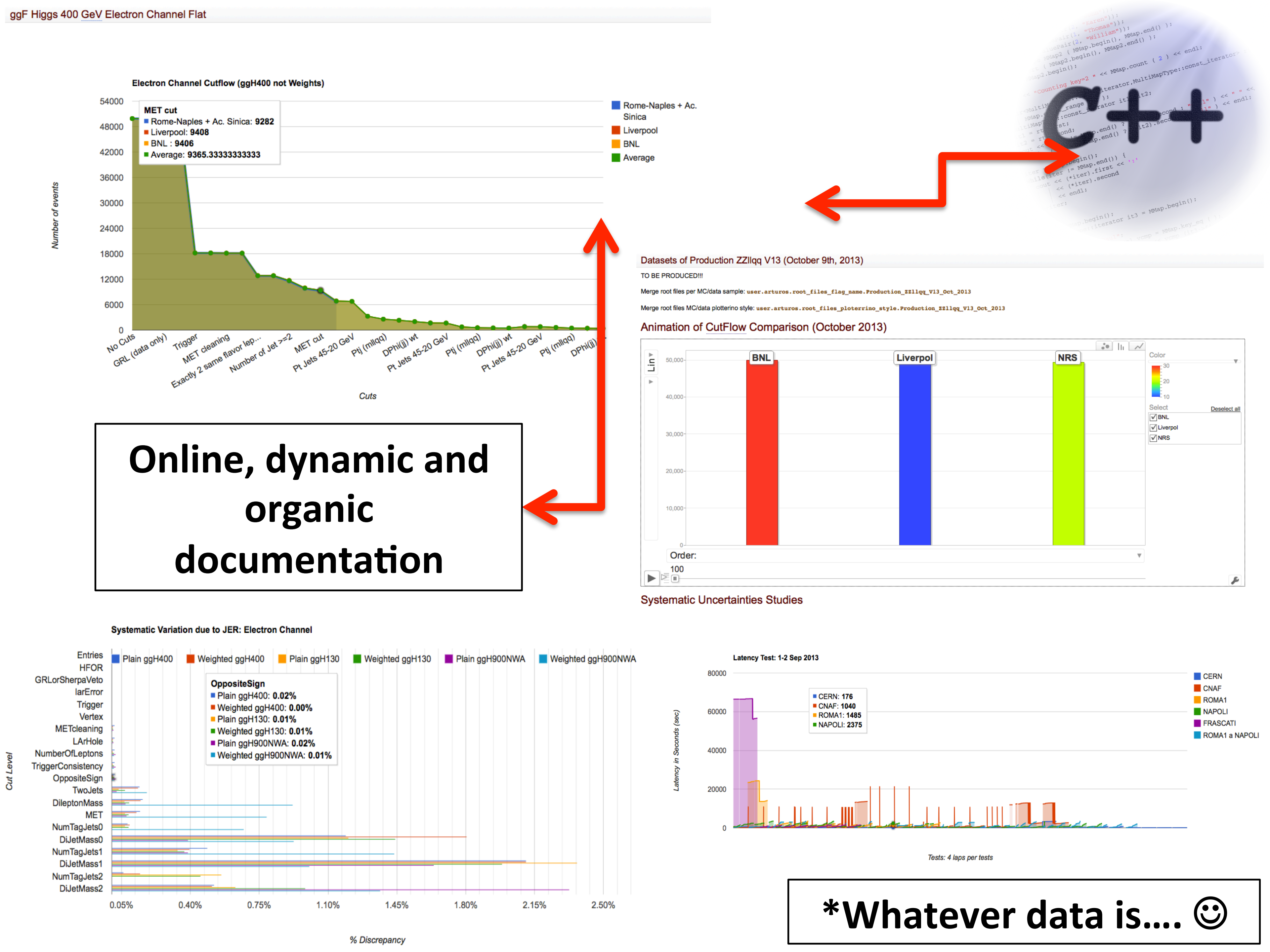
- Proof on Demand allows to enable a PROOF cluster on the Grid requesting workers trough Panda.
  - (Panda is the ATLAS workload management system to submit jobs on the grid)
  - We were able to obtain clusters with an high number of workers (up to 300 workers)
- Using a Proof-based analysis with optimized disk access
- Different from normal Grid jobs submitted to PanDA.
  - Once the requested PROOF cluster is available, the PROOF-based analysis can be directly send to the workers from the master (more interactive)
  - Same as a local proof cluster!



- Clusters can be enabled on any PanDA resource (Italian T2-T3 grid site)
  - Only one analysis (per site) can run at a time
- There are more possibilities
  - Proof based analysis on the proof cluster requested on grid with local data
  - Request workers and run analysis on a cluster where the datasets are
  - Run analysis in one site with data taken from another site via XrootD or http


Researchers and students
GRID resources
Google
Arturo Sanchez
Napoli 2013
C++
Objective:
Creation of a
Framework with tools
for data analysis*
KEK CRC GRID System
GRID CA
User Certification and
Authorization
Grid Services Request
Grid Clients
part of KEK CRC
Calc System
Job Dispatch
WLCG Sub System
We adopt
WLCG (gLite)
NAREGI
iRODS
Internet
Xen
Virtualization
KEK CRC HPSS
KEK CRC GPFS
Oversea
Grid Systems
between Grid Systems
Access to
HPSS/GPFS
Regional resources
Data and Simulation


Regional resources
GRID resources
Plot/results FACTORTY directly from the repositories
C++
KEK GRC GRID
User Certif
Grid
We adopt
WLCG (gLite)
NAREGI
iRODS
Internet
Xen
Virtualization
WLCG Sub System
NAREGI Sub System
a part of KEK GRC
Calc System
Job Dispa
Data Transfer
Overseas
Grid Systems
Job and Resource Request
between Grid Systems
KEK GRC HPSS
KEK GRC GPFS
Data Sharing Sub System
Data Replication and Move
between Grid Systems
Access to
HPSS/GPFS
Google
ATLAS 2011 - 2012
95% CL Limit on μ
Observed
Bkg. Expected
Local p0
Sig. Expected
Signal strength (μ)
m_H [GeV]
ATLAS
H→ZZ(*)→4l
Data
Background ZZ(*)
Signal (m_H=125 GeV)
Syst.Unc.
Events/5 GeV
m_4l [GeV]
ATLAS
Data
Sig+Bkg Fit (m_H=126.5 GeV)
Bkg (4th order polynomial)
H→γγ
Events / 2 GeV
Events - Bkg
Data S/B Weighted
Σ weights - Bkg
m_γγ [GeV]



ggF Higgs 400 GeV Electron Channel Flat
Electron Channel Cutflow (ggH400 not Weights)
MET cut
Rome-Naples + Ac. Sinica: 9282
Liverpool: 9408
BNL : 9406
Average: 9365.33333333333
Rome-Naples + Ac. Sinica
Liverpool
BNL
Average
Number of events
Cuts
No Cuts
GRL (data only)
Trigger
MET cleaning
Exactly 2 same flavor lep...
Number of Jet >=2
MET cut
Pt Jets 45-20 GeV
Ptj (mllqq)
DPhi(jj) wt
C++
Datasets of Production ZZllqq V13 (October 9th, 2013)
TO BE PRODUCED!!!
Merge root files per MC/data sample: user.arturos.root_files_flag_name.Production_ZZllqq_V13_Oct_2013
Merge root files MC/data plotterino style: user.arturos.root_files_ploterrino_style.Production_ZZllqq_V13_Oct_2013
Animation of CutFlow Comparison (October 2013)
BNL
Liverpol
NRS
Color
Select
Deselect all
Order:
100
Online, dynamic and organic documentation
Systematic Uncertainties Studies
Systematic Variation due to JER: Electron Channel
Plain ggH400
Weighted ggH400
Plain ggH130
Weighted ggH130
Plain ggH900NWA
Weighted ggH900NWA
OppositeSign
Plain ggH400: 0.02%
Weighted ggH400: 0.00%
Plain ggH130: 0.01%
Weighted ggH130: 0.01%
Plain ggH900NWA: 0.02%
Weighted ggH900NWA: 0.01%
Cut Level
Entries
HFOR
GRLorSherpaVeto
larError
Trigger
Vertex
METcleaning
LArHole
NumberOfLeptons
TriggerConsistency
OppositeSign
TwoJets
DileptonMass
MET
NumTagJets0
DiJetMass0
NumTagJets1
DiJetMass1
NumTagJets2
DiJetMass2
% Discrepancy
Latency Test: 1-2 Sep 2013
CERN: 176
CNAF: 1040
ROMA1: 1485
NAPOLI: 2375
CERN
CNAF
ROMA1
NAPOLI
FRASCATI
ROMA1 a NAPOLI
Latency in Seconds (sec)
Tests: 4 laps per tests
*Whatever data is.... ☺

Cristiano Santoni

- Research fellow at University of Perugia (from July 2013)
- Academic degree in computer science at University of Perugia (May 2013)
- Educational Grant at INFN Perugia (September 2010 – August 2012)

Scientific Computing experiences and activities

- Thesis:
  - Development of a GPU-based solver for Answer Set Programming
- Research:
  - Feasibility study for integration of GPU-computing and RTOS
  - Development of GPU-based trigger algorithms for RICH and Charged Hodoscope detectors

(NA62 experiment and KLEVER project)

Others activities

- Current:
  - Design and development of a low level (L0) trigger algorithm for RICH and Charged Hodoscope detectors (NA62), based on multiplicity and average hit time, able to operate at tens of MHz
- Past:
  - Firmware development for various FPGA-based TDAQ systems for sensors (CMOS pixel, SiPM) readout

CRISTINA TRONCONI

I work as an engineer at the Institute of Atmospheric Sciences and Climate (ISAC) of the Italian National Research Council (CNR) actively collaborating with the Satellite Oceanography Group.

I'm currently involved in the framework of national and international projects (MyOcean and SeaDatanet) whose main aim is the "**Realization of European Interoperability in Ocean Science**"

.

Within these projects my work consists of:

- Development of satellite oceanographic remote sensing data applications based on grid infrastructure, in particular for what concerns SST (Sea Surface Temperature) data and Management of TDS (THREDDS Data Server)
- Optimization and parallelization of data processing chains
- Re-engineering of old processing chains
- **Harmonisation of Data format** (NetCDF) in the framework of the "Realization of European Interoperability"

I’m deeply interested in this School in order to Improving:

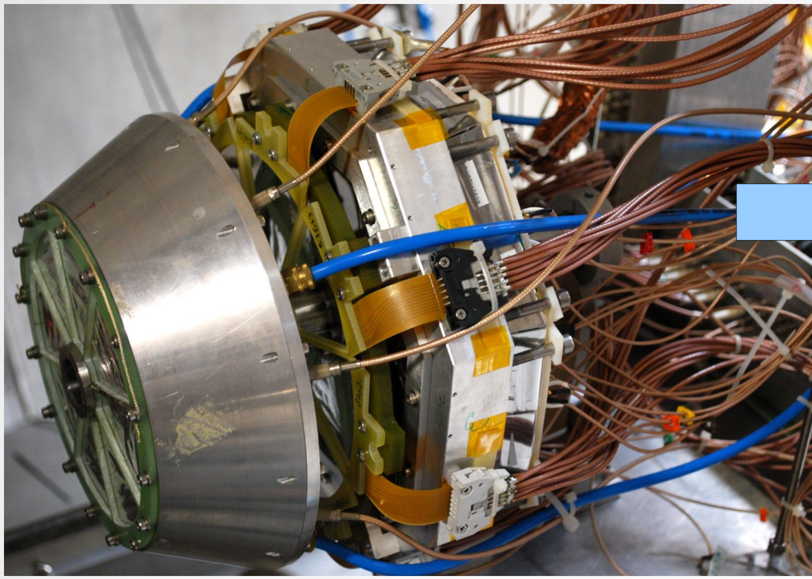
- my skill in Software optimisation and Parallelisation,
- the knowledge of new Parallel programming techniques
- the perfomances of C++ codes

THANKS

Simone Valdré

- I graduated in Physics at Università degli Studi di Firenze in December 2009 and took the Master's degree in October 2012.
  - I did my thesis works inside an experimental nuclear physics collaboration (Nucl-Ex / FAZIA)
- Now I'm a PhD student at Università degli Studi di Firenze
  - I'm still working inside the Nucl-Ex / FAZIA collaboration
  - During the first year of PhD I took a course on programming in kernel space
- I've always been attracted by programming and I write simple programs for personal interest since I was young.

Simone Valdré



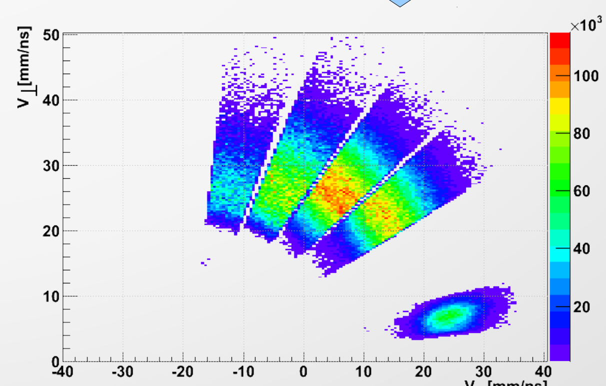
```
class GAWorker_GarfParticleMul1: public GAWorker{
 public:
  GAWorker_GarfParticleMul1();

  //! In this method all the modules and aliases must be initialized.
  //! The list all_modules_in is ready and can be used.
  //! The list all_modules_out must be filled with ALL the parameters except
  //! name and connection, that will be adjusted later by GAAnalisi
  virtual int Init();

  //! this function will be called at the beginning of each run.
  //! it is a good place to load the calibration values.
  virtual int InitRun(char *run_num);


  //! in this method data is processed.
  //! you can use the GAVirtualModule::is_fired to see which of the
  //! input module(s) have been fired.
  //! don't forget to set is_fired to 1 to the relevant output modules.
  //!
  //! IMPORTANT NOTE: you MUST manually reset all the output modules
  //!    quantities that you do not compute!!! For example, if you use
  //!    a GAVModule_Ion, but you cannot identify the mass:
  //!
  //!    ion->A=-1; ion->quality_A=0;
  //!
  virtual int ProcessData();

  virtual ~GAWorker_GarfParticleMul1();
```



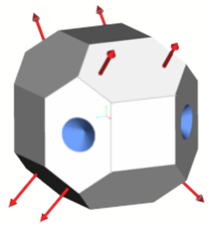
- In our collaboration we use C++ programs to analyze data and to do simulations
- I work daily on the code to perform more advanced data analysis

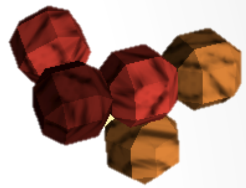
Simone Valdré

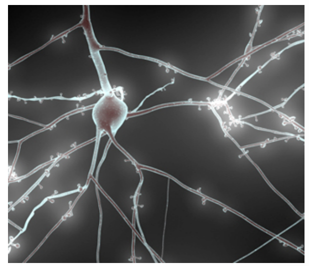
- ODIE is the main tool to calibrate data in our collaboration
  - It's entirely written and maintained in Florence.
  - It heavily uses object oriented features of C++
  - It has a modular structure that could be adapted to various experimental apparatuses
- GEMINI++ is a well known Monte Carlo simulation tool
- I actively contributed to develop a tool to analyze and compare ODIE and GEMINI++ outputs
- Here at ESC13 I expect to learn how to optimize at best our analysis software to improve our research

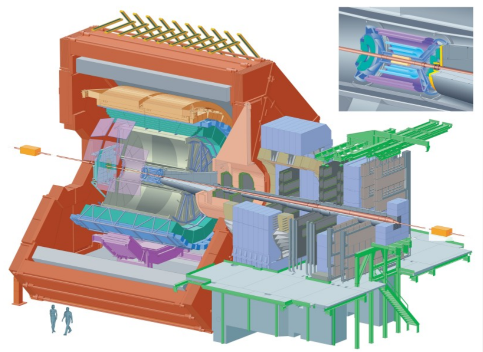
Barthélémy von Haller

- Swiss, 32 yo, engineer in computer science
- Studied at EPFL (Lausanne)
  - Master on bio-inspired modular robotics
- Work(ed) at
  - CERN IT – Administrative tools
    - Large Java web applications and Oracle DBs
  - EPFL – Blue / Human Brain project
    - SDK: Common base for simulation, analysis and visualization
    - C++ with Python and Java bindings
  - CERN PH – ALICE
    - Data Quality Monitoring (DQM)
    - C++ framework based on ROOT



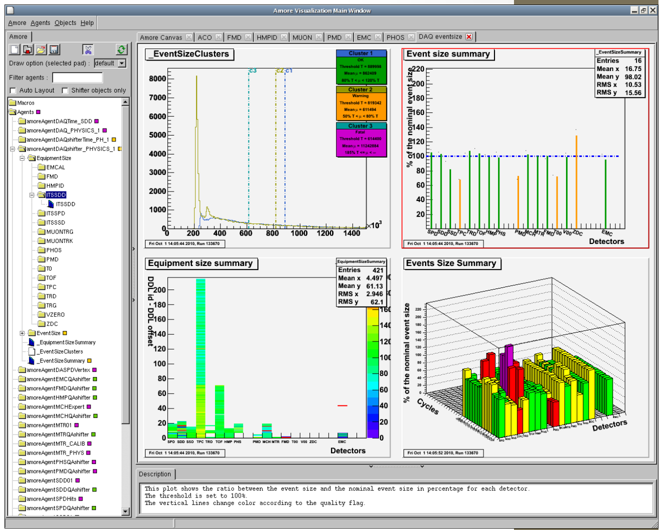






Barthélémy von Haller

- CERN PH – ALICE (DQM continued)
  - 40 agents, 10000 objects, 1 update per minute
  - 24/7 use by DQM shifter
  - → Can we make our code better ?
    → Improve our practices & procedures ?
  - Analysis is demanding
  - → can we parallelize ? How ?



- ALICE Online-Offline framework (O2)
  - 2018/19 LHC 2nd Long Shutdown
  - Upgrade of several detectors -> continuous readout electronics for TPC and ITS
  - Architecture and R&D -> TDR -> Implementation