Towards DRD Calorimetry
Software Needs - Transversal activities

Input Proposal Team and TF6+ task force

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Software commonalities

- DRD6 as a collaboration will allow to create an organic ecosystem for common activities all the R&D need to carry on
- Software-wise I'll focus on
  - Data acquisition (EUDAQ2)
  - Simulation
  - Particle Flow Algorithm
  - Machine (Deep) Learning Approach
  - ...

EUDAQ - Data Acquisition Framework

- EUDAQ is a Generic Multi-platform Data Acquisition Framework.
  - it was originally developed to read out data from the EUDET-type pixel telescopes.
  - Version 2 comes with more flexible cross connectivity between components, multiple data collectors, and a cleaner separation between core functionalities and user modules.
  - The modular and cross-platform data acquisition framework serves as
    - a flexible and simple-to-use data taking software for the EUDET-type pixel beam telescopes
    - easy integration of many other detectors.
  - Finite state machine based

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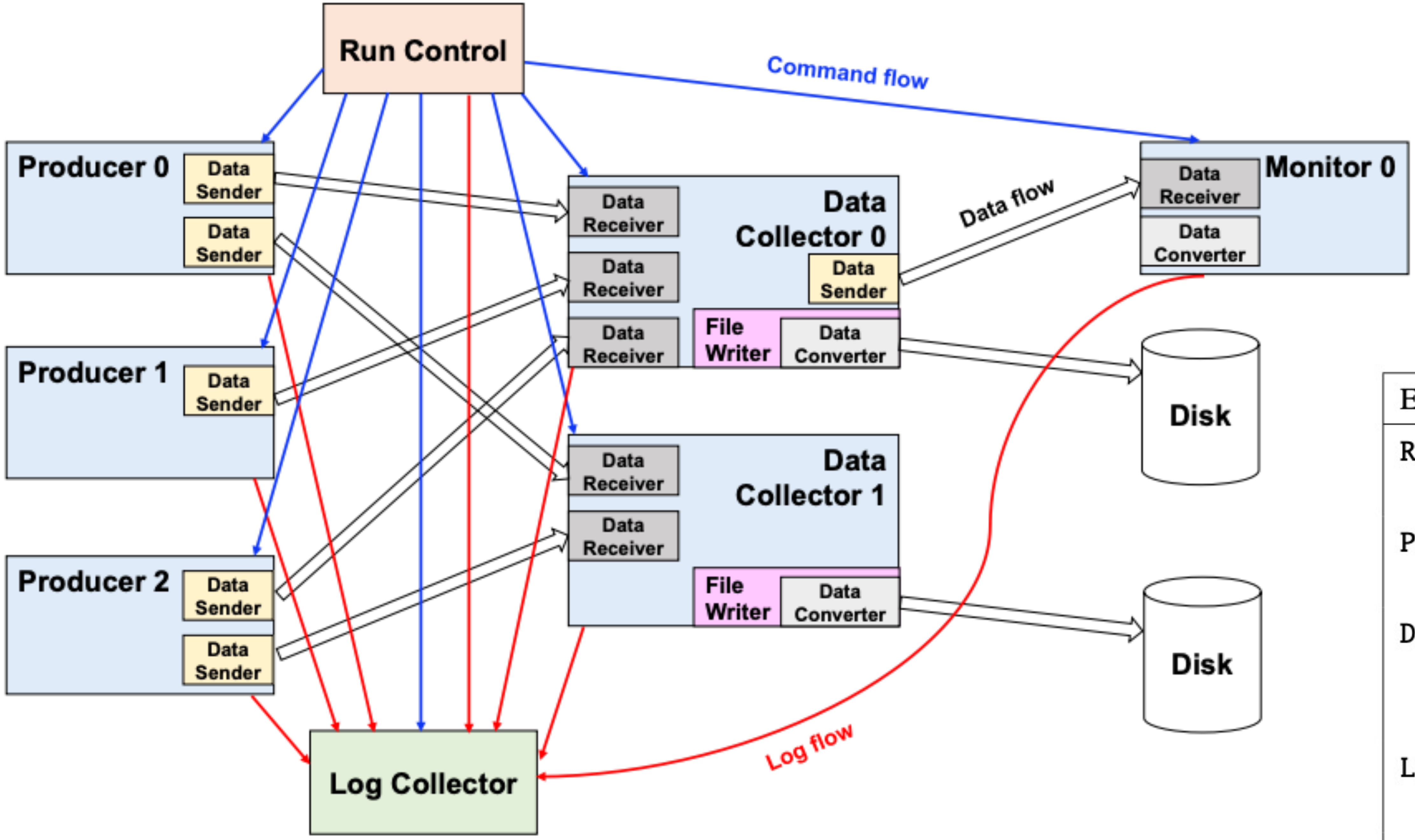
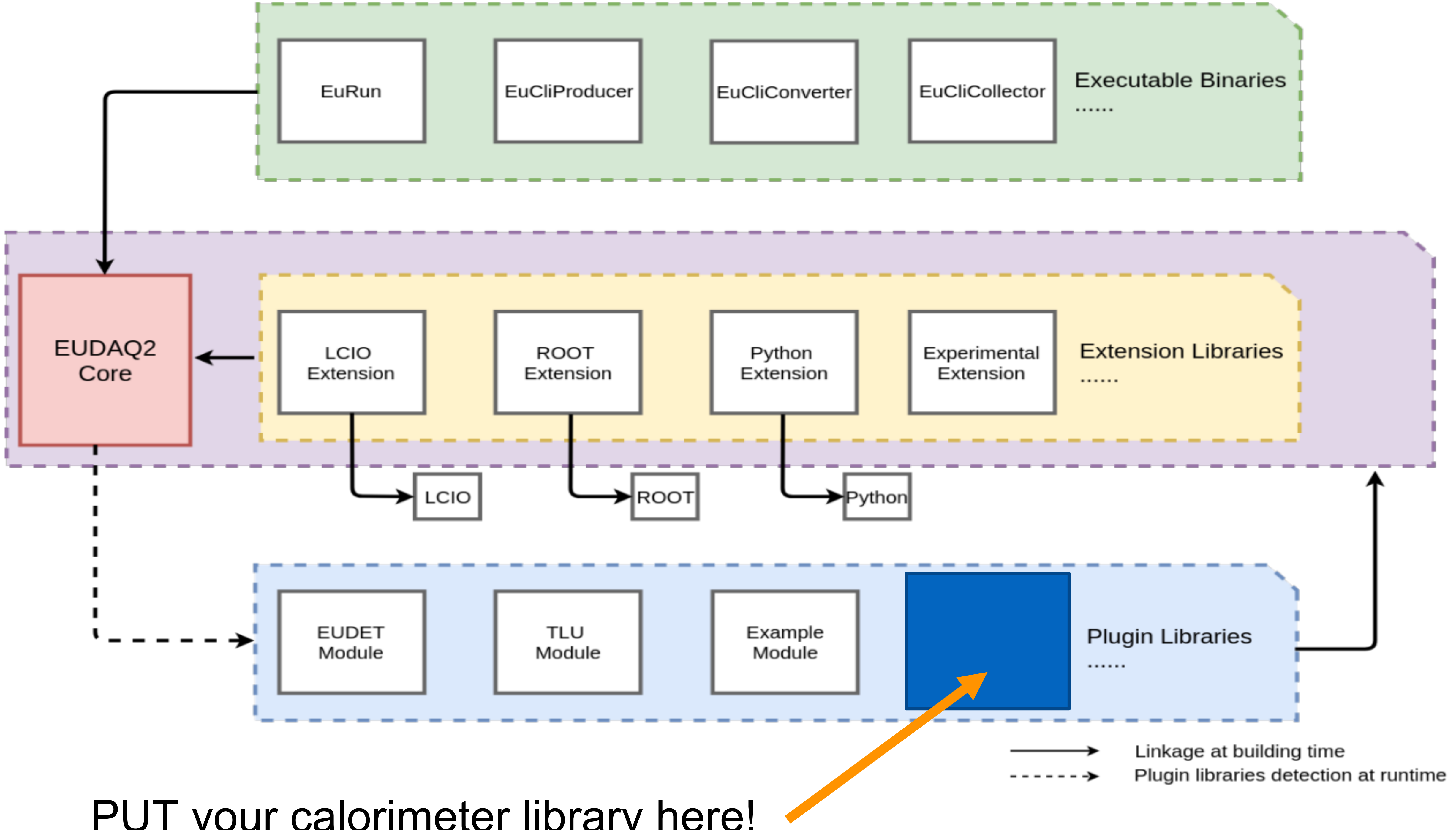
EUDAQ - Data Acquisition Framework



EUDAQ2 Role	Description
`Run Control`	Central controller for full EUDAQ2 system
`Producer`	Controls an individual detector, and sends detector data to EUDAQ2
`Data Collector`	Collects and merges data from individual `Producers`, then stores the data to disk file
`LogCollector`	Collects log messages from the entire EUDAQ2 system
`Monitor`	Online monitoring of data quality
`Offline Tools`	Fast offline data conversion and data analysis

ECFA EUDAQ - Data Acquisition Framework

European Strategy Update



PUT your calorimeter library here!

- Implementation of custom producers is rather simple
- easier integration with other eudaq producers (TLU, Telescopes)
- Already a long list of custom producers integrated:
- CALICE SiWECAL, CALICE AHCAL, CALICE SiWECAL + AHCAL, CMS HGCAL silicon prototype + CALICE AHCAL, ...

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EUDAQ2 @AIDAinnova (WP3: TB and DAQ infrastructure)

Task 3.4: Development of DAQ software for the next generation of beam tests

Two main targets:

- Fast timing support
- New online monitoring
  - event display (needs detector geometry definition)
  - Data Quality Monitoring

AIDA innova

Proposed Approach/First Use Case

Proposed Approach:

- Using experience from existing projects
- Provide a configurable set of quality monitoring plots:
  - → Correlations in space and time
  - → Tracking (GBL/Straight Line)
  - → DUT Performance
  - → ***User input***
- Flexible event definition scheme to accommodate different readout architectures
- Dynamic pre scaling

IDEA Experiment: A dual readout calorimeter

- Combination of PMT and SiPM cells
  - → 320 SiPM & PMTs to be monitored
- Data recorded with CAEN QDCs
  - → Existing EDUAQ2 integration of CAEN hardware
- First tests end of the year

ECFA

Geant4 simulation

- Calorimetry is among the detectors which has a wider support by G4 collaboration
- Among most common tasks
  - optimization of detector layout
  - data-MC comparison
  - extrapolation of performance for physic reach
- A few key elements:
  - use TB data for Geant-Val validation and code improvements
  - physics process e model
  - Fluka interface
  - R&D for better SW performance

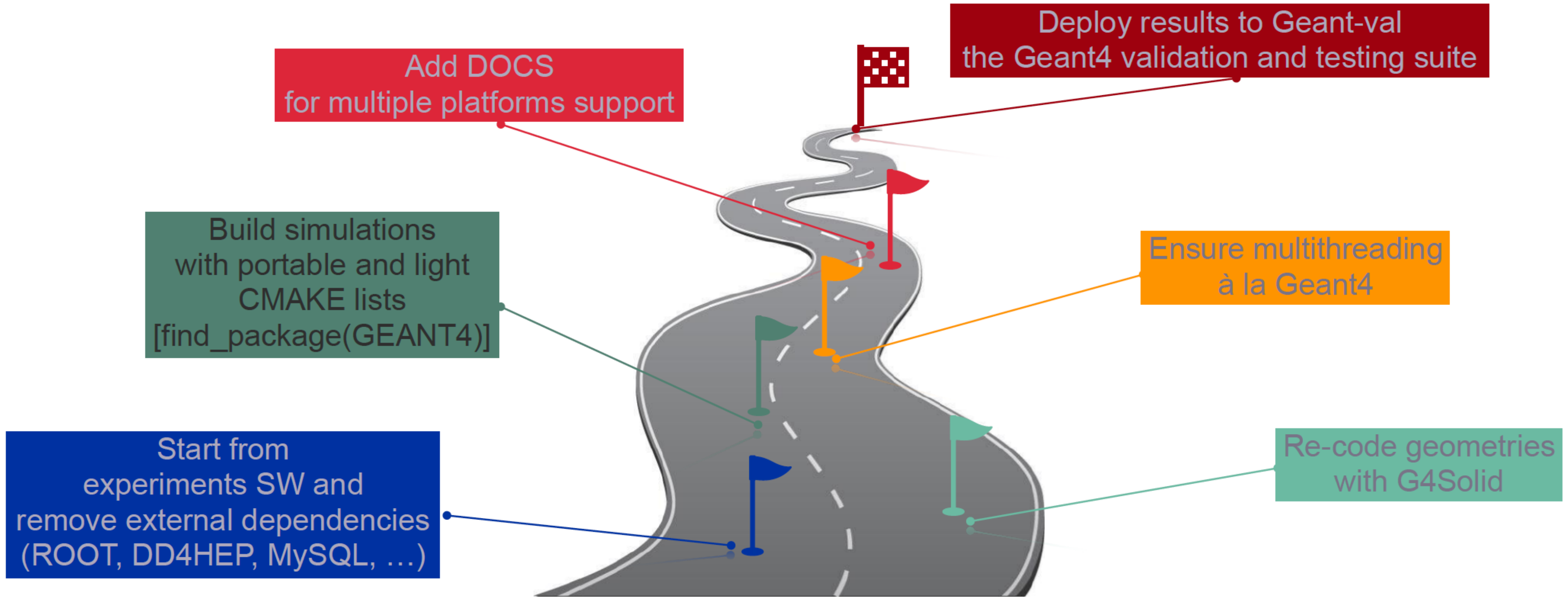
Generating calorimeter showers is the most challenging simulation task.

Several hadronic physics models are adopted within a single Physics List with often overlapping ranges of applicability.

Testbeam data for Geant-val

Slide material courtesy L. Pezzotti

From experiments to geant-val, a winding road



Better to involve G4 collaboration at the beginning of the testbeam. G4 collaboration available to help with the geant4-val inclusion

geant-val.cern.ch

Geant-val is the Geant4 validation and testing suite.

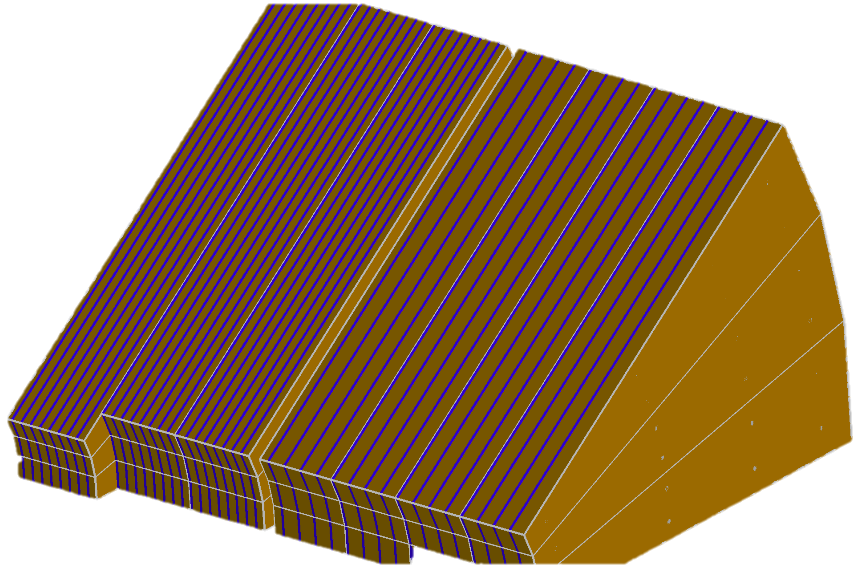
For the Community, it allows to deploy results on a common data-base and fetch the information via a web-interface.

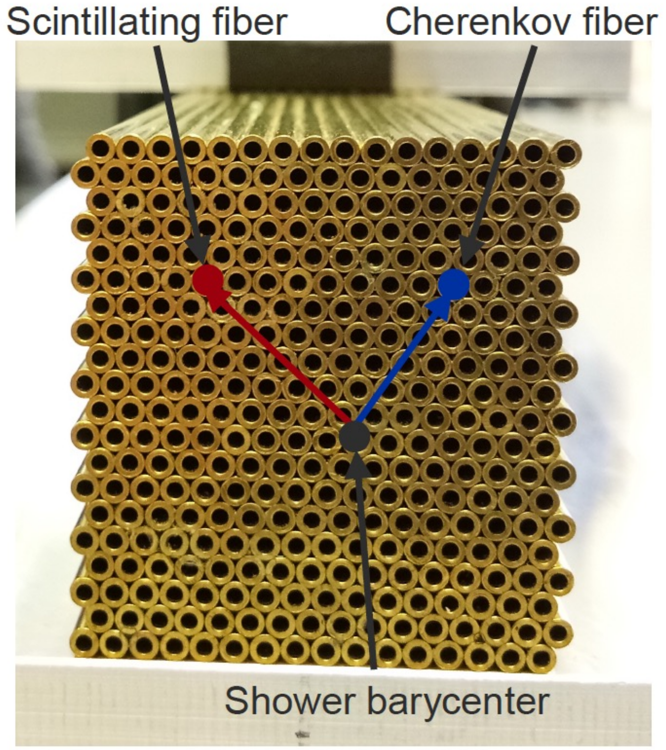
For the developers, it allows to create multiple jobs over beam energies, particle types, physics lists

ECFA **Testbeam data for Geant-val**

Slide material courtesy L. Pezzotti

- Among the calorimeter testbeam included in Geant-val
  - Atlas TileCal and HEC
  - Dual-readout Capillary-based fiber calorimeter
  - CALICE SiW calorimeter





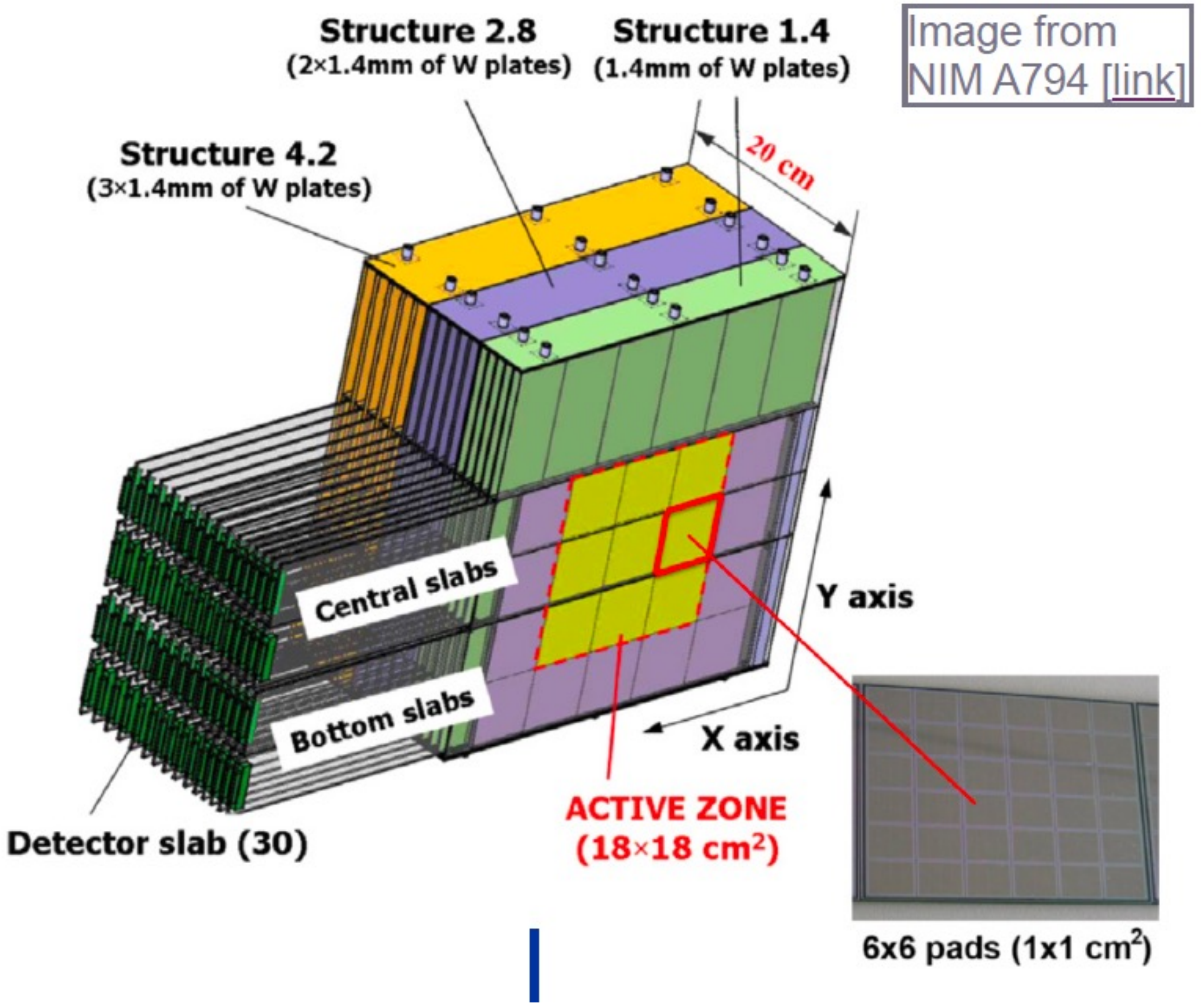


Image from NIM A794 [link]

Testbeam data for Geant-val

ECFA

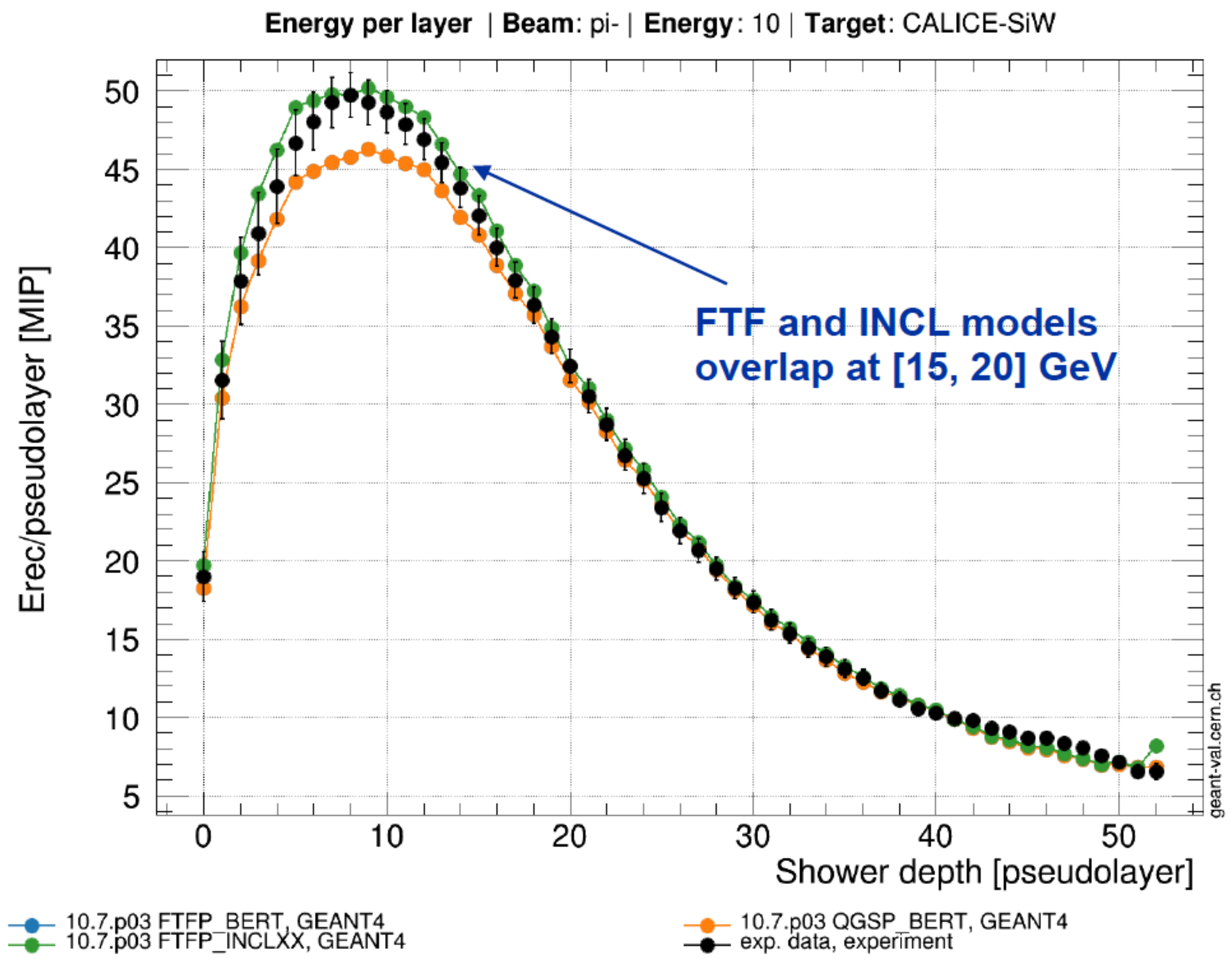
GEANT4 A SIMULATION TOOLKIT

European Strategy Update

Slide material courtesy L. Pezzotti

Data-MC comparison and simulation code improvement

10 GeV π^-, exp. data from NIM A794

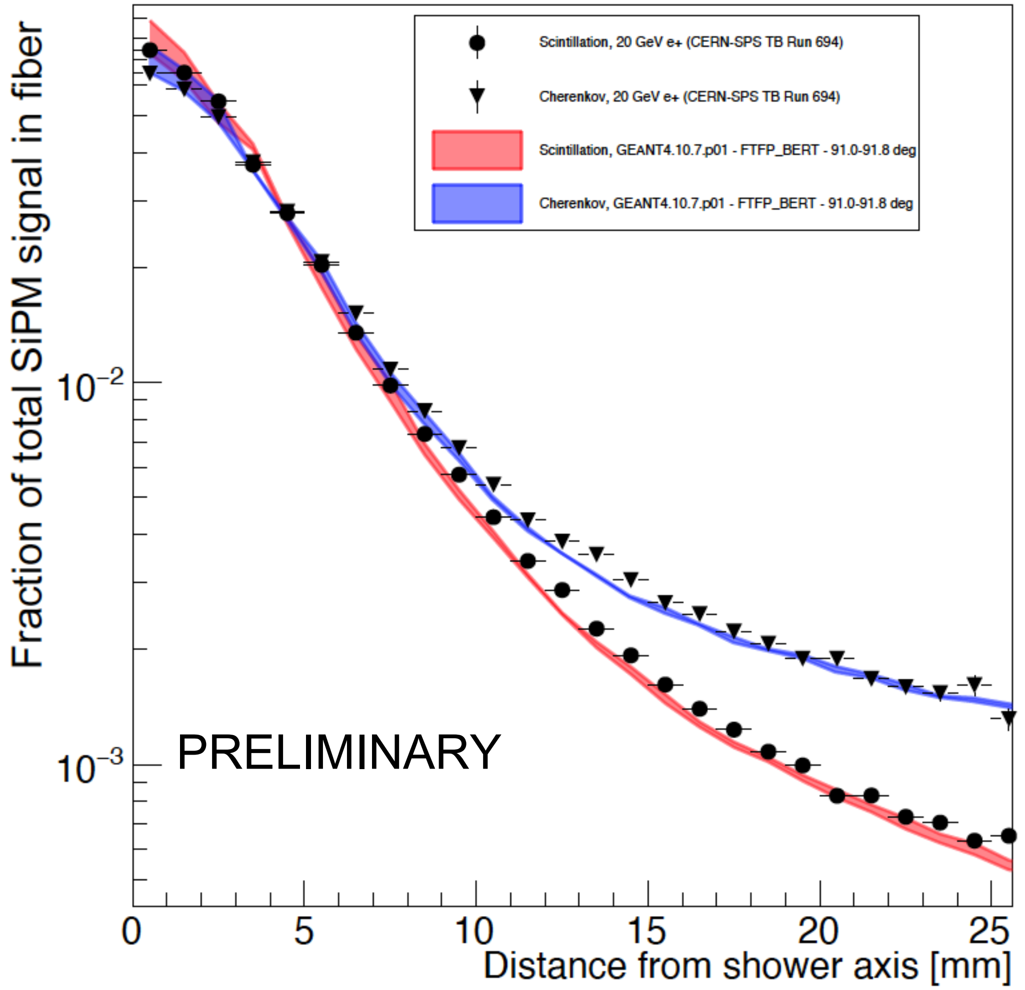


Physics Lists comparison - Geant4.10.7.p03

Large efforts in improving/testing existing hadronic models in Geant4

e.g.
Extension of the INCL model for annihilation

CERN SPS 20 GeV e^+ - GEANT4



TB data are very useful physics data!
Need to preserve them for later use!

Calling FLUKA in a G4 Simulation

Slide material courtesy L. Pezzotti

- Recent G4/FLUKA.CERN collaboration is ongoing to create a G4 interface to FLUKA hadronic models (FLUKA PEANUT).

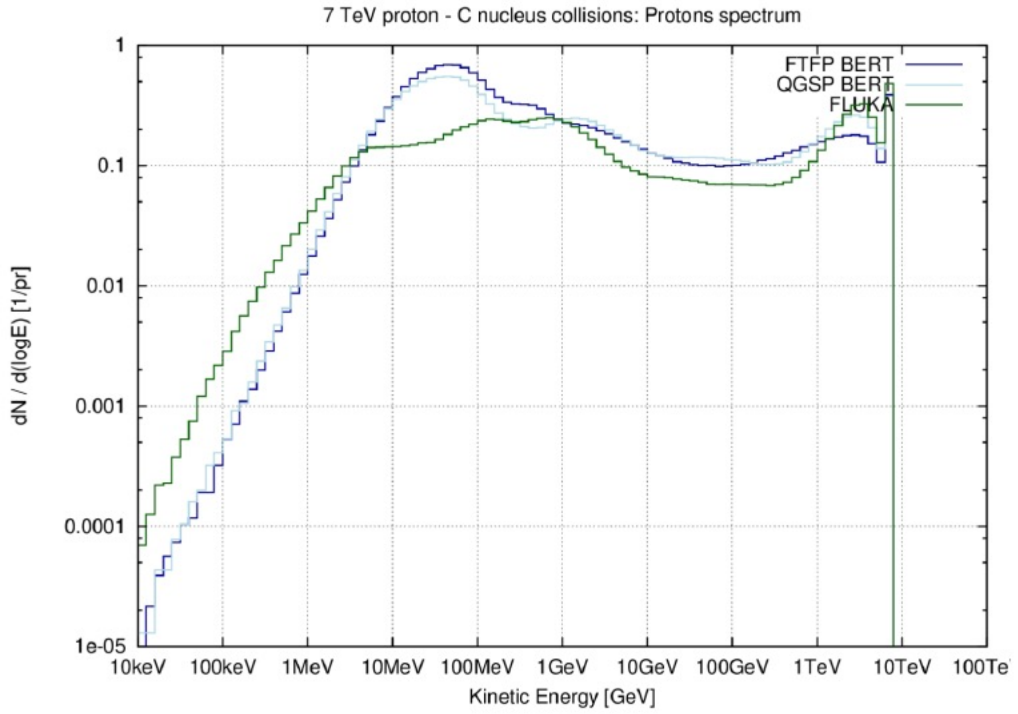
  Goals:

  - Give direct access to any G4 simulation to FLUKA hadronic models (might be extended to ion-nucleus models). At the moment targeting FORTRAN code, implementation of hadronic models in C++ (FLUKA++/FLUKA5) is a future step.
  - N.B. registration to FLUKA and agreement to FLUKA license is needed.

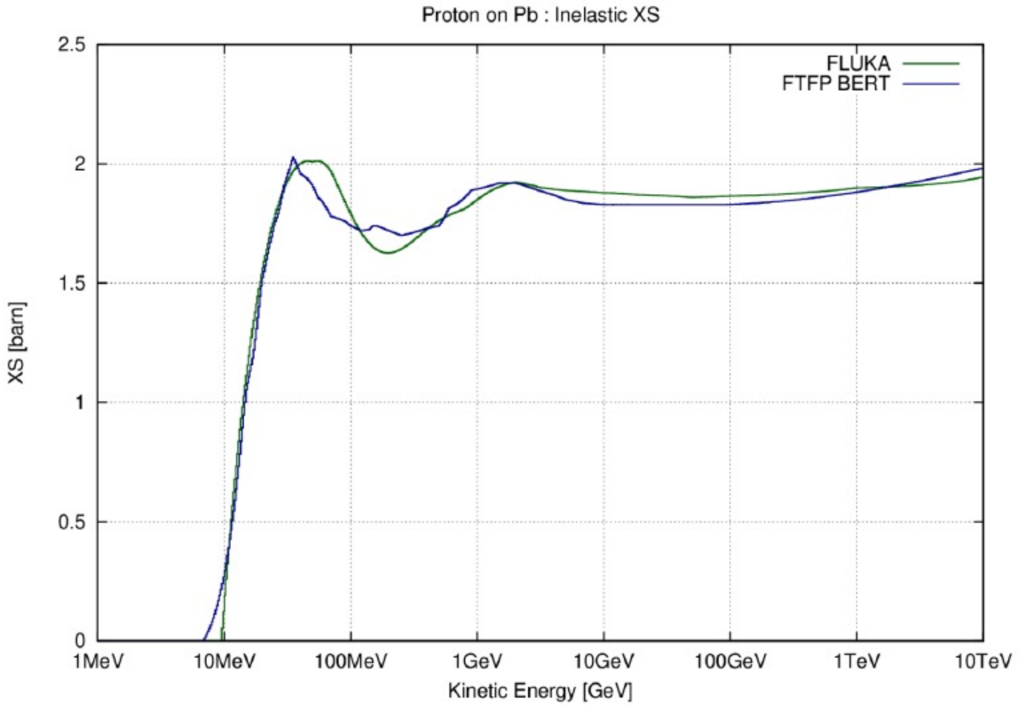
- A Geant4 example is in preparation (to be included in G4-11.2) to show how to access FLUKA.CERN hadronic cross sections and inelastic final-states from a Geant4 application.

- *Hadronic calorimeters tests housed on geant-val will soon be tested against FLUKA hadronic models with no additional efforts!*

Had inelastic final states (FLUKA vs G4)



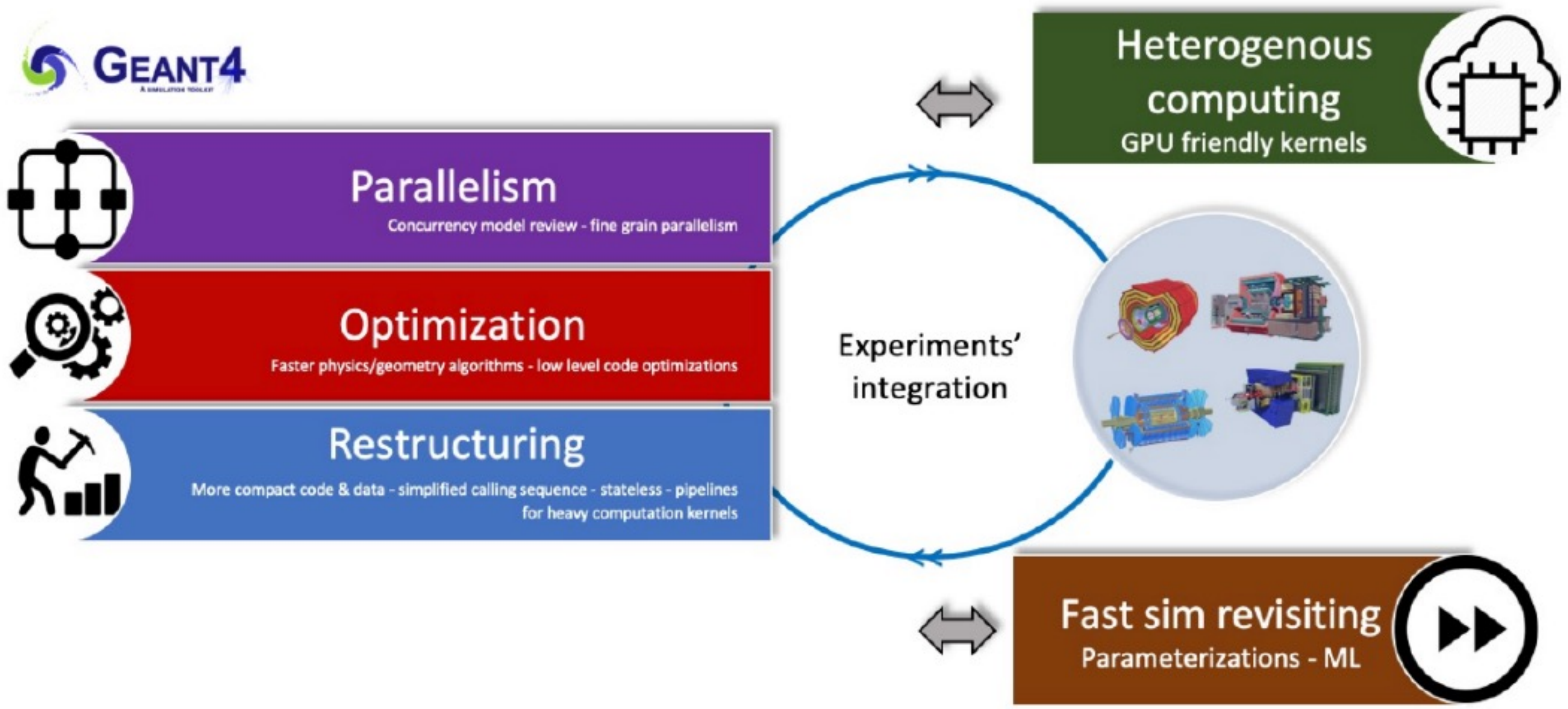
Inelastic XS (FLUKA vs G4)



Geant4 R&D

Slide material courtesy L. Pezzotti

- Three main R&D axes:
  1. Investigate the use of novel accelerators as GPUs (Adept, Celeritas and Opticks).
  2. Improve/modernize existing Geant4 code to gain in performance for detailed simulations (task-oriented parallelism, G4HepEM, Woodcock tracking, sub-event parallelism, …)
  3. Trade precision for performance using fast simulation techniques both with parameterization and ML.



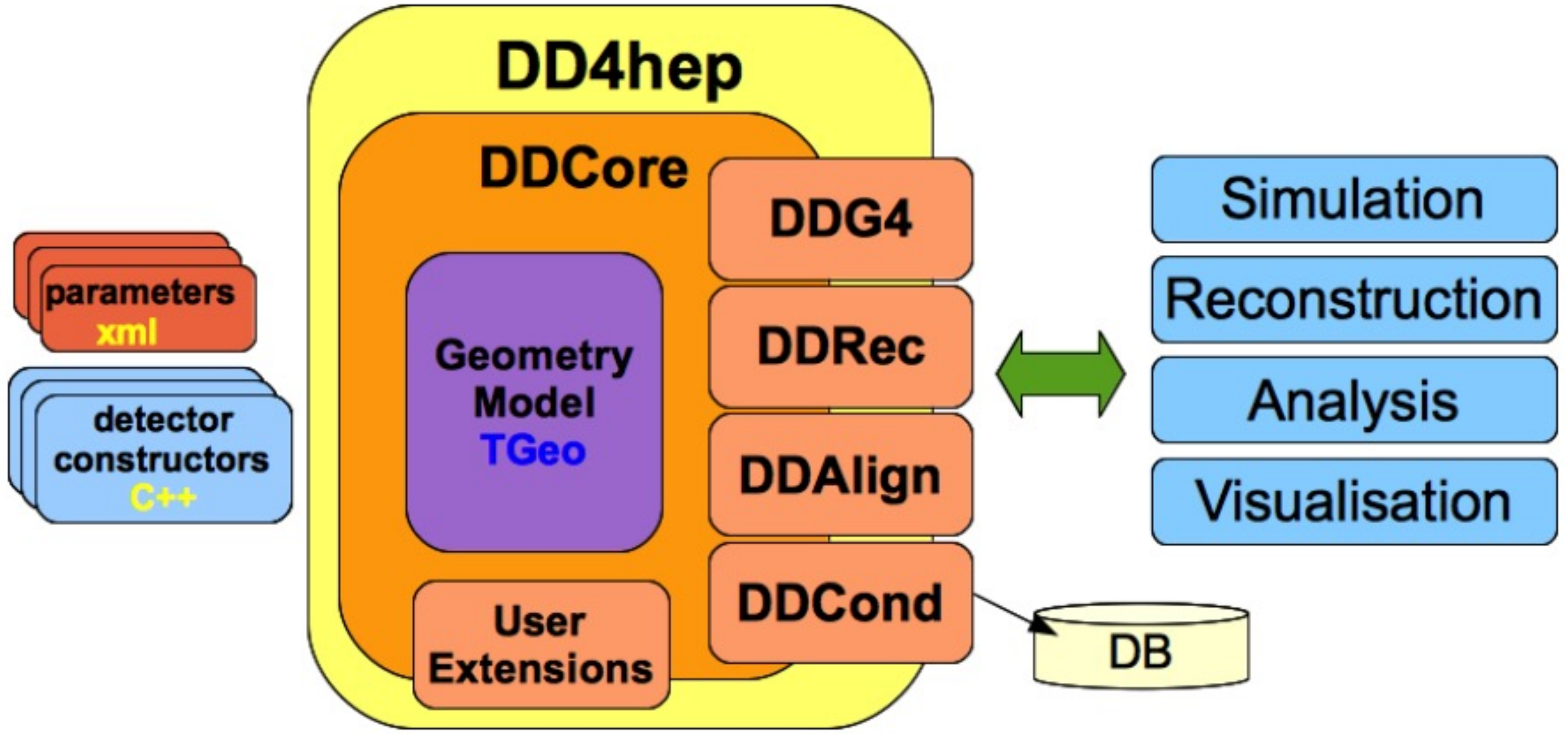
Of great interest for EM shower simulation and transport of photon in optical media

DD4HEP can be used for detector description

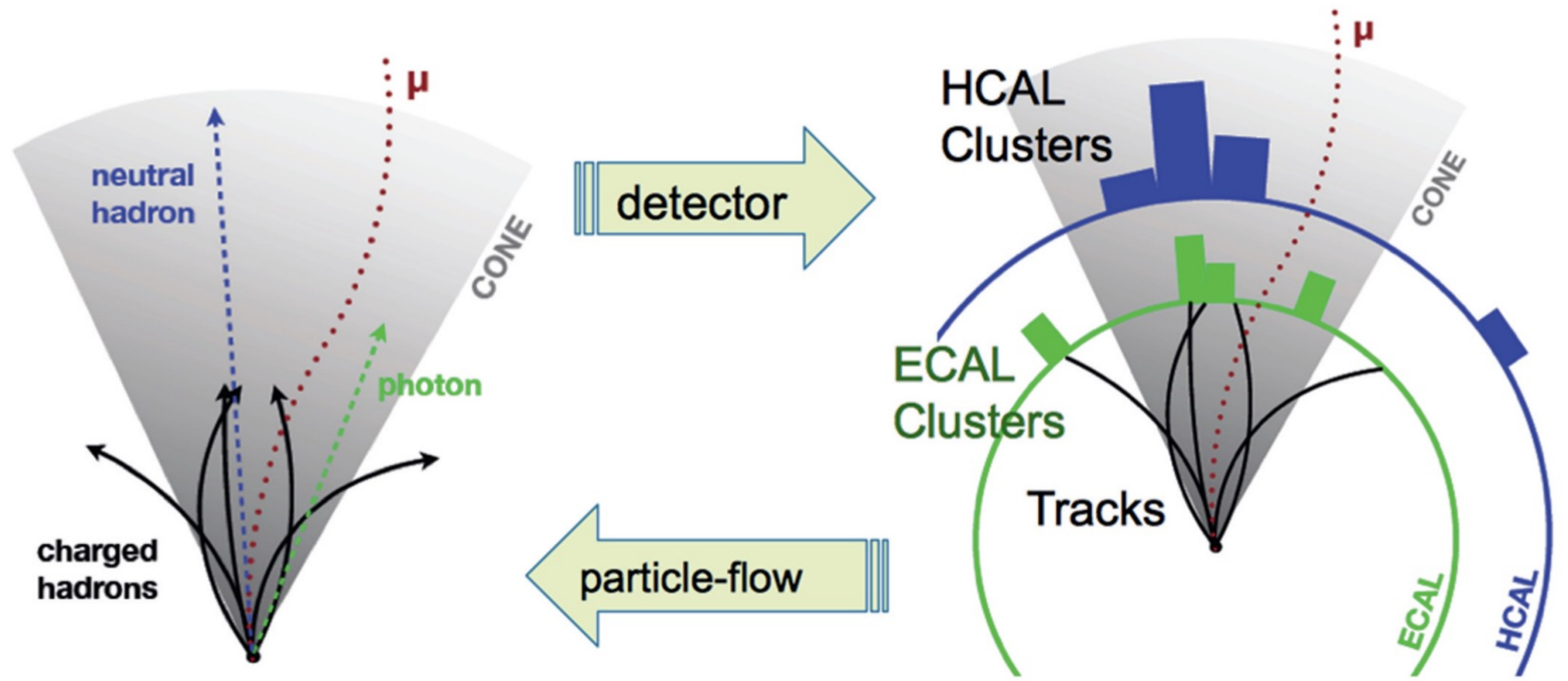
- easy to scale from prototype size simulation to “full experiment” one
- needed for physics performance assessment

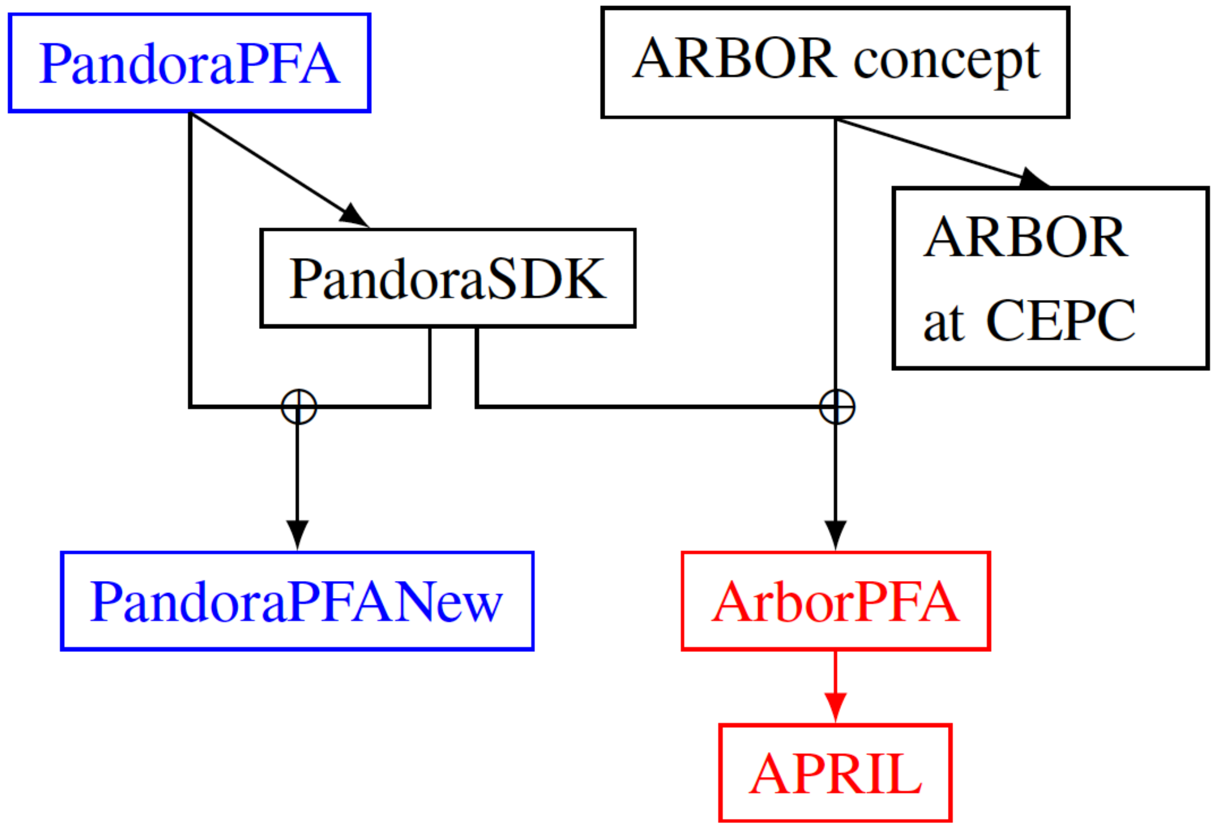
DD4hep follows a **modular, component based design**

- **DDG4**: full simulation with Geant4
- **DDRec**: *high level* interface for reconstruction
- **DDAlign**: interface for (mis-)alignment of detector components
- **DDCond**: interface to conditions data base



Particle Flow Algorithm in a nutshell





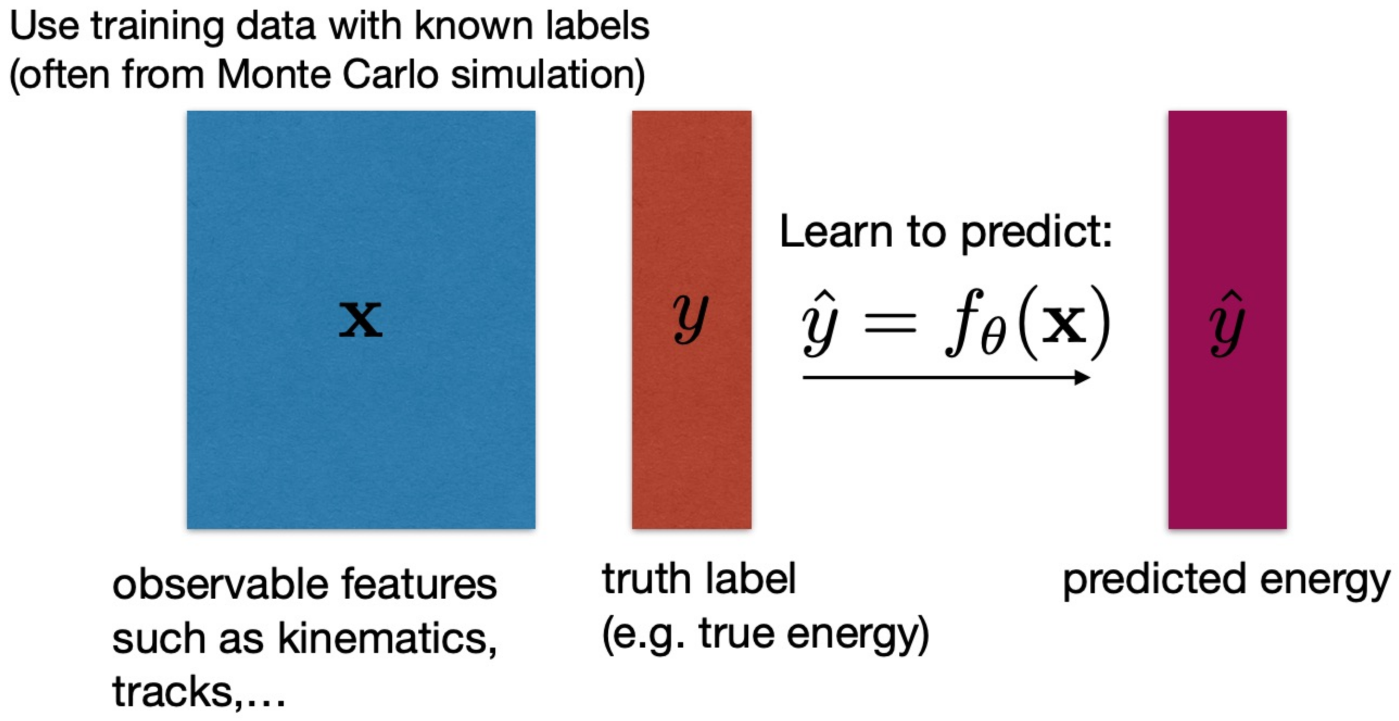
Component	Detector	Energy Fract.	Energy Res.	Jet Energy Res.
Charged Particles ($X^{\pm}$)	Tracker	$\sim 0.6\,E_j$	$10^{-4}\,E^2_{X^{\pm}}$	$< 3.6 \times 10^{-5}\,E^2_j$
Photons (γ)	ECAL	$\sim 0.3\,E_j$	$0.15\,\sqrt{E_\gamma}$	$0.08\,\sqrt{E_j}$
Neutral Hadrons (h^0)	HCAL	$\sim 0.1\,E_j$	$0.55\,\sqrt{E_{h^0}}$	$0.17\,\sqrt{E_j}$

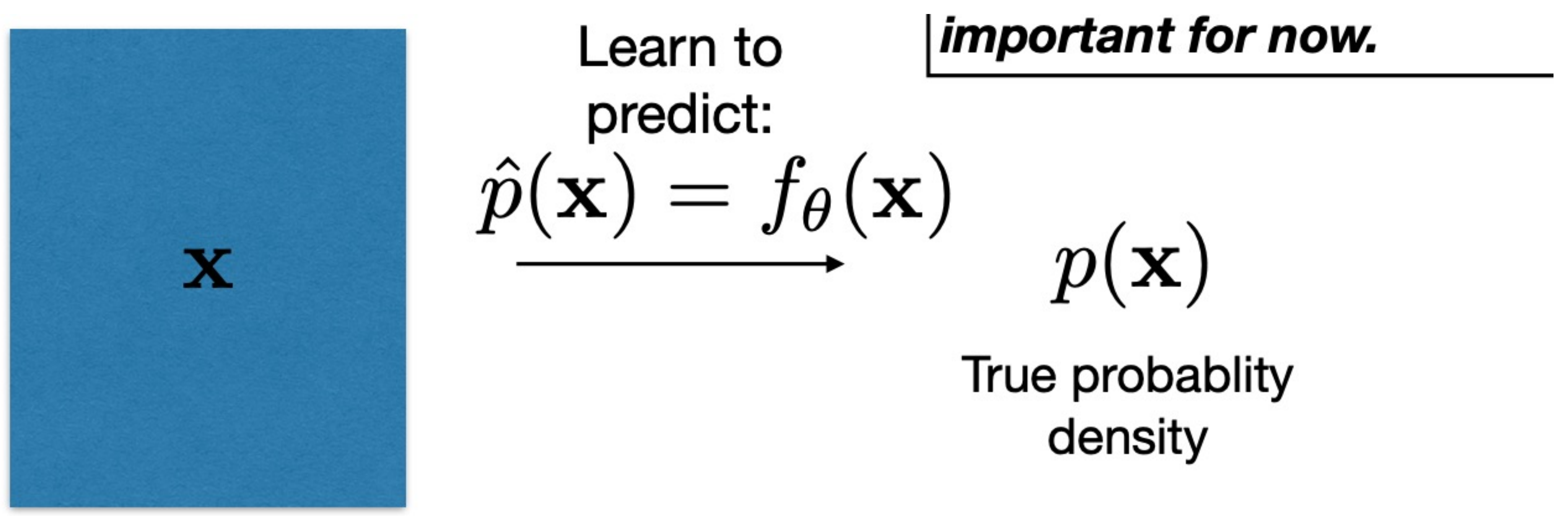
Particle Flow Algorithm

- Largely implemented in CALICE calorimeters
- 17/23 proposals mention PFA as desired/needed reconstruction algorithm
- Consequence of the high granularity layout of proposed calorimeter concept
- good PFA requires global ECAL+HCAL calorimetric system
  - ability to follow hadron interaction in the ECAL
  - PFA needs may put some constraints on homogeneous ECAL.

Machine (Deep) Learning Approach

- Machine Learning approach is gaining more and more importance in HEP and in calorimetry in particular
  - highly complex data with large number of detailed information
  - Simulation provides tagged data for supervised learning
  - Tracking, clustering, particle ID ...

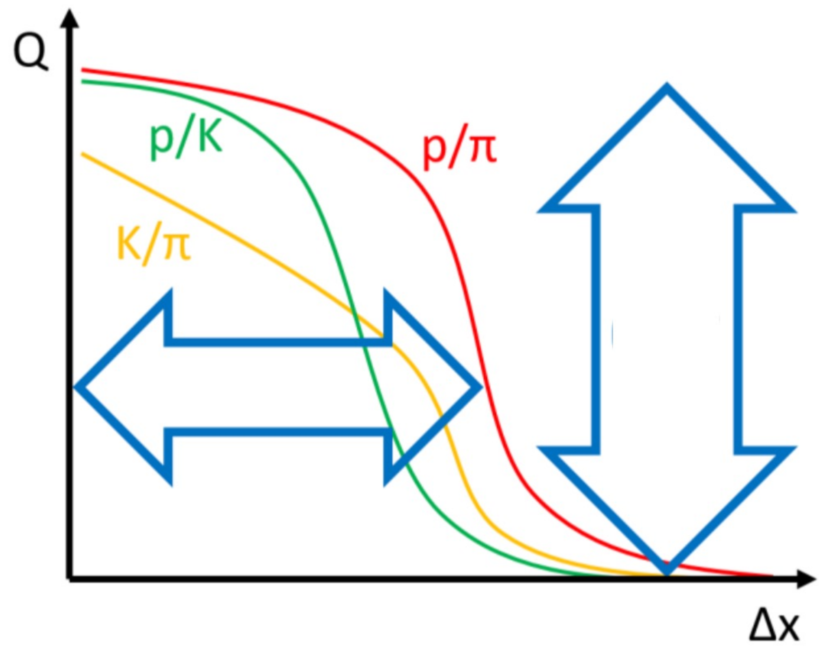




Full exploitation of information content in High Granular HadCalo

MODE collaboration
INFN-Padova
Lulea Tech. U.
U. Oviedo
U. Clermont Auvergne
KIT
Rheinland-Pfalzische Tech. U.

- Proposal in track 4 – blue sky project
- High granularity allows getting information with much richer level of details of hadron and jet shower development
  - PID from nuclear interaction (ultimate discrimination power, cell size dependence)
  - Use of neuromorphic computing to exploit information of higher granularity information before feature extraction at back-end elx
  - Hybridization of tracking and calorimetry (detector material density gradually increasing from tracking to calorimeters
  - Models for full optimization of tracking + calorimeter design



Software repositories

- Software we use (e.g., G4, EUDAQ, DD4HEP...) are developed by collaborations
  - each have its own repository – no duplication
- Specific applications for R&D in DRD6 could leave in the same repository area
  - Development of common code
    - DAQ & G4 simulation of common Test beam line
    - Reconstruction algorithms
    - ...
  - Save person-power and time (both for coding and cross-validation)
  - Common Event Data Model is also needed for both comparison and preservation of data for later analysis