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ICSC Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

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Benchmark interactive analyses ongoing at INFN Napoli

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Spoke 2 - WP2 weekly Meeting, 5th December 2023

Outline

- Brief introduction to the infrastructure used
- Use cases tested:
  - FCCee: simple test on Zee samples
  - CMS: top quark+MET analysis
    - ➡ collaboration with INFN Perugia
  - ATLAS: stop to 4-body SUSY analysis
    - ➡ collaboration with INFN Lecce

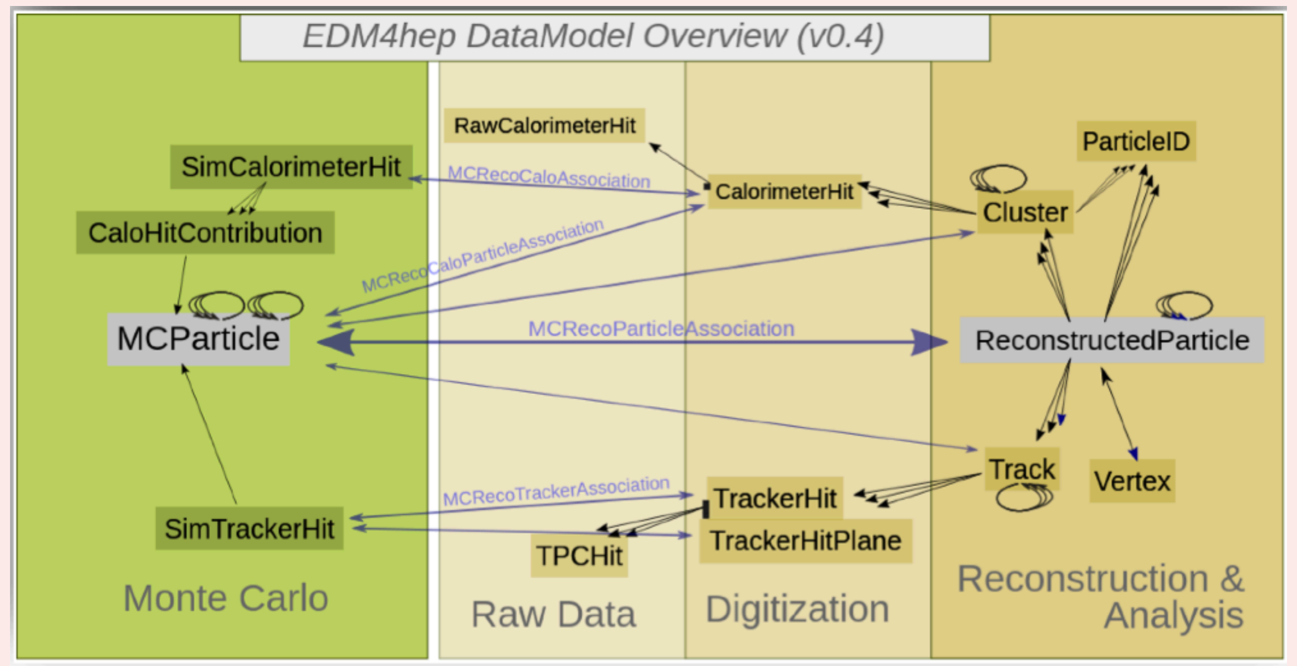
INFN Napoli infrastructure

- The local deployment is based on the *Open-Stack IaaS* paradigm
- Starting from the already existing *I.Bi.S.CO* installation, several updates were performed
- The cluster is made up of 2 identical virtual machines, each equipped with 1CPU quadCore and 8GB RAM, currently expanded up to 12 cores and 64GB
- Rocky Linux 8.6 is the operating system
- 2 nodes are equipped with **Docker** (20.10) for containerisation and **Kubernetes** (1.26.3) for the orchestration
  - One node plays as controlplane, etcf & worker; the other node acts as a plain worker
- The cluster is equipped with **JupyterHub** & **JupyterLAB** where the user can play with **Python, ROOT & Dask** libraries

13/10 WP2.5 presentation *link*

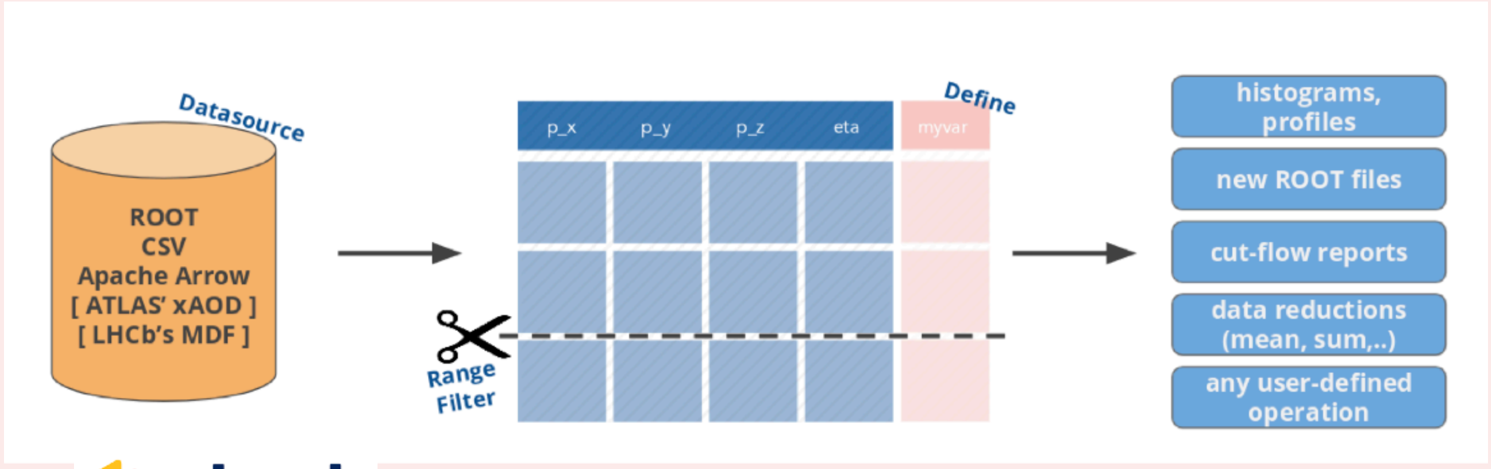
FCCee use-case Workflow

EDM4hep input data format

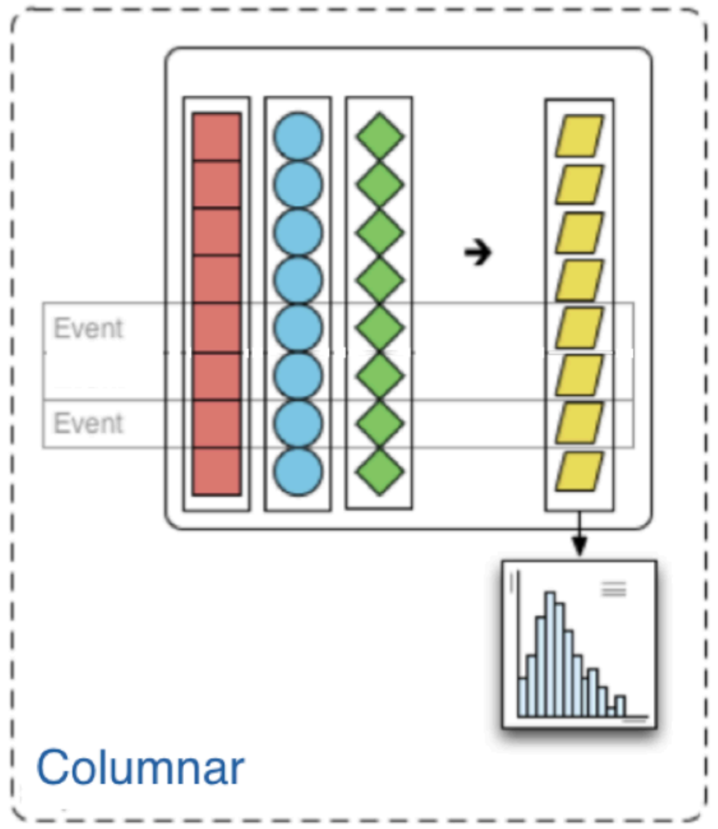


flat input ntuples

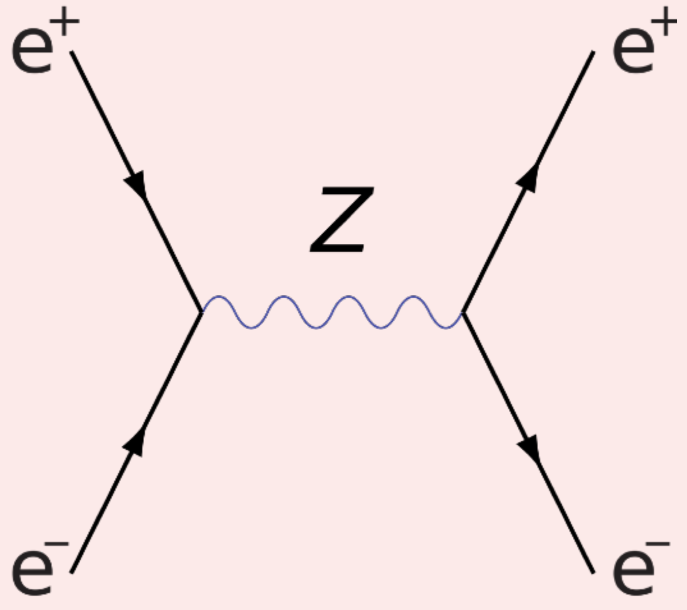
RDataFrame



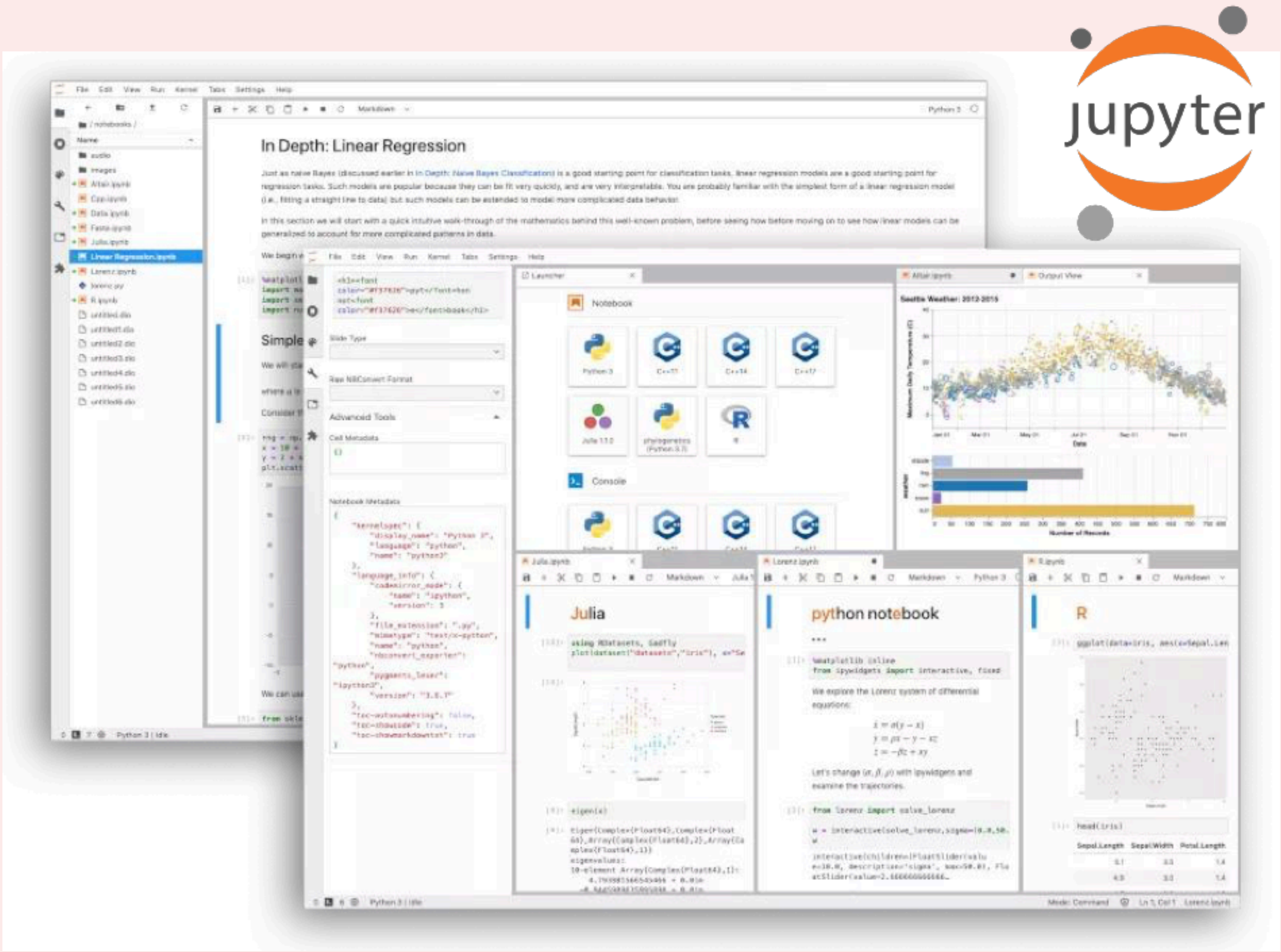
+ dask used as backend



Use case



New approach to data analysis

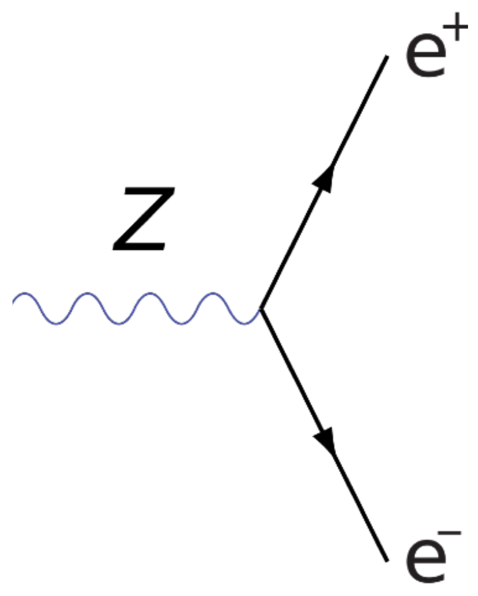


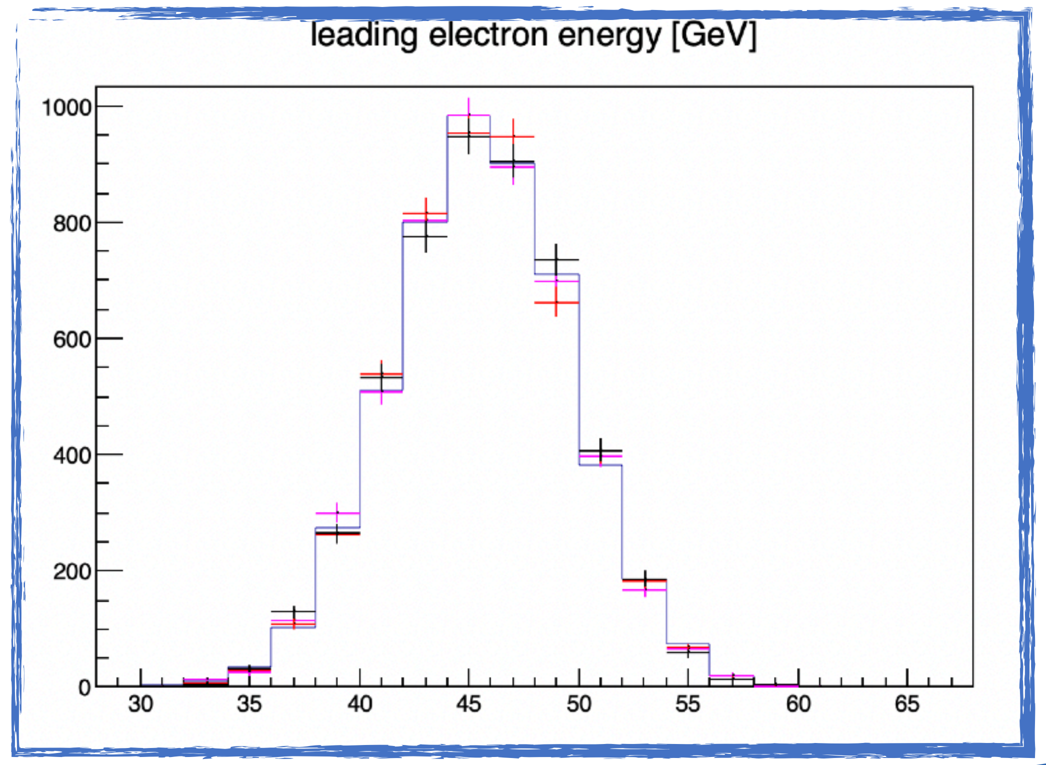
Feasibility study & Preliminary performance evaluation

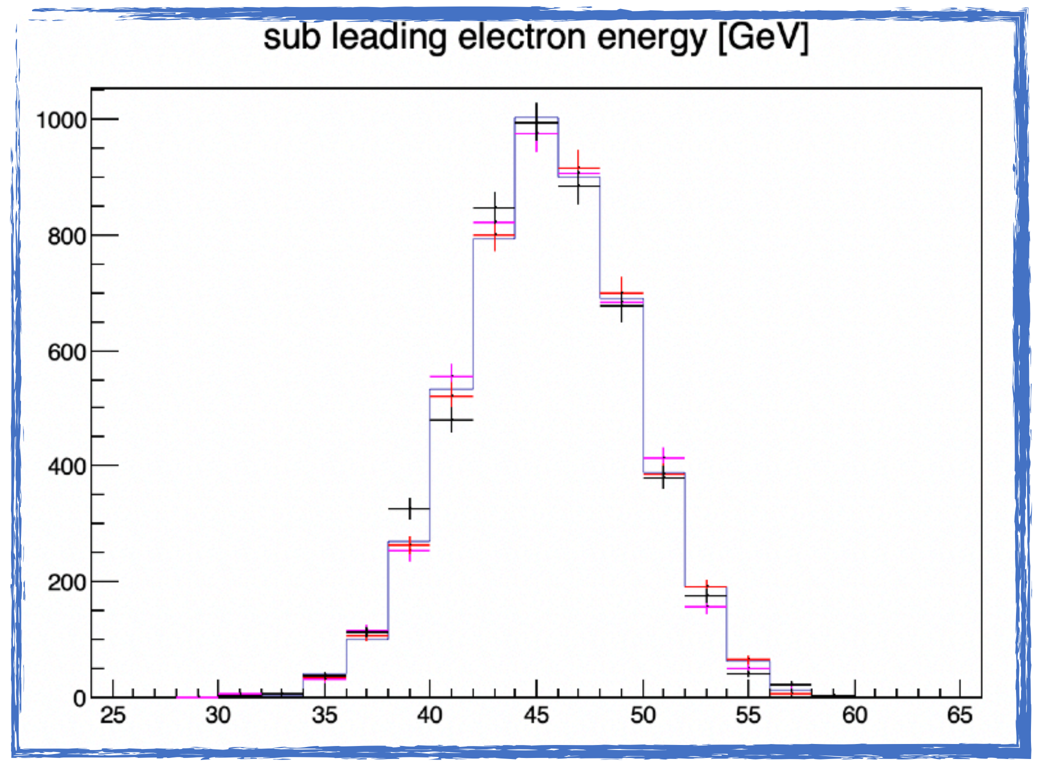
13/10 WP2.5 presentation *link*

Simple test

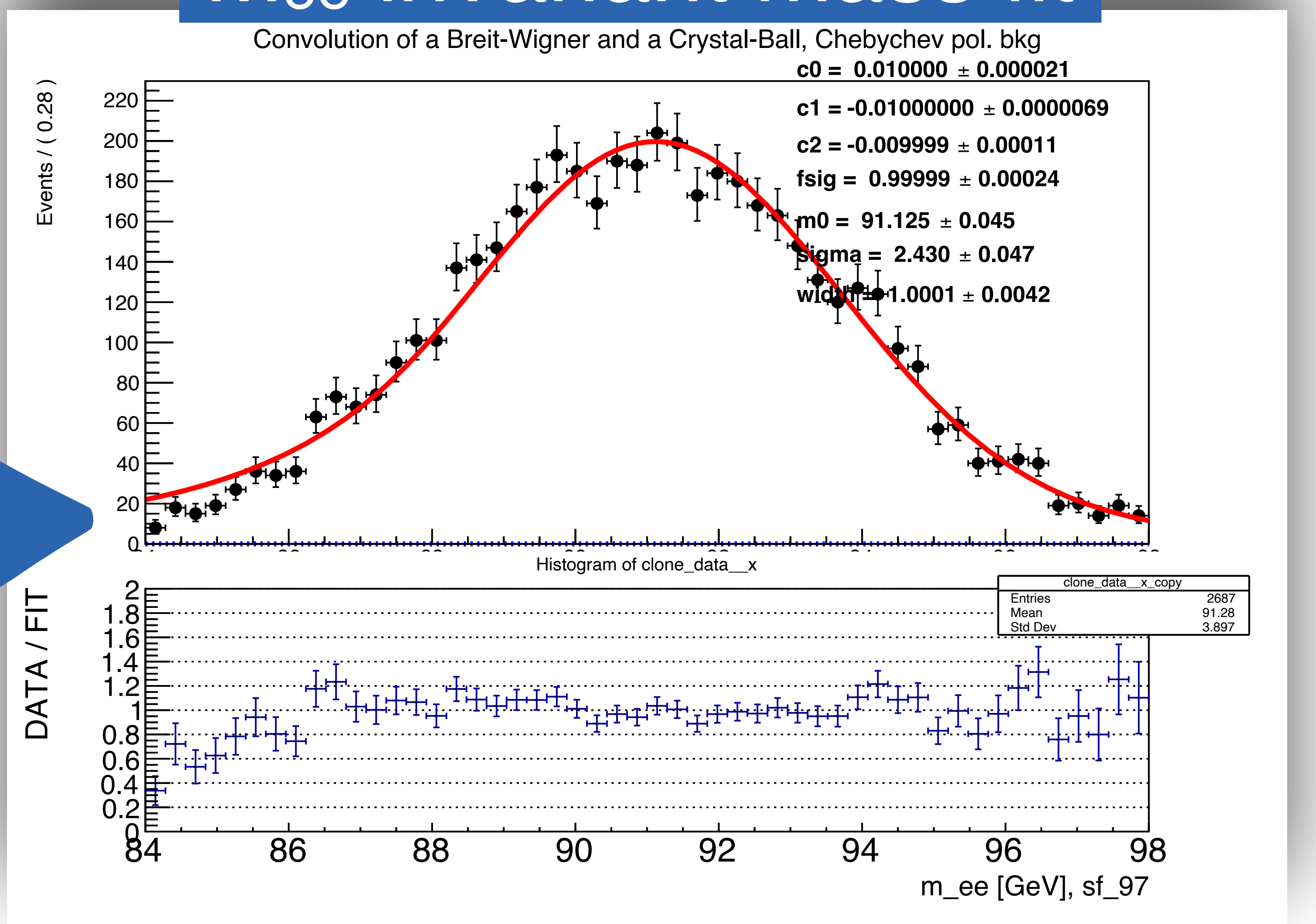
- FCCee simulation: /eos/experiment/fcc/ee/tmp/ee_Z_ee_EDM4Hep.root
  - 5k events, scaled to 1M events replicating the available dataset
  - Mimic systematic variations, gaussian smearing the electrons energy to compute M_{ee} resolution





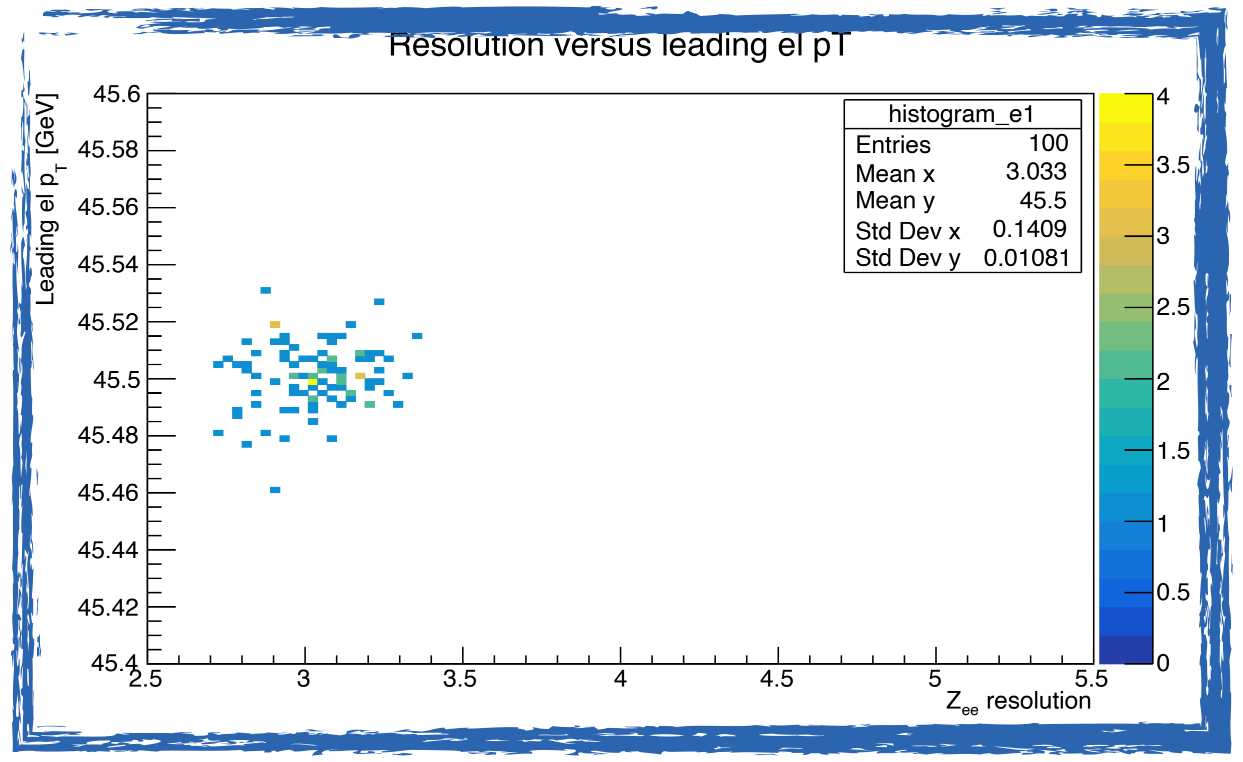


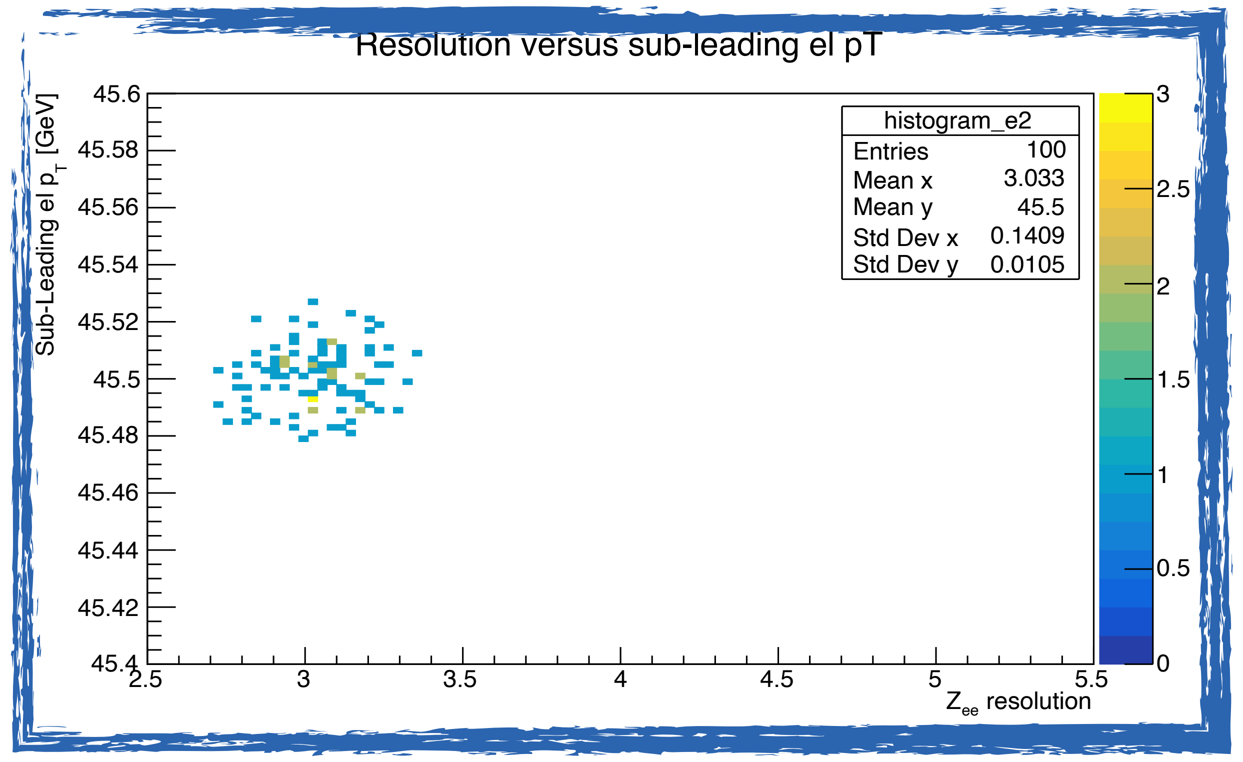
M_{ee} invariant mass fit



Selection and histogramming interactively via RDataFrame on JupyterHub

[github link to the code]





Preliminary results

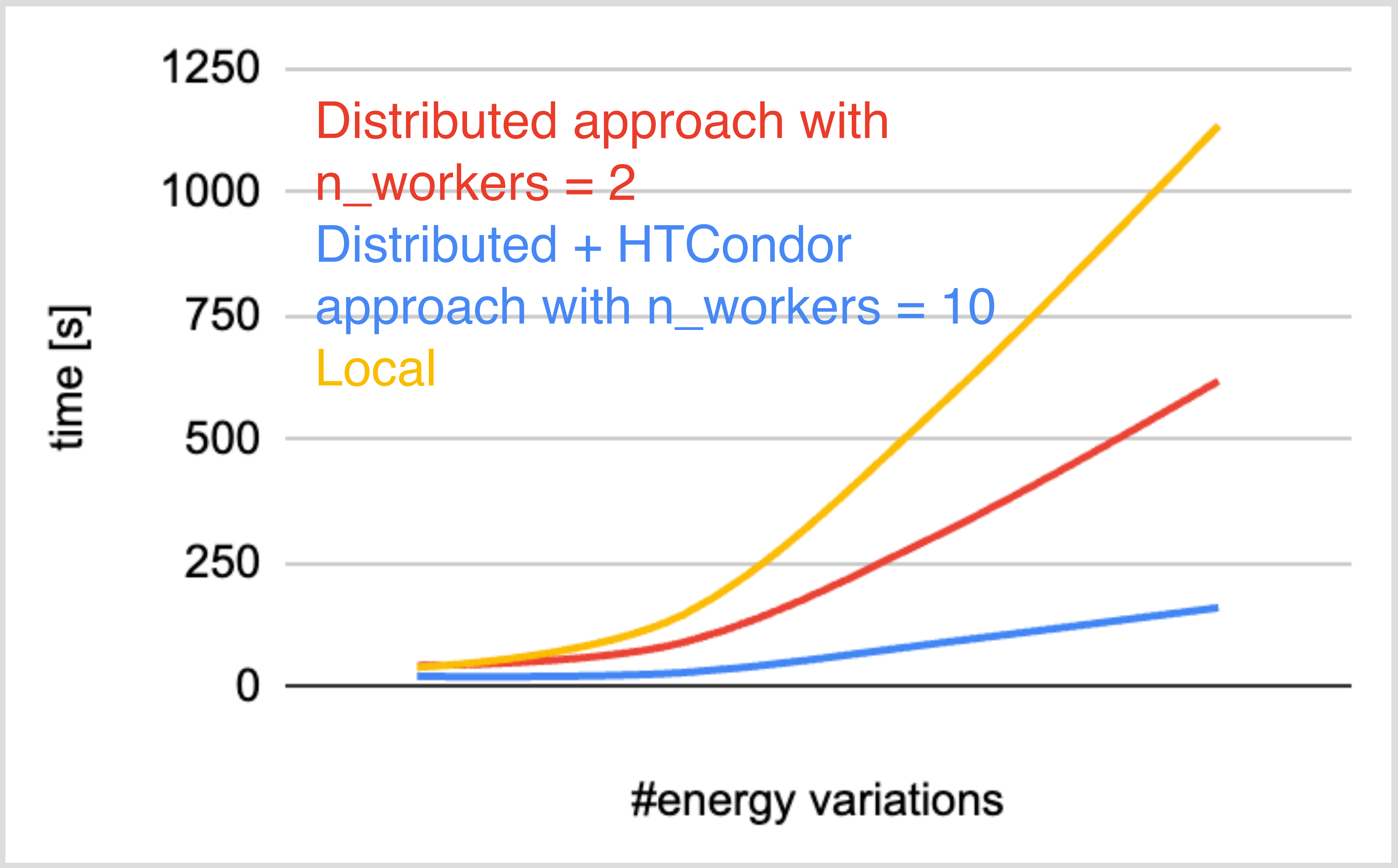
Scaling without changing your code

```
from dask.distributed import LocalCluster, Client
if distributed == True:
    RDataFrame = ROOT.RDF.Experimental.Distributed.Dask.RDataFrame
    ROOT.RDF.Experimental.Distributed.initialize(my_initialization_function)
else:
    RDataFrame = ROOT.RDataFrame
    my_initialization_function()
```

} Local

⋮ No changes required to the rest of the code

```
df = df.Define('w_nominal', '1')
df = df.Define("m_e","0.0005124") #GeV
df_ge = df.Define("goodelectrons", "Particle.charge[0]*Particle.charge[1] < 0.").Filter("goodelectrons > 1")
```

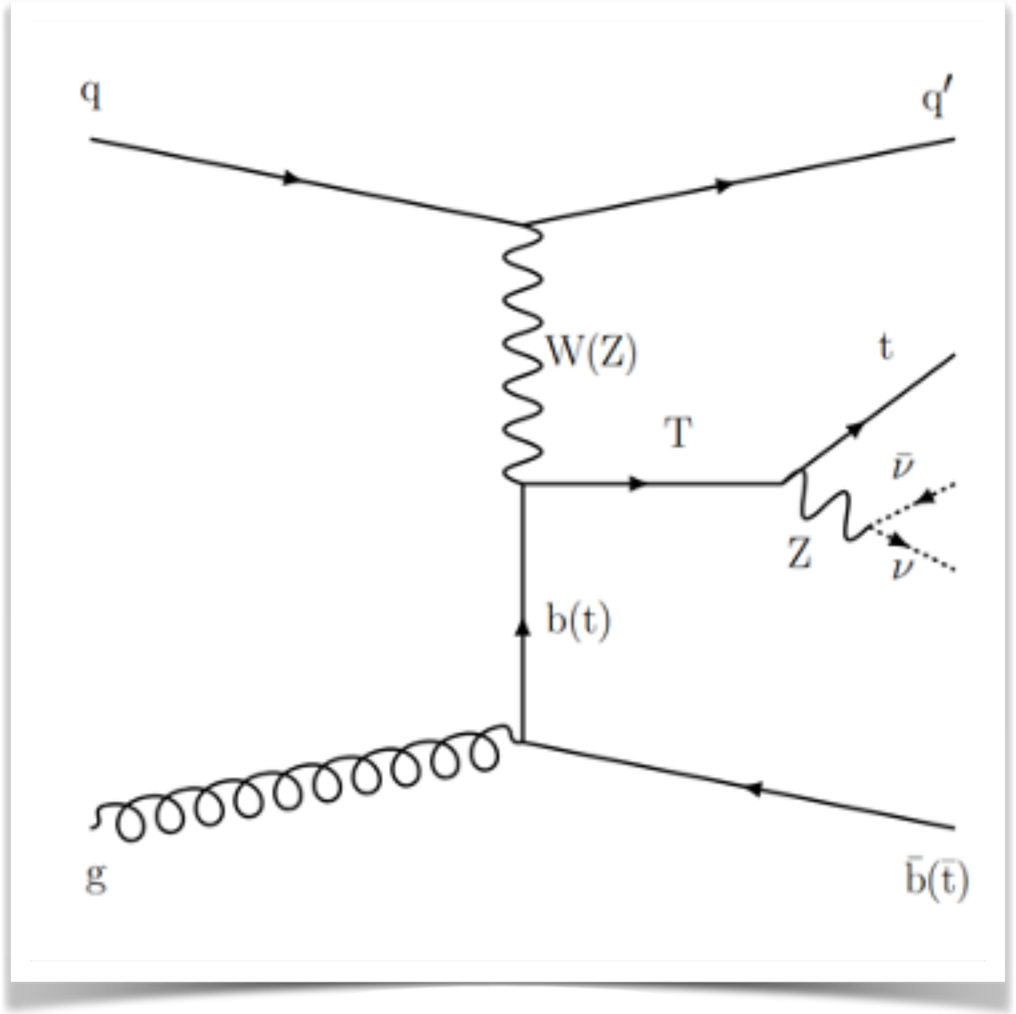


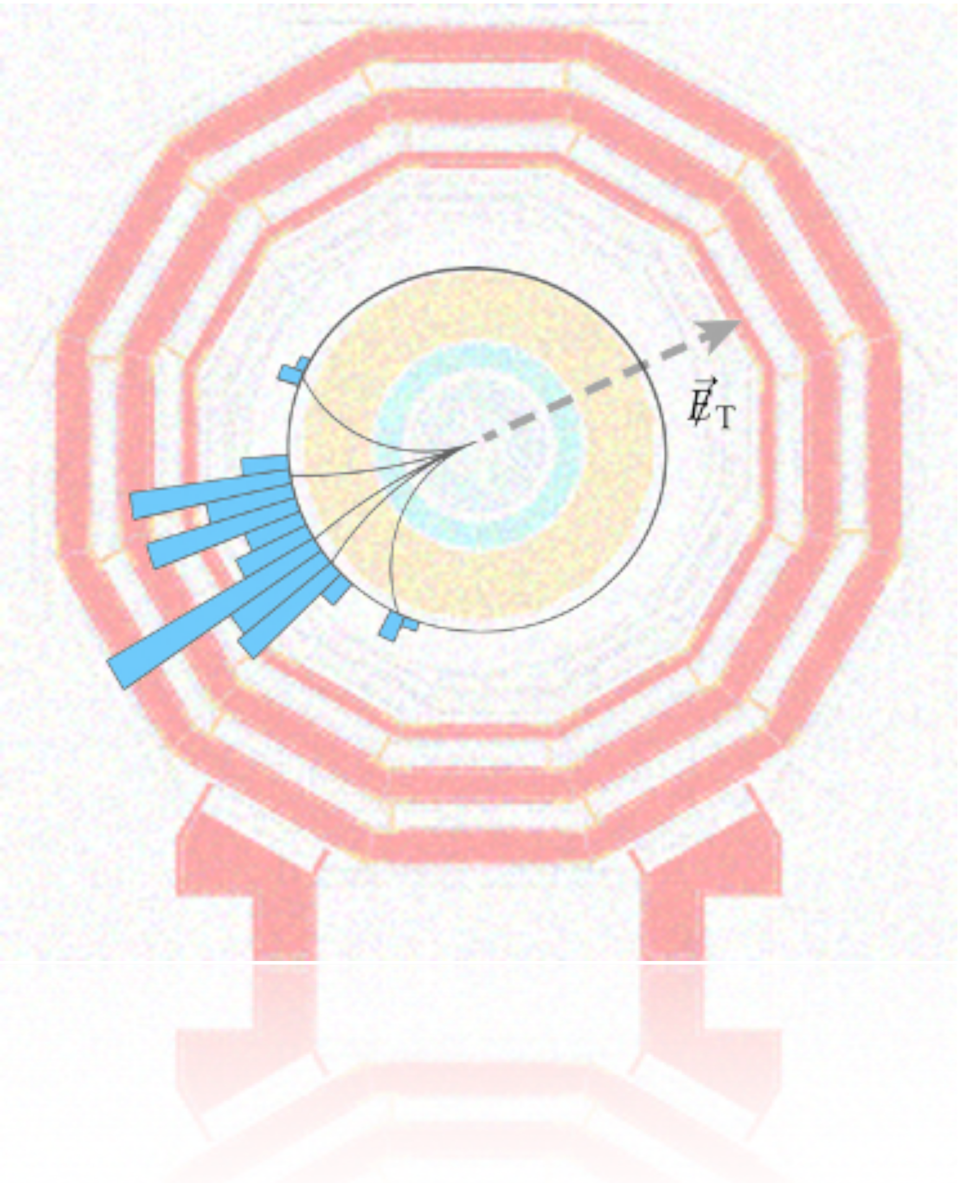
- Exploiting the distributed approach, the execution time halves wrt the local approach
- Moving to a Dask+HTCondor model, we gain up to another factor 2
  - Increasing the number of workers, the execution time further improves
- Advantage: use this use case as simple test for who wants to benefit from the WP5 infrastructure

CMS use-case

- Early Run 3 analysis (2022-2023 data taking)
- Beyond Standard Model searches
- Vector-Like Quark T in T→ tZ channel
- Final state: hadronic Top quark and Z (νν)
- Development of the already published full Run 2 analysis *JHEP05(2022)093*, with the idea to extend the results interpretation to more models predicting the same final state
  - Dark Matter production in association with a Top quark
  - Technicolor models *The Radiative Flavor Template at the LHC*

24/05 WP2.5 presentation *link*





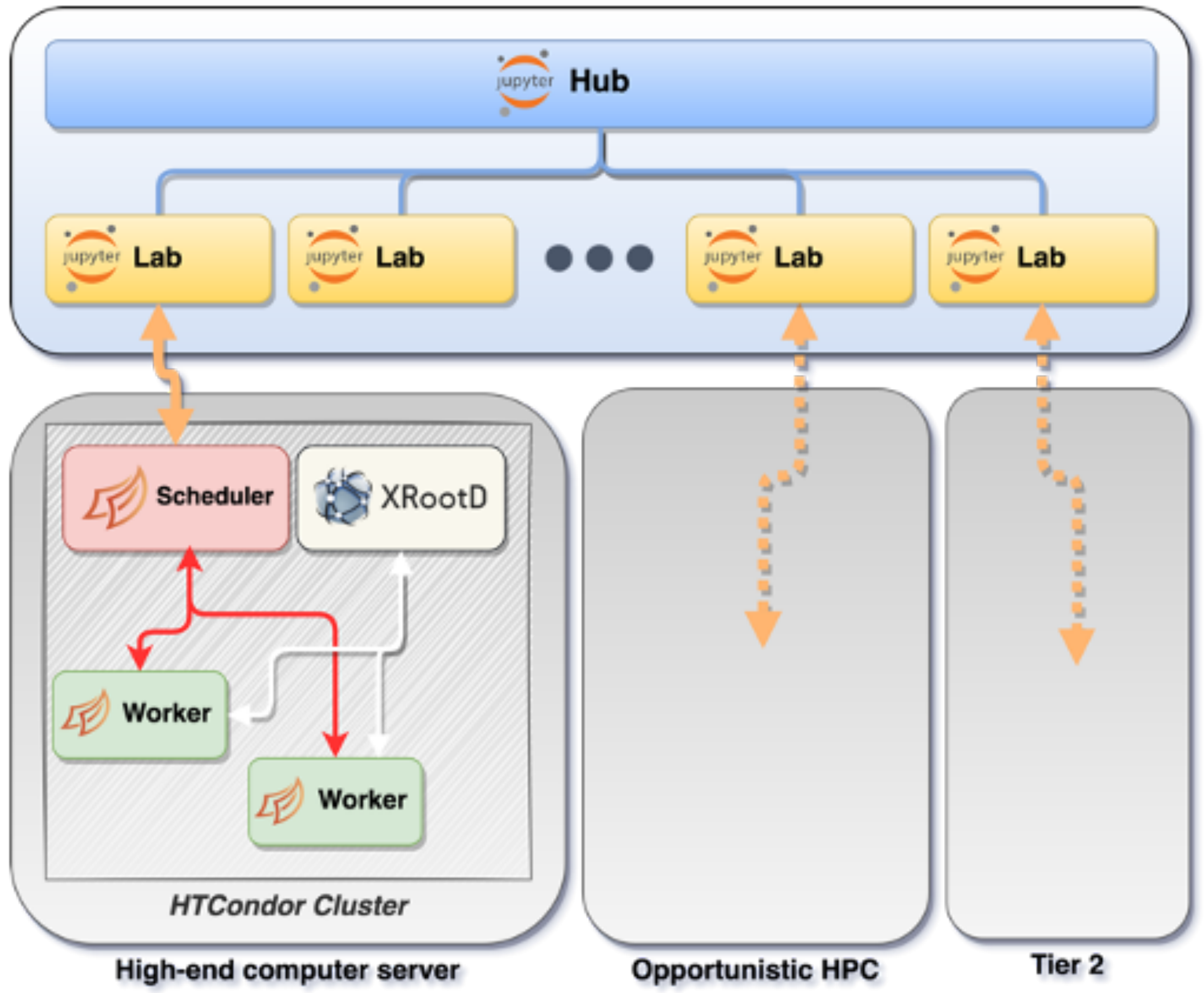
State of the art

CRAB
Cms Remote Analysis Builder

Workflow in 2 steps:

- Data preprocessing, evaluation through ML model.
  Using CMS NanoAOD tools (pyROOT-based) and CRAB.
- Skimming and selection using Interactive Analysis
  - Input: ntuple from the 1st step
  - Selection + variables calculation through RDataFrame
  - Distribution of the process using Dask
  - Output: TH1D easy to manage, also possible to store snapshot using remote storages

Working on Perugia's analysis facility

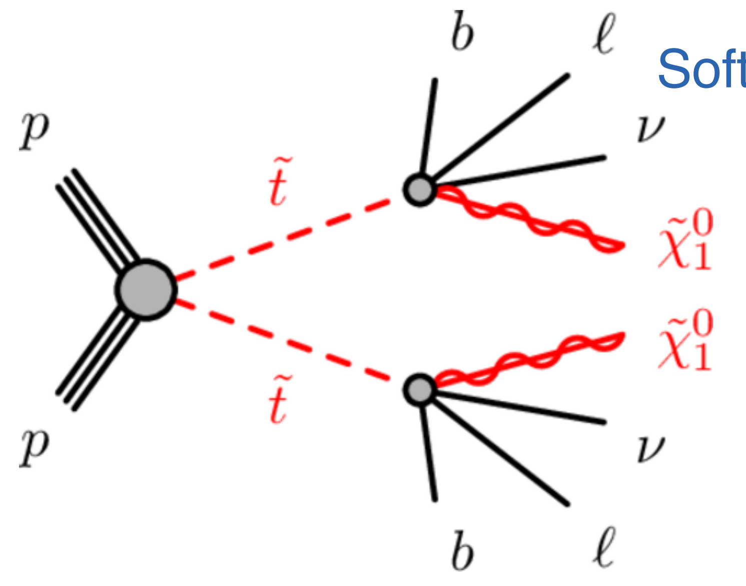


- Analysis still far from the end, more processes will have to be added that will slow it down
- Currently the results are very promising
  Time reduced from ~1d to ~3h and there is still room for development

ATLAS use-case

SUperSYmmetry: Beyond Standard Model theory

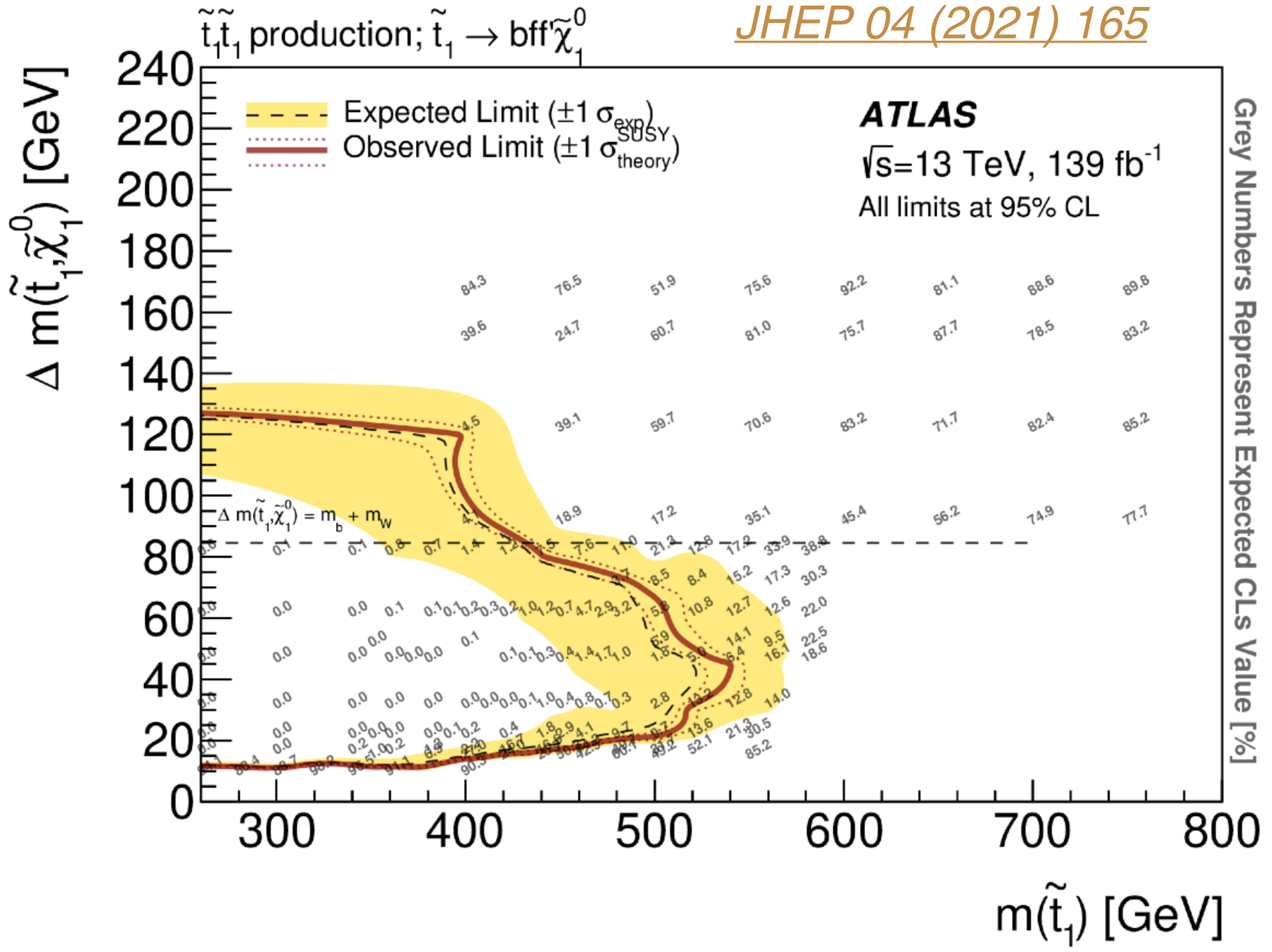
- Three different analysis in the Run 2 paper, already published, according to mass splitting between *stop* ($\tilde{t}_1$) and *neutralino* ($\tilde{\chi}^0_1$), allowing different decay modes:
  - 2 body → $\Delta m > m_t$
  - 3 body → $m_W + m_b < \Delta m < m_t$
  - 4 body, the one picked up → $\Delta m < m_W + m_b$
- Common final state signature: 2 OS leptons (electrons/muons), jets and missing transverse energy
- Cut & Count based approach
- Final, i.e. starting from flat ntuples, event selection done with *ROOT RDataFrame* and 3 helper classes, 100% python based
  - List of cuts, in dictionaries
  - I/O, mainly to define and store output structures/yields
- Main workflow, to extract nominal yields and systematic variations, starting from single *TTree(s)* and/or *TChain(s)*



Soft leptons coming from a virtual W* boson decay

Compressed mass spectra:
$\Delta m < m_W + m_b$

JHEP 04 (2021) 165



Preliminary results: execution time halved

Conclusions & Next Steps

- Three use cases tested, in different scenarios: different experiments and analyses
- Interactive analyses feasibility studies on the INFN Naples infrastructure succeeded
- Towards an INFN national cloud infrastructure with a datalake model to facilitate future analyses (hopefully starting from LHC Run 3)
- Very productive collaboration with other INFN divisions

➡ **Short term goals:**

- Deploy of the code & relative instructions to allow other users to test it when the AF will be released
  - Benchmark studies with local performance evaluation
- Porting finalisation of all the previously mentioned analysis and evaluate the performance obtained using dask on the local cluster, dask on kubernetes or distributed, wrt the original implementation

➡ **Medium-long term goals:**

- Move the analyses to the national AF, using ICSC resources
- Evaluate scalability and simultaneous performance with increasing number of workers

Thank you!

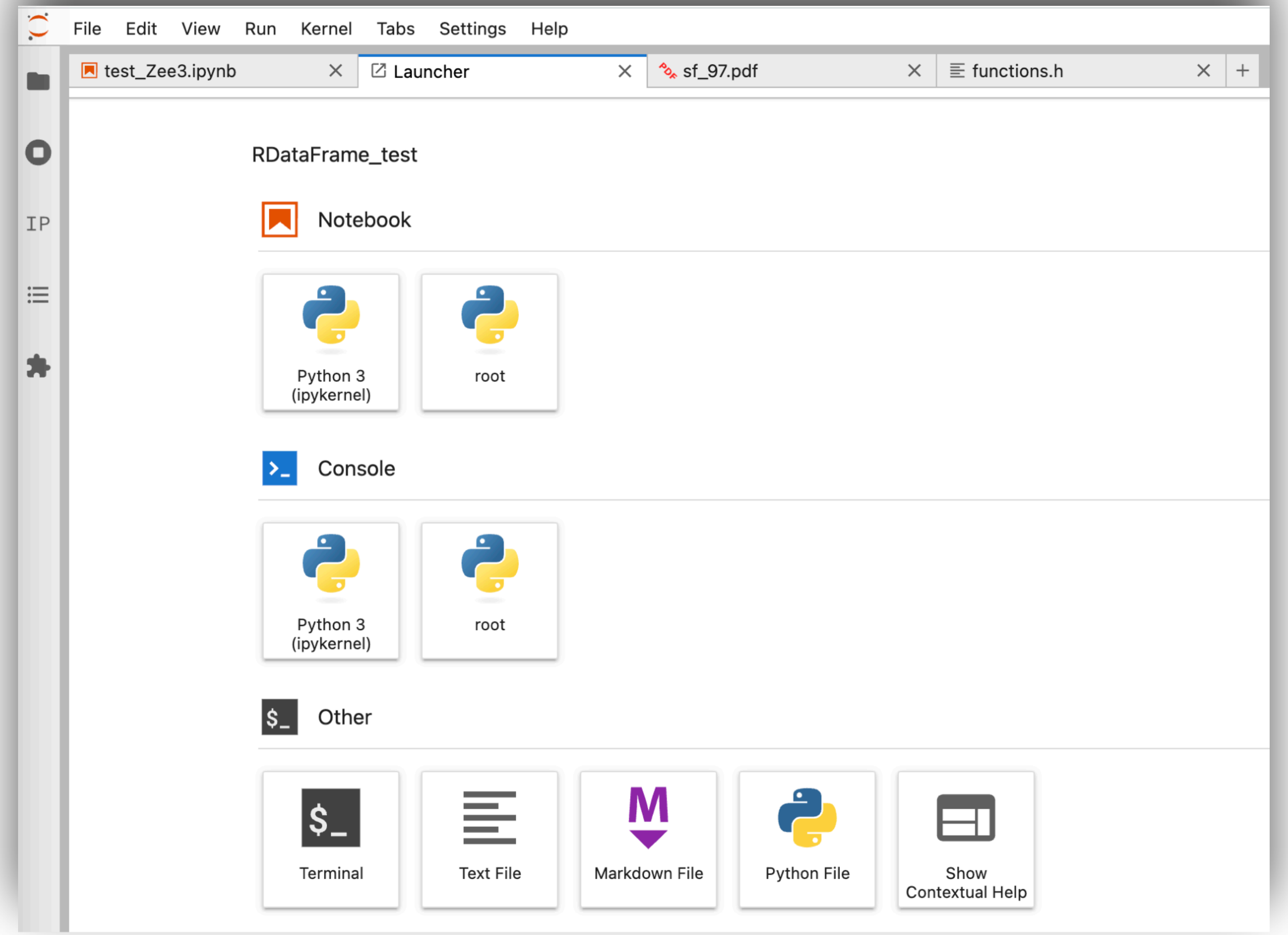
Back-up

Motivations

- Most of the LHC searches/measurements rely on locally developed scripts that process the datasets, with parallel tasks and on an asynchronous batch system
- **Challenges of the future** e+e− colliders are pushing to **re-think the HEP computing models**
  - Impact on several aspects, from software to the computing infrastructure
- From the software perspective, **interactive/quasi interactive analysis** is a promising paradigm
  - User-friendly environment
  - The implementation is simplified by adopting open-source industry standards: *Dask, Jupyter Notebooks* and *HTCondor*
  - Validating new frameworks (e.g. *ROOT RDataFrame* with multi-threading)
- **Preliminary feasibility studies** have been pursued on **FCCee pseudo-data,** exploiting **INFN Napoli** analysis Facilities (**AFs**)
  - Distributed infrastructure which leverages *Dask*

Efficient & user friendly infrastructure

- Python & ROOT (v 6.28) kernels available
- Terminal
- Notebook implementation
  - Completely exportable and replicable



Local *vs* distributed approach


```
from dask.distributed import LocalCluster, Client
if distributed == True:
    RDataFrame = ROOT.RDF.Experimental.Distributed.Dask.RDataFrame
    ROOT.RDF.Experimental.Distributed.initialize(my_initialization_function)
else:
    RDataFrame = ROOT.RDataFrame
    my_initialization_function()
```

Distributed }

Local }

⋮

No changes required to the rest of the code

```
df = df.Define('w_nominal', '1')
df = df.Define("m_e","0.0005124") #GeV
df_ge = df.Define("goodelectrons", "Particle.charge[0]*Particle.charge[1] < 0.").Filter("goodelectrons > 1")
```

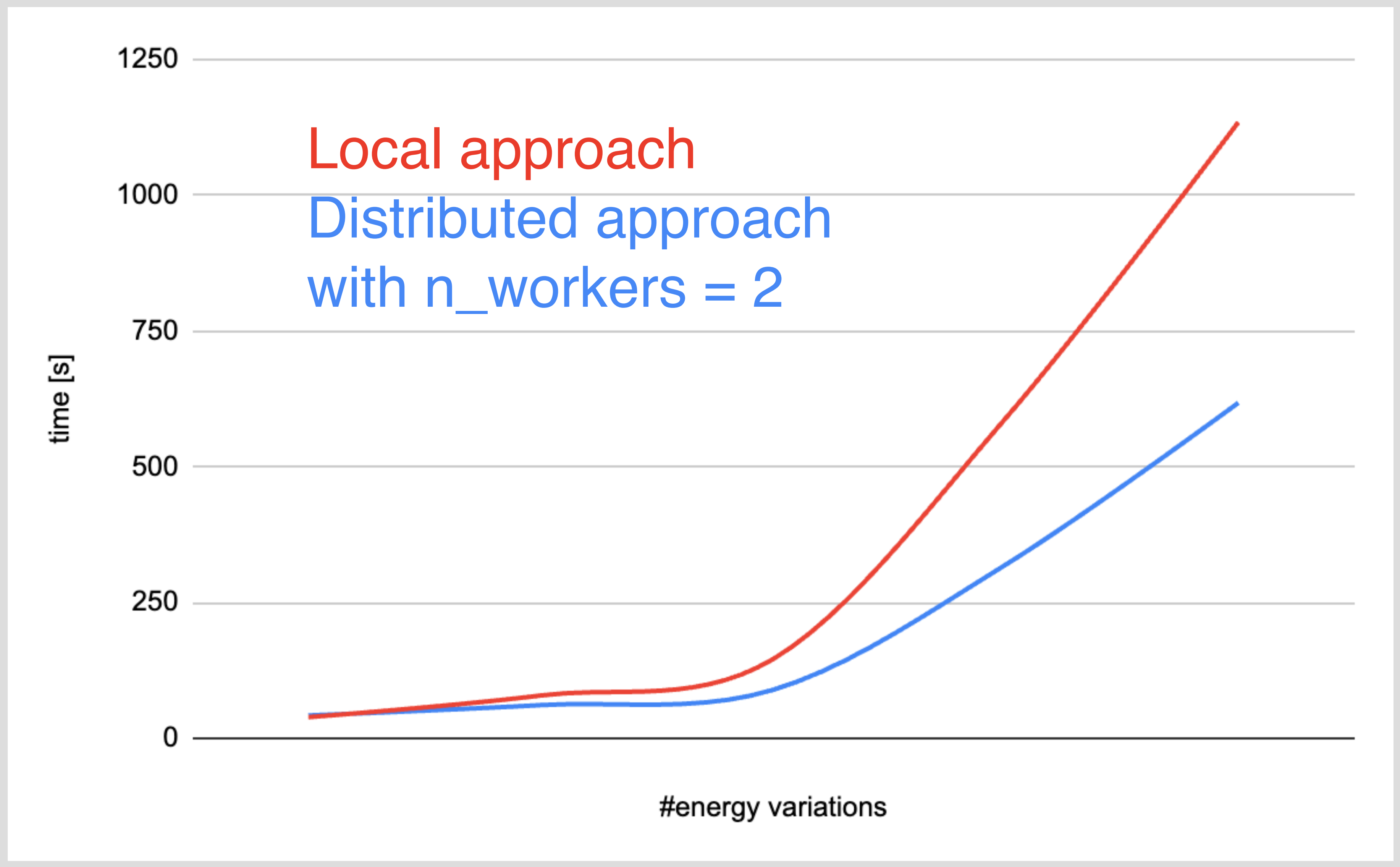
How to compare the performance?

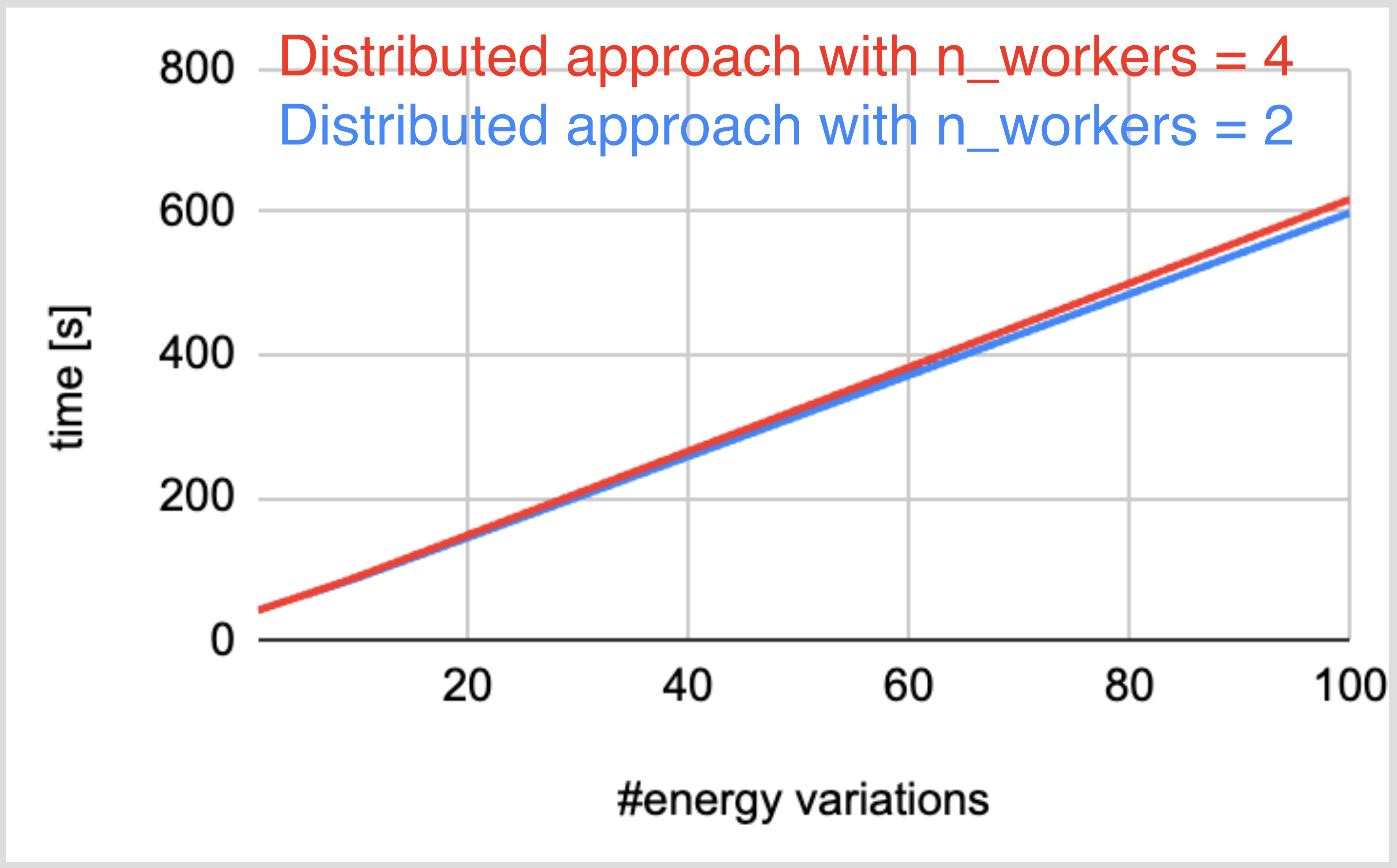
Defined Metric	
Overall execution time	Time elapsed from the start of the execution (execution triggered) to the end of execution

Local *vs* distributed approach

FCCee use-case

```
cluster = LocalCluster(n_workers=2, threads_per_worker=1, processes=True)
```

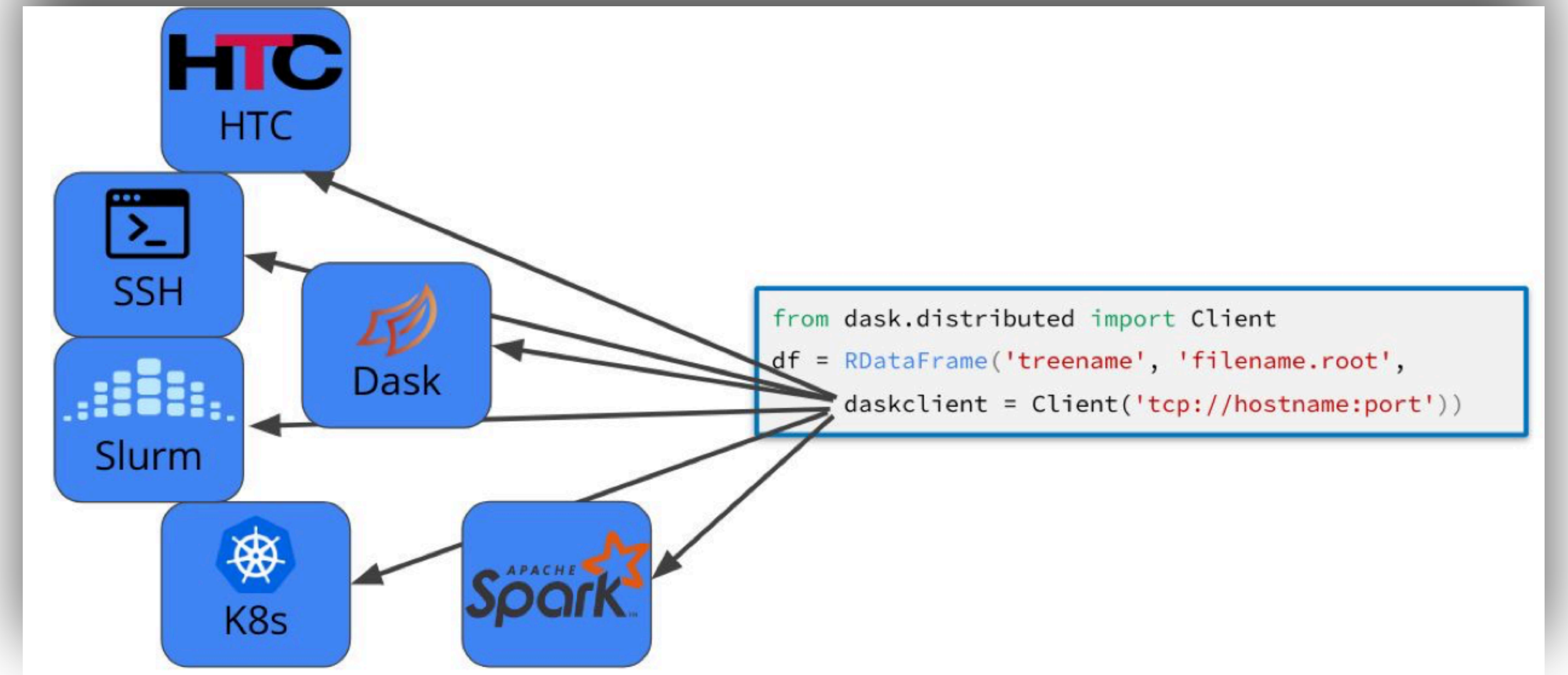




- Exploiting the distributed approach, the execution time halves wrt the local approach if we iterate over a significative number of energy variations (> 10)
- Changing the number of workers from 2 to 4, the execution time is stable

Towards a Dask + HTCondor model

- Based on INFN Perugia *analysis facility*
- Introducing HTCondor queues, the performance improves by a factor 2
- Increasing the number of workers is beneficial when running on many iterations



FCCee use-case

n_workers = 2

# iterations	Dask+HTCondor	Dask
1	22.96 s	42.02 s
50	258.35 s	320 s
100	497.71 s	618 s

Dask + HTCondor

# iterations	n_workers = 2	n_workers = 10
1	22.96 s	20.36 s
50	258.35 s	90.89 s
100	497.71 s	159.26 s