Common Software & Computing Discussion: Nuclear Physics Perspective

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with material from:

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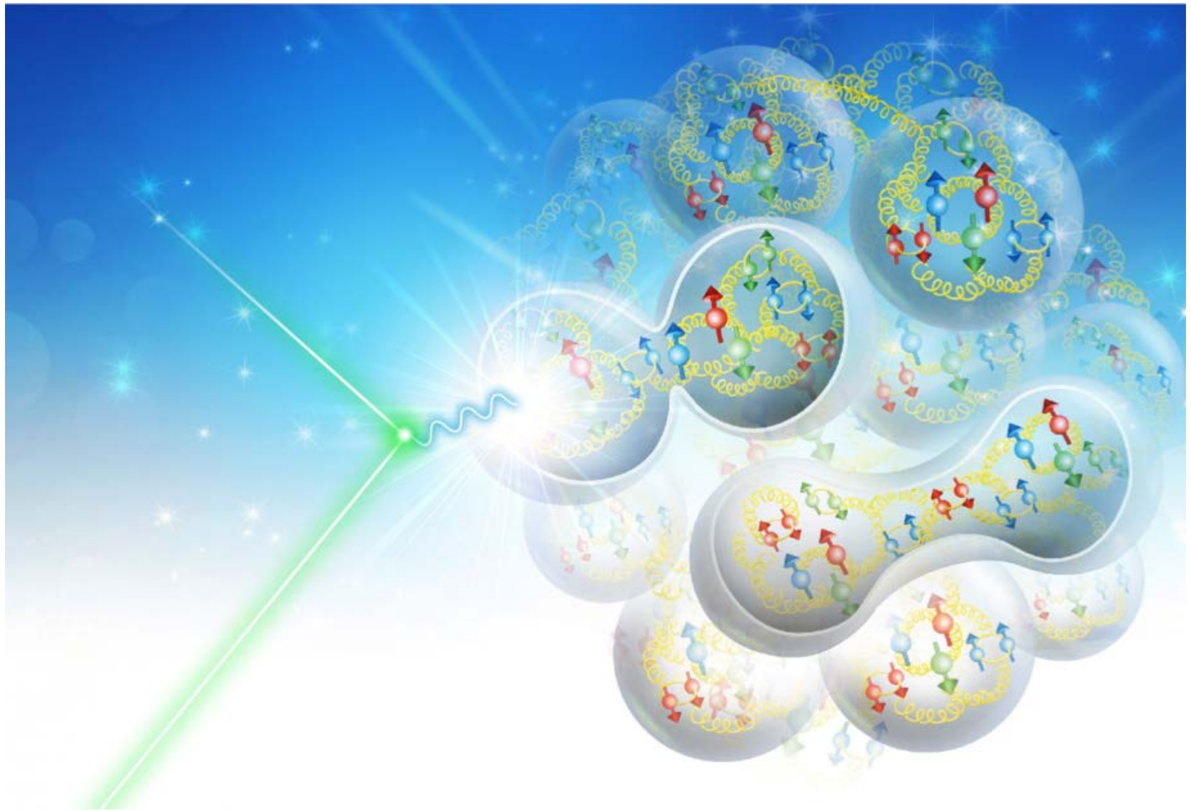
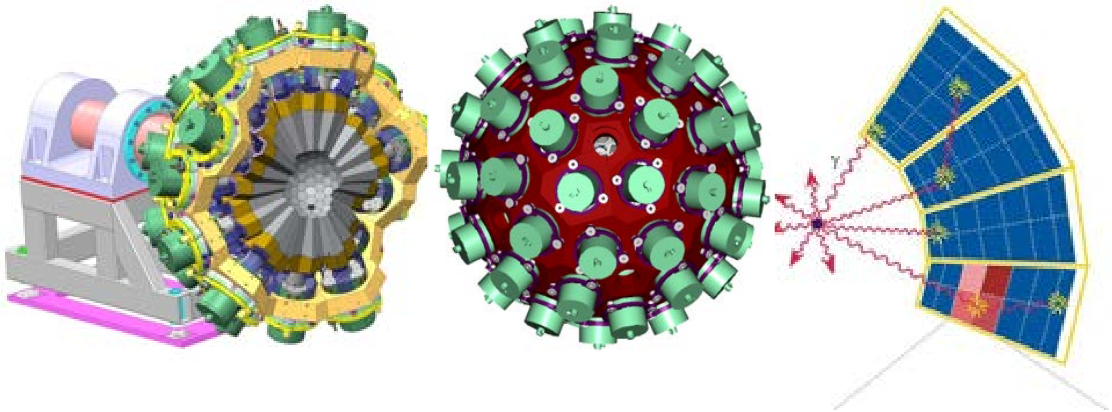
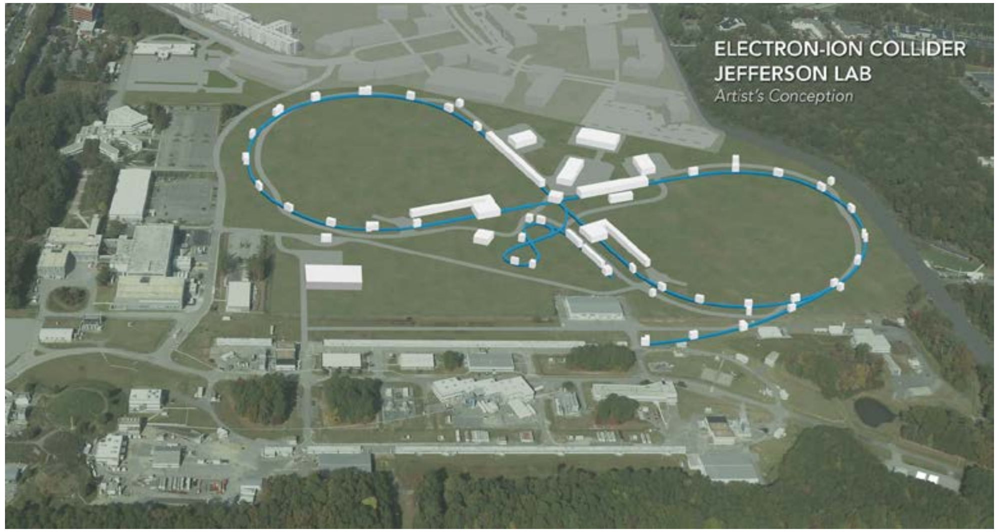


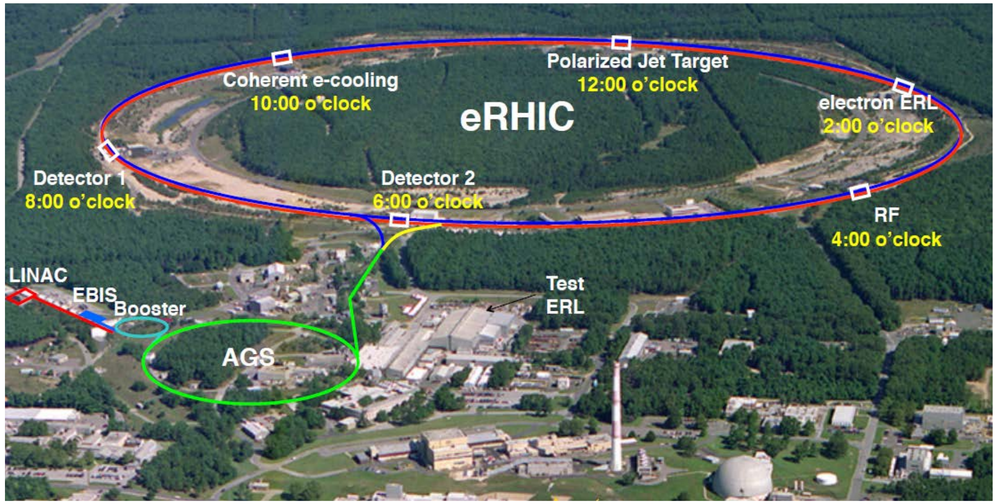
Outline

- Low energy nuclear physics: AGATA detector



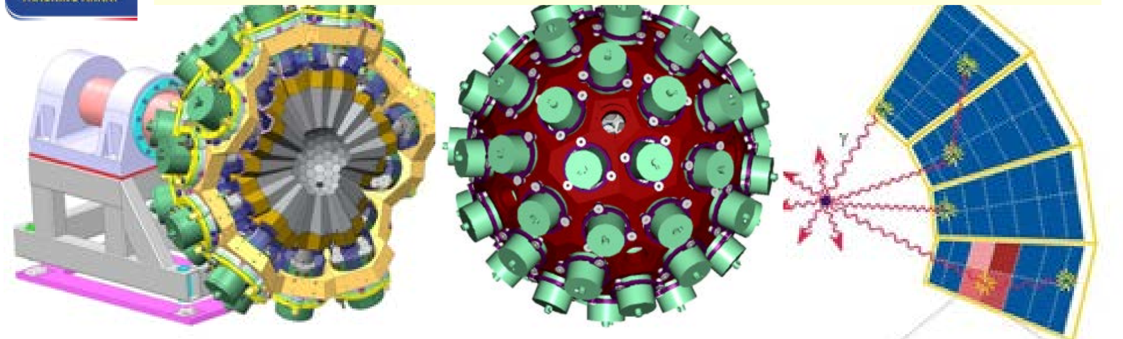
- High energy nuclear physics: The Electron-Ion Collider





NuPECC
Long Range Plan 2017
Perspectives
in Nuclear Physics

Support to the completion of AGATA in full geometry



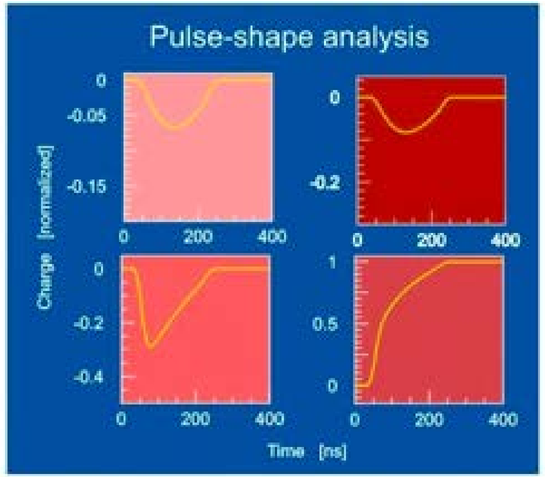
3D position sensitive Ge detector shell

AGATA@GANIL
Nuclear Physics News 2018

2 steps procedure

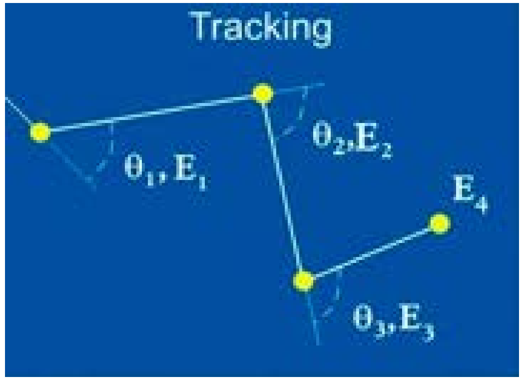
PSA : Resolve position and energy of interaction points

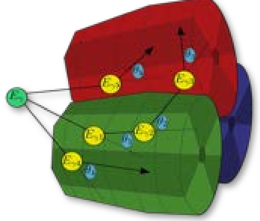
Experimental digitized traces are compared to simulated traces produced by charge collection models (ADL)



Determine scattering sequence

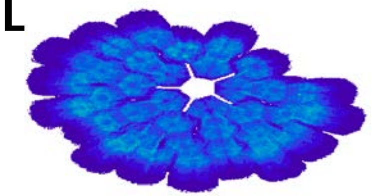
γ-ray tracking requires :
Position at resolution of 5 mm
Energy resolution at 10^{-3} MeV



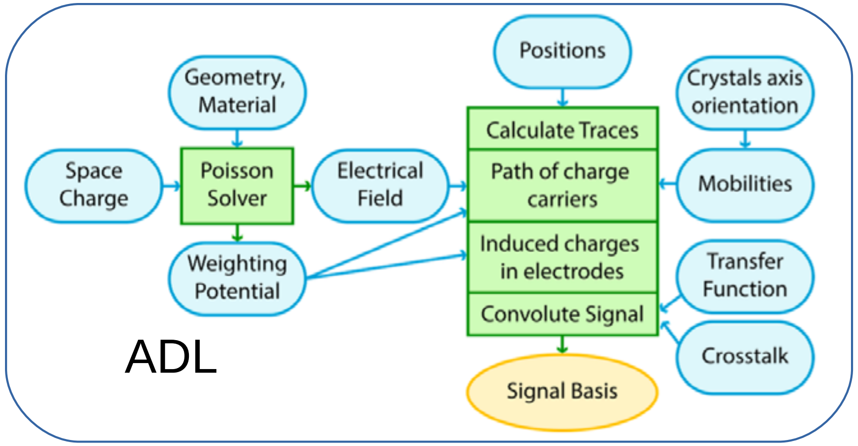


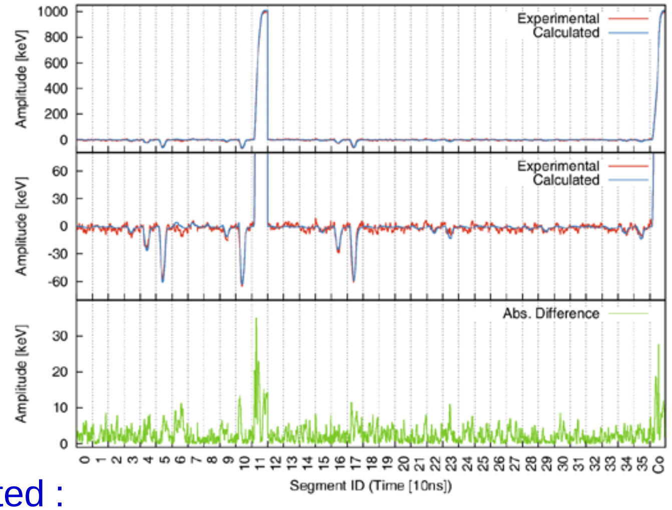
Novel PSA algorithm developments using TDA and ML

50 kHz/crystal (380 Mbytes/sec/crystal)   Full array : 180 crystals

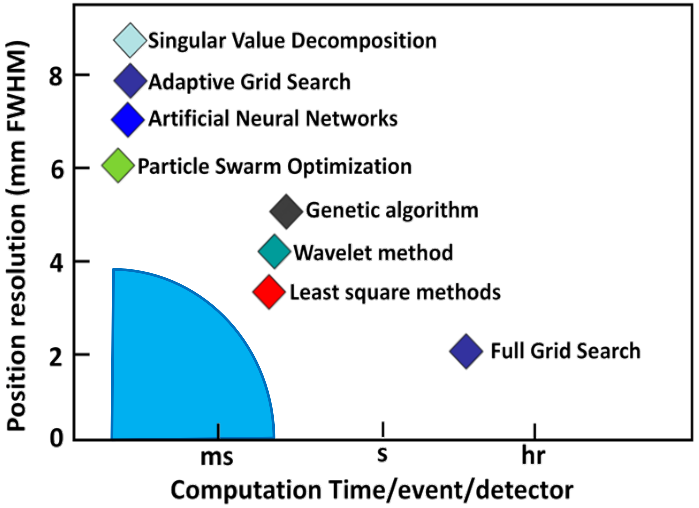


Several PSA algorithms have been tried for AGATA :
Grid Search is the current one algorithm





Time limits for online PSA → different solutions to be investigated :



Hyper-parallelize the search (GPU)

Use more efficient search methods (Topological Data Analysis)

Don't search but infer locations (ML)

Development using ML are underway in the AGATA collaboration

ML : simulated ADL only for training to learn trends via feature extraction

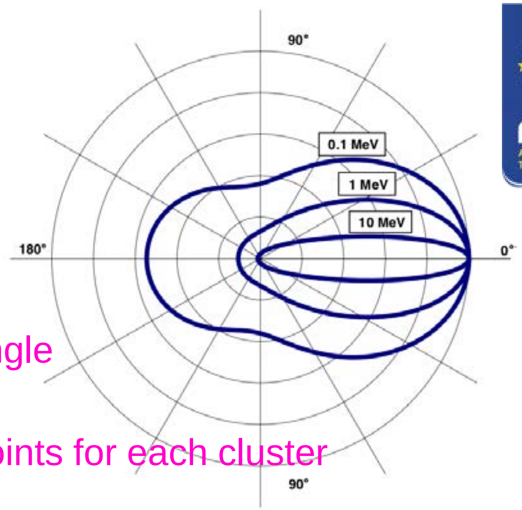
Moving beyond the basis simulations of AGATA
becomes a computing science problem

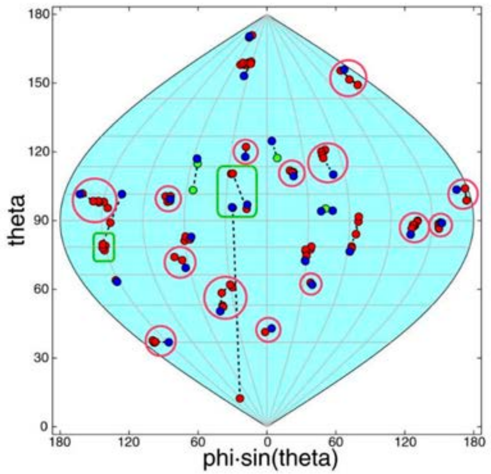
Novel tracking algorithm developments ML

Several tracking algorithms have been tried for AGATA :

Forward tracking is the current algorithm

Compton
Forward peaking

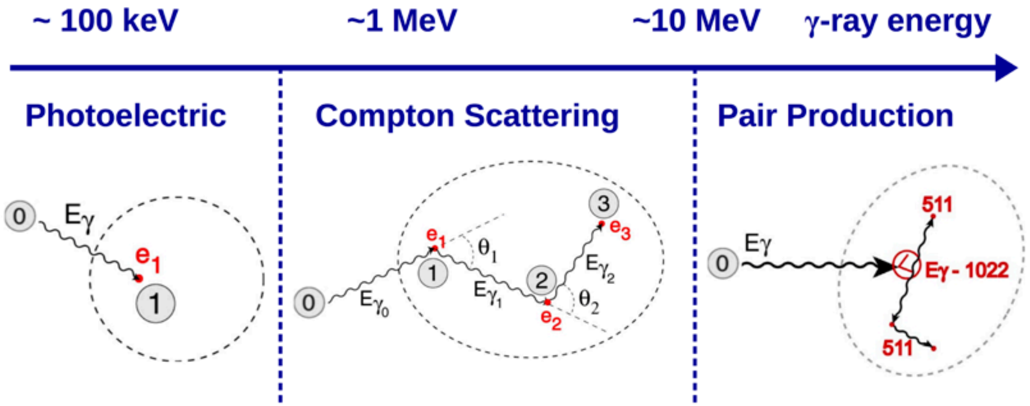




1- Create a pool of cluster within an clustering angle

2- Find most probable sequence of interaction points for each cluster

3- accept/reject or assign a penalty



Isolated hits | Angle/Energy | Pattern of hits

Probability of
Interaction depth

$$E'_\gamma = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_0c^2}(1 - cos\theta)}$$

$$E_{1st} = E_\gamma - 2m_0c^2$$

Machine Learning for AGATA :

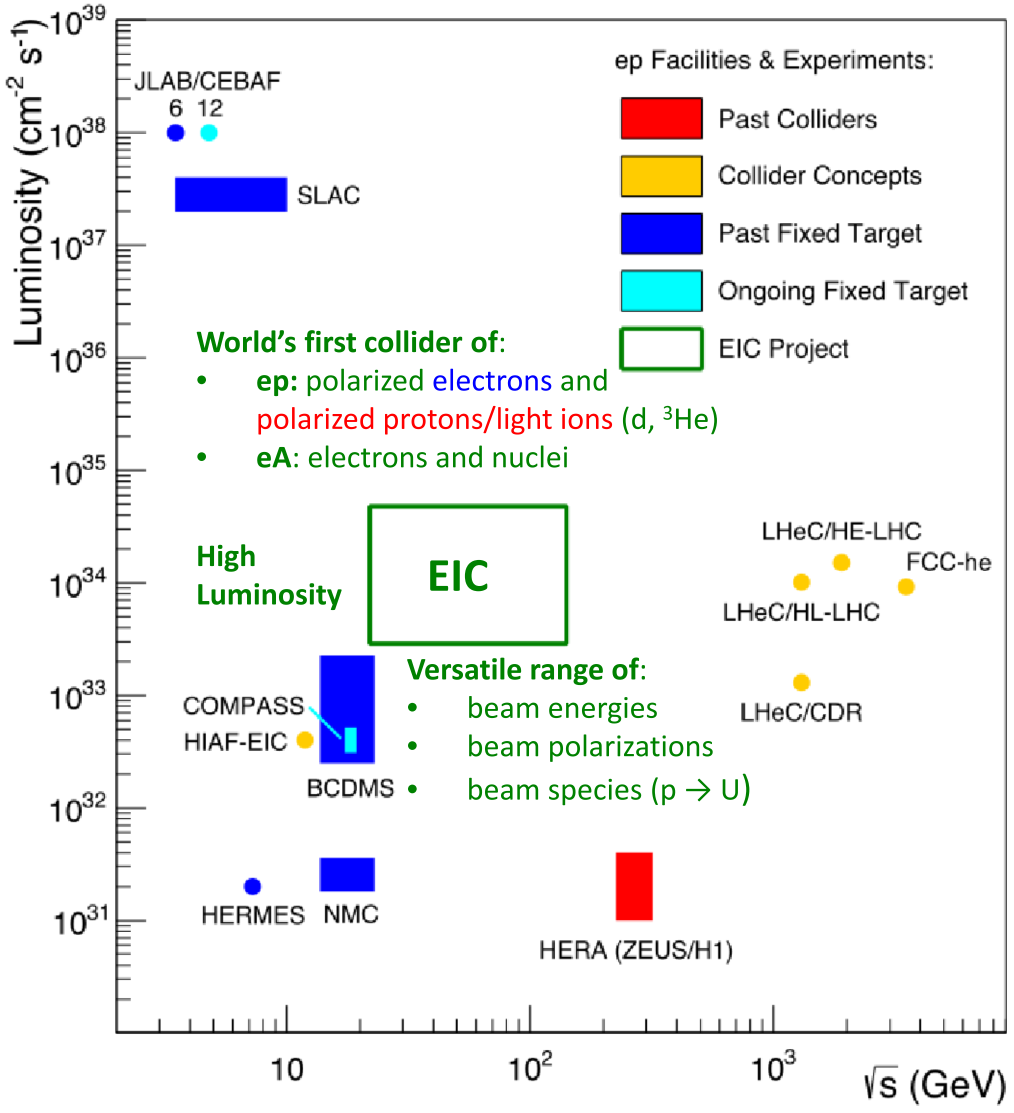
Pair-creation which is not complete

Better clusterization ?

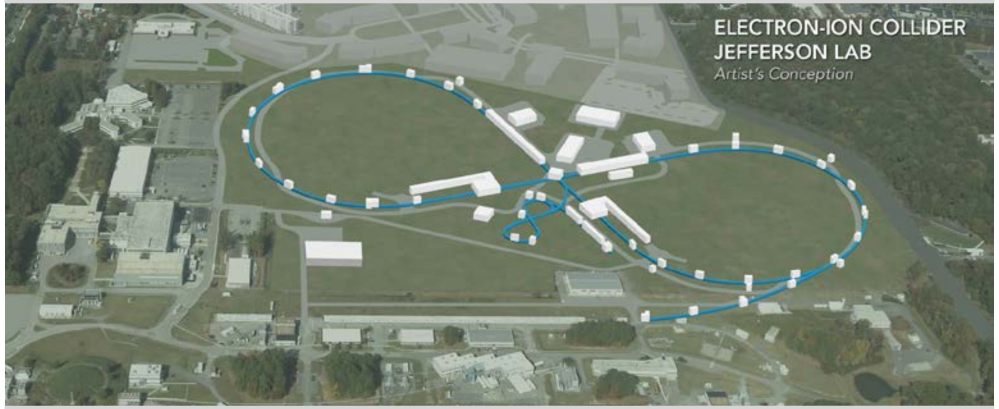
Better evaluation of the Compton sequense ?

In the framework of RESANET GdR, ML is being investigated for low energy nuclear physics
Synergies with HEP started : D. Rousseau invited to the AGATA-GRETA collaboration Meeting

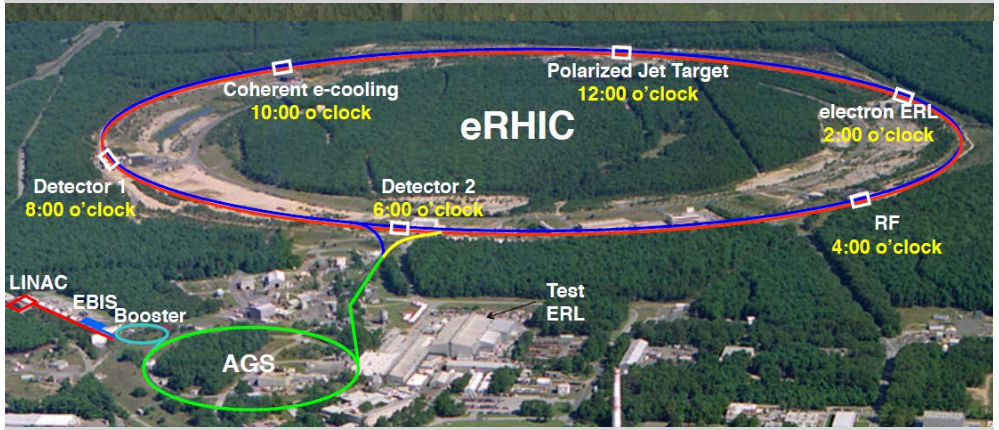
The Electron-Ion Collider: Frontier accelerator facility in the U.S.



Highest priority for new construction
for the U.S. Nuclear Physics program



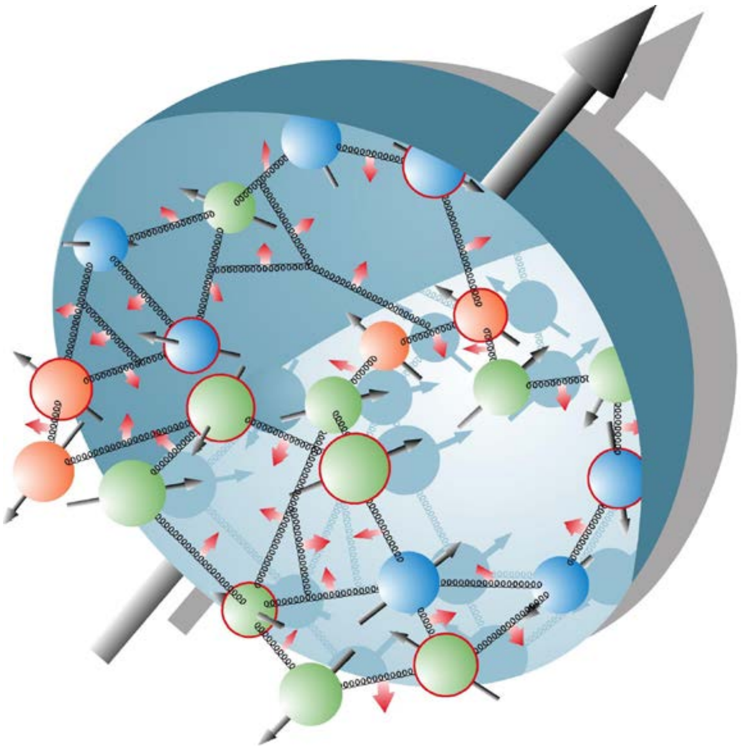
Proposal by Jefferson Lab



Proposal by Brookhaven Lab

The dynamical nature of nuclear matter

Nuclear Matter Interactions and structures are inextricably mixed up.



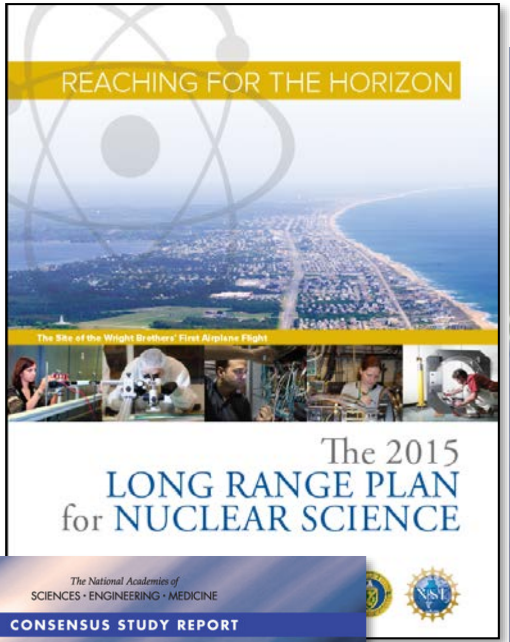
Observed properties such as mass and spin emerge out of the complex system.

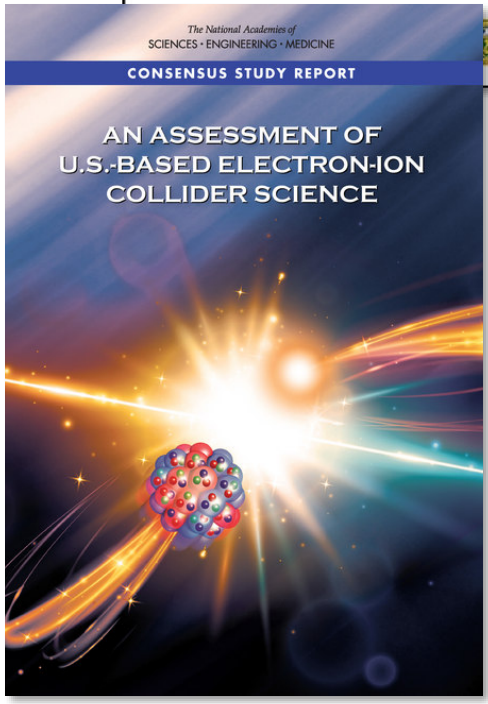
DOI 10.1103/PhysRevC.68.015203

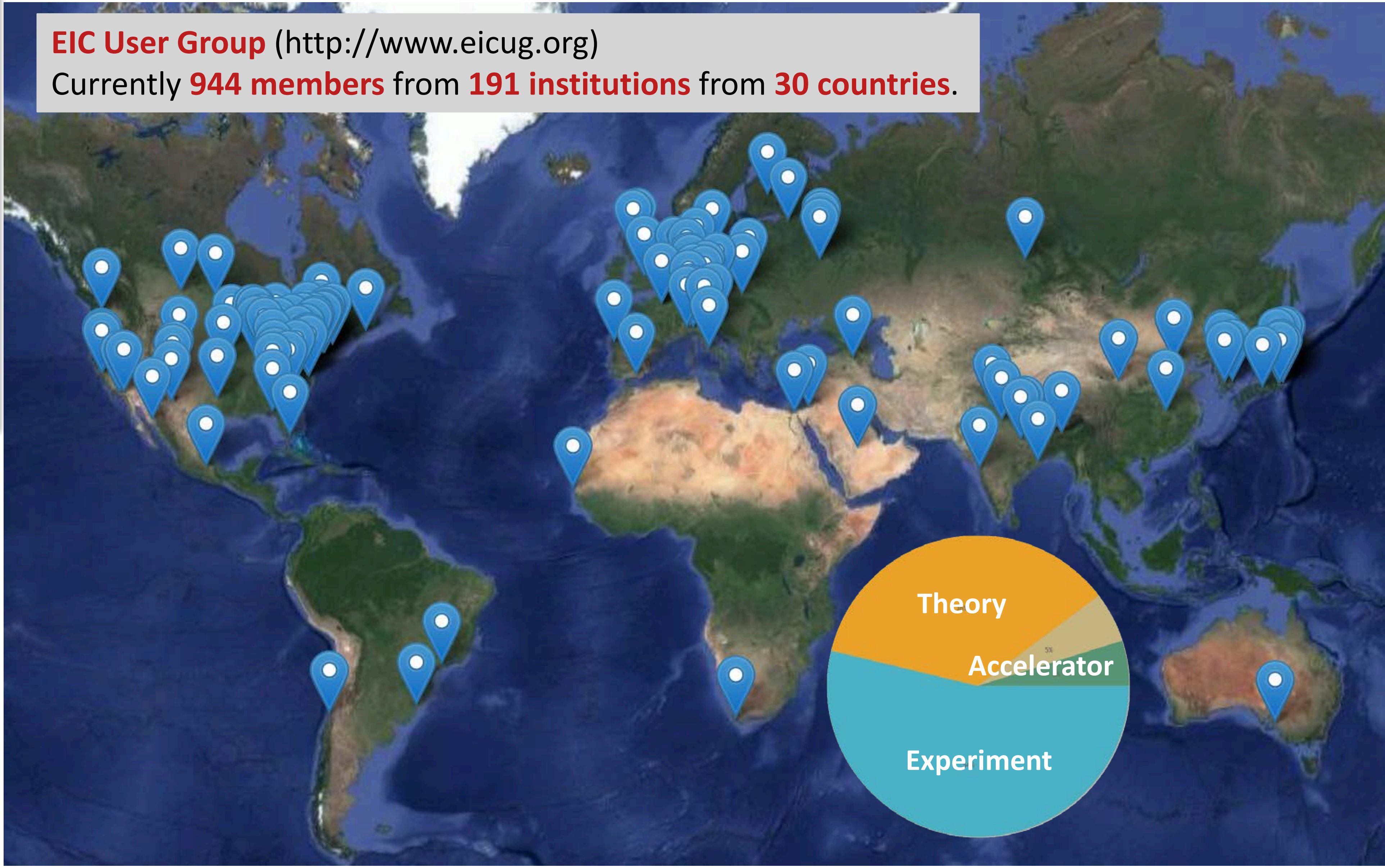
Ultimate goal Understand how nuclear matter at its most fundamental level is made.

To reach goal precisely image quarks and gluons and their strong interactions in nuclear matter.

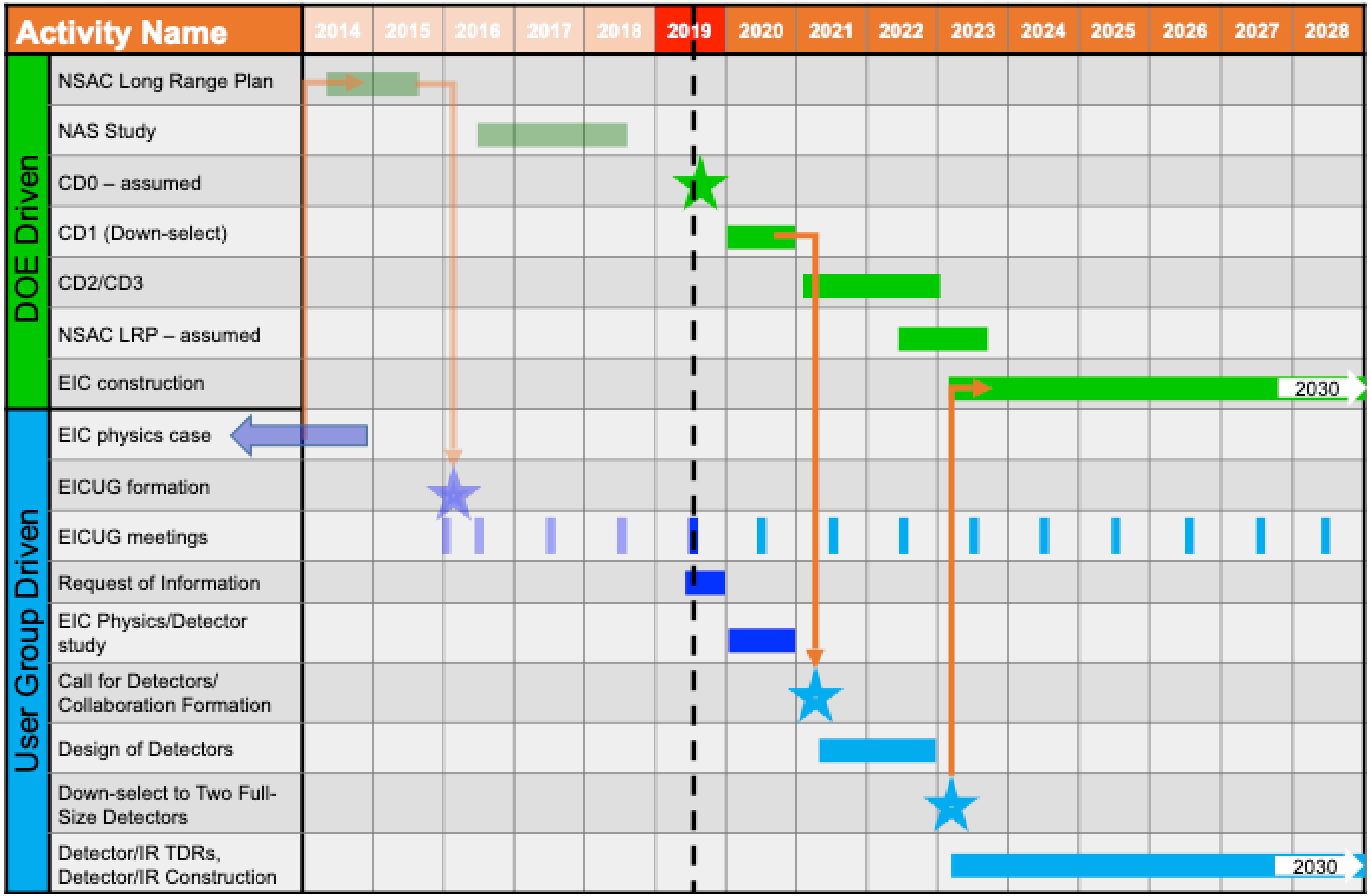
The Electron-Ion Collider: NSAC top priority for new facility construction







Timeline



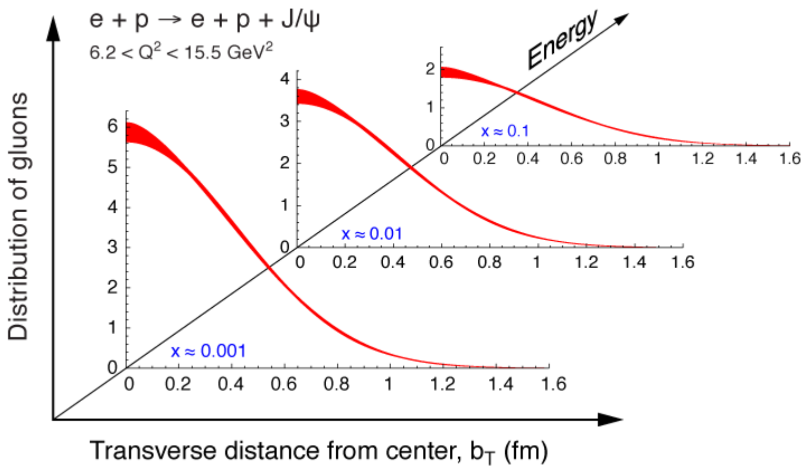
Activity Name
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
DOE Driven
User Group Driven
NSAC Long Range Plan
NAS Study
CD0 – assumed
CD1 (Down-select)
CD2/CD3
NSAC LRP – assumed
EIC construction
2030
EIC physics case
EICUG formation
EICUG meetings
Request of Information
EIC Physics/Detector study
Call for Detectors/ Collaboration Formation
Design of Detectors
Down-select to Two Full-Size Detectors
Detector/IR TDRs, Detector/IR Construction
2030

Computing Challenges for the EIC

NP experiments driven by beam intensity, polarization, exquisite control of background and systematics

multi-dimensional challenges

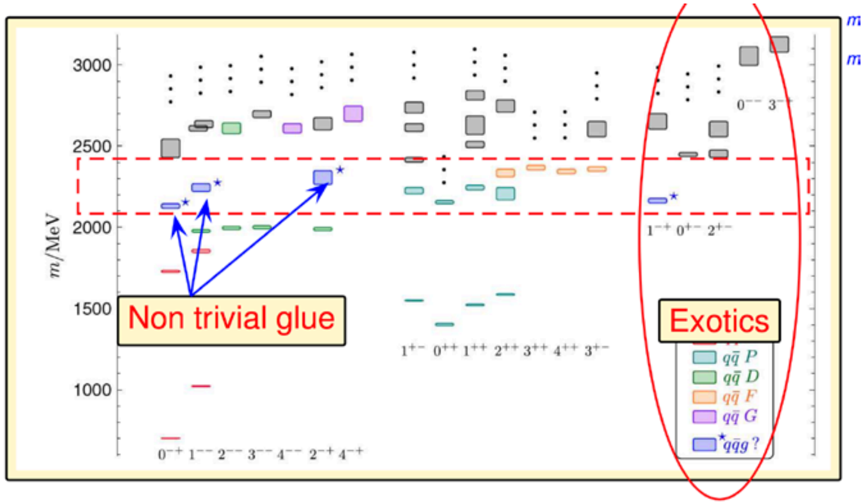
example 3D imaging of quarks and gluons



high statistics in five or more dimensions and multiple particles

multiple channel challenges

example discovery search of gluon-based exotic particles (PWA, 1000s of waves)



strongly iterative analysis for reliable, model-independent analysis

Computing trends and EIC Computing

EIC rates

- expected data rates similar to next phase LHCb
- not enormous rates creates opportunity for other initiatives

Think out of the box

- The way analysis is done has been largely shaped by kinds of computing that has been available.
- Computing begins to grow in very different ways in the future, driven by very different forces than in the past (e.g., Exascale Computing Initiative).
- This is an unique opportunity for Nuclear Physics to think about new possibilities and paradigms that can and should arise (e.g., real-time physics analysis).

Future compatibility hardware and software

- **Exascale Computing** Most powerful future computers will likely be very different from the kind of computers currently used in Nuclear Physics.
- This requires a modular design with structures robust against likely changes in computing environment so that changes in underlying code can be handled without an entire overhaul of the structure.

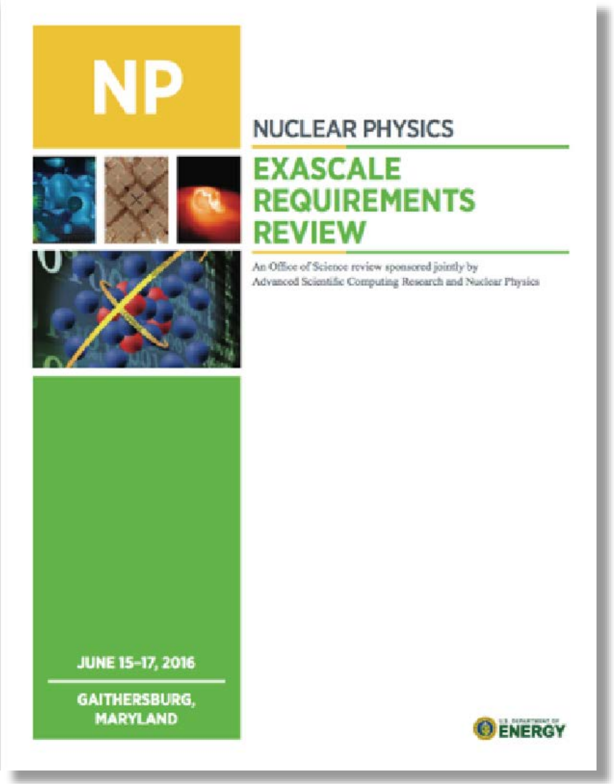
User centered design to enhance scientific productivity

- Engage wider community of physicists, whose primary interest is not computing, in software design to:
  - understand the user requirements first and foremost
  - make design decisions largely based on user requirements.

Implications of Exascale Computing

Past efforts in lattice QCD in collaboration with industry have driven development of new computing paradigms that benefit large scale computation. These capabilities underpin many important scientific challenges, e.g. studying climate and heat transport over the Earth.

The EIC will be the facility in the era of high precision QCD and the first Nuclear Physics facility in the **era of Exascale Computing**. This will affect the interplay of experiment, simulations, and theory profoundly and result in a new computing paradigm that can be applied to other fields of science and industry.



Petascale-capable systems at the beamline

- **unprecedented compute-detector integration**, extending work at LHCb
- requires fundamentally new and different algorithms
- computing model with artificial intelligence at the trigger level and a compute-detector integration to deliver **analysis-ready data from the DAQ system**:
  - responsive calibrations in real time
  - real-time event reconstruction
  - physics analysis in real time

A similar approach would allow **accelerator operations** to use real-time simulations and artificial intelligence over operational parameters to tune the machine for performance.

Beyond machine-detector interface

Integration of DAQ, analysis and theory to optimize physics reach

Integration of DAQ, analysis and theory

- research model with seamless data processing from DAQ to data analysis using artificial intelligence and strong interplay of experiment - theory
- not about building the best detector
- but the best detector that fully supports streaming readout and fast algorithms for real-time analysis

EICUG Software Working Group

The EICUG Software Working Group's initial focus will be on **simulations of physics processes and detector response** to enable quantitative assessment of measurement capabilities and their physics impact.

The Software working group is to **engage with new major initiatives that aim to further develop the EIC science case**, including for example the upcoming INT program(s), and is anticipated to play key roles also in the preparations for the EIC project(s) and its critical decisions. The working group will build on the considerable progress made within the EIC Software Consortium (eRD20) and other efforts. The evaluation or development of experiment-specific technologies, e.g. mass storage, clusters or other, are outside the initial scope of this working group until the actual experiment collaborations are formed.

Conveners:

Website: http://software.eicug.org/

Andrea Bressan
(INFN, University of Trieste)

Markus Diefenthaler
(EIC^2, Jefferson Lab)

Torre Wenaus
(Brookhaven Lab)

EIC Software Groups (beyond the simulation effort at the labs)

High Energy Physics

CERN ROOT
Possible collaboration

Geant4 International Collaboration
Established collaboration (M. Asai)

HEP Software Foundation
Started collaboration

- Artificial intelligence
- Frameworks
- Real-time processing

MCnet
Started collaboration

Nuclear Physics

EIC Software

- EICUG Software Working Group
- EIC Software Consortium

Same software suite Seamless data processing from DAQ to data analysis using AI

EIC Streaming Readout Consortium

Back-up

User requests

Ongoing EIC project
Software ✓
Documentation ✓
Requests none

EIC User Group
Common Software ✗
Common Documentation ✗
Requests software, documentation

EIC Generic Detector R&D projects
Software ✓
Documentation ✗ - ✓
Requests common software

Example projects
- ANL: TOPSiDE LDRD
- BNL: eRHIC preCDR
- JLAB: JLEIC preCDR

Focus on (pre)**CDRs and site selection as part of CD1** using existing lab software

Focus on preparation of EIC collaborations
- further develop EIC Science
- examine detector requirements
- work on detector designs
- work on detector concepts

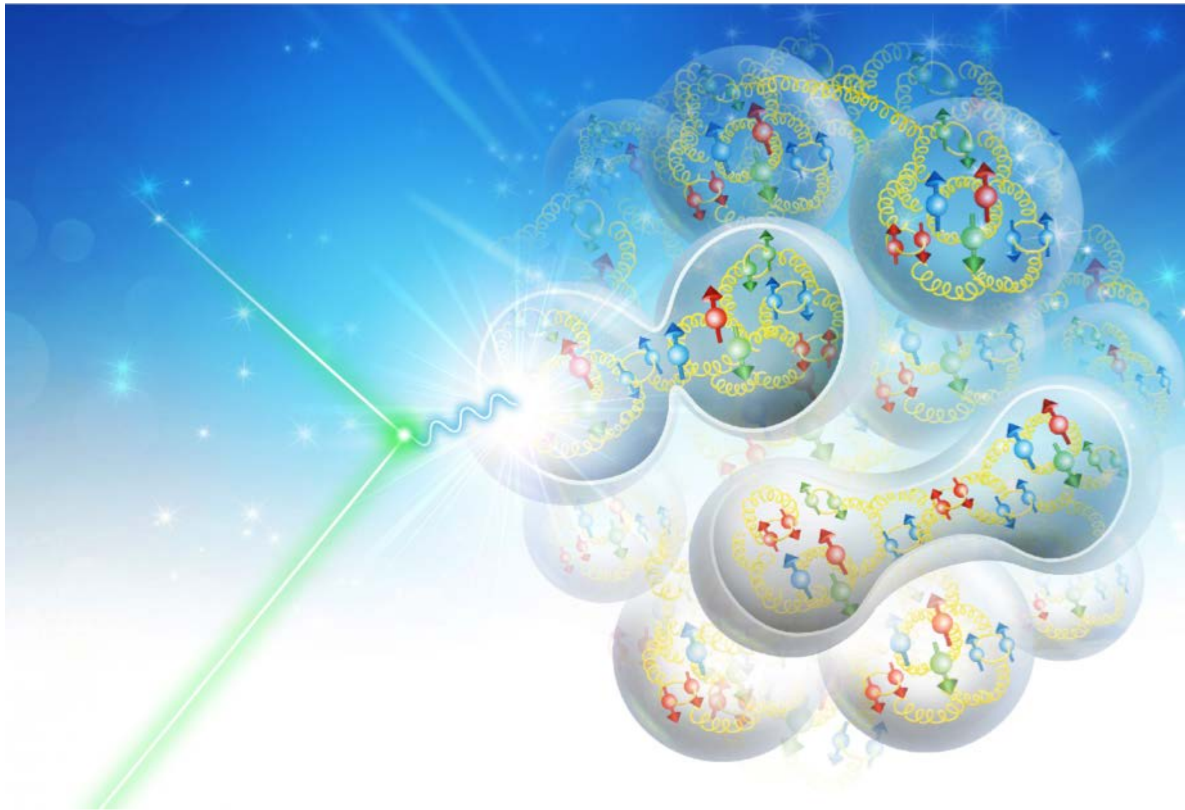
requires simulations of physics processes and detector response

Request from Thomas Ullrich, manager of the R&D program:
- in most cases only GEANT simulations are needed:
  - no need for sophisticated framework
  - no need for elaborate tracking
- a simple *lite setup* with a well defined geometry description standard might get them a long way as long if it is EIC wide and easy to use

Summary

Electron-Ion Collider (EIC)

- precision study of the nucleon and the nucleus at the scale of sea quarks and gluons
- extremely broad science program



Computing vision for the EIC

- seamless data processing from DAQ and trigger system to data analysis using artificial intelligence
- integration of DAQ, analysis and theory
- flexible, modular analysis ecosystem

Software Initiatives for the EIC

- EICUG Software Working Group
- Website http://software.eicug.org/