eRD20: Developing Simulation and Analysis Tools for the EIC

Markus Diefenthaler and Alexander Kiselev

on behalf of the EIC Software Consortium (ESC)

EIC Detector R&D Advisory Committee Meeting, CUA, July 2018

BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY | Office of Science

Jefferson Lab
Thomas Jefferson National Accelerator Facility

ESC members

ANL (3) W. Armstrong, S. Chekanov, D. Blyth

BNL (4) E.-C. Aschenauer, AK (**co-PI**) , J. Lauret, C. Pinkenburg

Fermilab (1) S. Prestel

INFN Trieste (1) A. Bressan

Jefferson Lab (4) MD (**co-PI**) , D. Lawrence, D. Romanov, M. Ungaro

SLAC (2) M. Asai, D. Wright

William & Mary (1) W. Deconinck

ESC goals and focus

- **Our global objectives**
  - Build an active working group of EIC software experts & developers
  - Connect existing software frameworks
  - Establish standards for the future EIC software

    - ***R&D Committee recommendation from Jul. 2017 meeting:***

      "… take a more active role in working with the detector consortia to help with the simulations and set up a process to easily implement new detector configurations to optimize the detector design"

- **Our particular present focus**
  - Reach out to the EIC community
    - Communicate present status
    - Bring existing software to the end users
    - Produce publicly available consensus-based documents on critical subjects
    - Provide vision for the future
  - Continue work on common interfaces (geometry, file formats, tracking, etc.)
  - Explore new avenues of software development (machine learning, etc.)

ESC presentations at the EICUG meeting

- Temple University Nov. 30 – Dec. 1 2017
- One full session dedicated to EIC software review and future prospects

11:00	**EIC Software Consortium: Review of EIC Software (25+5)**	*KISELEV, Alexander*
	Kiva Auditorium, Temple University	10:50 - 11:20
	EIC Software Consortium: Vision for EIC Computing (25+5)	*DIEFENTHALER, Markus*
	Kiva Auditorium, Temple University	11:20 - 11:50
12:00	**Discussion (30)**	*DIEFENTHALER, Markus et al.*
	Kiva Auditorium, Temple University	11:50 - 12:20

Overview of existing EIC software frameworks

- *ANL software, EicRoot, eic-smear, GEMC*

Other examples of EIC community software

- *background modeling tools, PID consortium software, silicon tracker simulations & others*

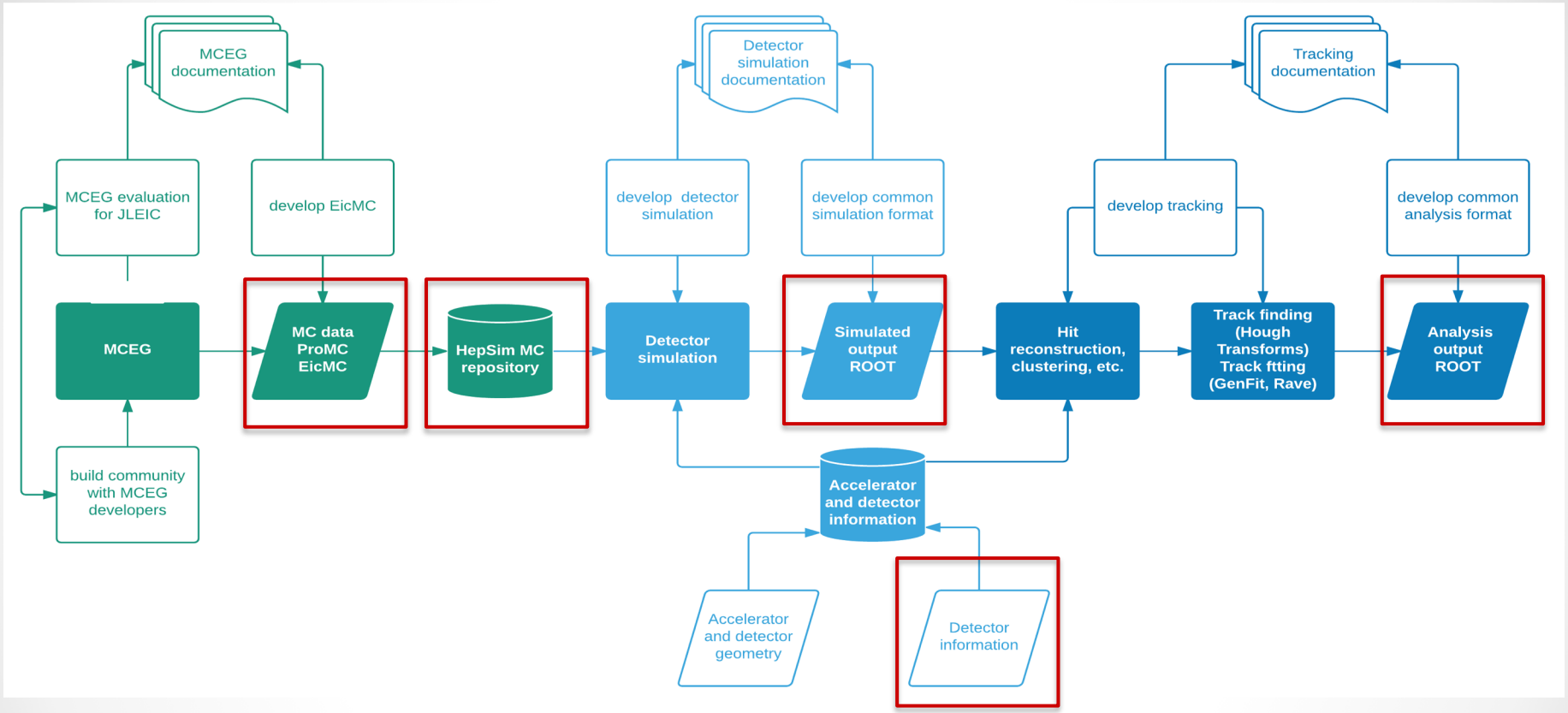
Other software expertise in the community

- *gas detector simulations, CAD import, FEA tools, PCB engineering & others*

Present community-wide software activities and vision for the future

- *Included in this talk, to a large extent*

Common interfaces

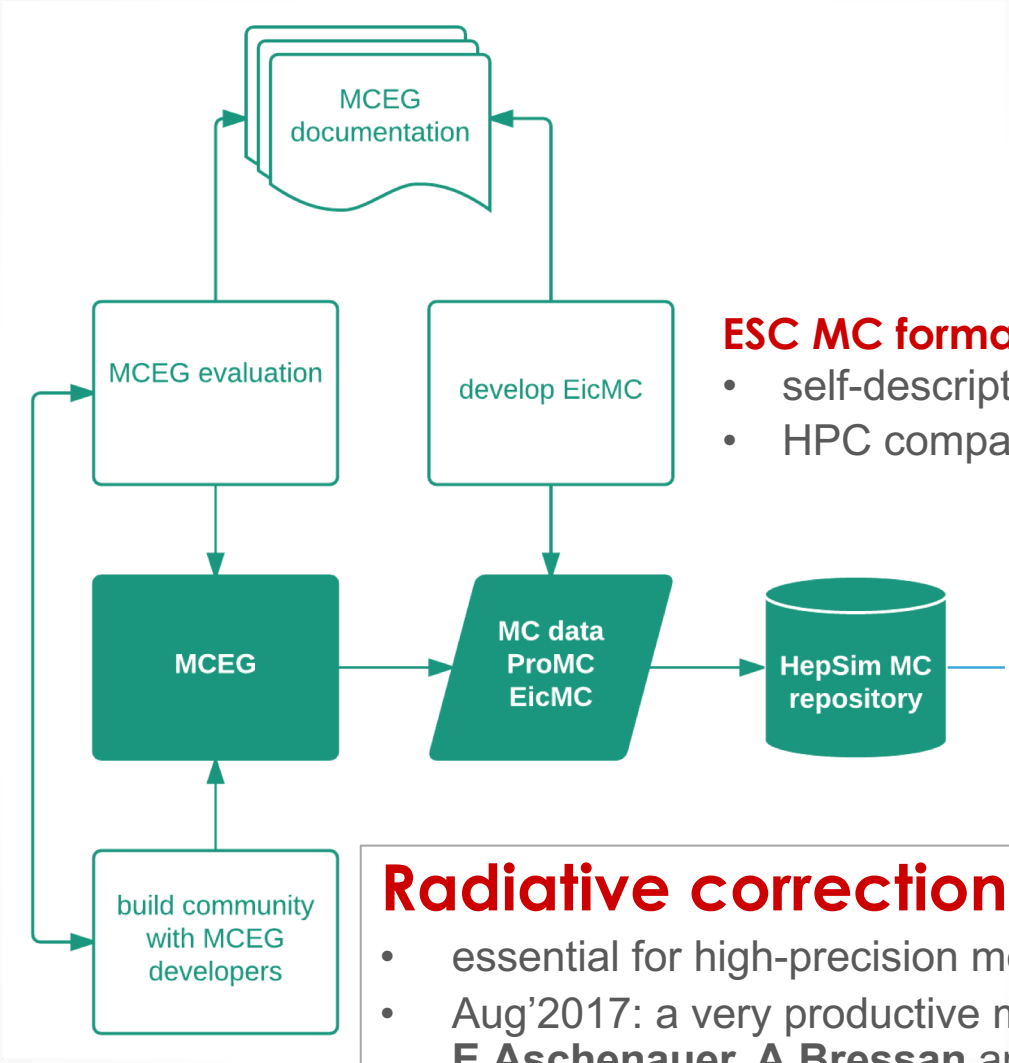


GOAL identify key points and focus on them

Monte-Carlo simulations

EIC MCEG initiative

- emphasize on strong interplay experiment – theory
- connect MCEG efforts NP-HEP



ESC MC format: ProIO

- self-descriptive data format
- HPC compatible

Radiative correction library

- essential for high-precision measurements at the EIC
- Aug'2017: a very productive meeting between **E.Aschenauer, A.Bressan** and **H.Spiesberger**:
  - start back from HERACLES part of Djangoh
  - work on interface to PYTHIA6/8

Monte-Carlo workshop

Monte Carlo Event Generators for future ep and eA facilities

Satellite Workshop during POETIC 8,

Mar. 22-23, 2018

Collaboration HEP - NP

Organizers

- **Elke-Caroline Aschenauer** (BNL)
- **Markus Diefenthaler** (JLab)
- **Simon Plätzer** (MCnet, University of Vienna)
- **Stefan Prestel** (FNAL)

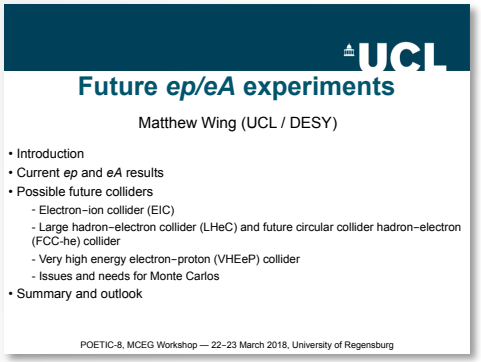
MCnet

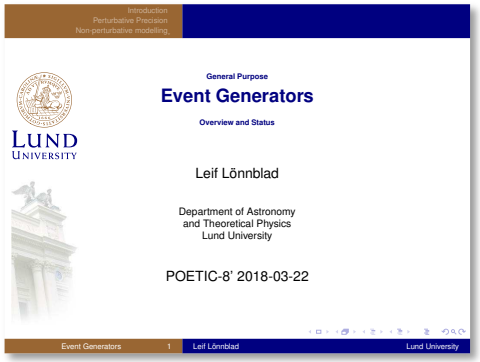
Goals

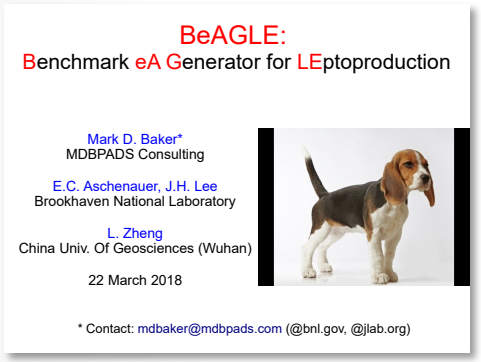
- MCEG requirements for upcoming ep and eA measurements
- Roadmap for MCEG developments for upcoming ep and eA measurements

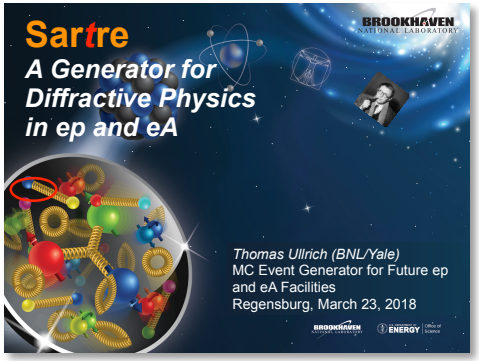
Workshop highlights

[Workshop summary]









Results

- MCEG not about tuning but about physics
- MCnet ready for R&D on ep/eA MCEG R&D but require easy access to data
  - What would be needed from HEP analysis tools to leverage them for NP as well?
  - How could we make the HERA data available?
- collaboration with MCnet will continue in 2019 workshop
- **community document on MCEG requirements for the EIC in preparation**

Self-descriptive file formats

Google protocol buffer based

- flexible
- portable
- no external dependencies

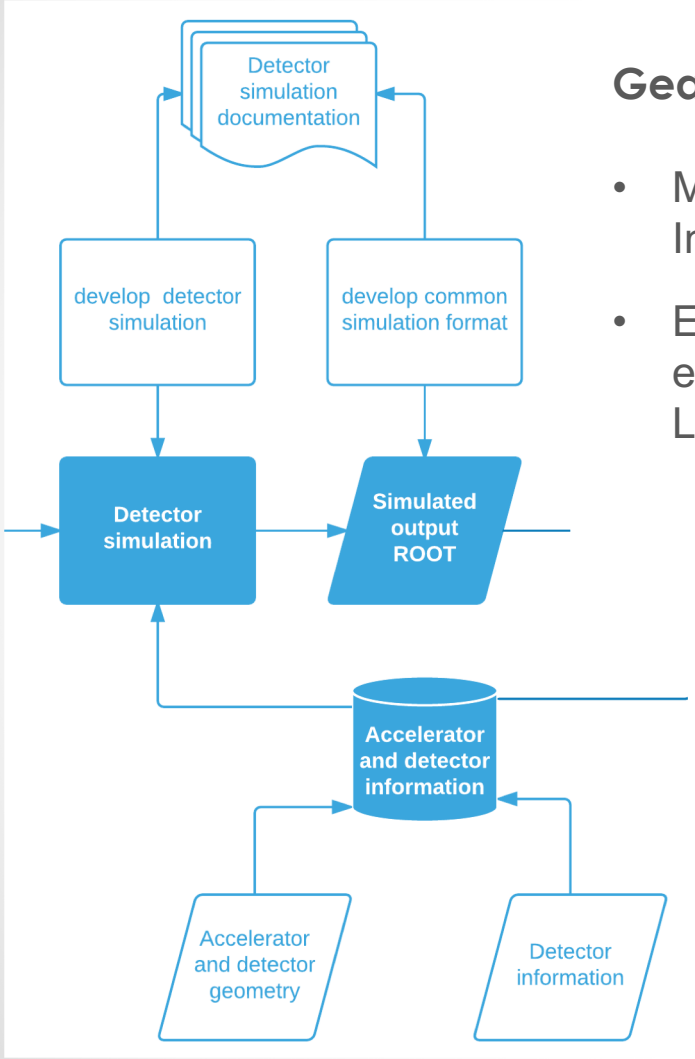
Development history within ESC

- Idea & original version (ProMC) by **S.Chekanov** for HepSim repository
  - limited functionality MC application
- Second version (EicMC) by **AK**
  - MC application with several advanced features
- Present development (ProIO) by **D.Blyth**
  - General-purpose format with multi-language support
  - Very close to the first official release

Next steps

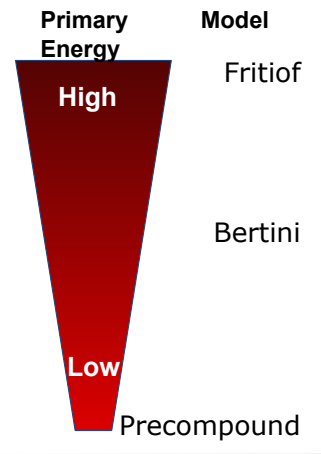
- **Community document being drafted on ESC event model**
- **Utilize ProIO for ESC data starting with MCEG data**

Detector simulations



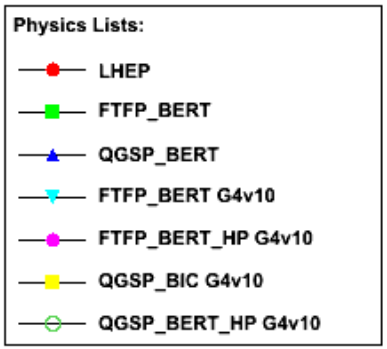
Geant4 - ESC Collaboration

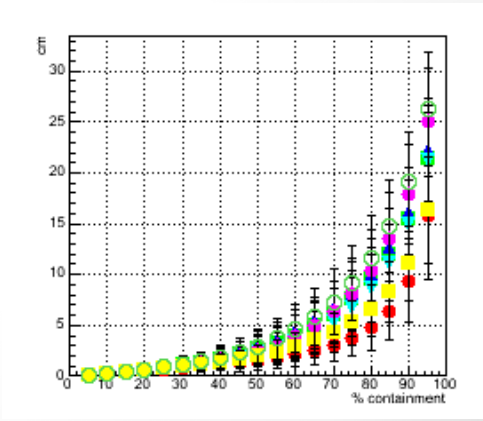
- Makoto Asai: liaison between Geant4 International Collaboration and ESC / EIC
- EIC physics list and validation, tuning and extension (energy range is different from LHC!), including test beam studies



tailored physics list for EIC studies available

10 GeV/c p^+ radial shower size in W:
major differences between models





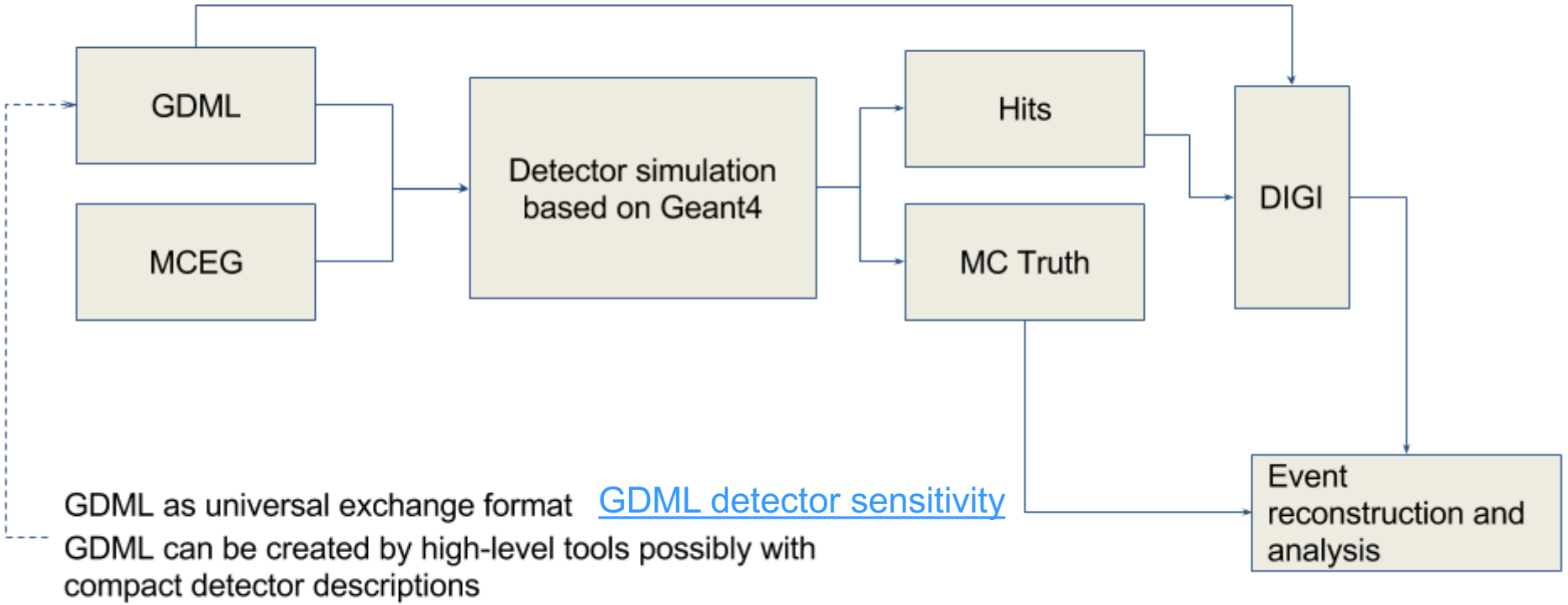
study by C. Pinkenburg

Geometry interface

Lightweight library

- that depends only on Geant4
- that can be used by any existing Geant4 framework
- that defines a minimalistic common data structure of hits

Vision



Key person left to industry

Community document released in FY17 *by* ***A.Dotti*** *(SLAC), MD (Jlab), AK (BNL), C. Pinkenburg (BNL) and other ESC contributors*

Implementation is delayed into FY19

Unified track reconstruction

Modular tracking software

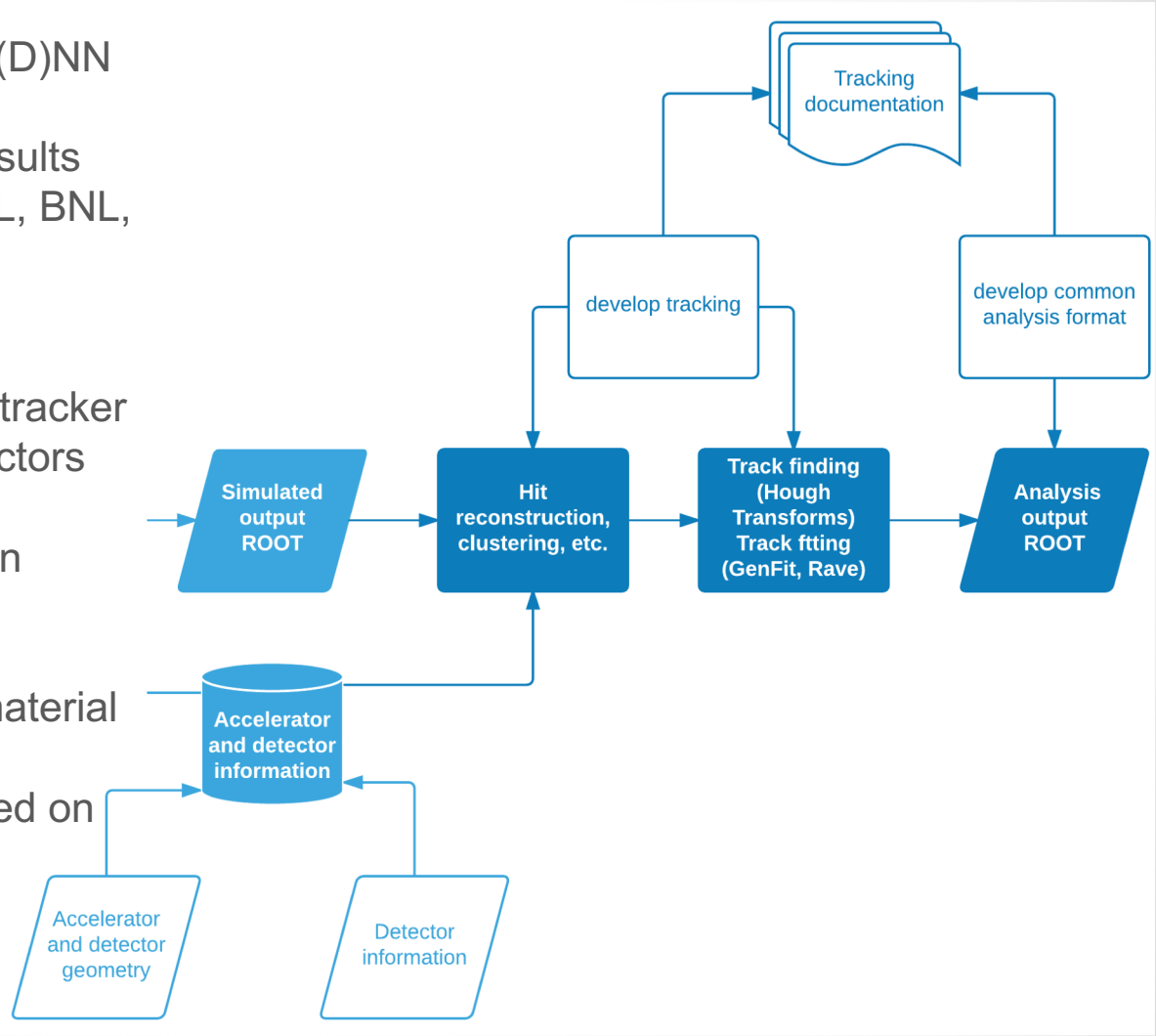
- for detector concepts
- for testing new algorithms (e.g., (D)NN for track finding)
- for comparing / validating EIC results
- based on EIC tracking tools (ANL, BNL, JLab)

Completed feasibility study

- similar requirements and similar tracker outline for all proposed EIC detectors
- similar dataflow: simulation -> digitization -> track reconstruction

Started development

- define libraries and interfaces (material db, reconstructed hits)
- setup sandbox environment based on JANA



ESC container project

Container technology

- **Container** := very lightweight Virtual Machine
- **Main players**
  - **Docker** industry standard, requires admin privilege on host
  - **Singularity** standard on OSG, can run entirely in unprivileged mode
  - **Shifter** (NERSC only)

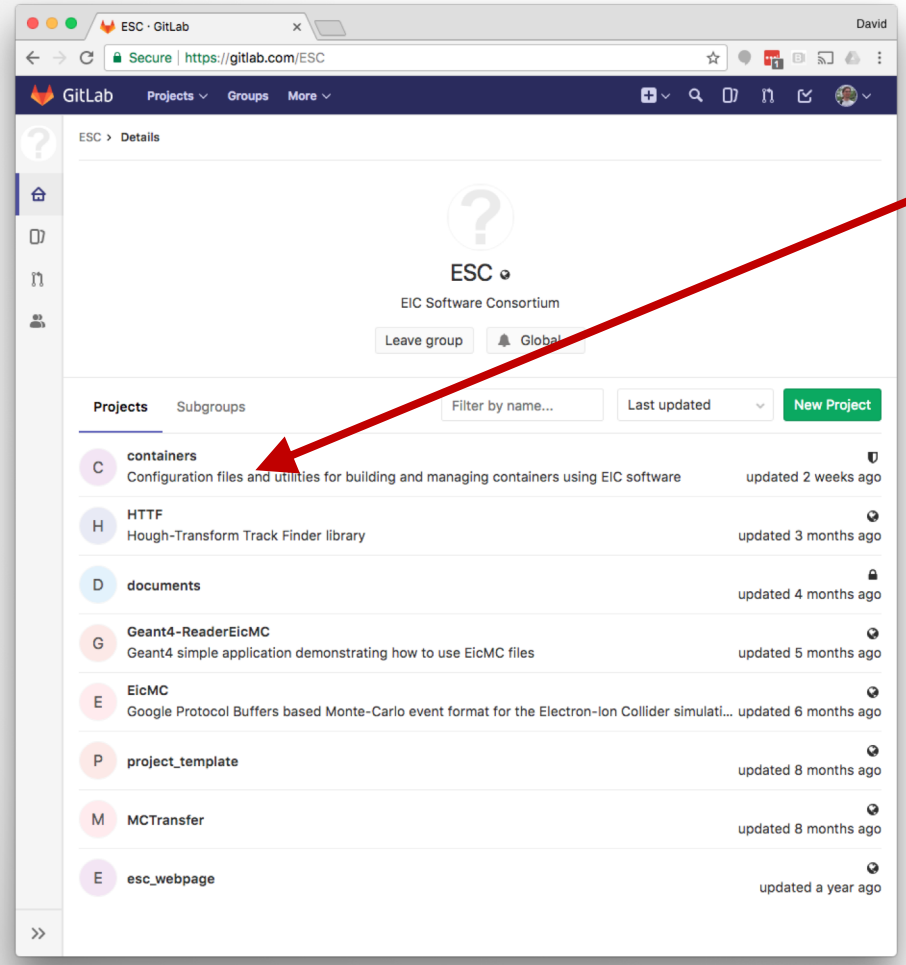
Benefits for EIC user community

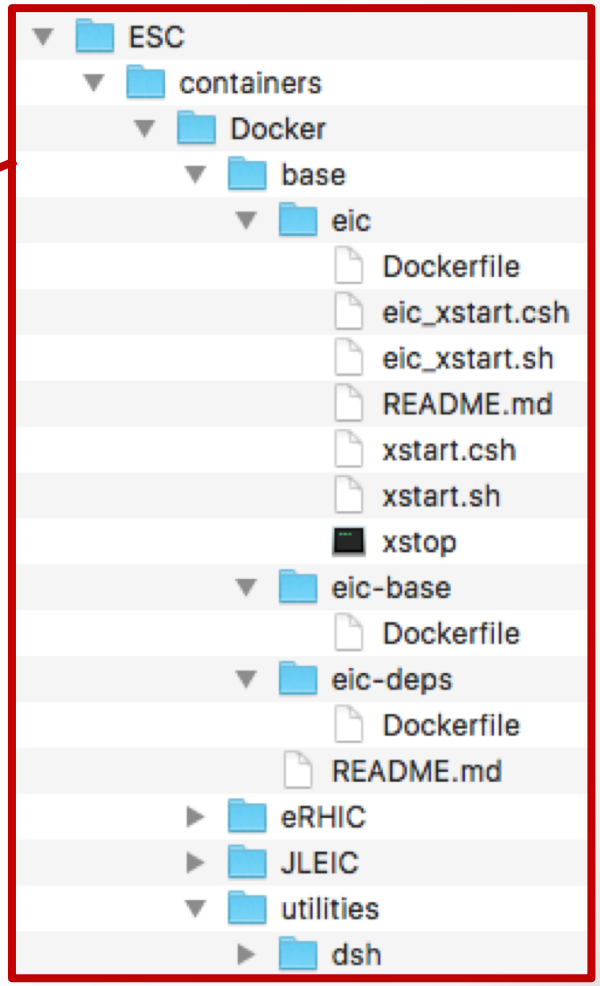
- Allow EIC users to run the same software under standardized environment on any Linux, Mac OS or Windows machine, eventually including GRID sites, commercial cloud systems, and HPC resources
- Provide consistency between software generated at different facilities
- Make it easier for new users to start working on the physics program and detector design for the EIC, by minimizing the pain of “installation overhead”

Community document draft released *by D. Blyth (ANL), W. Deconinck (William & Mary), MD (Jlab), A. Dotti (SLAC), AK (BNL), and* ***D. Lawrence (JLab)***

ESC container repository on GitLab

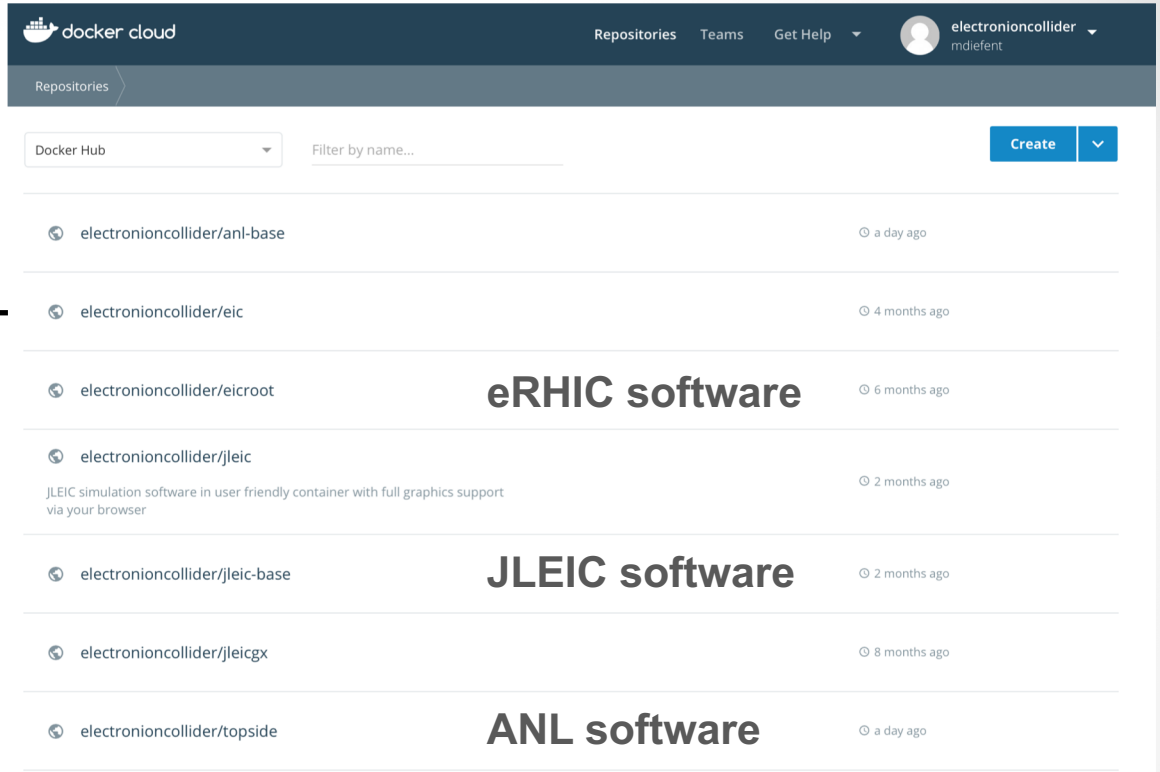
Source files for generating EIC containers are available: *https://gitlab.com/ESC*





ESC container images on Docker cloud

https://cloud.docker.com/swarm/electronioncollider/repository/list



Generic base image

- based on CentOS 7
- includes:
  - ROOT 6
  - Geant4 10.3.3
  - CLHEP 2.3.4.5
  - OpenGL graphics support

Also singularity hub support shub://electronioncollider/

FY19

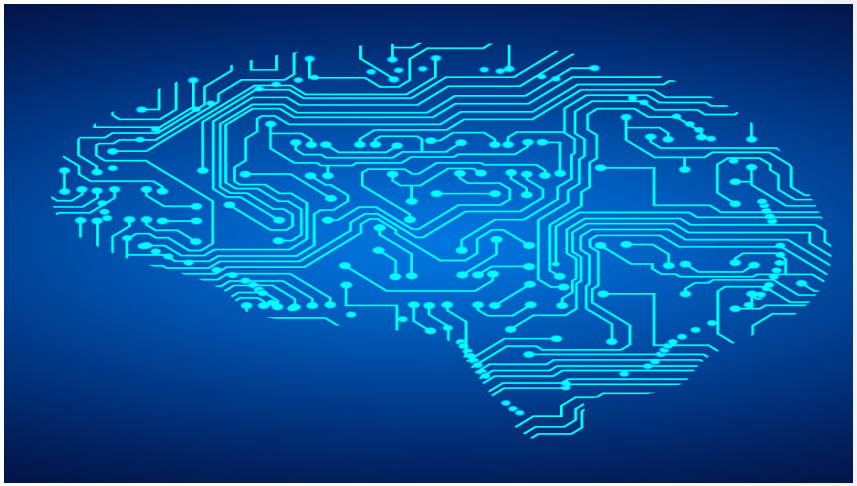
- **Tutorials**
- **EIC Software tour across the U.S. to popularize EIC tools among the community**

New ESC initiatives in FY18

High-performance computing

- prepare EIC HPC projects
- begin dialogue with ASCR-operated computational science user facilities

Deep neural networks



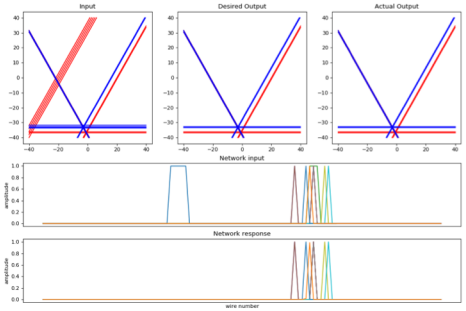
- Document selected examples for using (D)NNs at the EIC, e.g. lepton-hadron separation, RICH reconstruction, track finding, etc

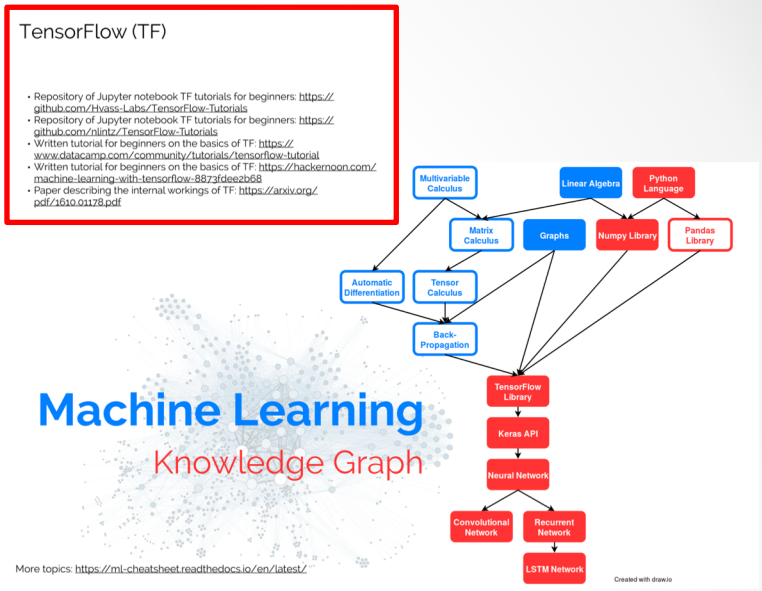
ULTIMATE GOAL be better prepared for the coming exascale computing era

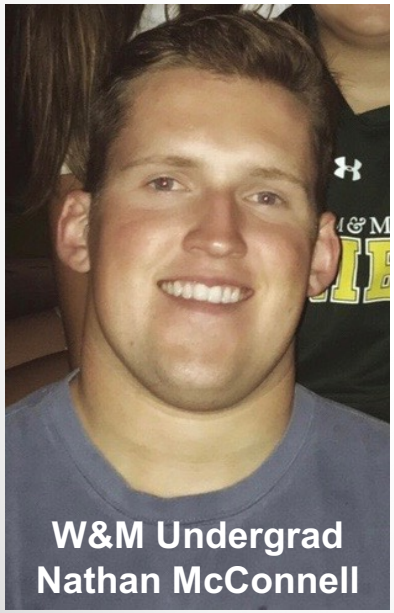
supported by ESC

W&M ML Initiative

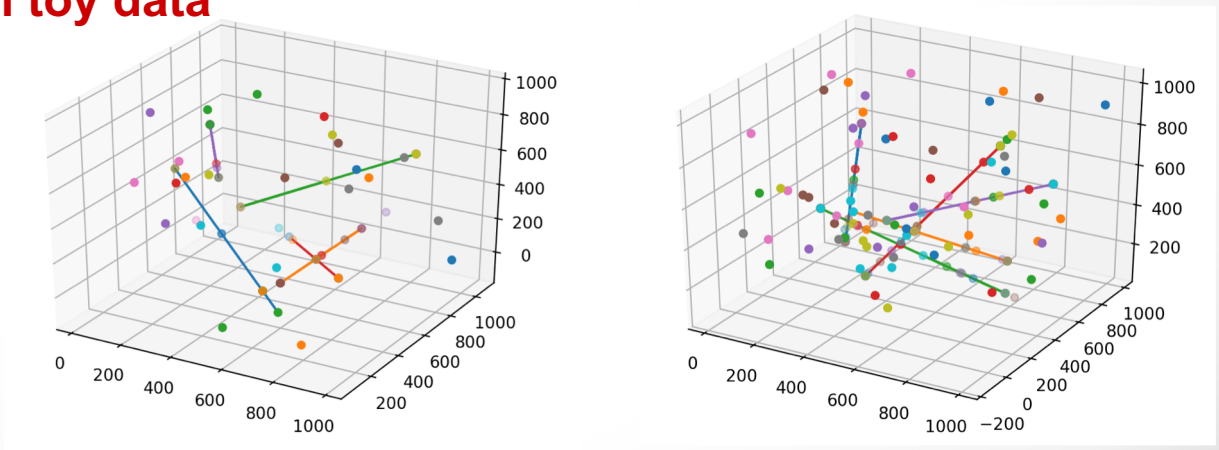
Track finding in Jlab 12 data







Track finding in toy data



Documentation under preparation

supported by ESC

ANL ProIO Initiative

Summer research on ProIO usage for EIC

- developing tools for inspecting the content of ProIO streams
- integrating the ProIO C++ library with Pythia8 MCEG
- performing benchmarks of ProIO files

HepSim

Repository with Monte Carlo simulations for particle physics

Dataset: "*gev35ep_pythia8_dis1q2ct14lo_v3*"

	Summary	Comments
Name:	*gev35ep_pythia8_dis1q2ct14lo_v3*	
Collisions:	e-p	
CM Energy:	0.035 TeV	
Entry ID:	325	
Topic:	SM	
Generator:	PYTHIA8	
Calculation level:	LO+PS+hadronisation	
Process:	DIS events at Q2>1 GeV2	
Total events:	495530	
Number of files:	10	
Cross section (σ):	3.350E+05 ± 805.1965 pb	Estimated from file
Luminosity (L):	1.4790 pb^{-1} *(or)* 0.0015 fb^{-1} *(or)* 1.479E-06 ab^{-1}	
Format:	ProIO	
Download URL:	http://mc1.hep.anl.gov/web/hepsim/events/ep/35gev/pythia8_dis1q2ct14lo_v3/	Status: Available
Mirrors:		

FY19 budget

eRD20 budget request to

- attract a limited undergraduate student manpower
- let the ESC members meet in person and work together on key tasks and
- be able to invite visiting scientists that are essential to the R&D effort
- attend important conferences and workshops related to our work,
- in particular to “Future Trends in NP Computing” workshop in 2019
- **EIC Software tour** across the U.S. to popularize EIC tools among the community

eRD20 budget scenarios

	USD 50,000	USD 40,000	USD 30,000
undergraduates	✓	✓	✓
in-person meetings	3	2	1
conference and workshop support	✓	✓/ -	-
EIC Software tour	✓	-	-

Work closely with EIC User Group

06/04

Announcement of **EICUG Software Working Group**

Charge

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. This will be pursued in a manner that is accessible, consistent, and reproducible to the EICUG as a whole. It will embody simulations of all processes that make up the EIC science case as articulated in the White-paper. 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. The working group will be open to all members of the EICUG to work on EICUG related software tasks. It will communicate via a new mailing list and organize regular online and in-person meetings that enable broad and active participation from within the EICUG as a whole.

Conveners

David Blyth, MD

Summary

Despite limited manpower we make sustained progress

- Reach out to the EIC community
- Bring existing EIC software to the end users

- Play active role in software-related workshop organization

- Gain missing knowledge and apply it to practical tasks
- Arrange expert discussions and come to a consensus-based decisions

- Take measures to prevent future EIC software divergence
- Try to establish forward looking vision of EIC software

Work closely with EICUG Software Working Group

FY19 goals

Development of Detector Simulations

- **Geant4 Simulations** physics list, validation
- **Interfaces and integration** “software sandbox”, event data model (ProIO)

ESC Initiatives Containers, Machine learning, Monte Carlo Event Generators