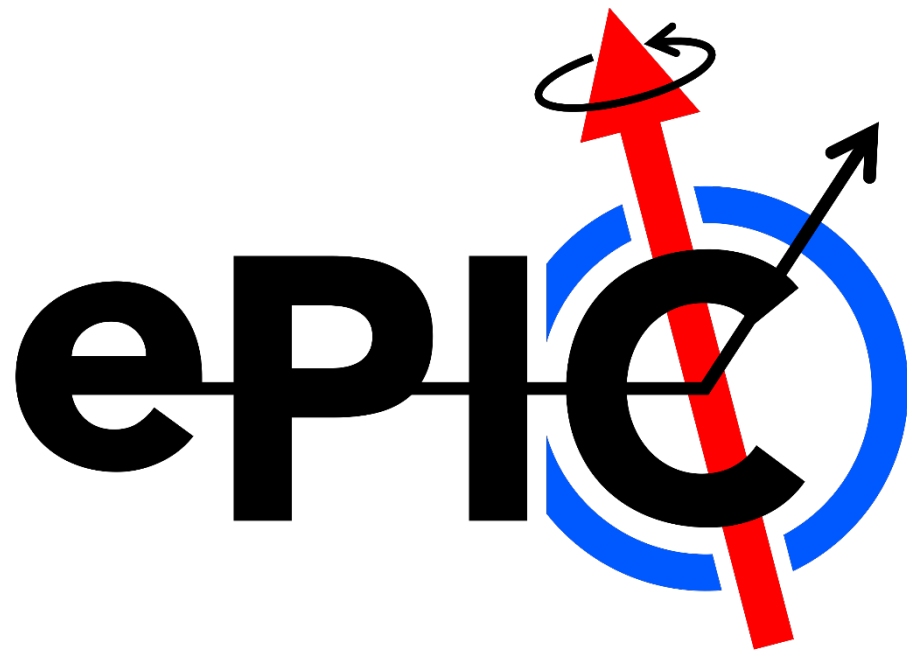


# Development of the ePIC Computing Model

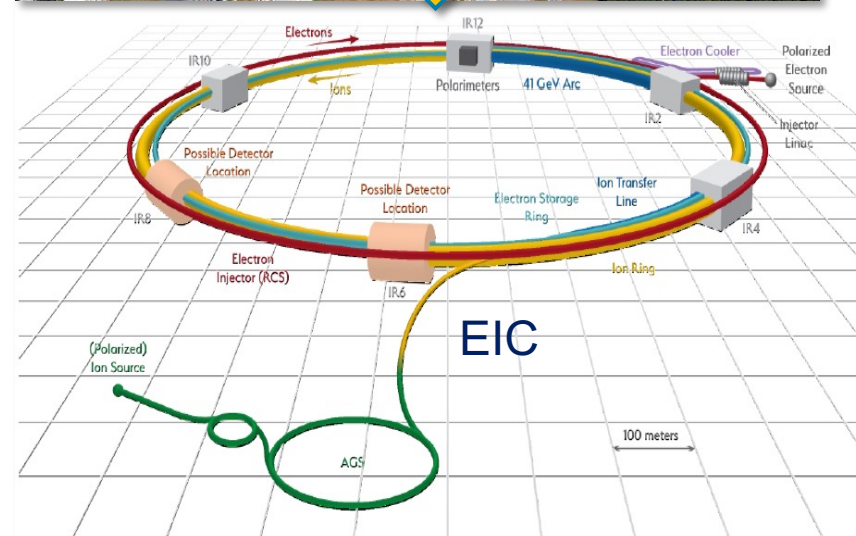
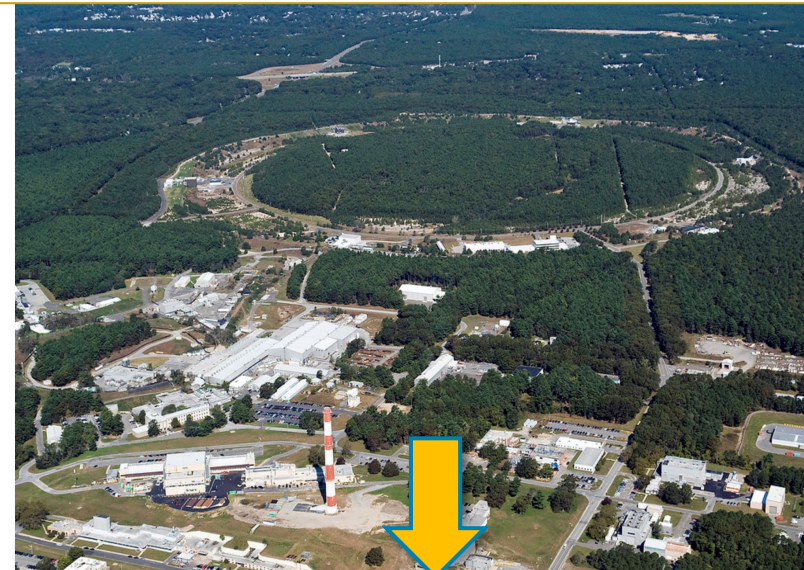


Domenico Elia  
(INFN Ba)

A. Bressan  
(University of Trieste and INFN Ts)

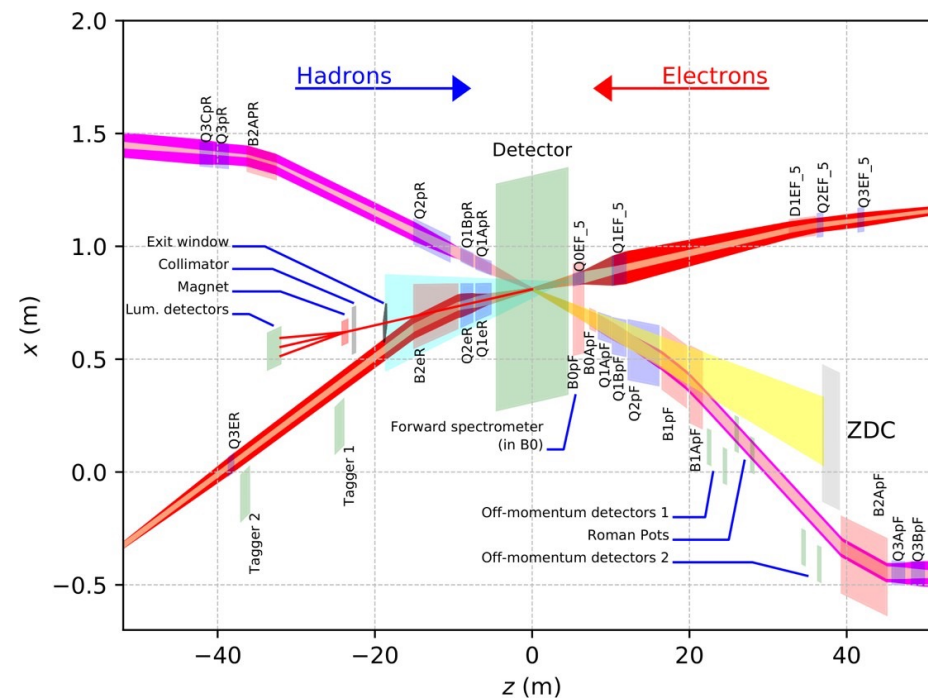
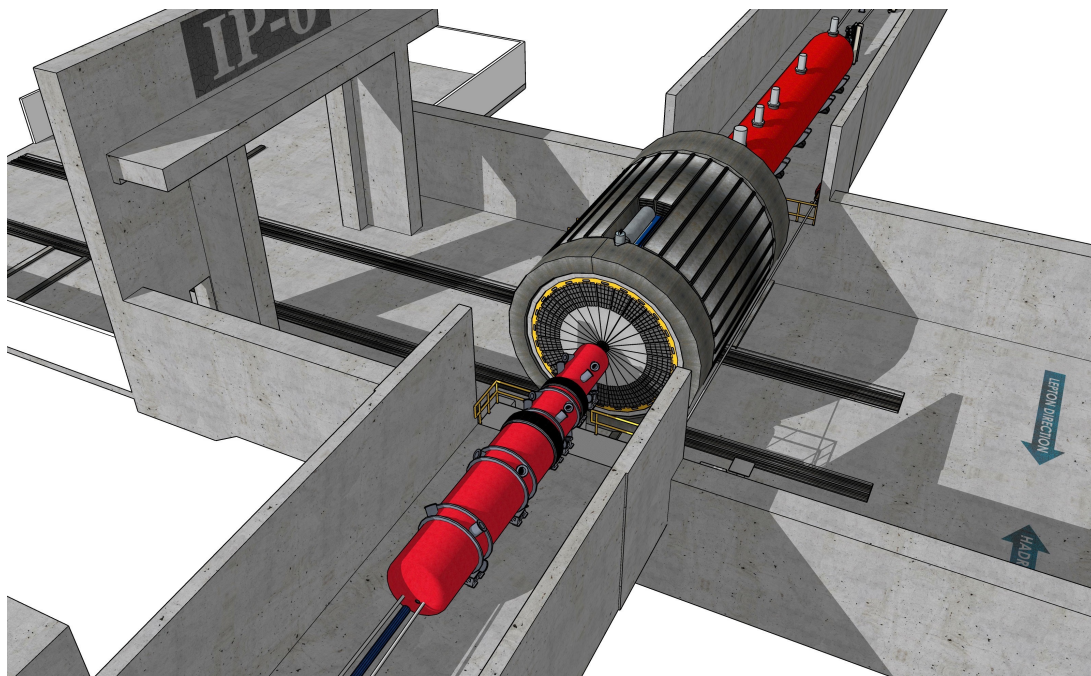
*Workshop sul Calcolo nell'INFN*, Palau, 20 maggio 2024

- Design based on **existing RHIC Complex**; RHIC accelerator chain will provide EIC Hadrons.
- EIC constructed in Collaboration with **JLab**
- **Hadron storage ring (HSR): 41-275 GeV (based on RHIC)**
  - up to 1160 bunches, 1A beam current (**3x RHIC**)
  - bright vertical beam emittance (1.5 nm)
  - strong cooling (coherent electron cooling, ERL)
- **Electron storage ring (ESR): 2.5–18 GeV (new)**
  - up to 1160 polarized bunches
    - high polarization by continual reinjection from RCS
  - large beam current (2.5 A) → 9 MW SR power
  - superconducting RF cavities
- **Rapid cycling synchrotron (RCS): 0.4-18 GeV (new)**
  - 2 bunches at 1 Hz; spin transparent due to high periodicity
- **High luminosity interaction region(s) (new)**
  - superconducting magnets
  - 25 mrad crossing angle with crab cavities
  - spin rotators (produce longitudinal spin at IP)



## Integrated interaction and detector region (90 m)

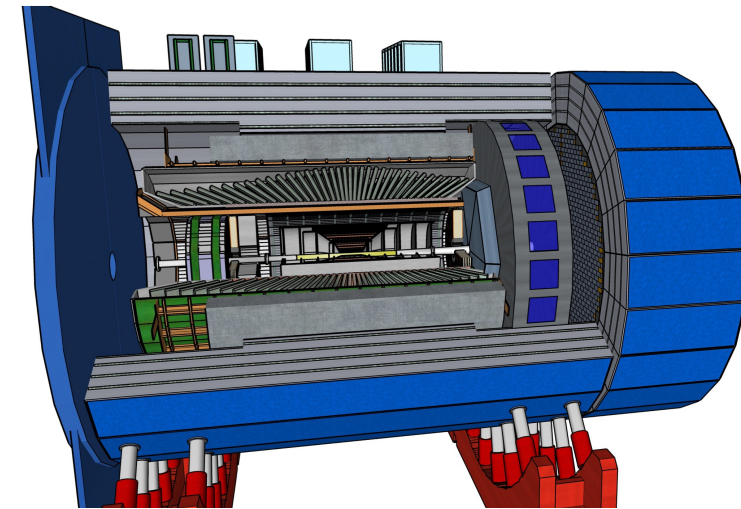
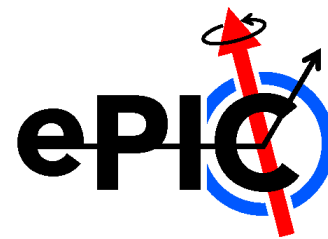
Get ~100% acceptance for all final state particles, and measure them with good resolution. All particles count!



## Compute-Detector Integration

Extend integrated interaction and detector region into detector readout (electronics), data acquisition, data processing and reconstruction, and physics analysis.

- EICUG Yellow Report (2020-21)
- Call for proposals issued jointly by BNL and JLab in **March 2021**
  - Proposals due Dec. 1, 2021: **ATHENA**, CORE and ECCE proposals submitted
- Public DPAP meetings Dec. 13-15, 2021
  - Presentations from proto-collaborations
  - Panel-assigned homework questions
- Second DPAP session Jan. 19-21, 2022
- DPAP closeout March 8th, 2022
  - Final report available March 21st, 2022
  - ECCE proposal chosen as basis for first EIC detector reference design
- Spring/Summer 2022 – ATHENA and ECCE form joint leadership team
  - Joint WG's formed and consolidation process undertaken
  - Coordination with EIC project on development of technical design
- Collaboration formation process started July, 2022
  - First IB Meeting July 18th
  - Charter writing committee formed and active
- First ePIC Collaboration meeting July 26-29, 2022
- ePIC Charter approved Dec. 14th, 2022
- Since 2023: structuring Collaboration, detector sub-system WGs etc
  - pre-TDR preparation
  - ongoing discussion on international engagement/agreements
  - latest RRB in Rome May 6-7, 2024



## ePIC Detector schedule

- To be sited at IP6 (25mr crossing angle)
- Addresses EIC science program as outlined in the EIC white paper and NAS report
- Working towards **pre-TDR and CD-2/3A (early to end 2025)**
- **Construction phase ~2026-2030**
- Ready for Day-1 EIC operations **CD-4A (end 2032)**
- **Start full science phase CD-4 (end 2034)**

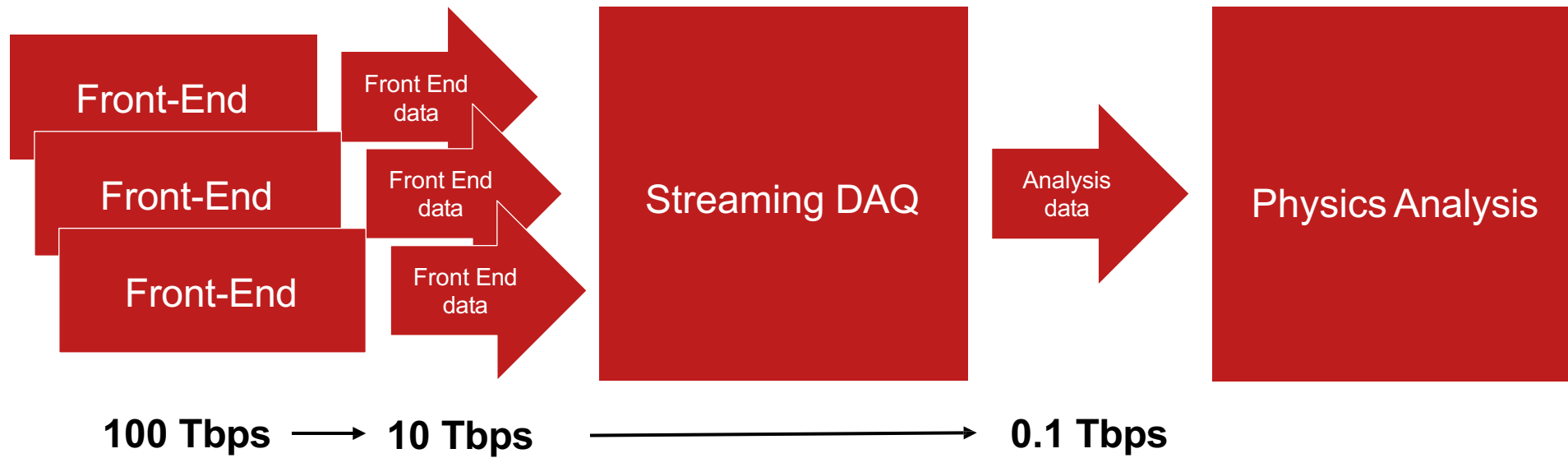
## Broad ePIC Science Program:

- Plethora of observables, with less distinct topologies where every event is significant.
- High-precision measurements: Reducing systematic uncertainties of paramount importance.

## Streaming Readout Capability

- **Capture every collision signal**, including background.
- Event selection using all available detector data for **holistic reconstruction**:
  - **Eliminate trigger bias** and provide accurate estimation of uncertainties during event selection.
- Streaming background estimates ideal to **reduce background** and related systematic uncertainties.

	EIC	RHIC	LHC → HL-LHC
Collision species	$\vec{e} + \vec{p}, \vec{e} + A$	$\vec{p} + \vec{p}/A, A + A$	$p + p/A, A + A$
Top x-N C.M. energy	140 GeV	510 GeV	13 TeV
Peak x-N luminosity	$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	$10^{32} \text{ cm}^{-2} \text{ s}^{-1}$	$10^{34} \rightarrow 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
<b>x-N cross section</b>	<b>50 <math>\mu\text{b}</math></b>	<b>40 mb</b>	<b>80 mb</b>
Top collision rate	500 kHz	10 MHz	1-6 GHz
$dN_{\text{ch}}/d\eta$	0.1-Few	$\sim 3$	$\sim 6$
<b>Charged particle rate</b>	<b>4M <math>N_{\text{ch}}/\text{s}</math></b>	<b>60M <math>N_{\text{ch}}/\text{s}</math></b>	<b>30G+ <math>N_{\text{ch}}/\text{s}</math></b>



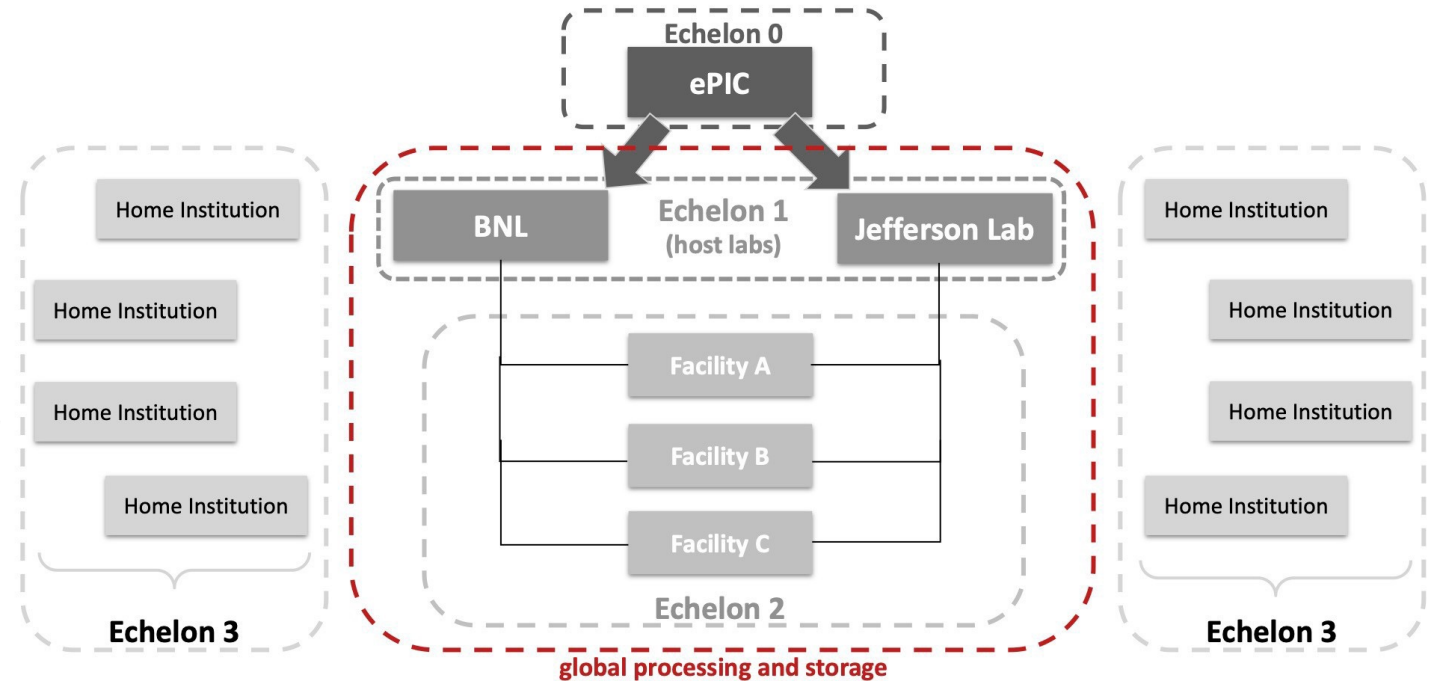
## Four Tiers:

**Echelon 0:** ePIC Experiment

**Echelon 1:** Host Labs

**Echelon 2:** Global processing and data facilities, includes HPC and HTC resources.

**Echelon 3:** Home institute computing



Initial version of a plan set to develop over the next decade.

**Echelon 0:** ePIC Experiment

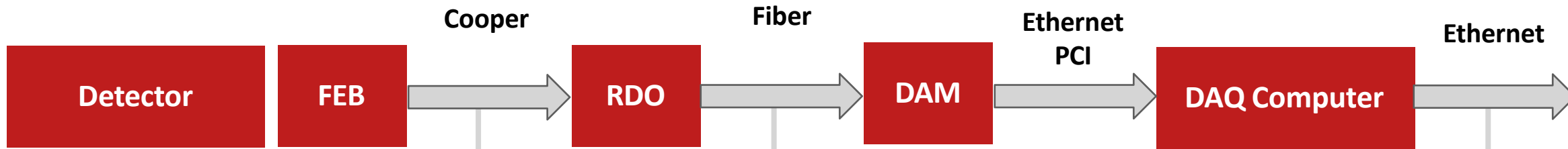
**Echelon 1:** Host Labs

**Echelon 2:** Global processing and data facilities

**Echelon 3:** Home institute computing

Use Case	Echelon 0	Echelon 1	Echelon 2	Echelon 3
Stored Data Streaming and Monitoring	✓	✓		
Alignment and Calibration		✓	✓	
Prompt Reconstruction		✓		
First Full Reconstruction		✓	✓	
Reprocessing		✓	✓	
Simulation		✓	✓	
Analysis		✓	✓	✓
Modeling and Digital Twin		✓	✓	





<b>Aggregate</b>	<b>2.0 Tbps</b>
Signal + Background	400 Gbps
Noise	1.6 Tbps

<b>Aggregate</b>	<b>2.0 Tbps</b>
Per RDO (Avg.)	0.7 Gbps

<b>Aggregate</b>	<b>96 Gbps</b>
Signal	38 Gbps
Synchrotron Radiation	0.1 Gbps
Electron Beam	22 Gbps
Hadron Beam	4 Gbps
Noise	32 Gbps

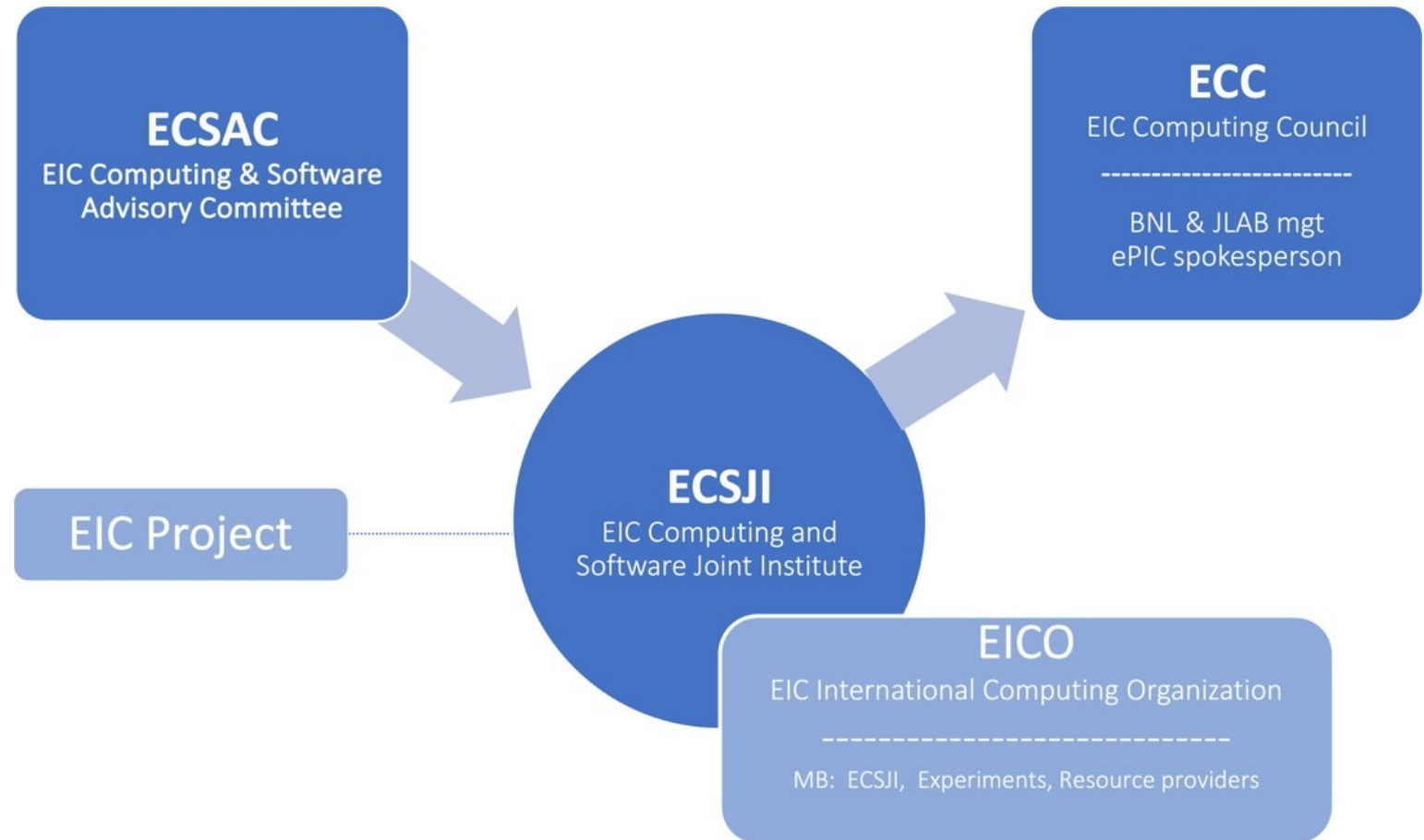
- **Max Luminosity and Bandwidth:**
  - Expected maximum luminosity  $\approx 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ .
  - Corresponding bandwidth  $\approx 100 \text{ Gbps}$ .
- **Design Considerations:** 100 Gbps between Echelon 0 and Echelon 1 at the host labs.
- **Outgoing Bandwidth:** Required: 200 Gbps

Resource	Type	Amount
<b>Outgoing bandwidth</b>	Raw data	200 Gbps
	Monitoring, slow controls, misc. meta data	$\leq 1 \text{ Gbps}$
	<b>TOTAL</b>	<b><math>\leq 201 \text{ Gbps}</math></b>
<b>Incoming bandwidth</b>	Monitoring, calibrations	$\leq 1 \text{ Gbps}$
<b>Storage</b>	Disk (outgoing data buffer w/ 24hr)	1PB

Resource	Type	Amount	
<b>Outgoing bandwidth</b>	Raw data – <i>immediate</i> (1/6 of total)	17 Gbps	
	Raw data – <i>replay</i> (contingency)	50 Gbps	
	Monitoring, slow controls, misc. meta data	1 Gbps	
	<b>TOTAL</b>	<b>≤ 68 Gbps</b>	
<b>Incoming bandwidth</b>	Monitoring, calibrations, slow controls (from Echelons 1–2)	1 Gbps	
<b>Storage</b>	Disk (temporary)	1PB	
	Raw+recon. only, no sim.	Disk (permanent)	20PB / yr
		Tape	220PB/yr

Values shown are for a single Echelon 1. There will be two.

- The Institute aims to provide efficient support to the EIC while acknowledging organizational differences at the two labs.
- The proposed governance model ensures that EIC experiments are well supported in matters of computing and software, the Institute's performance is monitored, and reporting is clearly defined.



*The proposed governance structure is composed of two central bodies, designed to facilitate communication, coordination, escalation of issues, and conflict resolution.*

- **Composition:** Management will comprise two co-directors, each nominated by one lab. The co-directors are currently Eric Lancon (BNL) and Amber Boehnlein (JLab).
- **Reporting:** The Institute's management will report jointly to host lab management.
- **Duties and accountability:**
  - The management will be responsible for organizing the Institute to deliver on the previously defined responsibilities.
  - The management will maintain a multi-year operation plan for the host labs, providing matrixed staff members to support activities.
  - Institute management will provide a yearly report to the host labs' management.

- **ePIC is an international collaboration and so is its computing:**
  - Echelon 2 includes **global resources contributed by collaborating institutions.**
  - Achieving scientific goals relies on effectively using Echelon 2's resources.
  - Design of computing model aims for **effective integration and management.**
  - Echelon 2 resources must have **MOUs specifying service requirements.**
  - These MOUs **assure technical compatibility with the ePIC computing model.**
  - **ePIC commits to facility integration** and robust testing/validation, includes monitoring and diagnostics.
- **Connectivity**
  - Echelon 2 sites connect equally to both Echelon 1 Host Labs.
  - Connection is ultimately through ESnet network backbone.

- Today level of support of for LHC experiment
  - 10 MHS days for ALICE, ATLAS and CMS, i.e  $30 \div 35$  k logical cores
  - About 20 PB increase/year for ALICE, ATLAS and CMS
  - About 6-7 PB increase/year for ALICE, ATLAS and CMS
- HL-LHC will scale previous numbers in 10 years by
  - $\sim \times 10$  for CPUs
  - $\sim \times 5$  for DISKs
  - $\sim \times 10$  for TAPE
- **As upper bound** and assuming a pure FTE scaling, the amount of investments that one may foresee at CNAF and other IT centers are:
  - **$20 \div 30$  k** logical cores or running job
  - **About 20 PB** of storage/year
  - **About 5 PB** of disk per year
- A larger amount of IT resources (not just scaling with FTE) might be part of specific in-kind contribution (TBD)

- INFN Computing Centers are sites of WLCG, build on for and driven by the LHC community
- Accounting, virtual organizations, certificates (or future tokens) as well as GRID tools are elements of WLCG
- Present WLCG organization foresees 1/3 of resources for TIER0, 1/3 for TIERs1 and 1/3 for TIERs2. A CM that include replicas/reconstruction outside Echelon1 will be relevant (maybe mandatory) for International Institutions
- The ePIC CM adopting these tools will have a positive relevant impact for the possible INFN contribution to computing



- ePIC is progressing in developing its Computing Model
- Still a lot to be defined also on Organization & Governance, gathering inputs from International Funding Agencies currently ongoing
- The level of possible support anticipated from Italy (as well as from Canada and United Kingdom as of now) is not a commitment, but it is based on “reasonable” expectations, while discussions are ongoing
- The choices made while developing the ePIC Computing Model may help members of the International community in the negotiation with their Funding Agency

# BackUp

# The Partnership

- Brookhaven National Laboratory (**BNL**) and Thomas Jefferson National Accelerator Facility (**JLab**), as Electron-Ion Collider host labs, are creating a joint structure, the EIC Computing and Software Joint Institute (**ECSJI**), incorporating parts of BNL and JLab facilities to support the EIC and computing and software needs and activities.
- ECSJI will leverage complementary expertise at the two labs and provide needed visibility to the respective lab management and stakeholders. The advantages of such a structure also include increased reliability and availability of resources for the ePIC collaboration.
- The success of the EIC, an international scientific endeavor, will benefit from contributions from international partners towards its computing effort.
- To facilitate efficient coordination, the Institute will administer the EIC International Computing Organization (**EICO**), which will include all the contributors to the computing effort.

# The Scope

## **The Institute will provide for EIC computing and software matters:**

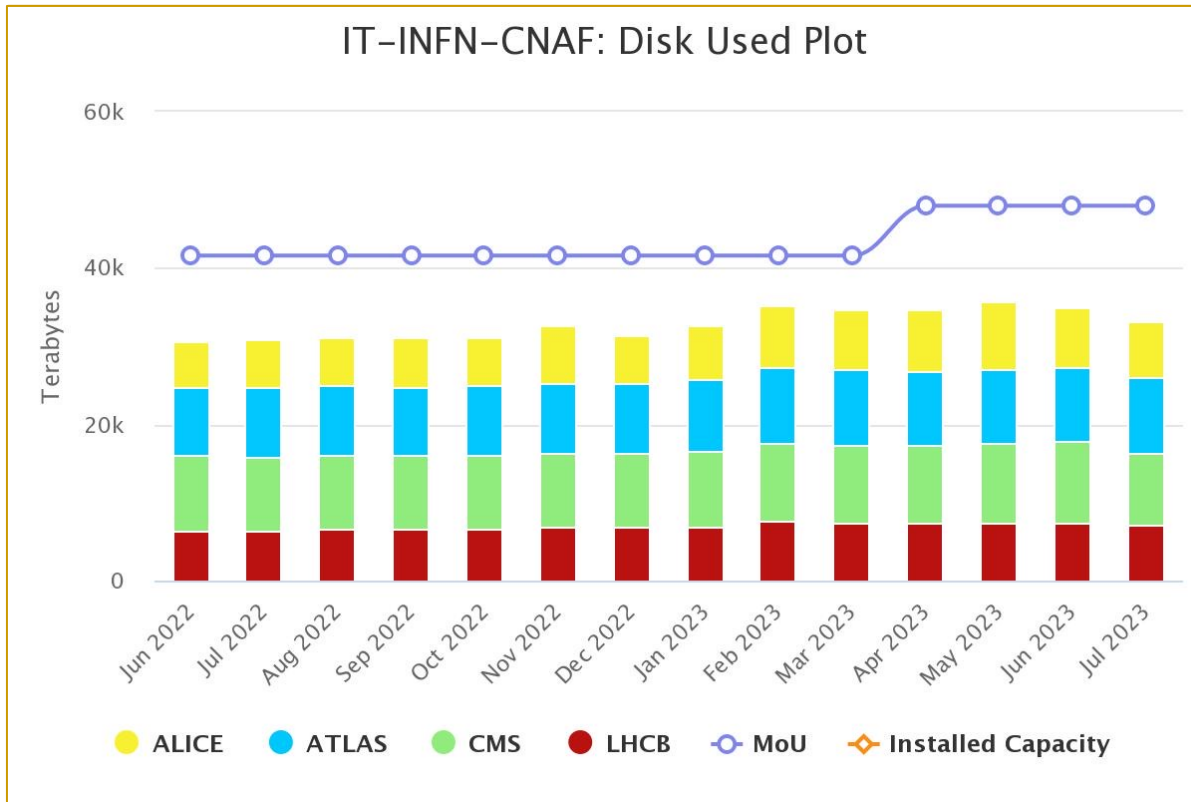
- 1) A single entity to interface with the EIC project and the ePIC collaboration.
- 2) Maintenance of service level agreements and statements of work outlining the host labs' contribution to the ePIC collaboration concerning computing resources, services, and personnel assigned to work on ePIC computing and software deliverables.
- 3) A coordinating body for interacting with international partners, providing computing resources as in-kind contributions, including:
  - Assessing resources.
  - Managing the MOUs with the sites delivering resources (including service levels).
  - Facilitating and assessing the delivery against the MOUs.
- 4) Execution of host lab responsibilities.

- At HL-LHC, both the ATLAS and CMS experiments will produce  $\sim 350$  PB of RAW data per year.
- The traffic from CERN to the T1s for RAW data quasi real time export will be  $\sim 400$  Gbps per experiment (7M seconds of LHC data taking per year).
- +  $\sim 100$  Gbps needed for other data formats
- The data at the T1 needs to be staged from tape and exported to the T2s for processing (assuming most of that processing happens outside the T1). This fix the need of T1-T2 bandwidth

- Infrastructure

- Renew infrastructures to be ready for the High Luminosity-LHC (HL-LHC) era, up to ~2035 or more
- Use more compact computing (from today's ~20 kW/rack to 80 or more)
- Lower the PUE (power usage effectiveness), be greener
- Extend and expand networking for a future-proof infrastructure

- Foster and simplify the utilization of more viable technologies (Eur/task or J/task), like GPUs, FPGA, ... down to Quantum when available
- Be more efficient, elastic and resilient
- Pervasive use of geographically distributed storage (“the datalake”)
- Abstract from physical machines, and form a national pool of resources and services (“the Cloud”)
- Extend elastically to external providers such as HPC@CINECA or other cloud providers (via “dynamic federations”)



- About 6-7 PB increase/year for ALICE, ATLAS and CMS
- ATLAS/IT about 270 FTEs
- CMS/IT about 200 FTEs
- ALICE/IT about 130 FTE (110 paying members for pledge)
- Or a total of 600 FTEs
- Estimate for ePIC:  $50 \pm 10$  FTEs

- IF ePIC **was running today**, assuming a level of support comparable to LHC experiments (**as upper bound**) and assuming a pure FTE scaling, the amount of investments that one may foresee at CNAF and other IT centers are:
  - About 3000 (virtual)COREs or running job
  - About 2 PB of storage/year
  - About 0.5 PB of disk per year
- HL-LHC will scale previous numbers in 10 years by (with some uncertainties)
  - $\sim \times 10$  for CPUs
  - $\sim \times 5$  for DISKs
  - $\sim \times 10$  for TAPE
- A larger amount of IT resources (not just scaling with FTE) might be part of specific in-kind contribution (TBD)