European Strategy Update

Instrumentation and Computing

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"Big questions"

Instrumentation:

(a) What **areas of instrumentation R&D** should be supported, and how, in order to meet the needs of future experimental programs?

(b) How to preserve knowledge, technical expertise and train the future generation of experts in detector R&D?

Computing:

(a) How should **HEP computing evolve** in order to support future scientific programs and their specific needs?

(b) What **R&D activities** must be supported, and how, in order to enable this computing evolution?

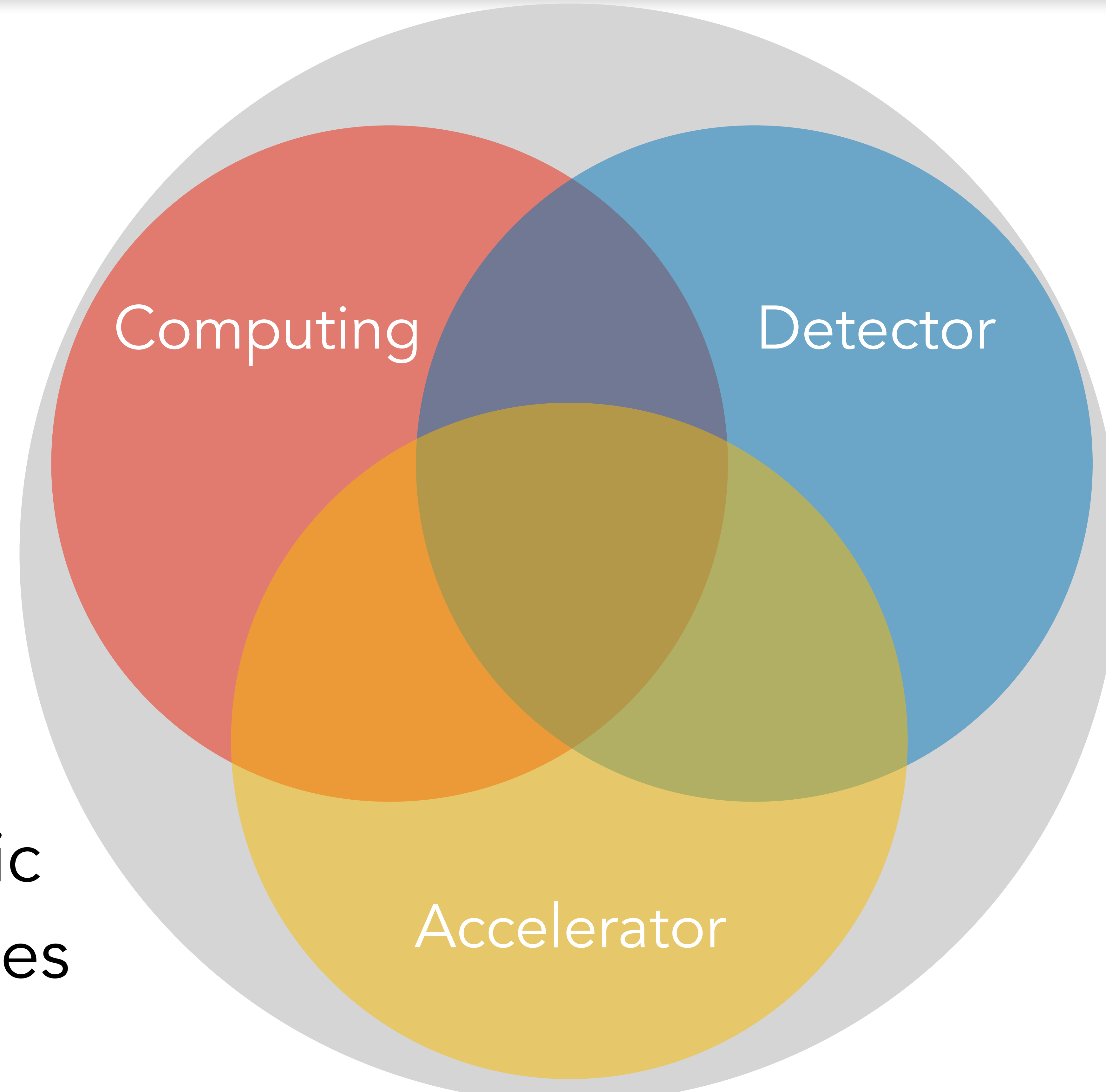
Parallel sessions summary

- Discussions organized around general themes.
  - Instrumentation:
    - Generic vs Guided detector R&D activities
    - Coordination of detector R&D activities
    - Knowledge preservation, training and career perspectives
  - Computing:
    - HEP Computing evolution
    - Coordination of computing-related R&D activities
    - Knowledge preservation, training and career perspectives.

Inputs to instrumentation/computing

- Considered about 60 written inputs submitted to EPPSU.
- Parallel sessions presentations.
  - Speakers 1-pager
- Panel discussions held during the parallel sessions.

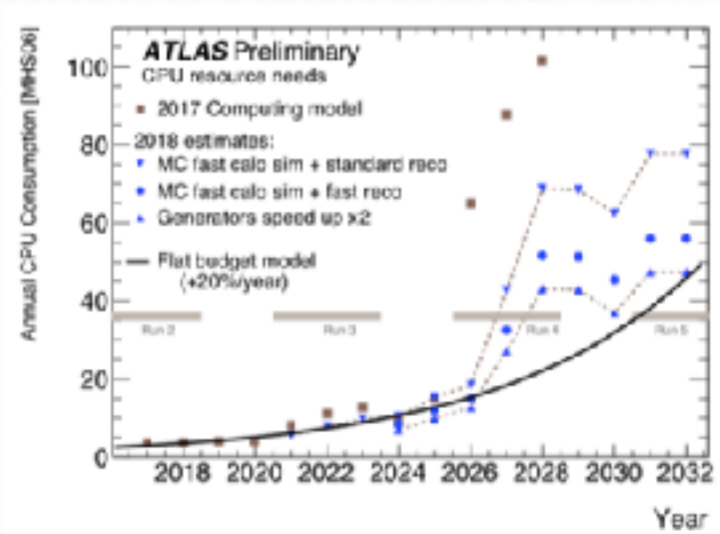
Research ingredients



Important challenges ahead

HL-LHC Run 4

- CPU projections for Run 4



- Expected (based on experience) resources do not meet the requirements (factor up to 2)
  - "flat budget" assumption is identified risk

L. Linssen

Summary

Future experiments require **very challenging detector technologies**
Depending on the application:

- Much improved spatial resolutions (few μm per hit, low mass)
- Much improved time resolutions (down to ~10 ps per hit)
- High-performance photodetectors
- Very high tolerance to radiation
- Combined features in the same detector (5D imaging)
- Very large numbers of channels, very high readout speed
- Very large area coverage at low cost
- Accompanied with a large diversity of engineering challenges

Electronics (CMOS technologies), **high speed links** and **optoelectronics** play increasingly important roles
Advanced detector simulation tools are necessary to reach ultimate performances

General comments

common to both instrumentation and computing themes

Our scientific questions are long term inquiries.

To reach our scientific goals, need to consider both human factor and R&D activities/coordination.

General comments

common to both instrumentation and computing themes

Human factor

- **Training**: Students/postdocs often lack basic knowledge (computing skills and instrumentation). University courses are often insufficiently oriented towards these technical aspects.
  - Would be profitable to enhance basic knowledge required for applied physics activities.
  - Instrumentation-focused activities need to be recognized as PhD-granting activities.
  - PhD/postdoc with some focus on detector/computing development should be encouraged.

General comments
common to both instrumentation and computing themes

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Human factor

- **Career recognition/opportunities**: Instrumentation and C&S activities need to be recognized as fundamental to research activities and bearing a large impact on the final physics results.
  - To advance the goal of proper recognition at universities and laboratories:
    - Consider what can be done to help at **all levels**: university groups, experimental collaborations, major labs, funding agencies.
    - Consider **creating a document** targeting universities and laboratories describing and advocating the specificity of instrumentation and C&S development, and the need for a change of paradigm.
    - Consider issuing recommendation for laboratories to **create a specific and prestigious career path**, through, e.g. fellowships, long-term positions.
    - **Engage with outreach and communication** units to raise awareness and visibility for technological/computing dimension of particle physics.

General comments
common to both instrumentation and computing themes

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Human factor

- **Special considerations in computing**: Teams working on S&C need to be well-rounded, including physicists and developers.
  - Developers:
    - Career path exists in industry.
    - Observed trend that younger professionals have interests in accumulating experiences, changing companies or career areas.
    - Opportunity for term positions targeted at particular skills at particular times that brings in current relevant skills and approaches in industry without building an unnecessarily large standing army.

General comments

common to both instrumentation and computing themes

- Detector/computing R&D needs strong support.
- Maintain/develop proper mixture of activities related to "**now, next, horizon**" (yes, even for computing)
  - Provides ability to foster tool-driven revolution and development of enabling technologies ("horizon");
  - Enable necessary R&D activities required to address needs of current/ future experimental programs ("now/next").
  - Also makes it possible to exploit technical progress that can potentially provide opportunities to improve performance and/or cost.

General comments
common to both instrumentation and computing themes

- General opinion that R&D should not be centralized exclusively in large-scale facilities and/or in major labs.

- Current R&D collaborations (eg. RDx, AIDA2020, CALICE,etc.) seen to be effective models of collaboration.
  - Conduit to facilitate constructive exchange of information/expertise
  - Effective framework to share resources.
  - Coordinate work to limit duplication of efforts
  - Support wide dissemination and growth of knowledge
  - Excellent training environment
  - Provide door to industry relations

- Need support to strengthen R&D consortia - and establish new ones - while preserving expertise and working relationships
  - Essential to maintain/establish strong links between future project studies (FCC, LC) and ongoing or planned upgrades
  - Evolve common views on goals and feasibilities
  - **Importance of international and independent review processes**, in addition to experimental collaboration-internal procedures, for recognition by national funding agencies

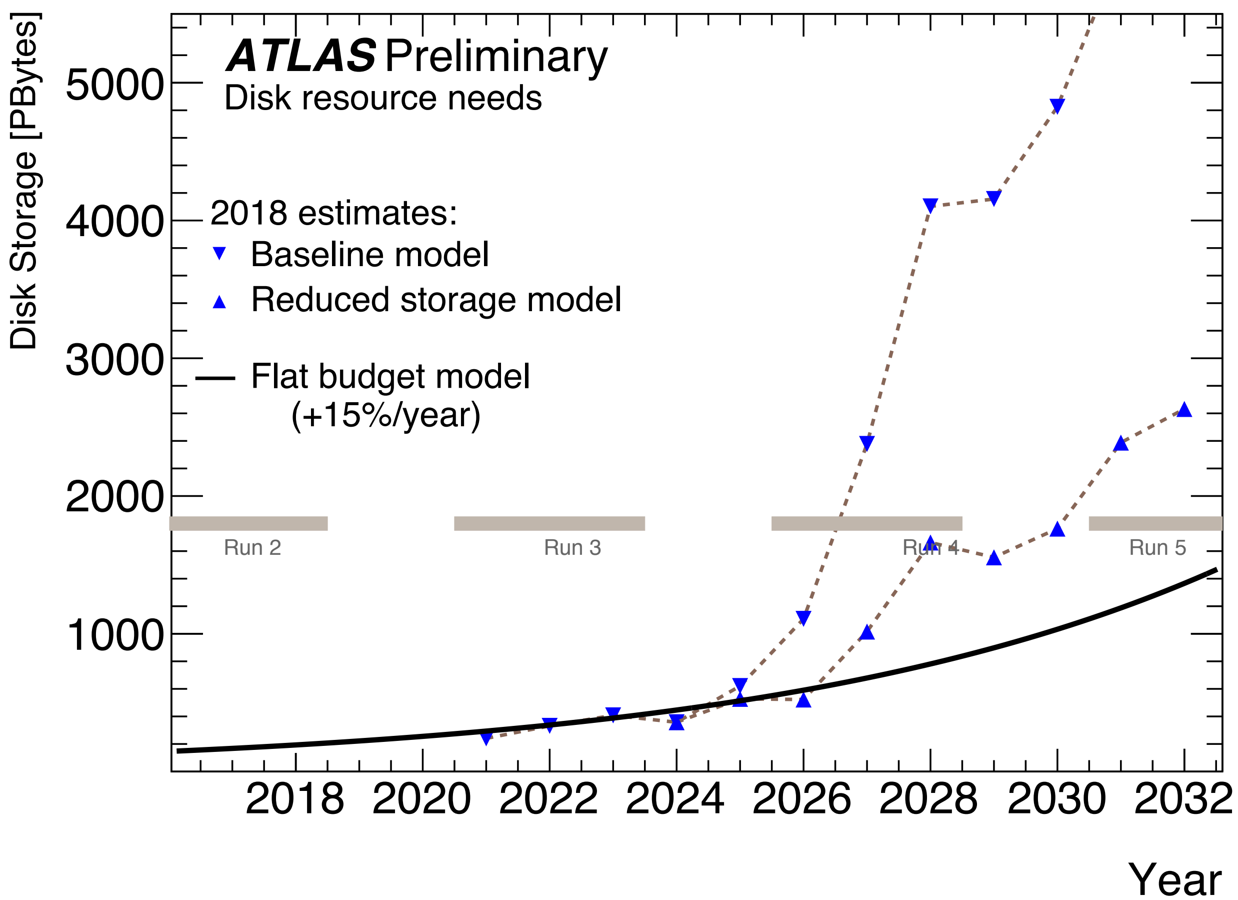
General comments

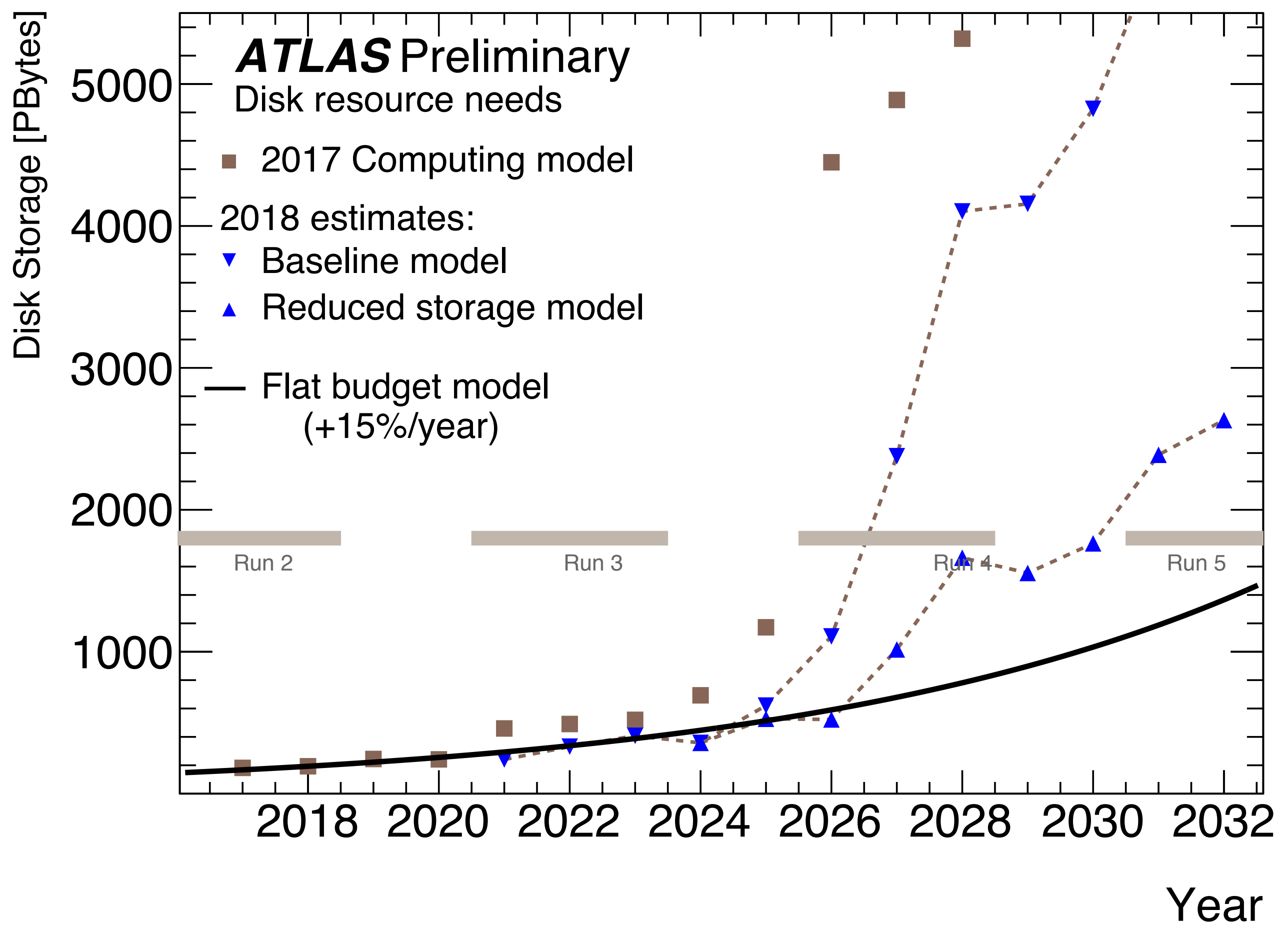
common to both instrumentation and computing themes

- Provide opportunities to build on, and benefit from, synergies with non-HEP and industry (e.g. through technology-centered R&D platforms across disciplines providing)
  - Pathway to tech transfer opportunities between fields (e.g. DarkSide use of ProtoDune cryostat, common computing/software tools)
  - Opportunity for developing industry partnership (non-trivial but necessary), and tech transfer (bringing fundamental research closer to the needs of the whole of society)
  - Multi-disciplinary approach could also address better exchange of the human capital and open up career opportunities.
  - Stimulating environment for new blue-sky ideas/development
  - Provide centralized source of information on ongoing activities to other fields and industry.

Computing comments

Bridging the gap between needs vs available resources





- HEP computing evolution required.
- At HL-LHC, may not be able to completely close the gap between needs and resource availabilities, in which case we need to be prepare to either:
  - Increase investment in computing
  - Accept to take decisions that will impact physics capability.

Computing comments

Bridging the gap between needs vs available resources

- Computing evolution:
  - **The landscape has shifted significantly** in the last decade (heterogeneity, accelerators, …):
    - "**Plan for change, and aim to be agile!**"
    - Need to be proactive (e.g. to engage in development of future HPC centres to ensure resources fit our needs).
  - Strong desire to **strengthen synergies and collaborations across HEP and with big data experiments for the future** – infrastructure, tools, and software (e.g. via wlcg, HSF, IRIS-HEP in US, etc.)
  - "Bad software is extremely expensive!" and "good and clever software allows much more physics to fit in the budget"
    - Re-iterate **need for adequate level of investment in skilled developers** → not currently available at the required level.

Computing comments

Bridging the gap between needs vs available resources

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- Adopt a more holistic approach:
  - By **considering the costs of both detector and computing** together when designing new projects, it is possible to optimize physics for the cost.
    - Detector design/layout should take into account impact on computing needs.
    - When possible, aim to bring intelligence as close as possible to detector to mitigate deluge of data.
    - Computing must be part of and funded, during the design phase of the project.
  - Define ahead of time a complete **data management plan** (data preservation, open access, etc.)
  - Computing costs must be a bigger factor in physics priority planning.

Computing comments

Bridging the gap between needs vs available resources

- Strategy/planning:
  - We should avoid taking short term decisions that can have long term implications; We should foster a measured approach that considers operational costs as well as development costs.
  - Plan investment in R&D effort for best long term cost benefit.
  - Need to find way that continues to foster innovation while developing shared and common projects that have a long-life span and typically an Open Source Model.

Summary

- Instrumentation and computing activities crucial to enable scientific programs.
- Important instrumentation and computing challenges ahead of us.
  - Exciting opportunities for innovation.
- Addressing these challenges will require taking into account
  - Human factor
  - R&D activities/coordination

Thank you!

- Parallel session contributors:
  - Ian Bird, Amber Boehnlein, Simone Campana, Ariella Cattai, Didier Contardo, Cinzia Da Via, Giuliana Fiorillo, Francesco Forti, Maria Girone, Roger Jones, Matthias Kasemann, Weidong Li, Emilia Leogrande, Lucie Linssen, Felix Sefkow, Graeme Stewart.
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