TDAQ BRN INTRO

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WELCOME !

- This meeting is meant to serve as an open forum to discuss US DOE R&D priorities in the Trigger & DAQ area
- First some background info to the BRN process and early thinking by our working group will be given here in this talk
  - Including also feedback from our community survey
- Then a series of topics will be introduced by facilitators who kindly agreed to put down their thoughts on the issues and challenges in these particular areas
- We aim for ample discussion time as well after each topic
  - If too many questions at once, please use the "Raise Hands" feature of Zoom to let us know you would like to speak

DOE OHEP INSTRUMENTATION BASIC RESEARCH NEEDS (BRN)

- Recognizes that instrumentation is the enabler of science and that development of instrumentation has a long gestation period:
  - Charged to articulate the case for an expanded instrumentation development program over the next 5 years (to 2025) and then 10 years further (to 2035) in support of the P5 mission.

Even further beyond if possible, e.g. for future colliders

- Identify *Priority Research Directions* (***PRDs***) in instrumentation for each physics driver (including the development program with timelines) and *Key Challenges* that could be game changers for HEP and may have a wider impact in other disciplines and in society.
  - The PRDs motivate a program for expanded KA25 funding, and Key Challenges are critical to unlock new money for OHEP

INSTRUMENTATION BRN SUBGROUPS

Technical Groups	
Quantum Sensors	Andy Geraci
	Kent Irwin
Noble Liquids	Roxanne Guenette
	Jocelyn Monroe
Calorimetry	Francesco Lanni
	Roger Rusack
Solid state and tracking	Marina Artuso
	Carl Haber
Photodetectors	Peter Krizan
	Lindley Winslow
TDAQ	Darin Acosta
	Tulika Bose
Readout and ASIC	Gabriella Carini
	Mitch Newcomer

Includes machine learning

Physics Groups	
Higgs and other energy frontier	Jim Hirschauer
	Gabriella Sciolla
Neutrinos	Ornella Palamara
	Kate Scholberg
Dark Matter	Jodi Cooley
	Dan McKinsey
Dark Energy and Inflation	Clarence Chang
	Brenna Flaugher
Explore the Unknown	Sarah Demers
	Monica Pepe-Altarelli

Cross Cutting Group:
Marcel DeMarteau, Abe Seiden,+ (invites out)

INSTRUMENTATION BRN PLAN

- Ultimately prepare a report (~10 pages per group) on PRDs, challenges, and R&D timeline across Frontiers (Energy, Intensity, Cosmic)
  - To be completed by Feb.2020
  - An early draft interim report is attached to this agenda page
- Final iteration: a BRN conveners' workshop to be held at DOE Dec.11-14
  - Capture all of the work done by then, plus new ideas arising from the workshop
  - The plenary talks on the first day will be streamed to the community
- Vital to have community input and transparency i.e. links to, and communication with, the broad community both US and internationally
  - Along with this virtual meeting (and survey), there is also the CPAD workshop early next week ahead of the BRN workshop: https://wp.physics.wisc.edu/cpad2019/

INSTRUMENTATION BRN FURTHER INFO

- Public website:
  - http://doe-brn-hep-detectorrandd.physics.ox.ac.uk
  - Includes an open Google doc for community to provide feedback
- TDAQ Google Form:
  - https://forms.gle/jZ1aqDTm2PtCvcJT9
  - Survey to collect input specifically from the TDAQ community
    - Initial summary later in this introduction

TDAQ R&D STARTING POINTS

From draft interim report

- Streaming DAQ   (aka “trigger-less”)
  - Read out data from expt. at natural rate.
  - Requires high bandwidth technology, data compression, and high performance software-based triggers
- Fast Machine Learning
  - Low latency, high data volume algorithms to achieve unprecedented data reduction
- Challenges for reading out a pixel detector at a reasonable rate for trigger
  - Future EF experiments will require highly granular detectors, yielding large data rates
  - A tracking trigger, or b-tag trigger, at Level-1 will require incorporation of pixel data
  - Requires high bandwidth data links (perhaps wireless), rad-hard, low power, low material

TDAQ R&D STARTING POINTS

From draft interim report

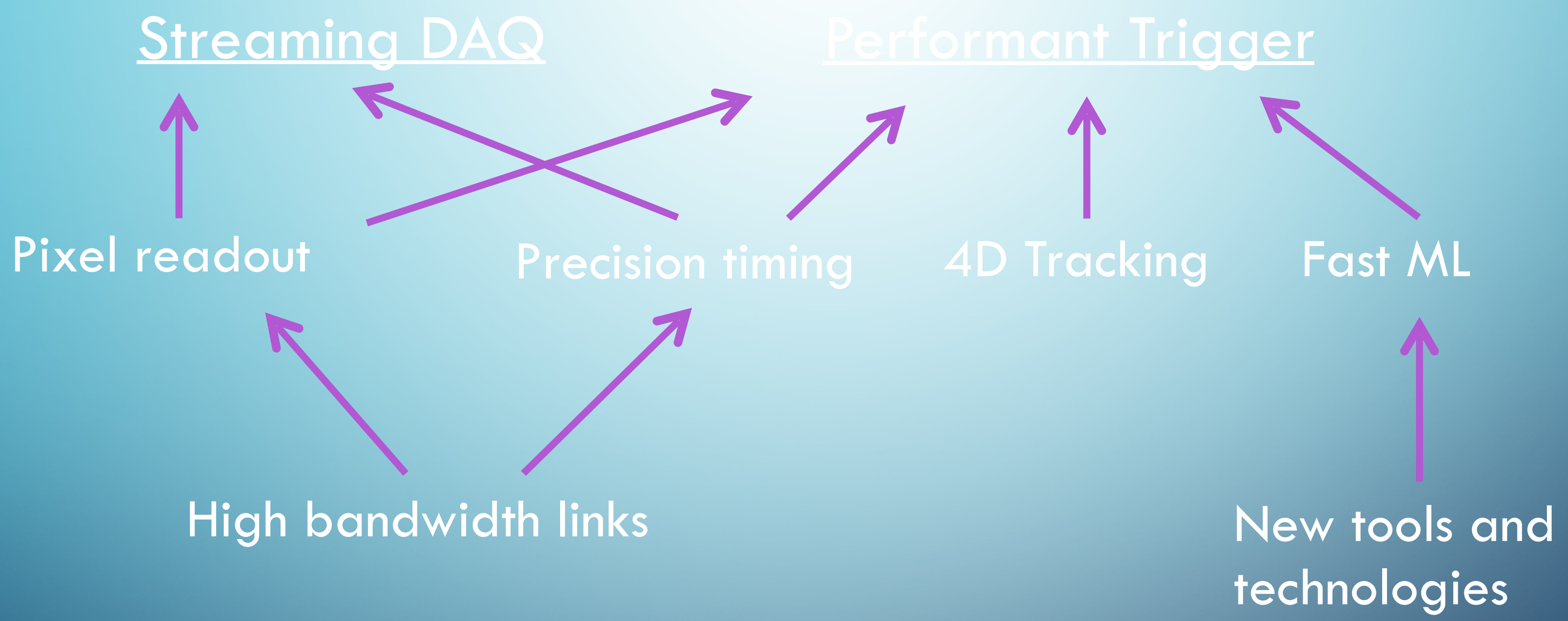
- Development of tools that leverage new technology
  - Tools to make use of new FPGA technologies, or more generally heterogeneous computing hardware, for real-time and power constrained applications
  - For example for machine learning (DNNs)
- Automated, self-running DAQ systems
  - Fast collection and processing of conditions data to detect and respond to faults in order to improve data collection efficiency for increasingly complex detectors
  - Could take advantage of AI

TDAQ R&D STARTING POINTS

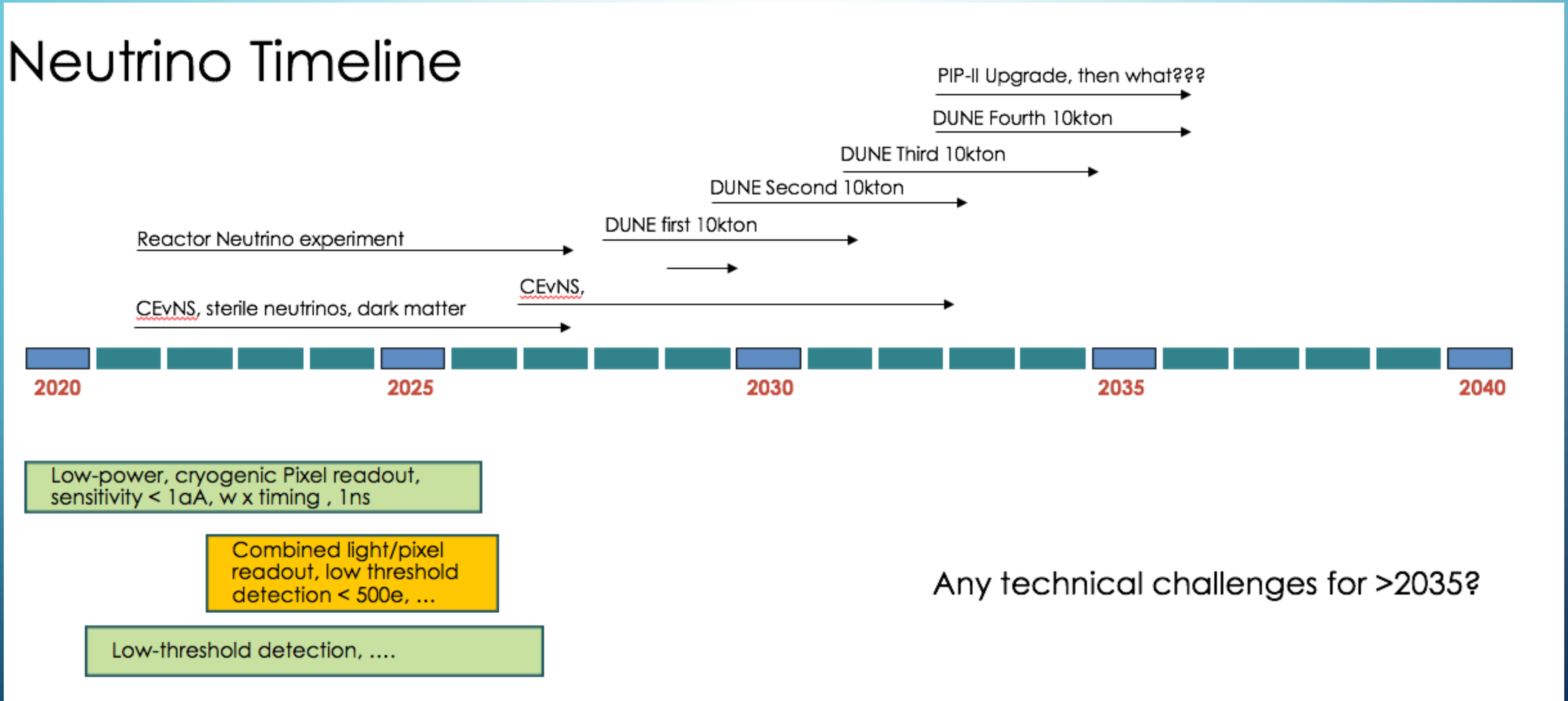
From draft interim report

- Precision timing in trigger, and precision synchronization
  - Cosmic and Intensity Frontier experiments rely on self-generating and distributing a master timing reference over large distances (km's, even 1000s of km's for multi-messenger)
  - Energy Frontier experiments will incorporate highly granular precision timing detectors to handle high pileup, requiring precise timing to 10's of ps. Use for real-time trigger faces same challenges as for pixel trigger
- 4D tracking with spatial and timing readout
  - Incorporation precision timing with spatial readout in real-time applications to improve tracking performance in high pileup conditions in EF experiments
- Rad-hard high bandwidth data links, high bandwidth wireless transmission
  - Fundamental for future EF hadron collider experiments

SOME INTERCONNECTION EXAMPLES, ENERGY FRONTIER EXPERIMENTS



TIMELINES TO CONSIDER FOR R&D



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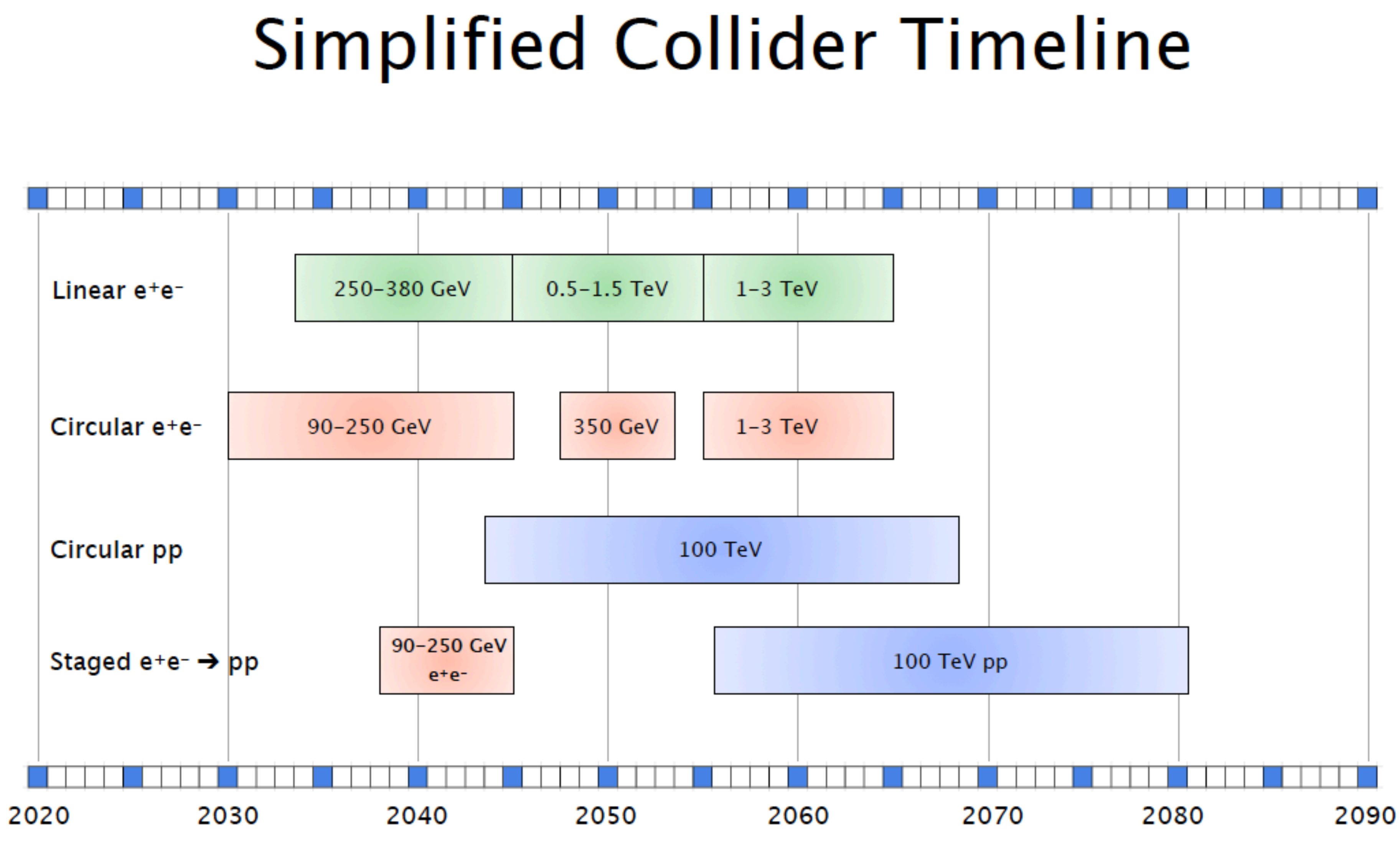
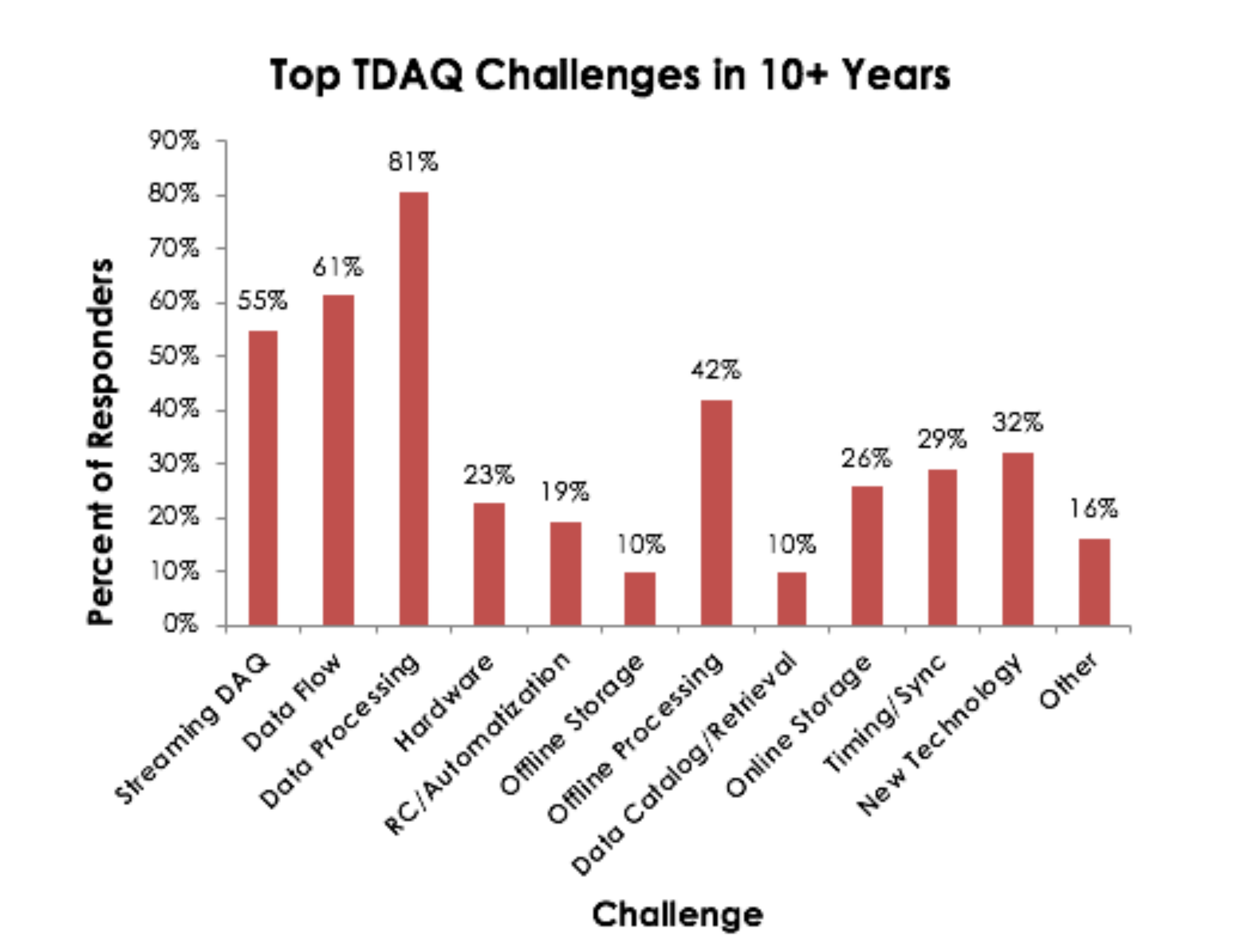


BRN TDAQ SURVEY RESULTS

- We conducted a community survey during November 2019
- 31 responses as of Nov. 26, 2019, from cross-experimental/ frontier HEP community
- Thank you to many of you who provided input!

Q1: TOP TDAQ CHALLENGES THE HEP COMMUNITY WILL BE FACING IN 10+ YEARS, THINKING ABOUT FUTURE-GENERATION HEP PROJECTS

- A list of identified challenges was provided for responders to select all that apply



"Other" responses included:

- Visualization technology to improve uptime and reduce operational support (related to Run Control)
- Energy economy in machine learning or computing systems
- Cooling
- Data links for challenging environments (related to Hardware)
- Data Quality Monitoring

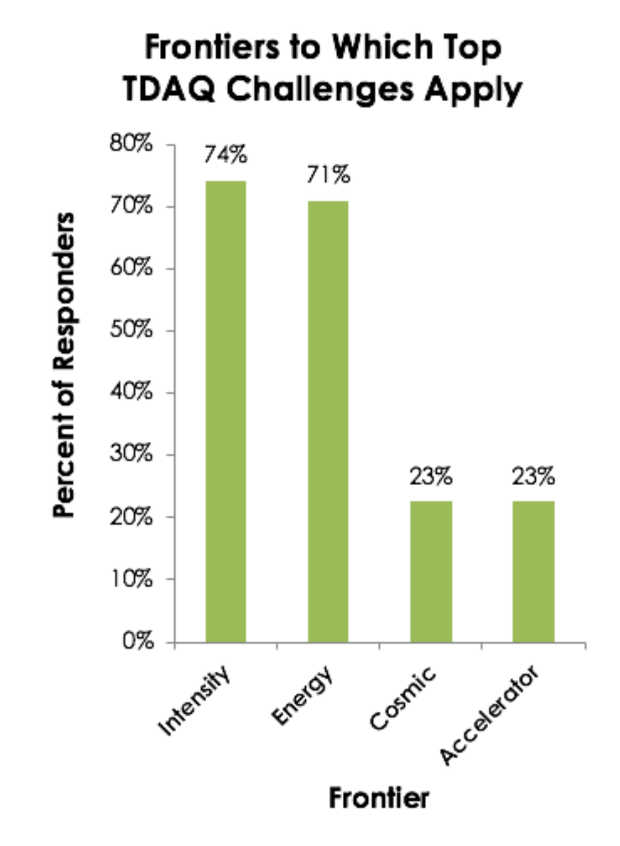
Q2: RESPONDERS WERE ASKED TO ELABORATE ON THE CHALLENGES COLLECTIVELY IDENTIFIED IN Q1

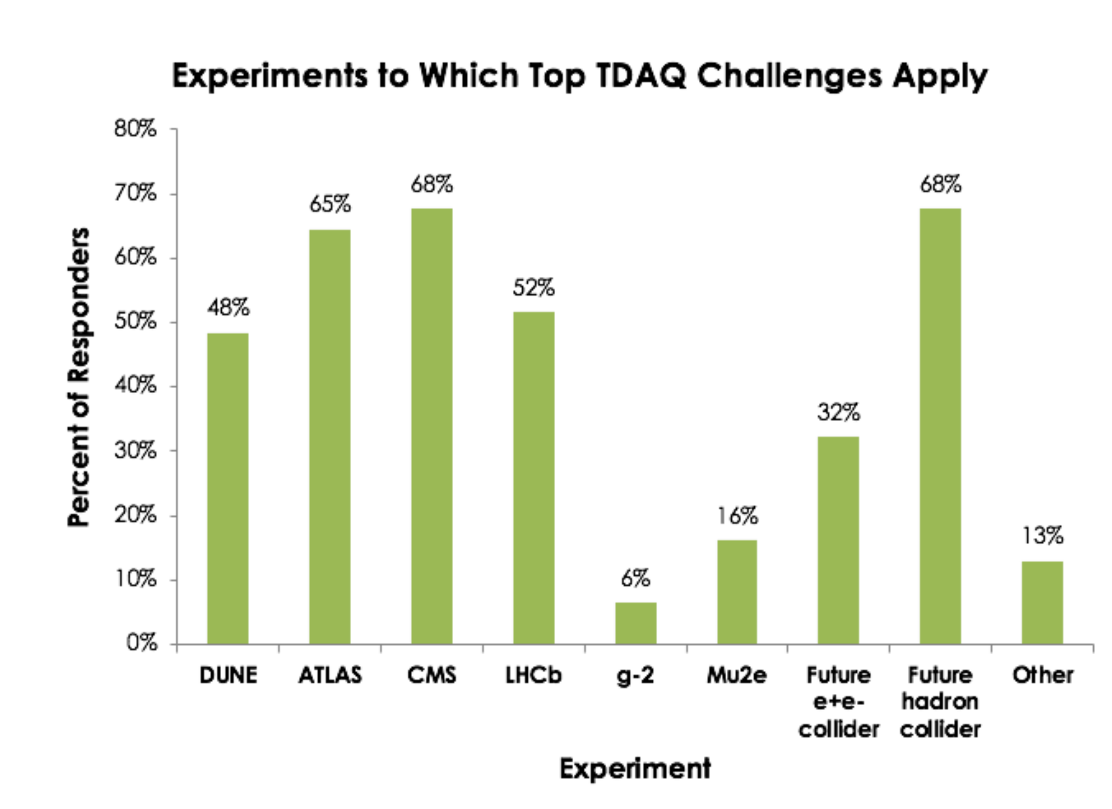
In summary, the prevalent message was that

> nearly every future experiment or upgrade will face increasingly high rates that outpace the reduction in storage/processing cost over time, and this will require the combination of streaming DAQ architectures with preprocessing which allows for efficient online analysis of the data. This in turn will rely on more effective algorithms and architectures, better use of timing information, etc. Storage was identified as merely a cost-issue.

Q3: RESPONDERS WERE ASKED TO INDICATE WHETHER ANY OF THE CHALLENGES IDENTIFIED IN Q1 APPLY TO A CURRENT/ FUTURE EXPERIMENT OR FRONTIER

- A list of identified challenges was provided for responders to select all that apply





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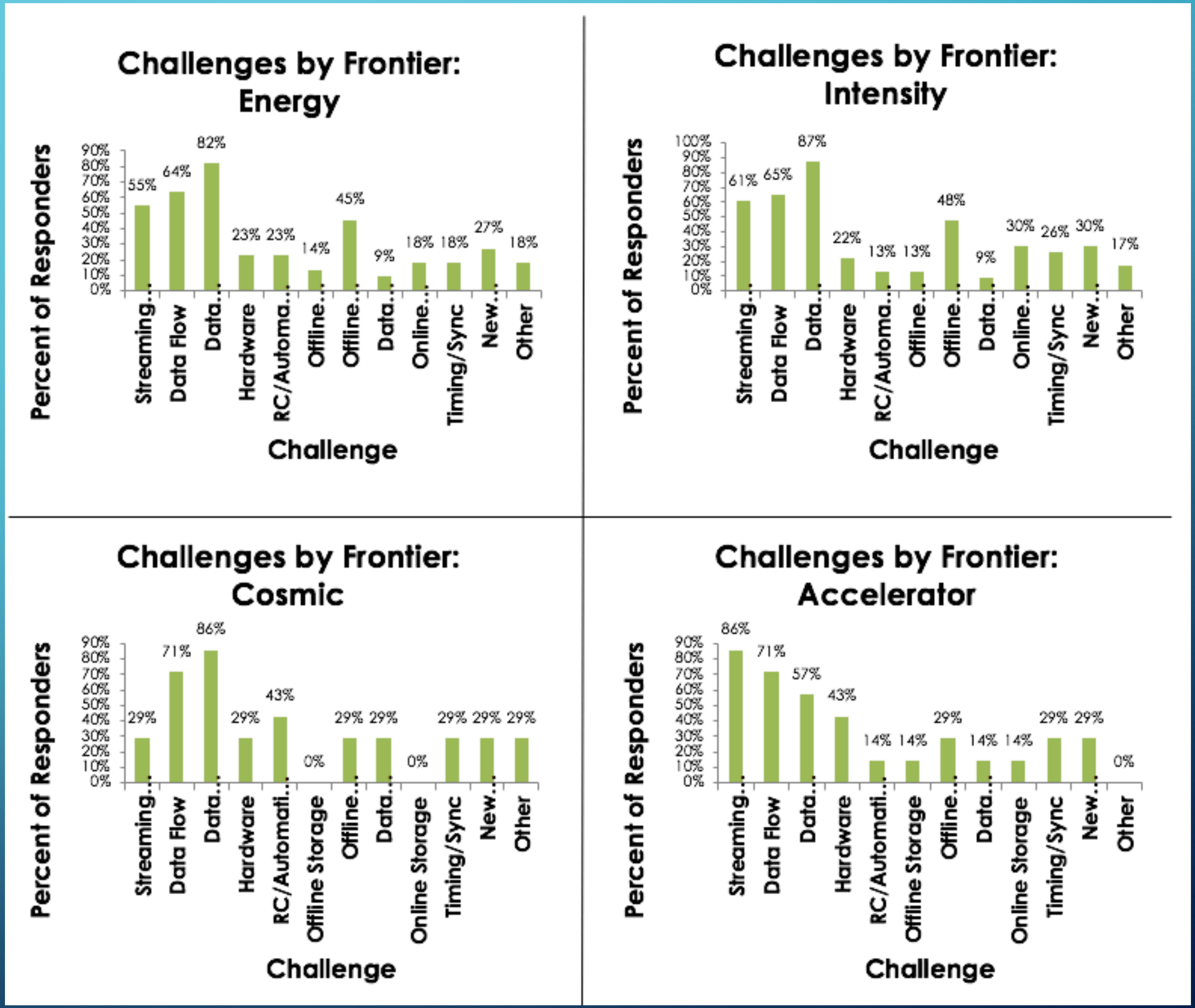
- Broken down by frontier (responders who identified frontier "A" as one where challenges apply, also selected these top challenges)



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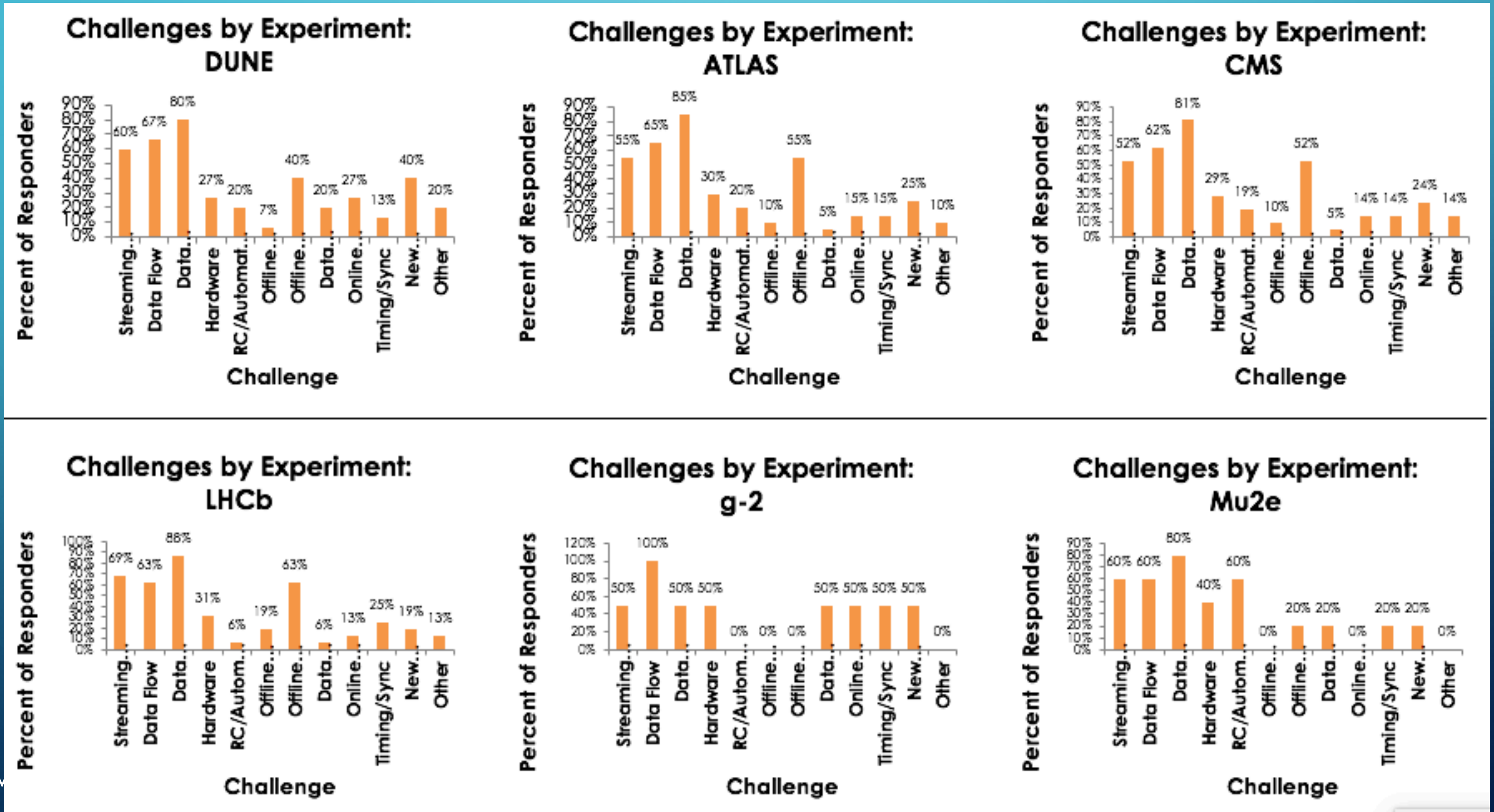

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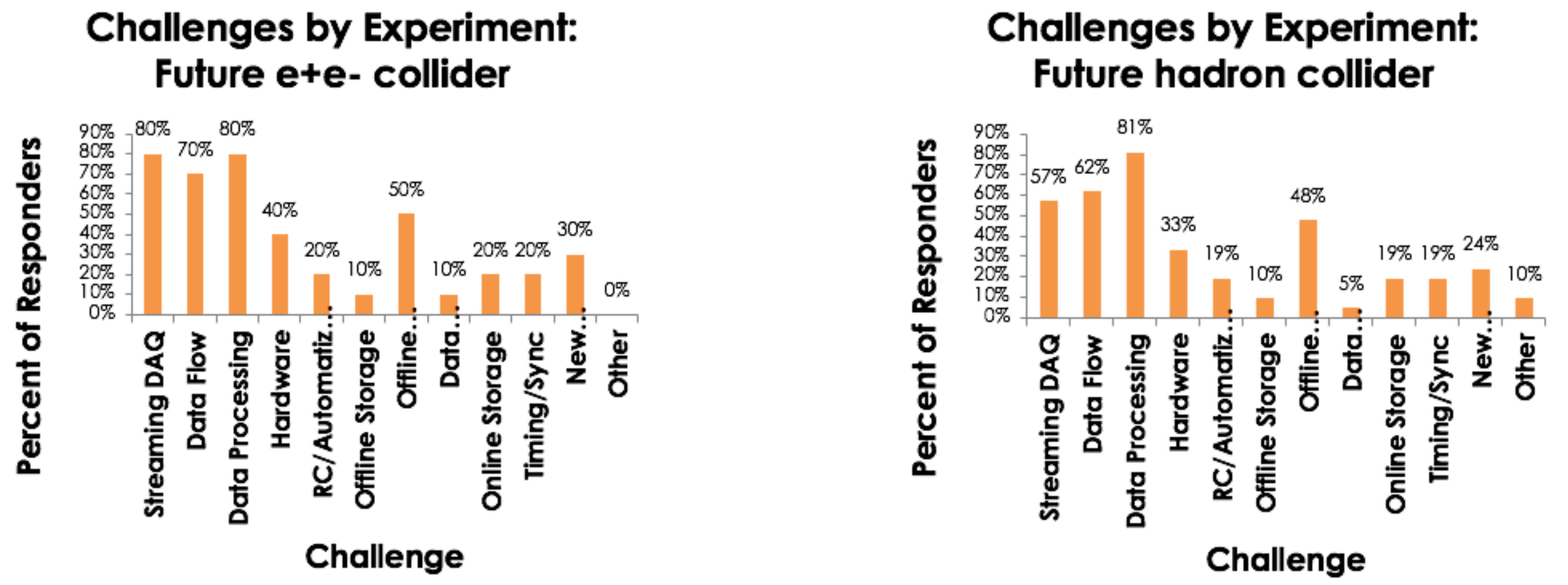

Q4: RESPONDERS WERE ASKED TO IDENTIFY WHAT THEY THOUGHT WERE THE MOST PROMISING AREAS OF R&D FOR PROVIDING SOLUTIONS TO ABOVE CHALLENGES

- Common themes identified in responses:
  - Move of (traditionally) software-based processing into front-end, hardware
  - Integrated sensor and readout/processing technology
  - Real-time ML/DL implementation with hardware acceleration
  - Parallelization through new technologies/architectures
  - High-bandwidth, low-power wireless links

- New perspectives included:
  - New approaches to information flows
  - Use of ML for data quality monitoring

Q5: RESPONDERS WERE ASKED TO IDENTIFY OTHER AREAS OF R&D THAT, ALTHOUGH NOT TARGETING A PARTICULAR CHALLENGE, COULD BE TRANSFORMATIONAL FOR HEP TDAQ

- Received numerous responses; selected list deviating from lists provided:
  - Standardizing the electronics platform, with a more up to date, longer term, user-friendly option than CAMAC, VME, MicroTCA, ATCA
  - Higher-throughput multi-purpose I/O boards that can be used across the field, and interfaces with hardware (e.g. GPUs) for sophisticated data processing
  - Image-analysis-based triggering (without the need of object reconstruction)
  - Autonomous detectors; use of ML more broadly, e.g. error detection, data taking monitoring, trigger rate monitoring
  - Timing detector technologies to perform per-hit-timing in a cost effective manner to alleviate pile-up problems
  - Wireless readout; fiber transmission of power (reducing heat load due to copper in cryogenics, provides high voltage isolation)
  - Manipulation of experimental data in a new form

TODAY'S AGENDA

Tuesday, 3 December 2019

14:30 - 14:45	Introduction to the BRN study *15'* Speakers: Darin Acosta (University of Florida), Prof. Tulika Bose (University of Wisconsin-Madison)
14:55 - 15:05	Streaming DAQ: LHCb experience *10'* Speaker: Michael Williams Material: **Slides**
15:10 - 15:25	Streaming DAQ: Energy/Intensity Frontier needs/challenges *15'* Speaker: Kai Chen Material: **Slides**
15:30 - 15:40	Streaming DAQ: cosmic frontier needs/challenges *10'* Speaker: Anze Slosar
15:50 - 16:00	Using the pixel detector for triggering *10'* Speakers: Peter Wittich, Karl Ecklund Material: **Slides**
16:10 - 16:20	Precision timing: Energy Frontier needs/challenges *10'* Speaker: Isobel Ojalvo (University Wisconsin Madison)
16:25 - 16:35	Precision timing and synchronization: Intensity Frontier needs/challenges *10'* Speakers: Jonathan Eisch, Matthew Wetstein
16:40 - 17:00	Fast machine learning for TDAQ (including brief status/needs across frontiers) *20'* Speaker: Phil Harris
17:10 - 17:20	Tools (e.g. for streaming DAQ, fast ML, automation/self running DAQ,...) *10'* Speakers: Nhan Tran (Fermilab), Mia Liu

ANY QUESTIONS OR COMMENTS ?