Instrumentation Frontier Contributions

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ENERGY FRONTIER COMMUNITY STUDY WORKSHOP

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IF1 Quantum Sensors

- Snowmass 2021: Quantum Sensors for HEP Science - Interferometers, Mechanics, Traps, and Clocks: https://arxiv.org/abs/2203.07250
- Quantum Sensors for high precision measurements of spin-dependent interactions: https://arxiv.org/abs/2203.09488

IF2 Photon Detectors

- Photon counting from the vacuum ultraviolet to the short wavelength infrared using semiconductor and superconducting technologies: last touches
- (Reading list for Photon Detector Developments in Snowmass white papers): document that will point to the submitted WPs with sections relevant to photon detectors, so that we have a full reading list to prepare our report

IF3 Silicon Tracking & Vertexing

- Simulations of Silicon Radiation Detectors for High Energy Physics Experiments: https://arxiv.org/abs/2203.06216
- Novel Sensors for Particle Tracking: a Contribution to the Snowmass Community Planning Exercise of 2021: https://arxiv.org/abs/2202.11828
- 4-Dimensional Trackers: https://arxiv.org/abs/2202.13900
- Integration and Packaging: https://arxiv.org/abs/2203.06093
- Mechanics, lightweight materials, cooling: authors expect to submit soon
- Monolithic Active Pixel Sensors on CMOS technologies: https://arxiv.org/abs/2203.07626

IF4 TDAQ

- Innovations in trigger and data acquisition systems for next-generation physics facilities: draft submitted, pending
- Readout Technologies for Future Detectors: being finalized very soon.
- Applications and Techniques for Fast Machine Learning in Science: https://arxiv.org/abs/2110.13041

IF5 MPGDs

- MPGDs: Recent advances and current R&D: https://arxiv.org/abs/2203.06562
- Micro Pattern Gaseous Detectors for Nuclear Physics: https://arxiv.org/abs/2203.06309
- Recoil imaging for dark matter, neutrinos, and physics beyond the Standard Model: https://arxiv.org/abs/2203.05914
- MPGDs for TPCs at future lepton colliders: https://arxiv.org/abs/2203.06267
- MPGDs for tracking and Muon detection at future high energy physics colliders: https://arxiv.org/abs/2203.06525

IF6 Calorimetry

- Precision timing for collider-experiment-based calorimetry: https://arxiv.org/abs/2203.07286
- Materials for Future Calorimeters: https://arxiv.org/abs/2203.07154
- Particle Flow Calorimetry for Future Colliders: will submit soon
- Dual Readout Calorimetry for Future Colliders: https://arxiv.org/abs/2203.04312
- New Calorimeter Techniques and Materials for Dark Matter Detection: submitted; waiting for arXiv link

IF7 Electronics & ASICs

- Enabling Capabilities for Infrastructure and Workforce in Electronics and ASICs: expect submission before 3/31
- Readout for Calorimetry: expect submission before 3/31
- Silicon and Photodectors: Awaiting input
- Electronics for Fast Timing: expect submission before 3/31
- Fast (optical) Links: expect submission before 3/31
- Smart sensors using artificial intelligence for on-detector electronics and ASICs: expect submission before 3/31
- Cryogenics Readout: expect submission before 3/31
- RF Electronics: expect submission before 3/31

IF8 Noble Element Detectors

IF08 organized Executive Summary pages instead of white papers. They will be located at: https://snowmass21.org/instrumentation/noble_elements

- Pixel readout for noble element time projection chambers
- Charge gain for noble element time projection chambers
- Light Collection for noble element time projection chambers
- Low-threshold TPCs
- Enabling directionality and micron precision in noble element time projection chambers
- Metastable Fluids detectors
- Enhancing physics reach at existing noble element infrastructure
- Barium Tagging in Xenon TPCs
- Scaling challenges for noble element detectors
- Noble element detector characterization and calibration

IF9 Cross-Cutting & Systems Integration

- Cryogenic User Facilities for R&D on Noble Liquid Detectors and Low Temperature Devices: https://arxiv.org/abs/2203.06146
- A Facility for Low-Radioactivity Underground Argon: not yet
- Test Beam and Irradiation Facilities: submitted on 3/15; http://arxiv.org/abs/2203.09944

IF10 Radio Detection

- Instrumentation Development for Radio Detection of High-Energy Neutrinos: not yet
- Large-Format, Transmission-Line-Coupled Kinetic Inductance Detector Arrays for HEP at Millimeter Wavelengths: not yet

- More papers of general interest has been submitted to the Snowmass 2021 Proceedings - Instrumentation Frontier: https://snowmass21.org/submissions/if
- Several IF Topical Groups need to coordinate sections in their summary reports with Topical Groups in other Frontiers (incl. Energy Frontier)
- Plan to organize either TG-level working meetings or IF-wide workshop with other Frontiers' TGs between now and Seattle

DOE Basic Research Needs Study on HEP Detector Research & Development

Guidance and structure of BRN is excellent resource to start and structure future plans →
The BRN has both a physics section to motivate goals and a very detailed technology section outlining where we are and what is needed: https://science.osti.gov/hep/Community-Resources/Reports

The transformative physics goals include 4 inspiring & distinct directions:

- Higgs properties @ sub-%
- Higgs self-coupling @ 5%
- Higgs connection to DM
- New multi-TeV particles

Science	Measurement	Technical Requirement (TR)	PRD
Higgs properties with sub-percent precision Higgs self-coupling with 5% precision	TR 1.1: Tracking for e^+e^-	TR 1.1.1: p_T resolution: $\sigma_{p_T}/p_T = 0.2\%$ for central tracks with $p_T < 100$ GeV, $\sigma_{p_T}/p_T^2 = 2 \times 10^{-5}$/GeV for central tracks with $p_T > 100$ GeV TR 1.1.2: Impact parameter resolution: $\sigma_{r\phi} = 5 \bigoplus 15\ (p\ [\text{GeV}]\ \sin^{\frac{3}{2}}\theta)^{-1}\ \mu$m TR 1.1.3: Granularity : $25 \times 50\ \mu\text{m}^2$ pixels TR 1.1.4: 5 μm single hit resolution TR 1.1.5: Per track timing resolution of 10 ps	18, 19, 20, 23
Higgs connection to dark matter	TR 1.2: Tracking for 100 TeV pp	Generally same as e^+e- (TR 1.1) except TR 1.2.1: Radiation tolerant to 300 MGy and 8×10^{17} n_{eq}/cm^2 TR 1.2.2: $\sigma_{p_T}/p_T = 0.5\%$ for tracks with $p_T < 100$ GeV TR 1.2.3: Per track timing resolution of 5 ps rejection and particle identification	16, 17, 18, 19, 20, 23, 26
New particles and phenomena at multi-TeV scale	TR 1.3: Calorimetry for e^+e^-	TR 1.3.1: Jet resolution: 4% particle flow jet energy resolution TR 1.3.2: High granularity: EM cells of 0.5×0.5 cm^2, hadronic cells of 1×1 cm^2 TR 1.3.3: EM resolution : $\sigma_E/E = 10\%/\sqrt{E} \bigoplus 1\%$ TR 1.3.4: Per shower timing resolution of 10 ps	1, 3, 7, 10, 11, 23
	TR 1.4: Calorimetry for 100 TeV pp	Generally same as e^+e- (TR 1.3) except TR 1.4.1: Radiation tolerant to 4 (5000) MGy and 3×10^{16} (5×10^{18}) n_{eq}/cm^2 in endcap (forward) electromagnetic calorimeter TR 1.4.2: Per shower timing resolution of 5 ps	1, 2, 3, 7, 9, 10, 11, 16, 17, 23, 26
	TR 1.5: Trigger and readout	TR 1.5.1: Logic and transmitters with radiation tolerance to 300 MGy and 8×10^{17} n_{eq}/cm^2 TR 1.5.2: Total throughput of 1 exabyte per second at 100 TeV pp collider	16, 17, 21, 26

Priority Research Directions for Tracking Detectors:

- ✓ Create building blocks for Systems-on-Chip for extreme environments
- ✓ Adapt new materials and fabrication/integration techniques for particle tracking
- ✓ Realize scalable, irreducible mass trackers
- ✓ Achieve on-detector, real-time, continuous data processing and transmission to reach the exascale

Primary Research needs related to Timing Detectors:

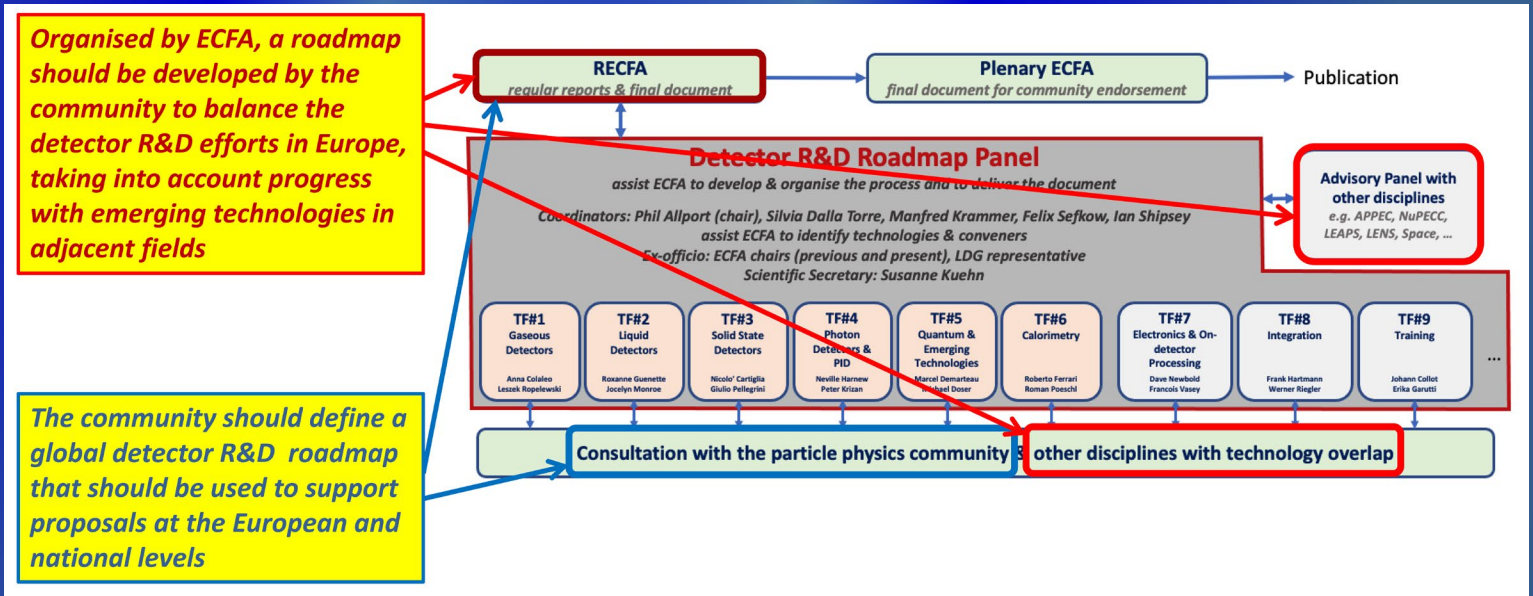
- ✓ Advance calorimetry with spatial and timing resolution and radiation hardness to master high-rate environments
- ✓ Design new devices and architectures to enable picosecond timing and event separation (for photo-detectors).
- ✓ Develop high spatial resolution pixel detectors with precise high per-pixel
- ✓ Time resolution to resolve individual interactions in high-collision-density environments (for solid state detectors).

ECFA Detector R&D Roadmap

ECFA
European Committee for Future Accelerators

- ✓ Focus on the technical aspects of detector R&D requirements given the 2020 EPPSU deliberation document listed "*High-priority future initiatives*" and "*Other essential scientific activities for particle physics*" as input and organise material by Task Force.
- ✓ Task Forces start from the future science programmes to identify main detector technology challenges to be met (both mandatory and highly desirable to optimise physics returns) to estimate the period over which the required detector R&D programmes may be expected to extend.
- ✓ Within each Task Force create a time-ordered technology requirements driven R&D roadmap in terms of capabilities not currently achievable.

The roadmap identify and describe diversified detector R&D portfolio that has the largest potential to enhance the performance of the particle physics programme in the near and long term."



❖ **Final report released in Dec. 2021: https://cds.cern.ch/record/2784893**

❖ European Strategy for Particle Physics Implementation of the Detector Research and Development Roadmap has been presented to SPC/CERN Council last week

The New AIDAinnova Project and Detector R&D for Higgs Factories

https://indico.cern.ch/event/932973/contributions/4066737/attachments/2140131/3606033/Ainnova-HiggsF-FSefkow20201110.pdf

History: EC-funded Detector R&D Projects

PF6: EUDET: 2006-2010
- Detector development for linear collider

FP7: AIDA: 2011-2014
- Detector development for LHC upgrades and linear colliders
- Project-specific work packages

FP8: AIDA-2020: 2015-2020
- Common LC and LHC work packages
- New communities: large cryogenic neutrino experiments, new topics
- New innovation measures, with industry

Increasing level of integration

EUDET

AIDA

AIDA2020

F. Sefkow

New AIDAinnova Call / Objectives:

- ✓ Support research **infrastructure** networks developing and implementing a **common strategy/ roadmap** including technological development required for improving their services through **partnership with industry**
- ✓ Support **incremental innovation** and cooperation with industry

- Complementarity to ATTRACT
- Increased focus on industrial partners
- No Transnational Access Proposed
- Funding 10 M€ for 4 years

Some targeted applications:

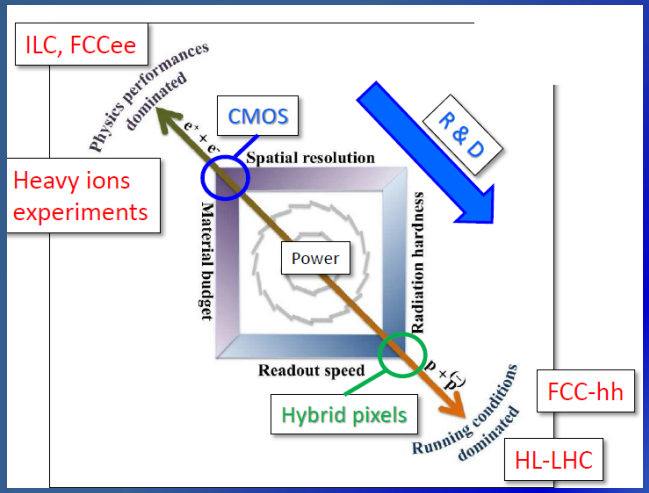
- ✓ **Higgs Factories**
- ✓ **ATLAS, CMS LS4, ALICE, LHCb LS3 pre-TDR**
- ✓ **Accelerator-based neutrino experiments**

Higgs Factory Detector R&D

AIDA innova

Detector Technology	Linear & Circular Colliders common R&D	Differences
All	test infrastructure prototype electronics software for reconstruction and optimisation	readout rates power and cooling requirements
Silicon Vertex and Track Detectors	highest granularity and resolution, timing ultra-thin sensors and interconnects simulation and design tools low-mass support structures cooling micro-structures	emphasis on timing (background) and position resolution
Gaseous Trackers and Muon Chambers	ultra-light structures for large volumes industrialisation for large area instrumentation eco-friendly gases	DC and TPC presently considered only at some colliders
Calorimeters and Particle ID	highly compact structures and interfaces advanced photo-sensors and optical materials ps timing sensors and electronics	emphasis on granularity and stability DR and LAr pesresently only considered for circular

Enabling Technologies for Low-Mass Tracking Detectors



- ✓ Basic applications are optimized for two different realms of interest : electron and hadron colliders → different optimizations/requirements (pp: radiation hardness, speed; e+e-: granularity, material budget)
- ✓ Design problems include: granularity vs the power (particularly for precision timing) and the inactive material to service power and data readout etc. for both accelerator types. Radiation hardness and a strong emphasis on data reduction / feature extraction for the on-detector electronics are particular issues for hadron colliders.

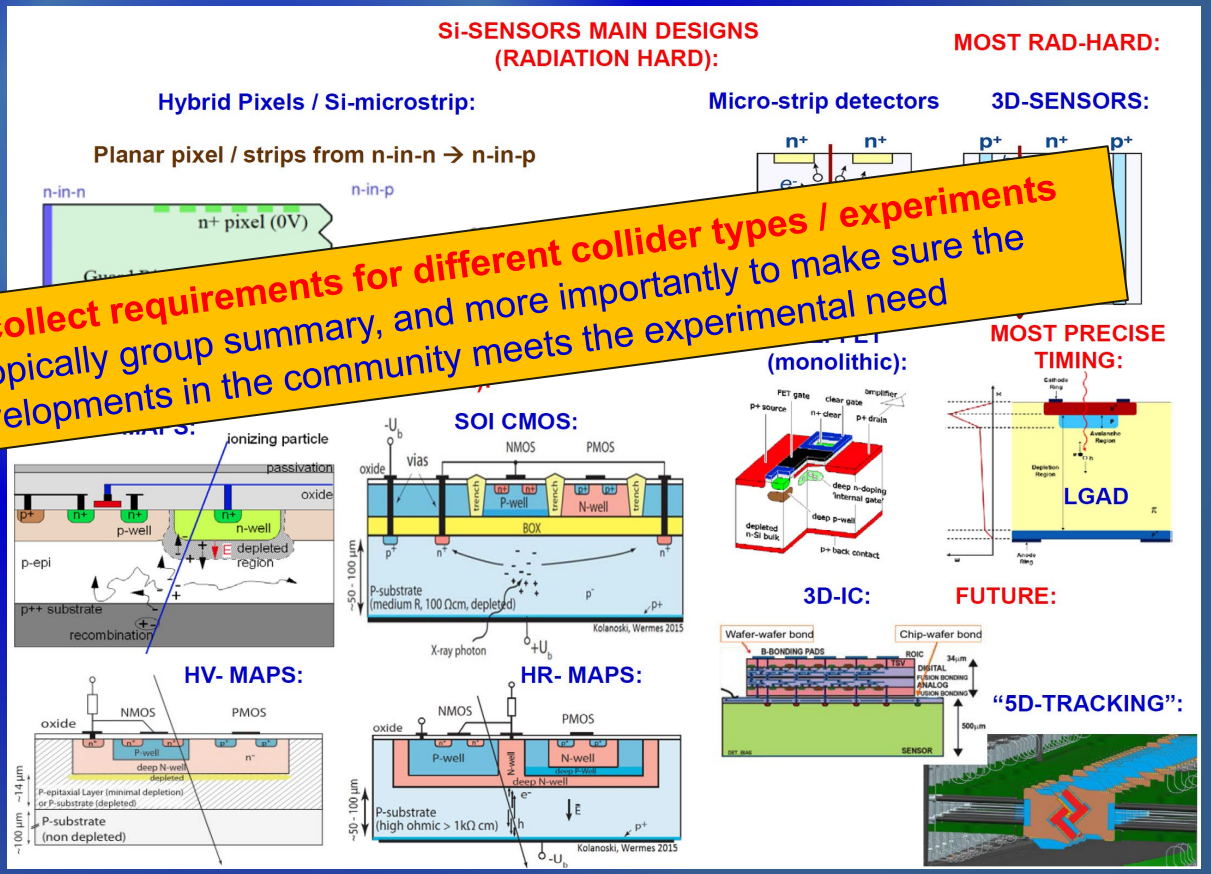
Hadron Colliders:

- ✓ Hybrid pixel detectors (planar & 3D)
- ✓ HV/HR-CMOS for outer pixel layers for HL-LHC upgrades;
- ✓ LGADs for ps-timing

Lepton Colliders:

- ✓ CMOS (STAR HFT, ALICE ITS)
- ✓ DEPFET (Belle II)
- ✓ Chronopix
- ✓ SoI
- ✓ FPCCD
- ✓ 3D-IC (Global Foundries, LAPIX, TJas,…industries)

Needs: collect requirements for different collider types / experiments
→ IF topically group summary, and more importantly to make sure the developments in the community meets the experimental need



Enabling Technologies for Picosecond-Timing Detectors

Picosecond-level timing was not the part of initial HL-LHC detector requirements:

Became available through pioneering R&D on LGAD / crystals / precise timing with Si:

Fast development of precise timing sensors:

- ✓ 4D pattern recognition for HL-LHC pile-up rejection: tracking ~O(10's) μm & timing detectors ~O(10's) ps

4-Dimensional Trackers

Doug Berry[1], Valentina Cairo[2], Angelo Dragone[3], Matteo Centis-Vignali[4], Gabriele Giacomini[5], Ryan Heller[1], Sergo Jindariani[1], Adriano Lai[6], Lucie Linssen[2], Ron Lipton[1], Chris Madrid[1], Bojan Markovic[3], Simone Mazza[7], Jennifer Ott[7], Ariel Schwartzman[3], Hannsjörg Weber[8], and Zhenyu Ye[9]

arXiv: 2203.13900

- ✓ ps-timing reconstruction in calorimetry (resolve develop. of hadron showers, triangulate H → γγ prim. vertices)
- ✓ TOF and TOP (RICH DIRC) PID → new DIRC applications (~ 10's of ps & 10's of μm per MIP/pixel) → both at hadron / lepton colliders
- ✓ General push for higher luminosity at LHC, Belle-II, Panda, Electron-Ion Collid. → Fast timing is needed at colliders, fixed target, and neutrino experiments

- ➢ Regular PMTs → large area, … but slow
- ➢ MCP-PMT → fast, but small, and not available in quantities to over large areas:
  - → ultimate time resolution ~ 3.8 ps (single-pixel devices)
  - → radiation hardness up to ~ 20 C/cm (HPK, ALD-coated MCP-PMT°

Detector	Experiment or beam test	Maximum rate	Maximum anode charge dose	Timing resolution	Ref.
MRPC presently	ALICE	~500 Hz/cm^2 *** (tracks)	-	~60 ps/track (present) ***	[4]
MRPC after upgrade	ALICE	Plan: ~50 kHz/cm^2 ** (tracks)	-	Plan: ~20 ps/track	[4]
MCP-PMT	Beam test	-	-	< 10 ps/track *	[7,8,9]
MCP-PMT	Laser test	-	-	~27 ps/photon *	[14]
MCP-PMT	PANDA Barrel test	10 MHz/cm^2 * (laser)	~20 C/cm^2 *	-	[11]
MCP-PMT	Panda Endcap	~1 MHz/cm^2 ** (photons)	-	-	[28]
MCP-PMT	TORCH test	-	3-4 C/cm^2*	~90 ps/photon *	[27]
MCP-PMT	TORCH	10-40 MHz/cm^2 ** (photons)	5 C/cm^2 **	~70 ps/photon **	[24-27]
MCP-PMT	Belle-II	< 4MHz/MCP *** (photons)	-	80-120 ps/photon ***	[23]
Low gain AD	ATLAS test	~40 MHz/cm^2 ** (tracks)	-	~ 34 ps/track/single sensor *	[34,35]
Medium gain AD	Beam test	-		< 18 ps/track *	[39]
Si PIN diode (no gain)	Beam test (electrons)	-		~23 ps/32 GeV e$^-$	[8]
SiPMT (high gain)	Beam test – quartz rad.	-	< 10^{10} neutrons/cm^2	~ 13 ps/track *	[8]
SiPMT (high gain)	Beam test - scint. tiles	-	< 10^{10} neutrons/cm^2	< 75 ps/track *	[41]
Diamond (no gain)	TOTEM	~3 MHz/cm^2 * (tracks)	-	~ 90 ps/track/single sensor *	[36]
Micromegas	Beam test	~100 Hz/cm^2 * (tracks)	-	~24 ps/track *	[31,32,40]
Micromegas	Laser test	~50 kHz/cm^2 * (laser test)	-	~76 ps/photon *	[31,32,40]

* Measured in a test
** Expect in the final experiment
*** Status of the present experiment

Challenges:

- ✓ Radiation hardness: LGAD-sensors, 3D-trench Si sensors, …
- ✓ Large scale applications : system aspects of timing detectors

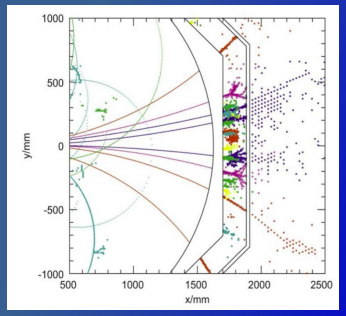
- ✓ "5D reconstruction": space-points / ps-timing are available at each point along the track → LHCb EoI for LS4 is of general interest across experiments;

- ✓ LAPPD → large-area ps- PID/TOF for hadron/lepton colliders Incom Inc. company started to produce LAPPDs → cost still has to be controlled

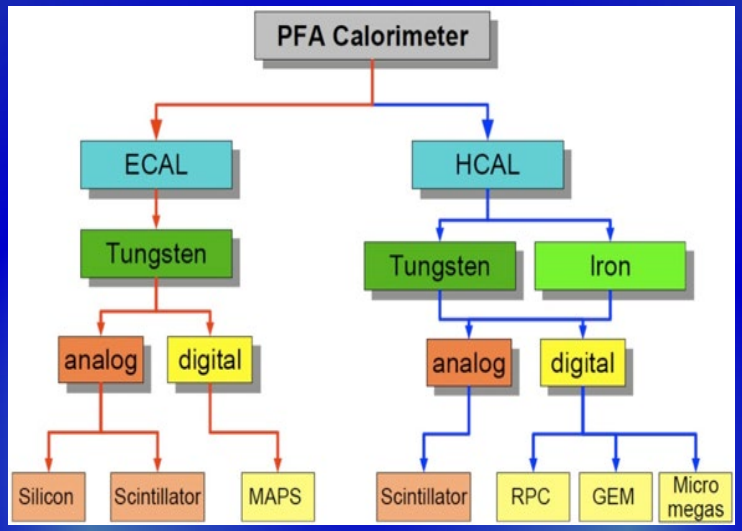
Particle Flow Calorimeters: CALICE Collaboration

Development and study of finely segmented / imaging calorimeters: initially focused on the ILC, now widening to include developments of all imaging calorimeters, e.g. CMS HGCAL for Phase II):

Imaging Calorimetry → high granularity (in 4D), efficient software (PFA).



Issues: overlap between showers, complicated topology, sep. "physics event" from beam-induced bkg.



Mixture of matured concepts and advanced ideas:

MATURED (CALICE):

- **SiW-ECAL**
- **SciW-ECAL**
- **AHCAL**
- **DHCAL (sDHCAL)**

→ (Almost) ready for large-scale prototype

→ Prepare for quick realization of 4-5 years to real detector

Example: **ILD detector for ILC**, proposing **CALICE** collaboration tech.

	ECAL option	ECAL option	HCAL option	HCAL option
Active layer	silicon	scint+SiPM	scint+SiPM	glass RPC
Absorber	tungsten	tungsten	steel	steel
Cell size (cm×cm)	0.5×0.5	0.5×4.5	3×3	1×1
# layers	30	30	48	48
Readout	analog	analog	analog	Semi-dig (2 bits)
Depth # (X_0/Λ_{int})	24 X_0	24 X_0	5.5 Λ_{int}	5.5 Λ_{int}
# channels [10^6]	100	10	8	70
Total surface	2500	2500	7000	7000

ADVANCED (beyond CALICE):

- **MAPS ECAL**
- **Dual-readout ECAL**
- **LGAD ECAL (CALICE)**

→ Evaluate additional physics impact to ILC experiment

→ Needs intensive R&D effort to realize as real detector

Imaging Calorimeters: The 5th Dimension ?

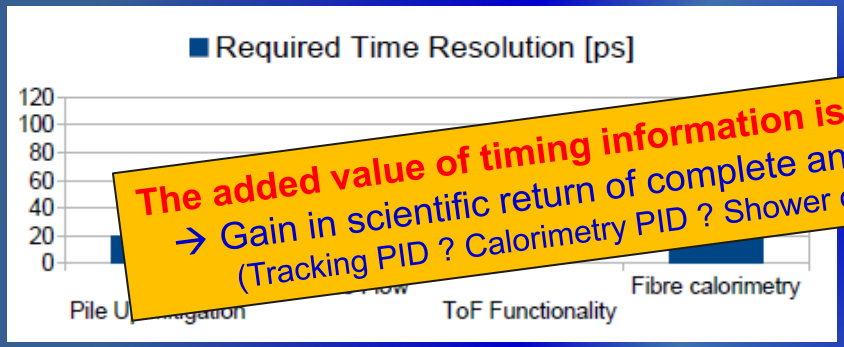
Impact of 5D calorimetry (x,y,z, energy, time) needs to be evaluated more deeply to undertand optimal time acc.

What are the real goals (physics wise)?

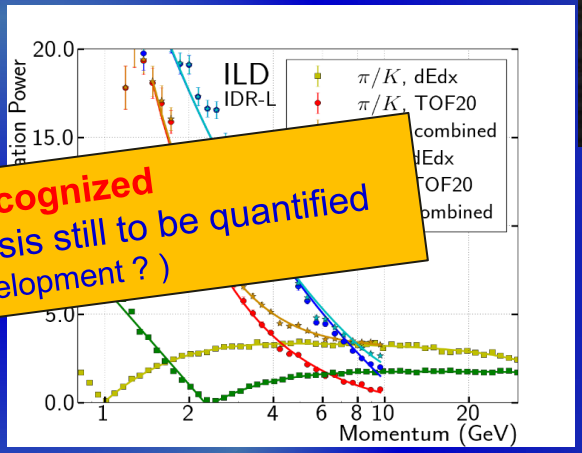
- Mitigation of pile-up (basically all high rates)
- Support for full 5D PFA → unchartered territory
- Calorimeters with ToF functionality in first layers?
- Longitudinally unsegmented fibre calorimeters

Replace (part of) ECAL with LGAD for O(10 ps) timing measurement

20 ps TOF per hit can separate π/k/p up to 5-10 GeV



The added value of timing information is recognized
→ Gain in scientific return of complete analysis still to be quantified
(Tracking PID ? Calorimetry PID ? Shower development ?)



Timing resolution
Is affected by noise

Sensor	Amp. th.	Time reso.
S8664-50K (inverse)	20 mV	123 psec
	40 mV	63 psec
S2385 (normal)	20 mV	178 psec
	40 mV	89 psec

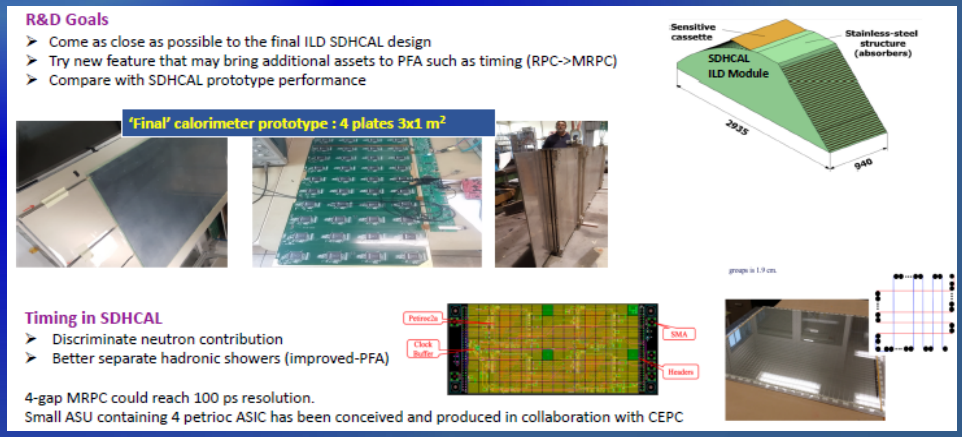
✓ **Trade-off between power consumption and timing capabilities (maybe higher noise level)**

✓ **Timing in calorimeters / energetic showers?**

→ **intelligent reconstruction using O(100) hits & NN can improve "poor" single cell timing**

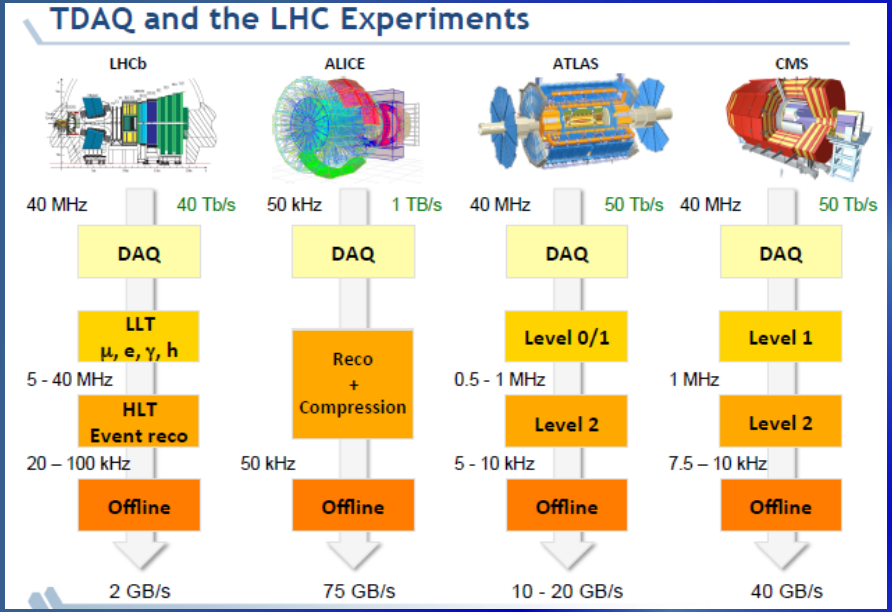
→ **can help to distinguish particle types: usable for flavour tagging (b/c/s), long-lived searches (decaying to neutrals) , enhance σ(E) / E**

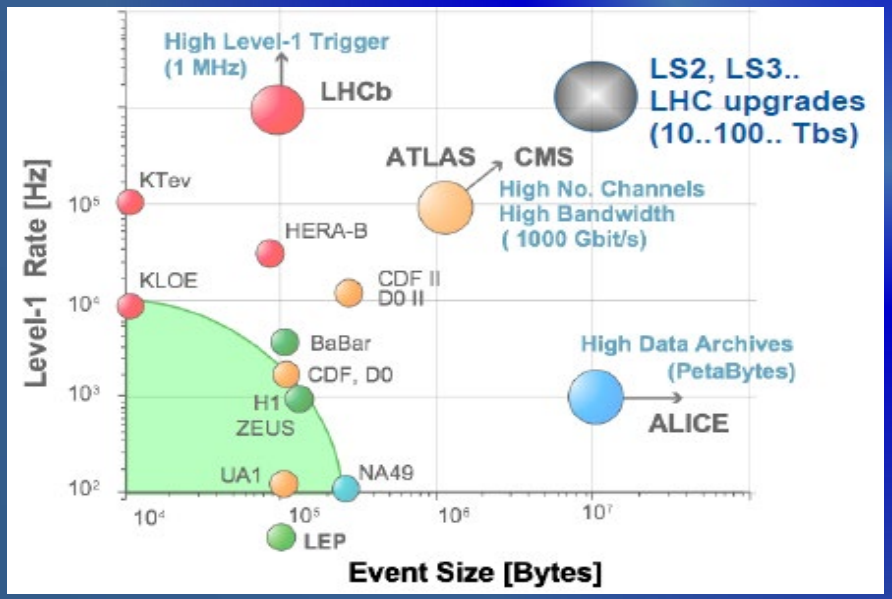
sDHCAL R&D: improved timing with replacement of RPC with MRPC → O(20-100) ps



Advanced Concepts in TRIGGER and DAQ (TDAQ)

Massive amounts of data coming of upgraded and next generation experiments





- Optical data transmission is key in readout modern HEP detectors:
  - ✓ Current links at 10 Gb/s, and limited to 5 x 10^{15} n_{eq}/cm^2, 100 Mrad in radiation tolerance; → current state-of-the art – VCSEL;
  - ✓ Silicon photonics for optical conversion and multiple amplitude modulation can provide high bandwidth;
- Wireless transmission (60 GHz), could allow on-detector data reduction (e. g. for trigger readout of trackers) → promising upcoming alternative

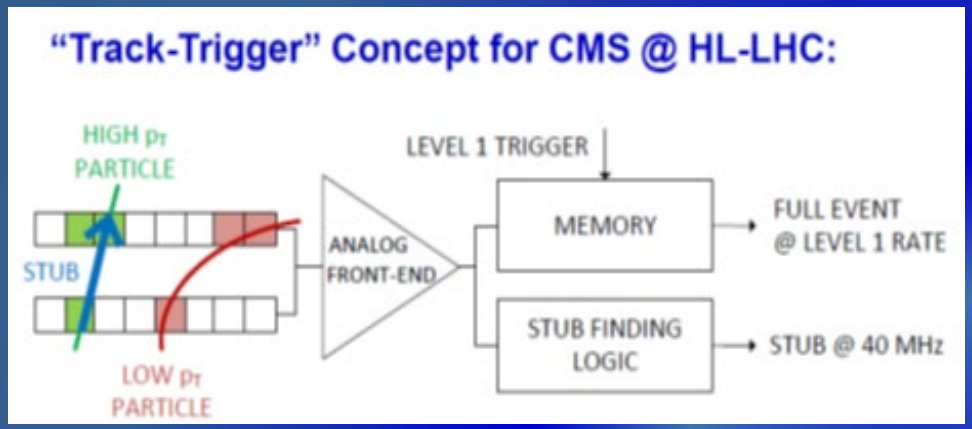
Trigger Architecture:
→ multi-layered (event building, event processing); triggerless, multi-level trigger;

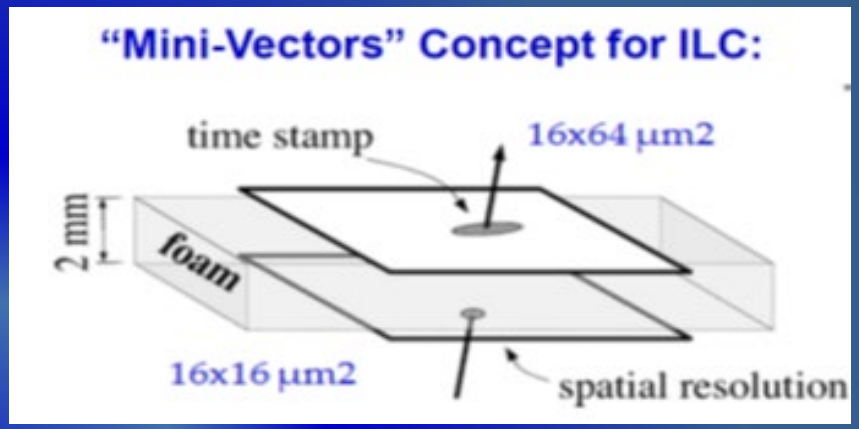
Trigger Tools:
→ ASICs, ATCA, FPGA, CPU, GPU

- General trend: progressive replacement of the complex multi-stage trigger system with a single level trigger system and a large farm of Linux computers for the final online selection:

➢ ATLAS TDAQ → single-level hardware trigger (max. rate 1 MHz and 1 um latency);
➢ ALICE and LHCb will be triggerless (no hardware trigger) after LHC Phase I upgrade

"Intelligent Trackers": Frontier Application for HEP ?





- ✓ Cannot send all hits to trigger at 40 MHz → local "intelligence" is based on recognition of high-p_T tracks using hit correlation in 2 closely-spaced layers:

  - Store billion(s) of patterns in dedicated associated memory for L1 Track-Trigger;
  - Region of Interest Builders;
  - Advanced FPGS for data processing/transmission;

- ✓ 65 nm CMOS ASIC allows to satisfy power requirem. Despite of large amount of necessary logic @ 40 Mhz

- ✓ Particle Flow" approach now possible at L1 trigger – use information from all detectors:
  - trigger on secondary vertices using NN
  - "anomaly detection" by machine learning

- ✓ Issues: L1 latency, background

- ✓ ILC will run without trigger

- ✓ Develop concept of 2-sided ladders using 50 µm thin CPS → "mini-vectors" providing high spatial resolution & time stamping

- ✓ Realization of double-sided ultra-light ladders (PLUME) equipped with two complementary types of CPS

- ✓ Introduce NN in CPS to mitigate data flow from beam-related background

- ✓ Issues: high precision alignment & power cycling in high magnetic field (ILC)

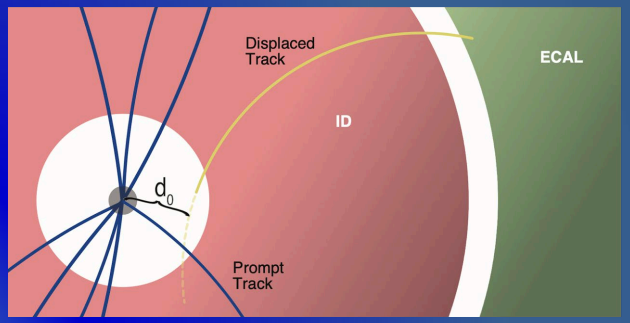
Physics Requirements for Collider Physics: EF / IF Interplay

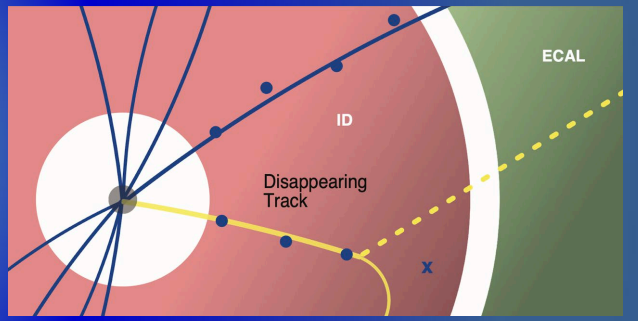
- LLP searches could be an important benchmark for timing / trigger

CPM Oct, 2020

- Importance of pixel / tracking double-layers for background rejection. How important to instrument far from the IP?
  Pixel size; physics vs detector technology challenges; some studies on double-layers with one precision layer and one larger-size high-speed layer (e.g. in context of ILC)

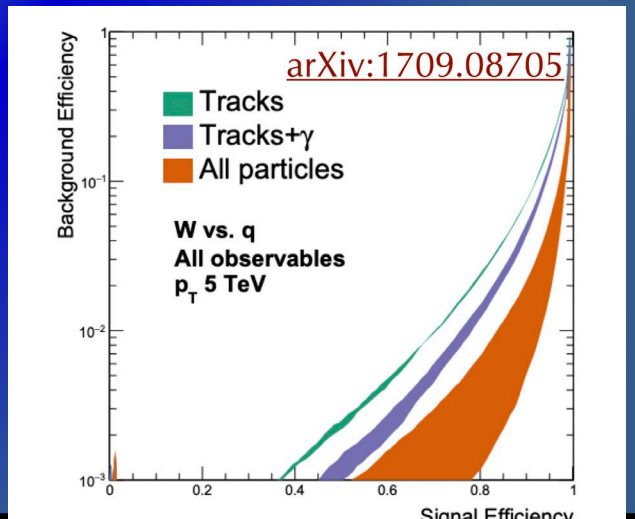
- Even for "triggerless there may still be significant data processing and potentially reduction pipelines that serve to ship the data off detector in some form between collisions. Any data/reduction compression may compromise the LLP sensitivity;





- Boosted/Substructure object reconstruction ("jet substructure") is an important driver at future multi-TeV machines

- Strong interest in MIP timing from jet reconstruction/substructure → Worth exploring (K/p/n)-pi separation with time of flight. O(10-20 ps) requirement for a MIP timing layer just in front of the EM calorimeter leads to improved acceptance for new heavy particles (e.g. mediator decaying to dark pions)
- Potential study: tagging boosted objects with timing detectors;
- Worth exploring jet resolution and substructure performance in dual readout calorimeter design;



M. Begel, EF5 Symmary, 28/03/2022

Snowmass: arXiv: 2203.07462

Jets and Jet Substructure at Future Colliders

Johan Bonilla,[1] Grigorios Chachamis,[2] Barry M. Dillon,[3] Sergei V. Chekanov[4] Robin Erbacher,[1] Loukas Gouskos,[5] Andreas Hinzmann,[6] Stefan Höche,[7] B. Todd Huffman,[8] Ashutosh. V. Kotwal[9] Deepak Kar,[10] Roman Kogler,[11] Clemens Lange,[12] Matt LeBlanc,[5] Roy Lemmon,[13] Christine McLean,[14] Benjamin Nachman,[15,*] Mark S. Neubauer,[16] Tilman Plehn,[3] Salvatore Rappoccio,[14,*] Debarati Roy,[17] Jennifer Roloff,[18] Giordon Stark,[19] Nhan Tran,[7,*] Marcel Vos[20] Chih-Hsiang Yeh[21] Shin-Shan Yu[21]

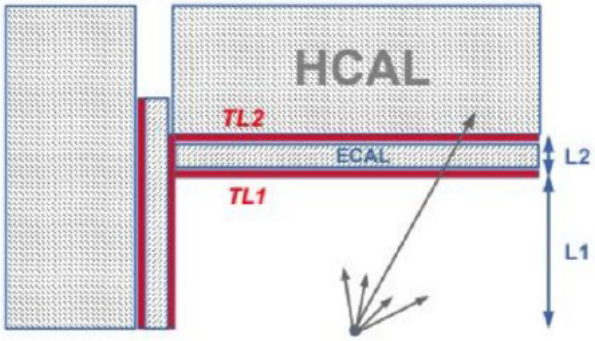
- Forward detector capabilities

Physics Requirements for Collider Physics: EF / IF Interplay

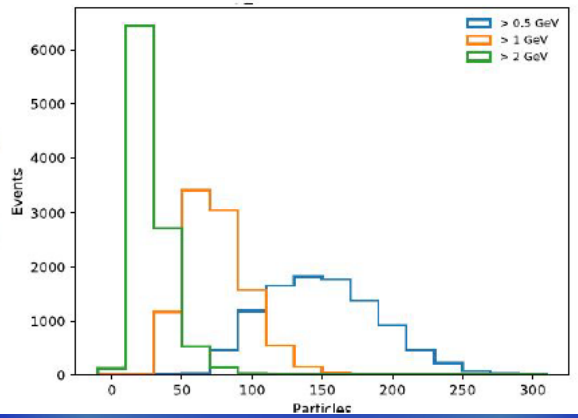
Several contribution highlighting how key detector R&D are tied to physics goals.

Interplay between detailed simulation studies and flexible rougher estimates.

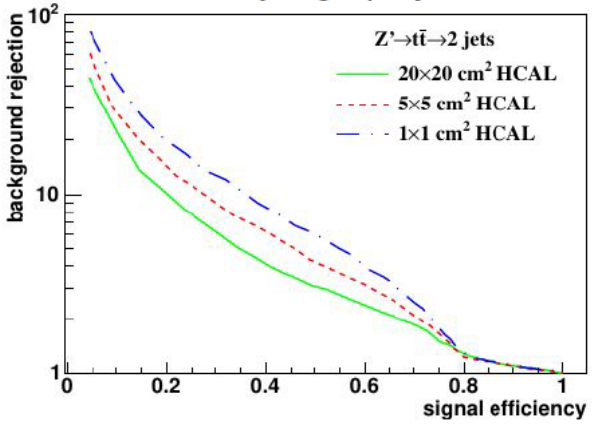
Timing layers



Tracking requirements for SUEPs



Calorimeter granularity For very high-pT jets



arXiv: 2203.07314

Track-Based Triggers for Exotic Signatures

K. F. Di Petrillo[a] J. N. Farr[b] C. Guo[c] T. Holmes[b] J. Nelson[d] K. Pachal[e]

arXiv: 1901.11146

ANL-HEP-149628

Studies of granularity of a hadronic calorimeter for tens-of-TeV jets at a 100 TeV *pp* collider

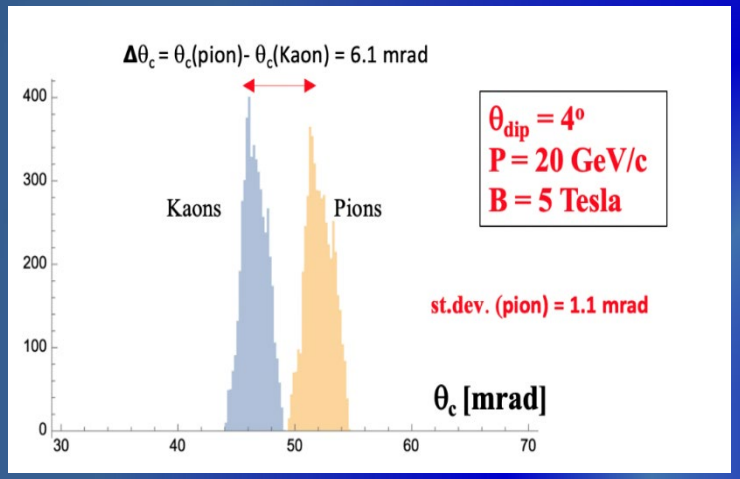
C.-H. Yeh[a], S.V. Chekanov[b], A.V. Kotwal[c], J. Proudfoot[b], S. Sen[c], N.V. Tran[d], S.-S. Yu[a]

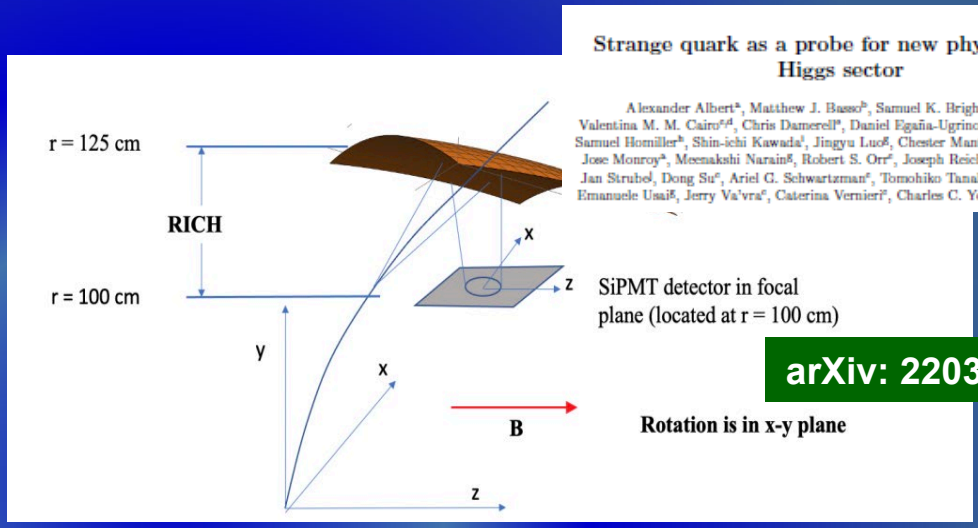
S. Pagan Griso, EF9 Symmary, 28/03/2022

And many more in performance-dedicated sections of future collider contributed papers submissions by the collaborations!

Physics Requirements for Collider Physics: EF / IF Interplay

- Higgs Couplings to strange quark demands enhanced π/K separation : RICH detector capable of π/K separation up to 25 GeV at the SiD or ILD detectors



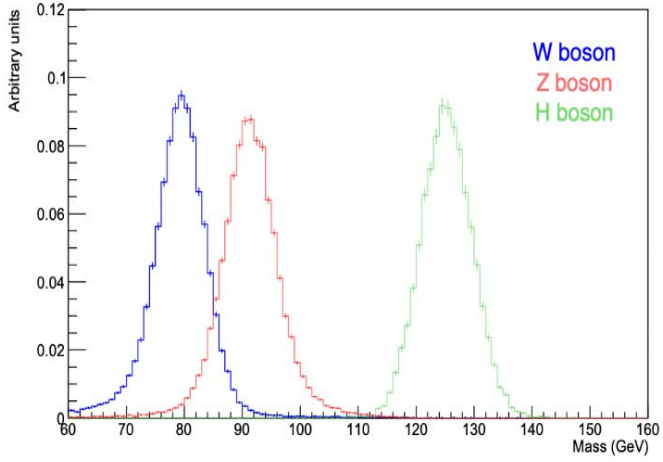


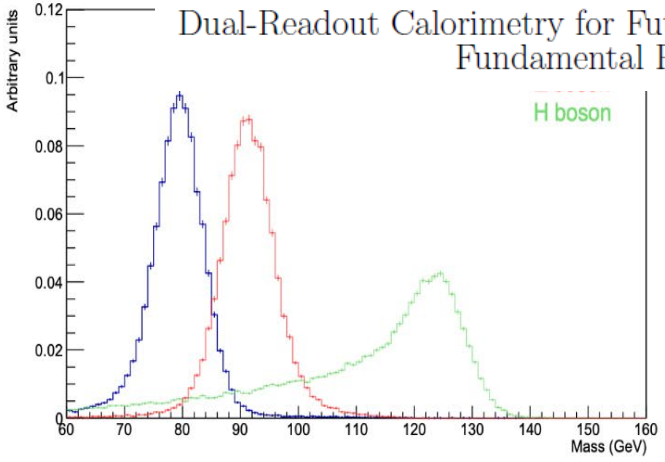
Strange quark as a probe for new physics in the Higgs sector

Alexander Albert[a], Matthew J. Basso[b], Samuel K. Bright-Thonney[a], Valentina M. M. Cairo[c,d], Chris Damerell[e], Daniel Egaña-Ugrinovic[f], Ulrich Heintz[g], Samuel Homiller[h], Shin-ichi Kawada[i], Jingyu Luo[g], Chester Mantel[g], Patrick Meade[k], Jose Monroy[a], Meenakshi Narain[g], Robert S. Orr[c], Joseph Reichert[a], Anders Ryd[a], Jan Strube[j], Dong Su[c], Ariel G. Schwartzman[c], Tomohiko Tanabe[j], Junping Tian[m], Emanuele Usai[g], Jerry Va'vra[c], Caterina Vernieri[c], Charles C. Young[c], and Rui Zou[a]

arXiv: 2203.07535

- Dual readout calorimetry: new types of particle flow algorithms that could have a big impact on precision on Higgs boson property measurements at future colliders.



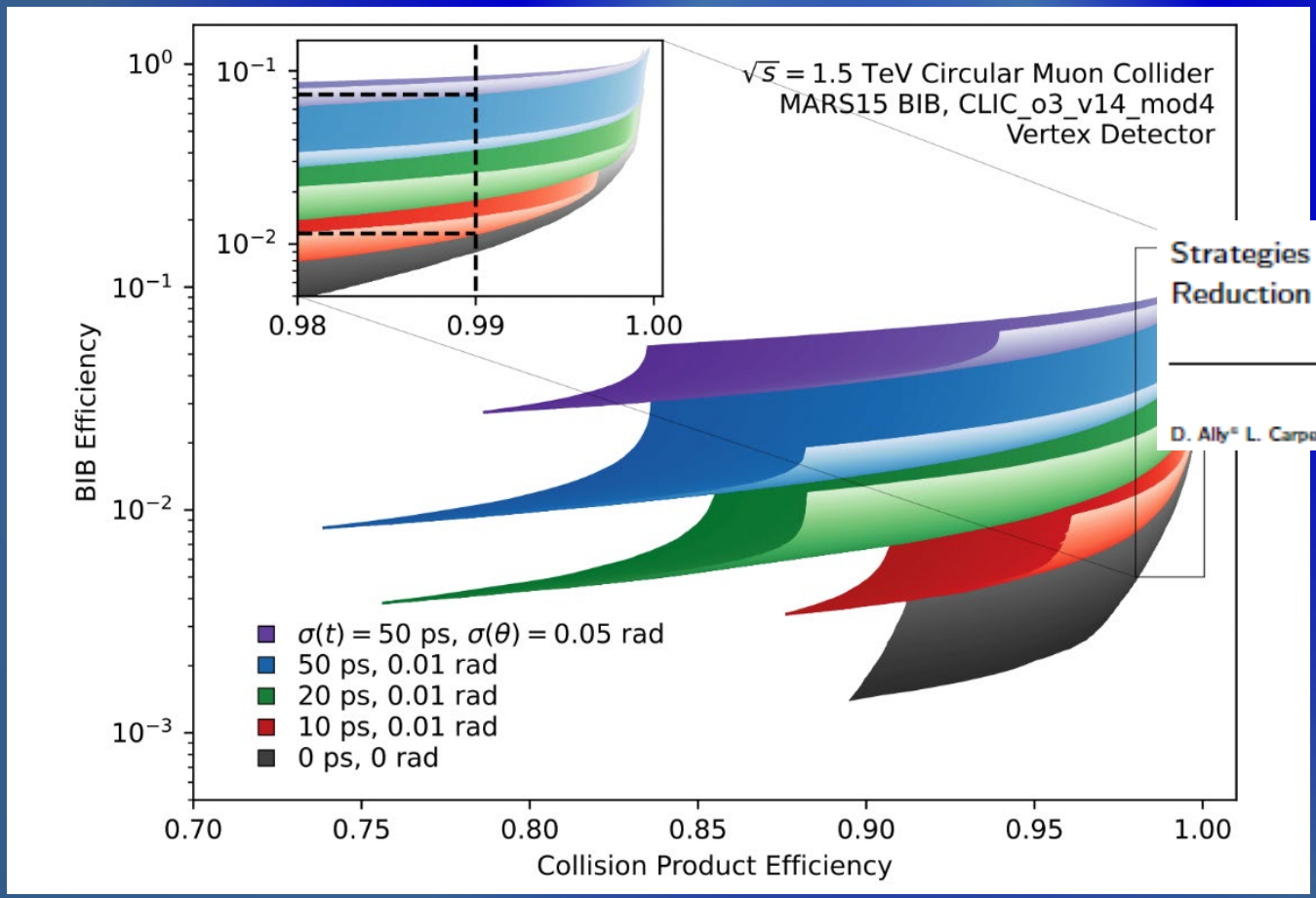


Dual-Readout Calorimetry for Future Experiments Probing Fundamental Physics

arXiv: 2203.04312

Physics Requirements for Collider Physics: EF / IF Interplay

- Timing capabilities for beam background reduction at muon collider :
- In the vertex detector, multiple orders of magnitudes of BIB rejection can be achieved with timing detectors and angular measurements from paired layers.
- Assuming 20 ps timing resolution and 0.01 rad angular resolution, 99% BIB reduction can be achieved, while retaining more than 95% of signal hits.



Strategies for Beam-Induced Background Reduction at Muon Colliders

D. Ally[a] L. Carpenter[a] T. Holmes[a] L. Lee[a,b] P. Wagenknecht[a]

arXiv: 2203.06773