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ECFA TF8 Report

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Introduction

- ECFA TF8: Integration symposium on 31st March 2021
- https://indico.cern.ch/event/999825/
- Symposium intended to seed the write-up
  - Additional feedback welcome until 7th May
  - *ECFA-DetectorRDRoadmap-TF8Integration-Input@cern.ch*

Welcome	Frank Hartman
Lightweight Mechanics	Corrado Gargiulo
Local Cooling	Marcel Vos & Paolo Petagna
Cooling Systems	Bart Verlaat
Magnet Systems	Herman Ten Kate
Machine Detector Integration MDI	Manuela Boscolo
Monitoring – Environmental	Georg Viehhauser
Monitoring – Radiation & Beam	Moritz Guthoff
Integration Challenges – Calorimetry	Martin Aleska
Integration Challenges – Neutrino	Filippo Resnati
Integration Challenges – Dark Matter	Aldo Ianni
Robotics	Lorenzo Teofili & Luca Rosario Buonocore

TF8 Matrix

ID	Future Facilities	Detector component	Technology to develop
		Movable vertex tracker	Ultrathin forming, Aluminum-beryllium alloy (AlBenMet,..), bending/mechanics
			Cooling air, convection, light-weight (ALICE ITS3)
			Low T cooling (define T to define technology), e.g. CO2, LKr, LN (LHCb VELO3), cryo*
			Cooling contacts, bridges, micro-channel cooling, TEC (for SiPM)
		Vertex	Ultra-light mechanics (also not out-gassing and stabiility against air flow), 3D printing
			Environmental monitoring, e.g. FBG (T (down to mK), RH, deformatiion, oscillation, flow, pressure - dynamic - standardization)
			Beam monitoriing, radiation monitoring
1	HL-LHC	General	Opening methods (ALARA), opening closing sensors, maintenance
			Feedthrough (compact ratio)
		Liquid Calo	Survey robots, cameras (working in cryo)
2	Neutrino Long Baseline	General	Purifiers, filter, radiopure materials, water
			Cooling air, convection, light-weight
			Cooling contacts, bridges
		Vertex, Tracker	Ultra-light mechanics (also not out-gassing and stabiility against air flow), 3D printing
			Lightweight Cryotank
		LAr calo	Feedthrough (compact ratio)
			Environmental monitoring, e.g. FBG (T (down to mK), RH, deformatiion, oscillation, flow, pressure - dynamic - standardization)
			Opening, closing methods & sensors
		General	Beam monitoring
		Magnet FCC-ee IDEA	Ultra-light solenoid cold mass; ultra light-radiation transparent cryostat; High yield strength Al stabilized NbTi conductors
3	EW-Higgs-Top Factories (ee)	Magnet	BLIMP/drone - B-field mappng
		Calorimeter (high granularity, rad	Low T cooling (define T to define technology), e.g. CO2, LKr, LN; TEC on SiPMs
		hard)	Feedthrough (compact ratio)
		TOF (SiPM)	Low T cooling (define T to define technology), e.g. CO2, LKr, LN; TEC on SiPMs
			Micro-fluidic interconnection
			Low T cooling (define T to define technology), e.g. CO2, LKr, LN, cryo*
			Cooling contacts, micro-channel cooling, TEC
		Tracker	Ultra-light support structures, 3D printing
			Environmental monitoring, e.g. FBG (T (down to mK), RH, deformatiion, oscillation, flow, pressure - dynamic - standardization)
			Beam monitoring, radiation monitoring
		General	Opening methods (ALARA), opening closing sensors, maintenance, design choice, e.g. connectors
		Magnet - FCC-hh	Dual solenoid & 4T 10m bore magnet; Large size Al stabilized NbTi coonductors
4	High-energy hadron collider	Magnet	BLIMP/drone - B-field mappng
5	Muon collider	see 3 (ee)	beam monitoring, especially BIB
6	Storage rings & fixed target		
		Magnet - EiC	Dual solenoid
		Magnet - EiC	MDI - integration with IP dipole, focussing and detector magnets
7	Lepton-hadron collider	see 3 (ee)	
		DM	Purifiers, cryo*, 3D printing
		Magnet	Long and wide bore magnets for large volume (IAXO-like) or for high field (MadMAX-like 9T)
8	Non-accelerator based experiments	Magnet	Large size ReBCO based spectrometer magnets at 50K (like for AMS100), conductor, cold mass, quench protection
		Magnet	5T class wide bore magnet for testing detector components
9	Evaluation and test facilities	General	Common fluence/dose measurement
10	Development facilities like gas systems, cooling		
11	Collaboration structures		

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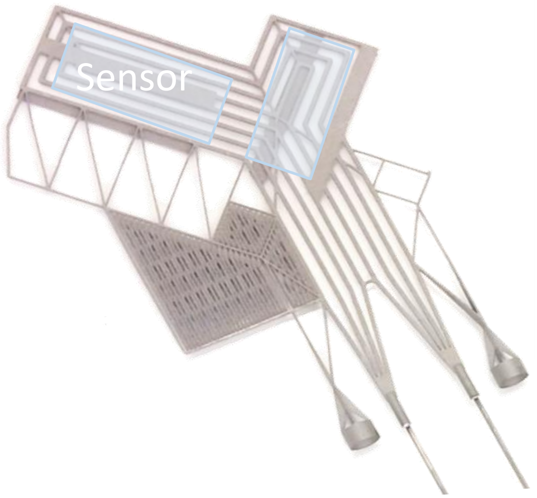
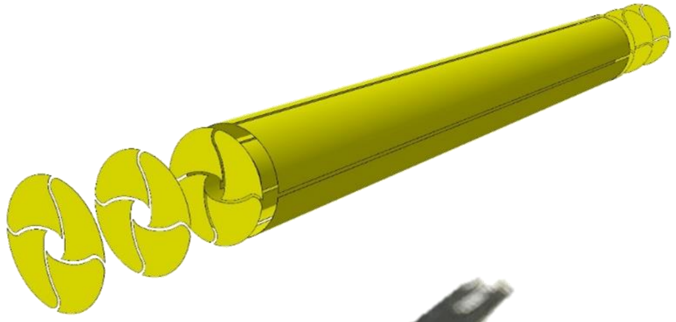
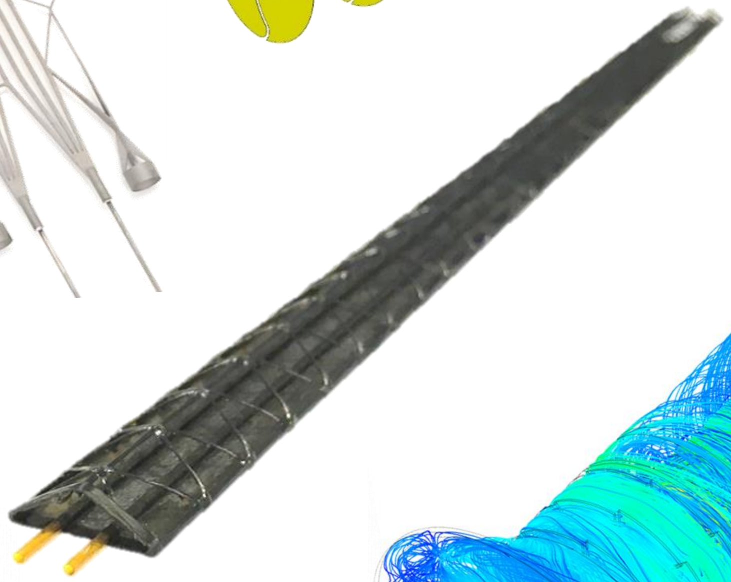
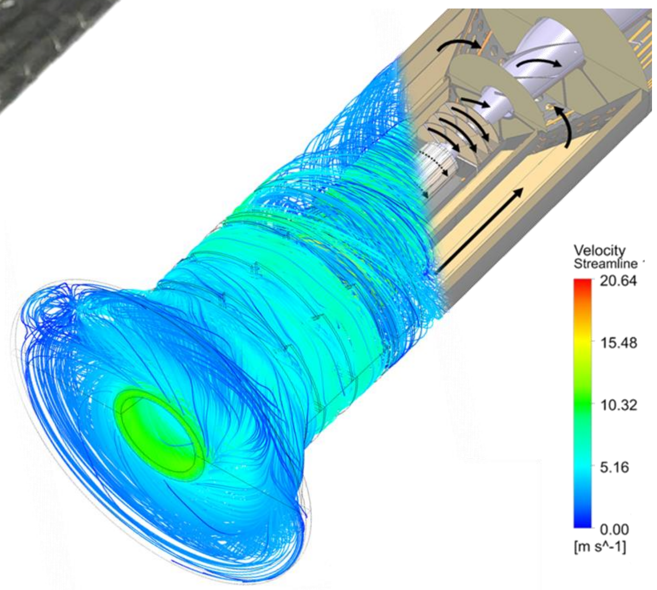
Lightweight Mechanics

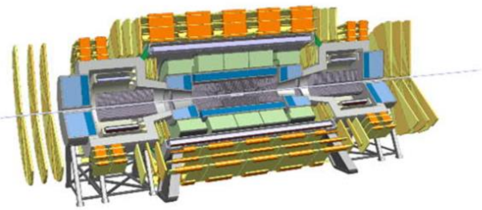
- Microchannel cooling
- Pipe cooling
- Air cooling
- Getting closer to the beampipe
- Cryostats
- Additive manufacturing



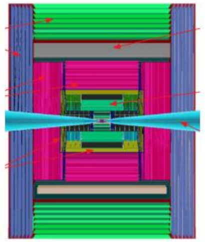


Local Cooling



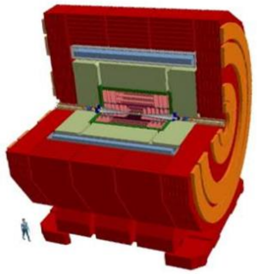
HL-LHC, HE-LHC, FCC-hh
(Rare decays: Kaons, Tau)

Tracker and Vertex: very cold and low TFM
ECAL: Lar? Digital Si/W? Analog Si/W?
Timing layers?



Muon colliders

Tracker and Vertex: a bit in-between
ECAL: Digital Si/W



Strong interaction (fixed target or collider)
Linear e+e-, Circular e+e-
(Rare decays: Mu->e+e+e-, Mu->e-)

Tracker and Vertex: remove heat at minimum X_0
ECAL: Si? SciFi + SiPMs? Gaseous?
Timing layers?

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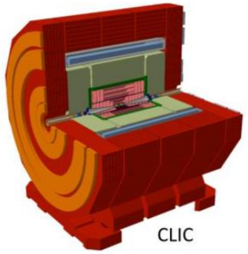
Cooling Systems

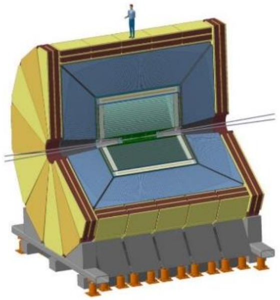
- For future detector cooling the following R&D areas have been localized:
  - High heat density cooling in the temperature domain below CO_2 (-40°C / -80°C)
    - Super and sub critical Krypton cooling using a trans critical cool down cycle
    - CF_4 is a non-green back-up solution
  - Low heat density cooling in the temperature domain below CO_2 (-40°C / -80°C)
    - CO_2/N_2O mixtures (or pure N_2O) in an oil free vapor compression cycle (With warm transfer lines) or 2PACL cycle
  - High heat density warm cooling applications (15°C / 35°C)
    - Super and sub critical CO_2 cooling
  - Low heat density warm cooling applications (15°C / 35°C)
    - Super and sub critical CO_2 cooling
    - Water and Novec single phase cooling
    - Direct air cooling solutions

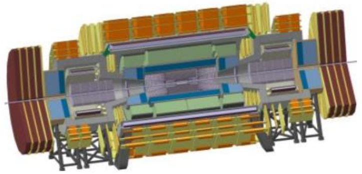
Plus discussion of environmental aspects of coolants

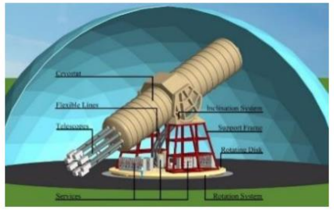
Magnet systems

- Requirements for future detector magnets were reviewed in order to formulate common global R&D targets.
- Many magnets are scaled up versions of CMS (3.8T in 6m bore), with larger bore of up to 7.5 m (FCCee/CIC/LC). This scaling is significant, requires R&D in particular in the development of larger and stronger conductors.
- Very challenging designs are proposed for FCC-hh 4T/10m and the ultra- light and transparent variants for both 2T FCC-ee and 3-4T FCC-hh. Again this requires R&D, specifically, but not only, on developing proper conductors, and for both a demonstrator to mitigate the risks.
- For non-colliding beam experiments, like for axions, examples were presented of unique and challenging magnets to be built.
- Global R&D issues for future detector magnet were identified and listed. These will be further detailed and put on a time line to enable timely readiness.









Environment Monitoring

		Setting			Status of development			Comments/R&D opportunities
		Monitoring	Debugging	R&D and QC	No radiation	Space	Hadron	
Temperature	RTDs							Integration
	FOS	?	?	?				0.1K
Pressure	MEMS					?	?	Rad hard MEMS
	Integration					?	?	
Magnet	ETI							Together with positioning
Position	FSI							3D triangular grid
	RASNIK					?	?	Sagitta measurements
Structural health/deformation	FBG							Integration
Vibration	MEMS							
Humidity	FBG							
	FOS							
Local gas flow	MEMS							
Gas mixture/contamination	Sonar						?	

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Radiation & Beam Monitoring

- Radiation environment and typical beam monitors
- Beam Loss Monitoring
  - Active protection
- Beam Condition Monitoring
  - Luminosity with BCMs
- Polarization measurements at e+e-
- Beam parameter monitoring through beamstrahlung at e+e-
- Radiation Monitoring
  - Experimental cavern
  - Irradiation exposure monitoring
- Radiation Simulation

- **Effects on experiment systems, definition of damage thresholds.**
  - Test of final pixel and strip systems in intense beams, e.g. [1,2].
- **Calibration of loss monitor response at abort level intensities.**
  - Saturation can be electronics or sensor. Both need to be qualified.
  - Needs high rate facilities and high rate reference detectors.
- **Simulation of beam loss scenarios & particle showers in experiments.**
  - Understand particle environment in any conceivable scenario.
- **Optimization of instrumentation.**
  - detector choice, location, high reliability, redundancy, abort logic,...
- **Radiation hard miniature signal current detectors (solid state IC)**
  - Improve on existing technologies: Diamond, Sapphire,...

- **Facilities include well understood infrastructure dedicated for irradiation tests with experienced manpower.**
  - Maintaining of facilities and know how is vital, even with future experiments far away.
  - Future needs being reviewed by the CERN Radiation Test Facility Steering Group [1]
- **Needed in the future: Facilities that can provide high radiation levels.**
  - Intense instantaneous beams: test BCMs, damage limits (e.g. HiRadMat)
  - Slow extracted beams / large gamma fields (e.g. IRRAD, GIF++)
  - High dose (many MGy) irradiation take a long time. Strong Co60 sources needed.
- **Improvement of quality of irradiation through standardization of exposure monitoring.**
  - Definition of monitoring technologies and evaluation techniques.
  - Cross calibration of irradiation facilities. [2]
  - Exchange of information (e.g. data management, common databases, etc.) [3]

Calorimeter Integration

- As discussed, some topics mentioned in this talk will **profit from current calorimeter projects** and/or **profit from fast progress in industry**
- Some topics, however, are **more specific to HEP**, and will probably not progress enough without strong participation by the HEP community. They will need to be **further developed by the HEP community** in strong collaboration with industry
  - **Low-mass cryostats** (Carbon fibre, Al honeycomb structures)
    - Mechanical strength (support of several 100s of tons), precision
    - Junctions between stainless steel / Aluminum / carbon fibre / epoxy
  - **High-precision large-scale support structures** capable of supporting large calorimeter masses (carbon fibre structures)
  - **Cryogenic high-density signal feedthroughs**
  - **Light thermal screens based on vacuum insulation technology** (a bit like a cryostat) to make them almost passive elements
  - **Radiation hard materials for calorimeters**
    - Hadron colliders with extreme radiation environment (1 MeV neutron eq. fluence up to $10^{16}/cm^2$, TID 1MGy)
    - Electrodes, spacers, mechanical structures, isolators,...
  - **Radiation hard reliable gluing connections**
    - 1 MeV neutron eq. fluence up to $10^{16}/cm^2$, TID 1MGy
  - **Cooling systems** for temperatures below -40^{o}C

Neutrino Integration

Challenges intrinsic to experiment location:
- Major civil engineering in *harsh* conditions
- Access limitation for equipment
- Access limitation for personnel
- Development with industries equipments, otherwise standard, suitable for underground deployment
- More strict safety requirements (material selection, fire retardant, emanations, …)

- Listed very diversified integration challenges for very different detector technologies

- Found development needs that are synergistic between different experiments

- Especially in integration, R&D activities and engineering go hand in hand

- Developments in strong collaboration with industry is paramount

- Need of facilities for R&D, prototypes, and integration tests

Dark Matter Integration

- Large arrays of SiPM-based photosensors
- Low-radon environments and radio-purity assay
- Application of Advance machining
- Magnets for IAXO
- R&D and facilities for crystal growth

Robotics

Systems to Move Large Masses
HIGHEST PRECISION
Absolute and Relative Positioning Sensors
Robots For Surveys and Operations
What Can Robots Measure and Do?
Detectors Design Challenges for Easy Manipulations
Robotics In Cryogenic Environments
Actuators and Magnetic Field

Conclusions?

- Lightweight mechanics and cooling go hand-in-hand and are difficult to disentangle
- Typically integration problems are the “large scale” problems
- By its nature, integration R&D is difficult to do on “small scale”

- “Medium scale” demonstrators required to do proper R&D for integration
- Coordinated proto-collaborations working towards demonstrators rather than smaller distributed efforts