ECFA Detector R&D Roadmap

TF1 Gaseous Detectors

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Technologies: overview, limitations and perspectives.

- MPGD: GEM, Micromegas, THGEM, uRWELL, and other ongoing developments
- RPC, MRPC, and other ongoing developments,
- Drift chambers, straw tubes, TGC, CSC, and other wire chambers
- PID: TPC, TRD, RICH and other large area detectors

Future applications.

- Tracking and muon detection at future colliders
- TPCs at future lepton and lepton-hadron colliders (TPCs, drift chambers, large volume gaseous detectors)
- Nuclear physics applications (tracking, extremely low mass detectors, photon detection, TRD, neutron detection)
- Recoils imaging for DM, neutrino, and BSM physics applications (TPCs variations, optical readout)
- Calorimetry (RPC, MPGD) at future colliders

Challenges and new developments.

- Detector stability (ageing, discharge issues) and rate capability: resistive electrodes
- Novel readout electrodes, optical readout, hybrids with ASICS
- Precise timing detectors
- IBF, photocathode stability and alternatives (including solid converters and nanotech)
- Precision manufacturing techniques (electrical and mechanical properties of detector components), additive manufacturing and new materials (low mass, radio-purity)
- Eco gas mixtures and mitigations procedures for GHG gas (recirculation, recuperation etc.)

Applications beyond fundamental research.

Development tools and R&D environment.

- Electronics (front-end and DAQ) for gaseous detectors R&D
- Software tools for detector physics simulations
- Infrastructures – development, testing and production facilities
- Relations with industry
- Networking – collaborations, technology dissemination and training

Main drivers from facilities:

1. **Muon systems**: large area, low cost, rate capability, efficiency, stability (radiation hardness, ageing, discharges)
2. **Inner and Central Tracking TPCs, DCs and Straws**: IBF, low mass (material and electronics), stability, gas mixtures (optical, NI, …)
3. **Calorimetry**: large area, uniformity, high granularity, time resolution
4. **ToF**: precise timing, large area, rate capability, stability
5. **TPC as a medium target** in rare event searches
6. **Photon detectors**: IBF, photocathode stability, high gain, stability, time resolution

Muon System

- Large area coverage, cost effective, high efficiency particle detection in a high background and high radiation environment.
- Trigger capability
- Standalone and global (+inner tracker) momentum measurement
- Adding precise timing information (~ns) allows to control uncorrelated background (Beam induced background), mitigate pile-up and to detect extremely long lived particle (heavy stable particle $\beta < 0.9$) that behave as slow muons propagating through the detector volume over a time as long as a few BXs

From LHC to HL-LHC

- many existing detectors remain: guarantee the operation for next decades (mitigation of aging effects, new electronics, accessibility to repair, greenhouse gas mitigation strategy)
- MPGD and new RPC included in ATLAS and CMS for high granularity, rate capability from RUN3 onward
- µRwell for LHCb and Muon tagger for Atlas at high $|\eta|$ for RUN4 and RUN5 [to be approved]

FCC-ee, CepC, ILC

- No performance challenges. Many technologies are available and proposed.

Muon collider:

- the effects of the background induced by the muon beam decays is extremely important. Many technologies proposed.

Hadron collider FCC-hh

- Rates can reach 500 kHz/cm^2 in forward region. Spatial res.: <100 µm. Time resolution < 3 ns (allows for and rad. hard.: ~ C/cm2. Many technologies proposed.

Tracking rare process at storage and fixed target experiments CBM and PANDA at FAIR

- Rates of 500 kHz/cm2 also expected with high spatial resolution.

Table: Muon System

Facility	Technologies	Challenges	Most challenging requirements at experiment
HL-LHC	RPC, Multi-GEM, resistive-GEM, Micromegas, micro-pixel Micromegas, µRwell, µPIC	Ageing, large area, low cost, space resolution, eco gases, spark-free, miniaturization of readout elements needed there to keep occupancy low, rate capability	**ATLAS** Upgrade: Max. rate: 10 MHz/cm2, Spatial res.: ~200 µm, Time res.: ~ 5 ns Rad. Hard.: ~ 10 C/cm^2 (10 years) -Efficiency > 95% within 25 ns
EW-Higgs-Top Factories (ee) (ILC/FCC-ee/CepC,/SCTF)	GEM, µRwell, Micromegas, RPC	Stability, ageing, large area, low cost, space resolution, no greenhouse gases, spark-free	**(IDEA)** Max. rate: 10 kHz/cm2 Spatial res.: ~60-80 µm Time res.: 5-7 ns Rad. Hard.: <100 mC/cm^2
Muon collider	Triple-GEM, µRWell, Micromegas, RPC, MRPC	Eco-gases, spark-free, high spatial resolution, fast/precise timing	Fluxes > 2 MHz/cm2 (θ>8 degree). The max. hit rate < 10 kHz/cm^2. Space res.: ~100µm, Time res.: <10 ns Rad. Hard.: < C/cm^2
Hadron physics (EIC, AMBER, PANDA and CMB@FAIR, NA60+)	Micromegas, GEM, RPC	High rate capability, good spatial resolution, radiation hard, self-triggered front-end electronics	**CBM@FAIR** Max rate: <500 kHz/cm2 , Spatial res.: < 1 mm Time res.: ~ 15ns, Rad hard.: 10^13 n.eq./cm2/year
FCC-hh (100 TeV hadron collider)	GEM, THGEM, µRWell, Micromegas, RPC, FTM	stability, ageing, large area, low cost, space resolution, no greenhouse gases, spark-free, excellent hit timing	**(**Max rate 500 Hz/cm2. Spat. res. = 50µm. ang. res = 70µrad (for η=0) to get ≤10% combined momentum resolution up to 20 TeV/c

Muon System: challenges and common R&D

- Radiation hardness and stability of those large area up to integrated charges of hundreds of C/cm^2
  - Aging issues and discharges.
- Operation in a stable and efficient manner with incident particle flows up to ~10 MHz/cm^2;
  - Miniaturization of readout elements needed to keep occupancy low;
- Manufacturing on an industrial scale
  - large detectors (thousands of square metres) at low cost, by means of a process of technological transfer to the industry, identify a process transferable to industry.
- Identification of eco-friendly gas mixture and operation of the installed detectors with those new mixtures
- Mitigation of the issue related to the operation with high WGP gas mixture:
  - gas tightness.
  - gas recuperation system.
  - accessibility for repairing
- Muon triggering and time resolution (< 1 ns)
- The main technological solution explored
  - study of resistive materials and related detector architectures for RPC and MPGD
    - higher gain in a single multiplication layer, with a remarkable advantage for assembly, mass production and cost.
    - New material and production techniques for resistive layers for increasing the rate capability
  - Thinner layers and mechanical precisions over large area

Also TF8

Inner and central tracking at colliders (excluding hadron collider)

- General requirements of the inner or central tracking with gaseous detectors are:
  - to operate at high rate, providing very precise spatial resolution for momentum measurement with low material in active area, excellent dE/dx capabilities, light material for the mechanics.
- Drift chambers (also PID), TPC with MPGD readout (also PID), multilayer cylindrical MPGD tracker, straw tubes.
- Proposed technologies at different facilities:
  - SCTF , CepC and FCC-ee : Drift Chambers, multilayer cylindrical MPGD tracker
  - Ion studies, ex. EIC , PANDA and CBM, NA60: TPC with MPGD, multilayer cylindrical MPGD tracker, straw tubes
  - Rare decays and rare events search at accelerators (SPS Kaons: K^+ Phase, K_L Phase, Mu2eII/COMET-II, ELENA (**GBAR**, Alpha-g): TPC, straw tubes

Table: Inner and central tracking at colliders (excluding hadron collider)

Facility	Technologies	Challenges	Most challenging requirements at experiment
HL-LHC	MPGD	high spatial resolution, high rate/occupancy, fast/precise timing, radiation hardness, low mass	**LHCb option:** replace Scintillating Fibre tracker. Spatial res.:70 um bending plane
Short and long baseline neutrinos experiments	High pressure gas TPC	very large volume, high pressure	**DUNE Near Detector (ND-GAr:** High Pressure gas TPC (1t) + ECAL + magnet)
EW-Higgs-Top Factories (ee) (ILC/FCCee/CEPS/SCTF)	TPC+(multi-GEM, Micromegas, Gridpix), Drift Chambers, Cylindrical layers of MPGD	Ultra-lightweight inner or central tracker, high spatial resolution, high rate/occupancy, radiation hardness, low mass, drift Chamber transparency, cluster counting, TPC continuous mode at high rate, IBF*Gain =1	**Inner tracker (SCTF)** ≥10kHz cm^{-2} s-1. Spatial res.: ~100 µm Time res.: 1 ns, 1% X/X0 **Central tracker (CEPS)** Max.rate:>100 kHz/cm2 Spatial res.: ~100µm Time res.: ~ 100 ns dE/dx: <5% Particle sepration with cluster counting at 2% level.
collider based studies of rare processes, DM, atomic and nuclear physics (SPS Kaons: K^+ Phase, K_L Phase, Mu2eII/COMET-II, ELENA)	TPC, Straw tubes	High spatial resolution, occupancy, fast/precise timing, radiation hardness, low mass, Gd-deposited MPGD detectors	• Max rate = 500 kHz/straw Thinner straw material (**Mu2e II** goal 8 µm) • X/X0 ~ 0.02% per layer, X/X0 ~ 1% total - Diameter = 4.8 mm (goal **COMET+**) • trailing time resolution = 1ns per track.
Hadron and nuclear physics (EIC, AMBER, PANDA and CMB@FAIR, ACTAR-TPC, SPECMAT, PRES MAINZ, NA60+, ESS experiments)	Micromegas, GEM, Rwell, straw tubes	High spatial resolution, good timing, radiation hard , tolerance to magnetic field	**(EIC)** Max rate = 100 kHz spas. res. ~50 um X/X0= 5 dE/dx=12%, continuos running

Inner and central tracking at colliders: challenges for Drift Chambers

High rate, unique volume, high granularity, all stereo, low mass cylindrical drift chamber

- operated with hydrocarbon based mixtures: not trustable for the long-term, high-rate operation.
  - alternative hydrocarbon-free mixture adapted to the desired DC performance at future colliders.
- Prove the cluster counting principle and a new related relectronics
  - provides the cluster counting to improve the dE/dx -resolution and extend the momentum range.
- Mechanics and new material:
  - New wiring procedure
  - Light material: new wire materials: carbon monofilament (high-power impulse magnetron sputtering)
- Integration:
  - Accessibility for repairing

Also TF8

Inner and central tracking at colliders: challenges and common R&D for TPC

R&D on detector sensors, based on MPGD, to suppress the IBF ratio, such as multi-GEM, cascaded GEM to micro-mesh gaseous structure (Micromegas) and micro-hole and strip plates (MHSP), double mesh or triple mesh, GridPix

- Optimize IBF together with energy resolution and preserving linearity
- Gain optimization for IBF and discharge stability.
- Uniformity of the response of the sensors
- Magnetic field (influence on IBF)
- High spatial resolution
- Very low material budget (few %) is required due to the high background
- Gas mixture optimization: stability, drift velocity, ion mobility, aging
- Mechanics:
  - thickness minimization but strong enough to keep the electric potential difference at a level of a few tens kilovolts and stable drift velocity.
- Integration:
  - Cooling of electronics

Also TF8

Inner and central tracking at colliders: challenges and common R&D for straw tubes

- 4D-measurement: 3D-space and (offline) track time
- High rate operation (500 kHz/straw):
  - Reduced drift time, Hit leading times (few ns) and trailing time resolutions improved and related electronics
  - Small straw diameter for faster timing, less occupancy
    - Challenges: 8 µm straw material, < 5 mm tube diameter

- Mechanics
  - Ultra-long (~m) and thin films tubes
  - Smart design: self-stabilized straw modules, flex. mountings compensate relaxation
  - Lower total material X/X_0 <0.02%
  - operate the over-pressurized tubes (1 bar) in vacuum

    ⇒ important the leakage rate, capability to maintain the cylindrical shape.

Calorimeters

The Particle-flow approach for jet energy resolution required by future lepton collider experiments .
Sampling detectors for high detection efficiency at high rate: low pad multiplicity in **DHCAL and (S)DHCAL**: the energy measurement of a single particle relies on the approximated linear relation between the particle energy and the number of fired pads (hits).

- Main requirements:
  - 3D granularity comparable or smaller than main shower features: X_0, ρ_M also in HCAL.
    - Cell sizes O(cm^2) for high longitudinal and transversal granularity and energy resolution
  - High sampling frequency: ~ 50 sampling layers for reasonable hadronic containment
    - 1k - 10k channels per m^2 in sampling layers, 10M - 100M channels, **10 000 m^2 active elements**
  - **Chamber and electronics integration in compact thin layers.**
- Additional feature: Fast- timing
  - new handle in associating photons with individual vertices and rejection of spurious energy deposits (O(100 ps)) in the calorimeter not consistent with the primary vertex timing and allows resolve the development of hadron showers, by separating their electromagnetic and hadronic components for the particle flow algorithm.
  - If pico-second-time and energy information are available at each point along the track ⇒ 5D imaging reconstruction

➔ Technologies: RPC, PicoSec, FTM

Also TF6

Table: Calorimeters

Facility	Technologies	Challenges	Most challenging requirements at experiment
EW-Higgs-Top Factories (ee) (ILC/FCCee/CEPS/SCTF)	RPC, Micromegas and GEM,µRwell, InGrid (integrated Micromegas grid with pixel readout), Pico-sec, FTM	high granularity, radiation hardness, excellent hit timing, large area detectors, stabiliy , uniform response	**(ILC)** Max.rate:1 kHz/cm2 Spatial res.: ~ 1cm Time res.: ~ 300 ns. Rad. Hard.: no
muon collider	RPC, Micromegas and GEM,µRwell, InGrid (integrated Micromegas grid with pixel readout), Pico-sec, FTM	high granularity, radiation hardness, large volume, excellent hit timing, 4D tracking, Development of HV power supplies with high sampling rate	• granularity (~1cm^2) • fat jet identification • time resolution= O(100ps) • Jet time resolution O(10ps) • Energy res =(5%)/sqrt(E) for fat-jet reconstruction algorithm. • High radiation hardness
Lepton-hadron collider	RPC, Micromegas and GEM,,µRwell, InGrid (integrated Micromegas grid with pixel readout), Pico-sec, FTM	high granularity, radiation hardness, large volume, excellent hit timing, 4D tracking	**EIC:** option DHCAL

Calorimeters: challenges and common R&D

- Uniformity of the response of the large area and dynamic energy range
- Semi-digital requires optimised weights for different thresholds
- Rate capability in detectors based on resistive materials.
  - Resistivity uniformity, discharge issue at high rate and in large area detector
- R&D on sub-ns in active elements:
  - resolution stables over wide range of fluxes
- Gas homogeneity and stable over time.
- Eco-friendly gas mixture for RPC
- Stability of the gas gain:
  - Gas mixture and environmental conditions
  - appropriate fast monitoring is part of the game
- Mechanics:
  - Large area needed, avoid dead zone.
  - Limitation on size of PCB: not easy to produce large PCB boards with high planarity.
  - Multi-gap (for improved timing) requires thin modules:
    - Mechanical issues on production of very thin layer of glass and HPL (RPC, MRPC)
    - Gas gap thickness uniformity few micron

Also TF8

Time of Flight

- Time of Flight measurement systems based on gas detectors have shown that they can work very well on particle accelerators
  - hadron identification capability may be extended by combining the PID information's from TPC and TOF.
  - Performance improved with lever arm
  - a reliable identification of electrons is possible up to a few GeV/*c*

Also TF4

- They are currently based on MRPC detectors
  - time resolution (<100 ps) coupled with high detection efficiency (> 99 %). The technology has proven to be robust, stable and reliable (Alice TOF).

- In principle reducing the time resolution down to 30 ps, with the same detector dimension, would lead to the same discrimination power at higher momentum or to more compact systems on the same momentum range
  - The future high-rate EIC and CBM experiments, have designed a large-area ToF to provide particle identification (PID) of charged hadrons at incident particle fluxes of up to **30 kHz/cm^2, time res < 80 ps.**
- R&D at future nuclear experiment (AIDAINNOVA): 100 kHz/cm^2, 20 ps
- Other technology MPGD with precision timing under investigation: PicoSec (goal σ_t (MIP) ~ 25 ps), FTM (300ps – *not proven yet)*

Time of Flight: challenges

Also TF7

MPRC

Timing: $\sigma_t \leq 50$ ps for large areas becomes a challenge

- More &thinner gas gaps: 20ps with 24 gaps (160um)
  - Thinner electrodes for better signal induction
    - Very thin gaps & glass, **Mechanically complicated multi-stacks**
- Time resolution below 15-20 ps will be very hard …
- Reaching the avalanche jitter floor
- Exploit best time resolution at system level: **New low noise FEE and DAQ**

Goal: 20ps time resolution at 50 kHz/cm²

Rate Capability:

- Standard float glass is limited to ~kHz/cm² [bulk resistivity ρ ~10^{12} Ω · cm]
- Lot of research ongoing to search for **new materials** [ρ down to $10^{9\text{-}10}$ Ω · cm]
  CBM requires rate capability up to 25 kHz/cm²
- Large sizes could be an issue due to material non-homogeneities
- Thinner electrodes will help but mechanics will be an issue.
- Gas distribution in thinner gaps at high rate could be an issue.
- Increase Temperature will decrease ρ (but increase the noise)

Lower the charge for efficient detection => Electronics!

Eco-gases mixtures

- *system time distribution, start time,…*

MPGD: Picosec, FTM

Picosec: expensive radiators (Quartz, MgF2) & non rad-hard photo-cathodes (CsI)

R&D on Rad-Hard Photocathodes (picosec)

- 2.5nm DLC is Rad-Hard & allows $\sigma_t < 50$ ps
- CsI with protection layer? (humidity, IBF)

R&D on amplification structure

- Improve timing / stability (different meshes)
- Resistive MM improve dynamic range (HIPs)
- No-flammable + low GWP gas mixture

R&D on Large Area

- Ceramic MM **(<10um flatness over 100cm²)**
- Larger areas: Tiles of 10x10 or 20x20 cm²
- Main challenge: mechanical stability (few um)
- Hermetic detector pursued

R&D on electronics / readout

- Low noise, fast rise time, sensitive to small charge
- Hybrid: Discrete Amplifier + ASIC for Timing
- Single ASIC: more complex (app specific)
- Possibly optical Readout

TPC as medium target for rare event searches

Gaseous TPCs provide an approximate lensing effect, in which density largely determines magnification (or demagnification, depending on the experimental needs)

MPGD used for the amplification and readout. Different approaches: charge-readout, negative-ion, dual-phase, optical readout.

- WIMPS, Solar Axion searches and neutrino experiments:
  - nuclear recoil discrimination: different ionization density of nuclear and electron types of events leads to a different yield-ratio in the detection medium (ionization/scintillation in the case of noble liquids)
    - Large Tons experiments at high pressure: e.g. of liquid Xe and Ar **double-phase detectors** (PandaX-4T, LZ, DarkSide -20k, Argo 200k, Dune FD, ARIADNE): Liquid target and Gas (MPGD) for amplification and readout.
  - Light element as target, detectors with very low energy threshold and low radioactive background (material with few μBq/cm^2, purified gas).
    - Operation at **1-10 bar with stable gain and without energy degradation in Ar o Ne mixture** (e.g TREX-DM with MM)
  - Direction of the WIMP flux and axion search : **20-mbar- 1 bar**: 3- dimensional (3D) reconstruction, very short recoil:
    - Different readout techniques: ionization electron charge (e.g MIMAC), negative ions at 20-40 mbar (e.g DRIFT), electron ionization and optically based readouts at atmospheric pressure (Cygnus), axion-photon conversion detected locally 2 T B, 2—160 mbar, TPC+MM (Iaxo)
  - particle trackers for the ND in neutrino oscillation experiments: **pressurized argon-based TPC** (10 bar) Dune ND.

TPC as medium target for rare event searches

Ion and nuclei detections:

- new-generation active target in order to study very rare nuclear processes and nuclei produced in very small quantities. Accurate 3D reconstruction of the event similar to what is usually done in TPCs at colliders using different gas target and pressures:
  - Eg. Actar: small volume, very ad sizes of 2×2 mm^2, chamber gas and pressure (in the range 0.1-3 bar) must be adjustable in order to ensure an adequate interaction probability and stopping power for a number of potentially relevant reactions.
  - Different gas and dE/dx conditions implies different charge amplification and readout.

- Nuclear astrophysics with high-intensity γ-ray: to study the ratio of carbon-to-oxygen produced at the end of the helium burning in stars by investigating the time reversal photodisintegration reaction.
  - The $_{16}O(\alpha,\gamma)\,_{12}C$ reaction will be studied at Extreme Light Infrastructure Nuclear Physics (ELI-NP): active-target at 100 mbar, TPC 30x20x20 cm^3 with GEM, strips electronic readout.

TPC as medium target for rare event searches: challenges

- High granularity and spatial resolution of sensors
- Radio purity of the gases and materials
- Issues related to cryogenic temperature
- Issue related to low and high pressure: mechanical constraints, pressurised vessel, uniformity and stability.
- Xenon procurement is challenging, limited market availability
- Argon extracted from underground wells
- Xenon and Argon must be purified (H_2O, electronegative impurities) for high light and charge yield
- Optical readout
- Choice of the gas
- Use of F-gases (CF_4) and gas tightness
- gas storage and recuperation techniques
- electronics with adequate dynamic range, robust against micro-discharges, flexible in terms of settings (e.g. shaping time, amplification, time range and sampling time), preferably self-triggerable, and scalable.

Also TF7, TF8

Photon detectors

Gas detectors are cost-effective solution to cover very large areas with photosensitive detectors, very low material budget and minimal sensitivity to magnetic field.

Cerenkov largely used: natural extension of the PHENIX Hadron-Blind Detector (HBD) achieved by adding focusing capability at low wavelength (CF4) and adequate gain for high efficiency detection of single-electron induced avalanches. Photo-detector at its focal plane. CsI on top of the first MPGD structure that is facing the radiator medium

Cerenkov technology is often the optimal choice for particle identification in high energy particle collision applications (Alice, EIC)

Typically, the most challenging regime is at high pseudo- rapidity (forward) where particle identification must perform well at high laboratory momenta.

- physics goals require hadron (π, K, p) identification up to 50 GeV/c
- π,$K^{\pm}$, $p^{\pm}$ separation over a wide range $|\eta|$ range. Resolution: $\pi/K \sim 3\text{-}4\ \sigma$, $K/\pi > 1\ \sigma$.

Also TF4

TRDs are ubiquitous at LHC and are considered for CMB, EIC:

- dE/dx improves PID at low momentum with tracking information. The problem is how to separate the TR radiation and the ionization process.
- The limitation of the gaseous detectors are related to the electron diffusion and photo/delta-electron production in the active gas.
- Due to the very small TR emission angle, the TR signal generated in a detector is overlapping with the ionization

Photon detection: challenges and common R&D

RICH

- Preserve the photocathode efficiency
- Radiation hardness photocathode
- IBF and more robust photocathode
- Gas radiator: alternative to CF4
- Gas tightness
- Very low noise when coupling large capacitance
- Large dynamic range of the FEE

Also TF7

TRD:

- separate the TR radiation and the ionization process:
  - ➔ Simulation
- Use cluster counting technique and improve it by means of a GridPix.

TF1 Gaseous Detectors: summary

Also TF7, TF8, TF9

Major challenges and new developments.

- Eco gas mixtures and mitigations procedures for GHG gas (recirculation, recuperation etc.)
- Integration: gas leak free, accessibility, replaceability, precision assembly
- Electronics for Gaseous Detectors
- Detector stability (ageing, discharge issues) and rate capability: resistive electrodes.
  resistive Micromegas, u-RWELL, GEM, high-granularity Micromegas, FTM, RPC, MRPC, sRPC, TGC, sTGC.
  (novel technologies, materials, architectures)
- Novel readout electrodes, optical readout, hybrids with ASICS.
  Optical readout with imaging sensors
  Hybrid readout (optical + electronic)
  Pixellated readout ASICs: Intensified TPX3Cam, GridPix, GEMPix
- Precise timing detectors
- IBF, photocathode stability and alternatives (including solid converters and nanotech)

TF1 Gaseous Detectors: summary

Development tools and R&D environment.

- Collaborative R&D environment
  - People – education, training, carrier development, continuity, and institutional memory
  - Synergies with CERN EP R&D programme, national and EU projects - diversified funding
  - Generic - project oriented R&D relation – funding of the blue-sky projects
- Infrastructures – development, testing and production facilities
  - Gaseous detector lab
  - Test beam facility with infrastructure (trackers, DAQ, …)
  - Production and R&D facility
- Access to modern technologies
- Tools - Electronics (front-end and DAQ) for gaseous detectors R&D
- Tools - Software tools for detector physics simulations
- Relations with industry – technology transfer and dissemination
- Applications beyond fundamental research – impact on the society

Backup

Questionnaire TF1: National Contacts

Questions on national strengths (equal to all TFs):

1) Areas of particular national strength or of minimal **significant activity** within the topics covered by the Task Force 1 Gaseous Detectors
2) Current national **plans for strategic investment** relevant to this Task Force area
3) Significant **opportunities for seeking future resources**, particularly (though not only) through European schemes (also in synergy with other science areas) that should be considered when highlighting R&D priorities

Specific questions related to TF1 topics:

Please let us know:

1) If there are **topics not covered** in the proposed TF1 Symposium agenda
2) For a given topic in the agenda the **R&Ds you think are particularly relevant** for your community and for which future application
3) Any **suggestions to facilitate** detector R&D on the international level

Summary of answers can be found here:
https://docs.google.com/document/d/1VCvbhsySyejost0BthNRTmqODFnXzn9S_pB3XN7zc0g/edit

About the interplay between experiment oriented R&D and generic R&D.

The core of our R&D is usually driven by the needs of possible future experiments.

- Typically the R&D effort focused on finalizing the prototyping phase before the production phase of the approved facilities and experiments.
- Common schema is: the **core of the National funding** is linked **to specific experiments**, while the **generic R&Ds or blue-sky R&Ds** are supported by applying to the **European program funding schema**.

- This hinders the exchange of experience between the groups and potential synergies cannot be optimally exploited.

➡ A constant investment into generic "blue sky" R&D is mandatory to retain the technical and engineering expertise to address the challenges of the future experiments.

Positive examples:

- *INFN dedicated National Commission (CSN5) funding to the technological and interdisciplinary research (next-generation prototypes of particle accelerators, radiation detectors, electronic and computer systems, and application outside the fundamental research). Also INFN **Calls for submission** for new ideas and technology challenges and **dedicated grants for young researchers** proposing new ideas.*
- *The German Research Foundation (DFG) is funding detector **R&D projects as well as small-scale experiments, but also for instance laboratory equipment.***

There is a need to setup laboratories for gaseous multi-technologies under common consortium or network that looks for synergies between the different groups making R&D in the different detector types.

The Universities also play a leading role in detector R&D through their academic staff, PhD, master and bachelor students, engineers and technicians, labs and equipment, but also through funding lines for smaller-scale R&D projects.

- The countries where the research is also supported and linked to the different university departments the multidisciplinary and exchange of information is more efficient.
- Some activities in the labs are needed to support the thesis work.

The exchange of ideas can be improved if there funding opportunities in each country which allow to support R&D across projects.

Positive examples:

- *Helmholtz Association of German Research Centres, with Labs like DESY and KIT, is a major player in technology development. It has formed a platform "Detector Technologies and Systems (DTS) which connects detector R&D activities of Helmholtz Research Centres.*
- *Spanish network for Future Colliders created in 2007, which now includes Higgs factories and FCC-hh. This network looks for synergies between the different groups making R&D in any detector type.*

About the promotion of CERN RD programs:

With the goal of promoting synergy and multidisciplinarity the R&D performed in cooperation with external research groups or embedded in a CERN R&D programme (such as RD51) is considered necessary.

- RD collaboration (such as RD51) are fundamental for R&D progressing in electronics, software tools, infrastructures and relation with industries since it allows easy exchange of ideas, common developments, experience and to exploit synergies.

  ⇒ CERN-RD51 collaboration has provided important stimulus for the development of MPGDs and focused on a broad networking effort to share the "know-how" and the technologies, and to promote "blue-sky" generic R&D: a seminal activity for the enlargement of the application portfolio.

  ⇒ A combination of generic and focused R&D with bottom-up decision processes

➡ The RD51 program has to be continued and the model exported to other detector technology domains.

➡ Proposal to stablish an European network of infrastructures for facilitating and advance in development and application of the new technologies.

- In the contest of CERN RD collaborations:
  - Setup a centralized facility at CERN, working as a pool of experts which would support groups in both R&D and detector construction. This facility would work as a hub linking National Laboratories and collaborations.

    - it allows also small groups with limited infrastructure to contribute to R&D through the access to the shared resources and infrastructures in the network.

  - This network of infrastructures would support and sponsor specific workshop activities on particular R&D topics, with full involvement of potentially interested industries.

- Export the CERN openlab - ICT model to the detector technology domain.
  - *"CERN openlab is **a collaboration between CERN and industrial partners** to develop new knowledge in ICT through the evaluation of advanced tools and joint research to be used by the worldwide community of scientists working at the Large Hadron Collider. **CERN collaborates with leading ICT companies and research institutes...provides access to its complex ICT infrastructure and its engineering experience — in some cases even extended to collaborating institutes worldwide.** "*

Opportunities for seeking future resources

Whenever possible dedicated national funding should be allowed for the generic R&D in order to improve the know-how and exchange of ideas in the country

Generic R&D across projects strongly relies on European Program funding schema:

- attention should be put on to bottom-up inputs when shaping the European calls dedicated to our research field.
- progress should be made in order to offer enough opportunities to countries with limited infrastructures and capabilities to co-fund the projects. Promote stronger interaction and support from large institutions with smallest independent groups as innovation drivers.
- continue the co-funding CERN fellowship programme (Marie-Curie, Fellini etc) that allows young researchers to stay at CERN and to benefit from the particular CERN environment.
- CERN openlab provides unique possibilities for young talents in computer science. It is hoped that the model can be extended and intensified also in the domain of detectors.