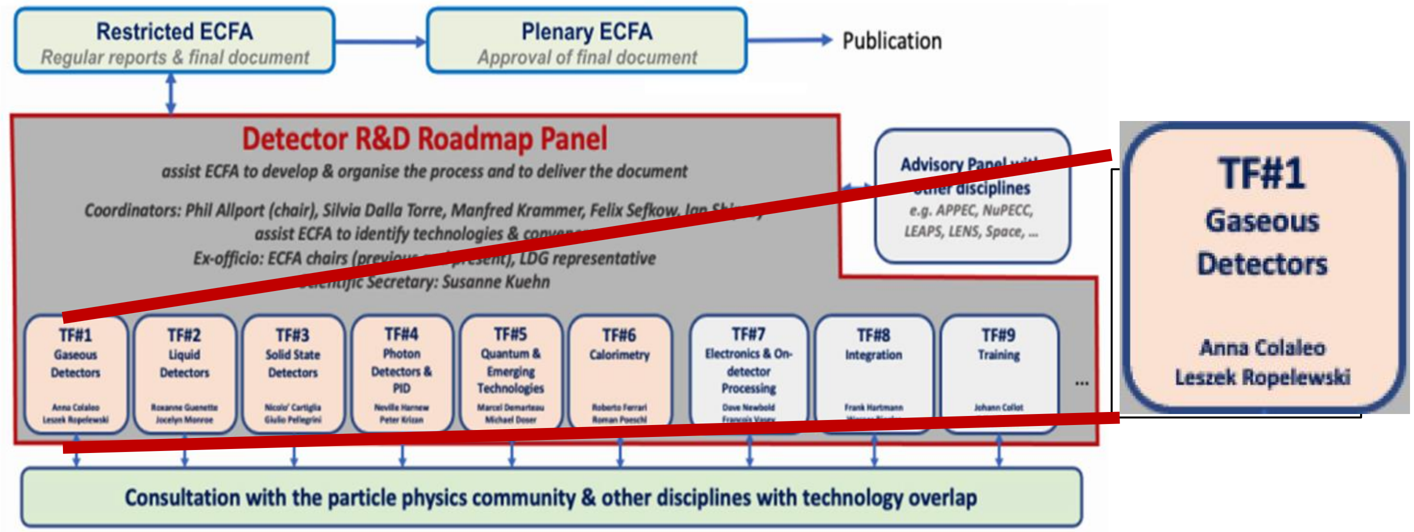
DRD1 (gaseous detectors) status and plans

Anna Colaleo (University and INFN Bari), Leszek Ropelewski (CERN)

ECFA WG3: Topical workshop on tracking and vertexing

Detector Roadmap TF1 organization



TF1 Gaseous Detectors team

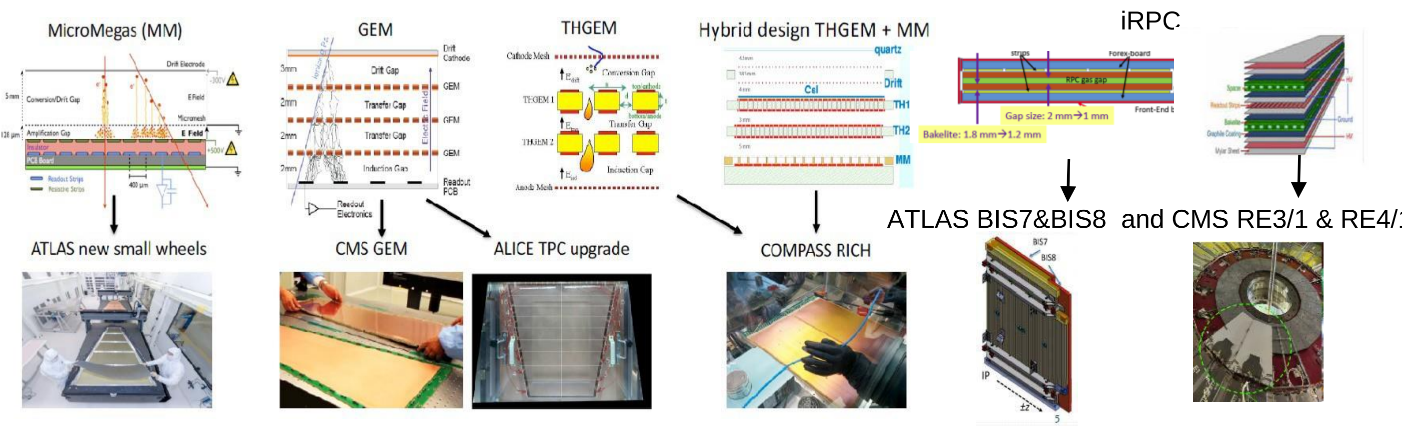
Conveners: Anna Colaleo (University and INFN Bari) , Leszek Ropelewski (CERN)

Experts: Klaus Dehmelt (SUNY), Barbara Liberti (INFN - Tor Vergata), Maxim Titov (CEA Paris-Saclay), Joao Veloso (University of Aveiro)

Link to the coordination team : Silvia Dalla Torre (INFN Trieste)

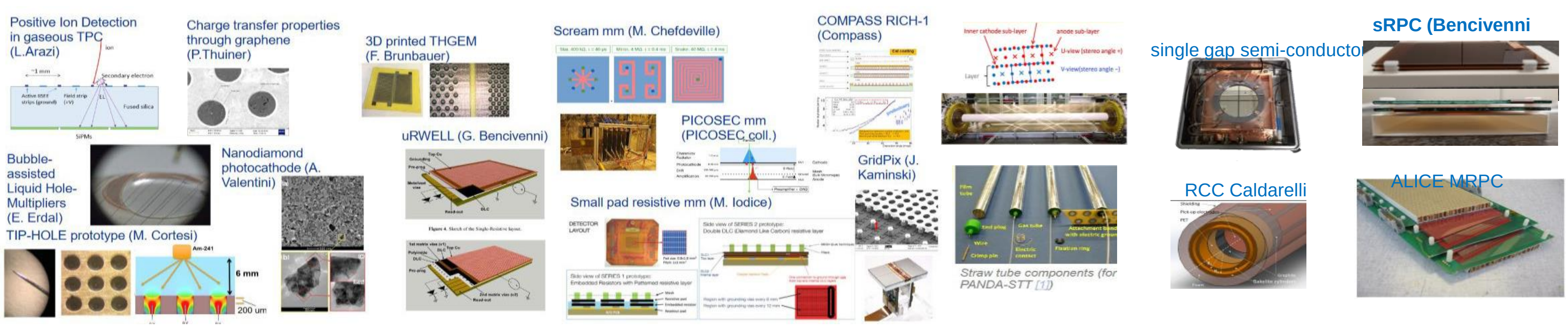
The wide family of gaseous detectors: technologies

- **Upgrades at the LHC** for tracking, muon spectroscopy and triggering have **taken advantage of the renaissance in gaseous detectors** (*ex.* MPGDs, RPC.)
- **New generation of TPCs use MPGD-based readout**: e.g. ALICE Upgrade, T2K, ILC CepC



- **Gaseous detectors offer very competitive timing** through e.g.
  - **Multi-gap Resistive Plate Chambers** (down to 60 ps time resolution) (Alice TOF)
  - An enabling emerging R&D: **Micromegas with timing** (PICOSEC concept)

New Technologies, New architectures and Hybridization of technologies



The wide family of gaseous detectors: applications

Summary of R&D Challenges for the different applications

Muon System	Inner and Central tracking	Calorimetry	Photon detection	TOF	Rare decays
• Radiation hardness and stability of large area up to integrated charges of hundreds of C/cm2: - aging issues and discharges; • Operation in a stable and efficient manner with incident particle flows up to ~10 MHz/cm2: - miniaturization of readout elements needed to keep occupancy low; • Manufacturing, on an industrial scale, large detectors at low cost, by means of a process of technological transfer to the industry and identifies processes transferable to industries • Identification of eco-friendly gas mixture and mitigation of the issue related to the operation with high WGP gas mixture: - gas tightness;gas recuperation system;accessibility for repairing. • Study of resistive materials (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 precision over large area	**Drift chambers** • High rate, unique volume, high granularity, low mass • Hydrocarbon-free mixture for long-term and high-rate operation • Prove the cluster counting principle with the related electronics • Mechanics: new wiring procedure, new wire materials • Integration: accessibility for repairing. **TPC** • R&D on detector sensors to suppress the IBF ratio • Optimize IBF together with energy resolution • Gain optimization: IBF, discharge stability • Uniformity of the response of the sensors • Gas mixture: stability, drift velocity, ion mobility, aging • Influence of Magnetic field on IBF) • High spatial resolution • Very low material budget (few %) • Mechanics: thickness minimization but robust for precise electrical properties for stable drift velocity. • Integration: cooling of electronics. **Straw chambers** • Ultra-long and thin film tubes; • "Smart" designs: self-stabilized straw module, compensating relaxation; • Small diameter for faster timing, less occupancy, high rate capability; • Reduced drift time, hit leading times and trailing time resolutions, with dedicated R&D on the electronics; • PID by dE/dx with "standard" time readout and time-over-threshold; • 4D-measurement: 3D-space and (offline) track time; • Over-pressurized tubes in vacuum: control the leakage rate to maintain the shape.	• Uniformity of the response of the large area and dynamic energy range; • Optimization of weights for different thresholds in digital calorimeters • 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: fast monitoring of gas mixture and environmental conditions; • Mechanics: - large area needed to avoid dead zone: limitation on size and planarity of PCB is an issue. - multi-gap with ultra-thin modules: very thin layer of glass and HPL electrodes, gas gap thickness uniformity few micron	• Preserve the photocathode efficiency by IBF and more robust photoconverters; • Gas radiator: alternative to CF4 • Gas tightness • Very low noise when coupling large capacitance; • Large dynamic range of the FEE; • Separate the TR radiation and the ionization process • InTDD use of cluster counting technique and improve it by means of a Ingrid.	• Uniform rate capability and time resolution over large detector area; • New material for high rate (low resistivity, radiation hardness); - uniform gas distribution; - thinner structures: mechanical stability and uniformity; • Eco-gas mixture; • Electronics: Low noise, fast rise time, sensitive to small charge; • Possibly optical readout; • Precise clock distribution and synchronization over large area.	• Radio-purity of the materials • Low background • High granularity • For large volume detectors: transparency over large distance • Pressure stability and control • Electronics with large dynamic range and flexible configuration. • Self-trigger capability • Low noise electronics • Fast electronics • Optical readout

Figure 1.8:

DRD1 Themes and timeline

DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

DRDT 1.1 - Improve time and spatial resolution for gaseous detectors with long-term stability

Future experiments require large areas to be instrumented with unprecedented timing capabilities both for time of fight particle identification and to aid track association to the correct event. Their physics programmes demand an improved momentum resolution and performance needs to be maintained over decades with minimal intervention.

DRD1 Themes and timeline

DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

DRDT 1.1 - Improve time and spatial resolution for gaseous detectors with long-term stability
Future experiments require large areas to be instrumented with unprecedented timing capabilities both for time of fight particle identification and to aid track association to the correct event. Their physics programmes demand an improved momentum resolution and performance needs to be maintained over decades with minimal intervention.

DRDT 1.2 - Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material Different readout methodologies are required for large volume tracking detectors including micro-pattern gas detector systems, optical readout and direct interfacing to ASICs. Low multiple scattering is essential as is enhanced particle identification through accurate determination of ionisation (either deposited energy or number of clusters) per unit length.

DRD1 Themes and timeline

DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

DRDT 1.1 - Improve time and spatial resolution for gaseous detectors with long-term stability
Future experiments require large areas to be instrumented with unprecedented timing capabilities both for time of fight particle identification and to aid track association to the correct event. Their physics programmes demand an improved momentum resolution and performance needs to be maintained over decades with minimal intervention.

DRDT 1.2 - Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material Different readout methodologies are required for large volume tracking detectors including micro-pattern gas detector systems, optical readout and direct interfacing to ASICs. Low multiple scattering is essential as is enhanced particle identification through accurate determination of ionisation (either deposited energy or number of clusters) per unit length.

DRDT 1.3 - Develop environmentally friendly gaseous detectors for very large areas with high-rate capability
The largest area detector systems in an experiment are typically gaseous detectors, often as part of an outer muon spectrometer. Ease of maintenance, stable operation and, for some applications, the ability to cope with very large fluxes of charged particles are required. Key to future applications is the development of more ecologically friendly gas mixtures for gaseous detectors and mitigation procedures for use of greenhouse gases when this is unavoidable.

DRD1 Themes and timeline

DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

DRDT 1.1 - Improve time and spatial resolution for gaseous detectors with long-term stability

Future experiments require large areas to be instrumented with unprecedented timing capabilities both for time of fight particle identification and to aid track association to the correct event. Their physics programmes demand an improved momentum resolution and performance needs to be maintained over decades with minimal intervention.

DRDT 1.2 - Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material Different readout methodologies are required for large volume tracking detectors including micro-pattern gas detector systems, optical readout and direct interfacing to ASICs. Low multiple scattering is essential as is enhanced particle identification through accurate determination of ionisation (either deposited energy or number of clusters) per unit length.

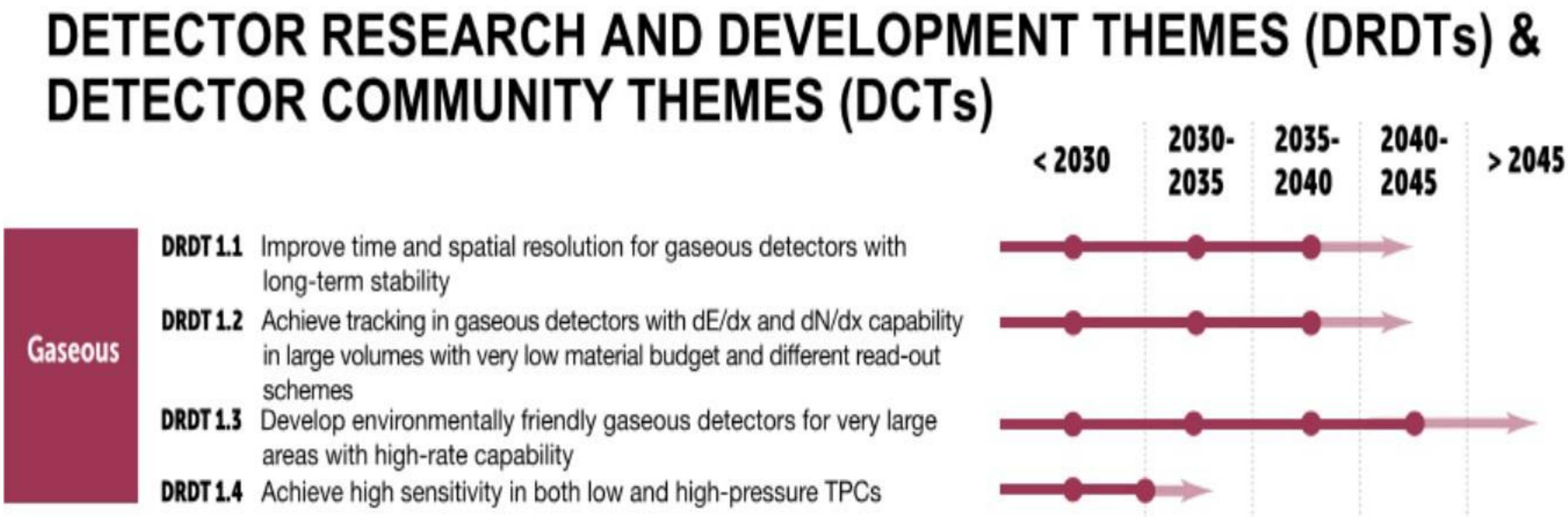
DRDT 1.3 - Develop environmentally friendly gaseous detectors for very large areas with high-rate capability

The largest area detector systems in an experiment are typically gaseous detectors, often as part of an outer muon spectrometer. Ease of maintenance, stable operation and, for some applications, the ability to cope with very large fluxes of charged particles are required. Key to future applications is the development of more ecologically friendly gas mixtures for gaseous detectors and mitigation procedures for use of greenhouse gases when this is unavoidable.

DRTD1.4: Achieve high sensitivity in both low and high-pressure TPCs

Large volume gaseous detectors provide a key technology for high efficiency searches for rare events with differing readout for optimizing the signal-to-noise ratio and reducing detector backgrounds

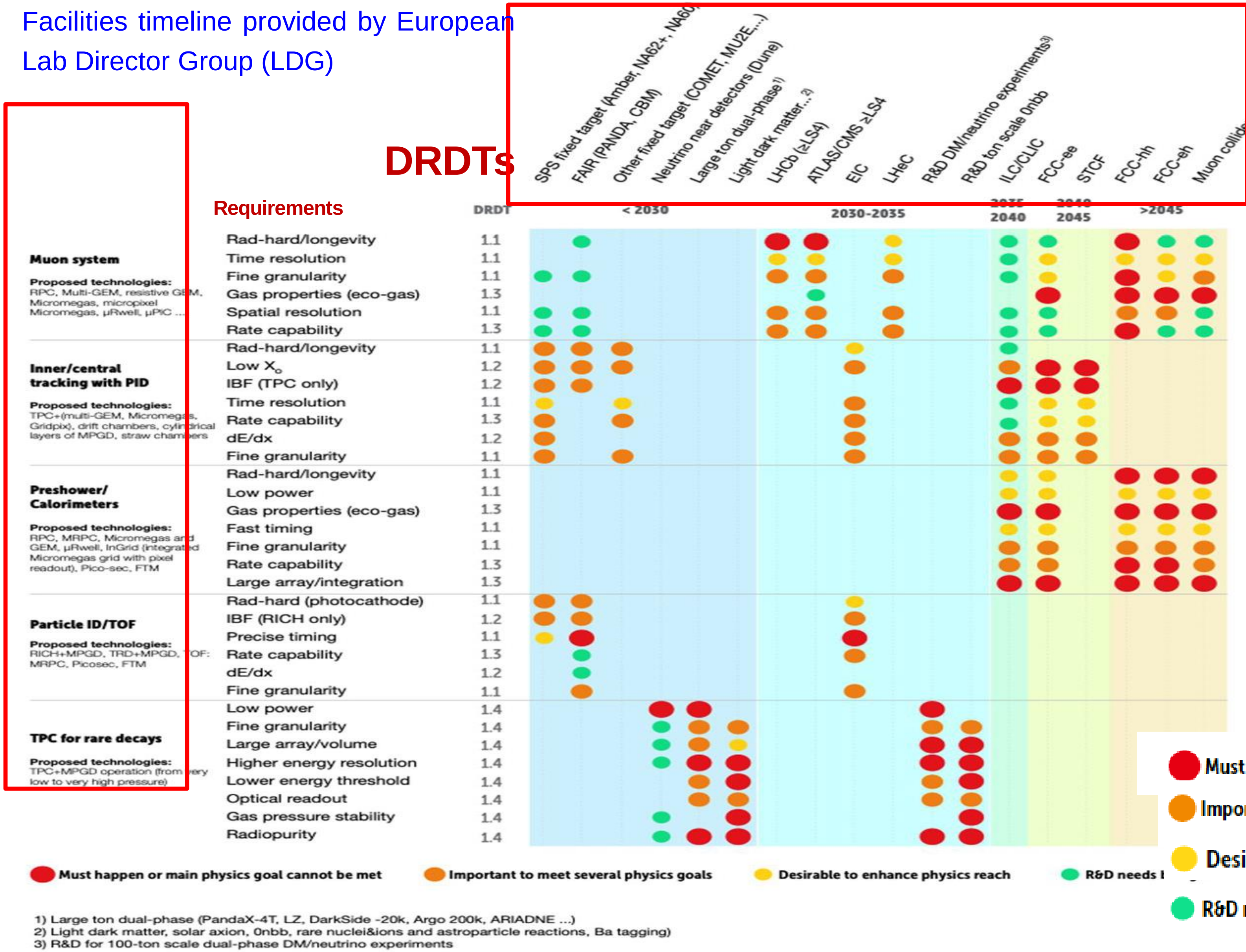
DRD1 Themes and timeline



- The faded region acknowledges the typical time needed between the completion of the R&D phase and the readiness of an experiment at a given facility.
- Stepping stones are shown to represent the R&D needs of facilities intermediate in time.
- It should be emphasised that the future beyond the end of the arrows is simply not yet defined, <u>not that there</u> <u>is an expectation that R&D for the further future beyond that point will not be needed</u>.

Gaseous detectors R&Ds timeline

Facilities timeline provided by European Lab Director Group (LDG)



Planning for the detector R&D to ensure the main physics goals of the updated strategy for particle physics do not risk being compromised by detector readiness

- Must happen or main physics goals cannot be met
- Important to meet several physics goals
- Desirable to enhance physics reach
- R&D needs being met

General Strategic recommendations

In addition to the Detector R&D Themes described above the following General Strategic Recommendations are made under the following headings.

GSR 1 - Supporting R&D facilities

GSR 2 - Engineering support for detector R&D

GSR 3 - Specific software for instrumentation

GSR 4 - International coordination and organisation of R&D activities

GSR 5 - Distributed R&D activities with centralised facilities

GSR 6 - Establish long-term strategic funding programmes

GSR 7 - Blue-sky R&D

GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts

GSR 9 - Industrial partnerships

GSR 10 - Open Science

Implementation started through the setting up of DRD collaboration

"Implementation roadmap"

See description in backup slides

DRD Implementation plan

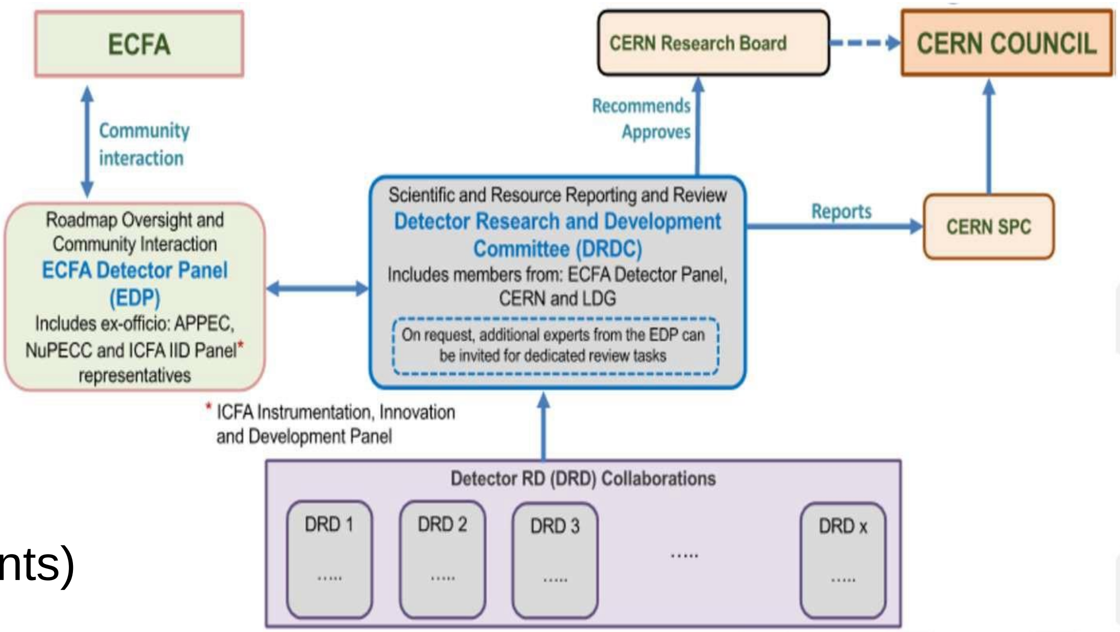
Requested by the CERN Council ECFA Roadmap Coordination Group worked out a proposal to organize long-term R&D effort into: new established **Detector R&D Collaboration anchored at CERN**

Three areas of Detector R&D:

1.**Strategic R&D** (long term strategic R&D (address the high priority items defined in the Roadmap via the DRDTs)

2.**Experiment specific R&D** (with very well defined detector specifications) (funded outside of DRD programme, via experiments)

3. **"Blue-sky" R&D** (competitive, short term responsive grants, nationally organised)



7 DRDs

https://cds.cern.ch/record/2838406?ln=en

DRD9 is taken care of by a new ECFA Training Panel
DRD8 felt their area is too experiment specific to be the topic of a "Strategic R&D" bid.

DRD1 Implementation timeline - 2023

Q4-2022/Q1-2023

- Formation of the DRD1 proposal team
- Collection of interest from the institutes (survey)
- 1st Workshop and shaping the direction of RD.

- DRDC mandate reviewed and agreed with CERN management and EDP

Q2-2023

- **Writing the proposal** (scientific and organization) that includes conclusion and feedback from the workshop and survey
- Collect feedback by institutes in contact with their funding agencies about the best funding schema
- 2nd Community Workshop

- Mechanisms agreed with funding agencies for country specific DRD funding request.

Q3-2023

End July –submission of the proposal, including resource information:

- resources needed
- resources already available
- Interest of institutes/FA to contribute to specific tasks

- DRDC review (scientific, milestones, feasibility, financials)

Q4-2023

- Establishing continuation of existing RD51 projects and carrying resources

- Follow the review revisions and upon green light from DRDC, CERN research board approves the formation of the collaboration

DRD1 Implementation timeline and approval

- New structures operational and new R&D programmes underway from beginning 2024.
- Through 2024, collection of MoU signatures with defined contribution areas per institute.
- Ramp up of new strategic funding and R&D activities 2024-2026

DRD1 implementation

The DRD1 should establish a programme and a collaborative framework to achieve the ECFA roadmap TF1 Detector R&D Themes (DRDTs)

The collaborative structure of DRD1 would allow:

- facilitating joined efforts along common goals defined by the ECFA roadmap document
- the development of common tools (detector physics simulation software, electronics)
- accessing, being anchored at CERN, the facilities for detector evaluation (such as test beams and irradiation source), and the infrastructures facilitating detector developments (such as workshops and laboratories).
- helping in the education and training, for cross-fertilization among different particle physics (and neighboring discipline) detector development programs.
- promoting the visibility and prospects of young researchers in detector technologies.

Towards a DRD1 Collaboration: team

Q4-2022/Q1-2023

- Taking advantage of existing RD51 experience and organization (AIDAinnova. CERN EPR&D)
- Through the organizer committee of major detector workshop/conferences (RD51, RPC, TPC)
- Through TF1 Members (experts) and speakers of the TF1 symposium.

the following **team of coordinators** has been put in place

- **ECFA TF1** Conveners: Anna Colaleo (Univ. and INFN-Bari), Leszek Ropelewski (CERN);
- Other TF1 Members: Klaus Dehmelt (Stony Brook Univ.-SUNY) , João Veloso (Univ. of Aveiro)
- **ECFA Coordinators Group Member:** Silvia Dalla Torre (INFN - Trieste)
- **MPGDs**: Eraldo Oliveri (CERN), Fulvio Tessarotto (INFN-Trieste), Maxim Titov (CEA Paris-Saclay)
- **RPCs**: Ingo Deppner (Univ. Heidelberg), Giuseppe Iaselli (Politecnico & INFN-Ba), Barbara Liberti (INFN –RM 2)
- **TPCs:** Esther Ferrer Ribas (IRFU/CEA), Jochen Kaminski (University of Bonn)
- **Large volume detectors:** Marco Panareo (Univ. and INFN-Lecce), Francesco Renga (INFN-Roma I)
- **Straw tubes, TGC, CSC, drift chambers, and other wire detectors:** Peter Wintz (IKP, FZ Jülich)
- **Infrastructure, R&D programs** (CERN EPR&D, AIDAinnova): Roberto Guida (CERN), Beatrice Mandelli (CERN)
- **Administrative support:** Hans Taureg (University of Bonn), Florian Brunbauer (CERN)

Q4-2022/Q1-2023

DRD1 Implementation process

- **From January 2023**: Through the coordinators we collected a preliminary list of contact person(s) for each institution interested in joining the collaboration, set up a proposal-writing group with the goal of preparing the DRD1 proposal
- **23 January:** Survey organized in **8 main sections** addressing specific topics of research

    1. Technologies
    2. Applications
    3. Gas and material studies
    4. Detector physics, simulation and software tools
    5. Electronics for gaseous detectors
    6. Detector development manufacturing and production
    7. Common test facilities
    8. Training and dissemination

    → Survey sent to contact persons to get the first feedback

- **End of January:** proposal writing group organised in corresponding **8 Working groups**, each steered by conveners

Survey topics WG1-2

1. Technologies of interest

Please select one or more technologies of interest for your group and add in the comment section more information or remarks and notes if needed.

Technologies of interest*

- ☐ MPGD
- ☐ RPC and MRPC
- ☐ Wire chambers (incl. Straws, TGC, CSC...)
- ☐ Large Volume Detectors (drift chambers, TPCs)
- ☐ New amplifying structures
- ☐ Other

2. Applications

Provide general research topics and when possible more specific lines carried out by your group of planned for future activities. If not included in the list, please add them in the comment/notes section.

Select application areas connected to the research activity of your group*

(Muon) Tracking and Triggering Systems

- ☐ Radiation hardness and stability (aging, discharges) of large area up to hundreds of C/cm2 of integrated charge.
- ☐ Stable and efficient operation (rate, occupancy) up to ~10 MHz/cm2.
- ☐ Manufacturing or large detectors and large systems at low cost. Technological transfer to the industry.
- ☐ Eco-friendly gas mixture and optimized operation with high WGP gas mixture (tightness, recuperation, accessibility)
- ☐ Study of resistive materials (RPC and MPGD): high gain in a single multiplication stage (beneficial for assembly, production and costs)
- ☐ New material and production techniques for resistive layers for increasing the rate capability
- ☐ Thinner layers and mechanical precision over large area
- ☐ Other

TPC...)

lications)

- ☐ Other

Comments/Notes

DRDT 1-3

Survey topics WG3-4

3. Gas and material studies

Please select relevant topics for your current and future research activities

Select relevant topics for your group on gas and material studies

- ☐ Gas Properties (e.g. cross-section, chemical characterization, measurements)
- ☐ Eco-gases studies
- ☐ Light emission in gases
- ☐ Gas recuperation and recirculation systems
- ☐ Gas systems
- ☐ Sealed detectors and systems
- ☐ Resistive electrodes
- ☐ Solid converters
- ☐ Photocathodes (novel, ageing, protection)
- ☐ Novel materials (e.g. nanomaterials)
- ☐ Material properties for detector and infrastructures
- ☐ Light (low material budget) materials
- ☐ Precise mechanics
- ☐ Ageing
- ☐ Outgassing
- ☐ Radiation hardn
- ☐ Other

R&D equipment, Infrastructures and service for Gas and material studies at your Institute

Please, list any relevant equipment, infrastructures and service at your Institute and if they are:
1. Existing
2. Planned via new strategic R&D programs at your institute
3. Needed but not available or foreseen in future at your institute
Please specify if external groups can access them at your institute.

Would you be willing to contribute or support common developments in the context of the DRD1 collaboration?*

If the answer is yes, please add more information in the Comments/Notes section if your team can take charge of specific tasks, or if member of your team are willing to supervise common developments or if member of your team are willing to take part of ongoing efforts or if you can financially support common developments of interest for your work.

4. Detector physics, simulations, and software tools

Research interests and activities

- ☐ Detector Physics (modelling and simulations)
- ☐ Detector Performance Studies (modelling and simulations)
- ☐ Software development and maintenance
- ☐ Gas Properties Databases (e.g. cross-sections) - Use and/or Maintenance
- ☐ Detector design
- ☐ Other

Please select the activities of interest for your group and specify in the comments if the interest is as user and/or developer

Relevant simulation and software

Which software/simulation development do you consider necessary on a term of 5-10 years to improve your work or, as users, to make progress in the field?

Development of and access to simulation and software

List, if any, relevant problems you experienced or you would expect on doing software work with your team, both as developers and as users...

Software Development*

Is your team involved in software development? If the answer is yes, please specify in the comments section the activity and the number of involved people.

Would you be willing to contribute or support common developments in the context of the DRD1 collaboration?*

If the answer is yes, please add more information in the comments section if your team can take charge of specific tasks, or if members of your team are willing to supervise common developments or if members of your team are willing to take part in ongoing efforts.

DRD1 Survey topics WG5-6

5. Electronics for gaseous detectors

Research interests, activities and needs

- Analog Electronics
- Digital Electronics
- Discrete Readout Front End Electronics
- Multichannel Integrated (ASIC) Readout Front End Electronics
- Pixels
- FE input protection
- Spark Quenching
- Charge readout
- Photon readout
- Waveforms and Digitizer
- Cluster Counting
- Signal Processing
- Timing
- High rate
- Low noise
- Wide Dynamic Range
- Grounding and shielding
- Calibration
- Trigger-less systems
- General purpose Data Acquisitio
- SoC based sensor readout
- FPGA based readout/trigger
- High Voltage Systems and High V
- High resolution floating ammete
- Monitoring and control systems
- Dedicated lab instrumentation
- LV Powering
- Cooling
- Other

Relevant electronics

What development in electronics do you consider necessary over a term of 5-10 years to improve your work or, as users, to make progress in the field?
Development, use and access to electronics

List, if any, relevant problems you experienced with electronics, both as developers and as users.

Electronics Development*

Is your team involved in electronic development?
If the answer is yes, please specify in the Comments/Notes section the activity and the number of involved people.

Would you be willing to contribute or support common developments in the context of the DRD1 collaboration?*

If the answer is yes, please add more information in the Comments/Notes section if your team can take charge of specific tasks, or if member of your team are willing to supervise common developments or if member of your team are willing to take part of ongoing efforts or if you can financially support common developments of interest for your work.

Do you have access at your institute to experts and services that can support common activities in the collaboration?*

If the answer is yes, please provide more information in the Comments/Notes section.
Add comments in case the answer is no but you plan to (or you would like to) ask for some support at your institute.

Do you have experience and industrial contacts for custom made electronics production?*

6. Detector Development, Manufacturing and Production

Provide your interest in facilities for prototype production and/or contribution to new production methods and/or industrialization aspects. If not included in the list, please add them.

Do you have production capabilities at your institute?*

If yes, please list them in the facility section at the beginning of the survey and specify if they are accessible to external users.

Is your group planning to produce detectors (components) or to support facilities (in your institute or external) that can do it?*

If yes, please add in the comment section more information

Interest in existing or potential production and facilities*

- CERN EP-DT Micro Pattern Technology (MPT) Workshop
- Saclay MPGD workshop
- RPC/MRPC workshop
- Wire chambers workshop
- Novel detector production methods
- CERN EP Thin Film & Glass service (photocathodes, coatings, ceramic)
- Other

Interest in manufacturing and production processes.

Please indicate if your team would like to develop some learning regarding the manufacturing and/or industrialization of detectors? (Definition of specifications, CAD, QA/QC)
Knowledge Dissemination

- Seminar
- Courses
- Training from industrial partners
- Other

If of interest, select potential ways to improve the knowledge transfer to your research group. Please add in the next Comments/Notes section if not listed.

Relationships of your group with industry*

- Development of new manufacturing processes
- Responsible of Technology Transfer
- Production
- Other

Survey topics WG7-8

7. Common Test Facilities

Includes development of common detector characterization standards. If applicable, provide the relevant test facilities for your detector characterization or interest in development of common detector characterization standards.

Please select Detector Characterization Facilities of interest for your research*

- ☐ General purpose detector development laboratories
- ☐ Ageing Study Facility
- ☐ Gas studies facility
- ☐ Irradiation facility
- ☐ Test beam facility
- ☐ Chemistry and material laboratory
- ☐ Clean Room
- ☐ Instrumentation for common detector characterization (e.g. gas, DAQ, HV systems)
- ☐ Other

Access and use of common facilities and services

List, if any, positive experiences and advantages or difficulties and relevant problems you experienced accessing and using common facilities and services.

Outline facilities and services present at your institute (that could be used by DRD collaborators):*

Please explain the facility

Is your institute interested in contributing to the management and operation of existing/planned facilities/services?*

If the answer is yes, please add in the Comments/Notes section more information.

Is your institute interested in contributing and/or financially supporting the development/construction of specific services for existing or new facilities?*

If the answer is yes, please add in the Comments/Notes section more information.

Is your institute interested in contributing and/or financially supporting the usage of specific services that you may need?*

8. Training and dissemination

Training and dissemination Activities your group could be interested in

- ☐ Schools and trainings
- ☐ Topical workshops
- ☐ Knowledge transfer
- ☐ Other

Please select where your team is involved. If not included in the list, please add them.

Training and dissemination Target

- ☐ Bachelor and Master Students
- ☐ Doctoral students
- ☐ Postdoc
- ☐ Senior

Training and dissemination

List examples of existing or potential training and dissemination activities that you would like to have in the context of the DRD1 collaborations?

Is your group interested in organising training and dissemination activities?*

Strategies to recognize and sustain the careers of R&D experts

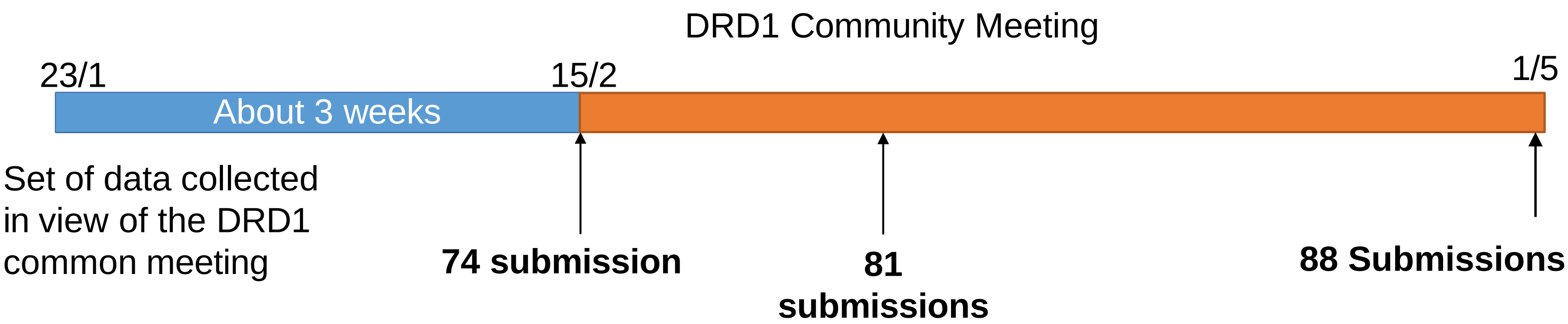
Please indicate strategies to recognize and sustain the careers of R&D experts already settled at your institute or suggest potential ones that could be implemented in the context of the DRD1 collaboration.

Young Researchers

Community survey: timeline

- Opening date: 23 January
- Intermediate closing date: 15 February
- DRD1 Community Meeting: 1-3 March
- Final closing date: 1 May 2023

- Survey was accessible only by the people in the list of contact persons, identified by the coordination team.
- Survey was neither a commitment nor a sine-qua-non for becoming a member of DRD1.
- The list of contact persons is still open to group interested in DRD1.



Survey: submission outcome

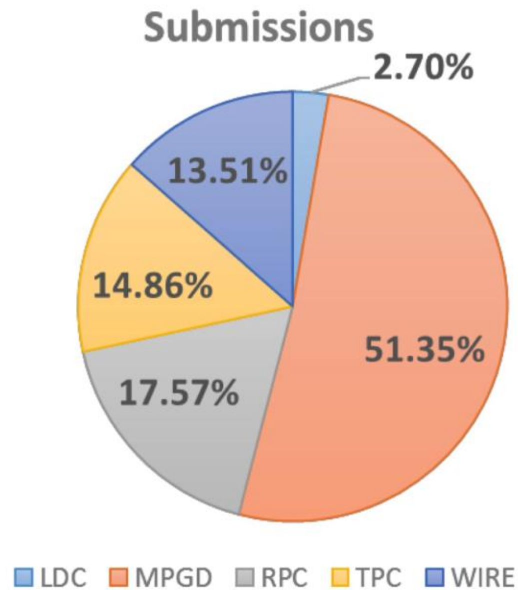
Survey outcome analysed by 8 working groups, one per each of the 8 topics:

Submissions

LDC	2
MPGD	38
RPC	13
TPC	11
WIRE	10

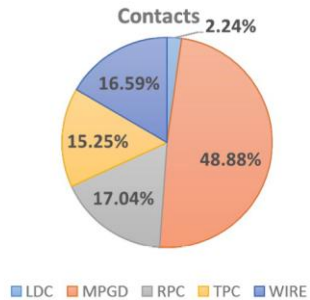
Total = 74

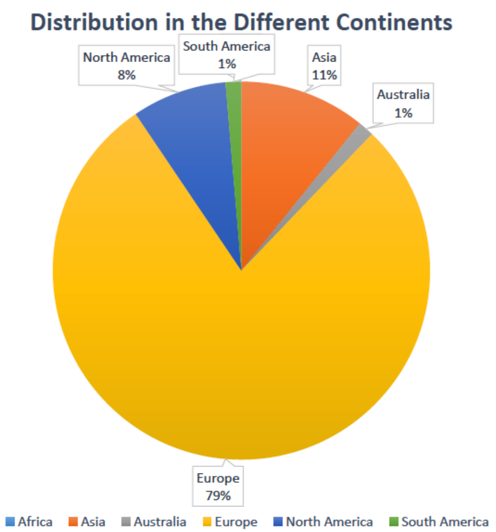
33%



(Contacts = 223)

LDC	5
MPGD	109
RPC	38
TPC	34
WIRE	37





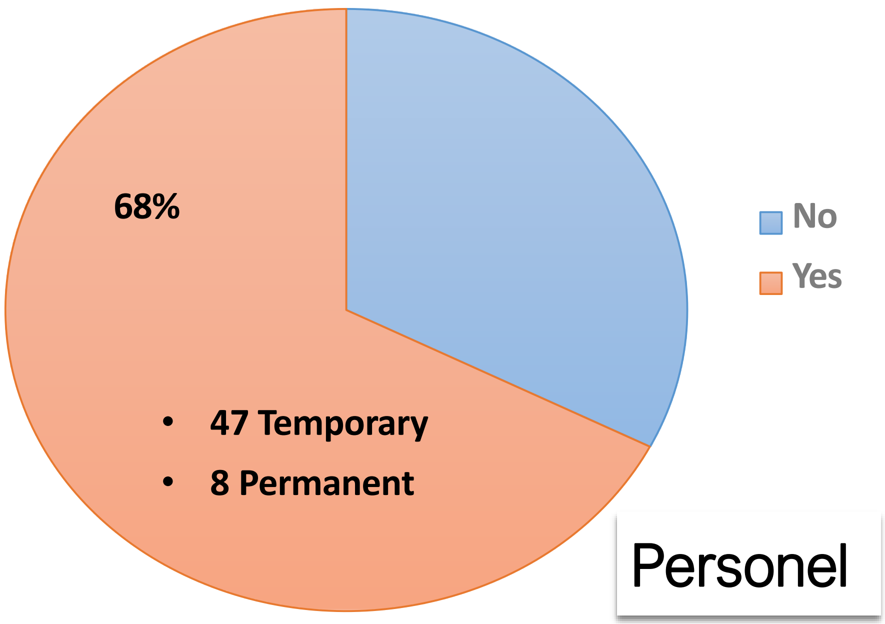
EU 80%

Survey: submission outcome

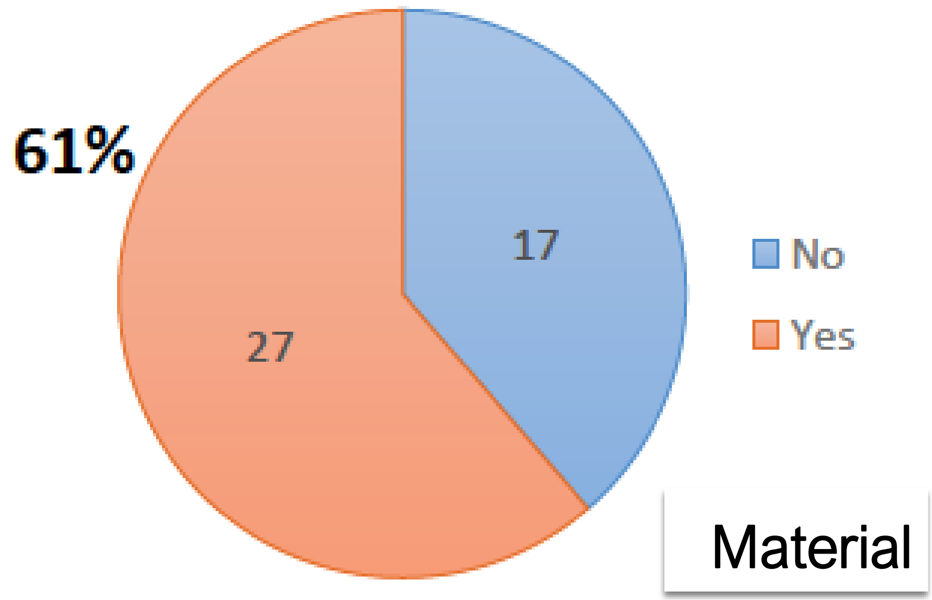
Interest on asking for new resources

OPTIONAL Feedback

Number of Analyzed Submissions : 74, 40 Answers



Number of Analyzed Submissions : 74, 43 Answers



DRD1 Community meeting 1-3 March

Q4-2022/Q1-2023

Wednesday/Thursday, March 1 -2:

- ✓ General Introduction - ECFA roadmap & roadmap implementation
- ✓ General survey outcome

- ✓ **WG1-WG8 (1 hour per session):**
  - WG1 Technologies
  - WG2 Applications
  - WG3 Gas and Material Studies
  - WG4 Detector Physics, Simulations, and Software Tools
  - WG5 Electronics for Gas Detectors
  - WG6 Detector Production
  - WG7 Common Test Facilities
  - WG8 Training and Dissemination

- ✓ **Collaboration issues:**
  - MoU and Common Fund(s)
  - Common Projects
  - Work Packages
  - Structure of the DRD1 Collaboration

Goals and charge to the WG Conveners:

1. Introduction to the topics covered by the WG
2. Analysis and summary of the Survey.
3. Essential aspects from the Survey with relevance/impact in the context of the collaboration (topics, facilities, ideas).
4. Existing assets that can support the collaboration.
5. Existing or potential assets that the collaboration can support.
6. Synergies and common aspects between technologies.
7. For WG2 (applications), overlap with the ECFA roadmap document.

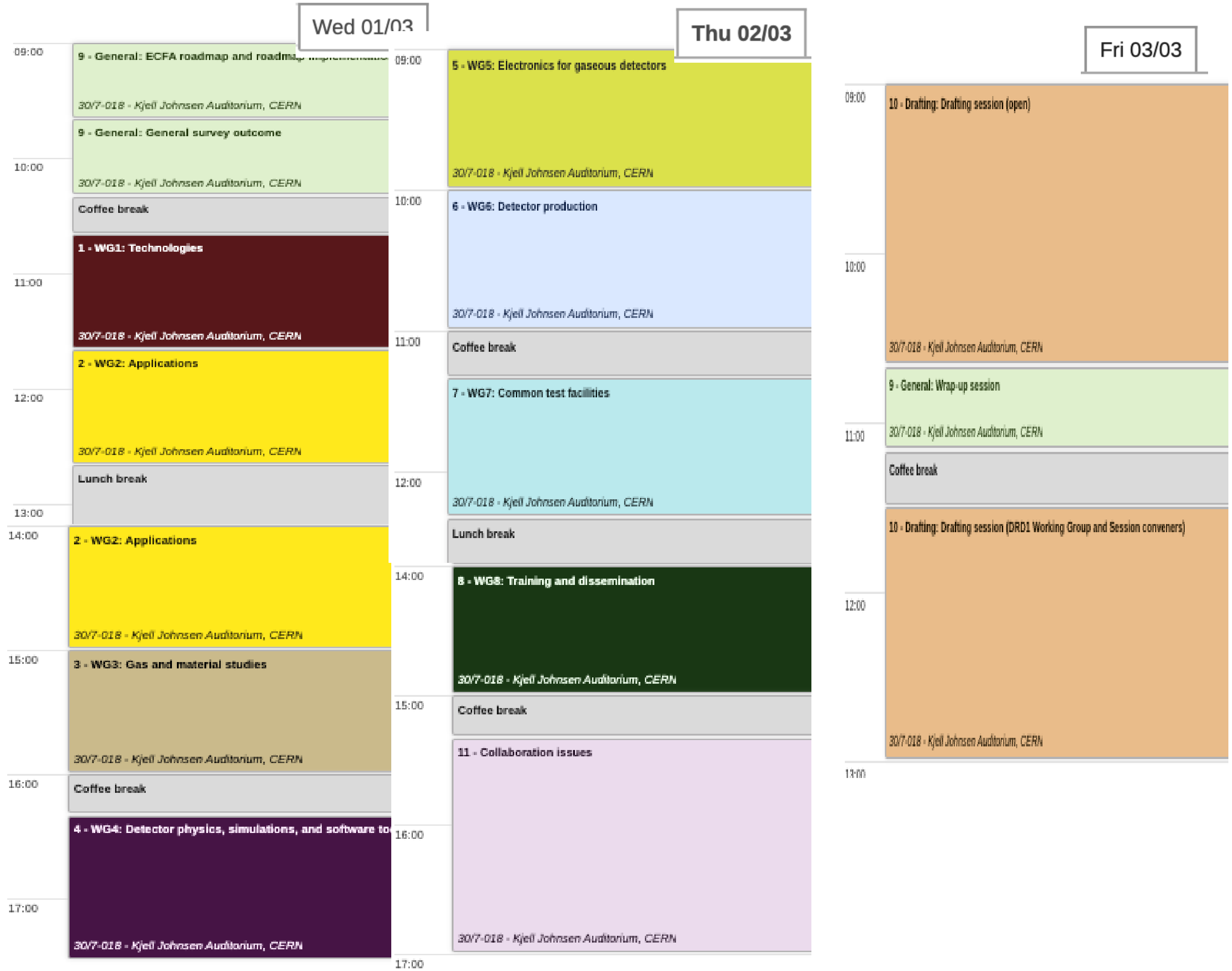
Friday, March 3:

- ✓ Wrap-up (Open and Closed) Discussions
- ✓ Proposal drafting (Skeleton with bullets)
- ✓ Identification of an editorial team for the
- ✓ proposal writing

DRD1 Community meeting 1-3 March

About 220 people registered, mainly connected remotley, about 60 people in the room

- 3 days of presentations and discussion
- Good attendance and participation
- Main discussion on organization
- Interest in “inclusion” of new groups (non European countries) and wide ranges of R&Ds



DRD1 Scientific structure

Community feedback

ECFA DRDT

Applications

Employing gaseous detectors at future facilities

- DRDT1.1
- DRDT1.2
- DRDT1.3
- DRDT1.4

- Inner and central tracking with PID capability
- Photon detection (PID)
- Timing detectors
- Muon system
- Calorimetry
- TPC for rare event searches

Tools and infrastructures

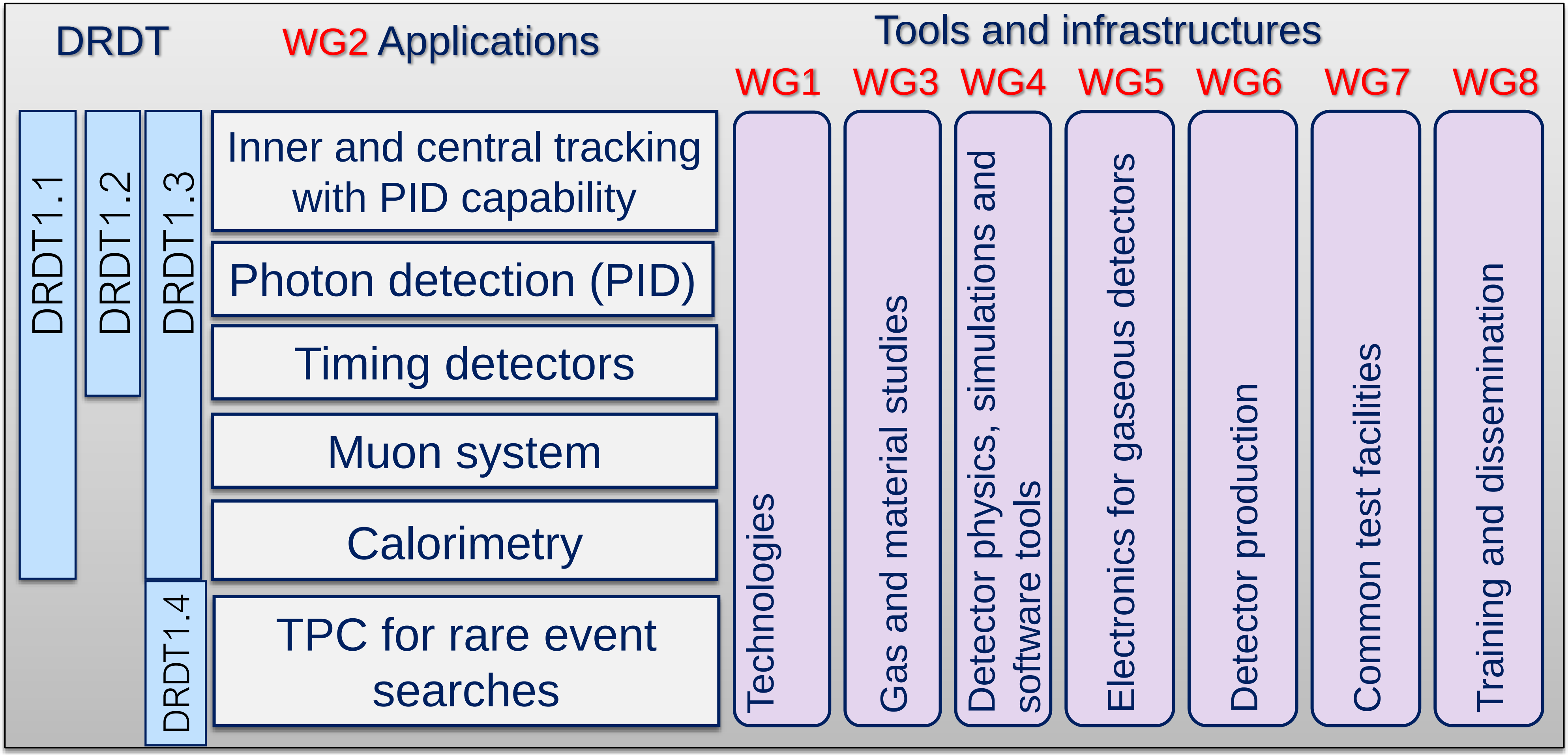
Transverse activities enabling and facilitating the R&D activities: simulation/characterization tools, beam test facilities, industrial partnership, dissemination & networking

- Technologies
- Gas and material studies
- Detector physics, simulations and software tools
- Electronics for gaseous detectors
- Detector production
- Common test facilities
- Training and dissemination

DRD1 Working group

Community feedback

Structure in **WGs, a**lignment with the scientific program of the ECFA roadmap through the applications, related to future facilities challenges outlined by R&D Themes (DRDT), but also to the GSRs



DRD1 scientific organization: Working groups

Working Groups are the core of the scientific collaboration.

- Coordinated by conveners
- Each WG address closely linked activities
- **Sharing experience** (Experiments, Blue Sky and generic R&D, and detector physics studies, production and test procedures)

- **Identifying directions for the future strategic detector R&D** supported by assisting in R&D
  - Look into the future R&D needs
  - Exploit and use synergies with other WGs/DRDs

- **Maintaining an R&D environment** for developing gaseous detector technologies:
  - Gas and material studies, and link to the novel technologies
  - Software tools and detector physics
  - Electronics for gaseous detectors
  - Detector production
  - Infrastructure for detector R&D
  - Training and dissemination

WGs and conveners

WG1: Technologies (**P.Colas**, F. Resnati, P. Wintz, I. Deppner, M. Tytgat, L. Moleri)

Includes experimental detector physics aspects

- MPGDs
- RPCs, MRPCs
- Large Volume Detectors (drift chambers, TPCs)
- Straw tubes, TGC, CSC, drift chambers, and other wire detectors
- New amplifying structures

WG2: Applications (F. Garcia, **P. Gasik**, F. Grancagnolo, D. Gonzalez Diaz, G. Aielli, G. Pugliese, R. Farinelli; A. Colaleo, M. Titov for the ECFA part)

Full alignment with the ECFA detector R&D roadmap Themes

- Muon systems
- Inner and central tracking with particle identification capability
- Calorimetry
- Photon detection
- Time of Flight systems
- TPCs for rare event searches
- Precision experiments
- Straw chambers in vacuum
- Fundamental research applications beyond HEP
- Medical and industrial applications

WG3: Gas and material studies (**B. Mandelli**, G. Morello, F. Renga, K. Dehmelt, S. Roth,D, Piccolo, A. Pastore, B. A. Gonzalez)

- Eco-gases searches
- Light emission in gases
- Ageing
- Radiation hardness
- Light (low material budget) materials
- Resistive electrodes
- Precise mechanics
- Photocathodes (novel, ageing, protection)
- New types of wires (coated carbon monofilaments)
- Solid converters
- Novel materials (nanomaterials)

WG4: Detector physics, simulations, and software tools (M.Abbrescia, M. Borysova, P. Fonte, O. Sahin, **P. Verwilligen**, R. Veenhof,)

- Detector Physics (modeling and simulations)
- Detector Performance Studies (modeling and simulations)
- Software development and maintenance
- Gas Properties Databases (e.g. cross-sections) - Use and/or Maintenance; Detector design

WGs and conveners

Links to GSRs

WG1: Technologies (P.Colas, F. Resnati, P. Wintz, I. Deppner, M. Tytgat, L. Moleri)

Includes experimental detector physics aspects

- MPGDs
- RPCs, MRPCs
- Large Volume Detectors (drift chambers, TPCs)
- Straw tubes, TGC, CSC, drift chambers, and other wire detectors
- New amplifying structures

WG2: Applications (F. Garcia, **P. Gasik**, F. Grancagnolo, D. Gonzalez Diaz, G. Aielli, G. Pugliese; A. Colaleo, M. Titov for the ECFA part)

Full alignment with the ECFA detector R&D roadmap Themes

- Muon systems
- Inner and central tracking with particle identification capability
- Calorimetry
- Photon detection
- Time of Flight systems
- TPCs for rare event searches
- Precision experiments
- Straw chambers in vacuum
- Fundamental research applications beyond HEP
- Medical and industrial applications

WG3: Gas and material studies (B. Mandelli, ... Morello, F. Renga, K. Dehmelt, S. Roth,D, Piccolo, A. ...e, B. A. Gonzalez)

- Eco-gases searches
- Light emission in gases
- Ageing
- Radiation hardness
- Light (low material bu...
- Resistive electrod...
- Precise mecha...
- Photocatho... ...eing, protection)
- New typ... ...ated carbon monofilaments)
- Solid...
- N... (nanomaterials)

GSR 2 - Engineering support for detector R&D

WG4: Detector physics, simulations ... e tools (M.Abbrescia, M. Borysova, P... Sahin, **P. Verwilligen**, R. Veenhof,)

- Detector Physics (mode... ...ations)
- Detector Performanc... ...deling and simulations)
- Software deve... ...aintenance
- Gas Prope... ...s (e.g. cross-sections) - Use and/or Ma... ...etector design

GSR 3 - Specific software for instrumentation

Towards a DRD1 Structure: WGs and conveners

WG5: Electronics for gaseous detectors (H. Muller, **J. Kaminski,** M. Gouzevitch, R. Cardarelli)

- Analog/Digital Electronics
- Discrete Readout Front End Electronics and ASICs
- Charge/Photon readout
- FE input protection & spark quenching
- Waveforms and Digitizer; Signal Processing
- Cluster Counting
- Specific needs: Timing, High rate, Low noise, Wide Dynamic Range,…)
- Grounding and Shielding; Calibration
- SoC based sensor readout
- General purpose DAQ, FPGA based readout/trigger and Trigger-less systems
- HV Systems and HV distribution schemes
- LV Powering, Cooling
- Laboratory instrumentation (High resolution floating ammeters, Monitoring and control systems)

WG8:Training and dissemination (**F. Brunbauer**, M. Iodice, E. Baracchini, B. Liberti, A. Paoloni)

- Schools and trainings
- Topical workshops
- Knowledge transfer
- (Young) Researcher Career
- Strategies to recognize and sustain the careers of R&D experts

WG6: Detector production (R. De Oliveira, **F. Jeanneau,** A. Delbart, G. Iaselli, I. Laktineh, G. Charles)

- CERN EP-DT Micro Pattern Technology (MPT) Workshop
- Saclay MPGD workshop
- RPC/MRPC workshop
- Wire chambers workshop
- Novel detector production methods
- CERN EP Thin Film & Glass service (photocathodes, coatings, ceramic)
- Technology and knowledge transfer (to industry and within the collaboration)
- Relationship with Industry

WG7: Common test facilities (**Y. Tsipolitis**, E. Oliveri, R. Guida, G. Iaselli, A. Ferretti)

Includes development of common detector characterization standards:

- General purpose detector development labs
- Ageing Study Facility
- Gas studies facility
- Irradiation facility
- Test beam facility
- Chemistry and material laboratory
- Clean Room
- Instrumentation for common detector characterization (e.g. gas, DAQ, HV systems)

Towards a DRD1 Structure: WGs and conveners

Links to GSRs

WG5: Electronics for gaseous detectors (H. Muller, **J. Kaminski,** M. Gouzevitch, R. Cardarelli)

- Analog/Digital Electronics
- Discrete Readout Front End Electronics and ASICs
- Charge/Photon readout
- FE input protection & spark quenching
- Waveforms and Digitizer; Signal Pro
- Cluster Counting
- Specific needs: Timing, High ... e, Wide Dynamic Range,…)
- Grounding and Shieldi
- SoC based sensor
- General purpos ... based readout/trigger and Trigger-less
- HV Syste ... tribution scheme
- LV Po ... g
- La ... nentation (High r... am... onitoring and cont

WG8:Training and diss ... **auer**, M. Iodice, E. Baracchini, B. Liberti

- Schools and t
- Topical wo
- Knowle
- (Yo ... reer
- S ... e and sustain the careers of R&D experts

WG6: Detector production (R. De Oliveira, **F. Jeanneau,** A. Delbart, G. Iaselli, I. Laktineh, G. Charles)

- CERN EP-DT Micro Pattern Technology (... orkshop
- Saclay MPGD workshop
- RPC/MRPC workshop
- Wire chambers workshop
- Novel detector production ...
- CERN EP Thin Film & C... rvice (photocathodes, coatings, ceramic)
- Technology and ... ge transfer (to industry and within the collabor
- Relation ... Industry

WG7: Common test facilities (**Y. Tsipoli** ... eri, R. Guida, G. Iaselli, A. Ferretti)

Includes development of common ... terization standards:

- General purpose detect ... labs
- Ageing Study Facility
- Gas studies facili
- Irradiation fac
- Test beam
- Chemi ... al laboratory
- Cl
- ... n for common detector characterization (e.g. ga ... HV systems)

GSR 2 - Engineering support for detector R&D

GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts

GSR 9 - Industrial partnerships

GSR 1 - Supporting R&D facilities

Organization of the collaboration activities

Community feedback

following the indication of EDP, identified the folllowing organization of the R&D efforts:

Two areas of Detector R&D :

- ”Blue-sky” R&D (competitive, short-term responsive grants, nationally organised)
- Strategic R&D via DRD Collaborations (long-term strategic R&D lines) (address the high-priority items defined in the Roadmap via the DRDTs)

Common projects

For low-TRL (blue sky) R&D, or other short term generic projects

Funding method:

- Metabolism of each group
- EU, National projects
- DRD1 common fund

Work Packages

Strategic R&D targeting the priority programmes outlined in the updated European Strategy for Particle Physics.

Funding method:

Each institute asks its funding agency and controls the funds

Common projects

Short-term, community supported

Common Projects support **low TRL (blue-sky) R&D** considered of interest by the collaboration, **or generic projects (not related to experiments) that are vital for the community and require** special backing:

- Technology R&D projects towards developments of novel techniques, improvements of existing technologies, characterization methods and dedicated tools;
- Development and optimization for novel applications;
- Improvement of the technology transfer to industry.

This is a well-defined path (RD51 experience)

- DRD1 Common Fund supports them with matching resources from participating Institutes.
- It requires for a minimum number of participating Institutes to encourage collaborative effort between new groups.
- They are limited in time (3 years).
- Support the collaboration is limited (example 20-30k/y) through common fund
- The large number of groups in DRD1 ensures strong R&D

Some Common Projects may evolve to **Work Packages.**

Reviewed by the DRD1 Collaboration

Strategic R&D

ECFA panel requests

Strategic R&D targeting the priority programmes outlined in the updated European Strategy for Particle Physics.

DRD should highlight the following:

- Technologies to be studied and performances to be expected with respect of the set goals
- Key R&D deliverables in the coming three years
- Estimated costing
- List of institutes
- Resources available:
  - Manpower (FTE)
  - Committed budget
  - Additional budget

Strategic R&Ds

Strategic R&D targeting the priority programmes outlined in the updated European Strategy for Particle Physics.

Application

- Defined by ECFA R&D Roadmap

Tasks

focusing on challenges (precise timing, high rates performances, longevity …)

- Connection to ECFA DRDTs

- WG2

Technological areas:

MPGD, RPC, Wire, LDC, TPC..

- WG1

R&D on Sensors, Electronics, Software Tools, Gas Properties studies;

Development of infrastructure and production techniques

Training

- WG3-8

Work Packages

Strategic R&D are organized in Work Packages, group activities of the Institutes with **shared research interests** around **Applications** with a focus on **specific task(s)** devoted to a specific DRDT challenge, typically related to a specific **Detector Technologies and the** development to **specific tool or infrastructure**..

There is no obligation to participate in the WP to be a member of DRD1.

WPs are organized and coordinated internally by participating Institutes:

- should pursue implementation of the milestones and deliverables and execute the workplan outlined in the approved scientific proposal
- funds are **fully controlled and operated by participating Institutes.**
    - **A formal agreement** between participating Institutes, DRD1 management, and the host lab (CERN) is being sorted out by CERN management

Work Packages **take full advantage and may contribute** to the DRD1 scientific program, R&D environment, infrastructure, and R&D tools (electronics, software).

The strategic R&D will be in the focus of the DRDC reviews.

DRD1 Work Packages

Preliminary list of tasks is being prepared associated to each application, according to the fe edback received by the community

DRDT	Applications	Link to WG activities	Milestones/interested institutions
DRDT1.3, DRDT1.2, DRDT1.3	Inner and central tracking with PID capability	• Tools/infrastructures (WGs)	• Task1 – Milestones, Institutions • Task2 – Milestones, Institutions • ….
DRDT1.3, DRDT1.2, DRDT1.3	Photon detection (PID)	• Tools/infrastructures (WGs)	• Task1 – Milestones, Institutions • Task2 – Milestones, Institutions • ….
DRDT1.3, DRDT1.2, DRDT1.3	Timing detectors	• Tools/infrastructures (WGs)	• Task1 – Milestones, Institutions • Task2 – Milestones, Institutions • ….
DRDT1.3, DRDT1.3	Muon system	• Tools/infrastructures (WGs)	• Task1 – Milestones, Institutions • Task2 – Milestones, Institutions • ….
DRDT1.3, DRDT1.3	Calorimetry	• Tools/infrastructures (WGs)	• Task1 – Milestones, Institutions • Task2 – Milestones, Institutions • ….
DRDT1.4	TPC for rare event searches	• Tools/infrastructures (WGs)	• Task1 – Milestones, Institutions • Task2 – Milestones, Institutions • ….

DRD1 Proposal

Q2-2023

DRD1 document in the making

Structure of the document:

- **Executive summary**
- **Research topics and Work plan**
  - 8 sections: one per Working Group
  - WorkPackages described in 3.2
- **Scientific organization**
- **Resource and infrastructures**

DRD1

DRD1 R&D PROPOSAL

Abstract

The proposal document provides a comprehensive overview of the state of the art and challenges for various gaseous detector technologies, as well as a detailed list of R&D tasks grouped into Work Packages (WPs). The latter are related to the strategic R&D programs to which funding agencies might commit, with related infrastructures and tools necessary to advance the technological goals, as outlined in the ECFA R&D roadmap. The main DRD1 document is structured into chapters, each describing the activity planned by the eight Working Groups (WG), which are the core of the future scientific organization. The current DRD1 proposal concentrates on the collaboration research program for the next 3 years.

Please, pay particular attention to your institute's research interests in chapter 3.2 devoted to applications, which is fully aligned with the ECFA Detector R&D roadmap themes and serves as the basis of the Work Packages.

1

Contents

The draft document already sent to the contact persons
Comments receiving ….

Example for Work Package: Muon system

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3 y	Interested Institutes
T1	New resistive materials (RPC) and production techniques for resistive layers	- Develop low-cost resistive layers (technology dependent) - increase rate capability	WG3 (3.1C, 3.2D), WG7 (7.1-5)	1.1, 1.2	- HPL, low resistivity glass - Semiconductors - Printed resistive patterns	- Design, construction and test of prototypes with new production techniques	INFN-RM2, INFN-PD, KOBE, Pavia
T2	New resistive materials (MPGD)	- Stable up to gains of $\mathcal{O}(10^6)$ - High gain in a single multiplication stage	WG3 (3.1C, 3.2D), WG4, WG7 (7.1-5)	1.2		- Design, construction and test of prototypes with new resistive materials	USTC, INFN-PD, INFN-RM3, INFN-LNF, INFN-FE
T3	New front-end electronics	- 1 fC threshold - High-sensitivity electronics (together with new detector structures) to achieve stable and efficient operation up to $\mathcal{O}$(MHz/cm^2)	WG5, WG7 (7.1,2)	1.1	- Integration of the FEE in the detector Faraday cage - Integration of electronics and readout PCB	- Conceptual electronics design based on gas detector simulation and experimental measurements - Development and test of a front-end prototype	Oviedo, IFIN-HH, INFN-FE
T4	Scalable multichannel readout system	- Front-end link concentrator to a powerful FPGA with possibilities of triggering and $\mathcal{O}$(20 GBit/s) to DAQ	WG5	1.1, 1.2	- FPGA-based architecture - FPGA with embedded processing for triggering and ML - Basic firmware and software can be bootstrapped from existing readout system	- First prototype by end of 2024 for commissioning at test beam	IFIN-HH
T5	Eco-friendly gases	- Guarantee long-term operation - Explore compatibility and optimized operation with high-GWP gases	WG3 (3.1A, 3.1B, 3.2C), WG4, WG7 (7.1-4)	1.1	- Ageing studies - Leak mitigation and maintenance of existing systems	- Test and characterization of gaseous-detection technologies with high-GWP gases (broadly)	CERN, Wurzburg, INFN-BA, INFN-LNF, Pavia
T6	Manufacturing	- Construction of large-area detectors at low cost - Modular design - Technology transfer scheme and training center for production	WG3 (3.2E), WG6, WG8	1.3	- Optimization of the manufacturing procedure to minimize time-consuming or costly steps	- Design and manufacturing of large area detector - Large area DLC production	Heidelberg, USTC, Weizmann, GSI, INFN-LNF
T7	Thinner layers and increased mechanical precision over large areas	- Test to experience the ultimate limits to thinning down the detector	WG3 (3.2E), WG5, WG7 (7.1,2)	1.3			
T8	Longevity on large detector areas	- Study discharge rate and the impact of irradiation and transported charge (C/cm^2)	WG1, WG3 (3.1B, 3.1D, 3.2B), WG4, WG7 (7.1,3)	1.1	- Discharge probability - Ageing		

Challenges for the future muon systems

- Extend state-of-the-art rate capability and longevity by minimum one order of magnitude or more in the highest eta region (up to an order of MHz/cm^2)
- Enable detectors efficiently working with suitable low GWP mixtures
- Two objectives above can be favored in 3 ways:
  - low noise electronics integrated in a highly stable and noise immune Faraday cage
  - detector geometries increasing the signal collection
  - use of innovative resistive material for suppressing discharges on the electrodes.

- Time resolution O(10-100ps) for timing applications in a very high rate collider, (e.g., for identifying bunch-crossing, pile-up mitigation, and improved determination of the particle velocity)

- Large-scale serial production.
- Large series industrializes production

Applications: future electron colliders (ILC, FCC-ee, CepC), Muon collider, Hadron Physics, FCC-hh). Technologies: RPC, Micromegas and GEM, mRWELL, gridsPix, m-PIC, FTM…

See G. Aielli's talk

Example for Work Package: Inner and central tracking

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y	Interested Institutes
T1	Optimize straw materials and technology	- Develop thin films and metallization - Resistance to ageing - Low cross-talk - Establish material relaxation control - Gas leakage control - Compatible with operation in vacuum	WG1, WG3 (3.1C, 3.2B), WG6, WG7 (7.1-4)	1.1 1.2 1.3		- Design and production of materials - Production of straw tubes	CERN, JU-Krakow, U-Manchester, FZJ-GSI-U Bochum, Univ. South Carolina
T2	Develop straw tubes of 5 mm-diameter	- Faster timing (<100 ns) - High rate capability, $\mathcal{O}(100\ \mathrm{kHz/cm^2})$	WG1, WG7 (7.1-3)	1.1 1.2 1.3	- Wire centering - Electrostatic stability - Establish assembly techniques and tools - Straw tracker mechanics	- Film tube production - Establish the technique for straw-tube assembly - Prototype setup	MPP Munich, HUJI, INFN-PV, AGH-Krakow, JU-Krakow, CERN, BURSA, U-Manchester, Univ. South Carolina
	Develop ultra-thin film walls	- < 20 µm thickness - $X/X_0 \sim 0.02\%$ per straw - Film metallization					INFN-PV, JU-Krakow, U-Manchester, Univ. South Carolina
	Develop ultra-long straws (up to 4 m)	- Establish good mechanical properties					HUJI, INFN-PV, JU-Krakow, CERN, U-Manchester, Univ. South Carolina
T3	Optimize straw tracker mechanics	- Develop self-supporting modules - Control relaxation - Develop a method for straw alignment	WG1, WG3 (3.2E), WG6, WG7 (7.1)	1.1 1.2 1.3	- Design of all mechanical tools - QA	- Develop assembly technique, prototype construction	HUJI, JU-Krakow, CERN, BURSA, U-Manchester, FZJ-GSI-U Bochum
T4	Optimization of electronic readout and ASIC development	- Time readout with sub-ns precision - Leading and trailing edge time readout	WG5, WG7 (7.1-2)	1.[illegible]	- Dedicated R&D on ASIC	- ASIC development - Development of readout system	IJCLab/ IN2P3/CNRS, INFN-PV, MPP Munich, HUJI, JU-Krakow, AGH-Krakow, CERN, BURSA, U-Manchester, Univ. South Carolina
T5	3D/4D-Tracking and PID via d*E*/d*x*	- Spatial resolution <150 µm - T_0-determination with $\mathcal{O}(ns)$ resolution - p/K/π-separation <1 GeV/c	WG1 WG4 WG7	1.1		- Development of SW algorithms - Analysis of (in-beam) test data	IJCLab/ IN2P3/CNRS, MPP Munich, INFN-LE, INFN-PV, AGH-Krakow, JU-Krakow, CERN, U-Manchester, ISTINYE, FZJ-GSI-U Bochum
T6	Longevity	- Ageing resistance at >1 C/cm	WG1, WG3 (3.2B), WG7 (7.2)	1.1	Various DRD1 test facilities	Prototype measurements	CERN, JU-Krakow, FZJ-GSI-U Bochum
T7	Software	- Straw tube simulation and calibration - Event simulation - Pattern recognition - Tracking and PID - Tracker alignment	WG4	1.1, 1.2	- Garfield, Geant - Alignment, e.g. Millepede - Real-time processing	- Development of new analysis algorithms and applications to (in-beam) test data	FZJ-GSI-U Bochum, CERN, Univ. South Carolina

Challenges for the straw chambers

- Minimization of the straw diameter down to 5 mm for high rate capability of the order of 100 kHz/cm^2 and drift time below 100 ns;
- Reduction of the thickness of the straw film to below 20 µm aiming at very low X/X_0, which is then comparable to the gas volume of the tube;
- Maximization of the detector straw area to few 10 m^2 by ultra-long straws with 2 cm diameter, up to 4 m length and low material budget;
- Extending the tracking information to 4D (space and t) and dE/dx for PID;
- Extending the application of straw tubes in vacuum to very large volumes (orders of 10m^3);
- Extending the longevity of the detector by increasing the material purity as well as developing new production techniques like ultrasonic welding to minimize the usage of glue.

Applications: future electron colliders (FCC-ee, CepC), FCC-hh, FAIR, Dark Matter, rare event searches, and neutrino physics.

Example for Work Package: Inner and central tracking

See F. Grancagnolo's talk

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y	Interested Institutes
T1	Development of Front-end ASICs for cluster counting	- High bandwidth - High gain - Low power - Low mass	WG5, WG7 (7.2)	1.1, 1.2	- Achieve efficient cluster counting and cluster timing performances	- Full design, construction and test of the first prototype of the front-end ASIC for cluster counting	IHEP, CAS, CNRS, INFN-RM, INFN-LE, INFN-PD, INFN-BA, Stony Brook
T2	Develop scalable multichannel DAQ board	- High sampling rate - Dead-time-less - DSP and filtering - Event time stamping - Track triggering	WG5, WG7 (7.2)	1.1, 1.2	- FPGA-based architecture - ML algorithms-based firmware	- A working prototype of a scalable multichannel DAQ board	IHEP, CAS, INFN-LE, INFN-BA
T3	Mechanics: develop new wiring procedures and new end-plate concepts	- Feedthrough-less wiring - More transparent end-plates ($X < 5\% X_0$)	WG3 (3.1C)	1.1, 1.3	- Separate the wire support function from the gas containment function	- Conceptual designs of novel wiring procedures - Full design of innovative end-plate concepts	USTC, GANIL, IJ-CLab, IN2P3, CNRS, GSI, MPI, INFN-RM, INFN-LE, INFN-BA, INFN-PD, CERN, PSI, Manchester, Stony Brook, IFAE
T4	Increase rate capability and granularity	- Smaller cell size and shorter drift time - Higher field-to-sense wire ratio	WG3 (3.2E), WG7 (7.2)	1.3	- Higher field-to-sense wire ratio allows increasing the number of field wires, decreasing the wire contribution to multiple scattering	- Performance evaluation on drift-cell prototypes at different granularities and with different field configurations	USTC, IJ-CLab, IN2P3, CNRS, MPI, Bose, INFN-RM, INFN-LE, INFN-BA, CERN, PSI, Bursa, Manchester, Stony Brook
T5	Consolidate new wire materials and wire metal coating	- Electrostatic stability - High YTS - Low mass, low Z - High conductivity - Low ageing	WG3 (3.1C)	1.1, 1.2	- Establish contacts with companies producing new wires - Develop metal coating of carbon wires	- Construction of a magnetron sputtering facility for metal coating of carbon wires	GSI, IJCLab, IN2P3, CNRS, INFN-RM, INFN-LE, INFN-BA, CERN, PSI, Manchester, Stony Brook
T6	Study ageing phenomena for new wire types	- Establish charge-collection limits for carbon wires as field and sense wires	WG3 (3.2B), WG7 (7.3,4)	1.1, 1.2	- Build prototypes with new wires as field and sense wires	- Prototype tests in beam and at irradiation facilities - Measurement of performance and dependence on total integrated charge	IJCLab, IN2P3, CNRS, INFN-RM, INFN-LE, INFN-BA
T7	Optimize gas mixing, recuperation, purification and recirculation systems	- Use non-flammable gases - Keep high quenching power - Keep low Z - Increase radiation length - Operate at high ionization density	WG3 (3.1B, 3.2C), WG4, WG7 (7.4)	1.3	- ATEX and safety requirements - cost of gas - Hydrocarbon-free mixtures	- Study the performance of hydrocarbon-free gas mixtures - Implement a complete design of a recirculating system	MPI, INFN-RM, INFN-LE, INFN-BA, PSI, Bursa, Stony Brook

Challenges for the drift chambers

Mechanics:
- new wiring procedures: high granularity resulting in a very large number of wires require novel feedthrough-less approaches to wiring
- new wire materials: High gas gains and electrostatic stability for long wires require lighter and more resistant wire materials. Carbon monofilaments are good candidates, requiring developments in metal coating for increased wire conductivity and ease of soldering.

Electronics:
- front-end: Large bandwidth and high gain pre-amplifiers for efficient application of cluster counting techniques, together low power consumption and low mass, demand designs and implementations of dedicated ASICs.
- DAQ: Waveform digitizers at high sampling rates and without dead time, coupled to FPGA-based data-processing systems, are needed for real-time signal processing, filtering, minimization of data throughput, event time stamping, and triggering purposes.

Gas:
- hydrocarbon-free mixtures: Safety requirements on flammable gases
- recirculation systems

Applications: future electron colliders (FCC-ee, CepC), flavor factories (SCTF)

Example for Work Package: Inner and central tracking

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y	Interested Institutes
T1	IBF reduction	- Gain×IBF ≈ 1-2 - IBF optimization together with energy resolution and discharge stability	WG4, WG7 (7.1-2,5)	1.2	- Hybrid stacks - Gating GEM - Distortion corrections - Space-charge monitoring - Development of simulation tools - Operation in magnetic fields	- Provide a large-area prototype with a uniform IBF distribution of G*IBF=5 keeping the energy resolution at a tolerable level - Present a structure with stable settings for G×IBF of 1-2 - Determine the ion blocking power of a GEM-based gate - Provide systematic studies and simulations of IBF performance for the most common structures in (high) magnetic fields - Introduce an IBF calculator (Garfield-based) for optimization of the HV parameters	IFUSP Sao P., GSI, Uni Bonn, IRFU/CEA, USTC, Uni Tsinghua, KEK, DESY, NIKHEF, GANIL, RWTH Aachen, INFN Padova, IP-PLM Poland, CERN, PSI, Bursa, Stony Brook
T2	Pixel TPC development	- Produce 50000-60000 GridPixes to read out a full TPC - Achieve dN/dx counting-resolution < 4%	WG5, WG7 (7.1-2,5)	1.1	- InGrids (grouping of channels) - Low-power FEE - Optimization of pixel size (>200 µm) or cost reduction	- Provide a large-area pixel-based (InGrid) readout module - Measuring IBF for Gridpix. Reduction with double-mesh - Present dN/dx measurements in beam	Uni Bonn, NIKHEF
T3	Optimization of the amplification stage and its mechanical structure, and development of low X/X_0 field cages (FC)	- Uniform response across the a readout unit area. - Keep $\sigma_{dE/dx} \approx 4\%$ - Point resolution of < 100 µm - Minimize static distortions by reducing insensitive areas - Minimize E×B - Achieve E-field homogeneity at $\sim 10^{-4}$ level	WG1, WG4, WG6, WG7 (7.1-2,5)	1.1 1.2	**Minimization of static distortions:** - Algorithms for distortion corrections - Field shaping wires - Minimize GEM frame area (use thicker GEMs) - Laser systems **Main ampl. stages:** - Encapsulated resistive-anode MMG - Multiple GEM - GridPix - Hybrids **FC:** - high-quality strips, suspended strips - module flatness	- Provide a solution for a large-volume TPC with $\mathcal{O}(10^6)$ pad-readout by means of pre-production of several readout modules of comparable quality	IRFU/CEA, Uni Bonn, IHEP CAS, USTC, GANIL, IN2P3, CNRS, GSI, RWTH Aachen, INFN Roma, INFN Padova INFN Bar, IPPLM Poland, PSI, Bursa, Stony Brook
T4	Low-power FEE	- <5 mW/ch for >10^6 pad TPC - ASIC development in 65 nm CMOS	WG5	1.3	- Continuous vs. pulsed	- Present stable operation of a multi-channel TPC prototype with a low-power ASIC	IHEP CAS
T5	FEE cooling	- Operate 10^6 channels per end-plate	WG5	1.2	- Two-phase CO_2 cooling - Micro-channel cooling with 300 µm pipes in carbon fiber tubes - 3D printing: complex structures, performance optimization, material selection	- Present a prototype of a cooling system for the 10^6 pad TPC option	IRFU/CEA,Lund Univ, INFN Pisa, INFN Lecce, INFN Padova
T6	Gas mixture	Optimize: - Longevity - Ageing - Discharge probability - Drift velocity - Ion mobility	WG1, WG3 (3.1D, 3.2A, 3.2B), WG4, WG7 (7.1-3,5)	1.1	- Discharge probability, ageing, gas properties - Optimization of the HV working point - Optimization wrt. the expected resolution (aim for <100 µm)	- Lower the discharge probability of readout units by 1-2 orders of magnitude down to $\sim 10^{-14}$ per hadron - Avoid secondary discharges in MPGD stacks	CERN, IFUSP Sao P., GSI, TUM, IHEP, GANIL, USTC, IN2P3, IRFU/CEA, CNRS, RWTH Aachen, Uni Bonn, Bose, INFN Roma, INFN Lecce, INFN Padova, INFN Bari, IP-PLM Poland, USC/IGFAE, Bursa, Stony Brook

See P. Colas talk

Challenges for the TPC

- Good dE/dx resolution, partly driven by a good gain uniformity;
- very low gainxIon Back Flow to drastically reduce space charge distortions;
- high readout granularity to cope with the particle multiplicity;
- electronics with low power dissipation to meet the increased density of readout channels.
- large area coverage at reduced low cost, relying on lightweight mechanical structures based on composite materials.

Area of application: future electron colliders (ILC, FCC-ee, CEPC). Timeline: 2035-2040, most of the R&D goals should be reached by 2030 to allow for timely construction.

DRD1 Implementation next steps

Q2-2023

- **17 April - 5 May**: **draft document** preparation including a preliminary **definition of WP**
- **15 May:** Start the community consultation. Draft shared with Institute Contacts.
- **15 May - 1 June**: Proposal Team works on the draft document within working groups, implementing the feedback from the community and preparation of the preliminary version of the Executive Summary with WP tables.
- **1 June:** End of the community feedback about the first draft
- **16 June:** Approval of the document for the community-wide discussion and release to the whole community.
- **22-23 June:** **DRD1 Community workshop** - wide discussions during the community workshop
- **June- July:** Definition of the required resources for the outlined programme need (split into personel effort (FTEs) and material plus services (non-FTE) costs. – institute's inputs
- **End-July:** **Submission of the proposal**

BACKUP SLIDES

46

With the intention to keep lightweight RD51 like MoU and flexibility

Work Packages - funds won, fully controlled, and operated by participating Institutes - **major funding lines** for strategic R&D projects as **identified** (scientific promotion) **by DRD1** (covered by MoU ~~addenda~~ annexes)

- a formal agreement between *participating inst*itutes and DRD1 management and/or host lab
- approved and co-signed by funding agencies
- scope, deliverables, work plan, resources
- coordinated internally by participating institutes, reported to DRD1, and reviewed by DRDC
- WG (software, electronics, ..) activities should be included when possible

Work Packages group activities of the Institutes with shared research interests around **Applications** (TPC, Muon Systems, Calorimetry,..), **Challenges** (Precise timing, High rate, Longevity,..), **Technologies** (Resistive electrodes, Photocathodes,..), **Detector Technologies** (MPGDs, RPCs, Wires,..), **or Working Group tasks** (Electronics, Software tools,..).

Major Common Investments (material, infrastructure) - a similar mechanism to WPs

art. 9.3 of the MoU for the RD-51 Collaboration:

independently from the RD-51 Common Fund, Parties to the RD-51 Collaboration may agree amongst themselves to share costs for common projects, such as the submission of wafer production or other procurements.

8

Proposal for the DRD1 organizzation

- **Collaboration type: Community-driven** with the **R&D environment** (common infrastructures and R&D tools):
- Everything in matters of collaboration is decided and run by the collaboration (including the structure of the work)

- **Scientific organization: Working Groups** structure with mixed technologies, flexibility, and possible parallel configurations addressing closely linked activities:

- **DRD1 funding model:**

- **light-weight** RD51-like **MoU** (focused on collaboration aspects including common fund and fund sharing, organization, and signed by all DRD1 Institutes)
- annexes with **Work Packages** (describing deliverables, work plan, and resources, and signed by participating funding agencies).

Working Group ≠ Work Package !!!

Proposal for the DRD1 organizzation

- **Collaboration type: Community-driven** with the **R&D environment** (common infrastructures and R&D tools):

- **Scientific organization: Working Groups** structure with mixed technologies, flexibility, and possible parallel configurations addressing closely linked activities:

- **DRD1 funding model:**

- **light-weight** RD51-like **MoU** (focused on collaboration aspects including common fund and fund sharing, organization, and signed by all DRD1 Institutes)
- annexes with **Work Packages** (describing deliverables, work plan, and resources, and signed by participating funding agencies).

Working Group $\neq$ Work Package !!!

Roadmap Implementation Brief History

Phil Allport :111th Plenary ECFA

- **CERN Council charged ECFA with developing an implementation plan for the Detector R&D Roadmap recommendations.**
- **Initial proposals, worked out by the Roadmap Coordination Group, were presented and discussed in the Rome RECFA meeting in March 2022, followed by extensive discussions with Funding Agencies and further refinement of the proposals.**
- **The proposed Detector and Accelerator implementation plans were presented to all Funding Agencies at the April 2022 Plenary RRB https://indico.cern.ch/event/1133070/timetable/ by ECFA and LDG Chairs (Karl Jakobs and Dave Newbold).**
  - **Given the diverse funding and costing models for different Funding Agencies it was decided to utilise the existing understood framework for funding long-term investments in particle physics experiments at CERN as the basis for supporting Detector R&D (DRD) collaborations to deliver the multi-decadal Strategic R&D programmes to meet requirements identified by the DRDTs in the Roadmap documents.**
  - **The clear need for "strategic" R&D was emphasised as separate from, but additional to, that for "blue-sky" and "experiment-specific" activities (*see also back-up*).**
- **Slightly updated implementation proposals were then presented during June 2022 Council Week and at Plenary ECFA on 22nd July 2022.**
- **Further refinements of the implementation plan for the Detector R&D Roadmap were discussed over the summer with the Roadmap Panel, CERN management plus RD50, RD51 and CALICE representation.**
- **These led to the September 2022 SPC and Council approved implementation plan: CERN/SPC/1190.**

CERN/SPC/1190
CERN/3679
Original: English
29 September 2022

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Action to be taken		Voting Procedure
For information	SCIENTIFIC POLICY COMMITTEE 330th Meeting 26-27 September 2022	-
For information	RESTRICTED COUNCIL 209th Session 29 September 2022	-

EUROPEAN STRATEGY FOR PARTICLE PHYSICS
DETECTOR R&D ROADMAP

In the context of the implementation of the 2020 update of the European Strategy for Particle Physics, the European Committee for Future Accelerators (ECFA) was mandated by the CERN Council in 2020 to develop a detector R&D roadmap. The 2021 ECFA Detector Research and Development Roadmap was presented to the Council at its meeting in December 2021 and the Council invited ECFA to elaborate a detailed implementation plan.

ECFA hereby invites the Council to take note of the implementation plan that has been developed, as set out in annex 1 of this document.

*community feedback via RECFA delegates and National Contacts

Restricted ECFA

Institutes have to get in touch with the RECFA

Restricted ECFA Composition

https://ecfa.web.cern.ch/restricted-ecfa

Chair	Prof. Dr Karl Jakobs	Appointed Jan. 2021
Secretary	Prof. Patricia Conde Muino	Appointed July 2021

Members		
Austria	Dr Manfred Jeitler	Appointed Jan. 2018
Belgium	Prof. Nick van Remortel	Appointed July 2018
Bulgaria	Prof. Plamen Iaydjiev	Appointed Jan. 2016
Croatia	Prof. Mirko Planinic	Appointed July 2020
Cyprus	Prof. Panos Razis	Appointed Oct. 2017
Czech Republic	Dr Marek Tasevsky	Appointed Jan. 2019
Denmark	Prof. Mogens Dam	Appointed Jan. 2018
Finland	Dr Kati Lassila-Perini	Appointed Jan. 2018
France	Dr Jean-Claude Brient	Appointed Jan. 2020
Germany	Prof. Heiko Lacker	Appointed July 2021
Greece	Prof. Paris Sphicas	Appointed July 2018
Hungary	Dr Ferenc Siklér	Appointed Jan. 2021
Italy	Prof. Chiara Meroni	Appointed July 2020
Israel	Prof. Eilam Gross	Appointed Jan. 2018
Netherlands	Prof. Stan Bentvelsen	Appointed Jan. 2015
Norway	Prof. Alexander Read	Appointed Jan. 2018
Poland	Prof. Justyna Łagoda	Appointed Jan. 2021
Portugal	Prof. Patricia Condes Muino	Appointed July 2020
Romania	Dr Alexandru-Mario Bragadireanu	Appointed Jan. 2019
Serbia	Prof. Peter Adžic	Appointed July 2012
Slovakia	Dr Pavol Stríženec	Appointed May 2016
Slovenia	Prof. Marko Mikuž	Appointed July 2018
Spain	Prof. Celso Martinez	Appointed Jan. 2021
Sweden	Prof. David Milstead	Appointed Jan. 2018
Switzerland	Dr Mike Seidel	Appointed Jan. 2019
Turkey	Prof. Mehmet Zeyrek	Appointed July 2018
United-Kingdom	Prof. Max Klein	Appointed Jan. 2021
Ukraine	Prof. Mykola Shul'ga	Appointed July 2018
CERN	Dr Roger Forty	Appointed Sept. 2015
Ex-Officio Members		
CERN	Dr Fabiola Gianotti Prof. Joachim Mnich	Appointed Jan. 2016 Appointed Jan. 2021
LDG	Prof. Dave Newbold	Appointed Jan. 2021
Observers		
EPS-HEPP Board Chair	Prof. Thomas Gehrmann	Appointed Sept. 2019
ApPEC Chair	Dr Andreas Haungs	Appointed Jan. 2021
NuPECC Chair	Prof. Marek Lewitowicz	Appointed March 2018
Russian Federation	Prof. Victor Matveev	Appointed Jan. 2007
Early Career Researchers (ECR)	Lydia Brenner	Appointed Feb. 2021

*community feedback via RECFA delegates and National Contac

Work Packages

Long-term, Strategic R&D, FA supported

Work Packages group activities of the Institutes with **shared research interests** around **Applications** (TPCs, Muon Systems, Calorimetry,..), **Challenges** (Precise Timing, High-Rate Performance, Longevity,..), **Technologies** (Resistive Electrodes, Photocathodes,..), **Detector Technologies** (MPGDs, RPCs, Wires,..), **or Working Group tasks** (Electronics, Software Tools, Gas Properties...).

Like CPs, **they may start at any time**.
There is no obligation to participate in the WP to be a member of DRD1.

WPs are organized and coordinated internally by participating Institutes.
They define their scope, deliverables, and work plan and describe involved resources.
They are reporting to DRD1 and are reviewed by DRDC.

Involved **funds come from participating Institute's Funding Agencies** through **major funding lines** for strategic detector R&D as identified by the ECFA detector R&D roadmap in compliance with DRD1 scientific program.

Funds are **fully controlled and operated by participating Institutes.**

A formal agreement (DRD1 MoU ~~Addendum~~ Annex) between participating Institutes, DRD1 management, and the host lab (CERN) is requisite **when required by FAs.** In this case, it should be approved and co-signed by Funding Agencies.

Work Packages **take full advantage and may contribute** to the DRD1 scientific program, R&D environment, infrastructure, and R&D tools (electronics, software).

National contacts – CERN Members States through ECFA

Not all countries have a national contact at this stage, i.e. table might be updated while we move forward

If TF convenors seek specific input from the CERN member state countries, these colleagues can be contacted with specific questions and they will organise such as to provide you with an

Country	Name	Function	email
Austria	Manfred Jeitler	RECFA member	Manfred.Jeitler@cern.ch
Belgium			
Bulgaria	Venelin Koshuharov	Sofia University "St. Kl. Ohridski"	Venelin.Kozhuharov@cern.ch
Croatia	Tome Anticic	Rudjer Boskovic Institute	anticic@irb.hr
Cyprus	Panos Razis		razis@ucy.ac.cy
Czech Republic	Tomáš Davídek		davidek@ipnp.mff.cuni.cz
Denmark			
Finland			
France	Didier Contardo	CEA/CNRS contact for France	contardo@cern.ch
Germany			
Greece	Dimitris Loukas	Institute of Nuclear Physics, Demokritos	loukas@inp.demokritos.gr
Hungary	Dezso Varga	Wigner RCP	varga.dezso@wigner.hu
Italy	Nadia Pastrone		nadia.pastrone@cern.ch
Israel	Erez Etzion	Tel Aviv University, head of School of Physics and Astronomy	ereze@tauex.tau.ac.il
Netherlands	Niels van Bakel	head of the R&D group at Nikhef	nielsvb@nikhef.nl
Norway	Gerald Eigen		Gerald.Eigen@ift.uib.no
Poland	Marek Idzik	University of Science and Technology AGH	idzik@ftj.agh.edu.pl
Portugal	Paulo Fonte	Polytechnic Institute of Coimbra	fonte@coimbra.lip.pt
Romania	Mihai Petrovici	Senior Researcher in IFIN-HH, Head of Hadronic Physics Department	mpetro@nipne.ro
Serbia	Lidija Zivkovic		Lidija.Zivkovic@cern.ch
Slovakia			
Slovenia	Gregor Kramberger		gregor.kramberger@ijs.si
Spain	Mary-Cruz Fouz	CIEMAT	mcruz.fouz@ciemat.es
Sweden	Christian Ohm		christian.ohm@cern.ch
Swtizerland	Ben Kilminster	Zurich University	ben.kilminster@physik.uzh.ch
Turkey	Kerem Cankocak	İstanbul Technical University	kerem.cankocak@cern.ch
United-Kingdom	Iacopo Vivarelli		I.Vivarelli@sussex.ac.uk
Ukraine			
CERN	Christian Joram		Christian.Joram@cern.ch

DRD1 Implementation timeline and approval

Q4-2022/Q1-2023 | Q2-2023 | Q3-2023 | Q4-2023

Q4-2022/Q1-2023

- F[illegible] the DR[illegible]sal team
- Colle[illegible] of interest from the in[illegible]vey)
- 1[illegible] and sh[illegible] direc[illegible] RD.
- D[illegible]te re[illegible] agreed wit[illegible] management and EDP – members ap[illegible] begin.

Q2-2023

- Writing the proposal and scientific proposal (~20 pages) that includes conclusions/feedback feedback from the workshop and survey
- Collect feedback by institutes in contact with their funding agencies about the best funding schema
- Mechanisms agreed with funding agencies for country specific DRD funding request.

Q3-2023

End July – submission of the costed proposal:

- resources needed and resources already available
- who covers what (pledges by the institutes/FA)
- DRDC review (scientific, milestones, feasibility, financials)

Q4-2023

- Establishing continuation of existing RD51 projects and carrying resources.
- Follow the review revisions and upon green light from DRDC, CERN research board approves the formation of the collaboration

DRD1 scientific organization: Working groups

- **Collaboration type: Community-driven** with the **R&D environment** (common infrastructures and R&D tools):

- **Scientific organization: Working Groups** structure with mixed technologies, flexibility, and possible parallel configurations addressing closely linked activities:

We propose a reasonable number of work groups dedicated to specific topic of research.

Working Groups are the core of the scientific collaboration.

- Coordinated by the conveners
- **Sharing experience** (Experiments, Blue Sky and generic R&D, and detector physics studies, production and test procedures)

- **Identifying directions for the future strategic detector R&D** supported by assisting in R&D
  - Look into the future R&D needs
  - Exploit and use synergies with other WGs/DRDs

- **Maintaining an R&D environment** for developing gaseous detector technologies:

Detector R&D Roadmap: General Strategic Recommendations

GSR 1 - Supporting R&D facilities

It is recommended that the structures to provide **Europe-wide coordinated infrastructure in the areas of: test beams, large scale generic prototyping and irradiation be consolidated and enhanced to meet the needs of next generation experiments** with adequate centralised investment to avoid less cost-effective, more widely distributed, solutions, and to maintain a network structure for existing distributed facilities, e.g. for irradiation

GSR 2 - Engineering support for detector R&D

In response to ever more integrated detector concepts, requiring holistic design approaches and large component counts, the R&D should be supported with **adequate mechanical and electronics engineering resources**, to bring in expertise in state-of-the-art microelectronics as well as advanced materials and manufacturing techniques, to tackle generic integration challenges, and to maintain scalability of production and quality control from the earliest stages.

GSR 3 - Specific software for instrumentation

Across DRDTs and through adequate capital investments, the availability to the community of **state-of-the-art R&D-specific software packages must be maintained and continuously updated**. The expert development of these packages - for core software frameworks, but also for commonly used simulation and reconstruction tools - should continue to be highly recognised and valued and the community effort to support these needs to be organised at a European level.

GSR 4 - International coordination and organisation of R&D activities

With a view to creating a vibrant ecosystem for R&D, connecting and involving all partners, there is a **need to refresh the CERN RD programme structure and encourage new programmes for next generation detectors**, where CERN and the other national laboratories can assist as major catalysers for these. It is also recommended to revisit and streamline the process of creating and reviewing these programmes, with an extended framework to help share the associated load and increase involvement, while enhancing the visibility of the detector R&D community and easing communication with neighbouring disciplines, for example in cooperation with the ICFA Instrumentation Panel.

Detector R&D Roadmap: General Strategic Recommendations

GSR 5 - Distributed R&D activities with centralised facilities

Establish in the relevant R&D areas a distributed yet connected and supportive tier-ed system for R&D efforts across Europe. Keeping in mind the growing complexity, the specialisation required, the learning curve and the increased cost, consider more focused investment for those themes where leverage can be reached through centralisation at large institutions, while addressing the challenge that distributed resources remain accessible to researchers across Europe and through them also be available to help provide enhanced training opportunities.

GSR 6 - Establish long-term strategic funding programmes

Establish, additional to short-term funding programmes for the early proof of principle phase of R&D, also **long-term strategic funding programmes to sustain both research and development of the multi-decade DRDTs** in order for the technology to mature and to be able to deliver the experimental requirements. Beyond capital investments of single funding agencies, international collaboration and support at the EU level should be established. In general, the cost for R&D has increased, which further strengthens the vital need to make concerted investments.

GSR 7 – "Blue-sky" R&D

It is essential that **adequate resources be provided to support more speculative R&D** which can be riskier in terms of immediate benefits but can bring significant and potentially transformational returns if successful both to particle physics: unlocking new physics may only be possible by unlocking novel technologies in instrumentation, and to society. Innovative instrumentation research is one of the defining characteristics of the field of particle physics. "Blue-sky" developments in particle physics have often been of broader application and had immense societal benefit. Examples include: the development of the World Wide Web, Magnetic Resonance Imaging, Positron Emission Tomography and X-ray imaging for photon science.

Detector R&D Roadmap: General Strategic Recommendations

GSR 8 - Attract, nurture, recognise and sustain the careers of R&D experts

Innovation in instrumentation is essential to make progress in particle physics, and R&D experts are essential for innovation. It is recommended that ECFA, with the involvement and support of its Detector R&D Panel, continues the study of **recognition with a view to consolidate the route to an adequate number of positions with a sustained career in instrumentation R&D** to realise the strategic aspirations expressed in the EPPSU. It is suggested that ECFA should explore mechanisms to develop concrete proposals in this area and to find mechanisms to follow up on these in terms of their implementation. Consideration needs to be given to creating sufficiently attractive remuneration packages to retain those with key skills which typically command much higher salaries outside academic research. It should be emphasised that, in parallel, society benefits from the training particle physics provides because the knowledge and skills acquired are in high demand by industries in high-technology economies.

GSR 9 - Industrial partnerships

It is recommended to **identify promising areas for close collaboration between academic and industrial partners**, to create international frameworks for exchange on academic and industrial trends, drivers and needs, and to establish strategic and resources-loaded cooperation schemes on a European scale to intensify the collaboration with industry, in particular for developments in solid state sensors and micro-electronics.

GSR 10 – Open Science

It is recommended that the concept of **Open Science be explicitly supported in the context of instrumentation**, taking account of the constraints of commercial confidentiality where these apply due to partnerships with industry. Specifically, for publicly-funded research the default, wherever possible, should be open access publication of results and it is proposed that the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP^3) should explore ensuring similar access is available to instrumentation journals (including for conference proceedings) as to other particle physics publications.

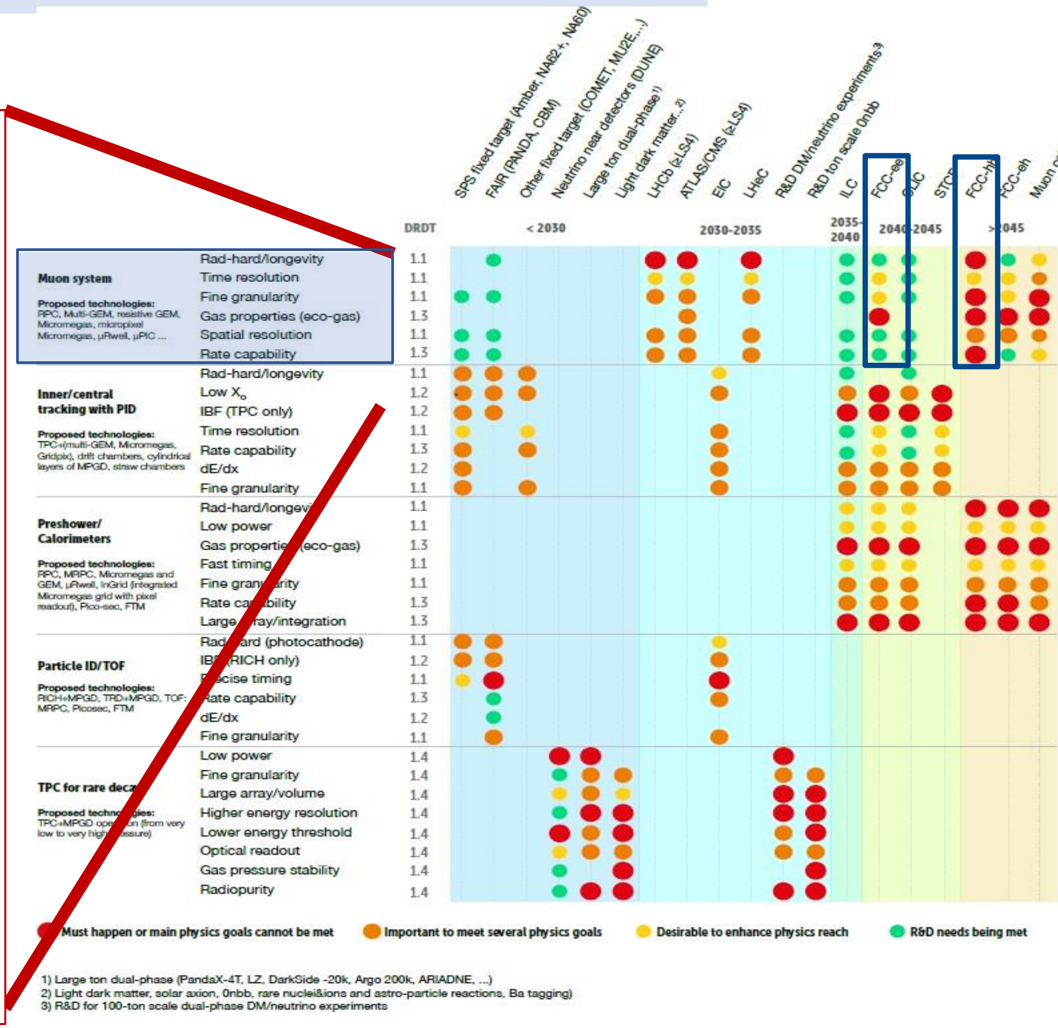
Muon System

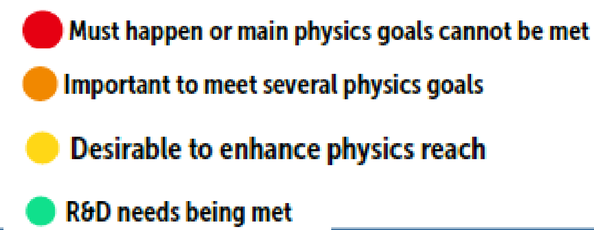
Main drivers from facilities:

Muon systems:

- radiation hardness, longevity and stability
  - O(100 C/cm^2)
  - relevance of discharge studies
- large area (low cost),
- time resolution (< 1 ns)
  - mitigate uncorrelated background and pile-up
- fine granularity
  - Pile-up and space resolution
  - space resolution ➔momentum resolution
- rate capability
  - O (10MHz/ cm^2)
  - Resistive materials

- **FACILITIES:** HL-LHC, EW-Higgs-Top facilities, Mu-collider, hadron physics (EIC and fix target), FCC-hh
- **TECHNOLOGIES:** MPGDs and new (M)RPC

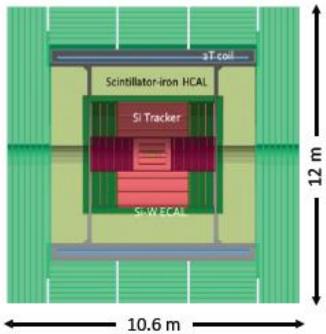




Muon system: FCC-ee

M. Dam,
M. Titov

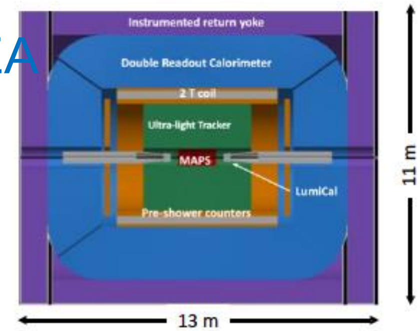
CLD



Based on CLIC detector design; profits from technology developments carried out for LCs

- All silicon vertex detector and tracker
- 3D-imaging highly-granular calorimeter system
- Coil outside calorimeter system

IDEA



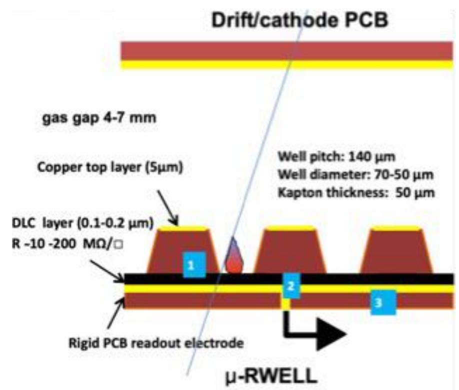
New, innovative, possibly more cost-effective concept

- Silicon vertex detector
- Short-drift, ultra-light wire chamber
- Dual-readout calorimeter
- Thin and light solenoid coil inside calorimeter system

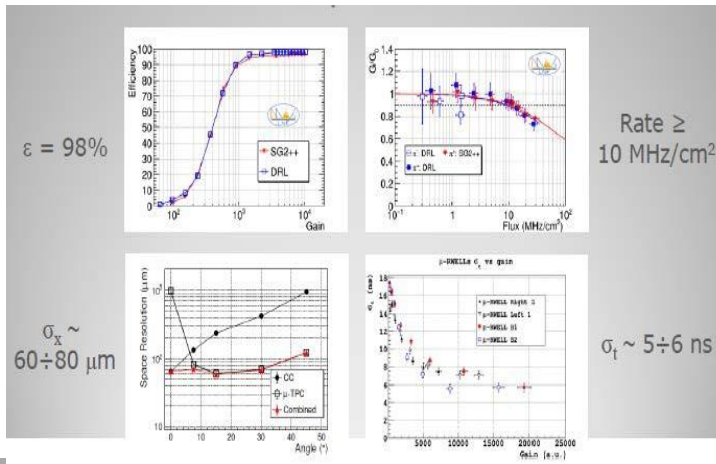
G.Bencivenni

Muon system in instrumented return yoke

- 3-7 layers considered: 3000-6000 m^2
- Proposed technologies
  - RPC (30 × 30 mm^2 cells)
  - µRWell chambers (1.5 × 500 mm^2 cells)
    - Also for IDEA pre-shower detector
    - Ongoing R&D work



G. Bencivenni et al., 2015_JINST_10_P02008



Pre-shower and Muon Detectors

P. Giacomelli

Preshower Detector

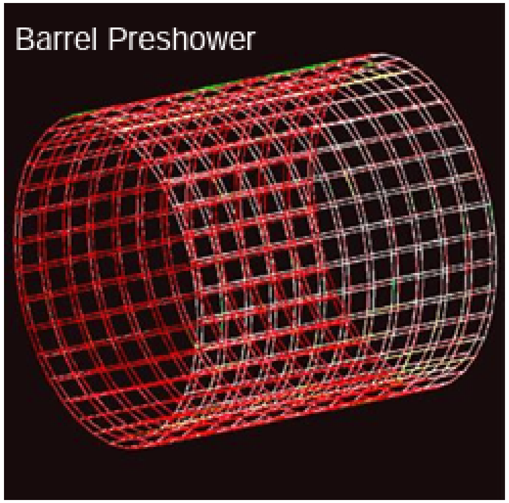
High resolution before the magnet
to improve cluster reconstruction

Efficiency > 98%
Space Resolution < 100 μm
Mass production
Optimization of FEE channels/cost

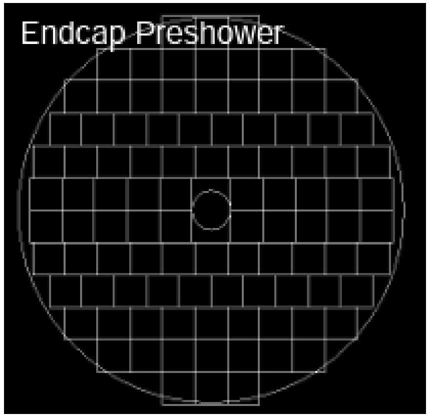
Muon Detector

Identify muons and search for LLPs

Efficiency > 98%
Space Resolution < 400 μm
Mass production
Optimization of FEE channels/cost



Similar design for
the Muon detector



Similar design for
the Muon detector

Detector technology: μ-RWELL

50x50 cm^2 2D tiles to
cover more than 4330 m^2

Preshower
pitch = 0.4 mm
FEE capacitance = 70 pF
1.5 million channels

Muon
pitch = 1.5 mm
FEE capacitance = 270 pF
5 million channels

Inner/central tracking

Main drivers from facilities:

Inner/central tracking with PID capabilities:
- radiation hardness, longevity and stability
- Low X_0
  - New materials as carbon monofilament
- Low IBF (TPC only)
- Time resolution
- dE/dx and Cluster counting:
  - *Grid-Pix, electronics*
- fine granularity
- rate capability

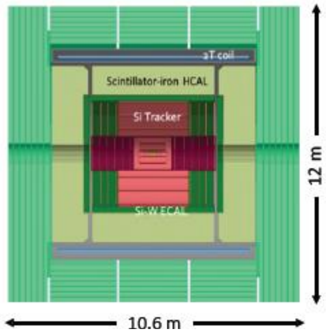
- **FACILITIES:** SCTF, CepC and FCC-ee, hadron physics, rare decays and rare events at accelerators, ν-physics
- **TECHNOLOGIES:** TPC, large volume drift chambers, straw tubes, set of co-axial cylindrical MPGDs

Gaseous central tracking: FCC-ee

Two Complementary Detector Concepts

M.Dam, P.Gasik

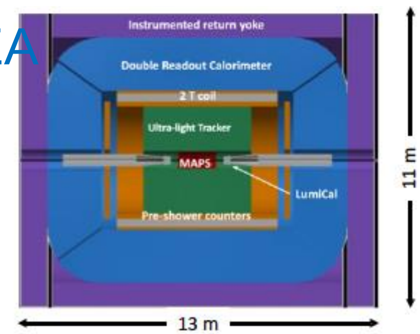
CLD



Based on CLIC detector design; profits from technology developments carried out for LCs

- All silicon vertex detector and tracker
- 3D-imaging highly-granular calorimeter system
- Coil outside calorimeter system

IDEA

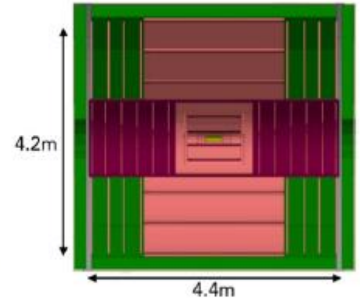


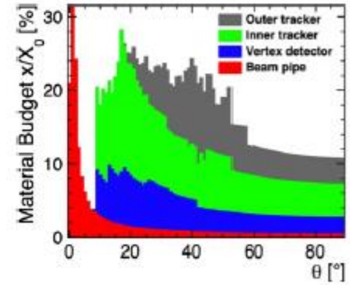
New, innovative, possibly more cost-effective concept

- Silicon vertex detector
- Short-drift, ultra-light wire chamber
- Dual-readout calorimeter
- Thin and light solenoid coil inside calorimeter system

Two solutions under study

- CLD: All silicon pixel (innermost) + strips
  - Inner: 3 (7) barrel (fwd) layers (1% X_0 each)
  - Outer: 3 (4) barrel (fwd) layers (1% X_0 each)
  - Separated by support tube (2.5% X_0)

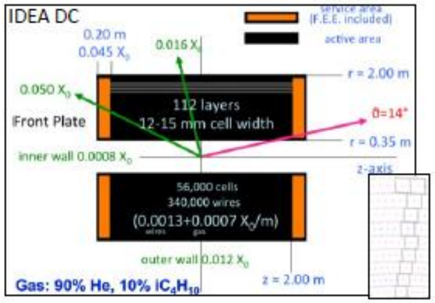


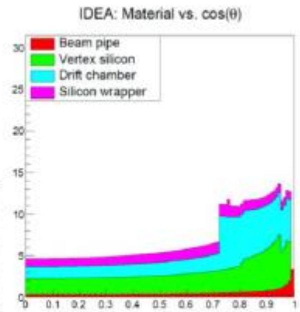


- IDEA: Extremely transparent Drift Chamber
  - GAS: 90% He – 10% iC_4H_{10}
  - Radius 0.35 – 2.00 m
  - Total thickness: 1.6% of X_0 at 90°
    - Tungsten wires dominant contribution
  - Full system includes Si VXTand Si "wrapper"

What about a TPC?

- Very high physics rate (70 kHz)
- B field limited to 2 Tesla
- Considered for CEPC, but having difficulties...



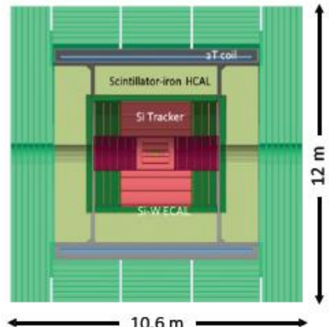


Gaseous tracking: FCC-ee

M.Dam, P.Gasik

Two Complementary Detector Concepts

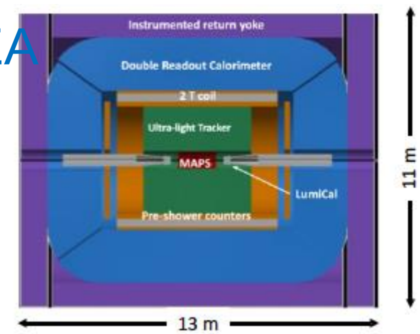
CLD



Based on CLIC detector design; profits from technology developments carried out for LCs

- All silicon vertex detector and tracker
- 3D-imaging highly-granular calorimeter system
- Coil outside calorimeter system

IDEA

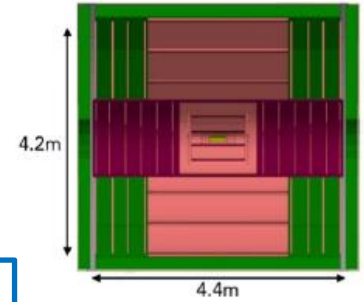


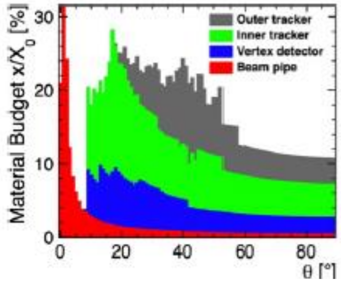
New, innovative, possibly more cost-effective concept

- Silicon vertex detector
- Short-drift, ultra-light wire chamber
- Dual-readout calorimeter
- Thin and light solenoid coil inside calorimeter system

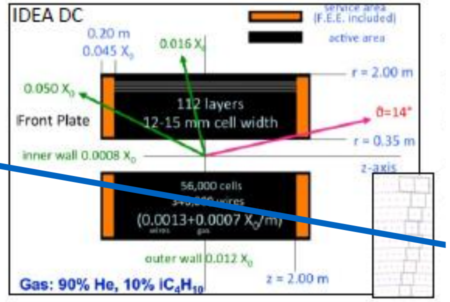
Two solutions under study

- CLD: All silicon pixel (innermost) + strips
  - Inner: 3 (7) barrel (fwd) layers (1% X_0 each)
  - Outer: 3 (4) barrel (fwd) layers (1% X_0 each)
  - Separated by support tube (2.5% X_0)





- IDEA: Extremely transparent Drift Chamber
  - GAS: 90% He – 10% iC_4H_{10}
  - Radius 0.35 – 2.00 m
  - Total thickness: 1.6% of X_0 at 90°
    - Tungsten wires dominant contribution
  - Full system includes Si VXTand Si "wrapper"

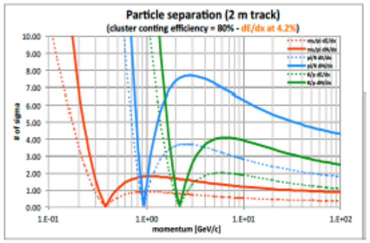


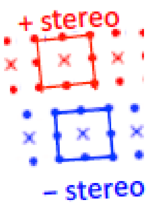
- **Point resolution:**
  - $\sigma_{xy} \leq 100$ µm
  - $\sigma_z = 750$ µm
- **Momentum resolution σ_{p_T}/p_T**
  - ~0.40% @ 100 GeV
  - ~0.25% @ 100 GeV
  - $\sim 0.6 \times 10^{-3} \oplus 4.0 \times 10^{-5} \times p_T$

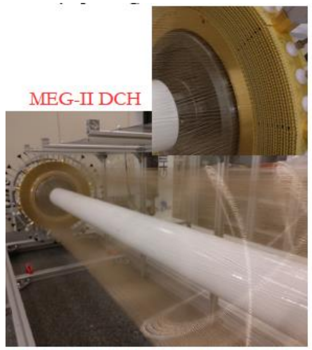
What about a TPC?

- Very high physics rate (70 kHz)
- B field limited to 2 Tesla
- Considered for CEPC, but having difficulties...

- Drift chamber (gaseous tracker) advantages
  - Extremely transparent: minimal multiple scattering and secondary interactions
  - Continous tracking: reconstruction of far-detached vertices (K^0_S, Λ, BSM LLPs)
  - Particle separation via dE/dx or cluster counting (dN/dx)
    - dE/dx much exploited in LEP analyses







High wire densities prevent the use of feed-through, needing novel approaches to the wiring procedures