DRD1 proposal drafting

WG2 Conveners:

- F. Garcia, P. Gasik, F. Grancagnolo, D. Gonzalez Diaz, G. Aielli, G. Pugliese;

- A. Colaleo, M. Titov for the ECFA part

WG2 chapter content

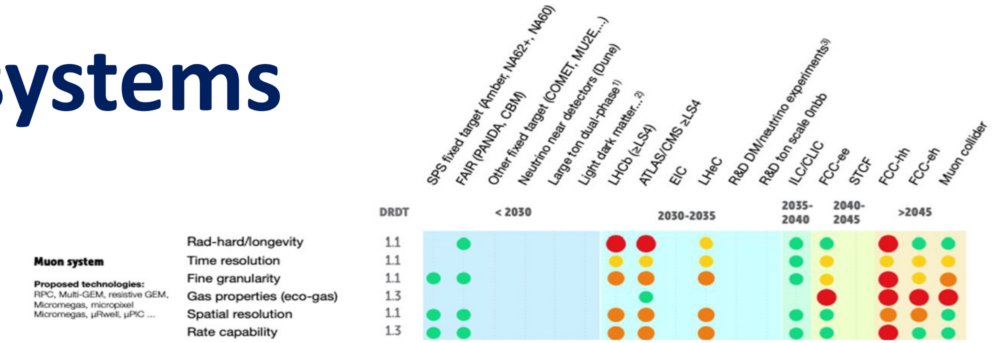
- **Summary of challenges**

  (ECFA compatible but filtered with survey results → define priorities)

- **DRD1 Task proposals** (compatible with ECFA but filtered with survey results)

- **… more?**

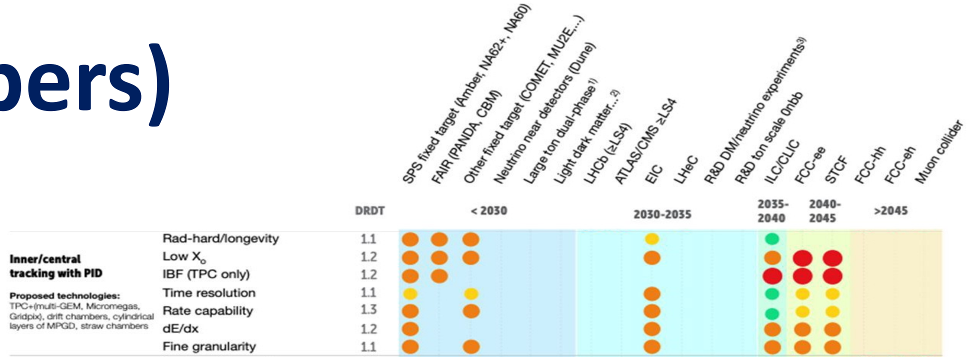
1. (Muon) tracking and triggering systems



Challenges/tasks 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 reliably and efficiently working with suitable low GWP mixtures
- reaching the two objectives above can be favored in 3 ways:
  - low noise electronics integrated in a highly stable and noise immune Faraday cage
  - new detector geometries increasing the signal collection yield
  - use of innovative resistive material for suppressing discharges on the electrodes.
- Time resolution O(20ps) for timing applications and of 200-300 ps to identify the BC in a very high rate collider, to help in cutting the pile up and to boost the ability to measure particle velocity
- large series industrializes production

2. Inner trackers (drift/straw chambers)



Drift Chambers: challenges/tasks

2.1 Mechanics: new wiring procedures, new wire materials

High gas gains ~**5×10⁵**, required for the application of the cluster counting techniques, high granularities (small cell size, order of 1 cm), long wires (order of 4-5 m) and electrostatic stability demand studies on new light materials with high YTS for wires.

2.2 Electronics: on-line, real time data processing algorithms

Waveform digitizers, signal processing for cluster counting exploiting new data processing algorithms

2.3 Hydrocarbon-free gas mixtures / recirculating gas systems

Safety requirements (**ATEX**) on flammable gases and ever-increasing costs of noble gas

Straw Chambers: challenges/tasks

2.4 Mechanics: thinner, smaller diameter, longer straw tubes / mechanical stability

6+6 μm mylar + 3 μm glue wound-type or 25 μm seamless (resistive) type, few mm diameter, several m length / self-supporting structures

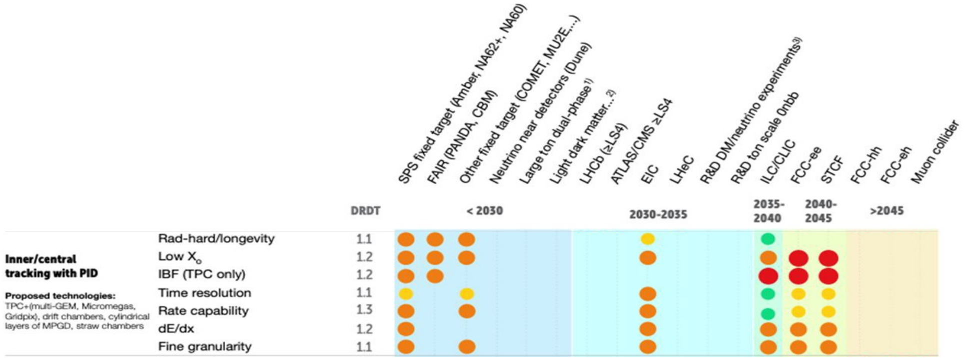
2.5 Material studies

Creep under tension (tension relaxation), gas leakage (operation under vacuum or overpressure)

2.6 Electronics

Leading and trailing time resolution for 4D measurements and for dE/dx with time over threshold

2. Inner trackers (TPCs)

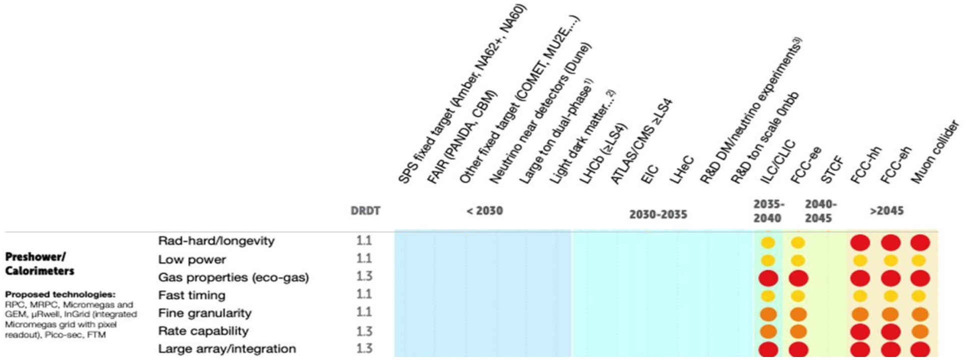


Challenges

- High rate,
- low mass,
- granularity,
- dE/dx & cluster counting
- Ion backflow suppression,
- gas mixture optimization and Eco gas mixtures

Tasks to be defined

3. Calorimetry



Challenges to develop large detector area

- Uniformity of the response and dynamic energy range
- Rate capability (x resistive material detector): 1 kHz/cm^2
- Time resolution O(100ps)

+ Not necessarily for large-area

+ Eco-gas mixture

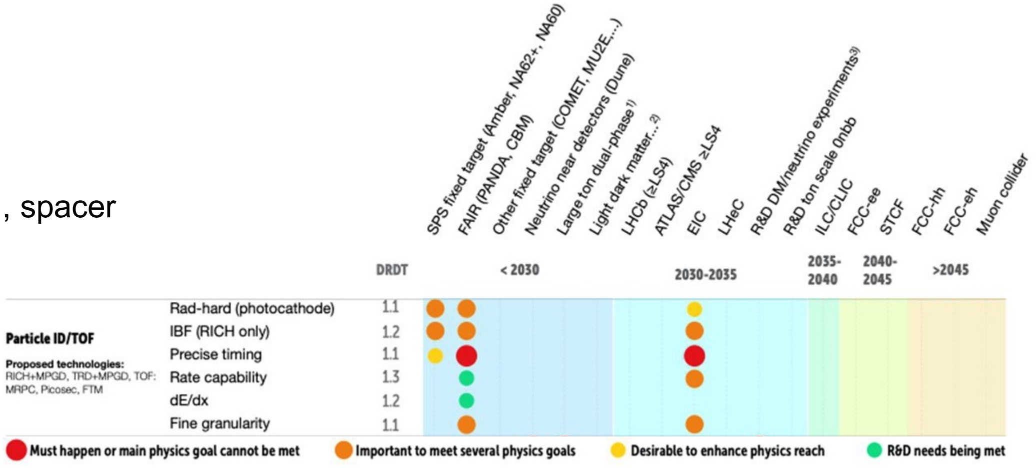
+ Stable performance (gas gain, time resolution, etc)

+ High radiation hardness

4. PID-Photo/ToF

Challenges ToF:

- Uniform rate capability, time resolution, and efficiency over large detector area
- New material for high rate (low res., rad.hard.): uniform gas distribution, spacer material, spacer geometry, thinner structures: mechanical stability and uniformity
- Eco-gas mixture, Gas recuperation systems
- Electronics: Low noise, fast rise time, sensitive to small charge



Challenges photodetectors:

- Preserve the photocathode efficiency by IBF and more robust photoconverters
- Very low noise, large dynamic range of the FEE
- Separate the TR radiation and the ionization process

4. PID-Photodetectors

Task 4.1: Development of large-area, high-rate, timing MRPCs

- Goal: rate and timing capabilities. 25 kHz/cm2, σ_t ~ 50 ps

Task 4.2: Development of MPGD-based timing detectors

- Goal: 15-20 ps time resolution, large areas, stability

Task 4.3: Ultra high-rate MRPC development

- Goal: 100-150 kHz/cm^2, σ_t ~ 50 ps , MRPC technology in single cell/channel layout

Task 4.4: Position Sensitive Timing RPCs.

- Development of large area (~m^2) position sensitive (< 1 mm) and timing (< 100 ps) RPCs

Task 4.5: Development of photocathodes for Cherenkov-based timing detectors

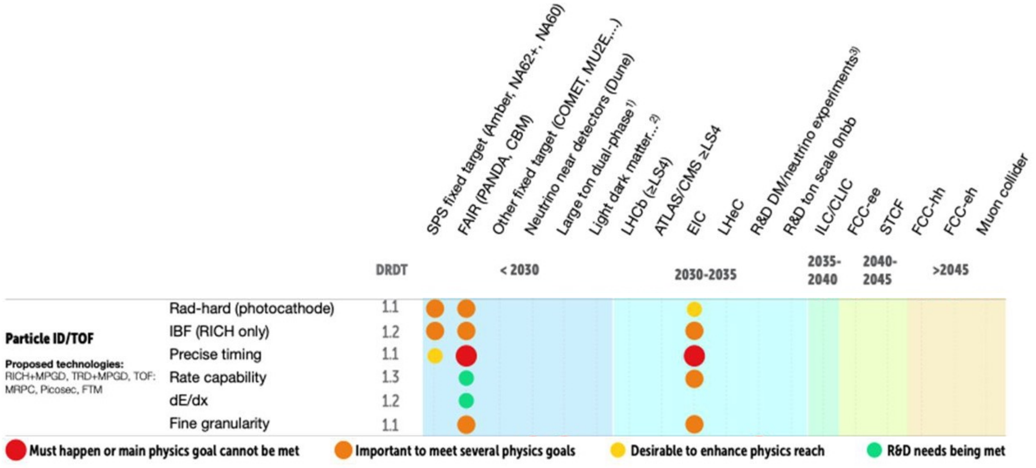
- Goal: preserve efficiency and lifetime

Task 4.6: Development of photoconverters for RICH

- Goal: robust photoconverters compatible with operation in gas detectors (hydrogenated nanodiamonds)

Task 4.7 New generation of TRDs

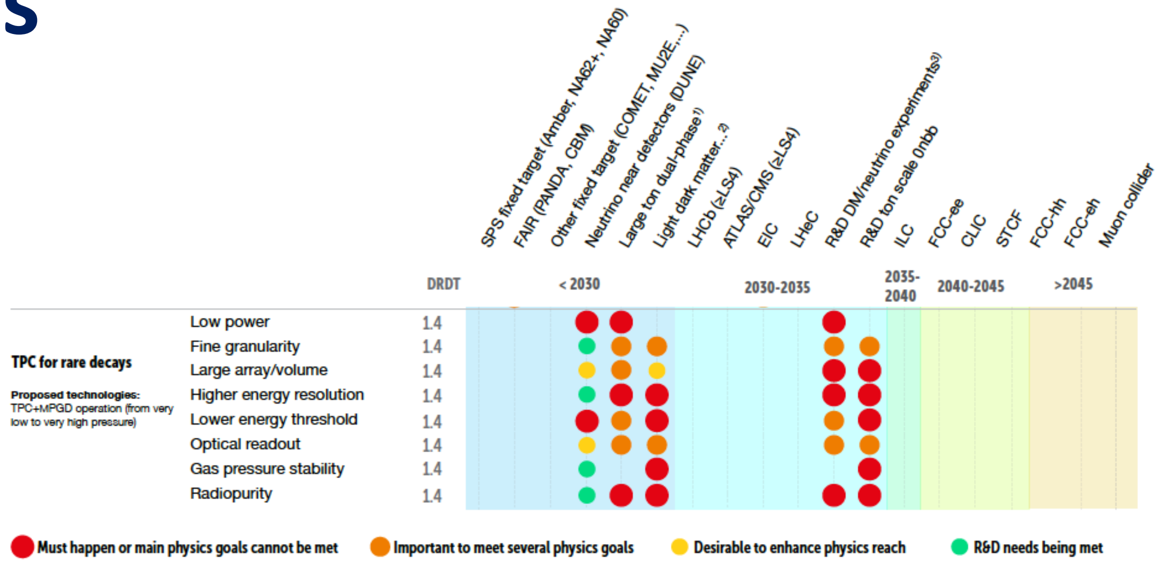
- Goal: differentiate response to X-ray and ionization



5. TPCs for rare event searches

Challenges:

- Reconstruct low-energy nuclear tracks (down to 10 keV energy-scale) with high granularity and close to the thermal diffusion limit.
- Low energy threshold (keV or less) far from atmospheric pressure (10mbar-20bar).
- Reach the intrinsic energy resolution limit of the gas (Fano factor).
- Achieve high optical gain across pressures and gas mixtures.
- Potentially achieve single-electron sensitivity.
- Develop radiopure amplification structures.



5. TPCs for rare event searches (tasks)

Task 5.1: Nuclear Recoil reconstruction (gas mixtures, structures, electronics, simulation)

- Goal: establish O(10keV) nuclear-track sensitivity close to the thermal diffusion limit, with O(100um) 3D reconstruction, and z-determination capabilities in conditions of scientific interest

Task 5.2: Optical readout in large volumes (gas mixtures, dual-phase, scintillation studies, structures, photon sensors, simulation)

- Goals: establish stable optical gain in the range 10^4-10^5 (10^3-10^4) ph/e for gas mixtures (and pure-noble gases) in conditions of scientific interest. Develop new T0-determination schemes based on scintillation.

Task 5.3: Radiopurity (isotope purification, material selection, radiopurity of amplification structure)

- Goal: increase radiopurity levels by a factor of at least x10 relative to today's levels.

Task 5.4: TPCs at the physical limit (single-electron sensitivity, Fano factor -level resolution, low energy threshold across pressures, high purity in large volumes, new geometries)

- Goal: achieving few-electron sensitivity, Fano factor –level energy resolution, and high purity (<10% charge loss) in large volumes

6. Beyond HEP

- It is very hard to identify common “Beyond-HEP” challenges because the applications are too different from each other
- We can identify different tasks:
  - 6.1 Single photon MPGD-based detector for medical imaging
  - 6.2 RPC-PET: Development of PET devices based on RPCs providing state-of-the-art PET position resolution (< 1 mm) and moderate efficiency focused on Preclinical-PET and Brain PET.
  - …. (further feedback from the community)

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- **Summary of challenges**

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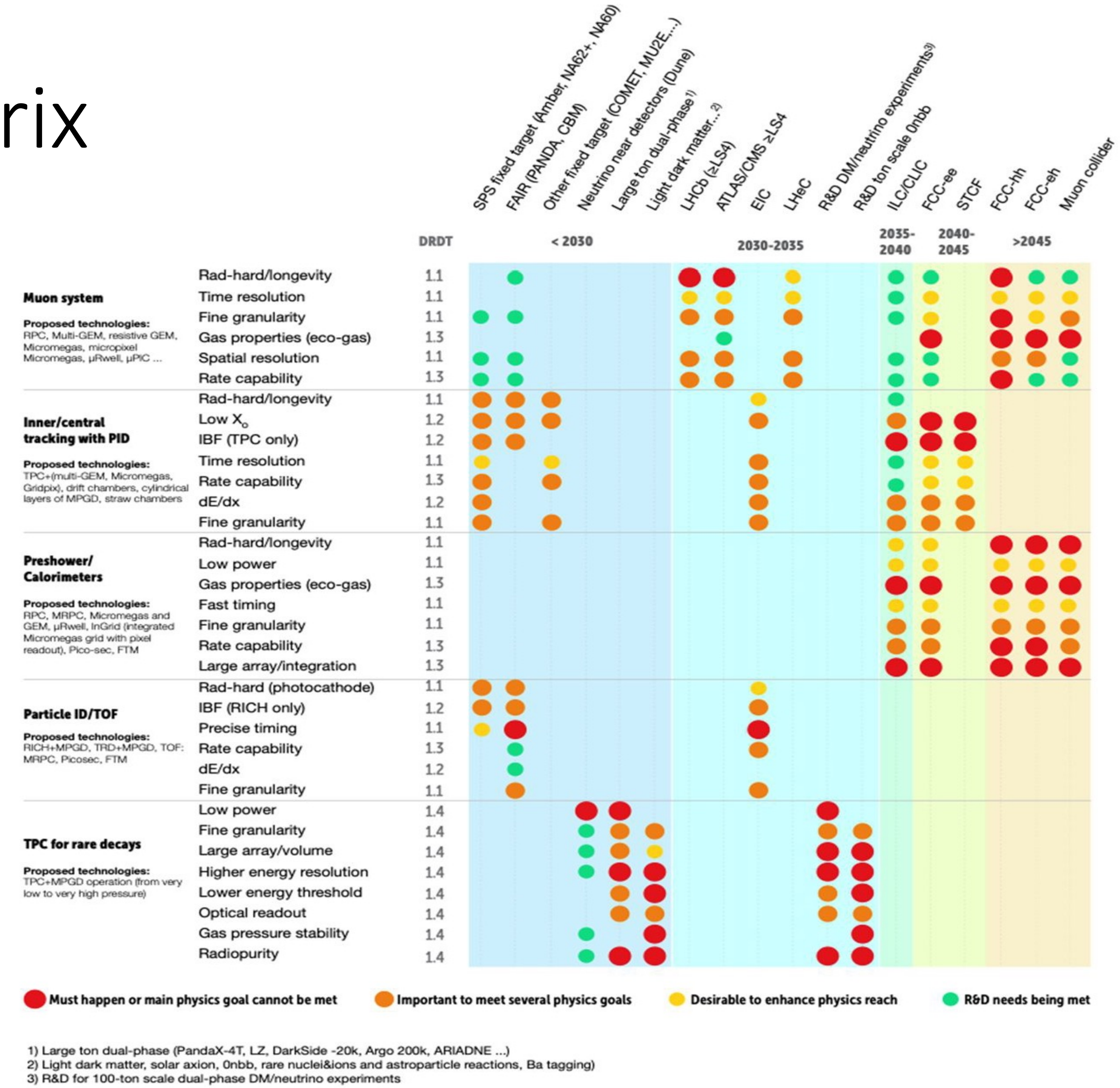
- **New ideas, things we would like to have, challenges not in line with ECFA strategic topics**
  - DRD1/WG2 proposal is not a strict copy of the ECFA roadmap, eventually. Include community feedback about possible cross-tasks, and new ideas for given applications. These could be a topic of common projects (and later strategic R&D). Not all ideas went to the survey (based on ECFA roadmap) → fill this part in the next proposal iterations, together with the community.

Next steps

- Elaborate on priority research topics
- Interact and iterate with the community
- The survey is ongoing – new priority topics may emerge

Backup

ECFA matrix


SPS fixed target (Amber, NA62+, NA60)
FAIR (PANDA, CBM)
Other fixed target (COMET, MU2E...)
Neutrino near detectors (Dune)
Large ton dual-phase 1)
Light dark matter... 2)
LHCb (≥LS4)
ATLAS/CMS ≥LS4
EIC
LHeC
R&D DM/neutrino experiments 3)
R&D ton scale 0nbb
ILC/CLIC
FCC-ee
STCF
FCC-hh
FCC-eh
Muon collider
DRDT
< 2030
2030-2035
2035-2040
2040-2045
>2045
Muon system
Proposed technologies:
RPC, Multi-GEM, resistive GEM, Micromegas, micropixel Micromegas, μRwell, μPIC ...
Rad-hard/longevity 1.1
Time resolution 1.1
Fine granularity 1.1
Gas properties (eco-gas) 1.3
Spatial resolution 1.1
Rate capability 1.3
Inner/central tracking with PID
Proposed technologies:
TPC+(multi-GEM, Micromegas, Gridpix), drift chambers, cylindrical layers of MPGD, straw chambers
Rad-hard/longevity 1.1
Low X0 1.2
IBF (TPC only) 1.2
Time resolution 1.1
Rate capability 1.3
dE/dx 1.2
Fine granularity 1.1
Preshower/ Calorimeters
Proposed technologies:
RPC, MRPC, Micromegas and GEM, μRwell, InGrid (integrated Micromegas grid with pixel readout), Pico-sec, FTM
Rad-hard/longevity 1.1
Low power 1.1
Gas properties (eco-gas) 1.3
Fast timing 1.1
Fine granularity 1.1
Rate capability 1.3
Large array/integration 1.3
Particle ID/TOF
Proposed technologies:
RICH+MPGD, TRD+MPGD, TOF: MRPC, Picosec, FTM
Rad-hard (photocathode) 1.1
IBF (RICH only) 1.2
Precise timing 1.1
Rate capability 1.3
dE/dx 1.2
Fine granularity 1.1
TPC for rare decays
Proposed technologies:
TPC+MPGD operation (from very low to very high pressure)
Low power 1.4
Fine granularity 1.4
Large array/volume 1.4
Higher energy resolution 1.4
Lower energy threshold 1.4
Optical readout 1.4
Gas pressure stability 1.4
Radiopurity 1.4
Must happen or main physics goal cannot be met
Important to meet several physics goals
Desirable to enhance physics reach
R&D needs being met
1) Large ton dual-phase (PandaX-4T, LZ, DarkSide -20k, Argo 200k, ARIADNE ...)
2) Light dark matter, solar axion, 0nbb, rare nuclei&ions and astroparticle reactions, Ba tagging)
3) R&D for 100-ton scale dual-phase DM/neutrino experiments

ECFA roadmap table 1.8

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: - miniaturisation 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 ● In TRD 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