European Strategy for Particle Physics

PLENARY / **DETECTOR TECHNOLOGIES**

From ECFA Detector Roadmap to DRD Collaborations and beyond

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ECFA Detector Roadmap

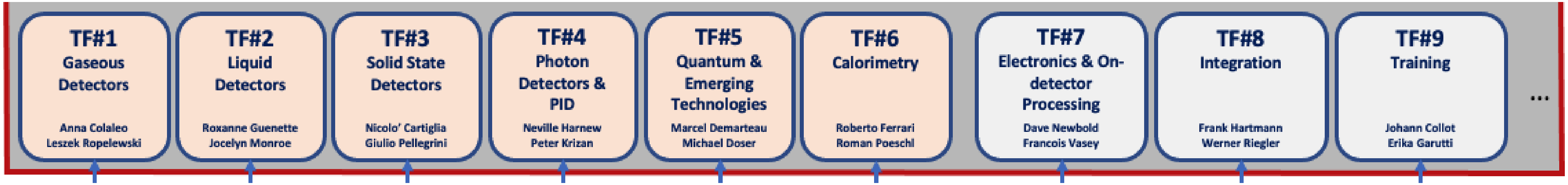
The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels. ***ESPPU 2020***

ECFA detector roadmap released in 2021 with full document (200 pages) and synopsis (~10 pages) based on a **community-driven effort** with many community meetings

The full document can be referenced as **DOI: 10.17181/CERN.XDPL.W2EX**

Document contains:

- Overview of **future facilities** (EIC, ILC, CLIC, FCC-ee/hh, Muon collider) or major **upgrades** (ALICE, Belle-II, LHC-b,…) and their **timelines**
- Ten "**General Strategic Recommendations**" (GSRs) see next slide….
- **Nine Technology domains** with **Task Forces (TF)** areas:
  - The **most urgent R&D topics** in each domain, identified as **Detector R&D Themes** (DRDTs)



General Strategic Recommendations

European Strategy for Particle Physics

Formulated in the ECFA Detector Roadmap as ten "action items"

- **International coordination** and organization of R&D activities (GSR 4)
- Establish long-term strategic **funding programs** (GSR 6) → ongoing
- Support "**Blue-sky**" R&D (GSR 7) → ongoing

DRD Collaborations

- Supporting **R&D facilities**: test beams, large-scale prototyping, irradiation (GSR 1)
- **Engineering support** for detector R&D (GSR 2)
- Specific **software** for instrumentation (GSR 3)
- Distributed R&D activities with **centralized facilities** (GSR 5)
- Attract, nurture, recognize, and sustain the **careers of R&D experts** (GSR 8)
- Establish and maintain **Industrial partnerships** (GSR 9)
- Support **Open Science** (GSR 10)

All topics still valid and highly relevant

From Roadmap to DRD collaborations

- ***Roadmap implementation plan*** defined that CERN will host the DRD collaborations
  - Approved by CERN SPC and Council in fall 2022 (CERN/SPC/1190 ; CERN/3679)
  - New committee created as reviewing body, the DRDC at the same level as LHCC, SPSC and others
- Most of the chapter's convenors ("Task Forces") from ECFA Roadmap process became part of *Proposal Writing Teams* for new DRD collaborations
  - Collected input from the communities in open meetings happening in the first half of 2023
- **Approval of DRD collaborations** by CERN Research Board:
  - DRD1,2 4 & 6 in December 2023
  - DRD3, 5 and 7 in June 2024
  - DRD 8 in December 2024

2021	• ECFA Detector Roadmap
2022	• Roadmap implementation plan
2023	•Q1/Q2: Community input by open meetings •Q3/Q4: Submission and review of proposals
2024	• Approval, then: Collaborations started

The DRD Collaborations

Eight DRD collaborations have been approved for an initial period of 3 years (extendable) with different histories and "maturity":

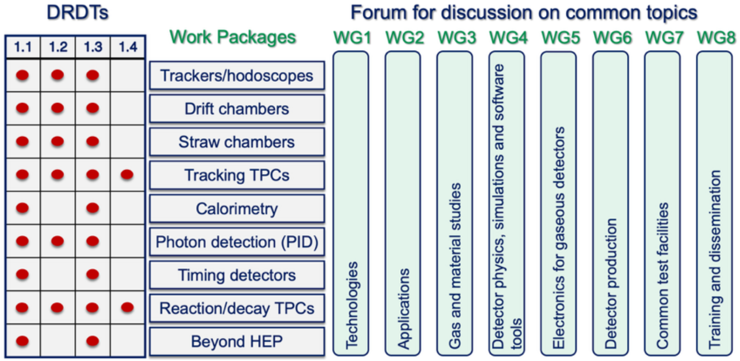
- Based on previous R&D collaborations:
  - **DRD1: Gaseous detectors** (based on RD51): *161 institutes, 700++ people*
  - **DRD3: Semiconductor Detectors** (previously RD42, RD50): *145 institutions / 700++ people*
  - **DRD6: Calorimetry** (CALICE, other proto-experiment collabs.): *135 institutes*

- Completely new: (community building, building trust, and finding benefit of being "CERN hosted")
  - **DRD2: Liquid Detectors:** *86 institutes, 205 members*
  - **DRD4: Photodetectors & PID:** *74 institutes*
  - **DRD5: Quantum Sensors and emerging technologies:** *112 involved groups*

- Transversal activities: no service provider, but with genuine R&D interest (TF9 → ECFA Training Panel)
  - **DRD7: Electronics:** *67 Institutes*
  - **DRD8: Mechanics & Integration:** *38 institutes*

All DRDs in similar shape

- Approved for an **initial period of three years** based on work programs in the proposals
  - Annual review by the DRDC committee
- Collaborations are organized in
  - **Working Groups**: (WG) serving as the backbone of R&D
  - **Work Packages**: resource-loaded; will reflect the DRDTs
- All administrative positions (WP/WG convenors) filled, but most work started in working groups so far
- CERN Greybook entries exist; Users can be registered to DRD collaborations
- Websites for all (but DRD6) exist following the schema https://drd1.web.cern.ch
- Certain DRD collaborations ask for a fixed **yearly membership fee** (Common Fund), targeting common projects, but also blue-sky R&D projects (GSR 7)
  - However, DRD collaborations are not funding proposals!
  - MoU's with resource requests to be signed by funding agencies → ongoing (GSR 6)



DRD1 input proposal #229

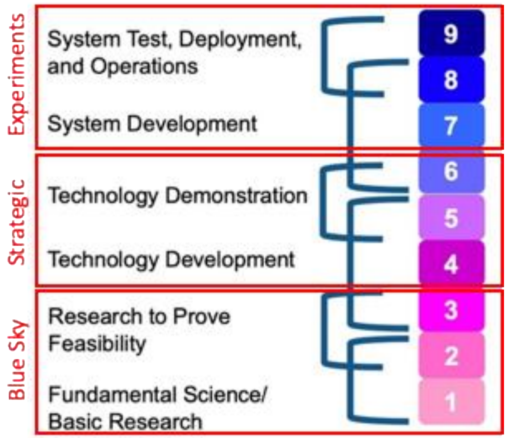
DRDs should cover Strategic R&D

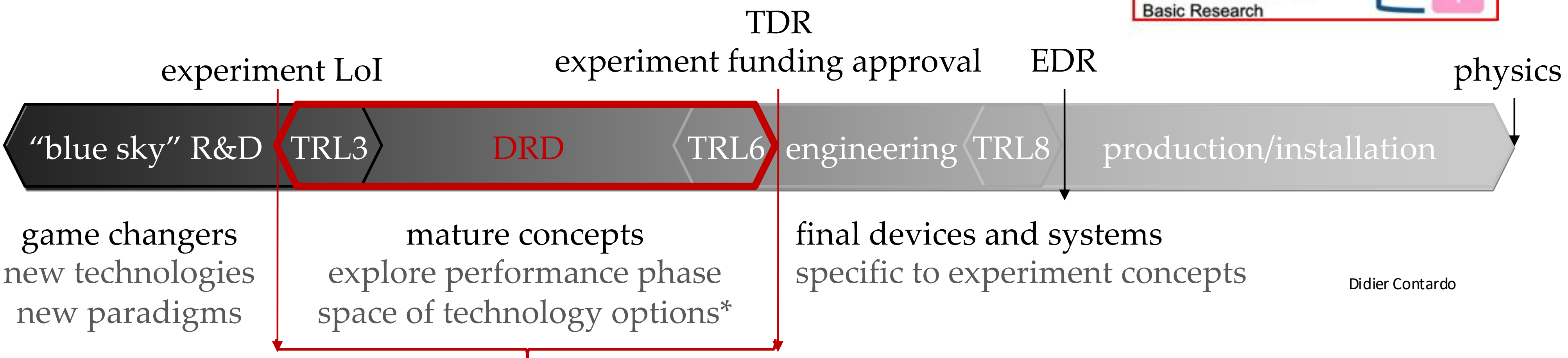
Strategic R&D bridges the gap between the idea ("**blue sky research**", low TRLs) and the **deployment and use in a HEP experiment** (TRL 8-9)

Covers the **development and maturing of technologies**, e.g.

- Iterating through different options
- Improving radiation hardness
- Scaling up challenges: detector area, number of channels, layers,..
- …

„NASA" TRL levels:



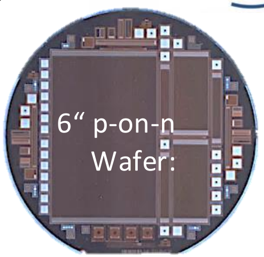


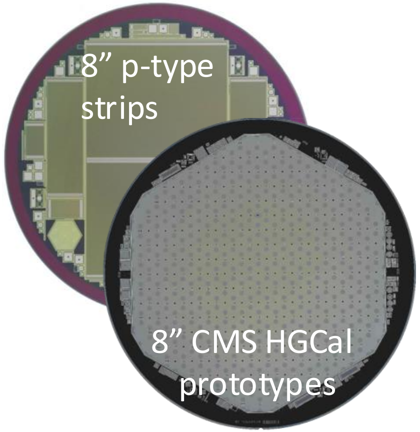
Didier Contardo

Example of the need for strategic R&D

There have been several efforts to establish European semiconductor companies as an alternative to Hamamatsu for large area planar sensors in the past:

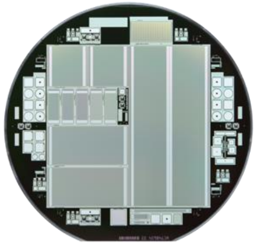
- For “Phase-0” : Several INFN institutes worked with **STMicroelectronics** for p-on-n strip sensors for CMS Outer Tracker
  → Influenced decision for “full silicon tracker” in CMS
- For “Phase-II” Upgrades: 9-year long R&D with **Infineon**: First large strip sensors on 8-inch wafers, first hexagonal pad sensors
  → Pushed HPK into developing 8” process now being used for CMS HGCal





Both projects stopped before becoming a success.

Several more wafer runs would have been necessary to mature the technology and to transfer it to series production → lack of funding



6” CMS PS-S prototypes

Work Program and Scientific Highlights of the DRD collaborations

Eight densely packed slides

ECFA Detector Panel #157

Parallel Talk:
M. Titov

DRD1: Gaseous Detectors

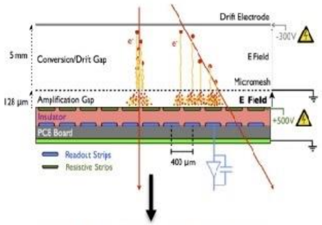
Gaseous Detector Technologies

#229

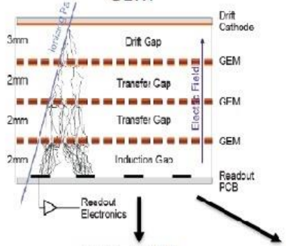
European Strategy for Particle Physics

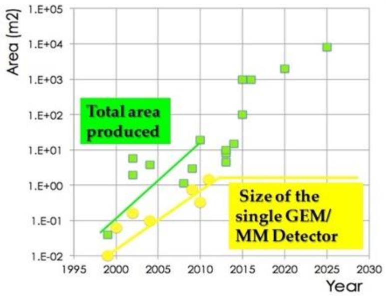
- **Long road** from MWPC → Drift Chamber → Time Projection Chamber (TPC) → Micro-Pattern Gas Detectors (MPGD)
- Primary choice for large-area coverage with low material budget & dE/dx measurement (TPC, Drift chamber) & ToF functionality (MRPC, PICOSEC)
  - Systems developed for LHC experiments led to unprecedentedly large systems, mostly based on MPGDs
  - Most FCC-ee detector concepts use gas detectors for the main tracker and muon systems

MicroMegas (MM)



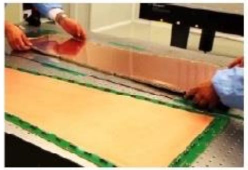
GEM



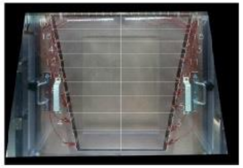


ATLAS new small wheels

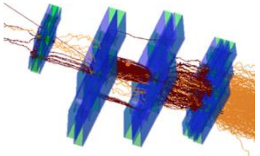
CMS GEM



ALICE TPC upgrade

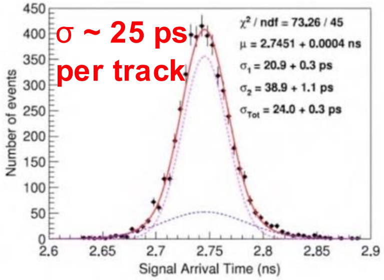


Garfield simulation of 4GEM stack



Working Topics Highlights:

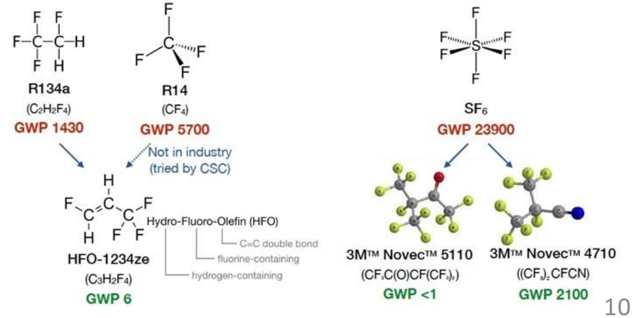
- **High rates:** reduce ion back drift
- **Reduce aging** and radiation hardness
- **Fast Timing:** Multi-Gap RPCs: achieved ~60ps time resolution (ALICE TOF Detector, Z.Liu, NIM A927 (2019) 396), Micromegas with timing (PICOSEC concept): 25ps
- **Eco-friendly gas mixtures:** with lower Global Warming Potential (GWP): 92% of CERN emissions related to LHC experiments
- Common readout system SRS for MPGDs, Beyond HEP



PICOSEC: NIMA903 (2018) 317

Possible alternatives to GHG gases

New eco-friendly liquids/gases have been developed for industry as refrigerants and HV insulating medium... ionisation properties in particle detection not well known



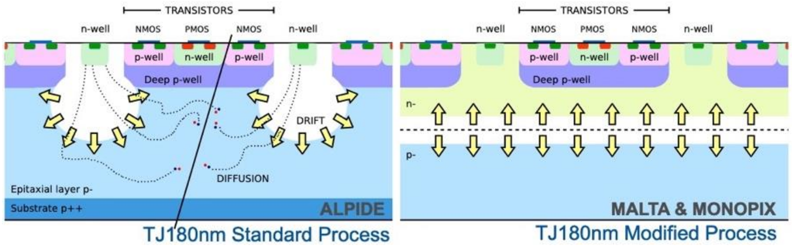
Parallel Talk:
D. Bortoletto

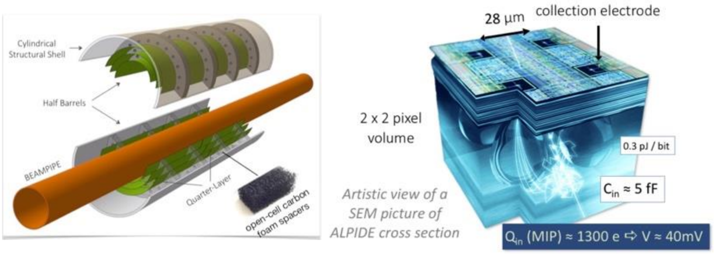
DRD3: Semiconductor Detectors

Higgs factory experiments: low mass, high precision **vertex** detectors: (~0.1% X_0)/layer, 3µm single-hit resolution; ToF wrappers around tracker for PID: ~O(20)ps

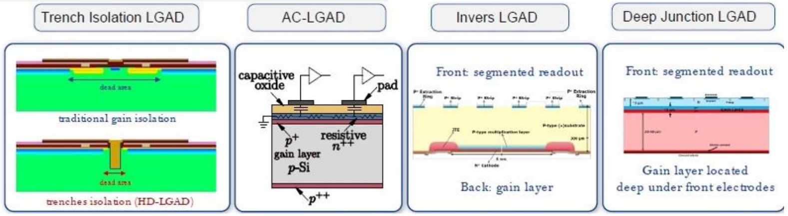
Research Topics in DRD3:

- **CMOS Monolithic Active Pixel sensors** (MAPS):
  - Sensor development becomes mixed-mode chip development,
  - Challenges: access to foundries, engineering workforce
  - Most advanced developments (ALICE) not strongly involved in DRD3, though
- **4D Tracking/ToF**: Timing using Low Gain Avalanche Detectors (LGAD)
  - Timing performance ~ 25 ps, but radiation hardness limited
- **Extreme Radiation hardness**: 3D sensors, wide bandgap sensors, e.g. SiC, GaN and Diamond
  - Activities from RD50 heritage, and for longer-term R&D towards FCC-hh
- **Interconnection technologies**





Different LGAD technologies:



Parallel Talk:
G. Gaudio

DRD6: Calorimetry

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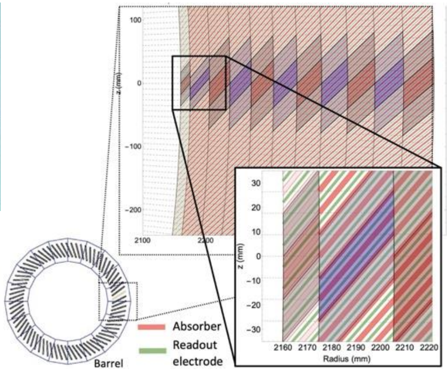
Calorimeters need many technologies from other DRDs

- **Sandwich calorimeters** with fully embedded electronics and CMOS MAPS, SiPM or gas-detector readout
- **Liquified Noble Gas**: ALLEGRO detector concept (lAr with lead)
- **Optical calorimeters**, homogeneous EM with scintillators (BGO, LYSO,..) and SiPM or MCP-PMT readout
- Electronics and DAQ: sophisticated FE chip developments

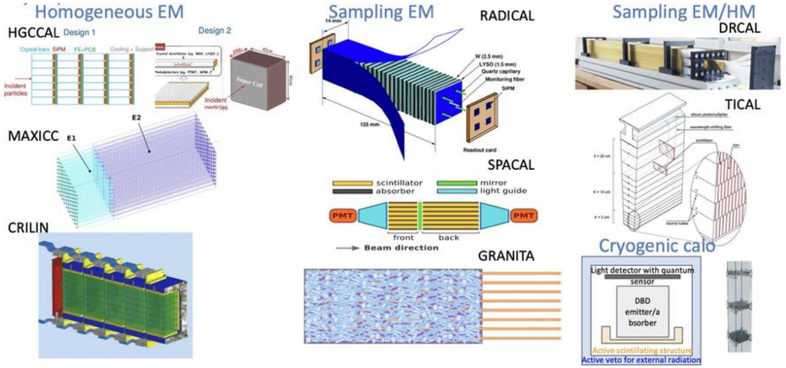


Overarching goals:

- **Dual Readout Calorimetry** to mitigate different response of EM and hadronic showers
- **Particle Flow** to improve jet energy resolution

Challenges:

- High pixelisation, 4π hermetic -> little room for services
- Large and challenging prototype setups, even in early stages. What can be done with simulations?



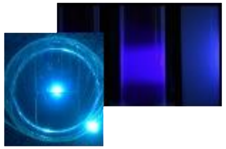
Parallel Talk:
I. Gil-Botella

DRD2 LIQUID DETECTORS Liquid detectors

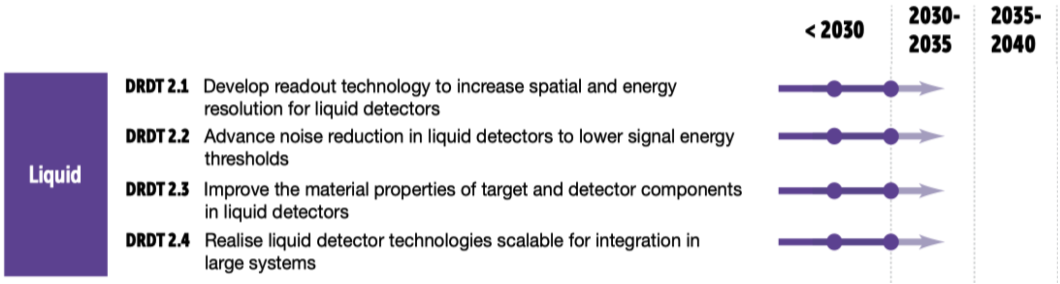
- Covers Dark Matter, Neutrino and 0νßß experiments, both accelerator and non-accelerator-based
- Underground Dark Matter Experiments – small and rare signals
- R&D for multi-ton scale noble liquids:
  - Target doping and purification
  - Detector components radiopurity and background mitigation
  - Lower energy thresholds
  - Efficient and fast cryogenic photodetectors → Increase of light yield and background reduction

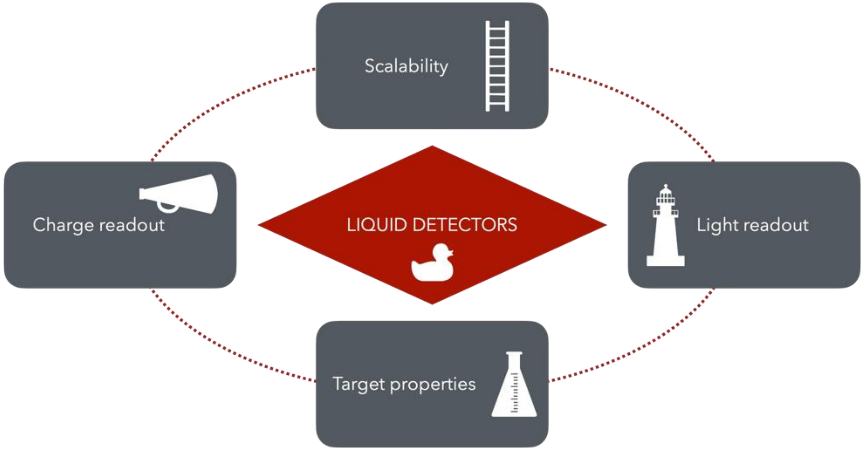
Noble Elements
- Argon & Xenon
- Ionisation charge & transport
- VUV Scintillation, light propagation & detection

Liquid Scintillators
- Visible Scintillation, light propagation
- Scintillator properties
- Isotope loading



Water Cherenkov
- Cherenkov light, light propagation
- Doping for n-capture

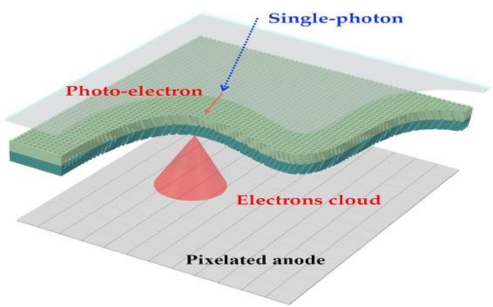


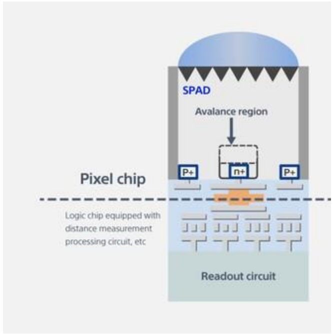


Parallel Talk:
G. Gaudio

Photodetectors & Particle ID

- **Developments** on PMTs, MCP-PMTs, SiPMs, SciFi
- **Applications** in Ring Imaging Cherenkov Detectors (RICH), Time-of-Flight (ToF), TRD and tracking (SciFi)



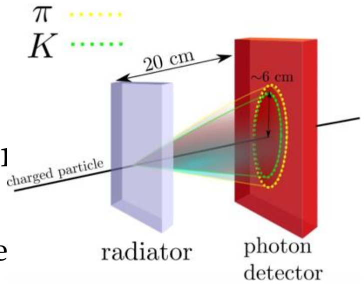


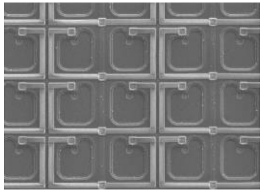
Multi-channel plate PMTs:

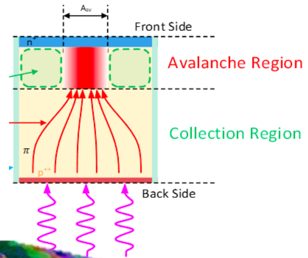
- Comsol simulation package
- E.g. Hybrid detector with Medipix4 readout

Silicon Photomultipliers (SiPMs): Array of APD/SPADs

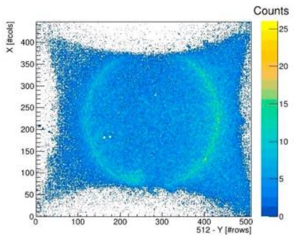
- Many developments, i.e. backside illuminated, integration with CMOS electronics
  - Challenges: improve QE, rad hard, timing, reduce dark count rate
- **Industry interest**: telecommunications, automotive (LIDAR with ToF), with commercial availability (e.g. Broadcom, FBK)

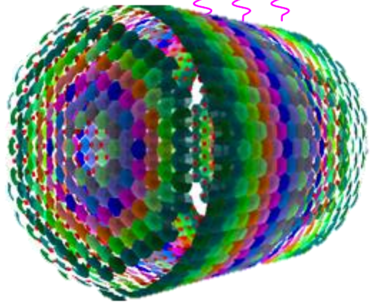






Array of Rich Cells (ARC) concept





Parallel Talk:
M. Doser

Quantum & Emerging Technologies

#204

Quantum Technologies are a **rapidly emerging area** of technology development to study fundamental physics

- Targeting Gravitational Waves, Axion, DM detection on shorter-term
- Development of HEP detectors on the longer term

DRD5: different sensors and technologies being investigated:

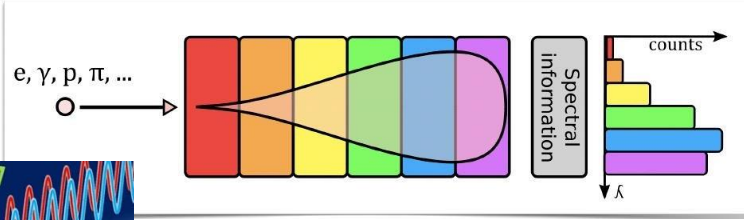
- Novel materials, kinetic detectors, spin-based, superconducting, optomechanical sensors, atoms/molecules/ions, interferometry, …
- Scaling up challenge: single → multi channels
- HEP-relevant topics: Superconducting nanowires, Chromatic calorimetry

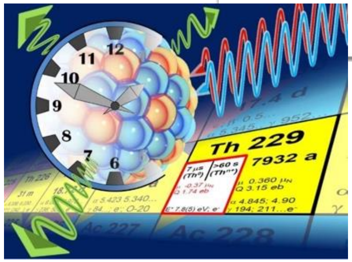
- Many small-scale setups so far. Now first considerations for common infrastructure

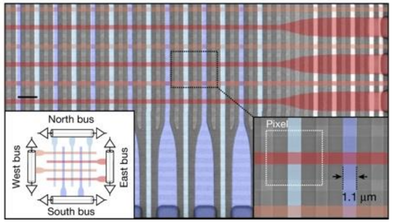
Roadmap topics

Proposal WP's

Sensor family → / Work Package ↓	clocks & clock networks	superconducting & spin-based sensors	kinetic detectors	atoms / ions / molecules & atom interferometry	opto-mechanical sensors	nano-engineered / low-dimensional / materials
WP1 *Atomic, Nuclear and Molecular Systems in traps & beams*	X			X	(X)	
WP2 *Quantum Materials (0-, 1-, 2-D)*		(X)	(X)		X	X
WP3 *Quantum superconducting devices*		X				(X)
WP4 *Scaled-up massive ensembles* (spin-sensitive devices, hybrid devices, mechanical sensors)		X	(X)	X	(X)	X
WP5 *Quantum Techniques for Sensing*	X	X	X	X	X	
WP6 *Capacity expansion*	X	X	X	X	X	X







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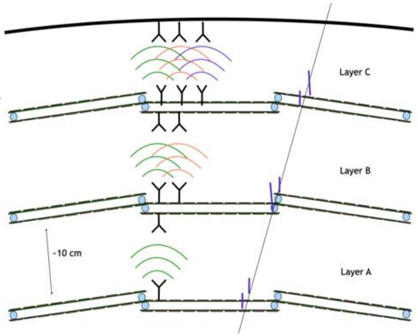
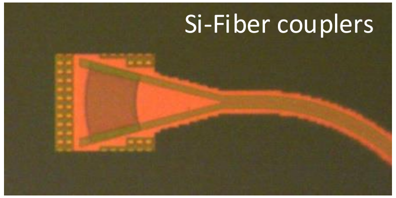
DRD7: Electronics

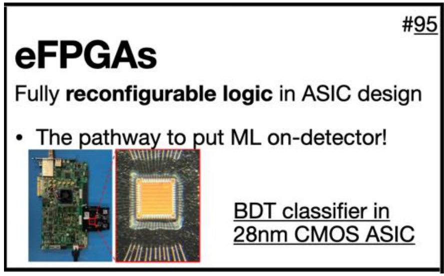
Electronics is vital to any detector system

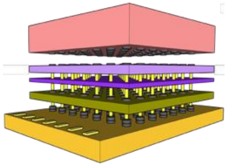
Modern technologies offer tremendous opportunities:

- Transmission speed @100 Gbit/s and beyond
- Extremely high integration density
- Very high-performance FPGAs
- Advanced packaging technologies
- **But the complexity and cost associated to their use do also increase**

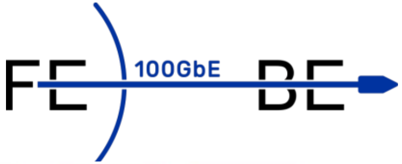


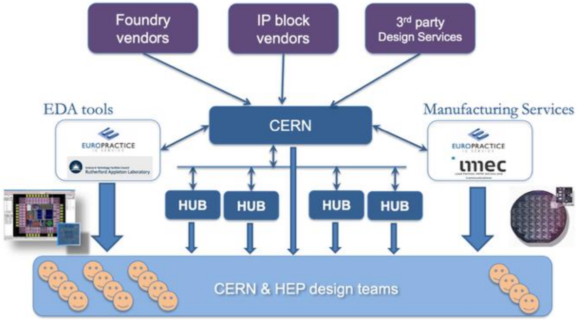






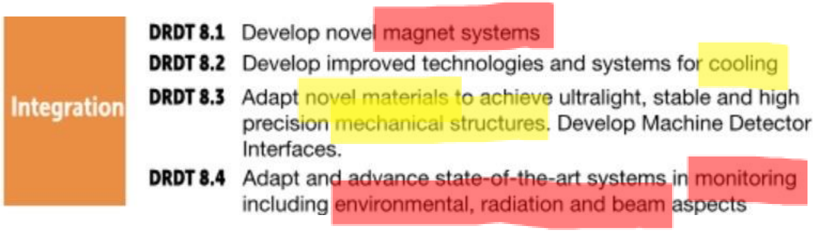
- Work topics in DRD7:
  - **Silicon photonics** transceivers, power distribution, **wireless data transmission** and power, interconnections
  - **Intelligence on the Front-End**: **e-FPGA** and RISC-V SoC
  - COTS and **no-backend solutions**, i.e. directly from FE to DAQ
  - **High Performance ADCs and TDCs** and time distribution
  - **Extreme environments**: cryogenic and radiation-hard electronics
  - **Shared access and hubs** to selected imaging technologies and 3D integration



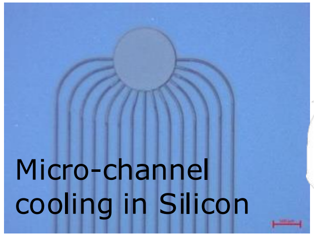


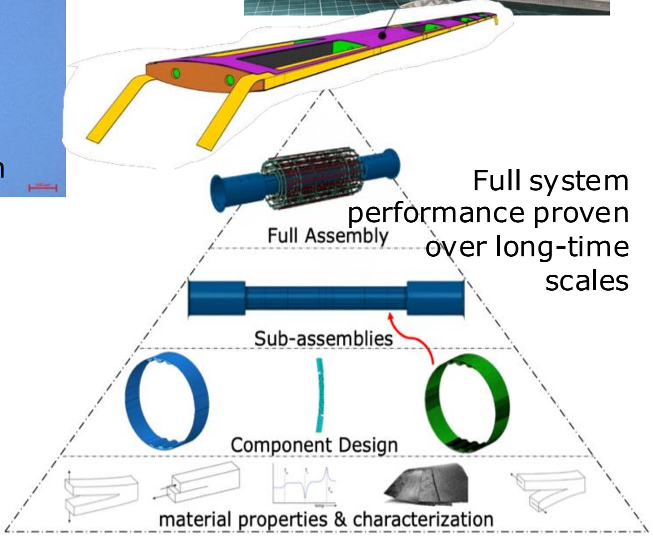
DRD8: Mechanics & Integration

- DRD8 proposal approved by Dec 2024
  - Does not cover all DRDTs, as they are quite diverse
  - Focus on vertex detector mechanics and cooling as emerged from “Forum on Tracker Mechanics” workshop series



- **Advanced materials** and structures for **vertex detectors:**
  - Mechanics for curved sensors, Thin beam pipe, Retractable detectors, MDI, Low-mass hardware, alignment
  - Characterization of Material properties and database
- **Cooling**: Airflow, Evaporative CO_2 and new fluids (Krypton), Microchannel cooling in Si, Cooling tubes welding and material investigations
- **Robots** and **Virtual reality** to simulate/remote control access in restricted areas
- **Software** tools to connect engineering design with physics simulation (e.g. connect GEANT4 with CAD)



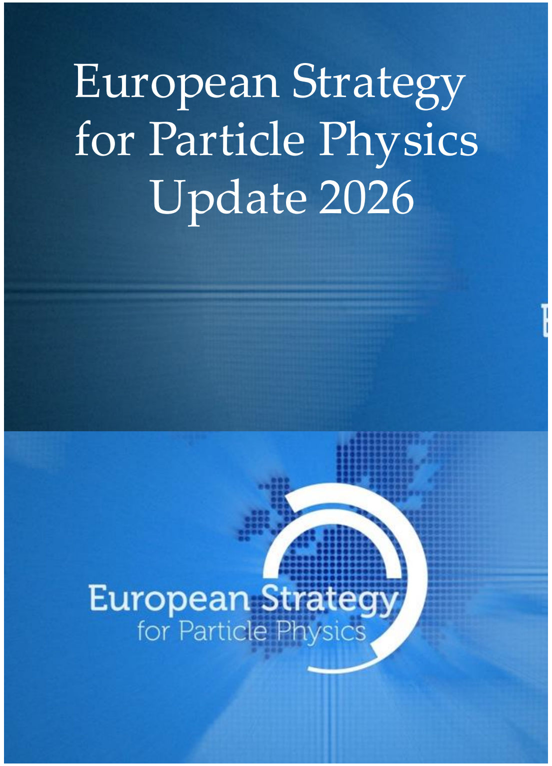


Full system performance proven over long-time scales

J. Hicks – FTDM 2021

Where to go from the present DRD collaborations?

Relevant Input proposals



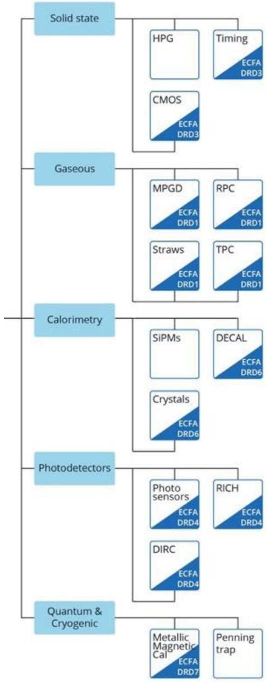
DRD collaborations are often referenced and seen as an already **established concept** in HEP (e.g. in many national submissions)

Neighboring fields:

- **Nuclear Physics**: large overlap with all DRD collaborations for high-energy NP, referenced in NuPPEC [long-range plan 2024] in detail; Also e.g. 40% groups in DRD1

- **Astroparticle physics**: connection with DRD2 and DRD4, Intensifying cooperation suggested (e.g. German astroparticle submission #126,..)

  APPEC welcomes the 2021 ECFA detector R&D roadmap for particle physics and acknowledges the synergy with particle physics detector R&D
  (APPEC Roadmap Update 2023)



Status in the US and Asia

US HEP community has been engaging broadly in the process on defining and shaping the DRD

- In addition, US Snowmass process recommended creating **Detector R&D collaborations (DRCs)**, organized by CPAD
  - P5 recommends to increase the budget for generic and targeted Detector R&D (#93 (CPAD) and #230 (P5 recommendations)
- Higgs Factory Steering Committee proposes organizational structure for the pre-project detector R&D scope

#229

Japan: *Instrumentation Technology Development Center* (ITDC) established at KEK in 2023 (input proposal #99)

- promotes semiconductor detectors, scintillators, optical sensors and quantum dots, gas and active media, magnets, Test Beam Line (electrons)

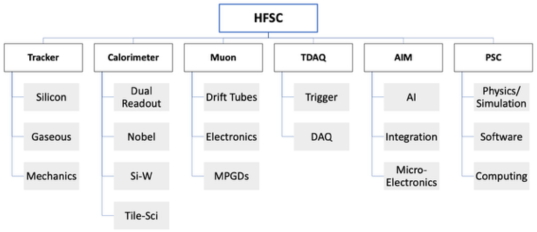
- Belle II (#205), Hyper-K (#238), J-PARC (e.g. #155)

China: Many Chinese groups joined and still join DRD collaborations

- Separate submissions about JUNO (#36), STCF (#231) and CEPC (#153)

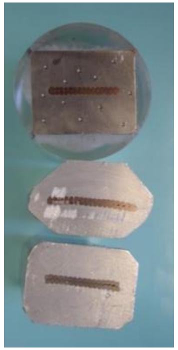
US RDC collaborations:

RDC#	TOPIC
1	Noble Element Detectors
2	Photodetectors
3	Solid State Tracking
4	Readout and ASICs
5	Trigger and DAQ
6	Gaseous Detectors
7	Low-Background Detectors
8	Quantum and Superconducting Sensors
9	Calorimetry
10	Detector Mechanics
11	Fast Timing



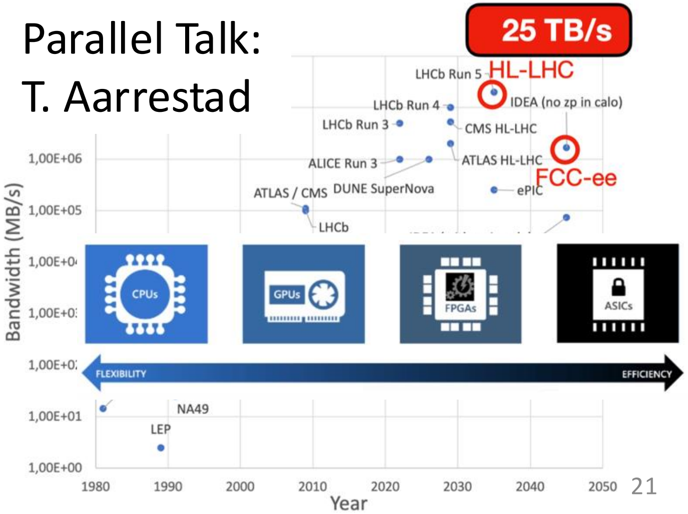
What is beyond the current DRDs?

- **Superconducting Experimental Magnets (initial in TF8)**
  - Al-stabilized Nb-Ti conductor technology used >20 years ago for LHC experiments, worldwide no vendor now, but ALICE3 and ePIC need
  - Research aligned with CERN activities, see 2022 workshop and arXiv:2203.07799
  - HTS as an alternative with possible synergy to accelerator magnet R&D
- **Rare event detectors**
  - Several submissions (e.g. #112)
  - DRD5 would also provide a suitable host for e.g. bolometers
- **New TDAQ methods** with AI, intelligence on the detector
  - “triggerless” DAQ creates high data rate, throughput challenge (e.g. #127)
  - AI-RDs collaborations proposed as a parallel structure to DRDs (#167)
  - Boundary between electronics (partly covered by DRD7) and computing
- New approach in **microelectronics** (#161)
- **Attracting more person power**, **funding**, and engaging new communities (#30, #95, #157,..)



CMS Solenoid 2005

Parallel Talk:
T. Aarrestad



Parallel Talk:
F. Simon

Microelectronics Challenge

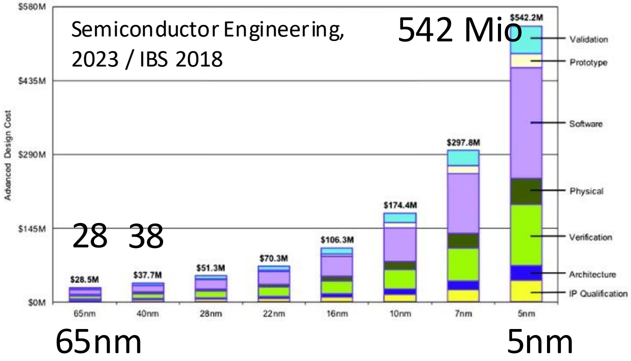
#161, GSR 2, GSR 5, GSR 9

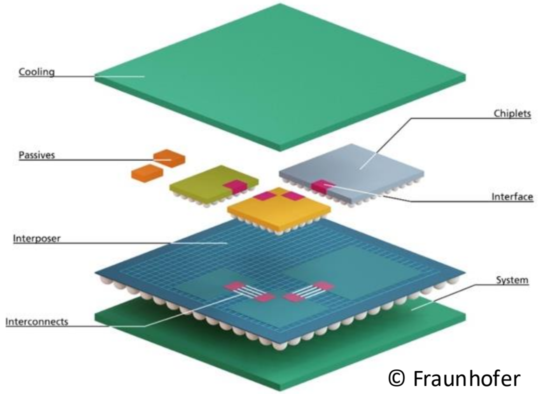
- The **cost and complexity** of developing advanced CMOS technologies have risen dramatically. **HEP is now lagging behind commercial technology**
  - 25 years ago: APV25 (CMS Tracker ASIC) and Pentium-II shared the same technology (250 nm)
  - Supply chain and obsolescence risks: how long is a technology supported?

- Mitigation by **seeking resources beyond HEP** and forming **broader collaborations**, actively encourages cross-disciplinary developments
  - **Fewer, common developments with higher volumes**
  - Use modern technologies with standardized, common **chiplets** combined to chips tailored to different needs

  → DRD collaborations can be instrumental by e.g. closer collaboration and developing common chiplet blocks (inter-DRD workshop on electronics needed?)

- Advances in Electronics are also connected to lower power consumption
  - Sustainability topic, less material budget for MAPS vertex detectors





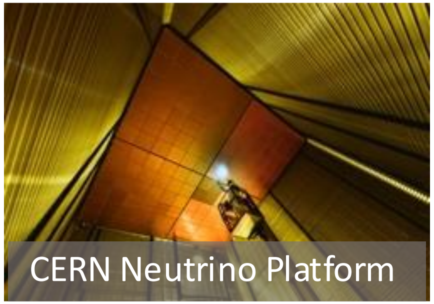
Parallel Talk:
M. Demarteau

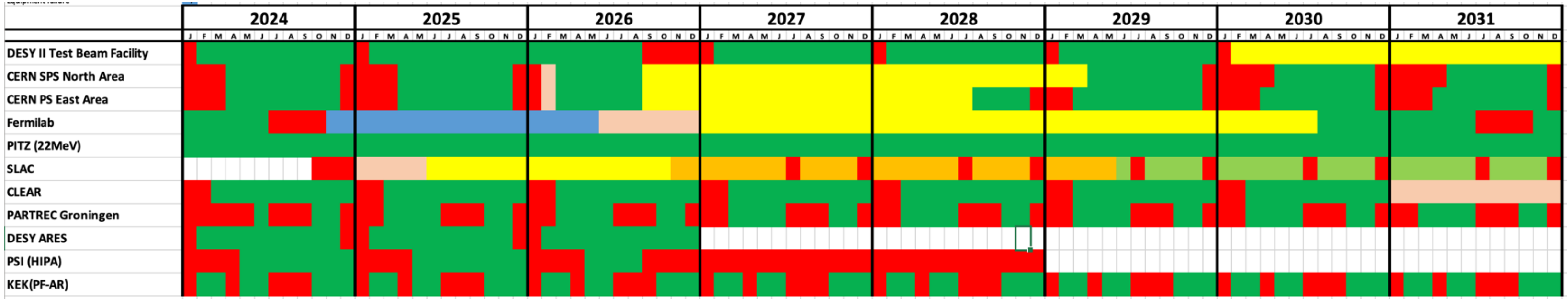
Infrastructures

FNAL #11, DESY #72, #244, GSR1

- Crucial for further advances in detector instrumentation
  - Most common include **test-beam** and **irradiation facilities**
  - But also CERN **neutrino platform**, facilities for **quantum sensor tests**, **magnet tests**, specialized **characterization** setups, **laser** facilities,…
- **European projects** were instrumental to access irradiation and testbeam facilities and develop them further, e.g. beam telescopes
  - AIDA(-2020)/AIDAinnova, Euro-LABS for TNA
- Accelerator upgrades also affect the interruption of testbeam facilities
  - No testbeam activity during CERN LS3


Triga Reactor JSI Ljubljana


CERN Neutrino Platform



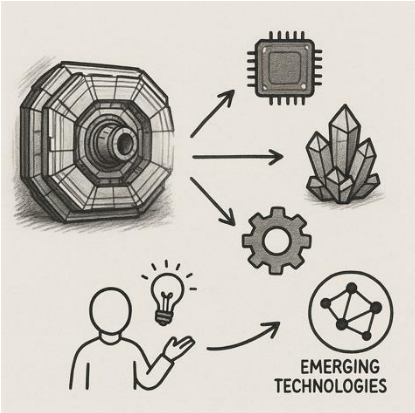
https-//cern.ch/international-facilities

Last Update 23/04/2025	
Running	1
Winter/Summer Shutdown	2
Longer Shutdown	3
Unclear	4
Likely	5
Pending Approval	6
Equipment failure	7

Parallel Talk:
M. Demarteau

Partnerships in Engineering

#95, #161, GSR2



- HEP detectors are electronic detectors with highly specific, "niche" requirements
  - Many technologies critical for HEP do not have a lucrative commercialization path, i.e. radiation hardness
  - Need to identify overlapping topics with mutual interest
- **Welcoming expertise from outside the traditional HEP** becomes necessary due to increasing complexity, size and large material count of HEP detectors, e.g. in
  - Material science
  - Advanced manufacturing, Mechanics, QA experts
  - **Bring in disruptive ideas and technologies**, e.g. in quantum sensing
- **Involve the industry early** in R&D processes and co-develop
  - Connecting with the right company is a challenge, so networking efforts can help, e.g. exploit Alumni networks of former students

Parallel Talk:
M. Demarteau

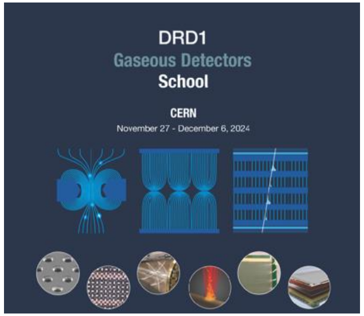
Training, Education and Careers

European Strategy for Particle Physics

- Sustainable **Career Models**: Addressing long-term career paths
  - **Competitive salaries** enable mobility between academia and industry to ensure a stable talent pipeline → Academia cannot compete with industry, thus alternatives necessary
  - **Find partnerships and open career paths** from closely connected technological domains **within academia**, i.e. undergraduates electrical/electronics engineering faculties
  - Start with engagement even earlier: Outreach in high schools

- Establishing a **European Curriculum in Instrumentation**
  - **Beginner level:** through university master's and graduate programs, supported by material compiled by HEP
  - **Intermediate level:** Erasmus Mundus Master in Instrumentation
  - **Advanced level:** (PhD and postdoc level): dedicated schools in instrumentation (e.g. EDIT) or DRD-specific schools
    - Establish a CERN-hosted instrumentation school similar to *CERN Accelerator School* and the *CERN School of Computing*

#30, GSR8



Establish long-term funding

GSR4

European Strategy for Particle Physics

DRD collaborations do not bring funding ab initio

- Only resource-loaded projects described in MoUs will be backed up by funding agencies commitments → 2nd phase of setting up DRD collaborations

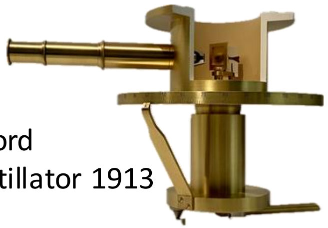
Funding agencies need to be convinced that detector R&D is a good investment

- Benefit not only for HEP, but also **astroparticle** and **nuclear** physics
- **Society at large**: job creation, education, training, applications and KT to other domains, e.g., medical physics (dosimetry, PET, imaging,..), automotive, environmental,…

- **No metric exists** to quantify socioeconomic impact of instrumentation, but other studies exist
  - Cebr study for EPS (to be updated soon)
  - WIFO report: FCC will generate €50 billion in worldwide value added and create around 26,000 jobs annually

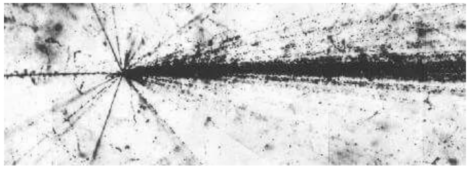
Summary

- Progress in instrumentation **allows new discoveries**
  - Instrumentation has come a long way from where it started
  - **Must not be the limiting factor for meeting the needs** of the long-term European particle physics, nuclear and astroparticle physics program
    → on the contrary, **it should be the driver**
- Eight CERN-hosted **Detector R&D (DRD) collaborations** have been set up following ECFA Detector roadmap to work on **strategic** R&D

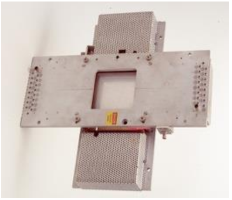


Rutherford
ZnS scintillator 1913

Emulsions (M. Blau 1922)



Ionization chamber
V. Hess 1932

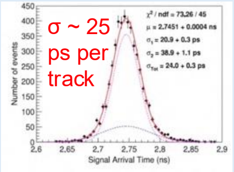


MWPC
G. Charpak 1968
Nobel prize 1992

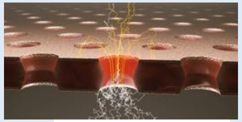
DRD Collaborations

DRD1: Gaseous Detectors

Large · Fast · eco-friendly gases · MPGD, e.g. GEMs

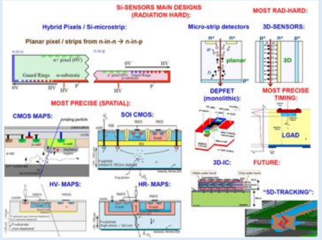


PICOSEC: NIMA903 (2018) 317



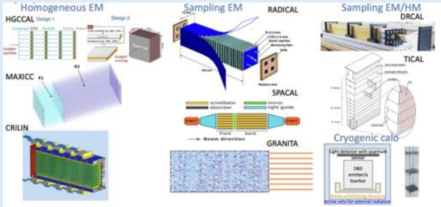
DRD3: Semiconductor Det.

Monolithic CMOS · LGADs · radiation hardness · interconns.



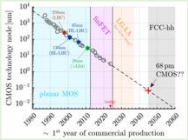
DRD6: Calorimetry

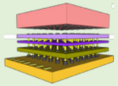
Energy resolution · High granularity · dual readout · particle flow · sandwich · optical

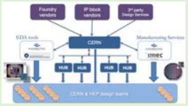


DRD7: Electronics

ADC/TDC IP Blocks · Opto-electronics · packaging · power · extreme environments · COTS · intelligence on detector · foundry access



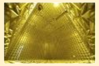


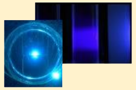


DRD2: Liquid Detectors

for Neutrinos · Dark Matter · 0vbb

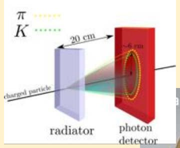
Noble Elements	Liquid Scintillators	Water Cherenkov
• Argon & Xenon • Ionisation charge & transport • VUV Scintillation, light propagation & detection	• Visible Scintillation, light propagation • Scintillator properties • Isotope loading	• Cherenkov light, light propagation • Doping for n-capture

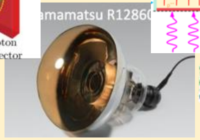


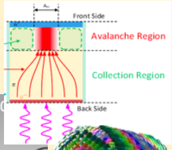


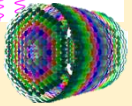
DRD4: Photon detectors

vacuum, solid-state (SiPM), hybrid single-photon and SciFi detectors · applications in PID, RICH, tracking





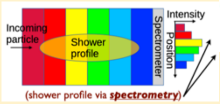


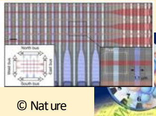


DRD5: Quantum Sensors

Quantum dots · superconduct. nanowires · bolometers · TES · MMC · nuclear clocks

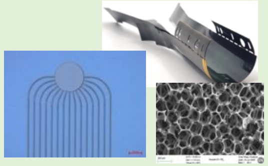
Applications in LEPP, first projects in HEPP happening

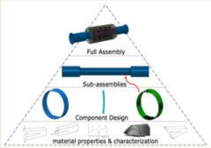




DRD8: Mechanics

Ultra-thin beam pipes · CF foam and new materials · curved, retractable sensors · air & micro-channel cooling · eco-friendly cooling fluids · robots · augmented reality





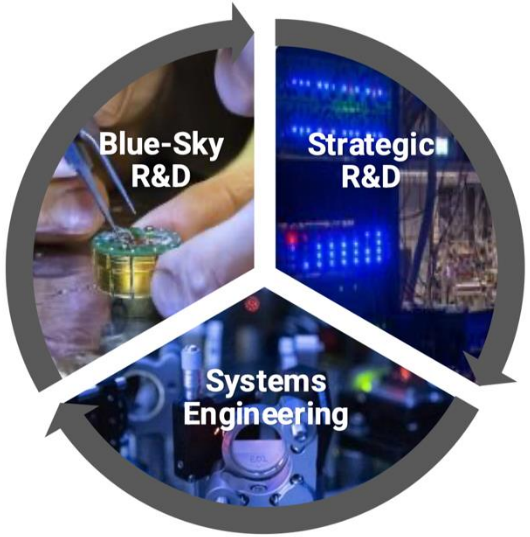
Outlook

A healthy environment in detector instrumentation is more than DRD Collaborations:

- **Blue-sky R&D** as an integral part of the R&D portfolio
- **Systems engineering** to be integrated in R&D efforts

DRD collaborations are still in their infancy

- Evolve on a coherent work program over the next years
- Expected to grow once the LHC Phase-II Upgrades are finished
- Engage with funding agencies to **secure funding** via MoU's



Need to be supported by:

- Excellent lab and test facilities, good career opportunities with training programs, openness for disruptive ideas, strong partnerships and collaborations beyond HEP
  - Many of these statements have been made at the ESPPU 2020 already

Thank you very much for your attention

Last Strategy Update 2020

http://europeanstrategy.cern

Brought us decisions for post-HL-LHC times

Concerning instrumentation, it reads (section 4.C):

- ***The success of particle physics experiments relies on innovative instrumentation and state-of-the-art infrastructures.***
- ***To prepare and realise future experimental research programmes, the community must maintain a strong focus on instrumentation.***
- ***Detector R&D programmes and associated infrastructures should be supported at CERN, national institutes, laboratories and universities.***
- ***Synergies between the needs of different scientific fields and industry should be identified and exploited to boost efficiency in the development process and increase opportunities for more technology transfer, benefiting society at large.***
- ***Collaborative platforms and consortia must be adequately supported to provide coherence in these R&D activities.***
- ***The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels.***

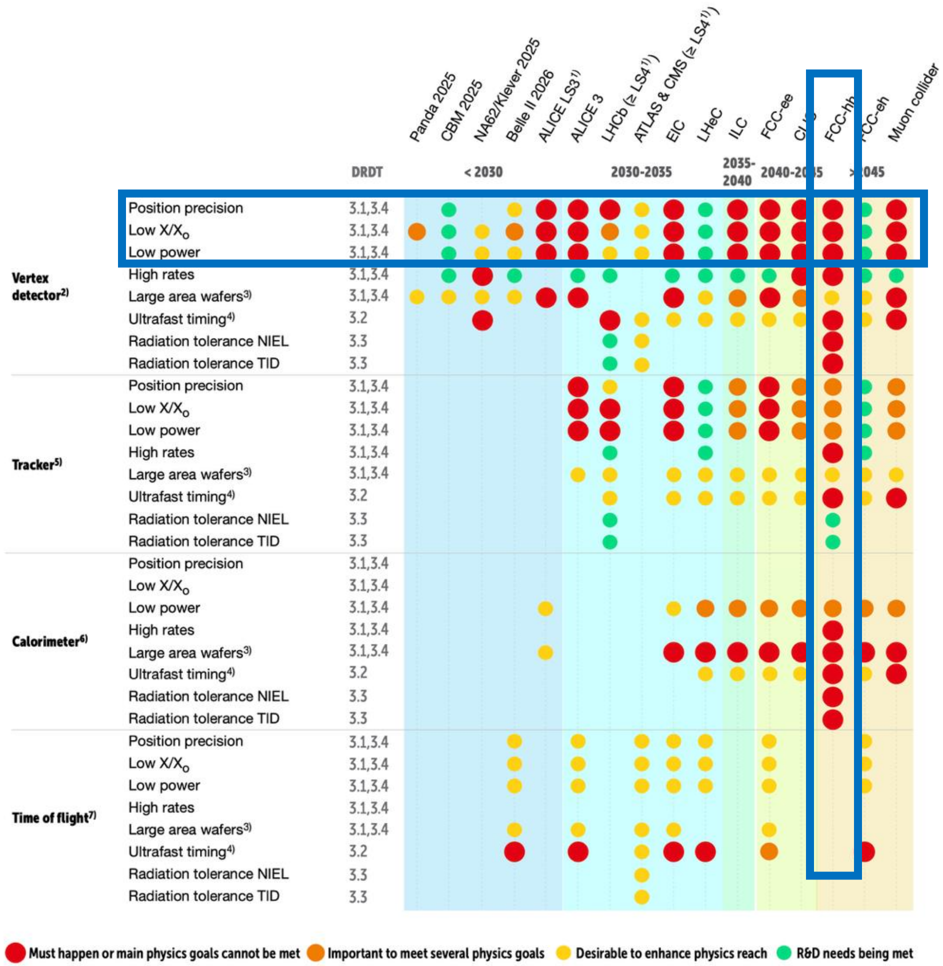
http://dx.doi.org/10.17181/CERN.JSC6.W89E

R&D Topics and DRDTs

- The most urgent R&D topics in each Task Force area are identified by **Detector Readiness Matrix**
- **Detector R&D Themes (DRDTs)** were formulated as high-level deliverables:

Solid state		
	DRDT 3.1	Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
	DRDT 3.2	Develop solid state sensors with 4D-capabilities for tracking and calorimetry
	DRDT 3.3	Extend capabilities of solid state sensors to operate at extreme fluences
	DRDT 3.4	Develop full 3D-interconnection technologies for solid state devices in particle physics

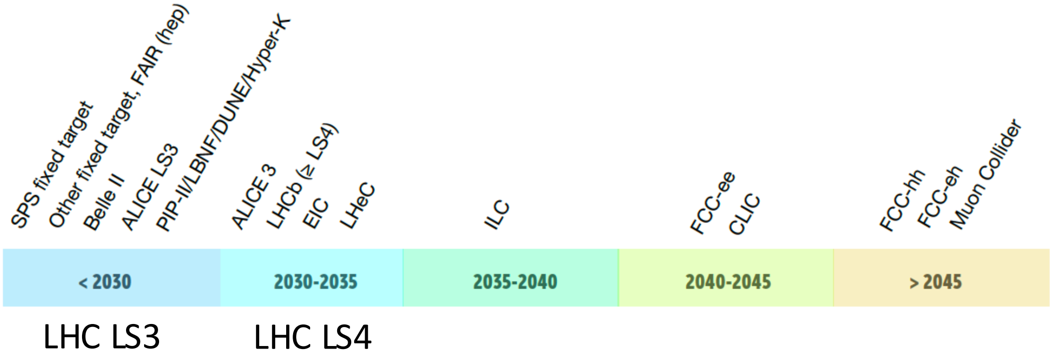
Semiconductor Example



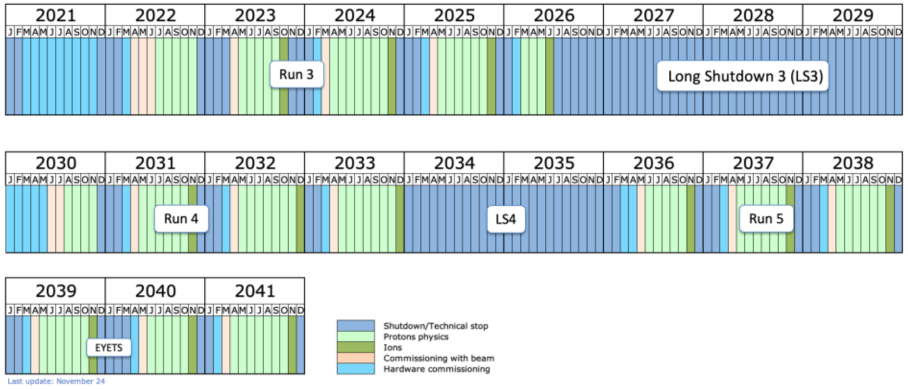
- Both were used to define work packages, projects, and deliverables in DRD collaboration proposals

Time Periods and Experiments

- Time periods for "Large experiments"
  - synchronized with LHC schedule



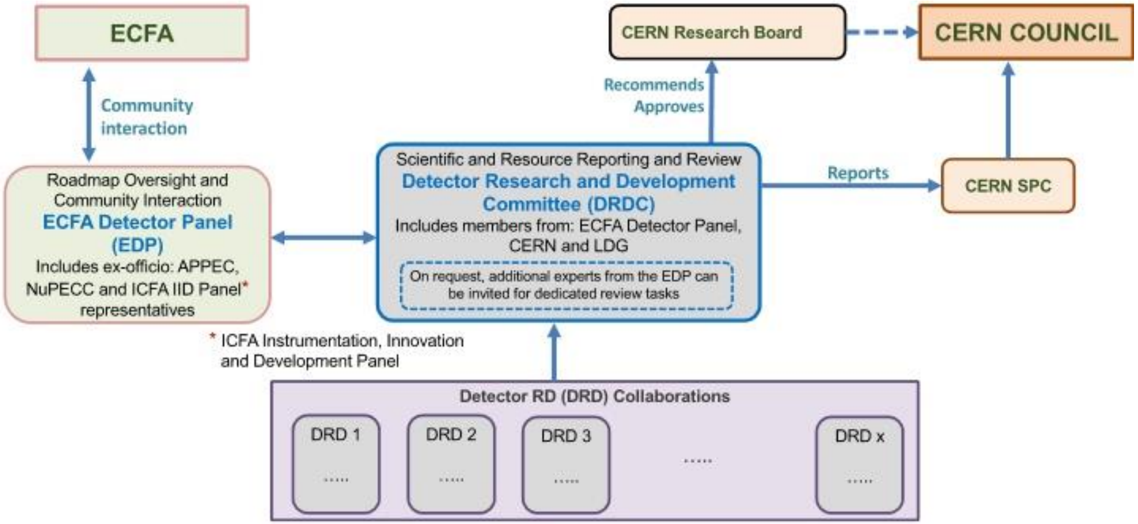
- Time periods for "Smaller Experiments"
  - DM and Neutrino



Roadmap implementation plan

- Approved by CERN SPC and Council in fall 2022 (CERN/SPC/1190 ; CERN/3679)
- **CERN will host DRD collaborations**
  - Interaction between DRD collaborations and committees through DRDC
  - Interface to ECFA via ECFA Detector panel: https://ecfa-dp.desy.de

- Distinction between reviewing body (DRDC) and advising body (EDP)
- EDP also provides input to the next Strategy update



DRD Collaboration Sizes

Collab.	Topic	Number of institutes	Interested people	FTE available	FTE requested	Budget available [kCHF per year]	Budget requested [kCHF per year]
DRD1	Gas det.	165	700+	281	123	3000	2800
DRD3	Solid-state	145	700+	171+156	171	5070	7898
DRD6	calo	135		~180	70/100	3200/1200	1300/2500-3000
DRD2	liquid	86	205	145	315	2500	7000
DRD4	Photo+PID	74		105	60	1600	7000
DRD5	Quantum	112	344	~100			
DRD7	electronics	67		110	69	~2300	~2000
DRD8	mechanics	38		35,3	62,3	1360	3825