Status report on DRD4

Massimiliano Fiorini

(INFN and University of Ferrara)

on behalf of the DRD4 Collaboration

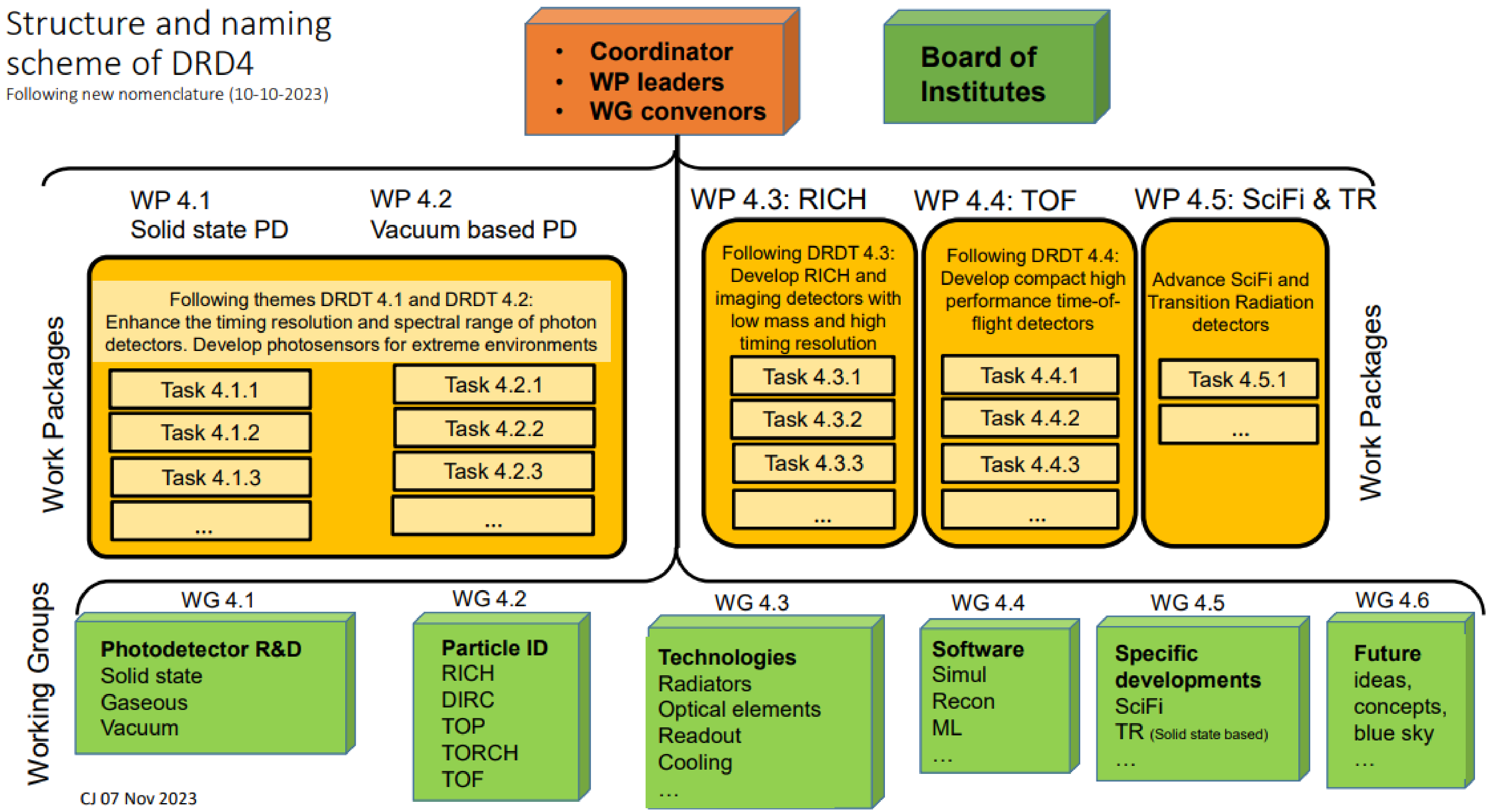
4th DRDC Meeting – Open session

CERN – November 13th, 2024

DRD4 Collaboration

- DRD4: international Collaboration with CERN as host laboratory
  - Approved by the CERN Research Board in December 2023
- Main goal: bundle and boost R&D activities in **photodetector technology** and **Particle Identification (PID) techniques** for future HEP experiments and facilities
- To be more specific, DRD4 covers the following topics:
  - Single-photon sensitive photodetectors (vacuum, solid state, hybrid)
  - PID techniques (Cherenkov based, Time of Flight)
  - Scintillating Fiber (SciFi) tracking
  - Transition Radiation (TR) using solid state X-ray detectors
- DRD4 structure initially defined in the Proposal document
  - 6 Working Groups (WGs) reflecting the main areas of R&D
    - Scientific forums for discussion: no agreed tasks, no committed resources
    - Facilitate exchange of information, know-how, samples, infrastructure, etc.
  - 5 Work Packages (WPs) reflecting the main ECFA roadmap themes and goals
    - Run like projects: divided in tasks, with agreed goals, milestones, deliverables, and are jointly funded by the resources of the participants

DRD4 structure (from the Proposal)



DRD4 institutes

- 74 institutes joined DRD4 at the time of Proposal
  - Additional institutes joined later (2 in January, 1 in June, 4 in October)
  - 20 nationalities
  - Many small groups, many with no prior experience in large R&D collaborations
  - Large effort to constitute a collaborative effort amongst a research community that has not traditionally worked together in the recent past
  - Industrial partners (very important asset)
- New groups are welcome to join DRD4
  - For more information: https://drd4.web.cern.ch
  - Contact us

DRD4 activities

- Different levels of activities
  - WG meetings organized by the corresponding Conveners
  - WP meetings organized by the corresponding Leaders
  - Management meeting
    - Periodic meetings between the WG Conveners, WP Leaders, SP and CB chair to monitor progress and proper inclusion of new teams and members
  - Collaboration meetings
- DRD4 scientific activities ramped up since the beginning of 2024: many scientific and technological discussions

DRD4 Collaboration Meetings

- Constitutional meeting (CERN, 23-24 January 2024)
- 1st DRD4 Collaboration meeting (CERN, 17-20 June 2024)
  - https://indico.cern.ch/event/1403486, 125 participants
- 2nd DRD4 Collaboration meeting (CERN, 21-25 October 2024)
  - https://indico.cern.ch/event/1456663, 134 participants
- Future meetings at CERN: 7-11 April 2025, 13-17 October 2025

WG meetings

- First WG meetings organized in May
  - See Indico pages for more details
  - WG stand-alone meetings + WG meetings in DRD4 Weeks plenary session
- These meetings are crucial to build our (new!) community, enabling discussion of activities and the spread of information
- Goals
  - Discuss scientific and technological interests; share expertise in the specific topics; availability/need of equipment and infrastructures for specific activities (and possibility of sharing or use by other DRD4 members); etc.

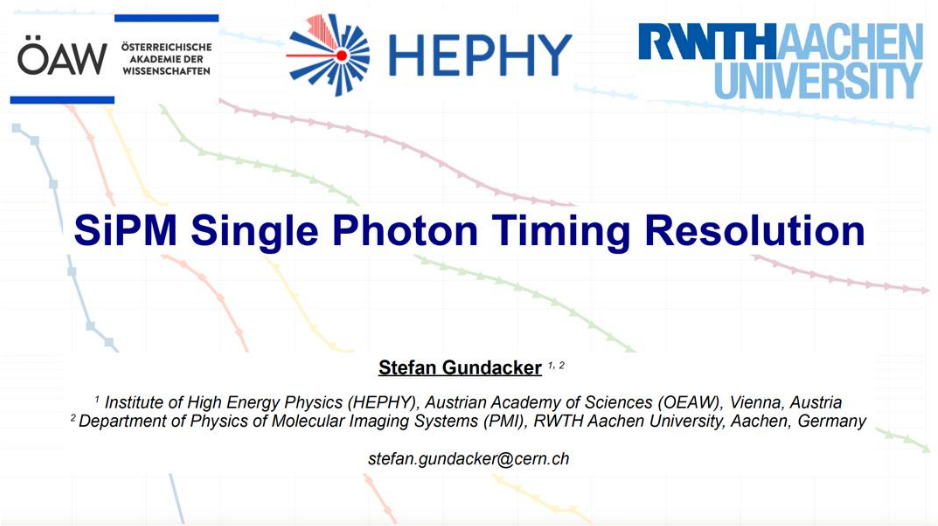
WG1: Photon Detectors

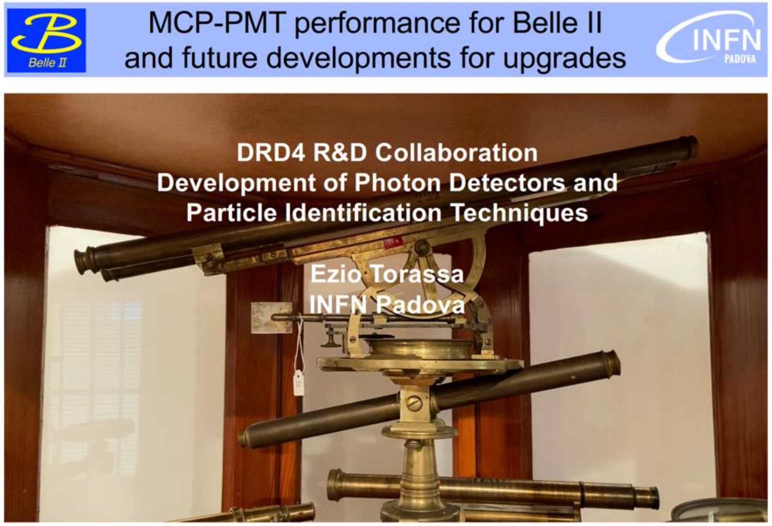
- Scientific forum for studies and development of novel photodetectors with focus on PID for future experiments
- Topics (selection):
  - Radiation hardness; timing resolution; high-rate capabilities; longevity
  - Extreme conditions: e.g., cryogenic and high magnetic field
  - Large-area (e.g. SiPMs arrays, LAPPDs, etc.); hybrid detectors
  - Fine granularity detectors for future high-rate experiments
  - New technologies: CMOS-SPADs, new SiPM structures, BSI SiPMs
  - New photocathode structures and materials
  - Novel materials for photon detection: e.g., Ge-on-Si APDs;
  - Read-out electronics for extreme environments, fast timing and high channel density; optimal sensors and R/O electronics integration
  - Simulations of photo-detector response
- Standardization of procedures for photodetectors characterization

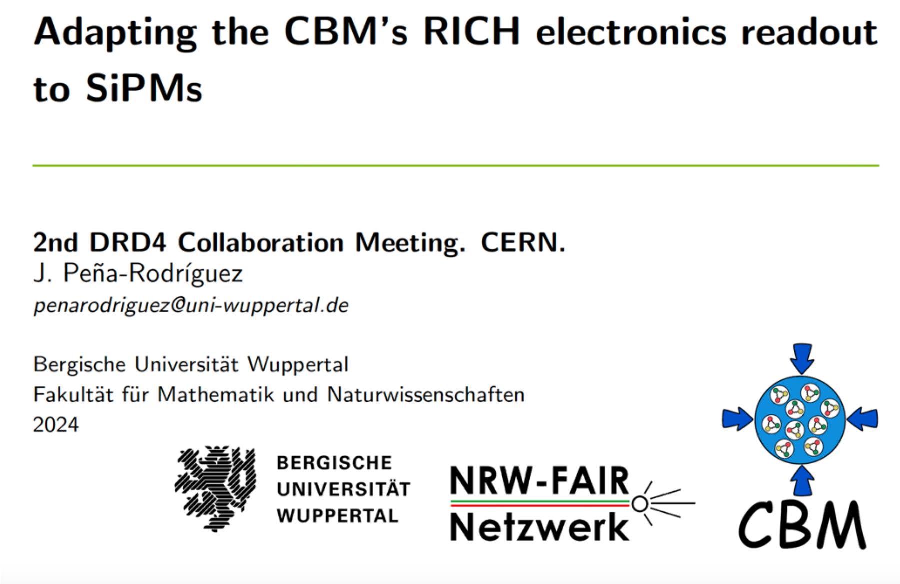
WG1 Convener: Fabrice Retiere (TRIUMF)
Deputies: Angela Romano (Birmingham), Qian Sen (IHEP-CAS)

WG1: Photon Detectors

Examples of presented activities







WG2: Particle ID

- Study of new and improved detector concepts, achievable performance, and intrinsic limitations of Cherenkov-based and TOF detectors employed for PID (such as RICH, DIRC, TOF, TOP, TORCH) plus any new concept
- Topics of interest
  - Study of advanced PID techniques
  - Development of new compact RICH concepts
  - Optimal operation of new detectors
  - Future DIRC detector applications
  - Development of innovative RICH configurations, like e.g. pressurized argon RICH, Aerogel-based RICH, lightweight RICH
  - Study the impact of time-resolved readout for future RICH detectors

WG2 Convener: Sajan Easo (RAL)

WG2: Particle ID

Examples of presented activities

A RICH detector for TeV Particles in the ALADDIN Experiment

Jascha Grabowski

University of Bonn

24-06-19

on behalf the proto-collaboration for the ALADDIN LoI

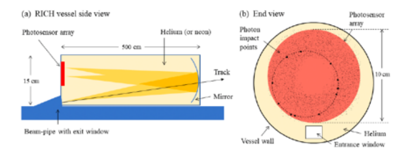
UNIVERSITÄT BONN

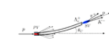
Layout

- use spherical mirror on one side, focal length 5m $\rightarrow R = 10m$
- Cherenkov angle = 8.4 mrad for helium $\rightarrow$ rings are quite small: $d = R\theta_C = 8.4$cm
- channeled Λ_c^+ have angle of 7 mrad $\rightarrow$ photons have 7 cm offset at detector plane [a]
- Λ_c^+ daughters highly boosted: most lie within $\theta_{track} \in [5, 11]$ mrad

$\rightarrow$ Cherenkov photons hit detector plane in a region of $\approx$ **10×10 cm²**

[a] plus contribution from tilt of mirror





RICH vessel could look like a telescope: **5 m** cylindrical pipe with **15 cm** diameter and a mirror on one side

Jascha Grabowski | A RICH for ALADDIN | 24-06-19 | 6

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM

"***Green radiators***": Controlling refractive index & reducing Cherenkov gas radiator GWP: a challenge in an era of diminishing fluorocarbon availability

Related paper: https://link.springer.com/article/10.1140/epjp/s13360-023-04703-w

See also:
https://indico.cern.ch/event/1263731/contributions/5398511/attachments/2648319/4584649/G_Hallewell_DRD4%20Rad%20Gas%20GWP%20with%20annexes%20May%2016%202023.pdf
https://indico.cern.ch/event/1371158/contributions/5773321/attachments/2788215/4861759/G_Hallewell_ATLAS_sustainability_forum_Jan_26_2024_v2.pptx

ICHEP2024 (July 2024): https://indico.cern.ch/event/1291157/contributions/5900402/

G. Hallewell
Aix Marseille Université,
CNRS/IN2P3, CPPM, Marseille, France

DRD4 Collaboration Meeting,
WG-2: CERN Oct 21-25 2024

CNRS IN2P3 Les deux infinis | Aix Marseille université

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM

Approaches to low-GWP fluorocarbon RICH radiator gases

See also:

(1) https://link.springer.com/article/10.1140/epjp/s13360-023-04703-w
(paper: EuroPhysics J. Plus, Dec 2023)

(2) https://indico.cern.ch/event/1263731/contributions/5398511/attachments/2648319/4584649/G_Hallewell_DRD4%20Rad%20Gas%20GWP%20with%20annexes%20May%2016%202023.pdf

(3) https://indico.cern.ch/event/1410802/ (DRD4 WG2 meeting 17 May 2024)

(4) https://indico.cern.ch/event/1420840/ (DRD4 WP_3.1 meeting 28 May 2024)

G. D. Hallewell
Aix Marseille Université, CNRS/IN2P3, CPPM, Marseille, France

With thanks to many people for information, as detailed in link (1) above

DRD4 Collaboration meeting: WG 2
Low GWP FC radiator gases: June 19 2024

CNRS IN2P3 Les deux infinis | Aix Marseille université

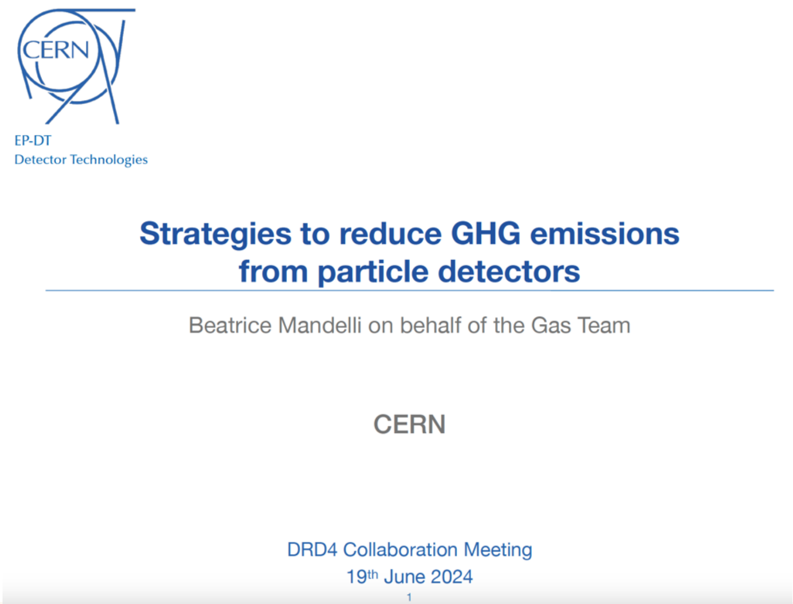
WG3: Technological activities

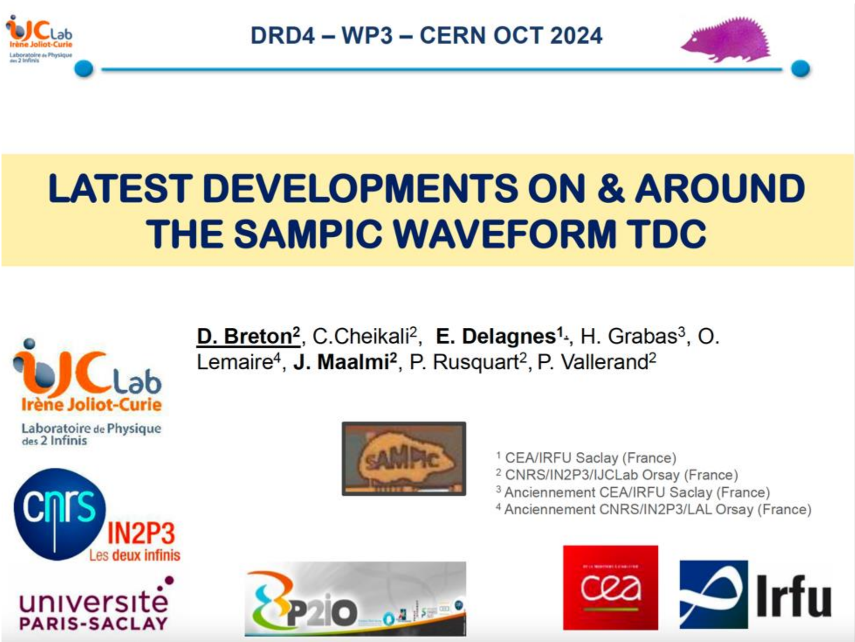
- Focus on the key technologies for RICH and other imaging detectors systems, including the full read-out chain
- WG3.A - Key technologies for RICH and other imaging detectors
  - Radiators (gas, aerogel, etc.) characterization, purity, fluid circulation, monitoring
  - Optical technologies: mirrors, lenses, coatings, aspherical elements, etc.
  - Thermo-mechanical engineering design: light materials, active local cooling, annealing in situ techniques, etc.
  - Ancillary instrumentation: for control of systematic uncertainties (calibration, alignment, monitoring) of PDE, (n-1), etc.
- WG3.B – Read-out electronics
  - Solutions to develop full read-out system chain for fast low-noise pixelated single-photon counters (for PMT/MCP/SiPM/etc.) with $O(10^3)$ channels, to be used as a general tool in DRD4 for laboratory tests, test-beam setups, etc.

WG3 Convener: Fulvio Tessarotto (Trieste)

WG3: Technological activities

Examples of presented activities





Aerogel characterization studies

Rocco Liotino, Eugenio Nappi, Nicola Nicassio, Giacomo Volpe

University & INFN, Bari

WG4: Software

- Address software issues related to the next generation of detectors developed in DRD4
  - Develop software packages of common interest to the DRD4 community and share experiences from software developments in different projects
  - Some of the recent advances in software technologies can provide significant improvements in the simulation and analysis of the data produced in Cherenkov detectors
- Topics (selection)
  - ML techniques to improve PID algorithms
  - Develop software that runs on GPUs to speed up simulation/reconstruction
  - Simulate the next generation of photon detectors and their read-out
  - Create framework to evaluate the new algorithms that will be developed on different software platforms

WG4 Convener: Maurizio Martinelli (Milano Bicocca)

WG4: Software

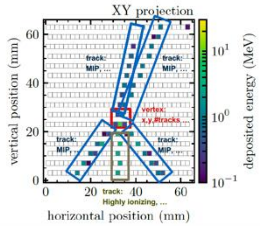
Examples of presented activities

Object Identification for Particle Detectors using Deep Learning

Thomas Pöschl[a,b], Sara Aumiller[a,b], Sergei Gerassimov[b], Nicole Hartman[b], Lukas Heinrich[b], Florian Kaspar[b], Karina-Sanziana Stelea[b], Stefan Wallner[c], Dominik Ecker[b], Luise Meyer-Hetling[b], Andrii Maltsev[b]

[a] European Organization for Nuclear Research (CERN)
[b] Technical University of Munich (TUM)
[c] Max-Planck-Institute for Physics, Munich (MPP)
thomas.poeschl@cern.ch

Credit: Futuris Tech



1

Simulation for the ClearMind Project

Viatcheslav Sharyy
For the ClearMind Collaboration

DRD4 meeting
May 31, 2024

Software Ecosystem for DRDs: Key4Hep

Alvaro Tolosa-Delgado (CERN)

Second DRD4 collaboration meeting (CERN)
Oct. 23th, 2024

Comprehensive Particle Identification (CPID) in Full-Detector Simulation

Uli Einhaus
2nd DRD4 Collaboration Meeting
23.10.2024

WG5: SciFi and TR Detectors

- R&D of segmented detectors based either on scintillating fibers or on pixelated semiconductor detectors for high precision tracking, eventually exploiting the transition radiation for PID
- WG5.A - Scintillating Fibers
  - Novel fast & radiation-hard scintillating fibers
  - Tracking with photon timing information in high occupancy environments
  - Micro-lenses on SiPMs
  - Fiber ribbon and detector plane production techniques (flexible ribbons)
  - Cryogenic cooling of SiPMs
- WG5.B - Transition Radiation Detectors
  - Development of a novel TRD based on highly segmented pixel semiconductor detectors (Si, GaAs, CdTe) for measuring both the energies and the emission angles of TR X-rays, for hadron ID in the TeV range

WG5 Convener: Sune Jakobsen (CERN)
Deputy: Francesco Loparco (Bari)

WG5: SciFi and TR Detectors

Examples of presented activities

Characterization of pixelated high-Z sensor for X and gamma-ray detection

Petr Smolyanski & Benedikt Bergmann
Institute of Experimental and Applied Physics, Czech Technical University in Prague
Petr.smolyanskiy@utef.cvut.cz
Benedikt.bergmann@utef.cvut.cz

MC simulation of TRDs based on GaAs sensors: tools and status

V.O.Tikhomirov[1,2]

[1] P.N.Lebedev Physical Institute of the Russian Academy of Sciences
and
[2] National Research Nuclear University "MEPhI"

DRD4 Collaboration Meeting, 20.06.2024

Current status of a simulation of the GaAs detector response

Ivan Zhutikov on behalf of DRD 4.5.2 working group

High purity electron and hadron beams for PID studies at SPS.

On behalf of the DRD _4.5.2 working group.

Anatoli Romaniouk. DRD 4.5 meeting, 25.10.2024.

WG6: Novel ideas and far-future R&D

- This WG will act as the DRD4 collaboration's gate for novel ideas and revolutionary concepts
  - New ideas shall find in WG6 the right environment to prosper
  - Help the new concepts to reach the required level of maturity
  - Hope to transform some of these ideas into breakthroughs in the field, impact the future of photon detection

WG6 Convener: Suat Ozkorucuklu (Istanbul)

WP activities

- WP meetings organized starting from February
  - See Indico pages for more details
- Goals:
  - Discussion on available and needed resources (persons, materials, equipment, funds); milestones and deliverables; sharing of responsibilities and synergies among the various groups; etc.
- Work Packages leaders and groups have been very active in discussing and updating Deliverables over the past months

WP1: Solid-State Photodetectors

- Task 1 - SSPD with new configurations and modes
  - Development of back-side illuminated SiPM (potential for better PDE and radiation tolerance); development of ultra-granular SiPM that integrates with the electronics by using 2.5D or 3D interconnection techniques; development of CMOS-SPAD light monolithic sensors for HEP; study of new materials for light detection
- Task 2 - Fast radiation hard SiPMs
  - Standardize procedures for quantification of radiation effects; irradiated SiPMs characterization in wide temperatures range (down to -200 ˚C); study of annealing; study and quantify other measures enabling the use of SiPM in highly irradiated areas (e.g. smaller SiPMs, macro- and micro-light collectors)
- Task 3 - Timing of SSPD, including readout electronics
  - Study and improve the timing of SiPMs; co-design of a multi-ch. readout ASIC exploiting the timing potential; integration and packaging with integrated cooling; vertical integration of SiPM arrays to FEE (better timing via reduction of interconnections' parasitic inductances and capacitances)

WP1 Leader: Rok Pestotnik (Ljubljana)

Task leaders: Alberto Gola (FBK), Lodovico Ratti (Pavia), David Gascon (Barcelona)

WP1: Solid-State Photodetectors

Examples of onoing activities

D1.1 First results of the samples of the BSI IBIS Run

NIR-BSI SiPMs
BSI NIR SiPMs: first results

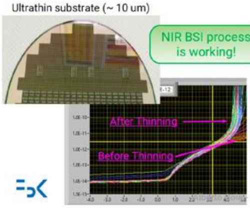
IPCEI on Microelectronics

The *first NIR-sensitive BSI wafers were fabricated* in FBK clean room (1x1 mm² devices).

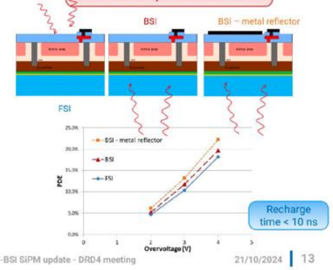
Minor differences in the IVs after thinning, compared to the FSI devices (without thinning).

Ultrathin substrate (~ 10 um)

NIR BSI process is working!



NIR PDE comparison at 905 nm



FBK NUV-BSI SiPM update - DRD4 meeting 21/10/2024 | 13

D1.2 SpadRICH

Radiation-hard digital analog silicon photomultipliers for future upgrades of Ring Imaging Cherenkov detectors – bilateral Weave project EPFL, JSI

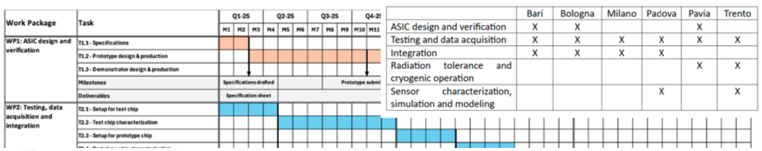
spadRICH Project objectives

- Develop radiation-hard photosensor optimized for RICH application
- Based on SiPMs including reconfigurable electronics → **digital analog SiPM**
- Radiation hardness achieve by means of:
  - rad-hard design techniques at transistor and SPAD level
  - integrated compensating electronics → switch off noisy SPADs, employ active recharge and custom hold-off times
  - microlenses → smaller SPADs
- Possible SPAD/architecture optimizations in a RICH detector scenario:
  - limited photon angular acceptance (NA) → reduce SPAD size (DCR↓), compensate with microlenses
  - timing resolution, gated operation → reduce DCR and data rates
  - cryogenic (liquid nitrogen) operation → reduce DCR, but potential increase in afterpulsing (irradiated samples)

EPFL Jožef Stefan Institute Ljubljana, Slovenia spadRICH

D1.2 ASPiDeS *(A CMOS SPAD and Digital SiPM Platform for High Energy Physics)*

L. Ratti
Approved INFN Project, starting in 2025



The following table summarizes the tasks assigned to the participating institutions

	Bari	Bologna	Milano	Padova	Pavia	Trento
ASIC design and verification	X	X			X	
Testing and data acquisition	X	X	X	X	X	X
Integration	X	X	X	X		
Radiation tolerance and cryogenic operation					X	X
Sensor characterization, simulation and modeling				X		X

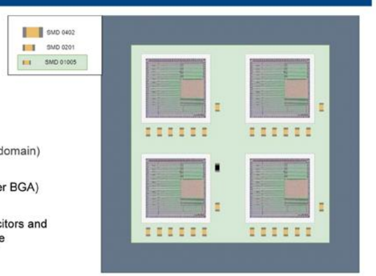
D1.4 Timing and close integration

I. FastIC+ BGA (32 channels) Package choice

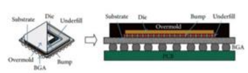
BGA Proposal:

- 10x10 pads
  - balls of 0.5mm/pitch of 1mm
- ~ 12x12 mm²
- 4x FastIC+ (3x3mm²)
  - Flip-chip
- Passive components (01005 metric):
  - 6 decoupling capacitors (1/power domain)
  - 1 BG decoupling capacitor
  - 1 reset pull-up resistor (just one per BGA)

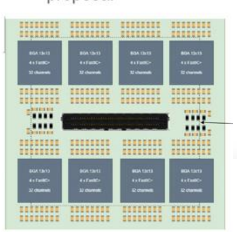
Including the passive components as capacitors and resistors makes it easier to integrate in large modules.



21 October 2024 ICCUB



256 Ch Module proposal



D1.3 AidaInnova run @ FBK

Experimental structures

Two different technologies:

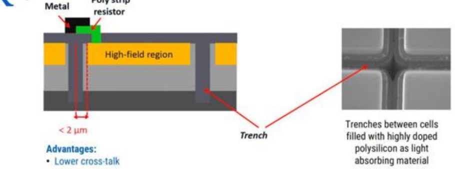
- Low electric field
- Ultra Low electric field

Different samples

- Die size: 3.15 mmx3.15mm
- Cell pitch: 15um, 25um, 40um, 75um

Expected end of production Feb 2024
To be tested in the framework of the AidaInnova
Samples will be available for testing for DRD4

NUV-HD for AIDAInnova



2x2 array of 1x1 mm² and mini-SiPM

Variants of 2x2 arrays:

1) 2x2 array of SiPM 1x1mm2 with 15um-25um-40um-75um cell size
2) 2x2 array of SiPM 0.75x0.75mm2 with 15um-25um-40um-75um cell size
3) 2x2 array of SiPM 0.5x0.5mm2 with 15um-25um-40um-75um cell size
4) 2x2 array of SiPM 0.25x0.25mm2 with 15um-25um-40um-75um cell size
5) 2x1 array of SiPM 1.5x1.5mm2 with 15um+25um cell size
6) 2x1 array of SiPM 1.5x1.5mm2 with 40um+75um cell size
7) single SiPM 2x2mm2 with 15um cell size
8) single SiPM 2x2mm2 with 40um cell size

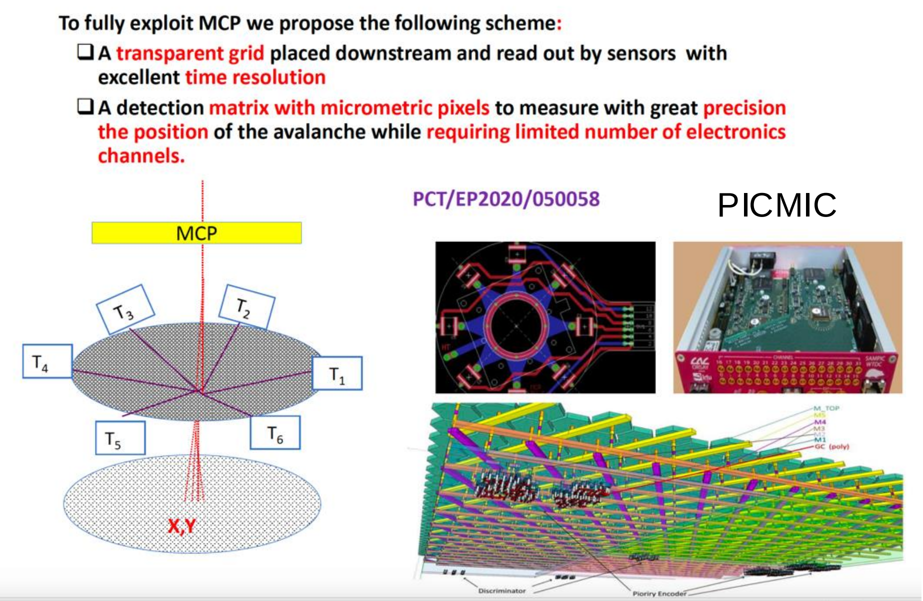
WP2: Vacuum-based Photodetectors

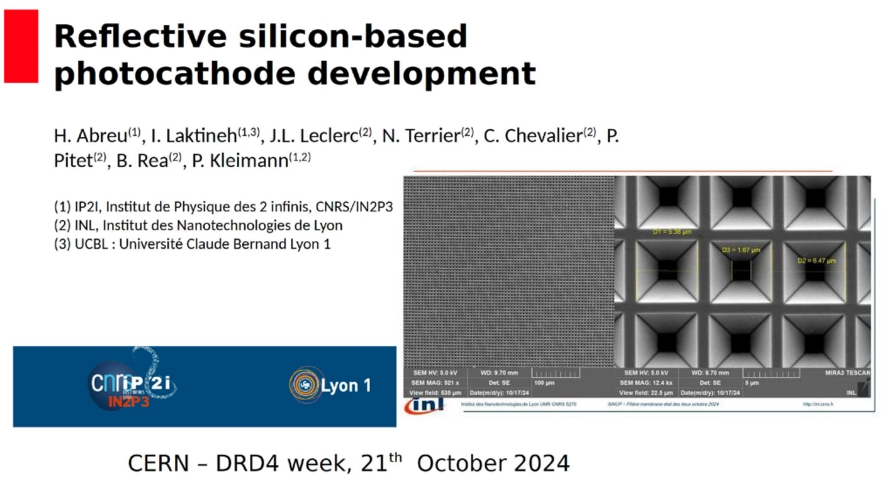
- Task 1 - New materials, coatings, longevity and rate capability studies
  - Develop new materials and techniques to increase MCP-PMT tube lifetime and improve rate capabilities; use new techniques with new materials to achieve high aspect ratio with small diameter for better gain, time, and spatial resolution
- Task 2 - New photocathode materials, structure and high QE VPD
  - Search for new materials with the required characteristics to be used as photocathodes; develop photocathodes with new structures
- Task 3 - VPD time and spatial resolution performance
  - Development of large area MCP-based photodetector with combined excellent timing and position resolution, including electronics integration

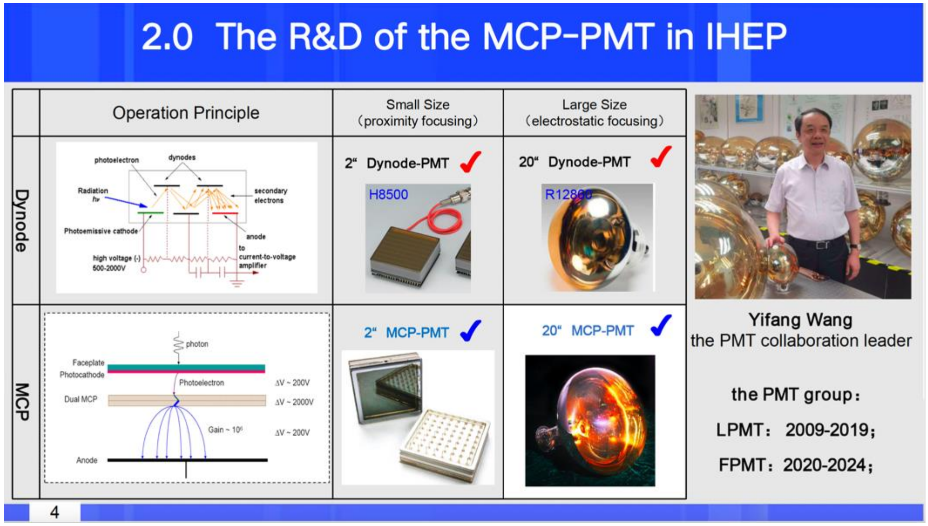
WP2 Leader: Imad Laktineh (Lyon)
Task leaders: Silvia Gambetta (Edinburgh), Thierry Gys (CERN), Ping Chen (XIOPM-CAS), Claudio Gotti (Milano Bicocca), Selma Conforti (Omega)

WP2: Vacuum-based Photodetectors

Examples of onoing activities







WP3: RICH and other imaging det.

- Task 1 - New Materials Radiators and Components
  - Gas alternatives; optimized aerogel modules; precise interferometric measurement of refractive index
- Task 2 - Development of new RICH detector concepts for improved performance
  - High-pressure gas radiator; fast timing, combined RICH/TOF; cryo-RICH; modular RICH; technological demonstrators & proof of concepts
- Task 3 - Prototype Single-Photon Sensitive Module for Imaging Arrays from sensor to DAQ and self-calibration systems
  - Fully functional autonomous modules; scalable R/O electronics; integration to arrays with cooling; on-detector calibration/alignment/monitoring
- Task 4 - Study of RICH detectors for future e^+e^- colliders
  - Prototype a cell for the ARC concept
- Task 5 - Software and Performance
  - Fast simulation; reconstruction for high occupancy, high background

WP3 Leader: Roberta Cardinale (Genova)
Task leaders: Fulvio Tessarotto (Trieste), Sneha Malde (Oxford), Chris Jones (Cambridge)

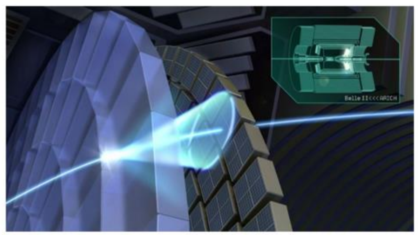
WP3: RICH and other imaging det.

Examples of onoing activities

Aerogel studies

Samo Korpar, Rok Pestotnik (Belle II ARICH group)
University of Maribor and Jožef Stefan Institute, Ljubljana
WP 4.3 session at Collaboration Week, 22 October 2024, CERN

Outline:
- Aerogel radiator of Belle II ARICH
- Investigation of upgrade options:
  - optimization of ref. indices
  - improved production of higher n tiles



22 October 2024, CERN
WP 4.3 session at Collaboration Week
22. 10. 2024
(slide 1)
Samo Korpar
Univ. of Maribor and J. Stefan Institute

The ePIC-dRICH
SiPM photodetector unit

Roberto Preghenella
INFN Bologna

preghenella@bo.infn.it
DRD4 Collaboration week – WP3 meeting, 22 October 2024

DRD4 WP3 meeting
22 October 2024

Steps towards a prototype ARC module

Roger Forty (CERN)

ARC is a compact RICH design for a future collider/Higgs Factory, aiming to provide excellent particle ID (3σ K-π separation over region 1–50 GeV/c), while limiting the radial thickness and material budget

Its potential is currently being studied thoroughly in software, as part of the FCC simulation studies
But to be credible it must also be prototyped in hardware, to demonstrate the feasibility of the design

This is included as a task of Work Package 3 of DRD4, aiming for delivery of a prototype cell in ~ 3 years

Demonstrator of Interferometer for gas refractive index monitoring

DRD4 Collaboration Meeting, WP4.3.1

22 October 2024

Fulvio Tessarotto

CERN, 22/10/2024 **DRD4 Collaboration Meeting, WP3 Session** Fulvio Tessarotto 1

WP4: Time of Flight Detectors

- Task 1 - Study the coupling of a thin Cherenkov radiator to a single-photon detector array, for TOF of charged particles
  - High precision timing (~10 ps) using high refractive index solid Cherenkov radiators coupled to SiPMs arrays or MCPs
- Task 2 - Develop a SiPM array for single-photon detection, with mm-scale pixelation, suitable for use in TOF prototypes
  - Integration of SiPM arrays with multichannel R/O electronics to provide mm-scale position sensitivity and fast timing of Cherenkov light at the very high rates expected with HL-LHC and future colliders
- Task 3 - Develop lightweight mechanical supports for DIRC-type TOF
  - Development of prototype support using lightweight materials with minimal distortion of quartz, detectors, electronics
- Task 4 - Develop techniques for measuring the optical properties of optical components for TOF detectors
  - Develop precision measurement characterization of quartz Cherenkov radiators; share existing facilities

WP4 Leader: Jon Lapington (Leicester); Deputy: Eugenio Nappi (Bari)
Task leaders: Christian Morel (Marseille), Neville Harnew (Oxford), Suat Ozkorucuklu (Istanbul)

WP4: Time of Flight Detectors

Examples of onoing activities

II. 256 Ch Module proposal integrating BGA FastIC+ 32Ch

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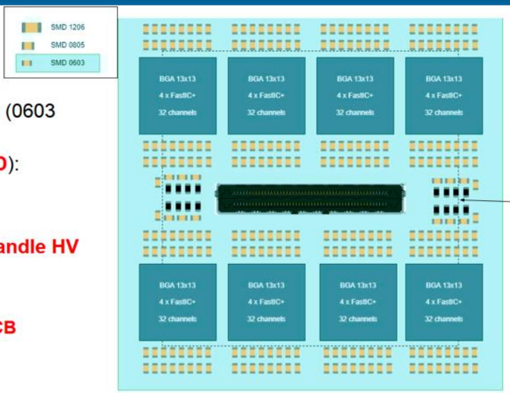
PCB proposal:
- **65x65 mm^2**
- 8x FastIC+32_BGA 12 x 12 mm
- 256 SiPM decoupling capacitors (0603 metric)
- 100 pin connector example (**TBD**): LSHM-150-02.5-L-DV-A-S-TR

Decoupling capacitors have to handle HV for the SiPM V_{BIAS}

***Voltage regulators are not in this PCB**



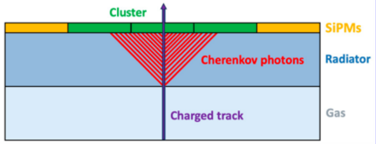
21-25 October 2024

ICCUB Institute of Cosmos Sciences

Cherenkov-based timing measurements

Principle of operation
- Implementation of a Cherenkov radiator coupled to SiPM layer
- Benefit of single photoelectron statistics for precise MIP timing

Possibility of achieving time resolutions down to ≈ 20 ps with ≈ 100 % charged particle detection efficiency !!!

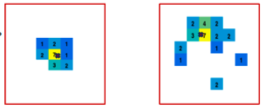


Radiator choice
- Use high refractive index material to minimize Cherenkov thresholds and to enhance photon yield and cluster size

1 mm SiO_2 (n=1.47) + 0.45 mm epoxy resin (n=1.55), 1x1 mm^2 SiPMs

▪MIP at 0° incidence

▪MIP at 50° incidence

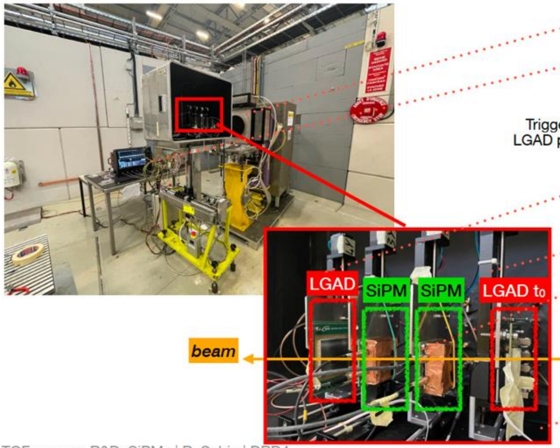


Material	Refractive index at 400 nm	$\beta_{thr.}$	$p_{thr.,\pi^\pm}$ [MeV/c]	Max θ_c [degree]	$N^*_{p.e.}$ at saturat. [mm^{-1}]
NaF	1.33	0.75	159	41.3	13
MgF_2	1.40	0.71	142	44.3	14
SiO_2	1.47	0.68	129	47.9	16
Silicone resin	1.50	0.66	124	48.2	16
Epoxy resin	1.55	0.64	117	49.8	17
High-n Corning	1.84	0.54	90	57.1	21

*Assuming PDE of S13360-3050CS SiPMs at V_{ov}= 3V
* Neglecting material absorption in the calculation

Nicola Nicassio – University and INFN Bari, Italy 4

Experimental setup CERN PS T10 beamline



protons/pions of 10 GeV/c

DAQ: Lecroy wave runner 94904M-MS **digital oscilloscope** 4 GHz bandwidth

Trigger and timing reference: 25 um and 35 um thick FBK LGAD prototypes of 1 x 1 mm^2 (Eur. Phys. J. Plus 138, 99 (2023))

4 independent micropositioners (10 um precision) added since Eur. Phys. J. Plus 138, 788 (2023)

Customized front-end XLEE amplifiers of **40 dB** gain

No cooling: T~25-28°C. Peltier cells from SiPM studied in paper in preparation.

TOF sensors R&D: SiPMs | B. Sabiu | DRD4

3/11

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA · ALICE · INFN Istituto Nazionale di Fisica Nucleare · FONDAZIONE BRUNO KESSLER · CERN

Update on ALICE3-TOF studies on SiPM sensors for charged particle detection

DRD4 WP4.4 session @ Collaboration Meeting

Bianca Sabiu, Università e INFN Bologna
22.10.2024

WP5: SciFi and TR Detectors

- Task 1 - Develop an improved radiation hard scintillating fiber with a fluorescence decay time near 4 ns
  - Standard fast fiber is over 25 years old (SCSF-78M and -78MJ from Kuraray); develop improved radiation hard fiber (should have same or better light yield, attenuation, decay time, and stable in time)

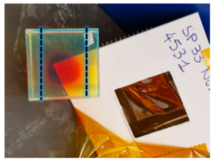
WP5 Leader: Blake Leverington (Heidelberg); Deputy: Guido Haefeli (EPFL)

WP5: SciFi and TR Detectors

Examples of onoing activities

4.5.1 Work in Progress

- Nuvea SP32 & SP33 samples confirmed to be irradiated ~~in July 2024~~ at IRRAD (in the hands of IRRAD now) facility
  - Cube samples irradiated in November 2023 showed large brown regions in the inner regions, but not the edges.
  - Now sliced in 2mm samples; more similar to a fibre mat than the cube samples
  - It took 1 year to repeat this… we need to find a better process



SP32 and SP33 Sample 2 months after irradiation at CERN (~50kGy).

- EPFL ordered fibres from Luxium (4km each of 3 types)
  - Small samples received
  - 3x4km Order was placed through CERN in April but not delivered yet
- CERN EP investigating a high light yield fibre with a 3rd scintillator dye

2024-10-24 Blake Leverington - ECFA DRD4 WP4.5 BMBF UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386 5

4.5.1 Work in Progress

Novel high light yield fiber research from CERN EP

Lead by Sune Jakobsen

- Simulations show it would work
- Contacts with 3 industry partners to determine a new WLS to enable this fibre
  - One WLS determined, but some concerns on the safety of using it. Being investigated
  - Two partners could produce the fibres, one to provide base materials
- Plans 2025:
  - Follow up with all 3 companies.
  - If a wls is identified, move forward with prototype fibers. The prototype fibers would then be characterized and if the results are encouraging, samples would be irradiated and re-characterized.
- "But it is not really part of the DRD at the moment."

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WP 4.5

Task 4.5.1:

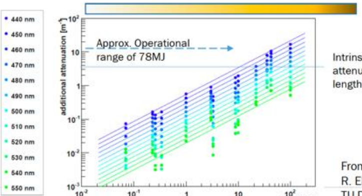
"Develop an improved radiation hard scintillating fibre with a fluorescence decay time less than 4 ns."

The standard fast fibre is over 25 years old (SCSF-78M and -78MJ from Kuraray)

- Peaks at 450nm, 3.5m attenuation length, 2.8ns decay time
- 3HF has a decay time of 8ns, but peaks at 550nm.

Goal: A new fibre with larger Stoke's Shift (to >500nm) would improve the transmission after irradiation of the fibre

- Should have same or better light yield, attenuation, decay time, and stable in time.



Intrinsic attenuation length 3.5m

From the thesis of R. Ekelhof, 2016. TU Dortmund

Progress in fast and red plastic scintillators
Matthieu Hamel

Matthieu Hamel. Progress in fast and red plastic scintillators. Chemosensors, 2022, 10 (2), pp.86. 10.3390/chemosensors10020086 cea-03582648

Tuning the decay time of plastic scintillators
Matthieu Hamel[a,*], Malik Soumaré[a], Hana Burešová[b] and Guillaume H. V. Bertrand[a]
[a] CEA, LIST, Laboratoire Capteurs et Architectures Electroniques, F-91191 Gif-sur-Yvette, France
[b] NUVIA a.s., Trojanova 117, 278 01 Kralupy nad Vltavou, Czech Republic
matthieu.hamel@cea.fr

From the R&D to the commercialization of a new green-emitting plastic scintillator
Matthieu Hamel, Radek Pjatkan, Hana Burešová

Chemistry A European Journal

Review
Current Status on Plastic Scintillators Modifications
Dr. Guillaume H. V. Bertrand, Dr. Matthieu Hamel, Dr. Fabien Sguerra

Review
A Review of Nanomaterial Based Scintillators
Sujung Min, Hara Kang, Bumkyung Seo, JaeHak Cheong, Changhyun Roh and Sangbum Hong

Lots of "promising, but…

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WP 4.5

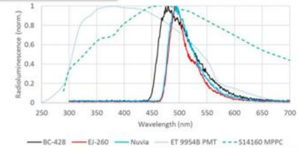
Task 4.5.1 Milestones:

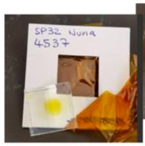
1. First, identify new scintillators, fluorescent dyes, or fibre modifications
   - Market, literature (organic chemistry journals), simulation. **Make contacts.**
2. Obtain samples and characterize the bulk scintillator material → Possibly the hardest part. We can't produce our own.
   - Radiation hardness, timing, wavelength
   - Irradiating thin slices of Nuvea SP32/33 in ~~May~~ July
3. Production of fibre samples (a few km) with Industry Partner(s)
   - In contact with positive response. Kuraray Production facility closed until mid-2024.
4. Testing and qualification of prototype fibre samples
   - Light yield, attenuation length, timing, radiation hardness

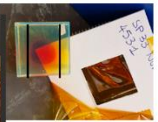
Task 4.5.1 Deliverables:

- Report on candidates (between 2 and 3)
- Report on any produced prototype. Not guaranteed to find any.

Green-Emitting Scintillators (SP33)
polystyrene
1.03 g/cm³
1.57
70 - 75°C
55%
4.4 ns
503 nm







SP32 and SP33 Sample 2 months after irradiation at CERN (~50kGy).

2024-10-24 Blake Leverington - ECFA DRD4 WP4.5 BMBF UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386 10

Status of the MoU

- Various meetings over the last months between DRDs management and CERN management to converge on a final Memorandum of Understanding (MoU) document
  - First MoU draft received from the CERN management end of June
  - Update in July on MoU annexes
  - Documents updated in September and October
- Current status
  - WPs finalised the definition of "Deliverables", that have been included in the tables of Annex 7
  - First draft of the DRD4 MoU document sent to the CERN management on November 8^{th}

Summary

- The DRD4 Collaboration has formed to propose a broad but focused R&D program on photodetectors and PID techniques
- The scope of DRD4 is very strong
  - PID is a key component in modern HEP experiments, and is often achieved with Cherenkov and TOF detectors, that often rely on photodetection
  - Photodetection is undergoing a strong transformation (e.g. SiPMs invade in fields that were occupied since decades by vacuum and gas-based devices)
  - DRD4 includes also SciFi tracking and TRD: they fit well into DRD4
- Thanks to the efforts of many active colleagues, we are building together the DRD4 Community
  - DRD4 scientific activity has started with information exchange within the Working Groups and the organization of Work Package activities
  - DRD4 is continuously attracting new groups
- The success of DRD4 will depend on the ability of the groups to grow and to find the necessary resources
  - Interactions and feedback from Funding Agencies