# WP3: Optimization of Straw Chamber Technologies

## (Description, Organization, Milestones & Deliverables, Next Tasks)

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Jan 29 – Feb 2, 2024 | DRD1 Collaboration Meeting



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# Reminder: WP3 in H2/2023

- Addressing potentially interested groups in straw/drift tube R&D
- Broad application range and R&D scope identified
- Divided work package into six work projects
- Set up collaborating groups and coordinators for each work project

In DRD1 proposal (executive summary)

- Description of key aspects and challenges in straw technologies
- WP3 work package table with R&D header tasks, goals, ..

Proposal annex contains (49 p.)

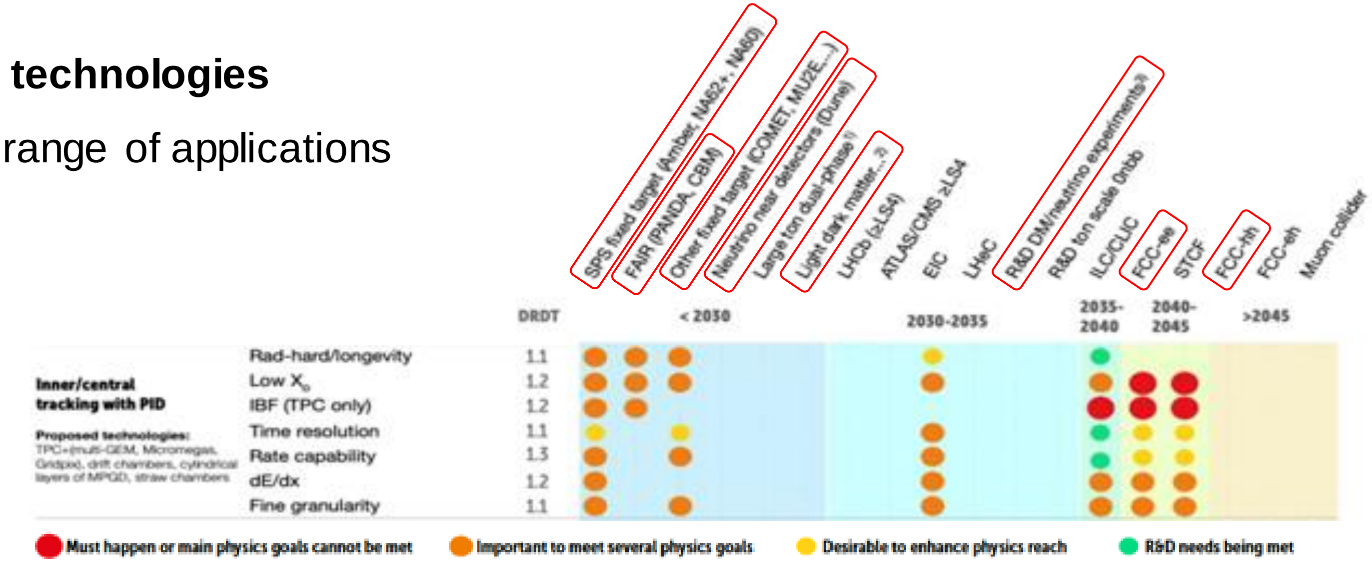
- Description of WP3 work package summary and organization
- Description of each work project, collaborators, resources, milestones, deliverables, ..

# Work-Package Description

**WP3: Optimization of straw chamber and drift tube technologies**

for next-generation straw trackers with broad scientific range of applications

- FCC-ee, CEPC, FCC-hh
- SPS: NA62+, HIKE; FAIR: PANDA, ..
- Dark sector experiments (SHiP, ..)
- Rare event searches (COMET, Mu2E, ..)
- Neutrino physics (DUNE, ..)




*Sketch from ECFA roadmap document and DRDT themes*

**Large variety of technical topics, scientific key aspects:**

- Minimal material budget by ultra-thin straws and e.g. self-supporting modules
- Small diameter straw tubes with thin walls for high rates, fast timing
- Large detector areas by ultra-long straws with thin film walls and in vacuum
- Tracker with enhanced 4D+PID measurements (time, charge readout for dE/dx)
- ASIC designs for broad application range
- Production techniques (e.g. US welding), mass productions and QA, ..
- Novel tracker concept, e.g. for neutrino experiments

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

**DRDT 1.2** - Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes.

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

# WP3 – R&D Tasks

**R&D table in DRD1 proposal, seven header tasks**

- **T1**: Optimize straw materials and straw production technologies
- **T2:** Improve straw tube designs
  - **T2a:** Straw tubes of 5mm diameter
  - **T2b:** Straws with ultra-thin film wall
  - **T2c:** Ultra-long straws (up to 5m)
  - **T2d:** Straw tubes with < 4mm diameter
- **T3:** Optimize the detector mechanical system
- **T4:** Optimize the front-end electronics (ASIC) and read-out system
- **T5:** Enhance the tracker measurement information (3D, t0, dE/dx)
- **T6:** Enhance the longevity of the detector
- **T7:** Optimize the online-/offline software

| # | Task | Performance Goal | DRD1 WGs | ECFA DRDT | Milestones/Deliverable 12M | Milestones/Deliverable 24M | Milestones/Deliverable 36M | Institutes |
|---|---|---|---|---|---|---|---|---|
| T1 | Optimize straw materials and production technologies | - Thin film materials<br>- Film metallization<br>- Low cross-talk<br>- Resistance to ageing<br>- Production techniques | WG1, WG2, WG3, WG4, WG5, WG6, WG7, WG8 | 1.1, 1.2, 1.3 | **M1**<br>**Work plan consolidation:** finalise work package objectives and decide final straw designs including simulation studies. Setting up laboratories, production and test facilities. Tendering and procurement of materials. **[T1-T7]** | **M2.1**<br>**Prototype design and construction:** optimization of straw materials, designs and production technologies for low radiation length, thin-wall tubes, small diameter tubes, long tubes and straws with enhanced longevity. **[T1-T3, T6]**<br>**M2.2**<br>**Optimization of the prototype mechanical system** with low material budget and high mechanical precision. Development of the alignment method. **[T3, T5, T7]**<br>**M2.3**<br>**Optimization of front-end electronic and ASIC design** based on existing ASICs and simulation studies for fast timing, signal leading and trailing edge time readout with high resolution and charge measurement for PID. **[T4, T5]** | **D**<br>**Prototype tests and results:** performance of prototype designs and measurement resolutions (3D-space <150 µm, time t0 of $\mathcal{O}$(1 ns), dE/dx < 10%). **[T1-T7]**<br>Evaluation of WP tasks with review of further enhancement and new potential. **[T1-T7]** | GTU, FZJ-GSI-U Bochum, U Hamburg, MPP, IITG, IITK, NISER Bhubaneswar, U Delhi, U Punjab, INFN-TO, INP-Almaty, JU-Krakow, IFIN-HH, CERN, U South Carolina, U Duke, BNL, FIT, JLab, U Massachusetts, Amherst, U Michigan, UC Irvine, UW–Madison, Tufts |
| T2 | Develop straw tubes of 5mm diameter | - Thin film wall<br>- Fast timing < 100 ns<br>- Rates ≃ 50 kHz/cm$^2$ | | | | | | |
| | Develop straw with ultra-thin film walls | - Film wall < 20 µm<br>- X/X0 ≃ 0.02% / straw<br>- Film metallization | | | | | | |
| | Develop ultra-long straws with thin film walls | - 4-5 m tube length<br>- Film walls < 30 µm<br>- Good mechanical properties | | | | | | |
| | Develop straws with ultra-small diameter | - Diameter < 4mm<br>- Rates > 500 kHz/cm$^2$<br>- Fast timing <50ns<br>- Charge load >10 C/cm | | | | | | |
| T3 | Optimize the detector mechanical system | - Develop self-supporting modules<br>- Control material relaxation<br>- Straw alignment method | | | | | | |
| T4 | Optimize the front-end electronics (ASIC) and readout system | - Leading and trailing edge time readout<br>- Charge readout<br>- Time readout with sub-ns precision | | | | | | |
| T5 | Enhance the tracker measurement information (3D/4D and PID via dE/dx) | - Spatial resolution < 150 µm<br>- Time t0 extraction with $O$(ns) resolution<br>- dE/dx resolution <10%<br>- p/K/π-separation | | | | | | |
| T6 | Enhance the detector longevity | Ageing resistance up to<br>- 1 C/cm for thin-wall straws<br>- >10 C/cm for straws for highest particle rates | | | | | | |
| T7 | Optimize the online-/offline software | - Straw tube simulation<br>- Straw calibrations<br>- Tracking simulation<br>- Pattern recognition<br>- Tracking and PID<br>- Tracker alignment | | | | | | |

# WP3 – R&D Tasks

## Institutes associated to the tasks

- **T1**: Optimize straw materials and straw production technologies
- **T2:** Improve straw tube designs
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  - **T2c:** Ultra-long straws (up to 5m)
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- **T3:** Optimize the detector mechanical system
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- **T5:** Enhance the tracker measurement information (3D, t0, dE/dx)
- **T6:** Enhance the longevity of the detector
- **T7:** Optimize the online-/offline software

| Institute | Contribution | | | | | | | Contact persons |
|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | |
| CERN | X | X | X | | | | | Hans Danielsson, Massimiliano Ferro-Luzzi |
| FZJ | | | X | X | X | | X | Peter Wintz |
| GSI | | | | | X | | X | Jenny Taylor |
| GTU | X | X | X | | X | | | Zviadi Tsamalaidze |
| IFIN-HH | | | X | X | X | | X | Mario Bragadireanu |
| IITG | X | X | X | X | X | | X | Bipul Bhuyan |
| IITK | | | | X | X | | | Navaneeth Poonthottathil |
| INFN-TO | | | | X | | | | Maxim Alexeev, Chiara Alice |
| INP-Almaty | X | X | X | X | X | X | X | Nurzhan Saduyev, Yerzhan Mukhamejanov, Temur Enik |
| JU Krakow | | X | | | | X | | Jerzy Smyrski |
| MPP | X | X | X | X | X | | | Oliver Kortner |
| NISER | X | | X | | | | | Sanjay Kumar Swain |
| RU Bochum | | | X | X | X | | X | Peter Wintz |
| U Hamburg | X | X | X | | | X | | Daniel Bick |
| U Punjab | X | | X | X | | | | Vipin Bhatnagar |
| U South Carolina | | X | X | X | X | | X | Roberto Petti |
| U Duke | | X | | | | | | Seog Oh |
| U Delhi | X | X | | X | | | | Ashok Kumar |
| BNL | | | | X | | | | US Cluster: Markus Hohlmann, Georgios Iakovidis, Bing Zhou |
| FIT | | | | X | | | | |
| JLab | | | | X | | | | |
| U Mass. Amherst | | | | X | | | | |
| U Michigan | X | X | X | X | | | | |
| UC Irvine | | | | X | | | | |
| U Wisconsin | | | | X | | | | |
| Tufts University | X | X | X | | | | | |

# WP3 – R&D Tasks

**Milestones and deliverables proposed**

- **M1: Work plan consolidation**
  - Final objectives, straw designs, simulation studies
  - Setting up laboratories, production and test facilities
  - Tendering and procurement

- **M2: Prototyping**
  - **2.1:** Prototype design & construction (materials, production, ..)
  - **2.2**: Prototype mechanical system, low $X/X_0$, straw alignment
  - **2.3**: FE electronic and ASIC design optimization

- **D: Prototype tests and results**
  - e.g. tracking resolution 3D-space, t0 extraction, dE/dx, low $X/X_0$
  - Review of tasks and further enhancements, new potential

| # | Task | Performance Goal | DRD1 WGs | ECFA DRDT | Milestones/Deliverable 12M | Milestones/Deliverable 24M | Milestones/Deliverable 36M | Institutes |
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| T2 | Develop straw tubes of 5mm diameter | - Thin film wall<br>- Fast timing < 100 ns<br>- Rates ≃ 50 kHz/cm² | | | | | | |
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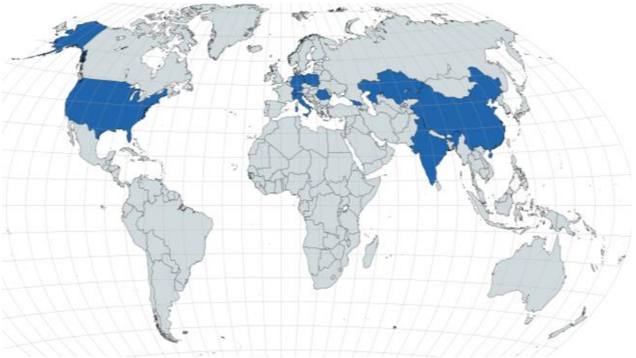
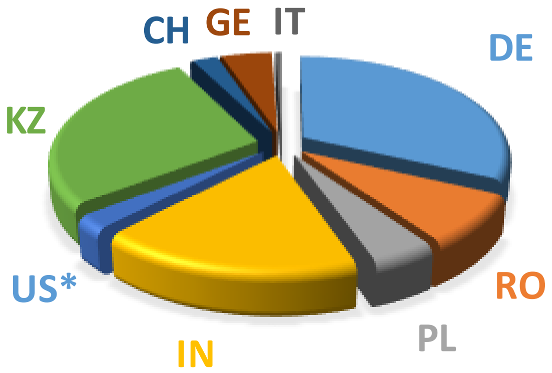
| T6 | Enhance the detector longevity | Ageing resistance up to<br>- 1 C/cm for thin-wall straws<br>- >10 C/cm for straws for highest particle rates | | | | | | |
| T7 | Optimize the online-/offline software | - Straw tube simulation<br>- Straw calibrations<br>- Tracking simulation<br>- Pattern recognition<br>- Tracking and PID<br>- Tracker alignment | | | | | | |

# WP3 – Organization

- **Member groups from 26 institutes in 9 countries** (+ China)
- Work-package consists of **six projects** (A-F)
  - address certain R&D aspects for the respective application
  - formation of collaborating sub-groups and common project description for funding application
- Propose self-organization of the work projects






**Project A** - Drift tube developments for new high-rate applications
Contact person: Oliver Kortner (kortner@mppmu.mpg.de)

**Project B** - Straw chamber technologies for hadron physics applications
Contact person: Peter Wintz (p.wintz@fz-juelich.de, pwintz@cern.ch)

**Project C** - Large area straw detector for Dark Sector applications
Contact person: Daniel Bick (daniel.bick@desy.de)

**Project D** - Straw tracker technologies for neutrino physics applications
Contact person: Roberto Petti (Roberto.Petti@cern.ch)

**Project E** - Optimization of straw materials and production technologies
Contact person: Temur Enik (temur.enik@cern.ch)

**Project F** - Optimization of electronic readout
Contact person: Katerina Kuznetsova (ekaterina.kuznetsova@cern.ch)

Resources

| **Cummulated*** | **Materials (kCHF)** | | | **FTE (y)** | | |
|---|---|---|---|---|---|---|
| | 2024 | 2025 | 2026 | 2024 | 2025 | 2026 |
| **Existing** | 163.5 | 70 | 65 | 32 | 37.3 | 40.3 |
| **Additional** | 525 | 325 | 330 | 11.7 | 12.9 | 12.9 |

*US not yet all included

# WP3 - Annex in DRD1 Proposal

## (Workpackage and Project Descriptions incl. Milestones, Funding, .. 49p)

### DRD1 WP3 – Optimization of Straw Chamber Technologies

**Participating institutes:**

Georgian Technical University (GTU) and Institute of quantum physics and engineering (IQPE), Tbilisi, Georgia
Forschungszentrum Jülich GmbH (FZJ), Germany
Gesellschaft für Schwerionenforschung GmbH (GSI), Germany
Hamburg University, Germany
Max-Planck Institute for Physics (MPP), Garching, Germany
Ruhr-Universität Bochum (RUB), Germany
IIT Guwahati (IITG), Guwahati, India
IIT Kanpur (IITK), Kanpur, India
NISER (NISER), Bhubaneswar, India
University of Delhi (U Delhi), Delhi, India
Punjab University (U Punjab), Chandigarh, India
Torino section of INFN and Università degli studi di Torino (INFN-TO), Italy
Institute of Nuclear Physics (INP-Almaty), Almaty, Kazakhstan
Jagiellonian University, Krakow (JU Krakow), Poland
Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Bucharest, Romania
European Organization for Nuclear Research (CERN), Switzerland
University of South Carolina (U South Carolina), Columbia, SC, USA
Duke University (U Duke), Durham, NC, USA
US Cluster
(Brookhaven National Laboratory, Florida Institute of Technology, Jefferson Lab, University of Massachusetts Amherst, University of Michigan, University of California Irvine, University of Wisconsin-Madison, Tufts University), USA

#### Description of the work package

Straw chamber and drift tube technologies are widely used in particle physics experiments and can cover a broad range of future applications from high-energy physics (HEP) and hadron physics at future accelerators (e.g. FCC-ee, CEPC, FCC-hh, FAIR) to Dark sector, rare event searches and neutrino physics experiments. An application-specific optimization of straw chamber technologies is required including the development of straw tube and detector designs, materials, production techniques, electronic readout with ASIC design, prototype or demonstrator setups with test measurements. Software algorithms for data analyses and simulation in parallel will be developed. Various simulation software packages and frameworks will be used for the mechanical detector and electronics designs and further developed.

Main straw specifications are the wire and tube material, tube diameter and wall thickness, straw length, end-cap design and electric contacting, gas mixture and the straw signal measurement information registered by the electronic readout. The front-end electronics (e.g. ASIC design) and readout system must be developed taking into account particle rates and timing requirements. In addition to the straw signal time for the spatial track information, the measurement of the particle-specific ionization (dE/dx) can be used for particle identification (PID) in the lower momentum region.

1

The optimization of straw tube materials focuses on thin films with less than 30μm and less than 20μm (maybe 12μm) thickness to reduce the radiation length of a straw to below 0.02% ($X/X_0$). Then, the contribution from the tube wall is comparable to the gas volume (for a 10mm tube diameter and 2bar absolute gas pressure). Different types of metallization of such thin films will be investigated with respect to high particle rate capability (up to 1MHz/tube), improved ageing and corrosion resistance, and low cross-talk between adjacent tubes. High purity and ageing resistance of all materials are mandatory to extend detector longevity. Tube diameters of 20mm, 10mm, and 5mm will be studied, the latter for fast timing (< 80ns) and high particle rates up to 50kHz/cm$^2$. The assembly of thin-wall straws with up to 5m length will be developed. New straw production technologies include assembly techniques, all tools, and definition of quality assurance (QA) methods during the production steps, important for future experiments requiring series production of hundred-thousands of straw tubes.

The mechanical detector system has to support and precisely align the straws with up to 5m length. Such ultra-long straws require innovative mechanical support techniques, like carbon-fibre suspension, constant-force springs or self-supporting cemented packs of straws. The use of very thin straw films for minimal material budget requires R&D on the film properties under mechanical stress and over a long time to investigate long-term material relaxation and creeping and develop methods for compensation. A unique application of straw detectors is their operation in surrounding vacuum due to their robust mechanical shape if the gas inside the thin film tubes is at over-pressure of about 1bar. This technology allows very large detection areas (~ 50sqm) together with thin foils (< 30μm) in vacuum. The control of gas leakage and change of the gas mixture ratio by a difference in the molecular permeation through the thin film wall are key aspects.

Various prototype straw and drift tube detectors will be set up with electronic readout consisting of new, custom-specific designed ASICs. ASICs for time and charge readout and for high or moderate particle rates will be developed. A demonstrator inner tracking straw detector consisting of 10mm diameter tubes arranged in about 20 close-packed layers will be built to perform and optimize 4D+PID track measurements (3D-space, time t0, dE/dx). The dE/dx information by the signal time-over-threshold will be used for particle identification (PID) in the lower momentum region. The 4D+PID track reconstruction and detector alignment software algorithms will be developed including simulation and data analysis.

Part of this work package is the set up of a new straw series production facility (at INP Almaty) with the technique of ultrasonic welding of thin film tubes of different diameter, different film tube thickness, and lengths up to 5m and including quality control procedures. This contribution is very important for this work package, but might also be of benefit for the whole straw detector community in future.

#### The 2021 ECFA detector research and development roadmap

The work package covers the following DRD themes (DRDT) which have been defined by the ECFA Detector R&D Roadmap Process Group. CERN-ESU-017. CERN, 2020, p. 248. DOI: 10.17181/CERN.XDPL.W2EX

- **DRDT 1.1** - Improve time and spatial resolution for gaseous detectors with long-term stability.
- **DRDT 1.2** - Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes.
- **DRDT 1.3** - Develop environmentally friendly gaseous detectors for very large areas with high-rate capability.

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#### List of R&D tasks of the work package

The R&D topics in this work package consists of seven tasks. **Table 1** lists the institutes with associated tasks.

- **T1**: Optimize straw materials and straw production technologies
- **T2:** Improve straw tube designs
  - **T2a:** Straw tubes of 5mm diameter
  - **T2b:** Straws with ultra-thin film wall
  - **T2c:** Ultra-long straws (up to 5m)
  - **T2d:** Straw tubes with < 4mm diameter
- **T3:** Optimize the detector mechanical system
- **T4:** Optimize the front-end electronics (ASIC) and read-out system
- **T5:** Enhance the tracker measurement information (3D, t0, dE/dx)
- **T6:** Enhance the longevity of the detector
- **T7:** Optimize the online-/offline software

#### Work package organization

The work package is organized in work projects, which address certain R&D aspects for the respective application, but also the formation of collaborating sub-groups and common project description for funding application.

The first four projects (A-D) refer to drift tube and straw chamber technologies for applications at future accelerators, including also non-HEP applications, like Dark Sector and neutrino physics experiment installations. Projects E and F have a more general approach.

**Project A** - Drift tube developments for new high-rate applications
Contact person: Oliver Kortner (kortner@mppmu.mpg.de)

**Project B** - Straw chamber technologies for hadron physics applications
Contact person: Peter Wintz (p.wintz@fz-juelich.de, pwintz@cern.ch)

**Project C** - Large area straw detector for Dark Sector applications
Contact person: Daniel Bick (daniel.bick@desy.de)

**Project D** - Straw chamber technologies for neutrino physics applications
Contact person: Roberto Petti (Roberto.Petti@cern.ch)

**Project E** - Optimization of straw materials and production technologies
Contact person: Temur Enik (temur.enik@cern.ch)

**Project F** - Optimization of electronic readout
Contact person: Katerina Kuznetsova (ekaterina.kuznetsova@cern.ch)

3


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# WP3 - Annex in DRD1 Proposal

## (Project Descriptions, Example: Neutrino Physics Application)

**WP3 - Work Package Project D**

**Straw tracker technologies for neutrino physics applications**

**Participating institutes:**

Georgian Technical University (GTU) and
Institute of quantum physics and engineering (IQPE), Tbilisi, Georgia

IIT Guwahati, Guwahati, India

IIT Kanpur, Kanpur, India

NISER, Bhubaneswar, India

Panjab University, Chandigarh, India

Institute of Nuclear Physics (INP), Almaty, Kazakhstan

University of South Carolina, Columbia, SC, USA

Duke University, Durham, NC, USA

.....

DESCRIPTION OF THE PROJECT
(AND POSITIONING W.R.T. THE ROADMAP)

Straw tubes provide the base technology for a novel detector concept for neutrino physics, addressing some of the main limitations of neutrino experiments. A Straw Tube Tracker (STT) for such applications is designed to offer an accurate control of the configuration, chemical composition and mass of the neutrino targets similar to electron scattering experiments, by physically separating the neutrino targets from the actual tracking system composed of straws with negligible mass. Many (70-100) thin target layers (each typically 1-2% of radiation length) of various passive materials with high chemical purity are dispersed between layers of straws distributing the target mass throughout a large magnetized volume. The average density is kept low enough ($\leq$0.17 g/cm$^3$) to obtain a total detector length comparable to one radiation length, for an accurate measurement of the four-momenta of the final state particles. The passive targets account for up to 97% of the total detector mass and can be easily replaced during data taking with a broad range of materials manufactured in the form

29

of thin planes. The high intensity of modern neutrino beams complements well the relatively small fiducial mass (a few tons) of the various targets integrated within the STT.

The STT offers unique detector capabilities for neutrino experiments. A key feature is the concept of "solid" hydrogen target, obtained by subtracting measurements on dedicated graphite (pure carbon) targets from those on polypropylene ($CH_2$) targets. This technique provides a powerful tool to reduce the systematic uncertainties affecting the measurements of neutrino interactions. In particular, it allows a determination of the unknown neutrino flux with precisions not achievable with other known techniques. The unique combination of hydrogen and nuclear targets within the same detector also allows to directly constrain the nuclear effects resulting in an accurate calibration of the neutrino energy scale. Particle identification is available throughout the STT volume by exploiting the ionization signals dE/dx by charged particles, the transition radiation by high energy electrons, momentum-range relations, and time of flight.

The STT technology will be relevant for future neutrino scattering experiments, as well as for next-generation long-baseline neutrino oscillation experiments. The first application is foreseen in the Deep Underground Neutrino Experiment (DUNE), in which a large STT including about 220,000 straws with an average length of about 3.2m will be part of the near detector complex. The STT detector in DUNE is expected to be operational in 2030. This project aims to optimize the design and performance of the STT technology for neutrino physics applications including DUNE and other future experiments. Important aspects to be considered are: (a) development of self-supporting multi-layer planar modules covering a large area; (b) compact mechanical design minimizing tracker mass and module thickness; (c) high module integration including gas distribution, readout electronics, cooling; (d) development of custom readout of both drift time and energy deposition; (e) target-tracker integration. The project includes the construction and test of detector prototypes, as well as a program of testbeam measurements for the evaluation of the detector performance and the optimization of the readout.

LIST OF PARTICIPATING INSTITUTES/LABS WITH A SHORT DESCRIPTION

**Institute D.1: GTU and IQPE, Georgia.**
Contact person: Zviadi Tsamalaidze

The High Energy Physics (HEP) group from the Georgian Technical University and the institute for quantum physics and engineering has a broad experience including contributions to the CDF, D0, Mu2e (Fermilab), PIBETA (PSI, Swiss), CMS and LHCb (CERN), E391a, ILC and COMET (KEK, J-PARC, Japan) experiments. The group is led by Zviadi Tsamalaidze and includes five scientists, an engineer, and graduate students. The expertise of the members of the group covers various hardware aspects related to the design, construction, calibration, and operation of detectors with organic & inorganic scintillators, electromagnetic and hadron calorimeters, as well as gaseous detectors like MWPC, Drift chambers, Straw trackers, and RPC detectors. The group has also experience in software development including system programming, firmware for electronics, databases, and reconstruction algorithms.

30

**APPENDIX: PARTICIPATING INSTITUTES AND THEIR RESOURCES**

| Project name:<br>Straw tracker technologies for neutrino physics applications | |
|---|---|
| **Tasks** | T1: Optimize material budget and gas tightness<br>T2: Study wire centering and mechanical properties of straws up to 4m long<br>T3: Optimize compact support, assembly procedure, and module integration<br>T4: Develop custom ASIC and integrated readout<br>T5: Optimize time and energy measurements<br>T7: Optimize track reconstruction |
| **Deliverables** | D1.1 Production of 4m straws with double metallization with ultrasonic welding<br>D1.2 Measure gas tightness vs. pressure<br>D2.1 Optimize endplug and wire fixation technology<br>D2.2 Optimize spacer for wire centering<br>D2.3 Measure straw deformations and tension vs. pressure<br>D3.1 Construction and test of straw tracker prototype<br>D3.2 Optimization of assembly procedure for mass production<br>D3.3 Test of module integration: gas, readout, cooling<br>D4.1 Testbeam measurements of straw tracker prototypes with different readouts<br>D4.2 Specifications and preliminary studies of custom ASIC<br>D5.1 Analysis of testbeam data with different readouts<br>D5.2 Develop algorithms for tracking and for particle identification<br>D7.1 Develop straw simulation software<br>D7.2 Develop software for track reconstruction |
| **Description of Technologies** | Straw trackers, thin low-mass planar design, self-supporting multi-layer modules, overpressure operation, readout electronics integrated within mechanical structure, readout of both drift time and dE/dx, low rate applications, target-tracker integration. |
| | integrated with tracking modules |
| **Planned dates and longer term plans** | **2024 - 2026:**<br>**Institute D.1:** Production of straw tubes for prototyping and tests, quality controls and functional tests, testbeam exposure of straw prototypes, assembly of STT prototypes, simulation and reconstruction.<br>**Institute D.2:** Production of straw tubes, quality controls and functional tests, ASIC and readout, testbeam exposure of straw prototypes, assembly of STT prototypes, simulation and reconstruction. |



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# Summary

***Strategic R&D for next generation Straw Trackers***

- *Drift tube developments for high-rate applications*
  *(FCC-ee/hh, **small diameter MDT**, large area muon tracker, ASIC optimization, $\gamma$-conv. reduction, double-sided readout ..)*
- *Straw chamber technologies for hadron physics*
  *(**4D+PID central tracker**, **low $X/X_0$:** ~1.3%/24 layers, <4% end cap region, dE/dx by time-over-thresh, continuous RO ..)*
- *Large area straw detector for Dark Sector applications*
  *(**4m long thin-wall straws, 50 sqm detector area in vacuum**, alignment, mass-production techniques, QA ..)*
- *Straw tracker technologies for neutrino physics*
  *(**"solid H2-target" detector,** stacked layers of targets and "transparent" straws, small diameter, **O(100k) straws**, mass prod. and QA, dE/dx, **electron-TR**, ASIC, ..)*
- *Optimization of straw materials & production technologies*
  *(e.g. **standardization of materials**, designs, **prod. techn**..)*
- *Optimization of electronic readout*
  *(new **ASIC designs, versatile applications**, time, charge RO, high/low rates, fast/moderate timing, continuous stream)*

***Broad range of application fields, technol. trends***

- *Thinner film walls (e.g. $X/X_0$ similar to gas contribution)*
- *Smaller diameter for high rates and fast timing*
- *Ultra-long straws with thin film wall*
- *Robust thin-film metallization and clean materials*
  *(e.g. US welding of straw film tube)*
- *Standardize straw materials and prod. technologies*
- *Thin-film straw detectors in vacuum unique application*
- *Enhanced tracking: 3D/4D + dE/dx, t0 - extraction*
- *ASIC design optimization for broad application range*
- *New tracker concepts, new benchmarks ..*

# Thoughts on Next Steps

- Consolidate WP3 structure
  - Self-organized WP projects (A-F) with project e-groups
  - Common WP3 e-group for information sharing
  - Policy for personal data protection (e.g. email lists)
- Active addressing of potential new groups continuing
  - Open for new R&D tasks/projects
  - Advising if WP or WG, or joining existing project
  - Information / existing project documents as template
- Information on web page (https://drd1.web.cern.ch/wp/wp3)
  - Projects and contact persons
  - Guiding interested groups
- MoU preparation, per project
  - Milestones and deliverables (light-weight)
  - Reasonable granularity and reachable deliverables
  - Project funding, timelines (e.g. if > 3 years)
- Reviewing aspects
  - within DRD1
  - relevant for DRDC
  - Key performance identifiers for broad scope

***Thank you very much***

***for***

***your attention!***



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