Future Ultra-Light Pixelated Tracking Devices

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(DMlab kick-off – 9 Decembre 2021)

Contents

- Physics objectives: search of DM particles
- Overview
- Double-sided detector modules
- Ultra-thin detector layers
- Context & Partners
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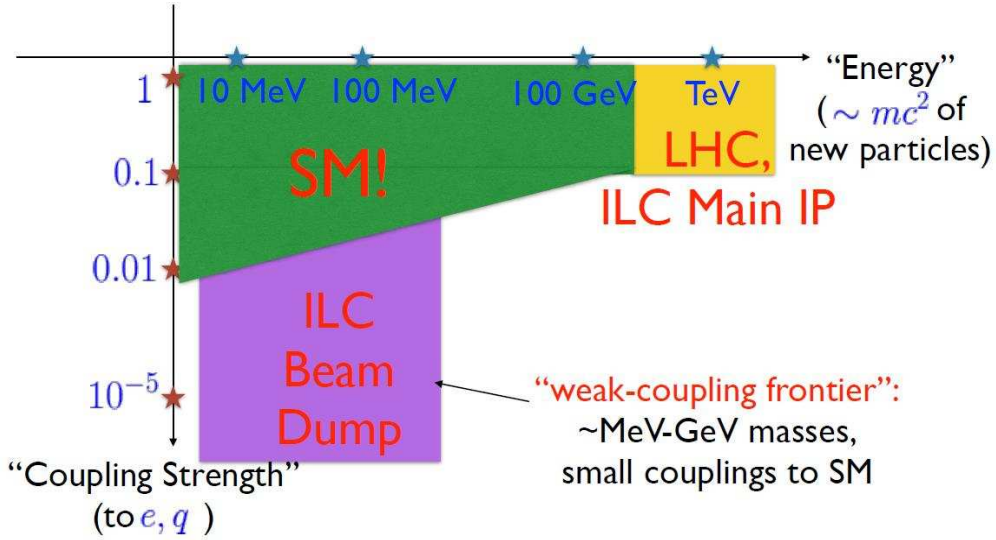
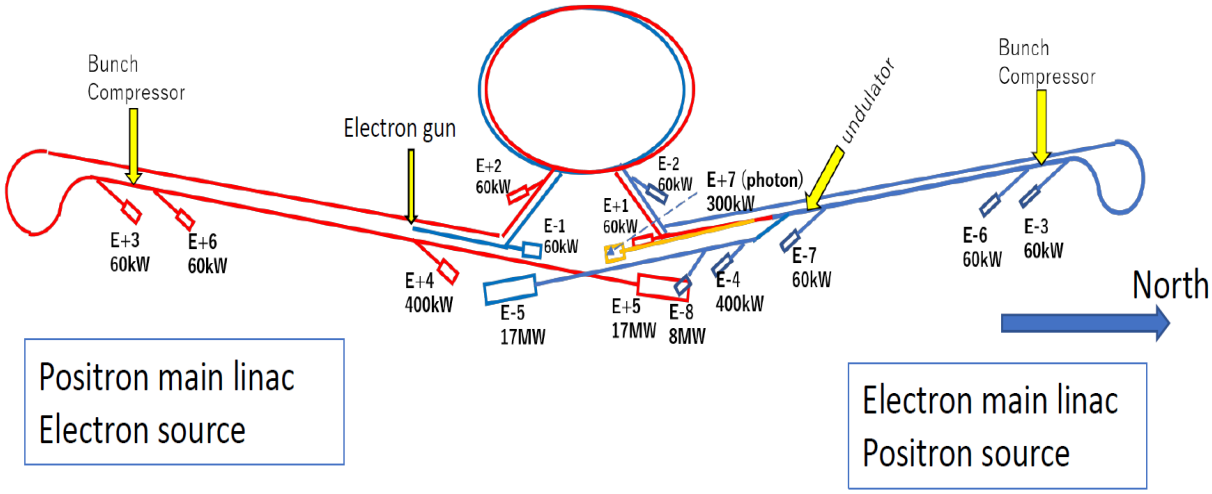
SOURCES: PLUME coll., Nucl. Instr. Meth. A650 (2011) 208-212;
CREMLInplus EU project (WP-7), H2020-INFRASUPP-2018-2020;
ALICE coll, CERN-LHCC-2019-018 / LHCC-I-034;
R. Brenner et al., CERN-LHCC-2017-002 ; LHCC-I-028
C. Garuglio (ITS-3), Forum on Tracking Detector Mechanics, 2021

Tracking and Search for DM at an e^+e^- Collider

- **Search for DM candidates at an e^+e^- collider:**
  - multipurpose experiments installed around the IPs
  - beam dumps absorbing $e^{\pm}$, γ beam remnants

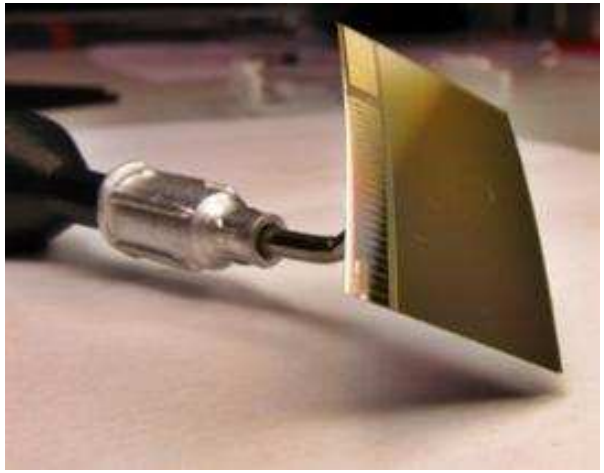


- **High performance tracking essential for the search of DM candidates:**
  - Reconstructing DM decay products:
    - * in crowded final states (e.g. H decay at IP)
    - * in boosted final states (e.g. beam dump)
  - Reconstructing precisely all tracks produced:
    - * imposes suppressed material budget
    - * calls for excellent coverage



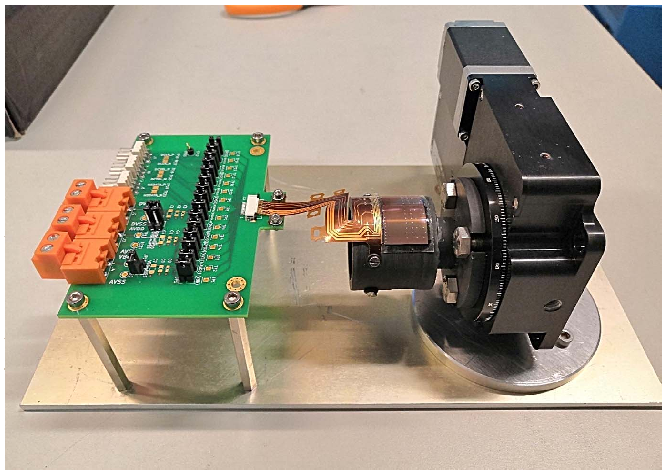
- **Synergies underlying the partnership:**
  - all Higgs factories (e.g. FCCee), LHCpp
  - Heavy ion collisions: CBM/FAIR, ALICE/LHC

Developping Novel Tracking Performances Based on Thin CMOS Pixel Sensors

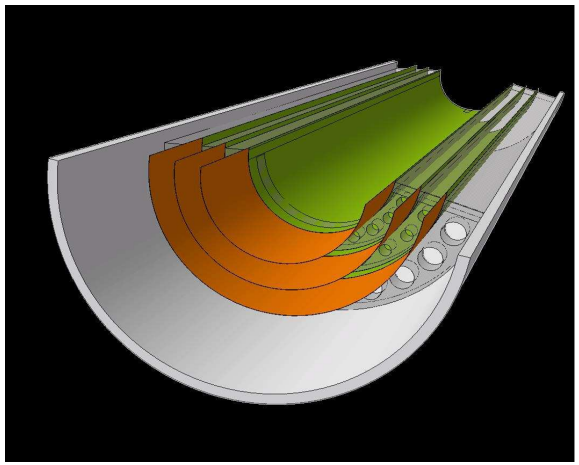


50 μm thin CMOS sensor

PLUME ladder



bending thin CMOS sensors

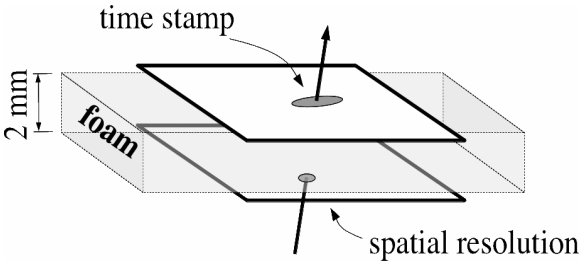


supportless Vx Det.

Exhaustive/Ambitious Overview

- **Technological goal:**
  - achieve new standards in charged particle detection (granularity & material budget), exploiting:
    - exploit thinned CMOS Pixel Sensors (CPS) and their industrial progress (feature size, stitching)
    - exploit new materials and their industrial progress
    - investigate potential asset of wireless short range signal transmission
  - two concepts addressed:
    - ultra-light double-sided detector modules for 1) large surface tracking devices and 2) vertex detectors
    - nearly unsupported large cylindrical detector modules for 1) vertexing and 2) tracking devices

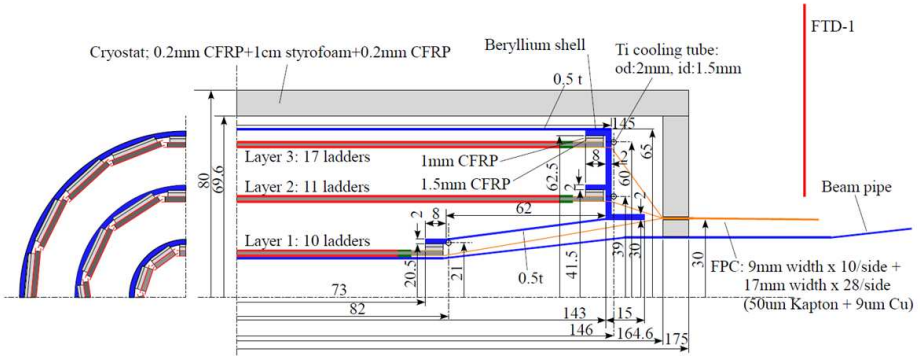
- **Ultra-light double-sided detector modules for large area trackers:**
  - start from PLUME double-sided ladder concept
  - investigate reduction of material budget
  - investigate power pulsing procedure
  - investigate (if relevant) wireless communication between detector layer faces
  - overlap with CBM-MVD chip devt (MIMOSIS/CREMAPS), CREMLIN+, AIDAinova

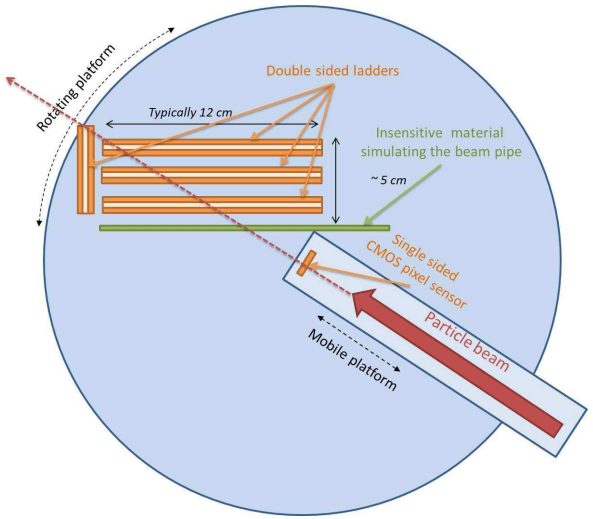


- **Cylindrical, nearly unsupported, detector modules for vertex detectors:**
  - exploit large area CPS manufactured with stitching techniques
  - investigate suppression of material due to flex cable and mechanical support
  - partnership with ALICE-ITS3 (and CERN R&D WP-1.2) & CREMLIN+

Use of ”PLUMOSIS” Ladders: The Tricky Corner of the Vertex Detector

- **General idea:** (derived from ILD experimental concept)
  - Reproduce approx. a small azimuthal sector of the vertex detector in polar angle sector ($\sim 30^\circ$ to 10°) in front of FW trackers (see fig.) with 2 ladder pairs for barrel and 1 pair for end-cap (+ telescope)
  - Install whole system on rotating table at DESY test beam (the rotation wrt beam line simulates the track polar angle)
  - Study track reconstruction (& hit clusters $\Rightarrow$ σ_{sp}) versus polar angle while varying the geometry (e.g. distance between detection planes)
  - Compare beam test results to M.C. simulations
  - Recalibrate anticipated/simulated track reconstruction performances of ILD with beam test results
  - Outcome of study: optimal vertex detector geometry and improved realism of ILD software

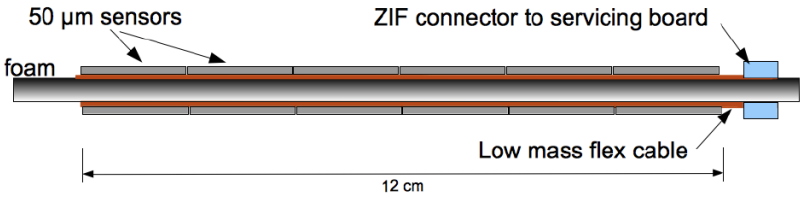


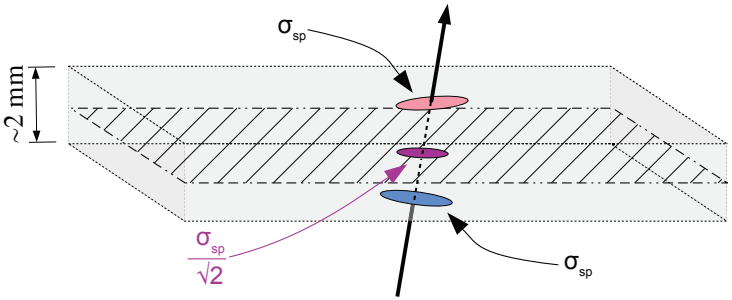


- **Components:**
  - 2 or 4 PLUME like ladders based on MIMOSIS standing for barrel of Vertex Detector
  - at least 2 ladders standing for a Vertex Detector end-cap
  - telescope based on MIMOSIS (alias CREMAPS) CPS, standing for tracking outside of Vertex Detector
  - all ladders mounted in a way allowing for rotations & translations wrt beam line (inside horizontal plane containing beam)

Ultra-Light Double-Sided Pixelated Tracker Modules

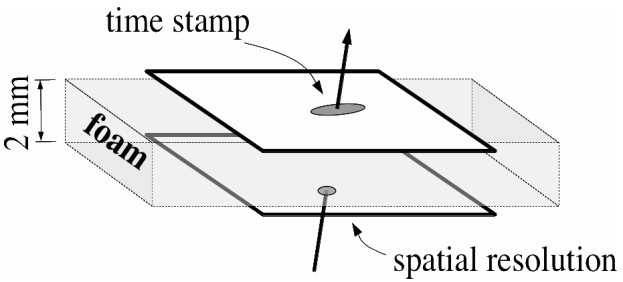
- **General remarks:**
  - Double-sided ladders for
    - excellent spatial resolution (granularity $\longmapsto$ face-to-face correlation)
    - coping with very high hit densities (speed $\longmapsto$ face-to-face correlatic
  - Caveate: material budget oughts to be suppressed enough
  - PLUME $\equiv$ Existing prototype, based on MIMOSA-26:
    8 million pixels, $\gtrsim$ 3 μm, 115 μs, 0.4 % X_0
  - 1st goal: improve r.o. speed to O(1) μs & squeeze mat. budget
    to $\lesssim$ 0.3 % X_0, validate face-to-face sensor correlation
  - 2ry goal: investigate wireless face-to-face signal transmission
  - Possibly: investigate power pulsing in mag. field ? (tbc)





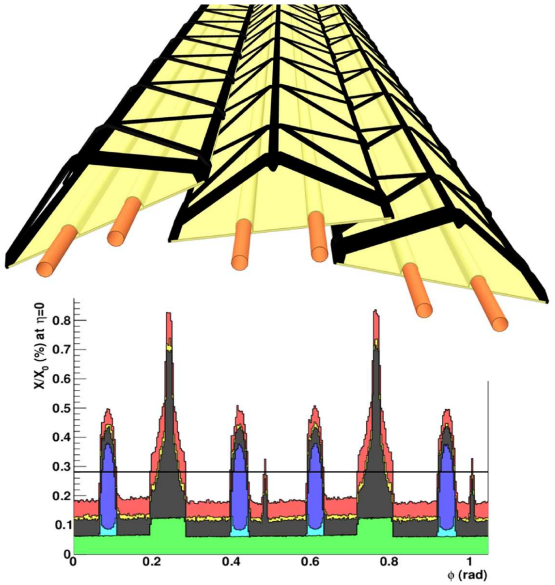
- **Sensor related objectives:**
  - Baseline MIMOSIS-2 proto.: $\sim$ 5 μm, $\lesssim$ 5 μs, $\lesssim$ 50 mW/cm^2, $\gtrsim$ 50 MHz/cm^2
  - Assess spatial resolution of ladder based on face-to-face correlations
  - Ideally: develop mixed MONOPIX/MALTA-MIMOSIS ladders (complicated !)

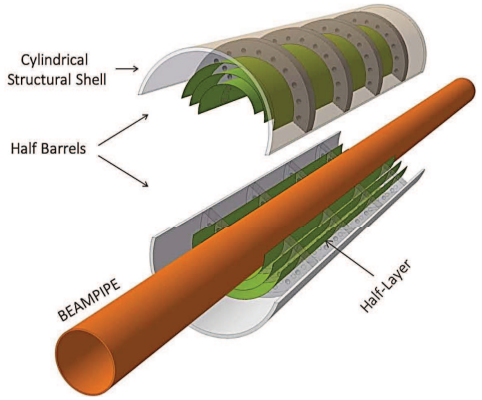
- **System related objectives:**
  - revisit structure of PLUME to compress its material budget
  - investigate new materials & micro-channel cooling possibilities

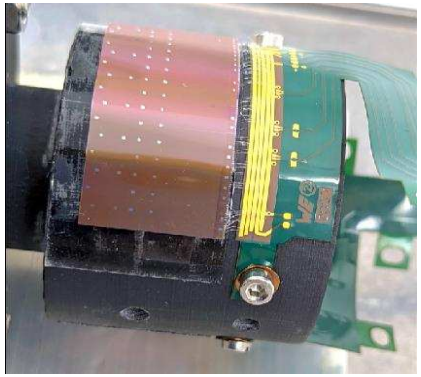


Ultra-Thin and Curved Pixelated Detector Modules

- **General idea:**
  - Suppress mat. budget due to overlaps between neighbouring staves
  - Revisit concept of ladder based on multi-reticle (stitched) CPS
  - Vertex detector innermost layer: use beam pipe as support
- **Mechanical issues:**
  - investigate concept of cylindrical bending of large sensors
  - investigate use of beam pipe as mechanical support
  - study mechanical support for large bent thinned CPS
- **CPS issues:**
  - realise stitched sensors: 65 nm or 180 nm CMOS process
  - investigate 65 nm imaging process detection capability
  - validate 65 nm process and assess its added value wrt 180 nm process
- **Framework:**
  - Partnership with ALICE-ITS3 & CERN-EP WP1.2
  - Adaptation to other experimental set-ups (e.g. searching DM particles)







Context and Partners

- **Existing framework underlying the proposed project:**
  - ILC related detector R&D addressing vertex and tracking detectors
  - Upstream R&D of CMOS pixel sensors (CPS) at IPHC-Strasbourg
  - Development of the CPS MIMOSIS for the CBM-MVD at FAIR/GSI
  - CREMLINplus E.U. project (2020 - 2024): WP-7 addressing future tracking detectors in IPHC-GSI partnership
  - ALICE-ITS3 upgrade project and CERN based R&D on future CPS, involving IPHC and DESY
  - AIDAinova E.U. project: WP-3 on beam telescopes with DESY and IPHC
  - former PLUME collaboration (IPHC-Strasbourg - DESY - Bristol Univ.)

- **Partners:**
  - GSI for MIMOSIS/CBM and CREMLINplus
  - DESY for PLUME, CREMLINplus, AIDAinova, ALICE-ITS3 and ILC related R&D
  - IPHC-Strasbourg for all topics above
  - IJCLab: ILC related detector R&D and CREMLINplus, AIDAinova

SUMMARY

- **Objectives of partnership :**
  - develop future high performance tracking systems improving DM particle search capability
  - work on concept of double-sided ladders equipped with thin CMOS sensors
  - work on concept of ”supportless detector module” based on curved multi-reticle CMOS sensors

- **Complementarity of Partners :** considering past and on-going connected activities
  - Development of CMOS sensors:

    design: IPHC, DESY **tests:** IPHC, GSI, DESY, IJClab
  - Development of double-sided detector modules:

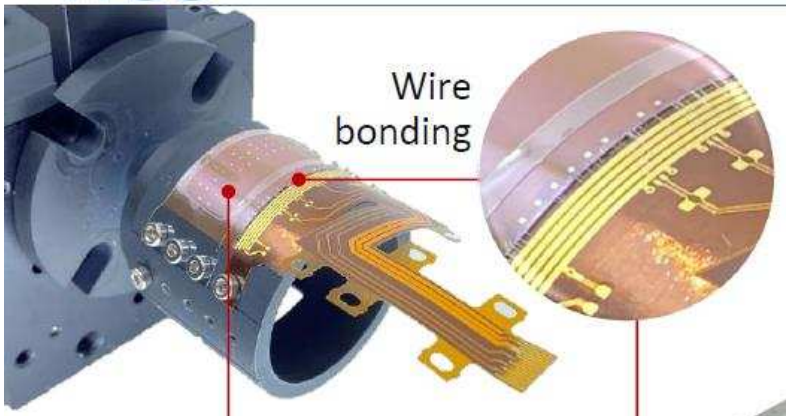
    system integ.: GSI, DESY, IJCLab (tbc) **tests:** IPHC, GSI, DESY, IJClab
  - Development of supportless detector modules:

    design: DESY, IJClab (tbc) **syst. integ.:** IPHC, DESY, IJClab (tbc), GSI **tests:** IPHC, DESY, IJClab

- **Status: project still emerging**
  - Deliverables and work plan still to be defined
  - Definition of contributions from each partner still in progress
  - Resources needed to achieve deliverables still incomplete

ITS3

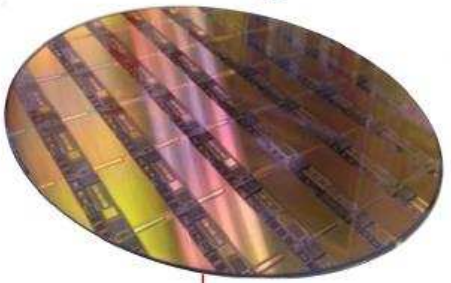
ALICE



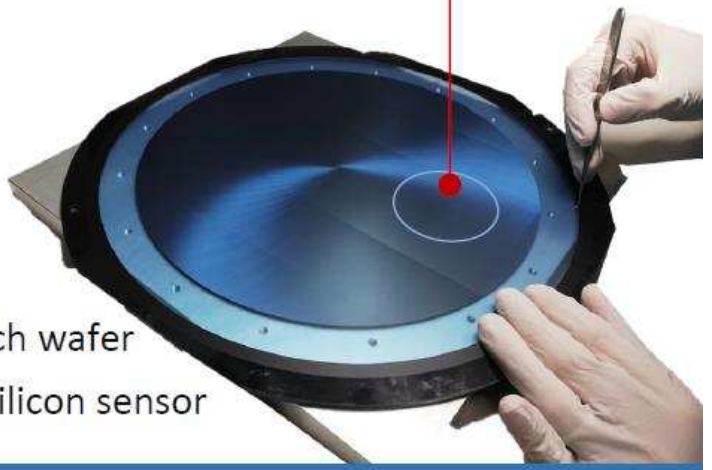
Wire bonding

Low Density Carbon foam

stitching



Curved Silicon ALPIDE sensors



12 inch wafer

40 µm dummy silicon sensor

➔ **R&D in HEP Directions towards unprecedented vertex minimum layers materials**

wire bonding on curved Si Sensor, Bending Si wafers + circuits, minimum material support and cooling.

➔ **R&D with Industry Chips stitching, i.e. aligned exposures of given parts of a reticule to produce a larger sensor**

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