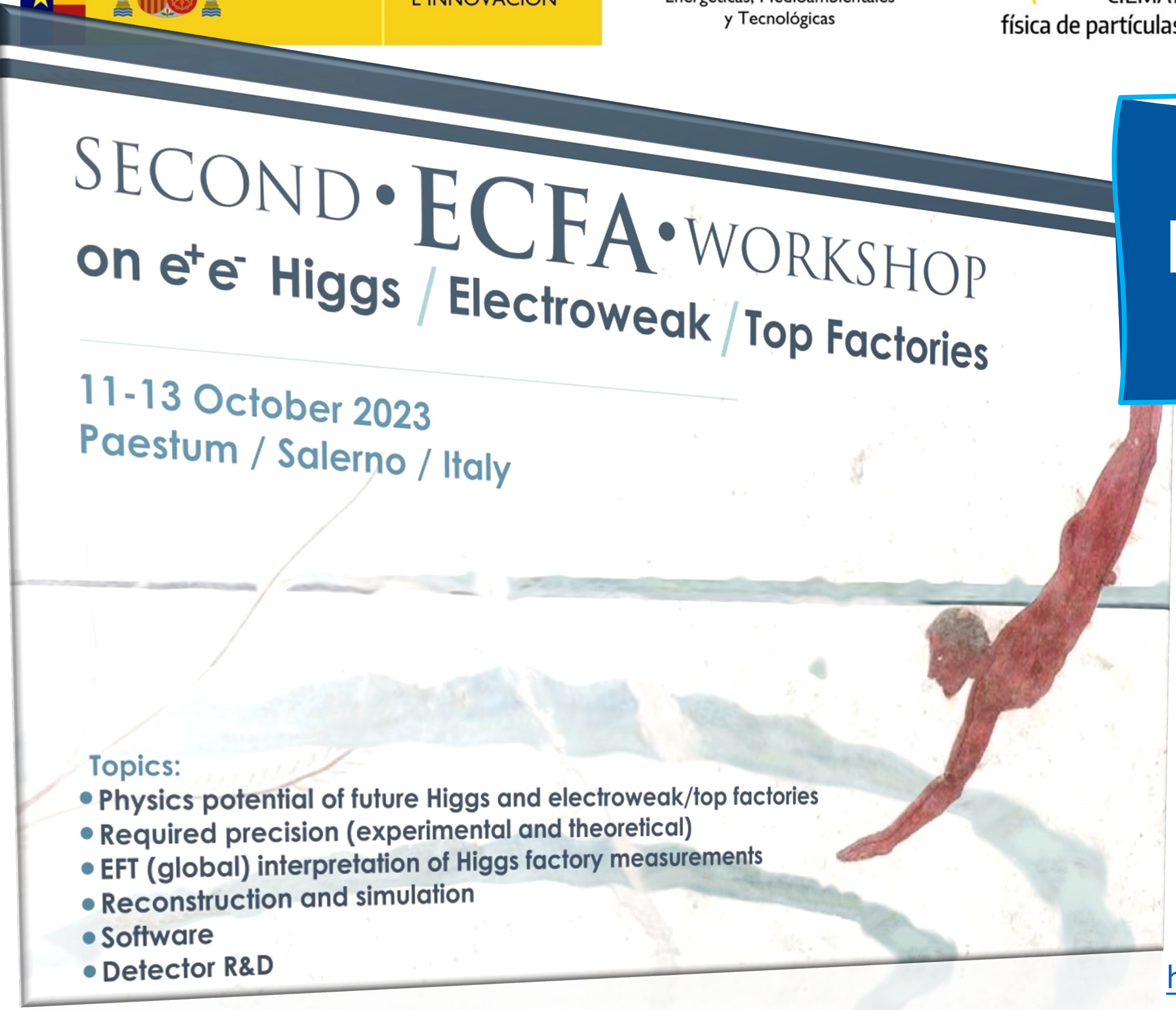
Report from the ECFA Higgs factory meeting in Paestum: Hardware



Mary-Cruz Fouz
CIEMAT

ILD meeting – 7 November 2023

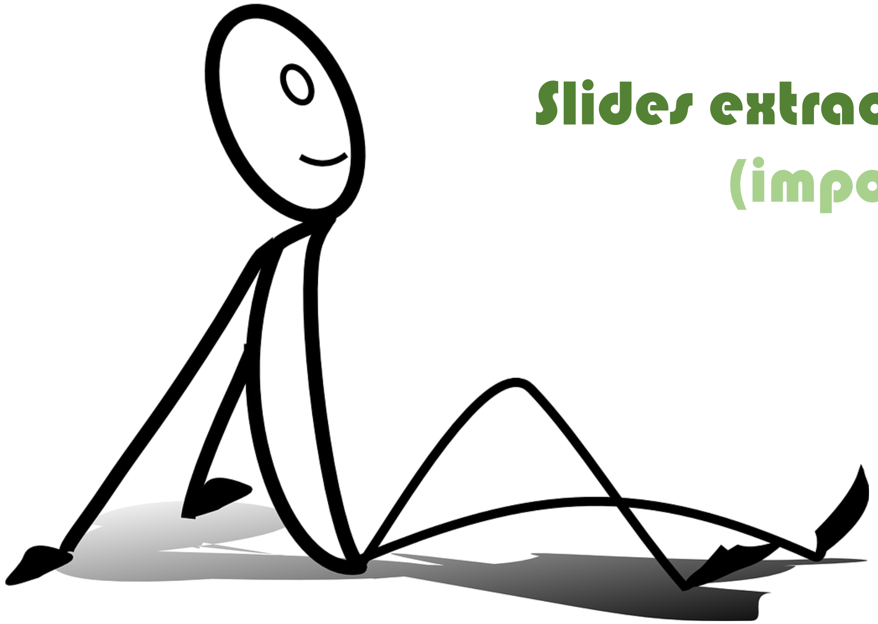
https://agenda.infn.it/event/34841/

Ciemat

Disclaimer

This report represents "my" own summary and interpretation of relevant topics and highlights

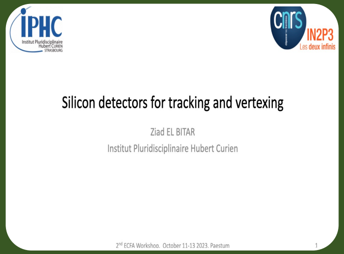
Slides extracted only from Plenary talks
(impossible to include also parallel in a 20 minutes talk)



Plenary Talks related to WG3

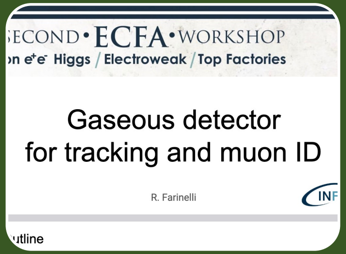
CALORIMETRY

Roman Pöschl



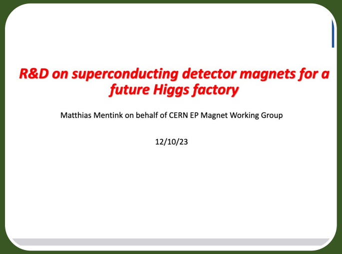
SILICON DETECTORS FOR TRACKING AND VERTEXING

Ziad El Bitar



GASEOUS DETECTORS FOR TRAKING & MUON ID

Riccardo Farinelli



R&D ON SUPERCONDUCTING MAGNETS FOR A FUTURE HIGGS FACTORY

Matthias Mentink

THE SUPERCONDUCTING THIN SOLENOID FOR IDEA. A TRADITIONAL DESIGN OR A STEP TOWARDS NEW TECHNOLOGIES

Michela Bracco

ACTIVITIES IN THE US TOWARDS AN e+e- HIGGS FACTORY - PHYSICS AND DETECTORS

Srini Rajagopalan

Detector Parallel Talks

16 WG3 parallel talks

Wed 11/10

Go back | Print

14:00	**Estimation of the fluxes in highly granular calorimeters**	*Vincent Boudry*	*Sala Nettuno, Hotel Ariston, Paestum*	14:00 - 14:20
	R&D of the calorimeter in the CEPC experiment	*Dr Fangyi Guo*	*Sala Nettuno, Hotel Ariston, Paestum*	14:20 - 14:40
	Noble Liquid Calorimetry for Future Collider Experiments	*Juska Pekkanen*	*Sala Nettuno, Hotel Ariston, Paestum*	14:40 - 15:00
15:00	**Dual readout calorimetry developments towards FCC**	*Giacomo Polesello*	*Sala Nettuno, Hotel Ariston, Paestum*	15:00 - 15:20
16:00	**FCC-ee Detector Full Simulation Implementation**	*Alvaro Tolosa Delgado*	*Sala Nettuno, Hotel Ariston, Paestum*	16:00 - 16:20
	Physics Performance and Detector Requirements at an Asymmetric Higgs Factory	*Antoine Laudrain et al.*	*Sala Nettuno, Hotel Ariston, Paestum*	16:20 - 16:40
	Out-of-Time Pileup Mixing for the C3 Collider Concept	*Lindsey Gray*	*Sala Nettuno, Hotel Ariston, Paestum*	16:40 - 17:00
17:00	**The IDEA Drift Chamber for a Lepton Collider**	*Francesco Massimiliano Procacci*	*Sala Nettuno, Hotel Ariston, Paestum*	17:00 - 17:20
	Particle identification for the IDEA drift chamber using the cluster counting technique	*Walaa Elmetenawee*	*Sala Nettuno, Hotel Ariston, Paestum*	17:20 - 17:40
	R&D on muon detectors for the IDEA experiment	*Riccardo Farinelli*	*Sala Nettuno, Hotel Ariston, Paestum*	17:40 - 18:00

Thu 12/10

Go back | Print

14:00	**Silicon detector technologies for the IDEA detector**	*Attilio Andreazza*	*Sala Nettuno, Hotel Ariston, Paestum*	14:00 - 14:20
	MAPS FOR LARGE AREA SENSORS WITH NANOSECOND TIMING	*Caterina Vernieri*	*Sala Nettuno, Hotel Ariston, Paestum*	14:20 - 14:40
	Characterization of monolithic CMOS pixel matrices with various pitch fabricated in a 65 nm process	*Ziad EL BITAR*	*Sala Nettuno, Hotel Ariston, Paestum*	14:40 - 15:00
15:00	**CLD layout and performance update**	*Andre Sailer*	*Sala Nettuno, Hotel Ariston, Paestum*	15:00 - 15:20
	Interaction region design of the future circular Collider FCC-ee	*Manuela Boscolo*	*Sala Nettuno, Hotel Ariston, Paestum*	15:20 - 15:40
	Design of the IDEA vertex detector and its integration with FCC-ee,	*Fabrizio Palla*	*Sala Nettuno, Hotel Ariston, Paestum*	15:40 - 16:00
16:00				

Detector Parallel Talks

16 WG3 parallel talks

Only 1 talk related to ILD

Most of talks about IDEA detectors

Wed 11/10 — Go back | Print

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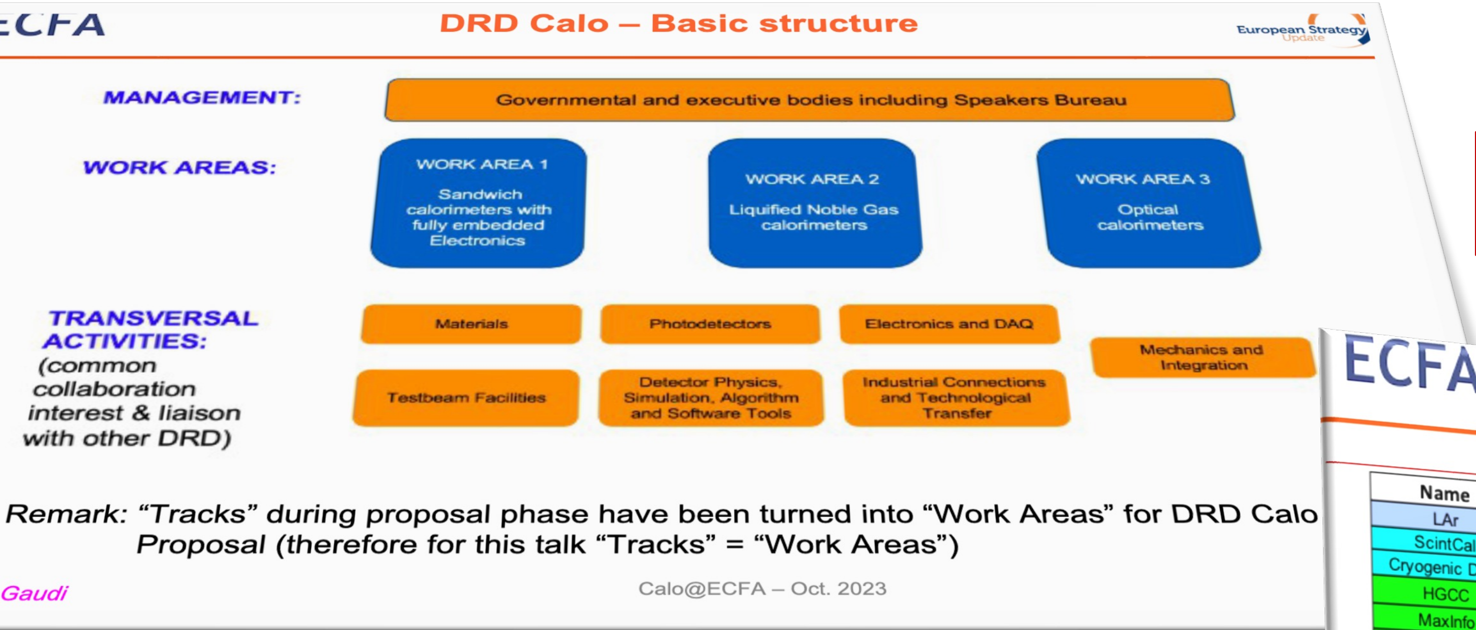
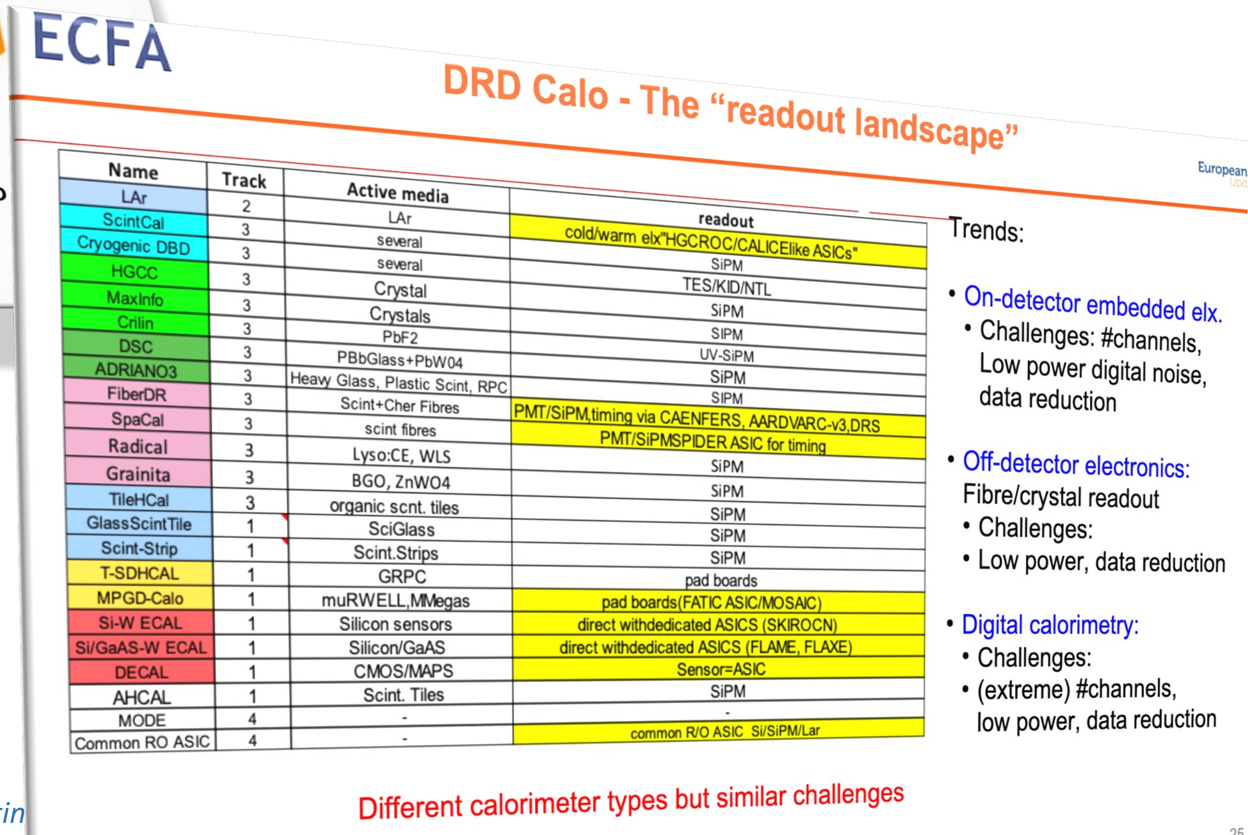
Calorimetry



Talk mainly focused on the organization towards the new DRD6 collaboration- See details

Roman Pöschl

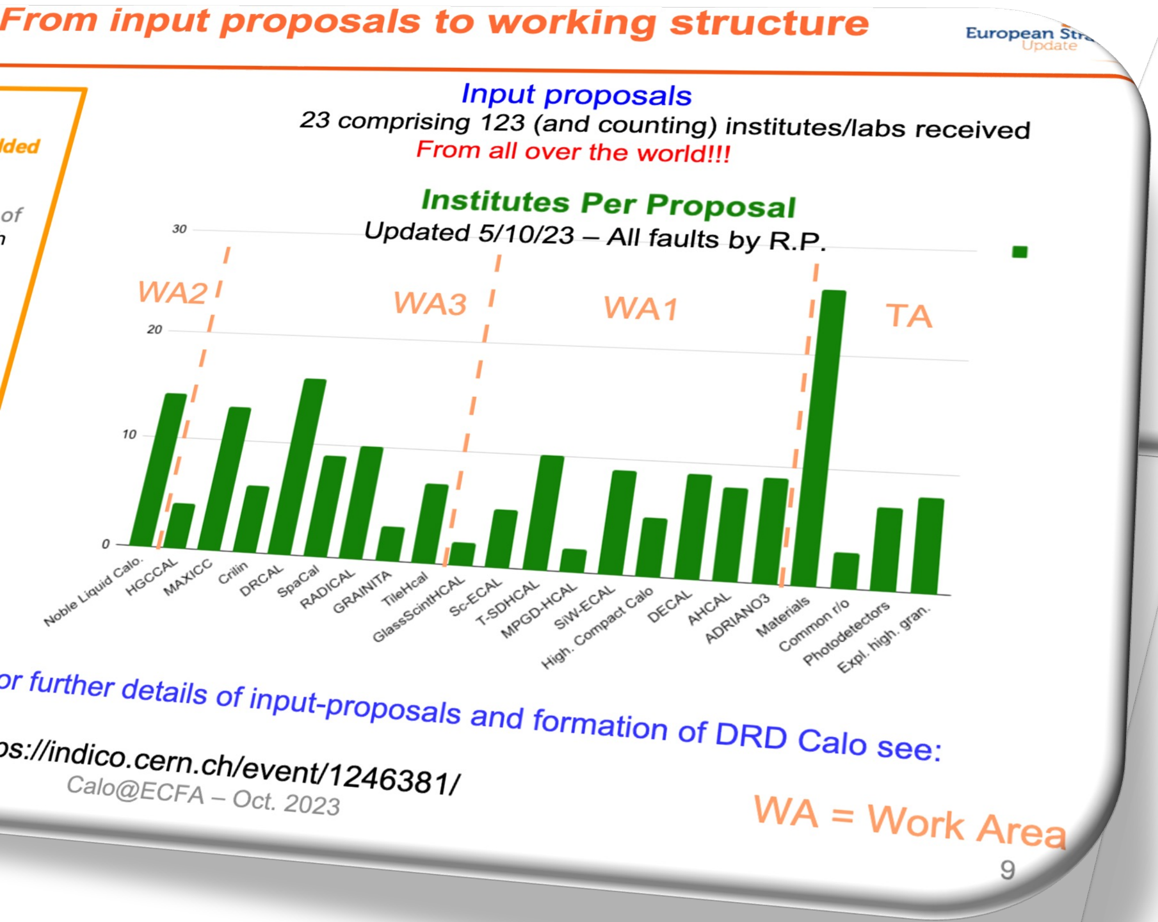
DRD Calo proposal available here

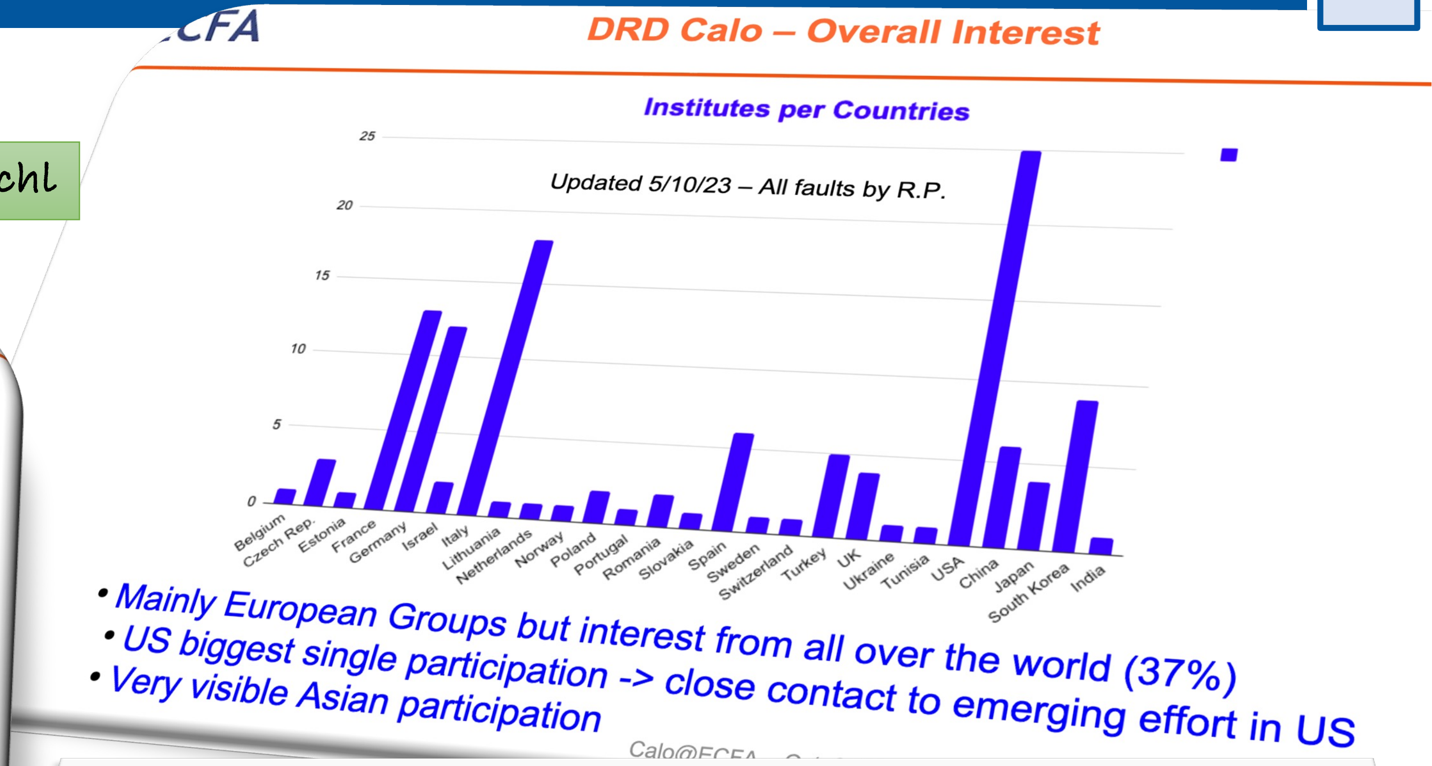


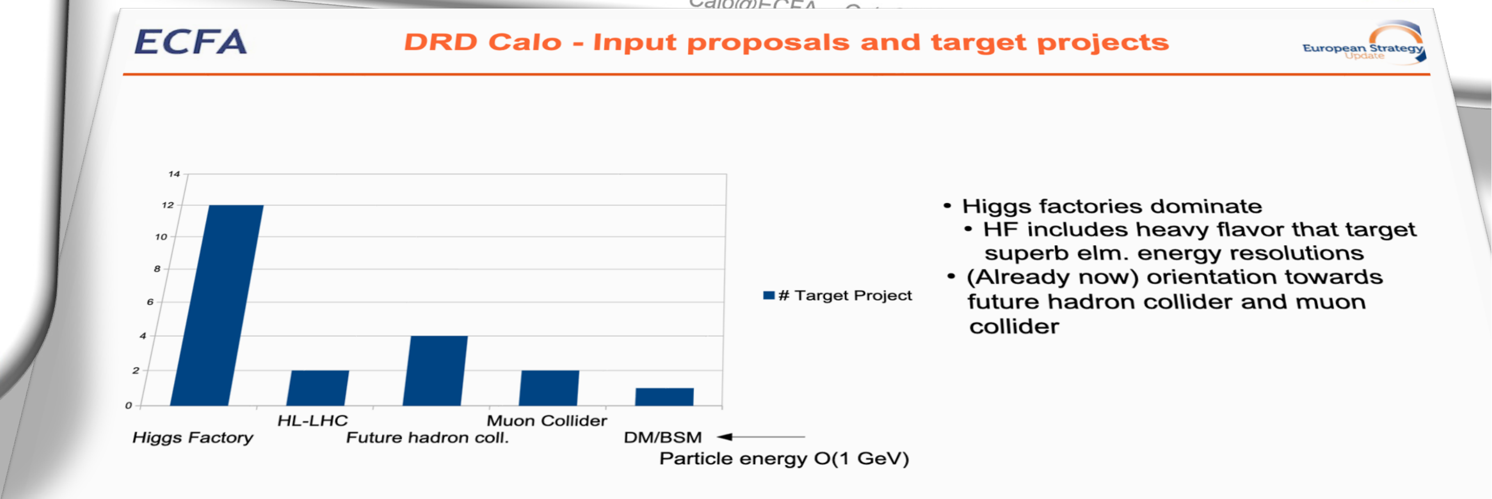
Name	Track	Active media	readout
LAr	2	LAr	cold/warm elx"HGCROC/CALICElike ASICs"
ScintCal	3	several	SiPM
Cryogenic DBD	3	several	TES/KID/NTL
HGCC	3	Crystal	SiPM
MaxInfo	3	Crystals	SiPM
Crilin	3	PbF2	UV-SiPM
DSC	3	PBbGlass+PbW04	SiPM
ADRIANO3	3	Heavy Glass, Plastic Scint, RPC	SiPM
FiberDR	3	Scint+Cher Fibres	PMT/SiPM,timing via CAENFERS, AARDVARC-v3,DRS
SpaCal	3	scint fibres	PMT/SiPMSPIDER ASIC for timing
Radical	3	Lyso:CE, WLS	SiPM
Grainita	3	BGO, ZnWO4	SiPM
TileHCal	3	organic scnt. tiles	SiPM
GlassScintTile	1	SciGlass	SiPM
Scint-Strip	1	Scint.Strips	SiPM
T-SDHCAL	1	GRPC	pad boards
MPGD-Calo	1	muRWELL,MMegas	pad boards(FATIC ASIC/MOSAIC)
Si-W ECAL	1	Silicon sensors	direct withdedicated ASICS (SKIROCN)
Si/GaAS-W ECAL	1	Silicon/GaAS	direct withdedicated ASICS (FLAME, FLAXE)
DECAL	1	CMOS/MAPS	Sensor=ASIC
AHCAL	1	Scint. Tiles	SiPM
MODE	4	-	-
Common RO ASIC	4	-	common R/O ASIC Si/SiPM/Lar

Calorimetry

Roman Pöschl







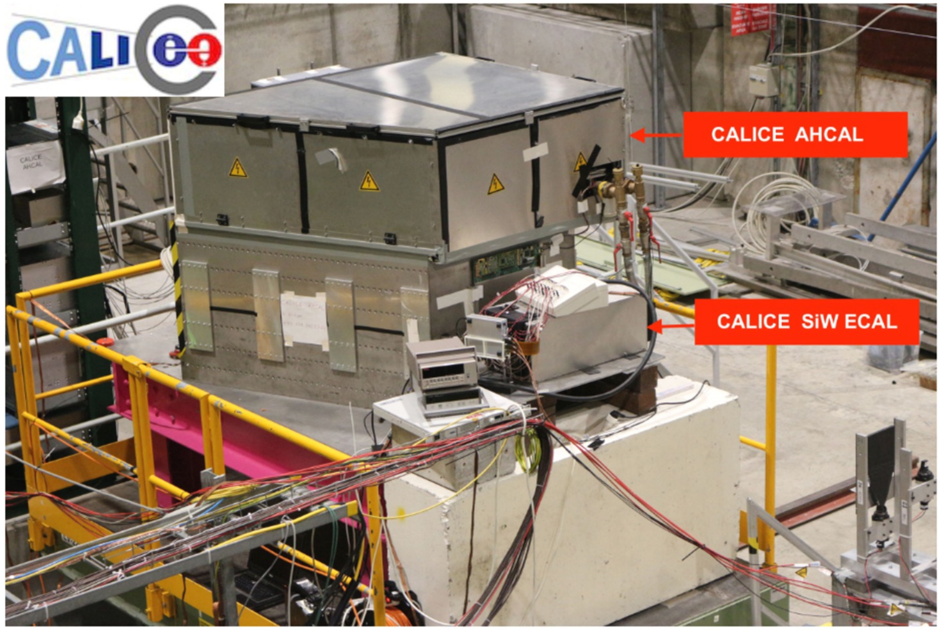
Calorimetry

Roman Pöschl

ECFA

Dedicated Calorimeter Beamline?

European Strategy Update



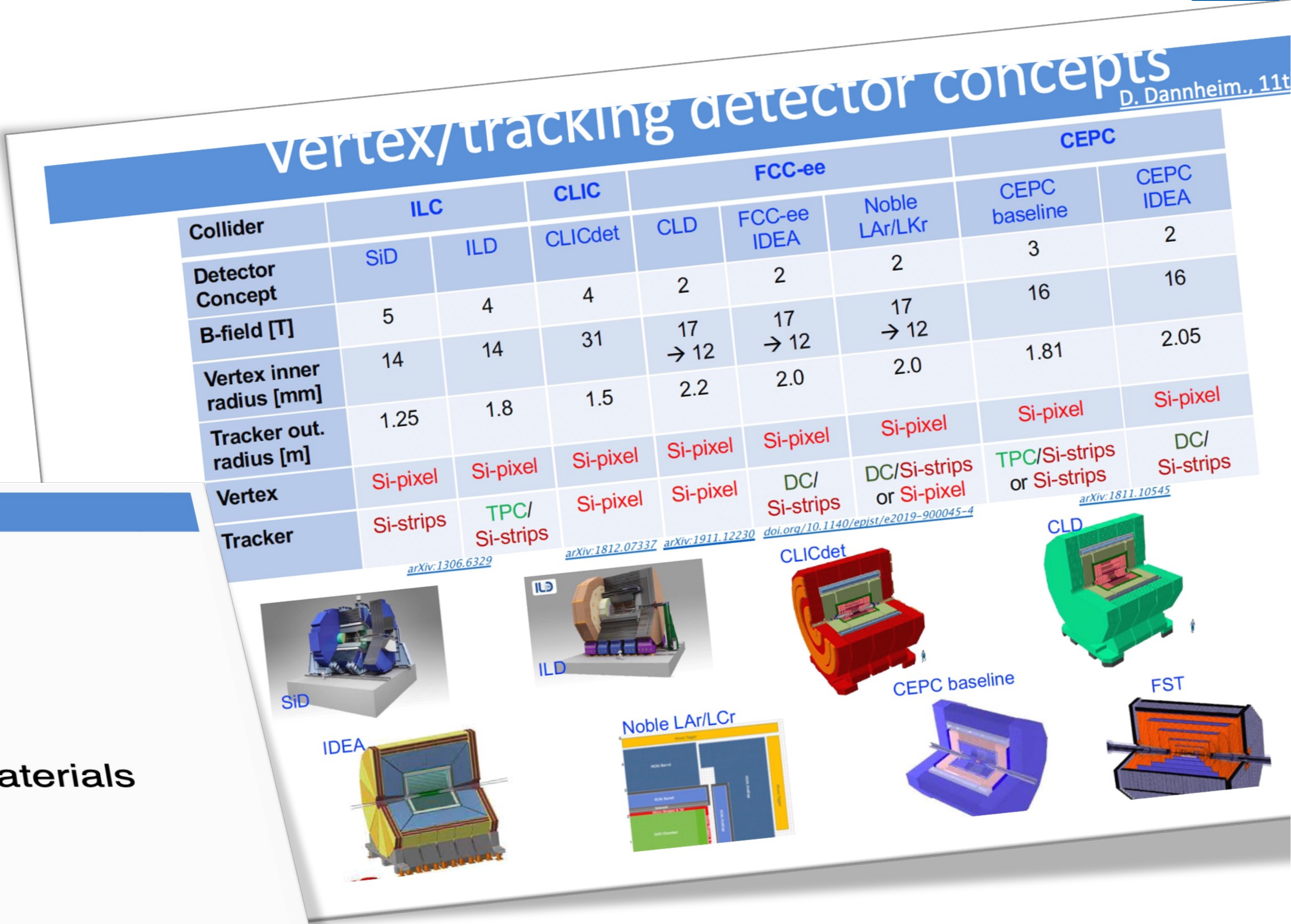
Common setup at CERN June 2022

- Calorimeters are typically large objects
  - A beam test is similar to a small experiment
- Difficult for facility managers to schedule calorimeter beam tests
  - No concurring running with other devices possible
- Takes lots of expertise to carry out a successful beam test campaign
  - Implies use of infrastructure
- A dedicated beam line maybe with dedicated slots during a year may help curing these issues
  - Would need sustained expertise on the beamline
- R&D programme has to cope with facility schedules
  - e.g. CERN-SPS essentially closed 2026-2028

Silicon Detectors for Tracking and Vertexing

Talk covering DRD organization and some R&D progress.
Talk available [here]

Ziad El Bitar

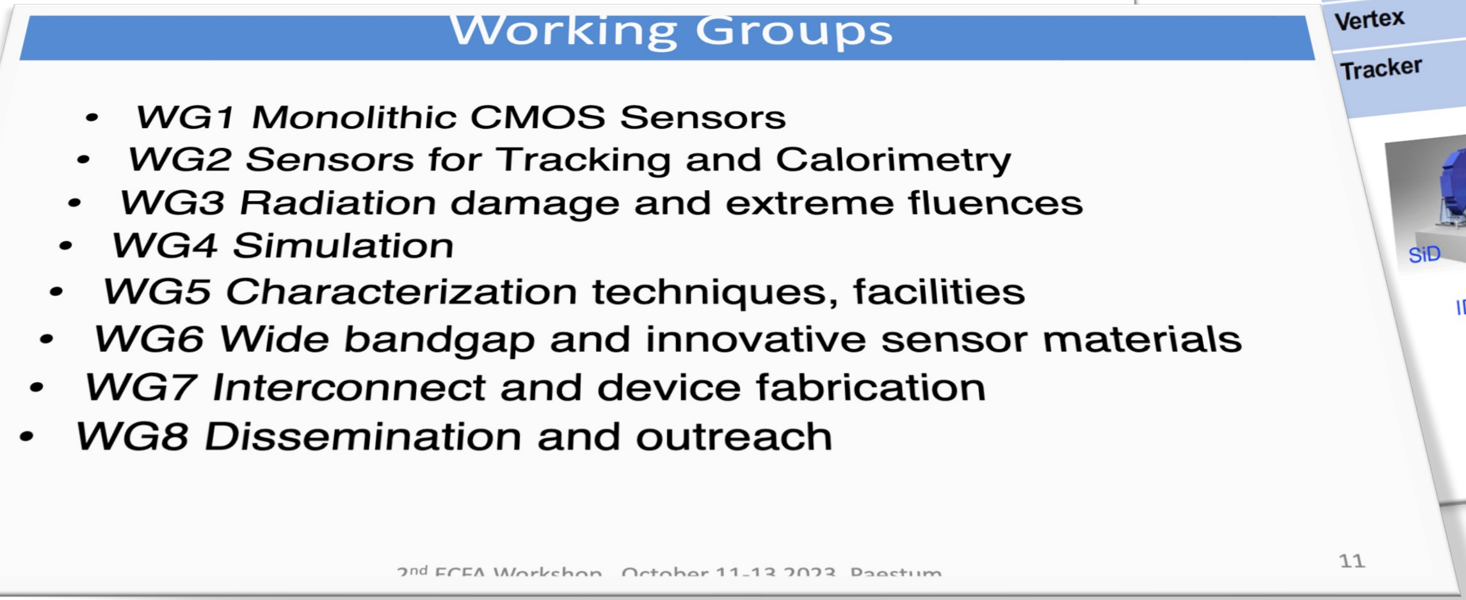


Vertex/tracking detector concepts

D. Dannheim., 11t

Collider	ILC		CLIC	FCC-ee			CEPC	
Detector Concept	SiD	ILD	CLICdet	CLD	FCC-ee IDEA	Noble LAr/LKr	CEPC baseline	CEPC IDEA
B-field [T]	5	4	4	2	2	2	3	2
Vertex inner radius [mm]	14	14	31	17 → 12	17 → 12	17 → 12	16	16
Tracker out. radius [m]	1.25	1.8	1.5	2.2	2.0	2.0	1.81	2.05
Vertex	Si-pixel	Si-pixel	Si-pixel	Si-pixel	Si-pixel	Si-pixel	Si-pixel	Si-pixel
Tracker	Si-strips	TPC/ Si-strips	Si-pixel	Si-pixel	DC/ Si-strips	DC/Si-strips or Si-pixel	TPC/Si-strips or Si-strips	DC/ Si-strips

arXiv:1306.6329 arXiv:1812.07337 arXiv:1911.12230 doi.org/10.1140/epjst/e2019-900045-4 arXiv:1811.10545



Working Groups

- WG1 Monolithic CMOS Sensors
- WG2 Sensors for Tracking and Calorimetry
- WG3 Radiation damage and extreme fluences
- WG4 Simulation
- WG5 Characterization techniques, facilities
- WG6 Wide bandgap and innovative sensor materials
- WG7 Interconnect and device fabrication
- WG8 Dissemination and outreach

2nd ECFA Workshop, October 11-13 2023, Paestum 11

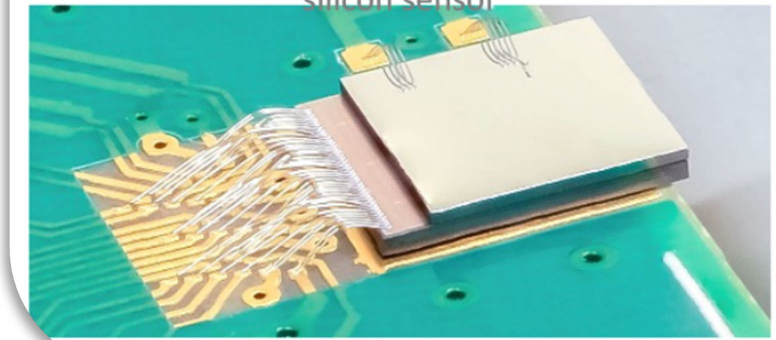
Hybrid pixel detectors – Bonding – different methods

Ziad El Bitar

R&D with Fraunhofer IZM for development of single-die bonding process

- Based on support wafer processing with SnAg bumps
- Verified for multiple CLICpix2 assemblies in lab and beam-test
  - 128x128 pixels with **25 µm pixel pitch**
  - 50 µm, 100 µm, 130 µm sensor thickness

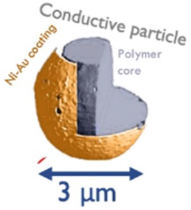
CLICpix2 ASIC bump-bonded to an active edge silicon sensor

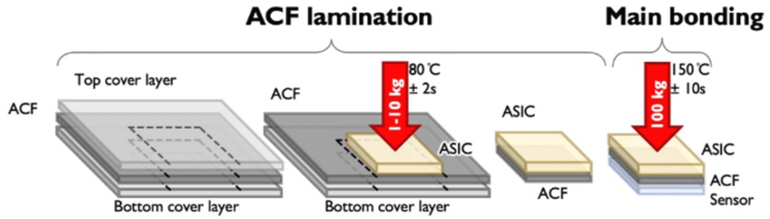


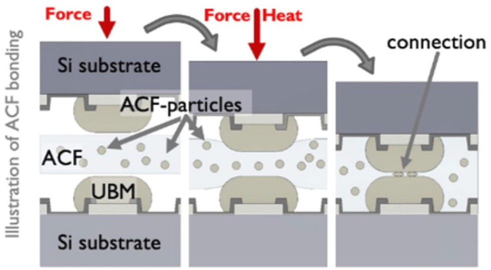
ANISOTROPIC CONDUCTIVE ADHESIVE BONDING

CERN EP R&D

- **A**nisotropic **C**onductive **F**ilm/**P**aste (or **N**on-conductive) – **ACF/ACP** or **NCF/NCP**
  - ACF widely used in industry (display manufacture, …)
  - Process needs adapting for 2D bonding (pixels)
- Bonding done at Geneva University using semi-automatic flip-chip bonder
  - Precise temperature, pressure and alignment control, heating up to 400 ˚C
- Film based bonding has two steps – lamination and bonding
  - Pressure applied to displace and compress particles
  - Epoxy cures at 150 °C for a few seconds only







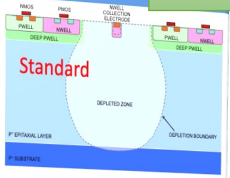
ETER.SVIHRA@CERN.CH 20.04.2023 9

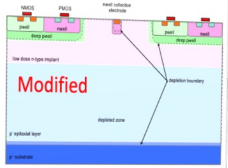
Silicon Detectors for Tracking and Vertexing

Exploring the TPSCo 65 nm

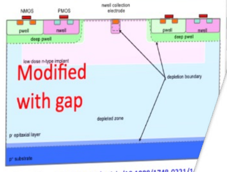
Ziad El Bitar

- Benefits : 65 nm vs 180 nm
  - Better spatial resolution due to smaller feature size.
  - Larger wafers : 300 mm vs 200 mm => final sensor : 27x9 cm^2.
  - Lower power supply : 1.2 V vs 1.8 V => Low power consumption.
  - Lower material budget : thinner sensitive layer (~$10\mu m$).
- Provides 2D stitching
- 7 metal layers
- Process modifications for full depletion:
  - Standard (no modifications)
  - Modified (low dose n-type implant)
  - Modified with gap (low dose n-type implant with gaps)



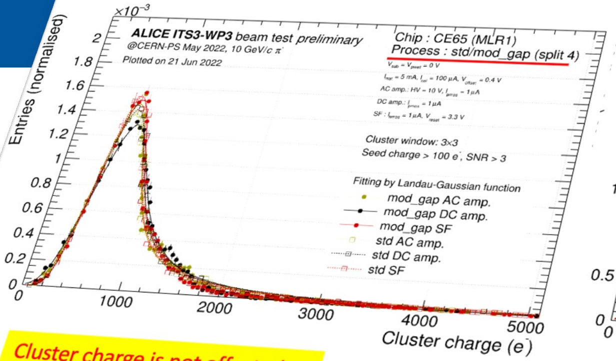


https://doi.org/10.1016/j.nima.2017.07.046

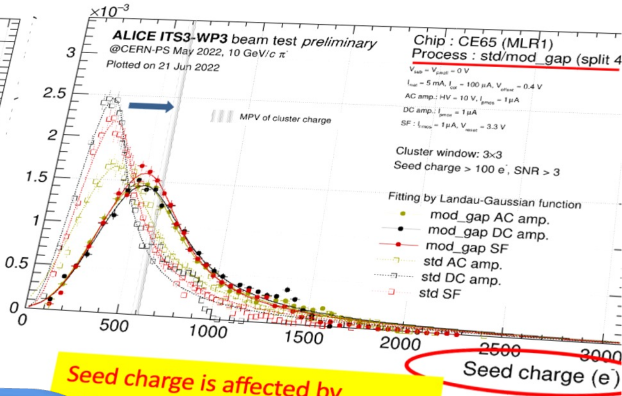


https://iopscience.iop.org/article/10.1088/1748-0221/

Modified process effective for depletion…



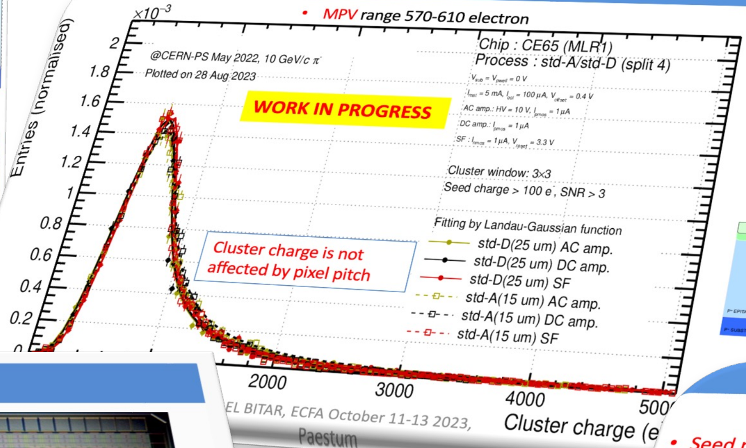
Cluster charge is not affected by process modification



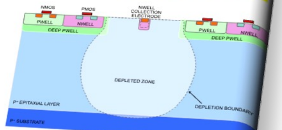
Seed charge is affected by process modification

Cluster charge

- MPV range 570-610 electron



Pixel pitch evaluation for standard process only



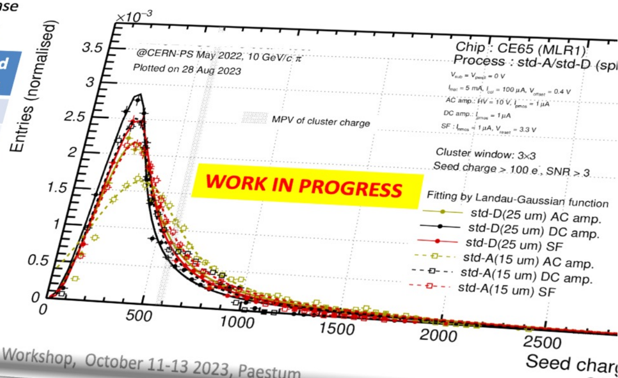
Seed charge

- Seed peaks

Charge sharing increase

Charge sharing increase

	A4-std 15 um	D4-std 25 um
AC	311	284
SF	297	269
DC	261	232

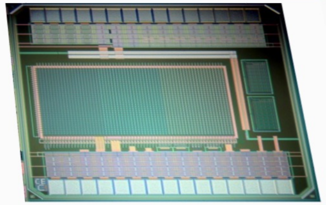


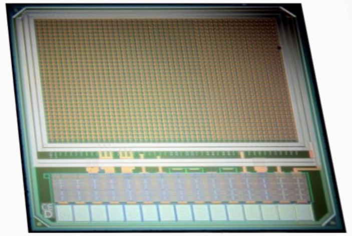
CE65 : Circuit Exploratoire 65 nm

- *2 matrix sizes*
  - *64×32 with 15 µm pitch*
  - *48×32 matrix with 25 µm pitch*
- *Rolling shutter readout (50 µs integration time)*
- *3 in-pixel architectures:*
  - *AC-coupled amplifier*
  - *DC-coupled amplifier*
  - *Source follower*
- *4 chip variants:*
  - ***Standard process 15 µm pitch***
  - *Modified process 15 µm pitch*
  - ***Modified process with gaps 15 µm pitch***
  - *Standard process 25 µm pitch*

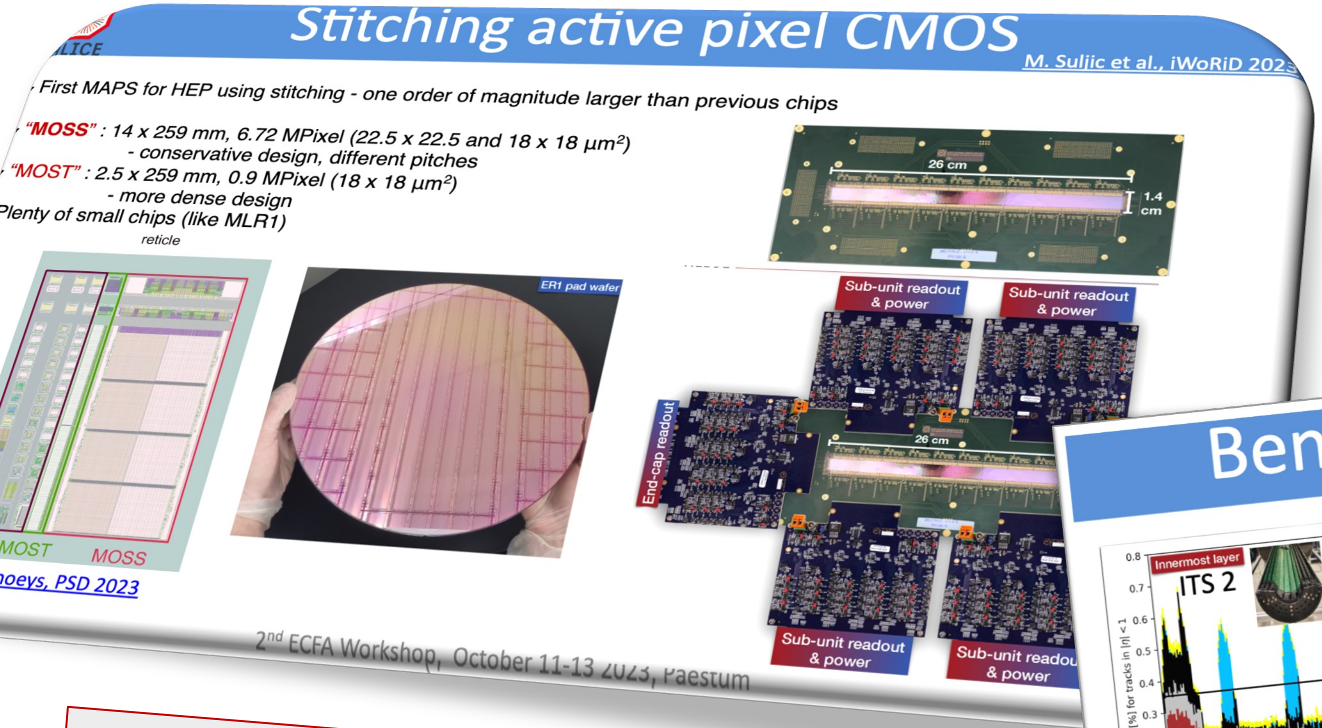
Fabrication in September 2021

Presented results from CERN PS beam test : May 2022

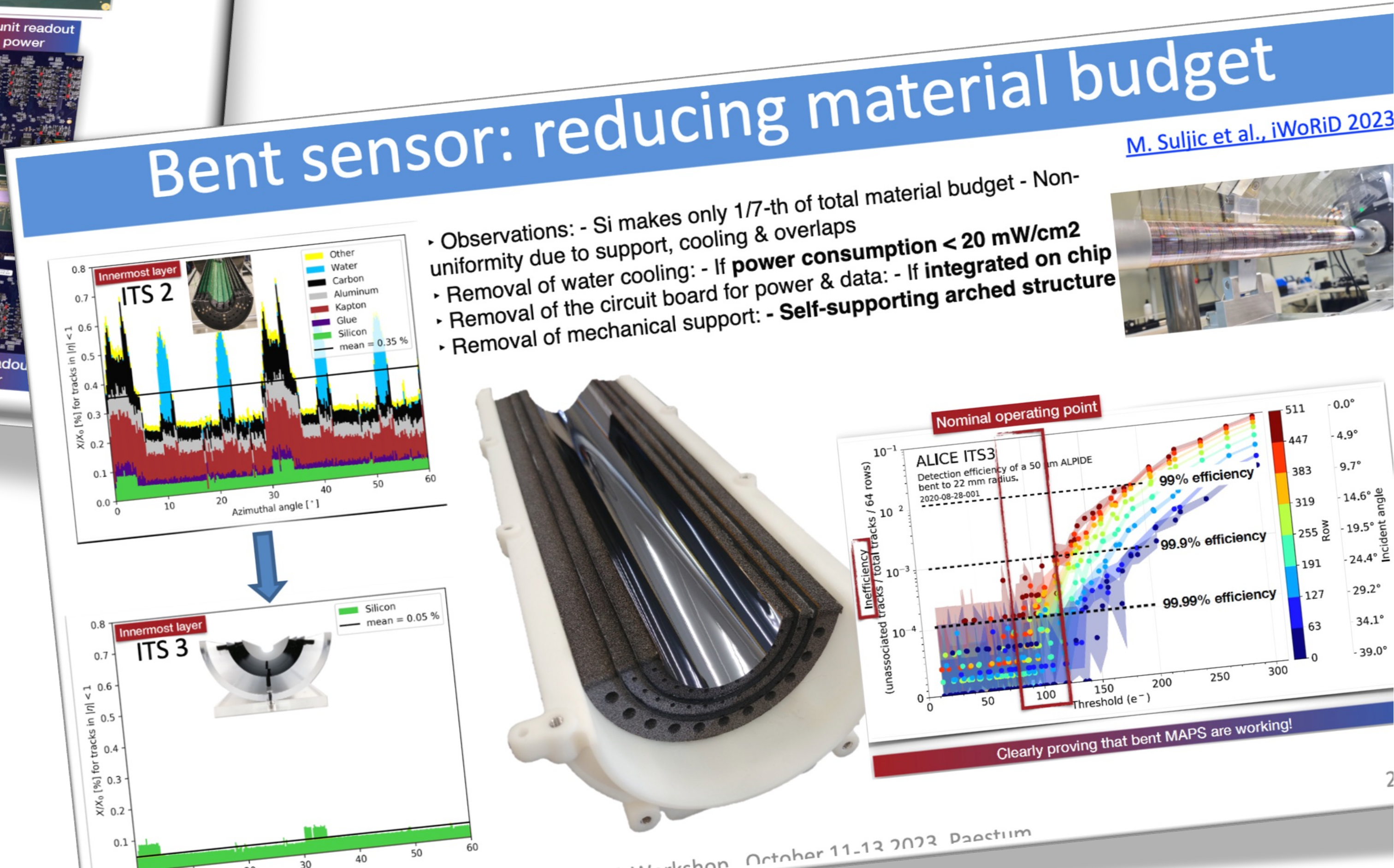




Silicon Detectors for Tracking and Vertexing



Ziad El Bitar



Stitching sensors very well advanced

Gaseous detector for tracking and muon ID

Talk covering DRD organization and some R&D progress. Talk available here

Gaseous detector @ Future collider

Experiment / Timescale	Application Domain	Gas Detector Technology	Total detector size / Single module size	Operation Characteristics / Performance	Special Requirements/ Remarks
ILC TPC DETECTOR: START: > 2035	e+e- Collider Tracking + dE/dx	MM, GEM (pads) InGrid (pixels)	Total area: ~ 20 m^2 Single unit detect: ~ 400 cm^2 (pads) ~ 130 cm^2 (pixels)	Max. rate: < 1 kHz Spatial res.: <150μm Time res.: ~ 15 ns dE/dx: 5 %	Si + TPC Momentum resolution : dp/p < 9*10^{-5} 1/GeV Power-pulsing
CEPC TPC DETECTOR START: > 2030	e+e- Collider Tracking + dE/dx	MM, GEM (pads) InGrid (pixels)	Total area: ~ 2x10 m^2 Single unit detect: up to 0.04 m^2	Max.rate:>100 kHz/cm^2 Spatial res.: ~100μm Time res.: ~ 100 ns dE/dx: <5%	- Higgs run - Z pole run - Continues readout - Low IBF and dE/dx
FCC-ee and/or CEPC IDEA CENTRAL TRACKER START: >2030	e+e- Collider Tracking/ Triggering	He based Drift Chamber	Total volume: 50 m^3 Single unit detect: (12 m^2 X 4 m)	Max. rate: < 25 kHz/cm^2 Spatial res.: <100 μm Time res.: 1 ns Rad. Hard.: NA	Particle sepration with cluster countin at 2% level
SUPER-CHARM TAU FACTORY START: > 2025	e+e- Collider Main Tracker	Drift Chamber	Total volume: ~ 3.6 m^3	Max. rate: 1 kHz/cm^2 Spatial res.: ~100 μm Time res.: ~ 100 ns Rad. Hard.: ~ 1 C/cm	
SUPER-CHARM TAU FACTORY START: > 2025	e+e- Collider Inner Tracker	Inner Tracker / (cylindrical μRWELL, or TPC / MPDG read.	Total area: ~ 2 - 4 m^2 Single unit detect: 0.5 m^2	Max. rate: 50-100 kHz/cm^2 Spatial res.: ~<100 μm Time res.: ~ 5 -10 ns Rad. Hard.: ~ 0.1-1 C/cm^2	Challenging mechanics & mat. budget < 1% X0
ELECTRON-ION COLLIDER (EIC) START: > 2025	Electron-Ion Collider Tracking	Barrel: cylindrical MM, μRWELL Endcap: GEM, MM, μRWELL	Total area: ~ 25 m^2	Luminosity (e-p): 10^{33} Spatial res.: ~ 50- 100 um Max. rate: ~ kHz/cm^2	Barrel technical challenges: low mass, large area Endcap: moderate technical challenges

7

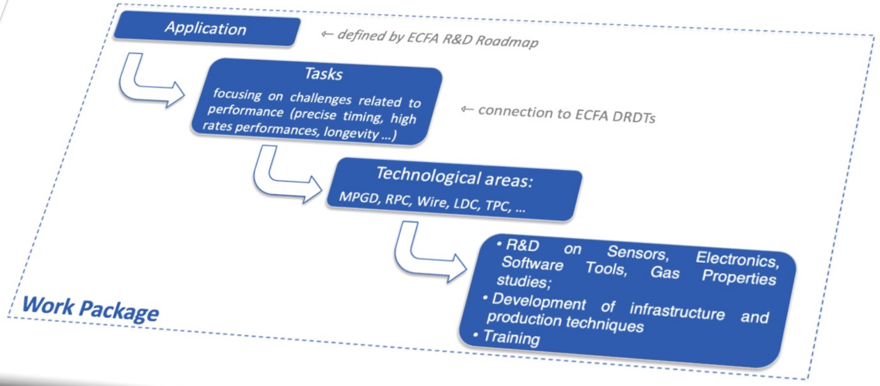
2023.10.13 - Paestum - Second ECFA Workshop - Riccardo Farinelli: Gaseous detectors for tracking & muon ID

INFN

Riccardo Farinelli

DRD1 Work Packages

*Work Packages will **consolidate** the activities of institutes with **shared research** interests in specific areas, including **applications** (e.g., TPC, Muon Systems, Calorimetry), **challenges** (e.g. Precise Timing, High Rate, Longevity), **technologies** (e.g. Resistive Electrodes, Photocathodes), detector technologies (e.g., MPGDs, RPCs, Wires), and Working Group **tasks** (e.g., electronics, software). These WPs will actively contribute to the scientific program, R&D environment, infrastructure, and R&D tools within DRD1.*



Currently envisaged WPs

- WP1: trackers/hodoscopes
- WP2: Drift Chambers
- WP3: Straw Chambers
- WP4: Tracking TPCs
- WP5: Calorimetry
- WP6: Photon detectors
- WP7: Timing detectors
- WP8: Reaction/Decay TPCs

Additional WP on beyond fundamental physics also considered

2023.10.13 - Paestum - Second ECFA Workshop - Riccardo Farinelli: Gaseous detectors for tracking & muon ID

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Gaseous detector for tracking and muon ID

Riccardo Farinelli

Tracking: Drift Chamber activities

F. Grancagnolo

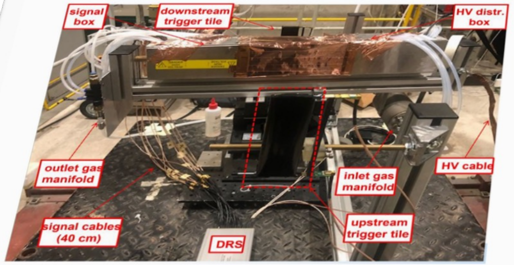
Electrostatic stability condition and **New wiring system** tested different wire materials and diameters in the assembly of drift tube prototypes.

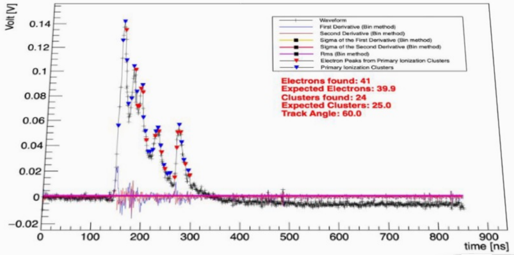
Simulation of the mechanical structure to support 10 tons on each endcap based on FEM analysis. Construction of a full scale prototype starting from 2024.

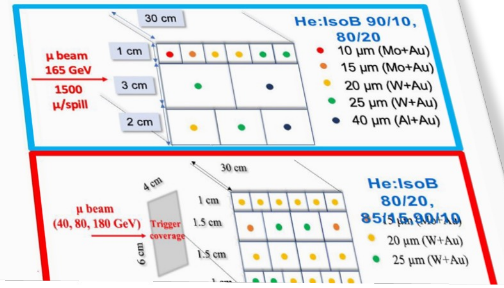
Simulation of the drift chamber in Geant4 and DD4HEP to validate the geometry and the signal reconstruction.

Data throughput
Two muon beam tests performed at CERN-H8 (βγ > 400) in Nov. 2021 and July 2022, a muon beam test in 2023 on going at CERN and an ultimate test at FNAL-MT6 in 2024 with π and K (βγ = 10−140) to fully exploit the relativistic rise.

Testbeam campaign on 2021, 2022 and 2023 to develop and measure the performance of cluster counting technique (wire and cell dimensions, electronics and software algorithms)







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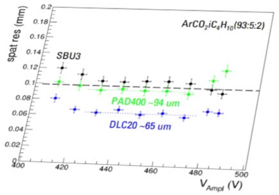
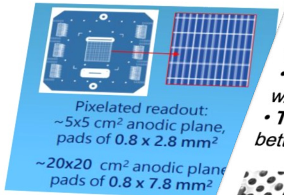
Tracking: Time Projection Chamber - Pad activities

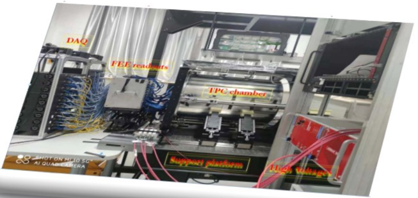
F. Petru... H. Qi

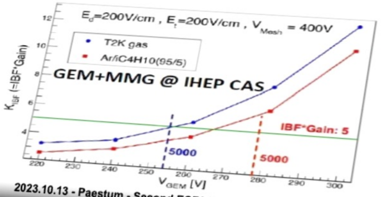
Resistive High granUlarity Micromegas
- particle tracking and trigger operation up to rate O(10 MHz cm-2) with stable HV behaviour, < 100 um spatial resolution for perpendicular tracks; < 10 ns time resolution;
- Reached a consolidated constructive techniques for large area detectors, to be considered in future experiment proposals (tracking, muon and calorimetry)





Pad TPC with multiple GEMs or GEMs/Micromegas
- Use of multiple layers of MPGDs significantly reduces ion back-flow (IBF) even without gating (crucial for circular colliders)
- TPC prototype recently developed by CEPC with integrated 266nm UV laser to generate pseudo-tracks
- dE/dx about 3.4% for (pseudo-)tracks with 220 hits (as expected for CEPC baseline detector concept)



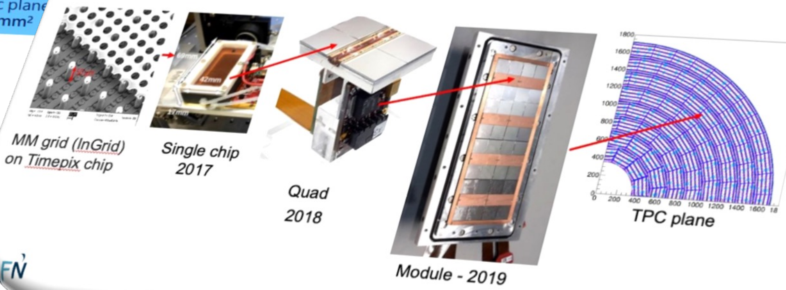


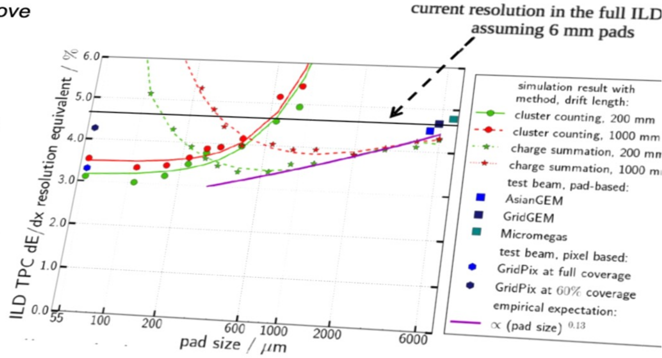
2023.10.13 - Paestum - Second ECFA Workshop - Riccardo Farinelli: Gaseous d...

Tracking: Time Projection Chamber - Pixel activities

J. Kami... P. Cola... H. Q...

- **Timepix3**-based GridPix detector module tests already indicate excellent tracking and dE/dx performance
- Prototype with **160 GridPixes** covering an active area of 320 cm2 (10M pixel detector) also built and tested in beam at B=1T in DESY in June 2021, to prove large-scale production, integration, and readout easier assembly, better coverage)
- **dN/dx cluster counting**: should be feasible with high granularity readout, challenging for low power consumption, to be addressed by dedicated R&D.
- Preliminary **full simulation studies** (Geant4) foresee, compared to pad TPC w/ 6mm pads:
- **Timepix4** development ongoing (lower power consumption, easier assembly, better coverage)





2023.10.13 - Paestum - Second ECFA W...

Gaseous detector for tracking and muon ID

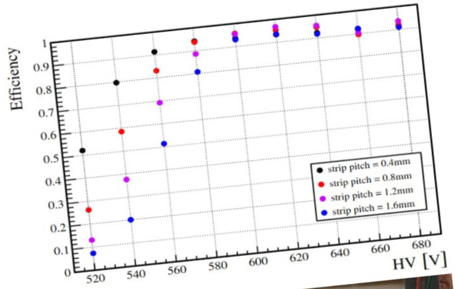
Muon system: μ-RWELL activities

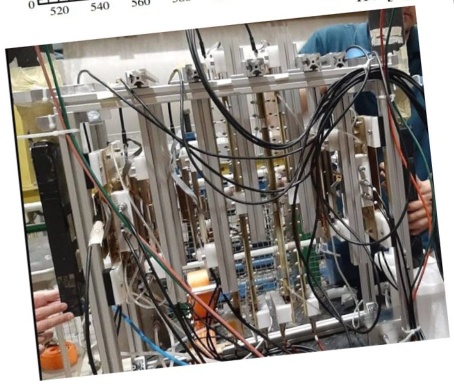
G. Bencivenni

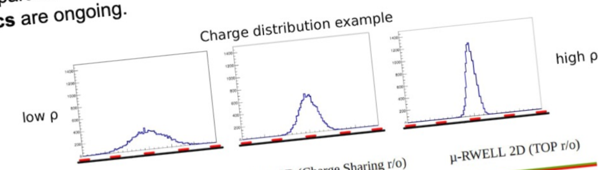
A testbeam campaign is ongoing since 2020 to optimize the detector, focussing on:
- **resistivity** of the DLC (charge dispersion, signal dimension, resolution)
- readout **segmentation** (pitch dimension, electronic noise, performance)
- **2D layouts** (2x1D, charge sharing, TOP segmentation)

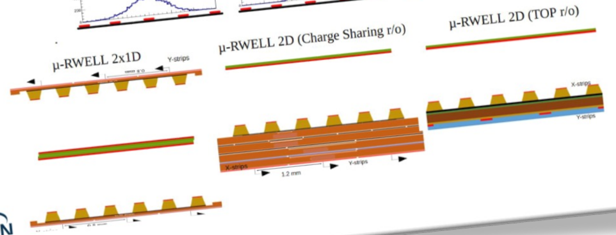
Technological transfer activities are ongoing to move some production steps from CERN to industries and open to large scale and low cost production.

Fast and parametrized **simulation** of the detector and integration with the TIGER electronics are ongoing.









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*The **engineering and industrialization** of the μ-RWELL technology is one of the main goals for large area production (i.e. 1525 m2).*

*Reduce the **number of channels** to reduce the muon system cost and match the IDEA requirements.*

Optimization of the layout is needed to improve the performance and reduce the dead-area.

***Resistive layer studies** are needed to define a stable manufacturing process to deposit DLC; study possible surface resistivity of DLC changes during the detector manufacturing; study the DLC stability under long-term irradiation.*

Riccardo Farinelli

RPC gas mixtures are based on Fluorinated greenhouse gases that are classified for their Global Warming Potential with respect to CO2

RPC EcoGas@GIF++ collaboration created in 2019 within ALICE, ATLAS, CERN EP-DT, CMS and LHCb/SHiP experiments to search for an eco-friendly RPC gas mixture

Muon system: RPC activities

G. Pugliese

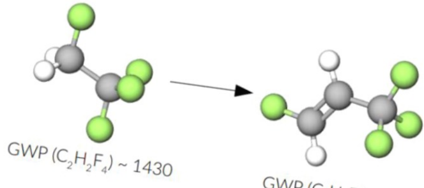
Possible candidate (already used in industrial applications) is **tetrafluoropropene** (C3H2 F4 , HFO-1234ze, HFO), with similar chemical structure as R134a but lower GWP1 ~ 6

Replacement of R134a with **HFO alone not possible** due to its lower first Townsend coefficient → Working voltage above 15 kV

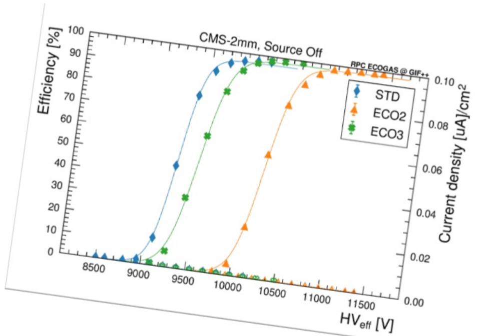
Several HFO based gas mixtures tested with a **fraction of CO2** to lower the HV working point.

Comparable efficiency plateau for ECO3 up to 500 Hz/cm2, lower efficiency but above 90% for ECO2

Aging effects to be carefully evaluated. Work is in progress to study long term aging of detectors under irradiation



Gas mixture	$C_2H_2F_4$	HFO-1234ze	CO_2	$i\text{-}C_4H_{10}$	SF_6
STD	95.2	0	0	4.5	0.3
ECO1	0	45	50	4	1
ECO2	0	35	60	4	1
ECO3	0	25	69	5	1



Superconducting Detector Magnets

Two Talks

R&D ON SUPERCONDUCTING DETECTOR MAGNETS FOR A FUTURE HIGGS FACTORY

M. Mentink

THE SUPERCONDUCTING THIN SOLENOID FOR IDEA. A TRADITIONAL DESIGN OR A STEP TOWARD NEW TECHNOLOGIES?

M. BRACCO

Superconducting detector magnets

The relevant parts of superconducting detector magnets were reviewed. See details

M. Mentink

Summary: R&D of superconducting detector magnet technologies for future Higgs factory

Cryogenics
- Existing cryogenic solutions work well, although helium price and availability is a concern
- Investigations within context of CERN EP R&D WP8:
  - Cryo-coolers and associated technologies
  - HTS-based high-efficiency current-leads to reduce cryogenic power requirement for superconducting detector magnets

Quench detection and protection
- Existing technology works well for conventional superconducting detector magnets
- Within context of EP R&D WP8: Novel method for quench detection and protection for both low- and high-temperature superconducting magnets under investigation

Ultra-transparent vacuum vessel technology:
- Effort within EP R&D WP4 to optimize transparency through smart geometries (such as honey-comb structure) and novel materials (carbon-based vacuum-vessel wall)

Conductor technology for superconducting detector magnets
- Commercial availability of work-horse aluminum-stabilized Nb-Ti conductor has been an issue in recent years, therefore an inter-departmental effort at CERN with KEK support was organized to see how availability may be re-established
- Other conductor types may be of interest as well, although there are presently no obvious fully developed, just-as-good, and commercially-available candidates (that I know of)

- Currently, modest cooling power and lower cryogenic efficiency compared to large plants, although higher-efficiency commercially available cryocoolers are expected this year and the next
- Compact and modular, contributing to enhanced reliability and redundancy
- Low-maintenance, closed-circuit without liquid helium → **Only modest amount of helium needed, important given future helium availability constraints and rising price of helium**
- Allows for localized liquefaction (less overall heat load), and compatible with thermosiphon cooling
- Localized helium gas circulation for thermal-shield cooling

Expectation with novel solution: 10x reduction in power consumption needed for maintaining the current lead temperature → Currently under investigation, in context of CERN EP R&D WP8

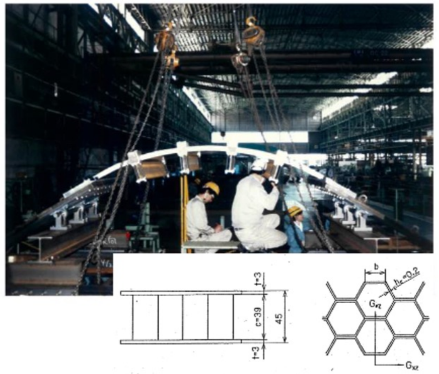


Figure 2. Honeycomb panel configuration in the preliminary design.

- Smart structures such as honey-combs, to increase effective thickness and resilience against buckling
- Smart materials, such as carbon-based materials

Under investigation in context of CERN EP R&D Work-package 4

Aluminum-based honey-comb vacuum-vessel technology, as demonstrated previously at KEK (Courtesy A. Yamamoto)

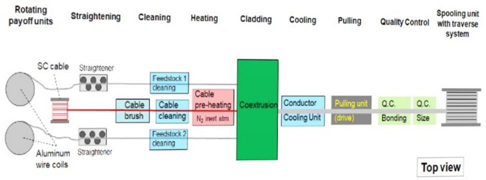
Superconducting detector magnets

M. Mentink

Critical need for future superconducting detector magnets: Conductor (2/3)

- Superconducting Detector Magnet Workshop (2022, co-organized by CERN and KEK):
  - Aluminum-stabilized conductor was a topic of key interest
  - Workshop included world-wide representatives from institutes and industry
  - Findings: On-going R&D effort at IHEP with Chinese industry, but **no commercial availability since a few years**
- Following this: Since 2023, organization of inter-departmental working group and associated steering committee at CERN supported by KEK expertise, for the purpose of re-establishing availability in context of CERN EP R&D
- Plans [17]:
  - Currently on-going: Effort to collaborate with industry using existing facilities on re-establishing conductor technology, which includes co-extrusion process and cold-working facility
  - Future options, depending on budget availability: Setup of a dedicated facility in industry or at institute

Superconducting Detector Magnet Workshop, held at CERN in 2022 (indico.cern.ch/event/sdmw)



Co-extrusion process needed for aluminum-stabilized Nb-Ti conductor production (Courtesy B. Cure [17])

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Critical need for future superconducting detector magnets: Conductor (3/3)

Some possible conductor long-term alternatives (not exhaustive):

- Aluminum-stabilized niobium-titanium:
  - **Proven over 50 years, affordable, well-understood, with sufficient magnetic field range to cover typical superconducting detector magnets, mechanically extremely resilient**
  - Requires low temperature operation (5 K), and currently not commercially available
  - On-going effort to re-establish availability through CERN EP R&D WP8
- Aluminum-stabilized Magnesium-diboride:
  - Of interest for superconducting busbars and magnets
  - Demonstrated for superconducting busbars, through LHC Hi-lumi superconducting link project
  - Would allow operation at elevated temperatures (10-20 K), albeit with limited magnetic field range
  - Likely more expensive than niobium-titanium, and requires development
  - On-going effort at INFN Genoa to investigate feasibility for proposed Alice-3 solenoid
- Aluminum-stabilized high-temperature superconducting (HTS) conductor (ReBCO / Bi-2223)
  - Of interest for superconducting busbars and magnets
  - Would allow operation over wide temperature range (4-77 K) and wide magnetic field range, significantly beyond the limits of niobium-titanium
  - Likely more expensive than niobium-titanium, and requires development
  - On-going effort within CERN EP R&D WP8 to fabricate short-length prototype conductors

Superconducting thin solenoids

Thin solenoids

Thin solenoids are based on adiabatic stability

⇩

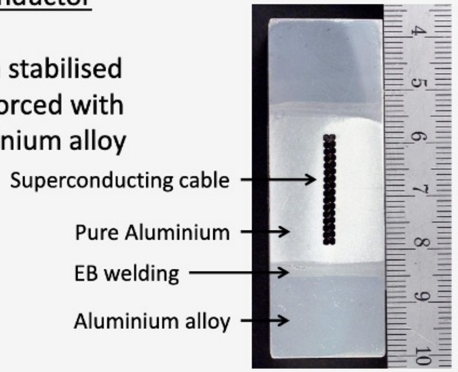
Aluminium stabilised NbTi conductors

Later, aluminium stabilised conductors have been manufactured by co-extrusion, in such a way that the superconducting cable is embedded in pure aluminium matrix

The co-extrusion technology was applied for the first time in the CDF magnet (FERMILAB) in 1984

CMS conductor

Aluminium stabilised cable reinforced with EBW Aluminium alloy



Co-extrusion is an expensive and delicate industrial process.
Very few firms have the expertise to perform co-extrusion.

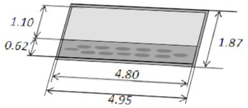
Would it make sense to use other superconductors?

Michela Bracco

SR2S Space Radiation Superconducting Shield

EU FP7 project to study superconducting shields to protect astronauts from space radiation

*Conductor: **Titanium clad MgB_2 tape + Aluminium strip***



Ti/MgB_2 ratio 2.7/1
75 µm thick insulation
Total conductor cross section: 9.25 mm²
Average mass density : 3000 kg/m³

R. Musenich et al., "Ti–MgB2 Conductor for Superconducting Space Magnets", IEEE Trans on Appl. Supercond26 (4), 2016

M. BRACCO

SECOND • ECFA • WORKSHOP on e⁺e⁻ Higgs / Electroweak / Top Factories — The superconducting thin solenoid for IDEA. A traditional design or a step towards new technologies? — Michela Bracco — INFN

Summary

MgB_2 could be an excellent candidate to replace NbTi in detector magnets

Detector magnets wound with MgB_2 conductors can operate at $T > 10K$, possibly up to 20 K.

Consequences of higher operative temperature are:

- *higher stability (aluminium is required for protection, not as stabiliser)*
- *higher thermal conductivity (better indirect cooling)*
- *higher refrigerator COP*

R&D is necessary to develop suitable conductors.

Detector magnet design should be rethought based on MgB_2 conductor features (as an example, the quench issue of MgB_2 detector magnets could be faced via controlled insulation technique)

SECOND • ECFA • on e⁺e⁻ Higgs / Elec

MgB_2 conductors are **already used** to wind magnets.

Open MRI based on cryogen free magnet wound with magnesium diboride tapes (ASG Superconductors)

Ciemat

Activities in the US towards an e+e- Higgs factory - physics and detectors

Solid State

- *Significant interests in monolithic CMOS technology*
  - *EIC is developing MAPS based tracking detector following ALICE ITS3 based on 12” wafer, 65 nm TowerJazz.*
  - *Basis of tracker & calorimeter readout in all e+e- detector concepts.*
  - *Provides increase density for circuits, Low power (20 mW/cm²), Low mass (0.05% Xo/layer), superior spatial resolution (3 μm hit precision),*
  - *SLAC developing prototypes as part of CERN ITS package WP1.2 (=DRD3) and will focus on improving timing resolution.*
- *Strong interests in U.S. to build on expertise to develop cost-effective vertex/tracker and EM calorimeter readout designs.*

Calorimetry

- Thrust areas where U.S. has and can continue to play key roles:
  - Cryo Front End electronics for Liquified noble gas calorimeters
    - Superior (~5x) SNR with cold electronics, coupled with fine segmentation (12 layers compared to 4 in current ATLAS) provides superior performance
  - Hybrid dual readout calorimeter
    - Segmented homogenous crystal EM calorimeter with SiPM readout and a Cerenkov/Scintillator fiber with time-domain readout for hadronic calorimeter, with fine long/trans segmentation
      - Hybrid mechanism has the potential to achieve 3-4% jet energy resolution for 50-150 GeV jets while maintaining superior EM resolution.
  - Si-W EM calorimeter with MAPS readout, Scintillating Tile with SiPM readout for Hadronic calorimeter, in part

Other Detector R&D areas

- *Gaseous Detectors:*
  - *MPGD facility, high resolution/fast timing detectors with eco-friendly gases*
- *Particle ID:*
  - *Dedicated TOF detectors using LGADS to improve π/K separation*
- *Readout/ASIC developments:*
  - *28 nm developments, coping with high rates, density, power, …*
- *Trigger/DAQ:*
  - *on-detector real-time data processing*
- *Quantum:*
  - *Explore engineered materials that can improve efficiencies via doping*
- *In addition, we have a dedicated group to address the software needs.*
- *U.S. groups eager to get engaged in this process and collaborate with Europe, awaiting P5 process to conclude and funding to enable this engagement. We are hopeful of a limited level of funding support beginning 2024 and ramping up in subsequent years.*

Srini Rajagopalan

See talk

Activities in the US towards an e+e- Higgs factory - physics and detectors

Srini Rajagopalan

See talk

Detector R&D

- Funded R&D efforts of interest to e+e- already ongoing in U.S in several areas, as part of efforts in SiD/ILD for ILC or for IDEA and ALLEGRO for FCC-ee.
  - Significant overlap in detector concepts amongst the e+e- collider options.
- U.S. Higgs Factory coordination group, bringing together the ILC, FCC and C^3 communities, have organized themselves along technological themes:
  - A community driven bottom-up proposal has been developed, documenting the interests and expertise of the U.S. groups. This was submitted to P5 for their consideration : https://arxiv.org/abs/2306.13567
  - This proposal also served as a starting point for discussions with the DRD groups: Coordinators are actively engaging with the ongoing DRD efforts and are in direct communication with the DRD group convenors.
- In addition, high level discussions are ongoing between DOE and CERN to enable cooperation in DRD projects.
  - There already exists strong collaboration in many focused R&D topics between U.S. and European groups. Important to support and strengthen this.

U.S. Higgs Factory Coordination Group

- *Solid State: A. Apresyan, C. Haber, C. Vernieri*
- *Calorimeter: H. Chen, C. Tully, A. White*
- *Gaseous Detector: M. Hohlmann, G. Iakovidis, B. Zhou*
- *Readout/ASICs: J. Gonski, J. Hirshchauer*
- *Trigger/DAQ: Z. Demiragli, J. Zhang*
- *Particle ID: M. Artuso, G. Wilson, Z. Ye*
- *Quantum: M. Demarteau, C. Pena, S. Xie*
- *Software: H. Gray, O. Gutsche, J. Strube*
- *ex-officios: J. Brau, A. Canepa, D. Denisov, S. Eno, P. Grannis, K. Jakobs, A. Lankford*
  - *plus representation from DOE and CPAD.*
- *Chair: S. Rajagopalan*

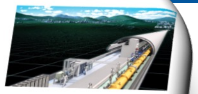
Moving forward

- We expect the Higgs Factory to be the next high priority Energy Frontier project following the completion of HL-LHC.
  - FCC-ee, ILC and C^3 all have challenges.
  - Comparable approval timelines for ILC and FCC were advocated by the proponents during the recent P5 town hall meeting at BNL.
  - This makes it essential for these communities to coordinate on detector technologies targeting these projects, at least for the next few years until respective project approval.
- We are waiting for P5 process to conclude, Report is planned to be released Dec 7-8, 2023.
  - We look forward to a strong support for a U.S. program in the next generation Higgs Factory. In anticipation for that, we are developing a prioritized list of short-term activities, identifying resources and preparing our ask to the agencies.
- Active engagement with DOE already underway. We have also begun the process to engage NSF to seek their support as it is equally vital for a nationally and internationally coordinated U.S. participation in a Higgs Factory.

ECFA activities towards an e+e- Higgs factory

Approval status

- **ILC:** - Under consideration by the Japanese Ministry / Government as a **global project**
  - 2023: increased resources, ILC Technology Network established, incl. CERN (coordination for Europe)

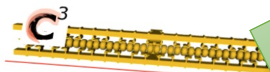


- **FCC-ee:** - Feasibility study ongoing, very good progress in many areas, mid-term report expected in November 2023;
  - **Priority 1 for CERN / Europe (CERN Council)**
  - Outcome (technical feasibility, costs,…) decisive for Europe

- **CEPC:** - TDR in preparation, incl. cost review
  - A lot of progress on the technical side
  - **Aiming for approval in next 5-year plan (2025)**
  - Ranked 1st in Chinese HEP preselection

- **CLIC:** - Possible alternative for CERN
  CLIC community is preparing a Project Readiness Report (PRR) for the next ESPP (2026/27)

- **CCC:** - R&D towards a demonstrator moving forward at SLAC;
  Waiting for P5, and for a commitment of a laboratory to host it



2nd ECFA Workshop, Paestum, 12th October 2023

Karl Jakobs,

Where do we go from here?

- Results of the study will be documented in an **ECFA report**
- This report is a key input for the next update of the European Strategy of Particle Physics (ESPP) (targeted for 2026/2027)

  Submission date of FCC Feasibility study: end of 2025
  (→ Dec. 2025 is a reasonable assumption for the input date for the strategy process)
- More details about the plans will be presented by Aidan Robson tomorrow, at the end of the workshop
  (driven by Main Editors (Aidan Robson, Christos Leonidopoulos) and WG conveners, obviously timeline will be adapted to changes of strategy timeline)
- We should use the remaining time to achieve as much as possible
  (Focus topics; eventually expand to enlarge the scope (additional topics))
- One more ECFA workshop planned: ~ autumn 2024;
  Call for hosting the next ECFA workshop will go out soon

ECFA

Detector R&D Committee (DRDC)

- DRDC has been set up and is complete:
  http://committees.web.cern.ch
- Recommendations on approval are expected to be issued by the DRDC early December
  → Final decision on approval by the CERN Research Board shortly after
- Start-up of new Collaborations in January 2024;
- During 2024 Memoranda of Understanding with Funding Agencies are expected to be signed.
- Funding-agency involvement is planned via RRB-like meetings
  (Details are still under discussion with CERN management)

BERGAUER, Thomas	HEPHY, Vienna, **Chairperson**
TROSKA, Jan	CERN, **Scientific Secretary**
Members - Referees	
BENTVELSEN, Stan	NIKHEF
BRESSLER, Shikma	Weizmann Institute of Science
BUDKER, Dimitry	Helmholtz Institute Mainz and Johannes Gutenberg University
FORTY, Roger	CERN
GEMME, Claudia	INFN and University, Genoa
GIL BOTELLA, Ines	CIEMAT
MERKEL, Petra	Fermilab
PESARESI, Mark	Imperial College
SERIN, Laurent	IJCLab - Laboratoire de physique des 2 infinis
Members Ex-officio	
ALLPORT, Phil	ECFA Detector Panel (EDP) Co-Chair
CONTARDO, Didier	ECFA Detector Panel (EDP) Co-Chair

DRDs Process

Timeline

- Aim for full report outline structure by spring 2024
- Try to identify lead authors for sections shortly after
- Largely final inputs come by May 2025
- Intensive editing session summer 2025, leading to version to be shared among projects
- Final iteration autumn 2025
- Submission end 2025

Aidan Robson