



RD_FCC

Attività in corso a Frascati

M. Boscolo

Organizzazione

RN Paolo Giacomelli (Bologna) since this year 2024

Activity organized in WP:

- **WP1 Physics & software** P. Azzi PD, N. De Filippis BA
- **WP2 Acceleratore** M. Boscolo **LNF**
- **WP3 Silicon/Vertex detectors** A. Andreazza MI, F. Palla PI
- **WP4 Drift chamber** M. Primavera, N. de Filippis Ba, F. Grancagnolo LE
- **WP5 MPGD for muon/preshower** M. Poli Lener **LNF**
- **WP6 Dual readout calorimetry** R. Ferrari PV

Anagrafica 2025

Sezione	FTE FCC	FTE altro	FTE tot	R/T total
BA	4.50	0.00	4.50	10
BO	4.35	1.10	5.45	22
CT.DTZ	0.10	0.60	0.70	3
FE	0.40	2.00	2.40	8
GE.DTZ	1.05	0.00	1.05	11
LE	1.80	0.20	2.00	9
LNF	6.60	0.00	6.60	14
LNL	2.20	1.20	3.40	6
MI	4.75	2.20	6.95	21
MIB.DTZ	0.10	0.20	0.30	1
NA	4.65	0.00	4.65	22
PD	2.10	1.10	3.20	12
PG	2.70	0.00	2.70	17
PI	2.15	0.10	2.25	22
PV	0.30	2.40	2.70	10
RM1.DTZ	0.60	0.00	0.60	2
RM3.DTZ	1.10	0.20	1.30	7
TO.DTZ	0.65	0.00	0.65	8
UD	2.80	0.00	2.80	9
Totali	42.90	11.30	54.20	214

- ❖ **2024: 19 sezioni**
 - ▶ 9 sigle RD_FCC locali
 - ▶ R/T: 186 persone
 - ▶ FTE: 27.20+13.10=40.30
- ❖ **2025: 19 sezioni**
 - ▶ Continua crescita
 - ▶ 13 sigle RD_FCC locali
 - ▶ R/T: 214 persone
 - ▶ FTE: 42.90+11.30=54.20

SEDE	NOMINATIVO	TIPO	CONTRATTO	QUALIFICA	RICERCATORI	TECNOLOGI		
LNF	Bencivenni Giovanni	DIP	Ricercatore	Dirigente di Ricerca	20			
	Bertani Monica	DIP	Ricercatore	Ricercatore	5			
	Boscolo Manuela	DIP	Tecnologo	Primo Tecnologo		100		
	Broggi Giacomo	ASSOC	Scientifica	Dottorando senza...	Dottorando	100		
	Ciarra Andrea	DIP	Tecnologo	Tecnologo		100		
	De Lucia Erika	DIP	Ricercatore	Primo Ricercatore	10			
	Di Pasquale Enrico	DIP	Tecnologo	Tecnologo		40		
	Domenici Danilo	DIP	Ricercatore	Ricercatore	5			
	Fransesini Francesco	DIP	Tecnologo	Tecnologo	100			
	Morello Gianfranco	DIP	Ricercatore	Ricercatore	15			
	Nigrelli Giulia	ASSOC	Scientifica	Dottorando con b...	Dottorando	100		
	Poli Lener Marco	DIP	Tecnologo	Primo Tecnologo		25		
	Rotondo Marcello	DIP	Ricercatore	Primo Ricercatore	10			
	Zobov Mikhail	DIP	Tecnologo	Dirigente Tecnologo		30		
LNF (14 PERSONE - 6.6 FTE)					3.65 fte	9 pers.	2.95 fte	5 pers.
					6.60 fte / 14 pers. (media 0.47)			

Team italiano FCC Acceleratore: WP2 RD_FCC

Ricca attività tra fisica e tecnologie su molti fronti

FTE (WP2) = 12.5
circa 25% FTE TOT

- Disegno Regione di Interazione con interfaccia rivelatore
- Disegno schema di collimazione nell'anello e nella regione MDI
- Simulazione fondi macchina nel rivelatore
- Ottica della regione di interazione
- Effetti collettivi
- Sorgente (ibrida) di positroni a cristalli
- Dinamica di fascio linea di cattura positroni
- Sistema diagnostico per il controllo della corrente via Compton scattering
- SRF
- Magneti HTS FCC-ee
- Solenoide detector HTS-based
- Studio schema alternativo di iniezione continua con ottica nonlineare

LNF

Progetti R&D per la Strategy sinergici e finanziati separatamente dalla GE

- FCC-ee IR mockup
- Cavita' SRF

LNF

Regione di Interazione (IR) e Interfaccia macchina-rivelatore (MDI) FCC-ee

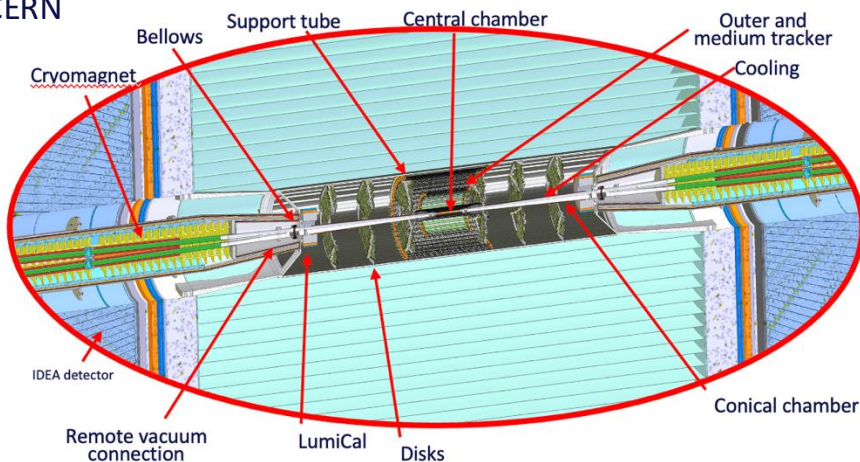
L'attività ai LNF si sviluppa su più fronti:

➤ **Coordinamento del gruppo di lavoro che disegna la IR e MDI per lo studio di fattibilità di FCC-ee**

- Studio fondi macchina e ottica
- Progettazione IR
 - Camere da vuoto con sistema di raffreddamento, integrazione del rivelatore di vertice, ideazione di un tubo di supporto per l'assemblaggio e l'integrazione*.

➤ Validazione sperimentale della IR con la realizzazione di un mockup

- Progetto finanziato dalla GE (ESPP_a_MDI) e dal CERN



* M Boscolo, F. Palla, et al., *Mechanical model for the FCC-ee MDI*, EPJ+ Techn. and Instr., <https://doi.org/10.1140/epjti/s40485-023-00103-7>

IR mockup

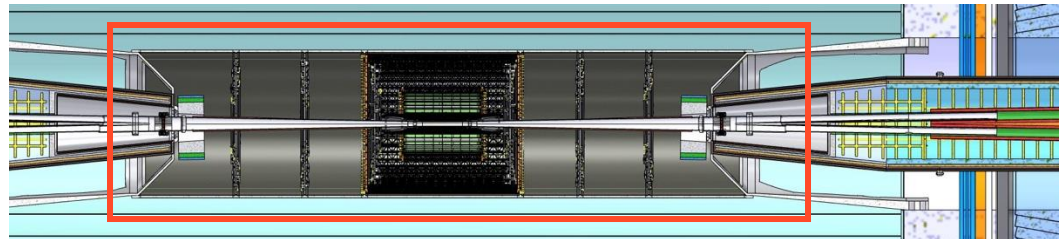
The mockup project has received a great deal of interest within the FCC community

- primarily for technology validation of the MDI design for the Feasibility Study
- Integrating vertex and chambers "on paper" has been proven to be difficult, more surprises expected with a real mock-up!
- Global assembly sequence to be studied

Main components

- ✓ Central vacuum chamber with paraffin cooling system
- ✓ Lateral vacuum chamber with water cooling system
- IR Bellows
- Support tube – carbon fibre + honeycomb
- Inner vertex detector with air cooling system + outer tracker and services routings
- Luminosity calorimeter and services routings

central region ± 1.2 m



Goal is to prove state-of-the-art technological solutions and test its feasibility
LNF, CERN and INFN-Pisa collaboration (LNF-CERN MoU)

Laboratorio di assemblaggio e test:

B. 5/a Serv. ing. mecc. (SIM)
div.acc.



B.5
a

Stato del progetto del mockup della IR

Goal: validazione dei disegni, buckling test, assemblaggio e test dei sistemi di raffreddamento



In arrivo dalla ditta COMEB

Camera centrale: realizzata in doppio strato di Al con paraffina all'interno



Pronte per ordinarle alla ditta

1020 mm

310 mm
Camera centrale

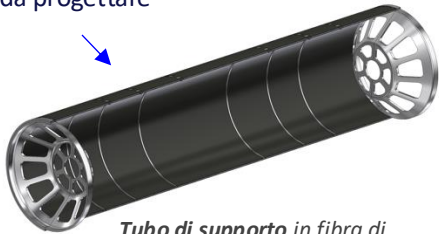
1020 mm

Soffietti

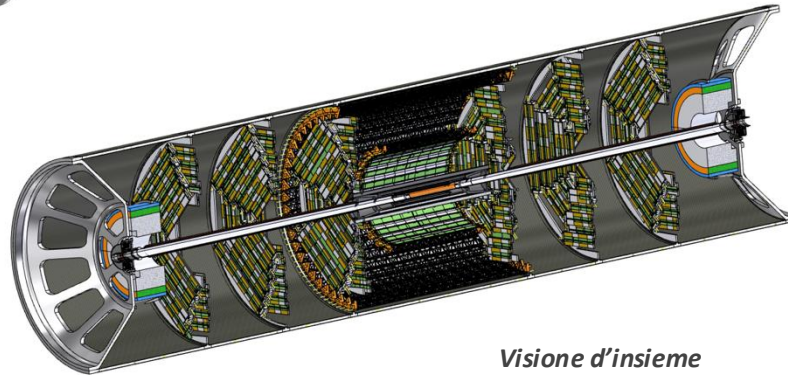
In progettazione

Camera laterale: realizzata in Al con sistema di raffreddamento esterno ad acqua

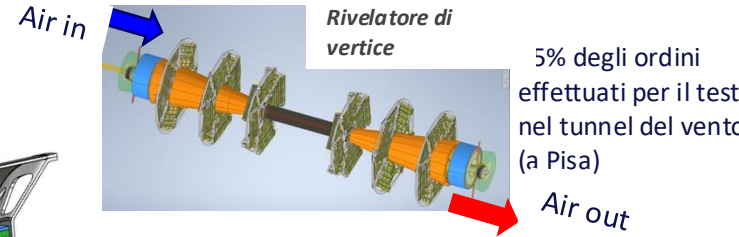
da progettare



Tubo di supporto in fibra di carbonio & honeycomb



Visione d'insieme
con il luminometro ed il vertex



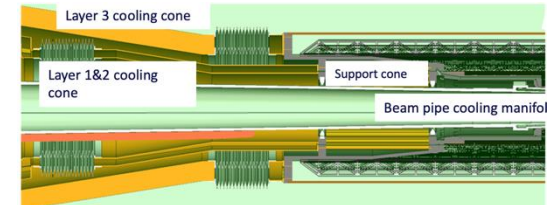
Air in

Rivelatore di vertice

5% degli ordini effettuati per il test nel tunnel del vento (a Pisa)

Air out

Fase finale ai LNF: integrazione nel mockup e test di raffreddamento



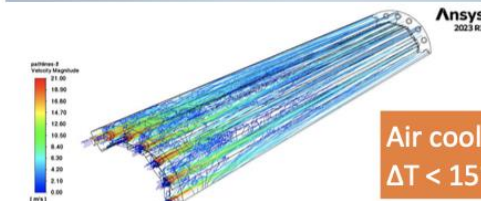
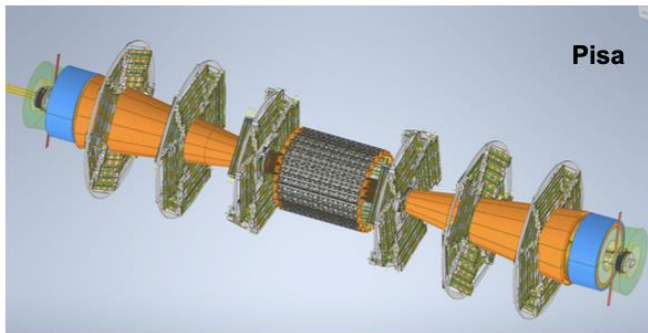
Layer 3 cooling cone

Layer 1&2 cooling cone

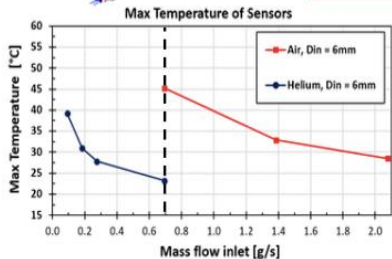
Support cone

Beam pipe cooling manifold

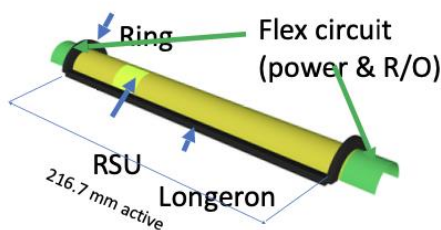
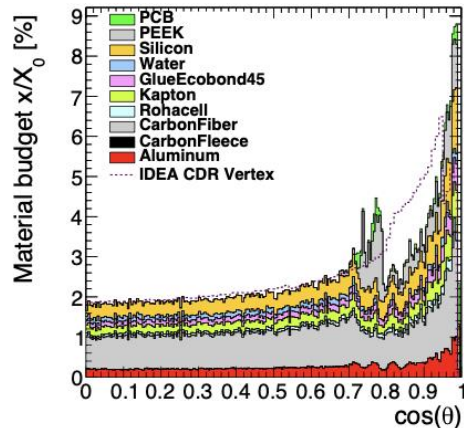
WP3 Silicon Tracker



Air cooling studies:
 $\Delta T < 15^\circ\text{C}$



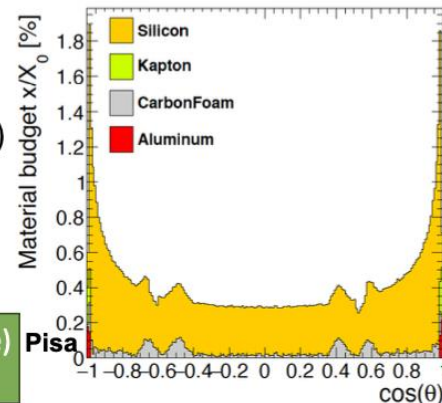
Perugia



Also studying curved Silicon layout (ITS3 like)
 ~4 smaller material budget for inner vertex

Outer vertex tracker:
 ATLASPix3 based (Milano)
 Modules of $50 \times 150 \mu\text{m}^2$ pixel

Inner Vertex detector:
 ARCADIA based (Torino, Milano, Padova, Pisa, Perugia)
 Modules of $25 \times 25 \mu\text{m}^2$ pixel size

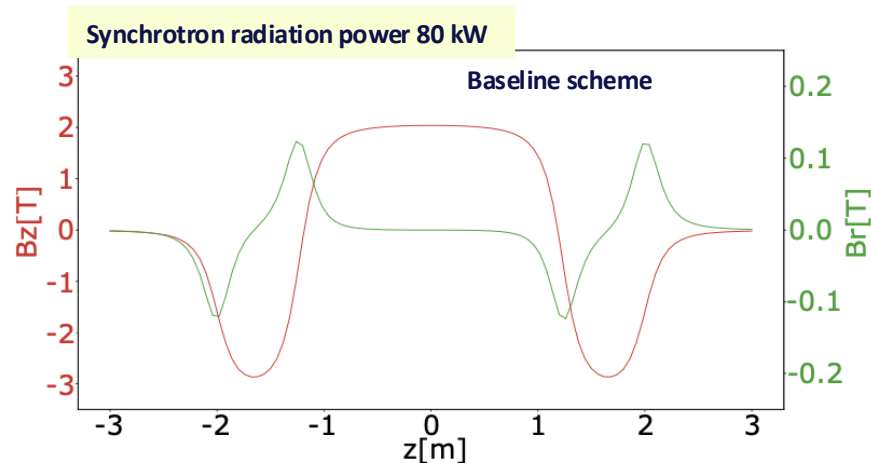
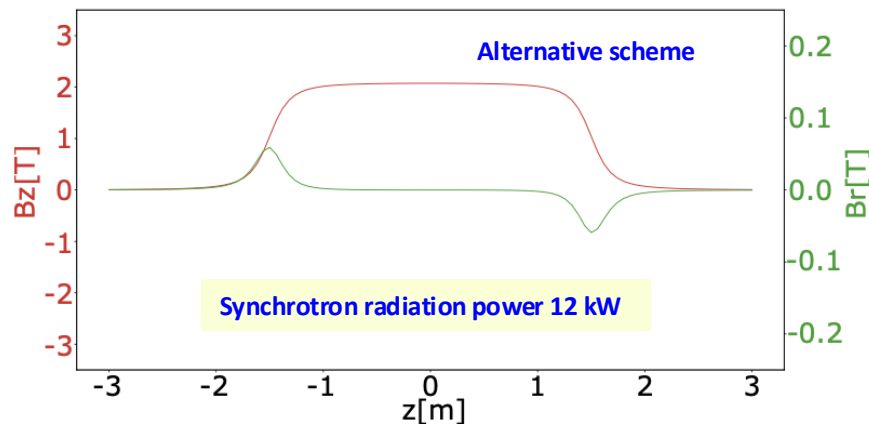


Fisica di Macchina per MDI

- **Disegno alternativo alla baseline per lo schema di compensazione del campo solenoidale del rivelatore (non-local compensation)** A.Ciarma et al. IPAC 24, [10.18429/JACoW-IPAC2024-TUPC68](https://doi.org/10.18429/JACoW-IPAC2024-TUPC68)
 - **Studio beam losses** G.Broggi et al, IPAC24, [10.18429/JACoW-IPAC2024-TUPC76](https://doi.org/10.18429/JACoW-IPAC2024-TUPC76)
 - **collimation design**
 - **Beamstrahlung radiation** M.B. and A.Ciarma, PRAB 26, 111002 (2023)
<https://journals.aps.org/prab/pdf/10.1103/PhysRevAccelBeams.26.111002>
 - **Studio dei fondi macchina nel rivelatore:**
 - Incoherent pair creation (IPC) generate e tracciate del rivelatore con valutazione occupanze
 - Radiazione di sincrotrone generata e tracciata fino alla camera di vuoto
 - Beam losses dovute all'interazione di beam-gas generate fino alla camera da vuoto
- A.Frasca et al., IPAC24: [10.18429/JACoW-IPAC2024-TUPC66](https://doi.org/10.18429/JACoW-IPAC2024-TUPC66)
K. Andre et al., IPAC24, [10.18429/JACoW-IPAC2024-WEPR09](https://doi.org/10.18429/JACoW-IPAC2024-WEPR09)

Solenoid Coupling Compensation Scheme

Longitudinal and radial magnetic fields along the 15 mrad axis



Skew quadrupolar components in the FFQs align the magnet axis to the rotated reference frame of the beam

Correctors right after the beam pipe separation and around the FFQs compensate the orbit distortion generated by the horizontal crossing angle in the detector field

Alternative scheme:

- Vertical emittance increase is only 0.2% of the nominal value of 1 pm.
- Chromatic behavior of the vertical emittance increase small in the range of $dE/E = \pm 4\%$.

Detector Background Studies

First occupancy calculations from Incoherent pairs in

- IDEA Vertex detector
- IDEA drift chamber
- Allegro ECAL

Next:

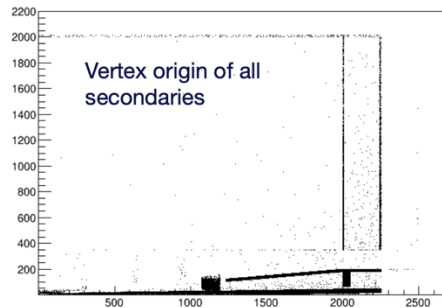
- Add more subdetectors
- Evaluate more background sources

IDEA-VTX

	ARCADIA	ALICE ITS3
Occupancy	$\sim 20 \times 10^{-6}$	$\sim 30 \times 10^{-6}$
Hit rate	170 MHz/cm ²	250 MHz/cm ²

data rates of
O(10 Gb/s) per module.

IDEA-DCH



SIM hit occupancy of $\sim 5\%$
over 400ns

ALLEGRO ECAL

Average occupancy per BX (over 1000 BXs):

	NO CUTS	20% MIP CUT	30% MIP CUT
Endcaps	0.1% ~ 0.6%	0.02% ~ 0.2%	0.01% ~ 0.15%
Barrel	< 0.45%	< 0.03%	< 0.01%

occupancy per layer up to $\sim 0.5\%/BX$

Contributi alla IPAC24 (USA), maggio 24

- M. Boscolo et al., **Progress in the design of the FCC-ee Interaction Region**, [TUPC67.pdf](#)
- A.Ciarma et al., **Alternative solenoid compensation scheme for the FCC-ee Interaction region**, [TUPC68.pdf](#)
- G.Broggi et al, **Optimizations and updates of the FCC-ee collimation system design**, [TUPC76.pdf](#)
- F. Franesini et al., **Mechanical design, structural requirements and optimization of the FCC-ee IR components** [THPS69.pdf](#)
- M. Migliorati et a, **Studies and mitigation of TMCI in FCC-ee**, [THPC60.pdf](#)

Multi Contributi alla FCC WEEK 2024

Paper Phys. Review Accelerators and Beams, Nov. 2023:

- M.Boscolo and A.Ciarma, **Characterization of the beamstrahlung radiation at the future high-energy circular collider**, PRAB 26, 111002 (2023) [link](#)

Premio miglior poster sessione acceleratori FCC WEEK24

“Structural Optimization of Future Circular Collider Interaction Region Support Structure”

Francesco Fransesini, LNF



Programma WP5 2024/2025

L'R&D 2024: lo studio delle **performance di rivelatori 50x50 cm² con lettura 2D X-Y** (resistività del DLC, strip pitch ottimizzati con TB-2021-2022) con i seguenti layout:

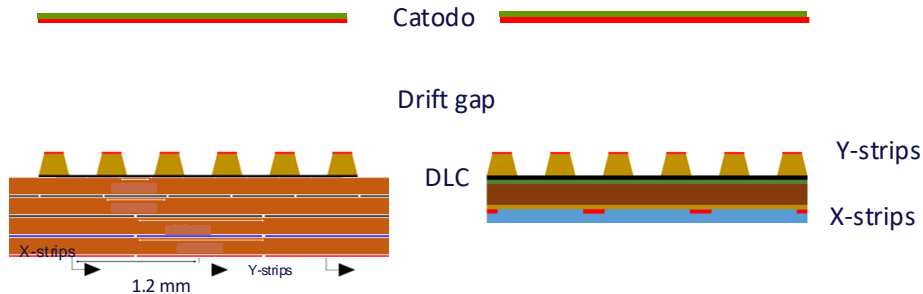
L'R&D 2025: prevede la realizzazione **di N. 2 Hybrid uRWELL**

→ **rivelatori 50x50 cm² del 2024 + stadio di pre-amplicazione (GEM)**

I 2 layout per il rivelatore 2D

u-RWELL bi-dimensionale (Charge Sharing)

u-RWELL bi-dimensionale (TOP r/o)



I rivelatori sono stati ordinati al CERN-Workshop di Rui a fine 2023 e in attesa di riceverli a inizio settembre (forti ritardi nella produzione).

Il rivelatore sarà:

- Caratterizzato con X-ray gun;
- Performance 2D (efficienza e ris. spaziale) con sistema tracciante e con cosmici

A seguirà verrà scelto il layout migliore così da produrre N.2 rivelatori 50x50 cm² (15k€ sj da sbloccare) insieme alla meccanica per il sistema dei cosmici (5 k€ sj da sbloccare)

MPGD

Tentative schedule 2024 & 2025

2024

- Gain measurement & Gain Uniformity with X-ray (November):

1. **u-RWELL pitch optimization;**
2. **CS layout;**
3. **Micro-RGroove layout**

- Finalization of the TB data analysis of u-RWELL+TIGER

- Digitization of the Pre-shower & Muon system

2025

- Gain measurement & Gain Uniformity with X-ray (June):

1. **CS layout with pad**
2. **Hybrid CS with strip readout**

- TB (Oct/Nov.) @ H8-SPS-CERN:

1. **CS layout + Hybrid CS;**
2. **Micro-RGroove layout;**
3. **CS layout with pad**

- MS effect on muons decay from Z/W/H and LLP

- Development of the TIGER/GEMROC systems for IDEA

Future Plans 2026-2027

The **R&D program for the years 2026/27** will primarily focus on developing the **TIGER chip** to integrate with the **u-RWELL detectors**. This electronics system is considered one of the best candidates for use with u-RWELL in the current landscape of chips for MPGD in **RD51, now known as DRD1**.

However, the use of the **TIGER+GEMROC system** for u-RWELL **is not guaranteed due to the different characteristics of GEM and u-RWELL** (different input capacitance, different integrated charge, and therefore different S/N). and the limitations imposed on the GEM-ROC FPGA when reading the TIGER chip in BESIII. **Data from TB 2024**, which will be analyzed in the second half of 2024, along with further studies, will determine whether **TIGER can be directly integrated with u-RWELL or will require additional development**. The off-detector part will clearly need to be fully developed.

Lastly, **simulation studies** on specific physics channels **will clarify in more detail the requirements for the pre-shower and muon systems**, which could lead to **adjustments to the detector layout while aiming to simplify it as much as possible**.

Conclusioni

- Forte spinta di FCC dal CERN e dalla comunità internazionale.
- Frascati è impegnata in un'attività cruciale per un collider, il disegno della regione di interazione integrato con il rivelatore di vertice, il luminometro, anche con un test di R&D fattibilità.
- In questi mesi siamo impegnati nella conclusione dello studio di fattibilità¹ e nella documentazione dell'attività svolta in questi anni nel FS report.
- Stiamo preparando una proposta di attività per il pre-TDR.
- Rappresentanza nella governance di FCC:
 - M. Boscolo executive board, rappresentante (unico) per l'INFN nel ICB, WG MDI Coordinator, e anche technical coordination group e PED coord. group member

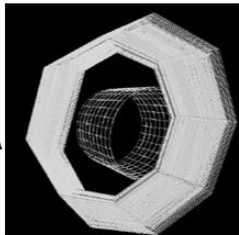
Backup

MPGD

Simulation

FULL IDEA DD4HEP IMPLEMENTATION

- The simple Muon System and Pre-shower have been included in the full IDEA DD4hep implementation.
- Current DR Calorimeter is still missed. A simple version has been implemented in order to study the **multiple scattering of muons**.



- The full implementation now is available on [k4geo READOUT SYSTEM](#)

- Description of the readout is made for every single layer represents the system (segmentation in ϕ and θ direction).
- Chamber represents the $50 * 50 \text{ cm}^2$ the μ RWELL
- The sensitive layer is the gas layer.

DIGITIZATION (ONGOING)

In order to convert the **SimHits** into **DigiHits**, some parameters have been implemented from the μ RWELL test beam results:

- μ RWELL efficiency: $>95\%$., pre-shower candidate space resolution: $\sim 100 \mu\text{m}$, muon system candidate space resolution: $\sim 400 \mu\text{m}$

Front-end Electronics



TIGER/GEMROC Front-end electronics

- Noise level very low ($\sim 1 \text{ fC}$)
- Input capacitance up to 100 pF
- TDC resolution $< 50 \text{ ps}$
- Average gain $\sim 10.75 \text{ mV/fc}$
- Maximum power consumption $\sim 12 \text{ mW/ch}$



A TB has been performed @ SPS in July 2024. The data analysis of [HV scan](#), [Drift scan](#) and [Thr. scan](#), with $\text{Ar:CO}_2\text{:CF}_4$ is ongoing and will be finalized in the next month

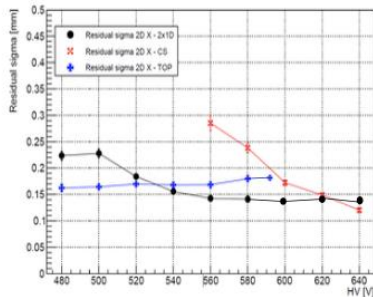
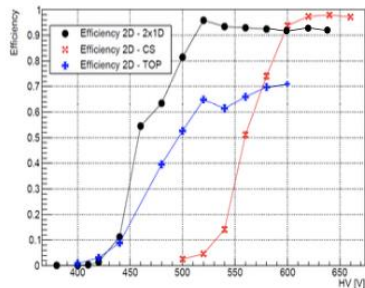
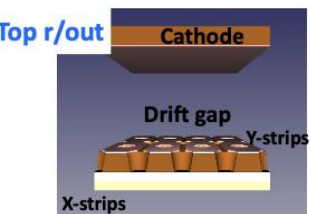
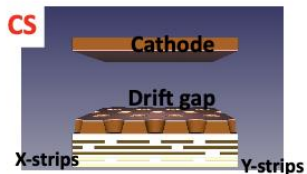
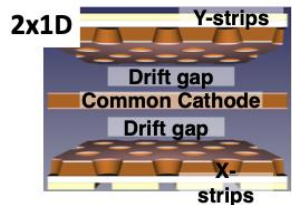
WG5 MPGD

The results of TB-22-23, where the 2D layouts have been compared, giving the following results:

2x1D layout: spatial resolution < 200 μm (pitch 0.8 mm), low voltage operating point $\sim 520\text{V}$, efficiency $\geq 98\%$ (large eff. plateau)

CS layout: spatial resolution < 200 μm (with pitch 1.2 mm), very high voltage operating point, $\geq 600\text{V}$, efficiency $\geq 98\%$

Top layout: spatial resolution < 200 μm (pitch 0.8 mm), low voltage operating point $\sim 520\text{V}$, efficiency $\sim 70\%$ (dead-zone)



Detector solution & program 2025:

- **Hybrid CS with strip readout** \rightarrow CS + GEM pre-amplification stage, to lower the operating point, greatly improving the RWELL stability and maintaining high spatial performance with millimetric pitches
- **Micro-RGroove** \rightarrow new layout, where the amplification stage is not based on the «wells» but on the «grooves». This facilitates the realization of the strip readout on the top, without introducing dead-zones (introduced by Z. Yi in RD51).

