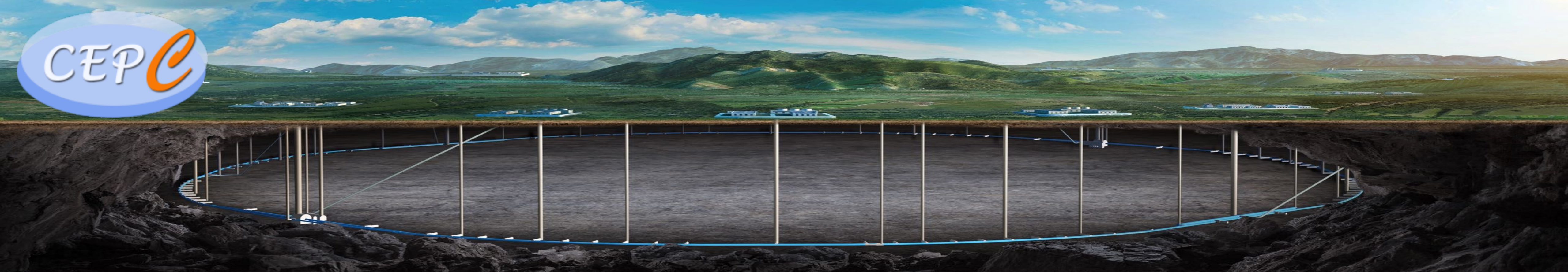
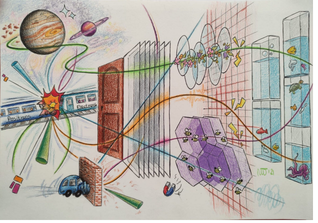


CEPC workshop tracker summary

Zhijun Liang

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

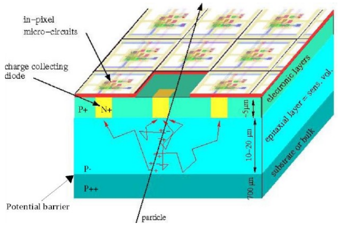


Paths of present silicon sensor R&D

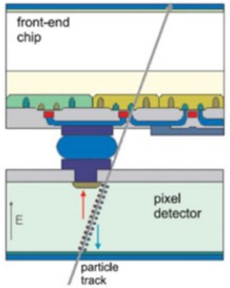
DRD3

From Gregor's talk

Monolithic devices
(WG1/WP1-CMOS)
55-180 nm processes

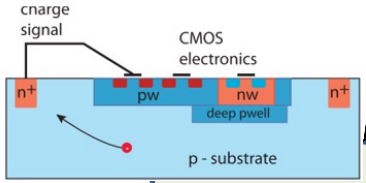


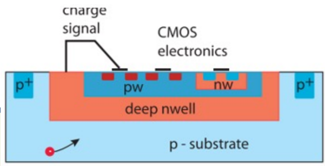
Hybrid devices
(WG2/WP2-4D tracking)

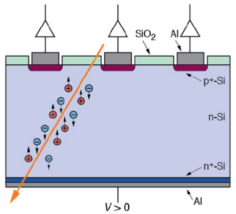


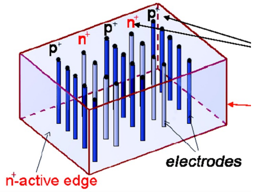
Readout ASIC chip

The sensor









MAPS

Small electrode device

Large electrode device

Planar

3D devices

Large area passive devices (strips)

with gain

Depleted MAPS wo Gain

Depleted MAPS wo Gain

with gain

With Gain (LGADs)

Trench 3D

Column 3D

With Gain

Optimized for rates/power/position resolution

Optimized for radiation hardness /timing-efficiency

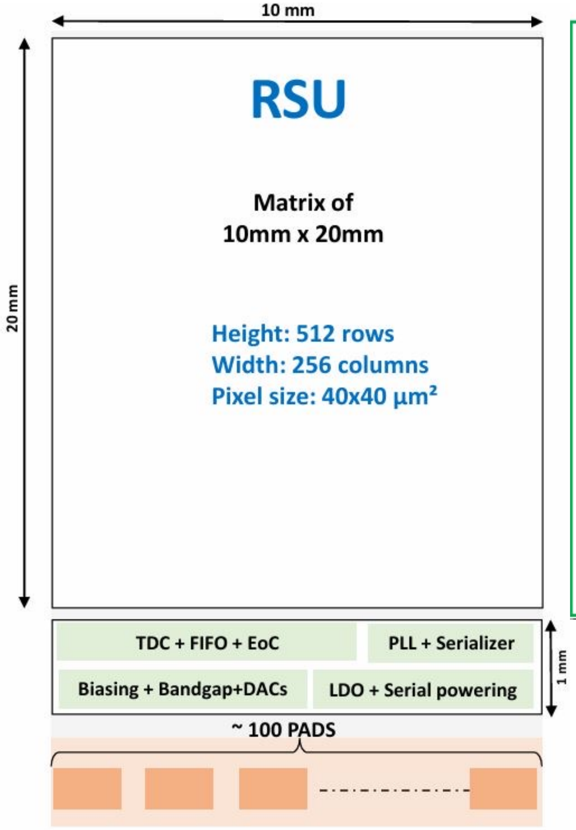
- proof of concept ongoing (red)
- recent research (working prototype) (orange)
- proven/demonstrated (green)

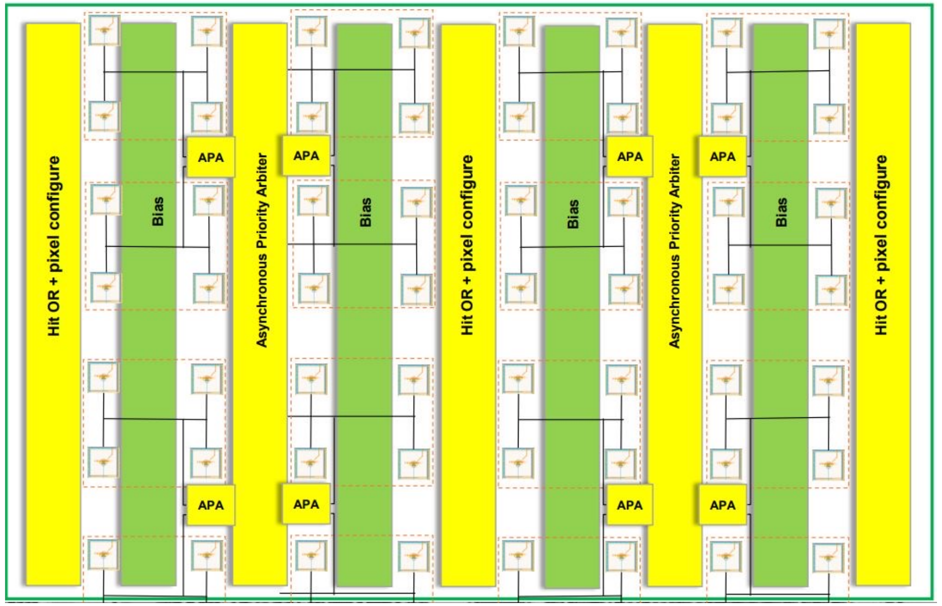
DRD3.1 Project: MANTA

Monolithic **A**synchronous sensor for **N**ext generation **T**r**A**ckers

- **Key final development goals** include:
  - **~10µm** position resolution
  - About **100ps** time resolution
  - Average power consumption about **20 mW/cm²**

From Danwei's talk





Significant overlap of IP blocks between MANTA and OCTOPUS

Architecture:

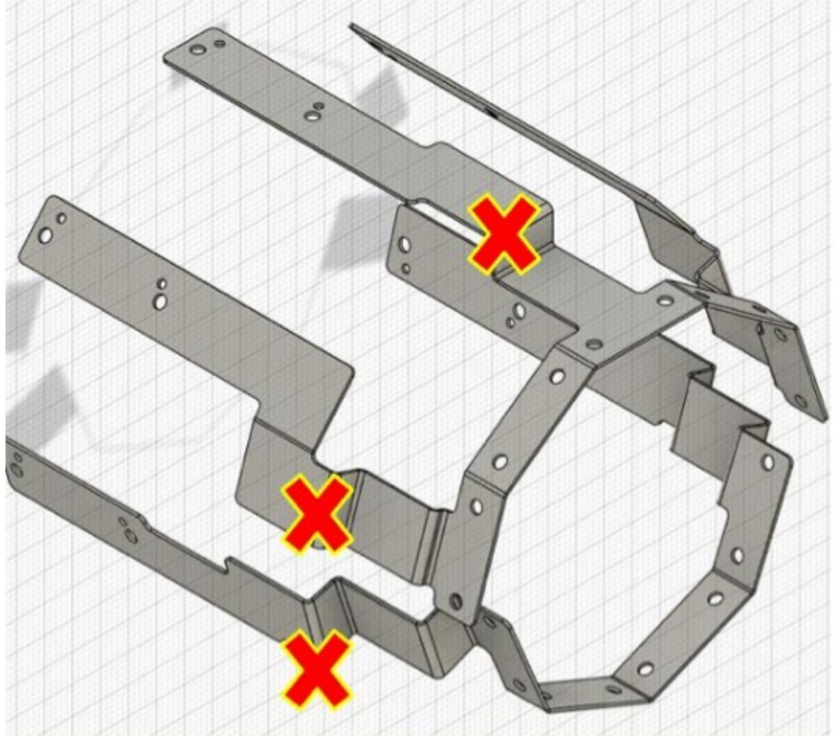
- Simplified and modular chip design
- **3-side buttable**
- Active matrix size : 10 mm x 20mm
- Pixel grouping, pitch : 40µm
  - Diode pitch: 20µm
  - Digital grouping / Analog grouping
  - Analog front-end :DPTS
- **Asynchronous Priority Arbiter**
- **Single-Layer Multiplexer Variants**
- FastOR: for high-precision time stamping
  - High-Resolution TDC : ~70ps
- Submission plan :
  - **MANTA0: ER3 – Q3 2026**
  - **MANTA1: MPR2 – Mid 2027**

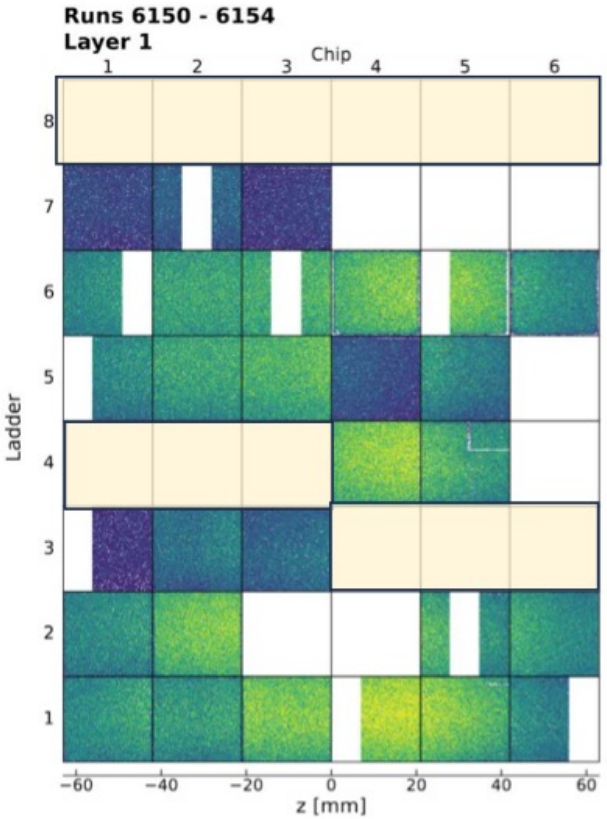
Vertex detector for Mu3E

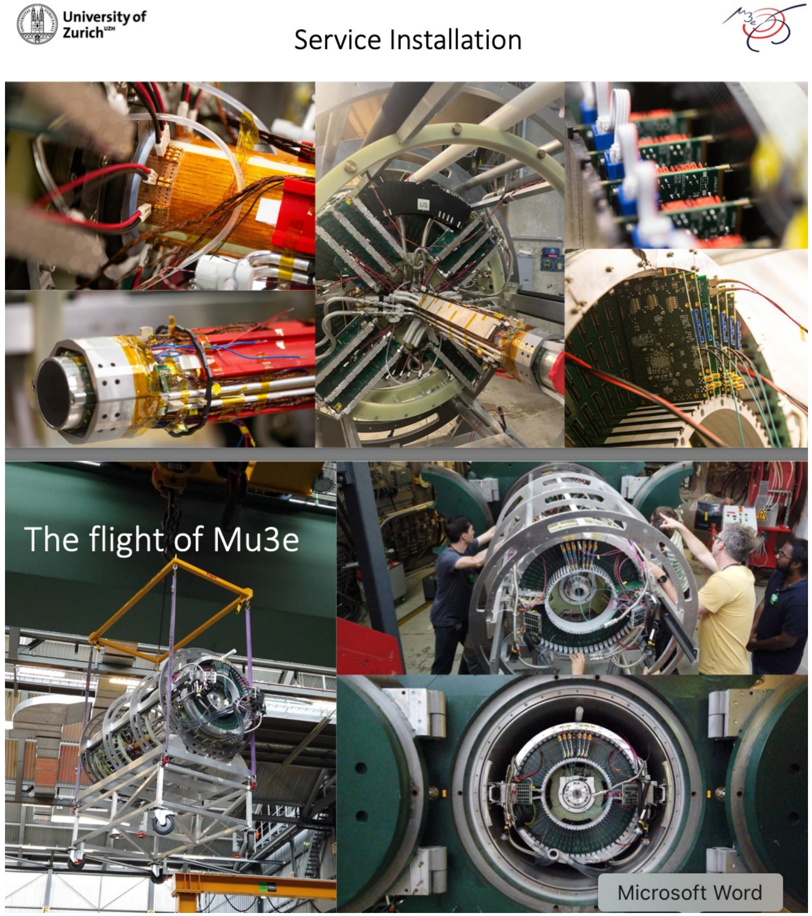
University of Zurich[UZH]

Successful Commissioning of the Mu3e Vertex Detector

From Thomas's talk for Mu3e vertex detector







CEPC vertex detector Working plan

- Development of 1st engineering run using MAPSs with HC90L 90nm technology
  - Prototype full size RSU-like sensor
  - Validate sensor and electronics performance without stitching
  - Expect to finalize the design by the end of 2026
- Work together with mechanics group on thermal mockup
  - Test air cooling and the vibration
- Longer term: Explore CIS stitching MAPSs sensor with HC90L 90nm
- Final goal: Built prototype close to ref-TDR design

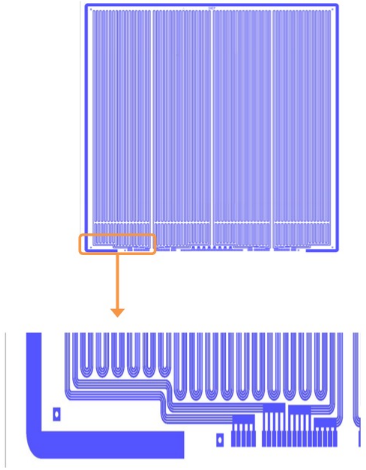
Vertex detector discussion

- Discussion on cooling mockup for vertex detector
  - Current plan with flex PCB, will likely to switch to silicon heater (Yiming's talk)
- Discussion about proposing HC90L technology in DRD3
- Cabling may learn from Mu3E vertex prototype

CEPC

Dummy sensor preparation

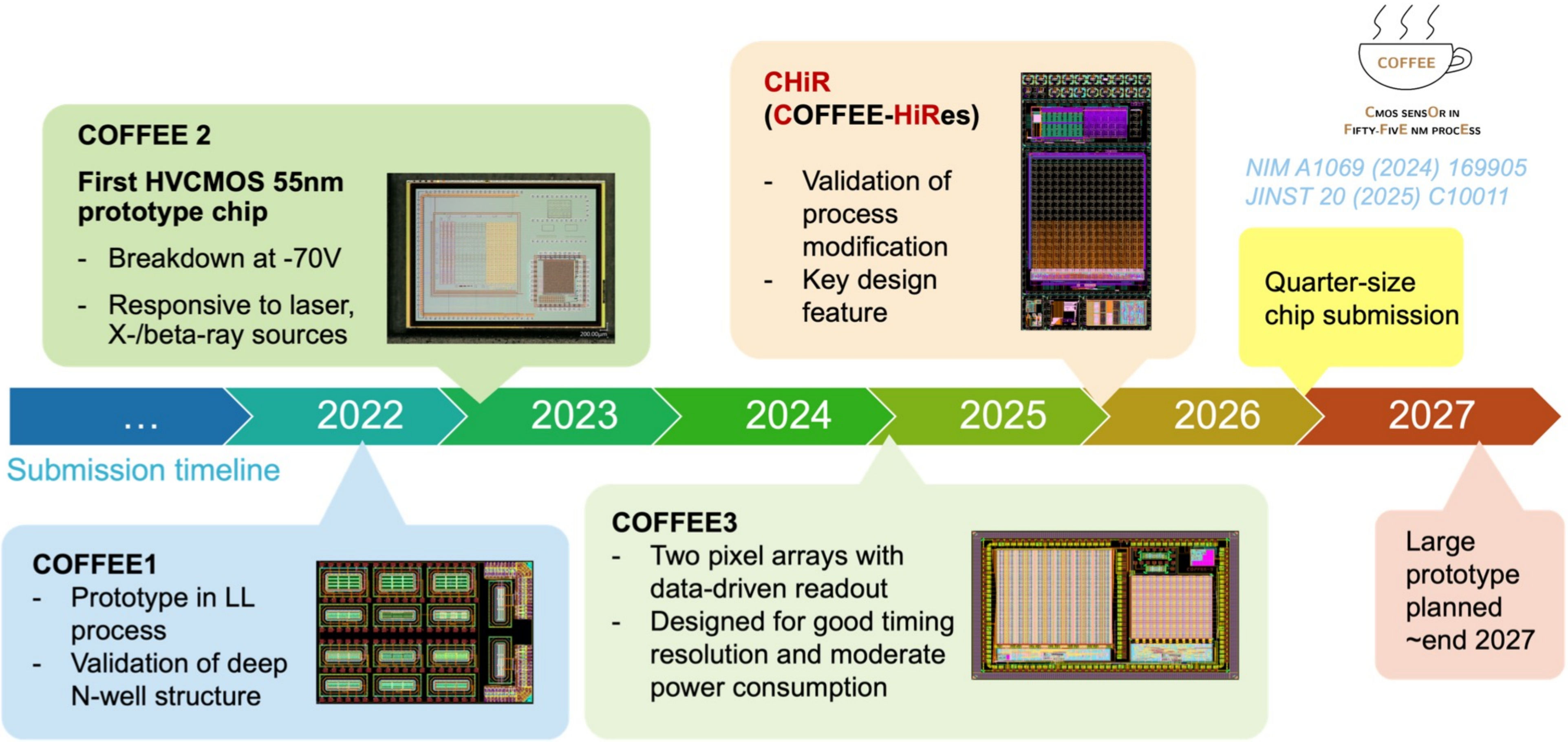
- For realistic study of material budget and development of assembly procedure, dummy modules with dummy sensors + flex is the first step
- Dummy sensor in production
  - Same size as the final chip
  - With metal traces for thermal study
  - With real pads and pattern to facilitate assembly
  - Expected to be back in end April



Thermal conductive layer(black)

CEPC Inner tracker

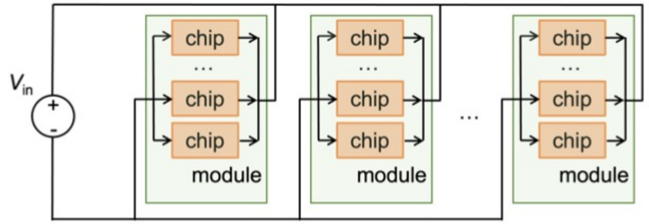
- ITK chip development plan by Yiming well received.
- Gregor asked us to finish DRD3 proposal

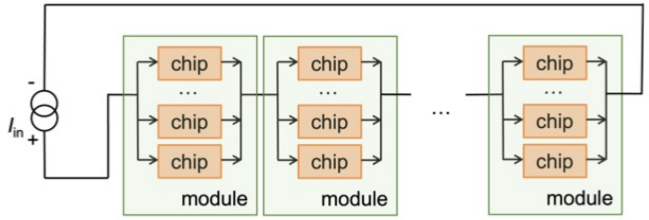


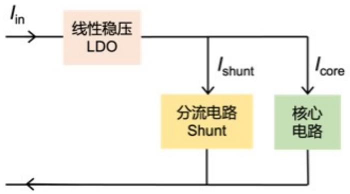
Serial powering for tracker

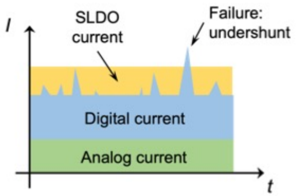
- Collaboration with UK colleagues on serial powering
- Validation with ATLASPix setup

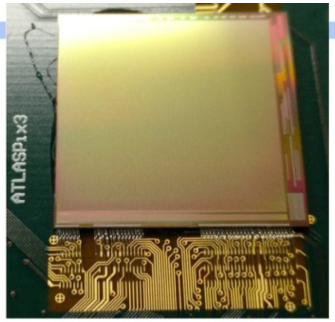
- As pixel size decrease by N, cables increase:
  - Parallel power (or +DCDC) by N^2
  - Serial power by N
- Adopted by ATLAS/CMS Phase II trackers
  - Hybrid pixel, SLDO functions developed by RD53
- Nicely align with ongoing DRD3 project to develop demonstrator for MAPS-based tracker
  - Lead by INFN Milan + Edinburgh
- Tasks:
  - Design of SLDO for 55nm process aiming IP for integration into final chip
  - Demonstrator of multi-module tests

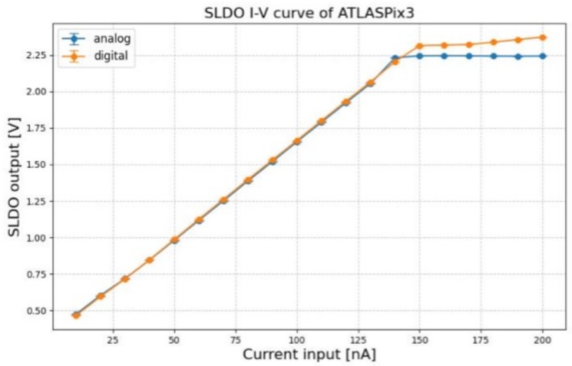












IV @ ATLASPIX3 SLDO

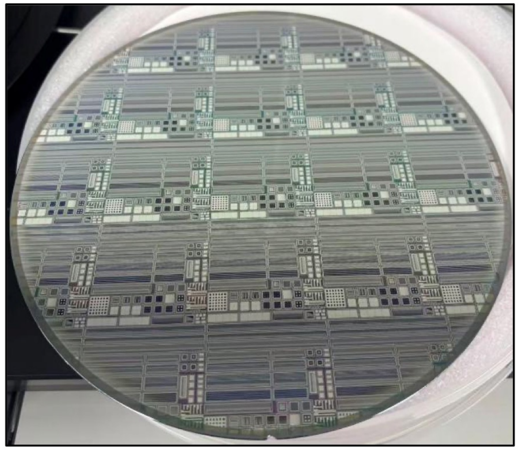
CEPC OTK

Mei Zhao's talk

- Gregor's comments:
  - Suggest to share with more groups for testing.
  - More groups can cross check each other, make sure we understood sensors.
  - Take times to tests new AC-LGAD in details before next submission
- Other suggestion
  - Use stitching to make longer strip (10cm)

AC-LGAD with long strip

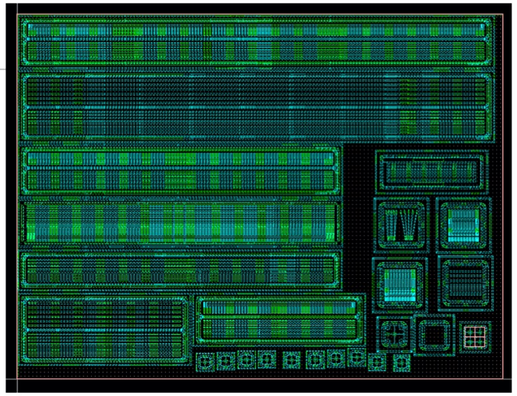
Wafer number	EPI thickness	n+ dose
1	50um	10p
2	50um	10p
3	50um	0.01p
7	80um	10p
8	80um	0.01p



- Five wafers been delivered.
- Testing been done on wafer 1, wafer 7: I-V, C-V, and timing performance
- Another 2 with n+ dose as 1p, 0.1p will be delivered this week.

Plan

- Tape out other wafers with different process parameters
- Testing of AC-LGAD with long strips and different process parameters
  - Different n+ dose, different coupling capacitance, different pad-pitch size, different strip length
  - I-V, C-V, timing performance by using Beta source, spatial resolution by using laser test system
- Testing of AC-LGAD(long strips) with ASIC(LATRIC1)
- New submission is planed in June, 2026, isolated AC-LGAD



- The design of LGAD with isolation structure is ongoing

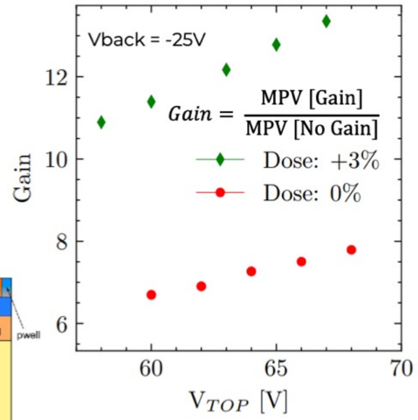
CMOS-LGAD development

- INFN colleague presented nice result from CMOS-LGAD.

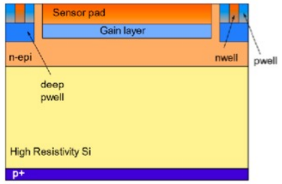
ARCADIA MADPix CMOS-LGAD Demonstrator

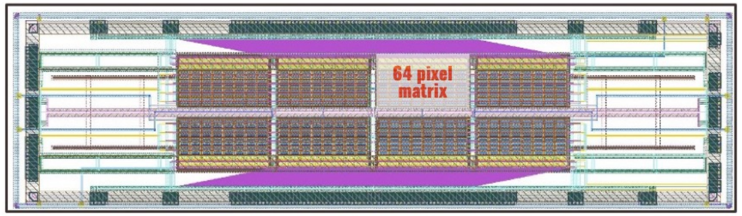
INFN

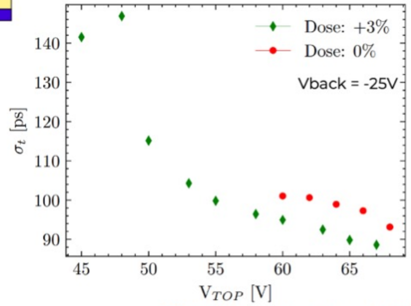
- **M**onolithic CMOS **A**valanche **D**etector **PIX**elated prototype first small-scale demonstrator (4 x 16 mm^2) with embedded electronics and gain layer
  - Backside HV (V_{BACK}): allow full depletion [-20 : -40]V*
  - Topside HV (V_{TOP}): adjust total gain [35 : 65]V*



- 8 matrices (64 250 x 100 µm^2 pixel pads each) implementing different sensor and front-end flavours
- 64 analogue outputs on each side, rolling shutter of single matrix readout





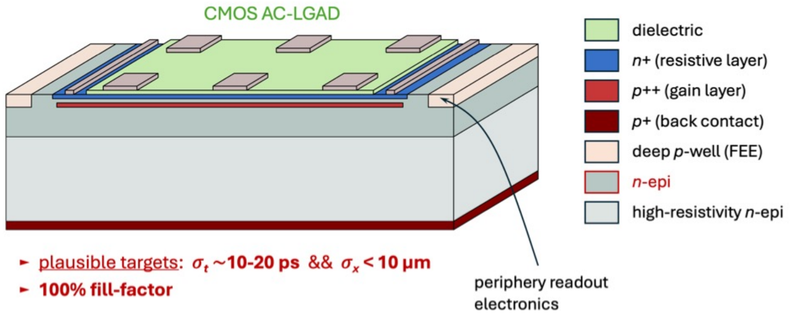


* voltage ranges for prototype with 48 µm active thickness

R&D for a Si-Wrapper with CMOS AC-LGADs

INFN

Mandurrino, M. et al., Numerical Proof-of-Concept of Monolithic AC-LGAD Detectors for 4D Particle Tracking. Sensors 2025, 25, 4185. https://doi.org/10.3390/s25134185



- LGAD detector with continuous gain layer (RSD), charge collection through resistive n-layer and readout by induction on AC coupled pads, for a

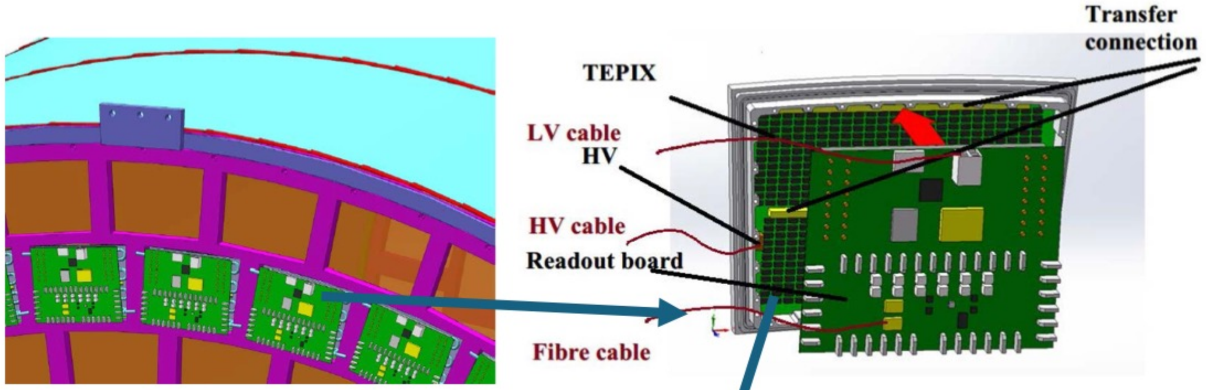
➡ fully active detector, avoiding isolation implants (used to prevent early breakdown) in segmented LGADs

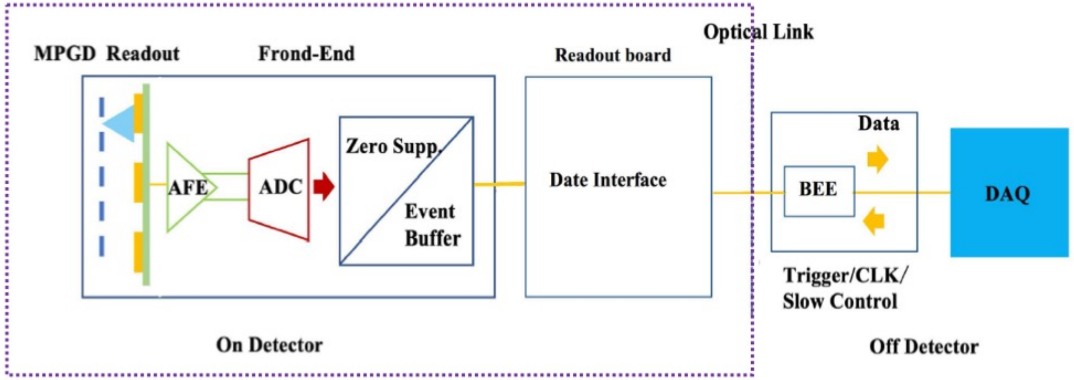
- Timing resolution approximatively independent from pixel pitch
- CMOS integration of the LGAD technology already demonstrated (in LF11is) with the ARCADIA masksets
- Up next for CMOS AC-LGAD: demonstrate the compatibility between the RSD readout scheme and the LF11is ARCADIA CMOS process flow, first prototypes in future silicon production runs.

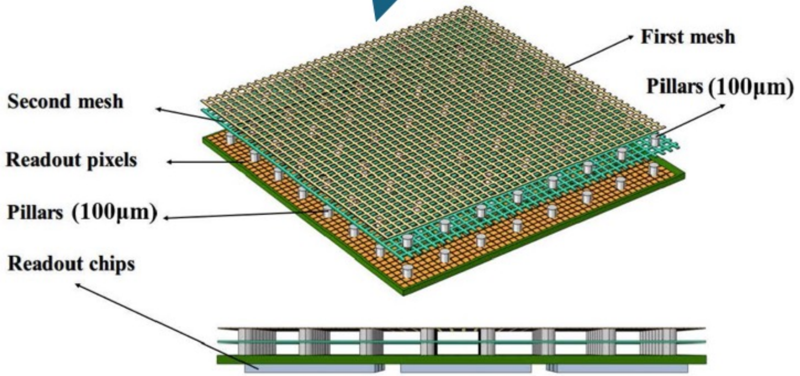
CEPC TPC

- Received some requests to increase the size for Micromegas.
- From mingyi: It is possible, but there is some risk

- **Readout modules**
  - Double-mesh Micromegas with high granularity readout pads
  - FEE board with readout ASIC chip (TEPIX) array. Interposer connection between pads and ASIC chips
  - Readout board: data interface and data concentrator





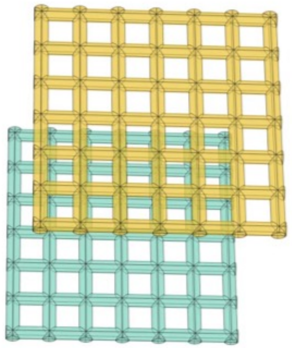


IBF for CEPC TPC

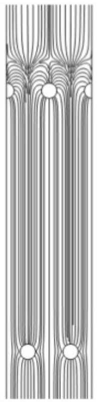
- INFN colleague interested in IBL study, raised lots questions on it.

IBF suppression with Double-Mesh Micromegas

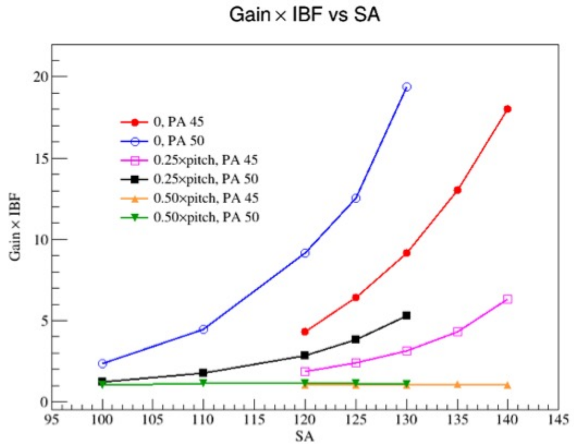
- Simulated the gain and the product of IBF and gain (IBF × gain) under different DMM layout configurations by shifting and rotating the second mesh
- DMM layout configuration does not affect gain, but it affects IBF

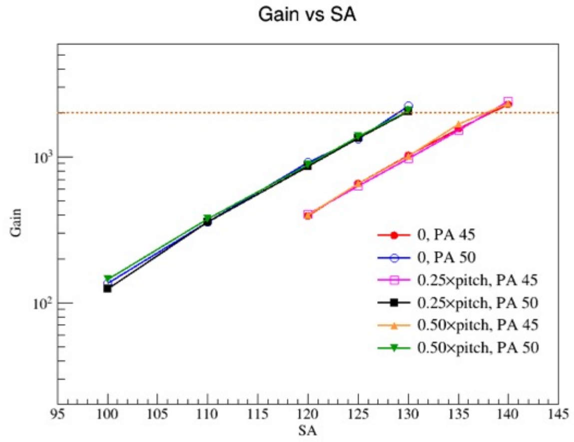


Distribution of electric field lines in double mesh



- The staggered arrangement of two meshes can achieve IBF × gain of about 1, which is consistent with test results of USTC (**NIMA 976 (2020), p. 164282**)
- Further simulation and tests will be conducted





CERN Beam test for drift chamber in 2026

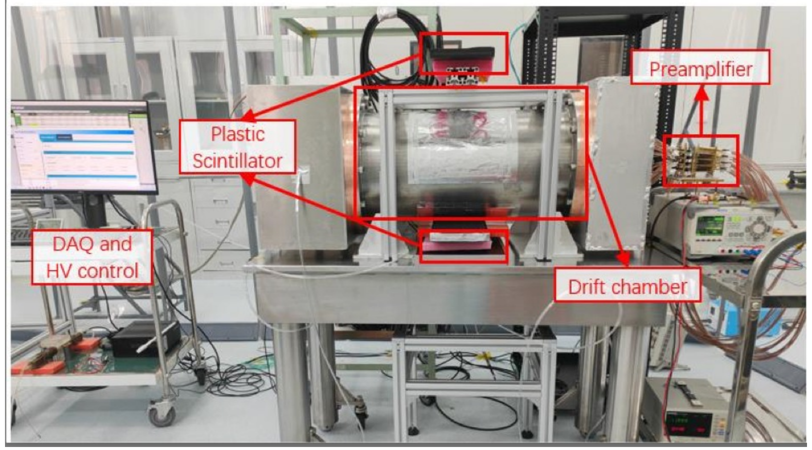
Secondary and tertiary beam from the PS at the East Area:

π :

- Negative pions almost 99% pure for 15 GeV 10 GeV, 6 GeV or 5 GeV
- basically 90% purity down to 1 GeV (below 1 GeV, the electron percentage goes up)
- the contamination from Muons is very low
- an absorber will be used to kill even the small percent of electrons that can exist in these momentum ranges; at 3 GeV, we have 35% electrons, but this can be killed with the absorber, to have almost pure pions.
- Rate: up to $10^{4/5}$ pions per spill (0.4 s)
- Positive pions are highly contaminated by protons and will not be used.

k :

- Positive Kaons percentage goes from from 1% to 3% in mostly pure pion beam, depending on the momenta, but it's quite flat in principle for the different momentum for the kaons → so we expect 100 kaons per second
- the only way to check the kaons would be to tag them with the Cherenkov detector, based on threshold pressure that will give the momenta up to what it would work
- beam spread: at higher momentum, beams experts are able to focus better the beam because of less multiple scattering → we can have up to 8mm sigma for the beam width at the highest momenta, and as we go to lower momenta, (more scattering) it can become 1, 1.5 cm.



Both the IDEA and IHEP CEPC team will join the test and work together

Summary

- Lots of useful discussion on technology
- Consolidation on international collaboration in tracker development
  - Test beam for drift chamber …
  - Write more proposal for DRD

Backup

technology for next R & D of CEPC vertex

- Next step foundry: SK hynix system fab in Wuxi China (90nm technology with stitching feasibility

	Requirements	TPSCo 65 nm	HLMC 55 nm	HC90L
Feature size	55 – 90 nm	65 nm	55 nm	90 nm
Epitaxial layer thickness	10 - 25 μm	10 μm	3-5 μm	4 – 8.5 μm (default) Can be changed to 20μm
Resistivity of epi-layer	> 1 kΩ•cm	~130 Ω•cm	Low resistivity ~10 Ω•cm	30-50 Ω•cm (default) Can upgraded to 5kΩcm
Availability of deep N-well	Yes	Yes	Yes	Yes
Availability of deep P-well	Yes	Yes	Yes	Optional
Numbers of metal layers	> 6	Max. 7	Max. 5	Max. 5
Availability of stitching	Yes	Yes	Yes	Yes
Cost (NRE)		~7.0 M RMB	~6.0 M RMB	2~3 M RMB

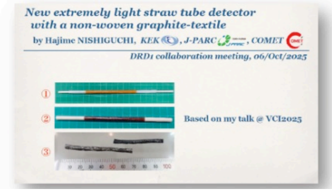
DRD1 Working Groups (WG): Highlights

Working Group 1

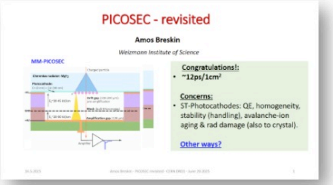
Advances the design and development of innovative detector architectures, including wire-based systems, RPCs, MPGDs, and large-volume detectors, ensuring robust, scalable, and adaptable solutions for future experiments.

Support efficient scientific exchange, with proper peer review and discussion within the c
and keeping track of all **Technological aspects and developments o**
common characterization and physics issues of interest f

Wire



MPGD

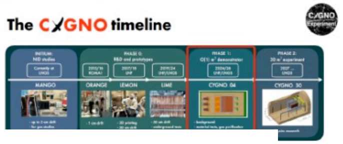


Working Group 2

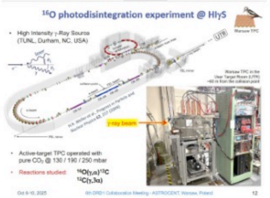
Bridges fundamental R&D and practical applications, identifying performance needs a particle physics and other fields.

Support efficient scientific exchange with proper peer revie
community, focusing on relevant aspects and keeping track of
the full DRD1 community.

Cygno Experiment



Active Target TPC @ HIgS



Working Group 3

Develops new materials and eco-friendly gas mixtures to enhance detector performance and longevity, addressing aging and sustainability for high-performance, low-impact detectors.

WG3: Gas and Materials

Facilitate contacts and exchange between different groups and expertise at Collaboration or Dedicated Meeting, supporting topical workshops, proposing common activities

Topical Workshops: Towards Sustainable Gas Mixtures for Future Detectors 2025

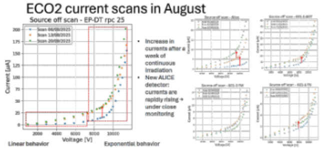
- **Regulatory landscape**, interdisciplinary and industrial perspectives
- Gas **Recovery, Recycling, and Closed-loop** Systems
- Gas **Replacement** Strategies: Physics and Performance

Planned Common Activities:

- Gas Properties and Studies of New Mixtures (syn. WG4)
- Ageing and Outgassing
- Recirculation and Recuperation Systems (syn. WG7)
- Resistive Materials (syn. WG6)
- Mechanics (syn. DRD8)

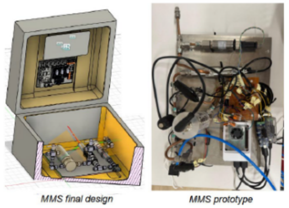
OTELLO:
Project proposal focused on the development of sustainable and high-performance gas mixtures for next-generation gaseous detectors

Long-term performance studies of RPC detectors operated with eco-friendly gas mixtures at the CERN GIF++ facility (CERN Summer Student)



https://tinyurl.com/drd1ecocss25

Gas monitoring sensors and real-time visualisation (CERN Summer Student)



https://tinyurl.com/3cm2s22n

Working Group 4

Advances simulation tools and modelling techniques to predict detector behaviour, optimize performance, and guide the design of future detectors.

WG4: Modelling and Simulation

Active contribution to the **DRD1 schools** (2024 and 2025) through lectures and tutoring.

Organization of **WG4 session** at Collaboration Meetings (**34 Contributions**)

Organization of **working meetings (9 events, 53 contribution)** on relevant topics:

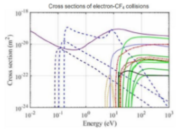
- Simulation of Resistive Detectors
- Large Avalanches Topical Meeting
- Low Pressure Simulation & Measurements

WG4 Mailing list with almost 200 subscription

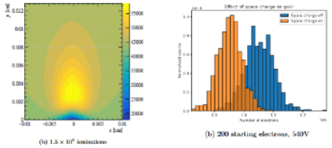
Upcoming:

Organization of a dedicated simulation school in Bari (18–22 May 2026).

Cross-Sections & MAGBOLTZ



Space Charge Effects in Simulations of Large Avalanche Dynamics (CERN Summer Student)



https://repository.cern/records/fpfgq-hc985

Working Group 5

Innovates front-end electronics and data acquisition systems, ensuring high-rate, low-nois

WG5 : Electronics for Gaseous Detectors

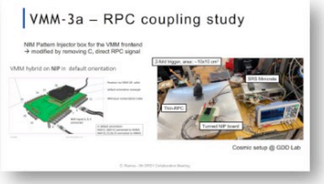
Common Development of FE, DAQ and Instrumentation.

WG session at CM and regular meetings with developers.

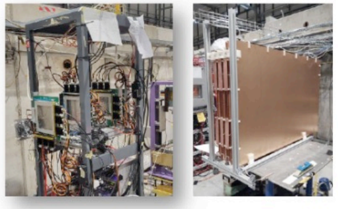
Planned Common Activities:

- Front-End ASICs
- Common and Scalable DAQ
- Custom Instrumentation (Powering and Monitoring)

Integration of Common Electronics (VMM3a) into different Detector Technologies (RPC)



FE & DAQ for Test Beam

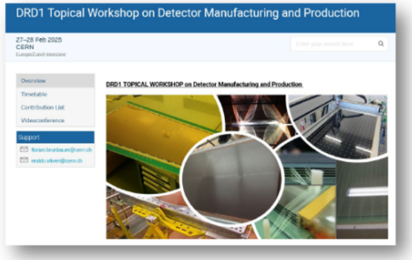


Working Group 6

Streamlines manufacturing and quality control, facilitating the transition of advanced detector technologies from lab research to industrial production, ensuring economic viability and accessibility.

WG6: Production and Technology Transfer

2025 Topical Workshops: Detector Manufacturing and Production



- Manufacturing Technologies
- New Manufacturing and Production Facilities
- Industrial Partners and Spin-Offs
- Existing Manufacturing and Production Facilities
- Production for Experiments and Projects (Lessons Learned)
- Visit to the CERN MPT Workshop

Planned Common Activities:

- Survey of production Needs and Capabilities and strategic guidelines in manufacturing and production facilities.
- QA/QC protocols and Instrumentation
- Technology transfer checklist and database (projects and Industrial Partners)
- Establishment of a Forum for sharing and knowledge transfer

Production and Manufacturing – crucial for Strategic R&D (DRD1) and future experiments – Fundamental to keep and improve manufacturing capability and capacity.

- **Strengthen strategic CERN support for the MPT workshop**
- **Facilitate and enhance the use of existing manufacturing facilities in the community**
- **Facilitate the establishment of new facilities at DRD1 institutions or research laboratories**
- **Support technology transfer to industry**
- **Proper Human Resources Considerations in terms of training and dissemination**