GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Progress of the R&D on the MIMOSIS sensors

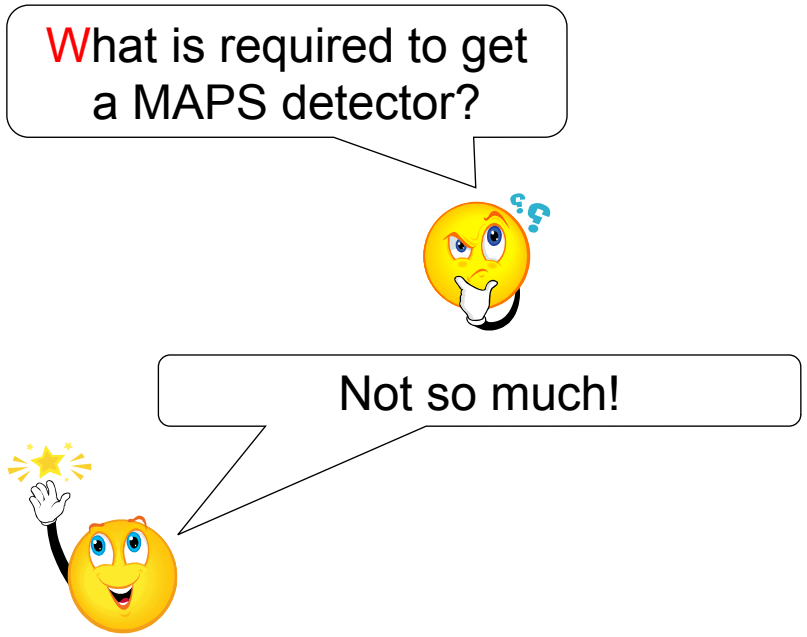
Benedict Arnoldi-Meadows
for the CBM-MVD team

16 October 2025

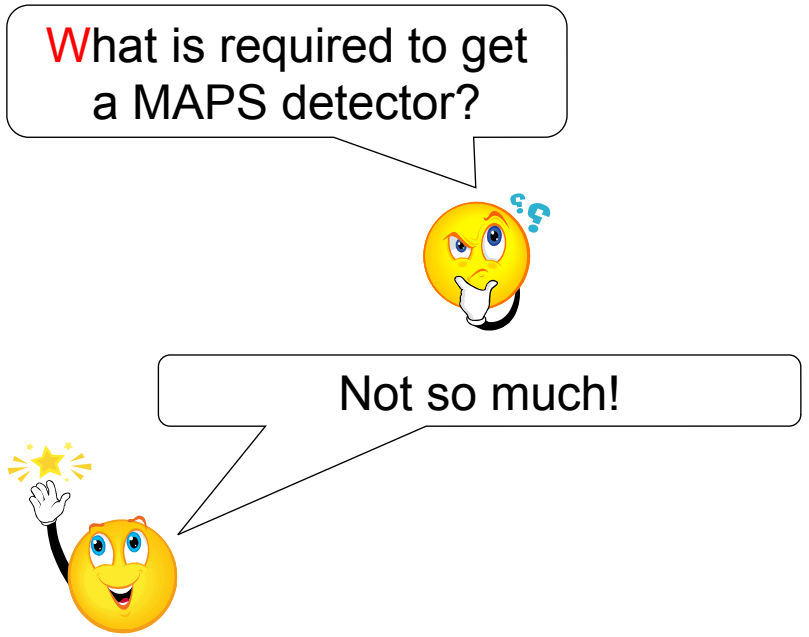
What do you need for a MAPS detector?

What is required to get a MAPS detector?

What do you need for a MAPS detector?

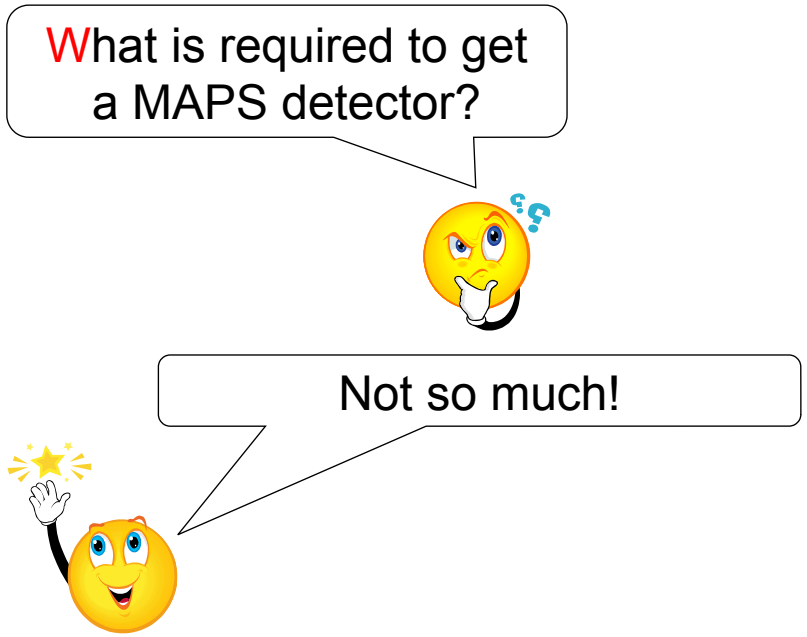


What do you need for a MAPS detector?



… a Webcam…

What do you need for a MAPS detector?



… a Webcam…

What do you need for a MAPS detector?

…Metal tape…

What is required to get a MAPS detector?

Not so much!

… a Webcam…

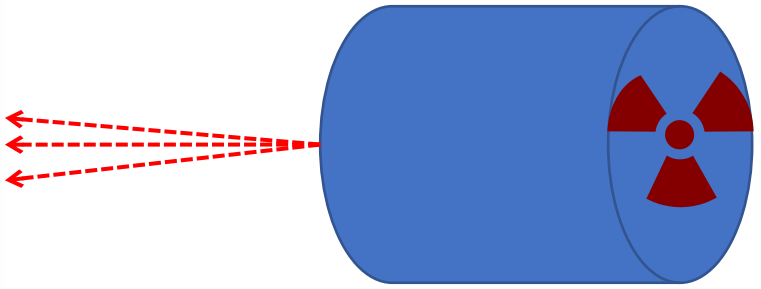
What do you need for a MAPS detector?

…Metal tape…

What is required to get a MAPS detector?

Not so much!

… a Webcam…



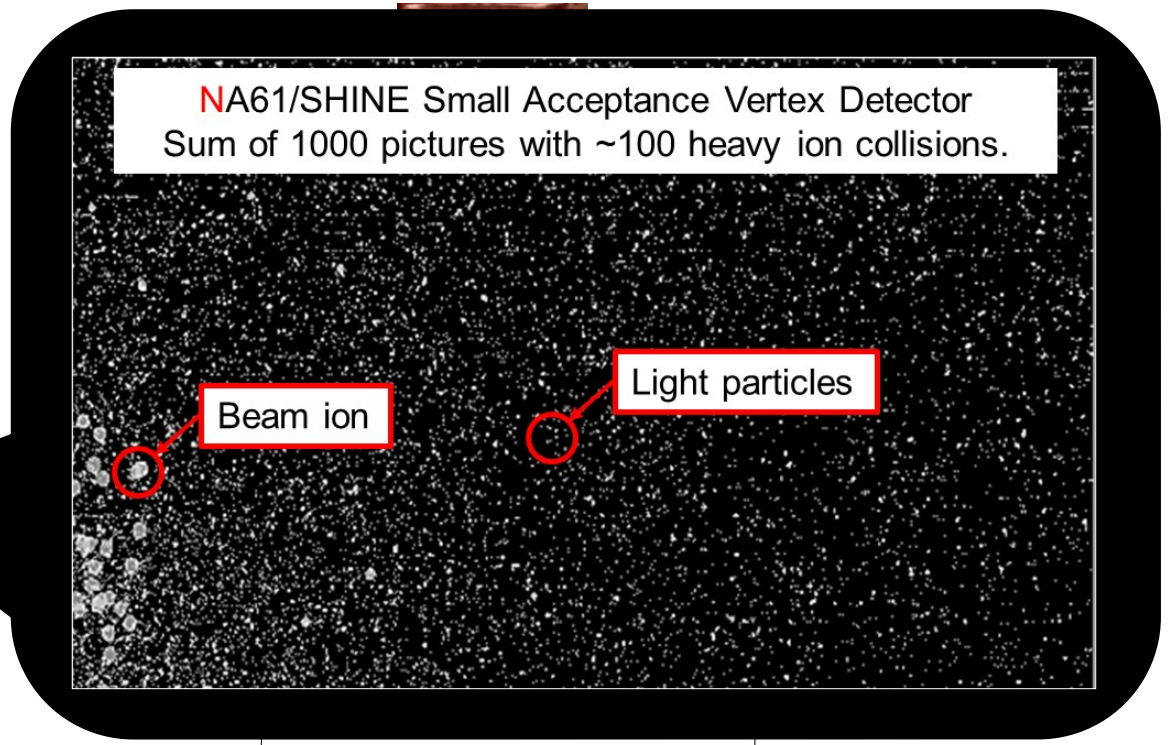
…and some radiation.

What do you need for a MAPS detector?

What is required to get a MAPS detector?

Not so much!

… a Webcam…



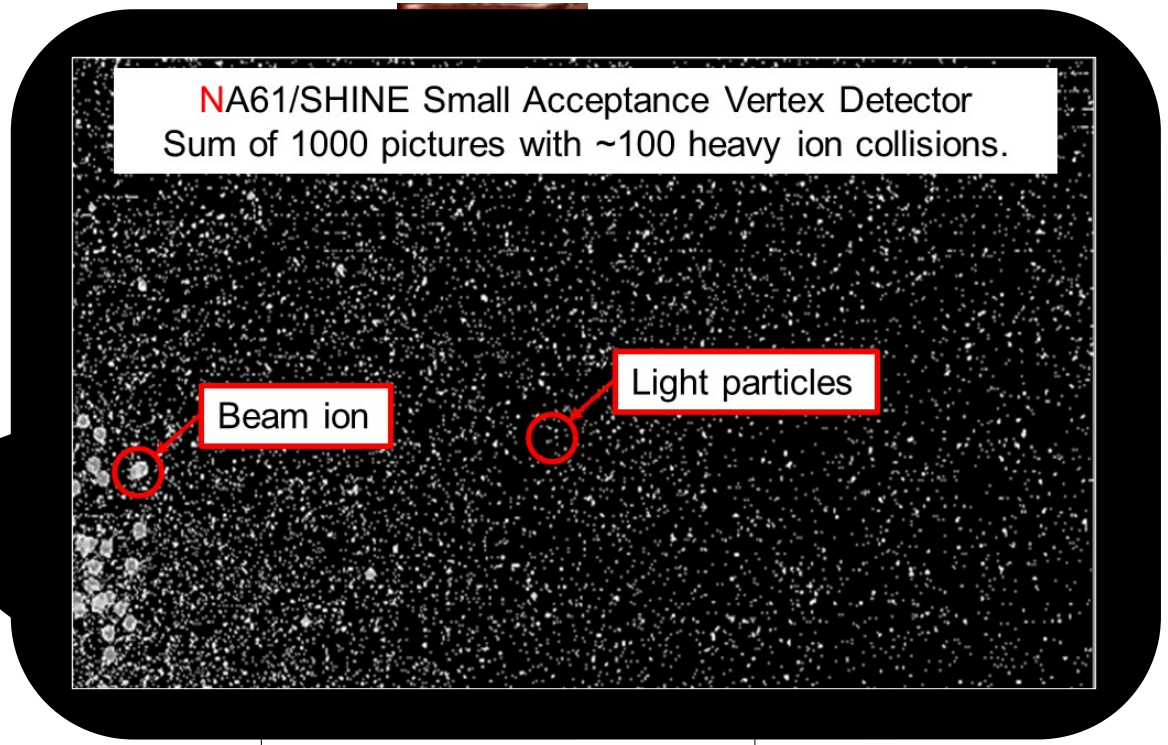
…and some radiation.

What do you need for a MAPS detector?

What is required to get a MAPS detector?

Not so much!

… a Webcam…



…and some radiation.

Benefits of Monolithic Active Pixel Sensors:

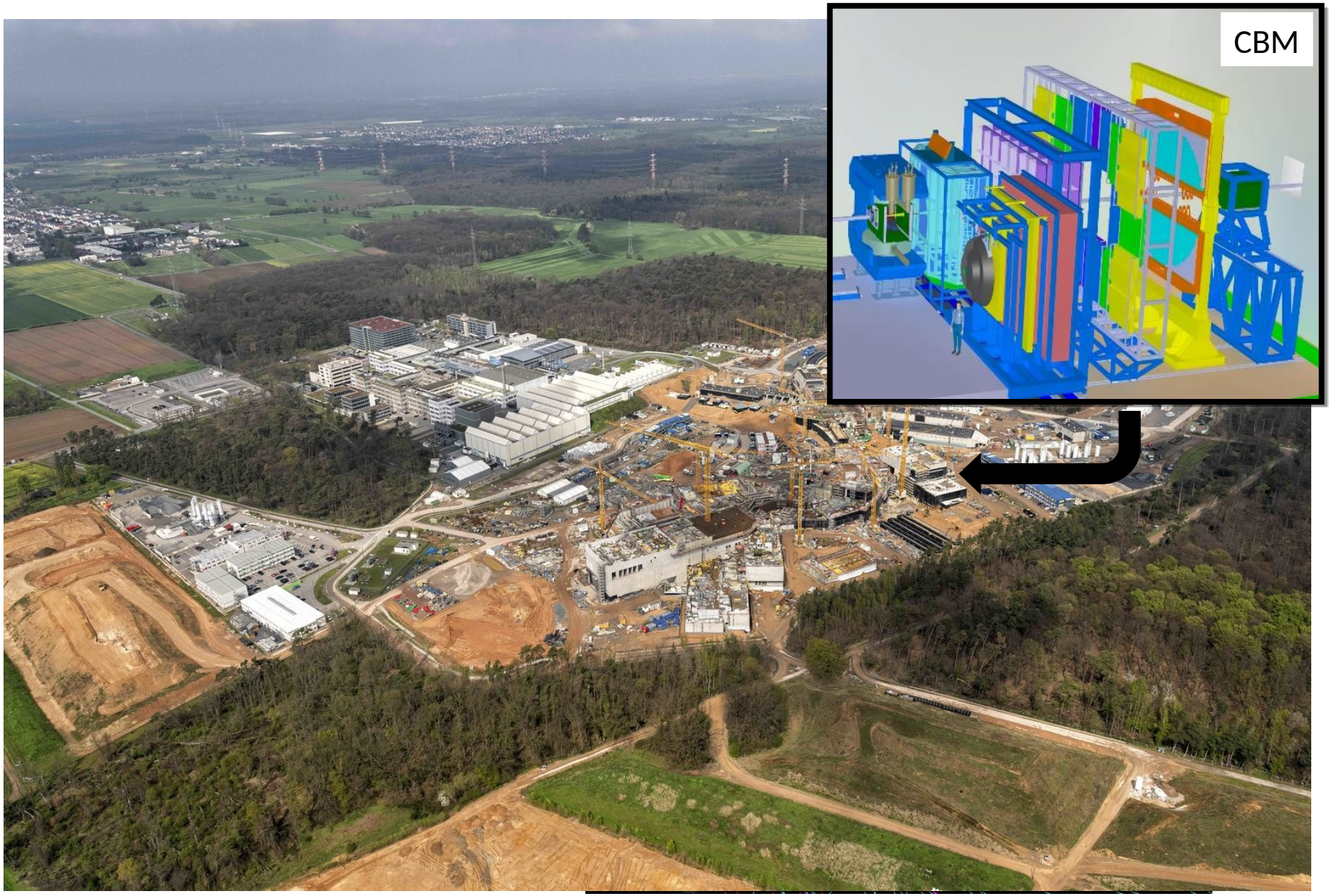
- Thin!
- Low power
- Low cost
- Commercially manufactuarble
- Highly customizable

Where will MIMOSIS be used?

Darmstadt, Germany

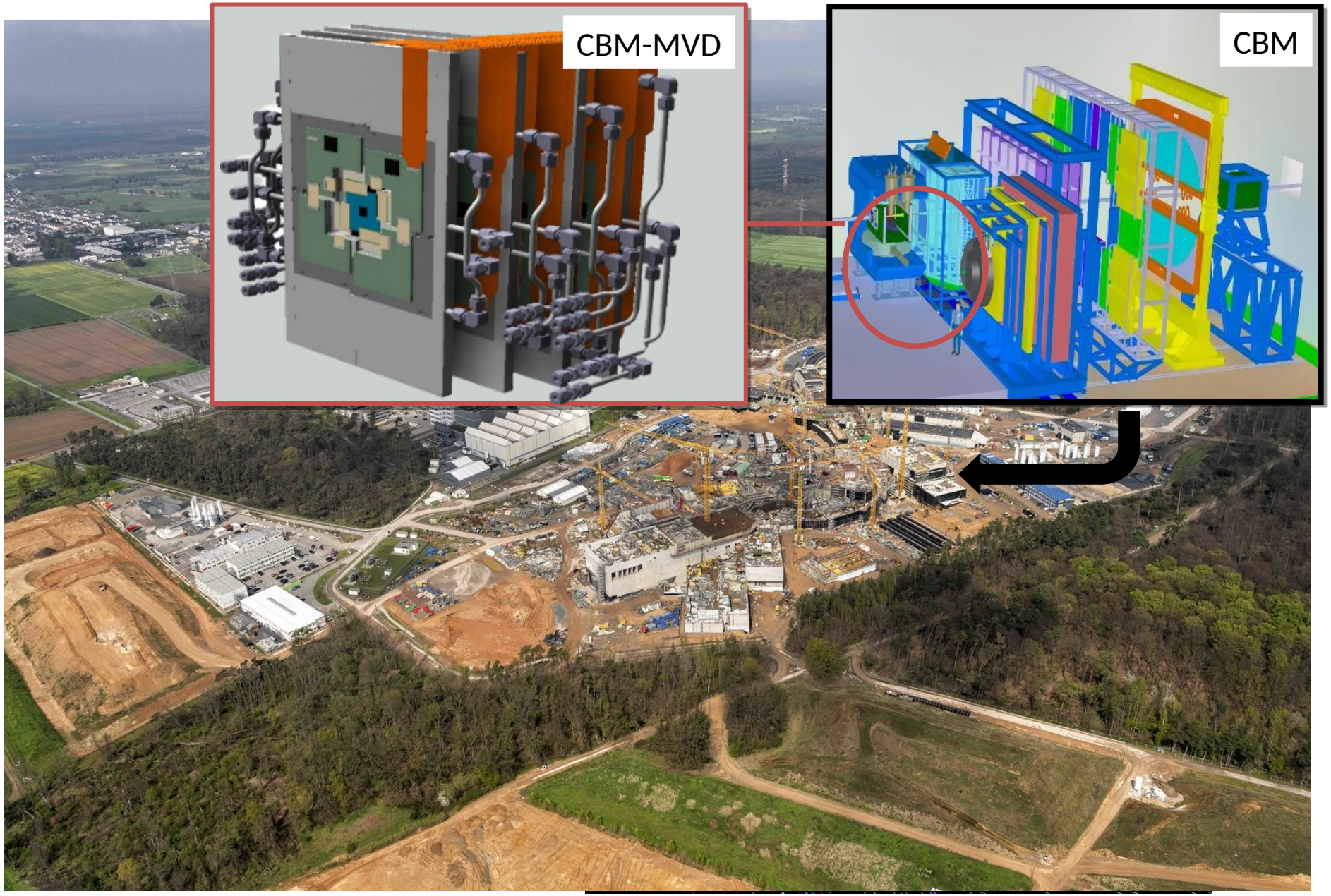
Where will MIMOSIS be used?

Darmstadt, Germany

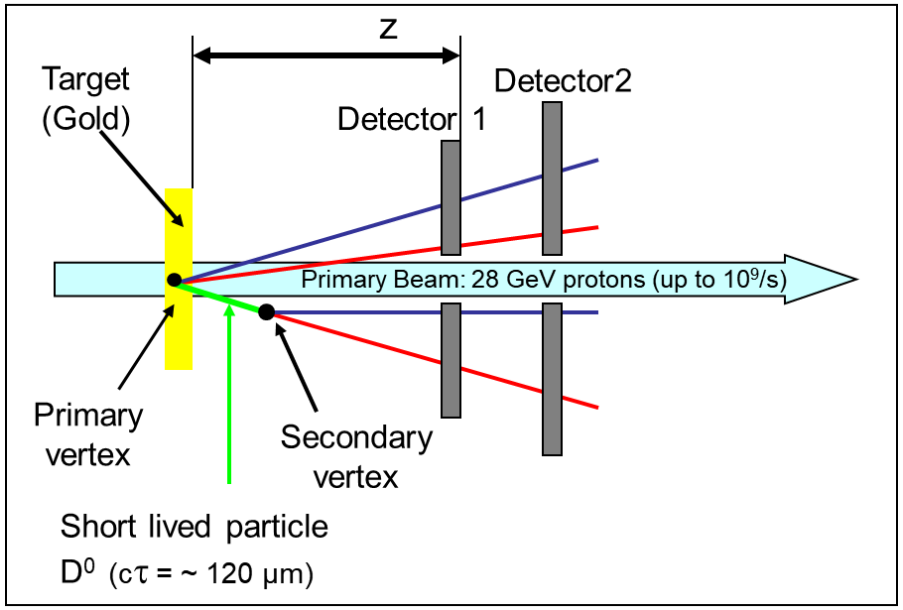


Where will MIMOSIS be used?

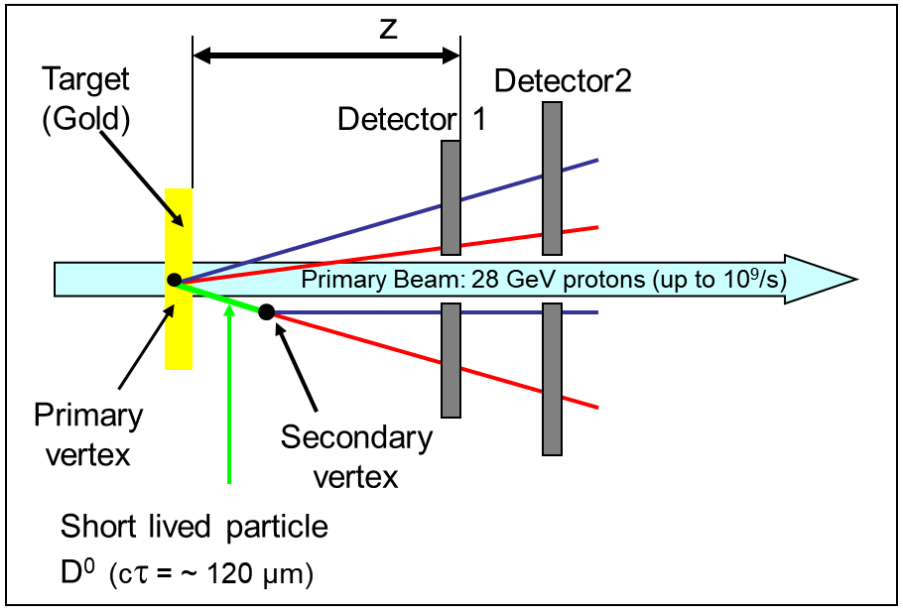
Darmstadt, Germany



Reconstructing short-lived particles at heavy ion experiments



Reconstructing short-lived particles at heavy ion experiments



Compute mother particle properties by:

- Adding energy + momentum of daughters (invariant mass).

Challenge:

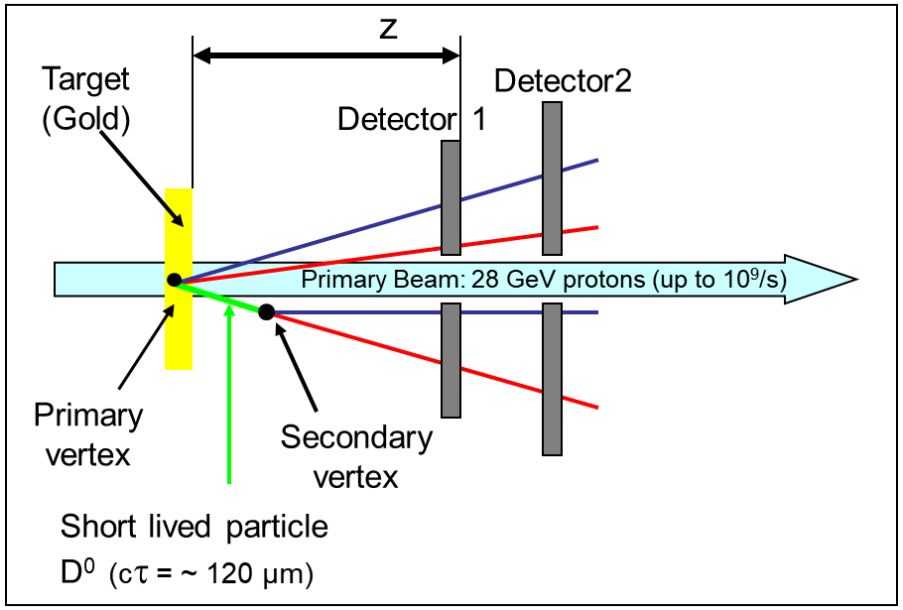
- Select good daughter particles by separating primary and secondary vertex.

⇒ Need 5µm spatial resolution,

⇒ Need 300 - 500 µm Si equivalent material per station (0.3% X_0).

… like ALICE ITS-2…

Reconstructing short-lived particles at heavy ion experiments



Compute mother particle properties by:

- Adding energy + momentum of daughters (invariant mass).

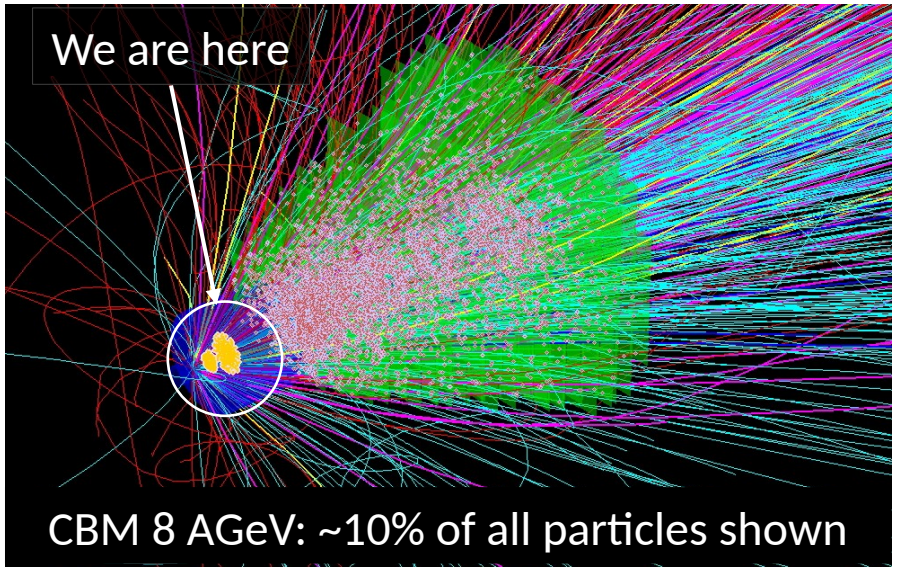
Challenge:

- Select good daughter particles by separating primary and secondary vertex.

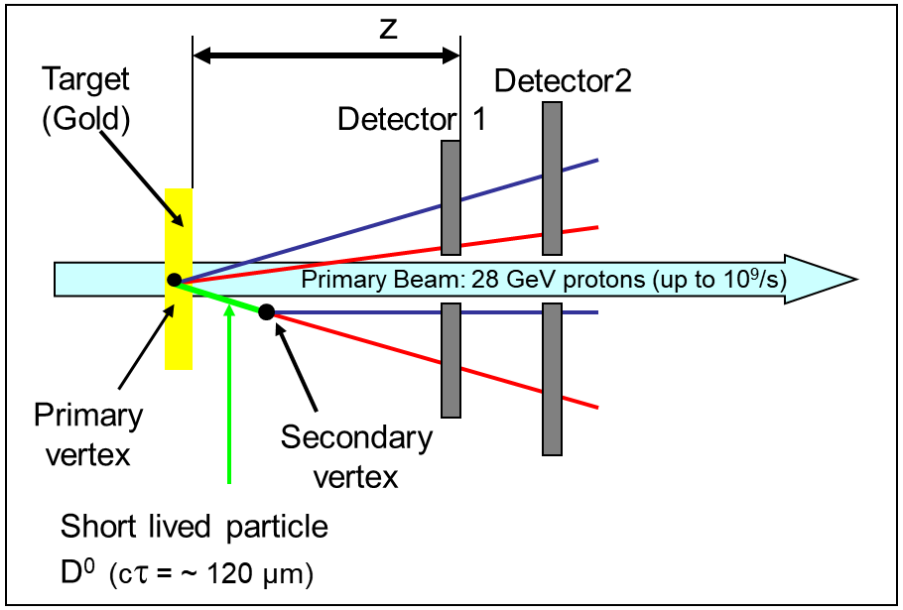
⇒ Need 5µm spatial resolution,

⇒ Need 300 - 500 µm Si equivalent material per station (0.3% X_0).

… like ALICE ITS-2…



Reconstructing short-lived particles at heavy ion experiments



Compute mother particle properties by:

- Adding energy + momentum of daughters (invariant mass).

Challenge:

- Select good daughter particles by separating primary and secondary vertex.

⇒ Need 5µm spatial resolution,

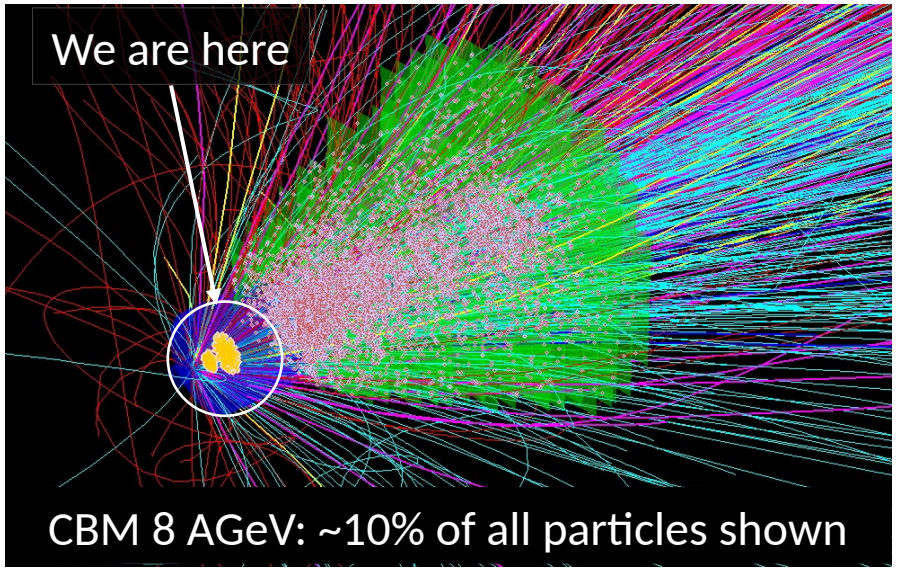
⇒ Need 300 - 500 µm Si equivalent material per station (0.3% X_0).

… like ALICE ITS-2…

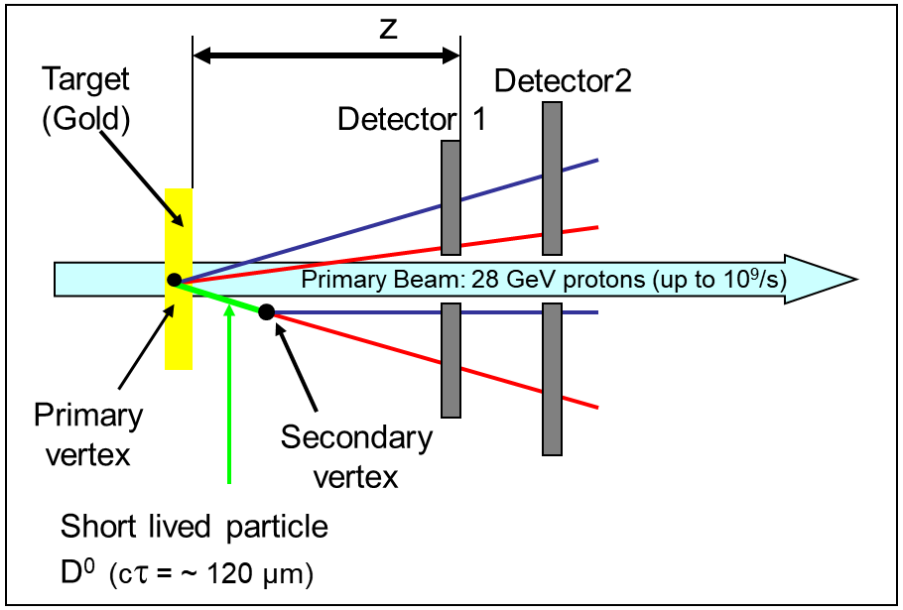
Sensor design goal (as required for CBM@FAIR):

- 5µs time resolution.
- 20 MHz/cm² (peak 80 MHz/cm²).
- ~10^{14} n_{eq}/cm² radiation tolerance.
- Tolerance to heavy ion hits (nuclear fragments).

(More compelete list of requirements in a few slides)



Reconstructing short-lived particles at heavy ion experiments



Compute mother particle properties by:

- Adding energy + momentum of daughters (invariant mass).

Challenge:

- Select good daughter particles by separating primary and secondary vertex.

⇒ Need 5µm spatial resolution,

⇒ Need 300 - 500 µm Si equivalent material per station (0.3% X_0).

… like ALICE ITS-2…

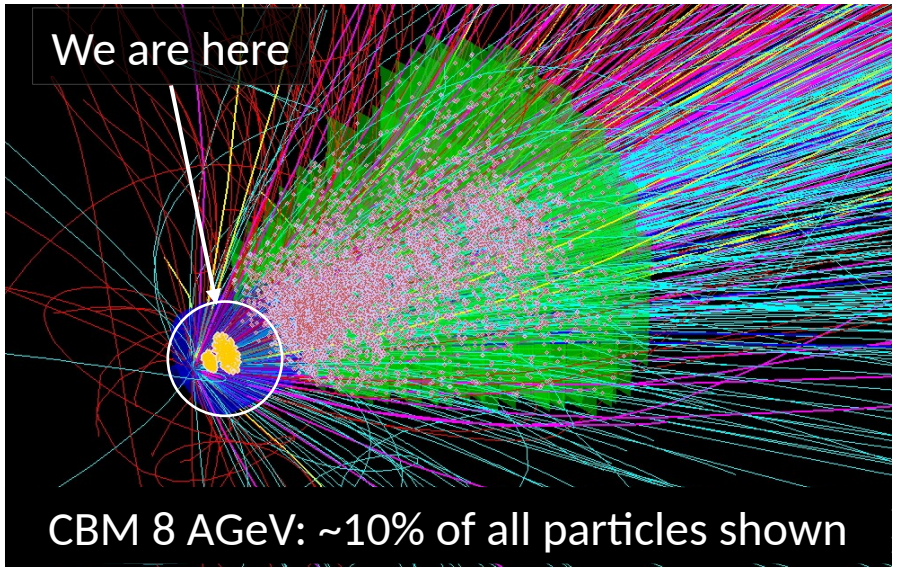
Sensor design goal (as required for CBM@FAIR):

- 5µs time resolution.
- 20 MHz/cm² (peak 80 MHz/cm²).
- ~10^{14} n_{eq}/cm² radiation tolerance.

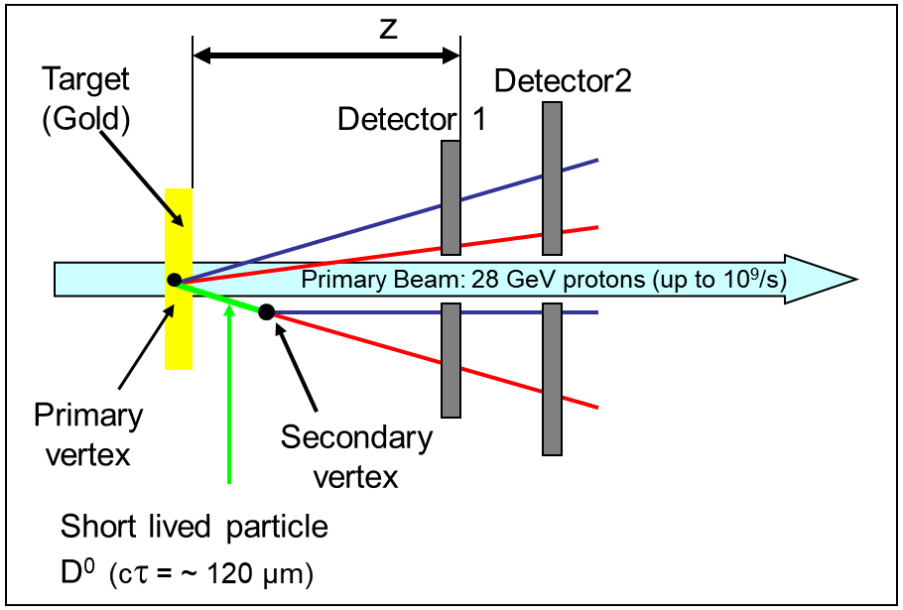
} ~10 x ALPIDE

- Tolerance to heavy ion hits (nuclear fragments).

(More compelete list of requirements in a few slides)



Reconstructing short-lived particles at heavy ion experiments



Compute mother particle properties by:

- Adding energy + momentum of daughters (invariant mass).

Challenge:

- Select good daughter particles by separating primary and secondary vertex.

⇒ Need 5µm spatial resolution,

⇒ Need 300 - 500 µm Si equivalent material per station (0.3% X_0).

… like ALICE ITS-2…

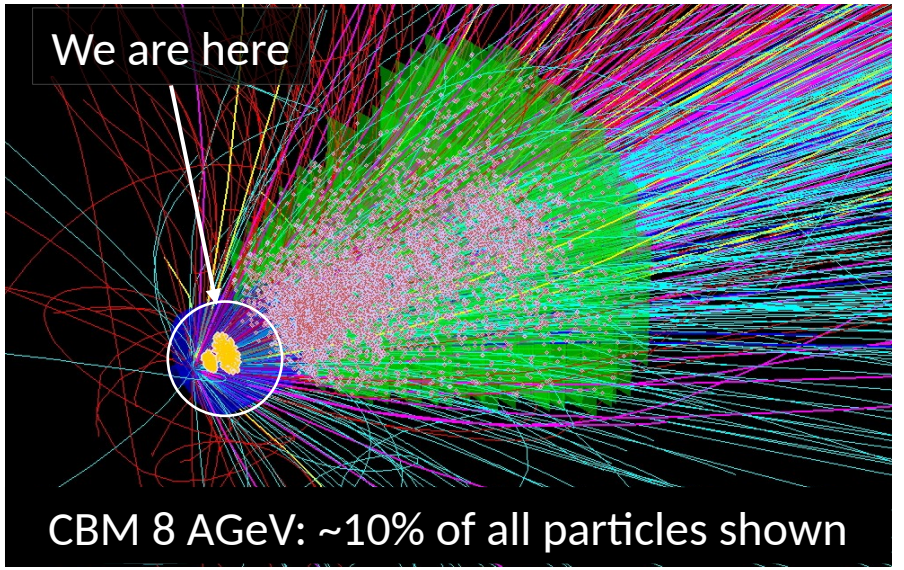
Sensor design goal (as required for CBM@FAIR):

- 5µs time resolution.
- 20 MHz/cm² (peak 80 MHz/cm²).
- ~10^{14} n_{eq}/cm² radiation tolerance.

} ~10 x ALPIDE

- Tolerance to heavy ion hits (nuclear fragments).

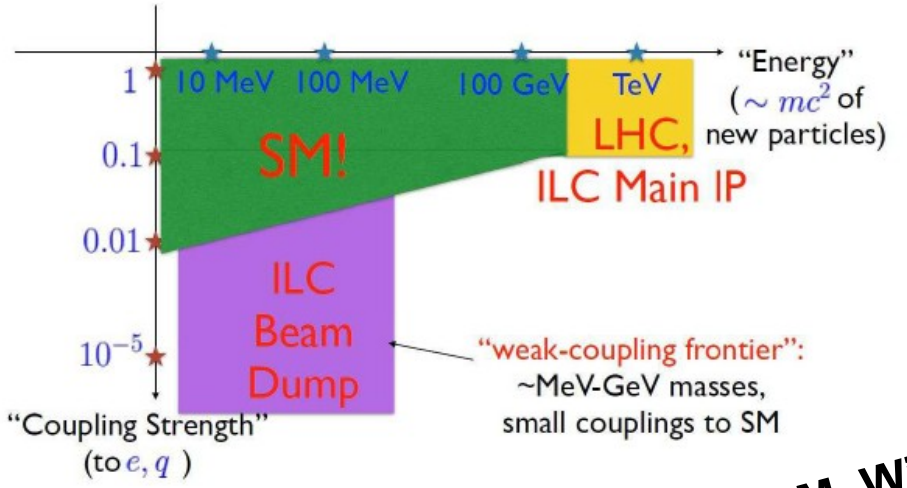
(More compelete list of requirements in a few slides)



Conclusion (2003, still true today):
Need specifically designed CMOS Monolithic Active Pixel Sensors.

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

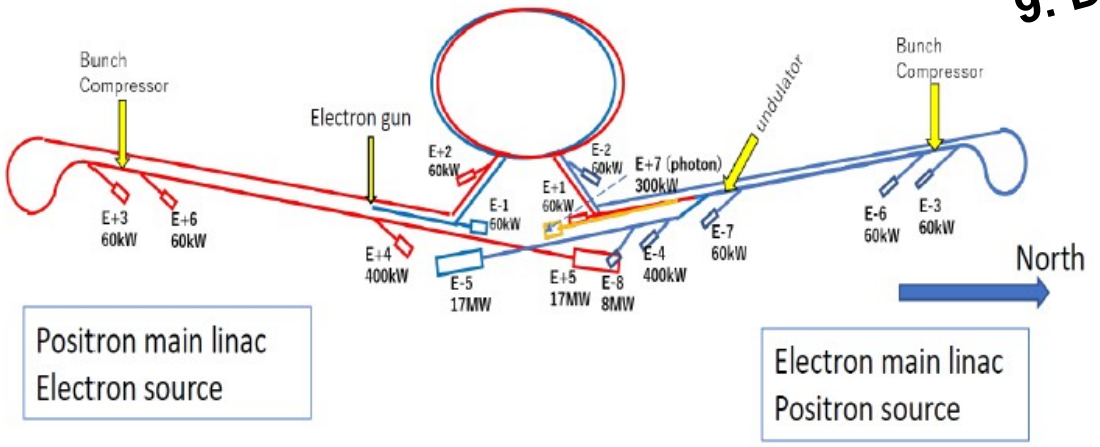
- **Search for DM candidates at an e^+e^- collider:**
  - multipurpose experiments installed around the IPs
  - beam dumps absorbing $e^{\pm}$, γ beam remnants



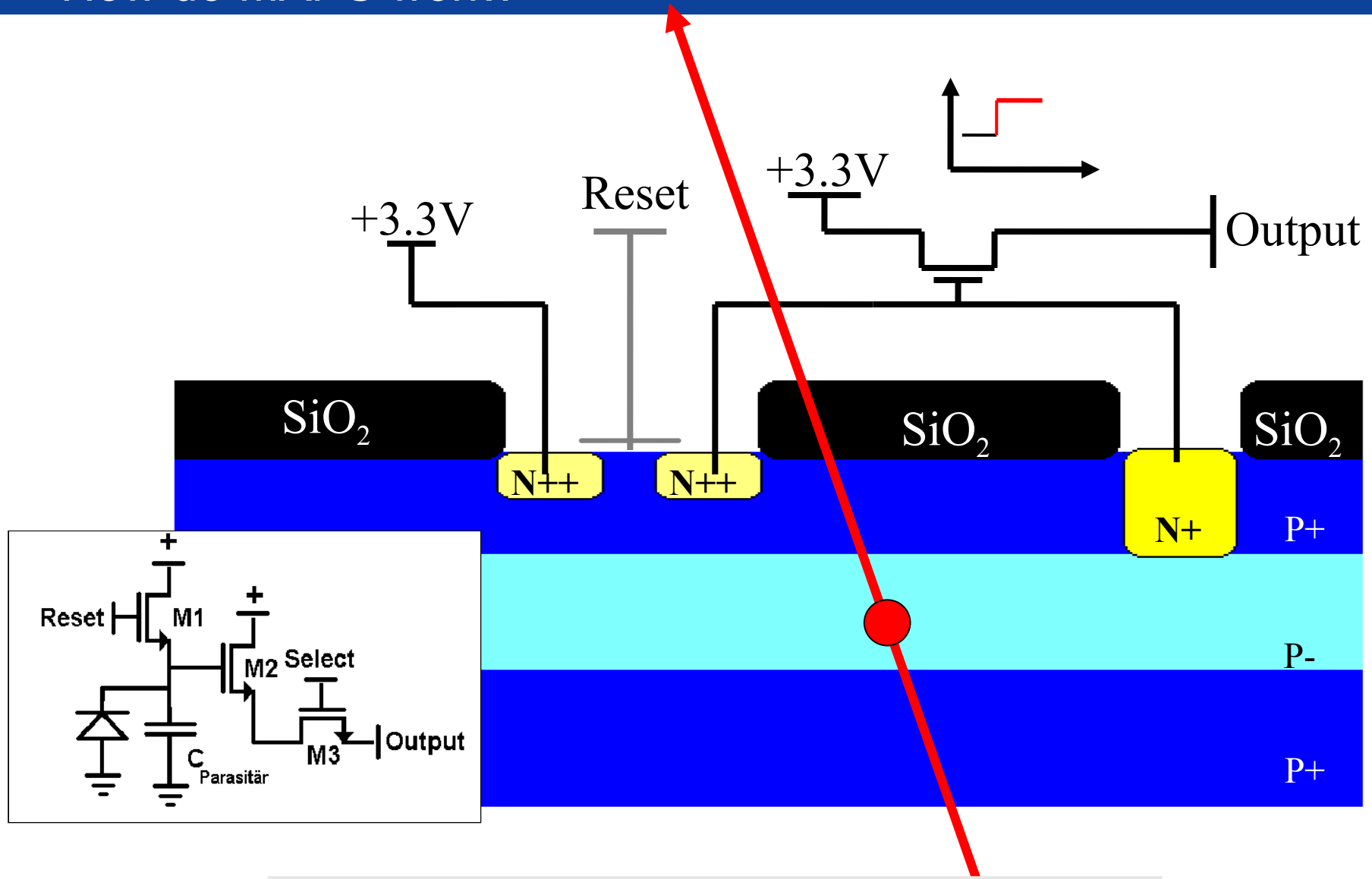
- **High performance tracking essential for the search of DM candidates:**
  - Reconstructing DM decay products:
    - * in crowded final states (e.g. H decay at IP)
    - * in boosted final states (e.g. beam dump)
  - Reconstructing precisely all tracks produced:
    - * imposes suppressed material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

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

M. Winter, DMLab Kick-off 9. Dec. 2021



How do MAPS work?

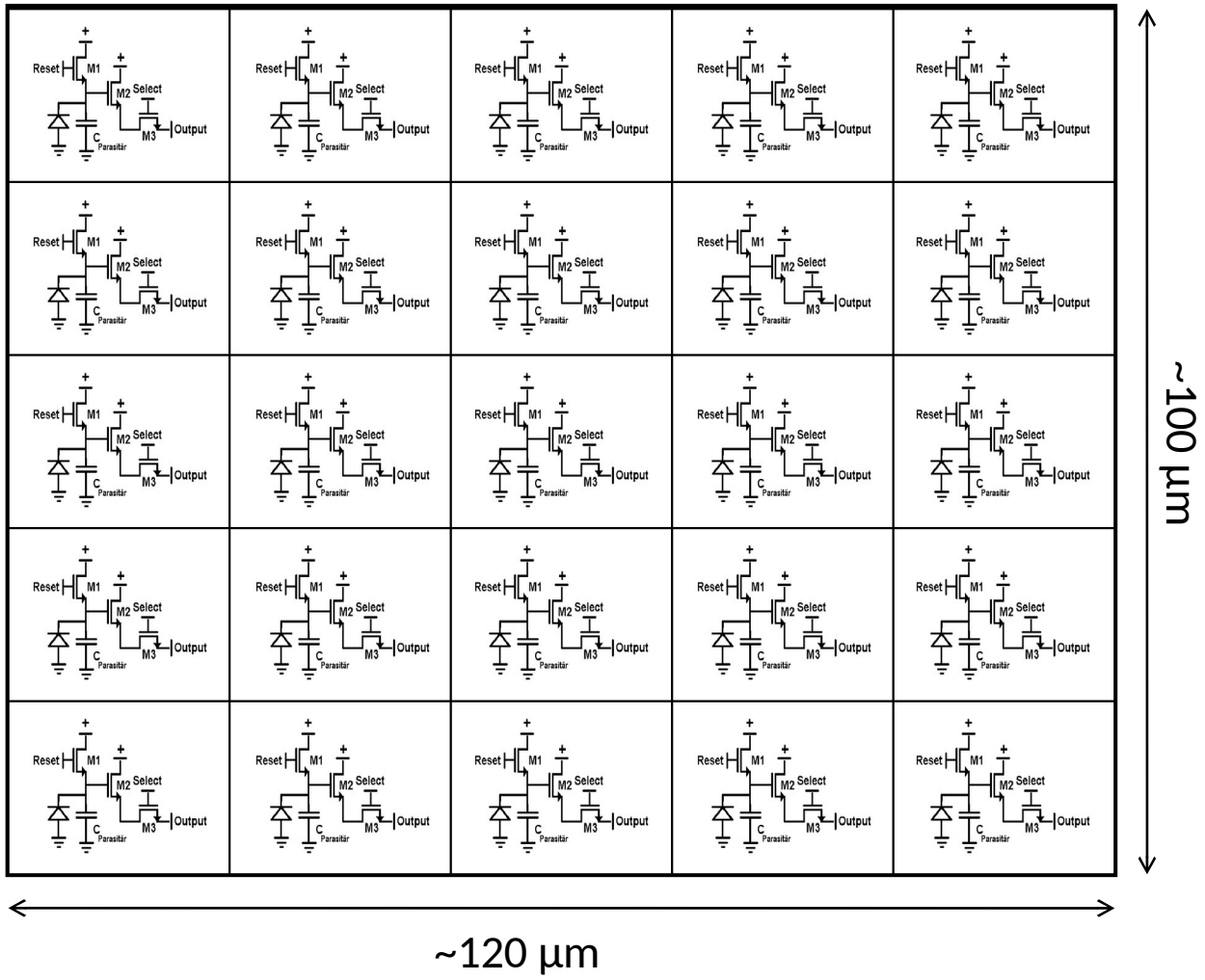


Digital camera: ~1000 photons produce one electron each.
Particle detector: One particle produces ~1000 electrons.

Other options than MAPS?

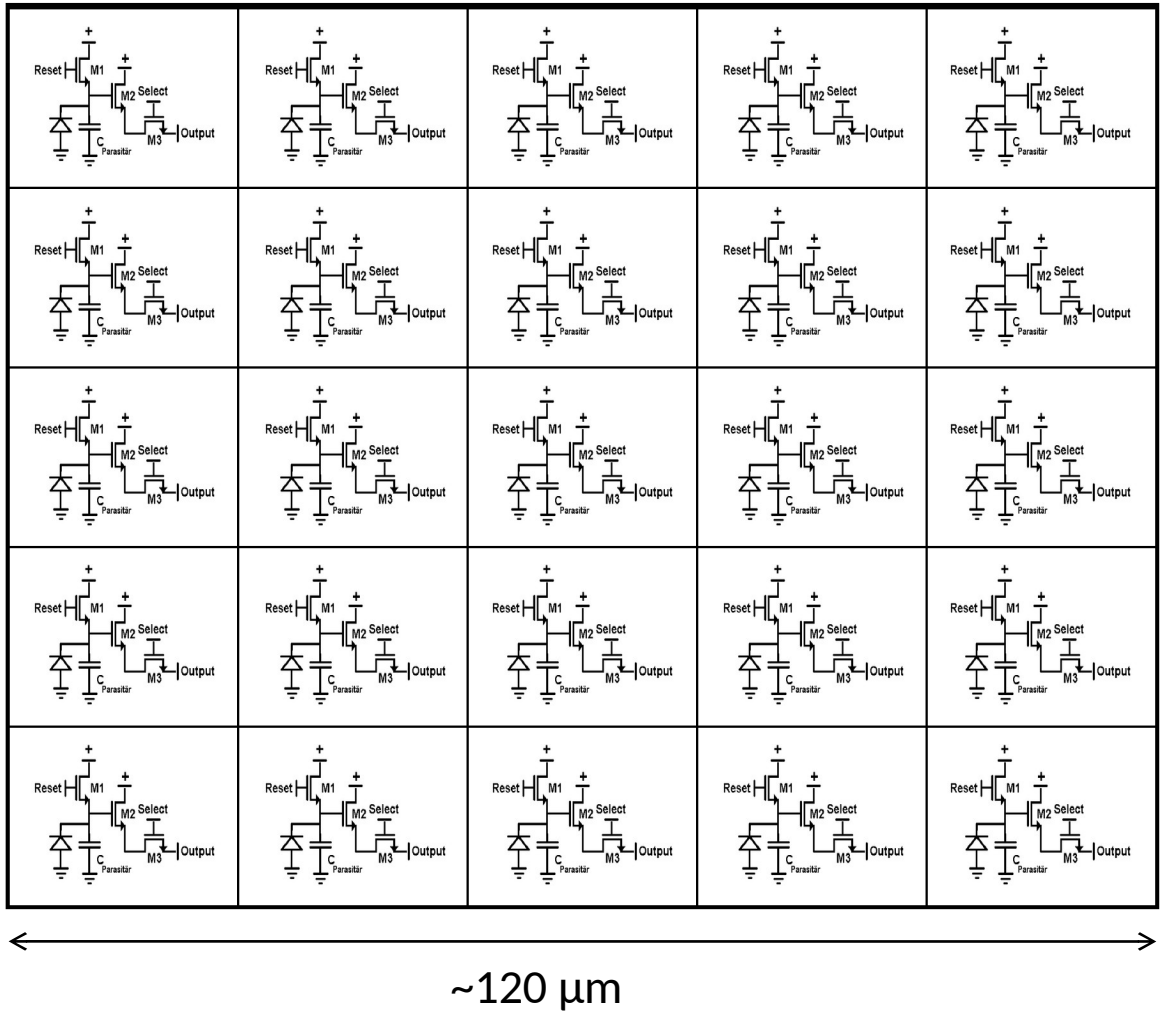
Other options than MAPS?

CMS @ LHC – Hybrid Pixel

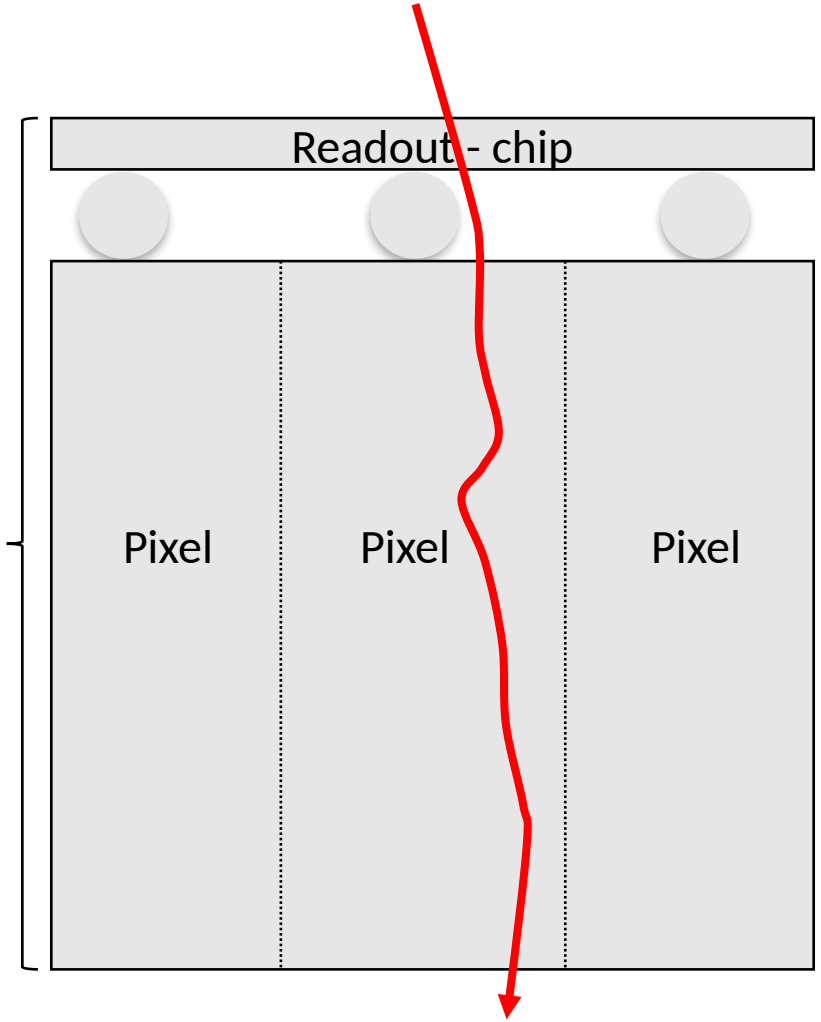


Other options than MAPS?

CMS @ LHC – Hybrid Pixel

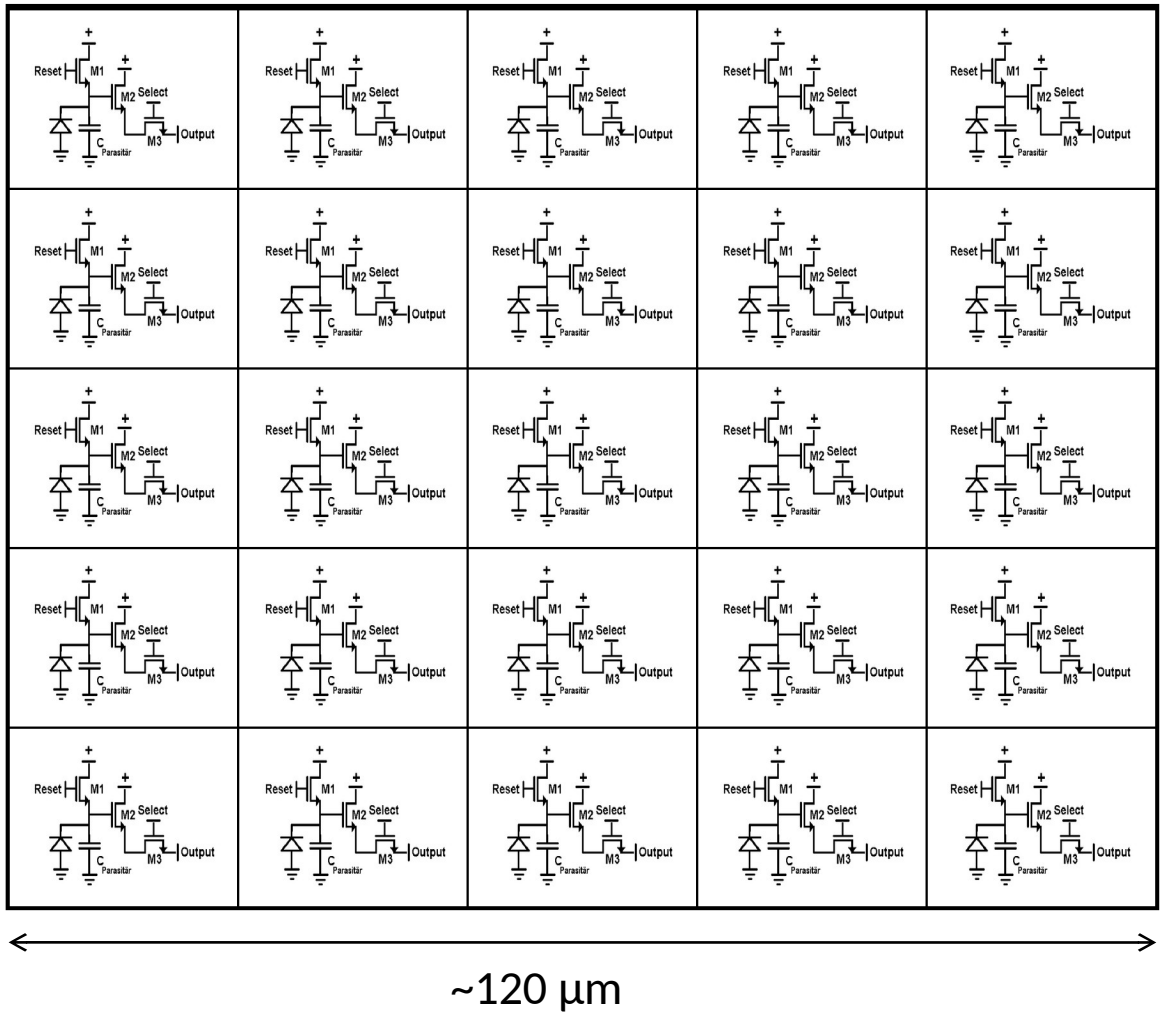


Hybrid:
0.5mm Si
equivalent



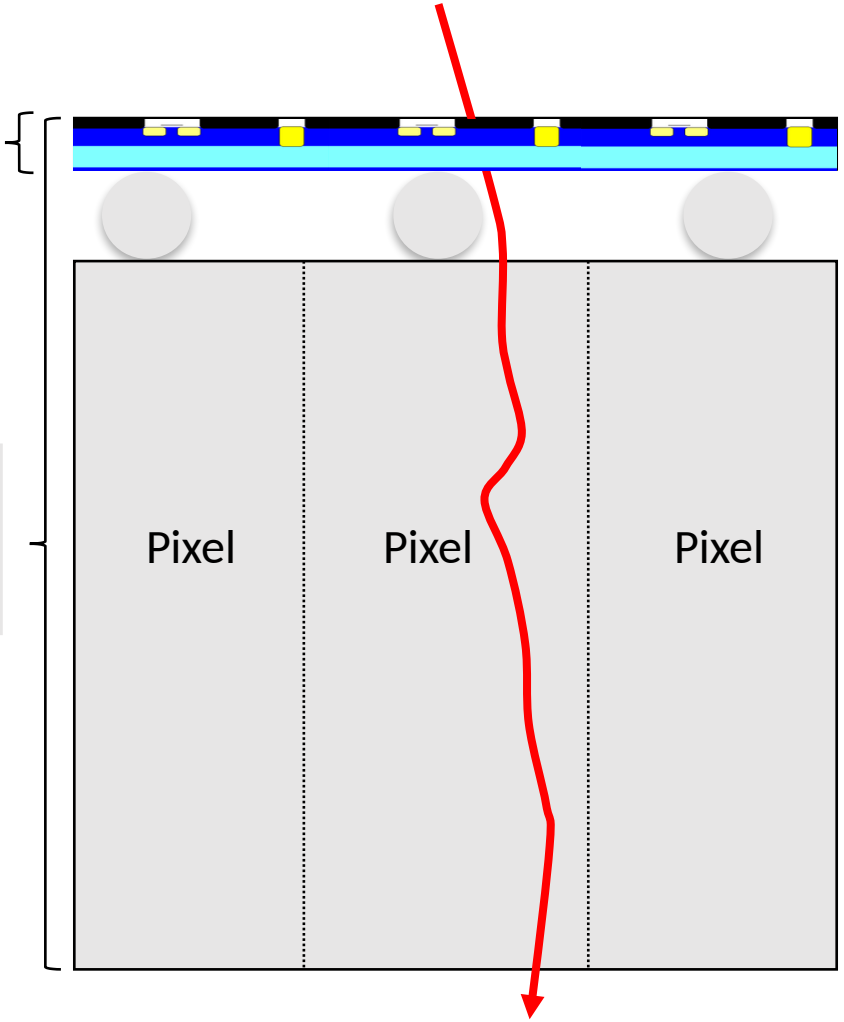
Other options than MAPS?

CMS @ LHC – Hybrid Pixel



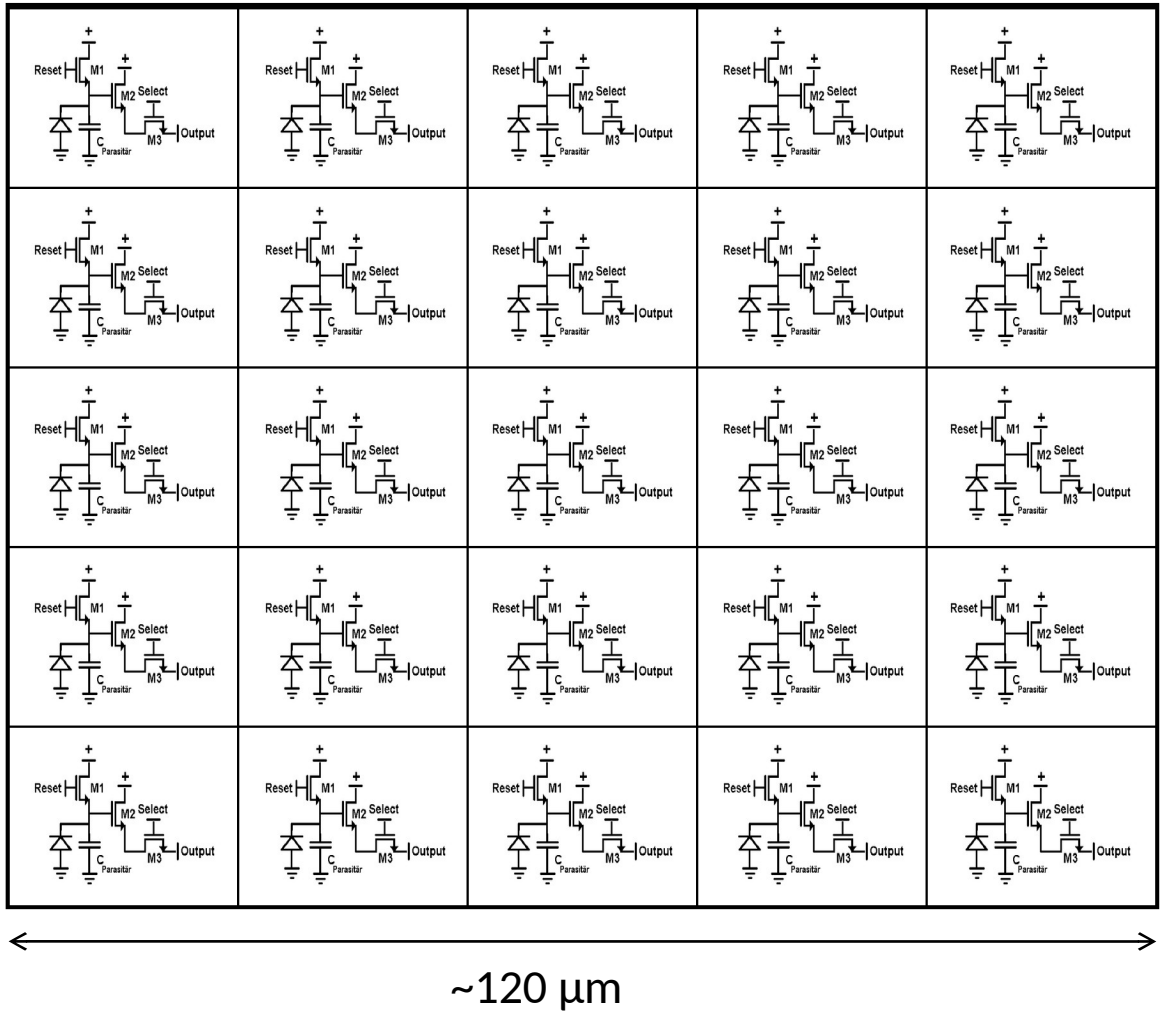
MAPS:
~0.05 µm
Si equivalent

Hybrid:
0.5mm Si
equivalent



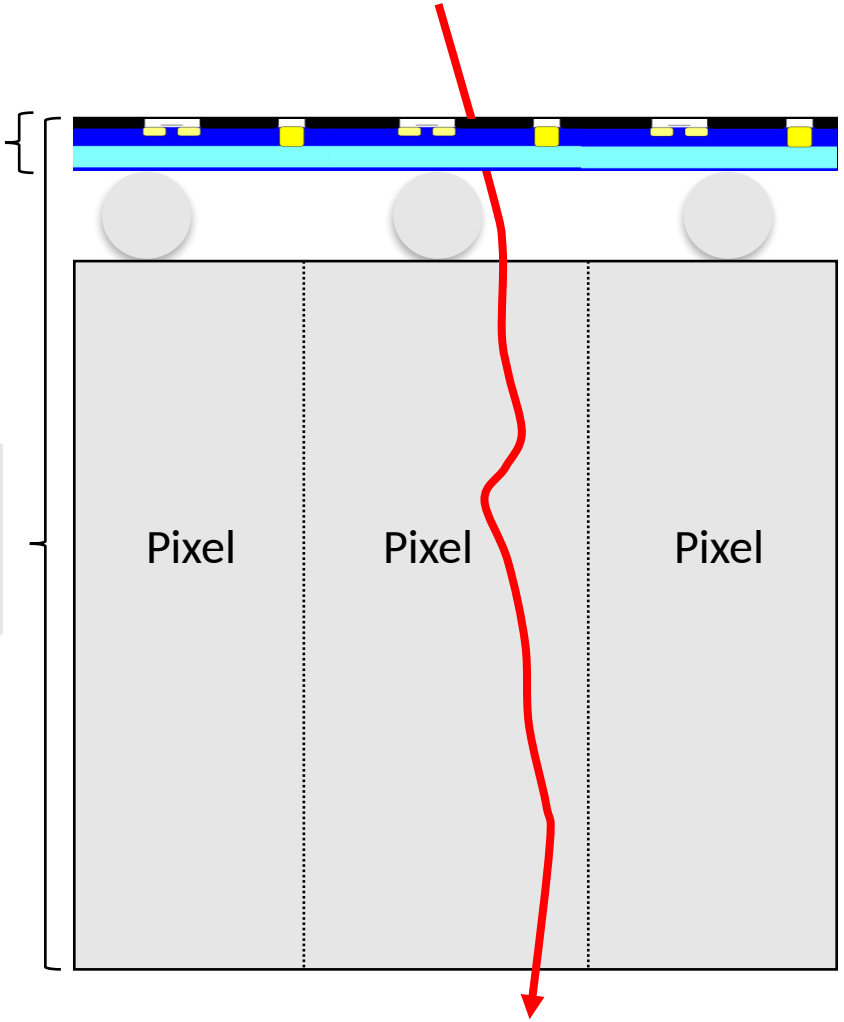
Other options than MAPS?

CMS @ LHC – Hybrid Pixel



MAPS:
~0.05 µm
Si equivalent

Hybrid:
0.5mm Si
equivalent



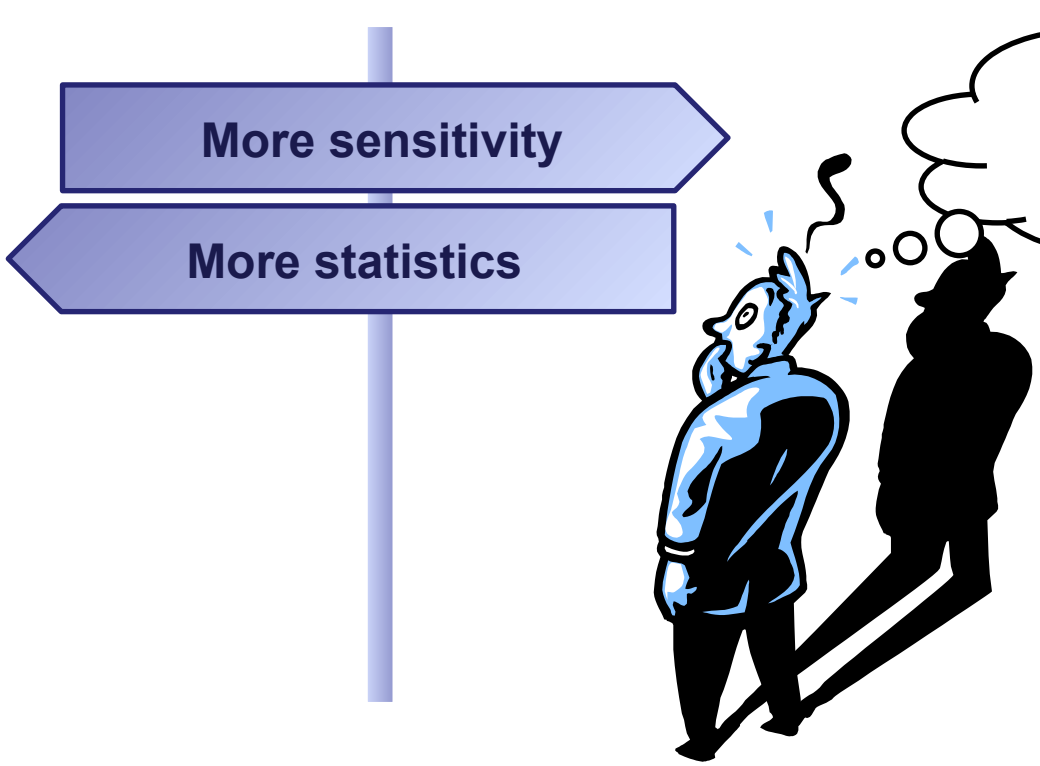
Multiple coulomb scattering:
Particle trajectory is manipulated by detector.
Angle scales with

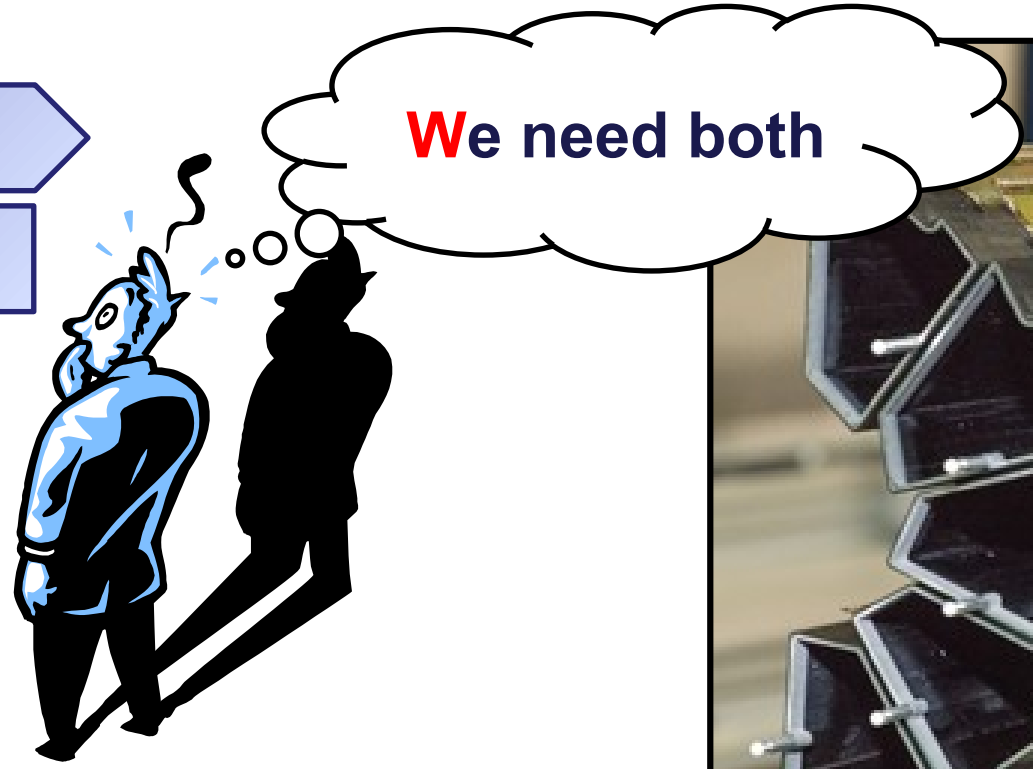
Other options than MAPS?

Other options than MAPS?

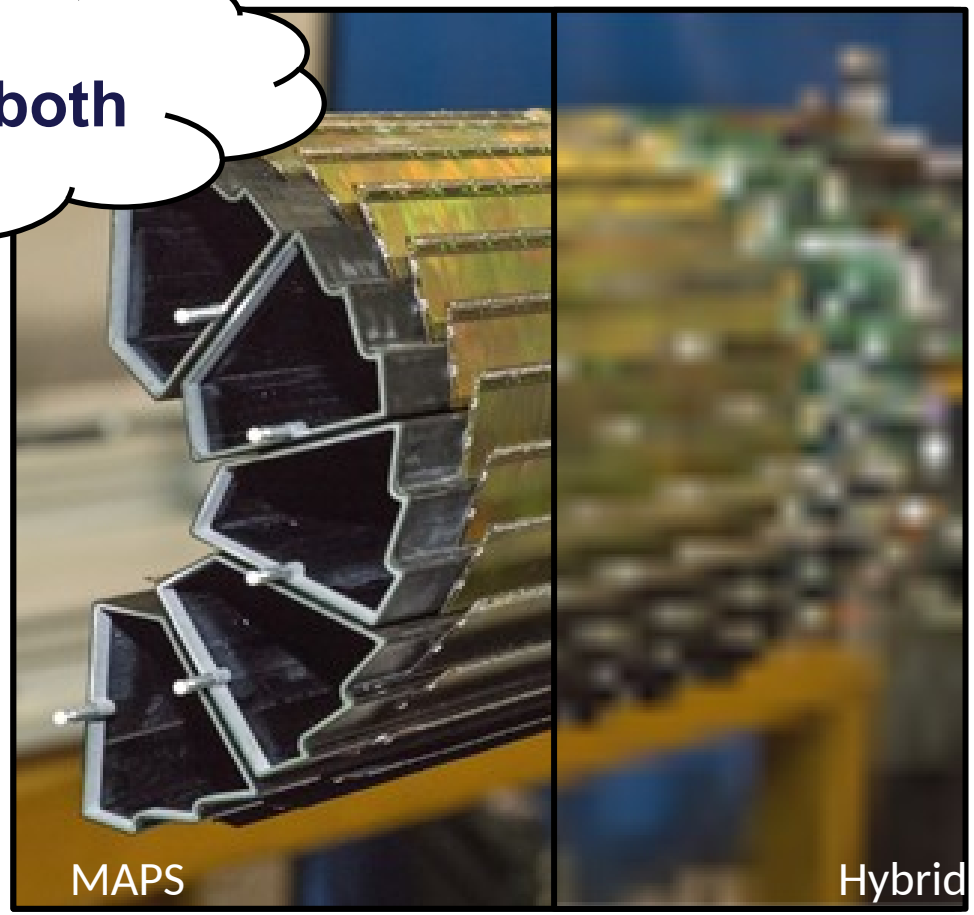
	Hybrid pixels (2001)	MAPS (2001)
Single point resolution	~ 30 µm	~2 µm
Material budget	~ 500 µm Si	~ 50 µm Si

Other options than MAPS?





	Hybrid pixels (2001)	MAPS (2001)
Single point resolution	~ 30 µm	~2 µm
Material budget	~ 500 µm Si	~ 50 µm Si



Requirements imposed on the technology in the MVD

Requirements imposed on the technology in the MVD

	Requirement
Time resolution	~5 µs
Spatial resolution	~5 µm
Sensor thickness	~50 µm
Power dissipation	200 mW/cm²
Radiation doses (non-ionizing)	> $7x10^{13}$ n_{eq}/cm²
Radiation doses (ionizing)	> 5 Mrad
Radiation gradient on chip	100%
HI-tolerance	10 Hz/mm²
Rate (average/peak)	150/700 kHz/mm²

Requirements imposed on the technology in the MVD

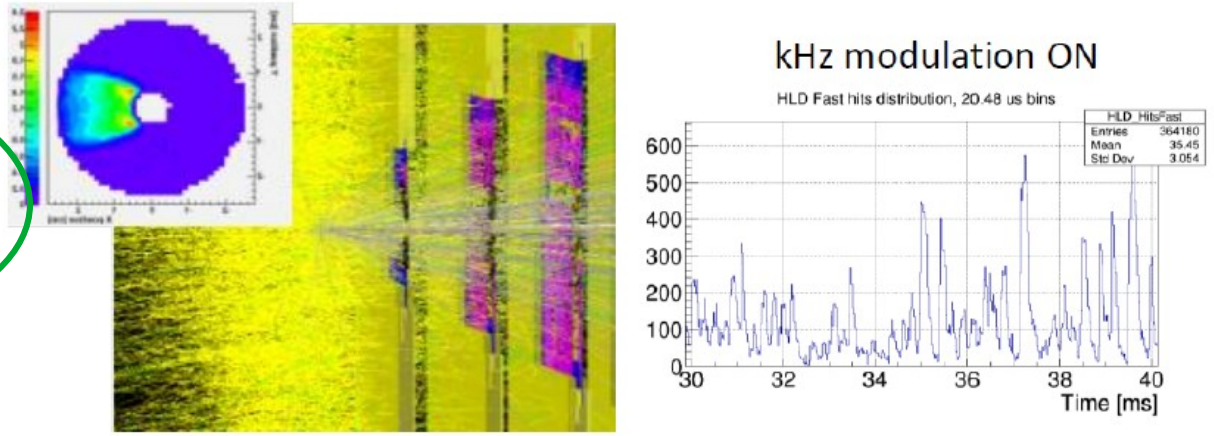
	Requirement
Time resolution	~5 µs
Spatial resolution	~5 µm
Sensor thickness	~50 µm
Power dissipation	200 mW/cm²
Radiation doses (non-ionizing)	> 7×10^{13} n_{eq}/cm^2
Radiation doses (ionizing)	> 5 Mrad
Radiation gradient on chip	100%
HI-tolerance	10 Hz/mm²
Rate (average/peak)	150/700 kHz/mm²

Mostly established by ALPIDE
(Sensor of ALICE ITS2 upgrade)

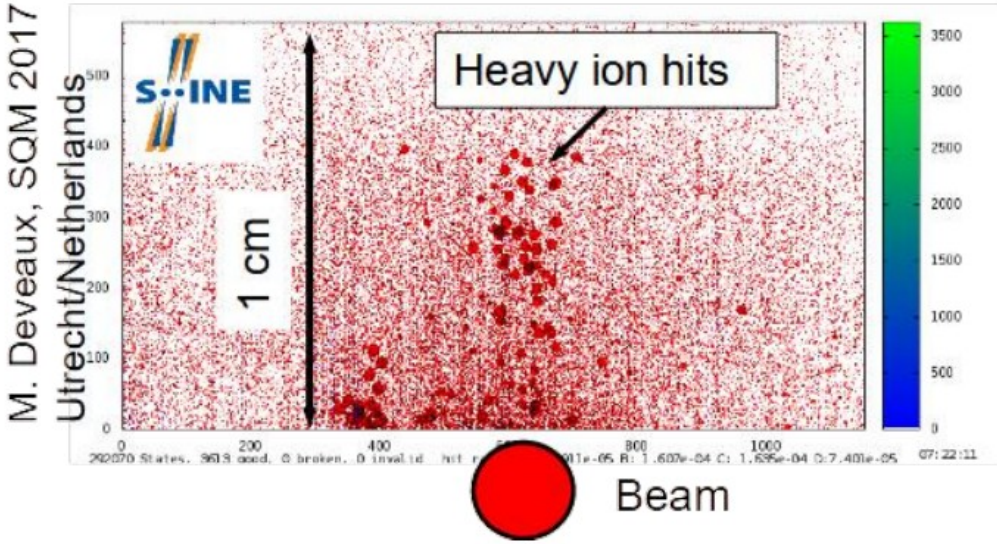
Requirements imposed on the technology in the MVD

	Requirement
Time resolution	~5 µs
Spatial resolution	~5 µm
Sensor thickness	~50 µm
Power dissipation	200 mW/cm²
Radiation doses (non-ionizing)	> 7x10^{13} n_{eq}/cm²
Radiation doses (ionizing)	> 5 Mrad
Radiation gradient on chip	100%
HI-tolerance	10 Hz/mm²
Rate (average/peak)	150/700 kHz/mm²

Mostly established by ALPIDE
(Sensor of ALICE ITS2 upgrade)



Delta electrons in 10 A GeV Au + Au collisions within 2.5 µs



Heavy ion impacts in NA61/SHINE Pixel detector

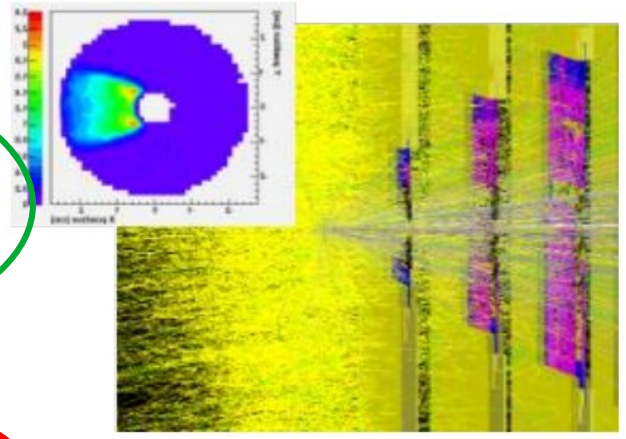
Requirements imposed on the technology in the MVD

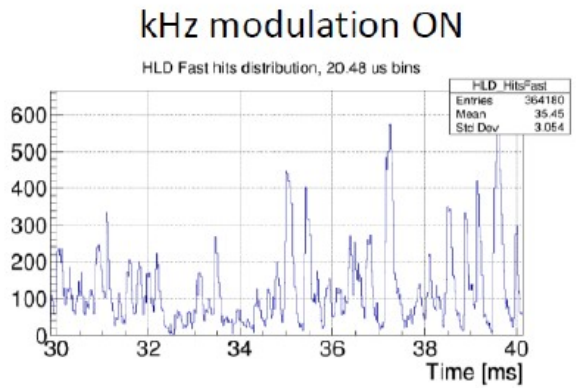
	Requirement
Time resolution	~5 µs
Spatial resolution	~5 µm
Sensor thickness	~50 µm
Power dissipation	200 mW/cm²
Radiation doses (non-ionizing)	> 7x10^{13} n_{eq}/cm²
Radiation doses (ionizing)	> 5 Mrad
Radiation gradient on chip	100%
HI-tolerance	10 Hz/mm²
Rate (average/peak)	150/700 kHz/mm²

Mostly established by ALPIDE
(Sensor of ALICE ITS2 upgrade)

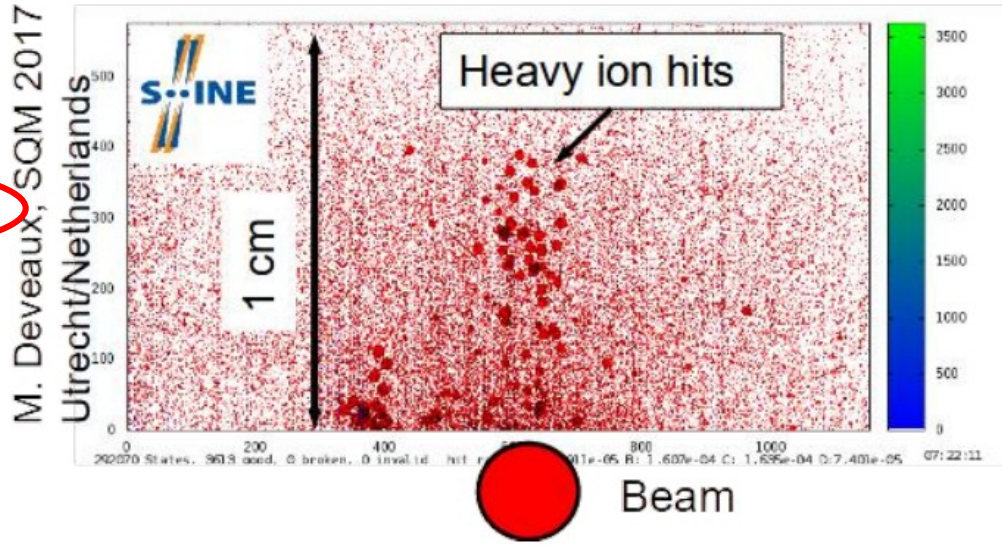
Incomp. With ALPIDE
20x internal bandwidth

Per lifetime. No safety factor
10x ALPIDE





Delta electrons in 10 A GeV Au + Au collisions within 2.5 µs



Heavy ion impacts in NA61/SHINE Pixel detector

The MIMOSIS research project

MIMOSIS-0 (2018)
- Demonstrate pixel concept. ✓
- Demonstrate zero suppression. ✓
- Demonstrate readout concept. ✓

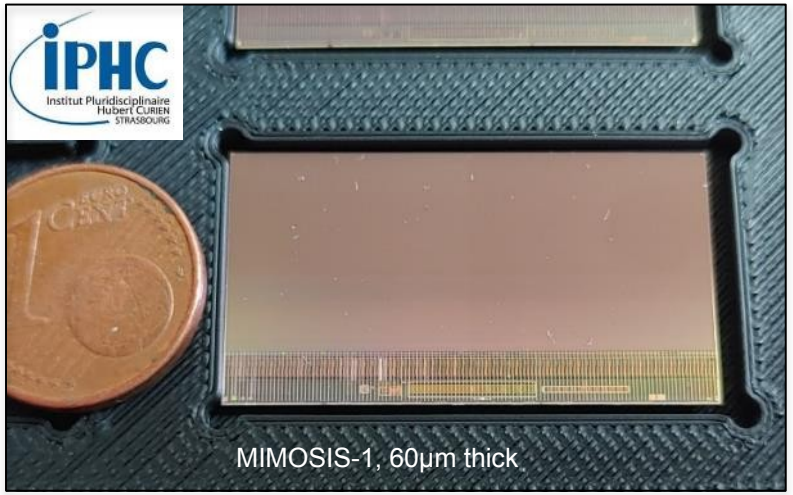
MIMOSIS-1 (2020)
- Full dimension sensor ✓
- Add buffer structure. ✓
- SEE hardening 1/2 ✓

MIMOSIS-2/-2.1 (Q2/2023)
- On-chip pixel grouping.
- Final pixels.
- SEE hardening 2/2

MIMOSIS-3
- Final sensor for mass production

All submissions:
Additional CE18 test structures to study specific design questions.

In synergy with:
eurizon
European network for developing new horizons for RIs



MIMOSIS-1

The MIMOSIS research project

MIMOSIS-0 (2018)
- Demonstrate pixel concept. ✓
- Demonstrate zero suppression. ✓
- Demonstrate readout concept. ✓

MIMOSIS-1 (2020)
- Full dimension sensor ✓
- Add buffer structure. ✓
- SEE hardening 1/2 ✓

Discussed at last meeting

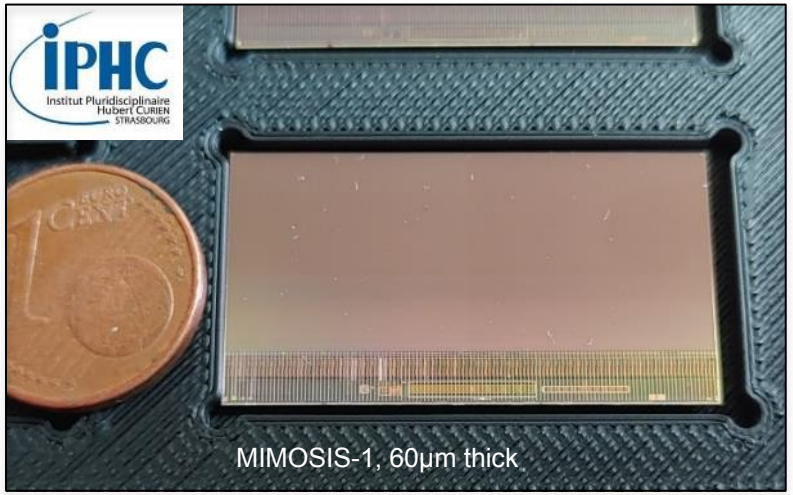
MIMOSIS-2/-2.1 (Q2/2023)
- On-chip pixel grouping.
- Final pixels.
- SEE hardening 2/2

Discussed today

MIMOSIS-3
- Final sensor for mass production

All submissions:
Additional CE18 test structures to study specific design questions.

In synergy with: eurizon
European network for developing new horizons for RIs



MIMOSIS-1

The MIMOSIS-1 sensor

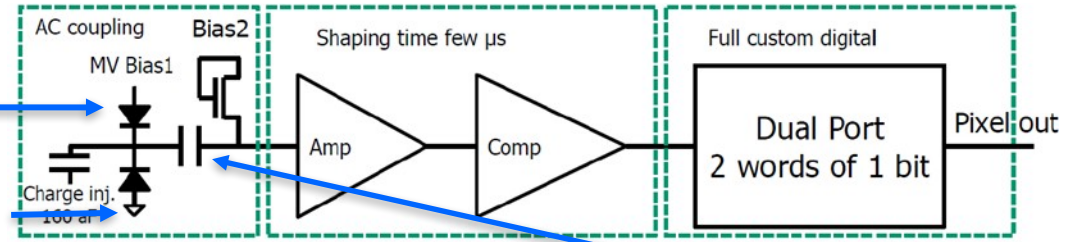
The MIMOSIS-1 sensor

Size: 504 x 1024 pixels (27x30µm²)
FEE integrated.
Pixels types: 2x DC, 2x AC (>20V depletion voltage)

AC-pixel

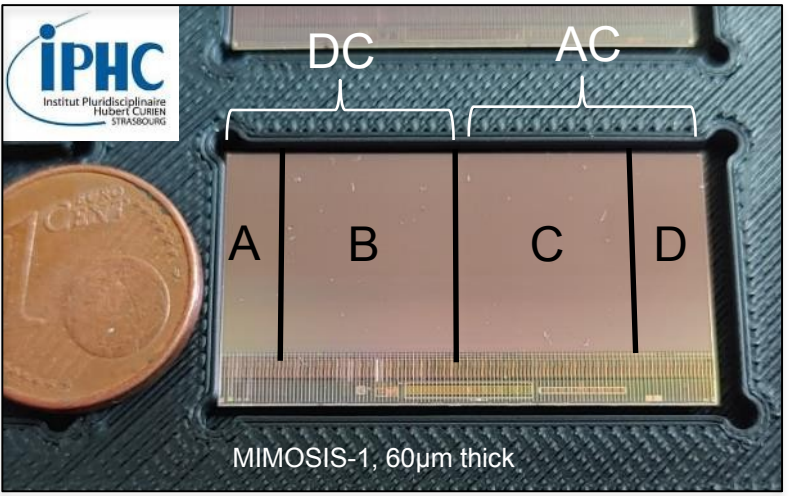
>20V HV top bias

Back bias possible.



Capacitor blocks HV

The MIMOSIS-1 sensor

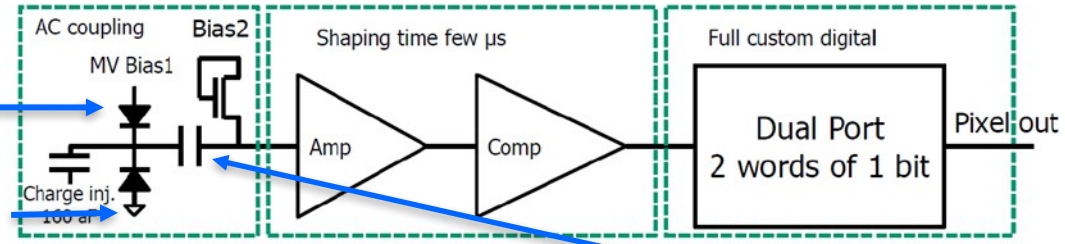


Size: 504 x 1024 pixels (27x30µm²)
FEE integrated.
Pixels types: 2x DC, 2x AC (>20V depletion voltage)

AC-pixel

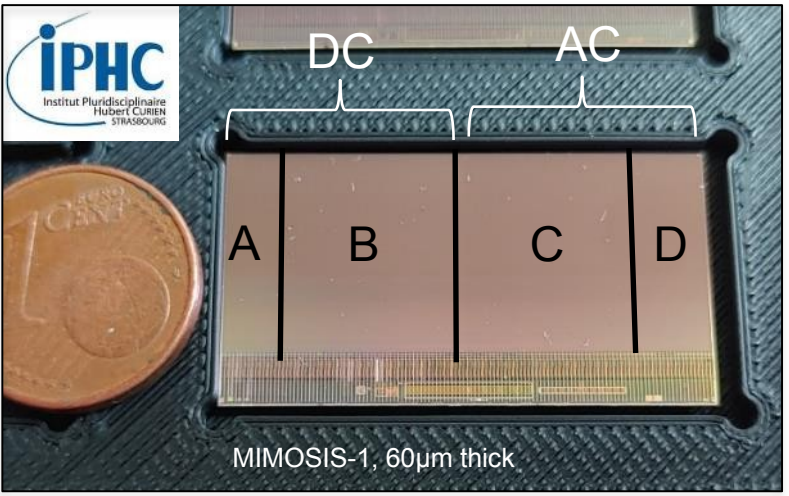
>20V HV top bias

Back bias possible.



Capacitor blocks HV

The MIMOSIS-1 sensor

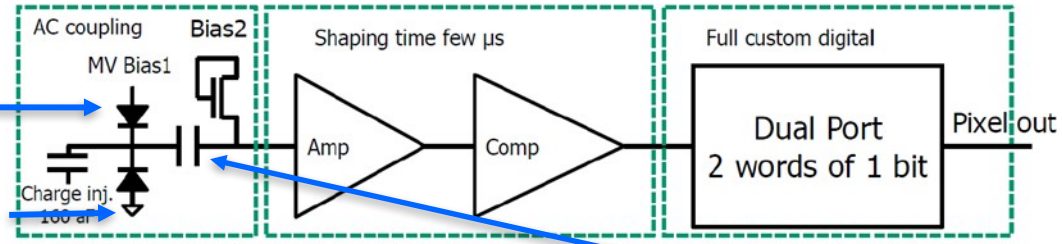


Size: 504 x 1024 pixels (27x30µm²)
FEE integrated.
Pixels types: 2x DC, 2x AC (>20V depletion voltage)

AC-pixel

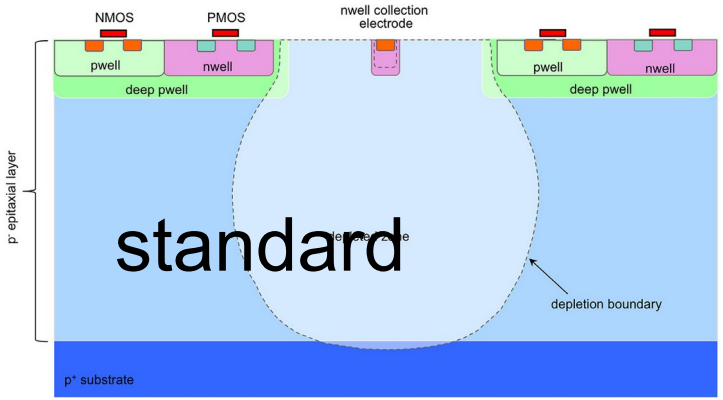
>20V HV top bias

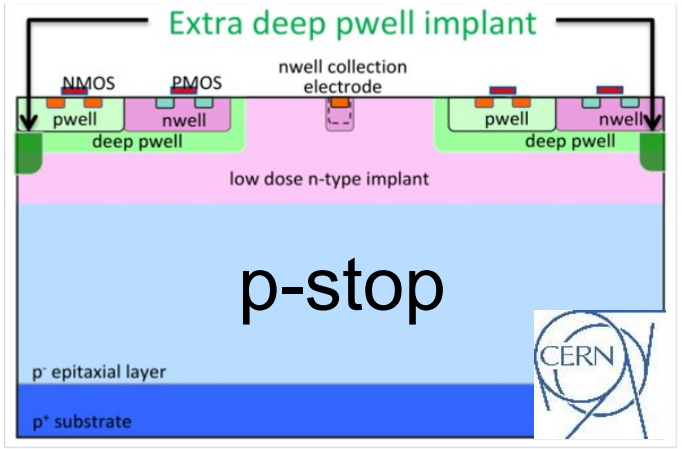
Back bias possible.



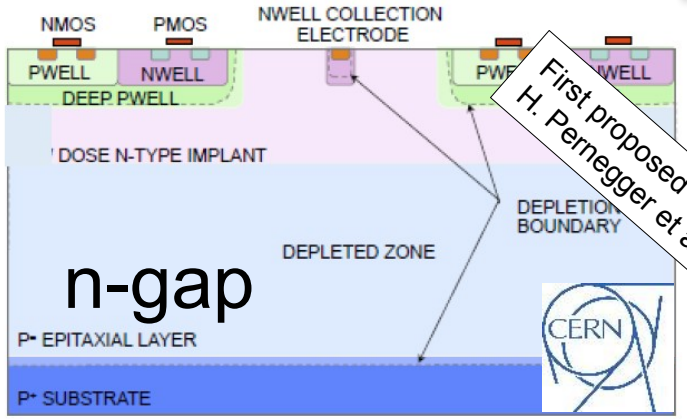
Capacitor blocks HV

Most likely Fully Depleted





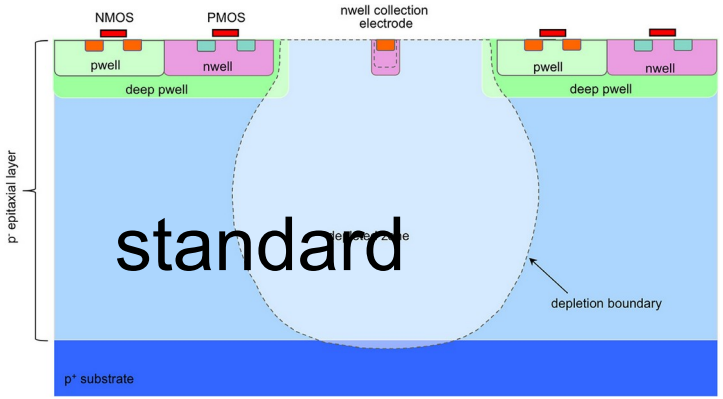
Rad. hard, candidate 1

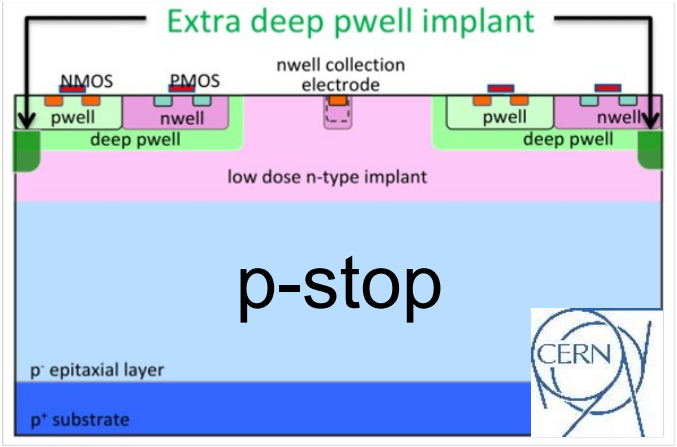


Rad. hard, candidate 2

First proposed by W. Snoeys et al.
H. Pernegger et al., 2017 JINST 12 P06008

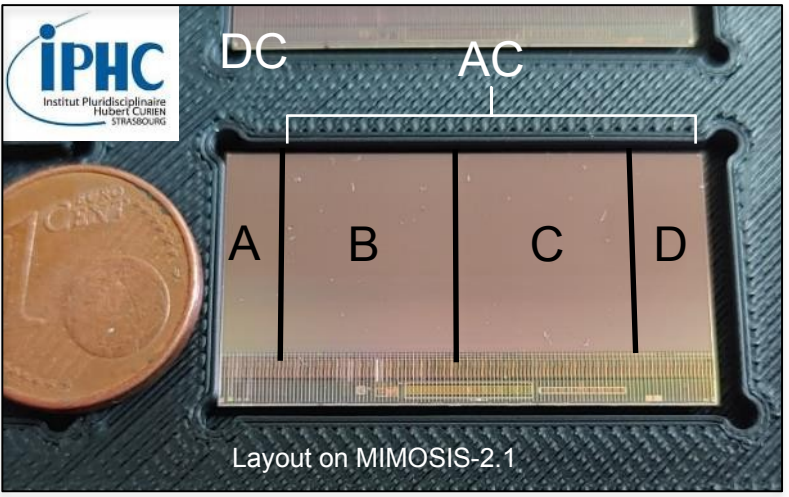
Changes to MIMOSIS-2.1



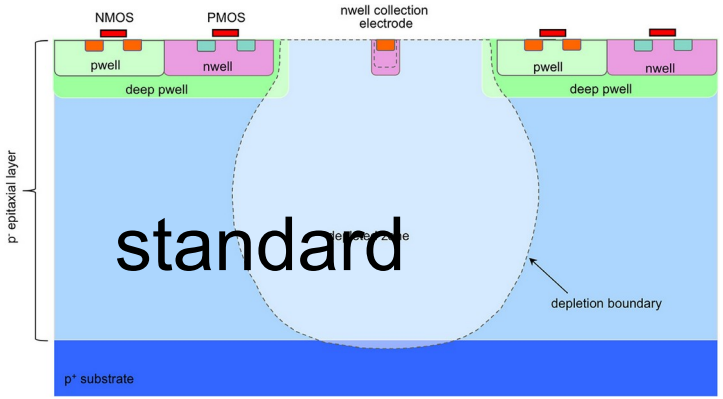


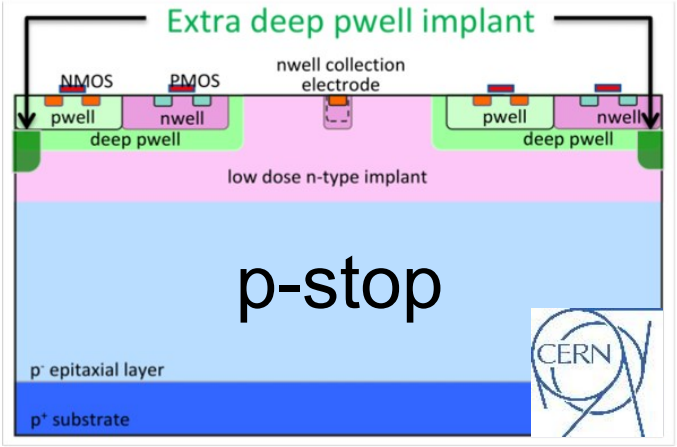
Rad. hard, candidate 1

Changes to MIMOSIS-2.1



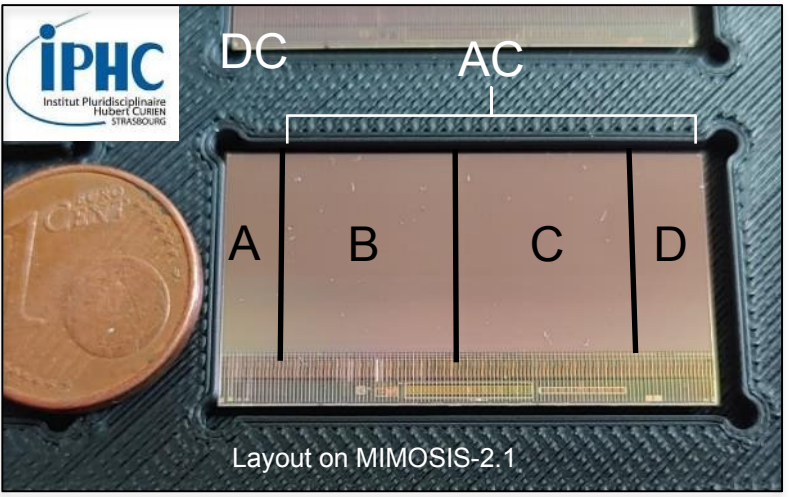
Size: 504 x 1024 pixels (27x30µm²)
Pixel clustering implemented.
Pixels types: 1x DC, 3x AC (>20V depletion voltage)



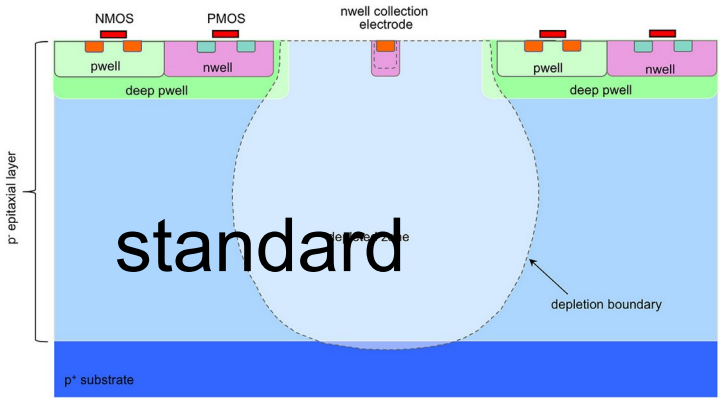


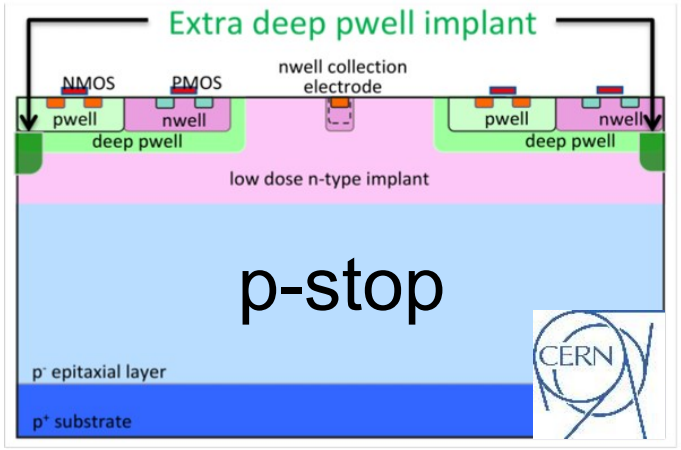
Rad. hard, candidate 1

Changes to MIMOSIS-2.1

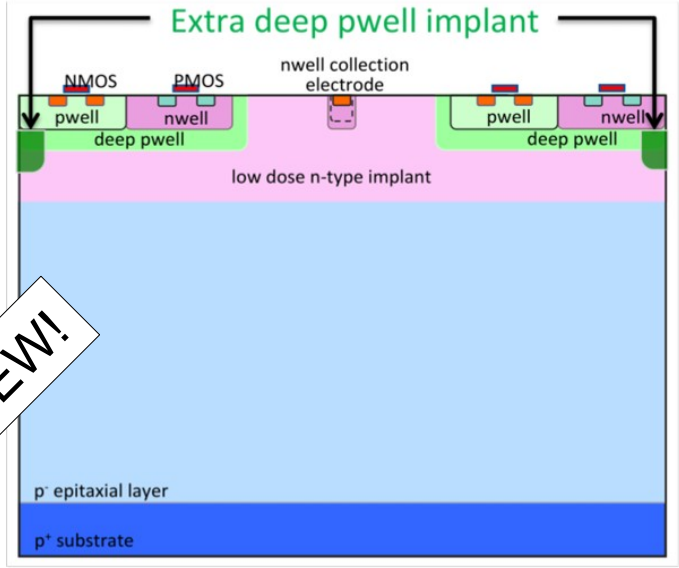


Size: 504 x 1024 pixels (27x30µm²)
Pixel clustering implemented.
Pixels types: 1x DC, 3x AC (>20V depletion voltage)



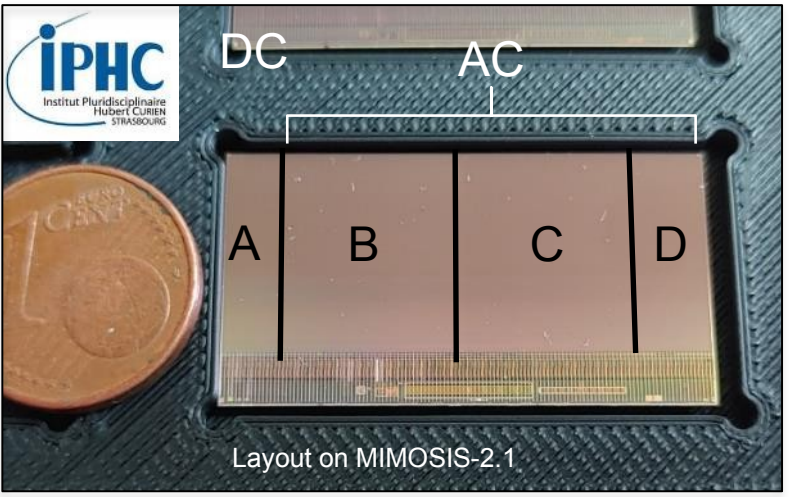


Rad. hard, candidate 1

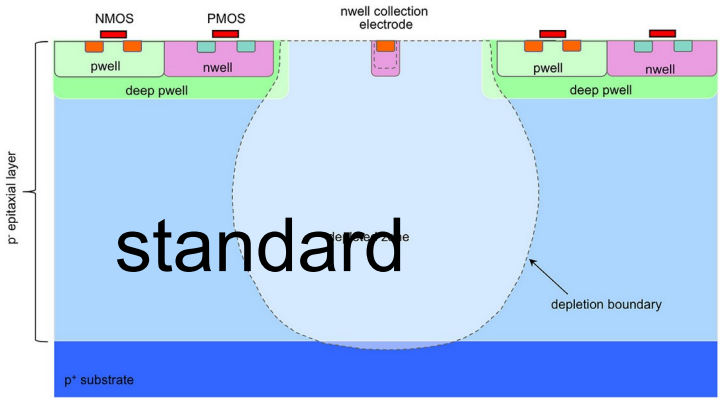


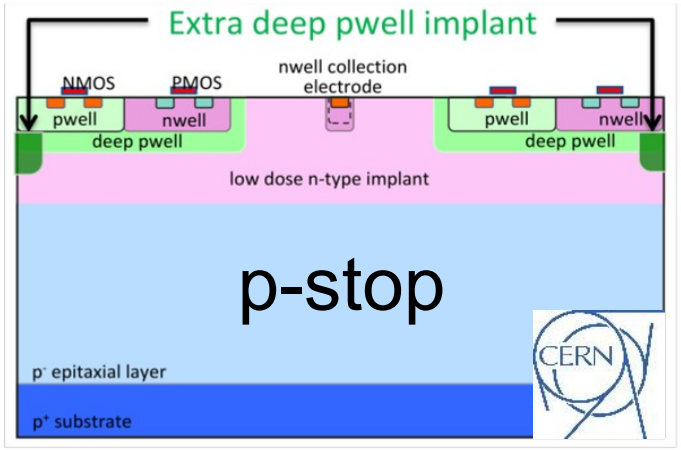
25 µm & 50 µm epi thicknesses

Changes to MIMOSIS-2.1

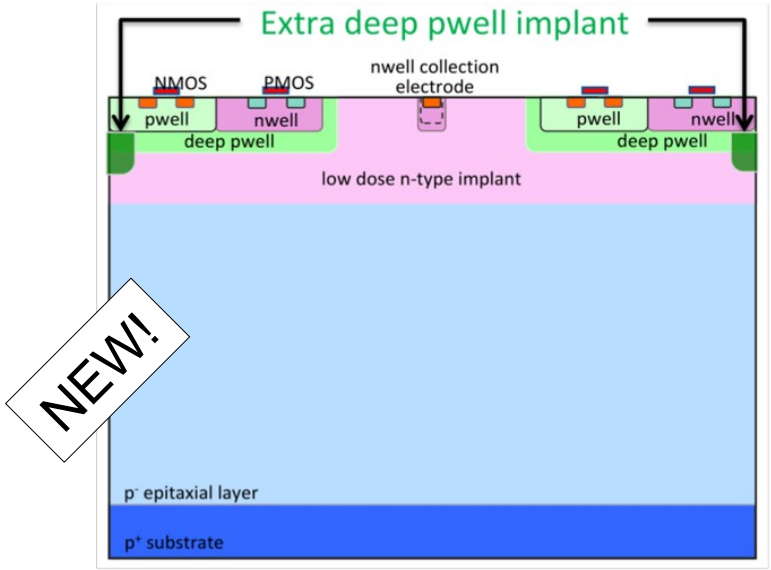


Size: 504 x 1024 pixels (27x30µm²)
Pixel clustering implemented.
Pixels types: 1x DC, 3x AC (>20V depletion voltage)





Rad. hard, candidate 1



25 µm & 50 µm epi thicknesses

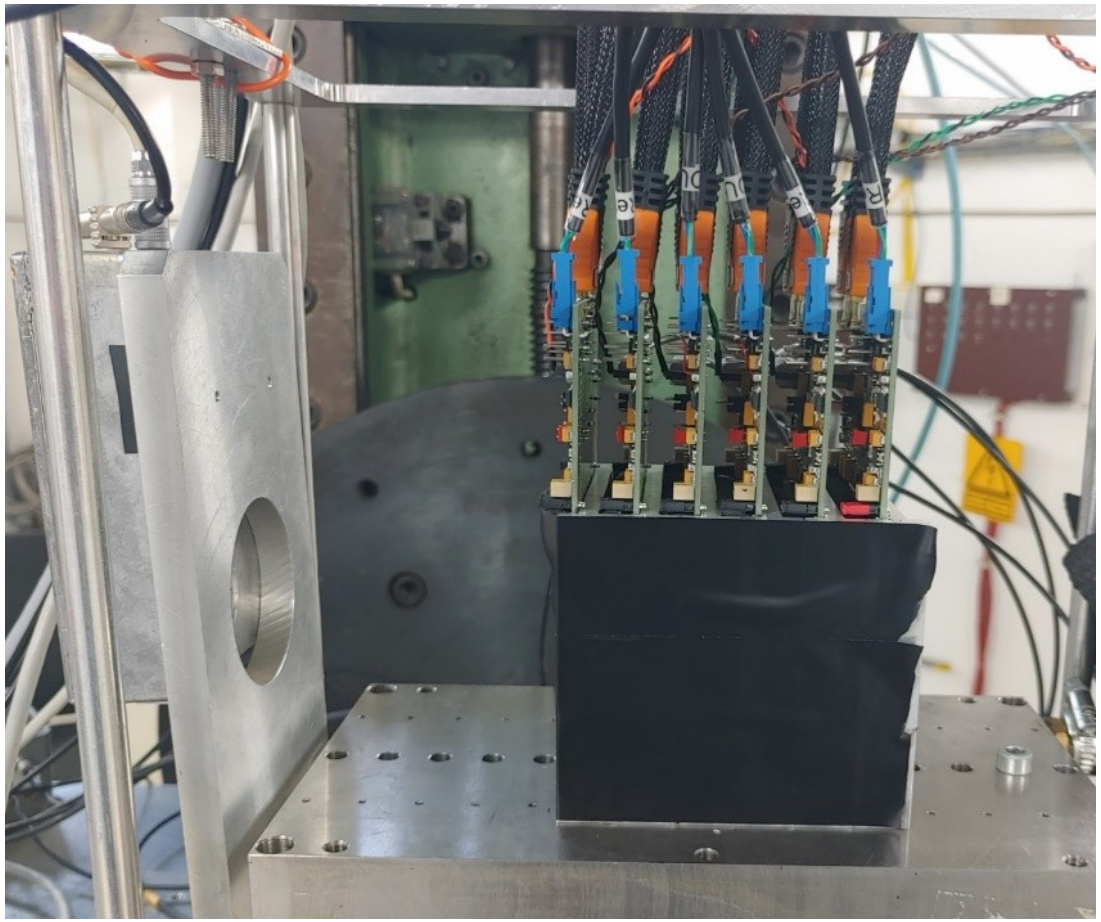
Evaluate most promising sensing element with thicker epi layer
→ More charge and higher charge sharing
→ Drawbacks wrt radiation tolerance?
→ Consistency checks with 25 µm to MIMOSIS-1

The in-beam performance test setup

MIMOSIS-1/-2.1 beam telescope:

- ✓ 6 all-MIMOSIS-1/-2.1 sensors
- ✓ 4 reference sensors (standard epi-layer)
- ✓ 2 device under test
- ✓ Reference Track Uncertainty:
  2.5 µm + 1.5 µm Mult. Scattering (DESY only)

preliminary



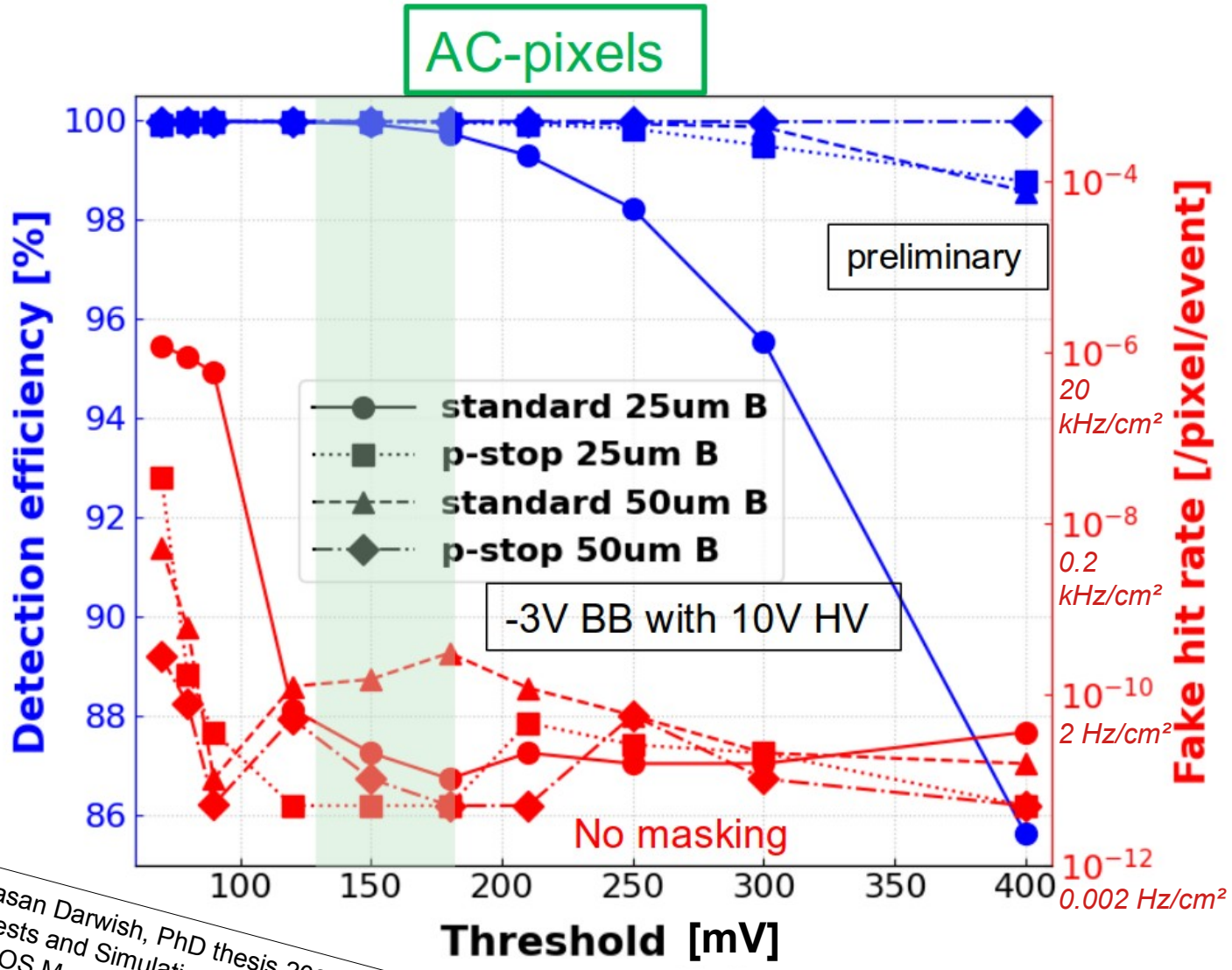
Irradiation:

- ✓ 1 MeV reactor neutrons (TRIGA, Ljubjana).
- ✓ Few 10 keV X-rays (KIT)
- ✓ Storage at room temperature.

Multiple beam test, common conditions:

- ✓ 5 GeV e- Beam @ DESY
- ✓ 120 GeV Pion Beam @SPS-CERN
- ✓ ~ 1 GeV d – beam @ COSY
- ✓ Stabilized room temperature

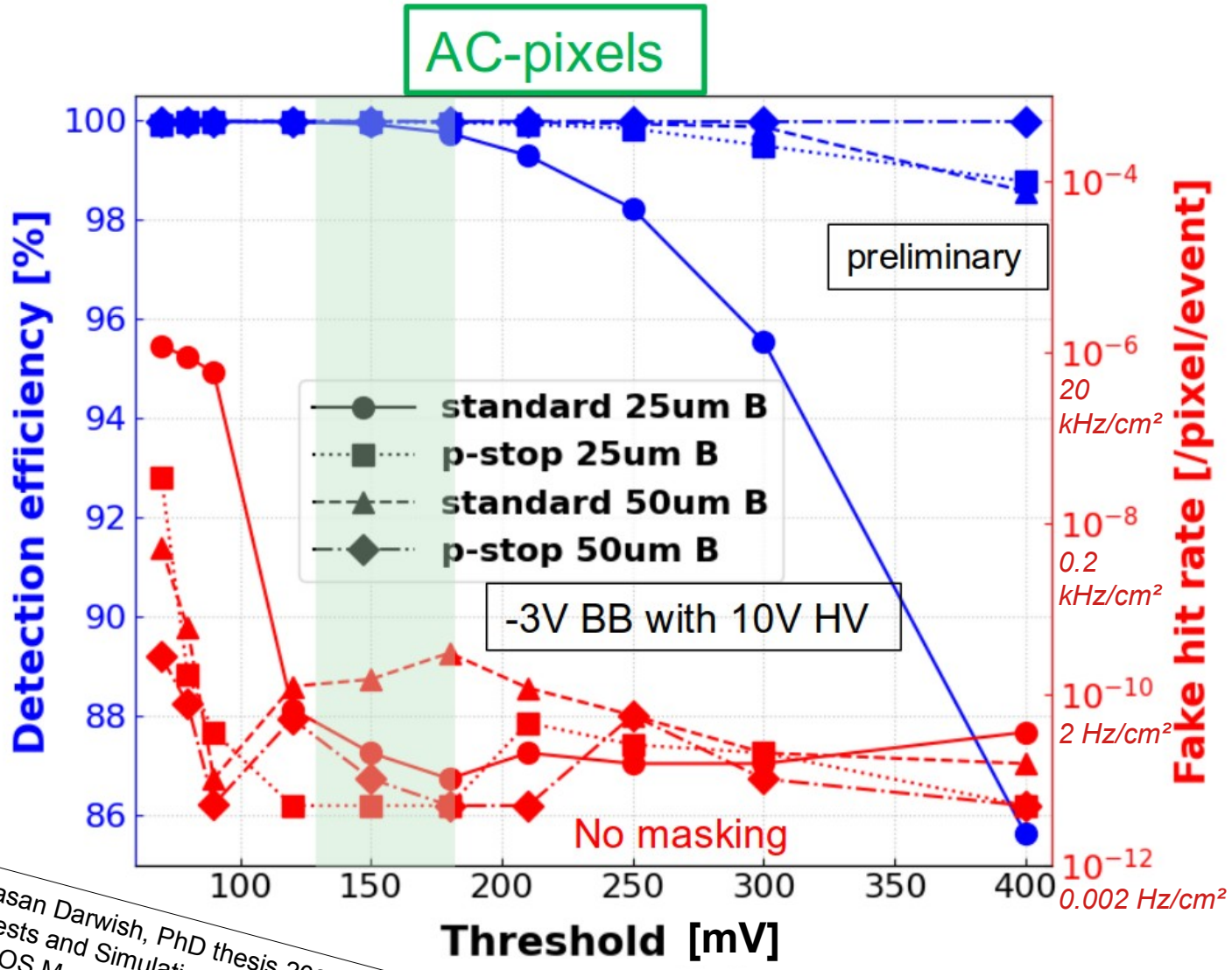
Non-irrad. MIMOSIS-2.1 beam test results (~MIPs @ DESY & CERN)



Hasan Darwish, PhD thesis 2025
»Tests and Simulations of the MIMOSIS CMOS Monolithic Active Pixel Sensor«

- Detection efficiency and fake hit rate consistent with MIMOSIS-1 results
- Excellent detection efficiency in exp. threshold regime
- Best performance: p-stop
  - Detection eff: 50 µm
  - Fake hit rate: 25 µm

Non-irrad. MIMOSIS-2.1 beam test results (~MIPs @ DESY & CERN)



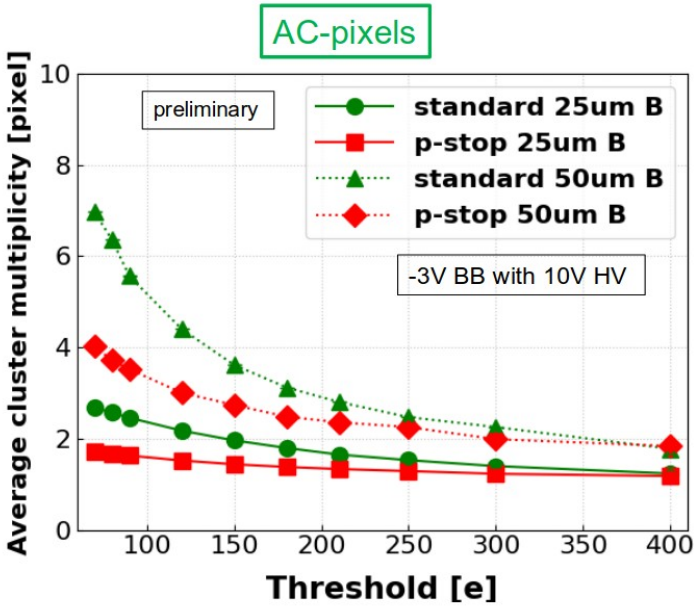
Hasan Darwish, PhD thesis 2025
»Tests and Simulations of the MIMOSIS CMOS Monolithic Active Pixel Sensor«

- Detection efficiency and fake hit rate consistent with MIMOSIS-1 results
- Excellent detection efficiency in exp. threshold regime
- Best performance: p-stop
  - Detection eff: 50 µm
  - Fake hit rate: 25 µm

~ 100% detection efficiency,
< 0.2 Hz/cm² fake hit rate
even without masking!

50 µm epi for γ detection?

Non-irrad. MIMOSIS-2.1 beam test results (~MIPs @ DESY & CERN)

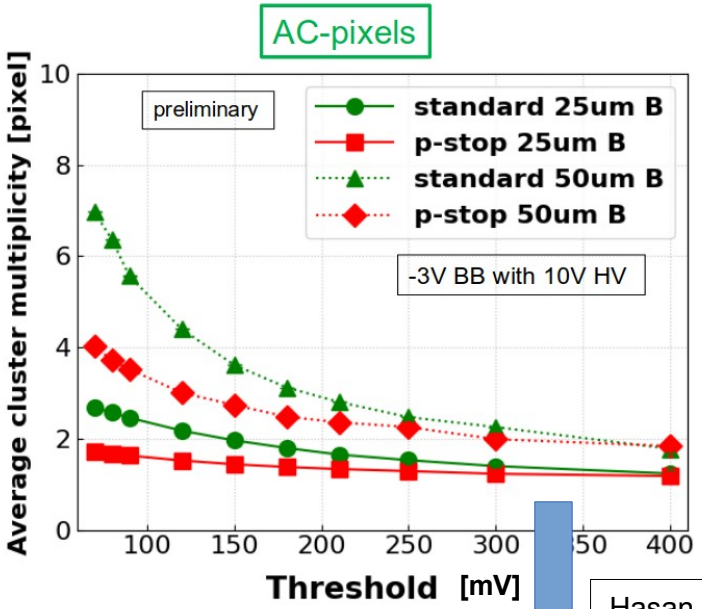


- Average cluster multiplicity increases
- with thickness (as expected)

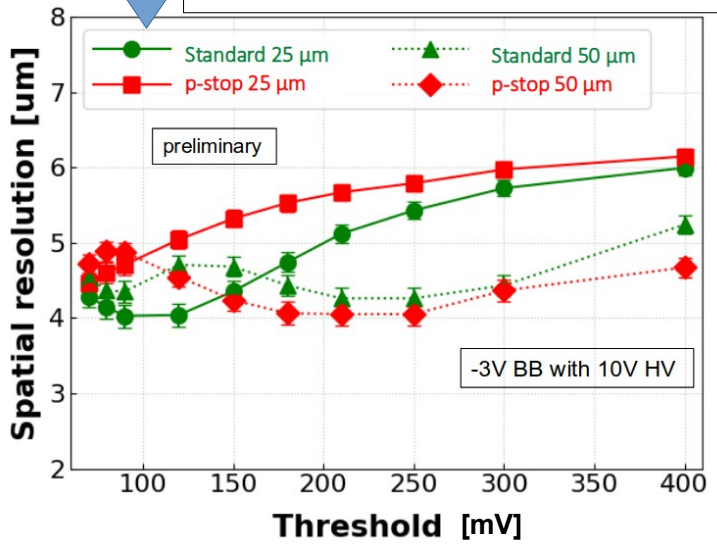
- P-stop cluster sizes systematically lower
- than for std epi (as expected)

- Regardless – spatial resolution determined
- corresponds well with requirements for MVD

Non-irrad. MIMOSIS-2.1 beam test results (~MIPs @ DESY & CERN)



Hasan Darwish, PhD thesis 2025
»Tests and Simulations of the MIMOSIS CMOS Monolithic Active Pixel Sensor«

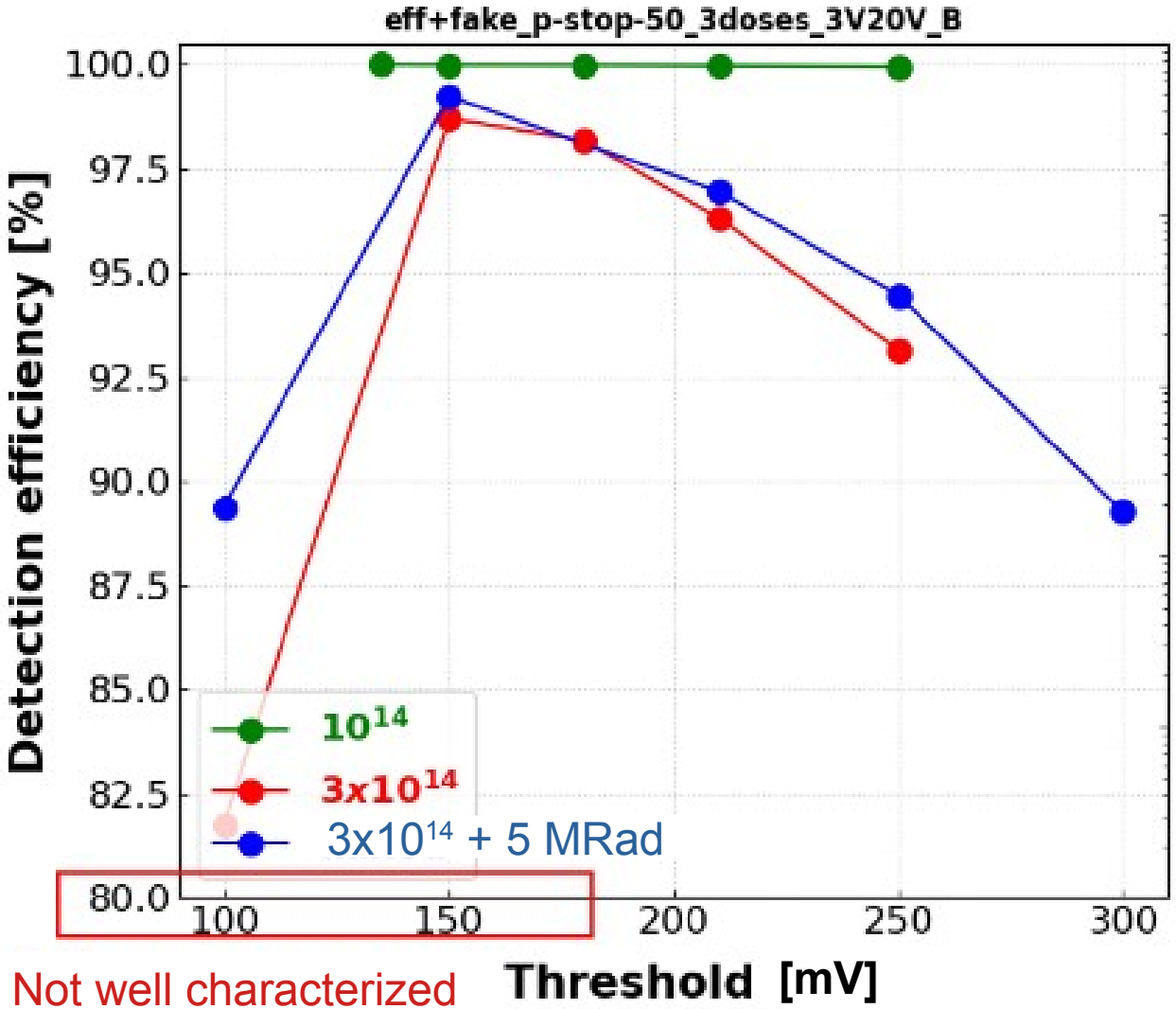


- Average cluster multiplicity increases
- with thickness (as expected)

- P-stop cluster sizes systematically lower
- than for std epi (as expected)

- Regardless – spatial resolution determined
- corresponds well with requirements for MVD

Irrad. MIMOSIS-2.1 beam test results (~MIPs @ DESY & CERN)



Not well characterized

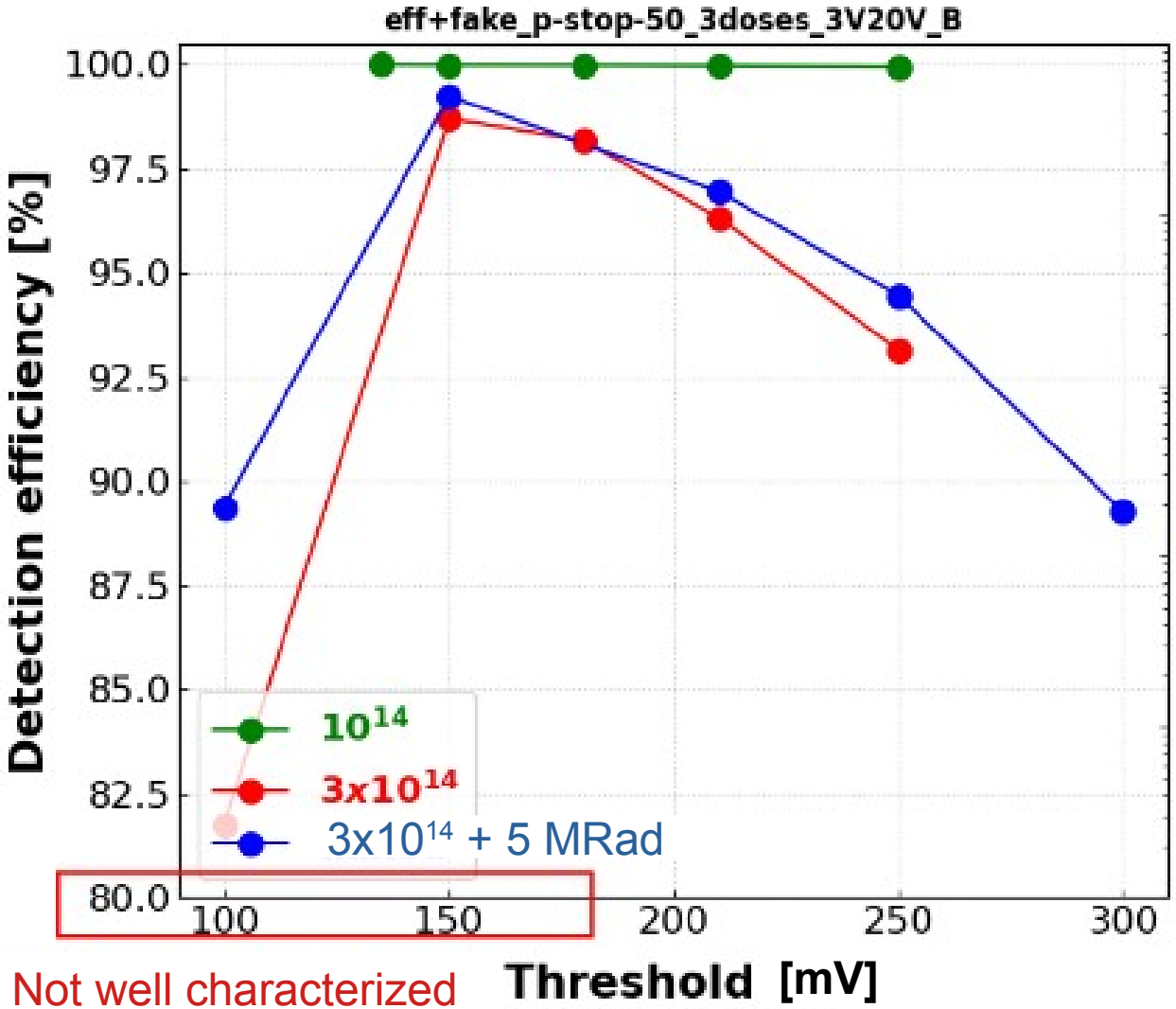
- No significant change in detection efficiency
- for < 10^{14} n_{eq}/cm^2

- Fake hit rate < 2 Hz/cm² at < 10^{14} n_{eq}/cm^2 (at 250 mV thresh.)

- Det. Eff. > 97 % in combined irrad. case

- Fake hit rate in order of 2 kHz/cm² to 20 Hz/cm² for 3x10^{14} n_{eq}/cm^2 combined irrad. case
- (at 250 mV thresh.)

Irrad. MIMOSIS-2.1 beam test results (~MIPs @ DESY & CERN)



Not well characterized

- No significant change in detection efficiency
- for < 10^{14} n_{eq}/cm^2

- Fake hit rate < 2 Hz/cm² at < 10^{14} n_{eq}/cm^2 (at 250 mV thresh.)

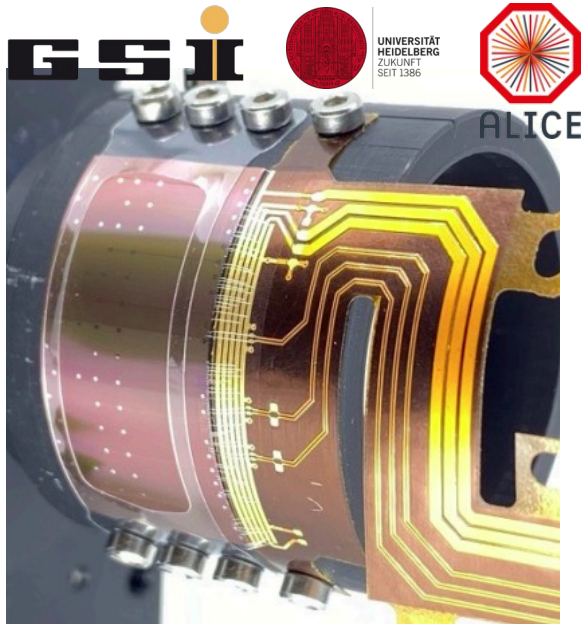
- Det. Eff. > 97 % in combined irrad. case

- Fake hit rate in order of 2 kHz/cm² to 20 Hz/cm² for 3x10^{14} n_{eq}/cm^2 combined irrad. case
- (at 250 mV thresh.)

Sufficiently high detection efficiency even after irradiation.

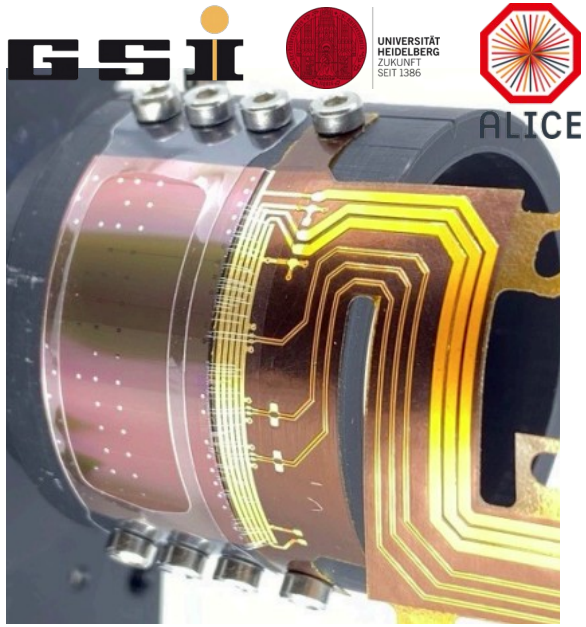
Fake hit rate increases with dose (as expected), still sufficiently low.

What are other groups doing? E.g. ITS3?



Bended ALPIDE

What are other groups doing? E.g. ITS3?

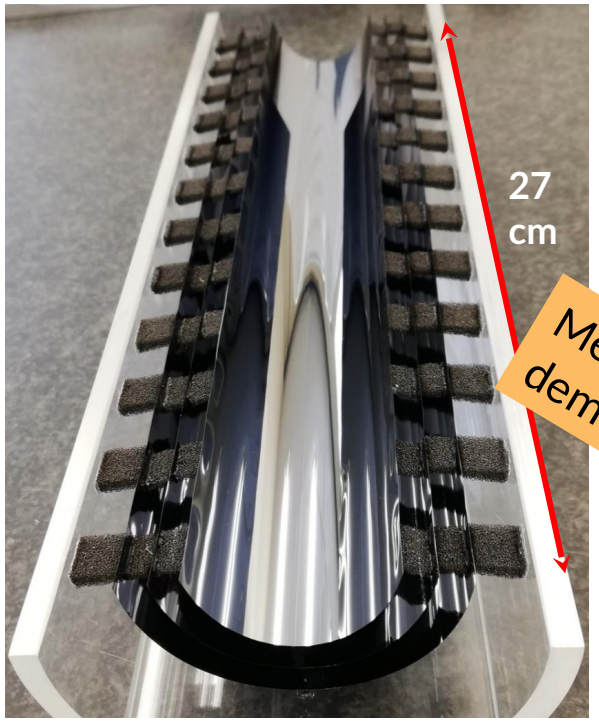


Bended ALPIDE

Followed up by GSI, IPHC (within ALICE)

ITS3

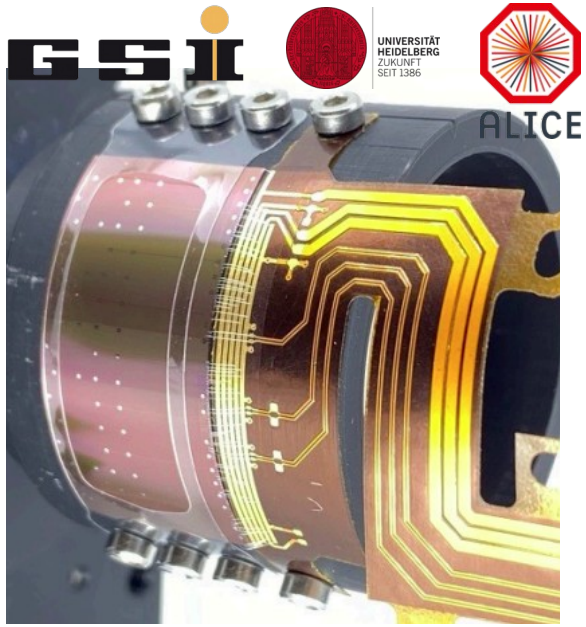
▸ **6 sensors** (wafer-size) only!



<0.05% x/X_0 /layer (Si-only)

Pictures: Courtesy S. Masciocchi, B. Blidaru , GSI, Uni HD

What are other groups doing? E.g. ITS3?

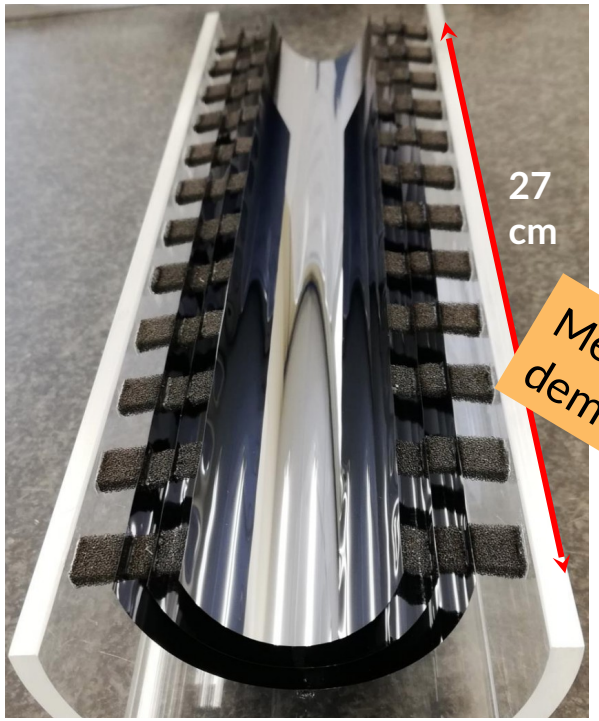


Bended ALPIDE

Followed up by GSI, IPHC (within ALICE)

ITS3

▸ **6 sensors** (wafer-size) only!



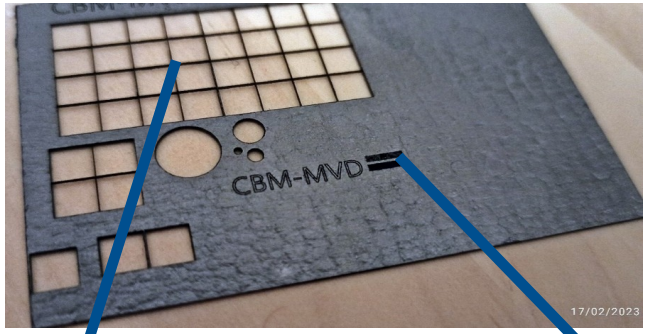
<0.05% x/X_0 /layer (Si-only)

Pictures: Courtesy S. Masciocchi, B. Blidaru , GSI, Uni HD

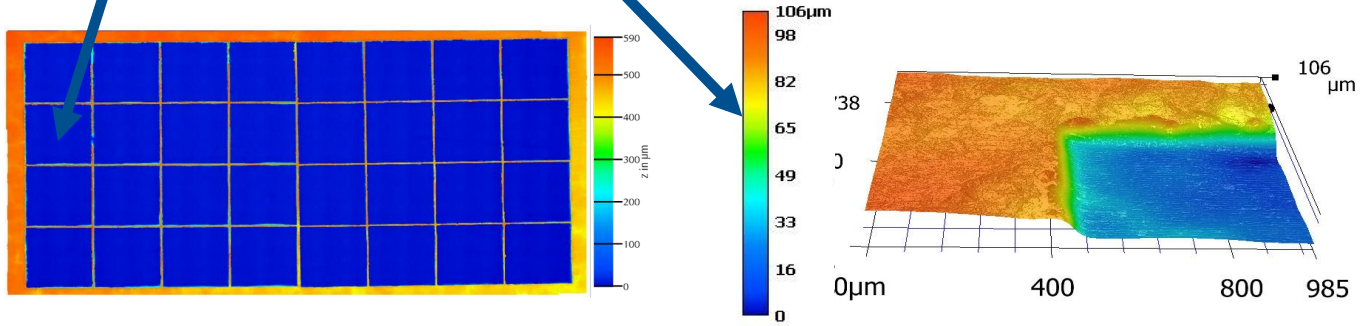
Modern system integration concepts (co-developed by GSI and IPHC) will allow to:

- Operate MAPS in vacuum at lowest mass (0.3 – 0.5% X_0) per layer, fixed target (followed up for CBM).
- Potentially 0.05% X_0 per layer (air cooled, bended wafer size sensors), collider (followed up for ALICE).

Overview over integration efforts



Laser-processed TPG:
Cuts and hatches



TPG (Thermal Pyrolytic Graphite)

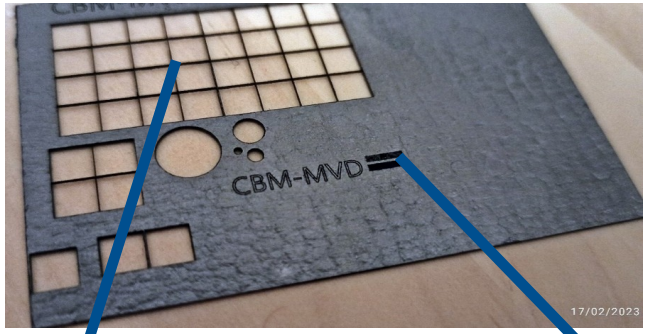
Thermal high performance material (1500 W/m/K)

Conductive cooling in acceptance

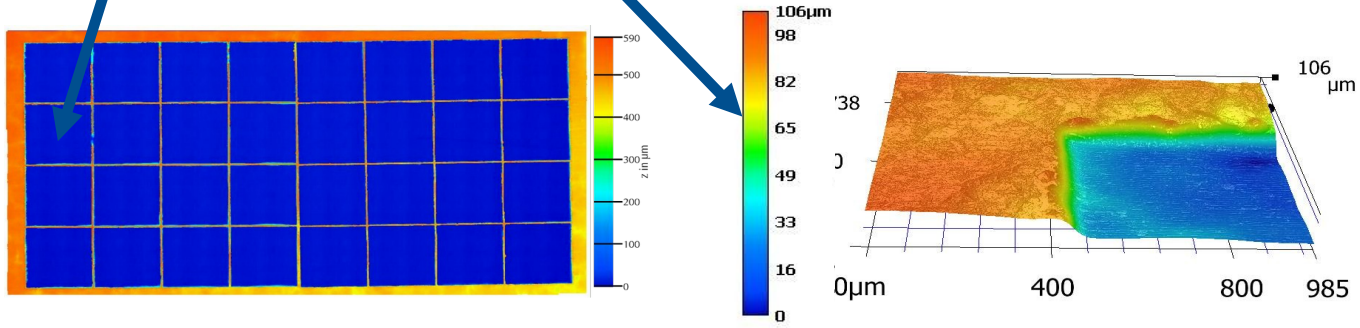
Baseline carrier for all stations

Overview over integration efforts

Laser ablation for TPG processing



Laser-processed TPG:
Cuts and hatches



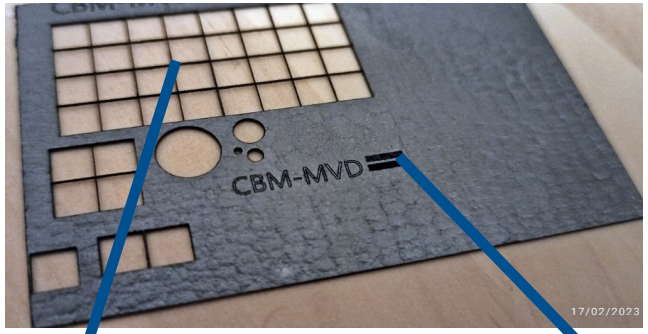
TPG (Thermal Pyrolytic Graphite)

Thermal high performance material (1500 W/m/K)

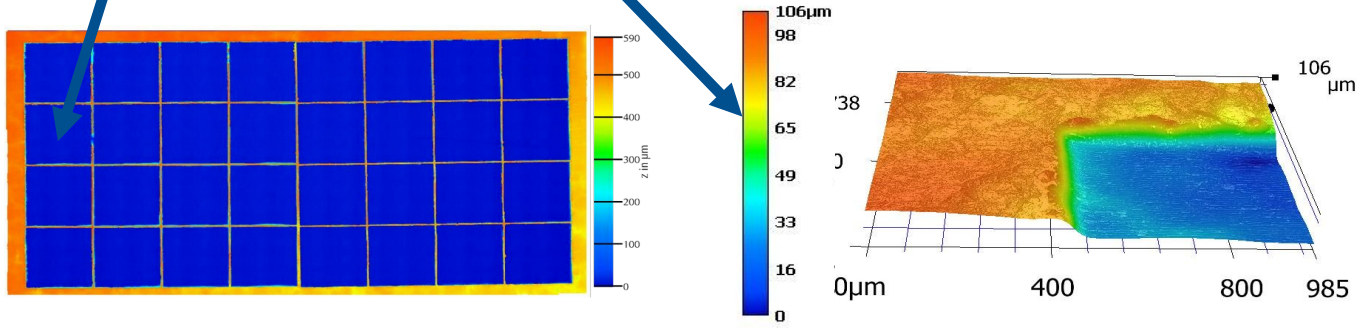
Conductive cooling in acceptance

Baseline carrier for all stations

Overview over integration efforts



Laser-processed TPG:
Cuts and hatches



TPG (Thermal Pyrolytic Graphite)

Thermal high performance material (1500 W/m/K)

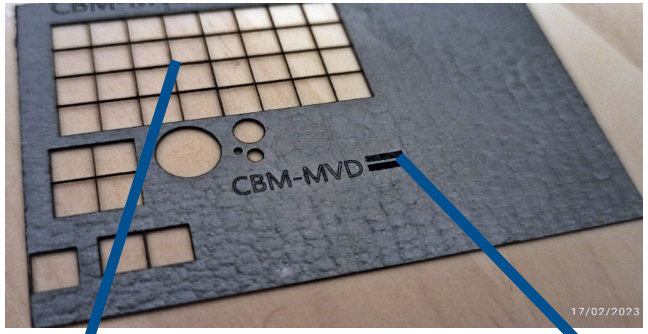
Conductive cooling in acceptance

Baseline carrier for all stations

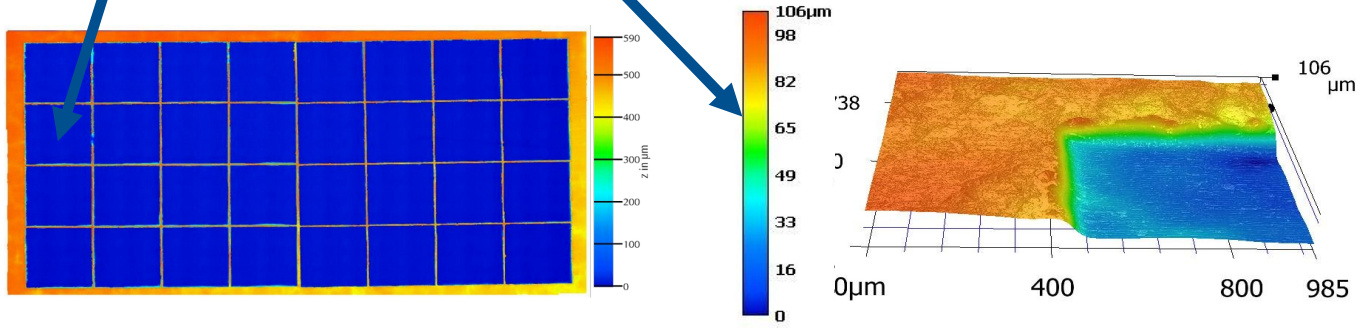
Laser ablation for TPG processing

Cutting and hatching

Overview over integration efforts



Laser-processed TPG:
Cuts and hatches



TPG (Thermal Pyrolytic Graphite)

Thermal high performance material (1500 W/m/K)

Conductive cooling in acceptance

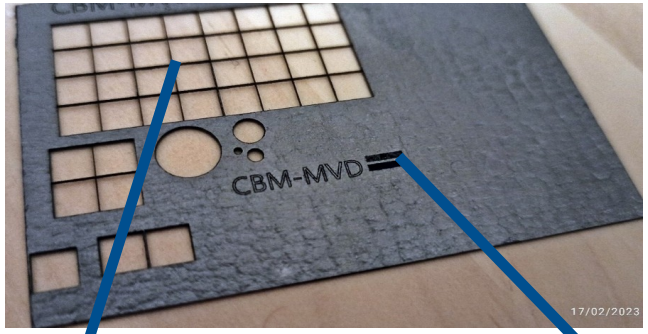
Baseline carrier for all stations

Laser ablation for TPG processing

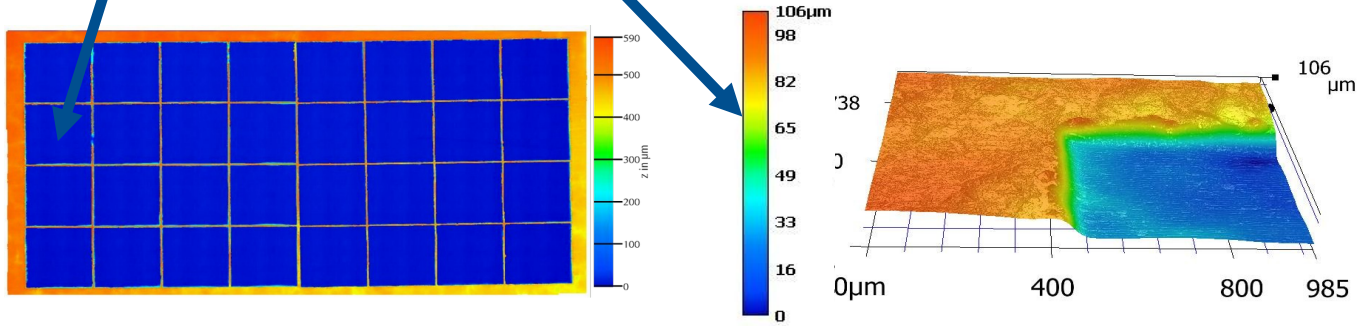
Cutting and hatching

High precision (~20 (~2) µm in xy(z) direction)

Overview over integration efforts



Laser-processed TPG:
Cuts and hatches



TPG (Thermal Pyrolytic Graphite)

Thermal high performance material (1500 W/m/K)

Conductive cooling in acceptance

Baseline carrier for all stations

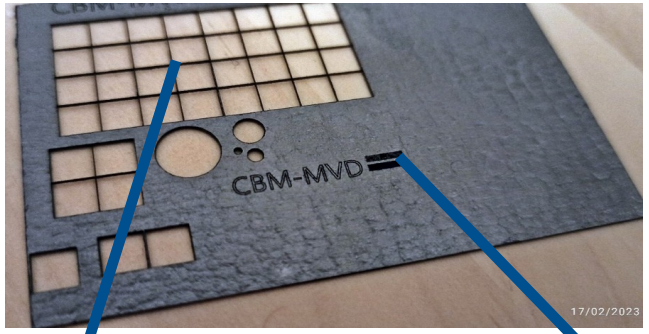
Laser ablation for TPG processing

Cutting and hatching

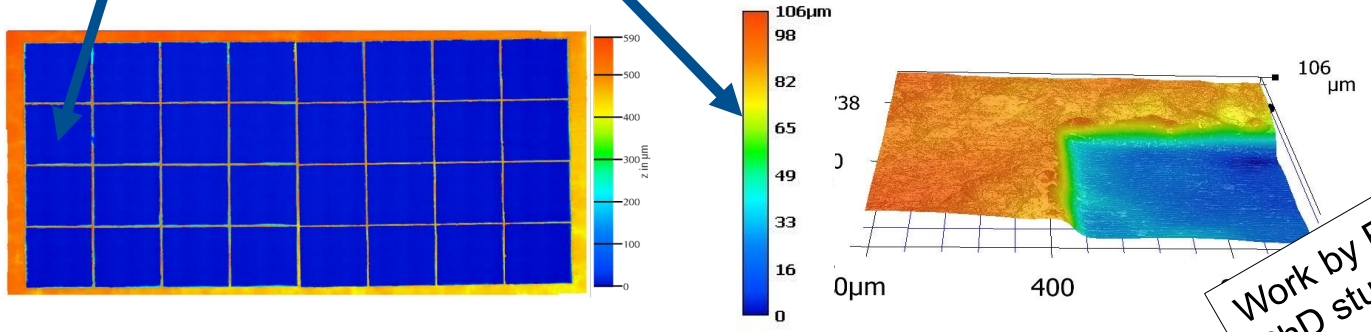
High precision (~20 (~2) µm in xy(z) direction)

No problems with softness, delamination, orthotropy

Overview over integration efforts



Laser-processed TPG:
Cuts and hatches



Work by Franz Matejcek
PhD student at Uni Frankfurt
in cooperation with GSI

TPG (Thermal Pyrolytic Graphite)

Thermal high performance material (1500 W/m/K)

Conductive cooling in acceptance

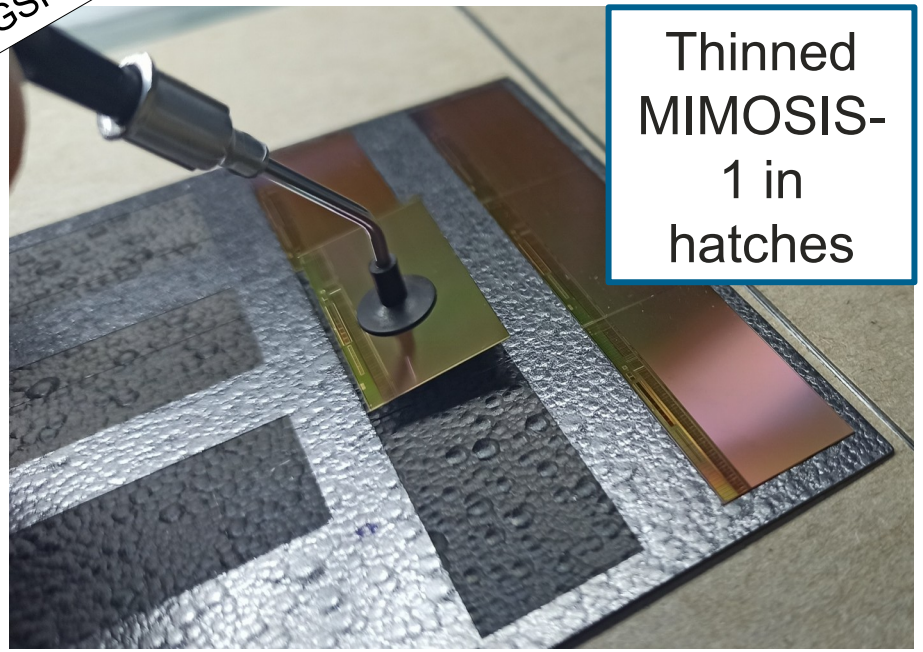
Baseline carrier for all stations

Laser ablation for TPG processing

Cutting and hatching

High precision (~20 (~2) µm in xy(z) direction)

No problems with softness, delamination, orthotropy



Thinned MIMOSIS-1 in hatches

Summary and conclusion

CMOS Monolithic Active Pixel Sensors

- form high end detectors for heavy flavor tagging in dense particle environments.
- are being developed in a common activity of IPHC Strasbourg and GSI for ALICE and CBM.

MIMOSIS-1 forms the first full size prototype of the MIMOSIS for the CBM-MVD.

- ✓ 5 µs / 5 µm time/spatial resolution.
- ✓ 80 MHz/cm² peak rate.

MIMOSIS-2.1 irradiated with up to $3x10^{14}$ n_{eq}/cm² + 5 MRad were tested in laboratory and in beam.
Thick 50 µm epitaxial layer design evaluated

- >> 99% detection efficiency after 10^{14} n_{eq}/cm², still satisfactory at combined irradiation
- 20-2000 Hz/cm² fake hit rate at realistic operation thresholds at combined irrad. case
- ~5 µm spatial resolution before and after irradiation.

Summary and conclusion

CMOS Monolithic Active Pixel Sensors

- form high end detectors for heavy flavor tagging in dense particle environments.
- are being developed in a common activity of IPHC Strasbourg and GSI for ALICE and CBM.

MIMOSIS-1 forms the first full size prototype of the MIMOSIS for the CBM-MVD.

- ✓ 5 µs / 5 µm time/spatial resolution.
- ✓ 80 MHz/cm² peak rate.

MIMOSIS-2.1 irradiated with up to 3×10^{14} n_{eq}/cm² + 5 MRad were tested in laboratory and in beam.
Thick 50 µm epitaxial layer design evaluated

- >> 99% detection efficiency after 10^{14} n_{eq}/cm², still satisfactory at combined irradiation
- 20-2000 Hz/cm² fake hit rate at realistic operation thresholds at combined irrad. case
- ~5 µm spatial resolution before and after irradiation.

MAPS turn into a standard technology in relativistic heavy ion physics (CBM, ALICE, others)
… and are suitable for use outside of heavy ion physics (perhaps *e.g.,* in DM search).

People and institutes involved in MIMOSIS activities

Supported by:

Bundesministerium für Bildung und Forschung

(05P21RFFC2)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072

People and institutes involved in MIMOSIS activities

Ali-Murteza Altingun[2], Julio Andary[1], Benedict Arnoldi-Meadows[1], Ole Artz[1], Jérôme Baudot[2], Grégory Bertolone[2], Auguste Besson[2], Norbert Bialas[1], Christopher Braun[1], Roma Bugiel[2], Gilles Claus[2], Claude Colledani[2], Hasan Darwish[1,2,3], Michael Deveaux[1,3,6], Andrei Dorokhov[2], Guy Dozière[2], Ziad El Bitar[2], Ingo Fröhlich[1,3], Mathieu Goffe[2], Benedikt Gutsche[1], Fabian Hebermehl[1], Abdelkader Himmi[2], Christine Hu-Guo[2], Kimmo Jaaskelainen[2], Oliver Michael Keller[6], Michal Koziel[1], Ajit Kumar[1], Franz Matejcek[1], Jan Michel[1], Frédéric Morel[2], Christian Müntz[1], Hung Pham[2], Christian Joachim Schmidt[3], Stefan Schreiber[1], Matthieu Specht[2], Dennis Spicker[1], Joachim Stroth[1,3,4], Eva-dhidho Taka[1], Isabelle Valin[2], Roland Weirich[1], Marc Winter[5] and Yue Zhao[2]

[1]Goethe-Universität Frankfurt, Germany
[2]Université de Strasbourg, CNRS, IPHC UMR 7178, Strasbourg, France
[3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany
[4]Helmholtz Forschungsakademie Hessen für FAIR, Germany
[5]IJCLab, UMR9012 – CNRS / Université Paris-Saclay / Université de Paris, France
[6]Facility for Antiproton and Ion Research in Europe GmbH,Germany

Supported by:

Bundesministerium für Bildung und Forschung

(05P21RFFC2)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072