

MIMOSIS,

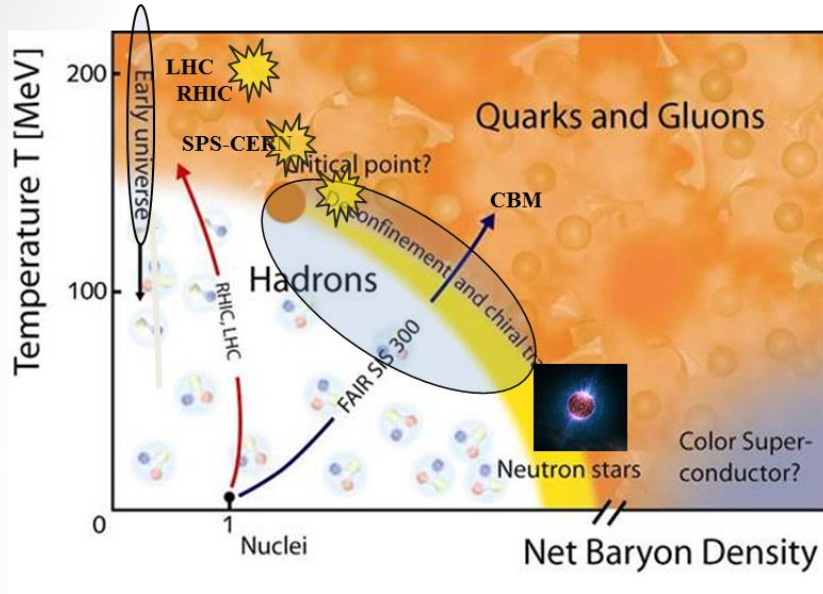
the CMOS Pixel Sensor for the CBM Micro-Vertex Detector

Frédéric Morel on behalf of the
mlcPHC team of IPHC and
IKF team

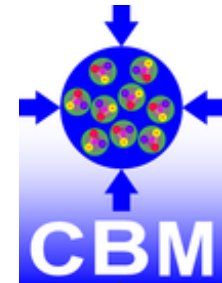
Outline

- CBM
 - Introduction
- MVD
 - Requirements
- MIMOSIS
 - Global architecture
- MIMOSIS0
 - Preliminary results
- Conclusion

CBM: experiment



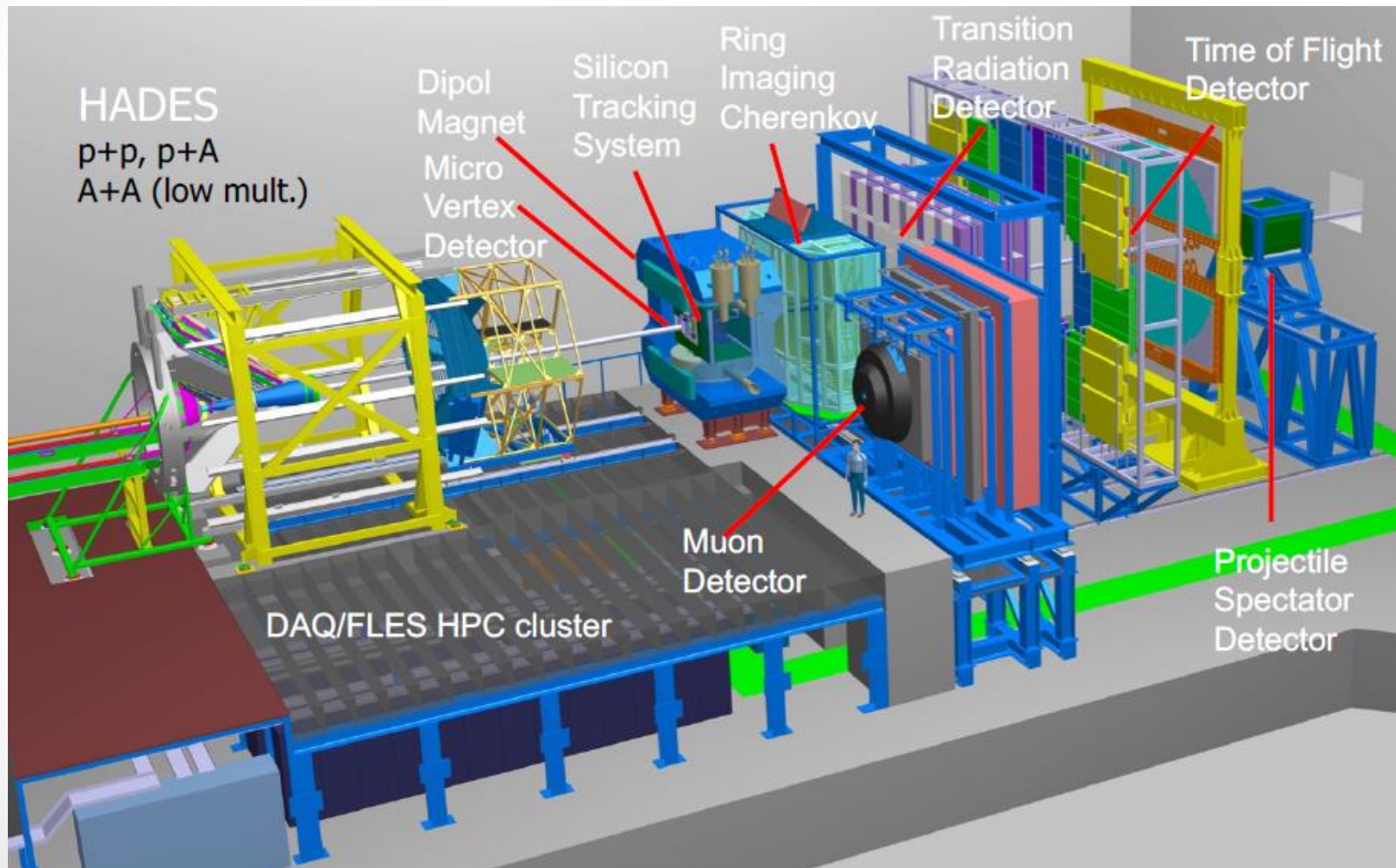
30/08/2018



Detector installation and
commissioning: 2021–2024
First beam: 2025

CBM: detector

Fixed Target experiment



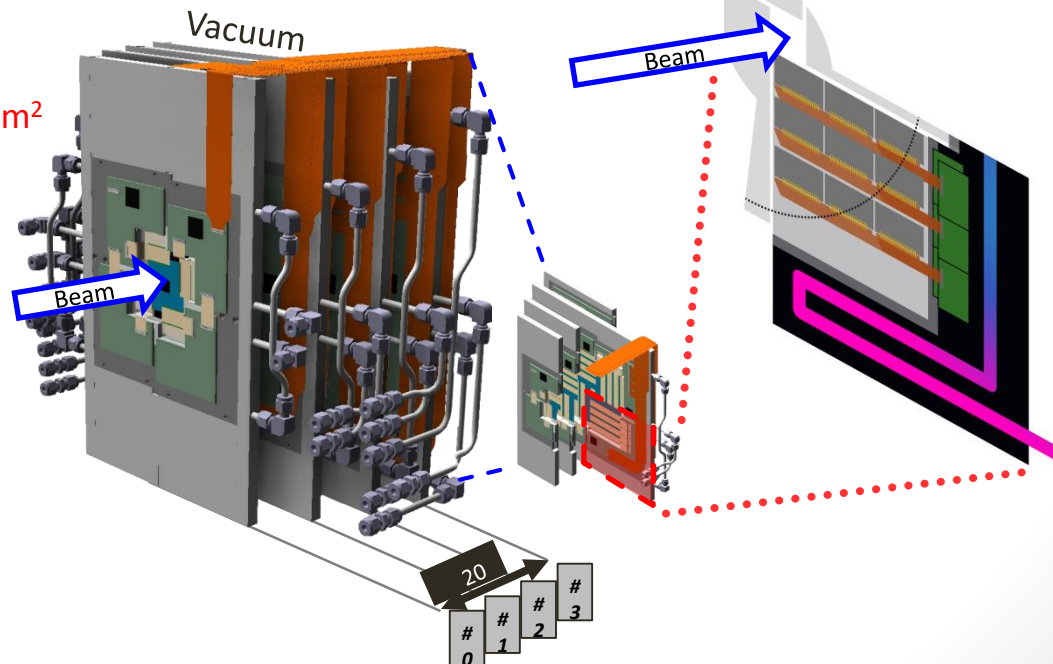
MVD: introduction

Micro Vertex Detector (MVD) for the CBM experiment at GSI/FAIR:

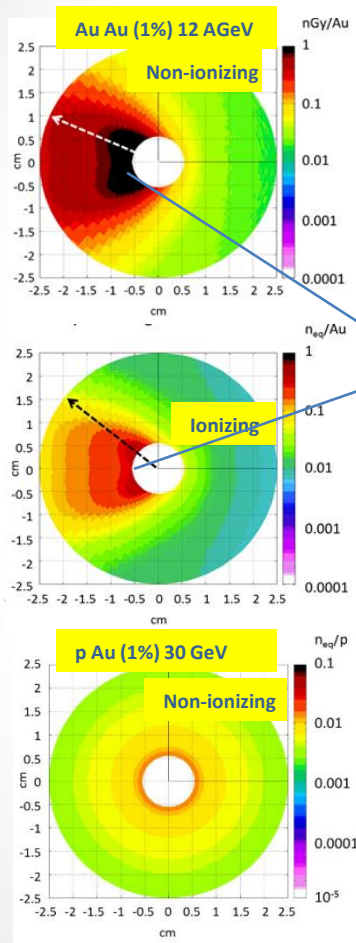
- Secondary vertex determination ($\sim 50 \mu\text{m}$), background rejection in di-electron spectroscopy, reconstruction of weak decays
- Vacuum/magnetic field operation
- 4 stations
- ~ 300 CMOS sensors
- Power dissipation: 150 W
- Radiation tolerance: $>3 \cdot 10^{13} n_{\text{eq}}/\text{cm}^2$ & $>3 \text{ Mrad}$

Quadrant (smallest functional unit):

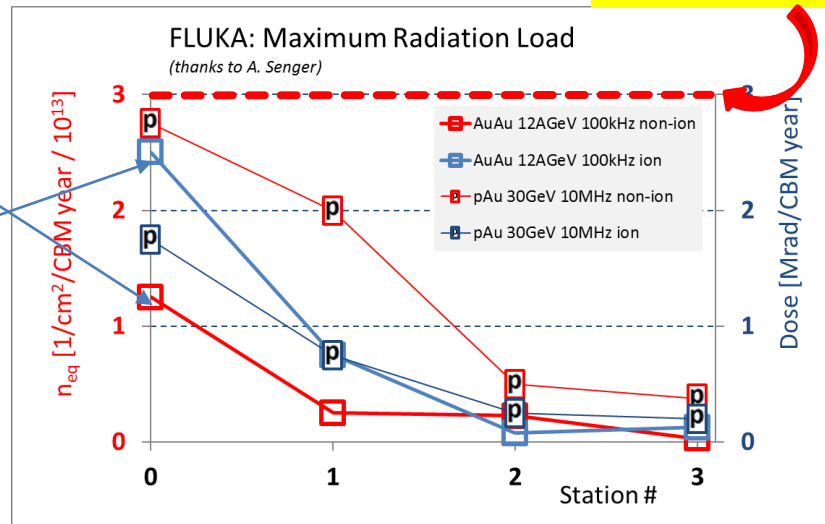
- CVD Diamond / TPG carrier for heat evacuation
- CMOS pixel sensors: $50 \mu\text{m}$ thin, $150 \text{ mW}/\text{cm}^2$, $\sim 10 \mu\text{s}$ read-out
- Aluminum heat-sink (actively cooled)



MVD: radiation



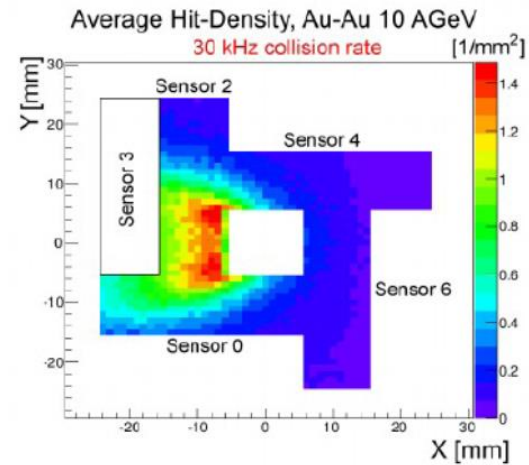
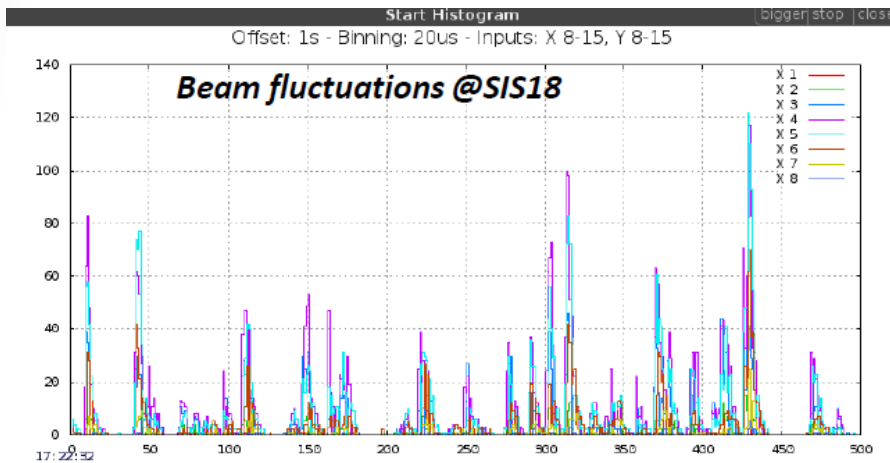
MIMOSIS benchmark
@ -20°C without safety margin



Stations at 5, 10, 15 and 20 cm

Reaction	Target	Reaction rate	Beam intensity [1/s]	Duty cycle	# of projectiles / CBM year
Au + Au, 12 AGeV	1 %	100 kHz	10^7	50%	2.5×10^{13}
p + Au, 30 GeV		10 MHz	10^9		2.5×10^{15}

MVD: hit density



Non uniform hit density in time and space

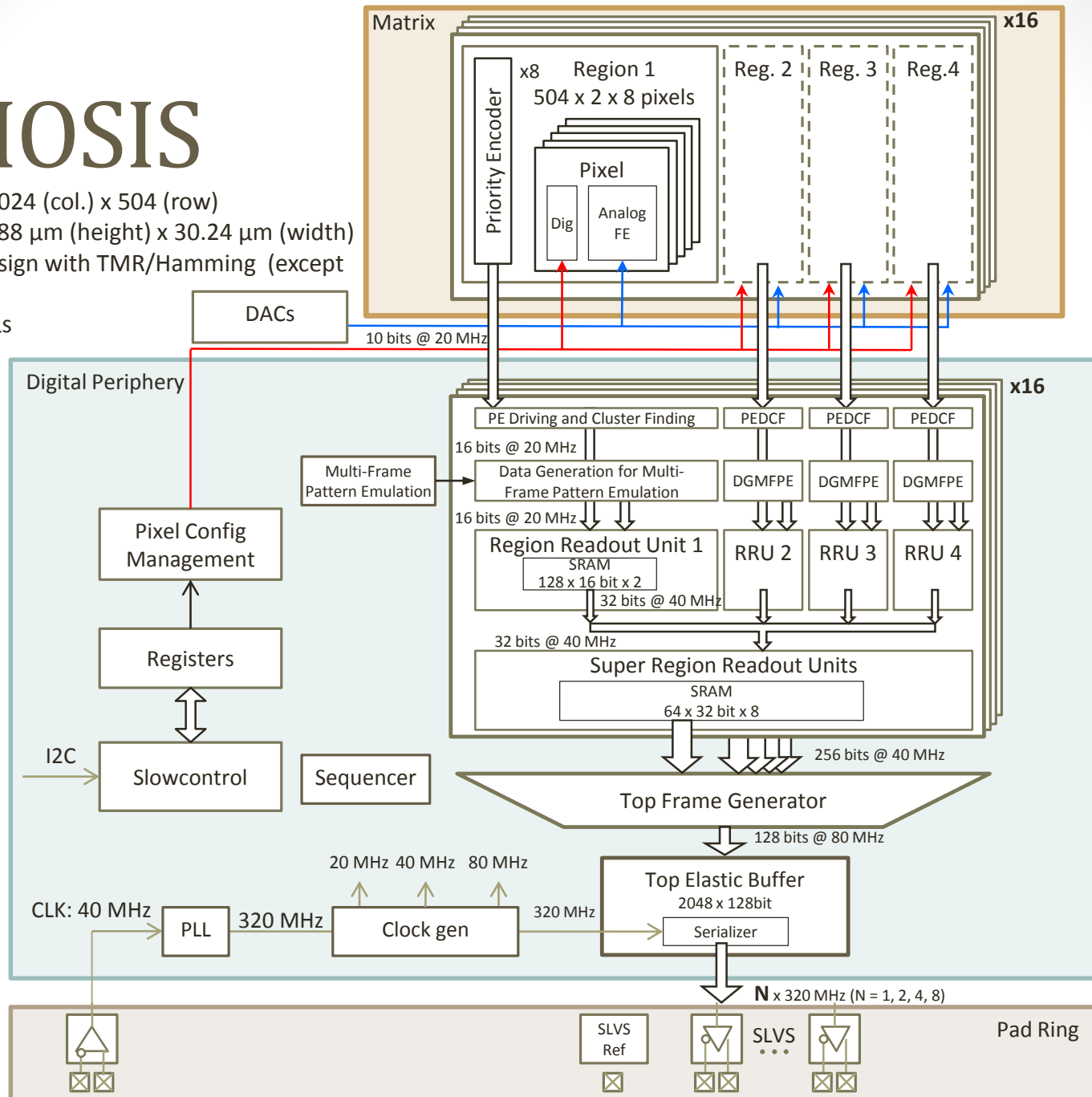
MVD: sensor requirement

	ALPIDE (demonstrated)	MIMOSIS (MVD design goal)	Factor
Ion. Rad. Tolerance	2.7 Mrad	> 3 Mrad	1
Non. Io. Tolerance	$1.7 \cdot 10^{13}$ neq/cm ²	$> 3 \times 10^{13}$ neq/cm ²	2
Heavy ion tolerance	N/A	1 kHz / cm ²	--
Time resolution	5-10 μ s	5 μ s	2
Hit rate	> 12 kHz/mm ²	700 kHz/mm ² (peak)	56
Data rate	1 Gbps	2.5 Gbps	2.5
Data reduction	Trigger	Elastic buffer	--
Power consumption (depending on hit density)	20-35 mW/cm ²	50-75 mW/cm ²	0.4
GBTx compatible	No	Yes	--

- **ALPIDE is not sufficient to fulfil all the requirements of the MVD**
- **Need a new architecture based on ALPIDE**

MIMOSIS

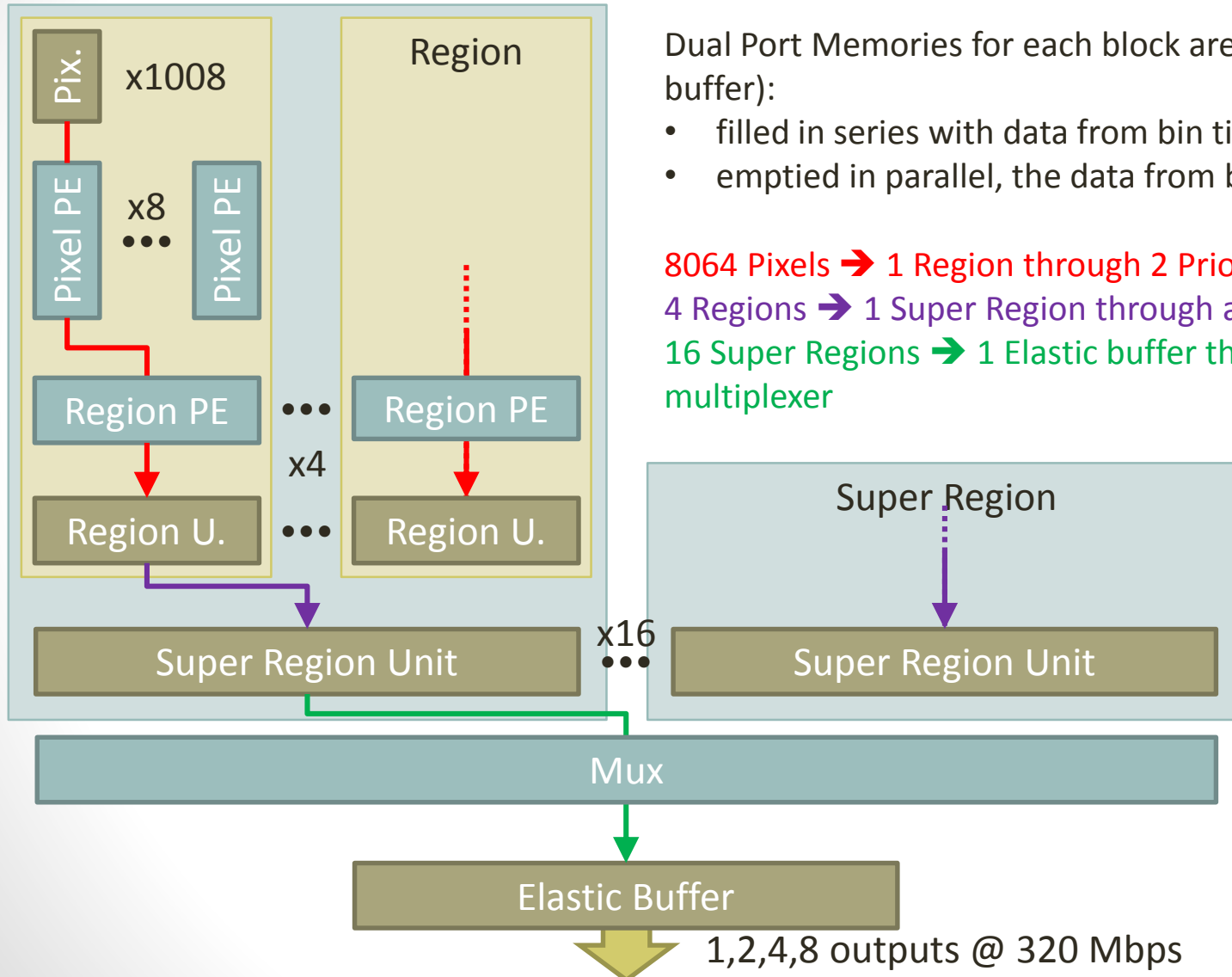
- Matrix dimension: 1024 (col.) x 504 (row)
- Pixel dimension: 26.88 μm (height) x 30.24 μm (width)
- SEU hardened by design with TMR/Hamming (except for data)
- Integration time: 5 μs
- TowerJazz 180 nm



Glue Logic Block

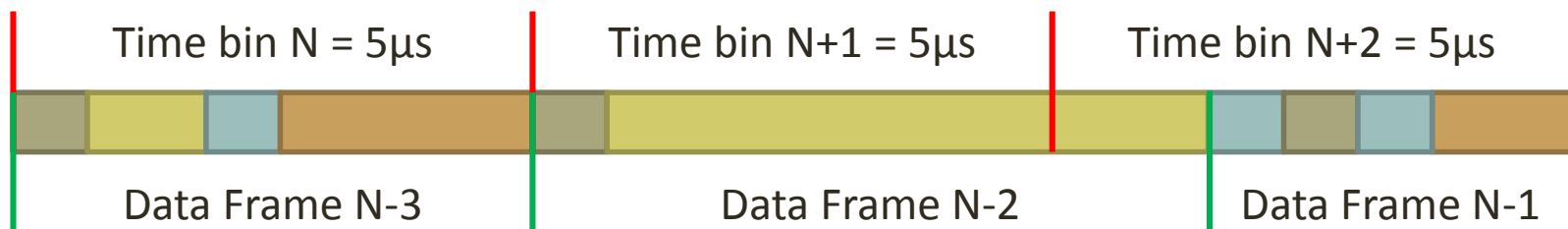
Block with Dual
Port Mem

MIMOSIS: Data Path



MIMOSIS: Elastic buffer

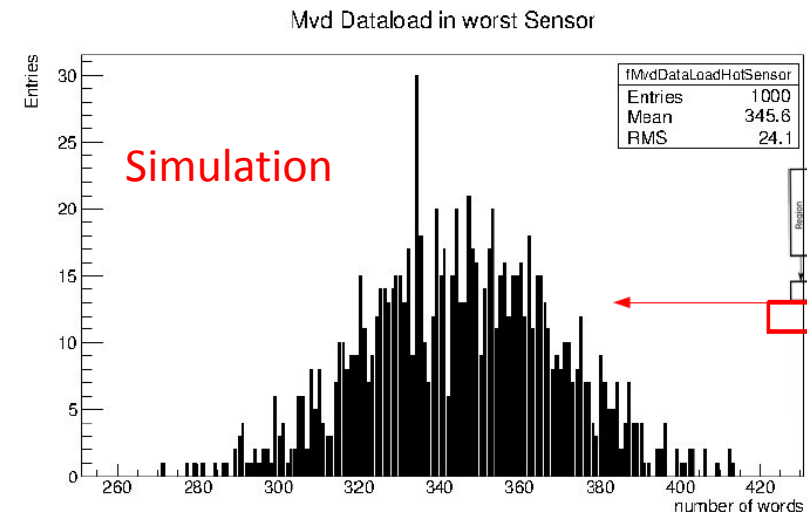
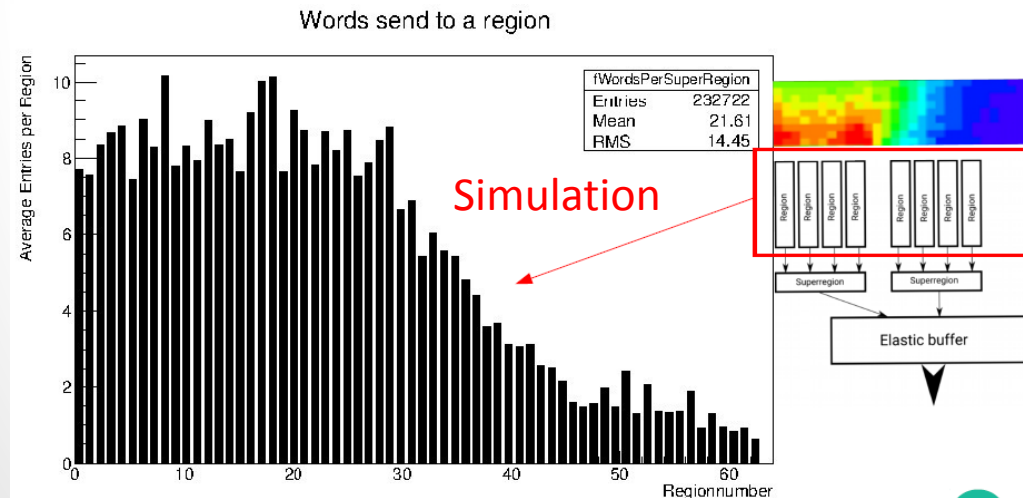
- Write speed is 4 times higher than read speed
- Use time structure of beam fluctuations to average data frames
- The buffer can store up to 9 maximal frames



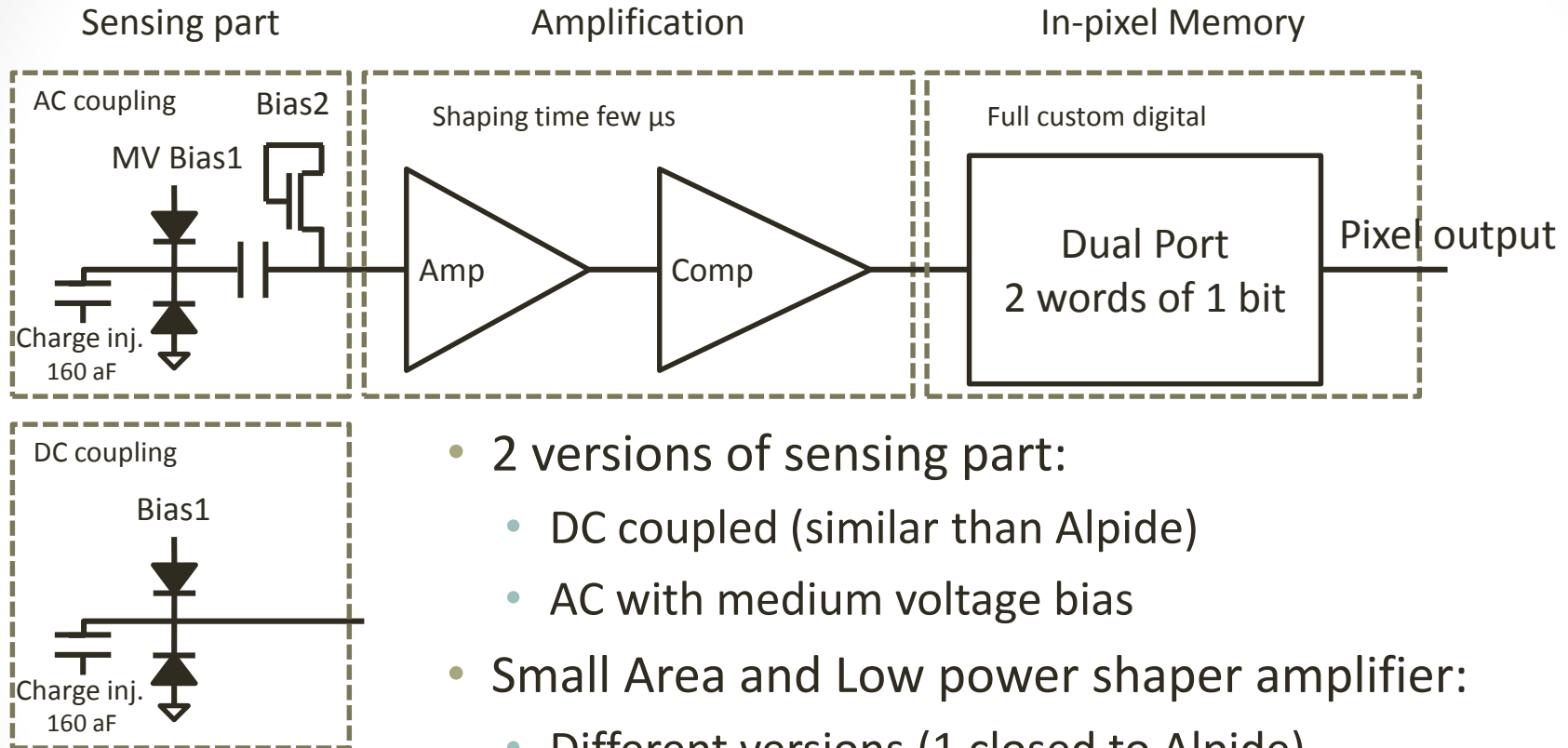
MIMOSIS: bandwidth

Component	Average	Maximum (3x average +2 sigma)	Available
Region	10/14	55/70	100
Super region	37/55	135/230	400
Elastic-Buffer input	345/600	1120/1790	3200
Elastic Buffer output			800

- Au/Au 10 AGeV 100kHz
- 16 bits words during 5 μ s
- Beam fluctuations:
 - Field: 100%/30%



MIMOSIS: Pixel

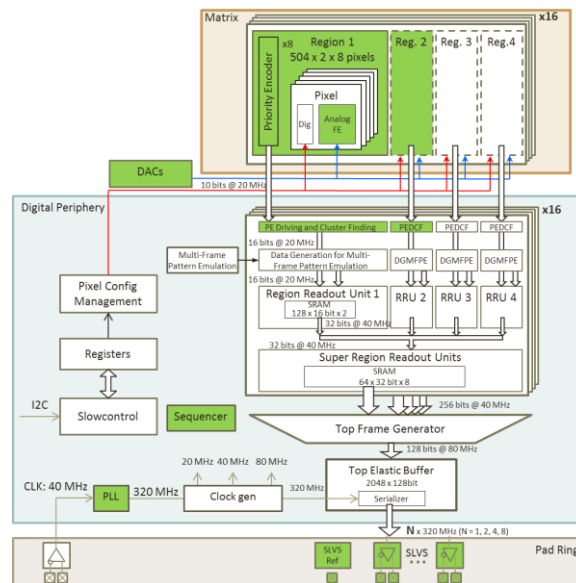


- 2 versions of sensing part:
 - DC coupled (similar than Alpide)
 - AC with medium voltage bias
- Small Area and Low power shaper amplifier:
 - Different versions (1 closed to Alpide)
- In-pixel Memory:
 - New version with double counting removal

Different pixel architecture tested with CE18 chips family
(see A. Dorokhov in Front End Electronics 2018)

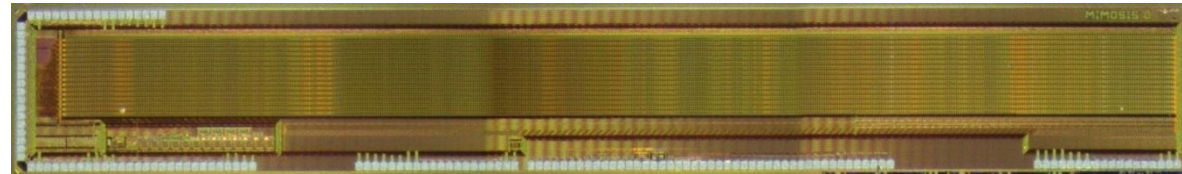
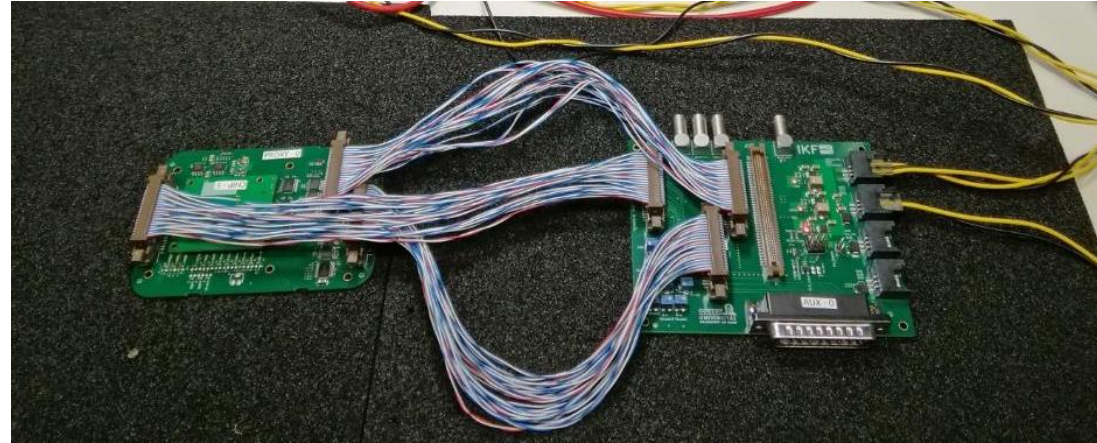
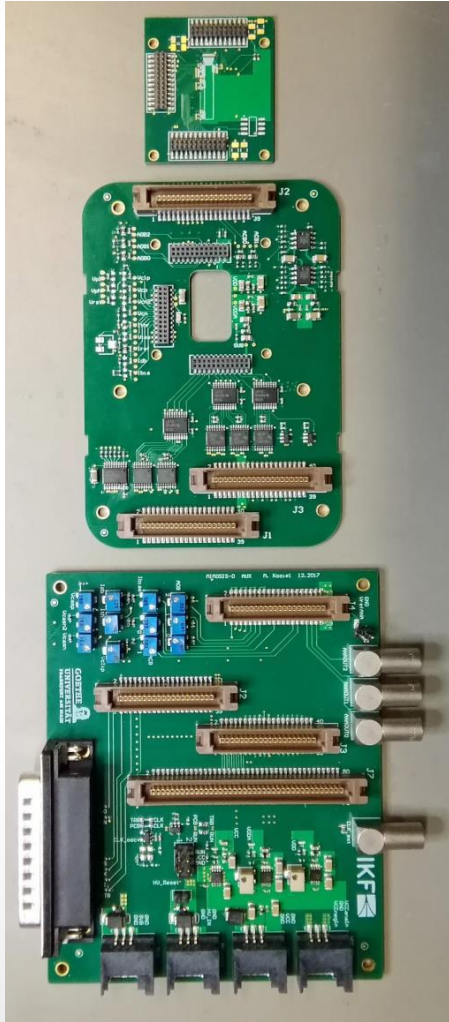
MIMOSIS: development plan

- MIMOSIS0: portion of pixel array → may 2017
 - 2 regions wide prototype with AC and DC coupled pixels



- MIMOSIS1: 1st full size sensor prototype → Q1 2019
- MIMOSIS2: 2nd full size sensor prototype → End 2019
- MIMOSIS3: final sensor pre-production → 2020

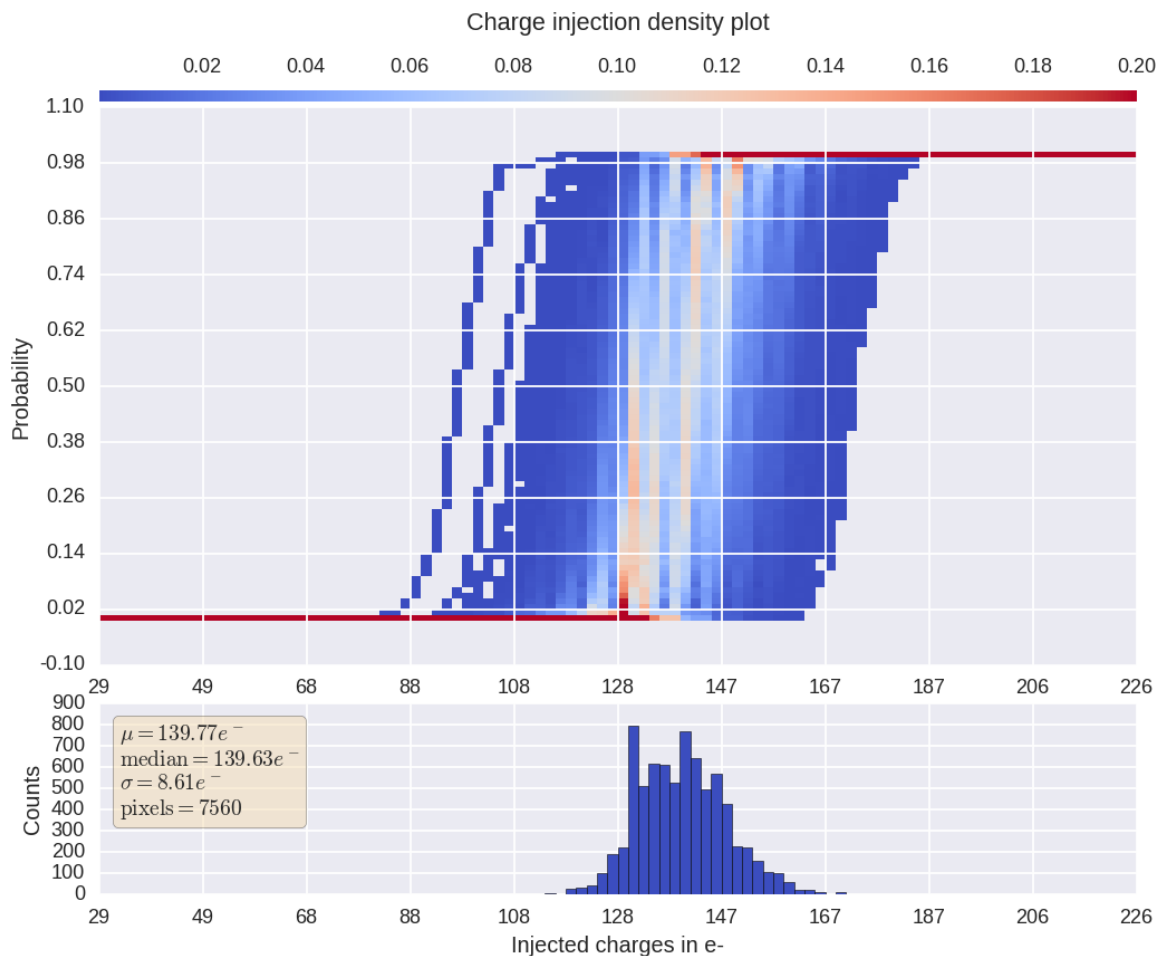
MIMOSIS0: test setup



Test setup developed by IKF with support of
IPHC test team

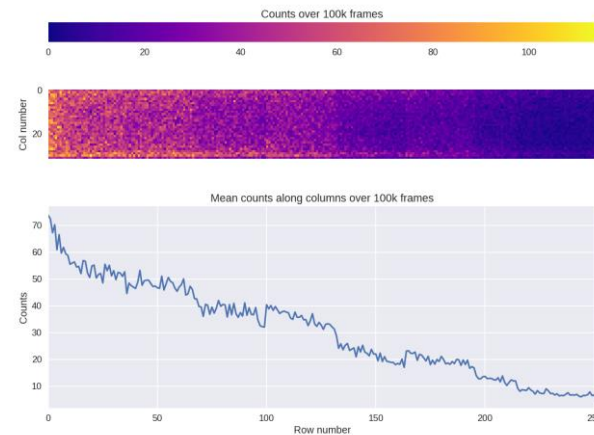
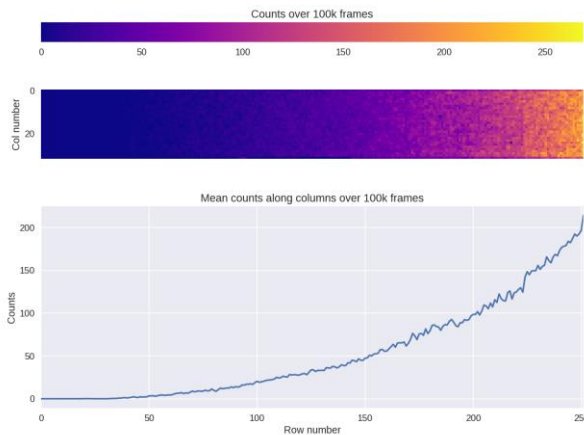
MIMOSIS0: preliminary results

- S-curves density plot from all DC coupled pixels

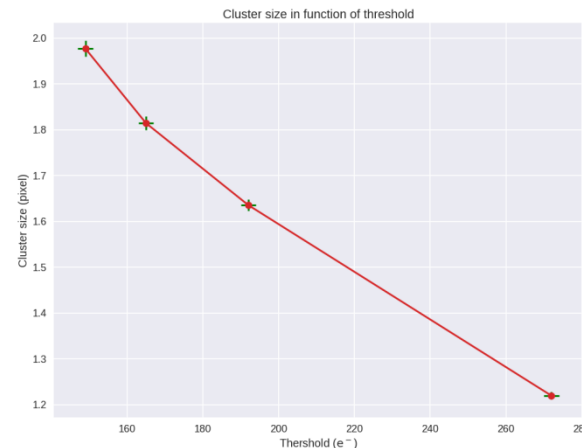


MIMOSIS0: preliminary results

- Fe55 response for DC and AC coupled Pixel

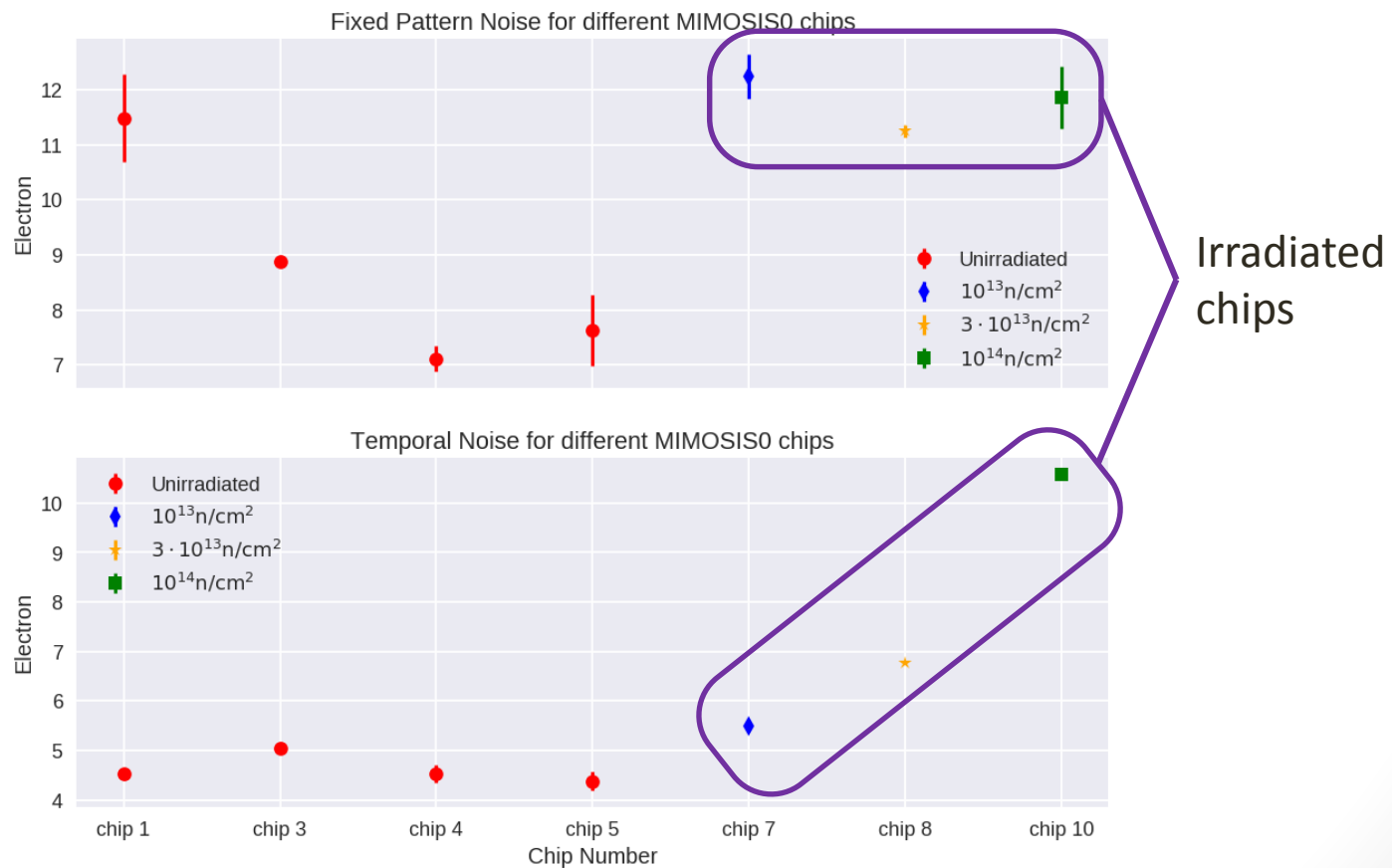


- Cluster size in function of threshold



MIMOSIS0: preliminary results

- Temporal Noise and Fixed Pattern Noise after Irradiation



Conclusion

- Close collaboration between IPHC and IKF for tests and design
- Tests:
 - Preliminary results of MIMOSIS0 are encouraging
 - AC coupled pixels are promising
 - Good accordance between tests from MIMOSIS0 and CE18 chips family
- Design:
 - MIMOSIS0 has validated a part of digital readout of MIMOSIS1
 - Digital periphery is under development → no showstopper seen
- Next steps:
 - Continuing heavy testing (radiations) of MIMOSIS0 and CE18 chips family
 - Finalize design of MIMOSIS1 which will be very closed to the final sensors