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THE MICRO VERTEX DETECTOR OF CBM

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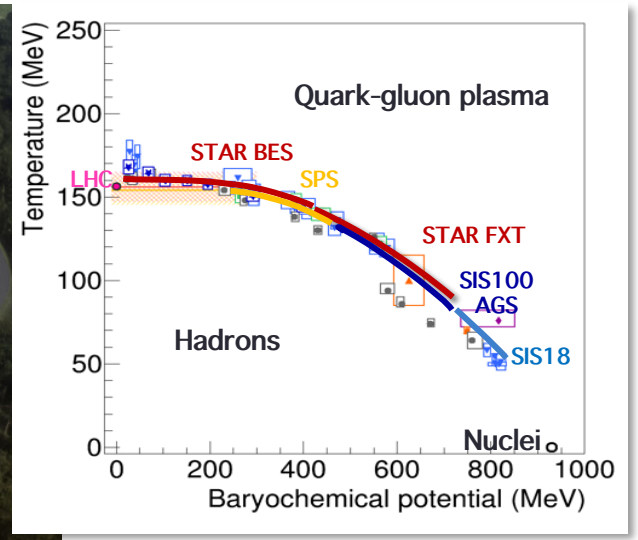
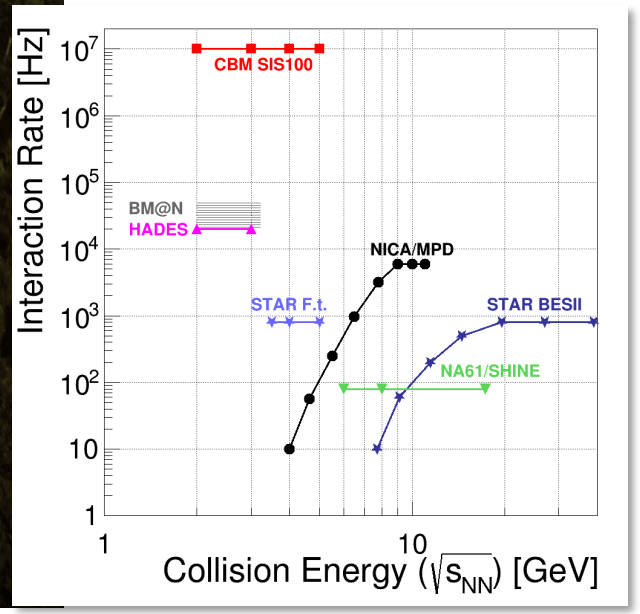
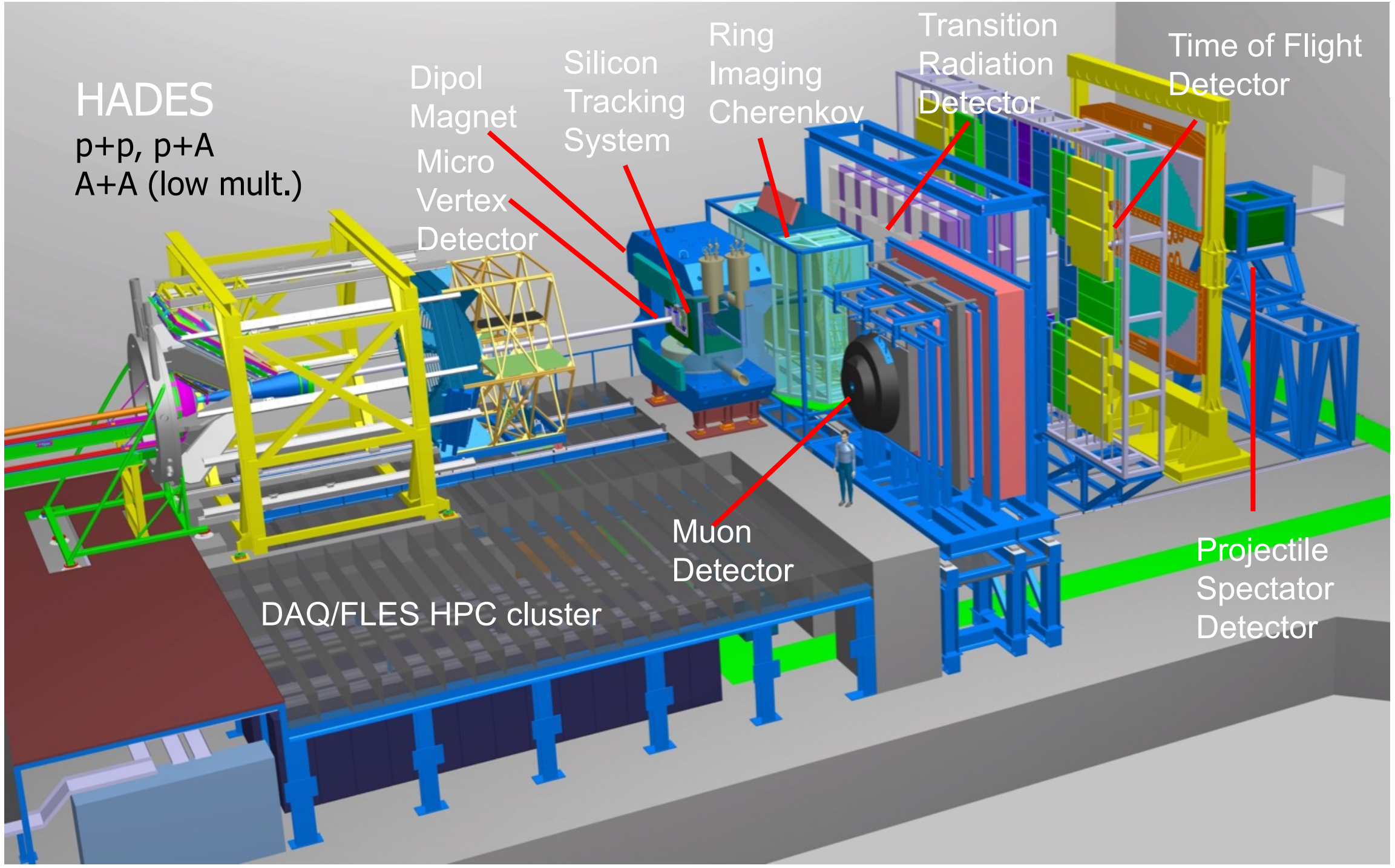
Goethe University Frankfurt / GSI
56th Winter Meeting on Nuclear Physics, Bormio,
January 23rd, 2018

THE CBM EXPERIMENT

The Compressed Baryonic Matter Program at FAIR






HADES
p+p, p+A
A+A (low mult.)
Dipol Magnet
Micro Vertex Detector
Silicon Tracking System
Ring Imaging Cherenkov
Transition Radiation Detector
Time of Flight Detector
Muon Detector
Projectile Spectator Detector
DAQ/FLES HPC cluster

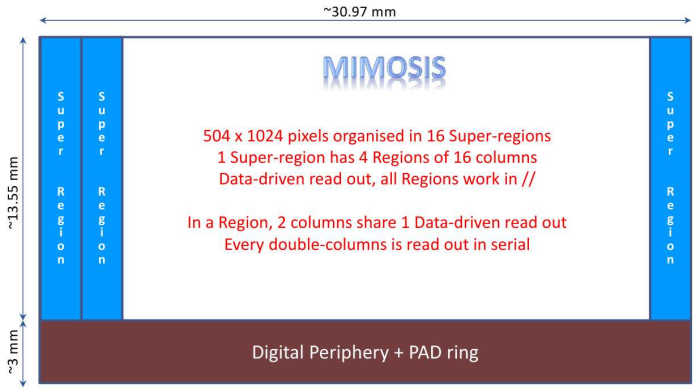
The CBM strategy

- 10^5 - 10^7 Au+Au reactions/sec
- determination of displaced vertices ($\sigma \approx 50\ \mu m$)
- identification of leptons and hadrons
- fast and radiation hard detectors and FEE
- free-streaming readout electronics
- high speed data acquisition and online event selection
- 4-D event reconstruction

MAPS BASED MVD

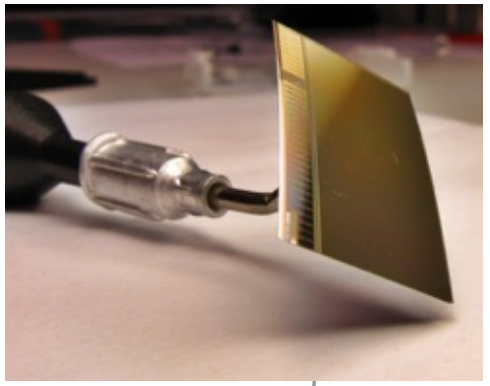
The Micro Vertex Detector

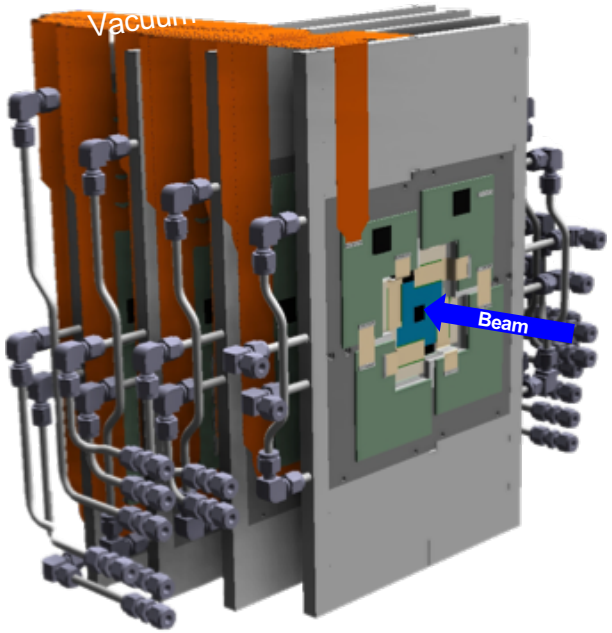
Monolithic Active Pixel Sensor



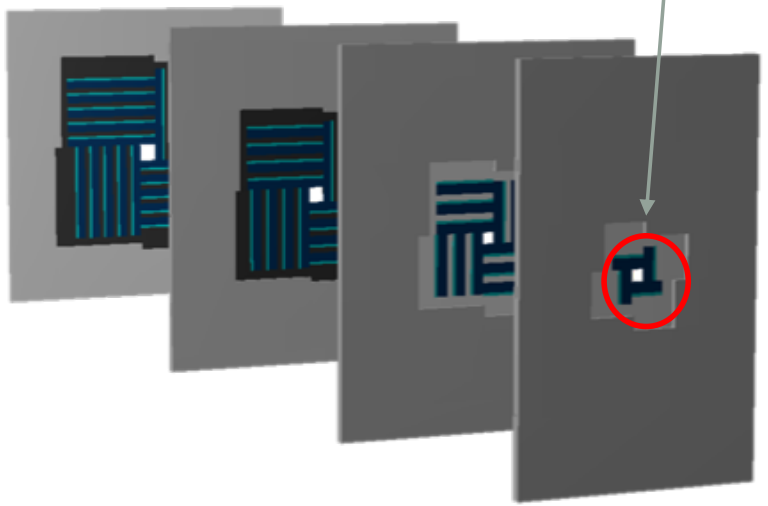
Commercial CMOS process
(180 nm TOWER-JAZZ)

Thinned down to about 50 μm.





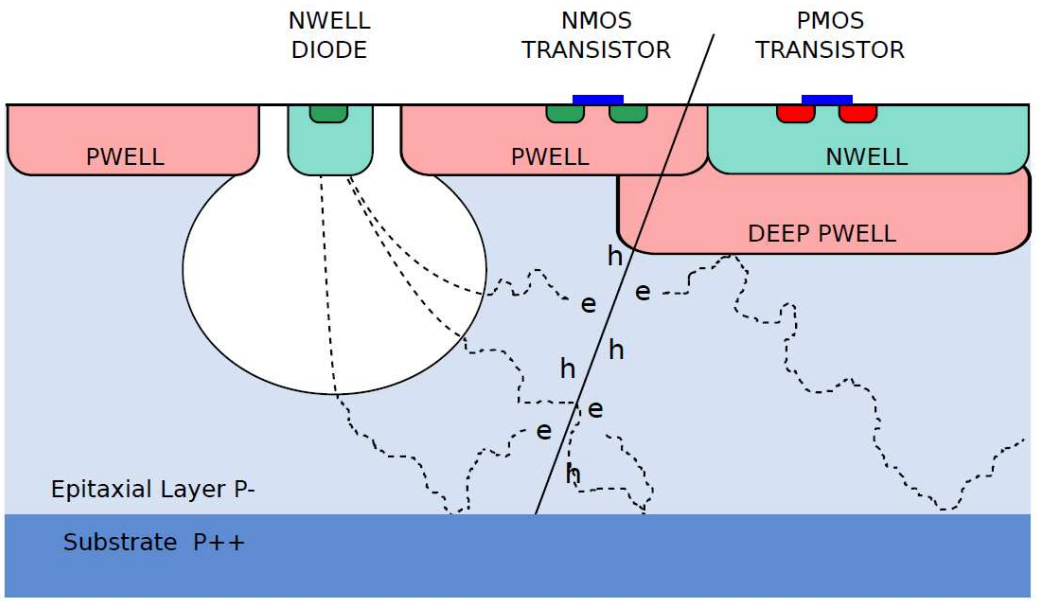
Placed inside vacuum

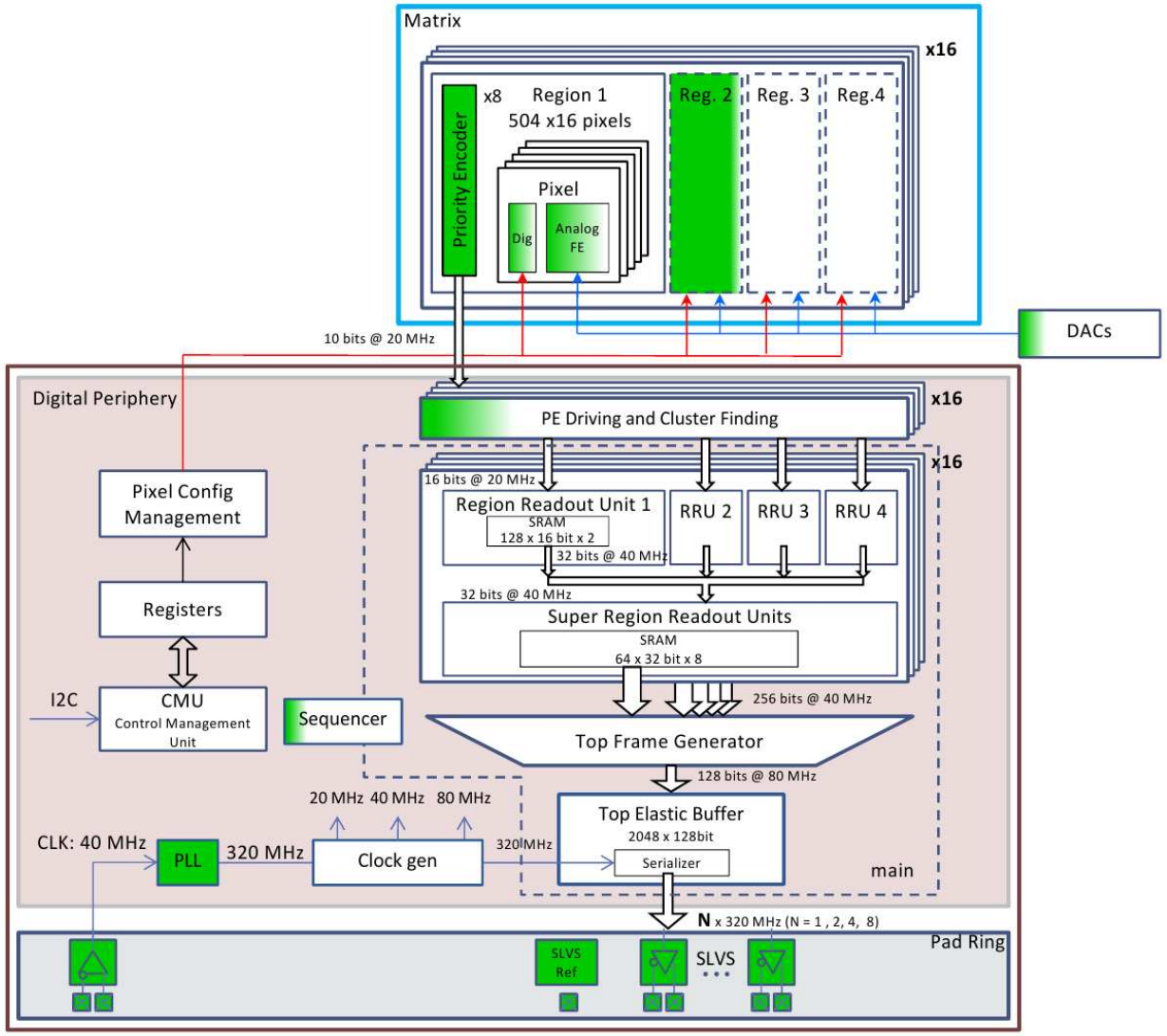


Integrated on CVD diamond and TPG.

Lateral heat evacuation and stability

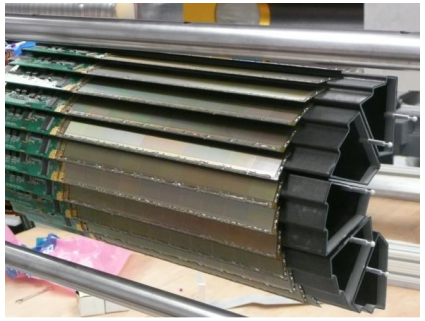
MIMOSIS Principle of Operation





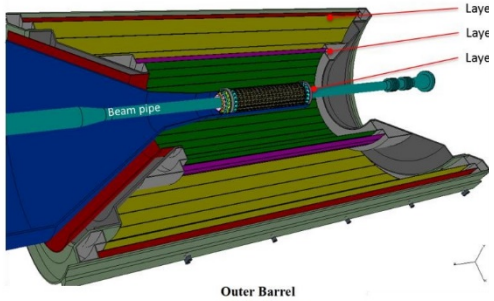
- Pixel dimension: 26.88 μm x 30.24 μm
- Full signal processing micro-circuitry integrated on chip (low noise !)
- Verymodestmaterialbudget:~0.05%X0
- Binary charge encoding often sufficient for O(μm) position resolution
- Data driven read-out (320 Mbit/s)

Applications of MAPS



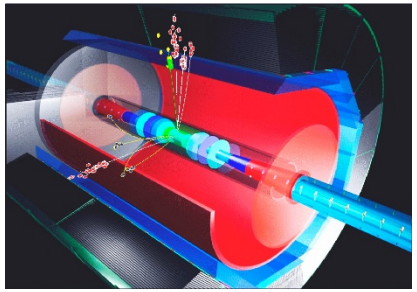
running

STAR HFT



ALICE ITS upgrade

ILC

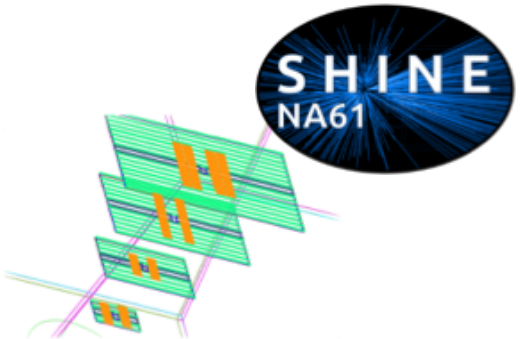


2008 2014 2016 2018 2020 2022 2024

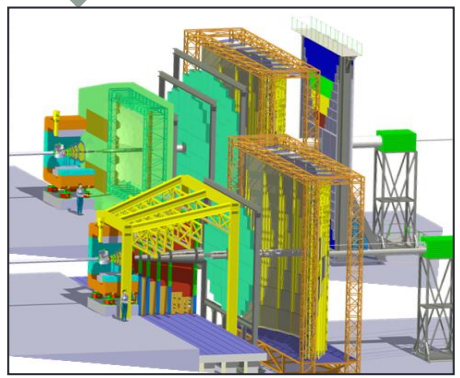
running

EUDet Telescope

running



NA61 SAVD



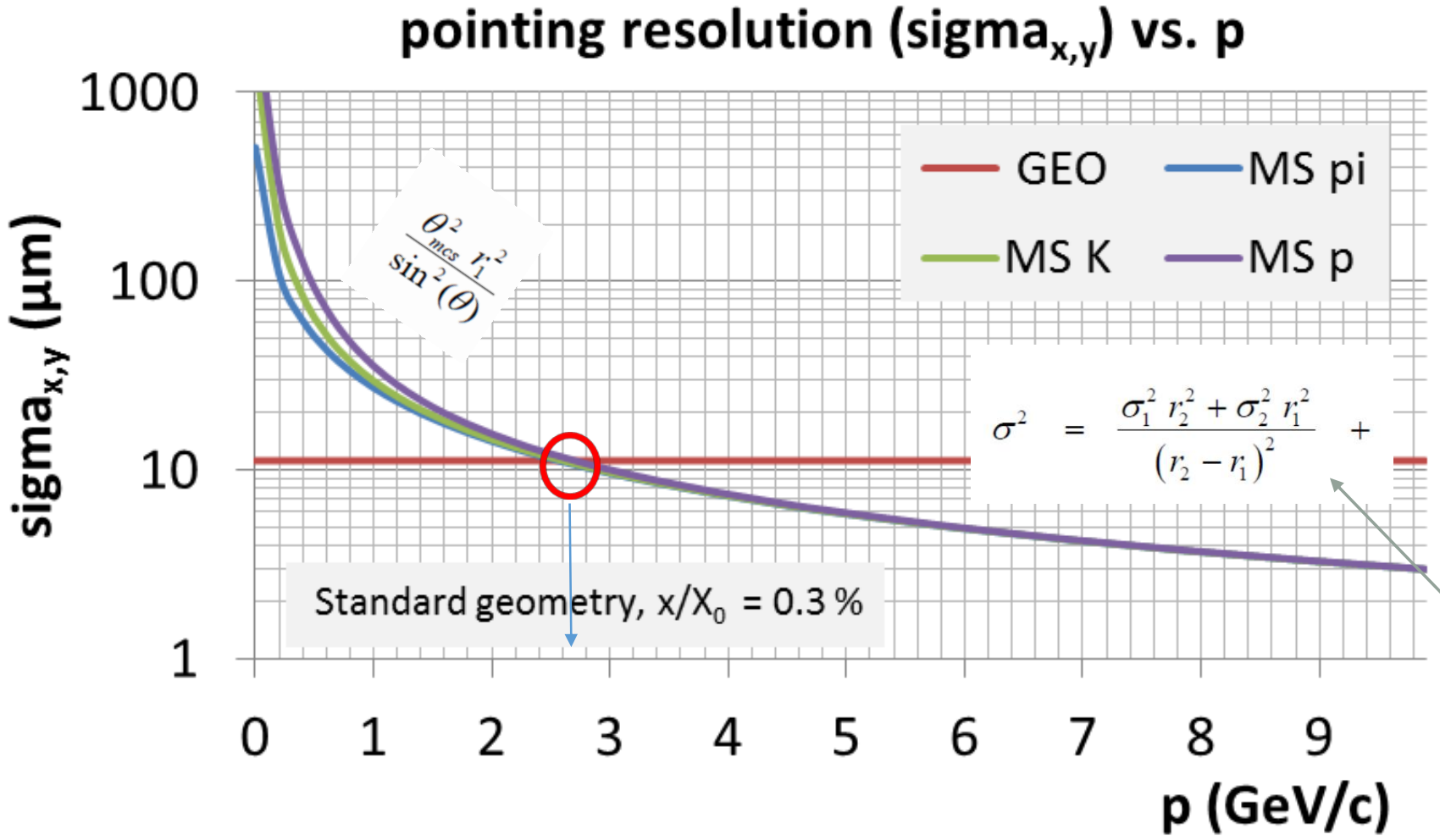
CBM - MVD

CBM-MVD Sensor Requirements

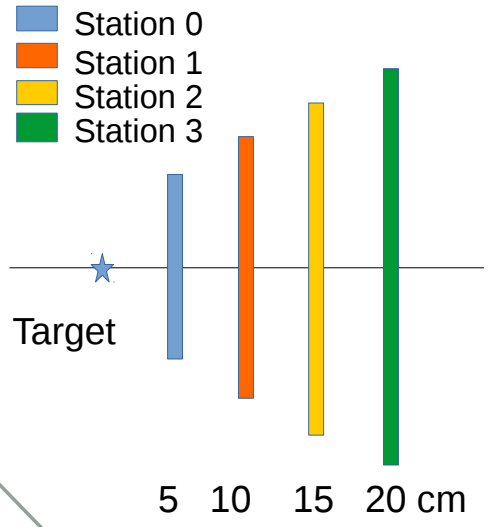
	ALPIDE (demonstrated)	MIMOSIS (MVD design goal)	Factor
Ion. Rad. Tolerance	0.3 Mrad	> 3 Mrad	10
Non. Io. Tolerance	10^{13} n_{eq}/cm^2	> $3x10^{13}$ n_{eq}/cm^2	3
Heavy ion tolerance	N/A	1 kHz / cm^2	--
Time resolution	~10 µs	5 µs	2
Data rate (internal)	~0.8 Gbps	20 Gbps	25
Data rate (external)	0.8 Gbps	2.5 Gbps	3
Data reduction	Trigger	Elastic buffer	--
GBTx compatible	No	Yes	--

INTEGRATION

Detector Configuration

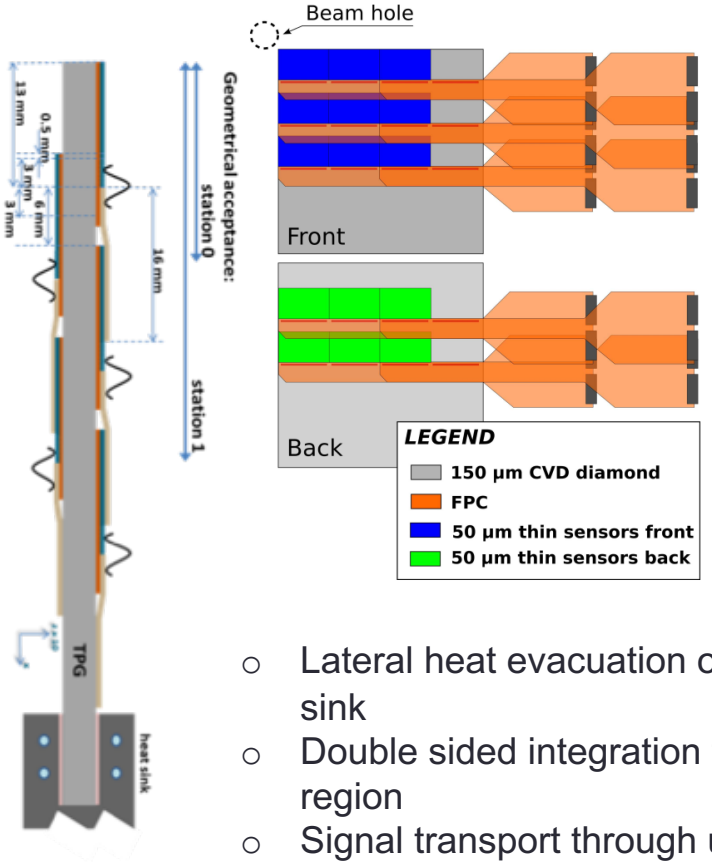


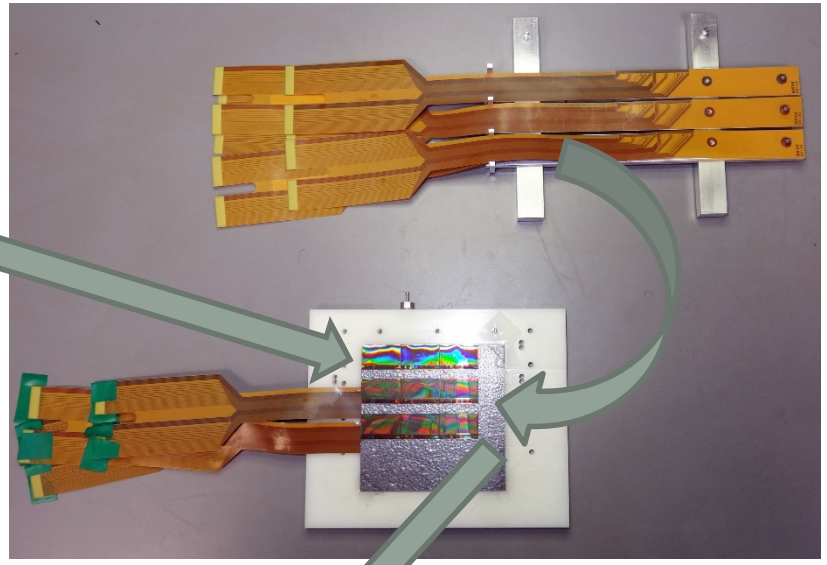
$$\theta_{MS} = \frac{10/MeV}{\beta\ p/GeV}\sqrt{\frac{X}{X_0}}\ \text{mrad}$$

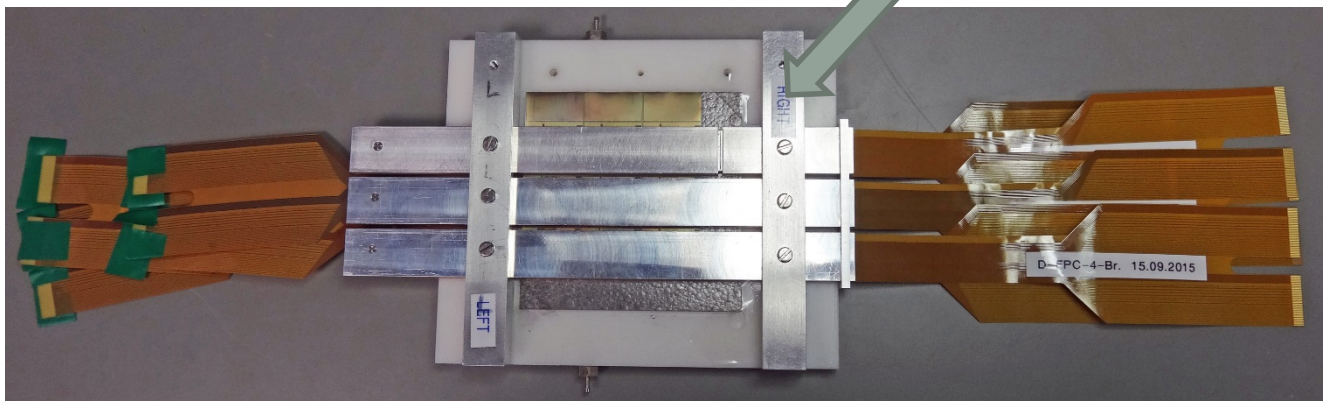


Approximate formular for the two nearest stations

Prototyping (double-sided integration)

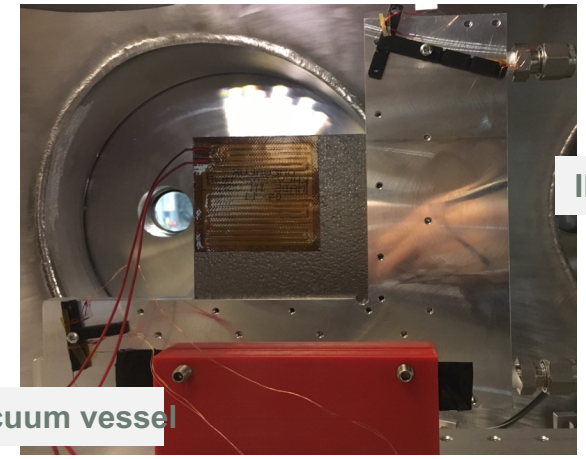


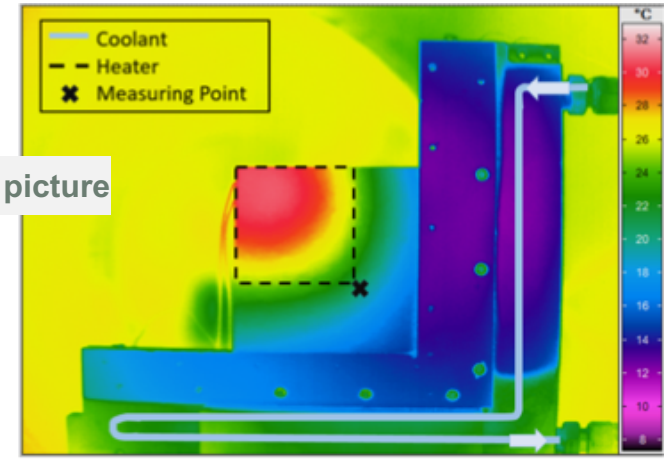


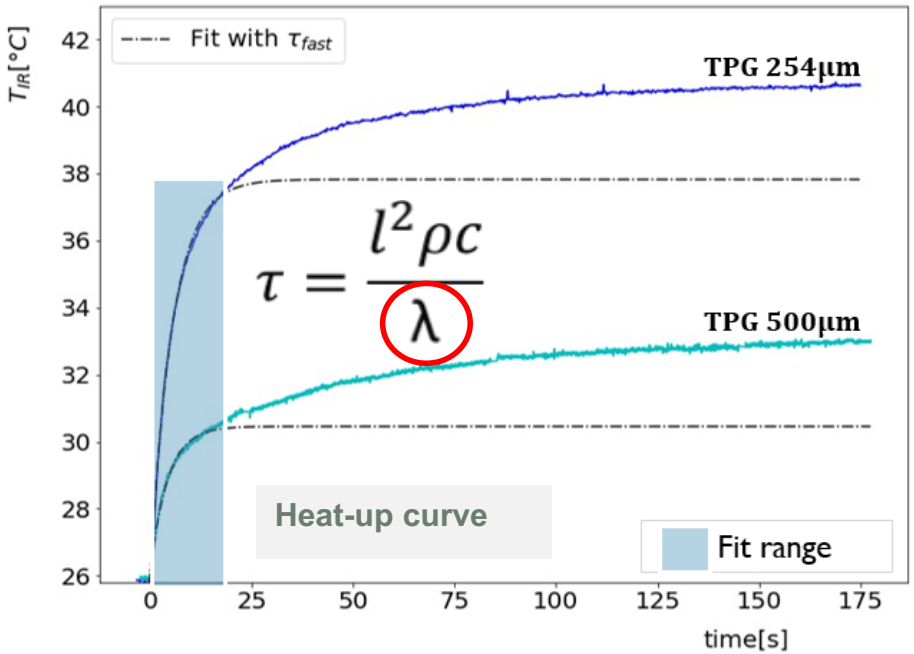


- Lateral heat evacuation on thin sheets to heat sink
- Double sided integration to avoid inactive region
- Signal transport through ultra-thin flex prints

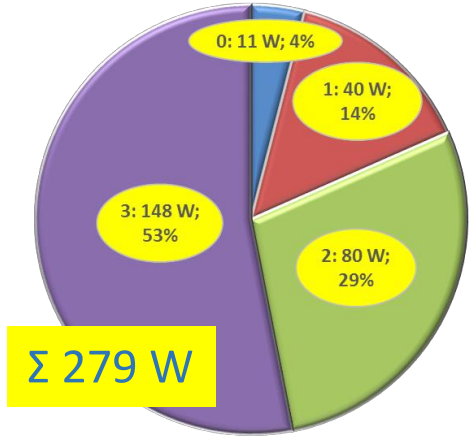
Cooling Performance







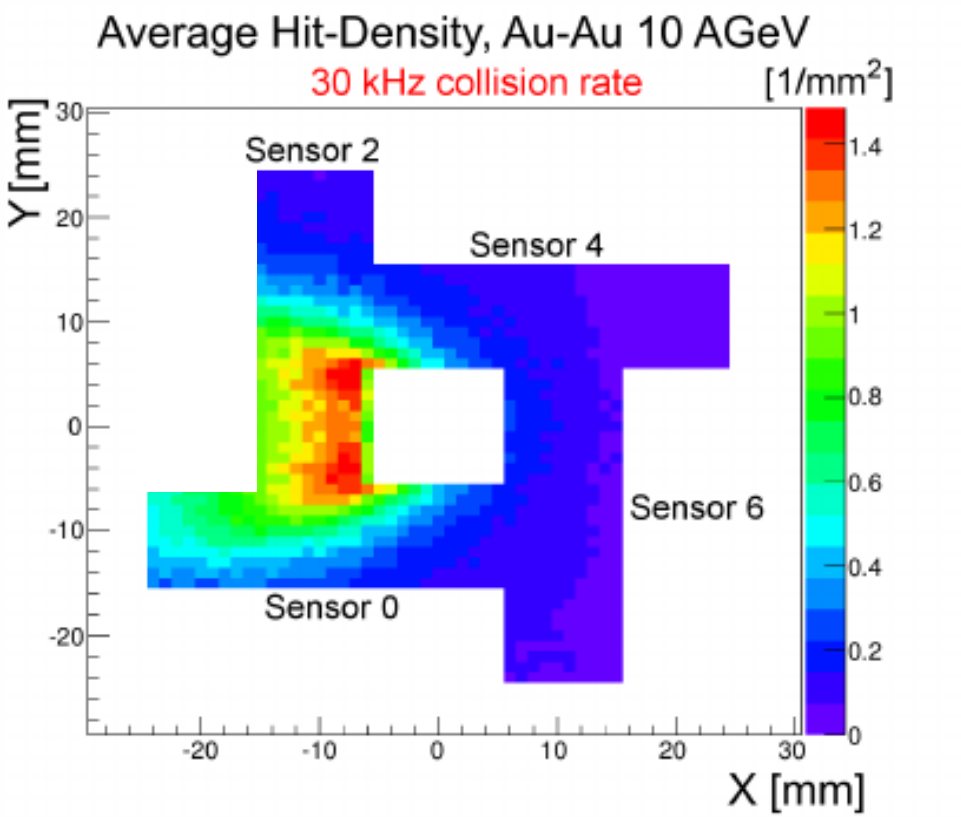
- Setup: MVD geometry & thermal heaters, vacuum
- IR: Thermal relaxation times & temperature differences
- 280 W total heat dissipation

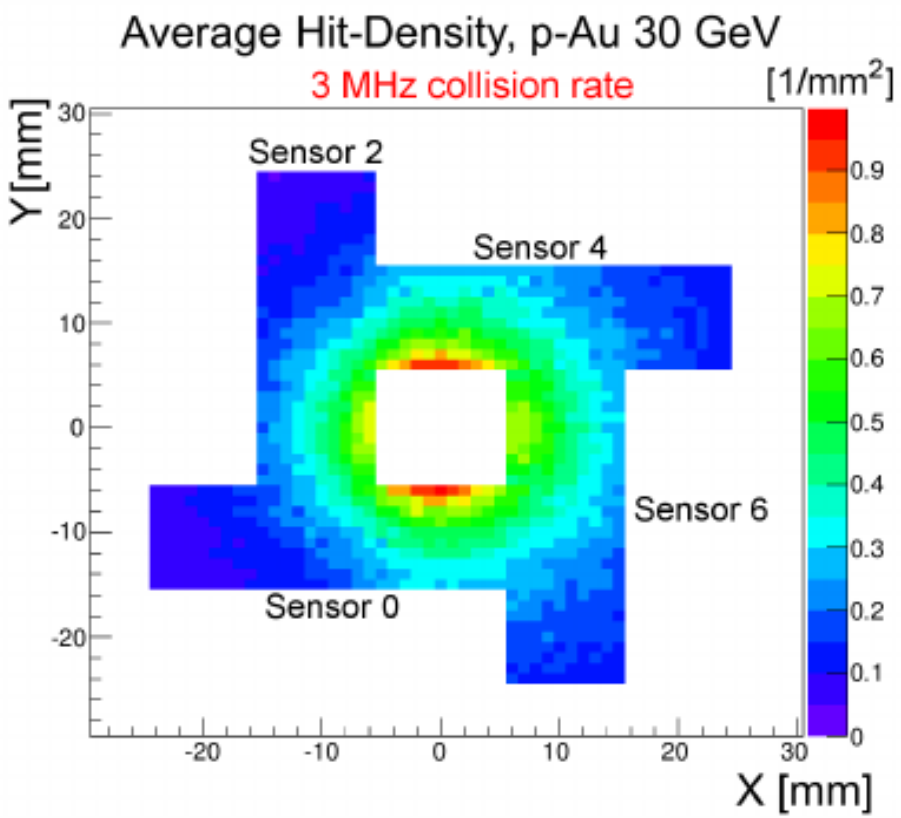


RADIATION HARDNESS

Occupancy

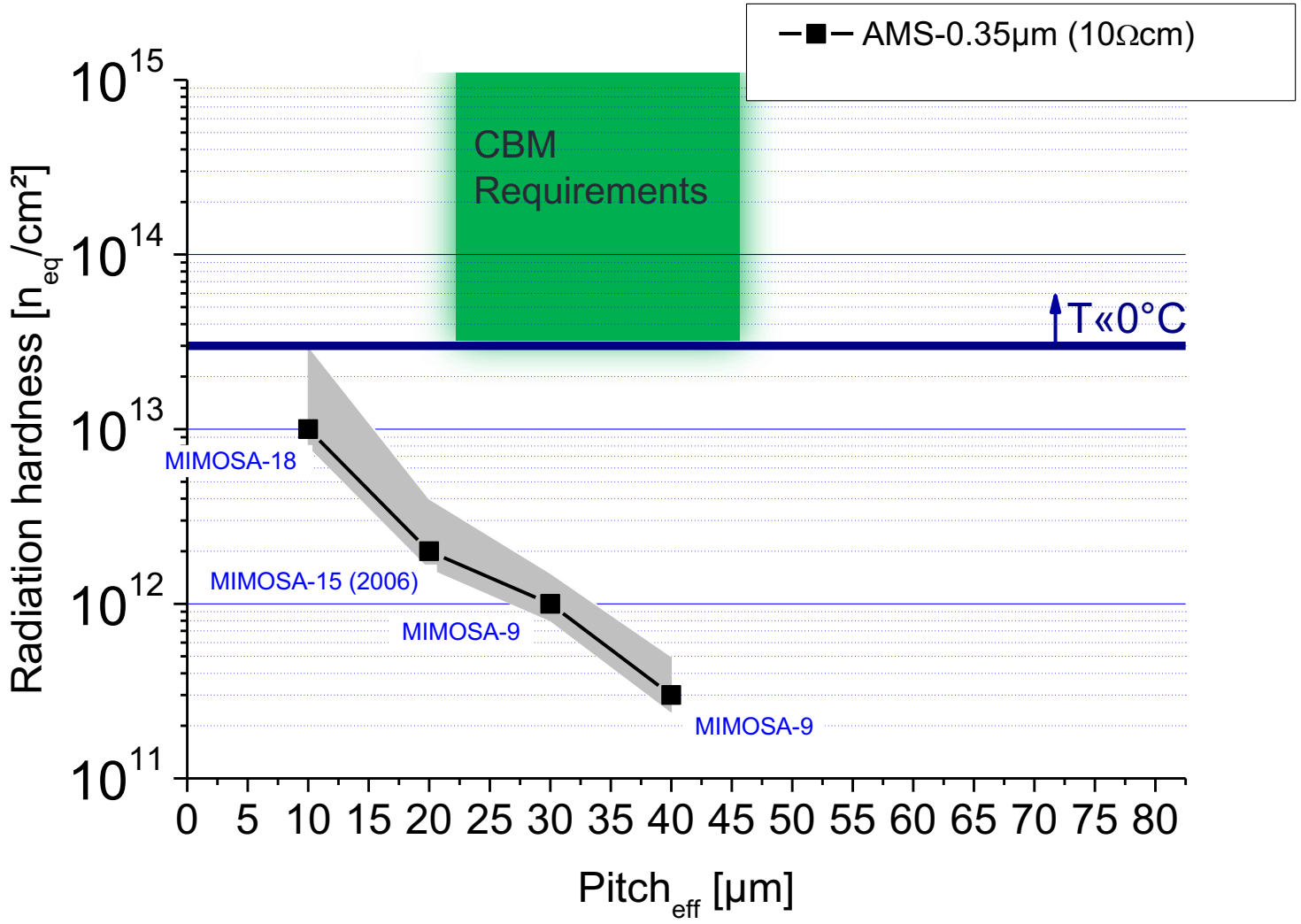
Two running scenarios. Substantial load due to δ-electrons in case of Au+Au





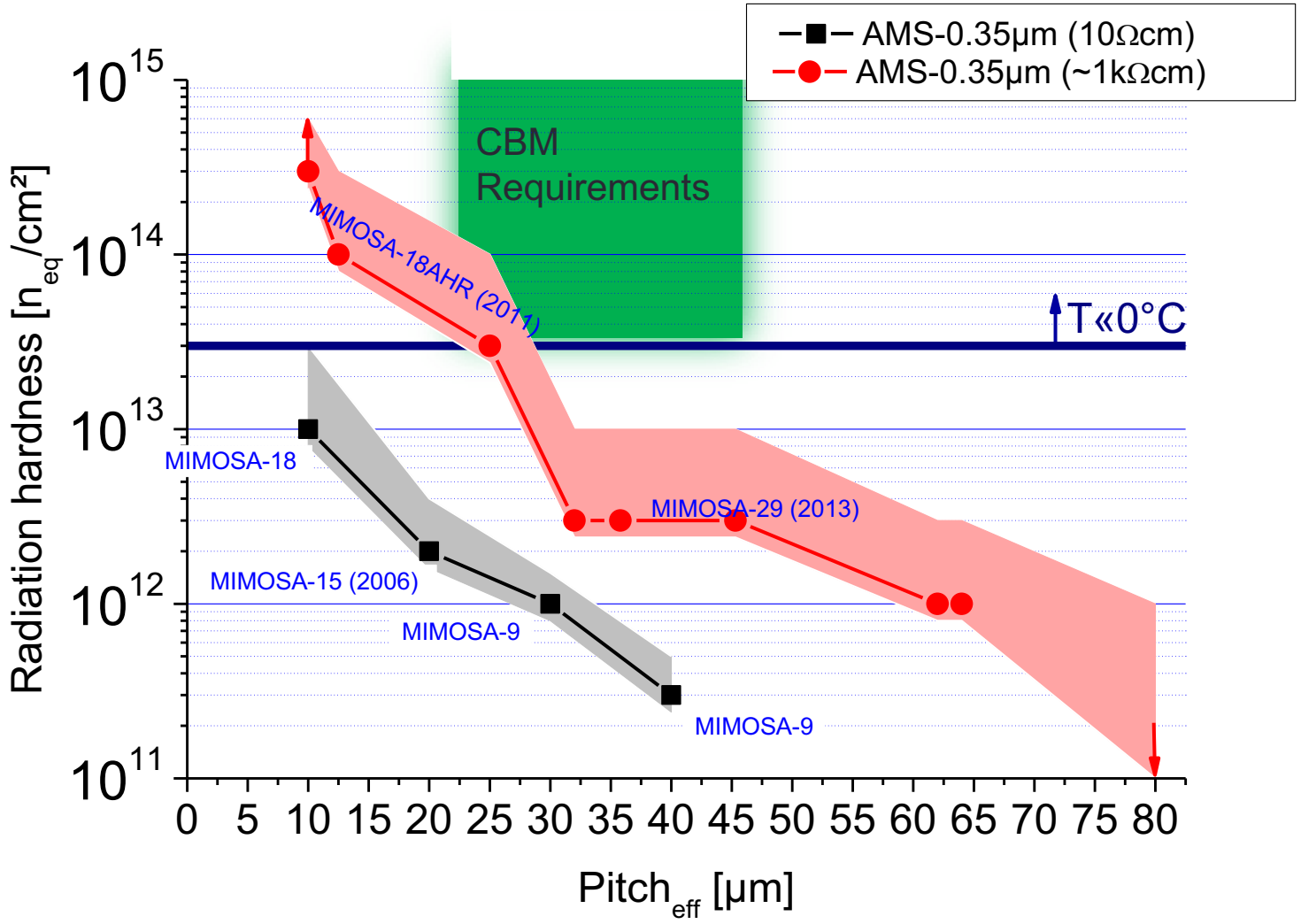
1230 pixel/mm^2

Established knowledge on radiation tolerance 2006



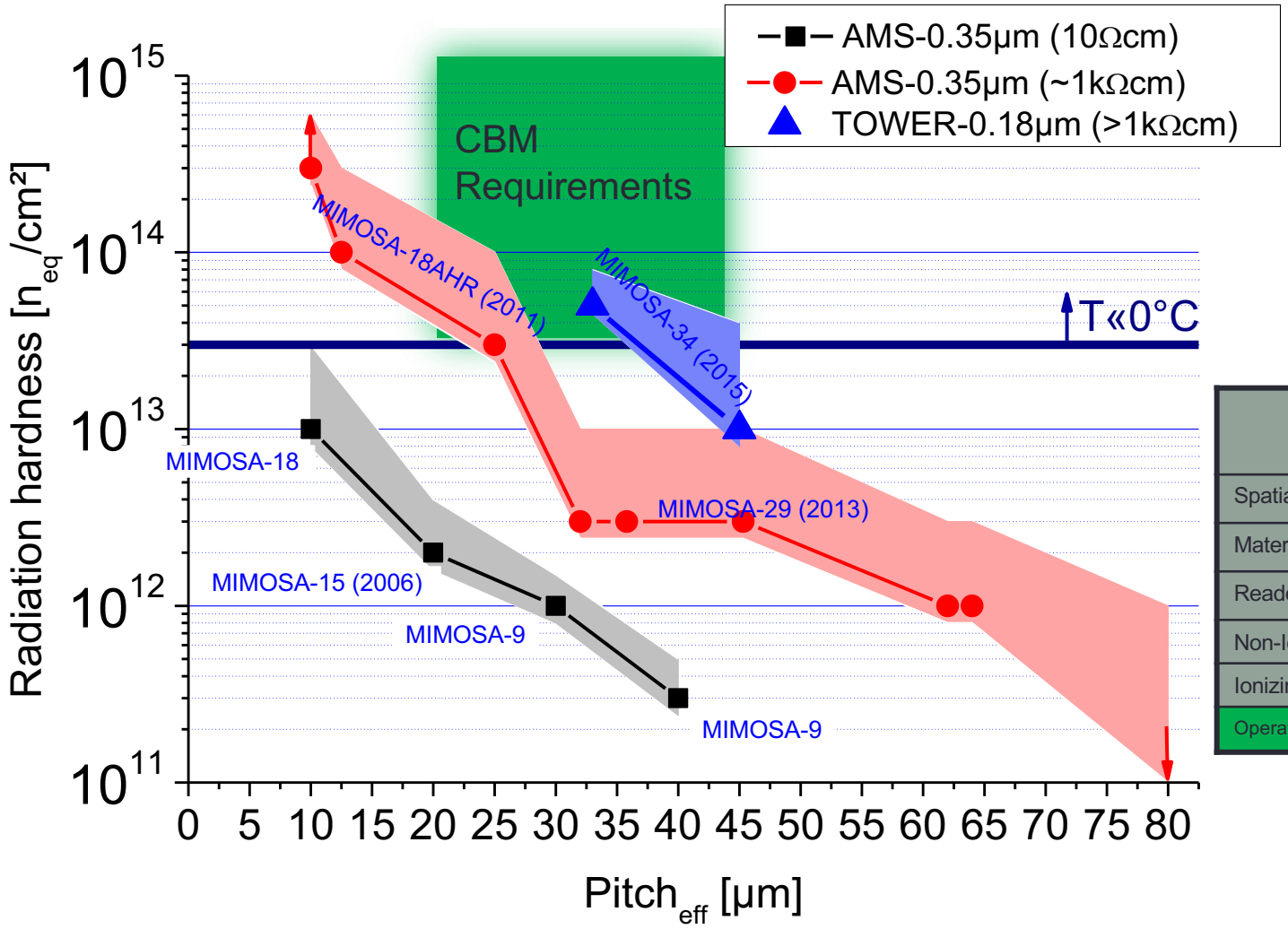
„standard“

Established knowledge on radiation tolerance 2013



High resistivity epitaxial layer

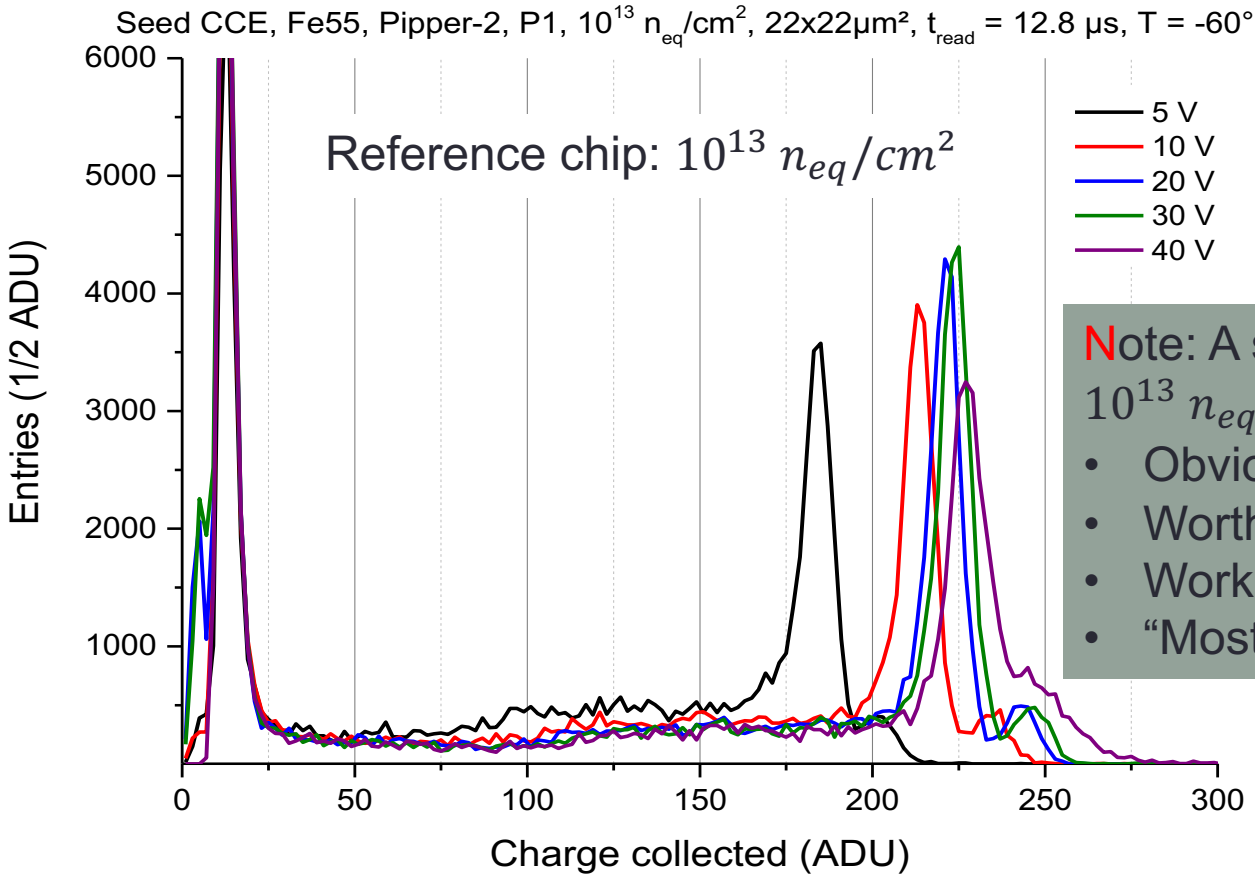
Established knowledge on radiation tolerance 2015



High-res & smaller feature size

	CBM Req.
Spatial resolution [µm]	5 - 10
Material budget [X_0]	< 0,05%
Readout speed [kfps]	> 30
Non-Ionizing rad. hardness[n_{eq}/cm^2]	$>3*10^{13}$
Ionizing radiation hardness [krad]	> 3 000
Operation in vacuum & magnetic field	

Apply voltage to the collecting diode



Note: A sensor irradiated to $10^{13}\ n_{eq}/cm^2$ is considered as:

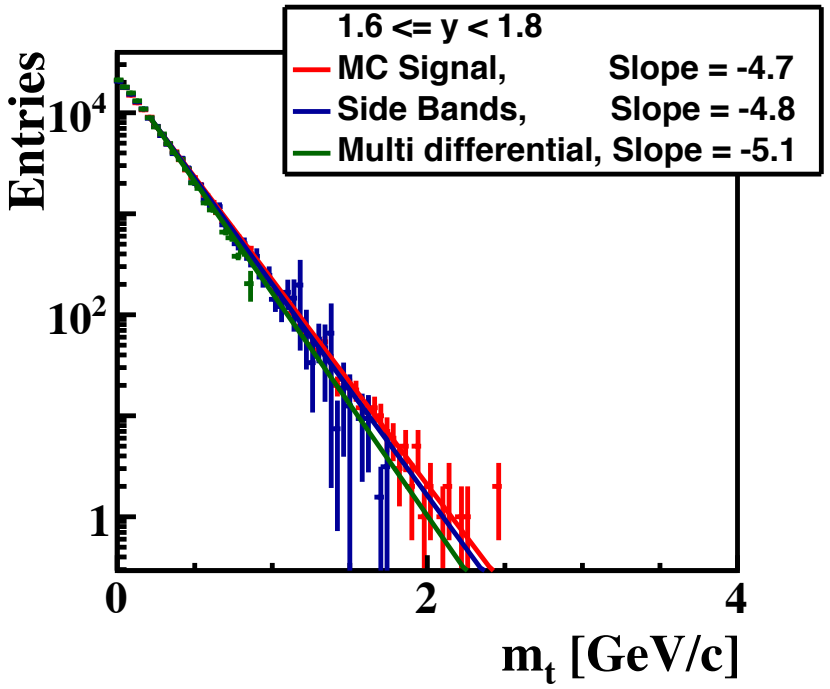
- Obviously destroyed (2003)
- Worth testing (2007)
- Working reasonably (2010)
- “Mostly not irradiated” (2017)

Sensor seems fully depleted after 5-10 V.
No charge sharing
=> Need ~17µm x 17µm pixel pitch to obtain CBM resolution.

PERFORMANCE

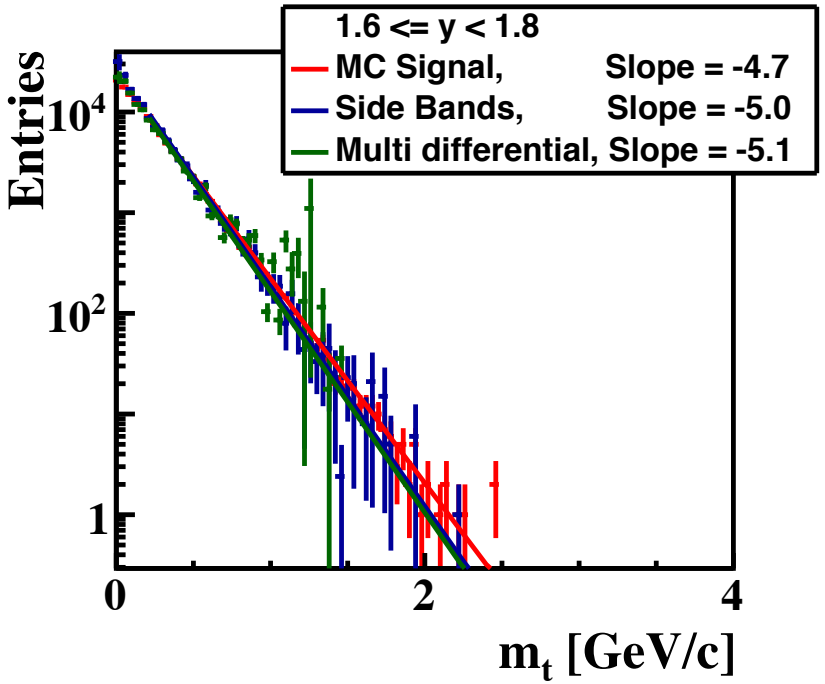
Alternative Ξ^- Reconstruction

conventional

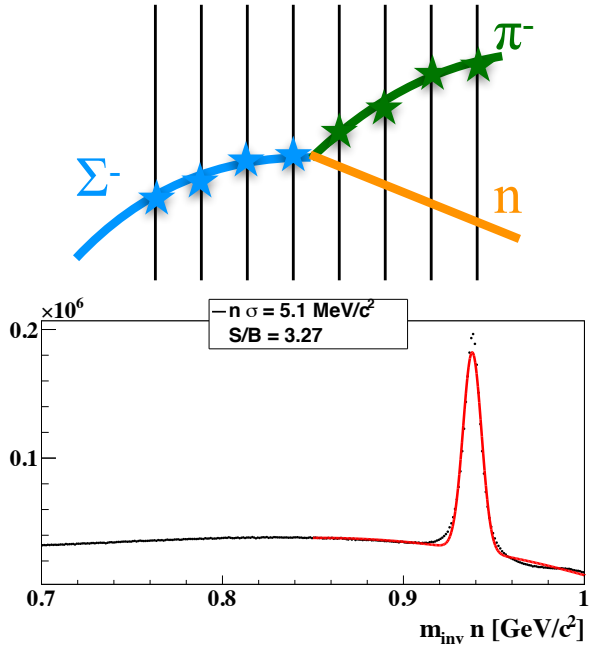


$\Xi^- \rightarrow \Lambda + \pi^- \rightarrow p + \pi^- + \pi^-$

M^3



$\Xi^- \rightarrow \Lambda_{\text{missing}} + \pi^-$



Thank You for Your Attention

&

and Marc Winter's team from