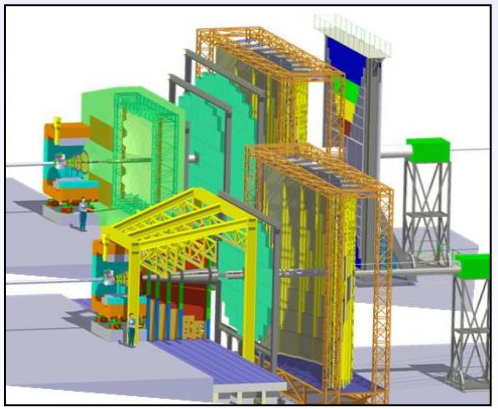
Open charm measurements with CBM

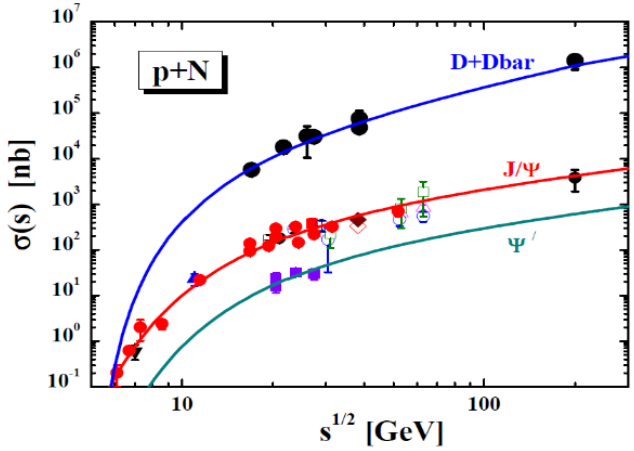
M. Deveaux, Goethe University Frankfurt
on behalf of the CBM collaboration.



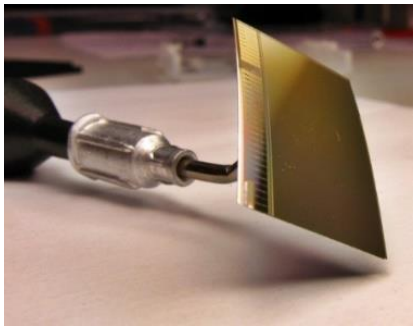
Outline

Physics goals of CBM on open charm

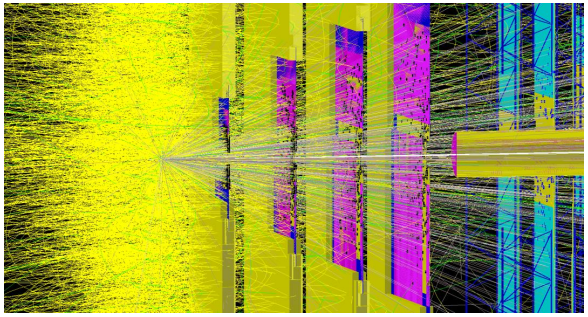
(Physics goals of CBM on charmonium
=> See talk of P.P. Bhaduri)



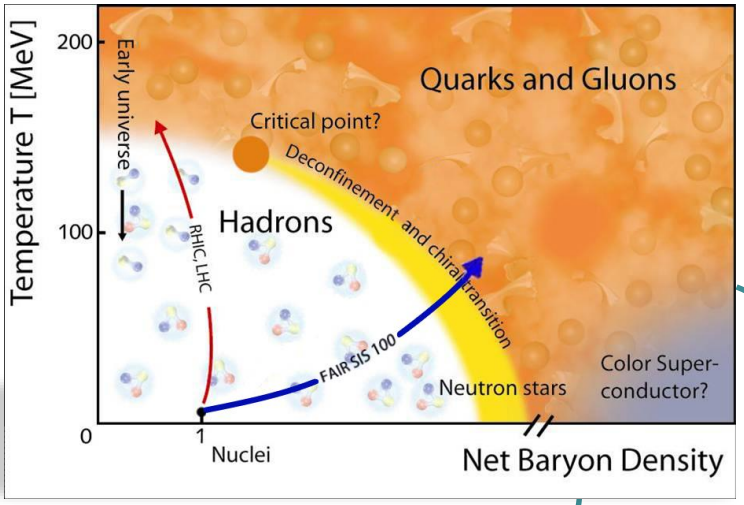
Status of the detector R&D.

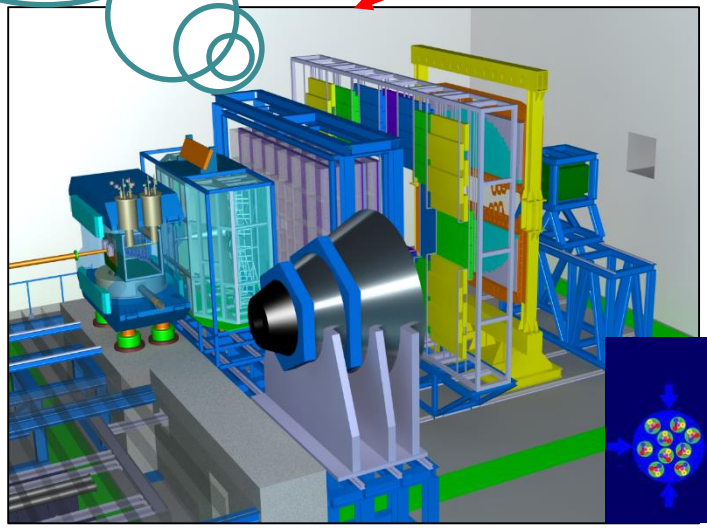


Status of the feasibility studies.



CBM @ FAIR



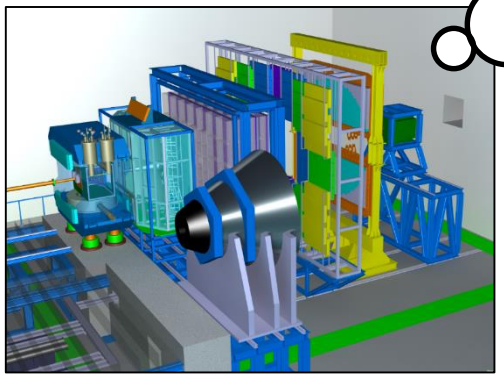


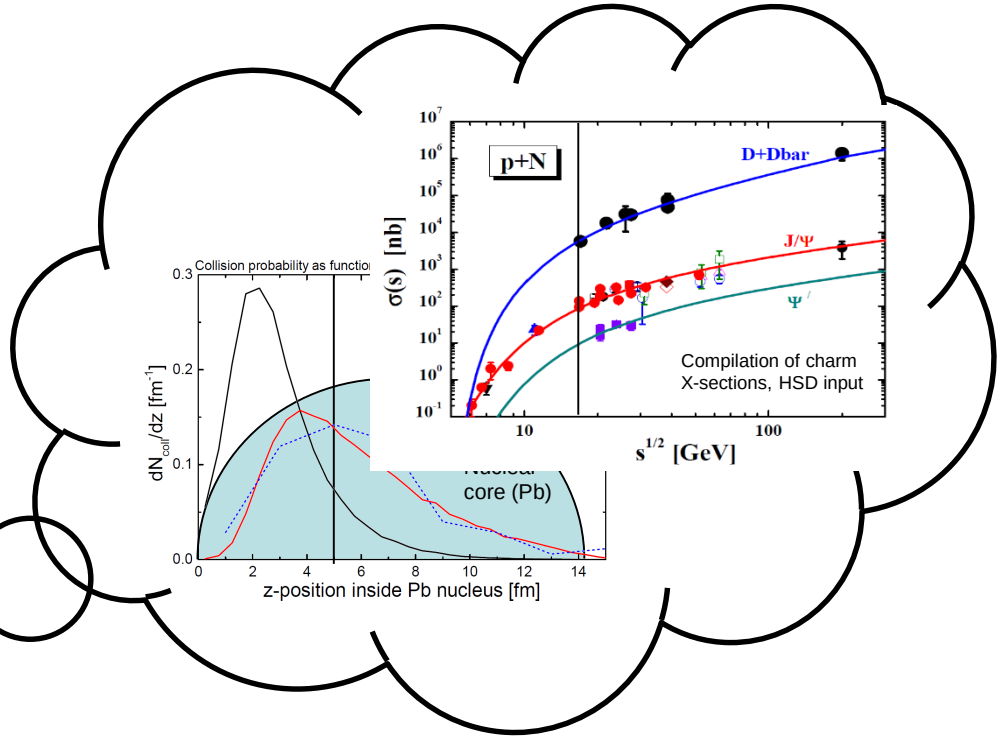
CBM:

- Explore phase diagram at ragion of highest net-baryon density.
- Use rare probes.

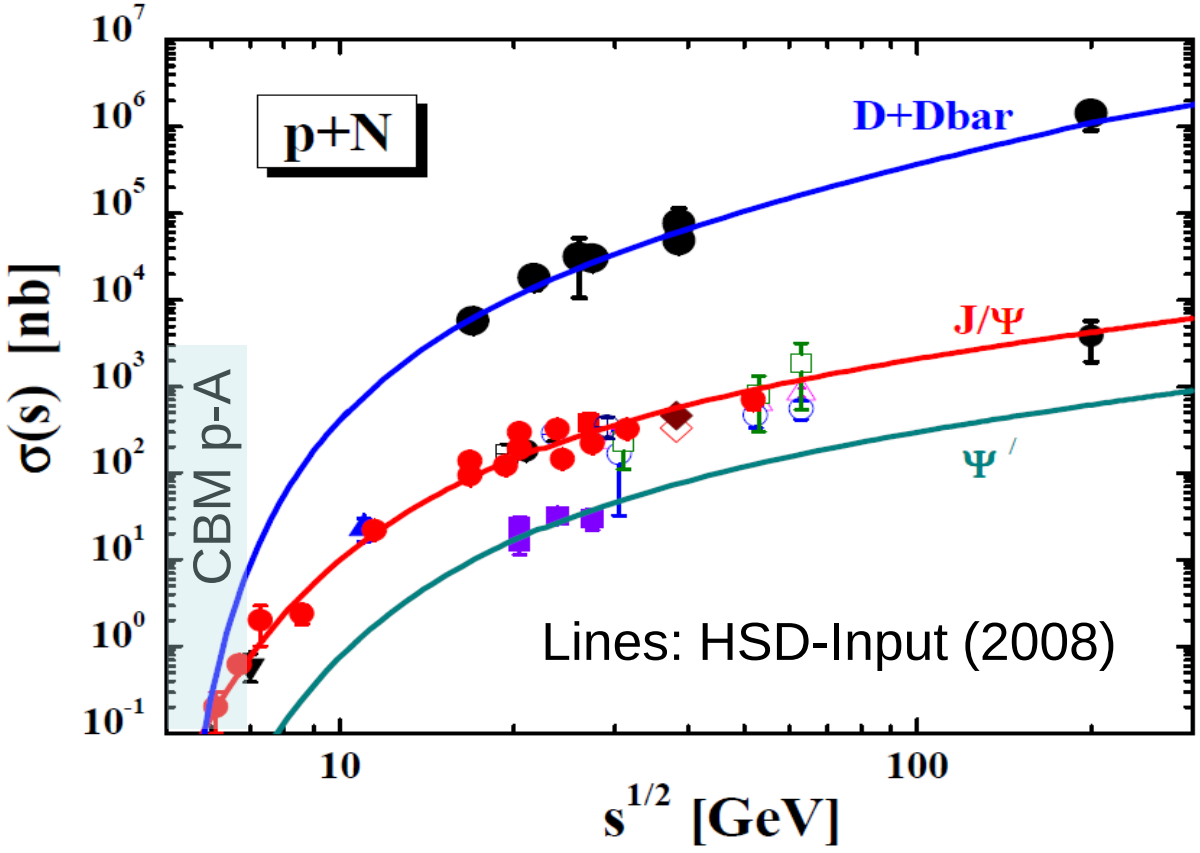
The Compressed Baryonic Matter experiment

Physics cases of open charm in CBM





Open charm physics at CBM – basic issues



Mission 1:

- Measure and understand the formation of charmed particles near threshold in p-p (=Be) and p + A.

=> Back up charmonium measurements (see talk of P.P. Bhaduri)

Sub-threshold charm production?

J. Steinheimer, A. Botvina and M. Bleicher, Phys. Rev. C 95, no. 1, 014911 (2017)

Idea:

- Add heavy resonances → to UrQMD.
- Allow decay $N^* \rightarrow (c + \bar{c}) + N$
- Fix free parameters with data:

$$p + p \rightarrow J/\psi + X \; @ \; \sqrt{S_{pp}} = 6.7 \; GeV$$

TABLE II. Newly introduced baryonic resonances.

Name	Mass [GeV]	Width [GeV]	Spin
$N^*(2600)$	2.600	0.65	11/2
$N^*(2700)$	2.700	0.40	13/2
$N^*(3100)$	3.100	1.30	15/2
$N^*(3500)$	3.500	1.30	17/2
$N^*(3800)$	3.800	1.30	17/2
$N^*(4600)$	4.600	1.30	19/2
$\Delta^*(2420)$	2.420	0.40	11/2
$\Delta^*(2750)$	2.750	0.40	13/2
$\Delta^*(2950)$	2.950	0.50	15/2
$\Delta^*(3300)$	3.300	1.00	17/2
$\Delta^*(3500)$	3.500	1.00	19/2
$\Delta^*(3700)$	3.700	1.00	19/2
$\Delta^*(4200)$	4.600	1.00	21/2

Effect:

Accumulate kinetic energy in p-A and A-A collisions, e.g.:

1st collision: $p + N + E_{kin} \rightarrow N^* + X$ (sub $c - \bar{c}$ threshold)

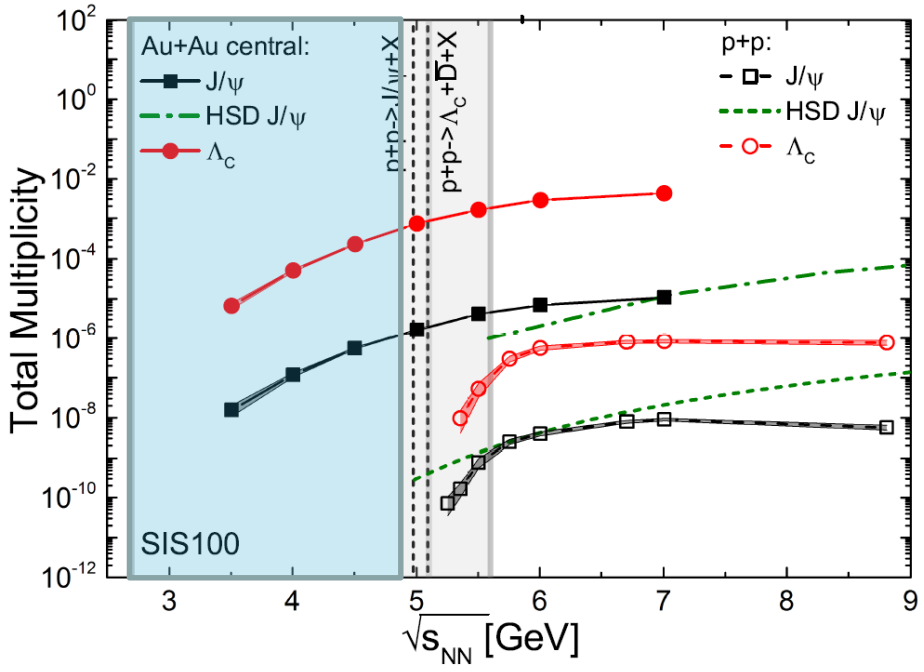
2nd collision: $N^* + N + E'_{kin} \rightarrow (c - \bar{c}) + X$ (above $c - \bar{c}$ threshold)

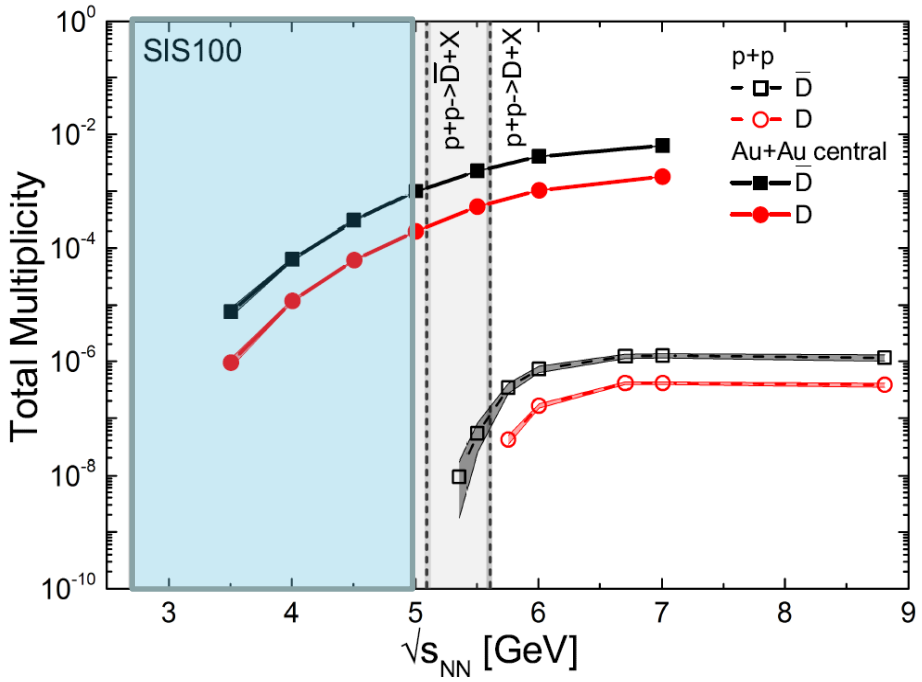
Approach was previously used for strange particles.

Open: Applicable to charm?

→ e.g. J. Steinheimer and M. Bleicher, J. Phys. G 43, no. 1, 015104 (2016)

Effect and results





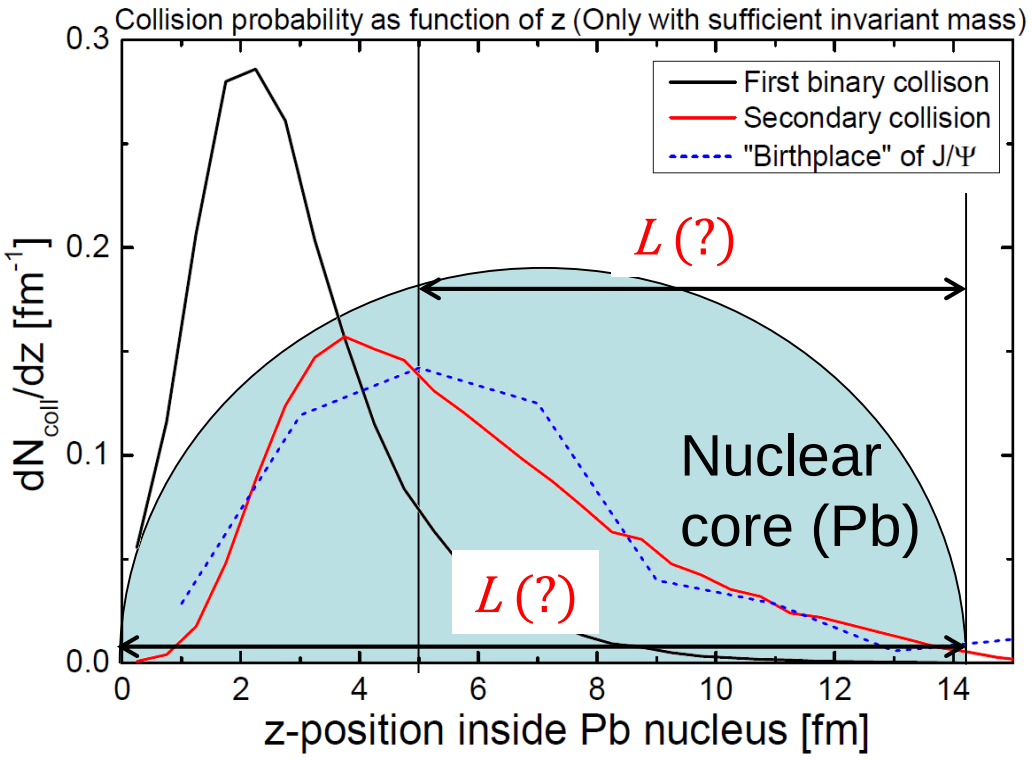
Model predictions:

- Substantial yield of J/Psi and D-mesons
- Yields for SIS100 energy range roughly equal to HSD yields for SIS300.

Model might be confirmed by observing sub threshold charm production with CBM at SIS100.

Impact of „Steinheimer model“

Multi-collisions displace birth of J/Psi by ~5fm @ 15 GeV.



Survival probability

$$\sigma_{diss} = -\frac{\mathrm{Log}[S]}{L \cdot 0.15\ \mathrm{fm}^{-3}}$$

Path of J/Psi in nuclear matter

Note:
L in Equation = Average path
Displayed qualitatively in figure.

J/Psi production by double collision modifies path length of J/Psi in nuclear matter.
=> Bias of dissociation X-section measurement.

Plot and simulation: J. Steinheimer, FIAS

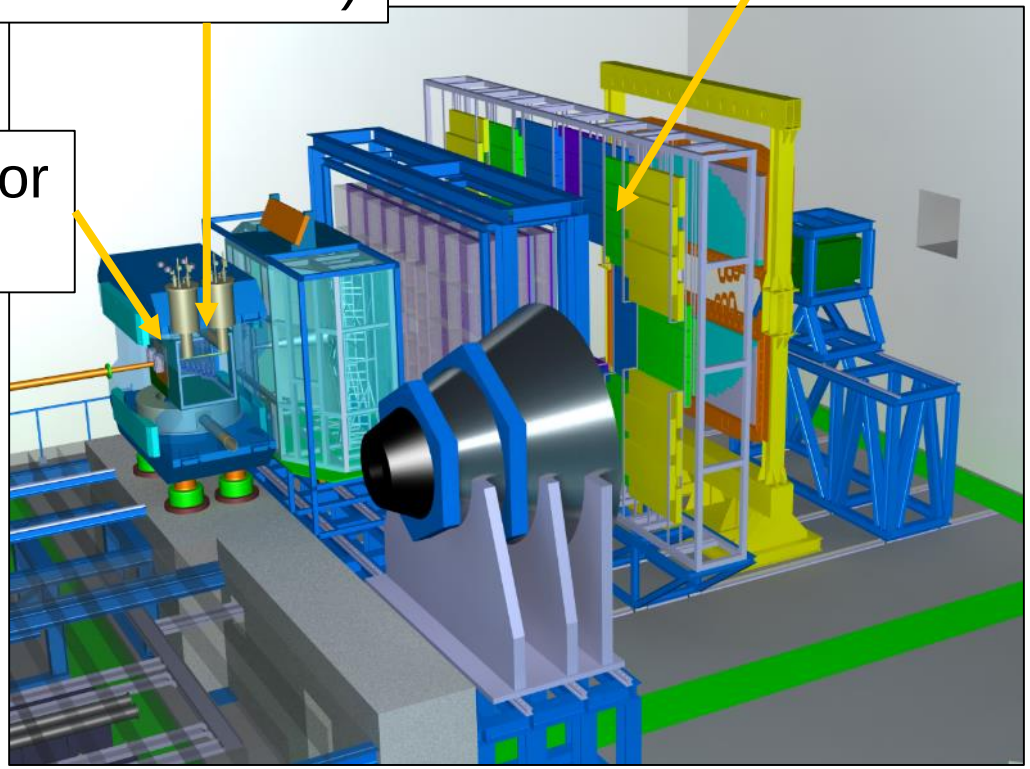
Open Charm Physics at CBM

Instrumentation: Relevant detectors

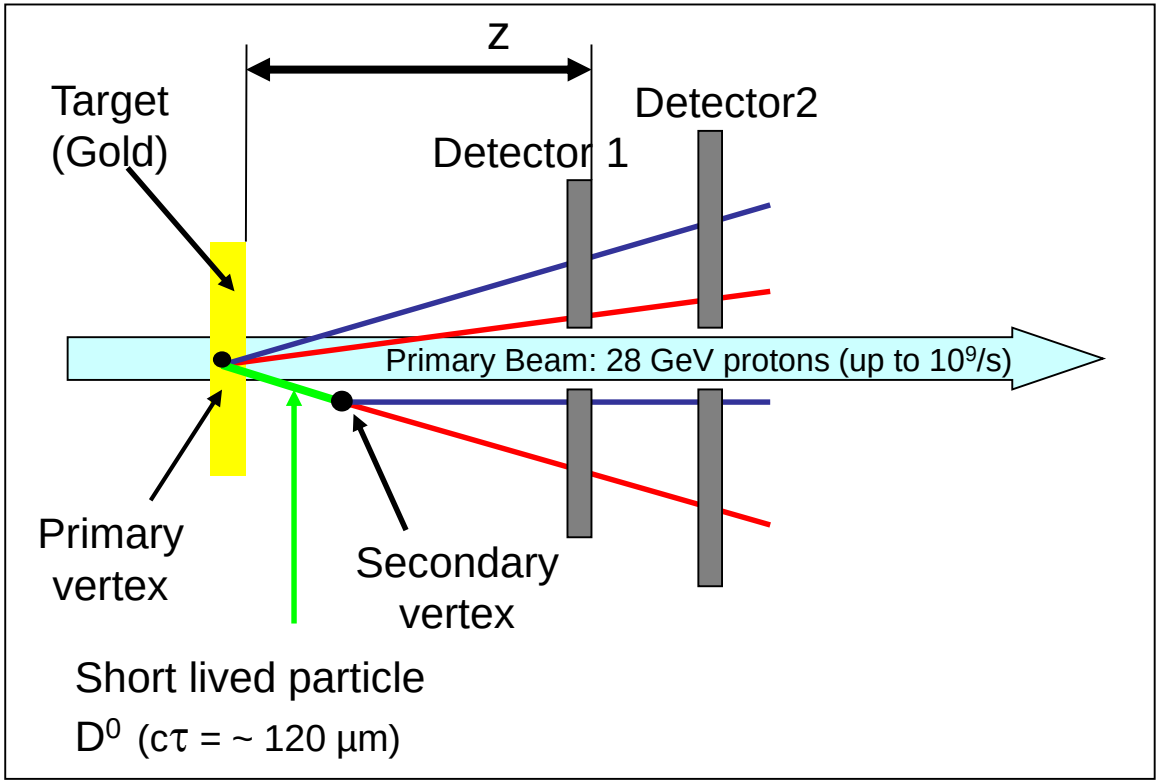
Time of Flight system
(Hadron identification)

Silicon Tracking System
(Momentum measurement)

Micro Vertex Detector
(Vertexing)



How to measure open charm



Reconstructing open charm requires:

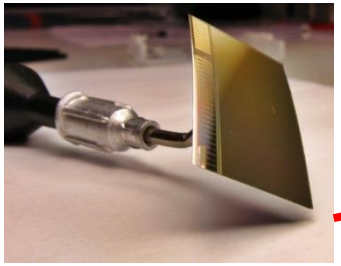
- Excellent secondary vertex resolution (~ 50 µm)

=> Excellent spatial resolution (~5 µm)

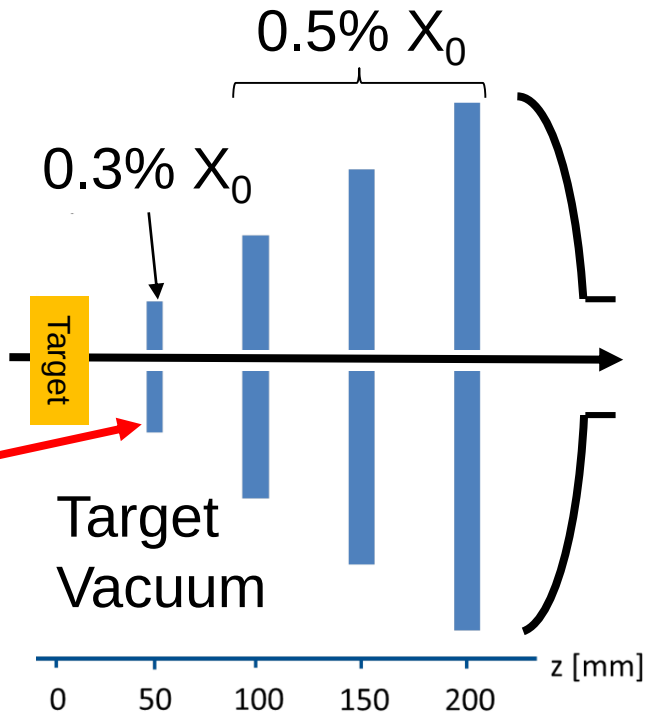
=> Very low material budget (few 0.1 % X_0)

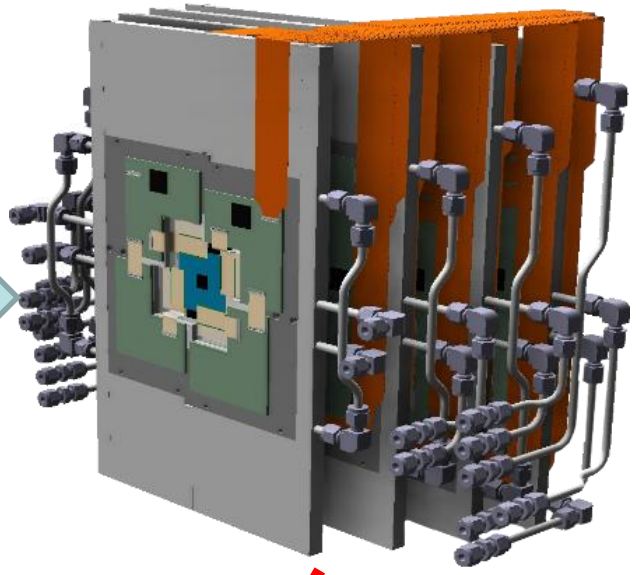
=> Detectors in vacuum

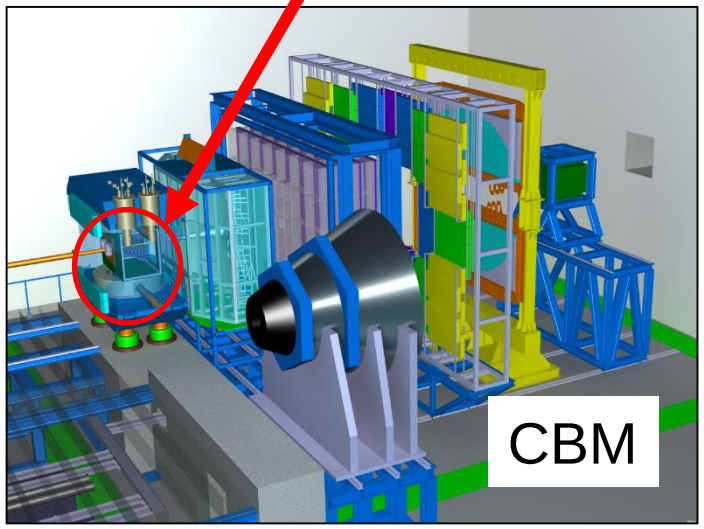
CBM Micro-Vertex-Detector basic concept



CMOS sensor



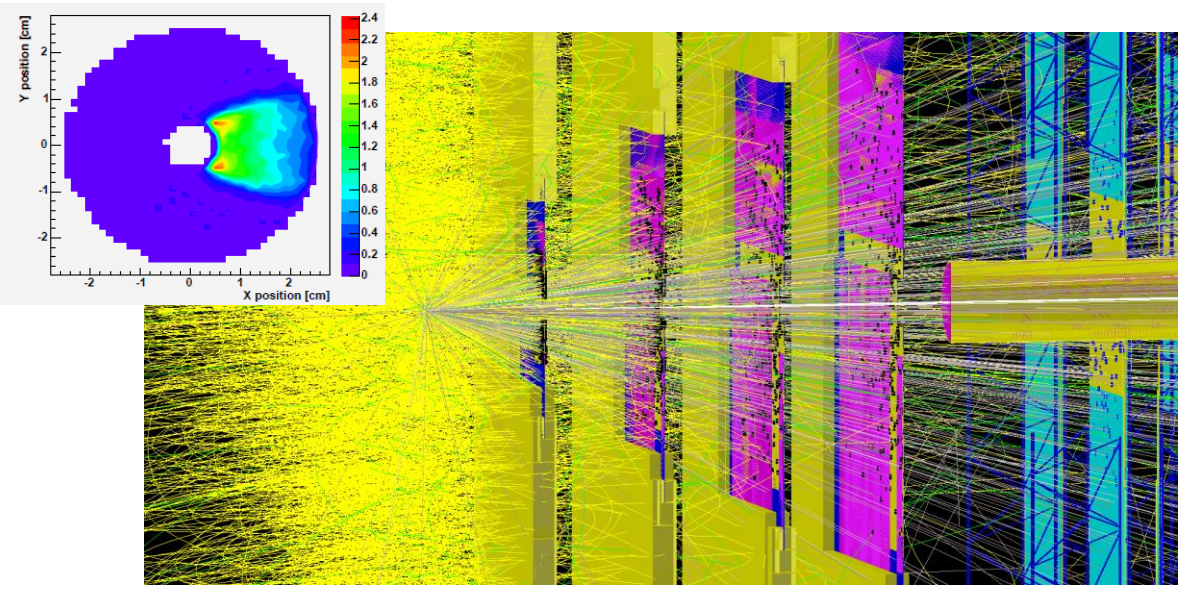




The CBM-MVD aims for:

- ~ 5µm spatial resolution
- 10^5 Au+Au/s (11 AGeV)
- 10^7 p+Au/s (30 GeV)

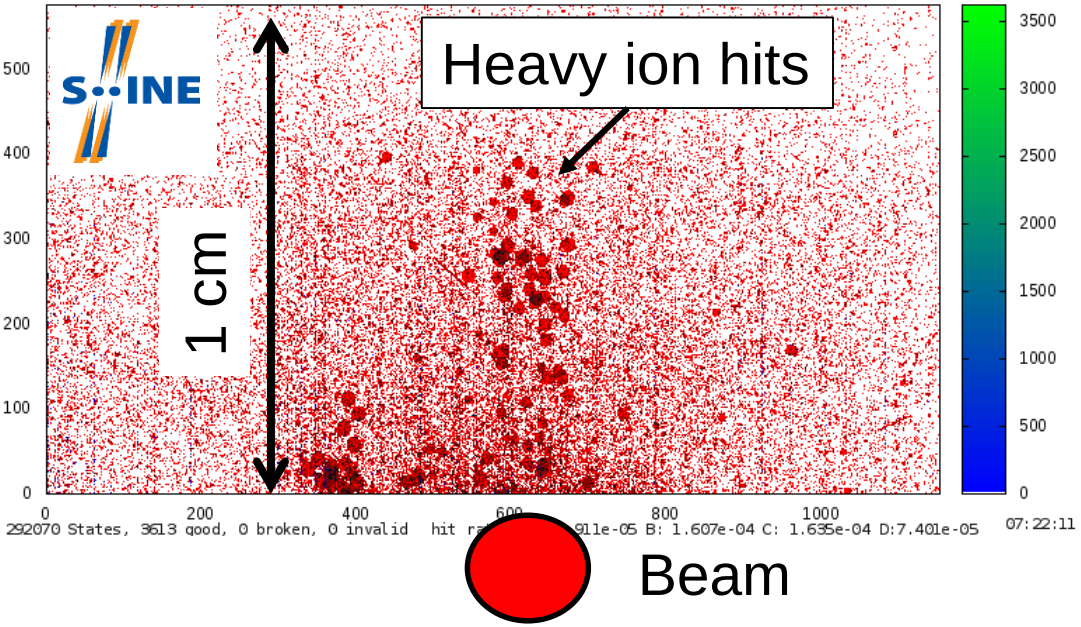
Fixed target – particuar challenges



Delta - electrons
10 AGeV Au+Au
2.5µs integration time.

Need increased rate capability and rad. tolerance.

M. Deveaux, SQM 2017
Utrecht/Netherlands



Contineous impacts of beam ions.
(Here: SPS-Pb beam).

Need extended tolerance to heavy ions.

Why dedicated sensors?

	ALPIDE (demonstrated)	MVD requirements MIMOSIS (design goal)	Factor
Ion. Rad. Tolerance	0.5 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)	~1 Gbps	20 Gbps (peak)	25
Data rate (external)	1 Gbps	2.5 Gbps	3
Data reduction	Trigger	Elastic buffer	--

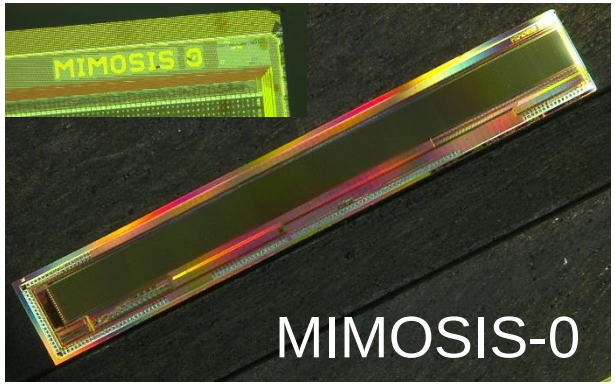
Not available in CBM

CBM approach:

Need next generation sensor – MIMOSIS – starting from ALPIDE.

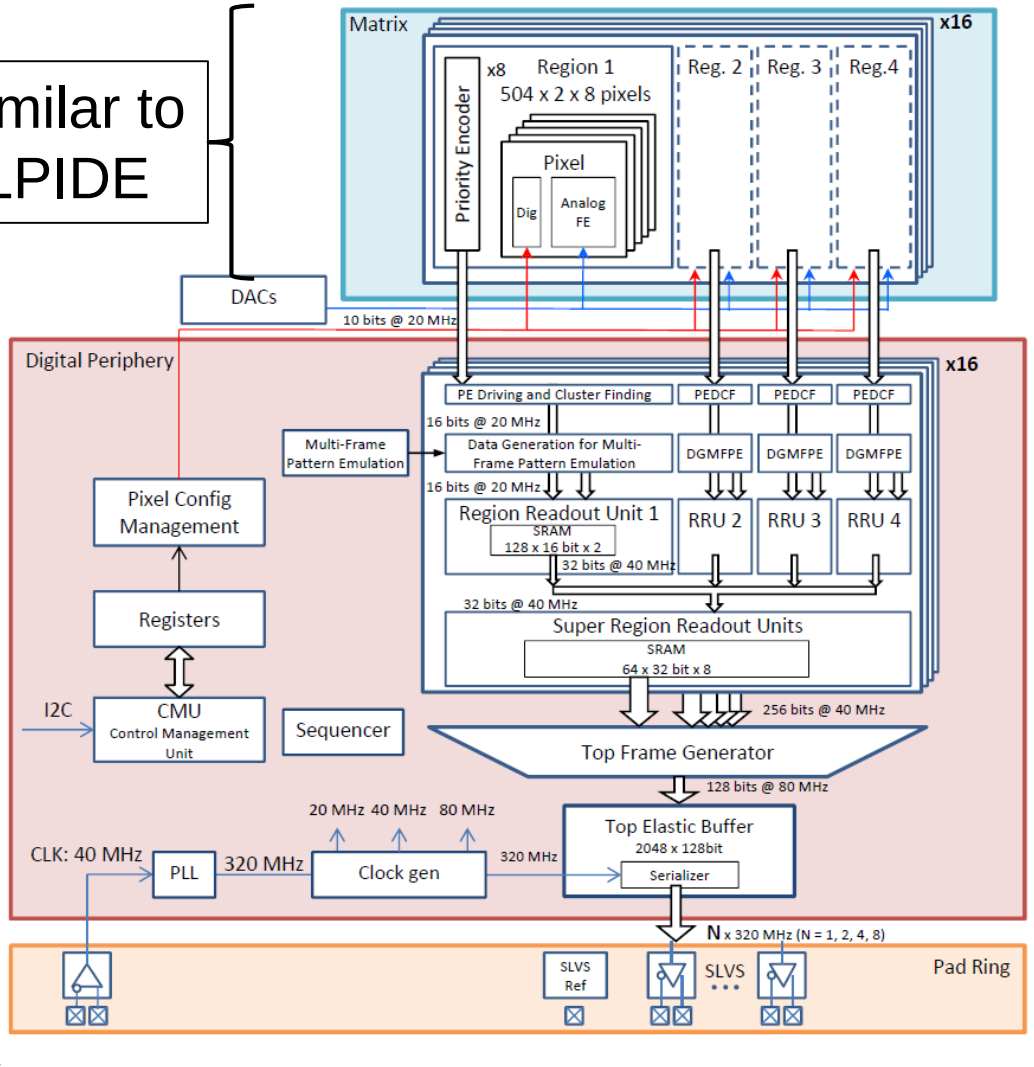
Partner: PICSEL group of IPHC Strasbourg (MIMOSA/ULTIMATE)

MIMOSIS – Sensor concept



MIMOSIS – Block diagram

Similar to ALPIDE



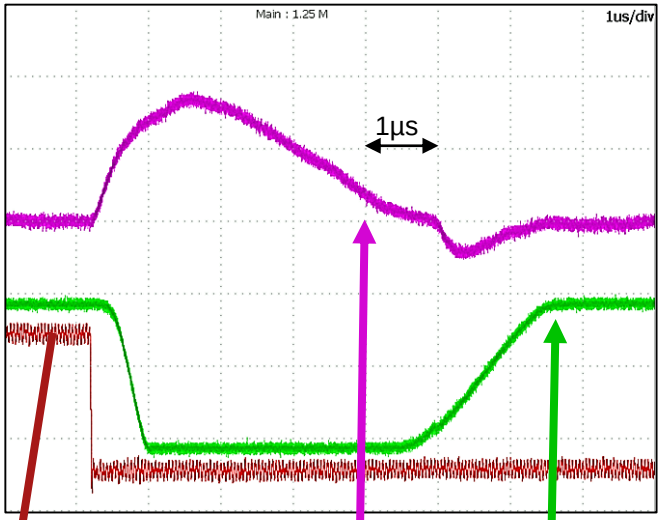
Adapt to CBM:

- Internal DAC
- Data paths
- Slow control
- Buffer structure
- I/O
- Rad. tolerance
- SEU tolerance

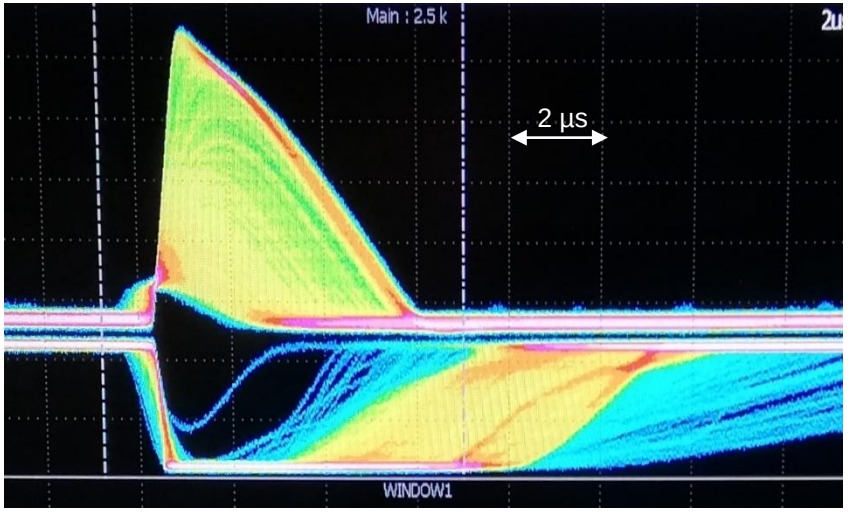
First prototype (MIMOSIS-0) returned from production.

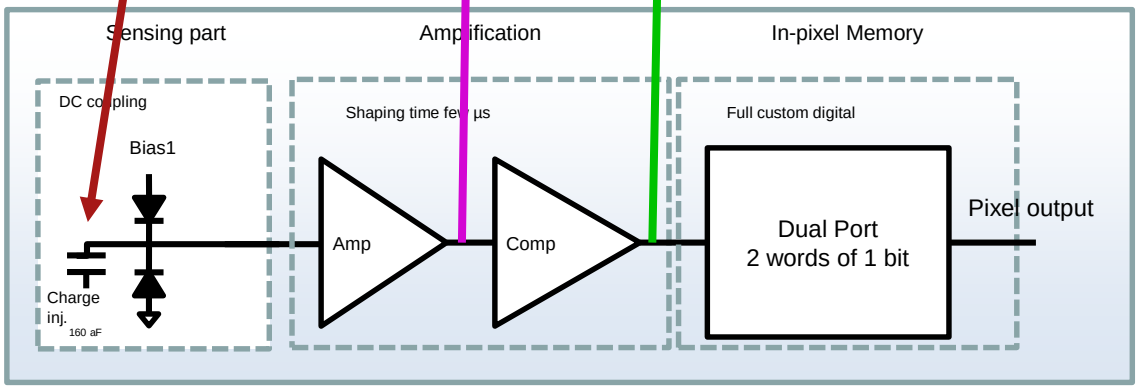
MIMOSIS-0 – first signs of life

Response to injected pulse



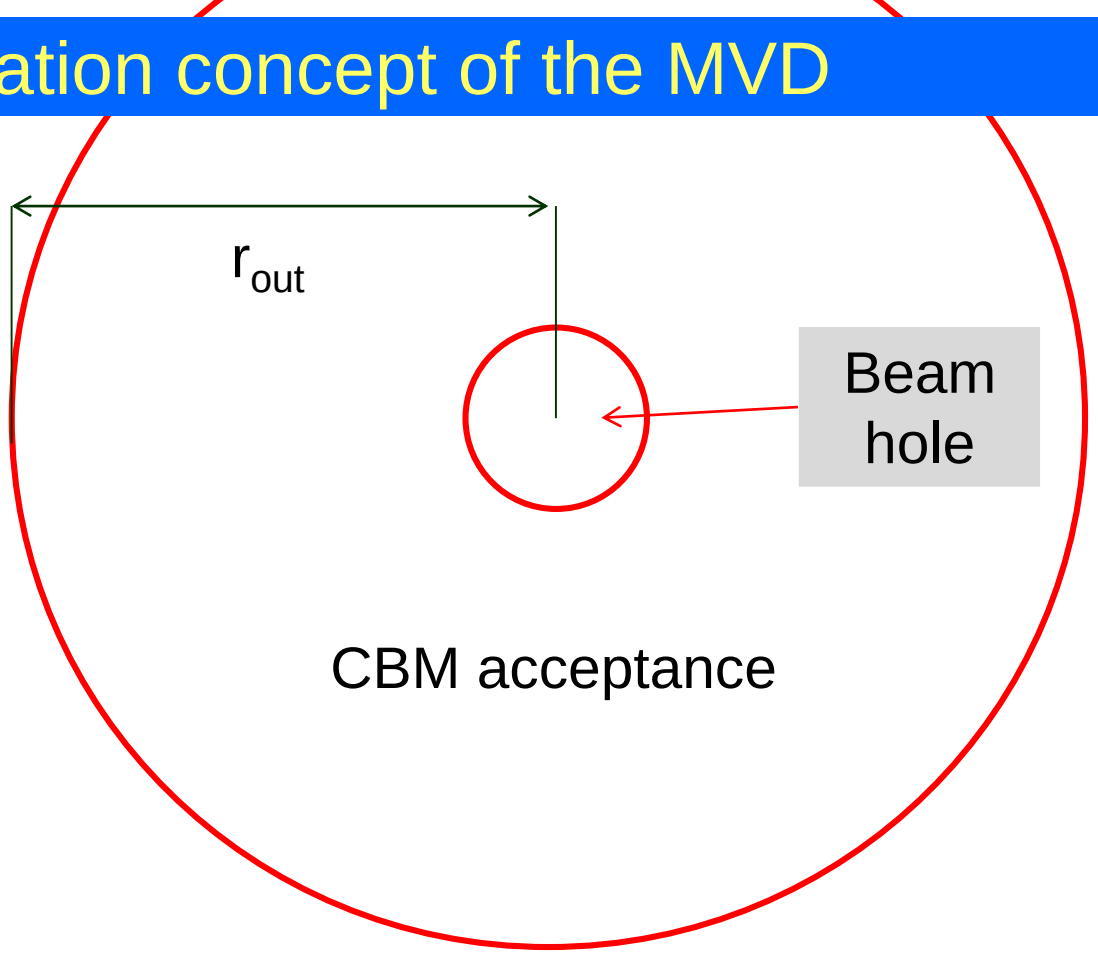
Response to ^{55}Fe (5.9 keV X-rays)





First results look promising… stay tuned.

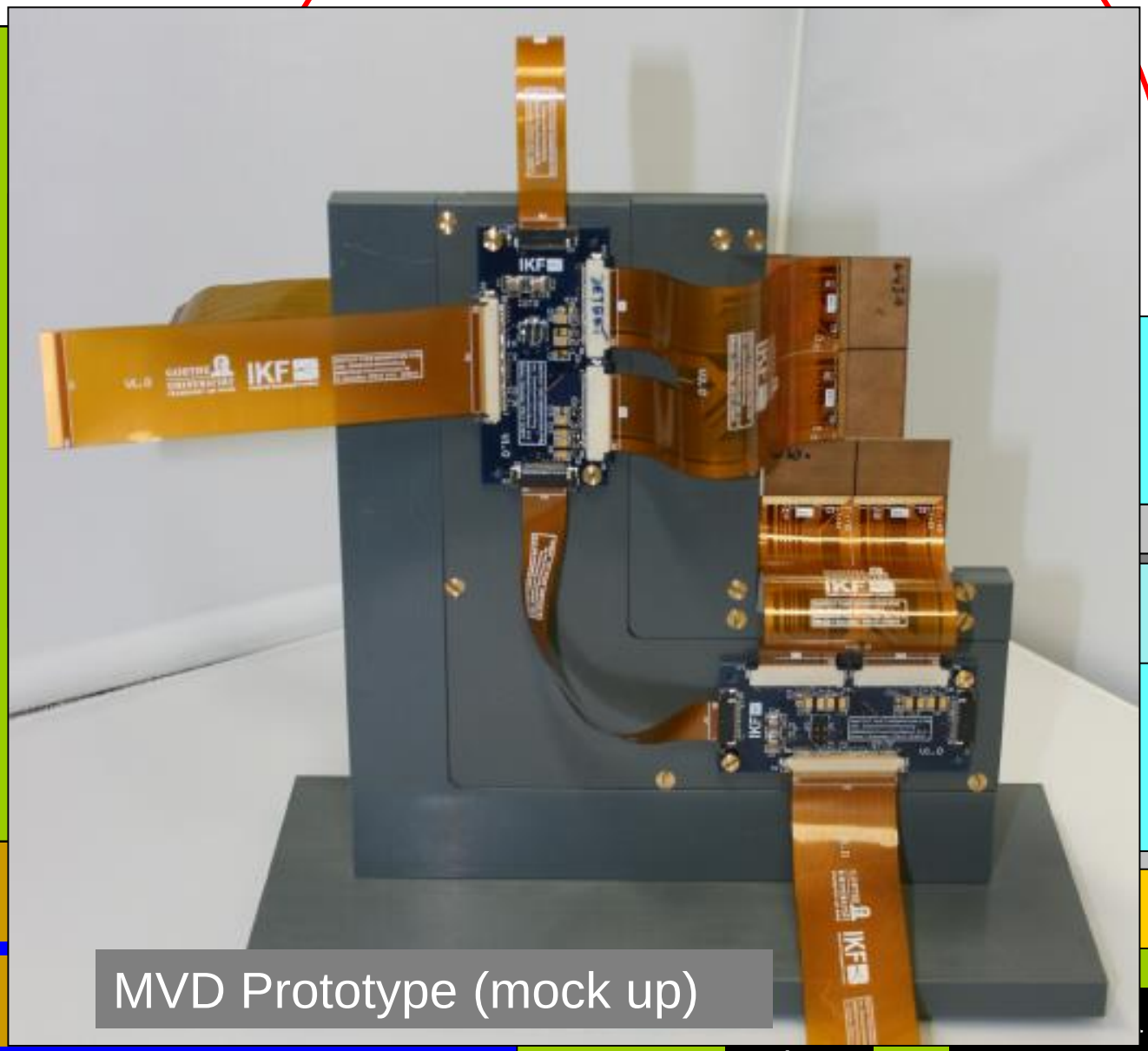
Integration concept of the MVD



Vacuum operation requires actively cooled device.

- Use cooling support from diamond to move heat out of acceptance
- Put heat sink and FEE outside acceptance

Integration concept of the MVD



MVD Prototype (mock up)

LV-re-gulator

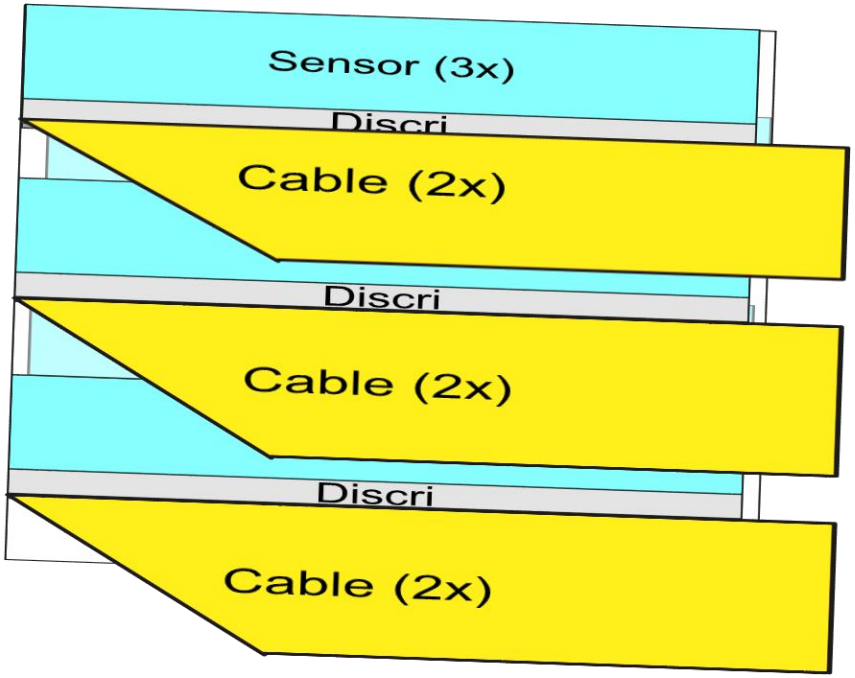
GBTx data concentrator

gulator

concentrator

Current status: PRESTO and NA61/SHINE VD

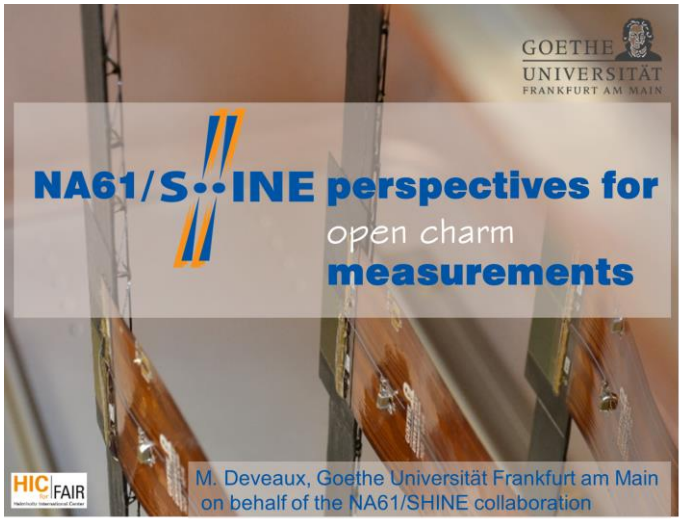
PRESTO:
Prototype of a quarter station incl. sensors (MIMOSA-26), cables, support etc.



Integration completed. Test:

- Vacuum compatibility
- Temperature cycling
- …

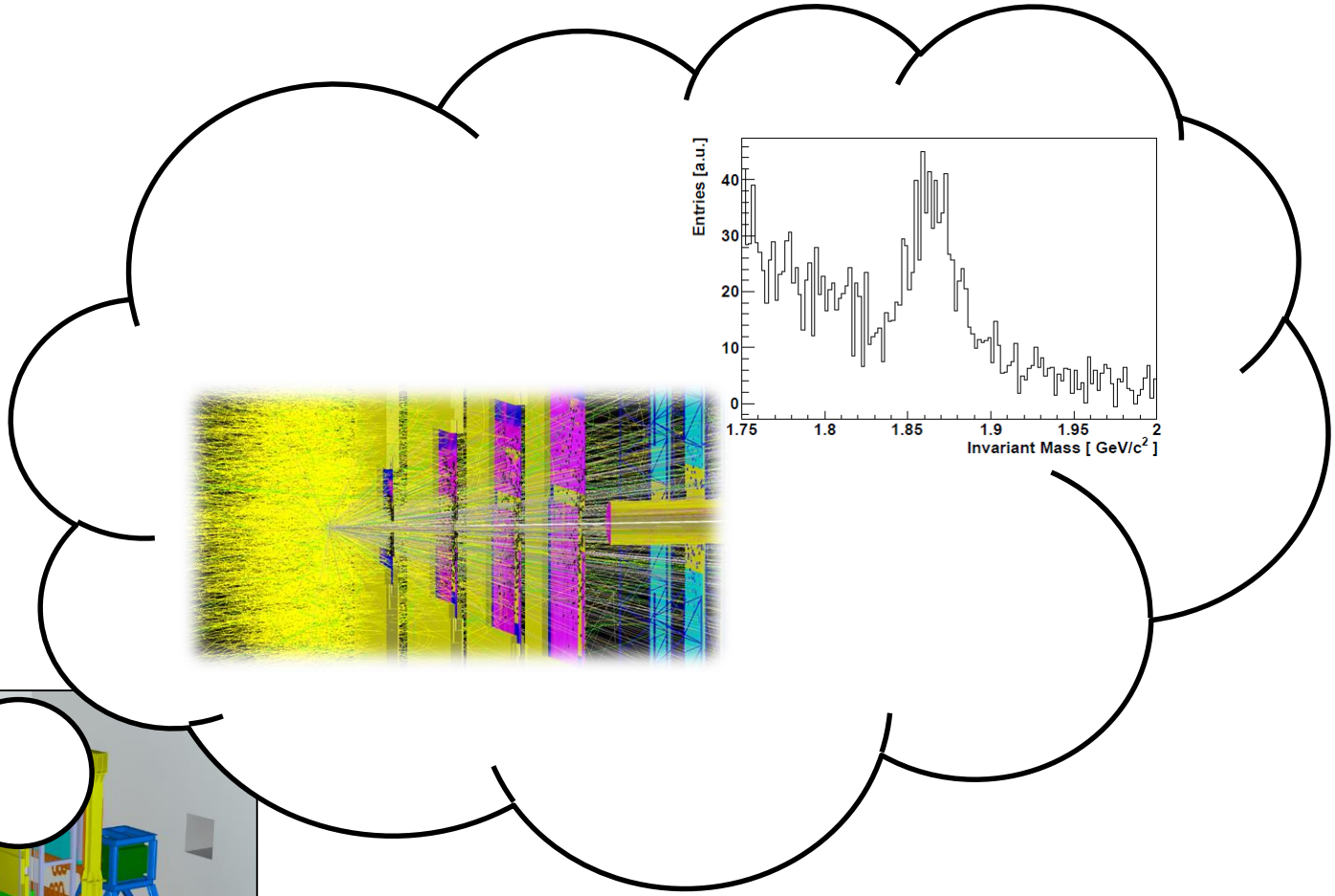
(More than) A spin-off:

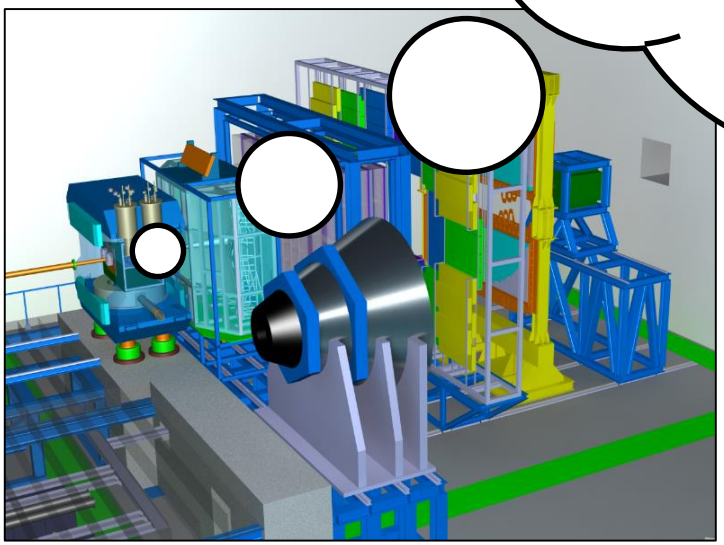


The NA61/SHINE vertex detector uses (and tests) MVD prototype/PRESTO electronics

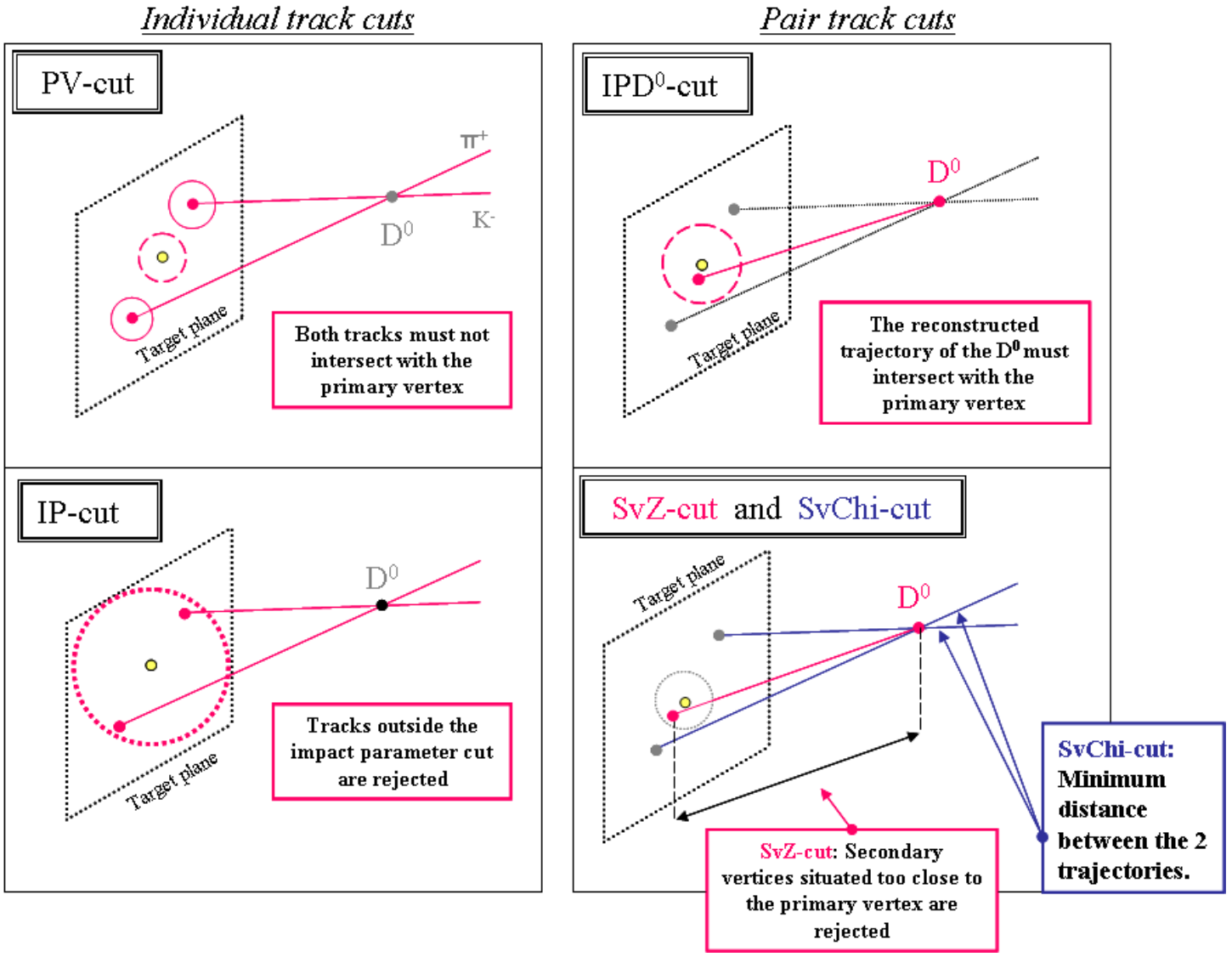
M. Deveaux for NA61/SHINE, SQM2017, Utrecht, Netherlands

Feasibility studies on open charm production





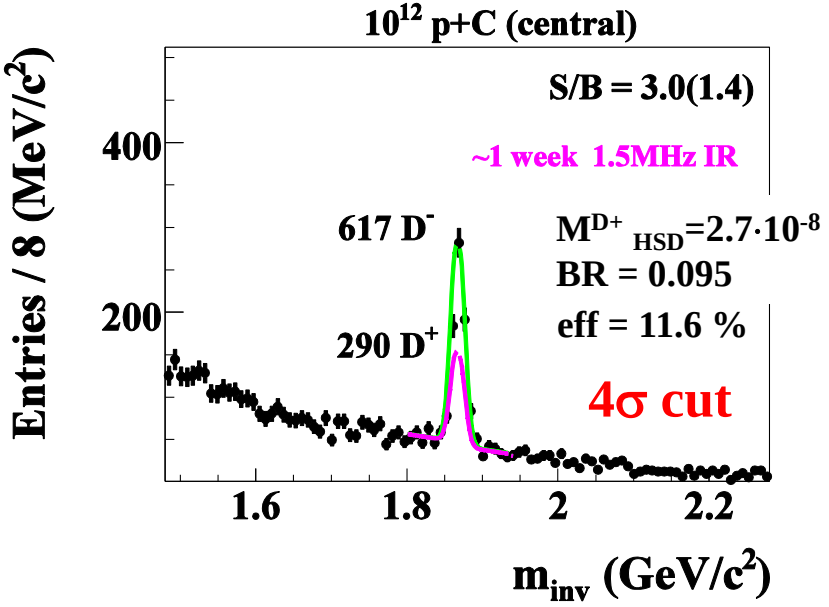
Reconstruction of open charm - Major cuts



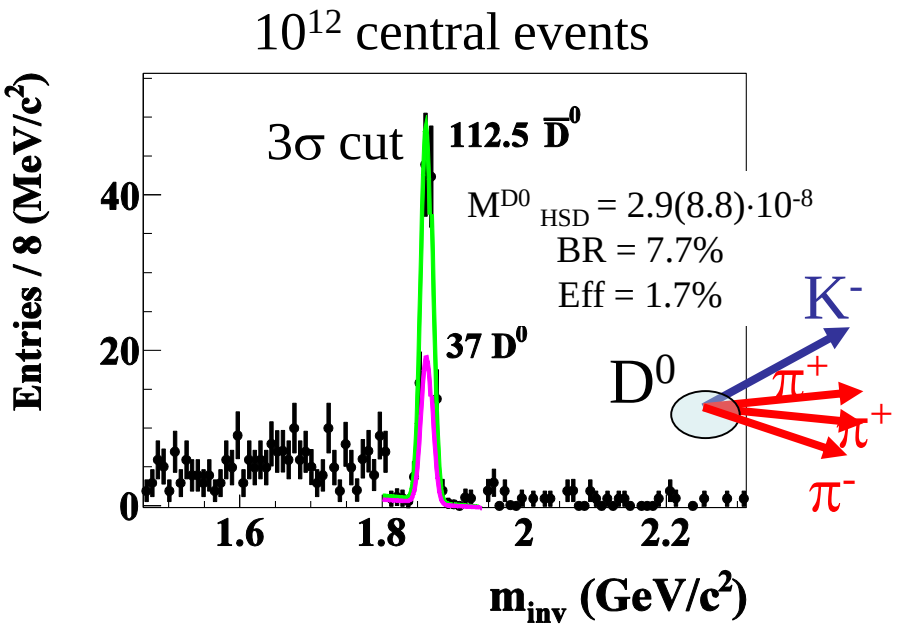
Anticipated: Protons are identified and rejected by TOF

Simulation p-C 30 AGeV

$D^+ \rightarrow K^- \pi^+\pi^+$

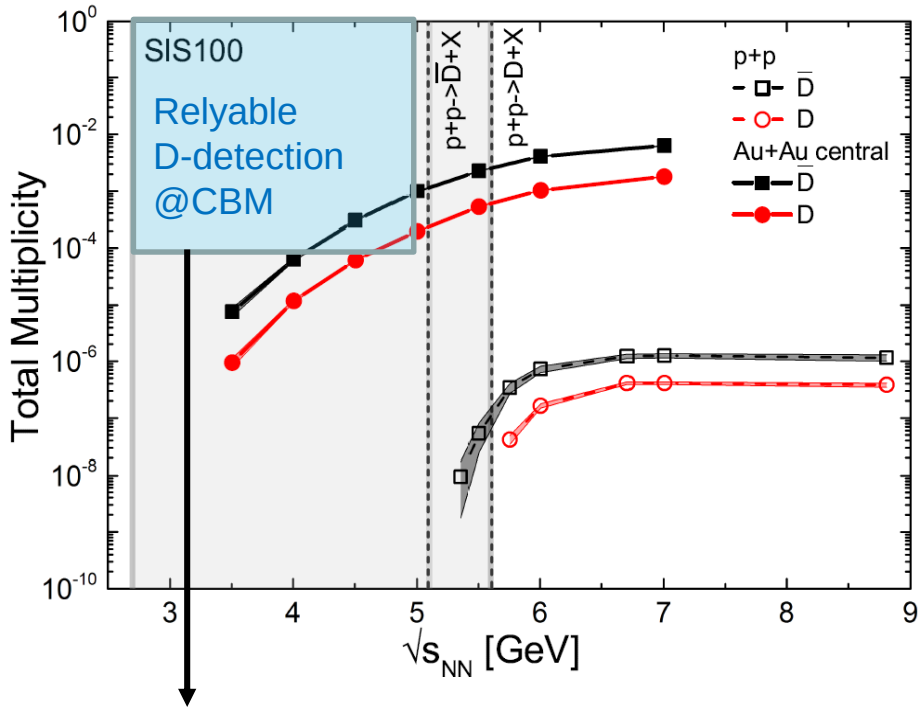


$D^0 \rightarrow K^- \pi^-\pi^+\pi^+$



Expect peak visible after few days beam on target at 10MHz p-A.
⇒ Open charm in p-A is possible at CBM.

Effect and results



More information on simulations:

C. Dritsa: „Design of the Micro Vertex Detector of the CBM experiment: Development of a detector response model and feasibility studies of open charm measurements.“, Phd Thesis, Frankfurt/Strasbourg 2011

I. Vasiliev: „Open Charm measurement with the CBM detector at FAIR”, HFM2 Kolkata, Feb.4, 2016

Scaled from simulations made for 25 AGeV Au+Au.

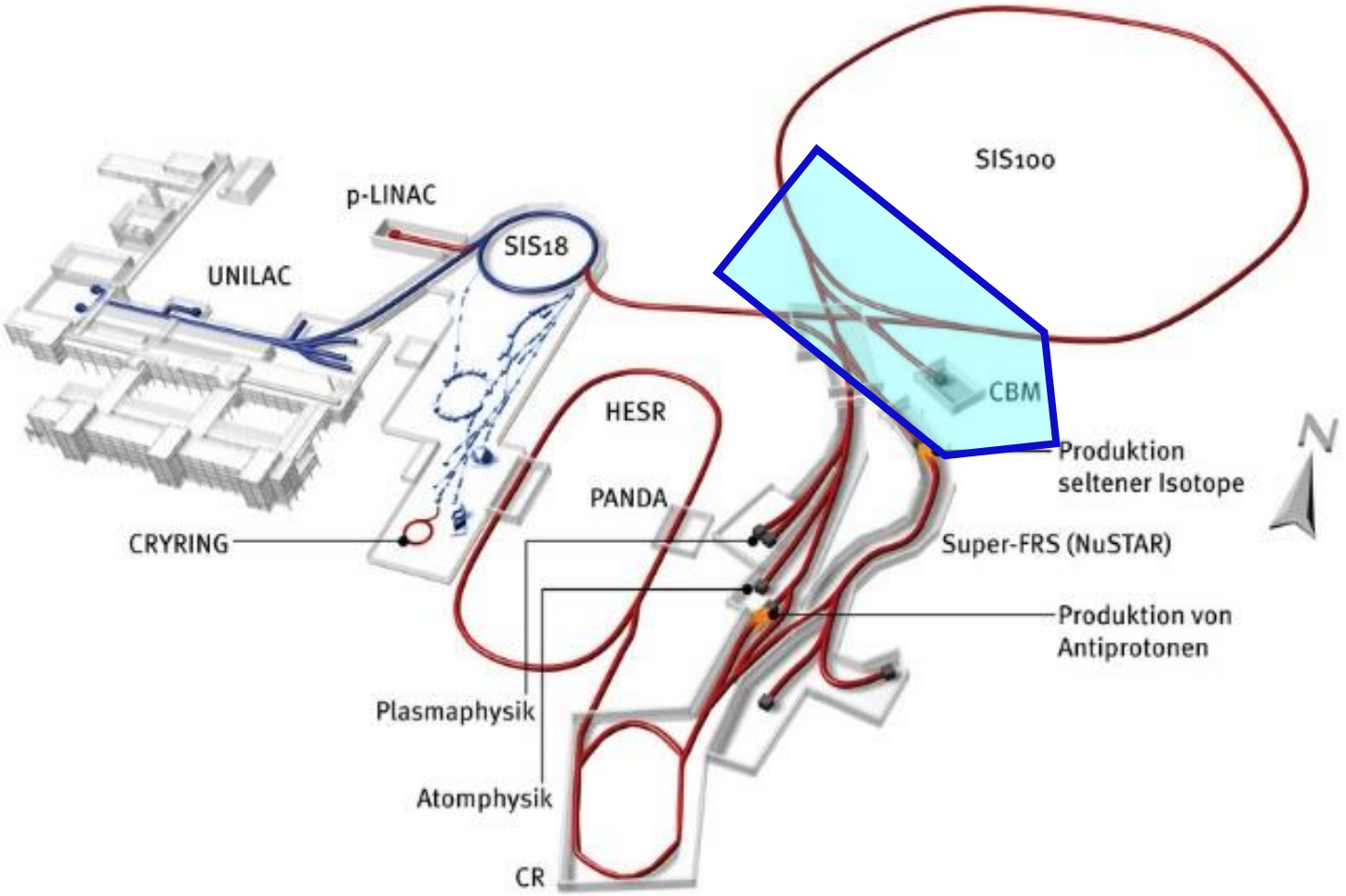
=> Significant uncertainties… next generation simulations pending.

However: Hardware improvement since then:

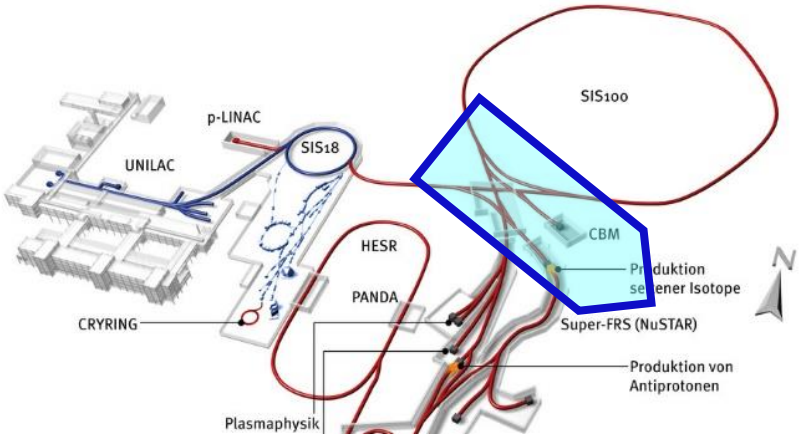
- Speed up of MVD sensors x6 => Eases tracking, less background.
- 4 MVD stations instead of 2 => Eases track matching, less background.
- …

Note: Measurement for D-mesons compatible with other physics cases. No additional beam time required.

Status of FAIR

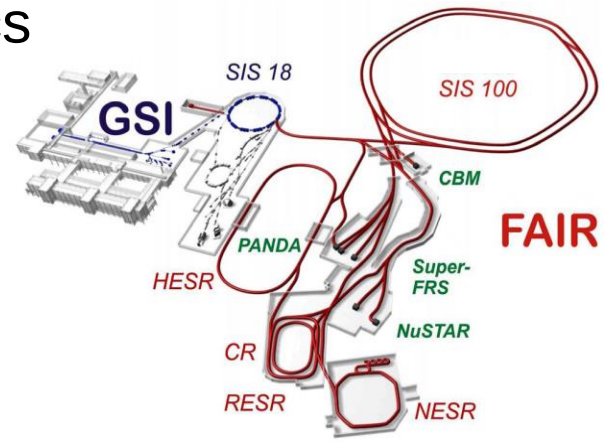


Status of FAIR



Physics cases of CBM (charm physics)

Initial idea:
Use SIS300 (15-35 AGeV) to do charm physics close to the threshold.



Issue:

- SIS300 not part of Modularized Start Version of FAIR.
- SIS100 provides max. 11 AGeV in Au+Au => Sub threshold for $N + N \rightarrow c - \bar{c}$

Detector hardware R&D is on track. Performance might exceed initial R&D goals.

Current process: Re-focus physics program to SIS100
Ideas:

- Do charm in p + A collision systems (30 GeV) and more.
- Study possible sub-threshold charm production in A+A

Work in progress => Help and ideas are welcome.

The team

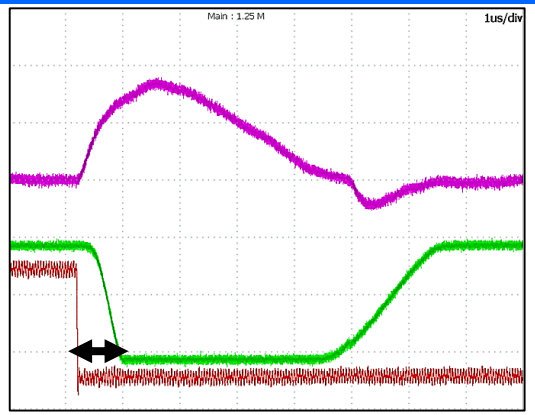
The PICSEL group
of IPHC Strasbourg

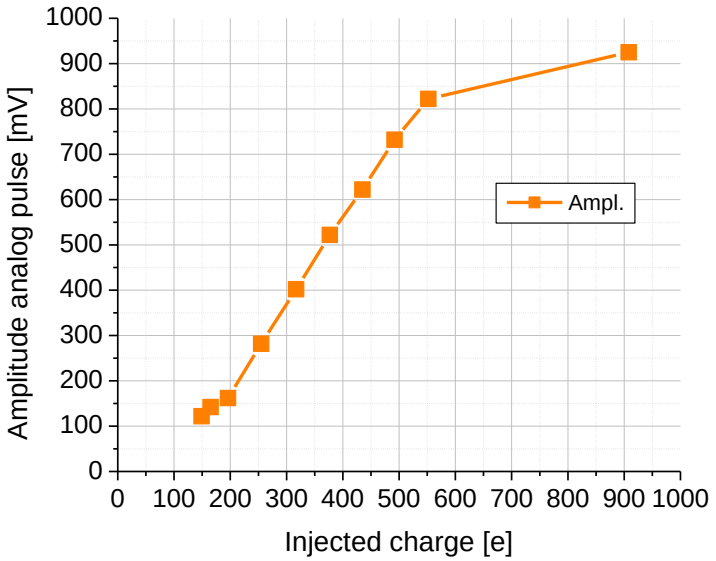
Group Prof. J. Stroth,
Goethe Uni Frankfurt/M

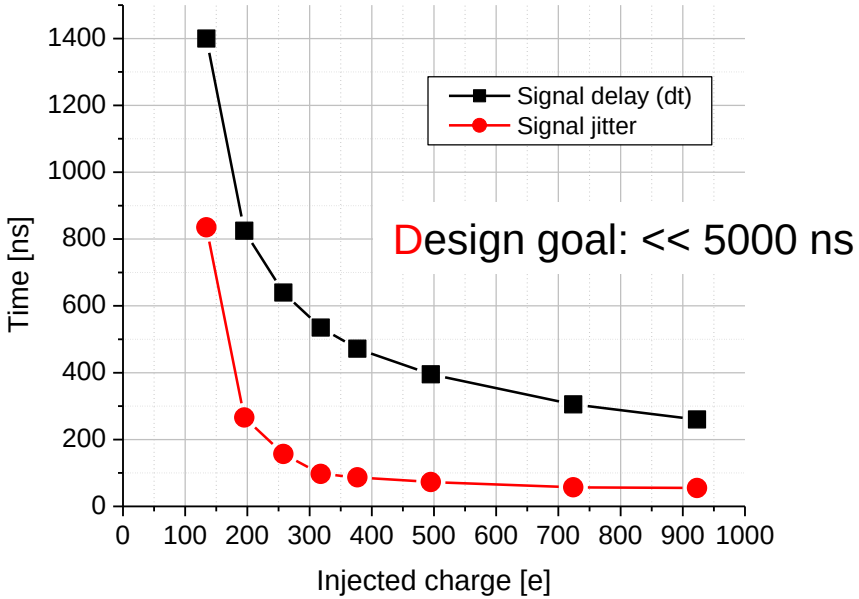
The CBM collaboration

Backup

MIMOSIS – 0 – first results







First results look promising.
MIMOSIS may to exceed CBM target on time resolution