Mini-Workshop on gas transport parameters for present and future generation of experiments

Gas mixture considerations for the CBM TOF system

Ingo Deppner

Physikalisches Institut, Heidelberg University

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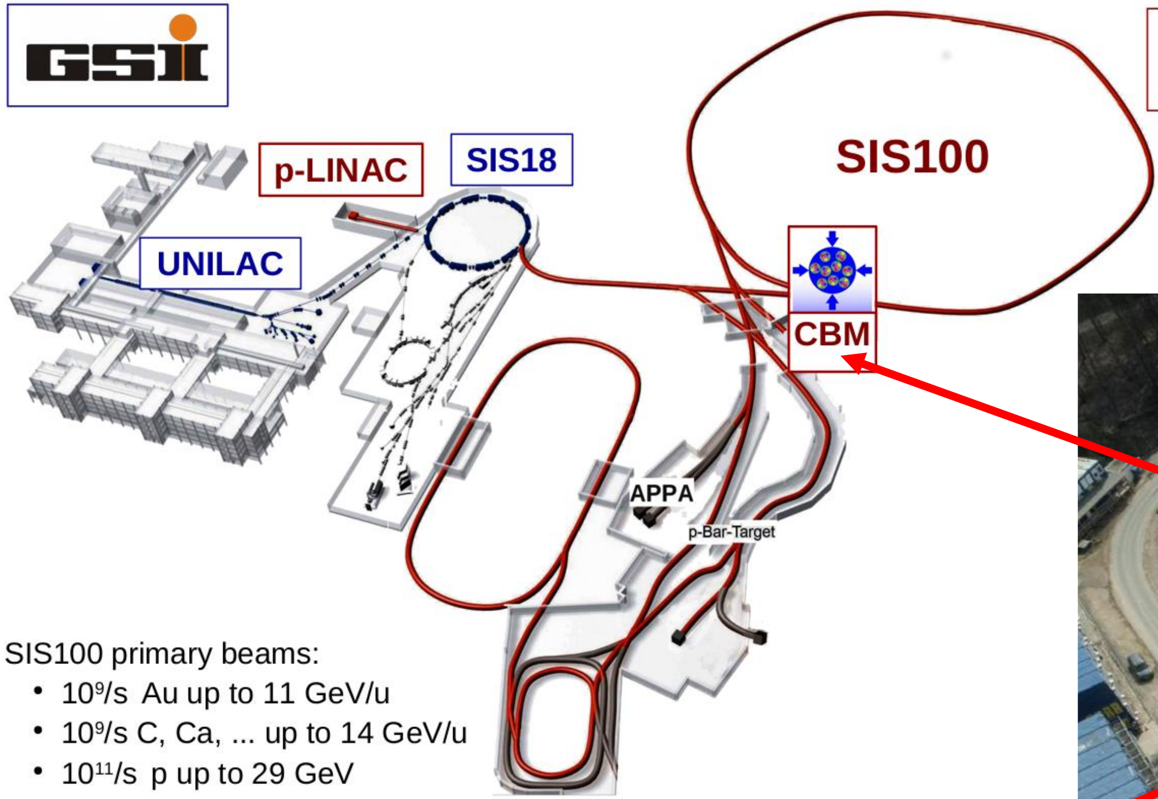
Outline

- Introduction to FAIR/CBM/CBM-TOF
- CBM TOF gas system
- Search for alternative MRPC gasses
- Aging of MRPCs
- Beam test results with old and new gas mixture
- Conclusions for the CBM TOF gas system

Introduction FAIR

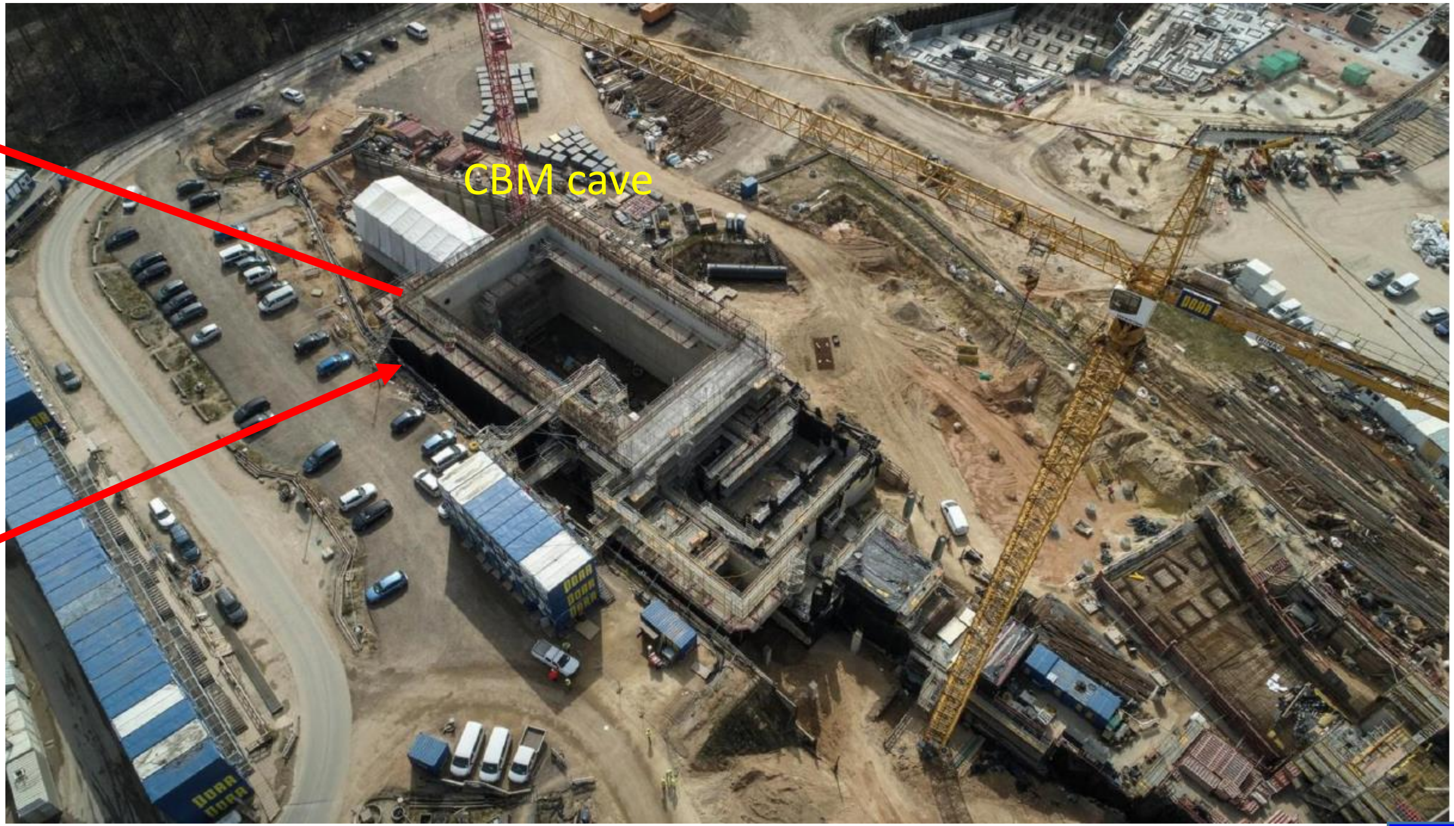
Facility for Antiproton and Ion Research



SIS100 primary beams:

- 10^9/s Au up to 11 GeV/u
- 10^9/s C, Ca, ... up to 14 GeV/u
- 10^{11}/s p up to 29 GeV

Construction Site - April 2021



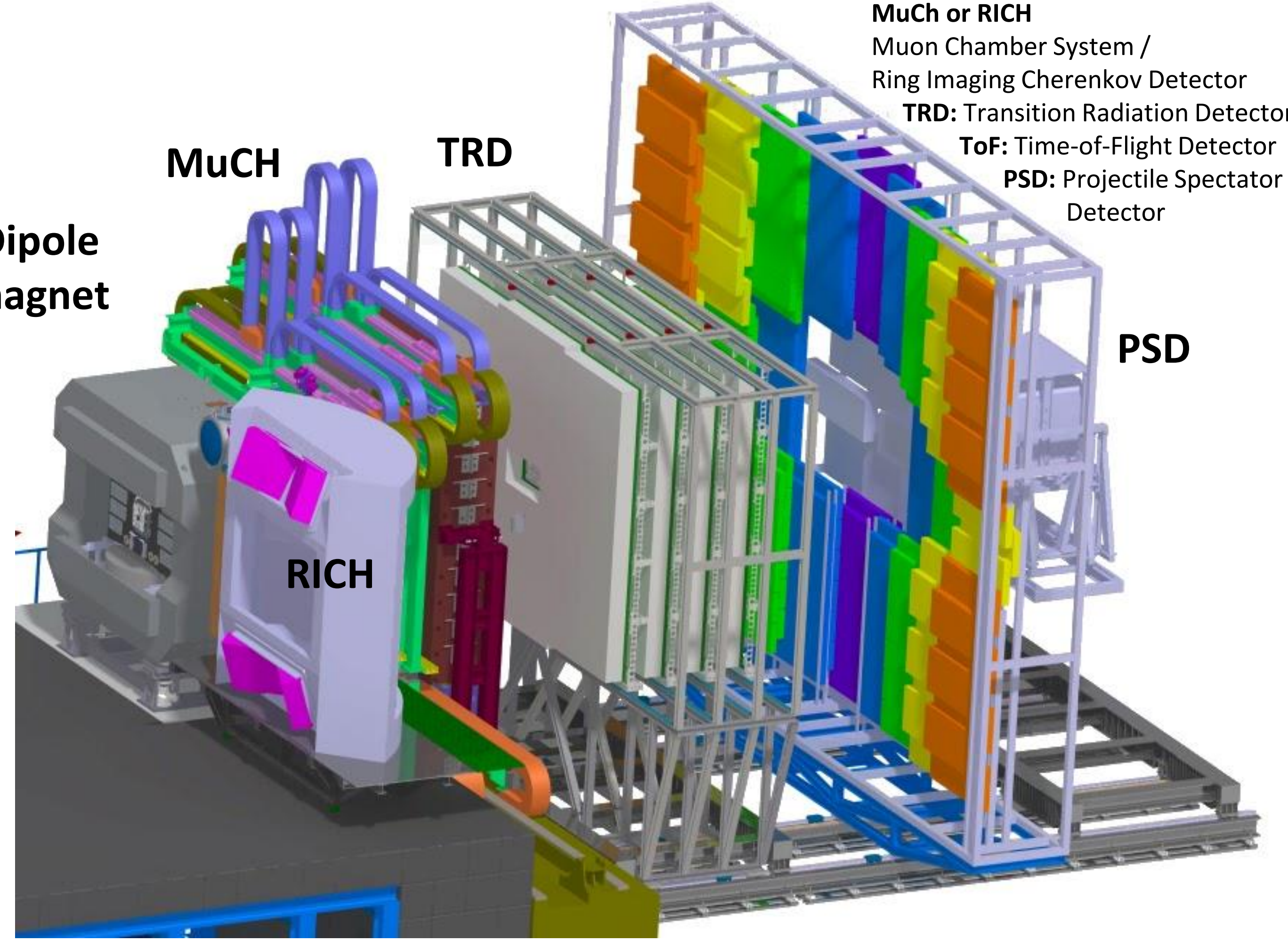
Timeline

- 2022: Buildings completed (including CBM cave)
- 2025: Completion of full facility and start of operations

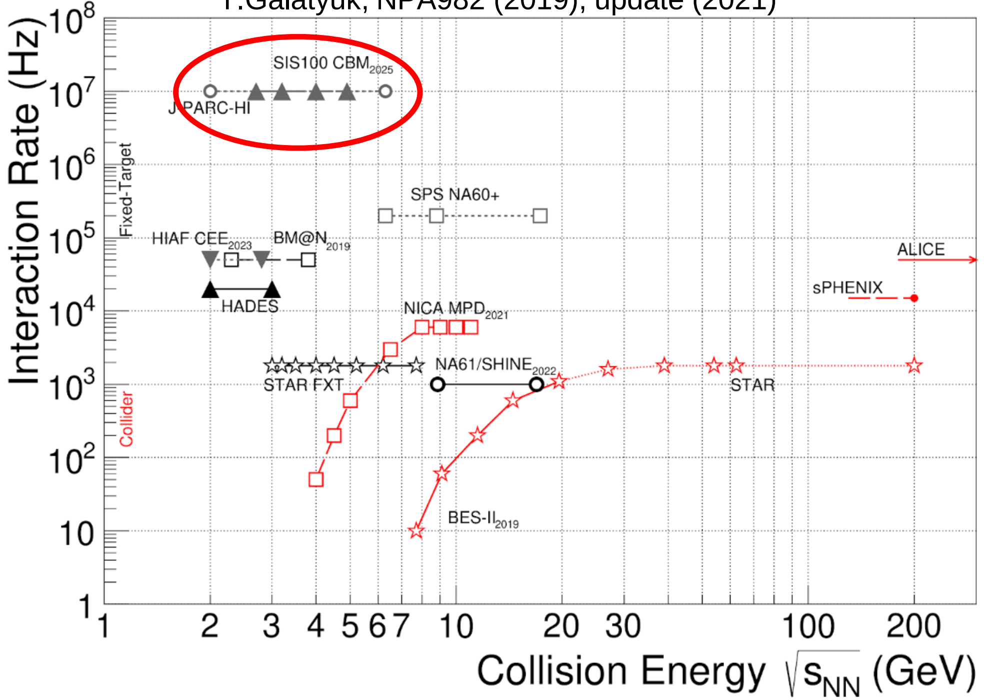
Introduction CBM

Compressed Baryonic Matter (CBM) Experiment

MVD: Micro Vertex Detector*
STS: Silicon Tracking System*
* inside magnetic field
MuCh or RICH
Muon Chamber System /
Ring Imaging Cherenkov Detector
TRD: Transition Radiation Detector
ToF: Time-of-Flight Detector
PSD: Projectile Spectator Detector



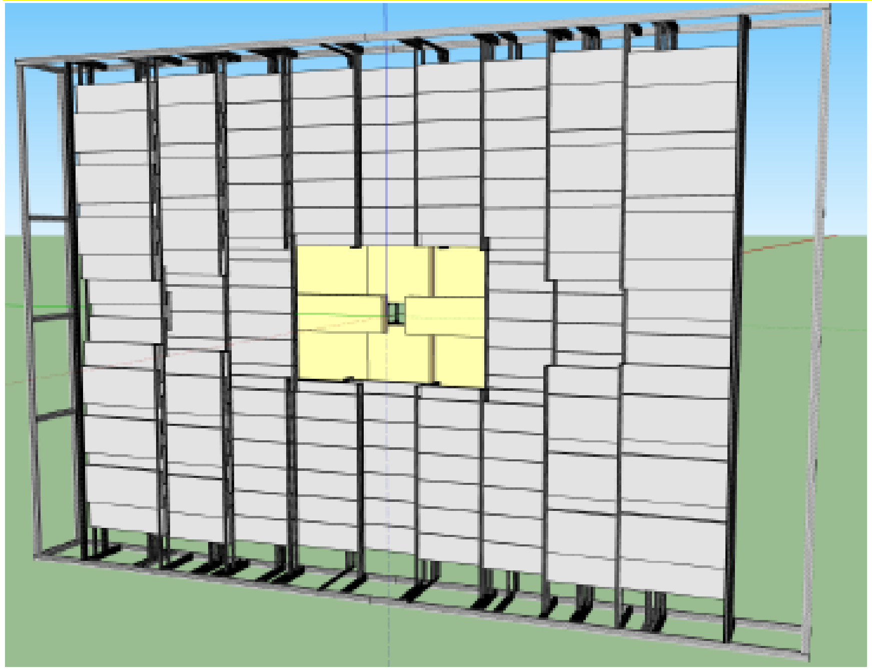
CBM Collaboration, EPJA 53 3 (2017) 60
T.Galatyuk, NPA982 (2019), update (2021)



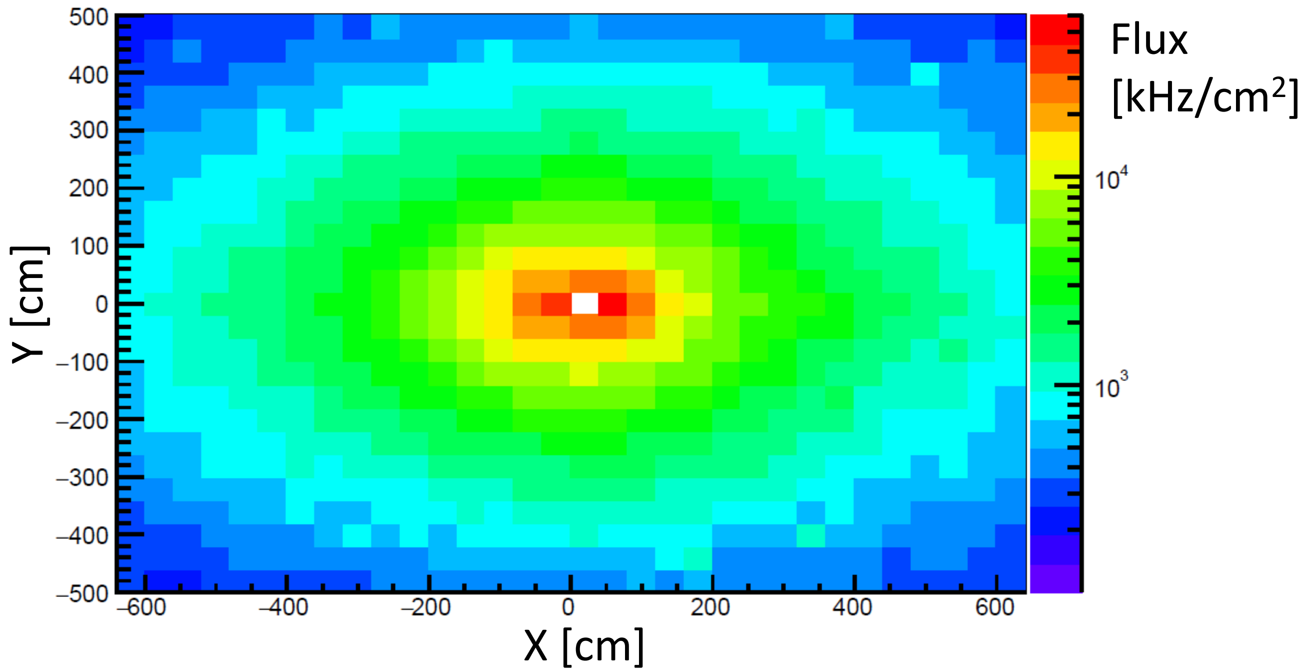
- Tracking acceptance: 2.5° < θ_{Lab} < 25°
- Peak R_{int} is 10 MHz for Au+Au (300 kHz for MVD)
- Fast & radiation hard detectors
- Free-streaming DAQ
- 4D tracking (space, time)
- Online event reconstruction and selection
- Data rate: 1 TB/sec

Introduction CBM TOF

Charged hadron identification is provided by Time-of-Flight (TOF) measurement



FLUKA simulation: Au + Au collisions at E_{kin} = 11 GeV, 10^7 interactions



CBM-TOF Requirements

- Full system time resolution σ_T ~ 80 ps
- Efficiency > 95 %
- Rate capability ≤ 30 kHz/cm^2
- Polar angular range 2.5° – 25°
- Active area of 120 m^2
- Occupancy < 5 %
- Low power electronics (~100.000 channels)
- Free streaming data acquisition

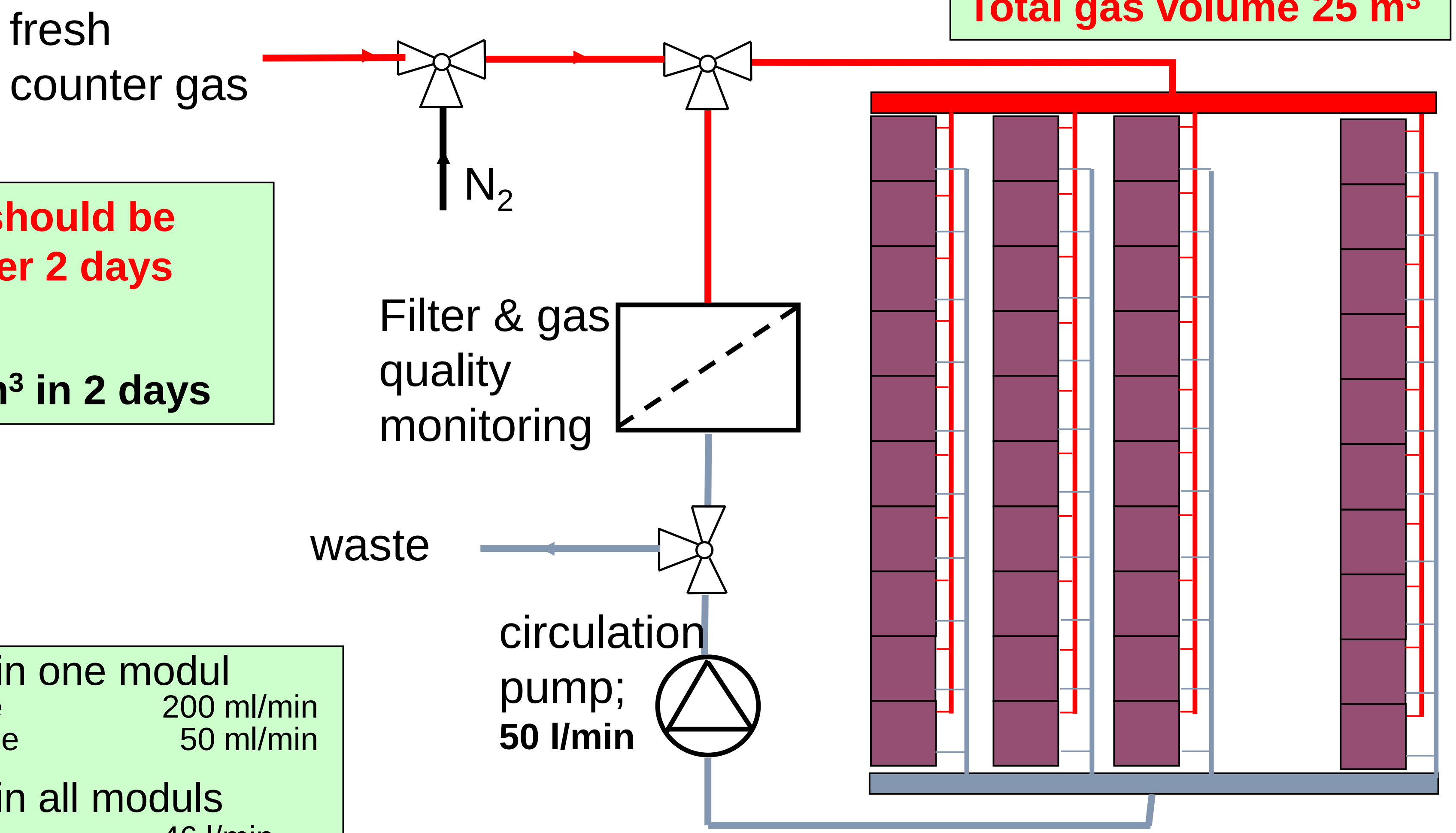
Multi-gap Resistive Plate Chambers (MRPC) are the most suitable TOF detectors fulfilling our requirements

CBM-TOF MRPCs

- About 1500 MRPC
- Multi-gap RPC with 8 – 10 gaps with gap size of 200 – 250 μm
- MRPC size ranging from 180 cm^2 up to 1700 cm^2
- Initially planed gas mixture: R134a/iso-Butan/SF_6: 90%/5%/5%

CBM TOF gas system

230 modules
Total gas volume 25 m³



System should be ready after 2 days purging

i.e. 125 m³ in 2 days

gas flow in one modul

purge mode	200 ml/min
cycling mode	50 ml/min

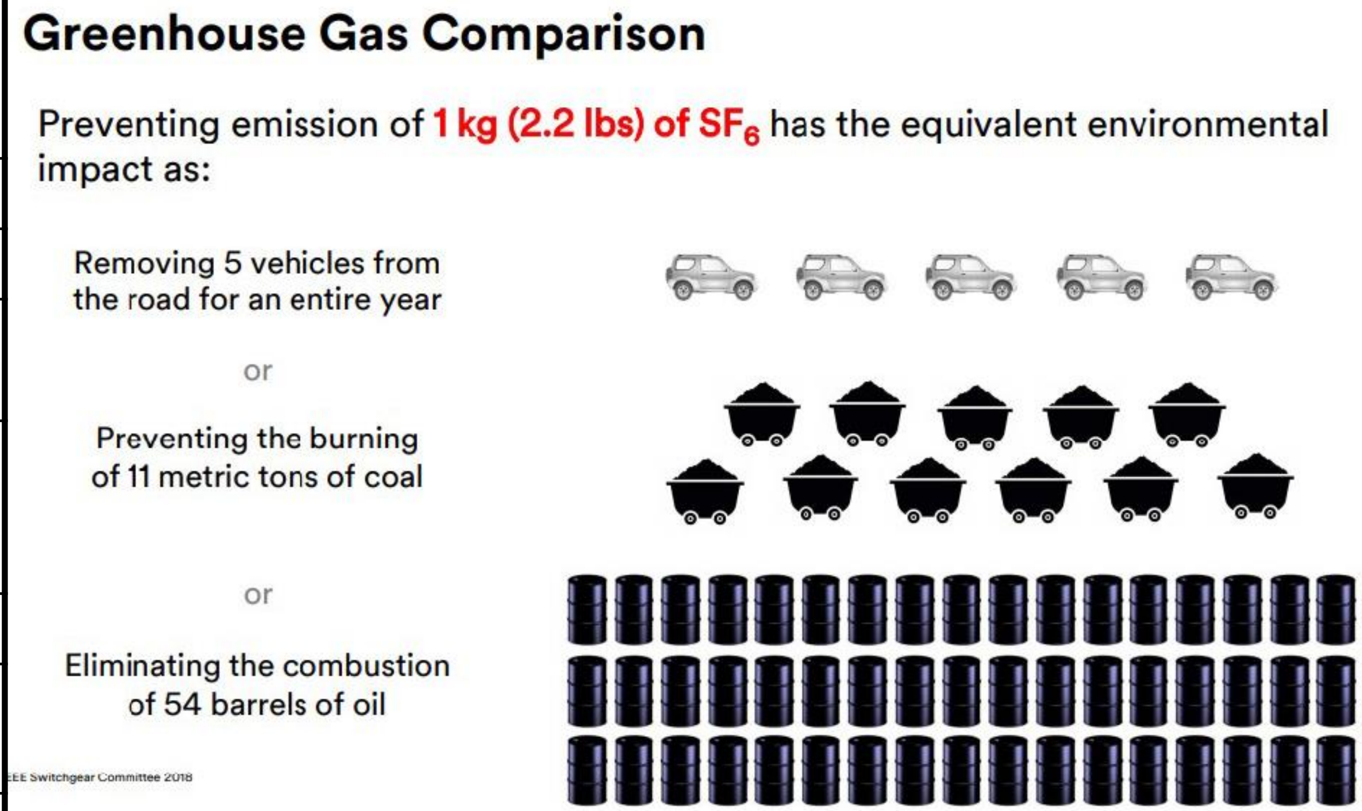
gas flow in all moduls

purge mode	46 l/min
cycling mode	11.5 l/min

CBM TOF gas system

Parameters for one CBM TOF refill

gas	Isobu-tane	Reclin® R134a	Sulfur-hexafluoride
chemical structure	i-C_4H_{10}	$C_2H_2F_4$	SF_6
fraction	5%	90%	5%
partial volume [m^3]	6.25	112.5	6.25
density at 1013 mbar [kg/m^3] (15 °C)	2,5	4,4	6,2
portion [kg]	15.625	495	38.75
CO_2 equivalent [tons]	0.047	707.9	910.6
price [Euro]		17400 (35.10 Euro/kg)	



John G. Owens, 3M, *Greenhouse Gas Emission Reductions from Electric Power Equipment through Use of Sustainable Alternatives to SF6*

1 CBM-TOF refill

200

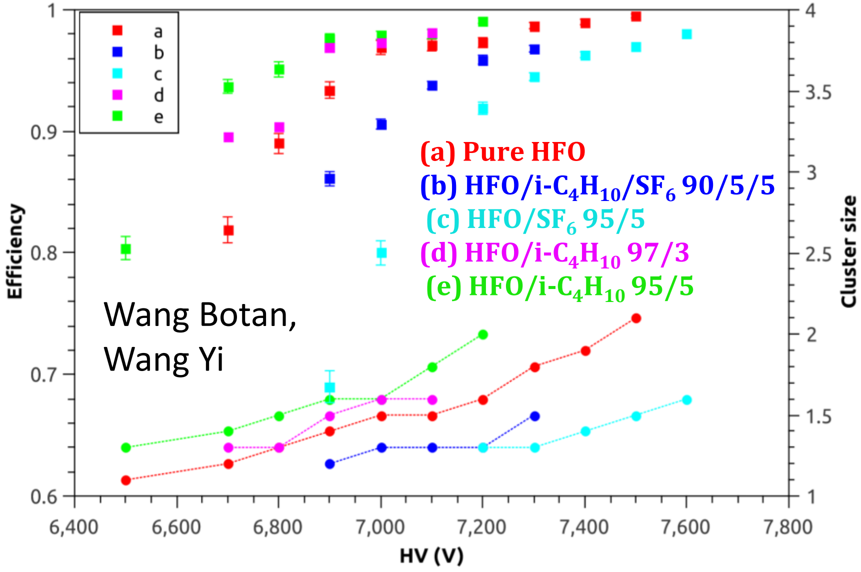
44

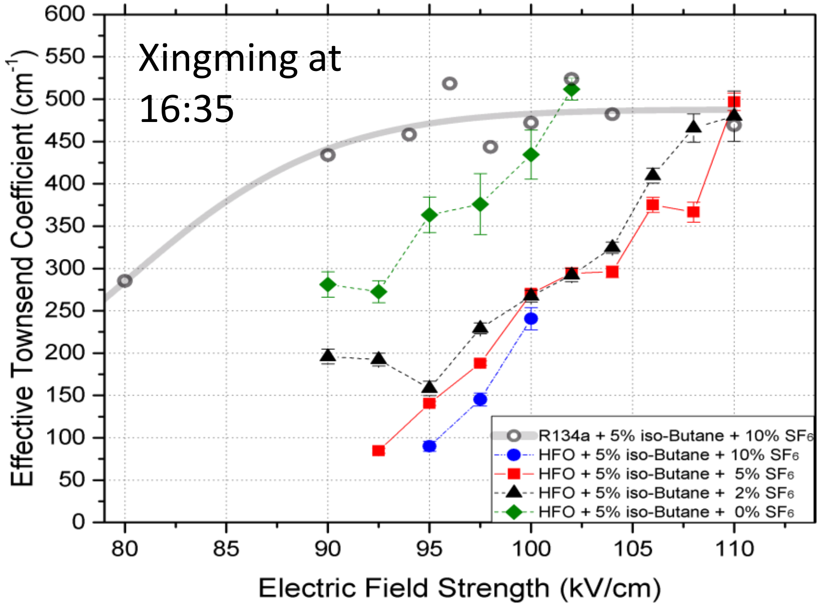
216

due to the high GWPs ⇒ - Alternative gases (HFO)
- Reduction of SF6
- Gas recycling

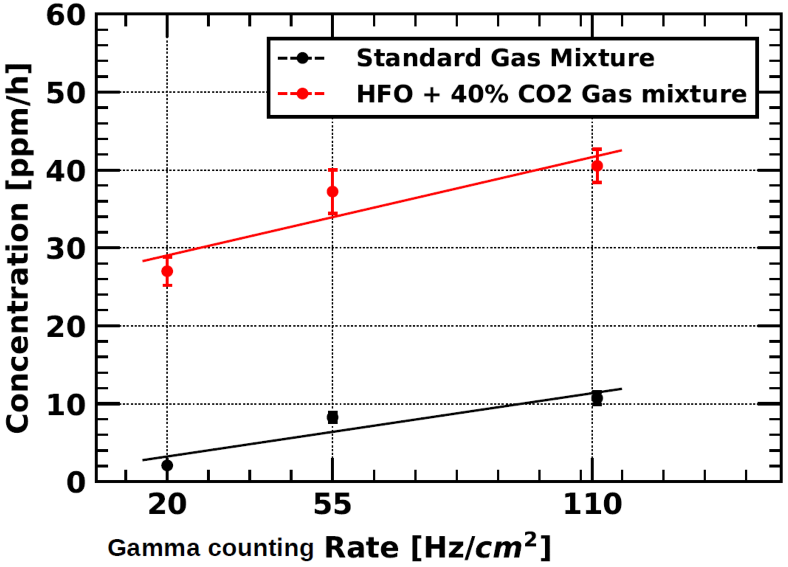
Alternative gas search in CBM TOF

- Alternative gas mixtures were investigated
- Time resolutions in the order of 80 ps to 100 ps were obtained
- Gas mixtures with HFO fulfil our TOF requirements
- Working point is shifted by about 2000 V
- Measurements of the eff. Townsend coefficient show no major difference for gas mixtures with more than 2 % SF_6 (see talk of Xingming at 16:35)
- The instability of HFO in comparison to R134a is counterproductive in a high rate environment





R. Guida, B. Mandelli, G. Rigoletti (RPC2020)

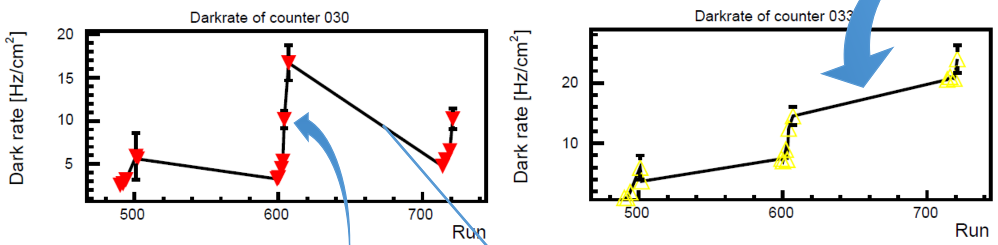


HFO is breaking ~10 times more easily than R134a

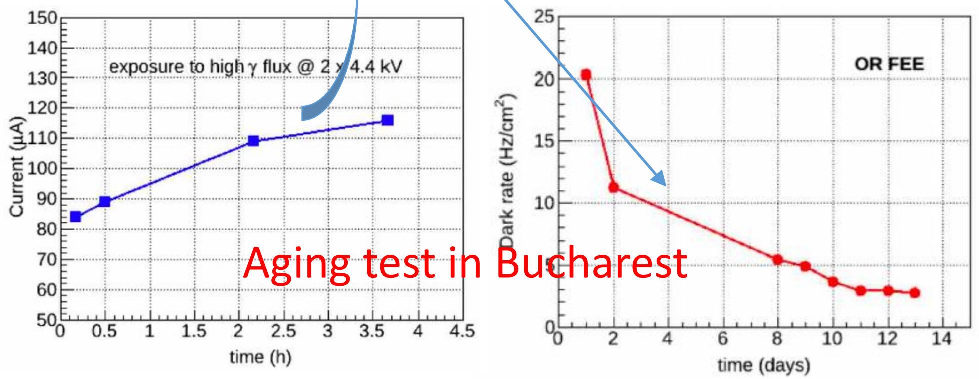
Gas aging & pollution

- Gas pollution effect observed at mCBM at high rate (about 5 – 10 kHz/cm^2)
- Gas pollution effect was reproduced at IRSAM (Bucharest) with high gamma flux
- X-Ray test at Beijing confirmed the gas pollution effect
- The effect was minimized by sealing the MRPC
- MRPC with intelligent gas management required (forced gas flow through gaps)

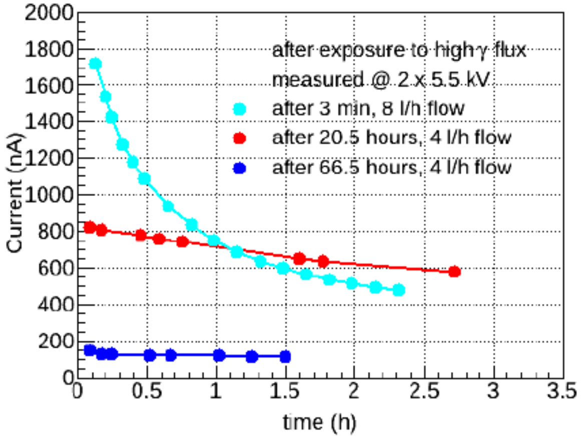
Observations @ mCBM



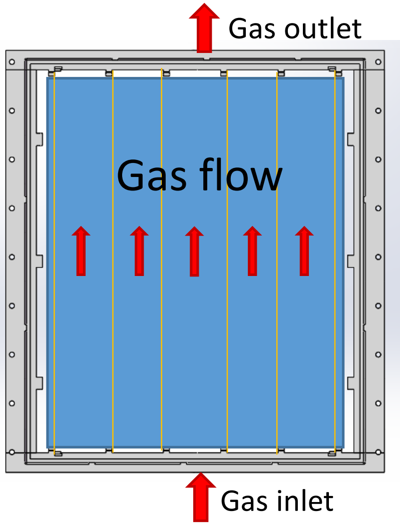
Persistent aging (Reason not understood yet)

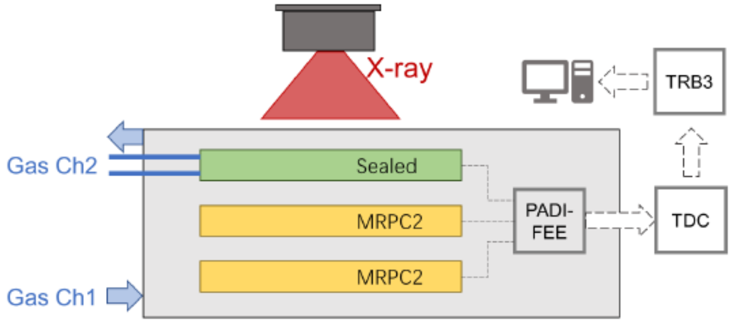


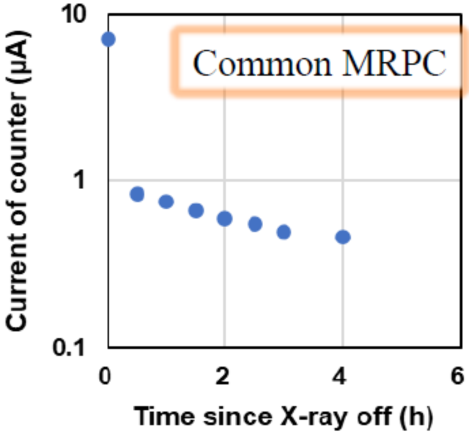
Aging test in Bucharest

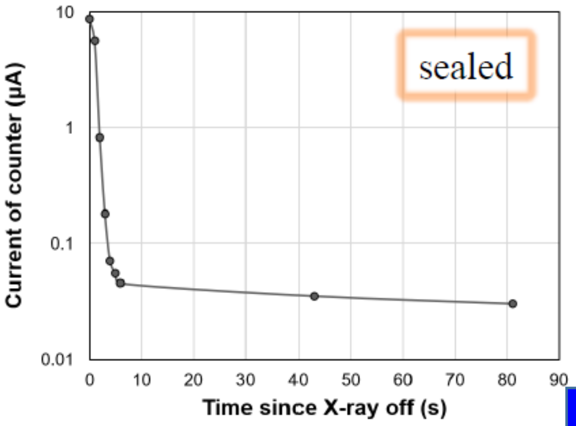


See CBM Progress Report 2020









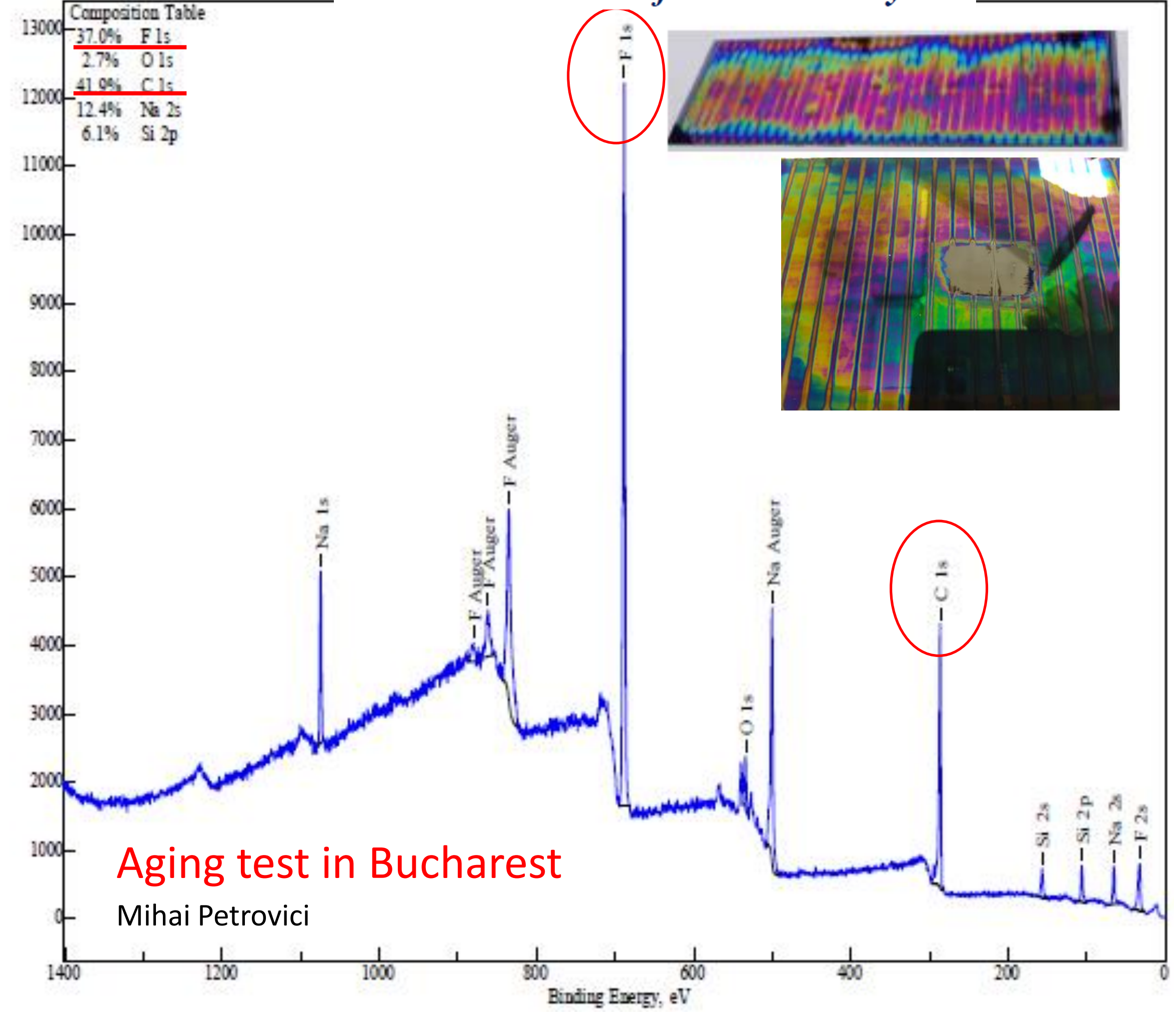
CBM

Gas aging & pollution

CBM ToF

Surface facing the cathode

XPS analysis - thanks to C. Negrila
National Institute of Materials Physics

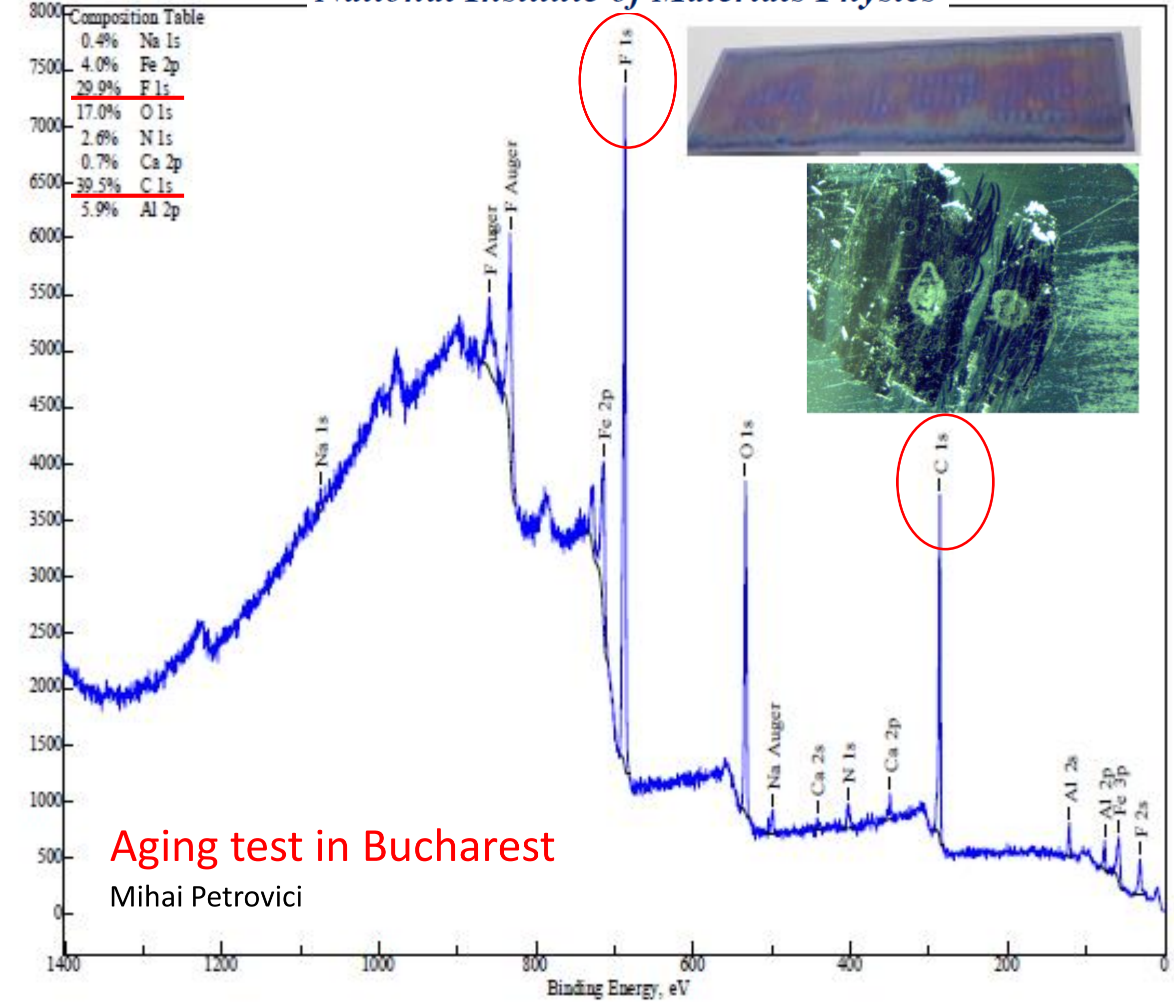


Aging test in Bucharest

Mihai Petrovici

surface facing the anode

XPS analysis - thanks to C. Negrila
National Institute of Materials Physics

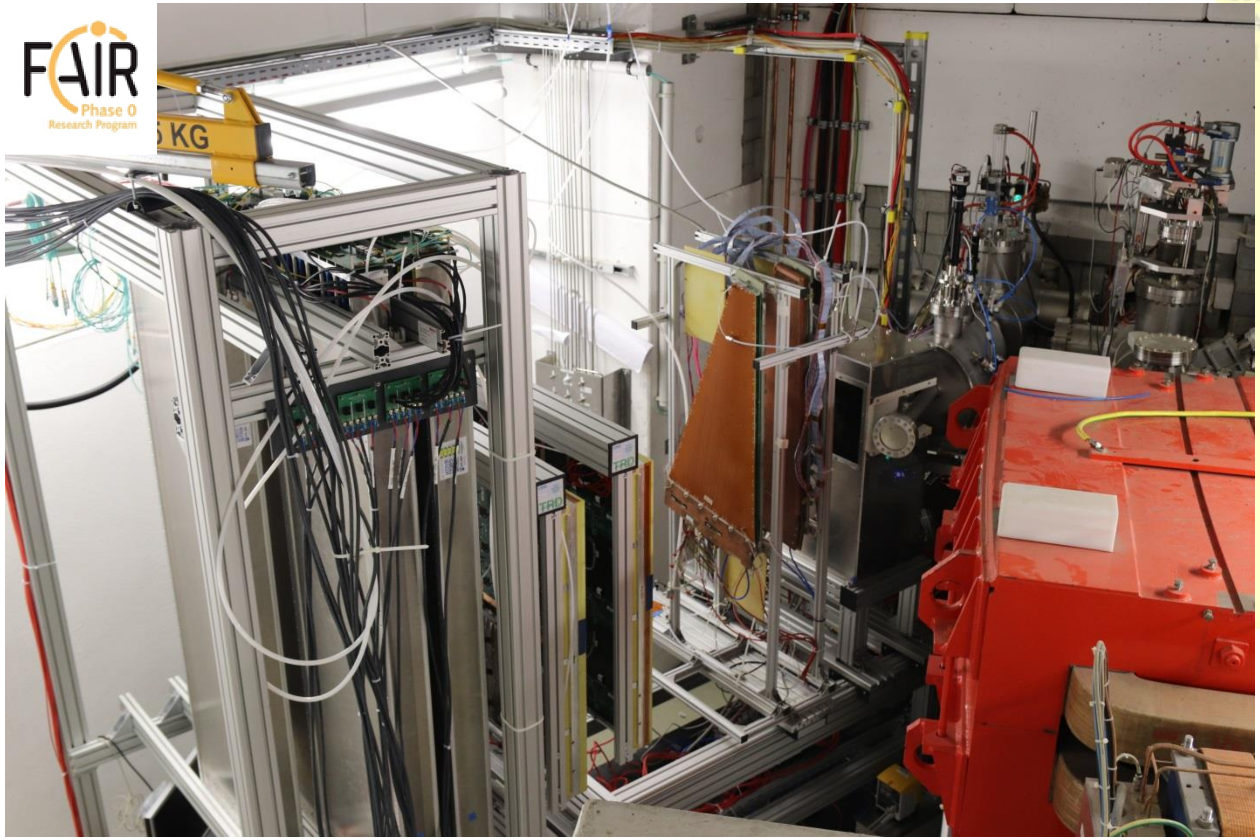


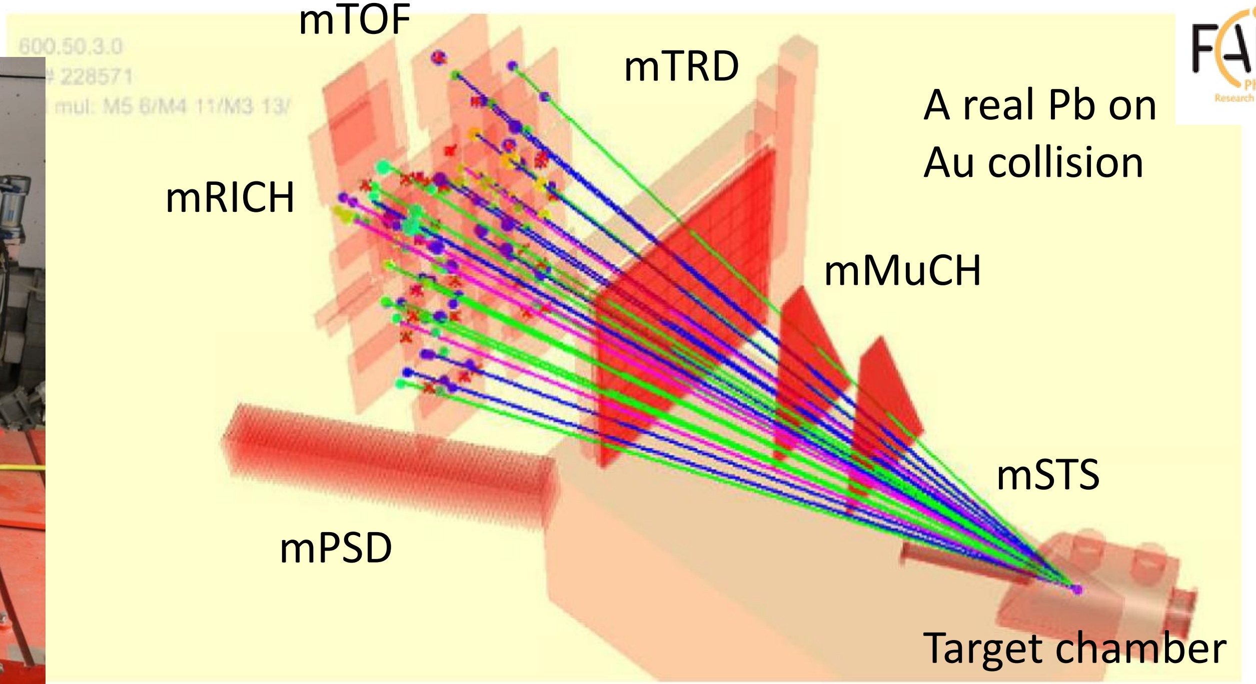
Aging test in Bucharest

Mihai Petrovici

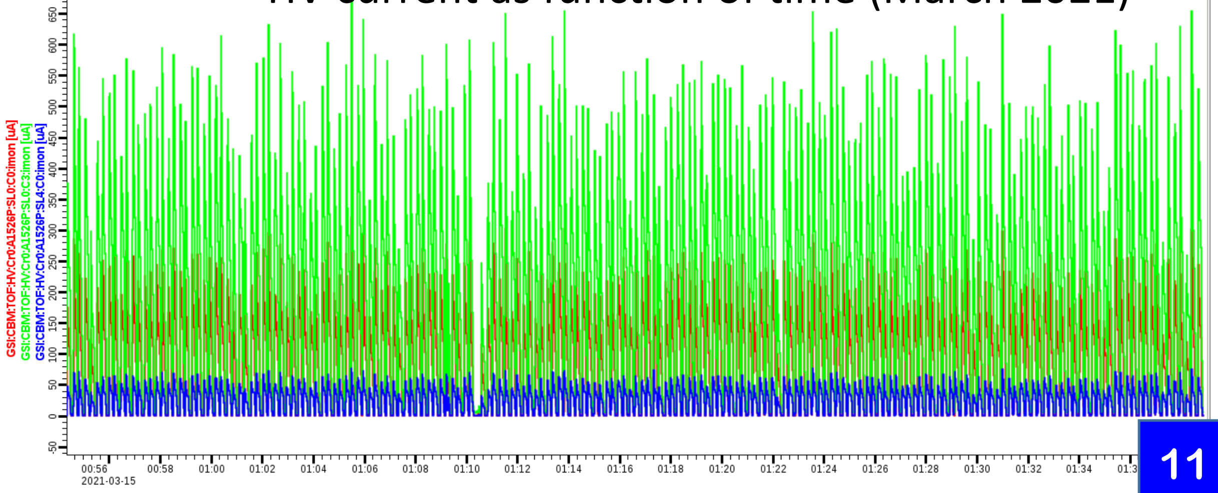
mCBM test setup at SIS18

FAIR Phase 0: mCBM setup @ SIS18





HV current as function of time (March 2021)



- mCBM is a test setup installed at SIS18/GSI dedicated for high rate detector and readout test including free streaming data acquisition and online event selection
- Charged particle fluxes of up to 20 kHz/cm^2

Beam test results

CBM ToF

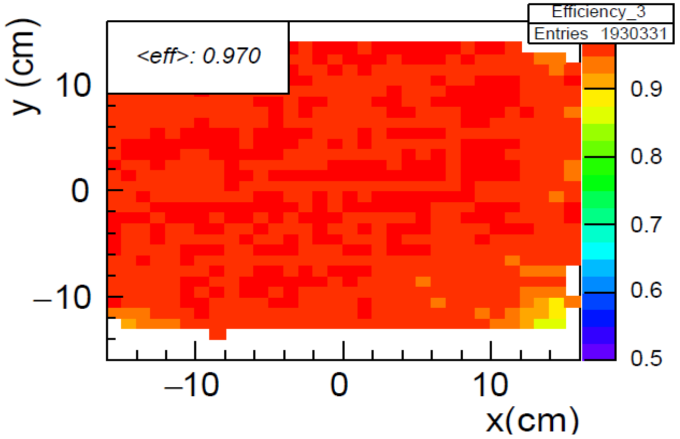
Beamtime mCBM May 2020

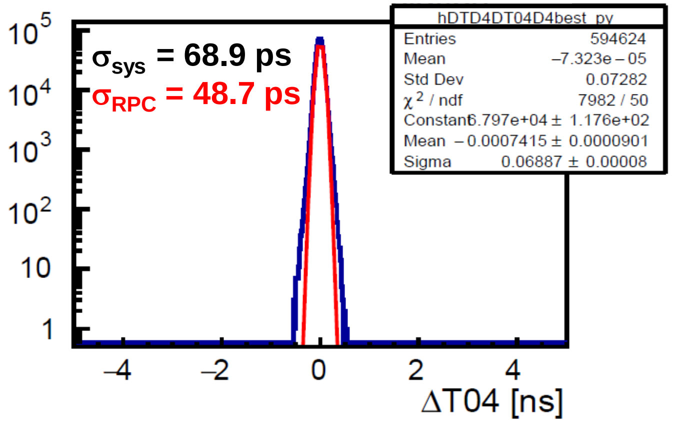
Gas Mixture: R134a/iso-But/SF_6 - 90%/5%/5%

Hit Rate: $6*10^5$ Hz

Flux: 500 Hz/cm^2

MRPC: low resistive glass





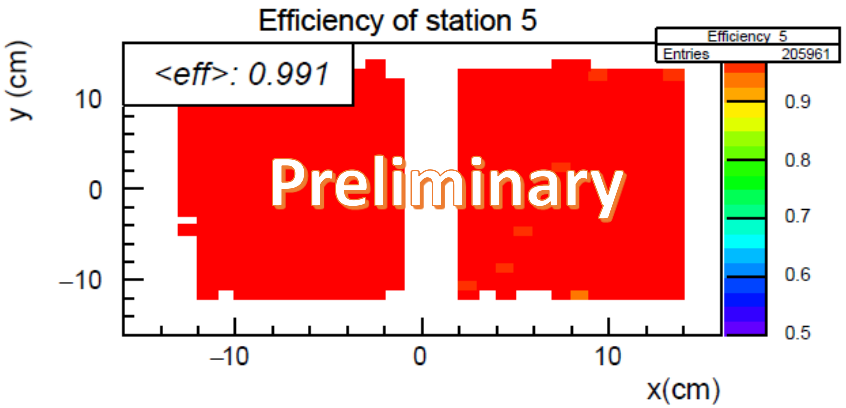
Beamtime mCBM March 2021

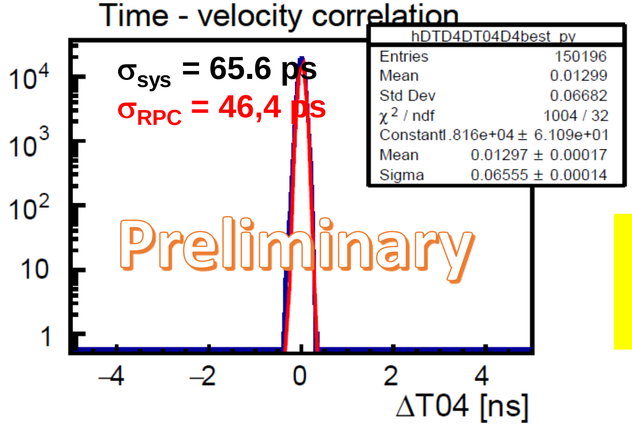
Gas Mixture: R134a/SF_6 - 97.5%/2.5%

Hit Rate: $2*10^6$ Hz

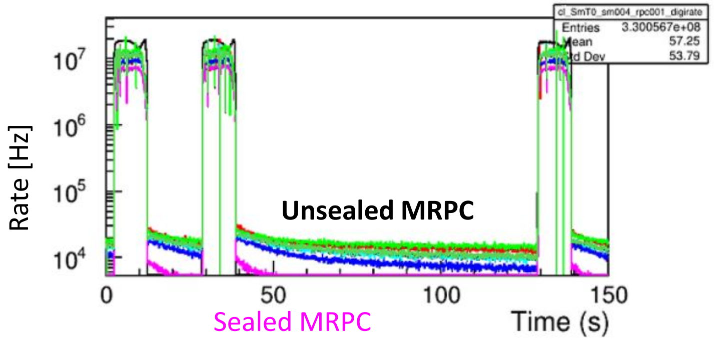
Flux: 2.3 kHz/cm^2

MRPC: thin float glass





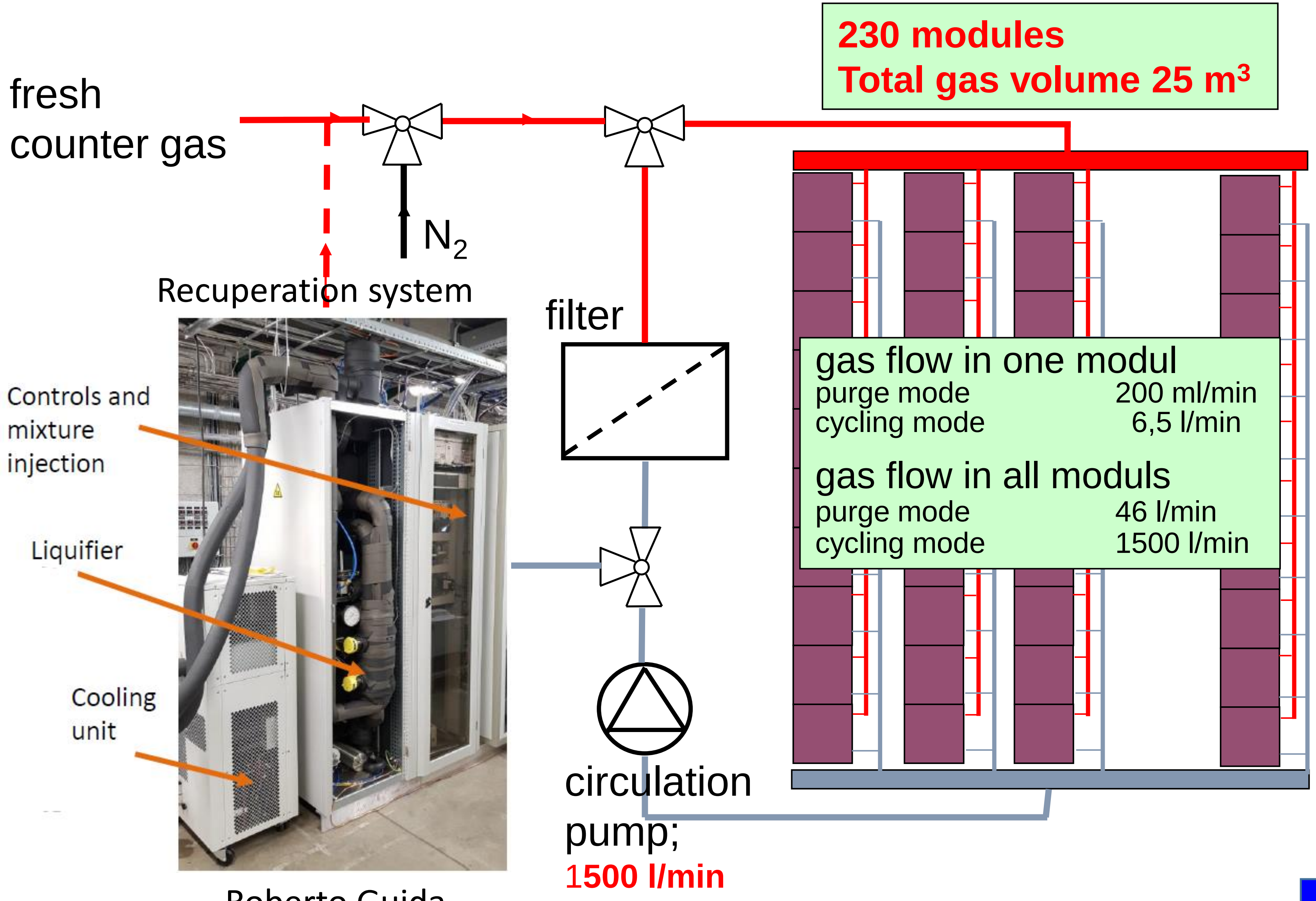
- Analysis of data at higher interaction rates are ongoing



No significant change in performance with new gas mixture observed

Conclusions for the CBM TOF gas system

- Stay with R134a (enhanced F-ion production for HFO in high rate environment)
- Abandon iso-Butan (Aging)
- Reduce fraction of SF_6 to 2.5% (reduction of GWP, difficult to recycle)
- Increase the flow rate dramatically (gas exchange in gaps within 10 s)
- Use intelligent gas management on MRPC (sealing, forced gas flow through the gaps)
- Go for a recuperation system (reuse of gas, cost reduction, GWP reduction)
- Help from expertise (e.g. CERN) is highly welcome



Roberto Guida

Thank you for your attention

Contributing institutions:

Tsinghua	Beijing,
NIPNE	Bucharest,
GSI	Darmstadt,
TU	Darmstadt,
USTC	Hefei,
PI	Heidelberg,
ITEP	Moscow,
HZDR	Rossendorf,
CCNU	Wuhan,

Backup slides