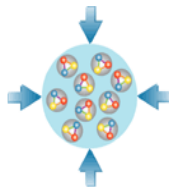
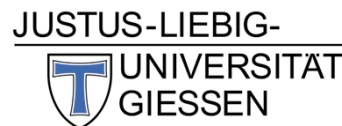


Status of the development of the RICH detector for CBM including a mRICH prototype in mCBM

**Claudia Höhne, University Giessen & GSI
for the CBM RICH collaboration**

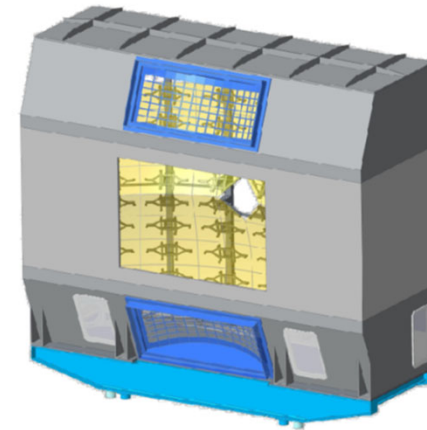


Outline

CBM @ FAIR

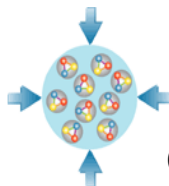
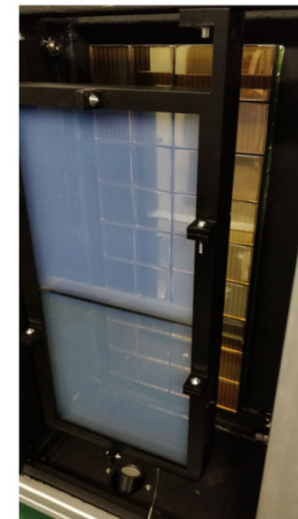
Status of RICH development/ construction

- Photodetector plane & cooling



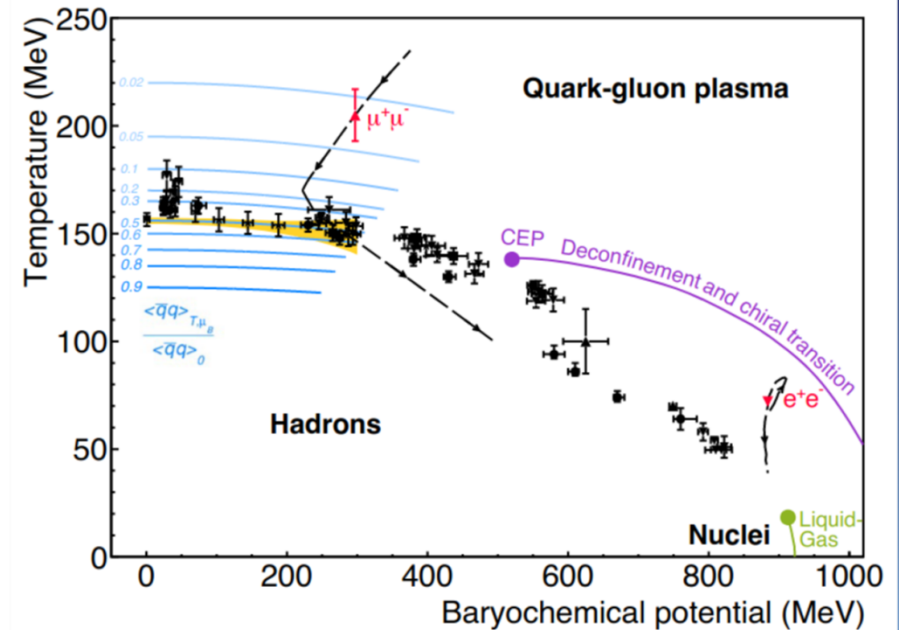
mRICH in mCBM

- DAQ concept
- Test with mRICH

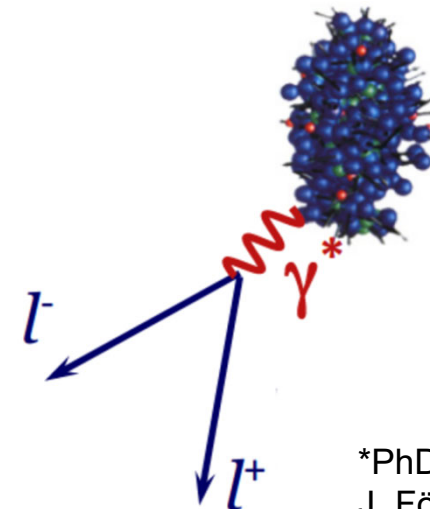


CBM Experiment @ FAIR

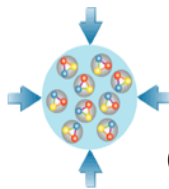
- **Measurement of A+A and p+A collisions at moderate beam energies in fixed target mode**
 - Investigation of the QCD phase diagram at moderate temperatures and high net-baryon densities – different region than investigated by ALICE
- **Important observable: Di-electrons = virtual photons!**
 - Carry nearly undisturbed information from the hot & dense fireball:
 - ✓ Temperature
 - ✓ Lifetime
 - ✓ Modification of hadronic properties (vector mesons!)
- **Close connection to and cooperation with HADES** (J. Förtsch, Monday 14:50)
 - RICH*: share MAPMTs, commonly developed readout electronics



Nature Physics volume 15, pages 1040–1045 (2019)

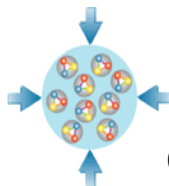
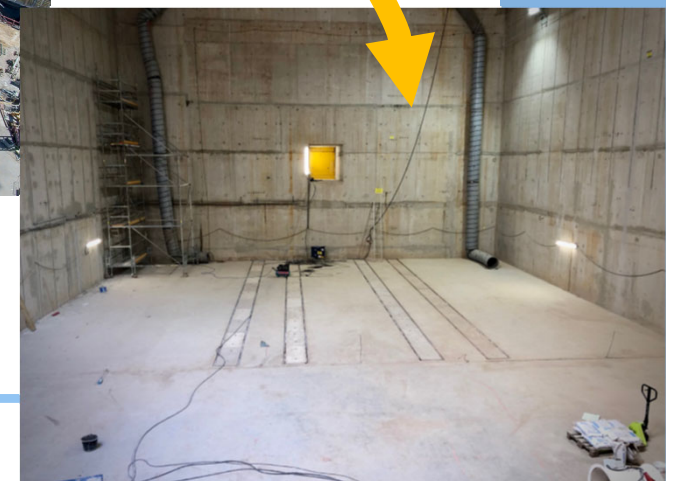


*PhD thesis
J. Förtsch, Univ. Wuppertal
A. Weber, Univ. Gießen



Status of FAIR & CBM

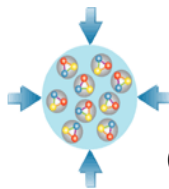
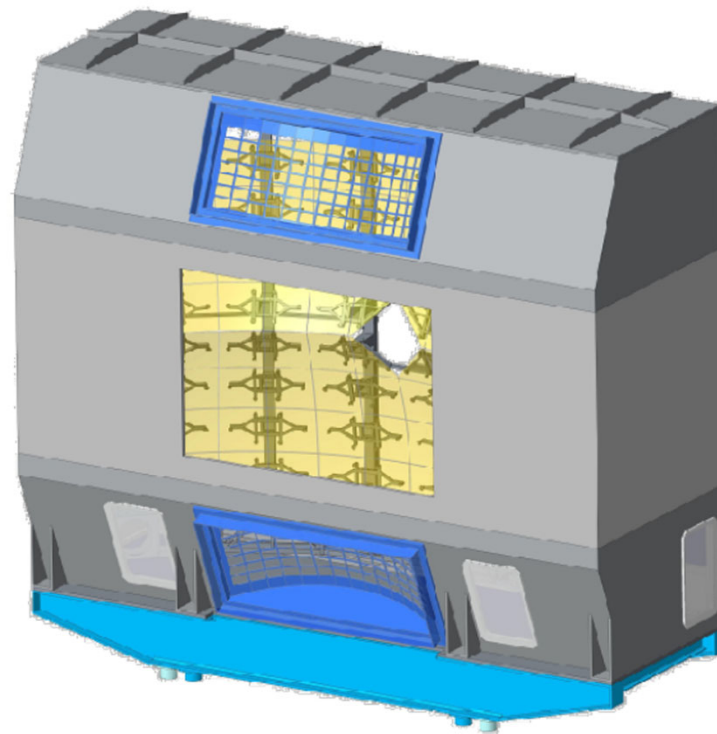
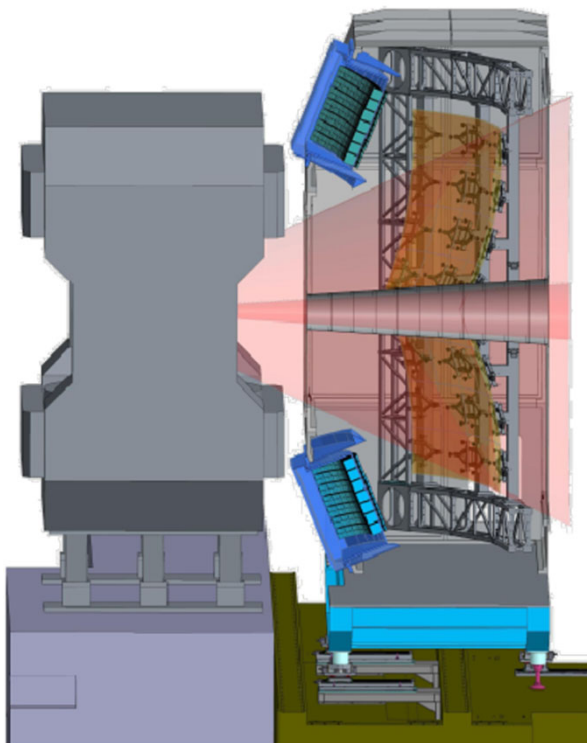
- FAIR construction progressing well
 - ✓ SIS 100 tunnel ready
 - ✓ CBM cave ready
 - ✓ Currently first beam@CBM expected 2028/2029



CBM RICH detector

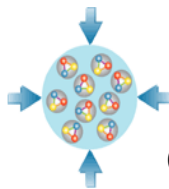
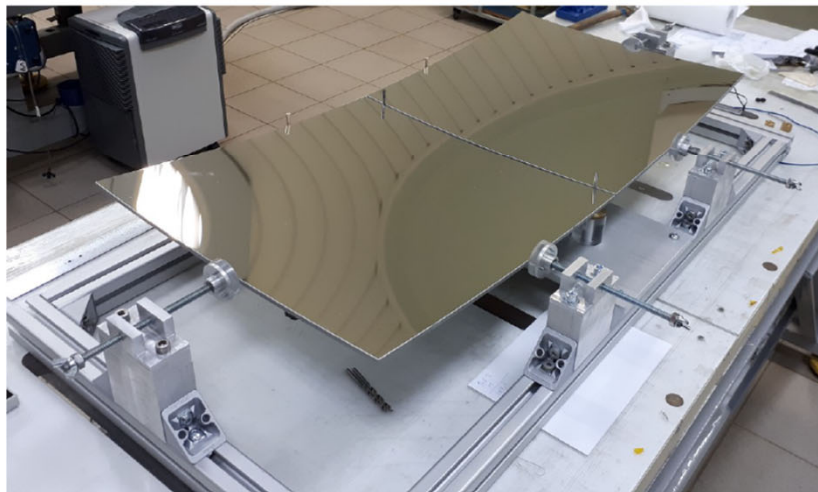
Gaseous RICH detector

- CO₂ radiator gas, vessel volume 2.2 x 6 x 5.06 m³ (l x w x h) = 67 m³
 - π -threshold 4.65 GeV/c, $n=1.00045$, UV cutoff 180 nm
- 13 m² segmented glass mirrors (80 tiles, 6 mm thickness, with Al+MgF₂ or Al+HfO₂ coating), R=3m, focal length 1.5m
- Photodetector planes: MAPMT (H12700) readout (1000 pcs), 64k channels, DiRICH readout, free streaming DAQ, placed inside large shielding boxes



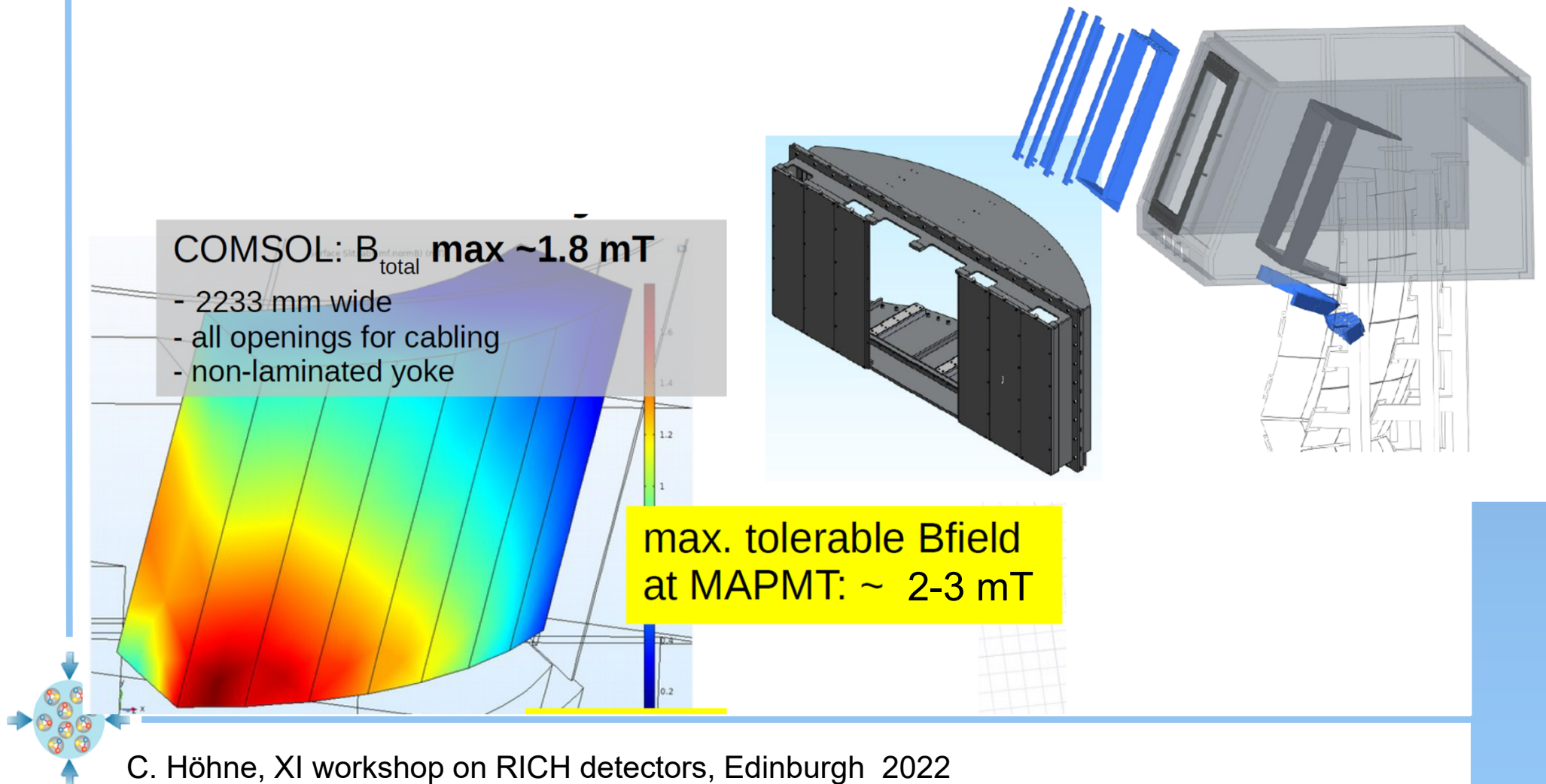
Mirror holding structure

- Mechanical concept well developed, prototype has been built at PNPI, St. Petersburg
- Currently work in progress re-establishing production procedure etc.



Photodetector plane

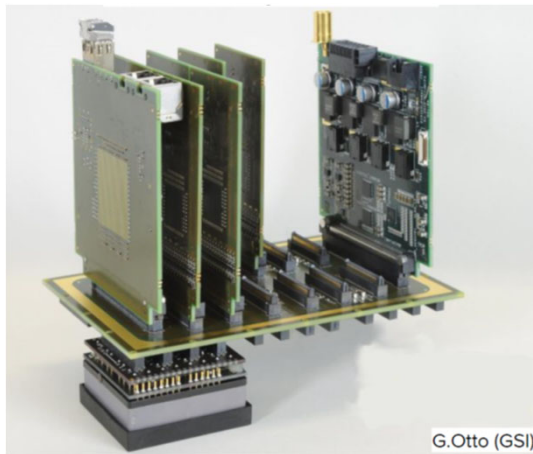
- Photodetector planes surrounded by shielding box, mechanically decoupled from photodetector plane
- central back cover non-magnetic as result of optimization
- CBM: 1 Tm magnet
- Stray field B_{total} in PMT plane reduced to max 1.8 mT



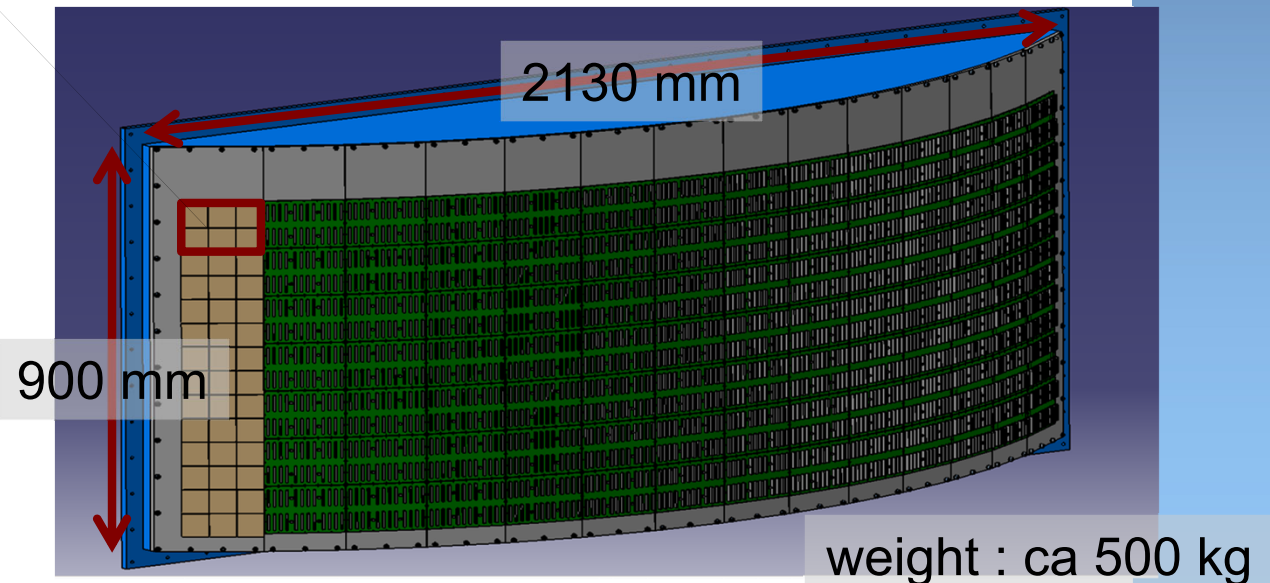
Photodetector plane

- Photocamera as curved plane, 14 columns with 7 backplanes each
- MAPMTs (H12700) shared with HADES
- readout electronics commonly developed*
- Rate capability of DiRICH sufficient for CBM (up to 300 kHz/pixel)
- Data transfer limited by 2.4Gbps connection from combiner; to be updated in future

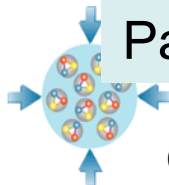
* Big thanks to the good cooperation with the TRB collaboration



individual
3x2 MAPMT
readout module



See CBM poster of
Pavish Subramani



Power module

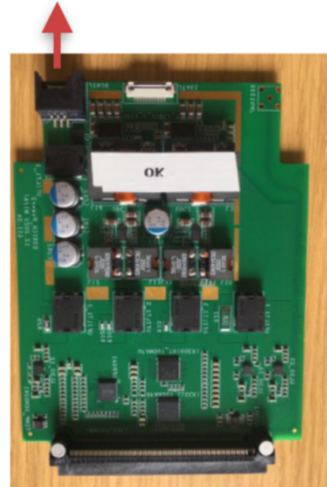
- HADES: external powering scheme used in experiment
- power module updated: Onboard DCDC convertor („silent switcher“)
32V \rightarrow {1.1, 1.2, 2.5, 3.3V}; possibility to add further shielding (Al, EMV foil)
- noise level achieved comparable to external powering scheme in HADES

External LV Connector

DC/DC Power Connector (36 V max)



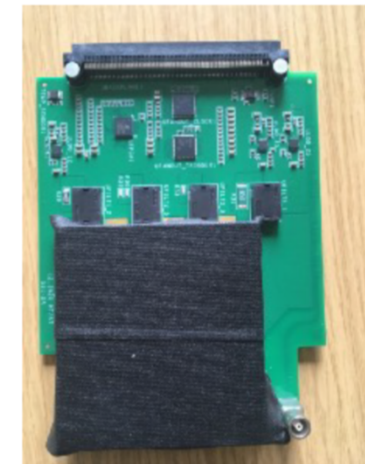
Old Module



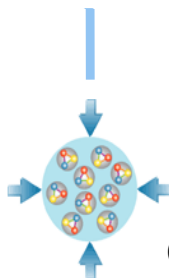
New Module



New Module with
Shielding box

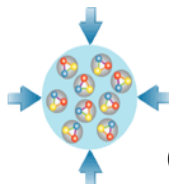
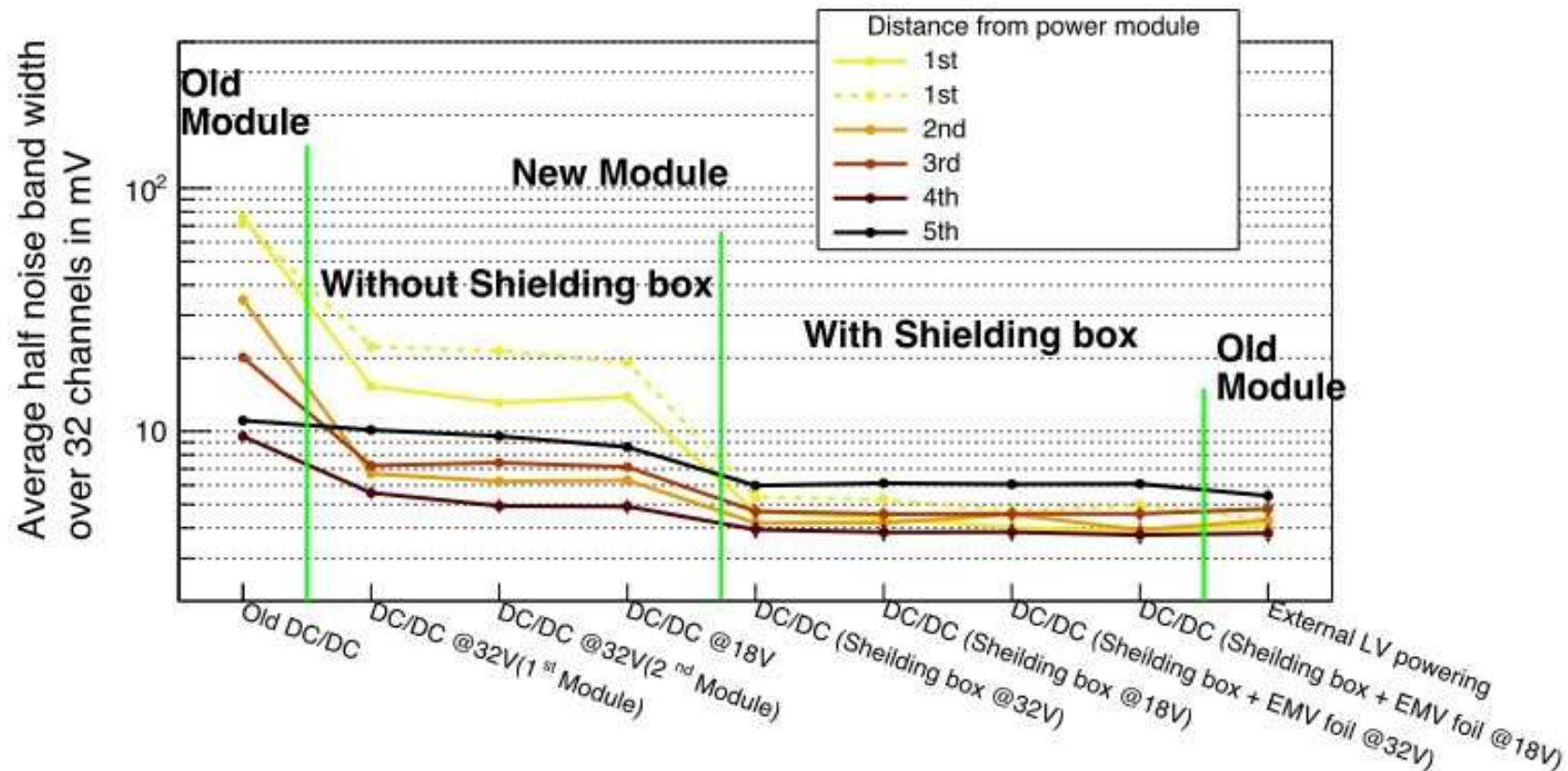


New Module with
Shielding box and EMV foil



Power module

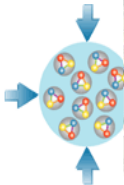
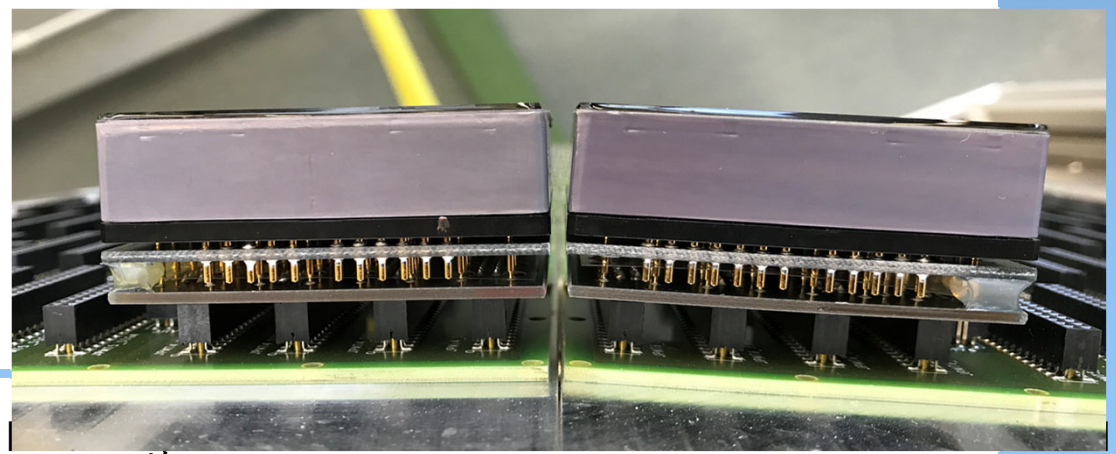
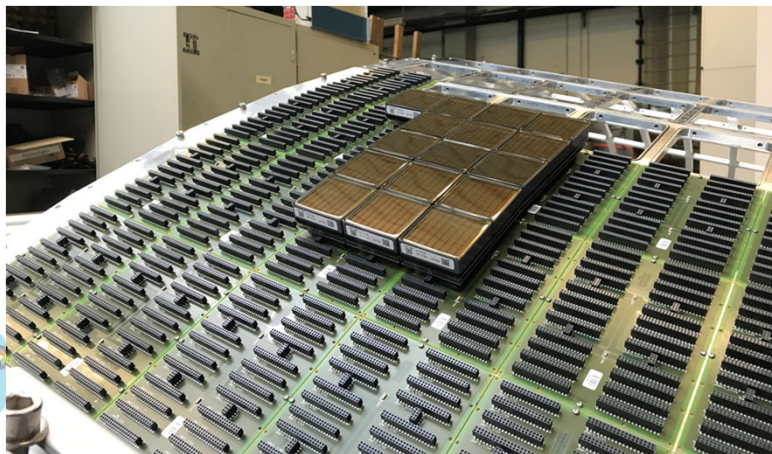
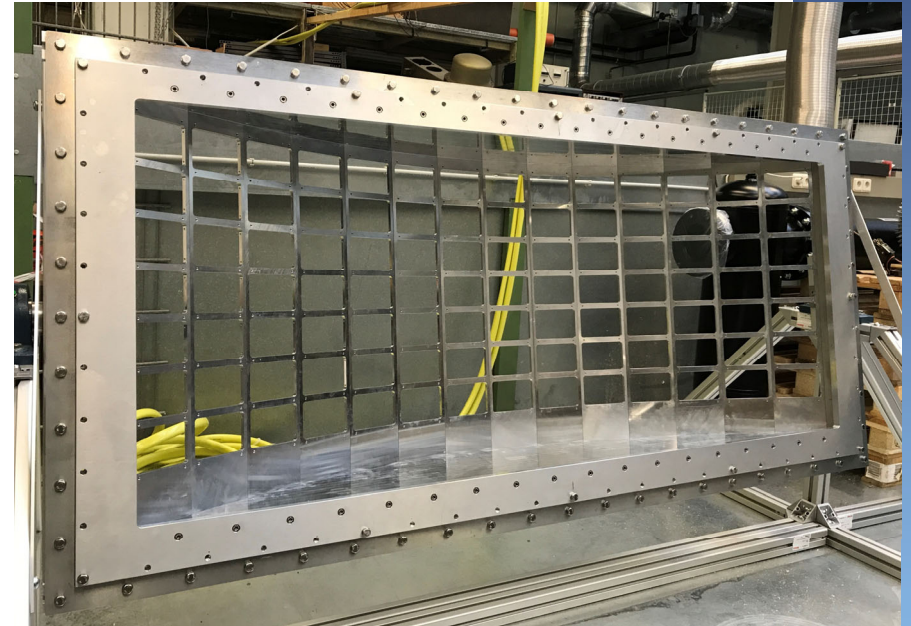
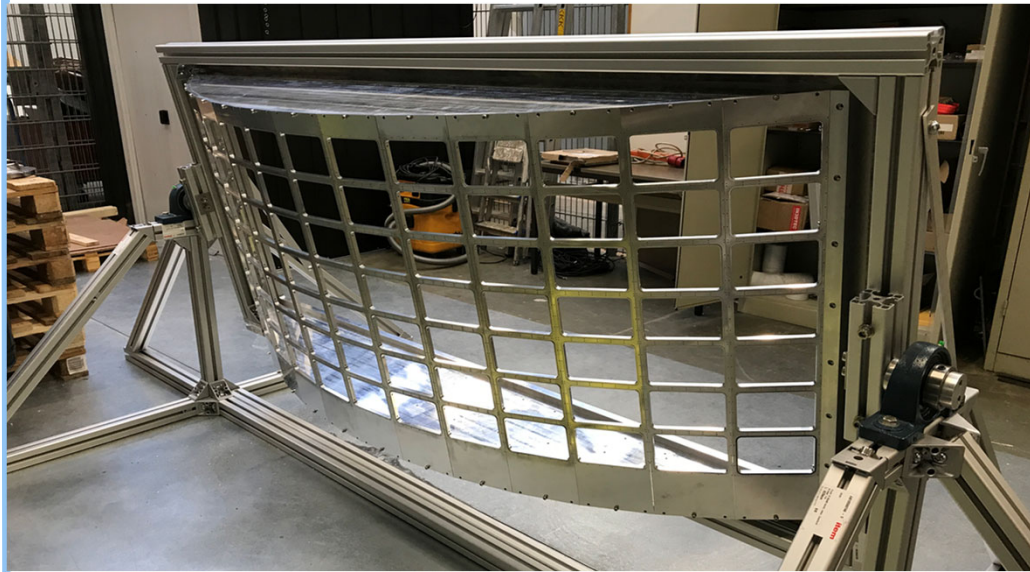
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32V \rightarrow {1.1, 1.2, 2.5, 3.3V}; possibility to add further shielding (Al, EMV foil)
- noise level achieved comparable to external powering scheme in HADES



Photocamera plane

Prototype of one full camera under construction:

- Test mechanical stability
- Test handling
- Test cooling concept
- Test gas tightness of camera

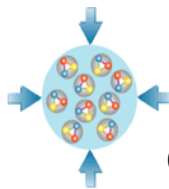
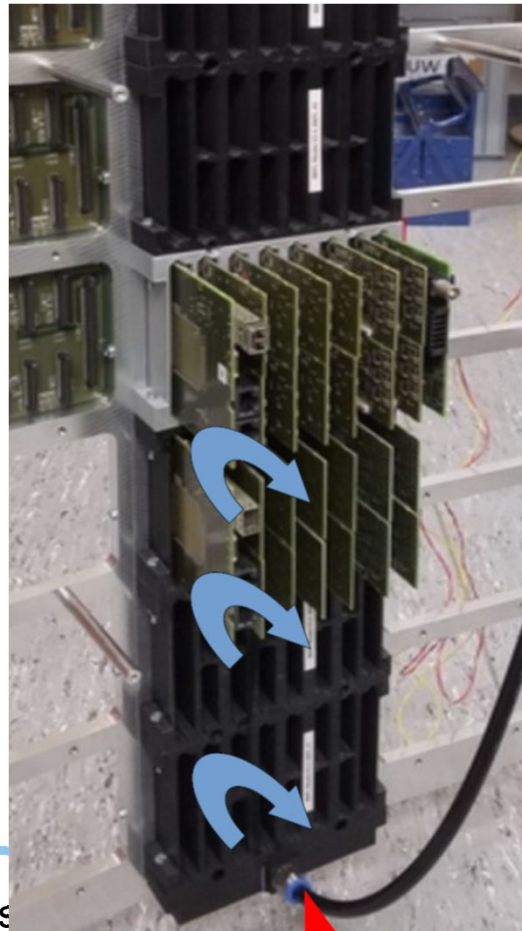


Cooling

- Each backplane: 12 DiRICH modules, combiner board, power module
 - Approx. 1400 electronic modules per camera
 - 3 kW heat dissipation per camera module (2 modules)
 - Closed volume inside shielding box
- concept: cooling with forced air flow via custom distribution masks, pushing warm air OUT of the electronic modules

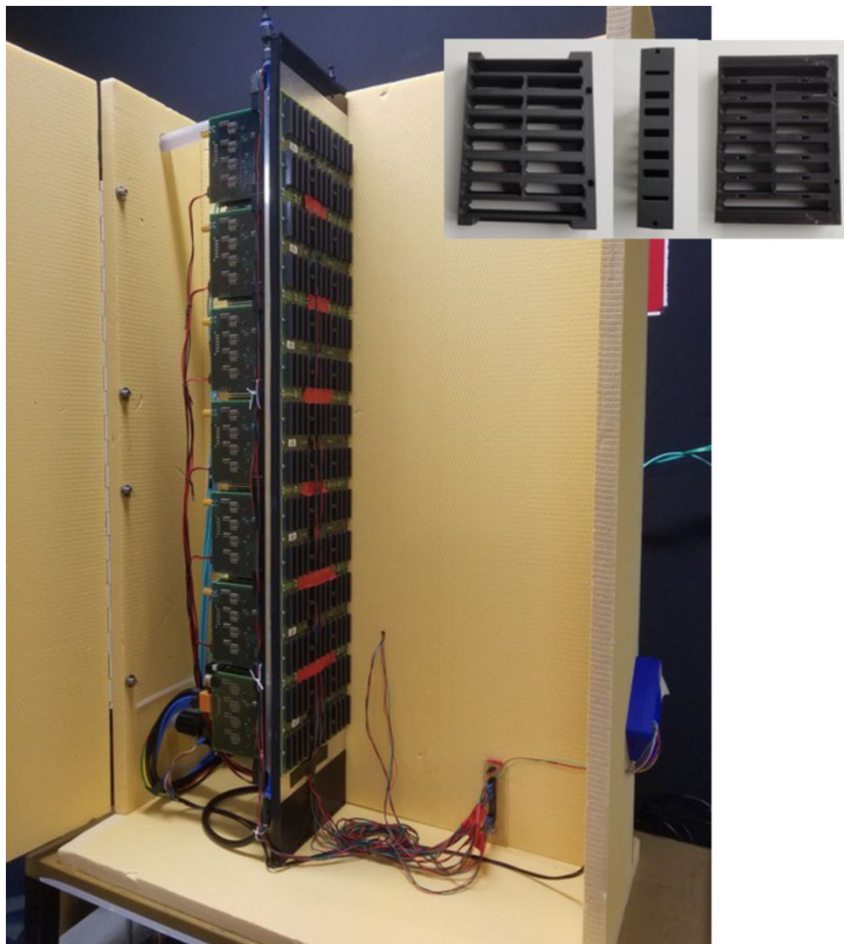


prototype of backplane mask

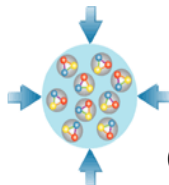
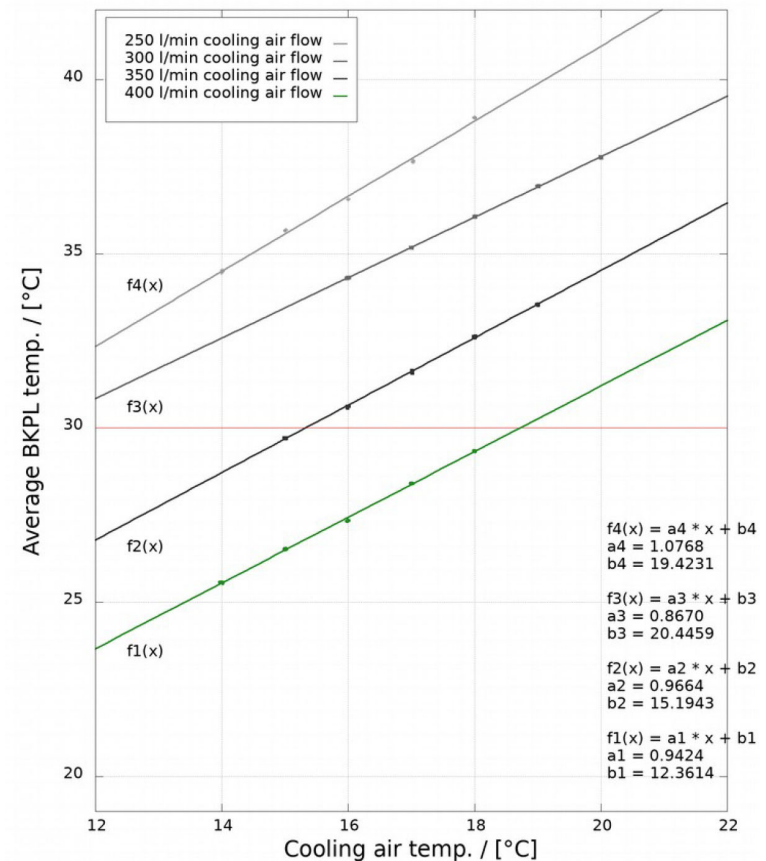


First cooling prototype

- Fully equipped single readout column, evaluate cooling air requirements
 - Many sensors for temperature/ flow
- Stay below 30°C for 15°C cooling air and 350 l/min air flow (i.e. approx. 5m³ / min per camera)

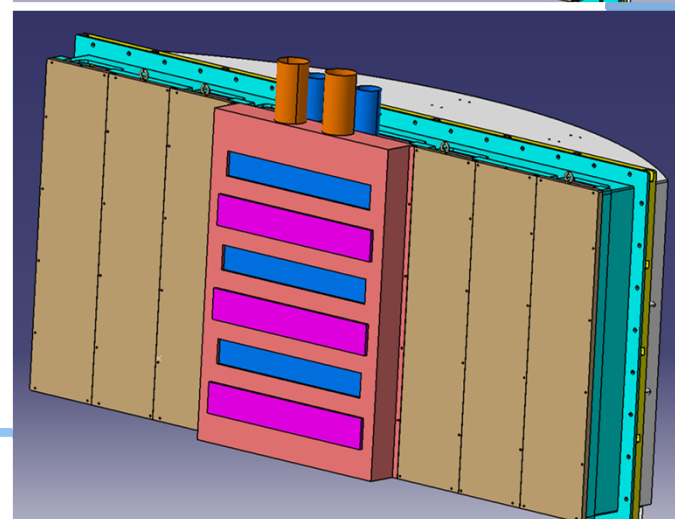
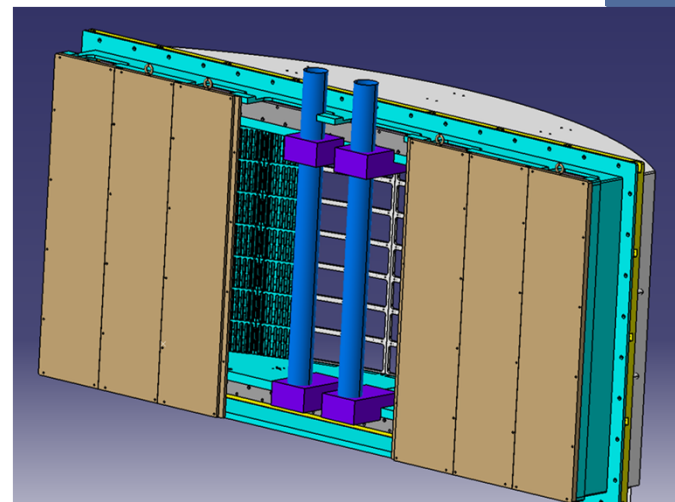
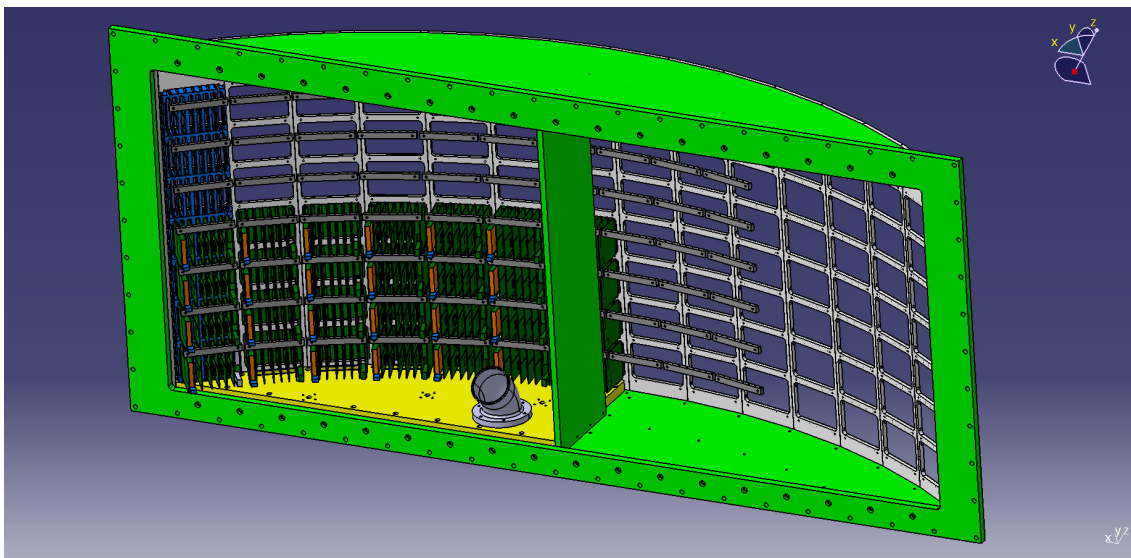


Average BKPL temp. versus cooling air temp.

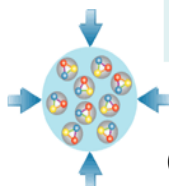


Cooling

- Cool air inlet via 2 hoses, distributed via top/ bottom plate to module columns
- Warm air outlet via air collection box (shielding box center part is non-magnetic)
- Large spring-loaded flaps in order to protect in case of under/over pressure
- Test setup under preparation, additional simulations started



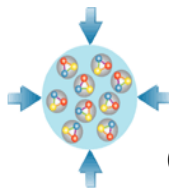
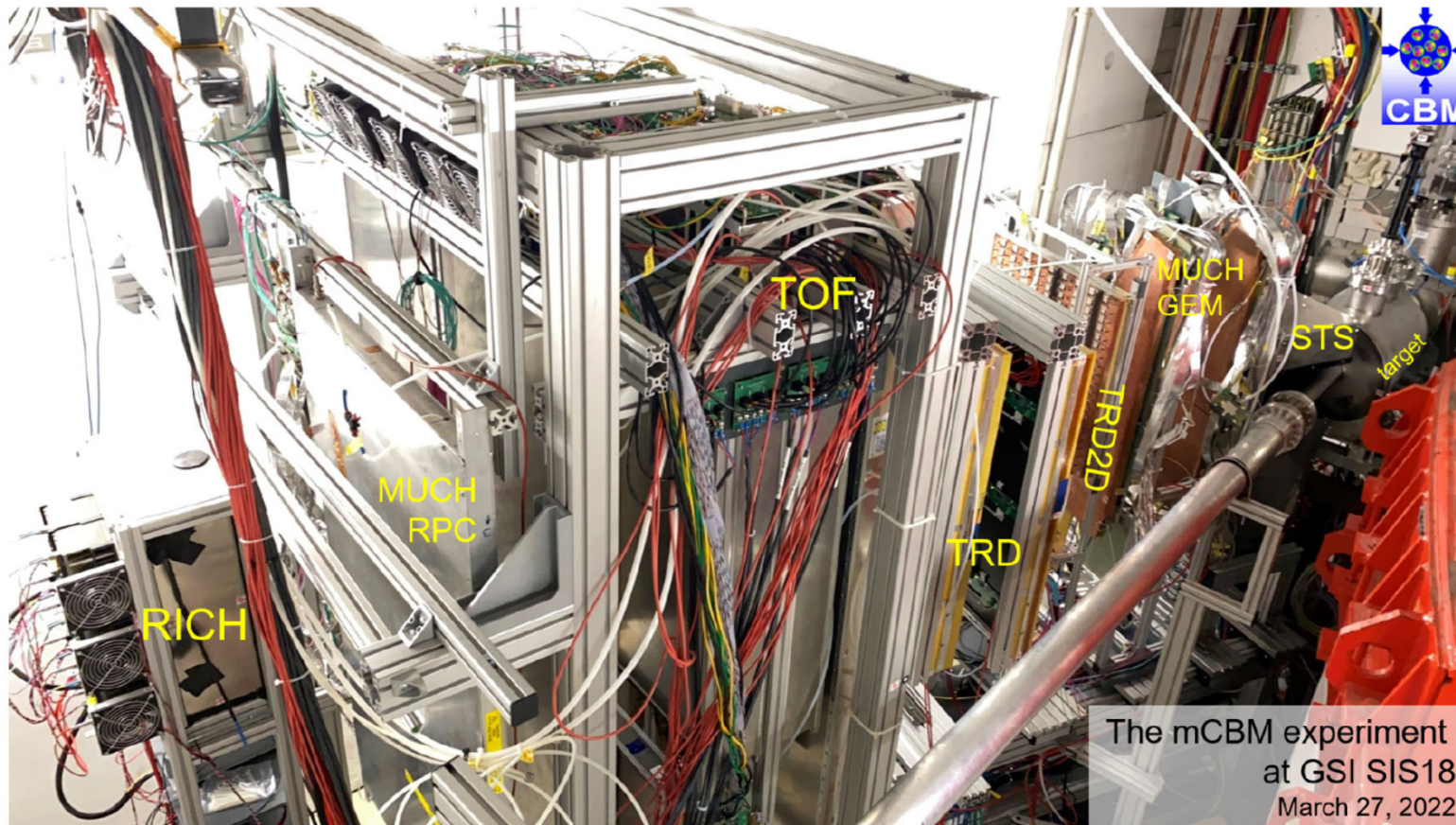
cooling air requirement (current estimate):
~ $5 \text{ m}^3 / \text{min} / \text{camera}$, $\leq 18^\circ\text{C}$
~ 3kW heat load (per camera)



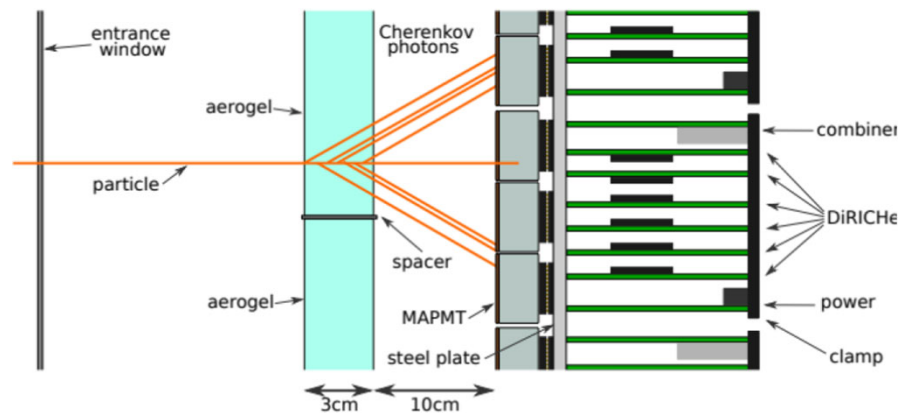
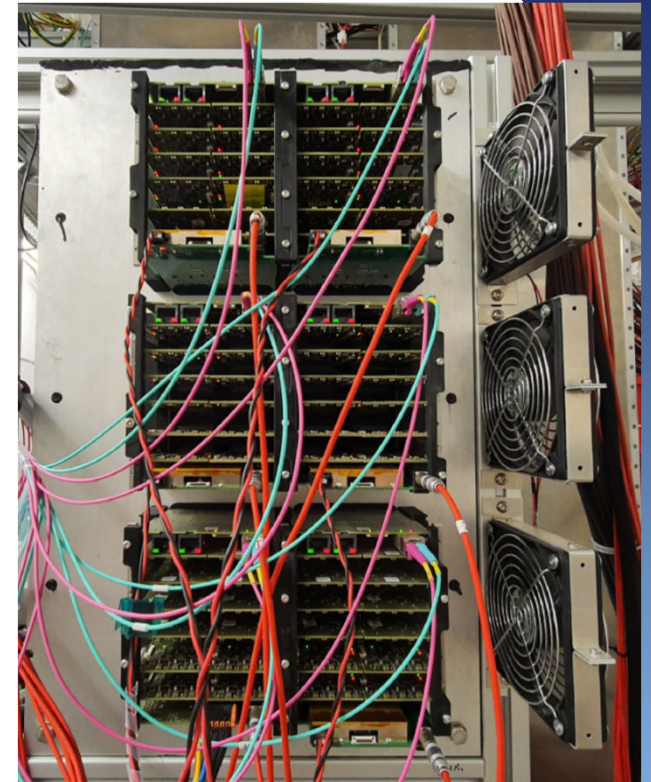
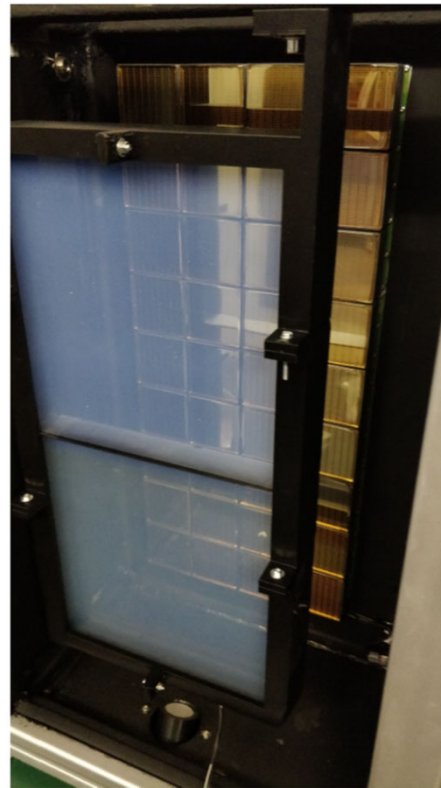
mCBM

CBM will be challenging due to anticipated rates

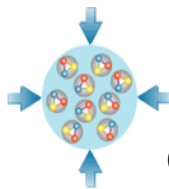
- RICH up to 100 kHz (10 MHz) interaction rate
 - Triggerless, free-streaming readout
 - Max 300 kHz/ pixel single photon hit rate (10 MHz, Au+Au @ 12 AGeV)
 - Approx. 30 hits/ring distributed among 4 MAPMTs: 8-9 hits/ring/MAPMT
- miniCBM (mCBM) as test bench at GSI @ SIS18



- Proximity focussing setup with 2 aerogel radiators each $20 \times 20 \times 3 \text{ cm}^3$ (CLAS12 type, $n=1.05$)
- 10 cm gap to MAPMT plane, 6 backplanes (2x3 MAPMTs each)
- CBM/HADES MAPMTs and readout electronics
→ Transfer triggered HADES readout into free-streaming CBM readout

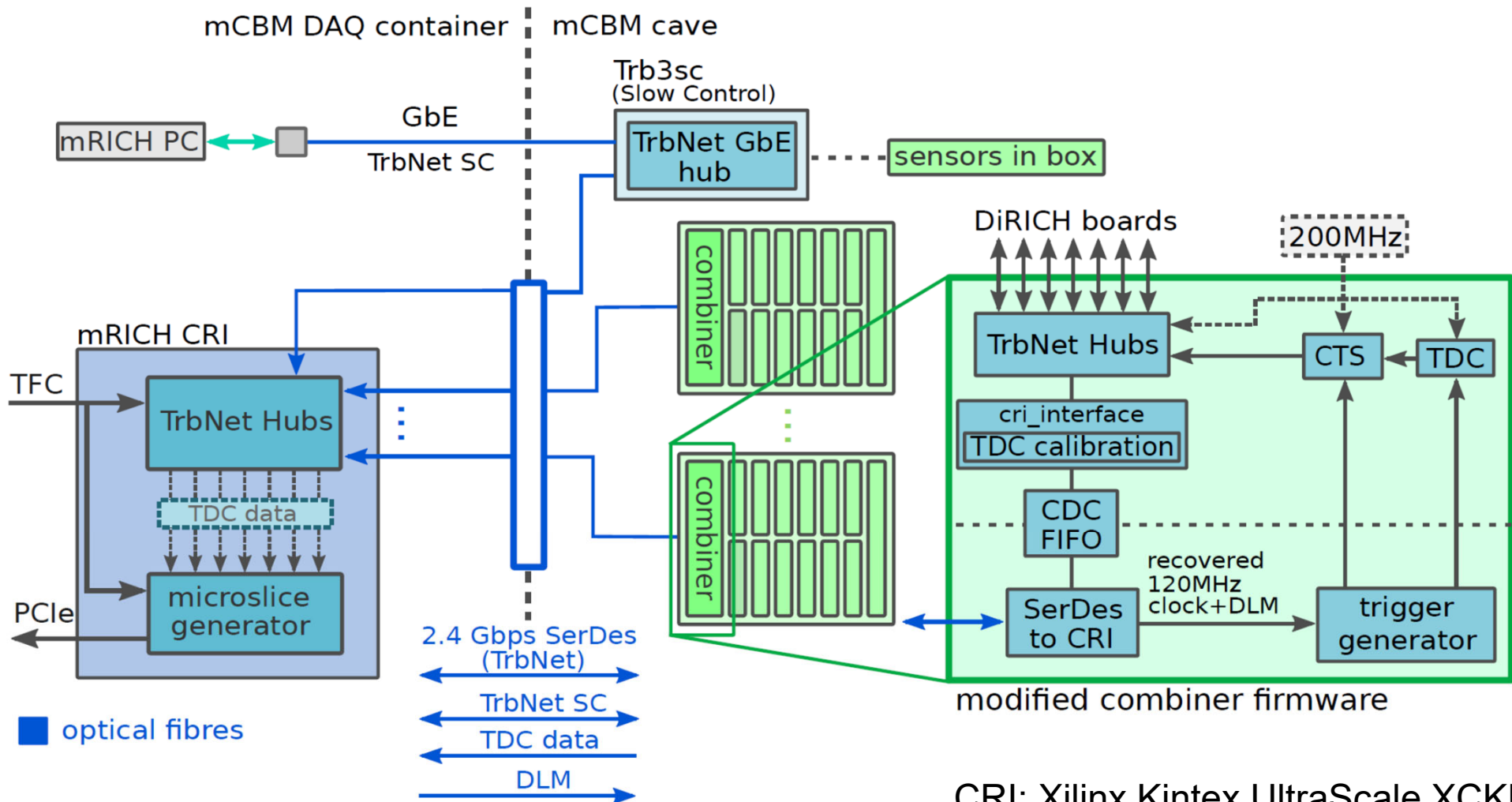


Side comment:
Upgraded power module in operation!
→ Not much cables...



mCBM DAQ

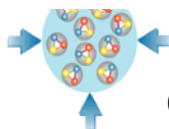
- mRICH DAQ (2022) based on final common readout interface (CRI)
- Scalable to full RICH
- TFC (Timing and Fast Control): central time distribution of CBM time



CRI: Xilinx Kintex UltraScale XCKU115

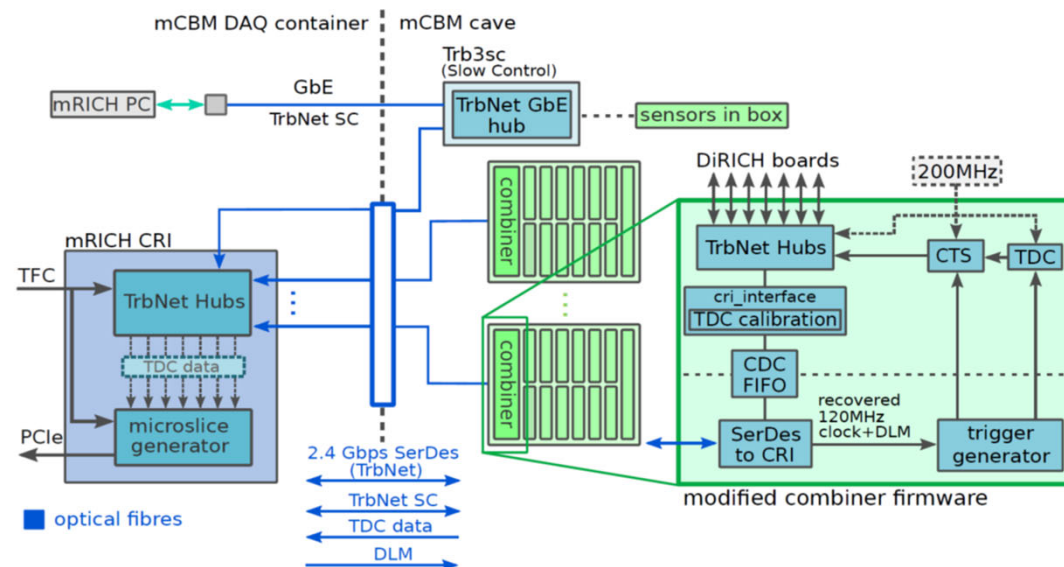
Combiner: Lattice ECP3

DiRICH: Lattice ECP5

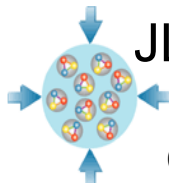


mCBM DAQ

- CRI (FLX-712/BNL-712 readout card) central part, can connect to up to 47 combiners (backplanes)
 - Merges data from combiners into microtimeslices (typ. length 12.8 ms) and sends them to FLES (first level event selection) entry node
- CBM time from central timing system CTS (120 MHz)
- Synchronization between CBM clock and local FEE clock (100 MHz) by TDC in combiner module
- Trigger generation for regular DiRICH readout in combiner board
 - 240 MHz clock recovery, data rate of 2.4 Gbps
- FPGA based online fine-time calibration in combiner (necessary due to FPGA routing)



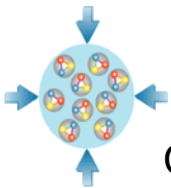
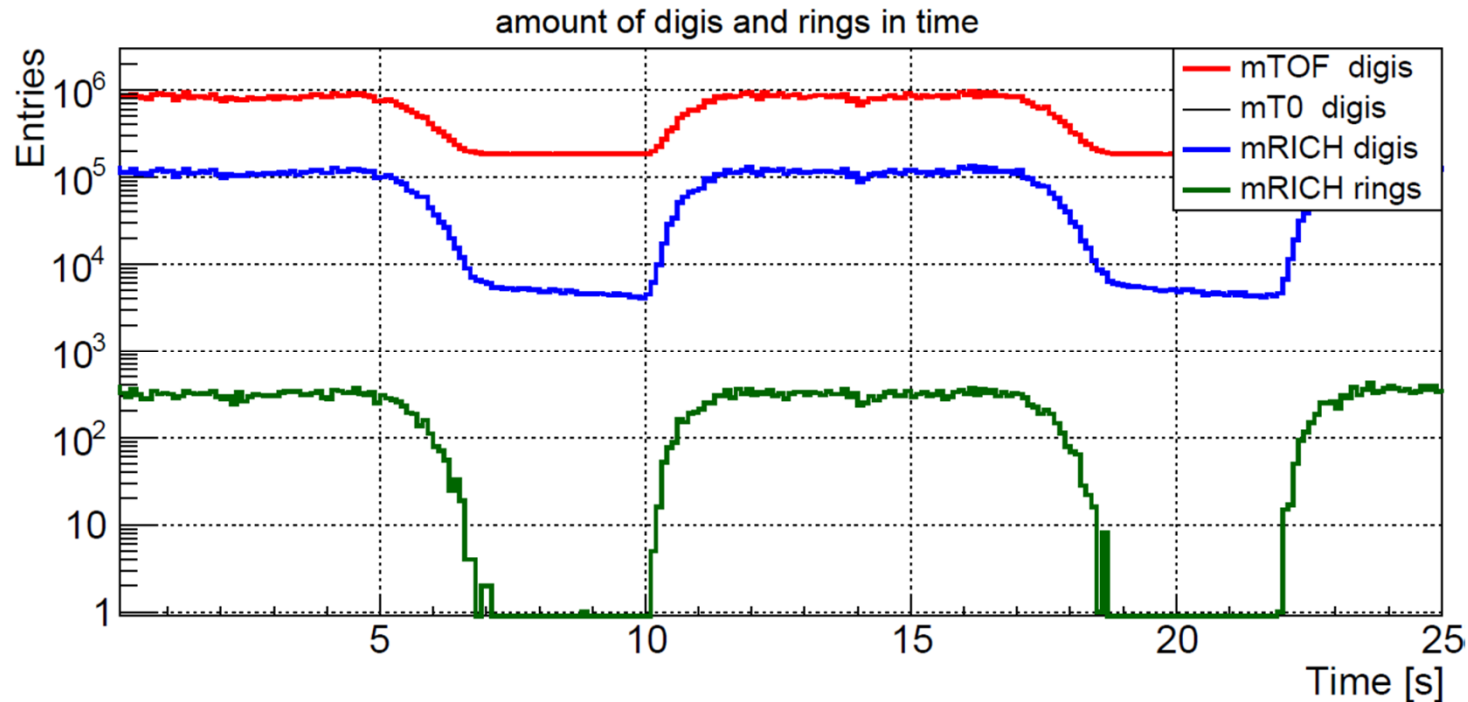
PhD thesis, Adrian Weber,
JLU Gießen



Results from beamtimes

Results from (various) test beams with A+A collisions (Au, Ag, O, Ni) at 1-2 AGeV beamenergy at GSI@SIS18 for 100kHz – 1MHz collision rates

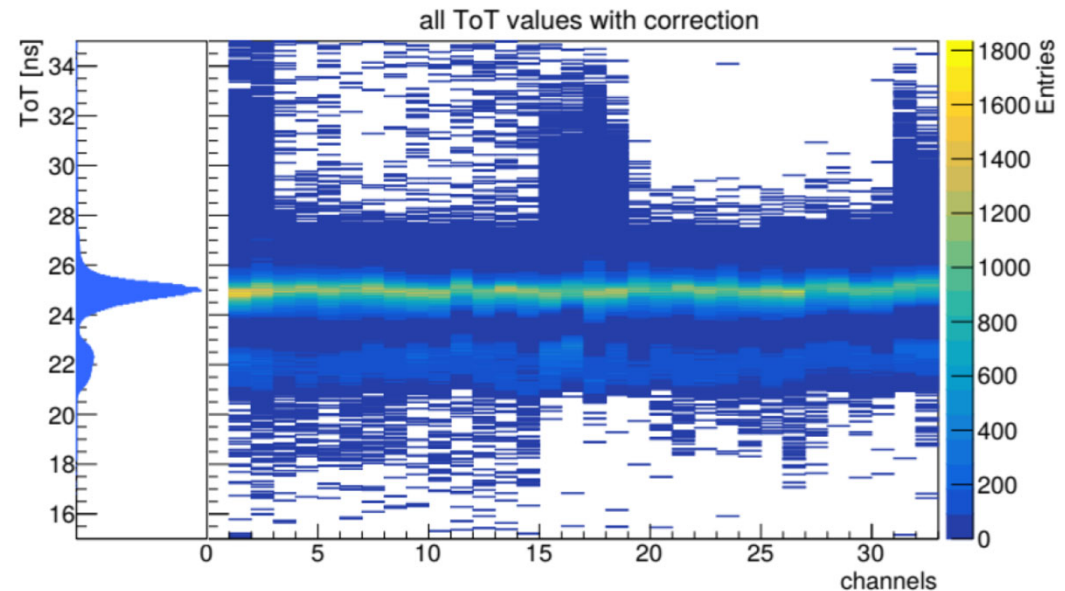
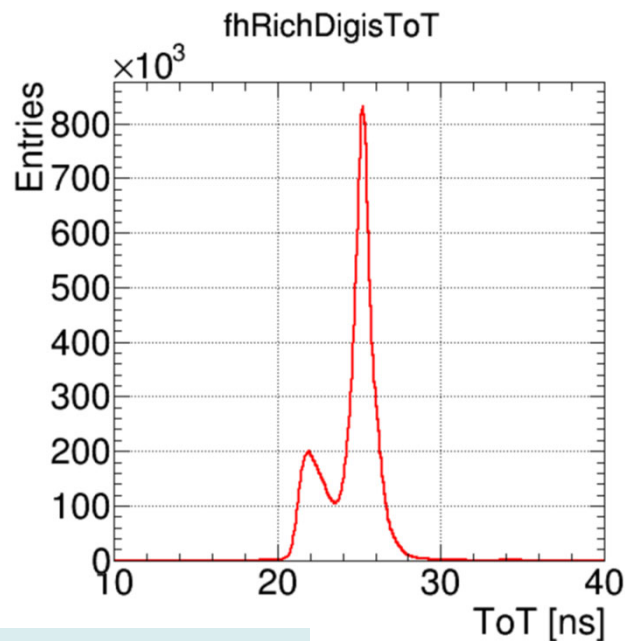
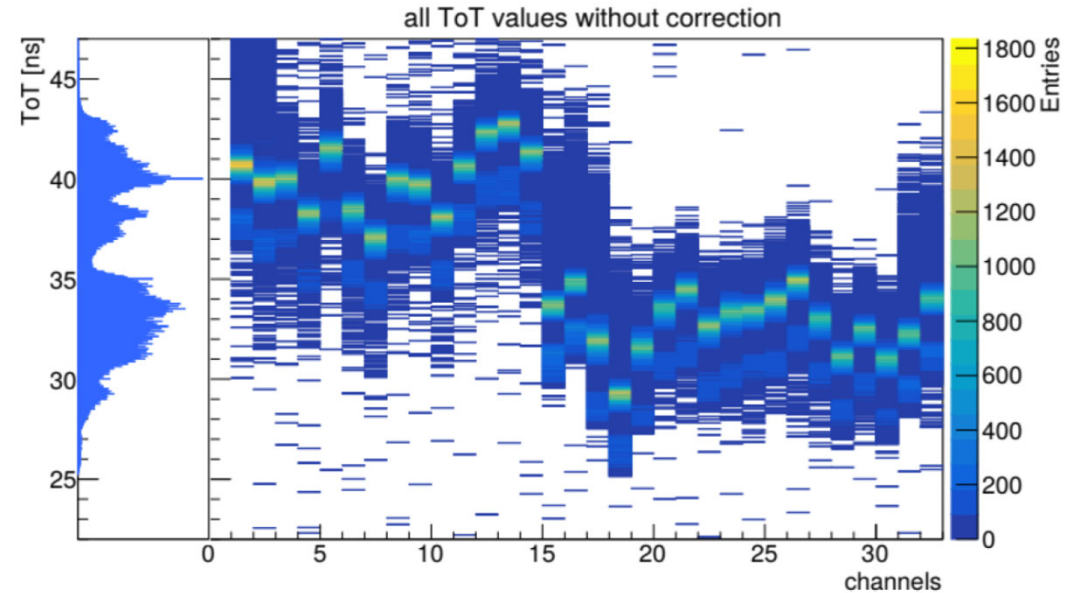
- Free streaming readout works
- Timing under control, including timing corrections
- Time-based ring finder
- No rings found in spill breaks



ToT correction

Timing corrections

- Fine-time calibration (online)
- ICD (Inter channel delay) correction
- Separate ToT correction for each channel
- ToT important for noise reduction (crosstalk)

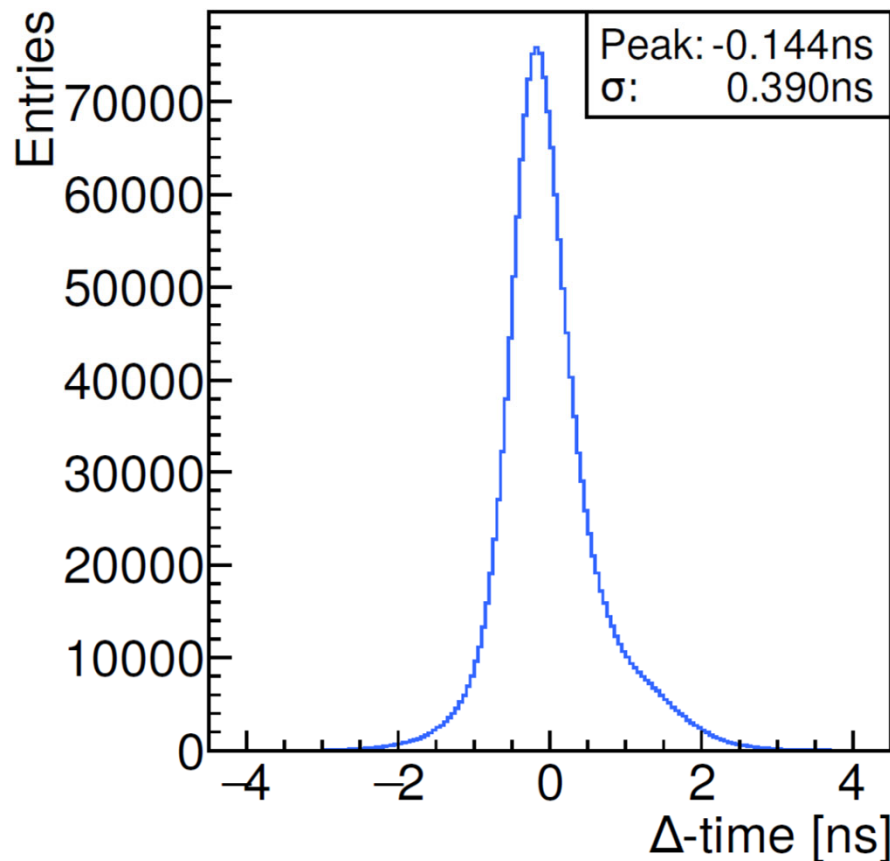


See CBM poster of Pavish Subramani

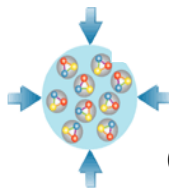
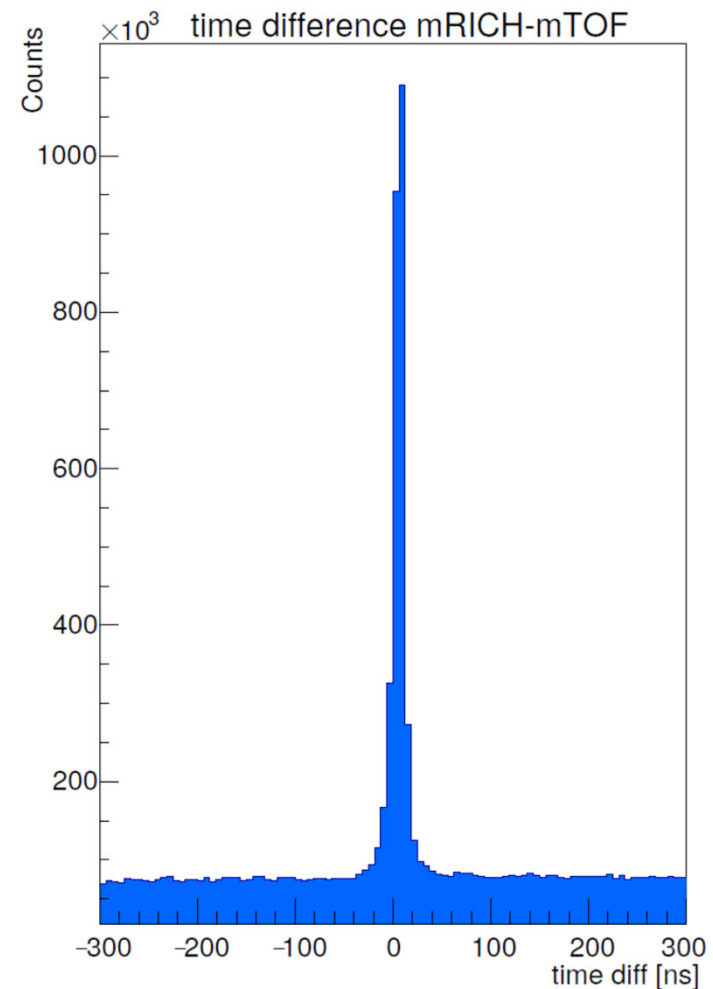
Workshop on RICH detectors, Edinburgh 2022

Time precision

- Time difference of hits within a ring to the mean time of the ring
- Slight tail to the right: contamination with hits later in time

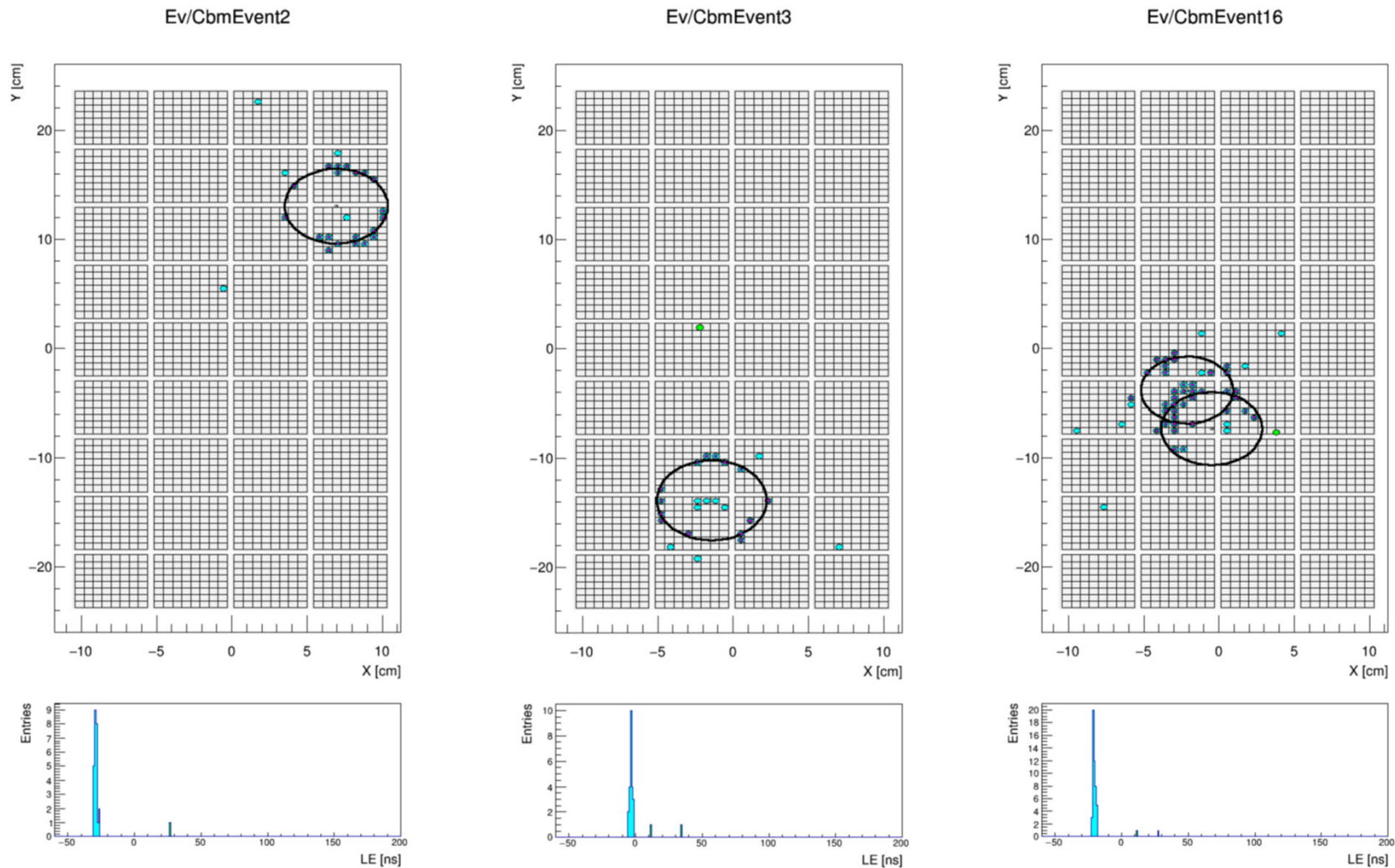


- Time correlation between mRICH and mTOF in first TFC synchronized run



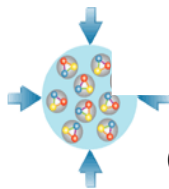
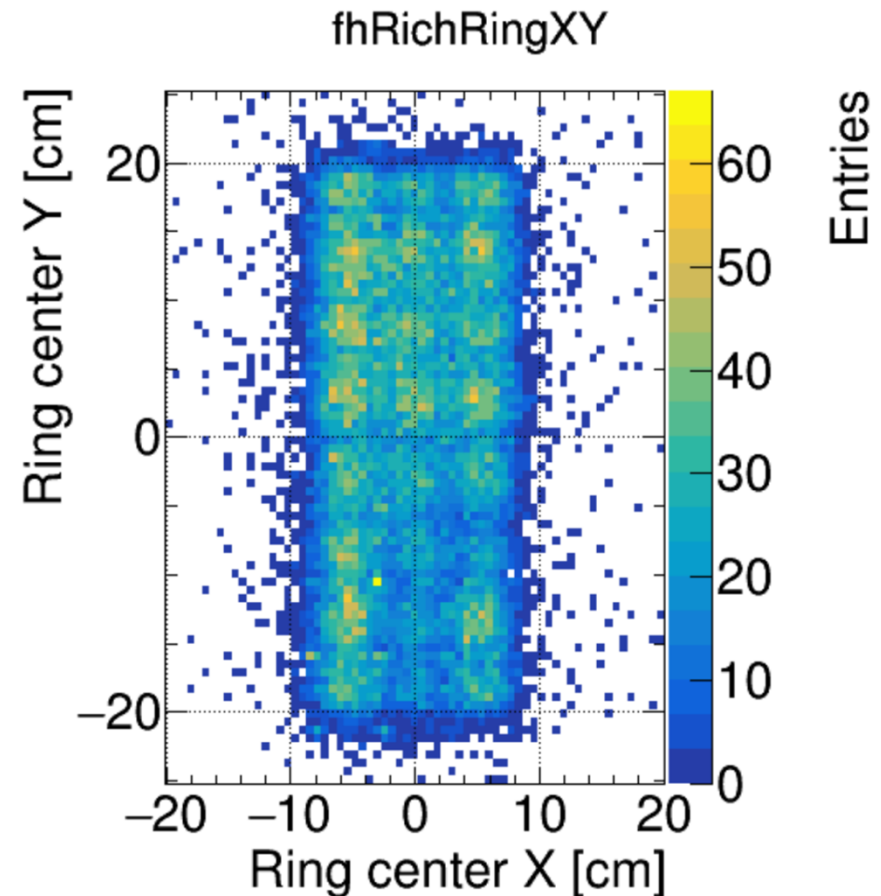
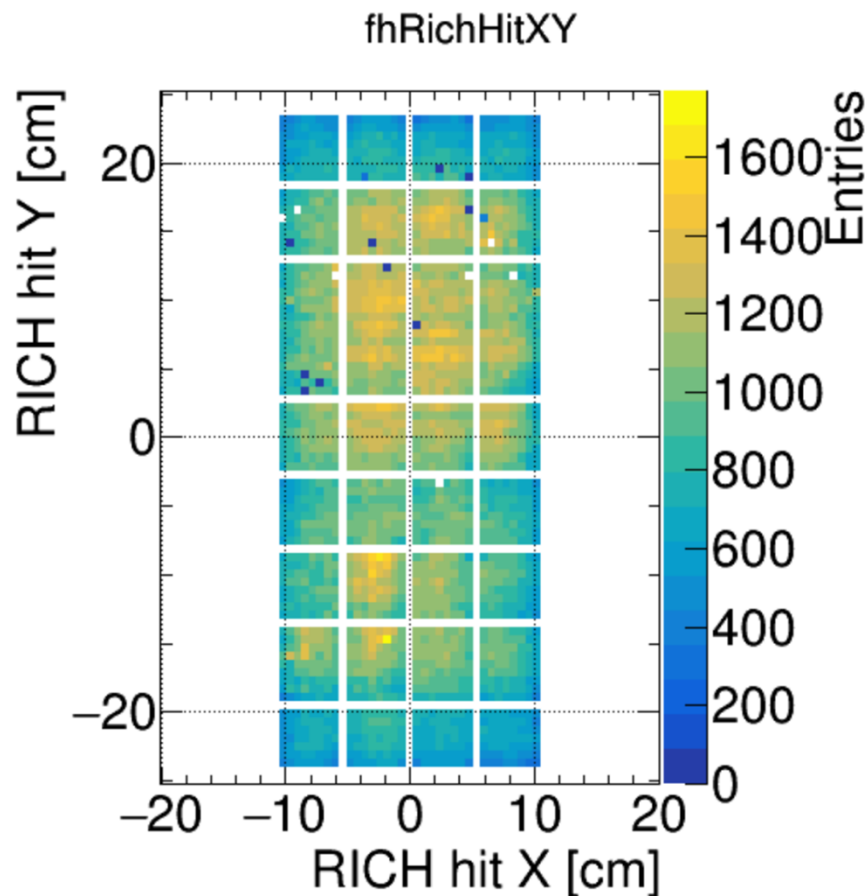
Single event displays

- Special hit pattern with center hits due to passing charged tracks
- Hough Transform ring finder (time based)
- 12 hits/ring



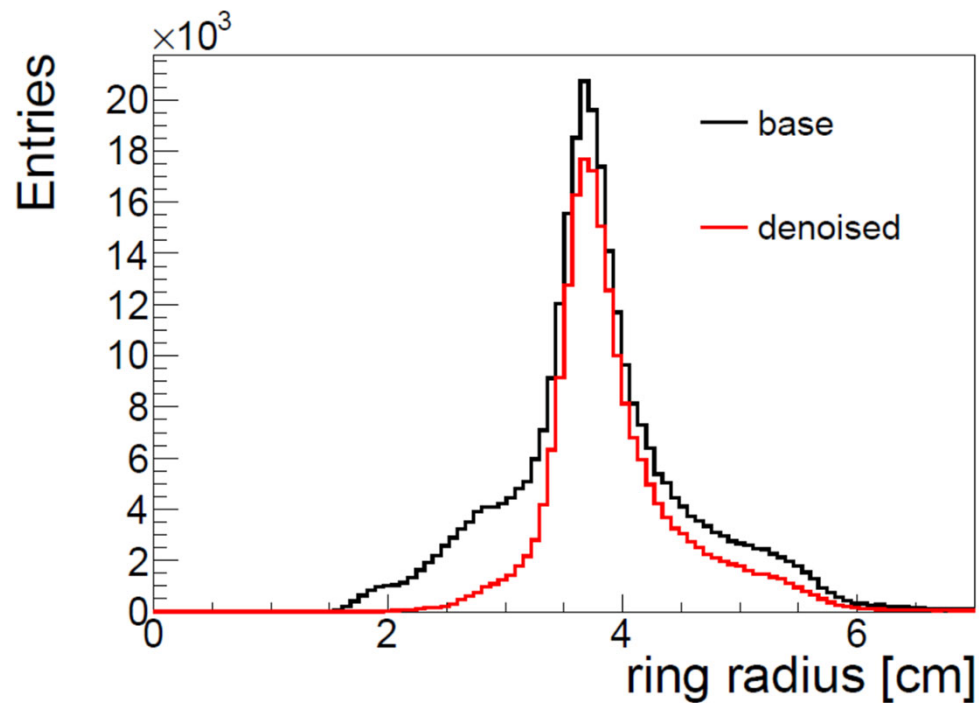
Hit/ ring distribution

- Distribution of hits on the photodetector plane
- Distribution of rings in the photodetector plane
 - Pattern with increased probability of ring centers in between MAPMTs can be reproduced in simulations and is correlated to hits in ring center

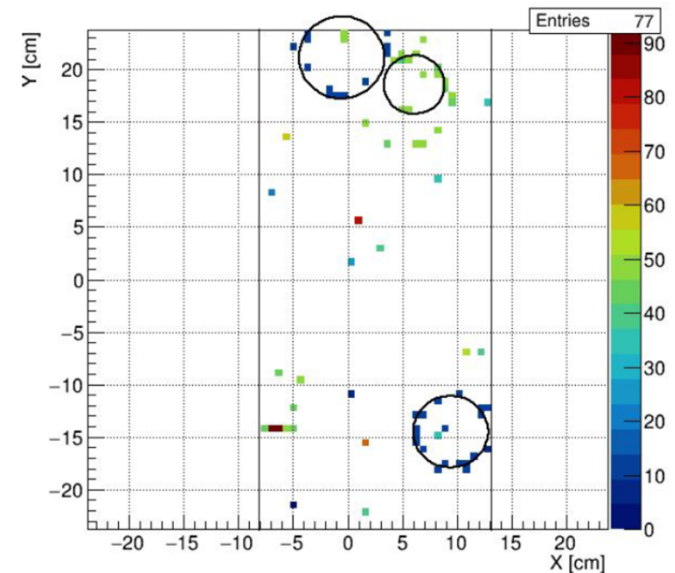


Ring radius

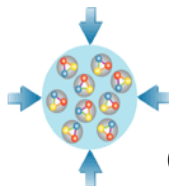
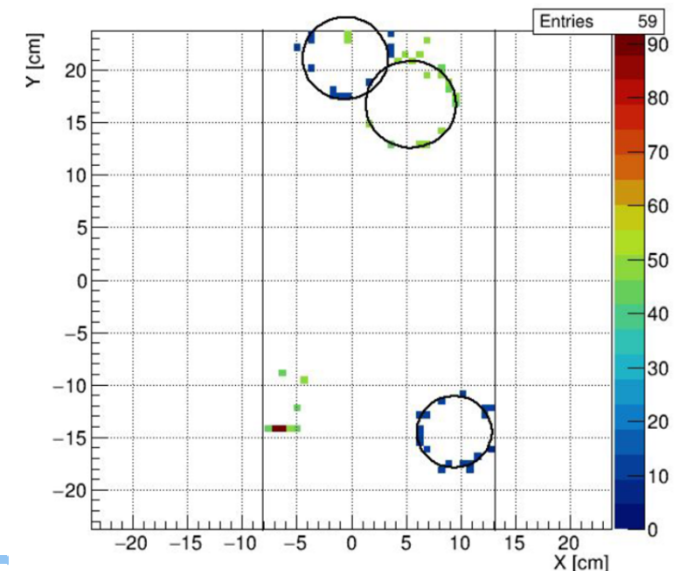
- Application of CNN in order to recognize center hits
- Remove those hits „denoise“
- Clear reduction of small rings (center hits used)



initial event

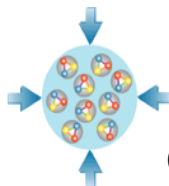
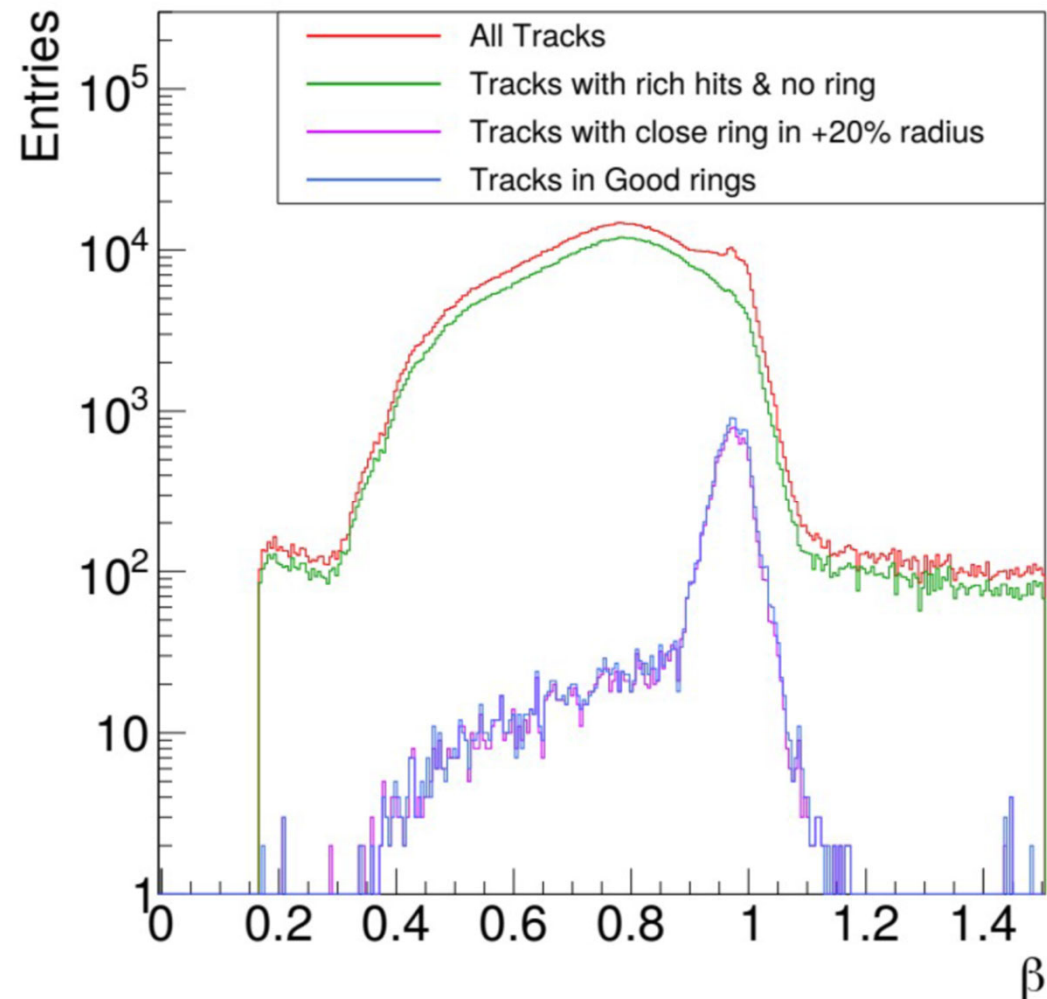
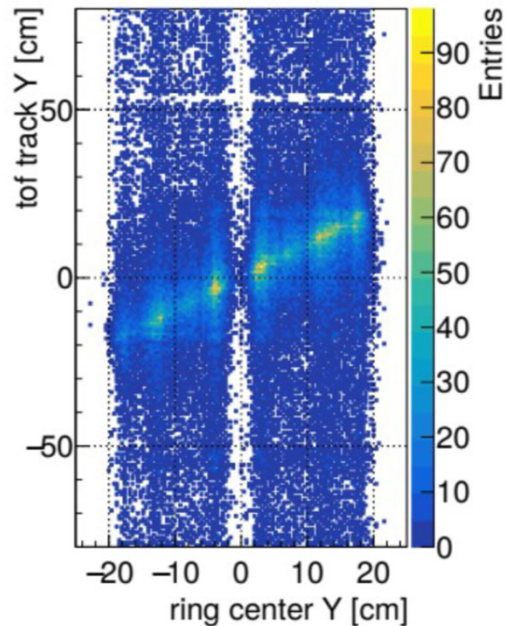


denoised event



Ring-track matching with mTOF

- mTOF triple stack allows for tracking
- Timing and spacial correlations with (most of all) mTOF tracks is seen
- Ring-track matching
- Beta distribution extracted



Summary

- **CBM RICH detector is being constructed**
 - Readout electronics validated with HADES and additional laboratory measurements; WLS validated
 - All MAPMTs purchased (1100pcs), all backplanes produced
 - Many of electronic components purchased (FPGAs!)
 - Completion of first photodetector plane in progress
 - Mirror EDR this year, timely order of mirrors
 - Work on recuperating the loss of PNPI as RICH member for reconstruction
- **mRICH detector successfully operated with free-streaming, triggerless readout**
 - Time calibration established
 - Ring reconstruction on time-based data
- **Looking forward to CBM RICH in operation end of this decade!**

