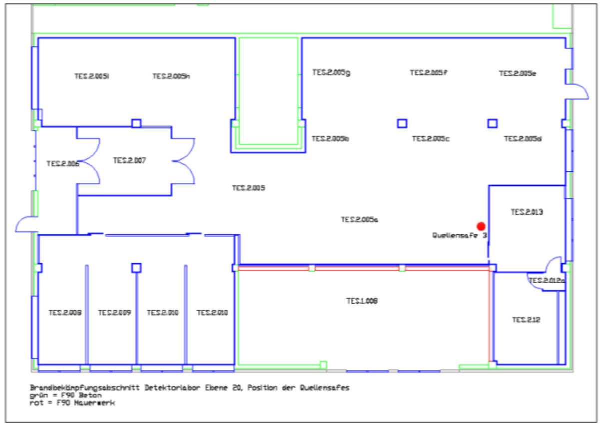
Detector Developments for FAIR Experiments in the vicinity of the GSI detector lab ...a panoramic, albeit selective view

Christian J. Schmidt,
GSI Darmstadt

Detector Laboratory at GSI: 600 m^2 Clean-Room

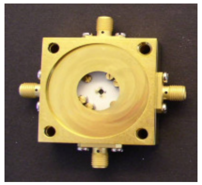
36 m

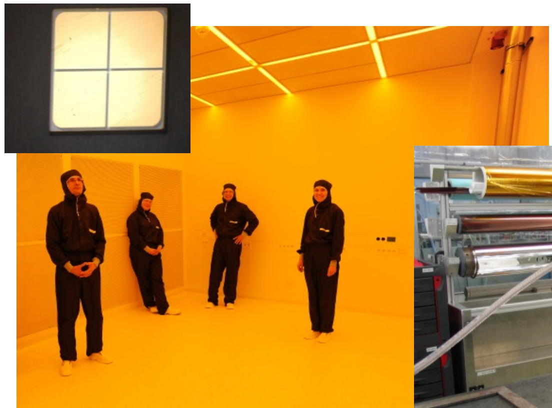
22 m

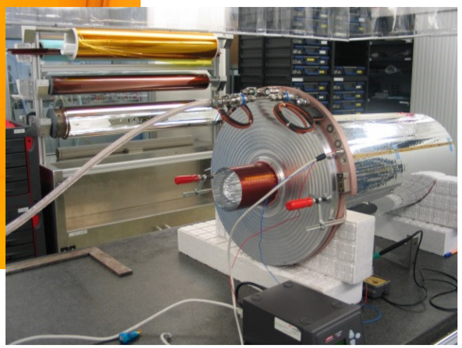


Competences:

- Micro Patterned Gaseous Detector Technology
- Silicon Strip Detector Integration
- ASIC Handling and Integration
- Diamond Detectors
- PSL APD-characterization lab

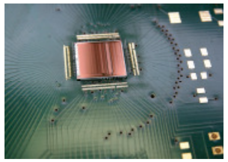




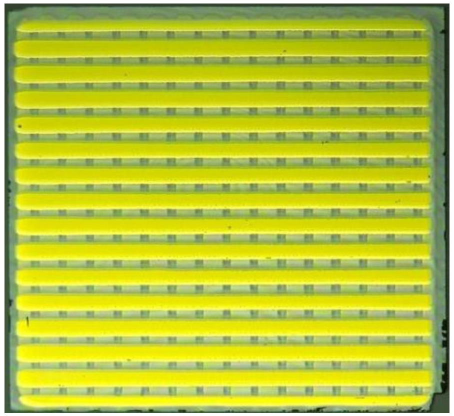


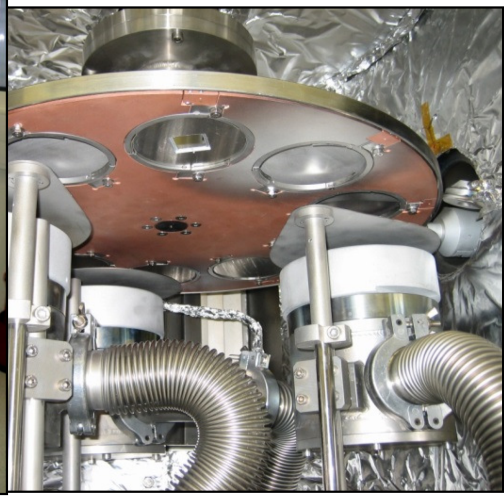
Machinery:

- Laser Lithography
- PVD
- Bonding Automates
- Probestation and Chip Handling
- Automated Wire Winding
- Digital Microscope
- Thin Foils Handling and Processing
- Gaseous Detector Ageing Teststands
- Large Prototyping CNC Milling Machine

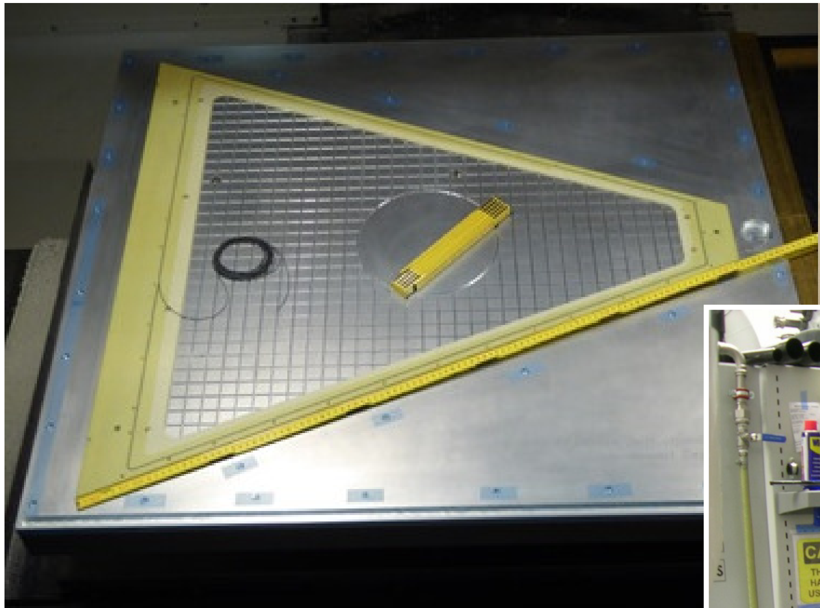


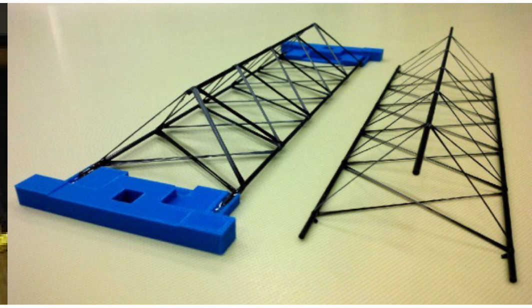
ISO 3 Clean Room for Laser Lithography 1µ

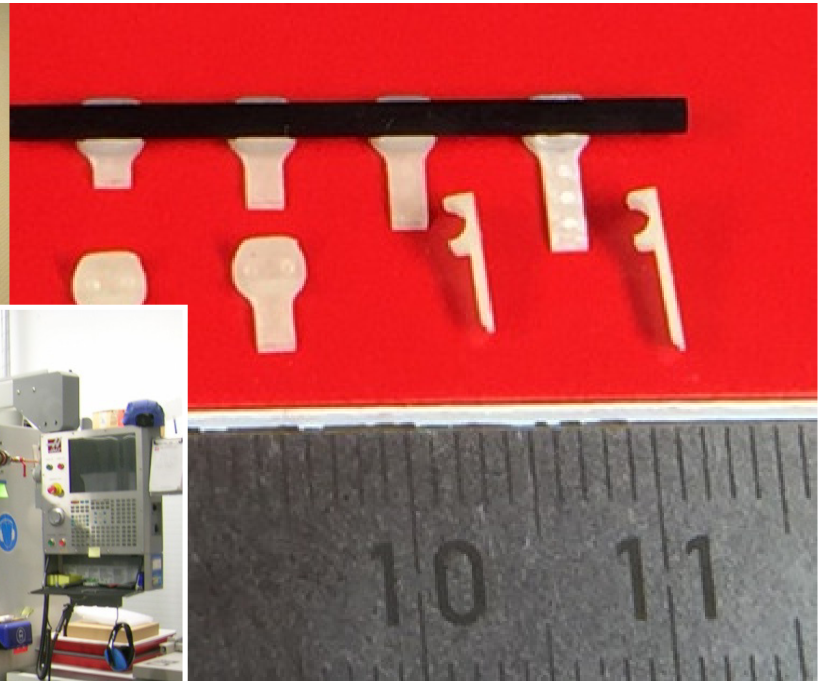


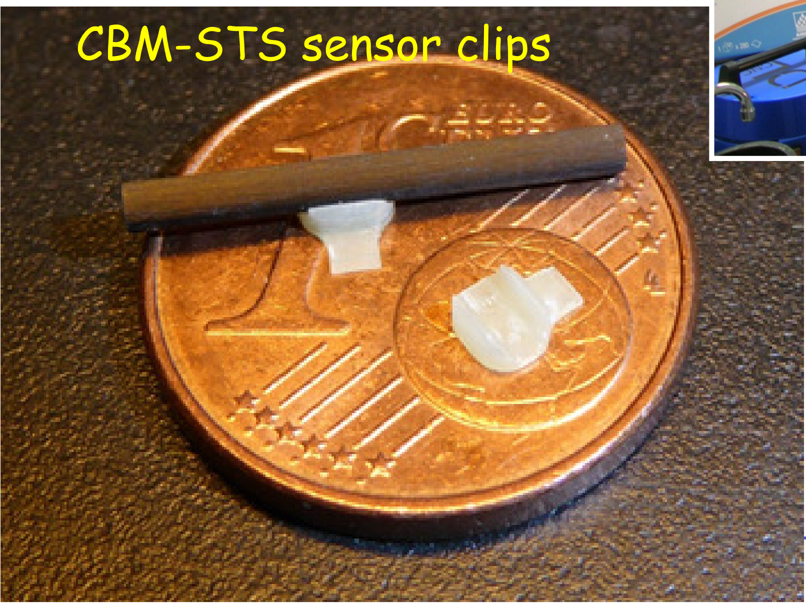


Precision fibre composite milling from very small to very large





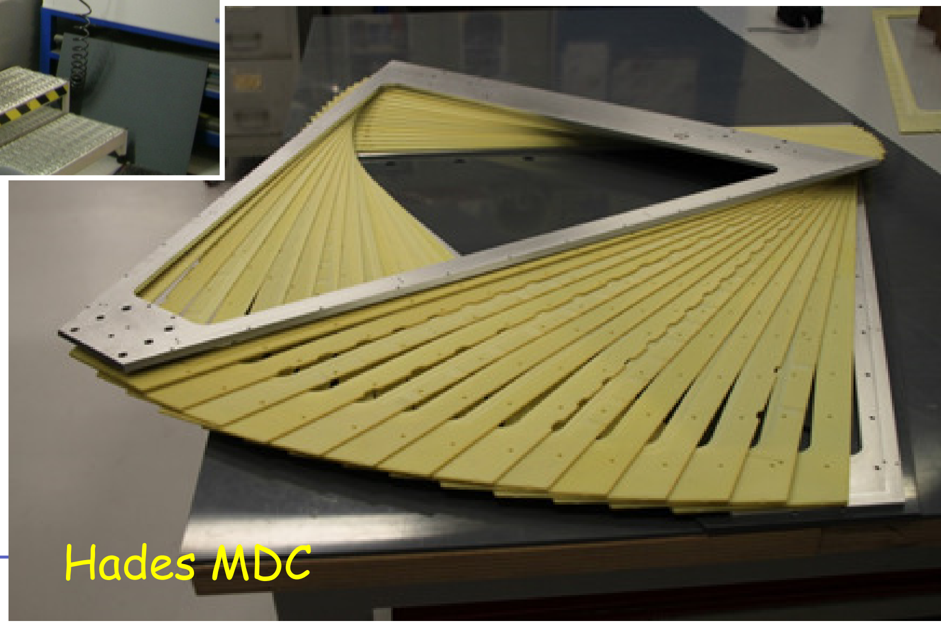


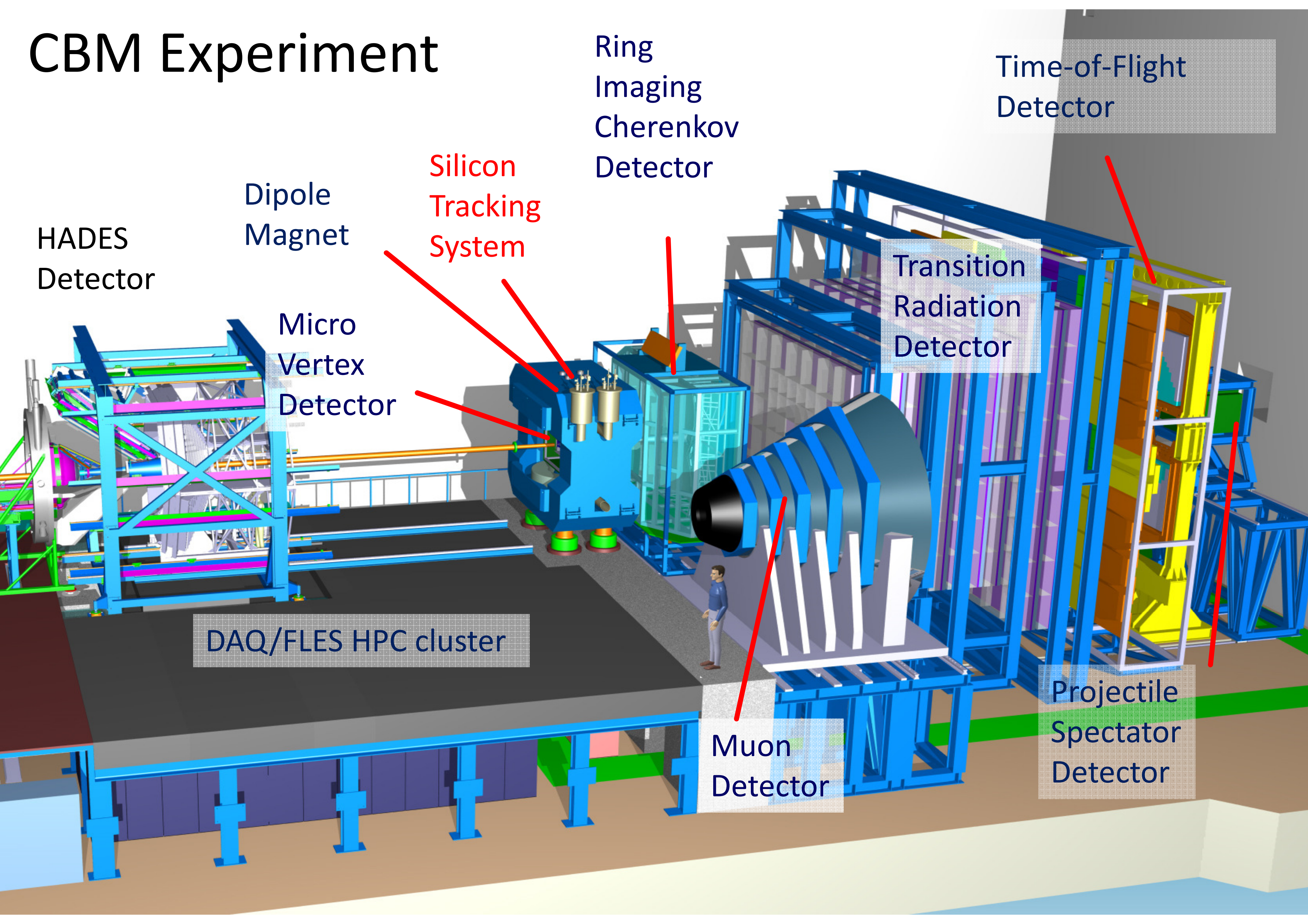


100cm x 160cm

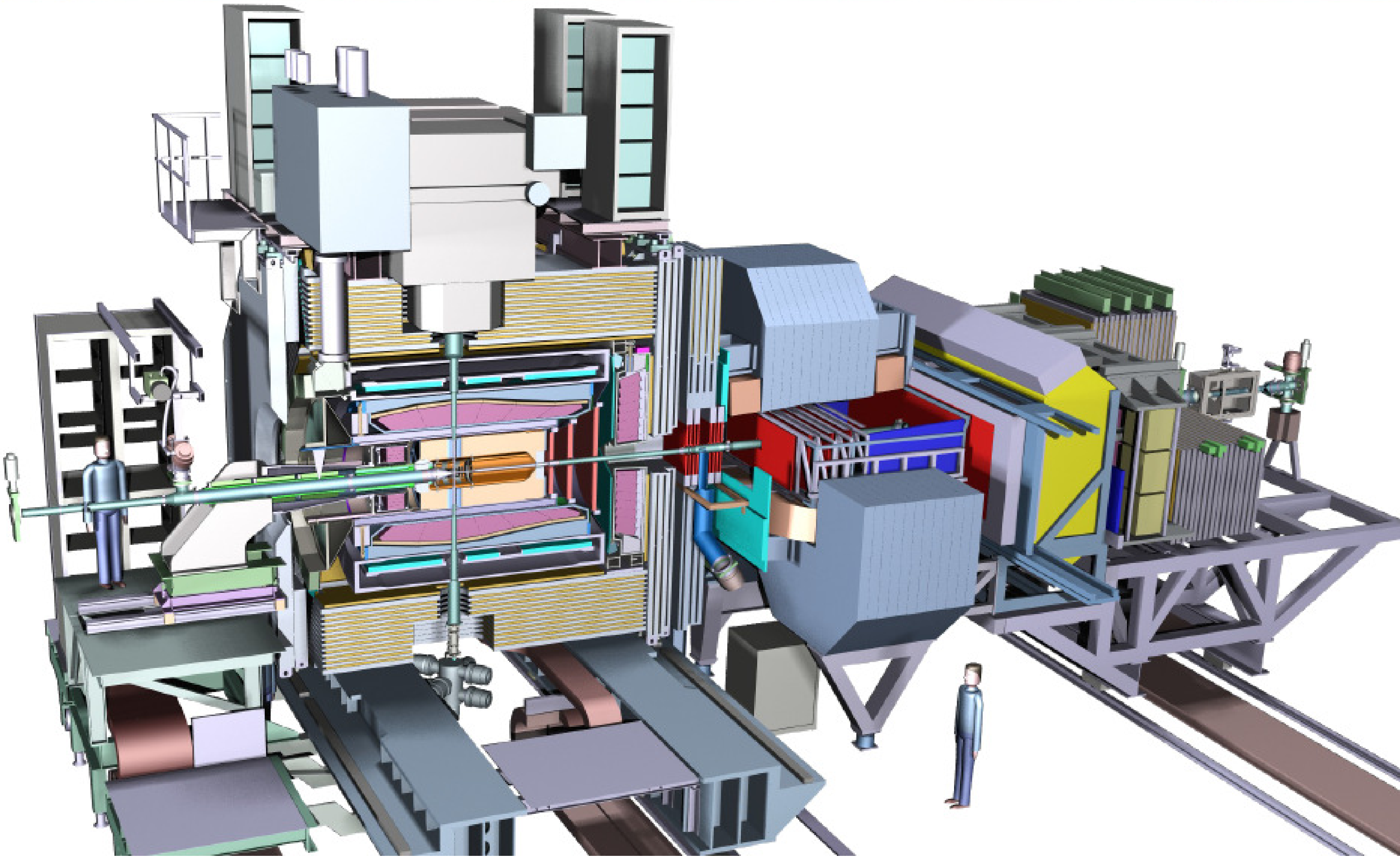
fibre composits

= 3D-mold manufacturing




CBM Experiment
Ring
Imaging
Cherenkov
Detector
Time-of-Flight
Detector
Silicon
Tracking
System
Dipole
Magnet
HADES
Detector
Transition
Radiation
Detector
Micro
Vertex
Detector
DAQ/FLES HPC cluster
Muon
Detector
Projectile
Spectator
Detector

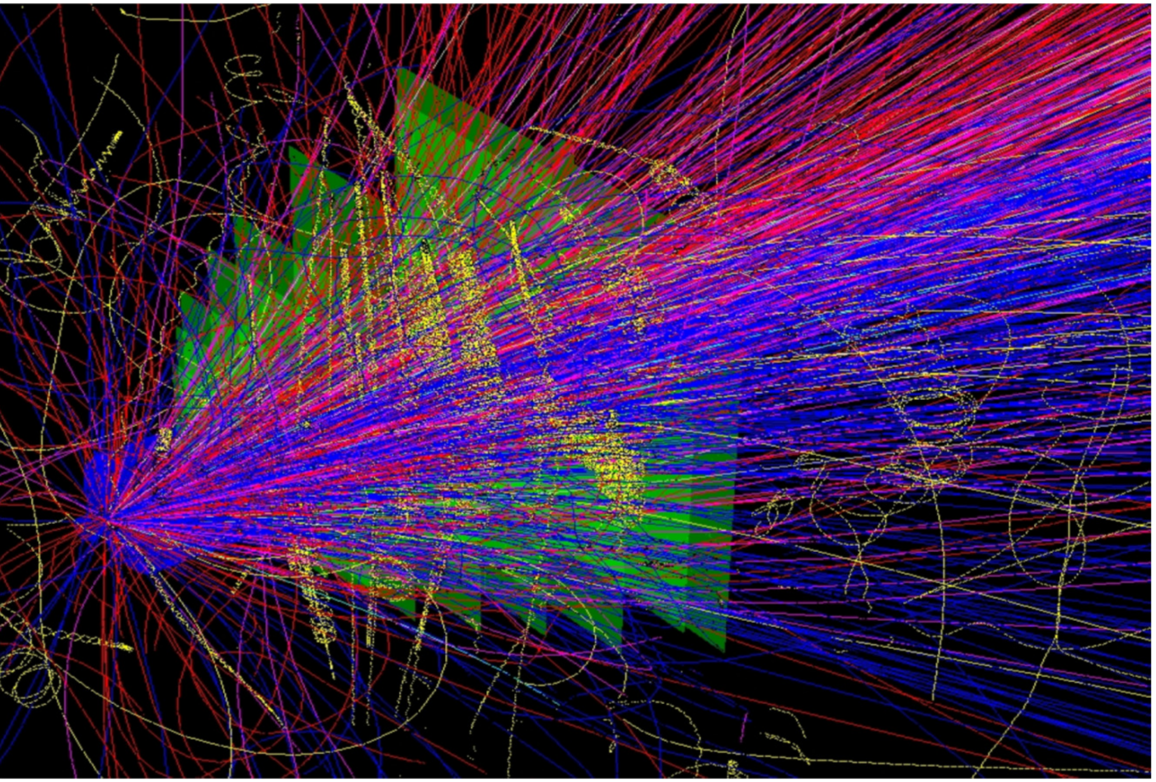
PANDA Systems

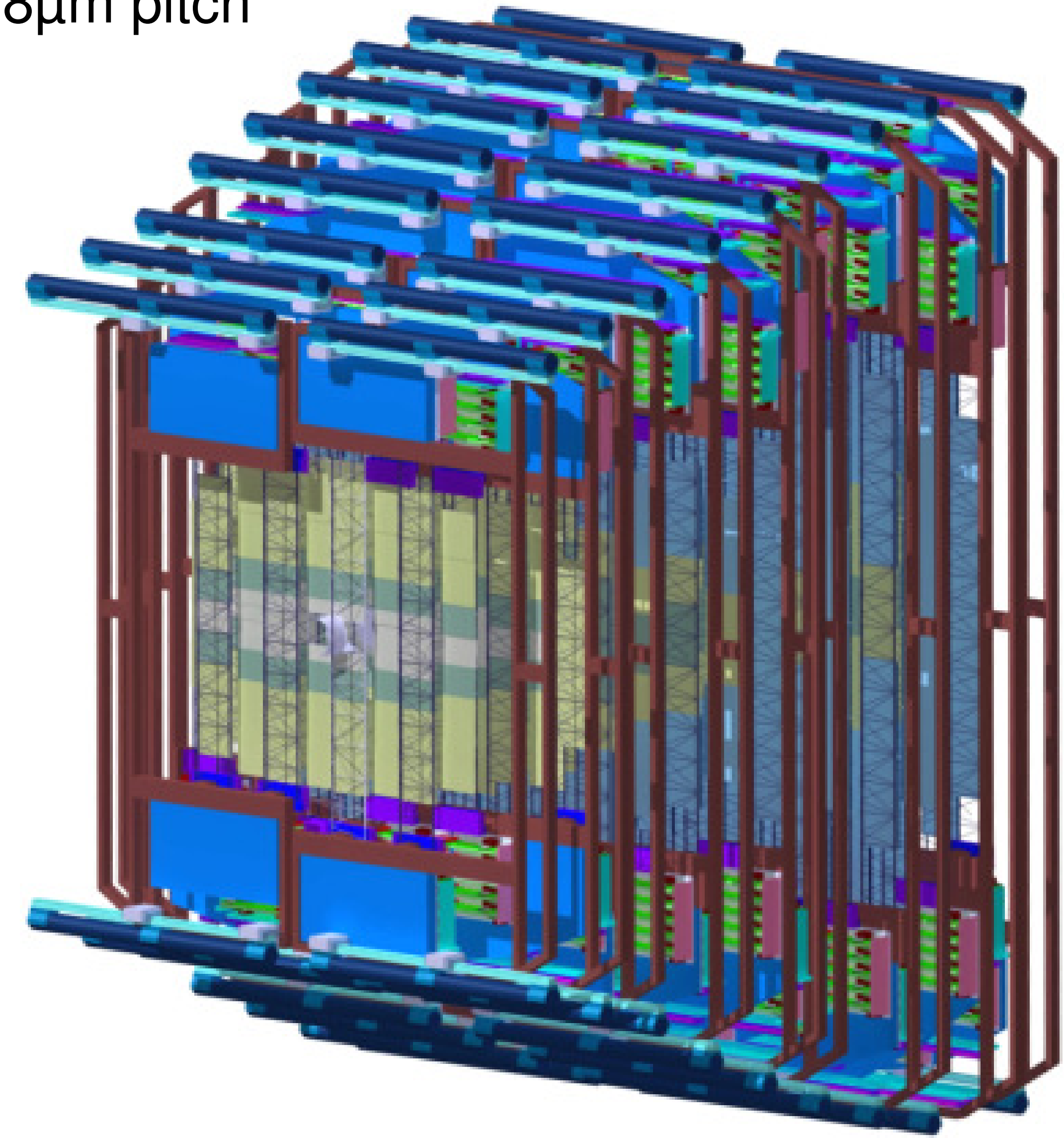


CBM Silicon Tracking System STS

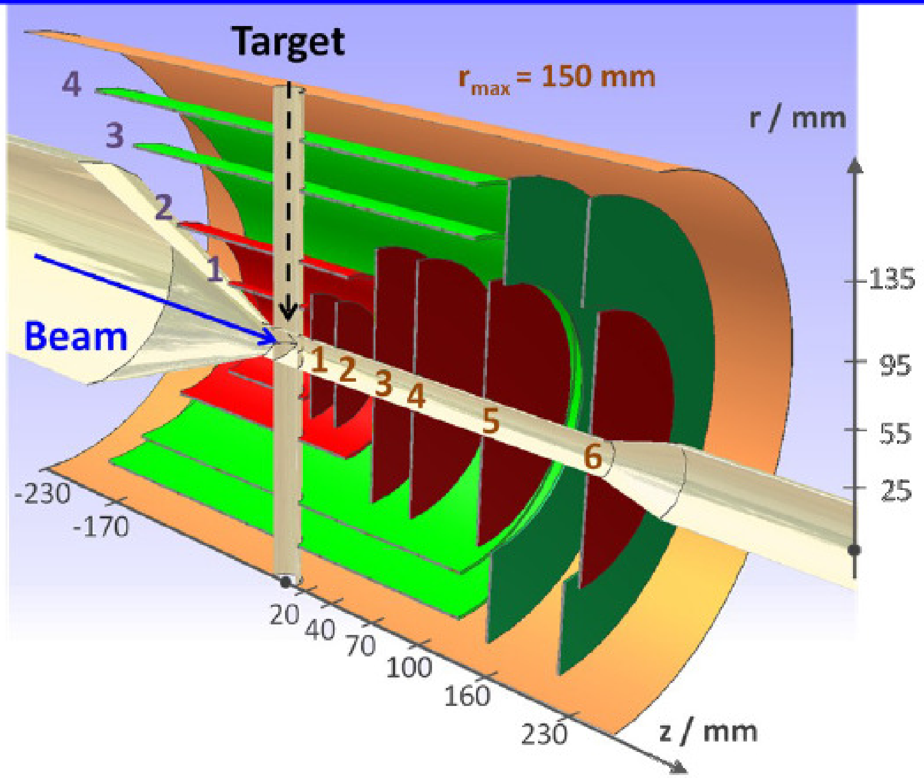
- Fixed Target Tracker, 2,5°< θ < 25°
- Double Sided Silicon Strips in 8 Layers, 58µm pitch
- 2 Mio. readout channels, ~ 3 m^2
- Event rate 10 MHz, freely streaming r/o
- less than 1% radiation length per layer

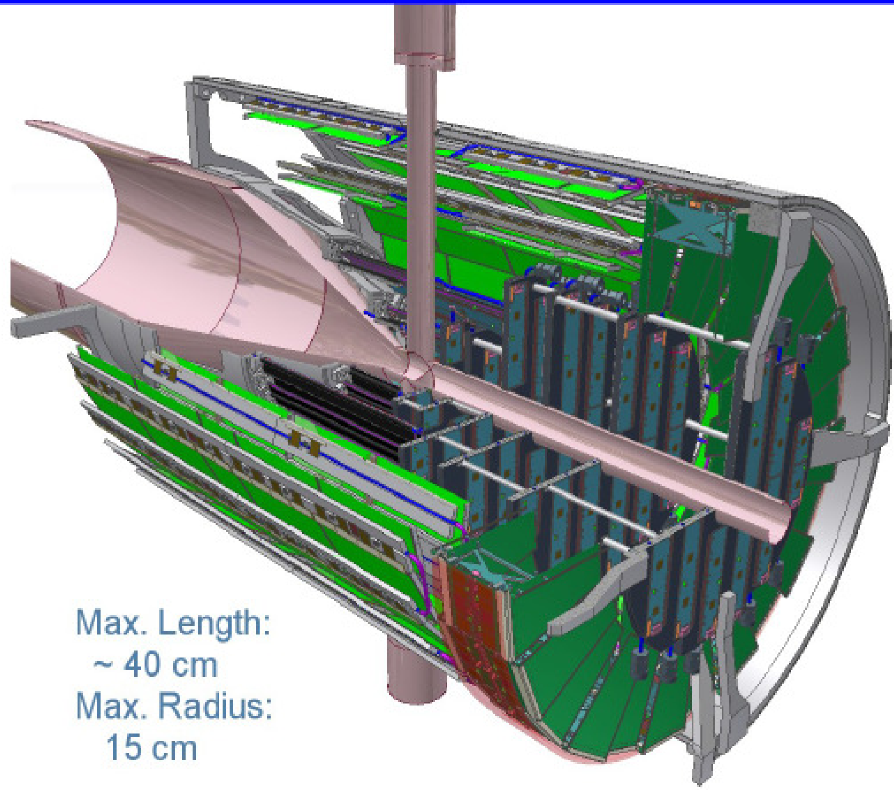
to be fit into magnet yoke (1,4m)

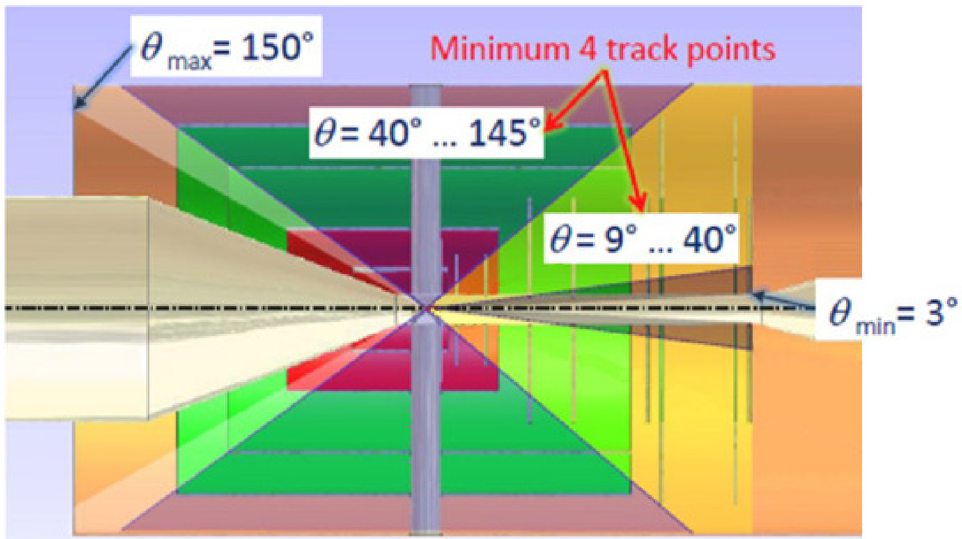




PANDA The Micro-Vertex Detector

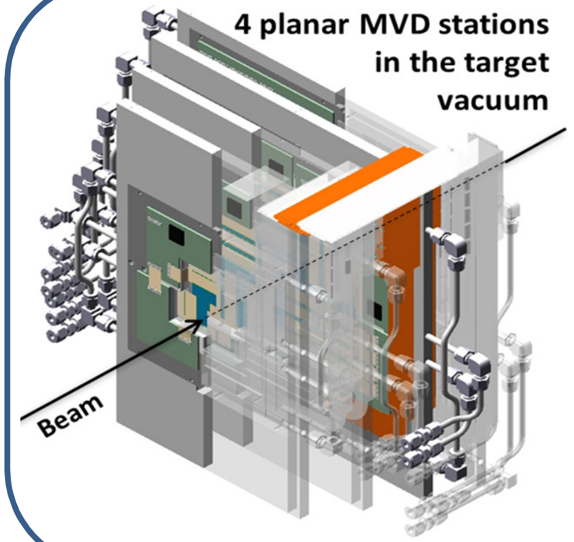




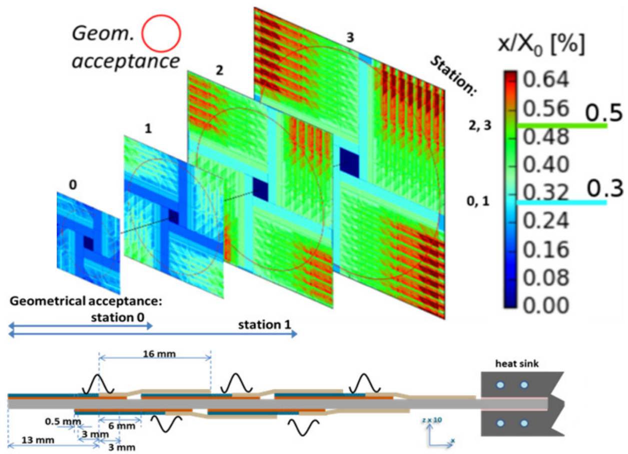


- 2 barrel pixel layers
- 4 pixel disks
- 2 barrel strip layers
- 2 mixed disks
- 2 optional forward wheels (@40 & 60 cm)

CBM Micro-Vertex Detector

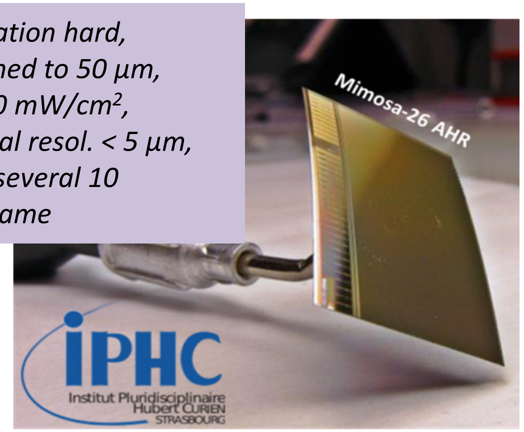


Ultra-thin: CVD diamond, TPG



Sensors: CMOS MAPS

- *Radiation hard,*
- *Thinned to 50 µm,*
- *< 150 mW/cm², *
- *spatial resol. < 5 µm,*
- *R/O several 10 µs/frame*

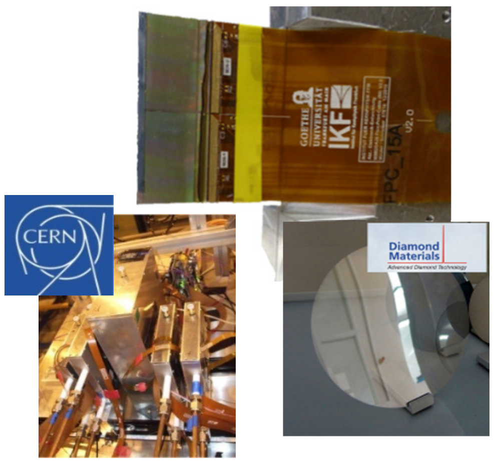


Prototyping & test beam:

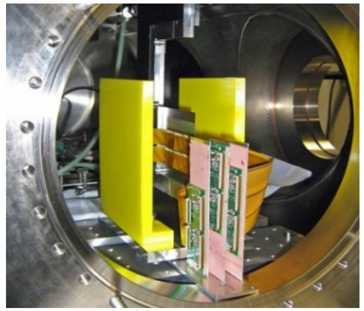
MVD demonstrator

RVC foam

MVD prototype



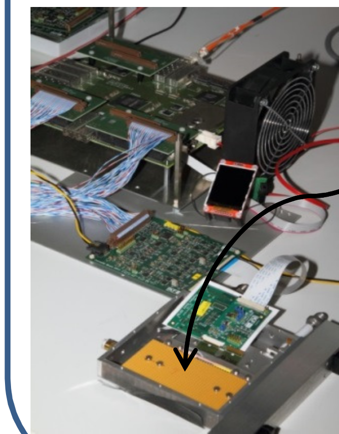
PRESTO

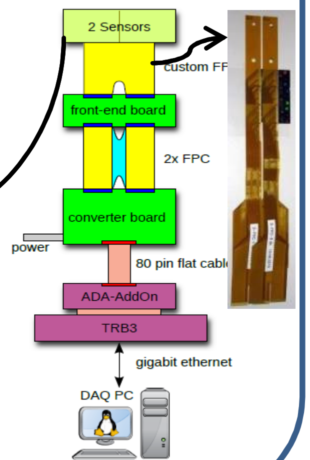


MOMENTIVE

Thermal **P**yrolytic **G**raphite

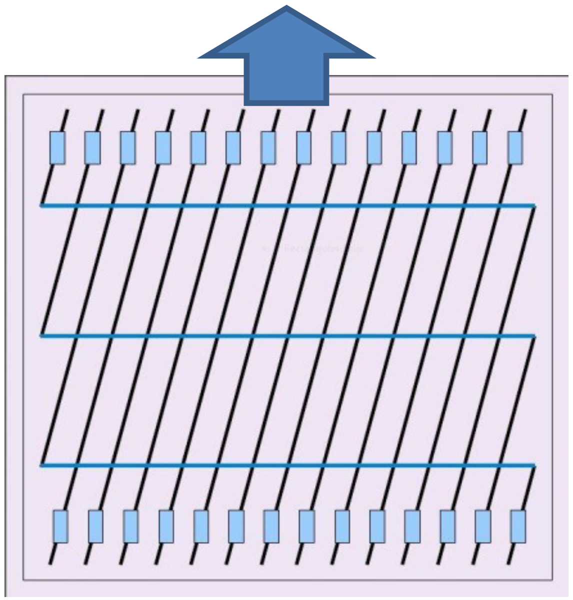
Customized FEE & DAQ: TRB-based

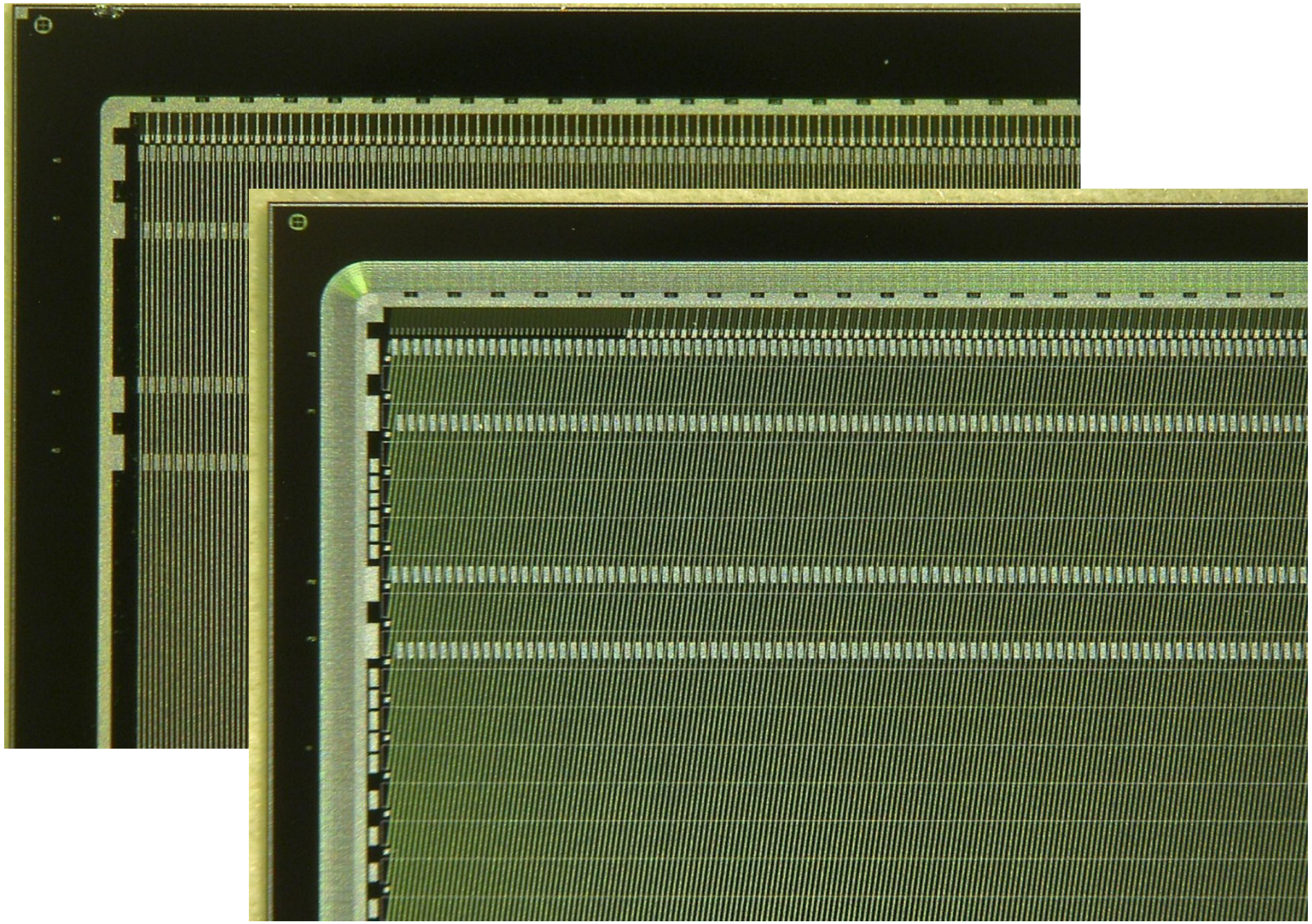




CBM-STS Silicon micro-strip sensors

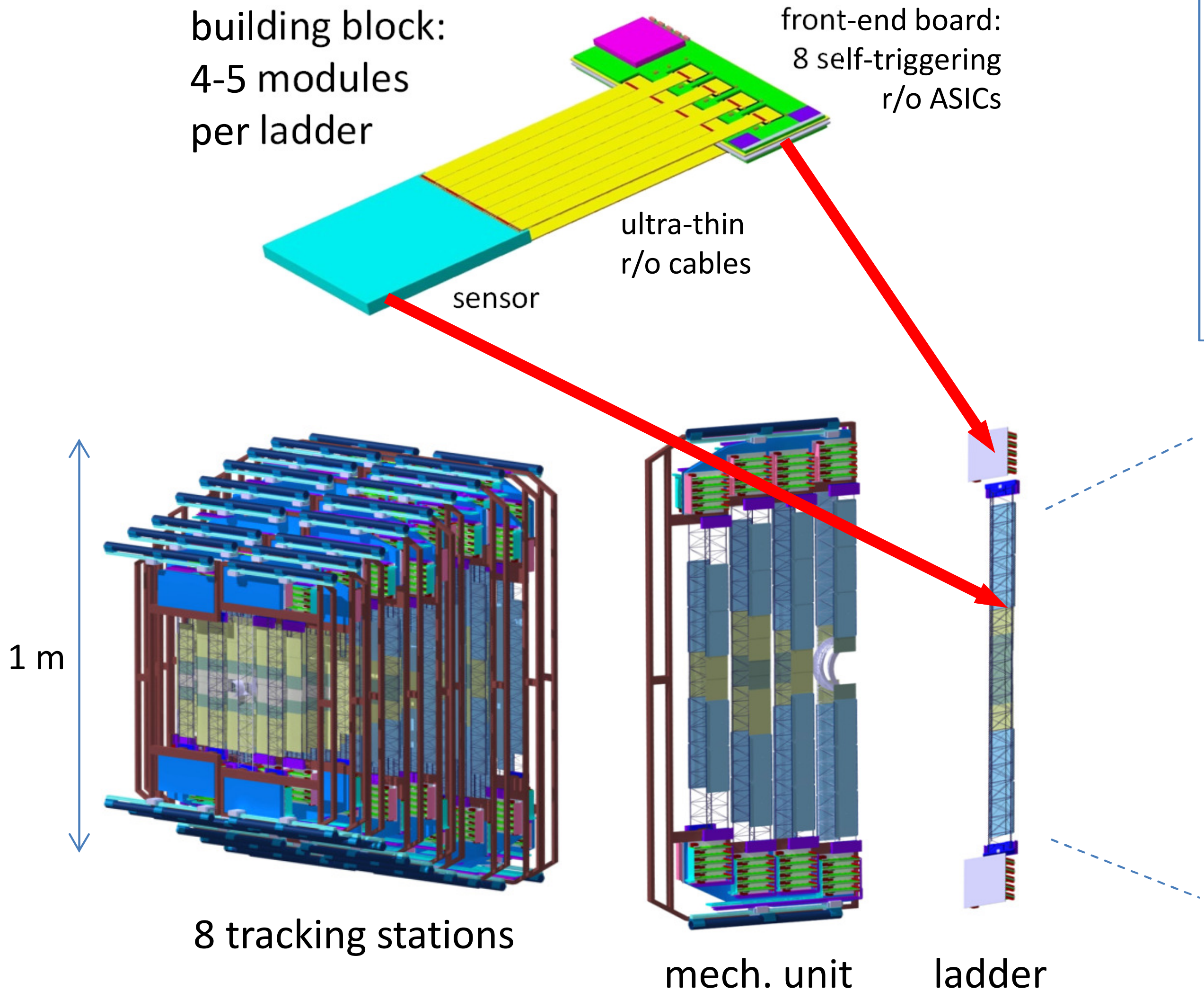
- 300 µm thick, n-type silicon
- double-sided segmentation
- 2nd metal routing lines
- 1024 strips of 58 µm pitch
- strip length 2/4/6/12 cm
- angle front/back: 7.5/0 deg
- read-out from top edge
- rad. tol. up to 10^{14} n_{eq}/cm^2

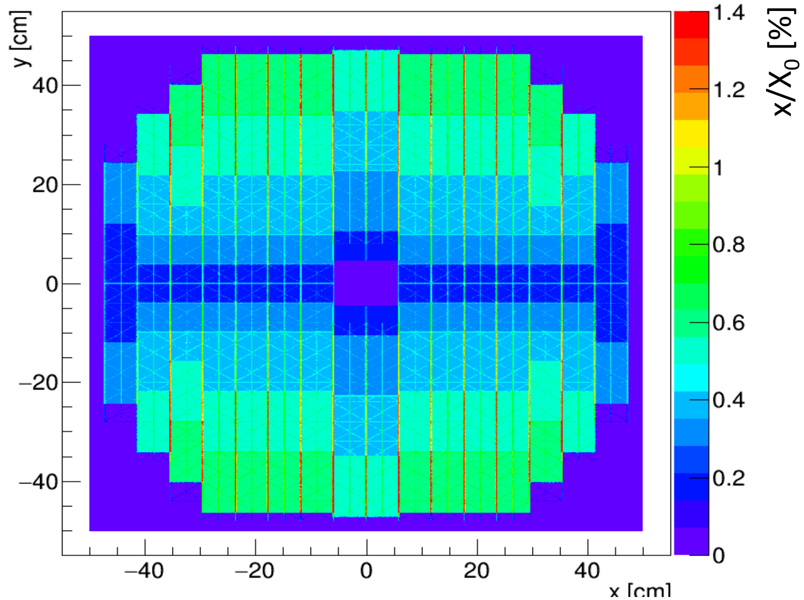




STS integration concept

- 8 stations, volume 2 m^3, area 4 m^2
- 896 detector modules
  - 1220 double-sided microstrip sensors
  - ~ 1.8 million read-out channels
  - ~ 16 000 r/o STS-XYTER ASICs
  - ~ 16 000 ultra-thin r/o cables (à 5 components)
- 106 detector ladders with 4-5 modules
- power dissipation: 42 kW (CO_2 cooling)

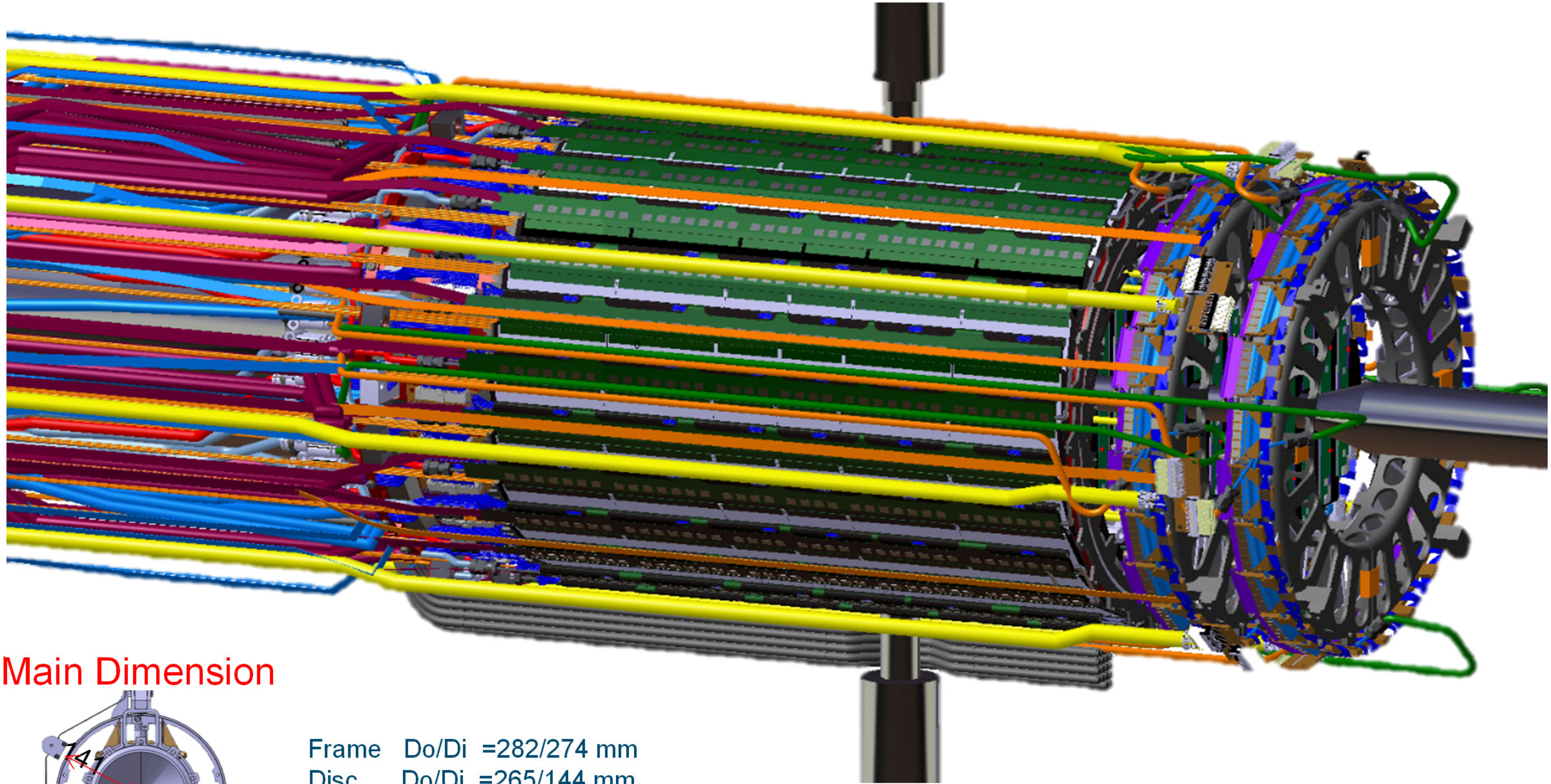




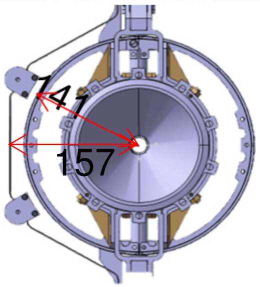
material budget per station

PANDA MVD Strip

Infrastructure integration at „zero mass“ is one of the challenges in tracker construction… power, cooling readout….

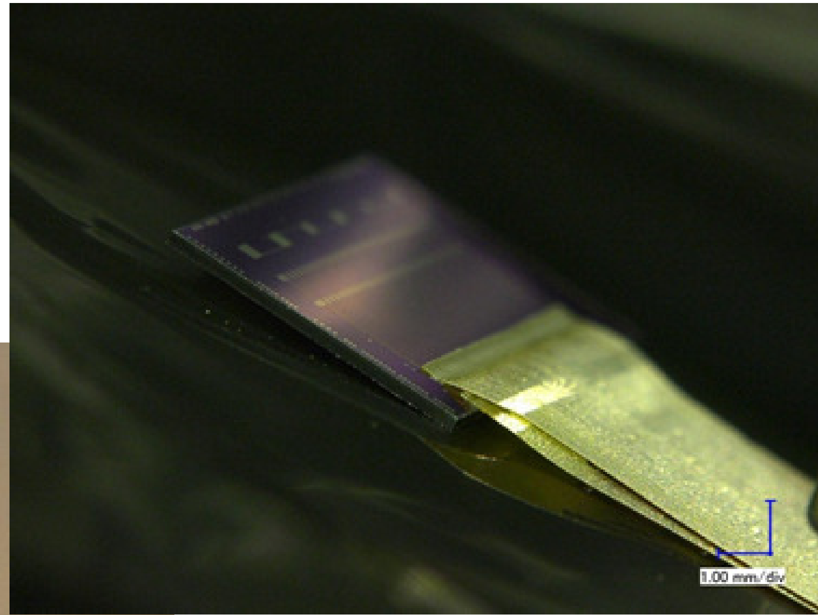


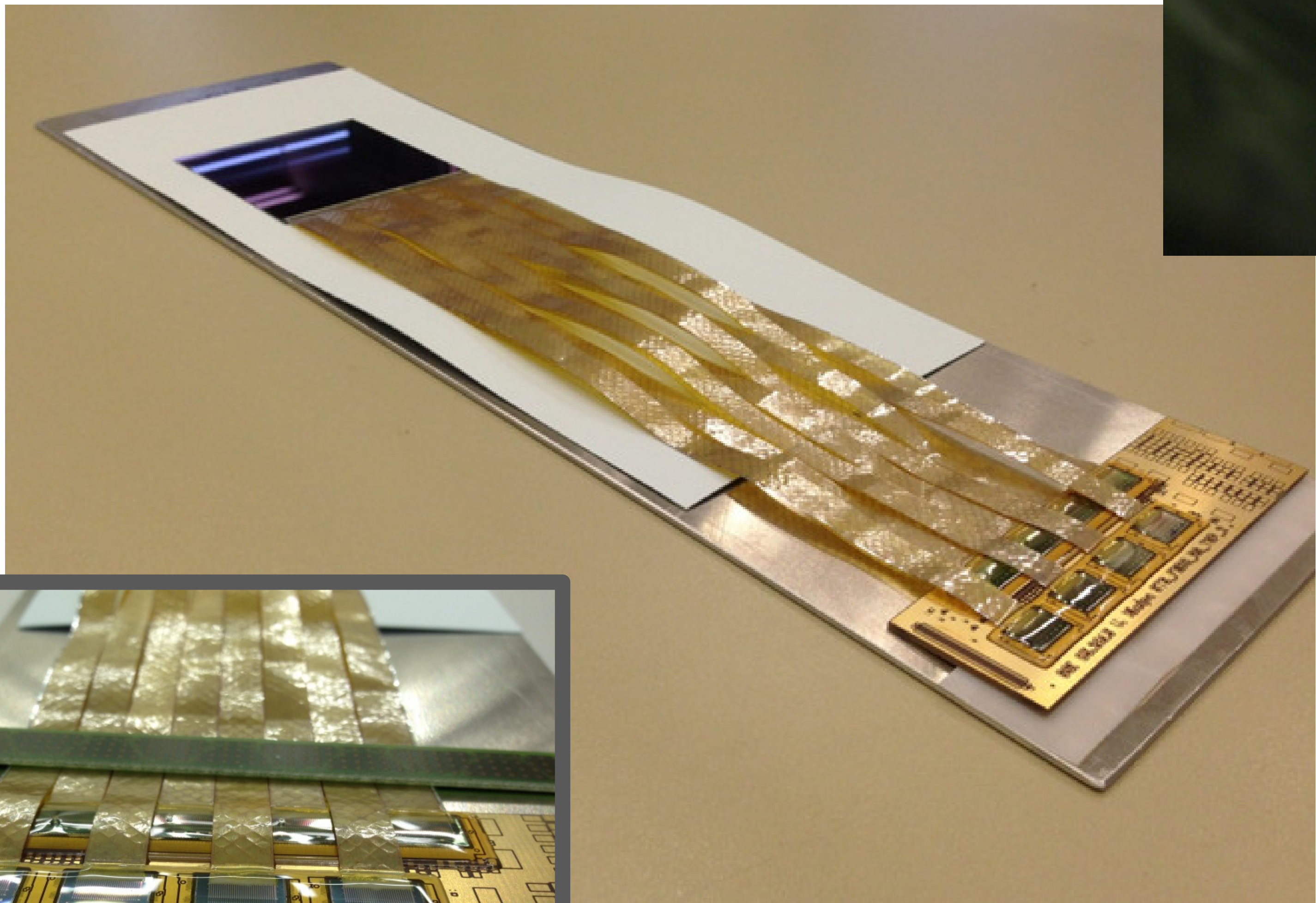
Main Dimension



Frame Do/Di =282/274 mm
Disc Do/Di =265/144 mm
Barrel Do/Di =259/259 mm

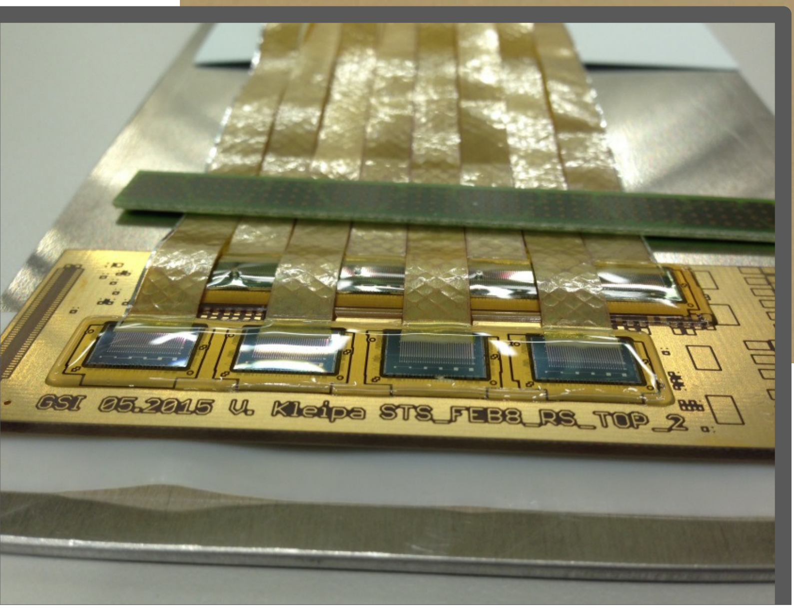
CBM-STS-module-assembly

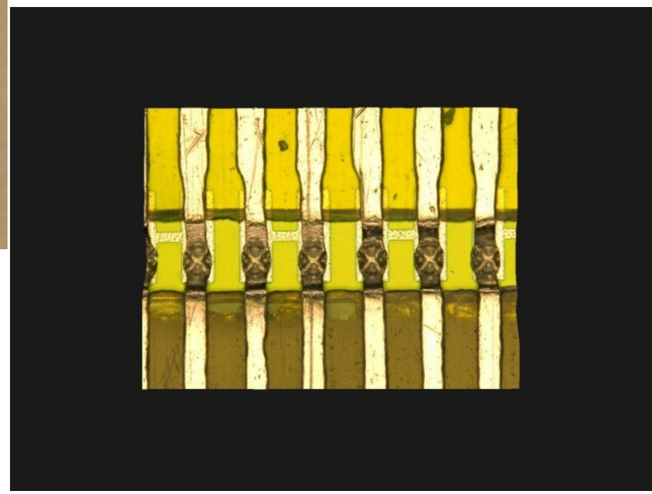




Numbers:

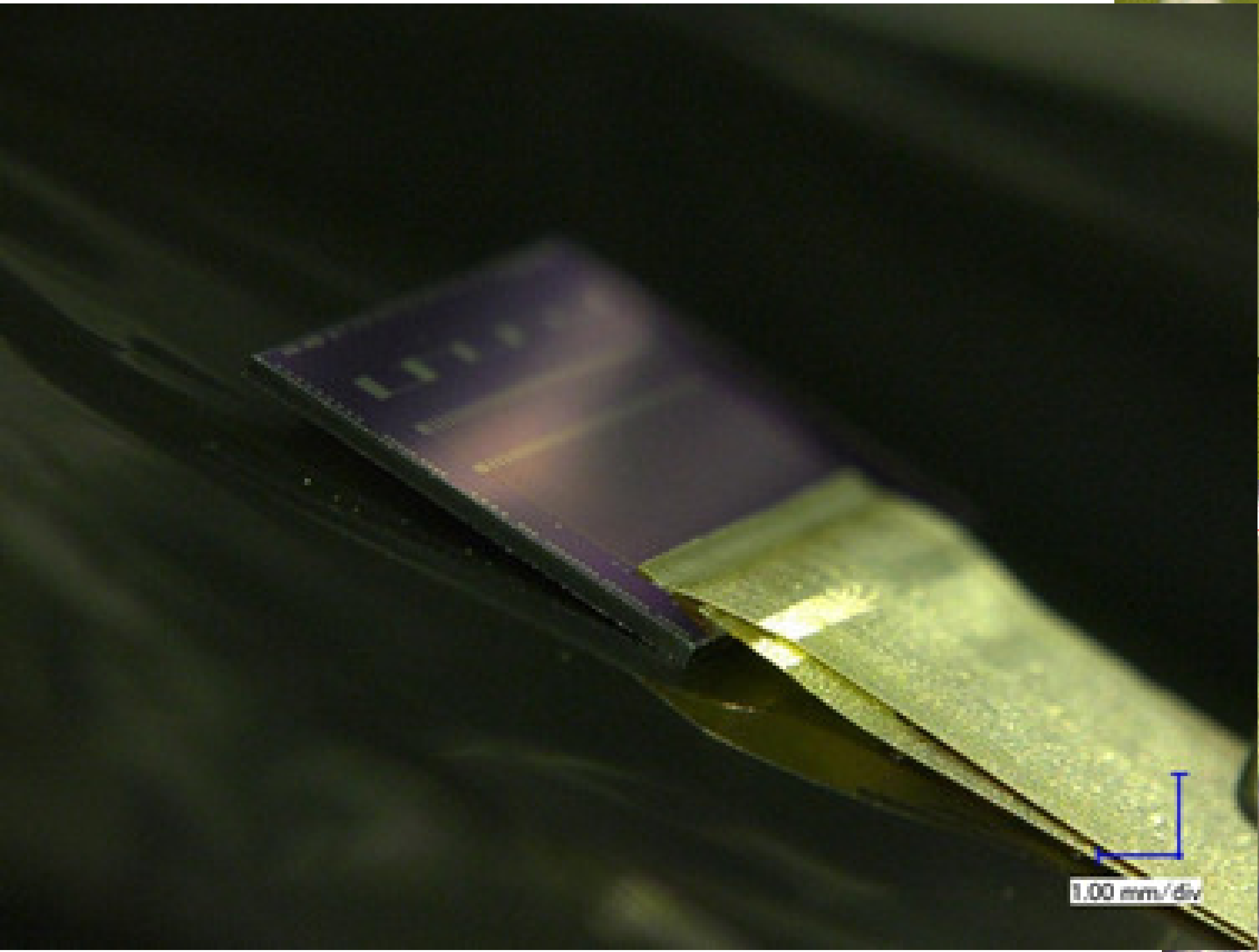
- 1000 Modules
- 32 cables per module
- 2048 ch per module
- Tab bonding
- Micro cables: 10µ Polyimide
  14µ Al traces

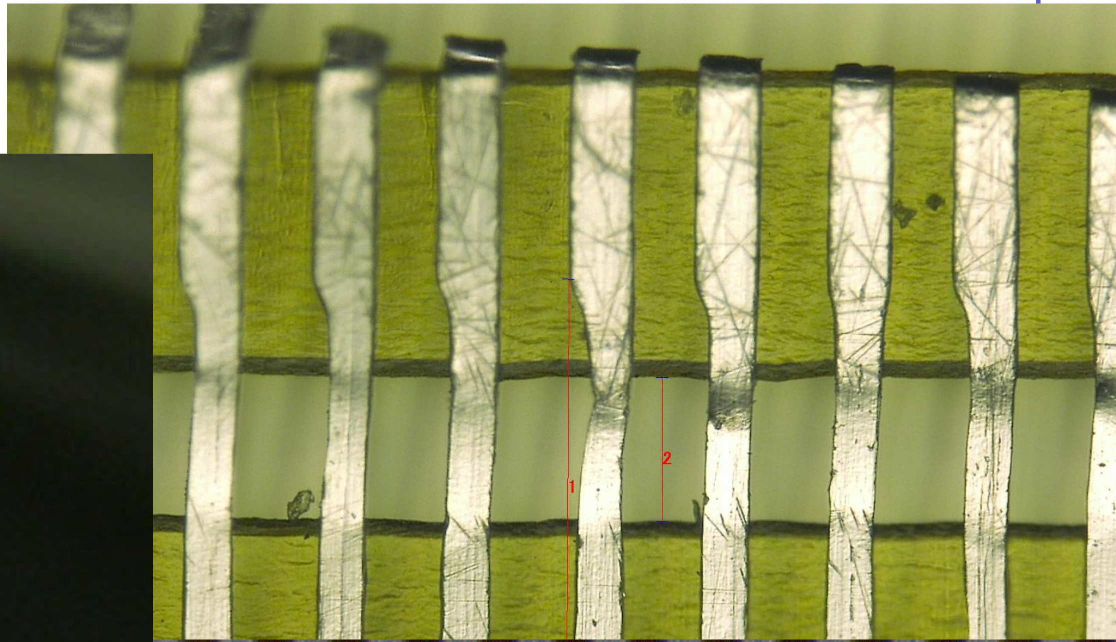


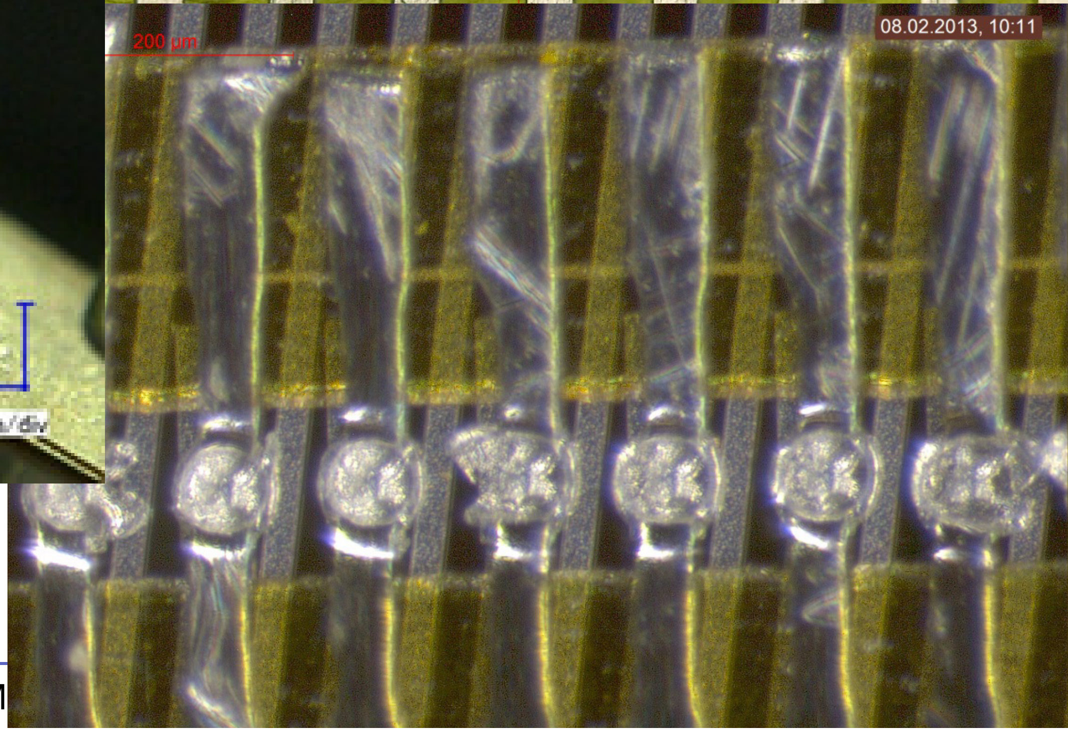


Micro Cable Technology with TAP-Bonding

- double cable layer bonded onto chip

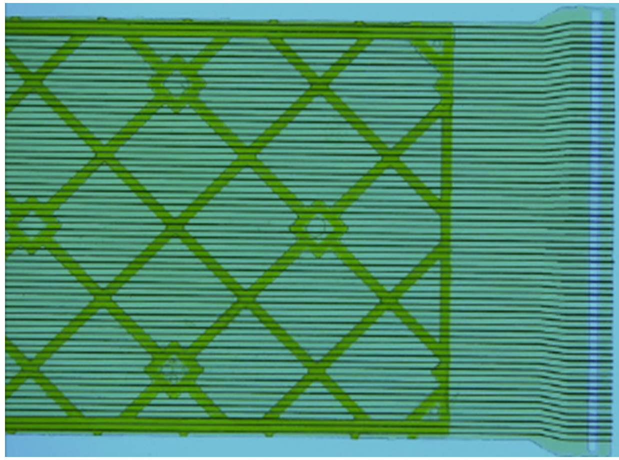




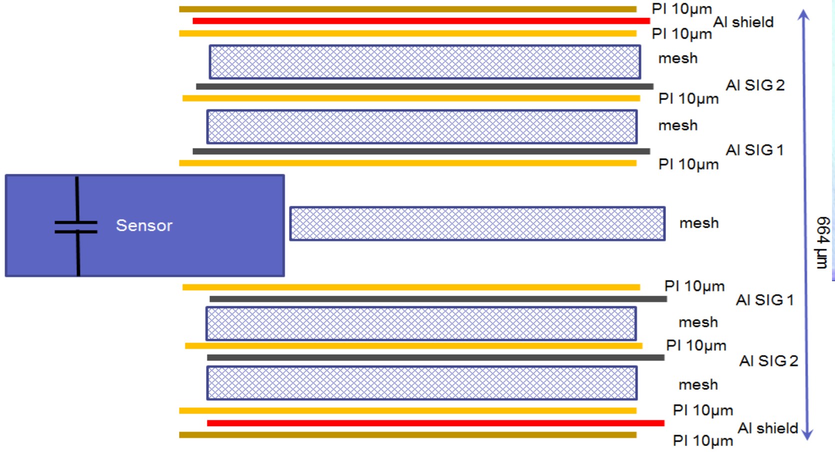


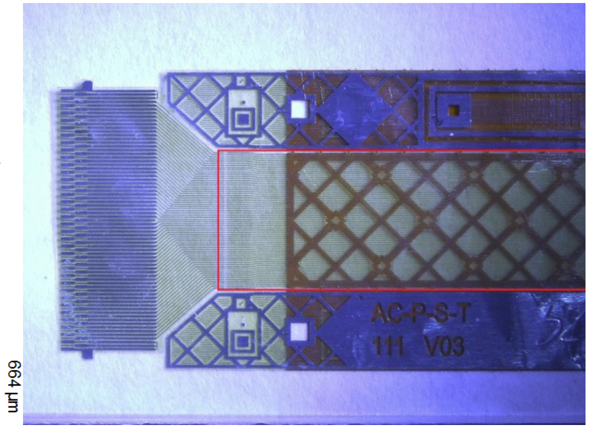
32.000 read-out cables cooperation with LTU, Ukraine

spacer layer

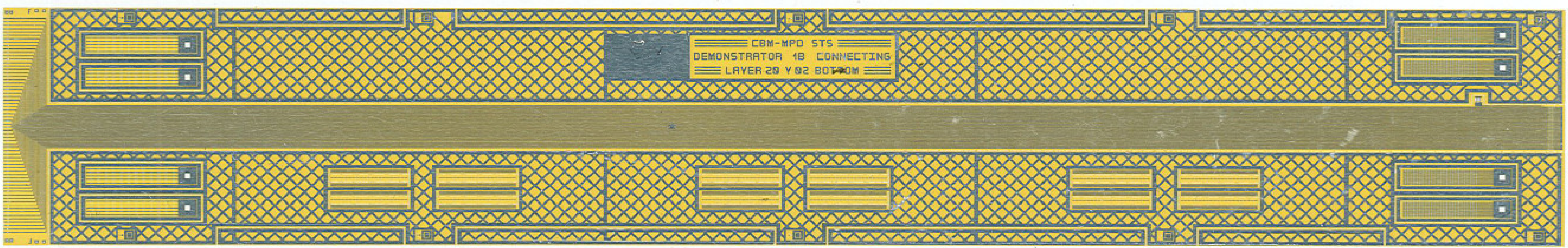


cable stack: *thickness 0.230 % X_0*

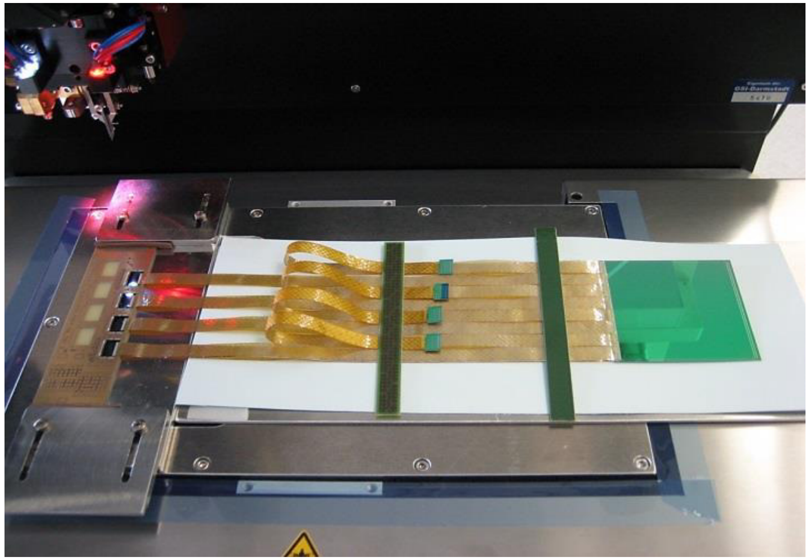


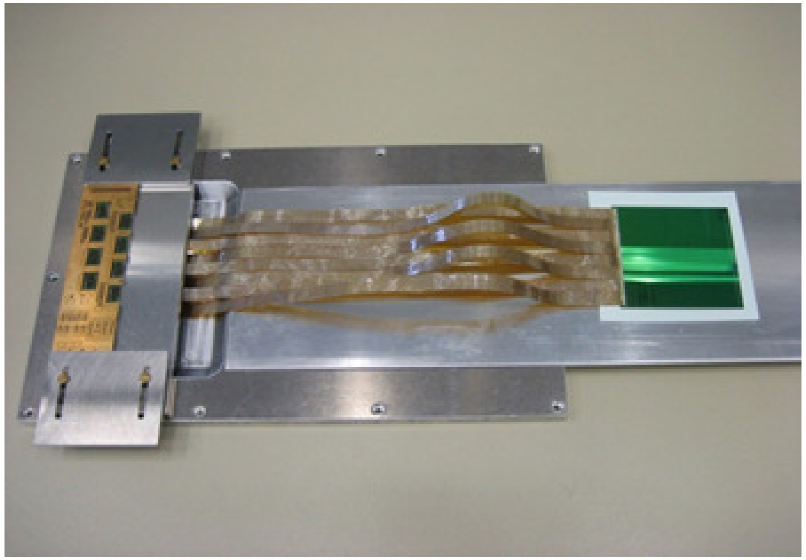


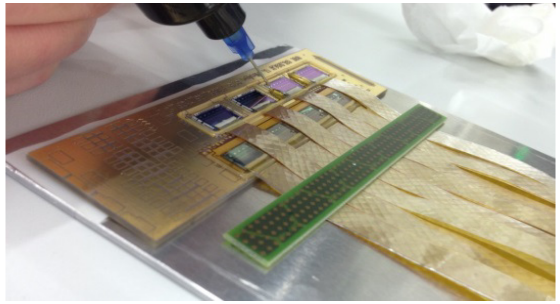
signal layer: *64 Al lines of 116 µm pitch, 14 µm thick on 10 µm polyimide, lengths up to 55 cm*

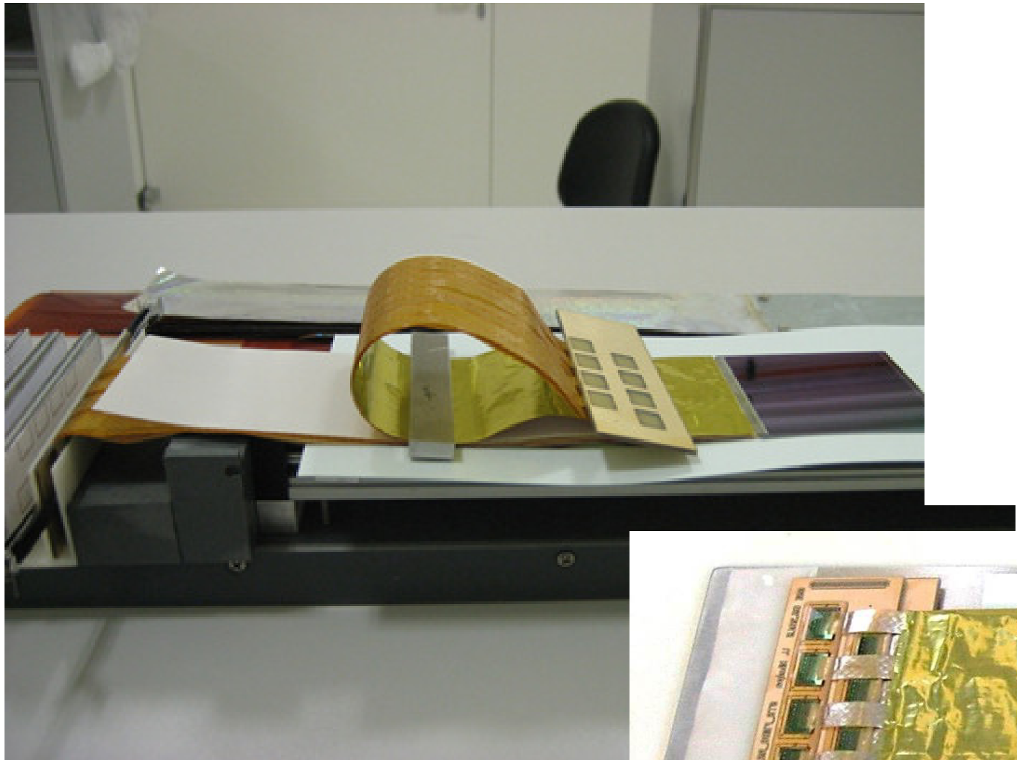


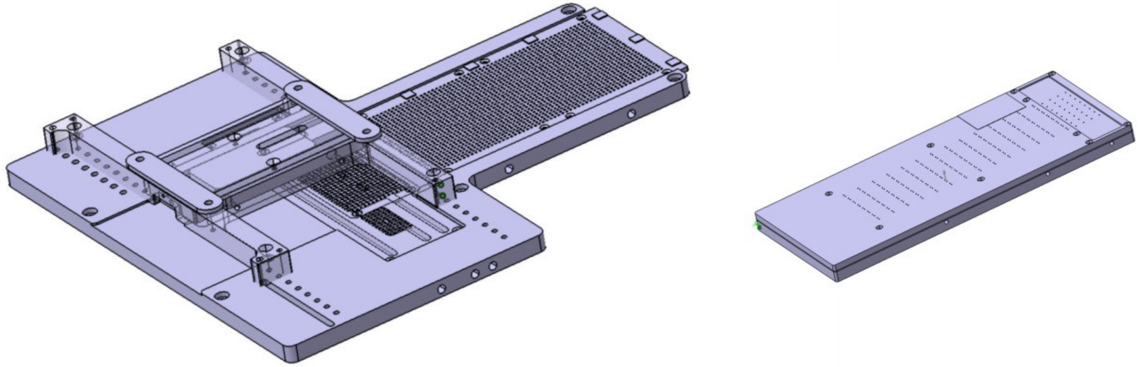
Pushing supplyer towards high yield industrial production…









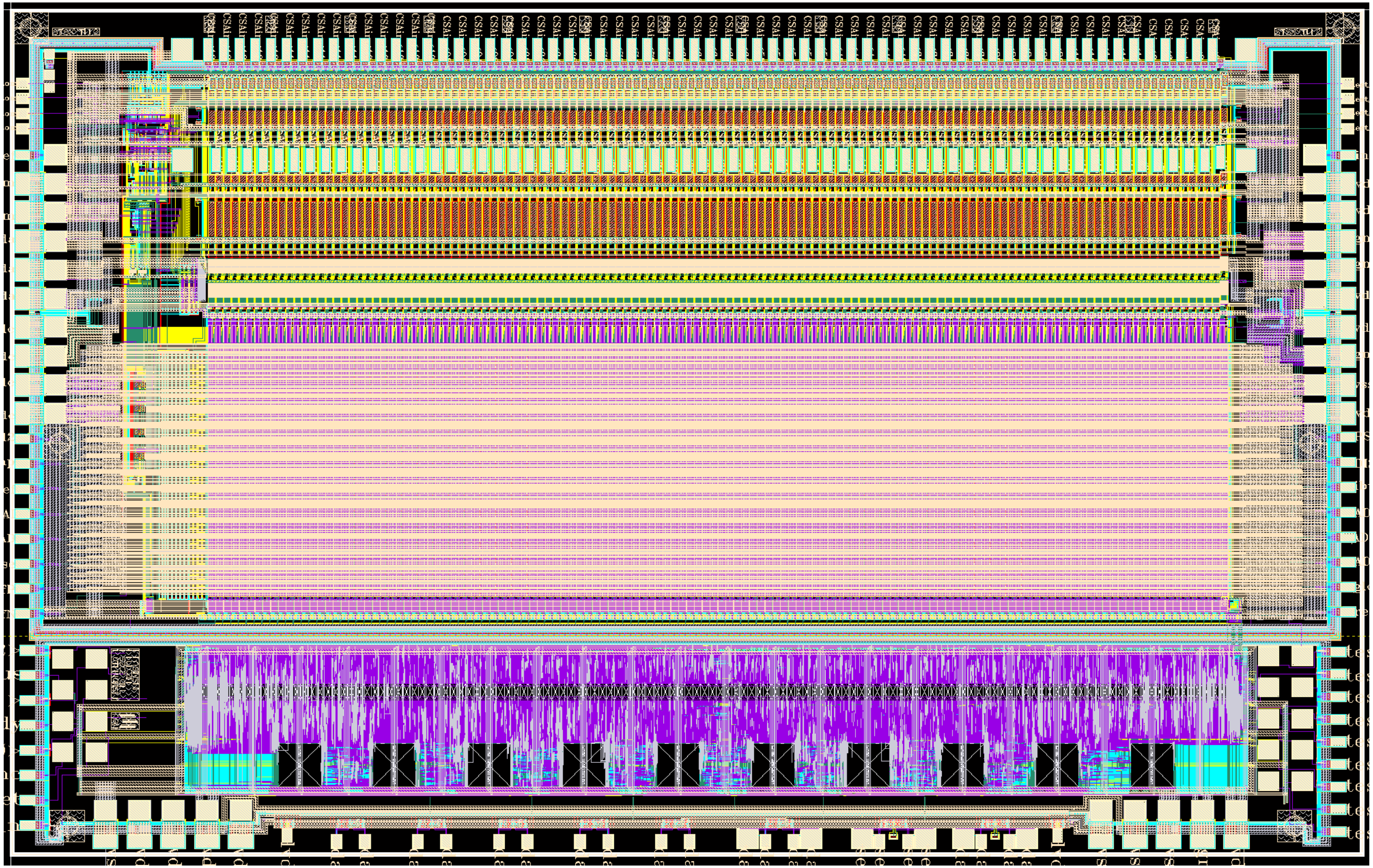


Development of assembly procedures

STS-XYTER: the CBM STS readout ASIC

Freely streaming data readout chip with GBTx compatible backend (AGH Krakow)

2 x 64 channels input in two rows, separated by 880µm



power

power

chip address

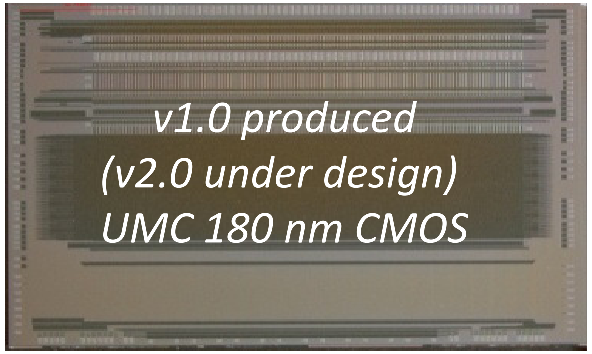
6 LVDS data and clk input and outputs

Read-out ASIC "STS-XYTER"

Dedicated rad hard chip in n-XYTER architecture with GBTx compatible interface
x5 gain switch allows employment for STS as well as CBM-MUCH

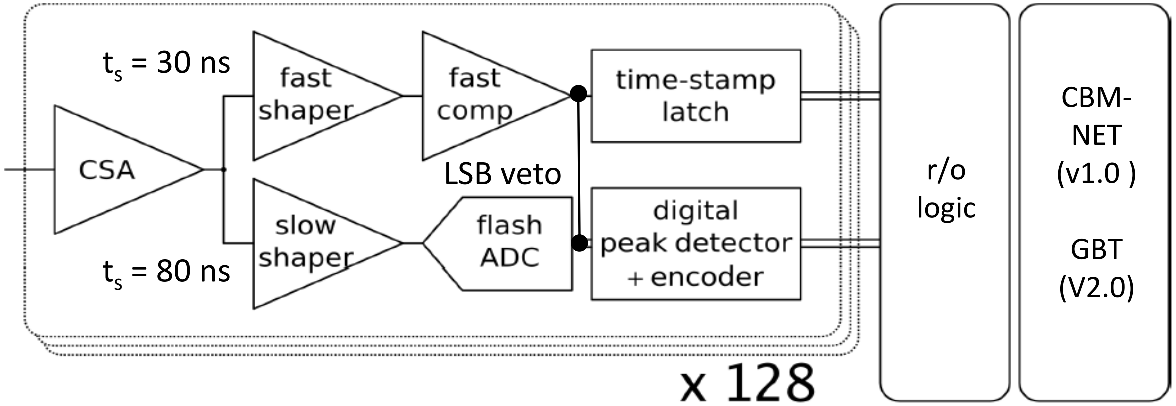
- *purely data driven read-out*
- *time-stamped data elements*

STS-XYTER ASIC



channels	128, polarity +/-
noise	1000 e^- under load
ADC range	16 fC, 5 bit
clock	160 MHz (GBTx)
power	< 10 mW/channel
timestamp	< 5 ns resolution
out interface	1 to 5 × 500 Mbit/s LVDS

- fast branch: time-stamp
- slow branch: signal pulse height digitization (5bit)

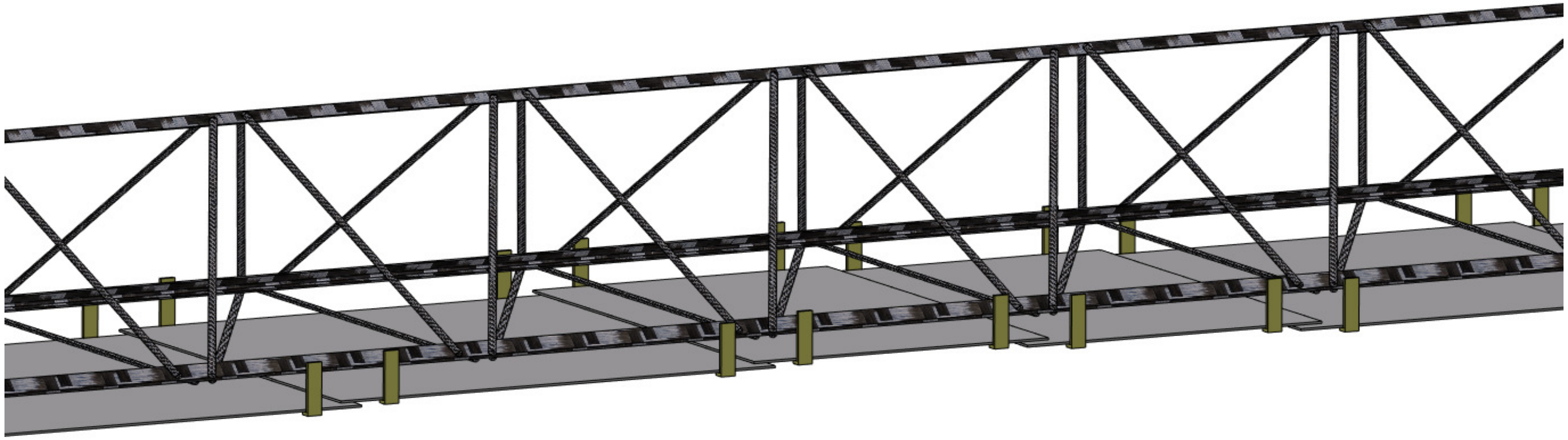


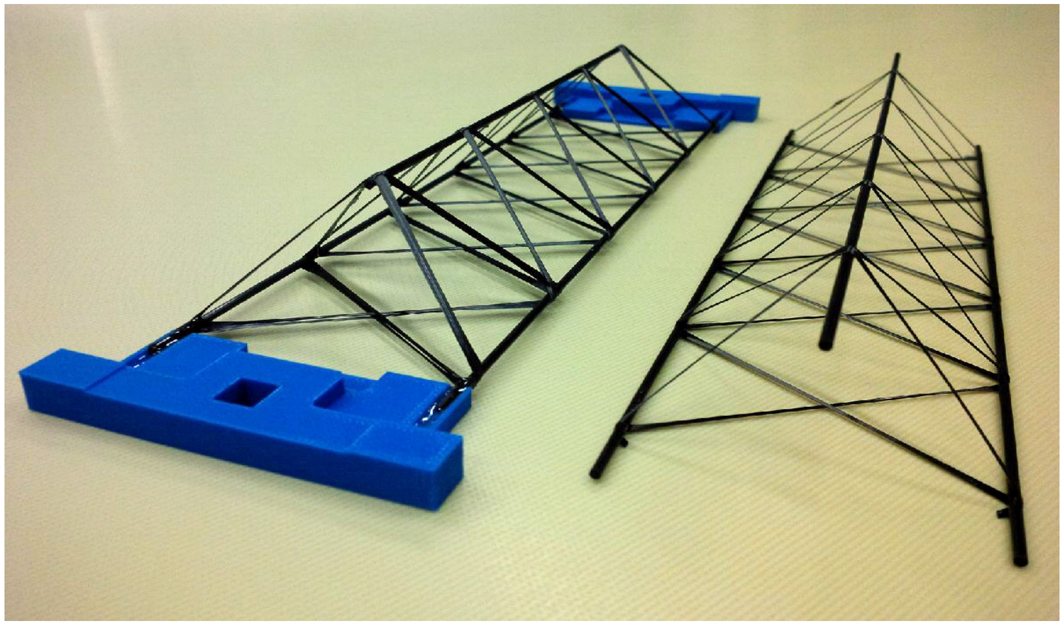
noise minimization in self-triggering system:

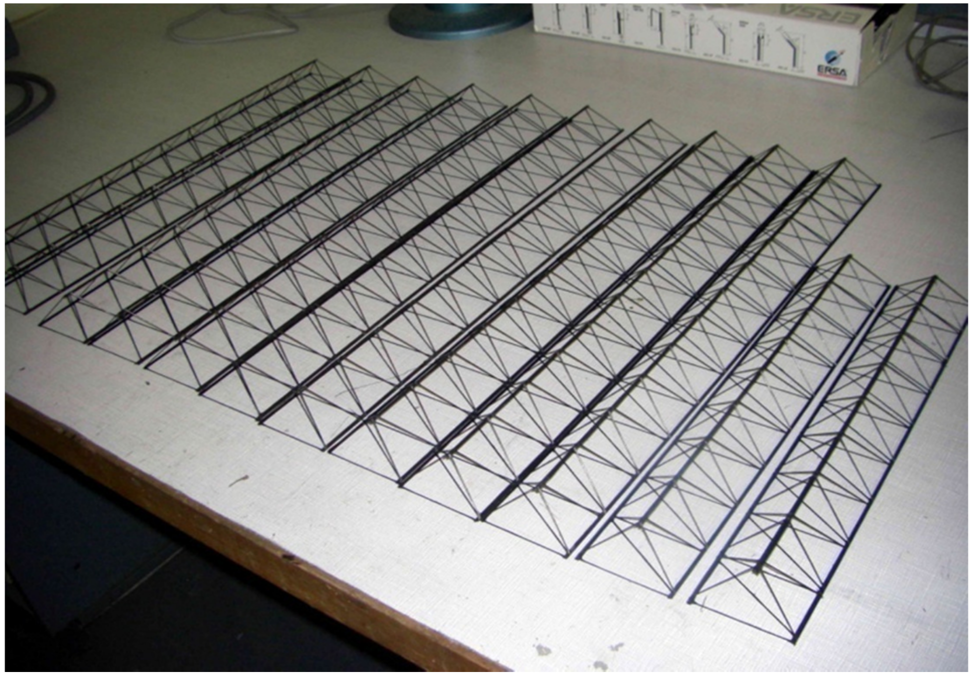
effective two-level discrimination

- trigger to the timestamp latch is vetoed if ADC-LSB generated no signal

Carbon fiber ladders



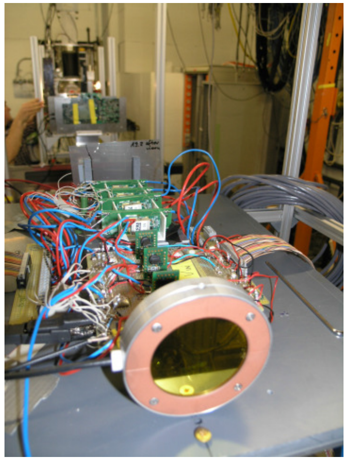


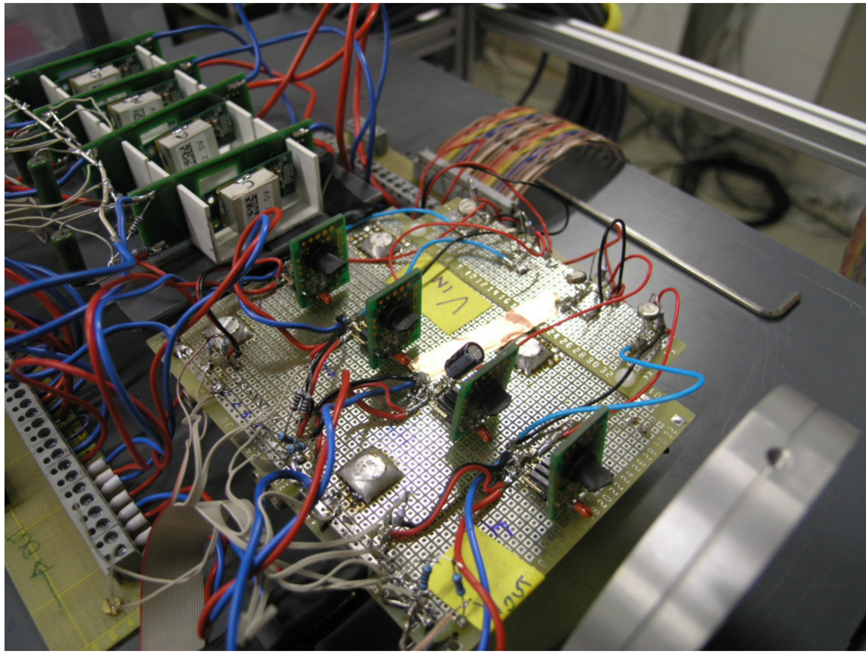


Power distribution in harsh environments

Towards Rad Hard LDOs

Cooperation with SCL Chandigarh

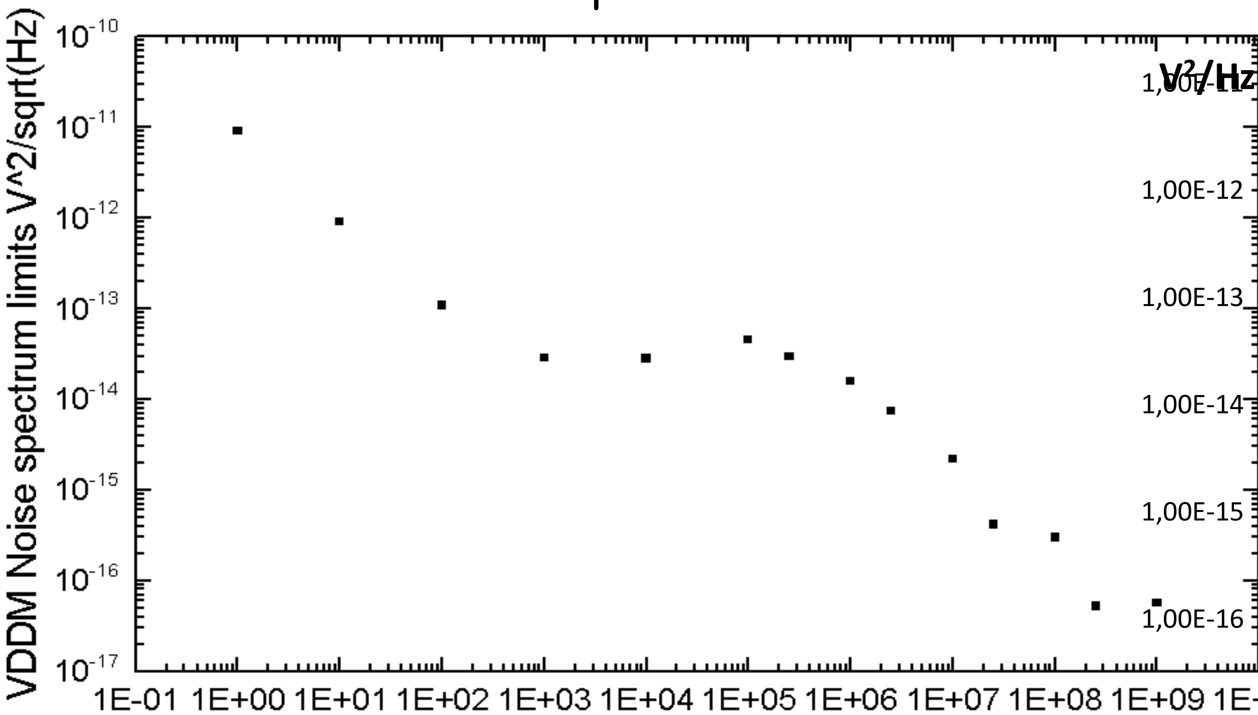


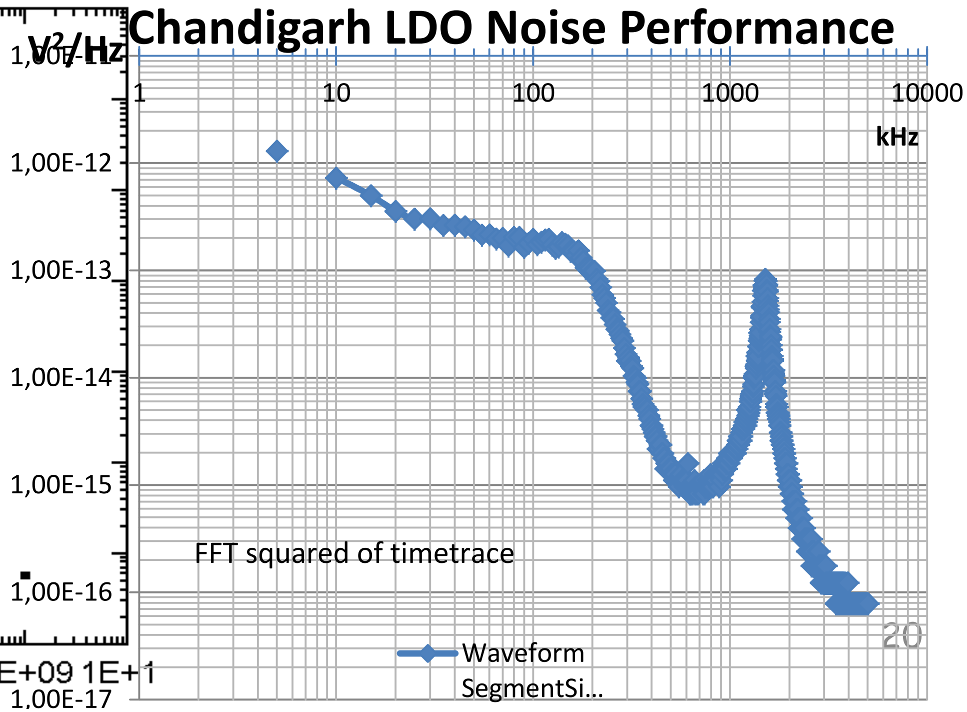


Three LDO chips survived $4x10^{13}/cm^2$ 2 GeV protons, no SEU observed

P. Koczon, S. Loechner, P. Wieczorek

STS-XYTER power needs





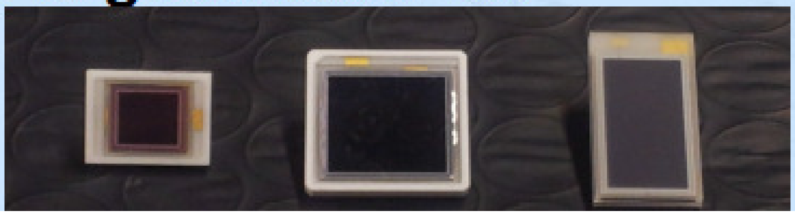
PANDA

Target Spectrometer EMC

PANDA PWO Crystals

- PWO is dense and fast
- Low γ threshold is a challenge
- Increase light yield:
  - improved PWO II (2xCMS)
  - operation at -25°C (4xCMS)
- Challenges:
  - temperature stable to 0.1°C
  - control radiation damage
  - low noise electronics
- Delivery of crystals 54%

Large Area APDs

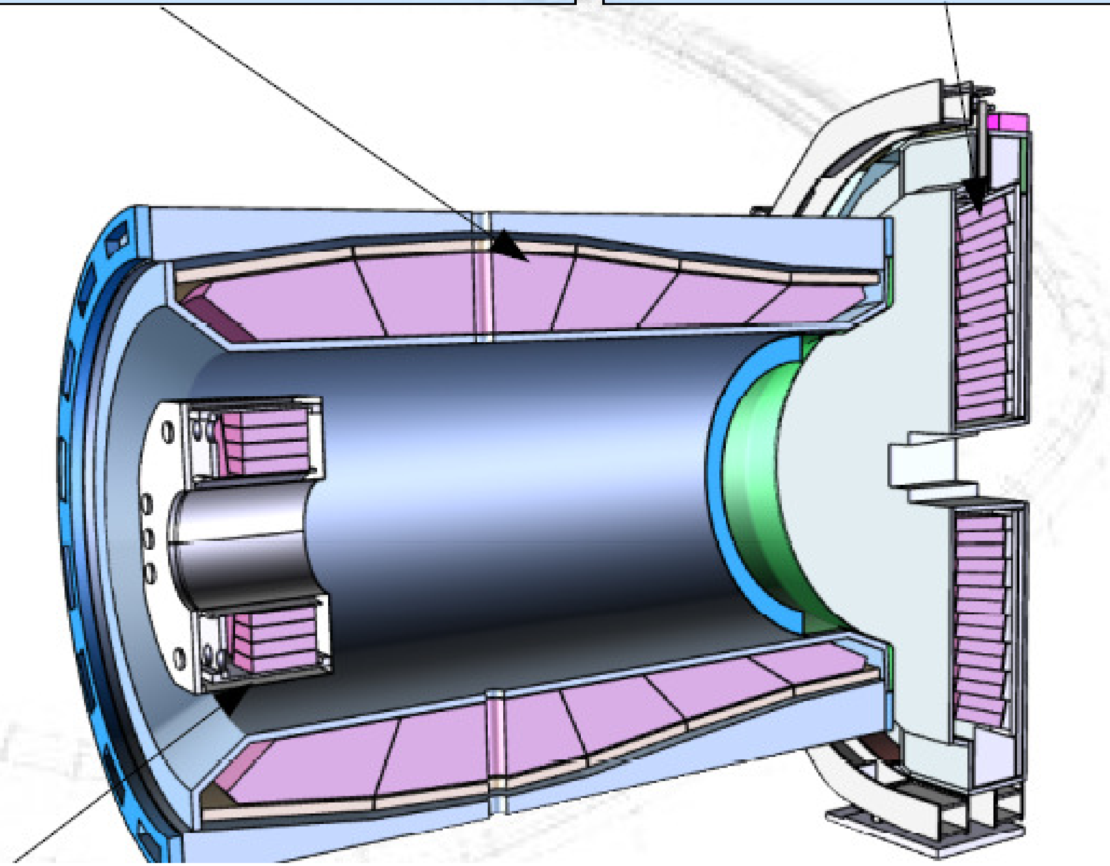


Barrel Calorimeter

- 11000 PWO Crystals
- LAAPD readout, 2x1cm^2
- $\sigma(E)/E \sim 1.5\%/\sqrt{E}$ + const.

Forward Endcap

- 4000 PWO crysta
- High occupancy i
- LA APD and VPT

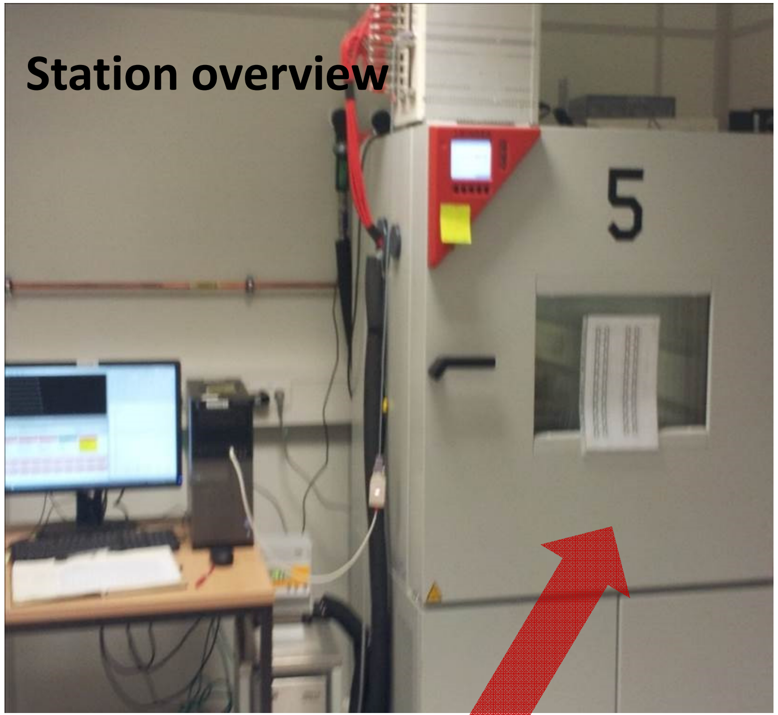


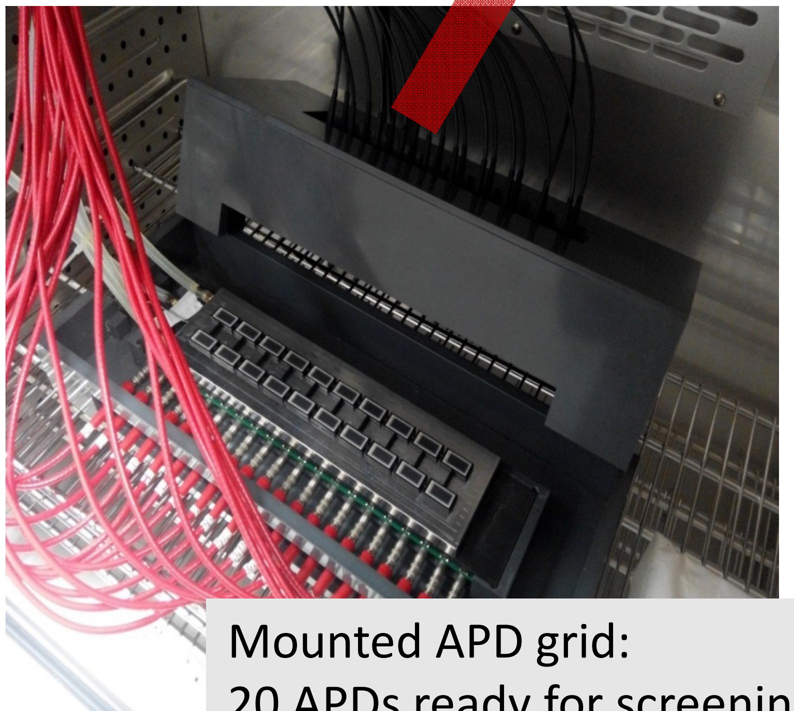
APD Screening lab PSL

5 stations for simultaneous screening of 100 APDs:
temperature and humidity controlled,
QE, gain, dark current...

Avalanche **P**hoto **D**iodes in high energy physics as electromagnetic calorimeter readout devices

Initial Project: PANDA EMC, 35.000 APDs





Mounted APD grid:
20 APDs ready for screening

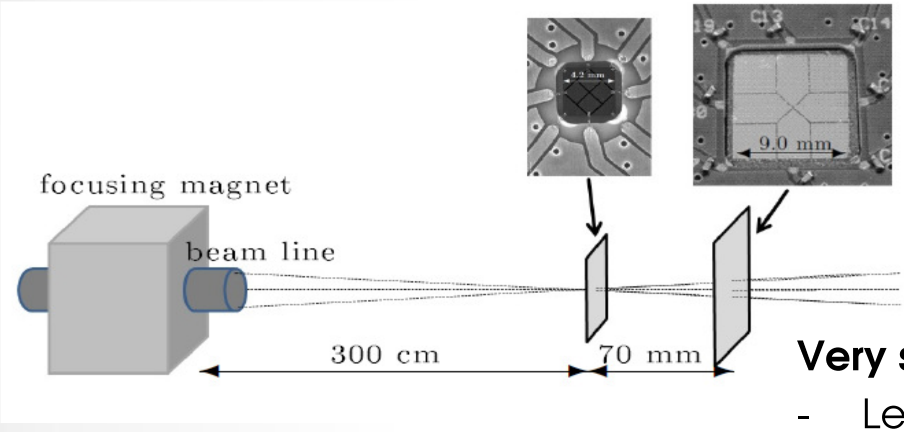
Diamond Detectors: Towards TOF Start

Radiation hardness test with Au beam

→ several days with well focused beam

→ 10^6 ^{197}Au ions/s (^{197}Au at 1.25 A GeV)

→ single particle readout → total number of particles



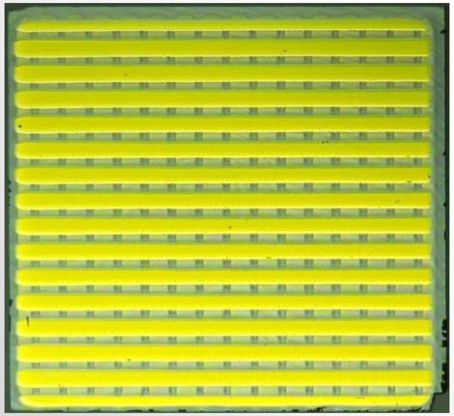
Localized ageing: Pulse height down to 20%

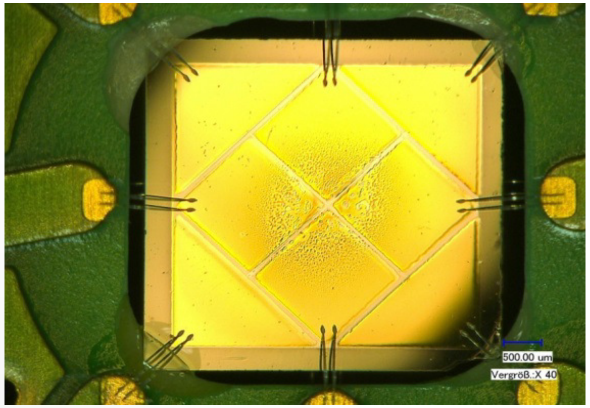
→ **3.04 x 10^{11} Au ions**

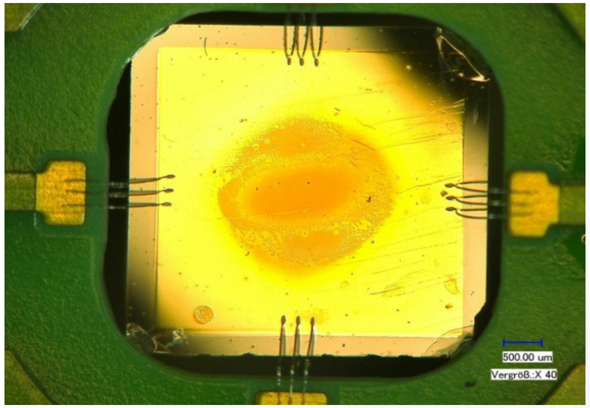
→ **total absorbed dose: 87 MGy**

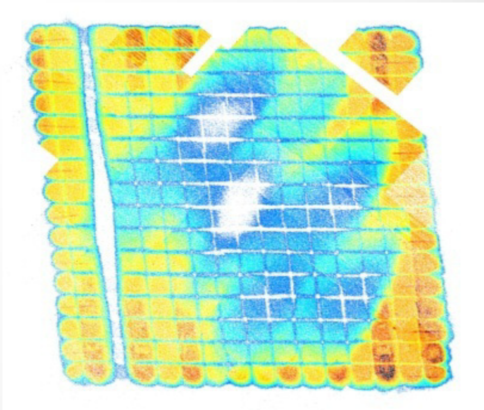
Very stable detector behavior after irradiation (~10^{12} Au ions / mm^2):

- Leakage current below 10 nA
- Time resolution below 60 ps









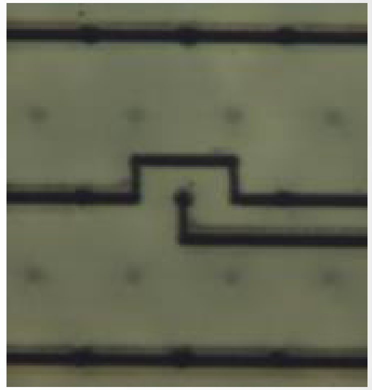
Summary on Diamond Activities

Diamond Membranes give fast sub ns detector response

Radiation damage

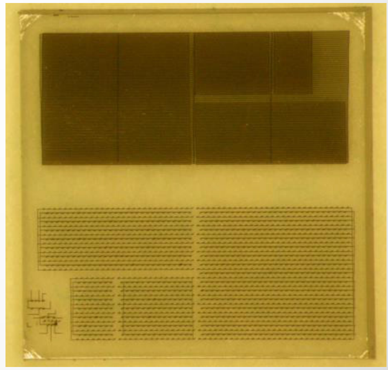
- Stable diamond operation after irradiation above 10^{11} Au ions/mm^2
- Leakage current below 10nA
- Time resolution below 60 ps
- Significant CCE reduction, more than a factor of 6 !
- Can be compensated by additional amplification x 10 or 3D

Diamond goes 3D



Diamonds for MIPs **ingredient: PADI-ASIC, development for TOF**

- Excellent time resolution for MIPs, below 100ps
- Position resolution better than 50 µm and can be improved

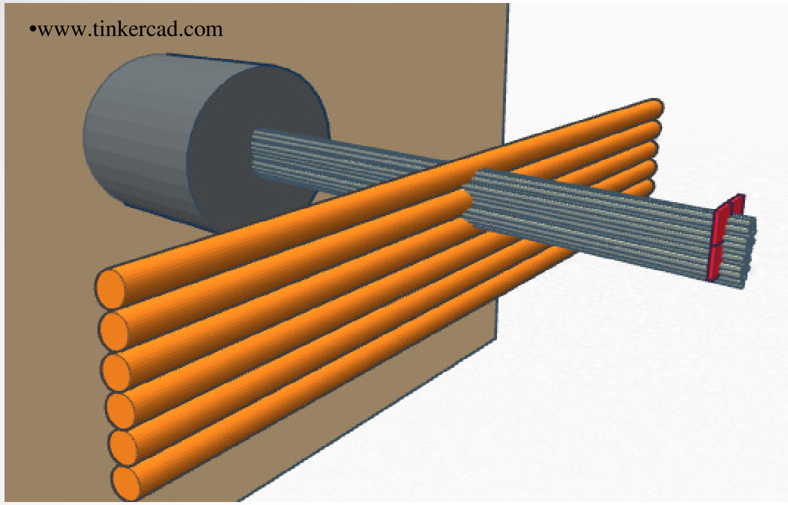


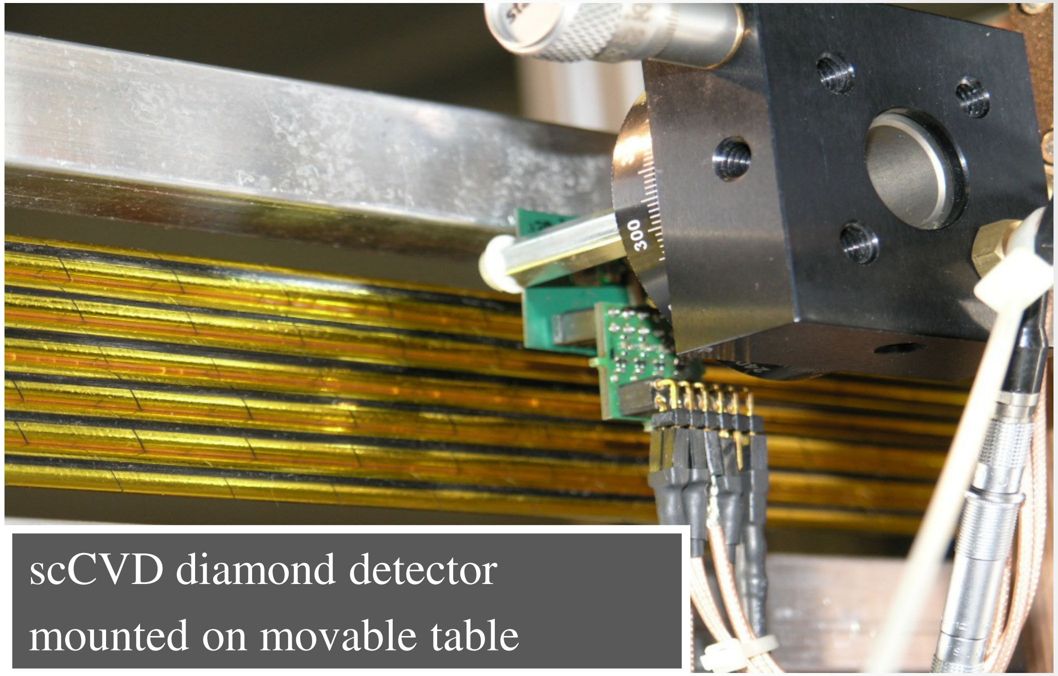
Materials

- PC CVD-Diamond (large areas)
- SC CVD-Diamond (small but spectroscopic)
- DOI CVD-Diamond: Quasi SC at larger areas → Uni Augsburg

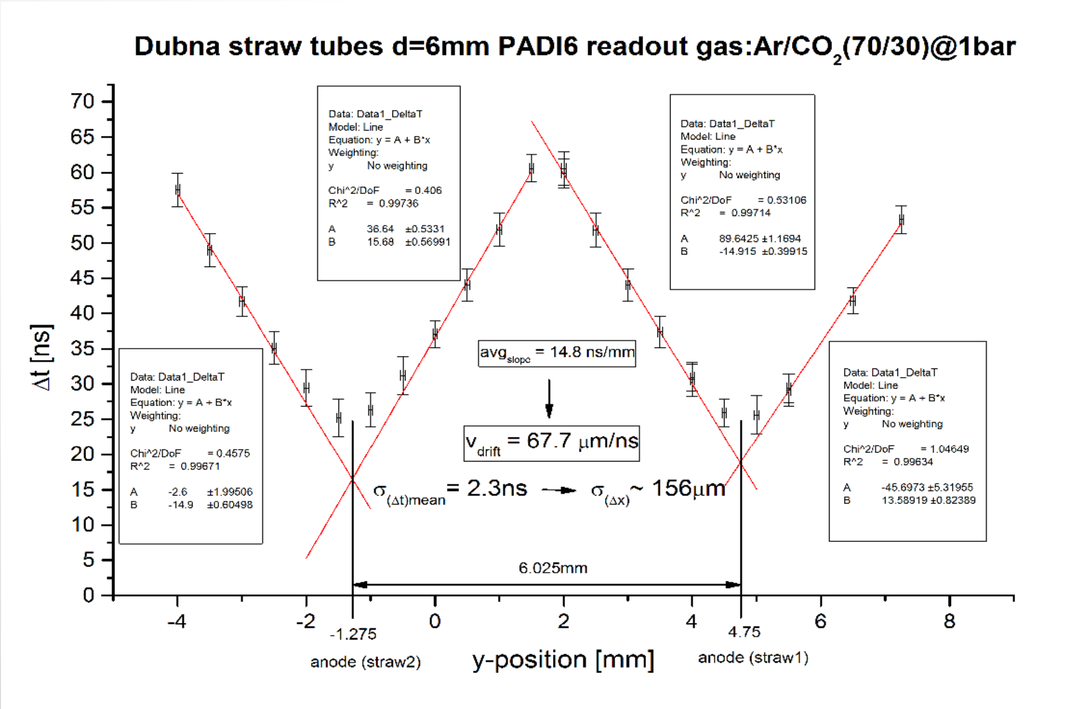
MuT cooperation
Uni Florence
Uni Manchester

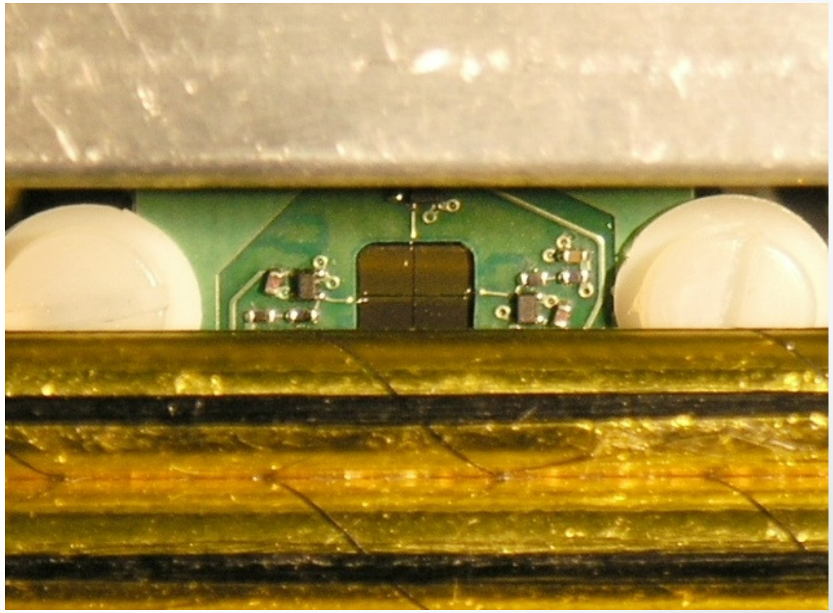
Evaluation: CBM-TOF Electronics for CBM-Much Straws





scCVD diamond detector mounted on movable table

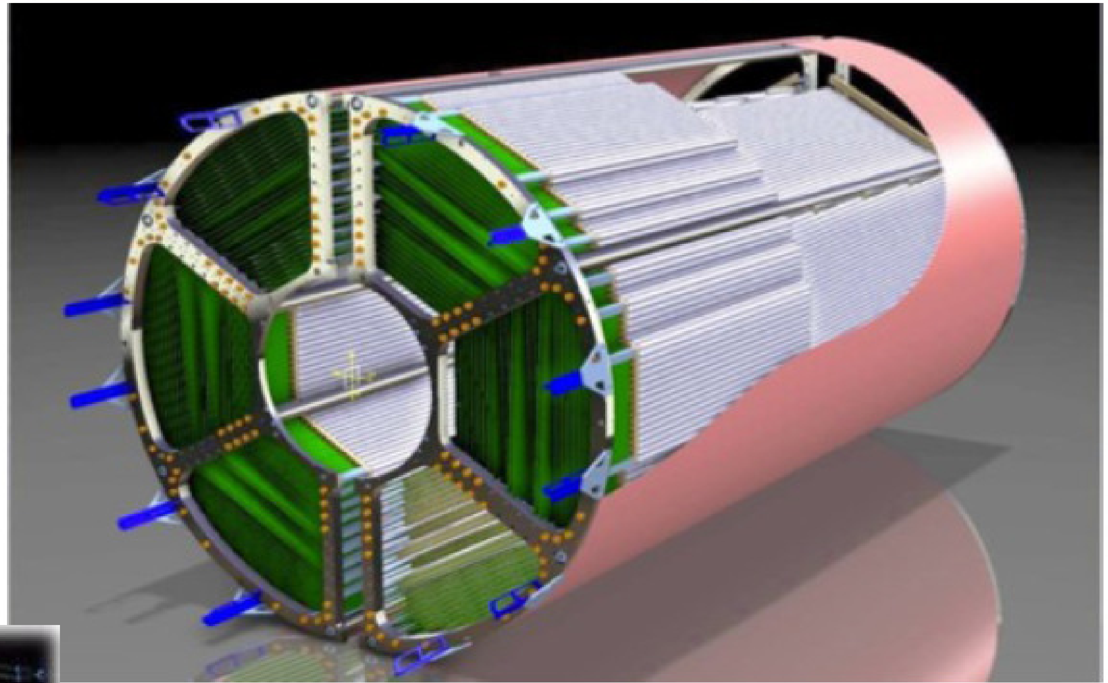


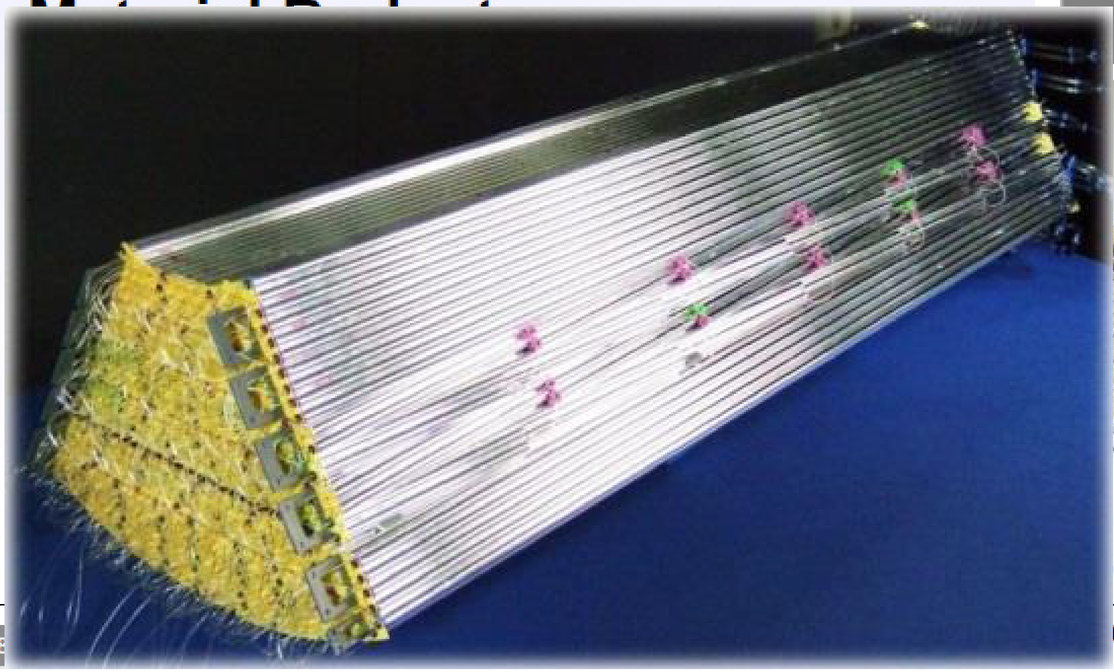


Straw Tube Tracker

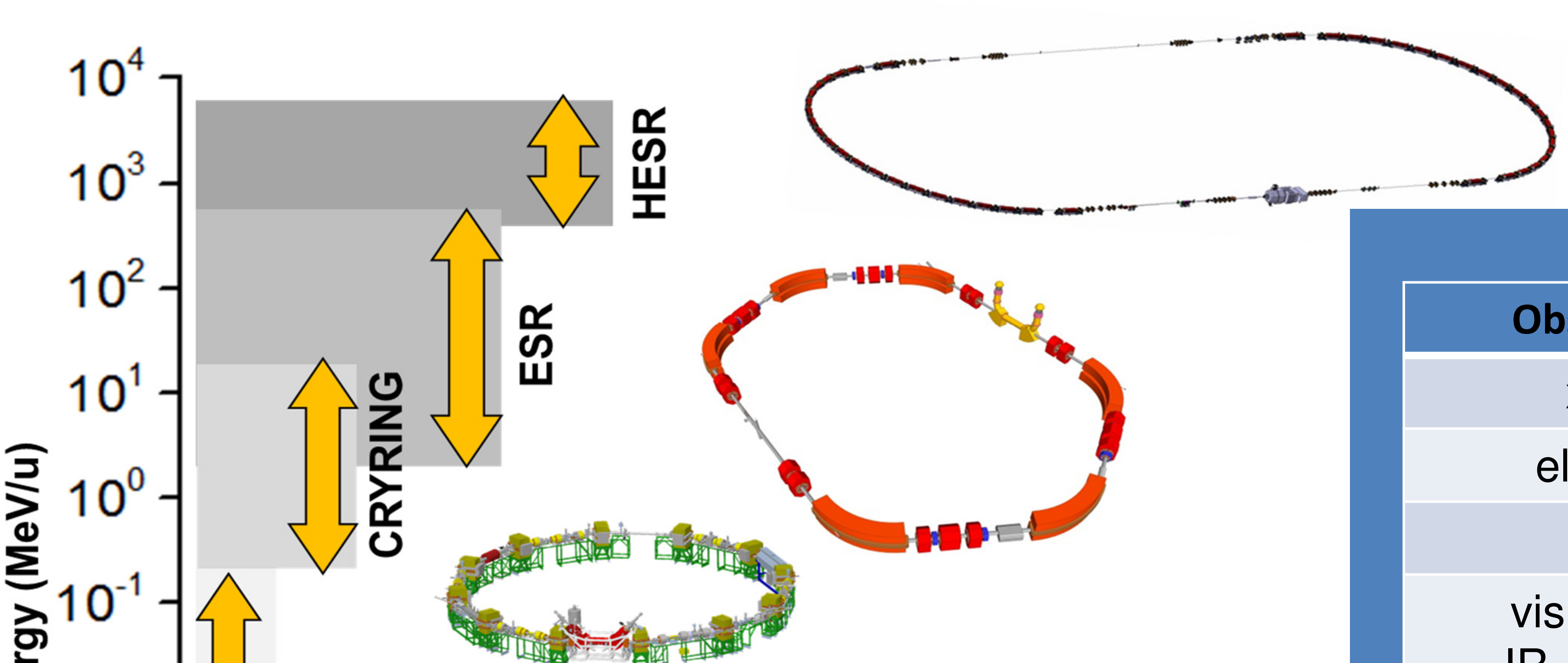
Detector Layout

- 4600 straws in 21-27 layers, of which 8 layers skewed at ~3°
- Tube made of 27 μm thin Al-mylar, Ø=1cm
- R_{in}= 150 mm, R_{out}= 420 mm, l=1500 mm
- **Self-supporting straw double layers at γ 1 bar overpressure (Ar/CO_2)**
- Readout with ASIC+TDC or FADC

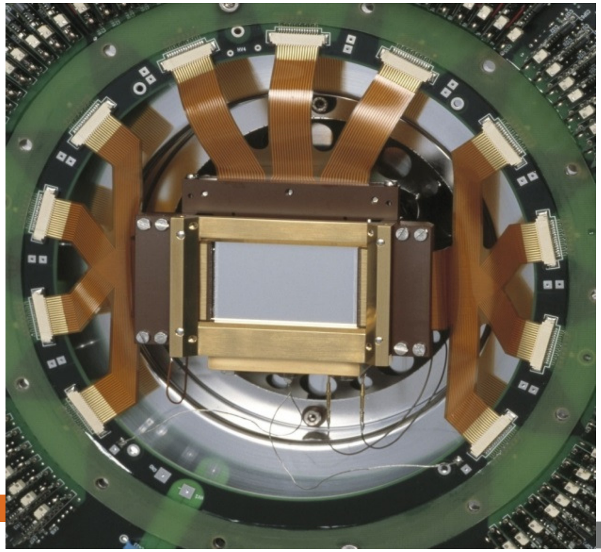




APPA SPARC@FAIR: Storage and Trapping



Observables
x-rays
electrons
ions
visible light, IR, UV, XUV

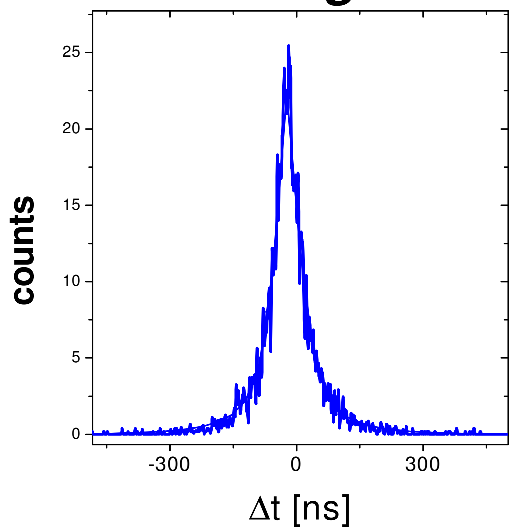


Detector Applications:
not that much tracking!

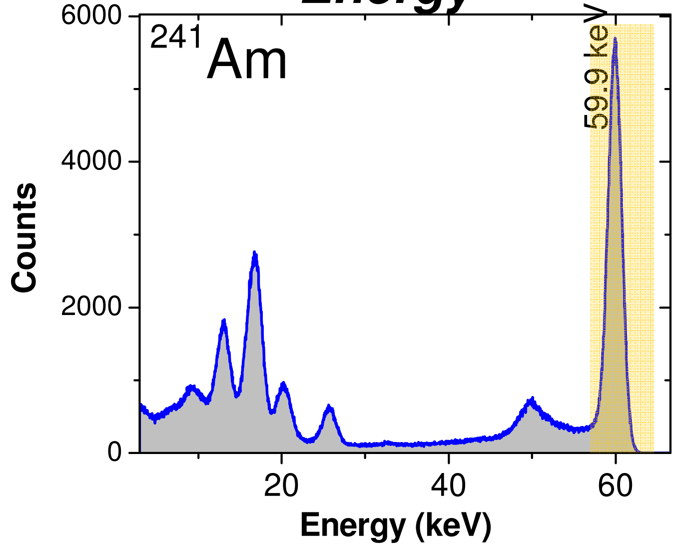
- spectroscopy
- energy resolution
- detection efficiency
- full absorbtion

Planar structured semiconductor detectors
Position sensitivity with good resolution

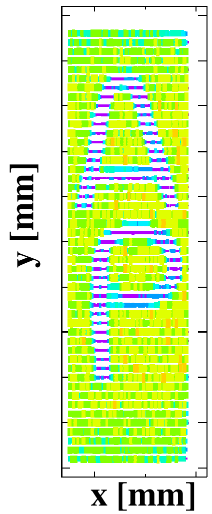
Timing

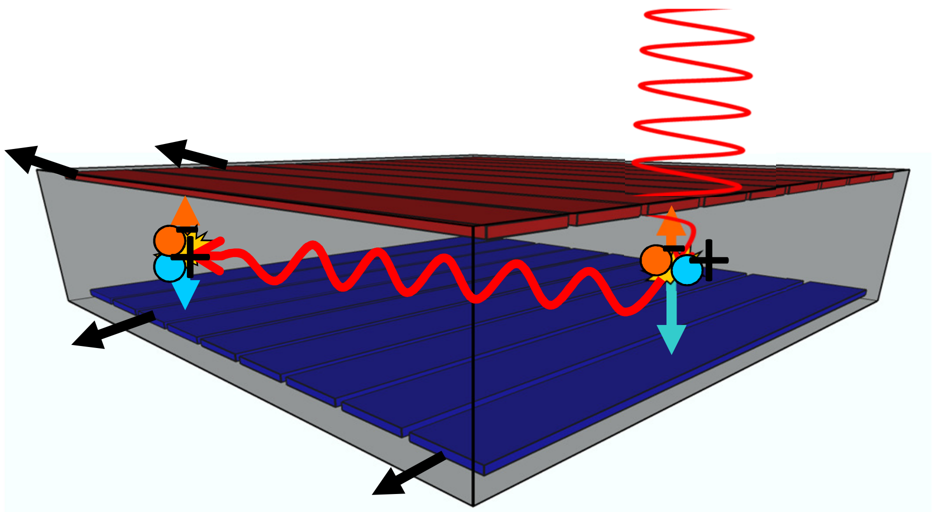


Energy



Position

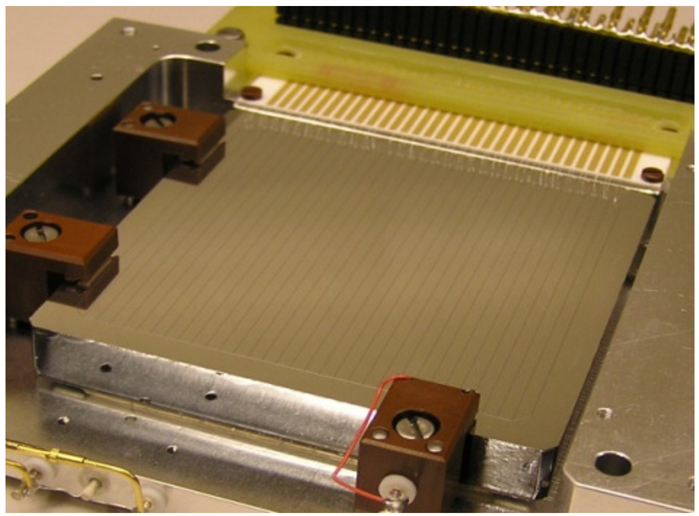




X,Y: strip contacts

Z: drift time

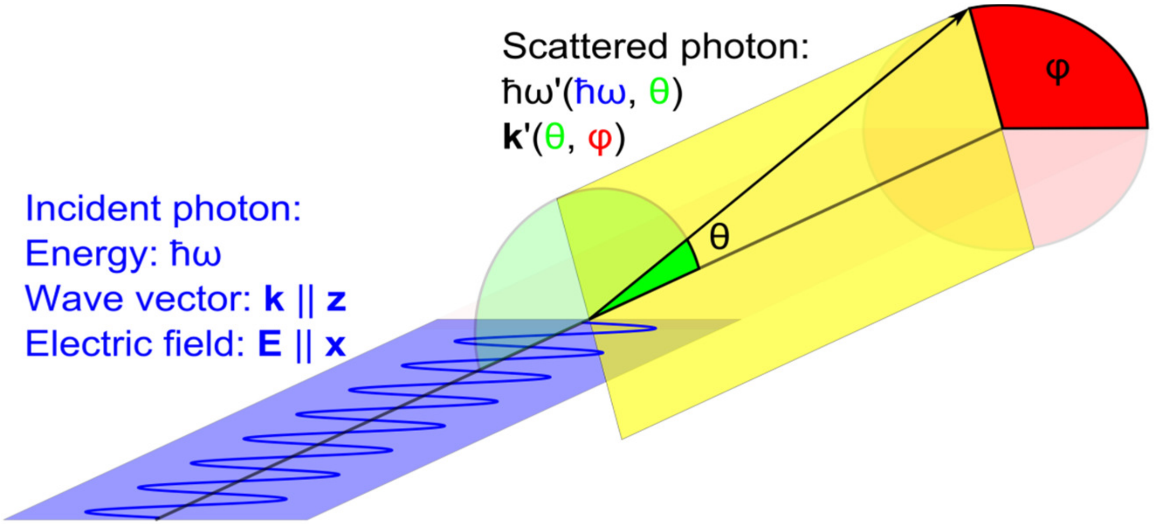
x-ray interacts with the detector bulk

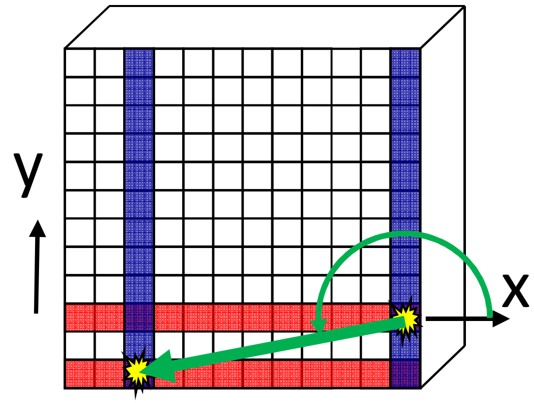


Si(Li)-strip-detector in a test holder

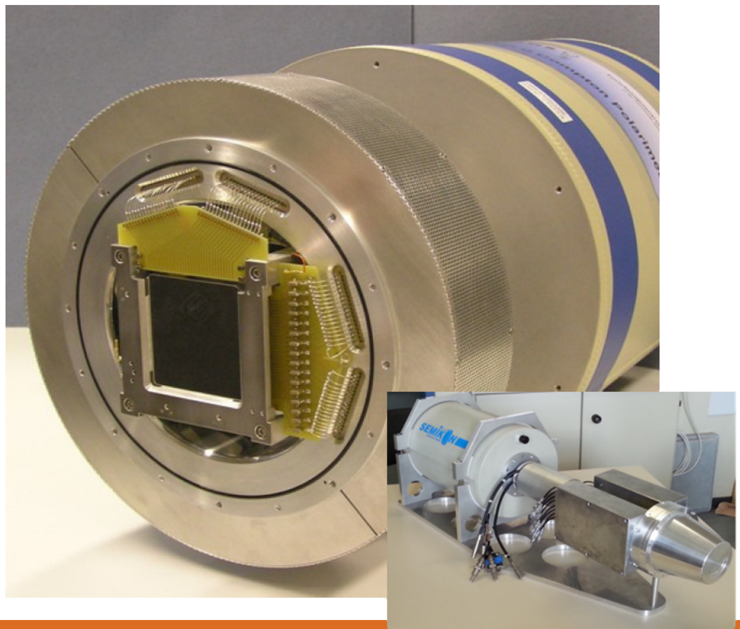
Compton Polarimetry: full compton scattering kinematics

Record Compton scattering events inside one detector





Compton Event reconstruction for recoil electron and scattered photon

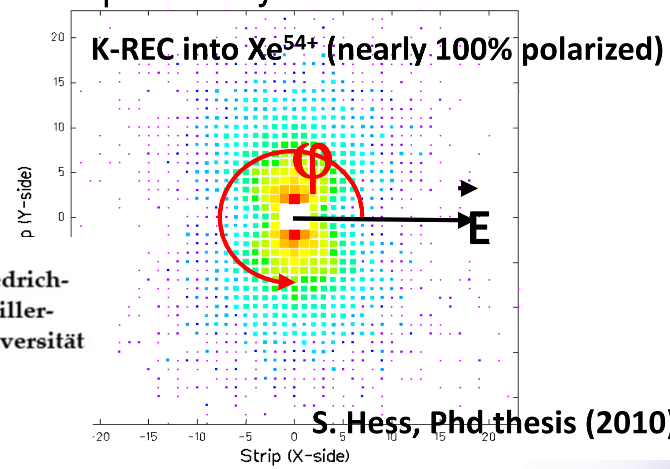


Planar Si(Li) Detector

32 strips per contact
pitch 2 mm
detector thickness 7 mm
⇒1024 stripsel
active area: 4100 mm²
Enhancement work→
ASIC readout,
cold pre-amp (σ 700eV),
smaller pitch

XY Position - Energy – Time

Compton scattered photon xy-distribution



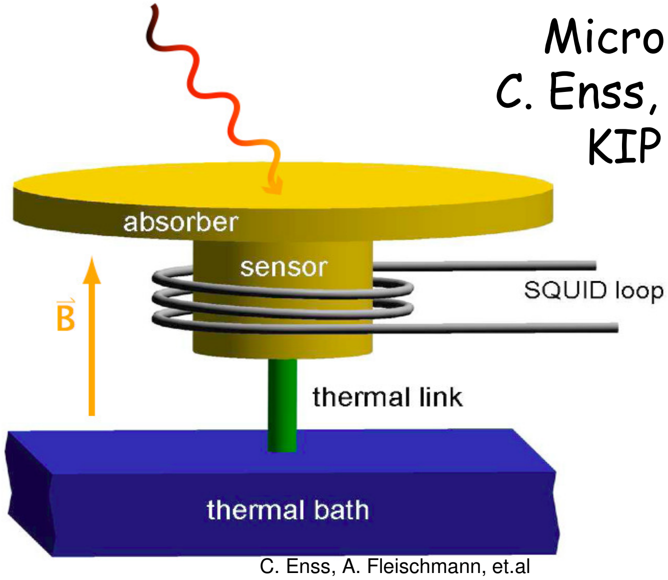
S. Hess, Phd thesis (2010)

Friedrich-Schiller-Universität Jena

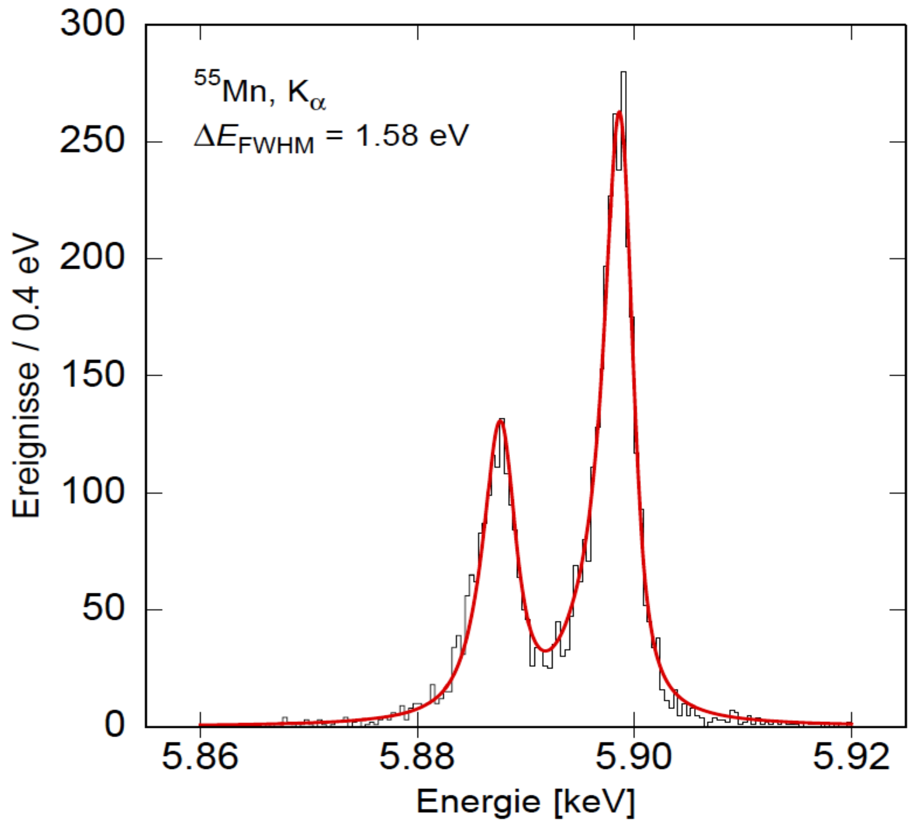
HI Jena
Helmholtz-Institut Jena

sparc

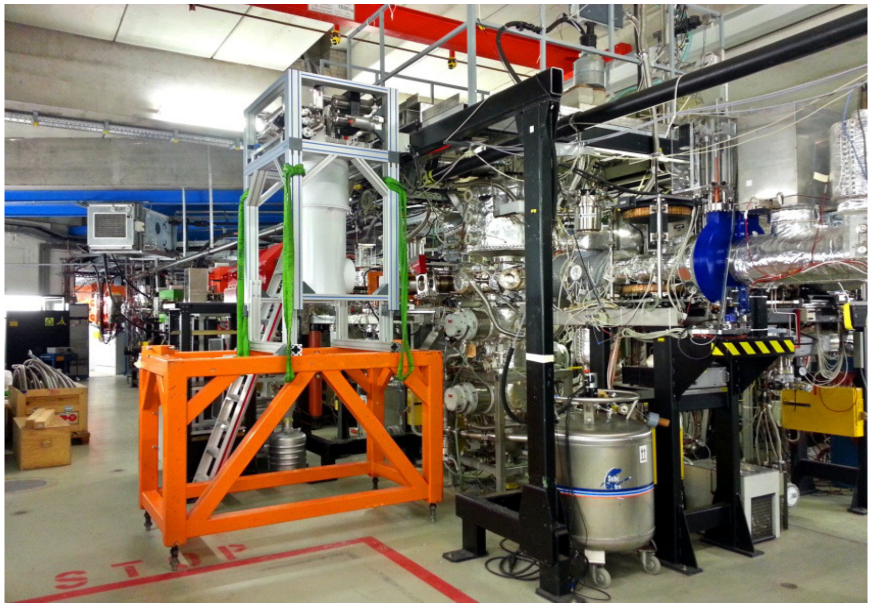
Metallic Magnetic Calorimeter maXs



Micro Calorimeters
C. Enss, A. Fleischmann
KIP Heidelberg



maXs @ ESR (2014)



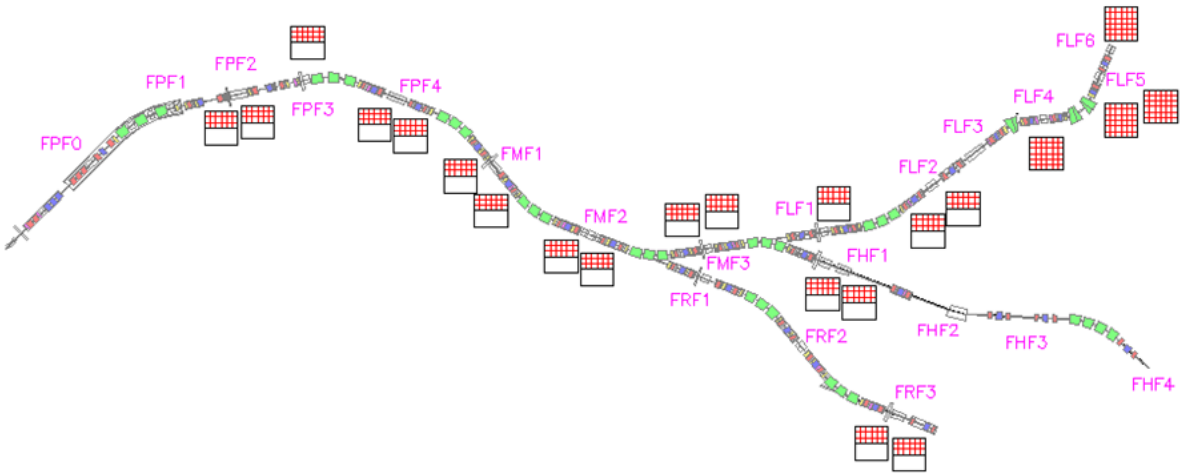
ΔE_{FWHM} = 1.6 eV @ 6 keV

World record together with TES-sensors of NASA-GSFC!

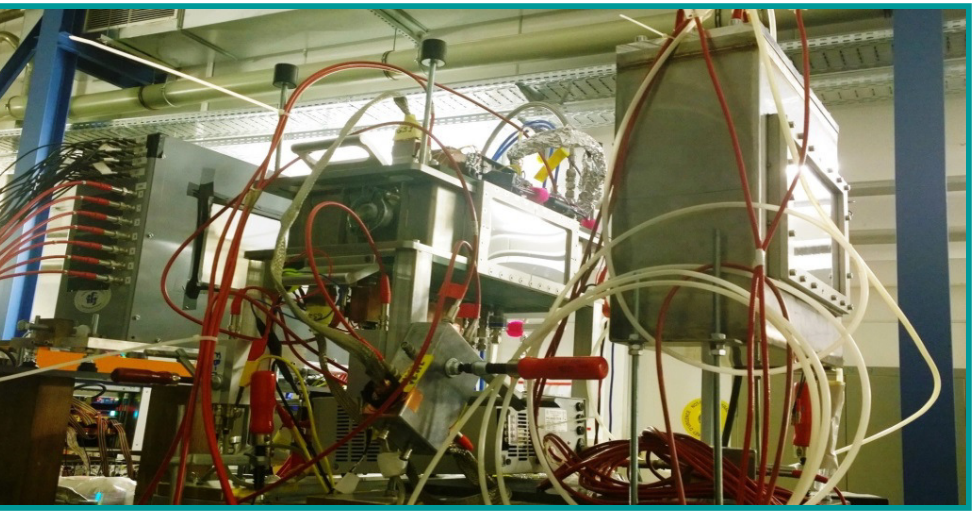
Micro calorimeters now also element of M&T POF III activities

GEM-TPC for tracking through SFRS

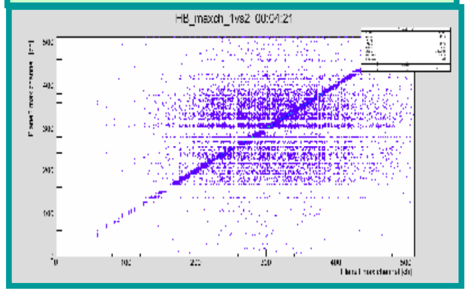
a Finnish IHP In-Kind to FAIR with a lot of support from GSI



- rate capability
- dynamic range to be covered for heavy ion fragments
- field cage
- ultra low mass
- tripple GEM amplification
- Twin TPC



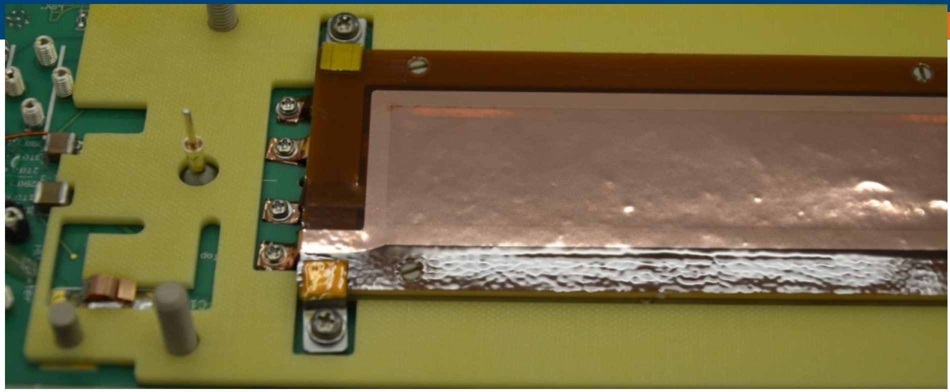
Correlation hits on X of front and back field cages



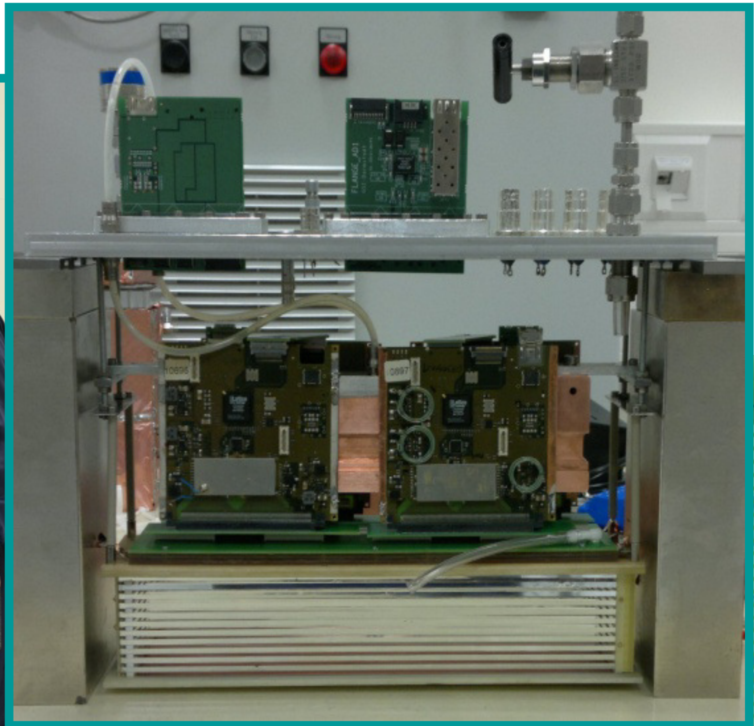
SFRS: Tracking → q/m of fragments
TOF → v
} map of isotopes

HB3 @ S2 and ready to take the Beam of ^{197}Au at 770 MeV/u

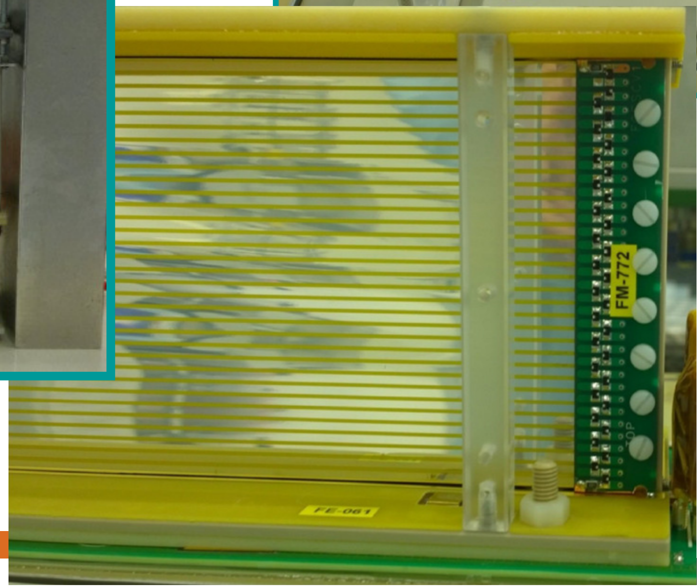
Twin GEM TPC Developments



GEM-amplification



n-XYTER r/o



low mass
field cage

SFRS-TOF in focal planes: Various options

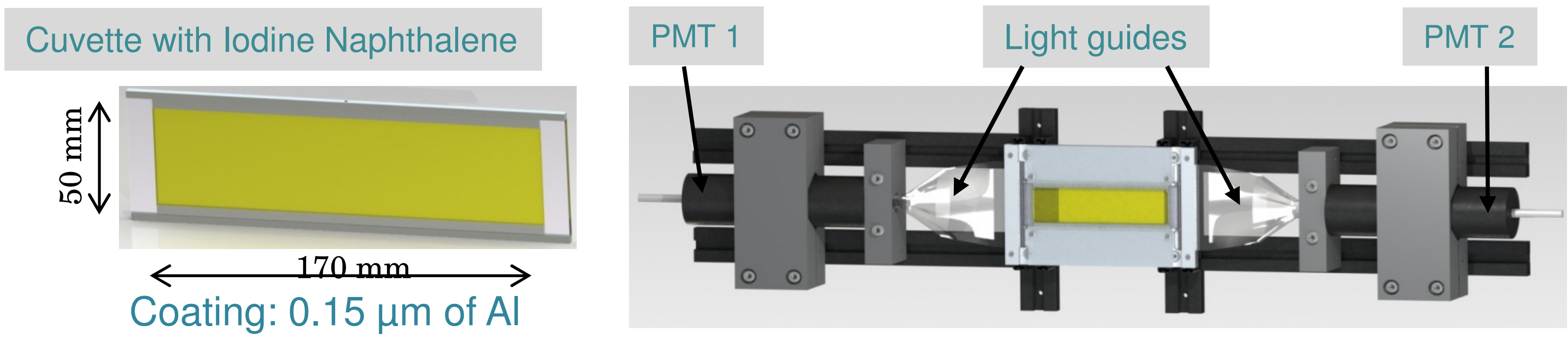
< 35 ps 1σ time resolution desired

- a) PC-CVD Diamond Array
- b) Silicon Strips
- c) Scintillators
- explorative:

High rates 10 MHz
High rad dose rate 1 Gy/h

Natalia Kuzminchuk

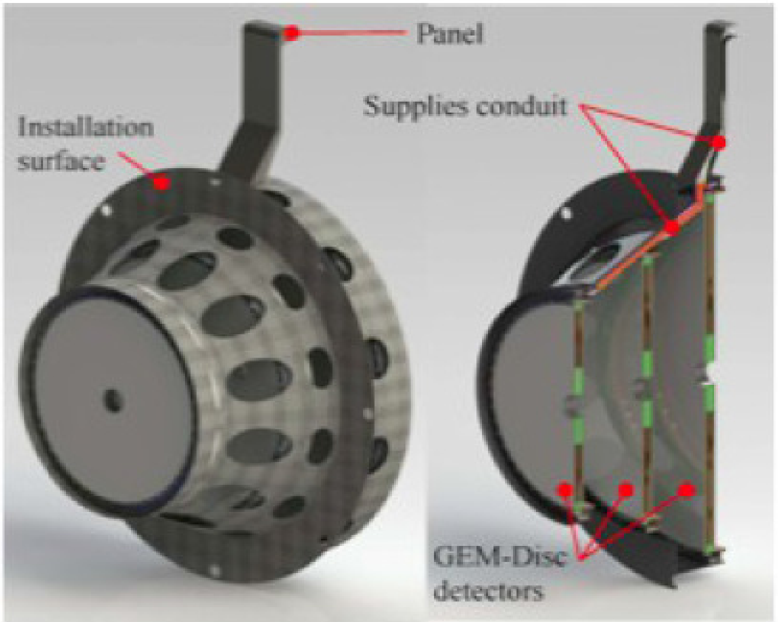
Cherenkov TOF-Option at SFRS: Focal Plane Prototype Design

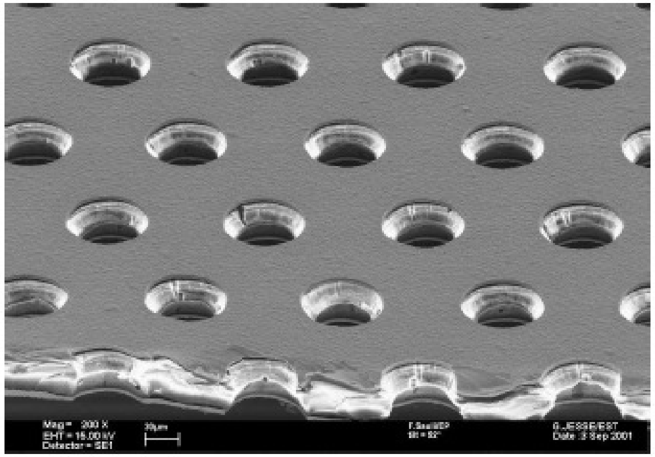


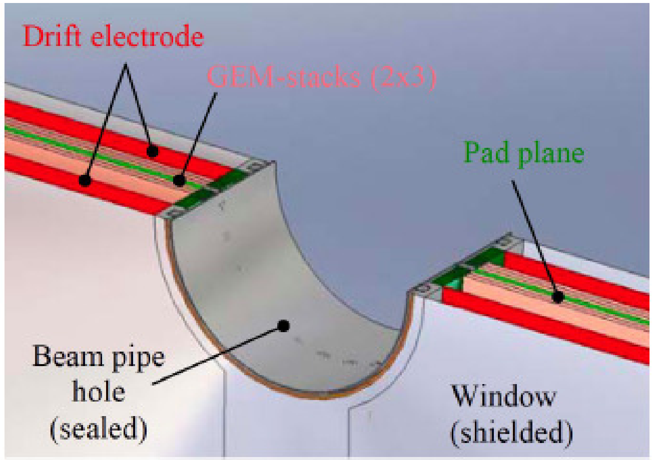
PANDA Forward GEM Tracker

Forward Tracking inside Solenoid

- 3-4 stations with 4 projections each
  - → Radial, concentric, x, y
- Central readout plane for 2 GEM stacks
- Large area GEM foils from CERN (50µm Kapton, 2-5µm copper coating)
- ADC readout for cluster centroids
  - → Approx. 35000 channels total
- Challenge to minimize material





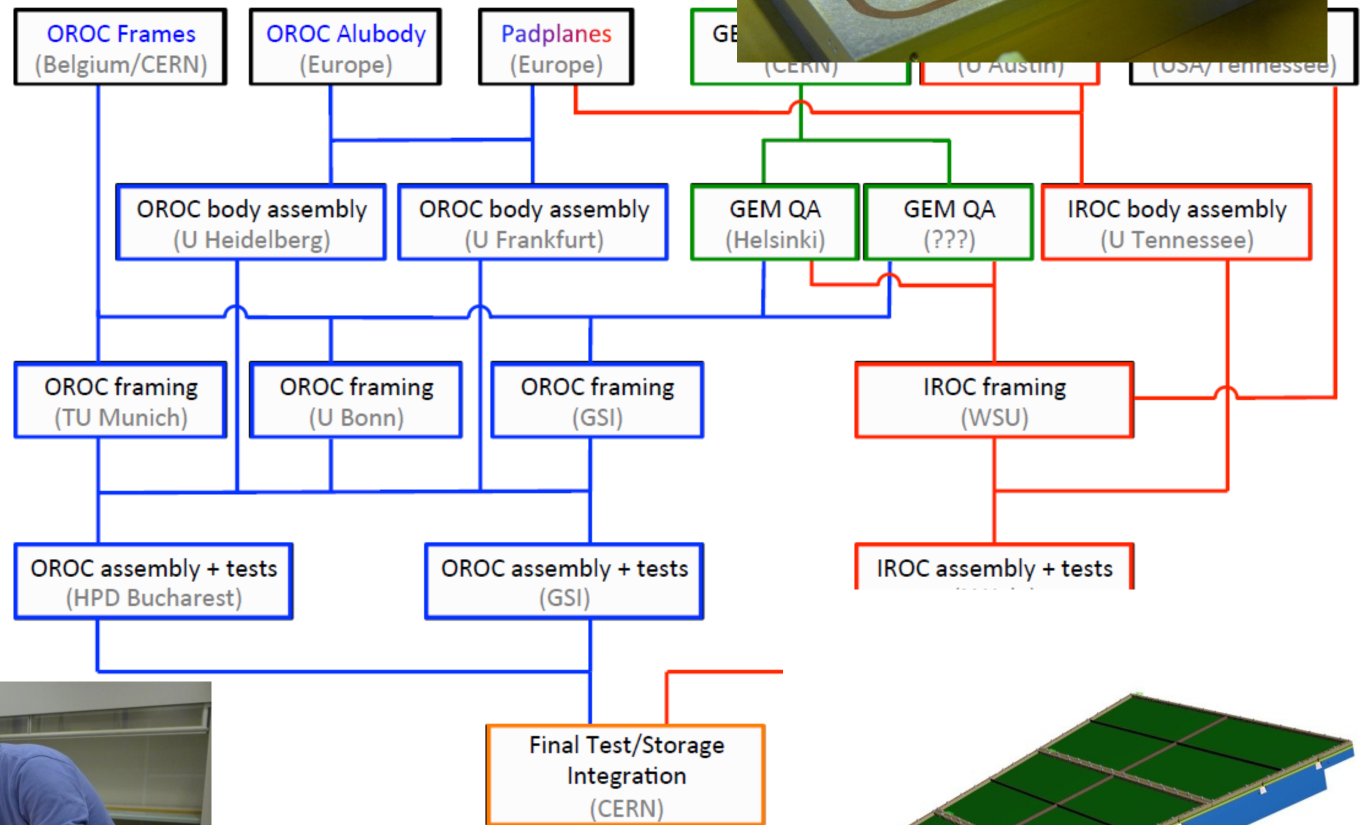


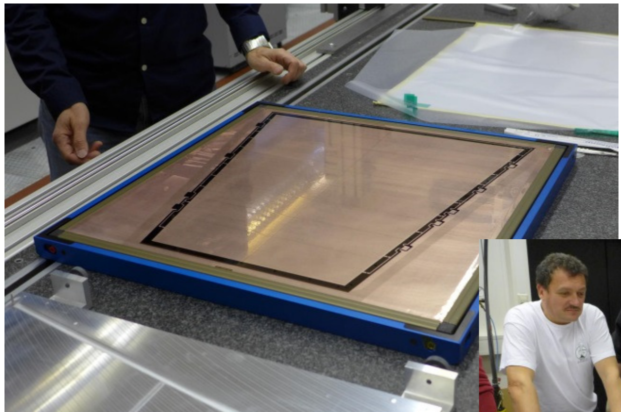
B. Voss, DL, and HIM

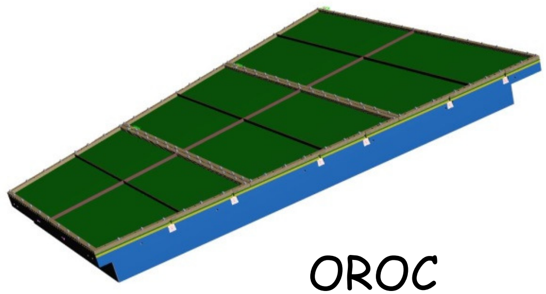
FAIR

ALICE TPC Upgrade → Quadruple GEM Readout

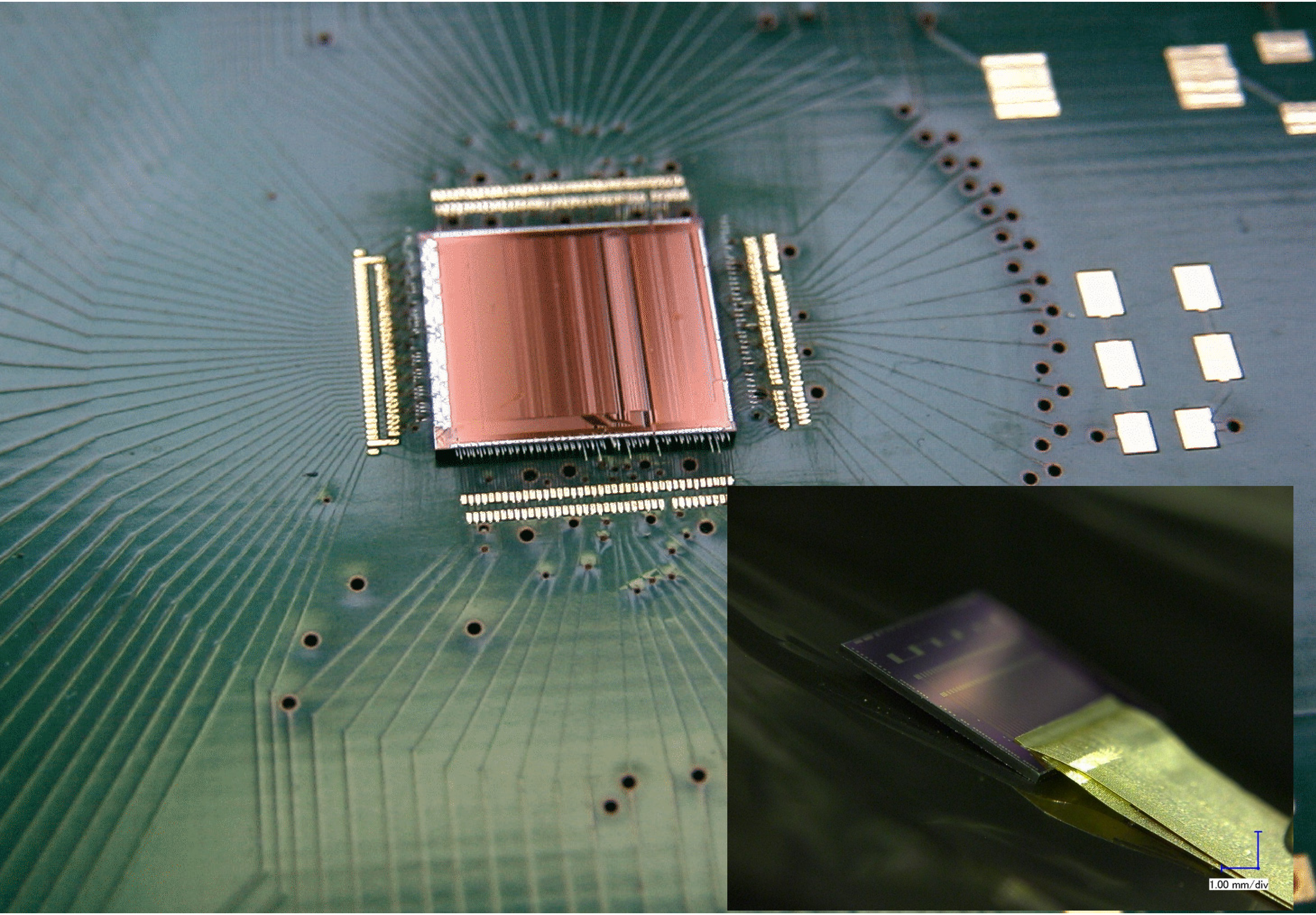
- Total active quadruple GEM r/o area 32,5m²
- Preparations ongoing







OROC


1.00 mm/div