Operation of HV-MAPS detectors in vacuum

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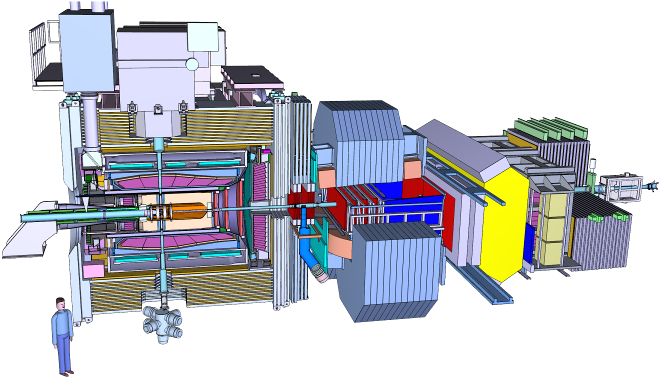
$\bar{\mathrm{P}}$ANDA at FAIR

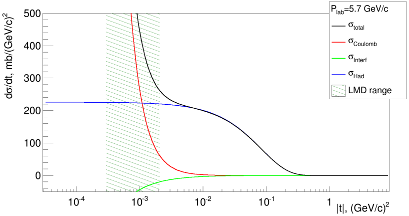


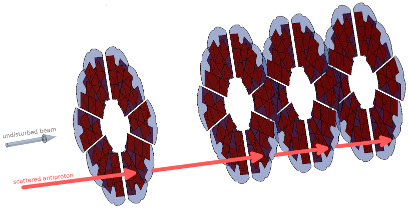
1.5 GeV/c to 15 GeV/c beam momentum, main research areas:

- Hadron spectroscopy
- Hypernuclei
- Hadrons in matter
- Nucleon structure

Precise luminosity needed ⇒ dedicated detector 11 m after IP

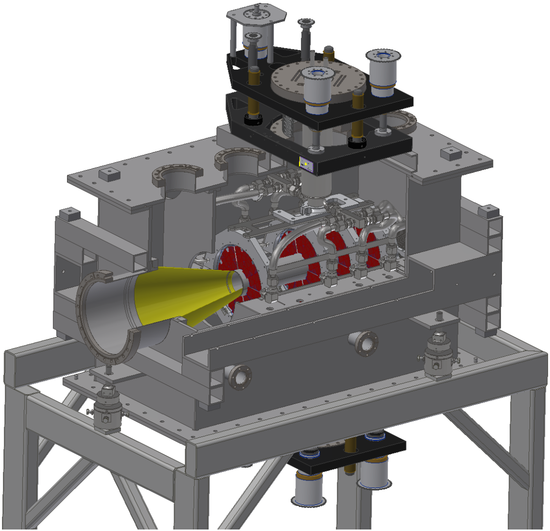
Luminosity measurement at $\bar{\text{P}}$ANDA





- Luminosity determintation from elastic scattering
- Coulomb part dominant at low momentum transfer
- Measurement at very small scattering angles (3 mrad to 8 mrad) after two magentic fields ⇒ tracking detector
- Required precision: 1% for relative and 5% for absolute luminosity
- Very sensitive to multiple scattering
- Low material budget ⇒ sensors in vacuum

Luminosity detector technical overview



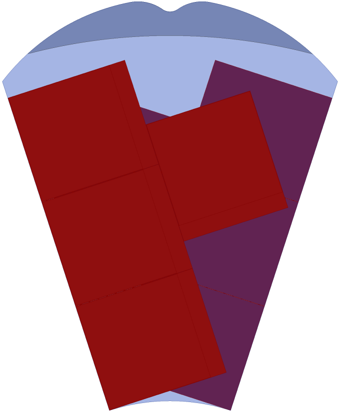
- Sensors in secondary vacuum
- Low material budget and active cooling
- Retractable during beam tunig
- Precise position necessary
- Modular design
- Vacuum box $\sim 1\,\mathrm{m}$ long

Module

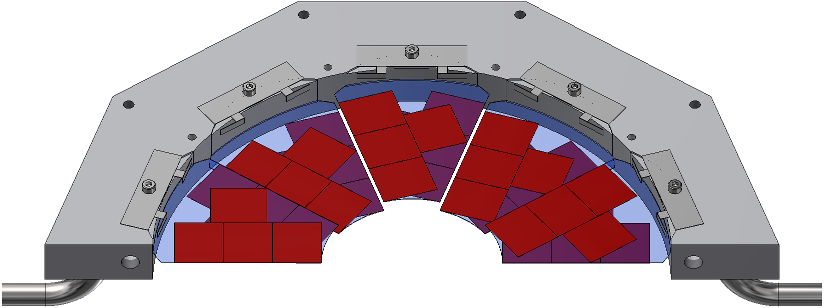
- Active sensors thinned to 50 μm with 20 mm × 20 mm active area: up to 400 mW cm^{-2} expected
- Low material budget: active cooling outside of detector acceptance

⇒ 8 Sensors glued on a 200 μm thick CVD-diamond wafer to form a "module"

- Diamond: very high thermal conductivity, low material budget
- Low viscosity glue allows thickness of ∼10 μm
- Aluminium trace flexcables with <30 μm aluminium
- Cooling by thermal conductivity ⇒ large thermal gradient on the module



Half Plane

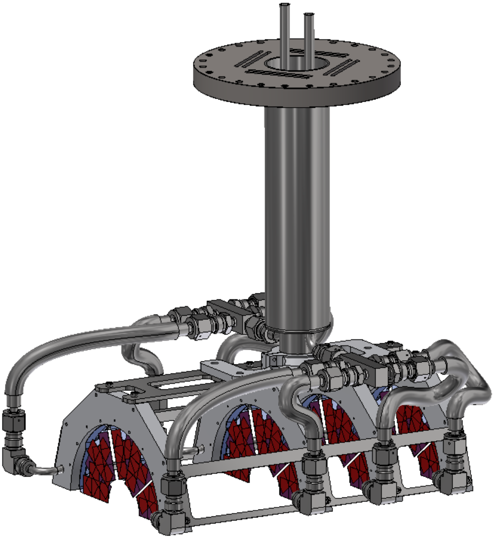


- Modules clamped in aluminium heatsink
- Aluminium heatsink actively cooled by integrated cooling pipe
- First electronics needed closeby ($\sim$10 cm)

$\Rightarrow$ PCB clamped to aluminium heatsink

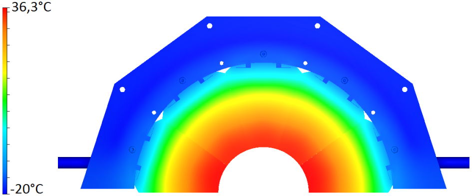
- Module placement staggered to avoid module collision

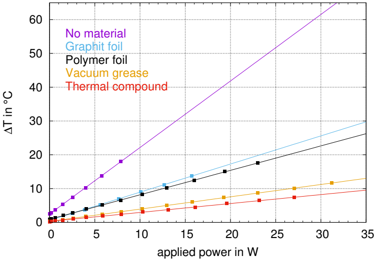
Half detector



- Four half planes connected to a half detector
- Common feedthrough for cooling lines
- Shape measured by stationary CMM $\rightarrow$ good knowledge of sensor position in half detector

Half Plane cooling



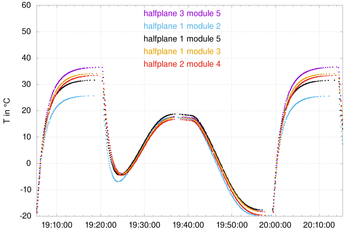


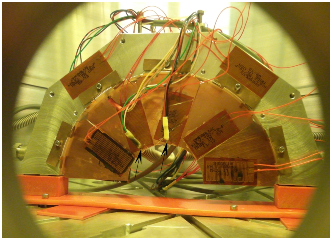
- Worst case assumption: 700 mW cm^{-2} heatload from sensors, resistive losses in cables, about 50 W per half plane from electronics

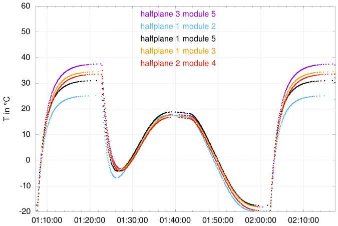
⇒ Large gradient on module: >50 °C, difference between modules <2 °C

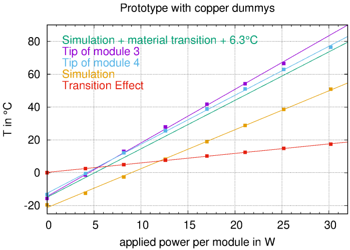
- Not included in simulation: transition effect between parts
- Contact materials measured, vacuum grease is preferred

Cooling tests









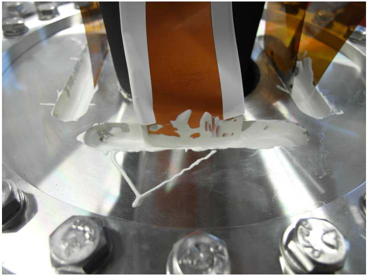
- Half plane consistent with simulation
- Long term test of half detector cooling: no aging after >1000 cycles

Concept of peripherie (feedthrough)

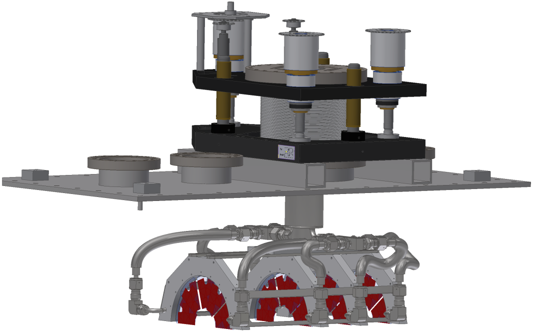
- $\sim$2000 traces per half detector, including up to 640 LVDS pairs

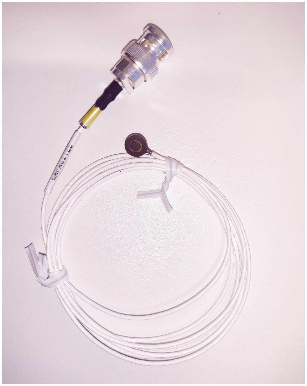
$\Rightarrow$ Glued in flexcables as high density option, first test promising

- Additional benefit in main feedthrough flange: no movement relative to the half detector
- LV feedthrough per half detector extra, high power ($\sim$200 A) needed



Movable detector: position problems and solutions

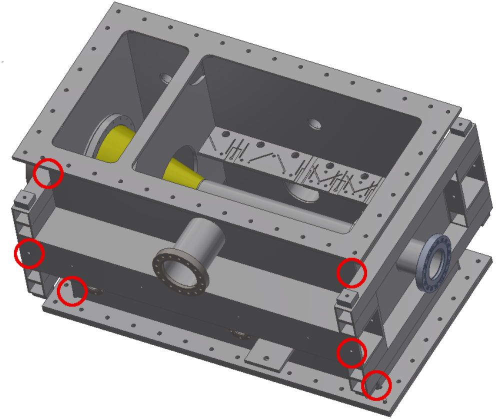




- Half detector mounted on LSM for movement
- Problem 1: position of half detector after movement?

$\Rightarrow$ Capacitive sensors in vacuum box measuring against half detector, resolution <2 μm

Movable detector: position problems and solutions 2

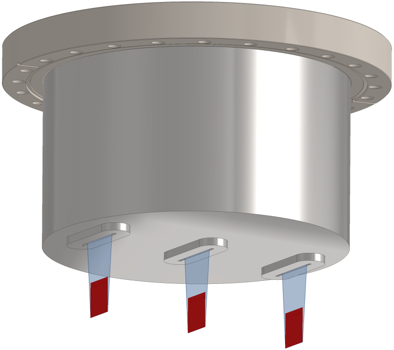


- Problem 2: Position of the capacitive sensors in the vacuum box?

⇒ Measurement of the sensor position relative to markers on the outside with a portable CMM (measurement arm), resolution <28 μm

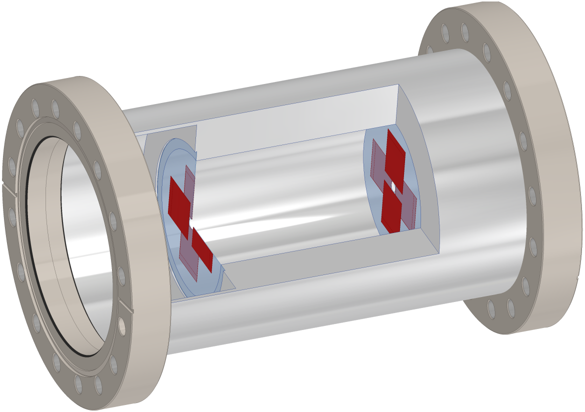
- Mechanical stability of vacuum box relevant!

Technology transfer to PRES: MicroLumi



- Based on CF200 flange, moveable by LSM
- Three modules with one sensor each, glued on diamond wafer
- Cable and diamond glued into custom flange ⇒ cooling and first electronics outside the vacuum ($\sim$10 cm distance to sensors)

Technology Transfer to PRES: Option B



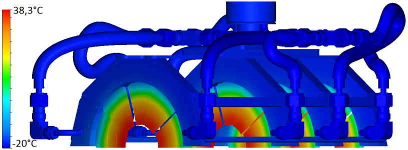
- Integrated in beampipe, no moveable parts
- Precise detector positioning and beam control needed
- Diamond wafer clamped into vacuum chamber, cooling from outside

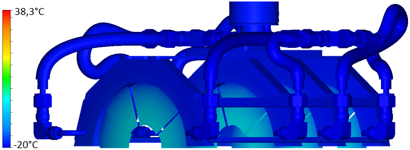
Backup

Heat loads and simulation

Expected heat dissipation per half detector:

	sensors	resistance in flexcables	LDO Voltage regulator	Multiplexer etc.
worst case	520 W	80 W	160 W	~50 W
likely case	190 W	10 W	60 W	~50 W





- simulated maximum temperature: 39 °C / 0 °C
- neglected in the simulations: material transitions, radiative effects
- additional temperature rise of 11 °C / 4 °C estimated from measurements