Tracking Detector for Luminosity Measurement at PANDA

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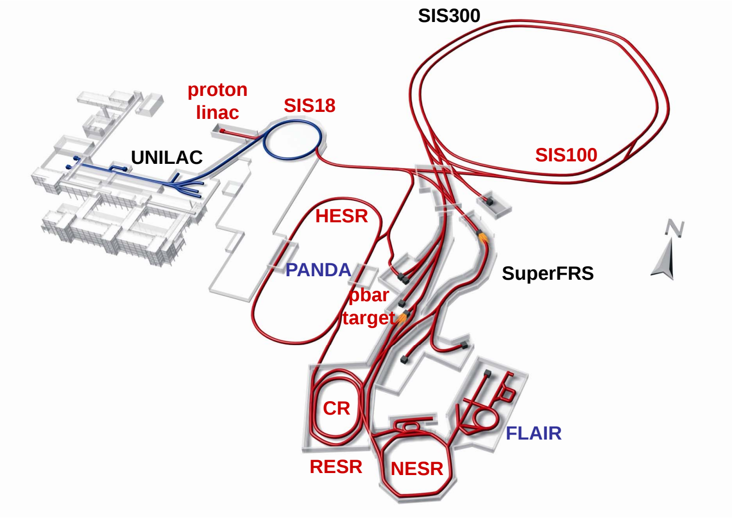
on behalf of the PANDA Luminosity Detector Group

Helmholtz-Institut Mainz
Johannes Gutenberg-Universität Mainz

February 28, 2017
Instrumentation for Colliding Beam Physics (INSTR-17)

FAIR - Facility for Antiproton and Ion Research



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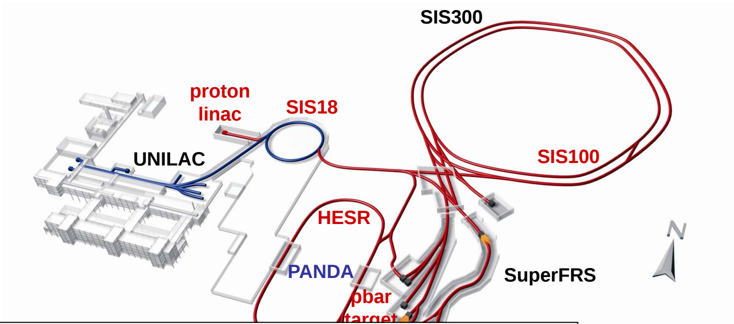
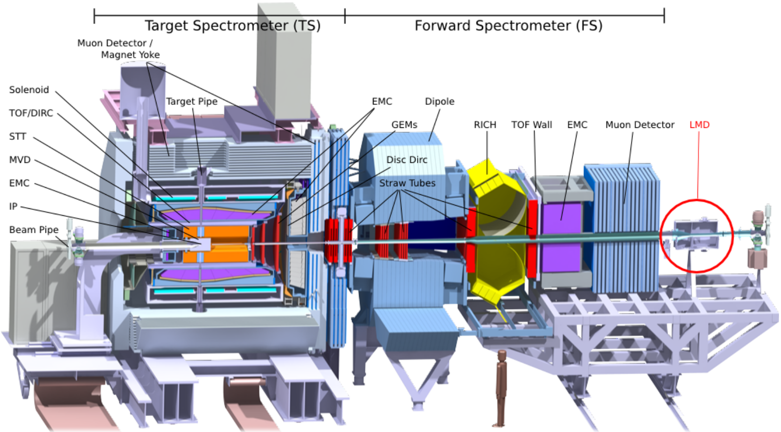


	High Luminosity	High Resolution
Antiproton p	$1.5 - 15\ GeV/c$	$1.5 - 8.9\ GeV/c$
N Antiprotons	10^{11}	10^{10}
Luminosity	$2 \cdot 10^{32}\ \text{cm}^{-2}\,\text{s}^{-1}$	$2 \cdot 10^{31}\ \text{cm}^{-2}\,\text{s}^{-1}$
$\Delta p/p$	10^{-4}	10^{-5}

PANDA

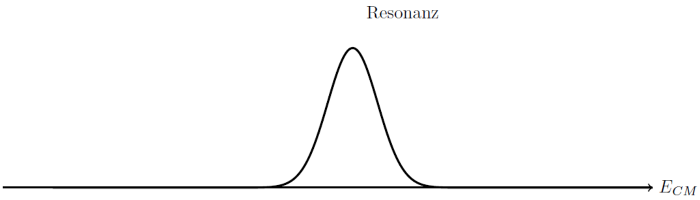


Physics at PANDA

- Hadron spectroscopy
- Hadron structure
- Hadron in medium
- Hypernuclear physics

PANDA Physics book: arXiv:0903.3905v1

Measurement of Line Shape via Energy Scan



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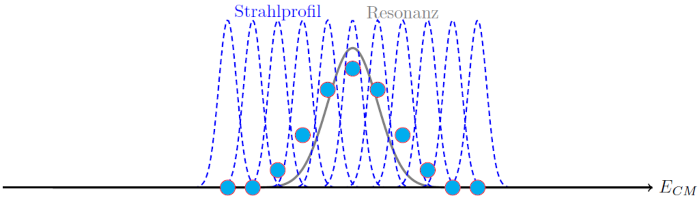

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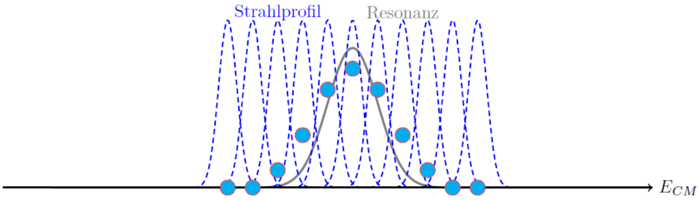

Normalization required:

$$\frac{\Delta N}{\Delta t} = \mathcal{L} \cdot \sigma$$

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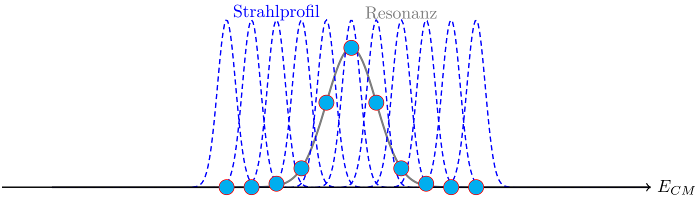

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Determination of Luminosity

$$\Rightarrow \mathcal{L} = \frac{\Delta N}{\Delta t} \cdot \frac{1}{\sigma}$$

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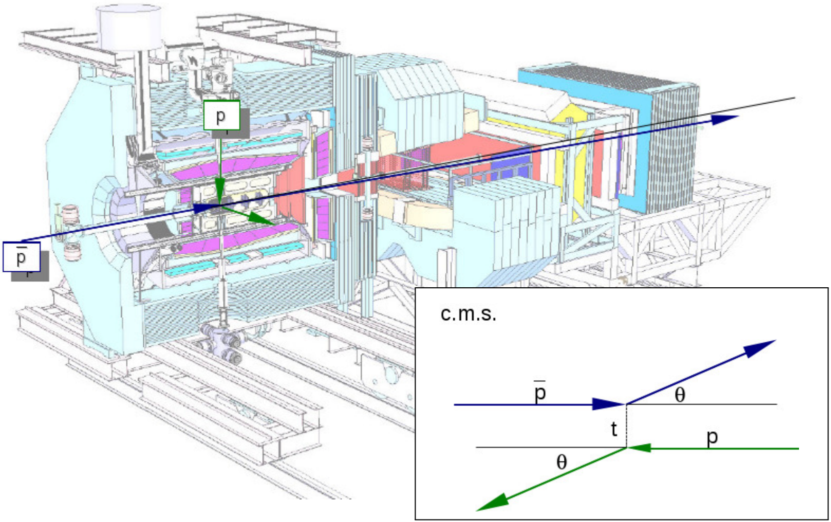
aimed resolution:	absolute	$\frac{\Delta \mathcal{L}}{\mathcal{L}} < 5\,\%$
	relative	$\frac{\Delta \mathcal{L}}{\mathcal{L}} < 1\,\%$

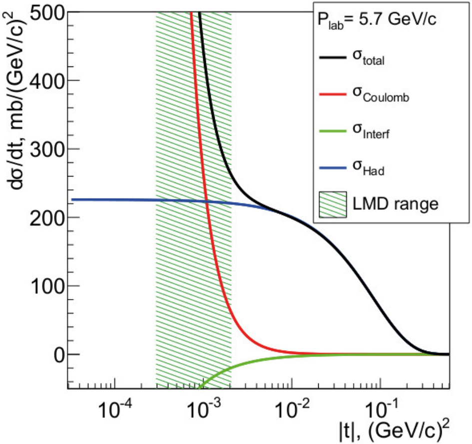
Elastic Scattering in PANDA



Measurement of elastic scattered antiprotons with $\Theta = 3\text{ - }8\,\mathrm{mrad}$

Elastic Scattering

PANDA: Measurement of elastic scattered antiprotons



At small |t|

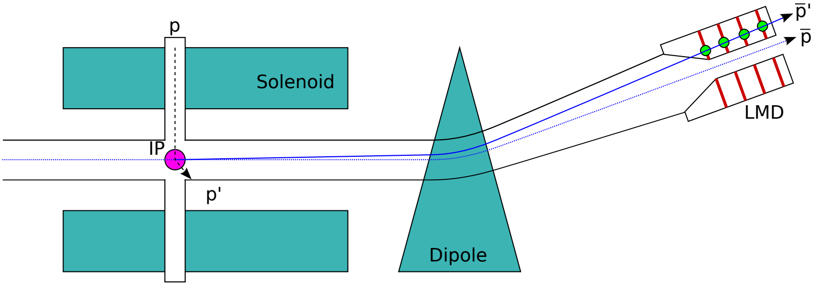
- Coulomb scattering dominates
- Differential cross section can be calculated

At larger |t|

- Hadronic part dominates
- Description by models using data
- Large uncertainties of the model

$$\frac{d\sigma_{el}}{dt} = \frac{d\sigma_{coul}}{dt} + \frac{d\sigma_{hadr}}{dt} + \frac{d\sigma_{int}}{dt}$$

Particle Track Reconstruction



Requirements for the Luminosity Detector

Requirements:

Luminosity Measurement

- Measurement at small angles
- High angular resolution
  - very precise
  - minimal material

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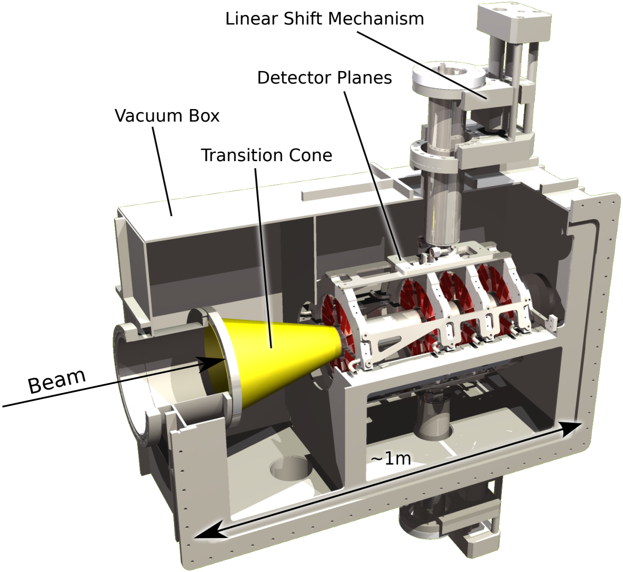
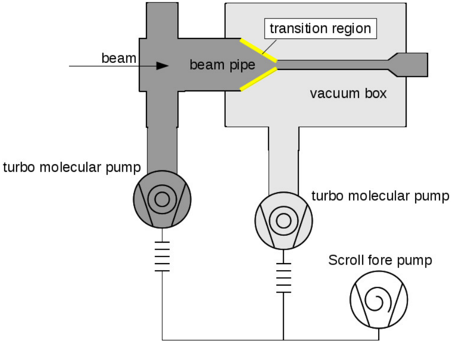
Storage Ring

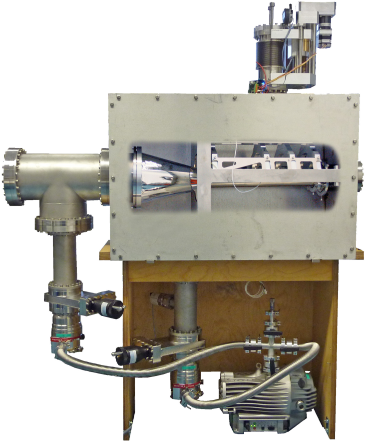
- High vacuum $< 10^{-9}$ mbar
- Slow changes of beam pipe diameter $< 15^\circ$
- Minimal distortion of the beam

Luminosity Detector Overview



Differential Pumping Scheme





Vacuum to reduce multiple scattering of antiprotons

⇒ Thin transition foil required to:

- Not disturb UHV of the beam pipe
- Not disturb the antiproton beam

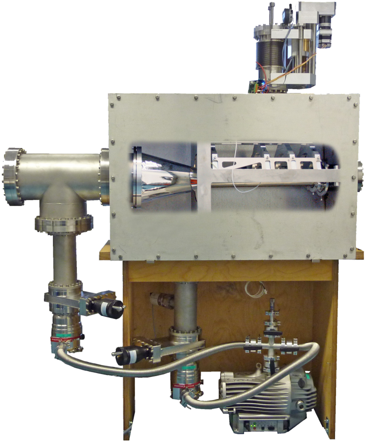
Differential Pumping Scheme

Requirements:

- Beam pipe: 10^{-9} mbar
- Vacuum box: 10^{-6} mbar

First test results:

- Beam pipe: $6{\cdot}10^{-8}$ mbar
- Vacuum box: $4{\cdot}10^{-7}$ mbar



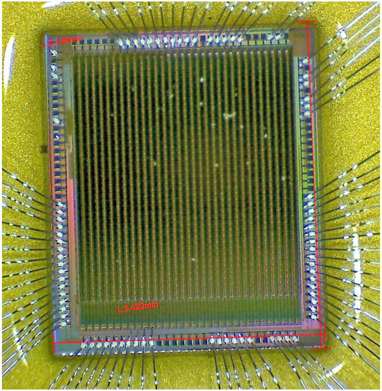
HV-MAPS

- High Volage Monolythic Active Pixel Sensor
- Under development (Mu3e group in Heidelberg)

  Status of the Mu3e detector: Dirk Wiedner 4:00 pm
- Standard CMOS production
- Digital part on chip
- High bias voltage increases S/N
- Pixel size: $80\,\mu\mathrm{m} \times 80\,\mu\mathrm{m}$
- Thikness: $\sim 50\,\mu\mathrm{m}$

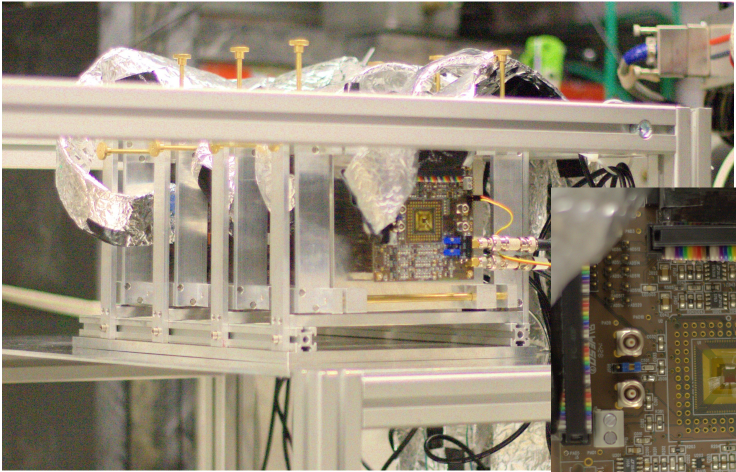
- Dimensions: $\sim 2 \times 2\,\mathrm{cm}^2$
- Expected power consumption $< 300\,\mathrm{mW/cm}^2$

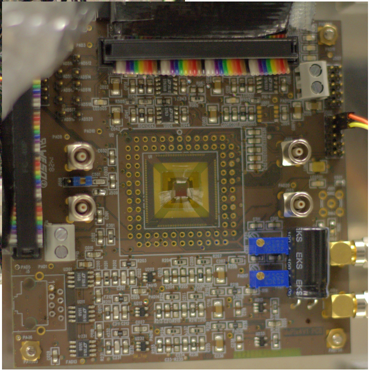
MuPix 4 prototype $3 \times 4\,\mathrm{mm}^2$



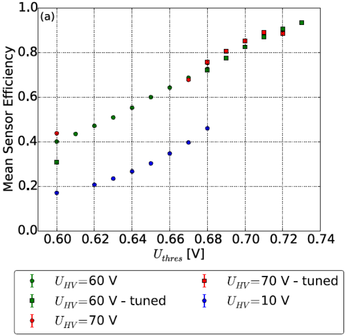
Test Beam at MAMI

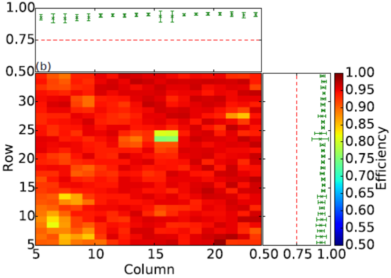
Test beam with a HV-MAPS (MuPix6) tracking station

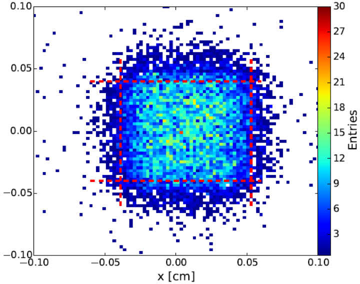




Results







- Efficiency: $> 99\,\%$
- Expected noise rate: 0.12 MHz per sensor $\Rightarrow \sim 1$ noise hit per timeframe
- Hit resolution given by pixel cell size
- Time resolution: 7 ns

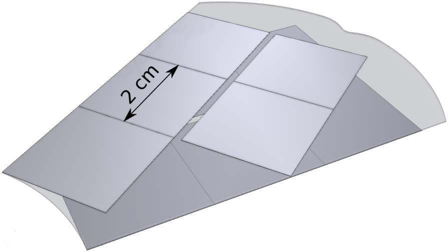
Arrangement of HV-MAPS

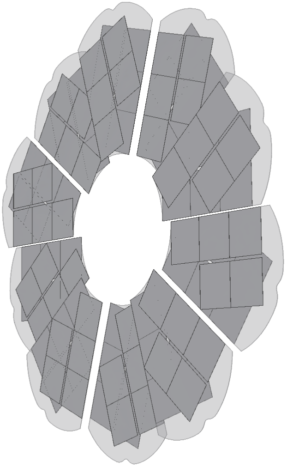
400 sensors (50 μm thick) glued on 40 CVD diamond wafers

- 4 planes with 10 modules
- Full azimuthal range

Advantages of CVD diamond:

- very high thermal conductivity
- very hard material
  $\Rightarrow$ very thin supply structure (200 μm)

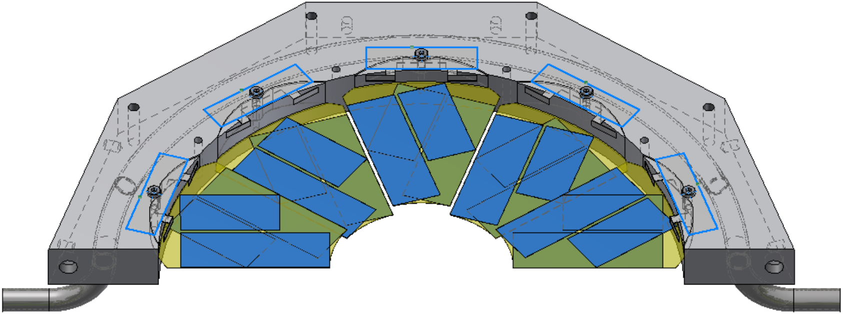




Support Structure

Modules clamped to a support structure

- V2A pipe melted inside aluminum structure
- Cooling of sensors and electronic



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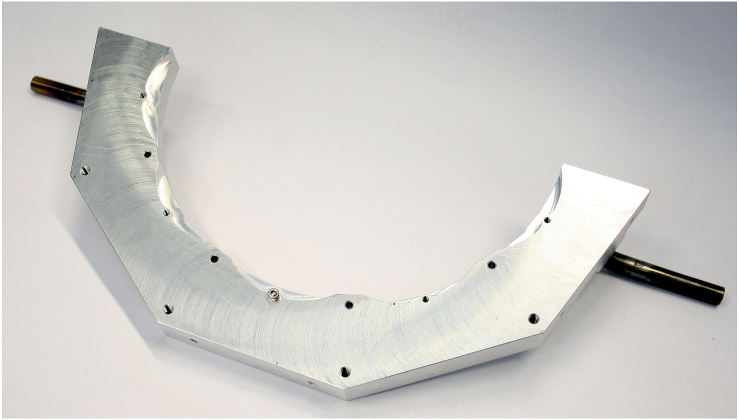
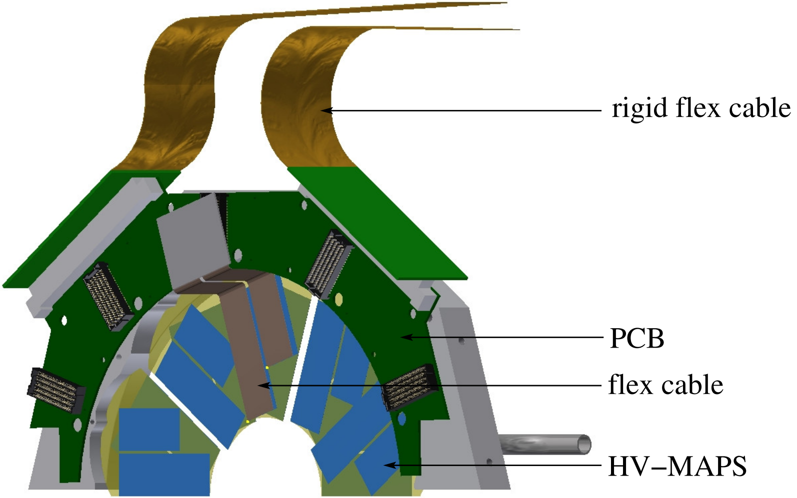
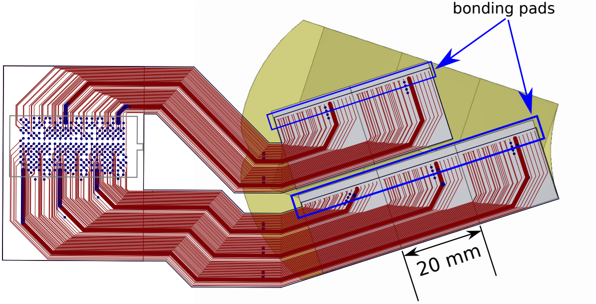


Signal Routing

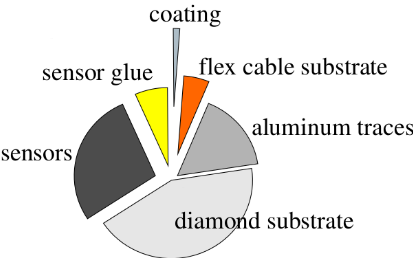


Connection of HV-MAPS



Average $X/X_0 = 0.32\,\%$
$\approx 350\,\mu$m silicon

With copper traces:
Average $X/X_0 = 0.55\,\%$



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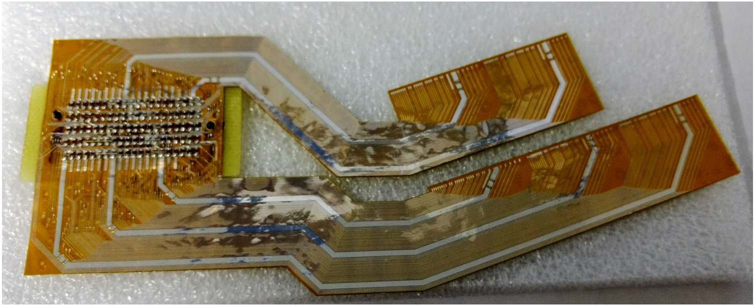

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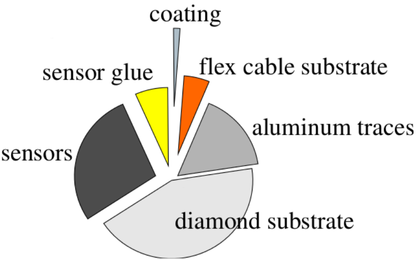
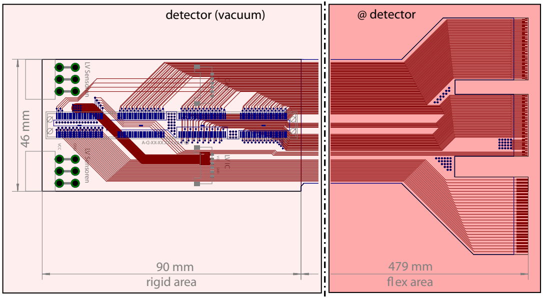
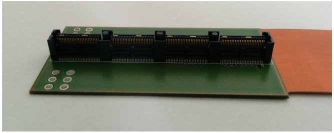
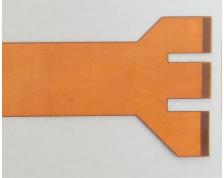


Rigid Flex Cable

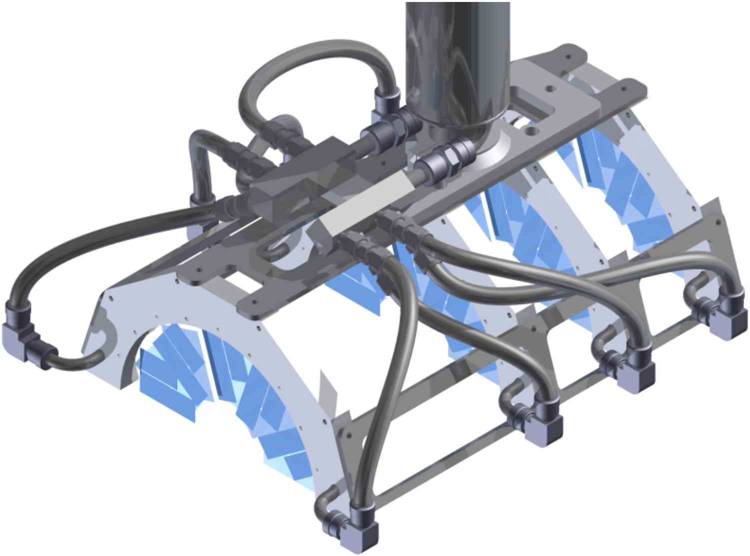


- FFC connector outside of the box
- Three layers for flex area:
  - 40 differential pairs (signal, clock, ...)
  - High voltage





Cooling

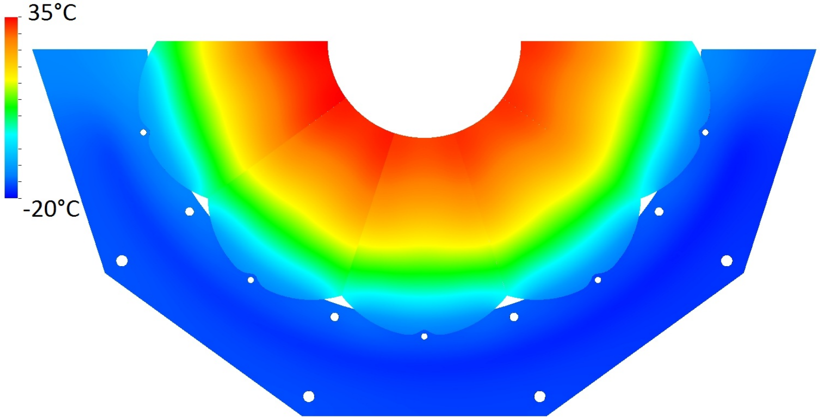


Simulations on Cooling

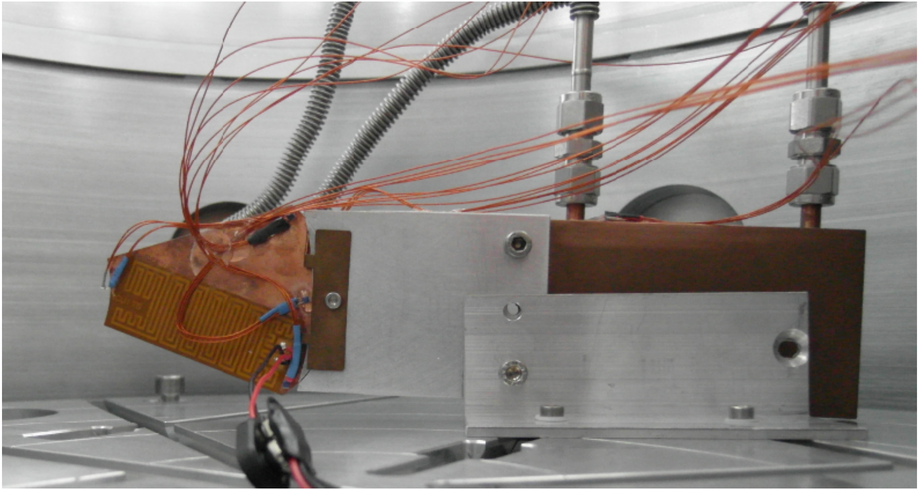
Simulation with up to 700 W/cm^2 and power dissipating electronics

Expected heat per half plane:

- Sensors: 140 W
- Electronics: 110 W

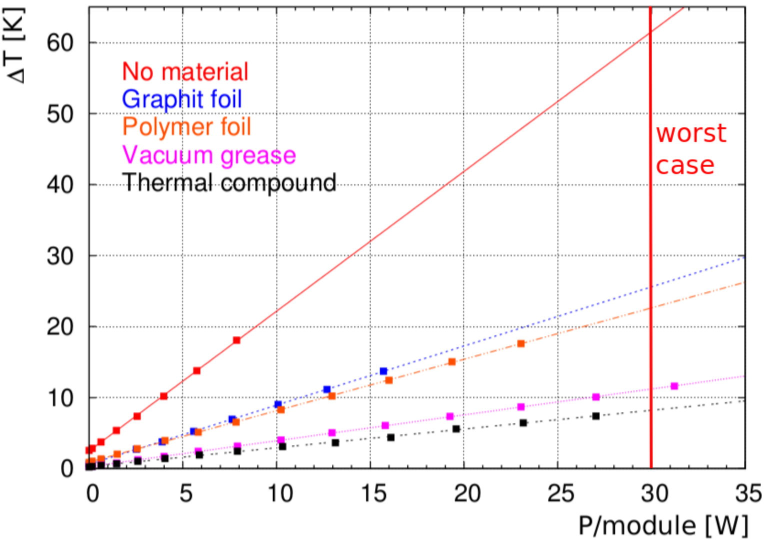


Contact Materials

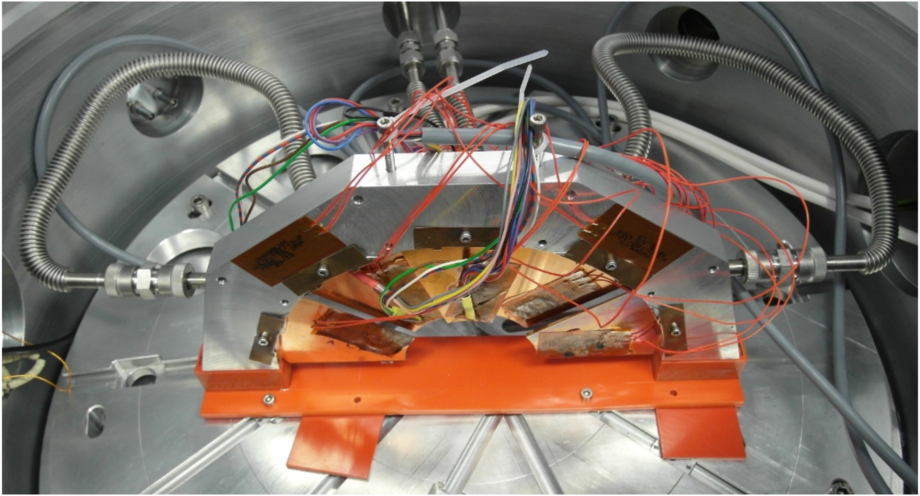


Testing of contact materials with a module clamp and a copper dummy

Contact Materials



Cooling Tests in Vacuum



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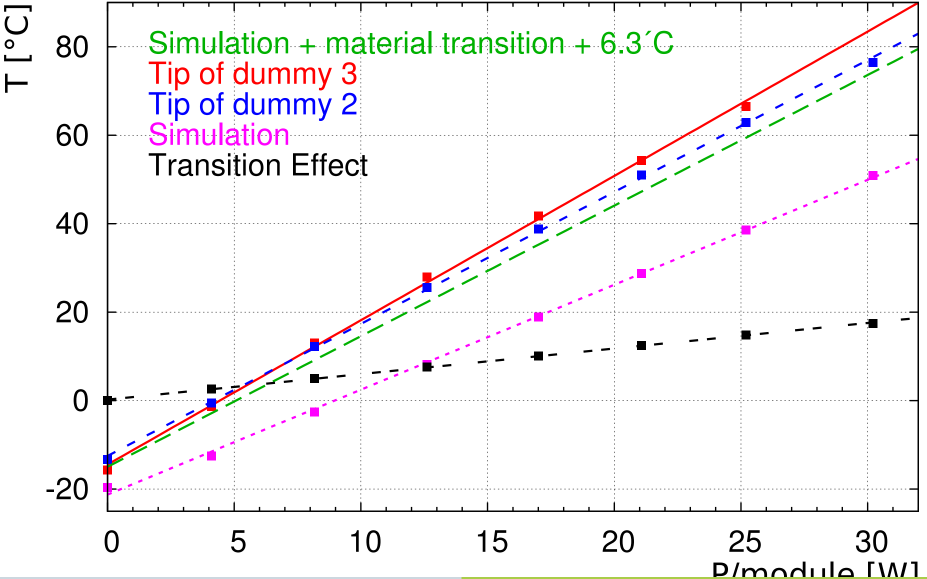

Software

Online

- Expected data rate: $> 5.5\,\mathrm{TB/d}$
  $\Rightarrow$ Online selection necessary
- Use of Cellular Automaton for track reconstruction
- Calculation on GPUs

Poster: Data acquisition for the PANDA luminosity detector with online track reconstruction: Stephan Maldaner 5:00 pm

Offline

- Use of Cellular Automaton and Track Follower for track reconstruction
  - Missed tracks $< 1\,\%$
  - Fake tracks $< 1\,\%$
- Precision for luminosity determination below % with realistic scenarios
- All beam influences can be corrected
  - IP distribution
  - IP displacement
  - Beam tilt
  - Beam divergence

Conclusion

- Design is ready
- Software completed
- TDR finished

To Do

Development of assembly procedure:

- Test of glueing of thin sensors
- Positioning of the sensors
- Mounting of the modules and half planes

Radiation test of all electronic components
Test of the flex cables
Test of full cooling circuit at full load
Online Software
Prototype is under the way