The $\overline{\text{P}}$ANDA Luminosity Detector

INSTR2020

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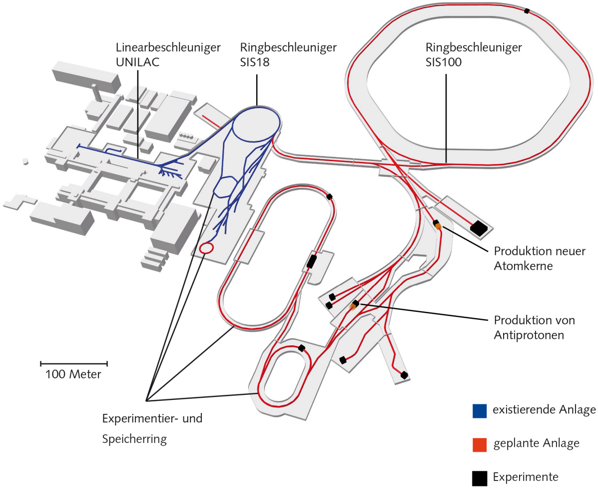
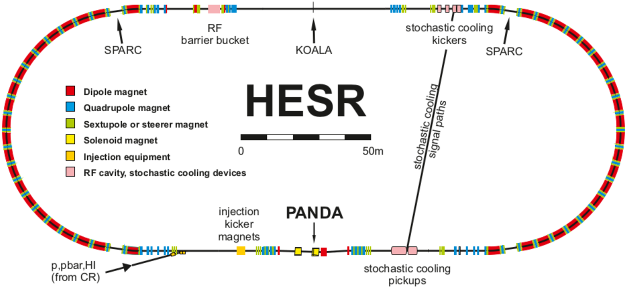
Ruhr-Universität Bochum - Experimentalphysik I AG

FAIR - Facility for Antiproton and Ion Research



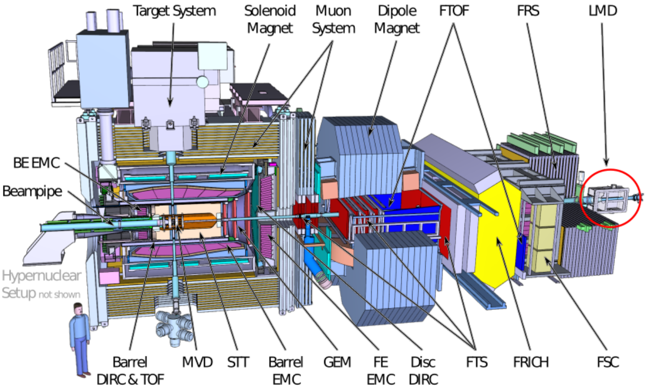
HESR - High Energy Storage Ring



$$p_{\bar{p}} = 1.5 - 15 \quad \mathrm{GeV}/c$$

	Phase 1	High Luminosity	High Resolution
$N_{\bar{p}}$	10^{10}	10^{11}	10^{10}
$\mathcal{L}$	$2 \cdot 10^{31}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$	$2 \cdot 10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$	$2 \cdot 10^{31}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
$\Delta p/p$	$5 \cdot 10^{-5}$	10^{-4}	$2 \cdot 10^{-5}$

The $\overline{\text{P}}$ANDA Detector



$\overline{\text{P}}$ANDA physics program:

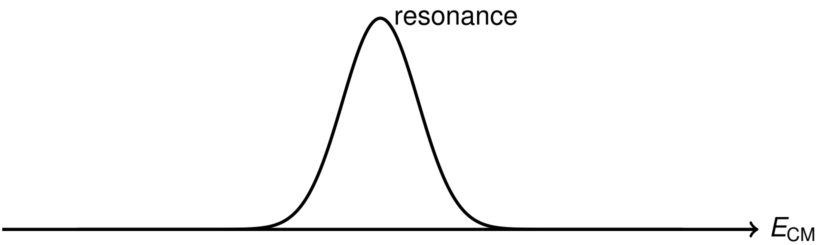
- Hadron spectroscopy
- Hadron structure
- Hadrons in medium
- Hypernuclear physics

Why we need the Luminosity Measurement

- Absolute time-integrated luminosity $\Rightarrow$ Absolute cross-section

$$N = \mathcal{L} \cdot \sigma$$

- Relative time-integrated luminosity $\Rightarrow$ Scan experiments



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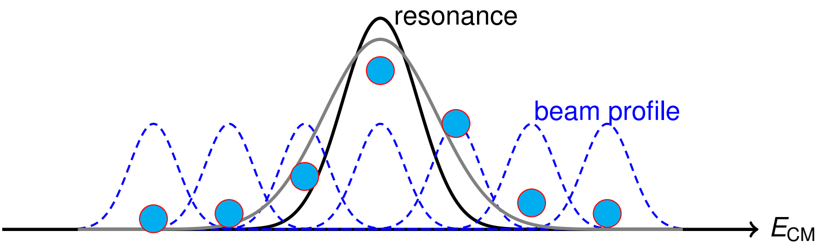

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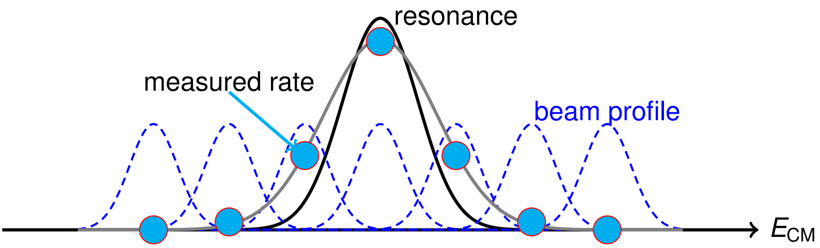


Determination of Luminosity

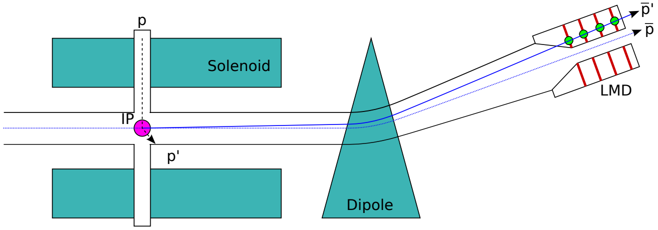
- Select process with known cross section σ and calculate luminosity $\mathcal{L}$ from number of events N:

$$\Rightarrow \mathcal{L} = \frac{N}{\sigma}$$

- We use elastic $\bar{p}p$ scattering

goal: absolute $\Delta\mathcal{L}/\mathcal{L} < 5\,\%$
relative $\Delta\mathcal{L}/\mathcal{L} < 1\,\%$

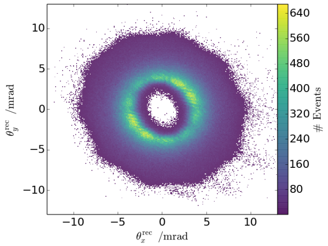
Particle Track Reconstruction



- Track reconstructed in Luminosity Detector

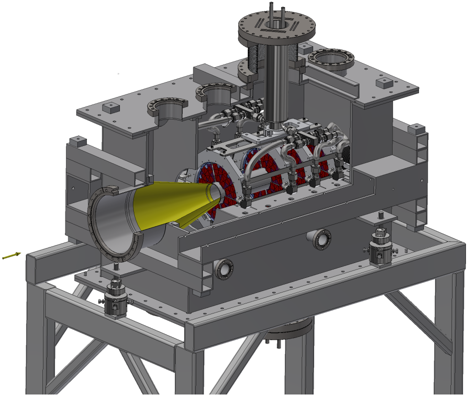
⇒ Backtracking through magnetic fields

- Angular distribution at IP
- Luminosity extraction via fit with correction of IP offset/distribution, beam tilt/divergence included



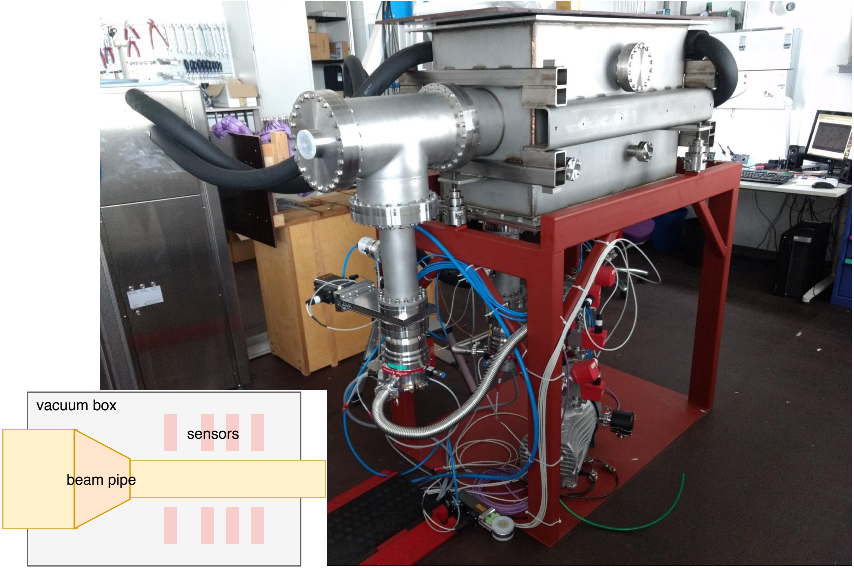
$\Rightarrow \Delta\mathcal{L}_{sys} < 1\%$

Luminosity Detector Overview



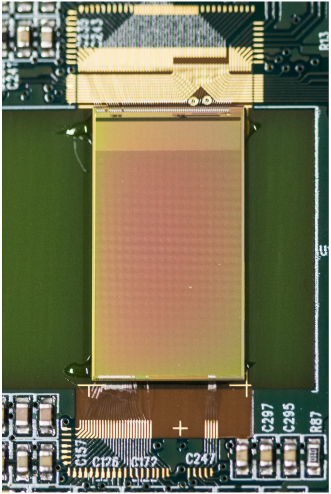
- Minimal track distortion by material ⇒ Measurement in vacuum
- Minimal distortion of the beam ⇒ Silicon pixel sensors

Prototype of the Vacuum Box



High Voltage Monolithic Active Pixel Sensors (HV-MAPS)

MuPix8 prototype $\sim 11 \times 20\,\mathrm{mm}^2$



Under development (Mu3e group in KIT and HD)
Final chip:

- Dimensions $20 \times 23\,\mathrm{mm}^2$
- Pixel size $80\,\mu\mathrm{m} \times 80\,\mu\mathrm{m}$
- Thickness $50\,\mu\mathrm{m}$ $(X/X_0 = 0.05\,\%)$
- Digital part on chip ($\sim 3\,\mathrm{mm}$
- Data send via LVDS links

Arrangement of HV-MAPS

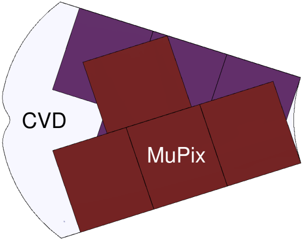
320 sensors glued on CVD diamond wafers

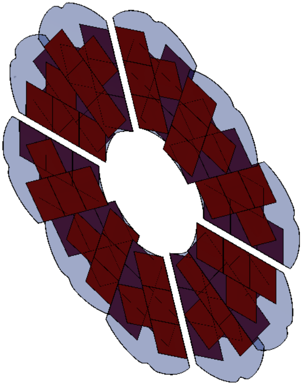
- 4 planes with 10 sensor modules
- Full azimuthal range

Advantages of CVD diamond:

- high thermal conductivity
- hard material

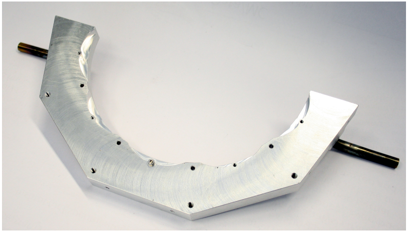
⇒ thin structure (200 µm)

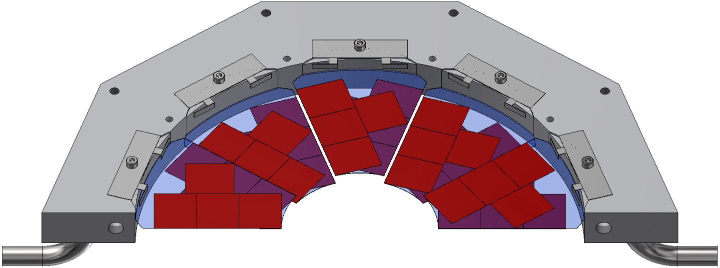




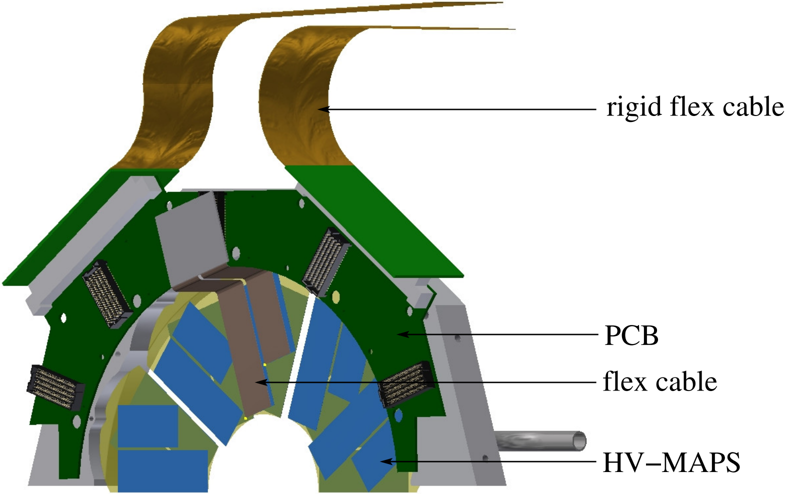
Support & Cooling Structure

Modules clamped to support structure made of stainless steel pipe melted inside aluminium structure
C.f. poster “Mechanics and Cooling for the PANDA Luminosity Detector” by H. Leithoff

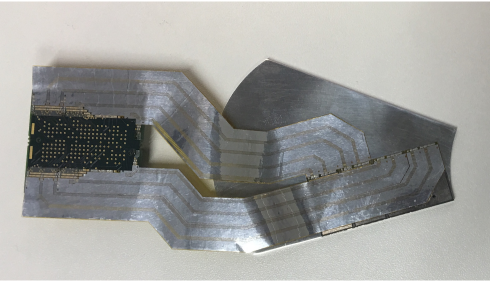




Signal Routing



Alu-Flex Cables

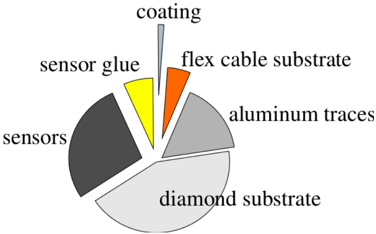


- Aluminium traces have higher radiation length compared to copper

⇒ less multiple scattering

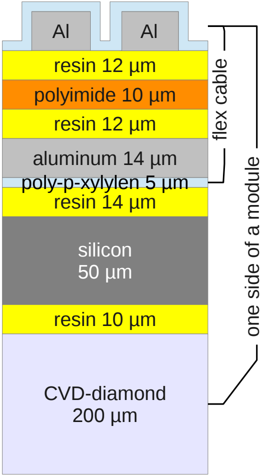
- 4 sensors bonded to one cable
- 8 differential, 10 single-ended signals per sensor
- Testing station for cables ready

Material Budget

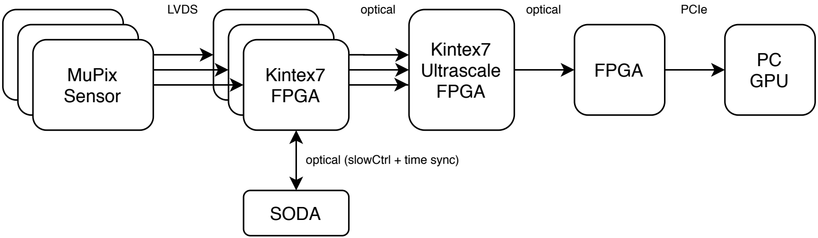


Average material budget per complete sensor module:
$X/X_0 = 0.32\,\%$ ($\sim$ 320 µm silicon)

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



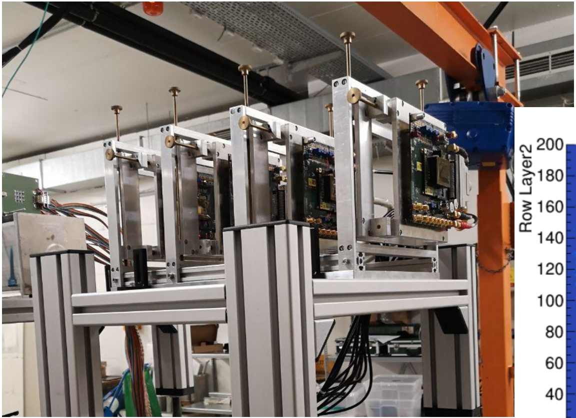
Data Aquisition

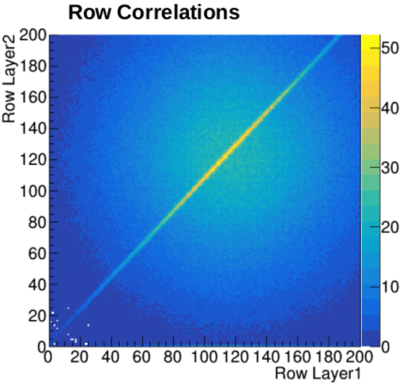


- Data stream from MuPiX via LVDS links
- 8 sensors per Kintex7
- Merging of Kintex7 data streams
- Data stream to PC via PCIe
- Nvidia GTX 1060 for track reconstruction (CUDA)

Test Beams at COSY

Test beam with HV-MAPS (MuPix8) tracking station





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Outlook

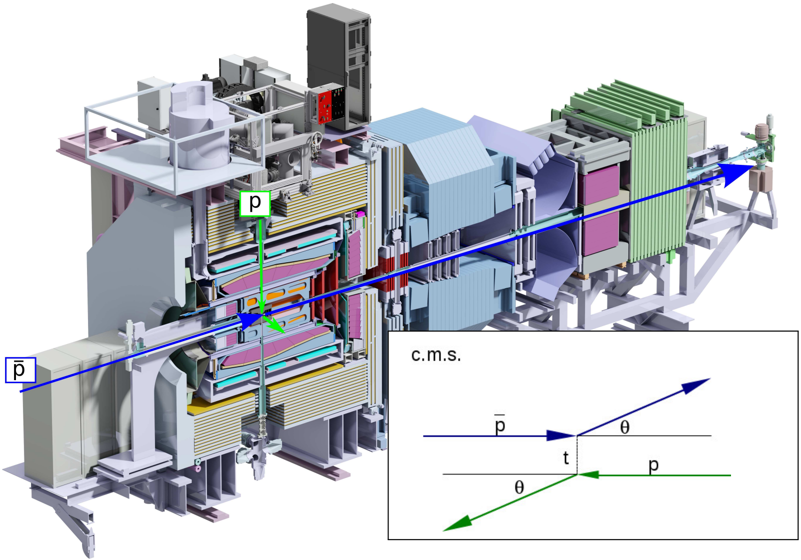
Not shown here:

- Detector Control System ready
- Offline Software implemented and tested

Ongoing Topics:

- New DAQ based on Kintex7 FPGA under development
- Prototype ready end of year
- Automatization of Linear Shift Mechanism
- Online trigger system
- Development of assembly procedure
- Software alignment of the sensors

Elastic Antiproton Proton Scattering



LMD Offline Software

Simulation: (complete)

- Simulation (detailed geometry + GEANT4)
- Digitization

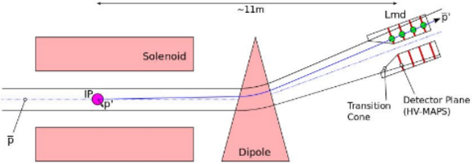
Track Reconstruction: (complete)

- Hit reconstruction (+ Hit merging)
- Track finding (using CA or track following)
- Track fitting (broken line fit)
- Backpropagation to IP
- Track Filtering (background < 2%)

Alignment: (ongoing)

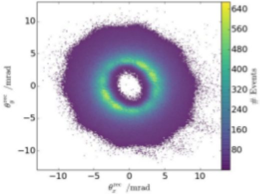
- Alignment of complete detector hierarchy
- Using Millipede & ICP algorithms

(within Pandaroot)



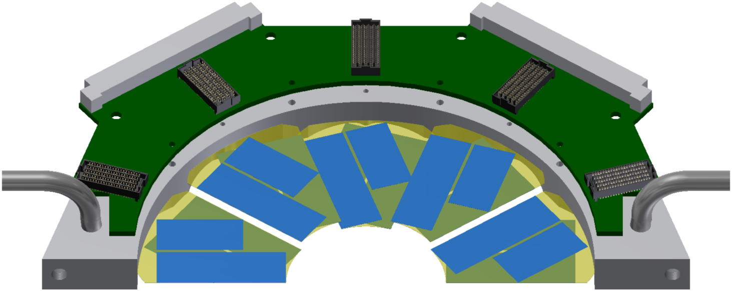
Luminosity Determination (LumiFit): (complete)

- Uses binned 2D angular track info at IP
- Modifies elastic scattering cross section
  - Coordinate transformations
  - Reconstruction efficiency
  - Detector resolution
- Additionally applies corrections:
  - IP offset & distribution
  - p-beam tilt (w.r.t z-axis) & divergence



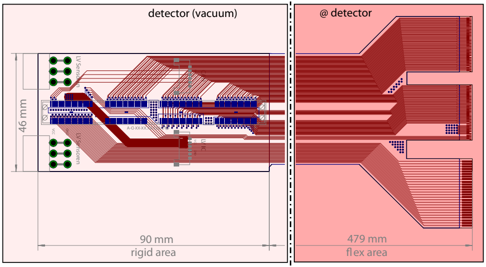
⇒ ΔL systematic uncertainty ~ 1%

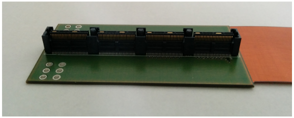
Supply Board

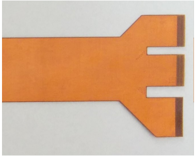


- PCB on both sides of the half plane
- Voltage regulators to supply MuPix
- LVDS Repeater to send signals out
- Power dissipating components attached to surface of heatsink
- Radiation tests with electronic parts were performed at COSY

Rigid Flex Cable

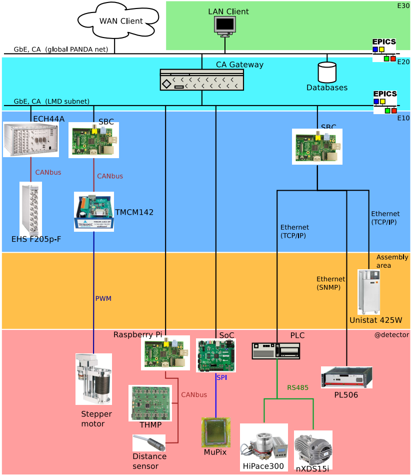






- Four cables per half plane
- Glued into vacuum feedthrough
- FFC connector outside of the box
- Three layer for flex area
  - 40 differential pairs (signal, clock,...)
  - High voltage

Detector Control System (DCS)



DCS based on EPICS

- IOC running on Single Board Computers (SBC)
- Different interfaces used (CAN, RS232, RS485, Ethernet)
- Structure in Lab already according to PANDA scheme

What is ready:

- HV / LV
- Pumps, Pressure sensors, Valves
- Chiller

What is missing:

- PLC for vacuum system (equipment safety)
- Distance sensors
- Motor control

Differential Pumping Scheme

- Thin transition foil

⇒ Vacuum in Box required

- Differential pumping to avoid large pressure differences
- Requirement
  - Beam pipe: $1 \cdot 10^{-9}$ mbar
  - Vacuum box: $1 \cdot 10^{-6}$ mbar
- First test results
  - Beam pipe: $6 \cdot 10^{-8}$ mbar
  - Vacuum box: $4 \cdot 10^{-7}$ mbar
  - Only turbo pumps