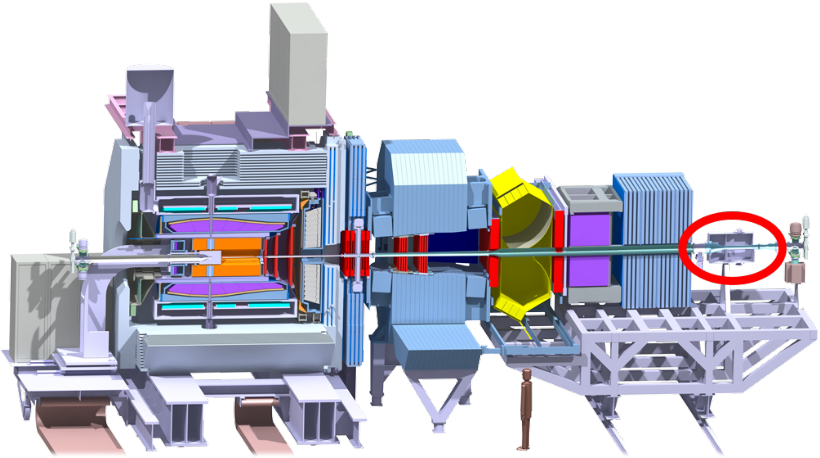
Survey and Alignment of the $\overline{\text{P}}$ANDA-Luminosity Detector

Roman Klasen
on behalf of the Luminosity Detector Group

Helmholtz-Institut Mainz
Johannes Gutenberg-Universität Mainz

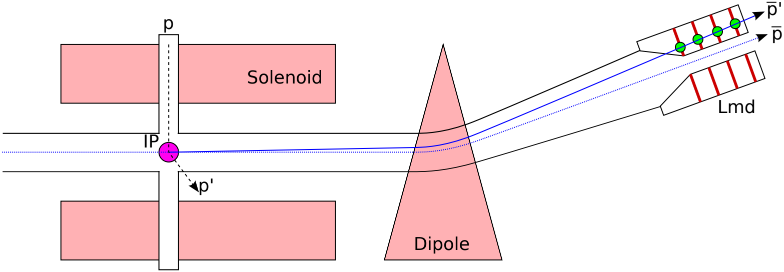
$\overline{\text{P}}$ANDA Collaboration Meeting
March 17, 2015

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



tracking detector for elastically scattered antiprotons from 3 - 8 mrad

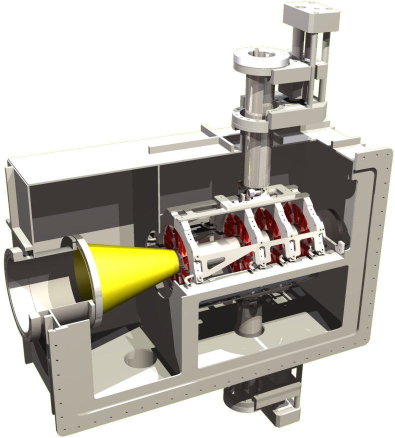
Tracking Detector



reconstruct elastically scattered antiproton tracks from interaction point

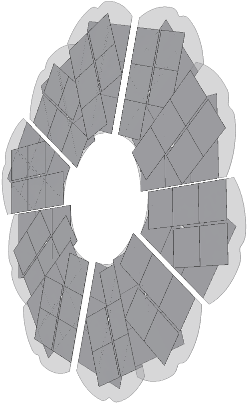
$\overline{\text{P}}$ANDA Luminosity Detector

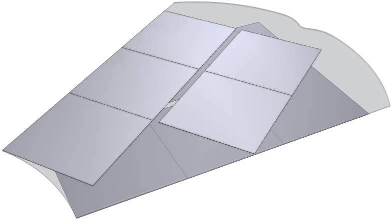
- 4 planes in line
- 10 modules on each plane
- 10 sensors on each module
- 400 pixel sensors in total



Single Plane, 10 Modules

- 10 modules, 36° angle between sensors
- High Voltage Monolythic Active Pixel Sensor
- silicon semiconductor detector, improvement of MAPS
- sensor size: 2 cm × 2 cm
- pixel size: 80 µm × 80 µm
- total module thickness: 250 µm





survey vs. hardware alignment vs. software alignment

survey

determine the positions of components in some reference frame, provide info to experiments

hardware alignment

change actual position of component with data from survey (e.g. magnets must be placed correctly)

software alignment

try to find actual position (not change it) by software and correct with appropriate correction matrices

Reconstructed Scattering Angle

reconstructed θ of scattered particle beam is most important for Lumi reconstruction

but:

- sensor position is invisible from outside!
- only outer shell of box is accessible for survey
- total uncertainty is total of external survey uncertainty and internal fiducialisation

Fiducialisation

Fiducialisation: Coordinate Measuring Machines

task: measure fiducials on device wrt sensors, magnetic axes etc.

use coordinate measuring machine (CMM)

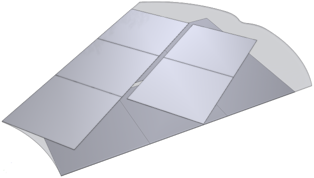
- Bridge-Type (typical accuracy of 10 - 100 µm)
- Arm-Type, portable (typical accuracy of ≈80 µm)

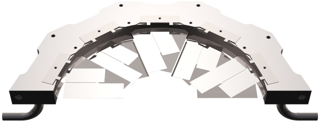
CMM in all sizes

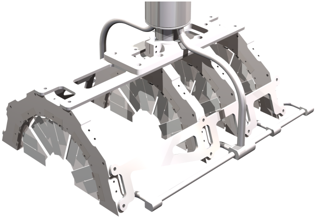
CMM

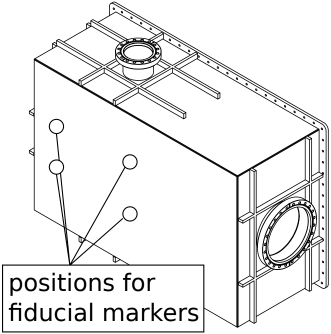
- (mostly) stationary
- measure parts (optically, haptically, capacitive)
- manual or fully automated (routine factory inspection)
- work area varies from (0.5m x 0.5m x 0.5m) to (6mx4x10m)
- high accuracy, scales with distance
- accuracy: $\approx$30 µm

Measuring sub-steps





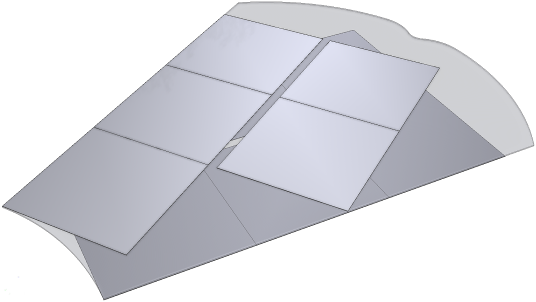




Measurement Path

sensor position on CVD diamond

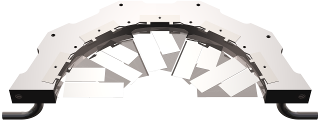
inter-sensor position easily accessible wrt reference sensor
position of reference sensor wrt diamond determined by microscope
Expected accuracy: $\approx$30 µm

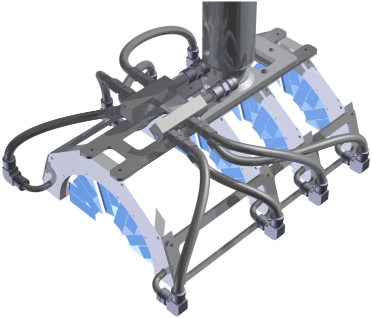


Measurement Path

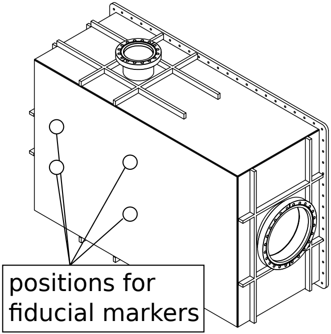
CVD diamond position in cooling support, cooling supports in lumi box

can be determined by CMM and attach capacitive probe to half plane, determine probe position wrt sensor/CVD position via CMM
Expected accuracy: $\approx$30 µm





Measurement Path



- good line of sight
- attached from both sides (higher confidence)
- not too close together (lever arm should be large)
- simple correlation between SMR and sensors
- Expected accuracy: $\approx$50 µm

but: one side of Lumi is detachable, SMR nests on moving or detachable surface not advised!

Measurement Path

Where is the box inside the experiment hall?

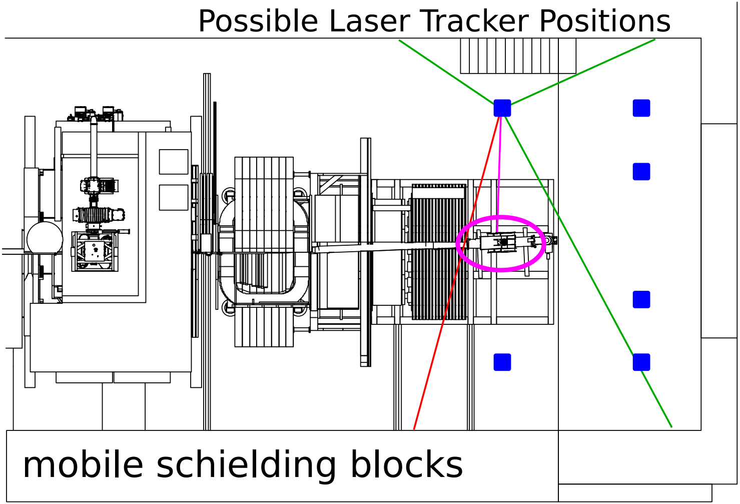
Survey Task

Determine box position wrt other components and walls.
Expected accuracy: $\approx$30 µm

errors are not correlated

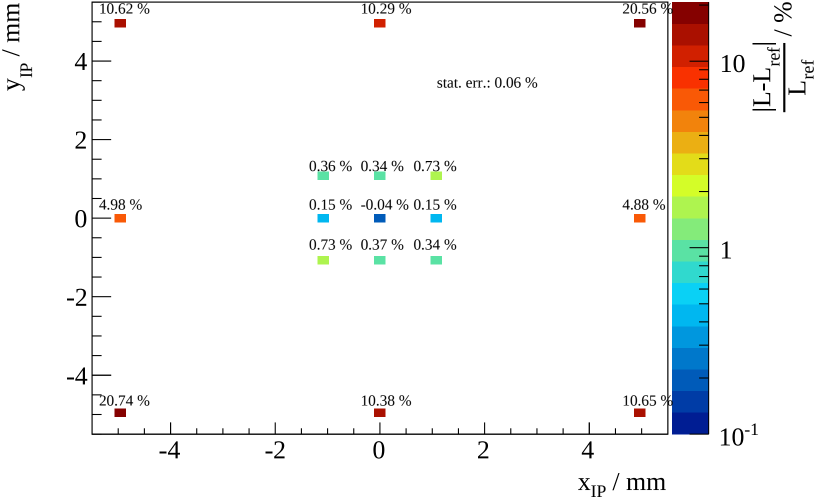
we expect to know sensor position below 100 µm error!

Example Positions for Survey of Lumi Box



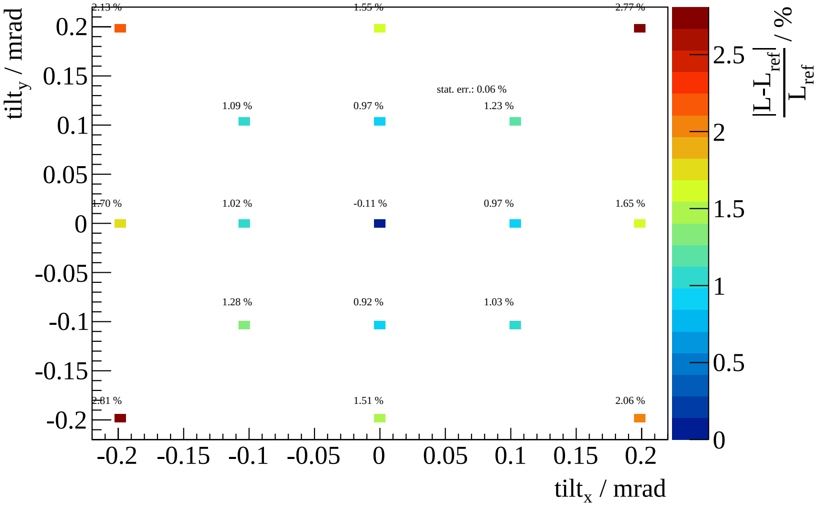
4 - 6 Targets per side, visible from multiple positions

Worst Case scenario - unknown relative shift



- simple shift is uncritical

Worst Case scenario - unknown relative tilt



- tilt much more severe, 1 mrad tilt ⇒ 70 % uncertainty survey procedure

GSI Survey Team

We can not do survey by ourselfs:
For everything survey-related:

head of survey team:

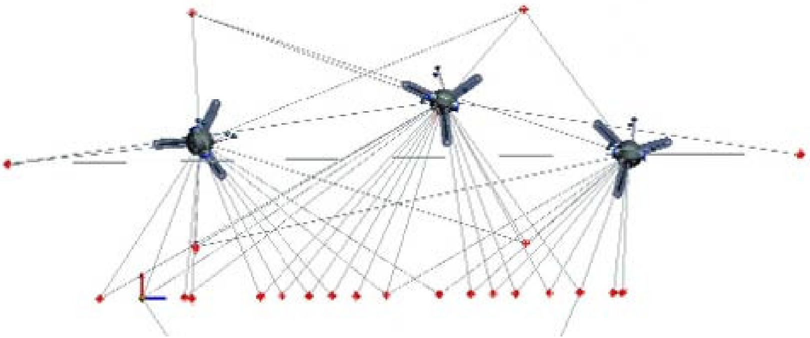
Ina Pschorn, `I.Pschorn@gsi.de`

I talked to GSI survey team: they are only four people. They will plan and supervise $\Rightarrow$ external companies will measure

Establish Reference Grid

install and measure fiducials

- establish and measure reference grid (technology-independent)
- get set of 3D points in space (marker positions)



Result: Position of Fiducials wrt each other

survey result

- set of 3D Points available
- $\Rightarrow$ Position of every component wrt to other components known
- hardware alignment can be done parallel to survey

Tools of Trade

in earlier days

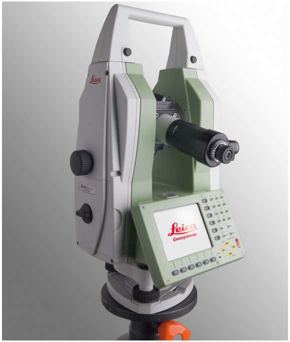
- Theodolites (manual or automatic)
- Total Stations (automatic theodolites with distance measurement)

disadvantage: cumbersome

current de-facto standard

- laser trackers
- Coordinate Measurement Machines (CMM) for fiducialisation

automatic, fast, precise ≈30 µm
disadvantage: expensive



Laser Tracker

laser tracker

- portable and light
- measure SMRs on components, walls etc.
- useful for range < 40 m (80 m version available)
- human SMR interaction necessary
- accuracy: ≈30 µm

- operating range: 40 m radius sphere[1]
- price: ≈ 75.000 Euros

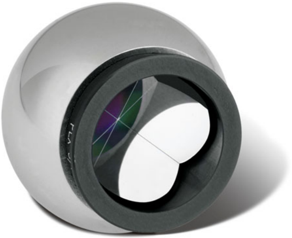
[1] http://www.leica-geosystems.com/

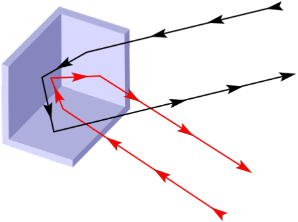
Theodolites vs. Laser Trackers

theodolite survey	laser tracker survey
▶ measure angles only between multiple targets, no distance info ▶ manual or automated ▶ target: printed, etched or scratched metal with cross or dot ▶ obtain position via triangulation (automated via software) ▶ accuracy: $\approx$100 µm	▶ measure absolute shperical coordinates (in tracker system) ▶ automated, just move target to position ▶ target: high precision retro reflecting corner cube mirror in steel ball ▶ transform to cartesian in real time ▶ accuracy: $\approx$30 µm

analysis done by software:
both deliver 3D Points, but laser trackers are faster and more precise

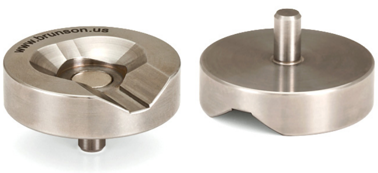
Spherically Mounted (Retro-)Reflectors (SMRs)

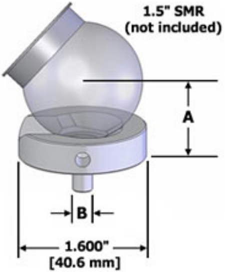




- milled to very high-precision (15 µm shape, 3 µm center)
- price: ≈ 1500 Euros/ Sphere

SMR Nests





- can be installed on detectors, magnets, walls, floors...
- sphere is held by magnet, high repeatability
- precision: ≈5 µm shank diameter, ≈15 µm centering, ≈15 µm offset [2]
- price: ≈ 150 Euros or self-made (datasheet available)

[2] http://www.brunson.us/

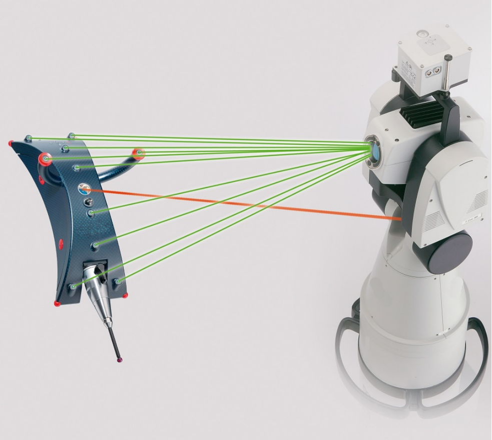
Part inspection by Laser Tracker

laser trackers used on small number part inspection with SMR [3]

[3] http://www.evektoraircraft.com/

Part inspection by Laser Tracker and hand held probe

hand-held measuring for secluded areas [4]



- "needles" available in multiple lengths
- typical accuracy: 100 µm

[4] http://www.de.nms-int.com/

We need to plan our Lumi Box accordingly

actual survey will be done by GSI survey team and external contractors. their equipment must 'see' SMRs in walls *and* in Lumi Box simultaneously (and from multiple positions)

we need to

- attach **at least** 3 fiducials (plan to use 6)
- leave room to place laser trackers
- attach fiducials on our Box visible from multiple points
- leave lines of sight to SMRs (in walls and our Lumi Box) unobstructed

cooperation with survey team is necessary

no moving SMRs

- survey team has to measure 1000s of SMRs
- every exception means more work for them

Cost

Who performs the survey? What does it cost?

at GSI, a dedicated team of four survey engineers plans and oversees survey of accelerator and detector components

however

multiple external contractors will perform the actual survey!

we need to coordinate our plans with the survey team

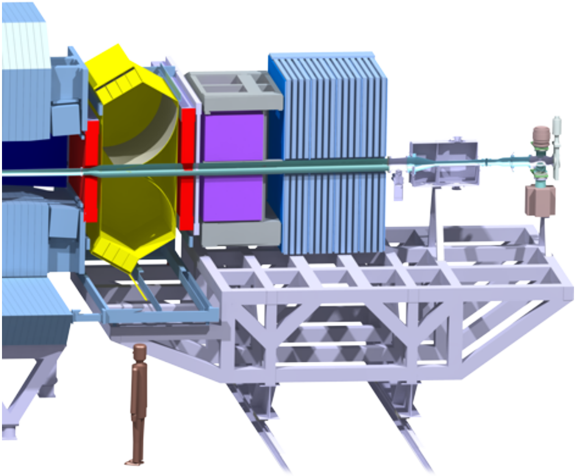
head of survey team:

Ina Pschorn, `I.Pschorn@gsi.de`

- still in planning phase $\rightarrow$ no reliable cost estimate available

Cost example

- one survey engineer costs $\approx 150 \frac{\text{Euros}}{\text{hour}}$
- survey of movable detector array alone $\approx$ 1000 Euros



Thank you for your Attention!