Software Alignment @ LMD

Accurate Luminosity Extraction with misaligned Detectors

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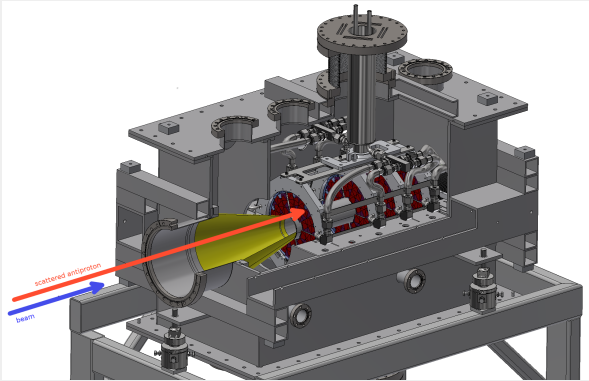
Luminosity Extraction @ PANDA

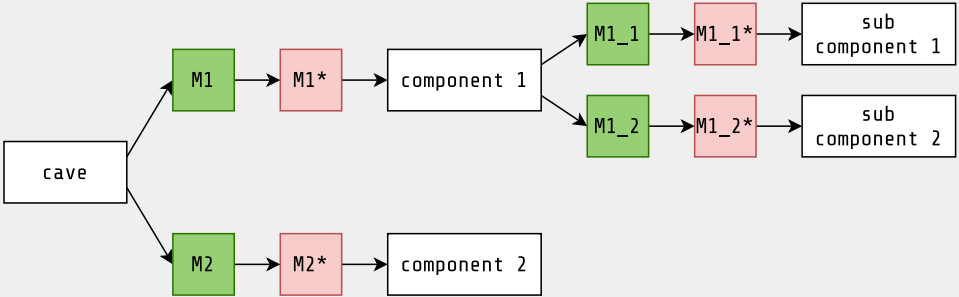
- Reconstruct angular distribution of elastic part of $\bar{p}p$ scattering
- Very small angles $\rightarrow$ Far away from IP
- Large lever Arm
- Sensitive to misalignment

Luminosity Detector:

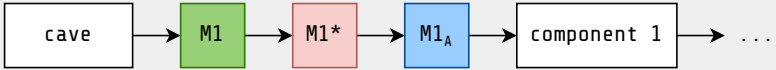
- Pixel-Sensor Tracking Detector
- Four Layers
- 320 individual sensors
- Very precise track reconstruction



Where is misalignment added?

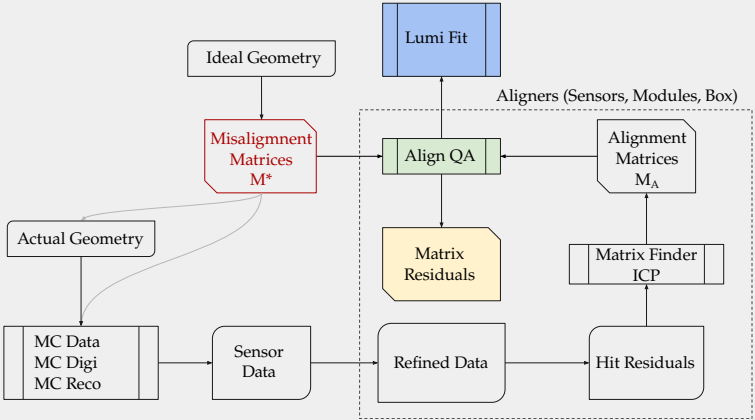


And alignment?



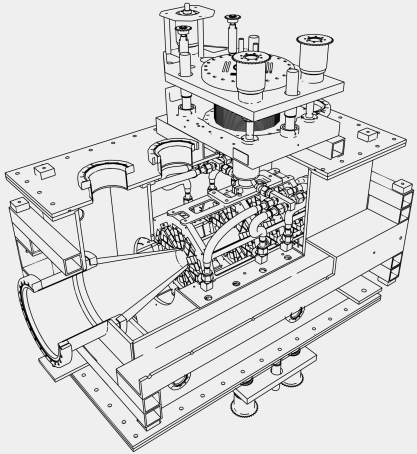
Alignment and QA Process

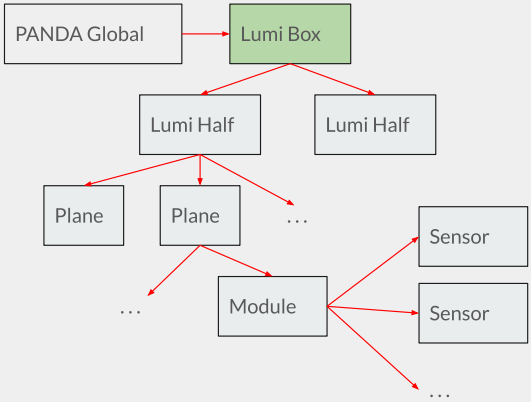
- Misplace Sensors, Modules, Box
- Determine luminosity
- Perform Software Alignment
- Compare calculated and actual misalignment
- Determine luminosity (aligned)



Only luminosity results will be shown, not misalignment matrix differences.

LMD Component Hierarchy



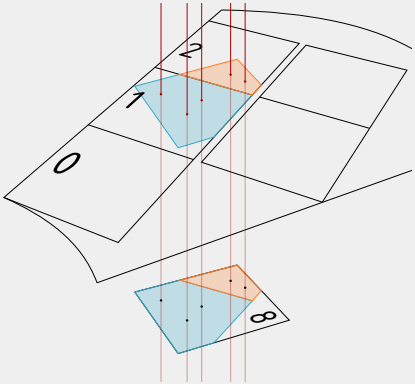


Sensors, Modules and Box can be aligned independently!

Sensor Alignment

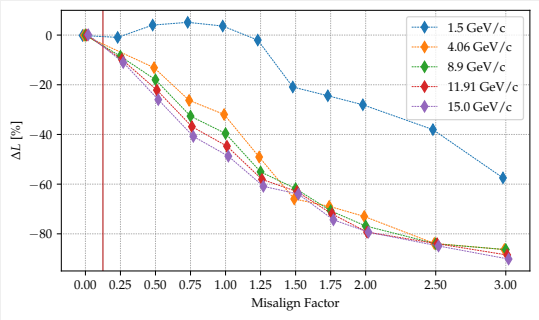
320 individual Sensors, all may be misaligned

- Use Overlapping Areas of Sensors to determine relative position
- ICP used for alignment
- Concatenate multiple Areas to get all Positions w.r.t. one Sensor
- Remaining sensor must be measured with CMM

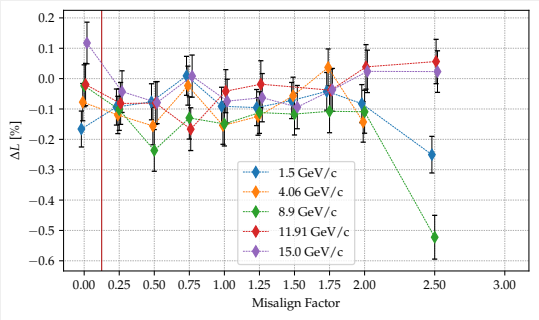


Now, Sensors positions w.r.t. CVD wafer are known.

Track cuts work differently @ 1.5 GeV,
but overall Luminosity extraction suffers at all momenta.



Without Alignment



With Alignment

Deviation $< 0.2\,\%$ as long as overlapping areas are large enough.

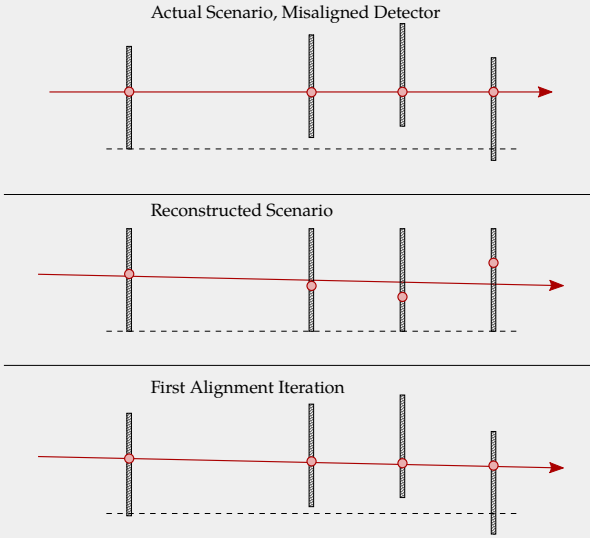
Module Alignment

Track based iterative alignment:

- Reconstruct hits
- Fit tracks to hits, residual remains
- Move Sensors until hits meet tracks
- Fit all tracks again

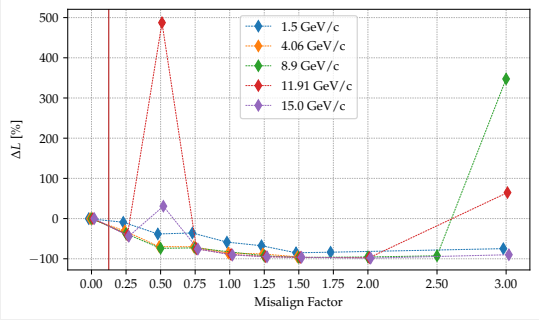
Track fit is done with PCA/SVD, sensor repositioning is done with ICP

$\Rightarrow$ very fast. Sectors can be aligned independently, multithreading is easy.

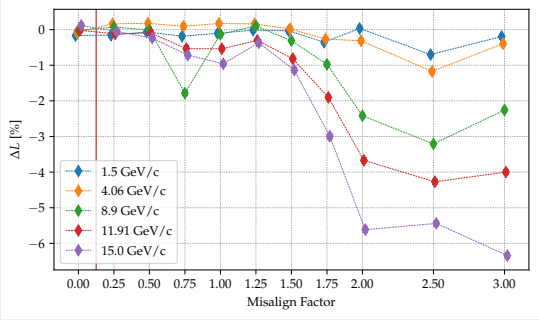


Luminosity Extraction / Module Alignment

Almost complete loss of luminosity even at small misalignment. Random outliers of severe over-estimation.



Without Alignment

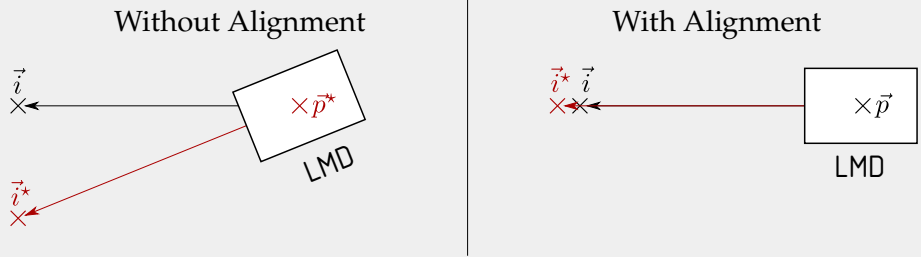


With Alignment

Deviation of $< 1\,\%$, because alignment can compensate up to $\approx 150\,\mu m$ misalignment.

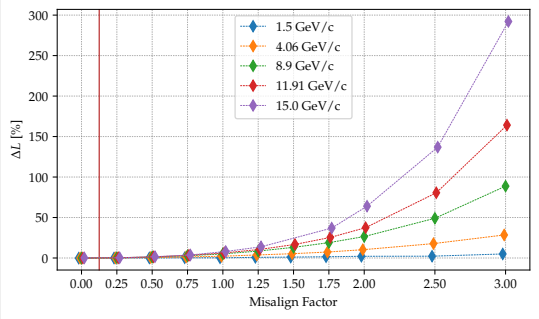
Box Rotation Alignment

LMD reconstructs an IP, but rest of PANDA reconstructs IP too. If they are different, LMD is rotated!

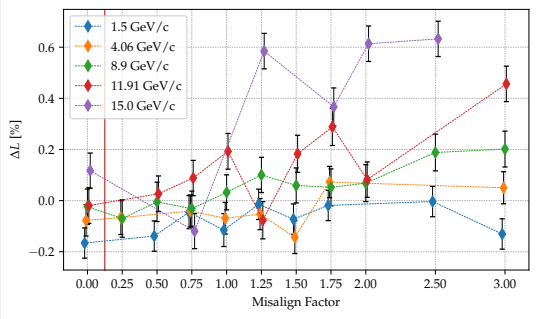


Problem: Only rotation around 2 axes accessible. But due to large lever arm, thats enough! (Neglect rotation around beam axis and Box translation.)

Without alignment, significant (and momentum dependent) Luminosity over-estimation.



Without Alignment

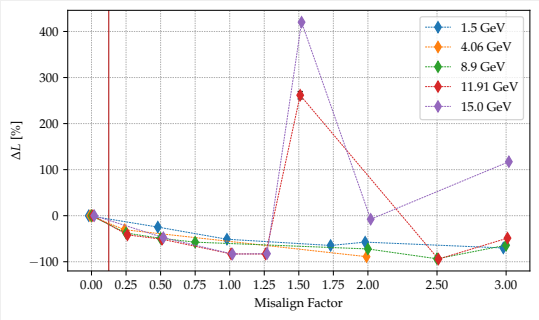


With Alignment

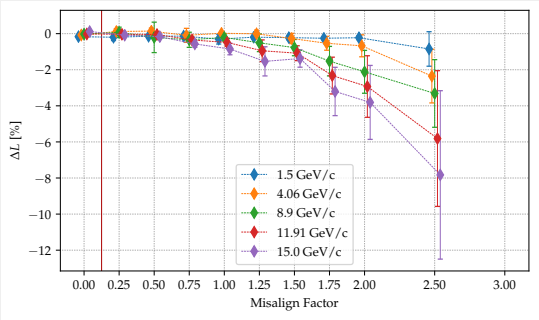
With Software Alignment, deviation is $< 0.6\,\%$ (but still momentum dependent).

Luminosity Extraction / All Alignment Methods

10 different detector geometries per degree of misalignment. Lumi deviations averaged, error bar is standard deviation.



Without Alignment

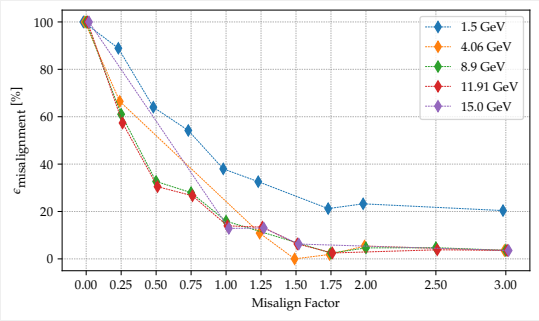


With Alignment

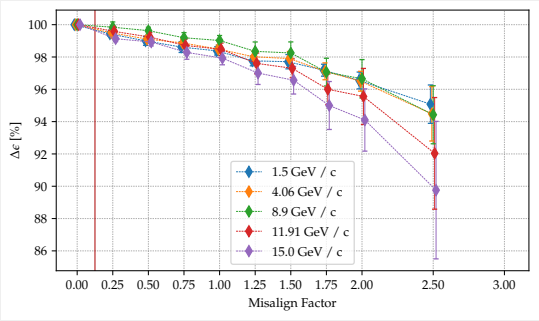
Sensor Alignment fails for misalignment $>$ 250 µm, so alignment overall fails.

Main Cause of Luminosity Error

Track reconstruction efficiency! Without alignment, we loose almost all tracks!



Without Alignment



With Alignment

With alignment, most tracks can be reconstructed again, but track quality cuts may still be too strict.

Conclusion

- Three alignment algorithms were developed & tested
- Ideal alignment method sequence is established
- Luminosity extraction is successful if positional uncertainty is $< 150\,\mu m$
- But: track quality cuts must be re-evaluated.

Thank you for your attention!