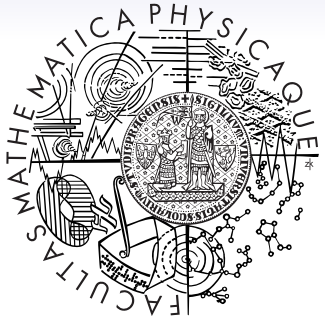

VXD Alignment: Phase II

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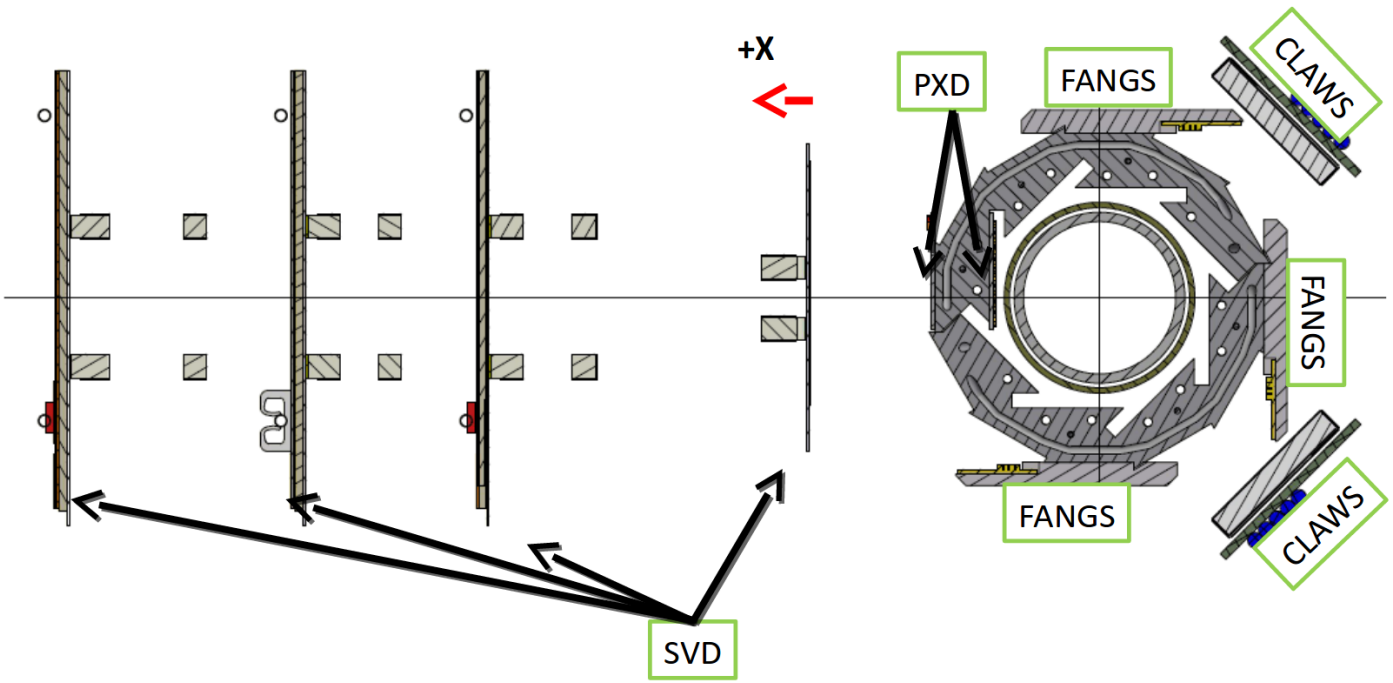
Outline

Geometry of Phase II

- ECL, CDC, VXD and Beast will be used.
- VXD: One ladder in each layer
- VXD: 4 sensors of PXD and 14 sensors of SVD
- Beast: Dedicated radiation monitors (FANGS, CLAWS, PLUME)
  - $\phi_{FANGS} = \{90°, 180°, 270°\}$
  - $\phi_{CLAWS} = \{135°, 225°\}$
  - $\phi_{PLUME} = \{135°, 225°\}$



VXD and Beast Geometry of VXD.

Geometry of Phase II

VXD Alignment of Phase II

Alignment using cosmic rays

Alignment using collision data

Alignment using mixed data

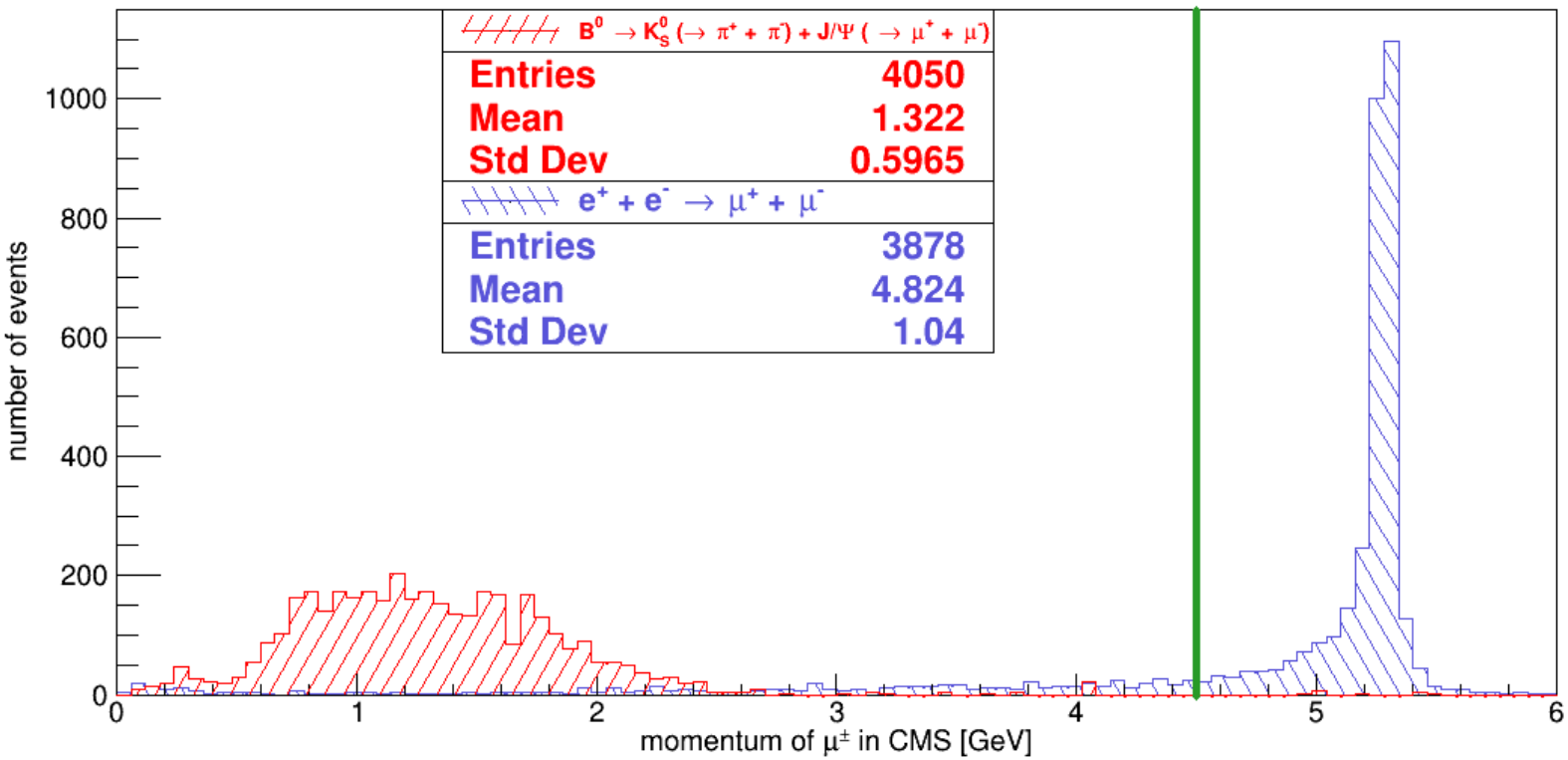
VXD Misalignment of Phase II

Summary

VXD Alignment of Phase II

VXD alignment based on different datasets:

I) Vertex constraint decay: $e^+ + e^- \rightarrow \mu^+ + \mu^-$
II) Other $\mu^\pm$ from beam collisions
III) Cosmic rays
IV) Tracks outside from IP



Explanation of analysis cut (green) for muons, because of alignment

Status of VXD alignment

Beam collision datasets

- Datasets of vertex constraint decay and $\mu^{\pm}$ from beam collisions are tested.
- Alignment is possible, but the sensors should be fixed in some parameters for precise result.
- It is necessity to use tracks outside of IP, or cosmic ray.

Cosmic rays

- Software for reconstruction of cosmic rays in phase 2 is done.
- Is it possible used cosmic rays in alignment?
- Is alignment using cosmic data helpful for alignment?

Tracks outside from IP

- Different way is using tracks outside of IP for alignment.
- It will be tried during phase 2 taking data.

VXD alignment

- We are fixing CDC. It is dependent of CDC alignment
- We are using magnetic field
- We are fixing all half-shells and ladders (in alignment hierarchy).
- The Millepede algorithm calculates 108 parameters (18 sensors $\times$ 6 parameters)

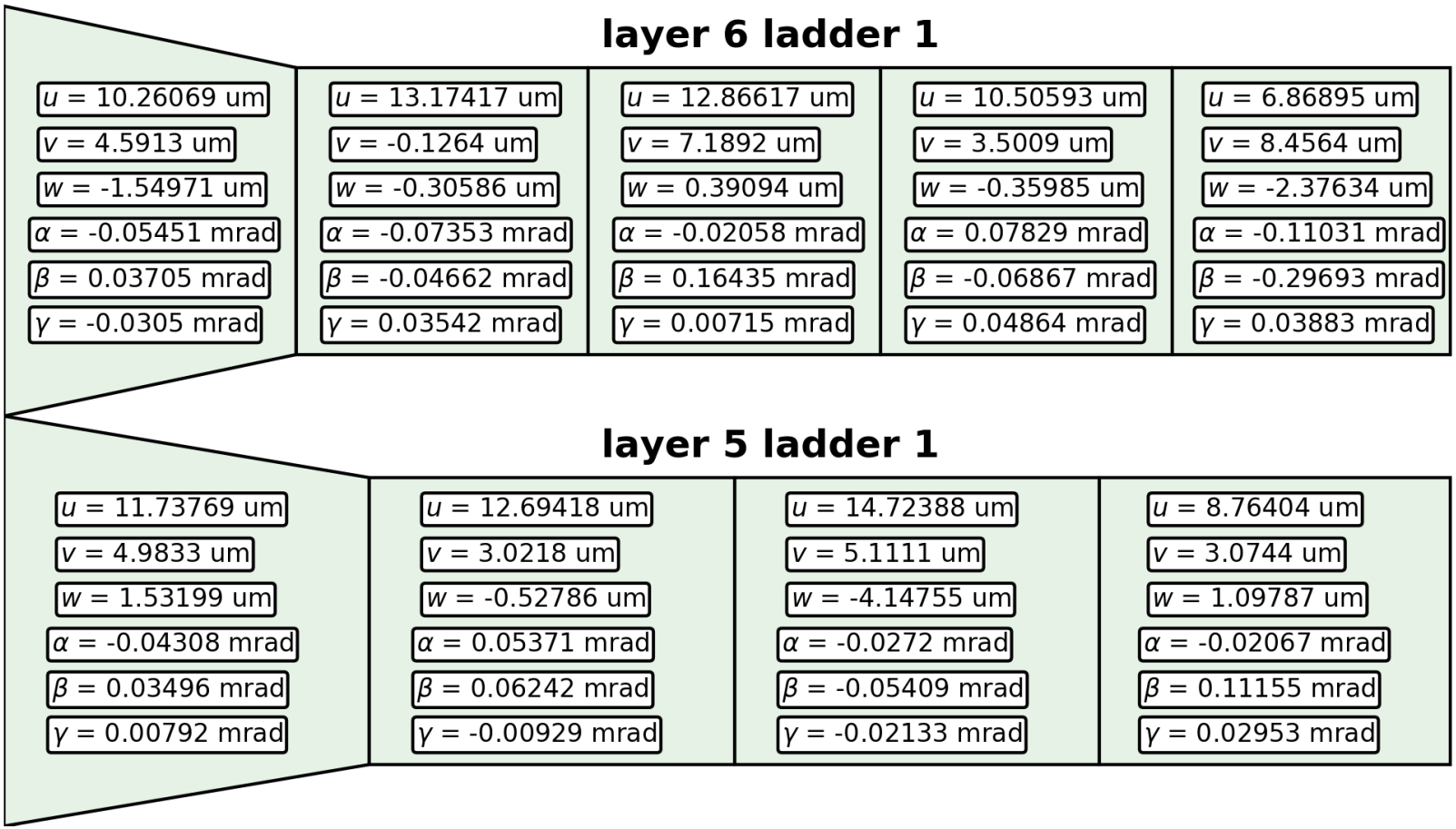
Alignment using cosmic rays

- The Millepede algorithm is using 22 krecords for alignment.
- Cosmic tracks are composed by one (85.65 %), two (9.99 %), three (3.45 %), four (0.65 %), five (0.07 %) or six (0.05 %) VXD hits.

Alignment using collision data

- The Millepede algorithm is using 90 krecords for alignment.
- The half of data are $e^+ + e^- \rightarrow \mu^+ + \mu^-$ and another half are other μ from collisions.

SVD alignment using cosmic data



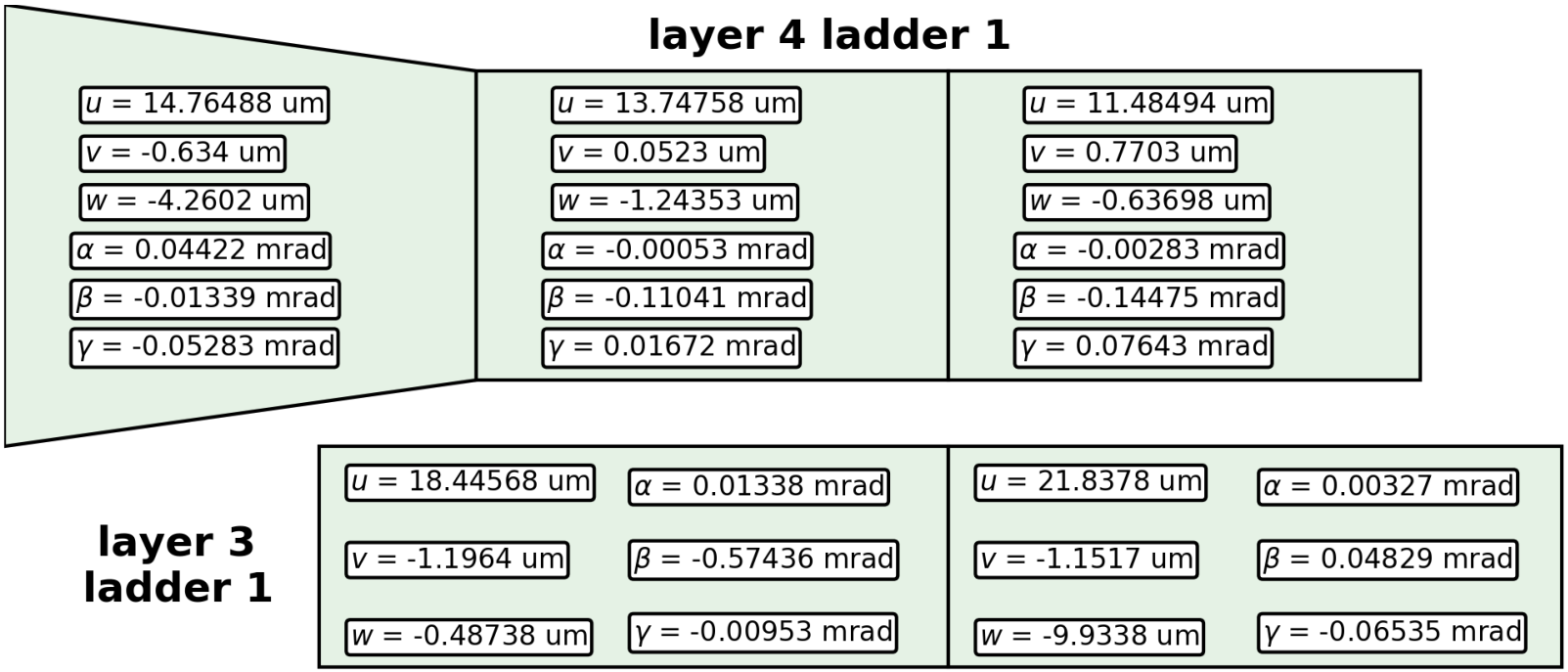
Results of alignment procedure using cosmic rays.

The worst results are for u alignment parameters.

The statistic errors for shifts are $u < 2$ um, $v < 4$ um and $w < 3$ um.

The statistic error for rotations are $\alpha < 0.2$ mrad, $\beta < 0.6$ mrad and $\gamma < 0.1$ mrad.

SVD alignment using cosmic data



Results of alignment procedure using cosmic rays.

The worst results are for u alignment parameters.

The statistic errors for shifts are $u < 2$ um, $v < 4$ um and $w < 3$ um.

The statistic error for rotations are $\alpha < 0.2$ mrad, $\beta < 0.6$ mrad and $\gamma < 0.1$ mrad.

PXD alignment using cosmic rays

layer 2 ladder 1	u = 20.57616 um	α = -0.21967 mrad	u = 15.7233 um	α = -0.40115 mrad
	v = 4.4935 um	β = -0.70415 mrad	v = 3.3858 um	β = -1.13189 mrad
	w = -5.1603 um	γ = 0.22826 mrad	w = -10.84347 um	γ = -0.26776 mrad
layer 1 ladder 1	u = 10.61439 um	α = -0.06142 mrad	u = 14.50351 um	α = -0.27381 mrad
	v = -1.2214 um	β = -0.30374 mrad	v = -1.6432 um	β = -1.30093 mrad
	w = 1.98835 um	γ = 0.28571 mrad	w = 1.9125 um	γ = -0.14583 mrad

Results of alignment procedure using cosmic rays.

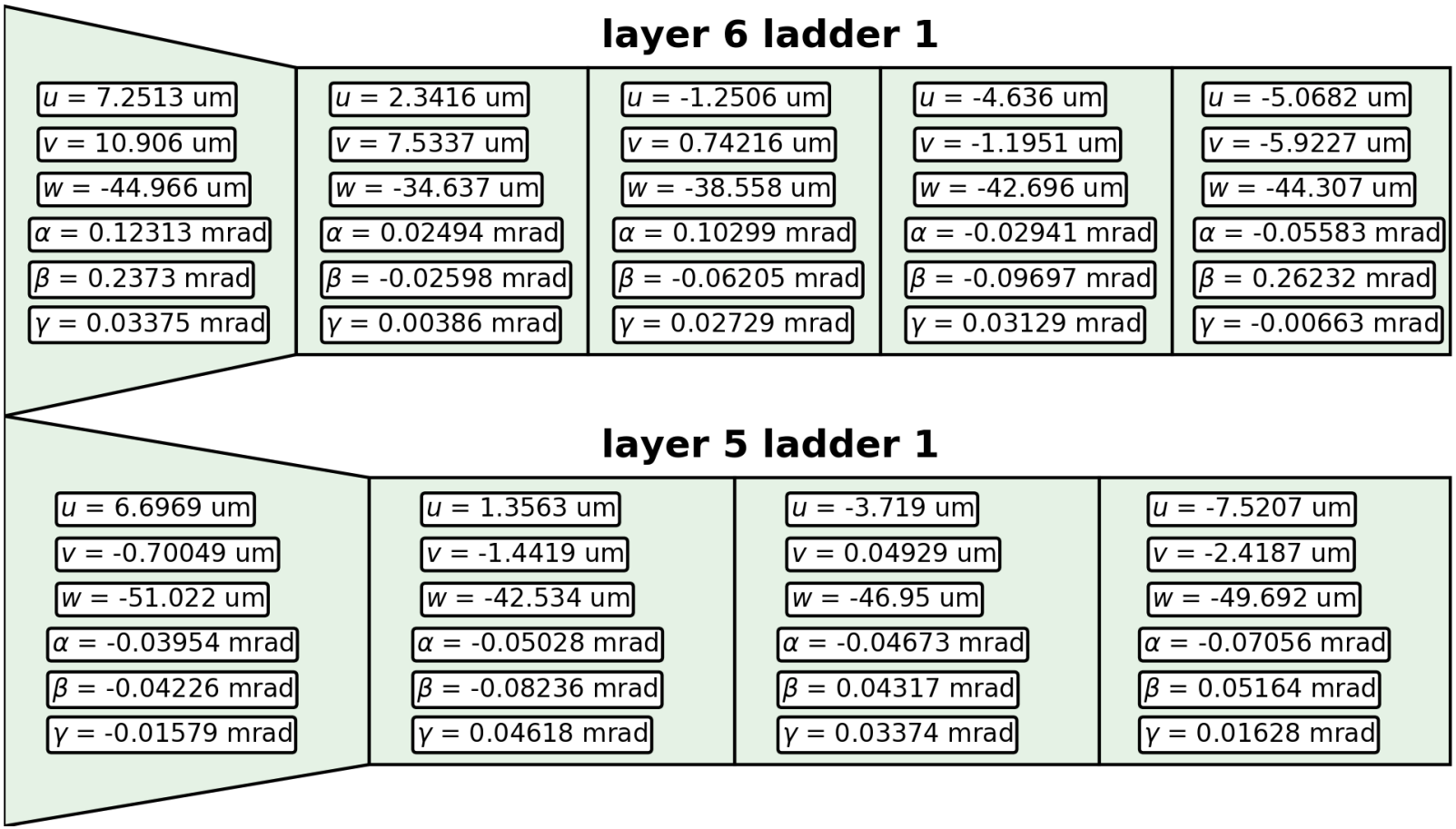
The worst results are for u alignment parameters.

The statistic errors for shifts are $u < 2$ um, $v < 4$ um and $w < 3$ um.

The statistic error for rotations are $\alpha < 0.2$ mrad, $\beta < 0.6$ mrad and $\gamma < 0.1$ mrad.

The reason for higher errors can be in statistic. Sensors are smaller, and it is difficult to hit them. Typically average for SVD sensors is 1200 hits per sensor and for PXD only 150 per sensor.

SVD alignment using collision data



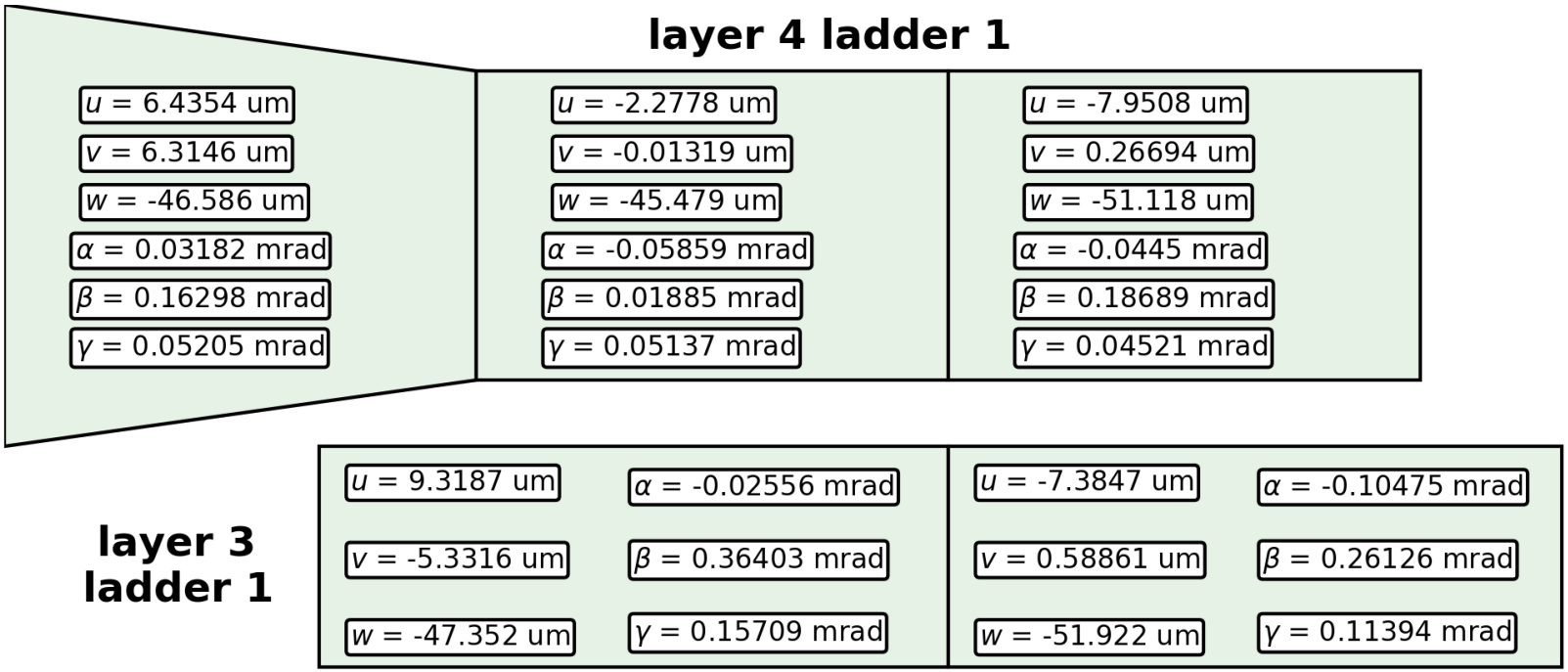
Results of alignment procedure using collision rays.

The worst results are for w alignment parameters.

The statistic errors for shifts are $u < 5$ um, $v < 27$ um and $w < 27$ um.

The statistic errors for rotations are $\alpha < 0.5$ mrad, $\beta < 2.0$ mrad and $\gamma < 0.2$ mrad.

SVD alignment using collision data



Results of alignment procedure using collision rays.

The worst results are for *w* alignment parameters.

The statistic errors for shifts are $u < 5$ um, $v < 27$ um and $w < 27$ um.

The statistic errors for rotations are $\alpha < 0.5$ mrad, $\beta < 2.0$ mrad and $\gamma < 0.2$ mrad.

PXD alignment using collision data

layer 2 ladder 1	u = 10.117 um	α = 0.01014 mrad	u = -6.3262 um	α = -0.22164 mrad
	v = 0.74172 um	β = 1.0982 mrad	v = -0.24122 um	β = 0.84255 mrad
	w = -41.54 um	γ = 0.34133 mrad	w = -50.248 um	γ = 0.22972 mrad
layer 1 ladder 1	u = 13.627 um	α = -0.14941 mrad	u = -7.07 um	α = -0.38574 mrad
	v = -5.9205 um	β = 1.5974 mrad	v = -0.94849 um	β = 1.0406 mrad
	w = -42.153 um	γ = 0.59839 mrad	w = -50.074 um	γ = 0.36805 mrad

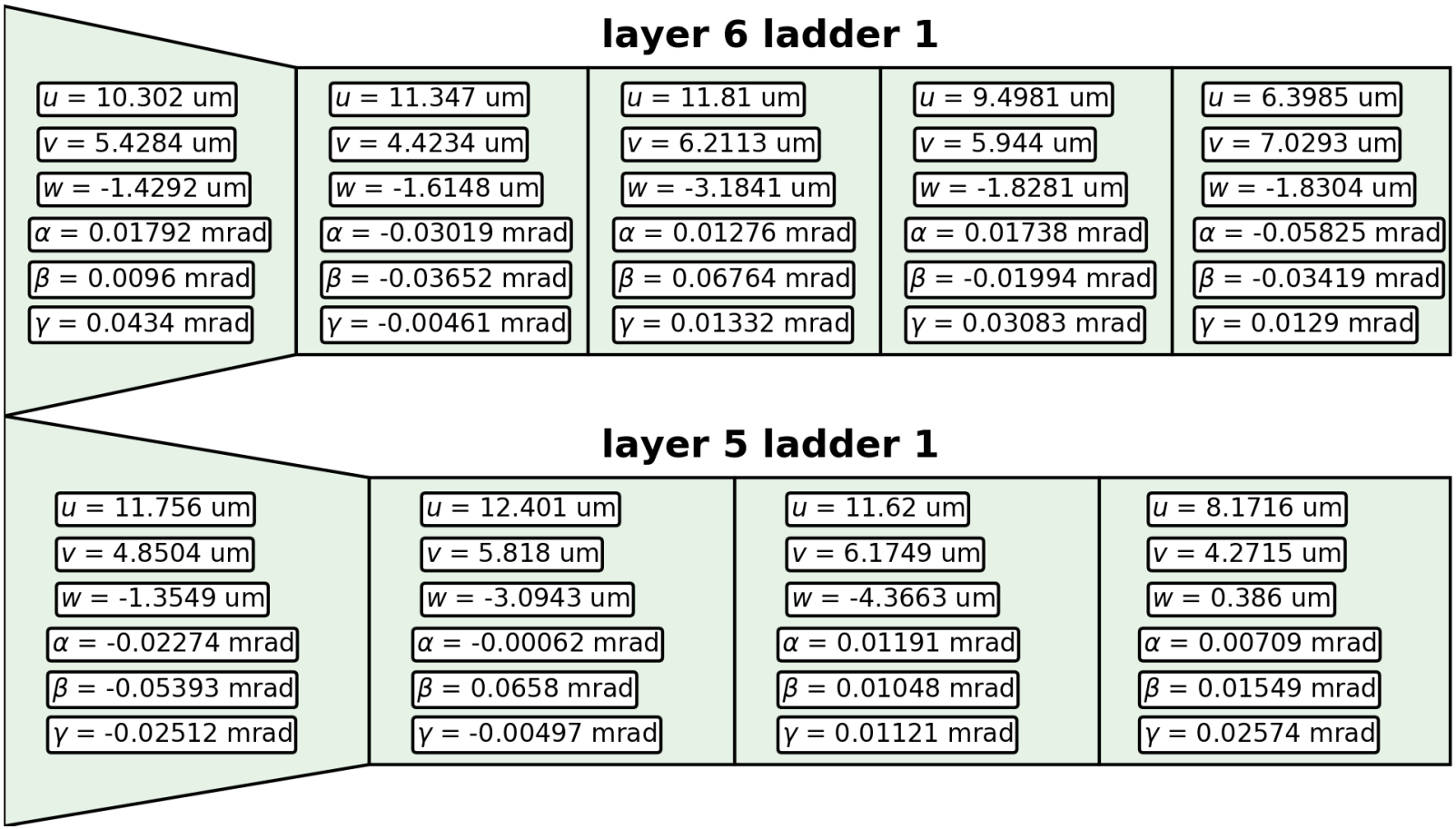
Results of alignment procedure using collision data.

The worst results are for w alignment parameters.

The statistic errors for shifts are $u < 5$ um, $v < 27$ um and $w < 27$ um.

The statistic errors for rotations are $\alpha < 0.5$ mrad, $\beta < 2.0$ mrad and $\gamma < 0.2$ mrad.

SVD alignment using mixed data



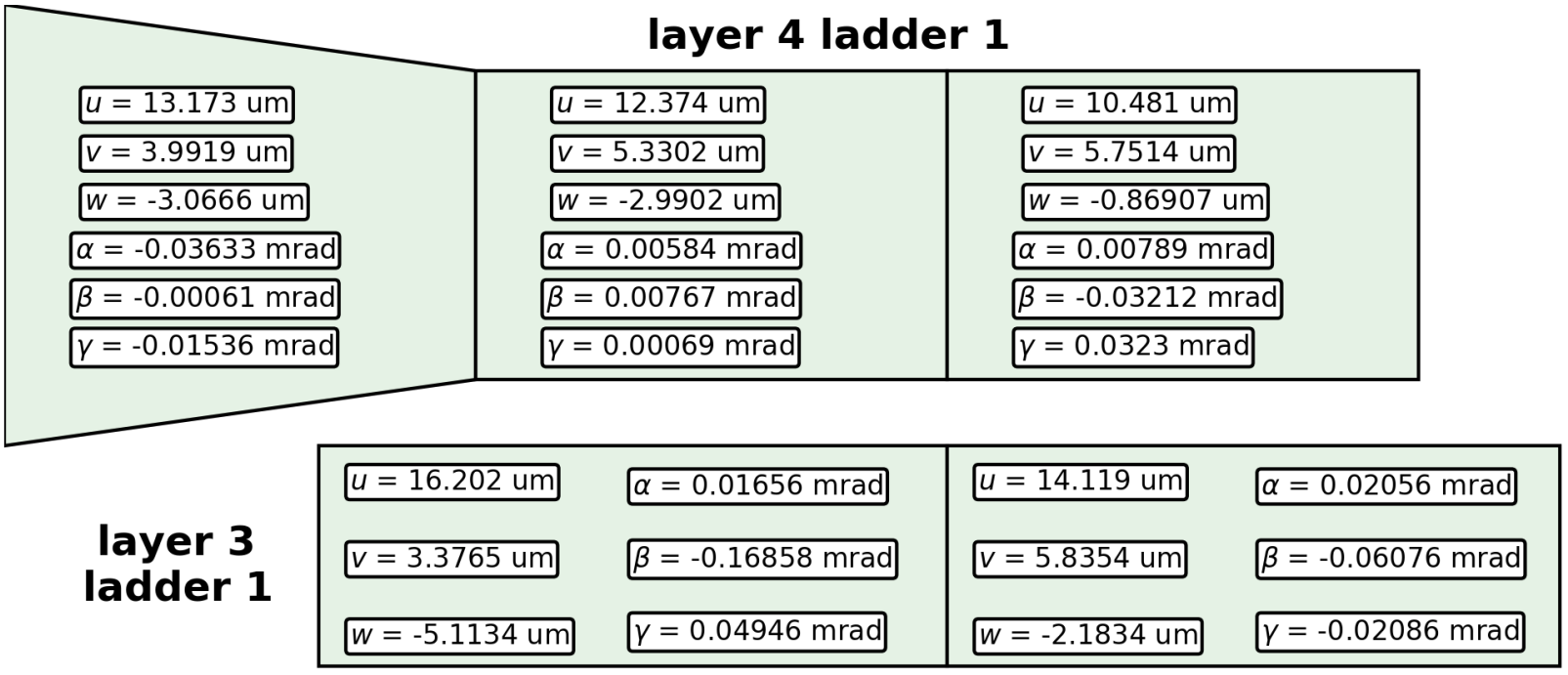
Results of alignment procedure using mixed rays.

The worst results are for u alignment parameters.

The statistic errors for shifts are $u < 1.0$ um, $v < 2.5$ um and $w < 1.5$ um.

The statistic errors for rotations are $\alpha < 0.08$ mrad, $\beta < 0.3$ mrad and $\gamma < 0.05$ mrad.

SVD alignment using mixed data



Results of alignment procedure using mixed rays.

The worst results are for u alignment parameters.

The statistic errors for shifts are $u < 1.0$ um, $v < 2.5$ um and $w < 1.5$ um.

The statistic errors for rotations are $\alpha < 0.08$ mrad, $\beta < 0.3$ mrad and $\gamma < 0.05$ mrad.

The statistic errors and dispersion of calculated values are smaller than for cosmic data.

PXD alignment using mixture of data

layer 2 ladder 1	u = 16.309 um	α = 0.02567 mrad	u = 14.486 um	α = 0.01435 mrad
	v = 4.6715 um	β = -0.10741 mrad	v = 5.6613 um	β = 0.10272 mrad
	w = -5.3545 um	γ = 0.11599 mrad	w = -3.528 um	γ = -0.04915 mrad
layer 1 ladder 1	u = 17.074 um	α = -0.00321 mrad	u = 14.759 um	α = -0.01006 mrad
	v = 2.4226 um	β = -0.36657 mrad	v = 5.344 um	β = -0.10317 mrad
	w = -7.102 um	γ = 0.16468 mrad	w = -3.6749 um	γ = -0.08959 mrad

Results of alignment procedure using mixture of cosmic and collision data.

The worst results are for u alignment parameters.

The statistic errors for shifts are $u < 1.0$ um, $v < 2.5$ um and $w < 1.5$ um.

The statistic errors for rotations are $\alpha < 0.08$ mrad, $\beta < 0.3$ mrad and $\gamma < 0.05$ mrad.

The statistic errors and dispersion of calculated values are smaller than for cosmic data.

Misalignment studies

- These misalignment scenarios was tested independently to each other:
  I) Shifts: 100 um, 50 um and 10 um
  II) Rotations: 1 mrad, 0.5 mrad and 0.1 mrad
- The misalignment larger than 50 um and 0.5 mrad are determined for mixture of cosmic and collision data.

Misalignment studies using cosmic rays

- The alignment procedure can not catch a misalignment, because of a bit VXD hits on a track.
- A misalignment generator rotate the sensor about 1.0 mrad, but the alignment procedure calculate moving a sensor.

Misalignment studies using collision data

- The alignment procedure catch a misalignment, but calculated alignment is not equivalent to misalignment scenario. The misalignment about 100 um in u (or w) parameter is calculated wrong as misalignment in u and w about 100 um.
- **If collision data are used in alignment, cosmic data must be used too.**

Remarks, experiences, ...

Cosmic rays

- It is possible using cosmic rays for VXD alignment.
- In phase II we are able observed 33k cosmic tracks, which are composed by VXD hits, per 11.5 hours.
- More than half of cosmic tracks used in alignment has one hit in VXD only.

Cosmic rays inside/outside magnetic field

- Momentum is needed for precise alignment, because the GBL is used in alignment procedure.
- The GBL should expect size of kinks on scatters via momentum.
- The momentum of cosmic tracks are clearly determined using magnetic field.
- If we do not use magnetic field, the momentum of cosmic tracks should be estimated according $\mathrm{dE/dx}$.

Summary

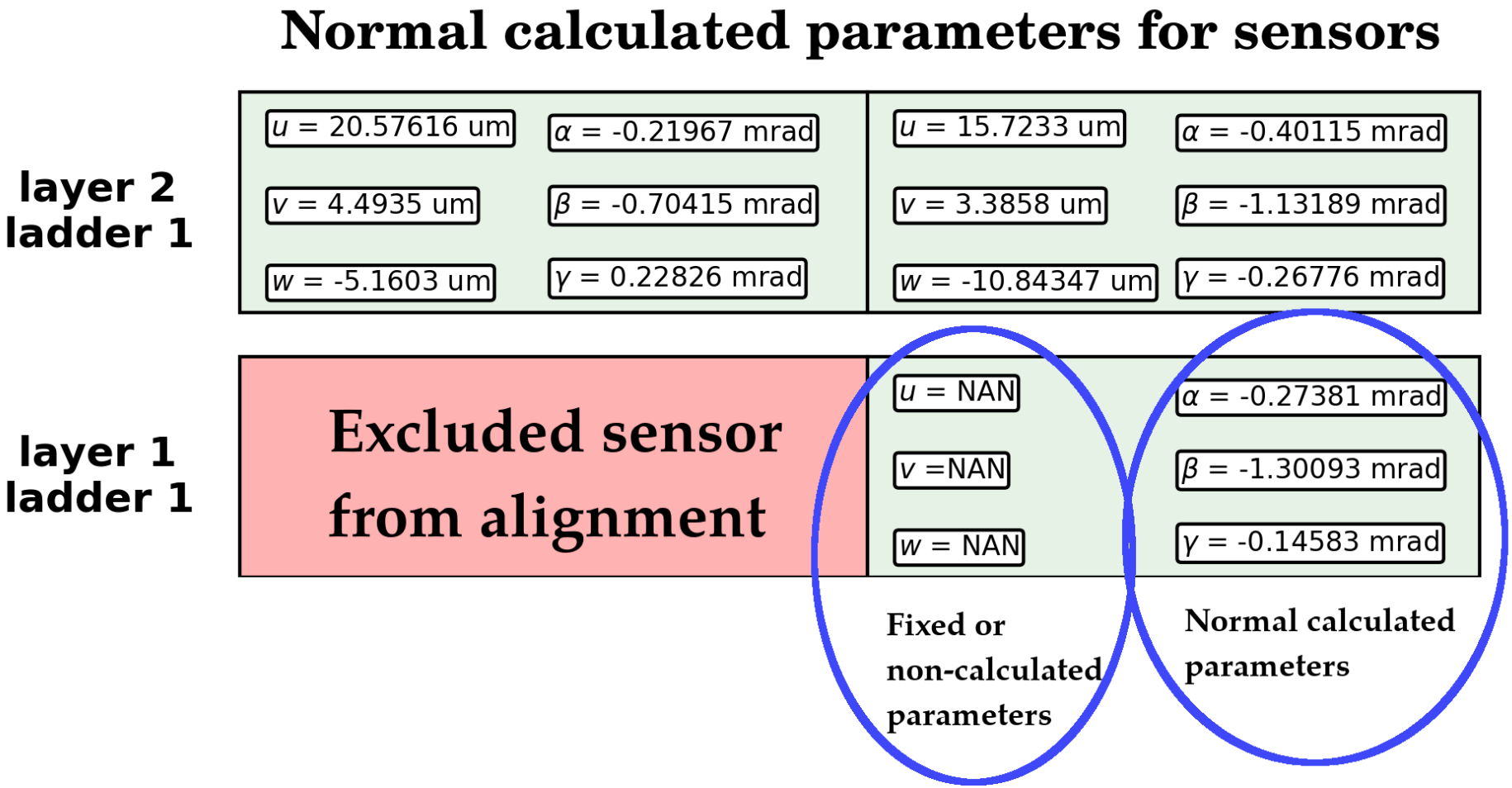
- VXD alignment sensor by sensor is working very well.
- During phase 2 the VXD alignment hierarchy will be determined.
- The worst results are in *u* alignment parameter (systematic shift).
- The alignment procedure is able to determined larger than 50 um and 0.5 mrad misalignment.
- **If collision data are used, cosmic data must be used too.**
- Monitoring tools (DQM) for Phase 2 is not necessary. The DQM is based on residuals are used in alignment procedure.
- Scripts are published in feature/BII-2837-cosmic-tracks-in-vxd-phase-ii
- Status of our study is published in JIRA issue BII-2837-cosmic-tracks-in-vxd-phase-ii
- Publishing official alignment procedure for phase 2 in master soon.

Plans for next weeks

- Publishing official alignment procedure of phase 2 in master soon.
- Determination alignment constants during data taking phase 2.
- Creating short online documentation of alignment procedure for phase 2.
- Development reconstruction software for cosmic rays in different geometries (VXD CR, phase 3, ...)
- Development alignment procedure for different purpose (e.g. VXD CR)
- Development of analysis alignment procedure for selection the most important channel for alignment during phase 2/3.

Backup

How to works script for plotting alignment result



The script recognizes excluded sensor (red) from alignment.

If parameters are fixed or non-calculated, they are shown as "NAN".

The used sensor are shown green and all calculated parameters are in white boxes.