VELO alignment with collision data

Silvia Borghi,
Marco Gersabeck, Chris Parkes

University of Glasgow

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Outline

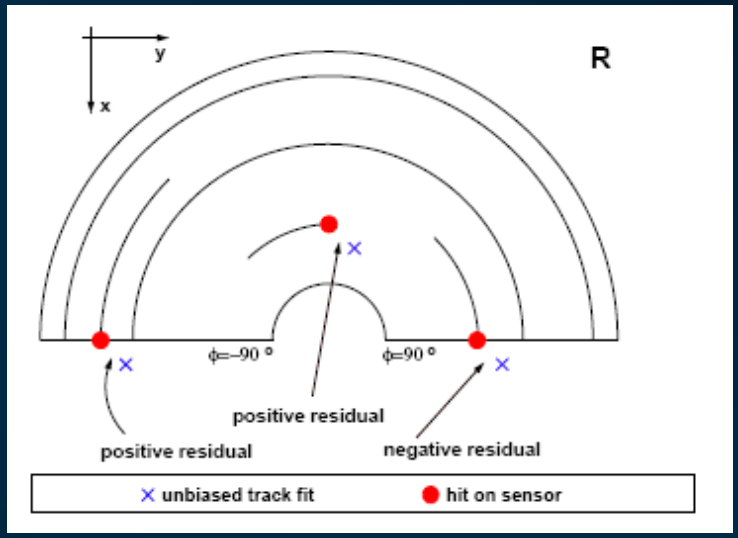
- Evaluation of Sensor misalignment by monitoring plots
- Evaluation of 2 half misalignment by monitoring plots
- Evaluation of 2 half alignment by Millepede
- Input: October TED data results for Module, Sensor and 2 half alignment
- Data Sample
  - Runs with velo open by 15 mm and magnet on (one sample for each LHC fill)
  - Run with velo open by 20 mm and magnet off

Sensor misalignment monitoring

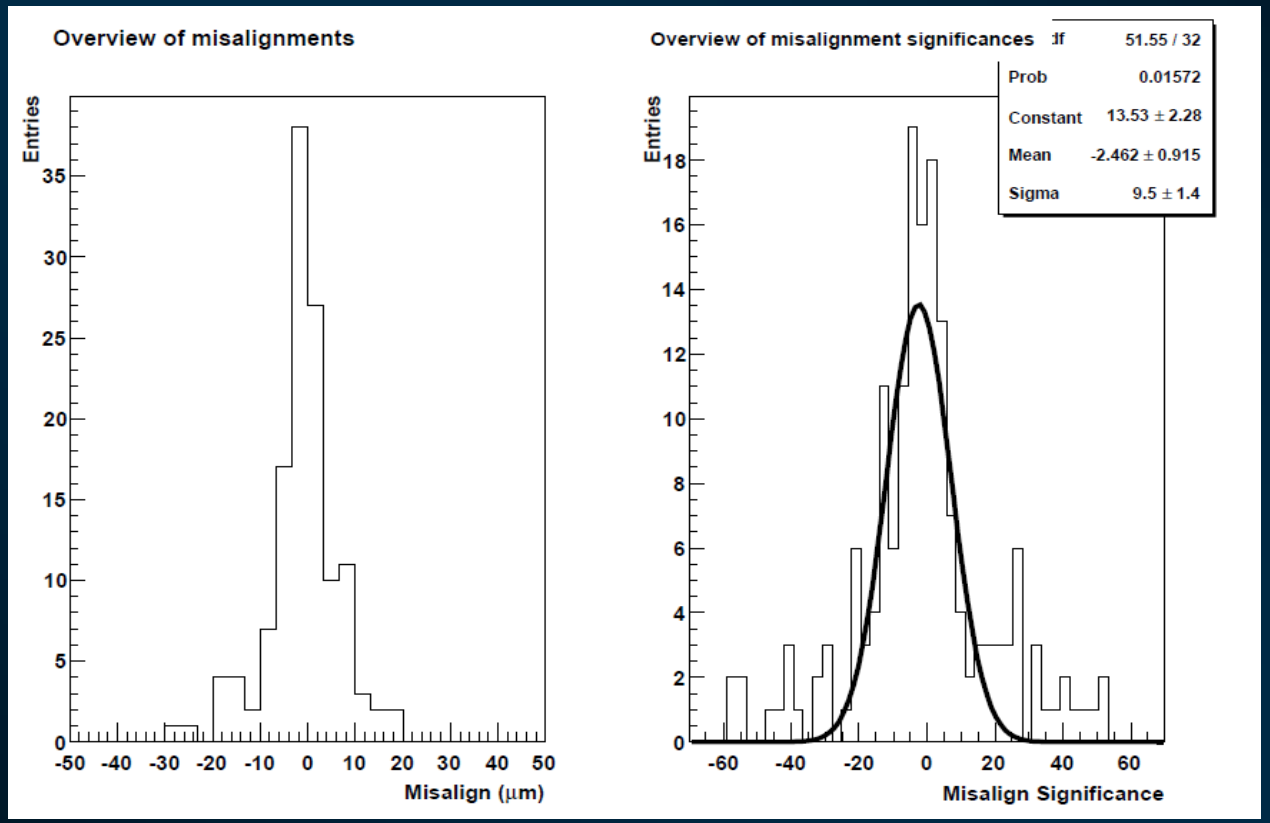
- R and ϕ residuals has a sinusoidal dependency on the misalignment

$$
\begin{aligned}
residual_R &= -\Delta x \cos\phi_{track} + \Delta y \sin\phi_{track} \quad (R \text{ sensor}) \\
residual_\Phi &= \Delta x \sin\phi_{track} + \Delta y \cos\phi_{track} + \Delta\gamma r_{track} \quad (\Phi \text{ sensor})
\end{aligned}
$$

- Monitoring the sensor misalignment by fitting the biased residual distribution by these sinusoidal functions



Sensor Misalignment overview for run 63949

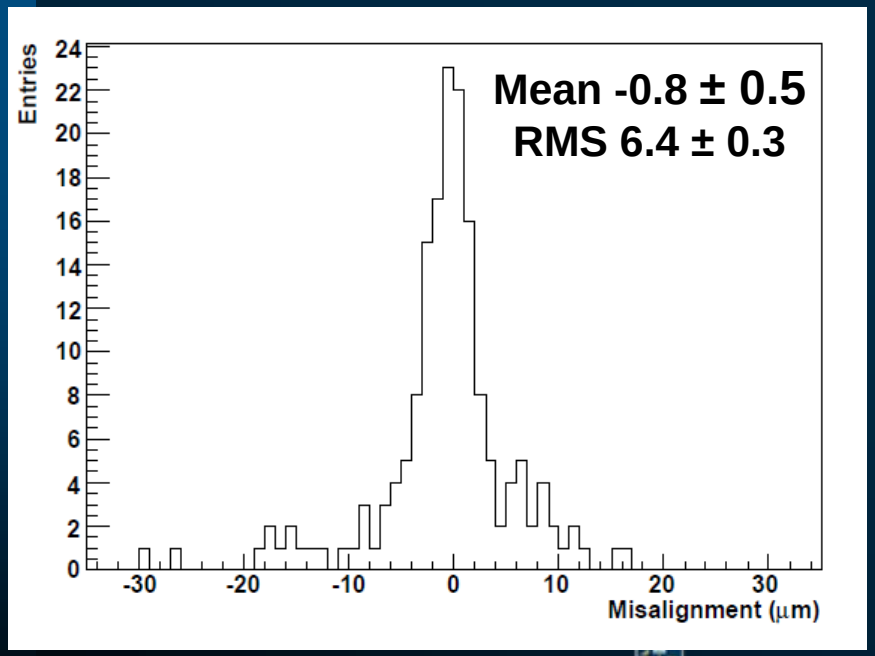


Sensor misalignment time dependency

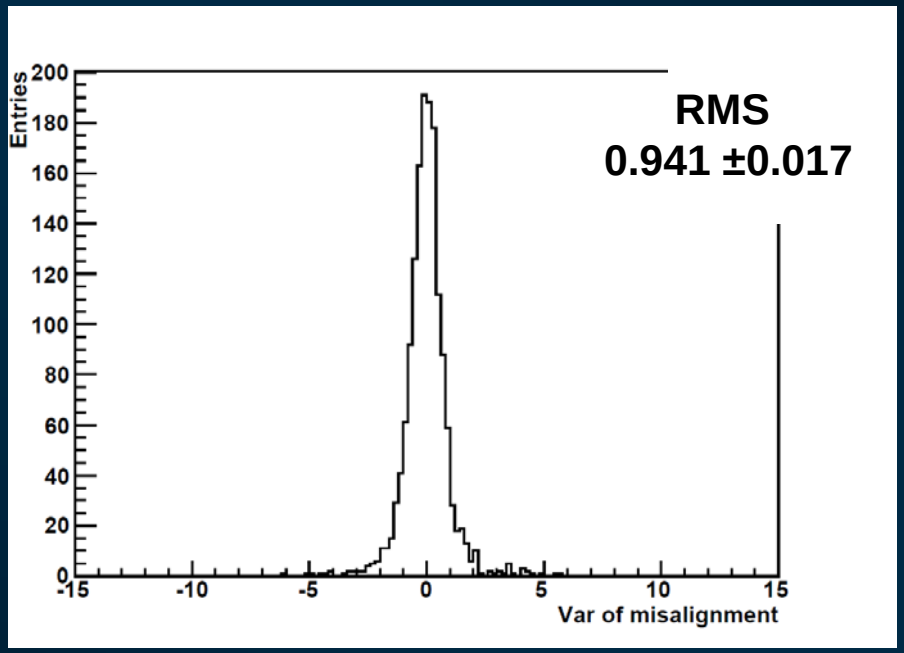
- Analysing all the data with VELO opened by 15 mm
- Each sample is defined by a LHC fill
- Evaluate the sensor misalignment by the monitoring procedure per each sample and per each run
- Plot the mean misalignment for each sensor and the variation of misalignment with respect to the mean value for each sample

Sample	Runs
1	63497
2	63566-63567
3	63596
4	63703-63713
5	63768-63772
6	63801
7	63807-63809
8	63813-63815
9	63949

Mean misalignment for X and Y transl.

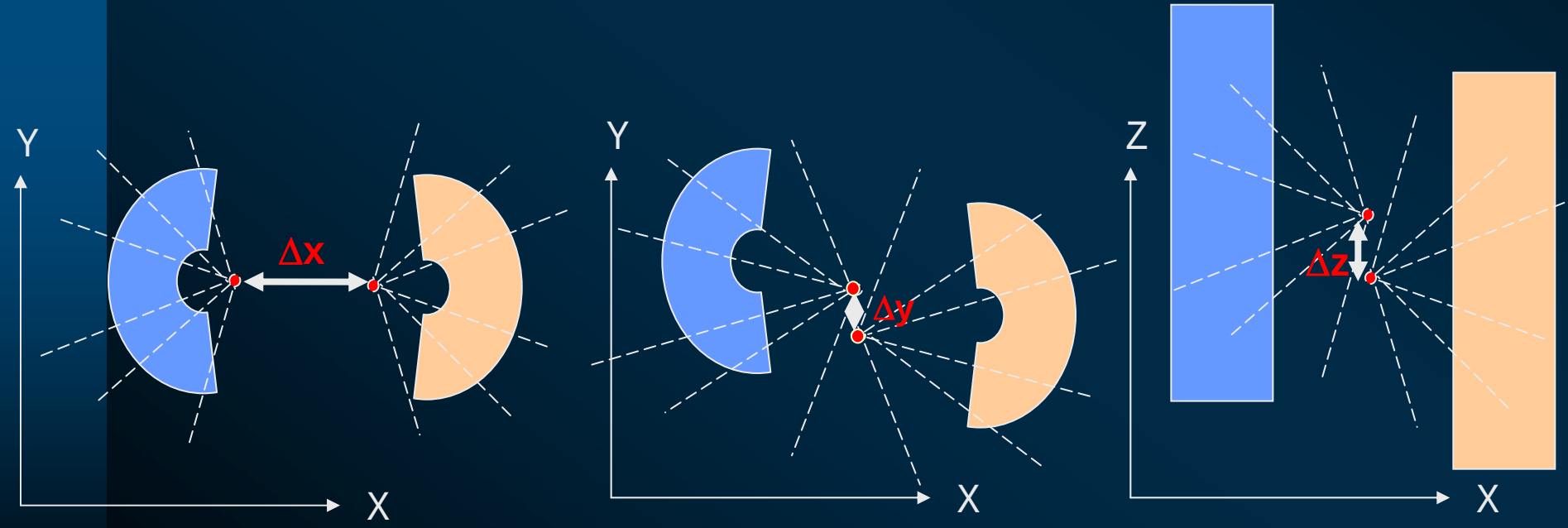


Variation of misalign. for X and Y transl.

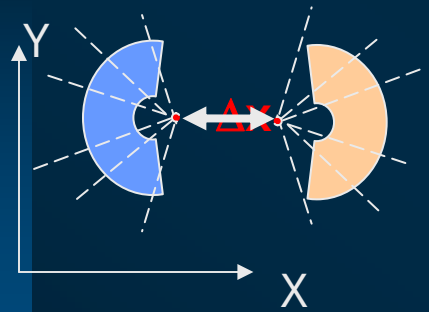


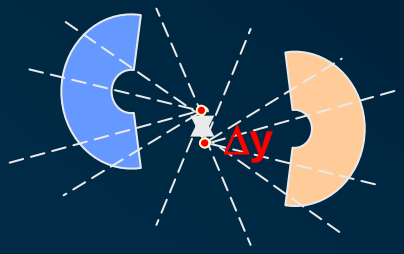
2 half alignment monitoring

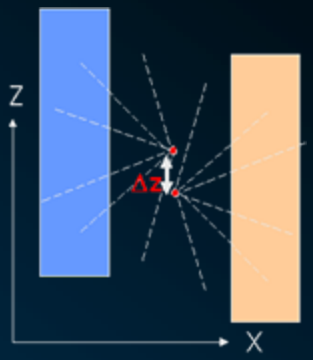
- **Monitoring through primary vertices**
  - Evaluate PV position with tracks reconstructed only in one half
  - Plot distance between PVx by A side tracks and C side tracks
  - Plot distance between PVy by A side tracks and C side tracks
  - Plot distance between PVz by A side tracks and C side tracks

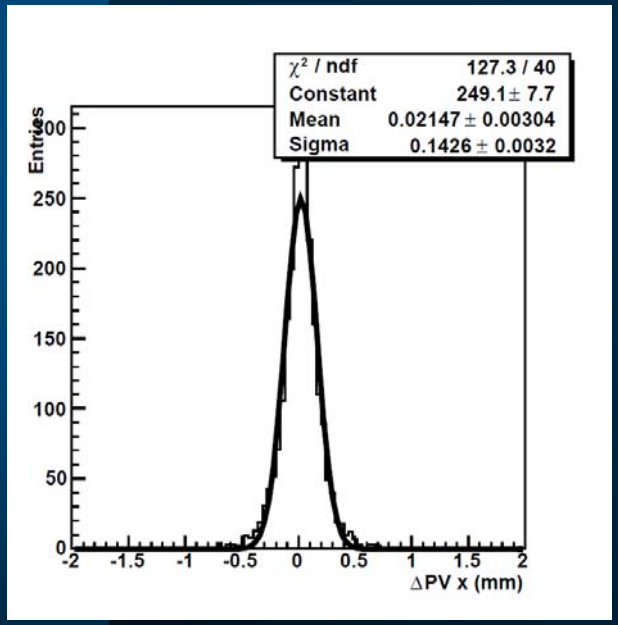


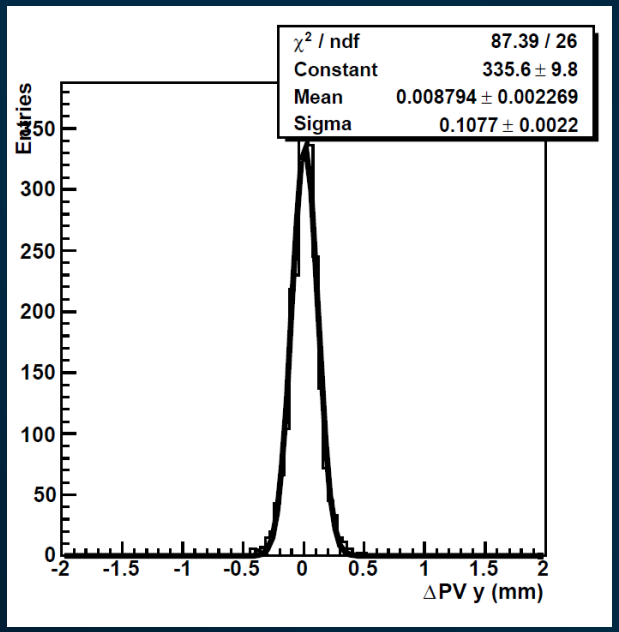
2 half alignment monitoring for run 63949

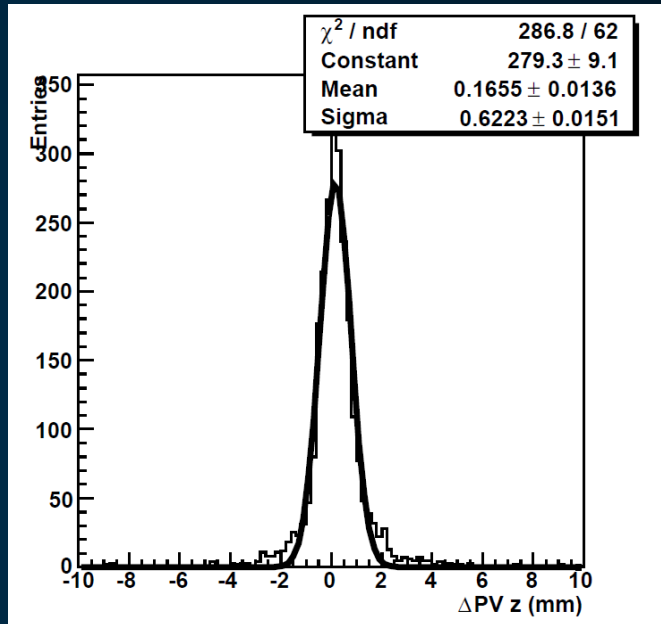












Events with only 1 reconstructed PV in both halves with at least 5 tracks

PV method in Millepede

- Vertex is the origin of a certain number of tracks and can be defined by

$$\begin{cases} v_x = a \cdot v_z + b \\ v_y = c \cdot v_z + d \end{cases}$$

- In case of half misalignment the vertex position is seen differently in each detector half frame

$$\begin{cases} v_x^{new} = v_x + \varepsilon_{v_x} = a \cdot v_z^{new} + b \\ v_y^{new} = v_y + \varepsilon_{v_y} = c \cdot v_z^{new} + d \end{cases}$$

and

$$\begin{cases} v_x^{new} = v_x - \Delta_x - v_y \cdot \Delta_\gamma + v_z \cdot \Delta_\beta \\ v_y^{new} = v_y - \Delta_y - v_x \cdot \Delta_\gamma + v_z \cdot \Delta_\alpha \\ v_z^{new} = v_z - \Delta_z - v_y \cdot \Delta_\alpha + v_x \cdot \Delta_\beta \end{cases}$$

- Millepede method does minimization with single matrix inversion: for local (vertices) and global parameters (misalignment). With some approximation (v_x and v_y <1mm)

$$\begin{cases} b = v_x - a \cdot v_z - \Delta_x + a \cdot \Delta_z + v_z \cdot \Delta_\beta \\ d = v_y - c \cdot v_z - \Delta_y + c \cdot \Delta_z + v_z \cdot \Delta_\alpha \end{cases}$$

- Extract the misalignment constants:
  - x, y, z translation
  - rotation around x and y axis

  Only a weak lever arm for any Z rotational constraint due to the small interaction region in X and Y plane

PV method in Millepede

- Evaluation of PV using only right or left track sample
- Select events with only 1 PV in both right and left side.
- Use PV offline tool to determine PV using only left (or right tracks)
  - using linear track fit
  - Loose cuts provide (requiring at least 3 tracks per PV)
- Evaluation of X, Y and Z translations
- Tested on MC data with VELO open by 15 mm
- Evaluation of the misalignment for 5 data samples with VELO at 15 mm and B on and with the run with B off and Velo at 20 mm

PV method by Millepede on MC data

- MC data: 450 GeV and VELO open by 15 mm
  - Use 4 different samples (55,000 events)
  - Run with no misalignment as input
  - Run with misalignment:
    Tx: 80 μm ; Ty: 100 μm; Tz: 300 μm

- Residual misalignment:
  - Tx 2 ± 3 μm
  - Ty 6 ± 4 μm
  - Tz 3 ± 5 μm

Results of the 2 half alignment using method based on Millepede

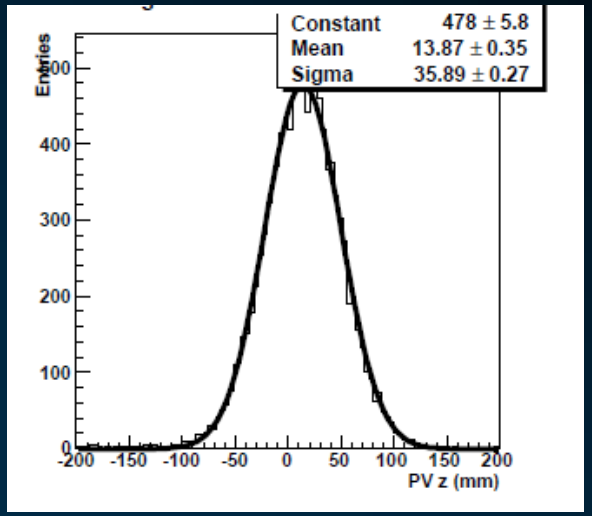
Runs	X trans (μm)	Y trans (μm)	Z trans (μm)	N of track used in align	N vertex used in align.
63596 (B off)	*74*	*60*	*272*	*17,806*	*379*
63949	27	3	144	388,040	10,135
63813-63815	27	3	135	531,244	14,809
63801	34	3	123	511,373	12,636
63703-63713	25	18	118	181,035	4,543
63686-63691	40	13	135	368260	9,042
Mean (weighted by N_{PV})	31.2	6.5	133		
$error = \sqrt{\frac{\sum (x - mean)^2}{N^2}}$	7.5	9.2	23		

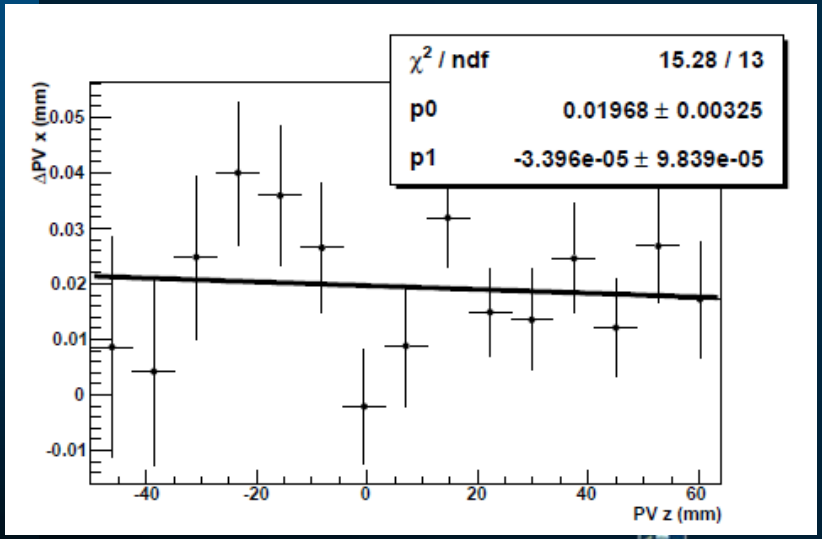
The variation includes also the motion system position accuracy (about ~10 μm).
The reproducibility of the motion system is about ~3 μm

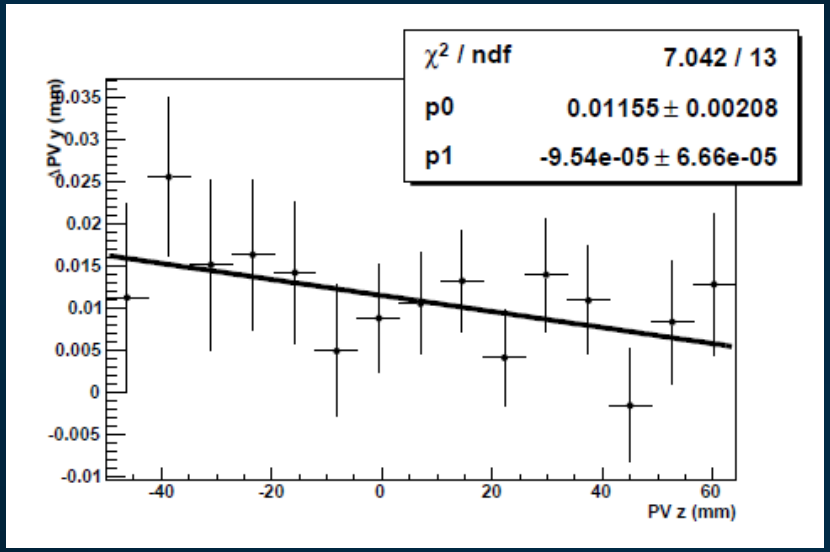
About rotation

- Rotation around Z:
  - Too small lever arm (beam size)
- Rotation around X and Y:
  - Lever arm (z length of collision region) is about 100 mm
  - accuracy on Tx and Ty
  - ⇨ accuracy ~ 300 μrad on Rx and Ry

Need overlap tracks or traversing tracks (VELO close)







Conclusion

- Sensor misalignment of the order of 7 μm
- 2 half alignment by Millepede:
  - X translation 31.2 ± 7.5 μm
  - Y translation 6.5 ± 9.2 μm
  - Z rotation 133 ± 23 μm
- First results using Kalman method are in agreement for Tx and Ty but systematic shift for Tz ➔ under investigation
- Next:
  - Evaluation of sensor and module alignment

Backup

Motion System Summary

- Three pieces of information available (through PVSS):
  - Steppermotor (number of pulses sent)
  - Resolver measurement
  - Potentiometer reading (detector safety system - 0.1mm accuracy)
- Motion accuracy for resolver position:
  - Position accuracy about ~10 μm
  - Position reproducible (moving in the same direction) ~3 μm

- In x:
  - Steppermotor sends 2000 pulses for 50mm (1:40 gearing)
  - 1mm in 9 seconds; i.e. 4½ minutes to drive 30mm
  - Open position is at |x|=29mm
  - Each half can drive up to 5mm beyond nominal x = 0
- In y:
  - Steppermotor sends 2000 pulses for 250mm (1:16 gearing)
  - 1mm in 3 seconds
  - Motion in y is only possible for |x|<16mm
  - Range is -4.7 < x < 4.7 mm

2 half alignment with TED data

Misalignment of C side with respect to A side

- TranslX: -0.283 ± 0.011 mm
- TranslY: 0.085 ± 0.018 mm
- RotX: -119 ± 63 μrad
- Roty: 75 ± 64 μrad