Study of the resolution of vertex detector in measurement of muons in Belle II experiment.

M1 internship

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Experiment BELLE II

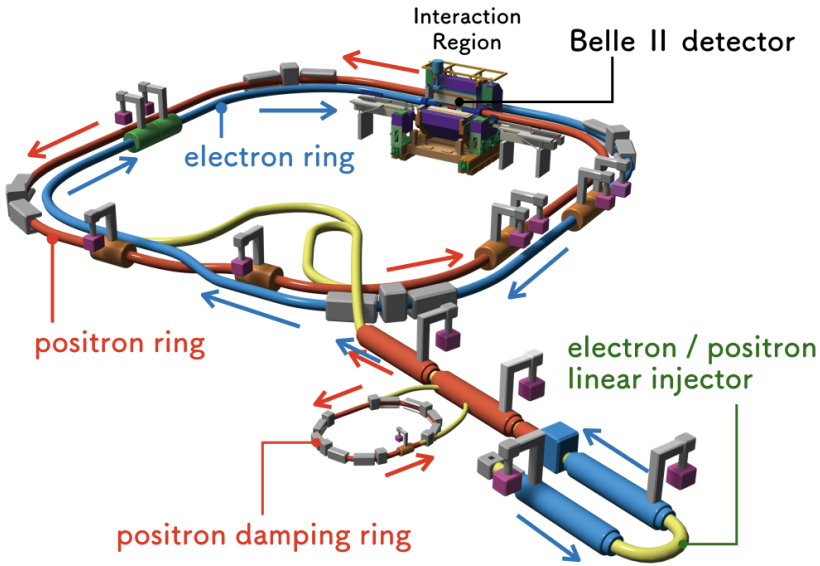

Figure – SuperKEKb's scheme, experiment located in Japan. Image taken from : https://www.bnl.gov.

- It Search to collide particles and mobe beyond standard model among interactions in elementary particles. Looking for new physics, new scenarios, new generations, new particles.
  - One of its particularities is about researches and investigations in CP violation topic.
- Reconstructs the production and the decay vertices of particles produced in $e^- e^+$ collisions.

SVD

- Two different direction in acquisition layers. Precisely U and V layers, which detect differents values in resolution of X-Y in its own framework .
- In SVD, the main purpose is to measure the two B decay vertices for the measurement of mixing-induced CP asymemtry.
- The design in Belle II SVD inherits the good characteristics of Belle vertex detector such as low mass, high presicion, immunity to background hits, radiation tolerance and long term stability.

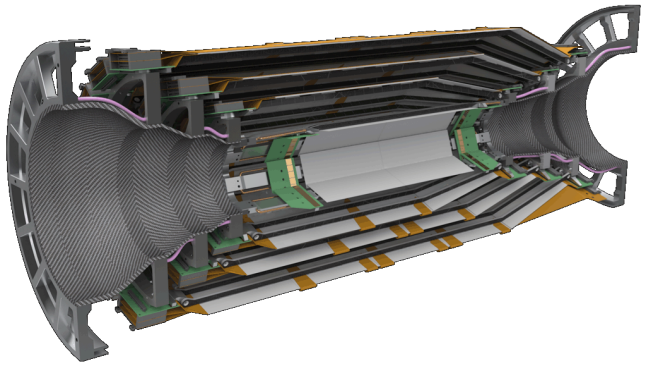

Figure – **Silicon Vertex Detector, image taken from :** https://web2.infn.it/Belle-II/index.php/detector/svd

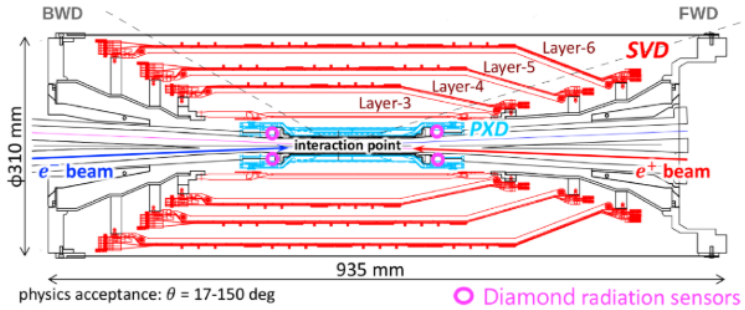

Figure – **Image taken from The Silicon Vertex of the Belle II Experiment.**

Before Starting

- Translation of the whole macro to python
-

$$\begin{aligned}\sigma_{cl}^2 &= \langle res^2 - \sigma_t^2 \rangle = \langle res^2 \rangle - \langle \sigma_t^2 \rangle \\ &= \sigma_{res}^2 - \langle \sigma_t^2 \rangle \\ &= mad(res)^2 - median(\sigma_t)^2 - mad(\sigma_t)^2\end{aligned}$$

$$\text{with : } \quad err_{res} = \frac{std(res)}{\sqrt{n}} \quad \& \quad err_{\sigma_t} = \frac{std(\sigma_t)}{\sqrt{n}}$$

- res [1]=svdClPos - svdTrkPosUnbiased , σ_t [2]=svdTrkPosErrUnbiased
- Resolution= $\sqrt{(\sigma_{cl}^2)}$,
  $Err_{\sigma_{cl}} = \sqrt{err_{mad}(res)^2 + err_{med}(\sigma_t)^2 + err_{mad}(\sigma_t)^2}$

1. Residues, which it is the subtraction of the detection in the cluster and distance in real position in the detector
2. Real position in the detection

Before Starting 2

- Alternative fitting methods.
- Cuts :
  - $|\text{svdRes}| < 120\ \mu m$.
  - $|\text{svdTrkPos}| < 1.8$ cm for layer U, < 5.9 cm for layer V.
  - svdTrkPXDHits > 0
    - MAD=median($|X_i - \bar{X}|$), with $\bar{X}$ =median(X_i)
    - $VAR(MAD) = \frac{RMS(|X_i|)}{\sqrt{n}}$
    - $\sigma = k \times MAD$ with k=1.4826
    - $mad = k \times MAD$

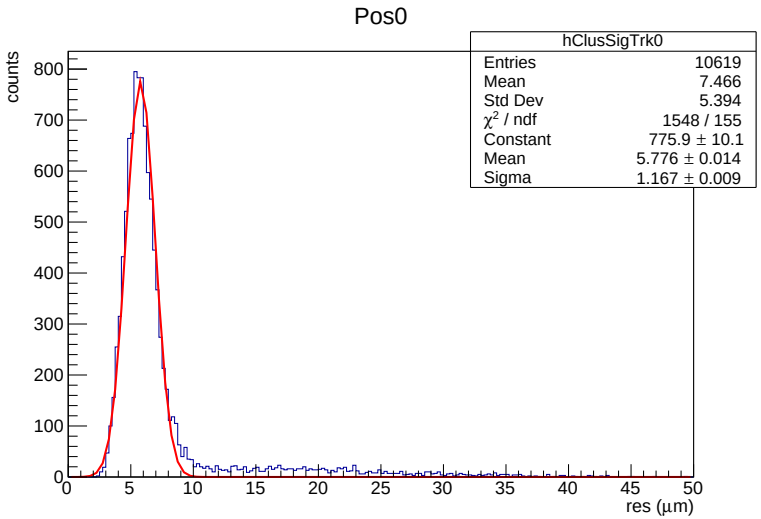

Figure – **Pos Histogram in Release 6**

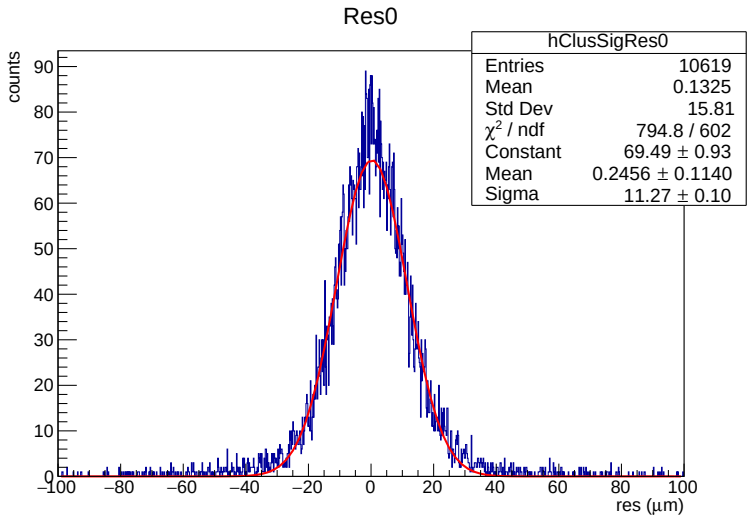

Figure – **Res Histogram in Release 6**

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Experiment & MonteCarlo

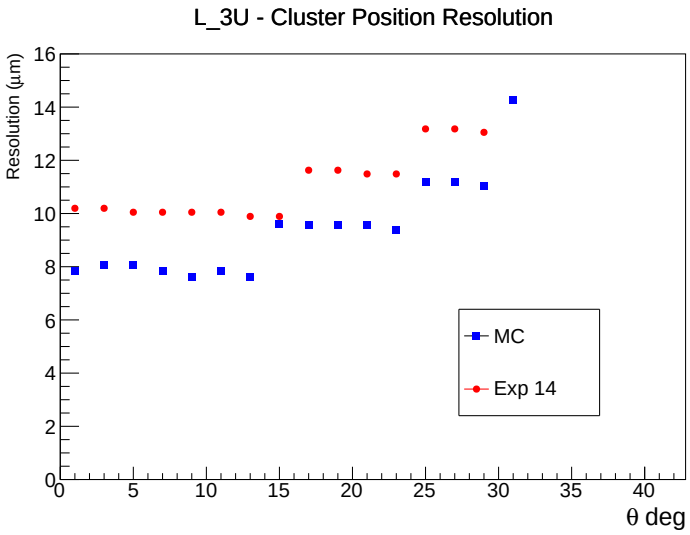

Figure – Release 6

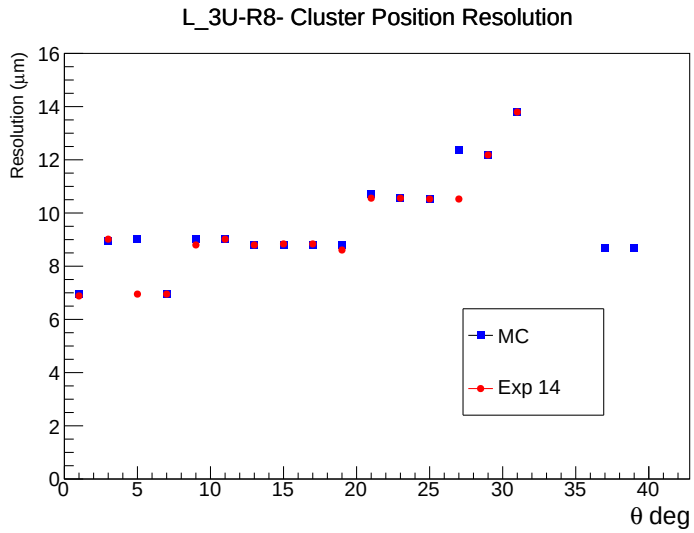

Figure – Release 8

- Entries Montecarlo : 2078956
- Entries Experience 14 : 1902847
- Total Entries used : 600000

- Entries Montecarlo : 1936036
- Entries Experience 14 : 1979852
- Total Entries used : 600000

- In the Release 6 there was an overestimation in mc data compared to the Release 8.
- Angle θ is related to the perpendicular of the sensor.

Graph Layer3U

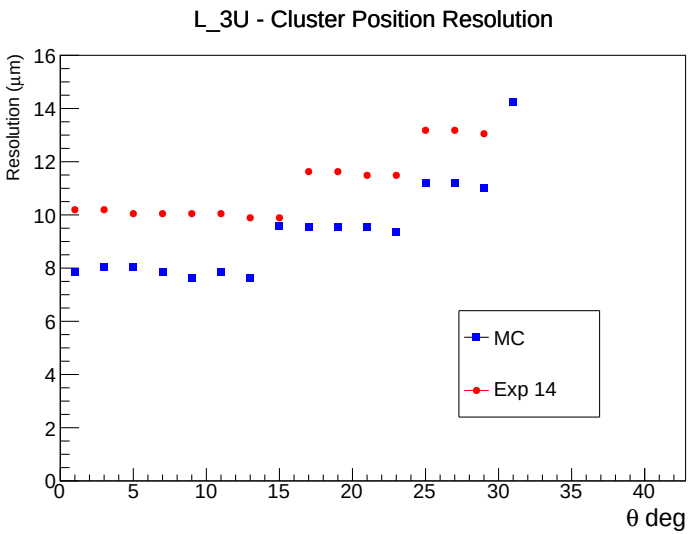

Figure –

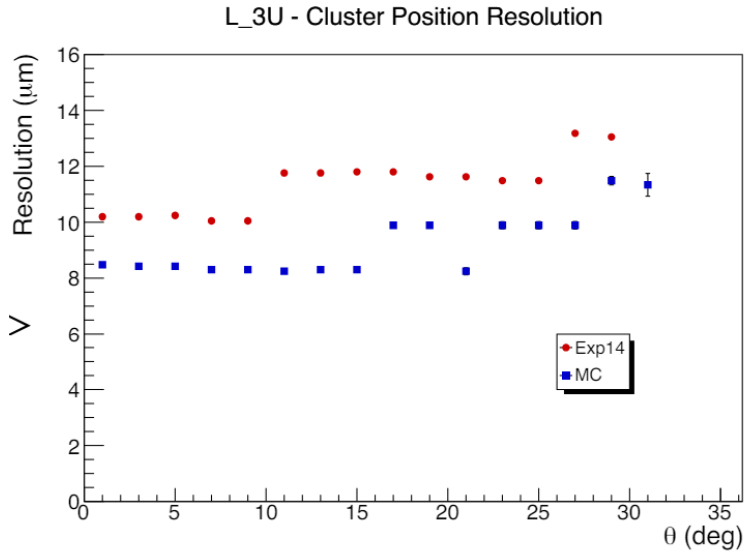

Figure – M.Finck's Curve

- The error bar should increase going further in the angle of detection. Nevertheless, for our simulation, we had a problem with it because of the error bar decreased instead of increase. Giving as a final error around 10^{-3}.

Graph Layer5U

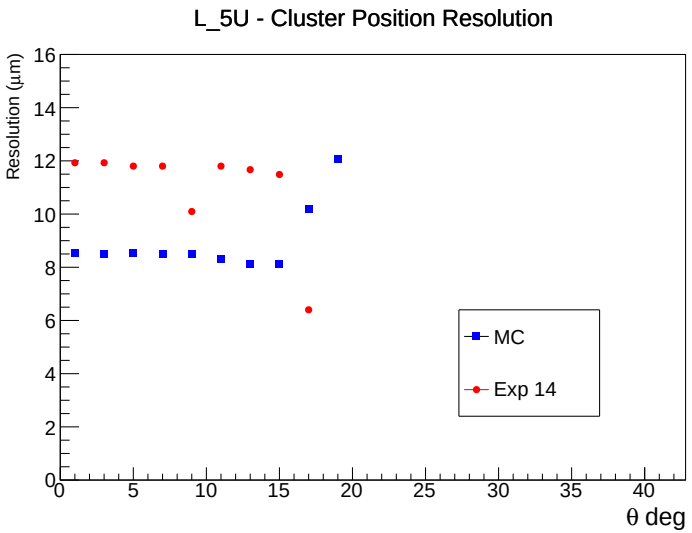

Figure –

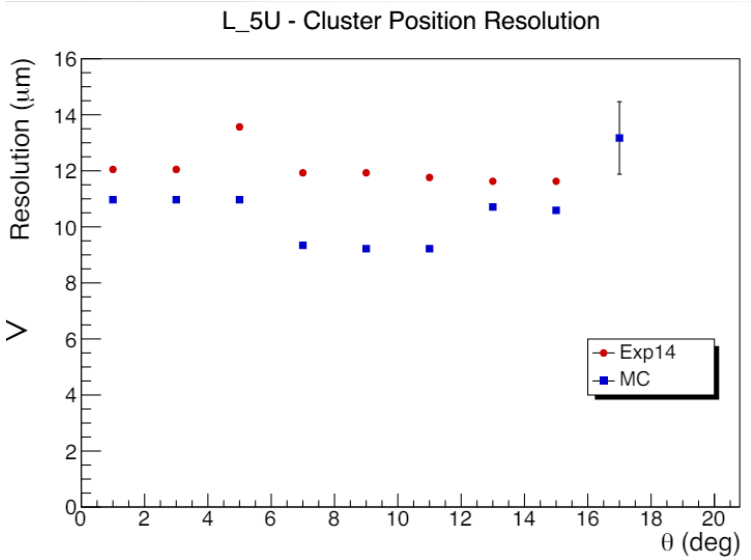

Figure – M.Finck's curve

- Better stability in simulation
- Bigger Fluctuation in theoretical curve

Graph Layer3V

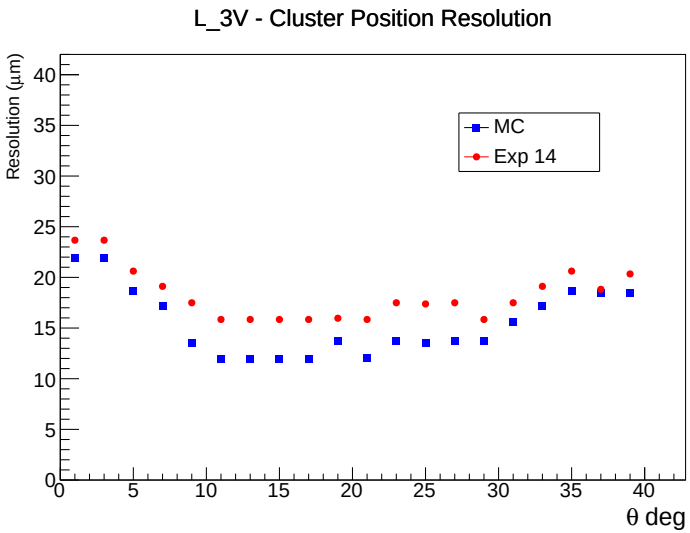

Figure –

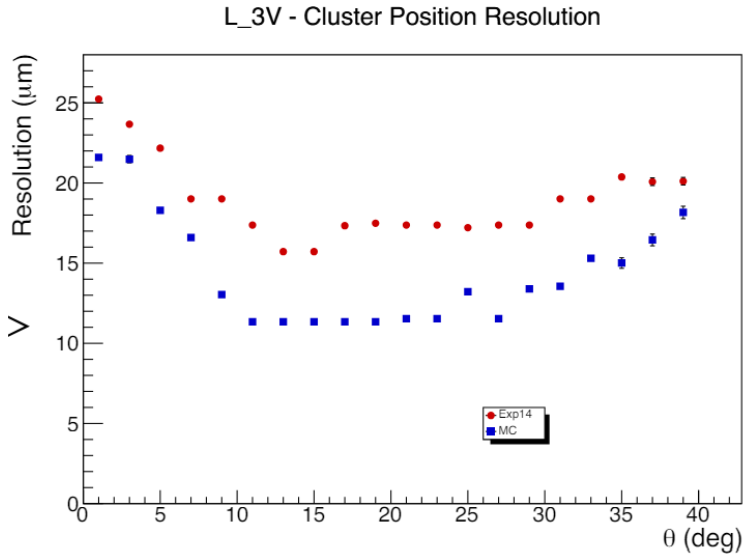

Figure – M.Finck's curve

- Smoothest approximation with the new simulations.

Graph Layer6V

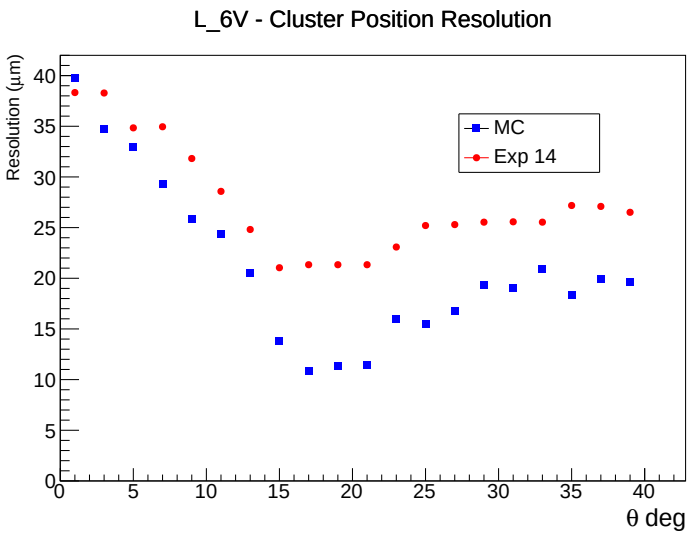

Figure –

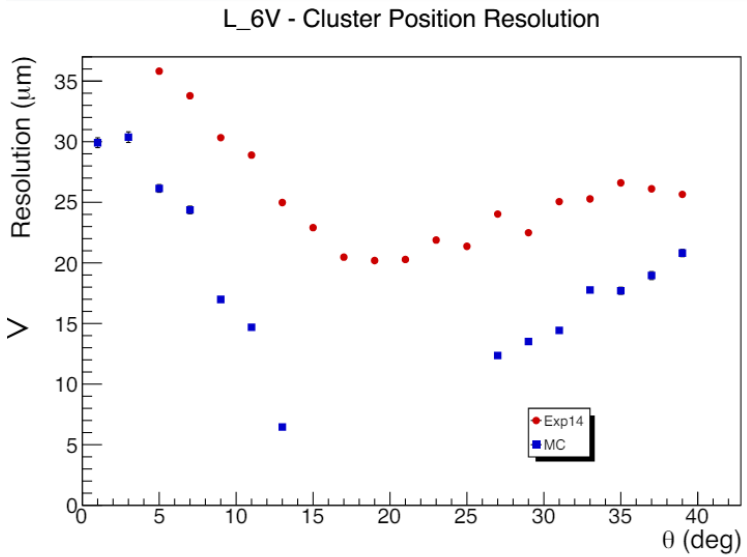

Figure – M.Finck's curve

- In new simulation, there is no the fall in the middle, giving us a better estimation in simulation.

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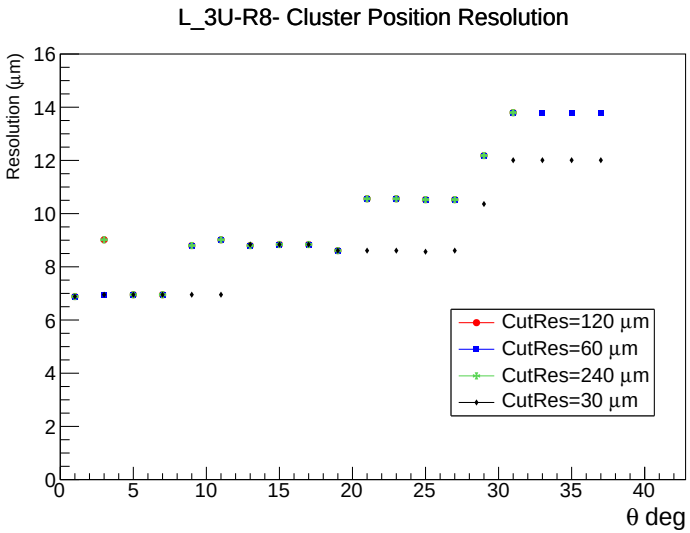
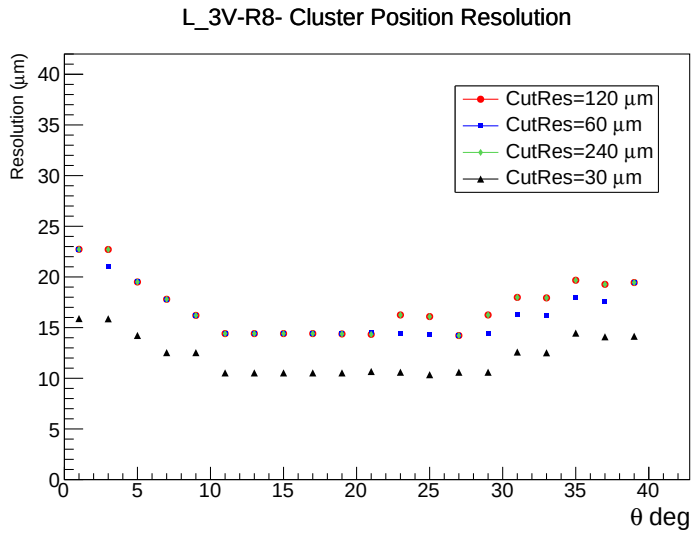
Change of Cut Res

- We've done all the simulation on layer 3 and release 8.
- different values of the cutRes 30 μm, 60μm, 120μm and 240μm





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Conclusion 1

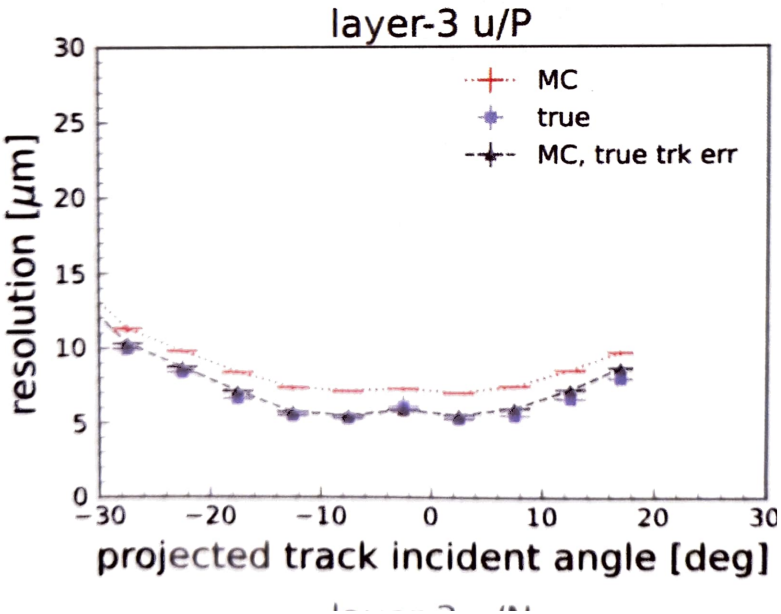


Figure – **Image taken from Belle2-NOTE-TE-2022-005**

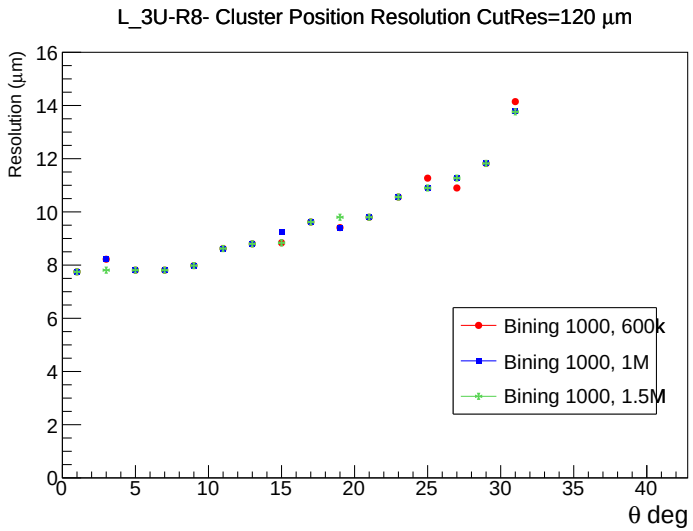
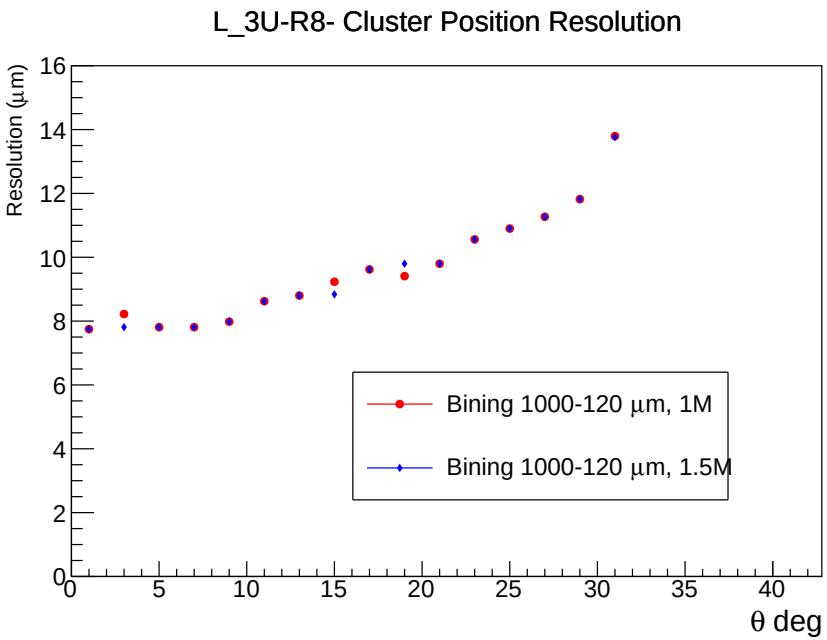


Figure –

- We decided to do a change of binning in the simulation to try to lift the stairs shape.
- Comparing the figure 7, we are ables to see the new evolution it sticks to theory.

Conclusion 2



- Changing the events values for simulations, it give us, obviously, different execution's times.
  - 40 minutes for 600.000
  - 3 hours for 1.000.000
  - 9 hours for 1.500.000
- There exist other ways to optimize the program ?
  - Passing through other language, C++ ?

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References

https ://web2.infn.it/Belle-II/index.php/detector/svd

Leboucher, R., Adamczyk, K., Aggarwal, L., Aihara, H., Aziz, T., Bacher, S., ... & Belle-II SVD Collaboration. (2022). Measurement of the cluster position resolution of the Belle II Silicon Vertex Detector. Nuclear Instruments and Methods in Physics Research Section A : Accelerators, Spectrometers, Detectors and Associated Equipment, 1033, 166746.

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