Precision Material Studies using Radiation Length Imaging for the Belle II Vertex Detectors

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WNPPC
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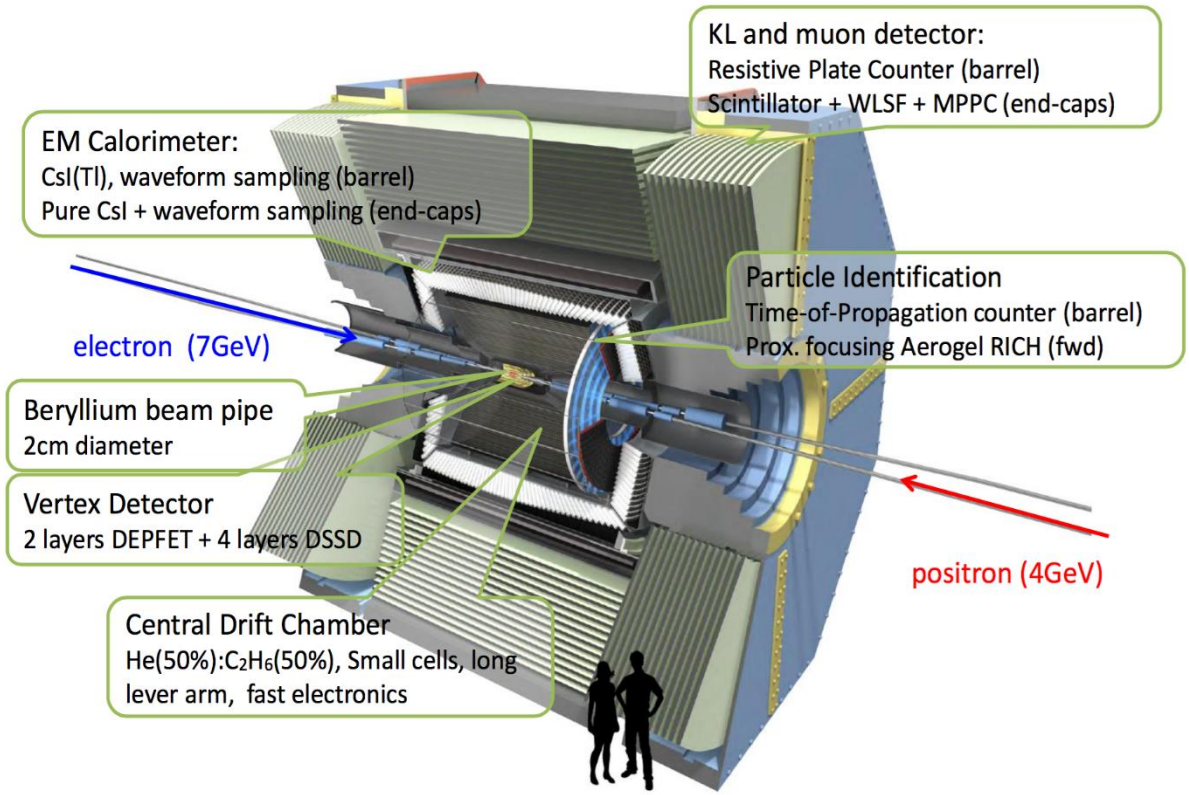
Belle II Overview



- Electron-positron collider experiment currently being commissioned at KEK lab in Japan; full detector expected to be online late 2018
- Upgrade to Belle experiment with 40x luminosity
- B-factory: physics goals include precision tests for SM and searches for BSM particles

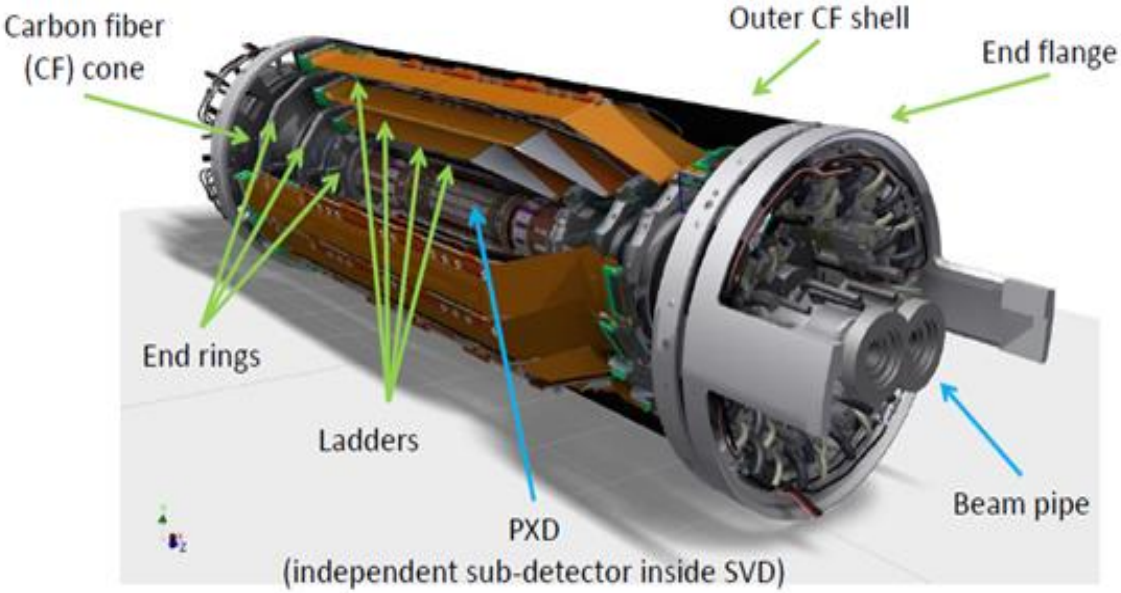
Introduction

- **Motivation:** detector's measurement quality depends on material distribution
  - Extra material causes scattering and degrades momentum resolution
  - Vertex resolution depends heavily on material model

    →Material impacts track reconstruction e.g. for 1 GeV/c electron, 1% material difference corresponds to spatial scattering angle of.25^{o} [Lubej et al.]
  - Need model validation until collision data is available
- **Objective:** compare material profile from radiation length (X/X_o) images of vertex detectors with simulation and identify discrepancies to improve it

Pixel Vertex Detector (PXD) and Silicon Vertex Detector (SVD)

- Detectors closest to the interaction point (IP)
- Used to identify the position of the decay vertex; enable the reconstruction software to find vertices by providing precise hit information very close to IP.
- Consists of *ladders* with semiconductor-based sensors that record hit and timing information
- Ladders assembled in a cylinder around the IP; 2 layers for PXD, 4 for SVD



Courtesy:
Chris
Schwanda

Methodology: Radiation Length (X/X_o) Imaging

Idea: Create 2D material profiles by using multi GeV test beam on detector components and reconstruct multiple scattering angles from charged particle tracks [ArXiv:1609.02402]

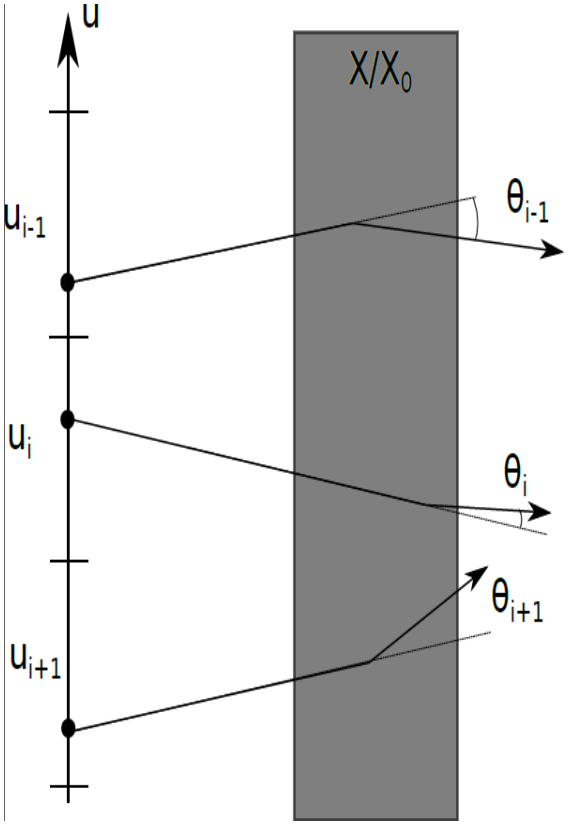
- material content measured in X_o : the mean distance over which an electron loses all but 1/e of its energy by bremsstrahlung

- scattering angles associated with a set of tracks are grouped together; width of angular distribution is proportional to radiation length in that region:

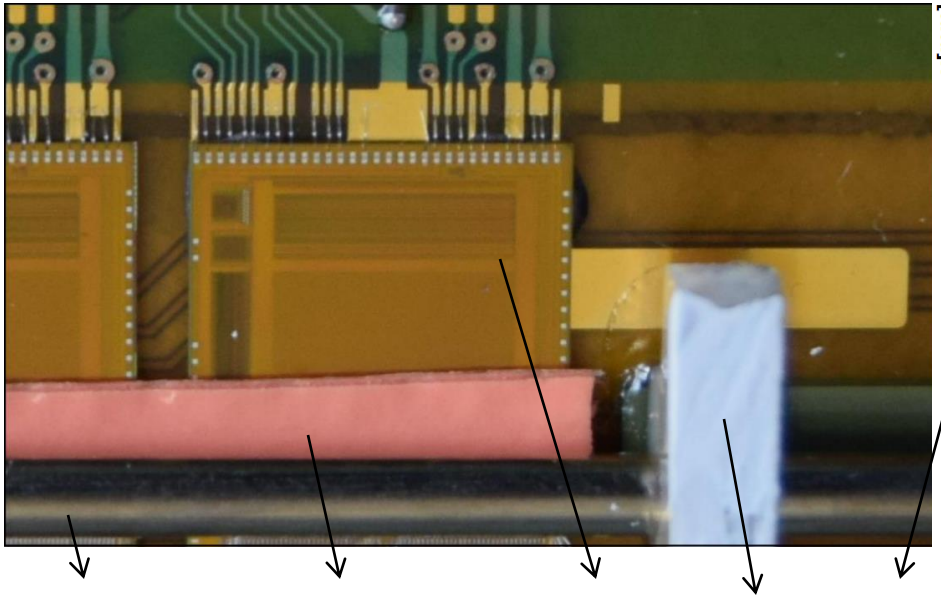
$$\theta \propto \sqrt{\frac{X}{X_0}}$$

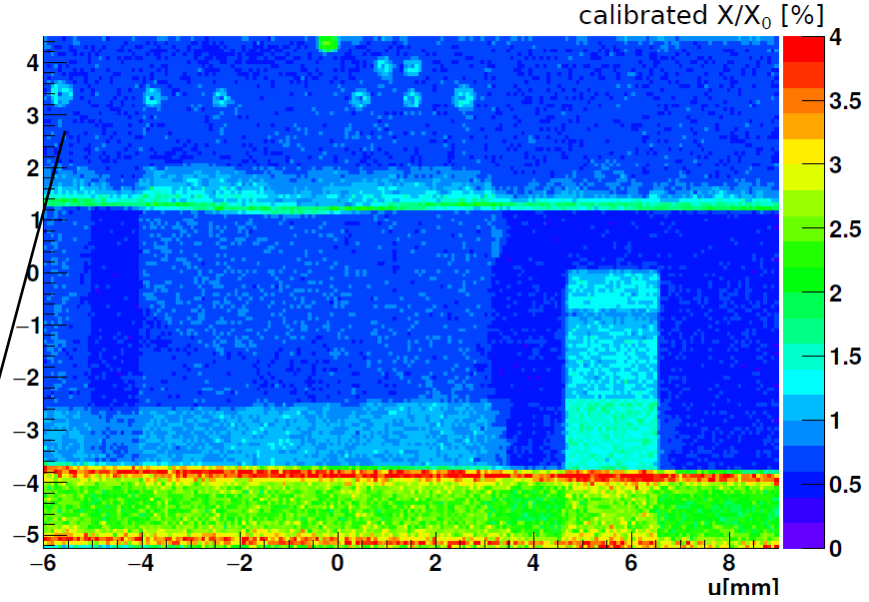
- radiation length extracted by fitting the angular distribution of each region to Highland's multiple scattering model [1]

- 4 GeV electron beam used at DESY; measurement conducted with AIDA tracking telescope [2]



X/X_0 Imaging: SVD ladder





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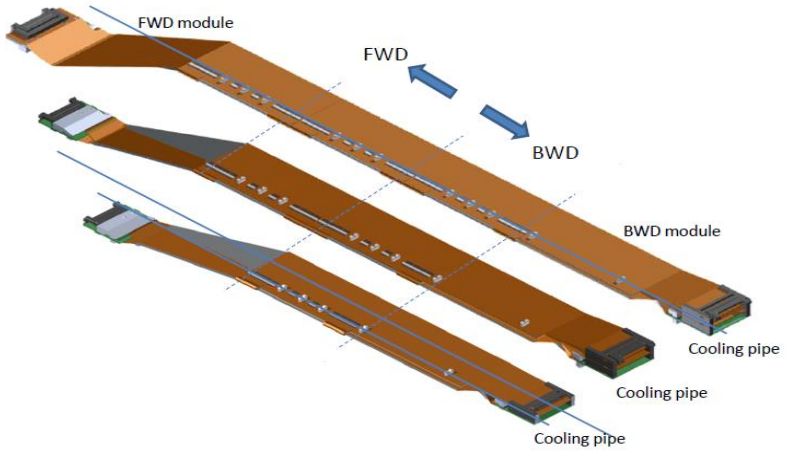
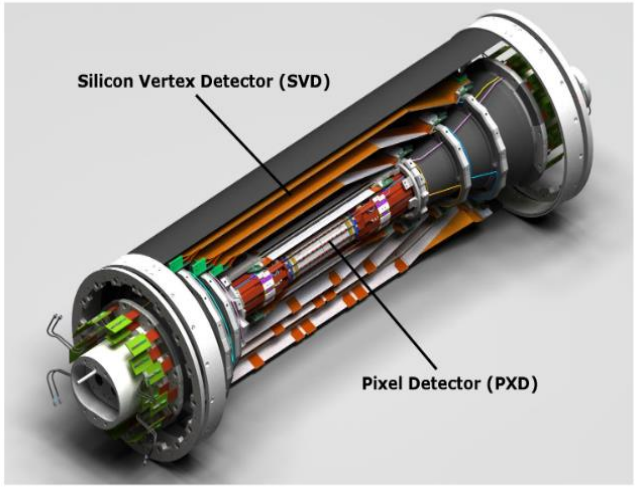
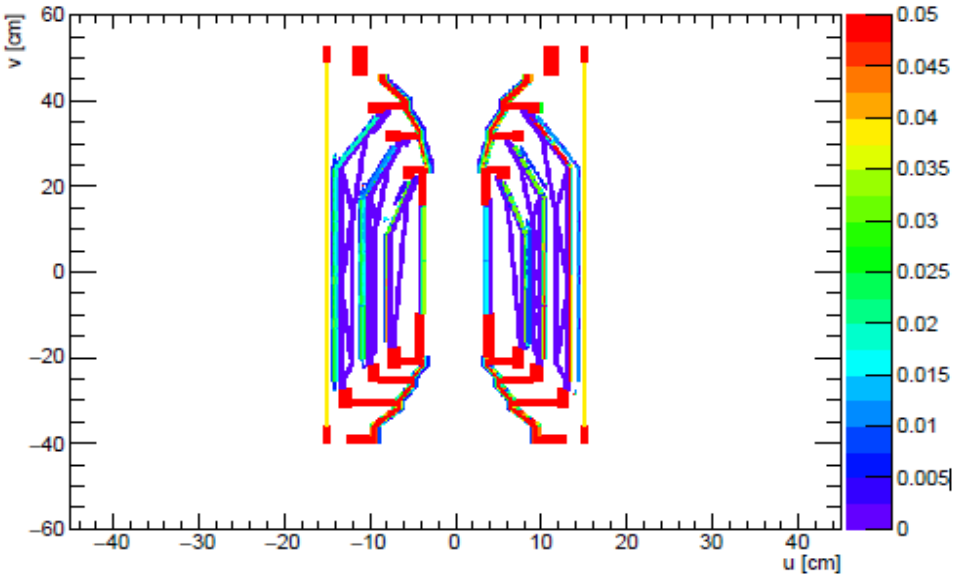


Methodology: Material Scan in Belle-II software (basf2)

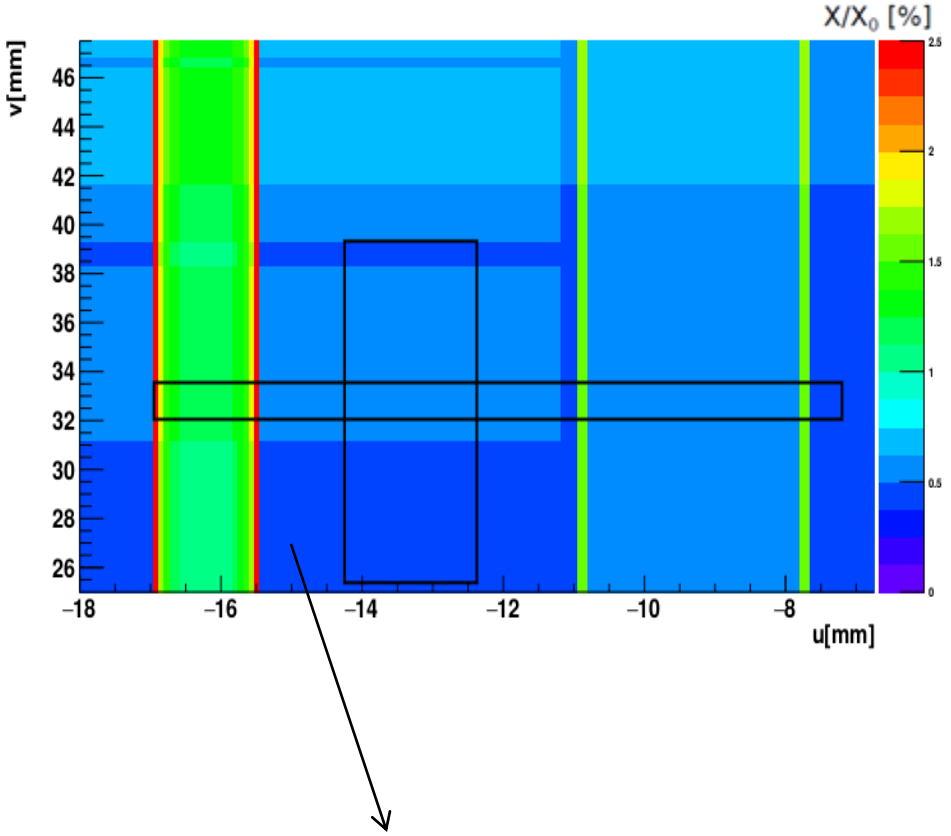
- Simulation creates fictitious particles called geantinos
- Non-interacting particles -> amount of material they traverse is computed by simulation
- ‘Particle gun’ shoots geantinos around the detector and creates a 2D profile of the material ‘seen’ by the particle

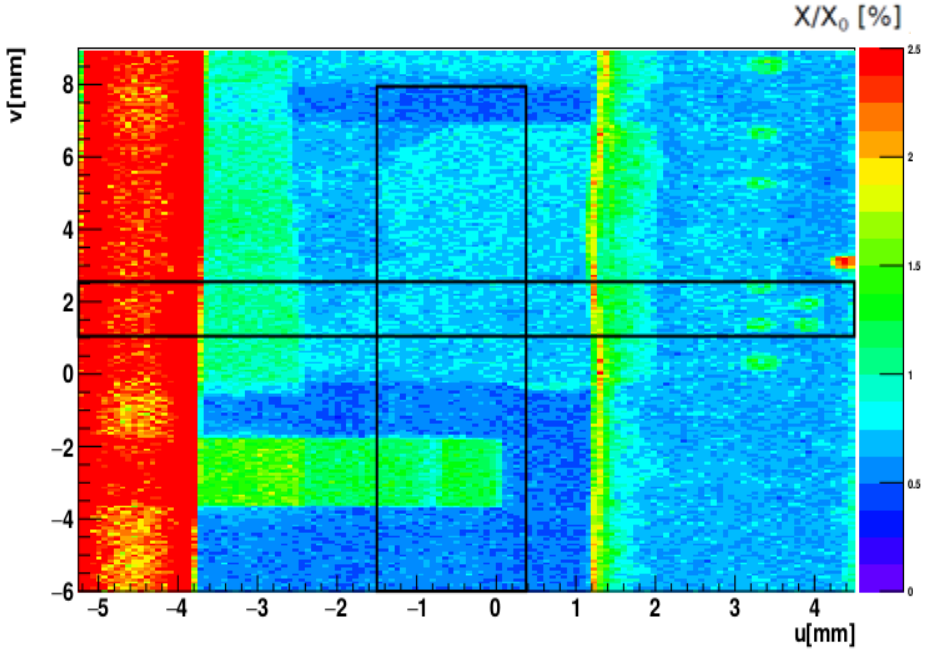




Material Scan of SVD in the XZ plane

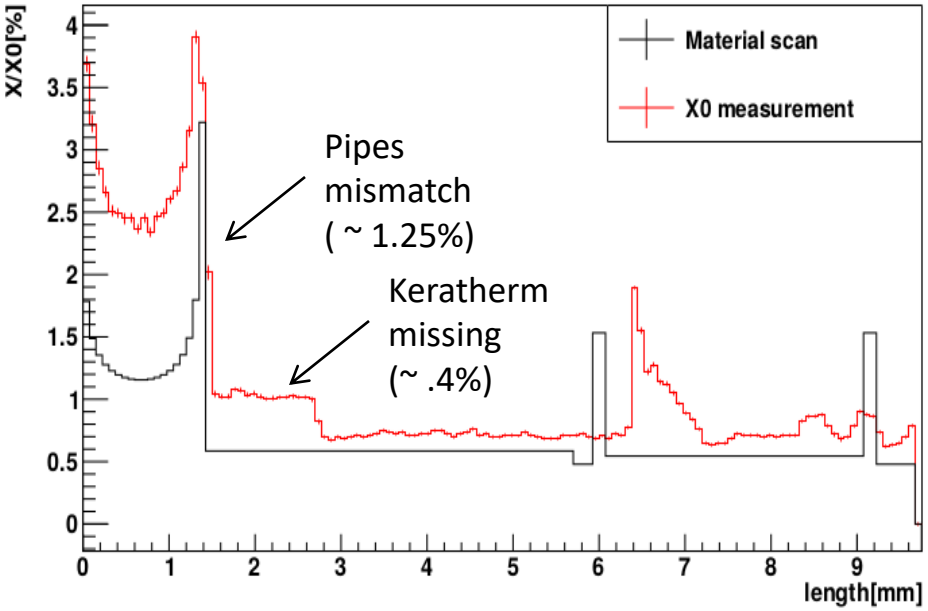
SVD Material Scan Vs X/X_o



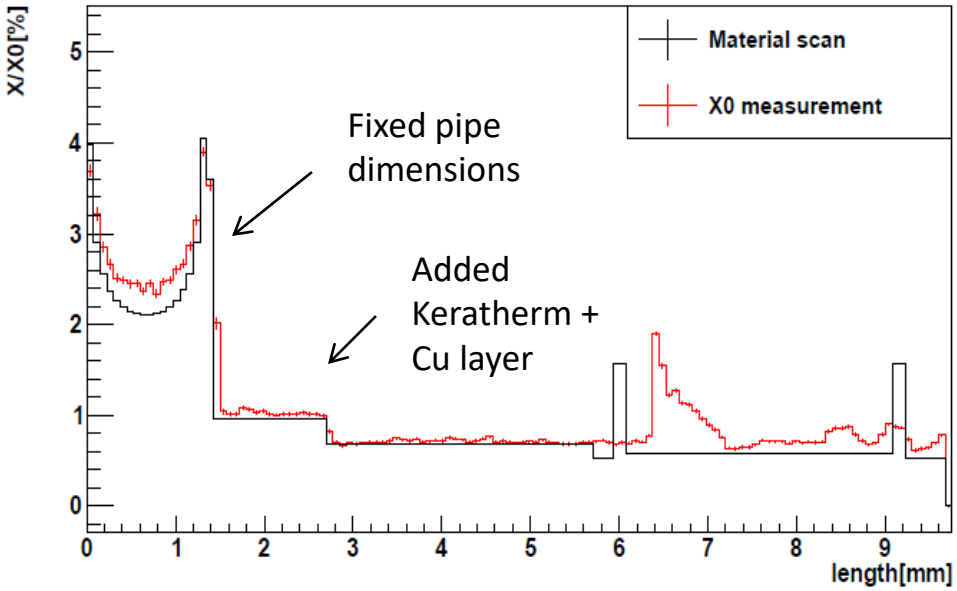


Differences: cooling pipe material, clamps, keratherm, copper layer, vias

SVD Material Scan Vs X/X_o – u profile

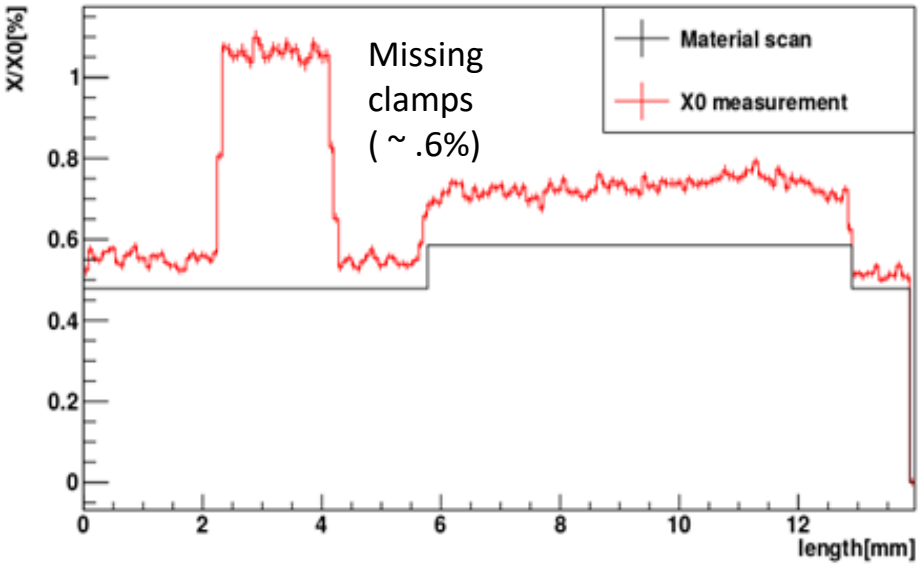


Before

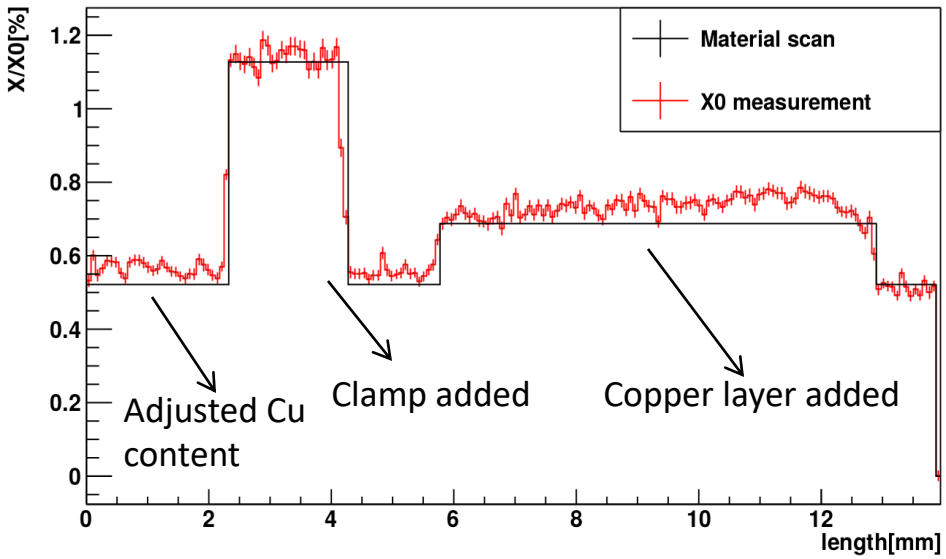


After Improvements

SVD Material Scan Vs X/X_o – v profile

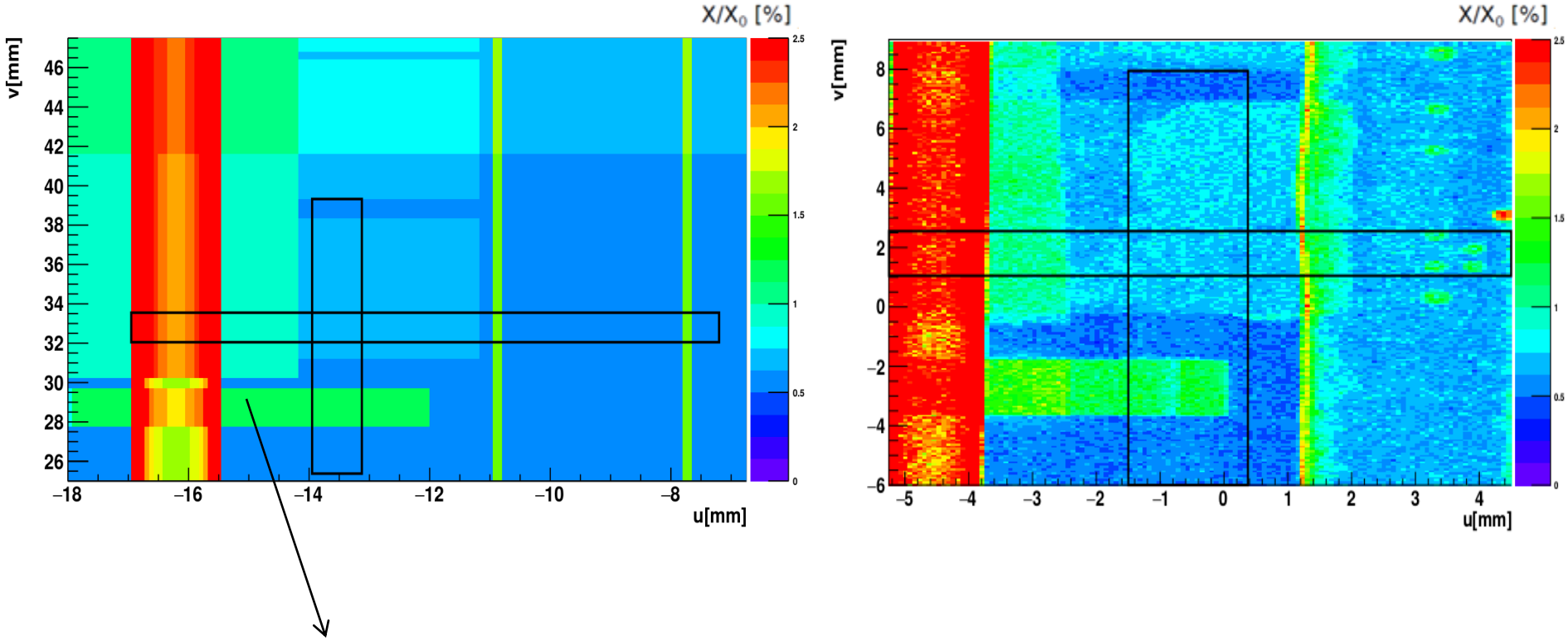


Before



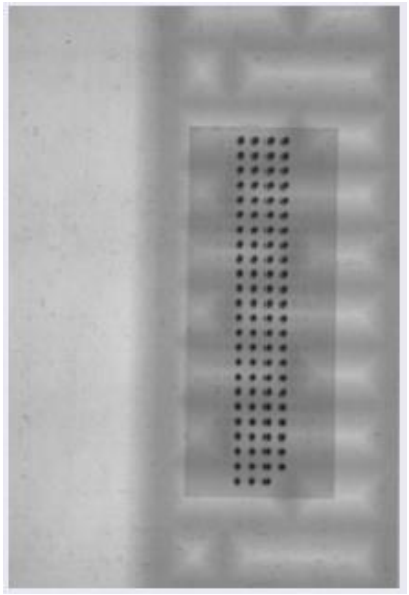
After Improvements

SVD Material Scan Vs X/X_o– improved model

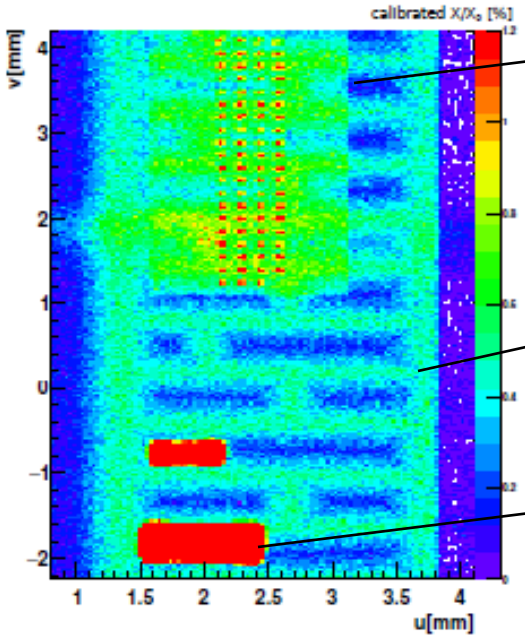


Added: clamp, keratherm, copper layer, fixed pipe dimensions

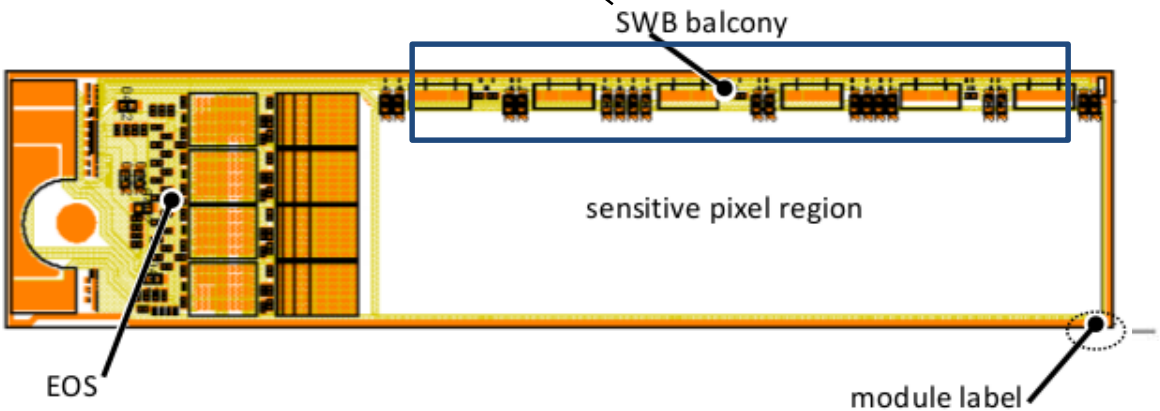
X/X_o Imaging of PXD Half-Ladder module



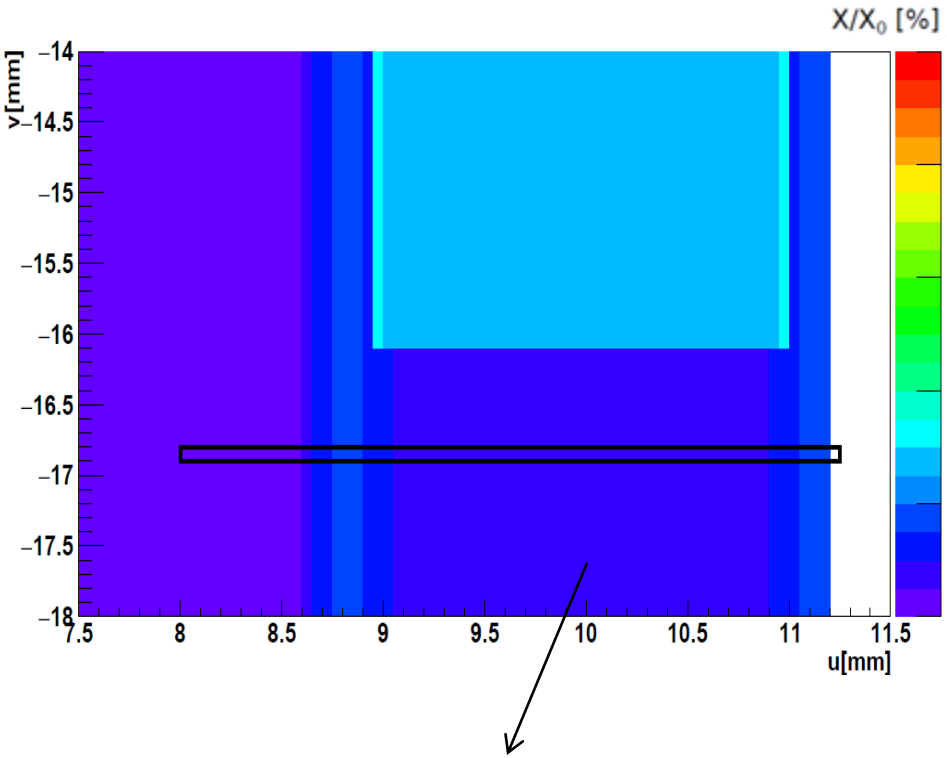
X-ray image of PXD ladder, balcony region

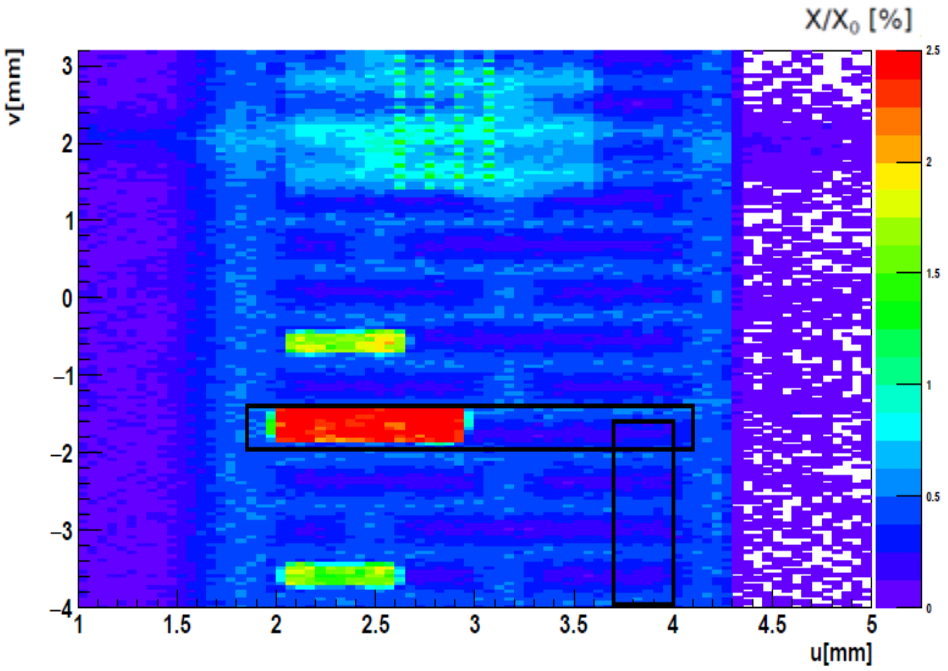


X/X0 image of PXD ladder, balcony region



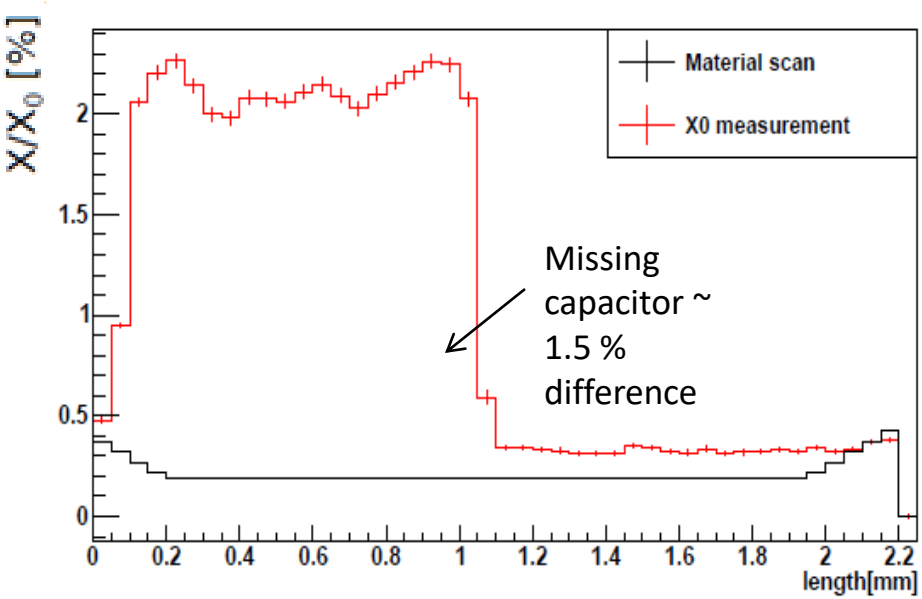
PXD Ladder, Balcony region: MaterialScan Vs. X/X_o





Differences: capacitors, groove profile, bump bonds in switcher

PXD Material Scan Vs. X/X_o – u profile



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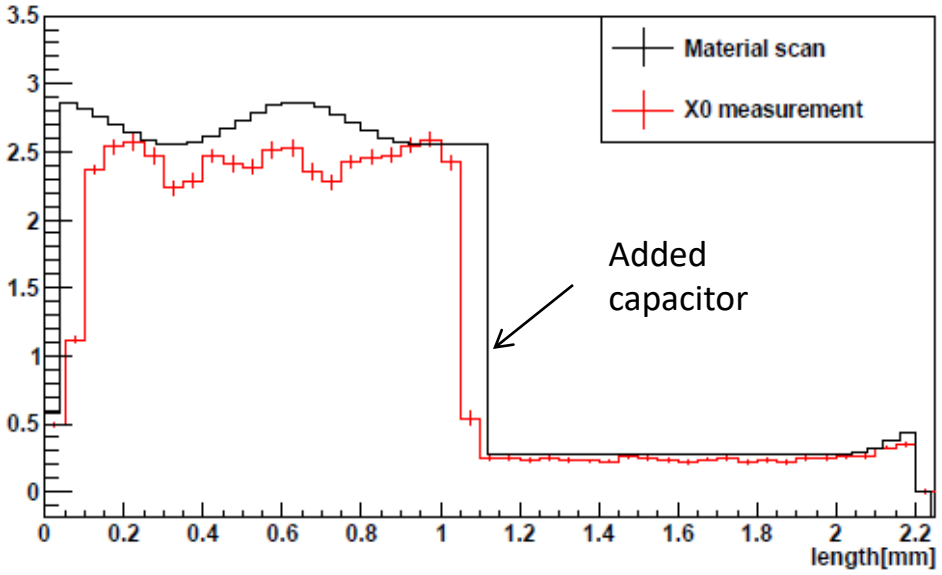
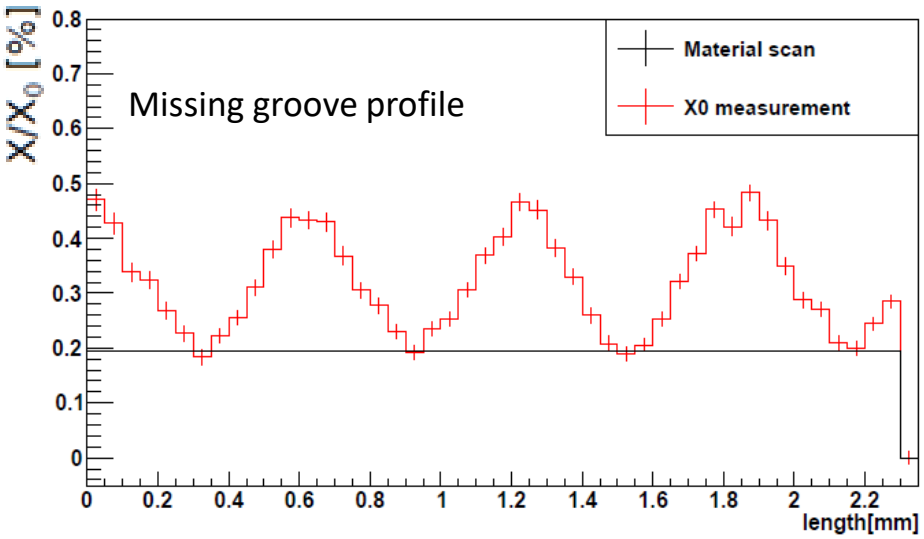
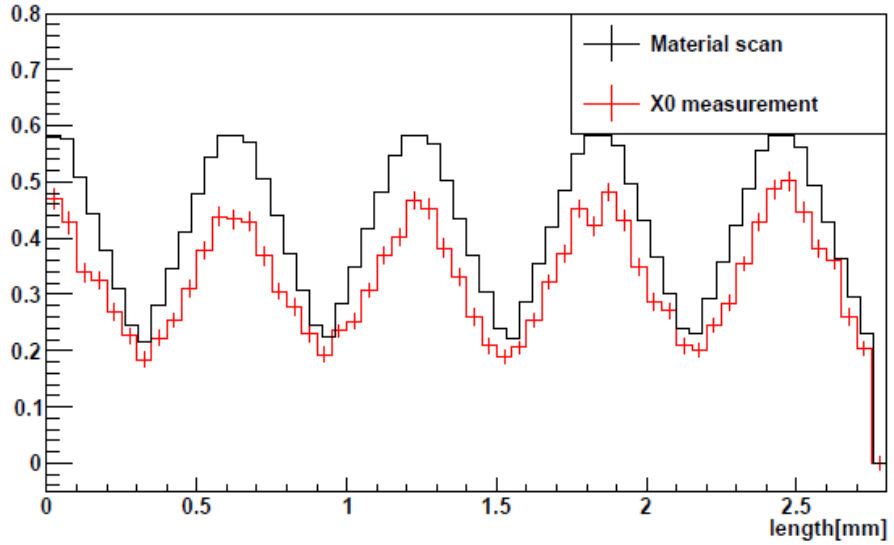


After Improvements

PXD Material Scan Vs. X/X_o – v profile

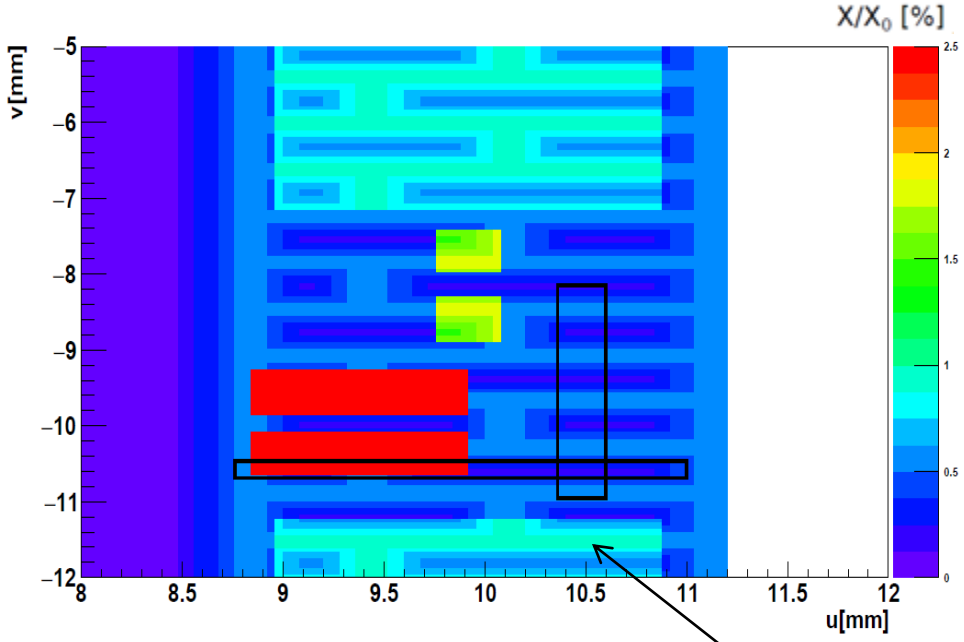


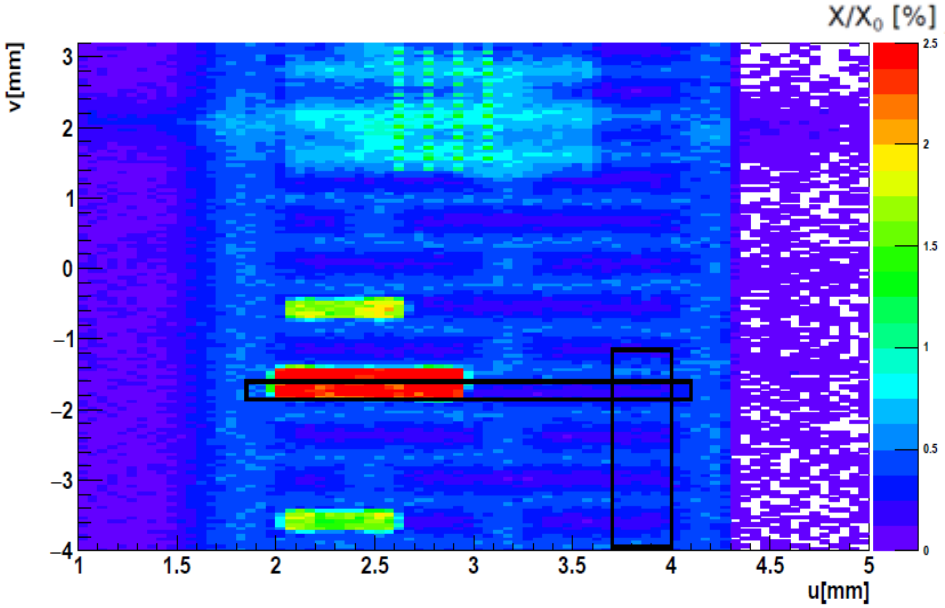


Before

After Improvements

PXD Ladder, Balcony region: Material Scan Vs. X/X_o – improved model





Added: capacitors, groove profile

Summary of PXD/SVD Studies

-> Improved Belle-II material simulation through precision material studies

-> New components added:

PXD: capacitors, grooves, fixed dimensions

SVD: keratherm, clamp, copper layer, fixed dimensions

-> Better agreement with actual detector material profile

Future Prospects

- Work in progress – addition of new parts still being validated and improved to match the real detector
- Once data taking starts, more validation can be performed using photon conversion studies in the real detector
- X/X_o imaging approach is not limited to vertex detectors. Other groups are using it to measure X/X_o for various glues, support materials and even FPGA boards at Belle-II.

The End

Thank you!

References

- Radiation Length Imaging Using High Resolution telescopes http://arxiv.org/abs/1609.02402
- M. Lubej,B.Golob. Belle2 Note: Amount of material in Belle-II Simulation, 2012.