Faculté de **physique et ingénierie**
Université de Strasbourg

CHARACTERIZATION OF DETECTORS FOR THE INNER TRACKING SYSTEM OF THE ALICE EXPERIMENT ON THE LHC

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Master thesis supervised by Felix Reidt and Boris Hippolyte | June 13, 2017

OUTLINE

1. ALICE ITS upgrade

- ALICE collaboration
- Current detector and ITS
- Upgrade motivations
- ITS upgrade layout
- ALPIDE pixel chip

2. Test beam framework

- Test beam setup
- One telescope plane
- Analysis software

3. Analysis steps

- Efficiency profile
- Multiple scattering
- Pixel response from data
- Pixel response model

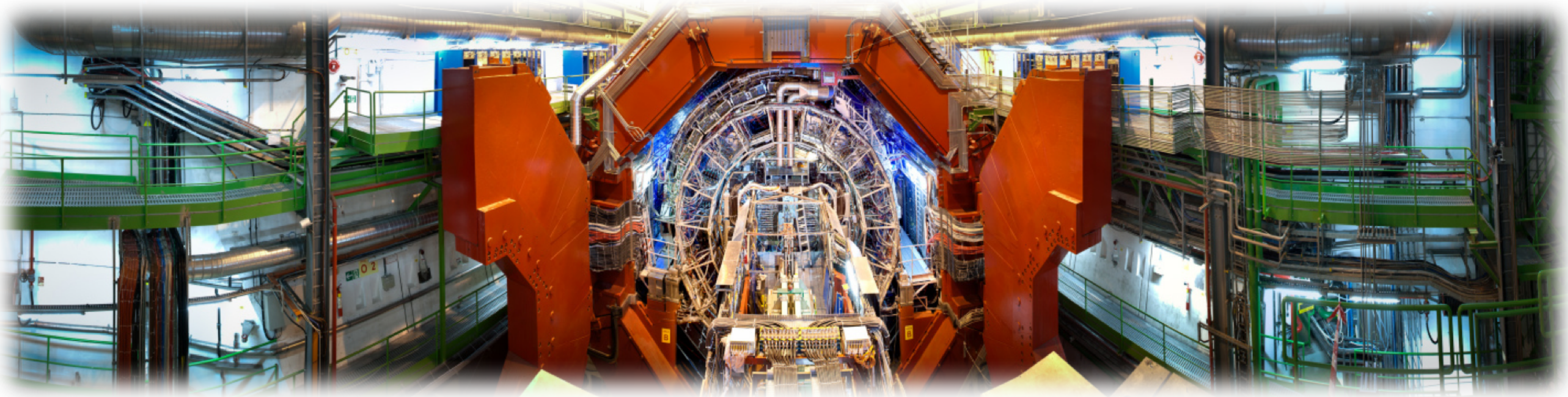
4. Pixel matrix edge

5. Dead double column

Conclusion & outlooks

1 ALICE ITS UPGRADE

1.1 ALICE collaboration

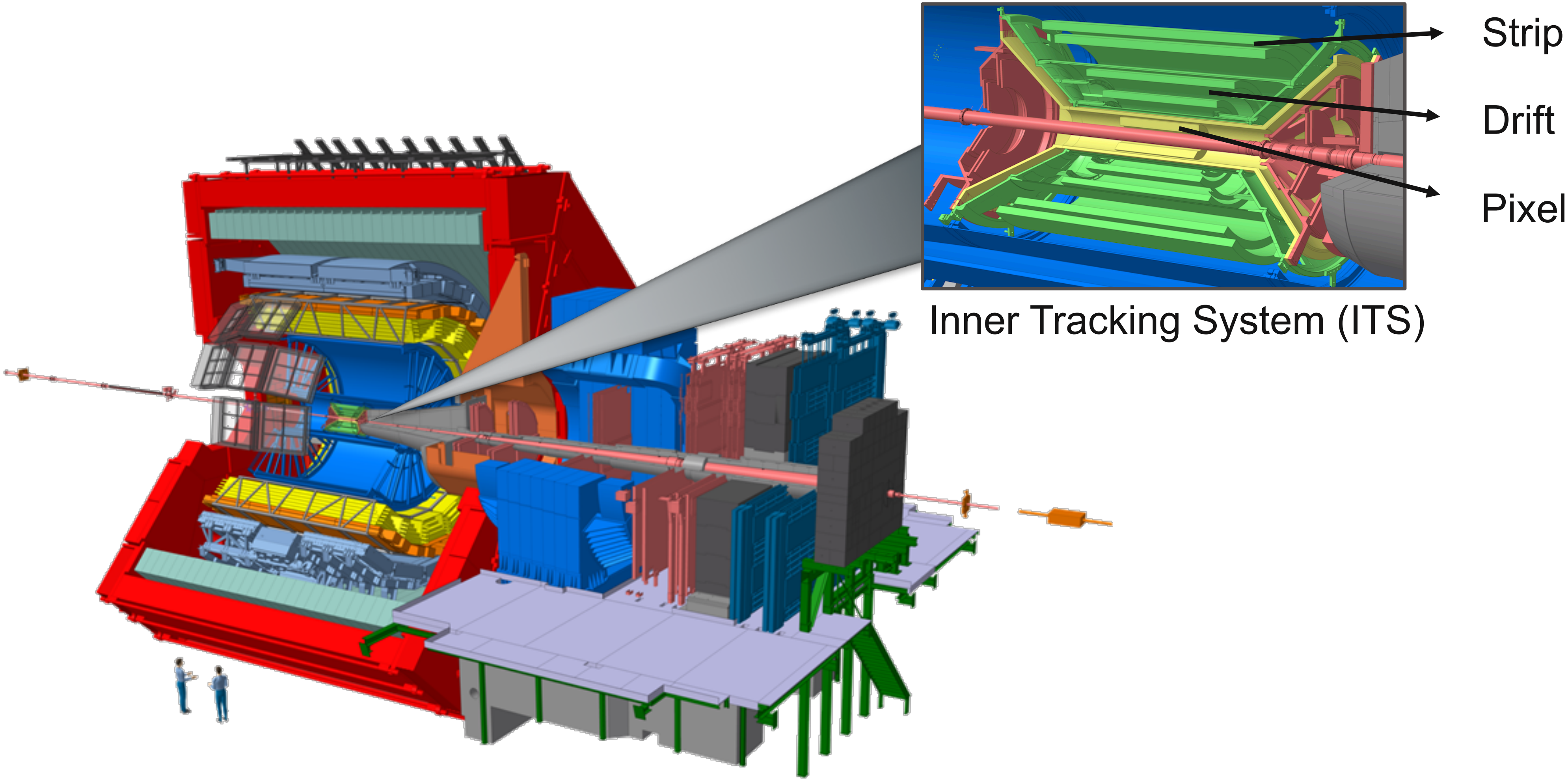


ALICE = A Large Ion Collider Experiment

- International collaboration
- 1800 members – 174 institutes – 42 countries
- Studying Quantum Chromodynamics (QCD) and Quark-Gluon Plasma (QGP)
- Experiment at the Large Hadron Collider (LHC) at CERN

1 ALICE ITS UPGRADE

1.2 Current Inner Tracking System



1 ALICE ITS UPGRADE

1.3 Upgrade motivations

ALICE physics program:

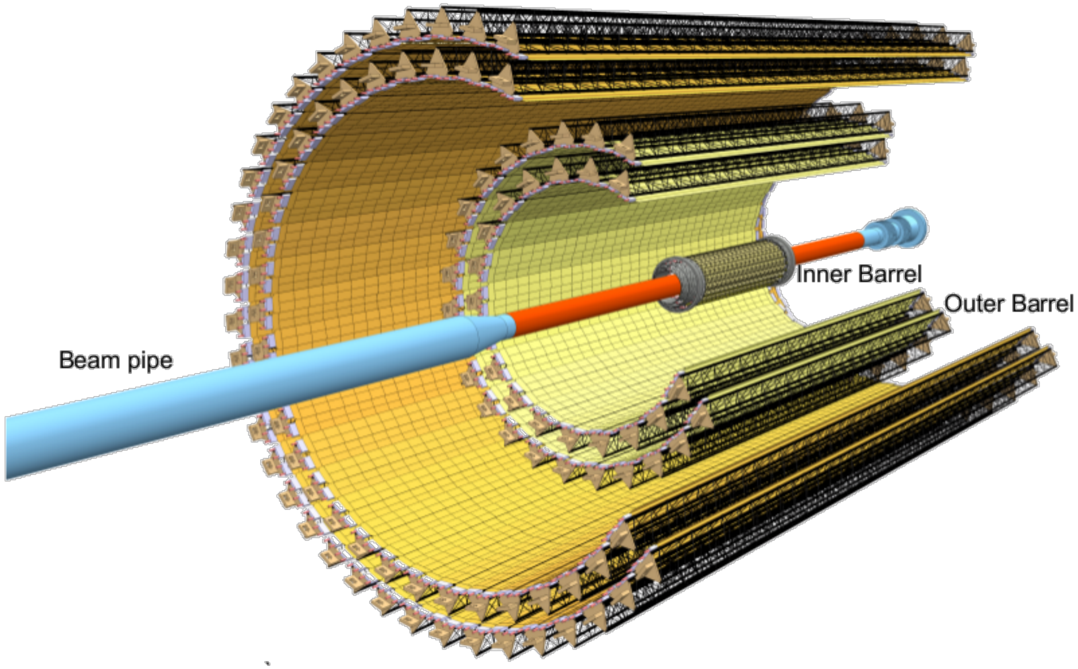
- Thermalization and hadronization of charm and beauty in QGP
- In-medium (QGP) parton energy loss
- Quarkonia dissociation

ITS upgrade goals:

- Highly efficient tracking with special emphasis on very low momenta.
- Very precise reconstruction of secondary vertices from decaying charm and beauty hadrons.

1 ALICE ITS UPGRADE

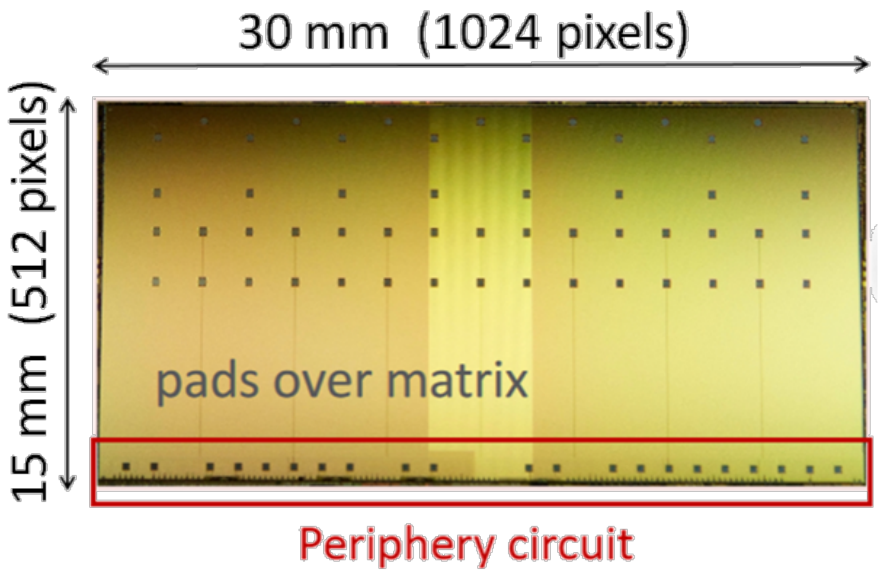
1.4 ITS upgrade layout

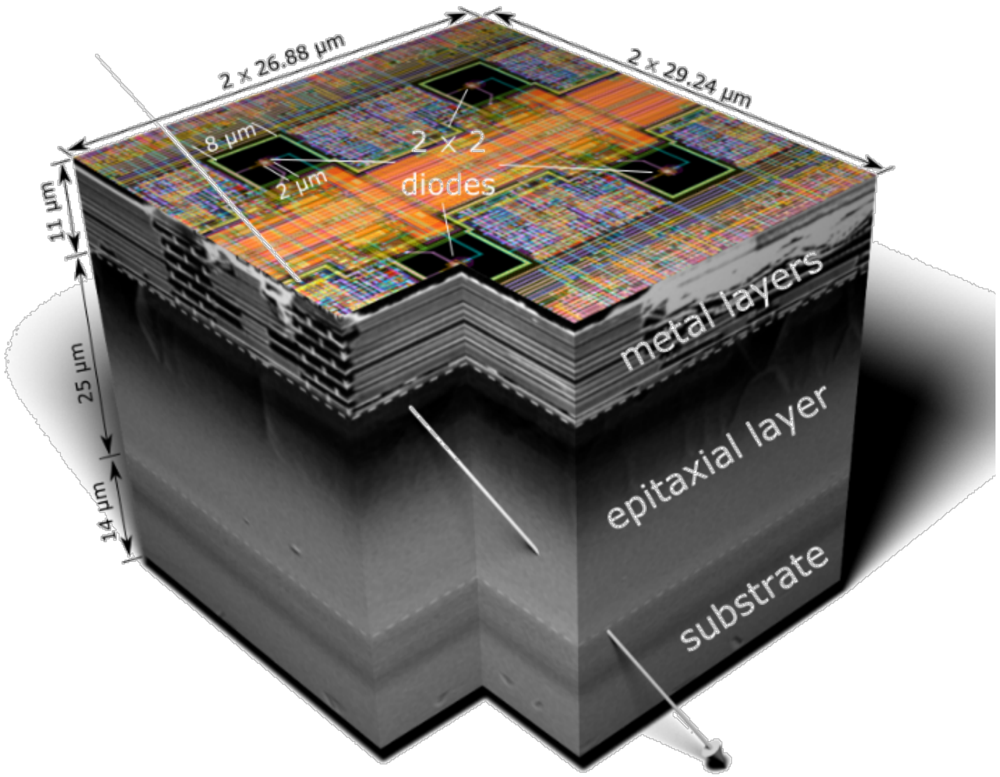


- Beam pipe diameter
  29.8 mm → 19.2 mm
- First detection layer
  39 mm → 22 mm
- Number of layers
  6 → 7
- Silicon pixel sensors
  resolution: 5 μm
- Read out rate
  1kHz → 50 kHz (Pb-Pb)
  200 kHz (p-p)
- Low material budget

1 ALICE ITS UPGRADE

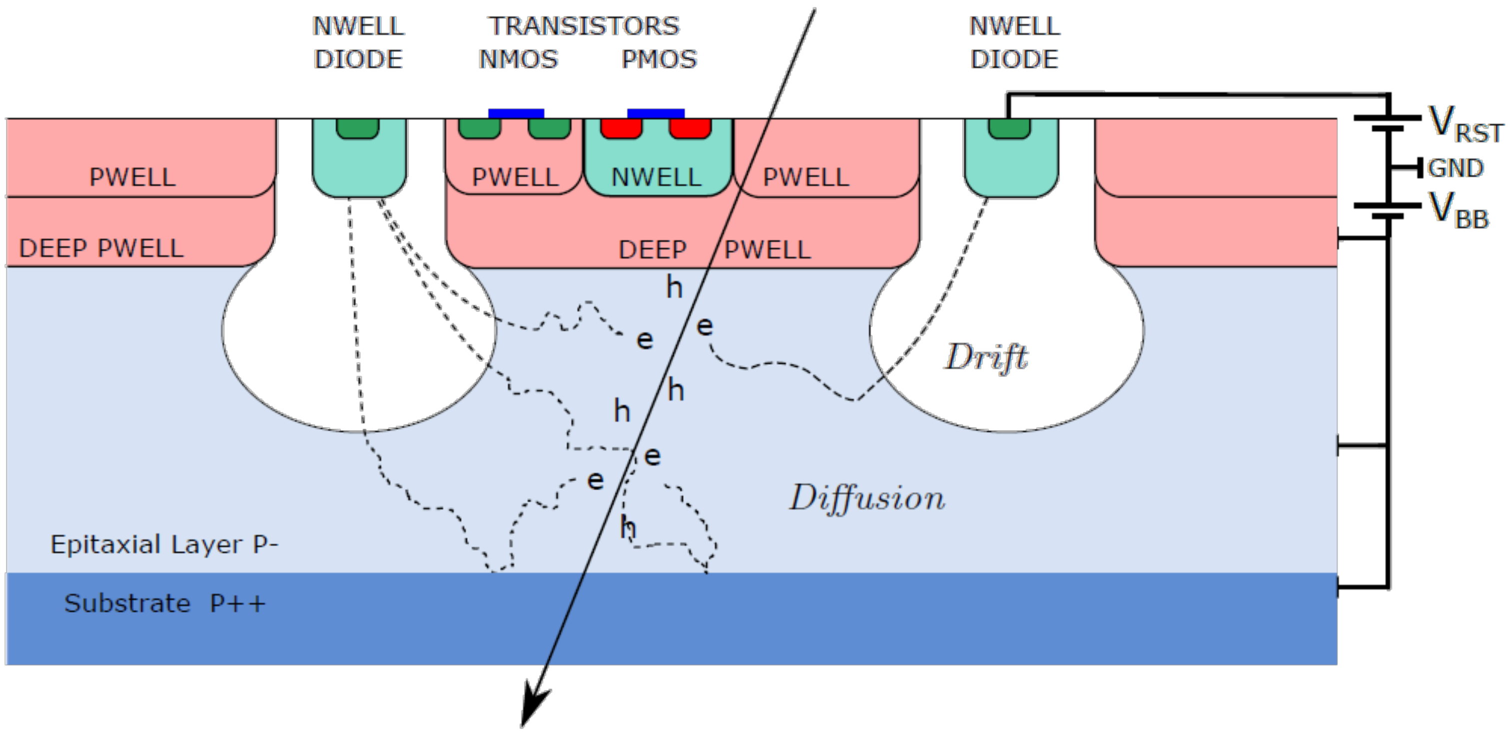
1.5 ALPIDE pixel chip





1 ALICE ITS UPGRADE

1.5 ALPIDE pixel chip – detection principle

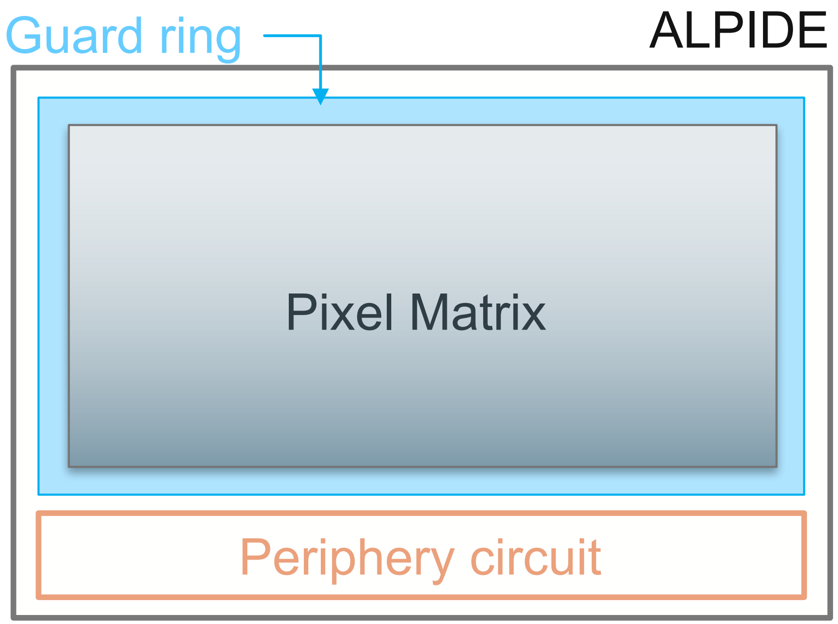


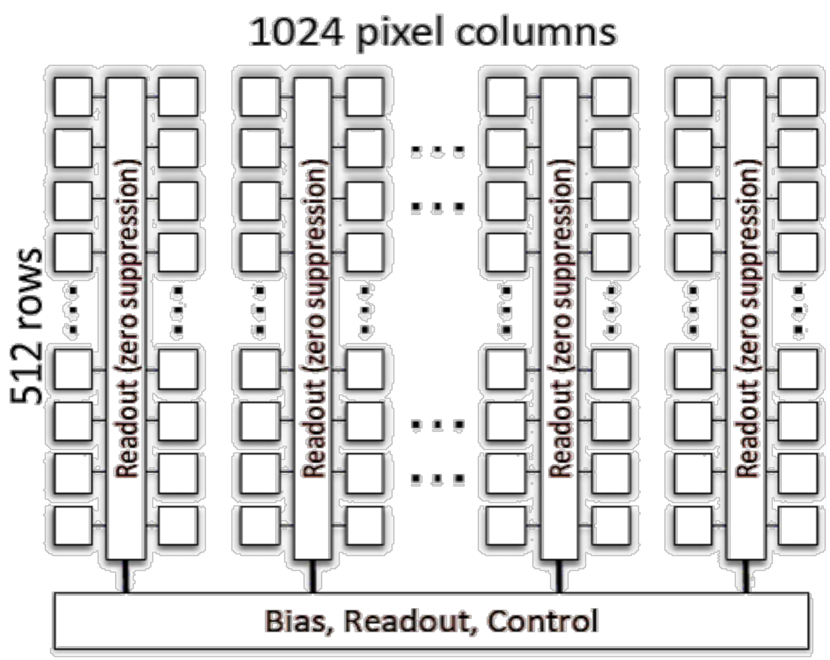
1 ALICE ITS UPGRADE

1.5 ALPIDE pixel chip – two important features

1. Guard ring

2. Double columns

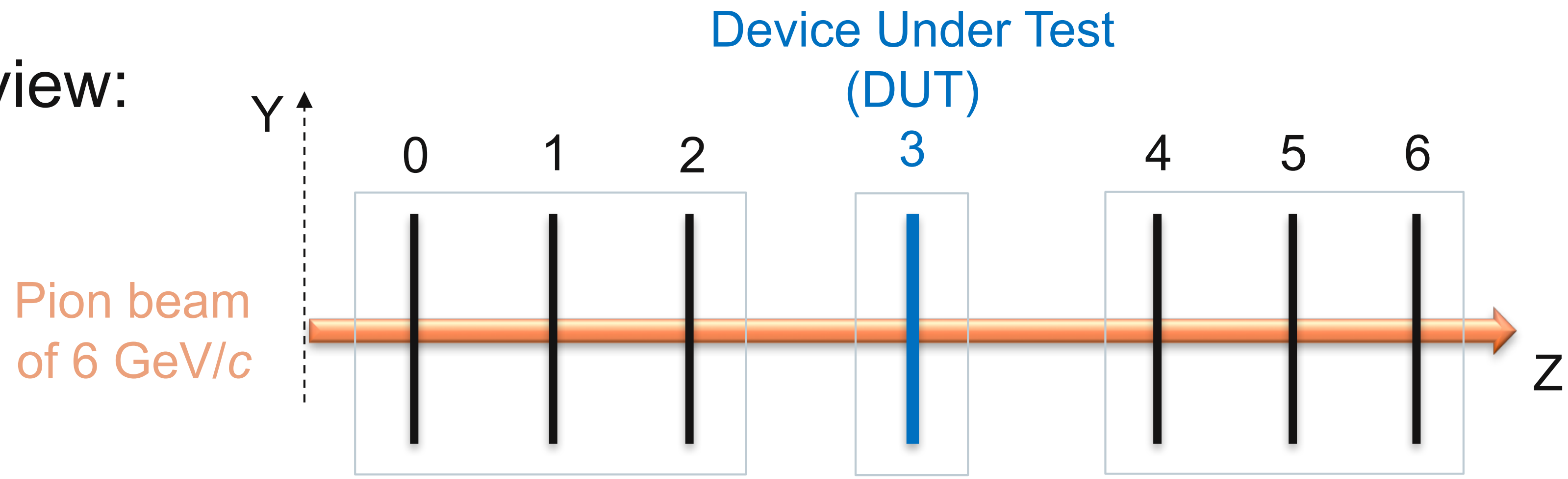




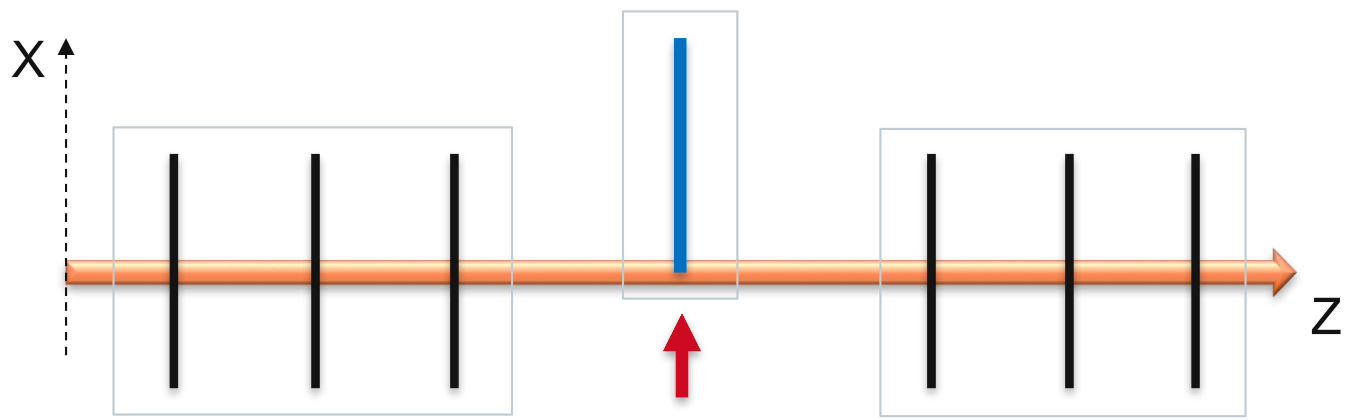
2 TEST BEAM FRAMEWORK

2.1 Test beam telescope

- Side view:

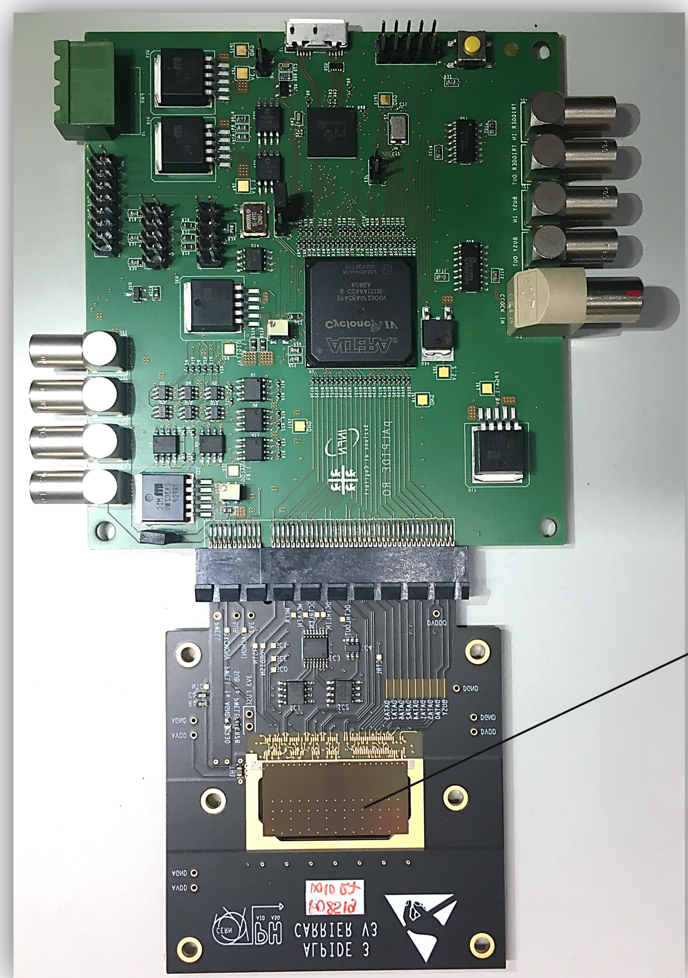


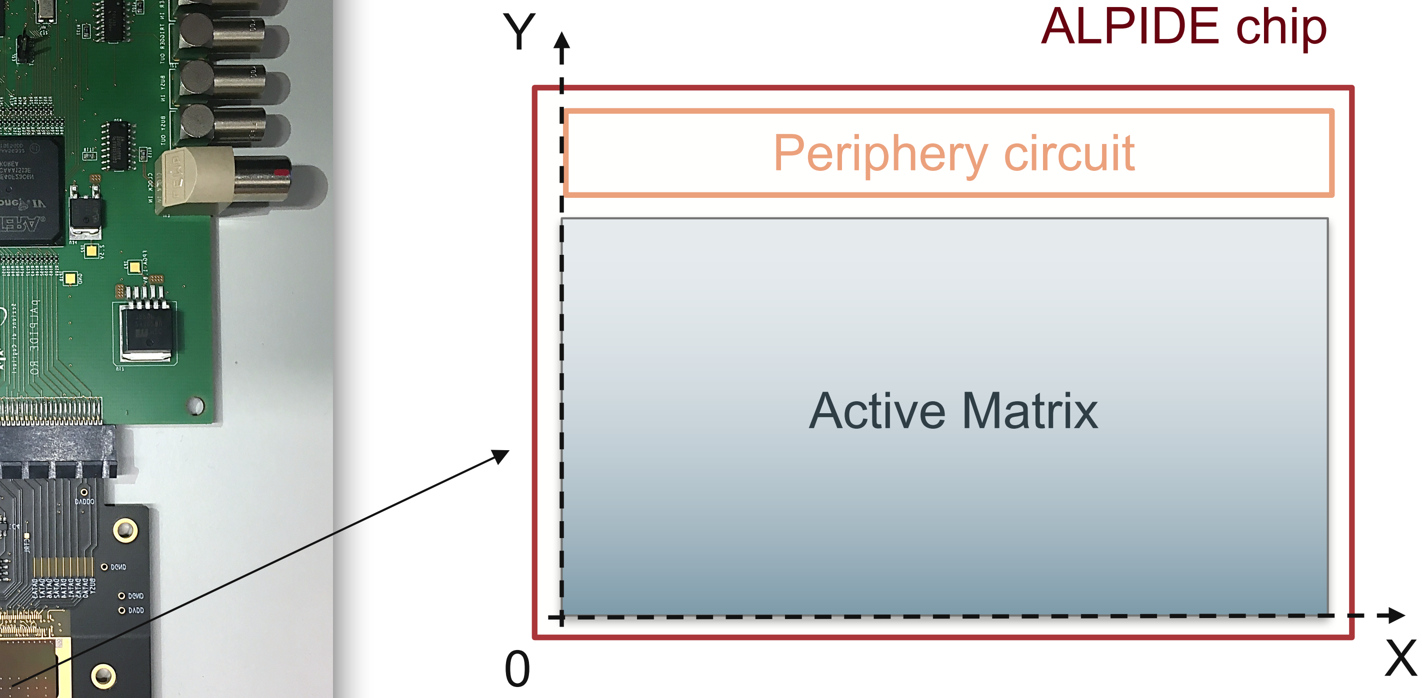
- Top view:



2 TEST BEAM FRAMEWORK

2.2 One telescope plane



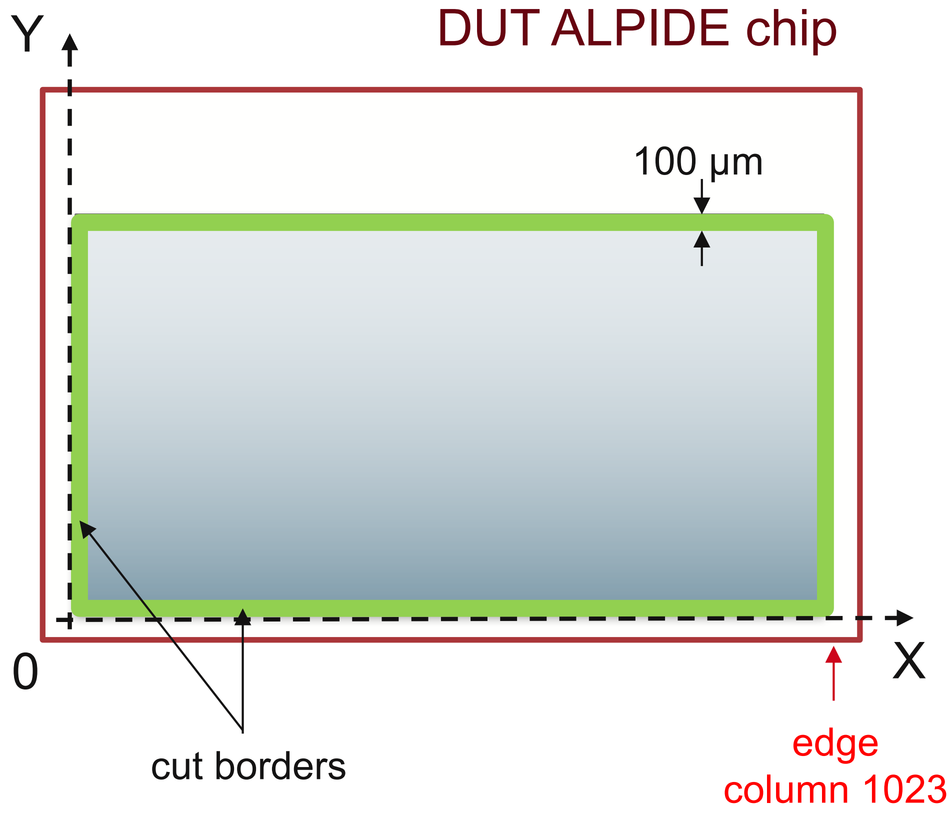


2 TEST BEAM FRAMEWORK

2.3 Analysis software

EUTelescope modifications

1. **ANALYSIS PROCESSOR:**
   Include the borders

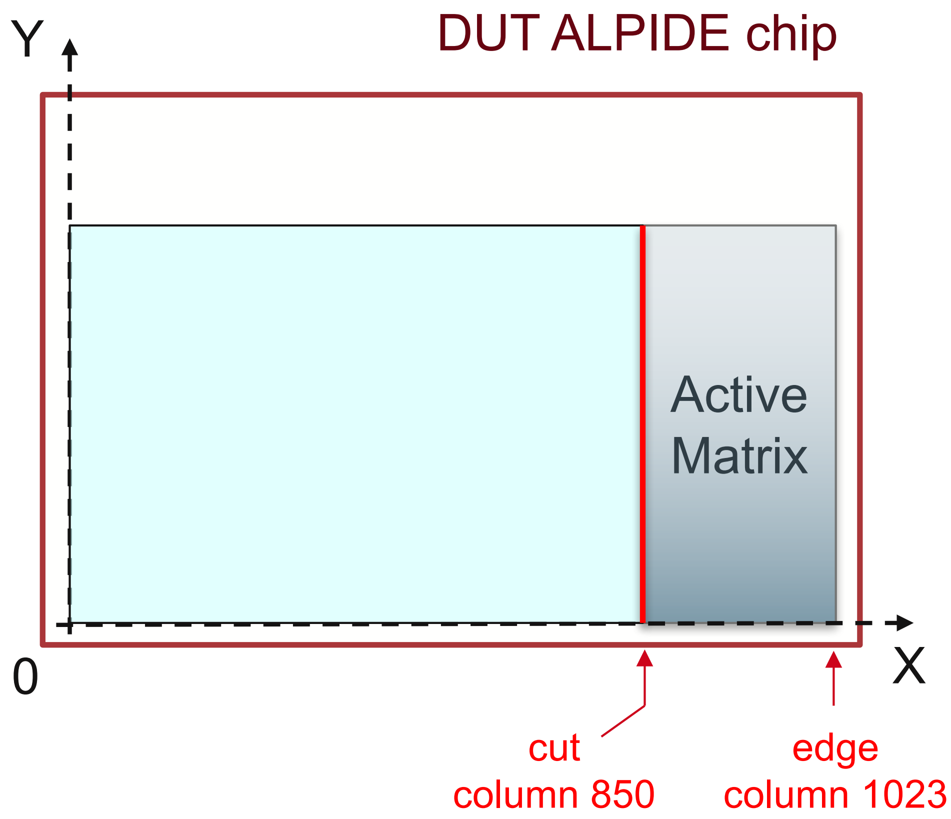


2 TEST BEAM FRAMEWORK

2.3 Analysis software

EUTelescope modifications

1. **ANALYSIS PROCESSOR**: Include the borders
2. **CONVERTER**: Create an artificial edge

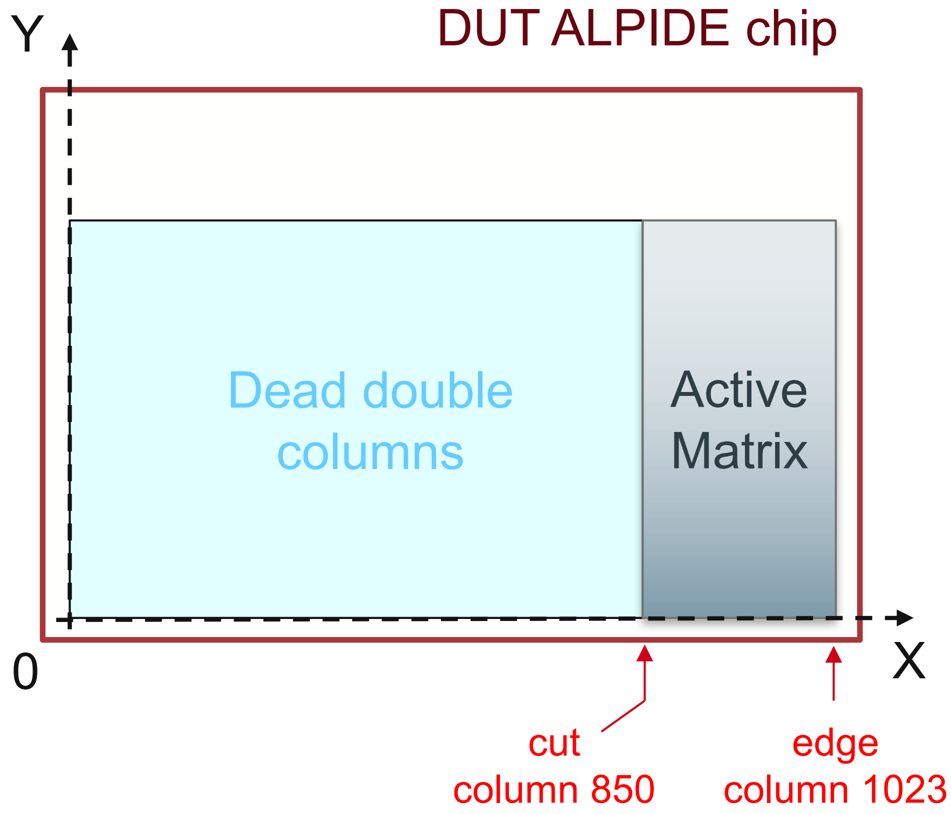


2 TEST BEAM FRAMEWORK

2.3 Analysis software

EUTelescope modifications

1. **ANALYSIS PROCESSOR**: Include the borders
2. **CONVERTER:** Create an artificial edge
3. **DEAD-DOUBLE-COLUMN FINDER:** 0 ≤ X ≤ 850 off



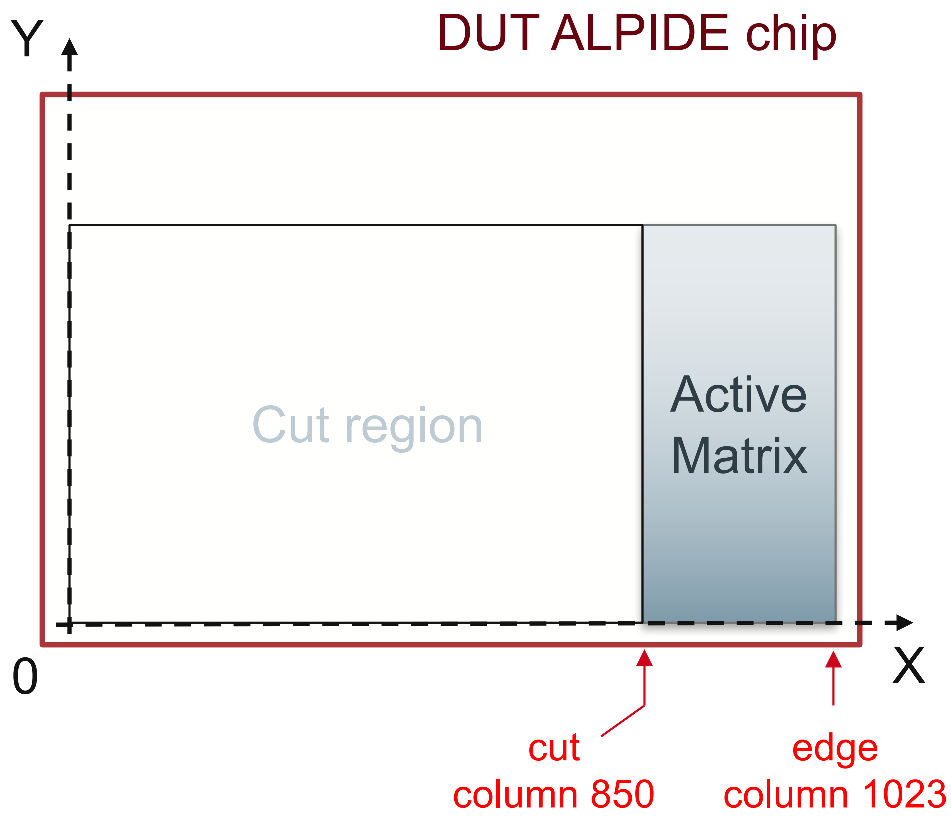
2 TEST BEAM FRAMEWORK

2.3 Analysis software

EUTelescope modifications

1. **ANALYSIS PROCESSOR**: Include the borders
2. **CONVERTER:** Create an artificial edge
3. **DEAD-DOUBLE-COLUMN FINDER:** 0 < X < 851 off
4. **ANALYSIS PROCESSOR**: Set 10 bins / pixel on X

+ development of post-processing macros



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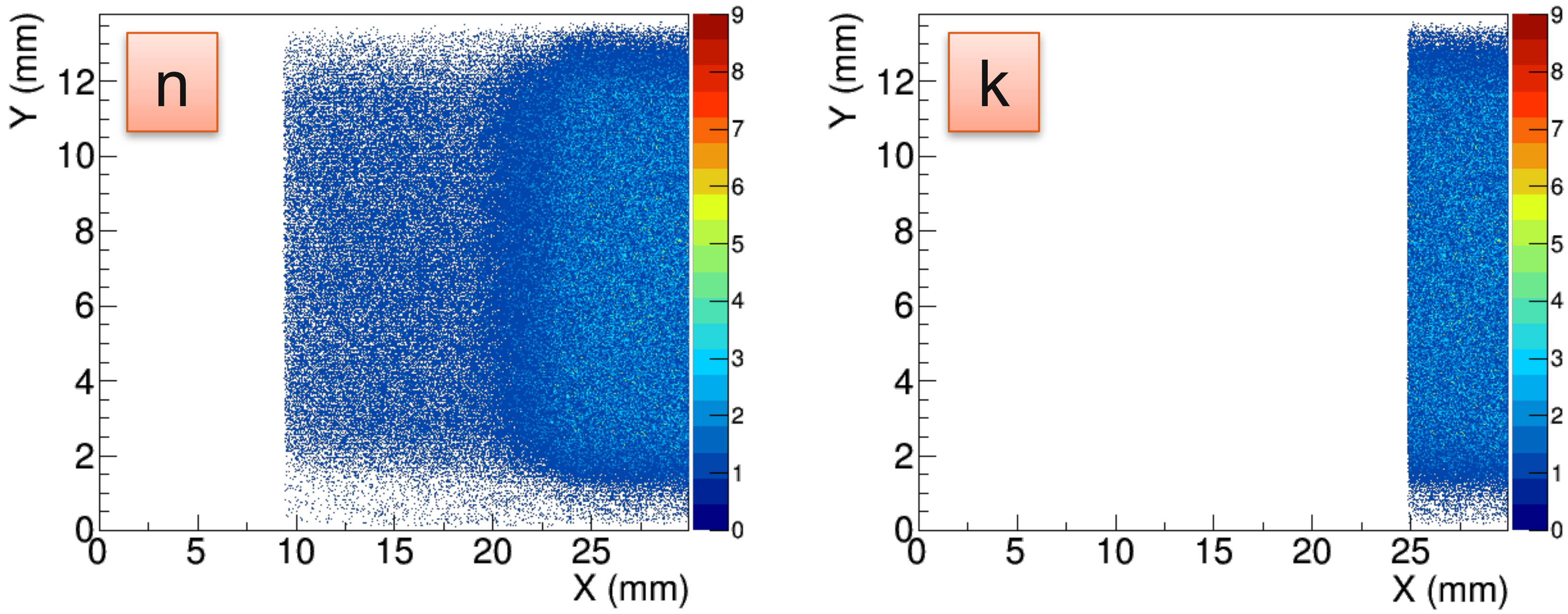
3 ANALYSIS

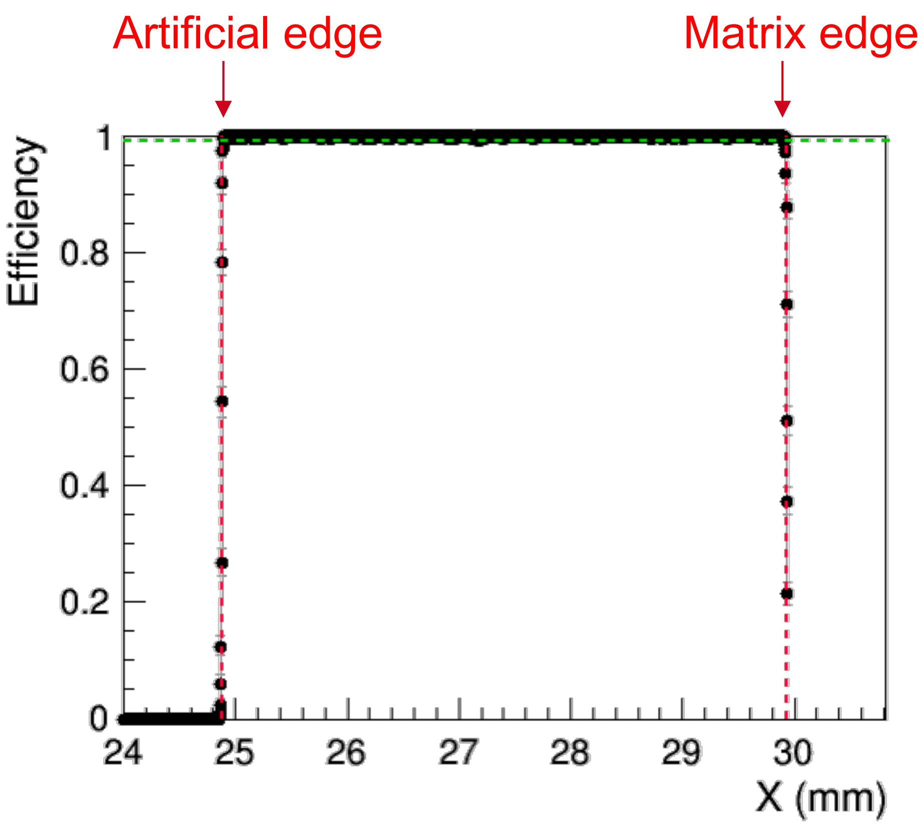
3.1 Efficiency profile



$$\varepsilon = \frac{\text{number of tracks with hit in the DUT}}{\text{total number of tracks}} = \frac{k}{n}$$

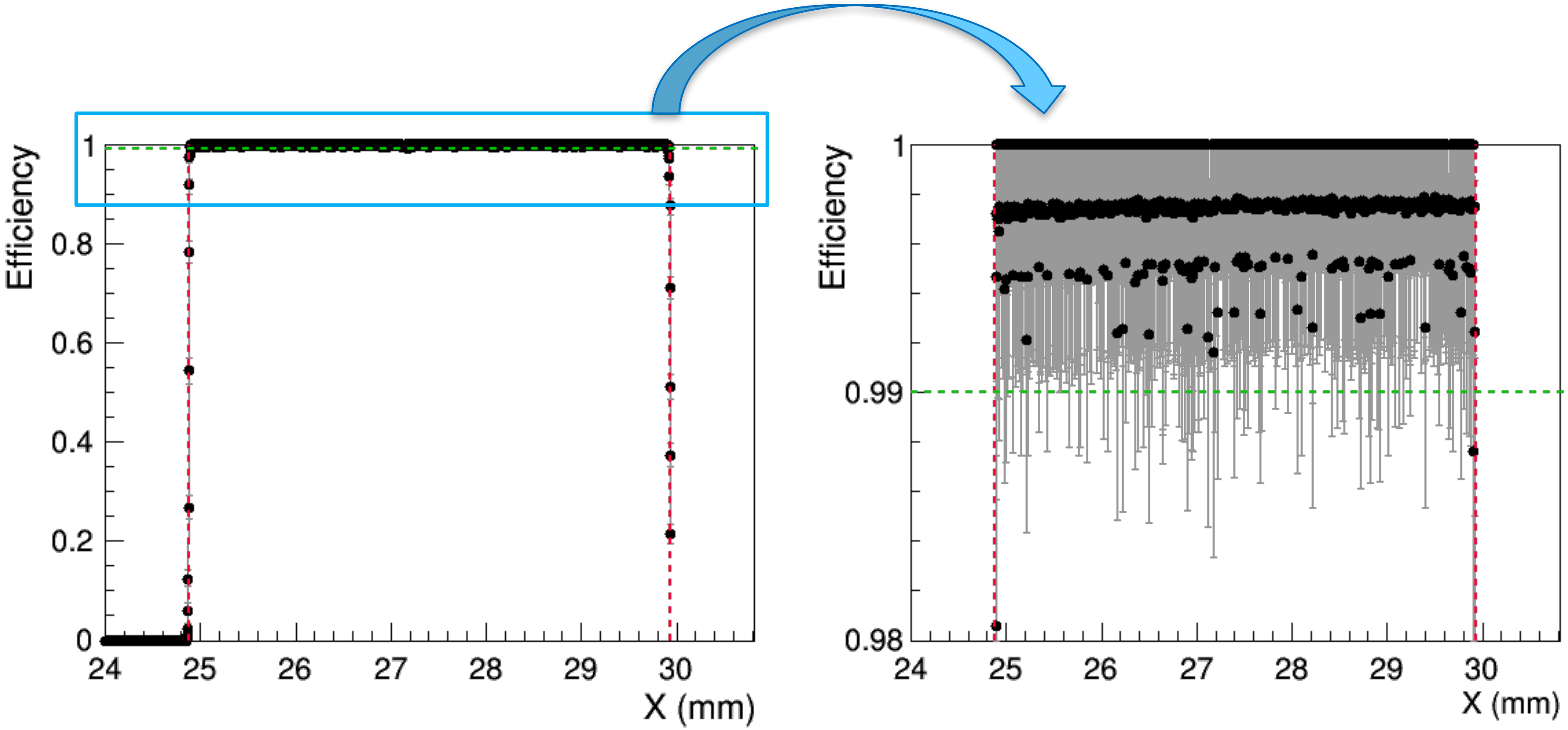
3 ANALYSIS

3.1 Efficiency profile



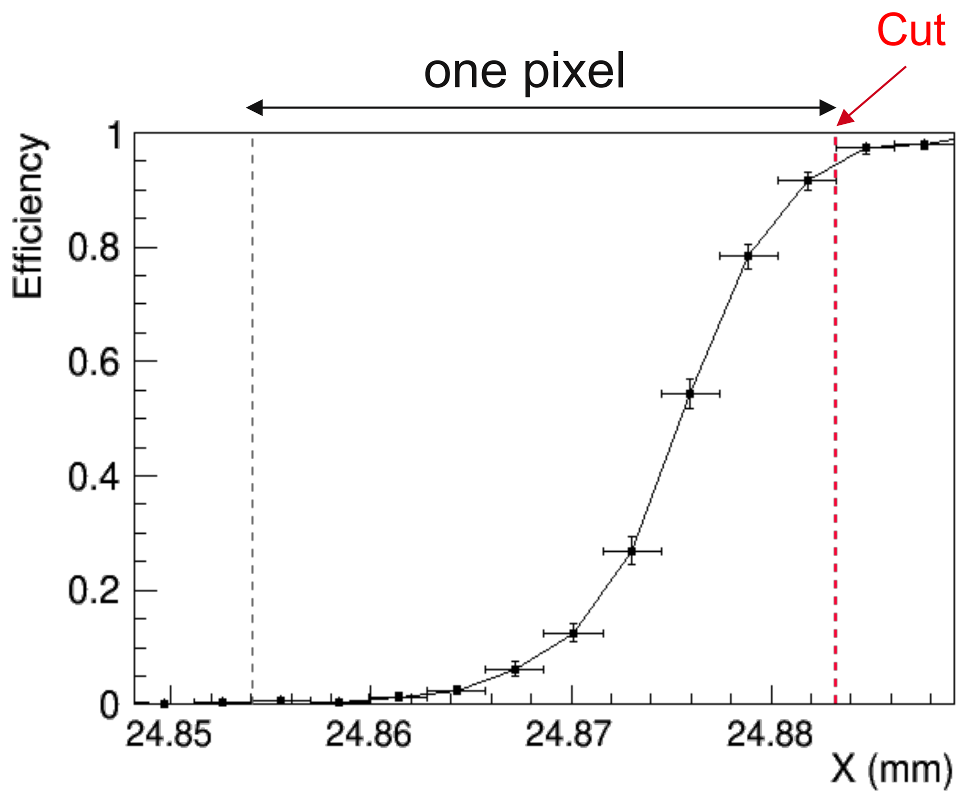
3 ANALYSIS

3.1 Efficiency profile

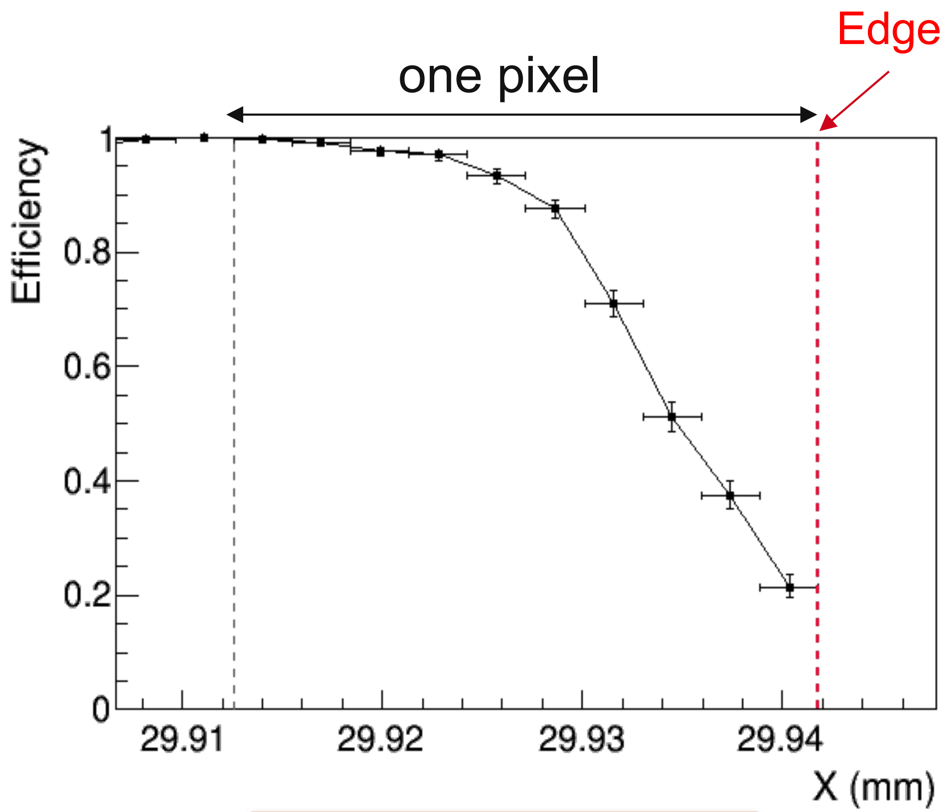


3 ANALYSIS

3.1 Efficiency profile



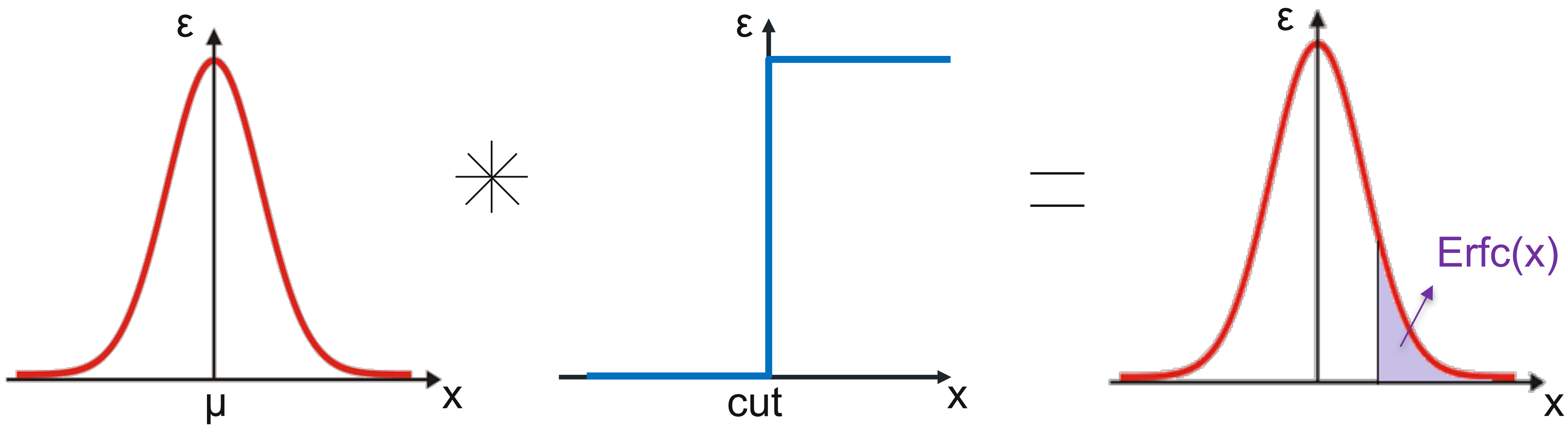
Artificial edge



Physical edge

3 ANALYSIS

3.2 Multiple scattering model

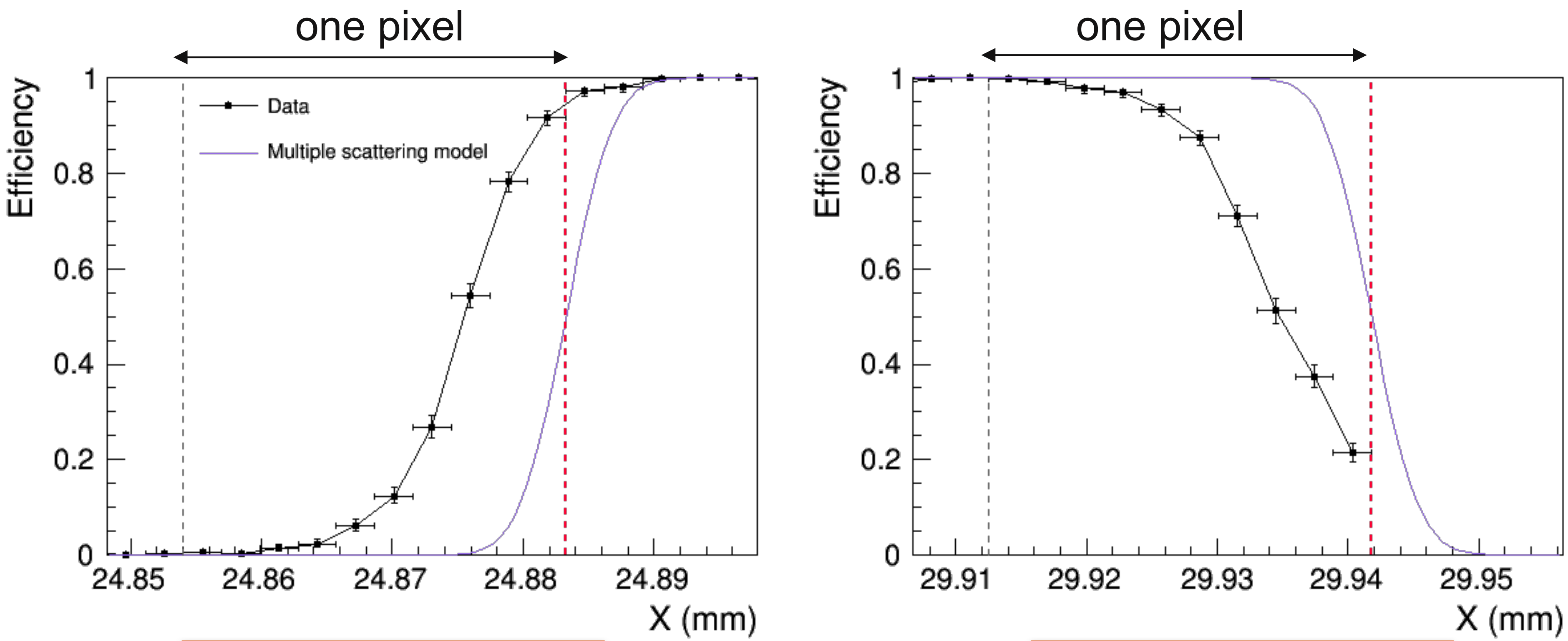


$\mathcal{N}(\mu, \sigma_{tr} = 2.8\ \mu m)$ Step function Error function

ALICE

3 ANALYSIS

3.2 Multiple scattering model

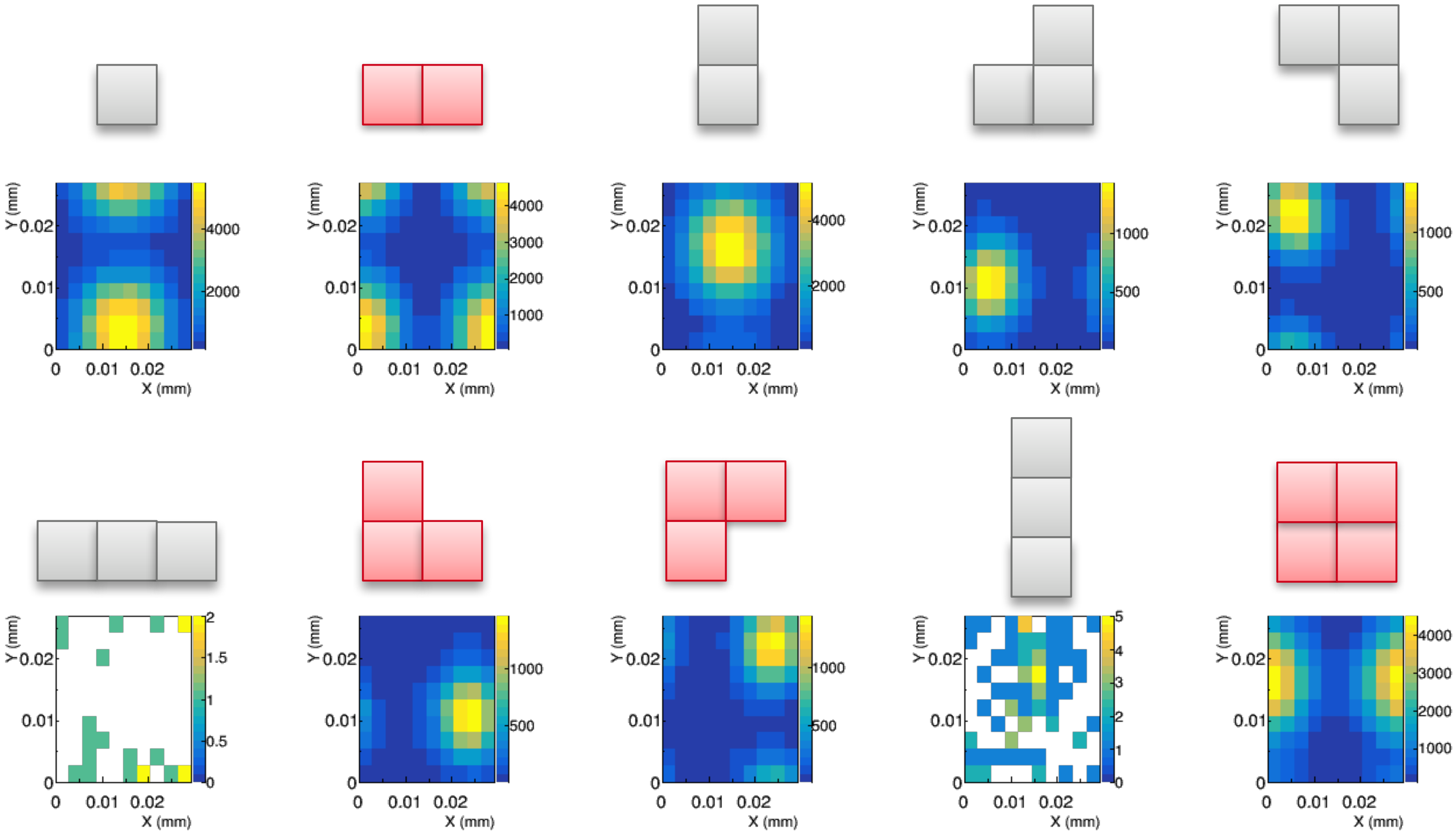


Artificial edge

Physical edge

3 ANALYSIS

3.3 Cluster shapes



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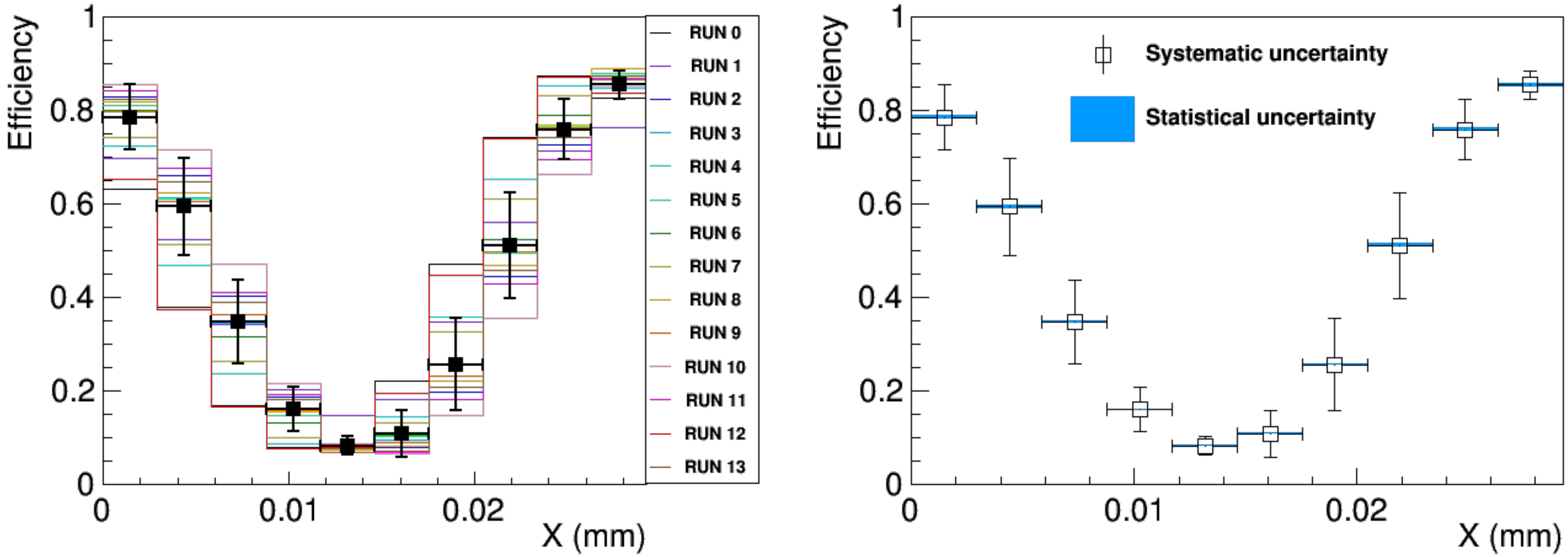
3 ANALYSIS

3.4 Pixel response from cluster shapes



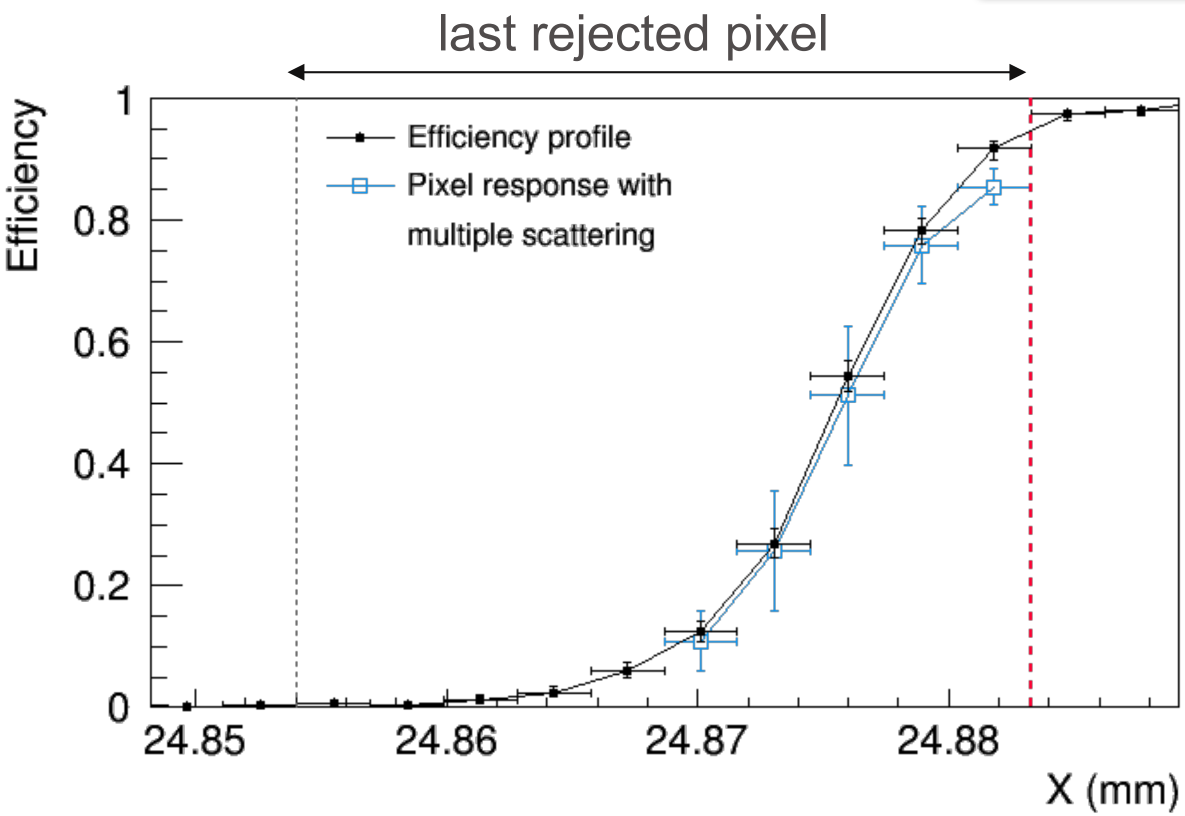
→ Systematic uncertainty dominating

→ Residual misalignment of the data

3 ANALYSIS

3.4 Pixel response from cluster shapes

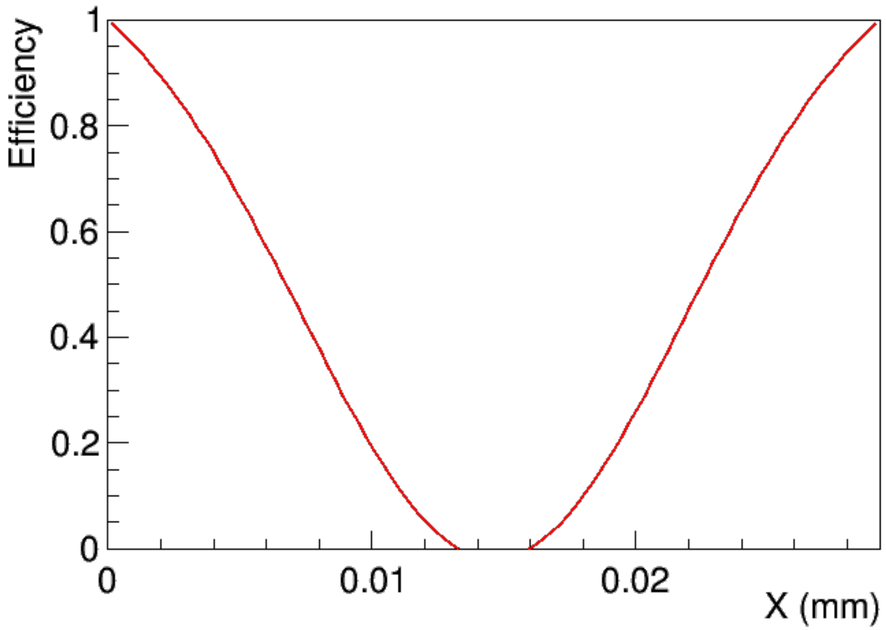
$$\frac{\chi^2}{ndf} = \frac{3.62}{5} = 0.724$$



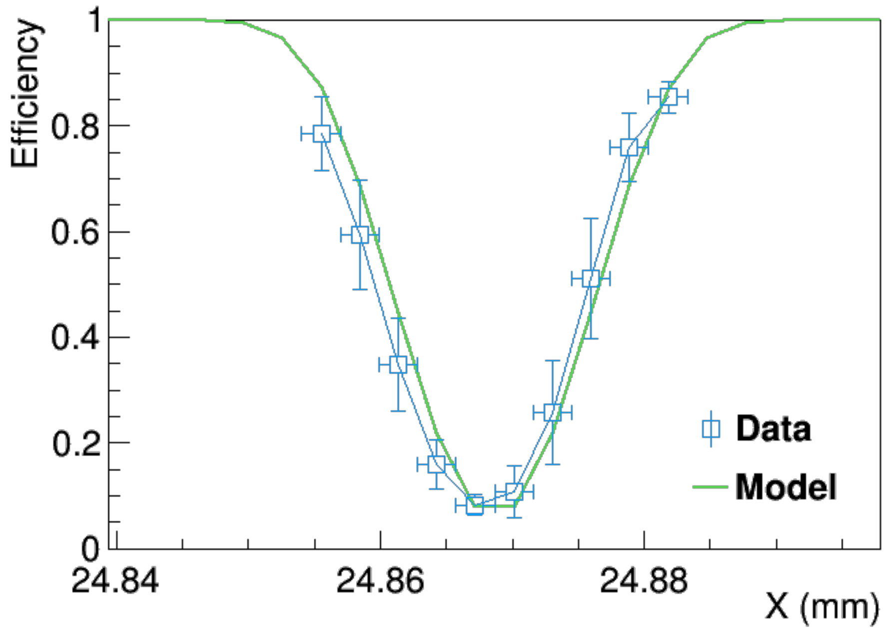
3 ANALYSIS

3.5 Pixel response model

$$\frac{\chi^2}{ndf} = \frac{7.59}{10} = 0.759$$



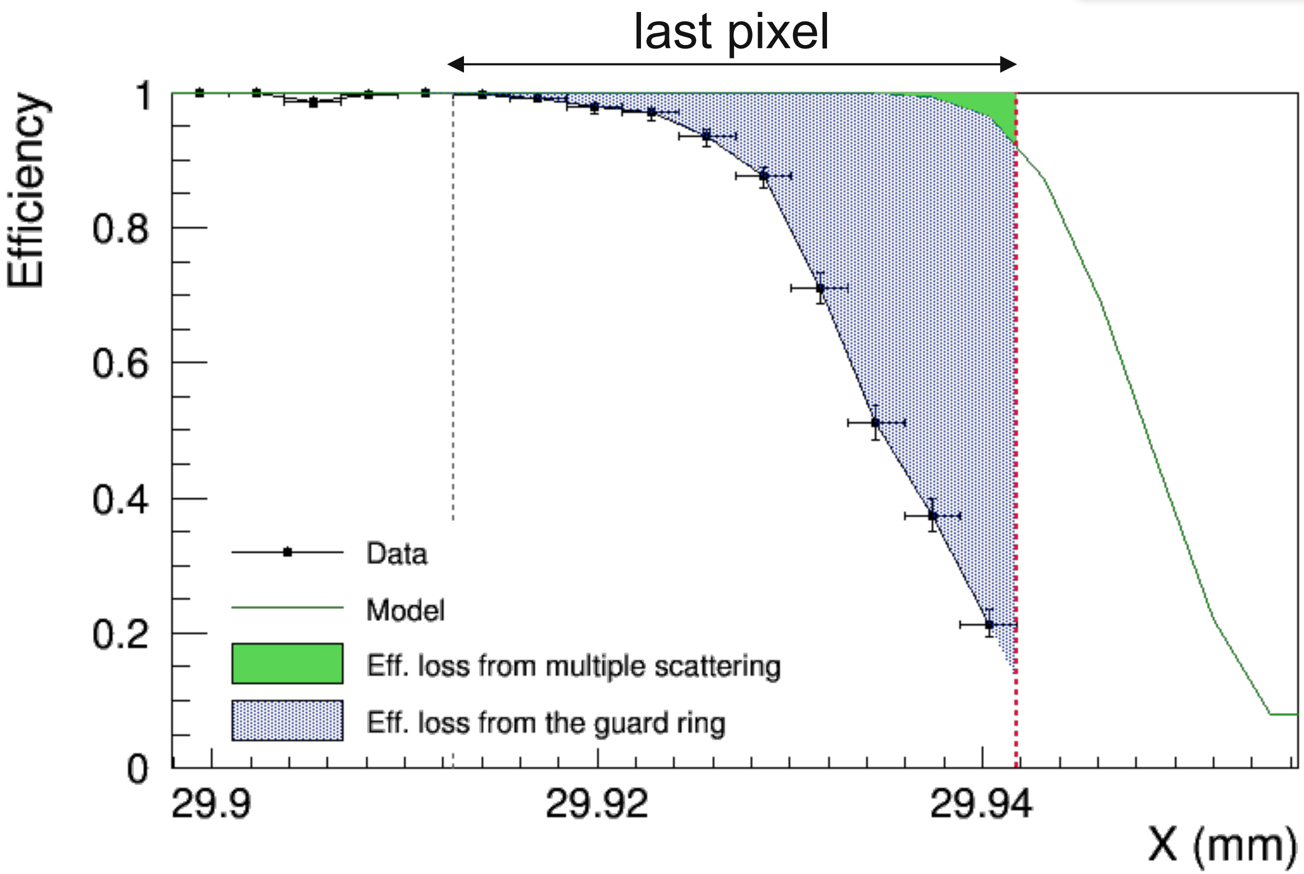
Before convolution



After convolution

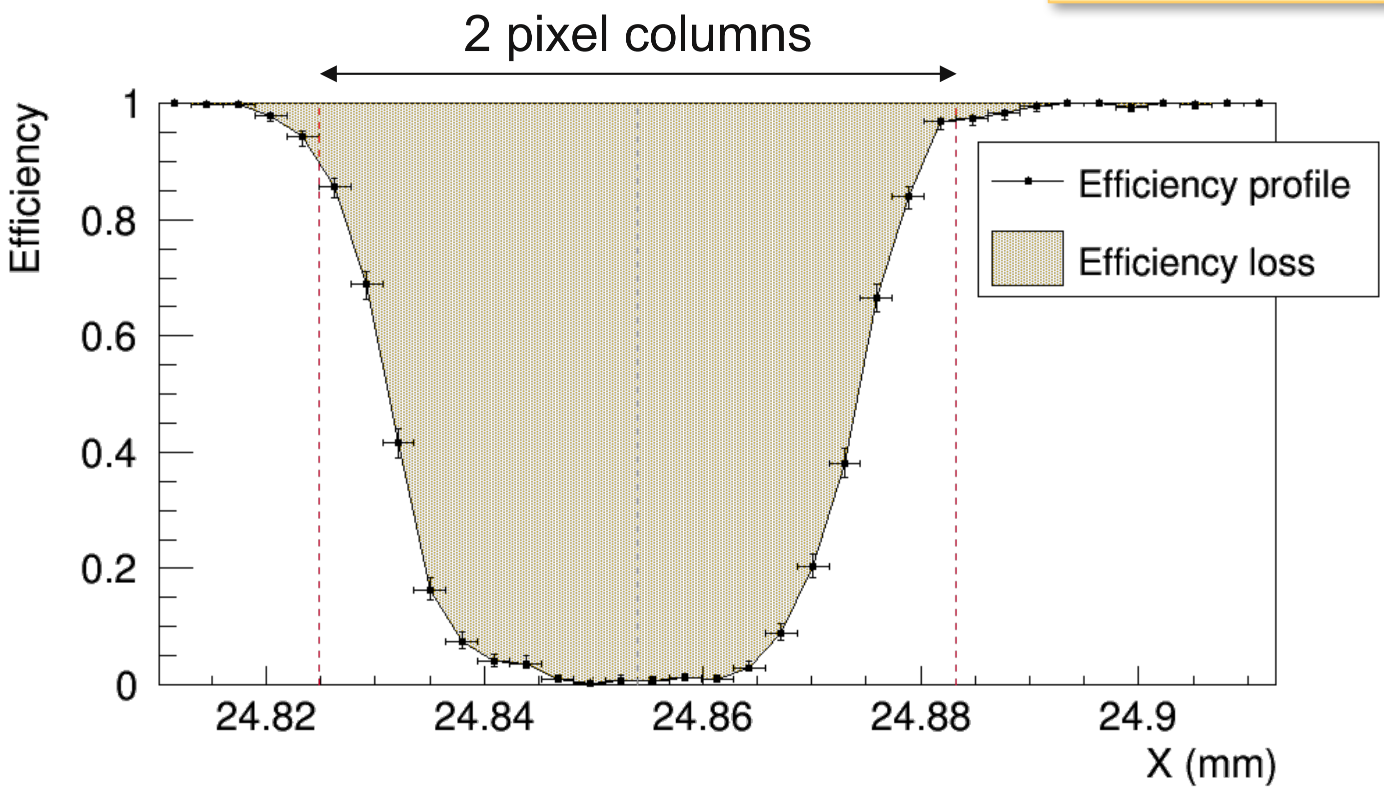
4 PIXEL MATRIX EDGE

$$(\mathbf{24.1}\,^{+1.6}_{-1.3})\ \%$$



5 DEAD DOUBLE COLUMN

$$(\mathbf{73.4}\ ^{+\,2.1}_{-\,1.7})\ \%$$



CONCLUSION

- In-pixel response study of the ALPIDE chip using test beam data
- The sensor edge:
    - Multiple scattering – minor effect
    - Pixel response dominant
    - Efficiency loss du to the guard ring ~ 24 %
    - Only in the last pixel column
- Dead double column:
    - Efficiency loss ~ 73 %
    - Charge sharing can recover ~ 27 %

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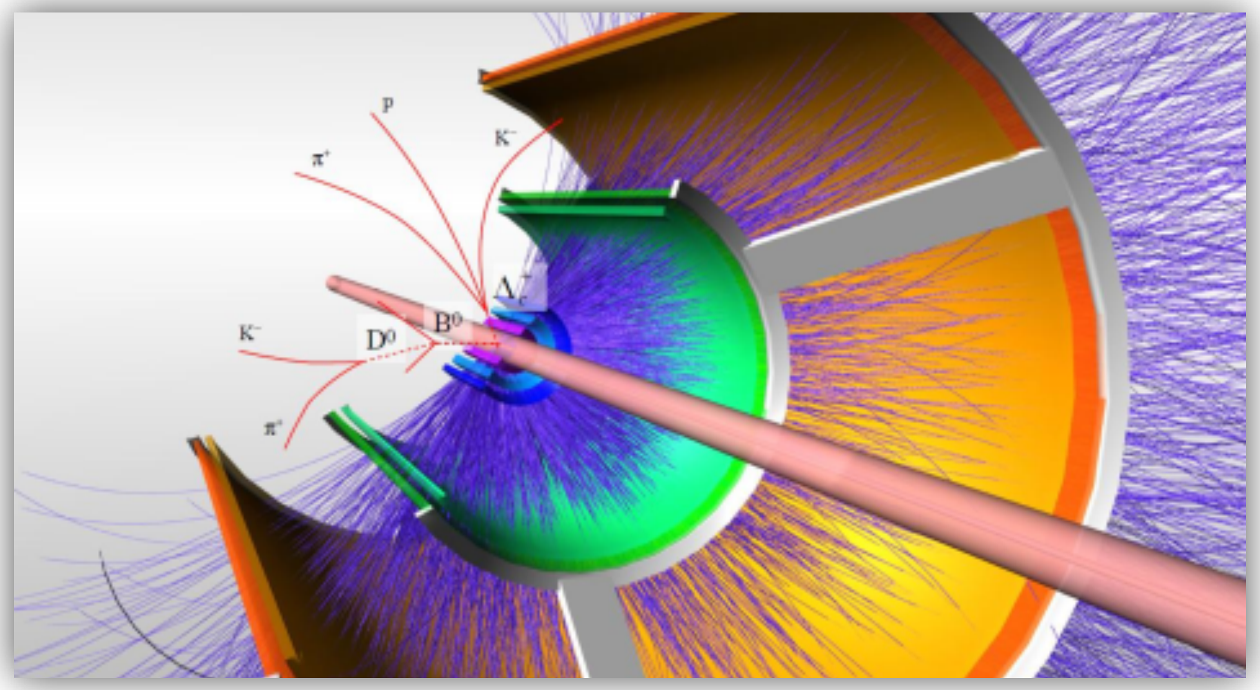
THANK YOU

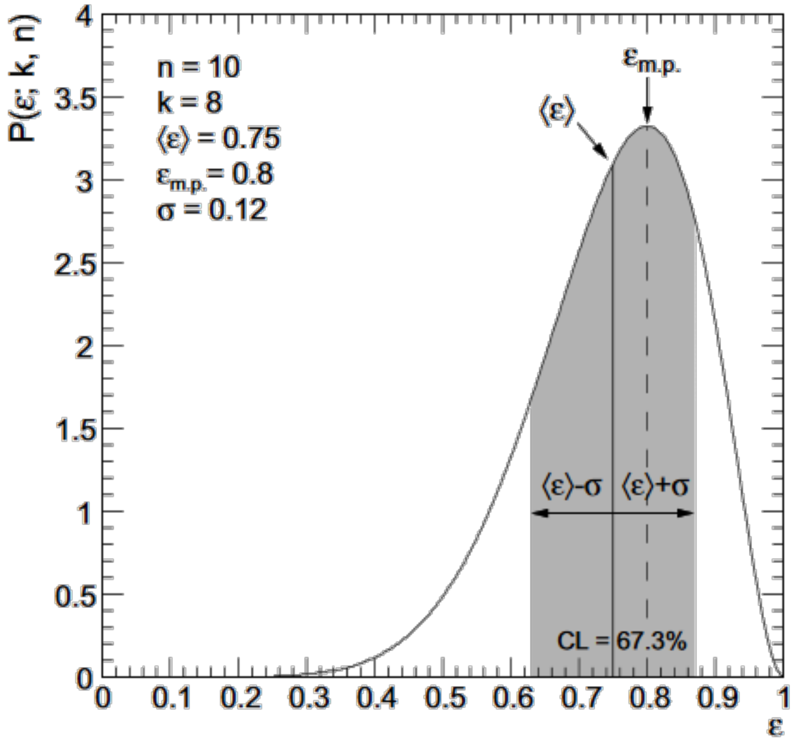


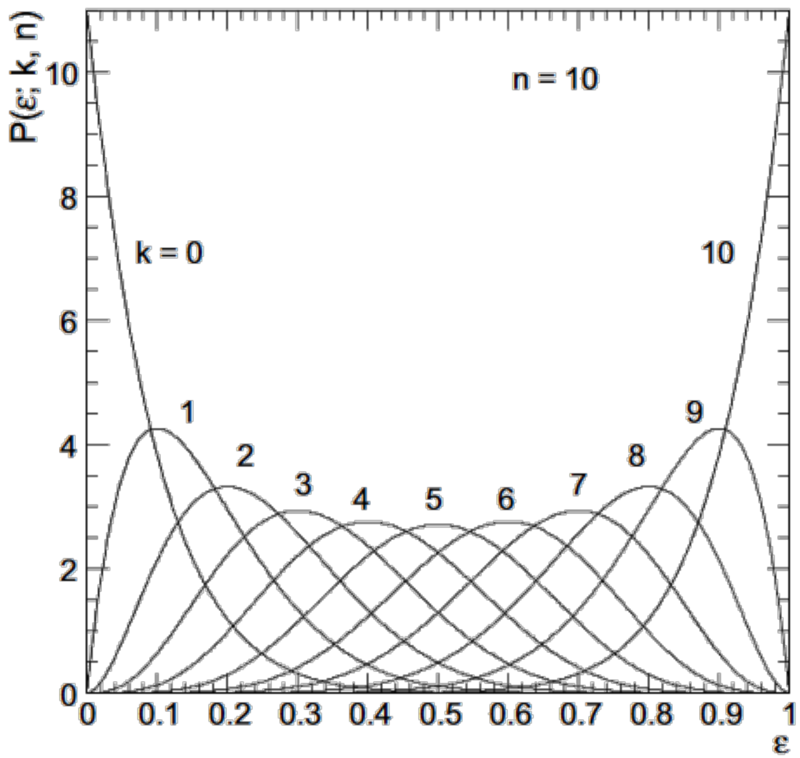
BACK UPS

RUNS USED IN THE ANALYSIS

Run number	Number of events
3180	15 251
3181	65 017
3182	169 399
3183	40 107
3184	40 440
3185	40 149
3186	35 873
3187	40 140
3189	39 838
3190	39 767
3191	39 172
3192	39 956
3193	40 159
3195	40 297
TOTAL	**685 562**

EFFICIENCY ERROR CALCULATION





$$\varepsilon = \frac{k}{n}$$

$$\langle \varepsilon \rangle = \frac{k+1}{n+2}$$

$$\sigma = \frac{(k+1)(k+2)}{(n+2)(n+3)} - \langle \varepsilon \rangle^2$$

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CALCULATION OF SIGMA TR

$$\sigma_{tr}^2 = \sigma_{res}^2 - \sigma_{pos}^2$$

Track resolution

2.833 μm

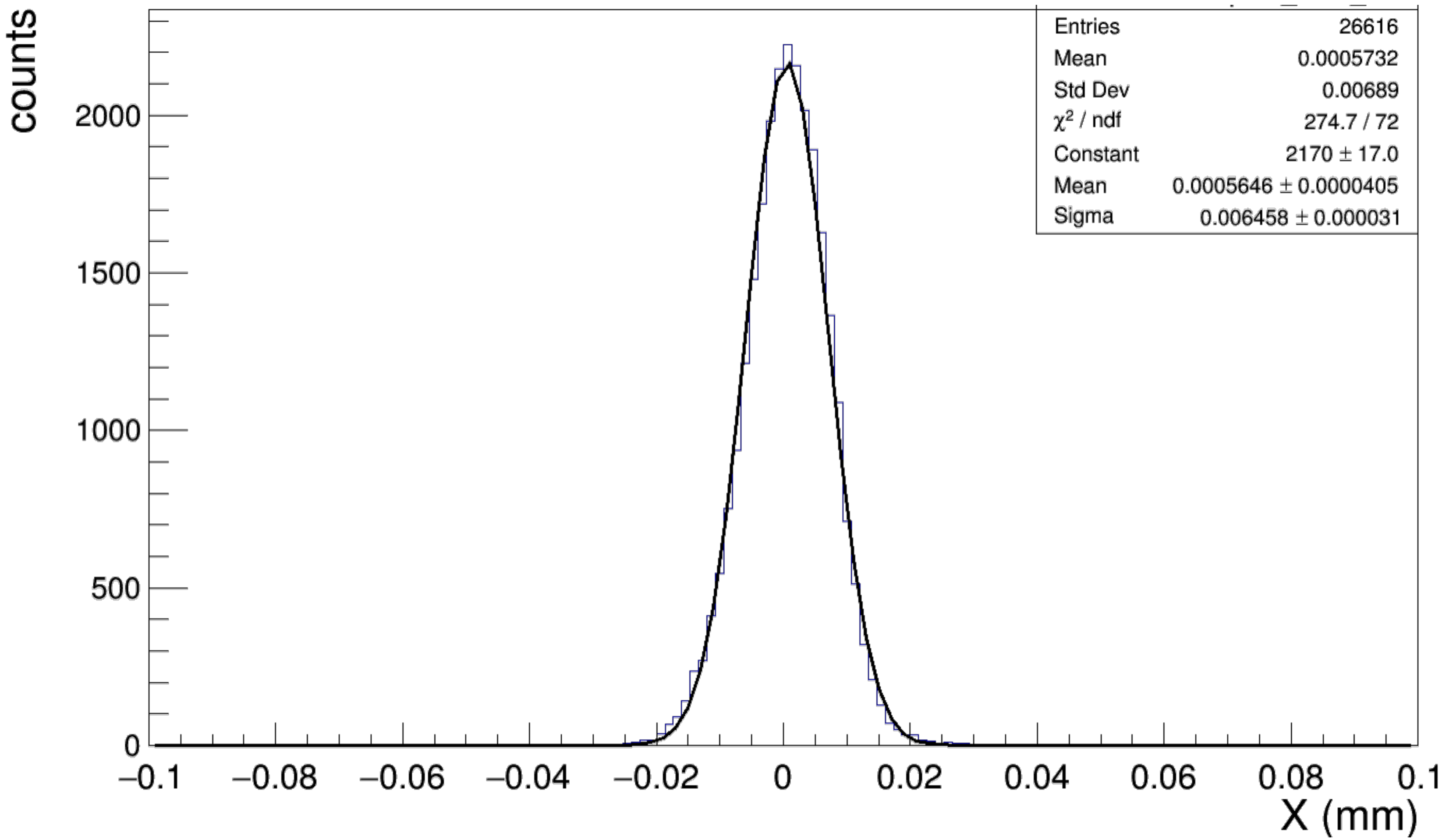
residual

6.009 μm

Single point resolution

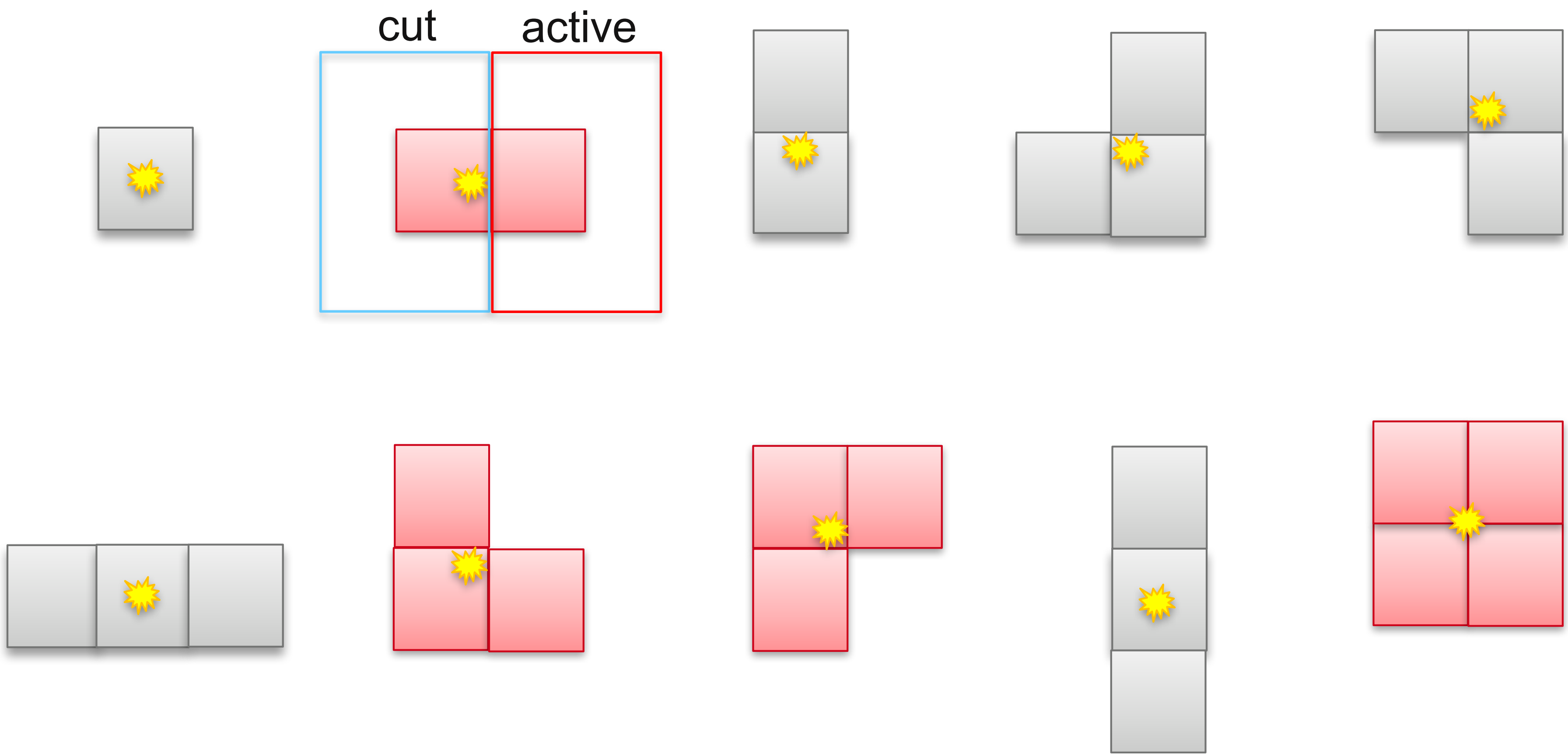
5.229 μm

RESIDUAL GAUSSIAN FIT



3 ANALYSIS

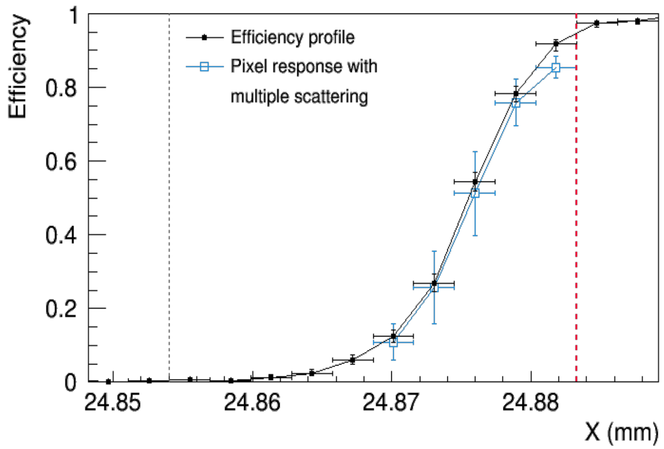
3.3 Cluster shapes



CHI² CALCULATIONS

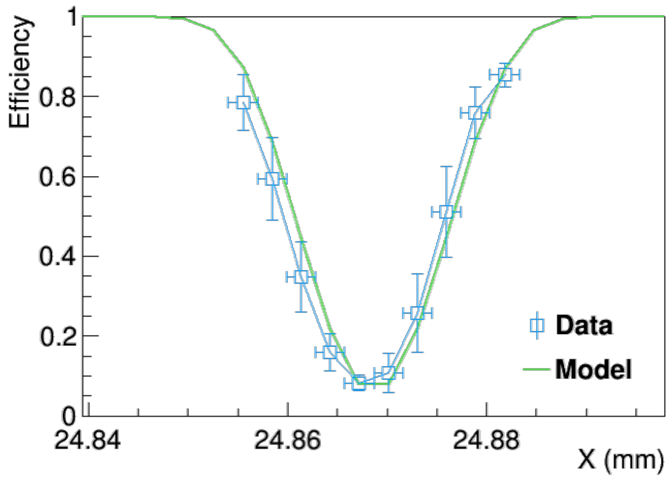
- Data vs. pixel response from cluster shapes

$$\chi^2 = \sum_{k=1}^{5} \frac{\left(\varepsilon_{data}(k) - \varepsilon_{pix}(k)\right)^2}{\sigma_{data}^2(k) + \sigma_{pix}^2(k)}$$



- Pixel response from cluster shapes vs. model

$$\chi^2 = \sum_{k=1}^{10} \frac{\left(\varepsilon_{pix}(k) - \varepsilon_{model}(k)\right)^2}{\sigma_{pix}^2(k)}$$



EFFICIENCY LOSS CALCULATIONS

ALICE

- Pixel matrix edge

Effect	Integral (μm)	Efficiency loss (%)
Total	$7.20\,^{+0.46}_{-0.39}$	$24.6\,^{+1.6}_{-1.3}$
Multiple scattering	0.15	0.5
Guard ring	$7.05\,^{+0.46}_{-0.39}$	$24.1\,^{+2.0}_{-1.7}$

- Dead double column

Effect	Integral (μm)	Efficiency loss (%)
Dead double column	$42.9\,^{+1.2}_{-1.0}$	$73.4\,^{+2.0}_{-1.7}$

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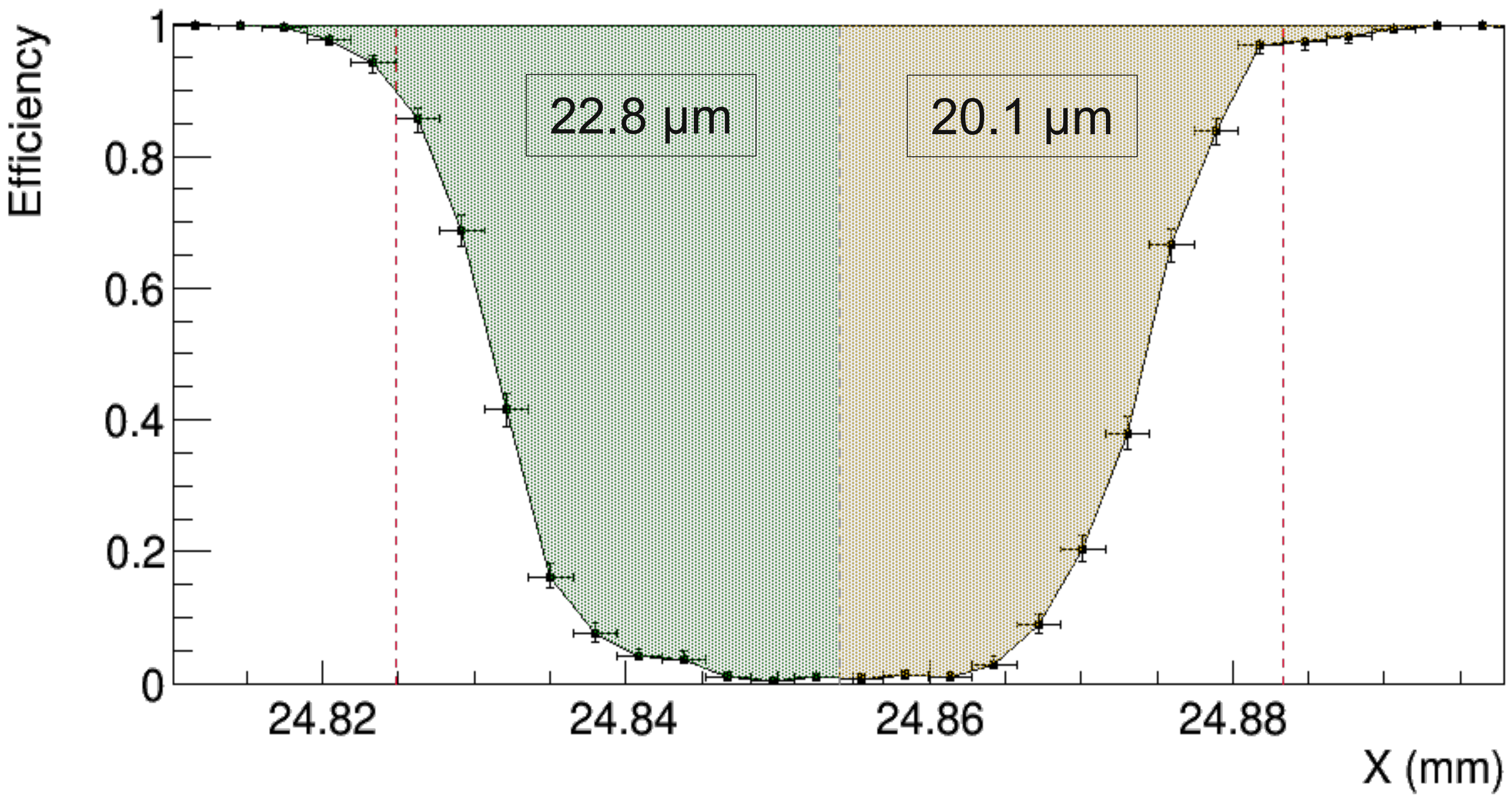
DEAD DOUBLE COLUMN ASYMMETRY



BETHE-BLOCH FORMULA